2” Photomultiplier Tube Testing in BNL EDG Lab 2-233

Dark Rates, Charge distributions, Gain Curves, Resolution Curves

Hamamatsu H2431-50 (PMT is R2083): PMTs 1 -33, 35– 44, 47- 77;

EMI 9954-KB05: PMTs 78 – 112

3rd draft of report, dated July 8, 2018

PMT test results:
Hamamatsu 2431-50 (PMT is R2083) from E802/866 inventory: 74 tested, 57 passed, 6 barely passed, 8 failed, 3 Retest, 0 discard
EMI 9954-KB05 with custom voltage divider base (from E949 range stack): 35 tested, 22 passed, 3 barely passed, 4 failed, 1 Retest, 5 discard

Raul Armendariz, Queensborough Community College

Aiwu Zhang, Brookhaven National Laboratory

Past student participants:

Liam Fortuna, Suffolk County Community College

Garret Stoddard, Stony Brook University

FIG. 1: EMI 9954KB05 PMTs in dark box

FIG. 2: A Hamamatsu tube Model Number H2431-50 on the left and an EMI tube Model number 9954KB05 on the right.

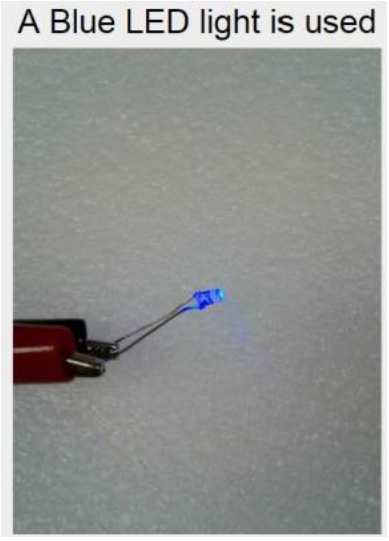


FIG. 3: Blue LED used to test PMTs

Purpose of the study

Characterize photomultiplier tubes in order to use them in an educational cosmic ray muon detector array with plastic scintillators.

PMT selection criteria:

Gain ≥ 10^6
Dark rate < 10 kHz at the operating high voltage (HV) corresponding to where the PMT has 10^6 gain
Peak to valley: the single photoelectron valley is visually resolved in the PMT charge distribution

Equipment:

Dark box (BNL trunk)
High Voltage Power Supplies, Ortec model 456 (QCC)
RG58 50 Ohm coaxial cable for signal
RG59 75 Ohm coaxial cable for HV

Dark rates were measured using NIM electronics:

x10 Amplifier, PS Model 776, primarily used SN 7846
30 mV Discriminator, PS model 711, SN 14344 and SN 5052
Scalar, Joerger model VS, #BNL 52935, and #428.
Timing Gate Delay Generator, PS model 794, SN 20992

Gain measurements were made using:

Blue/Violet LED
1GHz Oscilloscope, Tektronix model DPO4104, SN C011830 and SN C020623
Digital Delay/Pulse Generator, Stanford Research Systems model DG535, SN 18784 (BNL)
PC HP 64 bit OS Windows 7
LabView 2012 Data acquisition program
Python script
C++ script
ROOT for histograms

Testing Methods

Dark Box

PMTs were tested in a light tight box. First the box itself was tested and improvements made to make it light tight: more black tape and RTV black silicone, making it light tight to within 1%; this was determined by measuring PMT dark rates with the room lights on, then room lights off.

Dark Rates

PMT dark rates were measured using a x10 amplifier followed by a -30 mV discriminator, and recording the average dark rate per PMT over 8 second gated intervals. Dark rate was plotted as a function of HV.

Gain

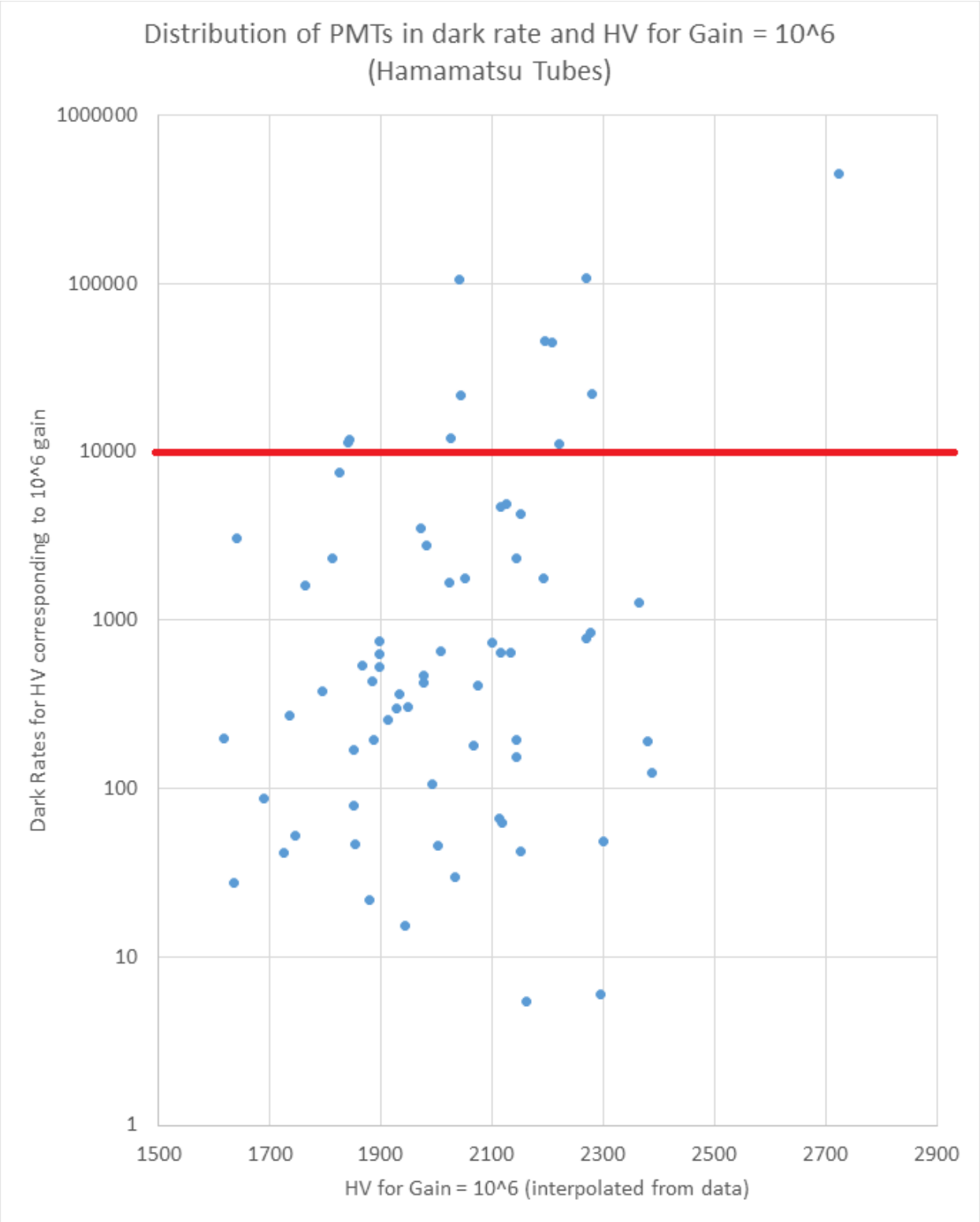
PMT gain was measured by flashing in front of the PMT very low levels of blue-violet light from an LED at a distance of about 30", typically at 1.6 V to 1.96 V; the LED was turned on with a pulse generator for 10 ns at a 10 Hz rate. The LED voltage was selected where each PMT detected light in no more than 1 flash out of 5 to 50 flashes. The output of each PMT was connected to a fast oscilloscope. The oscilloscope was triggered synchronously with the LED flash by the dual output pulse generator. The charge per pulse measured on the oscilloscope was recorded by a connected computer running a LabView data acquisition program. The charge Q in each oscilloscope waveform was integrated and a charge distribution filled, and fitted for multiple waveforms; the single photo-electron peak average charge Q_{peak} was extracted from the fit and PMT gain calculated as $g = Q_{peak}/e$. Gain is plotted as a function of high voltage.

Resolution

The PMT resolution was calculated as $Resolution = \sigma_{FWHM}/Q_{peak} = 2(2ln2)^{1/2}\sigma/Q_{peak} = 2.35\sigma/Q_{peak}$ where the width σ is the standard deviation of the single photo-electron peak extracted from the charge distribution fit. Resolution is plotted as a function of high voltage.

PMTs above the red line were rejected

(Only H2431-50 included here)



This table provides voltage at 10E6 gain and corresponding dark rate; this needs to be updated.

PMTs highlighted in red were rejected for dark rate > 10 kHz, or insufficient gain. The tubes were retested and some found to be acceptable and could be used as backup.

	Histogram Data		
2	Pmt #	V at G = 10^(	Dark rate at G
3	AA804	2294.97	5.991162352
4	AA903	1944.55	15.46027457
5	AA827	1879.71	21.72083611
6	AA1770	2032.72	29.74091265
7	AA1940	2152.44	42.59406007
8	AA720	1852.92	46.48737271
9	AA800	2299.05	48.94056597
10	AA1445	2118.37	62.51400602
11	AA1773	2112.66	66.78300437
12	AA1415	1852.2	79.73814151
13	AA1902	1991.5	106.8577173
14	AA2459	2143.16	153.6863733
15	AA1948	1850.38	168.7830208
16	AA1545	2065.86	179.5406136
17	AA1270	1618.26	198.0981711
18	AA1185	1735.62	270.4499185
19	AA1206	1929.14	301.7738793
20	AA1050	1932.64	364.1981141
21	AA1708	2074.86	410.7661274
22	AA1134	1883.35	436.2975197
23	AA889	1898.46	531.0011517
24	AA1986	2116.13	637.155663
25	AA1947	2007.54	648.4356141
26	AA979	2268.95	785.5955142
27	AA1648	2022.35	1668.388889
28	AA1897	2050.71	1769.309805
29	AA1071	2144.17	2314.792371
30	AA1677	1972.41	3491.484735
31	AA1061	2151.98	4268.473683
32	AA1266	2116.49	4716.25567
33	AA2054	1825.17	7474.002004
34	AA1346	2221.42	11175.97194
35	AA1379	1841.39	11356.10449
36	AA2363	1842.87	11760.56671
37	AA1950	2043.02	21495.9085
38	AA1946	2207.08	44917.69048
39	AA1202	2723.45	452625.0462
40	AA1491		2553.37814
41	AA1349	1896.41	756.6085272
42	AA1131	2026.69	12024.66099
43	AA1370	1763.82	1596.031919
44	AA1181	2133.33	642.2583642
45	AA774	2380.02	190.7961423
46	AA2322	1982.92	2773.281163
47	AA2099	1911.66	255.9200345
48	AA790	1865.1	542.8400238
49	AA1799	1888.06	196.4949678
50	AA2073	1634.25	27.42745276
51	AA1994	2041.24	106519.483
52	AA1839	1689.22	88.14343954
53	AA1942	1793.93	375.8815949
54	AA1356	2277.83	849.1771388
55	AA637	2388.01	125.0159292
56	AA1434	1813.73	2348.422355
57	AA1538	1977.97	426.5224941
58	AA1801	2193.88	45707.57494
59	AA1245	1745.74	52.34803229
60	AA1750	2268.68	107905.1861
61	AA2038	1640.33	3096.078556
62	AA1198	1724.56	41.42396707
63	AA1759	2100.48	735.5312436
64	AA828	2279.61	22253.98676
65	AA1336	2143.5	193.7962149
66	AA1235	2192.09	1785.687721
67	AA981	2124.63	4881.787319
68	AA765	2160.72	5.431783563
69	AA1378	1898.15	625.1877965
70	AA1258	2363.95	1264.766297
71	AA1330	2002.79	45.49007492
72	AA1052	1977.13	466.0057712
73	AA1227	1949.45	304.3555078

PMT acceptance criteria categories:
"Passed" means: 1) PMT works, i.e. detects light, resolves signal, 2) gain >= 10^6, 3) dark rate < 10 kHz at HV corresponding to 10^6 gain, 4) reasonable peak to valley resolution
"Barely passed" means: PMT almost failed in at least one category, or has flat gain, or some other tolerable problem
"Failed" means: PMT failed in any of the above criteria
"Discard" means either the PMT doesn't work (no signal or no resolved peaks), introduces a voltage offset on scope, causes electrical shorts, or other serious issue; before discarding PMT it should be determined if the PMT and/or the base is defective.
The HV at 10^6 gain was interpolated from the gain fit; the Dark rate at 10^6 gain was interpolated from the dark rate fits
PMTs tested and results summary:
Hamamatsu 2431-50 (PMT is R2083): 74 tested, 57 passed, 6 barely passed, 8 failed, 3 Retest, 0 discard
EMI 9954-KB05 (from E949 range stack): 35 tested, 22 passed, 3 barely passed, 4 failed, 1 Retest, 5 discard
Hamamatsu 9420: 2 tested, 2 passed (PMTs 45 and 46)

PMT Test #	Manufac.	Model	S/N	Type	Issues/Notes	Status
PMT 1	Hamamatsu	H2431-50	AA869	2"	DR is ok	Retest gain
PMT 2	Hamamatsu	H2431-50	AA1181	2"		passed
PMT 3	Hamamatsu	H2431-50	AA2064	2"	DR is ok	Retest gain
PMT 4	Hamamatsu	H2431-50	AA774	2"		passed
PMT 5	Hamamatsu	H2431-50	AA2320	2"		passed
PMT 6	Hamamatsu	H2431-50	AA2099	2"		passed
PMT 7	Hamamatsu	H2431-50	AA790	2"	Noisy, retest DR	barely passed
PMT 8	Hamamatsu	H2431-50	AA1799	2"	Do stability test, maybe caused oscope problem	Retest stability
PMT 9	Hamamatsu	H2431-50	AA2073	2"	retest DR	passed
PMT 10	Hamamatsu	H2431-50	AA1994	2"		passed
PMT 11	Hamamatsu	H2431-50	AA1839	2"		passed
PMT 12	Hamamatsu	H2431-50	AA1942	2"		passed
PMT 13	Hamamatsu	H2431-50	AA1356	2"	low gain; DR is large at higher HV	passed
PMT 14	Hamamatsu	H2431-50	AA637	2"	low gain; DR is large at higher HV	passed
PMT 15	Hamamatsu	H2431-50	AA1434	2"		passed
PMT 16	Hamamatsu	H2431-50	AA1538	2"		passed
PMT 17	Hamamatsu	H2431-50	AA1801	2"	Noisy, Dark rate ~ 12 kHz at 10^6 gain	failed
PMT 18	Hamamatsu	H2431-50	AA1245	2"		passed
PMT 19	Hamamatsu	H2431-50	AA1750	2"	Noisy, Dark rate ~ 45 kHz at 10^6 gain	failed
PMT 20	Hamamatsu	H2431-50	AA2038	2"		passed

PMT 21	Hamamatsu	H2431-50	AA1198	2"		passed
PMT 22	Hamamatsu	H2431-50	AA1759	2"		passed
PMT 23	Hamamatsu	H2431-50	AA828	2"	Noisy, Dark rate ~ 15 kHz at 10^6 gain	failed
PMT 24	Hamamatsu	H2431-50	AA1336	2"		passed
PMT 25	Hamamatsu	H2431-50	AA1902	2"		passed
PMT 26	Hamamatsu	H2431-50	AA1071	2"		passed
PMT 27	Hamamatsu	H2431-50	AA1346	2"	Noisy, retest DR	barely passed
PMT 28	Hamamatsu	H2431-50	AA1202	2"	Noisy, DR ~ 110 kHz at 10^6 gain	failed
PMT 29	Hamamatsu	H2431-50	AA1946	2"	Noisy, DR ~ 15 kHz at 10^6 gain	failed
PMT 30	Hamamatsu	H2431-50	AA1050	2"		passed
PMT 31	Hamamatsu	H2431-50	AA1708	2"		passed
PMT 32	Hamamatsu	H2431-50	AA1185	2"		passed
PMT 33	Hamamatsu	H2431-50	AA979	2"		passed
No PMT 34						
PMT 35	Hamamatsu	H2431-50	AA1947	2"		passed
PMT 36	Hamamatsu	H2431-50	AA1940	2"		passed
PMT 37	Hamamatsu	H2431-50	AA1545	2"		passed
PMT 38	Hamamatsu	H2431-50	AA2459	2"		passed
PMT 39	Hamamatsu	H2431-50	AA1986	2"		passed
PMT 40	Hamamatsu	H2431-50	AA1270	2"		passed
PMT 41	Hamamatsu	H2431-50	AA827	2"		passed
PMT 42	Hamamatsu	H2431-50	AA1950	2"	Noisy	failed
PMT 43	Hamamatsu	H2431-50	AA1648	2"		passed

PMT 44	Hamamatsu	H2431-50	AA1677	2"		passed
PMT 45	Hamamatsu	H9420	H9420-1	38mm	Aiwu using in other lab	passed
PMT 46	Hamamatsu	H9420	H9420-2	38mm	Aiwu using in other lab	passed
PMT 47	Hamamatsu	H2431-50	AA1773	2"	retest DR, results weren't repeatable	passed
PMT 48	Hamamatsu	H2431-50	AA903	2"		passed
PMT 49	Hamamatsu	H2431-50	AA1948	2"		passed
PMT 50	Hamamatsu	H2431-50	AA1061	2"	Noisy; previously marked "noisy"	failed
PMT 51	Hamamatsu	H2431-50	AA1445	2"		passed
PMT 52	Hamamatsu	H2431-50	AA1415	2"		passed
PMT 53	Hamamatsu	H2431-50	AA1379	2"	At 2000V DR ~ 15 kHz	passed
PMT 54	Hamamatsu	H2431-50	AA800	2"		passed
PMT 55	Hamamatsu	H2431-50	AA1770	2"		passed
PMT 56	Hamamatsu	H2431-50	AA1266	2"		passed
PMT 57	Hamamatsu	H2431-50	AA1134	2"		passed
PMT 58	Hamamatsu	H2431-50	AA720	2"		passed
PMT 59	Hamamatsu	H2431-50	AA889	2"		passed
PMT 60	Hamamatsu	H2431-50	AA804	2"		passed
PMT 61	Hamamatsu	H2431-50	AA2363	2"	Noisy	barely passed
PMT 62	Hamamatsu	H2431-50	AA1206	2"		passed
PMT 63	Hamamatsu	H2431-50	AA2054	2"	Noisy	barely passed
PMT 64	Hamamatsu	H2431-50	AA1897	2"		passed
PMT 65	Hamamatsu	H2431-50	AA1491	2"	Gain low and flat	failed

PMT 66	Hamamatsu	H2431-50	AA1349	2"		passed
PMT 67	Hamamatsu	H2431-50	AA1131	2"	Noisy	barely passed
PMT 68	Hamamatsu	H2431-50	AA1370	2"	Noisy	barely passed
PMT 69	Hamamatsu	H2431-50	AA1330	2"		passed
PMT 70	Hamamatsu	H2431-50	AA1052	2"		passed
PMT 71	Hamamatsu	H2431-50	AA1227	2"		passed
PMT 72	Hamamatsu	H2431-50	AA1076	2"		passed
PMT 73	Hamamatsu	H2431-50	AA1258	2"		passed
PMT 74	Hamamatsu	H2431-50	AA1378	2"		passed
PMT 75	Hamamatsu	H2431-50	AA1235	2"		passed
PMT 76	Hamamatsu	H2431-50	AA981	2"		passed
PMT 77	Hamamatsu	H2431-50	AA765	2"	Aiwu had been using in other lab	passed

PMT Test #	Manufac.	Model	S/N	Type	Condition	Status
PMT 78	EMI	9954KB 05	29746	2"	Noisy	barely passed
PMT 79	EMI	9954KB 05	30222	2"		passed
PMT 80	EMI	9954KB 05	30212	2"		passed
PMT 81	EMI	9954KB 05	30241	2"	No signal	discard
PMT 82	EMI	9954KB 05	28736	2"		passed
PMT 83	EMI	9954KB 05	30621	2"		passed
PMT 84	EMI	9954KB 05	31245	2"	~ 1400V electrically shorts other tubes	discard
PMT 85	EMI	9954KB 05	29887	2"	Creates 2mV offset on scope, otherwise passed	discard
PMT 86	EMI	9954KB 05	30002	2"	Has enough gain but gain is semi-flat	passed
PMT 87	EMI	9954KB 05	31790	2"	No signal	discard
PMT 88	EMI	9954KB 05	32018	2"	No signal	discard
PMT 89	EMI	9954KB 05	34996	2"		passed
PMT 90	EMI	9954KB 05	29787	2"		passed
PMT 91	EMI	9954KB 05	30281	2"	Poor peak to valley	barely passed
PMT 92	EMI	9954KB 05	28728	2"		passed
PMT 93	EMI	9954KB 05	30434	2"	Poor peak to valley	barely passed
PMT 94	EMI	9954KB 05	29028	2"	Low and flat gain	failed
PMT 95	EMI	9954KB 05	30213	2"		passed
PMT 96	EMI	9954KB 05	35635	2"		passed
PMT 97	EMI	9954KB 05	30890	2"		passed
PMT 98	EMI	9954KB 05	28978	2"		passed

PMT 99	EMI	9954KB 05	28972	2"	No valley, apparently from high RF pickup	failed
PMT 100	EMI	9954KB 05	30445	2"	Poor peak to valley; at higher HV has high DR	failed
PMT 101	EMI	9954KB 05	29984	2"	Lens has small chip	passed
PMT 102	EMI	9954KB 05	30598	2"	Lens has small chip	passed
PMT 103	EMI	9954KB 05	34981	2"	Base not original as used in E949	passed
PMT 104	EMI	9954KB 05	33269	2"	Base not original as used in E949	passed
PMT 105	EMI	9954KB 05	32053	2"		passed
PMT 106	EMI	9954KB 05	28275	2"		passed
PMT 107	EMI	9954KB 05	30337	2"	No valley	failed
PMT 108	EMI	9954KB 05	29990	2"		passed
PMT 109	EMI	9954KB 05	35775	2"		passed
PMT 110	EMI	9954KB 05	28979	2"		passed
PMT 111	EMI	9954KB 05	33154	2"	Previously marked unstable; DR passed	retest stability
PMT 112	EMI	9954KB 05	30202	2"		passed

PMTs 1 - 44, and 47 - 77 are H2431-50 assembly containing PMT R2083

This tube was from the E802/866 inventory. This type of tube was used in the BRAHMS TFW2 time of flight detectors with BC408 scintillators.

2″ Diameter Subnanosecond PMT

Subnanosecond time response (RT = 0.7 ns, TTS = 0.37 ns), 8-stage
For scintillation counting and high energy physics experiments

The R2083 is a 2-inch diameter, 8-stage, head-on type photomultiplier tube developed specially for pulse counting applications. It features subnanosecond rise time, small transit time spread and high pulse linearity. The anode output signal is derived through a coaxial connector to preserve good signal quality.

Or you can order a complete integral assembly (H2431) that consists of the R2083 photomultiplier tube, a voltage divider and a magnetic shield case.

Call or write for Data Sheets.

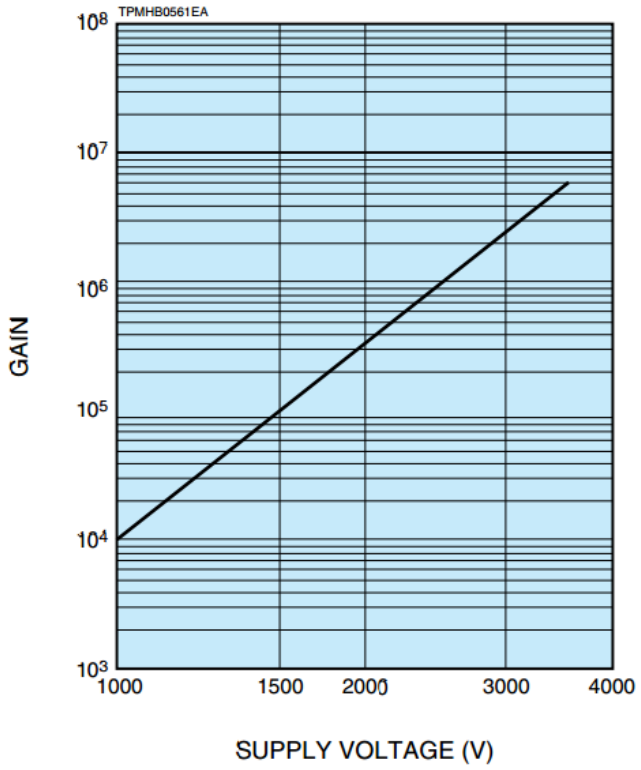
For Application Information
CALL 800-524-0504
In New Jersey Call 201-231-0960

HAMAMATSU

HAMAMATSU CORPORATION • 360 FOOTHILL ROAD, P.O. BOX 6910, BRIDGEWATER, NJ 08807 • PHONE: 201/231-0960

UNITED KINGDOM: Hamamatsu International (U.K.) Ltd. (phone: 0992-769293) • FRANCE: Hamamatsu Photonics France (phone: 46 55 47 56)
ITALY: Plesa S. P. A. (phone: 0321 34 92 579) • W. GERMANY: Hamamatsu Photonics Deutschland GmbH (phone: 08152-375-0)
SWEDEN, NORWAY, FINLAND, DENMARK: Lambda Electronics AB (phone: 08-620810) • JAPAN: Hamamatsu Photonics K.K.

Figure 2: Typical Gain Characteristics



HAMAMATSU

PHOTON IS OUR BUSINESS

PHOTOMULTIPLIER TUBES
R2083, R3377

For Scintillation Counting and High Energy Physics
51 mm (2 Inch) Diameter, Subnanosecond Time Response (Tr = 0.7 ns)
8-Stage, R2083: Borosilicate Window, R3377: Synthetic Silica Window, Bialkali Photocathode

GENERAL

Parameter		Description / Value	Unit
Spectral Response	R2083	300 to 650	nm
	R3377	160 to 650	nm
Wavelength of Maximum Response		420	nm
Photocathode	Material	Bialkali	—
	Minimum Effective Area	ϕ46	mm
Window Material	R2083	Borosilicate glass	—
	R3377	Synthetic silica glass	—
Dynode	Structure	Linear focused type	—
	Number of Stages	8	—
Operating Ambient Temperature		-30 to +50	°C
Storage Temperature		-30 to +50	°C
Base		19-pin glass base with SMA output connector	—
Suitable Socket		E678-19J (supplied)	—

MAXIMUM RATINGS (Absolute Maximum Values)

Parameter		Value	Unit
Supply Voltage	Between Anode and Cathode	3500	V
	Between Anode and Last Dynode	1000	V
Average Anode Current		0.2	mA

CHARACTERISTICS (at 25 °C)

Parameter			Min.	Typ.	Max.	Unit
Cathode Sensitivity	Luminous (2856 K)		60	80	—	μA/lm
	Radiant at 420 nm		—	80	—	mA/W
	Blue Sensitivity Index (CS 5-58)	R2083	—	10.0	—	—
		R3377	—	9.5	—	—
Anode Sensitivity	Luminous (2856 K)		50	200	—	A/lm
Gain			—	2.5×10^6	—	—
Anode Dark Current (after 30 min storage in darkness)			—	100	800	nA
Time Response	Anode Pulse Rise Time		—	0.7	—	ns
	Electron Transit Time		—	16	—	ns
	Transit Time Spread		—	0.37	—	ns
Pulse Linearity at 2 % Deviation			—	100	—	mA

VOLTAGE DISTRIBUTION RATIO AND SUPPLY VOLTAGE

Electrodes	K	G	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Acc	Dy7	Dy8	P
Ratio	1.3	4.8	1.2	1.8	1	1	1	1	0.5	3	2.5	

Supply Voltage: 3000 Vdc, K: Cathode, Dy: Dynode, P: Anode, G: Grid

PHOTOMULTIPLIER TUBES R2083, R3377

Figure 1: Typical Spectral Response

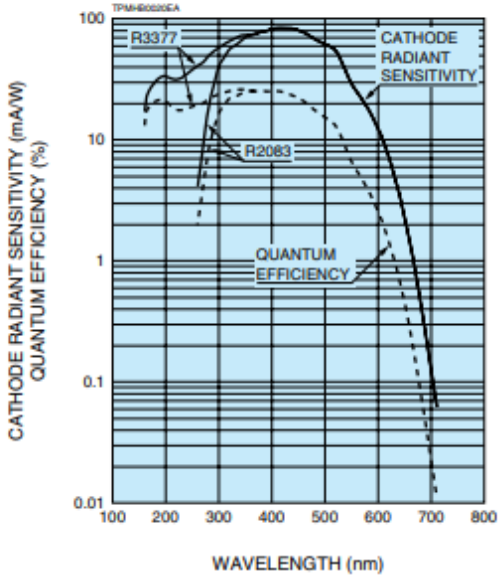


Figure 2: Typical Gain Characteristics

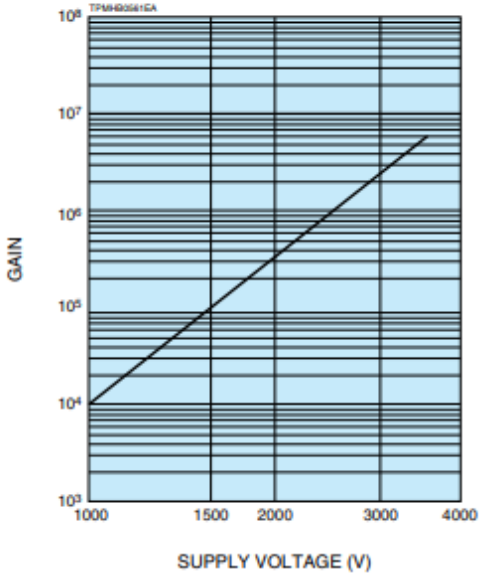
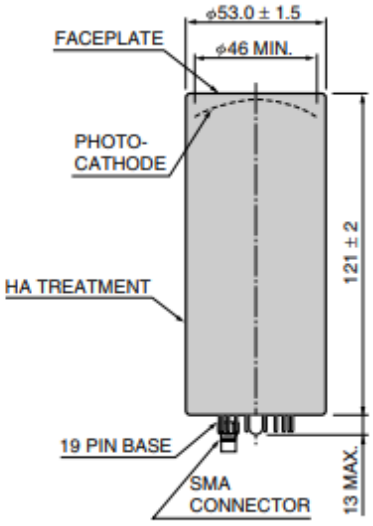
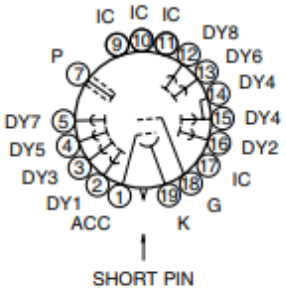
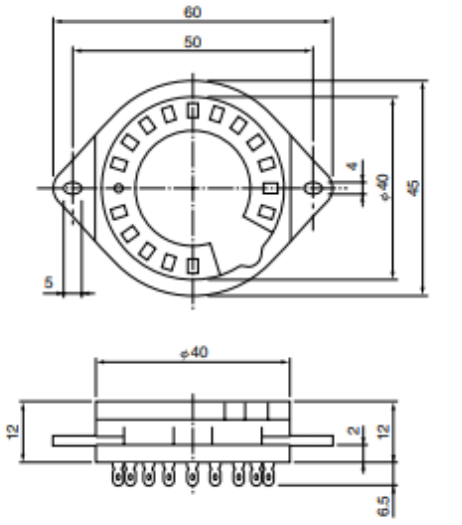


Figure 3: Dimensional Outline and Basing Diagram (Unit: mm)





Socket E678-19J (Supplied)



PMTs 78 – 112 are EMI 9954-KB05

Around 1995 the voltage divider was designed at BNL EDG. The following manufacturer specs were provided from Electron Tubes-ADIT (previously EMI);

“B05” specification is:

Corning Blue > 9

Volts @ 500 A/Lm < 1850 V

SER @ gain 10E7 > 1.5

Dark counts at gain 10E7 < 3000

51 mm (2") photomultiplier
9954B series data sheet

ET Enterprises electron tubes

1 description

The 9954B is a 51mm (2") diameter end window photomultiplier, with enhanced green sensitive bialkali photocathode, and 12 BeCu dynodes of linear focused design for good linearity and timing.

2 applications

- high energy physics studies

3 features

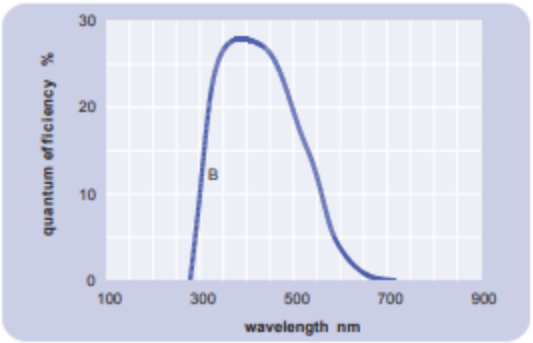
- good SER
- lower cost option of 9954B

4 window characteristics

	9954B borosilicate
spectral range *(nm)	290 - 680
refractive index (n_d)	1.49
K (ppm)	300
Th (ppb)	250
U (ppb)	100

* wavelength range over which quantum efficiency exceeds 1 % of peak

5 typical spectral response curves

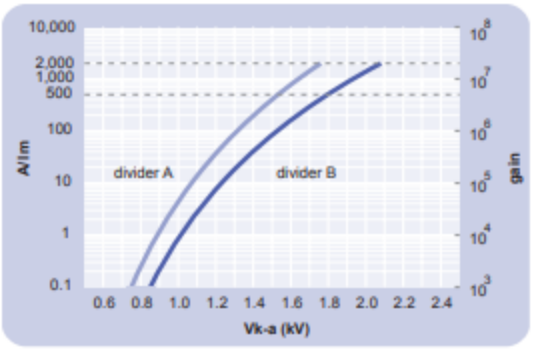


6 characteristics

	unit	min	typ	max
photocathode: bialkali				
active diameter	mm		46	
quantum efficiency at peak	%		28	
luminous sensitivity	µA/lm		110	
with CB filter		8	12	
with CR filter			9	
dynodes: 12LFBeCu				
anode sensitivity in divider A:				
nominal anode sensitivity	A/lm		500	
max. rated anode sensitivity	A/lm		2000	
overall V for nominal A/lm	V		1800	2300
overall V for max. rated A/lm	V		2100	
gain at nominal A/lm	x 10^6		5	
dark current at 20 °C:				
dc at nominal A/lm	nA		2	20
dc at max. rated A/lm	nA		8	
dark count rate	s^{-1}		800	
pulsed linearity (-5% deviation):				
divider A	mA		50	
divider B	mA		150	
pulse height resolution:				
single electron peak to valley	ratio		2	
rate effect (I_a for $\Delta g/g$=1%):	µA		1	
magnetic field sensitivity:				
the field for which the output decreases by 50 %				
most sensitive direction	T x 10^{-4}		1	
temperature coefficient:	% $°C^{-1}$		± 0.5	
timing:				
single electron rise time	ns		2	
single electron fwhm	ns		3	
transit time	ns		41	
weight:	g		150	
maximum ratings:				
anode current	µA			100
cathode current	nA			100
gain	x 10^6			18
sensitivity	A/lm			2000
temperature	°C	-30		60
V (k-a)[1]	V			2800
V (k-d1)	V			500
V (d-d)[2]	V			450
ambient pressure (absolute)	kPa			202

[1] subject to not exceeding max. rated sensitivity [2] subject to not exceeding max rated V(k-a)

7 typical voltage gain characteristics



8 voltage divider distribution

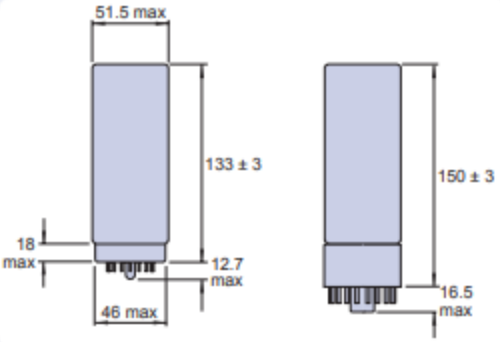
	k	d_1	d_2 ·····	d_8	d_9	d_{10}	d_{11}	d_{12}	a	
A	300V	R	·····	R	R	R	R	R		Standard
B	300V	R	·····	R	1.25R	1.5R	2R	3R		High Pulsed linearity

note: focus connected to d_1

Characteristics contained in this data sheet refer to divider A unless stated otherwise.

9 external dimensions mm

The drawings below show the 9954B in hardpin format and the 9954KB with the B20 cap fitted.



10 base configuration (viewed from below)

B19A hardpin base
(for 9954B)
'ic' indicates an internal connection

note: connect f to d_1

B20 cap
(for 9954KB)
'ic' indicates an internal connection

note: connect f to d_1

Our range of B19A sockets is available to suit the B19A hardpin base. Our range of B20 sockets is available to suit the B20 cap. Both socket ranges include versions with or without a mounting flange, and versions with contacts for mounting directly onto printed circuit boards.

11 ordering information

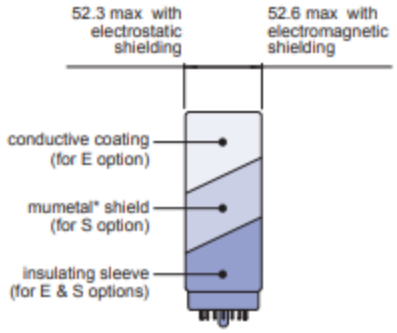
The 9954B meets the specification given in this data sheet. You may order **variants** by adding a suffix to the type number. You may also order **options** by adding a suffix to the type number. You may order product with **specification options** by discussing your requirements with us. If your selection option is for one-off order, then the product will be referred to as 9954A. For a repeat order, ET Enterprises will give the product a two digit suffix after the letter B, for example B21. This identifies your specific requirement.

9954

base options
K capped

options
E electrostatic shielding see drawing below
S electromagnetic shielding see drawing below
M supplied with spectral response calibration

specification options
B as given in data sheet
A single order to selected specification
Bnn repeat order to selected specification



12 voltage dividers

The standard voltage dividers available for hardpin variants of these pmts are tabulated below:

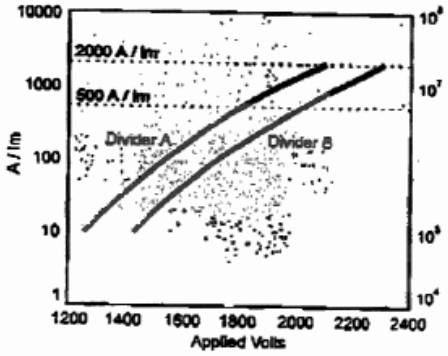
9954B	9954KB	k	d_1	d_2 ·····	d_8	d_9	d_{10}	d_{11}	d_{12}	a
C638A	C640A	3R	R	·····	R	R	R	R	R	
C638B	C640B	3R	R	·····	R	1.25R	1.5R	2R	3R	
C638C	C640C	300 V	R	·····	R	R	R	R	R	
C638D	C640D	300 V	R	·····	R	1.25R	1.5R	2R	3R	

R = 330 kΩ note: focus connected to d_1

*mumetal is a registered trademark of Magnetic Shield Corporation

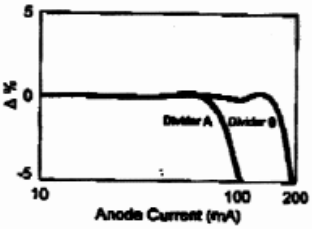
Voltage-Gain Characteristics

Gain versus voltage is shown for two dividers, divider A is standard for high gain and good linearity,whilst divider B is tapered to optimise linearity

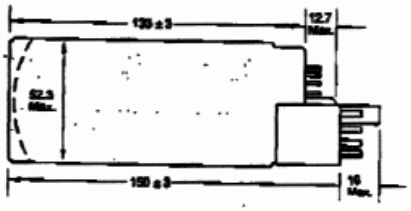


Linearity

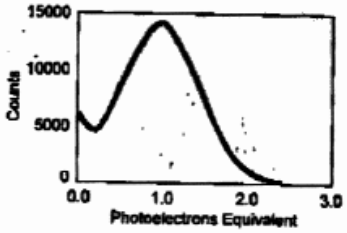
The deviation from linear amplification (Δ) is a function of the peak anode current.



Outline Drawing (mm)

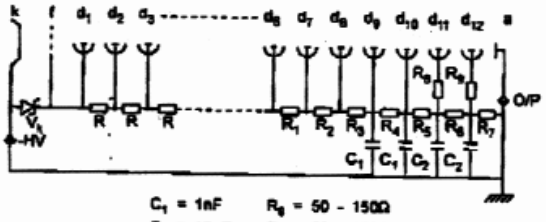


Single Electron Response



Voltage Divider

Type	V_K	R1	R2	R3	R4	R5	R6	R7
A	300V	R	R	R	1.25R	1.5R	2R	3R
B	450V	1.25R	1.25R	1.5R	2.25R	1.75R	2.75R	3R



C_1 = 1nF R_8 = 50 - 150Ω
C_2 = 10nF R_9 = 50 - 150Ω

V_K = one or more zenner diodes in series, to add up to the recommended voltage.

Pin Connections

Viewed from below, counting clockwise from short pin or key V
ic = internal connection. Socket contact not to be used.

Glass Base
Socket B19A

Plastic Base
Socket B20

Precautions

The photomultiplier is sensitive to magnetic fields. For optimum performance, magnetic screening is recommended. Contact ELECTRON TUBES for details of the range of mu-metal screens available.

This tube is normally supplied graphite coated (connected to cathode pin) and sleeved with black plastic for insulation purposes.

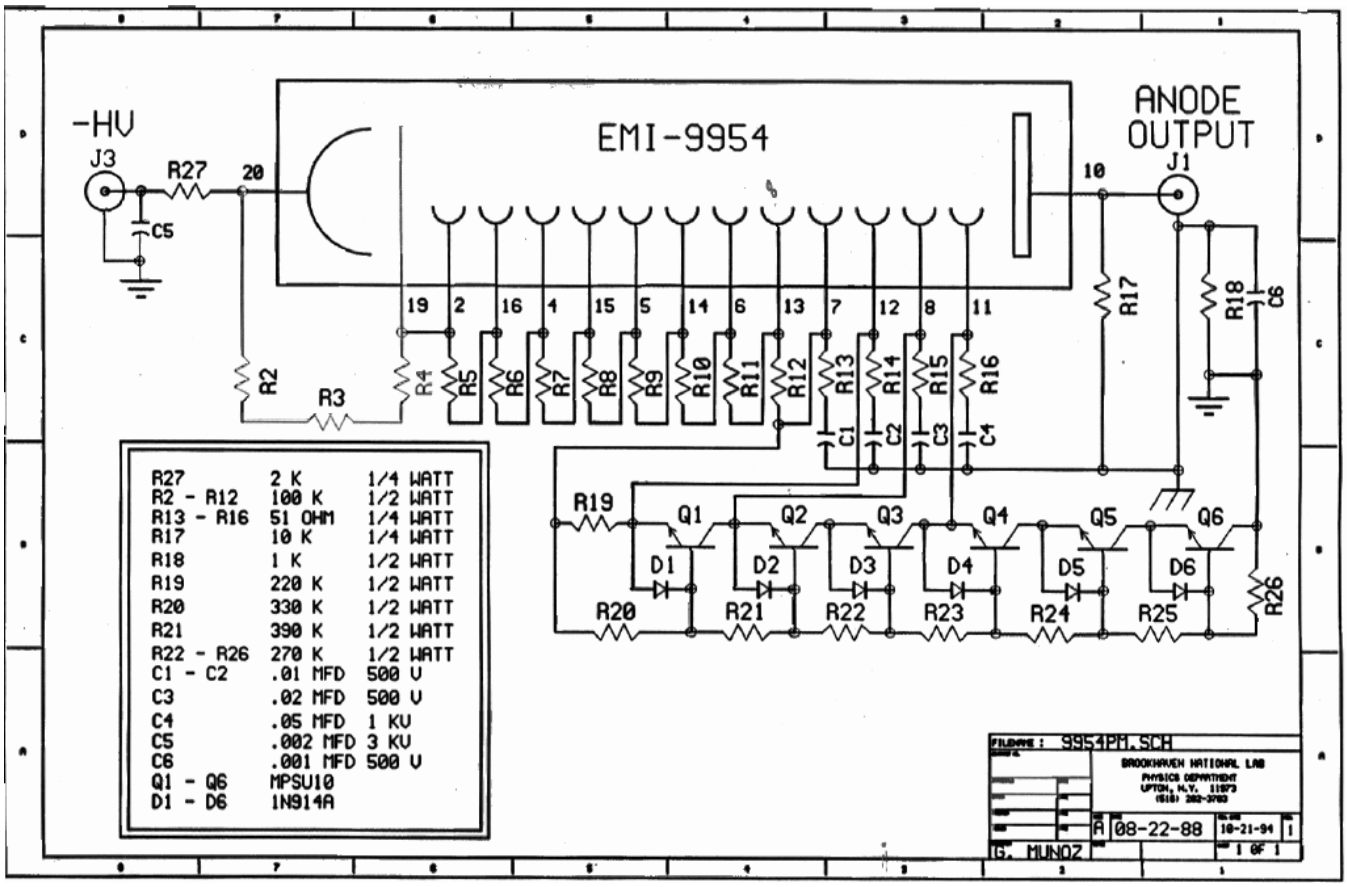
Warning

High voltages used by this photomultiplier may present a shock hazard. They should be installed and serviced only by qualified personnel and operated in accordance with the operating instructions.

Electron Tubes Limited Bury Street Ruislip Middlesex HA4 7TA England
tel: 01895 630771 fax: 01895 635053 e-mail: sales@electron-tubes.co.uk
Electron Tubes Inc. 100 Forge Way Unit F Rockaway NJ 07866 USA
tel: (800) 521 8382 fax: (201) 586 9771 e-mail: phototubes@aol.com

ISO 9001
registered

Figure 1EMI 9954-KB05 Specs from EMI (BNL records)

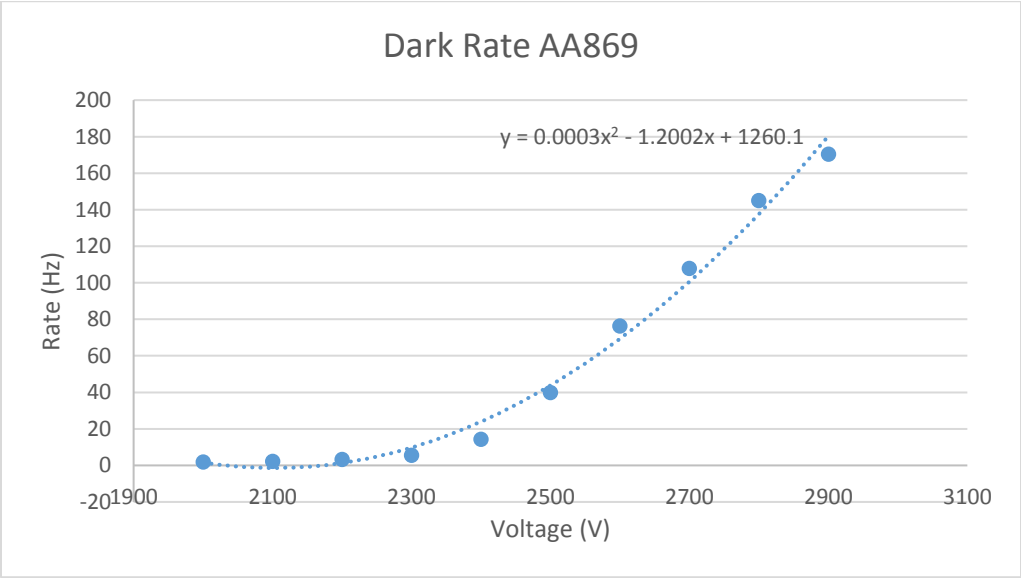

-HV
J3
R27
20
C5
EMI-9954
ANODE
OUTPUT
10
J1
19
2
16
4
15
5
14
6
13
7
12
8
11
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
R13
R14
R15
R16
C1
C2
C3
C4
R17
R18
C6
R19
Q1
Q2
Q3
Q4
Q5
Q6
D1
D2
D3
D4
D5
D6
R20
R21
R22
R23
R24
R25
R26
R27 2 K 1/4 WATT
R2 - R12 100 K 1/2 WATT
R13 - R16 51 OHM 1/4 WATT
R17 10 K 1/4 WATT
R18 1 K 1/2 WATT
R19 220 K 1/2 WATT
R20 330 K 1/2 WATT
R21 390 K 1/2 WATT
R22 - R26 270 K 1/2 WATT
C1 - C2 .01 MFD 500 V
C3 .02 MFD 500 V
C4 .05 MFD 1 KV
C5 .002 MFD 3 KV
C6 .001 MFD 500 V
Q1 - Q6 MPSU10
D1 - D6 1N914A
FILENAME : 9954PM.SCH
BROOKHAVEN NATIONAL LAB
PHYSICS DEPARTMENT
UPTON, N.Y. 11973
A 08-22-88
10-21-94
G. MUNOZ
1 OF 1

PMTs 1 - 44, 47 - 77 are H2431-50

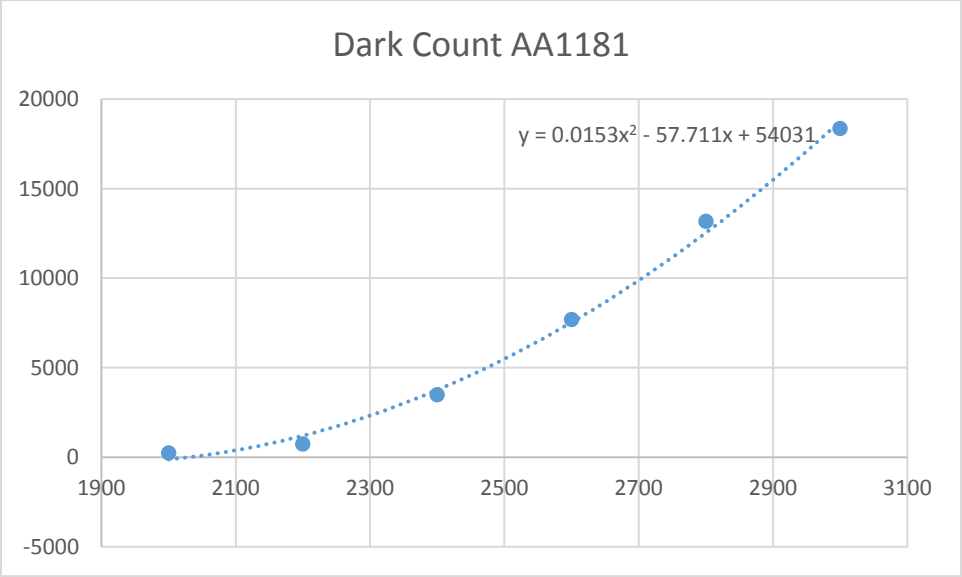
PMT's 1-4

PMT1 AA869
PMT2 AA1181
PMT3 AA2064
PMT4 AA774

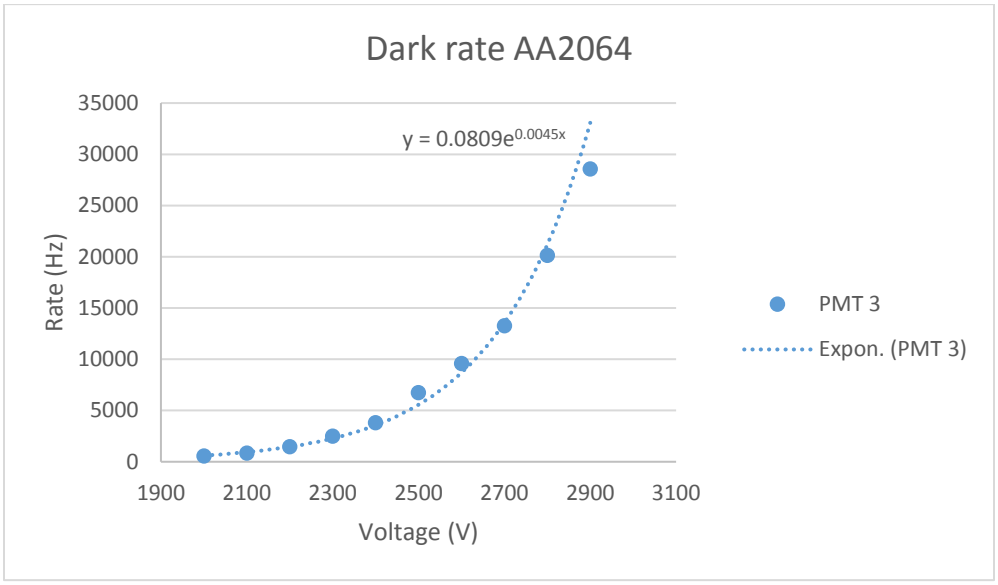
PMT1: AA869	tested on CH4					
Dark count in 12 sec with 10* amplification, and -30 mV threshold discrimination						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	22	20	23	21	26	1.866667
2100	23	20	34	31	29	2.283333
2200	47	38	37	31	41	3.233333
2300	63	75	63	64	72	5.616667
2400	165	181	163	194	163	14.43333
2500	442	481	453	504	515	39.91667
2600	941	897	954	894	900	76.43333
2700	1243	1258	1267	1333	1378	107.9833
2800	1790	1660	1691	1819	1739	144.9833
2900	2037	2088	1950	2097	2055	170.45



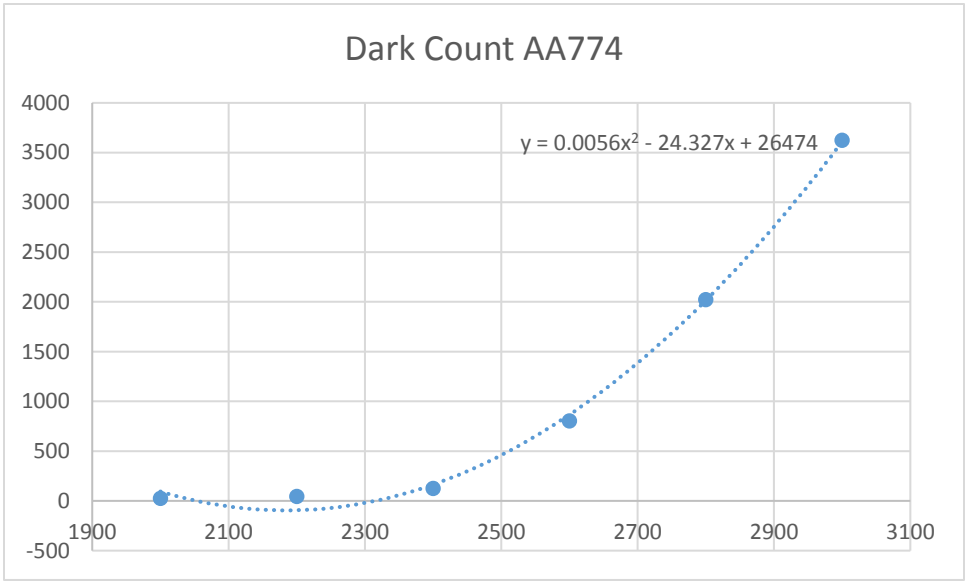
PMT 2: AA1181 Ch 2						
Dark Count in 12 sec., 10*amplification, -30mV threshold discrimination						
HV	count 1	count 2	count 3	count 4	count 5	count avg
2000	221	236	238	220	227	228.4
2200	794	757	778	641	702	734.4
2400	3544	3562	3378	3565	3372	3484.2
2600	7804	7680	7767	7637	7547	7687
2800	13856	13621	12737	12929	12735	13175.6
3000	18705	18574	18114	18376	17996	18353



PMT3: AA2064	CH3					
Dark count is in 12 sec with 10* amplification, and -30 mV threshold discrimination						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	6683	6722	6590	6761	6616	556.2
2100	10005	9877	9885	9811	9802	823
2200	17758	17406	17276	17176	17321	1448.95
2300	30048	29820	29976	29967	29585	2489.933
2400	45192	45369	44790	45763	45759	3781.217
2500	80318	80669	80961	80788	81243	6732.983
2600	115685	114237	114497	115896	114846	9586.017
2700	159438	157523	160424	160794	157827	13266.77
2800	240207	249823	240183	240610	236250	20117.88
2900	353632	346754	337886	335887	338937	28551.6



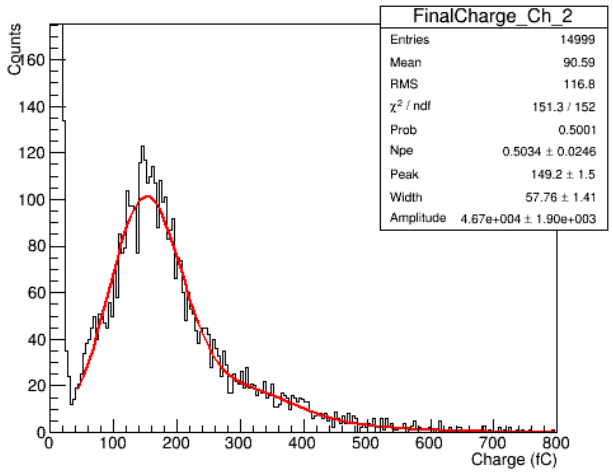
PMT 4: AA774, Ch. 4						
Dark Count in 12 sec., 10*amplification, -30mV threshold discrimination						
HV	count1	count2	count3	count4	count5	count avg
2000	28	34	25	25	25	27.4
2200	62	38	56	45	30	46.2
2400	130	143	103	134	120	126
2600	803	809	803	793	820	805.6
2800	1967	2106	2034	1982	2031	2024
3000	3573	3680	3562	3734	3584	3626.6

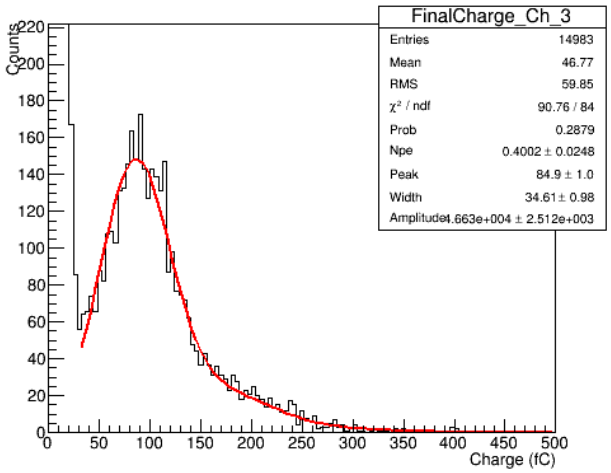


For PMT1-AA869 and PMT3-AA2064 we have yet to measure their gain.

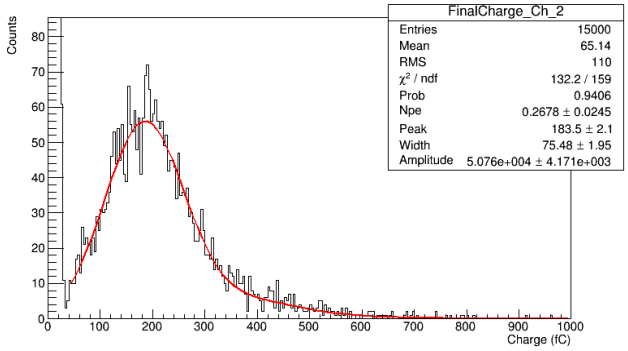
For these charge distribution histograms:
FinalCharge_Ch_2 = PMT2-AA1181 FinalCharge_Ch_3 = PMT4-AA774
Code used to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)
Code used to fit: fitnpe_XP2020

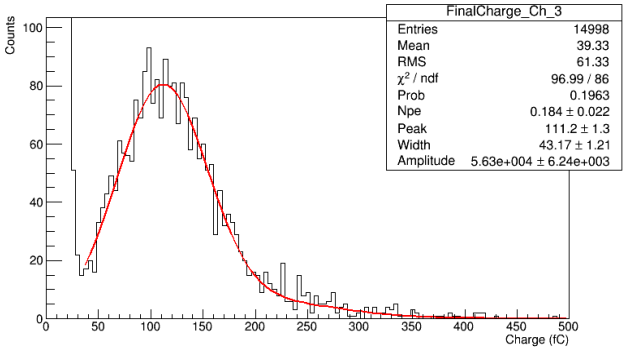
At HV = 2100V



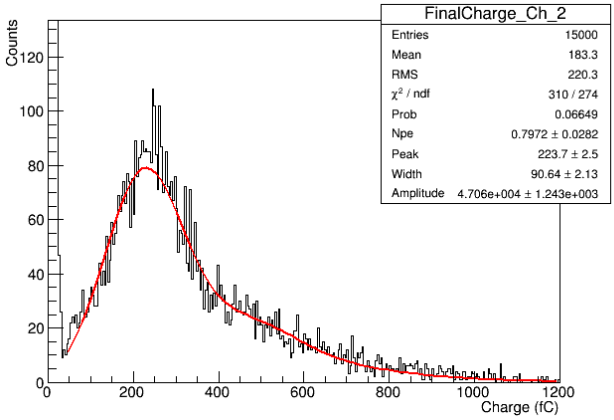


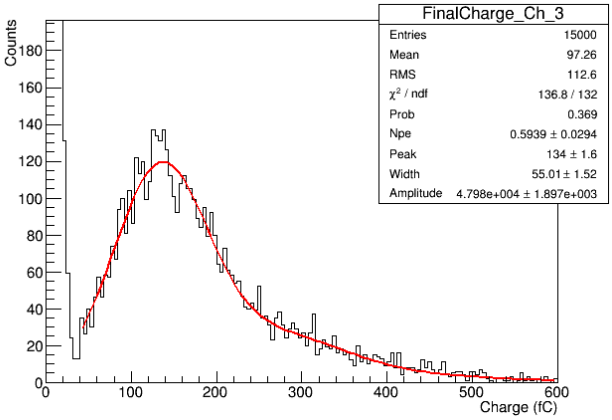
At 2200V

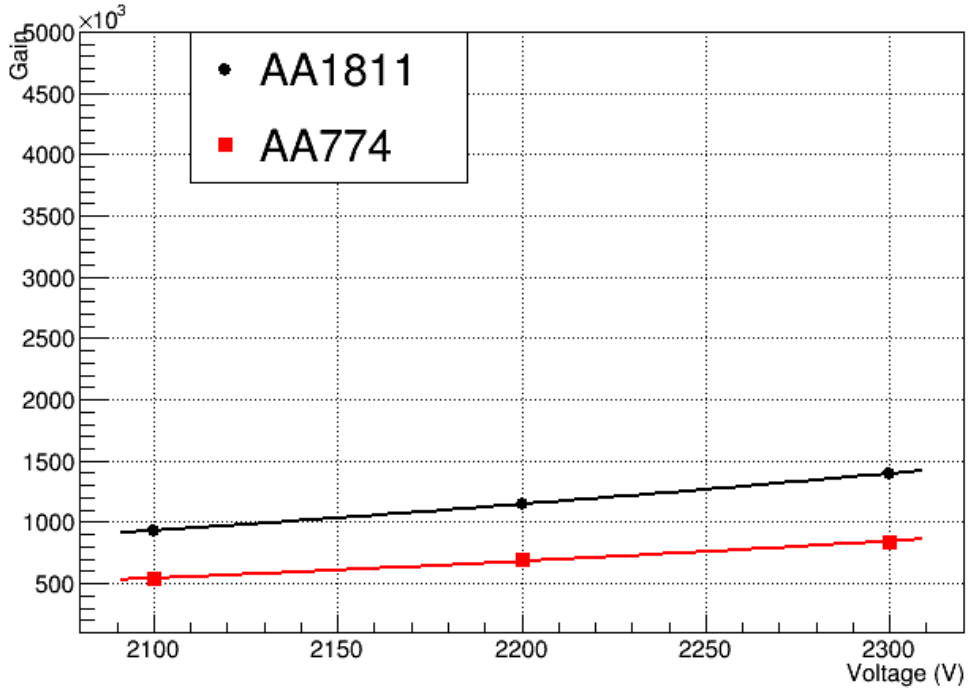




At 2300V







Gain Curves:
PMT2 AA1181
PMT4 AA774

Gain curve fit: Gain = C x V^P

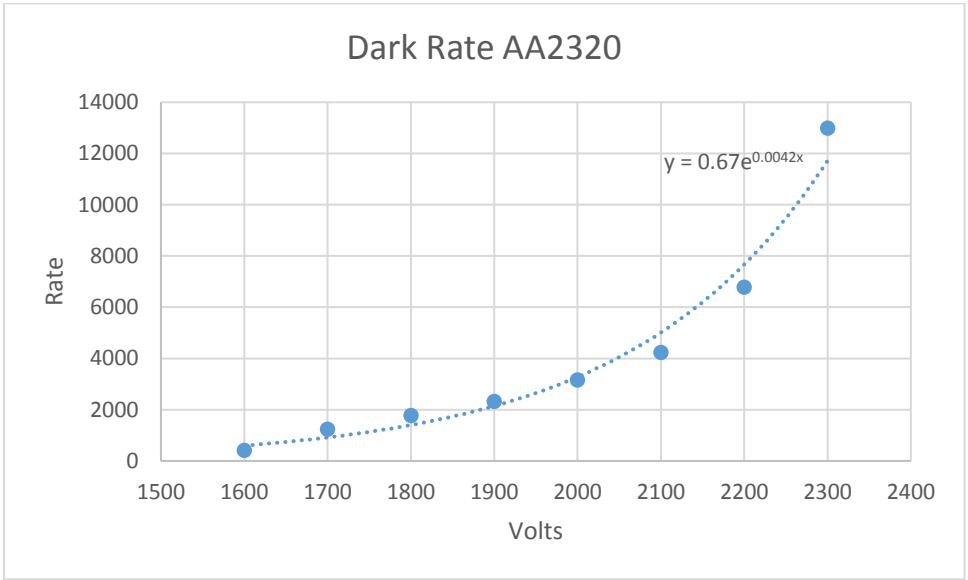
PMT#	**constant C**	**error on C**	**Power P**	**error on P**	**V at gain = 10E6**
AA1181	1.48901e-009	1.48271e-010	4.45384	0.0129432	2133.33
AA774	3.29889e-011	5.68122e-011	4.88116	0.223824	2380.02

PMT's 5-8

PMT5-AA2320
PMT6-AA2099
PMT7-AA790
PMT8-AA1799

PMT5-AA2320

PMT5: AA2320																	
Dark Count in 12 sec., 10* amplification, -30mV threshold discrimination																	
Voltage																	
1600 V		1700 V		1800 V		1900 V		2000 V		2100 V		2200 V		2300 V			
Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts
1	4740	1	9176	1	21367	1	29618	1	38273	1	51421	1	75259	1	152293		
2	4923	2	10054	2	21268	2	29470	2	38410	2	51093	2	81903	2	152869		
3	4865	3	11231	3	21713	3	29616	3	38040	3	51150	3	81592	3	153383		
4	4741	4	11385	4	21072	4	29497	4	38030	4	50938	4	81435	4	153488		
5	4706	5	11772	5	21339	5	29027	5 S	38150	5 S	51175	5	81760	5	152841		
6	4904	6	12215	10 S	21191	10 S	28967	6	38467	6	50551	10	82076	10 S	154159		
7	4838	7	11912	11	21301	11	29431	7	38066	7	50580	15 S	81928	11	153966		
8	4952	8	12245	12	21104	12	29044	8	38328	8	50753	16	81682	12	154252		
9	4937	9	12337	13	21279	13	28699	9	38233	9	50168	17	81501	13	154758		
10	5101	10	12250	14	21421	14	28044	10	37834	10	50745	18	81805	14	154626		
		15	15007	15	21622	15	28210	11	38299	11	50989	19	82015	15	154938		
		20	15014 S	16	21094	16	27421	12	37310	12	50883	20	81354	16	156809		
		21	14834	17	20948	17	26873	13	37699	13	50926	21	82028	17	157669		
		22	15073	18	21298	18	27111	14	37603	14	51137	22	80739	18	156649		
		23	15013	19	21237	19	26688	15	37787	15	50563	23	80855	19	158024		
		24	14764	20	21219	20	27000					24	80296	20	157351		
		25	14745									25	81285				
		26	14764														
		27	14798														
		28	14718														
		29	15006														
		30	14959														
avg	4870.7	avg	14867	avg	21252	avg	27852	avg	37963	avg	50730	avg	81356	avg	155304		
		after counts		after counts		after counts		after counts		after counts		after counts		after counts			
		stabilized		stabilized		stabilized		stabilized		stabilized		stabilized		stabilized			
Rate	405.89	Rate	1239	Rate	1771	Rate	2321	Rate	3163.6	Rate	4227.5	Rate	6779.7	Rate	12392		

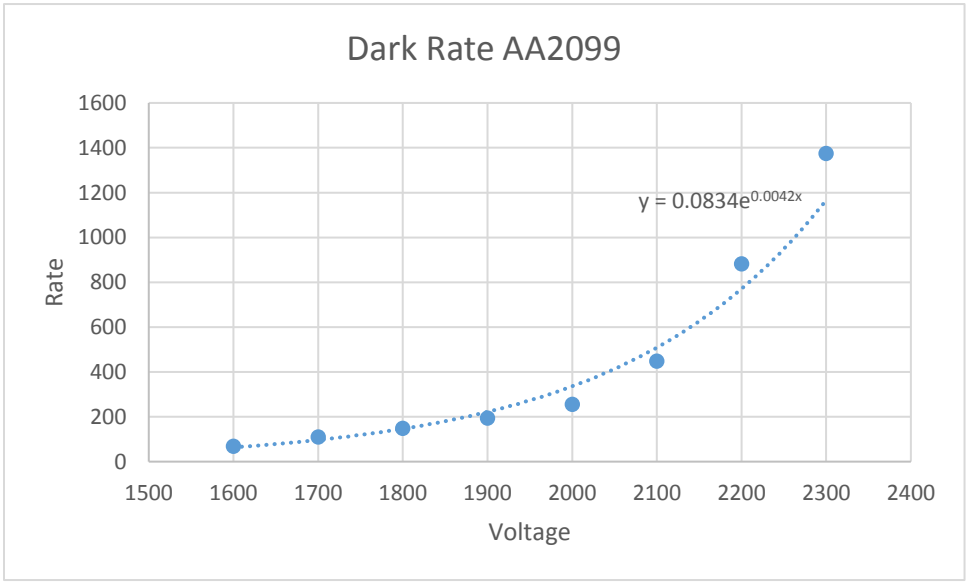


PMT6-AA2099

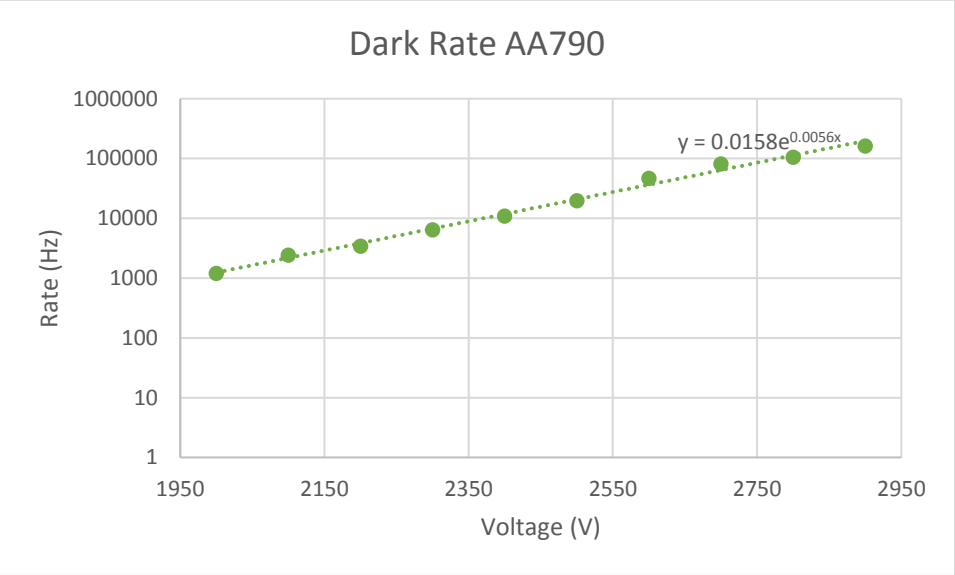
PMT6: AA2099

Dark Count in 12 sec., 10" amplification, -30mV threshold discrimination

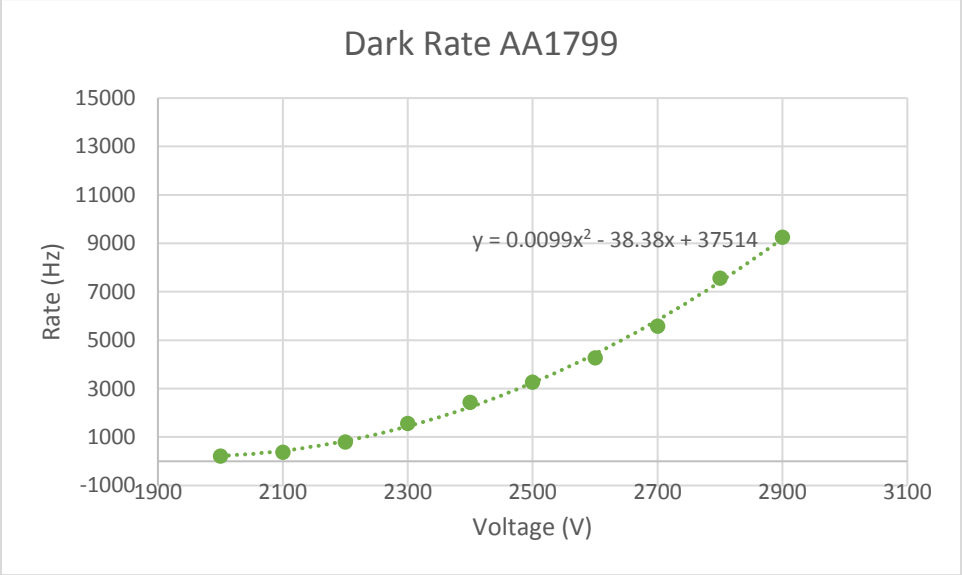
Voltage																	
1600 V		1700 V		1800 V		1900 V		2000 V		2100 V		2200 V		2300 V			
Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts	Time(min)	Counts		
1	824	1	1485	1	1794	1	2443	1	3153	1	5434	1	10985	1	17029		
2	882	2	1283	2	1818	2	2296	2	3125	2	5408	2	10795	2	16752		
3	865	3	1273	3	1803	3	2436	3	3068	3	5533	3	10646	3	16303		
4	820	4	1361	4	1803	4	2316	4	2961	4	5458	4	10864	4	16905		
5	832	5	1313	5	1760	5	2355	5 S	3053	5 S	5627	5	10694	5	16572		
6	827	6	1321	10 S	1768	10 S	2322	6	3135	6	5430	10	10461	10 S	16574		
7	836	7	1314	11	1785	11	2256	7	3169	7	5427	15 S	10414	11	16380		
8	833	8	1283	12	1807	12	2316	8	3045	8	5292	16	10547	12	16741		
9	791	9	1335	13	1798	13	2377	9	3038	9	5483	17	10322	13	16556		
10	830	10	1361	14	1795	14	2297	10	3120	10	5396	18	10693	14	16376		
		15	1241	15	1866	15	2385	11	2989	11	5466	19	10647	15	16439		
		20	1261 S	16	1796	16	2326	12	3048	12	5340	20	10596	16	16503		
		21	1268	17	1790	17	2307	13	3066	13	5354	21	10652	17	16609		
		22	1293	18	1766	18	2371	14	3031	14	5432	22	10612	18	16428		
		23	1359	19	1668	19	2317	15	3001	15	5287	23	10611	19	16521		
		24	1369	20	1813	20	2349					24	10493	20	16452		
		25	1315									25	10778				
		26	1386														
		27	1324														
		28	1372														
		29	1303														
		30	1278														
avg	834	avg	1326.7	avg	1788.4	avg	2330.1	avg	3064.2	avg	5390.7	avg	10595	avg	16500.5		
		after counts		after counts		after counts		after counts		after counts		after counts		after counts			
		stabilized		stabilized		stabilized		stabilized		stabilized		stabilized		stabilized			
Rate	69.5	Rate	110.56	Rate	149.03	Rate	194.18	Rate	255.35	Rate	449.23	Rate	882.93	Rate	1375.04		

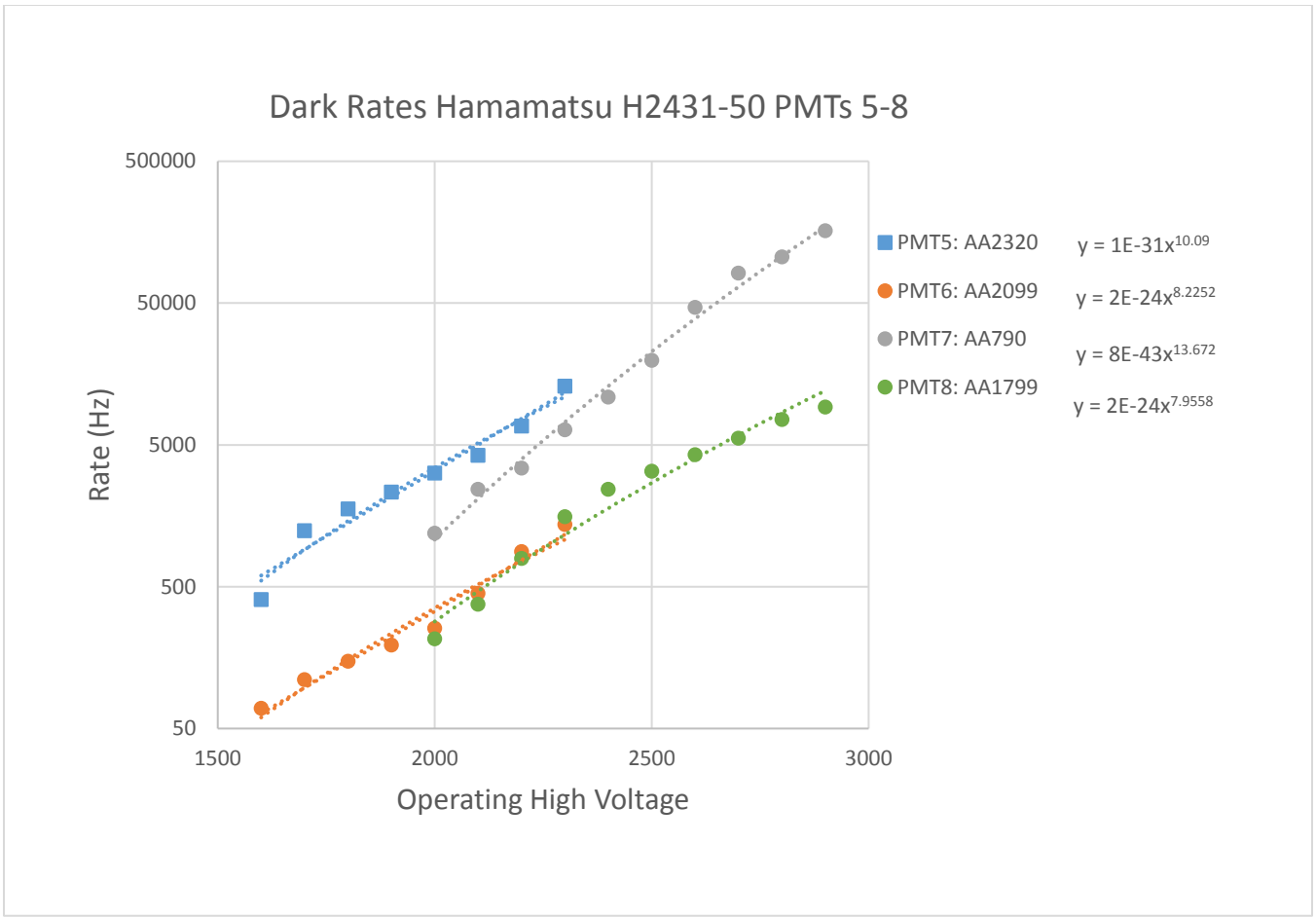


PMT7: AA790						
Dark count is in 12 sec with 10* amplification, and -30 mV threshold discrimination						
HV set at 2000V for 1 hour before testing						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	15278	14104	13867	14124	14334	1195.117
2100	25829	24560	29527	32538	33525	2432.983
2200	44720	44915	38526	37253	40104	3425.3
2300	58231	52323	107881	105581	60505	6408.683
2400	140115	162517	117295	110944	120469	10855.67
2500	180067	265580	241529	224330	270631	19702.28
2600	606805	569586	548456	600645	472649	46635.68
2700	893241	1059332	958134	1058664	912166	81358.95
2800	1453778	1446732	1100527	816211	1544257	106025.1
2900	2182521	1695486	1821610	2138386	1874723	161878.8



PMT8: AA1799	CH4					
Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination						
HV set > 2000V for 1 hour before testing; waited 10min after each HV change						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	1610	1658	1838	1761	1737	215.1
2100	2964	3007	2880	3083	3128	376.55
2200	5998	6299	6244	6274	6859	791.85
2300	12786	12377	12590	12325	12320	1559.95
2400	19670	19431	19513	19462	19206	2432.05
2500	26805	26114	26180	25662	25945	3267.65
2600	34063	33981	34644	34064	34094	4271.15
2700	44020	44981	44859	44723	44481	5576.6
2800	60183	60545	60540	60826	60435	7563.225
2900	74638	73552	73932	74187	73974	9257.075




Dark Rates Hamamatsu H2431-50 PMTs 5-8
500000
50000
5000
500
50
Rate (Hz)
1500
2000
2500
3000
Operating High Voltage
PMT5: AA2320
PMT6: AA2099
PMT7: AA790
PMT8: AA1799
y = 1E-31x^10.09
y = 2E-24x^8.2252
y = 8E-43x^13.672
y = 2E-24x^7.9558

For these Charge Distribution Histograms:

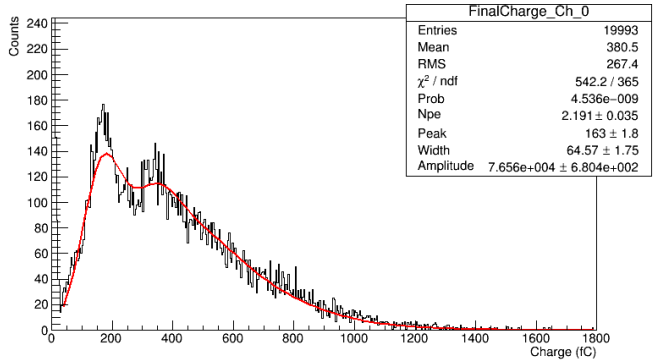
FinalCharge_Ch_0 = PMT5-AA2320 FinalCharge_Ch_1 = PMT6-AA2099

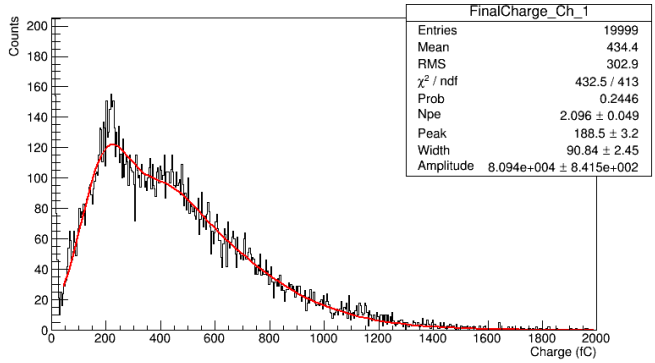
FinalCharge_Ch_2 = PMT7-AA790 FinalCharge_Ch_3 = PMT8-AA1799

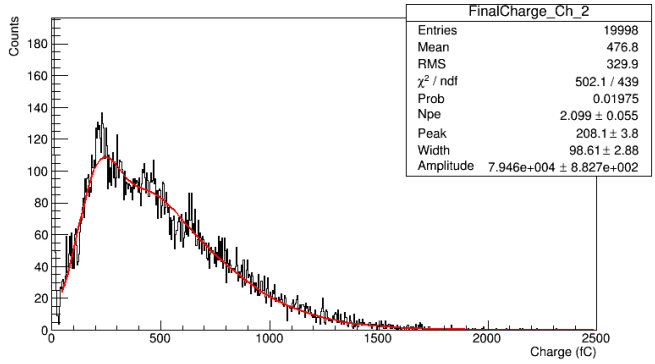
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

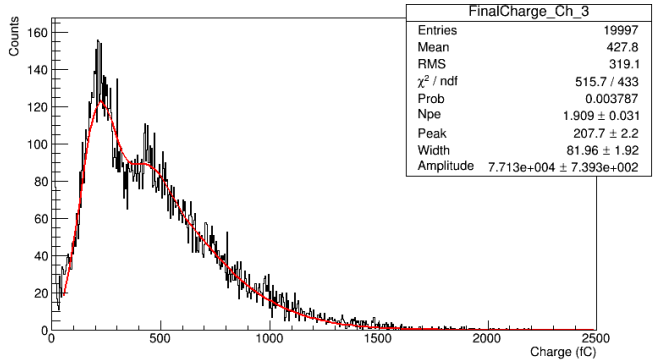
Code used to fit: fitnpe_XP2020

At HV = 2000V

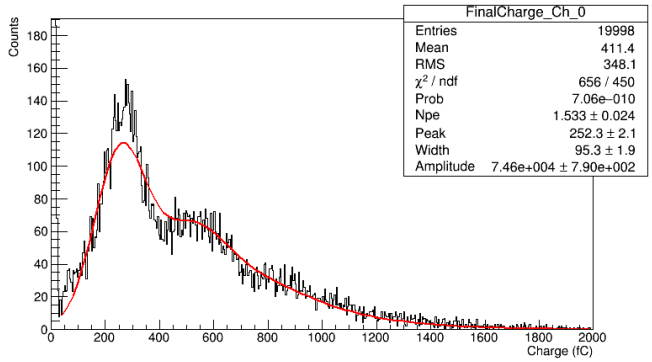


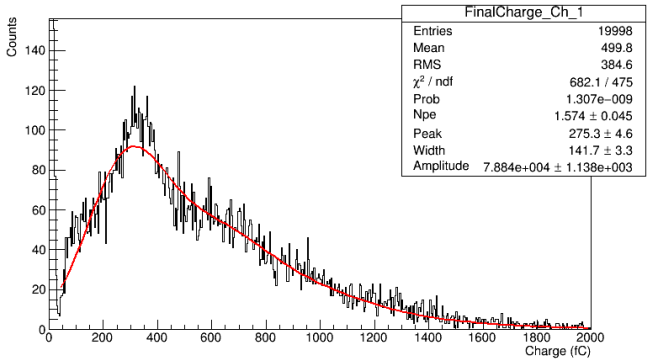


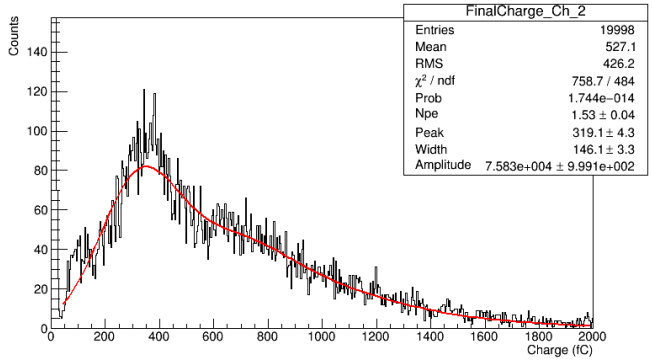


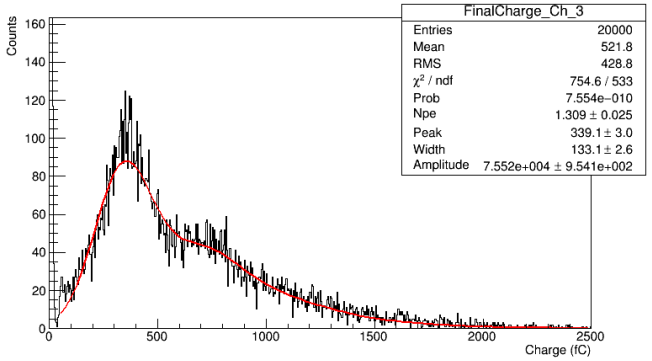


At 2200V

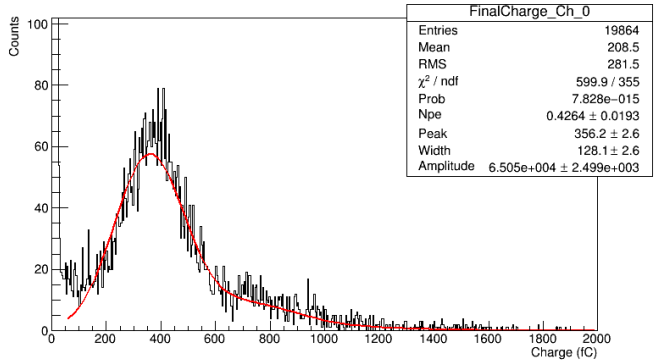


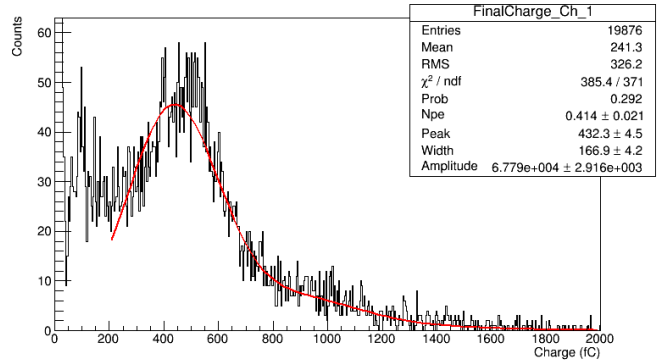


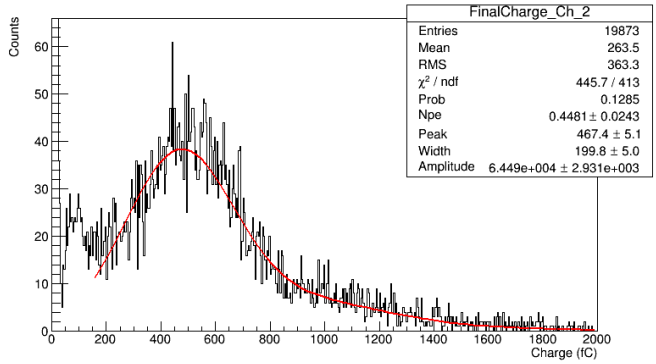


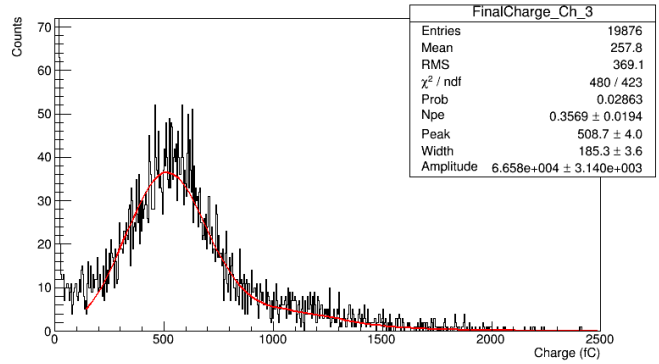


At 2400V

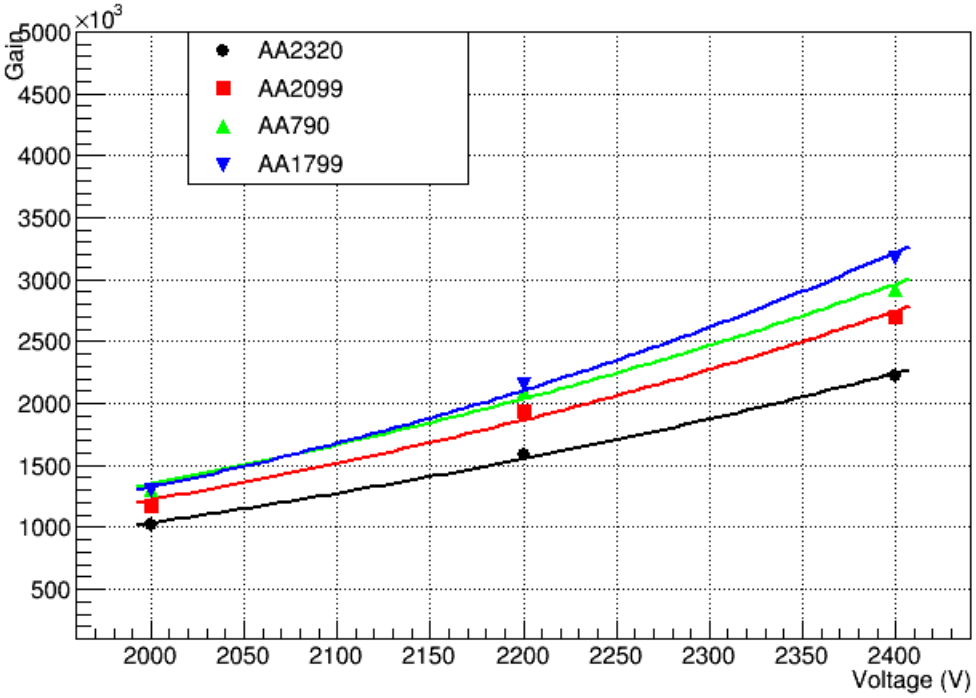


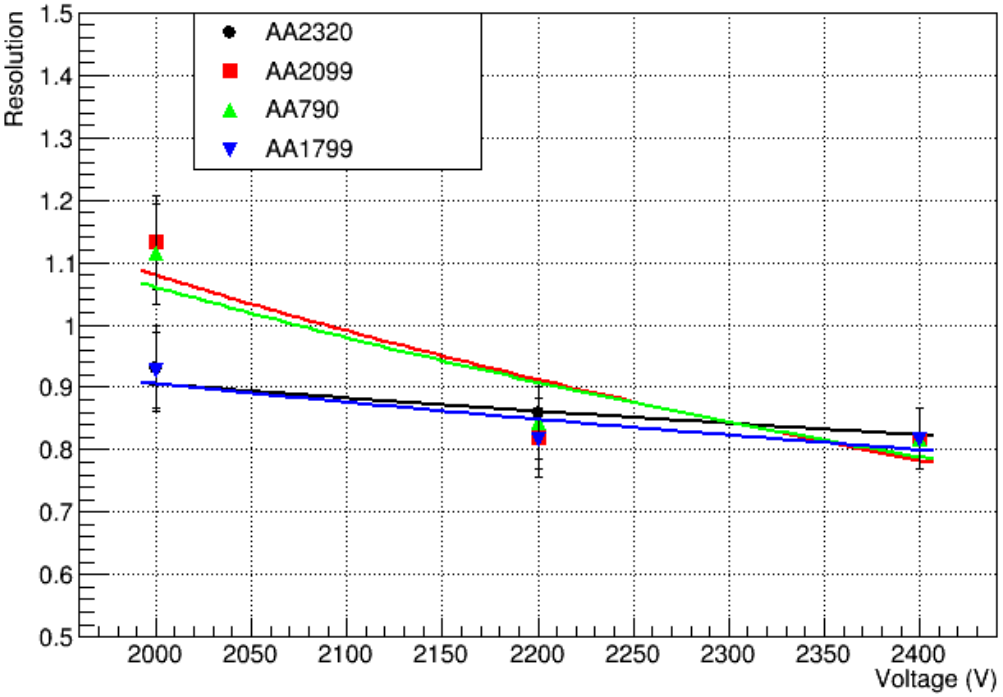






Gain curves and resolution curves: PMT5-AA2320, PMT6-AA2099, PMT7-AA790, PMT8-AA1799





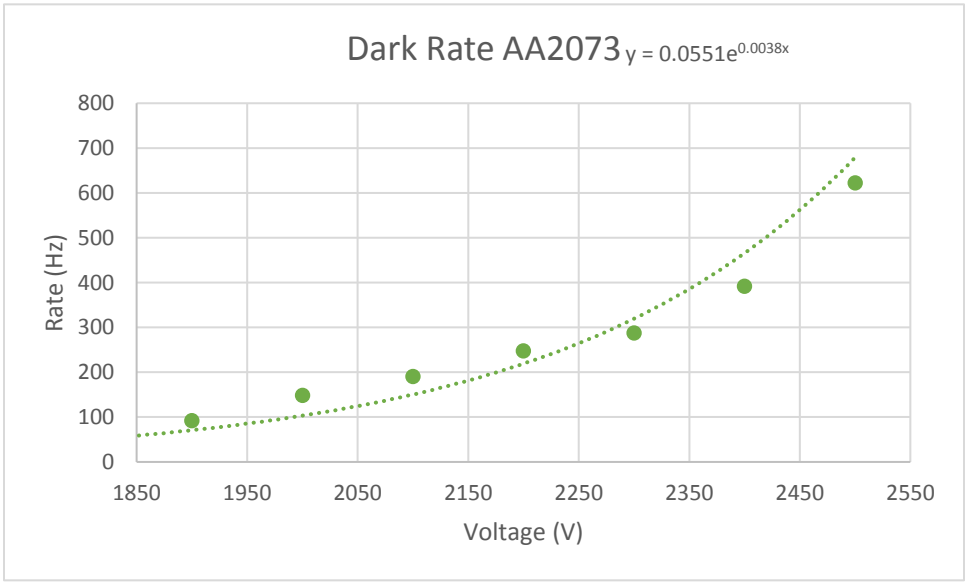
PMT's 9-12

PMT9-AA2073
PMT10-AA1994
PMT11-AA1839
PMT12-AA1942

PMT9-AA2073

Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination
HV set > 2000V for 1 hour before testing; waited 10min after each HV change

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	227	204	217	181	221	26.25
1900	715	677	788	748	753	92.025
2000	1155	1162	1169	1235	1208	148.225
2100	1522	1627	1480	1495	1483	190.175
2200	2078	1925	1917	2024	1952	247.4
2300	2391	2236	2331	2192	2337	287.175
2400	3187	3305	3091	3109	2976	391.7
2500	5603	5165	4795	4783	4548	622.35

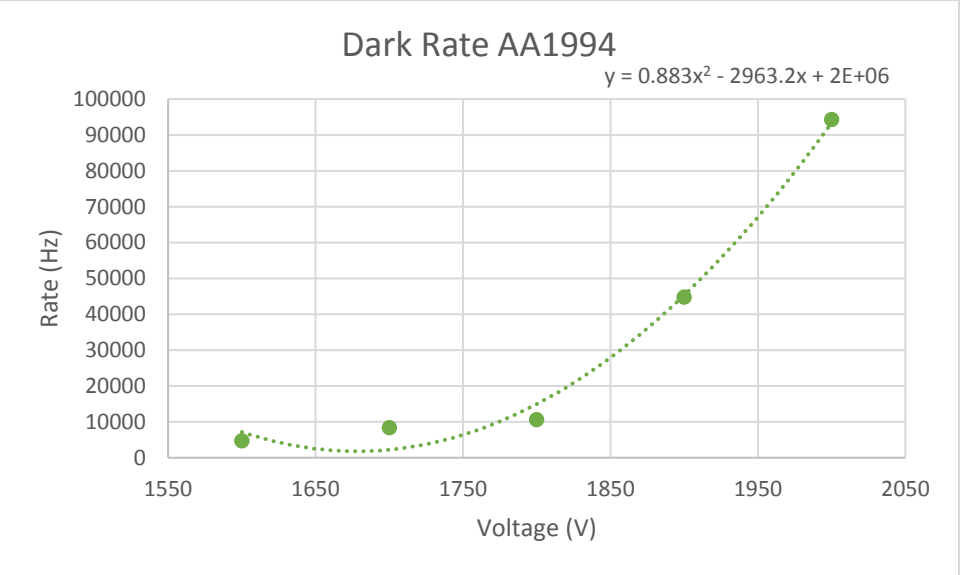


PMT10 – AA1994

Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination

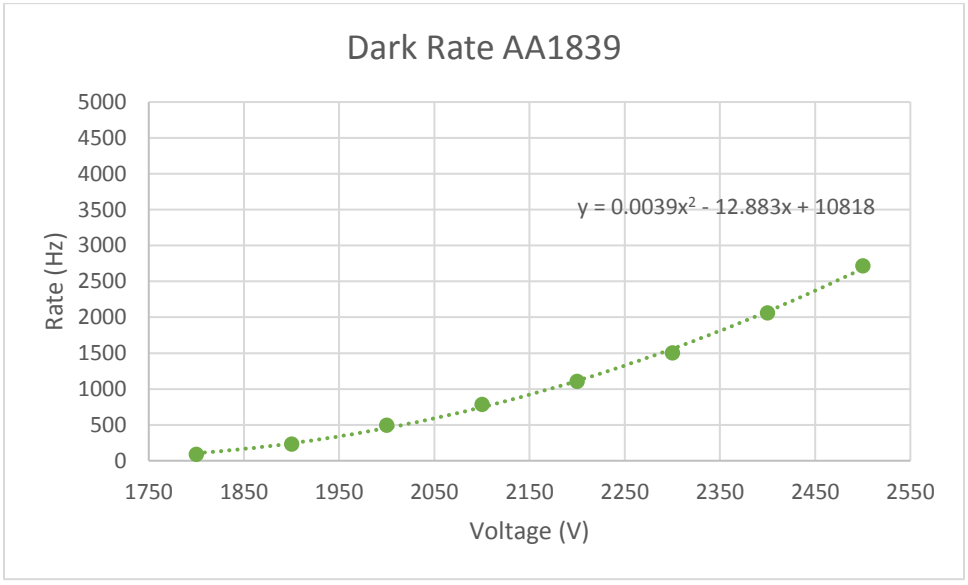
HV set > 2000V for 1 hour before testing; waited 10min after each HV change

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1600	38370	39612	36375	37470	40023	4796.25
1700	68522	69792	65792	68472	65501	8451.975
1800	87452	81715	82788	86199	88799	10673.83
1900	367406	366972	355558	344970	358616	44838.05
2000	769387	747058	750741	765157	740883	94330.65



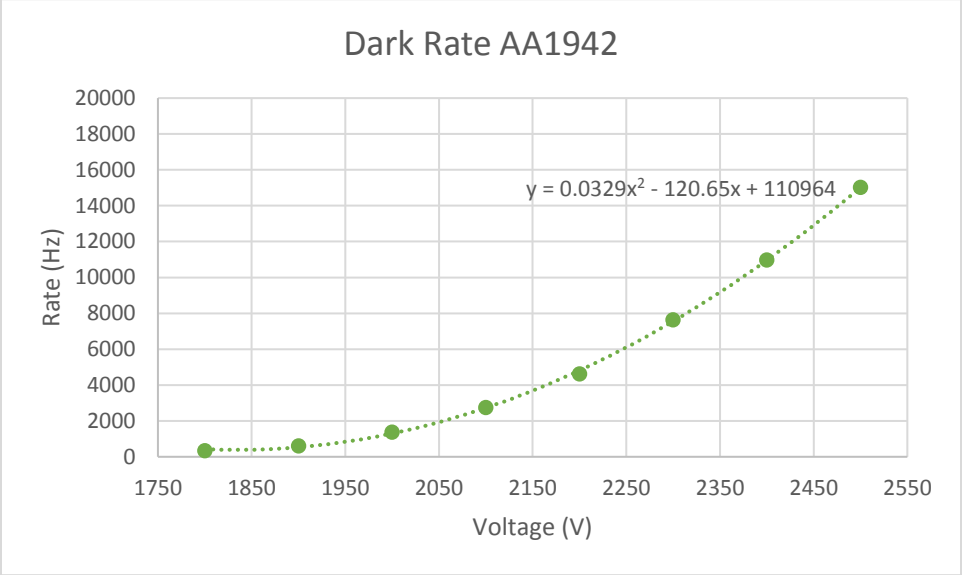
PMT11 – AA1839

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	727	748	671	695	693	88.35
1900	1910	1830	1930	1779	1860	232.725
2000	4047	4048	4041	3776	3788	492.5
2100	6558	6388	6186	6257	5993	784.55
2200	9131	9081	8783	8827	8484	1107.65
2300	12265	11793	11769	12232	12111	1504.25
2400	17006	16737	16770	16088	15803	2060.1
2500	21476	21612	21356	21854	22331	2715.725



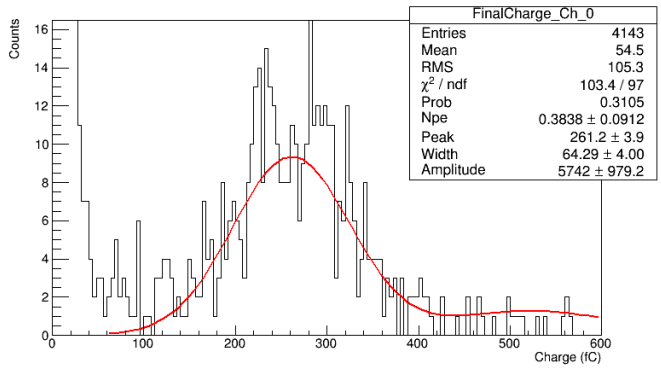
PMT12 – AA1942

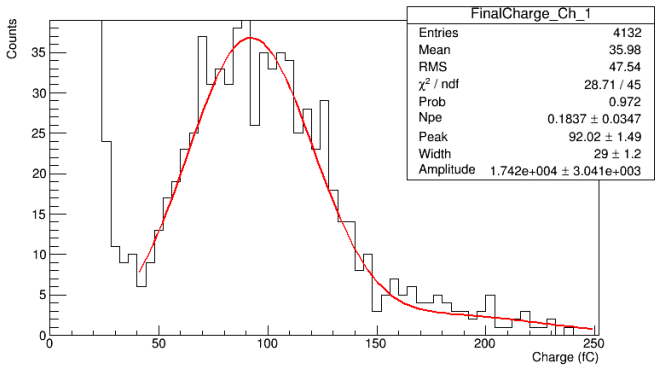
Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination						
HV set > 2000V for 1 hour before testing; waited 10min after each HV change						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	2796	2786	2778	2674	2766	345
1900	4803	4833	5056	4899	4874	611.625
2000	11105	11232	11131	10668	11120	1381.4
2100	22663	21906	21863	21662	21456	2738.75
2200	36625	37113	37640	36366	36888	4615.8
2300	60858	60706	62170	61688	60377	7644.975
2400	88356	87895	87177	87389	88032	10971.23
2500	116359	119807	118034	123468	123127	15019.88

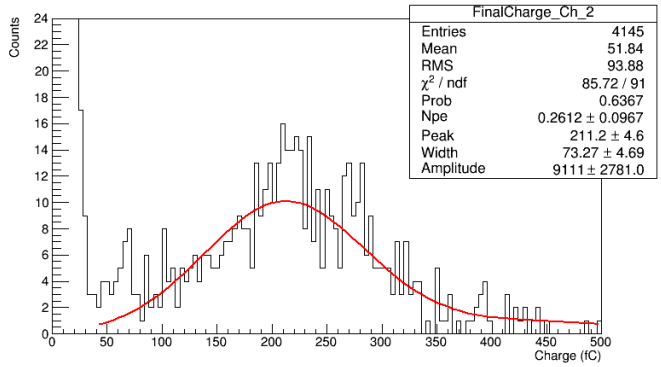


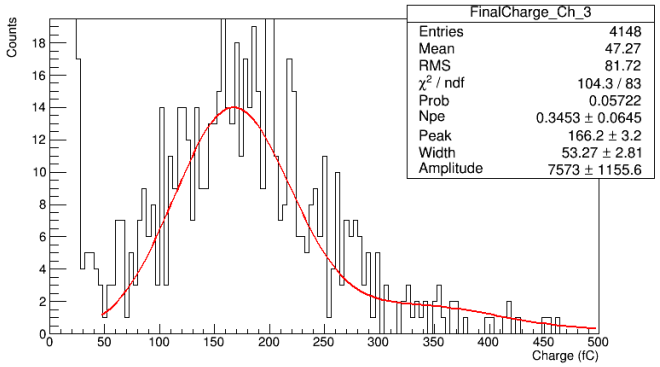
For these Charge Distribution Histograms:
FinalCharge_Ch_0 = PMT9-AA2073 FinalCharge_Ch_1 = PMT10-AA1994
FinalCharge_Ch_2 = PMT11-AA1839 FinalCharge_Ch_3 = PMT12-AA1942
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)
Code used to fit: fitnpe_XP2020

At 1800V

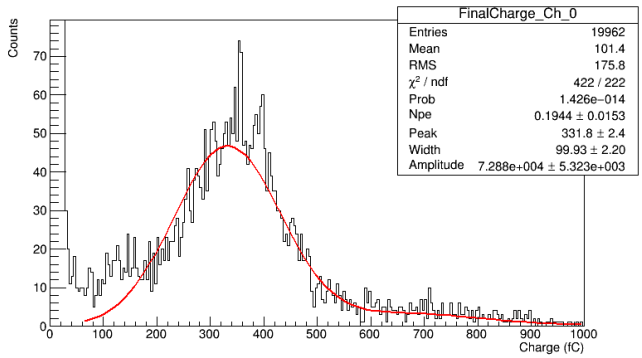


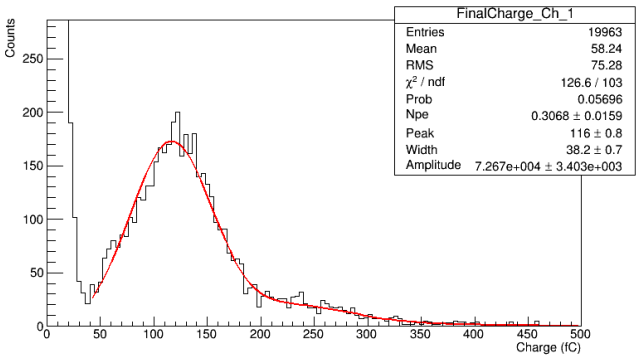


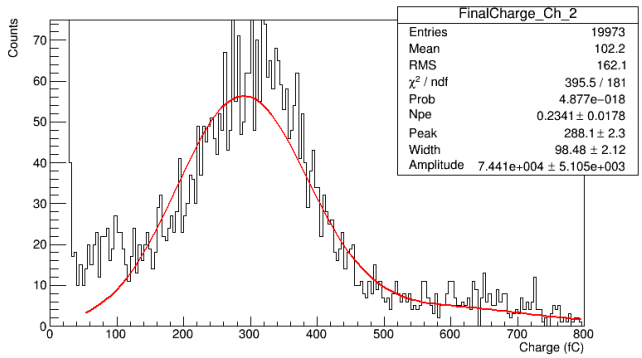


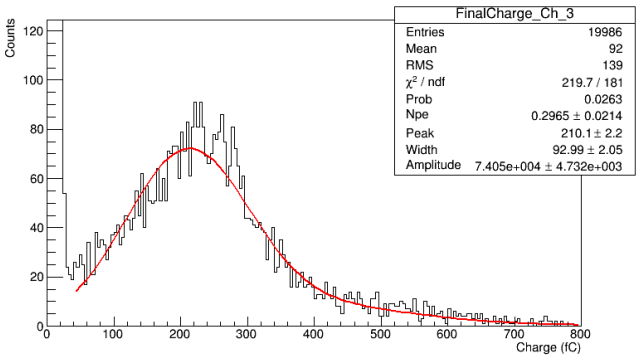


At 1900V

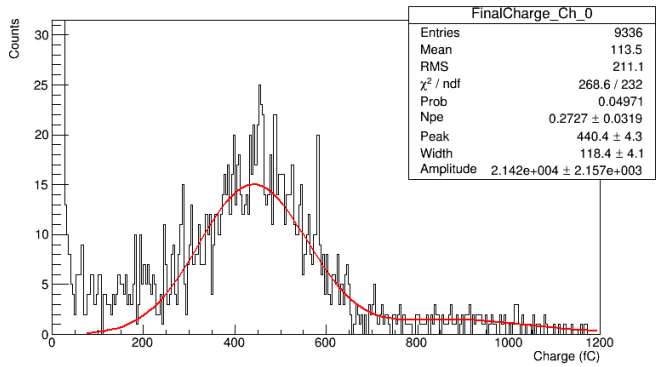


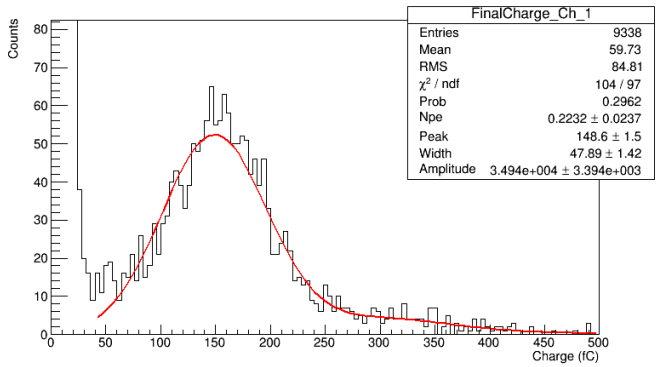


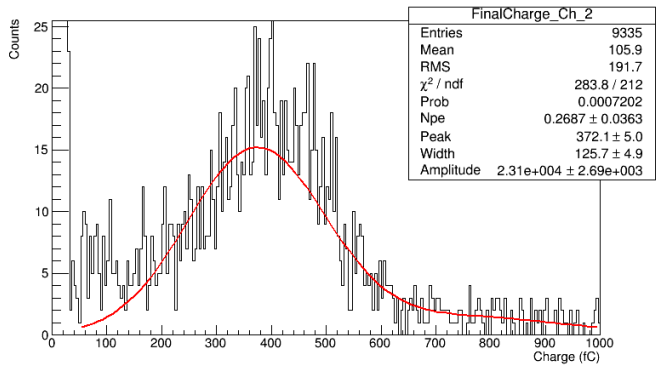


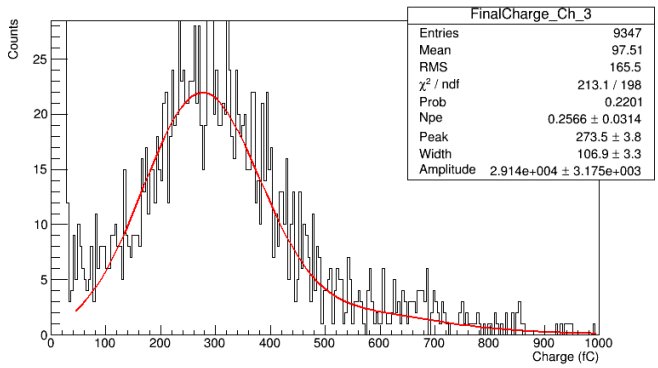


At 2000V

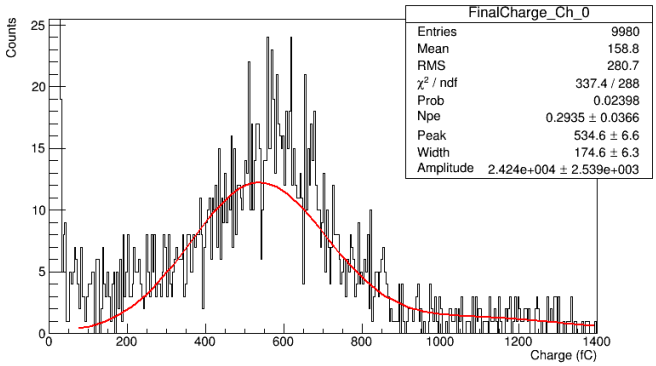


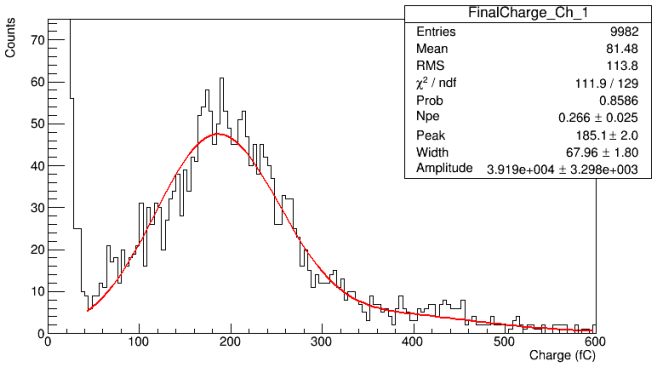


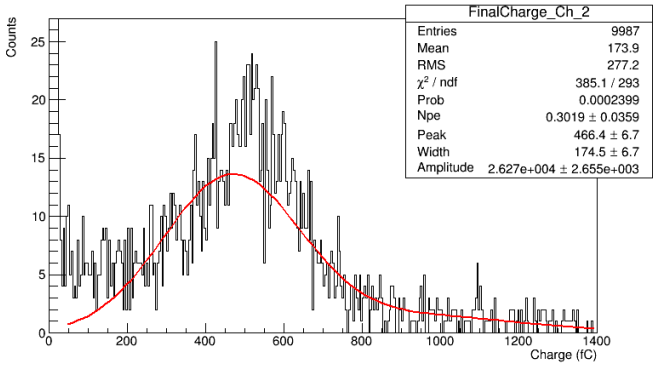


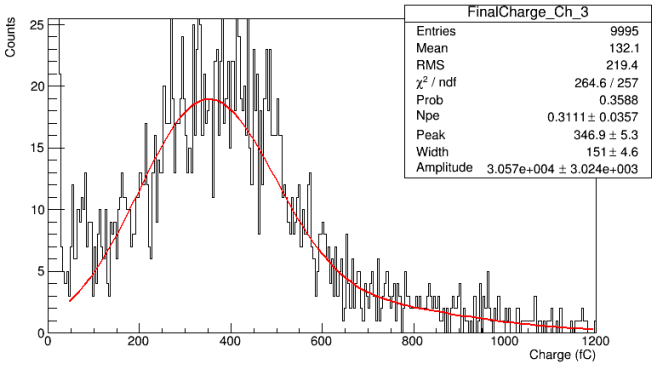


At 2100V

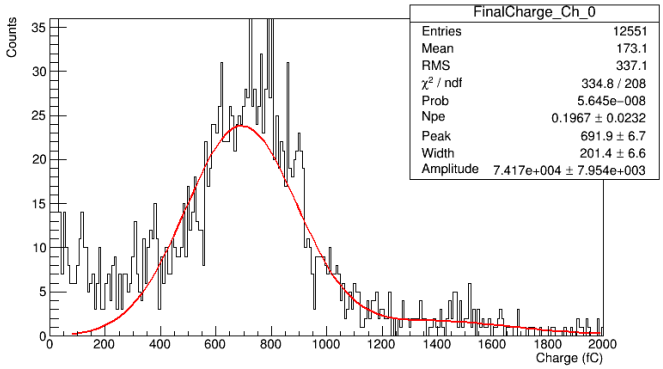


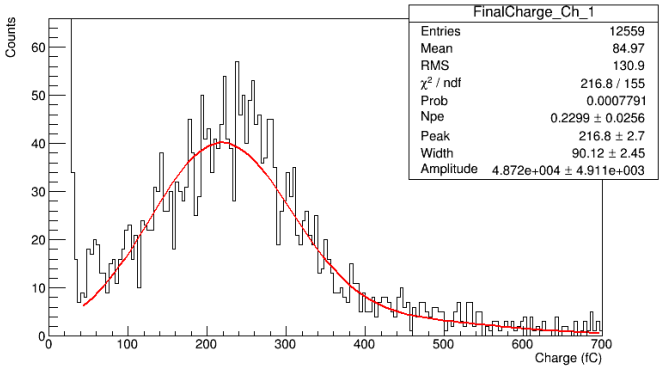


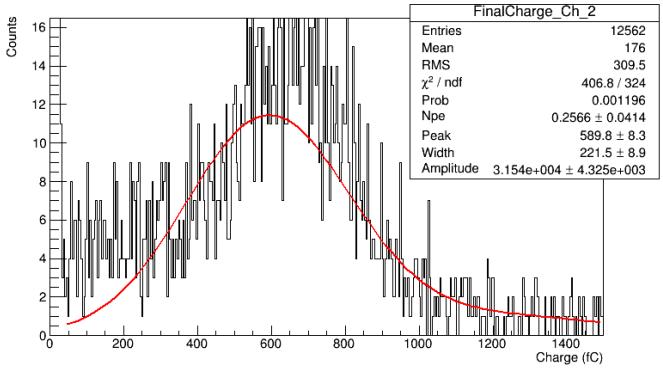


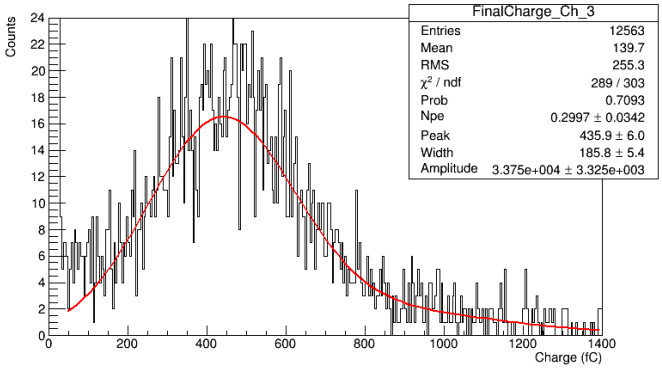


At 2200V

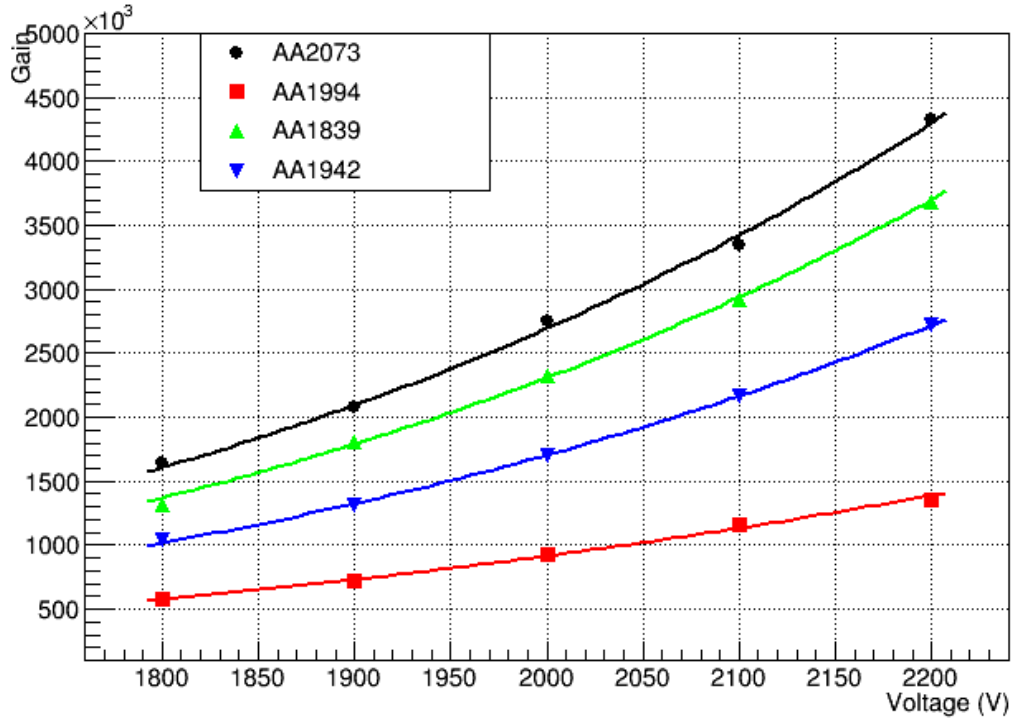


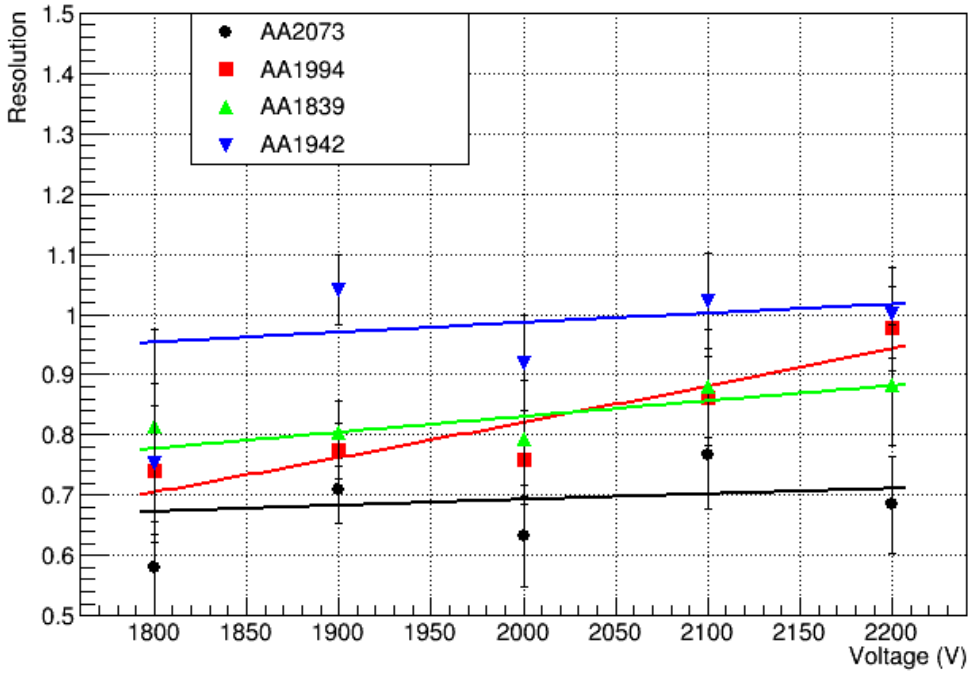






Gain and resolution curves: PMT9-AA2073, PMT10-AA1994**,** PMT11-AA1839, PMT12-AA1942

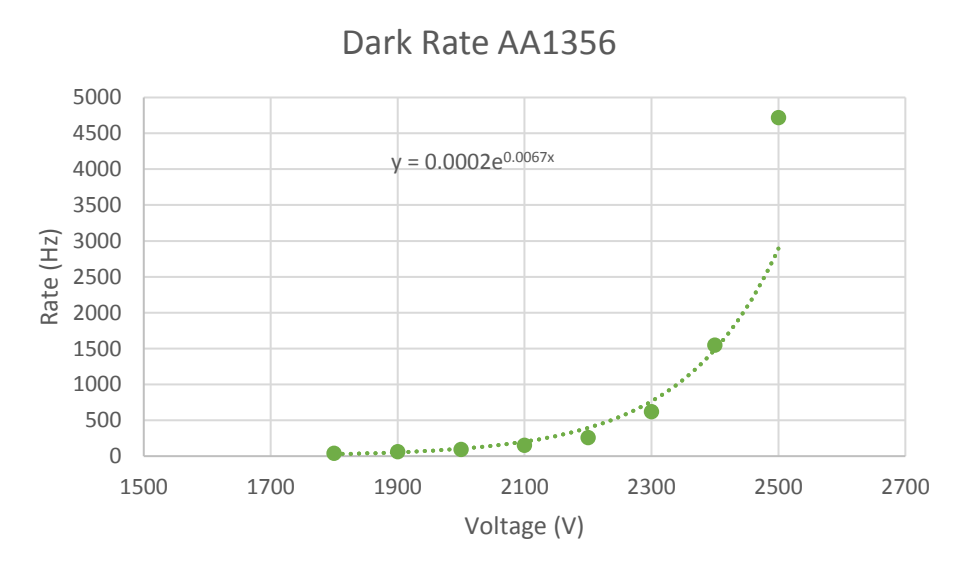




PMT's 13-16

PMT13-AA1356
PMT14-AA637
PMT15-AA1434
PMT16-AA1538

PMT 13 AA1356 CH1						
Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination						
HV set > 2000V for 1 hour before testing; waited 10min after each HV change						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	304	314	309	297	315	38.475
1900	513	487	537	500	495	63.3
2000	749	768	743	715	732	92.675
2100	1220	1200	1165	1205	1210	150
2200	2268	1882	1931	1928	2368	259.425
2300	4731	5096	4946	4768	5226	619.175
2400	10606	12574	13502	12831	12395	1547.7
2500	39282	35162	38963	38642	36793	4721.05

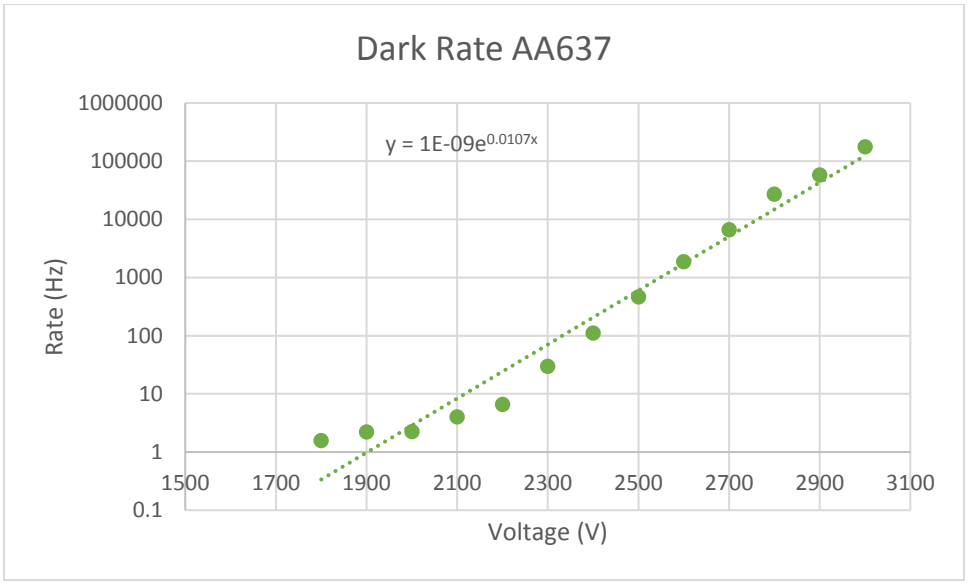


PMT 14 AA637 CH2

Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination

HV set > 2000V for 1 hour before testing; waited 10min after each HV change

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	12	13	12	11	15	1.575
1900	17	18	13	17	24	2.225
2000	12	17	25	17	19	2.25
2100	32	30	30	38	31	4.025
2200	70	48	59	46	43	6.65
2300	230	202	217	282	263	29.85
2400	921	802	943	921	864	111.275
2500	3699	3663	3674	3638	4068	468.55
2600	13595	14769	14027	16108	16384	1872.075
2700	55826	59871	45834	50526	55916	6699.325
2800	230883	211523	234475	209725	206767	27334.33
2900	437126	441570	428832	466361	539490	57834.48
3000	1413874	1272215	1534879	1427808	1466096	177871.8

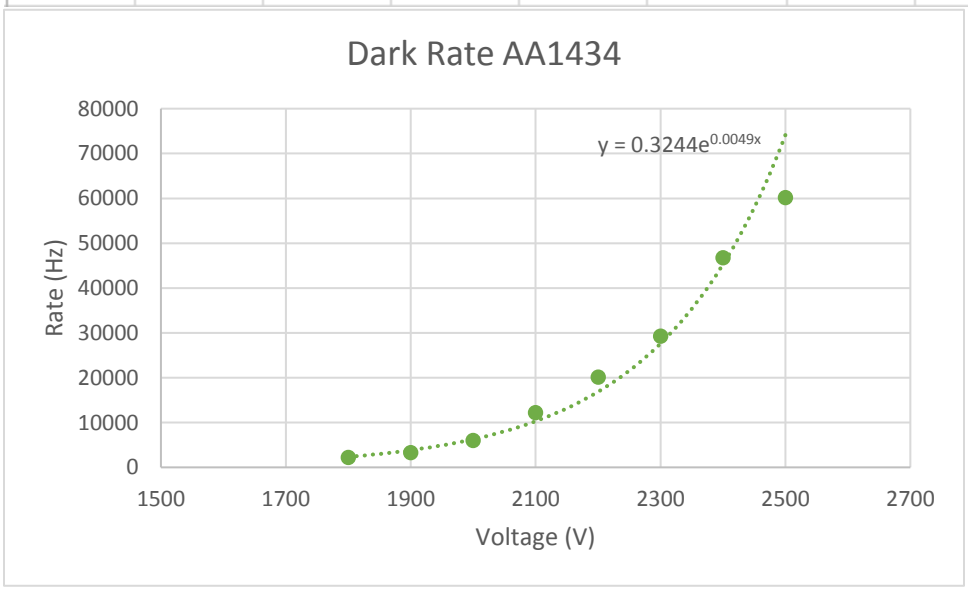


PMT 15 AA1434 CH3

Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination

HV set > 2000V for 1 hour before testing; waited 10min after each HV change

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	18312	17758	18176	18133	18022	2260.025
1900	26921	26680	26397	26017	26378	3309.825
2000	49417	47602	47626	47700	47964	6007.725
2100	97328	99196	97262	98582	96127	12212.38
2200	162583	159554	162532	160768	160233	20141.75
2300	235235	236007	231008	238001	230424	29266.88
2400	369344	385678	381565	363645	368865	46727.43
2500	453827	552964	450370	486865	462957	60174.58

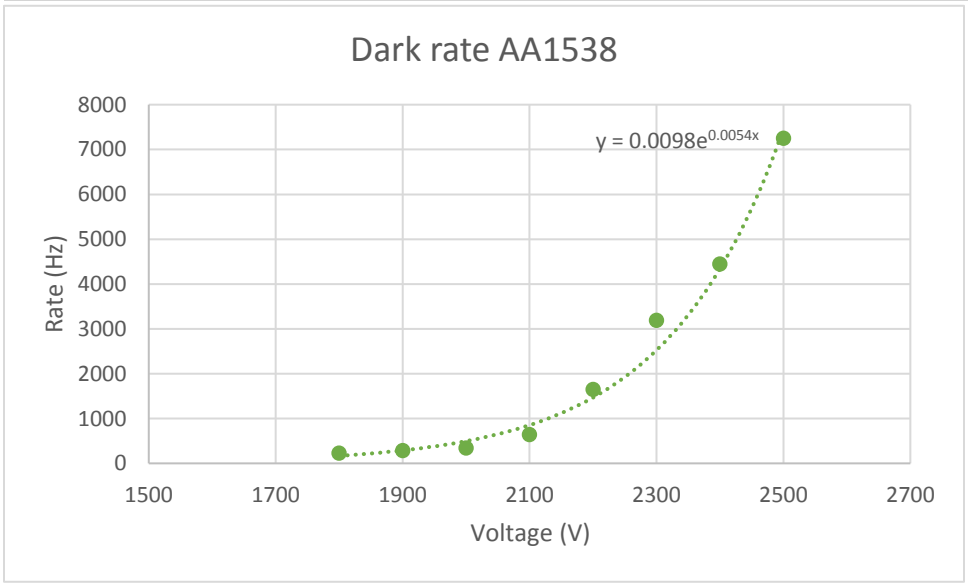


PMT 16 AA1538 CH4

Dark count is in 8 sec with 10* amplification, and -30 mV threshold discrimination

HV set > 2000V for 1 hour before testing; waited 10min after each HV change

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	2056	1686	1783	1918	1738	229.525
1900	2242	2103	2239	2476	2461	288.025
2000	2882	2611	2726	2781	2679	341.975
2100	5163	5211	4923	5182	5269	643.7
2200	13577	13060	13193	13360	12894	1652.1
2300	25558	25433	25448	25624	25718	3194.525
2400	33728	34428	34833	36634	38284	4447.675
2500	58416	57885	57772	59428	56635	7253.4



For these Charge Distribution Histograms:

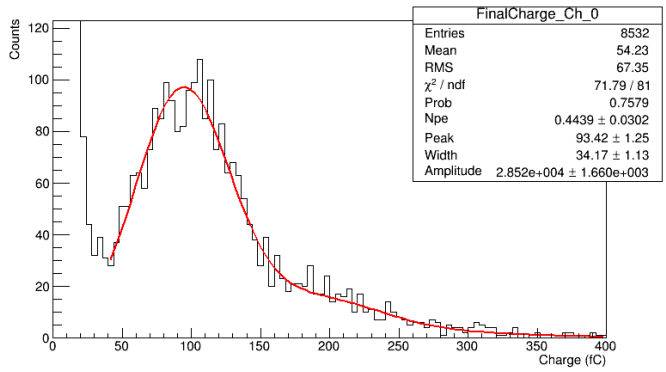
FinalCharge_Ch_0 = PMT13-AA1356 FinalCharge_Ch_1 = PMT14-AA637

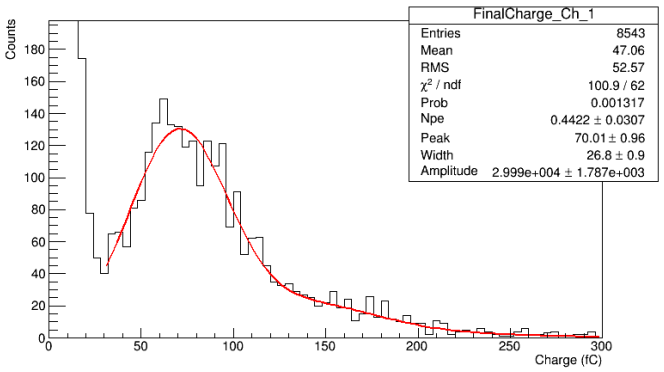
FinalCharge_Ch_2 = PMT15-AA1434 FinalCharge_Ch_3 = PMT16-AA1538

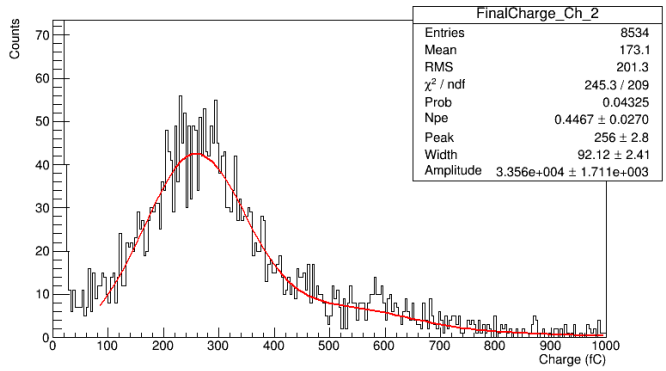
Code used to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

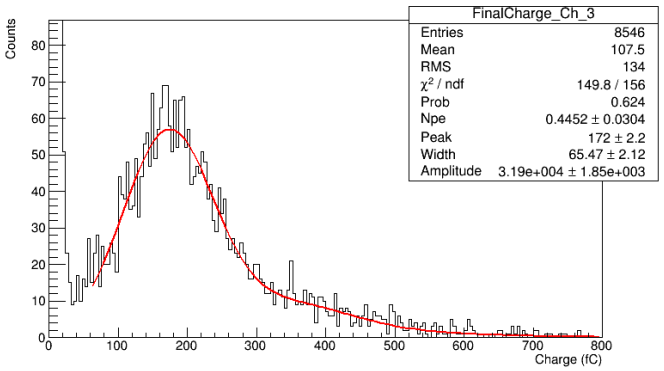
Code used to fit: fitnpe_XP2020

At 2000V

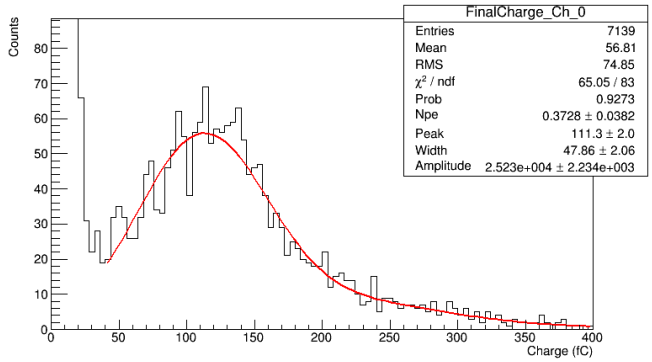


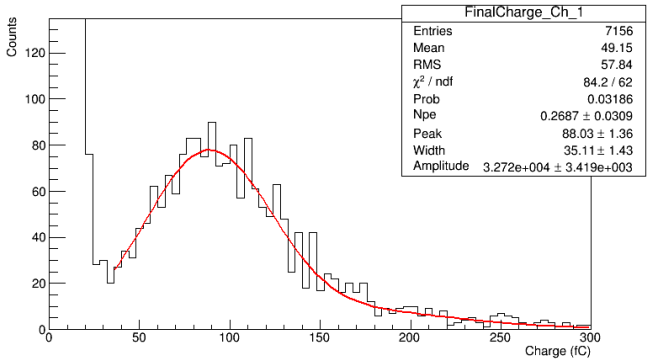


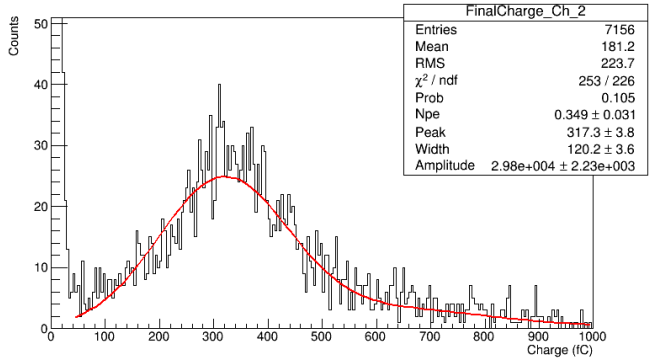


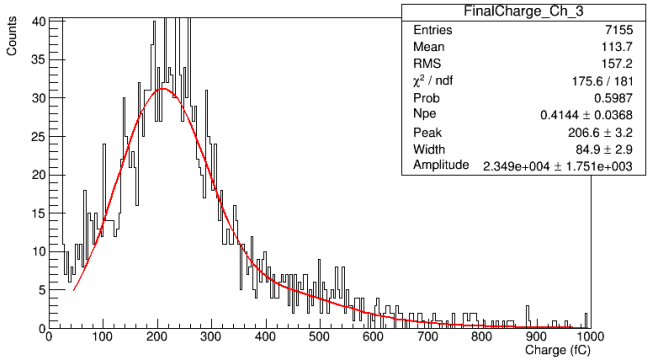


At 2100V

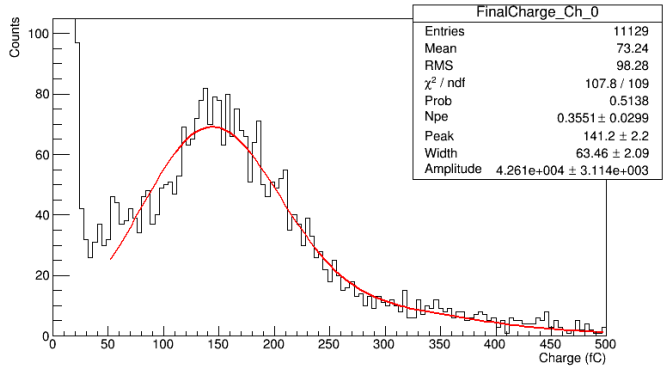


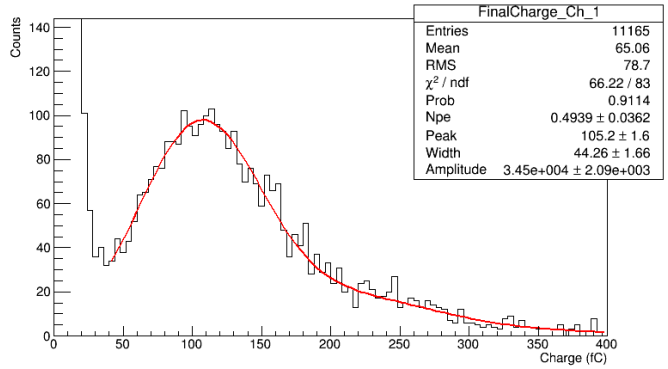


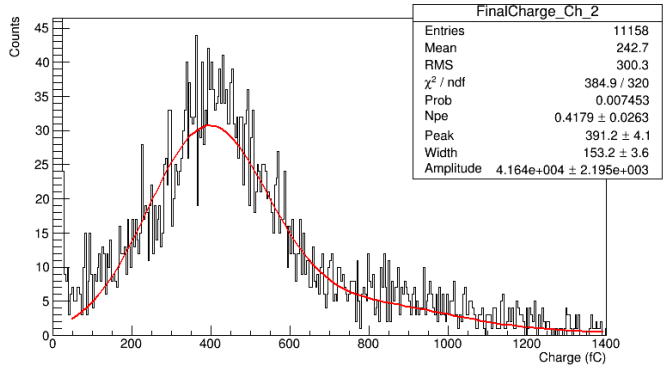


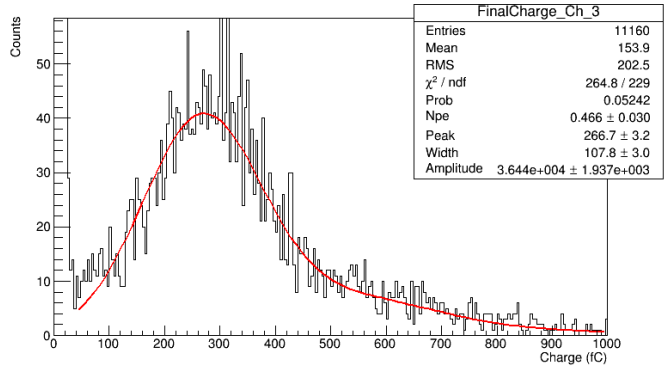


At 2200V

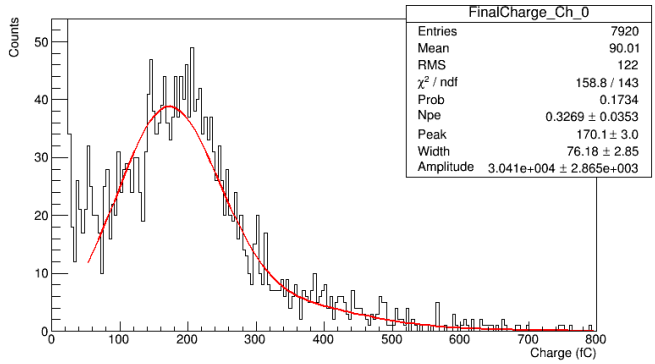


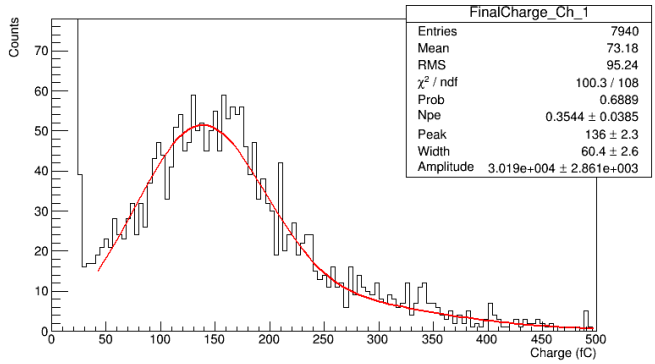


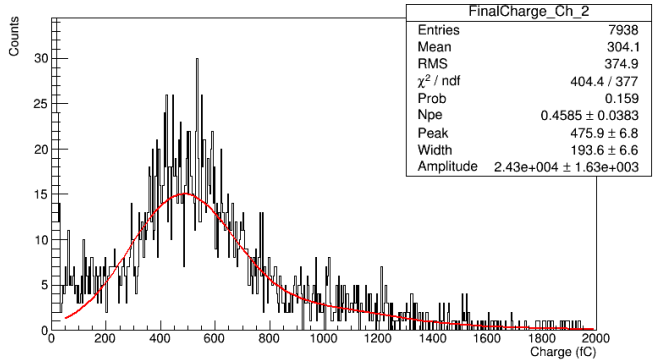


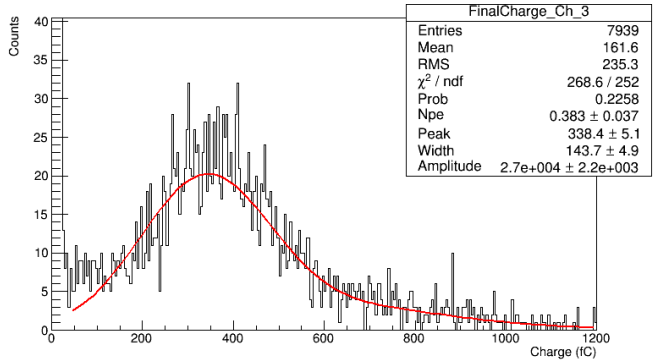


At 2300V

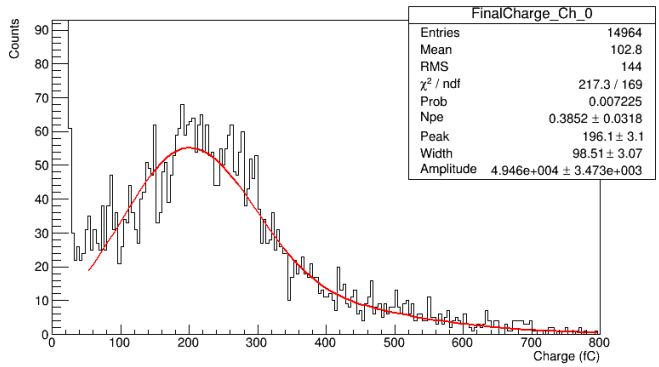


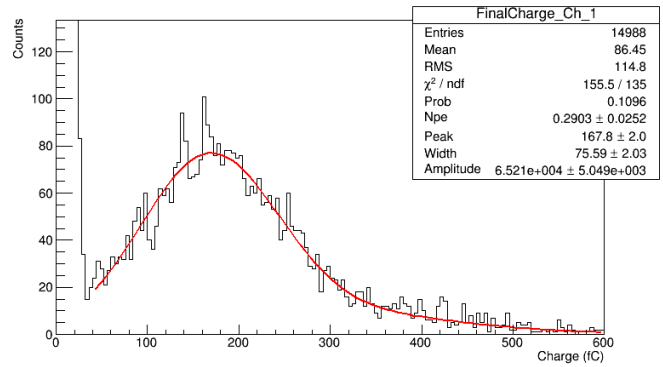


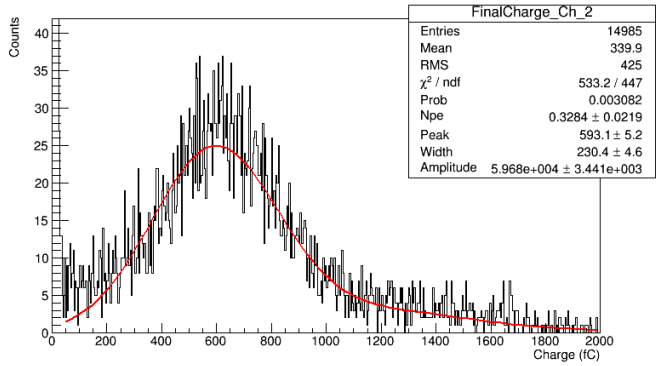


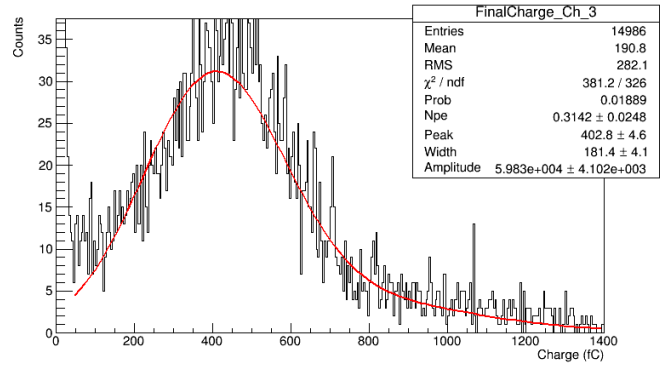


At 2400V

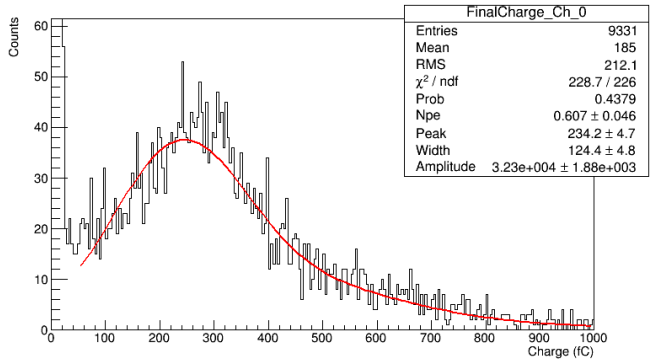


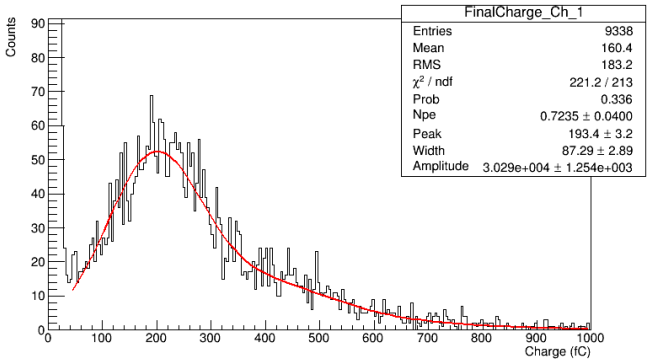


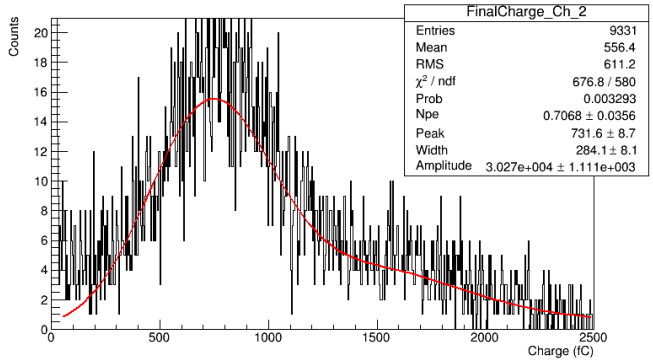


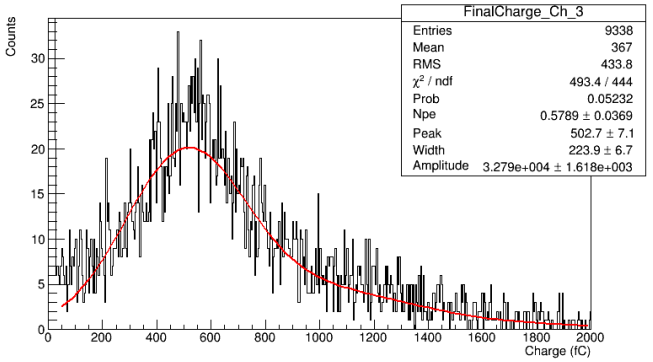


At 2500V

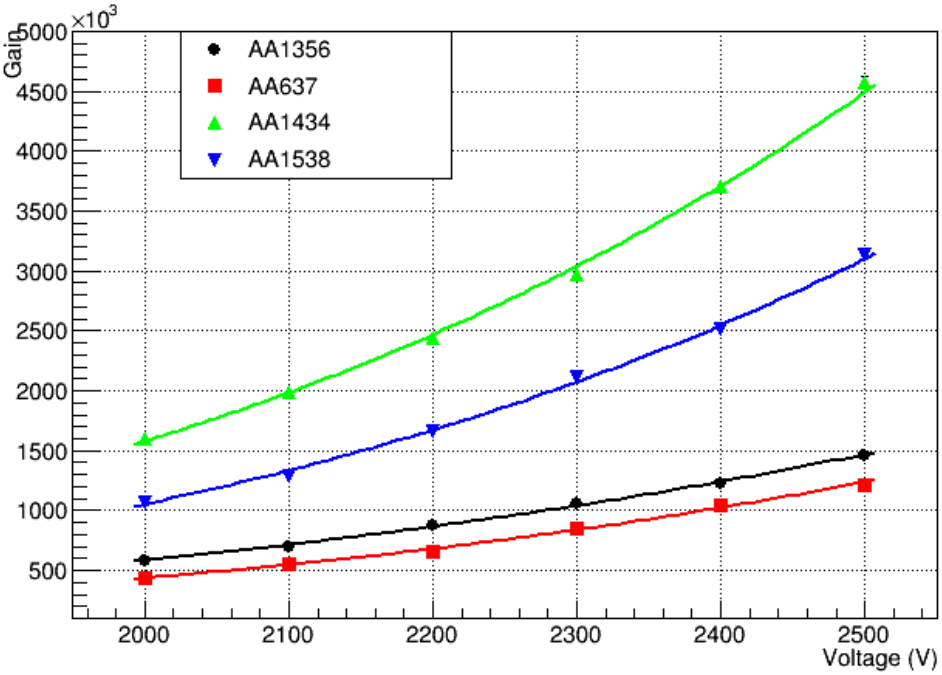

FinalCharge_Ch_0
Entries 9331
Mean 185
RMS 212.1
χ² / ndf 228.7 / 226
Prob 0.4379
Npe 0.607 ± 0.046
Peak 234.2 ± 4.7
Width 124.4 ± 4.8
Amplitude 3.23e+004 ± 1.88e+003
Counts
Charge (fC)

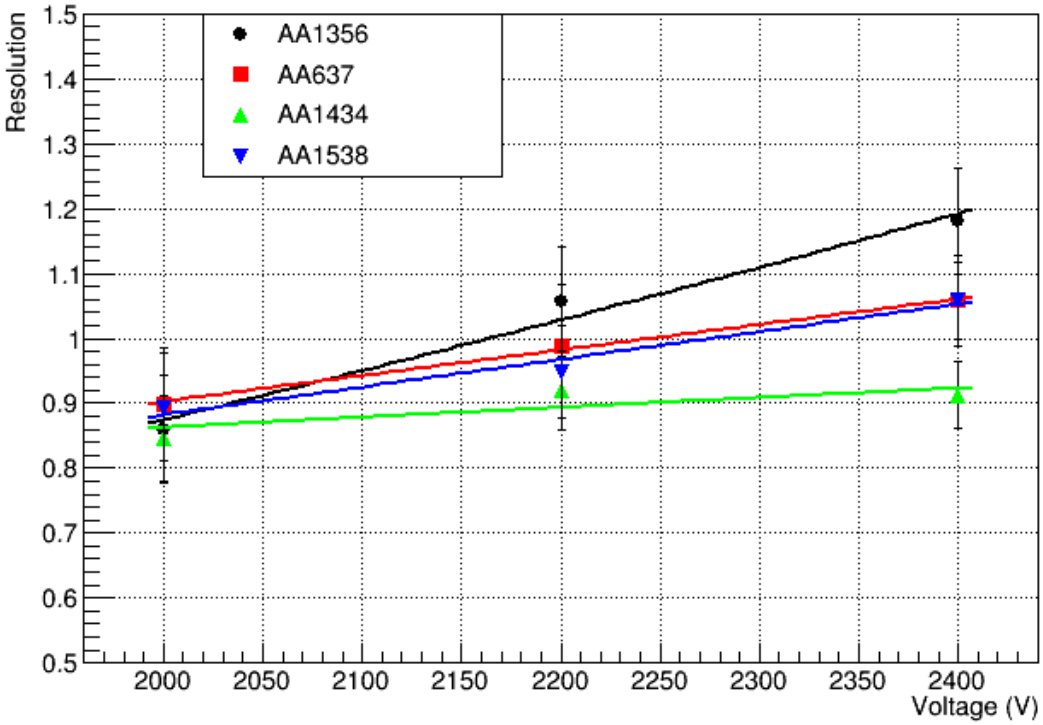

FinalCharge_Ch_1
Entries 9338
Mean 160.4
RMS 183.2
χ² / ndf 221.2 / 213
Prob 0.336
Npe 0.7235 ± 0.0400
Peak 193.4 ± 3.2
Width 87.29 ± 2.89
Amplitude 3.029e+004 ± 1.254e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 9331
Mean 556.4
RMS 611.2
χ² / ndf 676.8 / 580
Prob 0.003293
Npe 0.7068 ± 0.0356
Peak 731.6 ± 8.7
Width 284.1 ± 8.1
Amplitude 3.027e+004 ± 1.111e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 9338
Mean 367
RMS 433.8
χ² / ndf 493.4 / 444
Prob 0.05232
Npe 0.5789 ± 0.0369
Peak 502.7 ± 7.1
Width 223.9 ± 6.7
Amplitude 3.279e+004 ± 1.618e+003
Counts
Charge (fC)

Gain and resolution curves: PMT13-AA1356, PMT14-AA637, PMT15-AA1434, PMT16-AA1538

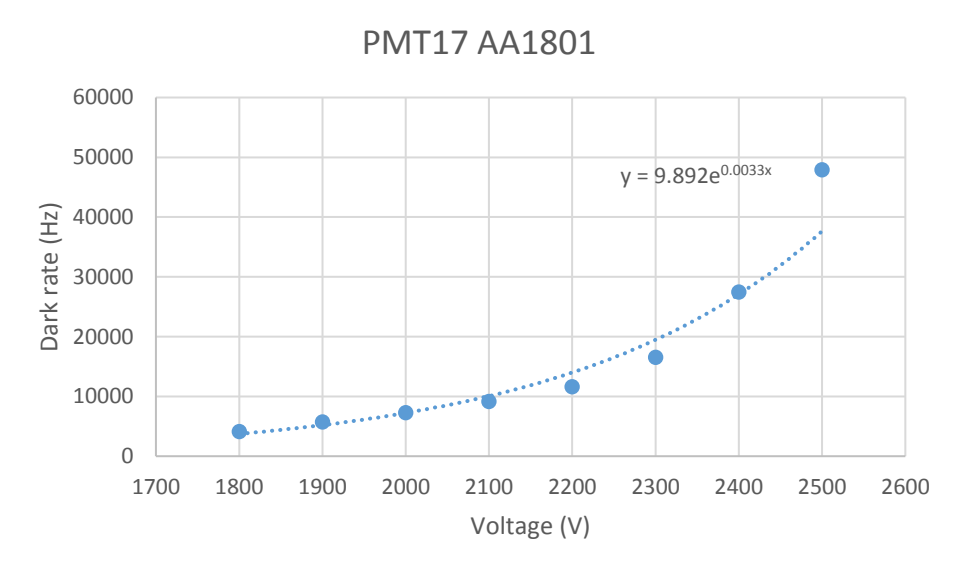




PMT's 17-20

PMT17-AA1801
PMT18-AA1245
PMT19-AA1750
PMT20-AA2038

PMT17 AA1801 Dark rate test repeated Feb 18, 2018						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	32308	32714	33026	33244	33635	4123.175
1900	45431	45470	45599	45494	46540	5713.35
2000	57445	59090	58114	57833	58684	7279.15
2100	73465	72971	73254	73400	73022	9152.8
2200	93802	90414	89456	94818	94486	11574.4
2300	128477	133439	132517	134278	132609	16533
2400	217233	220103	216961	221873	220658	27420.7
2500	390004	378496	377101	382410	386639	47866.25

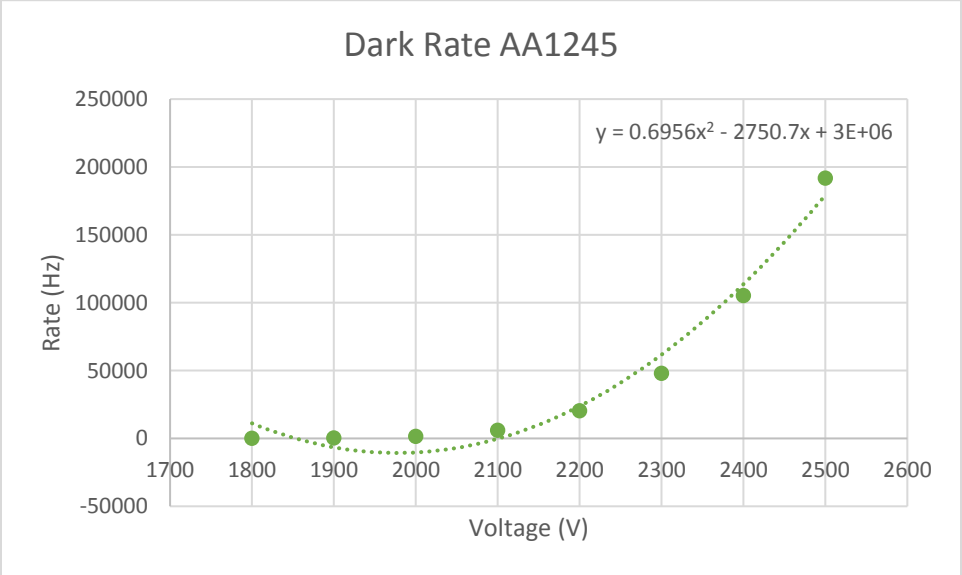


PMT 18 AA1245 CH2

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

HV set > 2000V for 15 min before testing

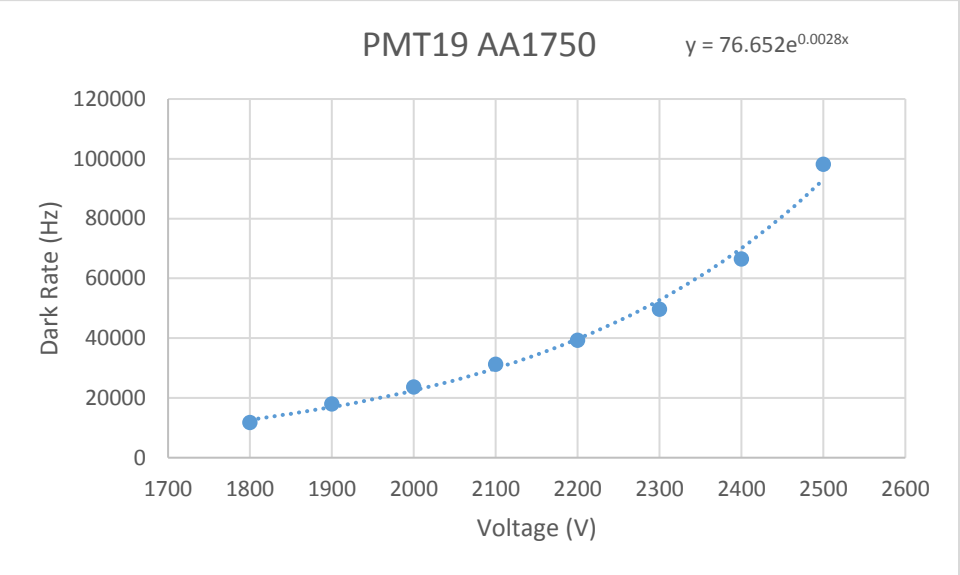
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	487	480	525	482	596	64.25
1900	2829	2907	2825	2642	2562	344.125
2000	12018	13221	12556	10545	12718	1526.45
2100	43947	44028	47323	46720	52953	5874.275
2200	144951	156297	166490	190421	151899	20251.45
2300	406938	374855	386014	413395	332810	47850.3
2400	819935	855845	897440	833387	801964	105214.3
2500	1659755	1718475	1117992	1781642	1386844	191617.7



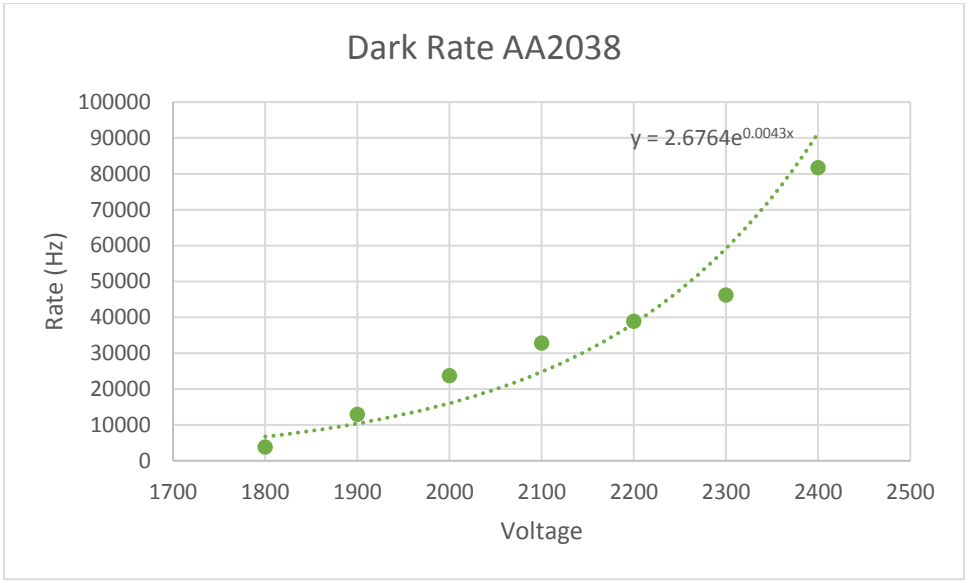
PMT19 AA1750 Dark rate test repeated Feb 18, 2018

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	94586	93957	93832	91811	94522	11717.7
1900	143165	141728	144964	145893	144441	18004.78
2000	188926	190581	188426	188306	189692	23648.28
2100	248541	248496	250081	248896	252726	31218.5
2200	310762	312288	315583	316504	316741	39296.95
2300	403112	394422	396456	396065	396945	49675
2400	530739	536055	533948	528497	527583	66420.55
2500	780670	785611	785216	786864	788816	98179.43



PMT20 AA2038 CH4						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2000V for 15 min before testing						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	33263	32924	29930	28787	30773	3891.925
1900	105204	103830	102138	103782	101625	12914.48
2000	194229	191348	187934	188005	188263	23744.48
2100	268774	265884	258918	261088	260502	32879.15
2200	344560	341941	330413	268789	269225	38873.2
2300	429160	426432	333375	327556	333584	46252.68
2400	539904	675191	689207	685381	680299	81749.55



For these Charge Distribution Histograms:

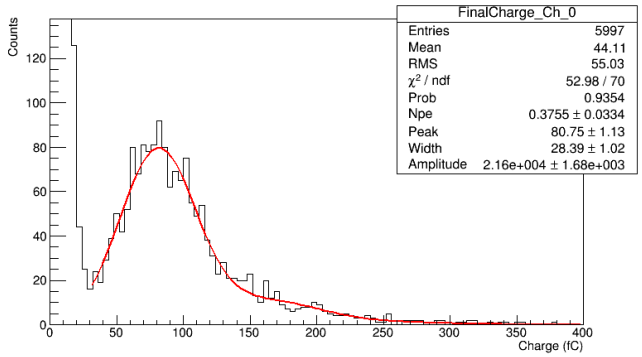
FinalCharge_Ch_0 = PMT17-AA1801 FinalCharge_Ch_1 = PMT18-AA1245

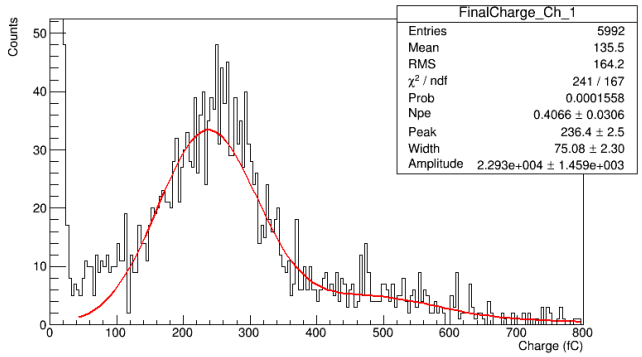
FinalCharge_Ch_2 = PMT19-AA1750 FinalCharge_Ch_3 = PMT20-AA2038

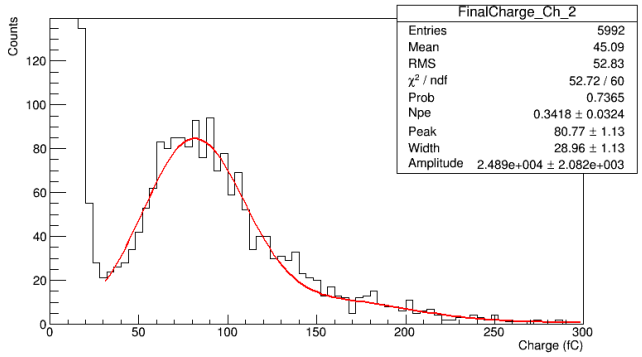
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

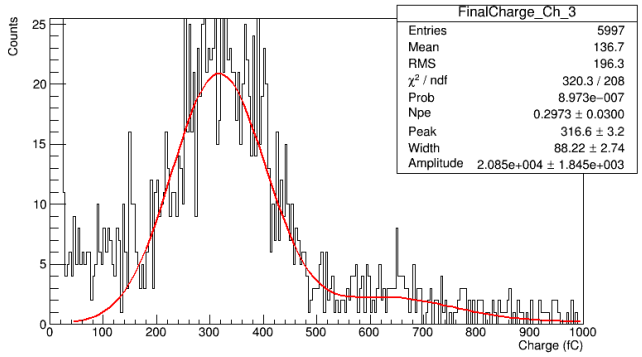
Code used to fit: fitnpe_XP2020

At 1900V

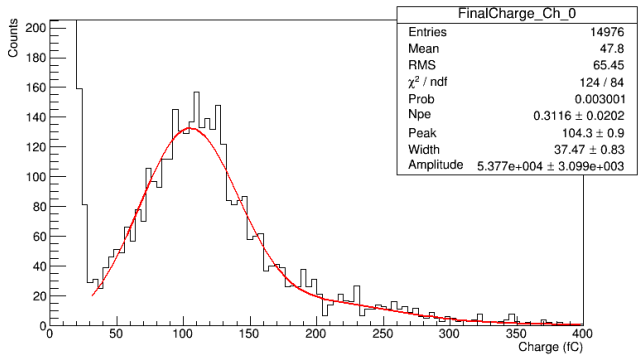


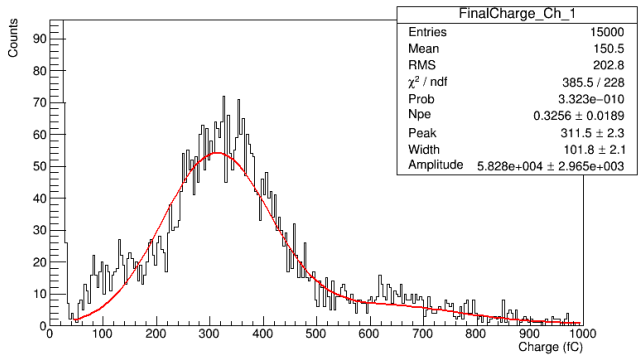


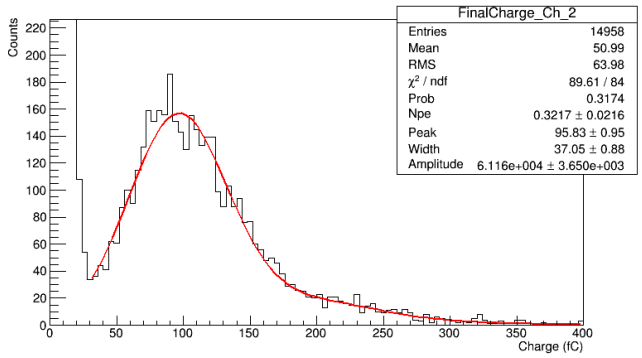


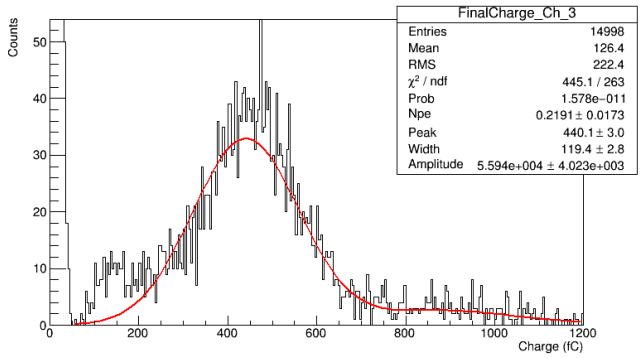


At 2000V

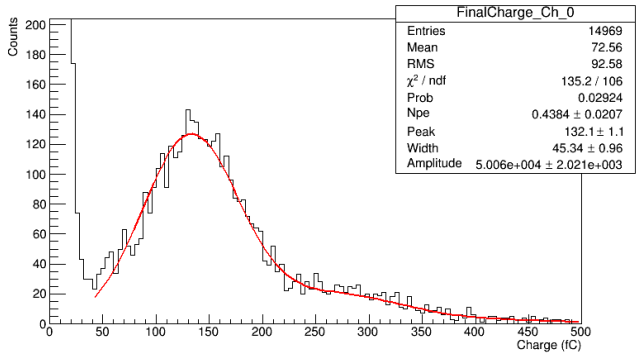


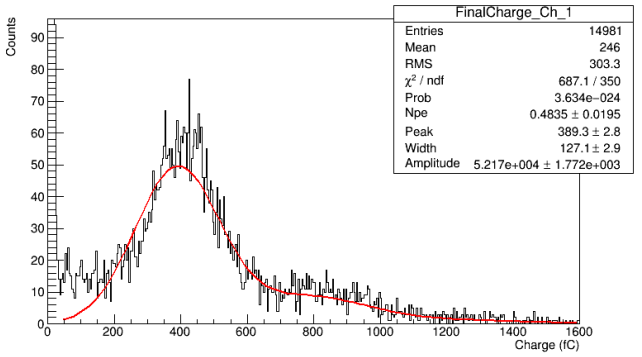


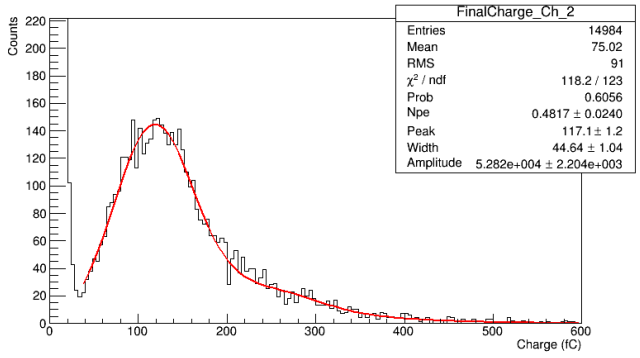


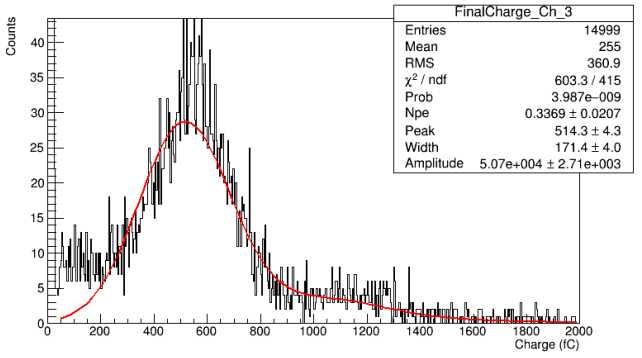


At 2100V

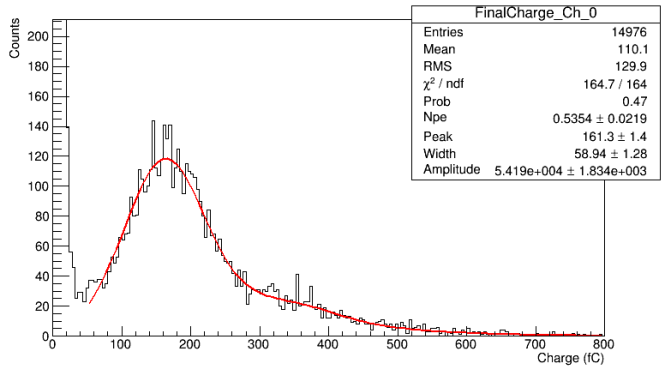


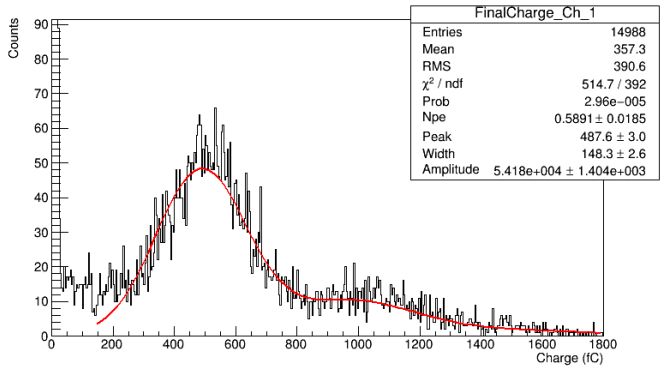


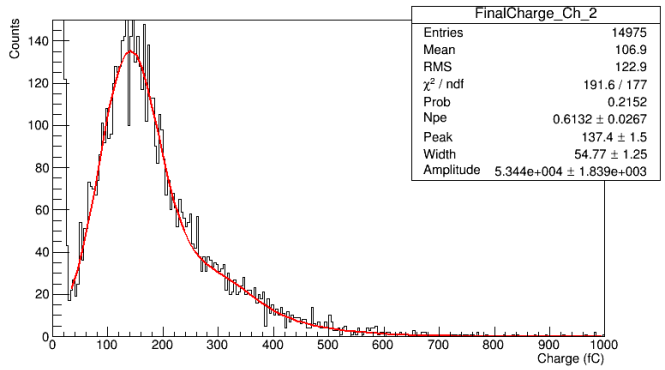


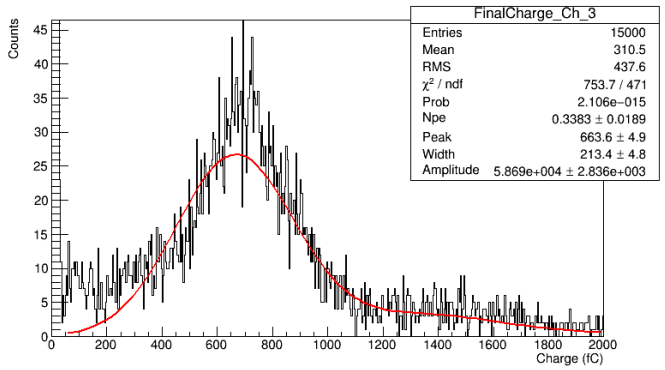


At 2200V

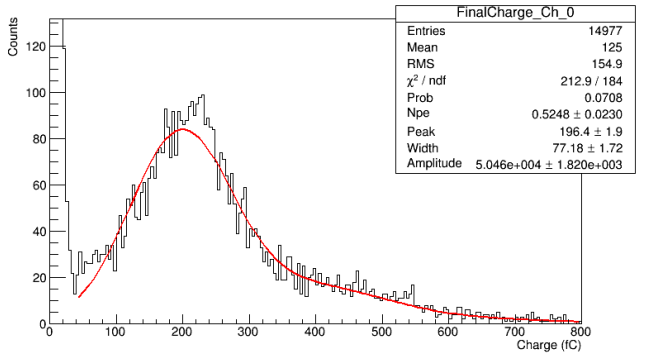


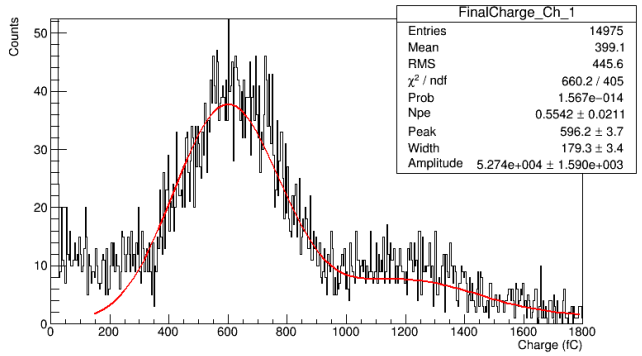


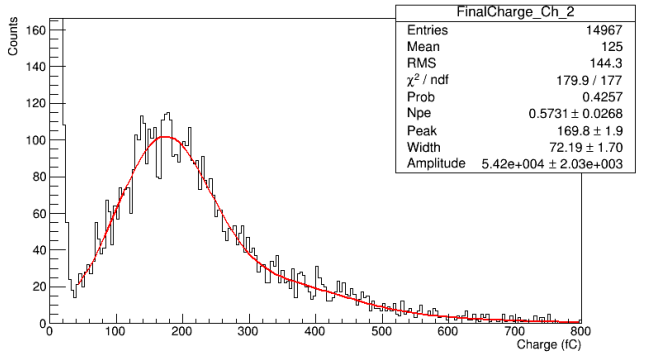


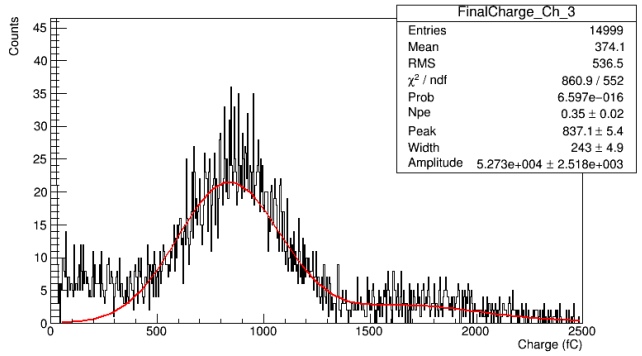


At 2300V

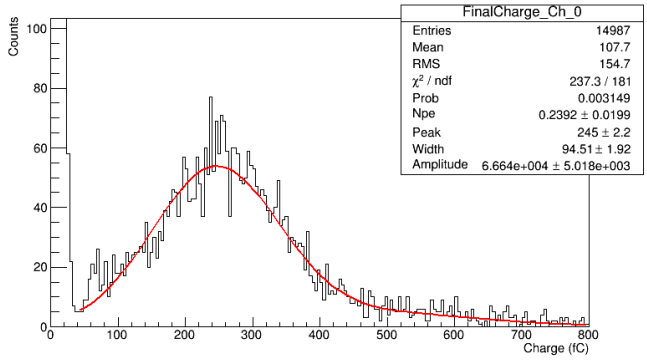


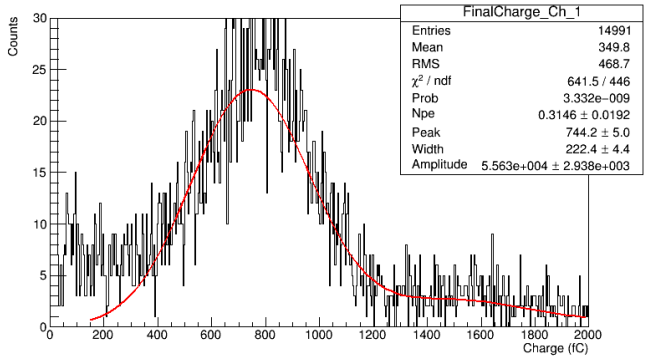


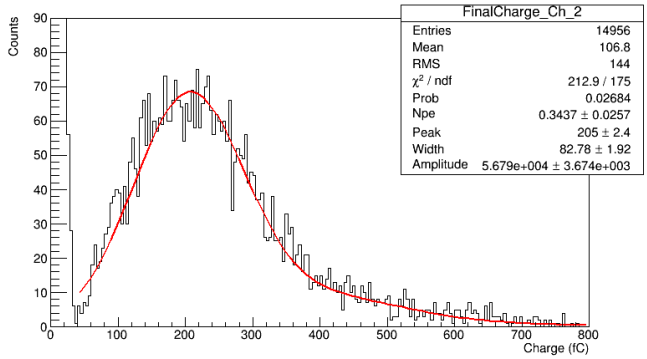


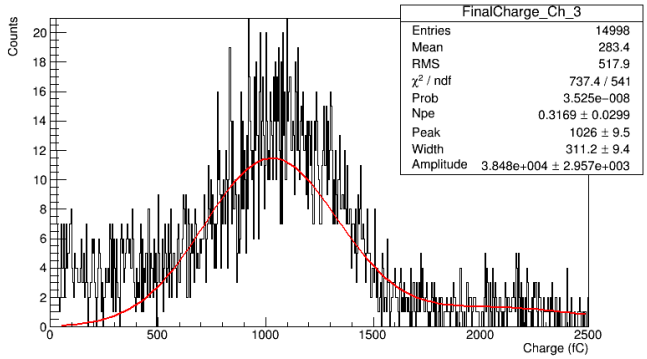


At 2400V

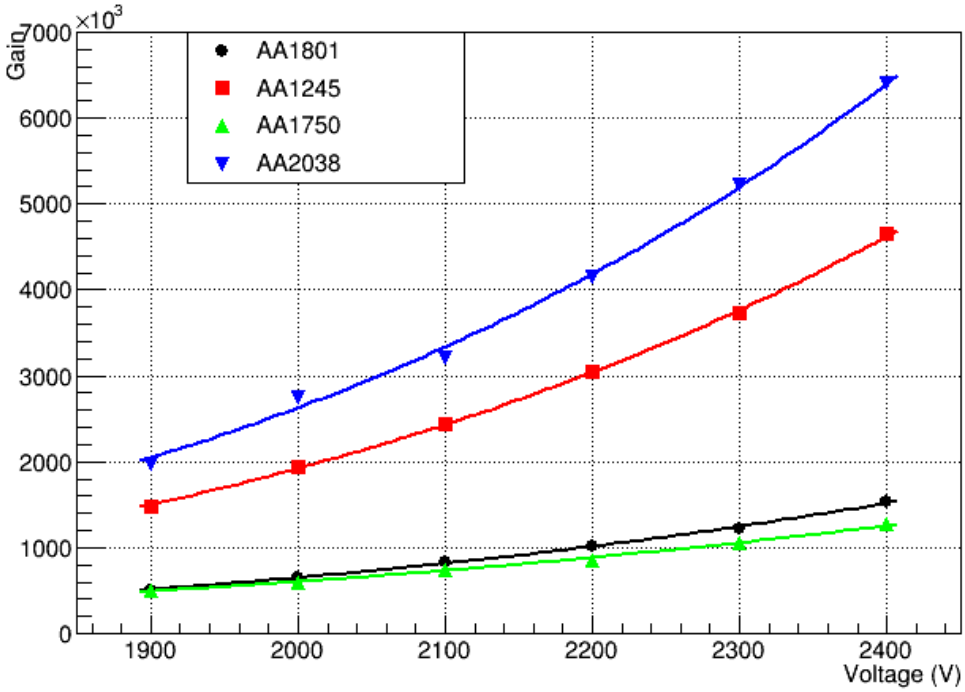

FinalCharge_Ch_0
Entries 14987
Mean 107.7
RMS 154.7
χ² / ndf 237.3 / 181
Prob 0.003149
Npe 0.2392 ± 0.0199
Peak 245 ± 2.2
Width 94.51 ± 1.92
Amplitude 6.664e+004 ± 5.018e+003
Counts
Charge (fC)

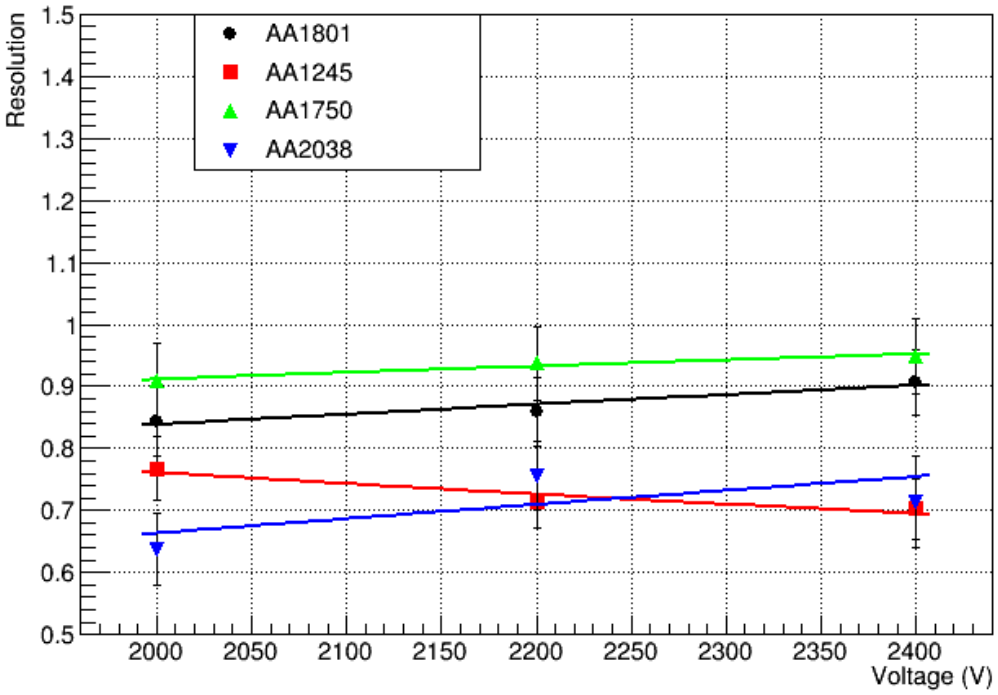

FinalCharge_Ch_1
Entries 14991
Mean 349.8
RMS 468.7
χ² / ndf 641.5 / 446
Prob 3.332e−009
Npe 0.3146 ± 0.0192
Peak 744.2 ± 5.0
Width 222.4 ± 4.4
Amplitude 5.563e+004 ± 2.938e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 14956
Mean 106.8
RMS 144
χ² / ndf 212.9 / 175
Prob 0.02684
Npe 0.3437 ± 0.0257
Peak 205 ± 2.4
Width 82.78 ± 1.92
Amplitude 5.679e+004 ± 3.674e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 14998
Mean 283.4
RMS 517.9
χ² / ndf 737.4 / 541
Prob 3.525e−008
Npe 0.3169 ± 0.0299
Peak 1026 ± 9.5
Width 311.2 ± 9.4
Amplitude 3.848e+004 ± 2.957e+003
Counts
Charge (fC)

Gain and resolution curves: PMT17-AA1801, PMT18-AA1245, PMT19-AA1750, PMT20-AA2038



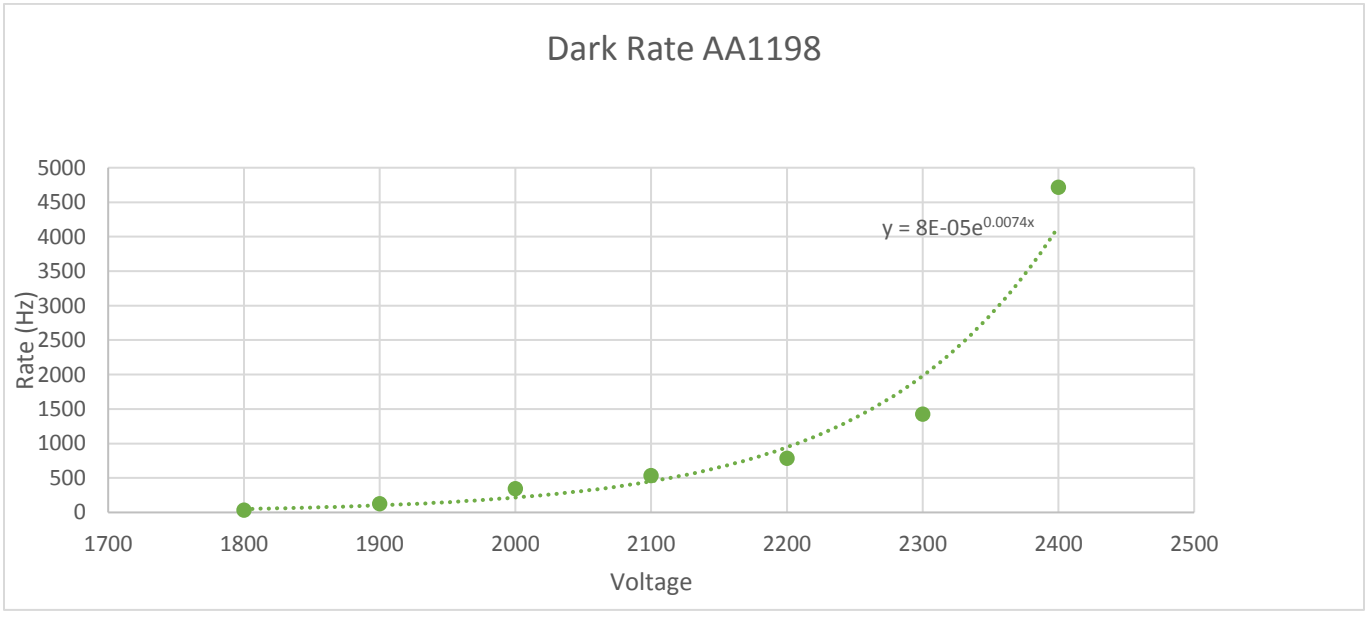


PMT's 21-24

PMT21-AA1198
PMT22-AA1759
PMT23-AA828
PMT24-AA1336

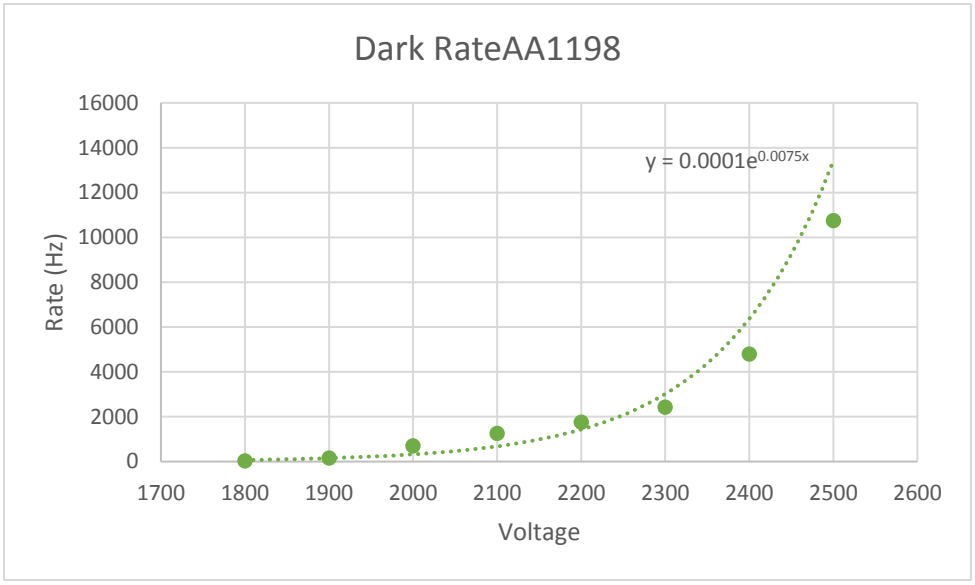
PMT21 AA1198 Ch1 (2nd Reading)

Several hours later					~1:30 pm	
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	251	236	247	256	260	31.25
1900	1042	978	1031	1019	1023	127.325
2000	2874	2659	2746	2709	2705	342.325
2100	4202	4282	4317	4264	4285	533.75
2200	6010	6163	6372	6406	6352	782.575
2300	11305	11145	11368	11549	11595	1424.05
2400	37722	38139	37229	37556	37931	4714.43



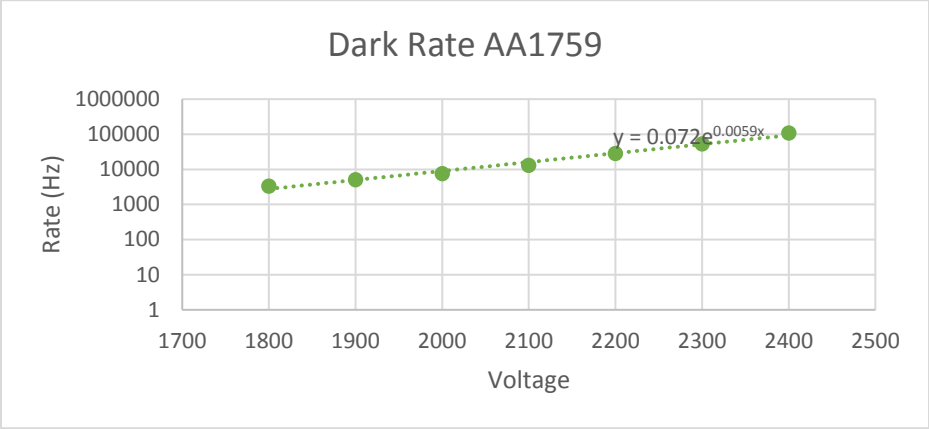
PMT21 AA1198 (3rd Reading)

PMT AA1198 CH1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2000V for 15 min before testing						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	228	218	226	203	217	27.3
1900	1393	1339	1352	1177	1336	164.925
2000	5914	6166	5549	5236	5499	709.1
2100	8912	11047	9245	10550	10488	1256.05
2200	14529	13119	15074	14532	13288	1763.55
2300	17335	19414	19572	18431	22601	2433.83
2400	38345	37325	39168	40391	36572	4795.03
2500	103988	106848	10129	104189	105001	10753.9



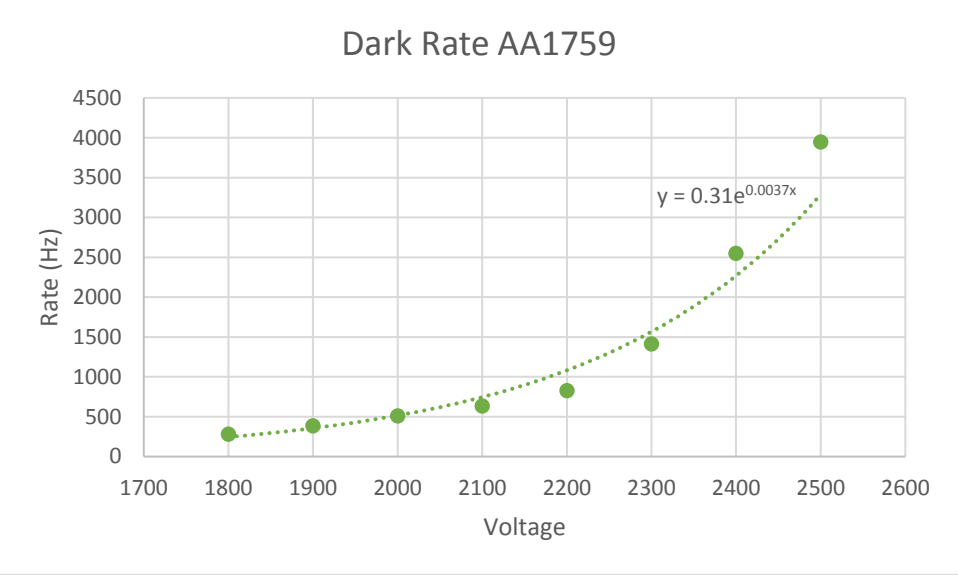
PMT22 – AA1759 (1st Reading)

PMT22 AA1759 CH2			~10 am	24-May		
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set at 1900V for 60 min before testing, for stabilization 1 min in between voltages						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	35539	32848	38720	37226	34557	4472.25
1900	57451	56935	65931	54090	59385	7344.8
2000	84440	91830	87805	76792	82322	10579.73
2100	126366	112538	133762	150520	129549	16318.38
2200	233016	242985	224101	194006	192076	27154.6
2300	457554	806412	716033	467694	534523	74555.4
2400	1113057	1213505	1236083	1481679	1273518	157946.1

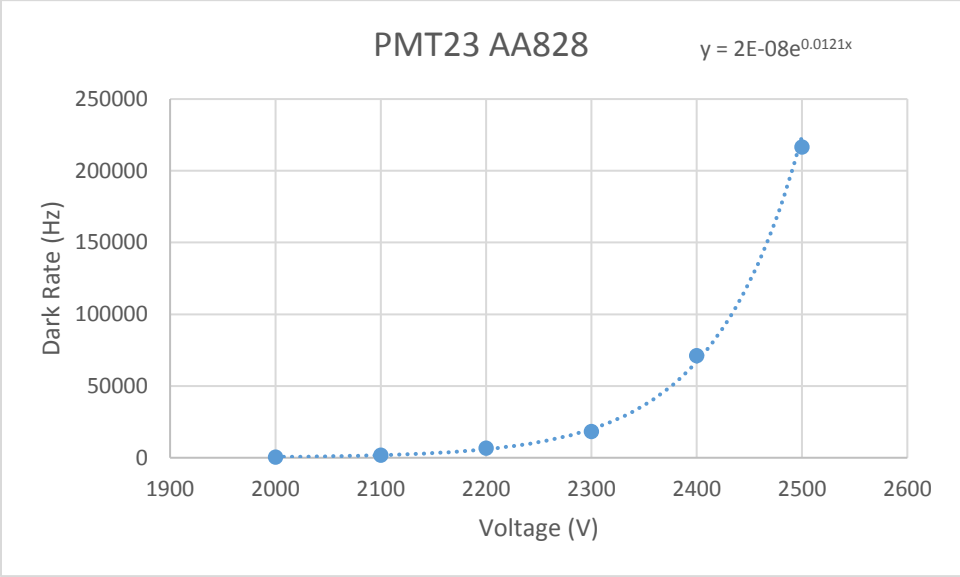


PMT22 AA1759 3rd Reading

PMT AA1759 CH2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2000V for 15 min before testing						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	2284	2218	2350	2252	2271	284.375
1900	3043	3123	3139	3095	3127	388.175
2000	4172	4070	4072	4038	4111	511.575
2100	5245	4993	5027	5160	5003	635.7
2200	6701	6631	6712	6578	6459	827.025
2300	11360	11358	11351	11132	11347	1413.7
2400	20780	20278	20241	20308	20435	2551.05
2500	31899	31570	31570	31465	31474	3949.45

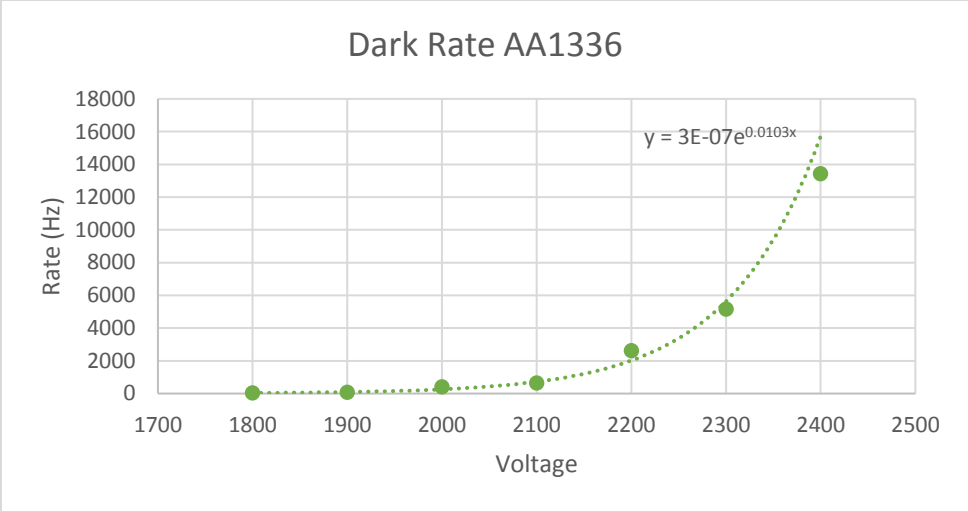


PMT23 AA828 Dark rate test repeated Feb 18, 2018						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	4130	4417	4221	3920	4068	518.9
2100	14205	12555	15194	12035	15642	1740.775
2200	57035	46618	47541	58482	56163	6645.975
2300	133915	133667	129328	192251	144576	18343.43
2400	549353	603256	582186	595563	513353	71092.78
2500	1621692	1735142	1801416	1830765	1675513	216613.2

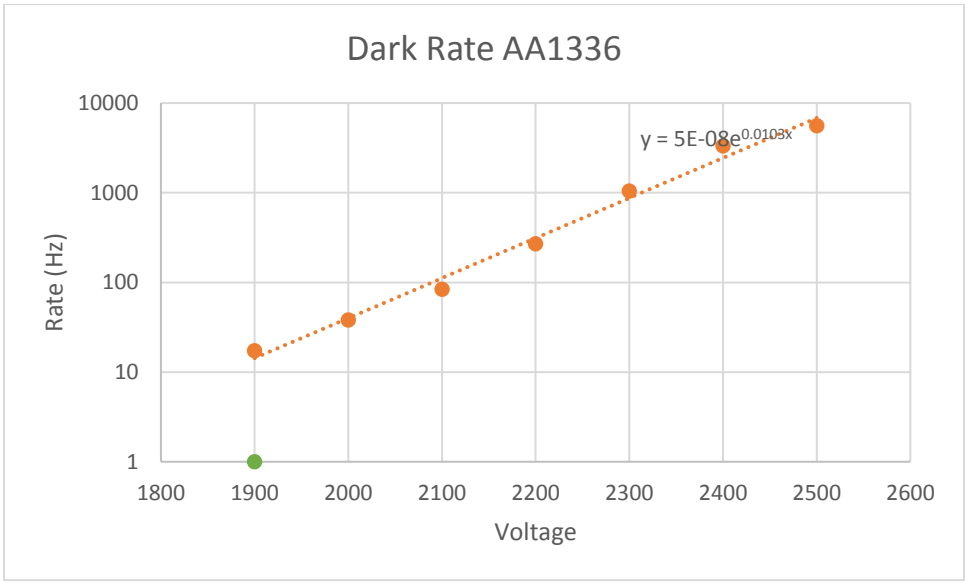


1st Reading

PMT24 AA1336 CH4		~1:30 pm	24-May			
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set at 1900V for 60 min before testing, for stabilization						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	191	223	205	204	335	28.95
1900	631	699	468	581	609	74.7
2000	3847	3633	3393	2715	2621	405.225
2100	4899	5399	5568	4652	5080	639.95
2200	21012	18033	17560	26258	21824	2617.175
2300	61373	63918	30750	24643	26015	5167.475
2400	155711	118698	61340	95063	106617	13435.73



PMT24 AA1336 CH4						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800						#DIV/0!
1900	145	137	147	128	134	17.275
2000	270	278	329	329	324	38.25
2100	623	558	616	765	788	83.75
2200	2819	1788	2102	1970	2091	269.25
2300	7332	9729	9206	8344	7018	1040.725
2400	22822	22235	27973	30125	30233	3334.7
2500	47298	49335	41110	43192	42626	5589.025



For these Charge Distribution Histograms:

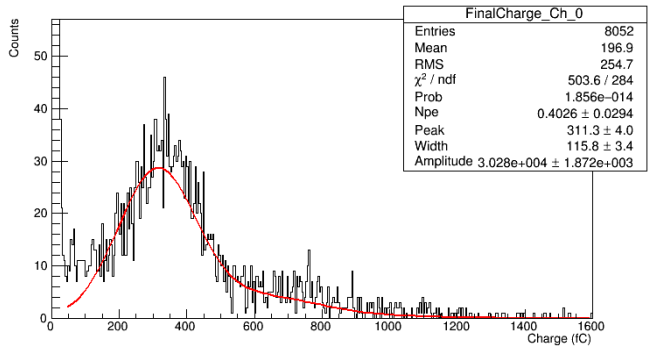
FinalCharge_Ch_0 = PMT21-AA1198 FinalCharge_Ch_1 = PMT22-AA1759

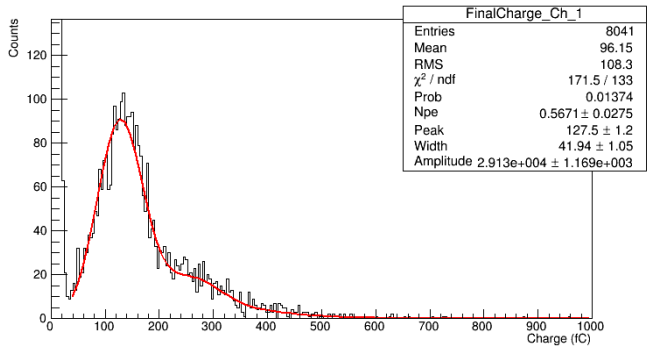
FinalCharge_Ch_2 = PMT23-AA828 FinalCharge_Ch_3 = PMT24-AA1336

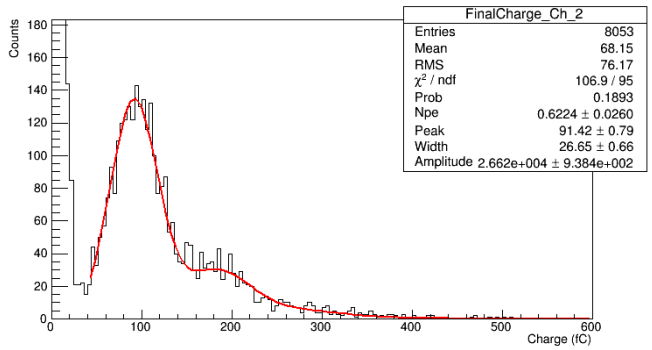
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

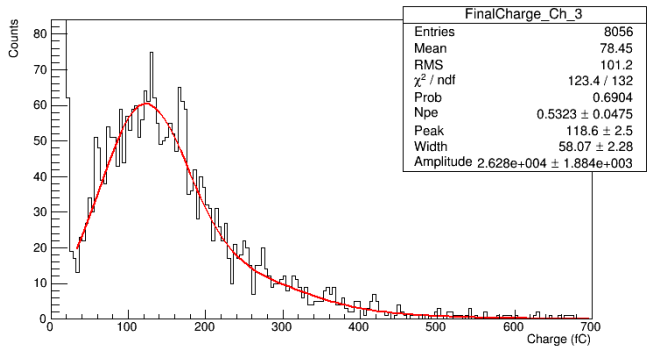
Code used to fit: fitnpe_XP2020

At 2000V

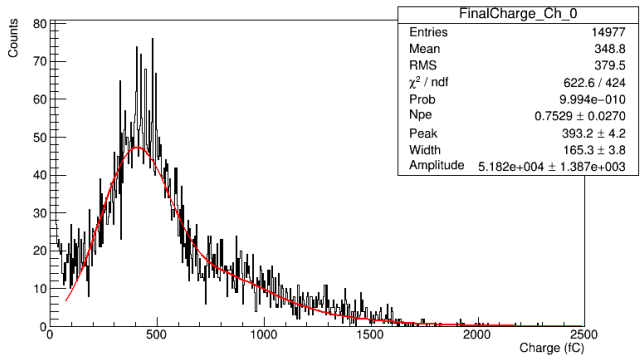


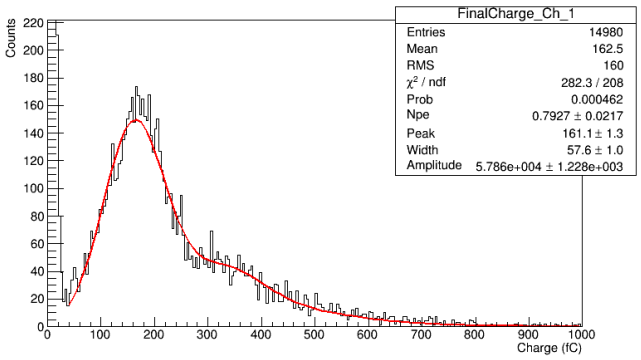


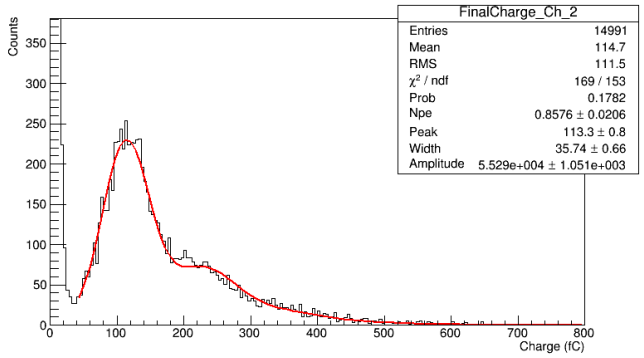


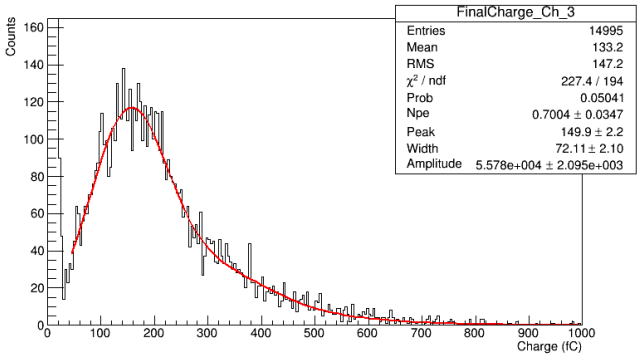


At 2100V

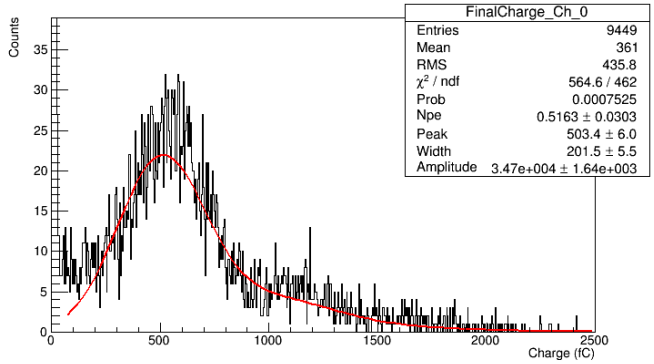


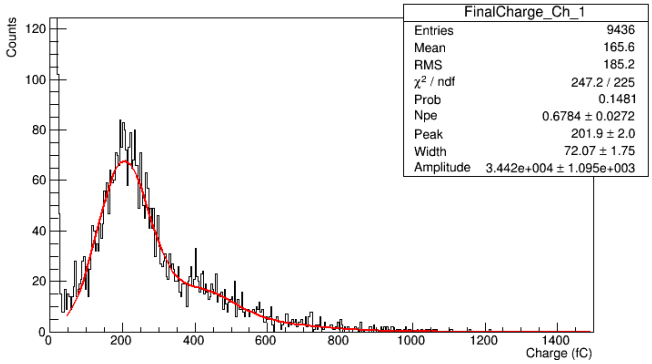


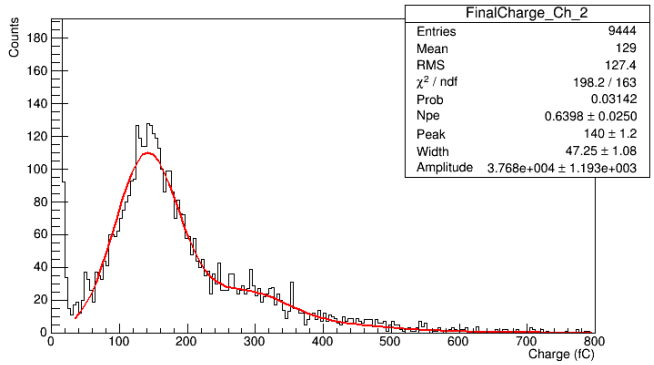


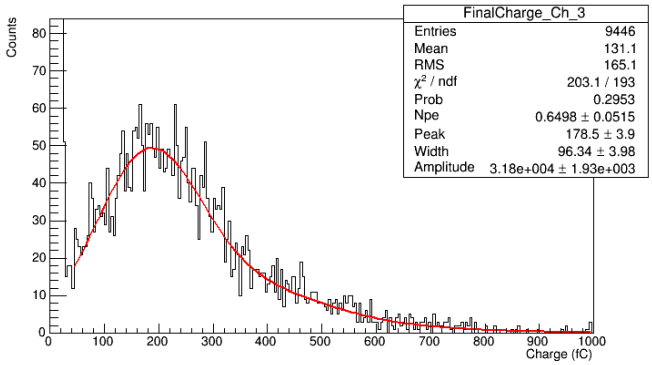


At 2200V

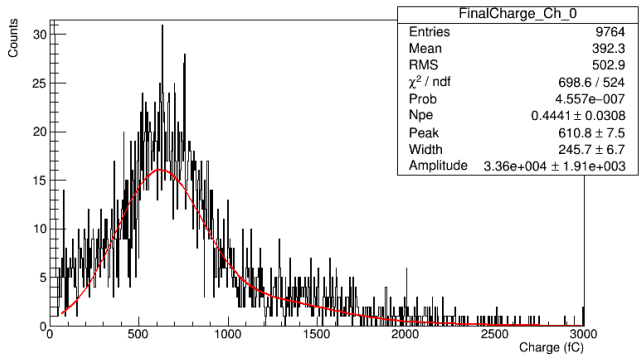


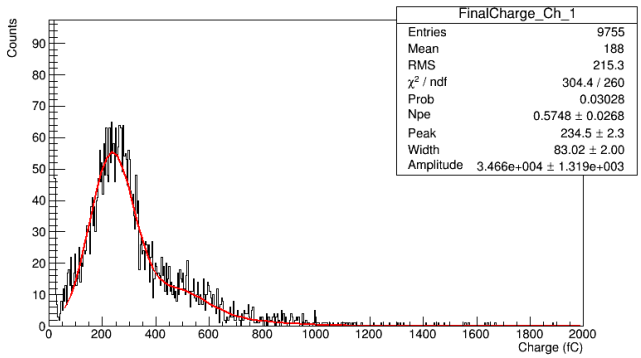


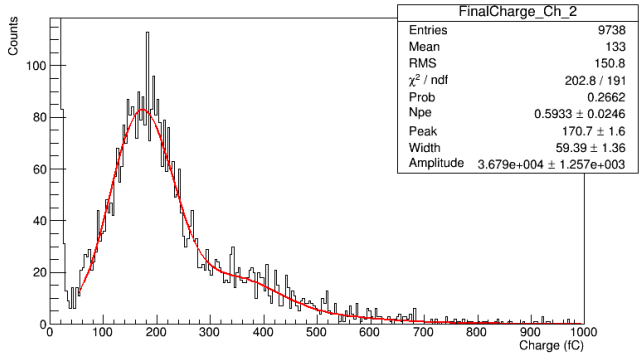


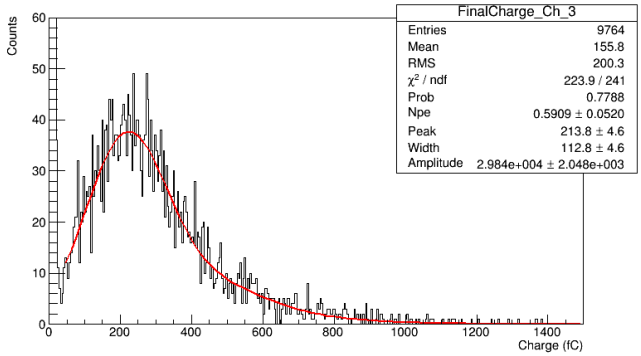


At 2300V

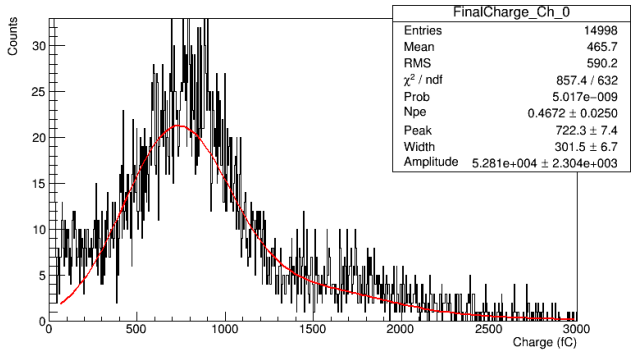


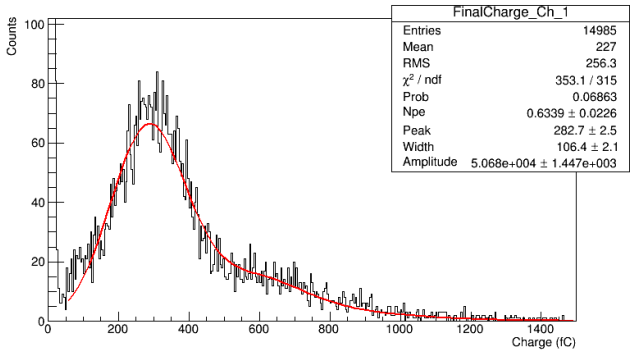


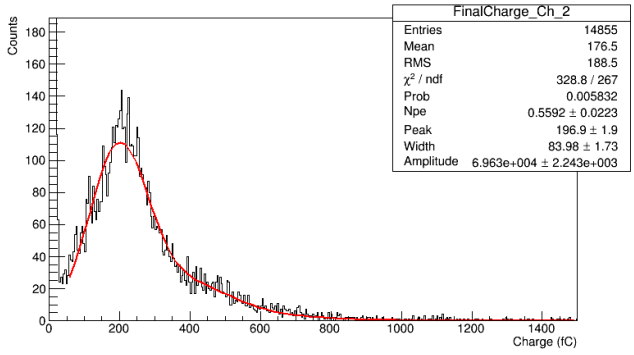


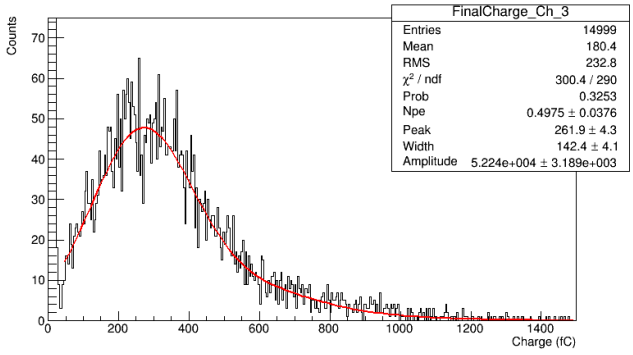


At 2400V

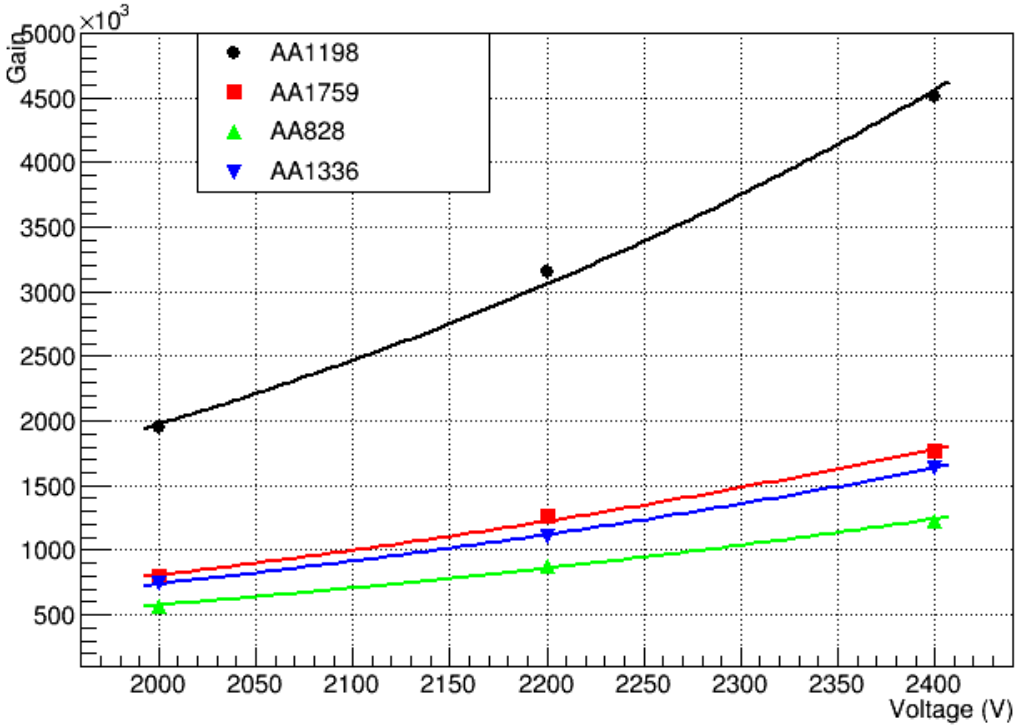


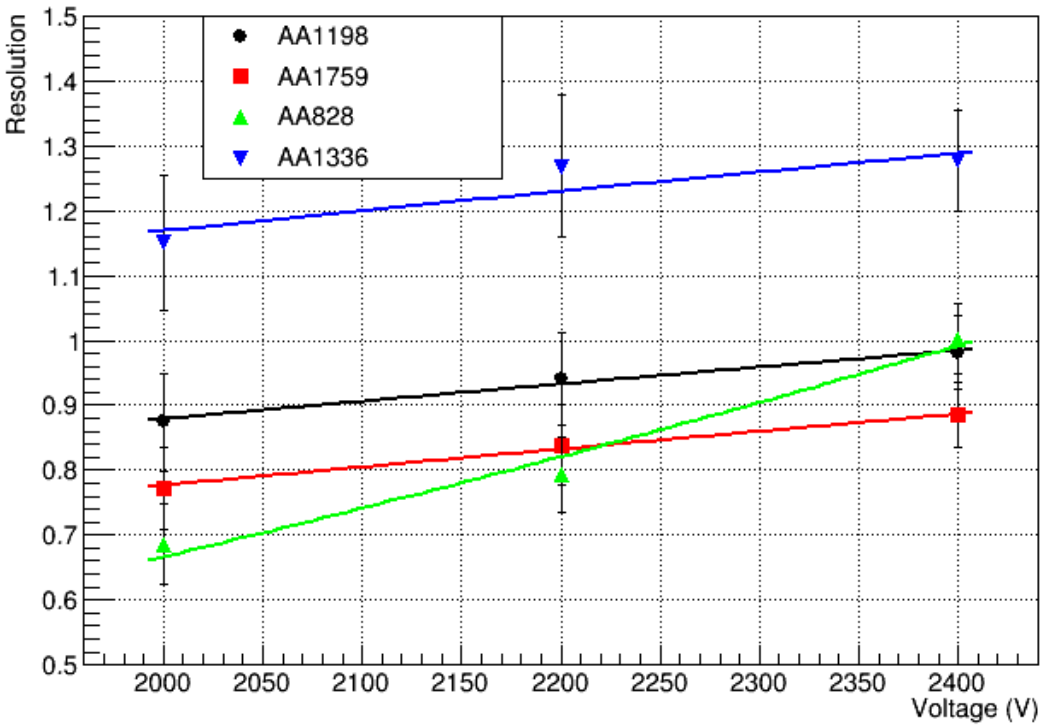






Gain Curves: PMT21-AA1198, PMT22-AA1759**,** PMT23-AA828, PMT24-AA1336

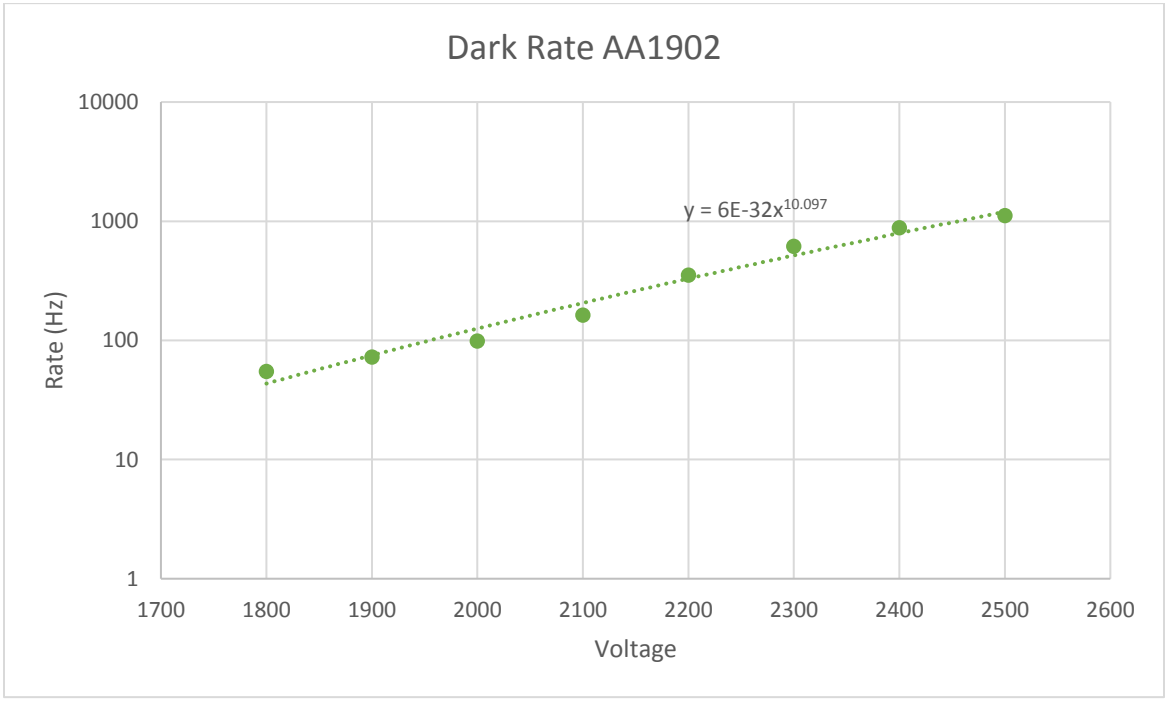




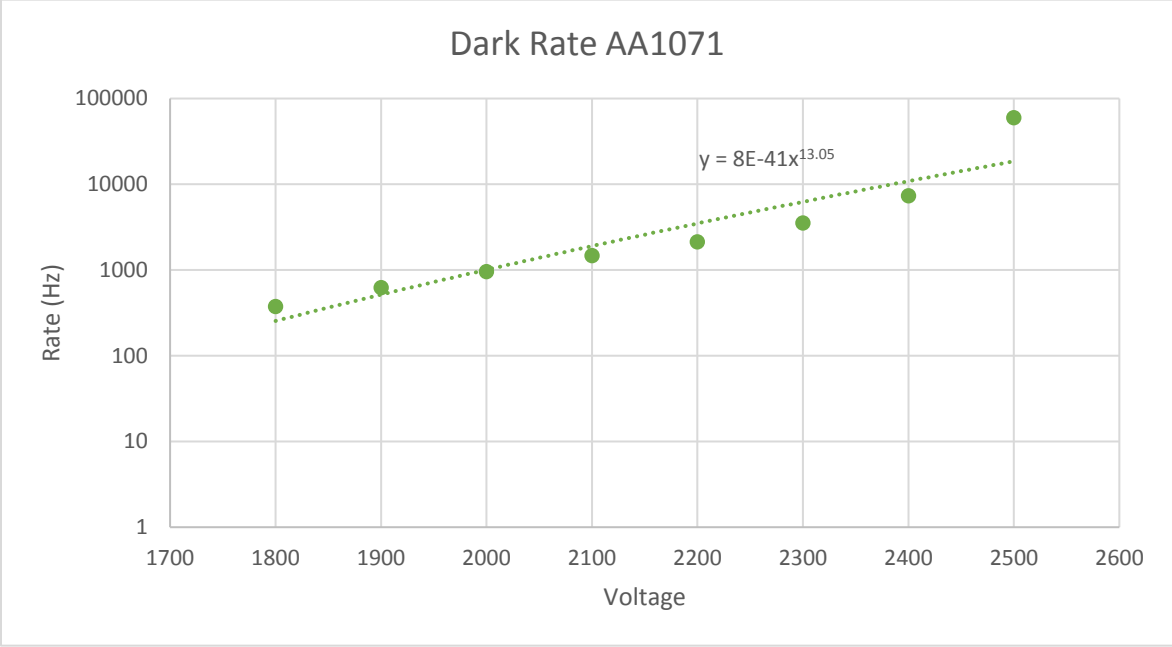
PMT's 25-28

PMT25-AA1902
PMT26-AA1071
PMT27-AA1346
PMT28-AA1202

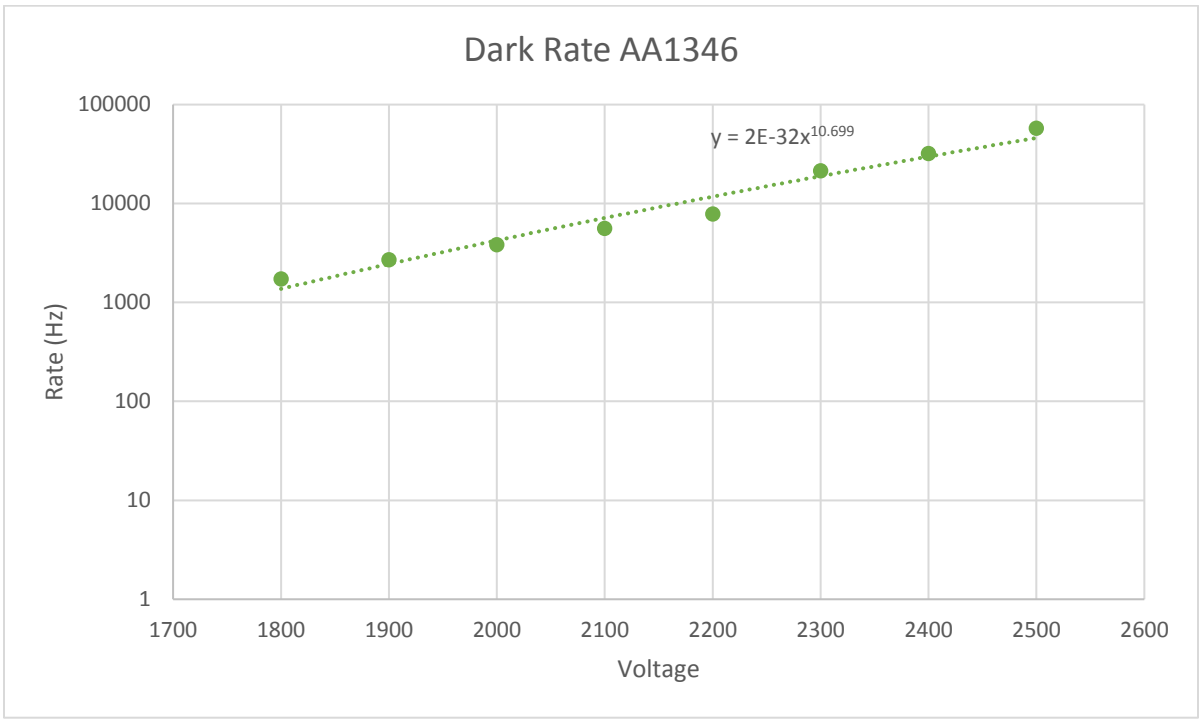
PMT25 AA1902 Ch1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2000V for 15 min before testing						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	451	396	422	458	468	54.875
1900	563	585	594	580	571	72.325
2000	750	792	828	760	815	98.625
2100	1253	1333	1267	1306	1363	163.05
2200	2894	2812	2790	2856	2735	352.175
2300	4938	4871	4918	5003	4939	616.725
2400	7055	7181	7010	6918	7007	879.275
2500	8865	8783	9155	8987	8780	1114.25



PMT26 AA1071 Ch2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2000V for 15 min before testing						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	3095	2960	2959	2930	3093	375.925
1900	4890	4911	5073	5233	4968	626.875
2000	7696	7629	7666	7629	7886	962.65
2100	11388	11503	11924	12038	11935	1469.7
2200	16565	17223	17579	17485	16433	2132.125
2300	27256	28456	28198	27831	29624	3534.125
2400	60042	57139	58922	59961	58975	7375.975
2500	456826	483396	448139	491348	505838	59638.68

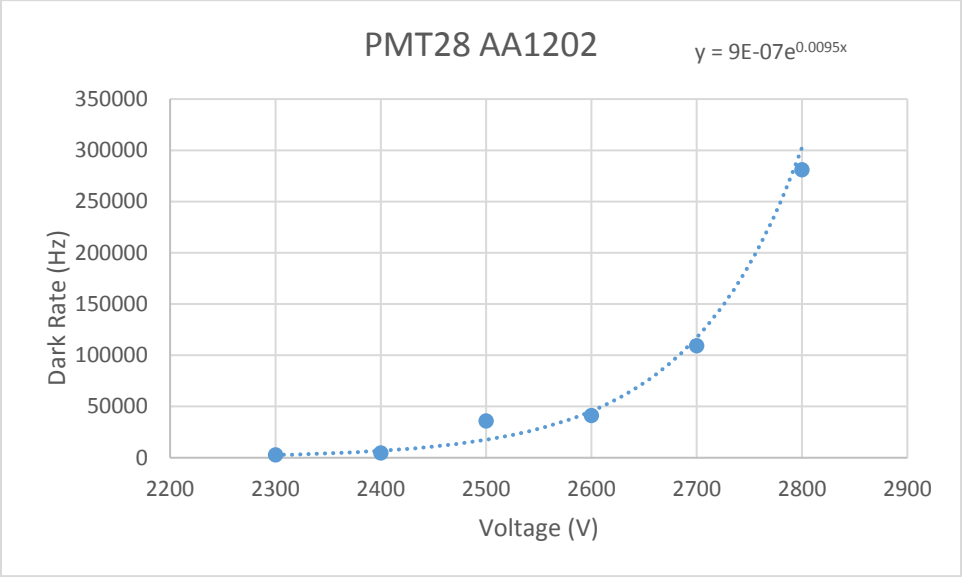


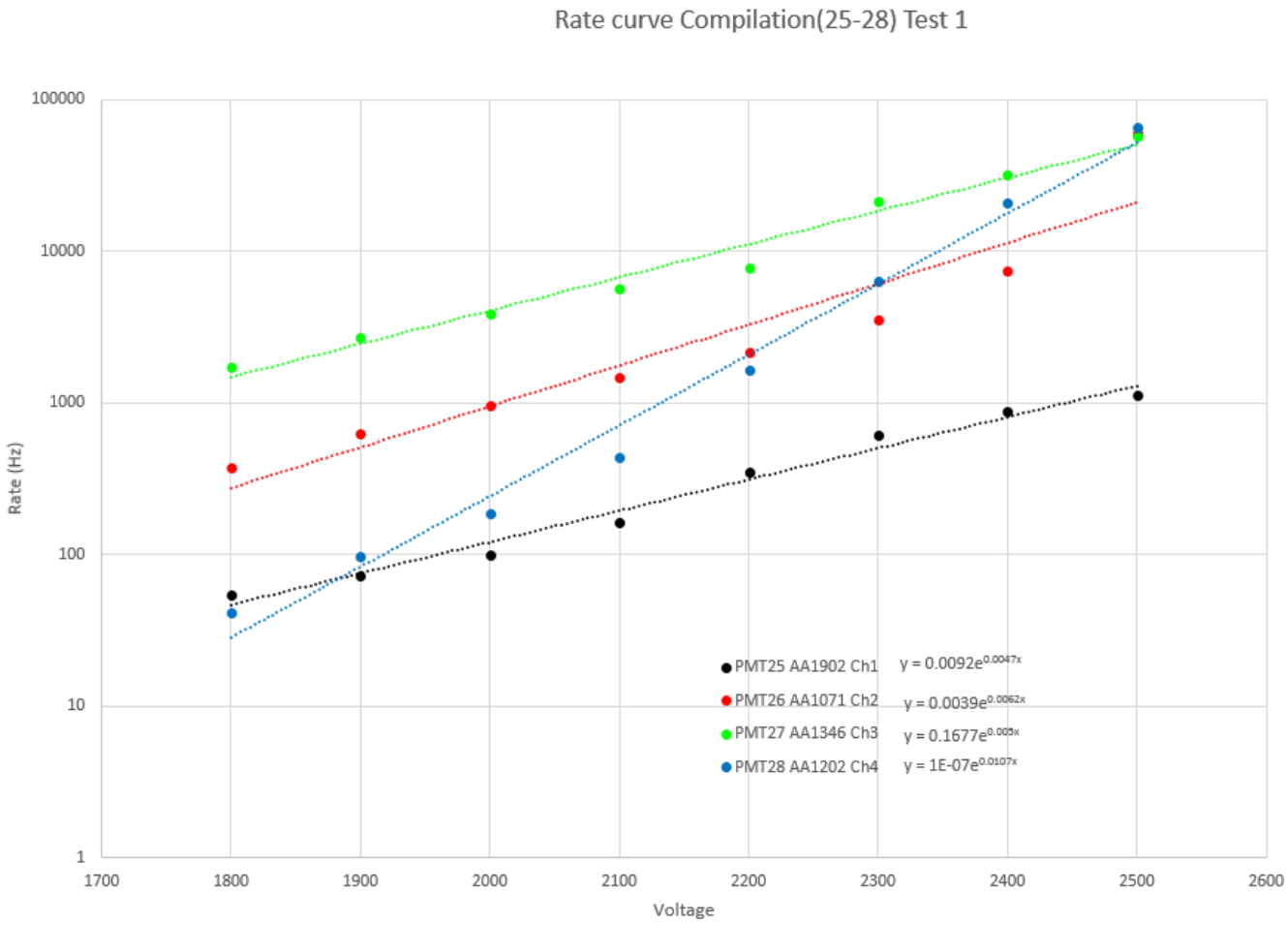
PMT27 AA1346 Ch3						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2000V for 15 min before testing						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	13749	13872	13536	13995	13914	1726.65
1900	21609	21442	21579	21389	21848	2696.675
2000	29195	30186	31834	32416	30139	3844.25
2100	42879	45249	47650	48463	40334	5614.375
2200	43645	44411	102929	82175	40284	7836.1
2300	160555	169997	155642	165656	203753	21390.08
2400	352948	241766	216972	243826	222466	31949.45
2500	392657	409572	557072	398014	545025	57558.5



PMT28 AA1202 Dark rate test repeated Feb 18, 2018 by

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800						#DIV/0!
1900						#DIV/0!
2000						#DIV/0!
2100						#DIV/0!
2200						#DIV/0!
2300	22127	20063	20102	19520	22171	2599.575
2400	35690	35069	35324	35751	35108	4423.55
2500	100359	1005553	106659	105761	105821	35603.83
2600	327308	332847	329147	330668	325075	41126.13
2700	884371	877094	892597	881652	832334	109201.2
2800	2415417	2441331	2490076	1827488	2064142	280961.4




Rate curve Compilation(25-28) Test 1
100000
10000
1000
100
10
1
Rate (Hz)
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Voltage
PMT25 AA1902 Ch1 y = 0.0092e^0.0047x
PMT26 AA1071 Ch2 y = 0.0039e^0.0062x
PMT27 AA1346 Ch3 y = 0.1677e^0.005x
PMT28 AA1202 Ch4 y = 1E-07e^0.0107x

For these Charge Distribution Histograms:

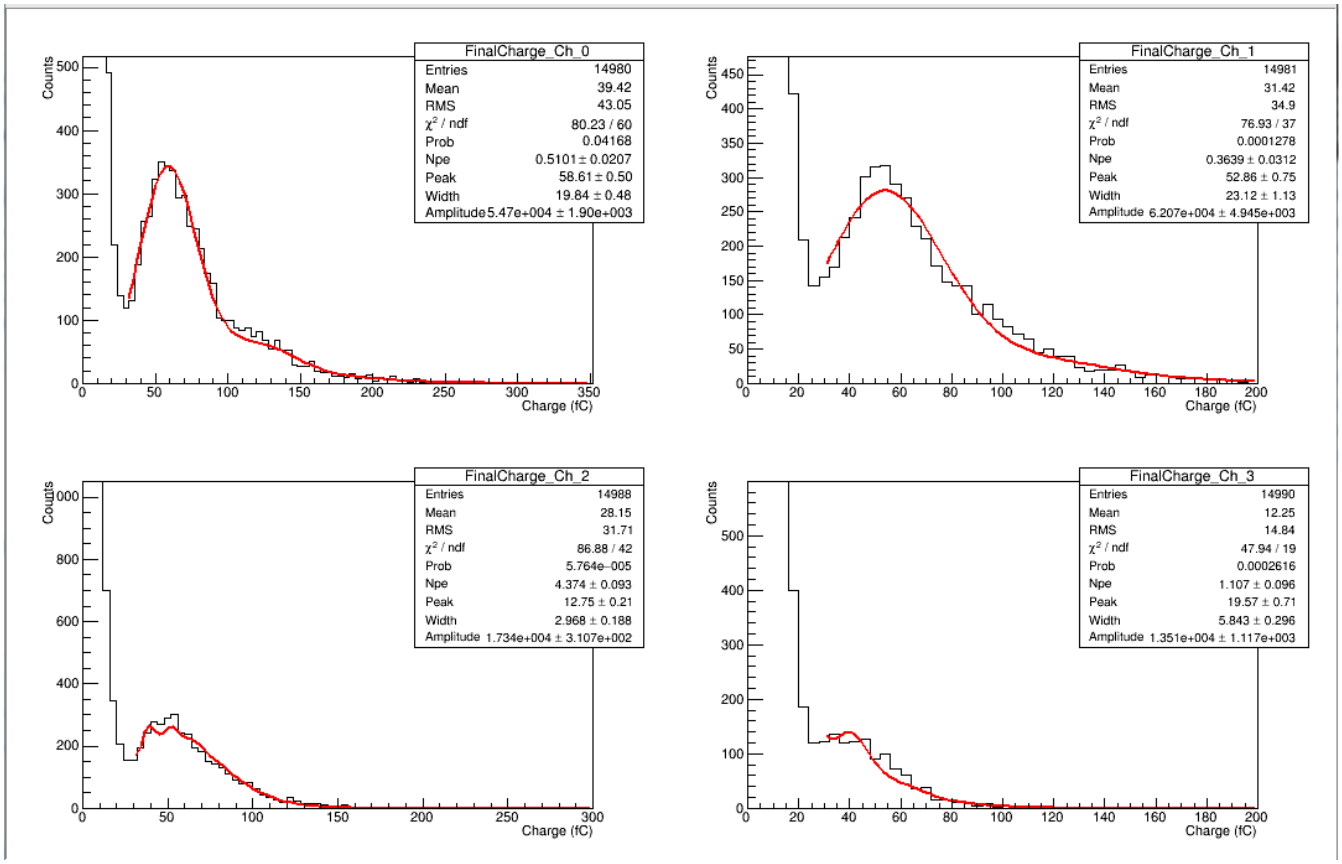
FinalCharge_Ch_0 = PMT25-AA1902 FinalCharge_Ch_1 = PMT26-AA1071

FinalCharge_Ch_2 = PMT27-AA1346 FinalCharge_Ch_3 = PMT28-AA1202

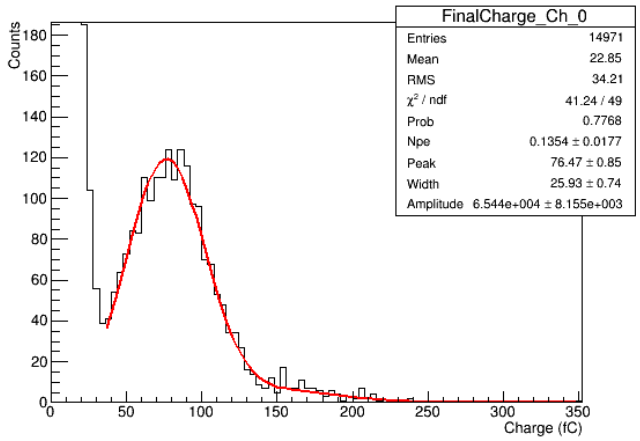
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

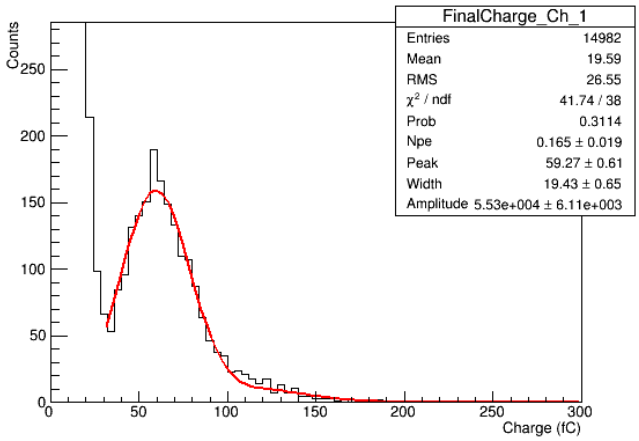
Code used to fit: fitnpe_XP2020

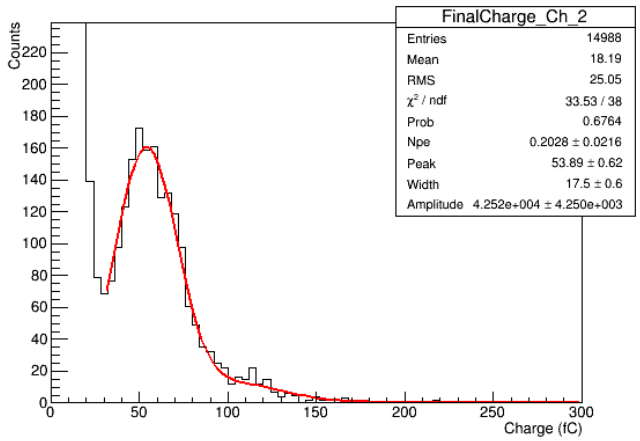
At 1600V

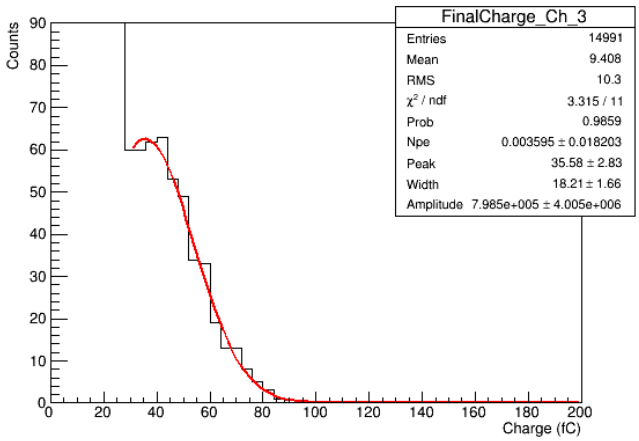


At 1700V

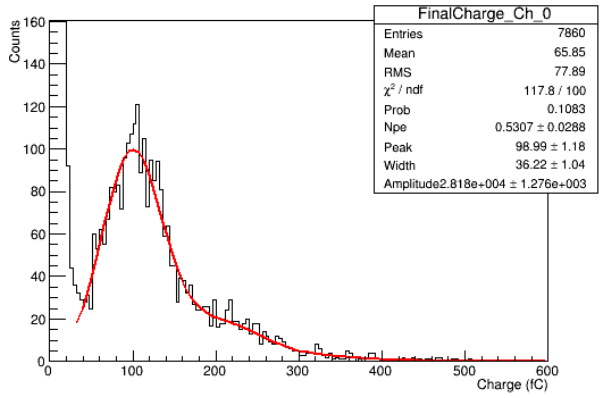

FinalCharge_Ch_0
Entries 14971
Mean 22.85
RMS 34.21
χ² / ndf 41.24 / 49
Prob 0.7768
Npe 0.1354 ± 0.0177
Peak 76.47 ± 0.85
Width 25.93 ± 0.74
Amplitude 6.544e+004 ± 8.155e+003
Counts
Charge (fC)

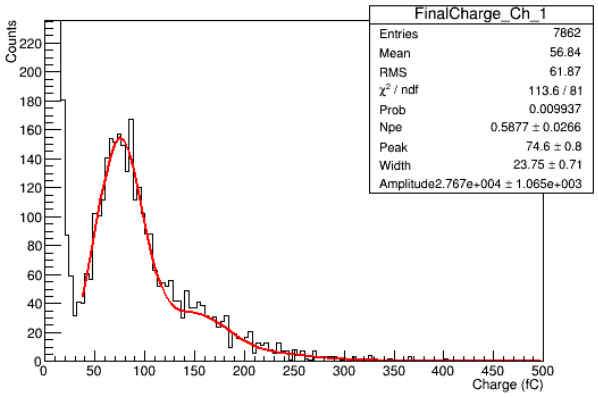

FinalCharge_Ch_1
Entries 14982
Mean 19.59
RMS 26.55
χ² / ndf 41.74 / 38
Prob 0.3114
Npe 0.165 ± 0.019
Peak 59.27 ± 0.61
Width 19.43 ± 0.65
Amplitude 5.53e+004 ± 6.11e+003
Counts
Charge (fC)

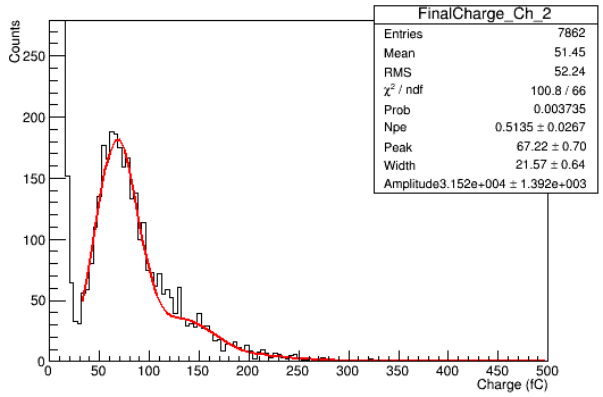

FinalCharge_Ch_2
Entries 14988
Mean 18.19
RMS 25.05
χ² / ndf 33.53 / 38
Prob 0.6764
Npe 0.2028 ± 0.0216
Peak 53.89 ± 0.62
Width 17.5 ± 0.6
Amplitude 4.252e+004 ± 4.250e+003
Counts
Charge (fC)

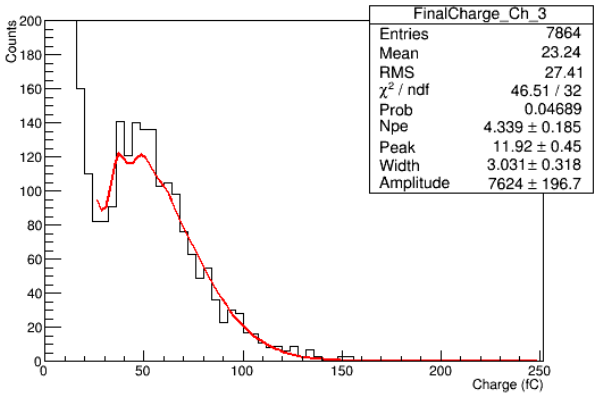

FinalCharge_Ch_3
Entries 14991
Mean 9.408
RMS 10.3
χ² / ndf 3.315 / 11
Prob 0.9859
Npe 0.003595 ± 0.018203
Peak 35.58 ± 2.83
Width 18.21 ± 1.66
Amplitude 7.985e+005 ± 4.005e+006
Counts
Charge (fC)

At 1800V

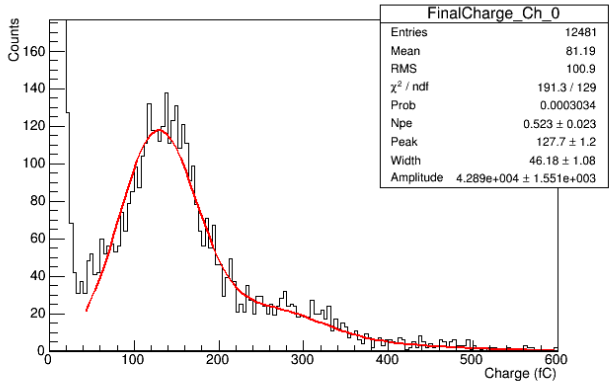

FinalCharge_Ch_0
Entries 7860
Mean 65.85
RMS 77.89
χ² / ndf 117.8 / 100
Prob 0.1083
Npe 0.5307 ± 0.0288
Peak 98.99 ± 1.18
Width 36.22 ± 1.04
Amplitude2.818e+004 ± 1.276e+003
Counts
Charge (fC)

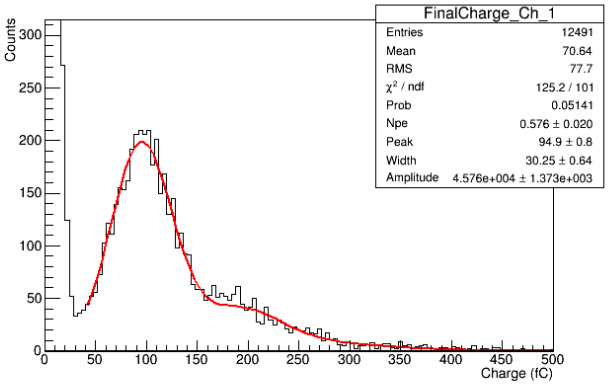

FinalCharge_Ch_1
Entries 7862
Mean 56.84
RMS 61.87
χ² / ndf 113.6 / 81
Prob 0.009937
Npe 0.5877 ± 0.0266
Peak 74.6 ± 0.8
Width 23.75 ± 0.71
Amplitude2.767e+004 ± 1.065e+003
Counts
Charge (fC)

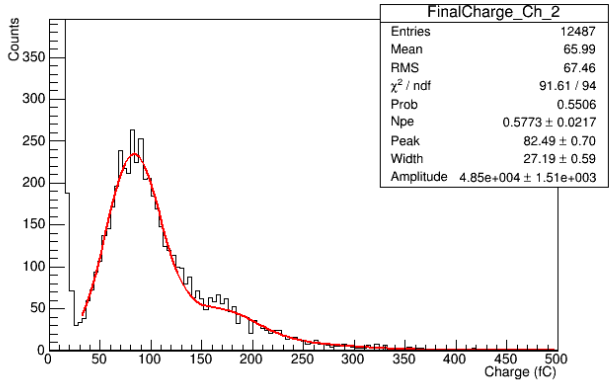

FinalCharge_Ch_2
Entries 7862
Mean 51.45
RMS 52.24
χ² / ndf 100.8 / 66
Prob 0.003735
Npe 0.5135 ± 0.0267
Peak 67.22 ± 0.70
Width 21.57 ± 0.64
Amplitude3.152e+004 ± 1.392e+003
Counts
Charge (fC)

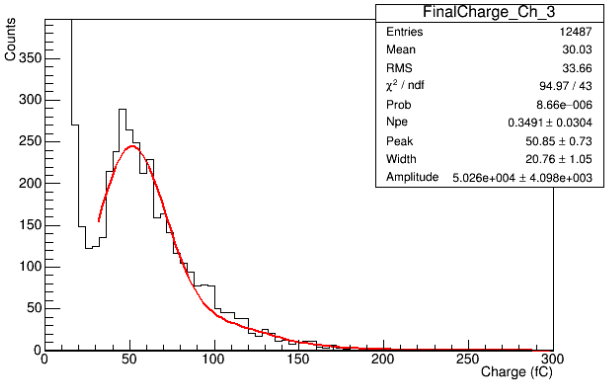

FinalCharge_Ch_3
Entries 7864
Mean 23.24
RMS 27.41
χ² / ndf 46.51 / 32
Prob 0.04689
Npe 4.339 ± 0.185
Peak 11.92 ± 0.45
Width 3.031 ± 0.318
Amplitude 7624 ± 196.7
Counts
Charge (fC)

At 1900V

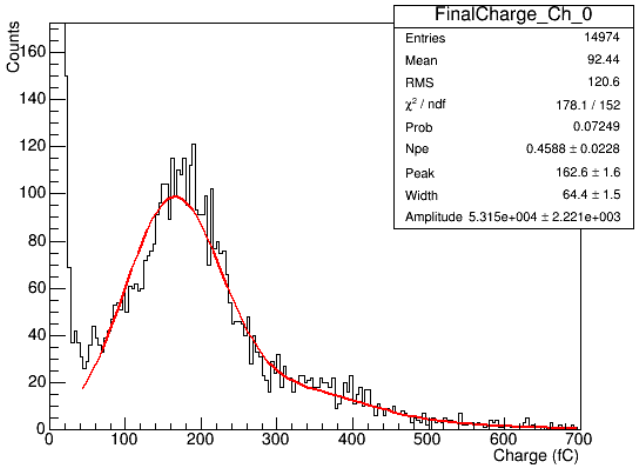

FinalCharge_Ch_0
Entries 12481
Mean 81.19
RMS 100.9
χ² / ndf 191.3 / 129
Prob 0.0003034
Npe 0.523 ± 0.023
Peak 127.7 ± 1.2
Width 46.18 ± 1.08
Amplitude 4.289e+004 ± 1.551e+003
Counts
Charge (fC)

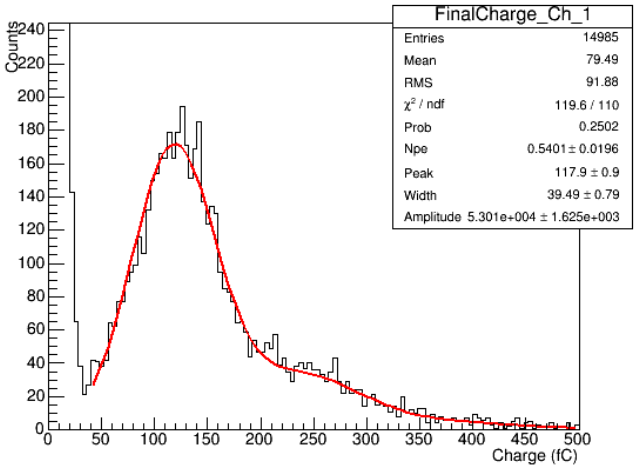

FinalCharge_Ch_1
Entries 12491
Mean 70.64
RMS 77.7
χ² / ndf 125.2 / 101
Prob 0.05141
Npe 0.576 ± 0.020
Peak 94.9 ± 0.8
Width 30.25 ± 0.64
Amplitude 4.576e+004 ± 1.373e+003
Counts
Charge (fC)

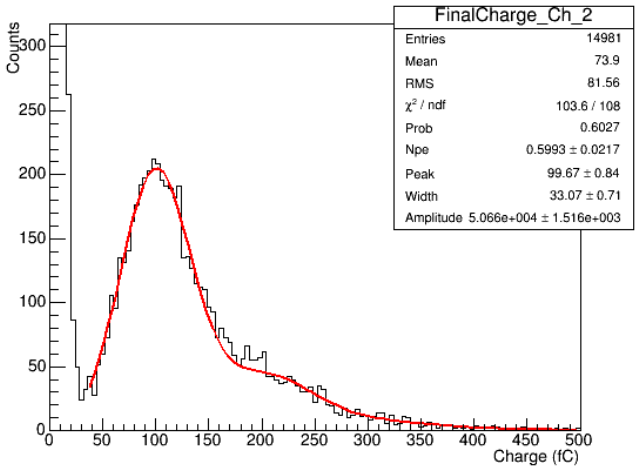

FinalCharge_Ch_2
Entries 12487
Mean 65.99
RMS 67.46
χ² / ndf 91.61 / 94
Prob 0.5506
Npe 0.5773 ± 0.0217
Peak 82.49 ± 0.70
Width 27.19 ± 0.59
Amplitude 4.85e+004 ± 1.51e+003
Counts
Charge (fC)

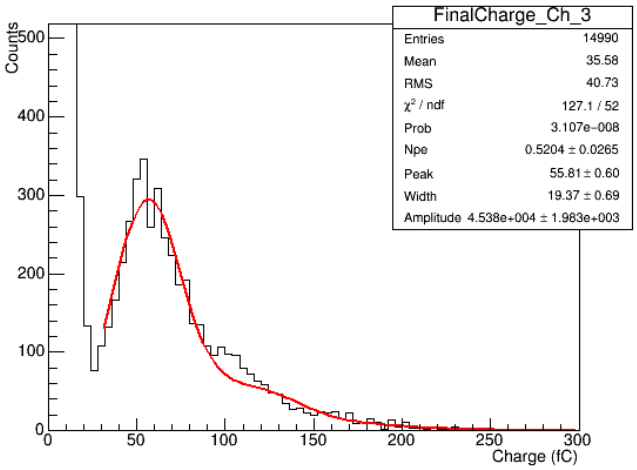

FinalCharge_Ch_3
Entries 12487
Mean 30.03
RMS 33.66
χ² / ndf 94.97 / 43
Prob 8.66e−006
Npe 0.3491 ± 0.0304
Peak 50.85 ± 0.73
Width 20.76 ± 1.05
Amplitude 5.026e+004 ± 4.098e+003
Counts
Charge (fC)

At 2000V

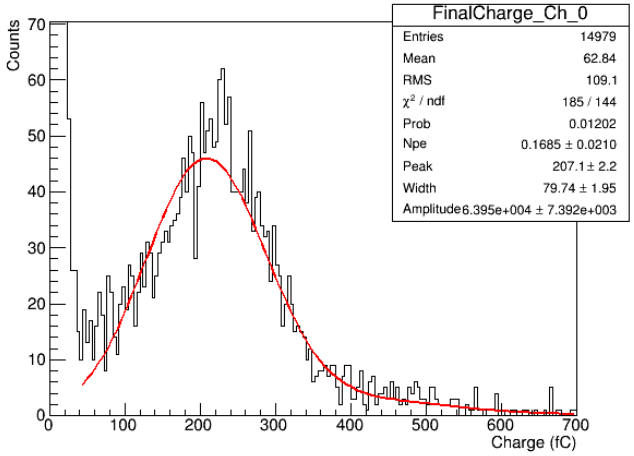

FinalCharge_Ch_0
Entries 14974
Mean 92.44
RMS 120.6
χ² / ndf 178.1 / 152
Prob 0.07249
Npe 0.4588 ± 0.0228
Peak 162.6 ± 1.6
Width 64.4 ± 1.5
Amplitude 5.315e+004 ± 2.221e+003
Counts
Charge (fC)

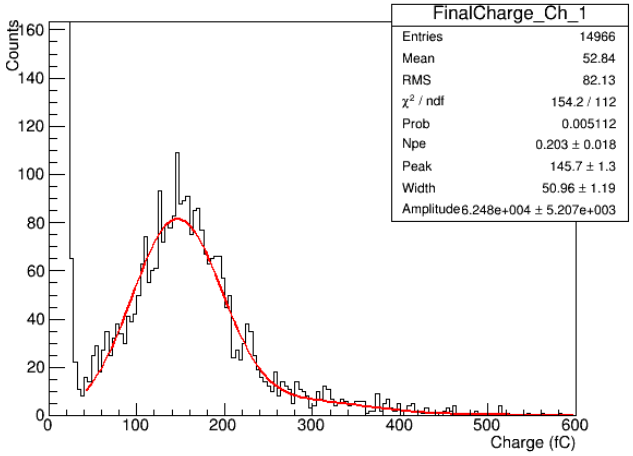

FinalCharge_Ch_1
Entries 14985
Mean 79.49
RMS 91.88
χ² / ndf 119.6 / 110
Prob 0.2502
Npe 0.5401 ± 0.0196
Peak 117.9 ± 0.9
Width 39.49 ± 0.79
Amplitude 5.301e+004 ± 1.625e+003
Counts
Charge (fC)

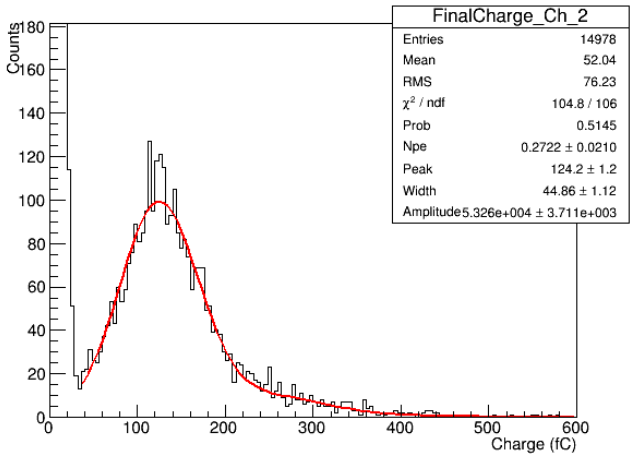

FinalCharge_Ch_2
Entries 14981
Mean 73.9
RMS 81.56
χ² / ndf 103.6 / 108
Prob 0.6027
Npe 0.5993 ± 0.0217
Peak 99.67 ± 0.84
Width 33.07 ± 0.71
Amplitude 5.066e+004 ± 1.516e+003
Counts
Charge (fC)

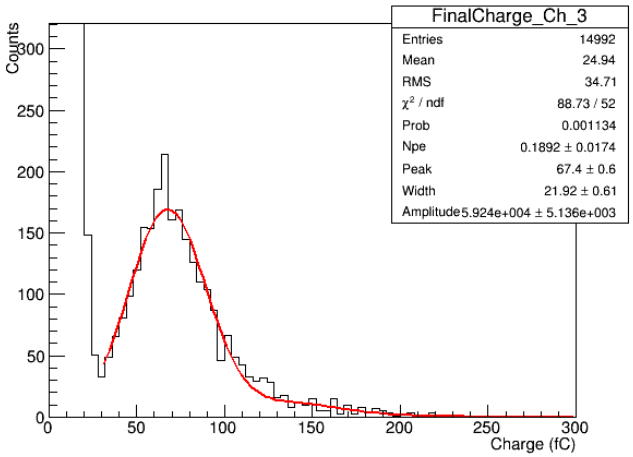

FinalCharge_Ch_3
Entries 14990
Mean 35.58
RMS 40.73
χ² / ndf 127.1 / 52
Prob 3.107e−008
Npe 0.5204 ± 0.0265
Peak 55.81 ± 0.60
Width 19.37 ± 0.69
Amplitude 4.538e+004 ± 1.983e+003
Counts
Charge (fC)

At 2100V

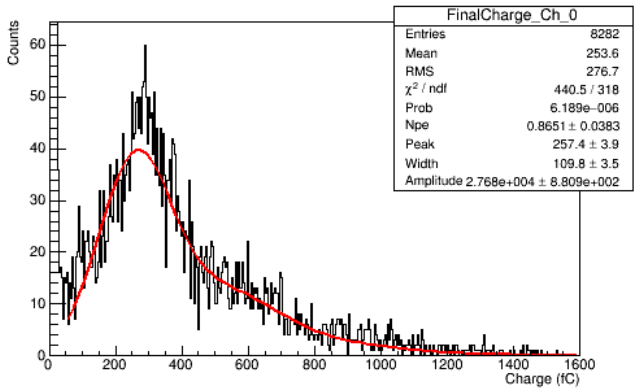

FinalCharge_Ch_0
Entries 14979
Mean 62.84
RMS 109.1
χ² / ndf 185 / 144
Prob 0.01202
Npe 0.1685 ± 0.0210
Peak 207.1 ± 2.2
Width 79.74 ± 1.95
Amplitude 6.395e+004 ± 7.392e+003
Counts
Charge (fC)

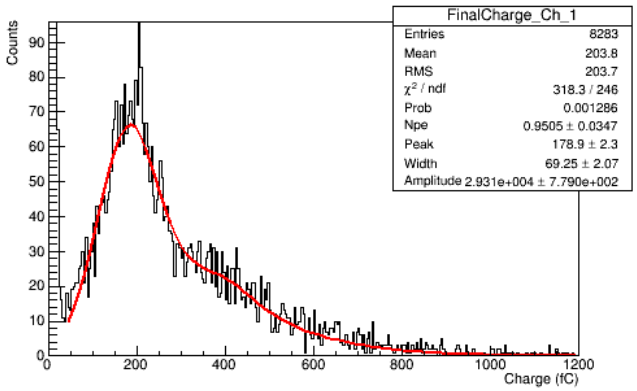

FinalCharge_Ch_1
Entries 14966
Mean 52.84
RMS 82.13
χ² / ndf 154.2 / 112
Prob 0.005112
Npe 0.203 ± 0.018
Peak 145.7 ± 1.3
Width 50.96 ± 1.19
Amplitude 6.248e+004 ± 5.207e+003
Counts
Charge (fC)

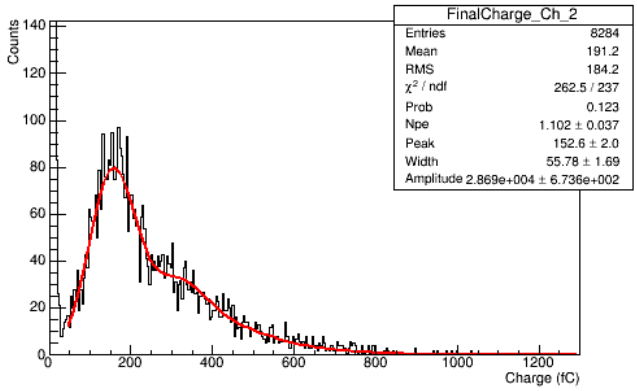

FinalCharge_Ch_2
Entries 14978
Mean 52.04
RMS 76.23
χ² / ndf 104.8 / 106
Prob 0.5145
Npe 0.2722 ± 0.0210
Peak 124.2 ± 1.2
Width 44.86 ± 1.12
Amplitude 5.326e+004 ± 3.711e+003
Counts
Charge (fC)

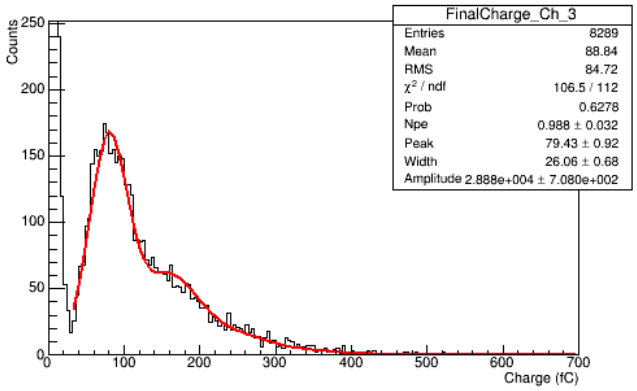

FinalCharge_Ch_3
Entries 14992
Mean 24.94
RMS 34.71
χ² / ndf 88.73 / 52
Prob 0.001134
Npe 0.1892 ± 0.0174
Peak 67.4 ± 0.6
Width 21.92 ± 0.61
Amplitude 5.924e+004 ± 5.136e+003
Counts
Charge (fC)

At 2200V

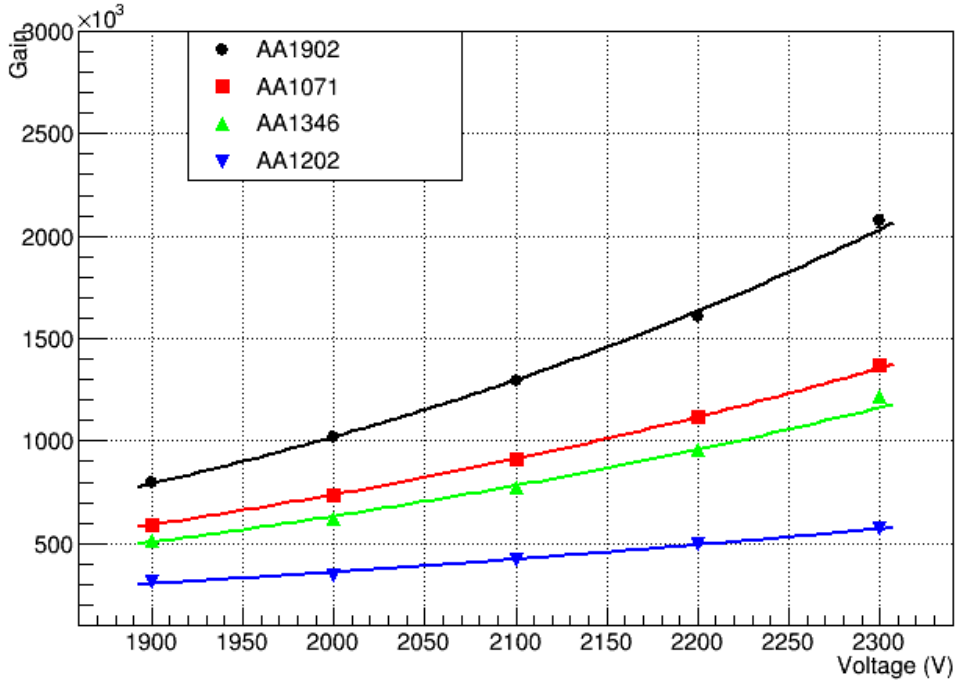

FinalCharge_Ch_0
Entries 8282
Mean 253.6
RMS 276.7
χ² / ndf 440.5 / 318
Prob 6.189e−006
Npe 0.8651 ± 0.0383
Peak 257.4 ± 3.9
Width 109.8 ± 3.5
Amplitude 2.768e+004 ± 8.809e+002
Counts
Charge (fC)

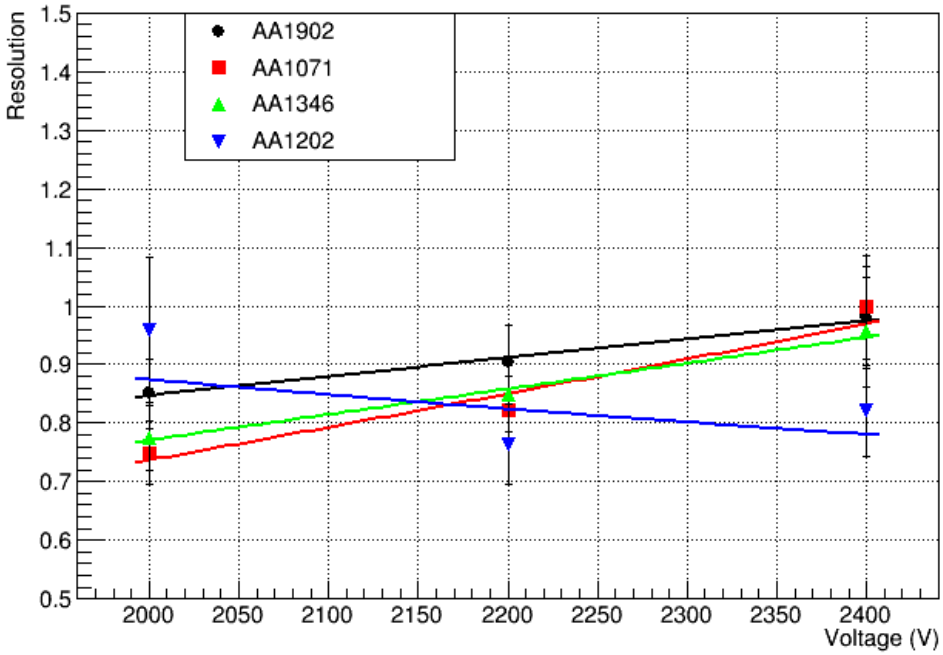

FinalCharge_Ch_1
Entries 8283
Mean 203.8
RMS 203.7
χ² / ndf 318.3 / 246
Prob 0.001286
Npe 0.9505 ± 0.0347
Peak 178.9 ± 2.3
Width 69.25 ± 2.07
Amplitude 2.931e+004 ± 7.790e+002
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 8284
Mean 191.2
RMS 184.2
χ² / ndf 262.5 / 237
Prob 0.123
Npe 1.102 ± 0.037
Peak 152.6 ± 2.0
Width 55.78 ± 1.69
Amplitude 2.869e+004 ± 6.736e+002
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 8289
Mean 88.84
RMS 84.72
χ² / ndf 106.5 / 112
Prob 0.6278
Npe 0.988 ± 0.032
Peak 79.43 ± 0.92
Width 26.06 ± 0.68
Amplitude 2.888e+004 ± 7.080e+002
Counts
Charge (fC)

Gain and resolution curves: PMT25-AA1902, PMT26-AA1071, PMT27-AA1346, PMT28-AA1202

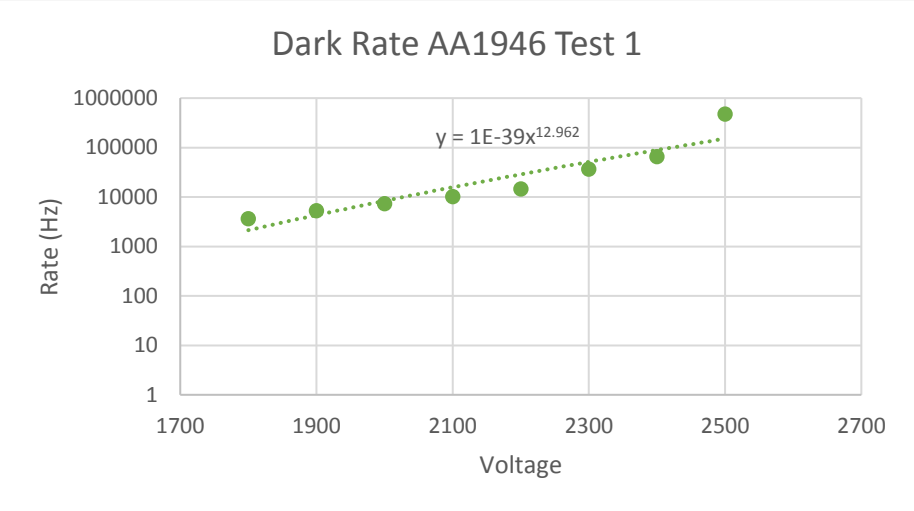




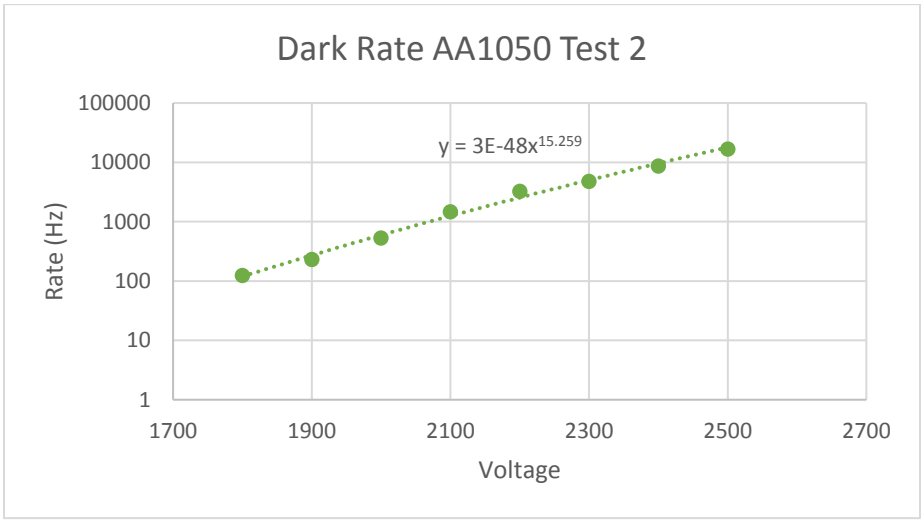
PMT's 29-32

PMT29-AA1946
PMT30-AA1050
PMT31-AA1708
PMT32-AA1185

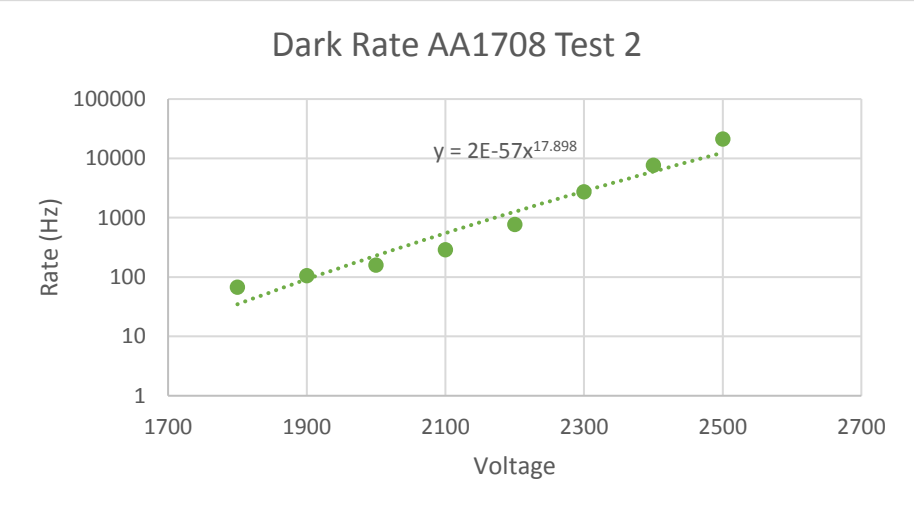
PMT29 AA1946 CH2-1 RETESTED						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	29627	30177	28376	29472	28649	3657.525
1900	42202	41939	43058	42362	42469	5300.75
2000	60037	59275	58187	58521	57352	7334.3
2100	80989	81864	81531	82600	81727	10217.78
2200	116728	118505	118710	116345	112703	14574.78
2300	285387	289711	292782	292143	294139	36354.05
2400	525064	522553	529292	524213	527889	65725.28
2500	3916519	3867827	3809959	3759817	3724827	476973.7



PMT30 AA1050 Ch2-2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Tubes were very warm by this point						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	973	1032	925	1002	1041	124.325
1900	1845	1791	1889	1996	1746	231.675
2000	3751	3993	4990	4327	4393	536.35
2100	10963	12588	12566	12014	11029	1479
2200	19912	20118	27578	32020	31323	3273.775
2300	33964	37572	38025	40393	42476	4810.75
2400	60535	65740	79116	78635	65866	8747.3
2500	349866	109291	68928	85460	63825	16934.25



PMT31 AA1708 Ch3-2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Tubes were very warm by this point						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	523	576	516	548	538	67.525
1900	854	851	792	807	872	104.4
2000	1281	1242	1296	1284	1216	157.975
2100	2250	2339	2229	2302	2326	286.15
2200	6192	6070	5967	6185	6086	762.5
2300	22069	21653	21456	21932	21219	2708.225
2400	59509	58054	57698	64843	63392	7587.4
2500	170467	171744	166300	172722	162752	21099.63

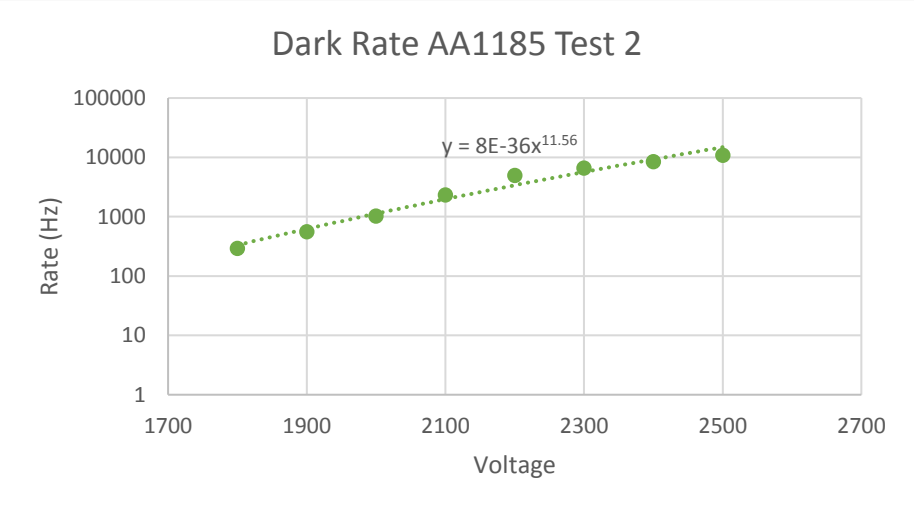


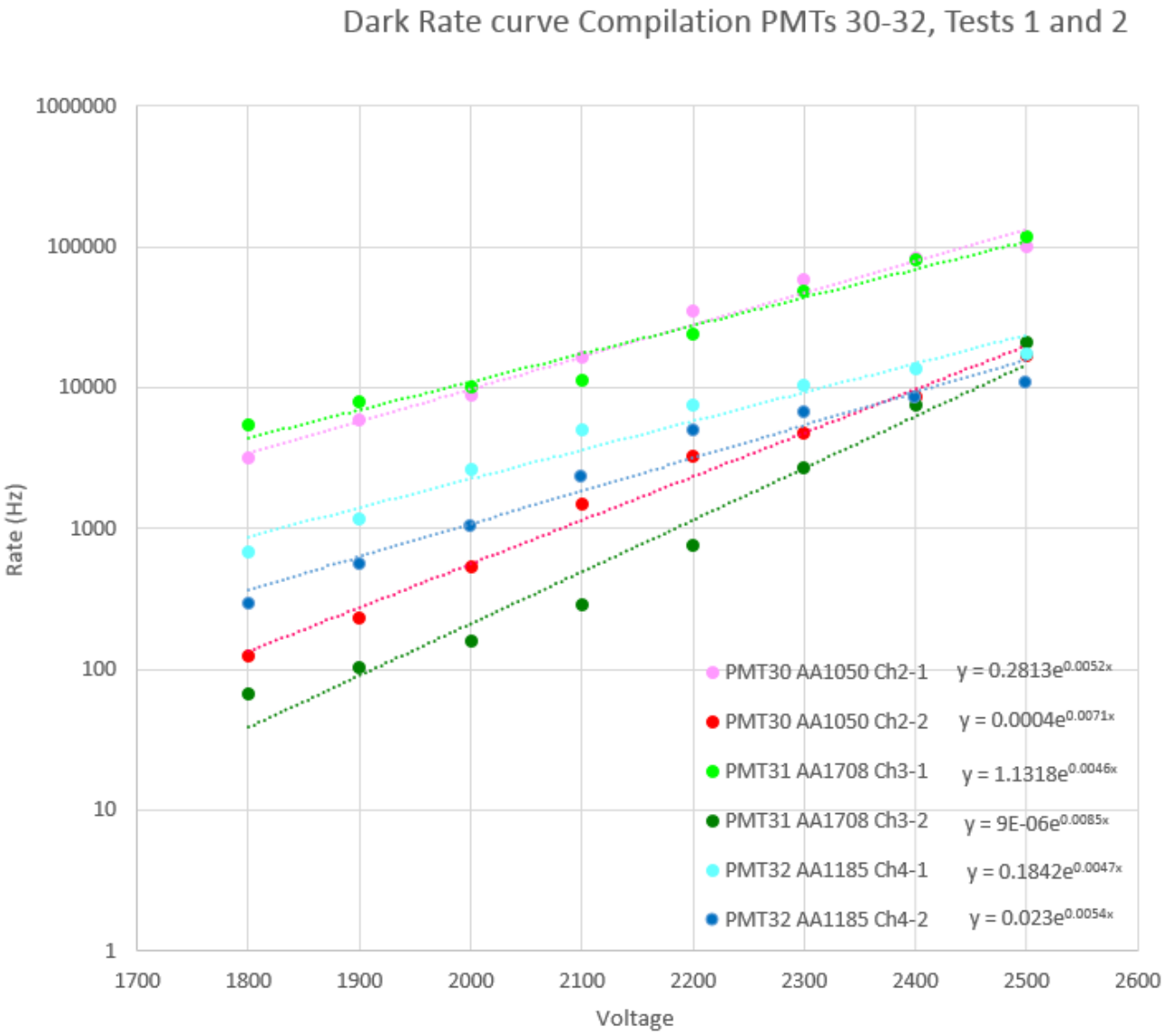
PMT32 AA1185 Ch4-2

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Tubes were very warm by this point

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	2340	2399	2342	2371	2334	294.65
1900	4579	4383	4486	4472	4520	561
2000	10118	1091	10065	9983	9898	1028.875
2100	18764	18908	18864	18862	18694	2352.3
2200	39945	39806	39784	39376	39417	4958.2
2300	53222	53482	52484	53264	52626	6626.95
2400	68708	68568	67949	68385	68294	8547.6
2500	87519	86361	86858	86217	86632	10839.68




Dark Rate curve Compilation PMTs 30-32, Tests 1 and 2
1000000
100000
10000
1000
100
10
1
Rate (Hz)
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Voltage
PMT30 AA1050 Ch2-1 y = 0.2813e^0.0052x
PMT30 AA1050 Ch2-2 y = 0.0004e^0.0071x
PMT31 AA1708 Ch3-1 y = 1.1318e^0.0046x
PMT31 AA1708 Ch3-2 y = 9E-06e^0.0085x
PMT32 AA1185 Ch4-1 y = 0.1842e^0.0047x
PMT32 AA1185 Ch4-2 y = 0.023e^0.0054x

For these Charge Distribution Histograms:

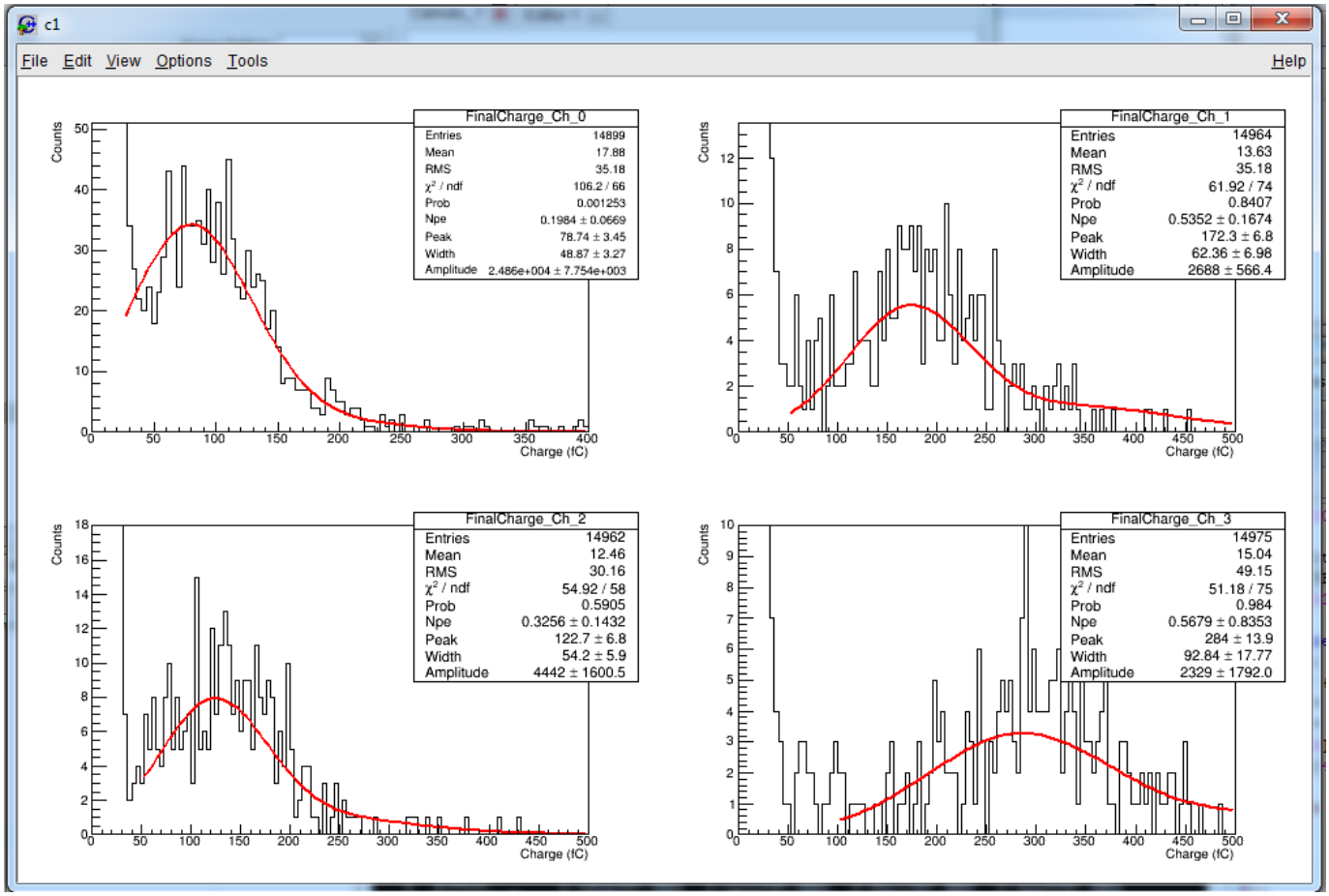
FinalCharge_Ch_0 = PMT29-AA1946 FinalCharge_Ch_1 = PMT30-AA1050

FinalCharge_Ch_2 = PMT31-AA1708 FinalCharge_Ch_3 = PMT32-AA1185

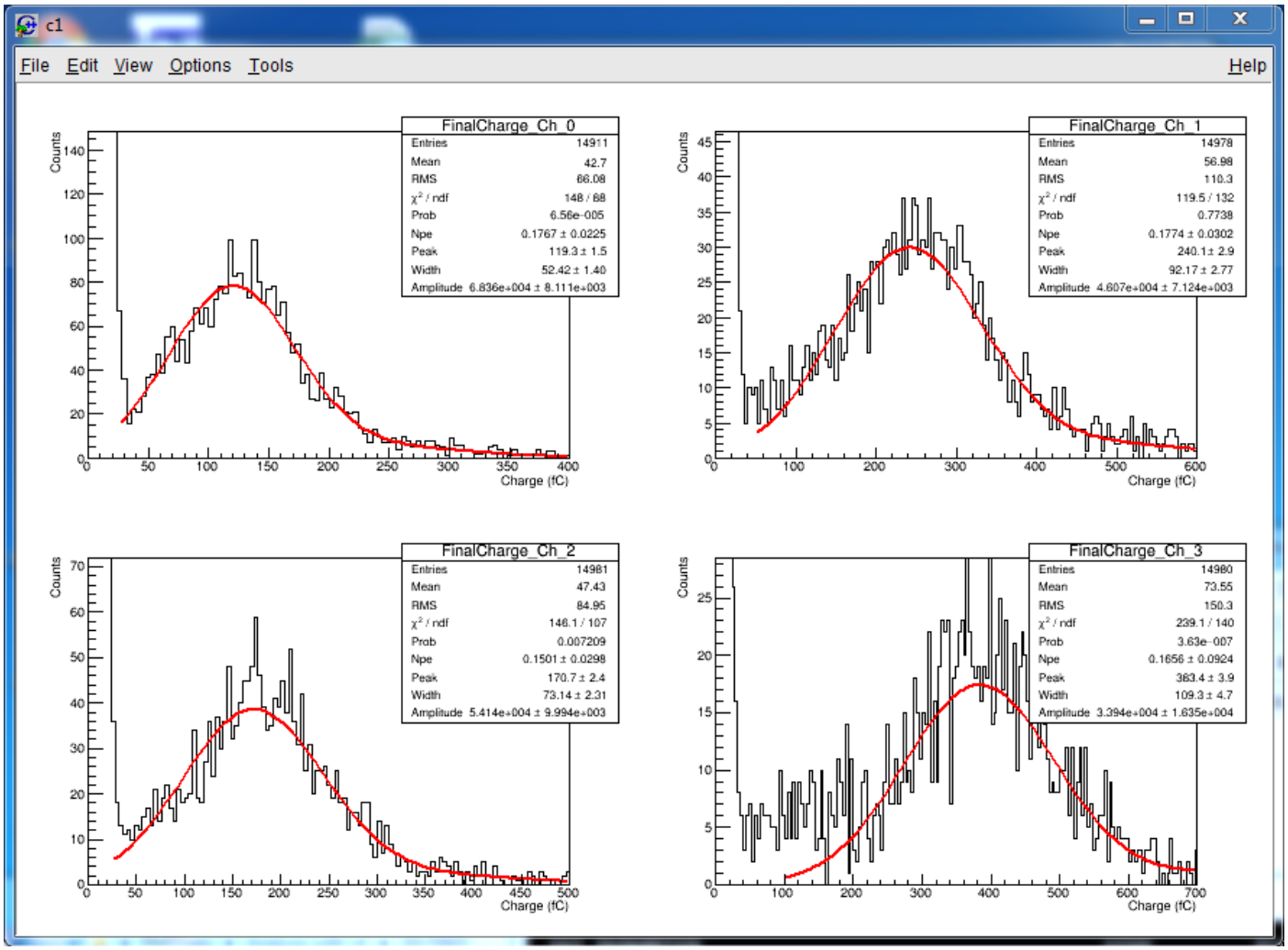
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

Code used to fit: fitnpe_XP2020

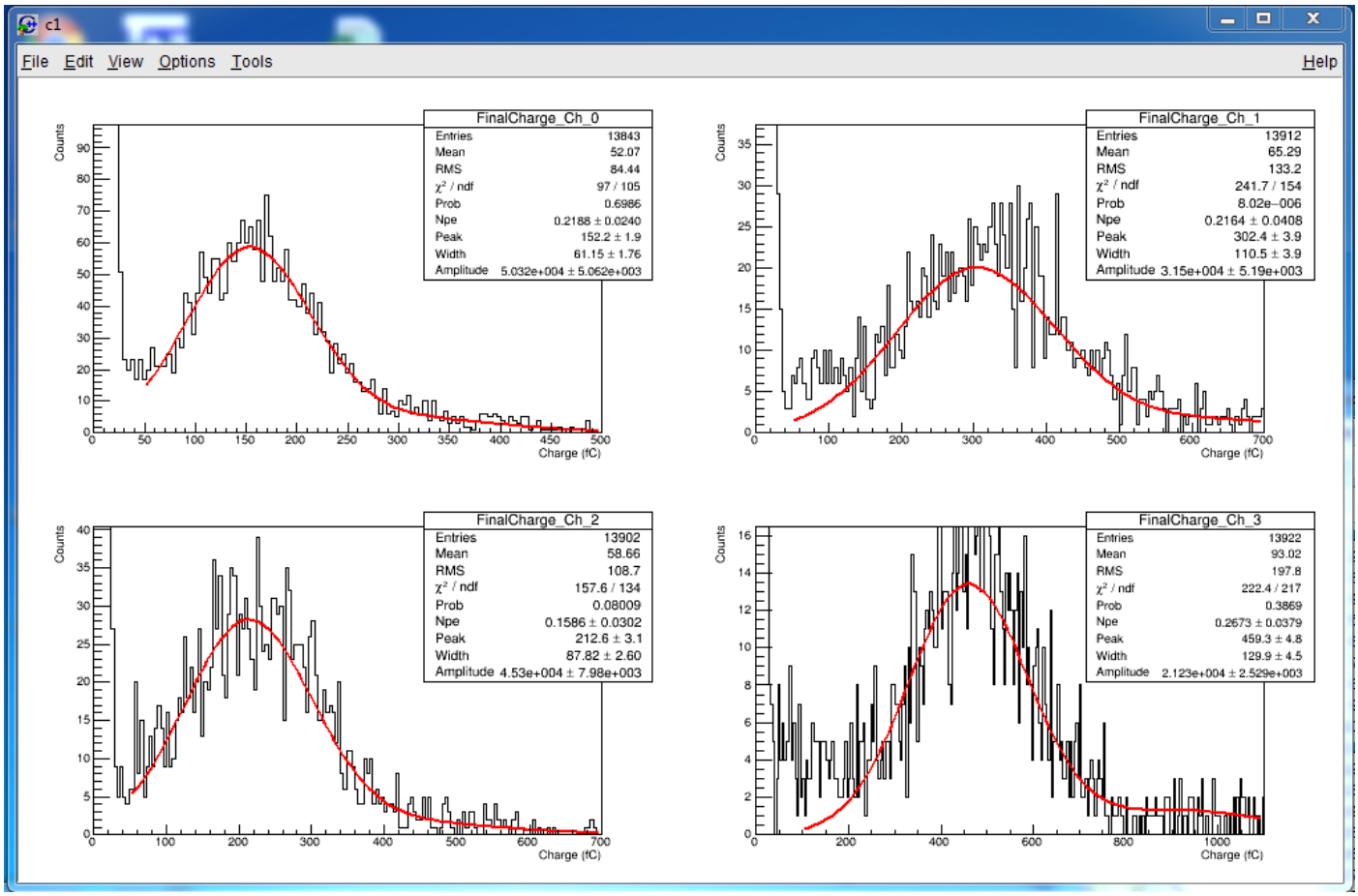
At 2000V



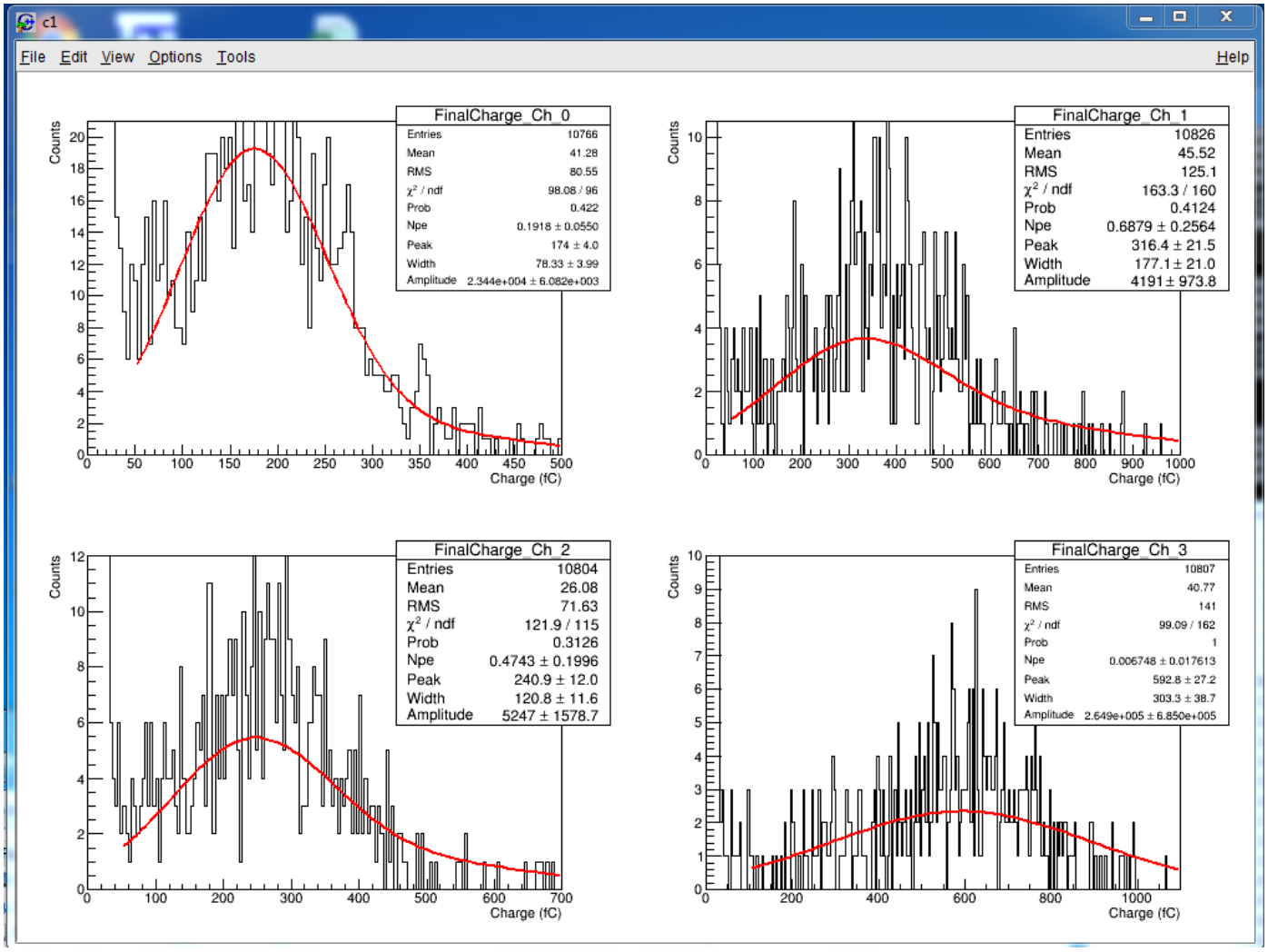
At 2100V


c1
File Edit View Options Tools Help
FinalCharge_Ch_0
Entries 14911
Mean 42.7
RMS 66.08
χ² / ndf 148 / 88
Prob 6.56e-005
Npe 0.1767 ± 0.0225
Peak 119.3 ± 1.5
Width 52.42 ± 1.40
Amplitude 6.836e+004 ± 8.111e+003
Counts
Charge (fC)
FinalCharge_Ch_1
Entries 14978
Mean 56.98
RMS 110.3
χ² / ndf 119.5 / 132
Prob 0.7738
Npe 0.1774 ± 0.0302
Peak 240.1 ± 2.9
Width 92.17 ± 2.77
Amplitude 4.607e+004 ± 7.124e+003
Counts
Charge (fC)
FinalCharge_Ch_2
Entries 14981
Mean 47.43
RMS 84.95
χ² / ndf 146.1 / 107
Prob 0.007209
Npe 0.1501 ± 0.0298
Peak 170.7 ± 2.4
Width 73.14 ± 2.31
Amplitude 5.414e+004 ± 9.994e+003
Counts
Charge (fC)
FinalCharge_Ch_3
Entries 14980
Mean 73.55
RMS 150.3
χ² / ndf 239.1 / 140
Prob 3.63e-007
Npe 0.1656 ± 0.0924
Peak 383.4 ± 3.9
Width 109.3 ± 4.7
Amplitude 3.394e+004 ± 1.635e+004
Counts
Charge (fC)

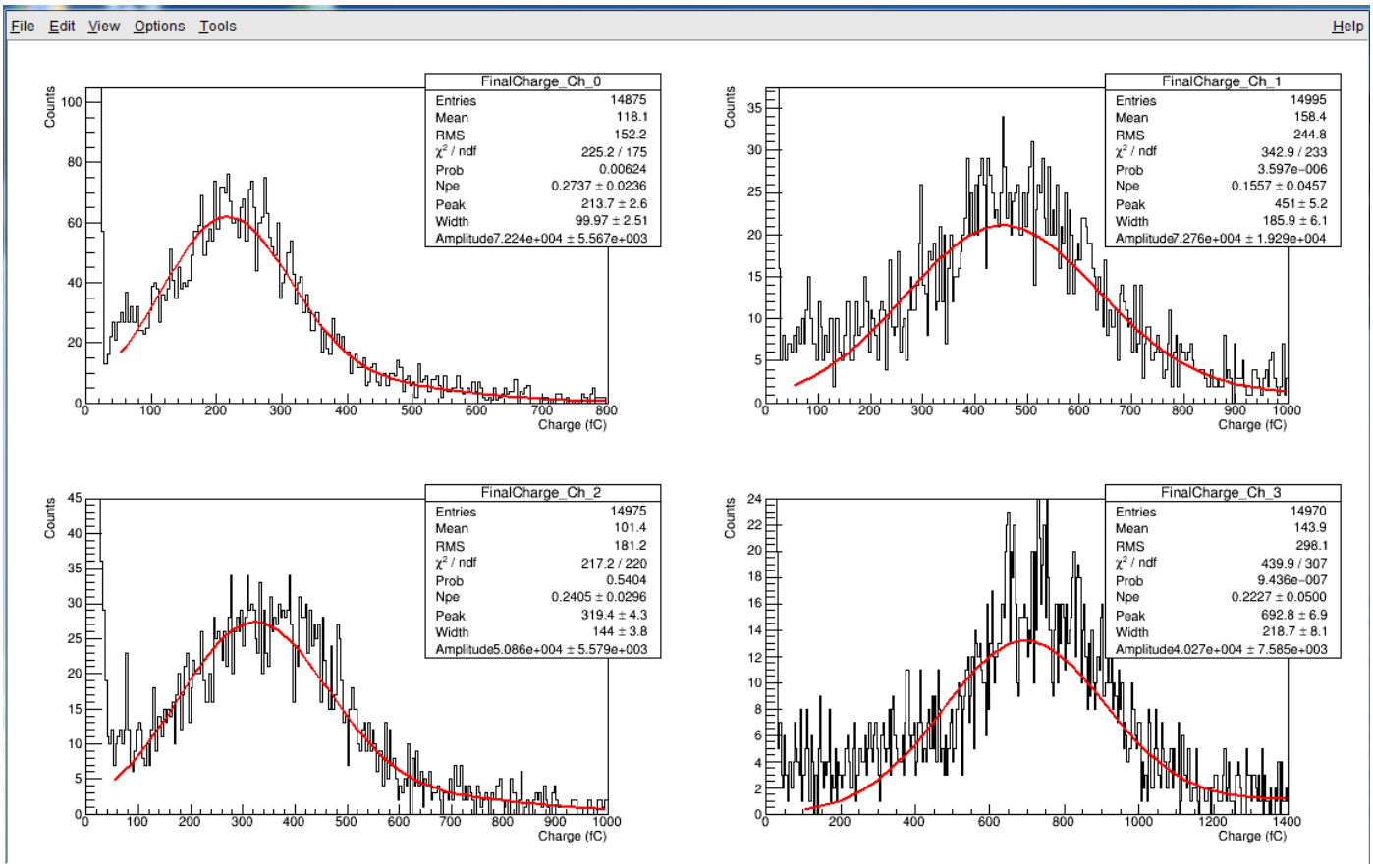
At 2200V


c1
File Edit View Options Tools Help
FinalCharge_Ch_0
Entries 13843
Mean 52.07
RMS 84.44
χ² / ndf 97 / 105
Prob 0.6986
Npe 0.2188 ± 0.0240
Peak 152.2 ± 1.9
Width 61.15 ± 1.76
Amplitude 5.032e+004 ± 5.062e+003
FinalCharge_Ch_1
Entries 13912
Mean 65.29
RMS 133.2
χ² / ndf 241.7 / 154
Prob 8.02e−006
Npe 0.2164 ± 0.0408
Peak 302.4 ± 3.9
Width 110.5 ± 3.9
Amplitude 3.15e+004 ± 5.19e+003
FinalCharge_Ch_2
Entries 13902
Mean 58.66
RMS 108.7
χ² / ndf 157.6 / 134
Prob 0.08009
Npe 0.1586 ± 0.0302
Peak 212.6 ± 3.1
Width 87.82 ± 2.60
Amplitude 4.53e+004 ± 7.98e+003
FinalCharge_Ch_3
Entries 13922
Mean 93.02
RMS 197.8
χ² / ndf 222.4 / 217
Prob 0.3869
Npe 0.2673 ± 0.0379
Peak 459.3 ± 4.8
Width 129.9 ± 4.5
Amplitude 2.123e+004 ± 2.529e+003
Counts
Charge (fC)

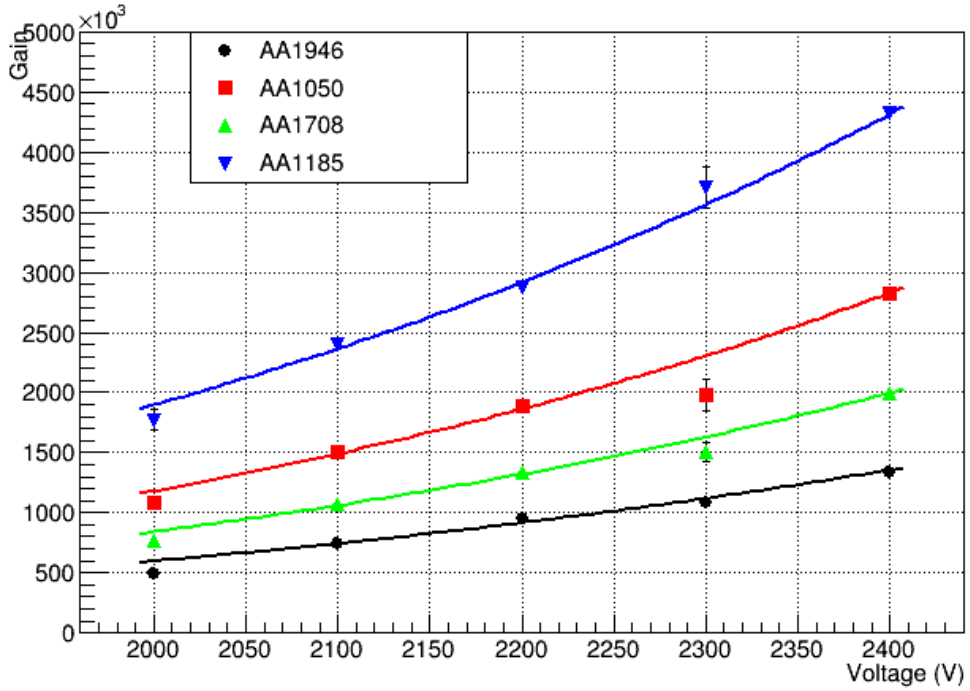
At 2300V

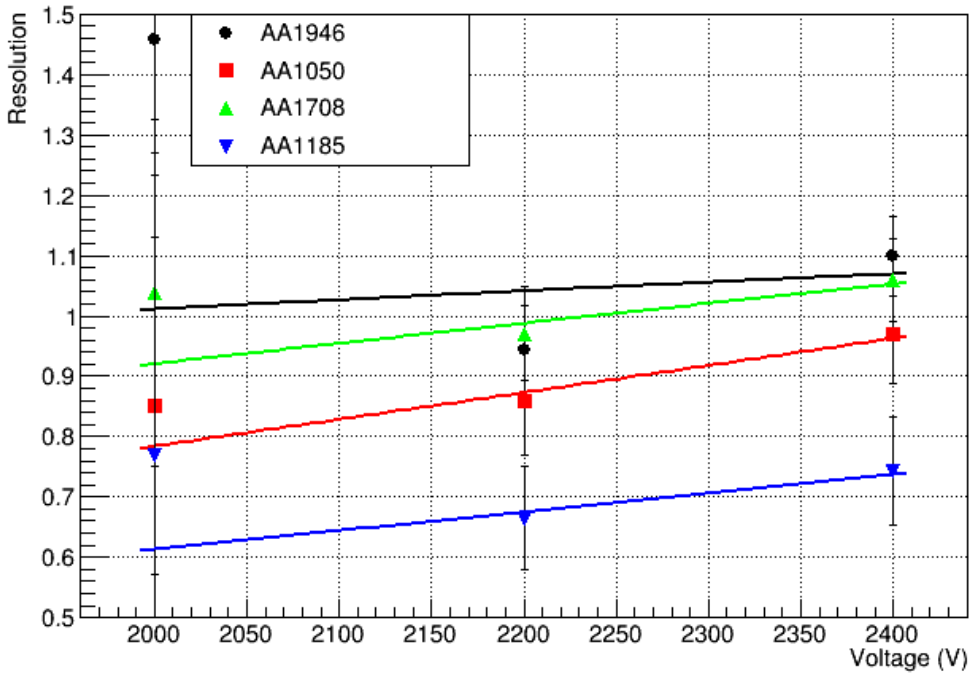

c1
File Edit View Options Tools Help
FinalCharge_Ch_0
Entries 10766
Mean 41.28
RMS 80.55
χ² / ndf 98.08 / 96
Prob 0.422
Npe 0.1918 ± 0.0550
Peak 174 ± 4.0
Width 78.33 ± 3.99
Amplitude 2.344e+004 ± 6.082e+003
FinalCharge_Ch_1
Entries 10826
Mean 45.52
RMS 125.1
χ² / ndf 163.3 / 160
Prob 0.4124
Npe 0.6879 ± 0.2564
Peak 316.4 ± 21.5
Width 177.1 ± 21.0
Amplitude 4191 ± 973.8
FinalCharge_Ch_2
Entries 10804
Mean 26.08
RMS 71.63
χ² / ndf 121.9 / 115
Prob 0.3126
Npe 0.4743 ± 0.1996
Peak 240.9 ± 12.0
Width 120.8 ± 11.6
Amplitude 5247 ± 1578.7
FinalCharge_Ch_3
Entries 10807
Mean 40.77
RMS 141
χ² / ndf 99.09 / 162
Prob 1
Npe 0.006748 ± 0.017613
Peak 592.8 ± 27.2
Width 303.3 ± 38.7
Amplitude 2.649e+005 ± 6.850e+005
Counts
Charge (fC)

At 2400V


File Edit View Options Tools
Help
FinalCharge_Ch_0
Entries 14875
Mean 118.1
RMS 152.2
χ² / ndf 225.2 / 175
Prob 0.00624
Npe 0.2737 ± 0.0236
Peak 213.7 ± 2.6
Width 99.97 ± 2.51
Amplitude 7.224e+004 ± 5.567e+003
FinalCharge_Ch_1
Entries 14995
Mean 158.4
RMS 244.8
χ² / ndf 342.9 / 233
Prob 3.597e−006
Npe 0.1557 ± 0.0457
Peak 451 ± 5.2
Width 185.9 ± 6.1
Amplitude 7.276e+004 ± 1.929e+004
FinalCharge_Ch_2
Entries 14975
Mean 101.4
RMS 181.2
χ² / ndf 217.2 / 220
Prob 0.5404
Npe 0.2405 ± 0.0296
Peak 319.4 ± 4.3
Width 144 ± 3.8
Amplitude 5.086e+004 ± 5.579e+003
FinalCharge_Ch_3
Entries 14970
Mean 143.9
RMS 298.1
χ² / ndf 439.9 / 307
Prob 9.436e−007
Npe 0.2227 ± 0.0500
Peak 692.8 ± 6.9
Width 218.7 ± 8.1
Amplitude 4.027e+004 ± 7.585e+003
Counts
Charge (fC)

Gain and resolution curves: PMT29-AA1946, PMT30-AA1050, PMT31-AA1708, PMT32-AA1185

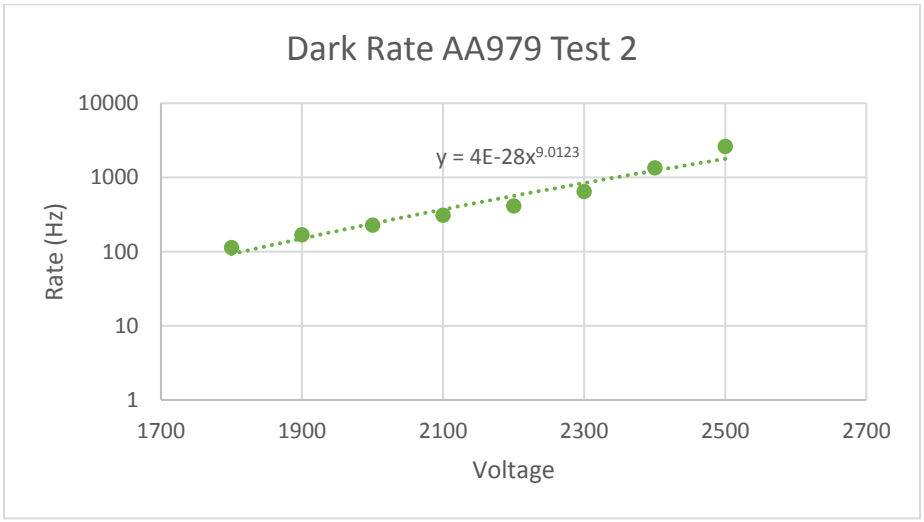




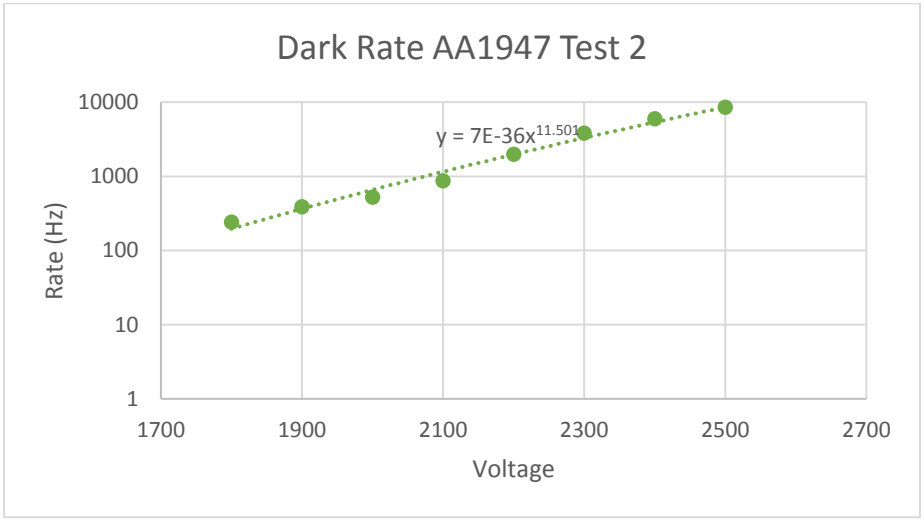
PMTs 33, 29 (remeasured here), 35, and 36 (there is no PMT34)

PMT33-AA979
PMT29-AA1946 (remeasured)
PMT35-AA1947
PMT36-AA1940

PMT33 AA979 CH1-2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Taken before the tubes were removed, maximum stability						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	899	980	893	864	906	113.55
1900	1346	1410	1335	1373	1307	169.275
2000	1857	1791	1805	1873	1785	227.775
2100	2400	2525	2445	2454	2534	308.95
2200	3316	3356	3346	3286	3214	412.95
2300	5171	5101	5182	5147	5301	647.55
2400	10794	10972	10611	10811	10639	1345.675
2500	21378	21073	21014	21068	20938	2636.775



PMT35 AA1947 CH3-2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Taken before the tubes were removed, maximum stability						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	1860	1845	2013	1887	1993	239.95
1900	3000	3062	3124	3110	3215	387.775
2000	4232	4103	4136	4100	4261	520.8
2100	7002	6983	6996	6943	6862	869.65
2200	16024	15859	16021	15859	15562	1983.125
2300	30426	30577	30601	30566	30696	3821.65
2400	47451	46570	47732	46940	48766	5936.475
2500	67639	68247	68455	67298	67231	8471.75

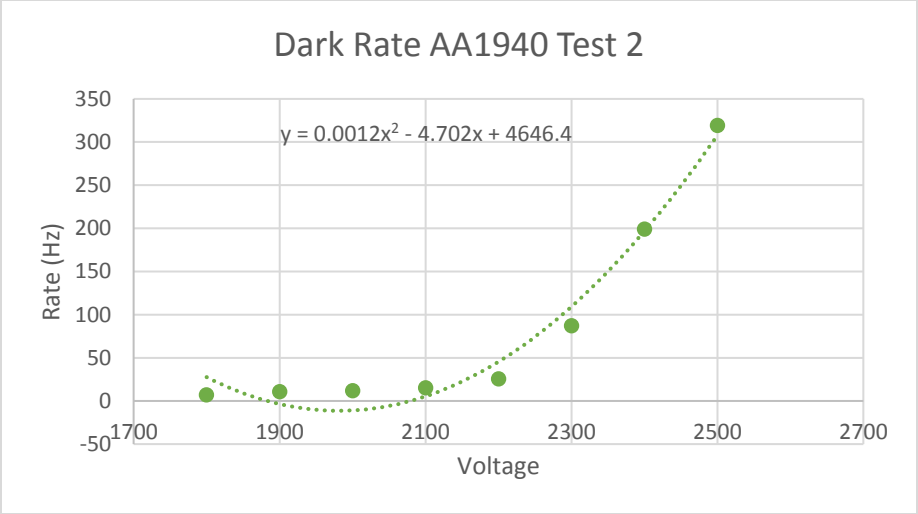


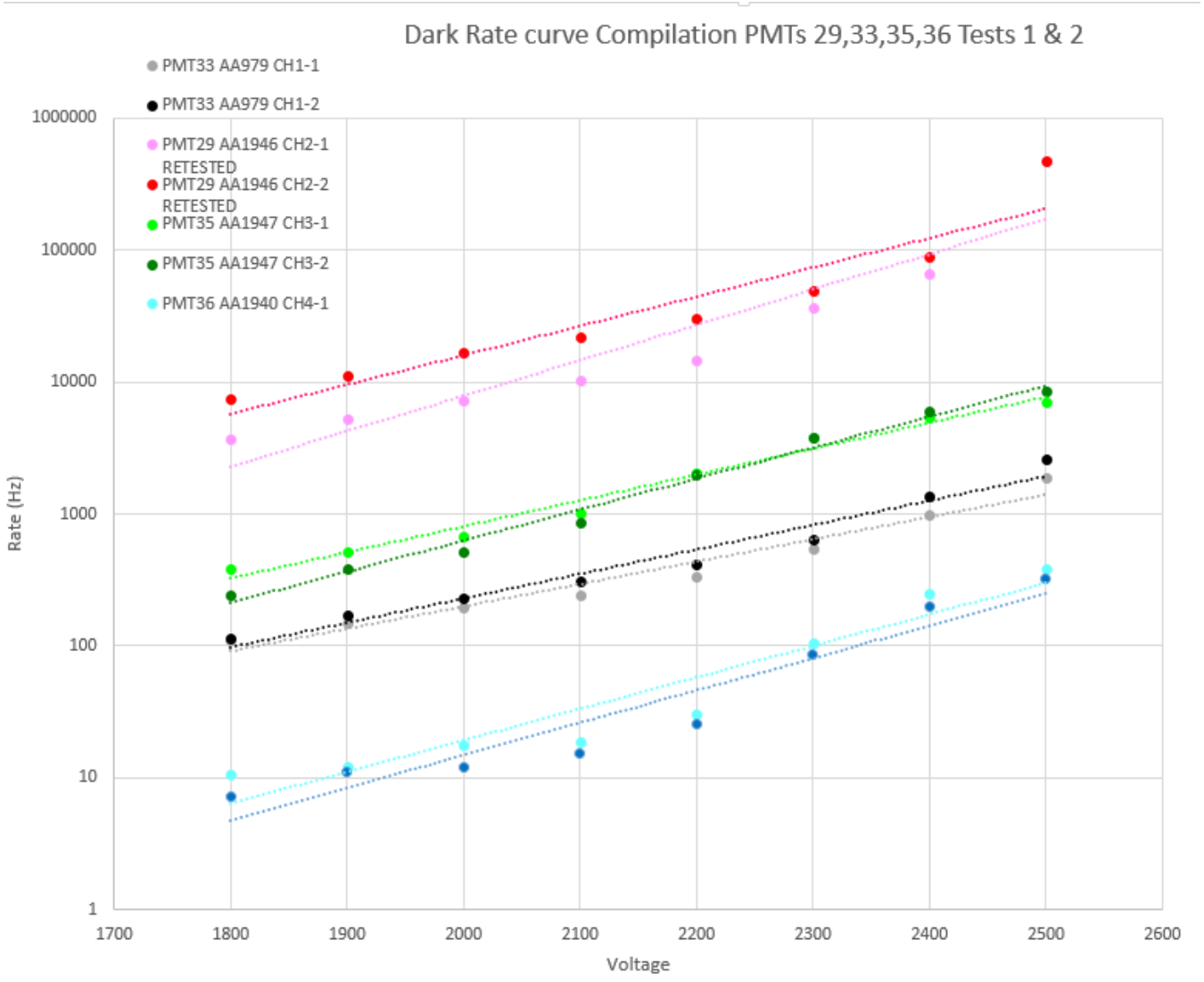
PMT36 AA1940 CH4-2

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Taken before the tubes were removed, maximum stability

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	55	68	48	55	64	7.25
1900	81	84	83	100	91	10.975
2000	88	109	84	94	104	11.975
2100	140	125	127	115	115	15.55
2200	223	187	195	216	216	25.925
2300	707	688	697	676	719	87.175
2400	1621	1539	1651	1608	1559	199.45
2500	2519	2595	2553	2550	2567	319.6




Dark Rate curve Compilation PMTs 29,33,35,36 Tests 1 & 2
PMT33 AA979 CH1-1
PMT33 AA979 CH1-2
PMT29 AA1946 CH2-1 RETESTED
PMT29 AA1946 CH2-2 RETESTED
PMT35 AA1947 CH3-1
PMT35 AA1947 CH3-2
PMT36 AA1940 CH4-1
Rate (Hz)
1000000
100000
10000
1000
100
10
1
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Voltage

For these Charge Distribution Histograms:

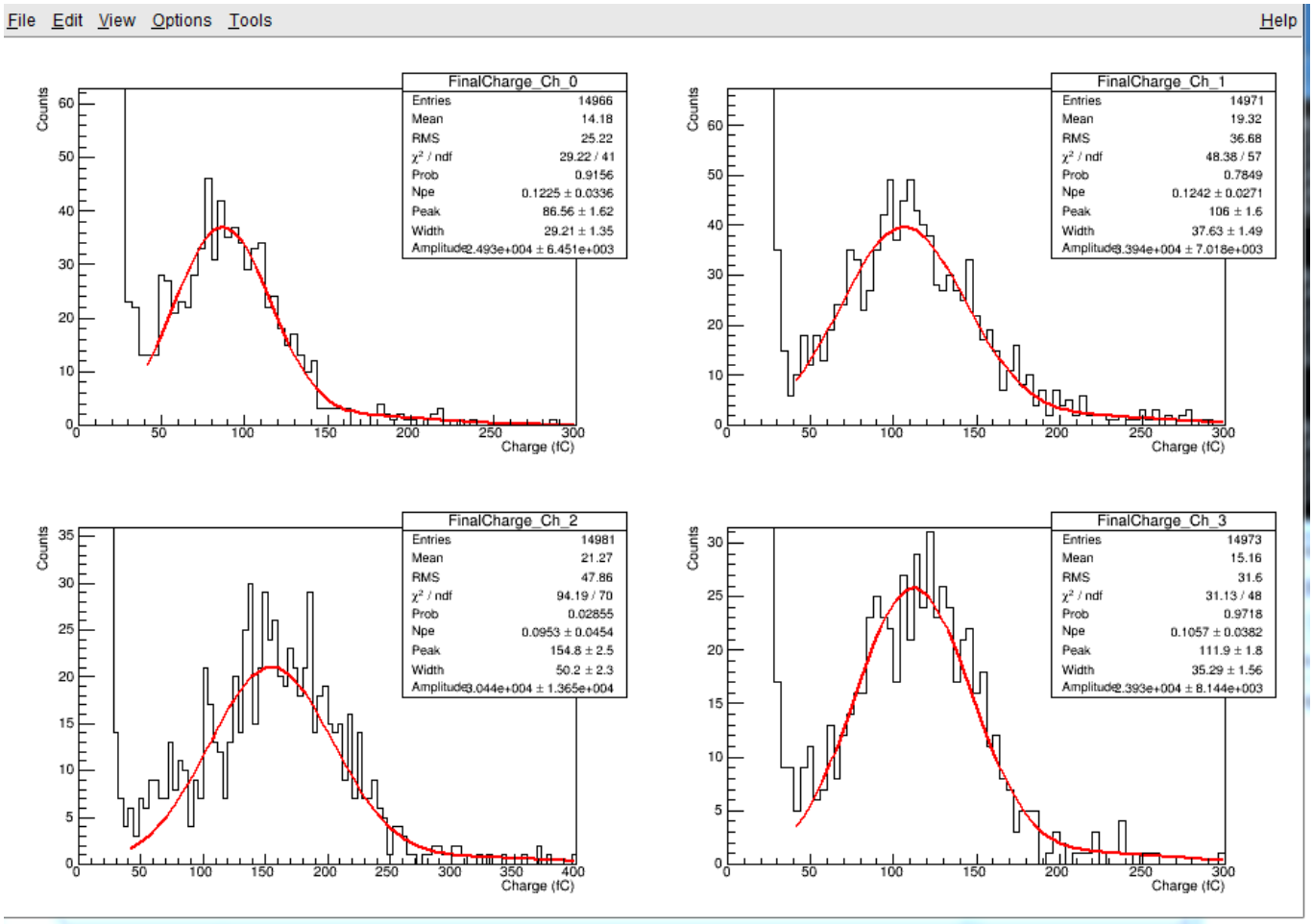
FinalCharge_Ch_0 = PMT33-AA979 FinalCharge_Ch_1 = PMT29-AA1946 (remeasured)

FinalCharge_Ch_2 = PMT35-AA1947 FinalCharge_Ch_3 = PMT36-AA1940

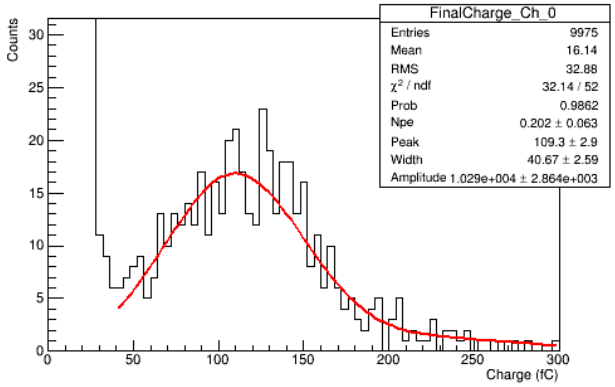
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

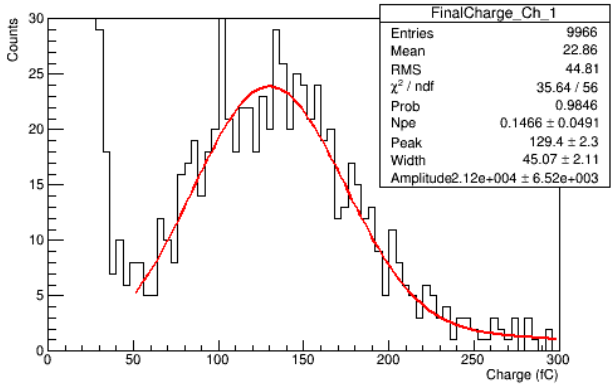
Code used to fit: fitnpe_XP2020

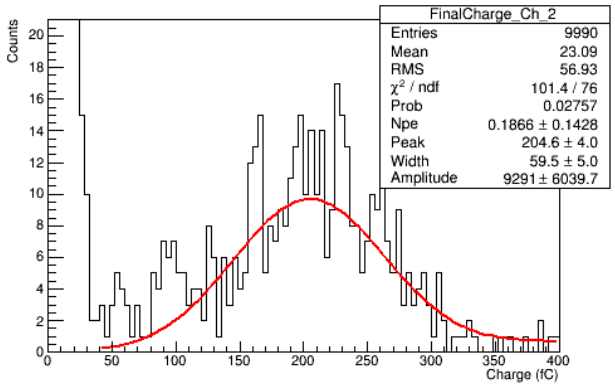
At 2000V

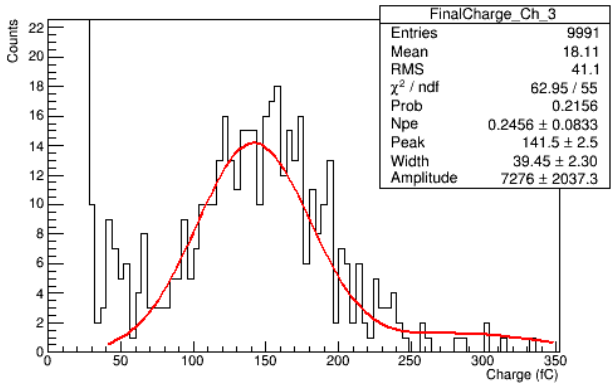


At 2100V

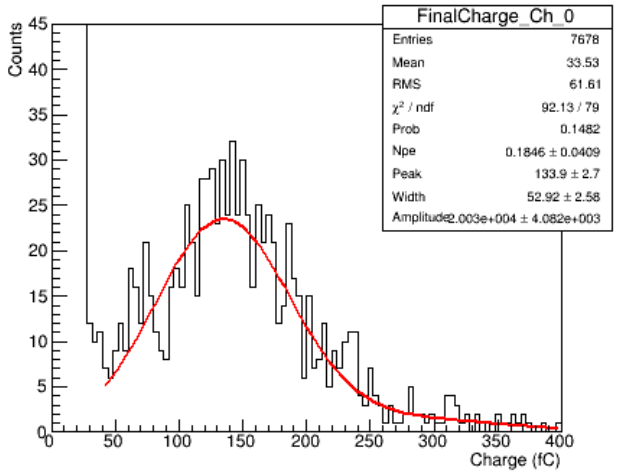

FinalCharge_Ch_0
Entries 9975
Mean 16.14
RMS 32.88
χ² / ndf 32.14 / 52
Prob 0.9862
Npe 0.202 ± 0.063
Peak 109.3 ± 2.9
Width 40.67 ± 2.59
Amplitude 1.029e+004 ± 2.864e+003
Counts
Charge (fC)

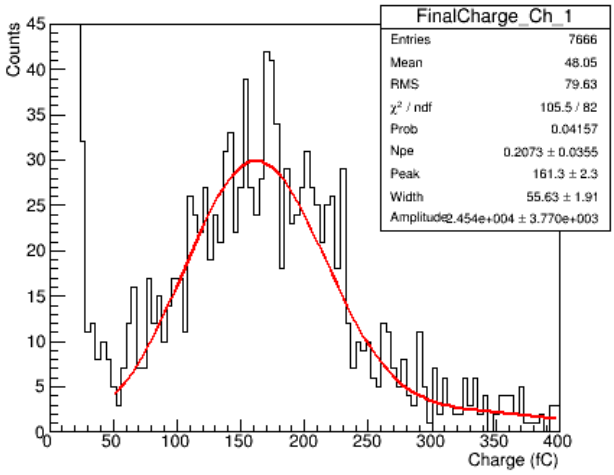

FinalCharge_Ch_1
Entries 9966
Mean 22.86
RMS 44.81
χ² / ndf 35.64 / 56
Prob 0.9846
Npe 0.1466 ± 0.0491
Peak 129.4 ± 2.3
Width 45.07 ± 2.11
Amplitude 2.12e+004 ± 6.52e+003
Counts
Charge (fC)

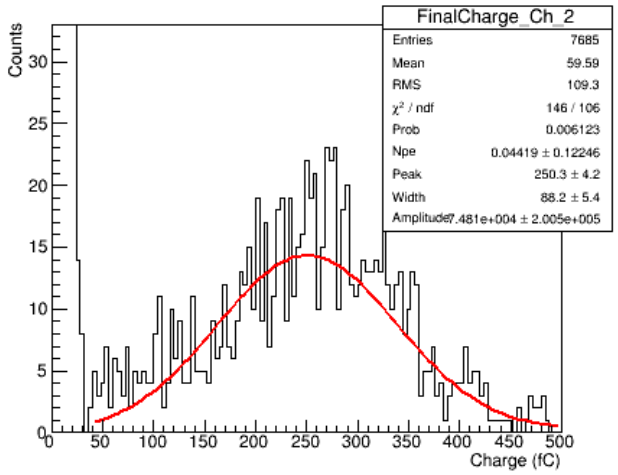

FinalCharge_Ch_2
Entries 9990
Mean 23.09
RMS 56.93
χ² / ndf 101.4 / 76
Prob 0.02757
Npe 0.1866 ± 0.1428
Peak 204.6 ± 4.0
Width 59.5 ± 5.0
Amplitude 9291 ± 6039.7
Counts
Charge (fC)

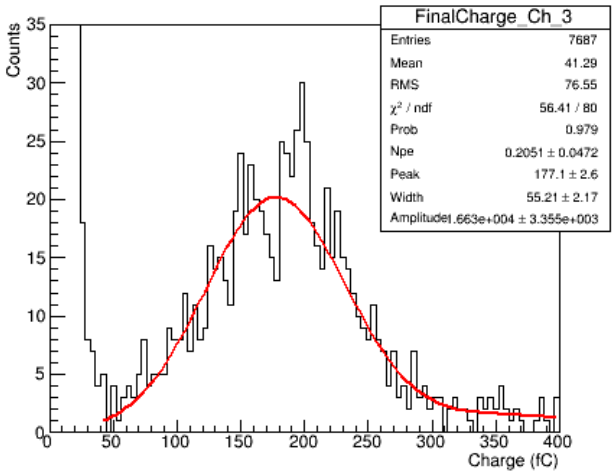

FinalCharge_Ch_3
Entries 9991
Mean 18.11
RMS 41.1
χ² / ndf 62.95 / 55
Prob 0.2156
Npe 0.2456 ± 0.0833
Peak 141.5 ± 2.5
Width 39.45 ± 2.30
Amplitude 7276 ± 2037.3
Counts
Charge (fC)

At 2200V

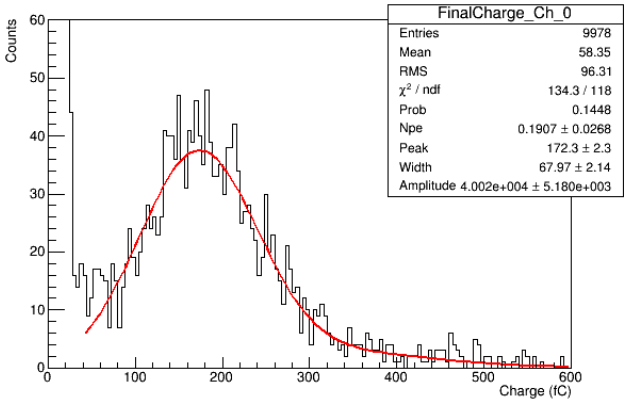

FinalCharge_Ch_0
Entries 7678
Mean 33.53
RMS 61.61
χ² / ndf 92.13 / 79
Prob 0.1482
Npe 0.1846 ± 0.0409
Peak 133.9 ± 2.7
Width 52.92 ± 2.58
Amplitude 2.003e+004 ± 4.082e+003
Counts
Charge (fC)

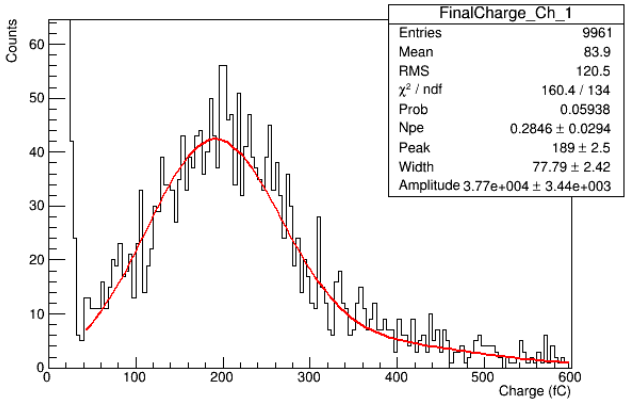

FinalCharge_Ch_1
Entries 7666
Mean 48.05
RMS 79.63
χ² / ndf 105.5 / 82
Prob 0.04157
Npe 0.2073 ± 0.0355
Peak 161.3 ± 2.3
Width 55.63 ± 1.91
Amplitude 2.454e+004 ± 3.770e+003
Counts
Charge (fC)

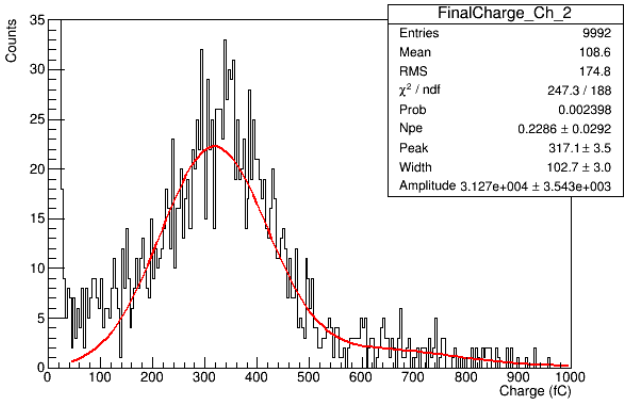

FinalCharge_Ch_2
Entries 7685
Mean 59.59
RMS 109.3
χ² / ndf 146 / 106
Prob 0.006123
Npe 0.04419 ± 0.12246
Peak 250.3 ± 4.2
Width 88.2 ± 5.4
Amplitude 7.481e+004 ± 2.005e+005
Counts
Charge (fC)

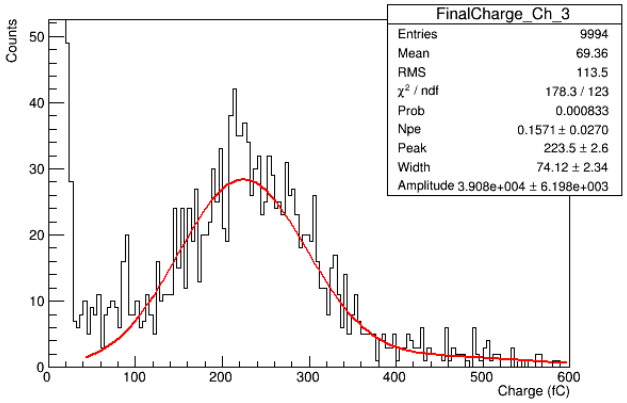

FinalCharge_Ch_3
Entries 7687
Mean 41.29
RMS 76.55
χ² / ndf 56.41 / 80
Prob 0.979
Npe 0.2051 ± 0.0472
Peak 177.1 ± 2.6
Width 55.21 ± 2.17
Amplitude 1.663e+004 ± 3.355e+003
Counts
Charge (fC)

At 2300V

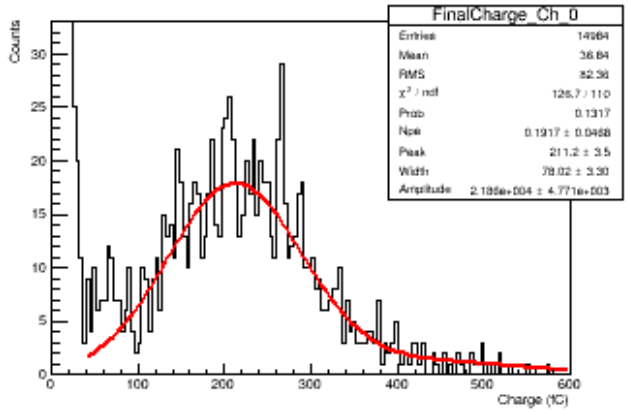

FinalCharge_Ch_0
Entries 9978
Mean 58.35
RMS 96.31
χ² / ndf 134.3 / 118
Prob 0.1448
Npe 0.1907 ± 0.0268
Peak 172.3 ± 2.3
Width 67.97 ± 2.14
Amplitude 4.002e+004 ± 5.180e+003
Counts
Charge (fC)

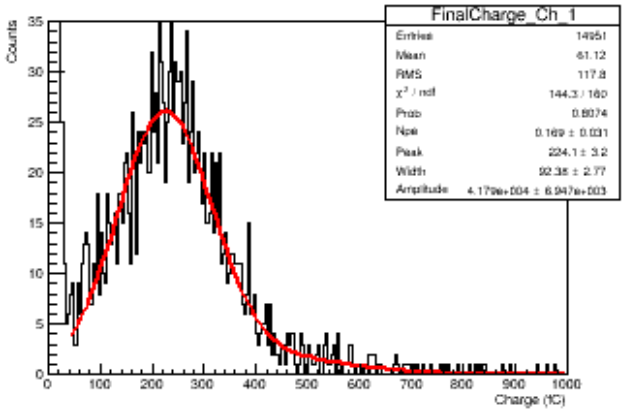

FinalCharge_Ch_1
Entries 9961
Mean 83.9
RMS 120.5
χ² / ndf 160.4 / 134
Prob 0.05938
Npe 0.2846 ± 0.0294
Peak 189 ± 2.5
Width 77.79 ± 2.42
Amplitude 3.77e+004 ± 3.44e+003
Counts
Charge (fC)

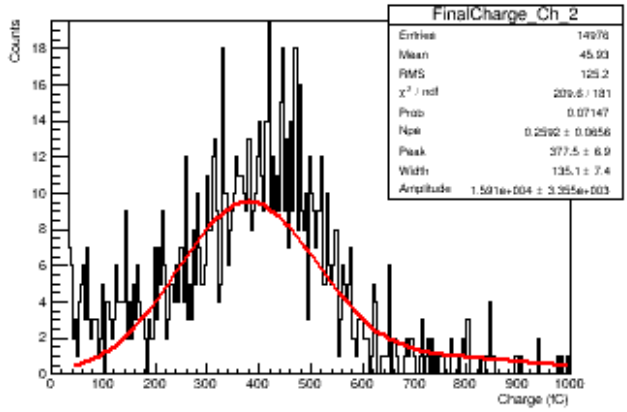

FinalCharge_Ch_2
Entries 9992
Mean 108.6
RMS 174.8
χ² / ndf 247.3 / 188
Prob 0.002398
Npe 0.2286 ± 0.0292
Peak 317.1 ± 3.5
Width 102.7 ± 3.0
Amplitude 3.127e+004 ± 3.543e+003
Counts
Charge (fC)

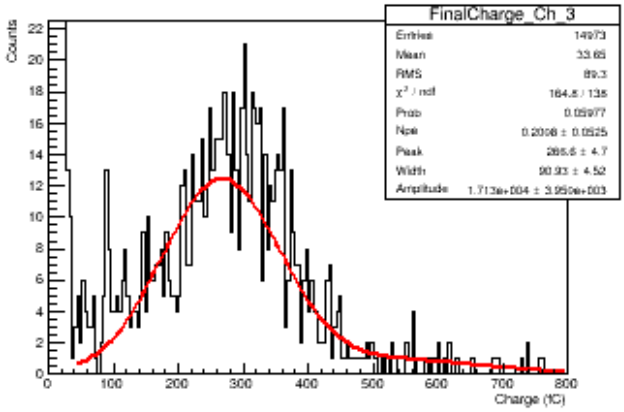

FinalCharge_Ch_3
Entries 9994
Mean 69.36
RMS 113.5
χ² / ndf 178.3 / 123
Prob 0.000833
Npe 0.1571 ± 0.0270
Peak 223.5 ± 2.6
Width 74.12 ± 2.34
Amplitude 3.908e+004 ± 6.198e+003
Counts
Charge (fC)

At 2400V

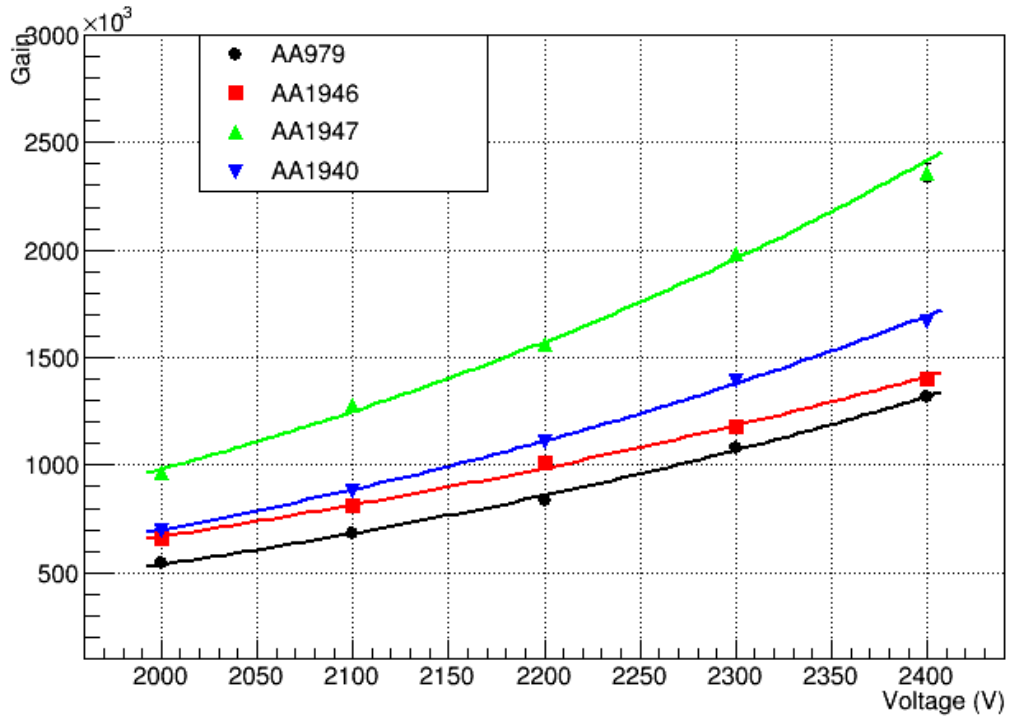

FinalCharge_Ch_0
Entries 14984
Mean 36.84
RMS 82.36
χ² / ndf 125.7 / 110
Prob 0.1317
Npe 0.1917 ± 0.0468
Peak 211.2 ± 3.5
Width 78.02 ± 3.30
Amplitude 2.185e+004 ± 4.771e+003
Counts
Charge (fC)

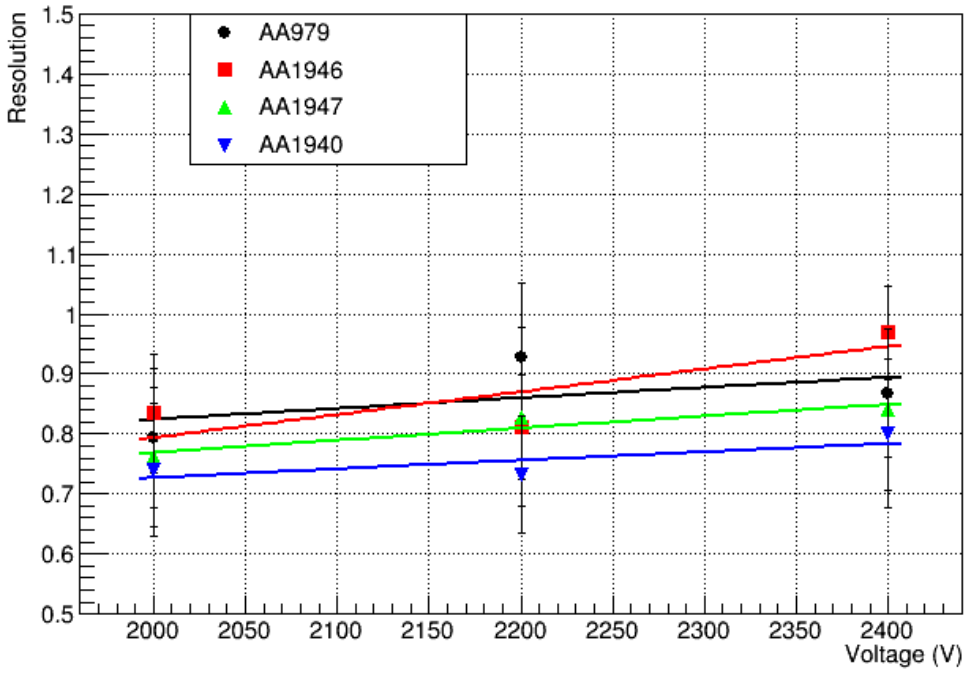

FinalCharge_Ch_1
Entries 14951
Mean 61.12
RMS 117.8
χ² / ndf 144.3 / 160
Prob 0.8074
Npe 0.169 ± 0.031
Peak 224.1 ± 3.2
Width 92.35 ± 2.77
Amplitude 4.179e+004 ± 6.947e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 14976
Mean 45.93
RMS 125.2
χ² / ndf 209.6 / 181
Prob 0.07147
Npe 0.2592 ± 0.0656
Peak 377.5 ± 6.9
Width 135.1 ± 7.4
Amplitude 1.591e+004 ± 3.355e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 14973
Mean 33.65
RMS 89.3
χ² / ndf 184.8 / 138
Prob 0.05977
Npe 0.2008 ± 0.0525
Peak 285.6 ± 4.7
Width 90.93 ± 4.52
Amplitude 1.713e+004 ± 3.950e+003
Counts
Charge (fC)

Gain Curves: PMT33-AA979, PMT29-AA1946 (remeasured), PMT35-AA1947, PMT36-AA1940

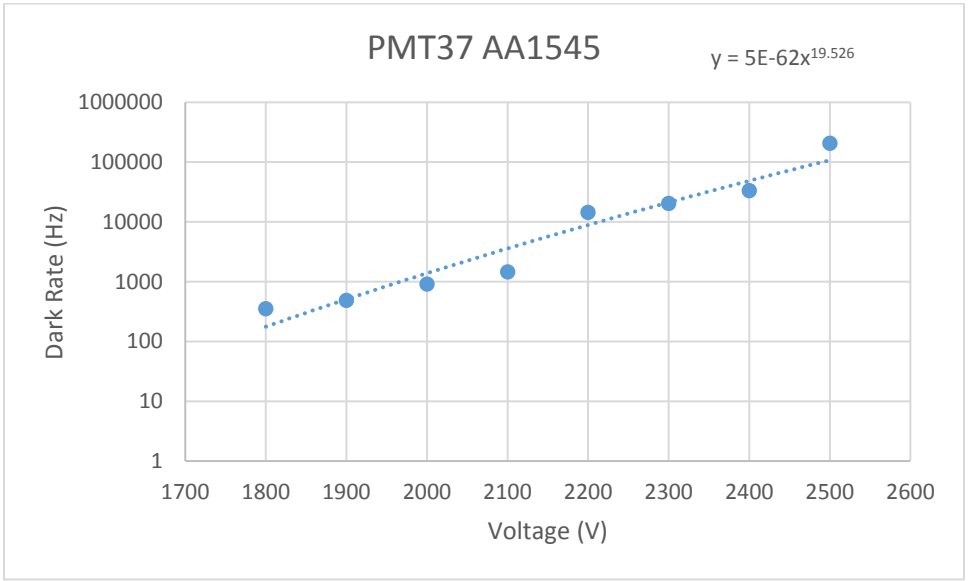




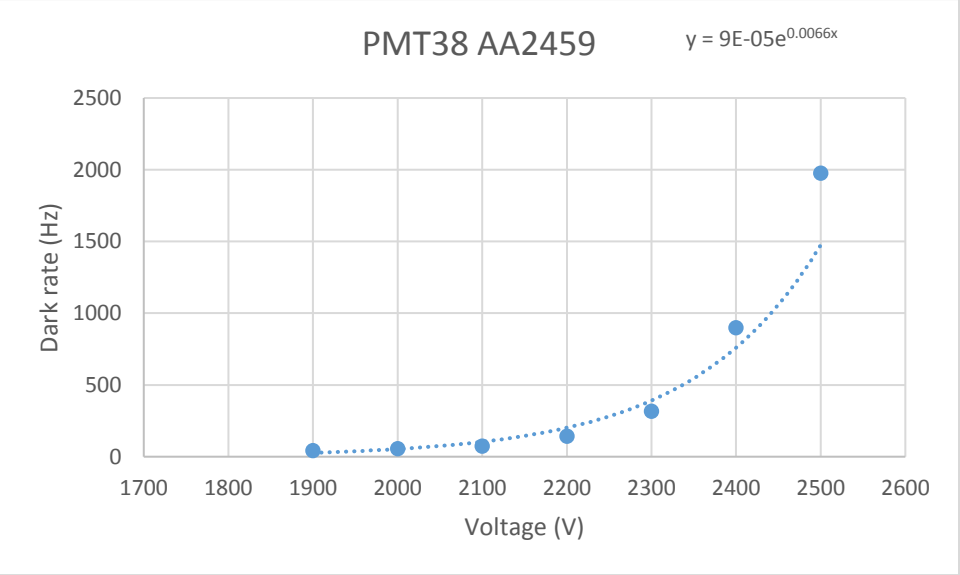
PMT'S 37-40

PMT37-AA1545
PMT38-AA2459
PMT39-AA1986
PMT40-AA1270

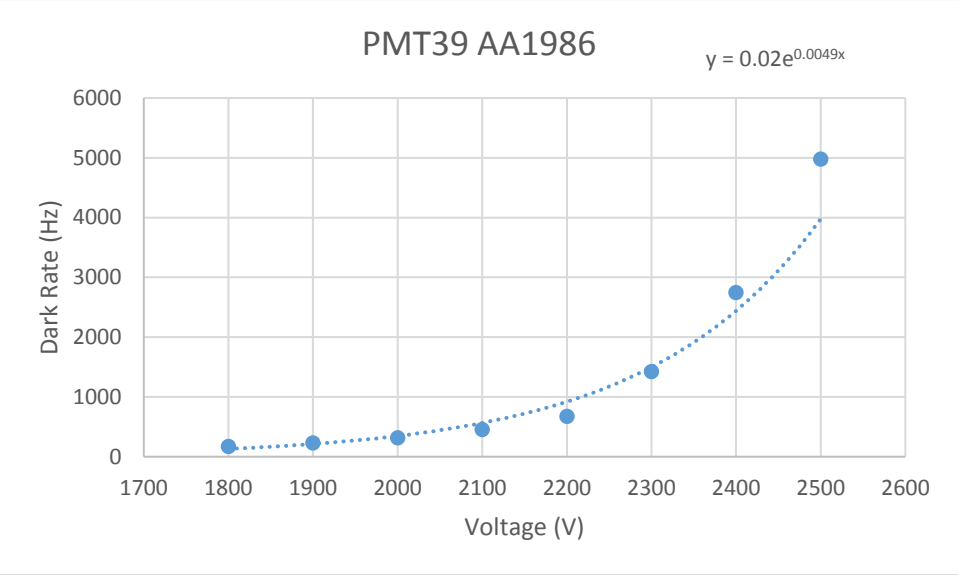
PMT37 AA1545 CH1-1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	2905	2851	2877	2654	2669	348.9
1900	3686	3978	3855	3764	3957	481
2000	6924	7244	7300	7637	7383	912.2
2100	11575	11009	12009	12053	11502	1453.7
2200	113385	113142	116348	115110	116024	14350.23
2300	154157	156973	165123	166226	168431	20272.75
2400	259939	264652	255284	275148	274020	33226.08
2500	1644498	1622028	1624570	1714454	1585280	204770.8



PMT38 AA2459 CH2-1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	228	238	254	244	267	30.775
1900	348	350	310	363	324	42.375
2000	443	467	443	404	431	54.7
2100	585	613	593	615	567	74.325
2200	1218	1153	1113	1066	1121	141.775
2300	2420	2444	2569	2551	2638	315.55
2400	7050	7726	7518	6895	6727	897.9
2500	14845	14801	17924	15699	15754	1975.575



PMT39 AA1986 CH3-1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	1309	1364	1308	1343	1423	168.675
1900	1849	1856	1885	1804	1849	231.075
2000	2465	2520	2529	2545	2525	314.6
2100	3585	3564	3697	3550	3755	453.775
2200	5381	5161	5488	5572	5395	674.925
2300	11135	11422	11484	11395	11417	1421.325
2400	22271	22045	20720	21313	23435	2744.6
2500	38141	39413	40838	39705	40996	4977.325

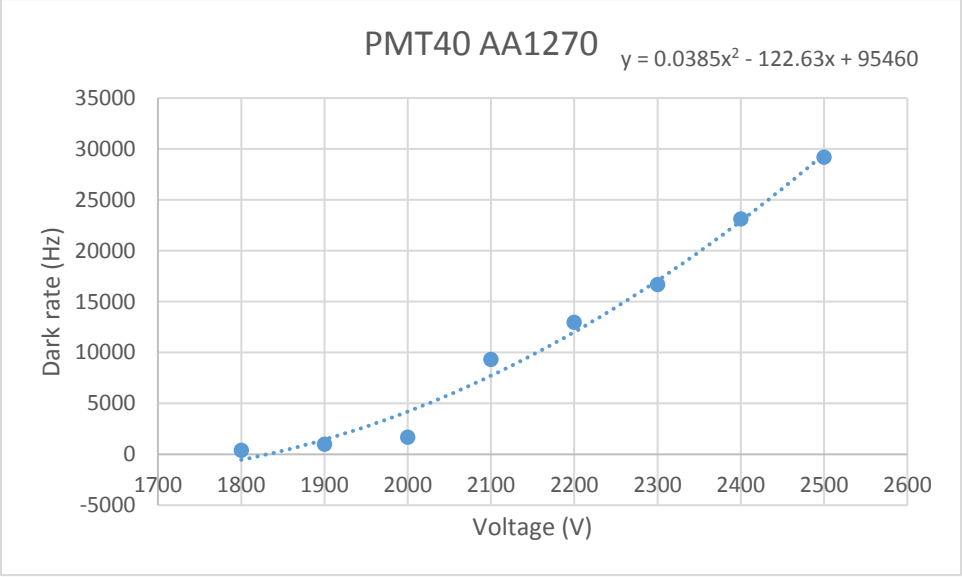


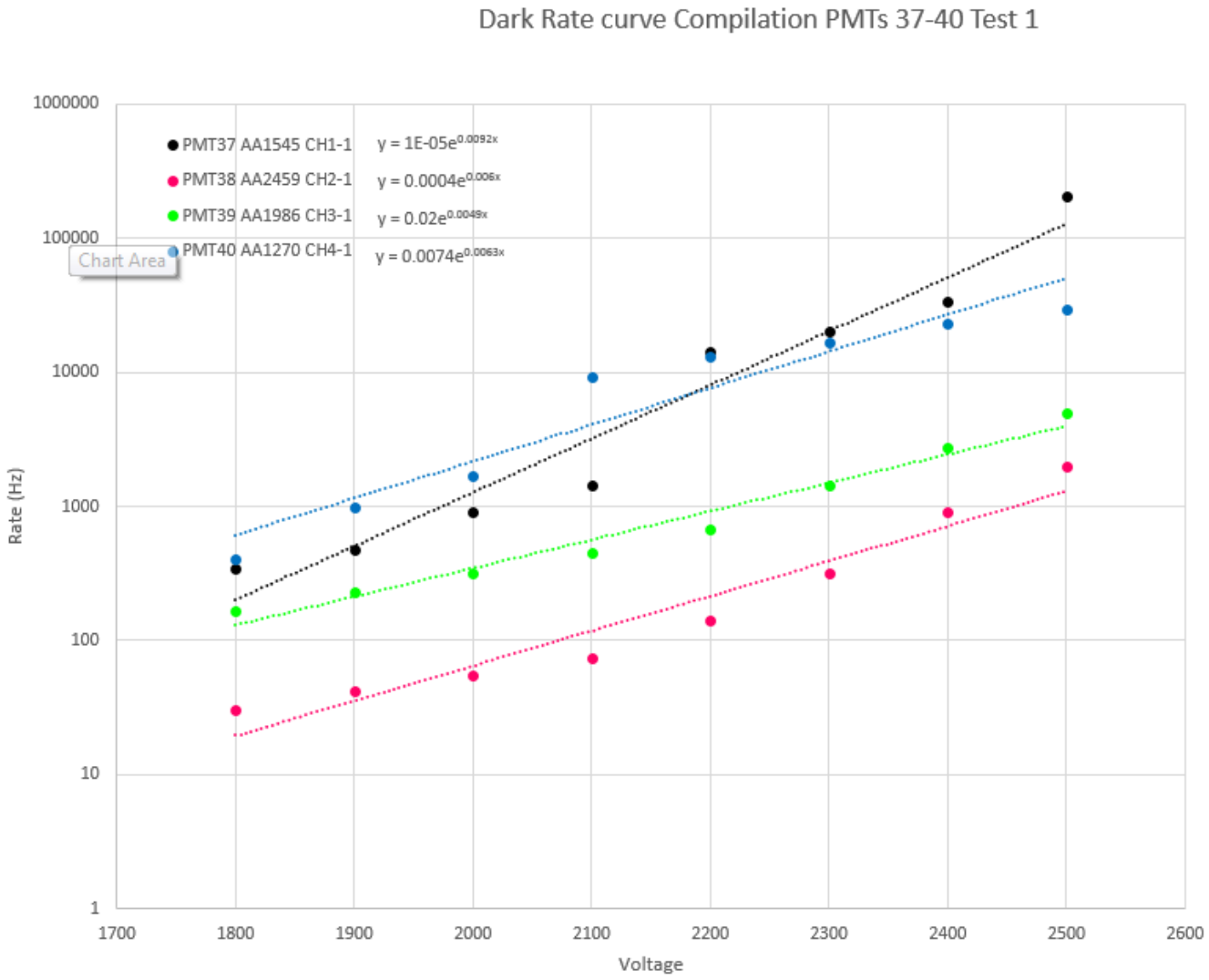
PMT40 AA1270 CH4-1

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

HV set > 2400V for 1 hour

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	3320	3207	3177	3184	3220	402.7
1900	8076	8254	7780	7878	7971	998.975
2000	13414	13143	13530	13617	13893	1689.925
2100	74530	75457	74275	75081	73978	9333.025
2200	100782	102624	105192	106240	103685	12963.08
2300	132316	134103	132043	133368	134589	16660.48
2400	182840	182595	181813	189811	187071	23103.25
2500	244292	205827	238582	243616	235063	29184.5




Dark Rate curve Compilation PMTs 37-40 Test 1
PMT37 AA1545 CH1-1
y = 1E-05e^0.0092x
PMT38 AA2459 CH2-1
y = 0.0004e^0.006x
PMT39 AA1986 CH3-1
y = 0.02e^0.0049x
PMT40 AA1270 CH4-1
y = 0.0074e^0.0063x
Chart Area
Rate (Hz)
1000000
100000
10000
1000
100
10
1
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Voltage

For these Charge Distribution Histograms:

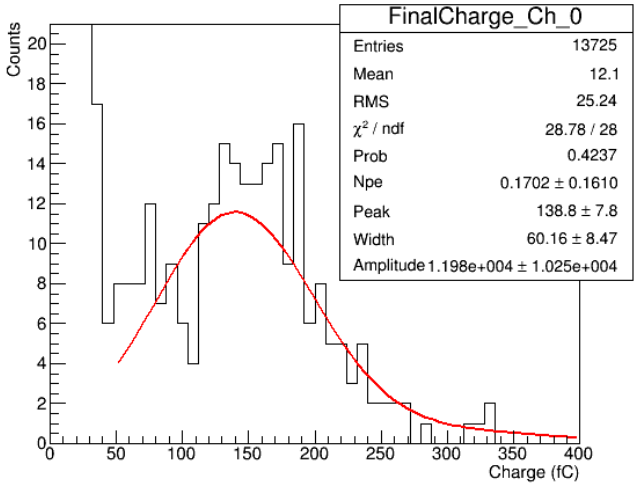
FinalCharge_Ch_0 = PMT37-AA1545 FinalCharge_Ch_1 = PMT38-AA2459

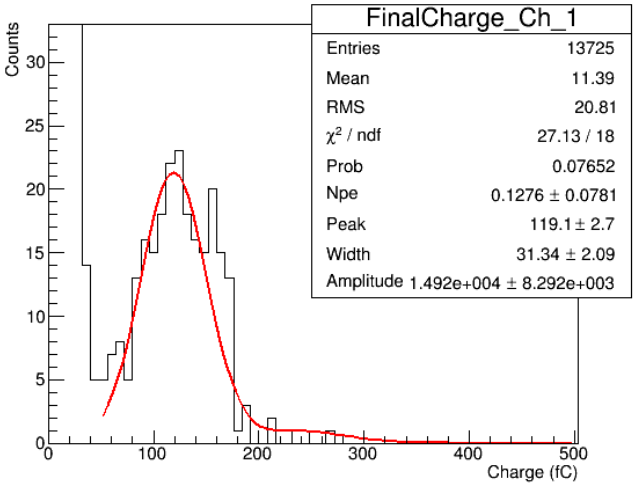
FinalCharge_Ch_2 = PMT39-AA1986 FinalCharge_Ch_3 = PMT40-AA1270

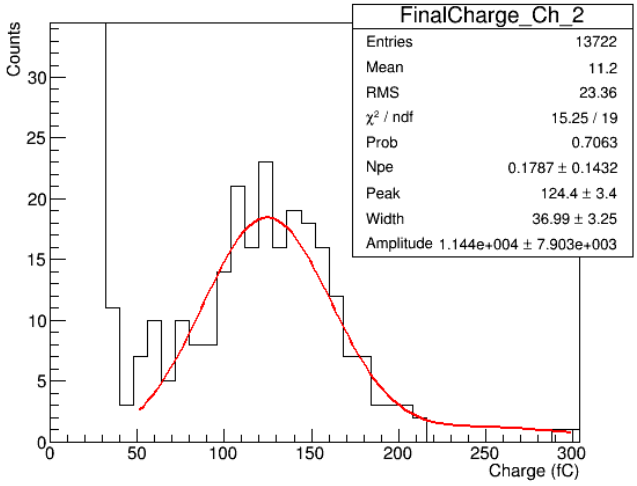
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

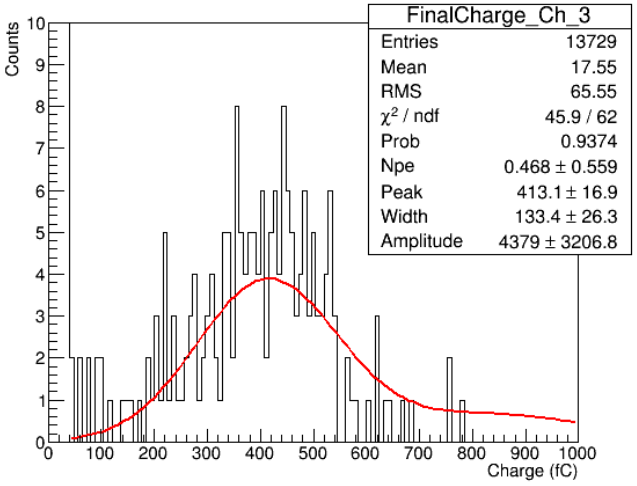
Code used to fit: fitnpe_XP2020

At 2000V

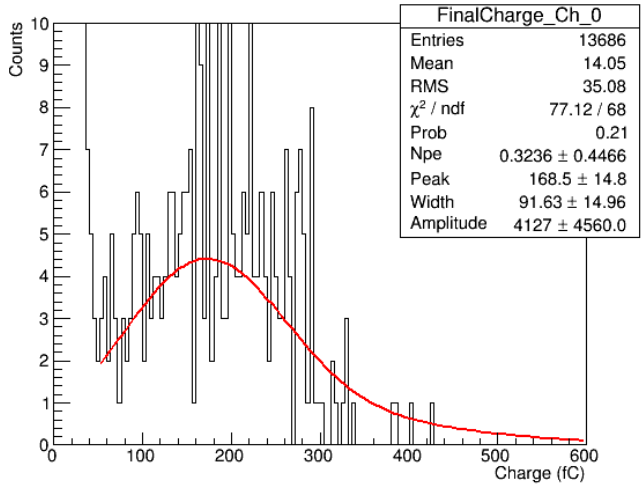


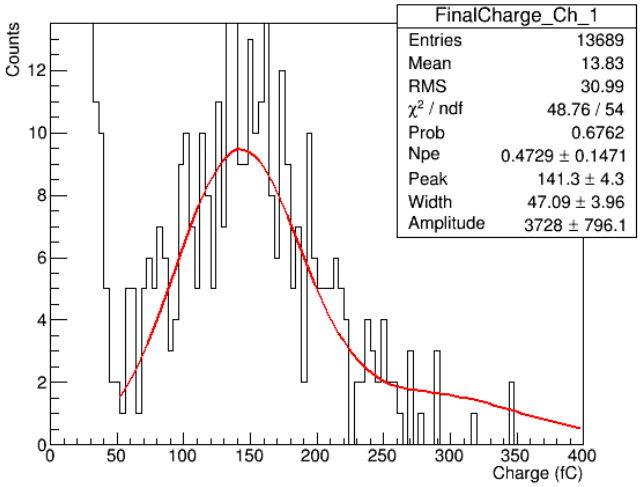


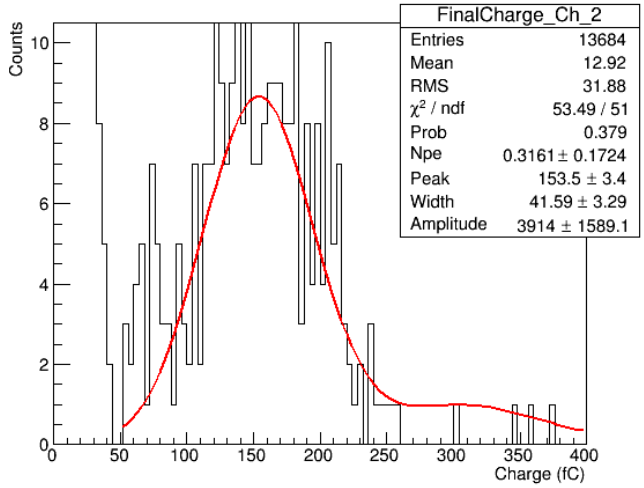


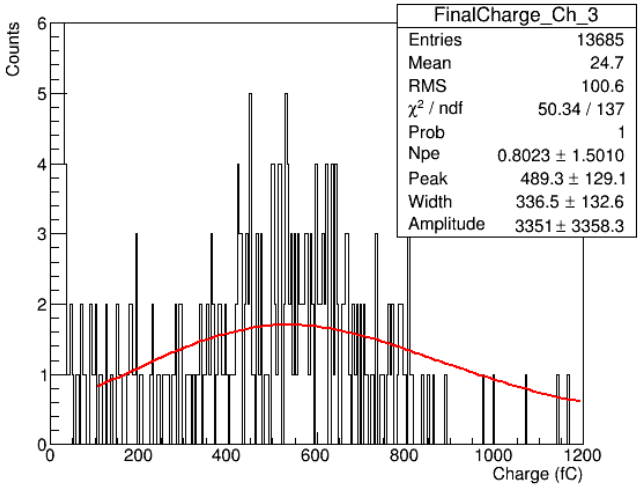


At 2100V

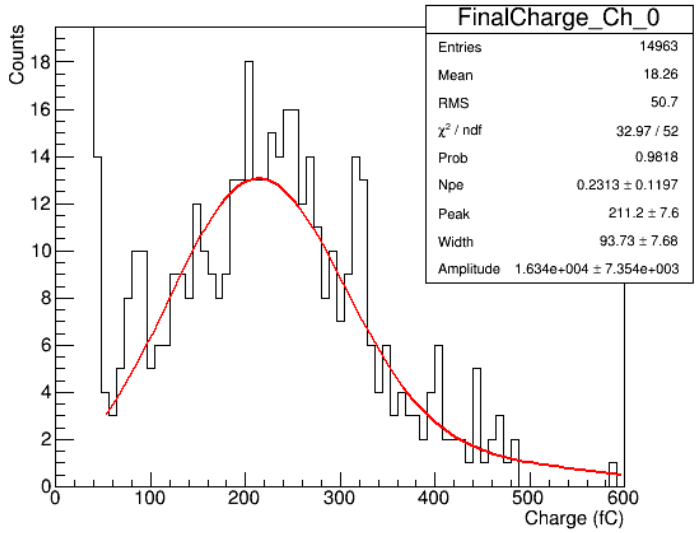

FinalCharge_Ch_0
Entries 13686
Mean 14.05
RMS 35.08
χ² / ndf 77.12 / 68
Prob 0.21
Npe 0.3236 ± 0.4466
Peak 168.5 ± 14.8
Width 91.63 ± 14.96
Amplitude 4127 ± 4560.0
Counts
Charge (fC)

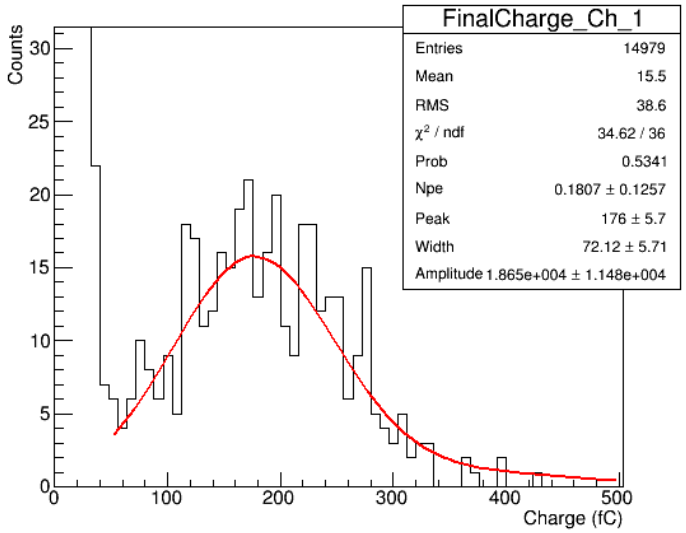

FinalCharge_Ch_1
Entries 13689
Mean 13.83
RMS 30.99
χ² / ndf 48.76 / 54
Prob 0.6762
Npe 0.4729 ± 0.1471
Peak 141.3 ± 4.3
Width 47.09 ± 3.96
Amplitude 3728 ± 796.1
Counts
Charge (fC)

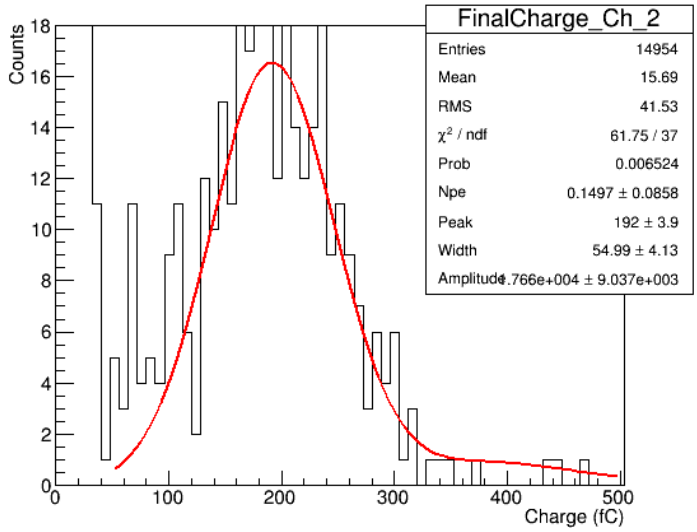

FinalCharge_Ch_2
Entries 13684
Mean 12.92
RMS 31.88
χ² / ndf 53.49 / 51
Prob 0.379
Npe 0.3161 ± 0.1724
Peak 153.5 ± 3.4
Width 41.59 ± 3.29
Amplitude 3914 ± 1589.1
Counts
Charge (fC)

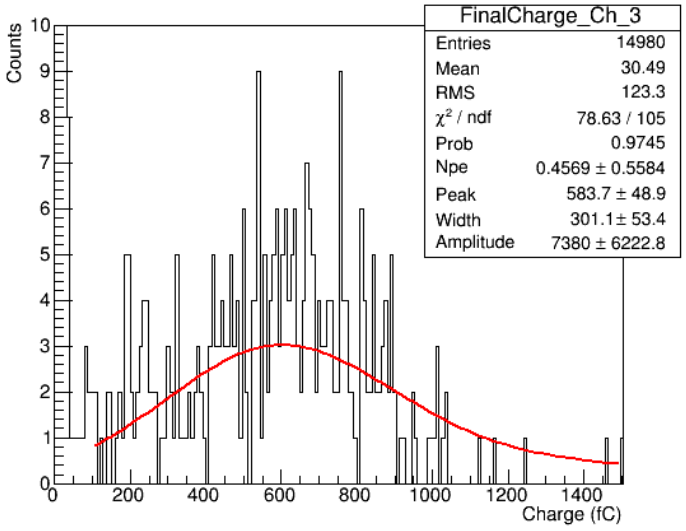

FinalCharge_Ch_3
Entries 13685
Mean 24.7
RMS 100.6
χ² / ndf 50.34 / 137
Prob 1
Npe 0.8023 ± 1.5010
Peak 489.3 ± 129.1
Width 336.5 ± 132.6
Amplitude 3351 ± 3358.3
Counts
Charge (fC)

At 2200V

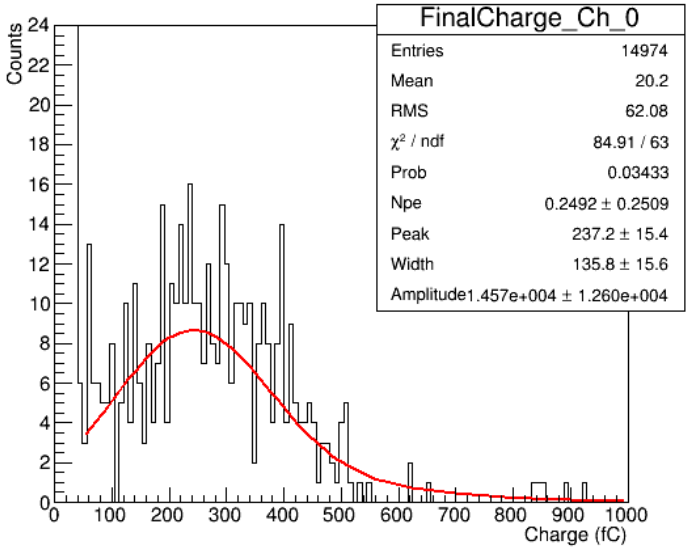

FinalCharge_Ch_0
Entries 14963
Mean 18.26
RMS 50.7
χ² / ndf 32.97 / 52
Prob 0.9818
Npe 0.2313 ± 0.1197
Peak 211.2 ± 7.6
Width 93.73 ± 7.68
Amplitude 1.634e+004 ± 7.354e+003
Counts
Charge (fC)

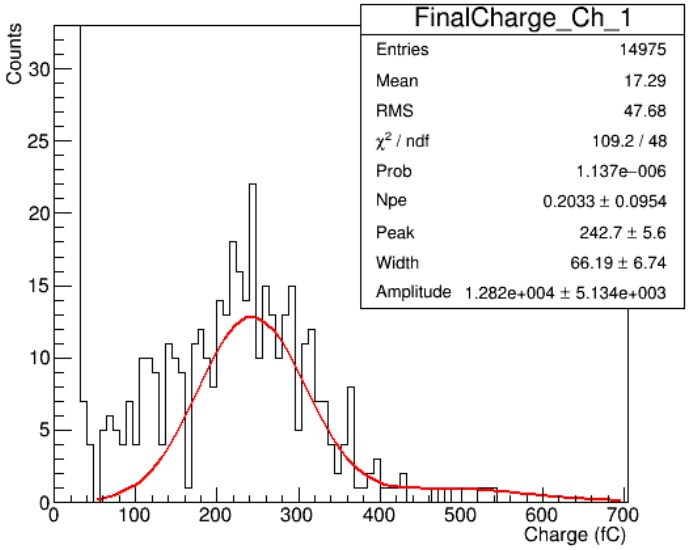

FinalCharge_Ch_1
Entries 14979
Mean 15.5
RMS 38.6
χ² / ndf 34.62 / 36
Prob 0.5341
Npe 0.1807 ± 0.1257
Peak 176 ± 5.7
Width 72.12 ± 5.71
Amplitude 1.865e+004 ± 1.148e+004
Counts
Charge (fC)

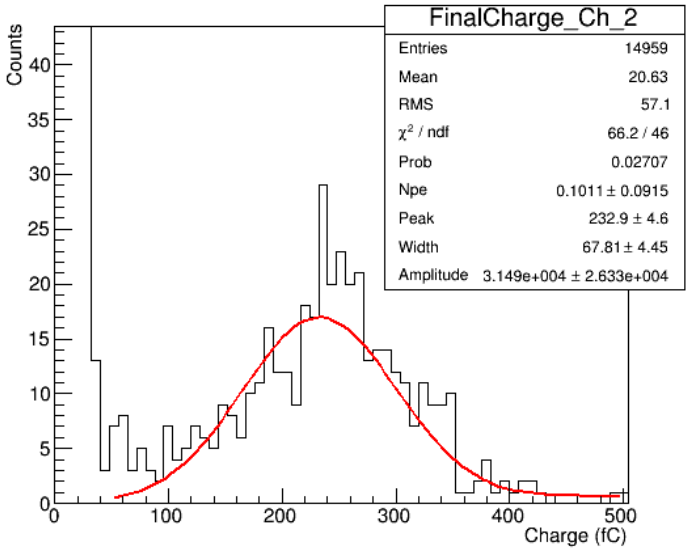

FinalCharge_Ch_2
Entries 14954
Mean 15.69
RMS 41.53
χ² / ndf 61.75 / 37
Prob 0.006524
Npe 0.1497 ± 0.0858
Peak 192 ± 3.9
Width 54.99 ± 4.13
Amplitude 8.766e+004 ± 9.037e+003
Counts
Charge (fC)

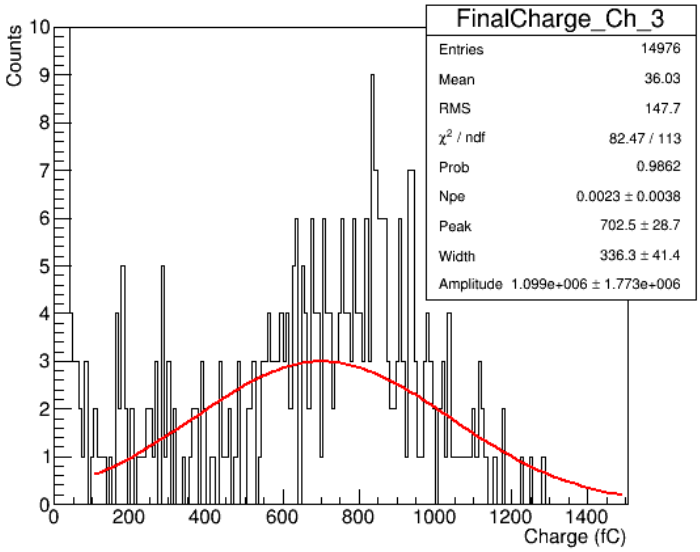

FinalCharge_Ch_3
Entries 14980
Mean 30.49
RMS 123.3
χ² / ndf 78.63 / 105
Prob 0.9745
Npe 0.4569 ± 0.5584
Peak 583.7 ± 48.9
Width 301.1 ± 53.4
Amplitude 7380 ± 6222.8
Counts
Charge (fC)

At 2300V

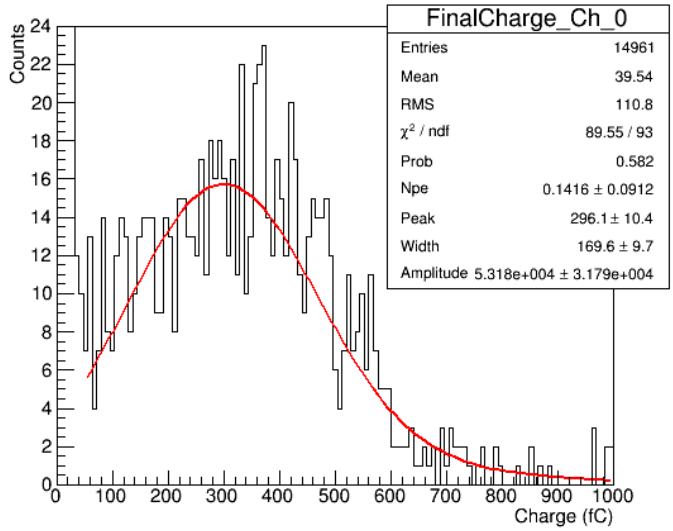

FinalCharge_Ch_0
Entries 14974
Mean 20.2
RMS 62.08
χ² / ndf 84.91 / 63
Prob 0.03433
Npe 0.2492 ± 0.2509
Peak 237.2 ± 15.4
Width 135.8 ± 15.6
Amplitude 1.457e+004 ± 1.260e+004
Counts
Charge (fC)

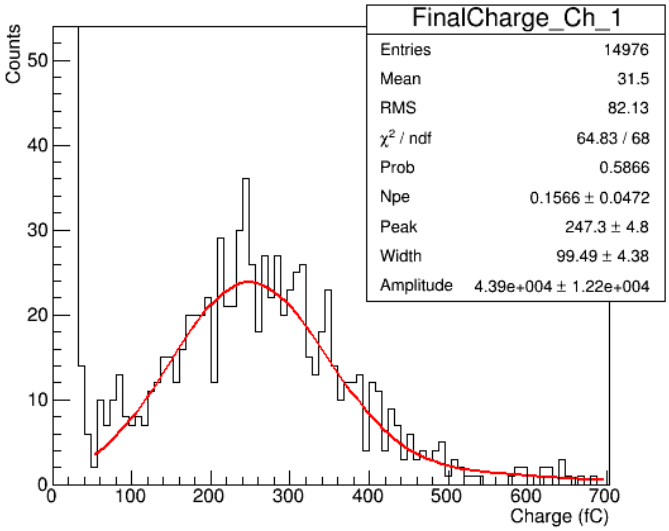

FinalCharge_Ch_1
Entries 14975
Mean 17.29
RMS 47.68
χ² / ndf 109.2 / 48
Prob 1.137e−006
Npe 0.2033 ± 0.0954
Peak 242.7 ± 5.6
Width 66.19 ± 6.74
Amplitude 1.282e+004 ± 5.134e+003
Counts
Charge (fC)

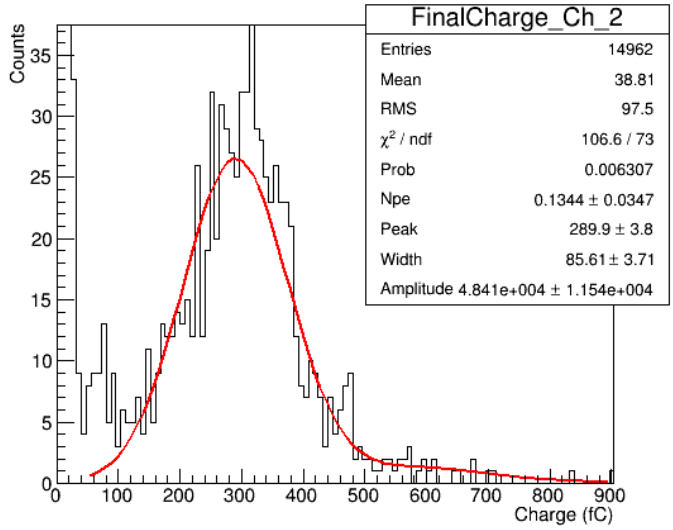

FinalCharge_Ch_2
Entries 14959
Mean 20.63
RMS 57.1
χ² / ndf 66.2 / 46
Prob 0.02707
Npe 0.1011 ± 0.0915
Peak 232.9 ± 4.6
Width 67.81 ± 4.45
Amplitude 3.149e+004 ± 2.633e+004
Counts
Charge (fC)

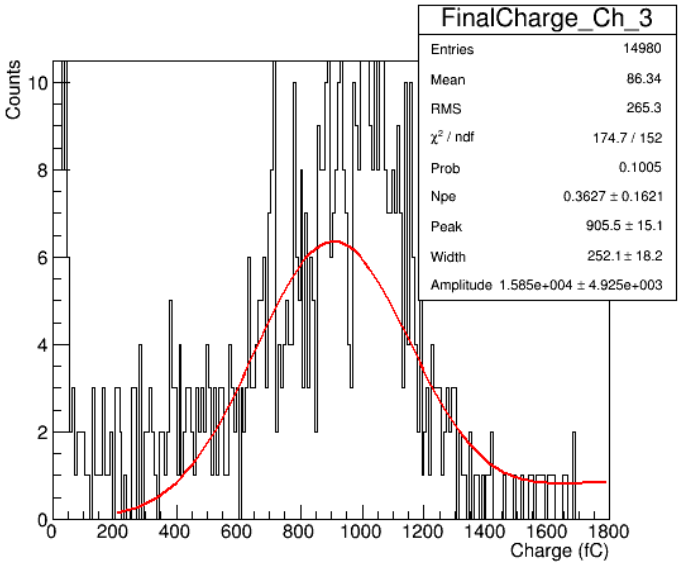

FinalCharge_Ch_3
Entries 14976
Mean 36.03
RMS 147.7
χ² / ndf 82.47 / 113
Prob 0.9862
Npe 0.0023 ± 0.0038
Peak 702.5 ± 28.7
Width 336.3 ± 41.4
Amplitude 1.099e+006 ± 1.773e+006
Counts
Charge (fC)

At 2400V

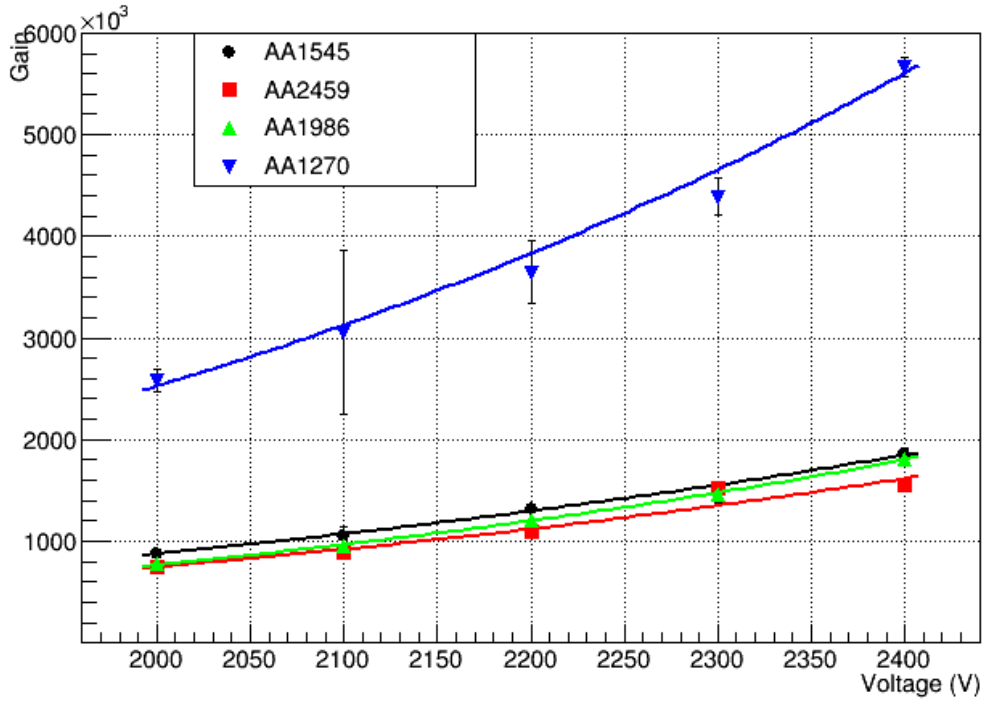

FinalCharge_Ch_0
Entries 14961
Mean 39.54
RMS 110.8
χ² / ndf 89.55 / 93
Prob 0.582
Npe 0.1416 ± 0.0912
Peak 296.1 ± 10.4
Width 169.6 ± 9.7
Amplitude 5.318e+004 ± 3.179e+004
Counts
Charge (fC)

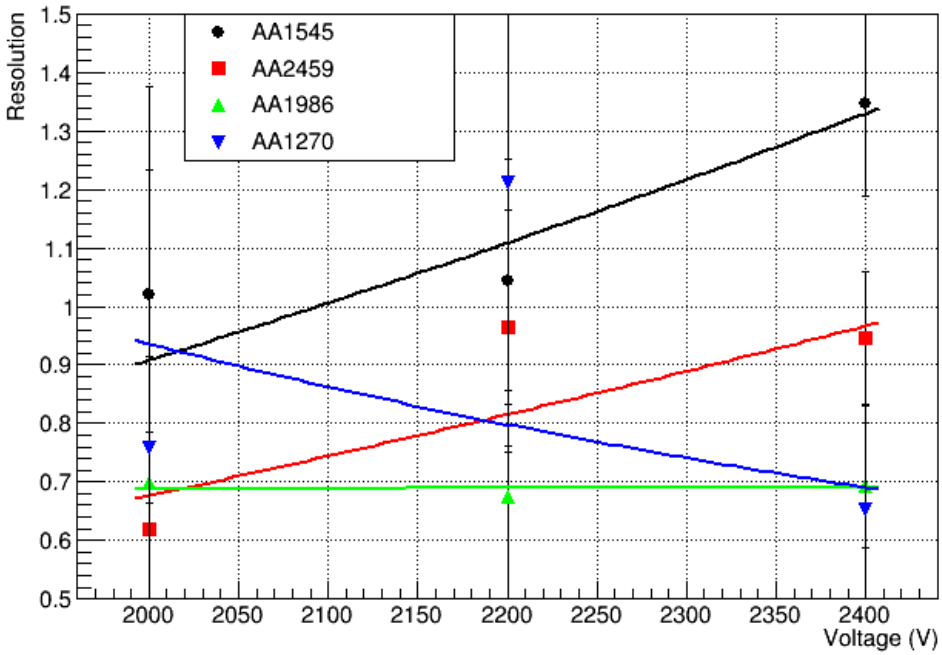

FinalCharge_Ch_1
Entries 14976
Mean 31.5
RMS 82.13
χ² / ndf 64.83 / 68
Prob 0.5866
Npe 0.1566 ± 0.0472
Peak 247.3 ± 4.8
Width 99.49 ± 4.38
Amplitude 4.39e+004 ± 1.22e+004
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 14962
Mean 38.81
RMS 97.5
χ² / ndf 106.6 / 73
Prob 0.006307
Npe 0.1344 ± 0.0347
Peak 289.9 ± 3.8
Width 85.61 ± 3.71
Amplitude 4.841e+004 ± 1.154e+004
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 14980
Mean 86.34
RMS 265.3
χ² / ndf 174.7 / 152
Prob 0.1005
Npe 0.3627 ± 0.1621
Peak 905.5 ± 15.1
Width 252.1 ± 18.2
Amplitude 1.585e+004 ± 4.925e+003
Counts
Charge (fC)

Gain Curves: PMT37-AA1545, PMT38-AA2459, PMT39-AA1986, PMT40-AA1270

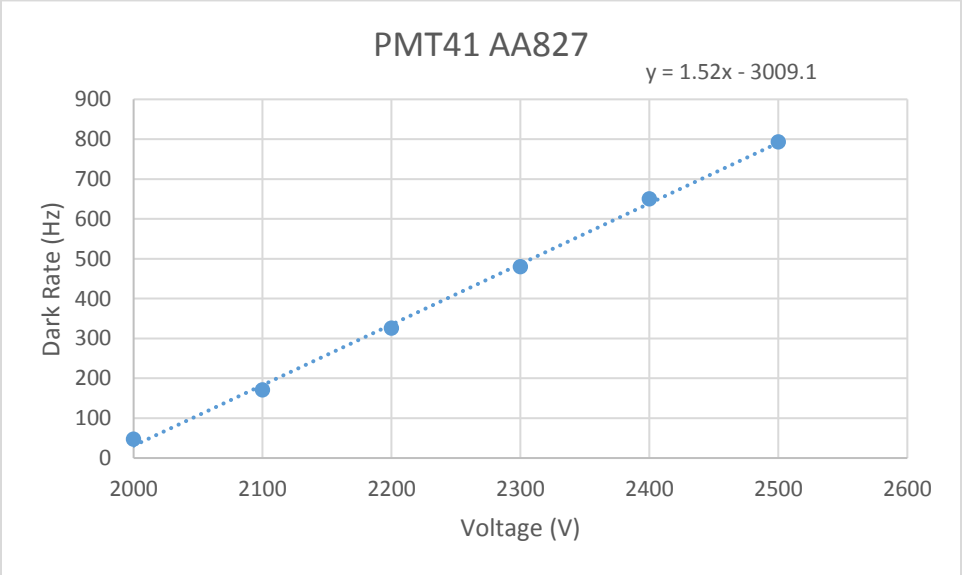




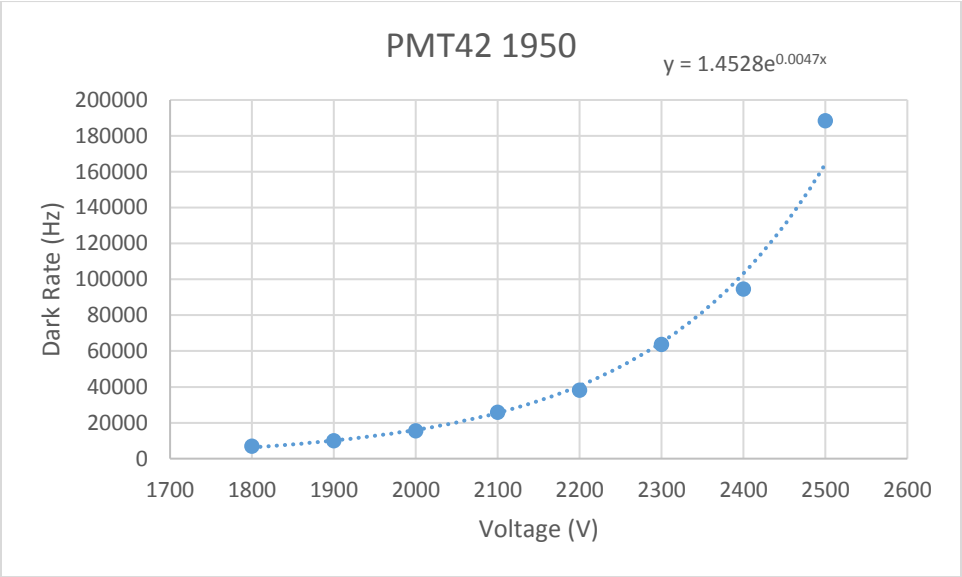
PMT's 41-44

PMT41-AA827
PMT42-AA1950
PMT43-AA1648
PMT44-AA1677

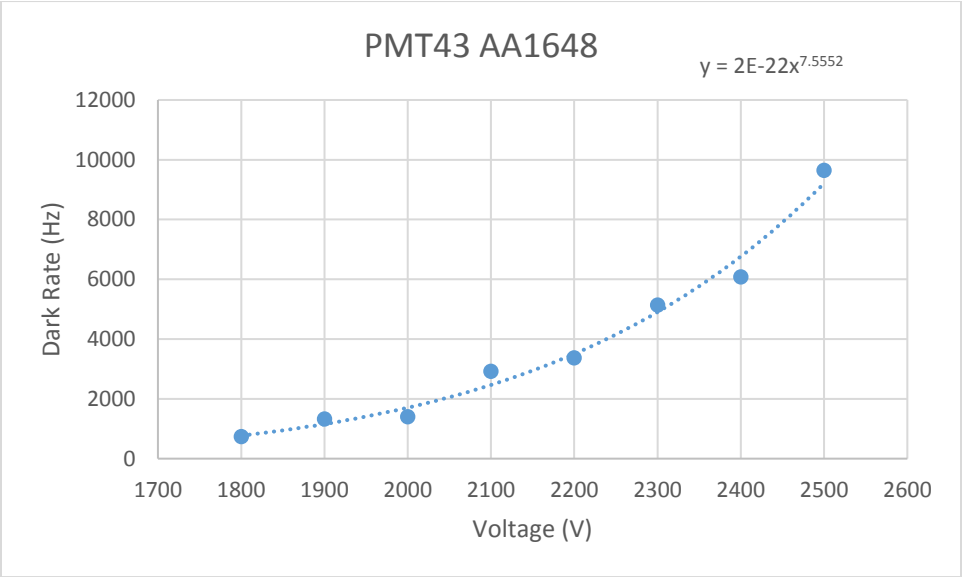
PMT41 AA827 Dark rate test repeated Feb 18, 2018						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	365	375	373	397	375	47.125
2100	1335	1414	1375	1278	1424	170.65
2200	2615	2604	2591	2623	2592	325.625
2300	3769	3846	3835	3971	3763	479.6
2400	5023	5180	5175	5311	5302	649.775
2500	6613	6200	6403	6122	6377	792.875



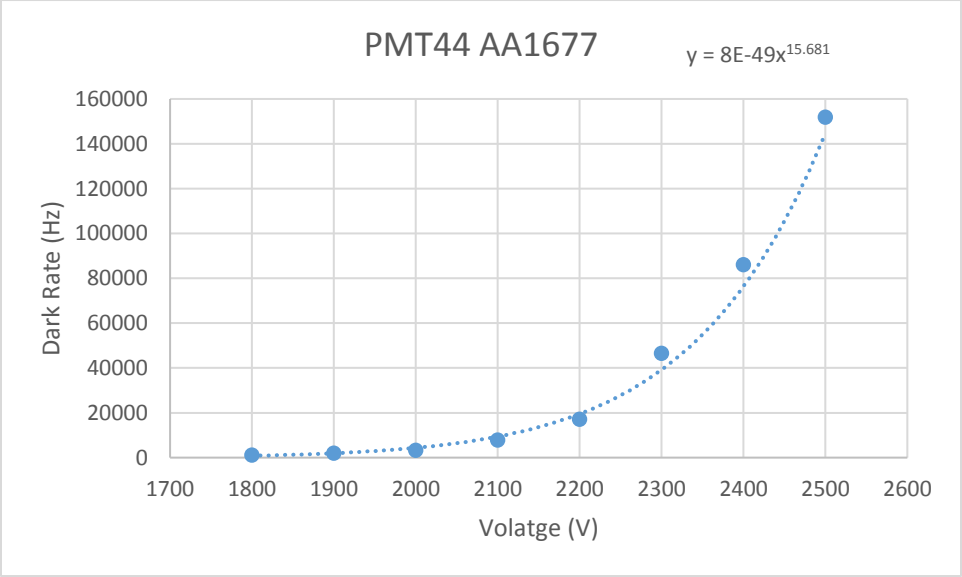
PMT42 AA1950 CH2-1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	57742	57102	56051	55011	48547	6861.325
1900	77787	76737	80753	79109	80117	9862.575
2000	126640	121627	126000	122475	124657	15534.98
2100	207218	207983	207034	204662	207121	25850.45
2200	295589	309125	321144	294359	304552	38119.23
2300	516924	501296	500338	510129	514342	63575.73
2400	755900	755128	754499	751767	764038	94533.3
2500	1822741	950960	1654191	1686773	1733020	188279.5

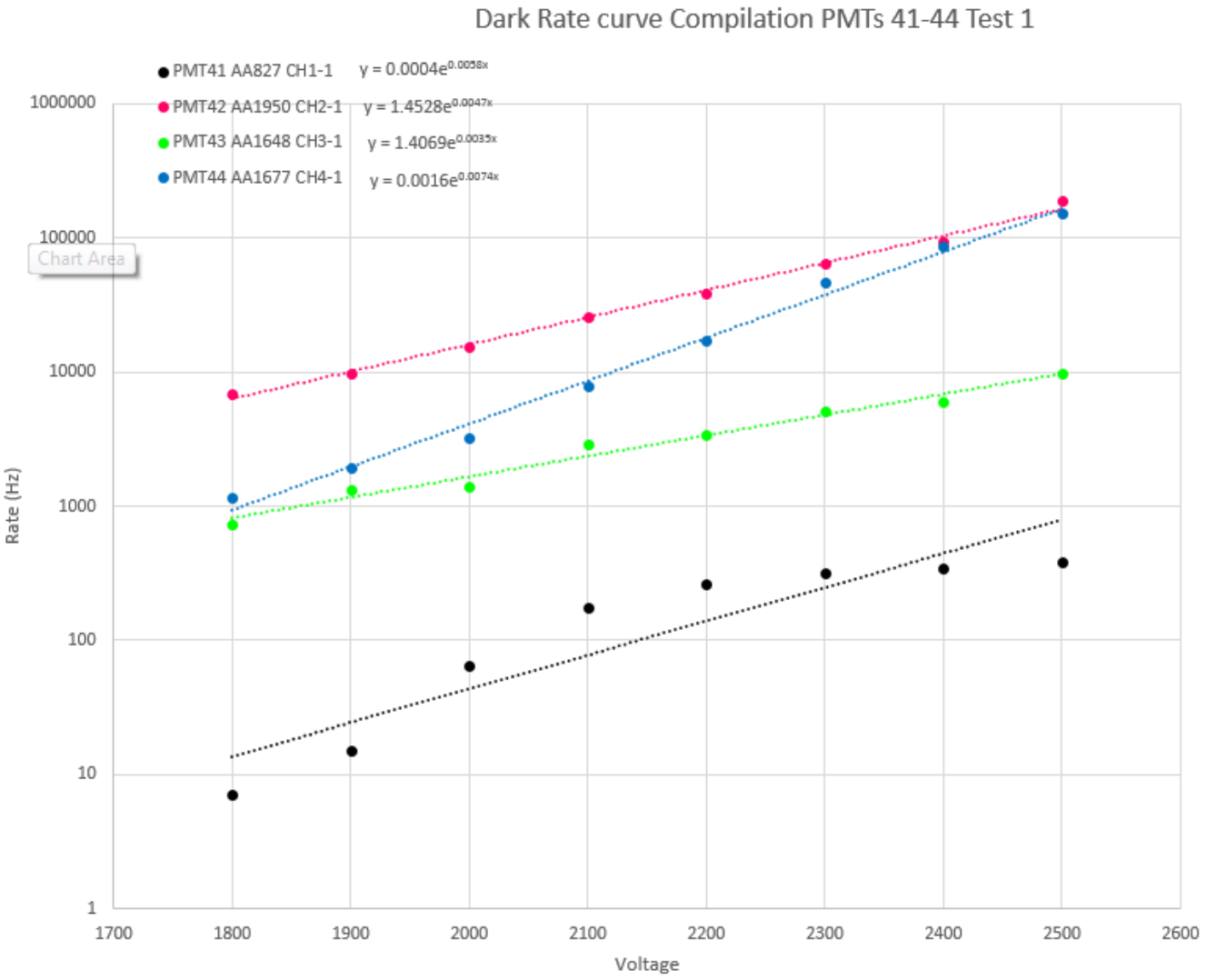


PMT43 AA1648 CH3-1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	5552	5914	5786	5779	6307	733.45
1900	10386	10055	11084	10928	10351	1320.1
2000	11529	10290	10728	11301	12222	1401.75
2100	15868	16444	16835	34014	33408	2914.225
2200	31988	29380	22597	24848	26125	3373.45
2300	38408	39243	40264	43363	44352	5140.75
2400	47553	46571	49669	53647	45563	6075.075
2500	80434	74868	76969	73437	79819	9638.175



PMT44 AA1677 CH4-1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	8928	9231	9320	9321	9338	1153.45
1900	15370	15426	15442	15888	15667	1944.825
2000	25758	25106	25994	25102	26177	3203.425
2100	63226	62121	61685	60491	62819	7758.55
2200	168274	16616	166445	162257	166711	17007.58
2300	369404	371776	374471	366518	377073	46481.05
2400	679986	676858	708530	706740	669683	86044.93
2500	1182631	1204721	1177712	1266307	1240962	151808.3




Dark Rate curve Compilation PMTs 41-44 Test 1
PMT41 AA827 CH1-1 y = 0.0004e^0.0058x
PMT42 AA1950 CH2-1 y = 1.4528e^0.0047x
PMT43 AA1648 CH3-1 y = 1.4069e^0.0035x
PMT44 AA1677 CH4-1 y = 0.0016e^0.0074x
Chart Area
Rate (Hz)
1000000
100000
10000
1000
100
10
1
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
Voltage

For these Charge Distribution Histograms:

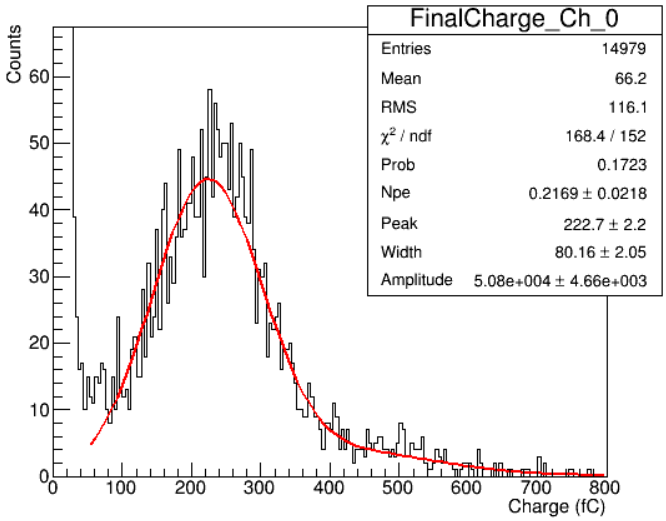
FinalCharge_Ch_0 = PMT41-AA827 FinalCharge_Ch_1 = PMT42-AA1950

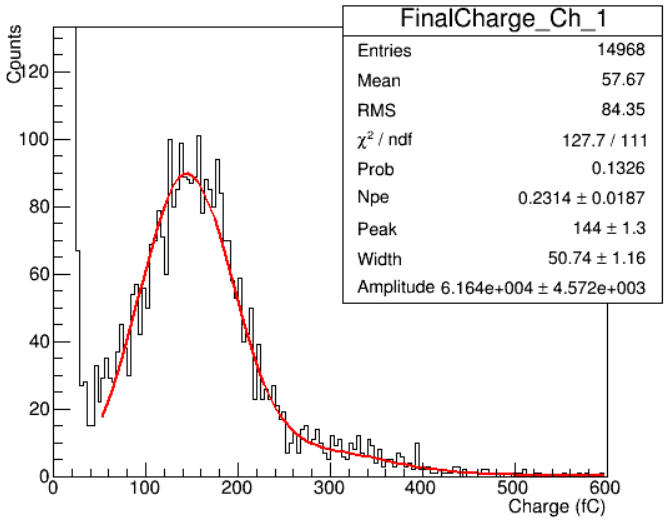
FinalCharge_Ch_2 = PMT43-AA1648 FinalCharge_Ch_3 = PMT44-AA1677

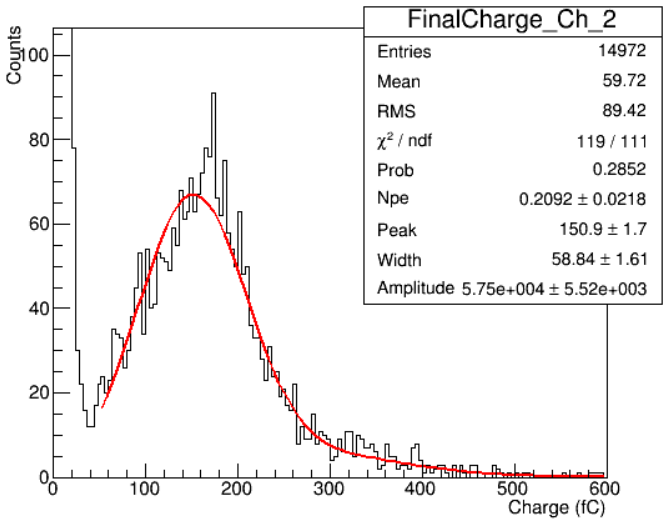
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

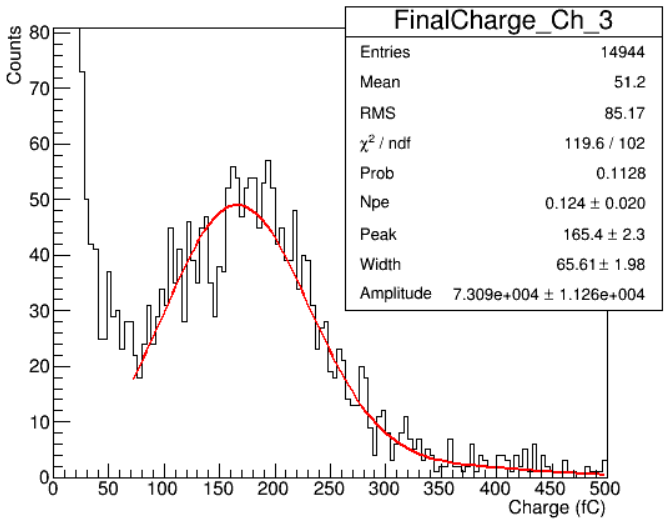
Code used to fit: fitnpe_XP2020

At 2000V

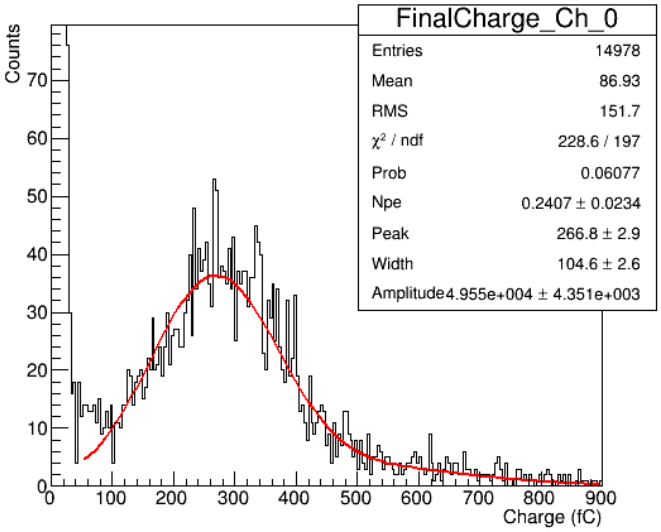


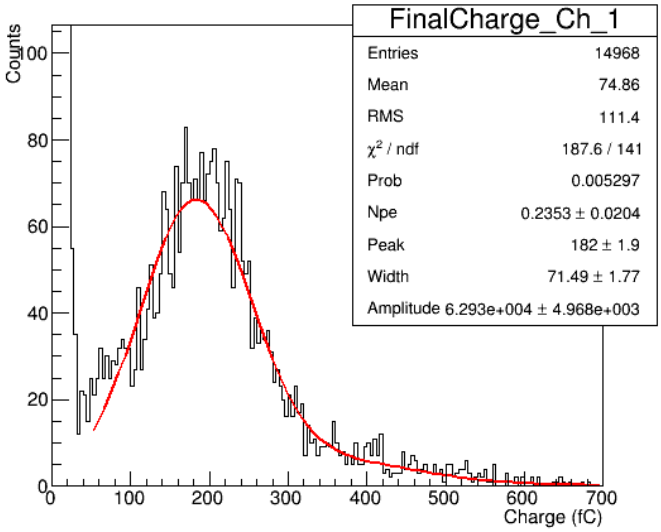


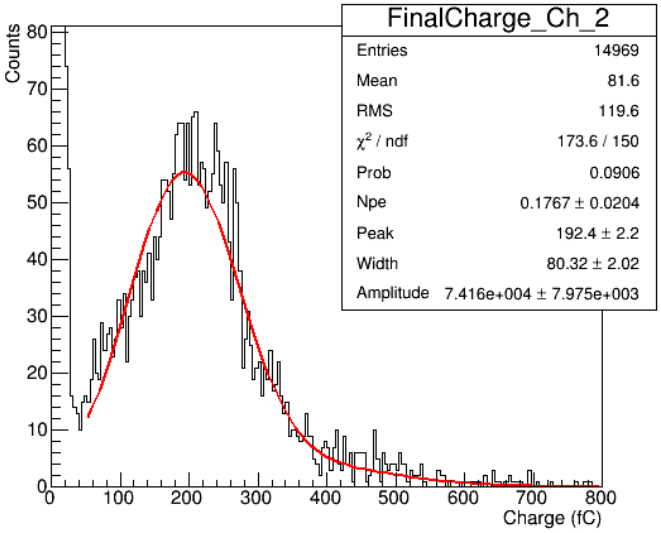


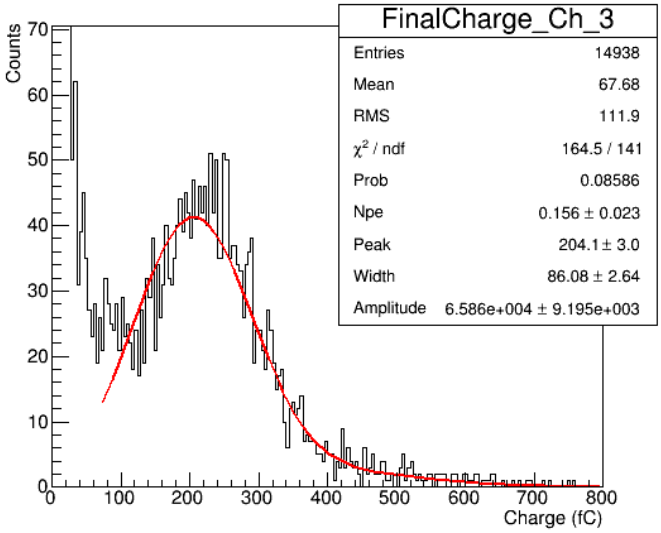


At 2100V

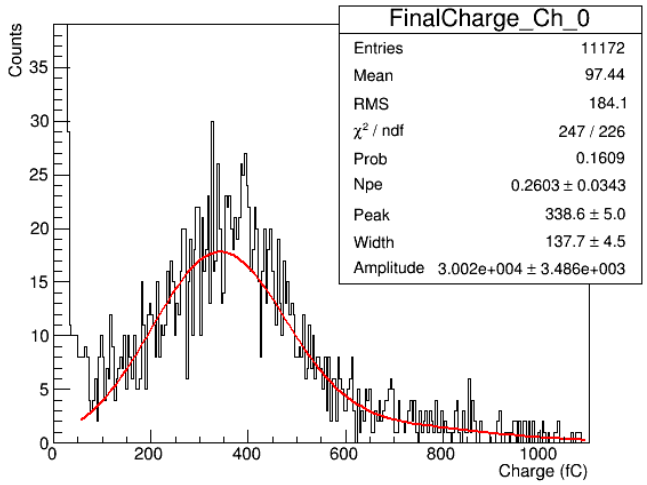

FinalCharge_Ch_0
Entries 14978
Mean 86.93
RMS 151.7
χ² / ndf 228.6 / 197
Prob 0.06077
Npe 0.2407 ± 0.0234
Peak 266.8 ± 2.9
Width 104.6 ± 2.6
Amplitude 4.955e+004 ± 4.351e+003
Counts
Charge (fC)

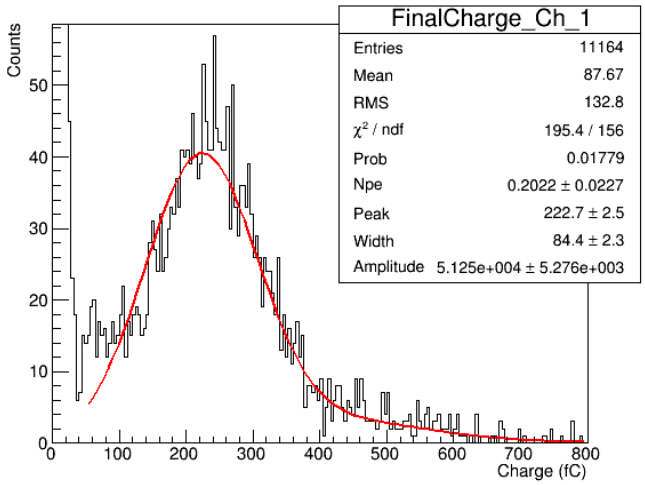

FinalCharge_Ch_1
Entries 14968
Mean 74.86
RMS 111.4
χ² / ndf 187.6 / 141
Prob 0.005297
Npe 0.2353 ± 0.0204
Peak 182 ± 1.9
Width 71.49 ± 1.77
Amplitude 6.293e+004 ± 4.968e+003
Counts
Charge (fC)

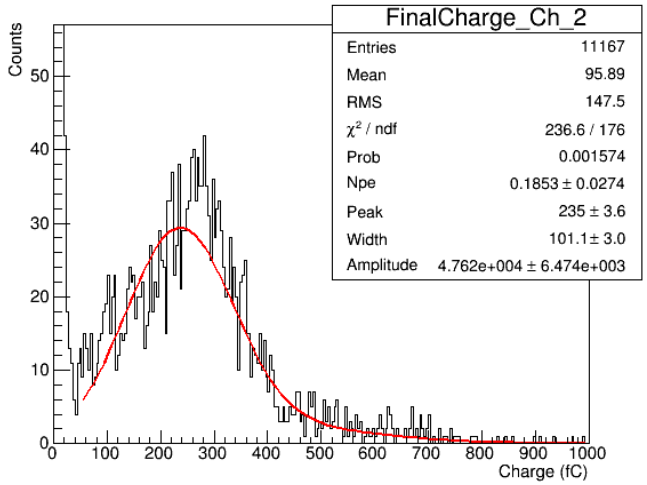

FinalCharge_Ch_2
Entries 14969
Mean 81.6
RMS 119.6
χ² / ndf 173.6 / 150
Prob 0.0906
Npe 0.1767 ± 0.0204
Peak 192.4 ± 2.2
Width 80.32 ± 2.02
Amplitude 7.416e+004 ± 7.975e+003
Counts
Charge (fC)

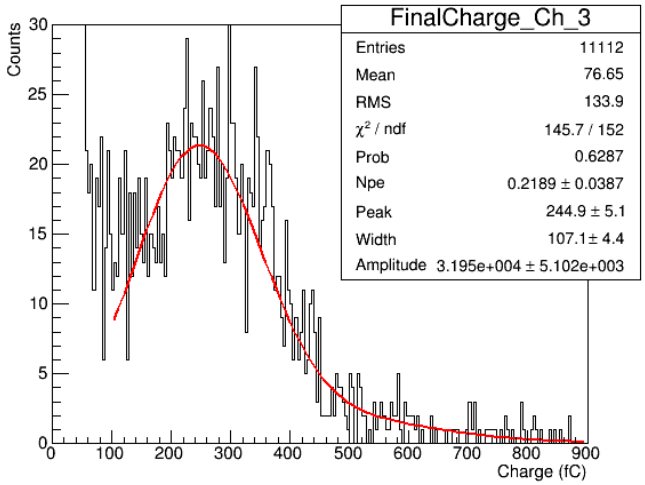

FinalCharge_Ch_3
Entries 14938
Mean 67.68
RMS 111.9
χ² / ndf 164.5 / 141
Prob 0.08586
Npe 0.156 ± 0.023
Peak 204.1 ± 3.0
Width 86.08 ± 2.64
Amplitude 6.586e+004 ± 9.195e+003
Counts
Charge (fC)

At 2200V

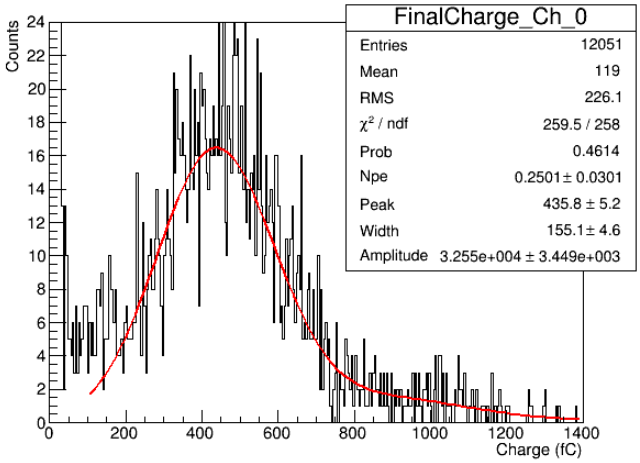

FinalCharge_Ch_0
Entries 11172
Mean 97.44
RMS 184.1
χ² / ndf 247 / 226
Prob 0.1609
Npe 0.2603 ± 0.0343
Peak 338.6 ± 5.0
Width 137.7 ± 4.5
Amplitude 3.002e+004 ± 3.486e+003
Counts
Charge (fC)

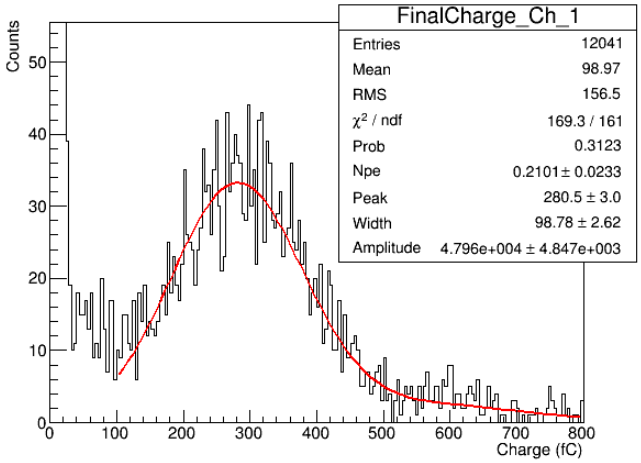

FinalCharge_Ch_1
Entries 11164
Mean 87.67
RMS 132.8
χ² / ndf 195.4 / 156
Prob 0.01779
Npe 0.2022 ± 0.0227
Peak 222.7 ± 2.5
Width 84.4 ± 2.3
Amplitude 5.125e+004 ± 5.276e+003
Counts
Charge (fC)

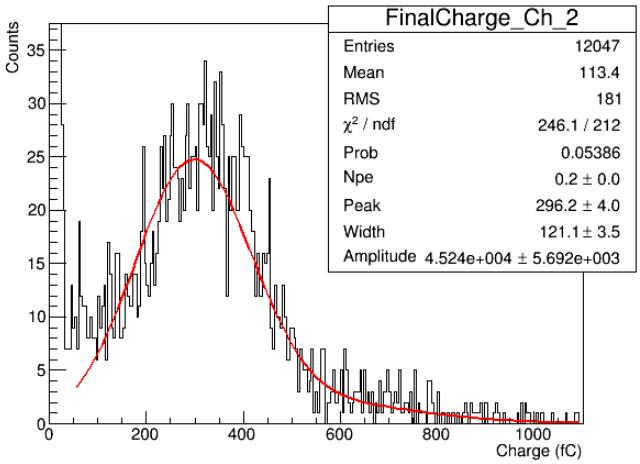

FinalCharge_Ch_2
Entries 11167
Mean 95.89
RMS 147.5
χ² / ndf 236.6 / 176
Prob 0.001574
Npe 0.1853 ± 0.0274
Peak 235 ± 3.6
Width 101.1 ± 3.0
Amplitude 4.762e+004 ± 6.474e+003
Counts
Charge (fC)

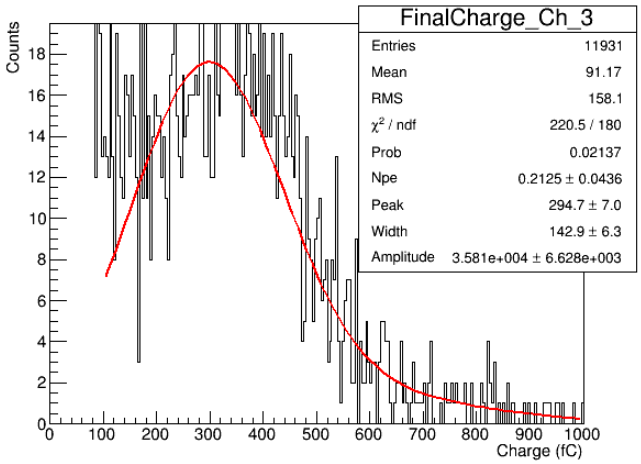

FinalCharge_Ch_3
Entries 11112
Mean 76.65
RMS 133.9
χ² / ndf 145.7 / 152
Prob 0.6287
Npe 0.2189 ± 0.0387
Peak 244.9 ± 5.1
Width 107.1 ± 4.4
Amplitude 3.195e+004 ± 5.102e+003
Counts
Charge (fC)

At 2300V

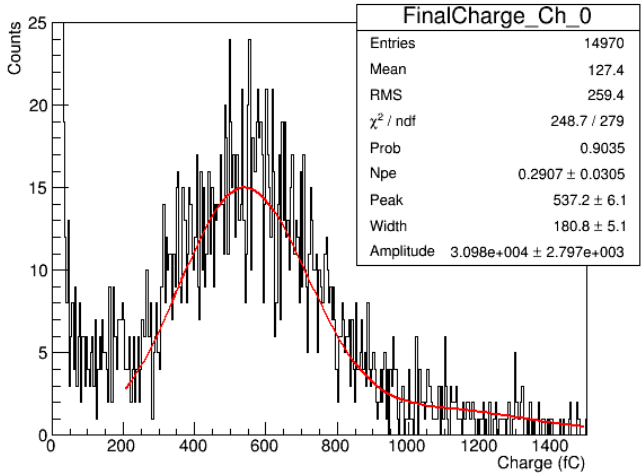

FinalCharge_Ch_0
Entries 12051
Mean 119
RMS 226.1
χ² / ndf 259.5 / 258
Prob 0.4614
Npe 0.2501 ± 0.0301
Peak 435.8 ± 5.2
Width 155.1 ± 4.6
Amplitude 3.255e+004 ± 3.449e+003
Counts
Charge (fC)

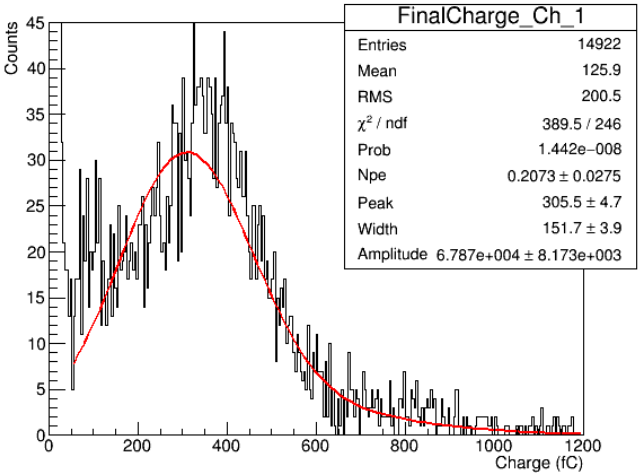

FinalCharge_Ch_1
Entries 12041
Mean 98.97
RMS 156.5
χ² / ndf 169.3 / 161
Prob 0.3123
Npe 0.2101 ± 0.0233
Peak 280.5 ± 3.0
Width 98.78 ± 2.62
Amplitude 4.796e+004 ± 4.847e+003
Counts
Charge (fC)

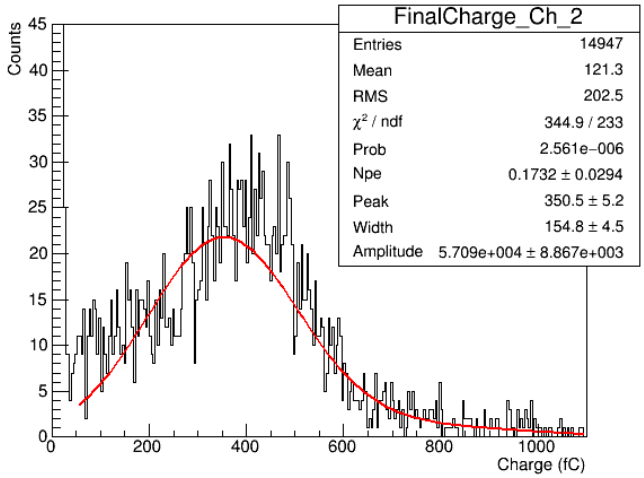

FinalCharge_Ch_2
Entries 12047
Mean 113.4
RMS 181
χ² / ndf 246.1 / 212
Prob 0.05386
Npe 0.2 ± 0.0
Peak 296.2 ± 4.0
Width 121.1 ± 3.5
Amplitude 4.524e+004 ± 5.692e+003
Counts
Charge (fC)

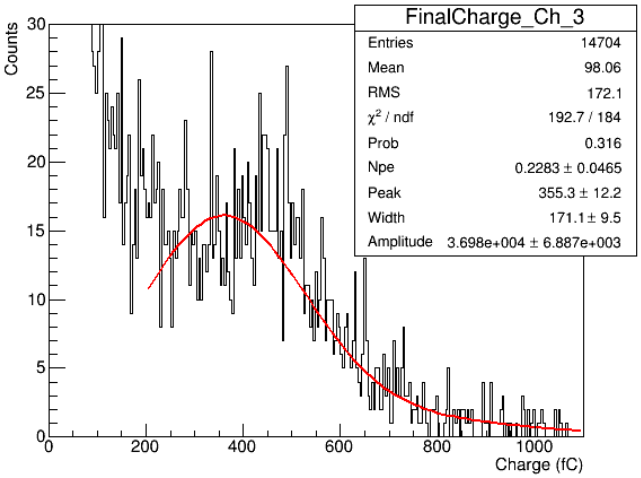

FinalCharge_Ch_3
Entries 11931
Mean 91.17
RMS 158.1
χ² / ndf 220.5 / 180
Prob 0.02137
Npe 0.2125 ± 0.0436
Peak 294.7 ± 7.0
Width 142.9 ± 6.3
Amplitude 3.581e+004 ± 6.628e+003
Counts
Charge (fC)

At 2400V

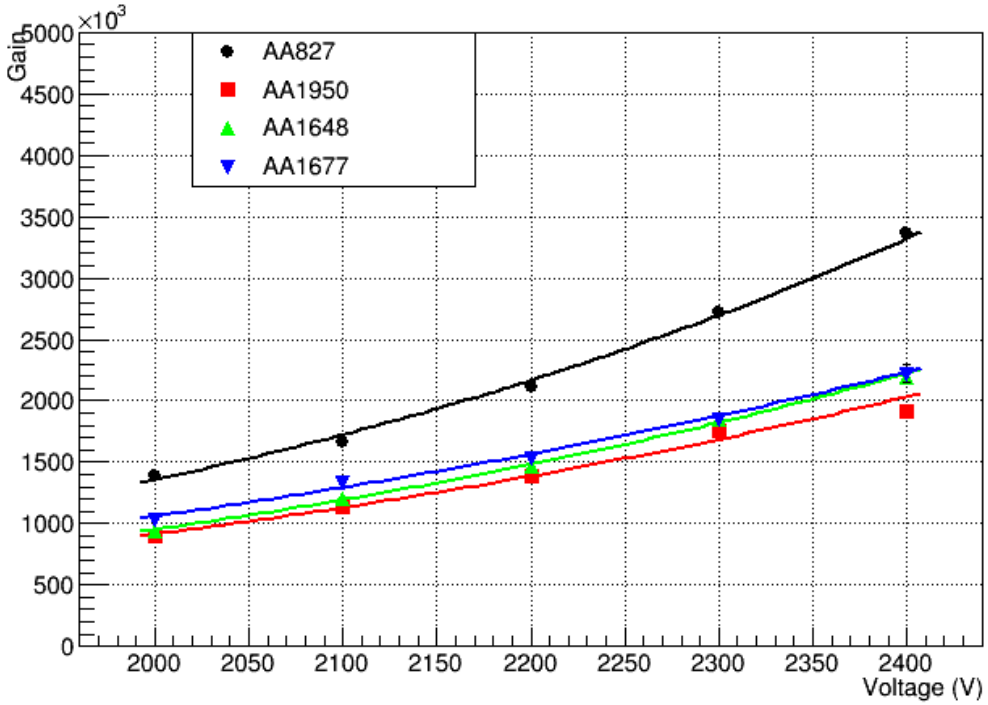

FinalCharge_Ch_0
Entries 14970
Mean 127.4
RMS 259.4
χ² / ndf 248.7 / 279
Prob 0.9035
Npe 0.2907 ± 0.0305
Peak 537.2 ± 6.1
Width 180.8 ± 5.1
Amplitude 3.098e+004 ± 2.797e+003
Counts
Charge (fC)

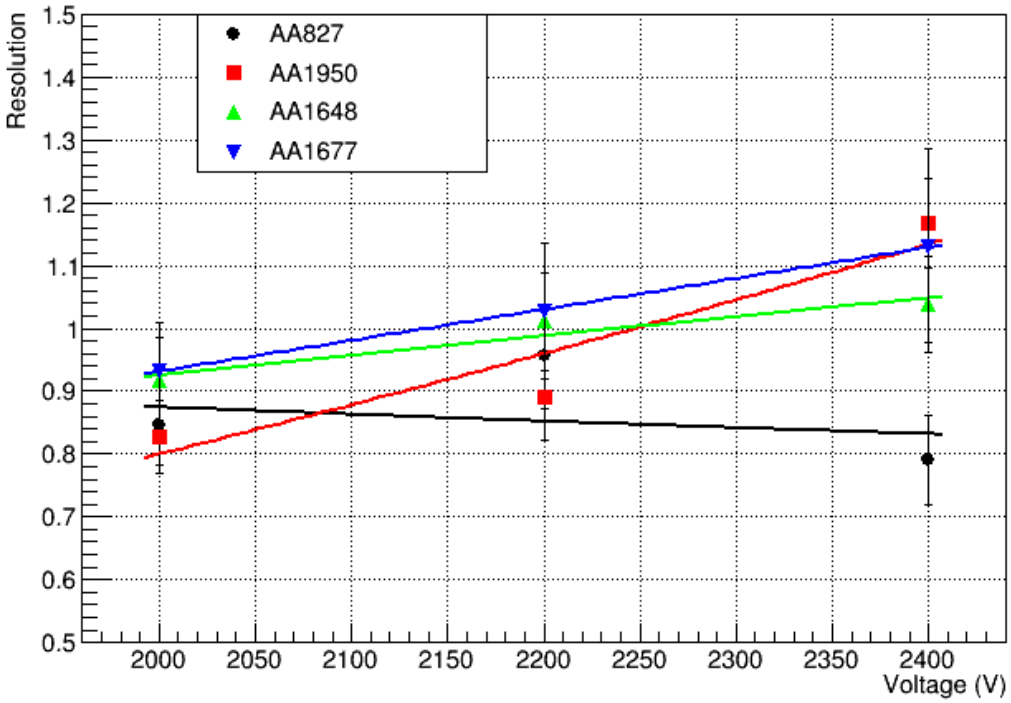

FinalCharge_Ch_1
Entries 14922
Mean 125.9
RMS 200.5
χ² / ndf 389.5 / 246
Prob 1.442e−008
Npe 0.2073 ± 0.0275
Peak 305.5 ± 4.7
Width 151.7 ± 3.9
Amplitude 6.787e+004 ± 8.173e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 14947
Mean 121.3
RMS 202.5
χ² / ndf 344.9 / 233
Prob 2.561e−006
Npe 0.1732 ± 0.0294
Peak 350.5 ± 5.2
Width 154.8 ± 4.5
Amplitude 5.709e+004 ± 8.867e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 14704
Mean 98.06
RMS 172.1
χ² / ndf 192.7 / 184
Prob 0.316
Npe 0.2283 ± 0.0465
Peak 355.3 ± 12.2
Width 171.1 ± 9.5
Amplitude 3.698e+004 ± 6.887e+003
Counts
Charge (fC)

Gain and resolution curves: PMT41-AA827, PMT42-AA1950, PMT43-AA1648, PMT44-AA1677





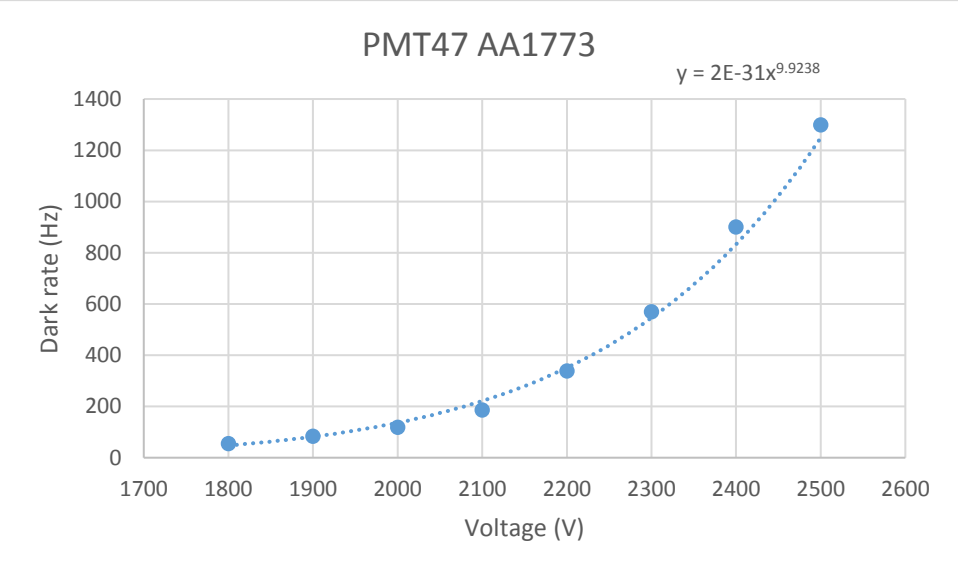
PMT's 45-48

PMT45-H9420-1 (not intended for use in cosmic ray detectors)
PMT46-H9420-2 (not intended for use in cosmic ray detectors)
PMT47-AA1773
PMT48-AA903

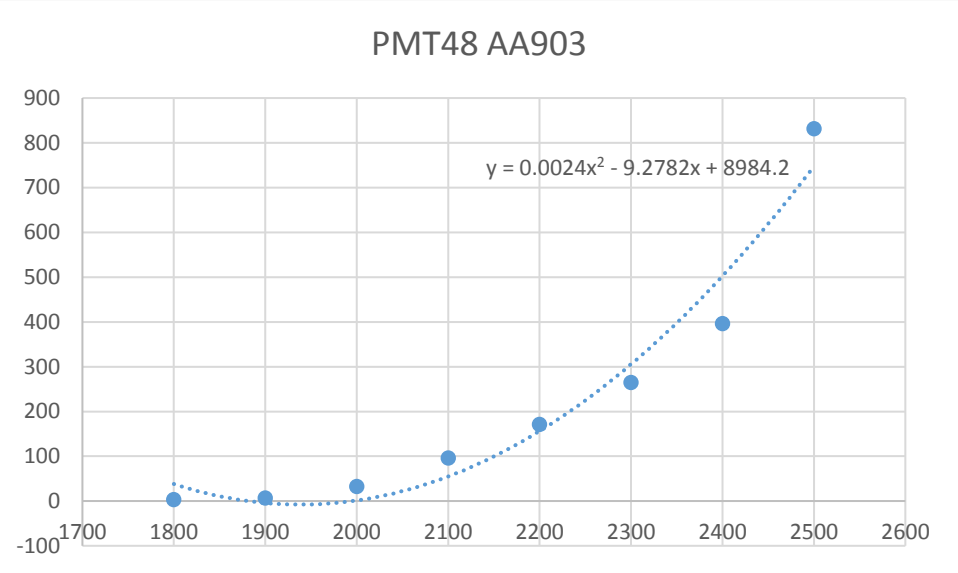
PMT45 H9420-1 CH1-1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1200	331	345	316	326	327	41.125
1300	1743	1752	1736	1683	1717	215.775
1350	2662	2867	2726	2646	2580	337.025
1400	4164	4093	4227	4250	4355	527.225
1450	5785	5806	5636	5409	5745	709.525

PMT46 H9420-2 CH2-2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1200	214	189	184	198	206	24.775
1300	814	836	850	779	902	104.525
1350	1351	1409	1309	1296	1349	167.85
1400	1901	1976	1836	1973	1950	240.9
1450	2446	2398	2506	2615	2315	307

PMT47 AA1773 CH3-2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	463	442	452	435	441	55.825
1900	698	676	698	663	644	84.475
2000	973	971	936	888	979	118.675
2100	1471	1486	1544	1501	1479	187.025
2200	2743	2671	2855	2712	2583	339.1
2300	4520	4611	4530	4519	4605	569.625
2400	7225	7199	7184	7197	7236	901.025
2500	10228	10765	10274	10307	10410	1299.6



PMT48 AA903 CH4-2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set > 2400V for 1 hour						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1800	29	25	31	29	24	3.45
1900	77	43	49	47	51	6.675
2000	272	215	271	246	282	32.15
2100	737	798	781	779	760	96.375
2200	1387	1361	1375	1416	1292	170.775
2300	2124	1998	2090	2248	2113	264.325
2400	3152	3231	3140	3275	3042	396
2500	7349	6721	6314	6933	5936	831.325



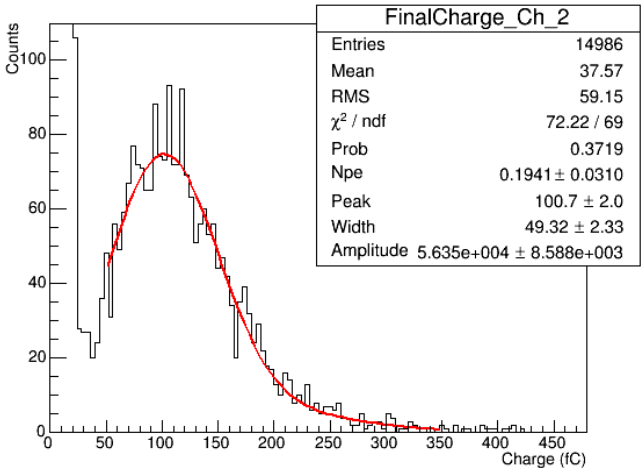
For these Charge Distribution Histograms:

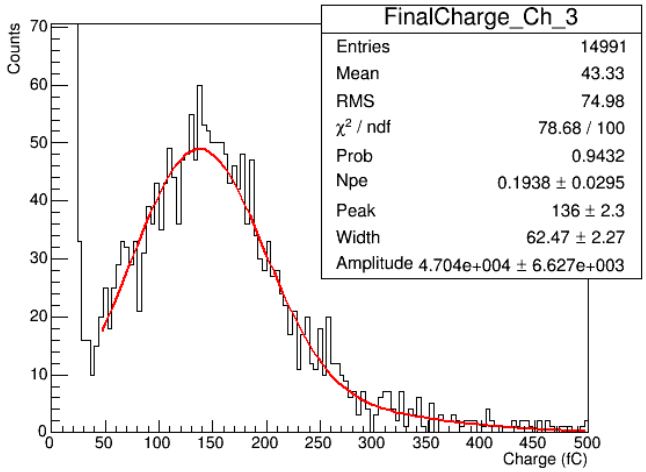
FinalCharge_Ch_2 = PMT47-AA1773 FinalCharge_Ch_3 = PMT48-AA903

Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

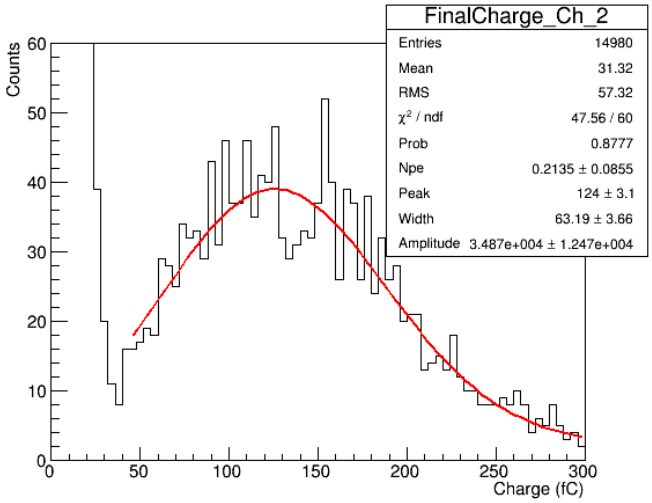
Code used to fit: fitnpe_XP2020

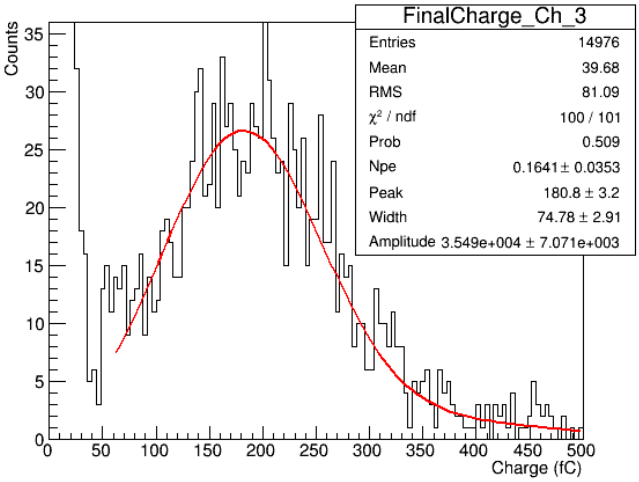
1900V



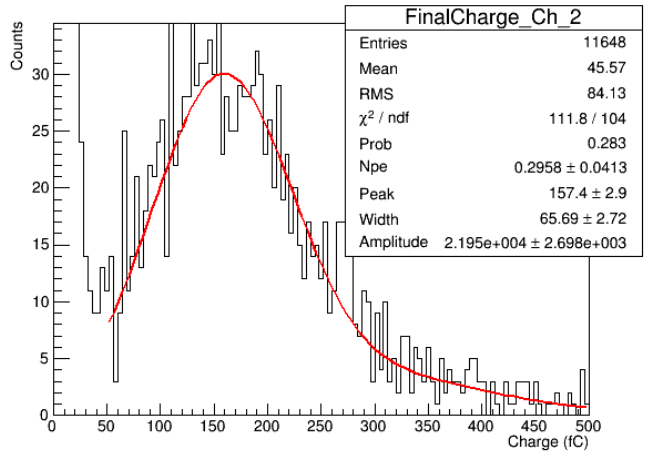


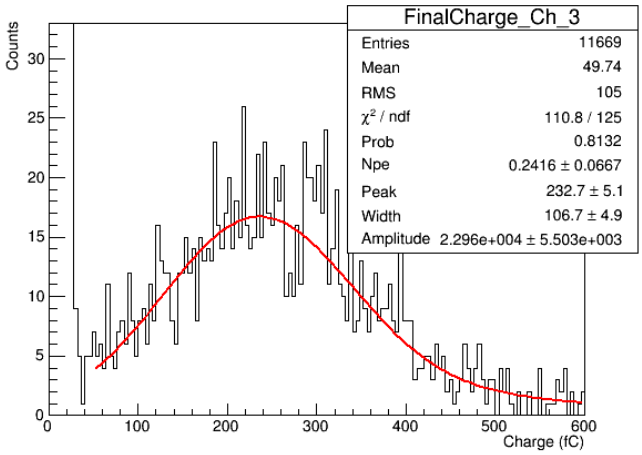
2000V



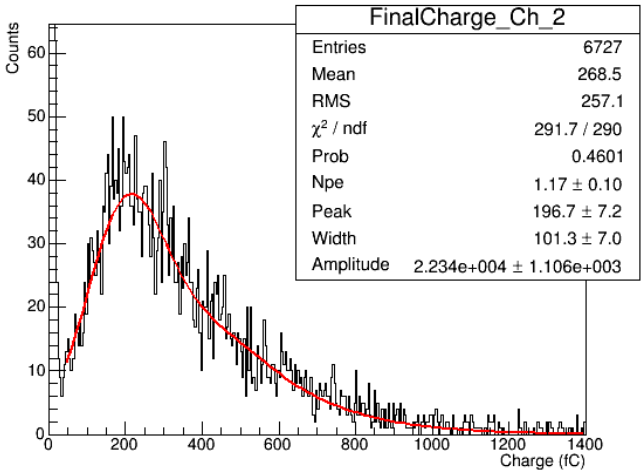


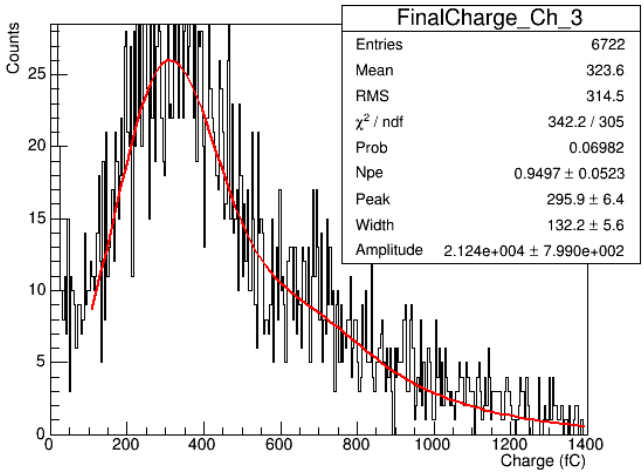
2100V



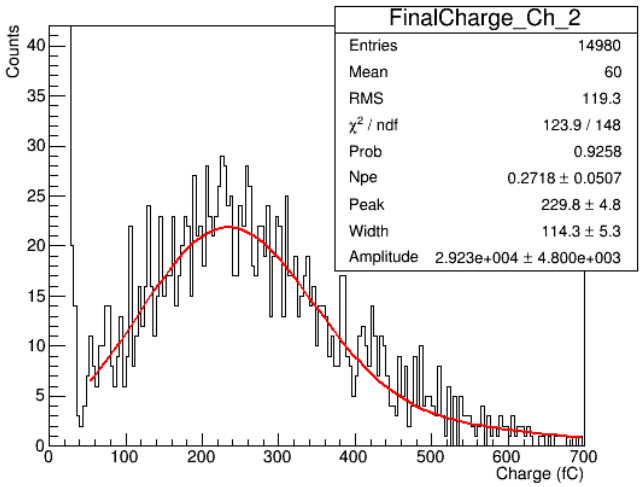


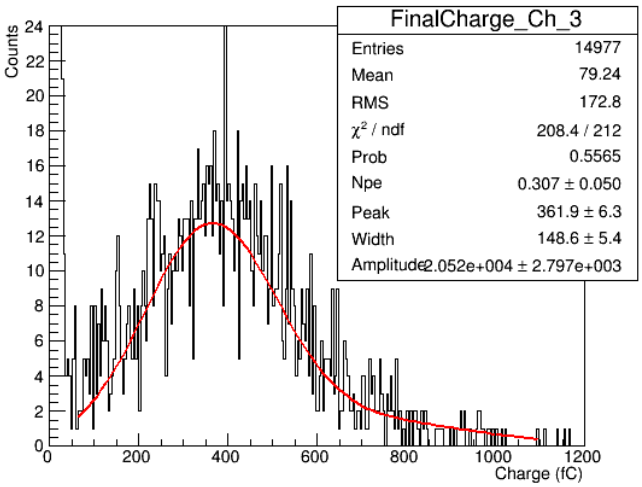
2200V



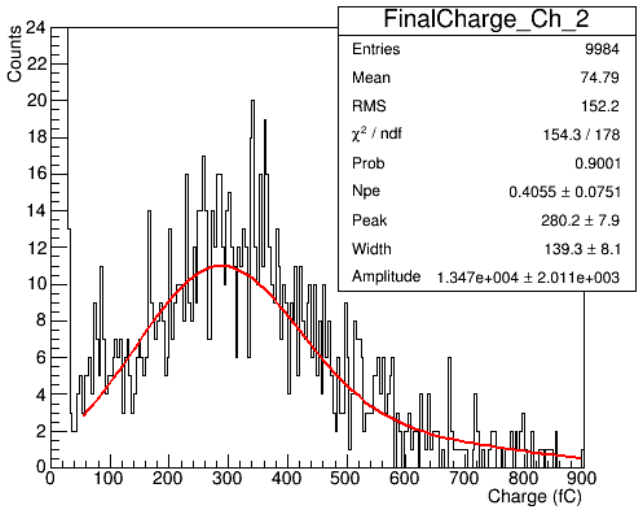


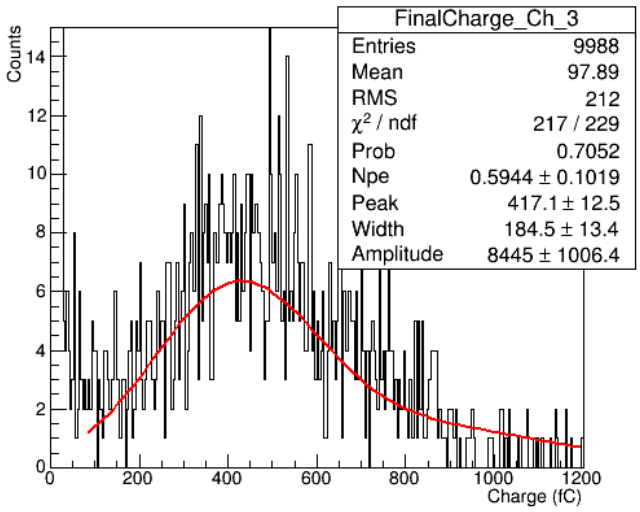
2300V



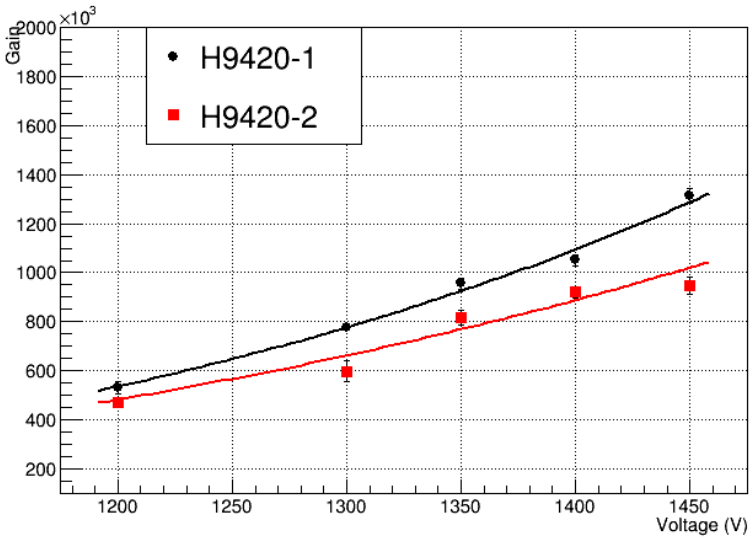


2400V

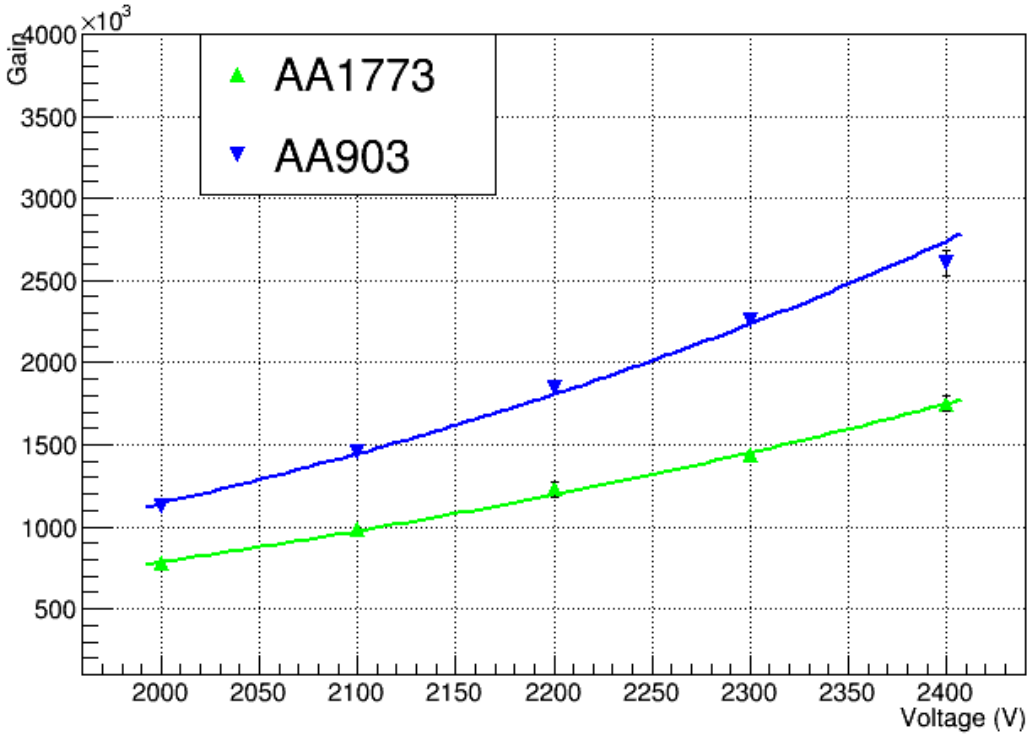

FinalCharge_Ch_2
Entries 9984
Mean 74.79
RMS 152.2
χ² / ndf 154.3 / 178
Prob 0.9001
Npe 0.4055 ± 0.0751
Peak 280.2 ± 7.9
Width 139.3 ± 8.1
Amplitude 1.347e+004 ± 2.011e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 9988
Mean 97.89
RMS 212
χ² / ndf 217 / 229
Prob 0.7052
Npe 0.5944 ± 0.1019
Peak 417.1 ± 12.5
Width 184.5 ± 13.4
Amplitude 8445 ± 1006.4
Counts
Charge (fC)

Gain Curves:
PMT45-H9420-1 (this PMT not intended for use in cosmic ray detectors)
PMT46-H9420-2 (this PMT not intended for use in cosmic ray detectors)



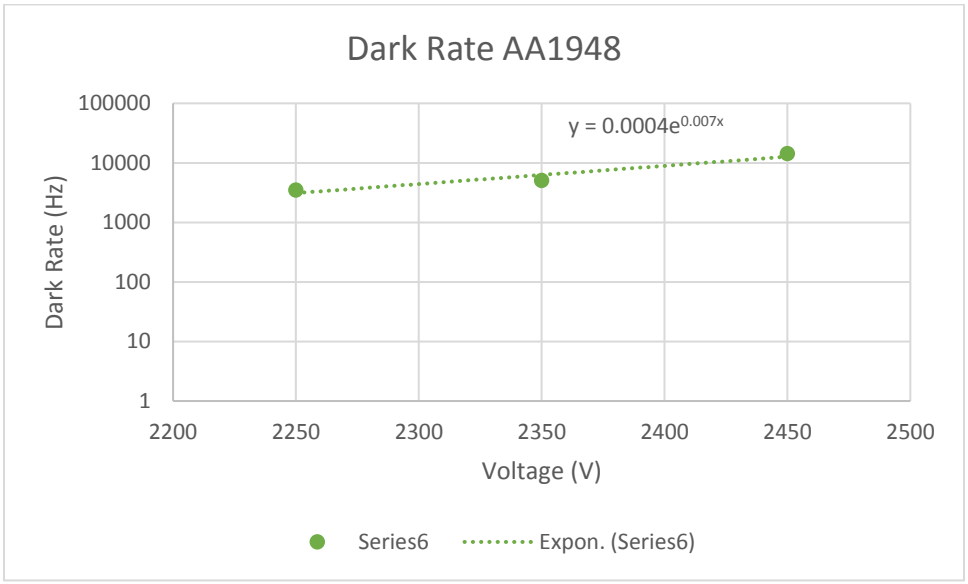
Gain Curves:
PMT47-AA1773
PMT48-AA903



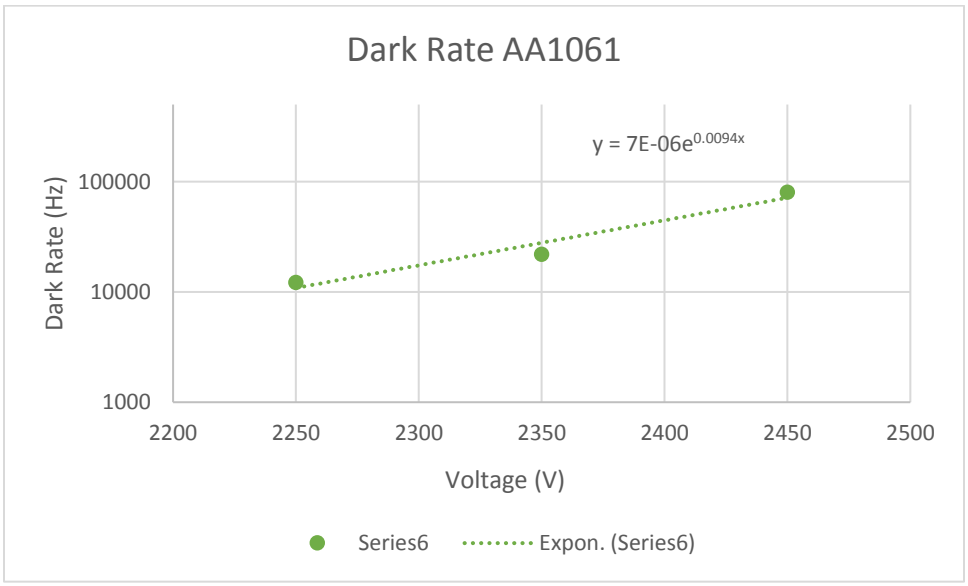
PMT's 49–52

PMT49-AA1948
PMT50-AA1061
PMT51-AA1445
PMT52-AA1415

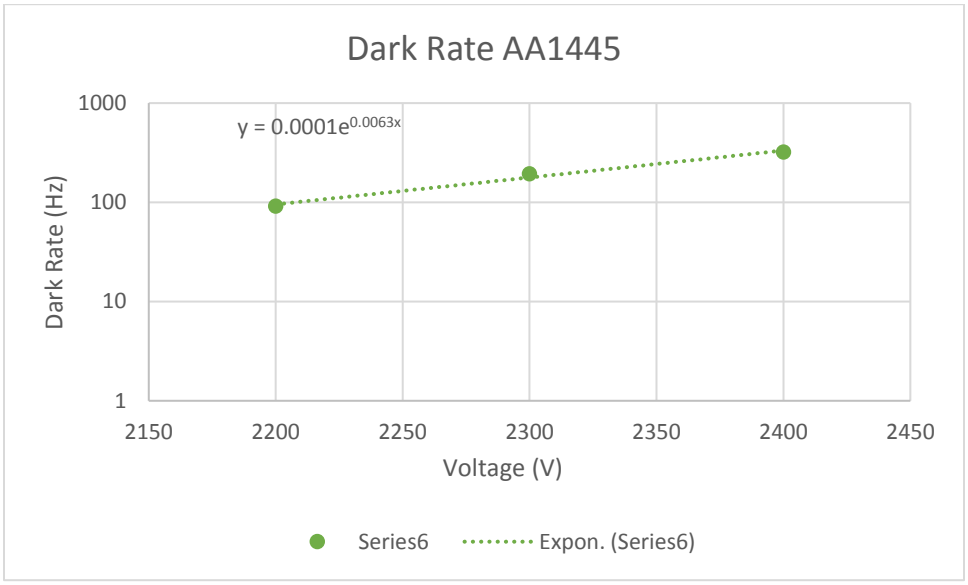
PMT49 AA1948 CH1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 3 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2250	28047	27453	27629	27779	27859	3469.175
2350	37680	42870	39208	41865	39196	5020.475
2450	109703	113424	116258	113711	113922	14175.45



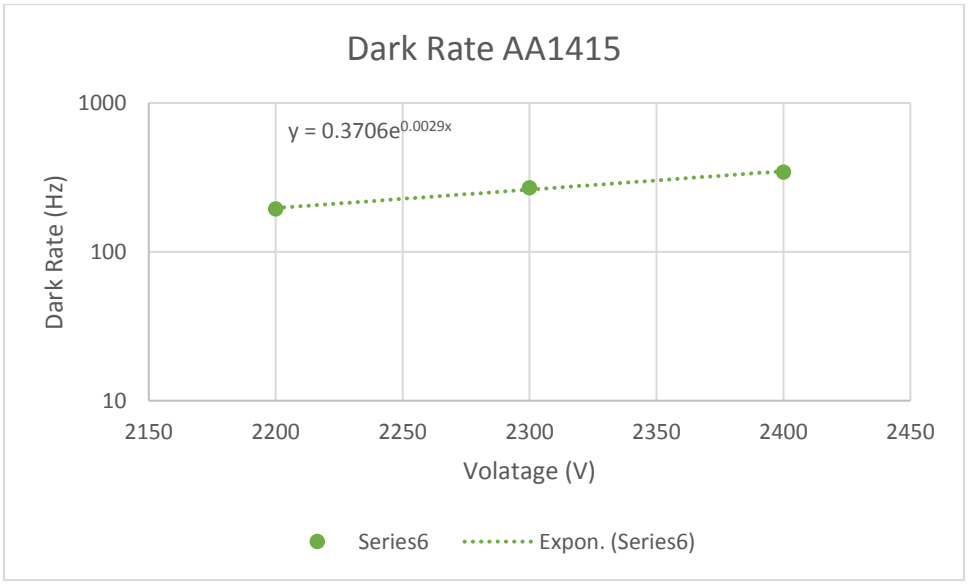
PMT50 AA1061 CH2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 3 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2250	97766	97381	98346	98736	97772	12250.03
2350	175912	174647	176873	175773	175723	21973.2
2450	647331	639949	648205	647042	635130	80441.43

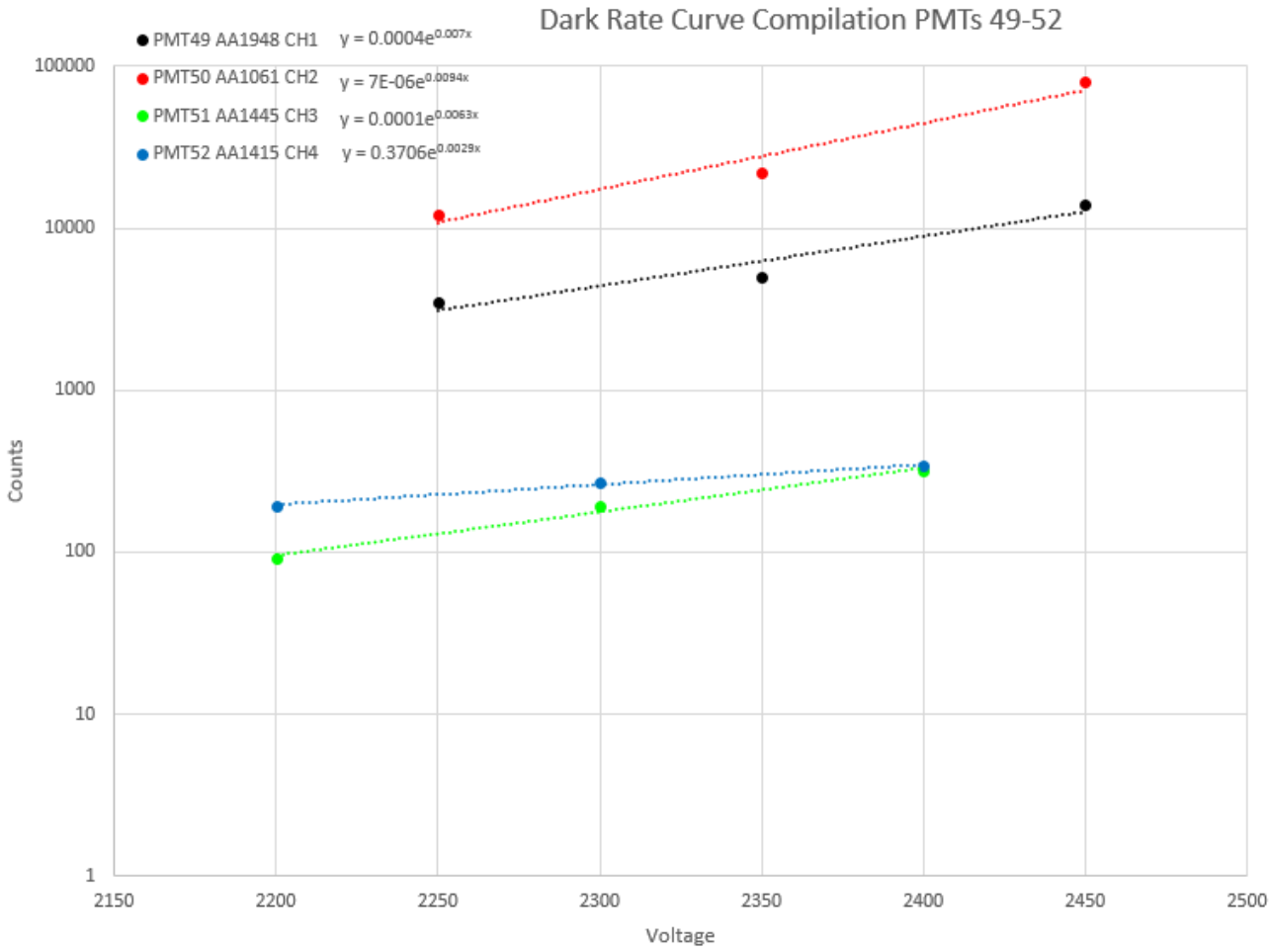


PMT51 AA1445 CH3						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 3 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2200	712	747	730	712	761	91.55
2300	1552	1532	1533	1554	1544	192.875
2400	2528	2588	2519	2623	2525	319.575



PMT52 AA1415 CH4						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 3 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2200	1518	1549	1568	1559	1577	194.275
2300	2225	2193	2090	2132	2123	269.075
2400	2715	2791	2748	2716	2778	343.7




Dark Rate Curve Compilation PMTs 49-52
PMT49 AA1948 CH1 y = 0.0004e^0.007x
PMT50 AA1061 CH2 y = 7E-06e^0.0094x
PMT51 AA1445 CH3 y = 0.0001e^0.0063x
PMT52 AA1415 CH4 y = 0.3706e^0.0029x
100000
10000
1000
100
10
1
Counts
2150
2200
2250
2300
2350
2400
2450
2500
Voltage

For these Charge Distribution Histograms:

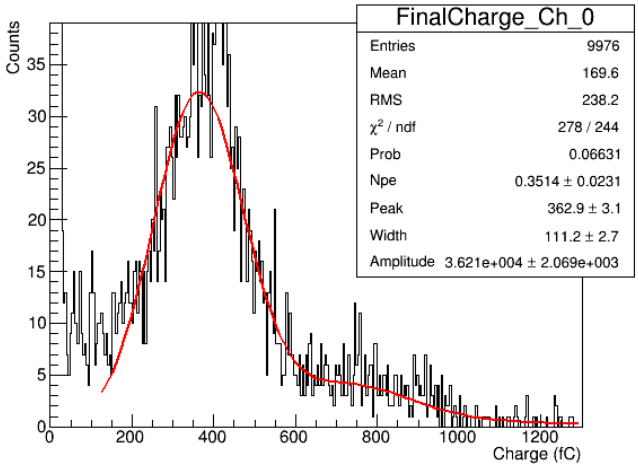
FinalCharge_Ch_0 = PMT49-AA1948 FinalCharge_Ch_1 = PMT50-AA1061

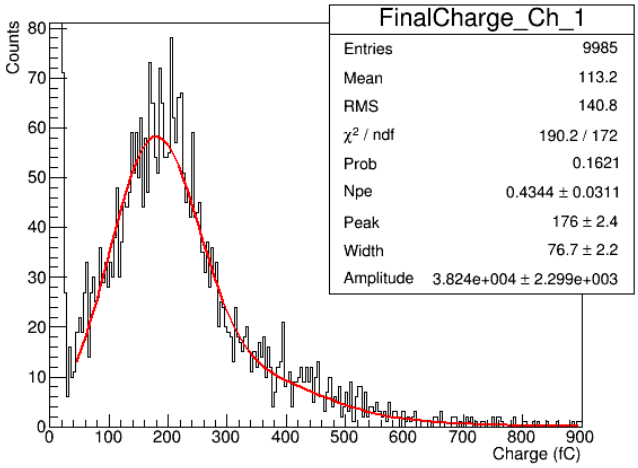
FinalCharge_Ch_2 = PMT51-AA1445 FinalCharge_Ch_3 = PMT52-AA1415

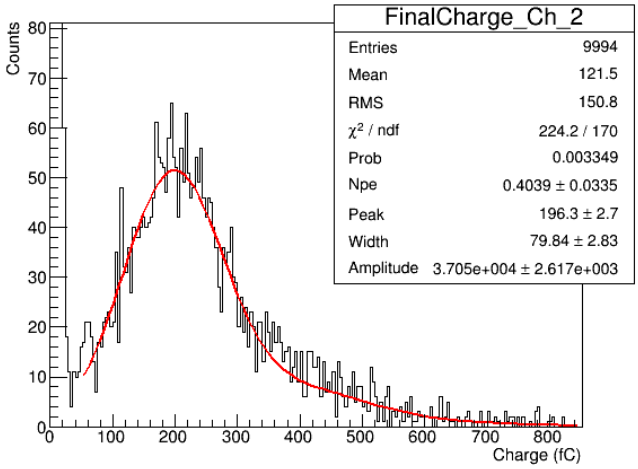
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

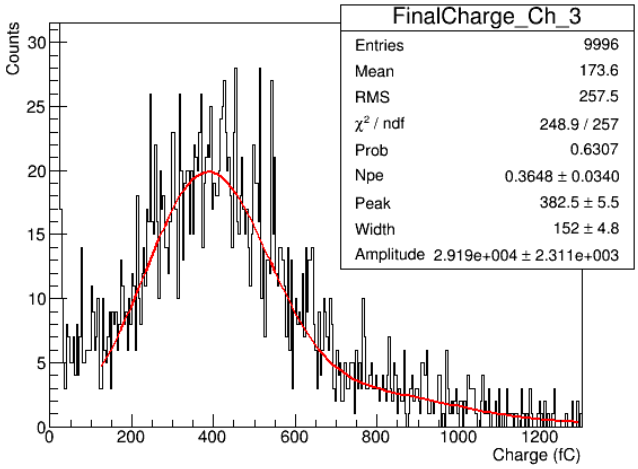
Code used to fit: fitnpe_XP2020

At 2200V

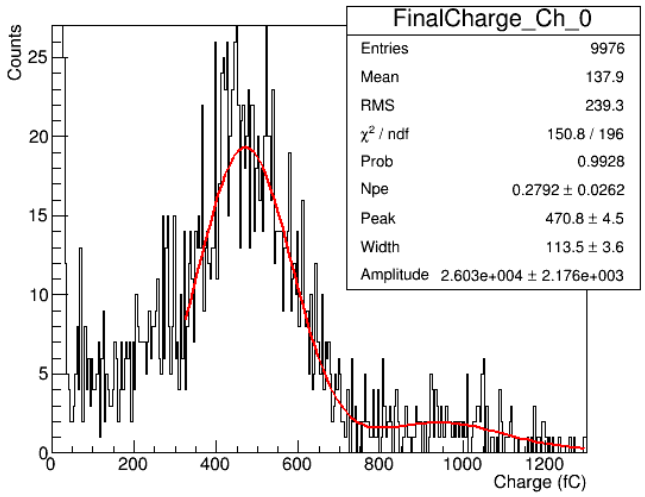


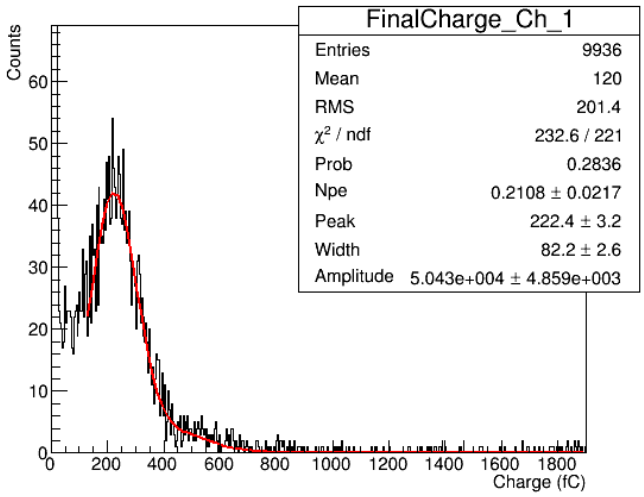


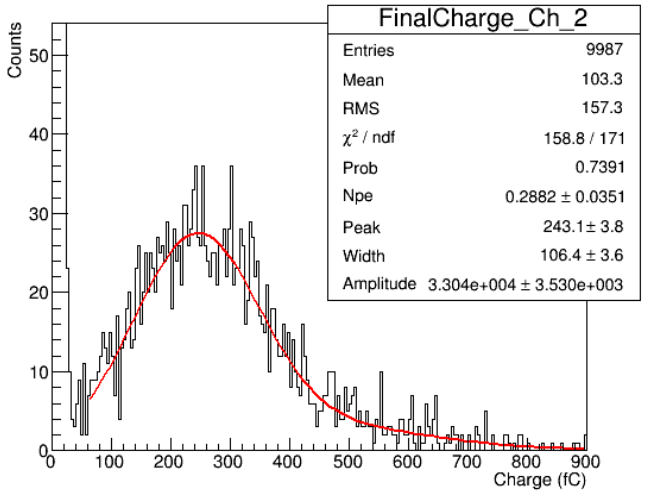


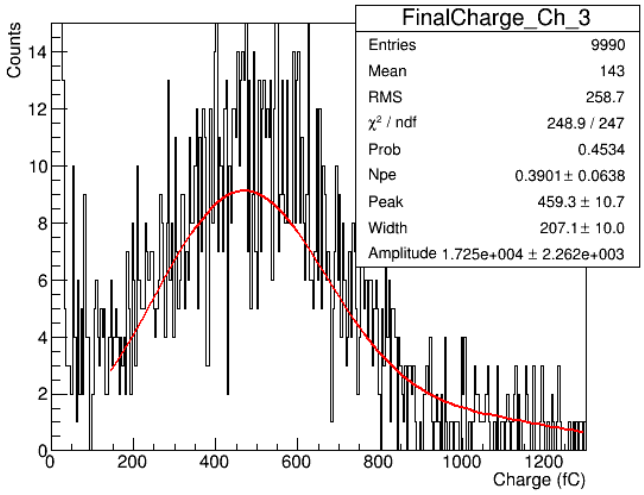


At 2300V

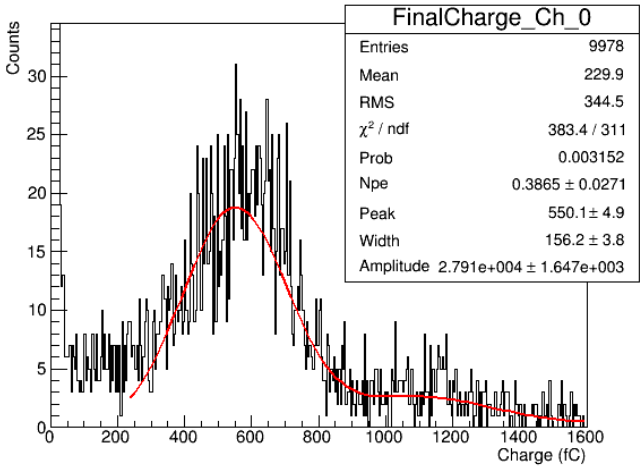

FinalCharge_Ch_0
Entries 9976
Mean 137.9
RMS 239.3
χ² / ndf 150.8 / 196
Prob 0.9928
Npe 0.2792 ± 0.0262
Peak 470.8 ± 4.5
Width 113.5 ± 3.6
Amplitude 2.603e+004 ± 2.176e+003
Counts
Charge (fC)

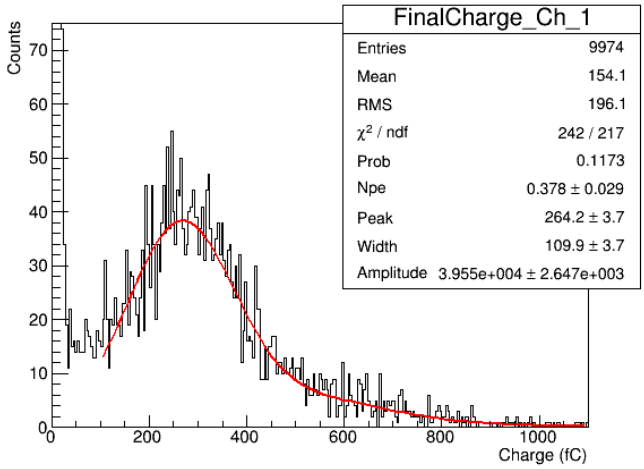

FinalCharge_Ch_1
Entries 9936
Mean 120
RMS 201.4
χ² / ndf 232.6 / 221
Prob 0.2836
Npe 0.2108 ± 0.0217
Peak 222.4 ± 3.2
Width 82.2 ± 2.6
Amplitude 5.043e+004 ± 4.859e+003
Counts
Charge (fC)

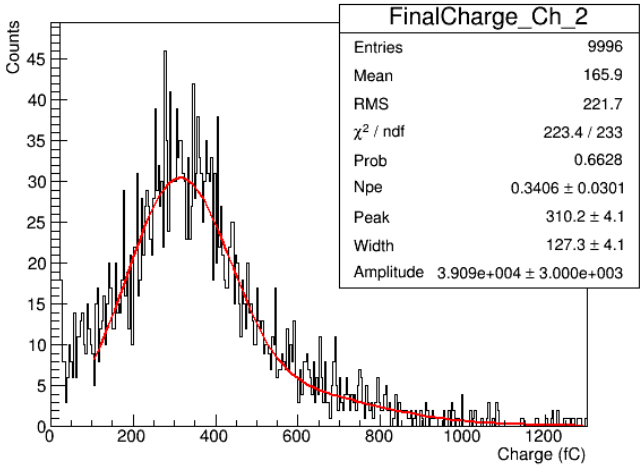

FinalCharge_Ch_2
Entries 9987
Mean 103.3
RMS 157.3
χ² / ndf 158.8 / 171
Prob 0.7391
Npe 0.2882 ± 0.0351
Peak 243.1 ± 3.8
Width 106.4 ± 3.6
Amplitude 3.304e+004 ± 3.530e+003
Counts
Charge (fC)

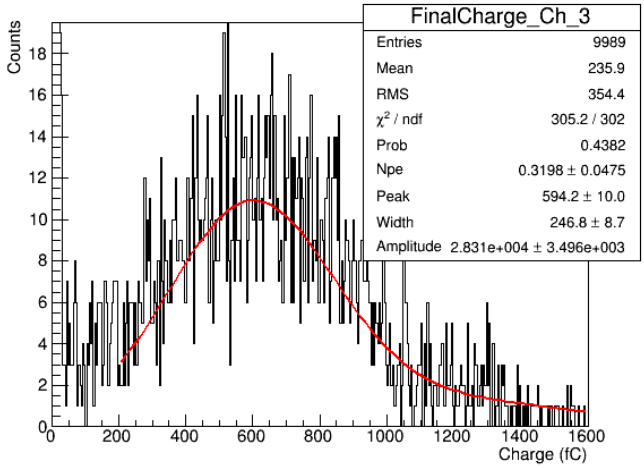

FinalCharge_Ch_3
Entries 9990
Mean 143
RMS 258.7
χ² / ndf 248.9 / 247
Prob 0.4534
Npe 0.3901 ± 0.0638
Peak 459.3 ± 10.7
Width 207.1 ± 10.0
Amplitude 1.725e+004 ± 2.262e+003
Counts
Charge (fC)

At 2400V

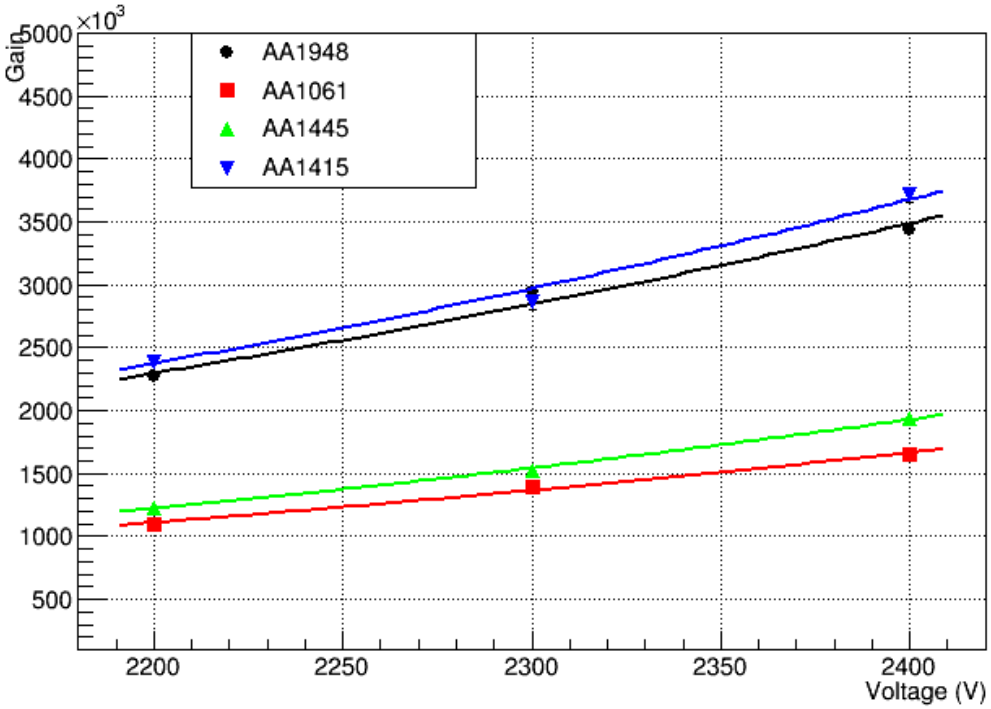

FinalCharge_Ch_0
Entries 9978
Mean 229.9
RMS 344.5
χ² / ndf 383.4 / 311
Prob 0.003152
Npe 0.3865 ± 0.0271
Peak 550.1 ± 4.9
Width 156.2 ± 3.8
Amplitude 2.791e+004 ± 1.647e+003
Counts
Charge (fC)

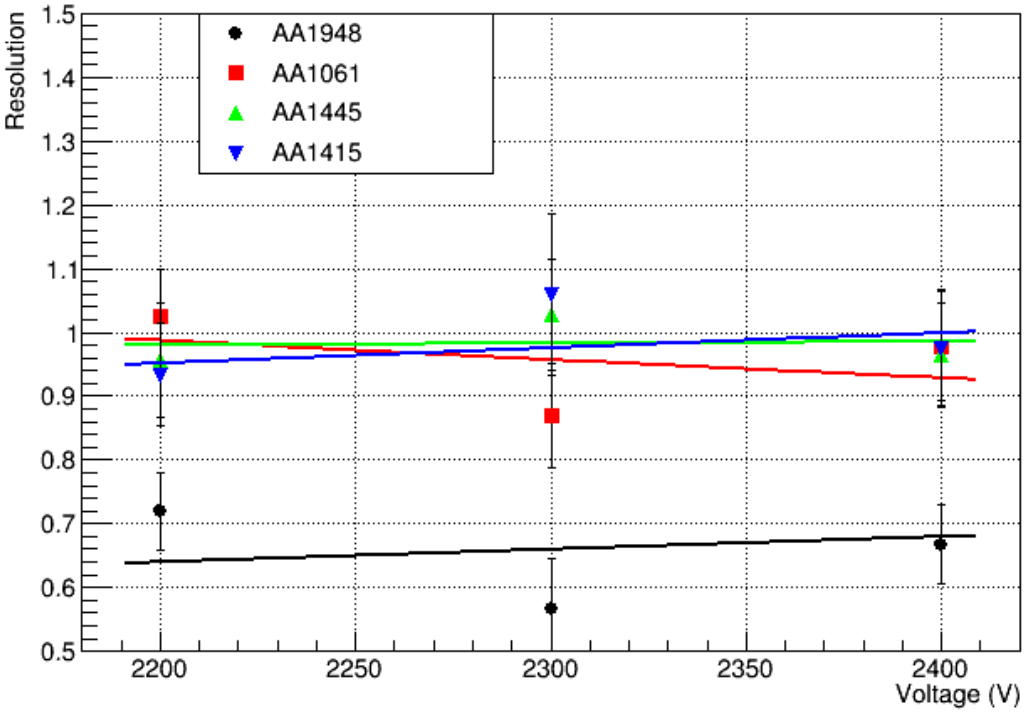

FinalCharge_Ch_1
Entries 9974
Mean 154.1
RMS 196.1
χ² / ndf 242 / 217
Prob 0.1173
Npe 0.378 ± 0.029
Peak 264.2 ± 3.7
Width 109.9 ± 3.7
Amplitude 3.955e+004 ± 2.647e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 9996
Mean 165.9
RMS 221.7
χ² / ndf 223.4 / 233
Prob 0.6628
Npe 0.3406 ± 0.0301
Peak 310.2 ± 4.1
Width 127.3 ± 4.1
Amplitude 3.909e+004 ± 3.000e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 9989
Mean 235.9
RMS 354.4
χ² / ndf 305.2 / 302
Prob 0.4382
Npe 0.3198 ± 0.0475
Peak 594.2 ± 10.0
Width 246.8 ± 8.7
Amplitude 2.831e+004 ± 3.496e+003
Counts
Charge (fC)

Gain and resolution curves: PMT49-AA1948, PMT50-AA1061, PMT51-AA1445, PMT52-AA1415

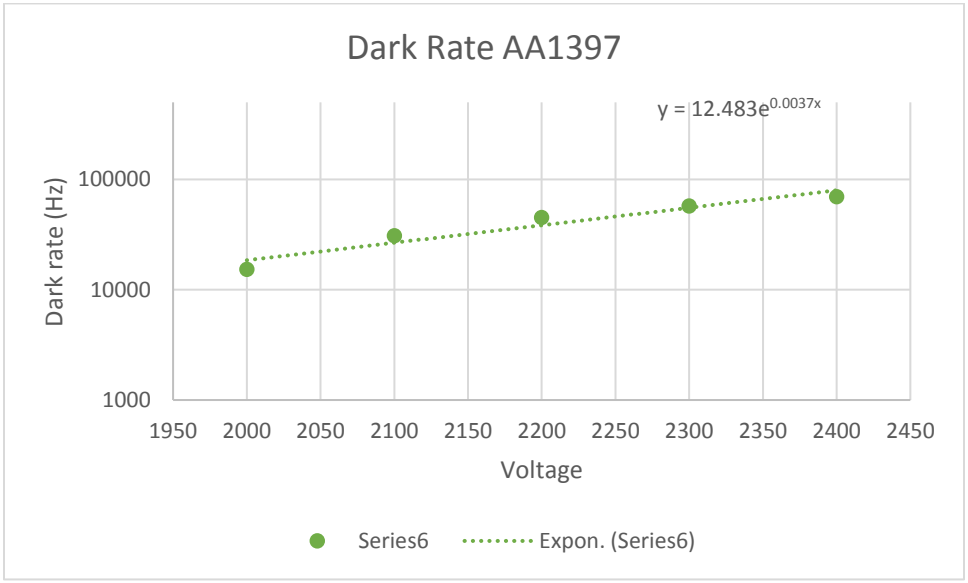




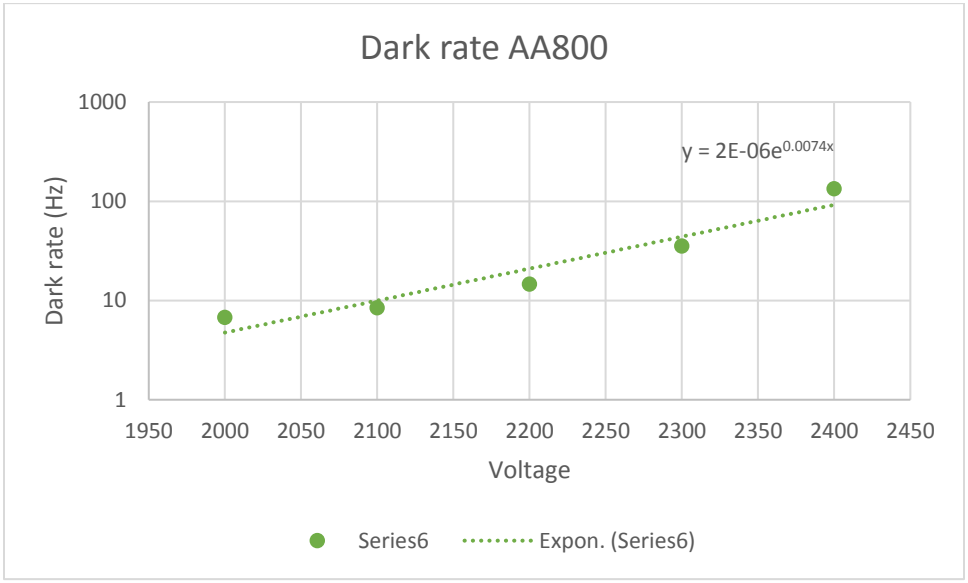
PMT's 53-56

PMT53-AA1379
PMT54-AA800
PMT55-AA1770
PMT56-AA1266

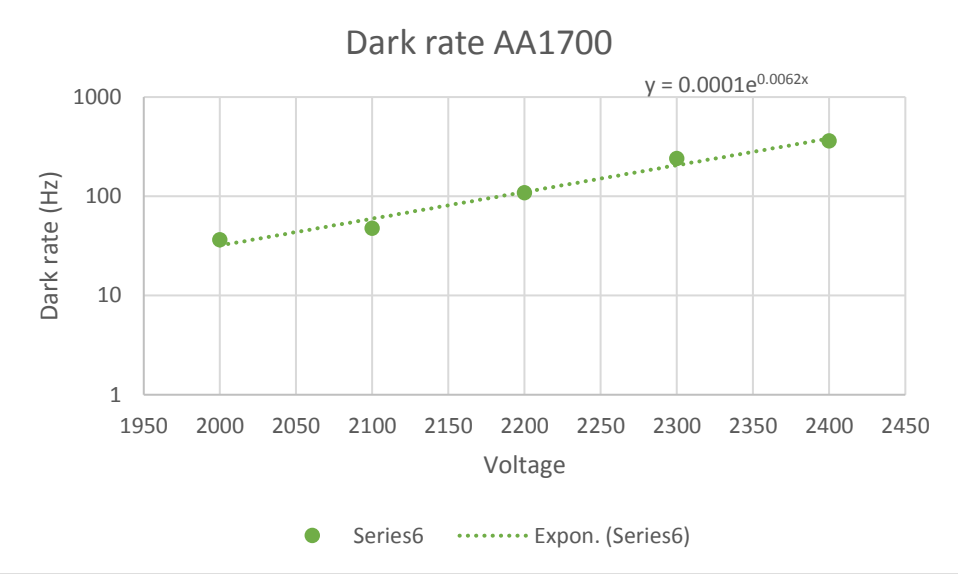
PMT53 AA1397 CH1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	118703	120450	125254	127868	117518	15244.83
2100	247778	246289	246878	243647	245680	30756.8
2200	359944	358445	361451	359723	355094	44866.43
2300	460016	455841	459872	459472	459279	57362
2400	555539	554251	552965	552533	555456	69268.6



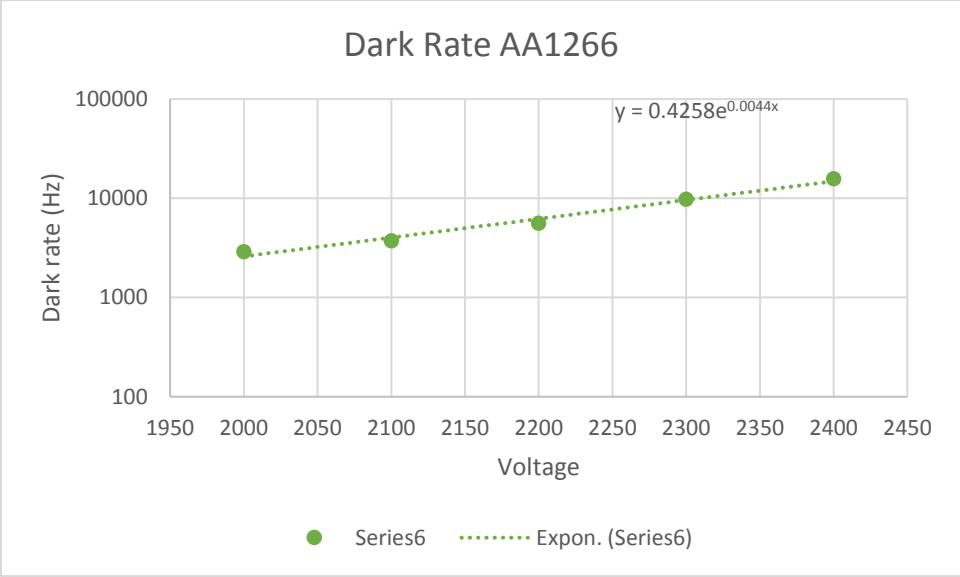
PMT54 AA800 CH2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	48	54	58	54	57	6.775
2100	60	67	62	72	77	8.45
2200	127	109	125	139	88	14.7
2300	260	386	234	273	265	35.45
2400	1012	1038	1006	1073	1258	134.675

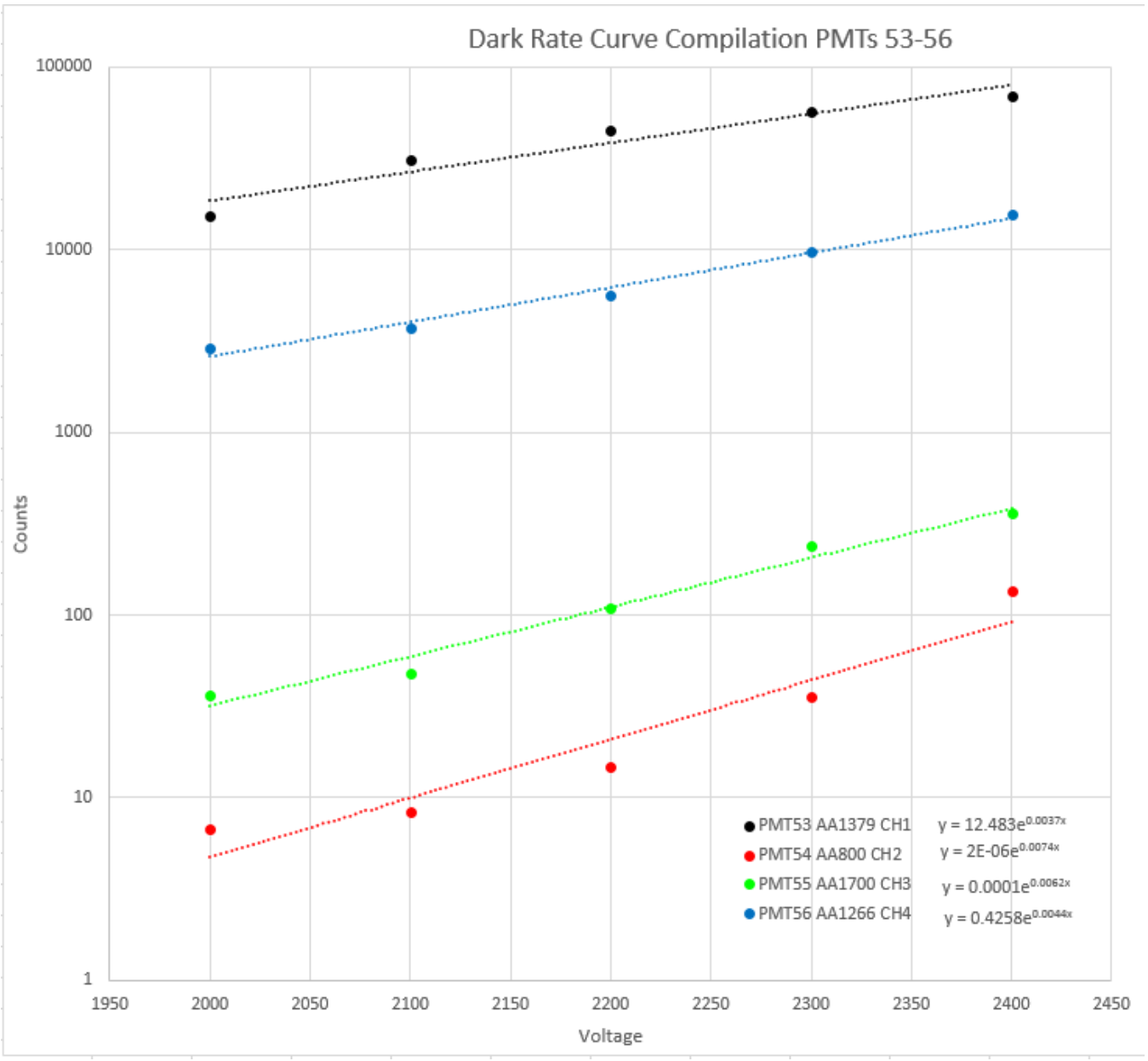


PMT55 AA1700 CH3						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 3 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	292	278	287	325	280	36.55
2100	379	390	351	409	383	47.8
2200	904	872	822	858	878	108.35
2300	1946	1925	1909	1918	1929	240.675
2400	2809	2872	2967	2992	2868	362.7



PMT56 AA1266 CH4						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2200V for > 3 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	23280	23147	22998	23129	23029	2889.575
2100	29808	29764	29690	29950	29507	3717.975
2200	45030	44812	44615	44681	44705	5596.075
2300	78328	78600	78205	78161	77262	9763.9
2400	127692	125944	125402	125346	126002	15759.65




Dark Rate Curve Compilation PMTs 53-56
100000
10000
1000
100
10
1
Counts
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
Voltage
PMT53 AA1379 CH1
y = 12.483e0.0037x
PMT54 AA800 CH2
y = 2E-06e0.0074x
PMT55 AA1700 CH3
y = 0.0001e0.0062x
PMT56 AA1266 CH4
y = 0.4258e0.0044x

For these Charge Distribution Histograms:

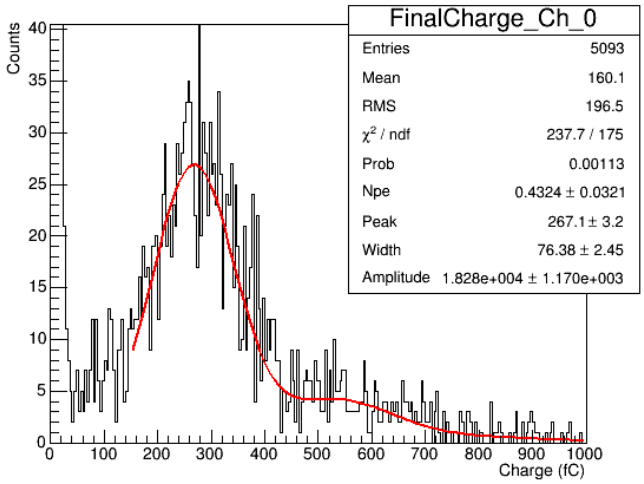
FinalCharge_Ch_0 = PMT53-AA1379 FinalCharge_Ch_1 = PMT54-AA800

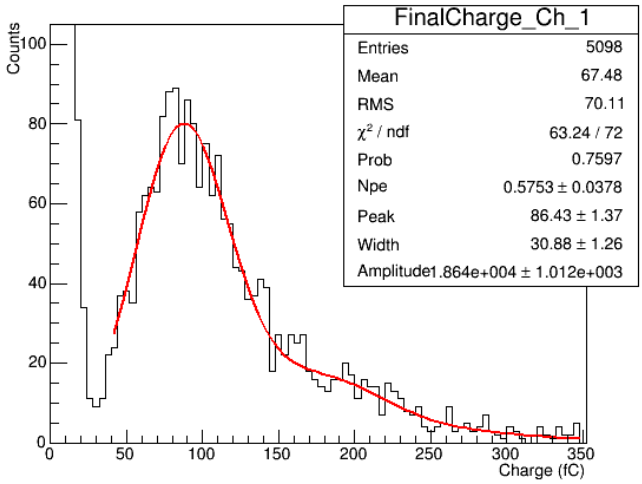
FinalCharge_Ch_2 = PMT55-AA1770 FinalCharge_Ch_3 = PMT56-AA1266

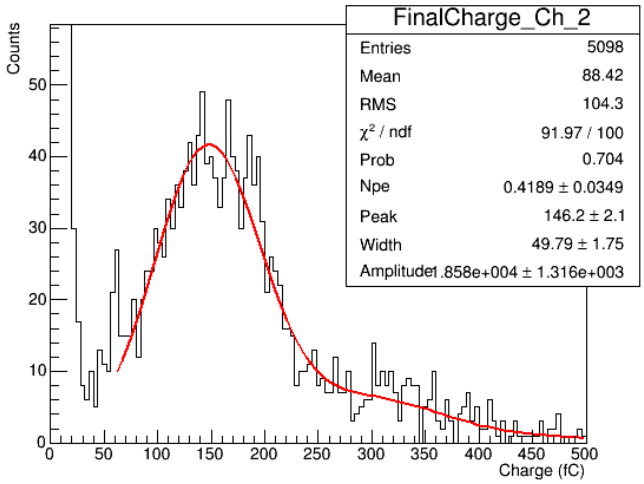
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

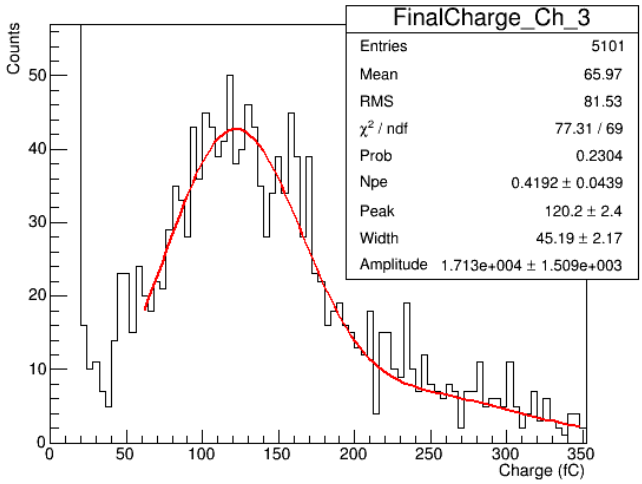
Code used to fit: fitnpe_XP2020

At 2000V

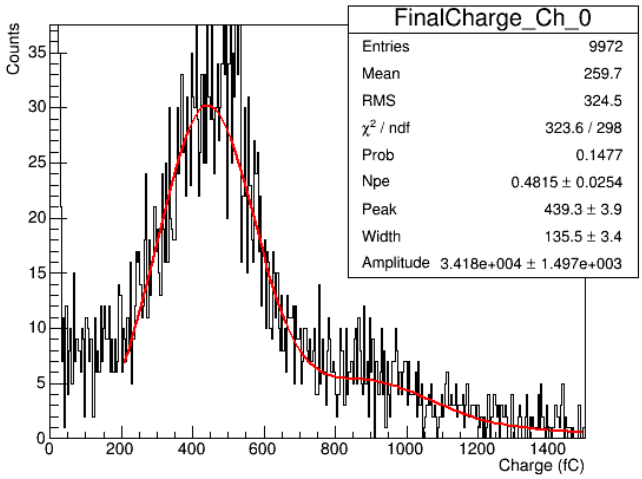


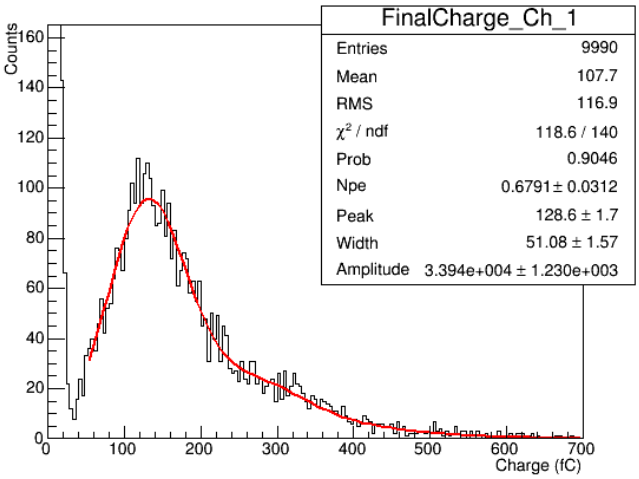


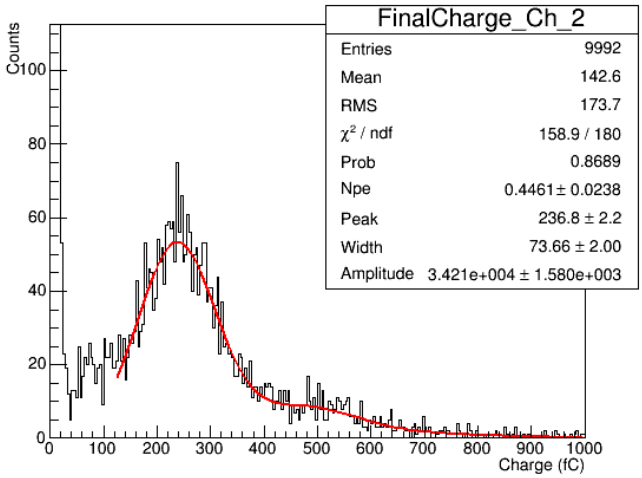


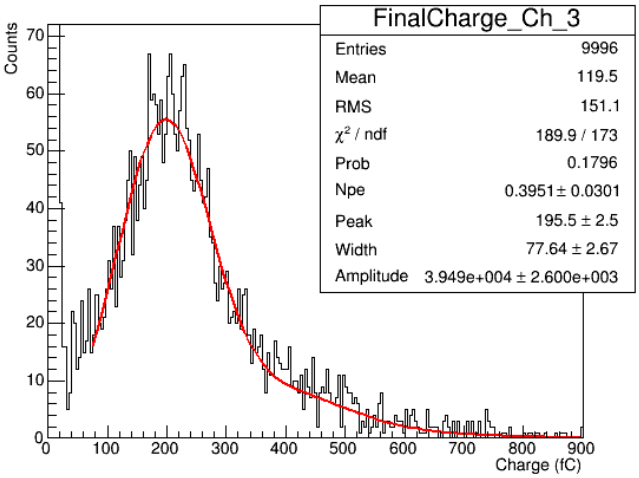


At 2200V

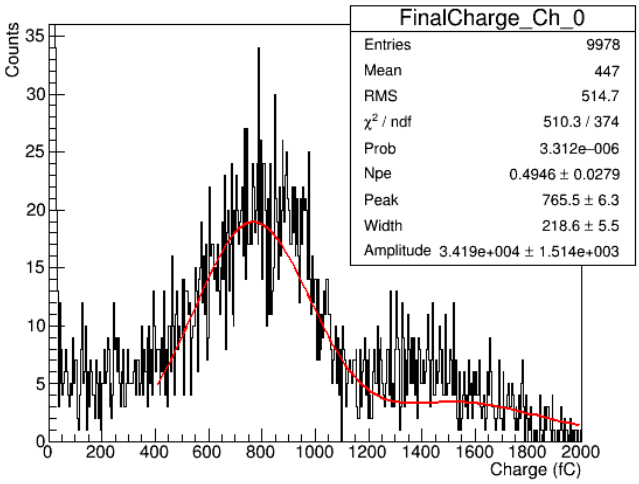

FinalCharge_Ch_0
Entries 9972
Mean 259.7
RMS 324.5
χ² / ndf 323.6 / 298
Prob 0.1477
Npe 0.4815 ± 0.0254
Peak 439.3 ± 3.9
Width 135.5 ± 3.4
Amplitude 3.418e+004 ± 1.497e+003
Counts
Charge (fC)

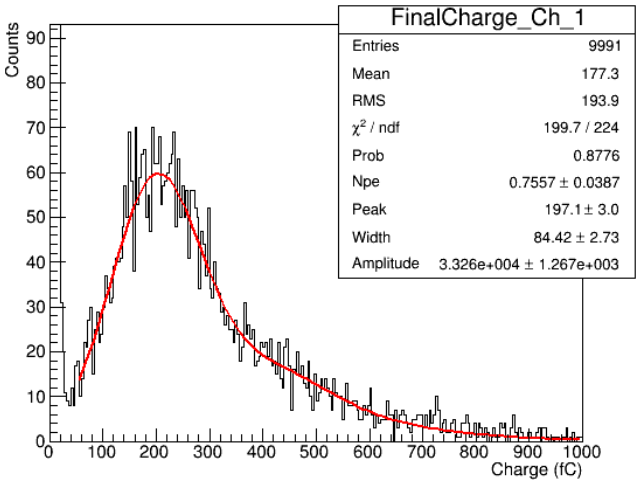

FinalCharge_Ch_1
Entries 9990
Mean 107.7
RMS 116.9
χ² / ndf 118.6 / 140
Prob 0.9046
Npe 0.6791 ± 0.0312
Peak 128.6 ± 1.7
Width 51.08 ± 1.57
Amplitude 3.394e+004 ± 1.230e+003
Counts
Charge (fC)

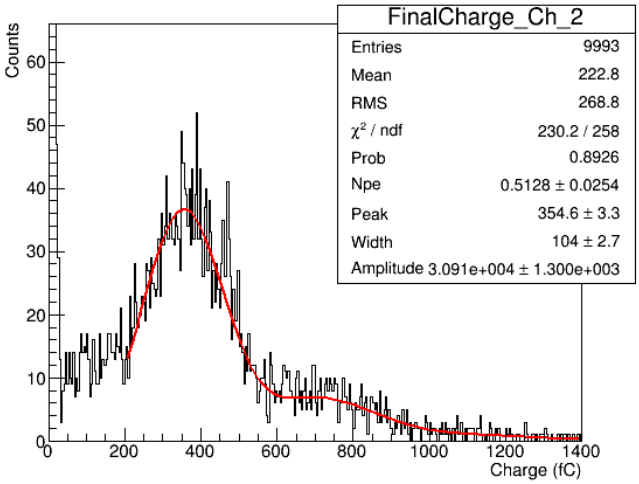

FinalCharge_Ch_2
Entries 9992
Mean 142.6
RMS 173.7
χ² / ndf 158.9 / 180
Prob 0.8689
Npe 0.4461 ± 0.0238
Peak 236.8 ± 2.2
Width 73.66 ± 2.00
Amplitude 3.421e+004 ± 1.580e+003
Counts
Charge (fC)

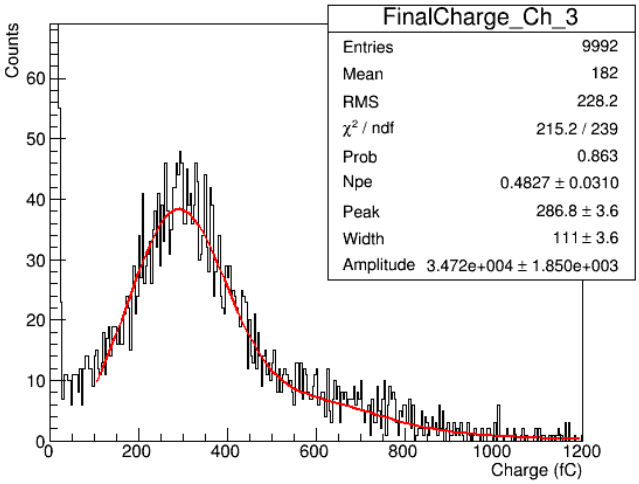

FinalCharge_Ch_3
Entries 9996
Mean 119.5
RMS 151.1
χ² / ndf 189.9 / 173
Prob 0.1796
Npe 0.3951 ± 0.0301
Peak 195.5 ± 2.5
Width 77.64 ± 2.67
Amplitude 3.949e+004 ± 2.600e+003
Counts
Charge (fC)

2450V for Ch_0 and Ch_1, and 2400V for Ch_2 and Ch_3

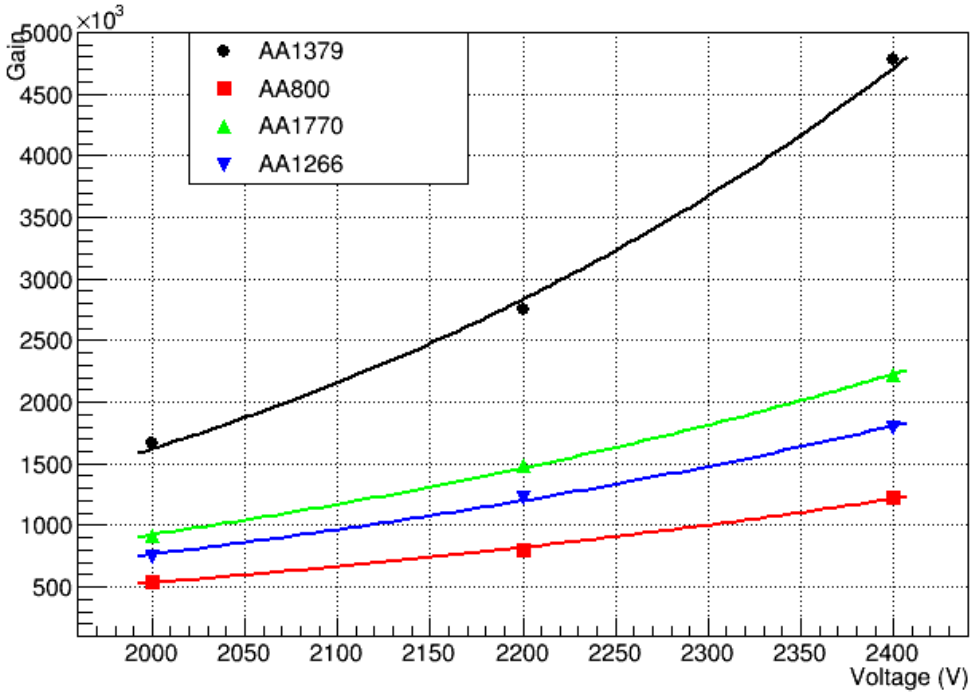


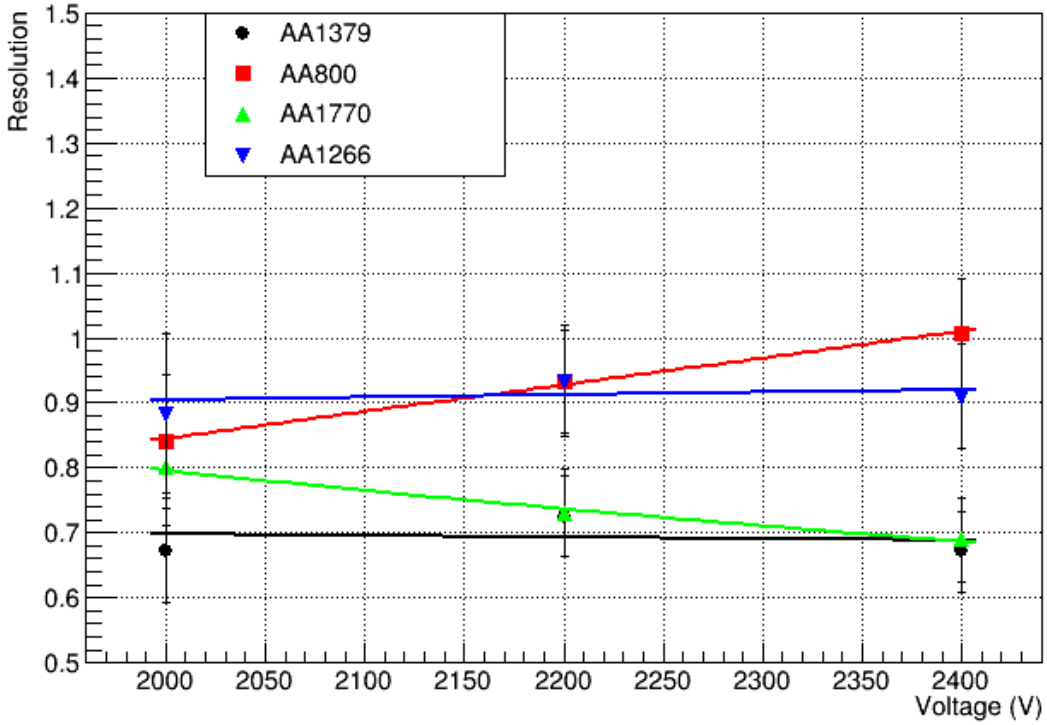






Gain and resolution curves: PMT53-AA1379, PMT54-AA800, PMT55-AA1770, PMT56-AA1266

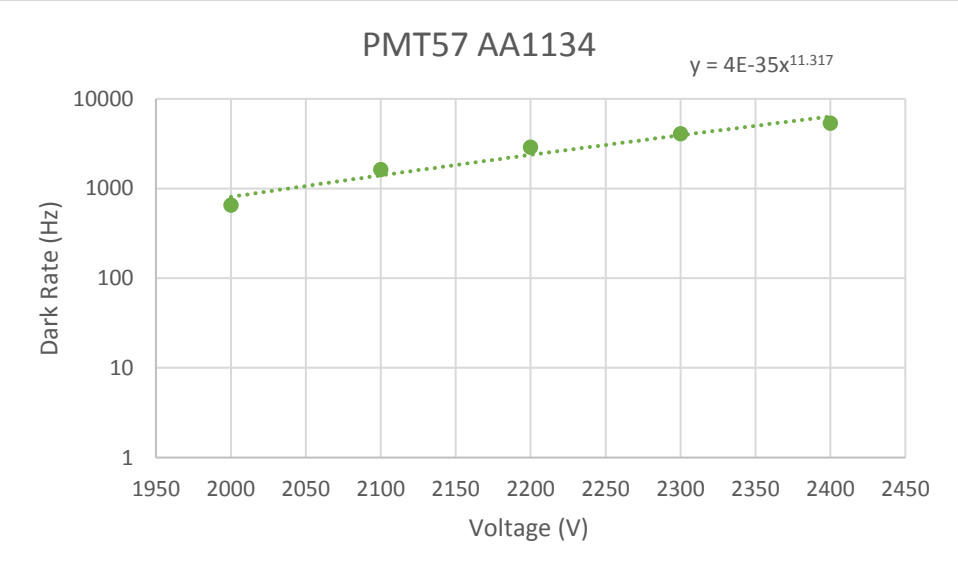




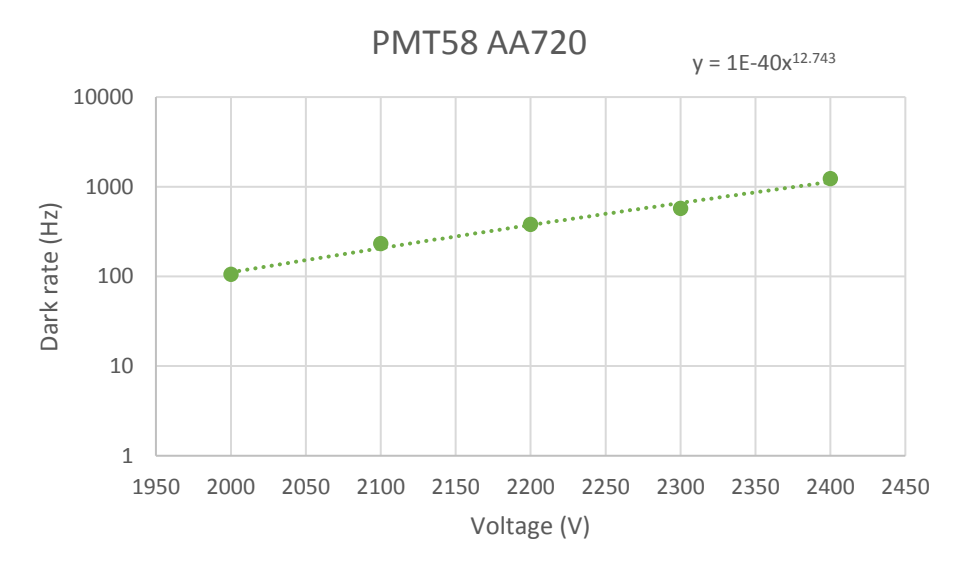
PMT's 57–60

PMT57-AA1134
PMT58-AA720
PMT59-AA889
PMT60-AA804

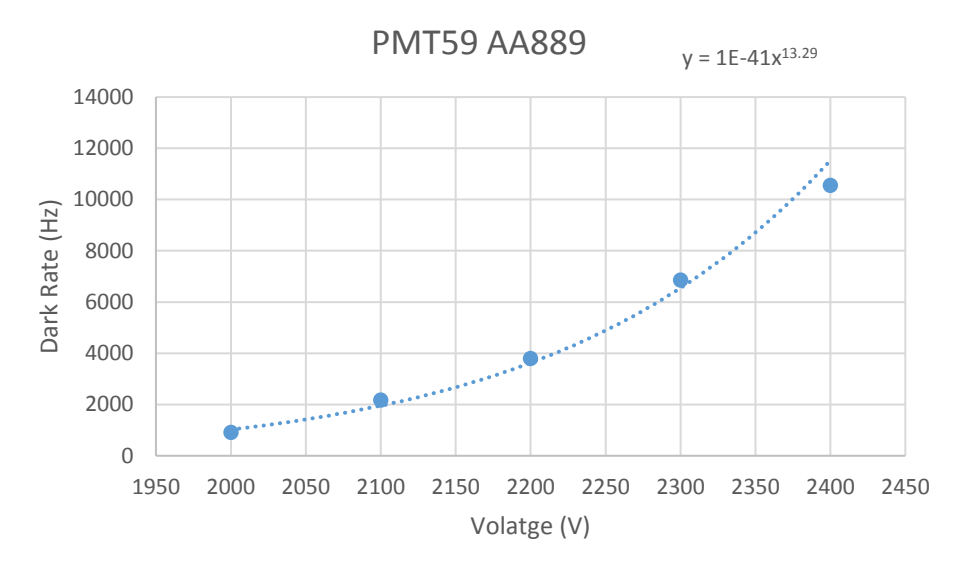
PMT57 AA1134 CH1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	5205	5191	5246	5298	5264	655.1
2100	13170	12584	12803	12993	13325	1621.875
2200	23331	23224	22956	23129	23165	2895.125
2300	32572	32731	32633	32838	32509	4082.075
2400	43018	42968	42733	43002	42527	5356.2



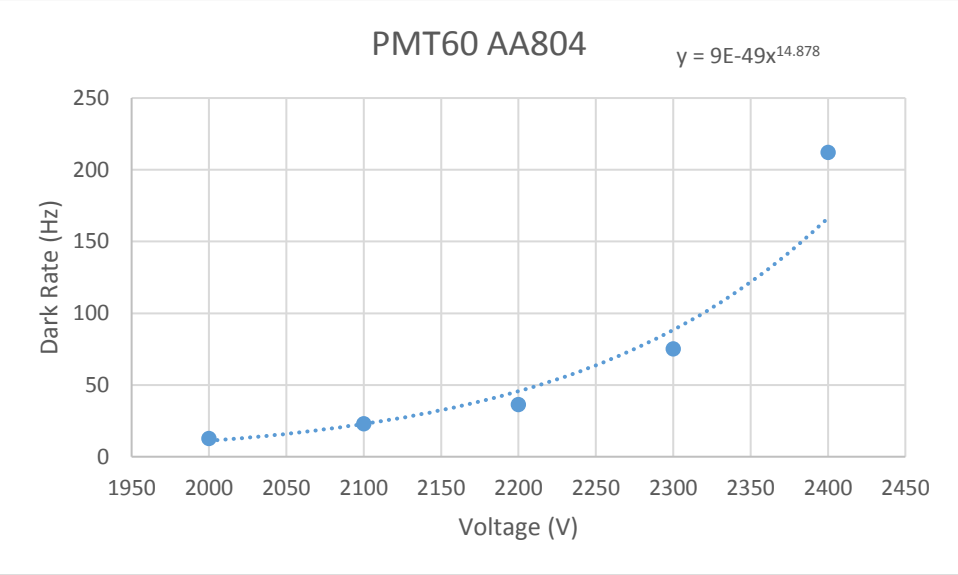
PMT58 AA720 CH2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	827	828	825	879	846	105.125
2100	1779	1832	1920	1862	1890	232.075
2200	3012	3074	2986	3164	2878	377.85
2300	4647	4593	4504	4353	4657	568.85
2400	9504	9668	10057	9814	9927	1224.25

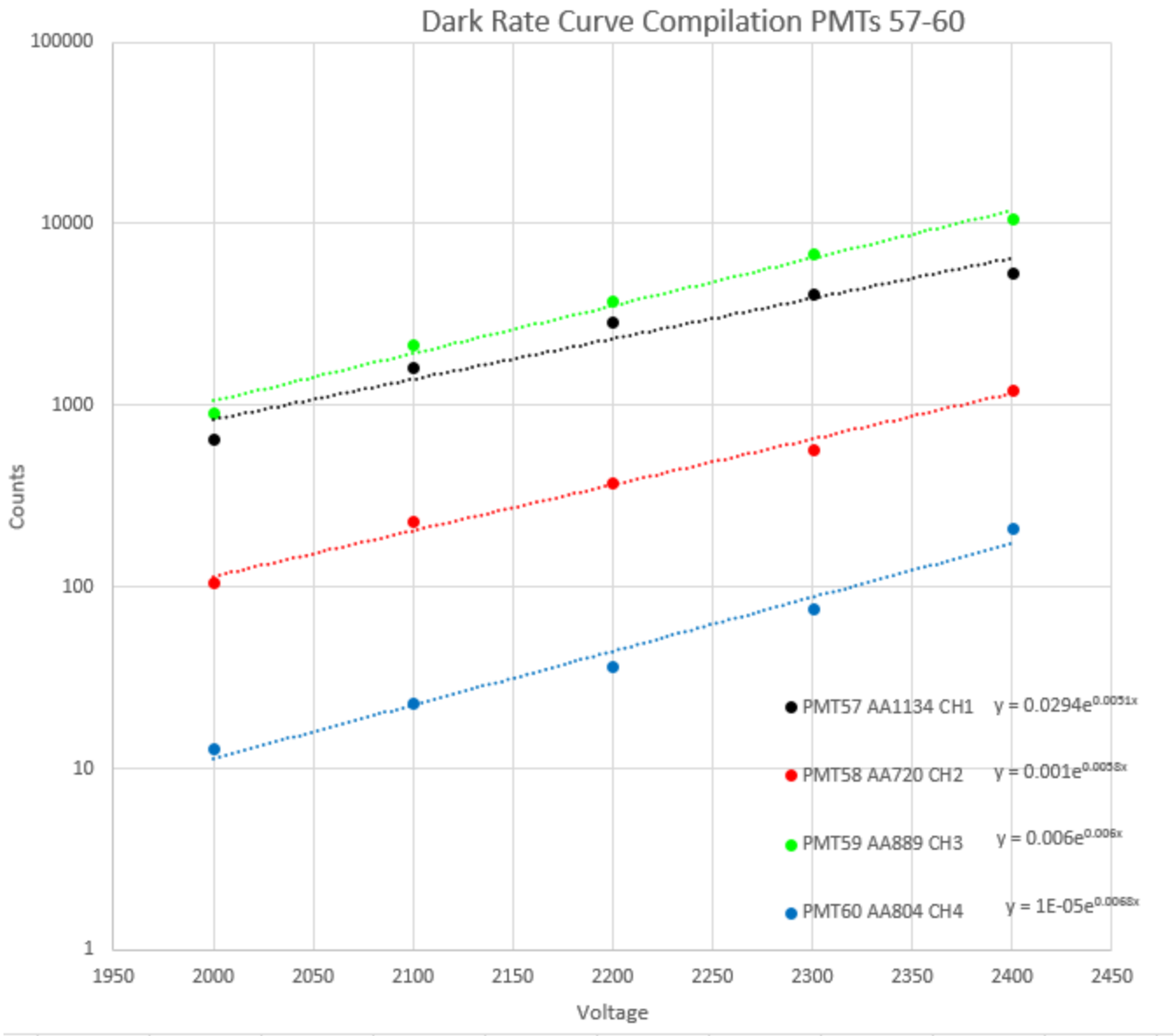


PMT59 AA889 CH3						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	6639	7484	7440	7383	7584	913.25
2100	17267	14010	24305	15445	16107	2178.35
2200	29145	29912	32891	27282	32882	3802.8
2300	45264	52417	63714	57818	54972	6854.625
2400	103196	104150	75408	69968	69269	10549.78



PMT60 AA804 CH4						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	109	98	105	114	85	12.775
2100	171	186	161	207	190	22.875
2200	243	315	309	299	286	36.3
2300	634	726	477	500	672	75.225
2400	1684	1592	1628	1669	1913	212.15




Dark Rate Curve Compilation PMTs 57-60
100000
10000
1000
100
10
1
Counts
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
Voltage
PMT57 AA1134 CH1 y = 0.0294e^0.0051x
PMT58 AA720 CH2 y = 0.001e^0.0058x
PMT59 AA889 CH3 y = 0.006e^0.006x
PMT60 AA804 CH4 y = 1E-05e^0.0068x

For these Charge Distribution Histograms:

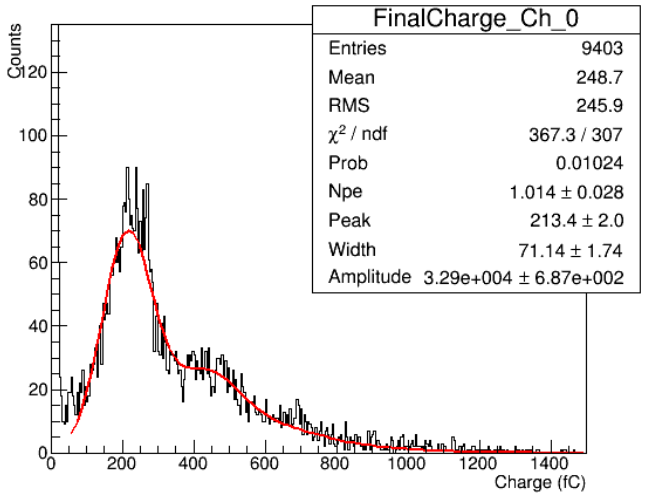
FinalCharge_Ch_0 = PMT57-AA1134 FinalCharge_Ch_1 = PMT58-AA720

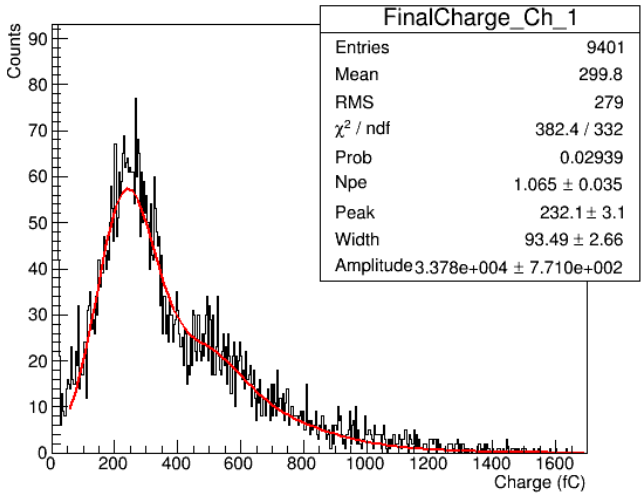
FinalCharge_Ch_2 = PMT59-AA889 FinalCharge_Ch_3 = PMT60-AA804

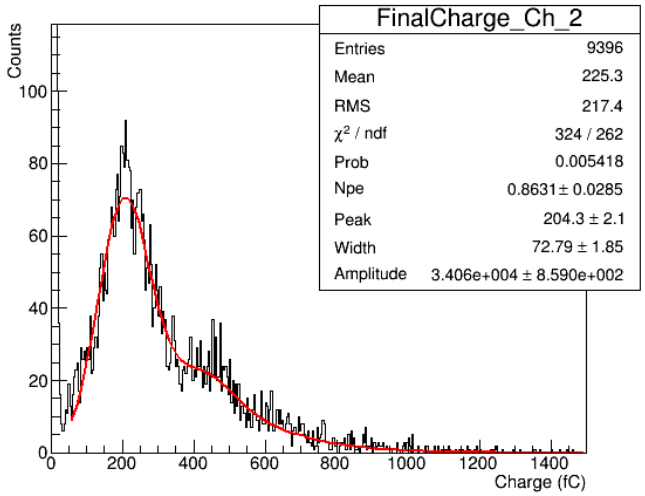
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

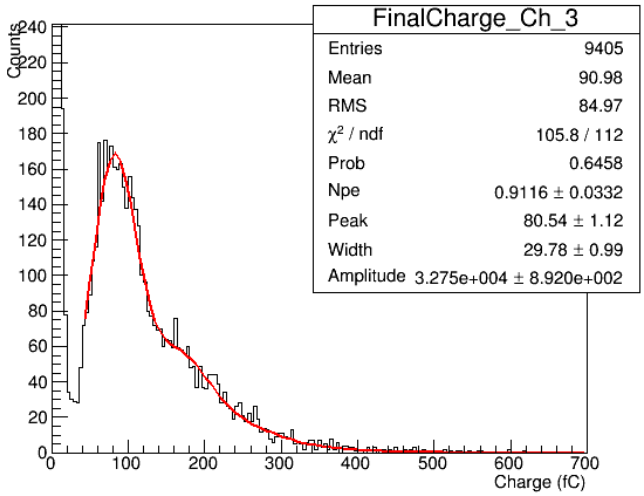
Code used to fit: fitnpe_XP2020

At 2000V

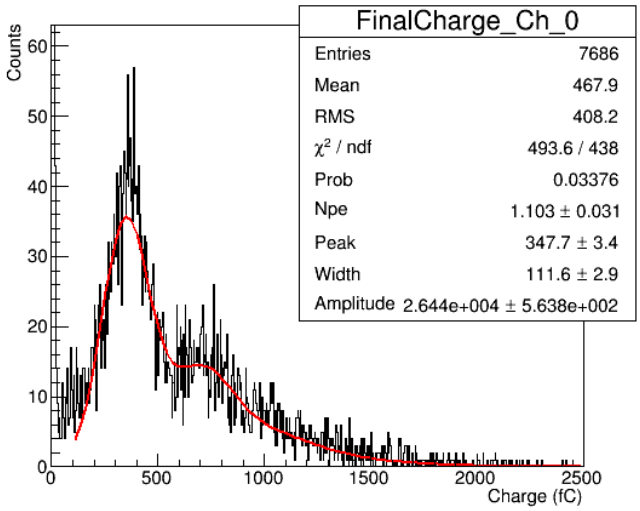


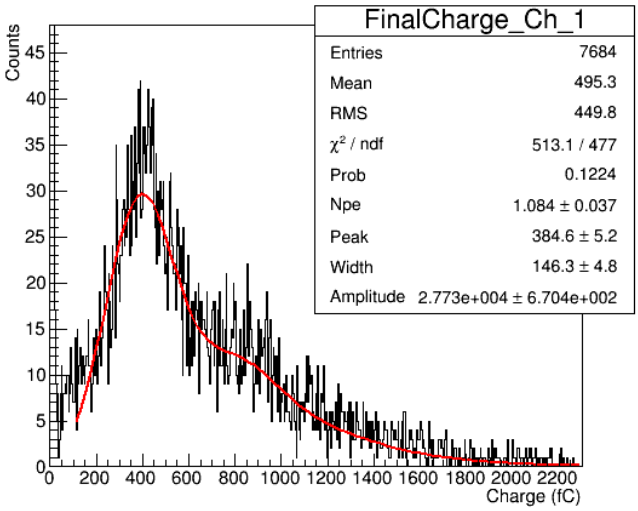


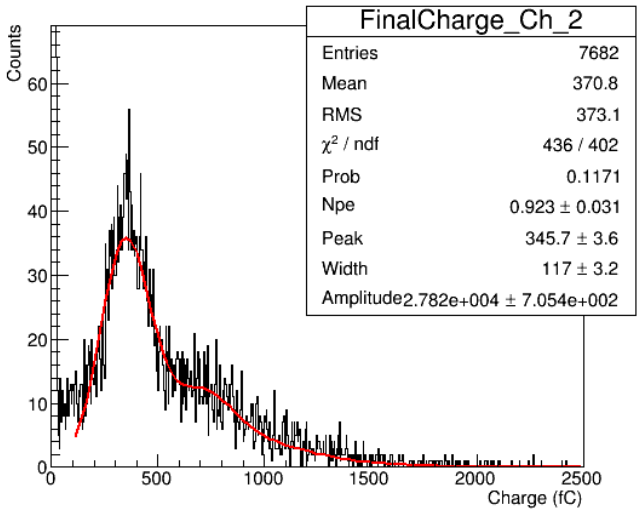


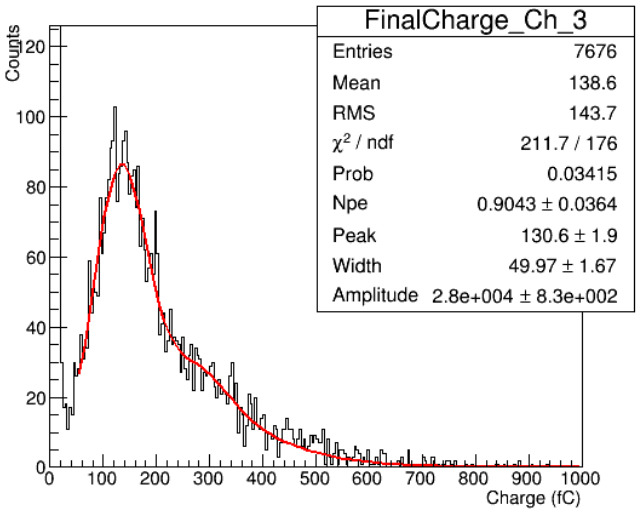


At 2200V

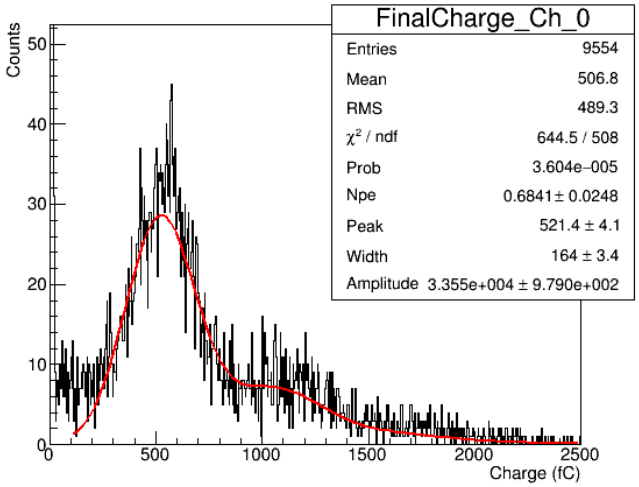

FinalCharge_Ch_0
Entries 7686
Mean 467.9
RMS 408.2
χ² / ndf 493.6 / 438
Prob 0.03376
Npe 1.103 ± 0.031
Peak 347.7 ± 3.4
Width 111.6 ± 2.9
Amplitude 2.644e+004 ± 5.638e+002
Counts
Charge (fC)

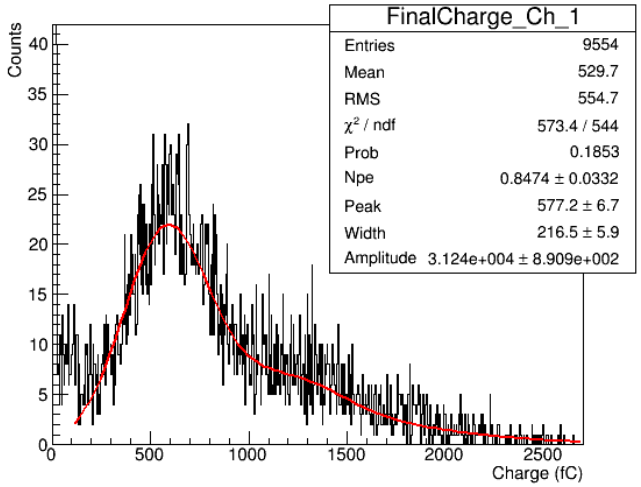

FinalCharge_Ch_1
Entries 7684
Mean 495.3
RMS 449.8
χ² / ndf 513.1 / 477
Prob 0.1224
Npe 1.084 ± 0.037
Peak 384.6 ± 5.2
Width 146.3 ± 4.8
Amplitude 2.773e+004 ± 6.704e+002
Counts
Charge (fC)

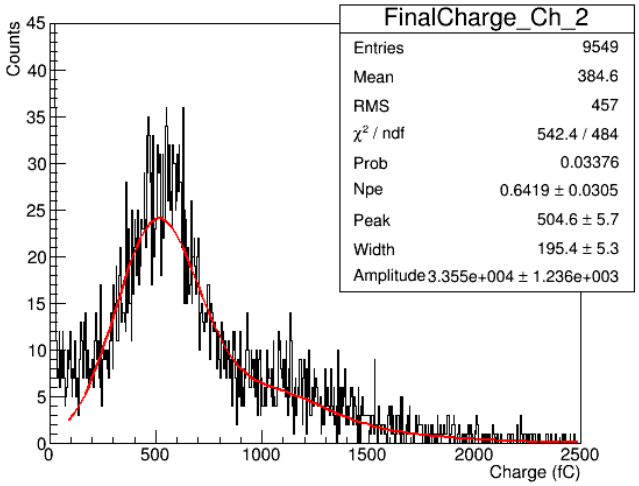

FinalCharge_Ch_2
Entries 7682
Mean 370.8
RMS 373.1
χ² / ndf 436 / 402
Prob 0.1171
Npe 0.923 ± 0.031
Peak 345.7 ± 3.6
Width 117 ± 3.2
Amplitude 2.782e+004 ± 7.054e+002
Counts
Charge (fC)

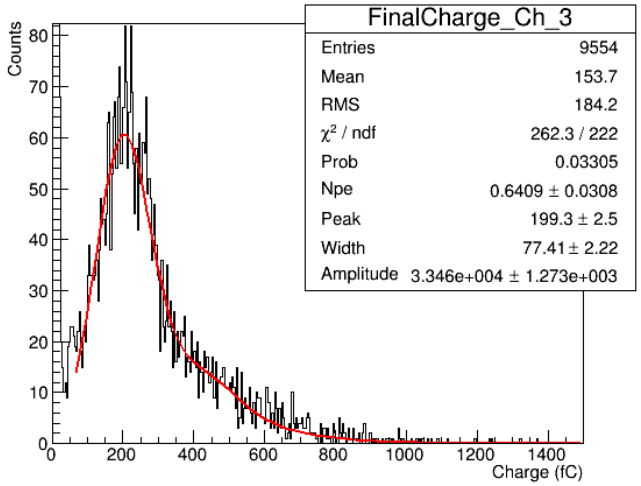

FinalCharge_Ch_3
Entries 7676
Mean 138.6
RMS 143.7
χ² / ndf 211.7 / 176
Prob 0.03415
Npe 0.9043 ± 0.0364
Peak 130.6 ± 1.9
Width 49.97 ± 1.67
Amplitude 2.8e+004 ± 8.3e+002
Counts
Charge (fC)

At 2400V

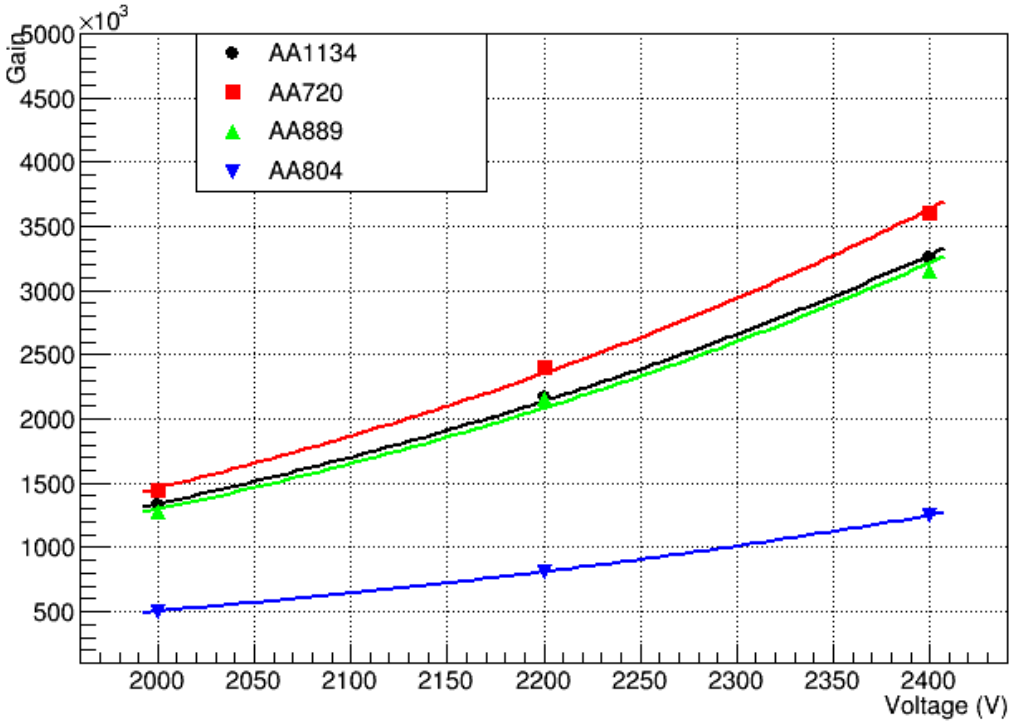

FinalCharge_Ch_0
Entries 9554
Mean 506.8
RMS 489.3
χ² / ndf 644.5 / 508
Prob 3.604e−005
Npe 0.6841 ± 0.0248
Peak 521.4 ± 4.1
Width 164 ± 3.4
Amplitude 3.355e+004 ± 9.790e+002
Counts
Charge (fC)

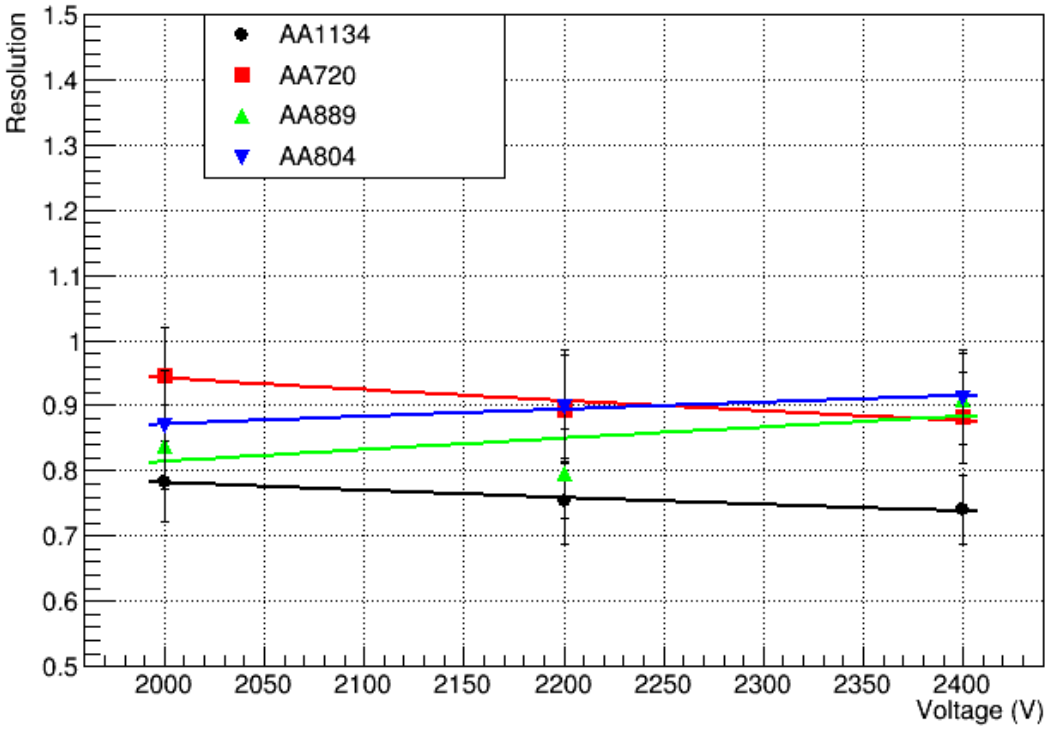

FinalCharge_Ch_1
Entries 9554
Mean 529.7
RMS 554.7
χ² / ndf 573.4 / 544
Prob 0.1853
Npe 0.8474 ± 0.0332
Peak 577.2 ± 6.7
Width 216.5 ± 5.9
Amplitude 3.124e+004 ± 8.909e+002
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 9549
Mean 384.6
RMS 457
χ² / ndf 542.4 / 484
Prob 0.03376
Npe 0.6419 ± 0.0305
Peak 504.6 ± 5.7
Width 195.4 ± 5.3
Amplitude 3.355e+004 ± 1.236e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 9554
Mean 153.7
RMS 184.2
χ² / ndf 262.3 / 222
Prob 0.03305
Npe 0.6409 ± 0.0308
Peak 199.3 ± 2.5
Width 77.41 ± 2.22
Amplitude 3.346e+004 ± 1.273e+003
Counts
Charge (fC)

Gain and resolution curves: PMT57-AA1134, PMT58-AA720, PMT59-AA889, PMT60-AA804

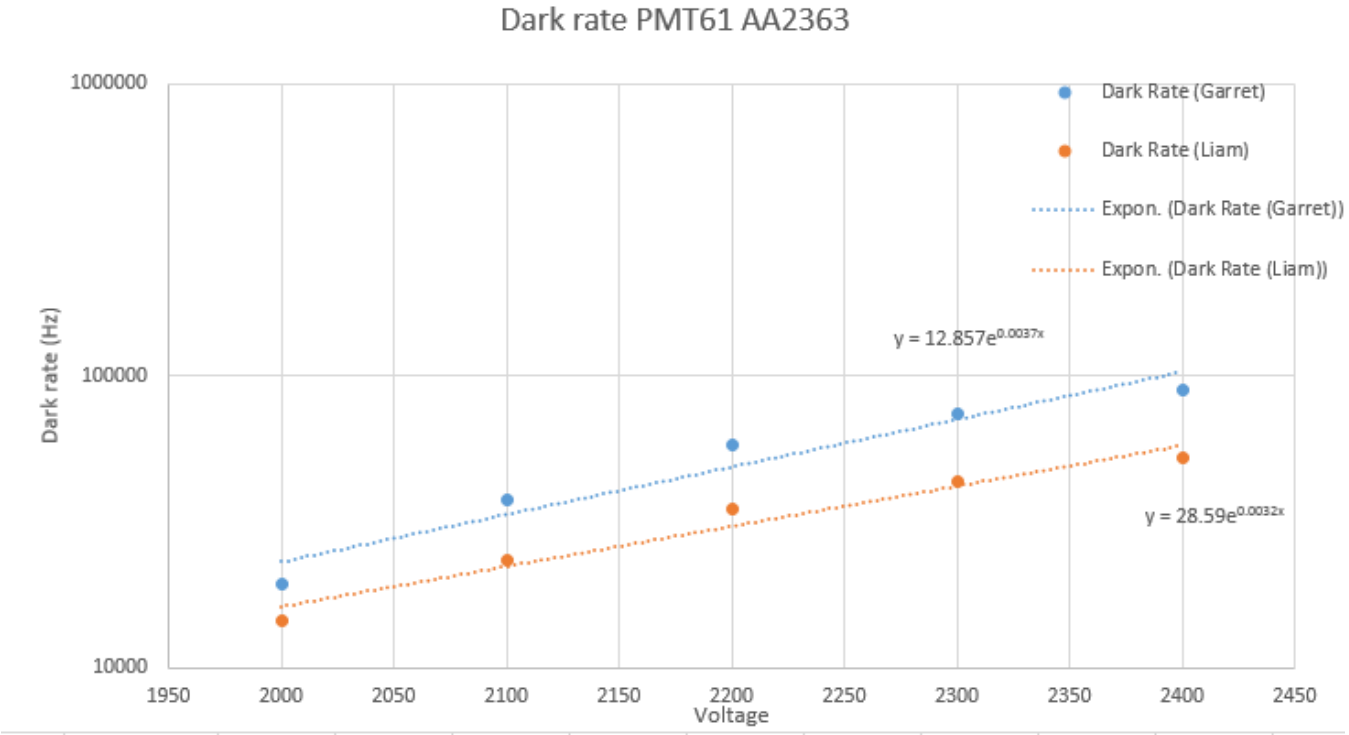




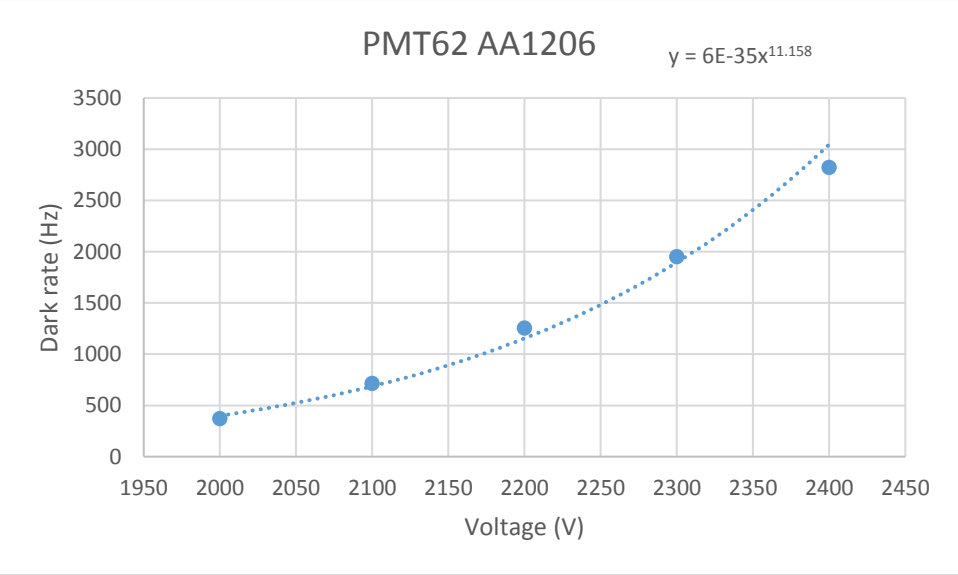
PMT's 61-64

PMT61-AA2363
PMT62-AA1206
PMT63-AA2054
PMT64-AA1897

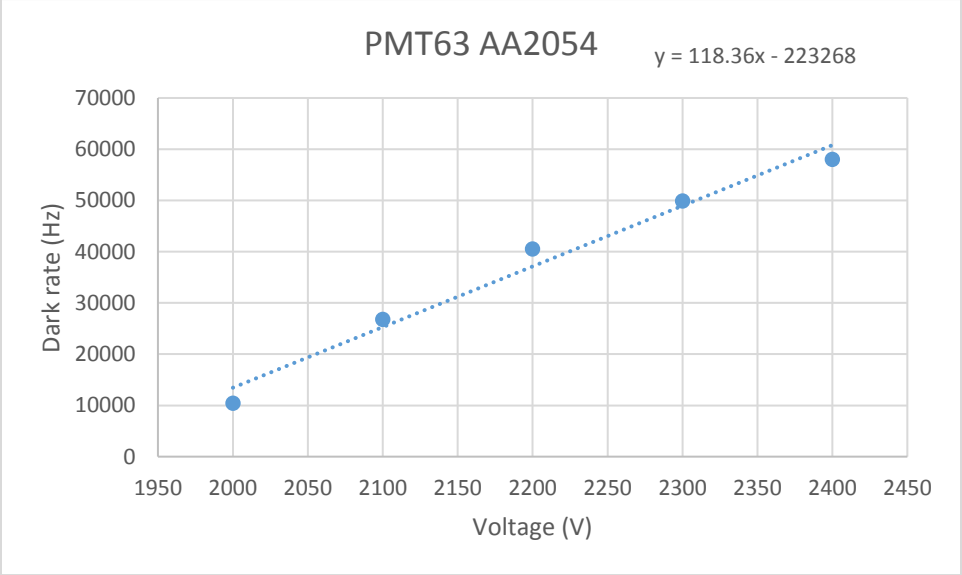
PMT61 AA2363						
Dark Count in 8 seconds			-27.5 mV threshold discrimination			
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average Hz
1800	30444	30869	30908	29793	30129	3803.575
1900	51110	49067	48855	48367	50732	6203.275
2000	117666	115733	116119	115310	114972	14495
2100	186252	185524	185437	187782	192859	23446.35
2200	281755	284191	278107	282650	268821	34888.1
2300	342684	343372	347698	346448	351443	43291.13
2400	440973	413897	411461	407500	408562	52059.83



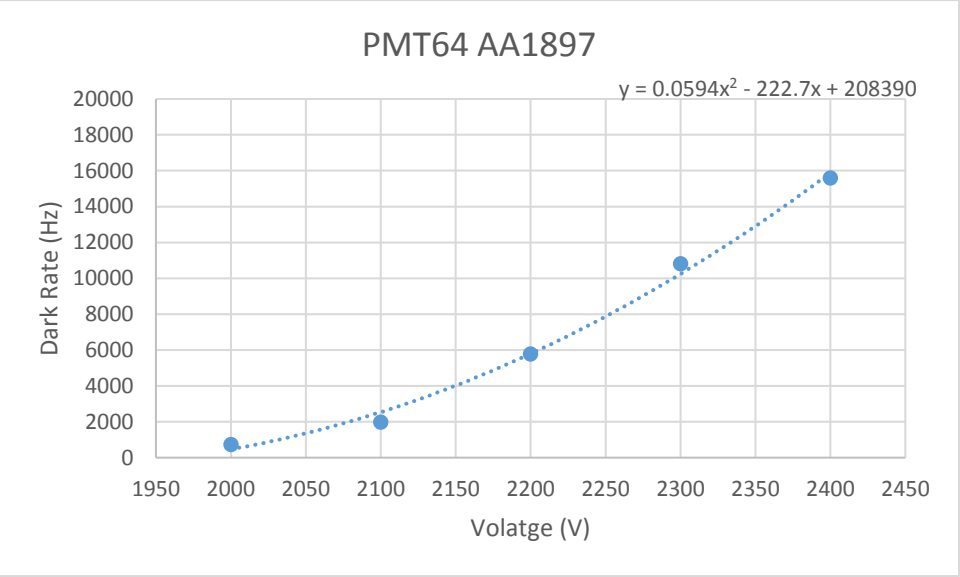
PMT62 AA1206 CH2						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	2979	3000	2966	2939	2895	369.475
2100	5768	5675	5832	5582	5686	713.575
2200	10156	10009	9730	10238	10079	1255.3
2300	16137	15937	15418	15235	15338	1951.625
2400	22658	22708	22696	22944	21824	2820.75

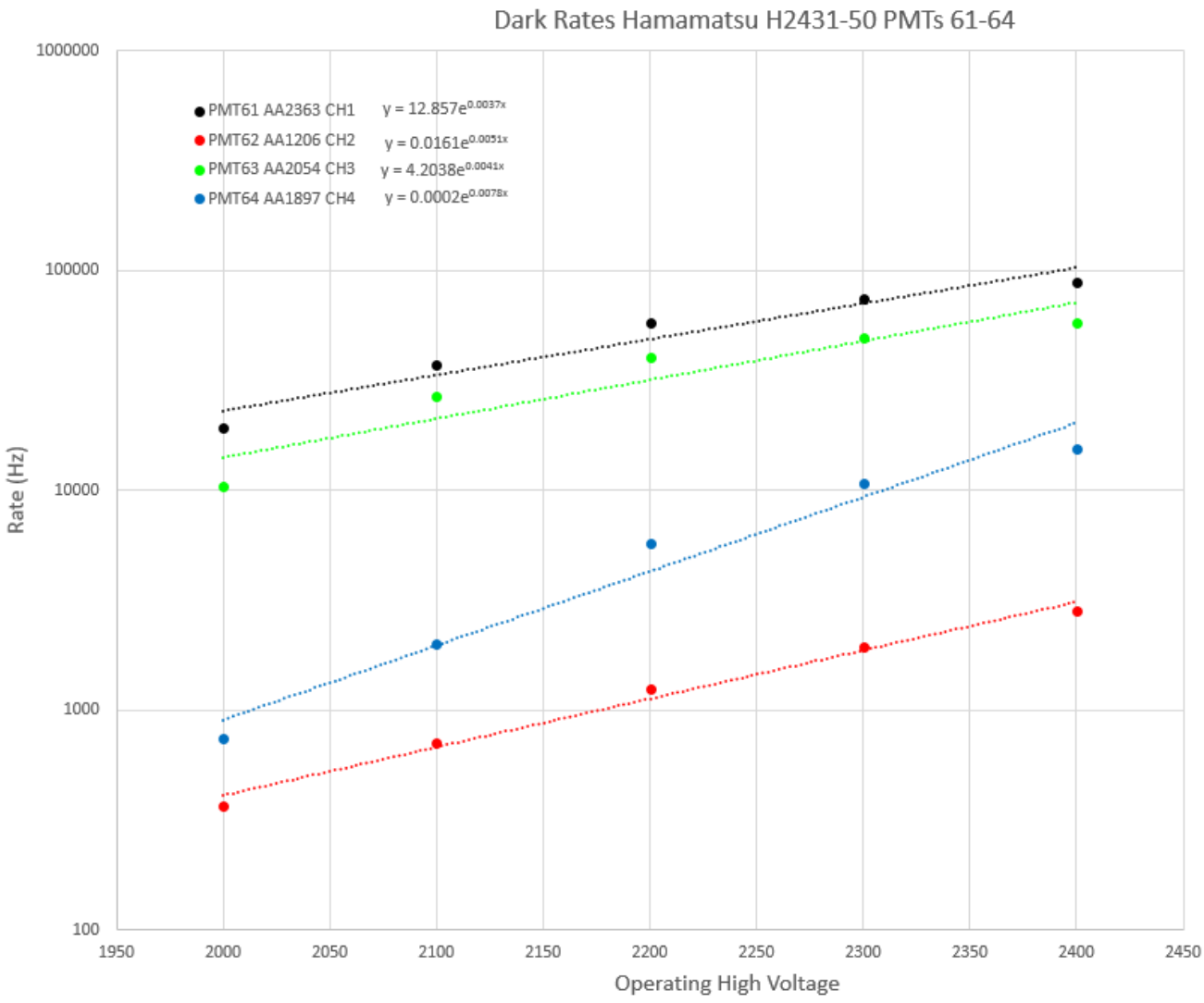


PMT63 AA2054 CH3						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	83556	83435	82944	82763	83350	10401.2
2100	212959	212449	215194	215976	214706	26782.1
2200	321042	322333	324737	326537	326120	40519.23
2300	397751	396982	399763	400889	400552	49898.43
2400	464916	465462	463095	464881	462576	58023.25



PMT64 AA1897 CH4						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	5879	6005	5876	5988	5992	743.5
2100	15796	16074	15919	15770	16131	1992.25
2200	46298	46130	46095	46158	46405	5777.15
2300	86578	86445	86303	86469	86898	10817.33
2400	139960	123424	120943	119635	119812	15594.35




Dark Rates Hamamatsu H2431-50 PMTs 61-64
PMT61 AA2363 CH1 y = 12.857e^0.0037x
PMT62 AA1206 CH2 y = 0.0161e^0.0051x
PMT63 AA2054 CH3 y = 4.2038e^0.0041x
PMT64 AA1897 CH4 y = 0.0002e^0.0078x
1000000
100000
10000
1000
100
Rate (Hz)
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
Operating High Voltage

For these Charge Distribution Histograms:

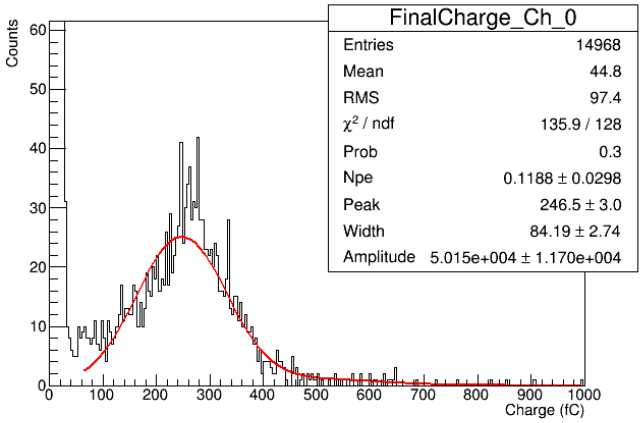
FinalCharge_Ch_0 = PMT61-AA2363 FinalCharge_Ch_1 = PMT62-AA1206

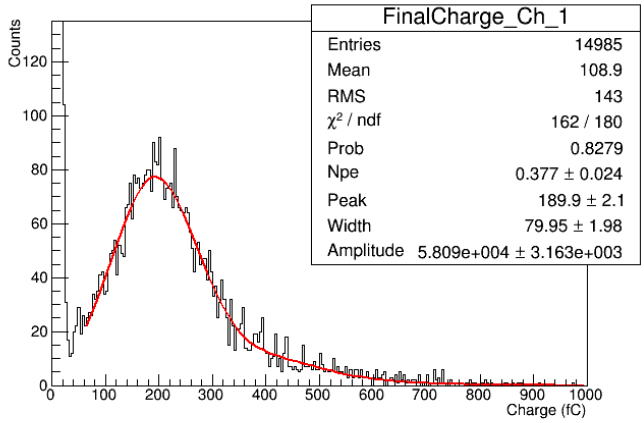
FinalCharge_Ch_2 = PMT63-AA2054 FinalCharge_Ch_3 = PMT64-AA1897

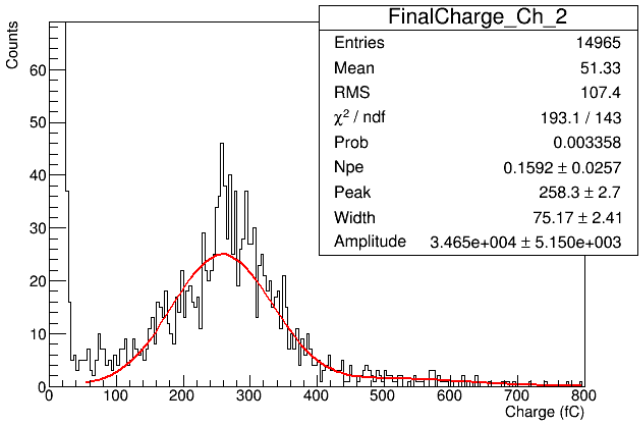
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

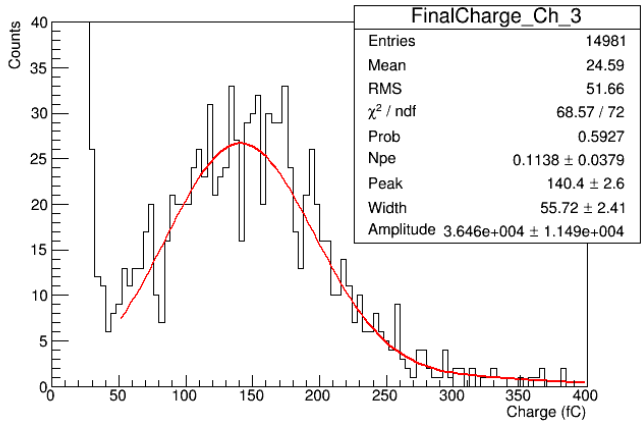
Code used to fit: fitnpe_XP2020

At 2000V

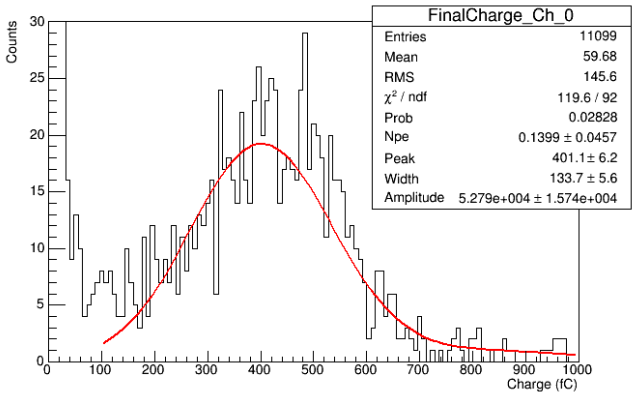


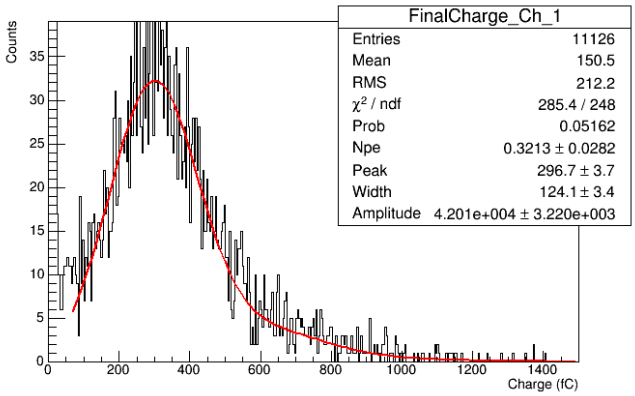


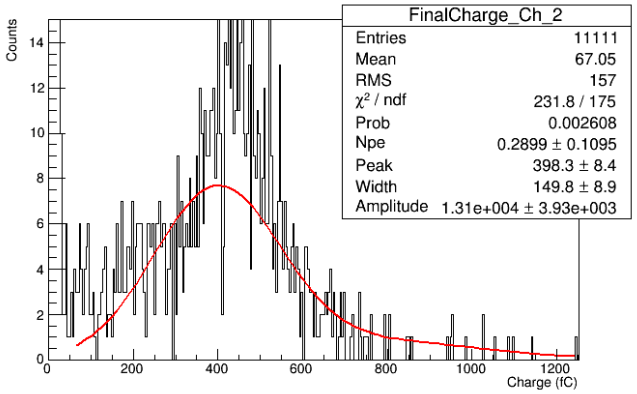


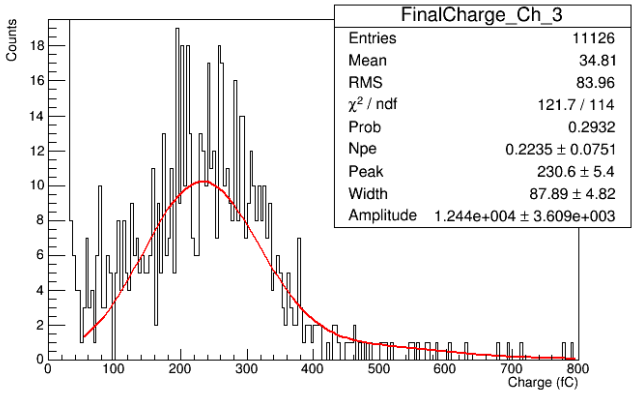


At 2200V

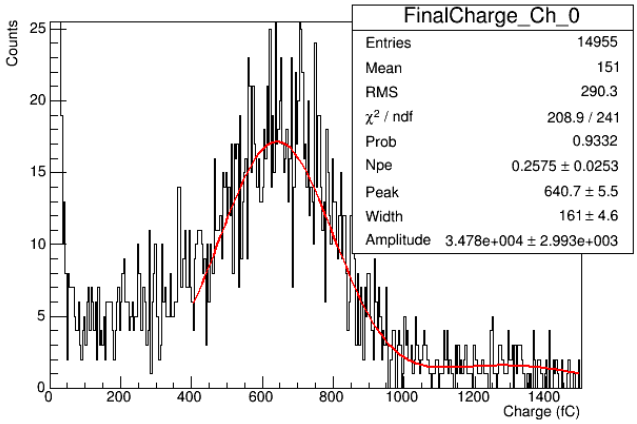

FinalCharge_Ch_0
Entries 11099
Mean 59.68
RMS 145.6
χ² / ndf 119.6 / 92
Prob 0.02828
Npe 0.1399 ± 0.0457
Peak 401.1 ± 6.2
Width 133.7 ± 5.6
Amplitude 5.279e+004 ± 1.574e+004
Counts
Charge (fC)

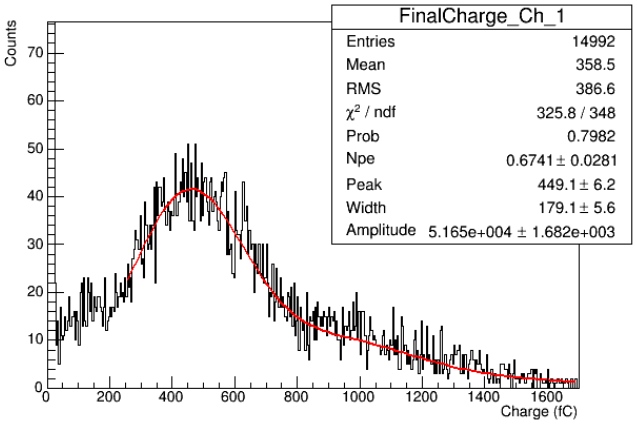

FinalCharge_Ch_1
Entries 11126
Mean 150.5
RMS 212.2
χ² / ndf 285.4 / 248
Prob 0.05162
Npe 0.3213 ± 0.0282
Peak 296.7 ± 3.7
Width 124.1 ± 3.4
Amplitude 4.201e+004 ± 3.220e+003
Counts
Charge (fC)

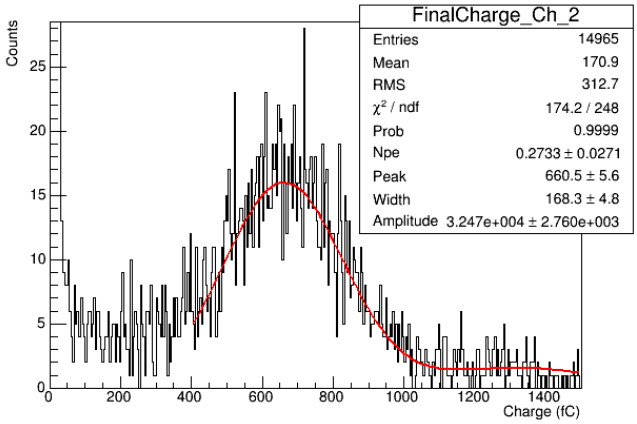

FinalCharge_Ch_2
Entries 11111
Mean 67.05
RMS 157
χ² / ndf 231.8 / 175
Prob 0.002608
Npe 0.2899 ± 0.1095
Peak 398.3 ± 8.4
Width 149.8 ± 8.9
Amplitude 1.31e+004 ± 3.93e+003
Counts
Charge (fC)

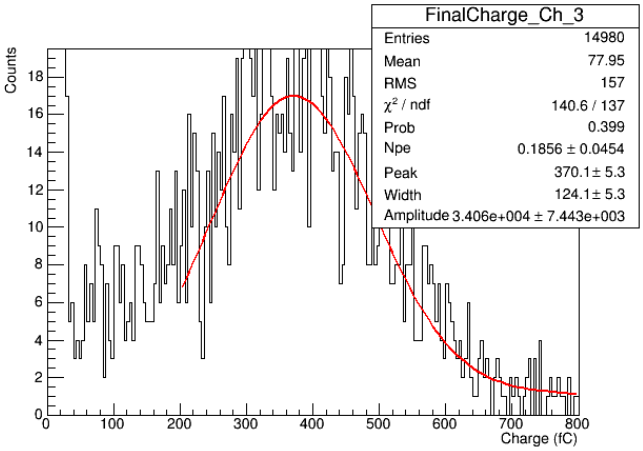

FinalCharge_Ch_3
Entries 11126
Mean 34.81
RMS 83.96
χ² / ndf 121.7 / 114
Prob 0.2932
Npe 0.2235 ± 0.0751
Peak 230.6 ± 5.4
Width 87.89 ± 4.82
Amplitude 1.244e+004 ± 3.609e+003
Counts
Charge (fC)

At 2400V

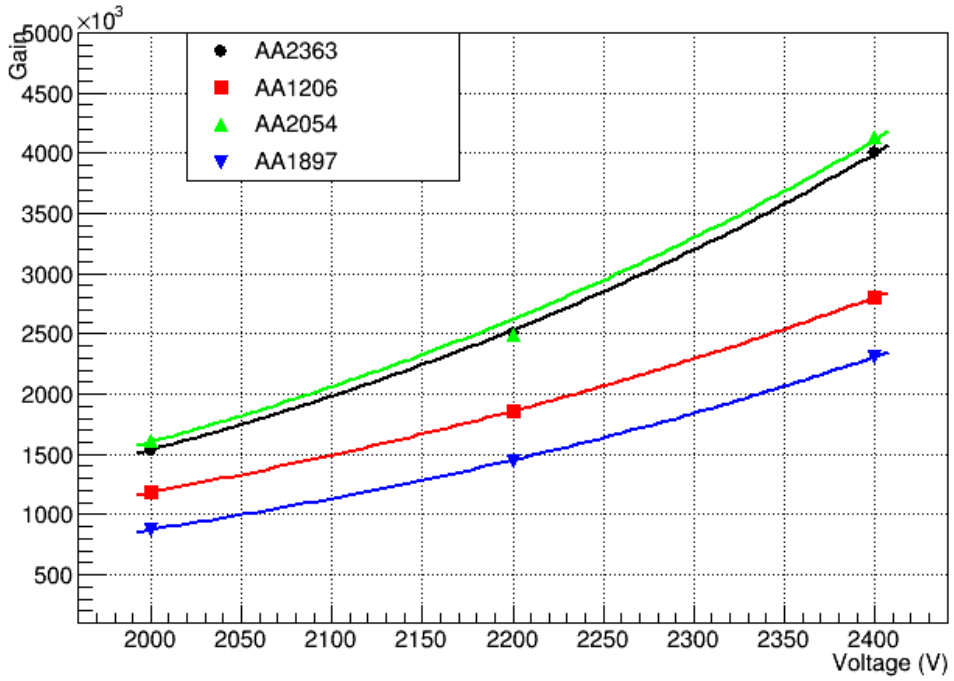

FinalCharge_Ch_0
Entries 14955
Mean 151
RMS 290.3
χ² / ndf 208.9 / 241
Prob 0.9332
Npe 0.2575 ± 0.0253
Peak 640.7 ± 5.5
Width 161 ± 4.6
Amplitude 3.478e+004 ± 2.993e+003
Counts
Charge (fC)

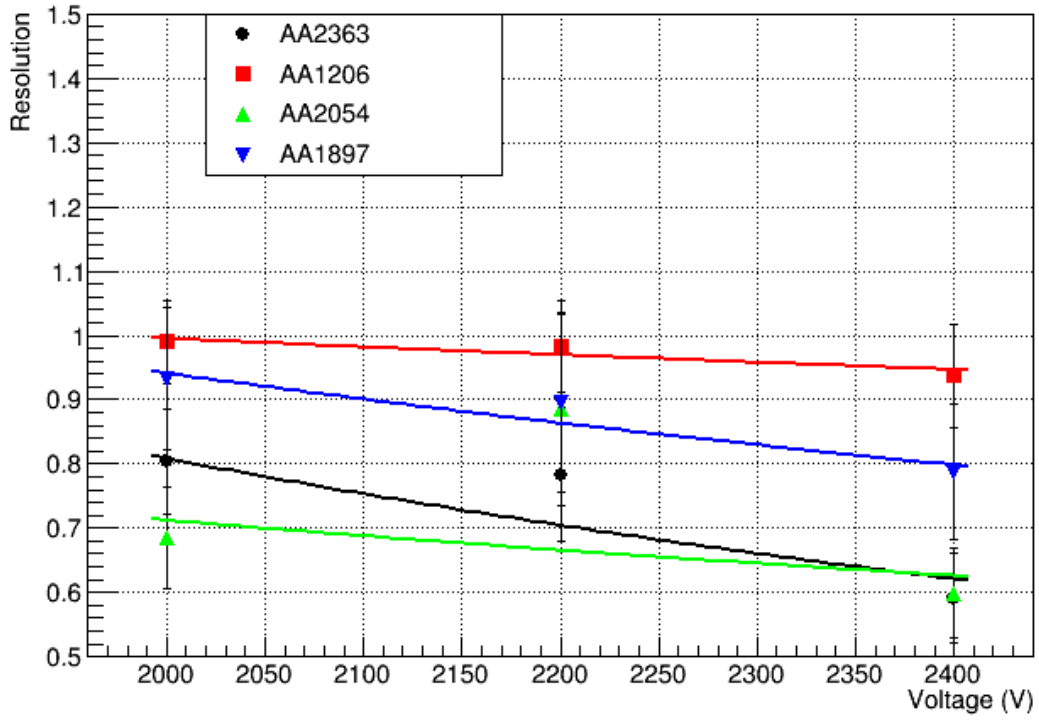

FinalCharge_Ch_1
Entries 14992
Mean 358.5
RMS 386.6
χ² / ndf 325.8 / 348
Prob 0.7982
Npe 0.6741 ± 0.0281
Peak 449.1 ± 6.2
Width 179.1 ± 5.6
Amplitude 5.165e+004 ± 1.682e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 14965
Mean 170.9
RMS 312.7
χ² / ndf 174.2 / 248
Prob 0.9999
Npe 0.2733 ± 0.0271
Peak 660.5 ± 5.6
Width 168.3 ± 4.8
Amplitude 3.247e+004 ± 2.760e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 14980
Mean 77.95
RMS 157
χ² / ndf 140.6 / 137
Prob 0.399
Npe 0.1856 ± 0.0454
Peak 370.1 ± 5.3
Width 124.1 ± 5.3
Amplitude 3.406e+004 ± 7.443e+003
Counts
Charge (fC)

Gain and resolution curves: PMT61-AA2363, PMT62-AA1206, PMT63-AA2054, PMT64-AA1897

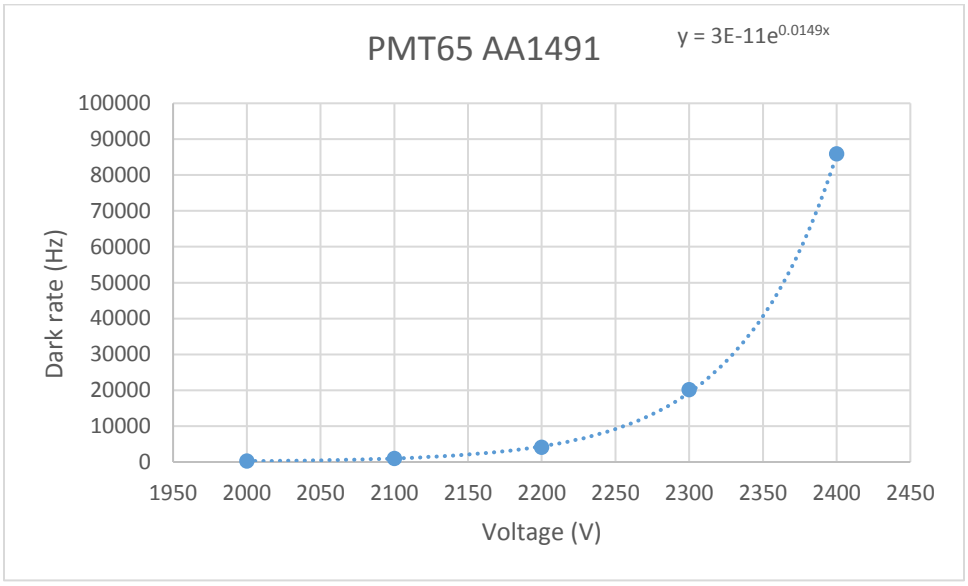




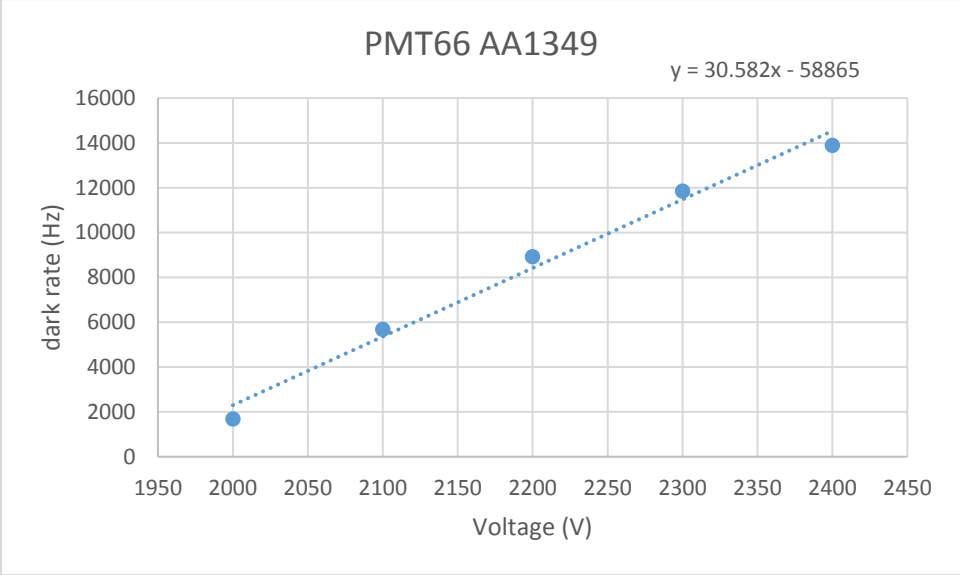
PMT's 65-68

PMT65-AA1491
PMT66-AA1349
PMT67-AA1131
PMT68-AA1370

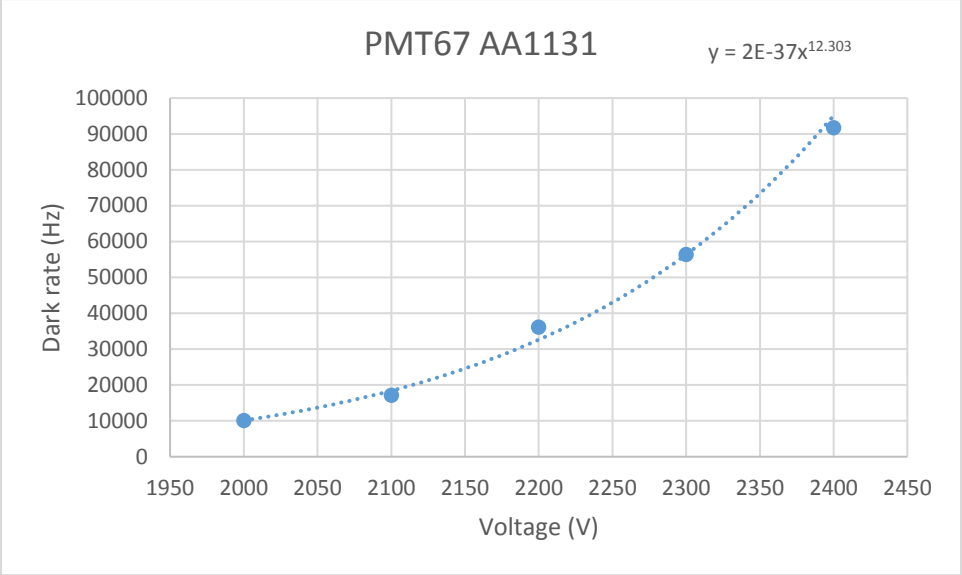
PMT65 AA1491 CH1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	1773	1819	1907	1853	1773	228.125
2100	7697	7735	7557	8119	7923	975.775
2200	34922	31819	27446	38276	30714	4079.425
2300	173026	167611	133032	162204	170149	20150.55
2400	762290	706141	712717	734249	520806	85905.08



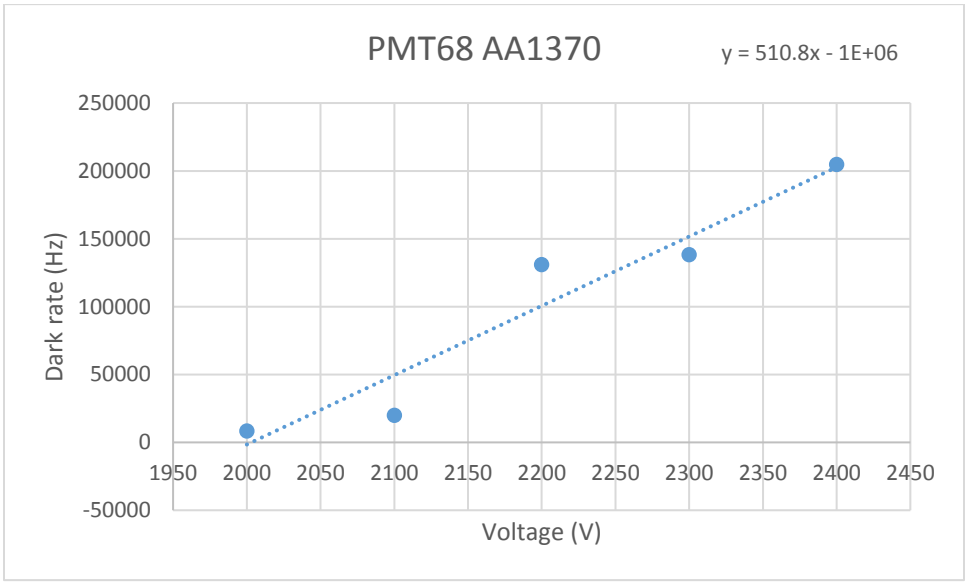
PMT66 AA1349 CH2. SHIELD WAS NOT ON TUBE						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	13582	13517	13646	13831	13231	1695.175
2100	46072	45117	45199	46131	45077	5689.9
2200	70902	71903	71441	71225	71867	8933.45
2300	94908	95649	95817	93857	94108	11858.48
2400	111205	112045	111108	111877	109841	13901.9

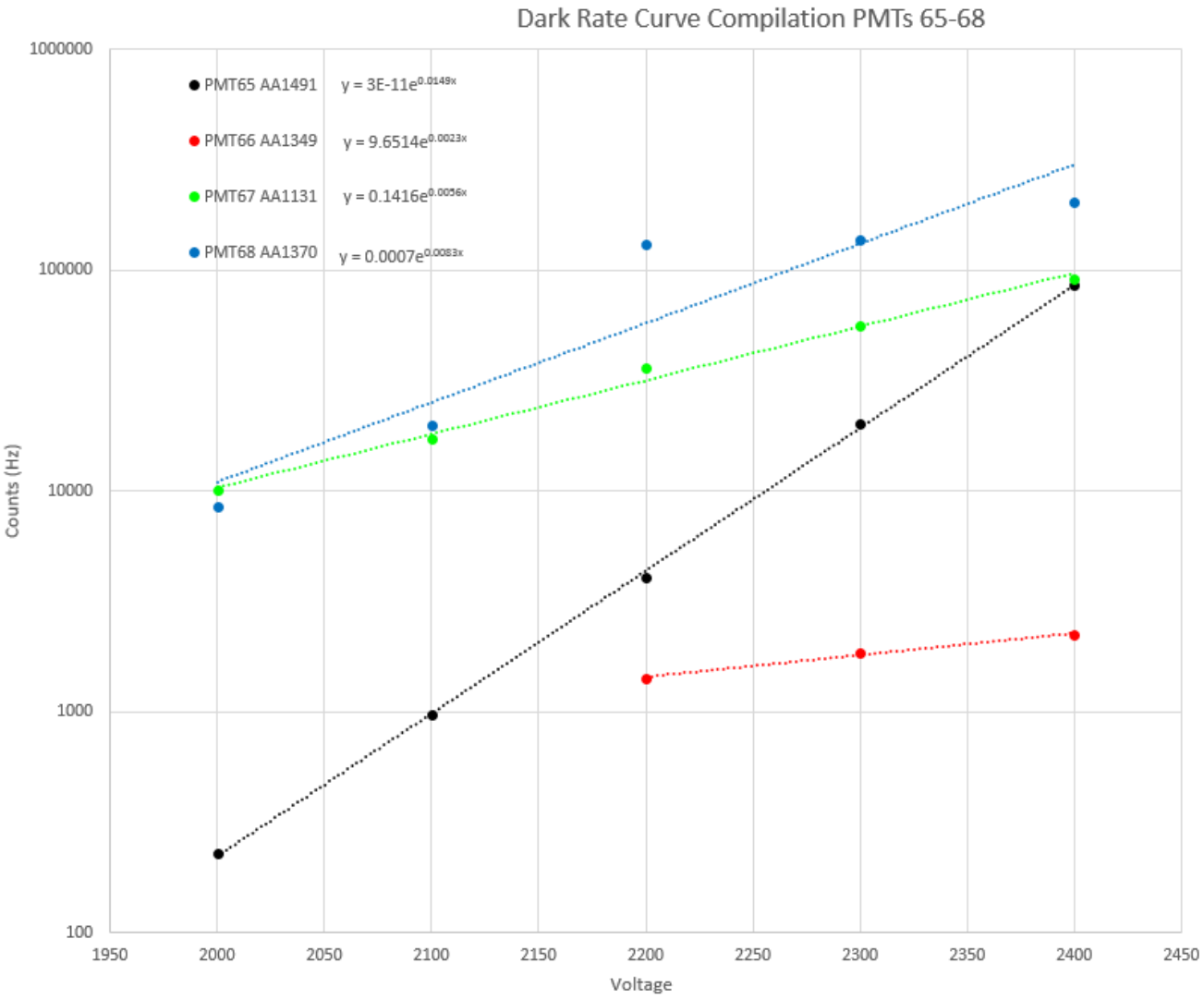


PMT67 AA1131 CH4						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	81238	80746	81194	81105	80425	10117.7
2100	136779	138172	138074	136742	136486	17156.33
2200	288003	287436	288576	291189	289862	36126.65
2300	510586	515351	212259	510958	508983	56453.43
2400	733525	735658	736265	731538	733386	91759.3



PMT68 AA1370 CH4						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
HV set = 2000V for > 8 hours						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	68654	69033	69242	68179	67597	8567.625
2100	158586	162166	161763	160502	159334	20058.78
2200	1054798	1041766	1036859	1061924	1051393	131168.5
2300	1352282	1348373	1346298	134009	1349665	138265.7
2400	1635811	1652379	1643679	1634248	1628546	204866.6




Dark Rate Curve Compilation PMTs 65-68
PMT65 AA1491 y = 3E-11e^0.0149x
PMT66 AA1349 y = 9.6514e^0.0023x
PMT67 AA1131 y = 0.1416e^0.0056x
PMT68 AA1370 y = 0.0007e^0.0083x
Counts (Hz)
1000000
100000
10000
1000
100
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
Voltage

For these Charge Distribution Histograms:

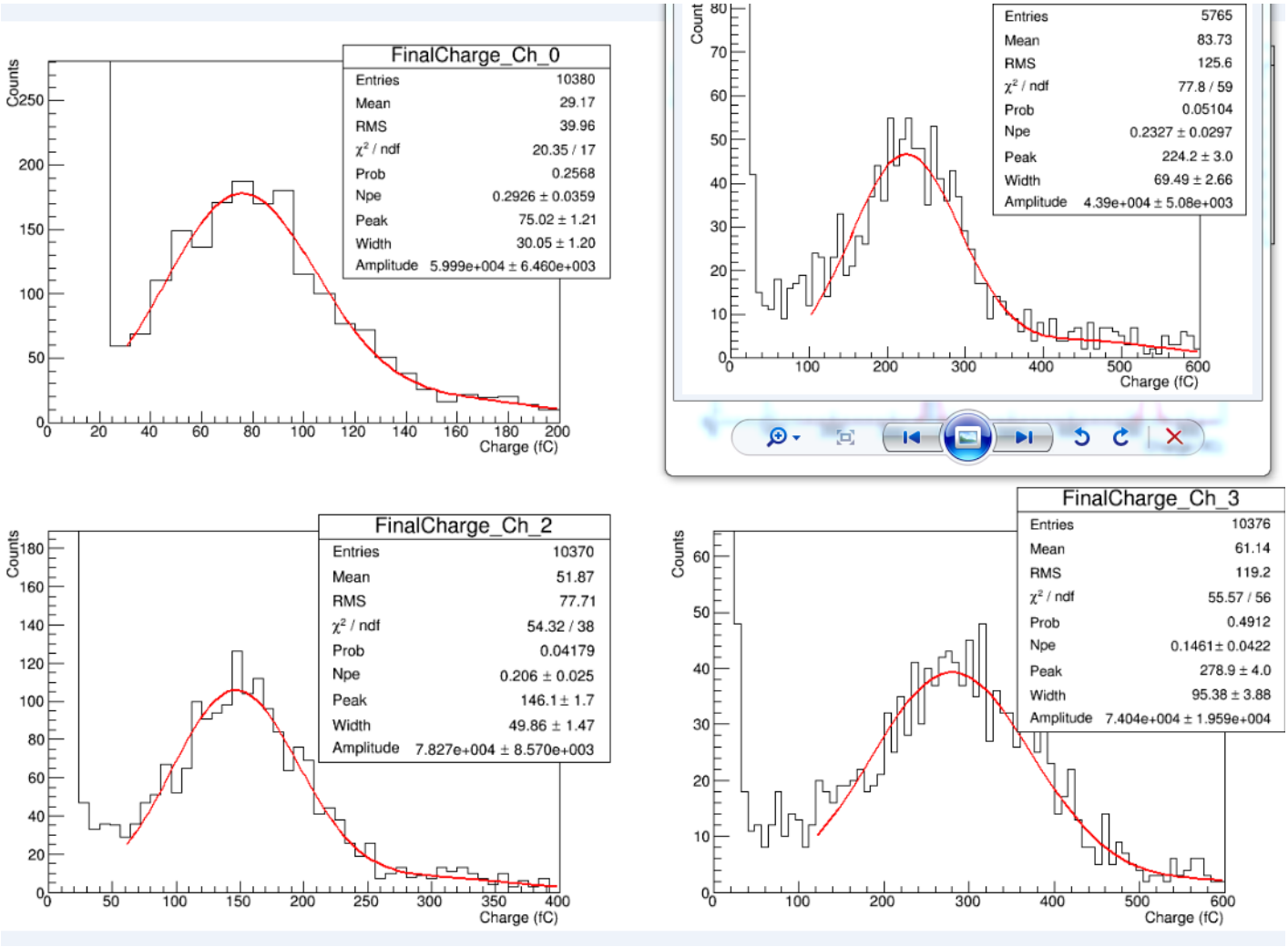
FinalCharge_Ch_0 = PMT65-AA1491 FinalCharge_Ch_1 = PMT66-AA1349

FinalCharge_Ch_2 = PMT67-AA1131 FinalCharge_Ch_3 = PMT68-AA1370

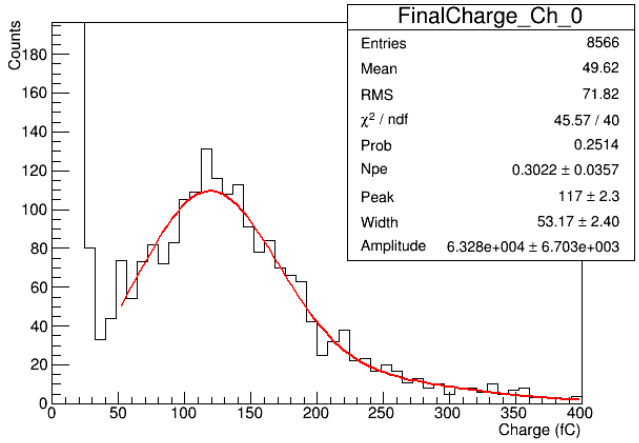
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

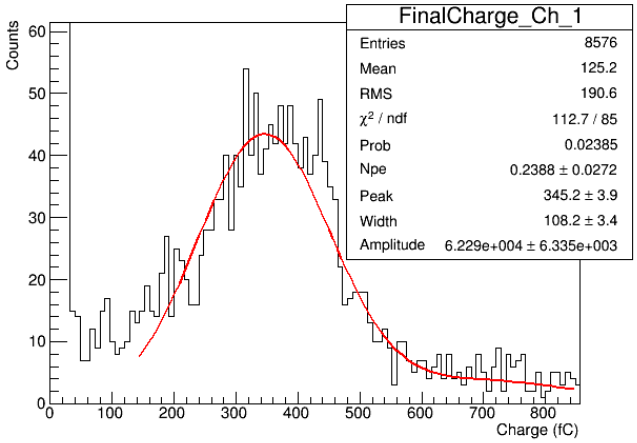
Code used to fit: fitnpe_XP2020

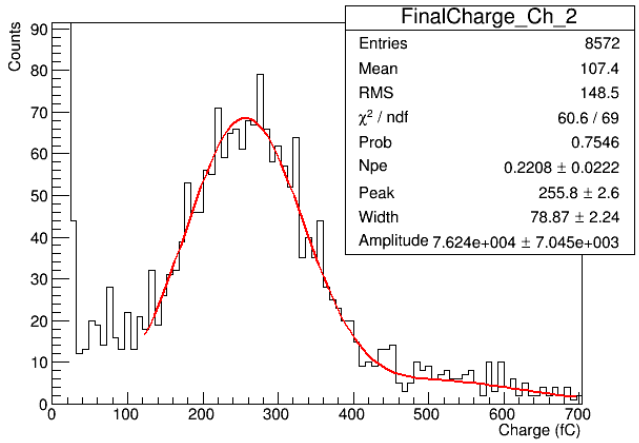
2000V (histogram in top right corner is the FinalCharge distribution forPMT66-AA1349)

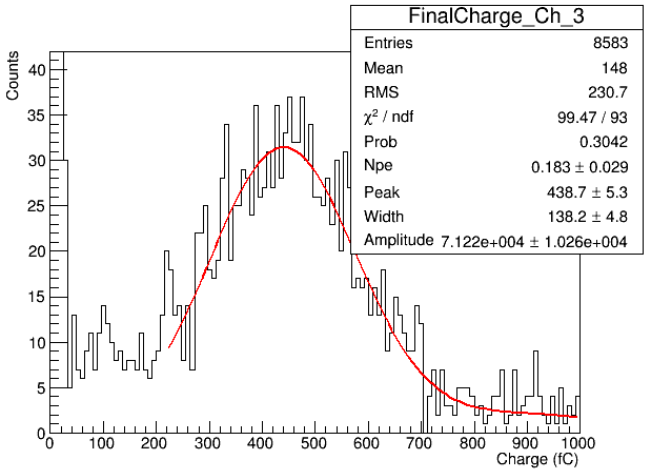


At 2200V

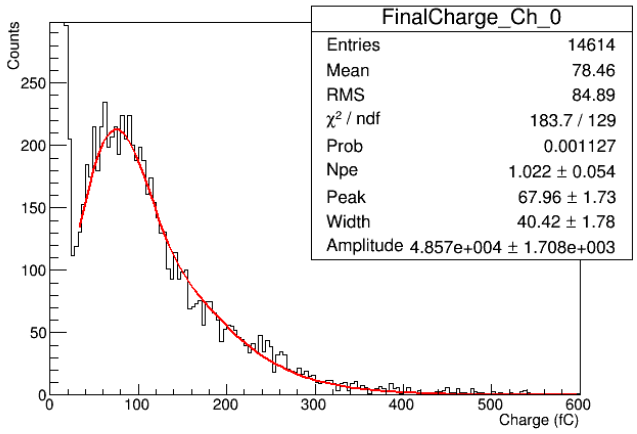

FinalCharge_Ch_0
Entries 8566
Mean 49.62
RMS 71.82
χ² / ndf 45.57 / 40
Prob 0.2514
Npe 0.3022 ± 0.0357
Peak 117 ± 2.3
Width 53.17 ± 2.40
Amplitude 6.328e+004 ± 6.703e+003
Counts
Charge (fC)

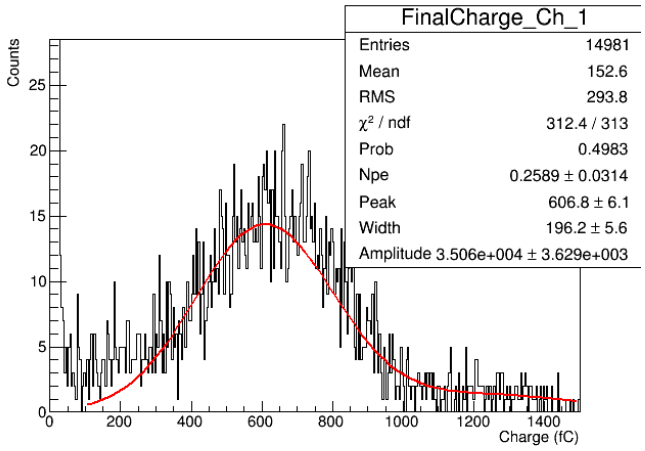

FinalCharge_Ch_1
Entries 8576
Mean 125.2
RMS 190.6
χ² / ndf 112.7 / 85
Prob 0.02385
Npe 0.2388 ± 0.0272
Peak 345.2 ± 3.9
Width 108.2 ± 3.4
Amplitude 6.229e+004 ± 6.335e+003
Counts
Charge (fC)

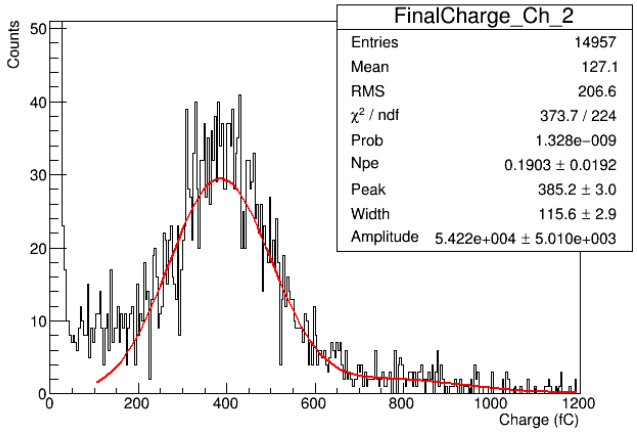

FinalCharge_Ch_2
Entries 8572
Mean 107.4
RMS 148.5
χ² / ndf 60.6 / 69
Prob 0.7546
Npe 0.2208 ± 0.0222
Peak 255.8 ± 2.6
Width 78.87 ± 2.24
Amplitude 7.624e+004 ± 7.045e+003
Counts
Charge (fC)

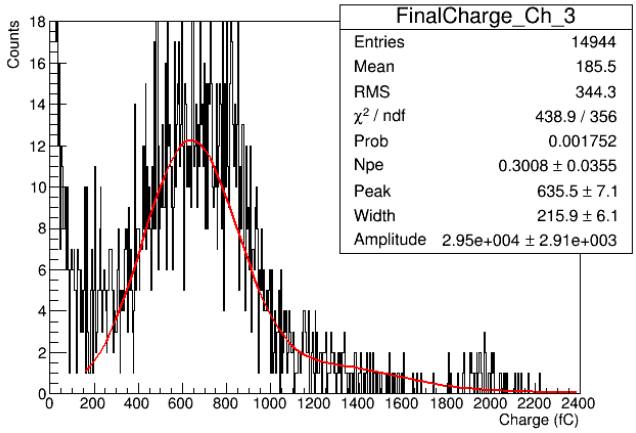

FinalCharge_Ch_3
Entries 8583
Mean 148
RMS 230.7
χ² / ndf 99.47 / 93
Prob 0.3042
Npe 0.183 ± 0.029
Peak 438.7 ± 5.3
Width 138.2 ± 4.8
Amplitude 7.122e+004 ± 1.026e+004
Counts
Charge (fC)

At 2400V

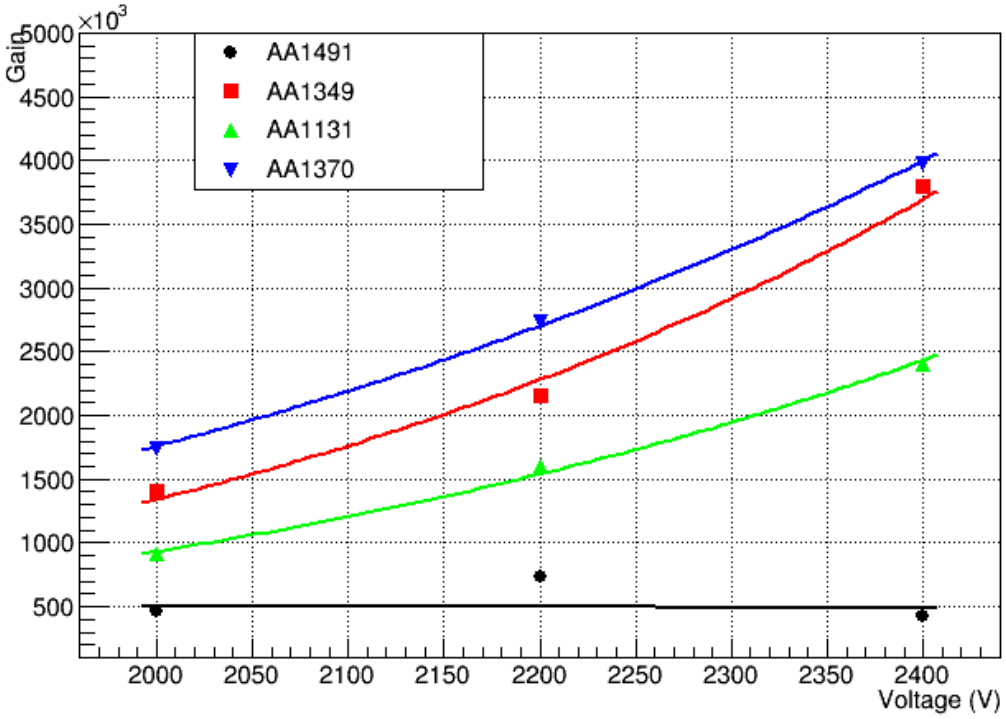

FinalCharge_Ch_0
Entries 14614
Mean 78.46
RMS 84.89
χ² / ndf 183.7 / 129
Prob 0.001127
Npe 1.022 ± 0.054
Peak 67.96 ± 1.73
Width 40.42 ± 1.78
Amplitude 4.857e+004 ± 1.708e+003
Counts
Charge (fC)

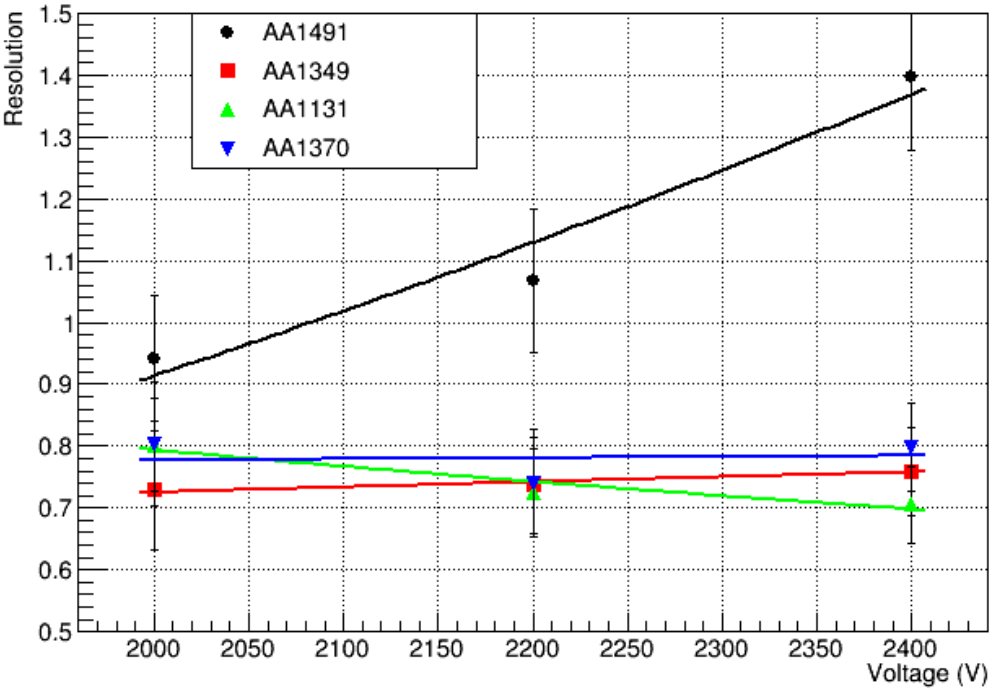

FinalCharge_Ch_1
Entries 14981
Mean 152.6
RMS 293.8
χ² / ndf 312.4 / 313
Prob 0.4983
Npe 0.2589 ± 0.0314
Peak 606.8 ± 6.1
Width 196.2 ± 5.6
Amplitude 3.506e+004 ± 3.629e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 14957
Mean 127.1
RMS 206.6
χ² / ndf 373.7 / 224
Prob 1.328e−009
Npe 0.1903 ± 0.0192
Peak 385.2 ± 3.0
Width 115.6 ± 2.9
Amplitude 5.422e+004 ± 5.010e+003
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 14944
Mean 185.5
RMS 344.3
χ² / ndf 438.9 / 356
Prob 0.001752
Npe 0.3008 ± 0.0355
Peak 635.5 ± 7.1
Width 215.9 ± 6.1
Amplitude 2.95e+004 ± 2.91e+003
Counts
Charge (fC)

Gain and resolution curves: PMT65-AA1491, PMT66-AA1349, PMT67-AA1131, PMT68-AA1370

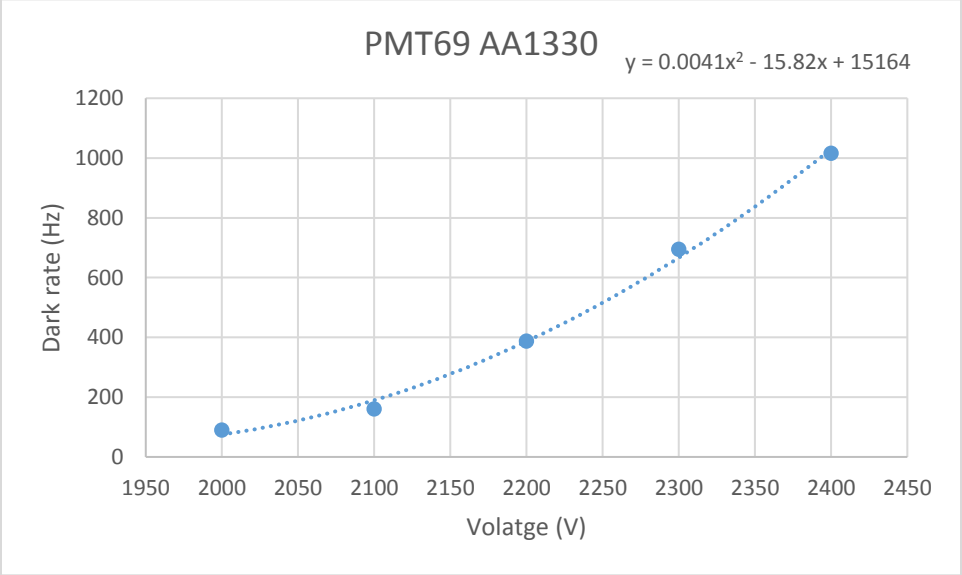




PMT's 69-71

PMT69-AA1330
PMT70-AA1052
PMT71-AA1227

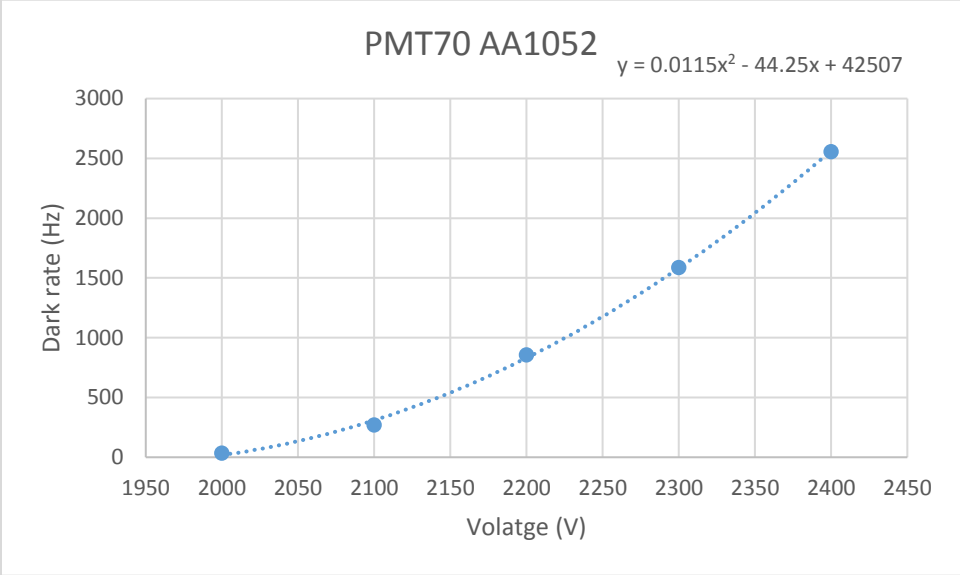
PMT69 AA1330 Dark rate measured on CH3						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	690	682	717	733	749	89.275
2100	1305	1248	1299	1275	1301	160.7
2200	3056	3068	3048	3244	3069	387.125
2300	5563	5360	5539	5660	5676	694.95
2400	8076	8186	7994	8148	8209	1015.325



PMT70 AA1052 Dark rate measured on CH4

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

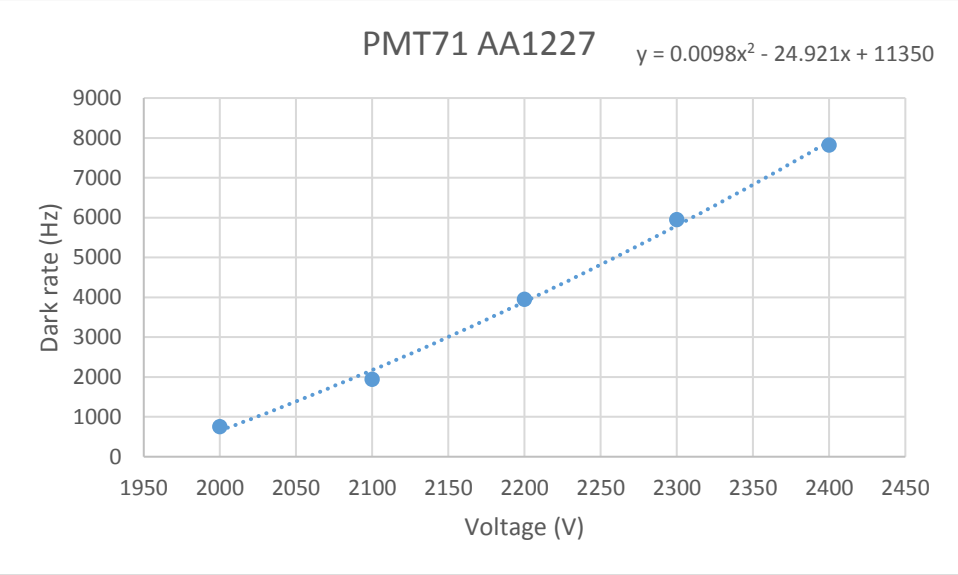
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	300	256	258	271	244	33.225
2100	2262	2173	2115	2195	2090	270.875
2200	6944	6925	6888	6714	6746	855.425
2300	12901	12970	12810	12666	12130	1586.925
2400	20979	20824	20453	20050	19946	2556.3

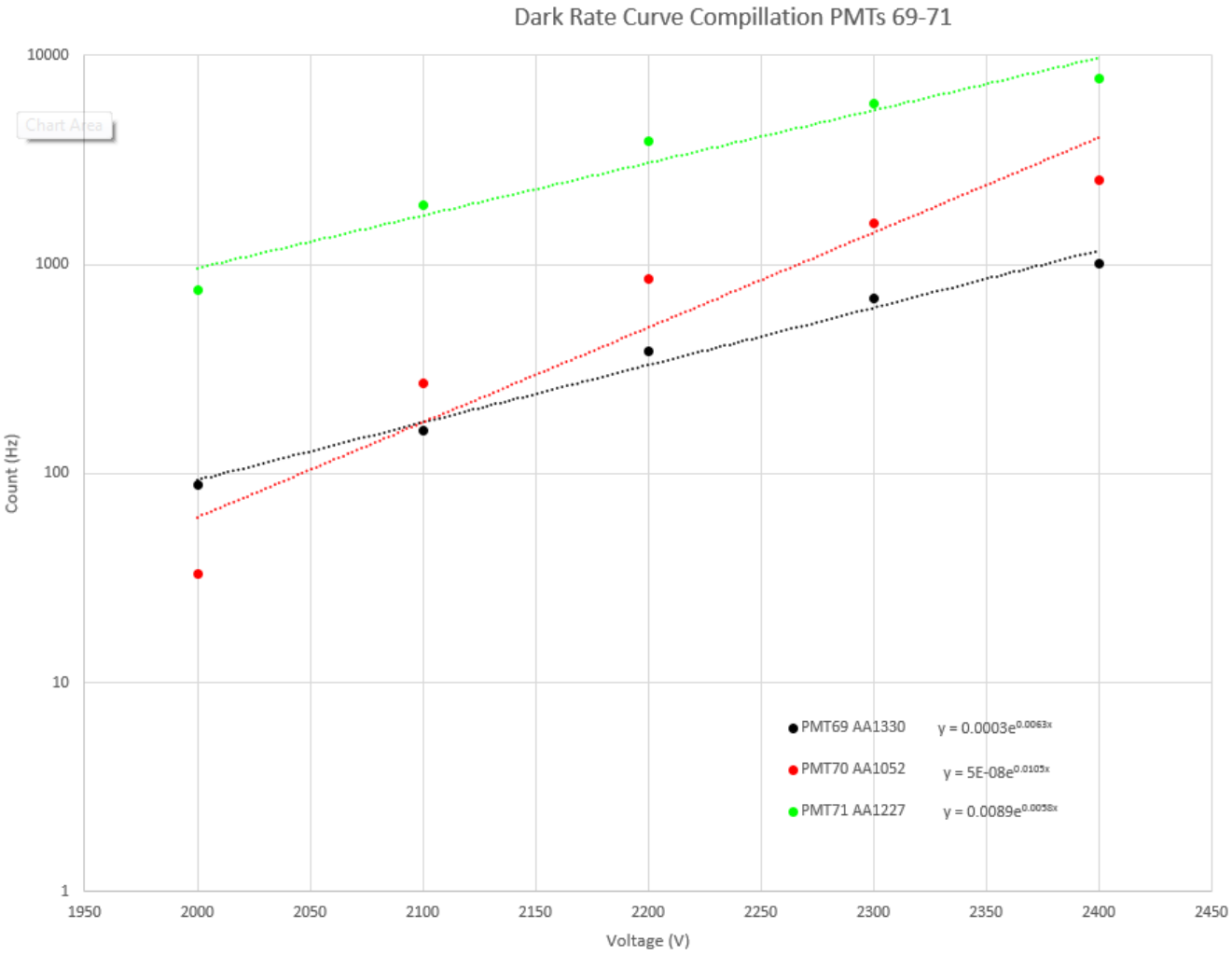


PMT71 AA1227 Dark rate measured on CH1

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	5904	6111	6128	6055	6008	755.15
2100	15915	15793	15639	15431	15033	1945.275
2200	32229	32166	31387	31229	30900	3947.775
2300	48571	47904	47377	46981	47000	5945.825
2400	64154	63545	62273	61883	61072	7823.175




Dark Rate Curve Compillation PMTs 69-71
Chart Area
10000
1000
100
10
1
Count (Hz)
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
Voltage (V)
PMT69 AA1330 y = 0.0003e^0.0063x
PMT70 AA1052 y = 5E-08e^0.0105x
PMT71 AA1227 y = 0.0089e^0.0058x

For these Charge Distribution Histograms:

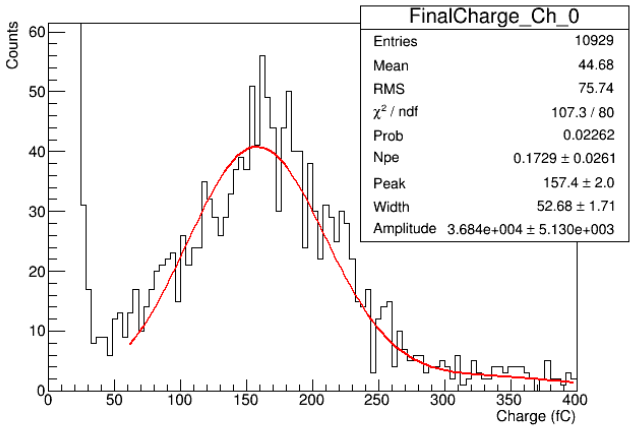
FinalCharge_Ch_0 = PMT69-AA1330 FinalCharge_Ch_1 = NO PMT TESTED ON THIS CHANNEL

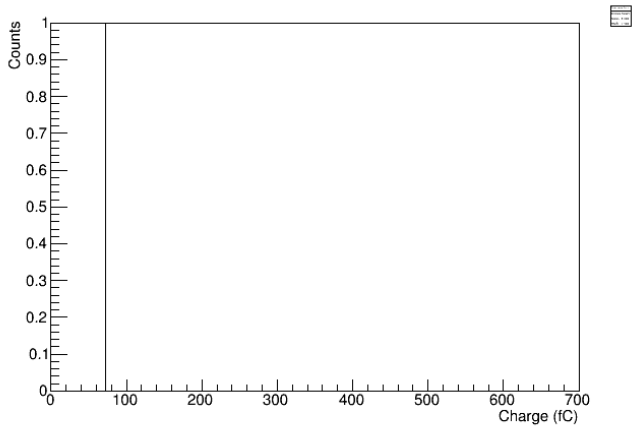
FinalCharge_Ch_2 = PMT70-AA1052 FinalCharge_Ch_3 = PMT71-AA1227

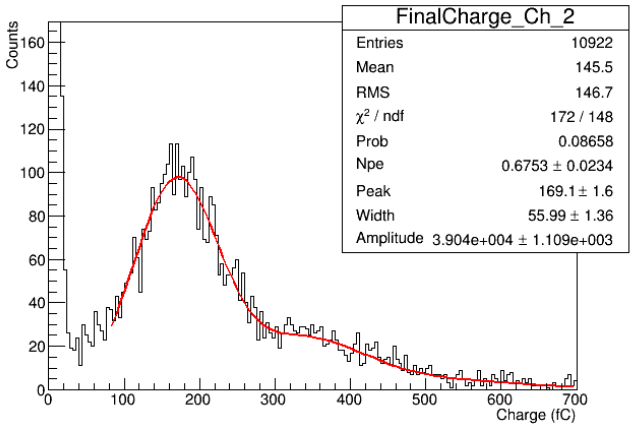
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

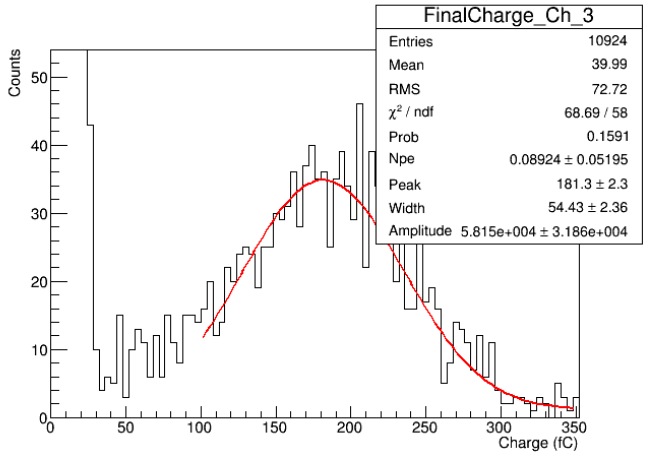
Code used to fit: fitnpe_XP2020

At 2000V

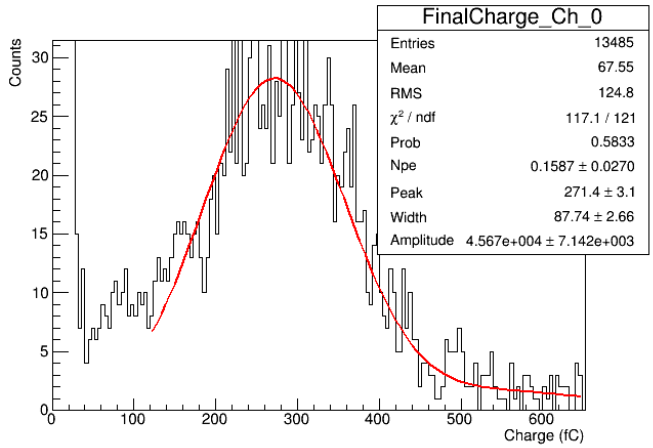


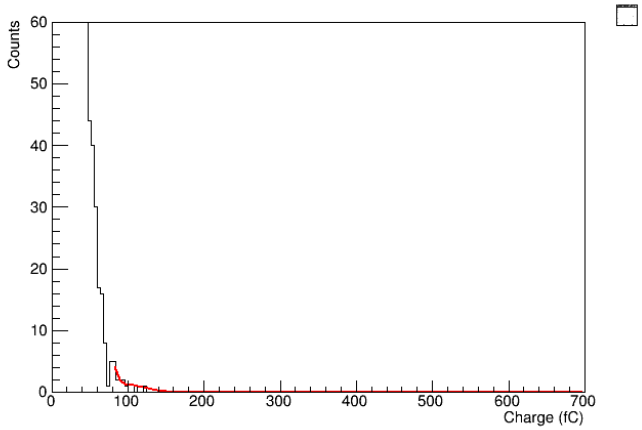


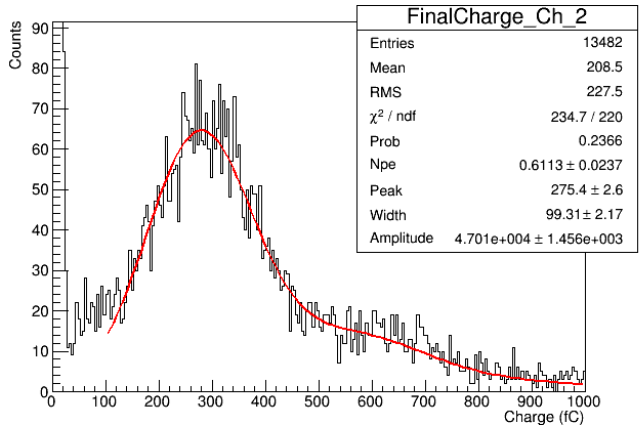


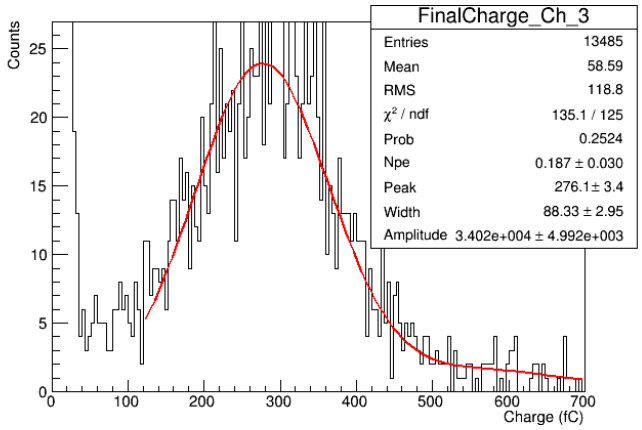


At 2200V

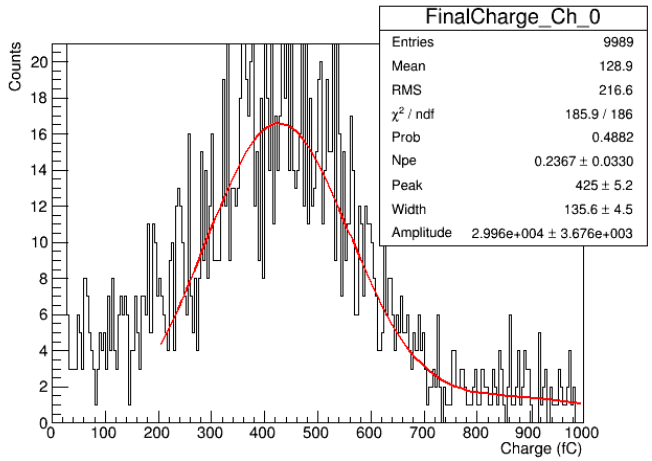

FinalCharge_Ch_0
Entries 13485
Mean 67.55
RMS 124.8
χ² / ndf 117.1 / 121
Prob 0.5833
Npe 0.1587 ± 0.0270
Peak 271.4 ± 3.1
Width 87.74 ± 2.66
Amplitude 4.567e+004 ± 7.142e+003
Counts
Charge (fC)

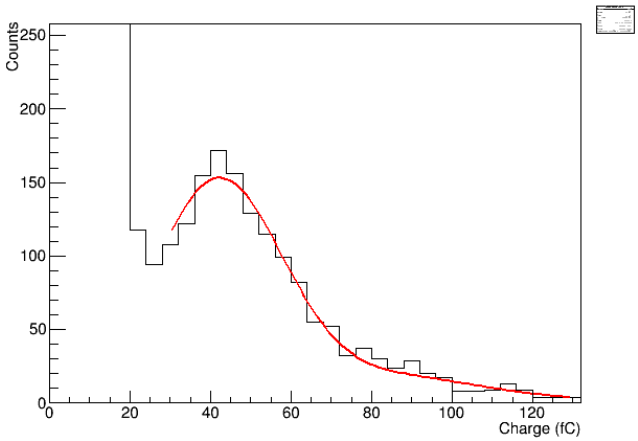

Counts
Charge (fC)

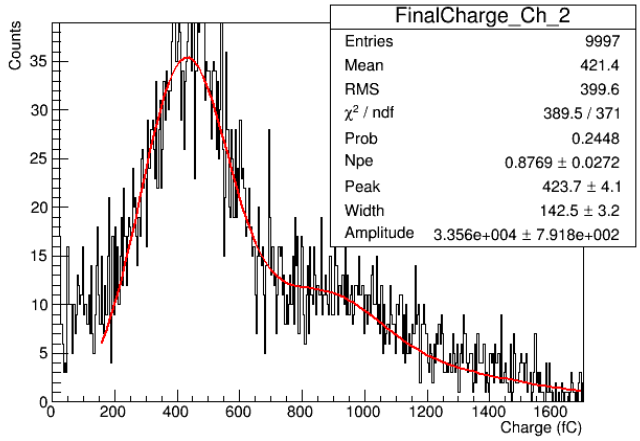

FinalCharge_Ch_2
Entries 13482
Mean 208.5
RMS 227.5
χ² / ndf 234.7 / 220
Prob 0.2366
Npe 0.6113 ± 0.0237
Peak 275.4 ± 2.6
Width 99.31 ± 2.17
Amplitude 4.701e+004 ± 1.456e+003
Counts
Charge (fC)

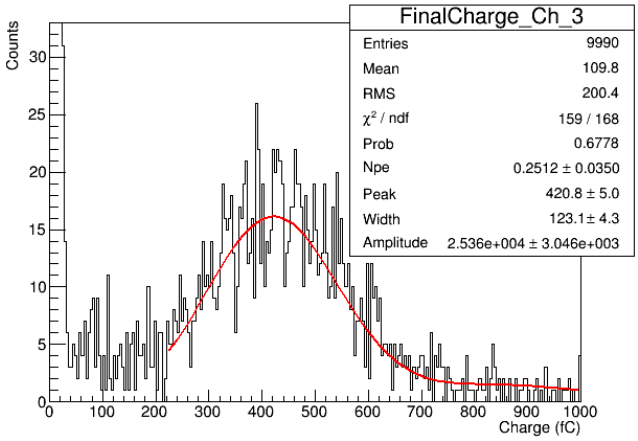

FinalCharge_Ch_3
Entries 13485
Mean 58.59
RMS 118.8
χ² / ndf 135.1 / 125
Prob 0.2524
Npe 0.187 ± 0.030
Peak 276.1 ± 3.4
Width 88.33 ± 2.95
Amplitude 3.402e+004 ± 4.992e+003
Counts
Charge (fC)

At 2400V

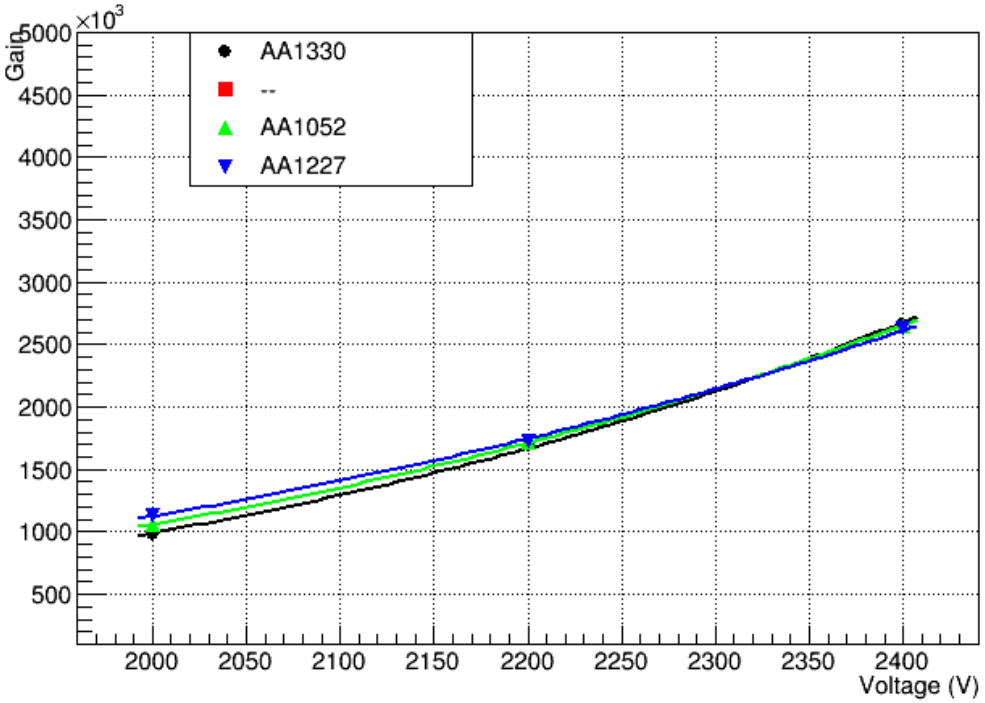

FinalCharge_Ch_0
Entries 9989
Mean 128.9
RMS 216.6
χ² / ndf 185.9 / 186
Prob 0.4882
Npe 0.2367 ± 0.0330
Peak 425 ± 5.2
Width 135.6 ± 4.5
Amplitude 2.996e+004 ± 3.676e+003
Counts
Charge (fC)

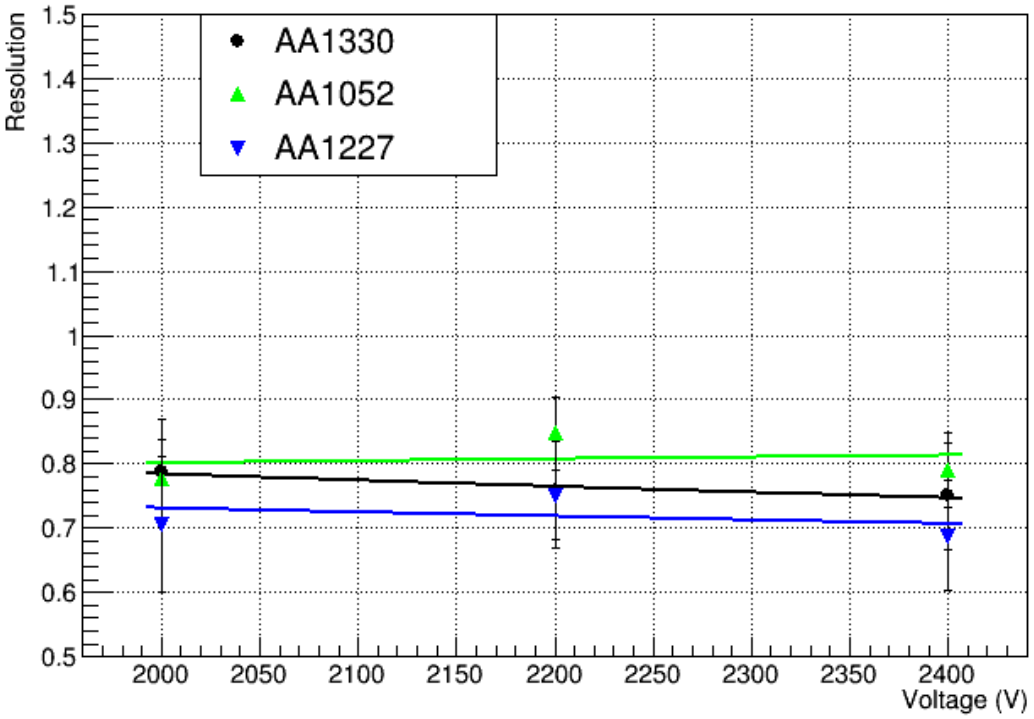

Counts
Charge (fC)


FinalCharge_Ch_2
Entries 9997
Mean 421.4
RMS 399.6
χ² / ndf 389.5 / 371
Prob 0.2448
Npe 0.8769 ± 0.0272
Peak 423.7 ± 4.1
Width 142.5 ± 3.2
Amplitude 3.356e+004 ± 7.918e+002
Counts
Charge (fC)


FinalCharge_Ch_3
Entries 9990
Mean 109.8
RMS 200.4
χ² / ndf 159 / 168
Prob 0.6778
Npe 0.2512 ± 0.0350
Peak 420.8 ± 5.0
Width 123.1 ± 4.3
Amplitude 2.536e+004 ± 3.046e+003
Counts
Charge (fC)

Gain and resolution curves: PMT69-AA1330**,** PMT70-AA1052**,** PMT71-AA1227

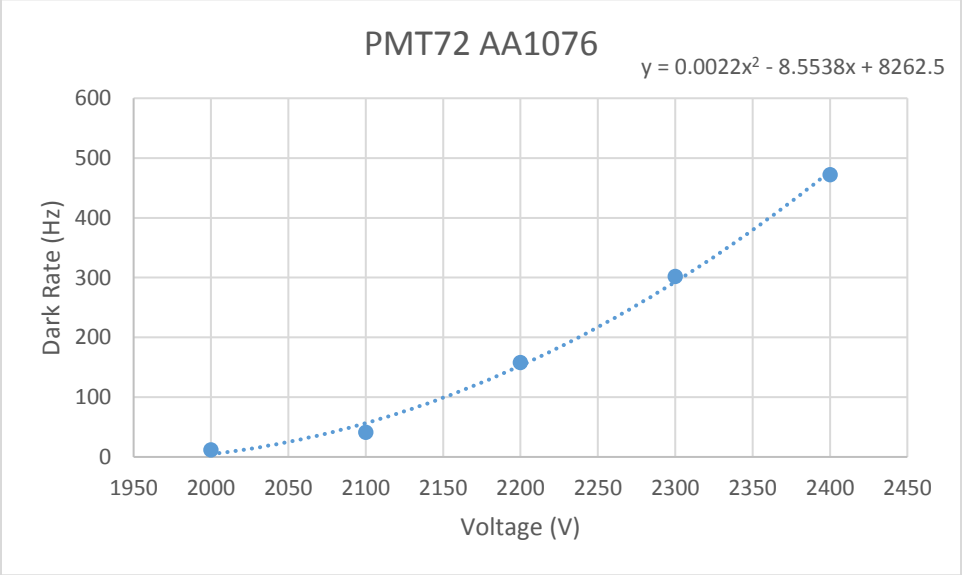




PMT's 72-74

PMT72-AA1076
PMT73-AA1258
PMT74-AA1378

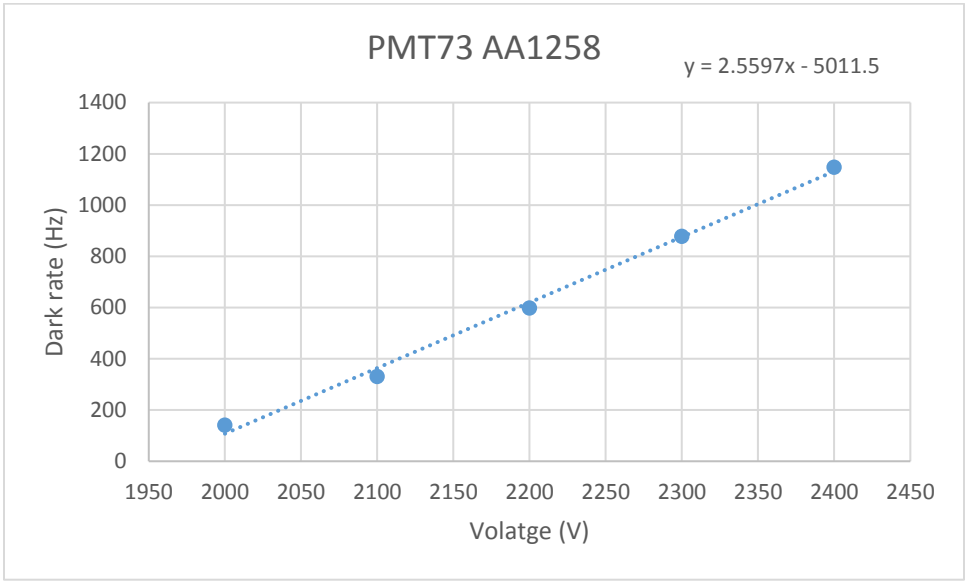
PMT72 AA1076 Dark rate measured on CH1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	118	76	94	102	81	11.775
2100	336	351	333	310	309	40.975
2200	1264	1239	1291	1280	1229	157.575
2300	2364	2425	2224	2656	2398	301.675
2400	3549	3590	3654	4107	3980	472



PMT73 AA1258 Dark rate measured on CH3

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

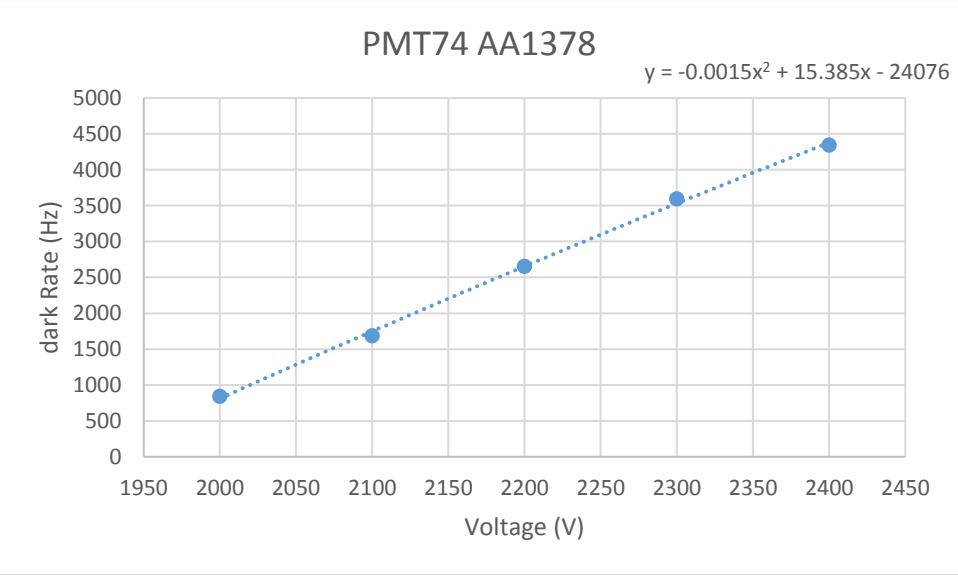
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	1143	1089	1111	1217	1117	141.925
2100	2585	2650	2613	2648	2745	331.025
2200	4675	4972	4921	4750	4642	599
2300	7033	7073	7010	6920	7101	878.425
2400	9228	9123	9365	9177	9029	1148.05



PMT74 AA1378 Dark rate measured on CH4

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	6849	6702	6788	6667	6771	844.425
2100	13934	13402	13786	13306	12954	1684.55
2200	21541	21140	20901	21115	21426	2653.075
2300	29204	28664	28752	29412	27831	3596.575
2400	27831	37471	36585	36100	35865	4346.3



For these Charge Distribution Histograms:

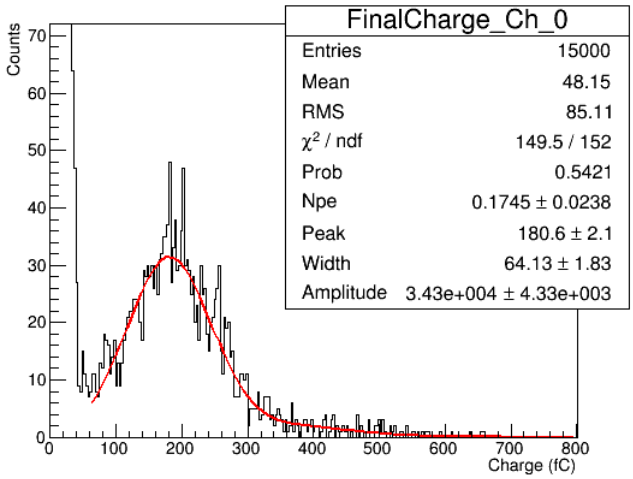
FinalCharge_Ch_0 = PMT72-AA1076 FinalCharge_Ch_1 = PMT73-AA1258

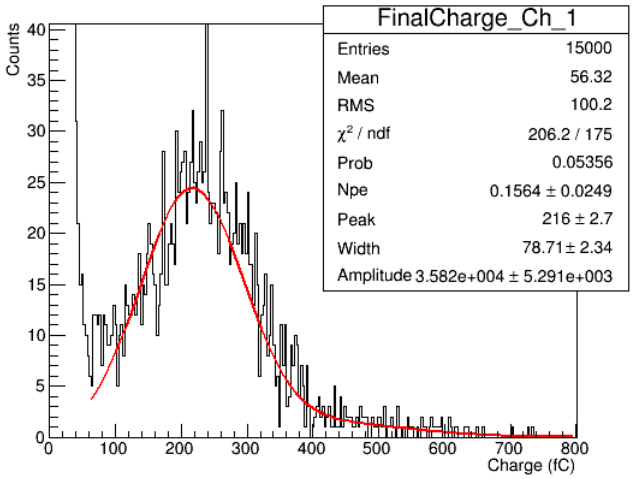
FinalCharge_Ch_2 = PMT74-AA1378

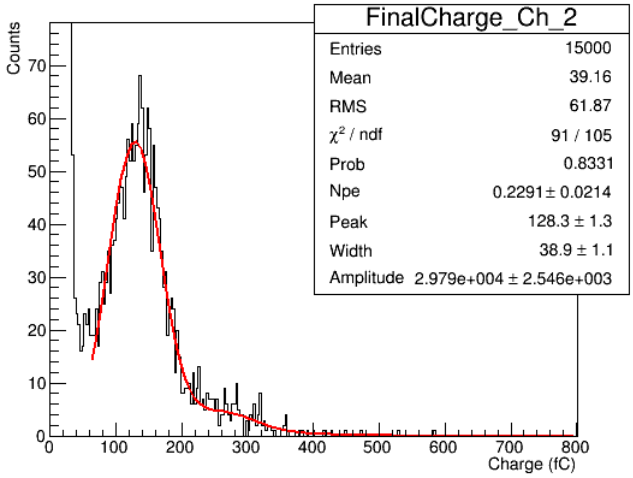
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)

Code used to fit: fitnpe_XP2020

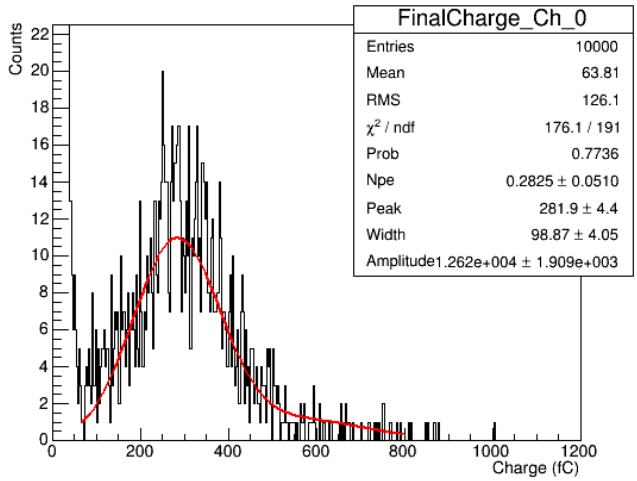
At 2000V

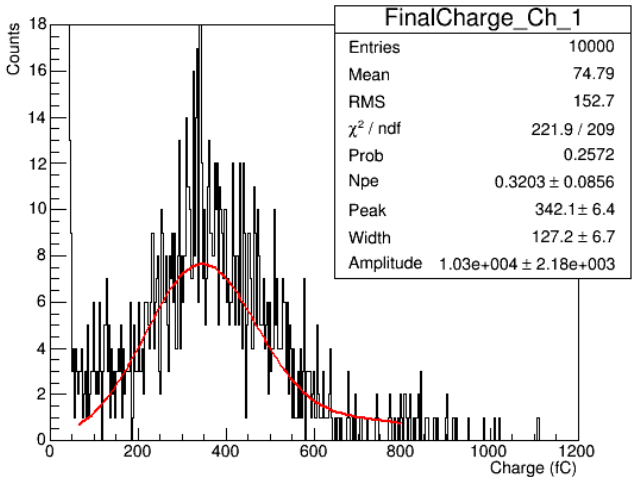


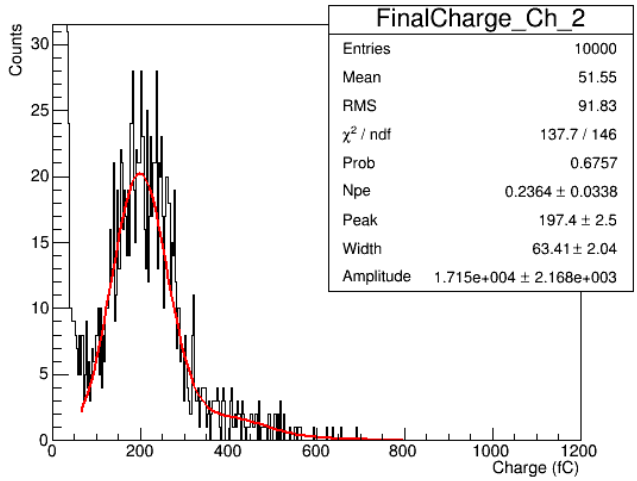




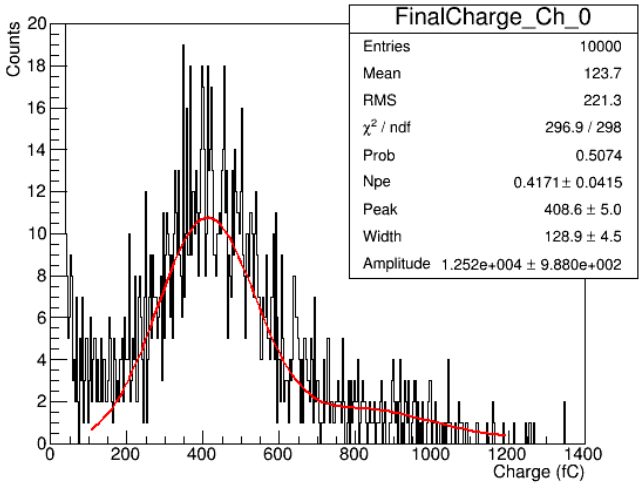
At 2200V

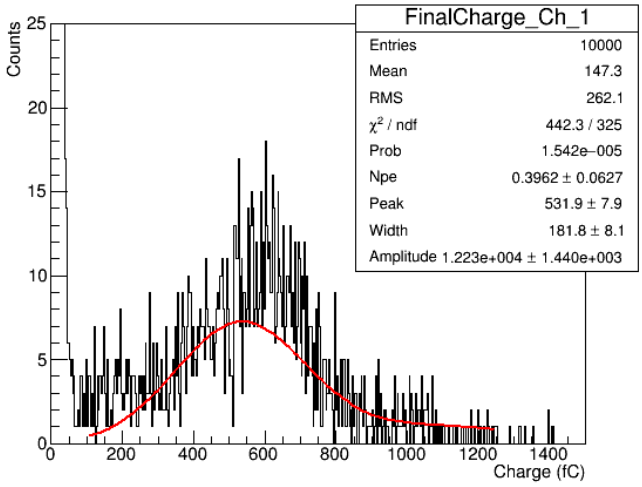

FinalCharge_Ch_0
Entries 10000
Mean 63.81
RMS 126.1
χ² / ndf 176.1 / 191
Prob 0.7736
Npe 0.2825 ± 0.0510
Peak 281.9 ± 4.4
Width 98.87 ± 4.05
Amplitude 1.262e+004 ± 1.909e+003
Counts
Charge (fC)

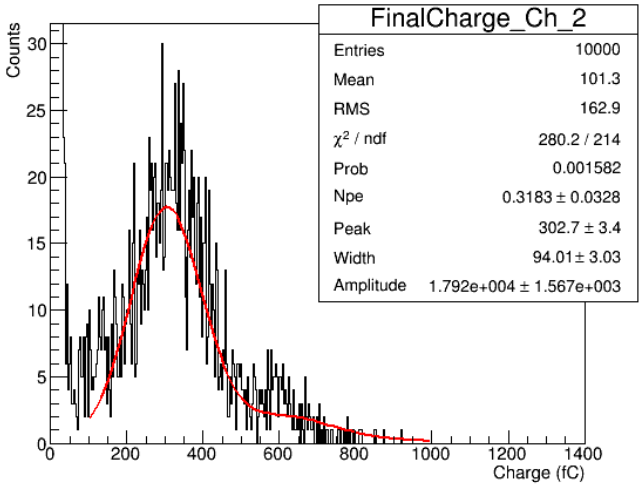

FinalCharge_Ch_1
Entries 10000
Mean 74.79
RMS 152.7
χ² / ndf 221.9 / 209
Prob 0.2572
Npe 0.3203 ± 0.0856
Peak 342.1 ± 6.4
Width 127.2 ± 6.7
Amplitude 1.03e+004 ± 2.18e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 10000
Mean 51.55
RMS 91.83
χ² / ndf 137.7 / 146
Prob 0.6757
Npe 0.2364 ± 0.0338
Peak 197.4 ± 2.5
Width 63.41 ± 2.04
Amplitude 1.715e+004 ± 2.168e+003
Counts
Charge (fC)

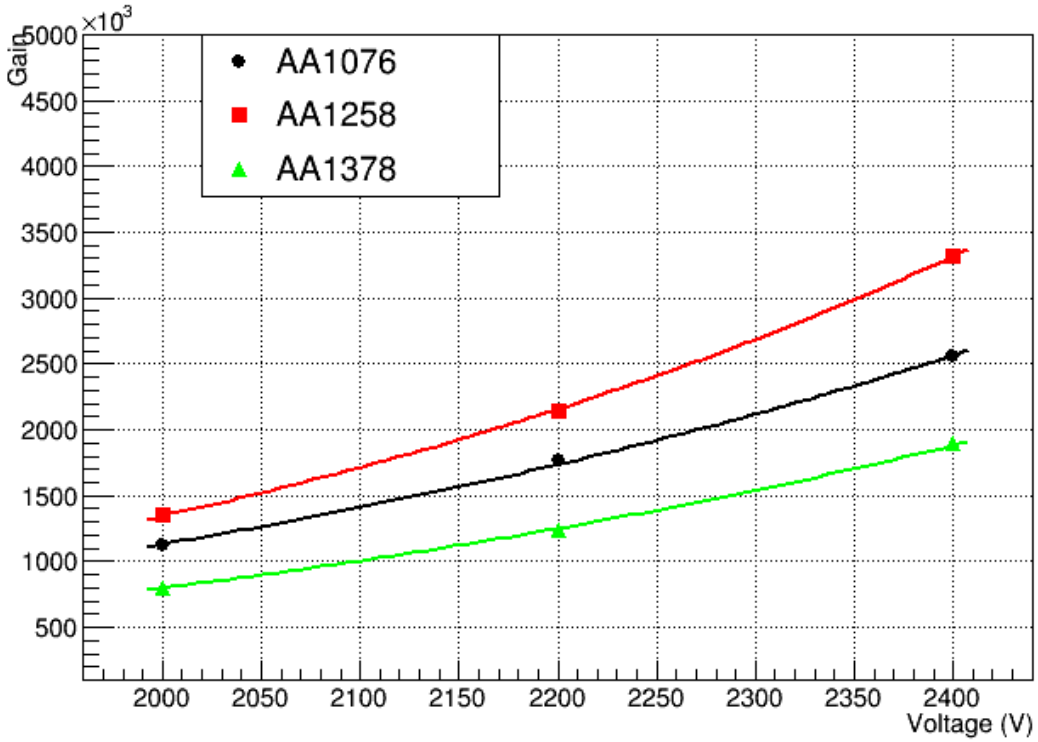
At 2400V

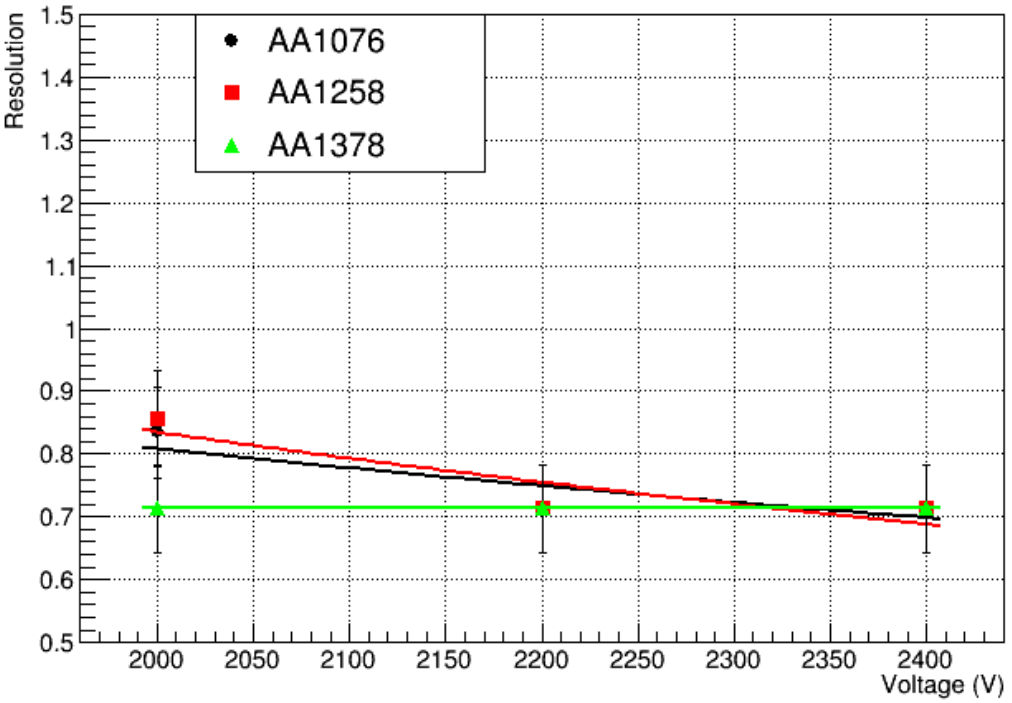

FinalCharge_Ch_0
Entries 10000
Mean 123.7
RMS 221.3
χ² / ndf 296.9 / 298
Prob 0.5074
Npe 0.4171 ± 0.0415
Peak 408.6 ± 5.0
Width 128.9 ± 4.5
Amplitude 1.252e+004 ± 9.880e+002
Counts
Charge (fC)


FinalCharge_Ch_1
Entries 10000
Mean 147.3
RMS 262.1
χ² / ndf 442.3 / 325
Prob 1.542e−005
Npe 0.3962 ± 0.0627
Peak 531.9 ± 7.9
Width 181.8 ± 8.1
Amplitude 1.223e+004 ± 1.440e+003
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 10000
Mean 101.3
RMS 162.9
χ² / ndf 280.2 / 214
Prob 0.001582
Npe 0.3183 ± 0.0328
Peak 302.7 ± 3.4
Width 94.01 ± 3.03
Amplitude 1.792e+004 ± 1.567e+003
Counts
Charge (fC)

Gain and resolution curves: PMT72-AA1076, PMT73-AA1258**,** PMT74-AA1378

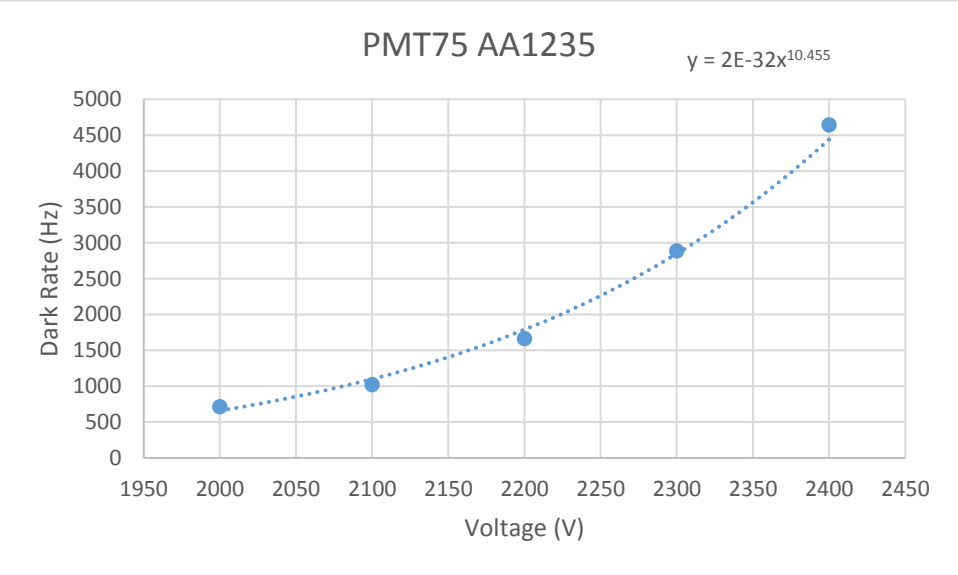




PMT's 75-77

PMT75-AA1235
PMT76-AA981
PMT77-AA765

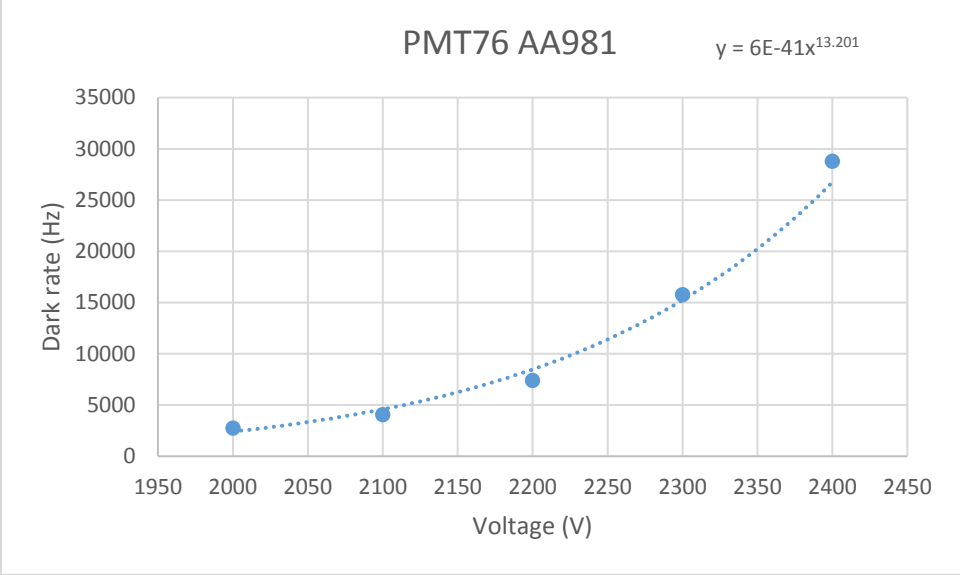
PMT75 AA1235 Dark rate measured on CH1						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	5784	5683	5869	5736	5637	717.725
2100	8195	8071	8157	8270	8210	1022.575
2200	13406	13215	13317	13376	13347	1666.525
2300	23231	23039	23168	22866	23280	2889.6
2400	37209	36930	36930	37664	37090	4645.575



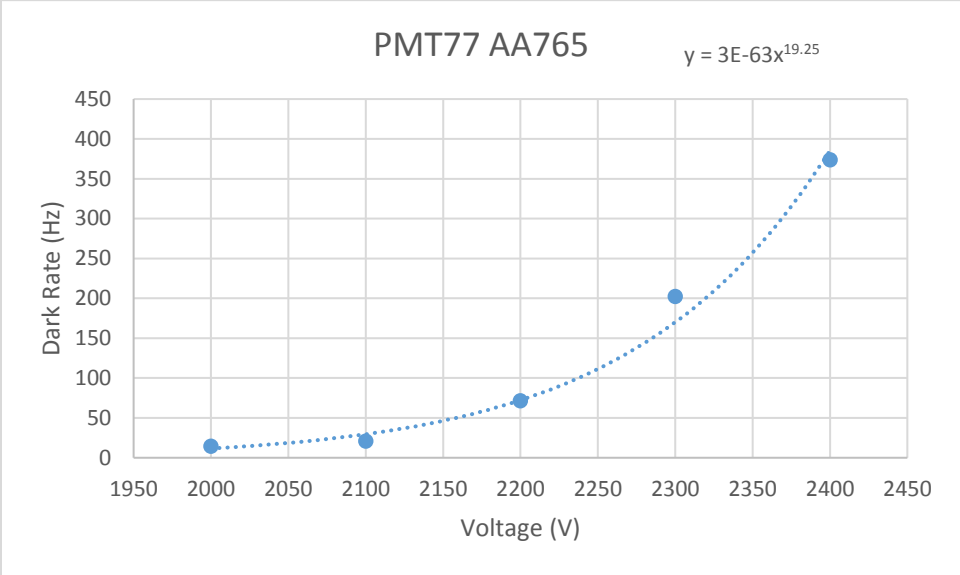
PMT76 AA981 Dark rate measured on CH2

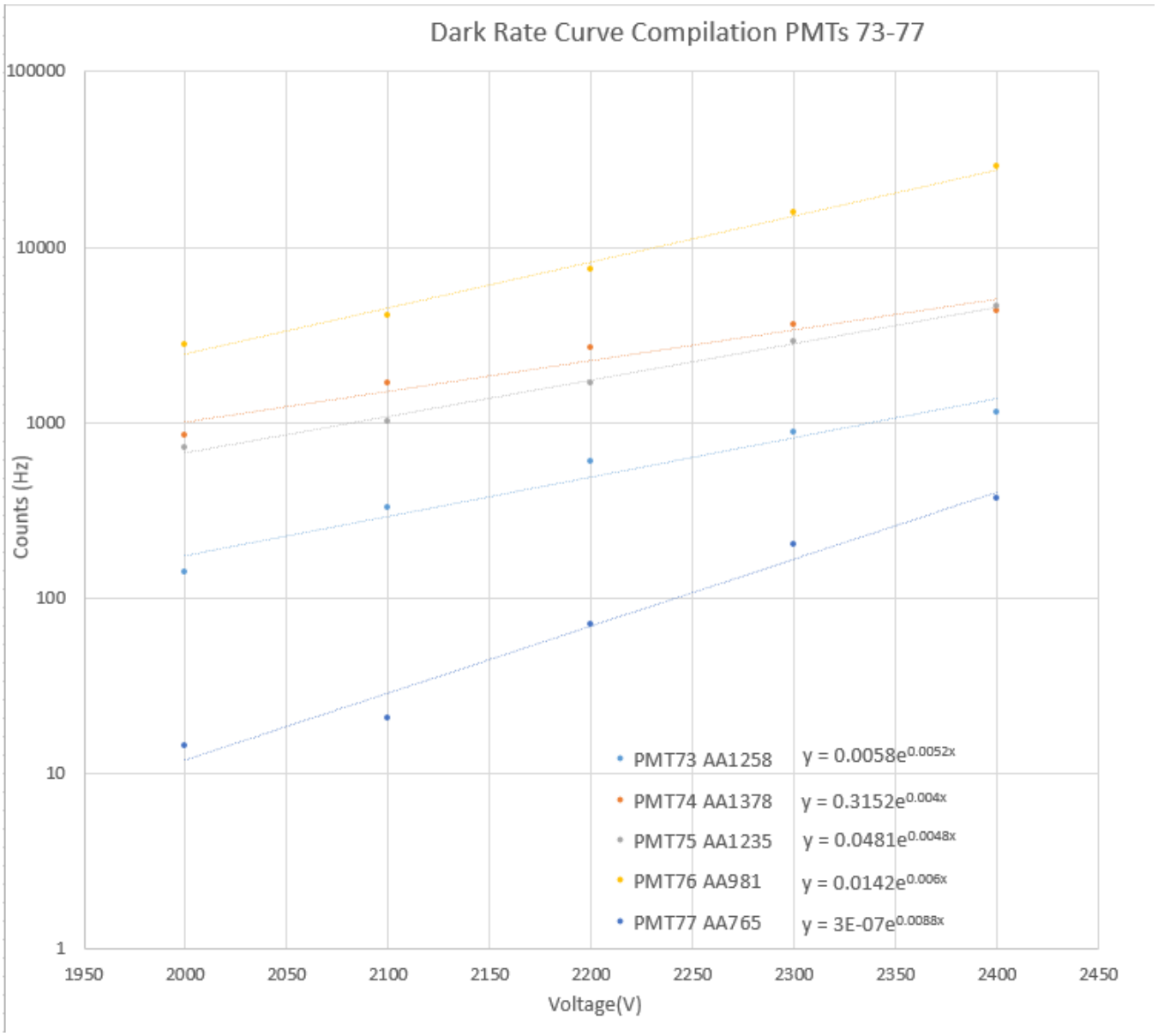
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	22227	21887	21687	22499	22631	2773.275
2100	32444	33188	32321	32567	32909	4085.725
2200	58897	59102	59397	59761	58820	7399.425
2300	125042	127029	125837	127006	126472	15784.65
2400	230383	229867	230609	231519	230013	28809.78



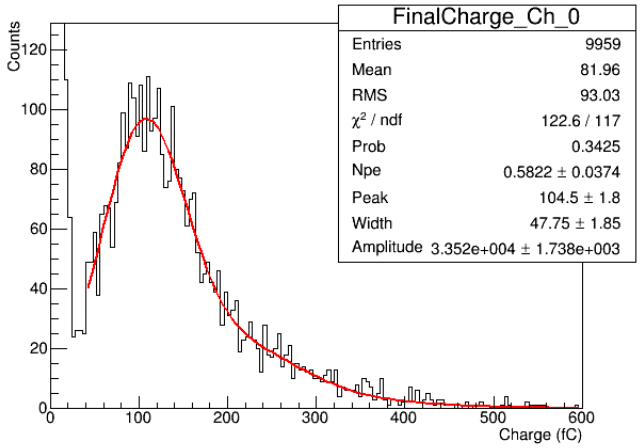
PMT77 AA765 Dark rate measured on CH3						
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination						
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
2000	119	123	119	94	120	14.375
2100	158	169	161	176	171	20.875
2200	611	562	584	562	530	71.225
2300	1616	1600	1588	1615	1665	202.1
2400	2985	2931	3018	2958	3045	373.425

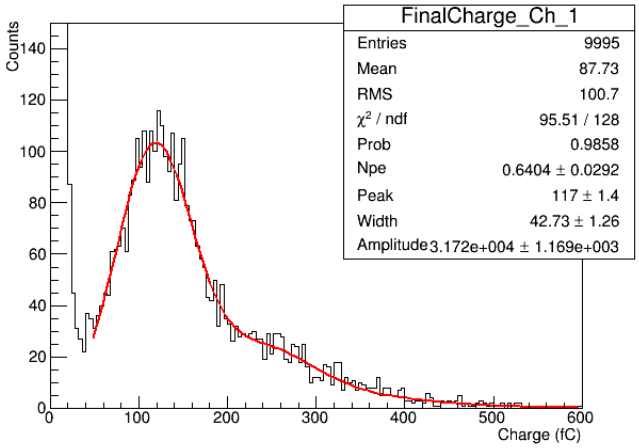


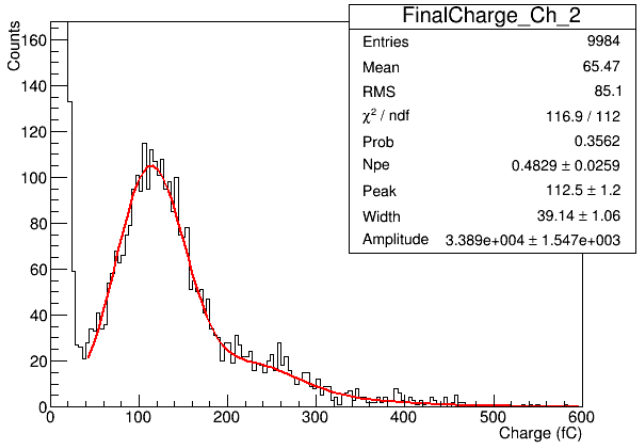

Dark Rate Curve Compilation PMTs 73-77
100000
10000
1000
100
10
1
Counts (Hz)
1950
2000
2050
2100
2150
2200
2250
2300
2350
2400
2450
Voltage(V)
PMT73 AA1258 y = 0.0058e^0.0052x
PMT74 AA1378 y = 0.3152e^0.004x
PMT75 AA1235 y = 0.0481e^0.0048x
PMT76 AA981 y = 0.0142e^0.006x
PMT77 AA765 y = 3E-07e^0.0088x

For these Charge Distribution Histograms:
FinalCharge_Ch_0 = PMT75-AA1235 FinalCharge_Ch_1 = PMT76-A981
FinalCharge_Ch_2 = PMT77-AA765
Code to fill histograms: ReadWaveForm_PlotChargeDist_v4 (pulse finding with 3-5 sigma cut)
Code used to fit: fitnpe_XP2020

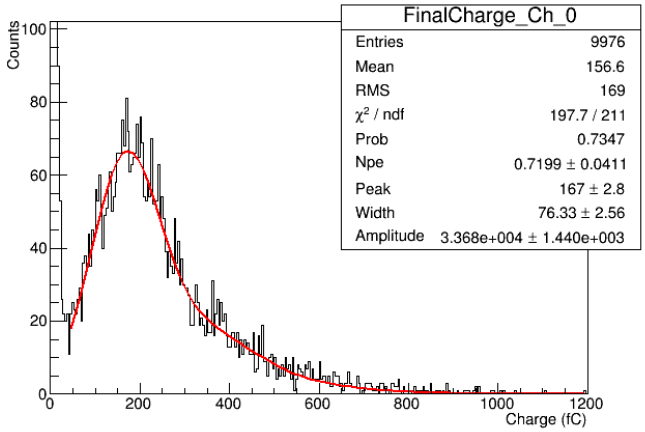
2000V

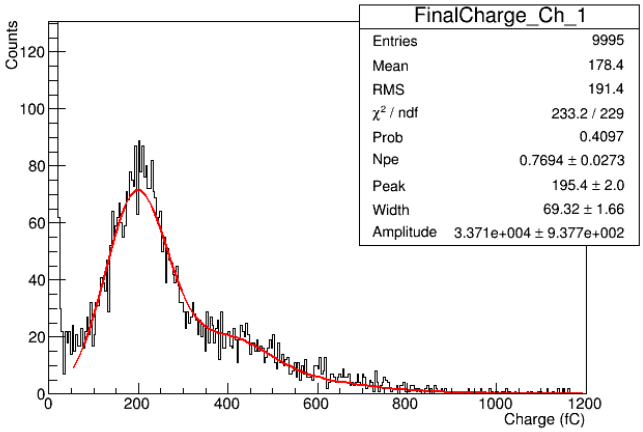


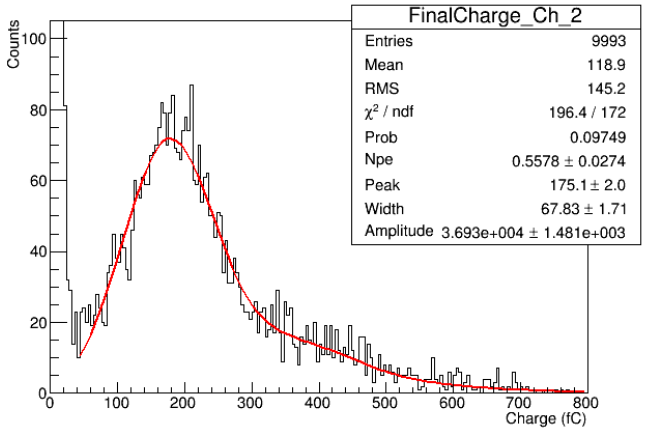




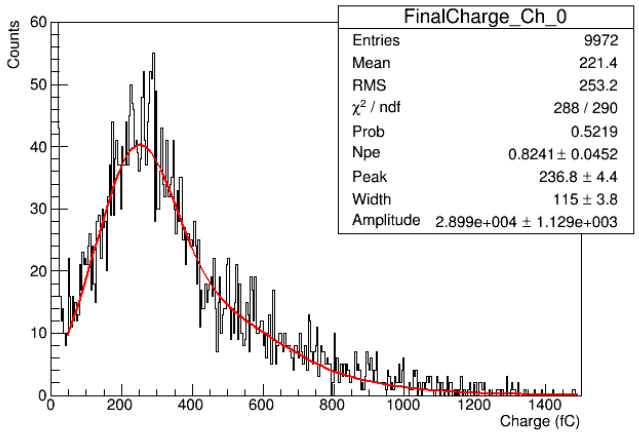
2200V

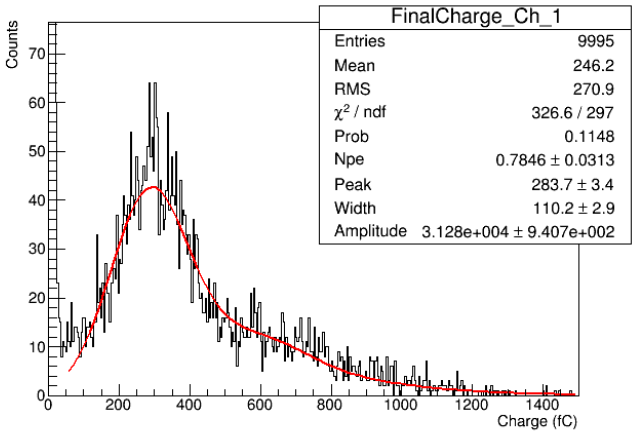

FinalCharge_Ch_0
Entries 9976
Mean 156.6
RMS 169
χ² / ndf 197.7 / 211
Prob 0.7347
Npe 0.7199 ± 0.0411
Peak 167 ± 2.8
Width 76.33 ± 2.56
Amplitude 3.368e+004 ± 1.440e+003
Counts
Charge (fC)

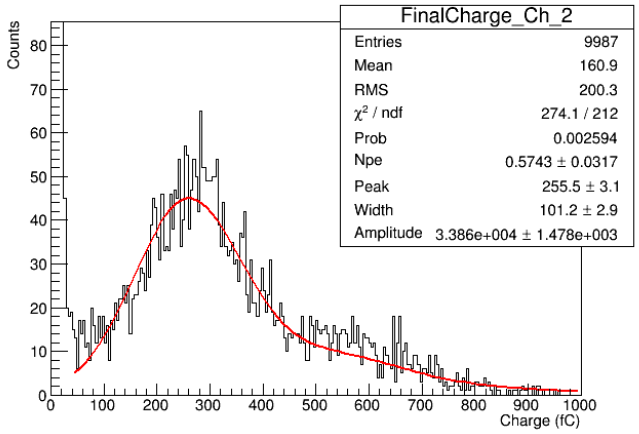

FinalCharge_Ch_1
Entries 9995
Mean 178.4
RMS 191.4
χ² / ndf 233.2 / 229
Prob 0.4097
Npe 0.7694 ± 0.0273
Peak 195.4 ± 2.0
Width 69.32 ± 1.66
Amplitude 3.371e+004 ± 9.377e+002
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 9993
Mean 118.9
RMS 145.2
χ² / ndf 196.4 / 172
Prob 0.09749
Npe 0.5578 ± 0.0274
Peak 175.1 ± 2.0
Width 67.83 ± 1.71
Amplitude 3.693e+004 ± 1.481e+003
Counts
Charge (fC)

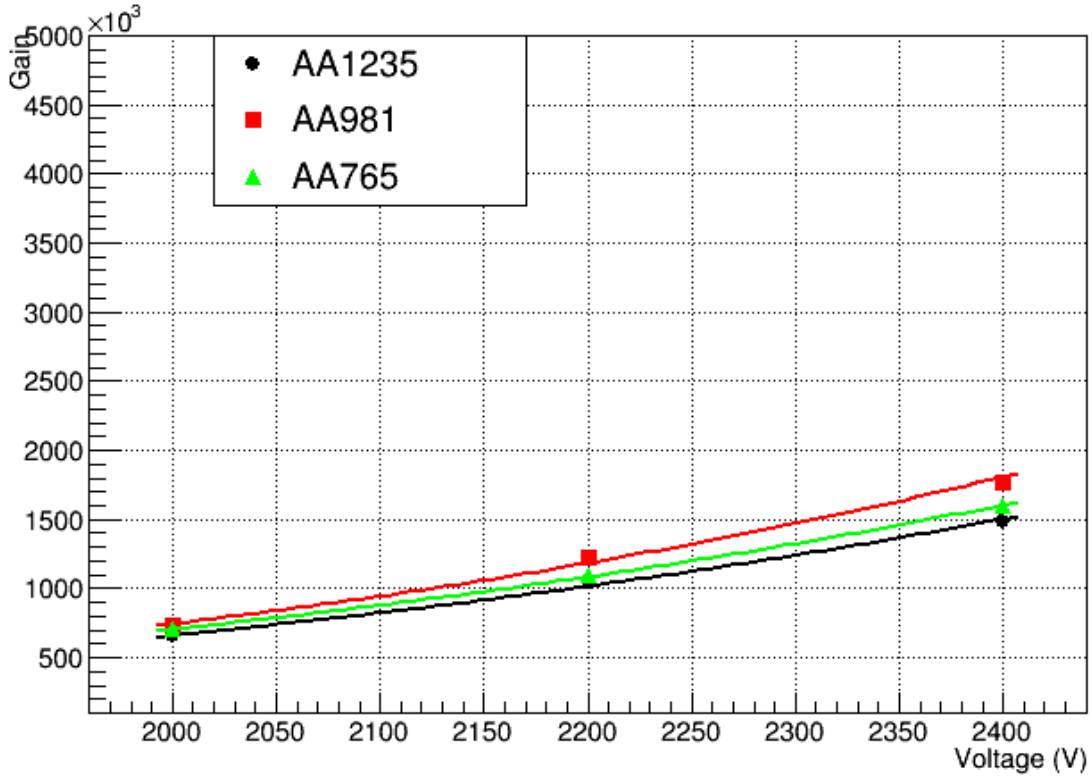
2400V

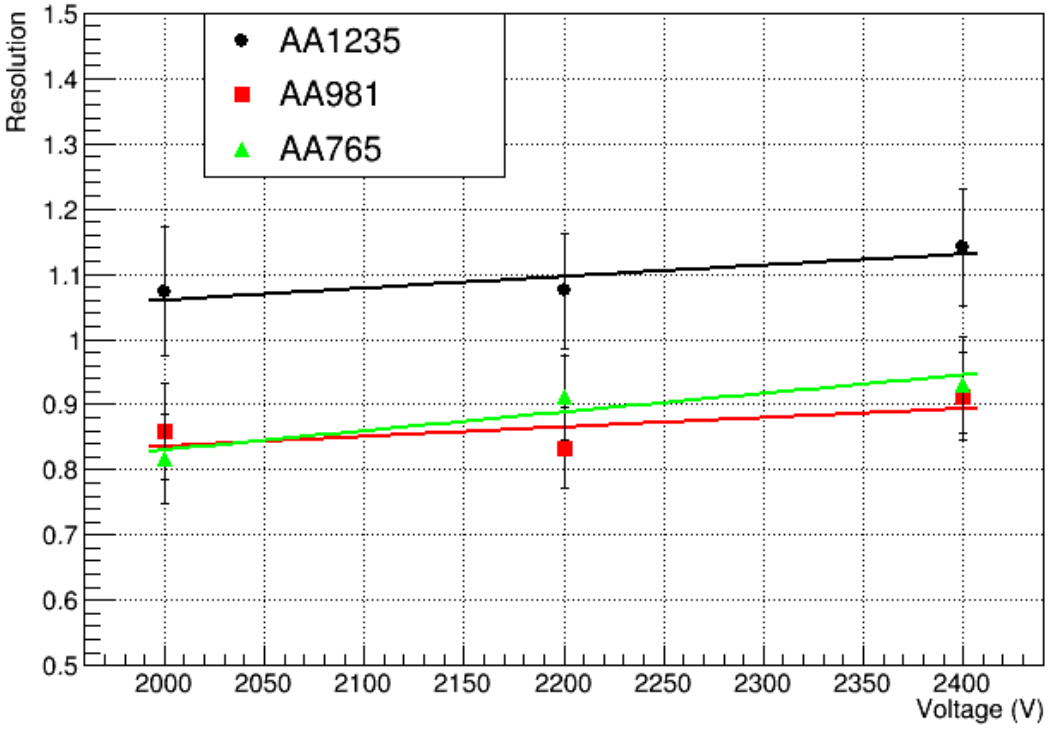

FinalCharge_Ch_0
Entries 9972
Mean 221.4
RMS 253.2
χ² / ndf 288 / 290
Prob 0.5219
Npe 0.8241 ± 0.0452
Peak 236.8 ± 4.4
Width 115 ± 3.8
Amplitude 2.899e+004 ± 1.129e+003
Counts
Charge (fC)


FinalCharge_Ch_1
Entries 9995
Mean 246.2
RMS 270.9
χ² / ndf 326.6 / 297
Prob 0.1148
Npe 0.7846 ± 0.0313
Peak 283.7 ± 3.4
Width 110.2 ± 2.9
Amplitude 3.128e+004 ± 9.407e+002
Counts
Charge (fC)


FinalCharge_Ch_2
Entries 9987
Mean 160.9
RMS 200.3
χ² / ndf 274.1 / 212
Prob 0.002594
Npe 0.5743 ± 0.0317
Peak 255.5 ± 3.1
Width 101.2 ± 2.9
Amplitude 3.386e+004 ± 1.478e+003
Counts
Charge (fC)

Gain and resolution curves: PMT75-AA1235**,** PMT76-AA981**,** PMT77-AA765





PMTs 78 – 112 are EMI 9954-KB05

PMTs 78 – 90:

The following charge distributions and gain results for PMTs 78 – 90 were measured between 20170703 and 20170804 before a source of RF noise was identified and removed; the source was a 4" long unshielded twisted pair of LV wire connected to the LED (see Figure). The EMI tubes' RF shielding is not very good and so the RF was picked up and included in each PMT measured waveform on the oscilloscope; to limit the integration of this RF each oscilloscope waveform was integrated over the finite PMT pulse. After the RF source was removed and PMTs were retested.

PMTs 79, 80, 82: were retested on 20171113 (not shown here)
PMTs 86, 89, 90: were retested on 20171105 (not shown here)
PMTs 78, 83, 85 have not yet been retested.
PMTs 81, 84, 87, 88 were previously determined to be BAD and thus not retested.

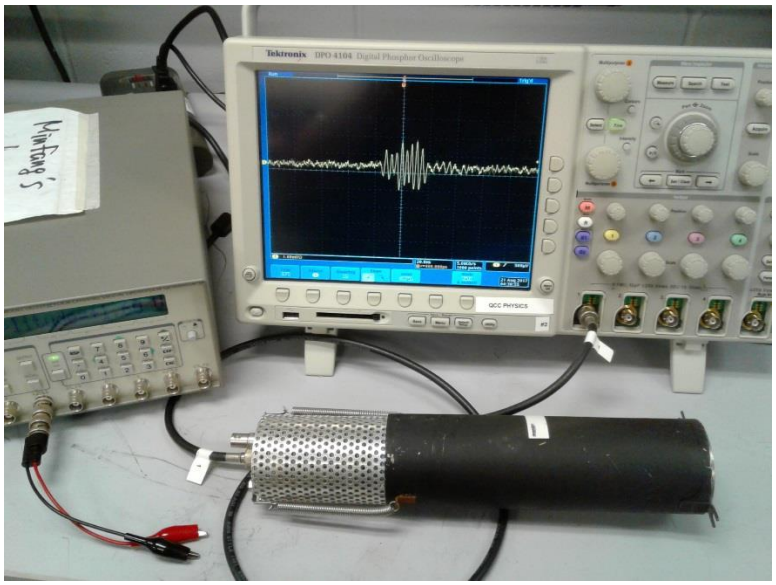


Figure 2 RF Noise generated by unshielded twisted cable pair is picked up by PMT and appears on PMT charge pulse. The unshielded cables were used to drive the flashing LED in testing PMT gain.

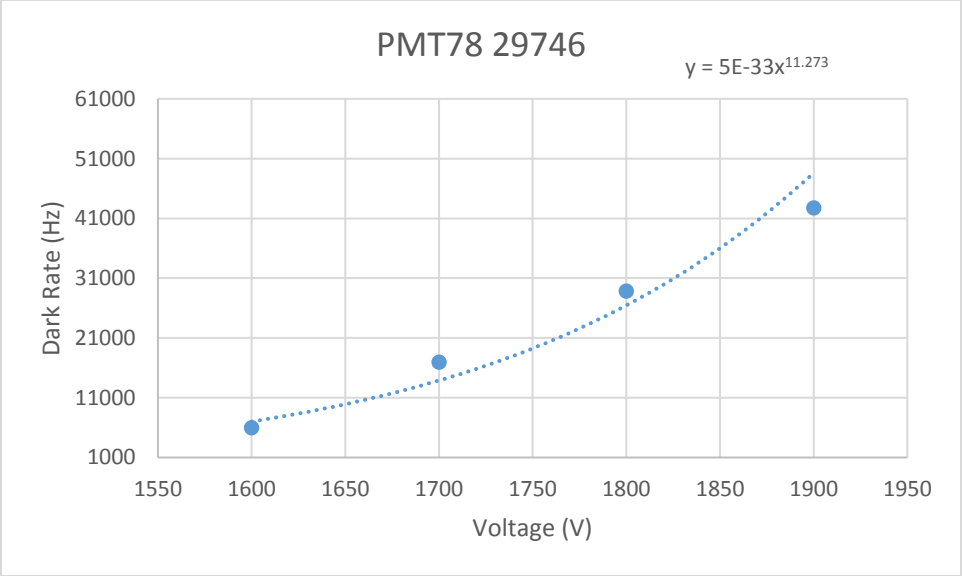
PMT's 78, 79, 80, and 82 (PMT 81 is bad, no signal, results are shown ahead)

PMT78-29746 CH1
PMT79-30222 CH2
PMT80-30212 CH3
PMT82-28736 CH4

PMT78 29746 CH1

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

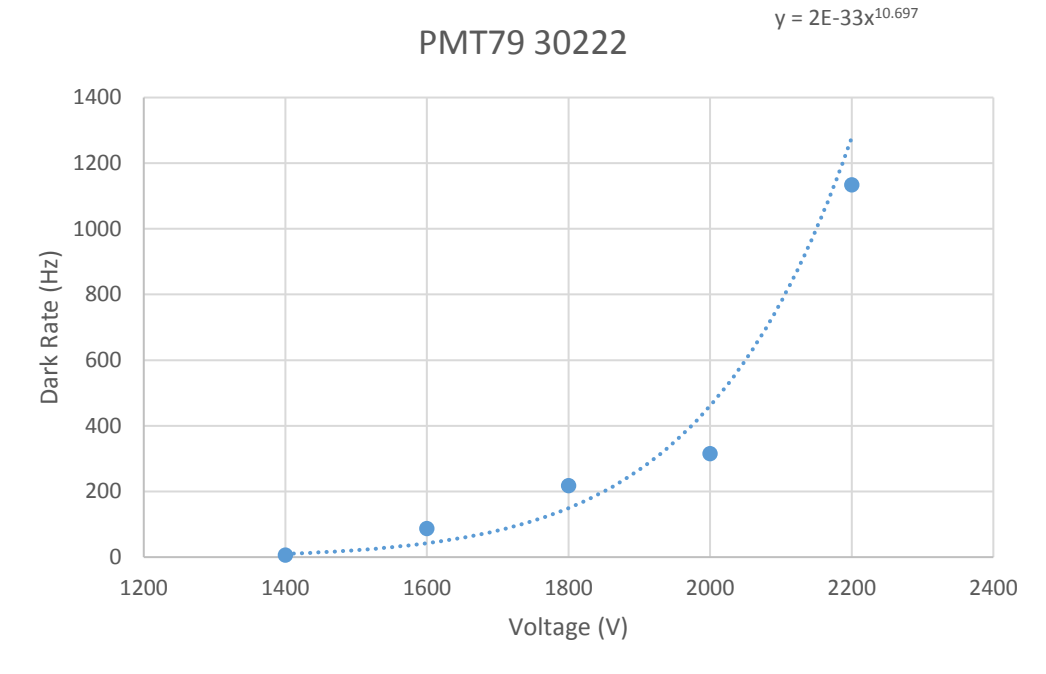
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1600	48126	47773	47770	48142	47986	5994.925
1700	136336	137210	135208	134884	134268	16947.65
1800	231570	229306	230628	230420	231245	28829.23
1900	342898	344845	341742	339554	340262	42732.53



PMT79 30222 CH4 NEW

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

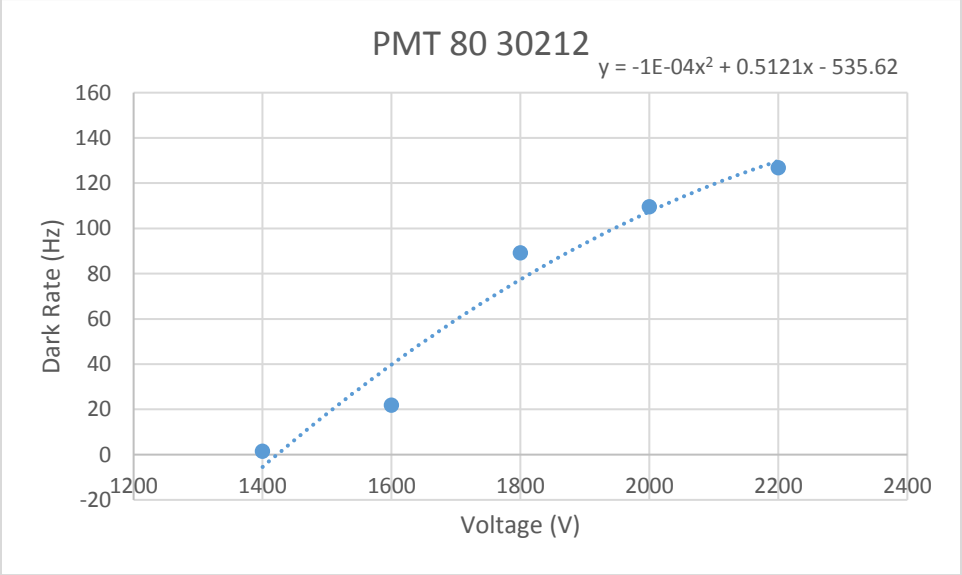
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1400	35	57	53	38	42	5.625
1600	685	678	665	743	700	86.775
1800	1716	1759	1818	1717	1707	217.925
2000	2470	2540	2590	2527	2475	315.05
2200	9141	9430	9035	8804	8934	1133.6



PMT80 30212 CH3 NEW

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

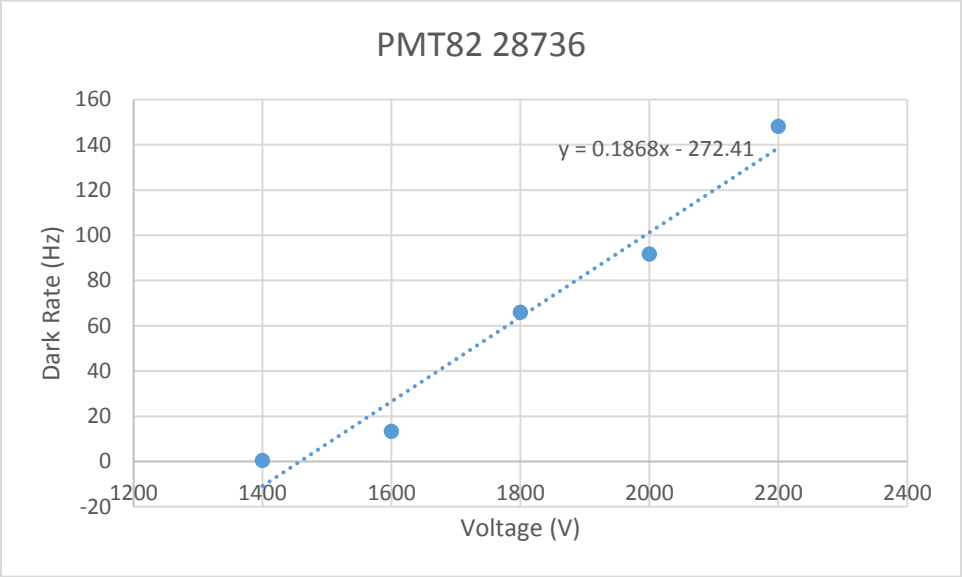
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1400	11	12	18	10	9	1.5
1600	187	174	164	197	156	21.95
1800	644	709	723	729	764	89.225
2000	877	899	876	892	838	109.55
2200	1027	1015	1036	1017	977	126.8



PMT82 28736 CH1 NEW

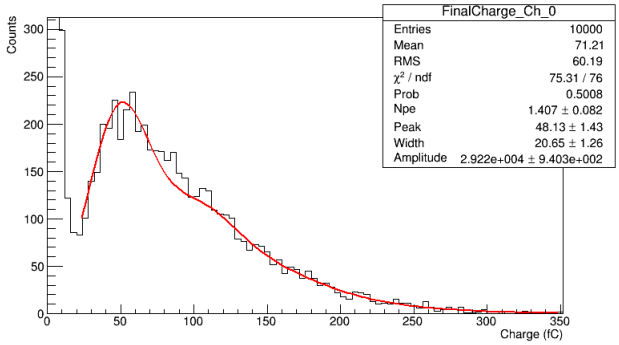
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

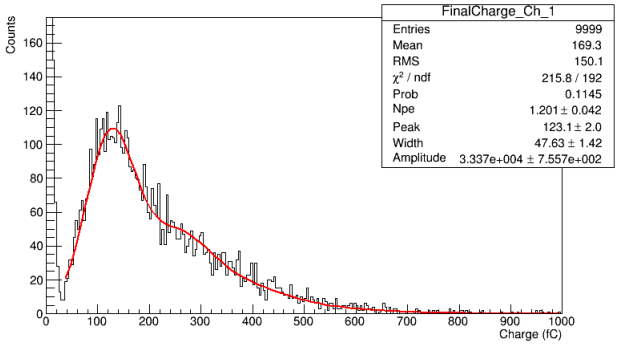
Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1400	4	5	4	5	1	0.475
1600	90	116	109	99	116	13.25
1800	486	540	567	529	514	65.9
2000	732	729	719	779	707	91.65
2200	1176	1212	1181	1231	1124	148.1

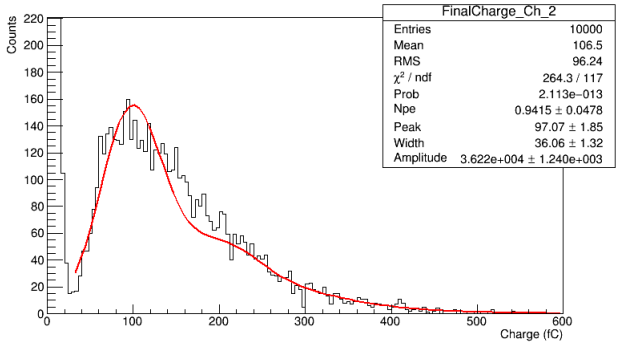


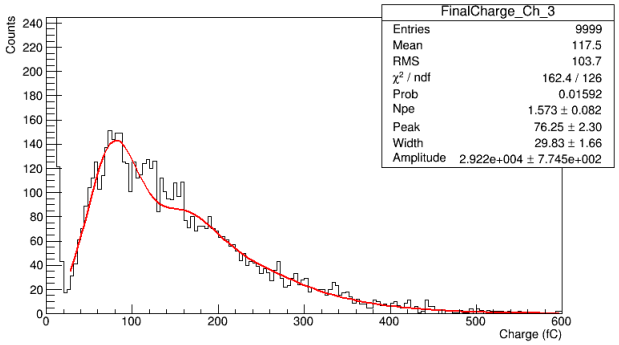
PMT78-29746 CH1
PMT79-30222 CH2
PMT80-30212 CH3
PMT82-28736 CH4

1400 V (measured on 20170804)

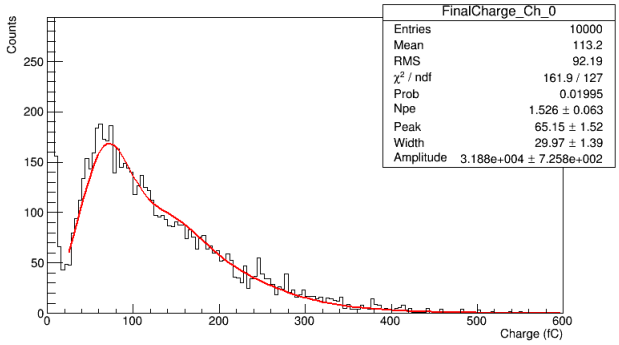


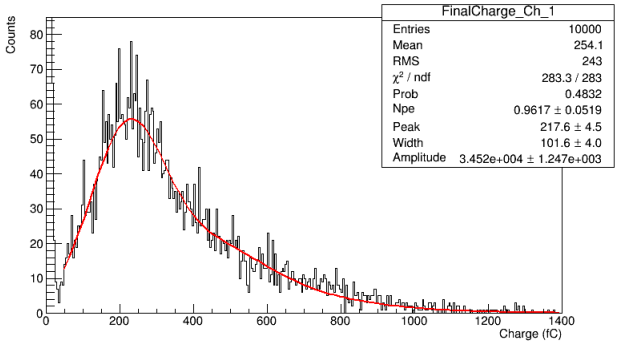


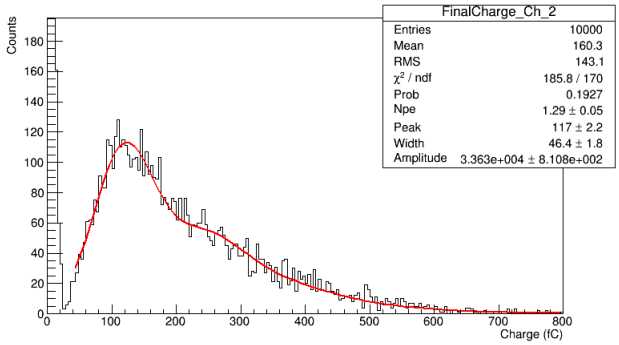


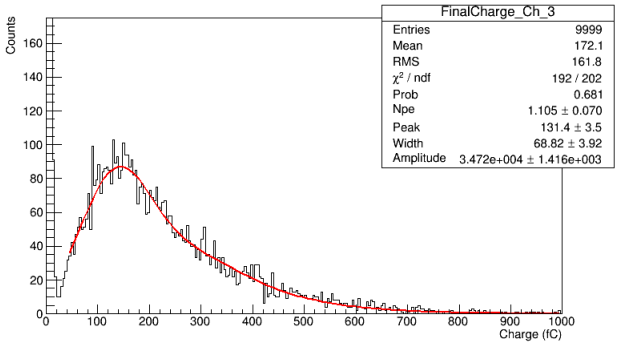


1500 V (measured on 20170804)

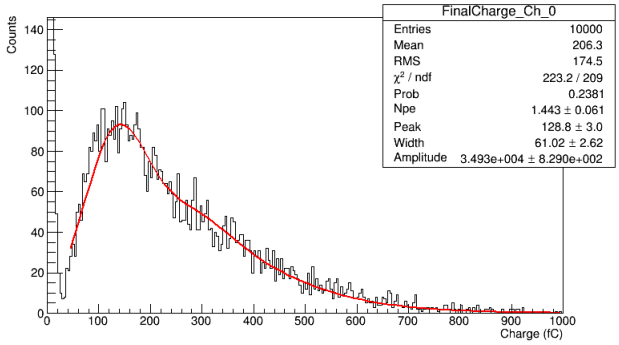


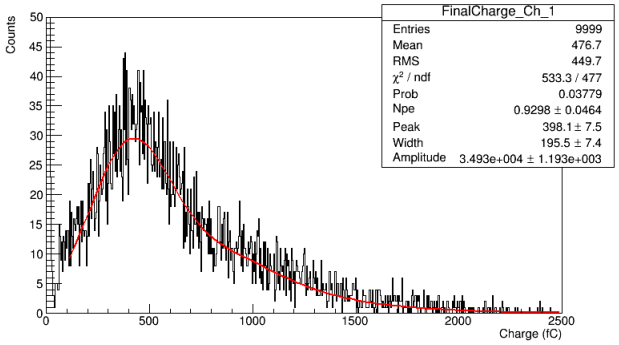


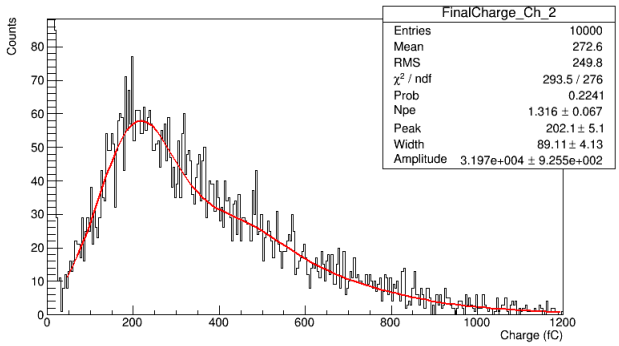


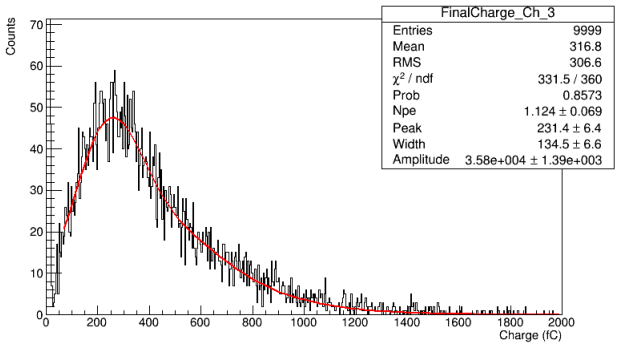


1600 V (measured on 20170804)

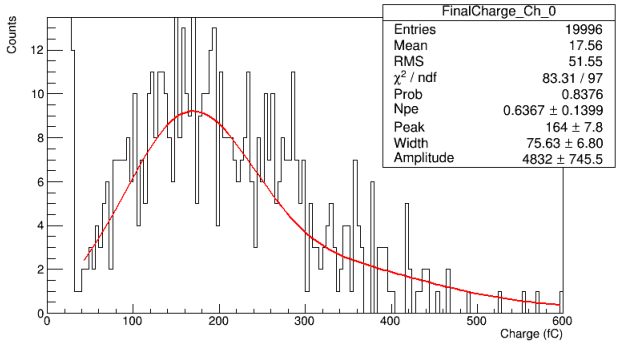


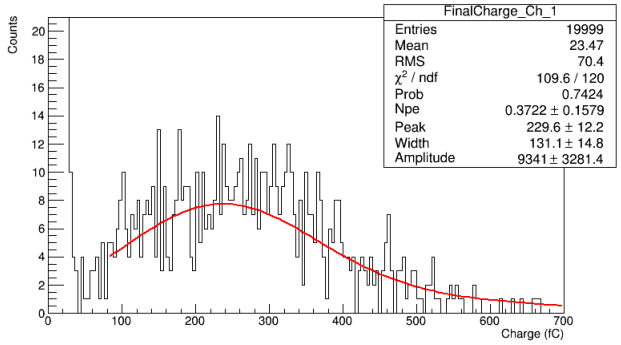


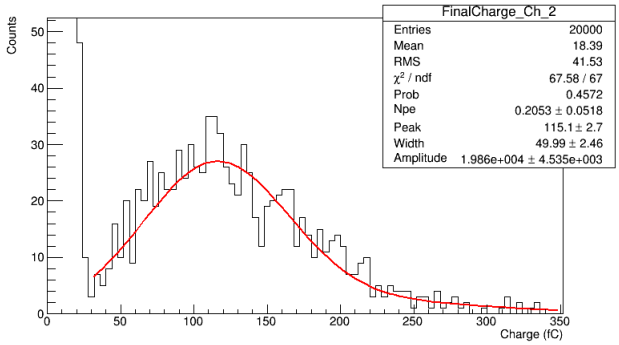


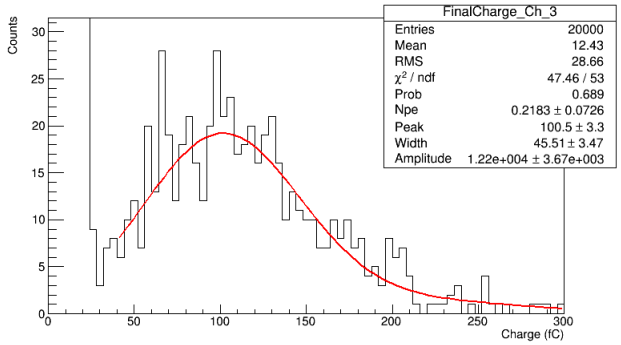


1600 V (measured on 20170721)

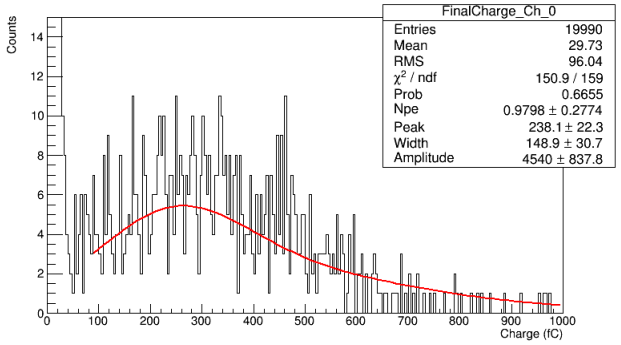


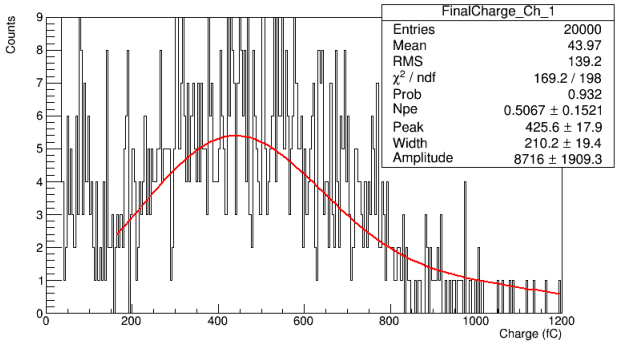


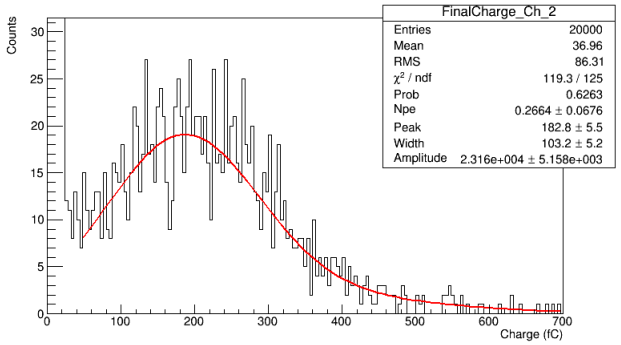


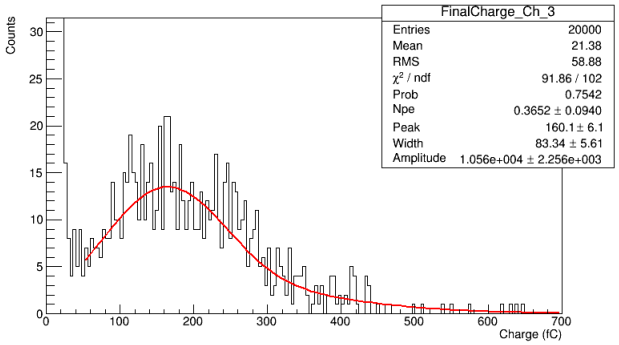


1700 V (measured on 20170721)

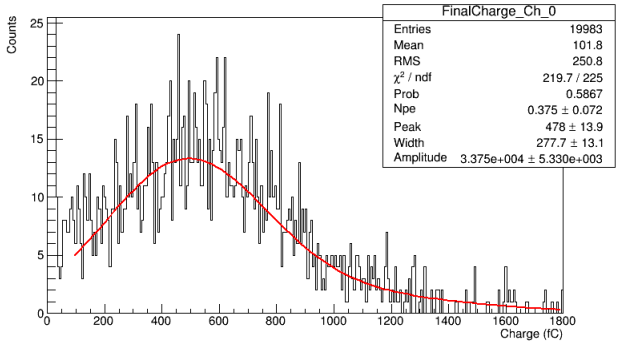


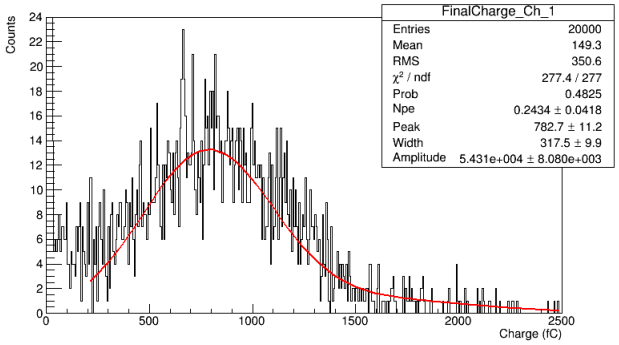


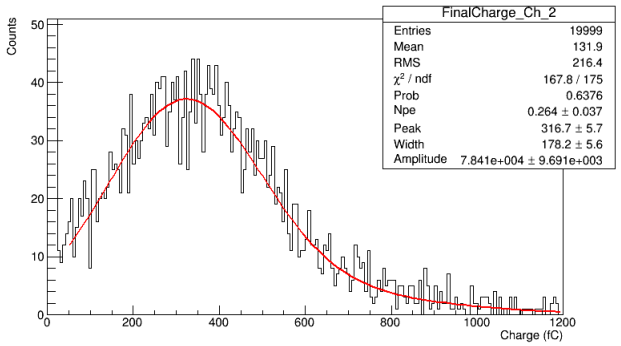


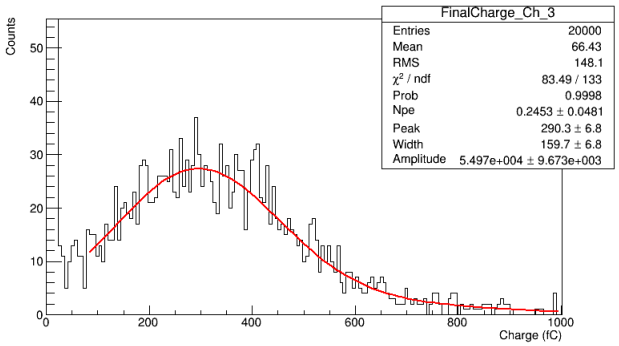


1800 V (measured on 20170721)



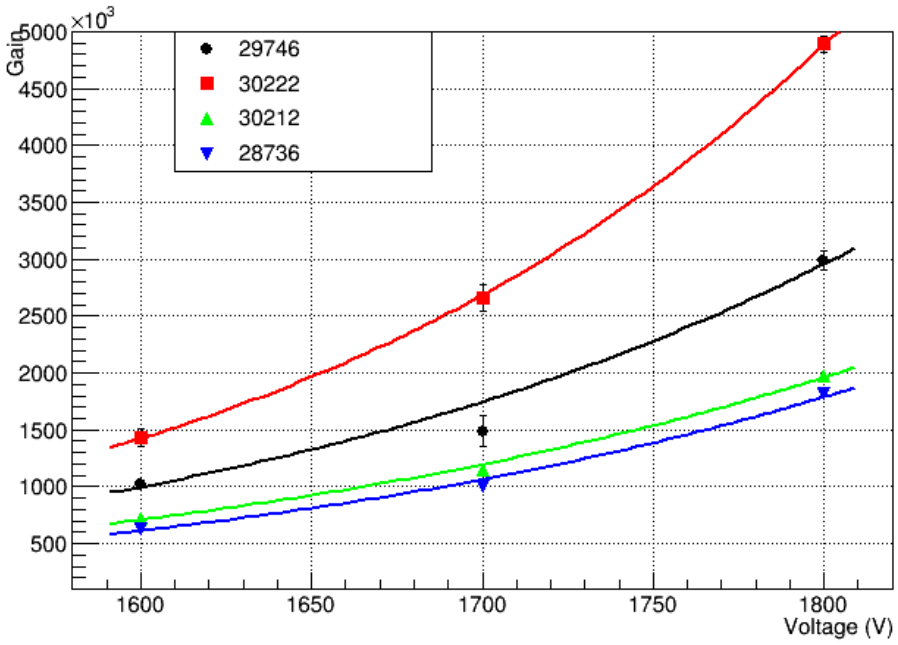




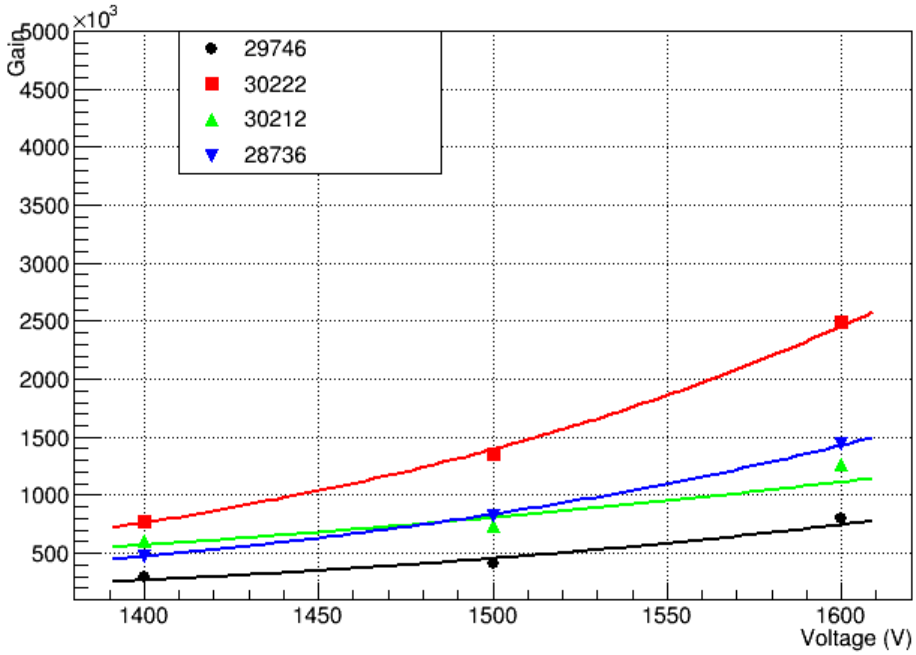


Gain curves (measured on 20170721)

PMT78-29746 CH1
PMT79-30222 CH2
PMT80-30212 CH3
PMT82-28736 CH4



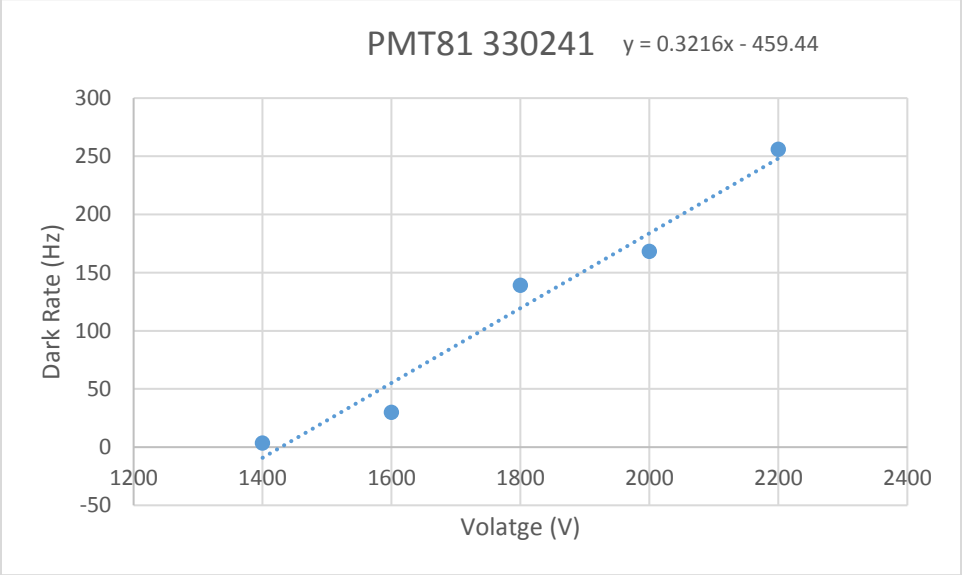
Gain curves (measured on 20170721)



PMT81 – 30241, Ch_3: PMT is bad, no signal (measured on 20170703)

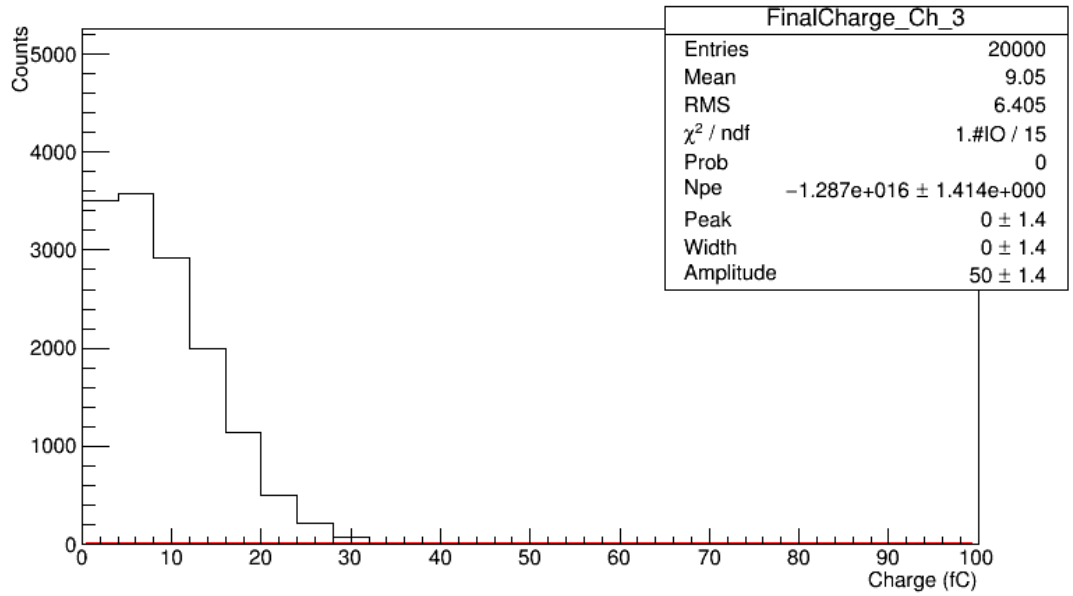
PMT81 330241
CH2
Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	count 1	count 2	count 3	count 4	count 5	rate (Hz)
1400	31	29	24	29	34	3.675
1600	238	231	213	245	275	30.05
1800	1125	1118	1122	1118	1083	139.15
2000	1414	1309	1334	1360	1323	168.5
2200	2079	2048	2135	1987	1994	256.075

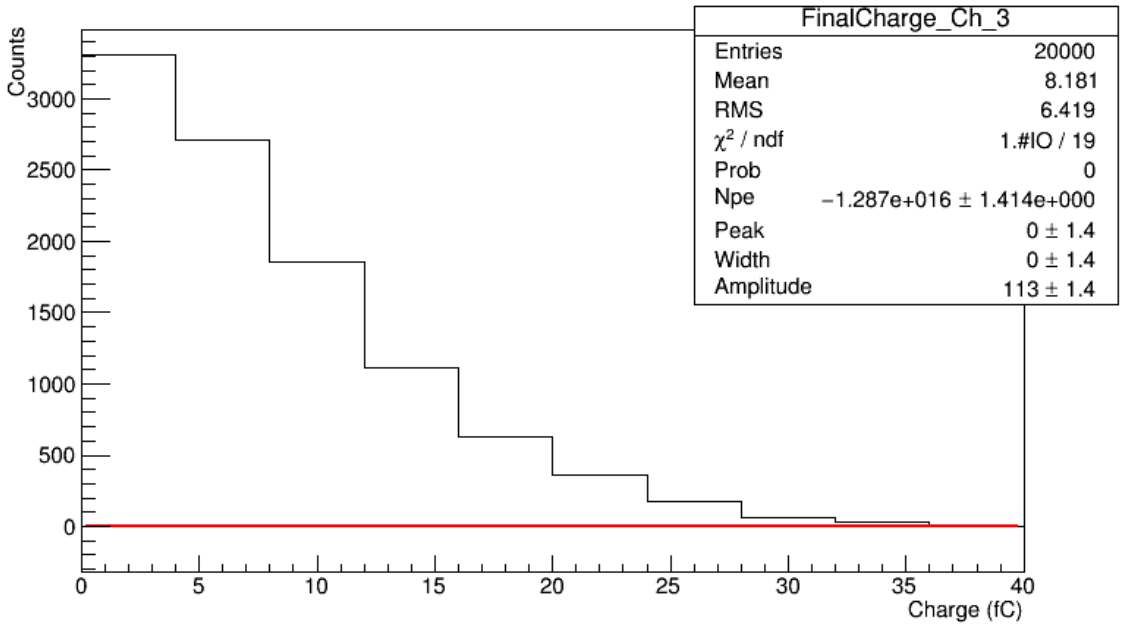


PMT81 – 30241

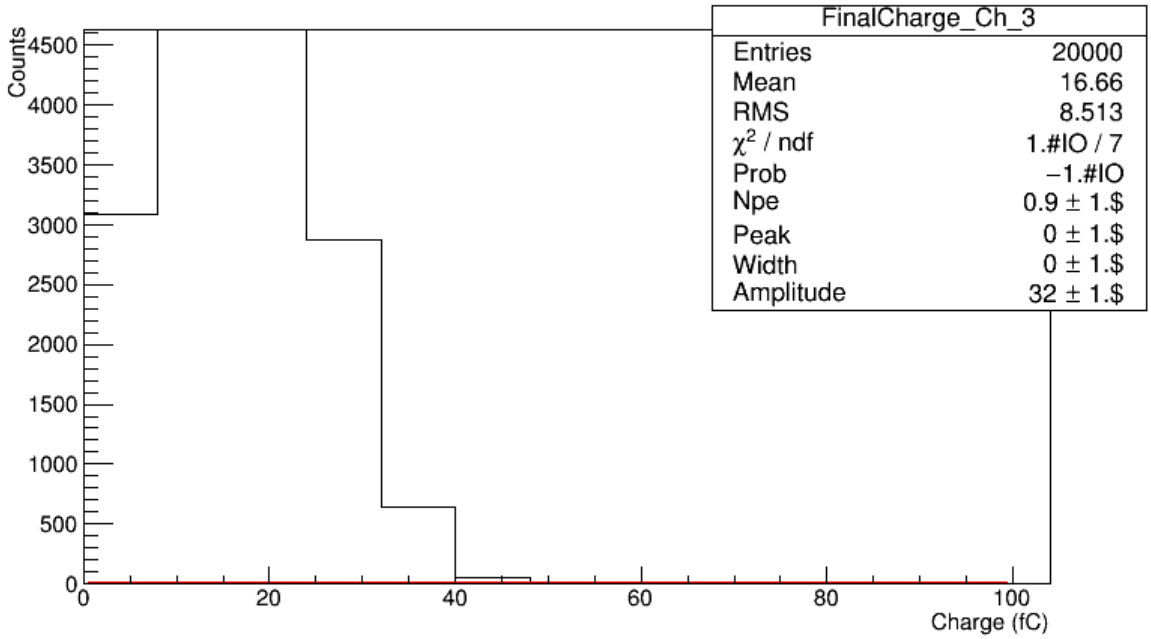
1600V



1700V



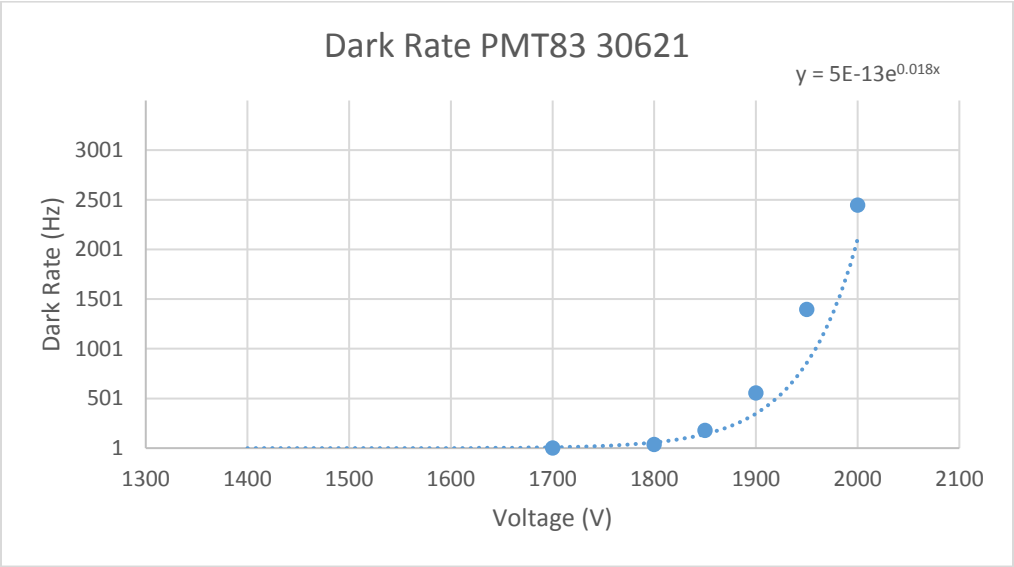
2000V


FinalCharge_Ch_3
Entries 20000
Mean 16.66
RMS 8.513
χ2 / ndf 1.#IO / 7
Prob −1.#IO
Npe 0.9 ± 1.$
Peak 0 ± 1.$
Width 0 ± 1.$
Amplitude 32 ± 1.$
Counts
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
20
40
60
80
100
Charge (fC)

PMT's 83, 84, 85, and 86

PMT83 30621 has a rattle noise inside its base

Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	2	2	0	0	0	0.1
1700	20	8	14	16	13	1.775
1800	289	291	305	302	281	36.7
1850	1485	1341	1395	1451	1457	178.225
1900	4408	4528	4516	4422	4306	554.5
1950	11084	11297	11238	11068	11098	1394.625
2000	19937	19785	19255	19384	19445	2445.15



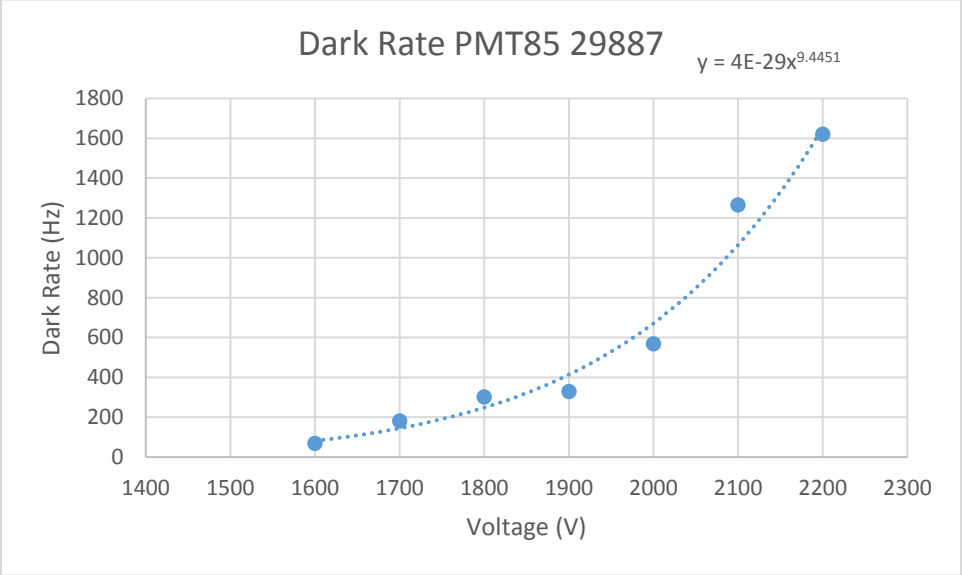
PMT84 31245 is bad:

it shorts out other tubes if all connected to NIM power rack and o-scope; it makes a clicking noise when HV about 1450V

PMT85 29887

Makes noise floor on oscilloscope drop about 2mV

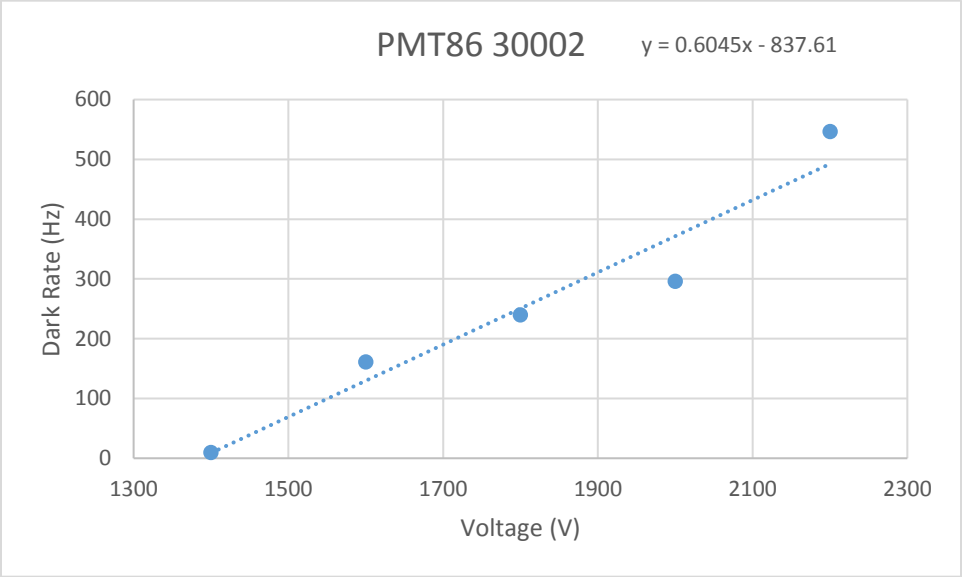
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	48	35	39	49	44	5.375
1500						#DIV/0!
1600	560	523	571	542	545	68.525
1700	1387	1489	1419	1523	1456	181.85
1800	2451	2274	2357	2436	2536	301.35
1900	2534	2461	2648	2676	2823	328.55
2000	4580	4574	4749	4333	4513	568.725
2100	11913	10397	8995	9041	10242	1264.7
2200	13769	13595	12331	11334	13779	1620.2



PMT86 30002 CH1 NEW

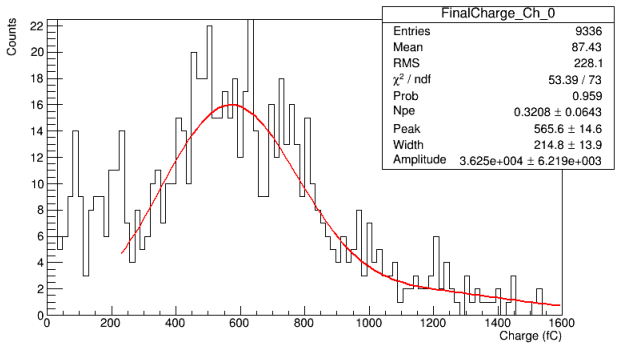
Dark Count in 8 seconds

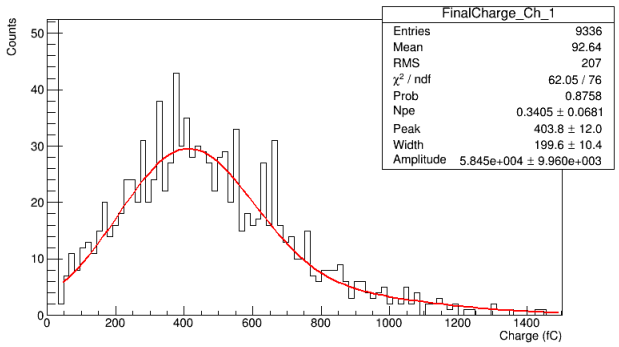
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	77	81	77	78	69	9.55
1600	1313	1311	1289	1217	1310	161
1800	1865	1955	1905	2011	1852	239.7
2000	2416	2346	2403	2325	2347	295.925
2200	3556	4460	4625	4546	4678	546.625

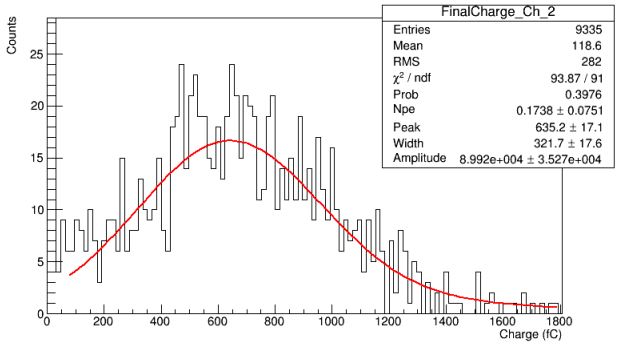


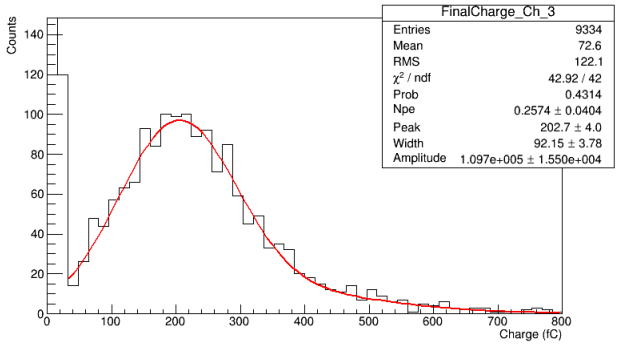
PMT83 30621 CH1
PMT84 31245 CH2
PMT85 29882 CH3
PMT86 30002 CH4

1700V (measured on 20170726, run4)

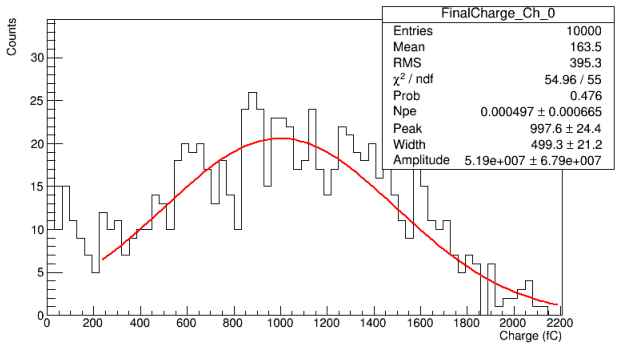


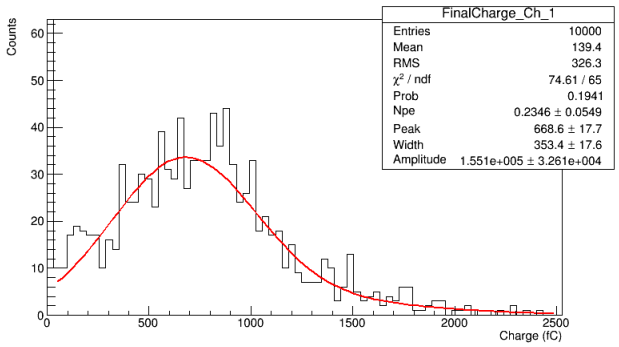


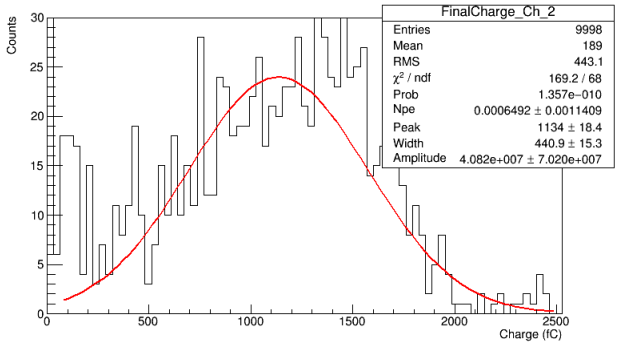


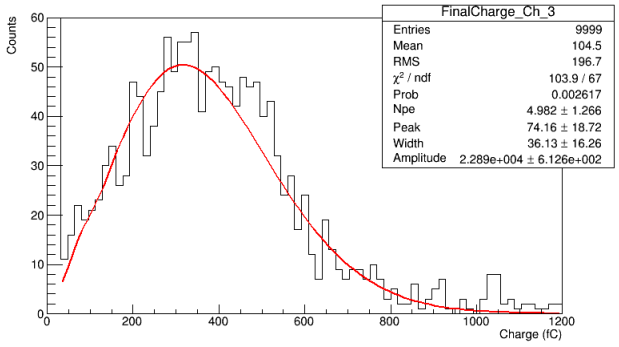


1800V (measured on 20170726, run4)

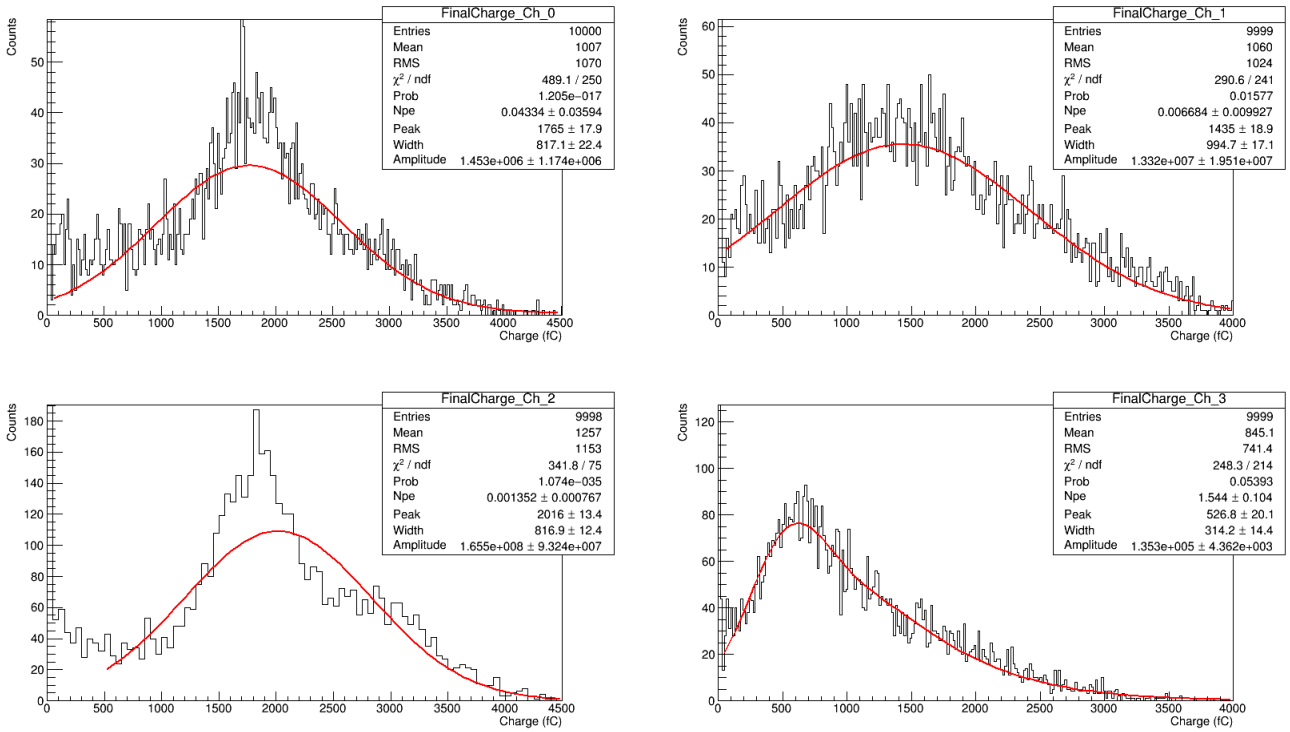




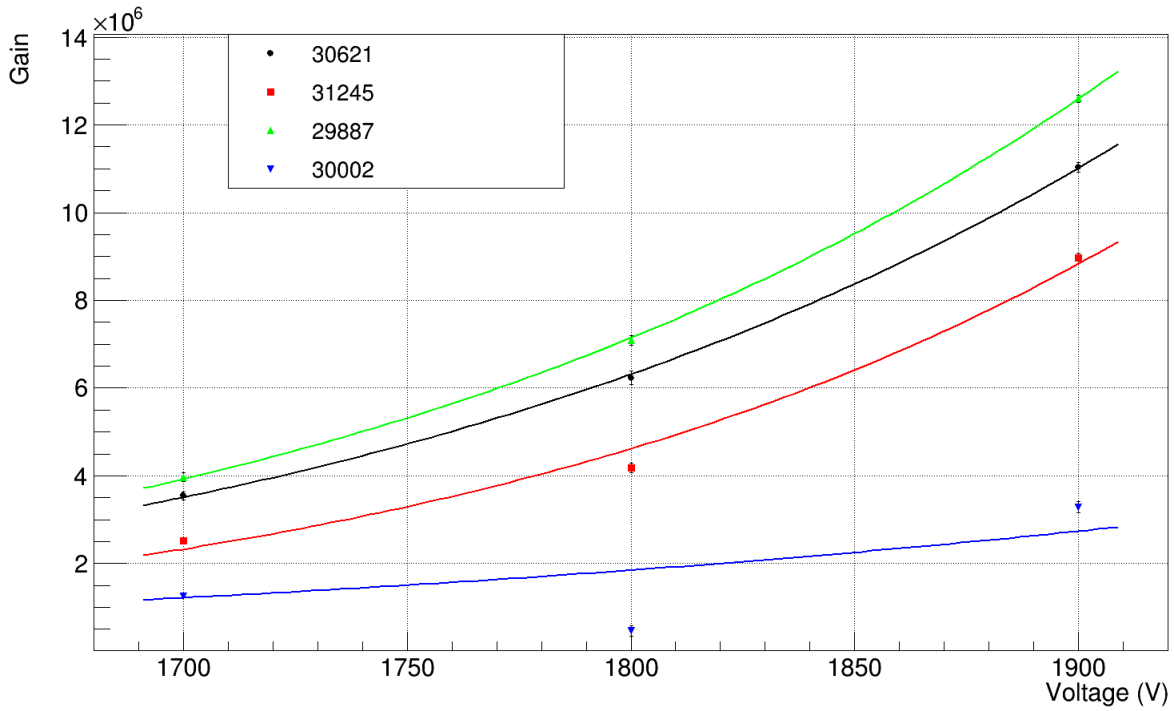




1900V (measured on 20170726, run4)



Gain Curves (measured on 20170726, run4)

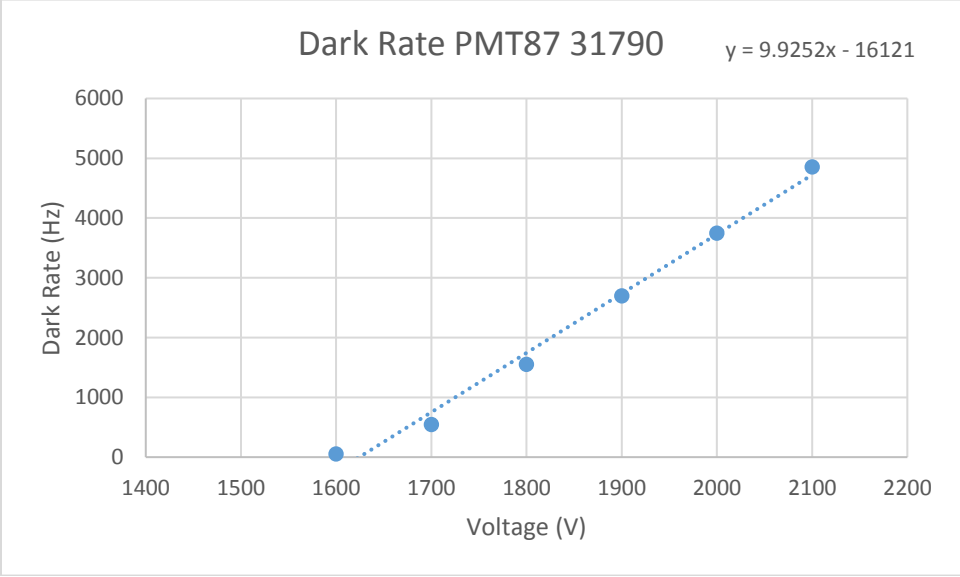


PMTs 87 – 90.
PMTs 87 and 88 are bad.

CH1 PMT87 31790
CH2 PMT88 32018
CH3 PMT89 34996
CH4 PMT90 29787

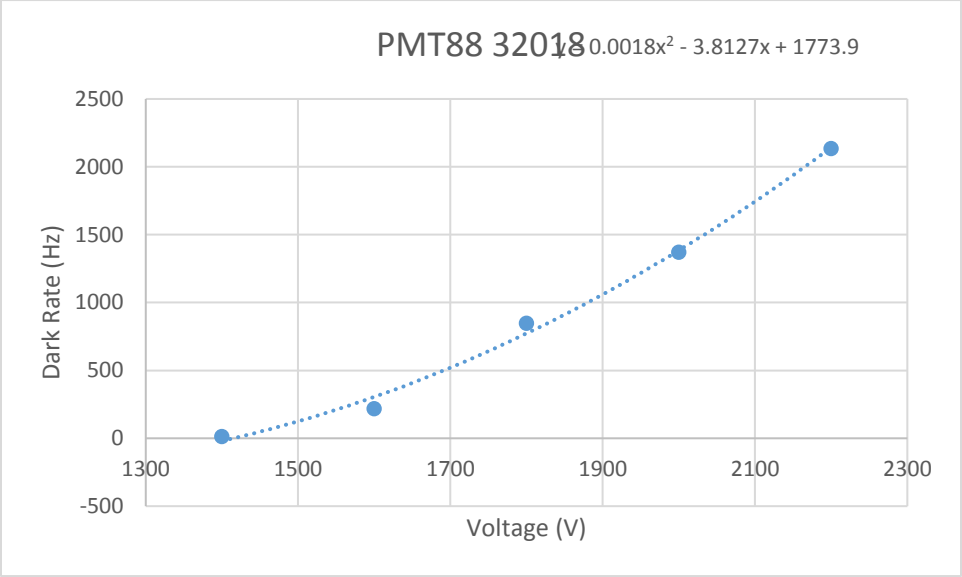
PMT87 31790 Bad, no gain

Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400						#DIV/0!
1500						#DIV/0!
1600	416	411	429	463	427	53.65
1700	4356	4312	4286	4441	4416	545.275
1800	12680	12390	12481	12359	12199	1552.725
1900	21730	21657	21610	21581	21147	2693.125
2000	29715	30195	29764	30174	29842	3742.25
2100	39115	38868	39168	38560	38490	4855.025



PMT88 32018 Bad, no gain

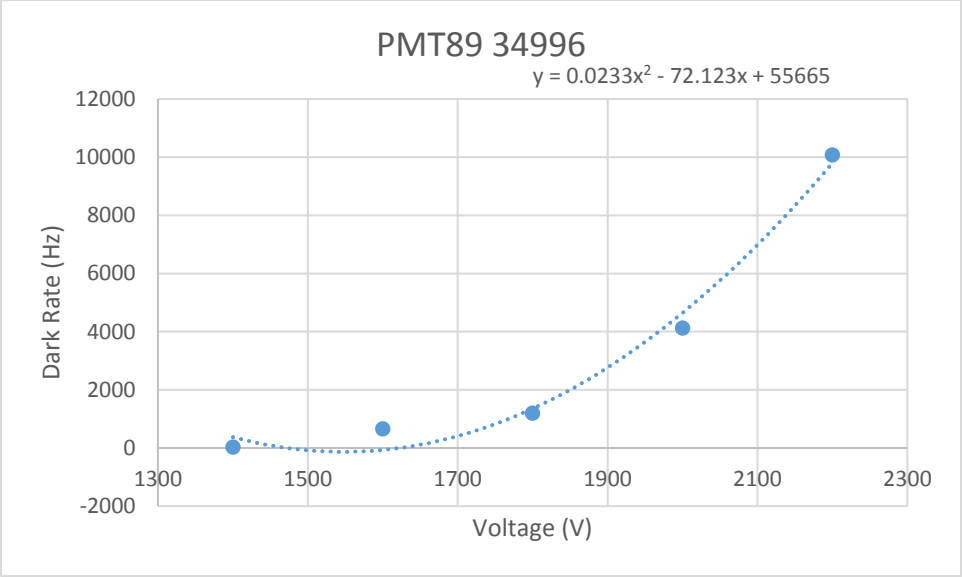
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average (Hz)
1400	101	109	80	111	110	12.775
1600	1736	1814	1704	1733	1709	217.4
1800	6814	6776	6899	6696	6709	847.35
2000	11029	11163	10804	10906	10949	1371.275
2200	17240	17210	16981	17021	16965	2135.425



PMT89 34996 CH3

Dark Count in 8 seconds

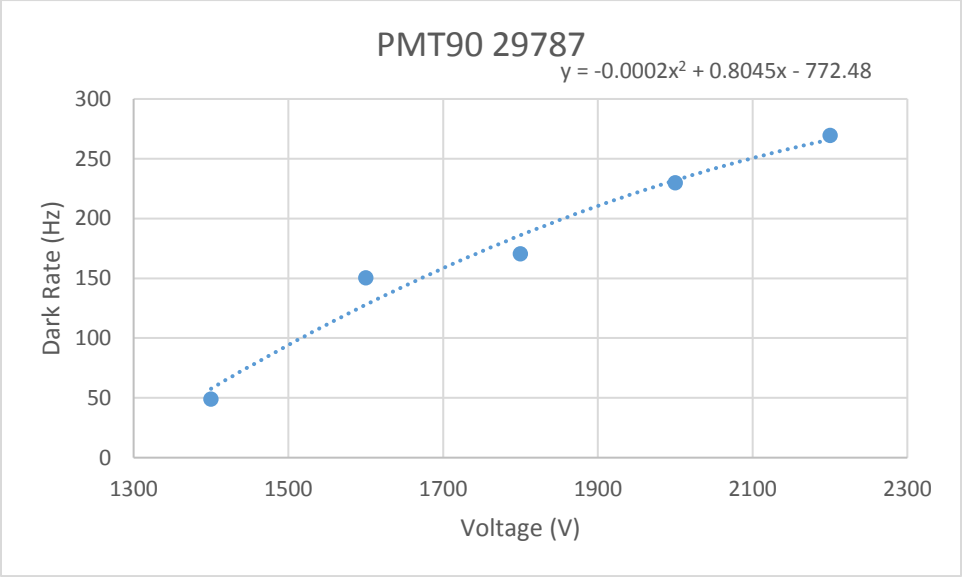
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average
1400	299	261	257	295	301	35.325
1600	5166	5357	5227	5195	5517	661.55
1800	9660	9579	9517	9530	9565	1196.275
2000	31061	34217	32547	33842	33443	4127.75
2200	82361	80845	81863	78101	80082	10081.3



PMT90 29787 CH4 NEW

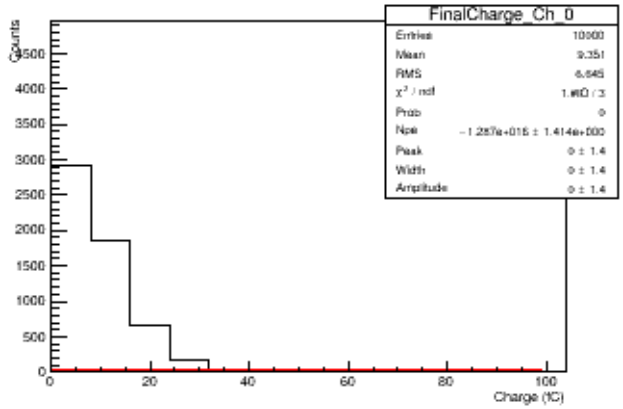
Dark Count in 8 seconds

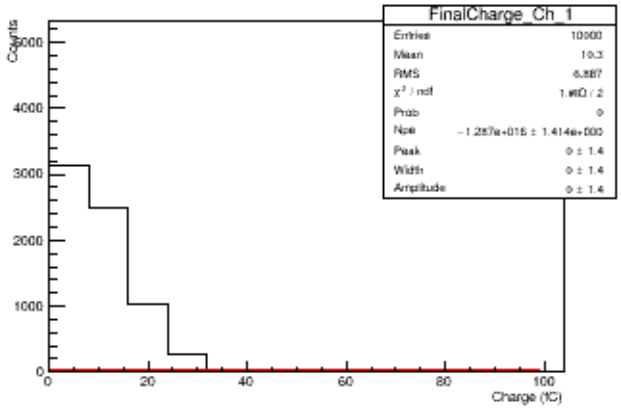
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average
1400	378	416	346	409	407	48.9
1600	1200	1244	1147	1161	1262	150.35
1800	1411	1341	1332	1317	1423	170.6
2000	1962	1932	1850	1738	1717	229.975
2200	2073	2162	2184	2186	2177	269.55

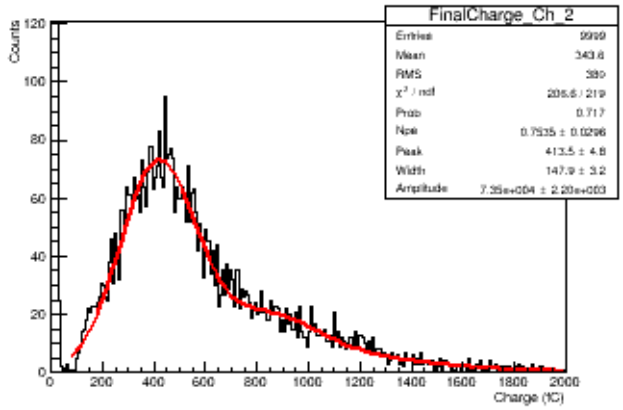


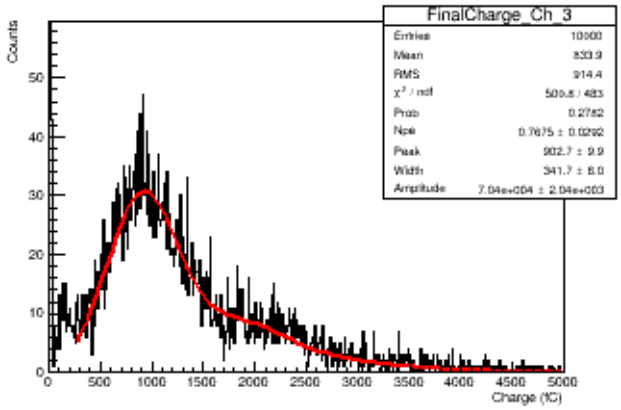
CH1 PMT87 31790
CH2 PMT88 32018
CH3 PMT89 34996
CH4 PMT90 29787

1700V (measured on 20170803)

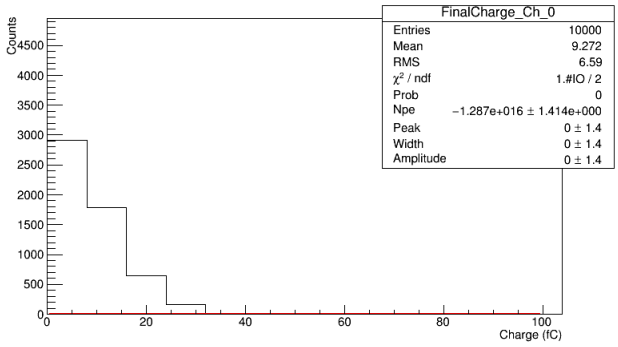


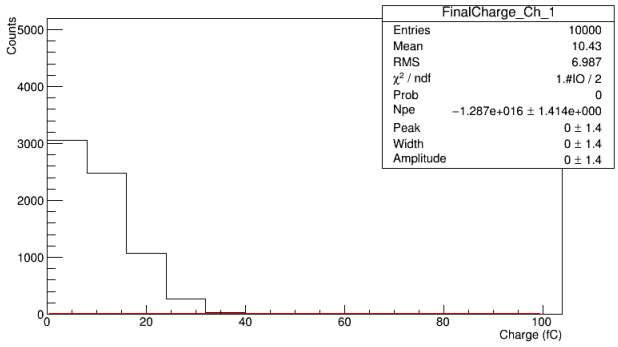


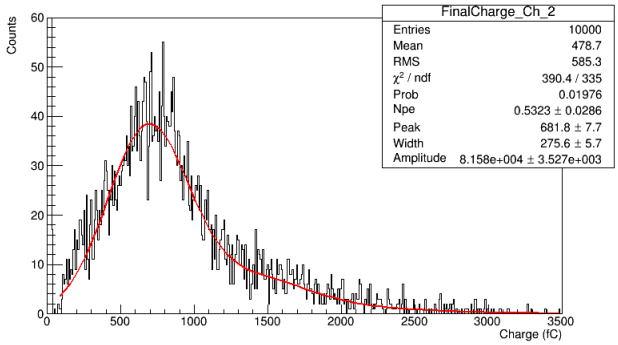


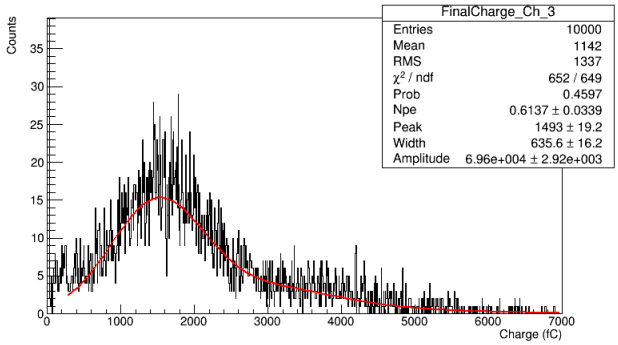


1800V (measured on 20170803)

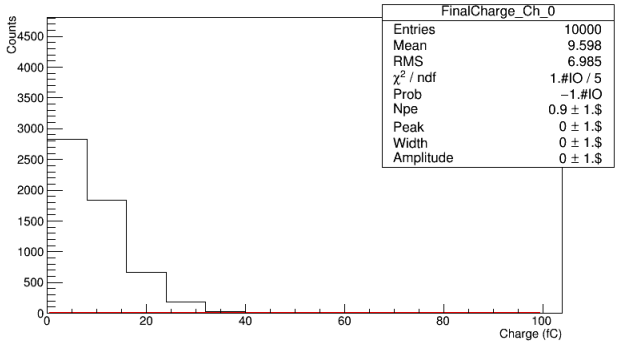


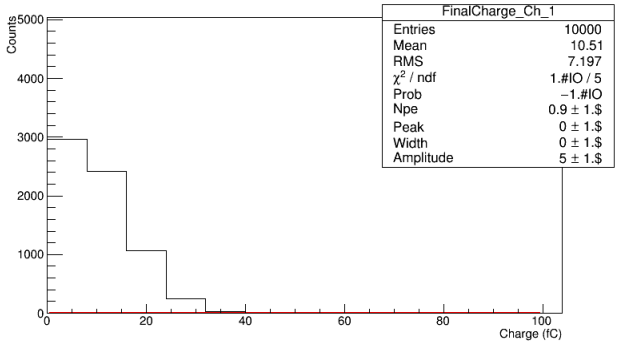


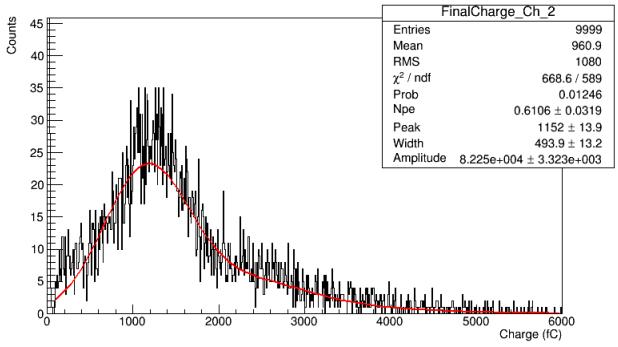


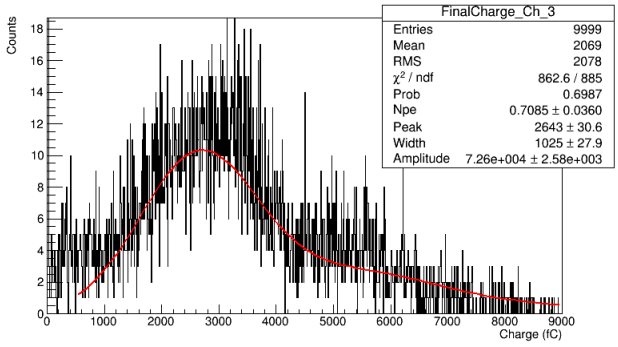


1900V (measured on 20170803)



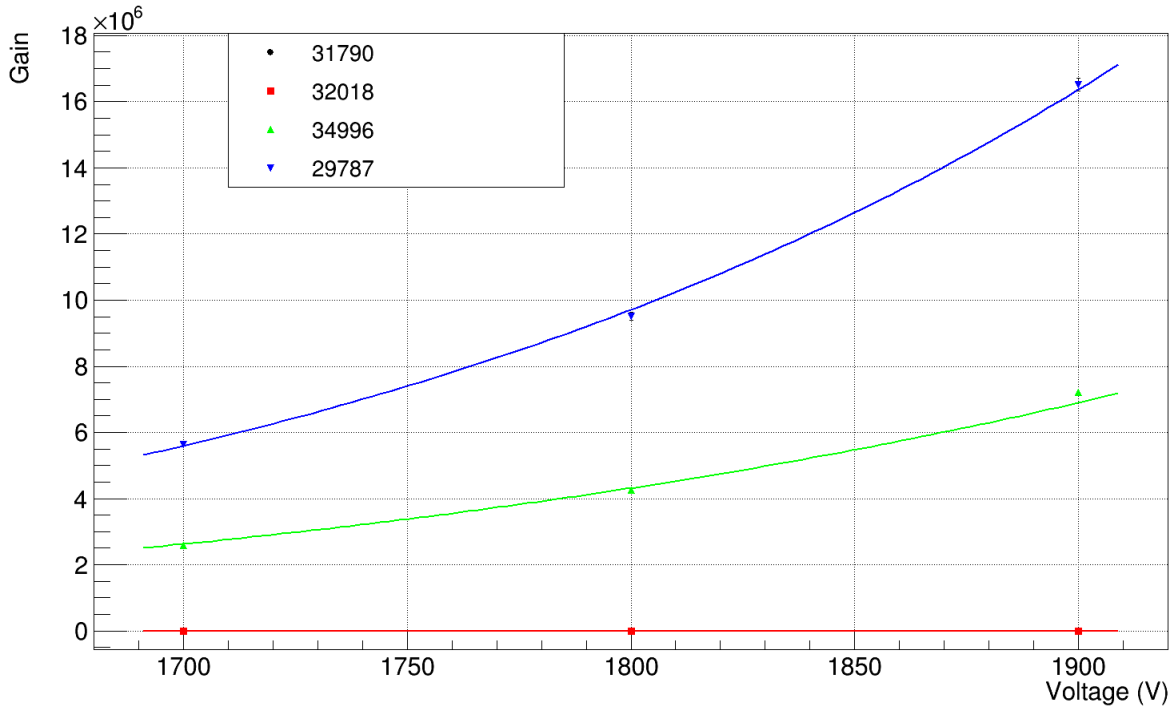






Gain Curves (measured on 20170803)

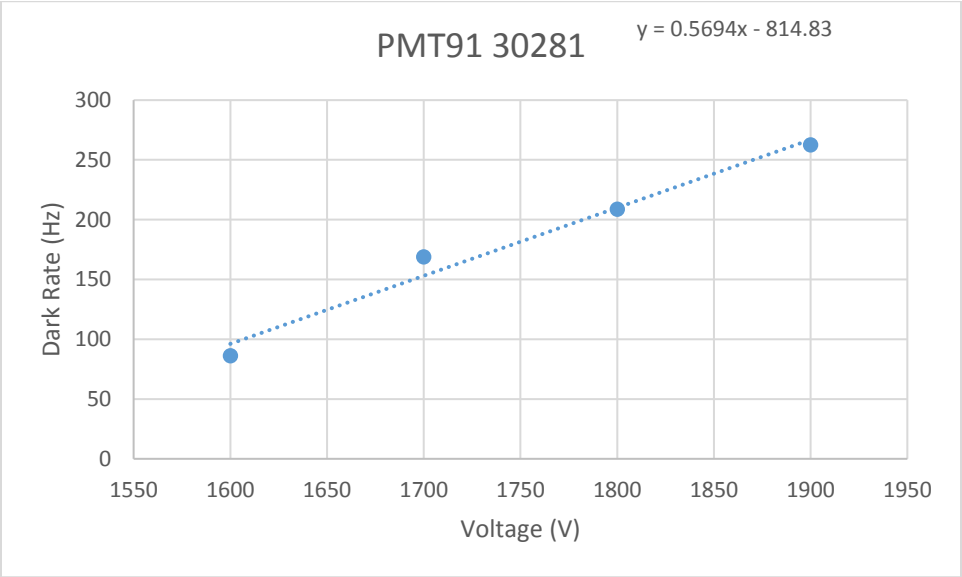
CH1 PMT87 31790
CH2 PMT88 32018
CH3 PMT89 34996
CH4 PMT90 29787



PMT91 30281

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

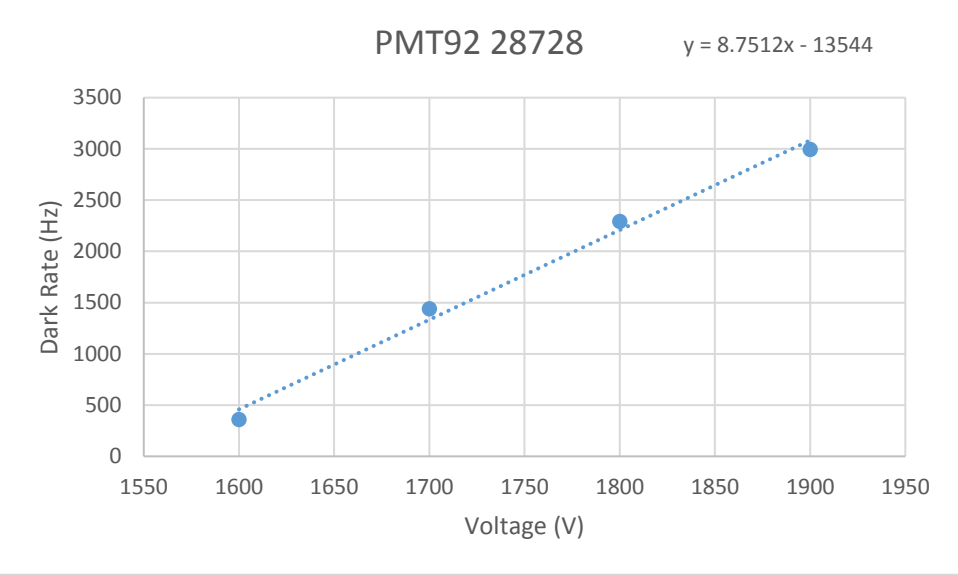
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average (Hz)
1400	56	69	48	45	60	6.95
1500	89	136	123	100	125	14.325
1600	733	753	667	641	650	86.1
1700	1309	1326	1354	1361	1401	168.775
1800	1791	1679	1680	1622	1576	208.7
1900	2127	2112	2109	2076	2079	262.575



PMT92 28728

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

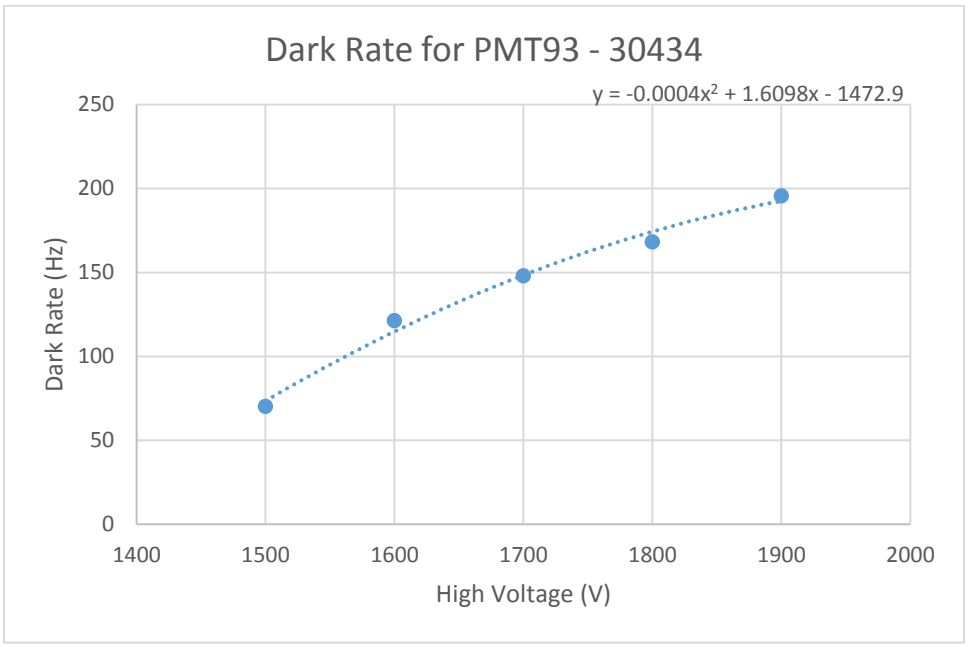
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average (Hz)
1400	20	17	18	14	15	2.1
1500	99	107	92	94	102	12.35
1600	2880	2826	2856	2877	2966	360.125
1700	11541	11720	11234	11403	11624	1438.05
1800	18519	18490	18231	18358	18066	2291.6
1900	23997	23892	24109	23973	23736	2992.675



PMT93 30434

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average (Hz)
1400	139	143	116	120	134	16.3
1500	507	597	550	603	553	70.25
1600	973	981	931	1027	944	121.4
1700	1160	1147	1124	1243	1250	148.1
1800	1377	1310	1358	1410	1276	168.275
1900	1616	1581	1523	1593	1514	195.675

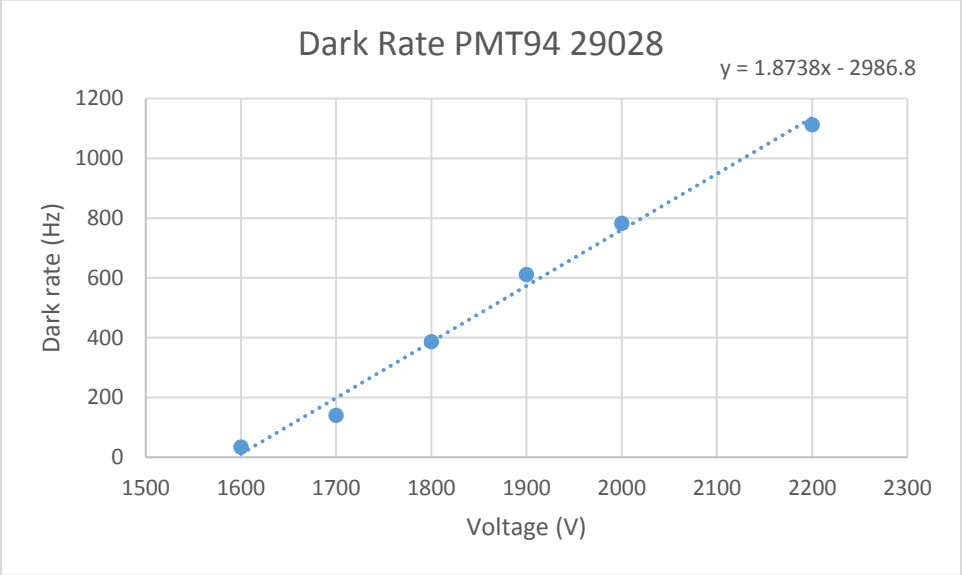


PMT94 29028

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Rechecked by Raul

Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average (Hz)
1400	22	8	20	26	16	2.3
						#DIV/0!
1600	264	275	281	251	290	34.025
1700	1044	1118	1194	1097	1137	139.75
1800	3107	3166	3029	3050	3111	386.575
1900	4867	4950	4810	4881	4921	610.725
2000	6425	6404	6177	6074	6228	782.7
2200	8864	8799	9010	8958	8845	1111.9

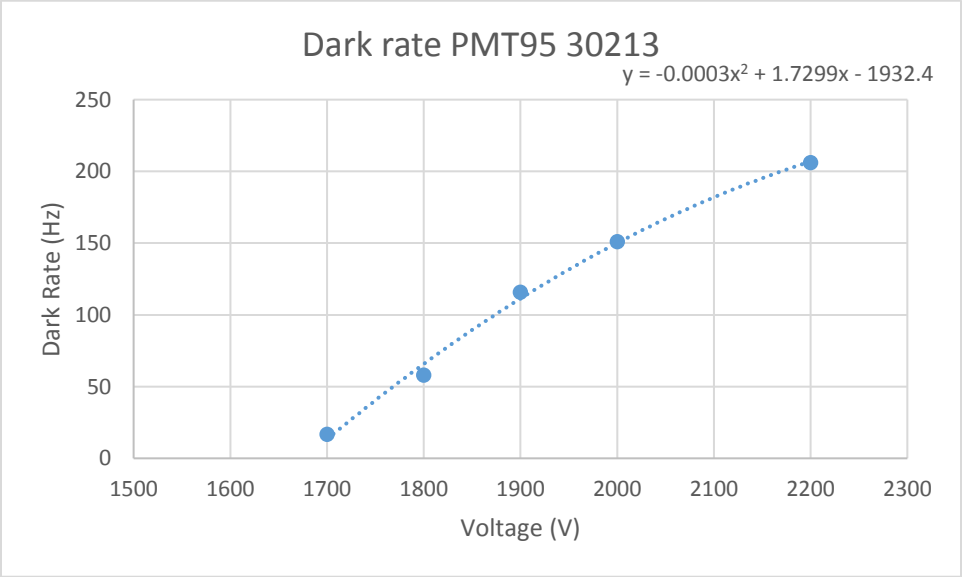


PMT95 30213

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Rechecked by Raul

Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average (Hz)
1400	1	1	1	3	1	0.175
1500	15	11	13	11	8	1.45
1600						#DIV/0!
1700	135	127	134	138	130	16.6
1800	460	450	458	482	472	58.05
1900	958	889	920	940	918	115.625
2000	1270	1285	1128	1235	1122	151
2200	1671	1705	1555	1652	1662	206.125

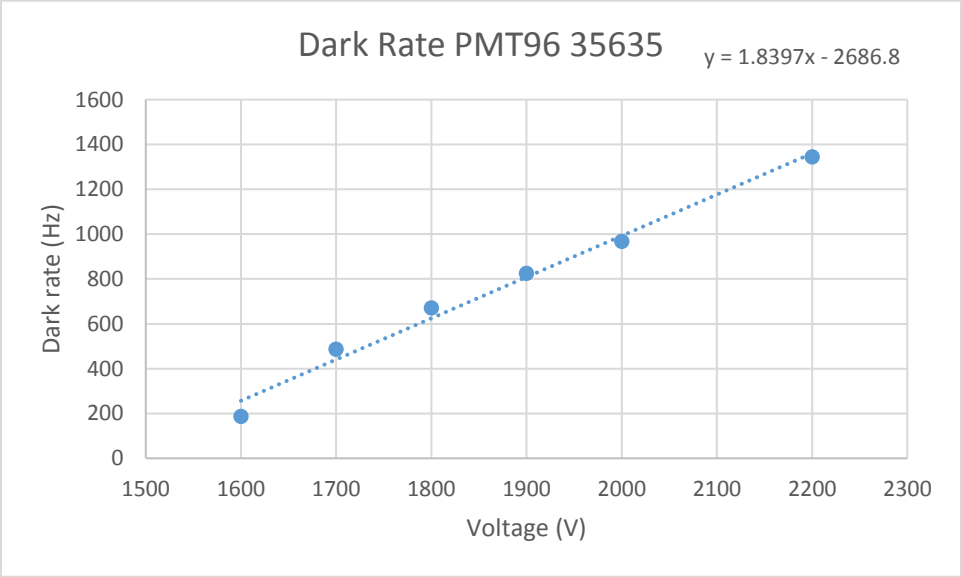


PMT96 35635

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Rechecked by Raul

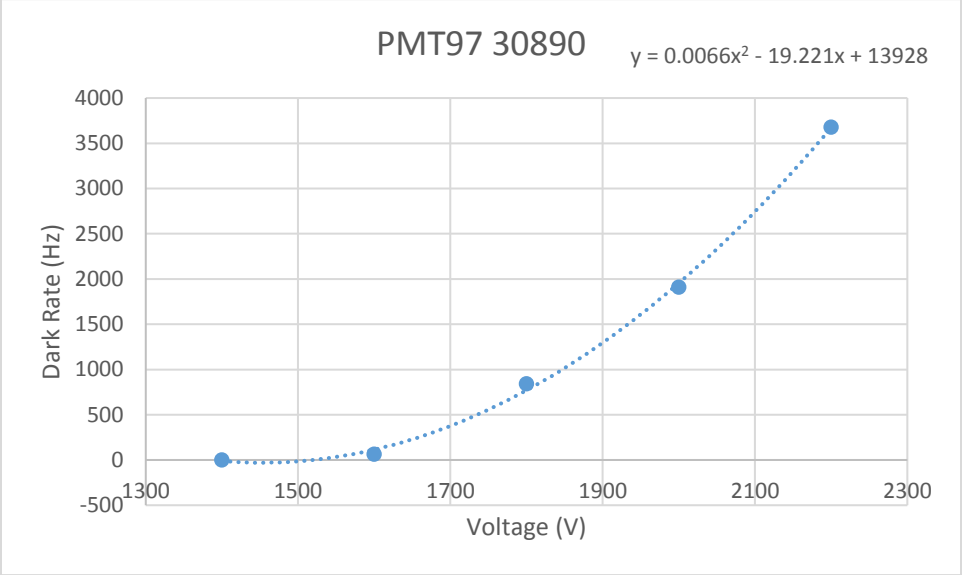
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Average (Hz)
1400						#DIV/0!
1500						#DIV/0!
1600	1439	1554	1486	1506	1474	186.475
1700	3917	3824	3899	3912	3936	487.2
1800	5390	5282	5351	5492	5343	671.45
1900	6594	6567	6474	6541	6832	825.2
2000	7727	7761	7766	7729	7746	968.225
2200	10074	10856	10790	11102	10979	1345.025



PMT97 30890

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

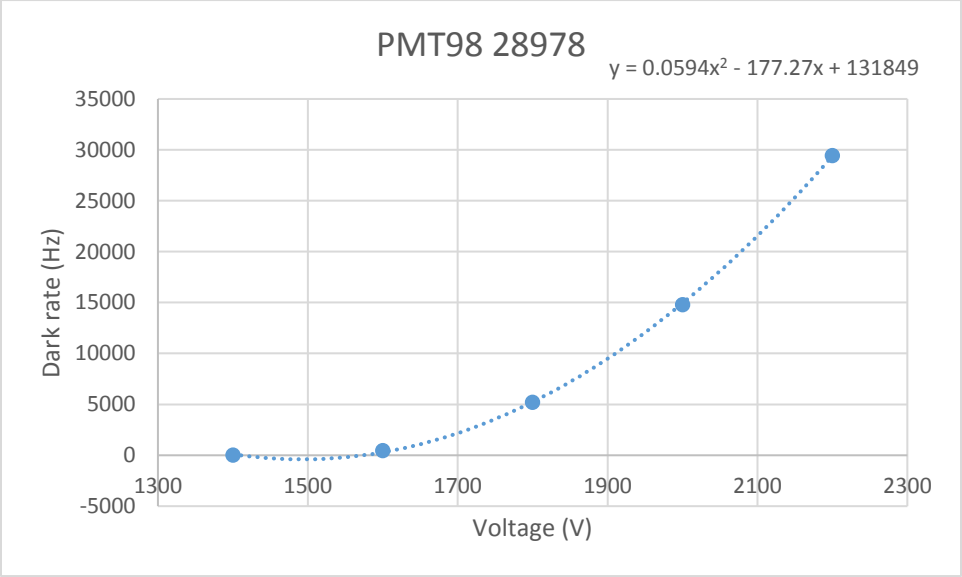
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	17	10	14	21	14	1.9
1600	518	524	473	499	553	64.175
1800	6675	6609	6702	6727	6946	841.475
2000	15497	15232	15340	15050	15276	1909.875
2200	29294	29528	29578	29400	29374	3679.35



PMT98 28978

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

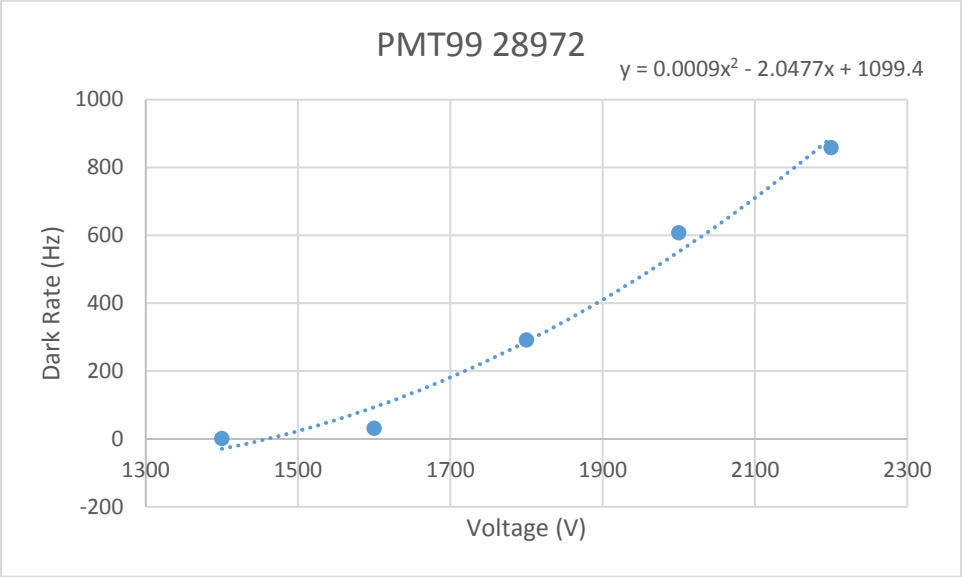
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	200	158	181	202	229	24.25
1600	3383	3736	4041	3980	3588	468.2
1800	41952	41052	42328	41760	41198	5207.25
2000	111120	120044	118954	121508	120364	14799.75
2200	231787	240144	237574	235009	233521	29450.88



PMT99 28972

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

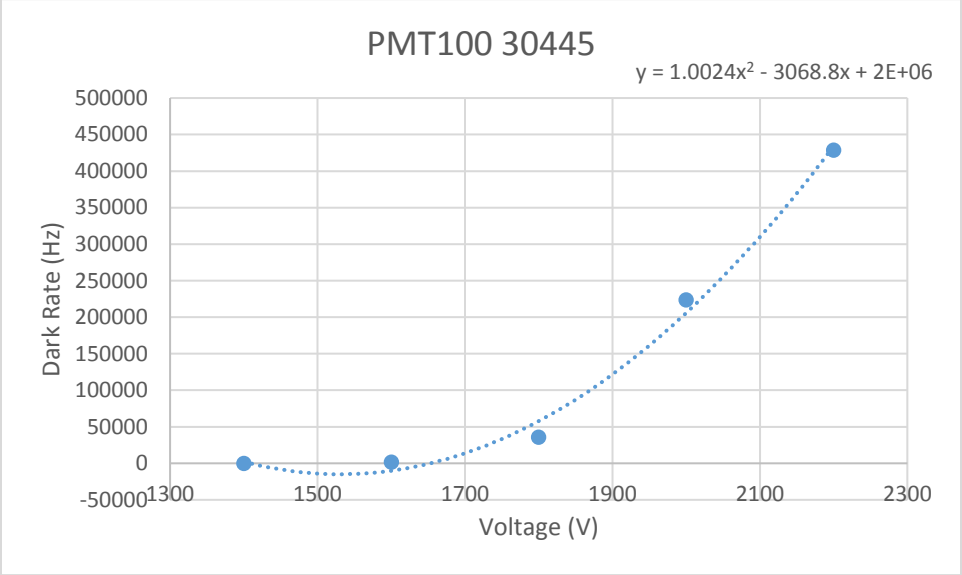
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	10	9	13	10	13	1.375
1600	247	240	263	226	275	31.275
1800	2328	2276	2310	2363	2405	292.05
2000	4876	4959	4763	4892	4814	607.6
2200	6941	6896	6838	6929	6734	858.45



PMT100 30445

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

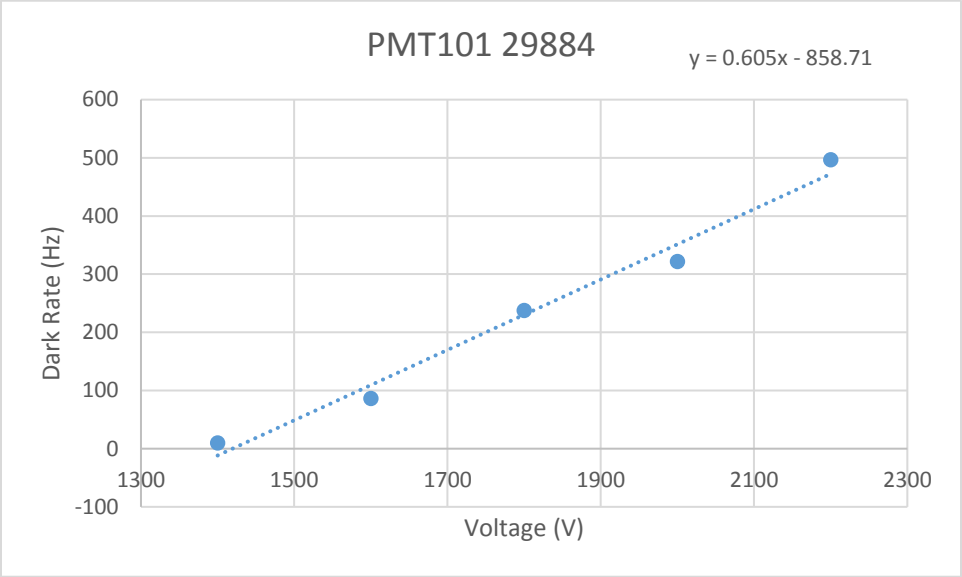
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	481	445	450	483	462	58.025
1600	11744	12810	12512	11911	10522	1487.475
1800	288402	311230	277012	291372	257099	35627.88
2000	1608566	1543413	1736252	2010306	2044616	223578.8
2200	3278774	3574605	3588945	3283177	3425191	428767.3



PMT101 29984

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

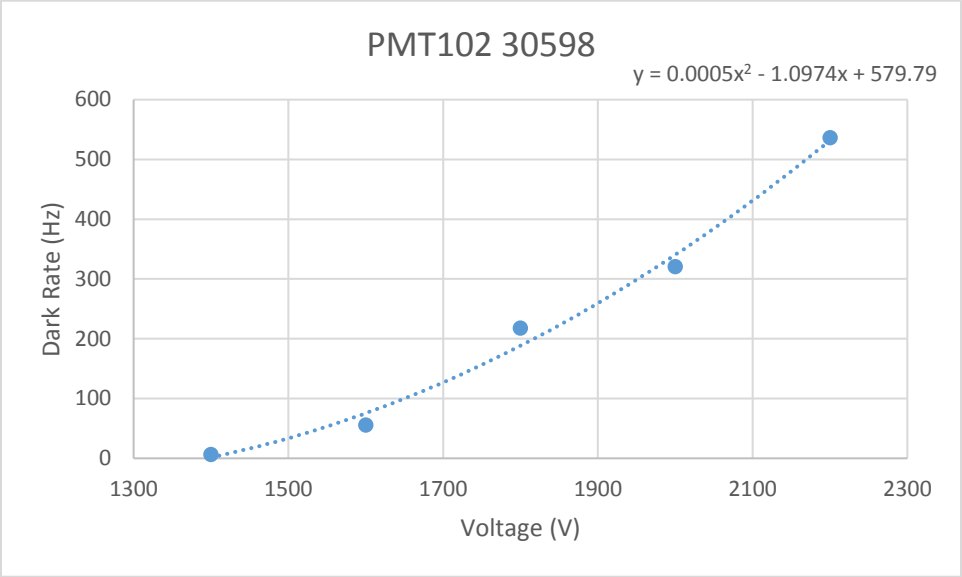
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	82	79	84	68	69	9.55
1600	685	720	735	669	635	86.1
1800	1901	1874	1867	1909	1940	237.275
2000	2570	2586	2509	2583	2626	321.85
2200	3973	4026	3937	3903	4028	496.675



PMT102 30598

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

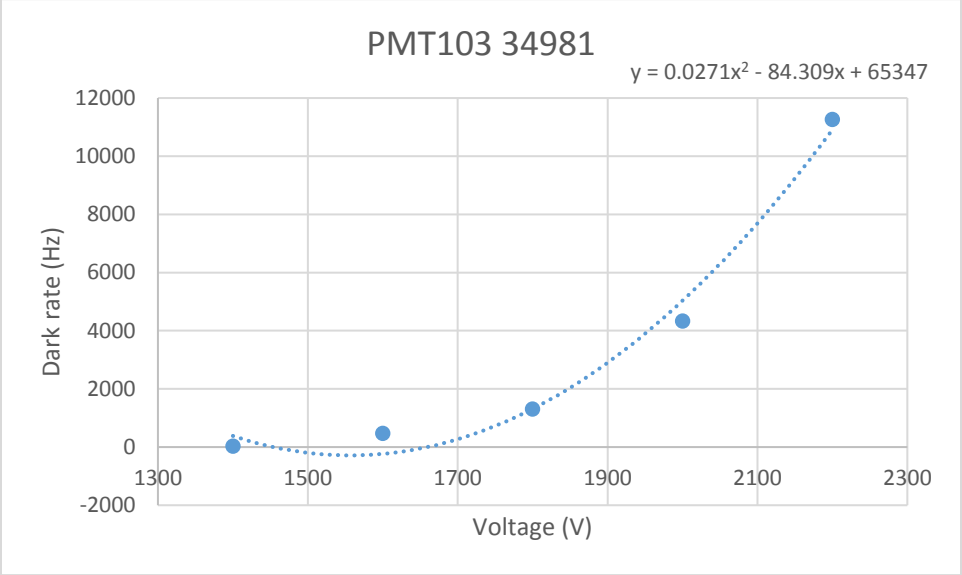
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	51	34	66	55	53	6.475
1600	433	455	441	425	481	55.875
1800	1699	1838	1735	1770	1666	217.7
2000	2604	2550	2533	2604	2542	320.825
2200	4266	4300	4322	4256	4314	536.45



PMT103 34981

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

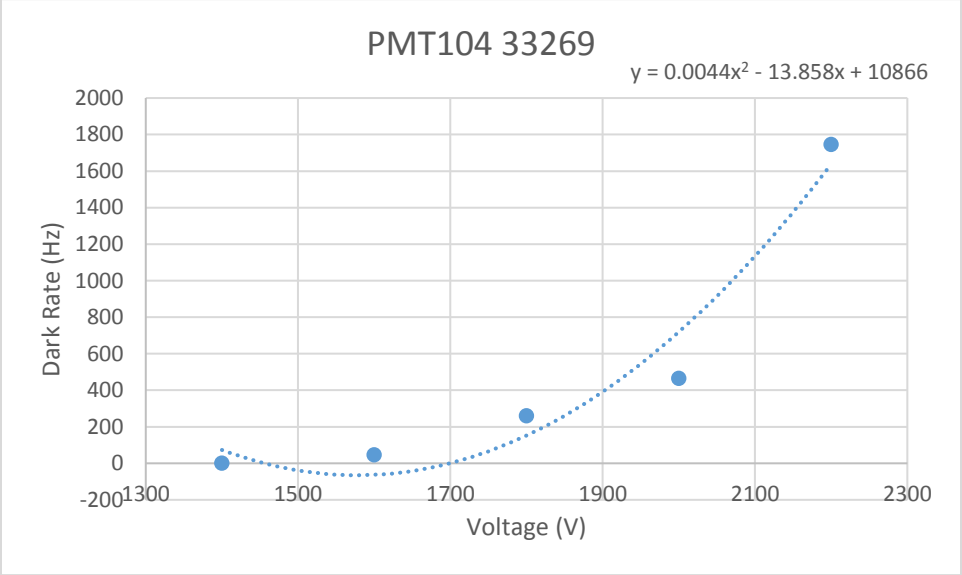
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	214	230	223	242	227	28.4
1600	3709	3641	3893	3738	3955	473.4
1800	10485	10407	10273	10473	10705	1308.575
2000	37296	35948	32408	35948	31560	4329
2200	87638	93805	85771	93159	90125	11262.45



PMT104 33269

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

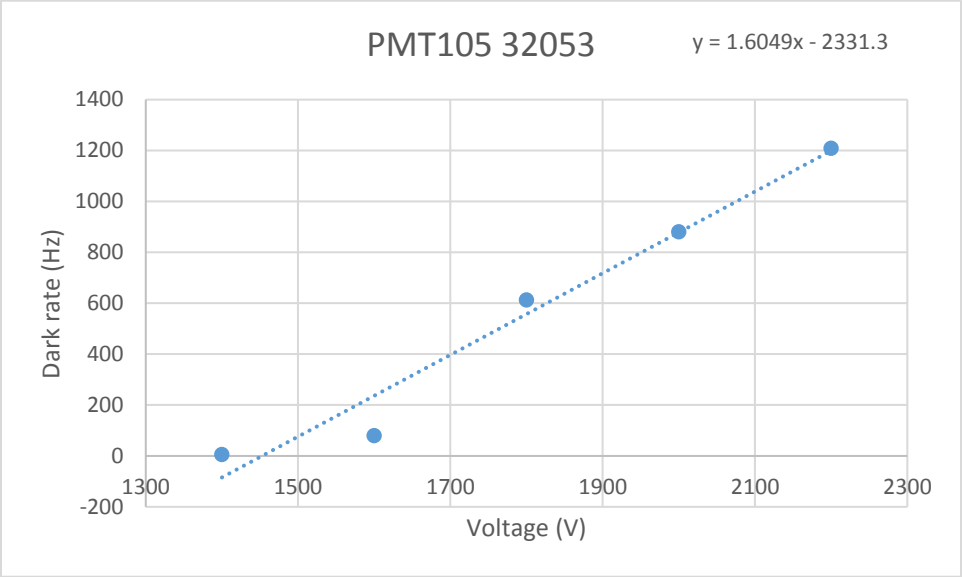
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	5	6	4	5	6	0.65
1600	394	416	348	353	366	46.925
1800	2200	1974	2099	2038	2109	260.5
2000	3503	3676	3764	3757	3934	465.85
2200	13713	13689	14078	14127	14240	1746.175



PMT105 32053

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

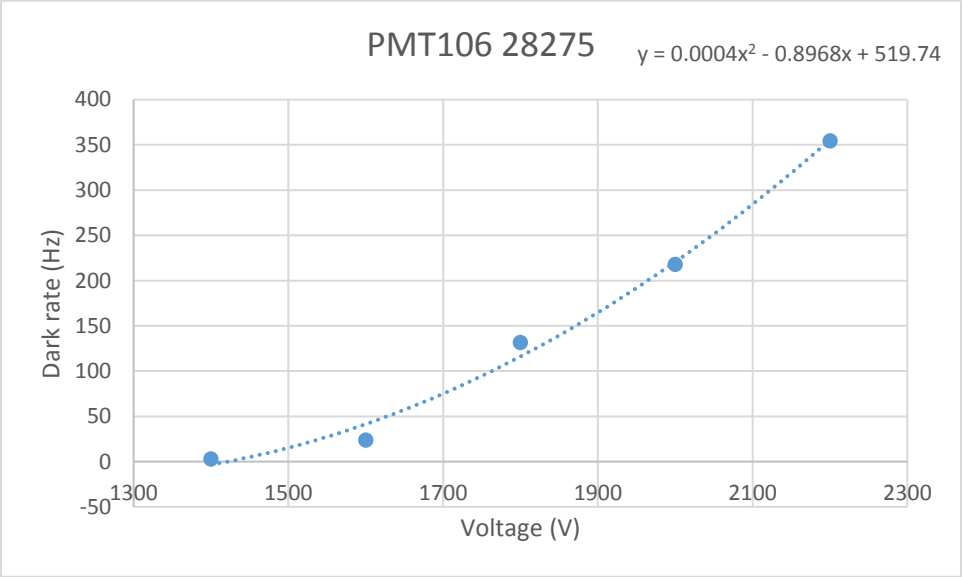
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	36	37	45	53	41	5.3
1600	661	610	643	635	623	79.3
1800	4903	4880	4941	4915	4857	612.4
2000	7168	6964	7085	7087	6945	881.225
2200	9745	9615	9684	9558	9766	1209.2



PMT106 28275

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

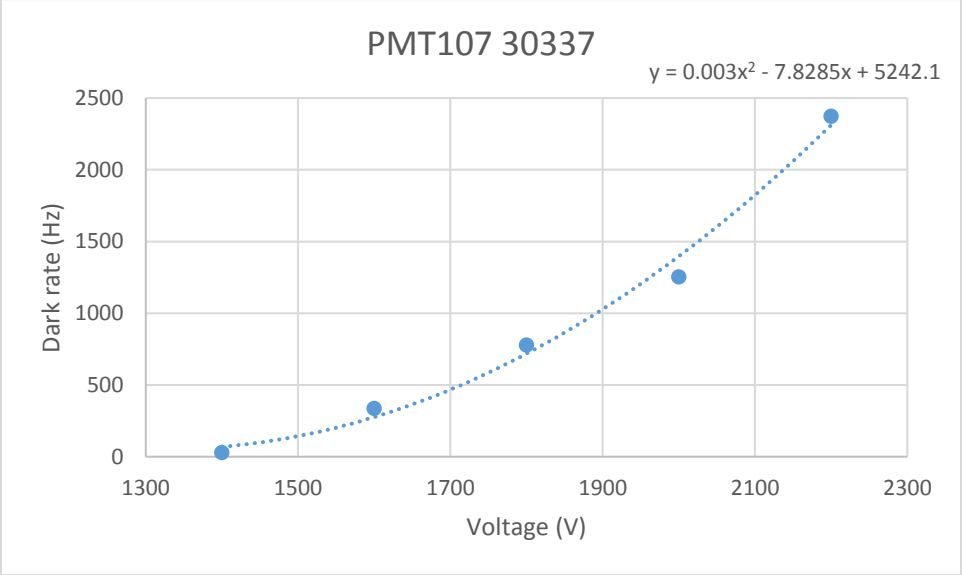
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	26	23	21	23	20	2.825
1600	185	179	200	187	200	23.775
1800	1043	1070	1029	1033	1092	131.675
2000	1710	1672	1785	1741	1801	217.725
2200	2888	2835	2839	2816	2791	354.225



PMT107 30337

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

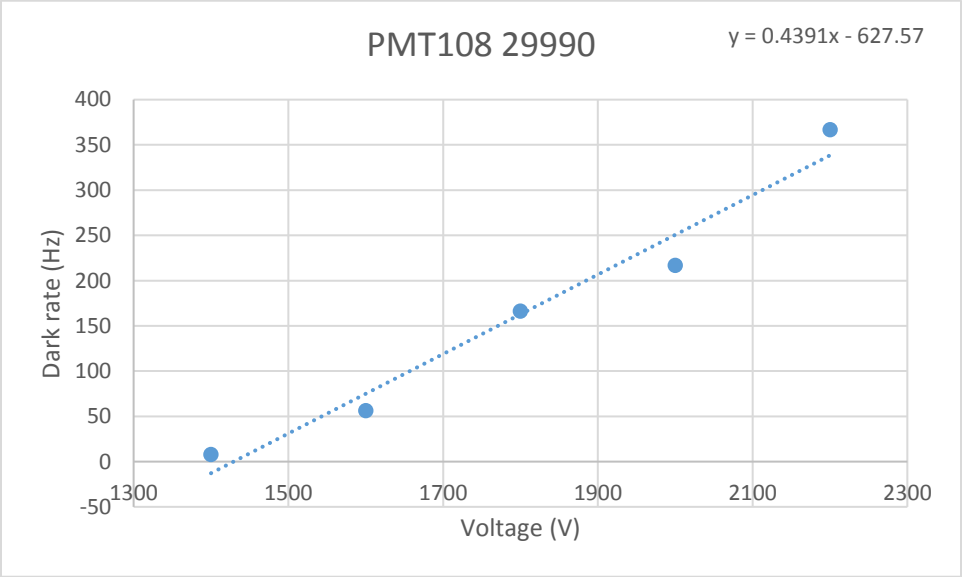
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	234	247	240	226	234	29.525
1600	2686	2697	2690	2620	2768	336.525
1800	6346	6226	6106	6359	6144	779.525
2000	10211	10152	9813	9990	10022	1254.7
2200	19018	18962	18905	18950	19062	2372.425



PMT108 29990

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

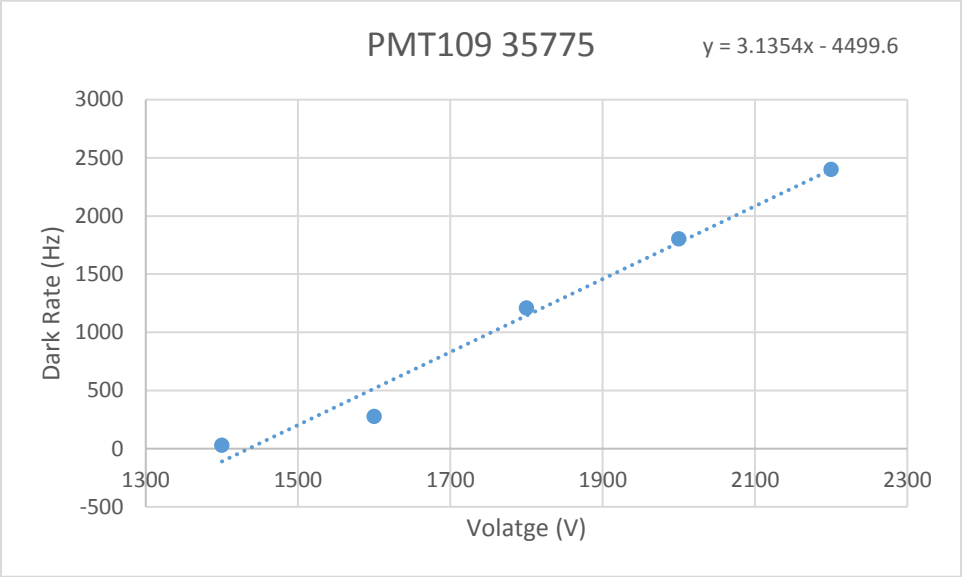
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	62	61	69	56	65	7.825
1600	409	478	457	462	448	56.35
1800	1370	1324	1275	1342	1337	166.2
2000	1756	1753	1828	1712	1630	216.975
2200	2955	2999	2923	2949	2838	366.6



PMT109 35775

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

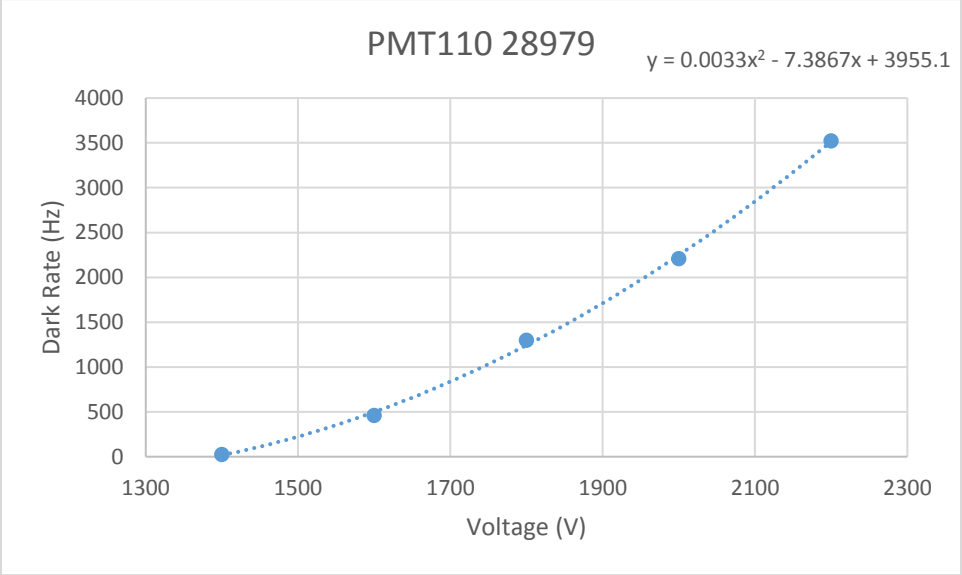
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	237	233	237	219	229	28.875
1600	2222	2162	2172	2225	2292	276.825
1800	9609	9807	9740	9715	9561	1210.8
2000	14383	14408	14371	14468	14484	1802.85
2200	19256	19066	19286	19108	19334	2401.25



PMT110 28979

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

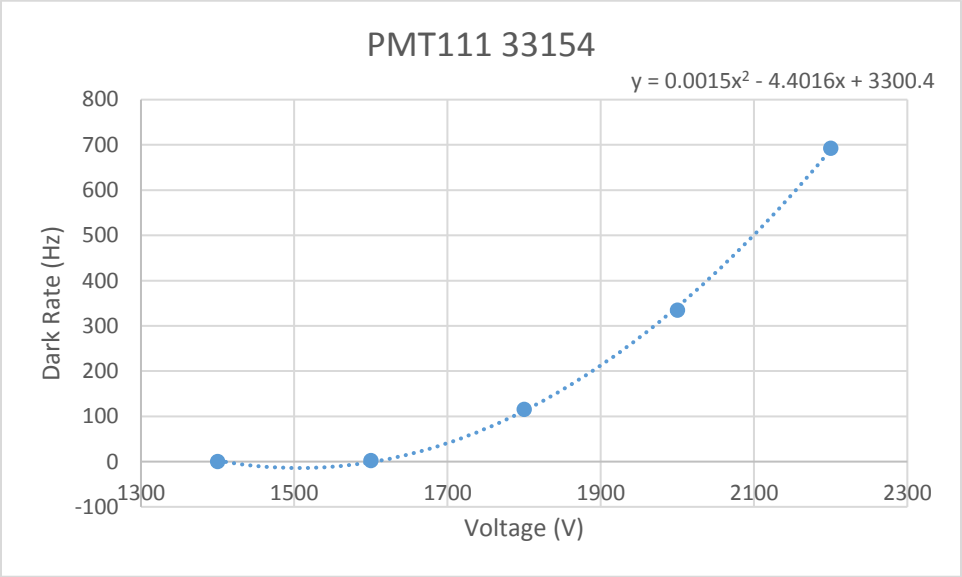
Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	190	193	209	194	209	24.875
1600	3801	3598	3818	3724	3559	462.5
1800	10221	10302	10440	10401	10574	1298.45
2000	18669	17479	17447	17493	17290	2209.45
2200	28540	28445	27695	28038	28249	3524.175



PMT111 33154

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	0	1	0	3	0	0.1
1600	22	21	15	12	18	2.2
1800	918	942	922	912	910	115.1
2000	2589	2734	2738	2672	2666	334.975
2200	5486	5669	5537	5553	5465	692.75



PMT112 30202

Dark count in 8 sec, 10* amplification, -30 mV threshold discrimination

Voltage	Count 1	Count 2	Count 3	Count 4	Count 5	Rate (Hz)
1400	7	6	10	9	8	1
1600	209	226	222	239	209	27.625
1800	1644	1710	1623	1715	1682	209.35
2000	2920	2986	3071	3024	2957	373.95
2200	6794	6726	6434	6551	6195	817.5