

# Higgs @ 10

José Ruiz



**I will tell you three stories ...**

**One about myself ...**  
**One about two experiments...**  
**One about the Higgs boson ...**

**This is my story.**  
(short version)

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Colombia







# Standard Model of Elementary Particles

	three generations of matter (fermions)			interactions / force carriers (bosons)	
	I	II	III		
mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b>g</b> gluon	<b>H</b> higgs
<b>QUARKS</b>	$\approx 4.7 \text{ MeV}/c^2$	$\approx 96 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	0	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon	
	$\approx 0.511 \text{ MeV}/c^2$	$\approx 105.66 \text{ MeV}/c^2$	$\approx 1.7768 \text{ GeV}/c^2$	$\approx 91.19 \text{ GeV}/c^2$	
	-1	-1	-1	0	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson	
<b>LEPTONS</b>	$< 1.0 \text{ eV}/c^2$	$< 0.17 \text{ MeV}/c^2$	$< 18.2 \text{ MeV}/c^2$	$\approx 80.39 \text{ GeV}/c^2$	
	0	0	0	$\pm 1$	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson	
					<b>GAUGE BOSONS</b> VECTOR BOSONS
					<b>SCALAR BOSONS</b>









**Let's do now the experiments.**



**First experiment.**



#618174

**There is an invisible bird in this  
forest.**

- 1. You can't catch it.**
- 2. You can't take pictures.**
- 3. You can't interact.**









# **Second experiment.**











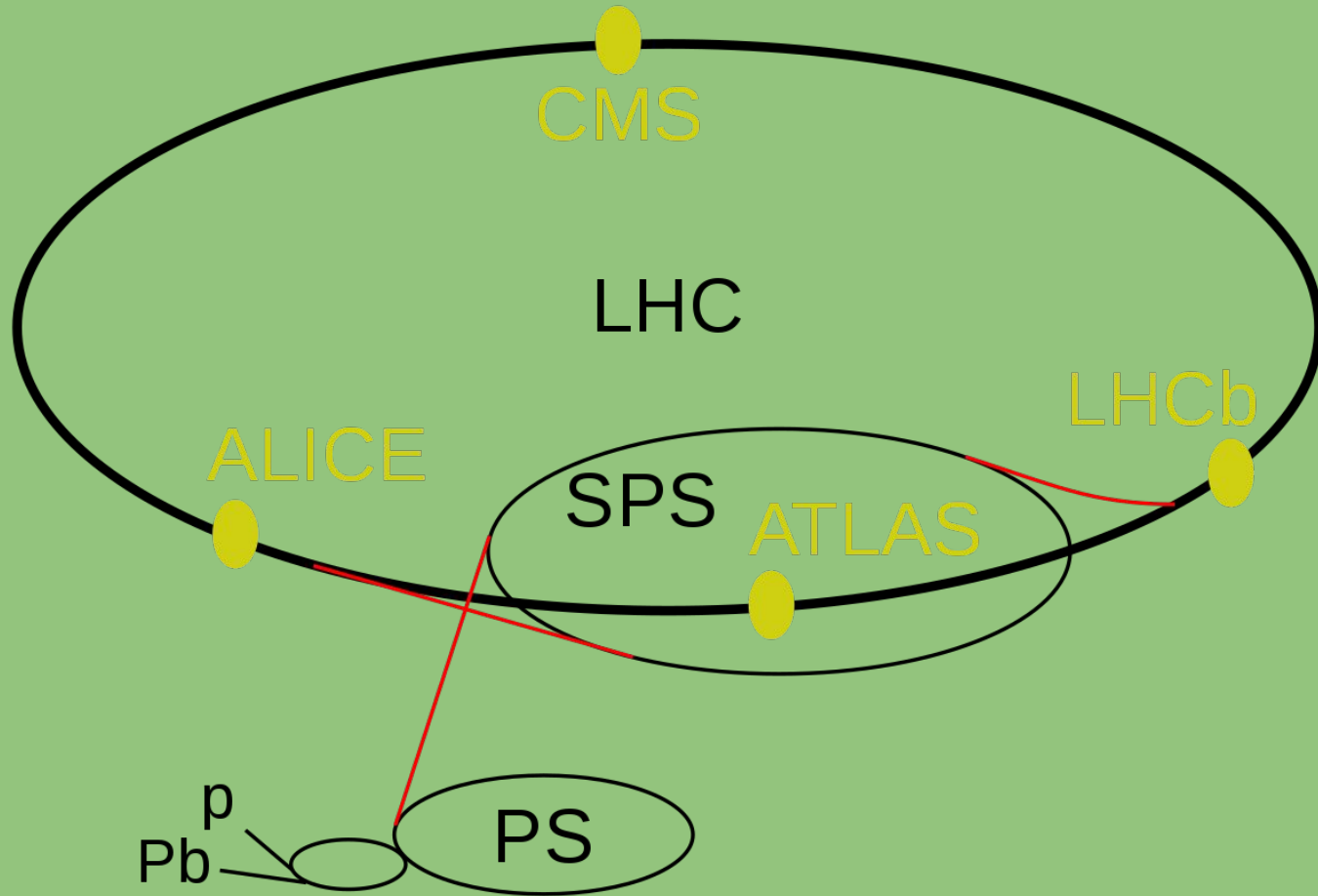




**Let's talk about the Higgs.**











## CMS DETECTOR

Total weight : 14,000 tonnes  
Overall diameter : 15.0 m  
Overall length : 28.7 m  
Magnetic field : 3.8 T

STEEL RETURN YOKE  
12,500 tonnes

SILICON TRACKERS  
Pixel ( $100 \times 150 \mu\text{m}^2$ )  $\sim 1.9 \text{ m}^2 \sim 124\text{M}$  channels  
Microstrips ( $80\text{--}180 \mu\text{m}$ )  $\sim 200 \text{ m}^2 \sim 9.6\text{M}$  channels

SUPERCONDUCTING SOLENOID  
Niobium titanium coil carrying  $\sim 18,000 \text{ A}$

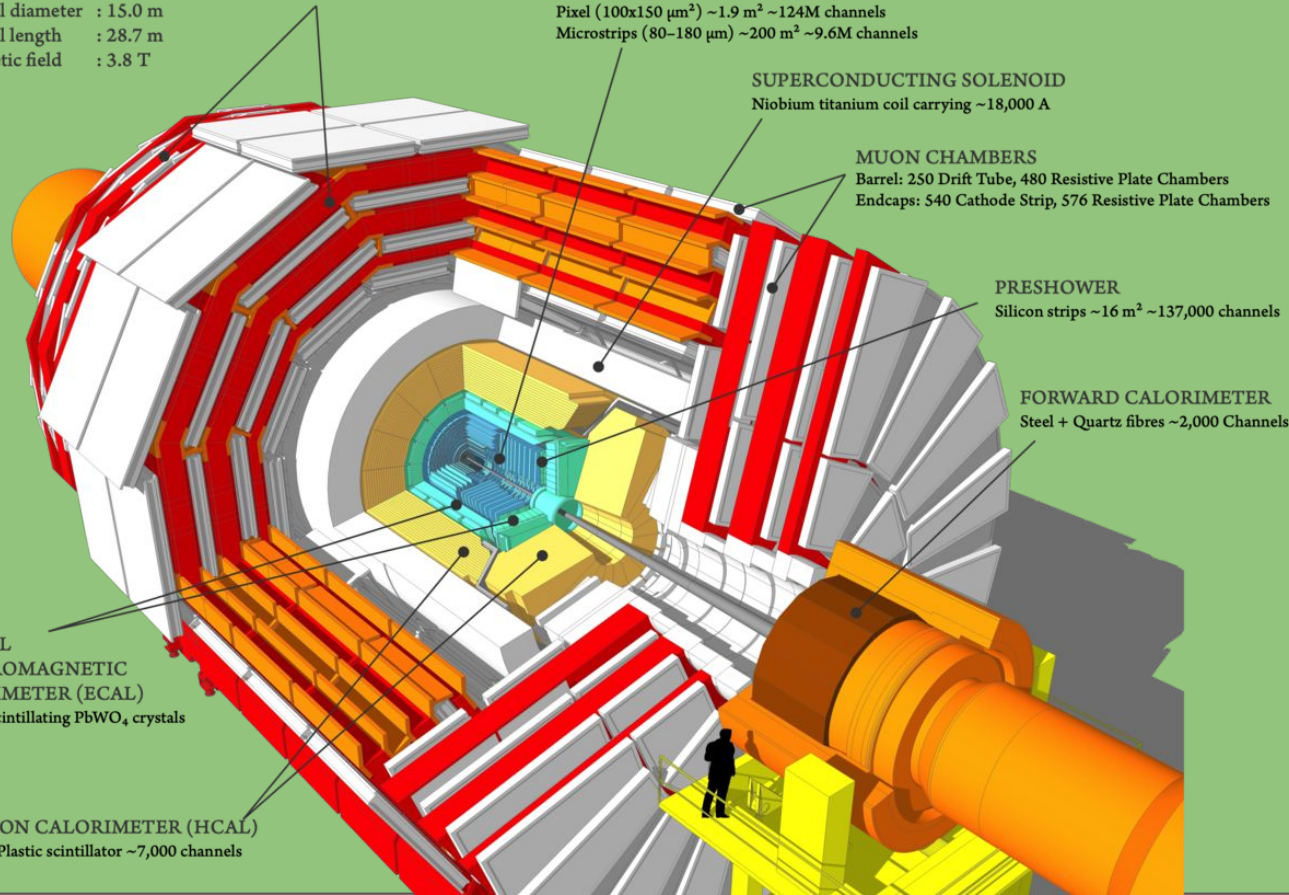
MUON CHAMBERS  
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers  
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

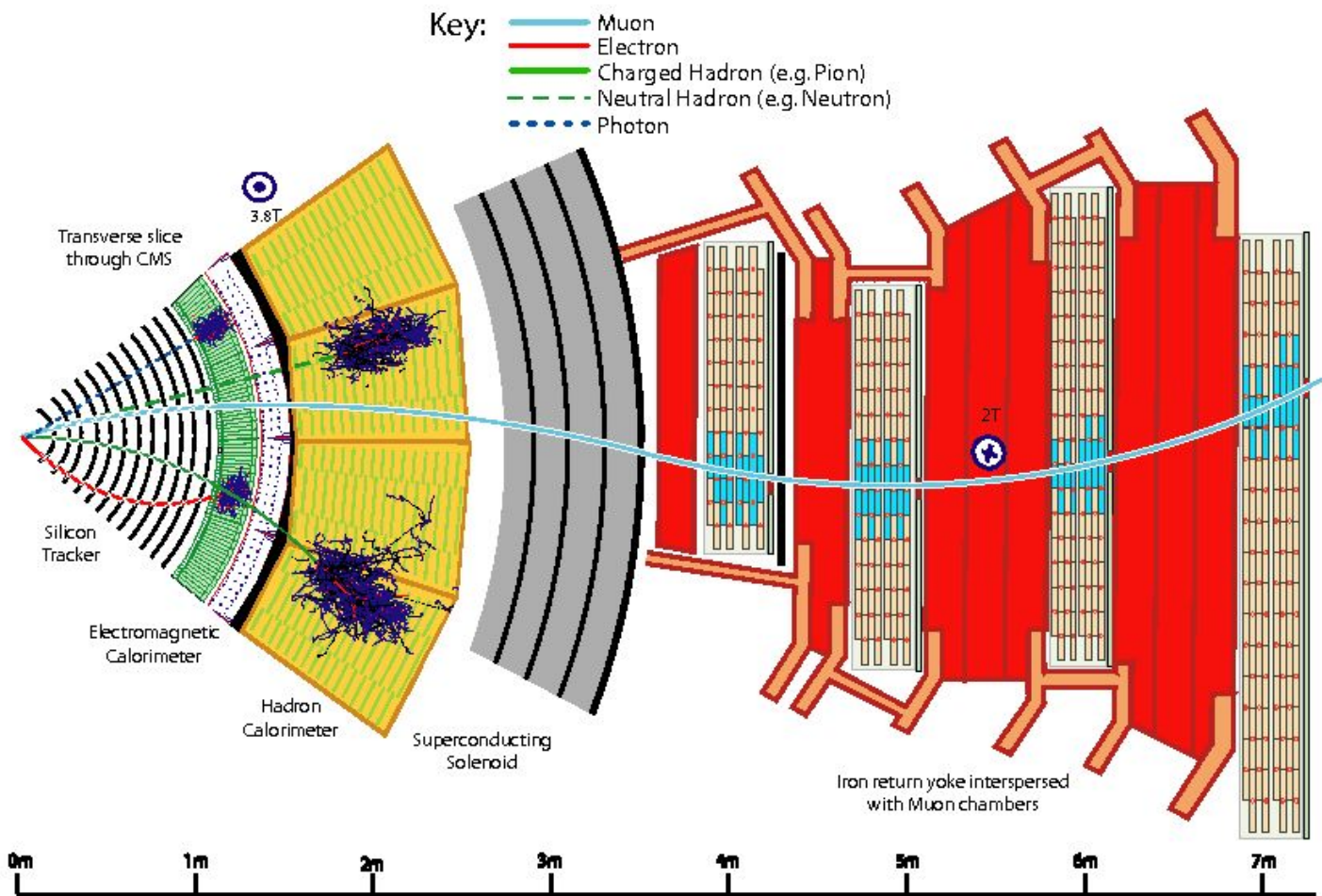
PRESHOWER  
Silicon strips  $\sim 16 \text{ m}^2 \sim 137,000$  channels

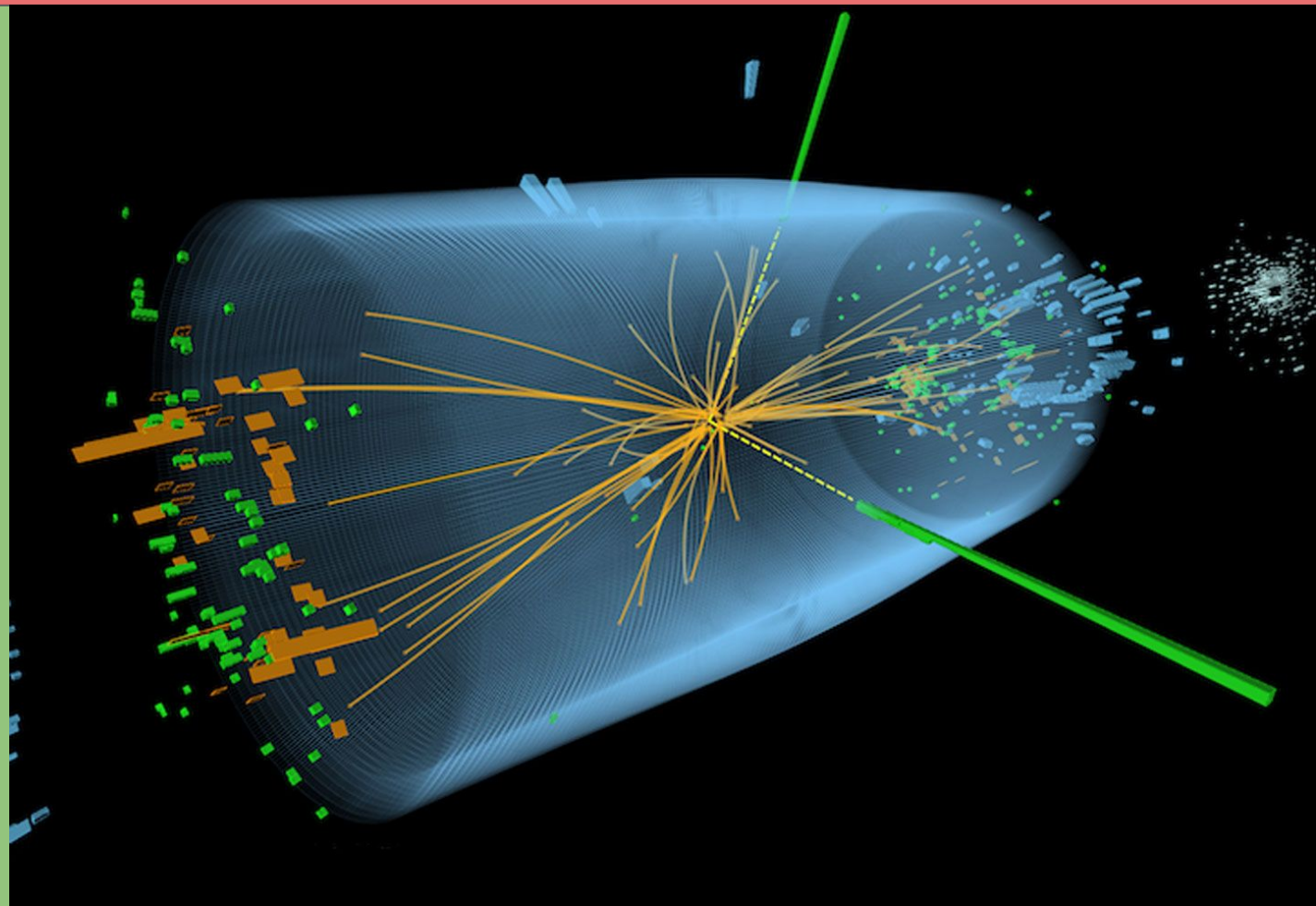
FORWARD CALORIMETER  
Steel + Quartz fibres  $\sim 2,000$  Channels

CRYSTAL  
ELECTROMAGNETIC  
CALORIMETER (ECAL)  
 $\sim 76,000$  scintillating  $\text{PbWO}_4$  crystals

HADRON CALORIMETER (HCAL)  
Brass + Plastic scintillator  $\sim 7,000$  channels









# Standard Model of Elementary Particles

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	<b>d</b> down	<b>s</b> strange	<b>b</b> bottom	<b><math>\gamma</math></b> photon	
	<b>e</b> electron	<b><math>\mu</math></b> muon	<b><math>\tau</math></b> tau	<b>Z</b> Z boson	
	<b><math>\nu_e</math></b> electron neutrino	<b><math>\nu_\mu</math></b> muon neutrino	<b><math>\nu_\tau</math></b> tau neutrino	<b>W</b> W boson	

QUARKS

LEPTONS

GAUGE BOSONS  
VECTOR BOSONS

SCALAR BOSONS

# Standard Model of Elementary Particles

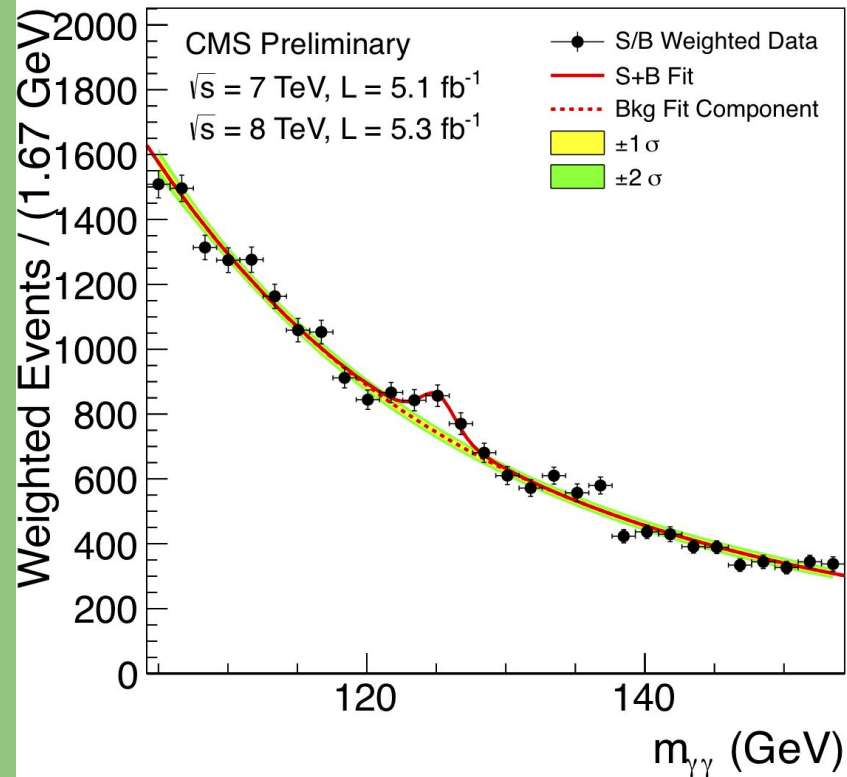
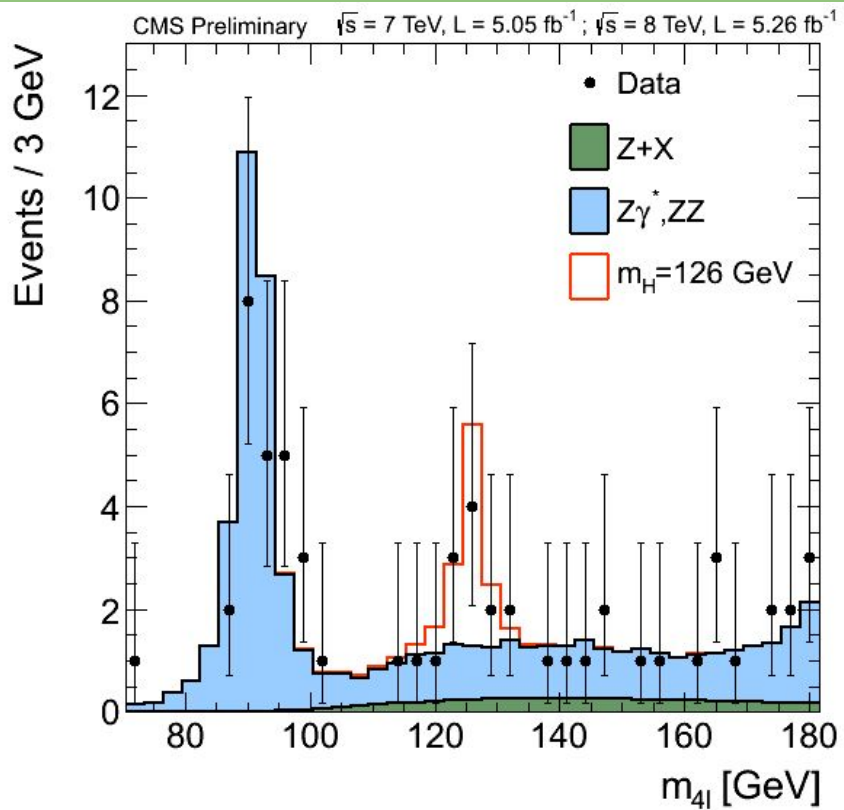
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QUARKS	<del>u up</del>	<del>c charm</del>	<del>t top</del>	<del>g gluon</del>	<del>H higgs</del>
	<del>d down</del>	<del>s strange</del>	<del>b bottom</del>	$\gamma$ photon	
	$e$ electron	$\mu$ muon	$\tau$ tau	$Z$ Z boson	
LEPTONS	<del><math>\nu_e</math> electron neutrino</del>	<del><math>\nu_\mu</math> muon neutrino</del>	<del><math>\nu_\tau</math> tau neutrino</del>	$W$ W boson	

GAUGE BOSONS  
VECTOR BOSONS

SCALAR BOSONS

**Back in to 2012.**

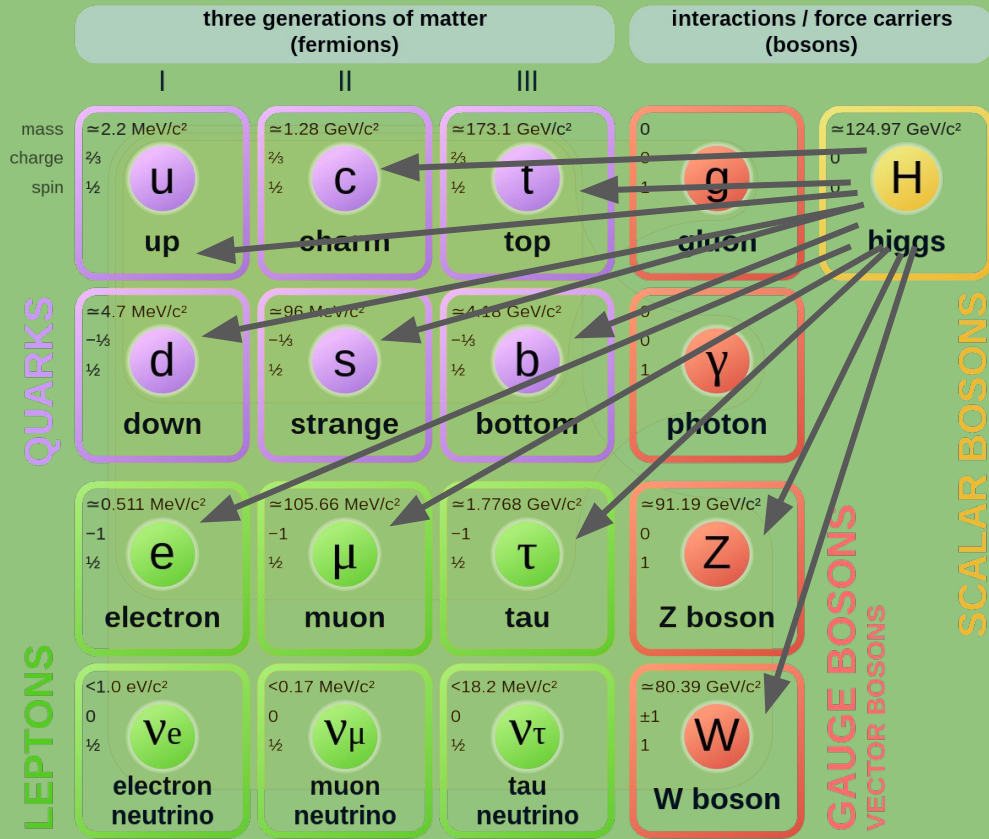
**Let's focus together on some things.**



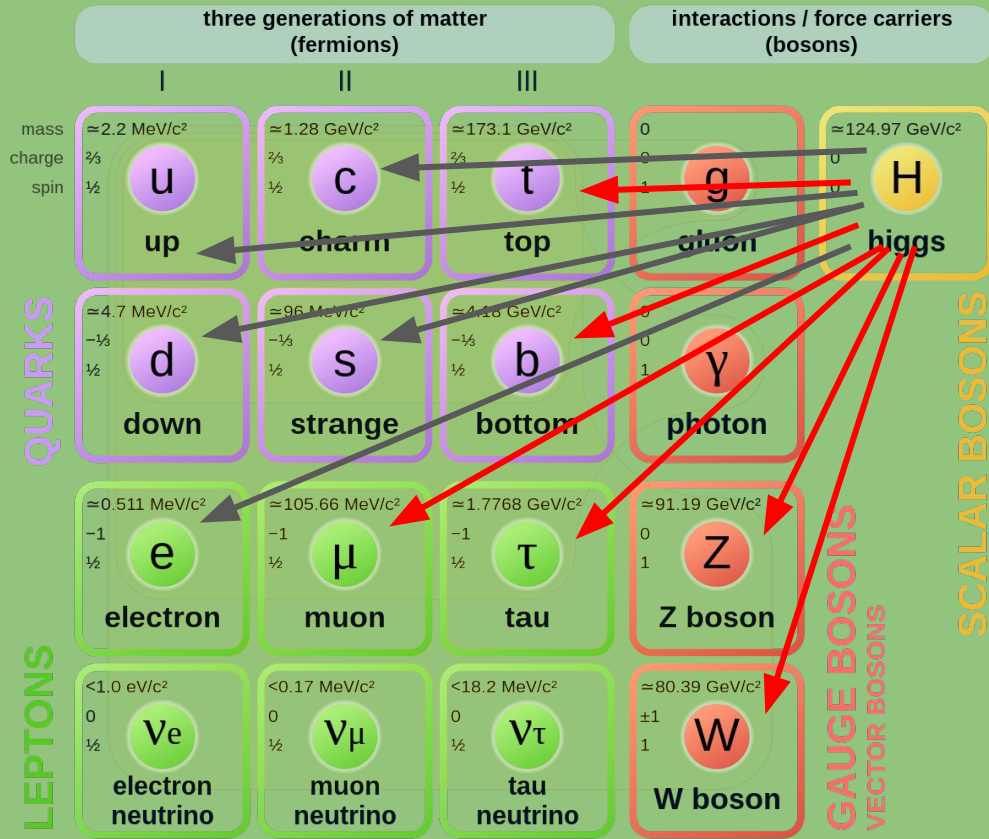


**Simplifying it to the extreme:  
We select events.  
We count.**

# Standard Model of Elementary Particles



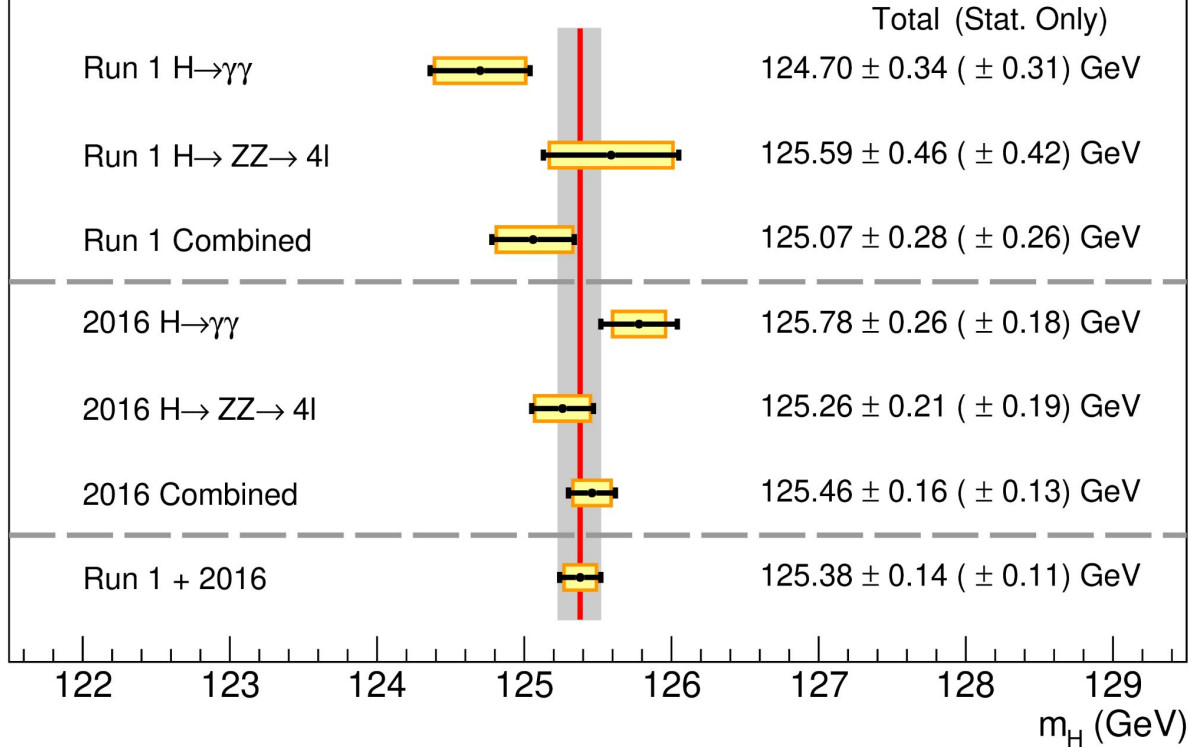
# Standard Model of Elementary Particles



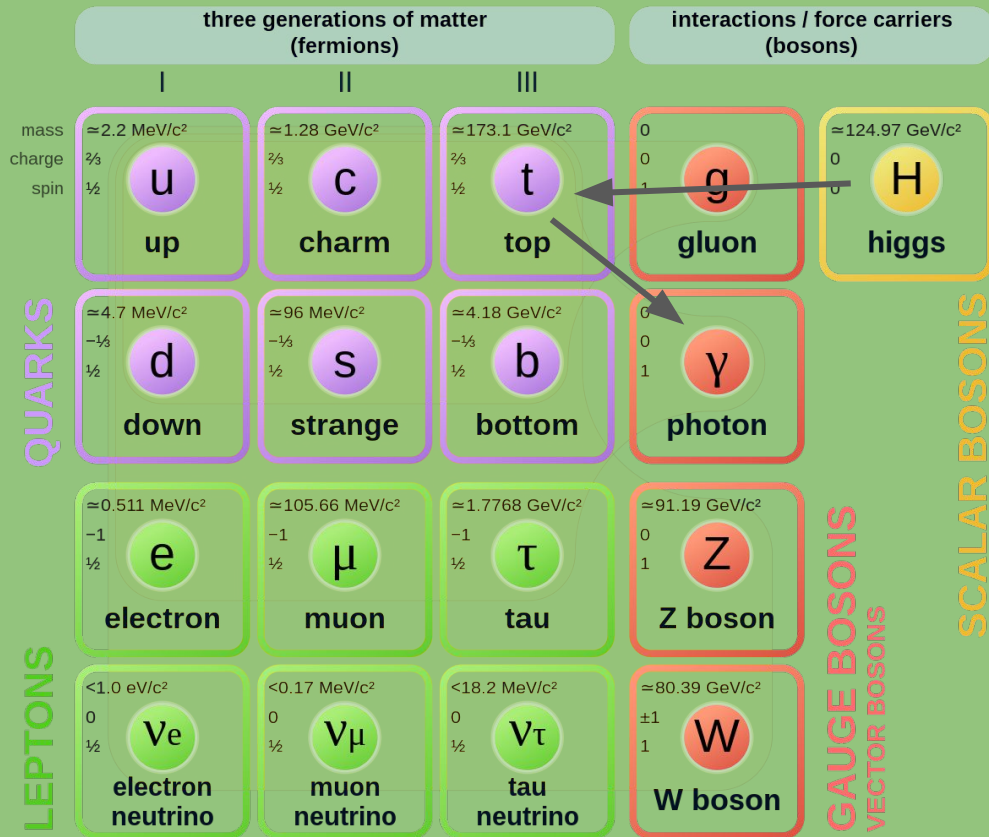
# CMS

Run 1: 5.1 fb<sup>-1</sup> (7 TeV) + 19.7 fb<sup>-1</sup> (8 TeV)  
2016: 35.9 fb<sup>-1</sup> (13 TeV)

— Total    □ Stat. Only

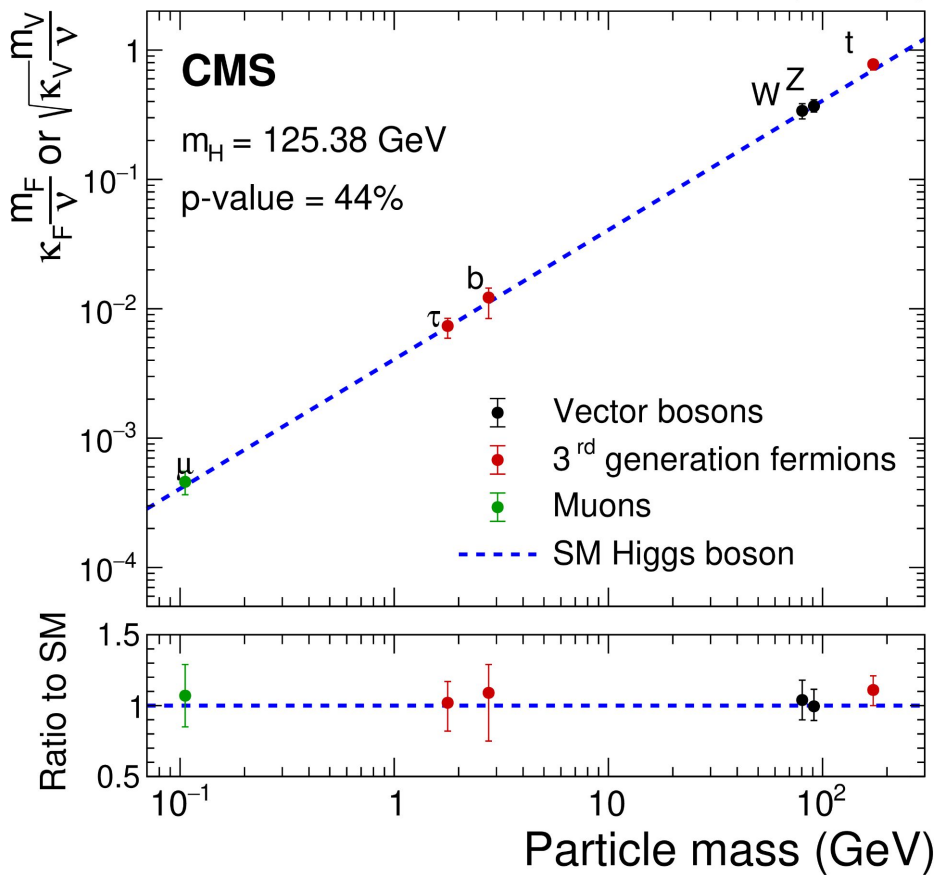


# Standard Model of Elementary Particles

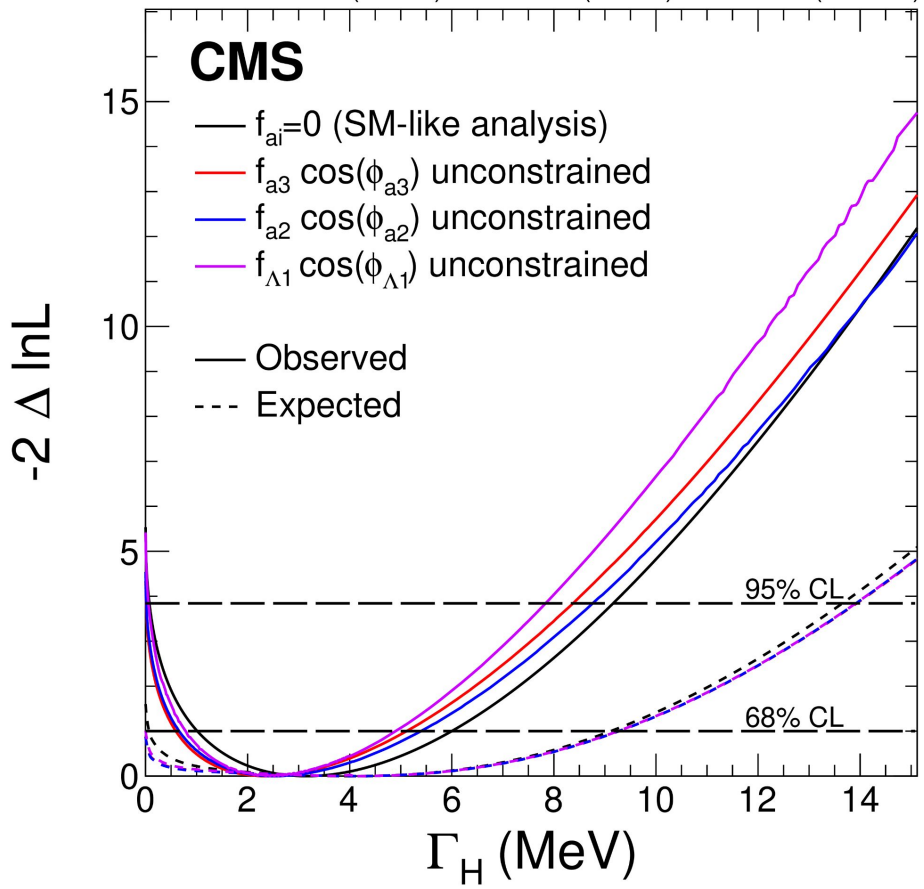


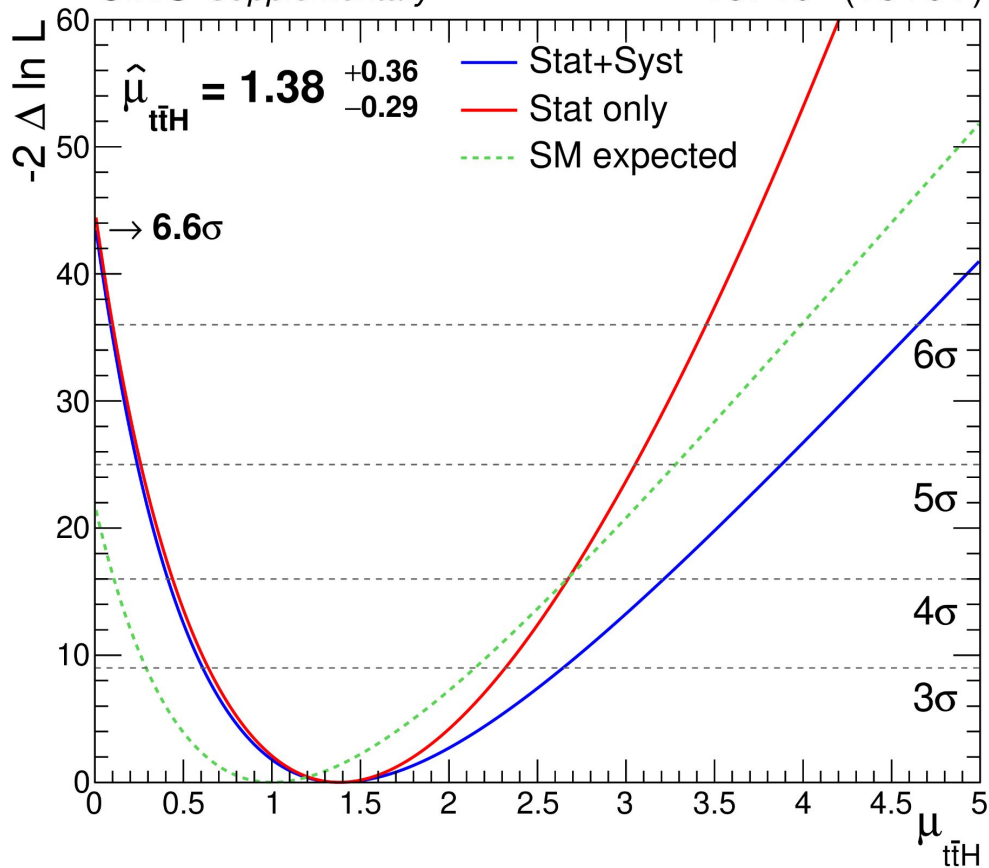


35.9-137 fb<sup>-1</sup> (13 TeV)



5.1 fb<sup>-1</sup> (7 TeV) + 19.7 fb<sup>-1</sup> (8 TeV) + 80.2 fb<sup>-1</sup> (13 TeV)





**So far, we have a SM Higgs.**



**Thanks!**