

# INTERNATIONAL MASTERCLASSES

## Current Status of International Particle Physics Masterclasses

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ICHEP 2020, Prague



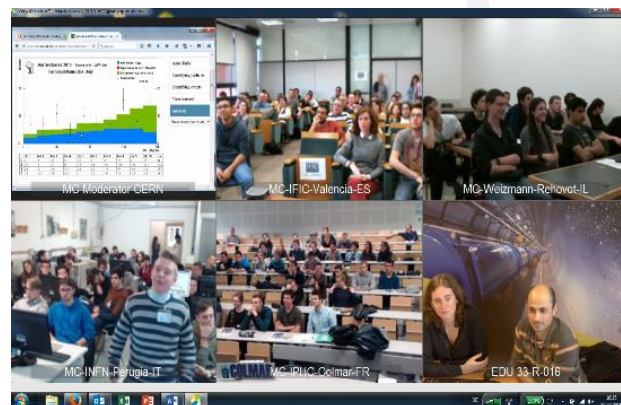
# Overview

## What is a Masterclass?

- “Particle physicist for a day”
- Intro
- Tour
- Analyze authentic HEP data
- Videoconference

## International Masterclasses

- 60 countries
- > 220 research labs
- > 10<sup>4</sup> Students
- Videoconferences at CERN, Fermilab, KEK, GSI, TRIUMF
- Organized by IPPOG, <http://ippog.org/>



# Broadening the Physics Scope

Historically: LEP → LHC

## Today:

- LHC (since 2005)
- MINERvA (since 2019)
- Belle II (since 2020)
- Particle Therapy (since 2020)

## New:

- Darkside

## Under development:

- MicroBooNE

More on the way...



**MINERvA Neutrino Masterclass**  
from 19 March 2020 to 4 April 2020

Overview  
Introduction  
Measurement  
Events  
MINERvA Experiment at Fermilab  
All Things Neutrino  
Library  
International Masterclasses

**MINERvA is about neutrinos**  
Our universe is awash in neutrinos. As you read this, millions of them pass right through you. Fortunately, they have negligible mass and negligible interactions with other matter, so you're OK. Negligible...but...that tiny amount of mass is enough to create mysteries about the nature of neutrinos and those tiny, rare interactions enable us to build dedicated detectors like MINERvA to study neutrinos.

Schematic of the MINERvA detector.

# LHC Masterclasses: ATLAS W and Z

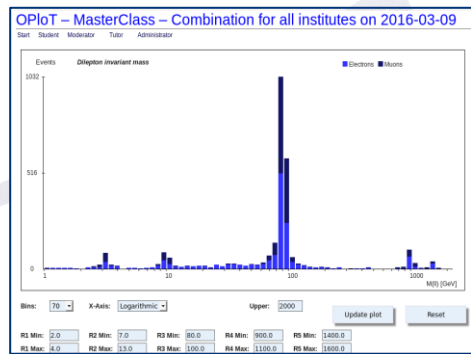
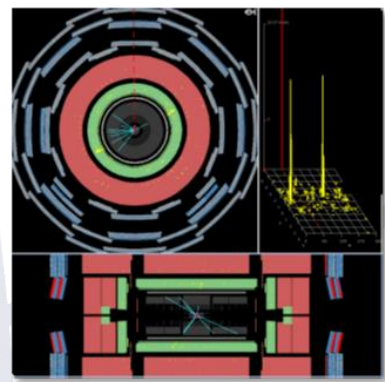
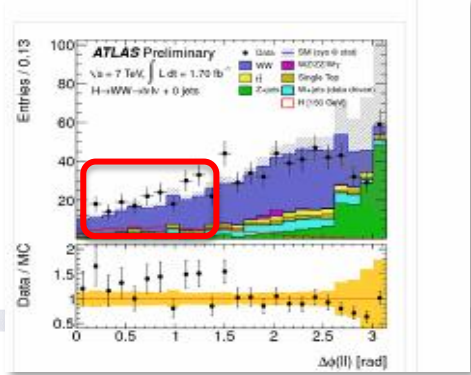
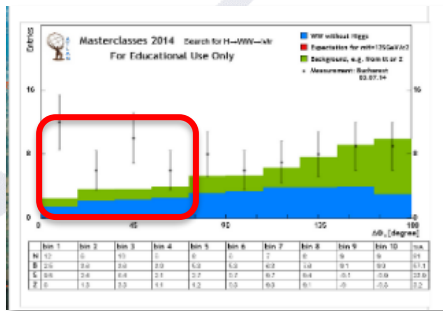


## W-path

- Students analyze event
- Identify W bosons
  - W+/W-
- Identify W pairs and measure azimuthal opening angle  $\Delta\phi_{ll}$ 
  - Gain insight into the process of discovering the Higgs at CERN
- <http://cern.ch/go/MHr6>

## Z-path

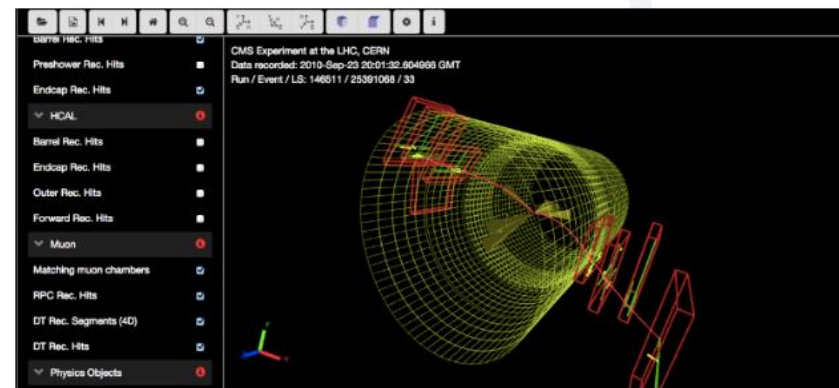
- Students search for 2-lep,  $\gamma\gamma$ , or 4-lep events, build invariant mass distributions
- Find 2-lep particles:  $Z^0$ ,  $J/\psi$ ,  $Y$
- Search for new particles
- Gain insight into the process of discovering the Higgs at CERN
- <http://cern.ch/go/cNW9>



# LHC Masterclasses: CMS and LHCb

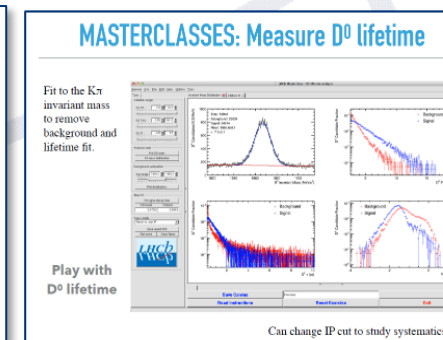
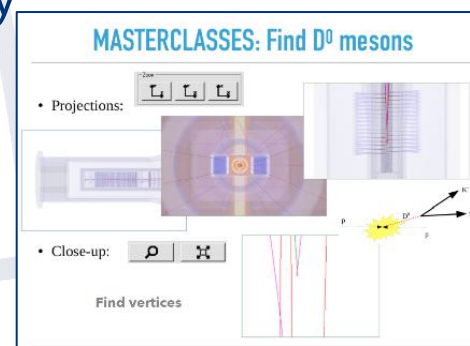
## CMS

- 1-, 2-, and 4-lepton events
- 1-lep (plus  $\nu$ ): W boson
- 2-lep and 4-lep: mass plots of standard model particles, plus hint of Higgs
- Ratios  $W^+/W^-$ ,  $e/m$
- <http://cern.ch/go/Xg8z>



## LHCb

- Students search for the  $D^0 \rightarrow K\pi$  decay
- Students perform a lifetime measurement at the 1 % level
- Live merging of histograms from all groups in the VC
- <http://cern.ch/go/s7s7>



# LHC Masterclasses: ALICE in 2.5 flavors

## Strange particles

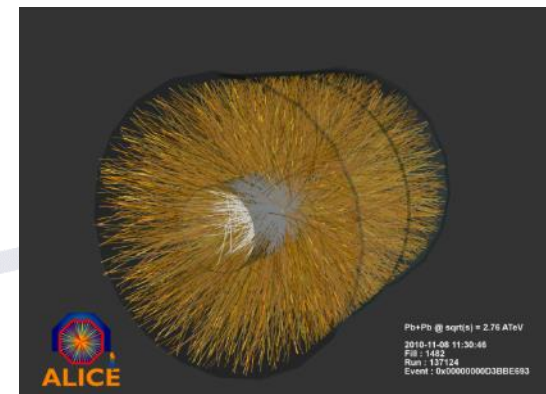
- First part: visual analysis of  $\sim 15$  V0 events per group
- Second part: Calculate numbers of Ks,  $\Lambda$ , anti- $\Lambda$  from different centrality regions in Pb-Pb collisions
- Observe strangeness enhancement
- <http://cern.ch/go/79HV>

## Nuclear modification factor

- event-display analysis
  - $R_{AA}$  simply via counting of tracks
- ROOT based large scale analysis
  - $R_{AA}$  from various Pb-Pb centralities
  - students discover jet suppression!
- <http://cern.ch/go/q7Gq>

## New $J/\psi$ measurement

- Electron identification via  $dE/dx$  measured in TPC
- Workflow:
  - load charged-particle tracks
  - fill PID and inverse mass histograms
  - extract  $J/\psi$  yield
- Standalone app



# Neutrino Masterclasses: MINERvA and more

## MINERvA

- Muon neutrinos interact with carbon target
- Discover Fermi motion
- Measure carbon nucleus to test interaction model
- <https://indico.fnal.gov/event/22340/>

## In development

- MicroBooNE instrumentation masterclass
  - Argon purity
  - Electron drift velocity
- NOvA neutrino oscillation (just starting)



MINERvA Neutrino Masterclass

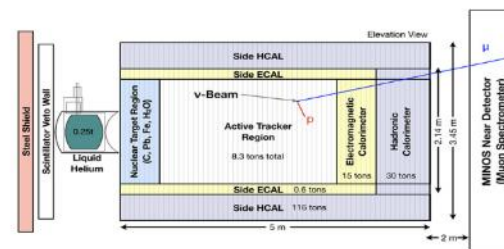
from 19 March 2020 to 4 April 2020

Search

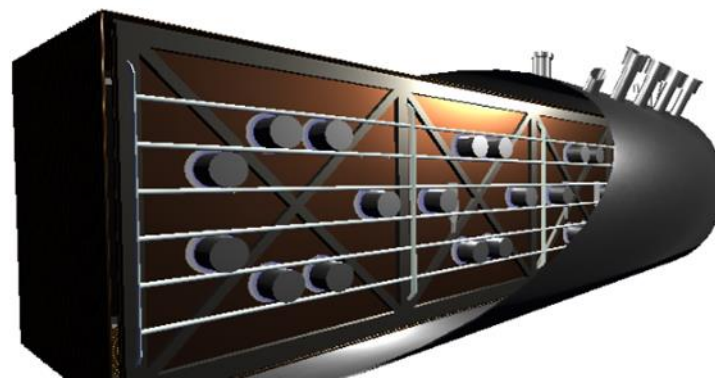
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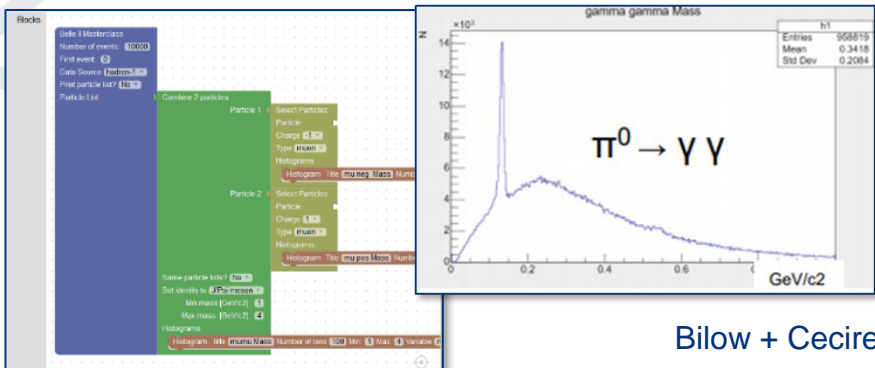
Schematic of the MINERvA detector.



# Belle II and Particle Therapy Masterclasses

## Belle II

- Students code B-physics analysis
  - Describe decays, make cuts, “discover” particles
  - Visual code editor Blockly
- Run from the web or virtual machine
- Analysis of 6M clean reconstructed events
- Basic/advanced level; KEK videocon
- <http://cern.ch/go/wcr8>



## Particle Therapy

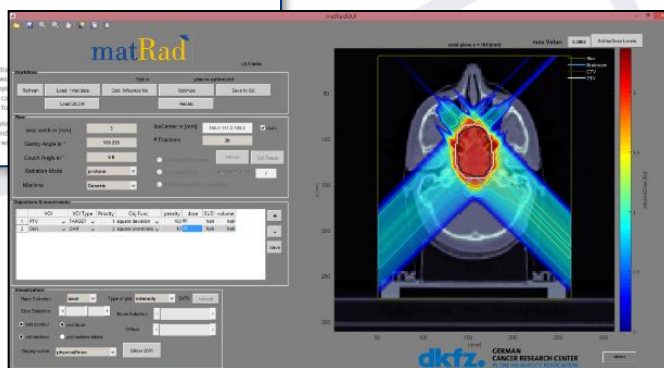
- Particle treatment planning
- highlights benefits for society from the particle physics technology
- Particularly in demand in Latin America
- <http://cern.ch/go/8WR8>



Particle Therapy Masterclass

The Particle Therapy Masterclass demonstrates applications. This Masterclass Project allows techniques used for cancer treatment engineering directed by software programs. A first idea is to build a tutorial showing the different steps of the process.

The Particle Therapy Masterclass is an integral part of the outreach activities of the European Organization for Nuclear Research (CERN) and the European Particle Therapy Group (EPTG), spread around the world.





# Future Masterclasses

## Darkside (Gran Sasso)

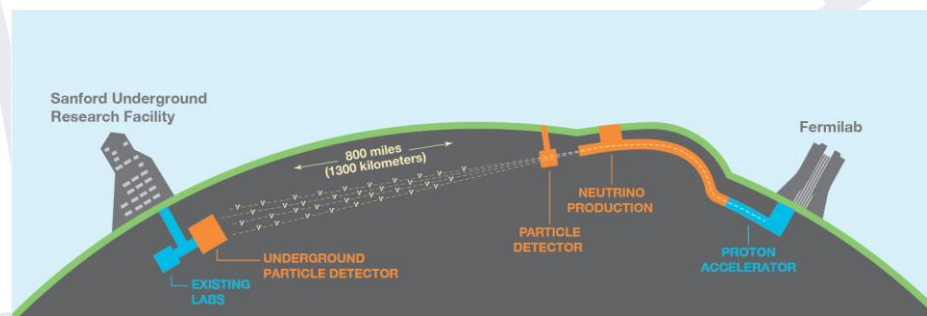
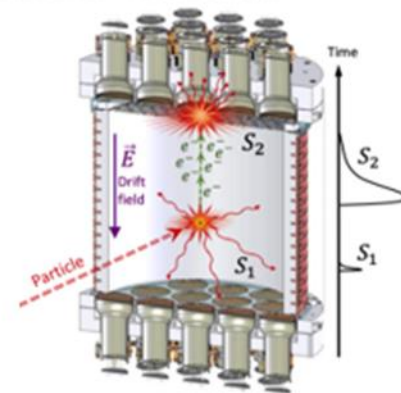
- By Francesca Carnesecchi, University and INFN of Bologna, Centro Fermi Roma, et al.
- Dark Matter / WIMPs in Ar TPC
- Data analysis via excel
  - Reconstruction position part (few events): exclude background
  - Analysis of ~20000 events: background and few “good” WIMPs
  - pilot in Jan 2020, 2 remote events during lockdown
- <http://cern.ch/go/Jkt7>

## Further neutrino masterclasses

- OPERA discussed
- DUNE is the goal

## Darkside experiment: how to detect WIMP

- WIMP-nucleus elastic collisions revealed by a detector capable of unambiguously identifying a small number of nuclear recoils
- **Dual phase (gas + liquid) Argon TPC** for direct detection of WIMPs



# Impact of the COVID-19 pandemic

- all videoconferences suspended by March 18
- only ~ 25 % of Masterclasses completed

Our response:

## 1) **BAMC** (Big Analysis of Muons in CMS)

Simplified analysis, online support, teachers involved

~700 students participated, Apr and May; ~35K events analyzed

## 2) **Masterclass@home**

Masterclass delivered online to groups of individual students, lectures+analysis spread over two afternoons

## 3) **IMC Summer VCs**

arranged end of June, offered to all IMC institutes, very low turnout

# Interested to get involved?

## At your institute

- Does your institute participate? Search <http://cern.ch/go/8V7h>
- Organize an event / help as a tutor at your research lab
  - How to get started: <http://cern.ch/go/9B77>

## At CERN/Fermilab

- Moderate videoconferences with high school students
  - Training provided
  - Moderate in pairs, 2-3 „shifts“, newcomers are paired with „veterans“

## Next International Masterclasses: Feb/March 2021

Interested? Contact: [uta.bilow@tu-dresden.de](mailto:uta.bilow@tu-dresden.de) or [kcecire@nd.edu](mailto:kcecire@nd.edu)

More info on [www.physicsmasterclasses.org](http://www.physicsmasterclasses.org)



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