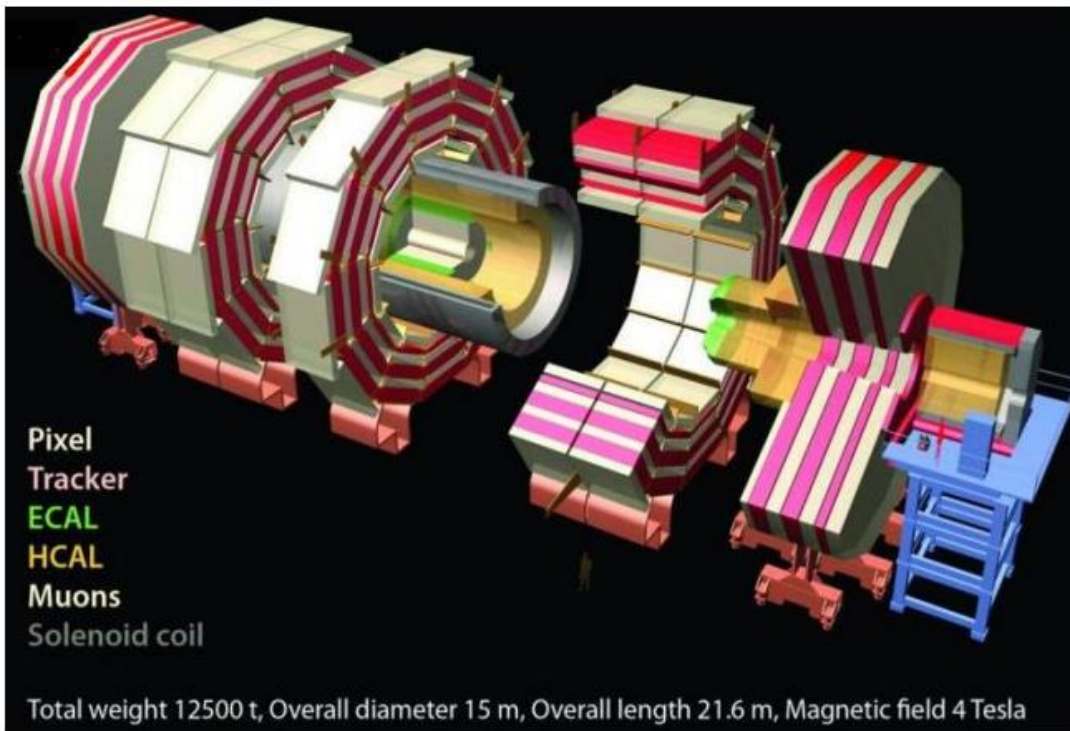
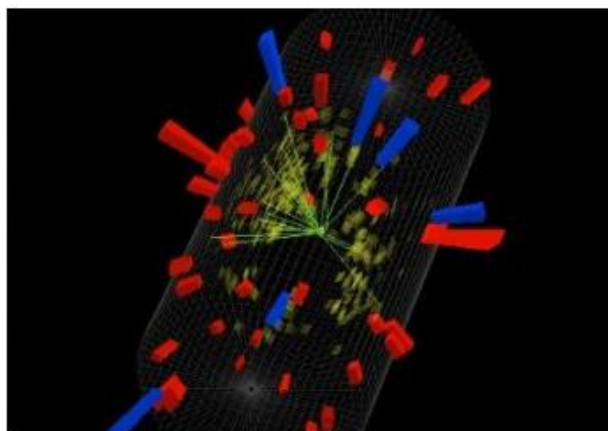


QuarkNet

CMS WZH Masterclass



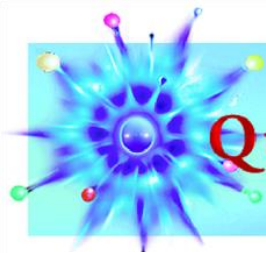
INTERNATIONAL
MASTERCLASSES
hands on particle physics



 Fermilab

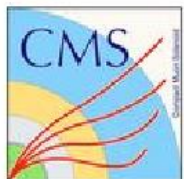


 UNIVERSITY OF
NOTRE DAME



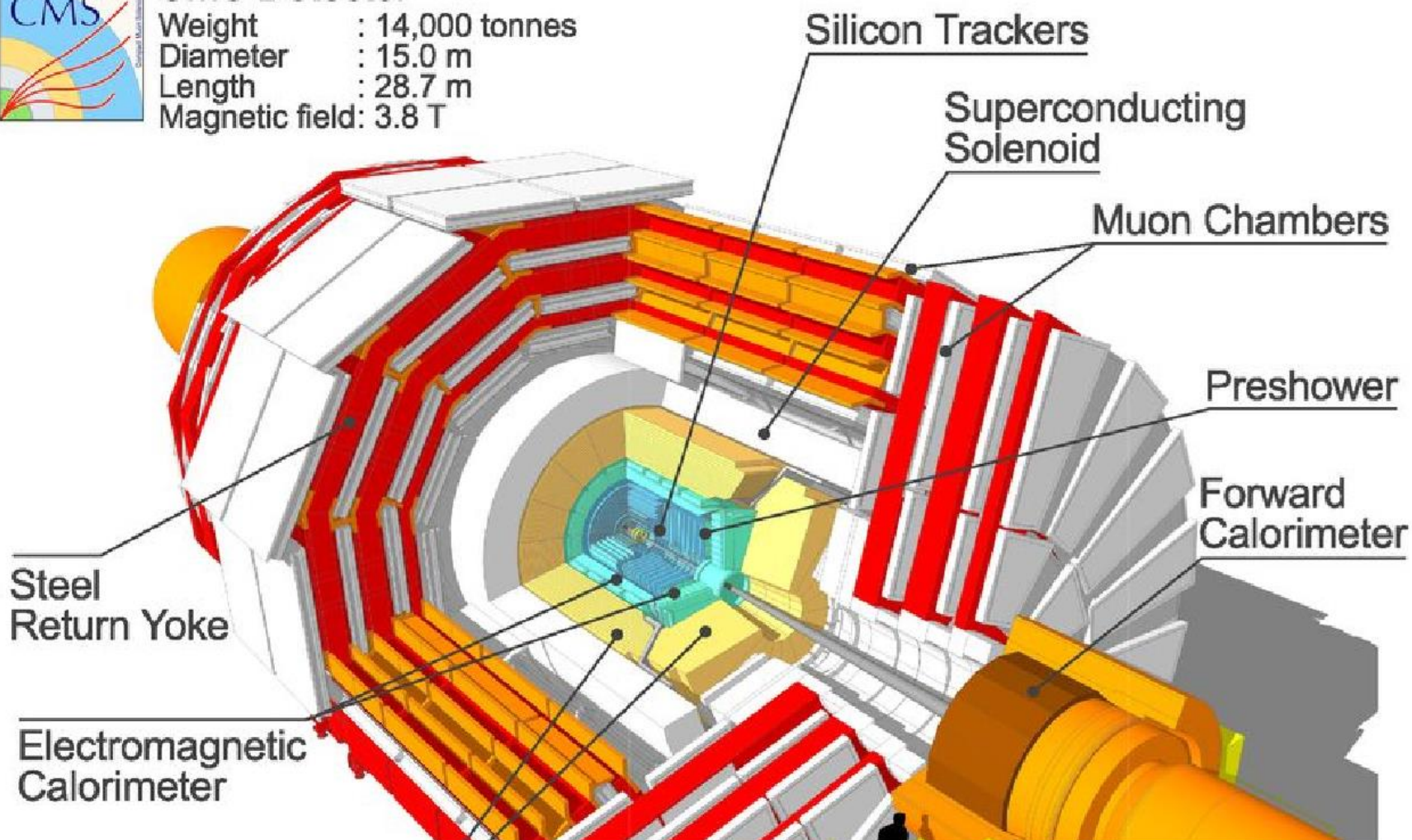
QuarkNet

The Compact Muon Solenoid (CMS)

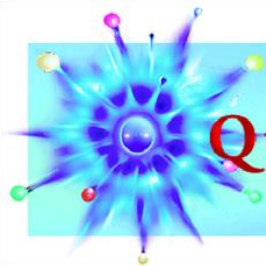


CMS Detector

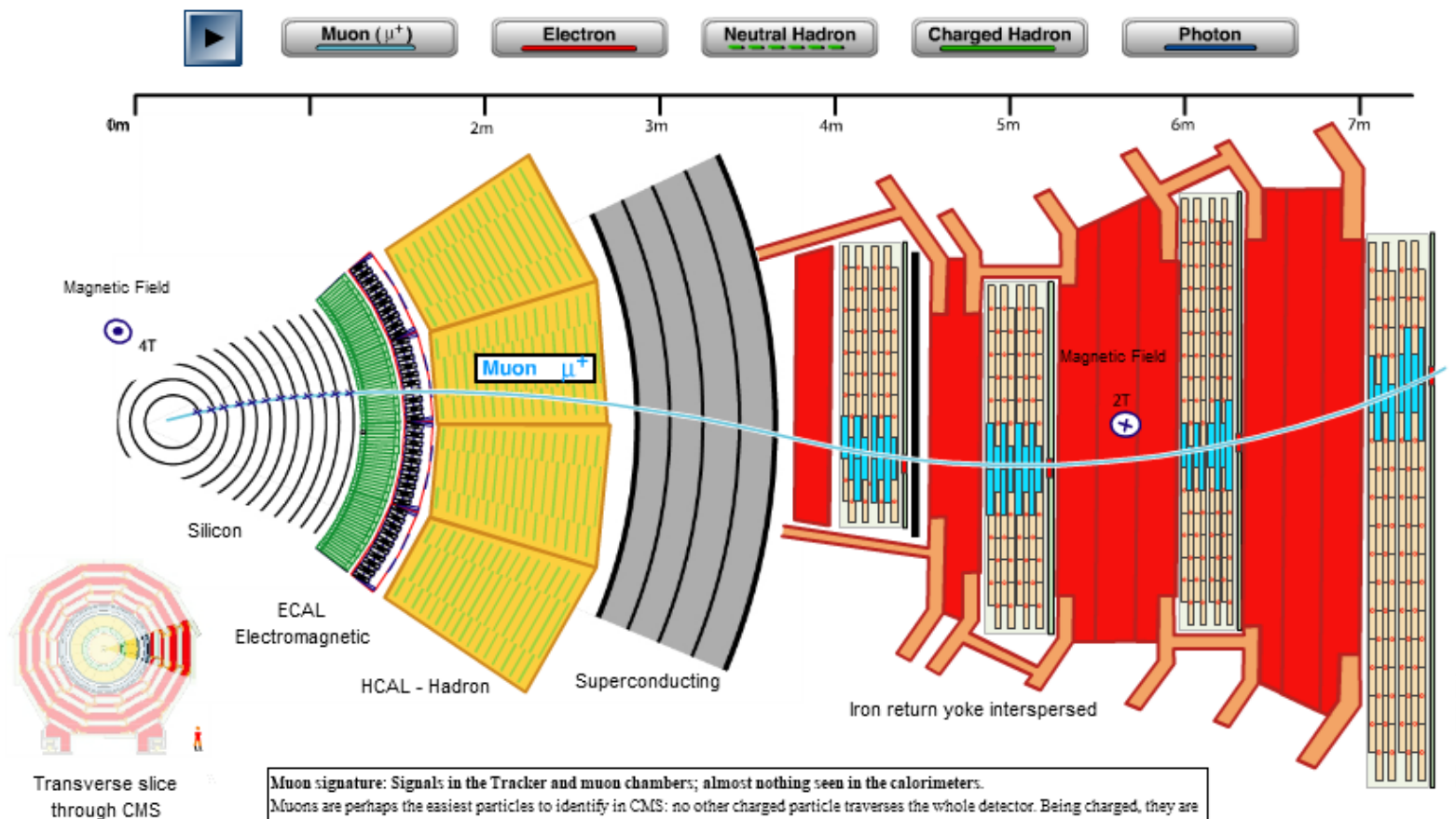
Weight : 14,000 tonnes
Diameter : 15.0 m
Length : 28.7 m
Magnetic field: 3.8 T



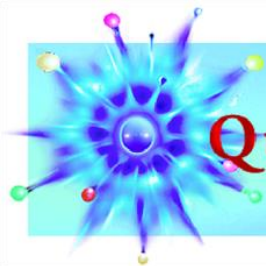
[Let's take a closer look at the real thing.](#)



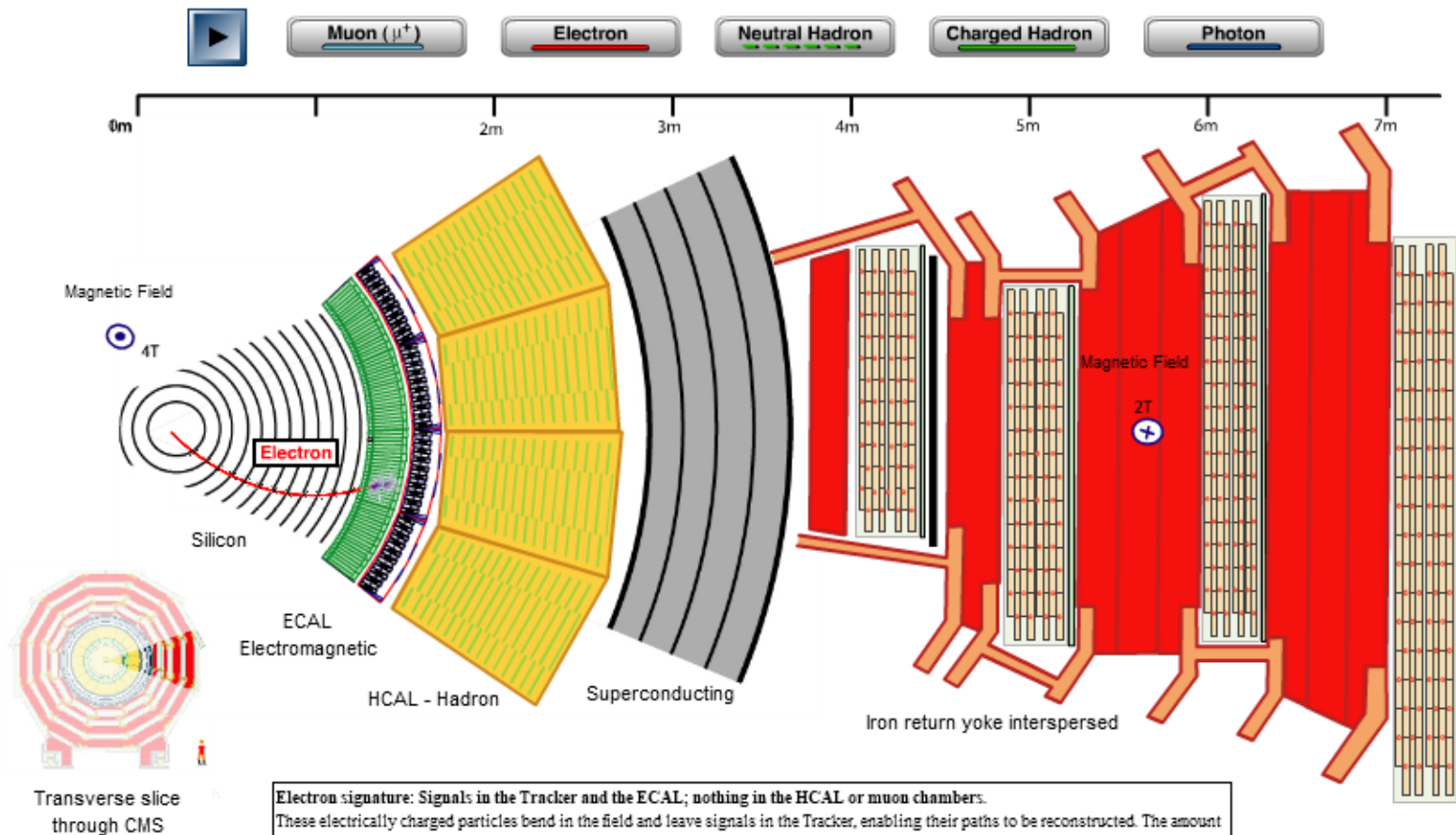
Transverse Slice of the Compact Muon Solenoid (CMS) Detector

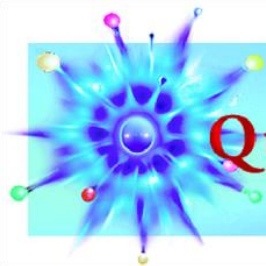


D. Barney, CERN, 2004



Transverse Slice of the Compact Muon Solenoid (CMS) Detector

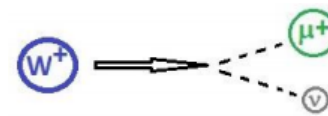
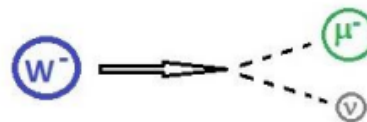
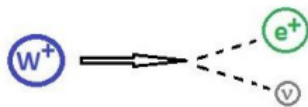
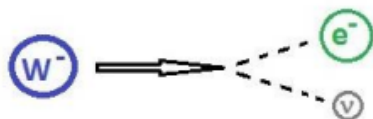
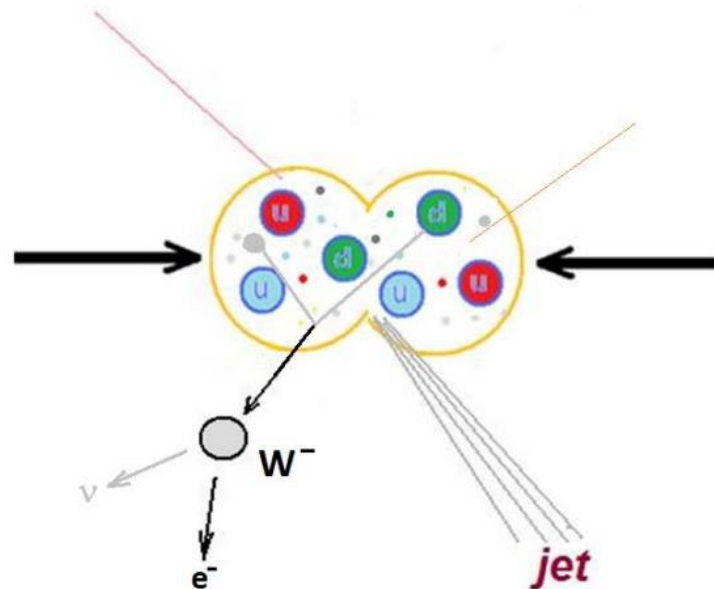


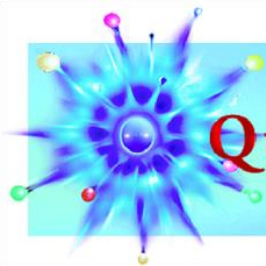


One-lepton events

The + or – charged W boson enables radioactive decay by transforming neutrons into protons.

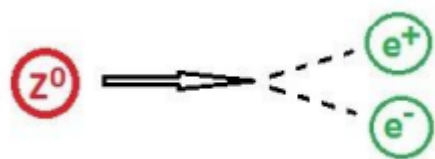
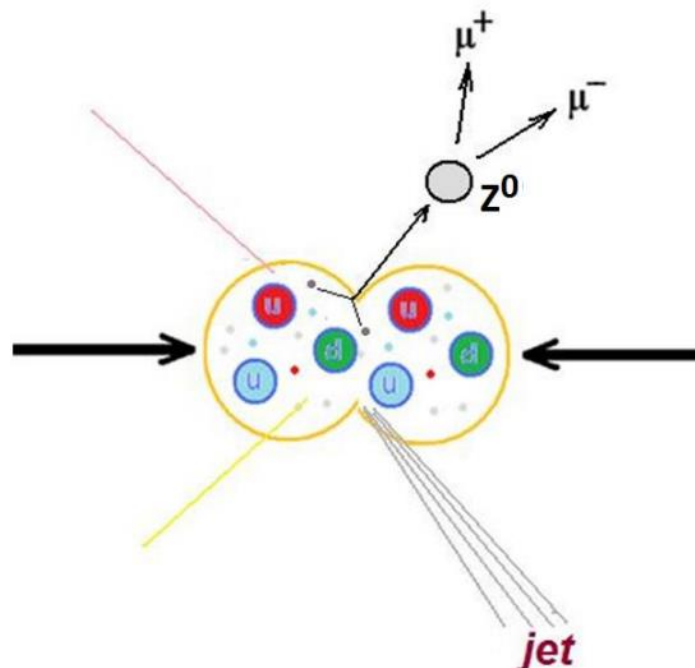
It decays into a neutrino and another lepton. Since CMS cannot detect the neutrino directly, we can call this a one-lepton event.

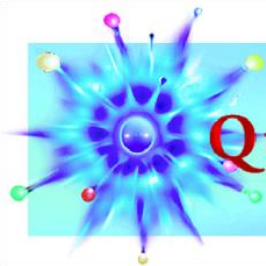




The Z boson is a neutral cousin of the W. It enables the “weak neutral current”.

It decays into two leptons of the same type but opposite charge – electron and positron or muon and antimuon. It has other decay paths but we are not looking for these.

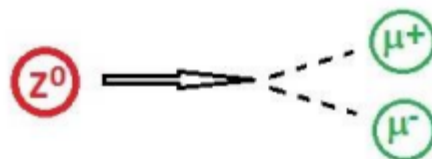
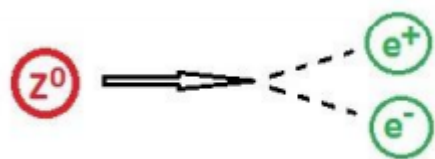
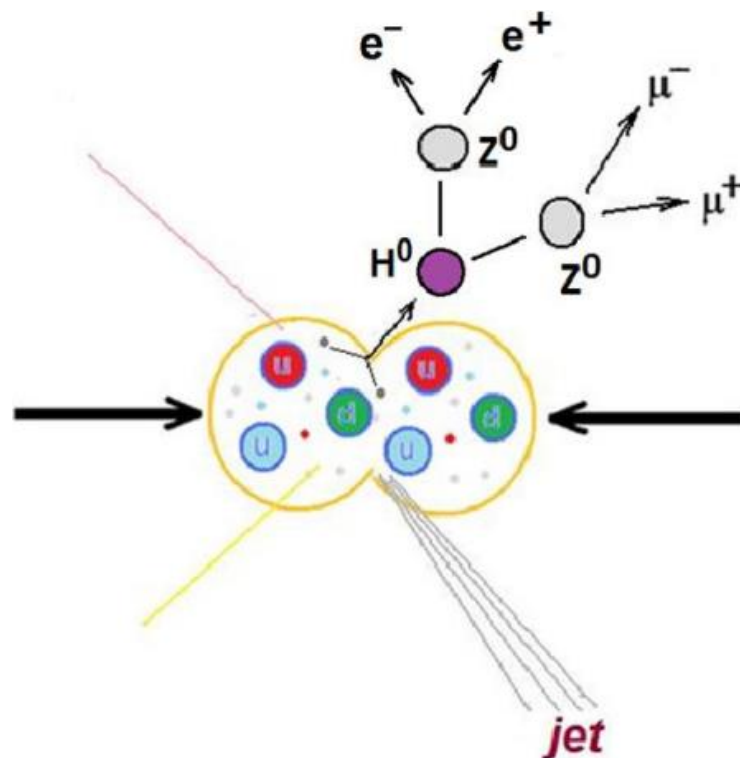


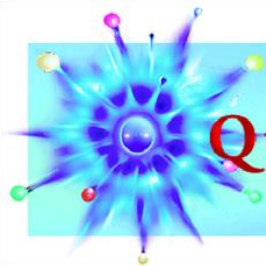


Four-lepton events

The Higgs boson is an expression of the field that gives other particles mass.

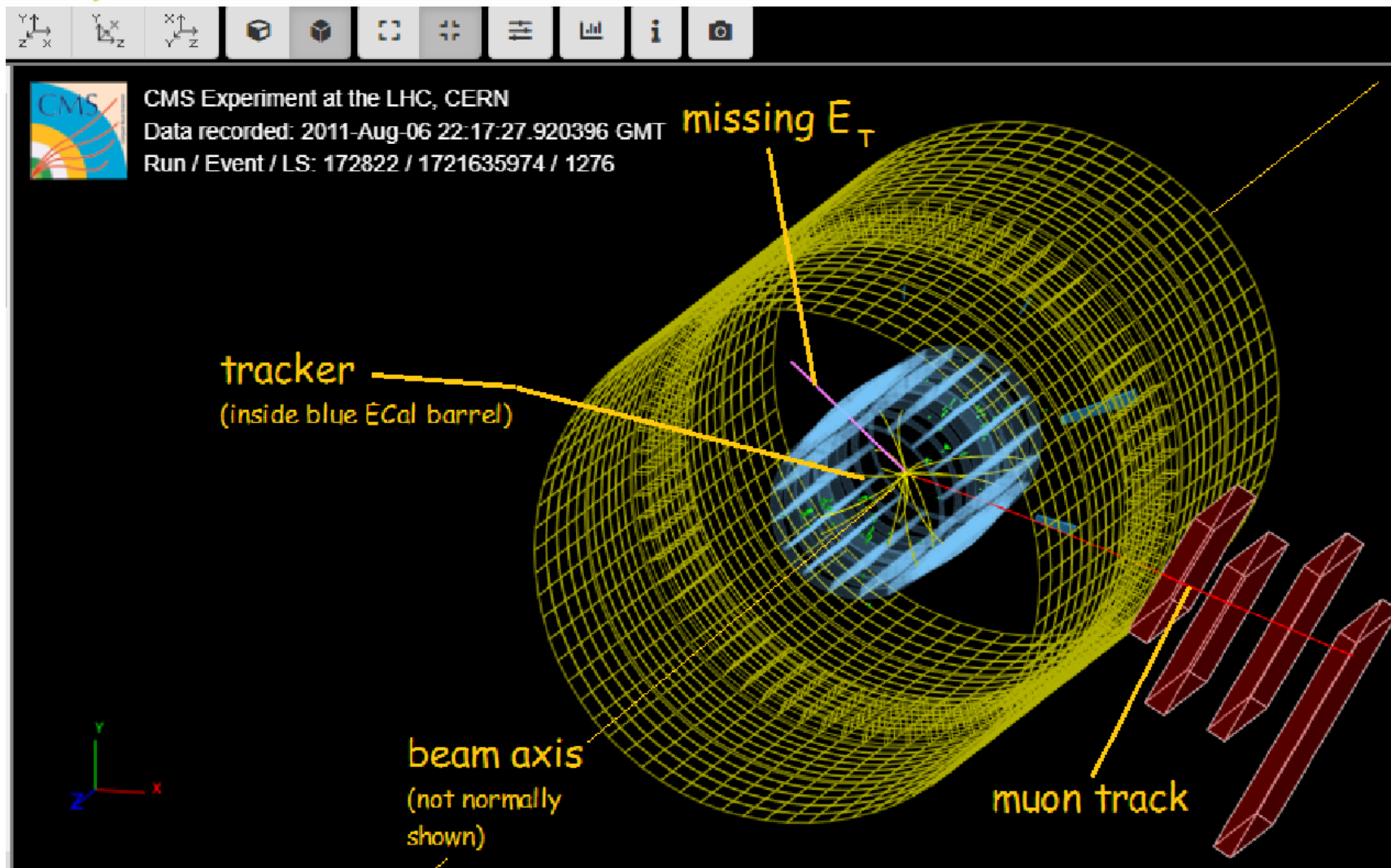
One decay mode of the Higgs is into two Z bosons, which themselves promptly decay. Thus we can get 2 muons and 2 electrons *or* 4 muons *or* 4 electrons.

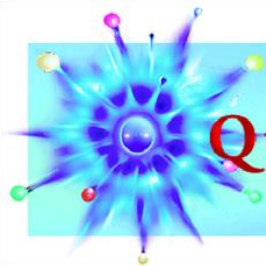




QuarkNet

iSpy event display for CMS

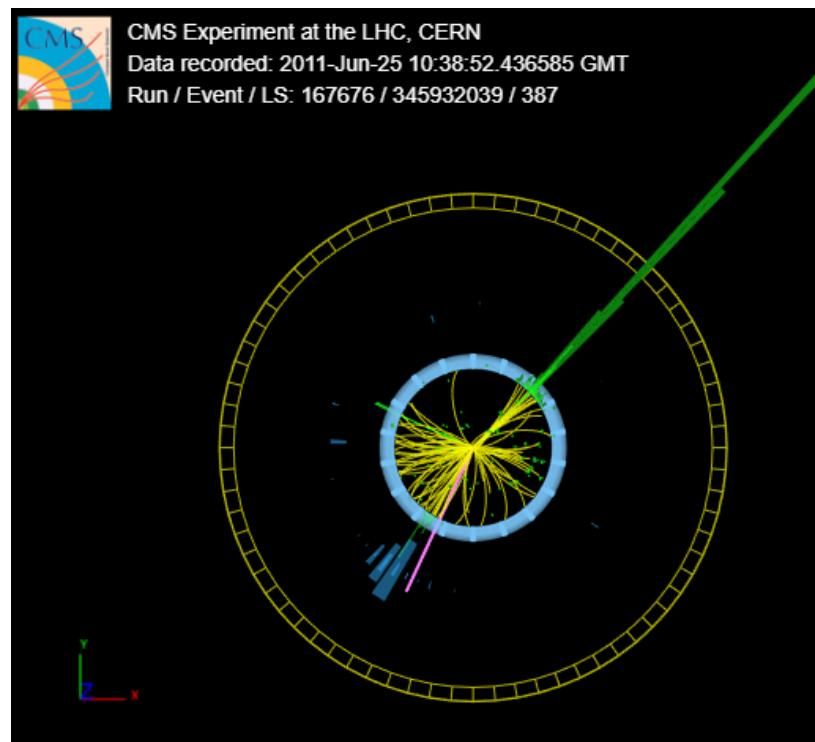
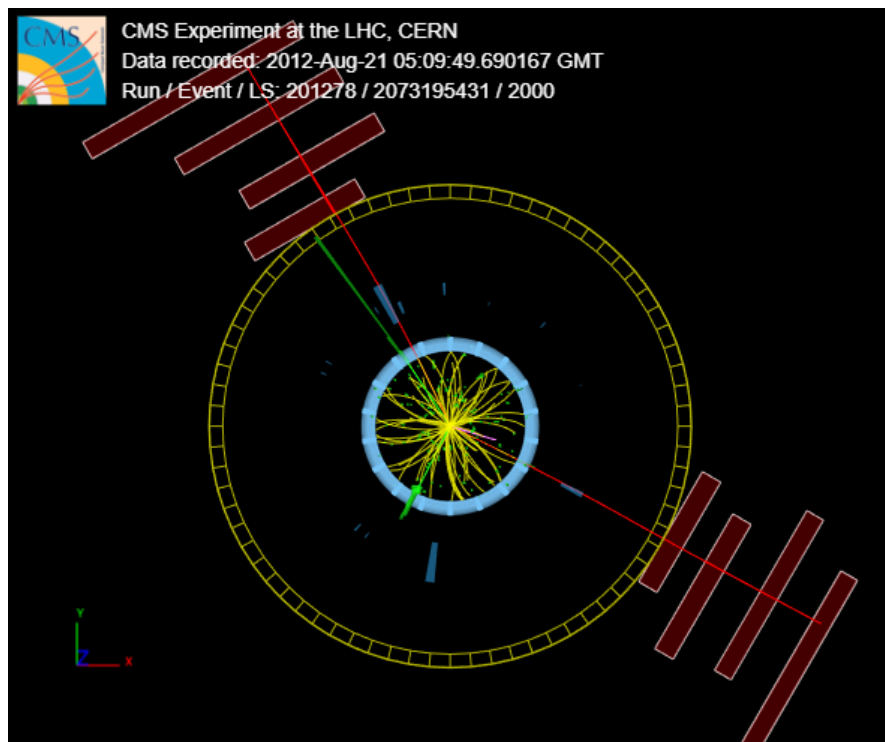


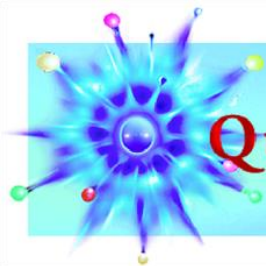


QuarkNet

1, 2, or 4 leptons?

Which of these events is 1-, 2-, or 4-lepton? Which flavors of leptons? What else do you see?

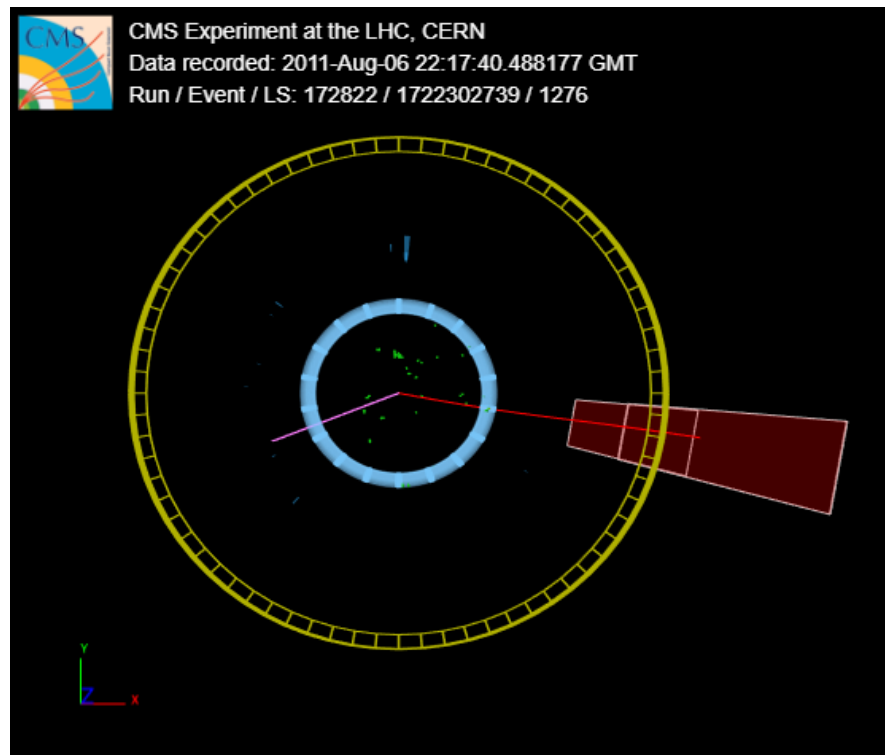
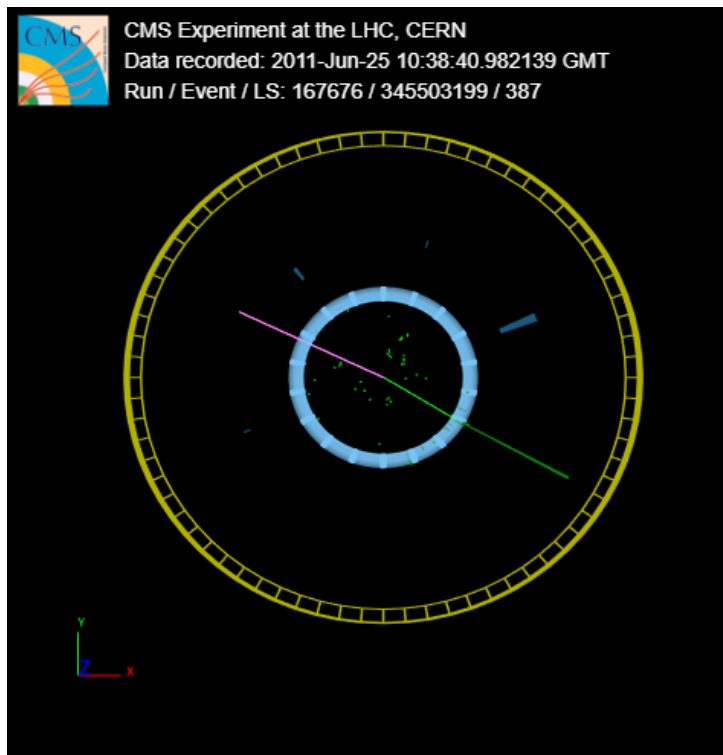


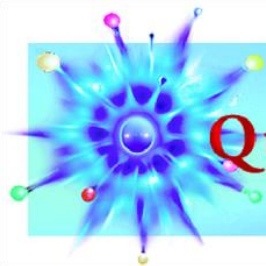


QuarkNet

1, 2, or 4 leptons?

Which of these events is 1-, 2-, or 4-lepton? Which flavors of leptons? What else do you see?

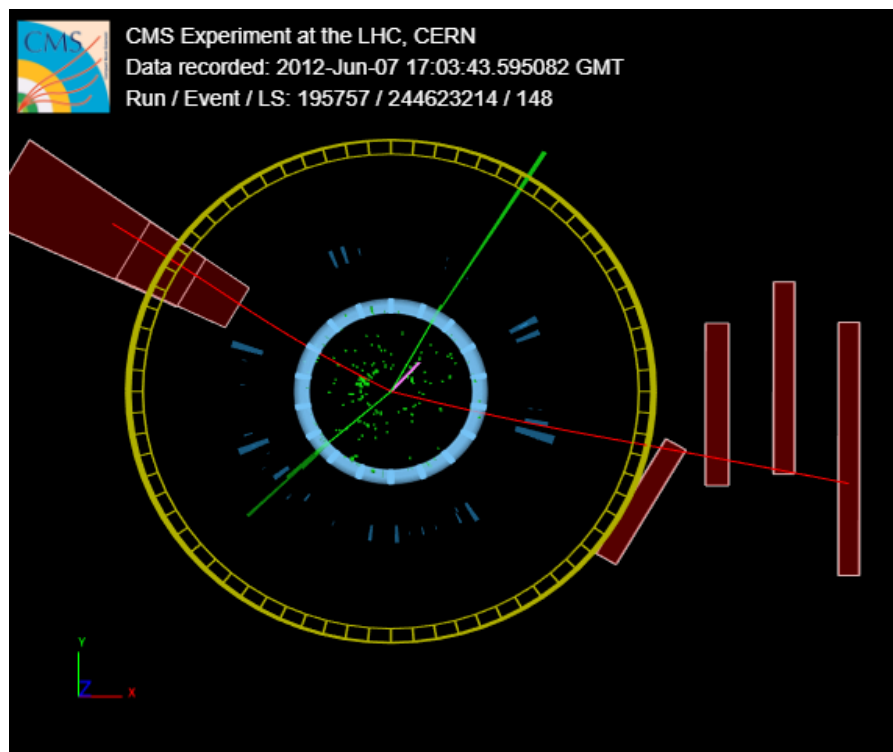
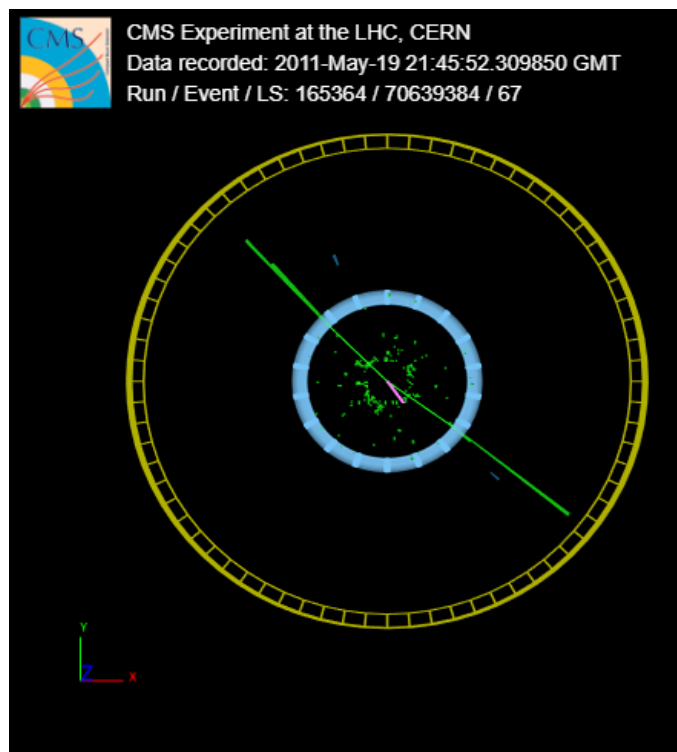


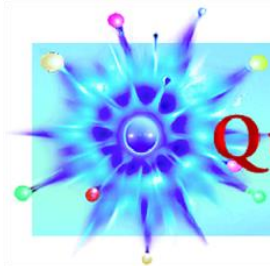


QuarkNet

1, 2, or 4 leptons?

Which of these events is 1-, 2-, or 4-lepton? Which flavors of leptons? What else do you see?





QuarkNet

CMS Instrument for Masterclass Analysis (CIMA)

Enter data on each event:

Back Events Table (Group 1) Mass Histogram (Table01) Results (Table01)

➔ Event Display

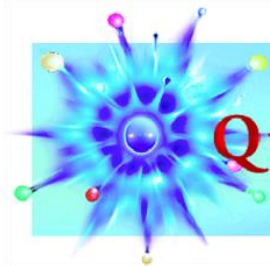
Masterclass: Event01

location: Table01

Group: 1

Select Event Event index: 14 ▾ Event number: 1-14	Final State <input type="radio"/> e ν <input type="radio"/> μ ν <input type="radio"/> e e <input type="radio"/> μ μ <input type="radio"/> 4e <input type="radio"/> 4 μ <input type="radio"/> 2e 2 μ	Primary State Charged Particle: <input type="radio"/> W ⁺ <input type="radio"/> W ⁻ <input type="radio"/> W \pm <input type="radio"/> Neutral Particle (Z, H) <input type="radio"/> Zoo	Enter Mass <input type="text"/> GeV/c ² <input type="button" value="Next"/>
--	--	---	---

Event index	Event number	Final state	Primary state	Mass
13	1-13	$\mu\nu$	W \pm	

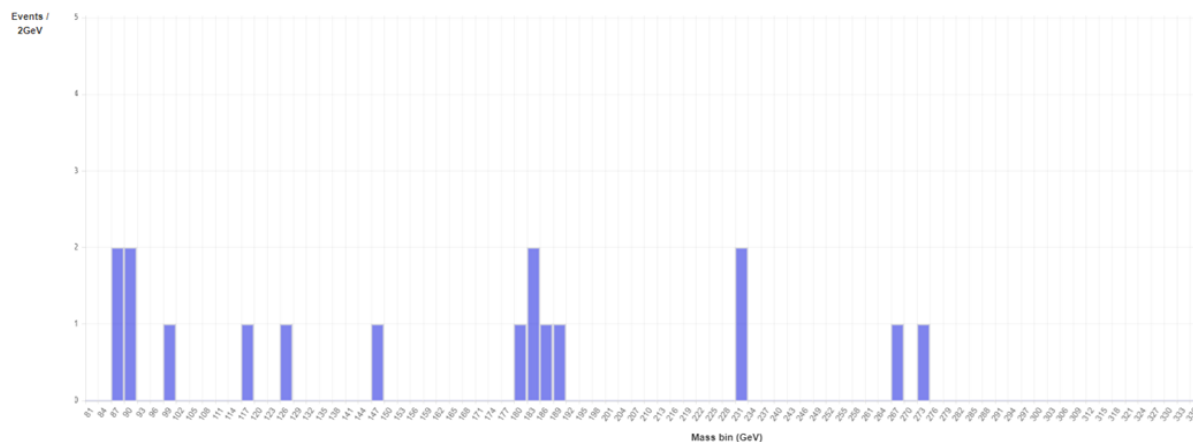
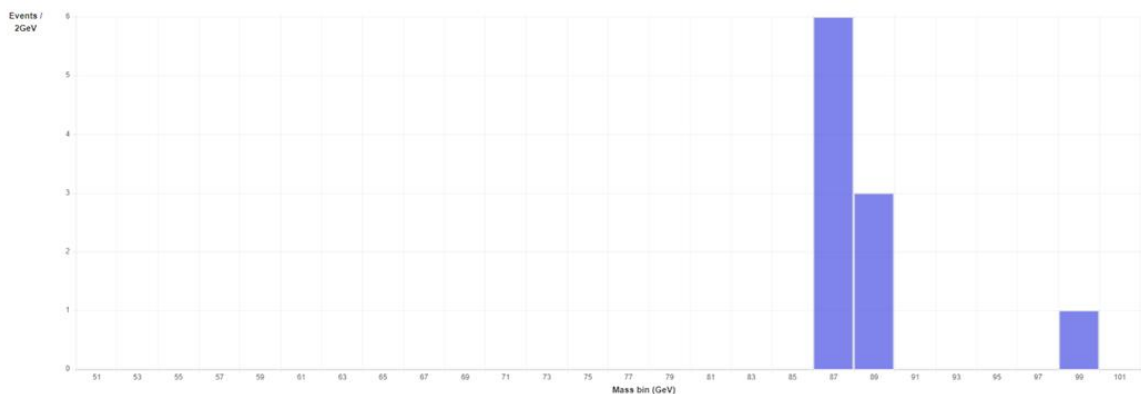


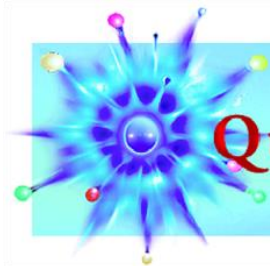
QuarkNet

CMS Instrument for Masterclass Analysis (CIMA)

CIMA makes mass histograms automatically:

Masterclass: CUA-FIU-VM-6Aug2019
location: FIU-Aug2019





QuarkNet

CMS Instrument for Masterclass Analysis (CIMA)

CIMA tabulates data for key ratios:

[Back](#) [Events Table \(Group 21\)](#) [Mass Histogram \(FIU-Aug2019\)](#) [Results \(FIU-Aug2019\)](#)

Masterclass: CUA-FIU-WM-6Aug2019

location: FIU-Aug2019

Group	e	μ	W+	W-	W \pm	Neutral	Zoo	Total
21	26	32	21	21	0	13	0	55
22	41	46	24	38	1	16	1	80
23	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0
25	10	12	10	5	0	5	1	21

Total:

Group	e	μ	W+	W-	W \pm	Neutral	Zoo	Total
All	77	90	55	64	1	34	2	156

Ratios:

e/ μ	W+/ W^-
0.92	0.86