

# CMS Masterclass 2025 for Moderators

## 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 (100x150  $\mu\text{m}$ )  $\sim 16\text{m}^2$   $\sim 66\text{M}$  channels  
Microstrips (80x180  $\mu\text{m}$ )  $\sim 200\text{m}^2$   $\sim 9.6\text{M}$  channels

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

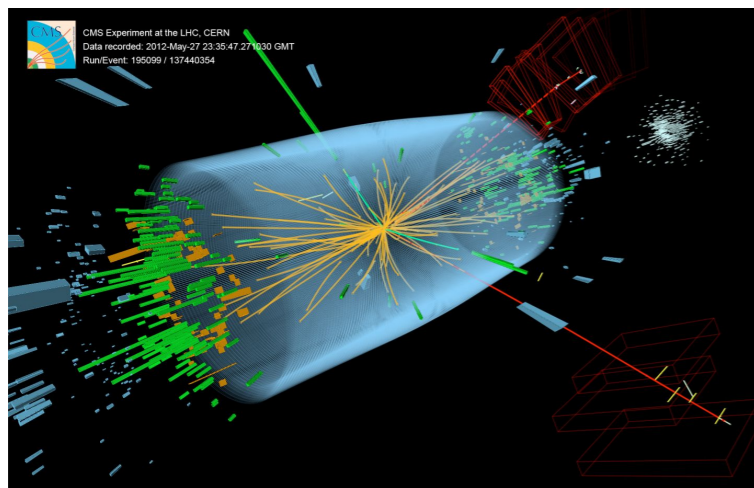
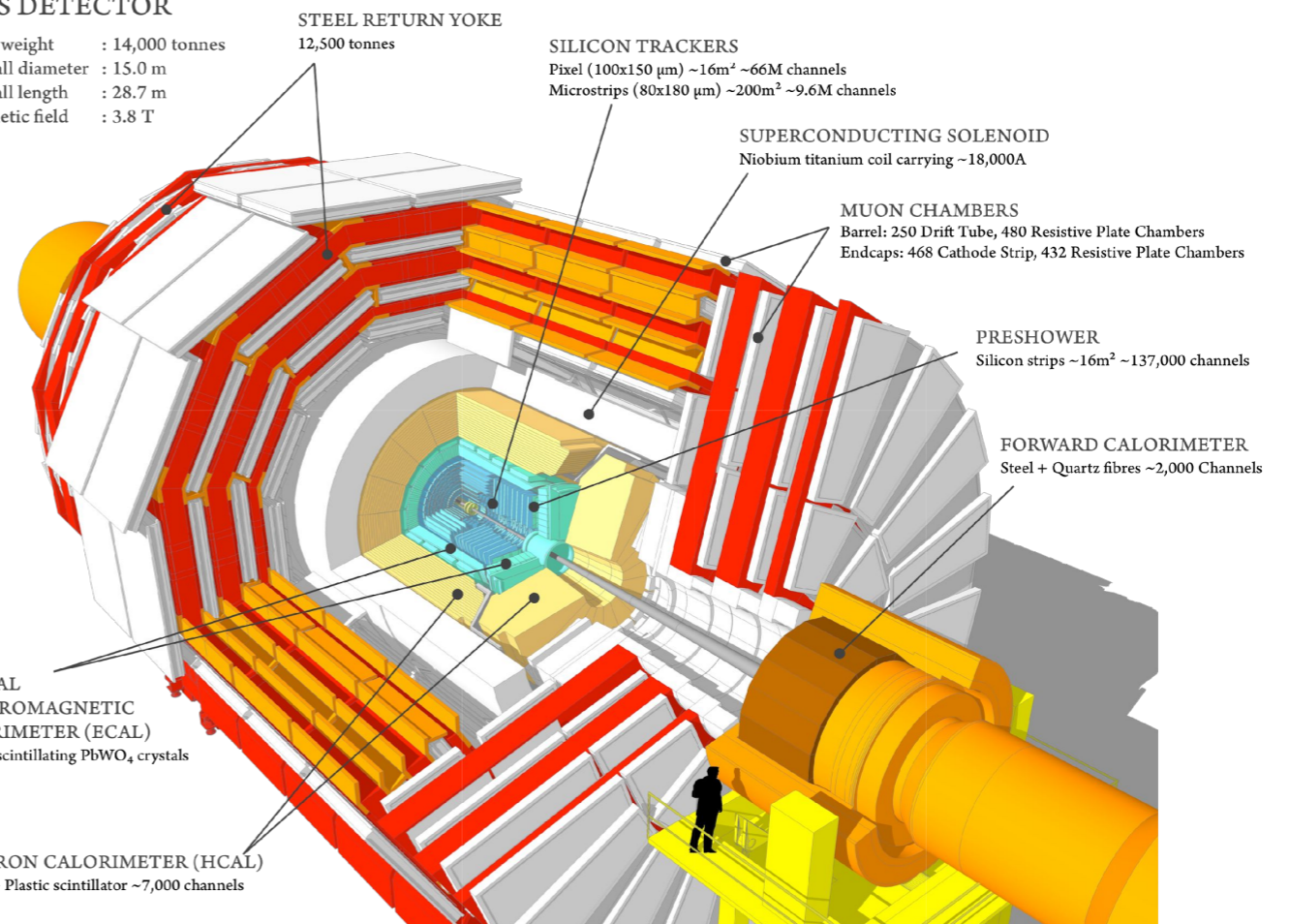
MUON CHAMBERS  
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers  
Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

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





## CMS masterclass features

- Nearly 20K events (divided into 190 datasets):
  - **1-lepton (plus missing  $E_T$ ):  $W$**
  - **2-lepton:  $Z$ ,  $J/\Psi$ , Upsilon**
  - **4-lepton:  $H$ ,  $ZZ$**
- Event display: iSpy-WebGL
- CIMA – CMS Instrument for Masterclass Analysis
- Documentation at <http://cern.ch/go/76BG>.

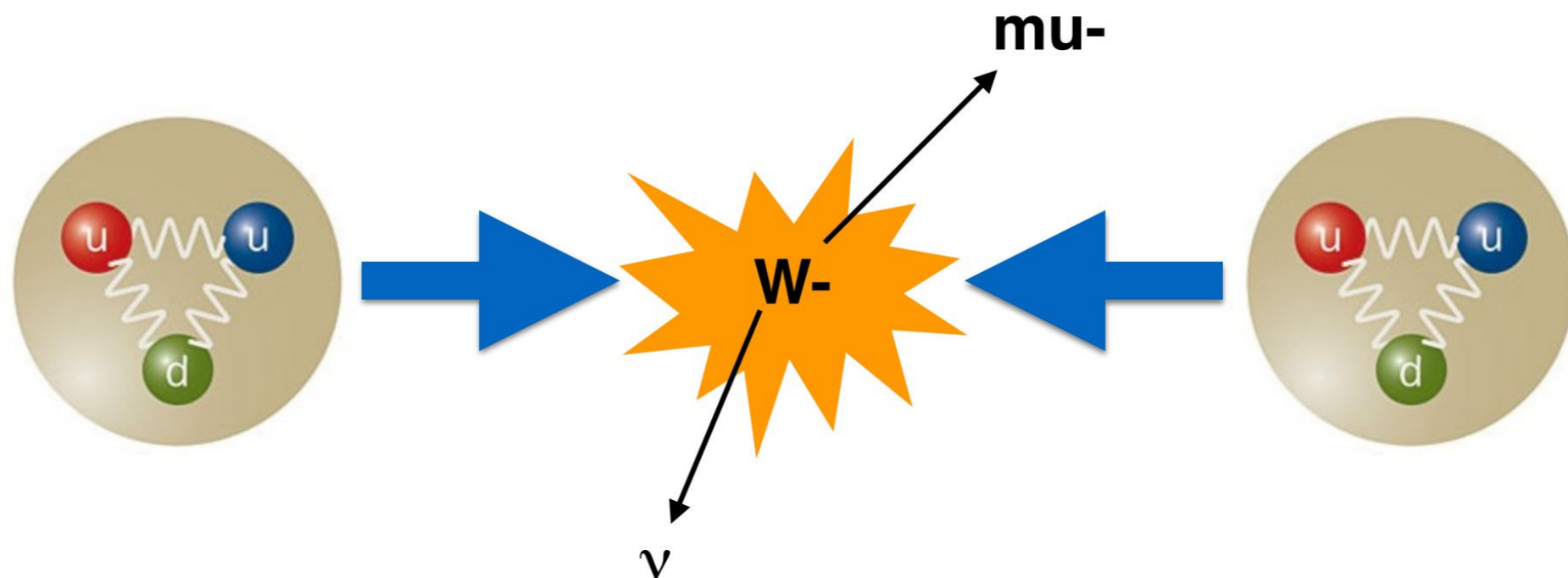
Students find  $e:\mu$  and  $W^+:W^-$ .

Students create dilepton and 4-lepton mass plots.



## About collisions

- Protons as “bags of partons”
- Parton-parton collisions
- Each parton shares only a portion of proton momentum
- $W^+ : W^-$  as probe of proton structure






# iSpy-WebGL

iSpy WebGL N10:Events/Run\_1/Event\_92 [92 of 100]

Navigation icons: Home, Search, 3D,  $r\phi$ ,  $\rho z$ , Coordinate systems (Y-Z, X-Z, X-Y), and View toggles.

 CMS Experiment at the LHC, CERN  
Data recorded: 2011-Aug-17 06:01:53.413606 GMT  
Run / Event / LS: 173389 / 490488072 / 370

**Matching muon chambers**

**Muon**

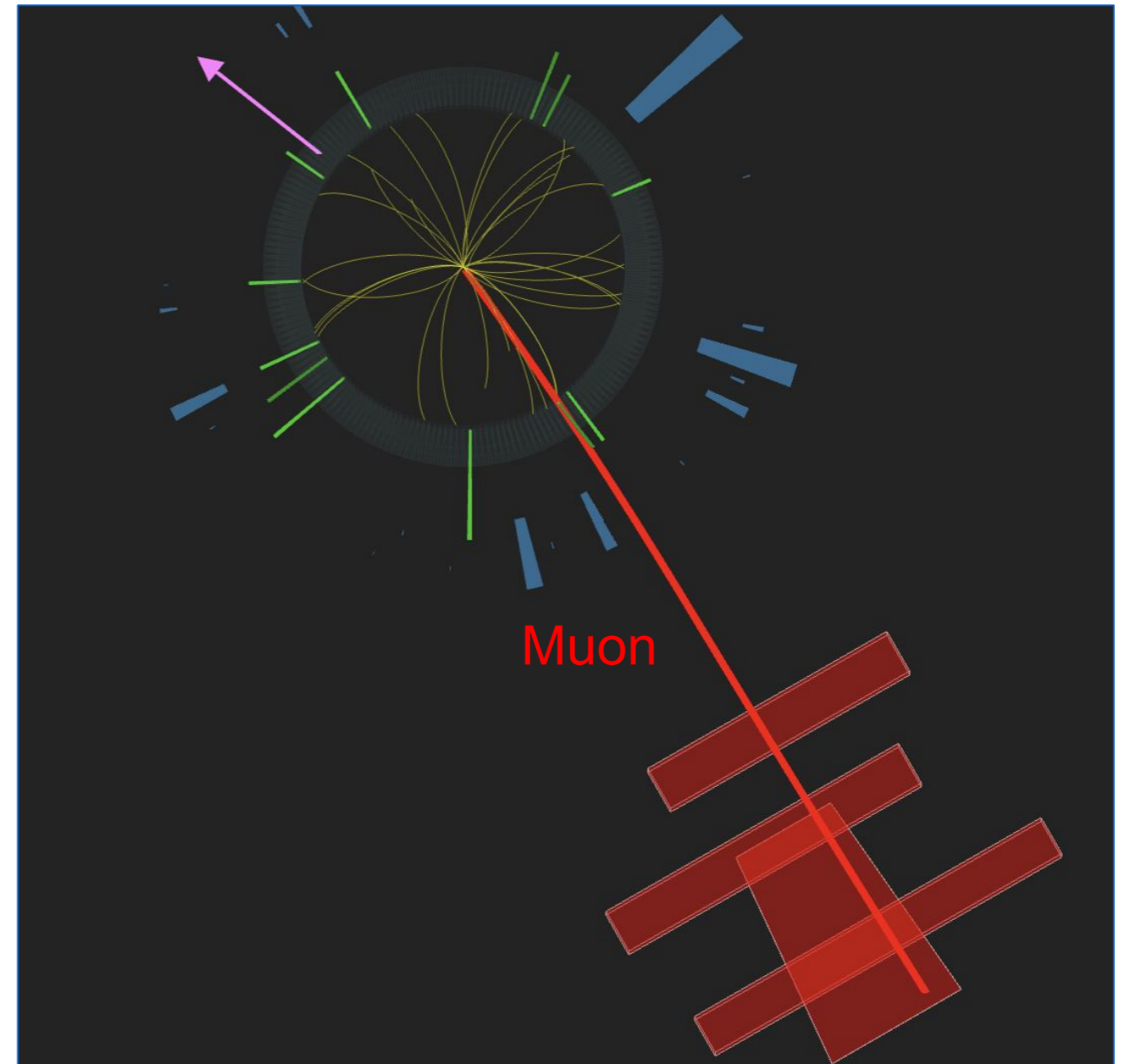
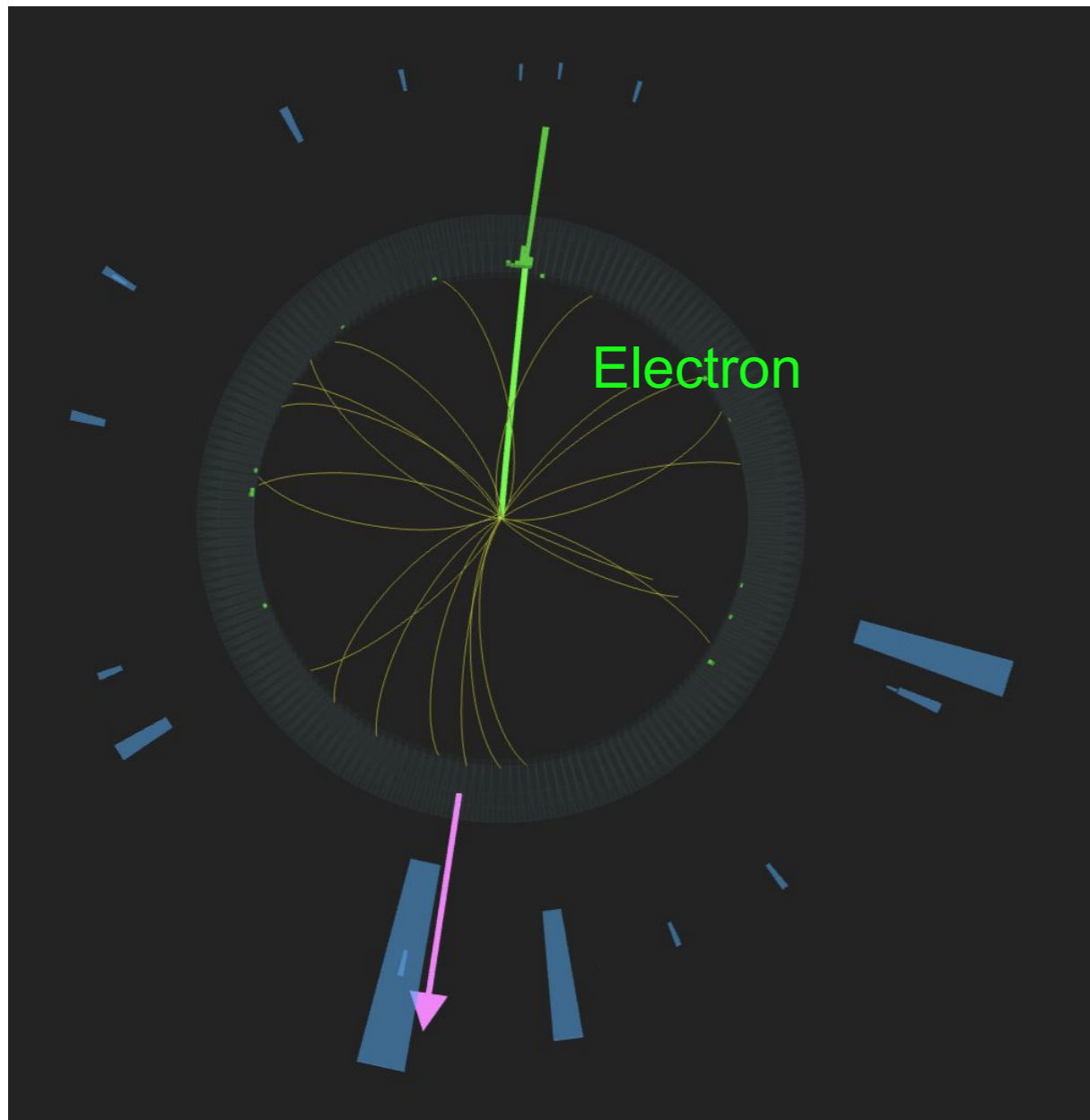
**MET**

**ECAL barrel**



## Student tasks

Students distinguish electron tracks from muon tracks.

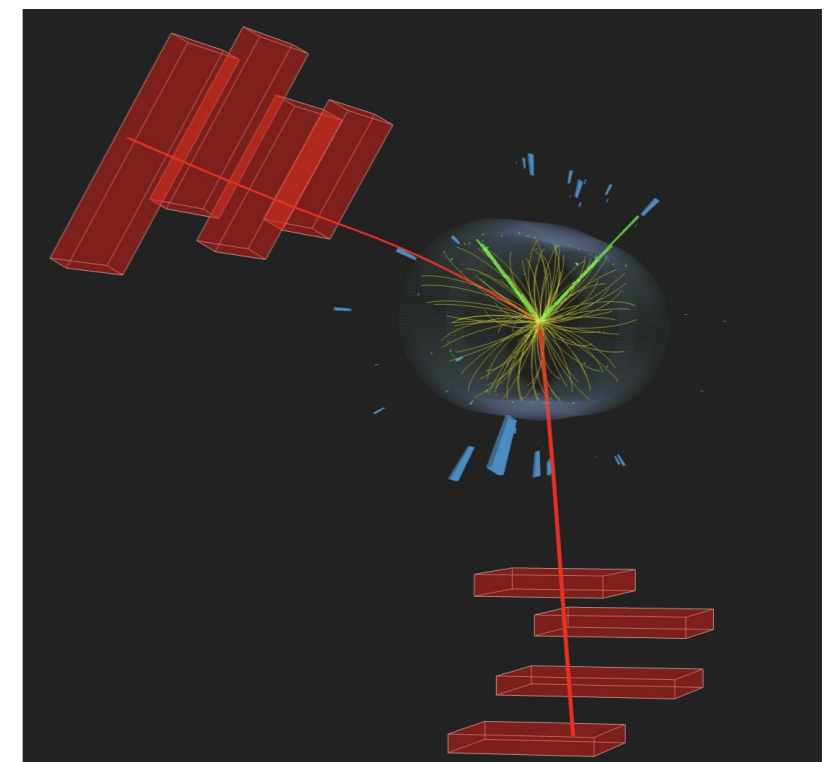
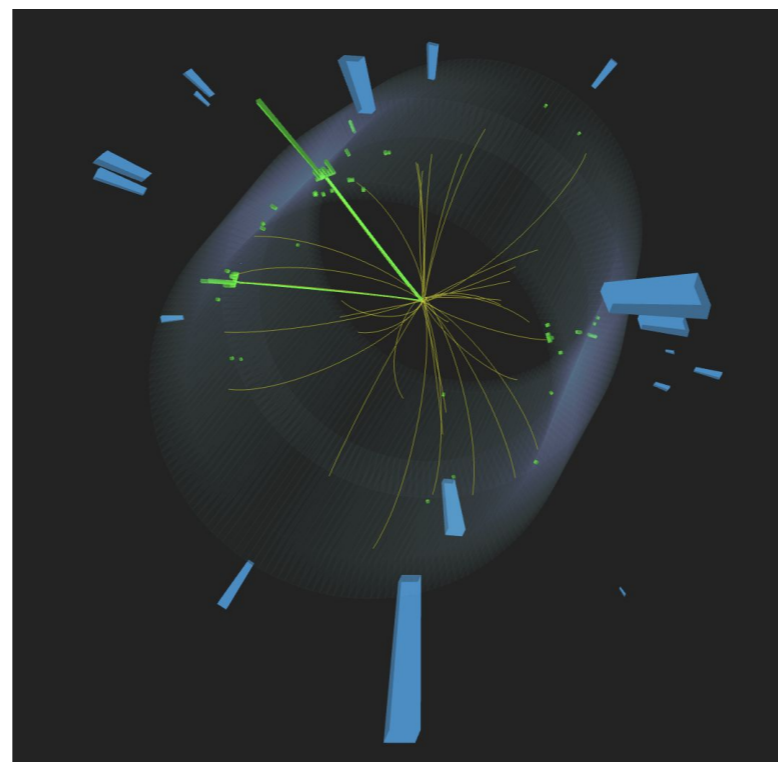
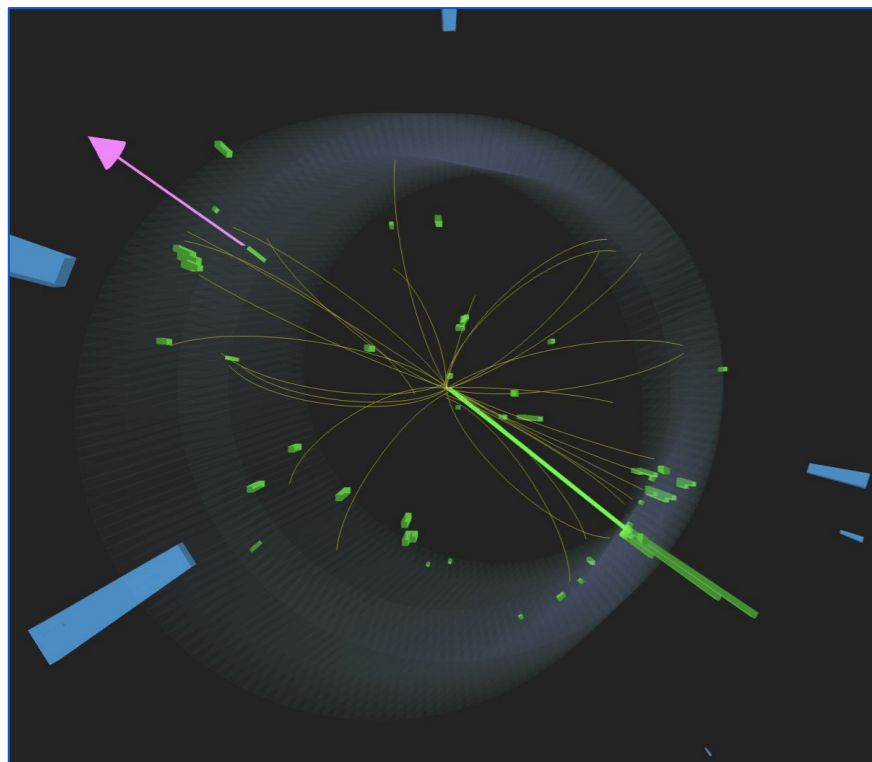




## Student tasks

Students must distinguish 1-lepton plus missing  $E_T$ , 2-lepton, and 4 lepton events.

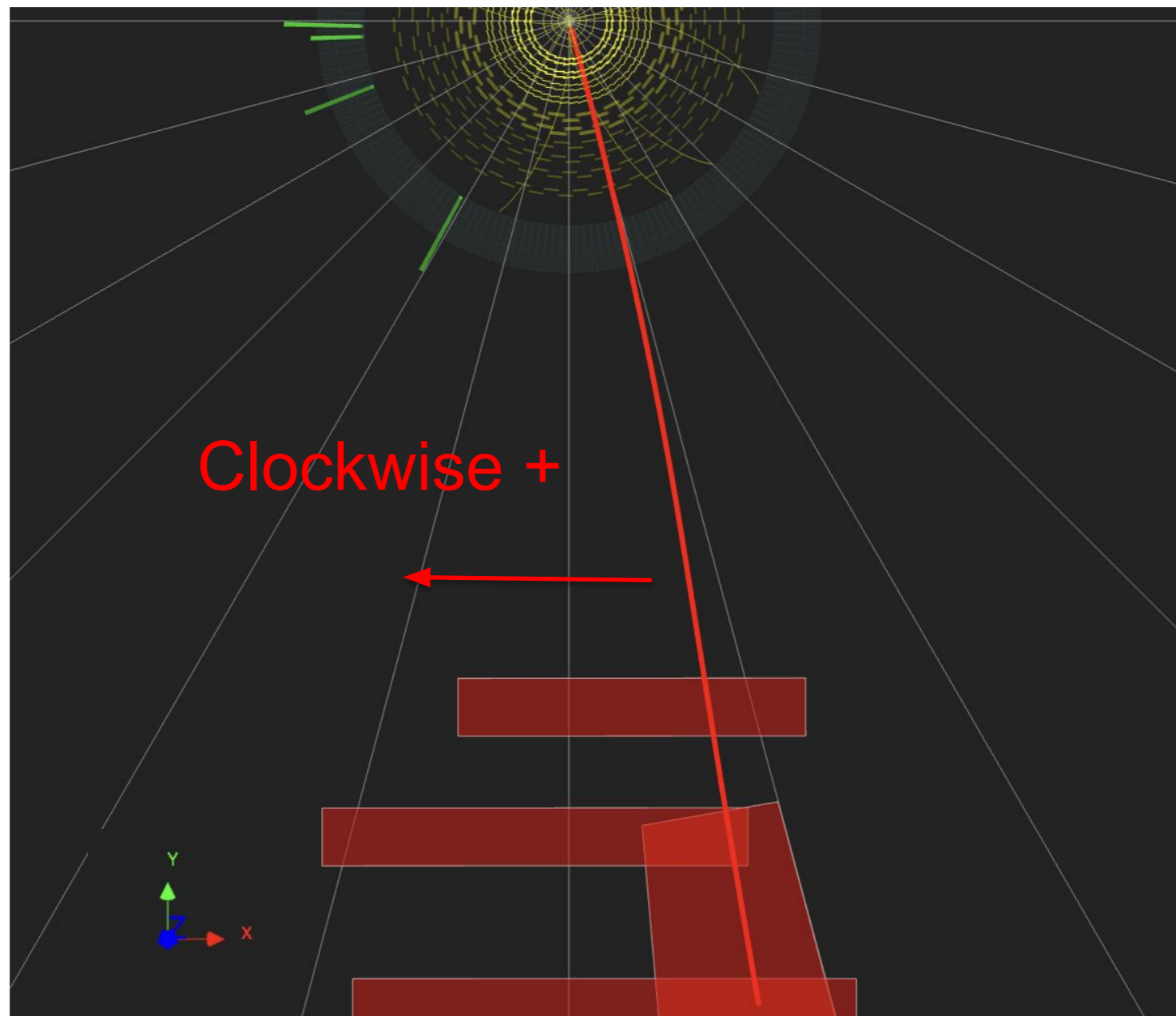
*Typical questions are about extra lepton tracks or missing  $E_T$  together with 2- or 4-lepton events.*





# Student Tasks

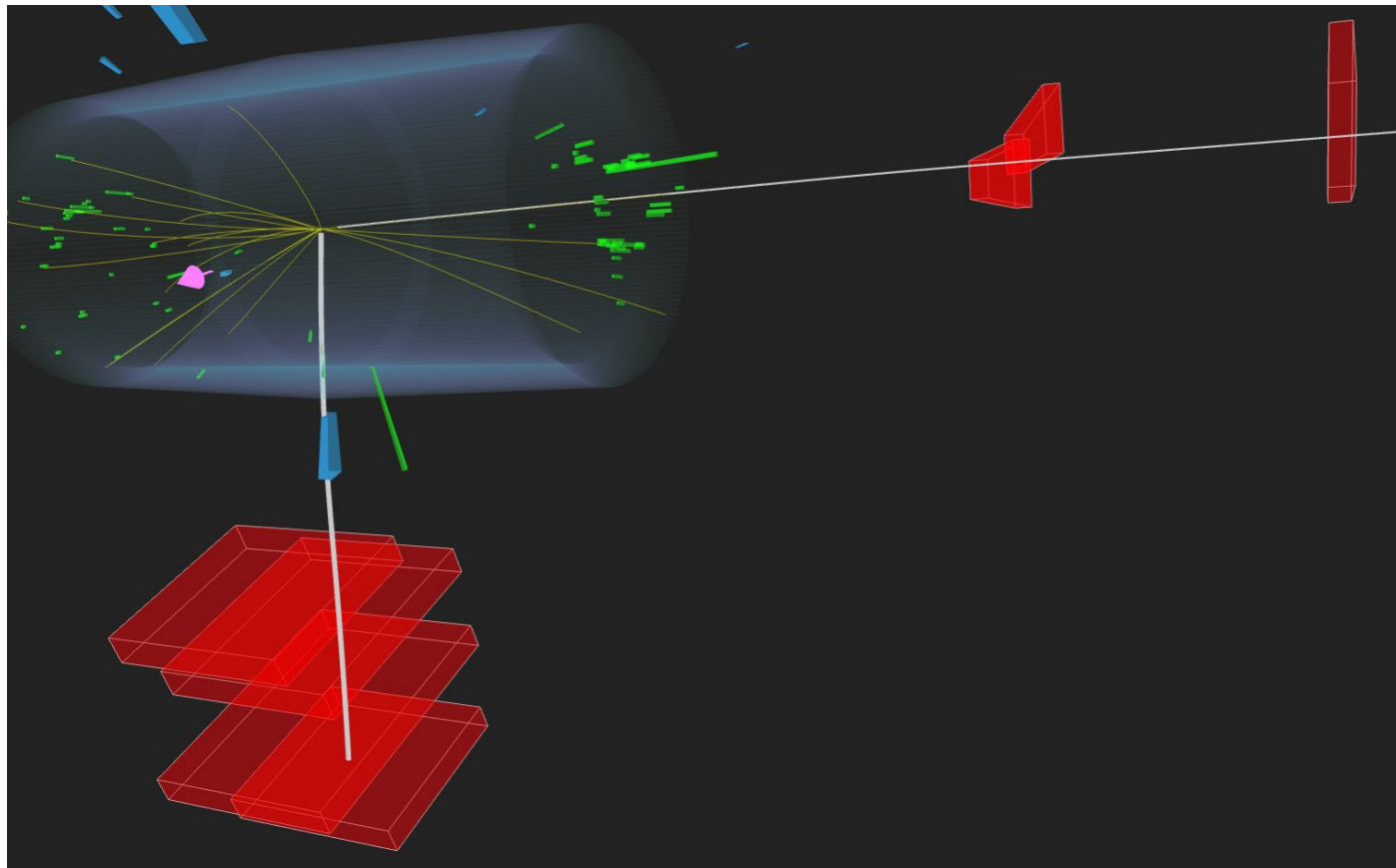
Students distinguish  $W^+$  from  $W^-$  using track curvature.





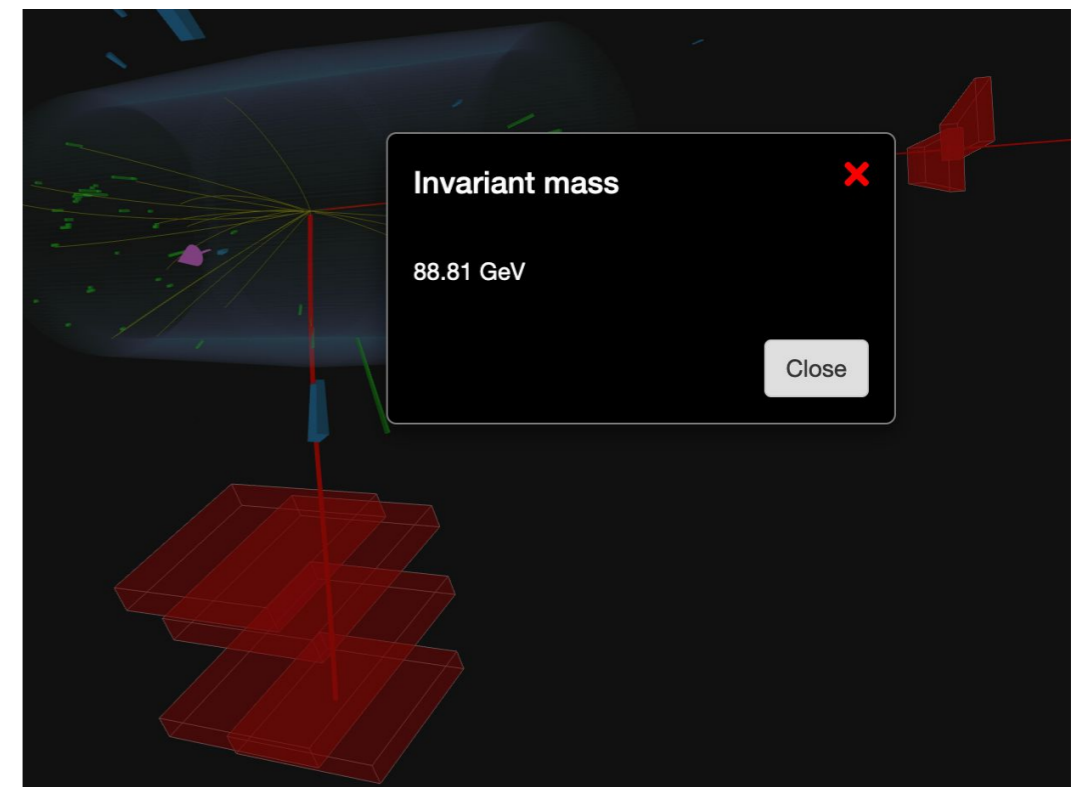
# Student Tasks

Students determine invariant mass.



Click on electron or muon tracks to highlight

Press “M” to reveal invariant mass







# Recording event data

Students find their dataset.

They record parent particles and decay modes.

**CIMA**  
CMS Instrument for Masterclass Analysis

Choose your Masterclass  
Event01  
Tallahasee-01Aug2019  
CUA-FIU-WM-6Aug2019  
VirtualQuarkNet-12Aug2019  
TW-SC-MN-03Jan2020-new  
NCU-TW-05Jan2020  
Examples-25Jan2020

Choose your location  
SampleTable1\_jan2020  
SampleTable2\_jan2020

Choose your data file  
10.1  
10.2  
10.3  
10.4  
10.5  
10.6  
10.7  
10.8  
10.9

Back Events Table (Group 10.4) Mass Histogram (SampleTable2\_jan2020) Results (SampleTable2\_jan2020) [Event Display](#)

Masterclass: Examples-25Jan2020  
Location: SampleTable2\_jan2020  
Group: 10.4

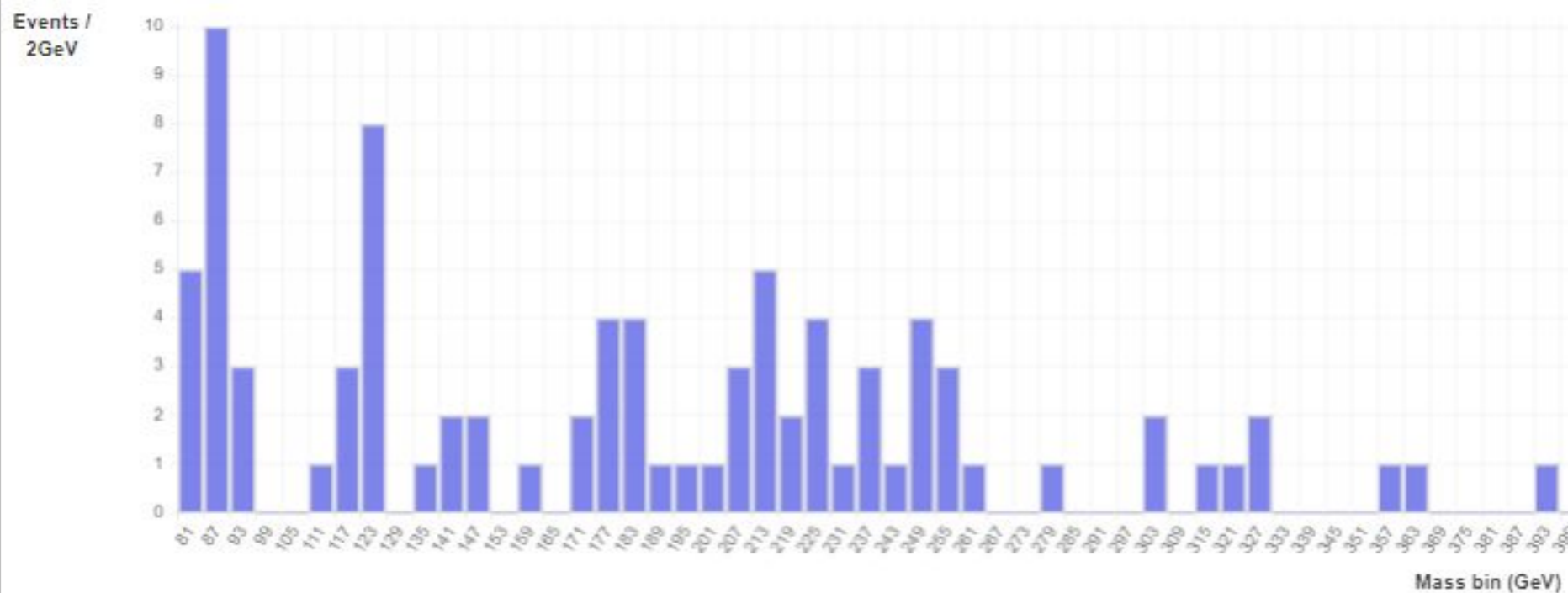
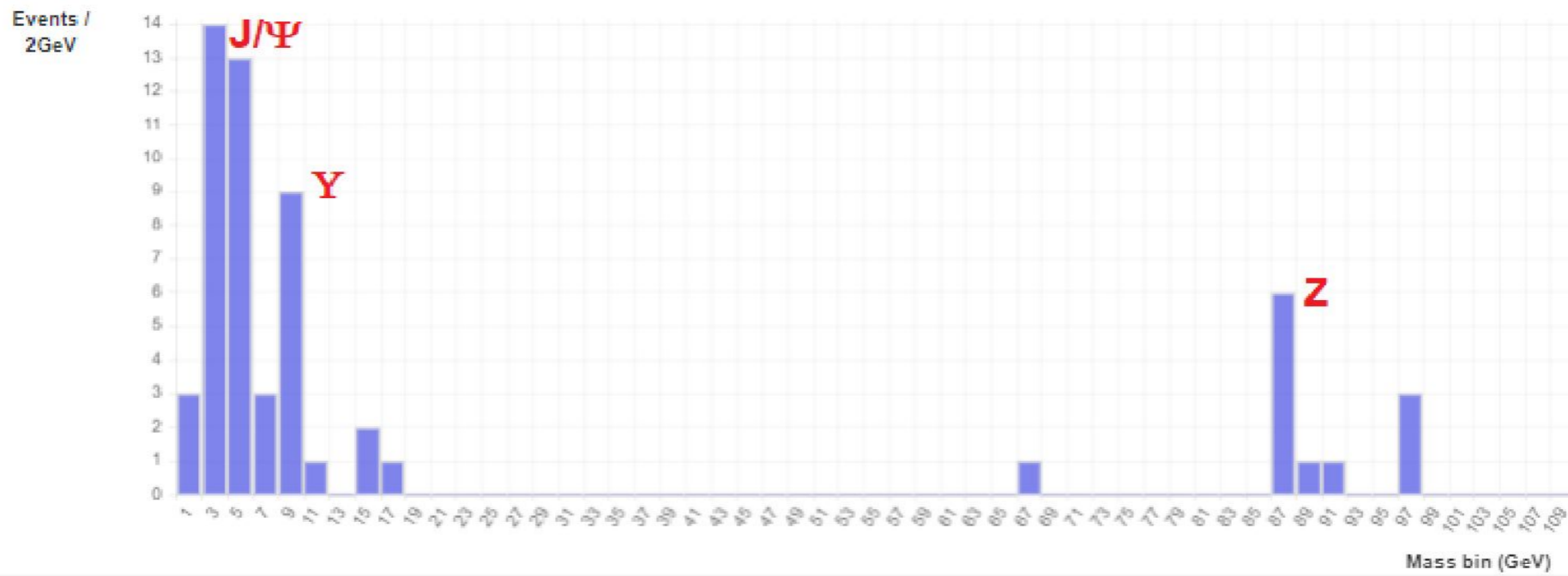
<b>Select Event</b> Event index: <input type="text" value="2"/> Event number: 10.4-2	<b>Final State</b> <input type="radio"/> e ν <input type="radio"/> μ ν <input type="radio"/> e e <input checked="" type="radio"/> μ μ <input type="radio"/> 4e <input type="radio"/> 4μ <input type="radio"/> 2e 2μ	<b>Primary State</b> Charged Particle: <input type="radio"/> W <sup>+</sup> <input type="radio"/> W <sup>-</sup> <input type="radio"/> W <sup>±</sup> <input checked="" type="radio"/> Neutral Particle (Z, H) <input type="radio"/> Zoo	<b>Enter Mass</b> <input type="text" value="10.27"/> GeV/c <sup>2</sup> <input type="button" value="Next"/>
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Event index	Event number	Final state	Primary state	Mass
9001	10.4-1	2e 2μ	neutral	209.96



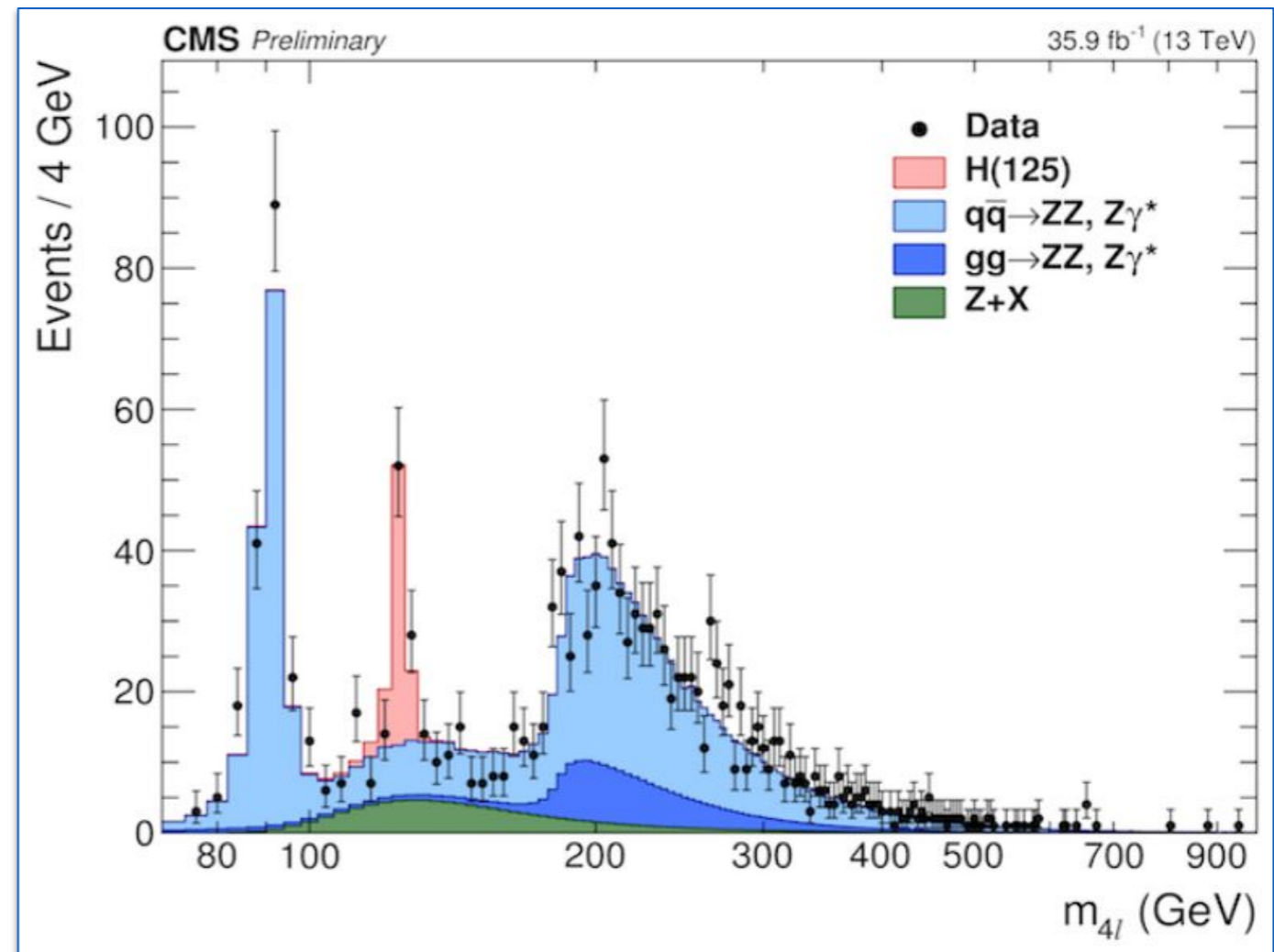
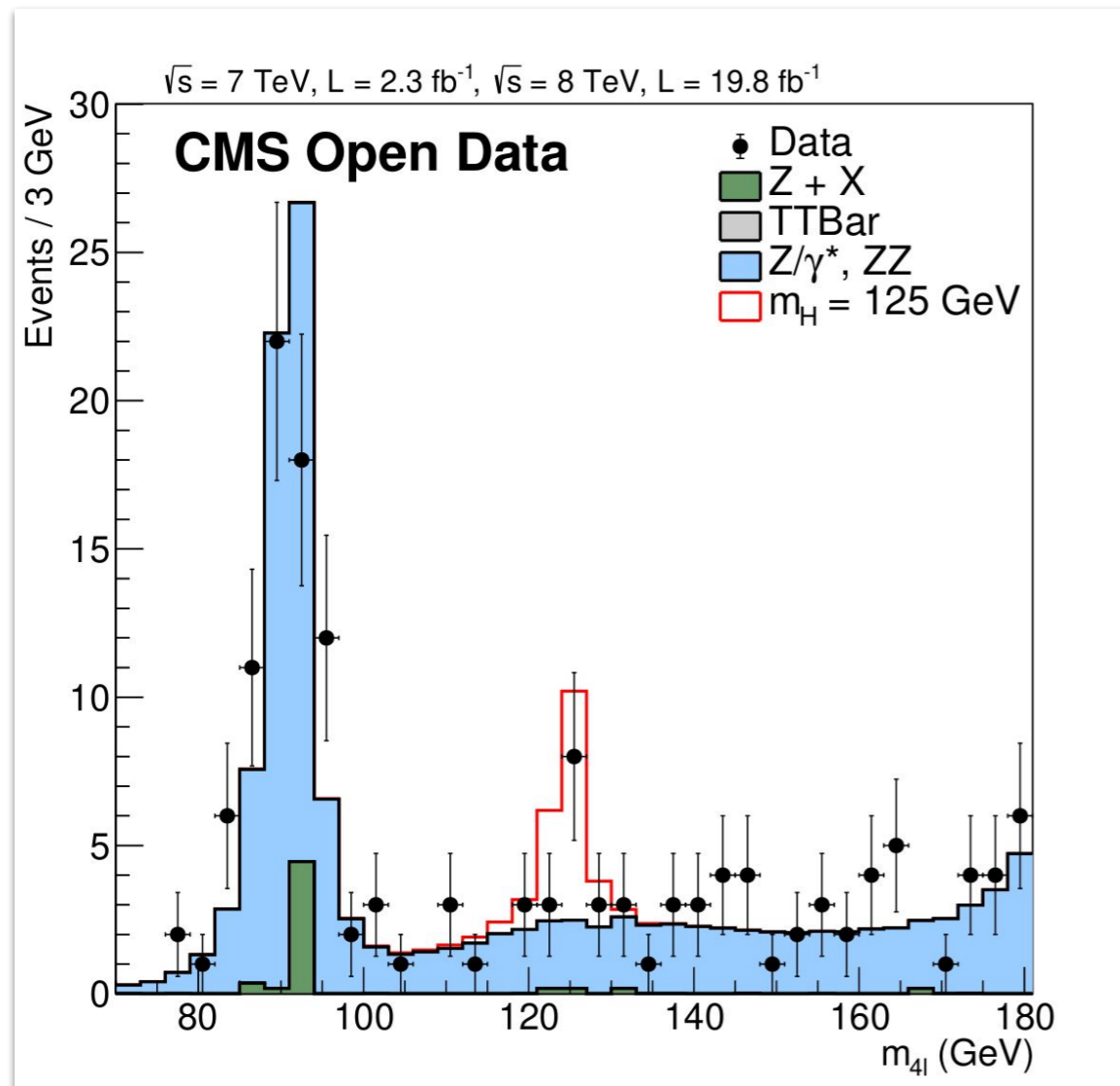
# What you see

Tables: TWV\_workshop-Jan2020 AAPT\_WM\_2020





# 4-lepton events





## Brief discussion of plots

- Ask students how many peaks they see. (Show of hands for 0, 1, 2, ... peaks.)
- Where is Z boson in the dilepton plot? Is there a similar peak in the 4-lepton plot?
- The Higgs should be at  $\sim 125$  GeV. Do we see that? Can we claim discovery?
- If a peak is uncertain, what do we expect at that mass? It might be useful to have CMS invariant mass plots handy.

*Do not ask leading or open-ended questions as this is often too time-consuming. Let students ask questions.*



# What you see

Back Events Table (Group 10.4) Mass Histogram (SampleTable2\_jan2020) Results (SampleTable2\_jan2020)

Masterclass: Examples-25Jan2020  
location: SampleTable2\_jan2020

Group	e	$\mu$	W+	W-	W $\pm$	Neutral	Zoo	Total
	0	0	0	0	0	0	0	0
10.1	0	0	0	0	0	0	0	0
10.2	0	0	0	0	0	0	0	0
10.3	0	0	0	0	0	0	0	0
10.4	3	7	2	2	0	5	0	9
10.5	0	0	0	0	0	0	0	0
10.6	0	0	0	0	0	0	0	0
10.7	0	0	0	0	0	0	0	0
10.8	0	0	0	0	0	0	0	0
10.9	0	0	0	0	0	0	0	0

Total:

Group	e	$\mu$	W+	W-	W $\pm$	Neutral	Zoo	Total
All	3	7	2	2	0	5	0	9

Ratios:

e/ $\mu$	W+/W-
0.67	1



## Brief discussion of ratios

- Ask students to calculate the e:mu ratio. (Hopefully done *before* videocon.) Is the result consistent with expectations?
- Do the same for the ratio of W+ to W- bosons. Ask students or point out how proton structure leads to this. (But do not over-explain: keep to the “2 up, 1 down” level.)

14	24	15		0	7	17	15	0	8	47
15	0	0		0	0	0	0	0	0	0
Total:										
Muon	Electron	W	W-	W+	Z	Higgs	Zoo	Sum	e/mu	W+/W-
185	174	21	87	124	127	6	103	468	0.94	1.43



# How to see results in CIMA

i2u2.org/elab/cms/cima-wzh/auth.php

### CIMA Administrator Login

username

password

Go!

*Get login and password from IMC Central Coordination!*



# How to see results in CIMA

**Create new Masterclass Event**  
Enter name of new event:  
Event name  **Create Event**

**Edit Event**  
Select event:  
Event01  **Edit Event**

**Manage Tables:**

**Masterclasses**

Masterclasses	status
Test-18Dec2019	(active)
test20dec2019-2	(active)
Test-20Dec2019	(active)
NewTest-23Dec2019	(active)
NewYearTest-02Jan2019	(active)
TW-SC-MN-03Jan2020	(inactive)
TW-SC-MN-03Jan2020-new	(inactive)
NCU-TW-05Jan2020	(inactive)
Examples-25Jan2020	(inactive)
unassigned tables	(inactive)
	(inactive)
	(active)
	(active)
	(active)

**Tables**

Tables	# of Groups
TW_workshop_Jan2020	26
AAPT_WM_2020	22

**Results**

Please do not touch any of these.

*Get login and password from IMC Central Coordination!*





## More Q&A

Students might ask:

- About individual events: try to keep it general
- Life at CERN or Fermilab
- Seemingly “weird” physics
- Why we do research; how do we justify it

Additionally you might ask or comment on:

- What did they learn?
- How their day went

Questions for Ken: [kcecire@nd.edu](mailto:kcecire@nd.edu)