

CMS Masterclass 2024 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 μm) $\sim 16\text{m}^2$ $\sim 66\text{M}$ channels
 Microstrips (80x180 μm) $\sim 200\text{m}^2$ $\sim 9.6\text{M}$ channels

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

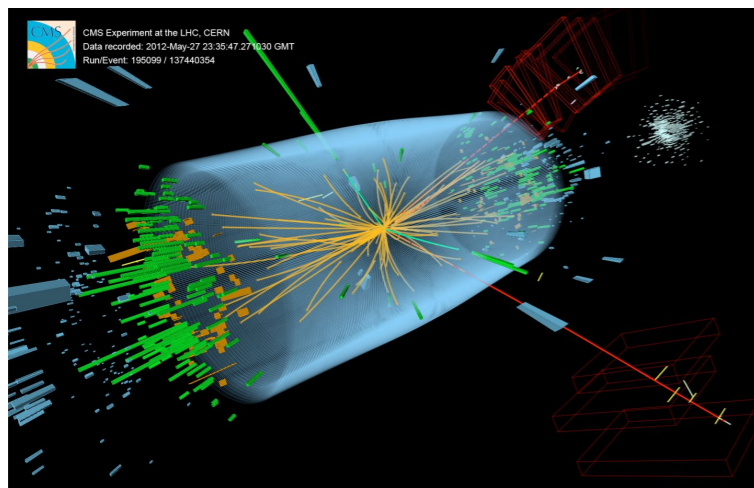
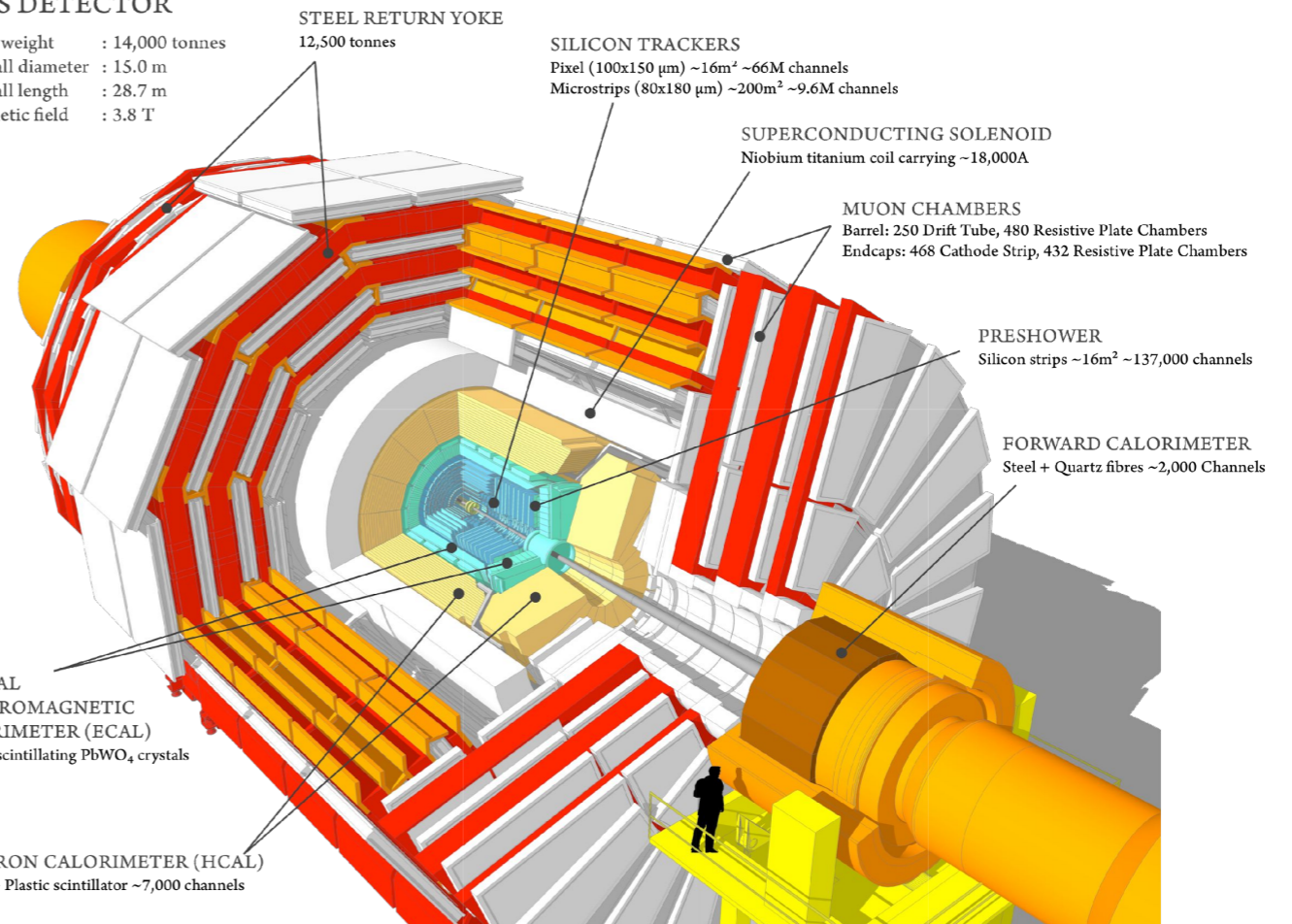
MUON CHAMBERS
 Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
 Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

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 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/Ψ , Upsilon**
 - **4-lepton: H , ZZ**
- Event display: iSpy-webgl
- CIMA – CMS Instrument for Masterclass Analysis
- Documentation at <http://cern.ch/go/76BG>.

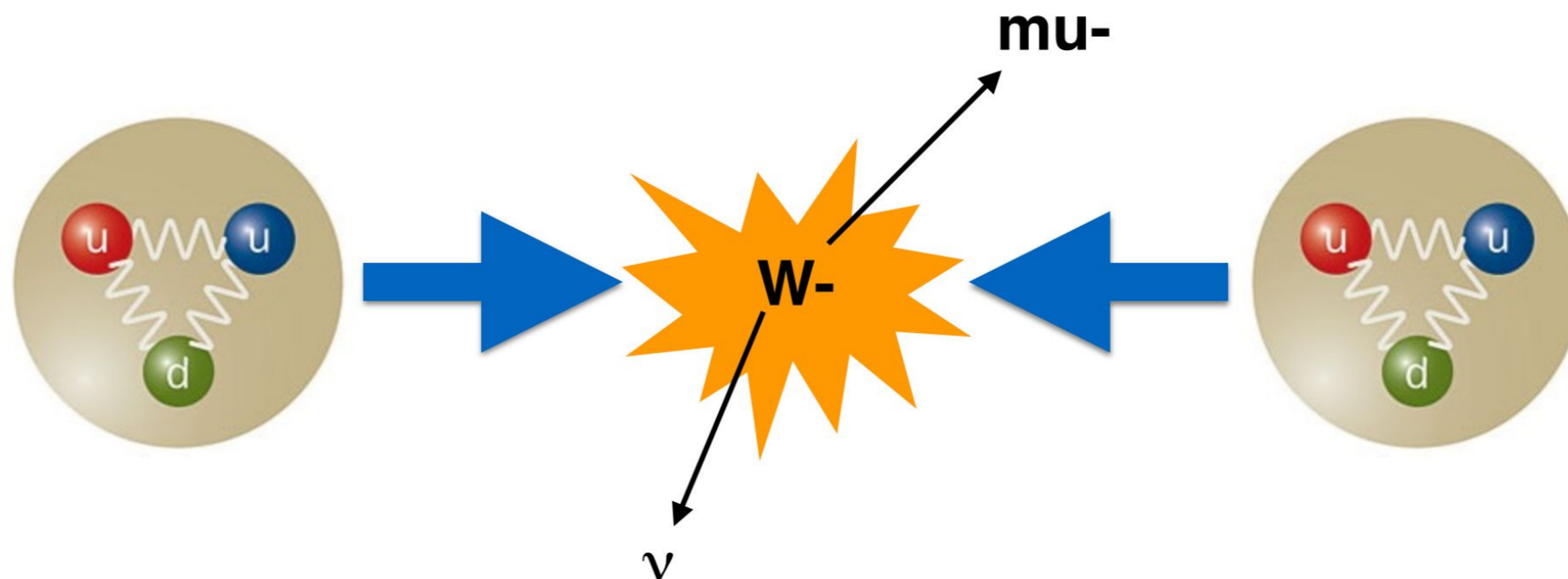
Students find $e:\mu$ and $W^+:W^-$.

Students create dilepton and 4-lepton mass plots.



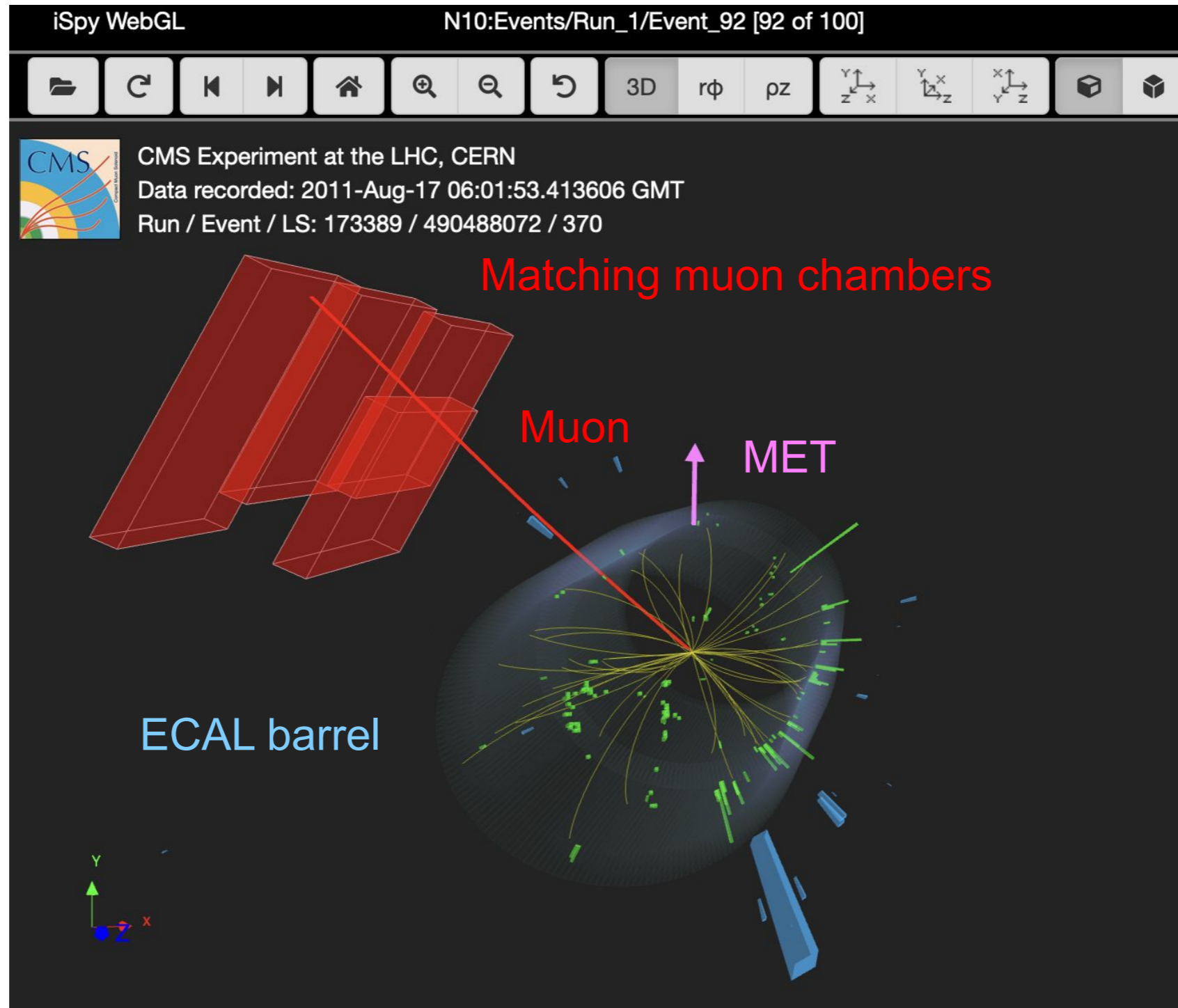
About collisions

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





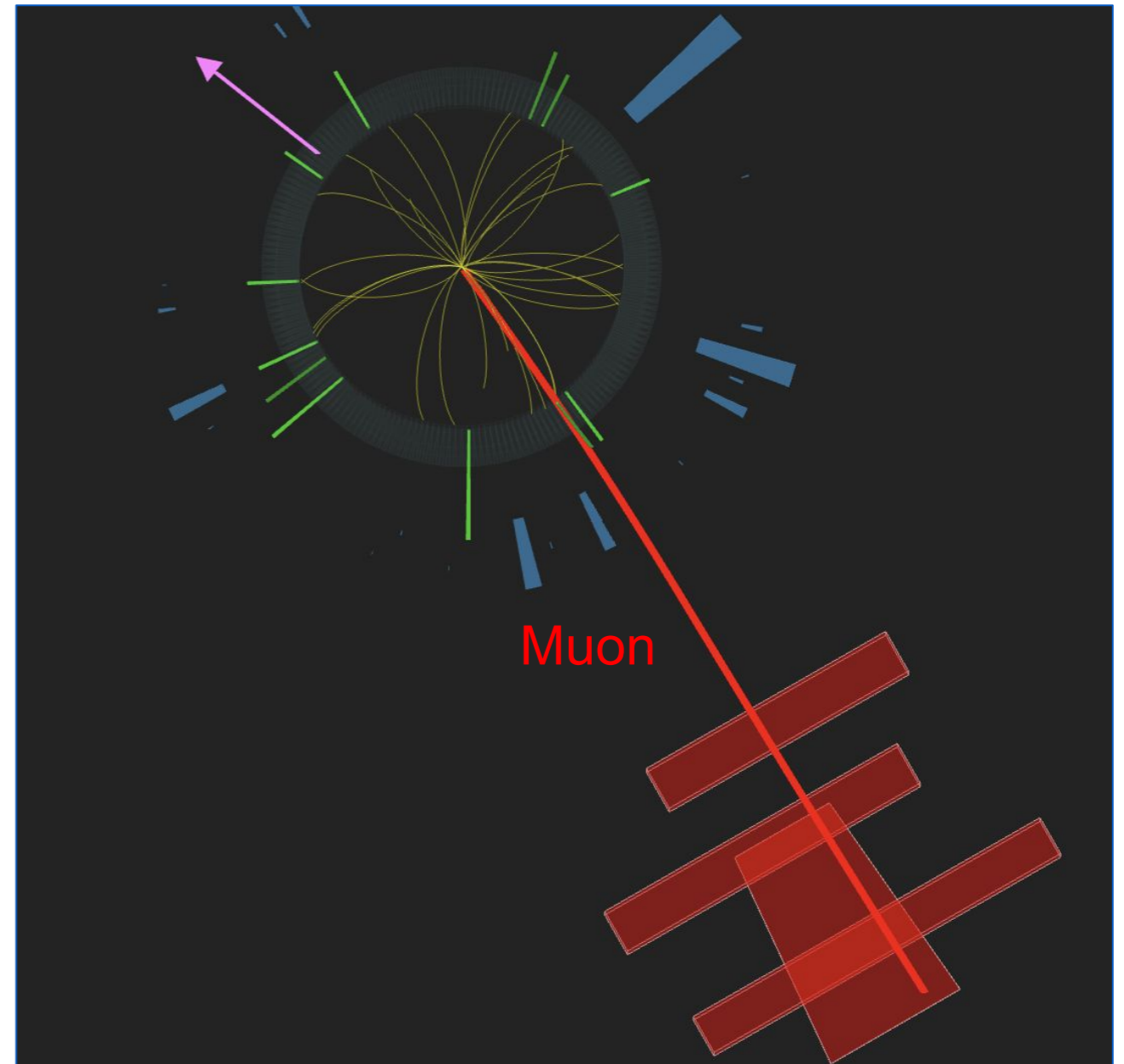
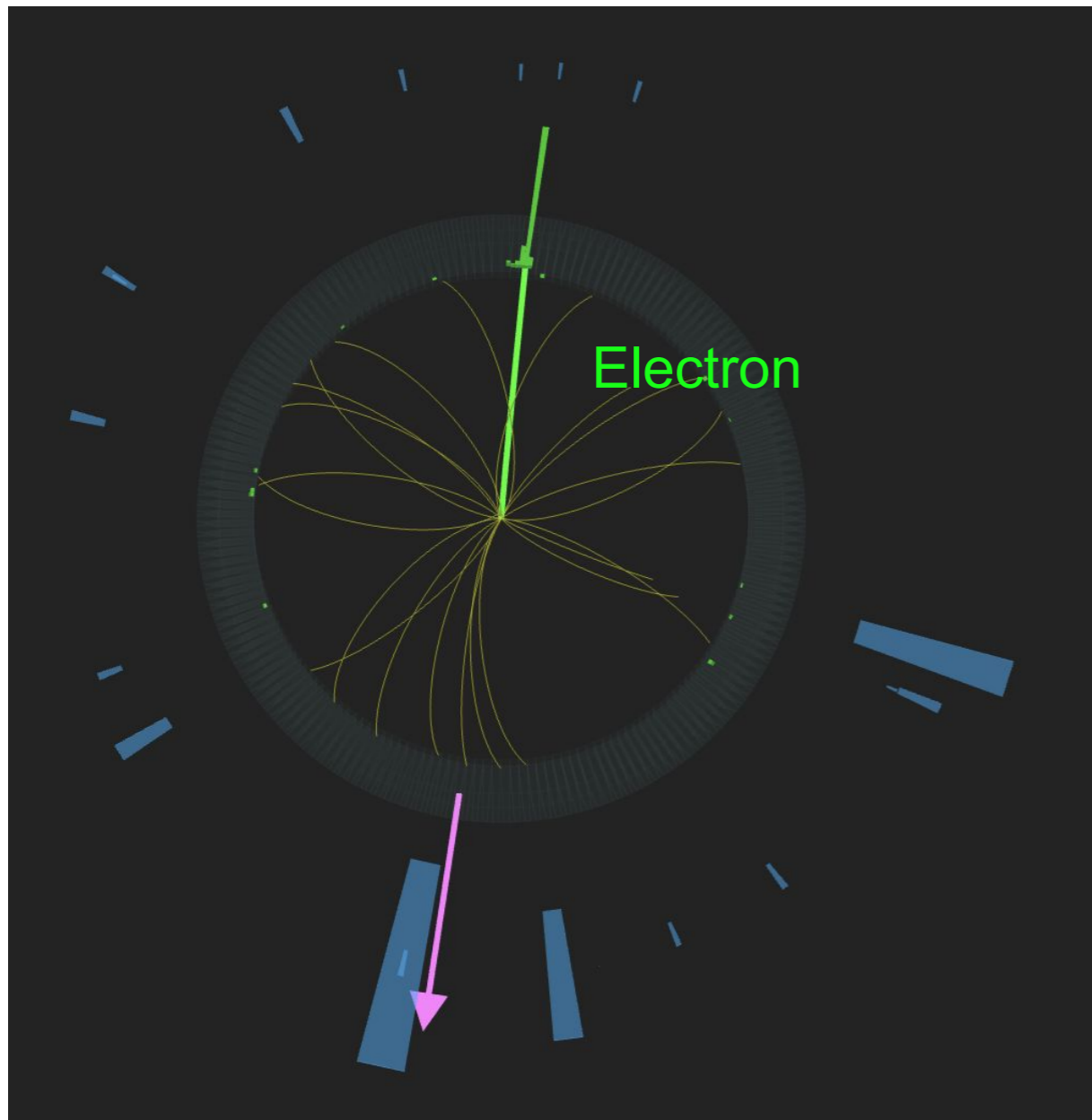
iSpy-WebGL





Student tasks

Students distinguish electron tracks from muon tracks.

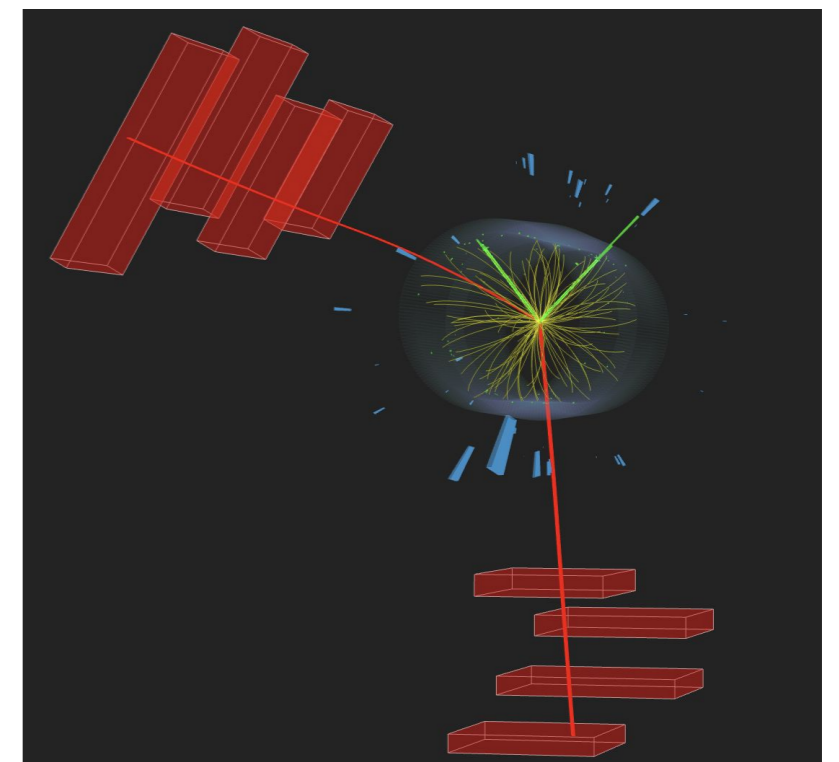
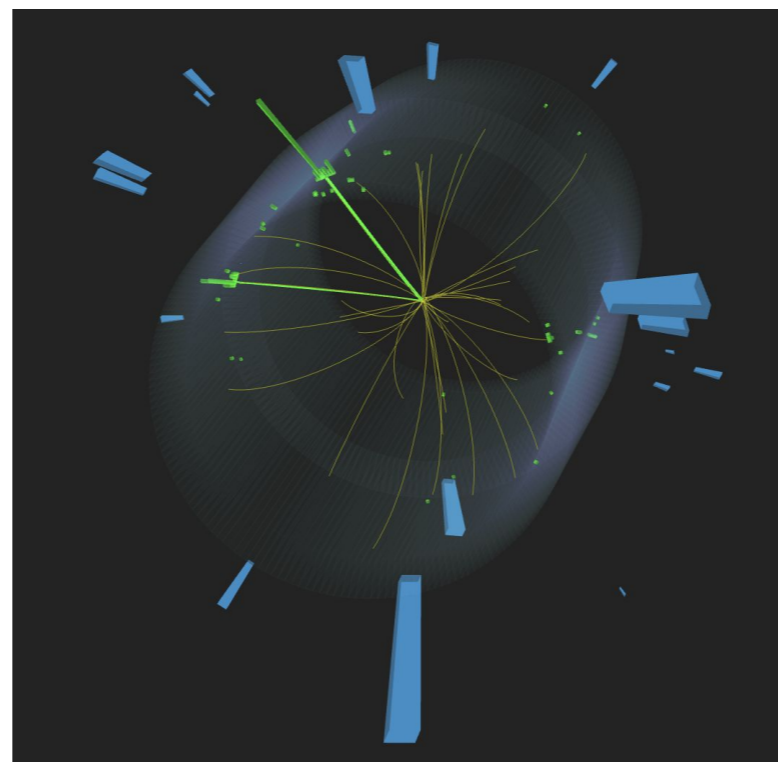
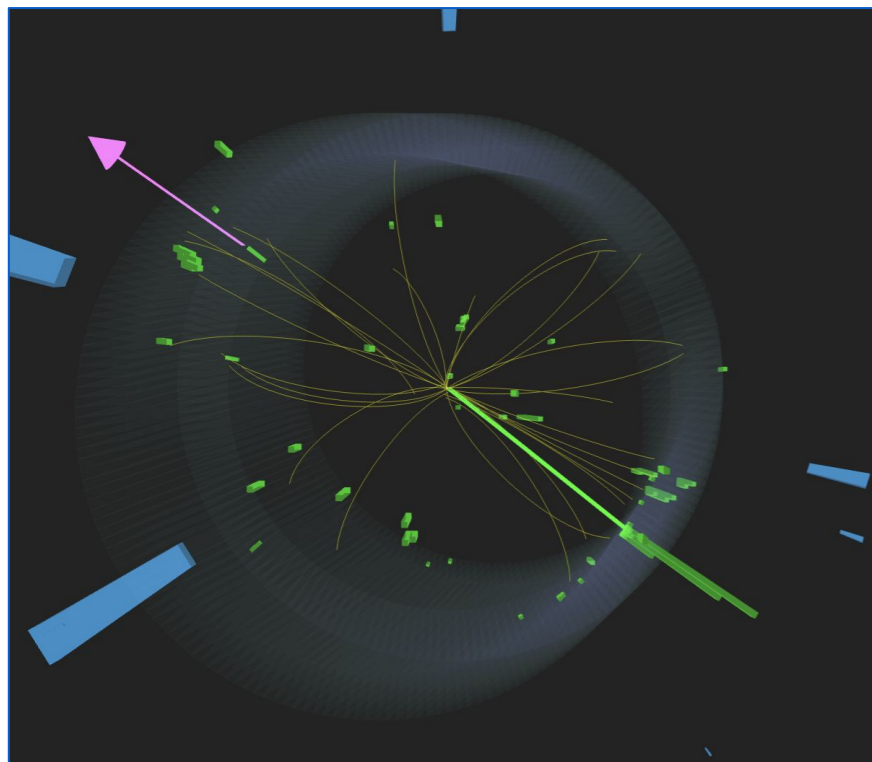




Student tasks

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

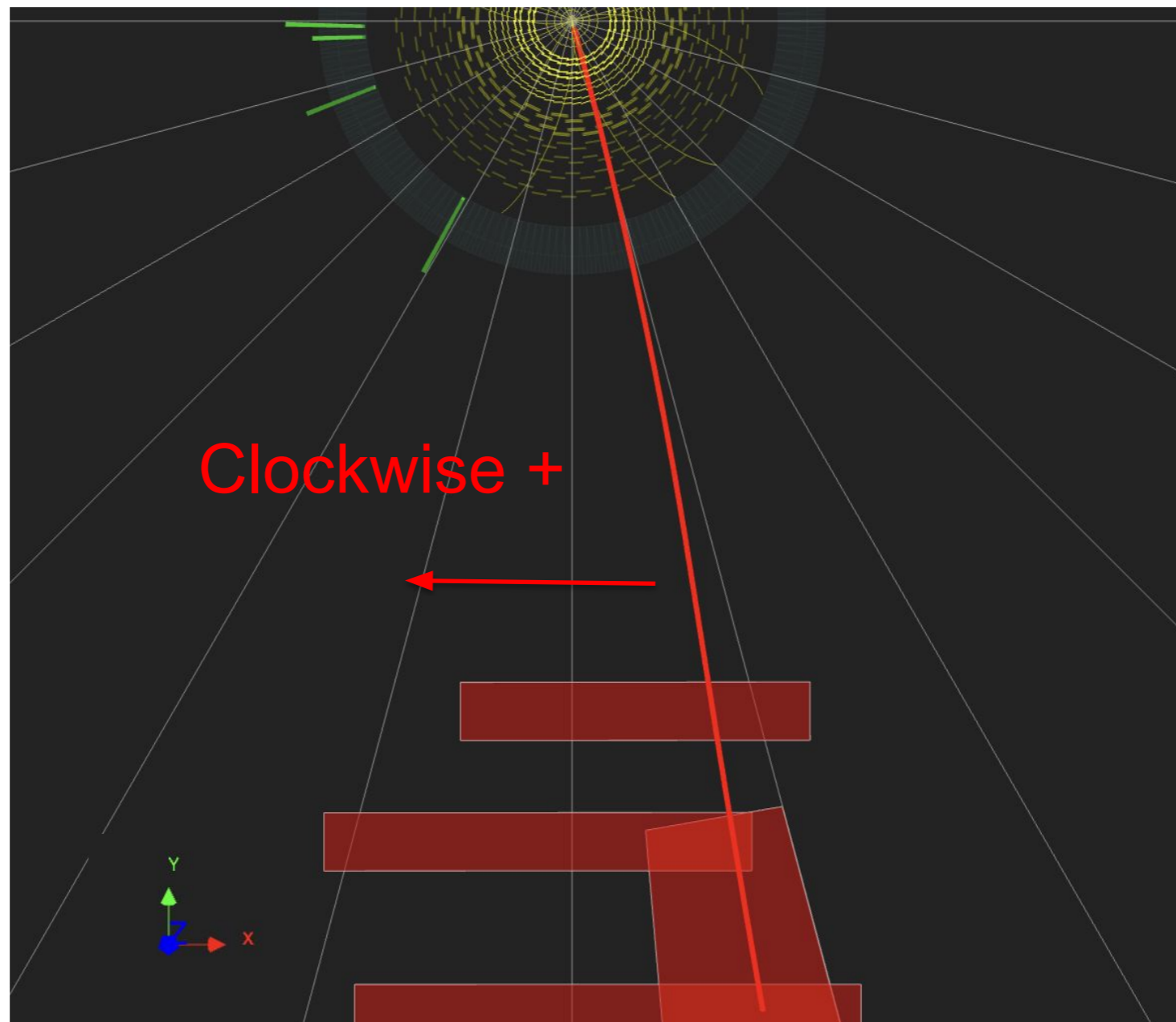
Typical questions are about extra lepton tracks or missing E_T together with 2- or 4-lepton events.





Student Tasks

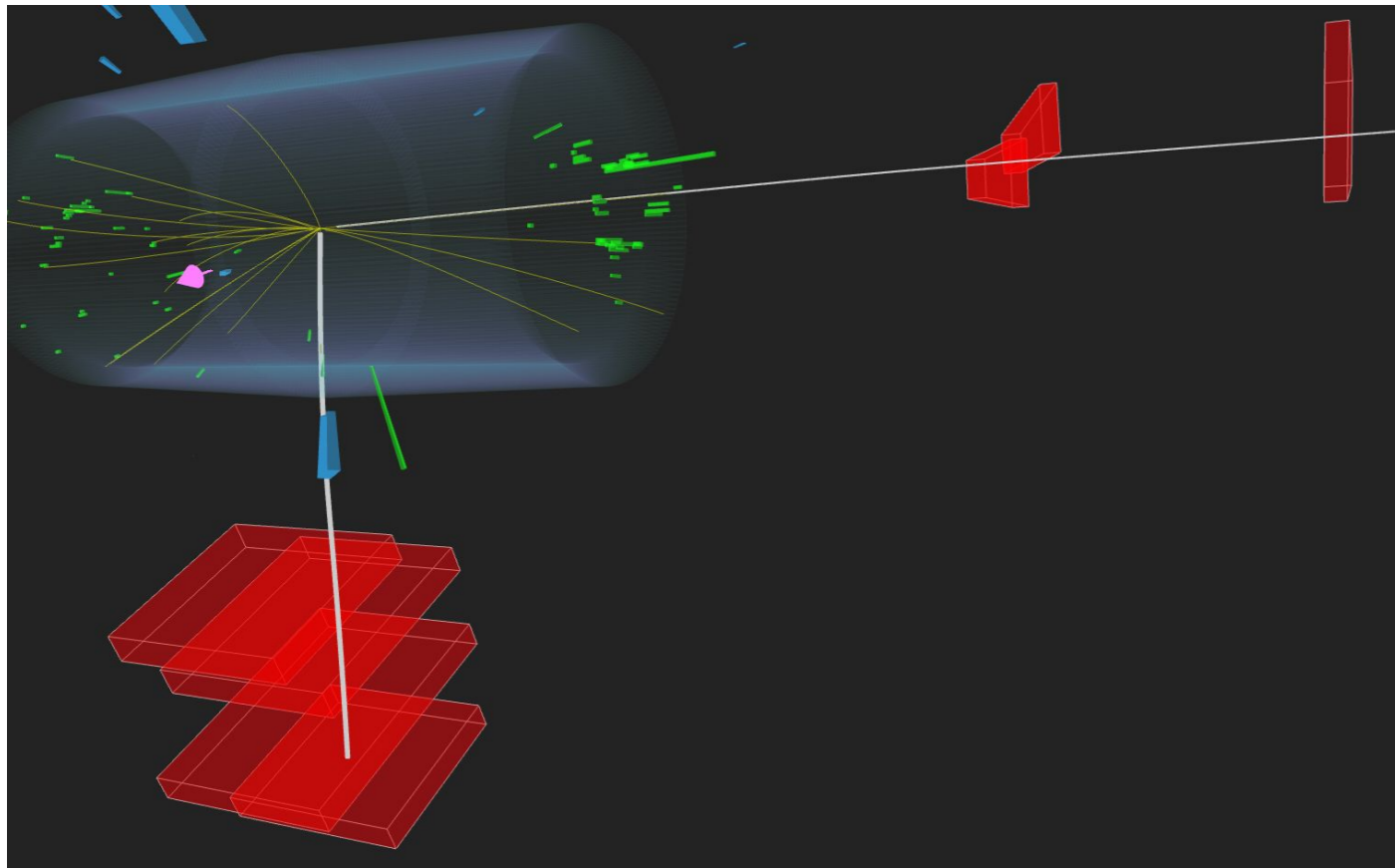
Students distinguish W^+ from W^- using track curvature.





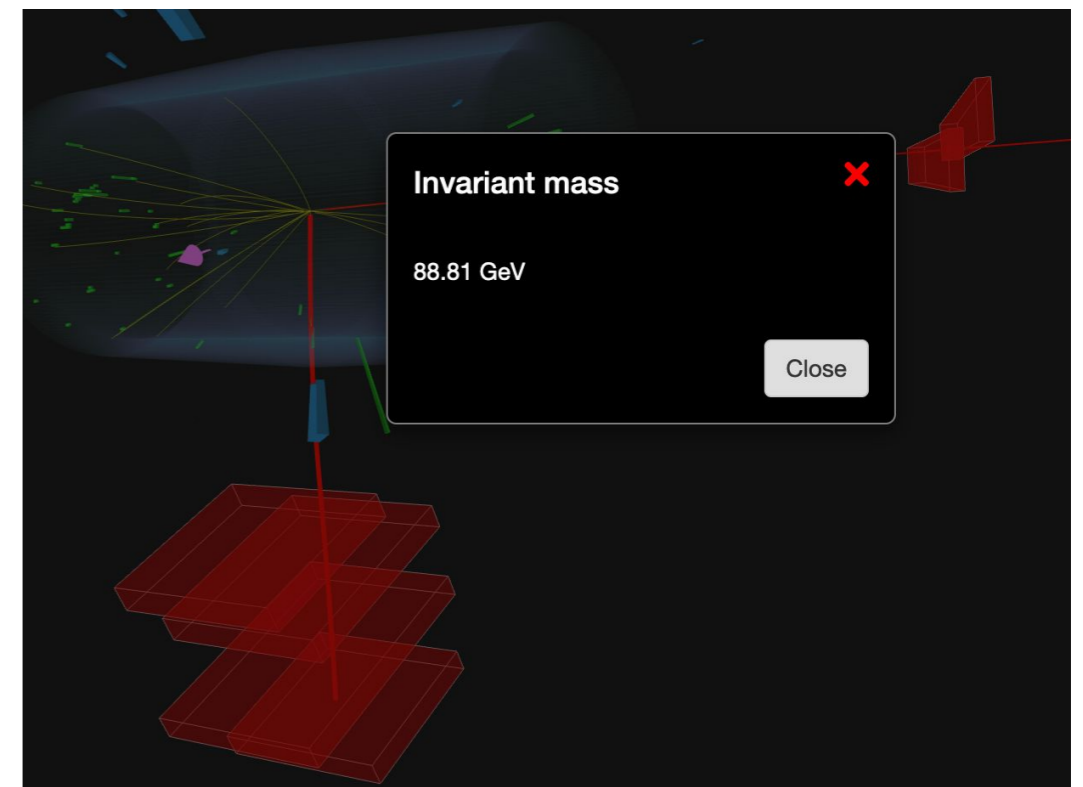
Student Tasks

Students determine invariant mass.



Click on electron or muon tracks to highlight

Press “M” to reveal invariant mass





Recording event data

Find your dataset.

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

Select Event
Event index: 2
Event number: 10.4-2

Final State
 e v μ v
 e e μ μ
 4e 4 μ
 2e 2 μ

Primary State
Charged Particle:
 W+ W- W \pm
 Neutral Particle (Z, H)
 Zoo

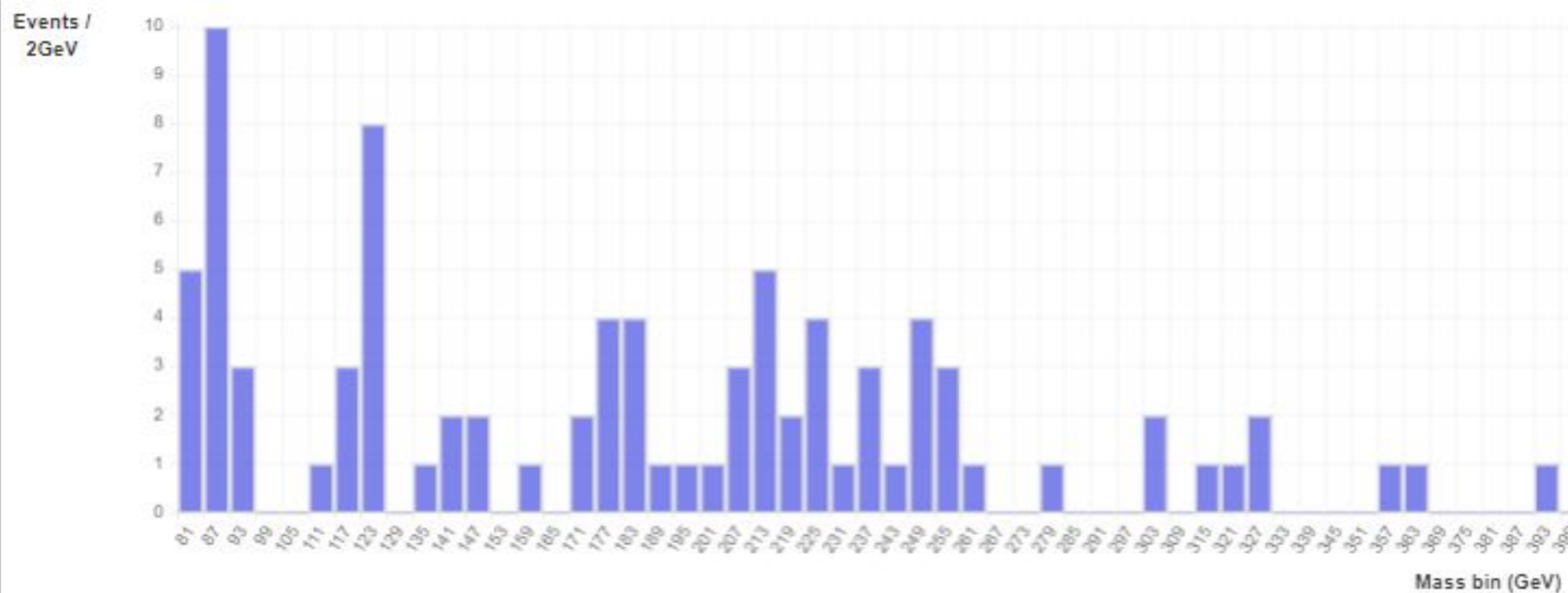
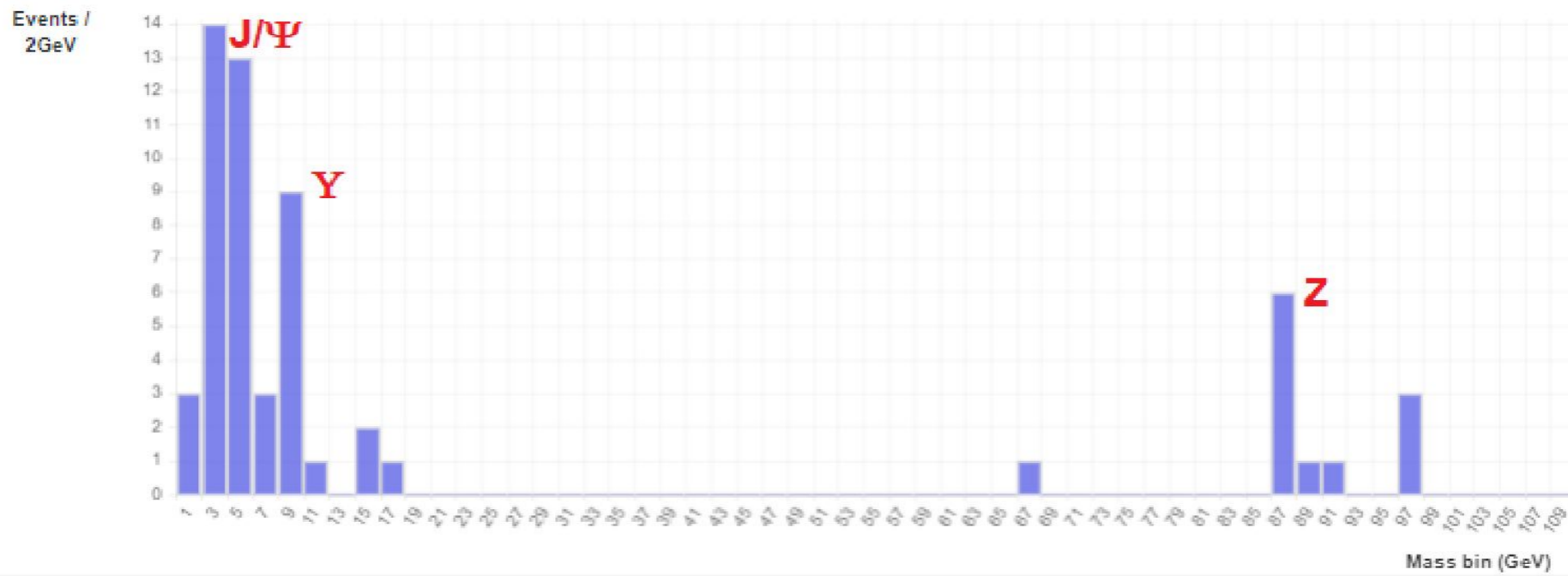
Enter Mass
10.27 GeV/c²
Next

Event index	Event number	Final state	Primary state	Mass
9001	10.4-1	2e 2 μ	neutral	209.96



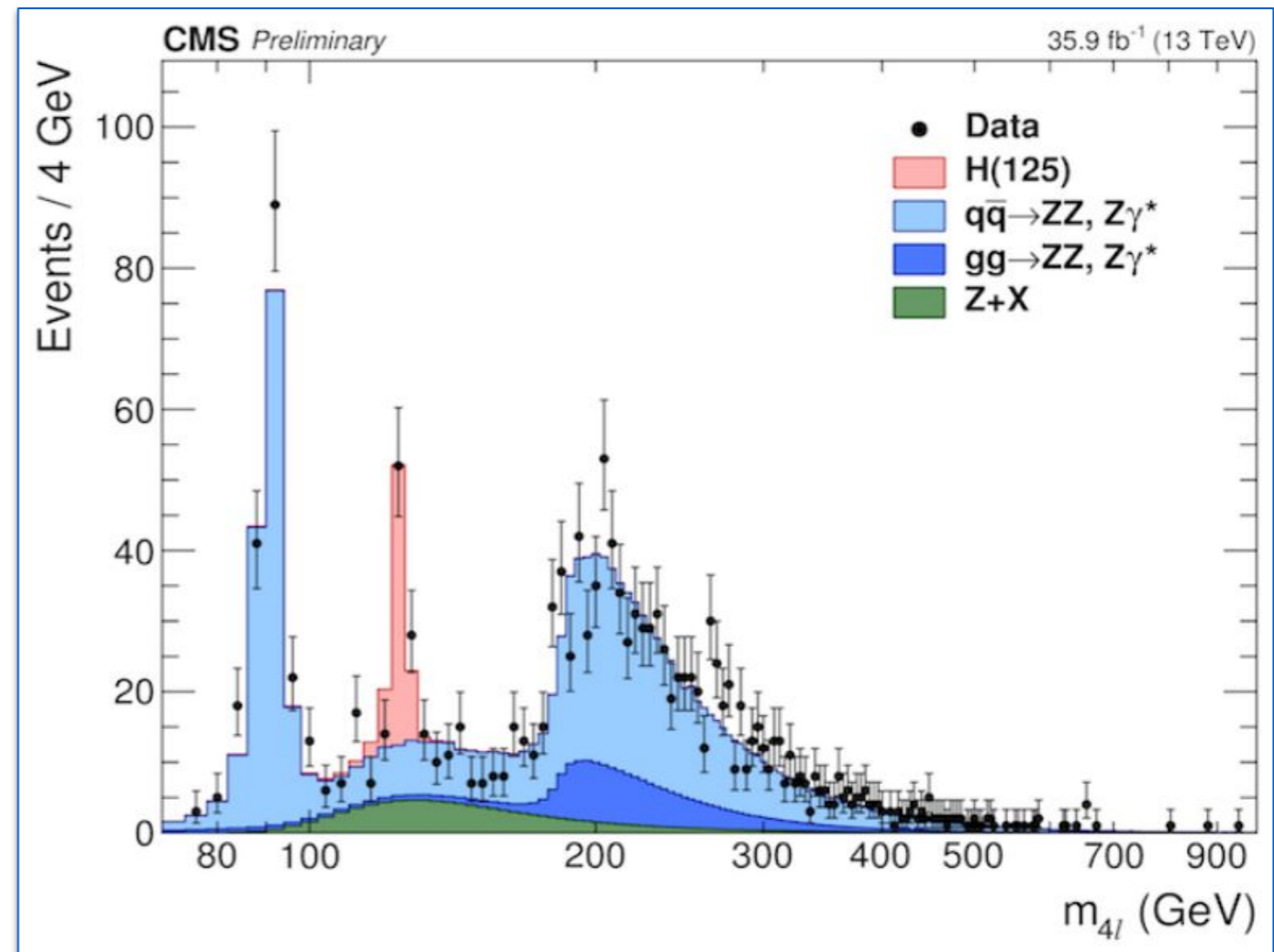
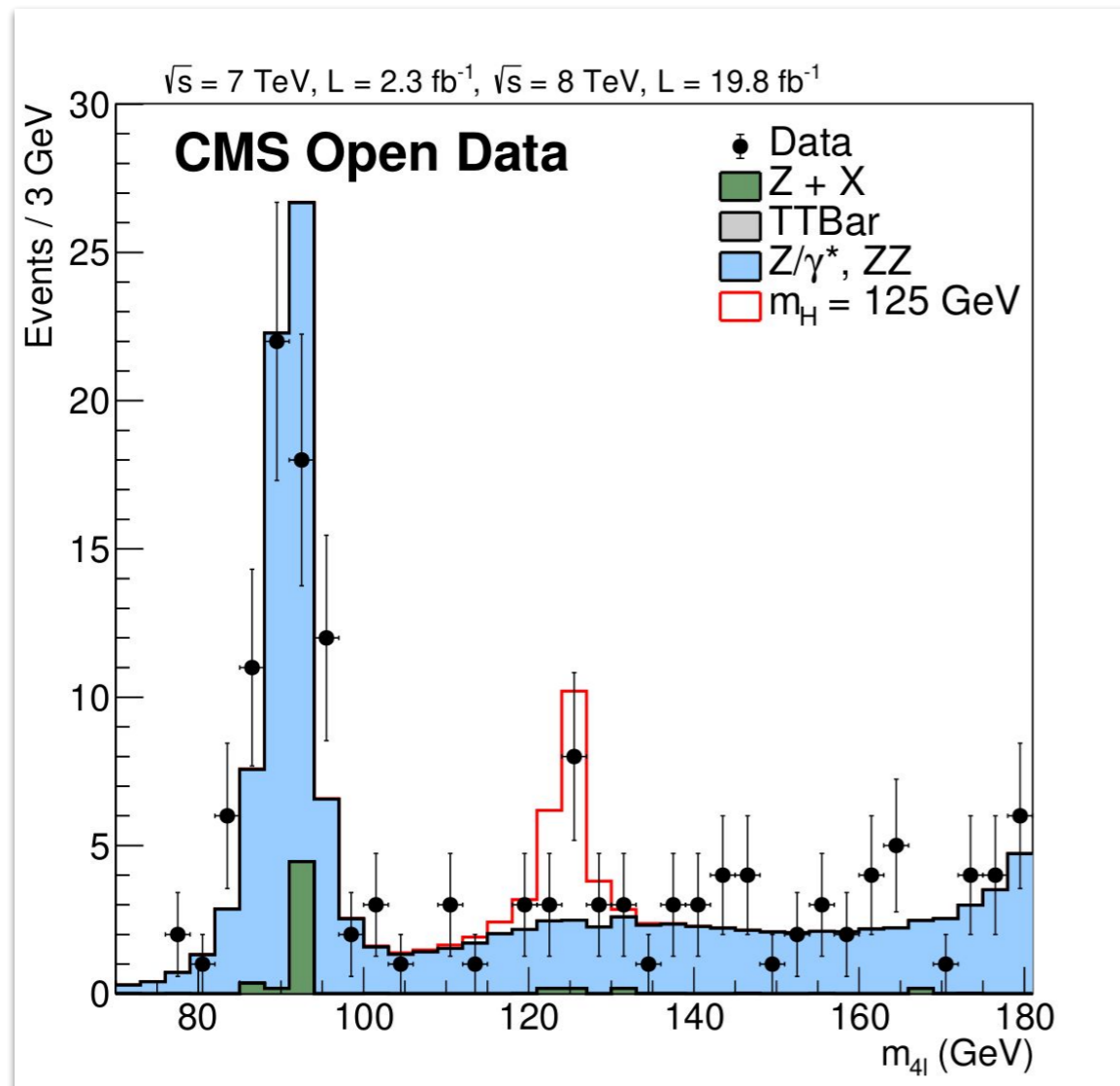
What you see

Tables: TWV_workshop-Jan2020 AAPT_WM_2020





4-lepton events





Questions you can ask

Ask the students:

- Where are the peaks in the dilepton Mass Histogram? What do they represent?
- Where is Z boson in the dilepton plot? Do you see a similar peak in the 4-lepton plot? What is it?
- Do you have possible Higgs events in the 4-lepton plot? Where? Can we claim discovery?
- What else do you observe in the mass plots?
- If you think a peak represents a signal what would you expect to happen when more data is taken?



What you see

Back Events Table (Group 10.4) Mass Histogram (SampleTable2_jan2020) Results (SampleTable2_jan2020)

Masterclass: Examples-25Jan2020
location: SampleTable2_jan2020

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

Ratios:

e/ μ	W+/W-
0.67	1



Questions you can ask

Ask the students:

- What do you expect the ratio of electron events to muon events to be? Is your result consistent with this?
- What is the ratio of W^+ to W^- bosons? What does this ratio tell us about protons?

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/μ	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	status	Tables	# of Groups
Test-18Dec2019	(active)	TW_workshop_Jan2020	26
test20dec2019-2	(active)	AAPT_WM_2020	22
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)		

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