

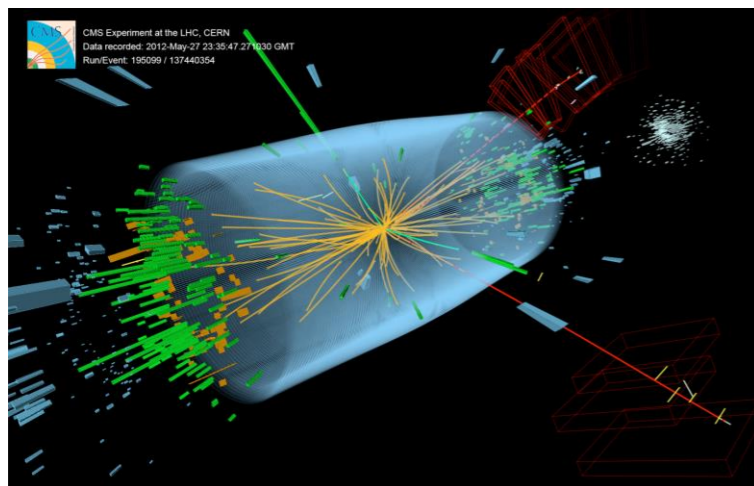
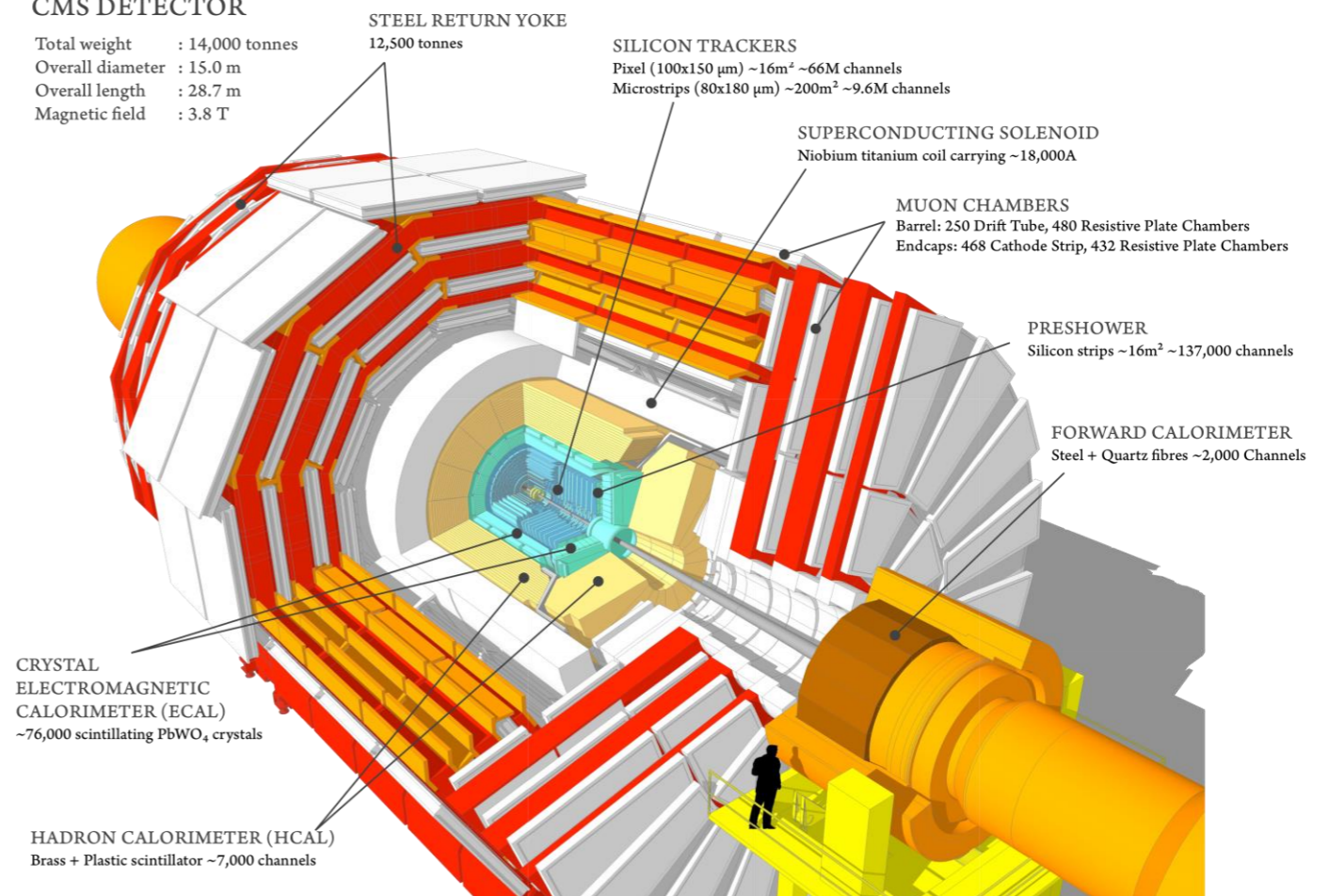


# CMS Masterclass 2018 for Moderators



## CMS DETECTOR

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





## CMS masterclass features

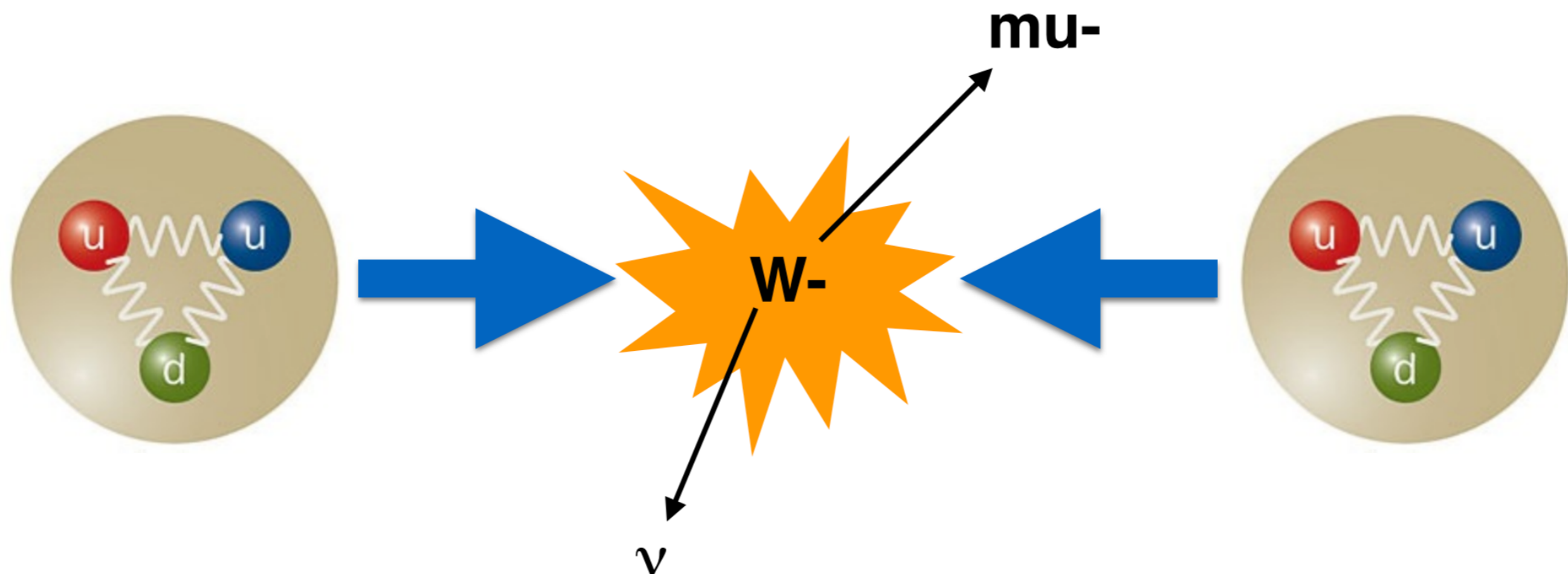
- *10 000 events (divided into 100 datasets):*
  - *W*
  - *Z, J/Psi, Upsilon*
  - *H → 2 photons, few, repeated*
  - *H → ZZ, few, repeated*
- *Event display: iSpy-WebGL*
- *CIMA – CMS Instrument for Masterclass Analysis*
- *Updated documentation at <http://tiny.cc/cms-doc-imc18>.*

**Students find e:mu and W+:W-; create dilepton mass plot.**



## 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

The screenshot displays the iSpy-WebGL interface for the CMS Experiment at the LHC, CERN. The main visualization area shows a 3D wireframe model of the detector with particle tracks and hit data. The tracks are colored green and blue, and the hit data is shown as small green and blue rectangles. A pink dashed line indicates a specific track. The detector is rendered in a light blue color. The interface includes a toolbar at the top with various icons for navigation and interaction. On the left side, there is a sidebar with a list of data categories and their corresponding checkboxes. The top right corner of the visualization area contains a CMS logo and text indicating the data recording date and time, and the run/event/LS information.

Tracks (reco.)

ECAL

Barrel Rec. Hits

Endcap Rec. Hits

HCAL

Barrel Rec. Hits

Muon

Physics

Vertices (Reco)

Electron Tracks (GSF)

Photons (Reco)

Jets (Reco)

Missing Et (PF)

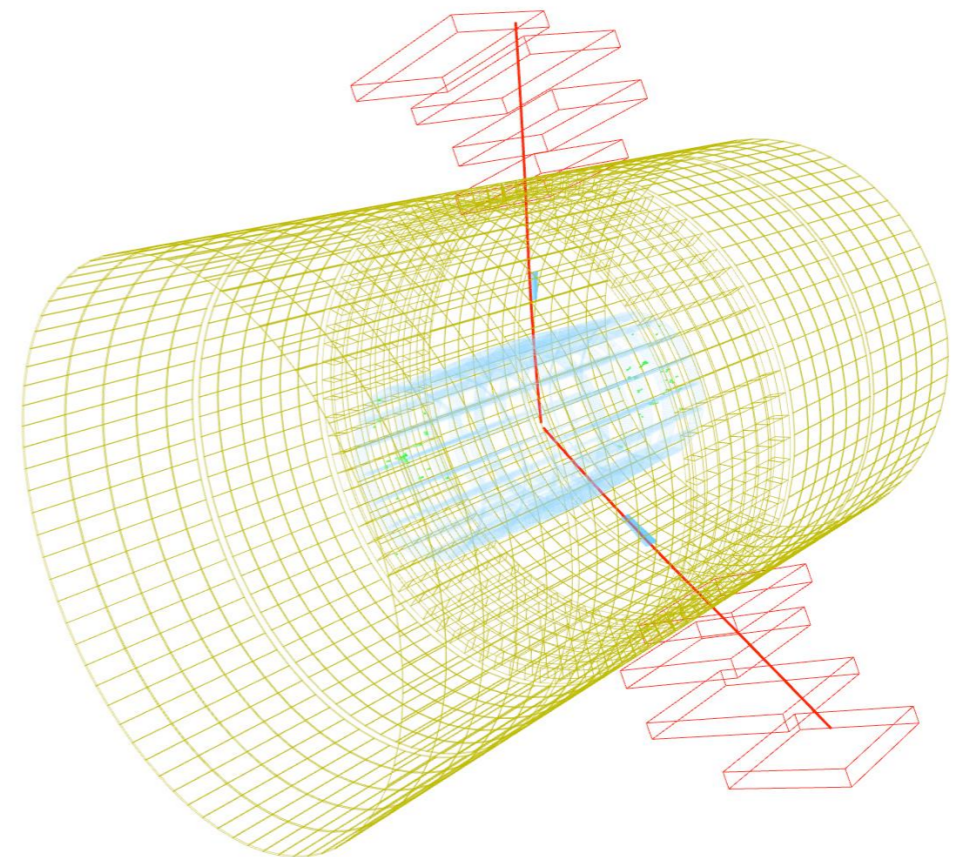
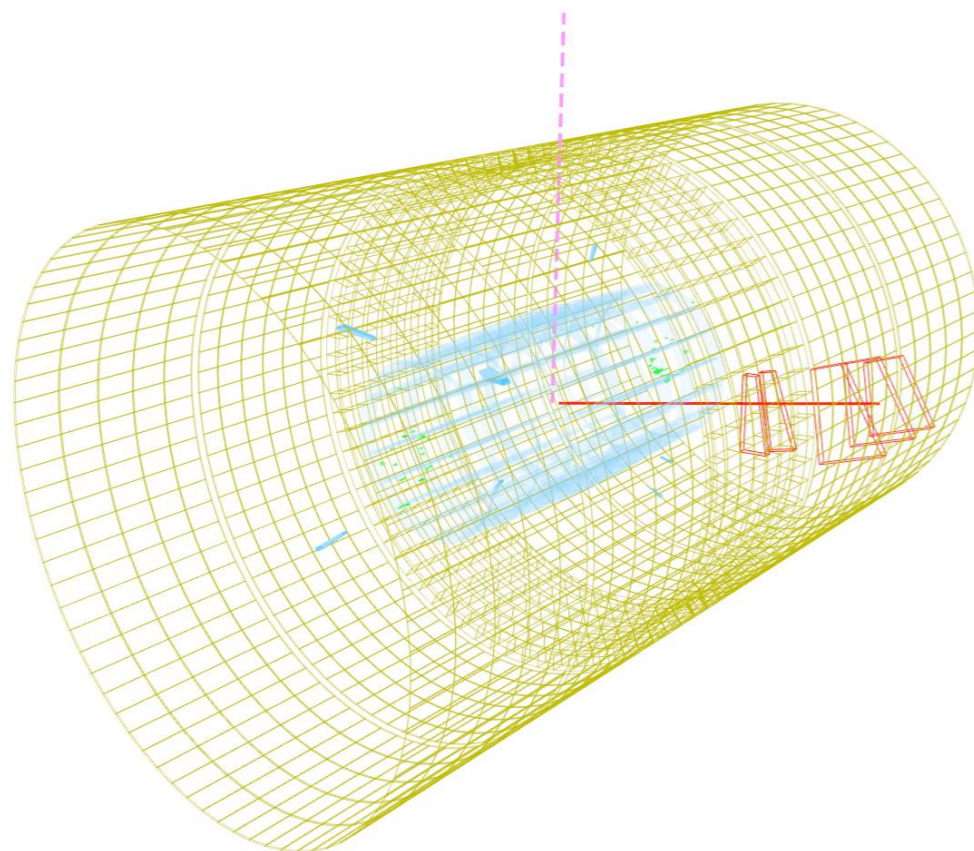
CMS Experiment at the LHC, CERN  
Data recorded: 2011-Jul-25 07:06:29.539698 GMT  
Run / Event / LS: 171484 / 254263520 / 224



## Student tasks

Students must distinguish W from Z candidates.

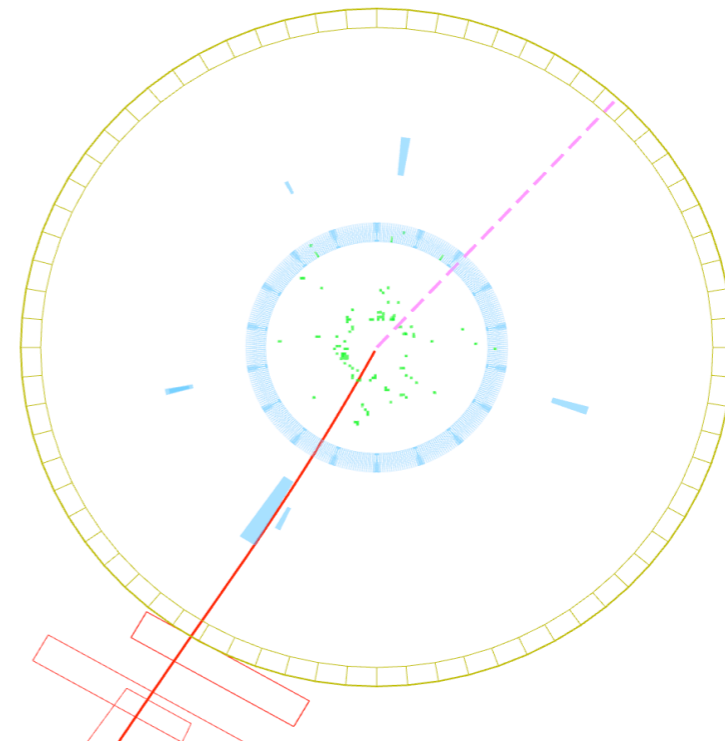
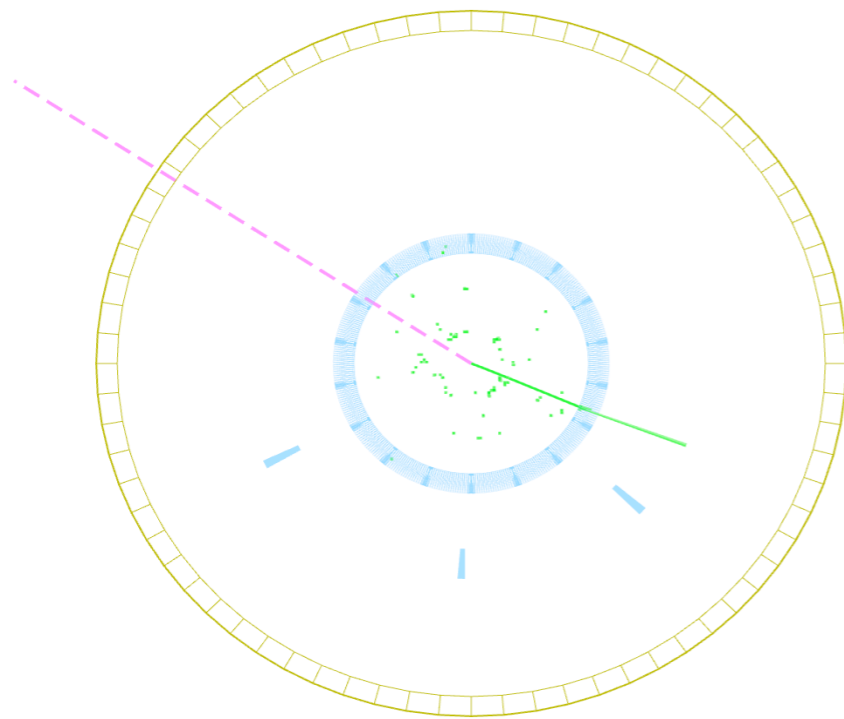
*Typical questions are about 2nd or 3rd lepton track  
(check pt)*





## Student tasks

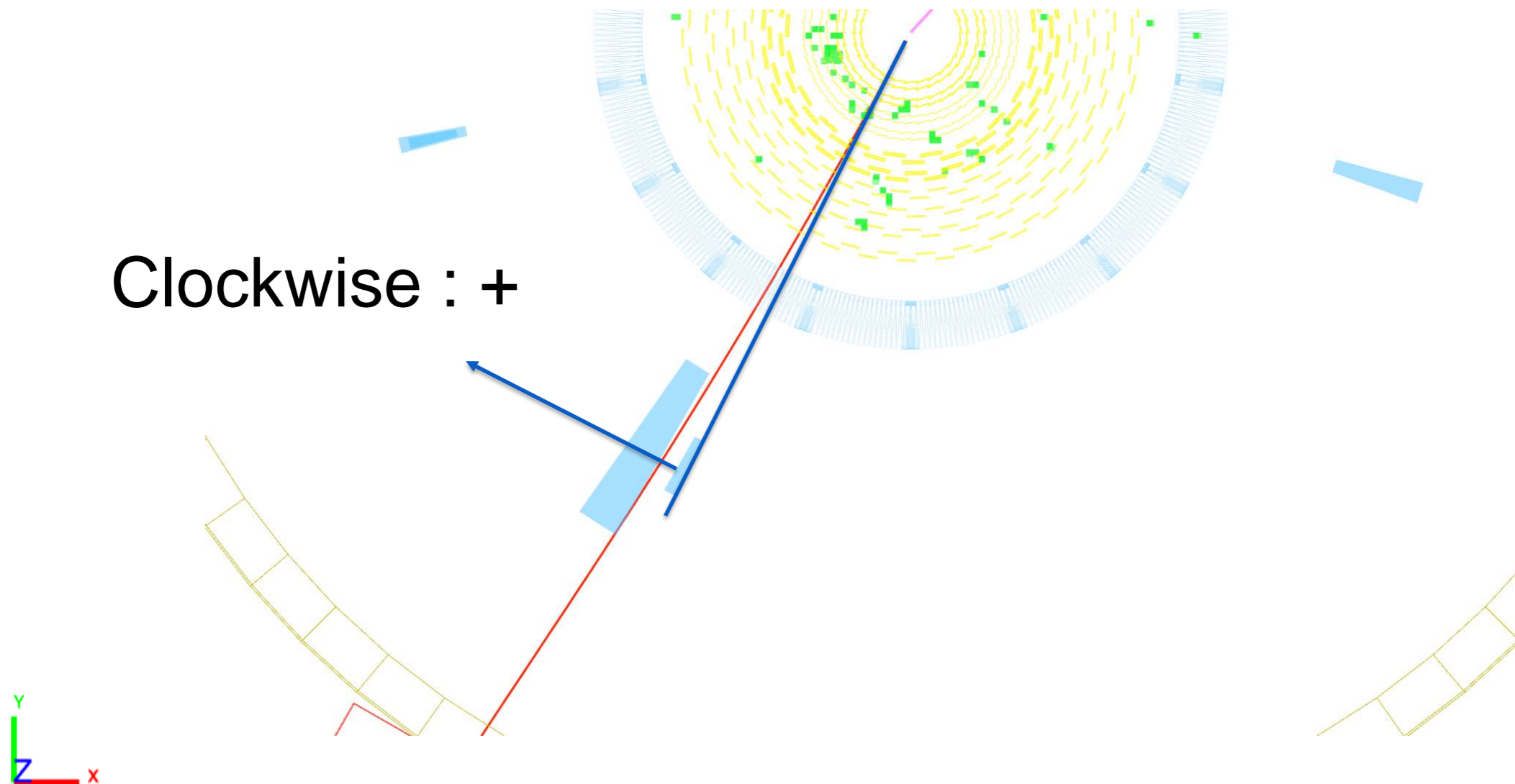
Students distinguish electron *events* from muon *events*.





# Student Tasks

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

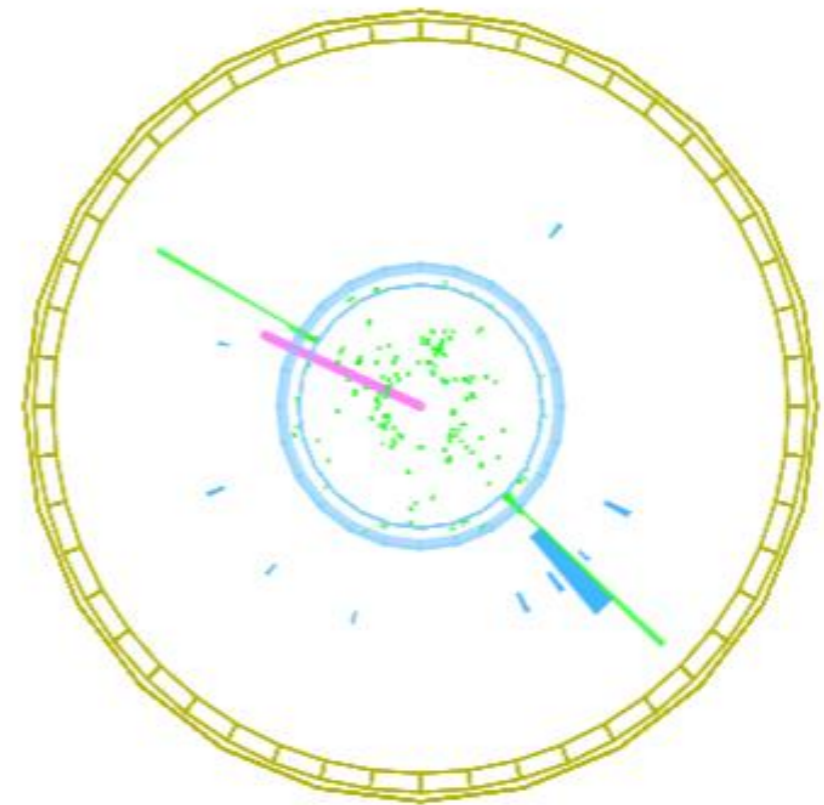
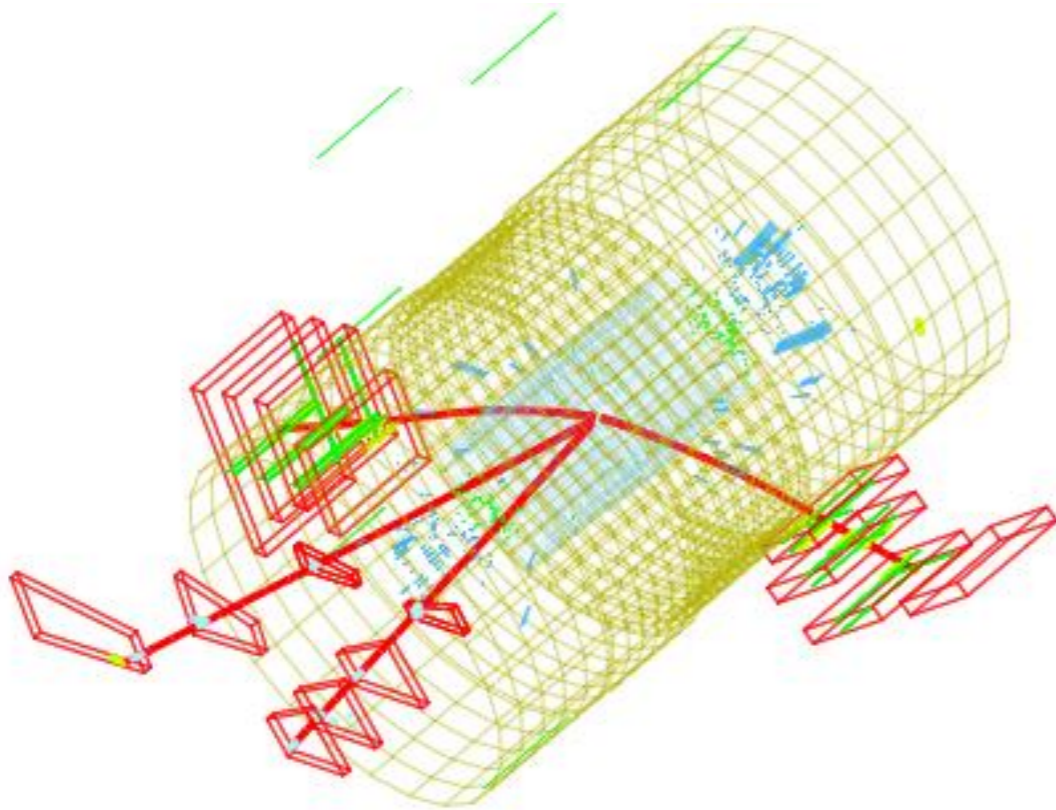




## Student tasks

Students look for  $H \rightarrow ZZ$  and  $H \rightarrow \text{diphoton}$  events.

*Occasionally, students “find” too many Higgs candidates.*







# Recording event data



Find your dataset.

Record parent particles and decay modes.

Choose your Masterclass: test, Test2, **31Jan2015**

Choose your location: Buffalo, **MexicoCity**, Quito

Choose your group: 6, **7**, 8, 9, 10

*Choose the date of your masterclass, the institute, and your dataset.*

Back Events Table (Group 1) Mass Histogram (TT1) Results (TT1) [Event Display](#)

Masterclass: TestTables-Feb2017  
 location: TT1  
 Group: 1

Instructions (also available as [screencast](#)):

- For each event, identify the final state and select a primary state candidate.
  - For Higgs or Zoo candidate, no final state is chosen
  - If you cannot decide between  $W^+$  and  $W^-$ , choose  $W$  instead
- If you think the final state is a neutral particle (like a  $Z$ ), but you don't know its exact type, select NP for "neutral particle." Find its mass from the Event Display and enter it.
- Once you have selected everything, click "Submit".

In case of an error, double clicking the data line will reload it; you can then try it again.

| Select Event                          | final state   | primary state candidate  | NP Mass: 4.55 <small>GeV/c<sup>2</sup></small>                 |
|---------------------------------------|---|--|--|
| Event index: 10<br>Event number: 1-10 | <input type="checkbox"/> Electron<br><input checked="" type="checkbox"/> Muon ( $\mu$ ) | <input type="checkbox"/> $W^-$<br><input type="checkbox"/> $W^+$<br><input checked="" type="checkbox"/> NP<br><input type="checkbox"/> W | <input type="checkbox"/> Higgs<br><input type="checkbox"/> Zoo |

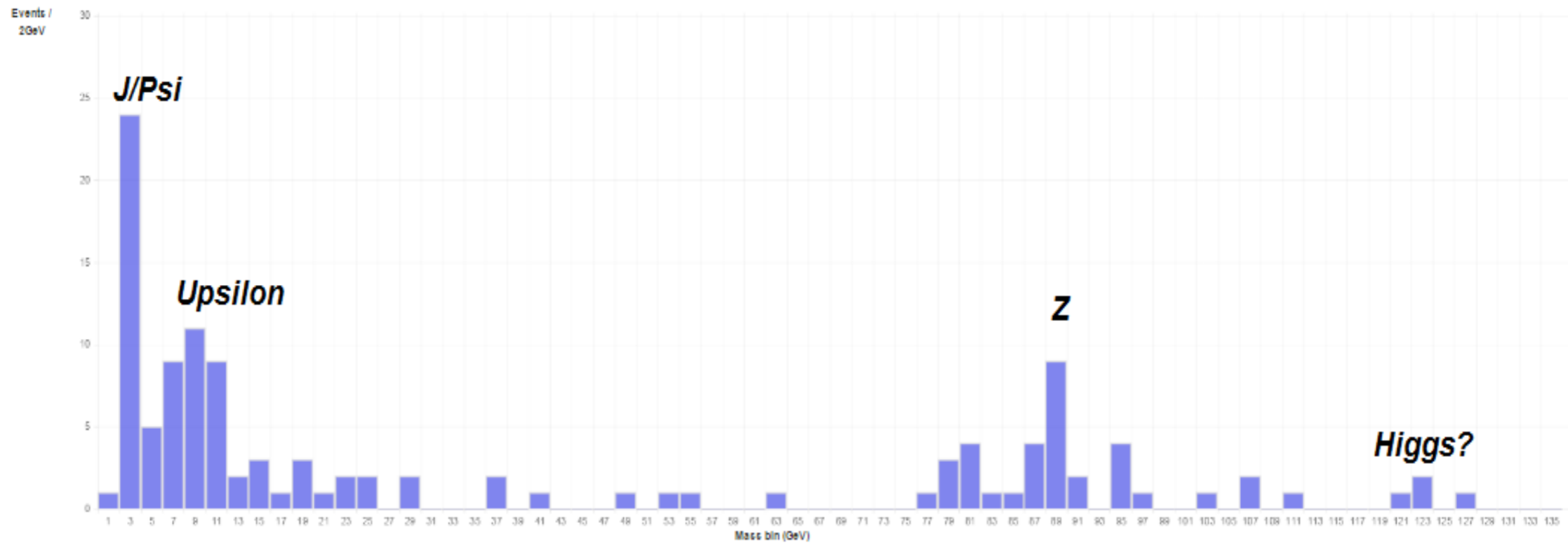
| Event index | Event number | Chosen Values | Mass |
|-------------|--------------|---------------|------|
| 9           | 1-9          | Z, $\mu$      | mu   |
| 8           | 1-8          | e, $W^+$      |      |
| 7           | 1-7          | $\mu$ , Z     | 95   |
| 6           | 1-6          | $\mu$ , Z     | NaN  |
| 5           | 1-5          | e, Z          | NaN  |
| 4           | 1-4          | $\mu$ , $W^+$ |      |
| 3           | 1-3          | $\mu$ , $W^+$ |      |
| 2           | 1-2          | e, $W^-$      |      |
| 1           | 1-1          | e, $W^+$      |      |



# What you see

Back Events Table **Mass Histogram** Results [Event Display](#)

Masterclass: 28Jan2015-NMC-Wirteltogym.  
location: Dueren



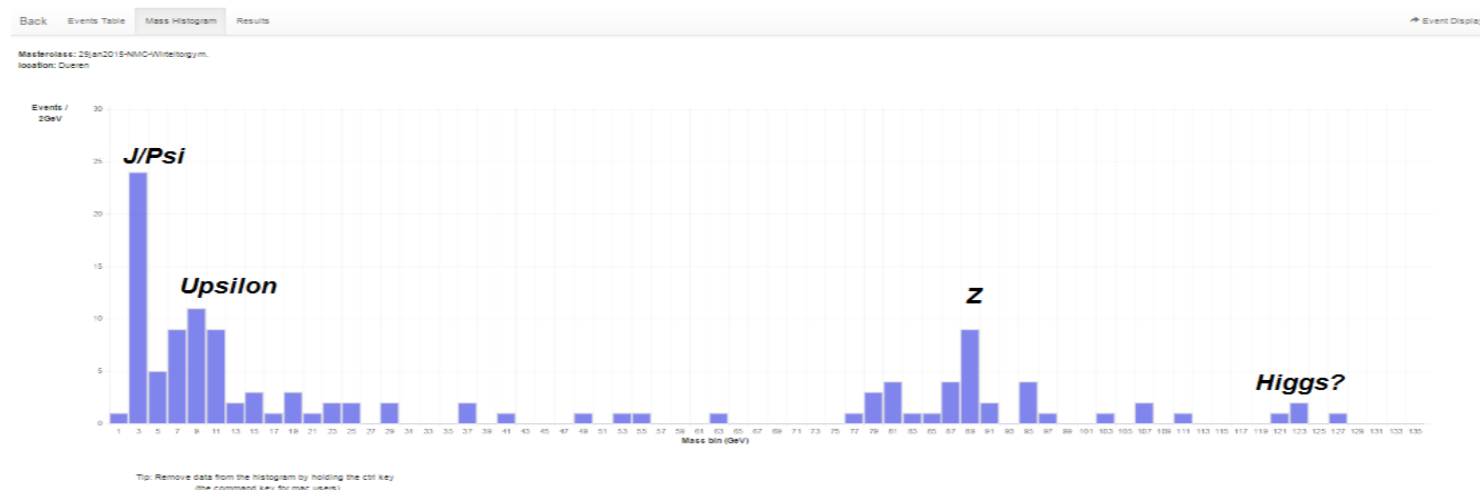
Tip: Remove data from the histogram by holding the ctrl key  
(the command key for mac users)



# Questions you can ask

## Ask the students:

- Where are the peaks in the Mass Histogram? What do they represent?
- Where is Z boson in the plot? What are the other peaks, then?
- Do you have possible Higgs events in the plot? Where? Can we claim discovery?





# What you see

[Back](#)
[Events Table](#)
[Mass Histogram](#)
[Results](#)

Masterclass: 29Jan2015-NMC-Winfeltogym.  
 location: Dueren

| Group | Muon | Electron | W  | W- | W+ | Z  | Higgs | Zoo | Total |
|-------|------|----------|----|----|----|----|-------|-----|-------|
| 1     | 0    | 0        | 0  | 0  | 0  | 0  | 0     | 0   | 0     |
| 2     | 0    | 0        | 0  | 0  | 0  | 0  | 0     | 0   | 0     |
| 3     | 19   | 22       | 6  | 6  | 10 | 19 | 0     | 18  | 59    |
| 4     | 23   | 15       | 0  | 9  | 16 | 13 | 1     | 13  | 52    |
| 5     | 18   | 21       | 10 | 9  | 9  | 11 | 0     | 8   | 47    |
| 6     | 8    | 8        | 1  | 6  | 4  | 5  | 0     | 11  | 27    |
| 7     | 0    | 0        | 0  | 0  | 0  | 0  | 0     | 0   | 0     |
| 8     | 16   | 15       | 2  | 7  | 10 | 12 | 1     | 14  | 46    |
| 9     | 21   | 13       | 2  | 11 | 10 | 11 | 0     | 14  | 48    |
| 10    | 0    | 0        | 0  | 0  | 0  | 0  | 0     | 0   | 0     |
| 11    | 26   | 24       | 0  | 14 | 19 | 17 | 0     | 1   | 51    |
| 12    | 15   | 19       | 0  | 7  | 13 | 14 | 3     | 10  | 47    |
| 13    | 15   | 22       | 0  | 11 | 16 | 10 | 1     | 6   | 44    |
| 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  |



# 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 | elmu | W+/W- |
| 185    | 174      | 21 | 87 | 124 | 127 | 6     | 103 | 488 | 0.94 | 1.43  |



# Additional step with CIMA

 <https://www.i2u2.org/elab/cms/cima/auth.php>

username

Admin

password

.....

Go!

 Cima4CMS









## Q&A

*Students might ask:*

- *About individual events → try to keep it general*
- *About double events, like  $W+W^-$  or  $WZ$  (nope)*
- *Life at CERN or Fermilab*
- *Popular doomsdays*

*You might ask or comment on:*

- *How students decided on specific candidate events*
- *No. of events needed for “good” results*
- *How their day went*

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