



- Work out a system for data transfer from student level to institute level and then for transmission of results to moderators.

### 3. Outline of the Day

*This is not a final schedule but a suggested outline for most institutes.*

- Arrival/Registration (~30 min)
- Cloud chamber, e/m apparatus, or other "gateway experience" apparatus setup for students to inspect
- Start and icebreaker activity (~30 min)
  - Students in small groups create 1–2 good questions about particle physics and/or LHC. Where practical, groups should be made of students from different schools.
- Mentor presentation
  - Template (~60 min, including Q&A)
- Tour of facilities/labs/cool stuff (~45 min)
- Analysis preparation (1–2 teachers facilitate; ~60 min, including Q&A)
  - Presentation
  - CMS data analysis slides (beta)
  - ATLAS data analysis slides (beta)
  - Guided practice with discussion
- Lunch with a physicist (~60 min)
- Data Analysis (~90 min)
- Pre-conference (~30 min)
  - Students and mentor discuss meaning of analysis results.
  - Students and mentor discuss questions for other institutes.
  - Revisit questions from icebreaker; discuss which to ask in videoconference.
- Designated IT expert preps video connection.
- Videoconference (~30 min)
  - Greetings
  - Presentation of results
  - Discussion of results
  - Q&A
- Summing up and evaluation (~15 min)
- Student tasks:
  - Each pair of students analyzes a set of 100 events.
  - For each event, distinguish between electron and muon decay and between  $W^+$ ,  $W^-$ , Z candidate, Higgs candidate, and zoo.
  - Record in CIMA.
  - Be prepared to discuss in masterclass institute and in videoconference; prepare good questions.

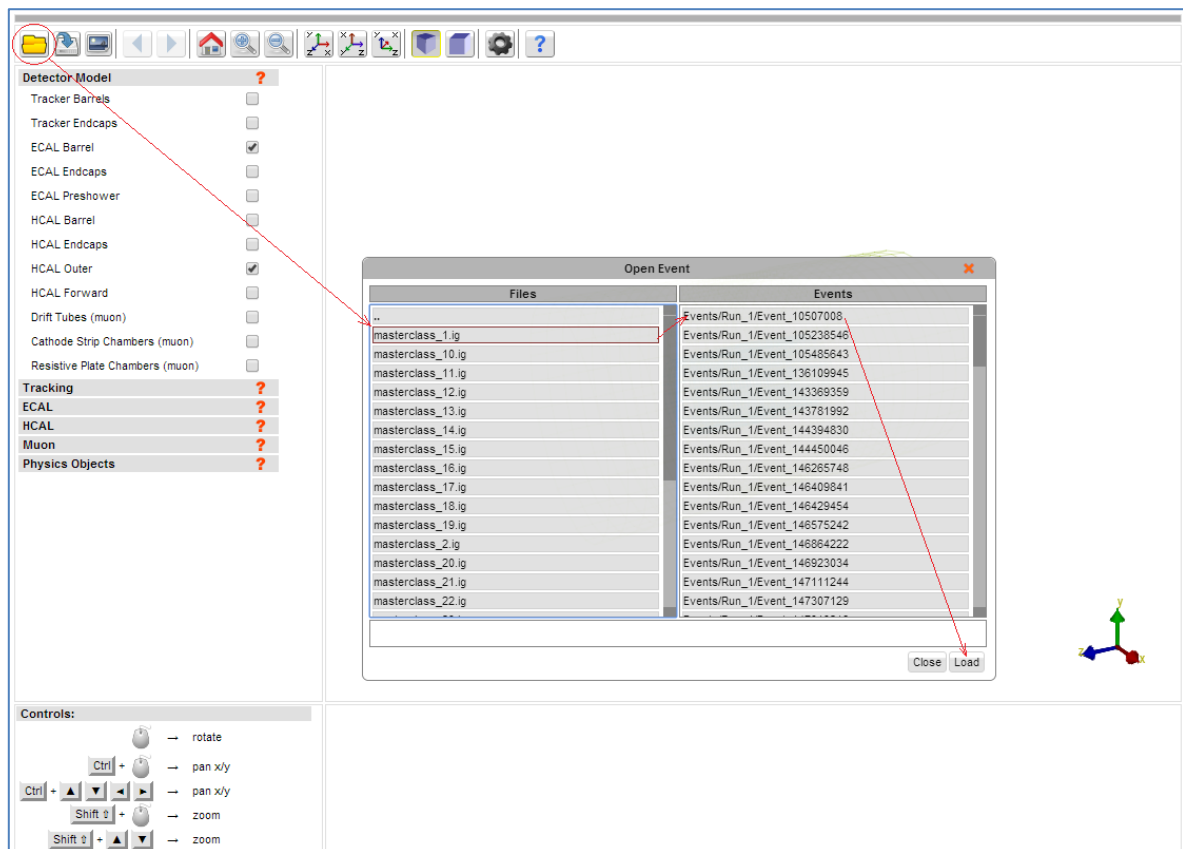
### 4. Student Procedure

*It is important to carefully note the following:*

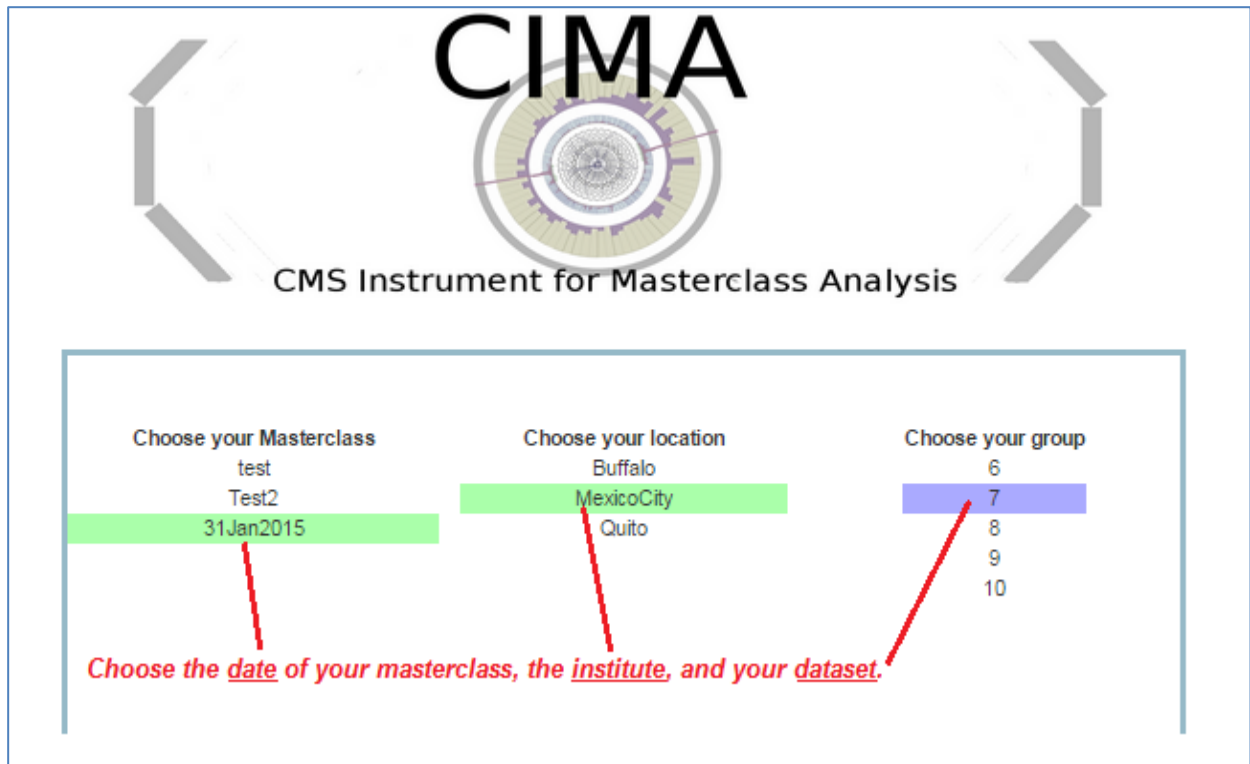
1. *The new CIMA data analysis tool is different from the previous spreadsheets. **Mentors and tutors need to be familiar with CIMA** in order to guide the students successfully.*
2. *The description below is for the current version of iSpy, which is still recommended for CMS masterclasses. There is a new, more capable WebGL version in testing. Select groups may choose to use this new version. To do so, they should study both the procedure below and the Event Display Supplement at [http://leptoquark.hep.nd.edu/~kcecire/drupal\\_lib/files2015/masterclass2015-ispyspywebgl.pdf](http://leptoquark.hep.nd.edu/~kcecire/drupal_lib/files2015/masterclass2015-ispyspywebgl.pdf) and then try the new version before the masterclass.*

Mentors should guide students to follow these procedures for the use of iSpy and CIMA:

- Pairs of students are assigned sets of 100 events to analyze in iSpy-online or iSpy-dvd.
- Event sets are found in the event display (<http://www.i2u2.org/elab/cms/event-display>) by choosing the folder icon (top left).
- A window appears. On the right side, students first choose "masterclass-2015" and then their event set (labelled masterclass\_1, masterclass\_2, etc.).
- Students also open CIMA and then find their masterclass by date ("Choose your Masterclass") and then institute ("Choose your location"). They then choose the number of their event set ("Choose your group"): this is the same number as the event set in iSpy.
- **Notes on CIMA for students:**
  - **All institutes are strongly encouraged to use CIMA rather than a local spreadsheet.**
  - **There are two copies of CIMA for students:**
    - **Production version for students at <https://www.i2u2.org/elab/cms/cima/index.php>**
    - **Backup/development copy at <http://leptoquark.hep.nd.edu/sschoppmann/index.php>.**
  - **Please use the production version of CIMA for your masterclass. It will have your date and your institute to choose from and will be at the URL for the masterclass videoconference in which you will participate.** If needed, Google spreadsheets will be provided online in case of any problems with CIMA.
- **CIMA is also linked at the CMS Library page at <https://quarknet.i2u2.org/content/cms-wzh-path-measurement-2015> (scroll down to Data Analysis).**



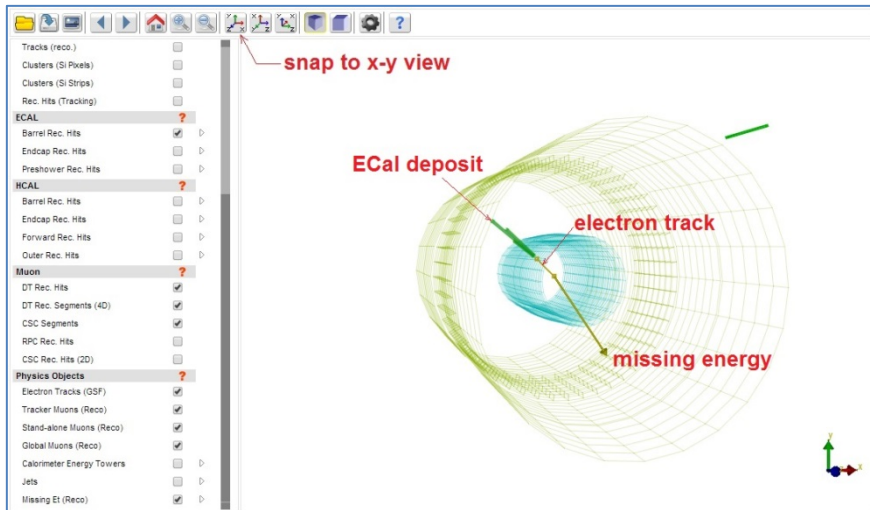
*Open iSpy-online event display. To find the correct dataset, choose the file folder icon at the top left; when the "Open Event" box appears, find your dataset, choose the first event, and then choose the "Load" button.*



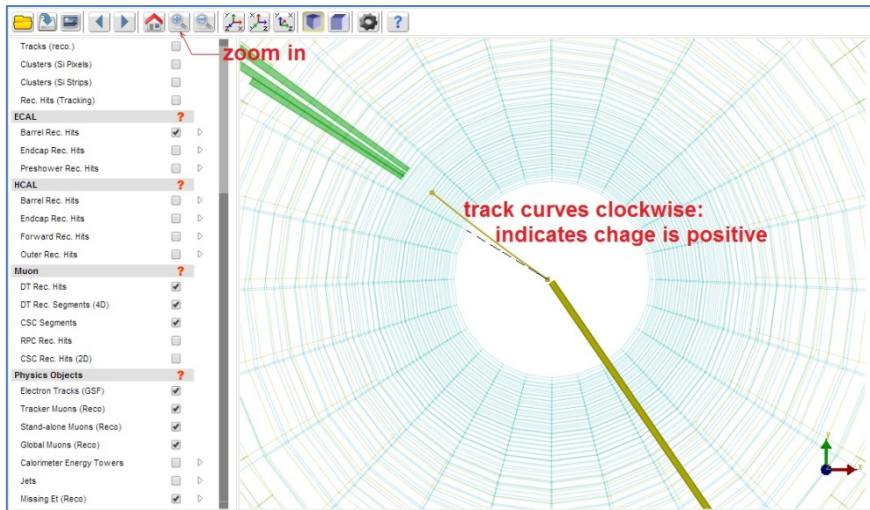
Open CIMA and find your dataset. First choose the date and then the location list appears. Choose your institute and then your set of events.

Students use event displays of (mostly) leptonic decays to determine:

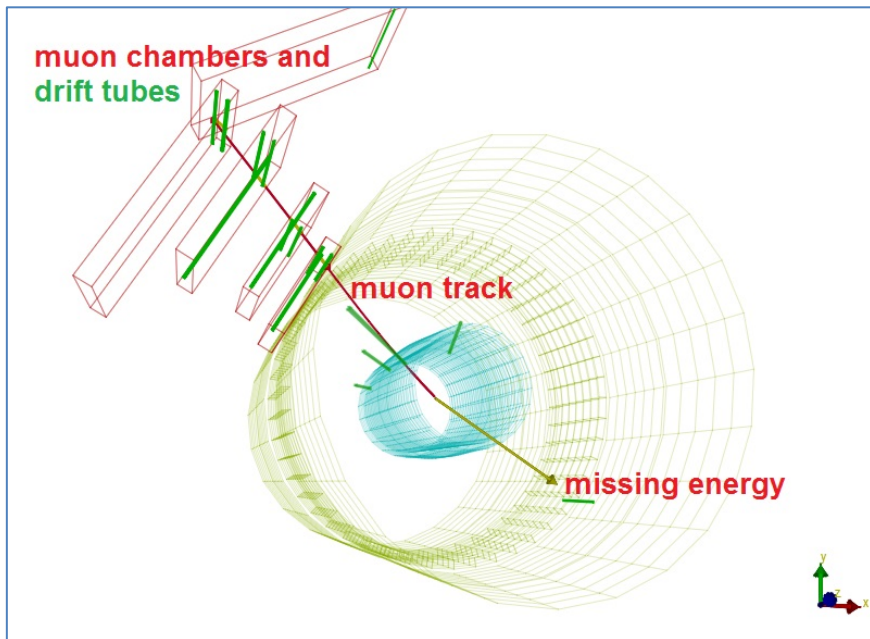
- Lepton ID (electron, muon). This is to characterize the event, not individual particles.
- If the event has one muon track (long, red) or two muon tracks (actually likely a muon-antimuon pair) it is a single muon event.
- If the event has one electron track (short, yellow) or two electron tracks (actually likely an electron-positron pair), it is a single electron event.
- Likely particle ID (W, Z, zoo, Higgs)
  - W candidate appears as a single electron track or muon track and a missing  $E_t$  vector (yellow arrow, always transverse to beamline).
  - Z candidate appears as 2 muons or 2 electrons. It is not always a Z. It may or may not have missing  $E_t$  in the event.
  - Higgs candidate (H); these are rare but noteworthy. Events show as:
    - $H \rightarrow ZZ$ : 2 electrons and 2 muons, or 4 electrons, or 4 muons.
    - $H \rightarrow \gamma\gamma$ : no electron tracks but two large energy deposits (seen as towers) in ECAL.
  - Zoo events are "none of the above," but there can be interesting events among these.
- Charge if W, using curvature of electron or muon tracks; it helps to select the X-Y view and "orthographic mode" (the "flat cube" button), zoom in and to use a paper straight edge.
- Mass if Z or H candidate (taken from CIMA)



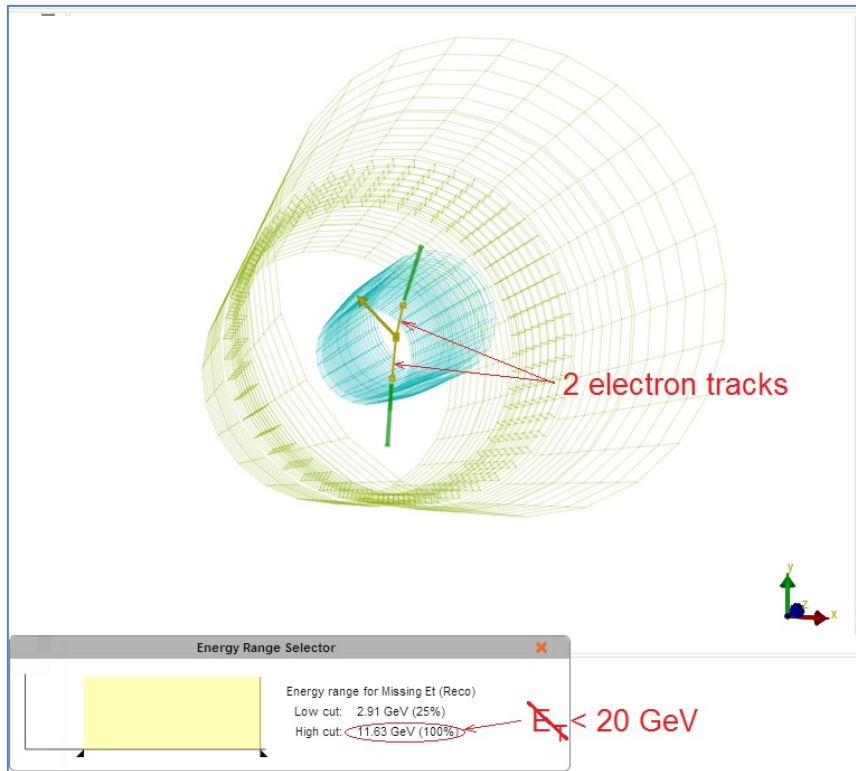
Adjust event settings to get x-y view for track curvature in case of W candidates.



Candidate  $W^+ \rightarrow e^+ + \nu_e$ .



Candidate  $W \rightarrow \mu^- + \text{anti-}\nu_\mu$ .



Candidate  $Z \rightarrow e^+ + e^-$ .

After a pair of students has found their "group" or dataset in CIMA, they will be sent to their Events Table. They will see checkboxes at the top to characterize each event. They should look at the corresponding event in iSpy (they can check the event numbers to be sure they do correspond) and determine which sort of event it is, following a few rules:

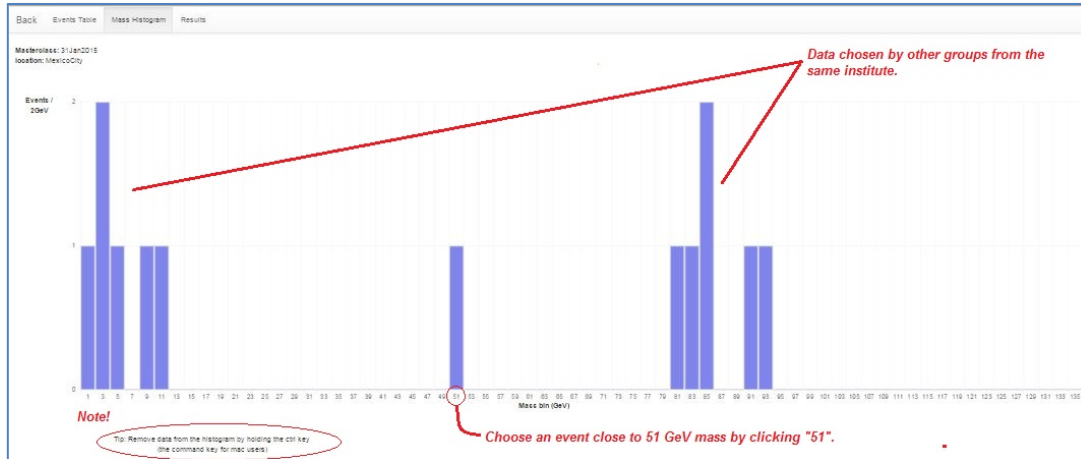
- Choose whether it is an electron or muon under "final state."
- If the event is a Higgs or zoo candidate, no final state is chosen.
- Choose the most likely parent particle under "primary." If it is a Z or Higgs candidate, a mass will appear. If it is a W or zoo, no mass will appear, as we do not include these in the mass plot. If a W and a charge can be determined, choose either W+ or W- instead of just W.
- Choose next. This puts the data below in a line corresponding to the Event Index number.
- In the case of an error, clicking the data line will erase it; they can try again.

Back		Events Table	Mass Histogram	Results
Masterclass: 31Jan2015				
Location: MexicoCity				
Group: 8				
Event index:	Event number:	final state	primary	Mass:
705	27431673	<input checked="" type="checkbox"/> Electron	<input type="checkbox"/> Higgs	7.512
		<input type="checkbox"/> Muon	<input type="checkbox"/> W	
			<input checked="" type="checkbox"/> Z	
			<input type="checkbox"/> W+	
			<input type="checkbox"/> Zoo	
			<input type="checkbox"/> W-	
				<input type="button" value="Next"/>
Event index	Event number	Chosen Values	Mass	
704	400912970	e;W+		
703	135353826	mu;W+		
702	500633024	Zoo		
701	329962807	Z,mu	50.642	

Sample data entered into CIMA. These entries were made randomly and do not show any preferred results.

- When a mass is shown in the line for an event, it should be recorded in the Mass Histogram. The student should:
  - Choose "Mass Histogram" at the top.

- Zoom to get a good size for the mass plot, if needed, using ctrl-minus (PC) or cmd-minus (Mac).
- The numbers on the horizontal axis are the values of the middle of the bins of width 1 GeV. Select the bin by clicking. This will iterate the mass plot up by one for that mass.
- To remove an errant mass iteration, use ctrl-click (PC) or cmd-click (Mac) on the same number.
- The total of number of events at each mass is then automatically transferred to the mass plot in the Results tab.



Enter masses the Mass Histogram for the entire institute (location). Refreshing will show any recently added masses.

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	0	0	0	0	0	0	0	0	0		
4	0	0	0	0	0	0	0	0	0		
5	0	0	0	0	0	0	0	0	0		
6	3	5	2	0	0	6	1	1	10		
7	0	0	0	0	0	0	0	0	0		
8	2	1	0	0	2	1	0	1	4		
9	4	3	1	1	1	4	1	1	9		
10	0	0	0	0	0	0	0	0	0		
11	0	0	0	0	0	0	0	0	0		
12	0	0	0	0	0	0	0	0	0		
13	0	0	0	0	0	0	0	0	0		
14	0	0	0	0	0	0	0	0	0		
15	0	0	0	0	0	0	0	0	0		
16	0	0	0	0	0	0	0	0	0		
17	0	0	0	0	0	0	0	0	0		
18	0	0	0	0	0	0	0	0	0		
19	0	0	0	0	0	0	0	0	0		
20	0	0	0	0	0	0	0	0	0		
21	0	0	0	0	0	0	0	0	0		
22	0	0	0	0	0	0	0	0	0		
23	0	0	0	0	0	0	0	0	0		
24	0	0	0	0	0	0	0	0	0		
25	0	0	0	0	0	0	0	0	0		
26	0	0	0	0	0	0	0	0	0		
27	0	0	0	0	0	0	0	0	0		
28	0	0	0	0	0	0	0	0	0		
29	0	0	0	0	0	0	0	0	0		
Total:	Muon	Electron	W	W-	W+	Z	Higgs	Zoo	Sum	e/mu	W+/W-
	9	9	3	1	3	11	2	3	23	1	3

Numerical results can be seen in the Results page for the institute (location).

## 5. Presentation of Results

The mass plot and summary of results are automatically built in the institute (location) Mass Histogram and Results pages. The mass plot will show not only a Z peak but also peaks due to other particles. The results will show the numbers of electron, muon, W+, W-, W (unknown charge), Z cand, H cand, and zoo events plus the key ratios e:mu and W+:W-. The mentor projects the mass plot and the count/ratio results

and discusses their significance with students. The mentor helps students generate questions for the videoconference or other later discussion.

*For Fermilab-based videoconferences, the mentor shows the students the Mass Histogram and Results for another institute. Each institute is assigned another one to which they may ask one or two questions. In our example, Buffalo may ask questions of Mexico City, and Mexico City may ask questions of Quito, etc.*

## 6. Sample Questions

In discussion, the moderator might ask students:

- How many peaks are there in the mass plot?
- Where is the Z peak? What is the mass of the Z boson?
- What do the other peaks mean?
- Is there anything interesting in the 120–130 GeV range? What is it?
- What is the ratio of electrons to muons? Is it close to what we should expect?
- What is the  $W^+ : W^-$  ratio? What should it be?

In the videoconference, students might ask questions like:

- Why are the widths or heights or numbers of peaks different from one institute to the next?
- Why do different institutes get different ratios? How did they identify electrons or muons or W candidates or Z candidates or zoo events? How did they measure charge for W candidates?
- Now that the Tevatron is shut down, what do you do at Fermilab?
- Is it boring at CERN when the LHC is not running?
- Why did you become a physicist?

... And better questions, which only students can create.

## 7. Moderators

Fermilab-based moderators refer to the [FNAL Masterclass 2014 Moderators page](#).

All moderators should note the following:

As long as all groups use CIMA, moderators do not need to look for uploads from any of the masterclass institutes or make histograms on their own. There is one "Table" for each masterclass institute (location) participating in a single videoconference. Each institute has a Mass Histogram and a Results page.

- Mass Histogram - Students use "Events Tables" to record W or Z candidates, e or  $\mu$  events, Higgs candidates, and "zoo" events. Choosing Z or Higgs candidates result in masses popping up, which students transfer into the Mass Histogram.
- Results - Numbers of different types of particles are automatically transferred here; e: $\mu$  and  $W^+ : W^-$  are calculated for the whole institute.

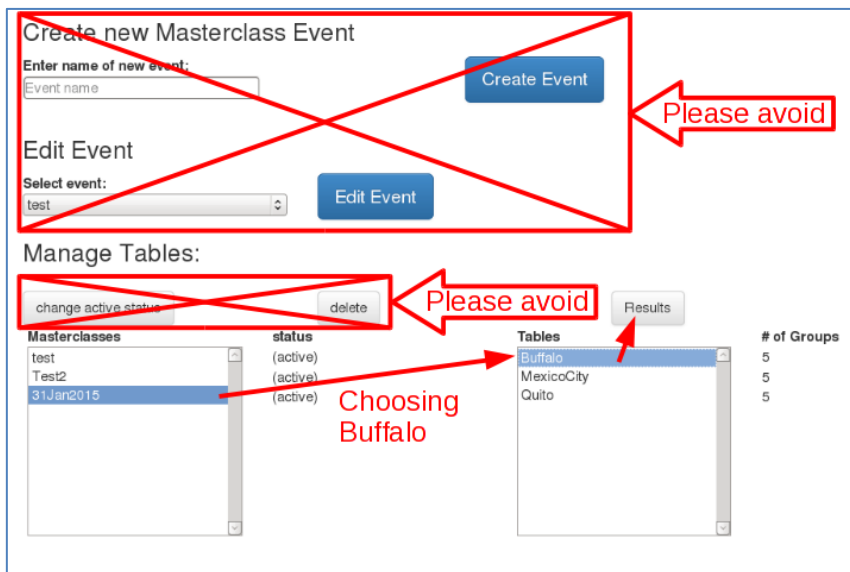
The moderators access the Admin page of CIMA to view these and share them on Vidyo. They view and share the combined Mass Histogram and combined Results for all institutes participating in their videoconference.

To get to the appropriate places, **moderators only** should:

1. Go to the [CIMA Admin page](#). There is also a [backup/development](#) copy.
2. Log in. The user name and password will be sent separately.
3. **Please do not touch anything above Manage Tables.**
4. Go to the part of the page under the Manage Tables heading. *To view the Results and Mass Histogram pages for one institute*, choose the date under Masterclasses and the institute under Table and then choose the Results button. *To view the combined Results and Mass Histogram for*

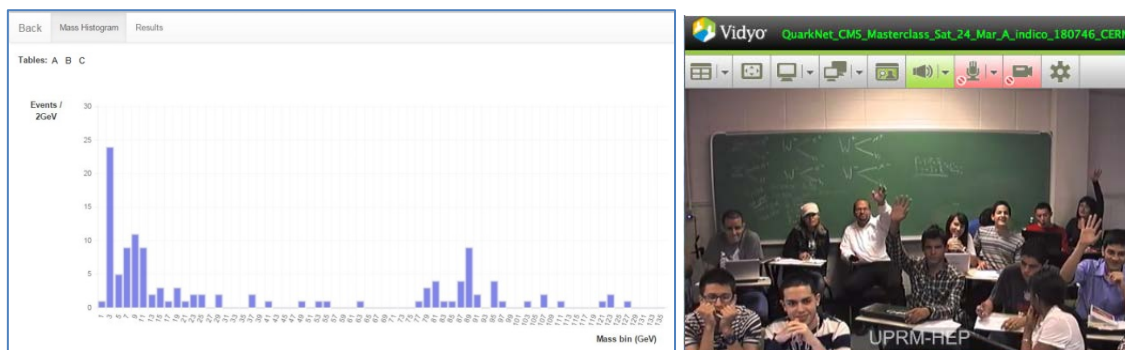


*all institutes that day*, choose the date under Masterclasses but do not choose anything under Table and then go to the Results button.



*CIMA Admin page. This shows how to choose results for Buffalo on 27 January. To choose combined results for Buffalo, Mexico City, and Quito, choose the date but not a location under Tables.*

Moderators discuss the results from each institute and the overall results with the students, making sure to stay within time constraints.



*Sample combined Mass Histogram and a masterclass institute on Vidyo to discuss results.*

If an institute does not use the online spreadsheet, the mentor for that institute shows their mass plot and results using Vidyo desktop sharing.

## 8. Material

*For students and teachers:*

- Classroom prep activities
  - Rolling with Rutherford at <https://quarknet.i2u2.org/data-portfolio/activity/rolling-rutherford>
  - Quark workbench at <https://quarknet.i2u2.org/data-portfolio/activity/quark-workbench>
  - Calculate the mass of the top quark from Tevatron data at <https://quarknet.i2u2.org/data-portfolio/activity/calculate-top-quark-mass>
  - Calculate the mass of the Z boson from LHC data at <https://quarknet.i2u2.org/data-portfolio/activity/calculate-z-mass>
- Aid in masterclass

- Analysis presentation  
at [https://quarknet.i2u2.org/sites/default/files/cmsanalysis2015\\_v0.ppt](https://quarknet.i2u2.org/sites/default/files/cmsanalysis2015_v0.ppt)
- CMS Masterclass "Cheat Sheet"  
at [http://leptoquark.hep.nd.edu/~kcecire/mclib/files2014/CMScheat\\_wzh\\_v0.doc](http://leptoquark.hep.nd.edu/~kcecire/mclib/files2014/CMScheat_wzh_v0.doc).

## 9. Low/No Bandwidth Supplement

In the case where bandwidth or connection to CIMA is a problem, please use these alternative steps:

- Use the DVD version if possible.
- Distribute the spreadsheet "mc2015dvd\_students" to students. It is in the "more" folder of the DVD or it can be downloaded from [https://quarknet.i2u2.org/sites/default/files/mc2015dvd\\_students.xlsx](https://quarknet.i2u2.org/sites/default/files/mc2015dvd_students.xlsx).
- Students should find their dataset in the Datasets tab. For each event they examine in iSpy-dvd, students should:
  - place a "1" (and *only* a "1") under electron or muon *only* if the event is a W- or Z-candidate.
  - place a "1" (and *only* a "1") under W+ cand, W- cand, W cand, or Z cand *only* if the event is a W- or Z-candidate.
  - place a "1" (and *only* a "1") under "zoo" if the event cannot be characterized.
  - place a "1" (and *only* a "1") under Higgs cand *only* if the event is a Higgs (diphoton or 4-lepton) candidate.
- If the student characterizes the event as a Z or Higgs candidate, a mass in GeV will appear in the rightmost column. The student should then go to the Results tab and place a "1" (and *only* a "1") above the mass (rounded to the nearest odd number) in the cell directly above the mass in row 33. If this cell is filled, the student goes to the next one up. The student then returns to the Datasets tab and continues to work.
- Once the data analysis has stopped, the student should find the total numbers of electrons, muons, W+, and W- from the bottom of their dataset and write these down. They should also write down the total non-zero number of events for each mass (with the mass) from the Results tabs. These numbers must be reported to the mentors. Students may use the Data Report Form found in the "more" folder of the DVD; it can also be downloaded from <https://quarknet.i2u2.org/sites/default/files/datareportform.pdf>.
- A mentor or a teacher can then type in the totals in the "mc2015dvd\_mentors" spreadsheet, found in the "more" folder or downloadable from <https://quarknet.i2u2.org/sites/default/files/mc2015dvd-mentors.xlsx>. This will create a combined  $e/\mu$ , W+/W-, and mass plot for the whole institute.

The results cannot be combined with the other masterclass institutes in a videoconference but they can be shared via the Vidyo desktop. Upon request, a Google version of the mentors spreadsheet can be made to make entering data much quicker. Send an e-mail to [kcecire@nd.edu](mailto:kcecire@nd.edu) for this.