

# CMS e-Lab Update

*Marge Bardeen & Tom McCauley*  
*Fermilab*

# What's a Fairhair @ CMS Side Masterclass



The screenshot shows a video conference interface for a "QuarkNet Masterclass - 13:00 - 16:30". The interface includes a top navigation bar with "Koala", "Meetings", "Help & Test", and "Search". A list of participants is shown at the top: Marge Bardeen, LPC WHIE, Kenneth Cecire, Dave Trapp, Tom Gallo, Andy White, and Laurance Hiller. The main area displays several video feeds: "SPK" (two people at laptops), "Tom Gallo" (a woman in a classroom), "Laurance Hiller" (a group of people in a classroom), and "UTA" (a group of people around a table). A "ViEVO" window shows a speed of 2.6 Mb/s. A "Kenneth Cecire [desk]" window displays a mass plot with the text "Masterclass Institute: Buffalo" and "Experiment: CMS". A chat window on the left shows a list of messages with timestamps. The bottom status bar indicates "Connected to Panda EVO07\_US".

QuarkNet Masterclass - 13:00 - 16:30

Participants: Marge Bardeen, LPC WHIE, Kenneth Cecire, Dave Trapp, Tom Gallo, Andy White, Laurance Hiller

Video Feeds: SPK, Tom Gallo, Laurance Hiller, UTA

Chat Log:

Time	Message
[13:31:40]	Tom
[13:31:52]	Tom
[13:40:15]	Andy
[13:41:02]	Andy
[13:41:53]	Laura
[13:43:50]	Andy
[13:43:56]	Kenn
[13:50:30]	Andy

Mass plot: upload image below

# What's Different: e-Lab Poster Session

## Investigating the Mass of a Z-Particle

Abby Compton and Abby Klein



**Investigating the Mass of a Z-Particle**  
Abby Compton and Abby Klein

**Abstract**

The team investigated the mass of a Z boson. Physicists use the CMS detector to confirm mass and other measurements of various particles such as a Z boson. They then create data pairs with the data they collect from CMS and use this information to determine the mass of each Z boson. The mass of each Z boson is then compared to the mass of each Z boson to see if they are the same.

**Introduction**

In its search for new particles, the CMS detector is constantly looking for new particles. This search is made possible through the data generated through the experiments at CERN. They look for new particles of the particles that make up our world. The experiments at CERN have discovered that the top and stop of the detector depend on what they are trying to measure. For example, the paths of certain particles may differ from those that would be expected. This means that there may be other particles in the detector that are not yet known. The experiments at CERN are constantly looking for new particles. The experiments at CERN are constantly looking for new particles. The experiments at CERN are constantly looking for new particles.

**Procedure**

The purpose of this experiment was to confirm the mass of a Z boson. We used data from the CMS detector to confirm the mass of a Z boson. We used data from the CMS detector to confirm the mass of a Z boson. We used data from the CMS detector to confirm the mass of a Z boson.

**Results**

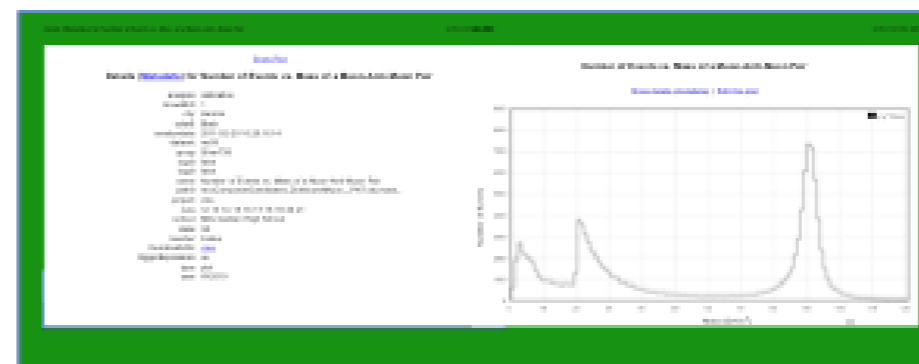
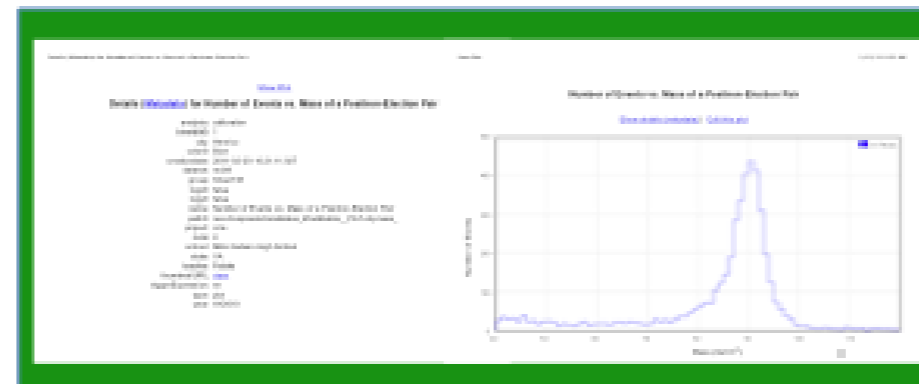
The results of this experiment show that the mass of a Z boson is approximately 91.1876 GeV. This is consistent with the known mass of a Z boson. The results of this experiment show that the mass of a Z boson is approximately 91.1876 GeV. This is consistent with the known mass of a Z boson.

**Conclusion & Discussion**


The results of this experiment show that the mass of a Z boson is approximately 91.1876 GeV. This is consistent with the known mass of a Z boson. The results of this experiment show that the mass of a Z boson is approximately 91.1876 GeV. This is consistent with the known mass of a Z boson.

**Bibliography**

<http://www.cern.ch>



# Knowledge Project Detector



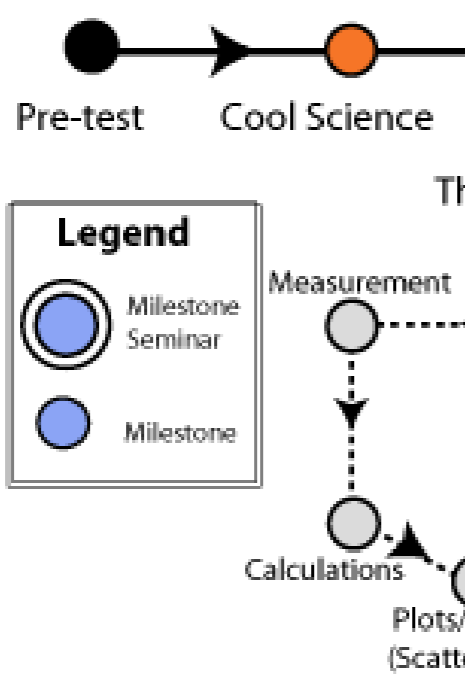
## CMS e-Lab

guest [Log out](#)

Project Map
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Data
Posters
Site Map
Assessment

**Home: Join a national**

**Project Map: To navigate spot to preview; click to o your work is going. Proje**



**Legend**

- Milestone Seminar
- Milestone

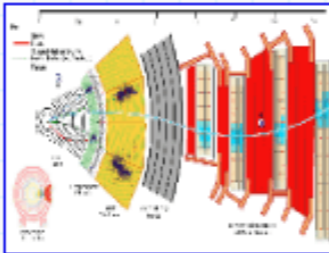
Pre-test → Cool Science → Measurement → Calculations → Plots/ (Scatte

**Your team may use the milesto progress, keep your teacher ap**

detector geom

**Milestone: Summarize the geometry and function of the CMS detector.**

*Scientists design and deploy instruments guided by the questions they are asking, available technologies and cost of materials.*



CMS is a complex detector.


Grasp the basic structure and function of the detector, the order and roles of the sub-detectors.

Click on the interactive graphic.

**CMS Detector Slice**

In your logbook:

- Discuss how CMS measurements affect the size and shape of the detector.
- Differentiate among the CMS sub-detectors in terms of function and location: trackers, calorimeters, muon chambers, magnet system.

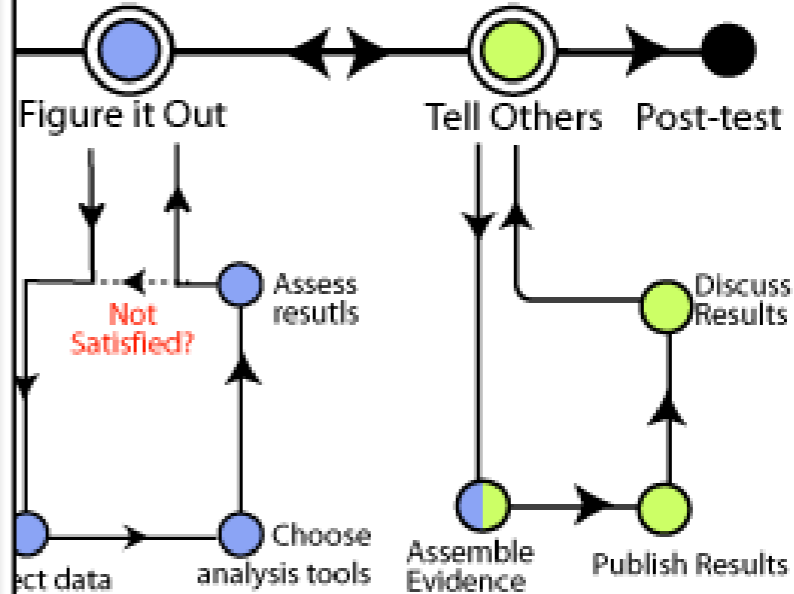
[Log it!](#) 

**To Learn More:**

- [USCMS's CMS Detector](#) - Interactive diagram with roll-over explanations of sub-detectors and US contributions from USCMS
- [The CMS Detector](#) - Short description and interactive image with photos and drawings of the sub-detectors from the CMS website
- [How does it work?](#) - Description with the interactive graphic slice above from the CMS website
- [How a Detector Works](#) - Descriptions of the sub-detectors and animation of particles from the CERN Website
- [Modern Detectors](#) - Extensive information about modern

**to study CMS data.**

**te the milestones. Hover over each hot seminars, opportunities to check how es. [Getting Around the e-Lab](#)**



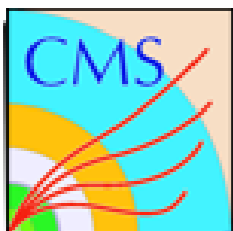
**Figure it Out** ↔ **Tell Others** → **Post-test**

Assess results (Not Satisfied?) → Choose analysis tools → Assemble Evidence → Publish Results → Discuss Results → Tell Others

Derived from CMS Detector Slice from CERN

*M. Bardeen & T. McCauley, IPPOG, April 2011*

# Interpret Data



CMS e-Lab

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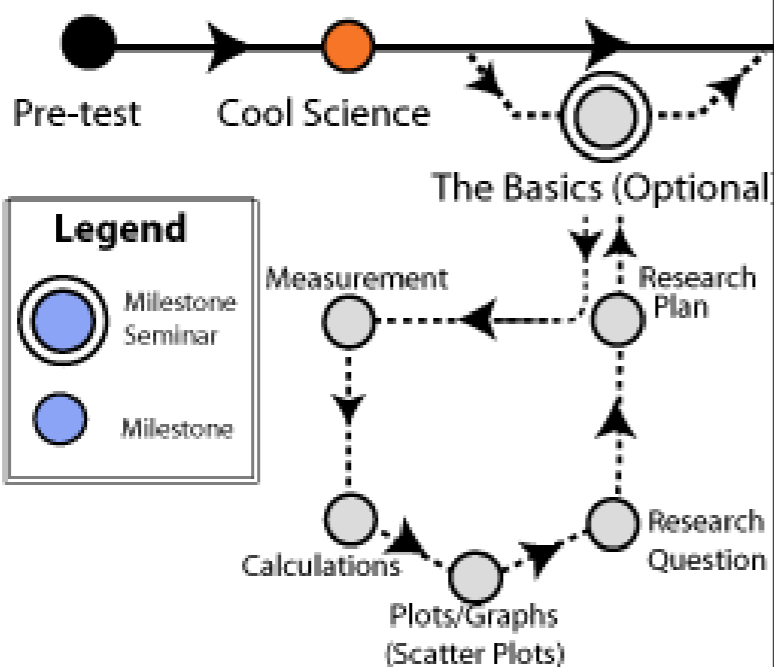
guest Log out

Text Version

interpret data

Home: Join a national collaboration

**Project Map: To navigate the CMS e-Lab spot to preview; click to open. Along the way, you can see how your work is going. Project milestones**

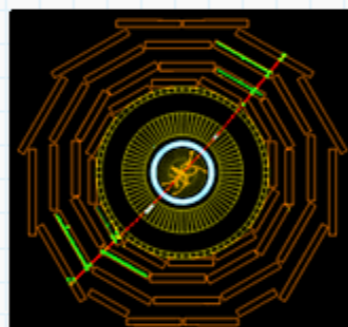


Your team may use the milestones above, or you can create your own. Keep your progress, keep your teacher apprised of your work.

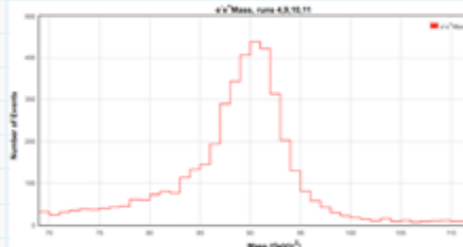
Milestone: : Interpret data.

Scientists often represent their data graphically . . .

You have already learned about particles that interact with the CMS detector. Physicists call the interaction an event. Physicists look at these events in data displays either as single or multiple events. Each approach yields important information. The plots below represent the two approaches. Click the plots to learn more about each approach.



**Approach 1: Single Event Displays**  
Single event displays are a great way to take a look at what happened in the collision.



**Approach 2: Data Displays of Multiple Events**  
Physicists study histograms of trillions of collisions. Any one of those trillion collisions can be viewed in an event display!

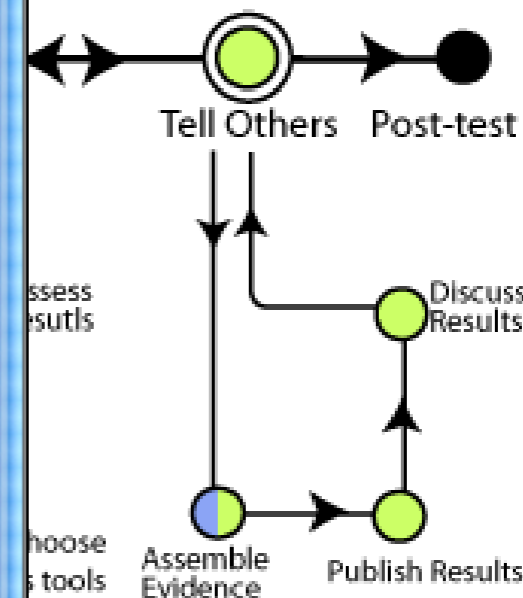
Combining lots of events yields results like this mass plot using data from events with two electrons.

In your logbook:

- Describe the characteristics that indicate a Z particle has decayed to two electrons, two muons, and two jets in LEP events. List any characteristics common to all three types of decay.
- Identify the CMS detector subsystems (trackers, electron and hadron calorimeters and muon chambers) involved in the detection of the dielectron, dimuon and dijet Z decays.
- Describe what physicists can discover when they combine millions of events.


CMS data.

ones. Hover over each hot spot to see more opportunities to check how your work is going around the e-Lab



you know how to record your

# Choose a Study



## CMS e-Lab

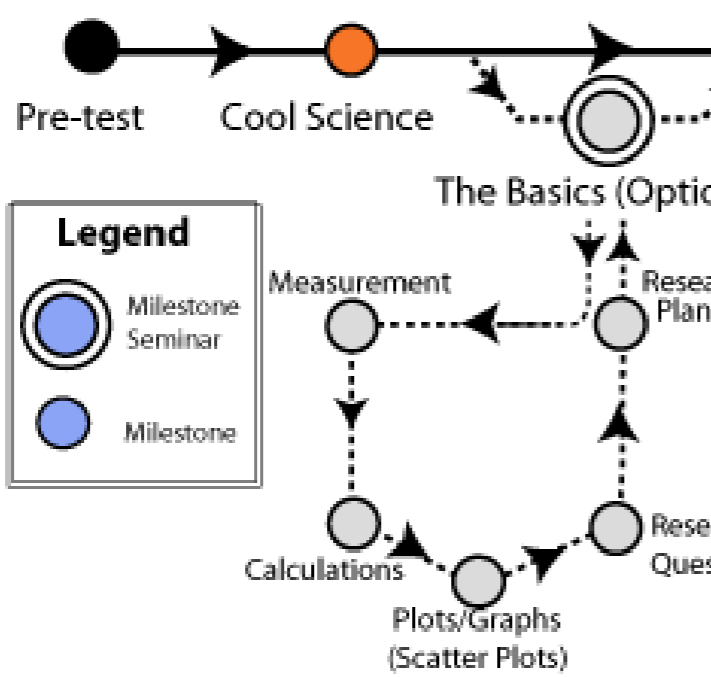
Project Map | Text Version

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Site Map | Assessment

**Home: Join a national collaboration**

**Project Map: To navigate the CMS e-Lab, click on a hot spot to preview; click to open. Along the way, you can see how your work is going. Project milestones are marked with a blue circle.**




**Milestone: Choose a study (or design your own!)**

The LHC and CMS are designed for discovery science. Scientists must calibrate new instruments based on confirmed measurements and data before they announce new discoveries. Follow along as CMS matures.

Now that you've grasped the big picture and some fundamental physics behind the CMS experiment, you can work alongside physicists. Begin asking some questions of your own.

[Calibration Studies](#) - descriptions of studies that will be the basis of your investigation. Warm up with simulated (Monte Carlo) data and then work with experimental data under the Exploration tab. [What's the difference?](#)


Put it altogether. Describe your study in your logbook.

[Log It!](#) 

When you are finished, check to see if you should attend a milestone seminar.

You can begin your study by going straight to the analysis tool.

Click on "Calibration" under "Data" in the navigation bar to analyze simulated data. Next click on "Exploration" to analyze experimental data.



This [screencast](#) shows how to use the analysis tool.

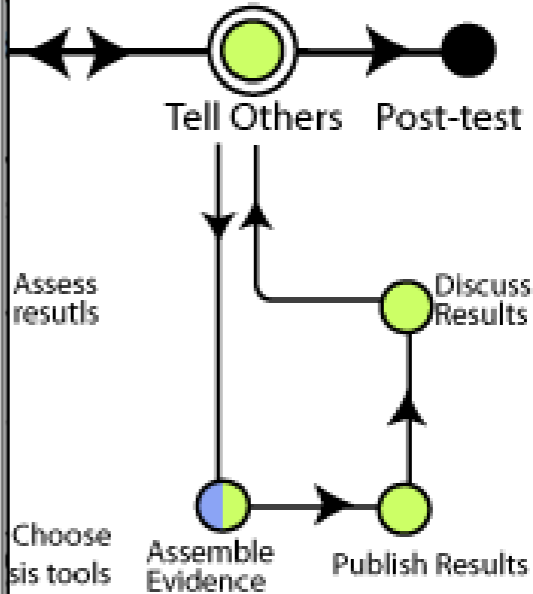
**To Learn More:**

[Rediscovering the weak force frontier](#) - Read Fermilab Today's article in the right hand column on how physicists are confirming their detector is working correctly.

[Close Window](#)

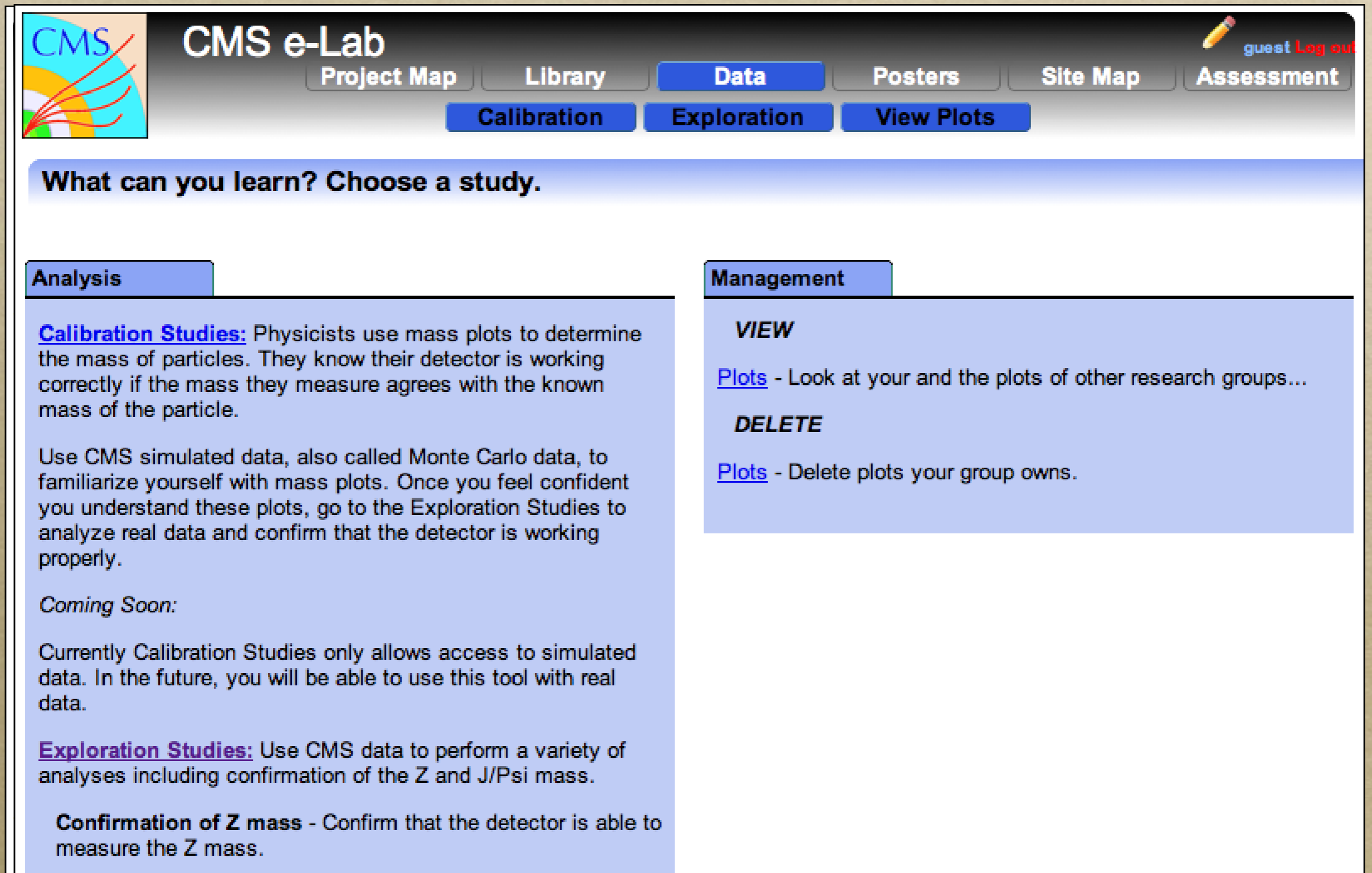
**CMS data.**

**Hot spots. Hover over each hot spot to preview; click to open. Along the way, you can see how your work is going. Project milestones are marked with a blue circle.**



**you know how to record your**

# Figure It Out



**CMS e-Lab** guest [Log out](#)

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[Calibration](#) [Exploration](#) [View Plots](#)

**What can you learn? Choose a study.**

**Analysis**

**Calibration Studies:** Physicists use mass plots to determine the mass of particles. They know their detector is working correctly if the mass they measure agrees with the known mass of the particle.

Use CMS simulated data, also called Monte Carlo data, to familiarize yourself with mass plots. Once you feel confident you understand these plots, go to the Exploration Studies to analyze real data and confirm that the detector is working properly.

*Coming Soon:*

Currently Calibration Studies only allows access to simulated data. In the future, you will be able to use this tool with real data.

**Exploration Studies:** Use CMS data to perform a variety of analyses including confirmation of the Z and J/Psi mass.

**Confirmation of Z mass** - Confirm that the detector is able to measure the Z mass.

**Management**

**VIEW**

[Plots](#) - Look at your and the plots of other research groups...

**DELETE**

[Plots](#) - Delete plots your group owns.

# CMS Data

*The CMS Collaboration has approved the following data to be made available for use in education and outreach:*

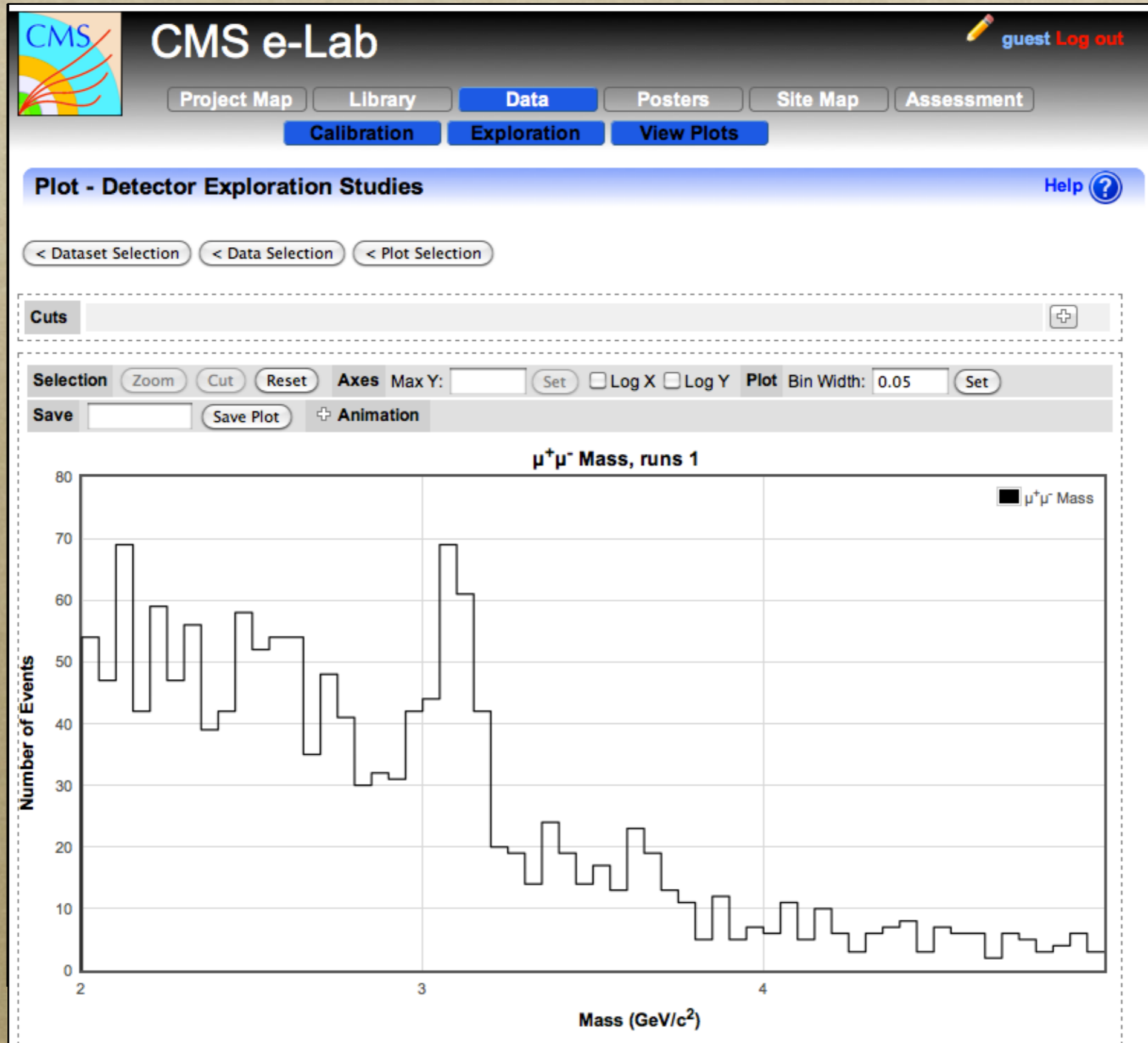
*(special thanks to D. Barney and R. Ruchti)*

- 2000 events each of  **$J/\psi \rightarrow \mu\mu$** ,  $J/\psi \rightarrow ee$
- 2000 events each of  $Y \rightarrow \mu\mu$ ,  $Y \rightarrow ee$
- 500 events each of  **$Z \rightarrow \mu\mu$** ,  **$Z \rightarrow ee$**
- 1000 events each of  $W \rightarrow \mu\nu$ ,  $W \rightarrow e\nu$
- 100,000(!) events each of dimuon, dielectron, and dijet events in the energy range 2-100 GeV

***Bold indicates sample already delivered and/or in use.***



# Explore the Data



# Explore an Event

The screenshot displays a software interface for exploring a particle physics event. The main window shows a 3D visualization of detector components and tracks. A dialog box titled "Energy Range Selector" is open, showing a histogram and the following parameters:

- Energy range for Barrel Rec. Hits
- Low cut: 0.06 GeV (3%)
- High cut: 2.23 GeV (100%)


The interface includes a sidebar with a tree view of detector components and their status:

- HCAL Forward:
- Drift Tubes (muon):
- Cathode Strip Chambers (muon):
- Resistive Plate Chambers (muon):
- Tracking:  ?
- Tracks (reco.)(190):
- Electron Tracks (GSF)(1):
- Clusters (Si Pixels)(1120):
- Clusters (Si Strips)(7272):
- Rec. Hits (Tracking)(2656):
- ECAL:  ?
- Barrel Rec. Hits(1363):
- Endcap Rec. Hits(875):
- Preshower Rec. Hits(976):
- HCAL:  ?
- Barrel Rec. Hits(885):
- Endcap Rec. Hits(268):
- Forward Rec. Hits(382):
- Outer Rec. Hits(367):
- Muon:  ?
- DT Rec. Hits(1):
- DT Rec. Segments (4D)(0):
- CSC Segments(8):
- RPC Rec. Hits(11):
- CSC Rec. Hits (2D)(52):
- Particle Flow:  ?
- Physics Objects:  ?
- Tracker Muons (Reco)(2):

At the bottom left, there are controls for navigation:

- rotate
- Ctrl + rotate → pan x / y
- Shift + rotate → pan z

# Report Your Results



## CMS e-Lab

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[New Poster](#) [Edit Posters](#) [View Posters](#) [Delete Poster](#) [View Plots](#) [Upload Image](#)

### New Poster: Make or edit your poster

- Fill in all the fields including Poster File Name if it is missing. This is the name the poster file will get on the server. If you are making a new poster, do not use a name you have already used. To see the posters you have made, click **Edit Posters** above.
- Look at the [characteristics of a good poster](#).
- Be sure to write a good [abstract](#).
- To view the plots that you might want to include for the figures in your poster, click **View Plots** in the navigation bar. You can fill in fields for up to five figures. You don't have to fill them all in.
- Click **Make Poster** to save the data for the poster and display your poster. If you have "pop-ups" blocked, you will need to click on Display Poster below.

Poster File Name:   
(e.g.,poster\_lifetime)

Title:

Subtitle:

Authors:


Date:

**Abstract:**  
(Brief Overview of purpose, procedures, results & conclusions)

**Introduction:**  
(Background and researchable question)

**Procedure:**  
(Research or study plan)

# Assess Your Work



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## Objectives: Assessing Your Work (CMS e-Lab)

The following objectives outline what you will learn and be able to do during this study of CMS data. For assessment follow the guidance your teacher gave you at the beginning of the project.

- **Content and Investigation Objectives:**
  - Describe particles colliding in and emerging from collisions detected by CMS as predicted by the Standard Model.
  - List in order and describe the CMS subdetectors in terms of the properties of the particles they detect.
  - Explain the role that conservation of mass/energy, momentum, and charge play in analyzing events detected at CMS.
  - Design, conduct and report on an investigation of a testable hypothesis for which evidence can be provided using CMS data.
- **Process:**
  - Explain the data collection process including what corrections need to be made in order to obtain reliable data.
  - Evaluate the data to decide which are reliable/usable and which are not and explain how they arrived at the decision to include some data and exclude others.
  - Collect, organize and analyze data to obtain meaningful findings.
  - Use the data to provide evidence to support their claims.
- **Computing:**
  - Explain why they used specific computing resources in their analysis.
- **Literacy:**
  - Demonstrate an ability to express meaning in writing (such as in science notebooks, reports) and come to agreement about meaning with others (such as peer review, discussion).

# Next Steps



Produce data

Improve tools

Develop background for new studies

# Kudos and Credits

**CMS e-Lab** Teacher Home Student Home

High school students use cutting-edge tools to do scientific investigations.

Particle physics aims to answer two questions: What are the elementary constituents of matter? What are the fundamental forces that control their behavior at the most basic level? CERN's Large Hadron Collider (LHC) and its experiments will probe deeper into matter than ever before. The Compact Muon Solenoid (CMS) detector is designed to detect fundamental particles: electrons, muons, tau leptons, photons, and quark jets and missing energy due to very weakly interacting particles such as neutrinos. Massive particles such as the Higgs boson will decay into these fundamental objects, the properties of which will be measured in the CMS detector's many subsystems.

The CMS e-Lab provides students with an opportunity to analyze data to calibrate the detector and participate in discovery science (as particle physicists do). Calibrating the detector to "rediscover" previous measured results is an important part of the early scientific activity at CMS. Later students will probe data where physicists expect to find answers to questions at the heart of 21st century particle physics.

Join our learning community. Go to the teacher pages to find learner objectives and assessment tools, standards, classroom notes and more. Your students begin the e-Lab at the Student Home and cannot access this page or teacher pages from the student pages.

[Information common for all e-Labs](#)

Simulated Event Superimposed on Detector  
Inner tracking barrel  
Splash of particles  
Detector before closure 2008  
Simulation Higgs

This project is supported in part by the National Science Foundation and the Office of High Energy Physics in the Office of Science, U.S. Department of Energy. Opinions expressed are those of the authors and not necessarily those of the Foundation or Department.

“Over the course of the program, I, along with the others in my class, had a chance to experiment with simulated data and develop skill sets in particle physics, as well as form an understanding of the CMS experiment at CERN. Though I doubted the ability of an online course to convey the details and intricacies of such a theoretical branch of physics, I was pleasantly surprised to discover that, through your course, I could fully learn and understand the “big questions” CERN physicists and experimenters hope to uncover; my lab partner and I found ourselves slowly being enchanted by the world of high energy physics that was then so new to us. Because the program you’ve established is such a brilliant way of teaching students who are interested in the questions and theories of particle physics, I thought I might pass along my feedback . . . .”

*Honors Physics Student, Mills Godwin High School*

Major Contributors: M. Bardeen – D. Barney - K. Cecire - M. Hategan - T. Jordan  
D. Karmgard - T. Loughran - L. Taylor - T. McCauley - P. Nguyen - L. Quigg - R. Ruchti - M. Wilde

*M. Bardeen & T. McCauley, IPPOG, April 2011*