

Homework instructions: CMS e-lab

Instructions:

1. Go to the CMS e-lab: <https://www.i2u2.org/elab/cms/home/index.jsp>

Sign in as a guest if you do not have an account. Note that if you have a cosmic ray or LIGO e-lab account, you can use that for the CMS e-lab as well.

We'll use the "Data" → "Exploration" tab in the Student view.

2. Explore the e-lab, trying to answer one of the **exploration questions** below. If you've never used the e-lab before, there is a very helpful screencast from Ken here: <http://www.screencast.com/t/m9QDaF4p>
3. Add a slide to the class Google slides (link sent via email). Your slide should include at least one of the plots you made on the e-lab and a descriptive caption. Read at least three other people's slides describing what they did and be prepared to discuss.

Exploration questions:

1. **Confirmation of Z mass** - Confirm that the detector is able to measure the Z mass.
2. **Confirmation of J/Psi mass** - Confirm that the detector is able to measure the J/Psi mass.
3. **Confirmation of Upsilon mass** - Confirm that the detector is able to measure the Upsilon mass.
4. **Cosmic rays (challenge question)** - Can you find evidence for cosmic ray muons in the "dimuon events with invariant mass between 2-110 GeV" dataset? A single cosmic ray muon would be reconstructed as two "back-to-back" muons ($\Delta\phi = \pi$) with opposite charges, similar pT, and small values of eta η .
5. Come up with your own!

Useful vocabulary:

- The transverse momentum **pt** is the projection of the particle's momentum into the plane perpendicular to the beam (the xy plane).
- The variable **eta** is the [pseudorapidity](#) η of the particle. It is zero for particles that are produced in the transverse plane, and approaches infinity for particles produced along the beamline (the z axis).
- The variable **phi** ϕ is the angle in the transverse plane, measured as the angle up from the horizontal axis pointing toward the center of the LHC ring.
- You can find some useful diagrams of the CMS coordinate system here: https://tikz.net/axis3d_cms/
- The invariant mass **M** is the combined mass of the two electrons/two muons. If some particle X decayed into two muons, then the histogram of **M** would have a "bump" at the mass of X.