CMS Calibration - Milestones

Work as a team to meet these milestones. The Level-3 project managers will visit your group to participate in a brief milestone 1 seminar once your team is ready.

Milestone 0: At team formation, each member can

1. Use a spreadsheet or other appropriate tool, to:
    a. perform simple arithmetic on columns of numbers
    b. make meaningful data plots
    c. create and interpret histograms
2. Make use of relativistic units that are common in particle physics (e.g. setting c equal to 1; using units of GeV/c for momentum, etc.)
3. Recognize that charge, energy and momentum are conserved in two-body decays both at rest and moving in the lab frame
4. Explain how charged particles are affected by electric and magnetic fields.

Milestone 1: Foundations for Data Analysis

Sample data & event files can be found [here](#). Completing these milestones gains the team access to the full dataset. **Each team member** can:

Theoretical background

1. Describe the particle your team is investigating, where it comes from, and how it decays. (EU11)

Using the event display

2. Explain the function of, and what is measured in, CMS's trackers, calorimeters and muon chambers. (EU2)
3. Describe the effect of a magnetic field on the trajectory of a charged particle. (EU7)
4. From the 10 events provided in the sample .ig file, use the [event display viewer](#) to select three events that correspond to the particle your team was assigned; save screenshots of both an end-view and side-view; and describe evidence for why they are appropriate selections. (EU3)

   You may find it helpful to access the [CMS Data Express](#) activity from the Data portfolio *to review/learn about the event display.*

Using the tabular data

5. Describe how to determine the mass of a particle given its energy and momentum. (EU2)
6. Demonstrate how to determine the invariant mass of a moving particle by measuring its decay products. (EU2)
7. Use a spreadsheet to plot a histogram using a small "sample" dataset. (EU5)
8. Describe the information in the sample data set spreadsheet. (EU6)

   You may find it useful to access the [Top Quark Mass](#) activity from the Data Portfolio *that explains some of the work scientists do to determine mass given the spreadsheet data.*

Milestone 2: Data Analysis

Completing these milestones finishes the CMS mass reconstruction "student hat" project. **Each team** can:

1. From the single large data set, complete an analysis that will calculate the invariant mass of the assigned particle. (EU10)

   Spreadsheets struggle with datasets of this size. Here's something better-suited to this task.

2. Distinguish and enhance signal by removing background from and applying cuts to the large data set. (EU9)
3. Fully describe both signal and background. (EU8)
4. Produce a final mass plot *that includes error bars*. (EU5)
5. State the "goodness" of the results and justify. (EU4)
6. Fully describe these particles. (EU1)
7. Following a discussion with a project leader, define and investigate additional research question(s) that are unique to your particle and/or decay channel. (EU12)
8. There is not a seminar for this set of milestones, but you will be briefly presenting (3 minutes or less) your findings. Please upload your presentation into the presentations folder (4 or fewer slides/pages). This presentation should be brief but include the following at minimum:
   a. Briefly describe your assigned particle and its properties, as well as the assigned decay channel. (EU11)
   b. Use your saved screenshots from the event display to present and explain evidence for why they are appropriate choices for the decay channel assigned to your group. (EU3)
   c. Present one or more mass plots (i.e., histograms) to illustrate the results of the data analysis and briefly describe evidence from these plots (EU5)
   d. Defend your conclusion as to whether the detector is appropriately calibrated. (EU1)
   e. Respond to questions posed by your audience (and ask questions when you are in the audience).

Link to presentation plan

Milestone 3. Data Portfolio Exploration

1. Explore at least three stand alone activities from the portfolio (e-lab, Masterclass, Pennies, Top Quark, Quark Workbench, etc.).
2. Identify three topics in your curriculum that can be addressed and enriched by portfolio activities.
3. Discuss with colleagues your ideas for implementation of one or more of these ideas.
4. Design a sequence of three or more activities to use in the classroom during the course of the upcoming school year.

Milestone 4. Data Portfolio Presentation

1. Work in small groups to plan a realistic and logical implementation for at least one of the activities you've chosen in your sequence (should include usual lesson components: standards, handouts, lesson plans, etc).
2. Complete the *Implementation Plan* (linked from the agenda) describing how you plan to use the Data Portfolio.
3. Prepare a brief (<5 min) presentation to share with the whole group on Friday afternoon.
4. Follow-up during and after implementation - possibility of graduate credit, which would require at minimum: summary and commentary of the process; collaboration with Data Camp colleagues; assessments; etc.