Particle Physics Project

Analyzing CMS Particle Physics Data

Introduction

The CMS Collaboration brings together members of the particle physics community from across the globe in a quest to advance humanity's knowledge of the very basic laws of our Universe. CMS has over 5000 particle physicists, engineers, computer scientists, technicians and students from 200 institutes and universities from more than 40 countries.

The collaboration operates and collects data from the Compact Muon Solenoid (CMS), one of the general-purpose particle detectors at CERN's Large Hadron Collider (LHC). Collaborators from all over the world helped design and fabricate components of the detector, which were brought to CERN in Geneva, Switzerland for final assembly. Data collected by CMS are shared with several computing centers via the Worldwide LHC Computing Grid. From there, they are distributed to CMS institutions in over forty countries for physics analysis.

In keeping with CERN's commitment to open access for high-energy physics, the scientific results from CMS are shared openly with the world. Additionally, CMS shares its particle physics data with the world. We will be analyzing some of this public data in this project.

In this particle physics project students will be doing the following:

1. Determining the charge of muons deflected by a magnetic field
2. Writing a Matlab program to:
   a. Histogram the "raw" data (diagnostic histograms).
   b. Calculate the invariant mass of dimuon pairs.
   c. Lorentz transform the data from the lab frame to the dimuon rest frame and repeat (a and b) in this frame.
3. Discussing the results of their analyses

Monday (13 July)

Background Information

1. Watch Video: //The Standard Model of Particle Physics// - 8 minutes
2. Review the effect of electric field (electric potential difference) on a charged particle; definition of an electron volt (eV) as a unit of energy See video Dan made (with some corrections): https://youtu.be/emnDDdRsOIs
3. Review the effect of a uniform magnetic field on a charged particle; review direction of deflection of moving charged particle in a uniform magnetic field; relationship between high momentum and small deflection of a charged particle in a uniform magnetic field
4. View 32 slides: Particle Physics and the LHC - 15 minutes (I would jump to slide 12 since Ken introduced LHC already)
5. View Sites: CMS Collaboration, Detector with Labels, Detector Side-View, Detector Simulation and Detector Simulation Static - 15 minutes (I would just talk about the transverse simulation here: Detector Simulation

   I would skip the following videos. Perhaps this video is better:

How particle physics research gets done:
https://www.youtube.com/watch?v=2LnGKdV30xg

6. Watch Video: //A Crash Course In Particle Physics (1 of 2)// - 13 minutes (skip)
7. Watch Video: //A Crash Course In Particle Physics (2 of 2)// - 27 minutes (skip)
8. Study the relativistic equations of momentum (gam*m*v) and energy (gam*m*c^2); study the relationship between E, p and m; $E^2=(p*c)^2+(m*c^2)^2$

Dan's colab activity:

https://github.com/dkallenberg/Quarknet_Data/blob/master/Coins_and_Dice_with_Python.ipynb

Be sure to SAVE A COPY in Drive:

https://colab.research.google.com/drive/1R7TGNVcv8u6KxIA8RkGixvHVNvFO4siu?usp=sharing

4

Identifying J/Ψ Candidates

9. View powerpoint: Low-Mass Dimuon Events and Muon Charge - 20 minutes
   CMSAnalysis.ppt

   The document below and the spreadsheet below should be considered together. I would preview both before studying either one too carefully.

10. Read this document: Strategy for Identifying J/Ψ Candidates
11. View this spreadsheet: 2000 Dimuon Events - This is the data we will be analyzing. Note the column headings.
12. Reread and review the above document and spreadsheet.

Monday Homework

- Watch Video: //A Crash Course In Particle Physics (1 of 2)// - 13 minutes
- Watch Video: //A Crash Course In Particle Physics (2 of 2)// - 27 minutes
- Study the relativistic equations of momentum (gam*m*v) and energy (gam*m*c^2); study the relationship between E, p and m; E^2=(p*c)^2+(m*c^2)^2

Writing a Python Program to Display and Analyze the Data

Tuesday (14 July) to Thursday (16 July)

1. Follow this link to open the Colab notebook, go to File, and click, "Save a copy in drive".
2. Recommendation for Layout of Histograms : Diagnostic histograms are used to confirm the success of the reading of the data and to confirm the success of the conversion of the 4-momenta from the Lab Frame to the DiMuon Rest Frame - the frame in which the J/Ψ is at rest.
3. Students: Start Writing Code for Diagnostic Histograms
4. Students: Continue to write code
5. These documents show how to transform the muon 4-momenta from the Lab Frame to the DiMuon Rest Frame with the Lorentz Transformation (look at the last equation at the bottom of the above-linked page). (Find some background information on the Lorentz Transformation here . Just take a glance. There's more information here than what we will need.)

Checking Your Colab Program Output

5. At appropriate time intervals I will release information and figures.

a. Here is the data for the 5th event to check if the data reading was successful.

b. I will make the following figures available for viewing at appropriate time intervals.

Figure 1 Figure 2 Figure 3 Figure 4 Figure 5 Figure 6

I recommend that you not only check the shapes of the distributions but also the axis labeling for the histograms.

c. DiMuon Analysis Project Reflection

Additional Opportunities to Access and Analyze LHC Data

1. 100K Dimuon Events from CMS (On Github, ready to analyze.)

2. 100K DiElectron Events from CMS (On Github, ready to analyze.)

2. 2000 terabytes from the LHC