Teacher Handout: DiMuon Histogram Lesson

Objectives:

Students will:

* create histograms of invariant mass vs # of events using Excel and SCILAB (the same way the Higgs Boson was discovered by CMS and ATLAS experiments at LHC)
* calculate invariant mass using relativistic mechanics (included in the IB Physics option: Relativity)
* use real data from LHC collisions collected by the CMS facility (Covers IB ICT requirement)
* vector sum momentum and calculate a resultant vector

Materials: [Marbles, markers, paper, hidden object kits], projector, computers with EXCEL and SCILAB installed – see instructions. Dry Erase Board/Chalkboard

Background:

Ask students: How can we discover a new elementary particle?

Activity: Rolling marbles/Collision and particle tracks -- see attached resource from TEMI

(15-20 minutes)

Discussion of:

* Activity (5 minutes)

Further presentation (ppt – 10 minutes) of:

* Particle tracks to try to understand geometry.
* Angle of deflection to understand properties (Rutherford)
* Magnetic deflection (Muon other charged particles)
* Calorimeter absorption (EM, Hadron detectors)
* How is the Higgs Boson discovered?

Simulation:

(15-30 minutes)

Have students go to <http://opendata.cern.ch/> -> education -> visualize events. Have them do the attached visualization activity.

Lecture-pass out lab handout and have student fill in the pre-lab notes:

(10-15 min)

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| http://1.bp.blogspot.com/-0LH8t5hJ-rE/UpNA7S4l2OI/AAAAAAAAAPY/kw5EYUqs5OQ/s320/Screen+Shot+2013-11-25+at+8.20.32+PM.png | Derive the equation for mass from the triangle.  Note that if m = 0 then E = pc (photons)  Note that if p = 0 then E = mc2 (rest energy)  Mention units – all units are in GeV in data sets.  Review vector addition (the magnitude of a 3D vector will be computed from its components) |

Programming:

(1 hour)

Encourage students to work in pairs but to individually compute their histograms. Teacher walks around the room and helps students create histograms.

Discussion with students:

(15-20 minutes)

* How much data do we need to be sure there is a statistical peak? (ppt)
* Compare and Contrast EXCEL and SCILAB
* Where did the data come from? How did we get it? Cost?
* Why should we pay for fundamental research? (think www, imaging, medical applications)
* What questions are physicists trying to answer?