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:

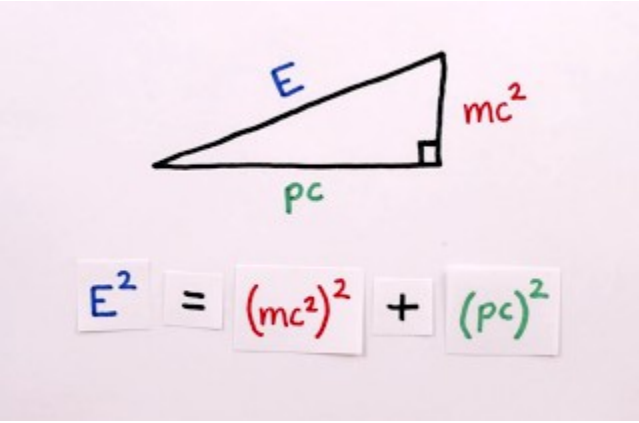
- Activity (5 minutes)

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)




Derive the equation for mass from the triangle.

Note that if m = 0 then E = pc (photons)
Note that if p = 0 then E = $mc^2$ (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?