

Getting Particle Physics into the High School Classroom



Perimeter Institute



Modern physics in secondary schools

- Special relativity
- Quantum physics
- Particle physics
- Astronomy
- cosmology

Fitting the Curriculum

- If possible, hands-on (experiments)
- Cheap, accessible materials
- Process of science
- Test with students --- and iterate.

Rutherford Scattering



Particle Zoo Cards

<p>p</p> <p>PROTON</p> <p>mass: 938 MeV spin-$\frac{1}{2}$ Q = +1 S = 0 discovered: 1919</p>	<p>Σ^{*-}</p> <p>SIGMA STAR MINUS</p> <p>mass: 1387 MeV spin-$\frac{3}{2}$ Q = -1 S = -1 discovered: 1960</p>	<p>π^0</p> <p>PION (PI ZERO)</p> <p>mass: 135 MeV spin-0 Q = 0 S = 0 discovered: 1949</p>
<p>Δ^-</p> <p>DELTA MINUS</p> <p>mass: 1232 MeV spin-$\frac{3}{2}$ Q = -1 S = 0 discovered: 1954</p>	<p>Ξ^0</p> <p>XI ZERO</p> <p>mass: 1315 MeV spin-$\frac{1}{2}$ Q = 0 S = -2 discovered: 1959</p>	<p>Ξ^{*-}</p> <p>XI STAR MINUS</p> <p>mass: 1535 MeV spin-$\frac{3}{2}$ Q = -1 S = -2 discovered: 1962</p>
<p>Σ^-</p> <p>SIGMA MINUS</p> <p>mass: 1197 MeV spin-$\frac{1}{2}$ Q = -1 S = -1 discovered: 1953</p>	<p>K^0</p> <p>KAON (K ZERO)</p> <p>mass: 498 MeV spin-0 Q = 0 S = +1 discovered: 1947</p>	<p>π^+</p> <p>PION (PI PLUS)</p> <p>mass: 140 MeV spin-0 Q = +1 S = 0 discovered: 1947</p>
<p>Ξ^{*0}</p> <p>XI STAR ZERO</p> <p>mass: 1532 MeV spin-$\frac{3}{2}$ Q = 0 S = -2 discovered: 1962</p>	<p>Σ^0</p> <p>SIGMA ZERO</p> <p>mass: 1193 MeV spin-$\frac{1}{2}$ Q = 0 S = -1 discovered: 1956</p>	<p>n</p> <p>NEUTRON</p> <p>mass: 940 MeV spin-$\frac{1}{2}$ Q = 0 S = 0 discovered: 1932</p>
<p>Σ^+</p> <p>SIGMA PLUS</p> <p>mass: 1189 MeV spin-$\frac{1}{2}$ Q = +1 S = -1 discovered: 1953</p>	<p>K^-</p> <p>KAON (K MINUS)</p> <p>mass: 494 MeV spin-0 Q = -1 S = -1 discovered: 1947</p>	<p>η</p> <p>ETA</p> <p>mass: 548 MeV spin-0 Q = 0 S = 0 discovered: 1961</p>

Bubble Chamber Physics

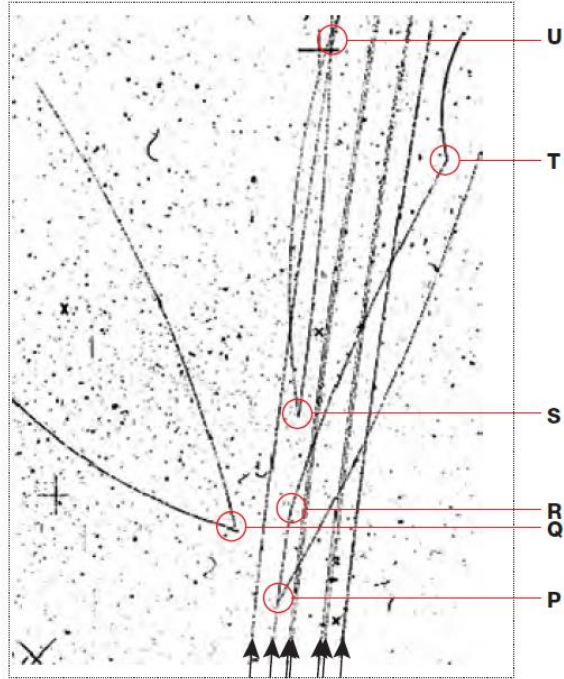


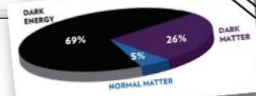
Figure 1 Photograph of CERN bubble chamber. Arrows indicate kaons moving up the page. There is a constant magnetic field into the page.

$$F_M = qvB$$

Particle physics virtual escape room

Dark Matter Information

All the matter we see around us makes up less than 5% of the matter-energy content of the universe. Another twenty-six percent of the matter-energy content is dark matter. We cannot see dark matter directly but we know it is there because we can see its gravitational effects. Most physicists think dark matter is a new particle we have yet to discover.

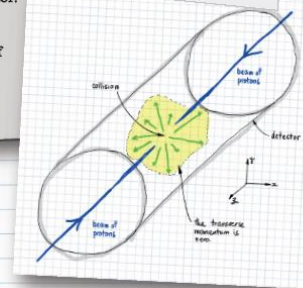


ATLAS Team Information

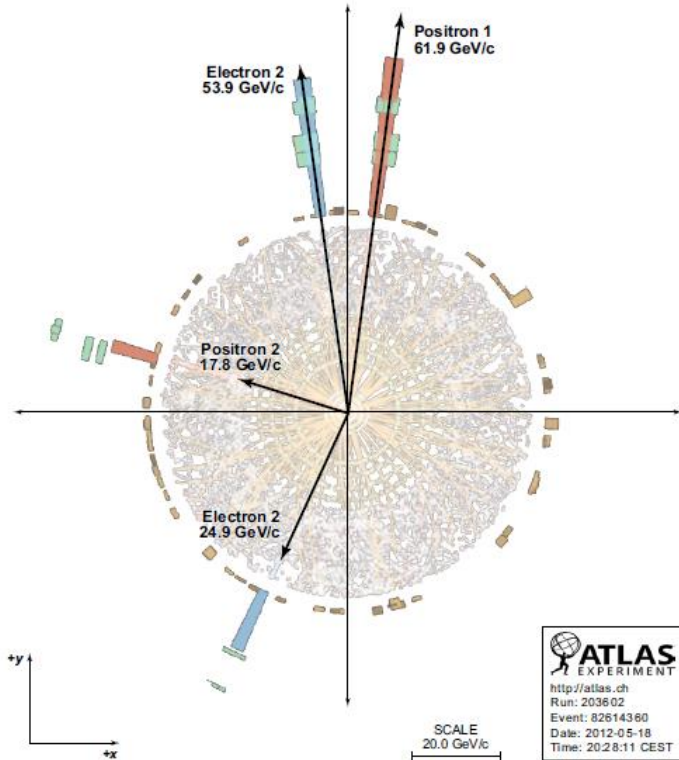
- Research team uses ATLAS to search for evidence of dark matter.
- So far, there is no sign that ATLAS has detected dark matter, but the search continues.
- Dark matter is dark and so any interaction with ordinary matter is very subtle. At ATLAS, they search for invisible particles in proton-proton collisions.
- The LHC was designed to achieve a maximum energy of 14 TeV.
- The protons zip along the LHC moving towards each other at equal speeds and collide. This means the sum of their transverse momenta will be zero.
- The energy of the collision can create new particles, some of which could be dark matter.
- Analyzing the momenta of all the visible particles produced in the collision allows us to determine if an invisible particle was created in the collision.
- An invisible particle could be a dark matter particle.

Momentum vectors shown are transverse - their sum should be zero.

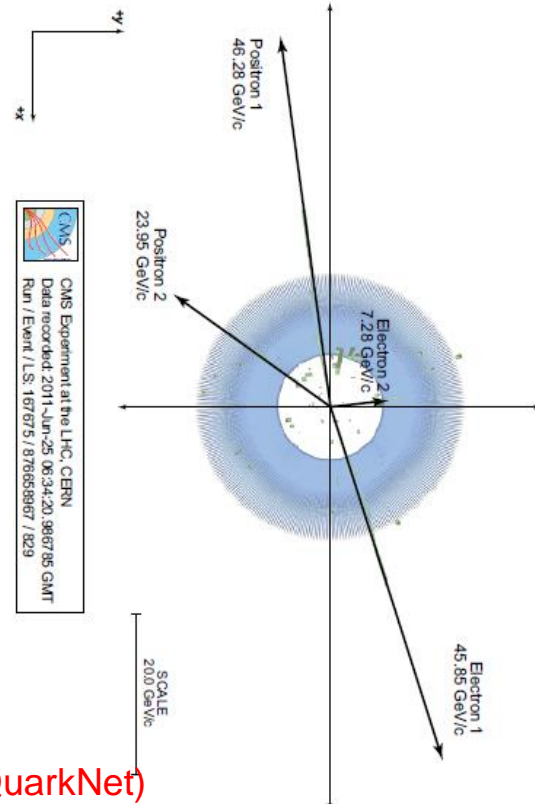
Momentum is conserved in a collision.



Mass of Higgs boson



ATLAS data for the possible decay of a Higgs boson into two electrons and two positrons. The rectangular shapes on the outside of the circle represent measured energy of each particle. Note the x- and y-axes.



Mass of Top Quark (QuarkNet)
CERN'S Masterclass (Z path)

- Conservation of momentum & energy

$$E^2 = (pc)^2 + (mc^2)^2$$

FREE Resources



<https://resources.perimeterinstitute.ca/>

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