HONORS 135 - Ideas in Honors - Week 3

Methods of Detection

Demo: Visit Tom Schwarz lab

Overview: How is a particle detected? Cerenkov, scintillator, scilicon, drift chamber, wire chamber. Photomultiplier tube. Give examples of each. Talk especially about dark mater xenon experiments and scilicon to relate to Tom's work.

Class plan:

- 10min. Review material from last week. Talk about standard model. Now how are these particles detected?
- 10min. Discussion to start thinking about detection:
  - What are the physical effects of particles?
  - Which of these effects can be used to detect particles?
  - The cloud chamber from last week: how useful is that?
  - What are the properties of particles that are useful to measure?
- 30min Slides to cover methods of detection.
  - Answer discussion questions. Properties are: charge, mass, decays to?, lifetime.
  - Cloud chamber - we saw this week. The "first" particle detector. A container with a supersaturated vapor. When a charged particle passes through, it ionizes atoms. These ions create nuclei for condensation - clouds - to form. Many tiny such clouds form along the path of the particle. This produces a visible path. Cloud chambers were used to discover the e^+, μ, K^0, Λ^0, Σ^-, π, and neutrino strongly indicated. A magnetic field in the chamber causes the tracks to curve , which yields the particle's momentum and charge. The appearance of the track can also be thin, sparse, etc - which helps with particle id. Decays can also be seen in sharp, sudden changes in the track. Cloud chambers were used at various altitudes to measure particle lifetimes in cosmic rays - using baloons and mountains.

- Cherenkov - light emitted when a charged particle travels through a medium at a speed faster than the speed of light in that medium (but slower than the speed of light in the vacuum, c). Physically, the moving charge polarizes the media - such as Aerogel, Lead glass, etc. When the polarized molecules revert back to their lower energy position, they oscillate and radiate photons - Cherenkov radiation. Cherenkov detectors use transparent dielectrics for the media. The transparancy allows the Cherenkov light to travel to photo detectors. The more dielectric the material, the more it polarizes. Light is then detected in a photomultiplier - a sensitive device that detects a single photon, and turns it into a large electric signal.
- Scintillator - similar to Cherenkov, Scintilation takes place when a particle traveling through a media - sometimes plastic or a liquid - excites electrons in the media. Excited electrons them emit scintillation radiation photons as they transition to their lowest energy state. These photons are then detected in a photomultiplier. Plastic scintillators can be built into an array to detect particles traveling through them (SeaQuest). A scintillating liquid like Xenon, argon, or water can be used in large quantities to search for neutrinos - electrons produced from an interaction may scintilate (Homesake). If dark mater decays to ionizing particles, they can be detected in large underground detectors (PandaX)
- Drift chamber - consists of a high voltage wire in a gas (often argon and methane). When a charged particle or photon passes through the gas, it leaves a trail of ions (similar to the cloud chamber). Instead of looking for the track, the electric field from the high voltage wire pulls the ions towards it. As the ions speed up, they ionize more gas atoms creating a cascade. The cascade neutralizes on the wire, causing an electrical signal that can be detected. Drift chambers (and wire chambers, resistive plates, thin gap chambers, etc) come in many shapes and sizes for various purposes. For example, ATLAS uses long aluminum tubes with a suspended wire inside to detect muons.
- Silicon - one of the newer and more precise tracking methods, silicon detectors take advantage of developments in silicon wafer etching, such as that used to make computer chips. They consist essentially of large silicon wafers, with tiny transistor (PN junction) based detectors on them. Ionizing radiation passing through creates a tiny current, which is then amplified and detected. Silicon detectors are

smaller, faster, more precise, and more sensitive to lower energies than gas detectors. Wafers are used close to the beamline in order to precisely track where a collision happened.

- 30min. Visit Schwarz lab, especially focus on detectors. Look at PMTs, CCD detector, MPandaX

Refferences:

- Daniela Bortoletto: https://indico.cern.ch/event/318372/material/slides/0.pdf
- Daniela Bortoletto: https://indico.cern.ch/event/318530/material/slides/0.pdf
- Daniela Bortoletto: https://indico.cern.ch/event/318429/material/slides/0.pdf