Activity Seven: Picturing Particles

Goal: To interpret some typical particle physics events.

This activity has students analyze and interpret a series of "event pictures" depicting the "tracks" of particle collisions produced by a detector. To introduce this activity, review with the class the physical characteristics of a particle detector, referring to the cross-section diagram of a detector in Activity Four.

Draw students' attention to the similar cross section of a detector here. Have them name the layers of the detector and describe their functions (referring to the Glossary if they need assistance). If any students studied detector components on their own, have them report their findings to the class now.

After discussing the layers and their functions, students will have a chance to evaluate particle events in a detector in the same way particle physicists do. Review the introductory material and the "rules of the game" as a class. Then have the students work independently or in pairs to analyze and interpret the four events pictured.

Answers:

1) Event 1:
   Particles are: an electron and a positron (i.e., antielectron) which emerge traveling back-to-back. Their paths are bent oppositely by the magnetic field.

   Event 2:
   Particles are: a muon and an antimuon.

   Event 3:
   Particles are: a muon and a positron, or an antimuon and an electron plus some unseen particles needed for momentum conservation.

   Event 4:
   Particles are: hadrons (more information is needed to identify them as specific hadrons).

2) Since the original particles were e^- and e^+, the total charge is zero. Thus, one of the final particles is positive and one is negative. You can tell which is which by using the curvature of the tracks.

3) Since the original particles had equal but opposite momenta, the total was zero. This means that there must be unseen particles (neutrinos) in this event that carried off some momentum, since the observed tracks cannot balance momenta.

Follow-up Activities

1. When students have completed this activity, open a class discussion regarding both

fundamental particles and the equipment that is used to record their behavior. Discuss why detectors are constructed in many layers and why each type of particle has a characteristic pattern of tracks.

2. Suggest that students evaluate what they have learned by taking another look at the first activity sheet for this program and again indicating their responses to each statement.

Additional Things to Do:

1. Illustrate how much empty space exists within an atom and a proton by constructing rough "models" on a football field, using a marble and three to six golf balls. The entire field represents an atom; a bright marble placed near the center of the field represents the nucleus, which on this scale would be a bit smaller than the marble. Have students look for it from the sidelines.

   Then have them imagine that a powerful microscope makes the nucleus expand until a single proton becomes as large as the football field; a vast space occupied only by three tiny objects -- the quarks -- represented by three golf balls randomly scattered on the field.

2. Encourage students to develop creative presentations about a specific table or illustration from the Standard Model of Fundamental Particles and Interactions chart. Possibilities include cartoons, stories told from a particle's point of view, dances representing particle characteristics and interactions and "daffy-nitions" that are humorous variations on the usual definitions. The Bibliography provided may be used as a starting point in their search for information.

3. Have students use a ripple tank to demonstrate that particles with long wavelengths (low energies) cannot detect small structures. Generate a straight wavefront and place an obstacle smaller than the wavelength in the water, then decrease the wavelength until it is about the same size as the obstacle. The resultant break in the waves illustrates that small structures are only visible to water waves of short wavelengths. In the same way, small particles are only visible with high-energy (extremely short wavelength) particle beams.

4. A simple cloud chamber -- one of the earliest types of particle detector -- can help you and your students experience particle tracks first hand! You can use a commercial chamber (such as a Wilson Cloud Chamber), or make your own. (Invert a wide-mouth glass jar so that the lid is on the bottom. Line the inside of the lid and the sides with black construction paper; leave a hole for a light source.) Fill the bottom of the chamber with 1/2 cm of methyl alcohol; place the chamber on dry ice.

   A commercial chamber will have its own radioactive source; if you build your own chamber, use a uranium rock or a radioactive smoke detector. Place the source in the chamber, and place a bright light about 10 cm from the chamber. Charged particles such as beta particles, protons and alpha particles will leave condensation trails as they ionize the air in the chamber; you may also see cosmic ray tracks.

Alpha particles will leave shorter tracks -- a few cm or less in length. The longer tracks are likely to be made by beta particles; these can be negative (electrons) or positive (positrons).