DRAFT MAKING TRACKS I: CLOUD CHAMBER DRAFT
TEACHER NOTES

DESCRIPTION
Students can "make" tracks in the sense of experiencing, analyzing, and understanding the tracks that particles make in cloud chambers and bubble chambers. These are old technologies, now mostly supplanted in experimental particle physics with complex detectors that can handle the much higher rates of events and data from modern accelerators. However, they are uniquely visual, giving students a view of tracks that particles directly produce in a medium, as opposed to the admittedly amazing digital reproductions of events produced by special software.

In Making Tracks I, students will first look at cloud chambers for the experience seeing particle tracks appear and disappear before their eyes. Then, in Making Tracks II, they will examine bubble chamber events to discover the behaviors of particles.

The bubble chamber portions of this activity are based on the teacher materials for the PBS Nova program *The Elegant Universe: Einstein's Dream*.

STANDARDS ADDRESSED
Next Generation Science Standards
- Science Practices
  - 1. Asking questions
  - 2. Developing and using models
  - 4. Analyzing and interpreting data
  - 6. Constructing explanations
  - 7. Engaging in argument from evidence
- Disciplinary Core Ideas – Physical Science
  - PS1.A: Structure and Properties of Matter
  - PS2.B: Types of Interactions
  - PS3.B: Conservation of Energy and Energy Transfer
- Crosscutting Concepts
  - 1. Patterns.
  - 2. Cause and effect: Mechanism and explanation.
  - 3. Scale, proportion, and quantity.

Common Core Literacy Standards
- Reading
  - 9-12.4 Determine the meaning of symbols, key terms . . .
  - 9-12.7 Translate quantitative or technical information . . .

Common Core Mathematics Standards
- MP2. Reason abstractly and quantitatively
- MP6. Attend to precision.

IB Physics Standard 7: The Structure of Matter
- Aim 4: particle physics involves the analysis and evaluation of very large amounts of data
  - Standard 7.3.4: Apply the Einstein mass-energy equivalence relationship

ENDURING UNDERSTANDING

Particles are real.

LEARNING OBJECTIVES

As a result of this activity students will be able to:

- Identify particle tracks in a cloud chamber.
- Predict the electric charge of a particle in a bubble chamber from its motion in a magnetic field.
- Apply conservation of charge to explain the shapes of tracks from particle decays.
- Use conservation of momentum to infer the existence of "hidden" particle tracks.

PRIOR KNOWLEDGE

None needed.

BACKGROUND MATERIAL

About Cloud Chambers:

- Wikipedia, https://bit.ly/3gVWof1
- Nuledo, https://bit.ly/308R2HC

RESOURCES

1. Prep material (optional):
   1.1. Seeing the Invisible, https://bit.ly/370Gn2P
2. Build a Cloud Chamber:
   2.1. CERN (with video), https://bit.ly/2z03yxI
   2.2. Symmetry, https://bit.ly/2Xvnx0D
   2.3. QuarkNet, https://bit.ly/3gUquje
   2.4. Inexpensive commercial kit, https://bit.ly/2z6W2RU
3. Cloud Chamber videos:
   3.1. Diffusion cloud chamber, https://bit.ly/2UbMxrI
   3.2. CERN cloud chamber, https://bit.ly/2MG5zCJ
   3.3. BNL/SB QuarkNet 2007, https://bit.ly/2zQ8HZT

IMPLEMENTATION

The purpose of this activity is for students to observe particles leaving tracks in a cloud chamber and perhaps even identify some. To understand what they are looking at, It helps but is not mandatory for students to examine the CERN page Seeing the Invisible (Resources 1.1). However, there is no substitute for the experience of building and operating a cloud chamber. Please check Resources 2.1-2.4 on building a cloud chamber and note that it takes some special materials like dry ice and isopropyl alcohol, time, and some trial-and-error. If you can do this with students, go for it.

The next phase is for students to work in small groups to observe a cloud chamber in action. Ask them to characterize the main types of tracks they see and take notes according to the format found

in the Student Guide. Students should look for four distinct types of track based on their own observation and categorization. (They may not get all four and they may not get what you expect.)

In the ensuing whole-class discussion, students can report what they have seen. By tabulating and comparing, you can guide them toward these main types:

- Long, thin, straight track (muon)
- Short, fat track (alpha particles coming from radon atoms)
- Curly or zig-zag tracks (electrons and positrons)
- V-shaped tracks (particle decays).

Students may not see all of these and they will see some that are unclear.

There may not be time or resources to build your own cloud chamber, or students may be engaged in remote learning. In that case, students should watch the video in Resource 2.1, in which Sarah Charley of US/LHC builds a cloud chamber and and explains how it works in just over 4 minutes. Each small student group then uses one of the cloud chamber videos (Resources 3.1-3.3) to make the observations described above. When they are done, have the same discussion described above.

ASSESSMENT

Assessment may be based upon:

- Observed student work on cloud chambers, if possible.
- Team Report Form or equivalent
- Participation in discussion.