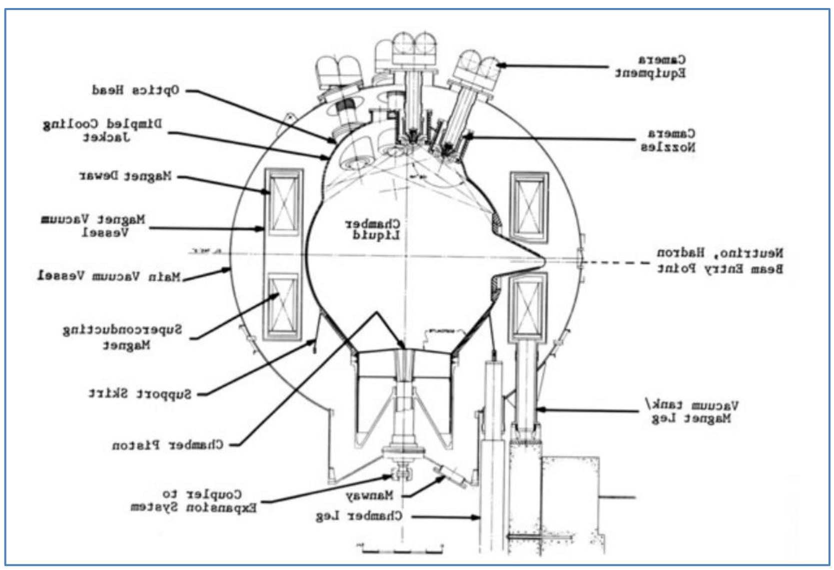
DRAFT MAKING TRACKS II: BUBBLE CHAMBER DRAFT
STUDENT GUIDE

To study interactions of elementary particles, physicists build accelerators which make beams of particles that interact with other particles. The other particles may be in an opposing beam: this type of accelerator is called a “collider”. Or the other particles may be set in a place where they are stationary and beam hits them. This is a “fixed-target experiment”. The target can be a solid material or a gas held inside a volume. Either way, the experimenters study the particle interactions that occur when energized particles strike particles. But how?

Physicists “see” atomic and subatomic particles with detectors, devices designed to interact with particles and produce some evidence of their existence and behavior. If you have not already, take a look at the CERN “Seeing the Invisible” site at https://bit.ly/370Gn2P.

Physicists use some rather sophisticated detectors to measure particles and their interactions. The ATLAS detector at CERN, for example, is a marvel of high technology, 46 m long and 25 m high, with superconducting magnets and multiple detector types in layers to capture almost any particle coming out of an interaction, all buried in a giant manmade cavern 100 m underground. It handles 1 billion events per second in 100 million electronic channels. If you want to learn more about it, go to http://atlas.cern/.

From the 1950s into the 1970s. data rates in particle physics were not nearly so high. Physicists were able to build detectors that were simpler, though quite sophisticated in their own way, and enabled them to actually examine photographs of real particle events. These were “bubble chambers”. Because of measurement of events with these was uniquely visual, we will study an image from one of these bubble chambers to learn how particles interact.



The image on the left, above, shows a bubble chamber used at Fermilab in the 1970s, now on display. The diagram to the right shows a diagram of the inside. In a nutshell, the bubble chamber contained a superheated liquid. When a charged particle would pass through, the liquid would take just enough energy to boil along the track of the particle, forming visible bubbles. Special cameras would take photographs of the events – lots of them, There were special technicians called “scanners” who were trained to spot interesting interactions in the photos. They would save these images for further study by physicists. We are going to do a bit of scanning and analyzing.

What is the research question?

- Is it possible to determine the properties of particles and characterize their interactions in a bubble chamber?

What tools do we need for our analysis?

You will need:

- An introduction to bubble chambers. We recommend one of these:
  - Bubble Chambers and Particle Detectors, https://bit.ly/304p3st
  - TBD.
- An image from a bubble chamber photograph. We have one for you, below.

What will we do?

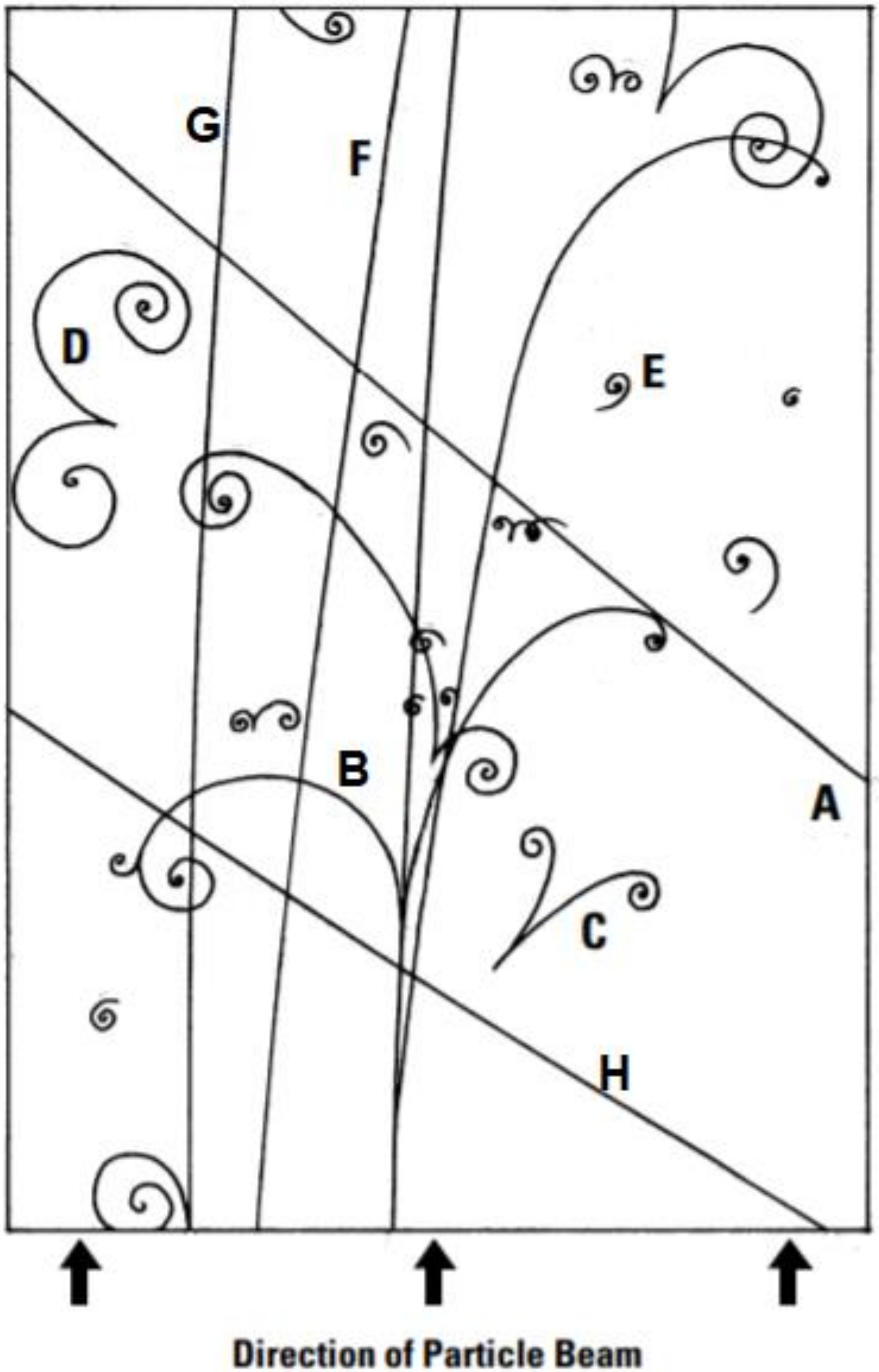
Work in teams as directed by your teacher. After your introduction, read "What do we know?" Keep it handy as a reference. Then examine the bubble chamber image on the next page and answer the questions which follow. Finally, discuss your answers in class.

What are our claims? What is our evidence?

What particle interactions do you observe? How can we tell based on the rules and on the behaviors of particles shown by their tracks?

What do we know?

1. The image is a replica of a photograph taken of a volume on the inside of a bubble chamber. It appears planar because the photograph is two-dimensional.
2. As shown, the region is exposed to a beam of particles. Assume the beam particles have positive electric charge.
3. There is a uniform magnetic field perpendicular to the plane of the image. The paths of charged particles are curved in a magnetic field. The radius of curvature depends on the magnetic field as well the momentum and charge of the particle. The direction of curvature also depends on the charge. How does each affect the path? How do we know?
4. Neutral (electrically uncharged) particles leave no tracks.
5. Charged particles can radiate photons, which have neither mass nor charge.
6. Particles lose energy as they interact with the medium in the bubble chamber.
7. In particle interactions, charge is conserved and momentum is conserved. Always.


G
F
D
E
B
A
C
H
Direction of Particle Beam

Questions

1. Can tracks F and G be from beam particles? Are they straight? Why or why not?
2. Tracks A and H look like F and G but are in a very different direction. Why? What might they be?
3. Look at track B. Why does it curve? Can you figure out its electric charge? (Hint: the beam particles are positive.) We will come back to B again later.
4. There are two tracks at C. Why do they curve in opposite directions? Why do their curves get smaller and smaller? These two tracks come from the decay (transformation) of one particle into two. What is the charge the parent particle? What can it be?
5. Explain D and E.
6. Let’s go back to B. How do you explain that “blossom” at the end?

Discussion

Discuss the questions above, your answers, and your own questions in class.