

## EXERCISE 2

### Questions:

1. In what direction is the beam going?
2. How many beam tracks are there?
3. How many collisions are there?
4. How many vees are there?
5. How many kinks are there?
6. What does the fact that you see a track indicate?
7. How can you tell if two tracks represent particles of the opposite charge?
8. What physical property of a particle is determined by the curvature of its track?
9. What causes a kink?
10. What causes a vee?
11. What are the small crosses?
12. What is the charge of the target particles?
13. What is the charge of the beam?
14. In which direction are the neutral particle(s) moving from the kinks?
15. What needs to happen for a track to kink twice?
16. How does the difference in mass between the initial state (before the kink) and the final state (after the kink) affect the angle of the kink?
17. What particles can cause a vee?
18. From which point do the particles that cause the vees come?

### Answers:

1. In this picture it is going from bottom to top, one way to see this is that there are more tracks near the top of the picture.
2. Seven beam tracks. (you might argue that the dark one on the right is composed of two tracks overlapping in this view)
3. One, on the 2<sup>nd</sup> track from the left.
4. Two.
5. Two, the 2<sup>nd</sup> track from the left kinks twice (after the collision).
6. That the particle is a charged particle. (A charged particle moving past hydrogen can atom to ionise it. The energy deposited causes a trail of bubbles to be formed and that is the track we see.)
7. They will curve in opposite directions.
8. A particle that has a higher momentum will have a less curved (more straight) track.
9. A decay of a charged particle to another charged particle (of the same charge) and one or more neutral particle(s) (which don't leave tracks).
10. A neutral particle decays into two oppositely charged particles.
11. They are 'fiducial marks' on the glass wall of the bubble chamber used as reference to measure position.
12. The charge is positive. Since it is hydrogen chamber the targets are protons.
13. Negatively charged. (The easy way is to find an electron spiral and use that to tell you which way a negative particle turns but in this picture we don't easily

see any spirals, so we must use conservation of charge in the collision. After the collision we have one positively charged and one negatively charged particle- a total of zero charge (neutral). We know this by looking at the tracks going out of the collision: one is curving left and the other one is curving right. (Actually it is hard to tell that the track is curving right but if you look at the track after the kink it is easy to see that it curves right). Since the target is hydrogen, in order to conserve charge the incoming beam must be negatively charged.)

14. The particles will move in such a way to conserve momentum. This means the neutral particle(s) must move in a direction opposite to that of the charged particle coming from the kink.
15. You need to have two decays one after the other.
16. If the mass change for the decay is small then there isn't much energy available to change direction, so the angle of the kink will be small. A larger change in mass will make available enough energy to increase the angle of the kink. This is a bit of a simplification, to really know the maximum angle you need to look at the change of mass and the initial momentum. Click [here](#) for more information.
17. Neutral particles that decay into two charged particles of opposite charge (conservation of charge).
18. Follow each vee backwards. The big vee looks as if it comes from the collision. The smaller vee crosses over itself so we can make a line from the two points the tracks cross and follow the line back to the 1<sup>st</sup> kink.

Now we are really ready to classify what particles we have.

Let us start with looking at the vee pointing to a kink. The neutral particle must be a  $\Lambda^0$  because the only vee pointing to a kink signature involves a  $\Lambda^0$ . We have a decay of a  $\Xi^-$  or a  $\Omega^-$ . The best bet is that it is an **omega minus** since the second kink has such a big angle that it could not come from the decay of a  $\pi^-$ .

Next we look at the vee pointing towards the collision. If you look at the vee it is fairly symmetric with a large opening and more likely to be a  $K^0$  decaying to two pions. Click [here](#).

The particles are now all identified, if we would look at the known momentum of the beam and do real measurement we would be able to calculate and see that no particles are missing.

For full details of this event, click [here](#).