University of Glasgow | Experimental Particle Physics

Glasgow Science Festival RealScience

1. The Elementary Cloud Chamber

Elementary
CERN and Scotland Collide

Building the best ever plastic tumbler cloud chamber

See beautiful paths made by charged particles with the naked eye with this simple and quick to make plastic tumbler cloud chamber. It needs a small amount of dry ice and pure isopropyl alcohol. Instructions for making the basic chamber are given below. This can be constructed in 10-15 minutes and is remarkably effective at imaging cosmic rays. Further instructions are then given for perfecting the viewing geometry. Although this refinement takes a little more time, one is rewarded with superb views of particle tracks. If you have any suggestions for further improvements, please contact us www.cernandscotland.tumblr.com

1. Apparatus

- a tall, transparent, pint-sized plastic tumbler
- a small foil pie tray with a larger diameter than that of the top of the tumbler
- a small bright torch
- an A4 sheet of black card
- black PVC insulating tape
- some black felt
- scissors
- glue
- pure isopropyl alcohol (99%)
- dry ice
- gloves and safety glasses
- polystyrene container to hold dry ice and to be the base the cloud chamber sits on

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2. Steps

1. Cut out a circle from the black felt. It should be the same diameter as the bottom of the plastic tumbler. Glue the felt circle into the inside bottom of the plastic tumbler. This felt will be soaked with alcohol later on when you operate the cloud chamber, so do not use alcohol-soluble tape or glue to attach it.

2. Re-shape the foil tray to fit onto the top of the tumbler, leaving a gap 2mm wide all the way round. Test the fit. Turn the tumbler over so that the felt is at the top and place the tumbler into the tray.

3. Use the black tape to cover the bottom of the foil tray. Using small pieces of tape to keep this flat and provide a smooth surface for the tumbler to sit flush and make a good seal. Cover the inside edges with black tape also.

4. The bottom 2cms of the chamber is where you will view the charged particle tracks. Therefore we will try to remove as many unhelpful reflections as possible with black tape. When you shine your torch into the chamber there will be distracting reflections off the inside plastic walls, therefore the black tape needs to be used on the inside walls. Cut strips of tape and place them around the rim of the *inside* of the tumbler, leaving two windows 180 degrees apart. The windows are for the torch beam to enter and exit and should be about 3 cm wide.

5. Build this dark zone up to around 4cm deep. Black tape all the way up to the top is not essential but it does help - just remember to leave about half the tumbler clear plastic for looking in.

6. Fold a strip of the tape over the lip of the tumbler all the way around its circumference. This is to make a seal with the tray and to prevent air leaks, so be sure the tape is down neatly and tight. Do the whole lip including the windows.

This is the "dry" configuration of the cloud chamber. You won't see anything yet, but now you are ready to go.

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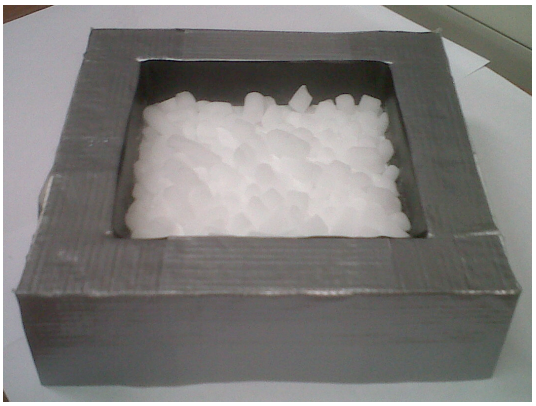
3. Operating the Chamber



1. Place half a cup of dry ice in the polystyrene container. Use gloves and safety goggles.

2. Soak the felt with the alcohol. Pour the alcohol in small amounts from the dispenser taking care not to spill it. Use enough to make the bottom wet. If you tilt the tumbler you should just begin to see liquid gather. Put the tumbler into the foil tray, press it firmly in and then place a drop or two of alcohol around the seal.

3. Put the chamber on top of the dry ice. Turn on the torch, turn out the lights and direct the torch downwards into the chamber. Watch what happens over the next few minutes.

4. You need to wait for the conditions inside the chamber to stabilise. At first, you will only see a mist of alcohol drops falling from the top. After about 5 minutes, you should start to see the tracks of particles, trails of droplets of various lengths. Some will be straight, some irregular. Some will be clear and bright, others dimmer. These tracks can be viewed fairly easily from a range of different geometries. However, with a little effort they can be made extremely clear to view. This is explored in section 7.

To the right is a photograph of a track taken on a mobile phone. Why not send us your photos and videos (to aidan.robson@glasgow.ac.uk)

4. Troubleshooting

You may find that the system works straight away without problems. If you do not see tracks here are a few common problems and some suggestions.

- If you can see the mist but no tracks wait another 5 minutes. The tracks get better over 5-10 minutes.
- Try viewing from lots of different directions, with the torch in a variety of positions.
- Try adding some more alcohol.
- Check that the chamber is sitting flat and undisturbed by draughts.
- Try not to disturb the chamber while viewing. If you knock it by accident wait for the chamber conditions to settle.

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5. How does it work?

The dry ice keeps the bottom cold while the top is at room temperature. The high temperature at the top means that the alcohol in the felt produces vapour, which falls downwards towards the very cold metal tray. The low temperature at the bottom means that as the vapour falls, it becomes supercooled.

In the zone 1-2cms above the cold tray the vapour becomes super-saturated. It will easily condense into liquid form, but there are no nucleation centres to start the droplets of condensation forming. An electrically charged particle travelling through this layer becomes visible because it starts the condensation. The charged particle ionizes the vapour in its path as it tears away the electrons in some of the gas atoms it passes by. This leaves these atoms positively charged. This ionized path starts the condensation process. The ionisation causes the nucleation which then allows droplets to form along the path of the particle through the super-saturated zone.

6. What can be seen

Background radiation Most of the droplet trails are caused by particles produced in the radioactive decay of naturally occurring elements, such as β-decays.

Relativistic muons It is also possible to see droplet trails caused by particles known as muons that are generated when high energy cosmic rays strike the top of the Earth's atmosphere. They tend to be mostly travelling downwards so only leave short tracks because the super-saturated zone is not very deep.

Very occasionally you may see a kinked track corresponding to a muon decay or a muon scattering event. Look for these different tracks:

- A track which goes straight, then "kinks" off to the left or right sharply. This is "muon decay".
- Three tracks which meet at a single point. In these events, one track is an incoming cosmic ray. This particle hits an atomic electron. The electron and the outgoing cosmic track are the two other tracks.

Things to try

- Use a mobile phone camera to record the events.
- Place a radioactive source in the chamber.
- Bend the particle tracks with a magnet.

7. Perfecting the viewing geometry with forward scattered light

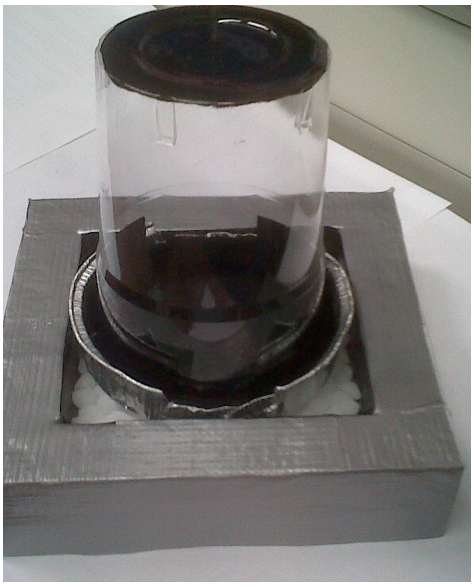
Tracks can be seen relatively easily with the setup so far, but the lighting and geometry are not ideal. The tracks are a little blurry and indistinct and there is a

lot of light reflected inside the chamber and onto the floor of the chamber. Much can be improved by darkening the chamber by removing reflections.

The best tracks are seen when you pass the torch light into the chamber very low down and direct the light out of the windows we left in the tape. If you collimate the torch beam with a simple card tube and then view forward scattered light, the tracks can be extremely clear.

1. Cut 2 windows into the rim of the foil tray to correspond to the windows on the tumbler. These are so we can shine light low and horizontal. Tape over all shiny edges that cause reflections. Be careful not to cut too low or this will cause turbulance.

2. By making a black card collimator tube to fit over your torch you can make a narrower beam and stop the torch light dispersing. By cutting a curve into the end of the tube to match the curving of the plastic tumbler, you can make the tube fit snugly against the tumbler and reduce stray light.



3. Position your torch to come through the entrance window as low down as possible. The beam should be horizontal and exit the chamber 180 degrees on the other side. If you use more black card to mask the light as it exits and you can view the tracks in a forward scattered light direction.

More improvements:

- Use a tall tumbler. The vertical height of the chamber affects the temperature gradient and therefore the thickness of the super-saturated layer.
- Let things settle undisturbed for longer.
- The edges of the tray should not be larger than necessary or they will warm the zone. Our tray is inserted into a home-made, insulating, polystyrene container, which both holds the layer of dry ice and provides insulation around the lower part of the chamber. Try to keep away from drafts.
- Keep the tray flat and horizontal.
- Try to eliminate all the reflections inside the chamber. By creating a black screen for the inside, reflections from the shiny plastic surface can be reduced. This can be done with more tape or black card.
- Use a small bright light source and try to produce an approximately parallel and horizontal beam.

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