CLOUD CHAMBER WORKSHOP

Do-it-yourself manual

Julia.Woithe@cern.ch

Build your own particle detector!

Particles coming from the universe are crossing the earth all the time – they are harmless but invisible to us. Cloud Chambers are detectors to make the tracks of the particles visible. Some decades ago – these detectors were used at CERN in the first experiments to detect particles. The following instruction will show you how to build your own Cloud Chamber at home.

History

The Cloud Chamber has been a very important research tool in the beginnings of particle physics. It won two Nobel prizes!

Charles T. R. Wilson (1869 - 1959)

This Scottish physicist actually wanted to study cloud formation and optical phenomena in moist air. He discovered soon, that by accident he had invented a particle detector. He perfected the first (expansion) cloud chamber in 1911 and received the Nobel Prize in 1927.

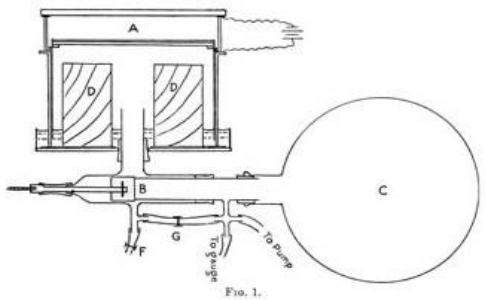


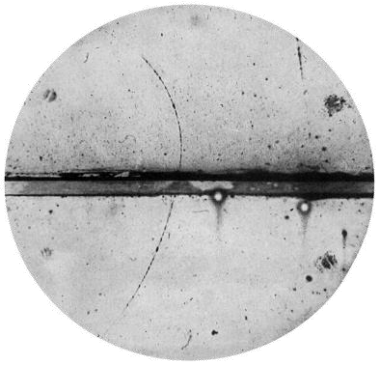
FIG. 1.

A diagram of Wilson's apparatus. The cylindrical cloud chamber ('A') is 16.5cm across by 3.4cm deep.

C. T. R. WILSON: On an Expansion Apparatus for Making Visible the Tracks of Ionising Particles in Gases and Some Results Obtained by Its Use. Proc. R. Soc. Lond. A. 1912 87 277-292 DOI:10.1098/rspa.1912.0081

Carl Anderson (1905 - 1991)

This physicist discovered the positron in 1932 and the muon in 1936 using a cloud chamber. He received the Nobel Prize in 1936. His invention: He used alcohol instead of water to form a more sensitive mist.



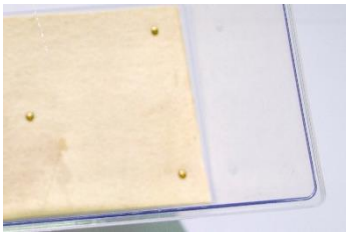
Carl D. Anderson (1905–1991) - Anderson, Carl D. (1933). "The Positive Electron". Physical Review 43 (6): 491–494. DOI:10.1103/PhysRev.43.491.

Shopping list

Plastic Container

- clear, see-through box-like plastic container
- with an open top
- roughly 20 x 30 x 15cm

S'Cool LAB: Aquarium 11 l
Alternatives: any plastic box, plastic cup, …



Felt

- a thick felt (few mm) to be attached to the bottom of the plastic box

S'Cool LAB: 5 mm thick white felt
Alternatives: sponge

Split Pins

- to attach the felt to the inside of the bottom of the box

Alternatives: cable ties, wire, …

Box

- a box that is just a little bit larger than the metal plate
- will contain the dry ice plates and the metal plate
- the sides should not be much higher than 5 cm, otherwise the will block the view

S'Cool LAB: Plastic box isolated inside with Styrofoam and foam rubber
Alternatives: Cardboard box, Styrofoam box, wooden boxes, …

Metal Plate

- to cover the open side of the container completely
- needs to be black and could have a little grooves matching the side walls of the plastic box (for isolation)

S'Cool LAB: anodised Aluminium plate (5 mm thick) with CNC milled groove
Alternatives: Baking tray, frying pan, book holder, metal plate and black electrical tape or black nail polish

Light Source

- a very intense, bundled light source

S'Cool LAB: LED Torch Light
Alternatives: overhead projector, LED strip, …

Protective Equipment

- to handle Isopropanol and Dry Ice it is necessary to wear personal protective equipment
  - Safety Goggles (dry ice and Isopropanol)
  - Nitril protection gloves (Isopropanol)
  - Leather Protection Gloves (dry ice)

Dry Ice

- Solid carbon dioxide at -78°C
- **Read the safety instructions!!!**
- touching it directly will cause burns
- evaporating dry ice will enrich the air with carbon dioxide → only

use in well ventilated rooms
- dry ice in airtight containers will build up high pressure

Where to buy:
- google “dry ice online shop”
- have a look at www.dryicedirectory.com

Other sources: Universities (chemistry institutes), fish processing, dry ice cleaning, …

Isopropanol / Isopropyl alcohol

- Pure (not 70%) isopropyl alcohol
- **Read the safety instructions!!!**
- Keep away from children
- never drink it, handle with gloves and goggles

Where to buy:
- drug store (e.g. as “Alcohol First Aid Antiseptic”)

Step by step instructions

1. Prepare the metal base plate

If you were not able to get a black metal plate, you have to wrap one side of a metal plate completely with the black electrical tape. This will make it much easier for you to see the “white particle tracks” later on in front of a black background. The bottom will be in contact with alcohol when you run the chamber, so do not use alcohol-soluble tape or glue to attach it. Alternatively you can use black nail polish or spray paint.
If you have already a black metal plate you can skip to point

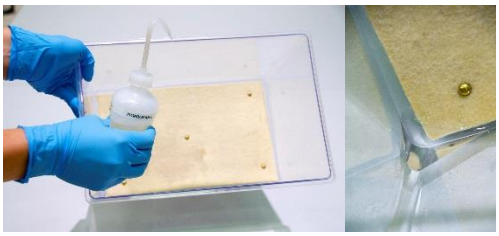
2. Prepare the alcohol dispensing felt

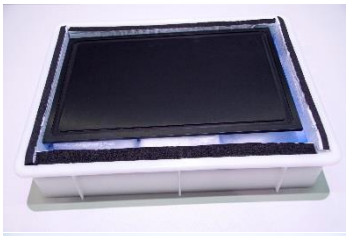
Drill small holes carefully in the bottom of your plastic container, e.g. aquarium. Attach the felt with the split pins to the bottom of the box. Later on this felt will be soaked with alcohol and will produce a rain-like mist of alcohol. Don’t use glue – the alcohol will solve it fast. One additional advantage of small holes: Through these holes air can come insight, so you won’t have this problem in the critical area at the interface between container and metal plate.

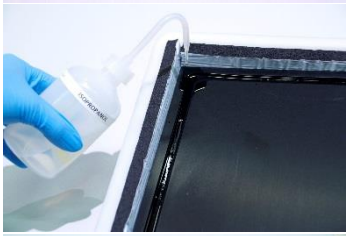
3. Assembly of the Cloud Chamber

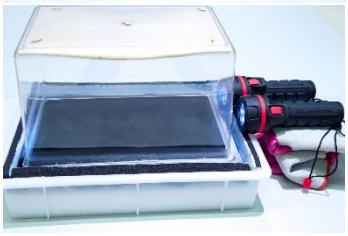
Put on leather gloves and safety goggles.
Put dry ice inside your box.

Next, you have to add the Isopropanol to the chamber. Make sure you wear plastic gloves and safety goggles. Again – never drink the alcohol and keep it away from children! It is very crucial that you use the right alcohol – the chamber will not work with another one!









You have to soak the felt with Isopropanol. This Isopropanol will later form the mist in which you see the tracks appearing. Tilt the chamber when you fill in the Isopropanol. You will see when the felt is completely soaked once there is a little “lake of Isopropanol” in one corner. Fill back this Isopropanol to the flask or use it late to fill the groove of the metal plate.

Place your black metal plate onto the dry ice. Make sure you have already soaked the felt inside the plastic container! If your plate becomes cold, the water inside the air will condensate on it and form a white “snow layer” after a few minutes. Since you need a black surface for contrast reasons, you would have to clean the plate. Use Isopropanol to fill the groove of your metal plate - if you have it. This will help sealing the box.

Place your plastic container upside down onto your metal plate. Fit the box so that the box walls fit the grooves in the metal plate. Now your chamber is ready to detect particles. It will only take a few minutes until everything has cooled down and a stable sensitive area has formed.

At first, you will only see a rain-like mist of alcohol. Place your torch lights in a way, that they illuminate the alcohol mist right above the metal plate – that is the sensitive area of the chamber.

Turn off the room lights and turn on your light. After a few minutes, you should start to see the tracks of particles passing through. The tracks look a little like spider's threads going along the chamber floor. You should be able to see a couple of tracks per minute. If needed, you can add extra alcohol through the holes in the top of the box without reopening the box.

How does the Cloud Chamber work?

As the top of the box is at room temperature, the Isopropanol evaporates from the felt (i.e. exists in gaseous form) and slowly sinks down in the direction of the bottom of the chamber, since Isopropanol vapour is heavier than air. Because there is so much alcohol, the air inside the chamber will be saturated with alcohol vapour.

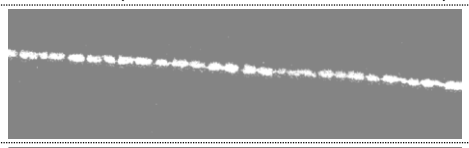
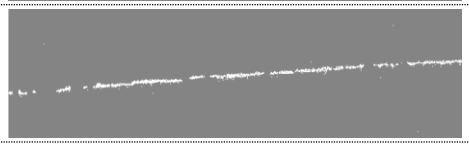
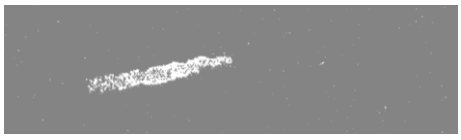
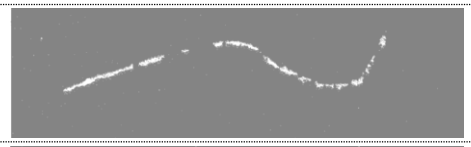
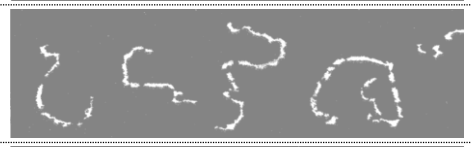
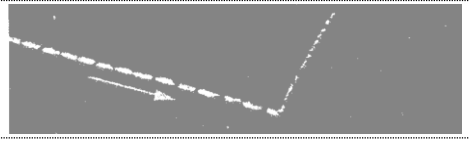
Since the dry ice keeps the bottom very cold, the alcohol cools down when falling. The result is a so called supersaturated environment. This means, the alcohol is in vapour form, but at a temperature at which

vapour normally can't exist. It is, as if you had made steam at 95°C. Since the vapour is at a temperature where it normally can't exist, it will very easily condense into liquid form if anything disturbs its equilibrium. Now what happens if a electrically charged particle crosses the chamber? The particle will *ionize* the vapour: it tears away the electrons in some of the gas molecules along its path. This leaves these molecules electrically positively charged. This is enough to start the condensation process: Small droplets of alcohol form along the path of the initial particle through the chamber. The ordered accumulation of these droplets are the tracks you see appearing.

What can you see?

You will see different kinds of tracks coming from different particles. You might notice that some tracks are very "bright" and thick, and others are very faint, some longer, some shorter. Besides straight lines of tracks from one particle you might see kinks, Y-shaped tracks, very curly tracks.
This ionization can be caused by cosmic particles or environmental radionuclide decay. The cloud chamber will sometimes enable differentiation between these two sources.

- Secondary cosmic rays present at ground level include muons and Photo-electrons.
- Natural radioisotopes present in the earth's crust produce another component of background radiation. Radon-222 is a chemically inert gas emanating from the soil and stone; it diffuses through the air and decays with the emission of an alpha particle.

Picture (from www.teilchenwelt.de)	**Particle**	**Explanation**
	**Muon or anti-muon**	Thin straight tracks - Fast particles with high kinetic energy - They ionise molecules without scattering - high energy muons, electrons or their corresponding anti-particles
	**Electron or positron**	
	**Alpha-particle**	Thick straight tracks: - massive particle with high "ionisation density" - mostly alpha-particles if at sea level - source: Radon-222, natural radiation
	**Electron** (e.g. from Beta-Emitter)	Curved tracks: - relatively slow particles scatter a lot via electromagnetic interaction - the lower the momentum of a particle, the more is scatters - Photoelectrons are low energy electron set free by high energy photons
	**Photo-Electron**	
	**Muon tranformation**	Kinks: - This could be a muon transforming into an electron and 2 neutrinos

Troubleshooting

Like in any real experiment, things might not work from the beginning and you may find yourself with difficulties. Here are a few common problems and their solutions:

"I don't see any tracks!".

Solution: Be sure the light is well placed. The sensitive part of the chamber is near the bottom where the alcohol is in its supersaturated state. Make sure the dry ice is neatly packed and in good contact with the metal plate. Try adding some alcohol so that the chamber is well saturated. Check that the chamber is airtight.

"I only see mist, and no tracks."
Solution: Wait. It takes about 5 minutes for the chamber to get to the right temperature. Make sure that you use the right alcohol – other alcohol have different "activation energies" that so that cosmic rays will not be able to start the condensation process.

"I see big clouds at the edges of the chamber."
Solution: This probably means you have an air leak. Be sure that the chamber is tightly sealed.

To learn more about it

If you want to learn more about cosmic particles and cloud chamber have a look at the following sites:

- A. Foland cloud chamber page (this is who **we** learned it from!)
  http://w4.lns.cornell.edu/~adf4/cloud.html
- Cambridgephysics
  www.outreach.phy.cam.ac.uk/camphy/cloudchamber/cloudchamber_index.htm
- Cloudchambers
  http://www.cloudchambers.com/
- Science Learning Network
  http://www.jsf.or.jp/sln/fog_e/indexpre.html
- Wikipedia
  http://en.wikipedia.org/wiki/Cloud_chamber
  http://en.wikipedia.org/wiki/Cosmic_ray

This is an updated version by Julia Woithe of the document:
CERN Cloud chamber workshop developed by: D. BERTOLA, M. CIRILLI, J. FLAMMER, G. SCHLAGER, S. SCHUH, P. SCHUNE 2004