26/03/2011
13/04/2011
19/04/2011

V3.0

Do It Yourself Guide Part I :
How to Build a Diffusion Cloud Chamber

See the DIY Guide Part II : Observations & discussions

Any comment or suggestions ? feel free to contact me at juliensimon.ujf@gmail.com

I. Introduction about this experiment

Why ?

To reveal an unvisible world to the naked eye. People can show that radioactivity is anywhere. We can realize how the nature is beautiful trough the complexity of the events we can observe with this experiment, made with very simple materials. These events come from natural radioactivity or from cosmic radiations emmited by stars in the farthest reaches of the visible universe. Cost price, now optimized by our previous research, should be à couple of hundred dollars.

What can we observe ?

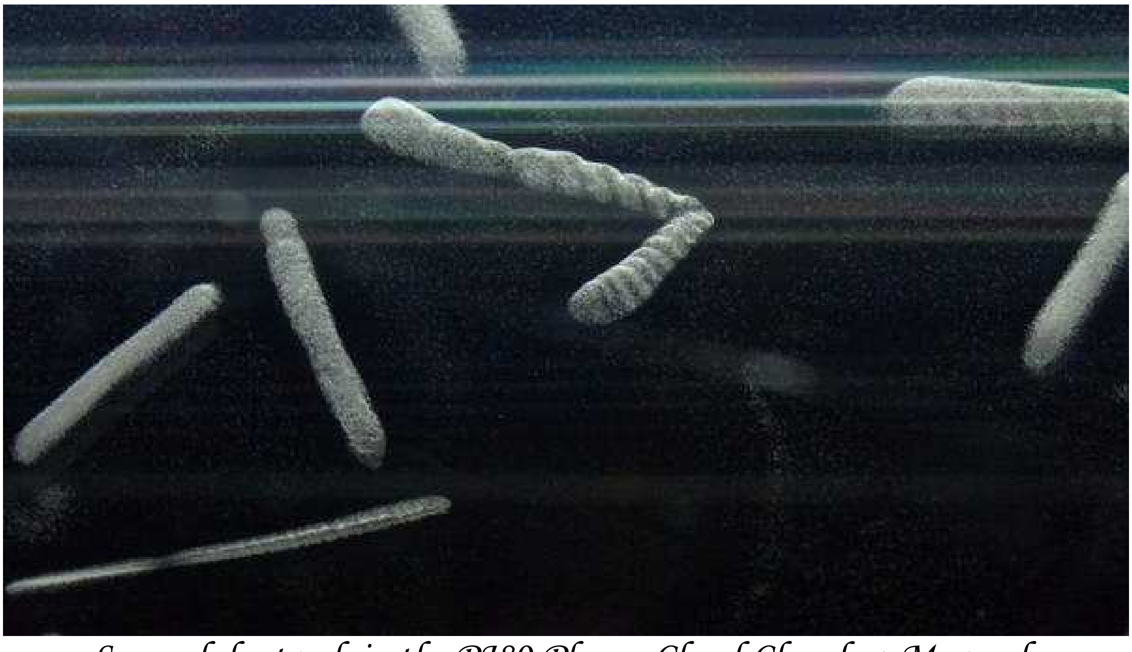
Any charged particle which interact in the layer of detection. It can be electron (e^-), proton (p), alpha (${}^4_2He^{2+}$), muons ($\mu^{+/-}$), and positons (e^+). Neutral particle (neutron, gamma, Xray) are detected by the production of secondary charged particles, when they interact with matter. See the DIY Guide part II for more information about nuclear events.

Alpha particles close up

Gamma annihilation into e^+,e^-

Where does this project come from ?

After having visited the Visiatom in Marcoule, France, I saw the Phywe PJ80 Cloud Chamber. I never thought that it could be possible to really see relativistic particles ! The quality was so amazing and the experiment so exciting that I started to think to build one. But the price (48k€) was the problem.



Some alpha track in the PJ80 Phywe Cloud Chamber, Marcoule

Many cloud chambers were built on Internet, and all required dry ice. I wanted a transportable setup without being limited with the dry ice supply. As I know well the behaviour of thermoelectric cooler, I started (17/03/2010) to make some test to determine the maximum negative temperature achievable. (The experiment needs at least -18°C to reveal particles). First tests were poor but it was possible to use peltiers (or Thermolectric Cooler (TEC)).

My first particle...

I meet Rich Olson after watching one of this video on Youtube, about a peltier air cooled cloud chamber. After 50+ emails, I finaly made a prototype working with air, thanks to his advices. He’s making fine cloud chamber for sale now. You can meet him at :

http://www.nothinglabs.com/electroniccloudchamber/

Rich Olson’s Cloud Chamber

One of the problems was to fix the electric field. In the beginning I used a Wimhurst machine for the high voltage. Other problem concerned thermal paste, to determine which was the best (the costly one didn’t performed as well as low cost one) to achieve the most negative temperature.


Early designs...

After one month I was close to the final setup :

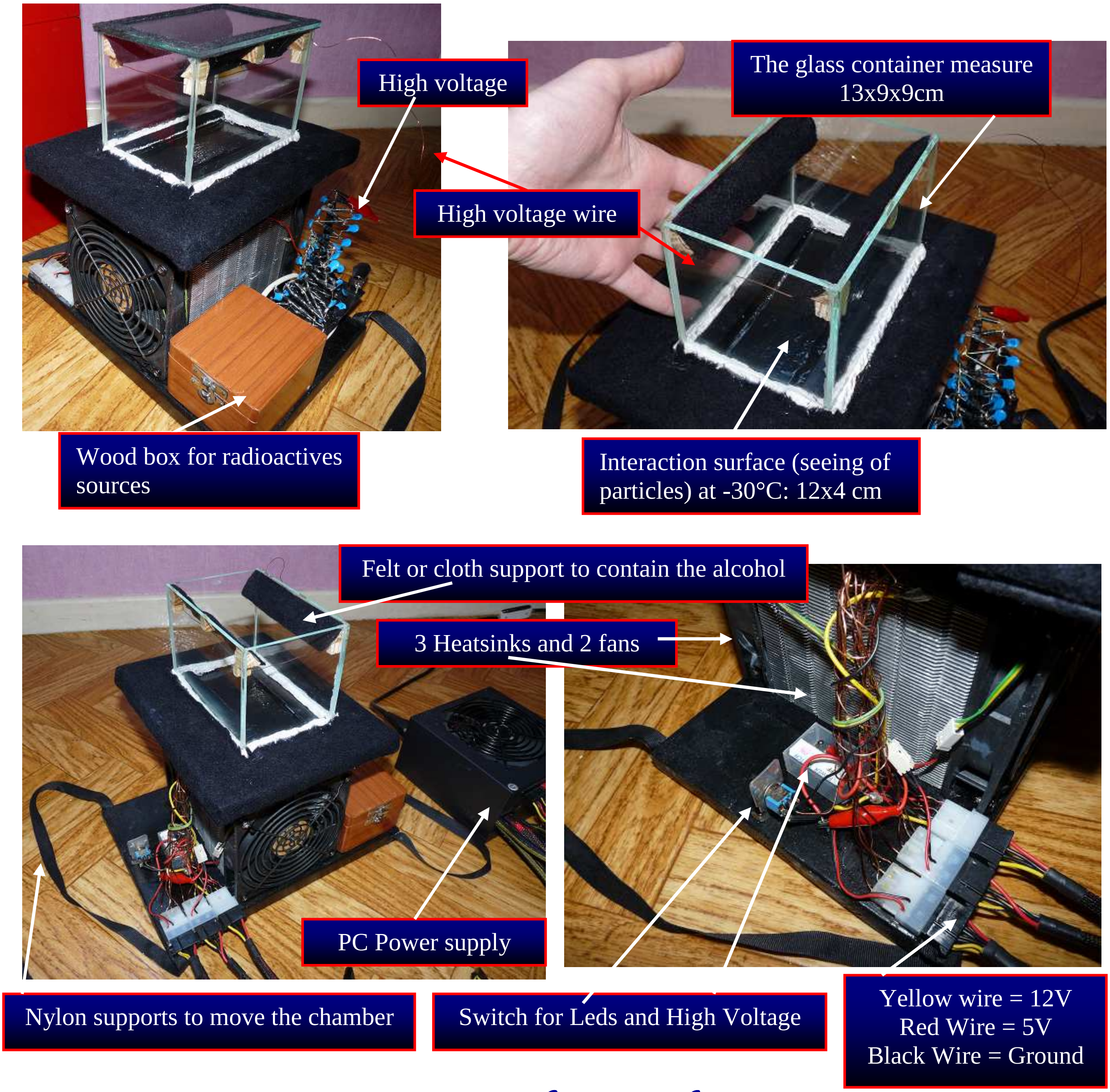
Cloud chamber V1 (2 peltiers)

Cloud chamber V2 (4 peltiers)

I observed most of my nuclear events with the V2 prototype.

Then I had time to build the V3 prototype (6 peltiers) presented here.

General Setup



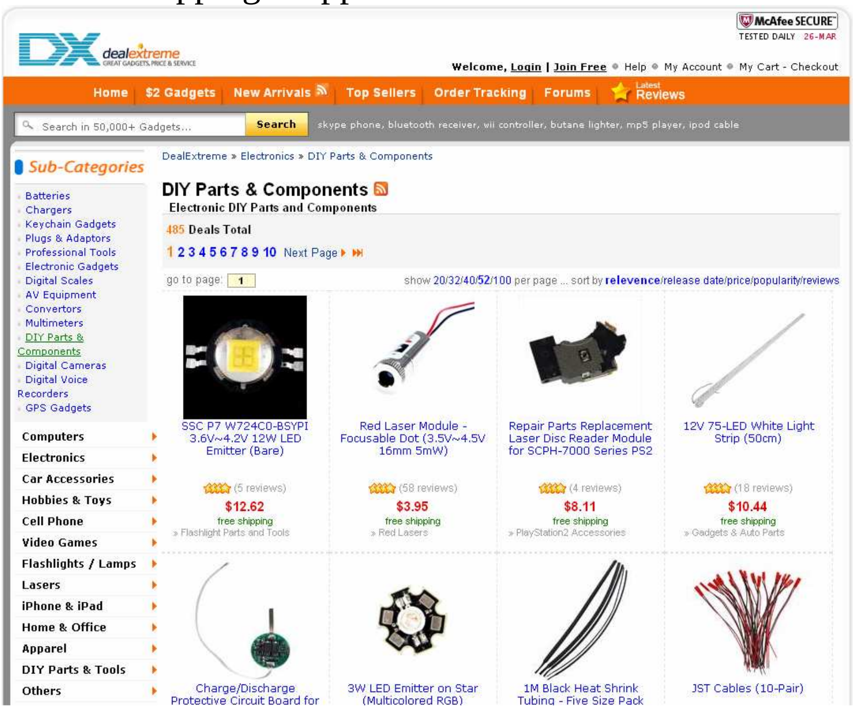
List of material

(This list may have miss some items ; look at each section to have the precise amount of material needed).
_A computer power supply
_Some glass to make the chamber, glue to make “aquarium”
_Lot of copper wire (big wire such as 1mm thick)
_Approximately 40, 3mm white led and switch, white Patafix
_3 heatsinks (for CPU’s computer) and 2 fans with moderate air flow + 2 fan grids
_Dozen of high voltage diodes and high voltage capacitors
_Electronic high voltage power supply
_Some piece of wood, plaster of Paris (slow cure), glue gun, and soldering tools

_3 female molex to connect the power supply to the setup
_Dealextreme thermal paste and tools, thermometers
_The most important thing : ultra black plastic bag
_Good quality peltiers
_One liter of acetone to clean the peltier and thermal grease, cyanocrylate glue
_Neodymium magnet, radioactive sources
_ Knowing the theory of peltier, and cloud chambers (DIY Part II)
_ Patience and time.

Overview about the materials

This DIY guide will explain you how to build a V3 Wilson Cloud Chamber. The cost of research was about 700$, but it will cost you only 100 or 200$.
Your best friend is http://www.dealextreme.com/.
This Chinese website (among other such as Focalprice) sells useful tools at very low price. The shipping is free and time of shipping is approx 2 weeks to France.

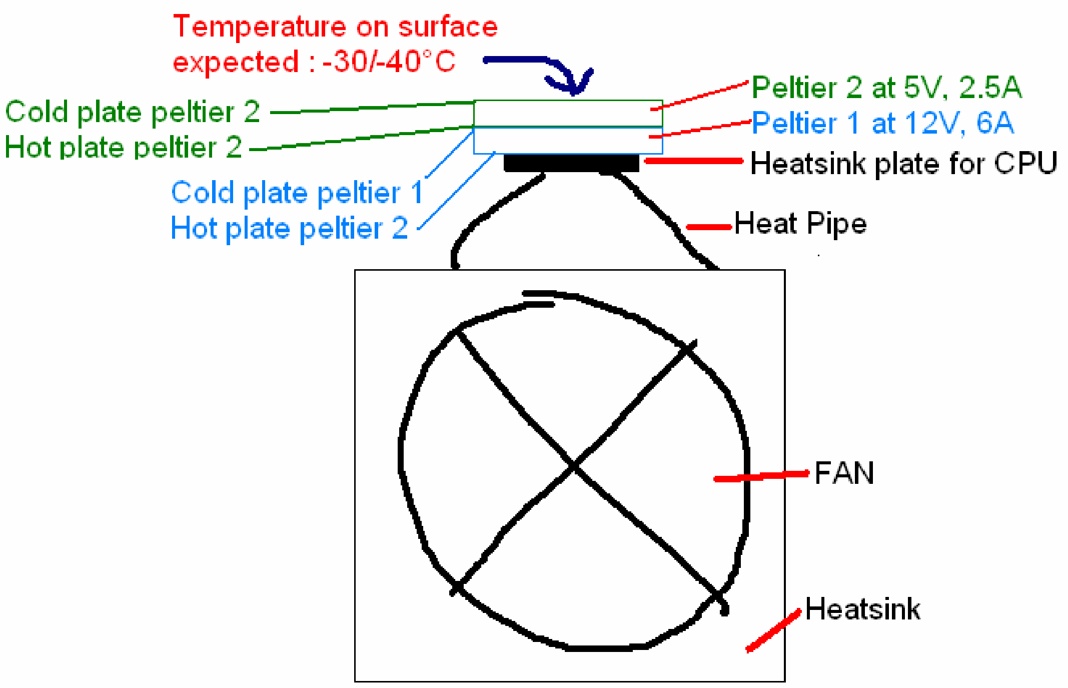


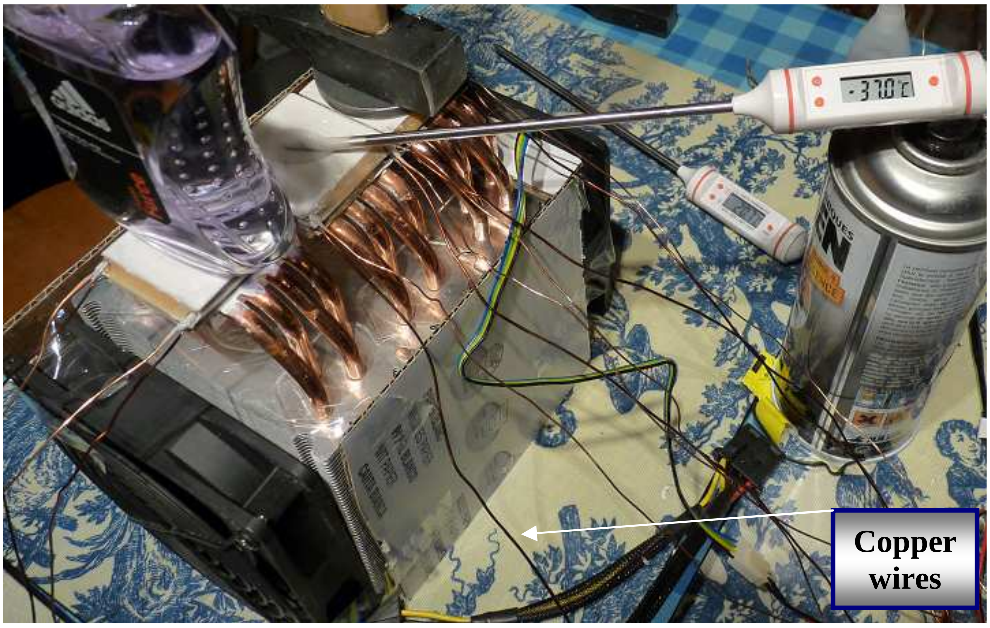
This guide can be upgraded with other ideas. You can make your own research to determine the best part needed for a working system.

You will suffer a lot with acetone. This solvent will eat your skin and you will regret it if you don't use gloves. I needed almost 2 weeks to recover my hands. It can also dissolve paint on tablecloth, make mark on wood...
But it's a wonderful solvent to clean everything, specially the thermal grease.

Before starting the construction, be sure to read this guide entirely in order to make a precise list about the quantity of material needed. You may also improve each section with your own ideas, only a prototype is presented here.

Principle of Operations





Two stacked peltier at different voltage can provide a very high negative temperature on the top surface. Such temperatures are possible because the heat generated by the top peltier, at a lower voltage, is completely evacuated by the cold surface of the first peltier. The heat of the first peltier is then evacuated by the heatsink, as if it was a CPU. If the heat of the first peltier is not evacuated, it will melt, because the quantity of heat is enormous, don't put your finger!

The #1 Objective is the **TEMPERATURE** that we could reach with the peltiers. It depends on the input voltage of peltiers, the power of dissipation of heatsink, the quality of peltier, the thermal grease, and the type of surface used (metal or plastic).

You need to reach at least -20°C on a final setup to detect particles. Lower temperature would give a better quality of track and the equilibrium will take less time to set up.

II. Critical material : Power Supply, TEC and Heatsinks

1. Power Supply

The power consumption of the 6 peltiers V3 cloud chamber is 255 Watts. The amount of current needed is about 26A.
You need a good power supply (PSU) for this experiment. Don’t buy a cheap one because you will regret it in the future. This experiment doesn’t take apart the power supply so you can reuse/sell it for a future computer. The amount of current is important and the wire will be hot if the power supply is a low-cost one (they often use aluminium wire instead of copper). You need also a very stable voltage for the peltiers (thermoelectric cooler). Cheap power supply have always important drop of voltage when there is a charge connected.

Mine is an Antec TruePower 750W, a bit overpowered but it’s for another project which will require much more than 30A of current.

You can find some test of power supply at :
http://www.jonnyguru.com/modules.php?name=NDReviews&op=Story&reid=140

Results from Antec True New 750W HOT load tests

Test #	+3.3V	+5V	+12V	DC Watts/ AC Watts	Eff.	Intake/ Exhaust
Simulated system load tests						
Test 1	2.5A	2.5A	10.5A	172W/ 204W	84.3%	28°C/ 28°C
	3.35V	5.13V	12.07V			
Test 2	5A	5A	21A	318W/ 372W	85.5%	32°C/ 35°C
	3.30V	5.08V	12.00V			
Test 3	7A	7A	31A	452W/ 527W	85.8%	37°C/ 41°C
	3.26V	5.04V	11.95V			
Test 4	9.5A	9.5A	41.5A	597W/ 706W	84.6%	41°C/ 52°C
	3.32V	5.05V	11.90V			
Test 5	12A	12A	52A	738W/ 894W	82.6%	49°C/ 59°C
	3.27V	4.99V	11.83V			
Test CL1	21A	20A	1A	204W/ 264W	77.3%	37°C/ 41°C
	3.27V	4.96V	12.03V			
Test CL2	1A	1A	62A	765W/ 916W	83.5%	45°C/ 58°C
	3.35V	5.10V	11.82V			

Antec True power tested

Results from Corsair CMPSU-950TX HOT load tests

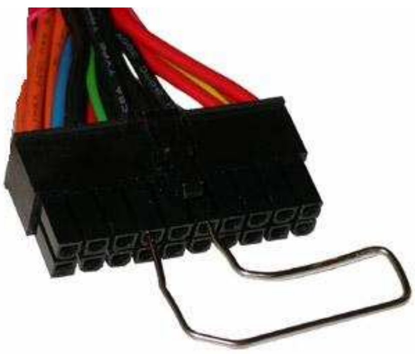
Test #	+3.3V	+5V	+12V	DC Watts/ AC Watts	Eff.	Intake/ Exhaust
Simulated system load tests						
Test 1	2A	2A	14A	192W/ 224W	85.7%	25°C/ 30°C
	3.32V	5.08V	12.13V			
Test 2	3A	3A	28A	372W/ 418W	89.0%	31°C/ 40°C
	3.29V	5.06V	12.12V			
Test 3	5A	5A	42A	556W/ 632W	88.0%	36°C/ 55°C
	3.27V	5.04V	12.07V			
Test 4	7A	7A	58A	767W/ 884W	86.8%	41°C/ 66°C
	3.26V	5.02V	12.04V			
Test 5	8A	8A	72A	947W/ 1119W	84.6%	45°C/ 76°C
	3.24V	5.01V	12.00V			
Test CL1	18A	18A	2A	179W/ 222W	80.6%	35°C/ 54°C
	3.26V	5.04V	12.13V			
Test CL2	1A	1A	78A	950W/ 1105W	86.0%	41°C/ 69°C
	3.26V	5.03V	12.00V			

Corsair 950W TX tested

There is many reliable PSU : Corsair, Seasonic, Coolermaster, Thermaltake...

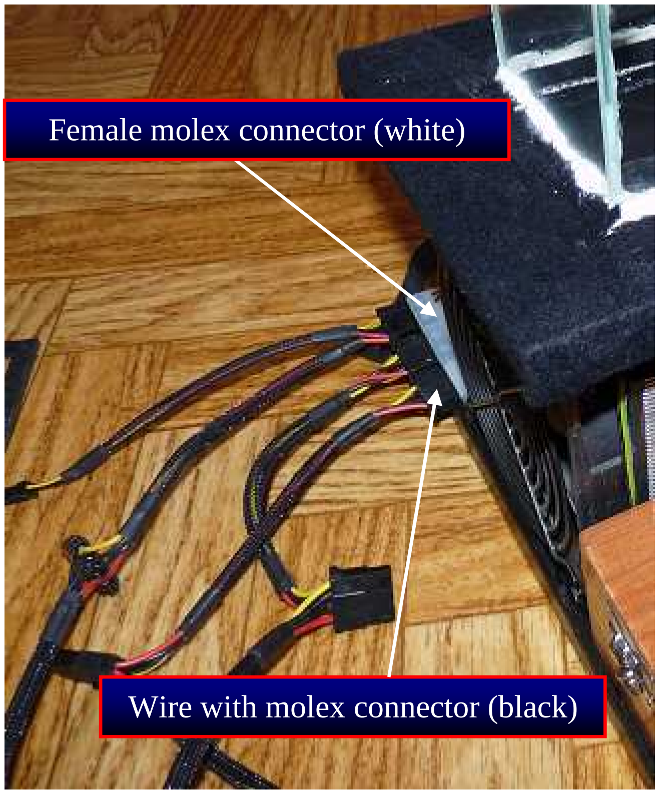
Tip 1 : You have to choose a good PSU where the voltage drop is low at 12V. For example in the last pictures, **Test 3** corresponds to the power requirement of the experiment (approx 20A at 12V, and 7.5A at 5V). You can see that there is a slight drop of voltage at 12V for Antec. We need the more voltage available, so I would choose the Corsair. But the price is also important !

This guide will focus using a PSU. 3 voltages are available: 12V, 5V, 3.3V. It is possible to reach higher temperature (gain of -10°C) with 14V or 17V output power supply (but they are hard to find because the amps needed are high so they are costly).



Tip 1.5 : How to run a PSU without a computer ?
Make a short circuit between the green wire and a ground wire (any black wire). On this connector you can also use the +3.3V : It is the orange wires. Red wire are 5V, yellow are 12V, other colors : Don’t touch =)
Approx cost of PSU : 90-130$

Tip 2 : Even if it's a good PSU, the amps are high for a molex (wire cable). The wires are warm when the setup is running several hours. Be sure that you don't concentrate the wires : air must pass freely between them to cool them. Check also the numbers of "rails" on the power supply. Don't take all the power of one rail if it's limited in current.



Upgrade 1 : The setup use 3 female molex connector to supply the 3 couples (3x2) peltiers.
One molex is feeding one couple. You can use more molex to feed one couple, so the input wire will be colder, but you will need more female connector and more input wire.

2. Material : Female molex connector and copper wires

http://www.dealextreme.com/p/1-to-3-pc-internal-power-supply-cable-splitter-5167

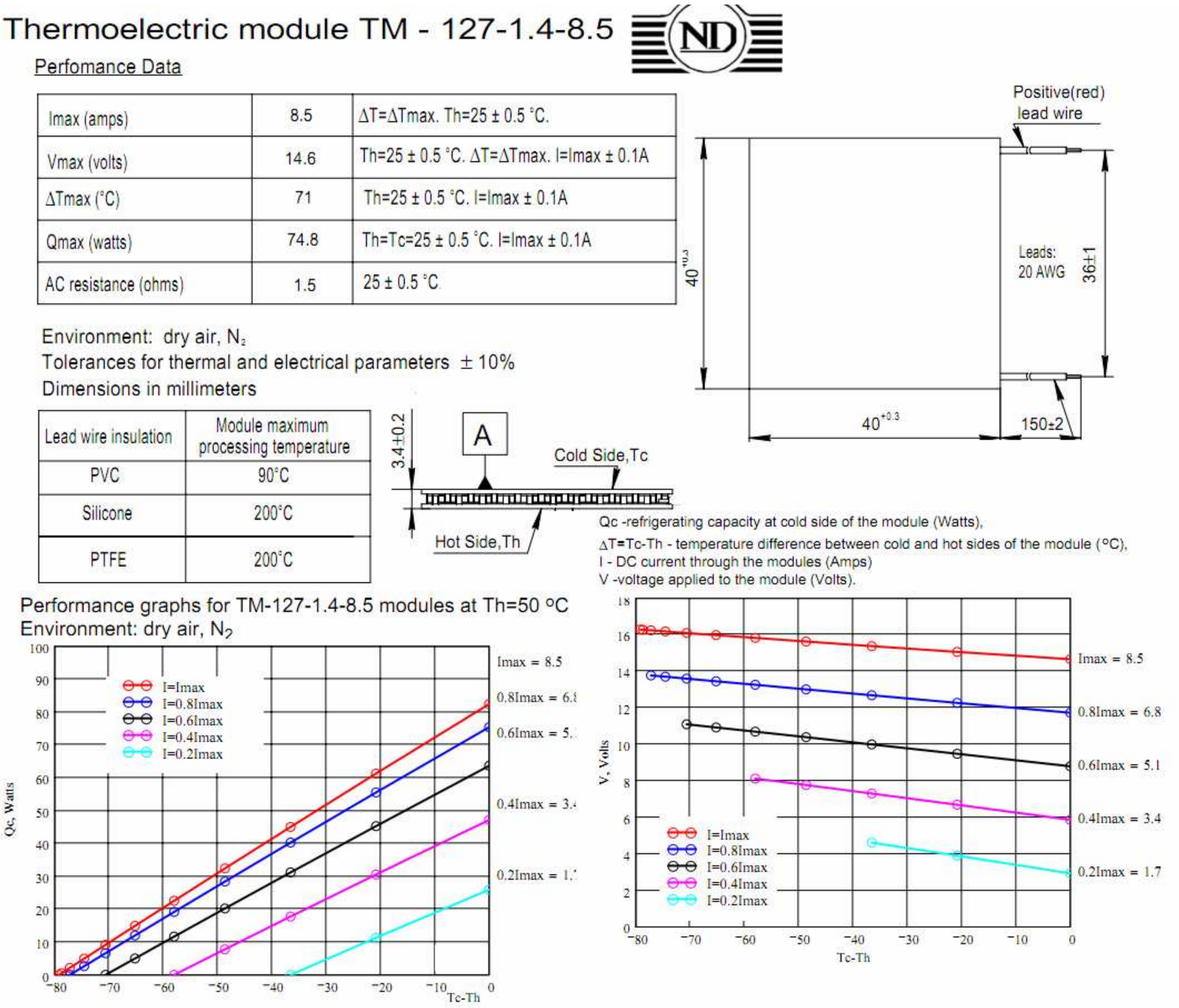
(or try ebay). Number needed : 3. But you will need at least 2 which have external 12V cables to connect the 2 fans (see picture 20 part 7 : Wiring)

Copper wires : We need to put the more voltage on 12V peltiers, so any drop of voltage from resistive wire should be avoided ! Use copper cable, the bigger is better. Mine are nearly 1 mm thick (they are slightly warm), but I didn't have bigger. Nearly 6A will go to each 12V peltier, and 3A in the 5V one (so you can use a smaller wire if you are low on copper). You can find copper wire in junkyards (old alternators), or on ebay...Quantity needed is approximately 20cm*12 ... 3 meters should be fine ! **Be sure to remove the resin (coating) on the copper wire before welding them ! (use a knife and rub the end of the wire)**

Upgrade 2 : Use bigger wire to feed the pelts. My drop of voltage is nearly 0.3V for the 5V, for a 20 cm length 1mm wire. Drop of voltage for the 5V peltier are welcome, but not for the 12V (in fact 5V is a bit high for the bottom TEC, 4V is the best).

3. Thermoelectric coolers

A very hard choice. Some will choose Chinese one easily found on ebay. There is a lack of research here. I obtained similar result on temperature with Chinese one, but the power consumption seemed to be higher. I'm using Nord Industrial Peltier from ebay :



Thermoelectric module TM - 127-1.4-8.5

Perfomance Data

Imax (amps)	8.5	ΔT=ΔTmax. Th=25 ± 0.5 °C.
Vmax (volts)	14.6	Th=25 ± 0.5 °C. ΔT=ΔTmax. I=Imax ± 0.1A
ΔTmax (°C)	71	Th=25 ± 0.5 °C. I=Imax ± 0.1A
Qmax (watts)	74.8	Th=Tc=25 ± 0.5 °C. I=Imax ± 0.1A
AC resistance (ohms)	1.5	25 ± 0.5 °C

Environment: dry air, N_2

Tolerances for thermal and electrical parameters ± 10%

Dimensions in millimeters

Lead wire insulation	Module maximum processing temperature
PVC	90°C
Silicone	200°C
PTFE	200°C

Qc -refrigerating capacity at cold side of the module (Watts),

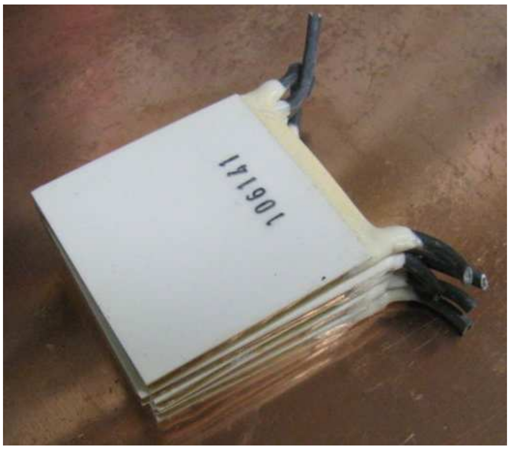
ΔT=Tc-Th - temperature difference between cold and hot sides of the module (°C),

I - DC current through the modules (Amps)

V -voltage applied to the module (Volts).

Performance graphs for TM-127-1.4-8.5 modules at Th=50 °C

Environment: dry air, N_2



I know that they perform very well, and are costless if you buy them in high quantity (I own 100 of them), you can think to future projects…

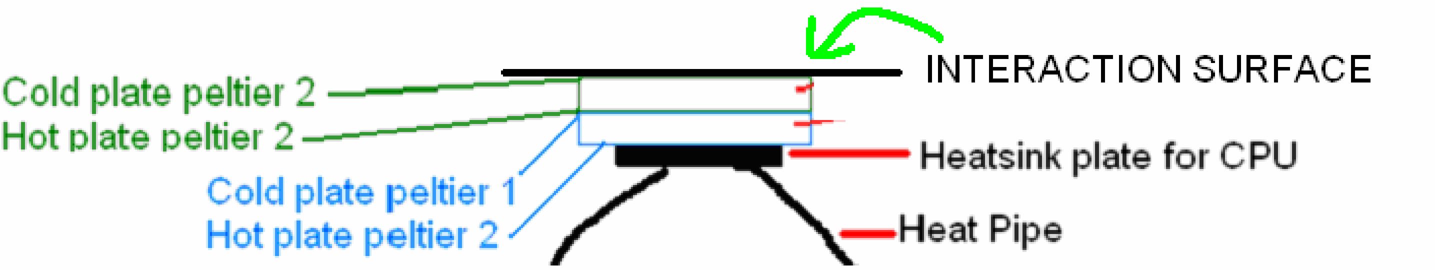
Rich Olson thought that it could be a difference using 2 different power rated peltiers. But I never tried this way.

Upgrade 3 : More research to determine what type of peltiers can provide the best temperature (Chinese, Nord Industrial, different rated power).

4. *Heatsink*

A critical material. First you have to determine if the power dissipation is good, according to computer review website. Just type the name of your heatsink on google + "review or test" and

you will find its performance with a CPU. But the choice is determined by another factor : the type of surface interaction.
Nearly 99% of cloud chambers on market use an aluminium plate placed on the top peltier. They can because they can cool it very well thanks to dry ice (-75°C). Peltier can cool only a very limited surface, mostly just their own.



We need to determine what would be the type of the interaction surface

On the picture in left, the 3 couples of peltiers are ready. But we need to put a layer of material on this surface to have an "alcohol proof" interface (otherwise alcohol will go in the peltier and will dissolve the thermal grease, or the cyanocrylate glue).

The surface must be as dark as possible to have the best contrast

We have several choices of materials :

RULE #1 : the thinier material on the peltiers, the better temperature you will get ! Choose a very thin material to have the best temperatures !

1. Aluminium foil + black paint

Advantages : extremely thin, and conduct heat.
But aluminium + propan-2-ol will react at low temp and will make holes in your aluminium foil. Mine smoked and burned during an experiment. It's possible to paint the aluminium surface with a black paint to have a good contrast, so the paint will protect the aluminium from the alcohol. But I never found a paint which can resist to alcohol, all paint or marker dissolve (just few can resist).

2. *Black Anodized Aluminium plate*

The way that use all the cloud chamber. Yes it work. The black ink inlaid in the aluminium resist to alcohol and the surface is really very dark. But there is limits using an aluminium plate with our setup based on a CPU heatsink.

Feedback of research about aluminium plate :

At the beginning of the V3 project, I was in the phase where I needed to put the aluminium plate on the peltiers :

In left : "Yeah ! I just need to put the aluminium plate and it's done !"

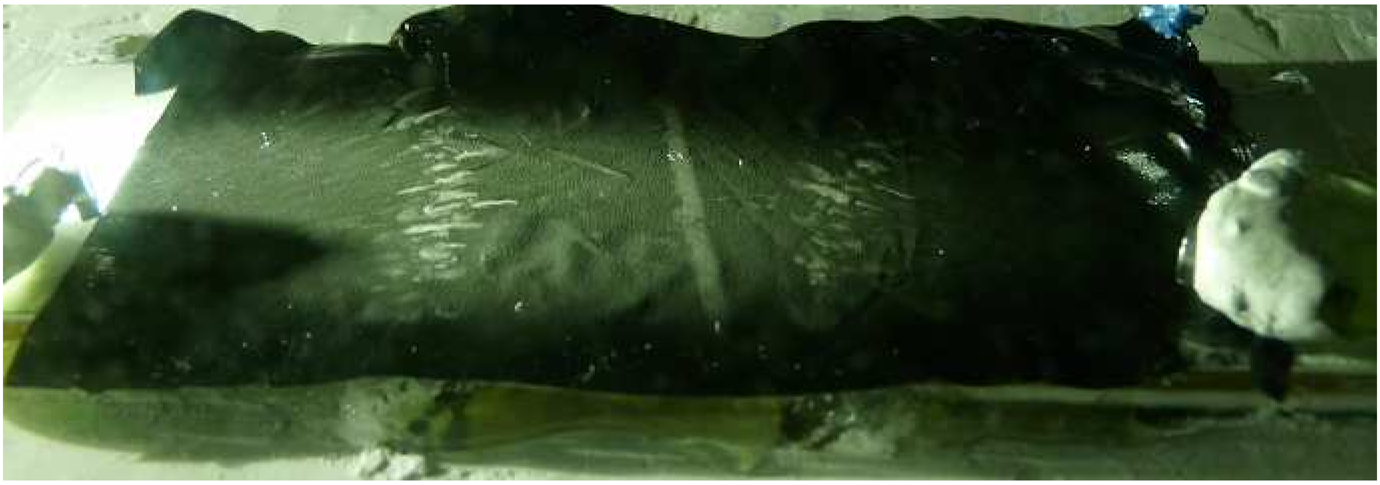
The advantage of using a metal as a surface is that it can conduct heat, so you can have a bigger surface even if your peltiers have a tiny cold surface. The larger the interaction surface, the more events you can see !
The surface of peltiers was 12*4cm (each peltier measure 4*4 cm). So I thought that I could put a 16*8 cm aluminium plate, with a thickness about 1 mm (I didn't find black anodized aluminium foil).

As my black aluminium anodized plate is anodized on the 2 faces, I spent fews hours to remove on one side the layer of anodization to have the best thermal conduction (21 to 63 W/m for anodized aluminium instead of 220 W/m for pure aluminium).

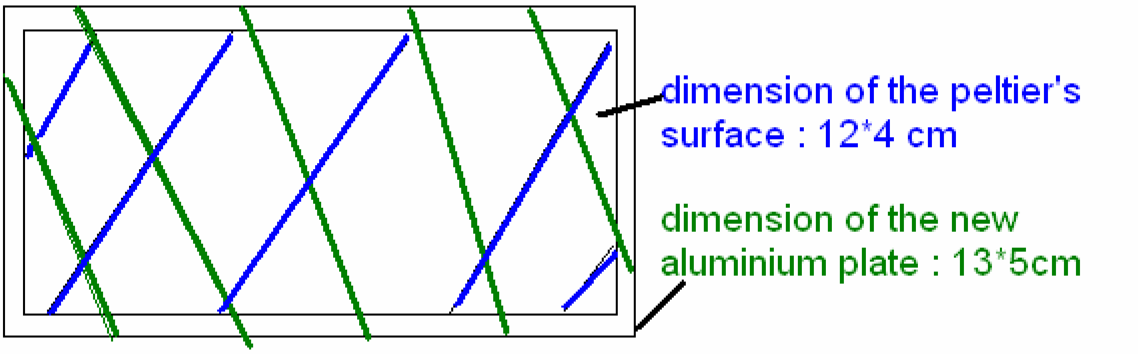
Then I placed this plate on the peltier, with some thermal grease.I thought that it worked because a short test in air made ice, I had -30°C in the middle of the plate, and -20°C in the corner. Perfect.

Then I sealed the bottom with my big glass container. I put some alcohol, high voltage, some Americium for radiations and... nothing ! None particles was detected, despite the temperatures obtained !

So I removed the aluminium plate. I put some plastic bag on the peltiers :



and it worked ! I removed the plastic, I put the aluminium plate again. Nothing. Duh !
Maybe the surface was too big to be cooled, as the condensation of alcohol requires more energy and that ice isolated the plate from surrounding air. So I cut the surface area of the aluminium plate in two : it worked.



But strangely, it appeared to me that the quality of particles track obtained with the aluminium plate was not as attractive as the one obtained with the plastic bag. In a lack of time, I went to the plastic bag as I know well the behaviour, and left my beloved black anodized plate. Maybe the temperature was lower with the plastic bag so the quality of track was improved ? Or perhaps that the electric field doesn't react in the same manner with the aluminium and plastic, which provided a better quality of viewing. The reactivity with the plastic was better too (time needed to view the first particles).

So my feedback is that you can use a black aluminium anodized plate 1mm thick, but the dimension of this plate mustn't exceed 0.5 cm on each side on each peltier. Maybe we can use up to 1 cm on each peltier, but I didn't tested this.

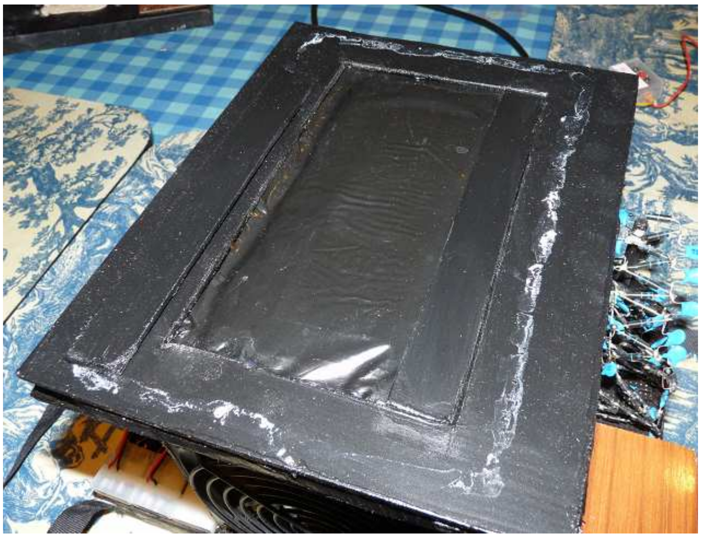
I was very disappointed because my system couldn't cool enough the big aluminium plate. With another dissipation system, it may be possible to use such a plate.

See the interesting design of Kamkelan on this Flickr page :
http://www.flickr.com/photos/kamkelan/4302112426/in/set-72157619300906497/

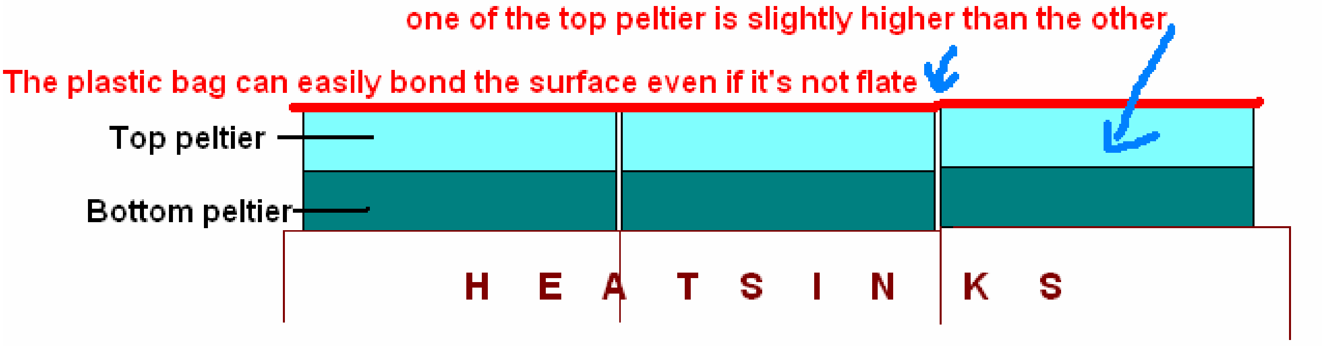
Note on Kamkelan design : Incredibly much more efficient than the one presented here. A real performance because the 4x4 cm peltier seems to cool a 9x9 cm surface.
However the quality of track needs to be confirmed. A few points :

_The massive heatsink that he used may not be as easy to find
_The massive fan can produce some loud (maybe a Delta fan 60 dbA?)
_Impossible to put a strong neodymium magnet to distinguish charge of particles
The design in this guide can offer the same area of sensibility than Kamkelan, using a 13*6 aluminium plate. But we will need 6 peltiers, where Kamkelan needed 3.

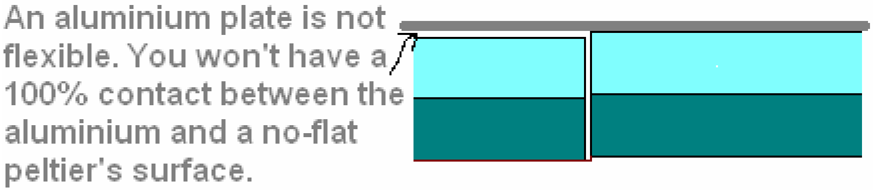
3. Black Plastic bag



A severe drawback of this type of surface is the non conduction of heat, so it's impossible to enlarge the interaction surface, which is limited to the peltiers's surface. Conventional plastic bin bag thickness is about 30 to 80 µm, nearly the same as an aluminium foil, so there is almost no loss of temperature. The temperature on the peltier will be the same on the plastic bag. It is also already black, alcohol proof, easily malleable and readily available. One of the big advantages of the plastic bag compared to an aluminium plate is that if your 3 top peltiers don't form a flat surface (if one is slightly higher than the others), you can easily bond the surface with the plastic (see pictures below).



If the surface is not flat, the plastic bag is perfect.



The peltier's surface must be perfectly flat if you want to fix an aluminium plate on it.

4. Copper foil

A very promising material is the copper foil. Nearly as thick as or less than the aluminium foil, the temperature loss is almost 0. Alcohol doesn't attack him and his high thermal conductivity may give enlarged surface.
Unfortunately I tested this material in the V1 version and results were bad because the copper foil was not isolated and the surface was too big. I didn't test this material with the V3 version because I didn't have some left. I guess we could find some secrets with this matter.
We can paint the surface with the Edding 8400 marker to have a black area. This guide will be upgraded when I will test this matter more closely.

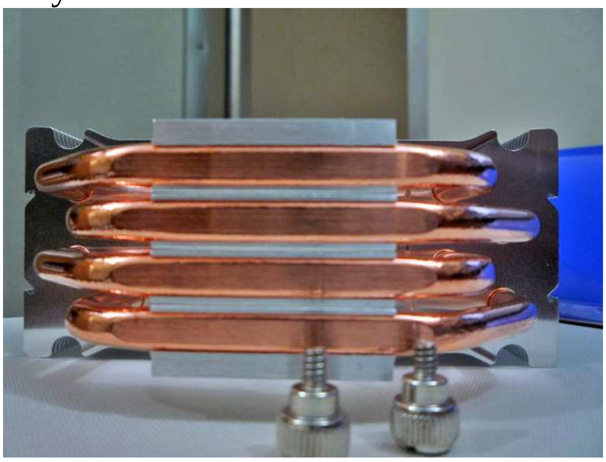
5. Edding 8400 marker

This CD/DVD marker can resist to alcohol if we don't rub the surface with the alcohol. It "won't dissolve" easily, the layer of paint is fragile and seems stable because it has a water based solvent. It's the one I found among many others to resist to the alcohol. Be patient painting the surface. High contrast can be obtained, which is perfect to see cosmic event that are hard to see.

<u>So in conclusion :</u>

_More research has to be carried about the heatsink. The one presented in this guide may be moderately efficient, because the heatpipes are turned upside down. But it work.
_Black anodized aluminium is usable in a limited area.
_Plastic bag, which is not really a "technologic" stuff, can make a very good performance
_Copper foil is not anodizable, but may be very interesting later.

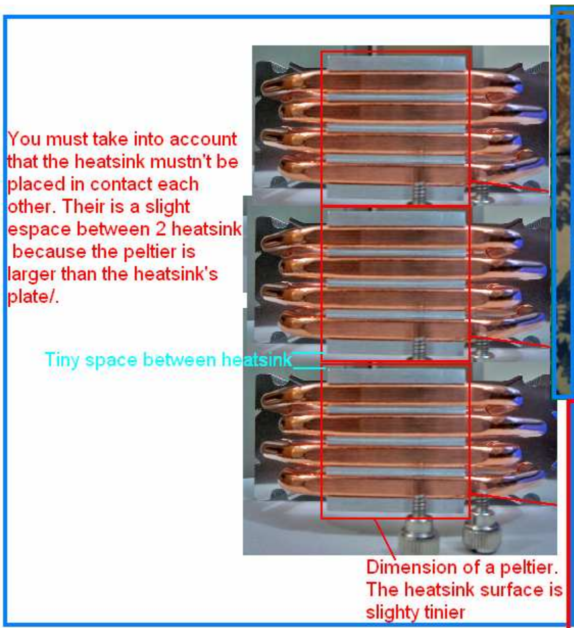
Let's go back to the choice of heatsink. The one used in this guide is the Coolermaster Hyper 212+, priced at 30$. There is other possibility of heatsink.

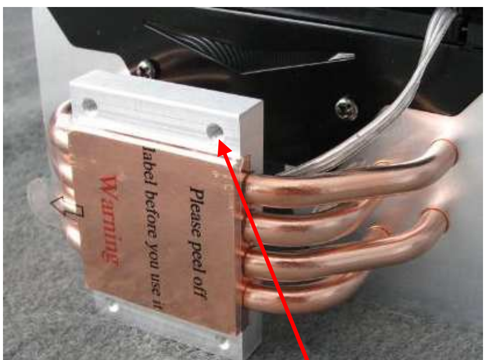
Depending about the type of interaction surface chosen, there is several configurations :

5. Plastic bag based design

With the Hyper212+ the dimension of the heatsink plate is slightly less than the peltier's surface. You must take this into account (see pictures below) :

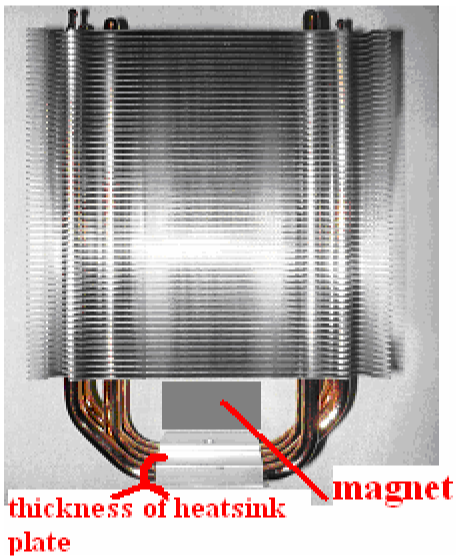


Good configuration of spacing, continuous surface of peltiers

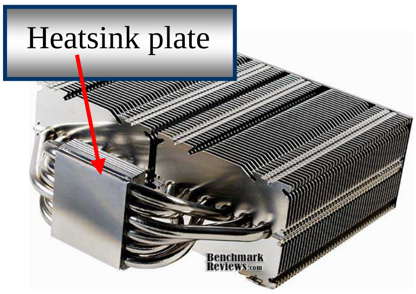


Spacer. If we put 2 heatsink in contact, there will be a space between the peltier surface.

The majority of heatsinks have a spacer under the heatsink plate, so they are not a good choice because it will be a space between the peltier : it will be some area of plastic which are not cold, particles track could be discontinued.



An important point in the choice of the heatsink is also the thickness of the heatsink plate. A 2cm height magnet must pass under the heatsink plate. Check the part 3 : Wood & Plaster.

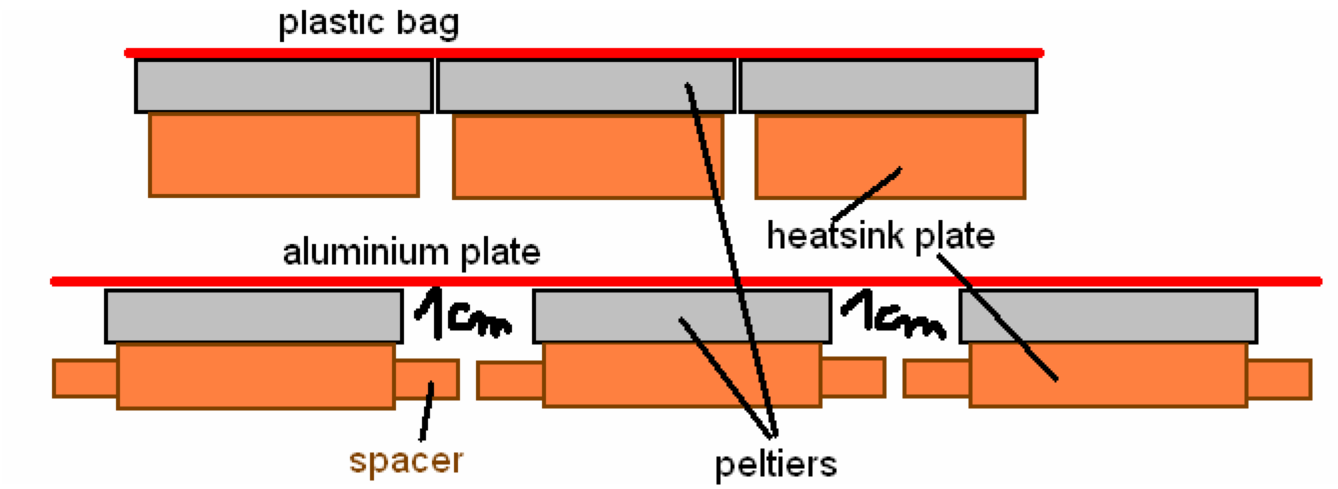


An interesting heatsink : the ProlimaTech Armageddon, much more heatpipes than the 212+, but 3x costly and maybe unable to contain a magnet under the heatsink plate.

Upgrade 3 : If you are rich, you can invest in high tech heatsink such as the one above, but check if there is enough room to put a big magnet under the heatsink plate. The thickness of the heatsink plate must be low, otherwise the magnet will be farther from the interaction surface and the magnetic field will be low (strenght of magnetic field varie with $1/R^3$). During the V1 and V2 version I was poor so I stayed with the same low cost heatsink, and did the same with the V3, because I already have two Hyper 212+.

6. Anodized aluminium based design

As I know that we could use an aluminium plate bigger up to 0.5 cm on each side of peltier, heatsinks who have a spacer could be used. Space between peltier is 1cm. A picture can illustrate the 2 configurations. Of course I tested just 0.5 cm of aluminium. It may also work with 1 cm on each side. Space between peltier could be 2 cm.



The rest of this guide will present the configuration “plastic bag”.

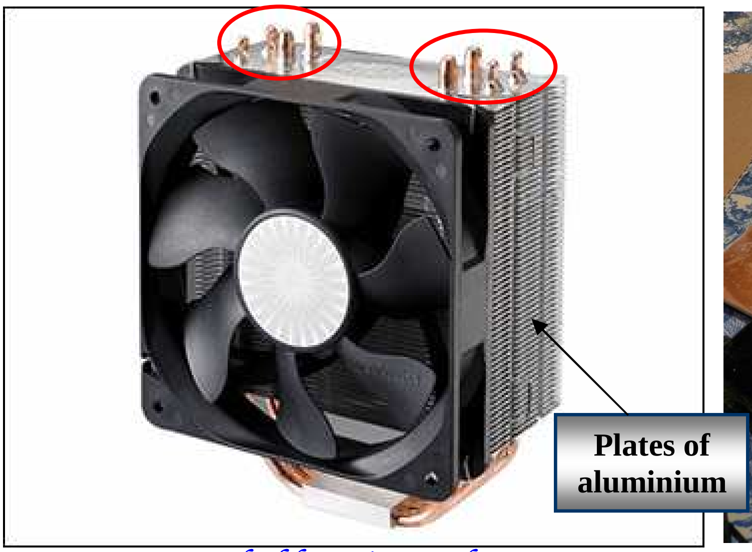
****

Before starting the construction with the *Part 1 Basic Structure* (below), go directly to the *Part 2 : testing the peltiers.* The heatsinks and peltiers that you have chosen must produce a negative temperature in a specific range.

III. Starting the Construction

Part 1 : Basic structure

If you look at the end of the heat pipes, you will find some spikes :



End of heatpipe on the 212+

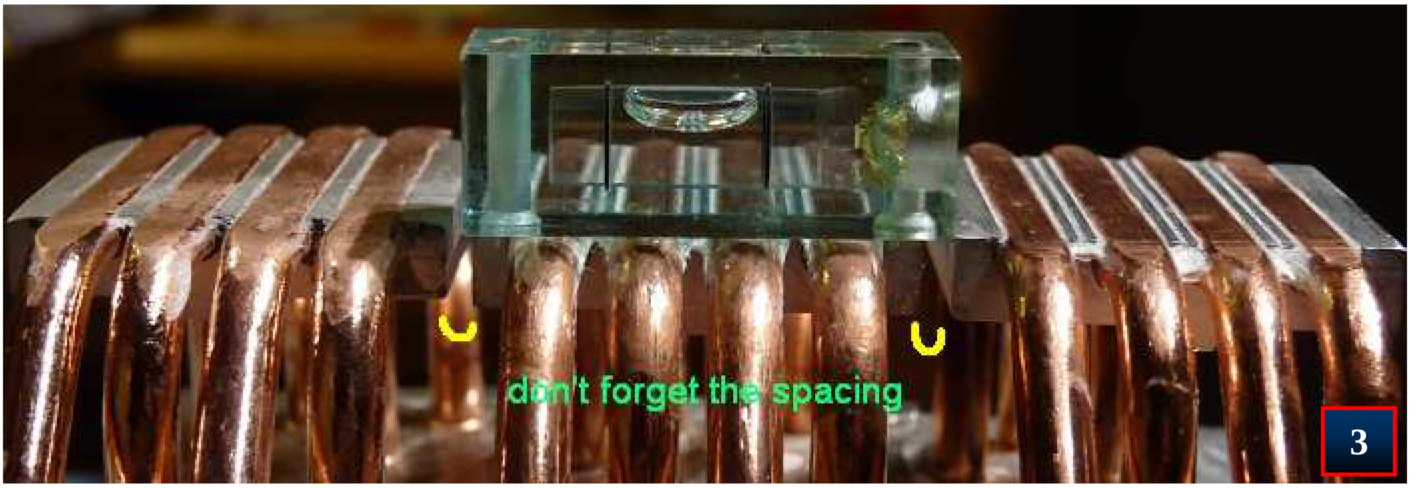

Wood plate 28x19x2cm thick

First, you need a wood plate. Mine measure 28x19x2cm. The spikes of the heatsinks will fit in the wood plate. Make some holes in the wood plate, until the spikes could pass and that you obtain an horizontal surface with a bubble level. Don't forget the little space between the heatsinks if you choose the plastic bag configuration. The hard part is to put the 3 heatsink close together until the plates of aluminium coincide.

YOU CAN GO TO THE PART 8 TO FIX THE STRAPS TO MANIPULATE THE SETUP

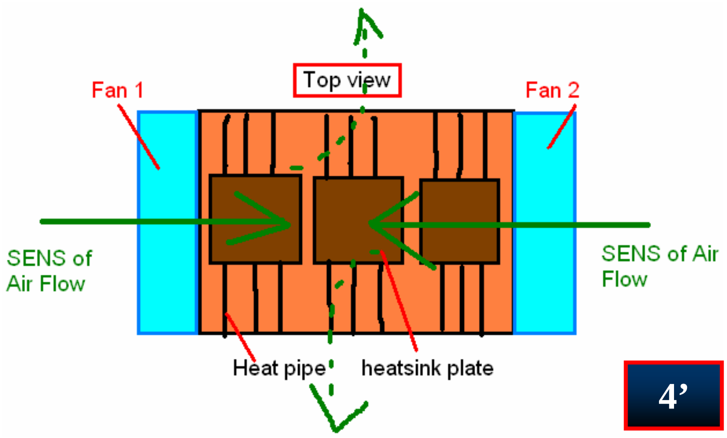
Once the 3 heatsink fit perfectly in the wood's holes [1], and if you didn't forgot the little space between the heatsink plates, we can set the heatsinks in the wood [2].

Before setting the heatsink with plaster, you can paint the wood with conventional black paint. [2] Fill the hole with plaster. It should be a "plaster of Paris" with a slow cure, so you will have some time to hold perfectly the heatsink.



[3] Wait 30 minutes until the plaster hold the structure and control the bubble level. The 3 surfaces must be perfectly flat (no level between them, or a little)

[4] Fix the fan according to drawing [4']



The sens of air flow is important. After several test, this setup gave me the best temperatures. The air escape in the laterals opening. You can fix the fans to the structure. Don't make a tight fixing, because you will have to remove them during the plaster process (Part 3). Be sure that they won't fall when you will run them because the blades can break easily.

Part 2 : Testing the peltiers

It's is the most critical part of the project, as it determine if you can continue or not ! The aim is to reach -20, -30 or even the -40°C needed. If you bought Nord Industrial peltier on ebay, you must know that some perform better than other (most of them were used), so always buy more unit than needed.

Materials :

You will need some tools now.

_Soldering iron + soldering paste
_Dealextreme thermal paste
_Copper wire
_PSU
_Thermometer, cyanocrylate glue


Lot of AS5 ... for nothing !

30g of thermal grease for 2.68$... you will tell me that this is "shit". http://www.dealextreme.com/p/professional-thermal-heat-sink-compound-with-injection-tube-30g-22510

Well, I spent 100$+ of Arctic Silver 5 and other known paste, I was sure that I will obtain better temperature. In fact I never obtained the best result that the silicone offered. There is no pressure on the peltier (not the case of a CPU) so as the silicone is more liquid than AS5, it fill the micro holes more easily and seems to perform better.

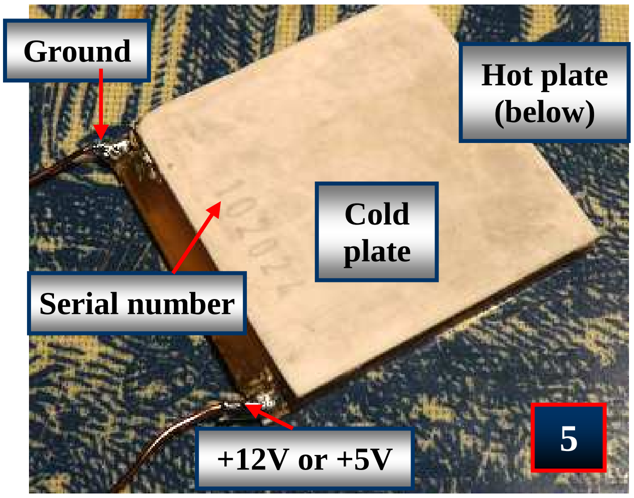
To solder the copper wire to the peltiers, you will need some soldering paste. It's easier this way, and the welding is more stable http://www.dealextreme.com/p/lodestar-soldering-paste-50g-4711

Buy at least 2 of this thermometer : http://www.dealextreme.com/p/grill-and-bbq-thermometer-50c-300c-11694

They can go to -50°C to +300°C, and are very reliable. I own 5 of them to control more temperature at the same time. Check for a known temperature if the temperature given is the same for the 2 thermometer.

At last, buy this super glue. It will make miracles.

http://www.dealextreme.com/p/instant-super-glue-with-tubes-and-needle-20ml-31742

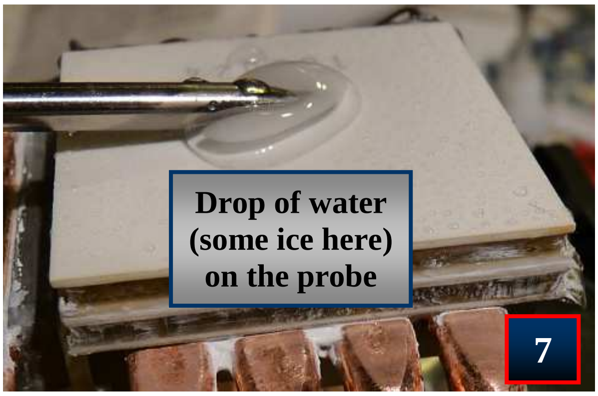


Clean the 6 peltiers with acetone, and weld the copper wires as pictured in [5]. Length of wires must be about 30 cm.
Respect the polarity as indicated in the picture. If you connect the peltier to 12V without an heatsink, the semiconductors will melt. Try a lower voltage to know the polarity, such as 5V : take a peltier in your hands, connect the +5V (red wire) of a molex to the (+) of the peltier. Connect the ground : you will feel in your hands the hot and cold face, but don't stay too long otherwise you will burn your hands.

The cold plate must be in top, the hot plate towards the heatsink plate.

Test of the peltiers. [5'] Clean all the surfaces (peltiers, heatsink) with acetone.

[6] Put some thermal grease on the 3 heatsink plate. Put also thermal grease on the hot face of the 3 TEC. Place the 3 peltiers on the 3 plates. The picture below show 6 peltiers, but I don't have the picture for this phase. Just imagine that there is only the 3 bottom peltiers on the heatsinks.



[7] Check if the 3 peltiers are in good contact with the heatsink. Put the end of the thermometer to the center of one peltier surface. The picture in left show 2 peltiers stacked together, but consider that there is only the bottom TEC ! Switch on the thermometer (fix it to an object, see picture page 8)

Add a drop of water on the end of the probe, it will favorise the thermal contact between the surface and the probe.

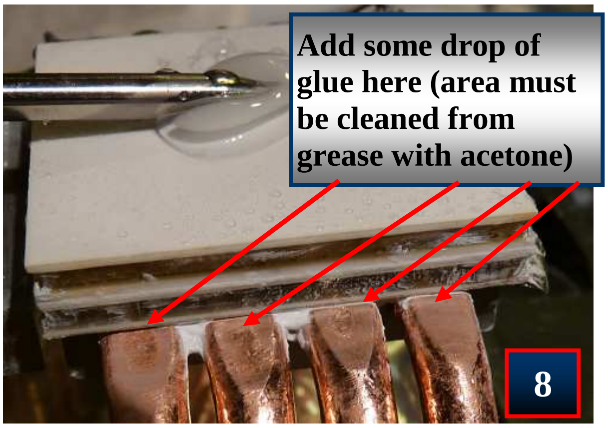
<u>We are going to test the temperature of one peltier at a time</u>
[8] Connect the fans. Then connect the first peltier to the +12V and ground. Read the thermometer. The temperature should fall really fast to nearly +4°C. If the drop of water on peltier boils, you put the wrong polarity ! in this case, stop PSU and check if your thermoelectric cooler is not damaged.
The temperature fall slowly near the +0°C range because the crystallisation of water into ice require a considerable amount of energy. The temperature fall slowly until it reach about -5°C : all the water is transformed into ice, then the temperature drop rapidly to -10 or -15°C.
Check the maximum achievable temperature with a single 12V peltier : you must obtain at least -14°C to -20°C. If the temperature is not in this range, change peltier or put more thermal grease, move the peltier to find a better position on the heatsink plate. You can add an ampmeter : the current going to a 12V peltier (Nord Industrial) should be between 5A and 6A. Check if your wires are hot (they mustn't. In this case, use bigger wire).

If you have obtained a temperature in the range -14/-20°C, let the peltier running some minute to be sure (with the high temperature on bottom, the thermal grease will spread and fill the microscopic holes on surfaces). You should observe the formation of much ice, coming from the humidity of air (picture in left).

When the temperature is stable, we will test the behaviour adding more heat to the air flux. Check the polarity of the 2 other peltiers. Connect the +12V and ground to them. You must have 2 cold surfaces. If the surfaces are cold, the dissipation is working. Check the temperature of the first peltier : it must remain stable or in the range of -14/-20°C even if the 2 other peltiers are running.

If the temperature remains in the range, it's ok and you can go to the next step.

Next step : fixing the first stage of peltiers with glue.



[9] In the picture on left, ignore the top peltier, it doesn't exist at now. There is only the bottom peltier which gives at least -14°C. Stop the PSU. Wait until the ice melt. Remove the thermometer, don't move the peltier. Try to clean the thermal grease which overflowed on the heatpipes.
Then, put some glue in the corner of the peltier and the heatpipe (as pictured in [8])

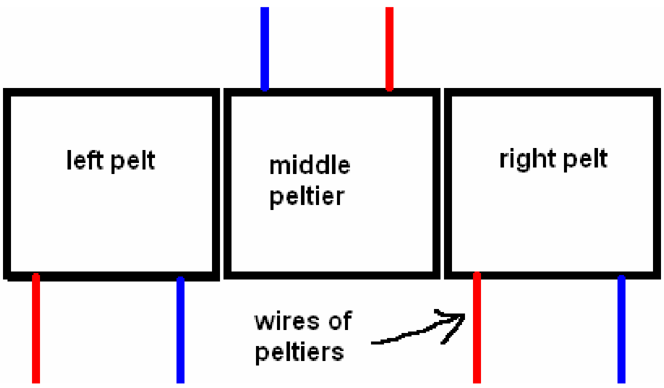
4 drop of glue can hold the peltier. Do the same procedure with the other side (near the wires). Don't put too much glue. Otherwise it will migrate to the interface between the heatsink plate and the TEC and will ruin the thermal contact.

[10] Wait 30s until the glue is dry. Put your finger on surface, and try to move gently the peltier : it shouldn't move. Now repeat the step [8] : put the thermometer, a drop of water, connect the +12V and ground to the 3 peltiers, and wait until you reach the equilibrium. You must have the same temperature as before. If you lost 2 or 3 °C, it's acceptable (only if you still are in the -14/-20 range). Sometimes with one peltier you can go lower in temp : -25°C.

If it's Ok, do the same for the peltier in middle : put the thermometer probe with a drop of water, connect the 2 others peltier to +12V and check the temperature. If the range is ok, you can glue it. Repeat procedure for the last peltier, and fix it.

Important :

The wires of the middle peltier must be in the other side of the right and left peltier. It will be more easier to prevent the short circuit between the connection of wires.



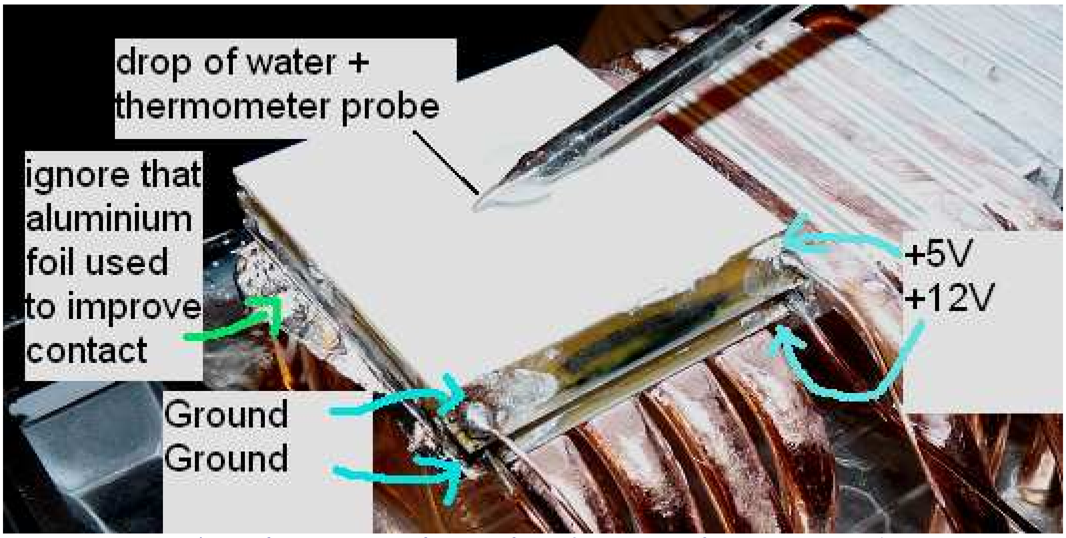
Finally, you must obtain 3 cold surfaces in the -14/-20°C range. You can add one thermometer to each peltier to control temperature in the same time, and see which is the best. Don't hesitate to remove a peltier and repeat steps until you have a satisfactory temperature.

Next step : fixing the second stage of peltiers with glue.

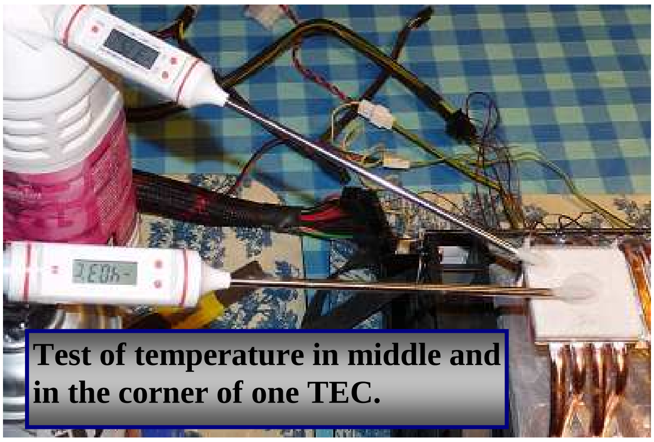
The aim is to obtain the picture 12 :

3 bottom peltiers at 12V and a layer of 3 top peltier at 5V. Note on picture that peltiers in middle are placed in the other side, so that the connection's wires won't be in contact with the side peltiers…

[11] Clean the surface of all peltiers with acetone. Put the 4th pelt on a bottom one (start with the right or left one) using thermal grease on the 2 surfaces. Put your thermometer in the middle of the top surface with a drop of water. Be sure that the top peltier is connected to the +5V of power supply, and that all the 3 bottom peltiers are connected to the +12V as previously.



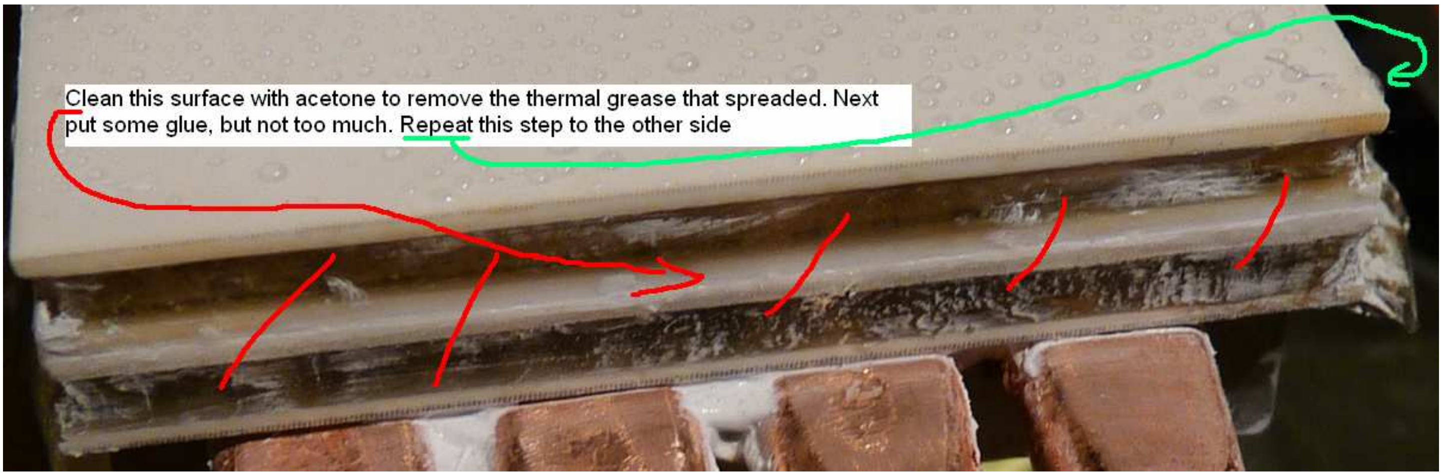
(On the picture, the 2 others bottom pelts are missing)



Test of temperature in middle and in the corner of one TEC.

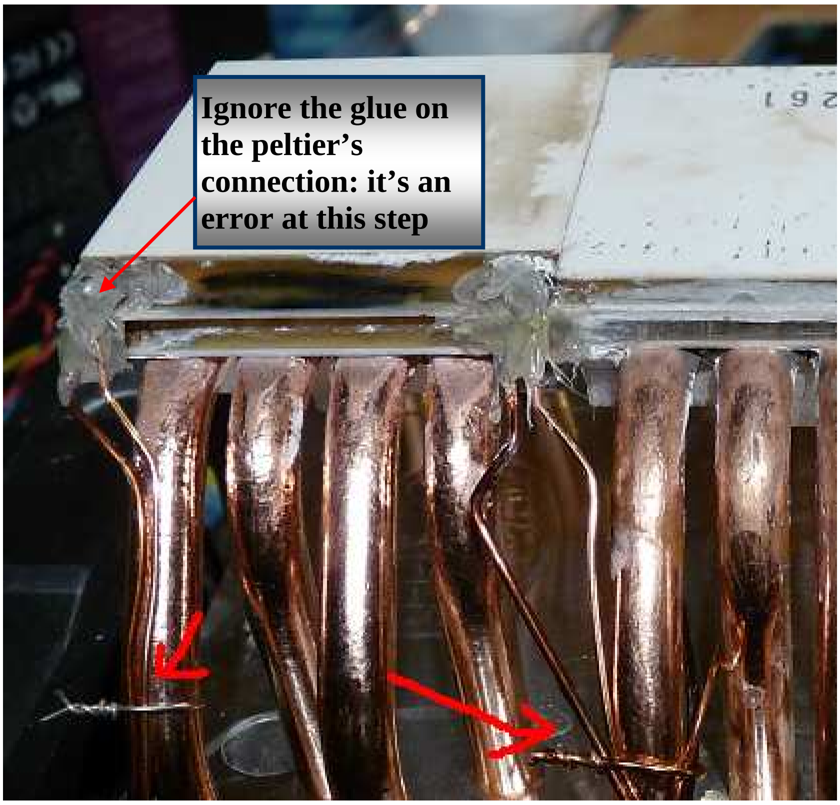
Start the PSU, the fans are on, and you should have a violent drop of temperature on this top peltier. Wait 2 minutes until the equilibrium is reached : you should obtain a temperature in the -20..-40°C range. If you are above -25°C, (for example -30 or -40) it's perfect. If you have less than -25°C, recheck the temperature of the bottom peltier. Make another test. You should obtain temperatures like in the picture in left.

If the temperatures are good, you can glue the 2 pelt each other as explained in the picture below :



Clean the surface, then add some glue to the 2 sides of the peltiers, along the interface

Wait 30s until the glue is dry. Put your finger on the top surface, and try to move gently the top peltier : it shouldn't move. Recheck the final temperature after fixing them.



Note about the wires :

Fix the wires of the peltier to the heat pipes, or better : wrap them several turn around it. The wire shouldn't pull on the peltiers !

When your first couple of peltiers (bottom and top) are fixed together, the wires fixed and a high negative temperature obtained, you can repeat the step [11] to the 2 others peltiers. You will finally obtain the picture 12 (as seen previously) or the picture in left if you let the system running some minutes. Some ice will appeared. You can check the final temperature with several thermometers in the same time.

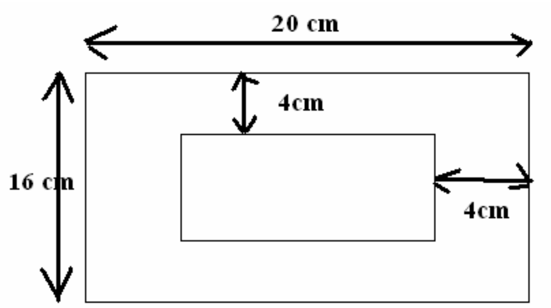
Final step is to bend the wire of the middle peltier, so that all the wires will go in the same direction.

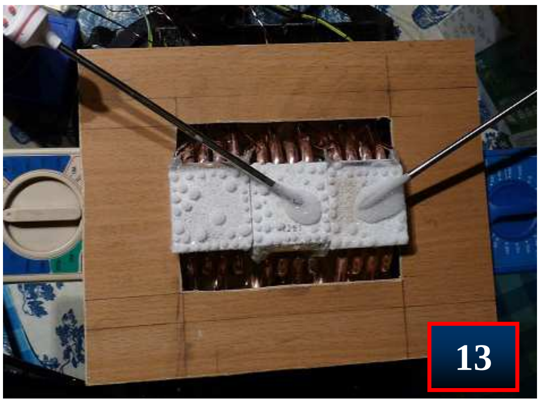
Crucial remark : we used 5V for the top peltiers. But don't forget that your PSU can give 3,3V (orange wires) : connect 3,3V to a top peltier instead of 5V. You may reach better temperature, or the same, that the one obtained at 5V.

On the picture, you can count 12 wires (4 for 2 couples of peltiers, so 3 couples gives 12 wires). All the wires are placed in the same side of the heatsinks. The wires of the middle peltier go below the heatsink plate. Be sure that they don't pull on the peltiers.

Part 3 : Wood & Plaster

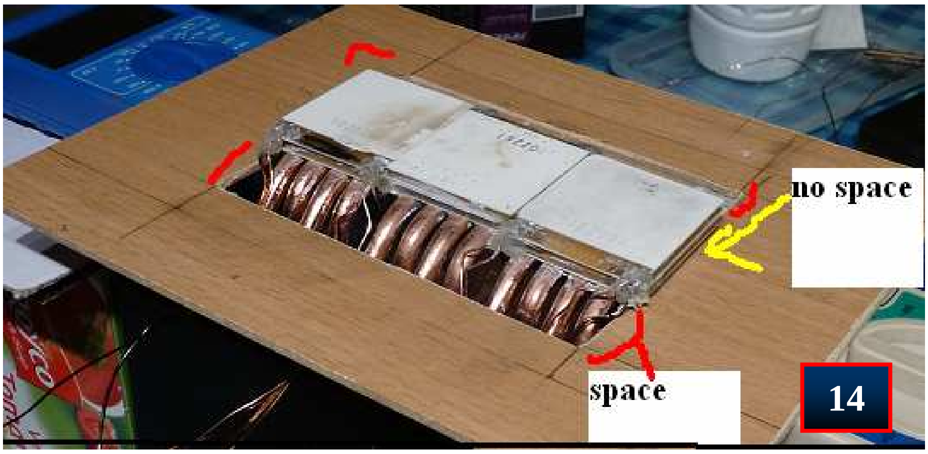
We will use 2 wood plates to support the glass chamber. The dimension of the first plate is approximately (it depend about the type of heatsink that you choose) 20x16cm with a rectangular hole of 12x8 cm in middle like the picture below :

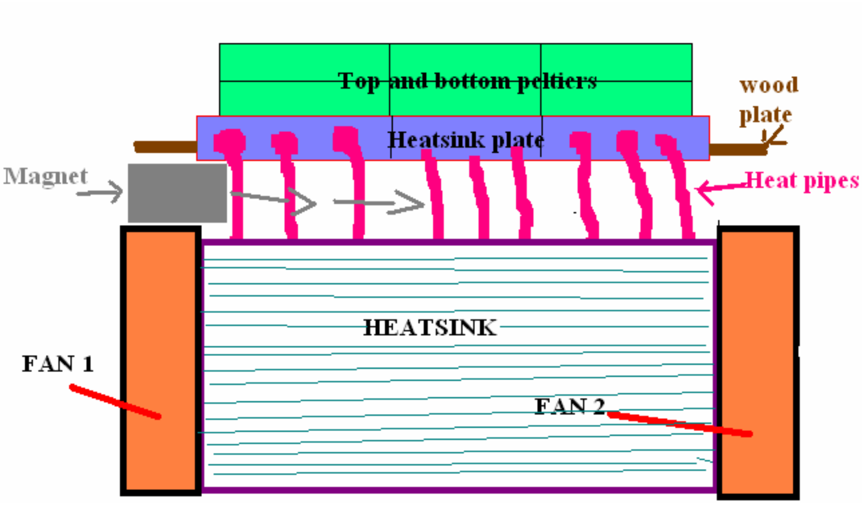




On the picture [13] you can see how the first wood plate must look like. Thickness of the plate is about 3mm. The rectangular hole can let the peltier pass through the wood plate. There is no space between the sides of the right and left peltiers and the wood plate (see picture 14), so the wood plate can maintain itself without support.

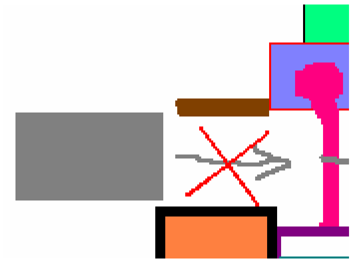
The second wood plate will be made after the plaster part (few pages later).

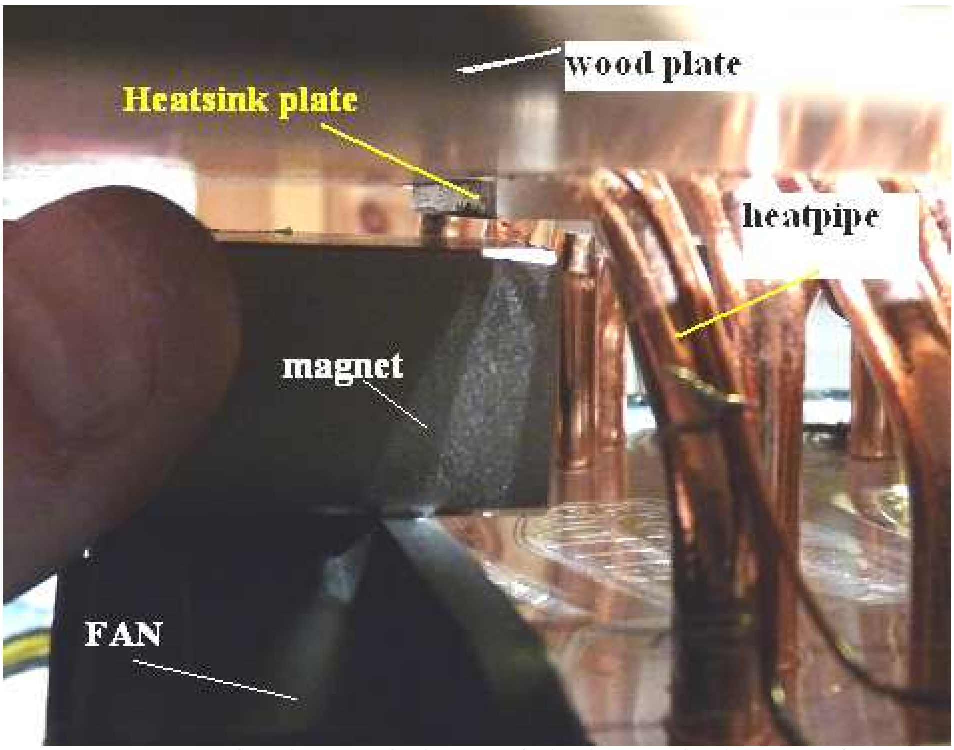




An important thing is to consider the location of the magnet (neodymium one). You must have enough space to put the magnet under the heatsink plate (the thickness of the heatsink plate is also an important point in the choice of the heatsink, the magnet must be the nearest possible of the interaction surface).

So you have to check if the wood plate is not under the heatsink plate. In this case, the magnet won't pass (schema in right, bad spacing of the wood plate)

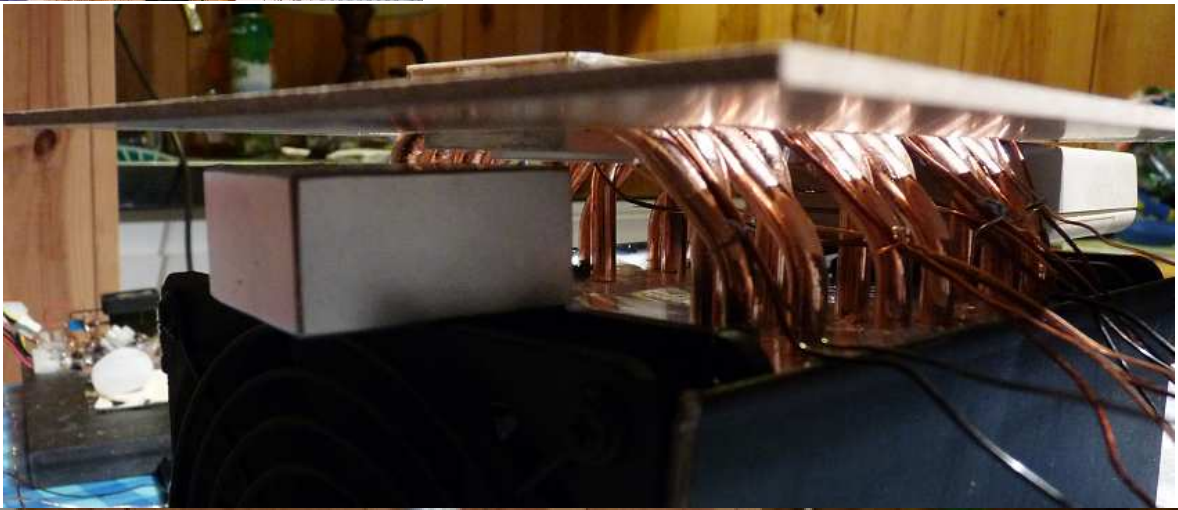




A 2cm height magnet must pass under the wood plate and the heatsink plate. In this picture, it's possible. For the final setup, place the magnet as closely as you can of the heatsink plate, using a wood support

Once the dimensions of the wood plate are optimum, make some scratch on it. The plaster will fix on it more easily.

See the pictures below : the wood plate should hold itself, but put some supports because the weight of the plaster will make it fall. I used 2 voltmeters which had the same height of my magnet.



The wood plate is maintained with some supports.

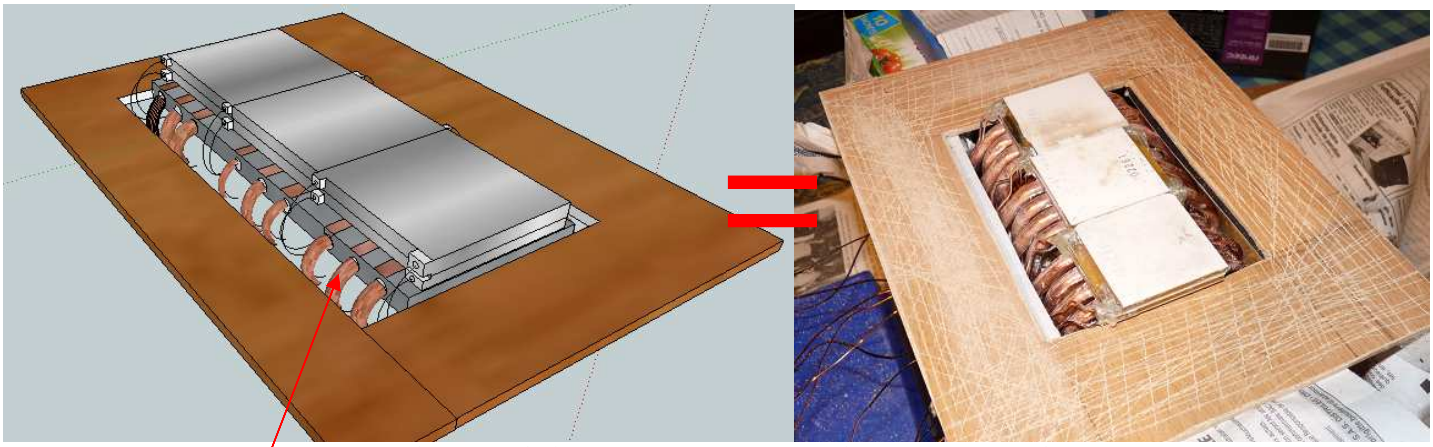
Some other views :

Put some protective layer of paper. The next step will be a bit dirty. You can remove the fans and fix their grids if you want.

Creative step : "plaster of Paris" with slow cure.

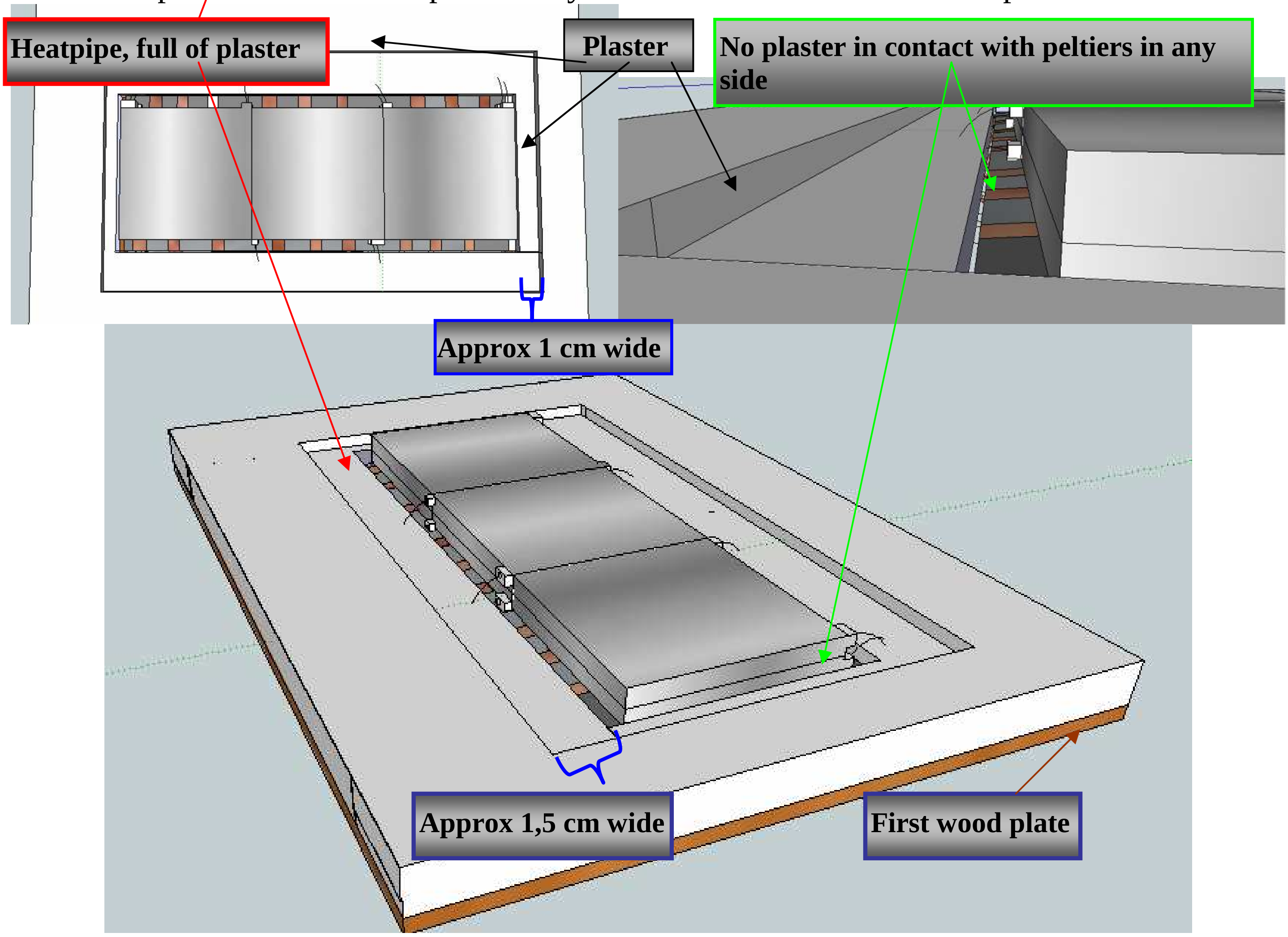
We will use some plaster to hold "definitely" the wood plate. The plaster will fix the wood plate with the heatpipes, it’s how the structure will support. It will make a basis for the glass container. This step requires enough time and patience (it can become more and more worse in some case).

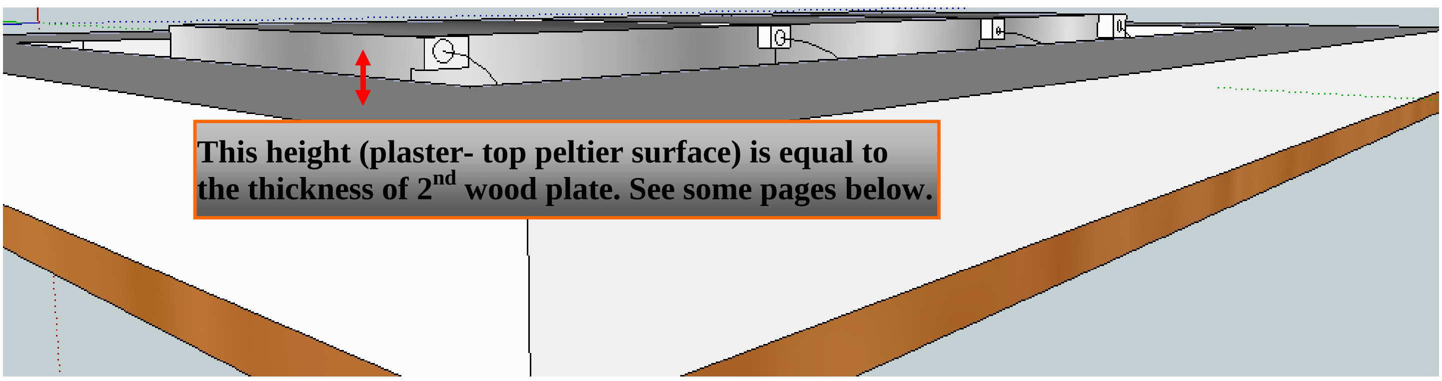
First, put some plaster with water. Make more plaster than necessary, the quantity in the picture in left was not enough and I loose a precious time making another. The plaster will be less and less usable as time pass (maybe 7-10 min of "scuplting"). Don't put too much water, the mixture must be mid-solid mid-liquid. Protect your peltier from plaster. It is VERY important that plaster mustn't touch the peltier in any side !
Put the plaster on the wood plate, and try to make a structure as explained below.



The SketchUp pictures represent the reality in right

Protect the peltier surface from plaster. Try to do the same like in the next pictures.





The top peltier surface is about 3mm, or more, above the plaster because we will add a second layer of wood. See the next page ***“finding the height of plaster”.***
The pictures of the construction (next page) are a bad example because some of plaster is in contact with the peltier. I had to remove it. It’s easy to remove the plaster when it hasn’t cured, and easier to put plaster everywhere. But you must be fast.
It’s very important that no plaster is in contact with peltiers because :

- When it will cure, plaster will contract and pull the peltier and if the glue fails (remember that we put a tiny amount) the TEC won’t be in contact with the heatsink plate and temperatures will be bad.

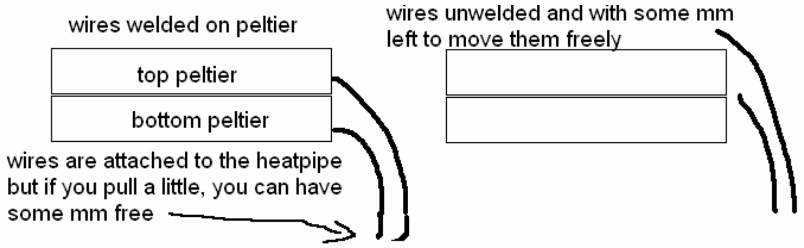
- Plaster has a good thermal conductivity. In my first design, I put plaster everywhere : I lost nearly 10°C when the plaster cured. I didn’t understand why, but I discovered that the heat of the heatsink was transferred in the top peltier, so my temperatures were bad.

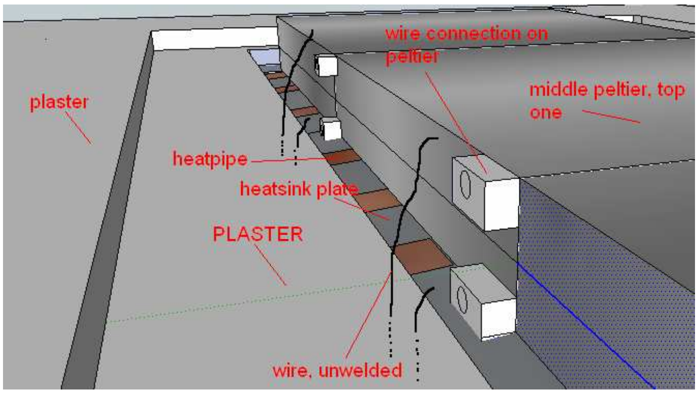
- If you have to replace a peltier on the heatsink plate, it will be easier without plaster around it (see next picture).

The same remark can be made about the peltier’s wires : I had enormous problem when plaster was around them. The wires were pulled by the plaster and they pulled on the peltiers, and some moved. I had to replace them. If you can avoid putting plaster on wires, it’s perfect, but it’s not as easy when you put the plaster for the first time on the structure.

You can follow these steps before putting plaster. It requires more work but you will save a lot of time.

1) Unweld all the peltier’s wires. Pull on them to have some millimeter in length free, we will weld them later. Be sure that the unwelded wire won’t fall.



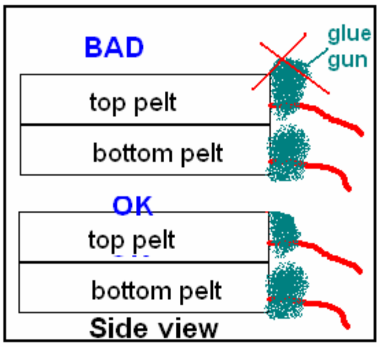


2) Put the plaster and make the structure. The wires should be contained in the plaster, only a fraction is free to be weld, see the picture in left.

3) After some hours, when the plaster have cured, weld the wire to the peltiers. Don’t invert 12V with 5V, check the voltage with a voltmeter to be sure. Then recheck the

temperature, which should be the same.

4) You can secure the wire's connection with a glue gun. Be sure that no glue go higher than the peltier's surface, otherwise it will block the plastic bag. (side picture)



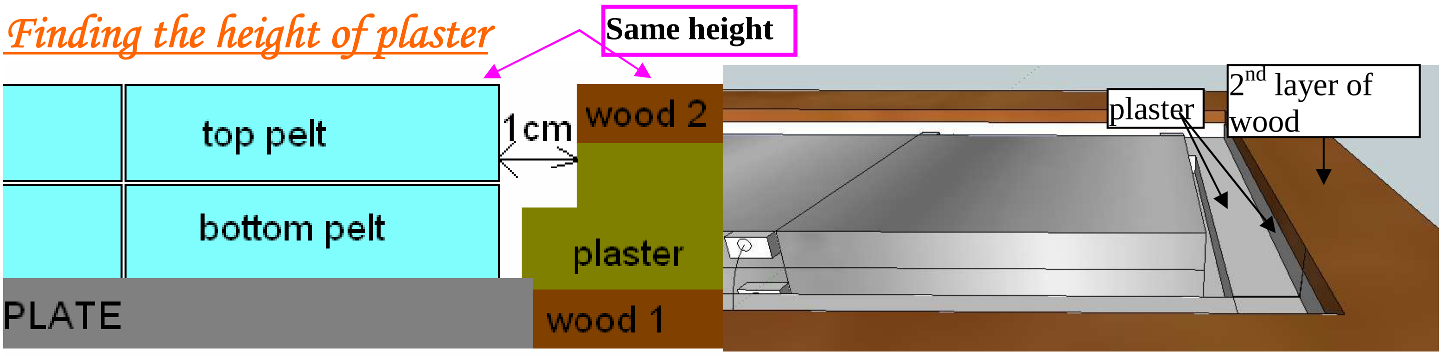
Pictures of the construction

Protect the peltier's surfaces from plaster

Some plaster is in contact with the peltier's side, bad pictures example.

Some plaster is in contact with the peltier's side, bad pictures example.

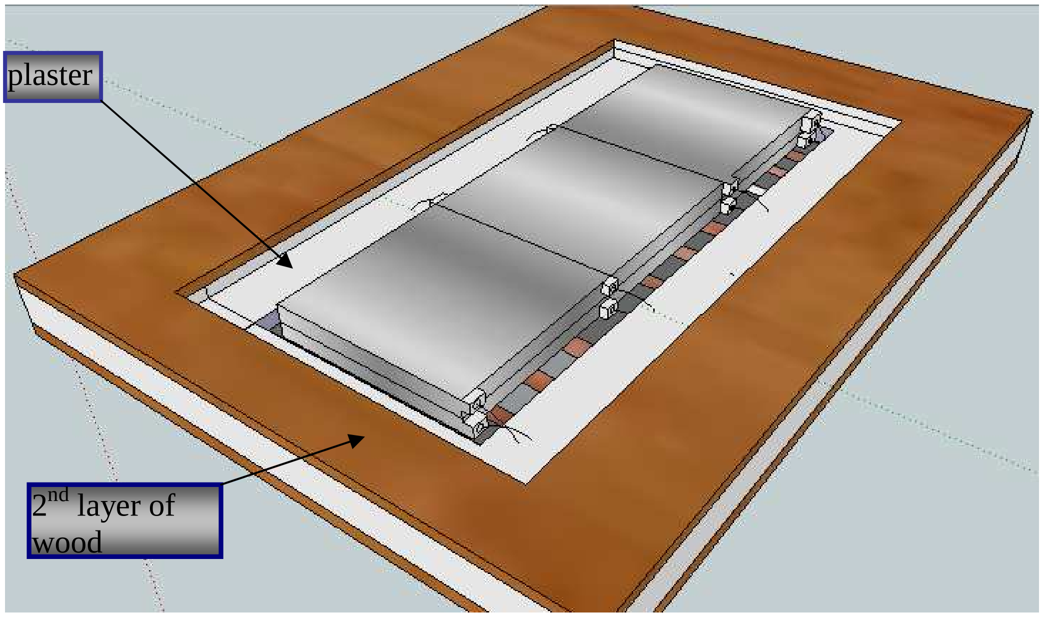
Finding the height of plaster



As pictured above, we will put a second layer of wood on the plaster surface. The thickness of the 2nd wood plate + the thickness of the plaster must be at the same height of the top peltier surface.

1) The second wood plate Part I

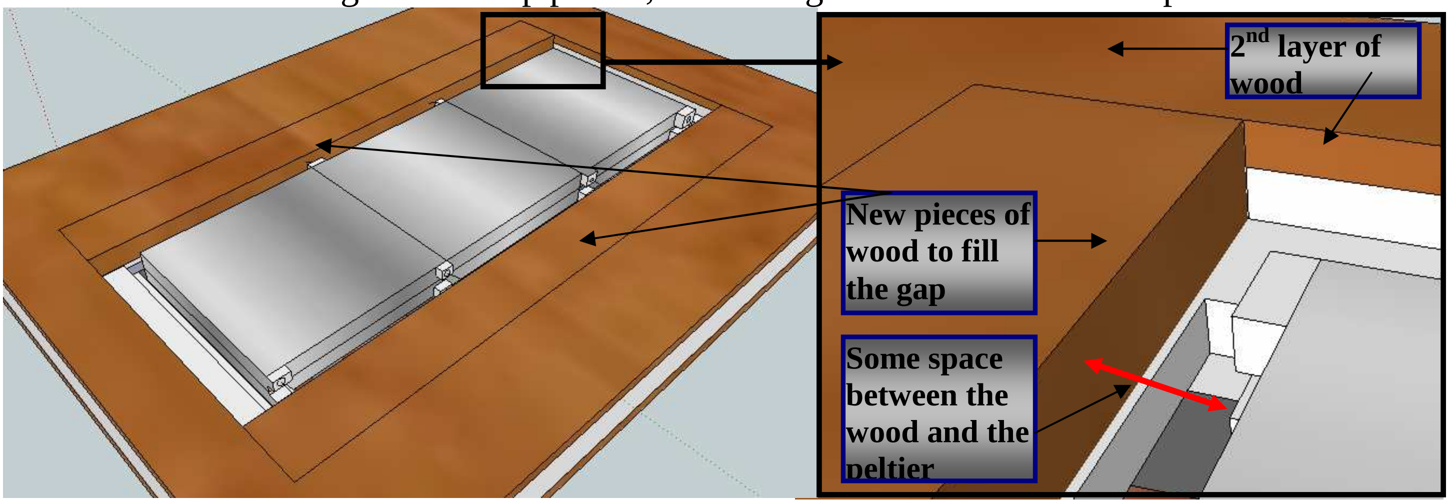
Its dimensions depend of your work. Take the dimensions from your plaster structure. It must look like this :



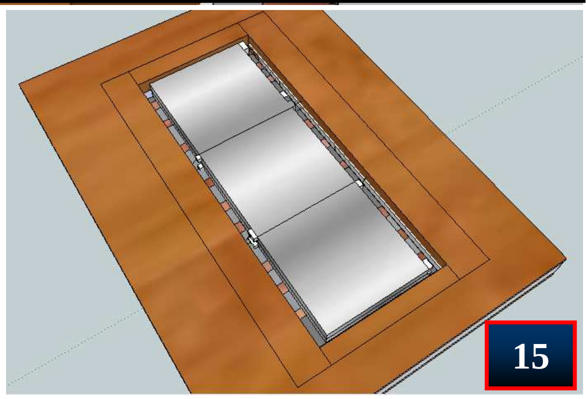
Once the plaster has cured, you can fix the 2nd wood plate on the plaster using a glue gun. Don't put too much glue, the height of the layer of wood mustn't be higher than the top peltiers surface. You can paint the wood in black and let the paint dry.

2) The second wood plate Part II

You need to cut 2 rectangular layers of woods to fill the gaps. The height of these wood pieces mustn't exceed the height of the top peltier, or the height of the second wood plate.



Let some space (5mm) between the wood and the peltiers. Do the same with the other sides. You should obtain the picture [15]. Disassemble this 4 piece puzzle and paint separately the 4 wood pieces with a black paint. Let the paint to dry. Try to put the 4 pieces on the structure again. Be sure that you can remove and place them without difficulties. They must be in close contact each other. This way, they mustn't move freely. The level must be flat like the 2nd wood layer.



Part 4 : Plastic & Glass Chamber

Test of temperature. In this pic, 2nd wood layer is missing, ignore the pieces of plastic

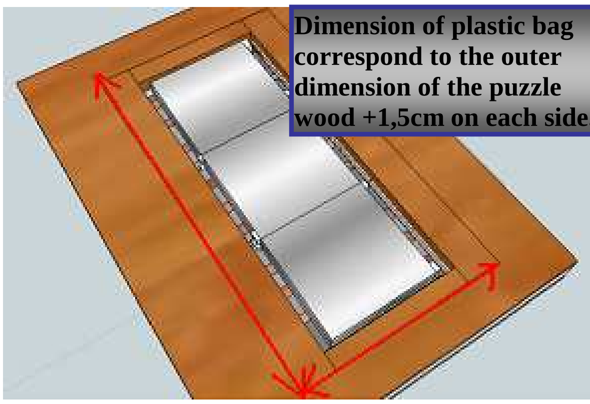
Before putting the plastic bag, you must check if you have good temperatures, check if all is OK. If not, one peltier moved and you will have to replace it : unweld it, carefully remove it from the heatsink plate, clean all surface and check the final temperature.

The next step is to put the plastic bag. The “puzzle” design with the 4 removable pieces of wood allow you to change the plastic bag after weeks of use, or if you scratched the surface with a radioactive mineral…

Find a very dark plastic bag. Sometimes, small mail packets are wrapped in a plastic container which is very black inside, and colored in the outside. You may also find a bin plastic bag but I prefer the mail’s plastic which is darker.

The dimensions of the plastic bag is indicated in the picture below. Take +1,5 cm on each side because…(it’s a long story!)

In this pic, 2nd wood layer is missing



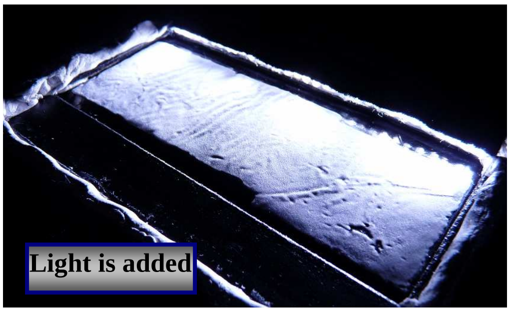
Dimension of plastic bag correspond to the outer dimension of the puzzle wood +1,5cm on each side.

Remove the 4 pieces of woods.
Clean the plastic and peltiers surface with acetone. Then, <u>put some thermal grease on the plastic and on the peltiers, it must be a tiny amount</u>. Put the plastic bag on the peltiers, and remove with your finger the air bubbles, you must have a flat plastic surface (in the picture 16, the 2nd layer of wood is missing but you should have it !).

2 pieces of wood are missing here. The plastic bag is now fixed and tightened with the 3nd wood structure.

Then enclose the plastic bag with the wood puzzle: the plastic should be stretched and fixed. You should end with the picture in left.

1 piece of wood is missing here. Surface of plastic bag not perfectly flat



Once this step is finished, make a test of temperature. You can put the thermometer probe with a drop of water on the plastic surface and check the temperature. It should produce ice quickly when you blow on it (picture in left), indicating that the temperature is homogenous on the surface.

1) The Glass Chamber

The bigger is not the better. The next pictures show my ancient glass container and the actual.

First glass chamber for the V3 project

Glass container from V2 project and used in V3

When I started with the V3 project, the aim was to use an aluminium plate for the interaction surface (in the picture in top left, you can see a rectangular white shape, it's the original aluminium plate with a white protective layer). So I built a big glass container. But the aluminium plate worked only if the surface was divised by 2, and I went to the plastic bag. I kept the big container despite the tiny surface of interaction. But again, it didn't worked much better. With the big container, I had to wait a long time to have equilibrium. Then I used my ancient glass chamber from the V2 version : within 1 min I could see the first track. Fortunately, even if the surface of interaction was increased by 1/3 with the V3 project, the V2 glass chamber fitted. The reactivity with this tiny glass chamber was very interesting compared to the big one, so I choose to pursue my project with this glass enclosure.

For the V3 project, my glass chamber is a bit short on one dimension. You will find the new dimensions for a 12x4cm interaction surface (surface of 3 peltiers side by side), in the next page.

About the thickness of glass : 3mm

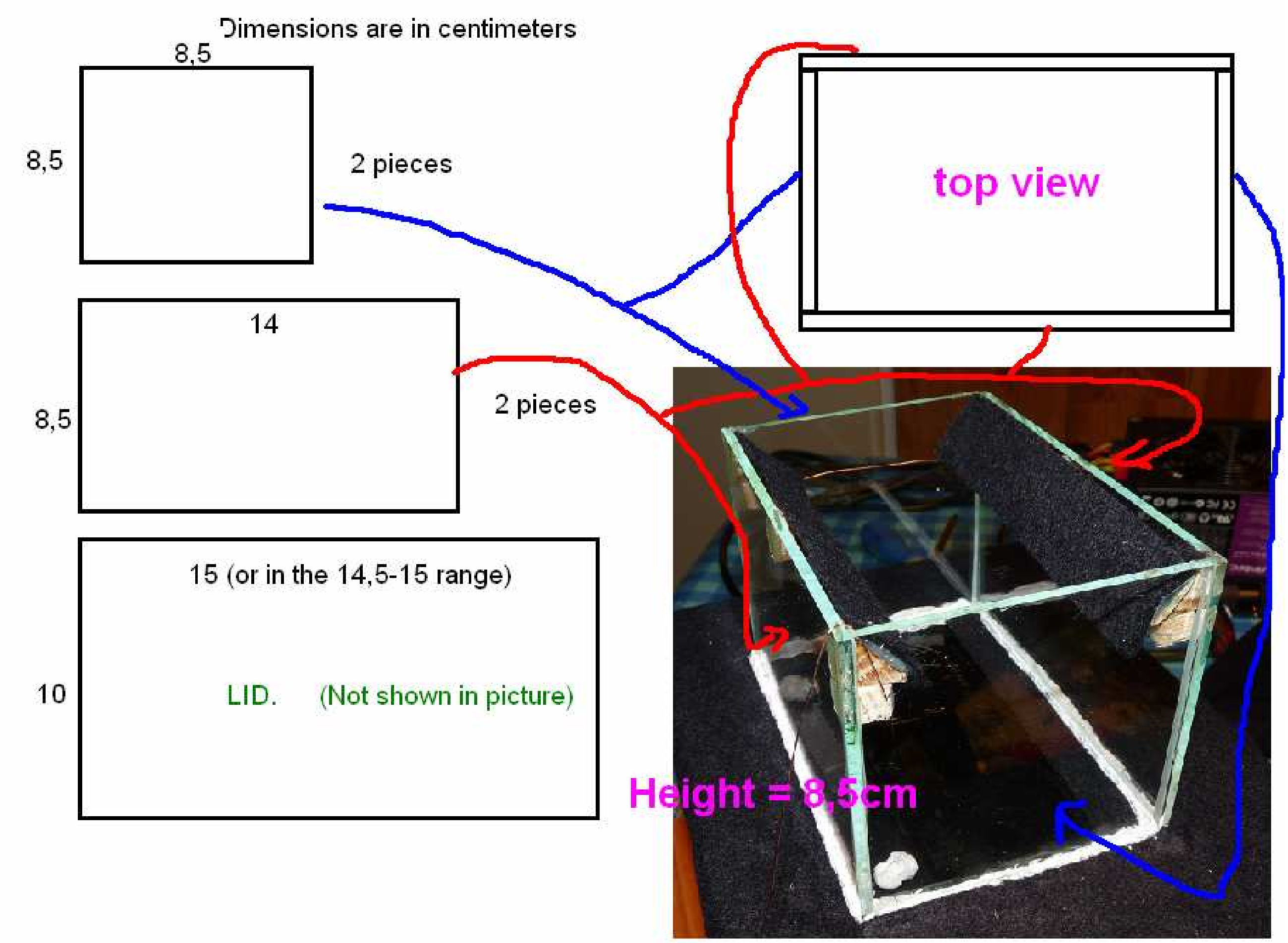
Why this thickness?

Because I know that we can observe this type of event (in left) with this thickness :

"An incident proton (coming from a natural neutron for example), interact with the glass wall of the chamber, ejecting another proton. The two protons are visible and entering in the bottom of the picture. One of the protons then collides with another proton which either comes from a water molecule (one of its two hydrogens atoms), or one of the hydrogen atoms in the alcohol molecule. This collision kicks the proton out of the water molecule and we now see both the scattered original proton and the new proton kicked out of the water molecule. The most striking signature is that the angle between the 2 emerging protons is 90 degrees (it appears a little bigger than 90° because the tracks are pointing away from the camera). Elastic scattering of two equal mass particles, where one is initially stationary, always gives an angle of 90 degrees between the two final particles." *From Jasper Kirbky, Cloud Experiment, Cern, about my observation.*

It should be interesting to study the influence of the thickness of wall on the performance of the cloud chamber. 3mm of glass isn't enough to block the entire energetic electrons coming from natural radioactivity. A thicker material should give a more stable isolation from the surrounding air outside the chamber. See the DIY part 2 for more discussion about this parameter.

2) Construction:



So you will need 5 pieces of glass (2 squares 8,5x8,5 cm + 2 rectangles 8,5x14cm + a rectangular lid 10x15(max)cm). It's like making an aquarium it must be "waterproof", look what are the materials needed (you will need only a special glue and wait 24hrs until all the glue is dry). Once the glass chamber is done you can continue further.

3) High Voltage wire and Alcohol supports.

You will need theses materials :

- nearly 50 cm of a copper wire (or aluminium, but not as nice to see (you can use the same copper wire used in the peltiers connections)
- some little pieces of wood
- glue gun
- black felt which can resist to alcohol

High voltage wires :

At the end of the copper wire, weld a "crocodile claw" or "clamp".

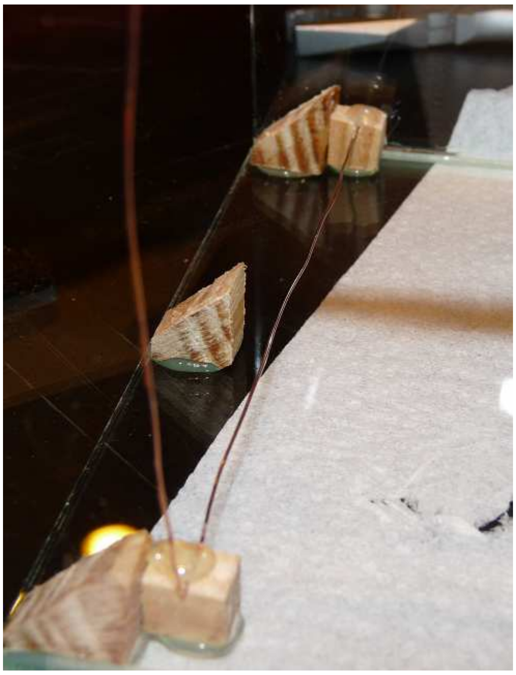
Pieces of woods and felt :

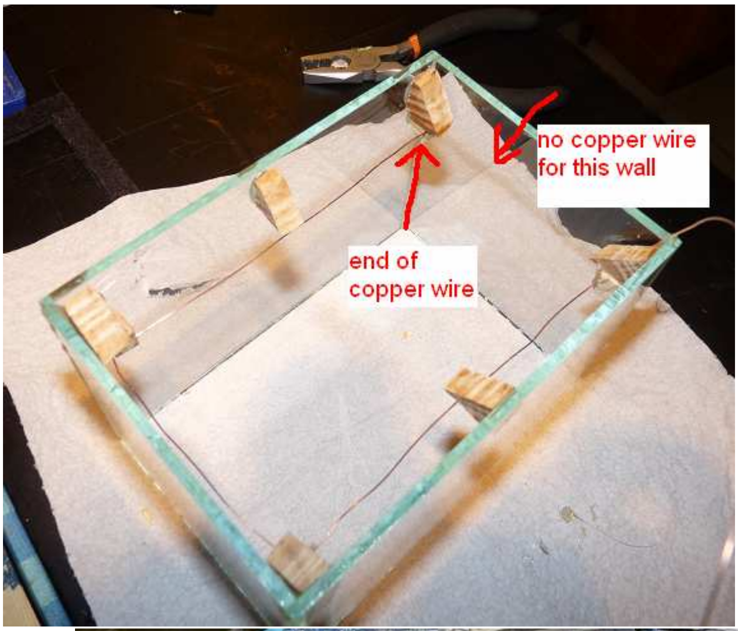
Cut 2 rectangular pieces of felt, dimensions are approx 2cmx14cm.

Then build :

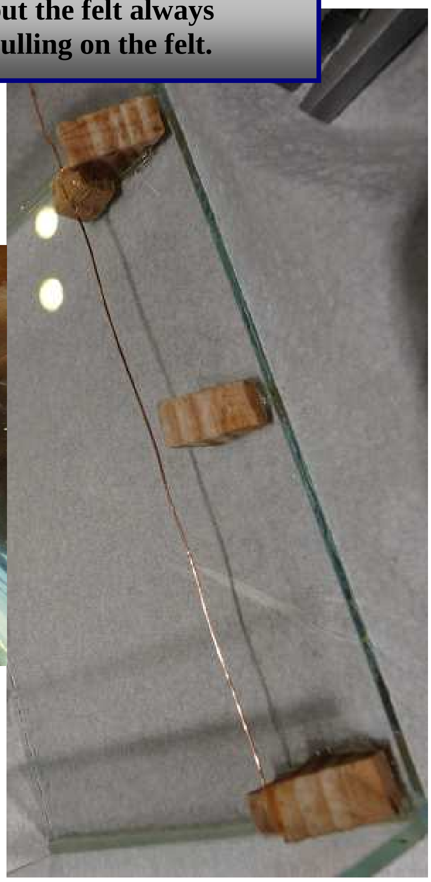
- 4 cubes of wood with a slot (the copper wire should pass inside).
- 6 triangulars wood pieces at 45°.

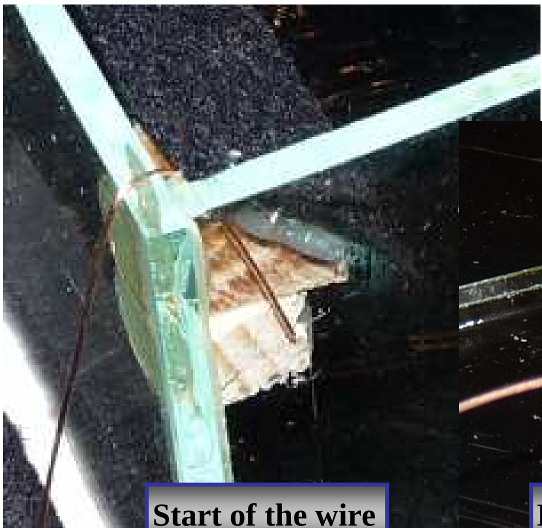
You will fix these pieces of woods on the glass walls with the glue gun. The next pictures are self explaining.



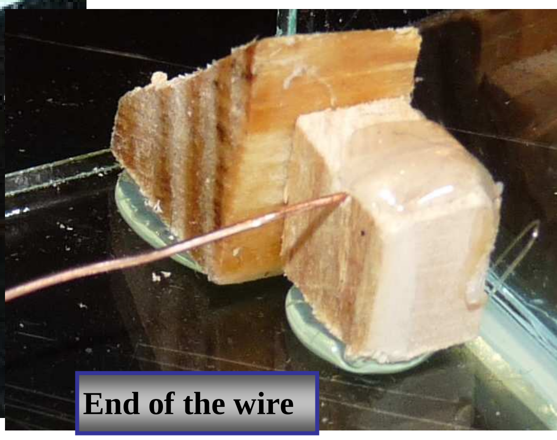


Put some glue gun on the triangular piece of wood, and put the felt. Try to have a tighten surface (fix one extremity, wait until it's fixed, pull gently on the felt, put glue on the middle piece of wood, and put the felt always pulling. When it's fixed fix the other extremity by pulling on the felt.



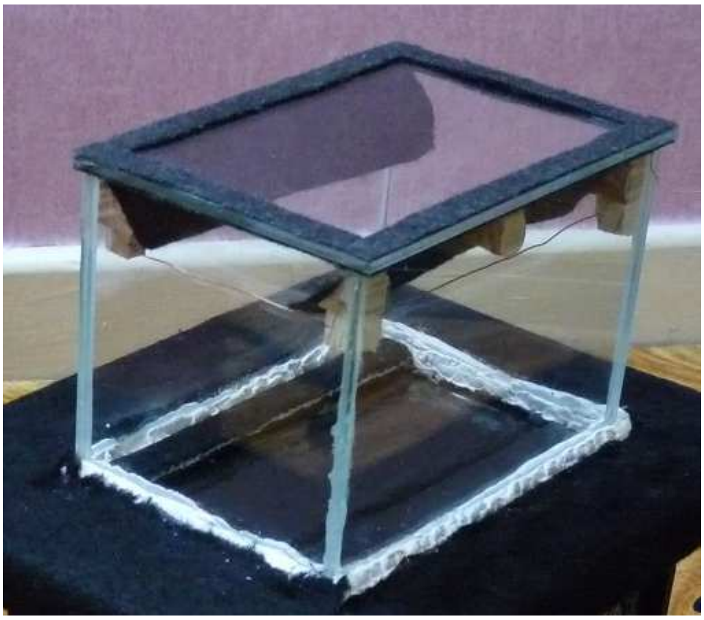


Start of the wire



End of the wire

The HV wire (copper wire) shouldn't touch the felt. Put some glue gun to fix it in the wood slot.

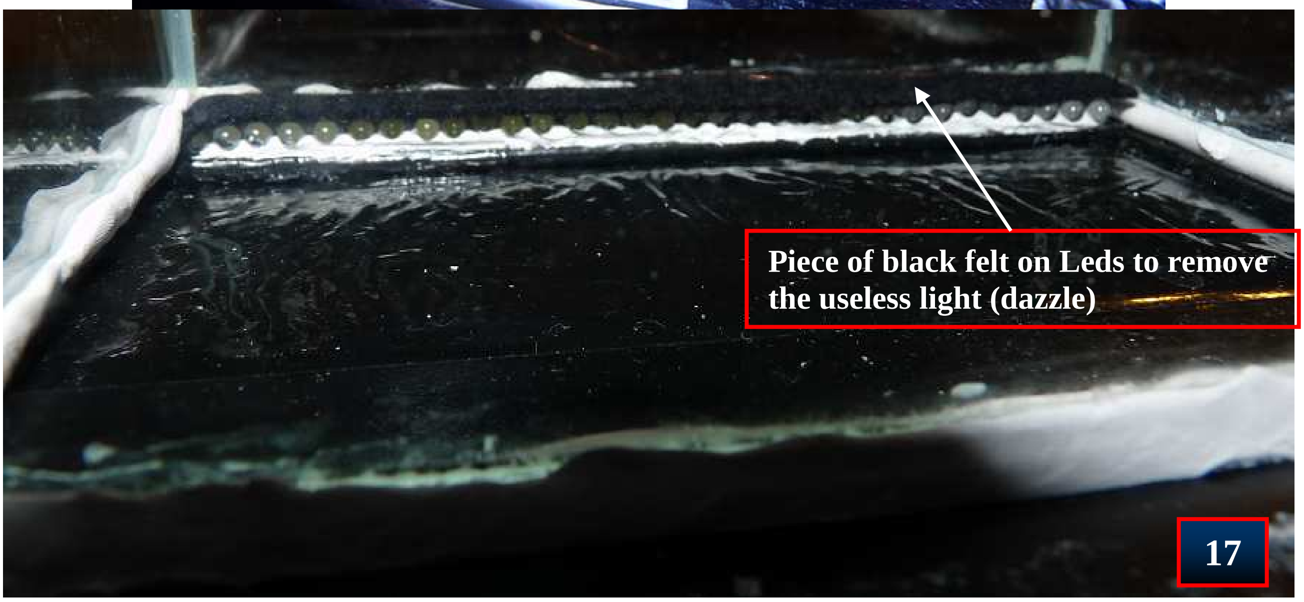


Put with the glue gun, or with cyanocrylate glue, some pieces of felt on the lid, as pictured in left. Put felt on the 2 sides of the lid glass.
This will make a more enclosed container and it will be nicer to see.

It's certain that the dimension of this glass chamber "may" not be optimum. The height might be an important parameter. You can experiment yourself with different container and check the reactivity (time needed to reach an equilibrium and to observe first particles). See the DIY part 2.

Part 5 : Ligthing

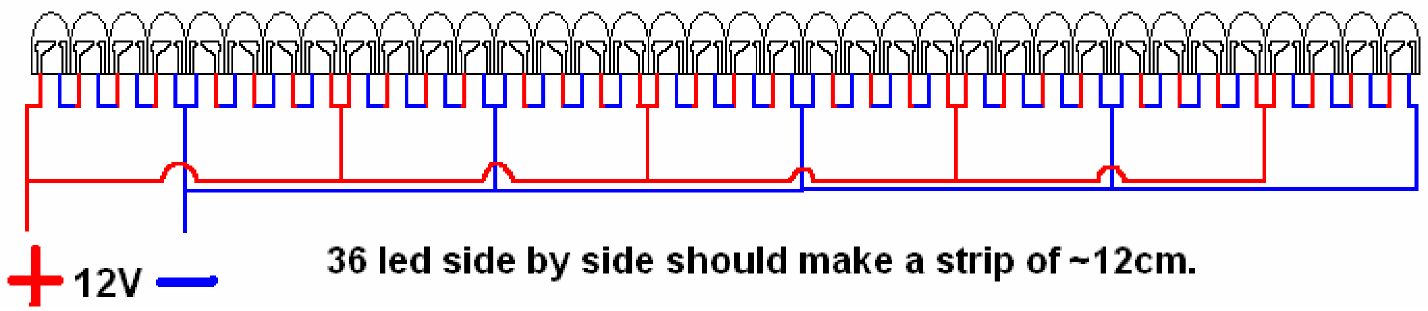
We will use about 40, 3mm white led high luminosity. Below you can see some pictures of the setup : the led strip with a piece of felt on it.



I prefer to use 3mm Led, because there is less "dark area" than using 5mm Led and also that the overall luminosity is better.

You can find some led on Ebay, Chinese seller always offer interesting deals (for example 500 led for 19$ with free shipping).

Then, make this circuit.

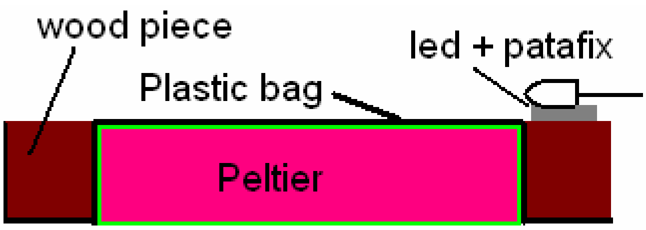


You have to weld all the Led together, according to their polarity. Use some soldering paste. Don't put too much time otherwise you will fry the led with the temperature of the soldering iron. Test your circuit using the 12V from the PSU.

If the circuit is working, take a strip of white Patafix and put the circuit of led on it. Try to have an homogenous strip of Patafix, not one with some slot on it. Don't put too much Patafix, the led should be the nearest possible of the ground.

Place the strip of patafix on one piece of wood, fix the patafix gently on wood with some pressure.

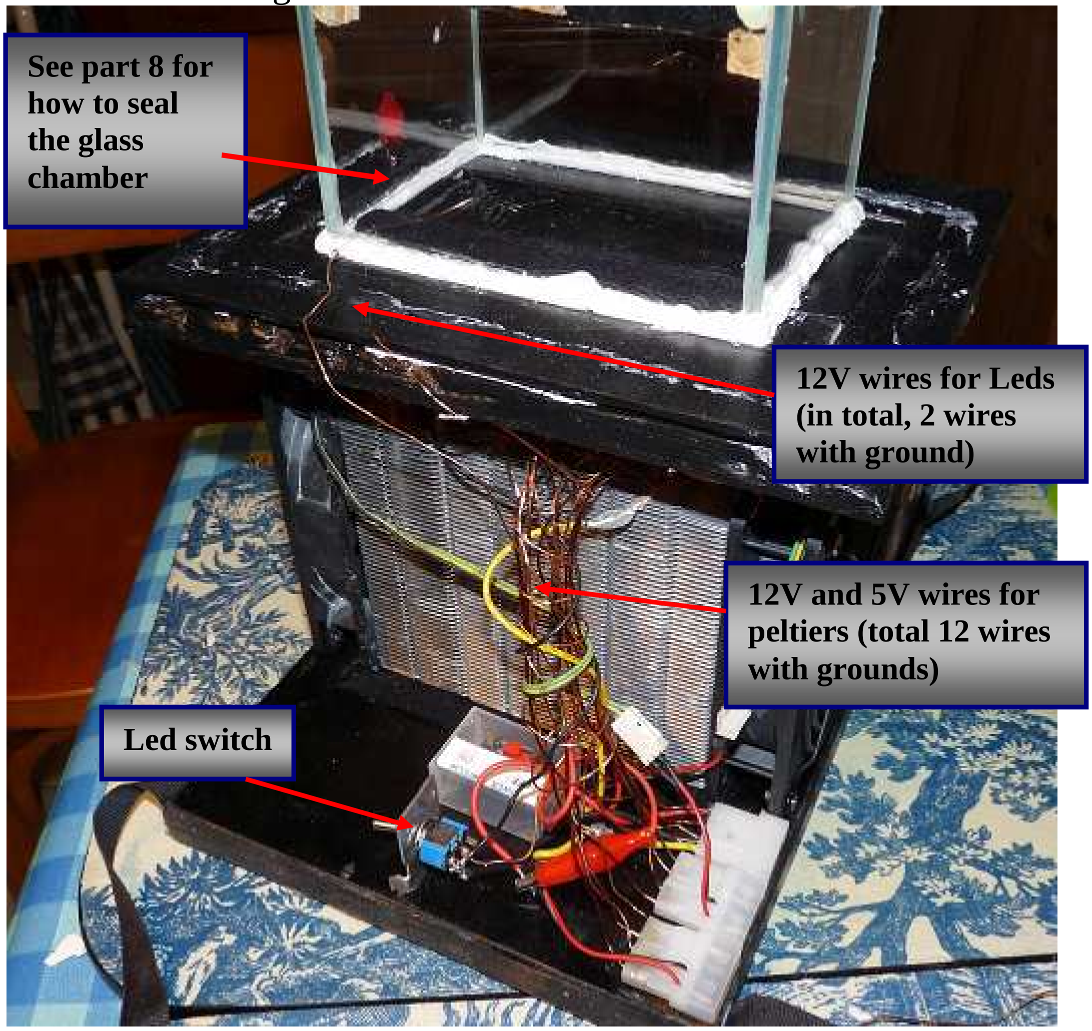
Then, fix the {Patafix+led} to one piece of wood. The led should be in front of the interaction surface. Or you can place the patafix first on wood, then add the led to the patafix.



Check if some leds are not hide by the patafix. Then place a piece of felt on the led to eliminate the dazzle, like in picture [17].

If you are lazy, you can find some quality led strips on dealextreme.

You should end with something like this :



The connections will be detailed in *Part 7 : Wiring.*

Led provide enough light with a weak current, so they didn't produce much heat. The spectrum is also interesting (white colour, no infrared radiations which can warm the interaction surface). They are also very tiny so they don't take much place.

Finally you can add a switch for the leds.

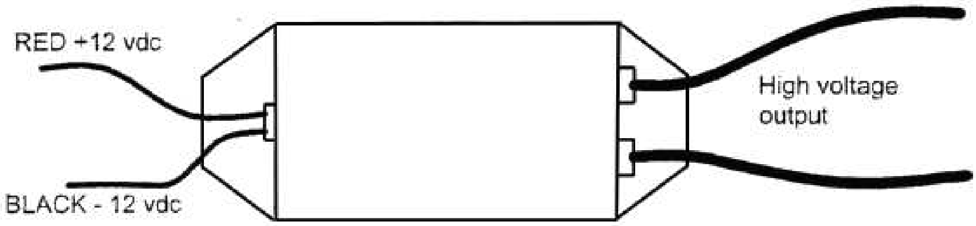
Part 6 : High Voltage

If you are poor, you can find a plastic cup, then rub it on your hair, and place it on the glass lid : the static electricity will make the same job as the next circuit, but you will need to recharge it. The high voltage is as much important as the contrast, lighting, and temperature of the surface. It will make all the difference cleaning all the unwanted ions and producing very thin tracks. But it's a capricious thing, depending on the experimental conditions (temperature, humidity of room…). You will see that the circuit is surprisingly rough and permit to have fine adjustment to have the best result. We will use a Cockroft Walton (CW) circuit, and an HV power supply.

Materials :

Gas tube power supply

MINIMAX3/NEONUL INSTRUCTIONS



This universal high voltage power supply was originally designed for neon displays in our laboratories. It is UL approved and virtually indestructible. It is open circuit and short circuit protected. Open circuit output voltage is over 3000 at a frequency of 30 Khz. Short circuit current is >15 ma. Unit load lines at 2000 vac delivering 10 ma. with 12 vdc input. Applications include powering gas discharge tubes up to eight feet, plasma generation for burning and etching, output is easily converted to high voltage dc up to 25 kv and can be used for capacitor charging and a host of high voltage experiments. Always allow to operate for an hour or so and check for heat. Unit never should be uncomfortably hot to touch.

Use a 12 volt 1 amp dc adapter for full output or a 12 volt .5 amp for ½ output. You may use a 12 volt 1.5 amp for increased output intermittently for experimental and laboratory use.

www.socalnevadausa.com/servlet/the-1065/Deluxe-12vdc-Gas-Tube/Detail

Deluxe 12vdc Gas Tube Power Supply w/switch + Clips

Price: $32.88
This item is in stock

Quantity: 1 **Add To Cart**

Brief Description | Detailed Description | Specifications

Fantastic 12 to 15Vdc input High Voltage Gas Tube Power Supply with switch and clips... plus a spiral neon tube for special effects... All you need to do is supply the power supply. The unit can be used with batteries or an ac adapter... This power supply with power our...

I purchased the unit above, on ebay. A bit pricey, but you have a nice box-switch +2 clamps

www.imagesco.com/science/high-voltage/high_voltage_devices.html

Gas Tube Power Supply

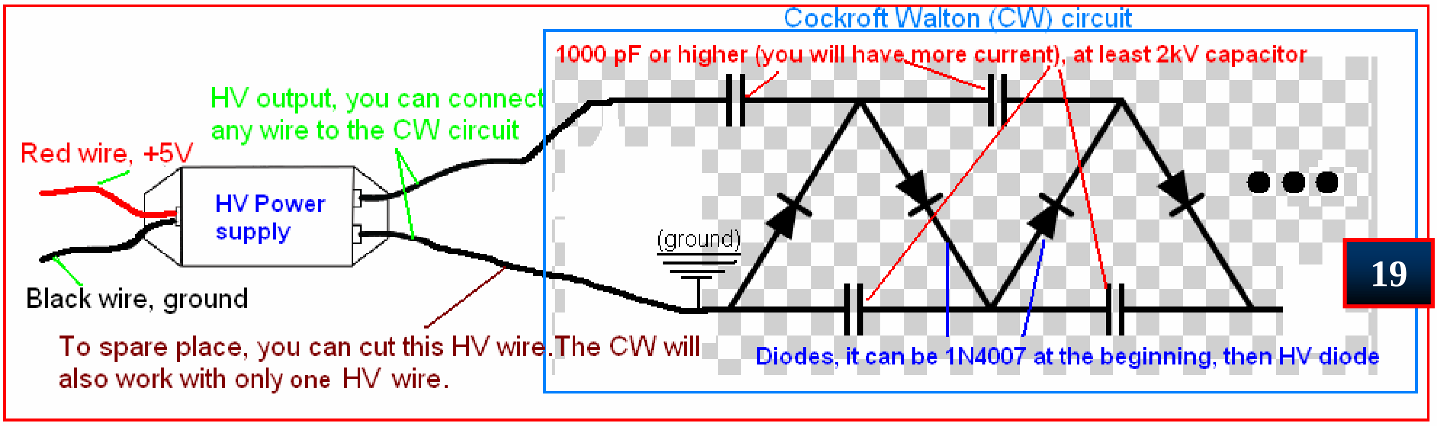
Originally designed to power neon displays, this high-voltage supply can power gas discharge tubes up to eight feet. It's rated at 2,000 Vac @ 10 mA. Input is 12 Vdc @ 1 Amp. Ideal for all kinds of high-voltage experiments, plasma generation, etching, high-voltage dc generators. 2.36" x 1.47" x 1.15" shielded case. Mounting flanges with holes on 3" centers. 18" silicon rubber insulated output leads. 6" color coded input leads. UL.

Specifications: Input: 12 Vdc @ 1 Amp (Suggested power source CAT# DCTX-1215). Output: 2,000 Vac @ 10 mA. Open circuit voltage: 3,000 Vac 30Khz. Short circuit current: 15 mA. UL.

HVPS-05 - $12.95

We will use an input of 5V instead of 12V (with 12V, it's slightly warm).

This power supply can convert 5V/12V DC into 2000V AC. But this voltage is not enough to clean all the ions, we will use a CW generator to have more voltage, and to lower the intensity so it will be safer to touch with hands the HV wire (don't try with the HV coming from the previous PSU).
We will make this circuit :



<u>Material needed for the CW circuit</u>

1N4007 1kV diodes


1N4007
100 pcs 1N4007 1000V 1kV 1.0A DO-41 Rectifier Diode New

Prix de vente :	2,82 USD
Quantité :	1
Sous-total :	2,82 USD
Délai de livraison estimé :	Varie
Taxe de vente :	(aucune)
Expédition et livraison :	Standard Flat Rate Shipping Service 0

Your best choice!

Buy them by 100 on ebay at a good price.

Capacitors, at least 2kV. 1000pf or higher

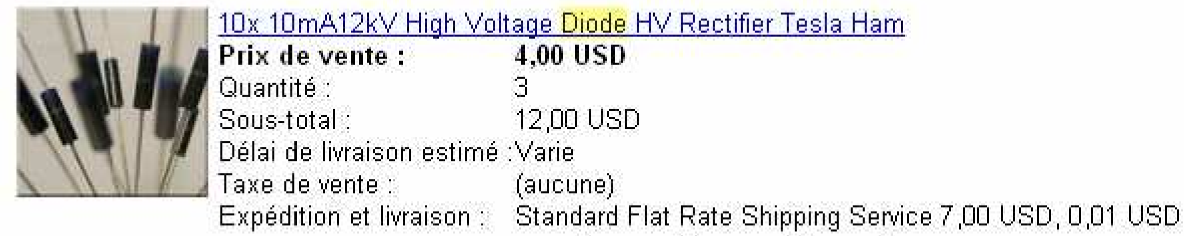

2KV 3300pF
100 pcs High Voltage Ceramic Capacitor 2KV 3300pF 332

Prix de vente :	4,50 USD
Quantité :	1
Sous-total :	4,50 USD
Délai de livraison estimé :	Varie
Taxe de vente :	(aucune)
Expédition et livraison :	Standard Flat Rate Shipping Service 4,95 USD, 3,00 USD

Your best choice!

Again, buy them by 100 …

High Voltage diodes 12kV

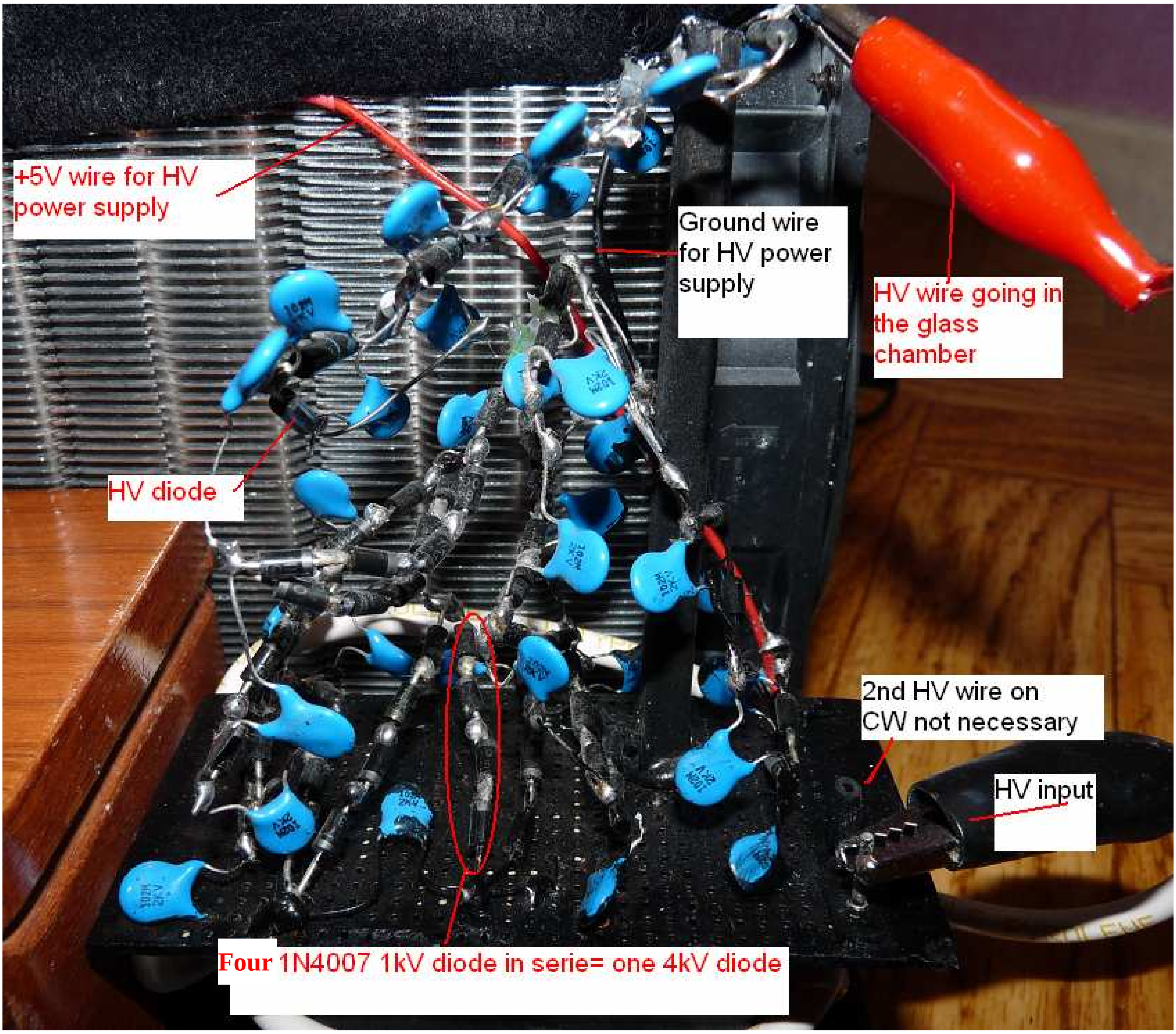

10x 10mA12kV High Voltage Diode HV Rectifier Tesla Ham

Prix de vente :	4,00 USD
Quantité :	3
Sous-total :	12,00 USD
Délai de livraison estimé :	Varie
Taxe de vente :	(aucune)
Expédition et livraison :	Standard Flat Rate Shipping Service 7,00 USD, 0,01 USD

12kV is a bit high, any HV diode above 4kV should be fine. We will need approx 20 of them.

Construction of the CW circuit

The CW circuit in picture 19 shows only 2 stages of multiplication (each stage multiplies the input voltage by a factor, the more stage, the more HV output). I don't remember how many stage I built, I would say 20 or 30.

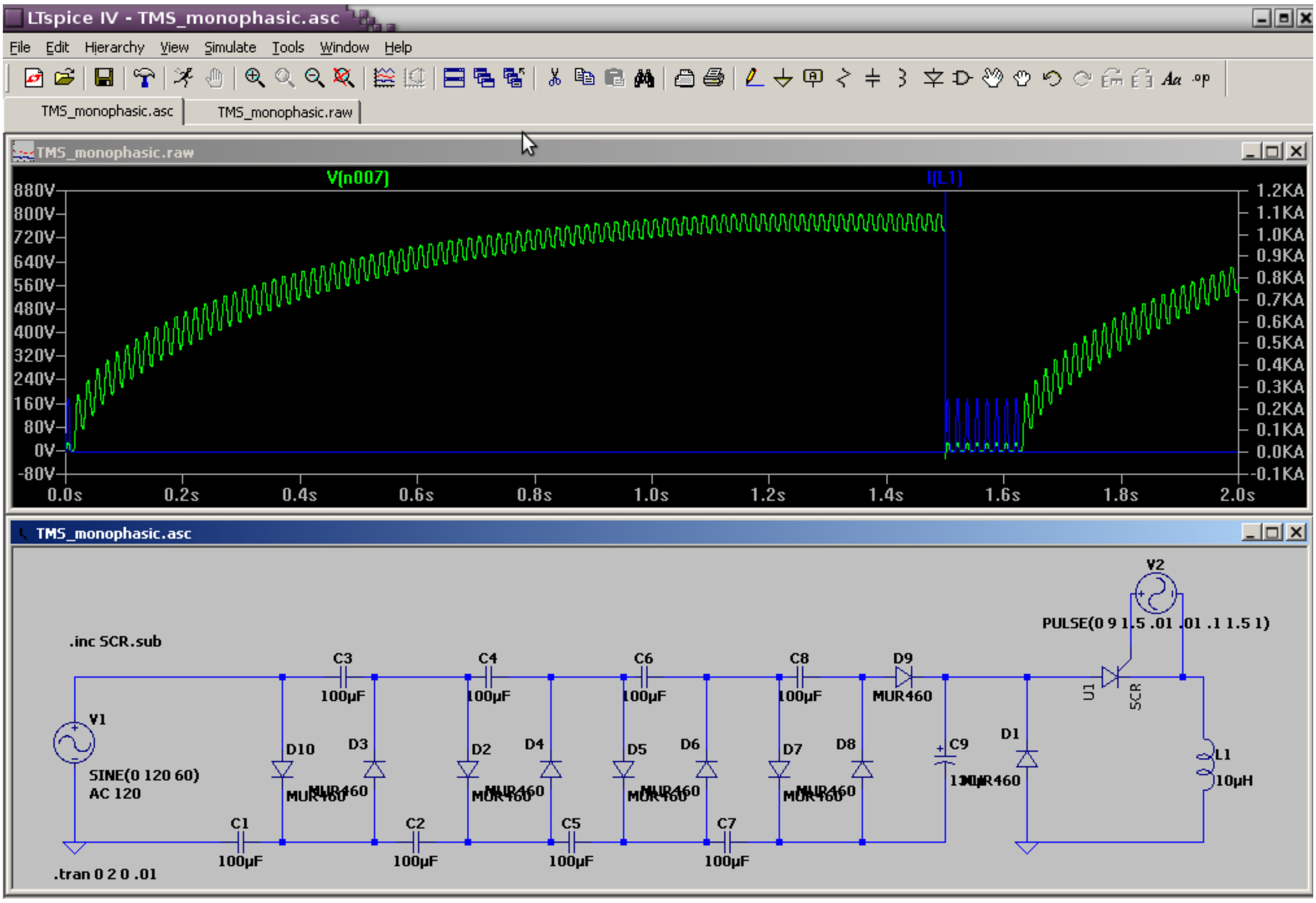


In the first stage of the CW, you can use one 1N4007 diode. The voltage input is in the range of the diode maximum voltage (1kV). But after some stage, we need HV diodes because the produced voltage is higher and the diodes may fail and let the current pass. Instead of using costly 12kV diodes, you can add several 1kV diodes in series to increase the maximum voltage. But after 4, 1N4007 diodes you should put one 12kV diode to spare time. If you have many HV diodes, you can use them in all the circuit. ***People always ask about the strange shape of the CW circuit. Try to make some Art with capacitors and diodes !***

Check in an obscure room if you don't have too much Corona Effect (a faint blue light). If it's the case, remove all the spike (near the welded connections), be sure that all stage are far from another (in order to low the loss by dielectric breakdown and corona).

Check if the HV power supply produce HV (use a neon lamp for example, or make a spark between the 2 output wires). Connect one HV cable to the CW circuit. You should obtain a tiny spark in the last stage.

You can use a free software, such as LTspice to simulate your circuit. You can construct it virtually in the program, then you will obtain the final voltage of your CW circuit. A powerful tool.

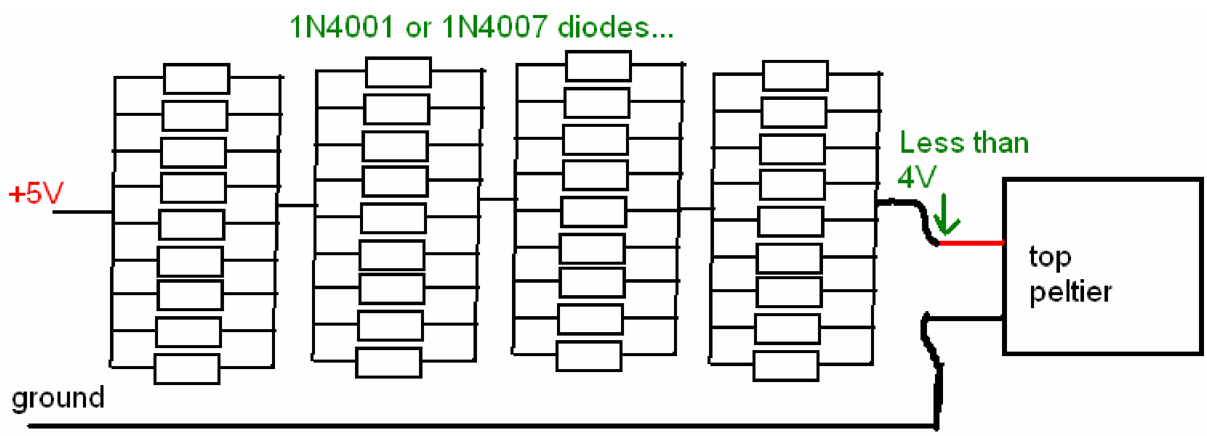


The circuit on picture is just an example, it's not yours

Part 7: Wiring

About the top peltier voltage

We choose 5V for the top peltier. But it could also work at 3,3V, because there is less heat produced at 3,3V than at 5V, so the bottom peltier can more easily absorb it.



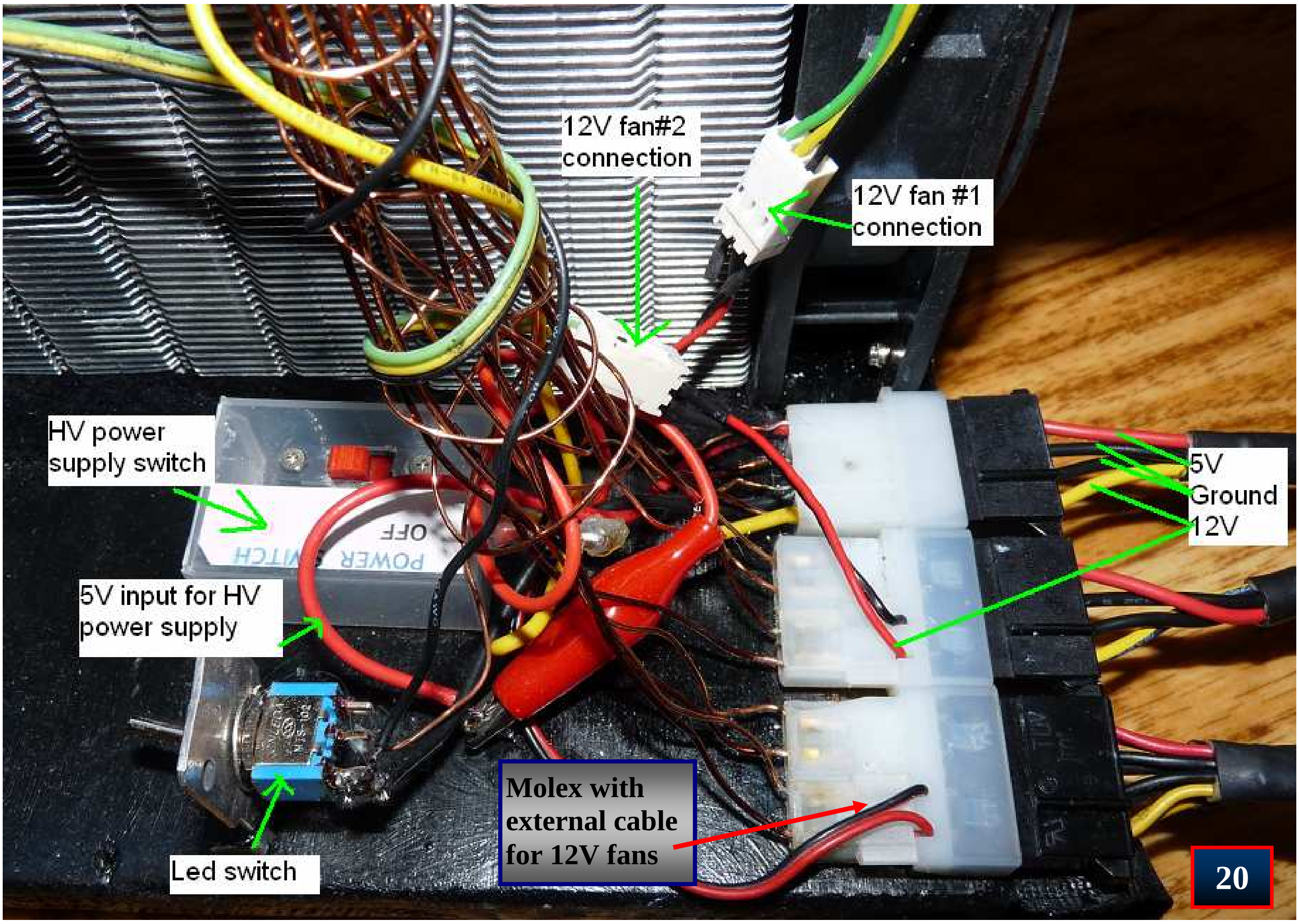
Unfortunately, there is no 3,3V on a molex cable (only on the 24 wires plug, orange wires). But you can obtain 3 or 4V with some diodes. Put them in parallel so they will share the current and won't overheat. Add them in series to lower the input voltage (one diode could lower the voltage by 0,6V, in reality it's less than that). You can check the temperature obtained with 5V, 4V and 3V. My best temperature that I obtained was at 4,2V. But I didn't had time to weld dozen of diodes. Remember that you have 3 top peltiers, so you will need 3 times the above diagram.
The V2 version was designed to work also with a 12V car battery. I used some 12V=>5V regulator but they become a bit hot, you can use diodes instead (you can see the regulators with the tiny fan page 5). The aim was to bring the cloud chamber to desert locations (influence of a granite soil on events) or in mountain (cosmic radiation is more intense with altitude), where no power plugs was available. It worked nice, but I never had the opportunity to bring my setup in such locations. It could be an interesting idea, to bring a cloud chamber to a camping, it could be romantic !

Wiring

You should have these wires which will be connected to the molex of the main power supply :

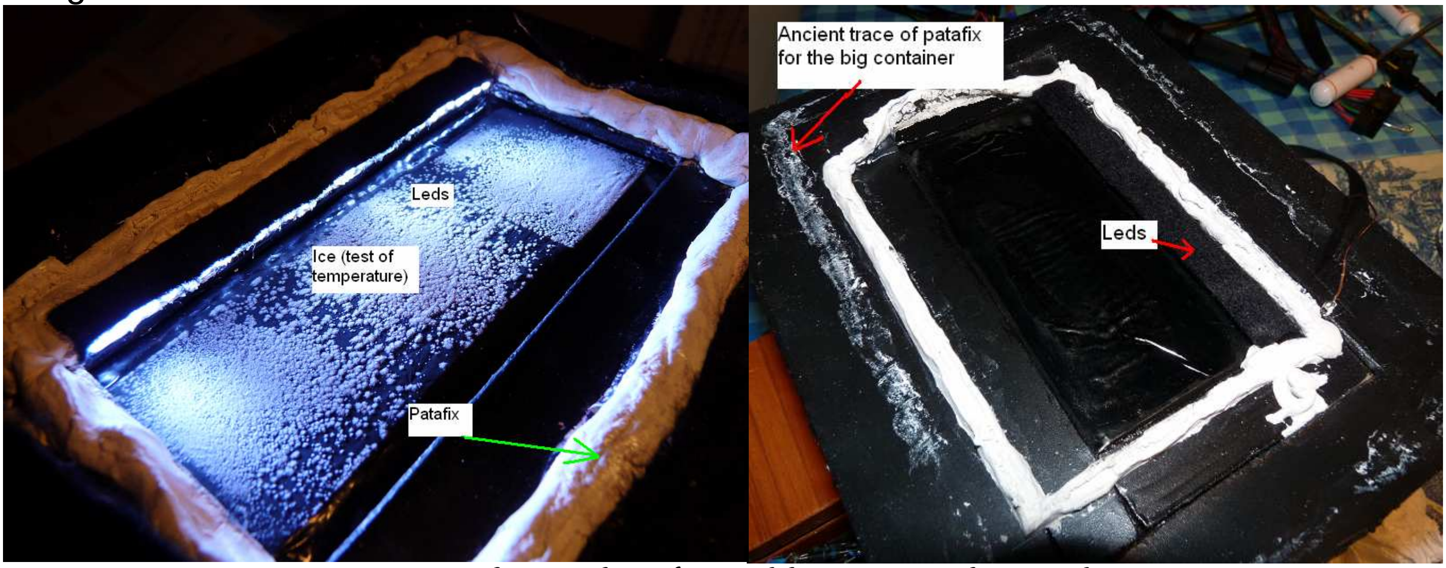
12V and ground for Leds.
5V and ground for HV power supply.
3x 12V and ground for bottom peltiers.
3x 5V and ground for top peltiers.
2x 12V and ground for the 2 fans.

You can weld these wires to the white female molex connector as shown in the picture below.



Part 8: Sealing the glass chamber and embellishment

Before sealing (in fact we can remove it easily) the chamber to the 2nd layer of wood, check if you have good temperatures with the plastic bag. Once you are sure that all is OK, put some strip of Patafix on the wood, according to the dimensions of the basis of the glass container.



Put some Patafix on the 2nd wood layer or on the wood pieces.

Then, for a first test of working, just place the glass chamber on the Patafix. Don't put too much pressure on the glass chamber to hold it tightly with the Patafix (REMENBER that the base that support the chamber is fragile : it's held with the plaster around the heatpipes !)
Use your finger to fill the holes, you should have no leakage in the interface glass/Patafix. Be sure that the chamber is horizontal (use a bubble level).

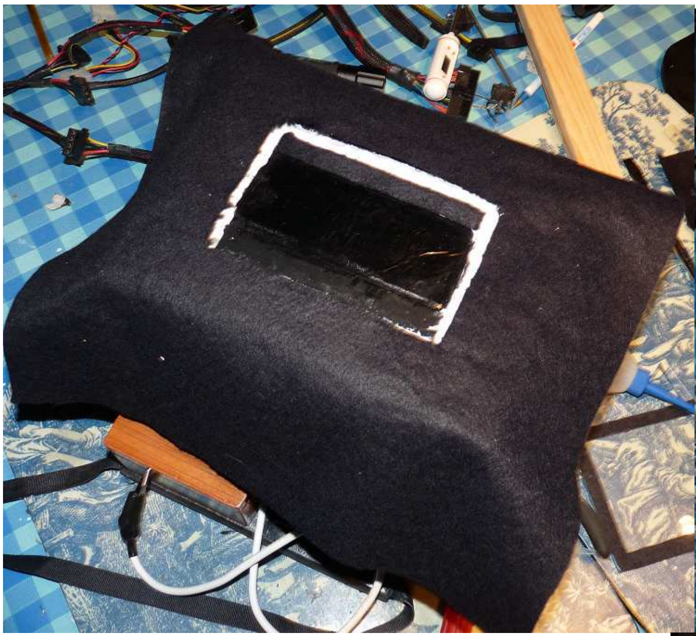
Once the chamber is fixed, you can make a test of working. Go to the Part 9 : Revealing the Invisible. If you see some particles, continue this part with the embellishment section.

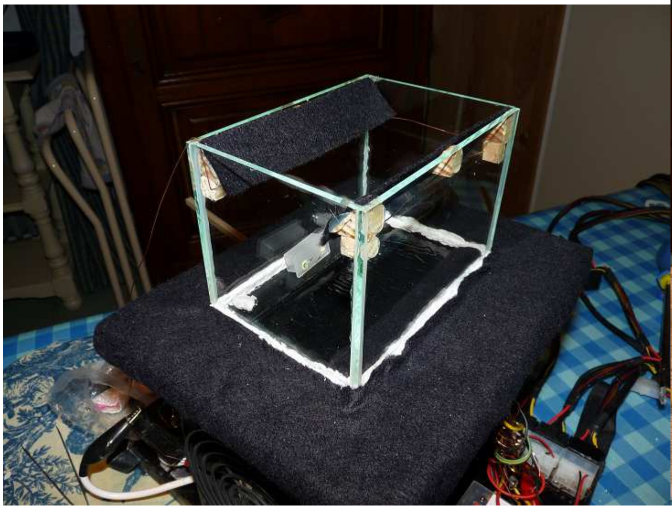
Embellishment

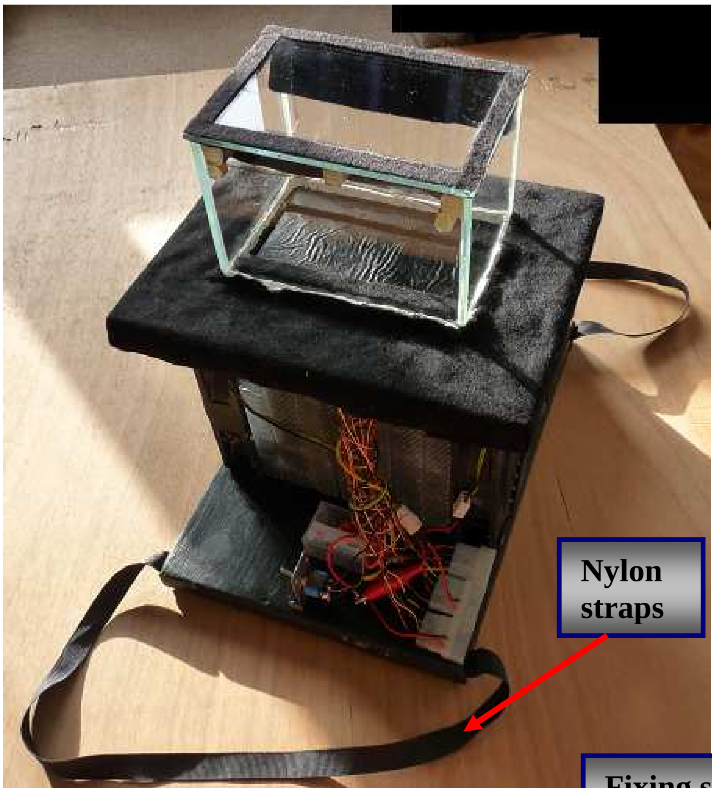
Put some discrete mark on wires to know were the cables will go (if you have to repair the setup in future). Use your creativity to hide the plaster, the wires and the Patafix : you can use the same black felt from the alcohol support, as I did. The first wood plate allows you to fix the felt with discrete staples. You can use cyanocrylate glue, but don't put too much otherwise the felt will become very hot (it's always reacting with glue).

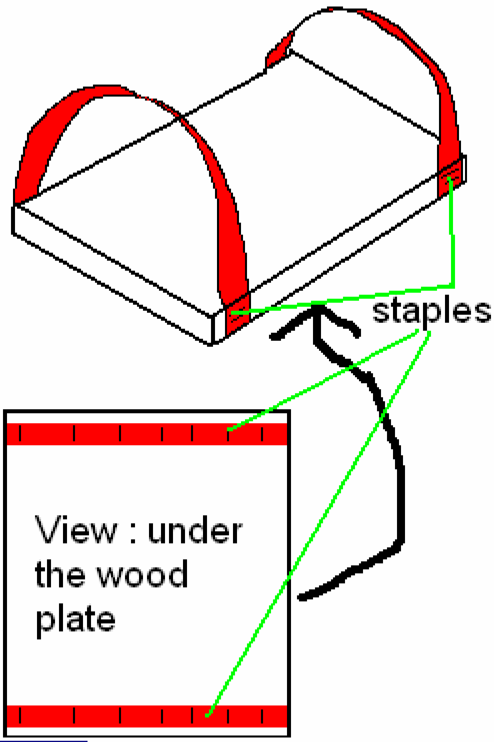
To manipulate the whole setup, you can staple some solid straps to the wood basis. See the next pictures.

Finally, you can find a nice tiny wood box to store the common sources. It's more useful that you may think.









Fixing some straps to displace the chamber

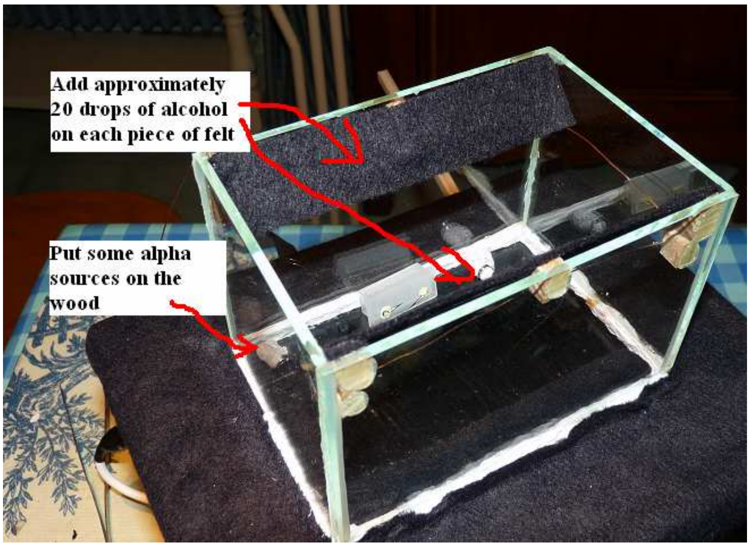
Part 9: Revealing the Invisible

First, buy this little container on dealextreme. The quality is very satisfying. I put some alcohol during weeks and I never had a leakage.

http://www.dealextreme.com/p/mini-container-bottle-with-funnel-5030

It's very easy to use the cloud chamber with this little container because it don't throw to much alcohol (only drop by drop) on the felts.

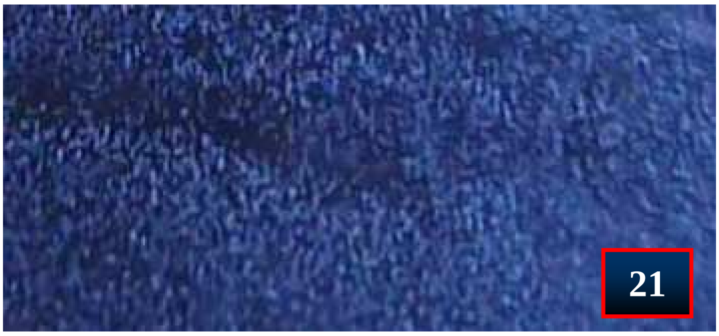
Starting



Put on each piece of top felt, 20 or 30 drop of alcohol. Put some alpha sources such as Am241 (best) or radium on the other piece of wood, in front of the leds. Viewing alpha particles is easy and depending on the quality of these tracks, we can set up the other parameters (electric field, quantity of alcohol).
High voltage should be off, put the clamp of the HV wire of the chamber, to the output of the CW circuit. Led should be on. Main supply is on, so fans are on.

After some seconds, you should see a mist (picture 21), it's the condensation of vapor into droplet. The density of droplet should be high, like the picture 21.

After 1 min, you should see near the Am241 source some very fat, big tracks. We will use the electric field to clean the unwanted ions to obtain a good quality of track. Put the clamp to the last stage of the CW circuit. Switch on the HV power supply.
The alpha tracks should jump from chaos.



If this short test is working, you can now remove the glass chamber, and cover the interaction surface with some Edding 8400 marker to have a better contrast. Be sure to not rub the surface with some minerals, the layer of marker is fragile. After months of use, the plastic bag may be scratched or damaged. You can change it easily by removing the glass chamber, the leds and the pieces of wood which left (I prefer to remove the piece of wood which hold the leds, instead of removing the led on the wood).

Part 10 : Troubleshooting

High Voltage

Touch with your finger the output of the CW generator, you should feel a slight shock indicating that the HV is working. You can make a spark between the final stage and another stage (the first) to see if there is HV on the last stage.
If the output is less than usual, check if you have some stages that are too close together (you can use a dark room to locate where some corona effect is present, remove the welded spike in this case). A capacitor may also have failed in a stage, put the HV input from the HV power supply to another stage. If you are in hurry, use only the high voltage power supply and put a HV diode on the output : you will obtain a DC high voltage.
Respect the polarity (the HV wire in the chamber should be a +) if you are using an other type of HV generator. Use a plastic cup, or a balloon, full of static electricity if you have no HV generator.

Temperature of Interaction Surface

You should have a temperature on the plastic in the -20/-40°C range. If you are watching a mist of alcohol, the temperature might be good, but check with a thermometer. If you obtain a change of temperature after months, it's probably a problem with the peltiers or thermal grease. (V2 version was stable during 6 month, but something moved during a transport and it was malfunctionning). This design allow you to repair "easily" the peltier system : remove the chamber and the patafix, remove the 4 pieces of wood, remove the plastic bag, and check temperature on peltier.
You can see rapidly if the temperature of the surface is good : just blow some air on it, ice should form nearly instantaneously. You can check also with an ampmeter the intensity going in each peltier. 12V TEC should get 5 or 6A, 5V get approx 2A.

Obtaining tracks

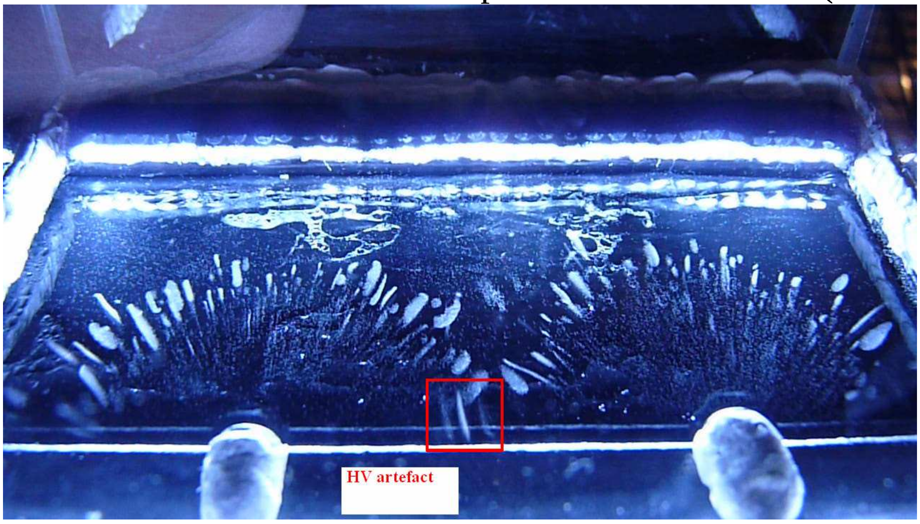
Temperature, HV and luminosity are critical parameters. They should work without problems. Anyway, it could be difficult to obtain some tracks because this experiment is dependant of the outside conditions (temperature of room, ventilated place) which are subject to change. If your room is full with a public, you have to take this into account : think about the infrared light generation and the absorption of theses wavelenght by the dark interaction surface : don't perturb too much the equilibrium in this case. The hot air that you introduce in the chamber (when you put a radioactive source) is increasing the time needed to have a newer equilibrium.

Don't put too much alcohol on the felt. If there is too much alcohol, you will produce a lot of vapor and it will be difficult to have stable conditions because of the convection (there will be some distorsion on track too). It's an important parameter often underestimated.

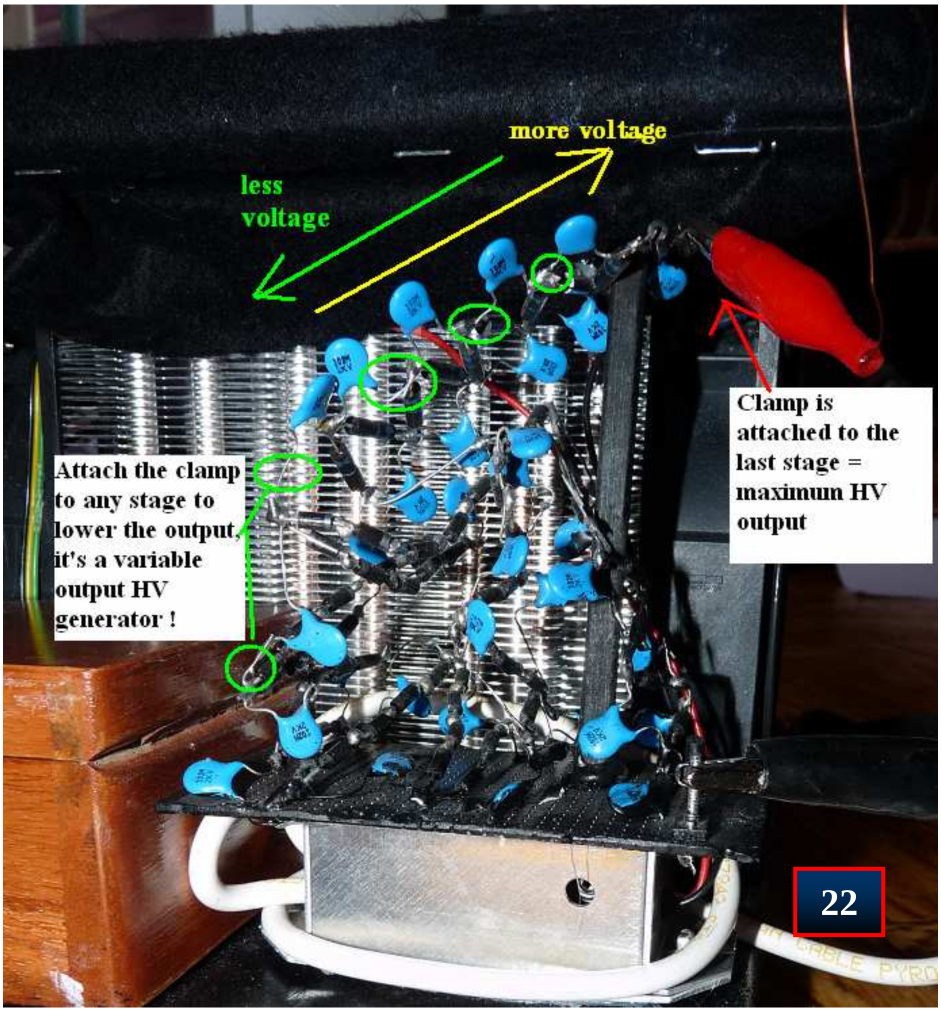
Check the formation of the mist. When there is a leakage between the basis of the glass chamber and the patafix, you could see some stream of vapor which goes near the leak. Be sure that the basis is sealed so that no air is going to the chamber. You can place a book on the lid of the cloud chamber to reinforce the sealing (don't put too much mass, the plaster is fragile).

When there is too much alcohol, you will have to wait a longer time to see the particles. In normal condition, this cloud chamber can display track in less than 2 minutes.

When the cloud chamber needs more alcohol, you can see that the background mist is less dense than usual. Add some drop of alcohol to the felt (20 for each felt should be fine).



When there is too much electric field, you will see some fountain of alcohol condensation (picture in left). Reduce the electric field by attaching the clamp to an other stage of the CW generator (pic. 22 with two Am241 source).



Sometimes, there is too much electric field. Switch off the HV power suppy, and discharge the capacitors of the CW circuit by touching the last stage of the circuit.

Note : you can touch the HV wire because the intensity is in the microamps range, as the circuit is built with 1000 pf capacitors ! if you put bigger capacitor, check with Ltspice the final intensity output ! you can touch the HV from the CW generator, but not the HV from the HV power supply ! you must have a dry hand without humidity if you want to touch the CW circuit. Otherwise you will better feel the shock than usual.

Then, put the HV again when the equilibrium is reach. By equilibrium, I mean the instant when the interaction surface seems to have big, spreaded track (with an alpha source), or when you can see that the mist seems to "boils" near the sources.

Alpha track are the reference. They should be thin. The thickness of these track depend on the electric field. I would say the more electric field, the thinier the track, but you will see too much

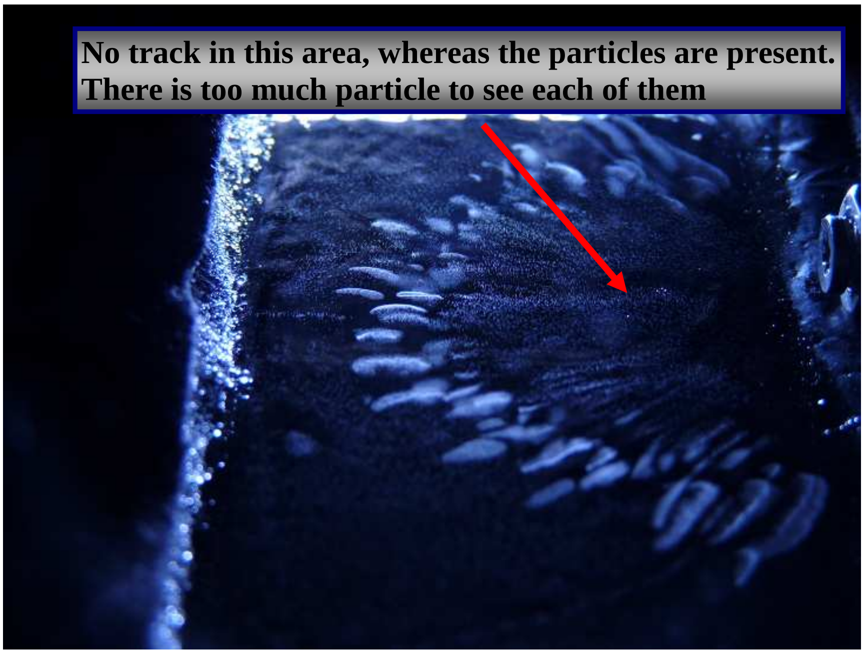
HV artefact. Play with the output of the HV to know which CW stage performs the best (it depend on external conditions too).

Remenber that you need to wait until the thermodynamic equilibrium is obtained. You have to be patient if you perturb this equilibrium, by introducing radioactives sources in the chamber.

After dozen minutes of use, you will see some liquid alcohol which condensed on the surface. You have to pump this liquid alcohol with a syringue (use a DX thermal paste syringue) and reinject it into the felts. You must'nt have to much liquid alcohol in the bottom of the chamber because it can be in contact with the wood and take too much energy from the peltiers. If you painted the surface with some Edding 8400, try to pump the alcohol not on the surface, but on sides.

Part 11 : Spectacle

Here is some advice to make a show in front of the public, or just for your eyes.
You need to interest people in the first sight, they won't have to search for particles. So you will start with alpha sources.


No track in this area, whereas the particles are present. There is too much particle to see each of them

Am241 is easily obtenable from ionization smoke detectors. If you put an Am241 source, you will only see the end of tracks. Their is too much nucleation site created near the origin of the source because of the presence of many particles : we can't discriminate each track so we see a "boiling" area. (picture in left).

To see a complete track from an Am241 source, you have to put some patafix on the source : no alpha will pass. Make a very tiny hole in the patafix to let some particle pass. You will see complete track because there is less particle, saturation won't appear.

You can place in the chamber an uncollimated source of Am241, and another with a tiny hole. People will show a complete alpha track, and the numerous particle emitted by the naked source of Am241. You can speak about the range of alpha particles in air : 3 or 4 cm for 5 MeV particles, its effect about health, where does Am241 come from…

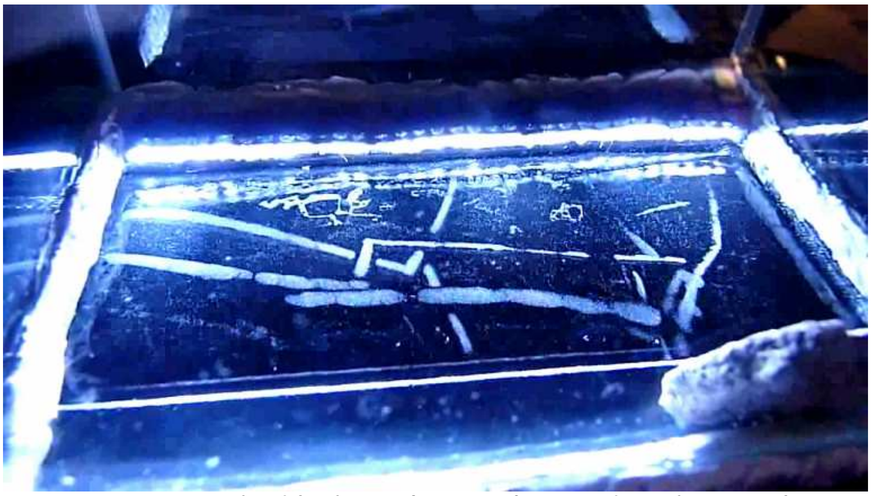

Pani's radium with some patafix on a support

Radium hands are a good example of sources. You can find some on ebay, or you can contact panirai@iafrica.com from vintagewatchmarket.com. He have many of radium hands to sell, at a very good price (nearly 10-15$ for 2 high activity hands). They emit less alpha than Am241 (hopefully for watch holders !)

To continue the spectacle, you can put a tiny piece of uraninite or pechblend in the chamber. It's very impressive to see that the stone emits "track" (origin is the source). As it's a natural stone, the public accept it more easily than Americium coming from nuclear waste.

The production of radon with uraninite is generally weak.

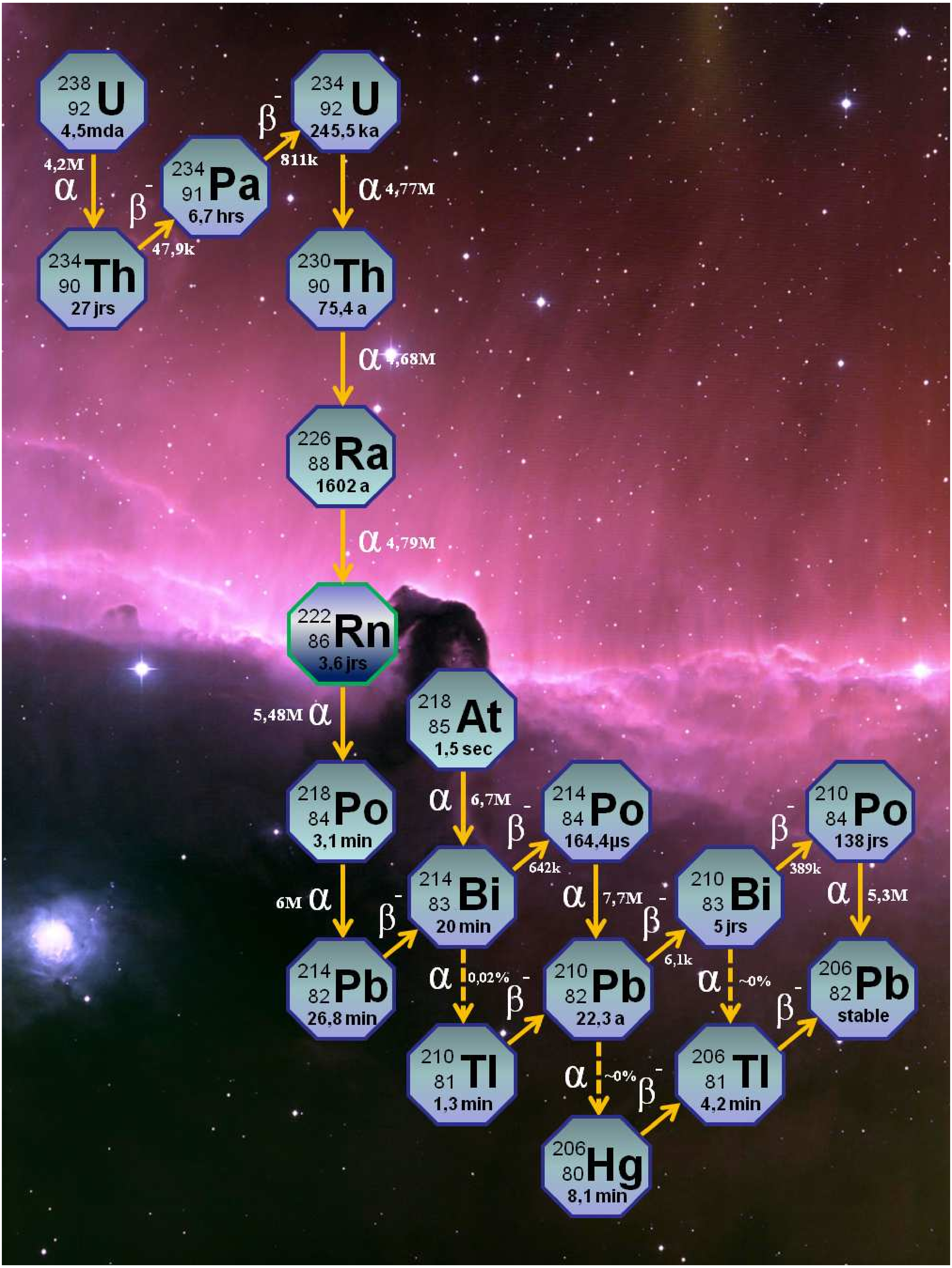
When you have finished with alphas source, you can go further with some thorium-based mineral, such as thorite which emit thoron, a gas, producing spectacular double track. There is other interesting mineral such as samarskite, or thorianite. Check ebay.com or get them on minresco.com



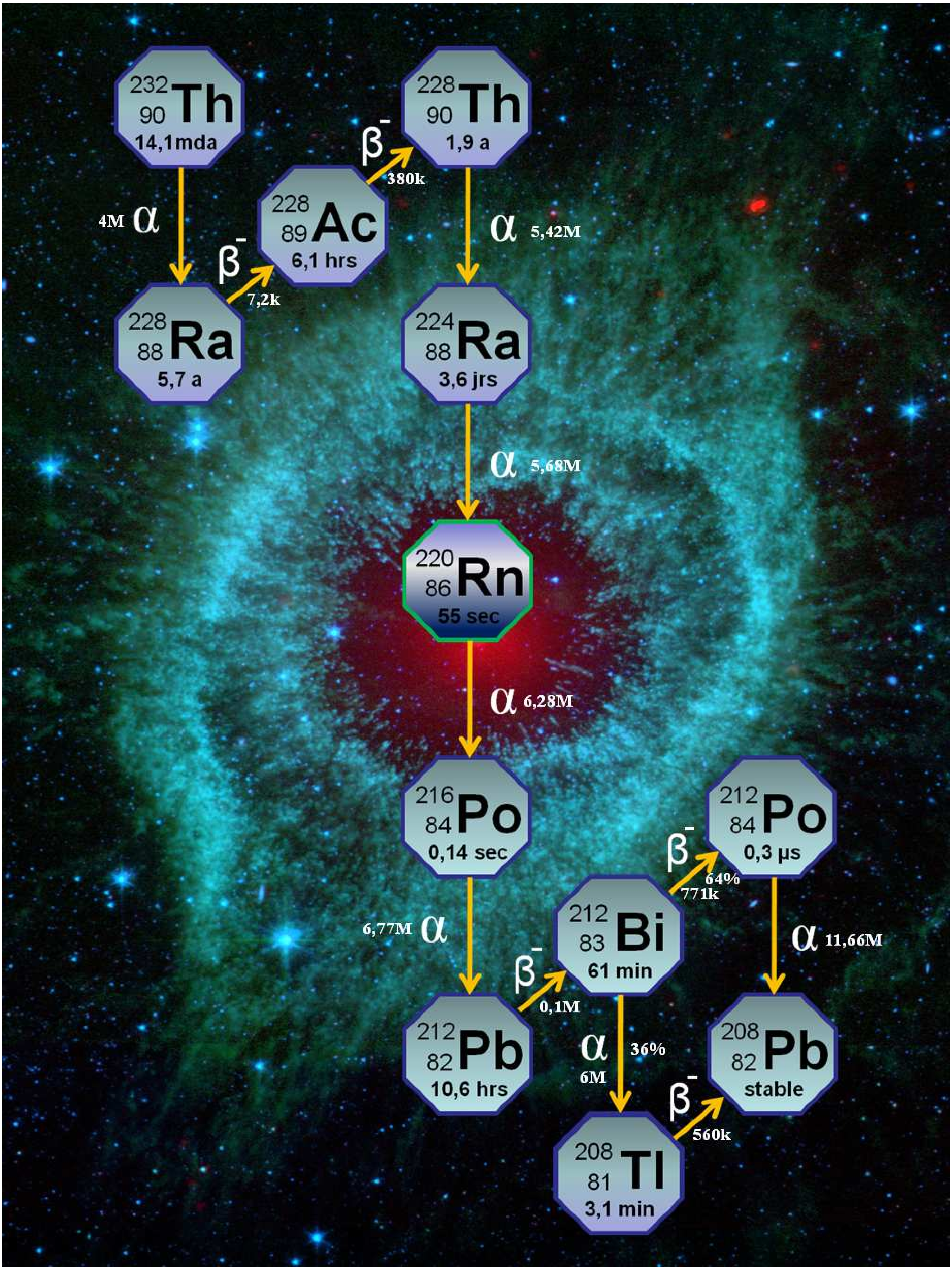
Fantastic double decay from a thorium based mineral. *Right : thoron gas introduced in the chamber*

In left, some mineral from minresco.com. The encapsuled thorite was probably the most incredible deal. The production of thoron is enormous (picture 23) !

To know what is the origin of this L or V shape, look at the decay chain below :



238 92 U 4,5mda
234 92 U 245,5 ka
234 91 Pa 6,7 hrs
234 90 Th 27 jrs
230 90 Th 75,4 a
226 88 Ra 1602 a
222 86 Rn 3,6 jrs
218 85 At 1,5 sec
218 84 Po 3,1 min
214 84 Po 164,4µs
210 84 Po 138 jrs
214 83 Bi 20 min
210 83 Bi 5 jrs
214 82 Pb 26,8 min
210 82 Pb 22,3 a
206 82 Pb stable
210 81 Tl 1,3 min
206 81 Tl 4,2 min
206 80 Hg 8,1 min
4,2M α
β- 47,9k
β- 811k
α 4,77M
α 4,68M
α 4,79M
5,48M α
6M α
β-
α 6,7M
β- 642k
α 7,7M
α 0,02%
β-
β- 6,1k
β- 389k
α 5,3M
α ~0%
α ~0%
β-
β-



232 90 Th 14,1mda
4M α
228 88 Ra 5,7 a
β- 7,2k
228 89 Ac 6,1 hrs
β- 380k
228 90 Th 1,9 a
α 5,42M
224 88 Ra 3,6 jrs
α 5,68M
220 86 Rn 55 sec
α 6,28M
216 84 Po 0,14 sec
6,77M α
212 82 Pb 10,6 hrs
β- 0,1M
212 83 Bi 61 min
β- 64% 771k
212 84 Po 0,3 µs
α 11,66M
α 6M 36%
208 81 Tl 3,1 min
β- 560k
208 82 Pb stable

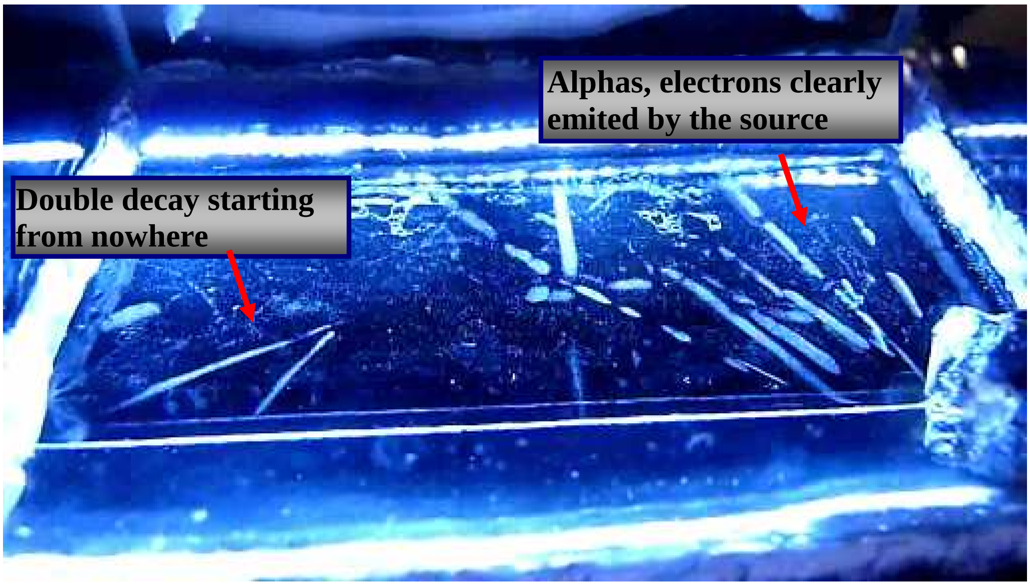
Origin of the "V" shape coming from Thoron decay

It exist four decay chains. U238, Th232, Np237, U235 are the natural parents of their chains. Np237 and other nuclides (when $Z>Z_{Fe}$) were created with the remnant of supernovae, through the nucleosynthesis. These radionuclides then fed the earth at its creation, and we are now excavating these nuclides for our energy. But they have all the same origin, and are maybe several times the age of the Earth old.

Nowadays, we can't find in nature the nuclides which have a "short" half life such as Np237 ($T_{1/2}$ = 2,14 million years). As the age of the Earth is about 4,5 billions years, all these short half life nuclide are now extinct, only their daughter can exist nowadays if they have a long half life. It's not the case for the Np237 decay chain, and we won't find theses nuclide in nature.

Isoptic composition of uranium is 99,3% U238 and 0,7% U235. The proportion of U235 is so weak that this decay chain can be ignored (unless if you are making some gamma spectrometry).

So, there is 2 decay chains where we can find all the decay daughter in a radioactive mineral, the Thorium 232 and Uranium 238 family. The proportion of Th232 and U238 in a mineral will give different observations, in the first case we will see some double decay from the thoron (Radon220) and in the last case, only one alpha track coming from the disintegration of radon 222.



Samarskite mineral in the cloud chamber

When you place in the cloud chamber a mineral which contain more thorium than uranium, you will see :

- Alpha and electron where their origin is the mineral
- More double alpha decay than singles which can appear in any point on the interaction surface.

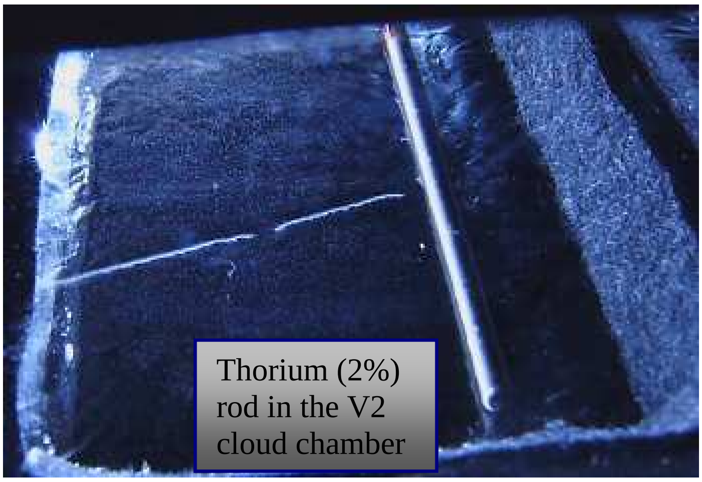
The alphas and electrons escaping from the mineral are emitted by the disintegration of the nuclides of the 2 decays chain.

The double decay (or single one for Radon 222) are produced by the successive disintegration of Radon220 (Thoron). A step in the Th232 decay chain is the production of Ra224 in the mineral. When this radium decay, it produce Radon220 which is in a gaseous form. If the gas can escape from the porous mineral without decaying, it can fill the glass chamber and start to decay in any point of the surface. Thoron have a short half life : 55 seconds, decaying to Polonium 216 which have a lesser half life : 0,14 sec. The Polonium 216 then decay with the emission of an alpha particle to Lead 212, beta emitter with $T_{1/2}$=3,1min.

So the double alpha track that we could see in the chamber come from the disintegration of Thoron into the unstable Polonium, which give another alpha to produce Lead 212. We see the both alpha coming from these "simultaneous" double decay. We can't see the electron emitted by the Lead 212 because the half life is longer. Sometimes you can see that the 2 branch of the V shape is not equal in length. The 2 alphas emitted don’t have the same energy.

With an uranium based mineral, we can see only one alpha track, coming from the decay of Radon 222 into Polonium 218. But in this case, the Polonium 218 is more stable than the Po216.

Back to the Spectacle

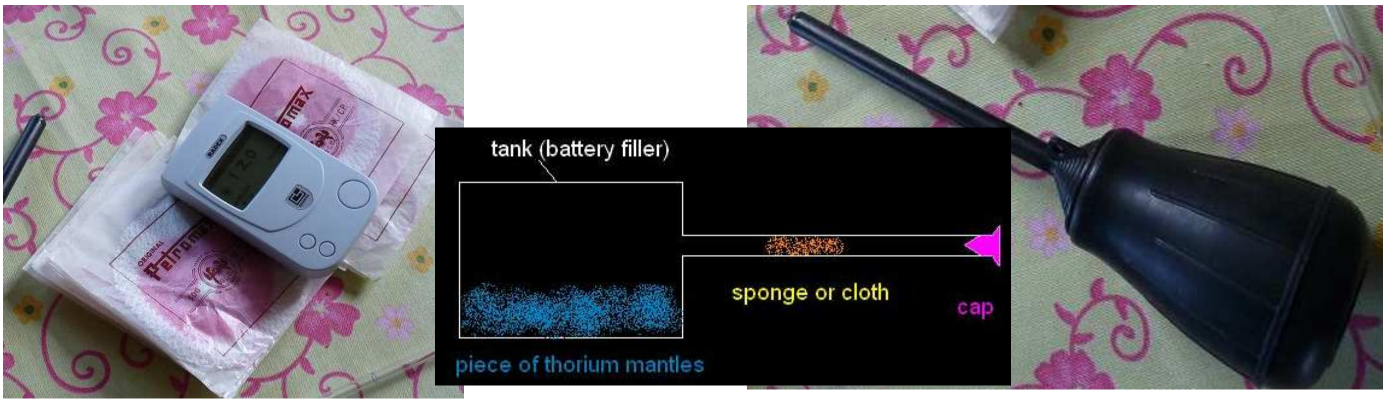

Thorium (2%) rod in the V2 cloud chamber

Before saturating the chamber with thoron or radon, you can use some thorium doped welding rod to see the alpha and electron emitted by this weak source. You will learn that the highly radioactive stuff (artificial or natural), are not the most interesting to see because the chamber will saturate (remenber the observations with a naked source of Am241). You will find these thorium rod on ebay (they are more and more scarce).

If you are patient you can put some KCl salt in a tiny plastic bag, and see the "possible" electron (1,46 MeV) emitted by the decay of K40, but the half life is enormous (1,27 Billion years) and the isotopic composition very low (0,0117 %), so you will need a lot of KCl to have a descent amount of K40 nucleus !

If you need a good source of thoron, you can buy some thorium mantles. They are more and more rare nowadays, but you can find some on

http://www.pelam.de/product_info.php?cPath=30_52_82&products_id=401



Pelam.de thorium mantles and a Radex 1706 *Battery filler containing some mantle (8 is fine)*

You can cut them and place them in an enclosed container, such as a car battery filler. The thoron will accumulate in the tank, then you can throw the gas in the chamber. But you need to introduce it very gently in order to keep the equilibrium. Open the lid to insert the funnel and press gently the container to put some Thoron. The spectacle will remain some minutes (several period of gas).

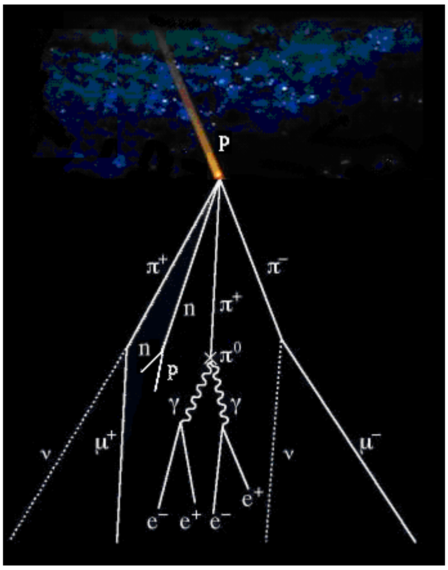
There is many other historic item which were (and still are) radioactive, but nowadays they are difficult to find. A good site to pick up some idea is periodictable.com from Theodore Gray.
You will find also some trinitite specimens on minresco.com. They contain a slight radioactivity (Plutonium) and produce few tracks in the cloud chamber. It's more to have an historic mineral than making a demonstration source in the chamber for the public.
Read this publication : http://www.ecolo.org/documents/documents_in_english/Trinitite-JER-2006.pdf
You can check my videos on youtube about some minerals to have an idea about the interactions displayed.

http://www.youtube.com/watch?v=T8A1UAuxp7g

Viewing the natural and cosmic radiations

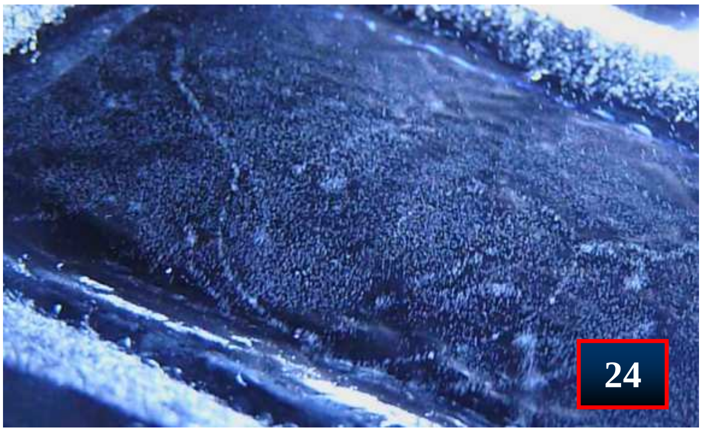
You will need a strong Neodymium magnet to identify the charge of particles. The magnet that I used in the V2 version was a 4x4x2cm N42. A stronger grade or a bigger magnet is much more interesting than my "tiny" magnet. I saw on ebay some 4x2x1 inch at 70$, so nearly all the interaction surface will be subject to a magnetic field !
There is several Java applets to play with the strenght of magnetic field to deflect the particles. You can also measure the momentum of theses particles with the radius of curvature.

http://www.kcvs.ca/site/projects/physics.html

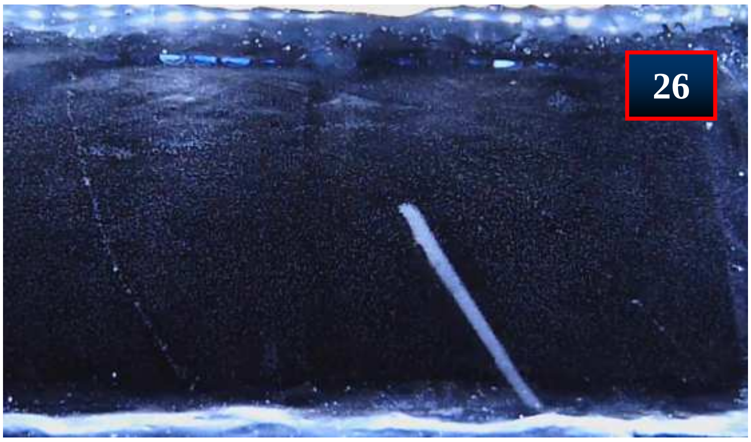


So to view the natural radiations, you need ... no sources ! except a room build with concrete (it contains some nuclide from the Th232, U238 and K40 chain), and some luck with cosmical showers. The electric field must be set to its maximum, where the first fountain of condensation starts to appear. Be sure that no excessive amount of radon or thoron remains. Then you have to wait for events. Some examples are presented below (from the V2 version) :

24: A track enter in left in the cloud chamber and is not really deflected by the magnetic field, due to a high mass. Then it "kinks" and is deflected to left by the magnetic field : it's now a lighter particle, a positon which in fact come from a μ^+ decay. The two neutrino are not detected.



About 10,000 muons reach every square meter of the earth's surface a minute. Traveling at relativistic speeds, muons can penetrate tens of meters into rocks and other matter before attenuating as a result of absorption or deflection by other atoms. Paralell track of muons come from the same cosmic ray shower .



25: An energetic beta particle (often electron) is knocking orbiting electron out of one atom. We can see the original electron deflected with an ejected electron at a few keV of energy. This event is called a “Delta ray”.

26: Ionization of an atom with an incoming muon or electron (delta ray). Sometimes a big ionizing track appears in the chamber : it may be generally a radon decay, or perhaps a nuclear reaction with a neutron. Some recoil protons ejected by neutron may be observed with thinier track than alpha particle**.**

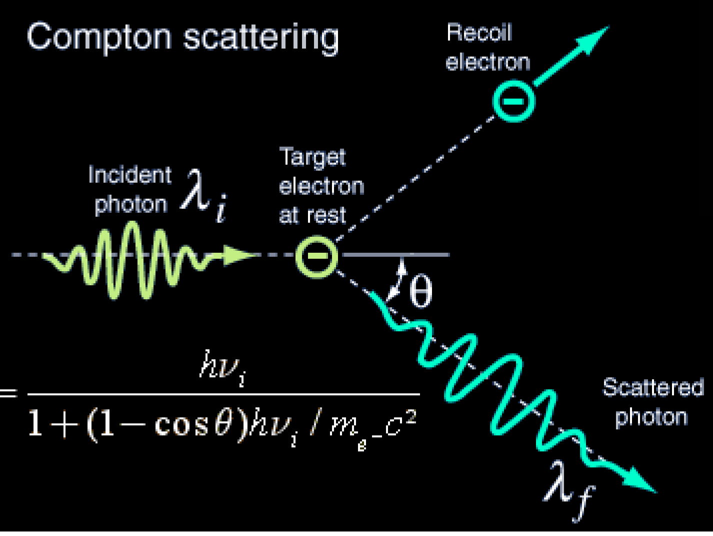
27: The annihilation of a gamma produce a pair of beta particles. The magnetic field, which go into the paper, deflect the positron towards left (The radius of curvature is given by the Lorentz’s Force by $R=mv(Bq)^{-1}$).
But something happen, mid flight : Strangely, the positron start curving in the opposite direction as if it had suddenly become negatively charged. What has happened is that the positon has run head-on into an electron, transferring all its momentum to that electron. This can only happen if the mass of the positon is equal to that of the electron. The positon that stops would eventually have been annihilated.

Some reminders :

Cosmic ray : **90 % p, 9% alpha, <1% e-, γ** **Energy > 10^{15} eV**
A collision of an incident cosmic proton with a nuclei of atmospheric gases produce a “shower” of particles with the production of neutrons, pions π and kaons κ which quickly decay into Muons μ (1936) :
Because muons do not interact strongly with the atmosphere and because of the relativistic effect of time dilation, many of these muons are able to reach the surface of the Earth.
Lifetime : 2.2 μs Mass : 207 times electron’s mass

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu, \quad \mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

Due to their greater mass, muons are not as sharply accelerated when they encounter magnetic fields, and do not emit as much Bremsstrahlung radiation. They lose their energy only with ionization, and thus penetrate matter far more deeply than electrons.



$$h\nu_f = \frac{h\nu_i}{1+(1-\cos\theta)h\nu_i / m_{e^-}c^2}$$

Photoelectric or Compton effect : In air, gamma do mostly photoelectric interaction under 30 keV, compton above 30 keV and pair creations above 10 Mev.

Alpha particles : are He^{2+} nucleus, 7350 times more heavier than electron so are not easily deflected by electromagnetic interaction. Due to their mass, their speed is lower and because of the high charge, alpha particle lose rapidly their energies with ionization, thus are easily absorbed by materials. Kinetic energy range from 3 to 7 MeV. For an alpha particle of 5 MeV (from Am241) : 15.000km.s^{-1}, 5000 ionization per µm in water, maximum range of 50µm in water or 4 cm in air.

Bêta particles : are electron or positon which have the same mass but opposite charge. Their speed is close to the speed of light (1 Mev~0.941c). Due to their little mass, they are easily deflected by electromagnetic interaction. Because they can easily accelerate when they come close to an atom, they lose most of their energies with Bremsstrahlung. They produce less ionization than alpha particle due to their monocharge, thus have a higher range. Positron when thermalized, annihilate with an electron to form gamma rays. For a bêta particle about 2 MeV :
Range : 6 meters in air, 1 cm in water, 3 mm in aluminium, 10 ionizations per µm in water.

241Am decay : Americium 241 is a by product of the fission of 235U and decay into 237Np with the emission of 5.5 Mev alpha particles, 60 keV gamma rays and few keV conversion or Auger electrons . It has a half life of 432.2 years. The amount of 241Am in the picture is about 1µCi. The end of alpha track is often dense due to the "Bragg" peak.

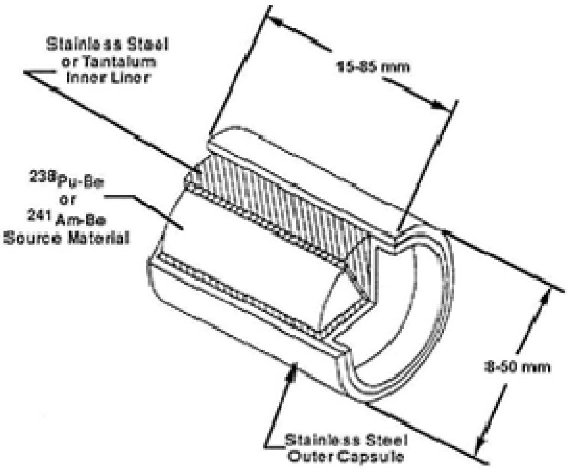
Gamma rays : They are not detected in a cloud chamber because these "particles" which are also electromagnetic radiations, are neutral and don't loose enough energy to give nucleation sites. They can interact in matter with Photoelectric, Compton, or Pair creation effect and produce secondary charged particle which are detectable. Photoelectric effect is the transfert of all the gamma's energy to an electron which is ejected from an atom. Compton effect is the inelastic scattering of a gamma with an electron who are ejected. When gamma energy is above 2x0.511 keV, the gamma can disappear and form a pair of bêta particles. For a gamma of 1 MeV, it need 900 meters of air to absorb 50% of the gamma, 5.1 cm of concrete, or 0.85 cm of lead.

Capture of events, further investigation…

To take pictures of events, you need a camera, with some options : sensibilty ISO, aperture, HD format. There is some positions where the viewpoint is better (for the camera and for eyes) : in front of the led, just a little above (don't saturate the camera with the high luminosity of led). Take movies of the events and use a tripod and a high space memory card. My camera was a Lumix FZ28, but now there is other camera which can perform better.

Building a neutron source

Certain isotopes undergo spontaneous fission with emission of neutrons. The most commonly used spontaneous fission source is the radioactive isotope californium-252. Cf-252 and all other spontaneous fission neutron sources are produced by irradiating uranium or another transuranic element in a nuclear reactor, where neutrons are absorbed in the starting material and its subsequent reaction products, transmuting the starting material into the Cf-252. Only about 3% of the decays of Californium-252 are by spontaneous fission, but even so, Californium-252 is over three orders of magnitude more efficient at neutron production than an AmBe source of the same activity. Californium-252 produces an average 2.3 MeV (6 MeV maximum) neutron as compared to the average 4 MeV (11 MeV maximum) AmBe neutron. When purchased new a typical Cf-252 neutron sources emit between 1×10^7 to 1×10^9 neutrons per second but, with a half life of 2.6 years, this neutron output rate drops to half of this original value in 2.6 years. The price of a typical Cf-252 neutron source is from $15,000 to $20,000.



Neutrons are produced when alpha particles impinge upon any of several low atomic weight isotopes including isotopes of lithium, beryllium, carbon and oxygen. This nuclear reaction can be used to construct a neutron source by intermixing a radioisotope that emits alpha particles such as radium or americium with a low atomic weight isotope, usually in the form of a mixture of powders of the two materials. Typical emission rates for alpha reaction neutron sources range from 10^6 to 10^8 neutrons per second. Usual combinations of materials are plutonium-beryllium (PuBe), americium-beryllium (AmBe), or americium-lithium (AmLi).

9/4Be + 4/2He =>12/6C+ 1/0 n

AmBe sources contain an intimate mixture of americium oxide and beryllium metal powders compacted at high pressure. The ratio of beryllium to americium oxide is in the range of 2:1 to 20:1 depending on the design and desired neutron output

CATALOG OF NEUTRON SOURCE MATERIALS

RADIOACTIVE MATERIAL	SYMBOL	HALF LIFE	NEUTRONS PER CURIE Per Second	NEUTRON ENERGY-MEV (Ave.)	(Max.)	OTHER EMISSIONS (Type) (mev)	GAMMAS PER CURIE Per Second	GAMMA RADIATION (r/h/m/c)
Polonium-beryllium	Po^{210}-Be	138d	2.5×10^5	4.2	10.87	α 5.3		.0001
						γ .80	1.54×10^6	
Californium	Cf^{252}	2.65y	4.4×10^9	2.3	6	α 6.11		
						γ .2-1.8	2.4×10^{10}	.15
Americium-beryllium	Am^{241}-Be	458.1y	2.2×10^6	4.0	11	α 5.44(13.8%) 5.48(85%)		
						γ .017(48.19%) .026(3.52%) .043(.08%) .060(48.19%) .099(.026%)	13.7×10^9 10.0×10^8 22.2×10^6 13.7×10^9 7.4×10^6 2.8×10^{10} (total)	.001
Radium-beryllium	Ra^{226}-Be	1,620y	1.5×10^7	3.9	13.08	α 4.8(94%) 4.6(6%)		
						γ .19 .2-2.2(daughters)	1.5×10^{11}	.974
Plutonium-beryllium	Pu^{239}-Be	24,400y	2.2×10^6	4.5	10.74	α 4.89(75%) 4.85(25%)		
						γ .017(99.36%) .039 (.07%) .053(.24%) .060* .1 (.18%) .124(.06%) .384(.08%)	10.7×10^8 7.4×10^5 25.9×10^5 20.25×10^5 9.25×10^5 5.6×10^5 10.8×10^8 (total)	.011

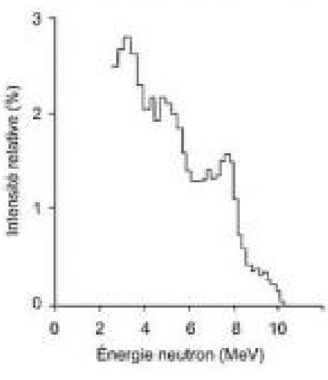
*Americium daughter build up with decay of plutonium

Les sources de neutrons américium-béryllium

Une source d'américium-béryllium est constituée d'un mélange du radio-isotope américium-241 (émetteur α d'énergie 5,44 MeV) et d'une poudre de béryllium-9 en vue de produire la réaction nucléaire suivante :

$$^{9}Be + \alpha \rightarrow {}^{12}C + n$$

La figure 3.32 représente l'allure du spectre de neutrons émis par une telle source d'activité 3,7.10⁶ Bq, de flux 2,2. 10⁶ neutrons/s dans l'angle solide 4 π et de débit d'équivalent de dose de 22 μSv/h à 1 m. La distribution énergétique est répartie entre 200 KeV et 10,9 MeV avec une énergie moyenne autour de 4.5 MeV pour les neutrons rapides.



Gamma radiation with an energy exceeding the neutron binding energy of a nucleus can eject a neutron. Two examples and their decay products:

9Be + 1.7 Mev photon => 1 neutron + 2 4/2He

2H + 2.26 MeV photon => 1 neutron + 1H

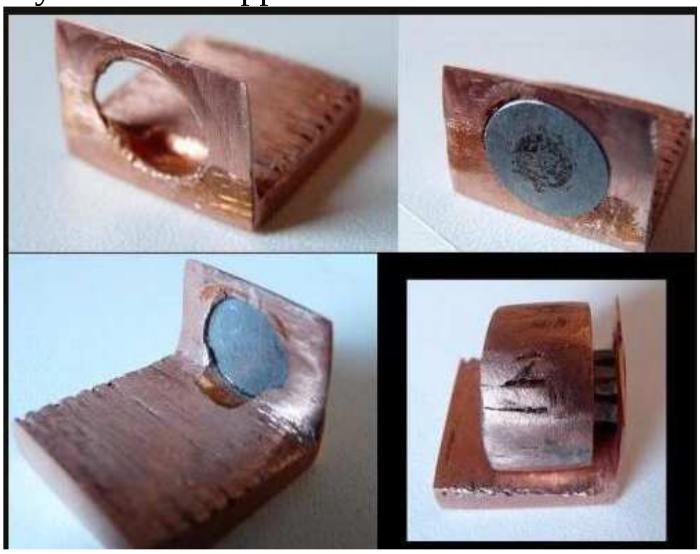
see also the Fusors.

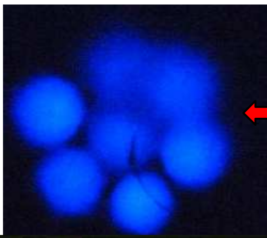
Construction of the neutron source with an AmBe device :

A round of Beryllium metal from ebay member vinni-pooh. Diameter is 1cm and thickness about 300 um. Price : nearly 30 $.

Smoke detectors (ionization technology type) contain a small amount of Am241. Nearly 1 uCi is sealed in a gold matrix to make sure that corrosion does not break it down and release it.

Due to the dimension of the beryllium layer, 7 Am241 sources are stick together and placed near the beryllium in a copper mount.

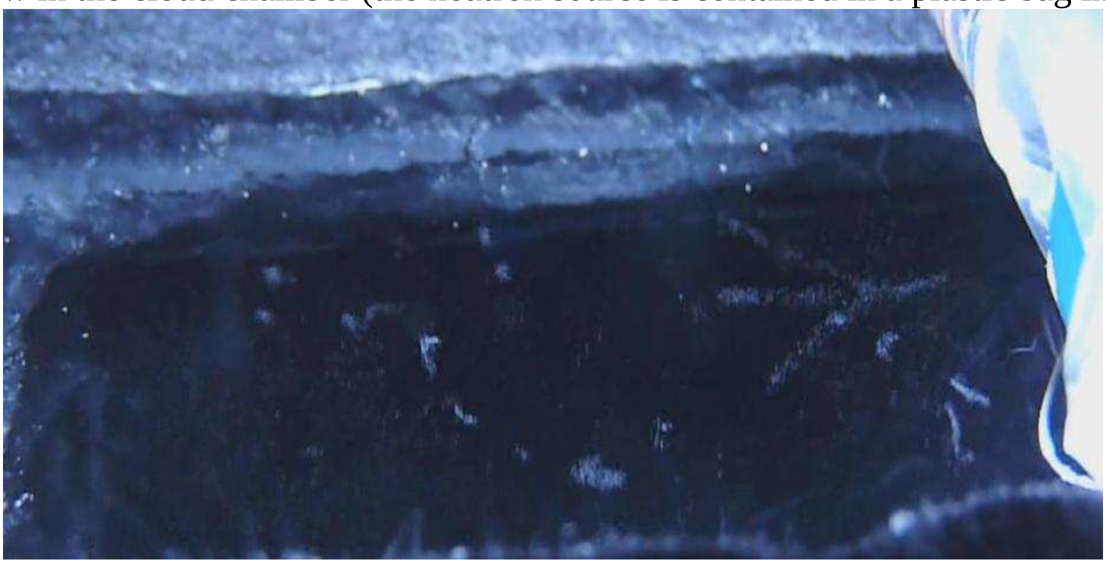




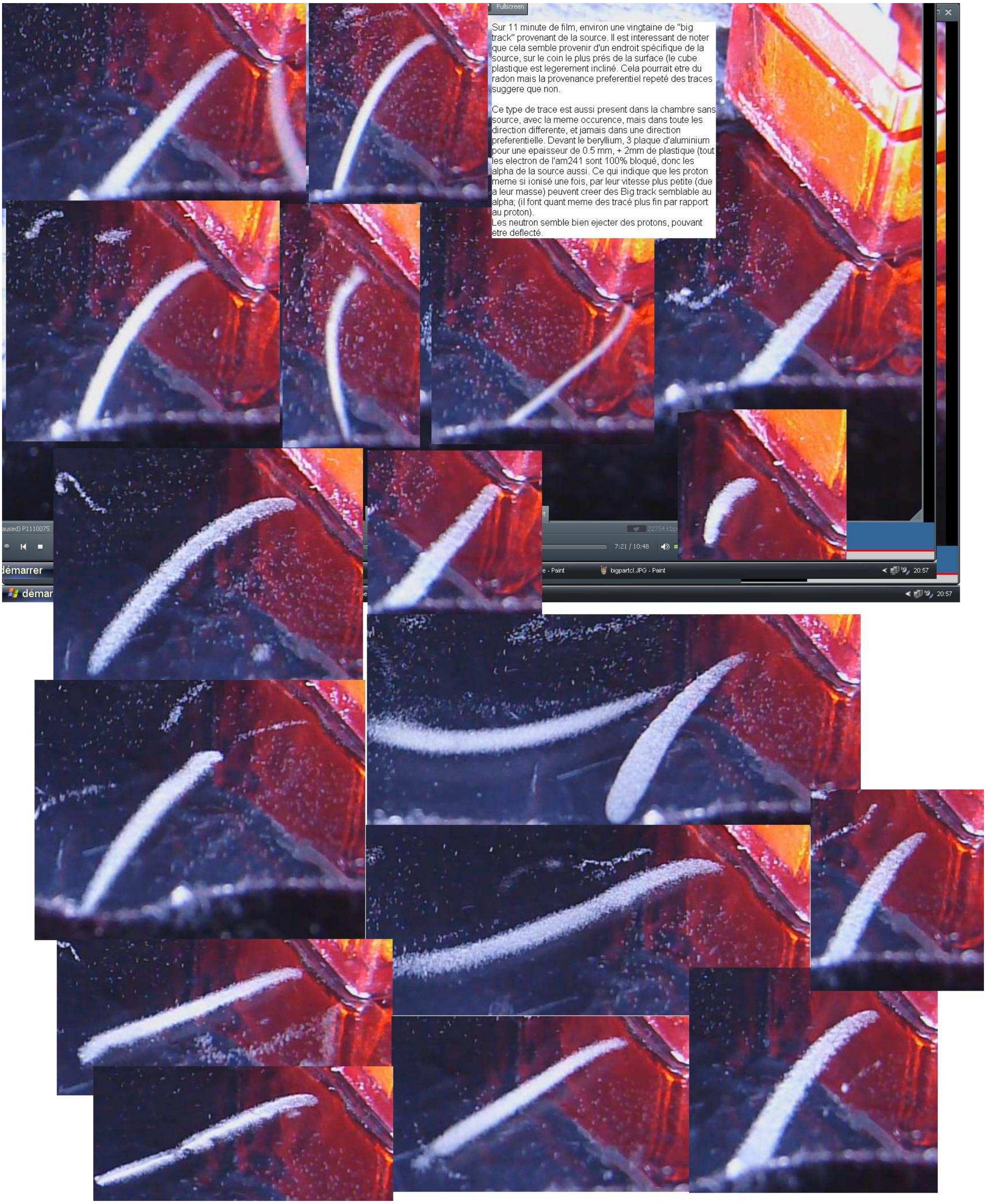
Fluorescence of a ZnS (Ag) screen with the alpha source

The beryllium is not mixed with the AmO_2 oxide, but we will assume that the calculus may be the same. So with a 7 uCi Am241 alpha source, we should expect an emission of 15.3 neutrons per second with 4 MeV average energy.

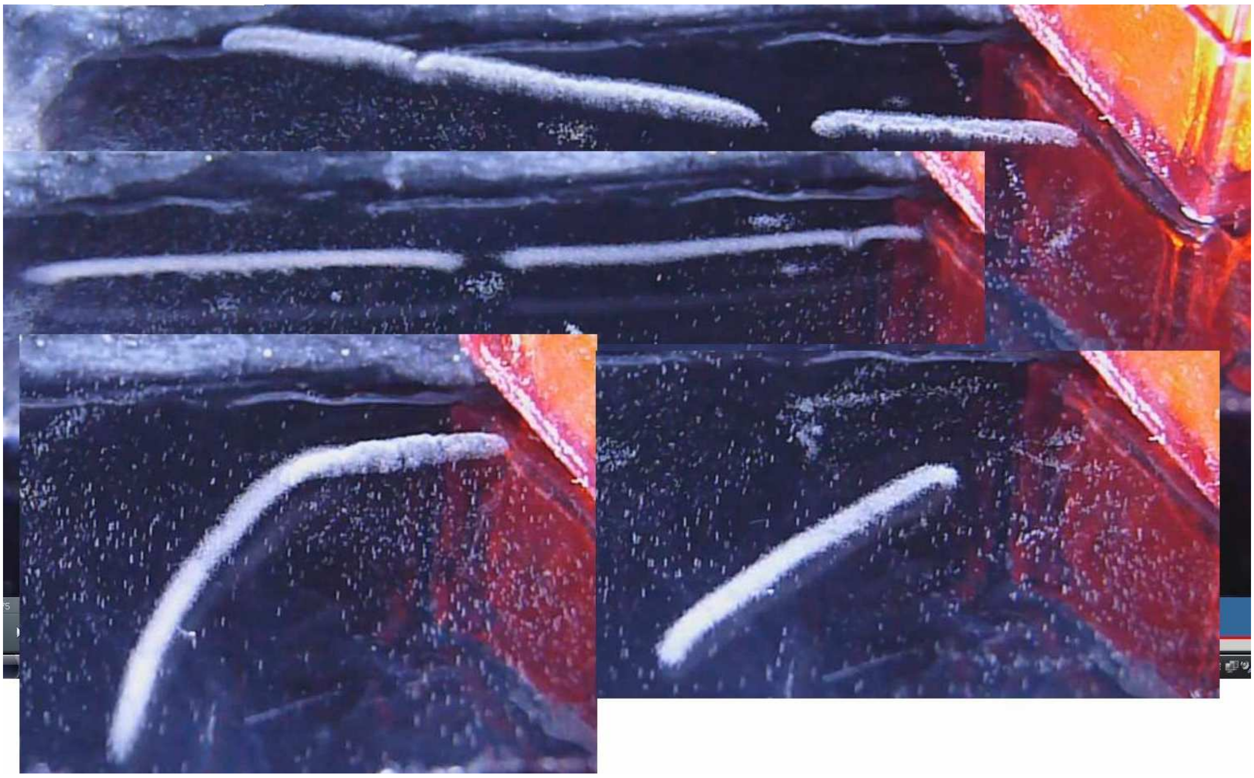
A short view in the cloud chamber (the neutron source is contained in a plastic bag in right)



I never observed this type of event without the neutron source. It may be a double proton collision : one neutron emitted by the source strike a molecule of water or alcohol and eject one proton, which eject 2 other protons from another molecule. We observe 3 thick tracks (so it could'nt be delta ray) and which have the same ion density. I didn't had time to pursue more my investigations about this neutron source, but the events in cloud chamber are different. See the next pictures (the source is in the plastic box in right). It could be protons, making highly ionized track because their velocity is slow. (in one word : * NUMBER OF BUBBLES/CENTIMETRE ~ $1/v^2$.)

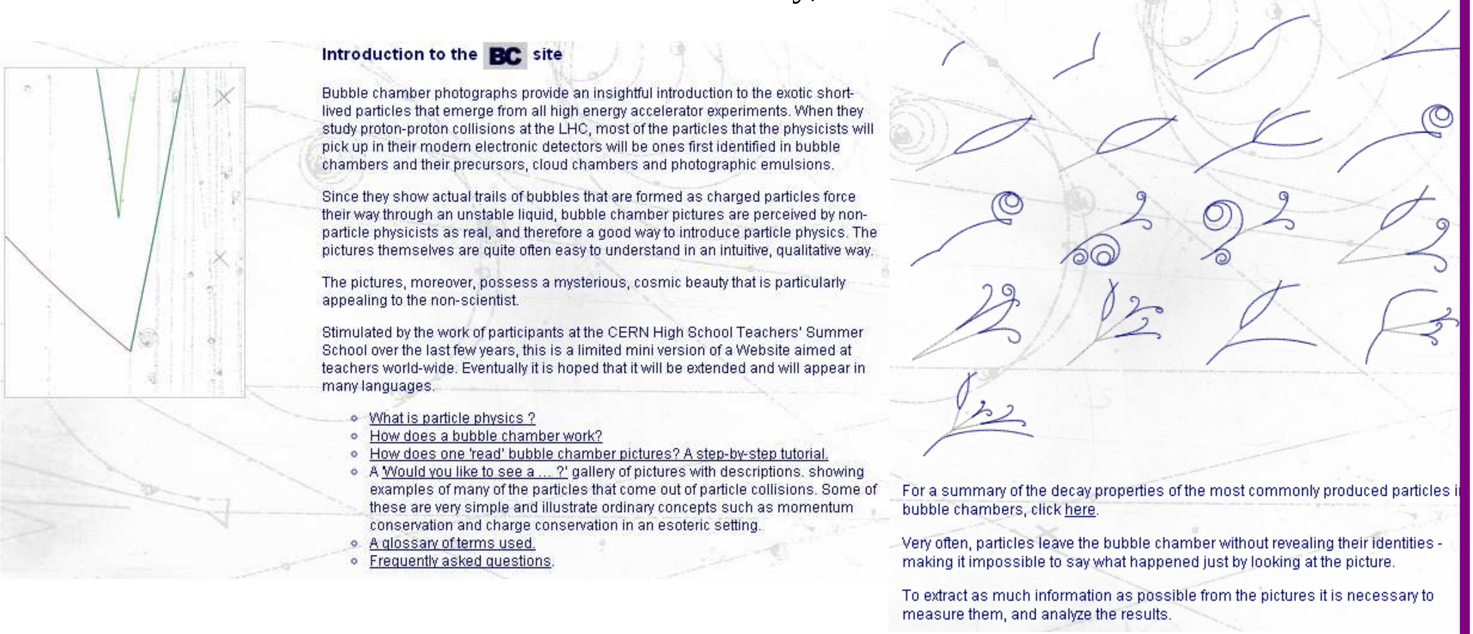


These events were taken during a 15 minutes movie. All of theses tracks take theirs origin from the source.



Documents

THE website about the bubble chambers. It's a beauty, a treasure of informations…♥♥♥♥



Introduction to the BC site

Bubble chamber photographs provide an insightful introduction to the exotic short-lived particles that emerge from all high energy accelerator experiments. When they study proton-proton collisions at the LHC, most of the particles that the physicists will pick up in their modern electronic detectors will be ones first identified in bubble chambers and their precursors, cloud chambers and photographic emulsions.

Since they show actual trails of bubbles that are formed as charged particles force their way through an unstable liquid, bubble chamber pictures are perceived by non-particle physicists as real, and therefore a good way to introduce particle physics. The pictures themselves are quite often easy to understand in an intuitive, qualitative way.

The pictures, moreover, possess a mysterious, cosmic beauty that is particularly appealing to the non-scientist.

Stimulated by the work of participants at the CERN High School Teachers' Summer School over the last few years, this is a limited mini version of a Website aimed at teachers world-wide. Eventually it is hoped that it will be extended and will appear in many languages.

- What is particle physics ?
- How does a bubble chamber work?
- How does one 'read' bubble chamber pictures? A step-by-step tutorial.
- A 'Would you like to see a … ?' gallery of pictures with descriptions. showing examples of many of the particles that come out of particle collisions. Some of these are very simple and illustrate ordinary concepts such as momentum conservation and charge conservation in an esoteric setting.
- A glossary of terms used.
- Frequently asked questions.

For a summary of the decay properties of the most commonly produced particles in bubble chambers, click here.

Very often, particles leave the bubble chamber without revealing their identities - making it impossible to say what happened just by looking at the picture.

To extract as much information as possible from the pictures it is necessary to measure them, and analyze the results.

http://teachers.web.cern.ch/teachers/archiv/HST2005/bubble_chambers/BCwebsite/index.htm

The nobel lecture from Blackett :

http://nobelprize.org/nobel_prizes/physics/laureates/1948/blackett-lecture.pdf

The chart of the nuclides and their nuclear propriety :

http://www.nndc.bnl.gov/chart/

A site where you can estimate the flux of a NdFeB magnet :

http://www.magnetsales.com/Design/Calc_filles/FluxDensityPlainRect.asp

GOOD LUCK WITH YOUR CONSTRUCTION ! =)

(you are welcome to send me your design or your events !)