Theremino System

Construction of the Ion Chamber

The complete Ion Chamber

Construction of the external structure

Take care to maintain the same mechanical structure as our prototypes, this will allow you to calibrate all chambers, within a +/-20% accuracy, using a single calibration coefficient.
(As already explained, we will be satisfied, reaching an accuracy range of +/-30%, up to +/-50%)

The ion chamber consists of a cylinder with a diameter of 8 cm to 20 cm in height, for a total volume of one liter and three covers that protect the electronic components from electrical noise and dust. The cylinder and the lids **(Black bars)** are **in tinplate** and painted black.

The cover on the left has a single hole:
- A hole of 25mm (3) with a grid of welded brass and a dust filter (2)

The base of the main cylinder has two holes:
- A 25 mm hole, (1) for the passage of the air.
- A 4-mm hole (4) to fit the central electrode.

The cover that closes the cylinder has three holes:
- A hole of 25mm (5) for the passage of the air.
- A 4-mm hole (8) to pass the support of the FET and the central electrode.
- A 4-mm hole (9) for passing the high-voltage wire.

The second cover to the right has two holes:
- A 25mm hole (7) with a grid of welded brass and a dust filter (6)
- A 6 mm hole (10) for the female jack of the connecting cable.

How to Get Started

The biggest challenge of this project has been not the electronics, but finding a method to build a Ion Chamber, with the following characteristics:

- Materials readily available to anyone, in common hardware stores
- A Structure with dimensions to ensure repeatable precise operation (+/- 20%) without individual calibration.
- A container for the chamber, easy to work with common tools and soldering tin
- A chamber diameter, greater than 6 inches, to allow the alpha rays to develop all their energy, with a good total volume.
- A chamber diameter, not exceeding 8 inches, avoiding the need of too high voltages.
- A total volume sufficient to allow accurate measurements, in a short time (1 liter).
- Ease of construction and inexpensive materials.

There's nothing better, than a thin sheet of tinned iron, the common can, as the base material, for our building. It has been a nice surprise, to discover how easy it is to work, you can cut it with scissors and makes things really easy. It doesn't matter if painted or not, you just scratch it slightly with the screwdriver to weld it easily. If you don't like the color or the graphics of the original container, you can always paint it with spray color (matte black synthetic).
Who knows how many problems could have been resolved easily, knowing this before.

Natural source of tin are cans, which exist in many forms, with smooth or ribbed walls and in many dimensions. The next page explains how to use this wonderful material and its characteristics.

The can, an excellent material for electronics

The can ("latta" in Italian) is composed of a thin sheet of iron (about 0.2mm) coated with tin electrolyte, to protect the iron from oxidation (rust). See: http://it.wikipedia.org/wiki/Latta and http://en.wikipedia.org/wiki/Tinplate

Some types of iron (depending on the composition and carbon content) are not possible to weld or are hard to solder and possible only using fluxe, but the iron cans is among the most weldable. And the tin plating electrolyte facilitates its welding, even more.

Tinned iron cans have metallic reflections and are readily available. The can of this image, has undulating walls, but some have smooth walls from which we can obtain a large flat sheet.

With a sheet of tin available, you can build small mechanical parts in seconds. You can cut it with scissors, bend it with pliers and solder it, easily. Its magnetic properties allow to shield both the electric fields and magnetic ones. You can even make brackets and clamps to be welded or drilled and fixed with screws.

Some cans, such as those used for beer, are made of aluminum, not tin and can be recognized by the whitish color (which has never blue reflections). To distinguish it from aluminum, you can use a magnet. Tin, instead of aluminum, is magnetic.

Aluminum is not good because it is not solderable and cannot be used as a screen for magnetic fields.

Here is an example of a screen of tin, used in this ion chamber, to separate the power supply zone from the area destined to the amplification circuit.

The screen blocks the electrical noise produced by the power supply switching and even the magnetic fields produced by its coil and protects the delicate amplification and discrimination.

The round base is made of tin, spray painted with a can of matte black. If you remove the paint from the area you want to weld, with the tip of a screwdriver, soldering will be easier.

One liter container for the structure of the chamber

All around the world, any shop that looks vaguely like a hardware store, certainly has cans of trichloroethylene, dichloroethylene, acetone or turpentine. Turpentine is probably the cheaper, but one-liter jars are all the same. They exist with this form and dimensions, certainly before 1950, having all the same size : 8 cm (diameter) by 20 cm (height)

These cans, all have the same triangle symbol in relief. Probably just one company is producing them, or maybe all manufacturers have agreed on a standard.

Cutting the outer wall with scissors, you get a flat sheet of tin about 20 x 25 centimeters, almost an A4 sheet, which can be used to obtain mechanical and welded plates for electronic assembly.

Using them whole instead, you get a good ion chamber, being of exactly one liter.

These cans cost a few Euros and their content may also be helpful. To preserve turpentine you can pour it in used PET bottles. For other solvents (trichlorethylene, acetone and dichlorethylene) would be better using glass. You can obtain even large rectangular oil containers, with the capacity of several liters each.

Painting

The appearance of the cans just purchased is a bit "confusing"

Just a little bit of black paint, make them neutral and professional. Lightly sand them with fine sandpaper and then wipe them with a dry cloth with alcohol. You can also spray them without too much preparation. A can of black synthetic paint covers enough in one coat, if you give two, better.

What to buy at the hardware store

All the material to make the structure of the ion chamber, can be purchased for less than four euros. For each ion chamber, you need a one liter can of solvent and three caps for jam jars (Quattro Stagioni brand are perfect) with a diameter of 86 mm.

The caps are made of tin and a solderable one. They can be found in any hardware store and seem to be made expressly to close the cylinder and to hold the electronics of this project.

The caps are not screwed, but their sizes are so precise that sometimes it is necessary to unscrew them.

Welding

Both these caps and the cans are made of a material that is easily welded . A 30Watt soldering iron with a small tip, the one used for SMD components, is able to make perfect welds in seconds, on this material. This incredible weldability is due to the very thin surface of the iron, which cannot absorb to much heat, and the fact that the iron has been coated at the factory with a thin layer of tin, to protect it from rust.

For pure sake, before welding, scratch the painted parts with a screwdriver, but most of the times without doing this, you weld equally well.

Some cans and caps in the early stages of processing

Here we can observe, how the coating gives a decent look to our future chambers.

All three , should have a the large hole of 25mm.

A single cover for each chamber must have both the large hole and the central hole of 4mm

Even the cylinder at the base, must have both the large hole and the central hole of 4mm

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When you need to solder in a point already painted black, it is important to first remove the paint with a screwdriver and be careful with temperature, to avoid burning the surrounding paint or the one on the opposite surface of the sheet. To avoid burning the paint, don't heat the same place for more than a few seconds.

Remove the top of the can

The upper side must be opened, as we need to work within, soon. The first cans were opened with drill pliers and clippers, don't try that!

Being careful, it might be possible to complete the task without being harmed, but it's still a hard work to cut well all across the edge and render it harmless.

Much better to use a good can opener!

And then file and sandpaper, to smooth the burrs of the inner edge and make it safe.

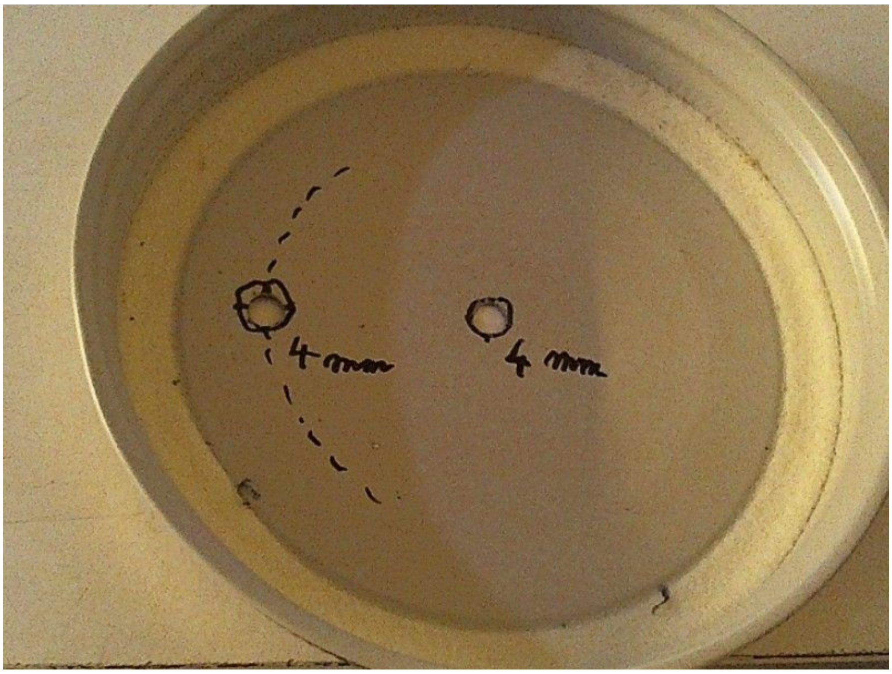
Some Dremel accessories are fine for the job. We must obtain a smooth edge to avoid the risk of cutting during subsequent machining.

The upper part of the can is not very rigid, but it will become, inserting the cap which enters in a precise way and is almost screwed.

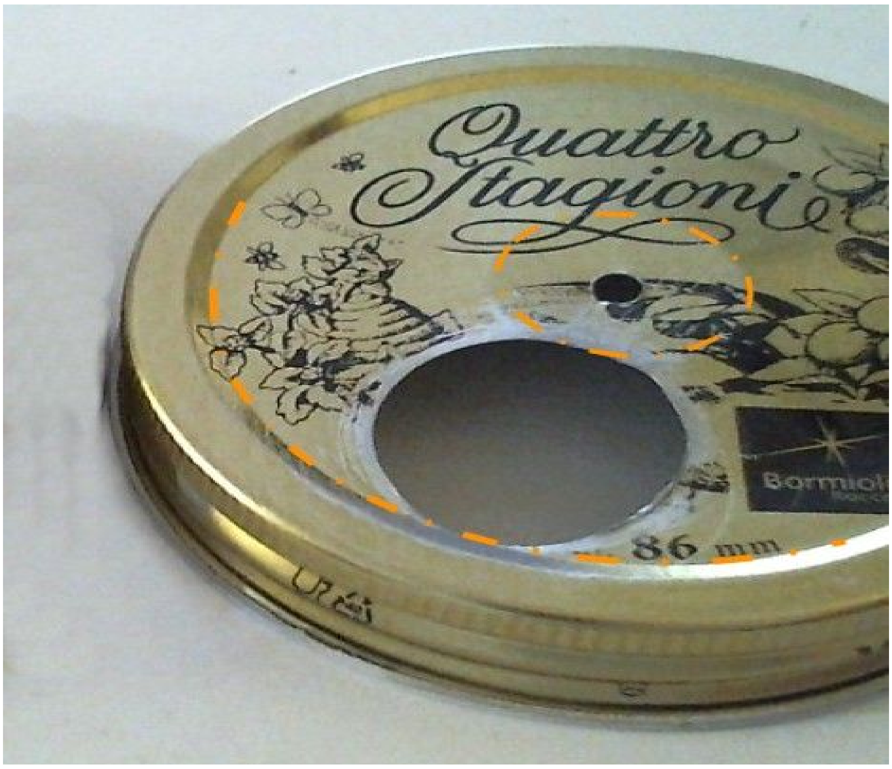
Even the side walls are thin and can easily bend up, until they are not stiffened by the inner lining.

To avoid dents, be careful not to press too much with your fingers, during the early stages of process.

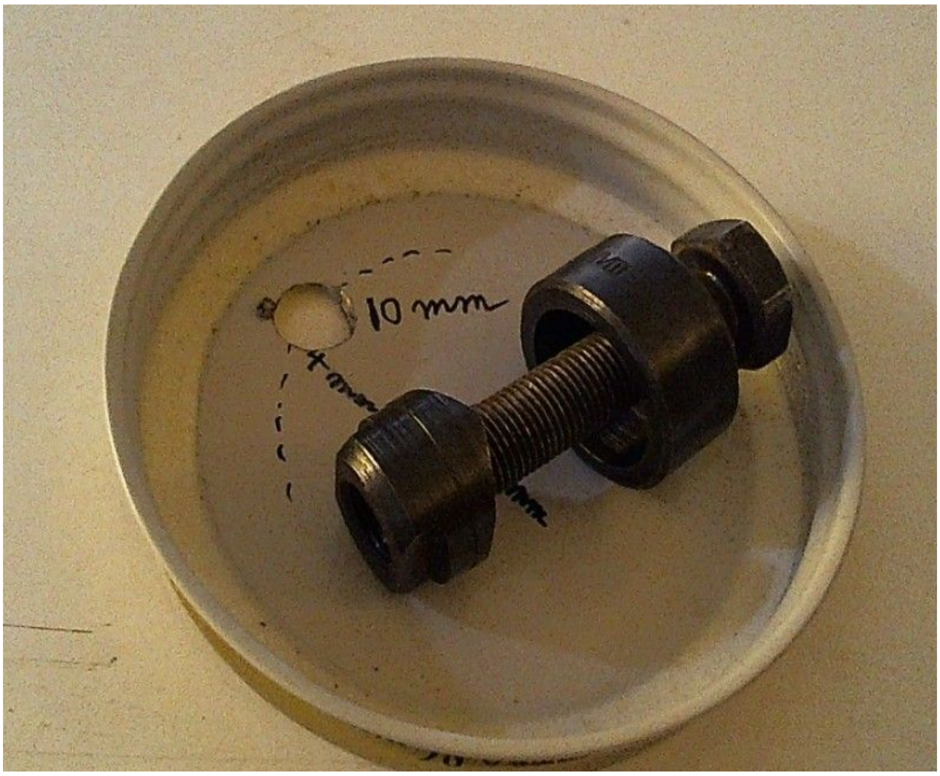
Drill holes in the caps and cans



Mark two points, one perfectly in the center of the cap and another one in the middle, between the two circular folds, those marked in yellow in the picture below.



You then widen the outer hole, to 10mm.



A punch screw makes excellent holes.

You screw the punch and move it slightly in the hole, that is wider than the stem, centering it between the inner and outer bending. You then tight it by hand and finally give many turns with the wrench, until the sheet metal shear.

Here we see the opposite side of the punch, which in this case is 25 mm.

Holes of 25 mm require greater precision, but **allow the radon to diffuse faster inside the chamber.** Five millimeters more may seem just little more, but in reality, the area of the hole increases more than 50%.

Position of the hole

In this picture you can notice, that the hole is too far outside on the left, while the hole on the right, is perfectly centered.

Whatever the method you choose to make the 25mm hole, you should try to make it exactly in the space between the inner and the outer circular fold.

If you make it too close to the edge, it might get difficult to apply the filter, because the hole is not flat, instead of a hole too inside, gets too close to the center hole and worsens the elasticity of the cap.

The elasticity of these caps (originally intended, to keep the vacuum) can be tested by pushing the central hole, the cap will behave like a spring.

The elasticity is important to keep the central wire taut even when it lengthens and shortens due to temperature changes.

Tools to work the can

You can find these tools on eBay or from a hardware store. Look for "punching screw", one of the companies that produce them is "WURTH" (**eshop.wuerth.it/ eShop_ssh**)

Be careful to choose a 25 mm one, which is the proper size for the ion chamber and useful in many other occasions, as well. Smaller diameters holes might be done with the drill, larger ones rarely are useful.

If you do not find the "Punch screw", also a "steps cutter" may be fine.

On eBay, you can find very good cutters, from 4 to 32 mm. or 4 to 39 mm. for about 14 Euros.

With the steps cutter the hole is less clean and you then have to work it a little bit with a file and sandpaper.

Another great tool is the "BETA nibbler shears 1120 model", that allows you to do **straight and curved cuts in sheet metal, with great precision.** It can make holes of any shape, even very large.

This tool is very expensive (40 € and more) and fortunately is not needed for the ion chamber, we report on it, only for completeness.

Painting completely jar and caps

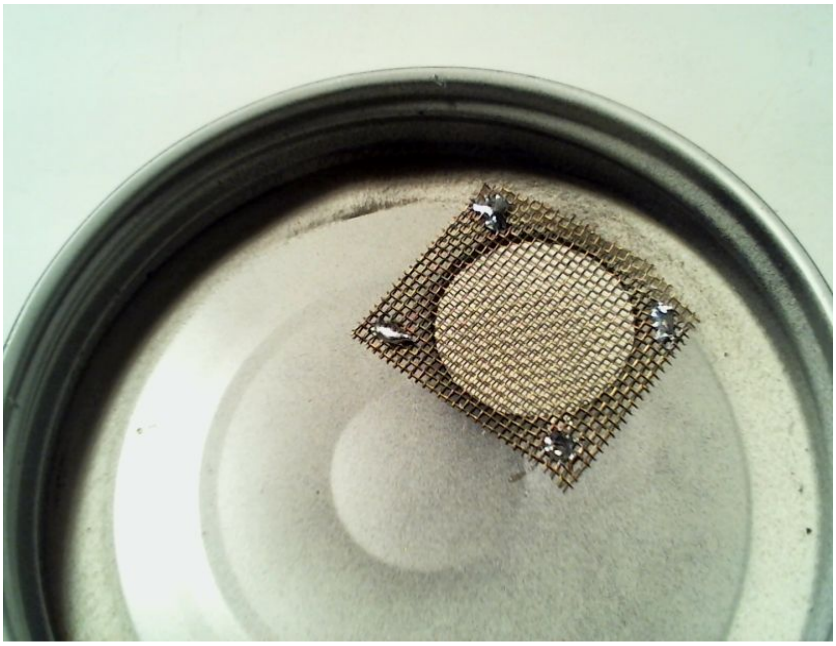
Here you see some cans with the end unpainted. It's not good to leave them like that, because after a few years it may oxidize. The tin coating protects the iron, but the material is soft and just a few scratches can make the way to rust.

Paint completely, even the inside of **both the cans and that caps**. This needs to be done, **before starting to place electronic parts.** Later it would be at risk of making it dirty, same with the inner lining of aluminum.

The grids of brass on the lids

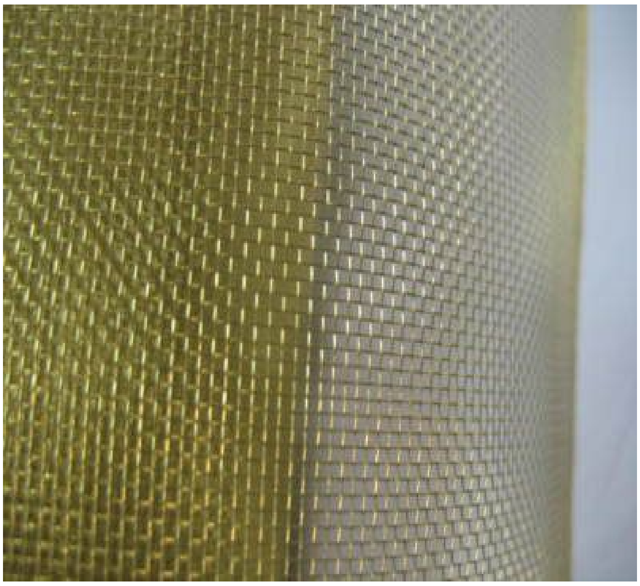
Only two covers (those without the central hole) must have holes closed with a metallic grille, to shield the delicate internal circuitry from electrical fields (mainly noise from the power supply).

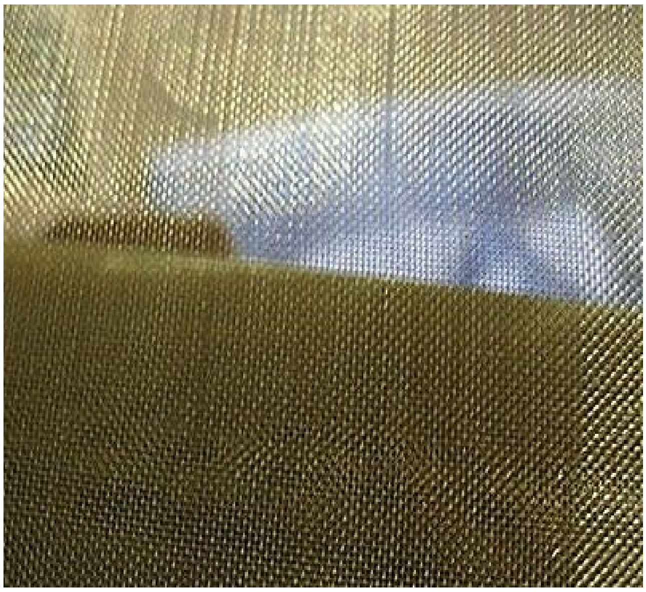
The only metallic grilles, easy to weld are made of brass; regarding the availability, see on the next page.



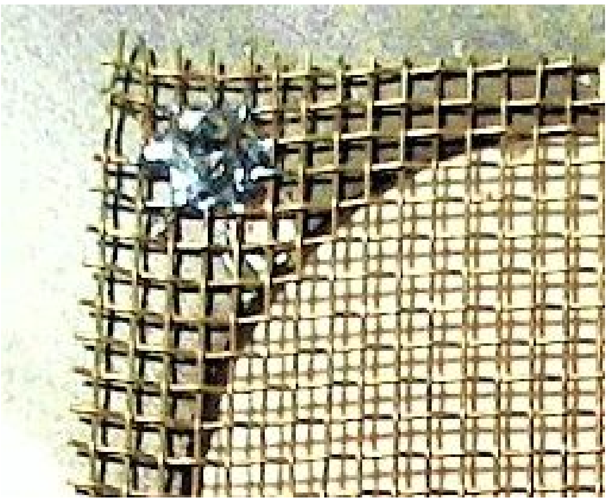
Scratch four small areas around the hole with a screwdriver and prepare them with a soldering iron and a drop of tin. Lay down the net and join it, heating the drops. Be careful not to heat too long, otherwise the paint behind will burn out. You might paint the lids after putting the grill, they will turn black as well; electrically speaking, it doesn't matter.

The brass mesh





There are two types of brass mesh, large or tight. The two types measure 1.0 mm and 0.5 mm, which is the distance between wire and wire. **Both types are good for the ion chamber.**



For the ion chamber, two small squares of 35 x 35 mm are enough. The brass mesh, can be useful in many electronic devices, you might decide to spend a little bit more, to buy a few tens of centimeters.

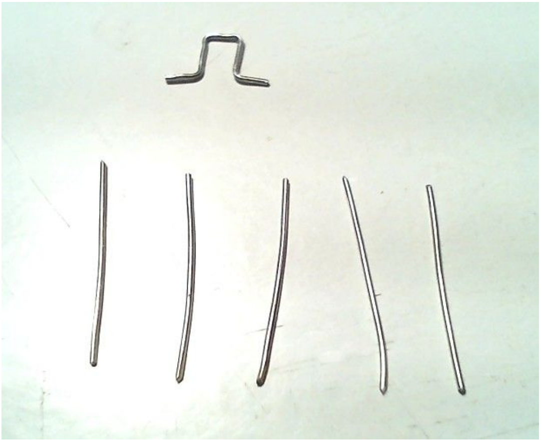
You may want to look at hardware stores and hydraulic components stores, for the best deals, as in the past has been used in taps, filters for irrigation systems and other devices for agriculture. The best shops to look for, are located in country and in rural areas.

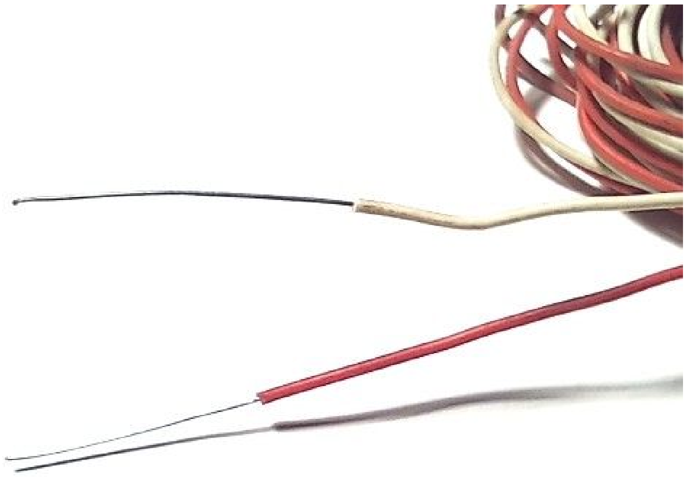
If you cannot find it easily, you might search on eBay, you must buy at least a half of a meter and even so, the shipping costs double the final price.

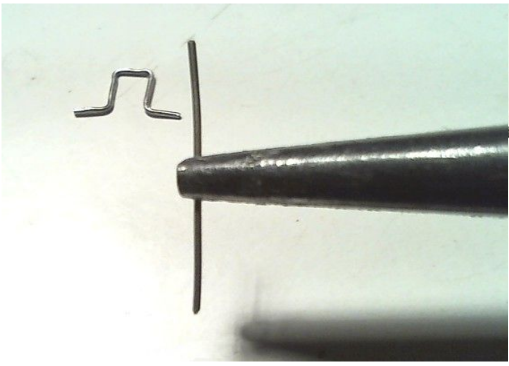
To look for it on eBay **you should search for "brass mesh",** you should find offers for 0.5 x 0.5 meters, at around 4 to 10 Euro, plus postage.

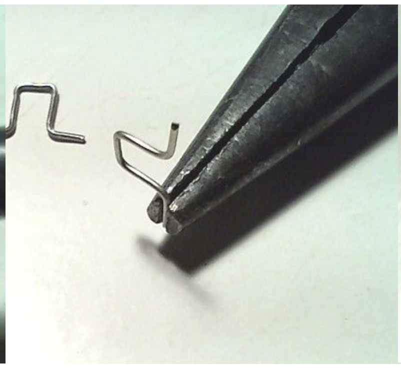
Preparing clips for the caps

First of all, prepare six pieces of wire 25 mm long, by peeling some standard telephone wire (0.6 mm diameter) or any other stiff wire with a similar diameter.









The clips are then welded to the lids.

You must prepare the lid, scratching with a screwdriver two points, at a distance of 8 mm from each other, with a drop of tin, then approach the clip, holding it with tweezers and weld it as seen in this picture.

Two clips for each lid, should be welded, one facing the another. **Be careful to find two positions, where the edge of the thread is not too high,** otherwise the clips occupy too much space.

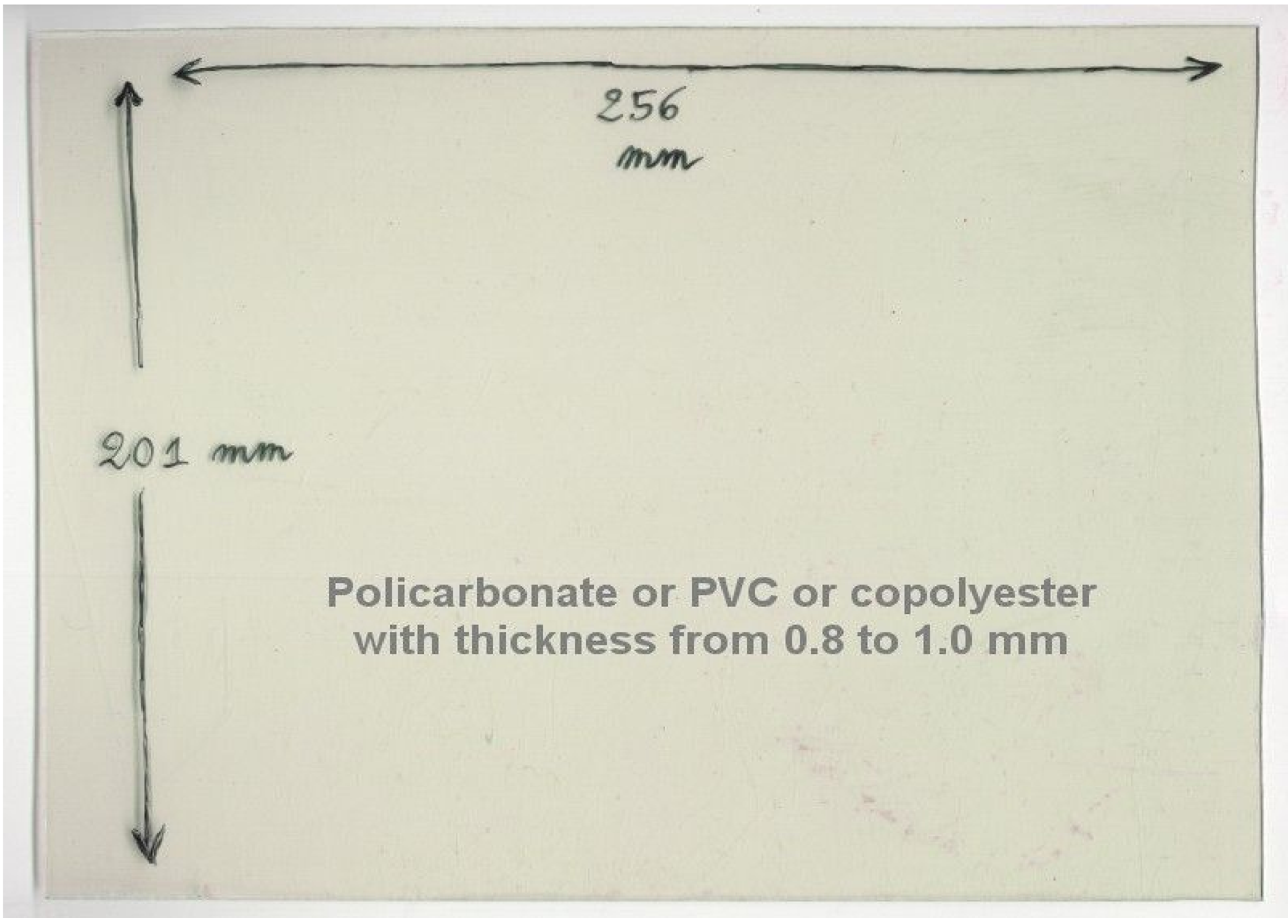
Welding the clips

This operation will be performed only at the end of the construction, but we show it anyway, to understand what are the clips for and facilitate their construction.

You should scratch the paint with the screwdriver underneath the clip.
Before, **you should be careful to turn the cover in an appropriate manner,** aligning the two 25 mm holes. Be careful, that the 25 mm holes from of the base of the chamber remain offset, with respect to the holes of the base. When the chamber is horizontal, one hole should stay at the top and the other at the bottom (this is to facilitate the passage of air by convection)

Time now for welding. Be careful not to heat too much, to avoid unsoldering the wire from the inside of the lid and not burning the surrounding paint. I suggest to give a bit of black paint, to cover the soldering and the clip.

Inner lining



First of all, a sheet of insulating plastic which serves to isolate the aluminum coating from the metal of the can, must be prepared. The internal coating of the jar alone, would not be able to withstand 400 volts. It would also be difficult, to paste the aluminum tape inside the jar. We prepare this kind of plastic tray covering it, before inserting it rolled up, inside the can.

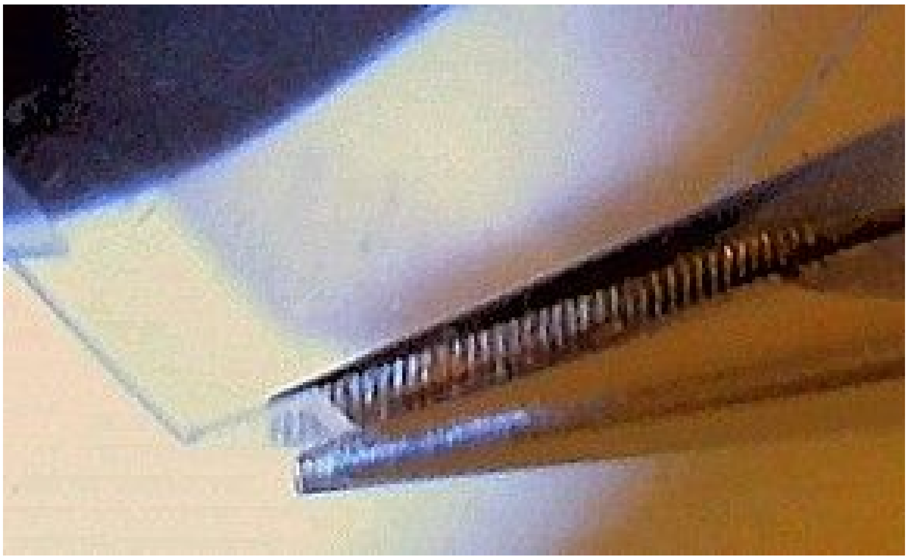
It's better if this sheet is very thick (from 0.8 mm to 1 mm), not for electrical insulation, but to strengthen the structure and to dump the walls of the jar. Without this coating the thin walls of the can, vibrate easily and can enter into resonance with strong ambient noise, disturbing and giving false counts.

For this same reason, the plastic sheet in addition to being thick, must be of the exact length, so that it it requires some force, to be fit in the can.

Having done the job properly, **lightly tapping the can, you should hear a sound very dull, well-damped** and very different from the sound of the empty jar.

Checking the length of the insulating sheet

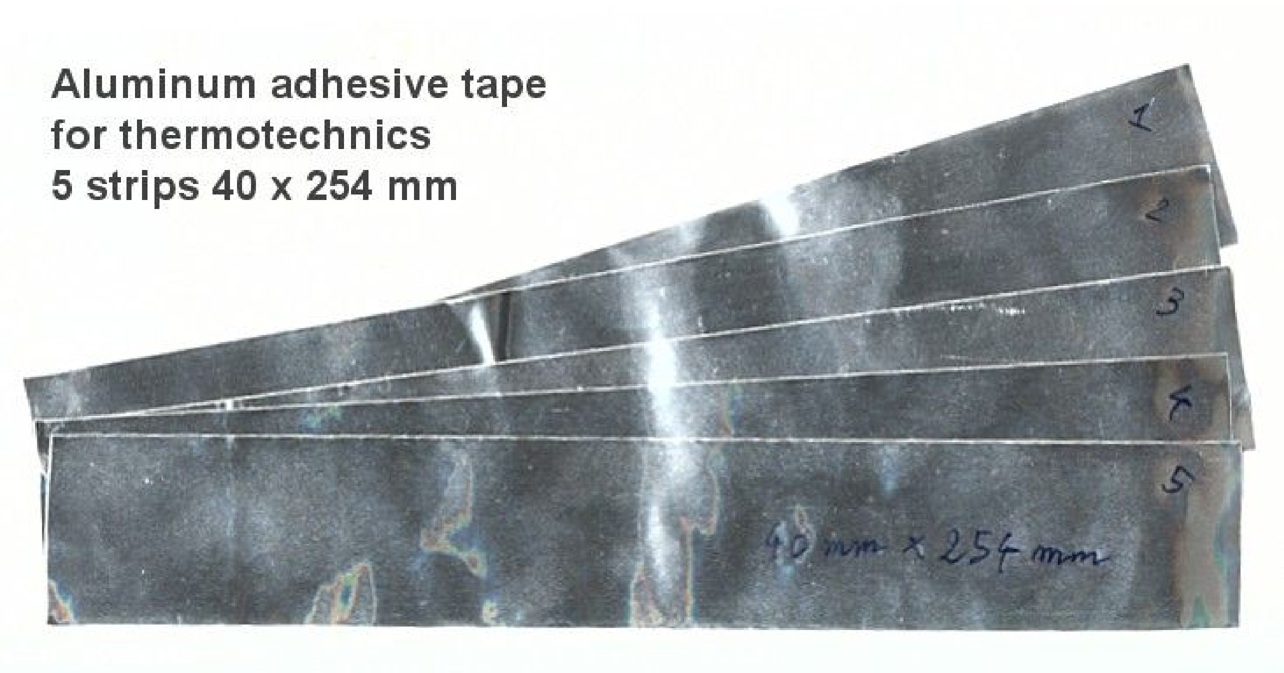
After cutting the plastic sheet, check if it enters well into the jar. At the exact length, when you insert the seam, it should make a "crack" and become a continuous surface without overlapping and without leaving a gap.



Before inserting it for the first time, **bend a corner with pliers** as is seen in this picture, otherwise would become very difficult to pull it out for subsequent machining. Without this, to remove the plastic sheet, you should shove under with a screwdriver, possibly scratching the already painted inside.

Aluminum coating

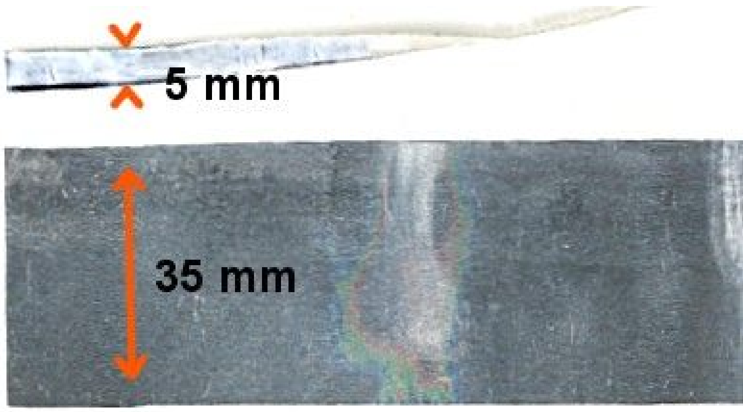
First of all, you should buy a roll of aluminum adhesive tape. These rolls are normally from 4 inches to 4 feet. As we need less than a meter and a half, with a single roll you can make nearly three ion chambers, spending about 2 Euros each.

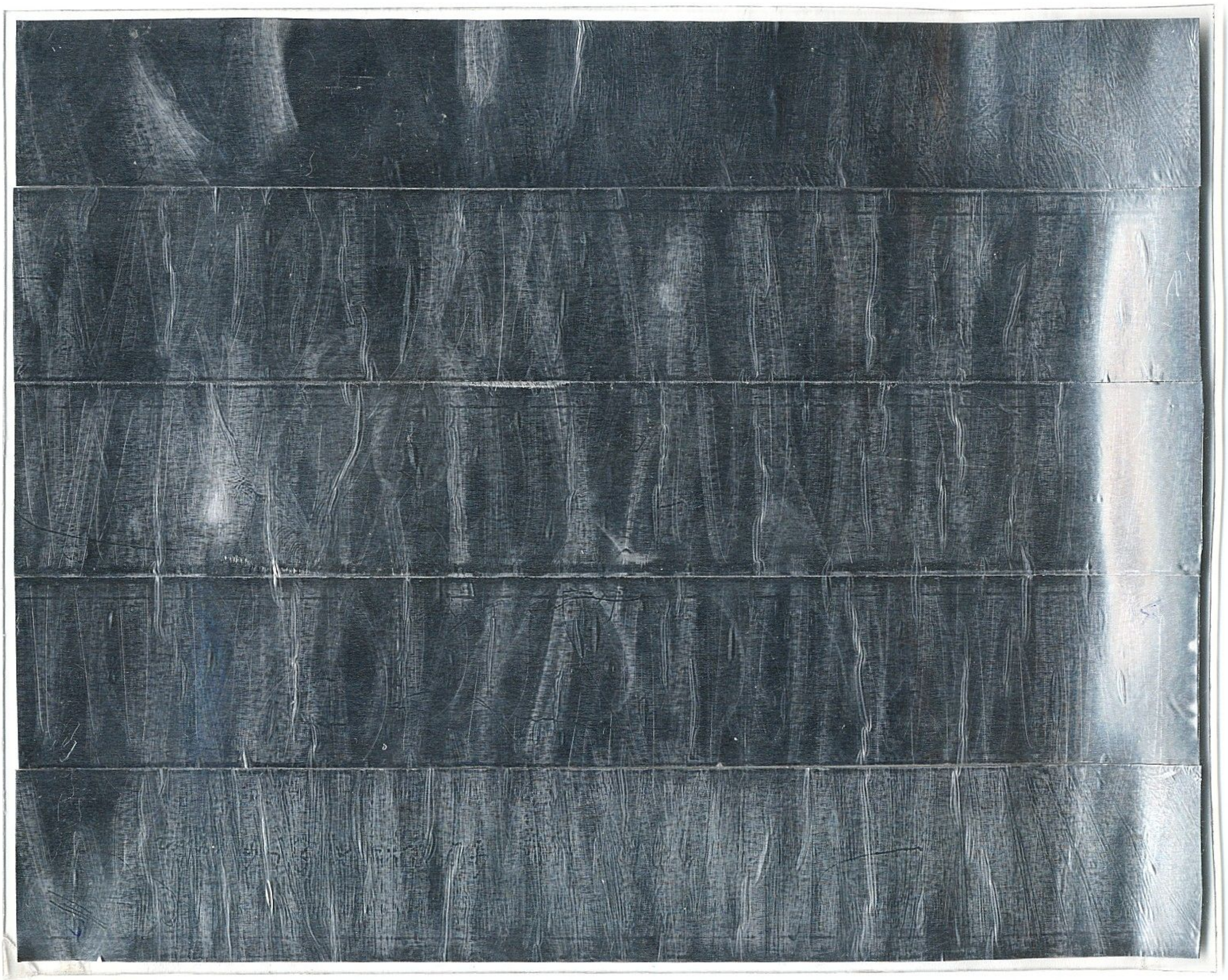


Five strips 254 mm long, are cut from the roll.

One of the five strips must be only 35 mm wide.

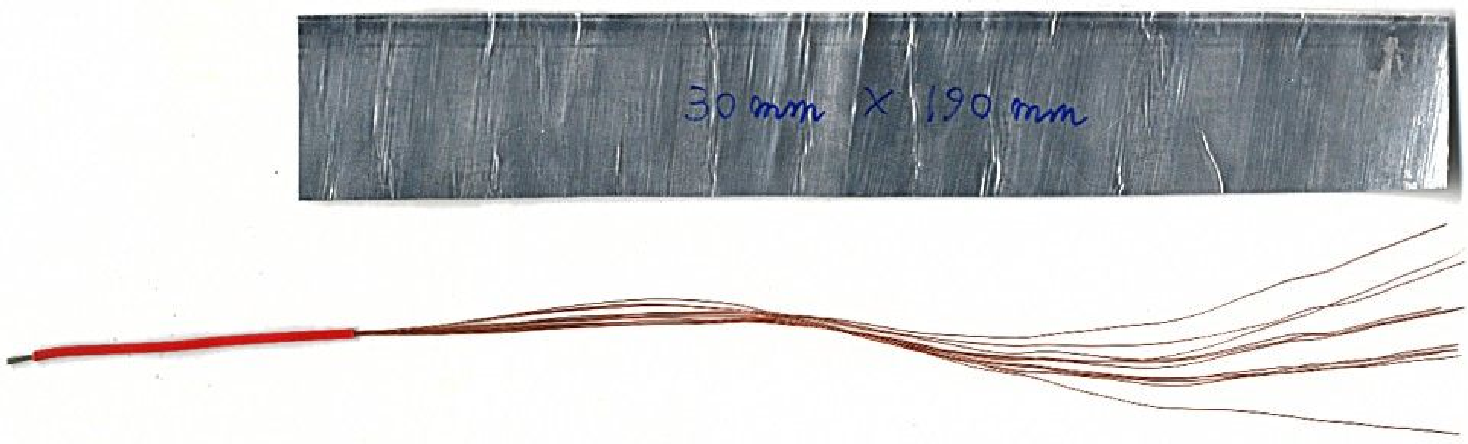
It's marked with a pencil and then cut with scissors.





Finally, the strips are glued to the plastic very carefully, without overlapping them and with no gaps, leaving all around, an **insulating flange of about two or three millimeters**.

Connecting the wire to the lining



Before you roll the coating, in the cylinder of the chamber, you must connect the wire that will bring the high voltage. This wire must connect all the strips, but as you can not weld aluminum, you must peel something like 180 mm and preparing an other strip of 30 mm by 190 mm which will be used to cover it.

*The strip that covers the wire must **adhere very well on it**! If remains isolated may be loading slowly, until very high voltages and periodically discharge, via invisible sparks to the underlying strips, producing spurious counts.*

As the upper strip doesn't make contact with the lower ones due to the adhesive layer, you should use the technique of the "seam" that means going in and out with the wire, as seen in the center of this picture. Alternatively, use the technique of "the square folded below" as you can see, in the enlargement on the right.
The folded square technique, consists of folding a part of the upper strip nonadhesive face, against the one of the bottom strip, making a good contact.

In all cases, **double check and measure with a meter,** for a safe contact between the wire and all of the strips. Remember to check **the strip that covers the wire,** as well.

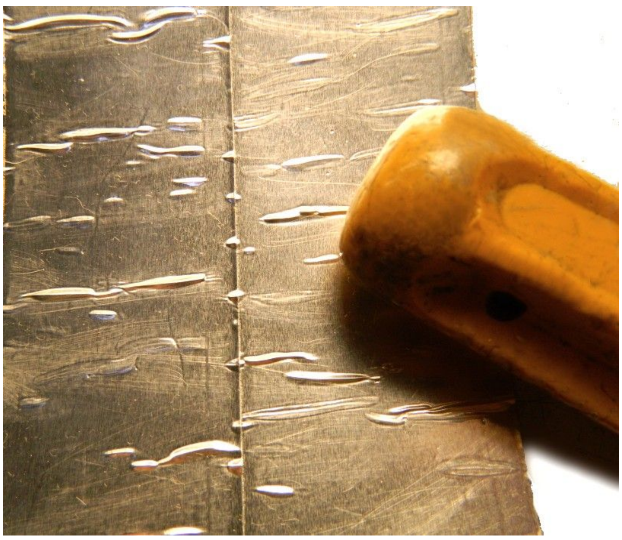
Copper coating

Copper adhesive tape (found easily on eBay) could make the construction of the coating, even easier . With a 10 centimeters wide roll, two strips side by side are enough, with 2.5 inches tape (like the one on the right) strips become eight.

As copper can be welded, it is easy to solder the wire and make sure that all strips are in contact.

Even using copper tape, remember to check with a tester, that ***all the strips are well connected. If one remains isolated,*** *it would result in a decreased sensitivity and, even worse, the periodic charge and sparkling of the strip to the adjacent ones. This would cause noise and spurious counts and* ***would prevent the proper functioning of the chamber****.*

Roll out the wrinkles of the coating

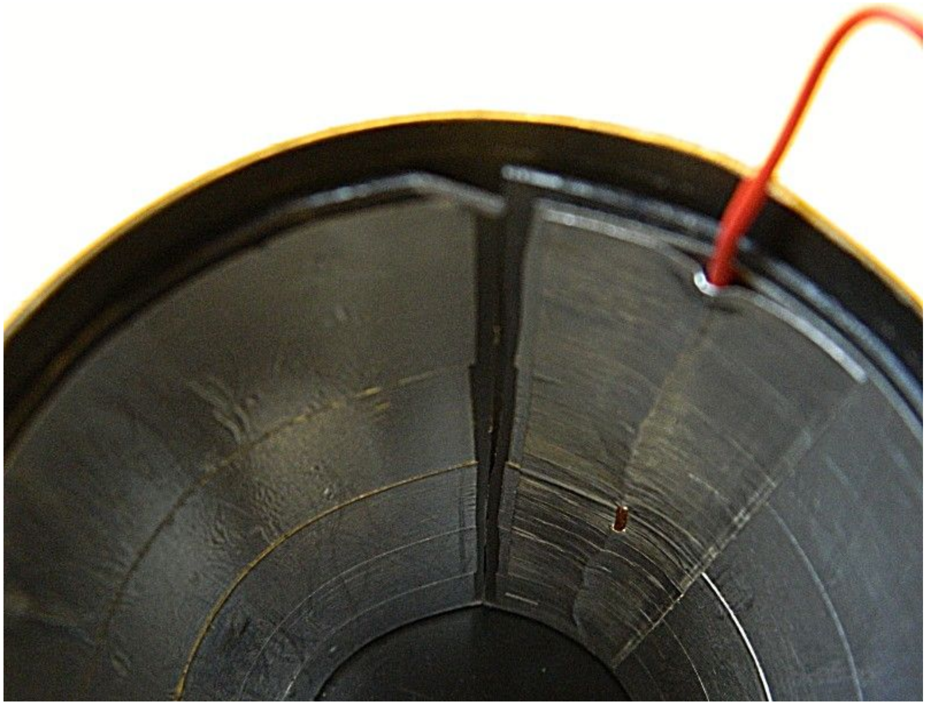


When the coating is rolled into the cylinder chamber the tape (both aluminum and copper) tends to make folds. Probably the folds would not create operational problems, but they are definitely ugly. To flatten the folds you can use a screwdriver handle, with a rounded head. This operation will be repeated, placing the coating inside the cylinder, in a definitive way.

Insert the coating

The coating must be inserted by turning it in the right manner. First of all, you have the cylinder with the large hole in the bottom and the cover with a large hole on the top, as seen in the picture.

You then install the coating, rotated so that the high-voltage wire is in the upper right corner, around the position of the small hole of the lid, from which it will have to pass.



Finally, before you put the lid on, remove the remaining folds on the coating with the screwdriver handle, as explained above.

Preparing the cover

Iron or copper shield - Thickness 0.3 to 0.5 mm

First of all prepare a metal lamina (tin or tin-plated copper) that will act as a screen between the high voltage power supply and the delicate signal amplifier.

We then prepare both the plate and the cover, with four drops of tin, finally placing the plate in vertical in its place and welding.

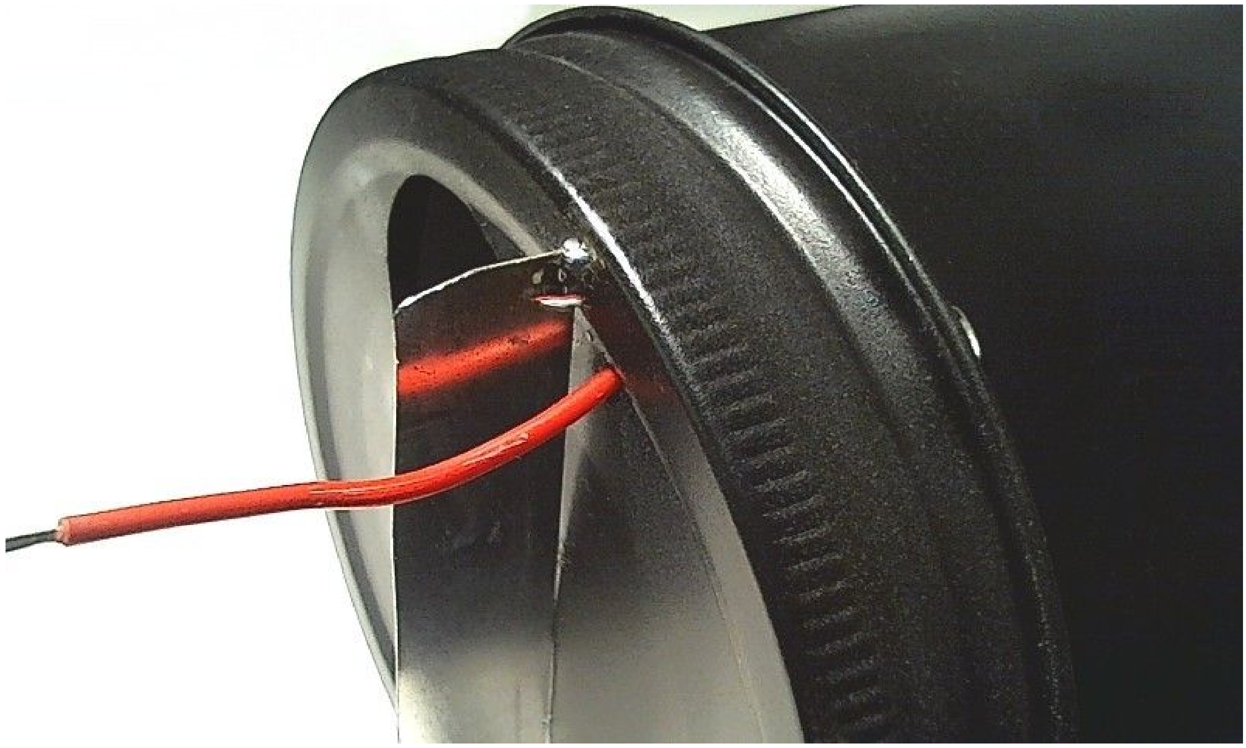
Be careful, not to weld too close to the center of the lid, as the central part of the cap, must remain elastic for the central wire, leaving it free to rise and fall.

Try pressing the center of the lid to check this movement. It doesn't matter if releasing the cover it touches the plate because this will always be pulled down.

Be careful as well, of the **position of the 4 mm hole with respect to the plate.** The hole is where the high-voltage wire passes and must be located beyond the sheet, in the small half-moon that will host the high voltage power supply.

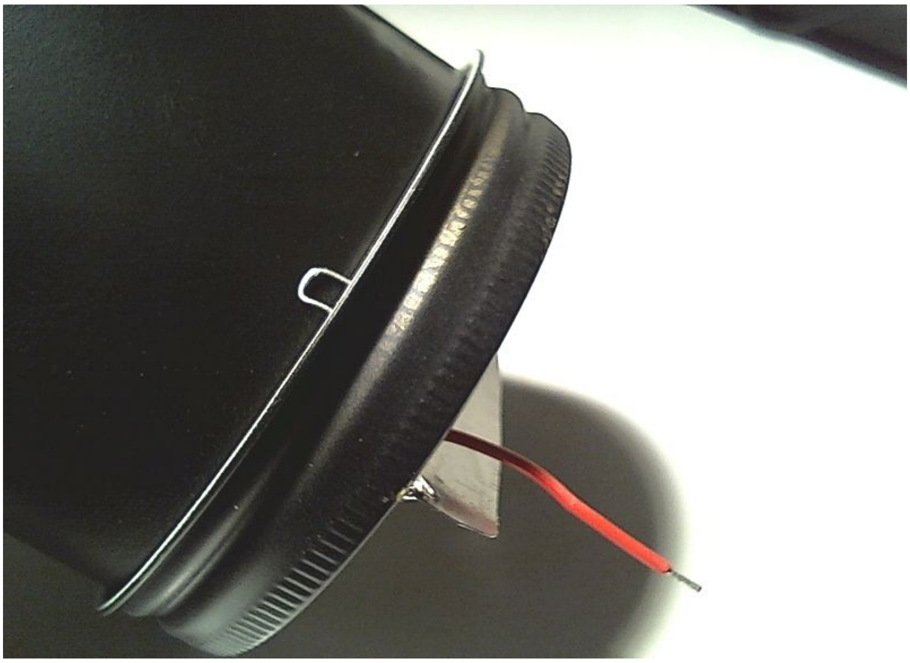
The large holes of the lid and of the bottom of the chamber, **must not have filters and brass grill**. These holes must remain open, to let you inspect the internal components and insert them easily with the help of tweezers. Filters and grid will instead be on the two external covers.

Place the lid



It's now time to close the chamber.

Be careful to turn it so that the large hole is exactly on the opposite side of the big hole, located at the base of the jar. After welding the clips, will no longer be possible to rotate the cover.

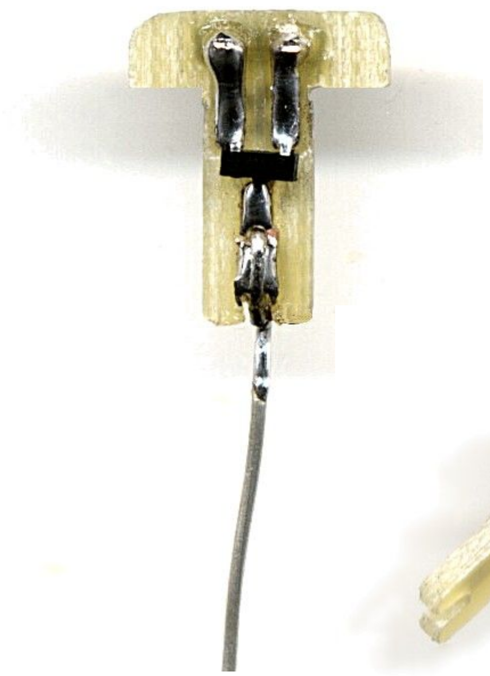


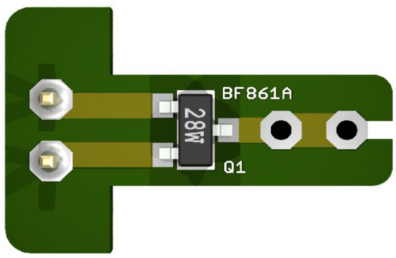
It might also be a good idea, **not scratching the paint now,** but wait until the final stages and **weld the lid just before the electrical tests**.

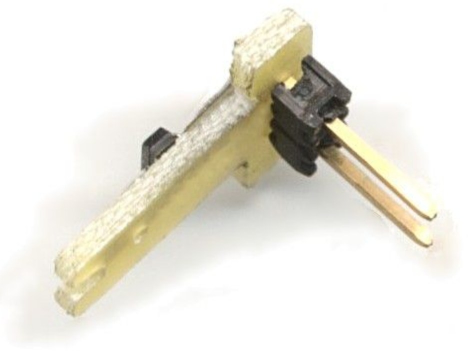
The center electrode

We are almost at the end of the mechanical engineering. The center electrode part, will be explained in detail in the document "Radon_IonChamberElectronics"

These images, show the "T" shaped board, that holds the FET low noise BF861A and the wire from the side cover.







At the base of the cylinder, the wire is anchored with a piece of wire insulation. Here you can see how we used the outside of a telephone wire, but you could derive it from peeling all kind of wire harness, both rigid or in stranded wires.

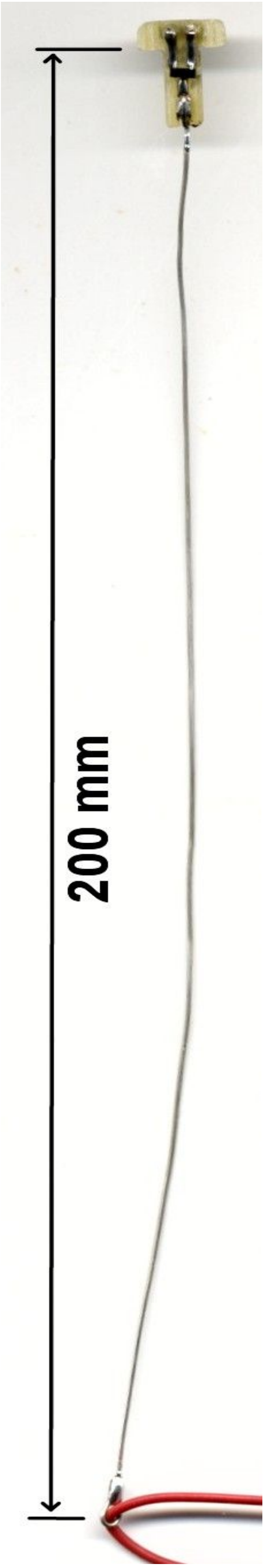
After stripping the wire, check its resistance to traction. To be more confident on its features you could use nylon thread, instead.

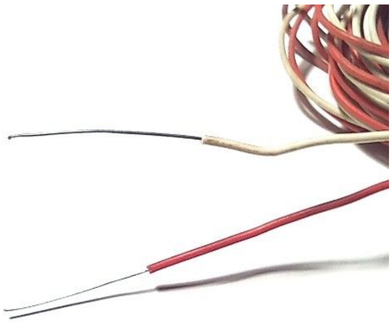
Here you can see an enlargement of the eyelet that passes the wire insulation. Note the soft welding, without tips. Since the electric fields increase on the tips, it's a good rule, to round all the metallic components inside the main cylinder.

These fine details may not be too important, but when in doubt, better to exceed, it doesn't need too much work.

Be careful that the central wire is connected to the FET, which may burn if hit by an electric shock. So handle with care, better in damp days, never getting up from the chair (rising from the seat, causes the creation of strong electrostatic charges).

The central wire





The central wire is made from usual telephone cables.

The length of the wire, measured from the point of support of the "T" until the eyelet below, must be of 200 mm precisely (+/- 0.5mm).

Be precise with the length, to ensure that all chambers, have the same sensitivity to ions.

About 10 millimeters, will remain In the top, between the place you welded the wire and the point of support of the "T" (the actual length of the wire, is only 190 mm and not 200)

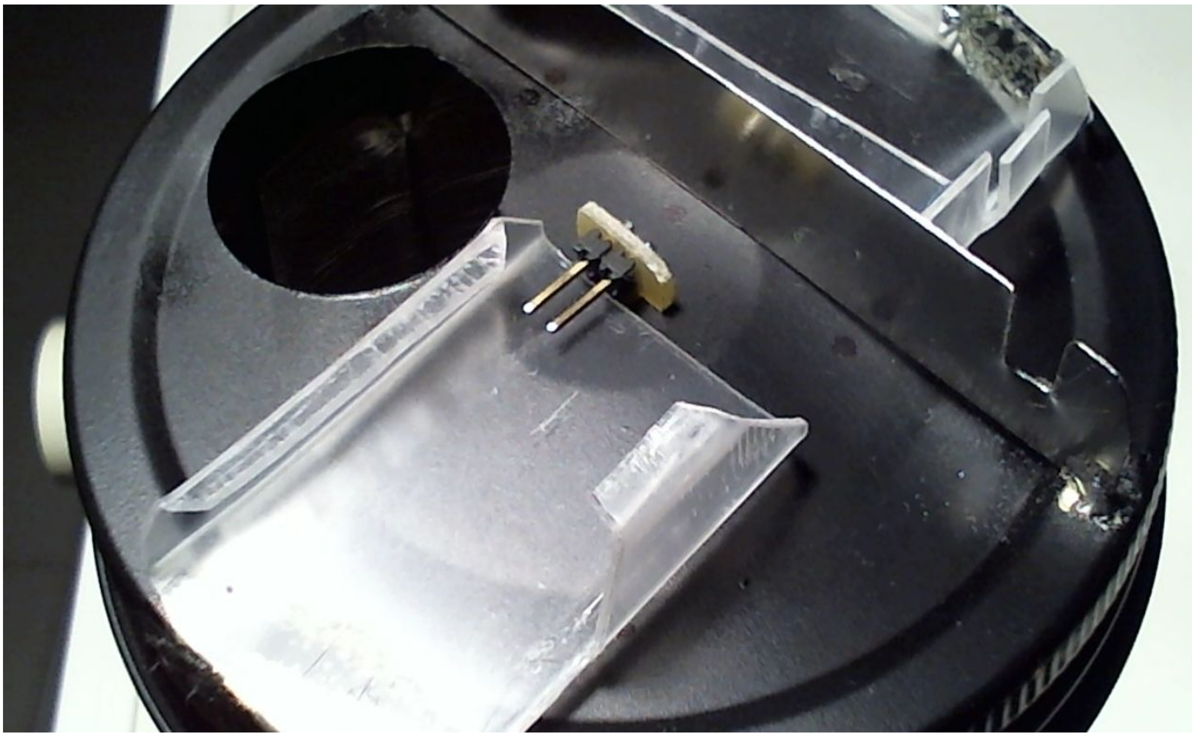
At the base of the can, close to the hole, we will have about 10 millimeters of wire insulation.

The container is 210 mm in height, hole to hole. You can check this by inserting a ruler in the top hole.

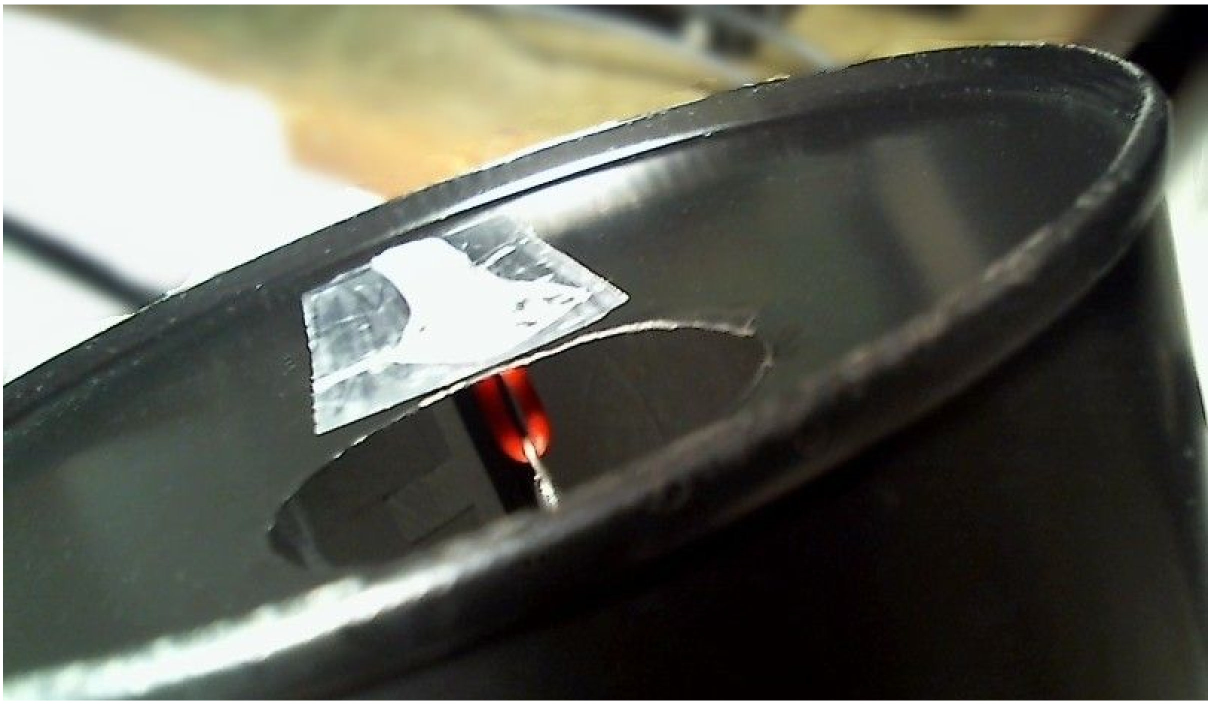
Before inserting the central wire is good to cover the FET and the vertical tracks with a piece of heat-shrinkable sheath. This, to avoid short circuits, that may occur with the metal around the hole.

The tension between the central wire and the metal of the container is very low, a few volts maximum, any insulating tube should be okay. Its function, is only to center the "T" in the hole and not to withstand high voltages.

Inserting the central wire



The wire is inserted into the top center hole, as seen here. Don't focus on the plastic housings of the electronics, which will be explained in detail in the next document.



Pull out the insulation wire from the bottom hole, using a pair of tweezers, folding it on a side and securing it with tape.

Attaching the central wire

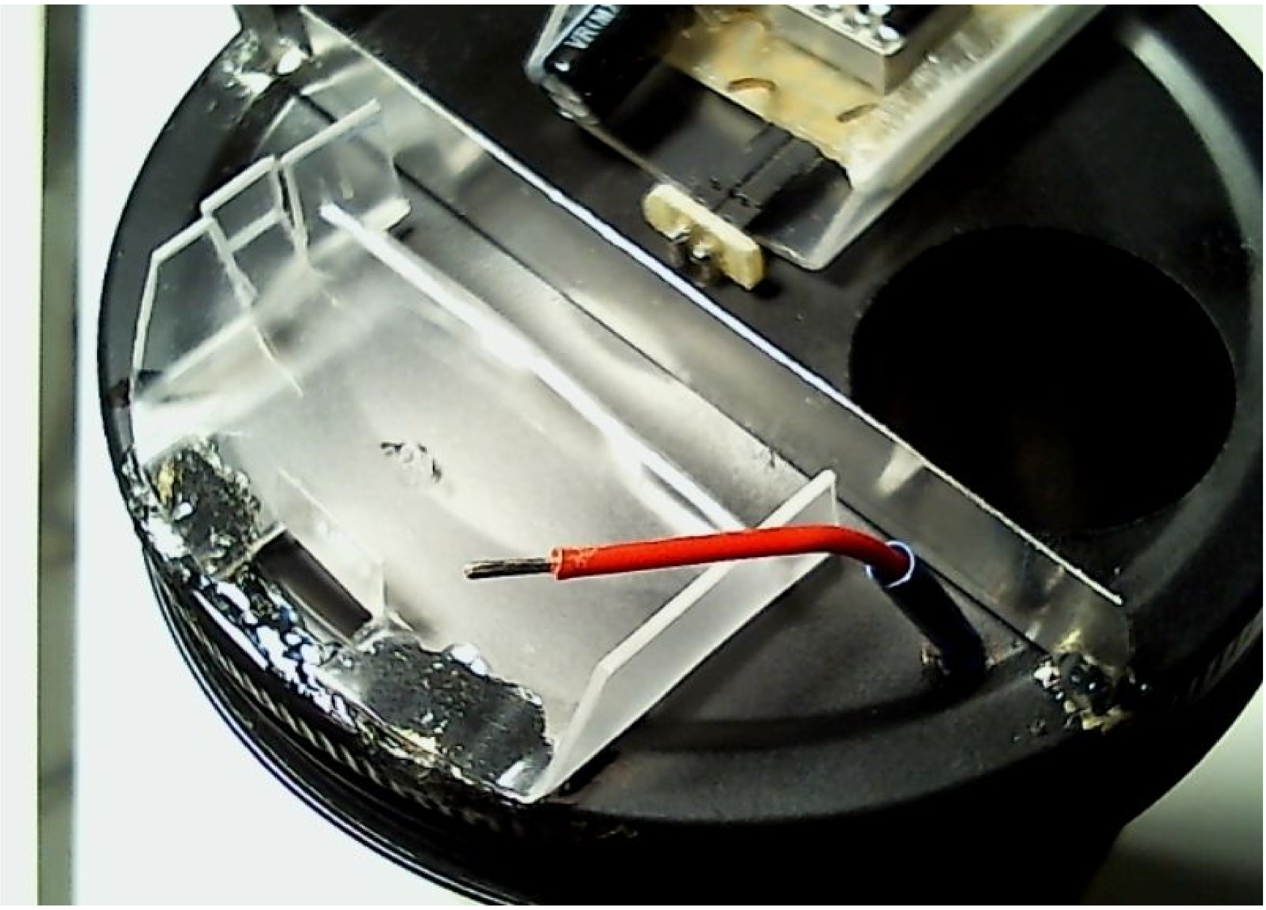
Prepare a piece of tape a few centimeters long, before attaching the wire, pasted to the table, close to our working surface.

Press the top cover (which is made to act like a spring), firmly pull the wire out of the bottom hole (without tearing it) and then bend it at ninety degrees, as seen in this picture, securing it with tape. Check again to make sure it is well pulled down.

At the end, for greater security, add a drop of hot glue or silicone at the point where the wire enters the hole (raise a bit the portion of the tape that covers the hole and glue it)

Ensure a good thread tension. Having the lid which acts as a spring is required to recover the elongation of the wire, when the ambient temperature increases. If the wire becomes loose and slips into the hole, it could cause electrical noise.

Connections with the electronics



Here you can see, how the top "T" part, will be connected to the electronics, please pay no attention to the plastic housings and a bit abundant glue (transparent Bostik)

Completed this last task, the hard part is over. In the next document, we will work on the electronics, much easier and with more fun.