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# TRITIUM:
# Aveiro prototype

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Tritium report
Department: nuclear and particle physics

# Índice

# 1. Introduction

In this report I will explain the work which we did from 9th april to 13th april when I travelled to Aveiro. This work was carried out within the framework of Tritium project. For explaining this work I will divide it in three parts:

- First of all I will explain the prototype which was designed and built by Aveiro people.
- Second I will explain the automatize polishing device which we developed. This machine emerges as a necessity when we tried to prepare the fibers which we used in this prototype.
- Finally I will show the conclusion which we have obtained and what we pretend to do as next step.

When we finish the building of this prototype and the checking task, we will put this prototype in Almaraz nuclear power plant together with the Valencia prototype so that we can start to learn about both prototypes and the possible problems which we will have in this place.

# 2. Tritium prototype designed by Aveiro people

The prototype which Aveiro people designed is quite similar to the prototype which was designed by Valencia people but it has a few difference which is very important from point of view of physics.

Both prototypes are formed for a external cilinder whose material is teflon. The impotance to use teflon here is that the fibers which we use in our experiment (BCF-12) have a emision spectrum with a peak at $\lambda = 435$ nm and the reflection coefficient which have the teflon is close to 1 for this type of photons.

In the Figure 1 I show you this external cilinder whose length is 200 mm. It's internal and external diameter is 43 mm and 61 mm respectively. Moreover this cilinder have two holes like the hole which appear in the figure 2. We will use this holes for filling and emptying this prototype which tritium water. You have to take into account that you need two holes every time that you fill or empty your prototype because you will use one out of this holes for filling or emptying your prototype and the other hole for emptying or filling the air your prototype respectively.

In the figure 3 we can compare both, Aveiro (3a) and Valencia (3b) prototype. There you can see that both prototypes have nearly the same external cilinder and their measurements are very close.

The first difference between both prototypes is that the Valencia prototype uses fibers whose diameter is 1 mm while the fibers, which are used by Aveiro prototype, is exactly the same type but with 2 mm of diameter. It seems like a trivial difference but it is very important from point of view of physics.


(a) (b)

Figura 1: External cilinder of the Aveiro prototype.

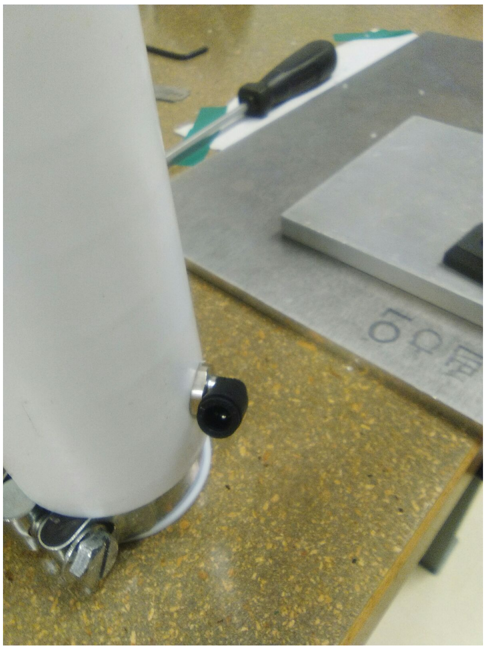


Figura 2: Filling and emptying holes

(a) Aveiro prototype (b) Valencia prototype

Figura 3: Comparison between prototypes

For doing a good election between both we have to take into account that we want to detect the electrons which are emitted by desintegration of tritium, whose mean free path is about 5 or 6 $\mu m$. Therefore, you could think that the best option is 1 mm fibers because you can get a bigger active area (area which you can detect this electrons) since you can put more fibers in the same space. But the problem is that, if you use 1 mm fibers you need to use a structure like the structure which appear in the figure 4.

This structure is used by the Valencia prototype. The reason of this is that you need that your fibers are separated because if you don't do it, tritium water won't pass between your fibers so your active area will be less. You can avoid this problem if you use 2 mm fibers because in this case, this size is enough for allowing that tiritum water pass between the fibers. In this case you have to take into account that fibers are touching each other and some of them are touching the teflon walls so your active area will be the total area of the fibers minus the area which is in contact between fibers.

In summary, if we use 1 mm fibers we will have more active area in the same conditions but we need to use a structure for the fibers whereas if we use 2 mm fibers, we will have less active area in the same conditions but we can avoid to use this structure so we can put more fibers in the same space for getting a bigger active area. Furthermore, 2 mm fibers have more resistance which is very important because these will be subject to a continuous flow of water so we need that they are resistant.

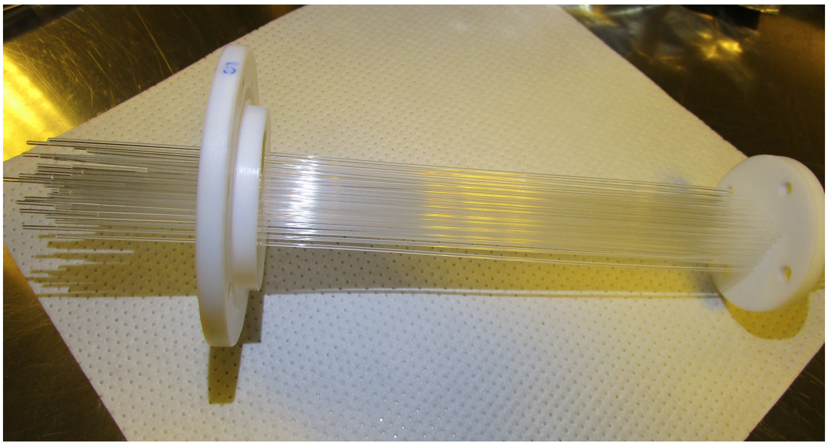
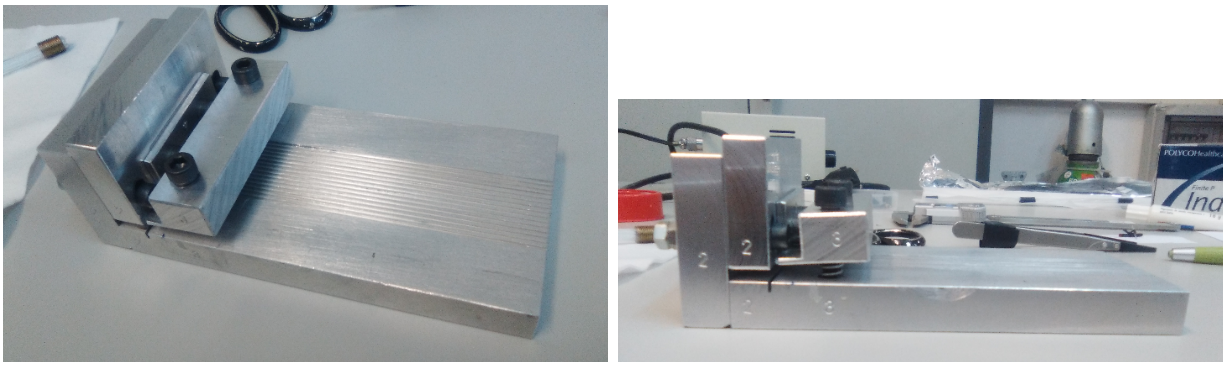


Figura 4: Structure of the fibers of the valencia prototype

In short, the Valencia prototype uses a structure that organize fibers whose diameter is 1 mm while the aveiro prototype use 2 mm fibers whitout any structure.

We can't estimate what is the best option because the contact area between fibers and between the fiber and the telfon walls will depend on the imperfection of the shape of every fiber since ideally it is a line, not a area and there's not exist any simulation program which can simulate these things. Moreover there are many other things which will affect in every configurate of the prototype differently like collection efficiency or signal-noise relation. You can't estimate it neither although you do several simulations of this experiment because it depends on the state of the surface of every fiber and the teflon walls. So the best option will be to put both prototypes in almaraz nuclear power plant and compare both results.

Next step will be to cut this 2 mm fibers. It is more complex than 1 mm fibers because if you use a thick blade you damage the fiber when you cut it but if you use a thin blade you damage the blade and it affect to your fiber. We tried to cut with several techniques and the only device, in which we were able to obtain a cutting optically acceptable, was with the cuttinc device which Valencia people developed and built in their workshop. In the figure 5 you can observe this one.

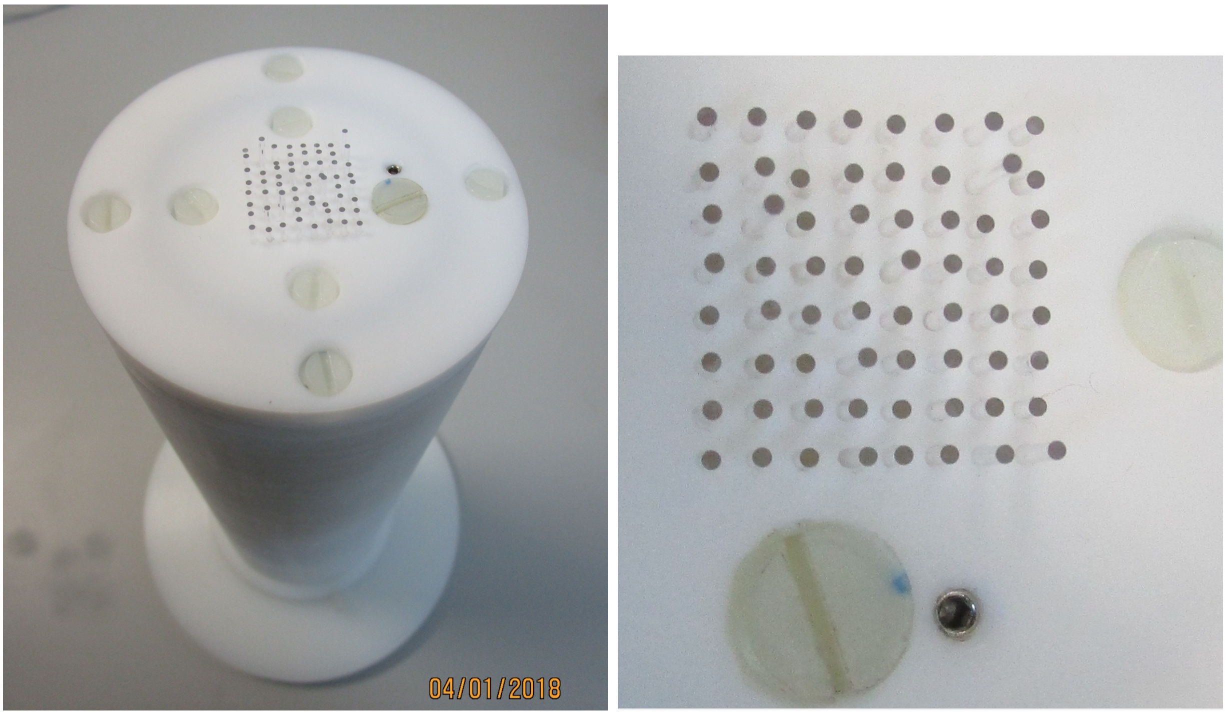


(a) (b)

Figura 5: Valencia cutting device

We have to take into account that we need to do the transmission of the photons, which are creating inside the fibers due to tritium events, between this fibers, which will be inside the prototype in contact with tritium water, and the PMT or SiPM, which will be outside the prototype and it can't touch the tritium water.

Doing this step in a correctly way is more easy for Valencia people than Aveiro people because the Valencia prototype uses a structure for hold every fiber so we can make several holes with the same matrix that this structure so that fibers through the prototype and it get out. Therefore, now, we only have to use optical grass to couple correctly this fibers to the photons counter. In the figure 6 you can see the cilinder cover which have this holes matrix.




(a) Holes matrix of the valencia prototype

(b) Holes matrix of the valencia prototype (zoom)

Figura 6: Holes matrix of the Valencia prototype

But Aveiro preople, contrary to Valencia people, can't do this because they don't have any structure of the fibers. Their idea for doing this task is to use a methacrylated glass (PMMA), which have a transmission coefficient clouse to 1 for this kind of photons, in every extrem of the prototype and it will be to fix with metalics belts which you can observe in the figure 1. In this case you will can get that the photons through this glass whitout tritium water do it. Now, likewise valencia prototype, we only have to use optical grass to couple correctly this methacrylated glass to the photons counter. The length of this methacrylated glass is 10 mm so the length of fibers, which will be inside, have to be 180 mm. We cut about 370 fibers, of which about 350 out of them we put inside the prototype. This is the number which we can put inside of this prototype without they being too narrow. You can see it in the figure 7.

We have seen that with this cutting device we have obtained a lower precision than 1 mm in their length.

The Aveiro way for doing the transmission of the light have a problem which don't exit with the Valencia configuration. We can control quite good the conexion between fibers and photons counter for valencia prototype but, for aveiro prototype, we can control quite good the

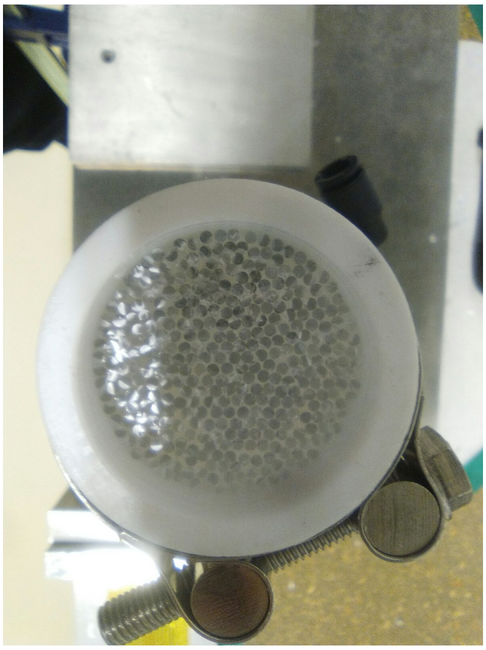


Figura 7: Fibers inside the prototype

conexion between methacrylated glass and photons counter but we can't control the conexion between fibers and methacrylated glass because we can't use optical grass since it will be in contact with tritium water. It is a critical point because a bad conexion could produce a huge loss in our signal.

Therefore we need that all fibers have exactly the same length for ensuring that all fibers will be in contact with both glass pieces correctly. As I said berfore, we can get a lower precision than 1 mm in their length with our cutting devices but it isn't enough. Therefore we need to polish every fiber for two reasons.

- First we need to polish because in spite of we obtain a good final state with our cutting device we can improve this results if we polish fibers before that. It is very important because we can improve our signal which is essential in our experiemnt.
- Second we need to polish because we can improve the presicion in the length of fibers. It is other essential thing in aveiro porotoype because we can improve the transmission of the light, which can affect to the signal a lot.

The thing is that until now we was polishing the fibers one by one handly and we had to spend 10 minuts more or less in every fiber. In the past we could do this because we work with few fibers but now we have 350 fibers. You can see that we need too much time for doing this task so we though about some alternative way for doing this task efficiently. We look for in internet but there are not any comercial device which doing this so we have started to build a simply device which do this task and which have a precision better than 1 mm in their length. In the section 3 of this report I will explain this device.

## 3. Automatize polishing device

In the previous section we have seen the necessity to designed a device which do the polishing task in the fibers automatically. In this section we will explain it. This mechanical device, which we have designed, consists of two parts:

- On the one hand it have a metalic piece which hold and fix the papers that we use for polishing the fibers. We will move this piece instead of the piece which will hold the several fibers. The only reason of this decision is for mechanical simplicity.

  Our objective is that we can describe the way which we want with this metalic piece in a bidimensional flat, whose size is delimited by the polishing papers and the position of the fibers which we are polishing. We have to take into account that, mathematicaly, we can describe any point inside of this flat with two non-parallel vectors so for moving inside of this flat we only need two screw, whose direction will be different. We will choose perpendicular directions for simplicity. You can see this configuration in the figure 8.

Figura 8: Configuration of the table

  This device consist of two perpendiculas screws which are attached to a nut every one. The metalic piece, which hold the polishing papers, rest on both screws. When we move one nut out of both, the screw, which are attached, rotates. Therefore, the metalic piece move in this direction. As a result we can move this metalic piece following the way which we want inside of this flat with both nuts.

  Hence we have a machine which is able to describe the movement which we want in a bidimensional flat with a pair of nuts. Now we only have to automate this movement. The idea is to connect a motor in every nut which we will control for doing this automatical movement. In the figure 9 you can observe both motors, every one of them are inside of every blue boxes and each one is connected to a nut.

  So that we control both motors we are going to use arduino technology. Specifically we will use an arduino whose model is Genuino Uno Rev3 where we will connect a special card for working with motors. The name of this card is CNC SHIELD and I show it in the figure 10a. You can observe that this card allow to connect 4 different microchips. Concrectly

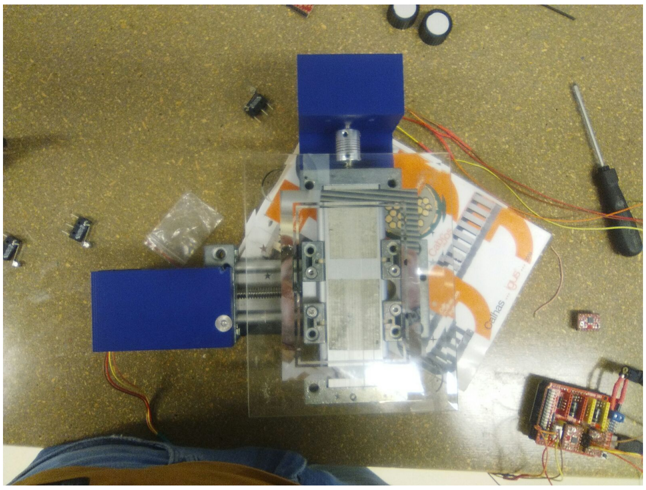
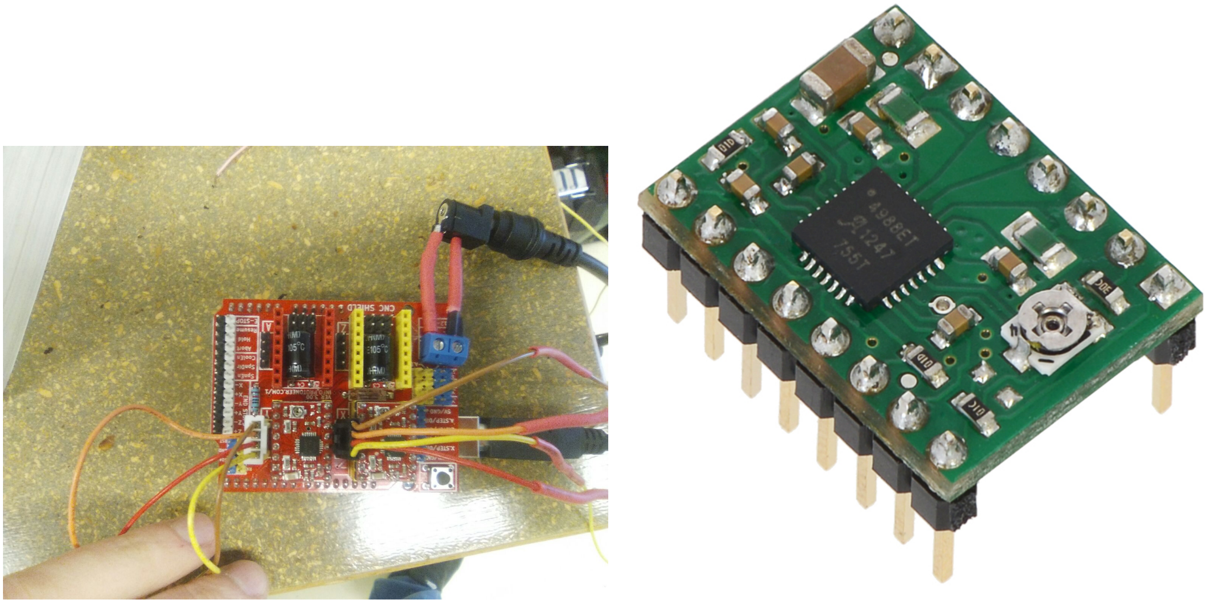


Figura 9: Two motors connect to the nuts

the microchip which we will use is 4988ET which is a DMOS Microstepping Driver with Translator and Overcurrent Protection and you can see it in the figure 10b.



(a) CNC SHIELD card

(b) 4988ET

Figura 10: Arduino technology.

As I said before this card allow to connect four different microchips and every microchip allow to control one different thing at the same time. As a result we can control 4 different things which could be 4 different motors if we want. By the moment we only need to control two motors for doing the movement which we want so we can reserve this other connections for doing other things. The main idea is to use one out of two rest connections for programing a emergency stop. For instance we can do it if we can use a switch, like the switch which appear in the figure 11. We can put a switch in every limit of metalic piece way, which we move, along the every screw (in both sides). In this case, if this metalic piece arrive to this limit along the screws, it will press this switch and this movimint will stop fastly. In this way we can avoid misused of this machine that could affect to the operation of this device. The electronical circuit, which control this switch, could be really simply. We only need a typical electronic circuit, which is normal open but, when the metalic piece press the switch, this circuit will close. In this case we will have a signal that will travel in this circuit and will arrive to the arduino which, when received this signal, will stop.

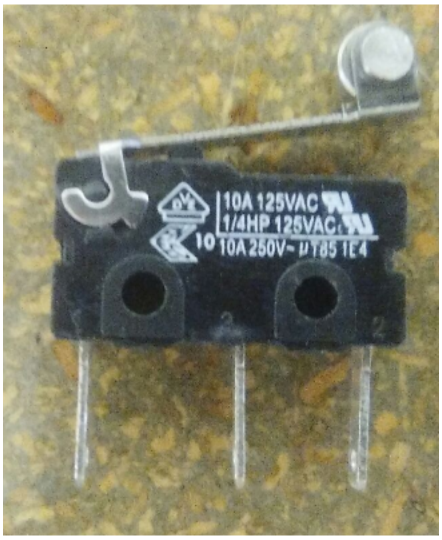



Figura 11: Switch for emergency stop

- On the other hand it have one piece which hold several fibers. This piece is really simply. We only need that this piece can hold several fibers at the same time. For simplicity this piece will be fix when we are polishing and, as I said before, we will move the metalic piece.

  Moreover we have to take into account that it is really important that both flat (the piece which hold the fibers and the metalic piece) to be parallel so that we can get the spatial accuracy which we want. You can see the piece, which we have designed for holding the fibers, in the figure 12

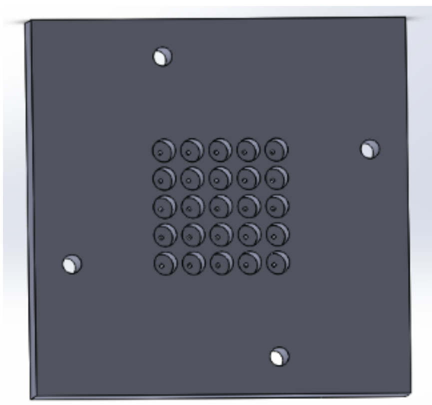


Figura 12: Piece which hold the fibers

We have designed this piece with one hold in every side where we will put a screw in every one for holding this piece and connecting both piece. Therefore we can change the orientation of this piece respect to the metalic piece with this screws for getting that both flats are parallel.

Moreover we have several holes for holding the fibers. In concret these holes have two diameters as you can see in the figure 12. We have first a bigger diameter where we pass the fiber and a metalic piece which we need for increase the weight of every fiber. With this bigger diameter we get to fix the fiber and this metalic piece for safety reasons. You can see this metalic piece in the figure 13.

Figura 13: Metalic piece which press every fiber

The weight of this piece is more or less 100 g. We have checked that with this weight we can obtain a good results when we polish but we want to check what is the minimum weight of this piece with which we obtain the best results because the smaller weight of this piece, the lower damage we obtain in the fiber. We will fix this metalic piece to every fiber with a plastic belt whose position will mark the maximum distance which we loss when we polish this fiber.

Finally, every hole of the piece, which hold the fibers, will have another smallest diameter where we only pass the fiber.

As this piece isn't in contact to the piece which is moving when we are polishing we can use the material which we want for designing this piece since this won't affect to the result. We can use a cheaper material which have little weight. The piece which you can see in the figura 12 only have twenty five holes so you only can hold twenty five fibers at the same time. It isn't important because this piece is cheaper so you can designed other similar piece which have very many holes if your experiment need it.

Until now we have described this device. Now we are going to speak about the code which we will use for automate this device.

We have several options for doing this programmating task. By he moment we are going to program directly the CNC SHIELD (special card) instead of programing the arduino. The problem is that we have to learn other different programing language, whose name is Gcode but with this we obtain a big profit because Gcode is a pseudocode and, as I said before, this card is specially prepare for working with motors so there are a lot of functions which will be really useful for our task. As a result we will need less code with this programming language for doing the same task.

By the moment we are working in line from the computer for controling this motors but our final idea is to write a gcode in a python file and upload this file in the arduino. In this case, We won't need a laptop for controling this device. Moreover if we use a battery we will have a portable devices.

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## 4. Conclusion

Finally I are going to explain the conclusions which we have obtained in these studies and next step which we will do for following these one.

- First of all we have prepared a new prototype which is apparently similar to the Valencia prototype but it has several important differences from point of view of the physics. Beforehand we can't know what is the best configuration because we can't simulate these prototypes. The reason of this is that there are a lot of important concepts, like the imperfections of the fiber shape, which will affect at the signal of every prototype differently. The problem is that, nowadays, there's not exist any simulator which can do this type of task.

  As a result, the only way, which we have for checking what is the best configuration for the final prototype, is to put both prototypes in Almaraz power nuclear plant and we start to mesure with both at the same time. When we analyze the results of every prototype we will can discuss what is the best configuration for this task.

  As I said before, we have to take into account that the internal volum is different in every prototype so the quantity of tritium water, which is the radiactive source that we pretend to mesure, will be different in every prototype. Therefore, in order that we are able to compare the results between both, we have to scale the results of each one at the same internal volum.

- Second, by the moment, the electronics, which control this signal, is the typical electronics for general use because this is the electronics which we have in our laboratories and it is the electronics which we know. In this way we reduce the uncertainty in our study.

  When we calibrate our prototype we will have to develop a new type of electronics which will have very low noise and we will have to study this electronics for undestanding it before we install all this thing in Almaraz power nuclear plant. It will be really important step because our main problem is that the tritium signal, with which we pretend to work, will be very low so we need that the noise in our experiment is really low so that we can obtain a good tritium signal in less than ten minuts.

- Third we have to take into account that we have to polish the fibers which we have prepared for the Aveiro prototype. This work was easier for Valencia prototype because this has only 64 fibers but the Aveiro prototype has 350 fibers. As I have explained in the section 3 we need too much time for doing this task handly so, as there are not any device which do this task, we have start to develop this kind of machine.

Until now we have checked that, with arduino technology, we can program this machine for describing the way which we want at the speed which we want. We are able to do several figures with several speeds.

The main problem which we have found in our first prototype is that the motors, which we use for moving this machine, have some limitations like the torque. This torque imposes a limit in the maximum speed with which we can move this piece and, therefore, it imposes a limit in the minimum time which you need for polishing the fibers. Although we have get a speed with which we can do this task with an acceptable time we want to improve the system for increasing this limit in the speed. For doing this task we have several options like use a fast screws or to use other type of motors with bigger torque. In this case we will can check what is the minimum time which we need for polishing the fibers without we damage the fibers.

- Finally, we have to take into account that there's not exist any commercial devices like this one. Therefore, if you have to take into account that, nowadays, there are a lot of experiments, which need to use a big quantity of fibers in their configuration, you can sense that the device, which we are developing, is really useful.

  As a result, if this devices work and we create a easy display so that users can manipulate the parameters of the moviment, which is described by the device, we could patent this one.