Designing, Building and Testing a Multi Wire Proportional Chamber at the CERN Particle Beam

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"The Wire Wizards"

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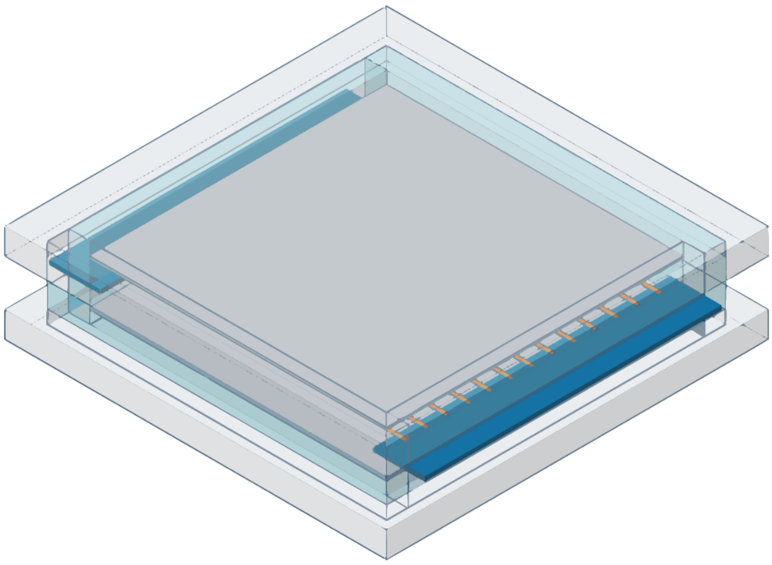
Our proposal for the Beamline for Schools Competition



11th April 2023, Eindhoven, The Netherlands

Why we want to go to CERN

Our team consists of 5 students, all from the Netherlands. All of us are very passionate about science, so we were very motivated to take part in the competition. We think that doing an experiment at CERN is an excellent way to learn about particle physics and teamwork. Though we don't have a lot of members in our team, every one of us has different qualities, thus we think we will be able to work efficiently and effectively.

In the end, we hope to have acquired knowledge, and inspire and introduce other students in our school to particle physics.

Experiment proposal

Ionising radiation like X-rays and charged particles can be detected by measuring ionisation in a gas. The first gaseous detector was the Geiger counter [1], invented by E. Rutherford and H. Geiger in 1908. The Geiger counter only detects charge and can be used to measure the amount of radiation by counting hits. The multi wire proportional chamber [2](MWPC), invented in 1968 by G. Charpak, can also determine the position of a hit. The MWPC is a detector which uses the ionising characteristics of certain particles to detect them. It can detect and measure the energy and trajectories of particles. It is made with thin metal wires stretched across a gas filled chamber, with high voltages applied to the wire to create electric fields. We wanted to make a particle detector and chose this type, because it will give a lot of information about the particles and is feasible to build for students like us.

When a charged particle enters the chamber and ionizes the gas particles, the resulting electrons move to the wire, and will cause an avalanche [3] of other electrons that will be detected as an electric pulse. The magnitude of the signal is proportional to the amount of charge deposited by the particle, allowing the energy of that particle to be measured. By arranging the chambers in arrays, it will be possible to form a tracking detector, allowing the trajectory of the particle to be determined.

The concept is relatively simple, but making a MWPC is a challenge. For example, the design must be airtight, and the geometry must be precise. But we like a challenge, so that's why we already started developing it at home!

Our objective is to successfully design, build, test and optimize a home-made multi wire proportional chamber at the CERN beamline.

Our detector

Our MWPC detector consists of 4 smaller wire chambers stacked on top of each other (see Figure 1 and 2). The anode wires are spaced 10mm from each other, and also 10mm from the cathode plates. Each detector has 13 wires because we want to use an Arduino that has 13 usable digital inputs to register pulses. The wire that we used is 0.03mm gold plated tungsten wire. The outer material that we used is plexiglass for its chemical stability. As cathode plates we used aluminium plates of 1mm thick., We used epoxy resin as glue for its chemical stability. More specific dimensions can be found here, which is our final design (click on tinker this): https://www.tinkercad.com/things/5CJg7BNnr6G?sharecode=dStObXCcI2FHrkSrNPU6AHleot8eBuTPZndRzp6DATY

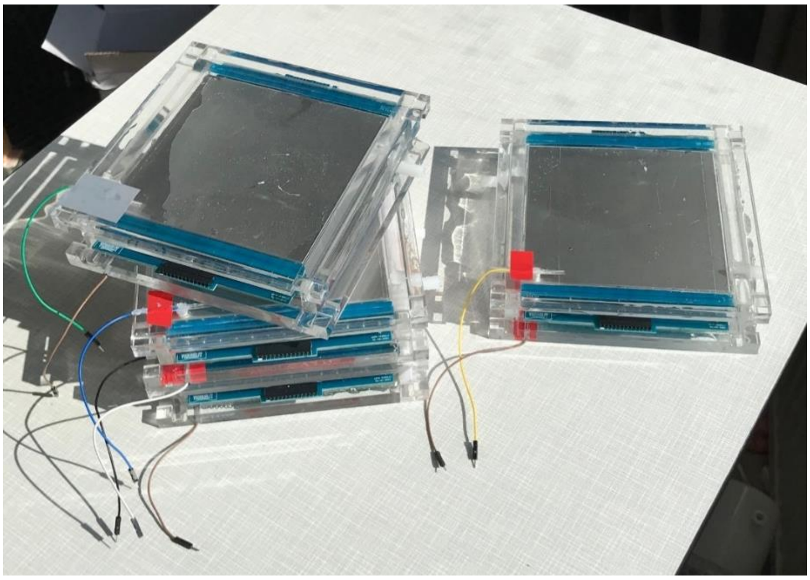


Figure 1: Four MWPC's that we prepared, picture made by us

To achieve wire precision, we soldered the wires to PCB connectors that a team member designed in KiCad. We put little holes around the soldering points for the wires to go through, so now our precision relies on the drilling machines from the PCB manufacturer (which is probably more than good enough).

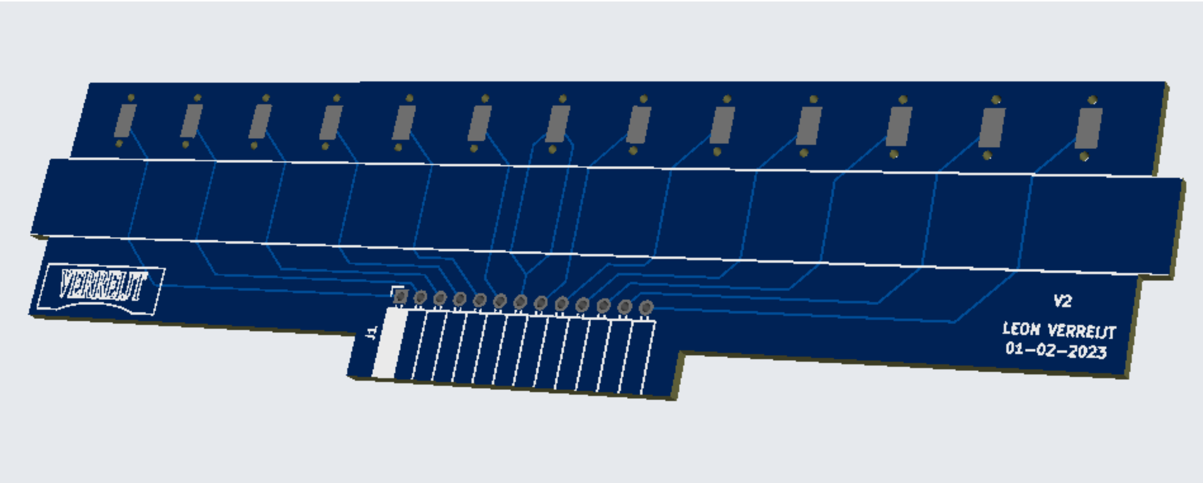


Figure 2: Our final design of the wire connections that we made. picture from JLCPCB gerber viewer

We contacted Nikhef for help (our nation's institute of particle physics) to build our MWPC. Luckily, they were very enthusiastic, and we received guidance and the required gold-plated tungsten wires.

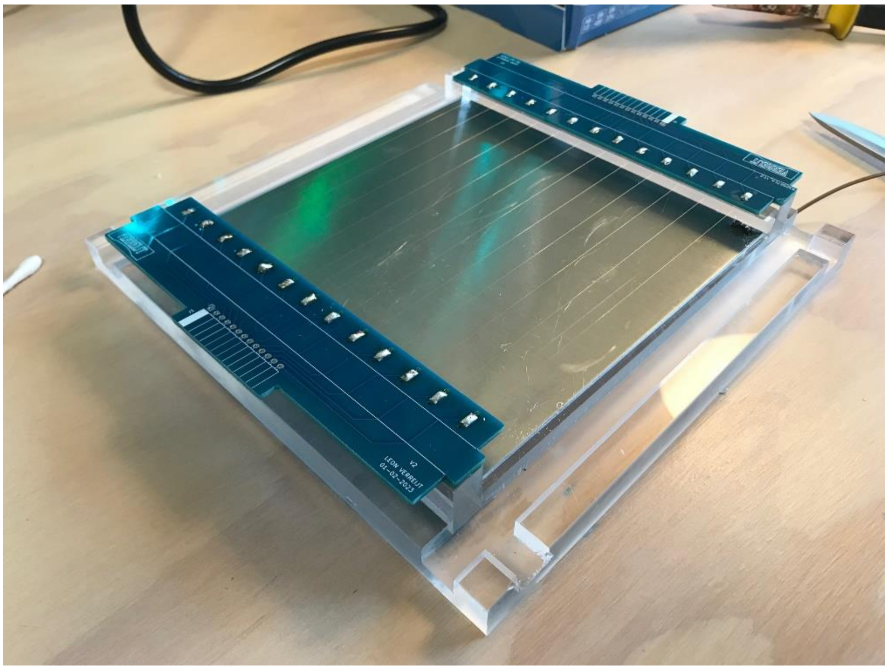


Figure 3: Building of our second iteration wire chamber, and wire precision is achieved. Picture made by us

Though we completed building the chambers, we do not yet have the required electronics for our chamber. We tried making the necessary amplifiers using, among other things, an OPA657 (an opamp that works well for wire chambers), however our equipment was old and worn out, so working with the small signals was difficult. We also realised we were simply not experienced enough to make such precise circuits ourselves.

Regarding the gases, our parents were worried about our safety while working with the necessary quenching gases (such as methane or isobutane as they are flammable), so we haven't been able to test them. Moreover, the gases in the chamber must be very pure, which will cost a lot. However, we were allowed to buy and use argon to check if the chambers were airtight using gas bubblers.

Our plan

We want to use the proton synchrotron to create all kinds of different particles, and we will track and identify them with our detector. We hope to at least be able to distinguish muons, electrons, and kaons. Before we begin hypothesising on how to exactly do that, we prefer discussing it with professionals first.

We will place a scintillator plate on top of our MWPC stack. A scintillator with a photomultiplier tube (PMT) is a very reliable way to trigger a signal when a particle goes through it. This way a coincidence trigger will be formed and will help establish the reliability of the detector.

Most wire chambers are flushed with a mixture of a noble gas and a quenching gas [4] with a ratio of around 80:20. We will research the effects of changing gas mixtures and ratios to improve our detector. For noble gases, we want to try argon and helium. For quenching gases, we want to use CO2, methane, isobutane, ethane and freon (if available).

To visualize the particles, we will make a computer program which will display the detections in a 3d space. It reads every output, and our idea is to make a 3d visualisation where a line which represents the particle will appear when a particle is detected. This is why we made four detectors: two for the y-axis and two for the x-axis. Positioning the detectors in a cross shape will enable us to track the path of the particle. Using the signal from wires in chambers 1 and 3, the computer will create a plane, and a separate plane will be generated using the signal generated in chambers 2 and 4. particle. See figure 4 for a visual guide.

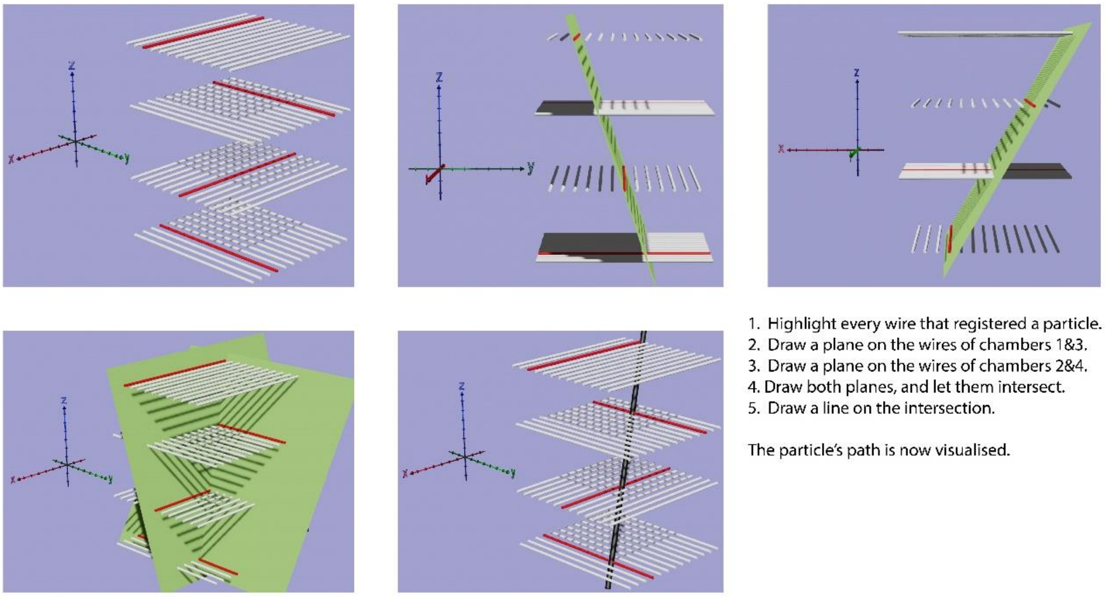


Figure 4: Guide for visualising the particle’s path. Illustration made by us

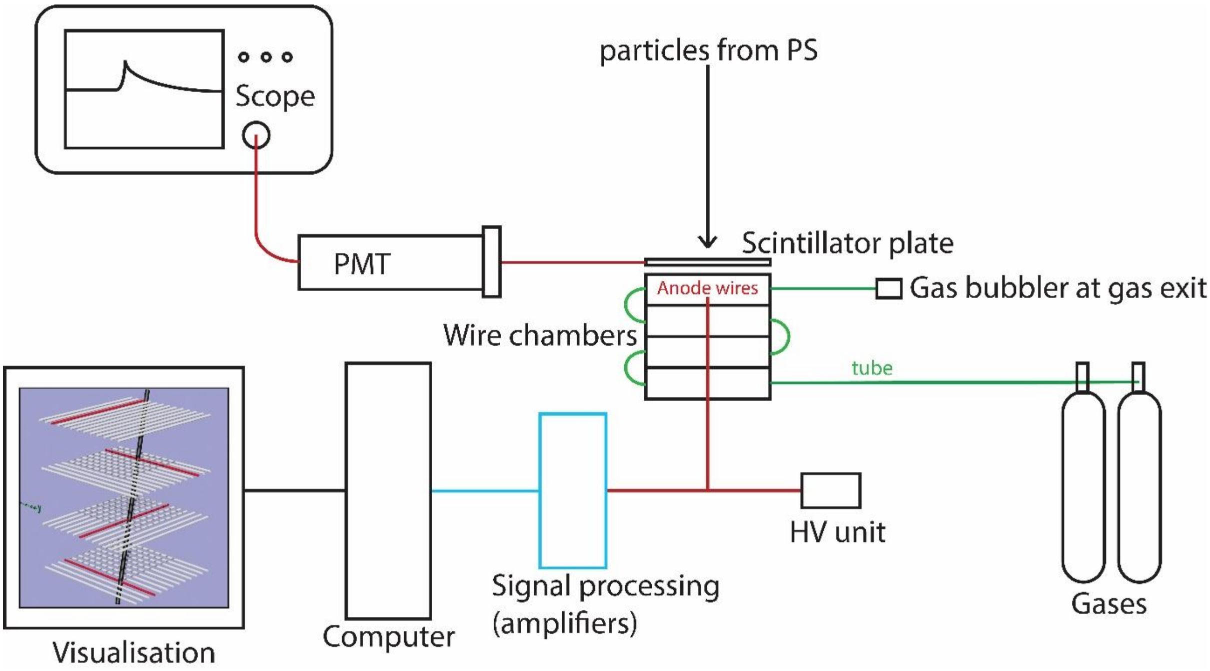


Figure 5: Visualisation of the setup we had in mind. Illustration made by us

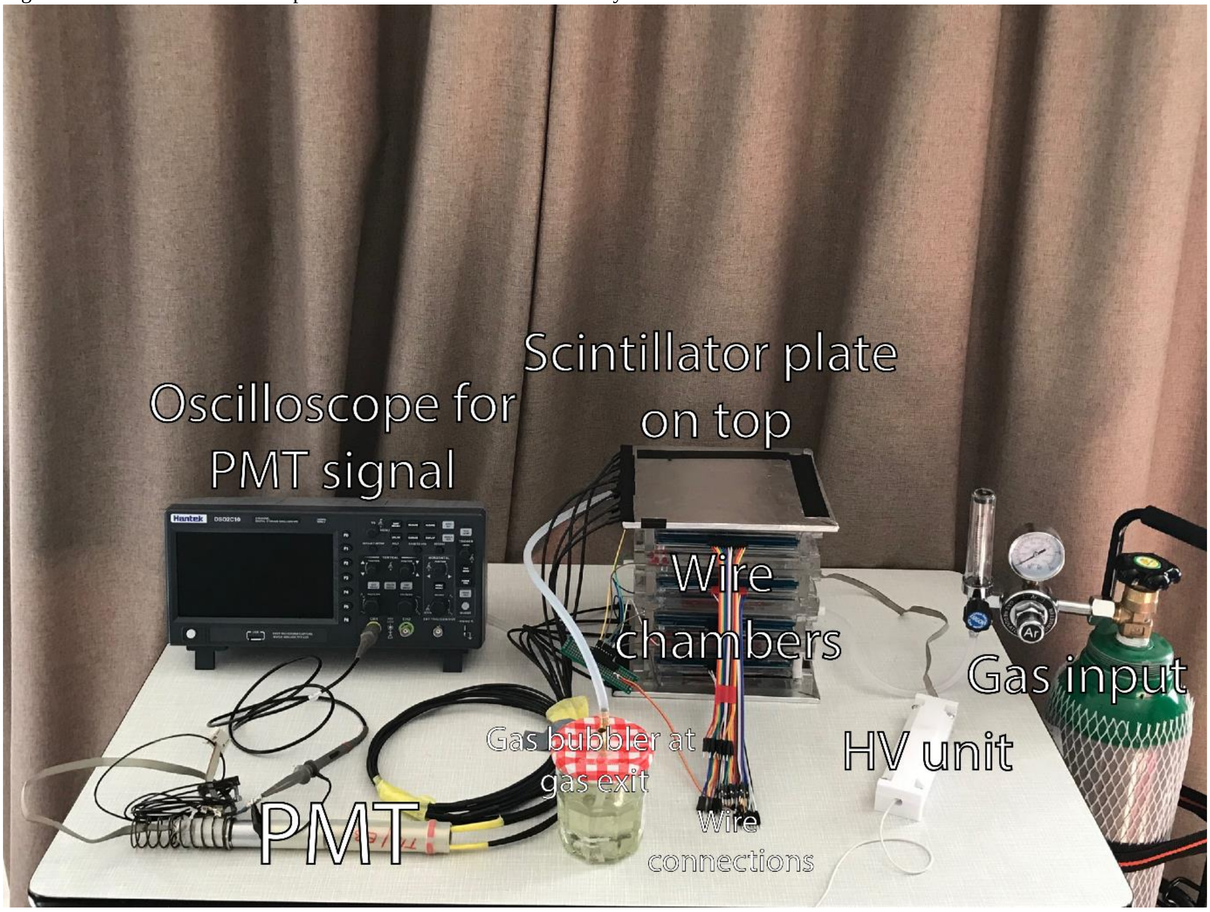


Figure 6: Picture of everything we have yet prepared. Picture taken by us

Our detector is expected to run for 10 days. The tasks to be performed for every day are as follows:

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14
T1	x	x	x	x										
T2	x	x	x											
T3				x	x									
T4						x								
T5						x	x							
T6								x						
T7									x	x				
EXTRA											x	x	x	x

Task 1: Developing reliable amplification circuits

Task 2: Developing a program that will visualize the particles

Task 3: Setting up the detector

Task 4: First test at the beamline

Task 5: Reviewing and improving/calibrating our setup

Task 6: Second test at the beamline

Task 7: Processing data

We left 4 days from the 14 total days open giving us time for more tests at the beamline or extra unexpected tasks.

What science education or outreach activity can we organize in our community?

Firstly, we hope to be able to present our results to students in and around our school. The spark that started our interest in particle detection was seeing a real spark chamber in a CERN building. We found it so interesting, that we wanted to make our own detector. We hope that students can be excited about particle physics when they are also exposed to particle detectors just like how it went with members of our team!

Secondly, we want to share our journey online, to other people who also want to build a wire chamber. While building the detector, we noticed that the only documents giving us information were made by experienced scientists, for experienced scientists. It was often hard to gain basic information we needed while building the detector. We think that with proper guidance many motivated students would be able to build their own wire chamber. That’s why we will make full tutorials and tips while building it.

References

[1] E. Rutherford and H. Geiger, An electrical method of counting the number of particles from radioactive substances. Proceedings of the royal society (London). Ser.A, vol.81, 141-161, 1908.

[2] G. Charpak et al, The use of multiwire proportional counters to select and localize charged particles. Nuclear Instruments & Methods, 62, 262, 1968.

[3] Little, P. F. (1956). "Secondary effects". In Flügge, Siegfried (ed.). Electron-emission • Gas discharges I. Handbuch der Physik (Encyclopedia of Physics). Vol. XXI. Berlin-Heidelberg-New York City: Springer-Verlag. pp. 574–663

[4] J. Va'vra, Wire Chamber Gases. Stanford Linear Accelerator Center, Stanford University, Stanford, CA 9430, Nucl.Instrum.Meth.A 323 (1992) 34-47