Project 2

In

FYS5555

By

Furkan Kaya

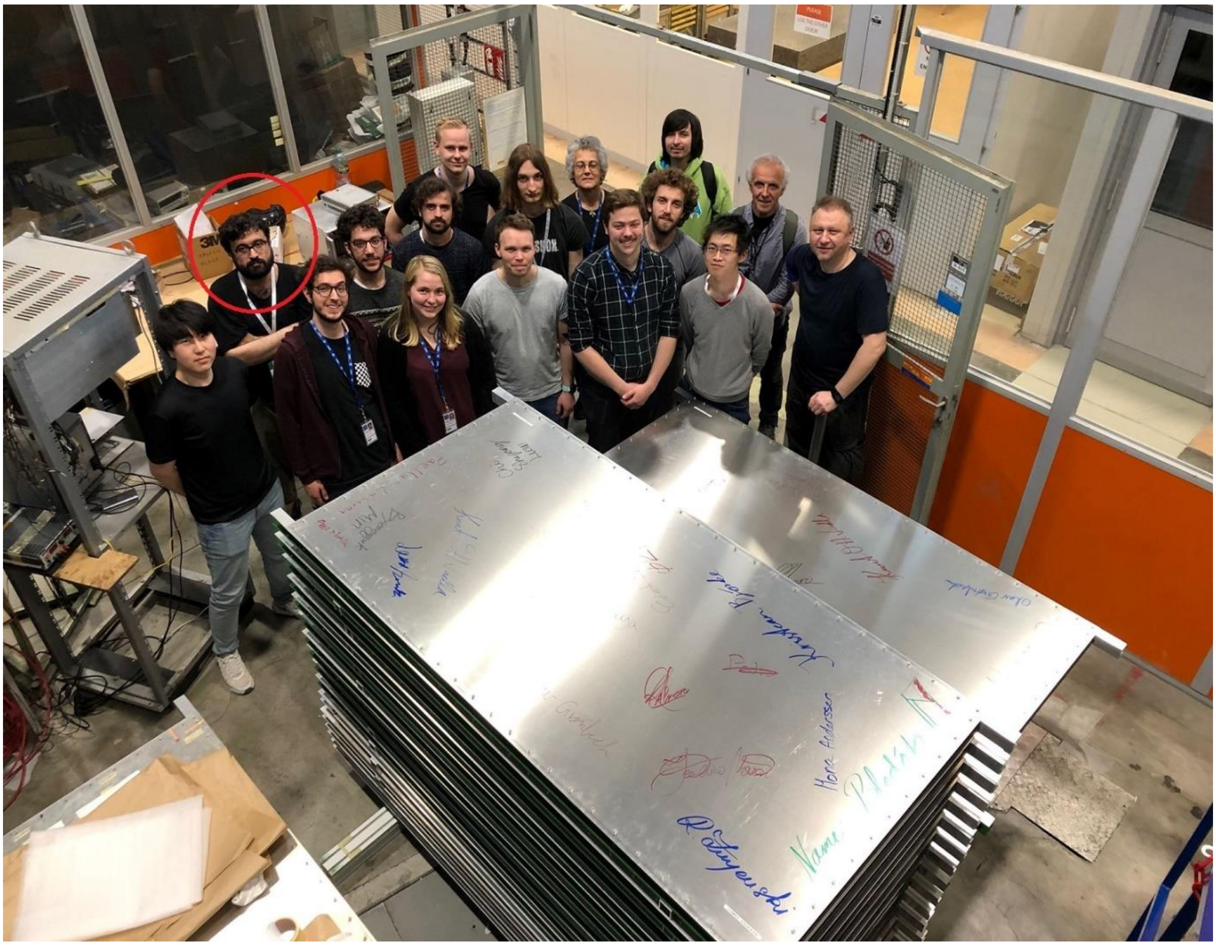

Figure 1: Image shows the group that participated in the task of creating the detectors. Person in red circle is Furkan Kaya, author of this text

CONTENT

Motivation:

The class that took the course FYS5555 spent a week in Switzerland building detectors at the CERN facility. Detectors are very important in Particle Physics because without them it would be impossible to measure the energies before and after the collisions. Actually creating your own and testing previously created detectors would therefore give a new perspective on the processes in Particle Physics.

Introduction:

In Particle Physics a detector detects a particle after an interaction has occurred and energy has been deposited. The purpose of this type of detector in question is to detect atmospheric showers of extreme energy by detecting secondary muons on the ground coming from cosmic rays.[1] This work has been done as part of a collaboration between various high schools in Italy and CERN. Extreme Energy Event (EEE) was the name given to this collaboration. The class partaking in FYS555 this semester obligated itself to make two detectors and test detectors made by a previous group.

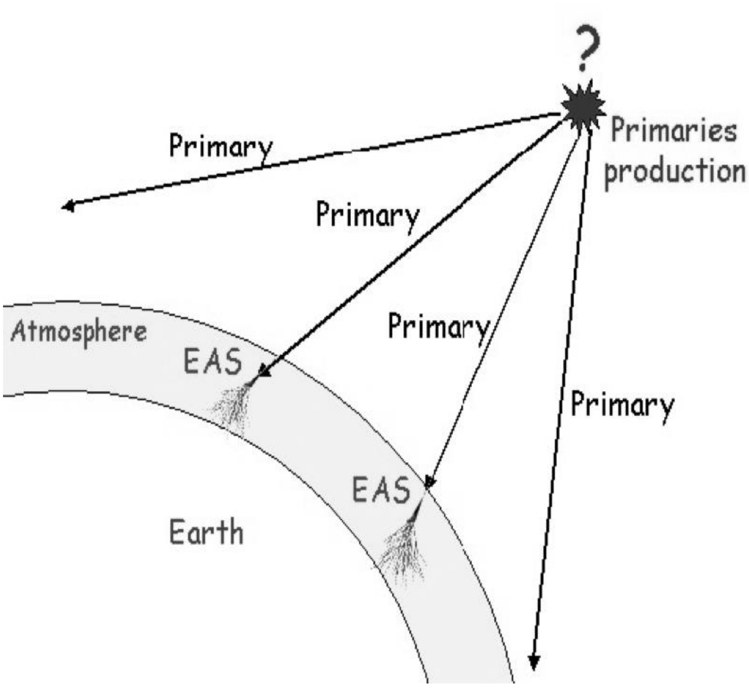

Figure 2: Schematic that shows how secondary muons are detected on the ground. The primary cosmic rays produce a large amount of muons on the ground

After the introduction a short description of the detector built follows, then a more detailed subsection of our practical work, before results from our tests and measurements from the official EEE-database comes at the end.

The detector:

The EEE detector is a very sophisticated particle detector with outstanding timing capabilities. It is based on the principle of Multigap Resistive Plate Chamber (MRCP).[2] The actual way the MRCP is built is shown in figure 3.

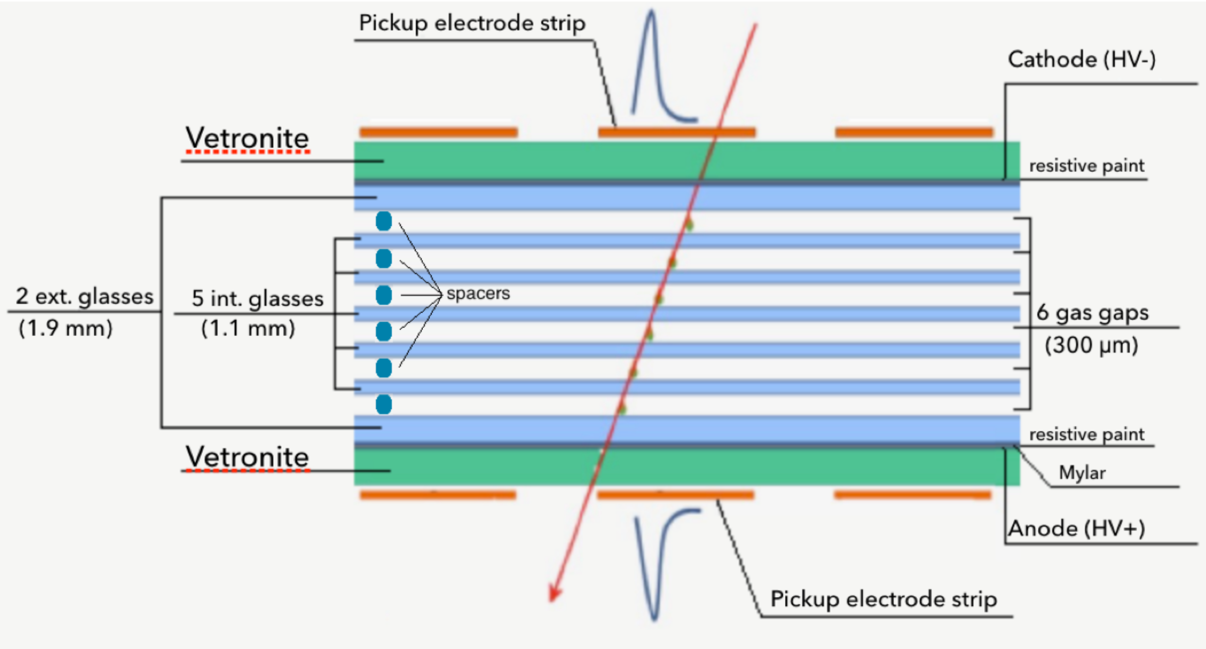

Figure 3:Schematic that shows the buildup of one detector.[1]

A cathode, meaning a part that gives away electrons, is placed on top and an anode, meaning a part that receives electrons, is placed on the bottom. On the vetronite plates on the top and bottom glass one has 24 readout strips made out of Copper (Cu). And since readout strips lie longitudinally on the chambers, one coordinate of the muon impact point is given by the difference of the signal arrival times at the two strip extremities, while the other is directly obtained from the position of the fired strip.

In the MRCP there are 6 gas gaps in each chamber. These gaps are 300 μm thick and are separated by thin glass plates. Nylon fishing lines are used as spacers in this regard.[1] The gas gap is used for both creation of primary ionization clusters and gas gain.[2] The gas used is Freon. In the text so far, two form of glass plates have been mentioned. To differentiate between them: the outer plates are coated with resistive paint, and they act as high-voltage electrodes. The inner plates are left electrically floating.[1]

The signal generated is by avalanche multiplication across the gap. The working principle of avalanche process is that a carrier collides with a bound electron in order to create a new electron-hole pair through its excess energy. This pair goes on to excite further electron-hole pairs, reminiscing of an avalanche.[3]

$$N = N_0 \exp(\alpha x)$$

is the number of electrons created in the avalanche process. α is the Townsend coefficient, x is the distance of the avalanche and N_0 is number of initial electrons. These form of detectors are used in the ALICE experiment at CERN due to longer efficiency plateau (because of lower Townsend coefficient) and better rate capability (because of one les resistive plate used in the chamber compared to its competitors).

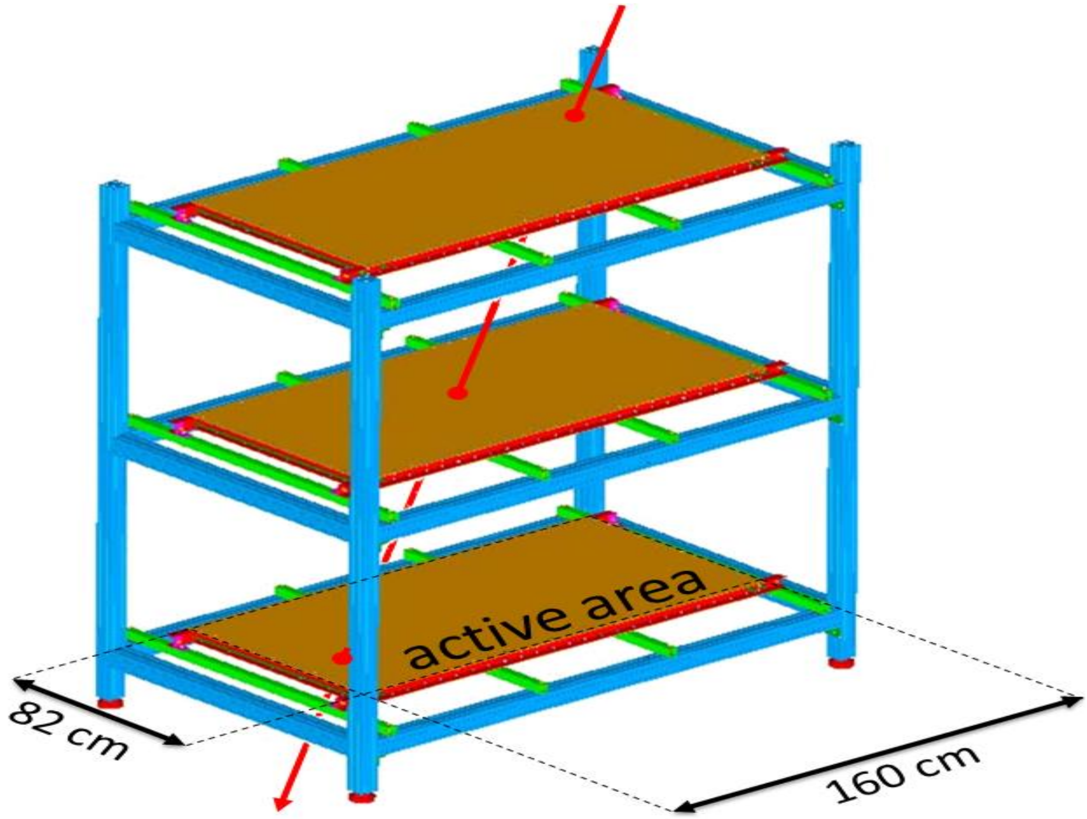

Figure 4: 3 detector chambers stacked on top of each other. The system is referred to as a "telescope".[1]

The detector is part of a 3-detector chamber system referred to as a “telescope”, as seen on figure 4.

In the project description it was required that the group test a chamber made by an earlier group. The strategy to test a new chamber is seen on figure 5.[4] The chamber being tested is placed on top of the three CERN-01 chambers.

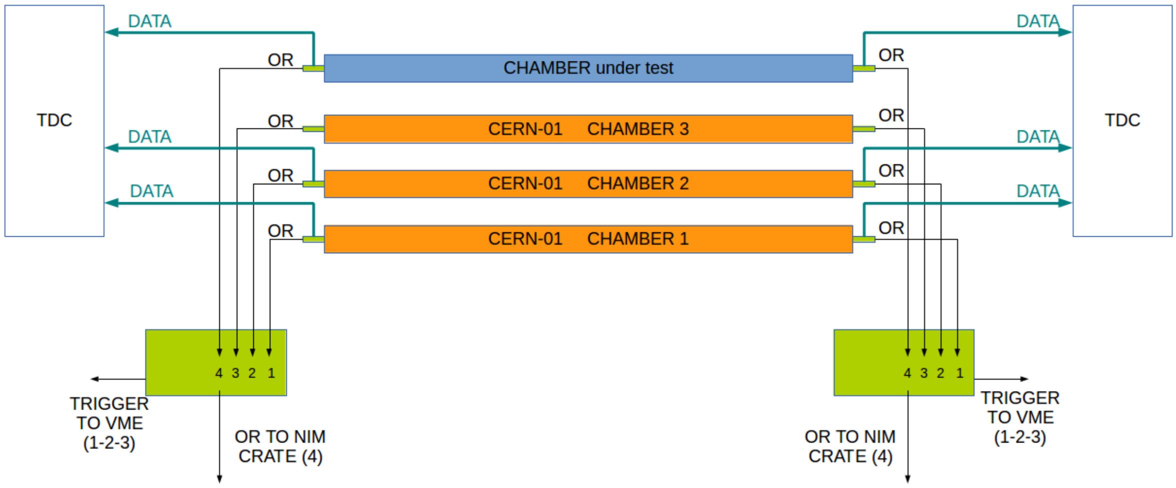

Figure 5: Scheme of the setup for the test of new chambers.[4]

The three lowest chambers are used as triggers. CERN-01 chambers 1 and 2 are where the data is collected, alongside the collection of data from the chamber being tested. So one needs to swap the FEC between chambers 3 and the test chamber before getting started.

Walkthrough of the practical work done at CERN:

The workplace at CERN had three different stations. At each station a different process was being done. But the combined work would lead to the production of a detector. The class was therefore divided into three and each group spent a certain amount of time at each station. The stations were: the cleanroom, the place for test of a chamber and the mechanical engineering workshop room.

Mechanical engineering workshop room station:

A metal-plate is placed on a table and cleaned by applying ethanol and using paper wipes. This involved a special wiping technique where one wipes to the sides firmly. Then a large, thin layer of Styrofoam was placed on top of the metal plate. Two aluminium metal rectangular shaped rods were bolted on the shorter side of the plate manually. How firm the screws were fixed was double checked manually. Then some glue was applied on these,

Figure 6: Image shows the mechanical engineering room with the engineer responsible for the work, Roman, and D. Hatzifoutiadou. Image at the courtesy of Eirik Sæther Hatlen

before two new aluminium rods were placed on the longer side. It should also be mentioned that the rods on the short side had electronic circuitry on them.

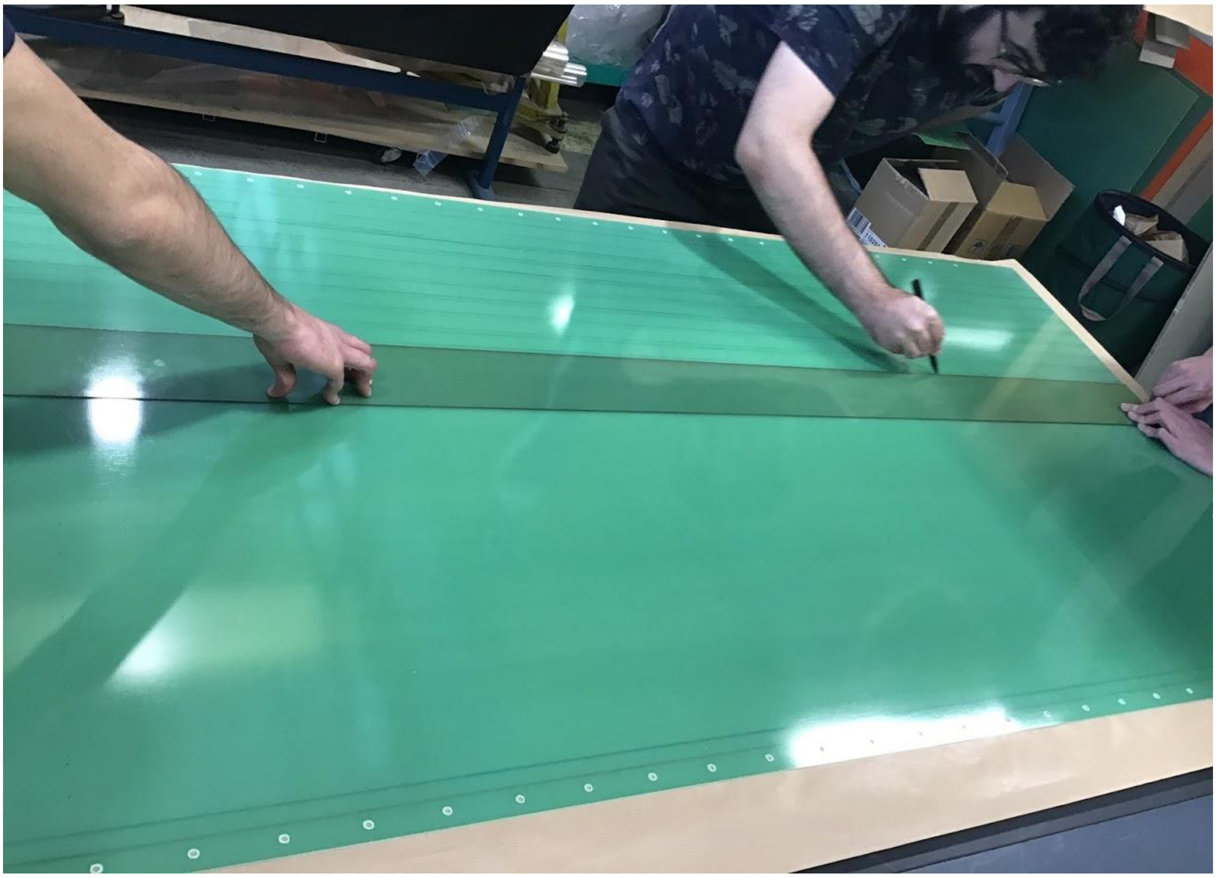

Figure 7: Schematic shows Furkan Kaya drawing a line for the copper strips. Image at the courtesy of Federico Nardi

After this a new metal-plate was cleaned and placed on top of the entire system. The component was then moved on to the other room were the analysis occurred. Then the work began on the honeycomb-type panel. First the protective layer was removed. Then the group drew a lane on them with the help of a pre-defined long green rectangular-shaped form. These lanes were so used to place tape on each of these lanes. This was done on two panels.

The group proceeded to clean two thin layer green panels as well. Final task was to create two squares, one blue and one red on the honeycomb panels. These two squares are useful when nylon fishing lines are put on the panels to create a separation between the glass-parts.

24 copper strips were placed on the two honeycombs after a meticulous process. First their lanes were drawn on. The drawing was required to be very precise, meaning at the millimetre scale. Then the strips were placed on the two panels (see figure 8). It was required that this work was done with a partner.

Figure 8: Schematic shows the copper strips being put on the honeycomb panel. Image at the courtesy of Federico Nardi

After the mandatory cleaning with ethanol to remove dust, the chamber was assembled. The chamber was then moved to the cleanroom for the second part of the process.

Test of chamber station:

The procedure for working on this station has partially been explained

Figure 9: Image shows the setup of the chambers, each green part with the designation HV(+ or -) is a chamber. Image at the courtesy of Olav Grønbech

in the text around figure 5. The first thing is obviously to exchange the FEC's so that the correct chamber in question is being tested.

The work began with adjusting the voltage across the system. The value given at the generator had to be multiplied with a factor of 2000, meaning that the groups had to work with voltages in the kV-range. The voltage interval was increased with 0.5 kV for each read. There was a desired voltage, beginning at 12 kV that was to be compared with the voltage at HV+ and HV- (HV+ and HV- must be added together).

Another part of the work at the station was to analyse the data found on a computer desktop. The work here was to measure the amount of real events. There was a combined total of 20 000 events and the group was to find out how many fake events there were at each voltage. This number was then used to find the efficiency of the detector.

Figure 10: Despina nad some members of the group are at the desktop getting guidance. Image at the courtesy of Eirik Sæther Hatlen

Cleanroom station:

The work in the cleanroom was compartmentalized into:

- Putting glass layers on. The glasses were separated by nylon fishing lines and these lines had to be put on individually as well.
- Soldering of wires to Copper to make circuits
- Cleaning glass

The glass was put on by lifting it with the use of vacuum.

Figure 11: Image shows lifting of glass by the use of vacuum. Image at the courtesy of Eirik Sæther Hatlen

Figure 11 shows how this was done. It required manpower and a vacuum machine. This part of the work was preceded by the placing nylon fishing lines in order to create a gap. For the entire detector there was a need for 6 gaps and therefore several glass stacked on top of each other.

(L) (R)

Figure 12: Image shows the process of placing the nylon fishing line on (L) and how it looks finished on (R). Image at the courtesy of Eirik Sæther Hatlen and Olav Grønbech

After this part, soldering followed to connect wires to the Copper. The final product is seen on figure 13.

Figure 13: Image shows the soldering of wires to Copper. Image at the courtesy of Eirik Sæther Hatlen

The rest of the work at the station was to clean the glass in the cleanroom.

Results of tests and measurements:

The first results are to show that the process went as expected for the detector created by the group before the class of FYS5555. The most important columns are HVtot-wanted (the first column) and the fourth column (actual HVtot). Values of column 1 and 4 must be close to each other. Or approximately the same.

Hvtot-wanted	HV+(kV)	HV-(kV)	Hvtot(kV)	Vi+ (kV)	Vi- (kV)	I+(uA)	I-(uA)
12	5.92	6.02	11.94	7.2	7.8	1.88	1.18
12.5	6.25	6.26	12.51	7.75	7.91	1.66	1.49
13	6.5	6.52	13.02	8.19	8.16	1.66	1.67
13.5	6.75	6.75	13.50	8.54	8.54	1.79	1.79
14	6.97	7	13.97	8.63	8.51	1.54	1.63
14.5	7.24	7.25	14.49	9.36	9.27	2.03	2.11
15	7.5	7.49	14.99	9.81	9.75	2.25	2.32

15.5	7.76	7.76	15.52	10.36	10.26	2.50	2.60
16	8.01	8	16.01	10.54	10.15	2.14	2.54
16.5	8.25	8.25	16.50	11.05	11	2.75	2.80
17	8.5	8.49	16.99	11.61	11.52	3.02	3.12
17.5	8.76	8.75	17.51	12.29	12.14	3.38	3.54
18	8.99	9.01	18.00	13.12	13	4.01	4.11
18.5	9.24	9.25	18.49	14.08	13.82	4.58	4.83
19	9.49	9.48	18.97	15.28	14.91	5.42	5.80
19.5	9.75	9.75	19.50	16.78	16.24	6.49	7.03

Most important results were measuring the multiplicity. The lower amount means that more real events are found. Higher level of multiplicity means that there is a lot of noise.

zero multiplicity – L	zero multiplicity – R	zero multiplicity – worst	zero mult worst among bot and midd	Ntriggers	eff	error
19763	19766	19766	623	20000	0.012	0.007
19258	19259	19259	623	20000	0.038	0.007
17961	17967	17967	628	20000	0.105	0.007
16204	16179	16204	633	20000	0.196	0.007
14833	14864	14864	627	20000	0.265	0.006
12018	11995	12018	632	20000	0.412	0.006
10261	10219	10261	631	20000	0.503	0.005
9177	9176	9177	632	20000	0.559	0.005
8133	8116	8133	625	20000	0.612	0.005
7464	7469	7469	638	20000	0.647	0.004
7024	7015	7024	631	20000	0.670	0.004
6594	6586	6594	635	20000	0.692	0.004
6322	6333	6333	632	20000	0.706	0.004
6130	6139	6139	644	20000	0.716	0.004
5752	5767	5767	640	20000	0.735	0.004
5868	5863	5868	625	20000	0.729	0.004

Other important columns are the efficiency and the error. In order to understand this better, a plot of this is required. The plot has the voltage on the x-axis and efficiency on the y-axis.

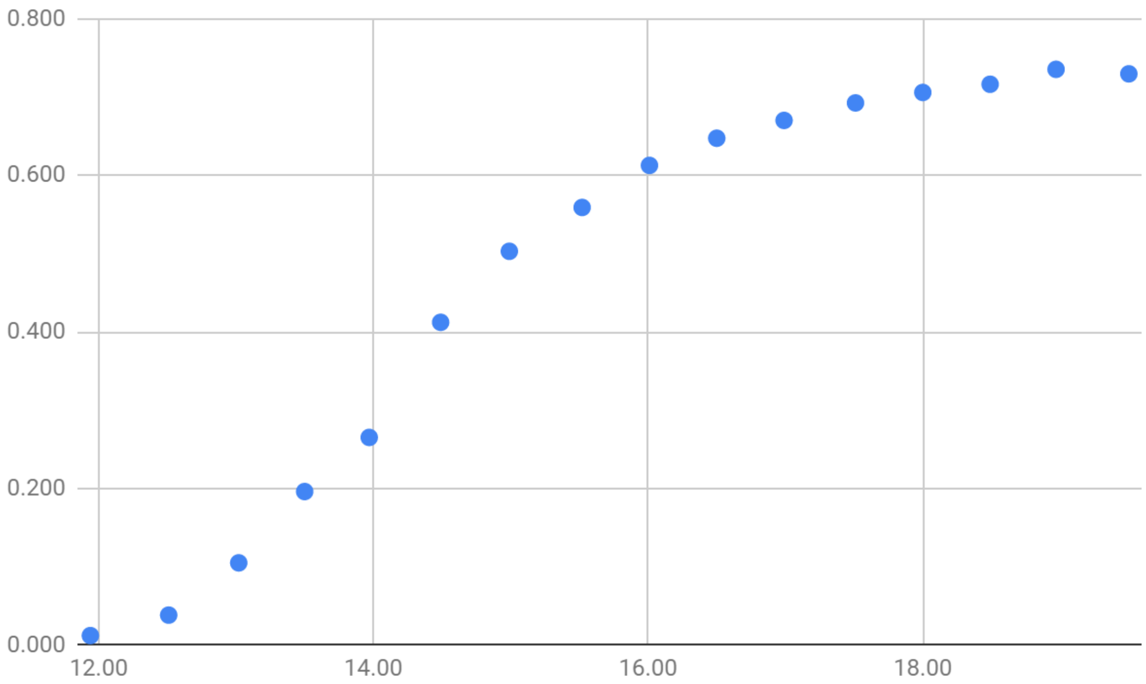

Figure 14: Schematic shows the efficiency on the y-axis and voltage applied on the y-axis

As seen on figure 14, there is low efficiency at the lowest voltage. That means there is a lot of noise. As the voltage applied increases, there is an increase in efficiency up to 16 kV where it sort of stabilizes. A plateau is seen at that voltage.

The noise is most likely dominating at the lower voltages because the energy is lower than the absorption for Silicon (1.13 eV). As the voltage increases, the energy does as well. The noise level increases with the voltage (noise is separated into signal noise, detector noise and dark noise) since the signal noise would increase. At 18 kV the chamber has a breakdown with a big jump in the hit rate, with multiplicities above 25. This means that the chamber shouldn't be operated at this high voltage for data-taking, because of too much noise.

Results obtained from the EEE-website:

The results in this section are obtained from the EEE-website where high schools in Italy store their data.[5] This paper will focus on data from a high school in Bari (BARI-01). First piece of information shows the number of files transferred per day. One can compare the number of files transferred per day and check if the detector functions as it should.

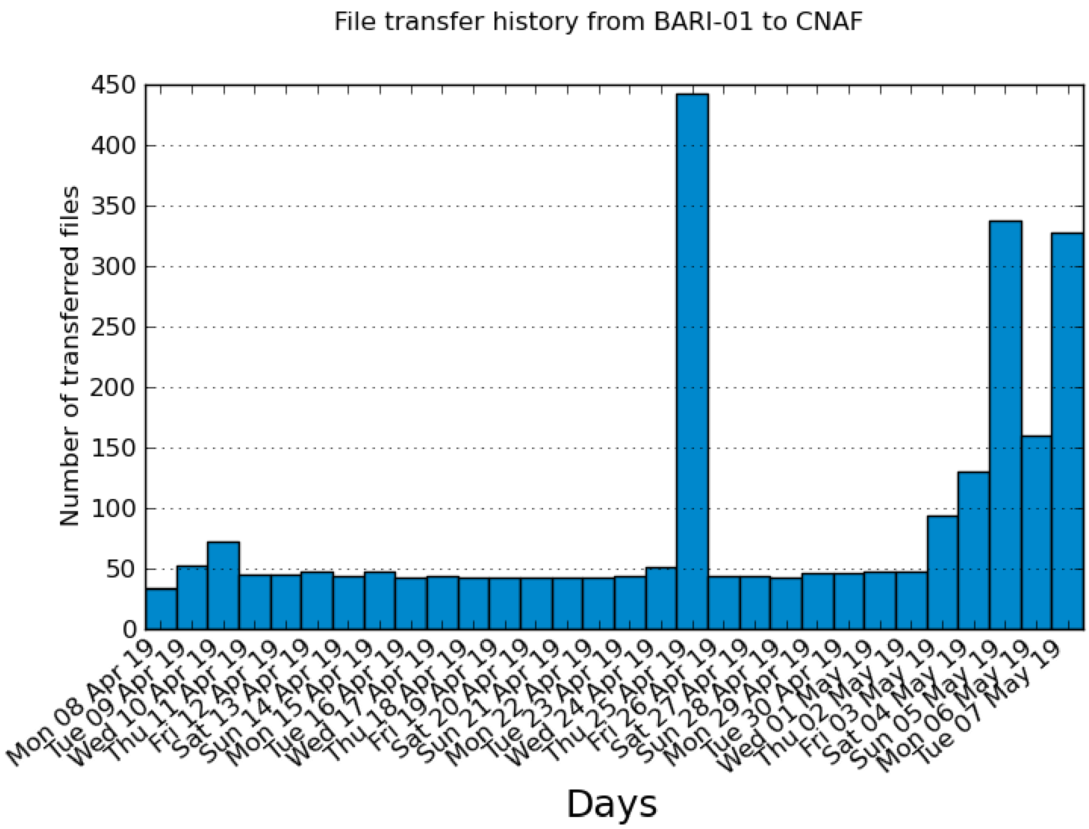

Figure 15: Schematic shows the number of files transferred per day.[5]

Figure 16 shows the number of events and hits for the last 4 months (to February).

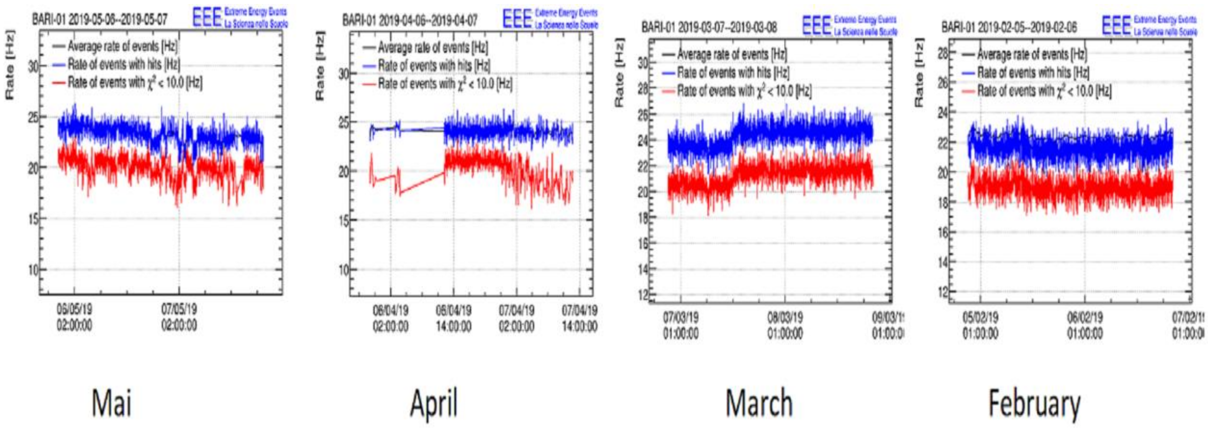

Figure 16: Schematic from the high school in Bari. Black = average rate of events, Blue = rate of events with hits, Red = Rate of events with \Chi^2 < 10.[5]

The final figure shows an individual measurements and some properties attached to it. This is done to provide an understanding for how this particular process is done. The properties comes first and the schematic follows on figure 17.

RUN SUMMARY

- DST file path: /home/analisi/tempNewAnalyzer2/BARI-01-2019-04-18-00001_dst.root
- Unique run identifier: 4448900001
- Smallest event timestamp: 387930414.048 s UTC
- Largest event timestamp: 387932419.999 s UTC
- Run duration (largest - smallest timestamp): 2005.951 s
- Total number of events: 45986
- Number of events with hits: 45895
- Number of events with a track: 40121
- Number of "no hits" (GPS?) events: 91
- Number of "no hit" events: 91
- Number of malformed events: 0
- Number of events out of order: 1

WEATHER STATION

- Readout at 387932400.000 s UTC (1985.952 s after (!!) the start of the run)
- Outdoor temperature: 0.00 deg C
- Indoor temperature: 21.20 deg C
- Pressure: 1022 hPa

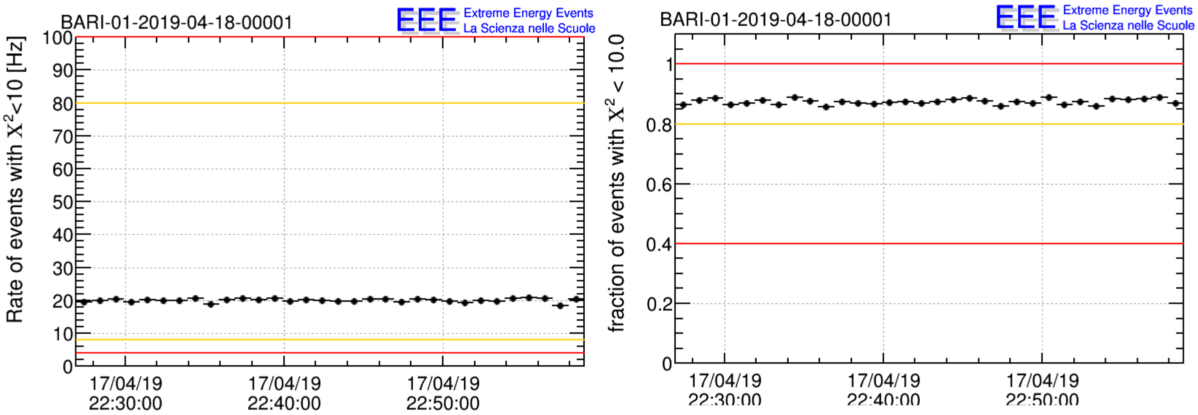

Figure 17: Schematic shows the plots for an individual measurement.[5]

References:

[1] L. Cifarelli, *Measuring cosmic ray showers up to the North Pole,* 2018

[2] D. Hatzifoutiadou et al, *The Multigap Resistive Gas Chamber,* 1996. Retrieved from:

http://www.slac.stanford.edu/pubs/icfa/spring96/paper2/paper2.pdf

[3] T. Skauli, *Lecture notes in UNIK4330*, 2017

[4] D. Hatzifoutiadou, *EEE chambers efficiency test procedure,* Note delivered out by CERN

[5] EEE-website, Retrieved from: https://iatw.cnaf.infn.it/eee/monitor/