# Noise studies and Detection studies for the OPERA setup in Hamburg

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# 1 The Opera Experiment[1]

The OPERA experimental goal is the detection of tau neutrinos in a nearly pure muon neutrino beam from CERN. This will lead to the first direct observation of $\nu_\mu \rightarrow \nu_\tau$ neutrino oscillation. The OPERA detector is placed underground in Gran Sasso massif in Italy and the CGNS facility at CERN provides the beam, nearly 732km from Gran Sasso in a straight line

## 1.1 The OPERA Detector

The OPERA detector is a hybrid detector consisted of two identical supermodules. Each supermodule consists of a 800 ton lead target with a scintillator target and an electronic muon spectrometer. The muon spectrometer is located behind the lead target and consists of a magnet and a series of Resistive Plate Champers, Cross resistive Plate Champers and Precision Target drift tubes.

## 1.2 The $\nu_\tau$ detection

The $\tau$-detection is done in the mussive lead emulsion target through the Emulsion Cloud Chamber technique. The $\nu_\tau$ appearance is done via the $\tau$ produced in the charged current reaction

$$\nu_\tau + N \rightarrow \tau^- + X$$

The $\tau$ lepton has a lifetime of 87.11 $\mu$m in ct and will decay further.

The target module consists of 100 000 ECC bricks arranged in 31 walls. Each brick consists of a stack of 56 layers of lead of a thickness of 1mm, interleaved with 44microm thick emulsion layers on both sides of a 205 m plastic base, as seen in the schematic layout. Each brick is finalised on its downstream face by two additional emulsion layers, also called changeable sheet. A robotic device is used for the packing and unpacking of the bricks that need to be examined.

Very important is the fact that the photo emulsion gel contains 5-methylobenzotriazole that increases the fading process so that recorded tracks are erased after a certain amount of time, thus reducing the background in the bricks that was caused by transportation of the bricks on the surface of the earth. Subsequently, the bricks need to be examined close and fast after the event. The

European Scanning system provides this opportunity, having a high resolution high speed camera that produces 3-dimensional reconstruction of tracks and vertices.

Behind the lead target are crossed polystyrene scintillator strips that are used as a target tracker. Secondary particles that are produced from the neutrino interactions are detected and determine the bricks that could have interesting events depicted on them. Those bricks are removed by the robotic system and first the examination sheet is examined. If it does not reveal any interaction the brick will be returned into the detector. Otherwise it will proceed for further examination without replacement.

## 1.3 The muon spectrometer

The ECC technique is capable of reconstructing the vertex of the neutrino interactions as well as tracks of secondary particles produced it provides no information about the momentum of the particle, nor the energy and, thus, no particle can be determined. The muon spectrometer is needed for the identification of muons and their momentum. Also it suppresses the background of the decay of charmed particles which have the same topology. Electrons lose their energy mainly through the Bremsstrahlung radiation and release most of their energy inside the lead bricks. This results in the formation of secondary particles which create particle showers. The analysis of these showers can provide information about the energy of the primary electron. Hadrons also create showers due to energy loss due to traverse medium ionisation.

Unlike electrons and hadrons, high energy muons pass the detector without significant energy loss. Their momentum is measured in the precision tracker by bending their tracks with a dipole magnet that is placed between the drift tube walls. The iron arms of the magnets are replaced by Resistive Plate Chambers for track reconstruction, as they serve as triggers for the precision tracker, but also for range measurement of the stopping particles and hadron calorimetric analysis.

The precision tracker is used for reconstruction of the muons track in the horizontal plane and also to determine the energy and the momentum of the particle. Main elements of the precision tracker are the drift tubes. Each drift tube consists of an aluminium shell and has a metal wire in the centre and is filled with gas. When a particle runs through the tube it loses energy by ionising and exciting the gas atoms. Applying high voltage between the shell and the wire in the centre, the wire turns into an anode and attracts the electrons, which respectively, accelerated by the electric field excite and ionise more atoms, creating more free electrons. This avalanche of negative charges creates a signal when it reaches the anode that can be measured. The time needed for the electrons to reach the anode is called drift time and is related to the minimum distance from the centre of the tube of the particle track. By measuring the drift time of the excited tubes we can reconstruct the particle track.

### 1.4 Data Acquisition

The signal from the anode is amplified by the preamp boards on top of each module and then sent to Time-to-Digital-Converter boards where the time measurement starts. For the measurement to be completed a stop signal is needed and provided by the Opera Trigger Boards. They provide a large variety of trigger schemes. Assuming the stop signal is produced, it is being stalled for a certain amount of time tdelay and then it reaches the TDC boards. Then the drift time is

$$t_{drift} = t_{delay} - t_{tdc}$$

Also, signal arriving time variation due to cable length should also be considered. The data collected are saved in a database.

The precision tracker still has room for improvement and advance. Mainly the new elements that can improve the efficiency of the precision tracker are in the area of gas mixtures for the reduction of noise and increase of the detector efficiency but also in the area of electronics. Better signal width measurement from the drift tubes will result in better assessment of the particle's energy and different trigger techniques could also prove more efficient in collecting data such as the drift time.

## 2 Hamburg Experimental Setup

The model device at DESY Hamburg provides the opportunity for further tests and experimentations. The device consists of four modules of drift tubes. Each module has 48 drift tubes, arranged on four layers of twelve drift tubes. Each drift tube is 1m long and has an outer diameter of 38mm. The arrangement of the tubes is so that the minimum number of activated

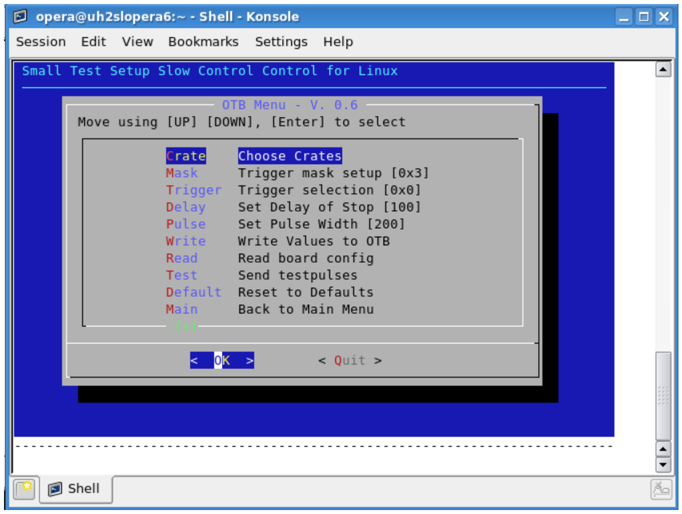



Figure 1: The slow screen menu includes all the necessary adjustments for the device

tubes per hit is 3. The tubes contain a gas mixture of 80% Ar and 20% CO2 in a v/v analogy. Each tube is connected to a preamp, which amplifies the signal, and a discriminator which is used for signal filtering.

On top and underneath the modules two scintillators are attached, each one 0.5 meter wide and 1 meter long (they do not cover the whole surface). The scintillators serve for triggering. Each one is connected to a photomultiplier and the signal of both is driven to an AND gate. According to current triggering scheme both scintillators have to be activated for drift time measurement. Also the scintillators provide the stop signal to the TDC boards, delayed by a certain amount of time.

The TDC boards measure the drift time from the tubes as mentioned above. Data from the boards are saved to a computer that serves as server nearby. Data analysis is done by a ROOT based software created for the specific experimental device. The software provides control over the main aspects of the device, such as the threshold applied, the trigger schemes and data aqcuisition. Also provides screens for the general device overview such as the event display. A very useful aspect of the software are the testpulses modules that can test the device obviating the triggers. In this project, the Opera Triggerboard testpulses proved very useful in noise studies.

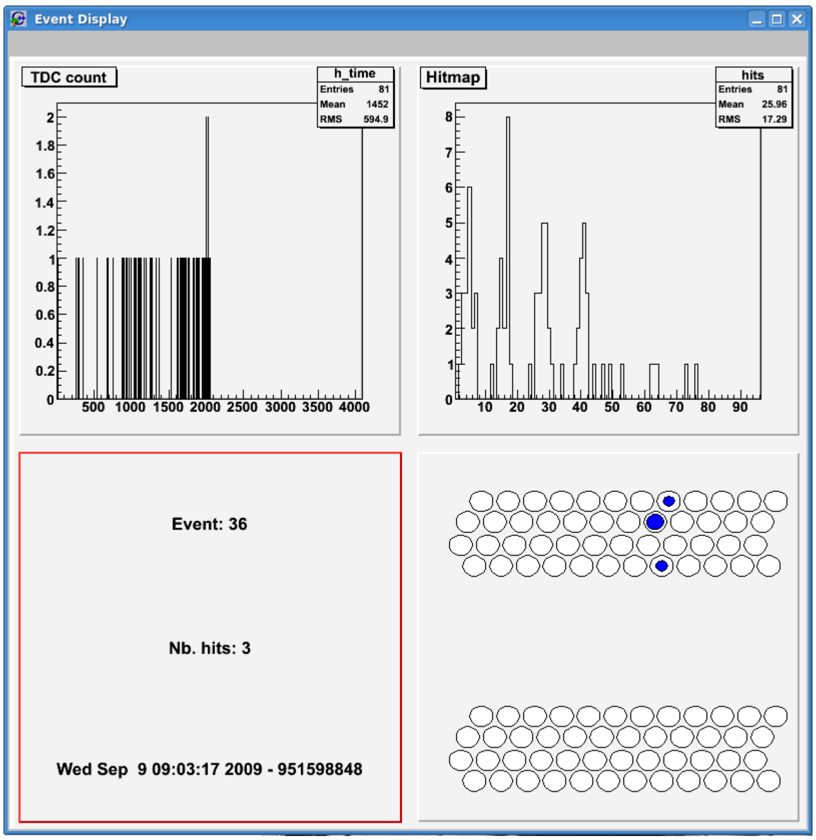



Figure 2: The event display shows events that are being recorded from the experimental device, with a small delay

# 3 Studies on the Hamburg experimental module

My task was to calibrate the small experimental device described above. This can be divided in two main tasks;

## 3.1 Noise Studies

Noise on the device can be attributed mainly to the electronics. The study of the noise shows the behaviour of the noise for every high voltage applied on the drift tubes and reveals the ideal threshold for the measurements.

### 3.1.1 Description

By software I applied a different thresholds through the Opera SUpport Boards menu and acquired data from test pulses send by the Opera Trigger Boards menu. I used a threshold range from 10 mV to 50 mV. This threshold range was applied for a range of voltages from 0 Volts to 2600 Volts with a step of 200 Volts. For every high voltage data is processed through the ROOT menu, and information acquired about the mean number of hits per event for every drift tube. The mean number of hits was plotted in perspective of the threshold values.

### 3.1.2 Results

From the data collected, I created an event diagram for every single threshold I applied and observed the noise behaviour. The error for the data collected was set to mean number of hits divided by 10. Below there are all the plots extracted for every high voltage with the technique explained above.

In the diagrams we can observe an exponential noise reduction as the threshold was raised.

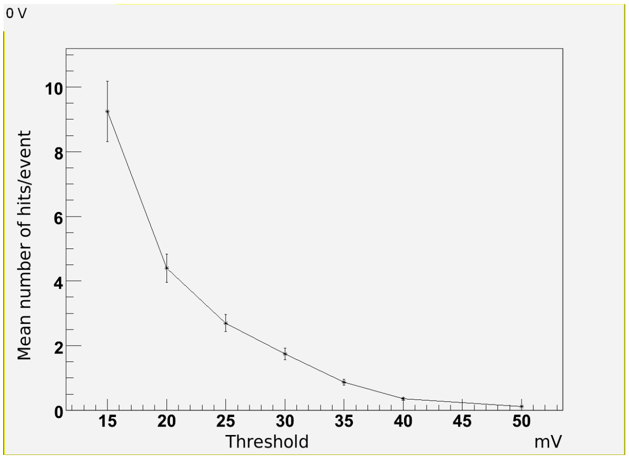



Figure 3: 0V

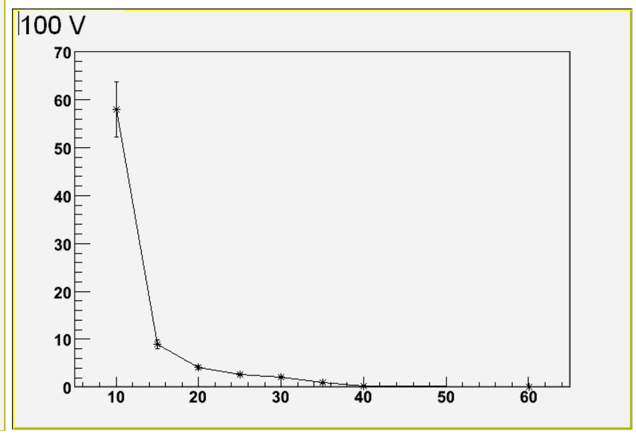



Figure 4: 100V

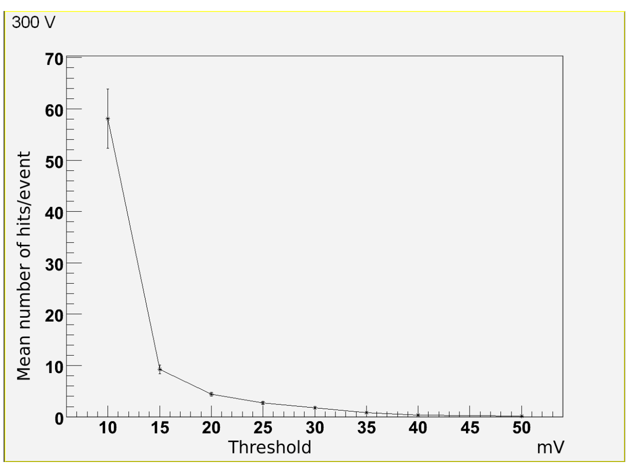



Figure 5: 300V

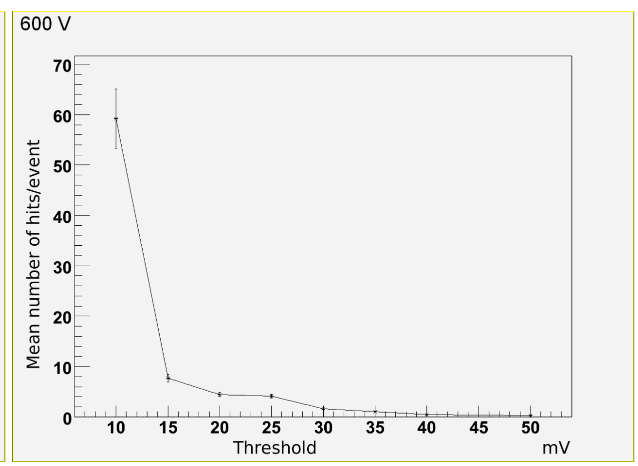



Figure 6: 600V

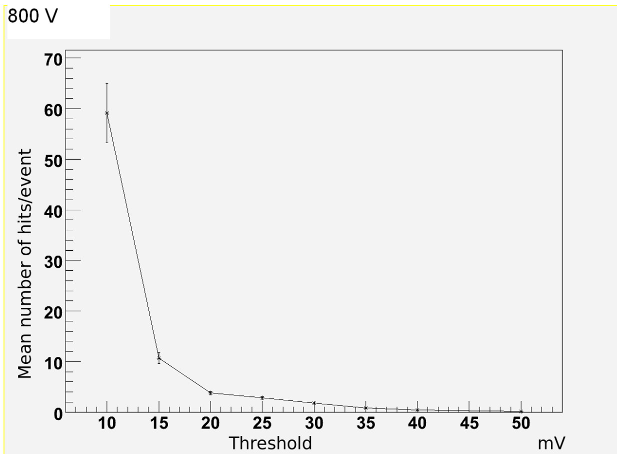



Figure 7: 800V

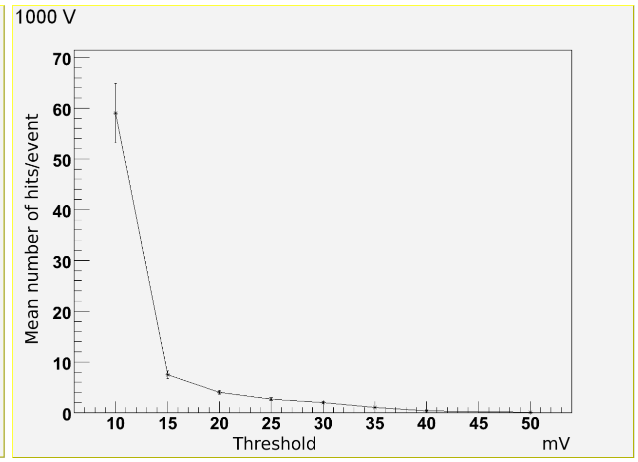



Figure 8: 1000V

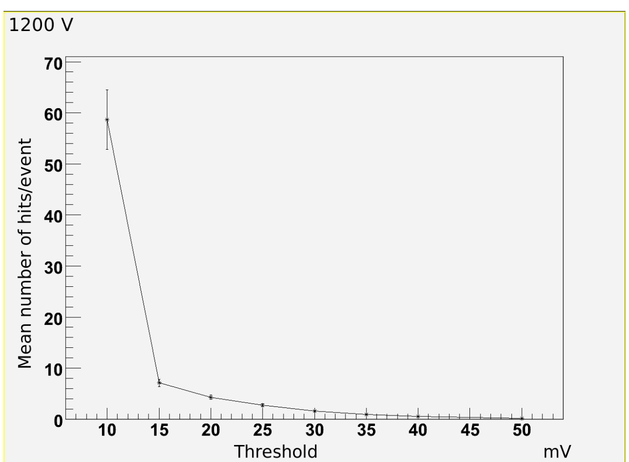



Figure 9: 1200V

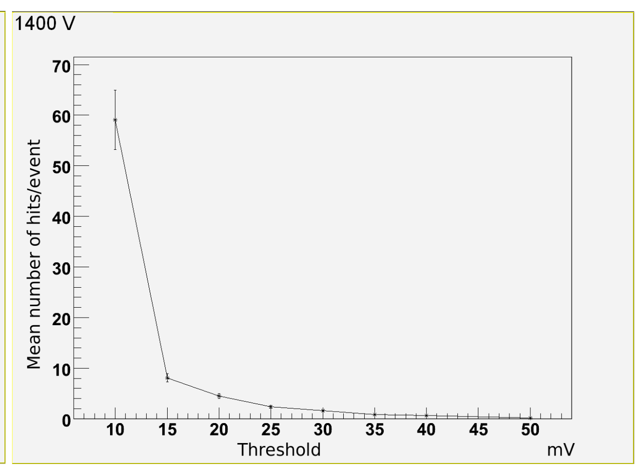



Figure 10: 1400V

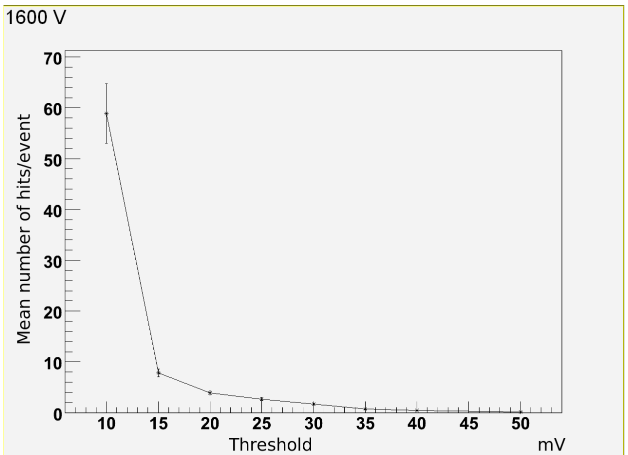



Figure 11: 1600V

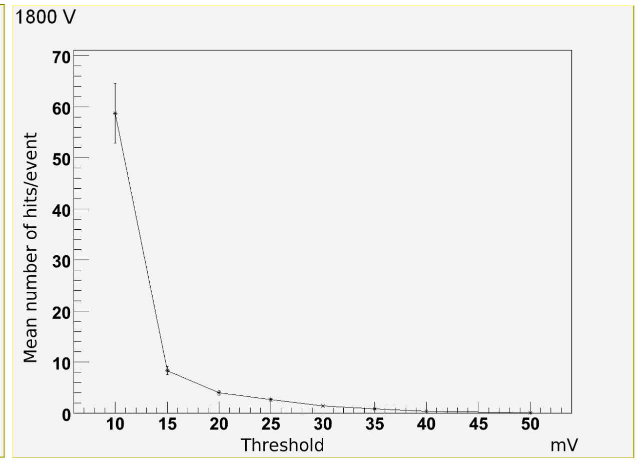



Figure 12: 1800V

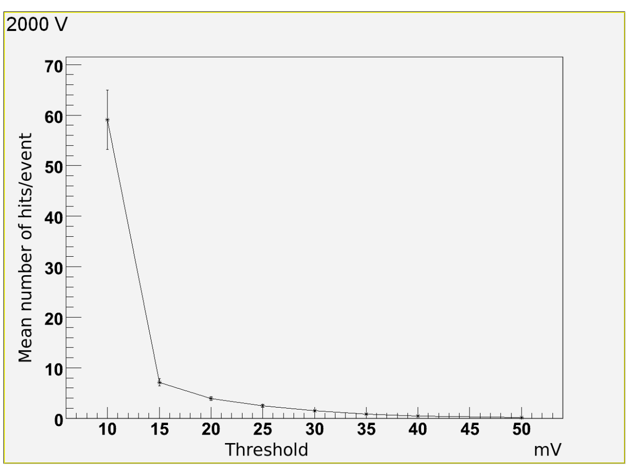



Figure 13: 2000V

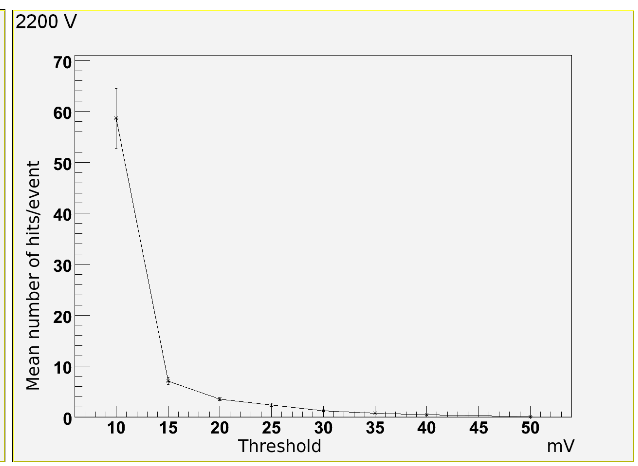



Figure 14: 2200V

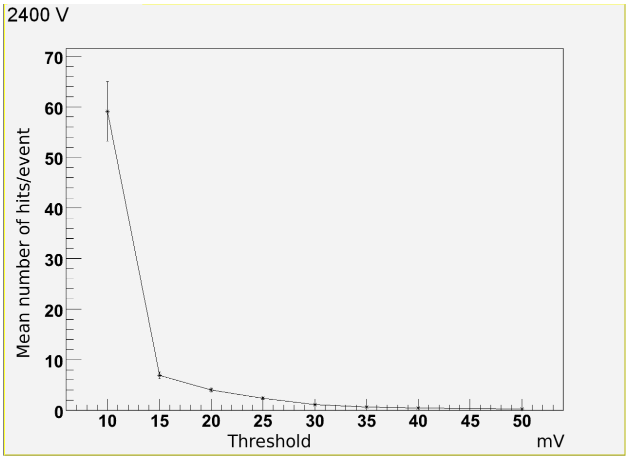



Figure 15: 2400V

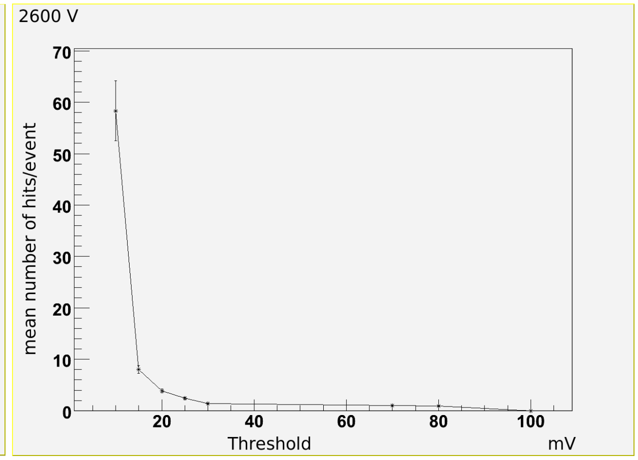
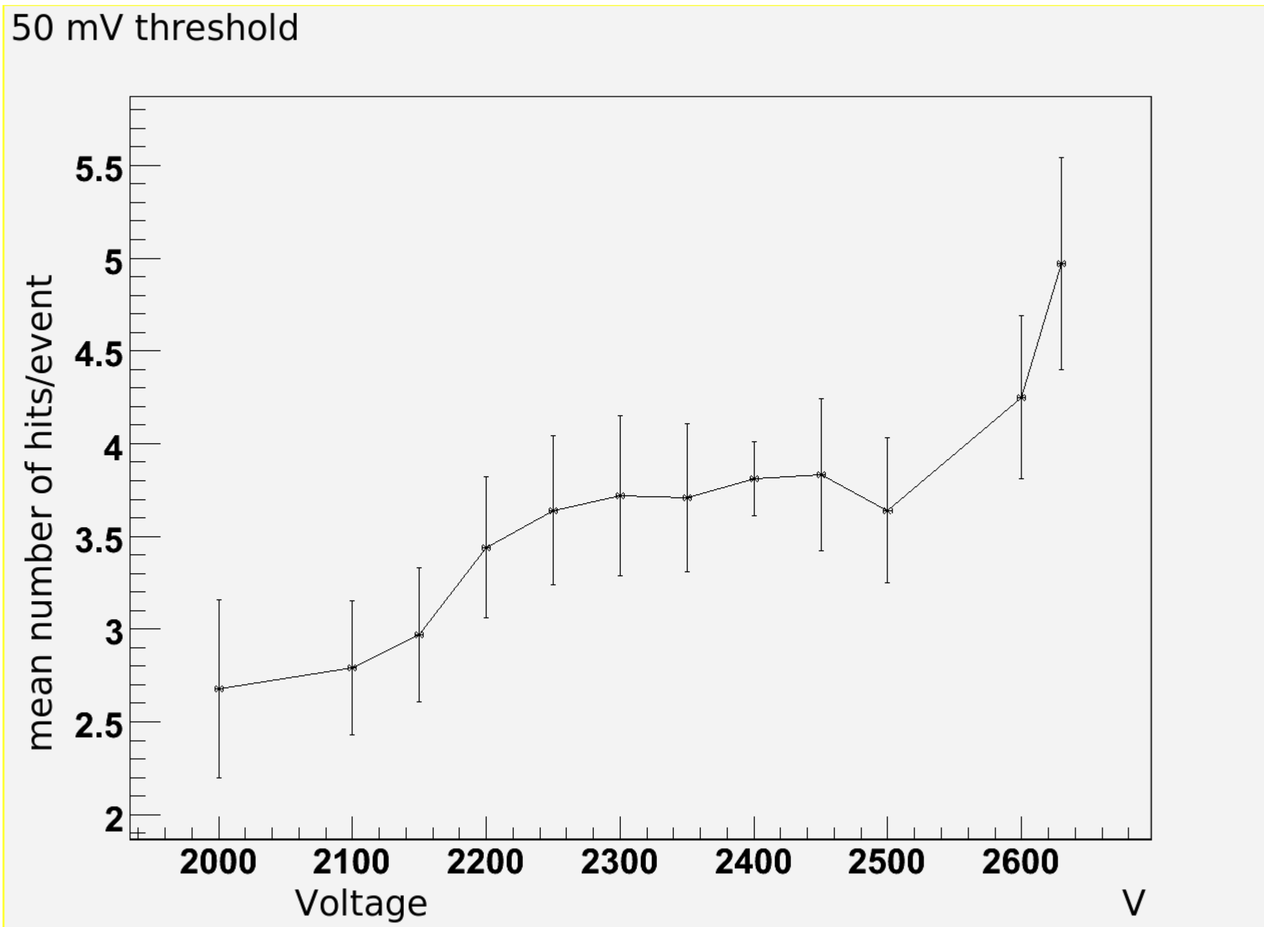


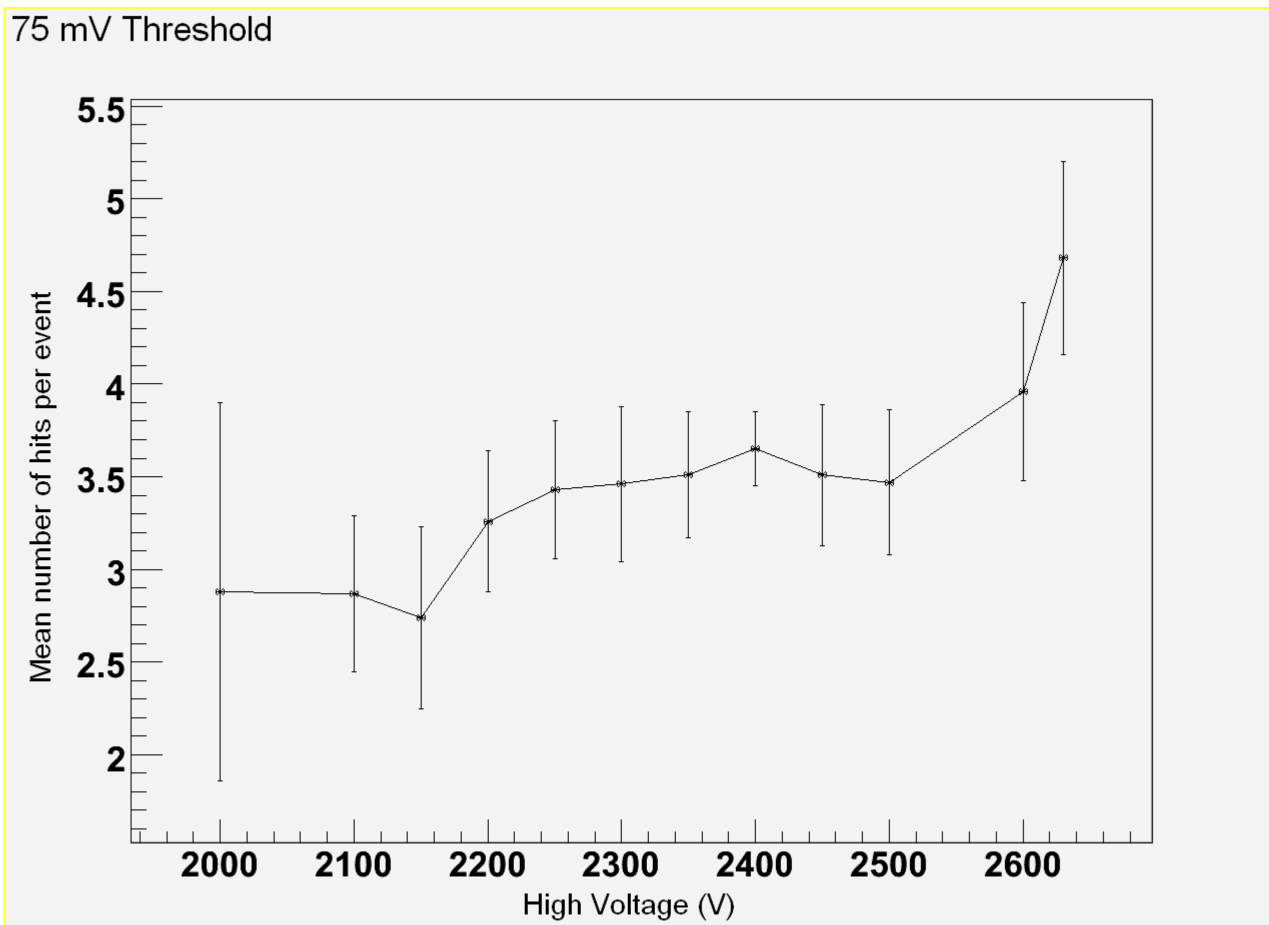

Figure 16: 2600V

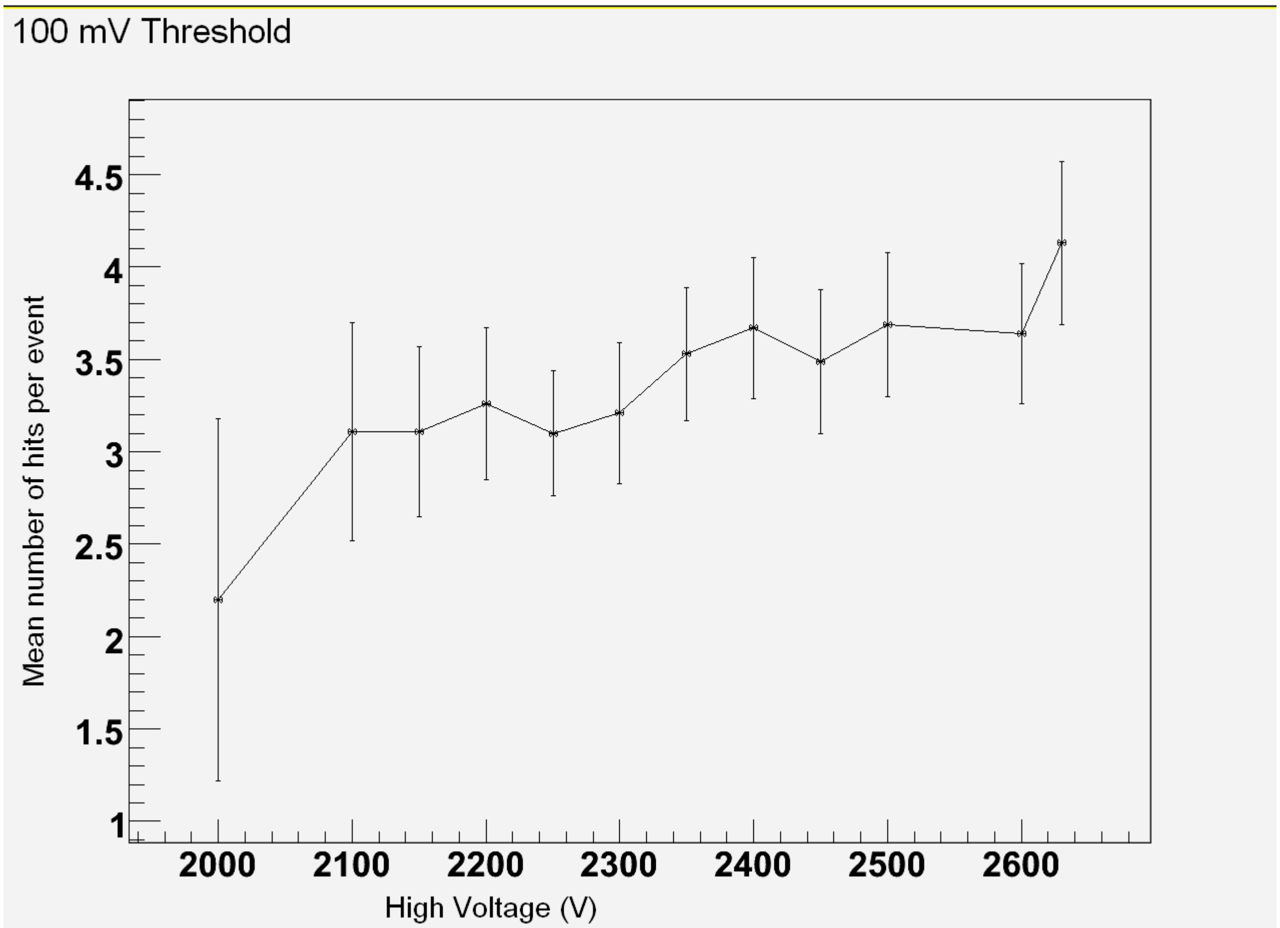
## 3.2 Detector Sensitivity Studies

Besides the study of the noise it is very important to study the detection ability of our device and how it changes with high voltage and the threshold applied. There is a strong correlation between the events detected and high voltage applied in the drift tubes. For low voltage, below 2000 V the sensitivity of the detector is reduced and there is not the expected amount of hits per event. On the contrary, for high voltage levels of noise are also increased and this is the reason why the mean number of hits per event is above the normal. This is why the study was done in perspective of the threshold applied. Also, a measurement was taken for 2630 Volts, above the limit of the gas insulation for having a better view of the drift tubes behaviour

For the purposes of this study we measured the mean number of hits per event for a number of events and for 3 different thresholds. The error is again set at the mean/sqrt(events) . Data was collected through cosmics and then examined on the ROOT environment. Our first results where quite unclear because of the noise. So a mask was applied to the data. Since the device was arranged in four layers of driftubes we considered that the minimum number of hits per event is 2 and the maximum 8. Thus, all events that were considered noise were not taken into account. These are the results;


50 mV threshold
mean number of hits/event
2
2.5
3
3.5
4
4.5
5
5.5
2000
2100
2200
2300
2400
2500
2600
Voltage
V


75 mV Threshold
Mean number of hits per event
5.5
5
4.5
4
3.5
3
2.5
2
2000
2100
2200
2300
2400
2500
2600
High Voltage (V)



100 mV Threshold
Mean number of hits per event
High Voltage (V)
1
1.5
2
2.5
3
3.5
4
4.5
2000
2100
2200
2300
2400
2500
2600

## 4 Conclusion

The results of this report show a view of noise behaviour in perspective of high voltage and also the event detection. Always the threshold applied for the measurements is taken into account. This study can be helpful for comparison of noise studies and event studies with other gas mixtures or triggering techniques.

## References


[1] D. Bick, *Data Evaluation and CGNS beam localization with the precision tracker*