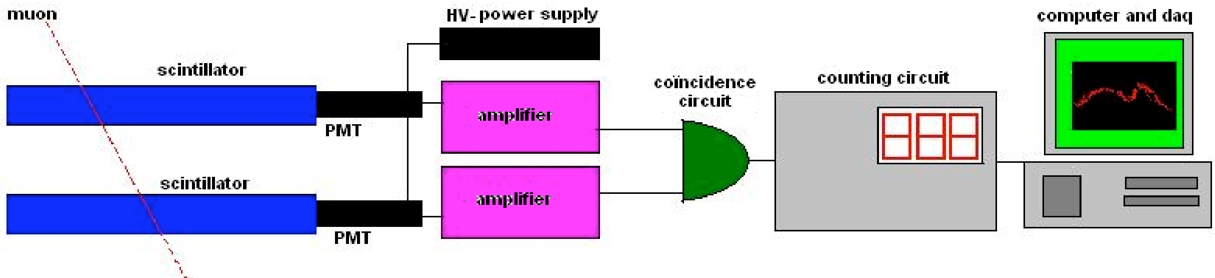
Cosmic ray detector

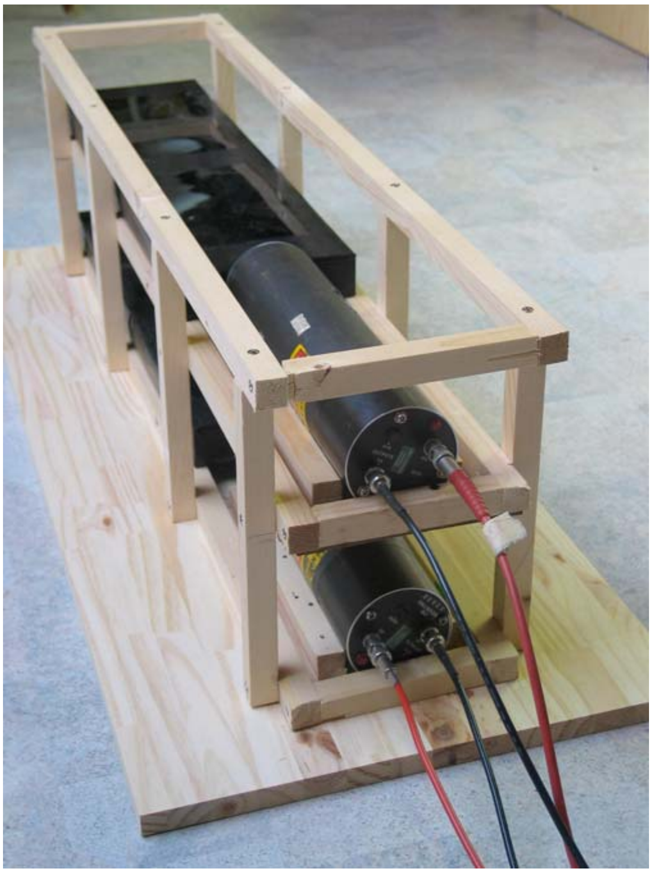
Preface

We are constantly bombarded with particles from outer space. We cannot see them, we cannot smell, hear, taste or feel them. But we *can* detect them. That is why I decided to make a cosmic ray detector. Since I am only a high-school student I could not do this by myself. That is why I want to thank everybody who helped me with this project. Especially Catherine De Clercq from the VUB (Vrije Universiteit Brussel) and Howard Matis who donated me the LBNL cosmic ray detector circuit board. In this small report I shall describe my detector and some experiments that I have done with it.

The detector

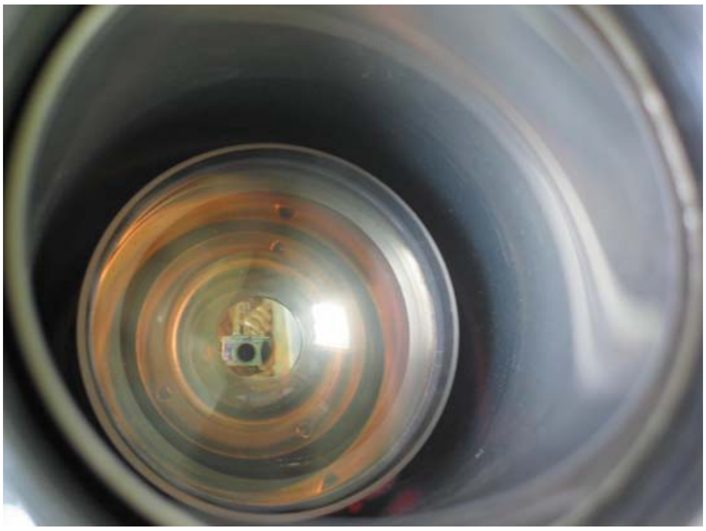


The detector consists of two scintillation counters switched in coincidence and connected to a computer that takes data. The scintillators measure 50cm * 15cm * 4cm, so compared to other cosmic ray detectors of this kind, the scintillators are quite big. The scintillators were donated to me by Eljen Technology and are general purpose EJ-200 scintillators.



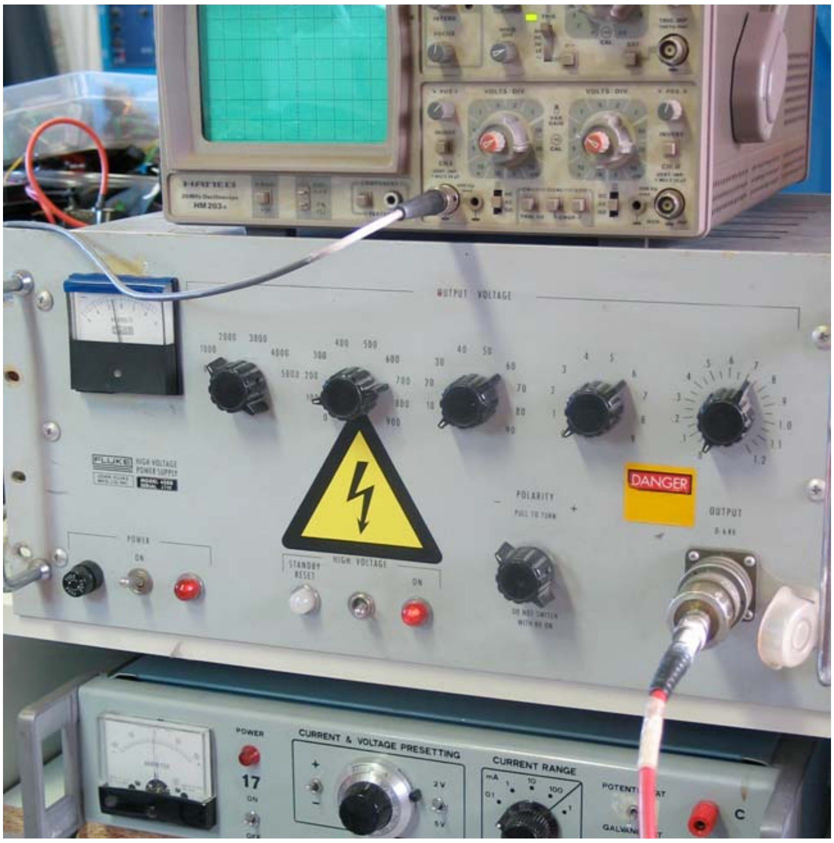
the detector (two scintillators and two PMT's)

The photo multiplier tubes where donated to me by the VUB and are a leftover from the dismantled DELPHI detector in CERN. For each PMT the ideal voltage was determined by finding the plateau of the PMT's. The PMT's are mounted in a heavy housing which acts as electric and magnetic shielding. The PM's are then screwed on the light guide (plexi tube) which is glued to the scintillator. This means the PM's can be disconnected and reconnected at all times, which is a great advantage (mainly when transporting the detector).



The photocathode , the electric and magnetic shielding *The rear of the PM*

The ideal voltage for both PMT's is 1200 volts and is supplied by an old fluke high voltage power supply (model 4088). The biggest disadvantage of this power supply is it's weight (about 30 kg) which makes it difficult to transport.

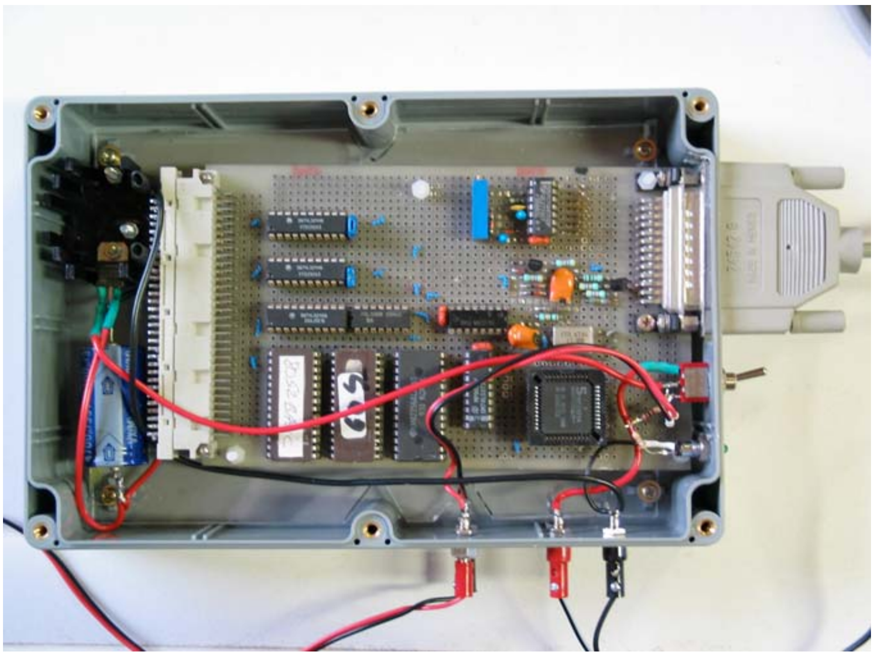


The HV power supply

The photo multipliers are then connected to the LBNL circuit board. This circuit amplifies and filters the signals from the PM's, makes the coincidence and counts the number of hits. Coincidence means that only when a particle goes through both scintillators, a hit will be registered. Since only muons have enough energy to do this, only muons will be detected.

The LBNL circuit board in a plastic housing

There is also an interface card which counts muons in intervals of 60 seconds and then sends the data to a computer which stores the data. The circuit board was donated to me by Benny Croonen.

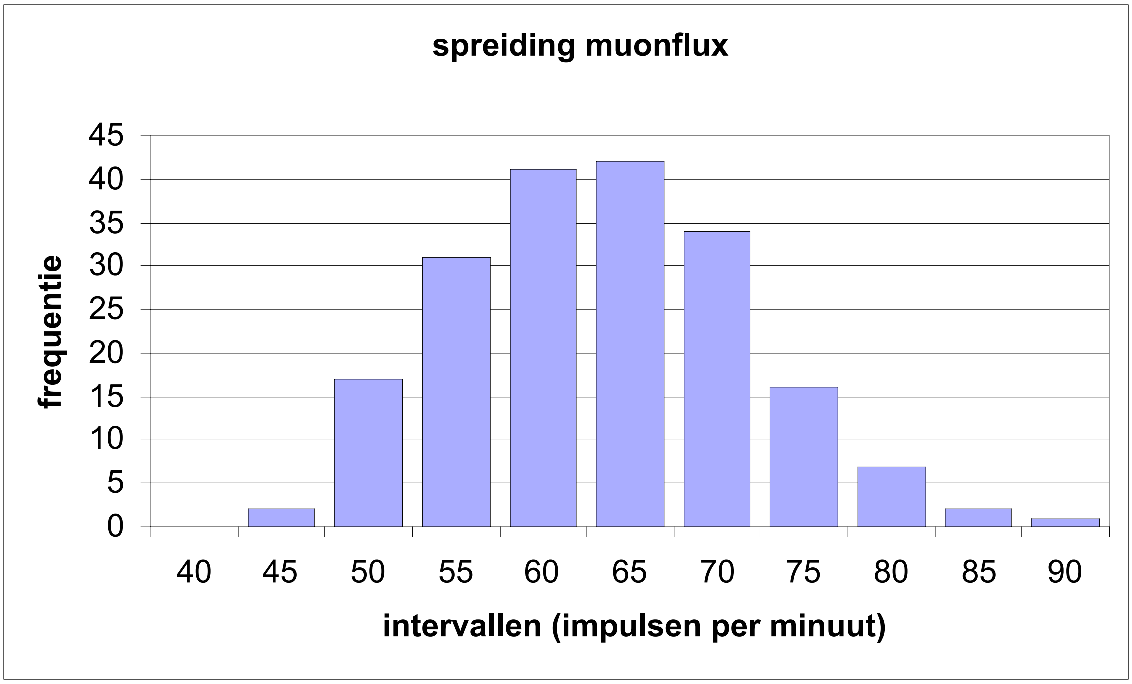


The interface card

Experiments

Muonflux measurements

The first experiment was a test whether the detector worked properly and whether it was reliable. To do this the vertical cosmic muonflux was measured for a long period. Then out of this data (muons per min) the average cosmic ray muonflux was calculated (number of muons $m^{-2}s^{-1}st^{-1}$). The scintillators where placed 72.5 cm apart (this has to be big for correct flux-calculations), it was measured on 18-01-04 starting from 11h and it was measured in Ghent (Belgium). 204 measurements where done and the results are plotted in the distribution below. You can clearly see it is a normal distribution (Gauss curve).



the distribution of the raw data

The average muonflux was then calculated using the following formula:

$$F = \frac{\text{(number of muons per min)} * \text{(distance between the scintillators)}^2}{\text{(surface of scintillator 1)} * \text{(surface of scintillator 2)}}$$

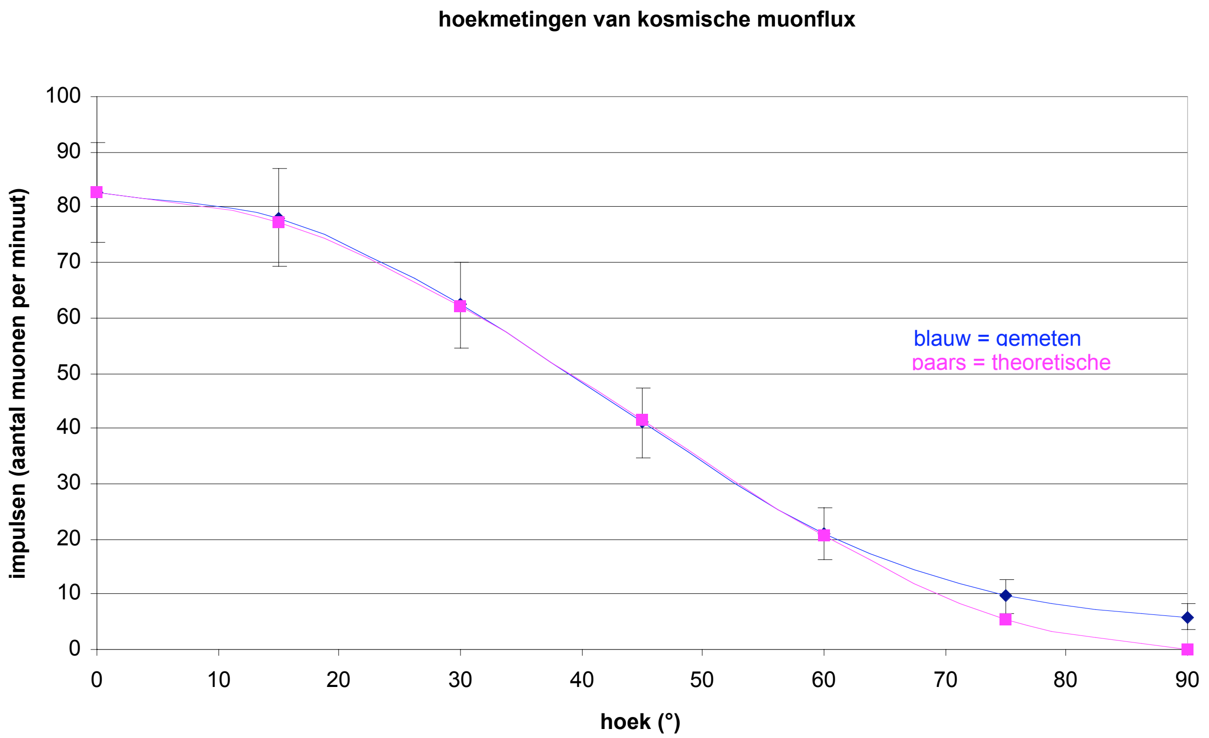
The error on this result was calculated by adding up and subtracting the square root of this result. This is not completely correct but it is a good method of approach. The result of my measurements was:

$$F = 0.482486\ cm^{-2}min^{-1}st^{-1} \pm 0.06049\ cm^{-2}min^{-1}st^{-1}$$
$$(= 80.41433\ m^{-2}s^{-1}st^{-1} \pm 10.0816\ m^{-2}s^{-1}st^{-1})$$

This value comes very close to the published value (0.48 $cm^{-2}s^{-1}st^{-1}$) which means that the detector works properly and is very reliable!

Angular distribution

In this experiment the muondetector was tilted and the angular distribution was measured. This time the scintillators where placed 57.5 cm apart. The measurements where done in Ghent (Belgium) at 14h at 25/01/04. Muonflux was measured every 15° and at every angle 15 measurements of one minute were done. In the plot you can see the average of every measurement and the error (calculated on the same way as the muonflux experiment described above). The blue line represents the measured data and the purple line is the theoretical prediction. This was found in 'Physical Review D particles and fields (2002)'. Recording to the literature the theory is correct until 70°, then the curve should flatten.



The purple curve was calculated using the following formula:

$$\mathbf{F(\theta) = F_{\theta 0} \cos(\theta)}$$

$F(\theta)$ is the muonflux at the angle θ and $F_{\theta 0}$ is the measured muonflux with the detector in vertical measuring position ($\theta = 0$). Again the theory matches perfectly with the measured data, and indeed the measured flux-curve flattens at approximately 70°. That is because muons can also come in the detector horizontally and, what is more, from two different sides (viz. from left to right and the other way around), whereas at smaller angles muons only come in one direction; downwards.

If you have any questions or comments about my cosmic ray detector, please feel free to contact me.

Email: bart.royeaerd@pandora.be
Address: Vinkendal 47
9031 Drongen
Belgium