

A Low Cost Educational Cosmic Ray Telescope

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on behalf of

The Particle and Astroparticle Physics Group
Hellenic Open University

Outline

- Introduction to Extensive Air Showers and Educational Cosmic Rays Telescopes

- The Hellenic Open University Telescope Array
- MicroCosmics (MiCos) detector: A light, portable EAS detector
 - Conceptual design
 - Construction
 - Performance & MC studies

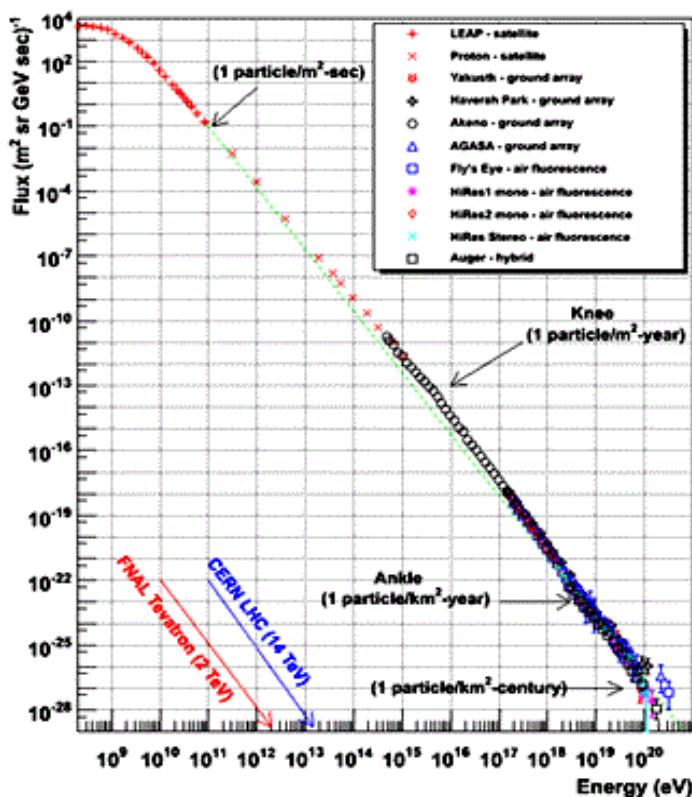
- Educational Activities

- Plans

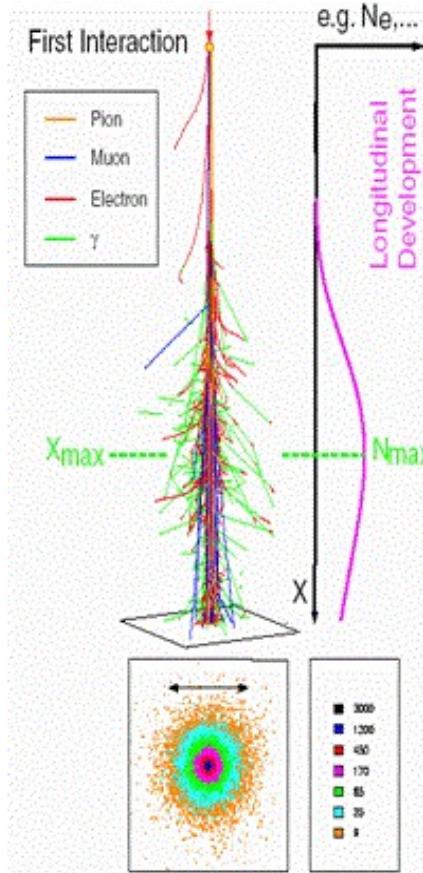
Cosmic Rays and Detection

- Cosmic Rays and Elementary Particles
- Scientific Interest (the wide energy spectrum, the unknown origin of high energy cosmic rays, the acceleration mechanisms, the composition of the primary particles, detection techniques etc)

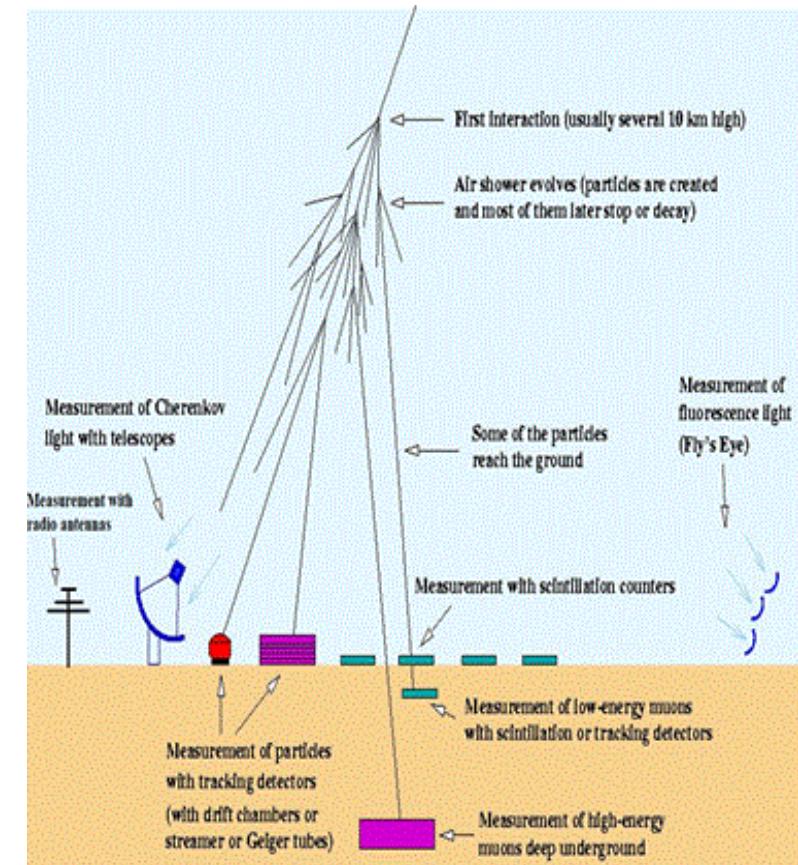
Cosmic Ray Spectra of Various Experiments



Energy Spectrum



EAS



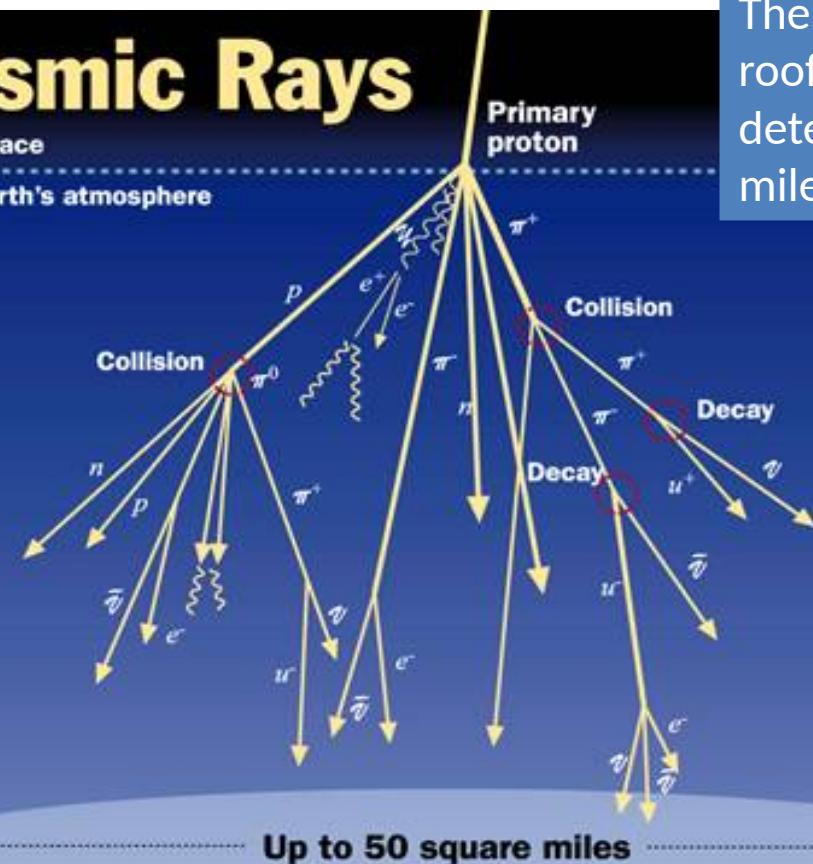
Detection

Educational Cosmic Ray Telescope

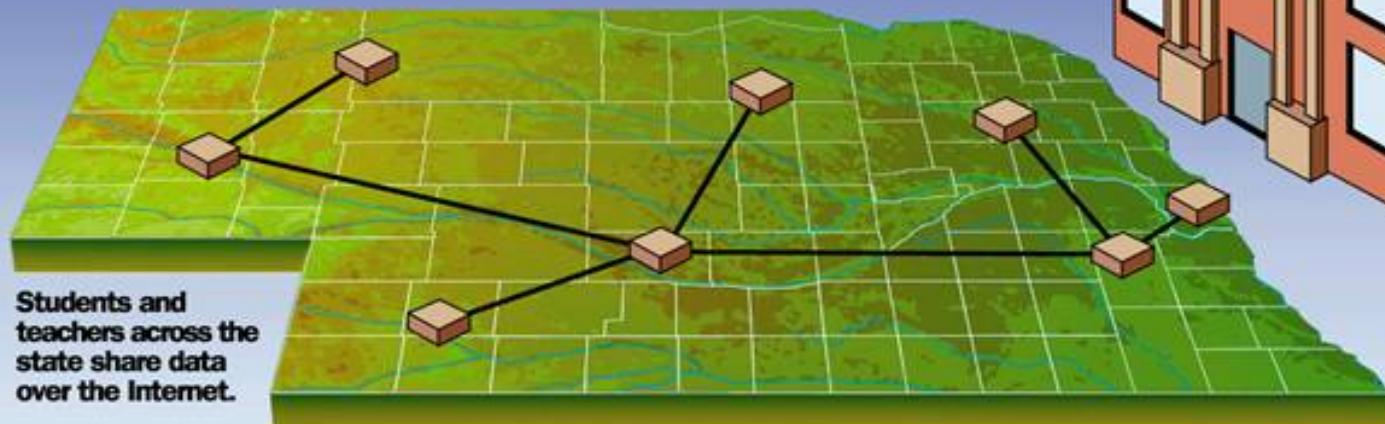
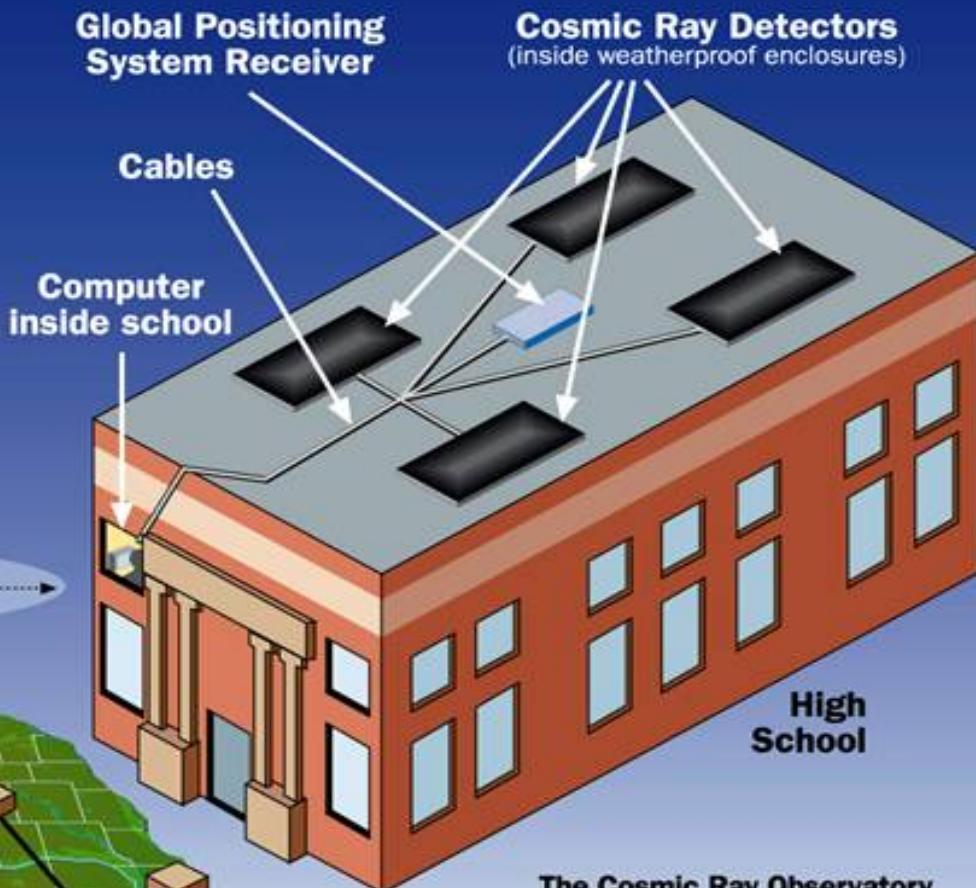
Cosmic Rays

Space

Earth's atmosphere



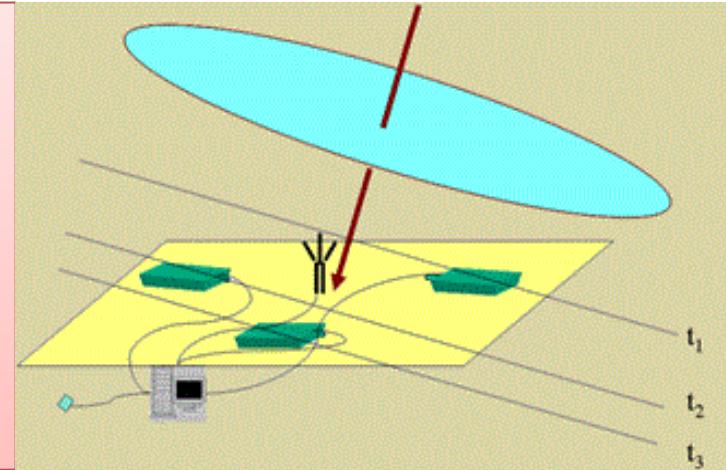
The idea is that scintillator counters positioned on the roofs of high schools can form a large sparse array of detectors across big cities covering an area of many square miles..



The Cosmic Ray Observatory Project, started by physicists at the University of Nebraska-Lincoln, aims to put cosmic ray detectors on high school rooftops across the state and collect data through a computer network.

Educational Cosmic Ray Telescope

A typical educational array consists of between three and four plastic scintillator detectors connected to photomultiplier tubes and read out by custom built electronics. The detectors are placed a few meters apart on the roof of a school, college or university building along with an antenna which uses the global positioning system to provide an absolute time reference



Local Coincidence , Relative Timing and Triangulation

Shower axis reconstruction with an accuracy of a few degrees.

Activities for Students and Teachers

- Classroom lessons for the history of Cosmic rays, the detection techniques, Instrumentation, statistical techniques, MC simulation etc
- The Assembly of the station (polishing and cleaning of the scintillator, connecting high-voltage supply, gluing PMT, wrapping the scintillator)
- Calibration and testing of the PMT and the Scintillator counters
- Control and Monitoring of the array
- Shower reconstruction and Data Analysis (local or combined data from several stations)
- Workshops for presentation of the results, public lectures etc



Worldwide Educational Cosmic Ray Telescopes

CANADA

[ALTA](#), [VICTA](#), [TRIUMF](#)

USA

[WALTA](#), [CHICOS](#), [CROP](#), [SALTA](#), [TECOSE](#),
[PARTICLE](#), [CLASA](#), [SCROD](#), [QUARKNET](#)

UK

[The Cosmic Ray Project](#), [QuarkNet Cymru](#),
[Detecting Cosmic Rays – possible student projects](#)

GERMANY

[Skyview](#), [Cosmic@Web](#), [The Netzwerk](#)
[Teilchenwelt network](#)

FRANCE

[Cosmos à l'École](#), [e-PÉRON](#)

NETHERLANDS

[High School Project on Astrophysics Research with Cosmics](#) (HiSPARC)

SWEDEN

[SEASA](#), [Cosmic ray outreach in Stockholm](#)

POLAND

[MAZE](#), [CREDO](#)

RUSSIA

[Showers of Knowledge](#)

SPAIN

[Cazadores de Rayos](#) Gamma

FINLAND

[Callio Lab](#)

CZECH REPUBLIC

[CZELTA](#)

ITALY

[Extreme Energy Events](#)

ROMANIA

[ROCOSMICS](#)

SLOVAKIA

[SKALTA](#)

GREECE

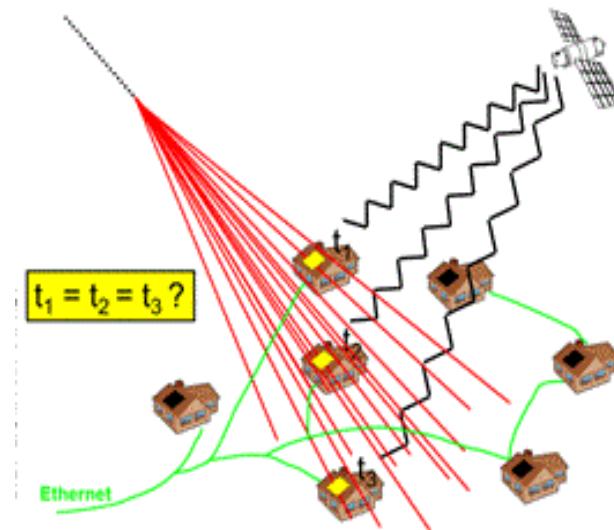
[HELYCON](#)

The Hellenic Open University Educational Cosmic Ray Telescope



Physics Laboratory
School of Science & Technology
Hellenic Open University

S. Tzamarias, A. Leisos, A. Tsirigotis, G. Bourlis



3 stations at the University Campus
And one more station deployed in the Physics Lab (3.5 km apart)



HOU Cosmic Ray Telescope Software

HOURS-EAS

Hellenic Open University Reconstruction and Simulation of Extended Air Showers

Initialization

CORSIKA Particle Information
on the Detector Level

Fast Simulation of Scintillation
& WLS Processes

Generation Of PMT
Photoelectrons

PMT Response Pulse

Signal Transmission and
Digitization

Raw Data Creation

Parameterizations using Geant4 full simulation
Slewing correction
Digitization DAQ functionality
Signal processing
Reconstruction Studies

Detector Database

Counter Positions &
Orientations,
Counter characteristics,
PMT characteristics,
Cable Calibration,
Digitization Parameters

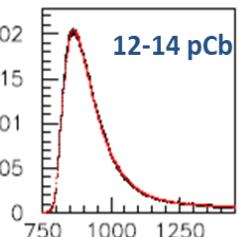
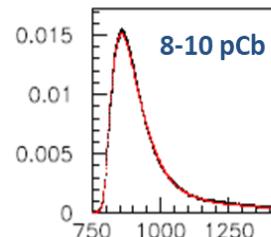
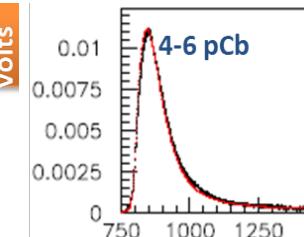
Initialization

Signal Processing

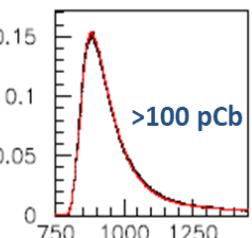
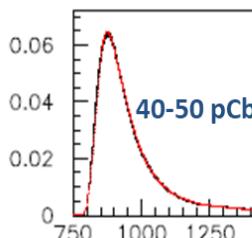
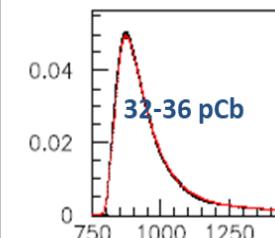
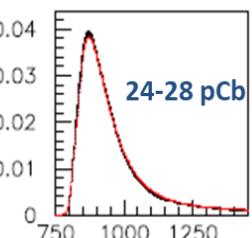
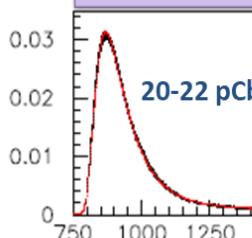
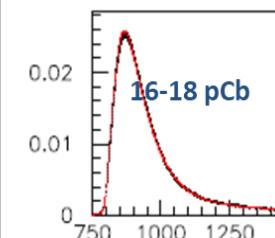
Data Quality

Shower Reconstruction

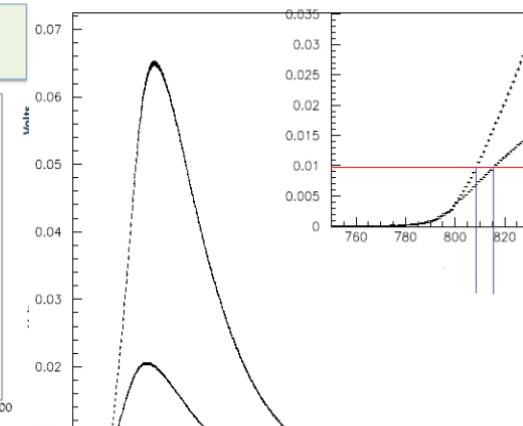
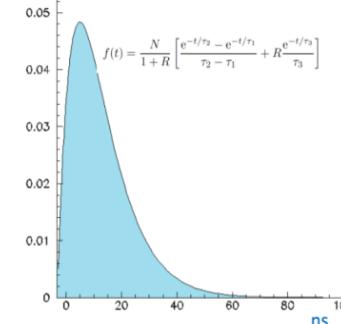
Volts



Red: MC
Black: Data



Components of Scintillation Process



HOU Cosmic Ray Telescope

Activities for High School students

- Visits of high school students to the HOU Telescope (University Campus in Patras)
- Lectures for the Cosmic rays and the detection techniques
- Hands on experimentation in:
 - PMT calibration
 - Scintillator Counter uniformity and response to mip
 - Timing studies
 - Coincidence studies
 - DAQ performance
 - Signal processing
 - Operation and Monitoring of a station
 - Analysis and shower reconstruction
- Offline data analysis and interpretation
 - Correlation studies (day-night, atm pressure, east-west anisotropy, zenith angle dependence)
 - Geometries study - Monte Carlo simulation
- Evaluation and Feedback

- Due to the cost and the size/weight of the scintillation counters these activities can be performed only at the HOU campus
- Design a portable and cheap Micro EAS detector Array (Micro Cosmics - MiCos) with significant performance capabilities for use at High Schools

Micro Cosmics Telescope

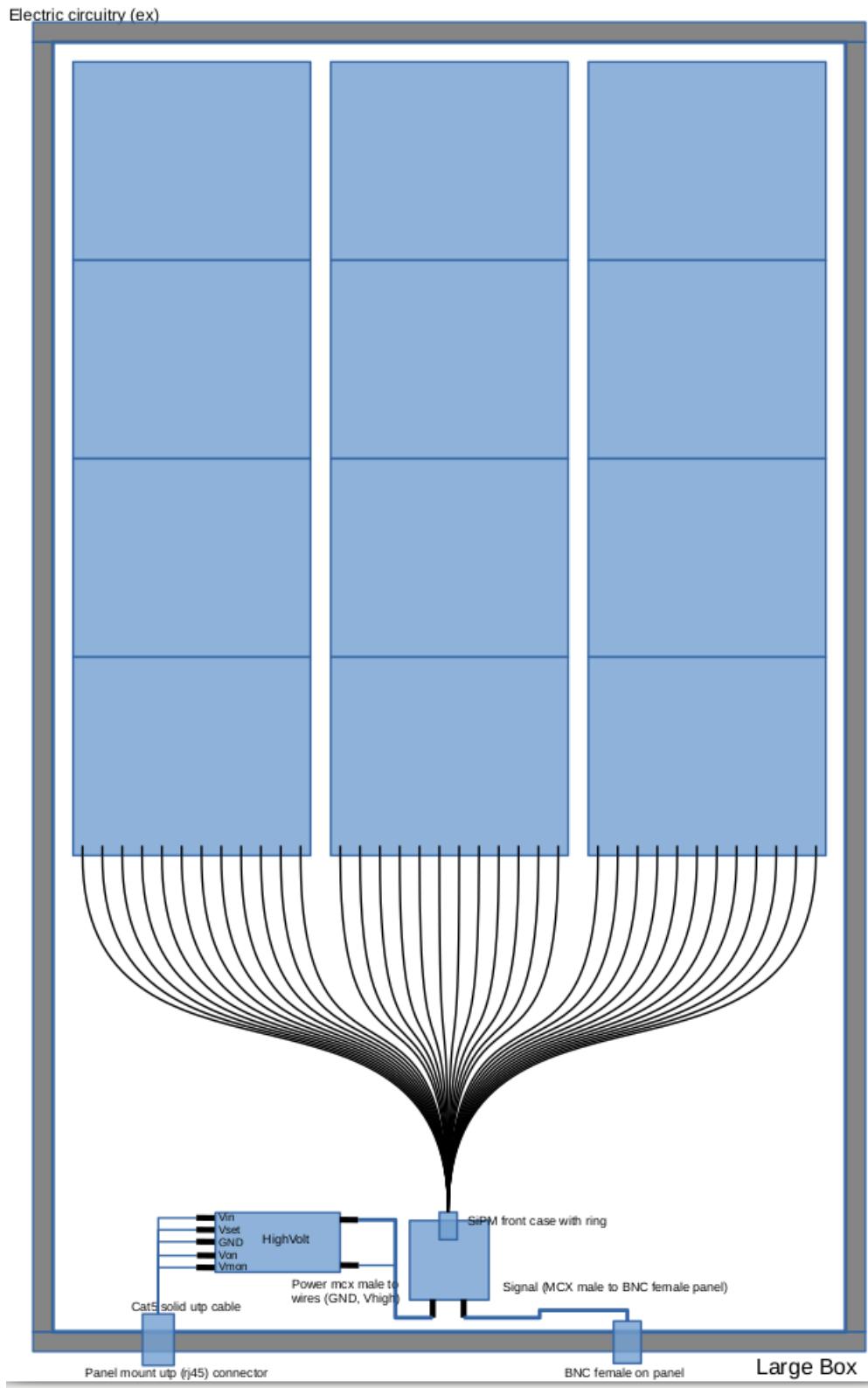
Activities for High School students

- Visits of high school students to the HOU Telescope (University Campus in Patras)
- Lectures for the Cosmic rays and the detection techniques
- Hands on experimentation in:
 - PMT calibration (requires dark room)
 - Scintillator Counter uniformity and response to mip
 - Timing studies
 - Coincidence studies
 - DAQ performance
 - Signal processing
 - Operation and Monitoring of a station
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Designing the MiCos detector

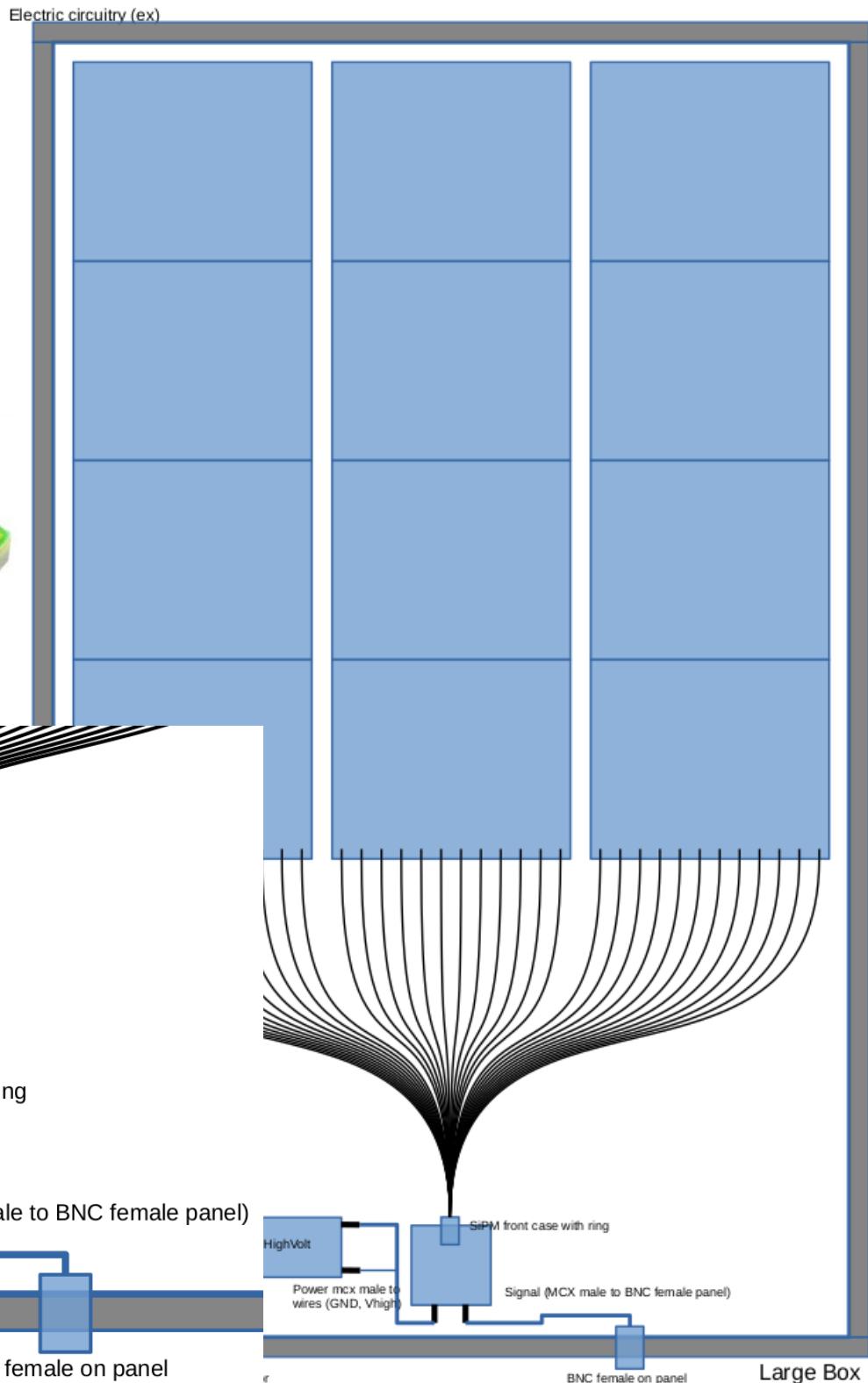
- Portable (67x42x7cm, ~6kgr each counter)
- Cheap (~2500 euro a full station with 4 counters)
- No High Voltages (<40V)



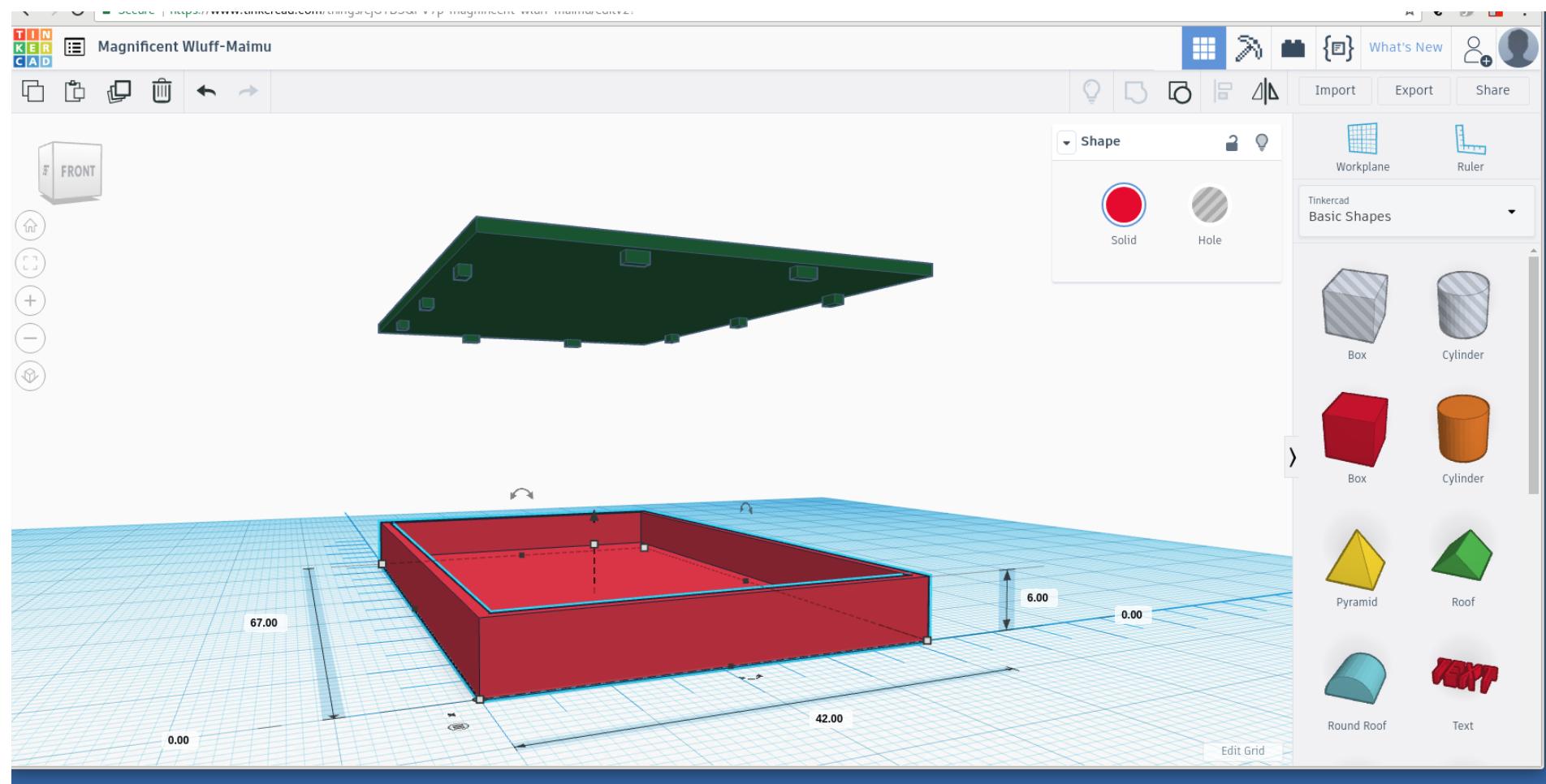
Designing the MiCos detector

- Portable (67x42x7cm, ~6kgr each counter)
- Cheap (~2500 euro a full station with 4 counters)
- No High Voltages (<40V)

**SiPM – Silicon Photomultiplier
PM6650-EB**



The detector enclosure and the support structure of the scintillator tiles



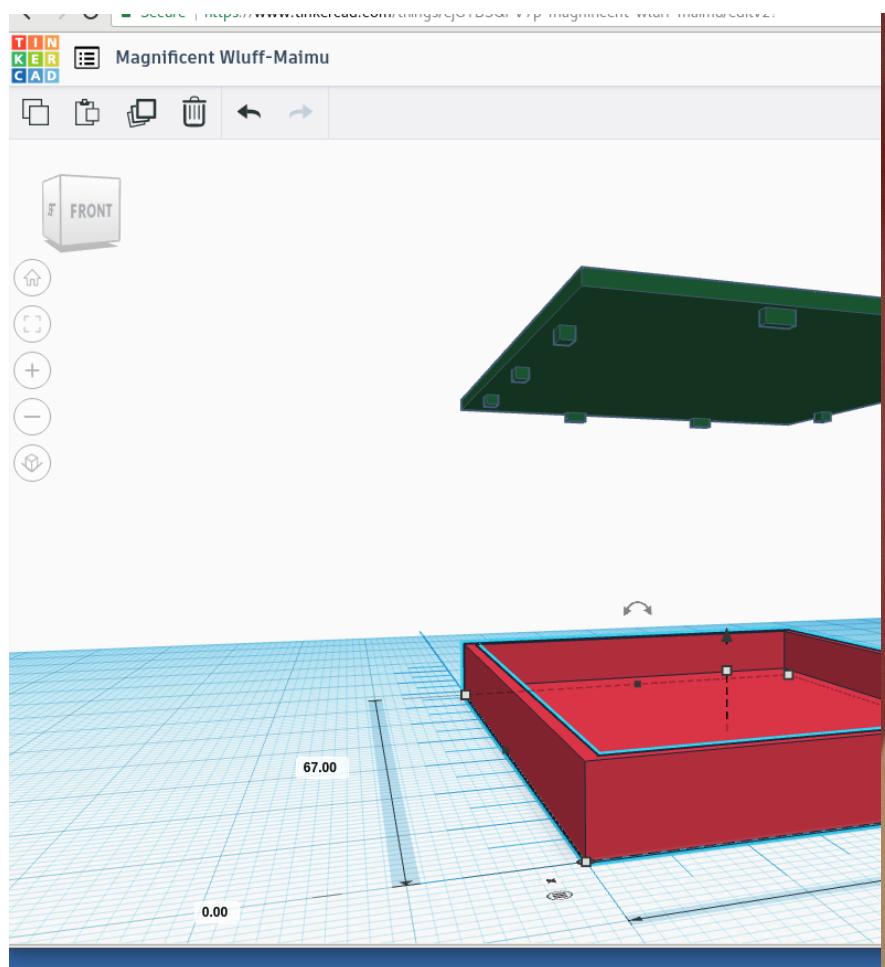
Detector enclosure from foam PVC 10mm

- Light
- Rigid enough

Support structure from MDF wood (13mm)

- Very rigid
- Easy to work

The detector enclosure and the support structure of the scintillator tiles



Detector enclosure from foam PVC 10mm

- Light
- Rigid enough

Support structure from MDF wood (13mm)

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- Easy to work

The SiPM

PM6650-EB

- 6x6mm

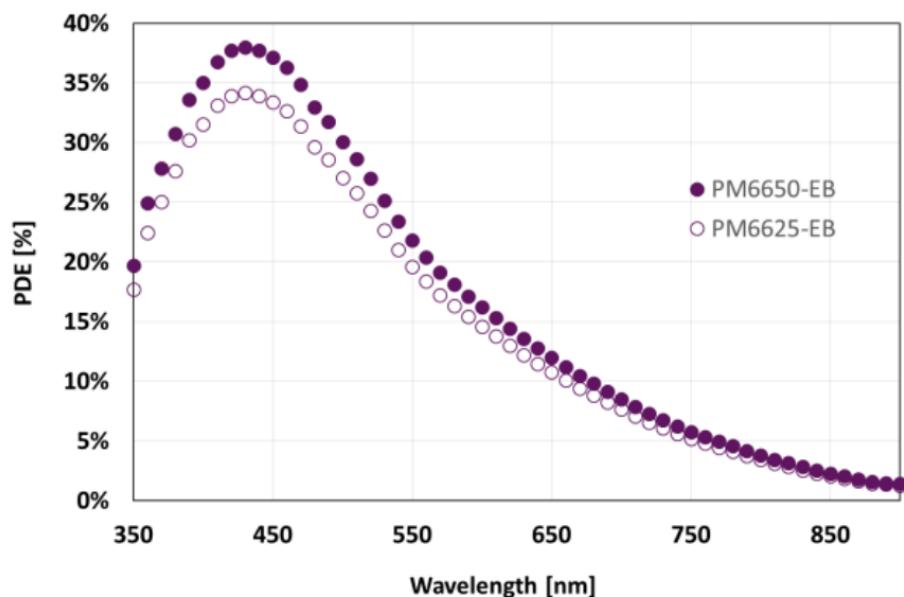
- 50 μ m micro cell size

- 14272 cells

- 38% QE at 430nm

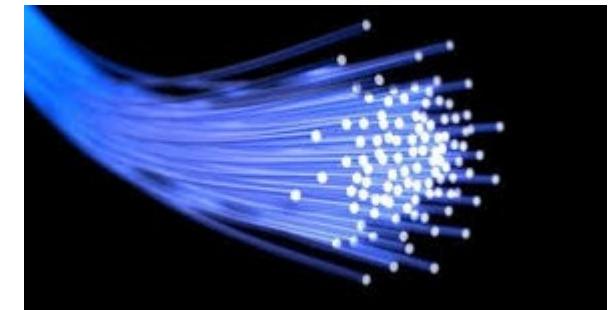
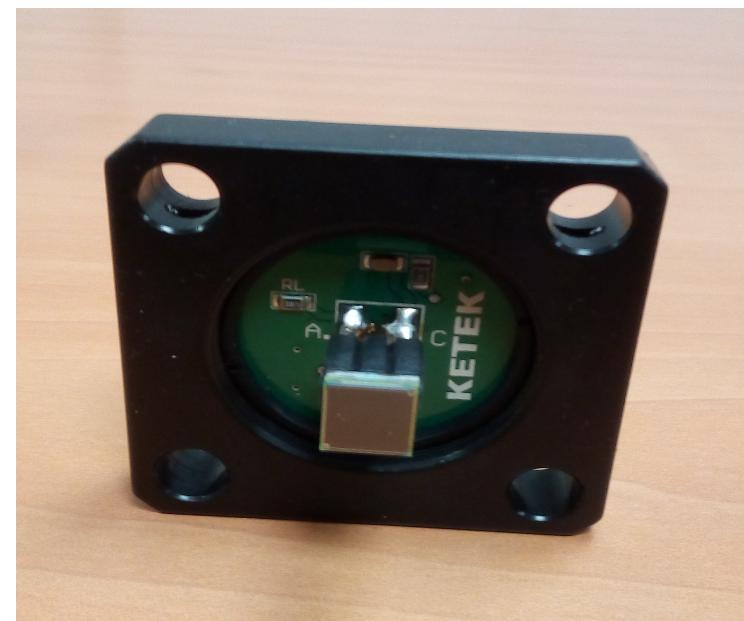


Absolute Photo Detection Efficiency
at 5 V overvoltage



Had to find a way to attach the optical fibers to the Silicon PMT

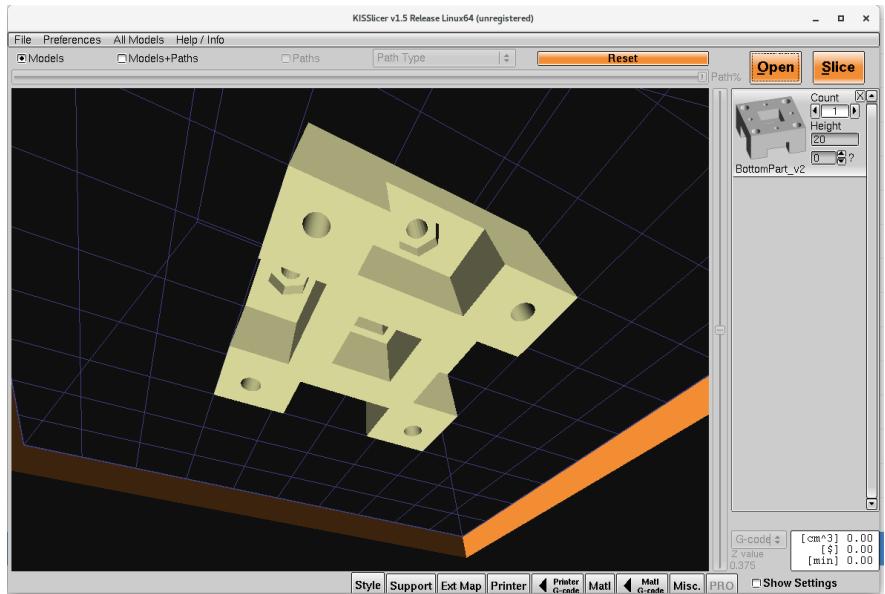
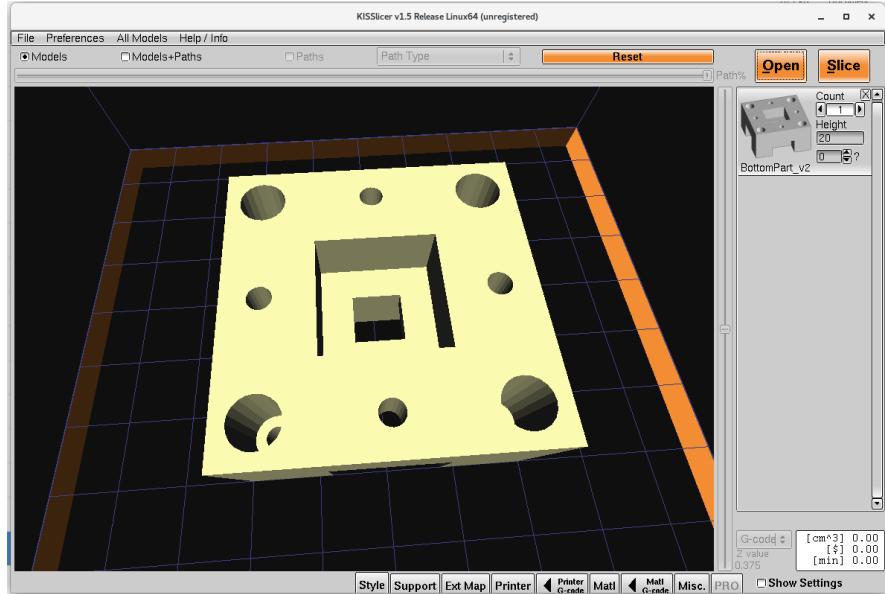
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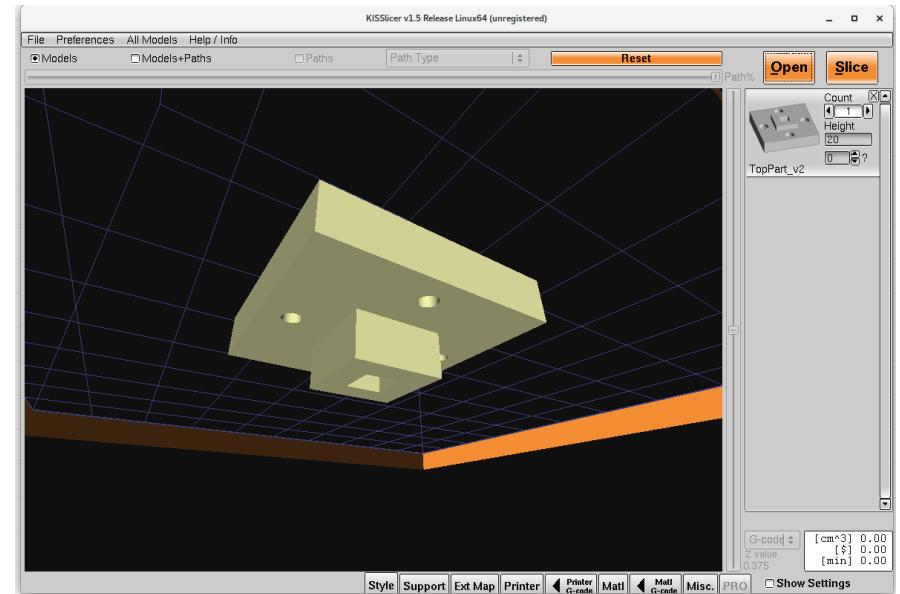
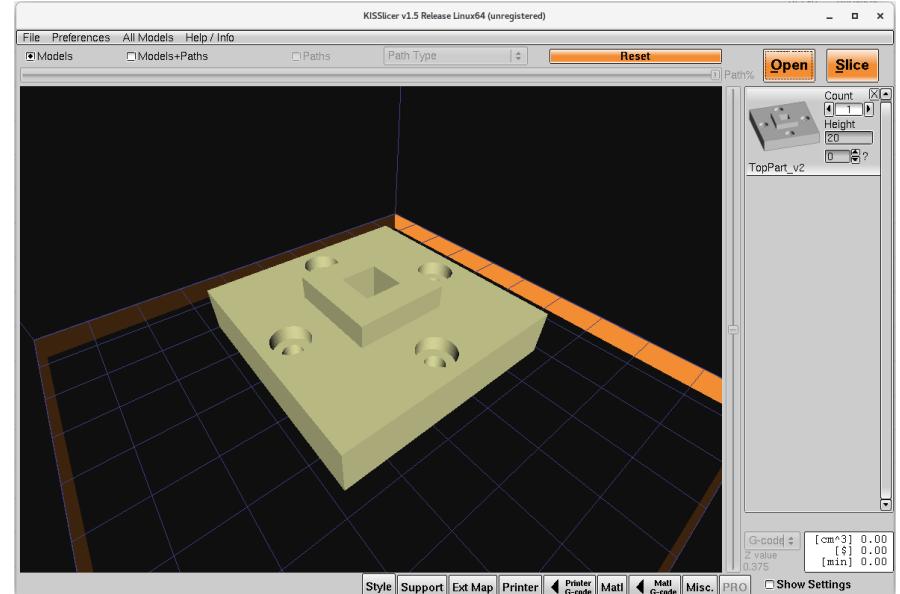
The enclosure of the SiPM and of the optical fibers – The design

Designed by us in two parts

Bottom part holds the SiPM in place



Top part holds the optical fibers

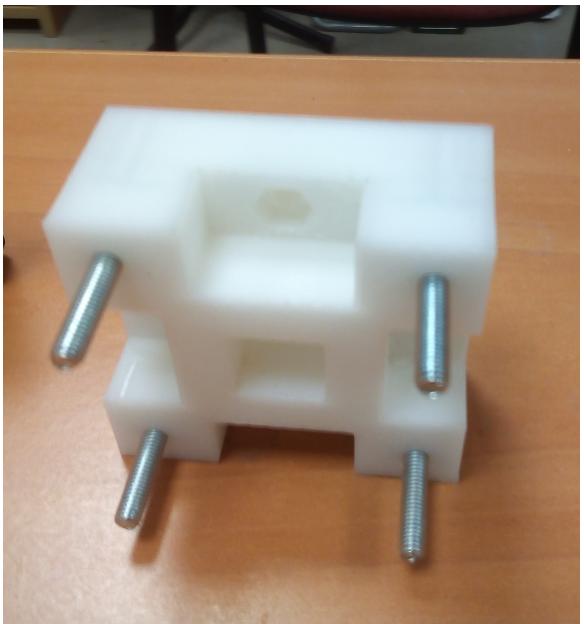
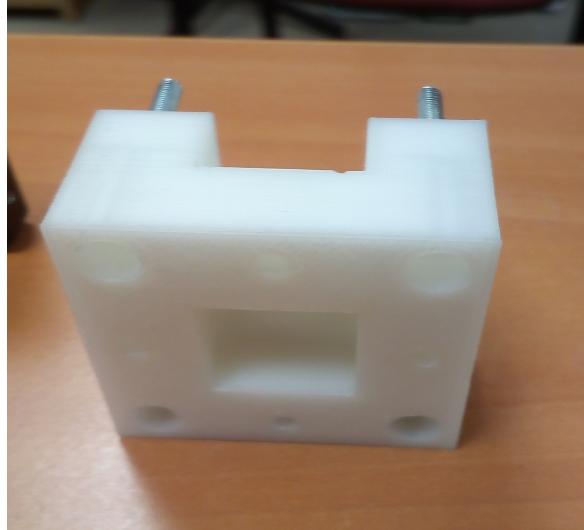


The enclosure of the SiPM and of the optical fibers – The making

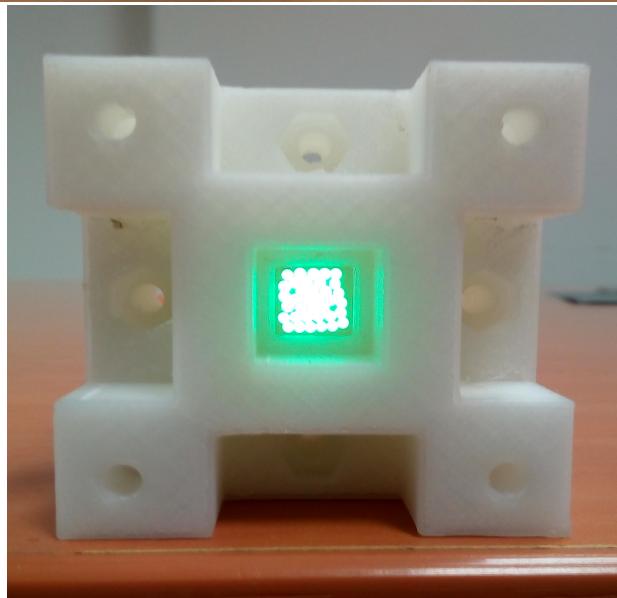
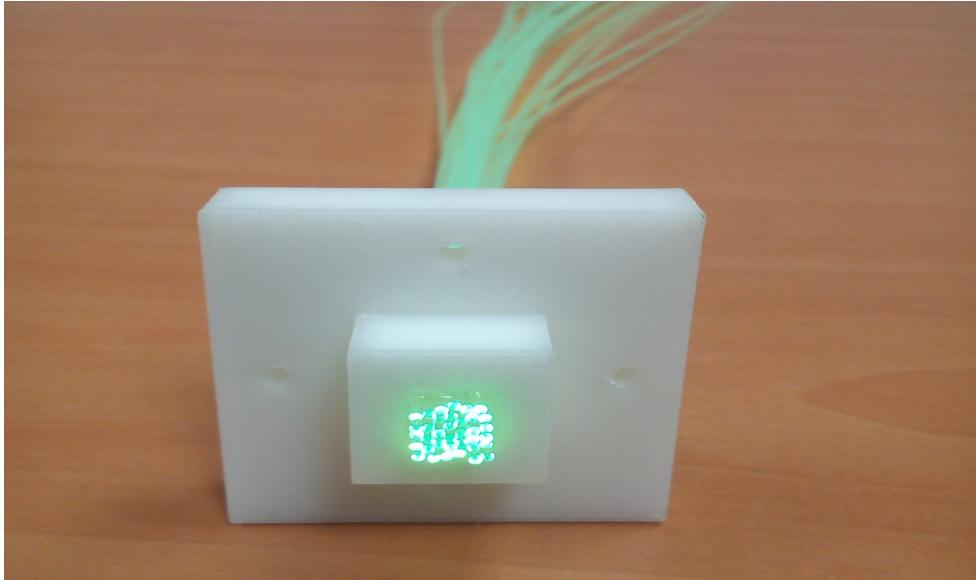
Cheap solution

- 3d printing

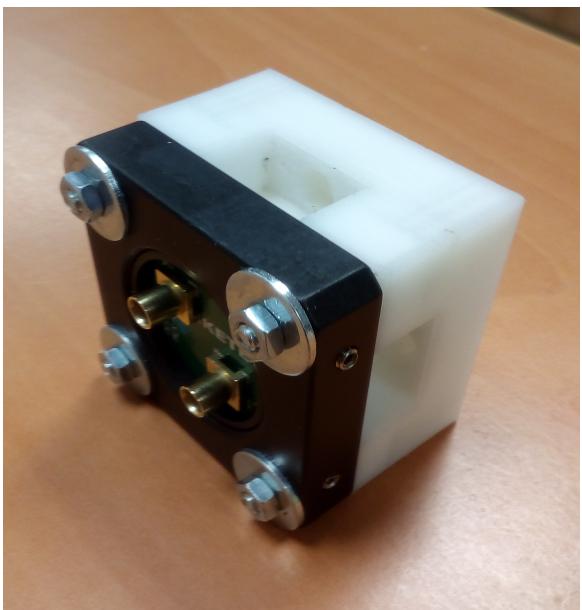
- ABS high density material



Optical fibers are glued on top part and then are polished



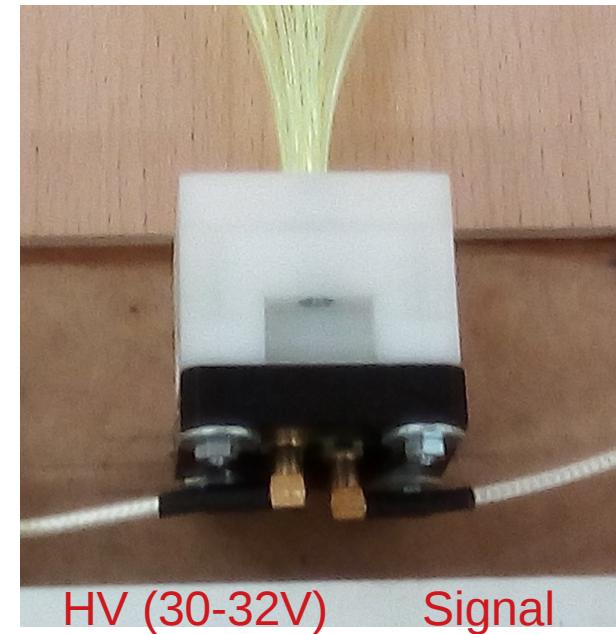
The enclosure of the SiPM and of the optical fibers – The assembly



+



=



HV (30-32V)

Signal

The power supply of the SiPM

HMA-0.2N2.5-5



0.5W

5V Vcc

Outputs 0 to -200VDC

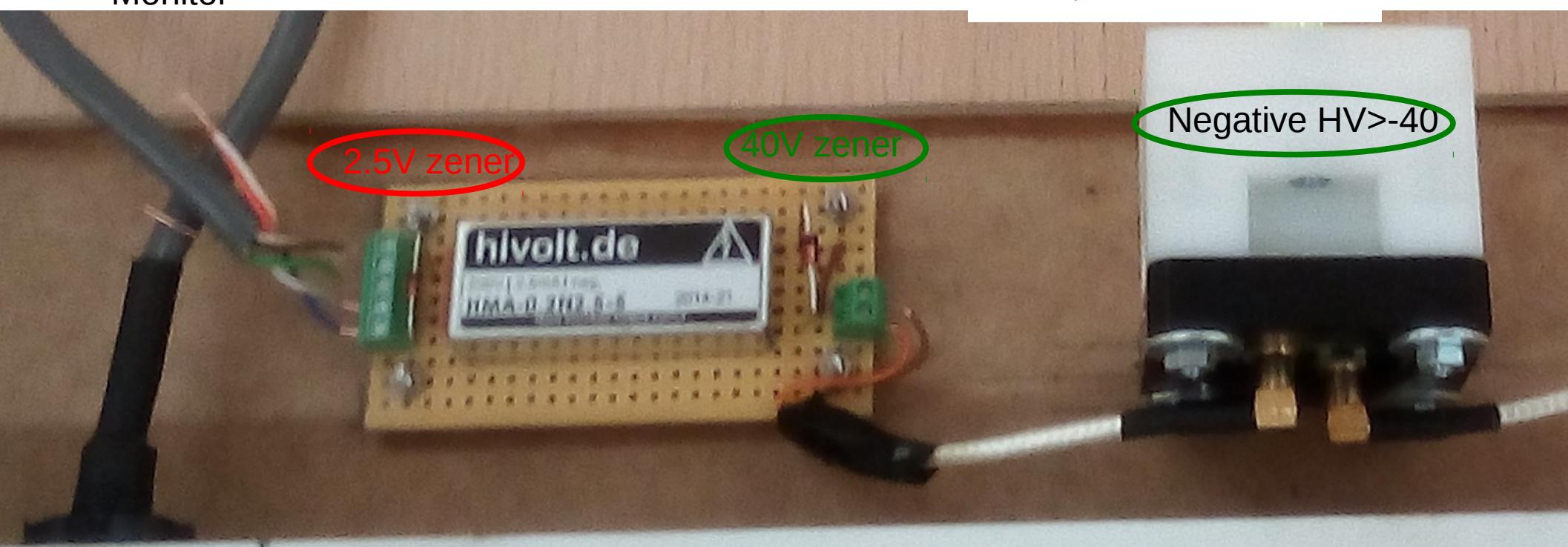
Control 0 to 2.5V

On/Off

Monitor

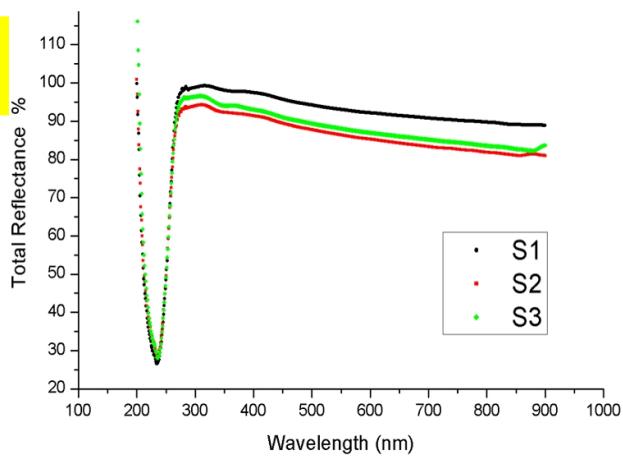
LucidControl AO4 for the control of the HV supply through UTP cable

- 4 Channel Analog Output USB Module
- Output voltage 0-5V
- Controls up to 4 detectors (a station)

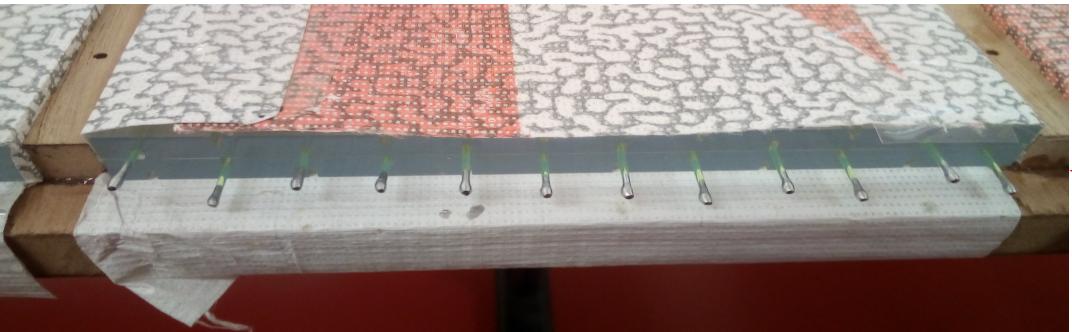


Construction 1

Using Tyvek paper for enhancing the light output of the scintillator

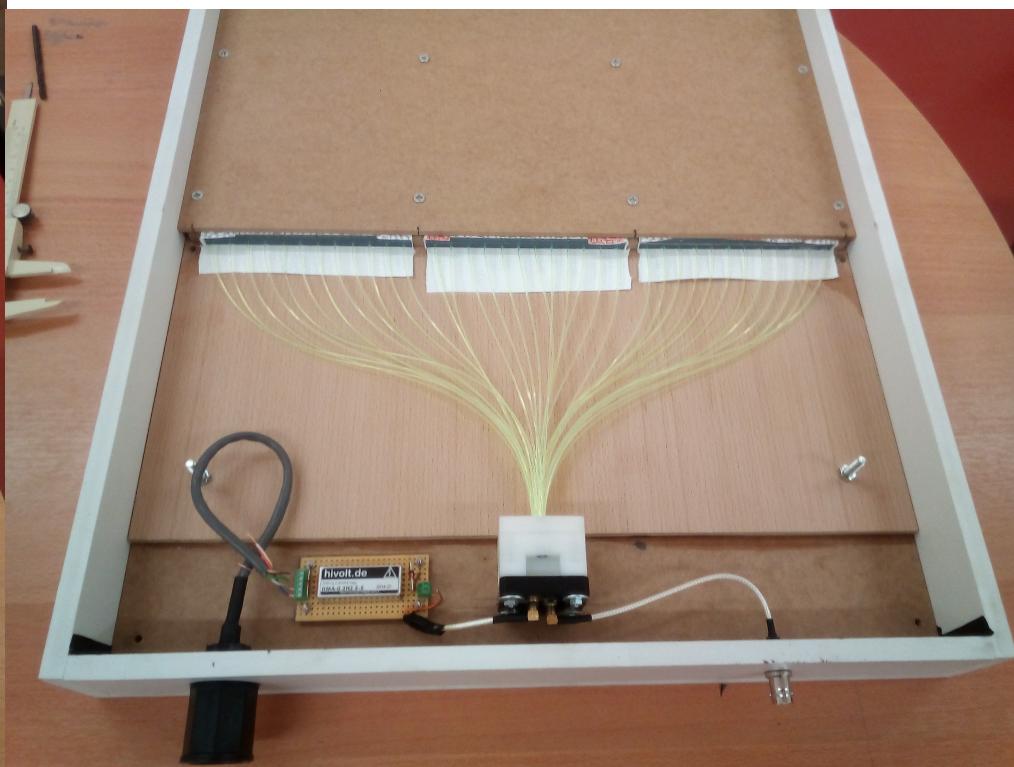
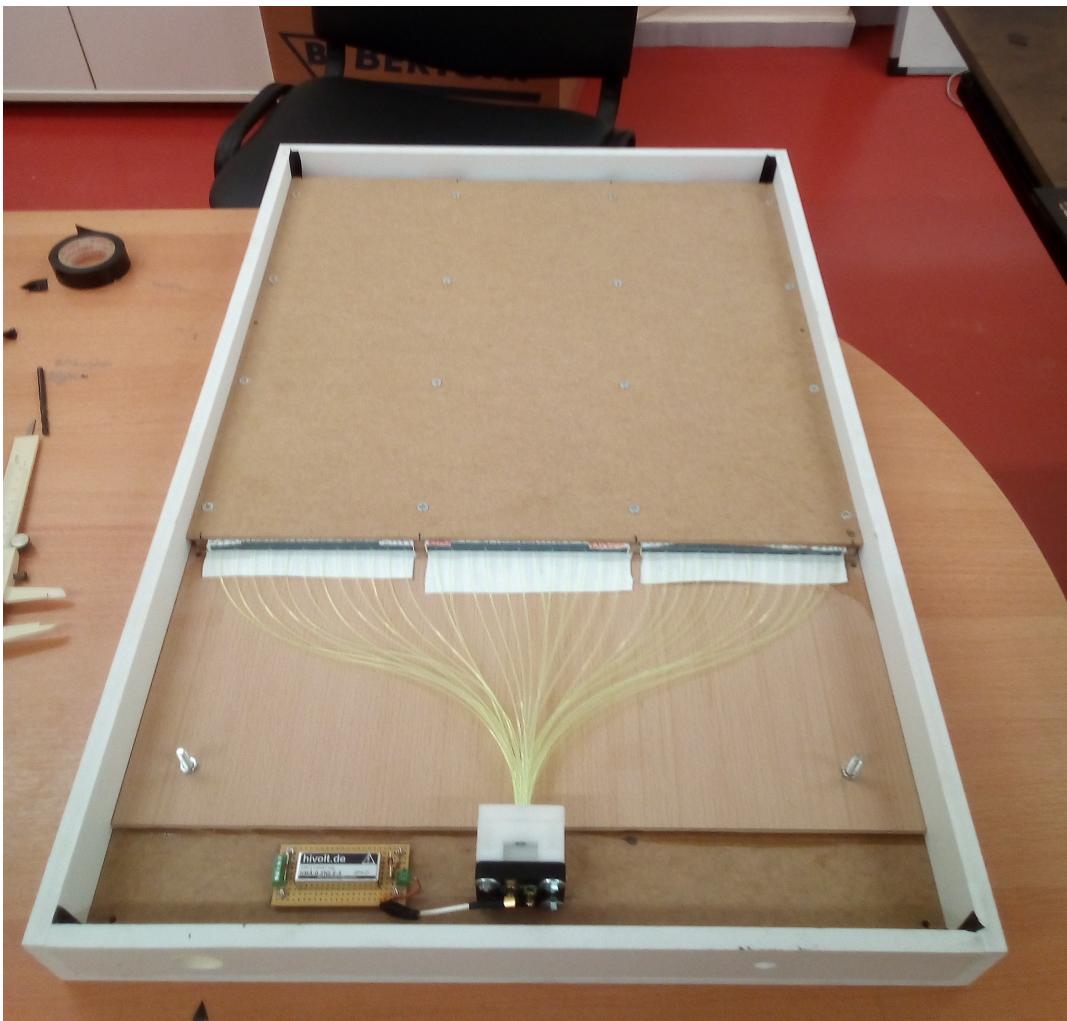


The ends of the fibers are cut as sharply as possible and coated with reflective paint



Construction 2

The SiPM and power supply
are attached to the MDF panel
and the UTP, BNC connectors are
tightened to the PVC enclosure



Construction 3

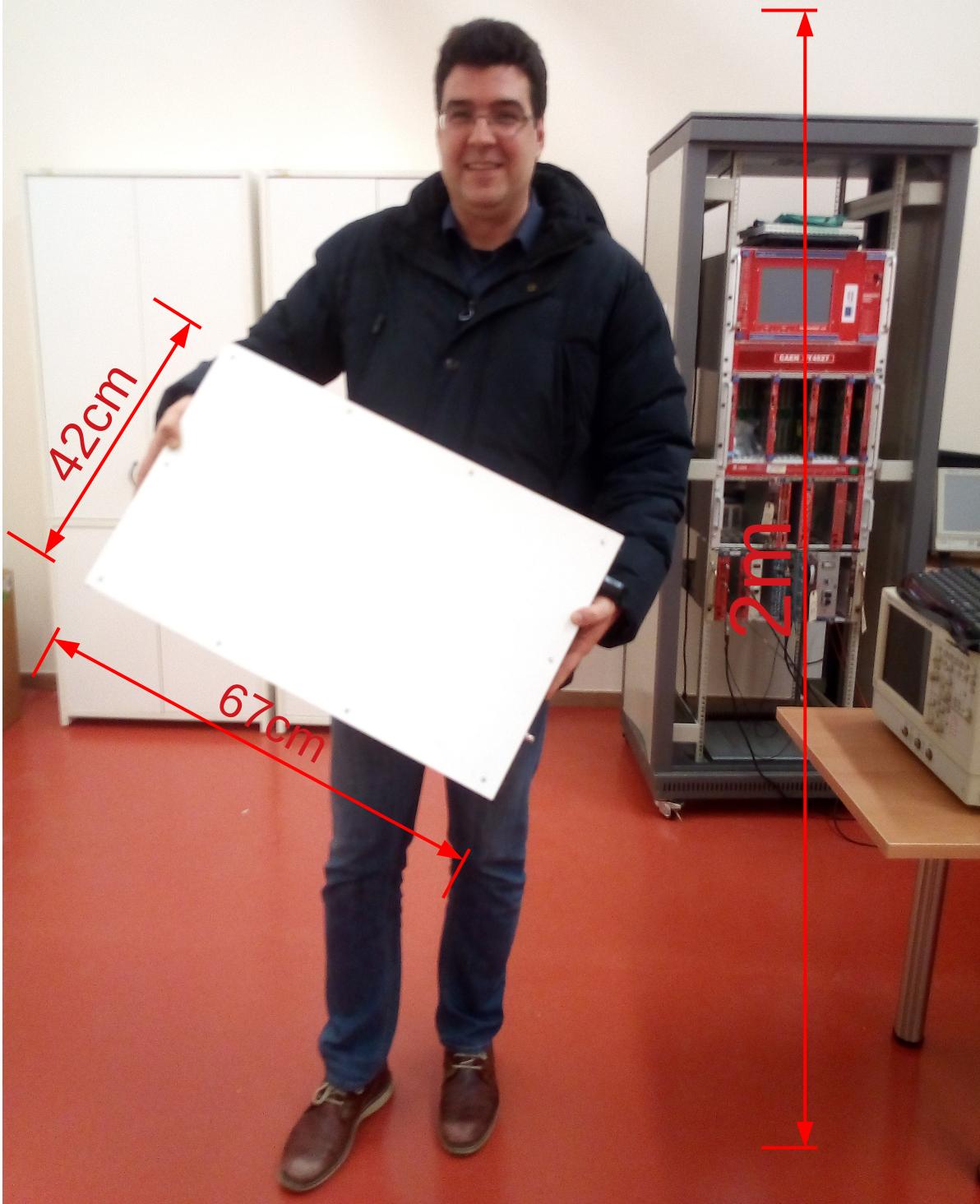
The optical fibers are covered with hard paperboard
And a rubber gasket is used for light proofing



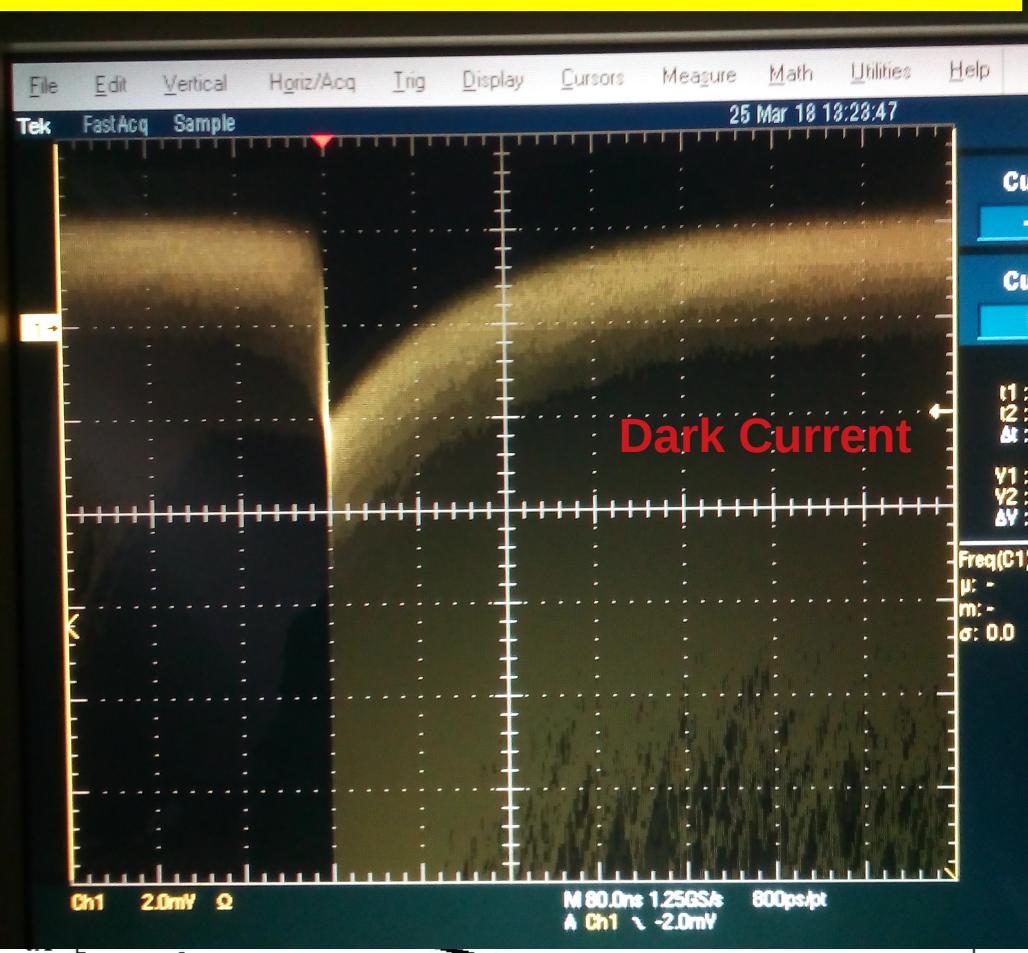
The completed detector
-67x42x7cm
-6kgr
--~450 euro all included



Size comparison



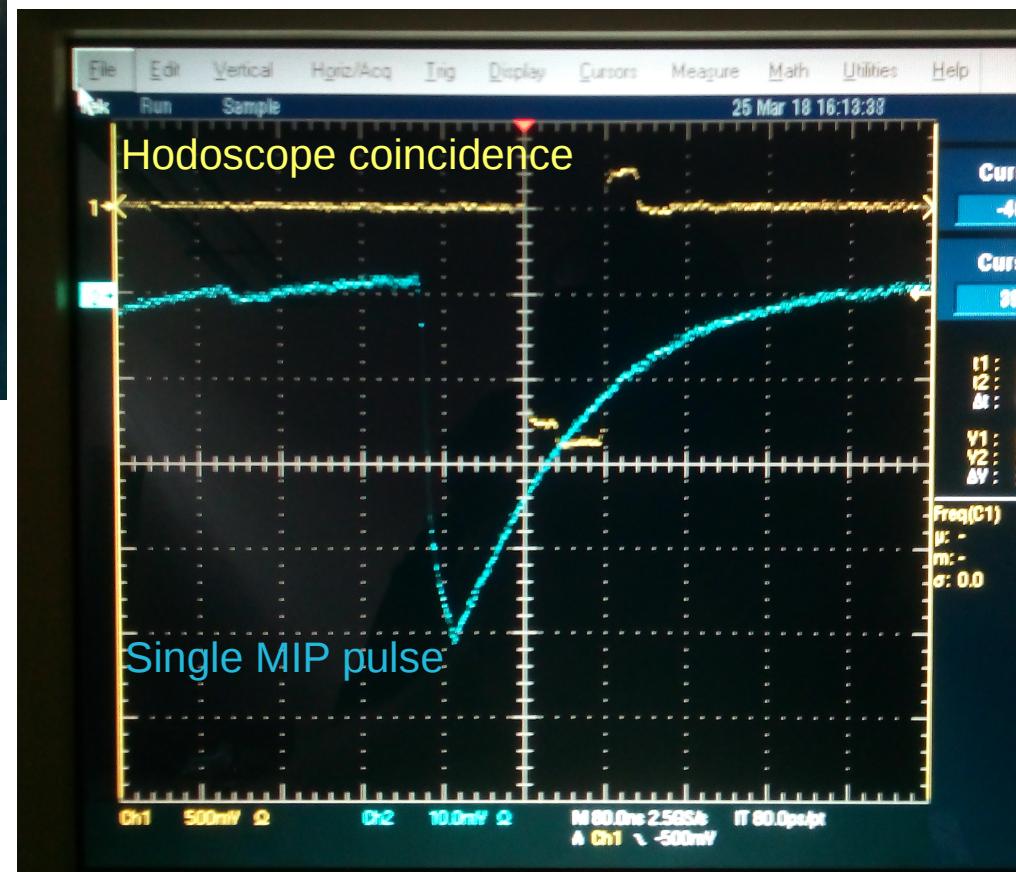
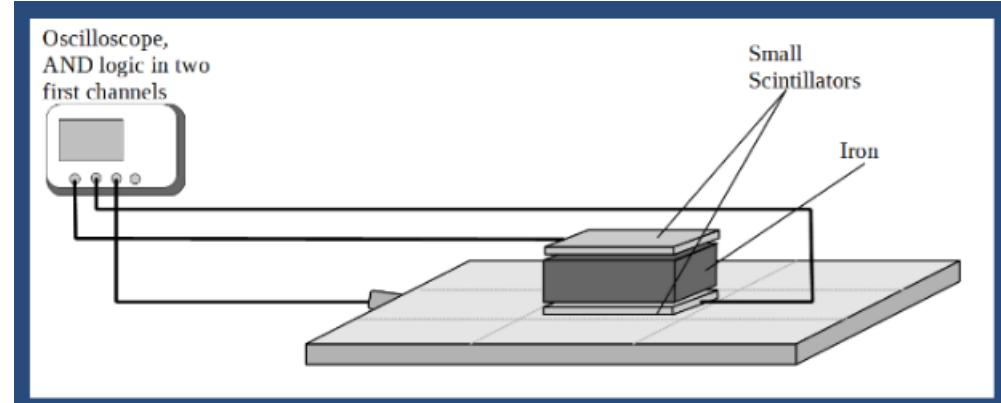
Performance – Pulse characteristics



Mean single photoelectron pulse for HV 32V

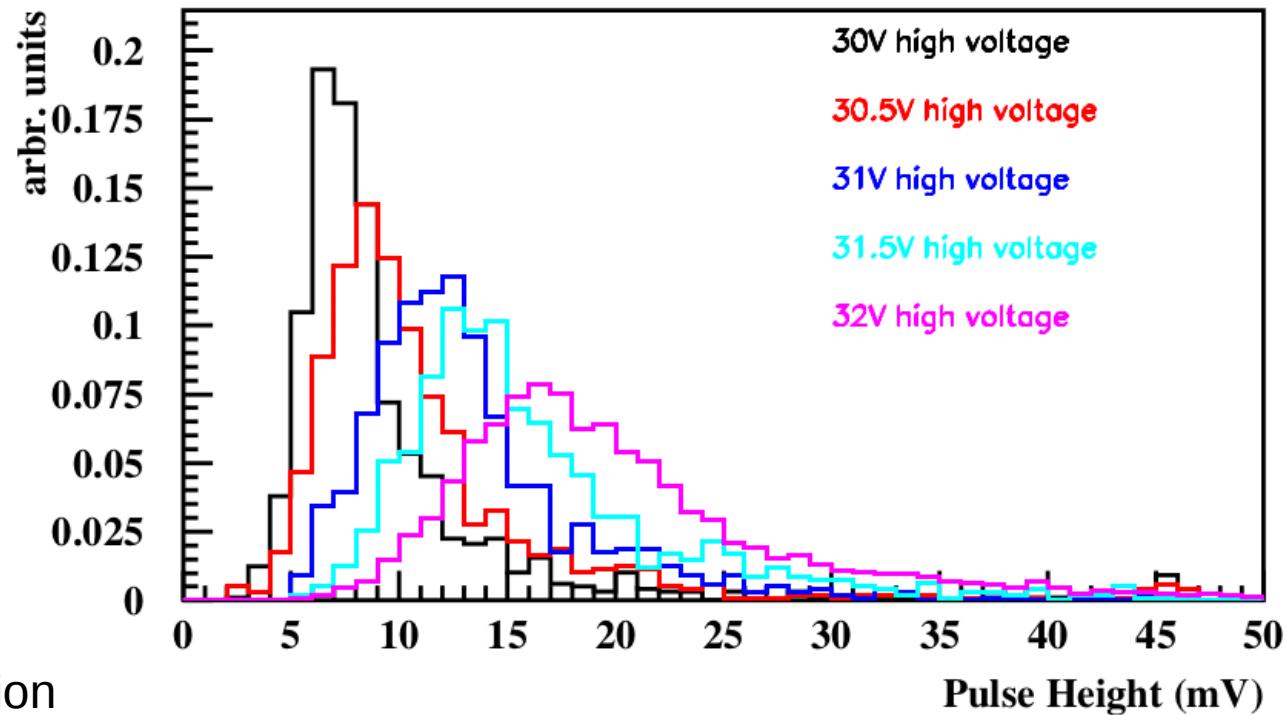
- Rise time ~ 2ns
- Fall time exponential with $\tau \sim 140$ ns

Detecting single muons (MIPs) using a hodoscope

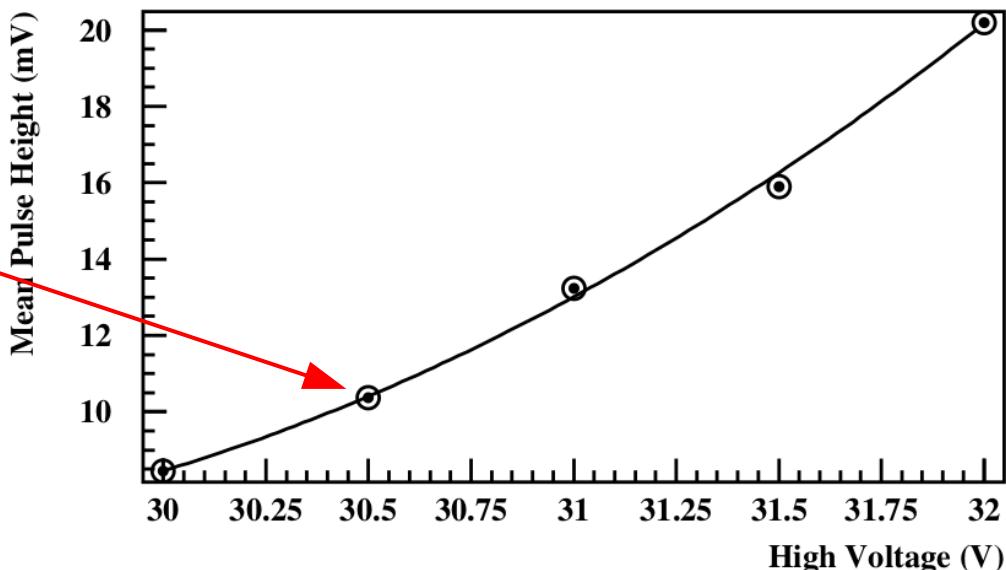
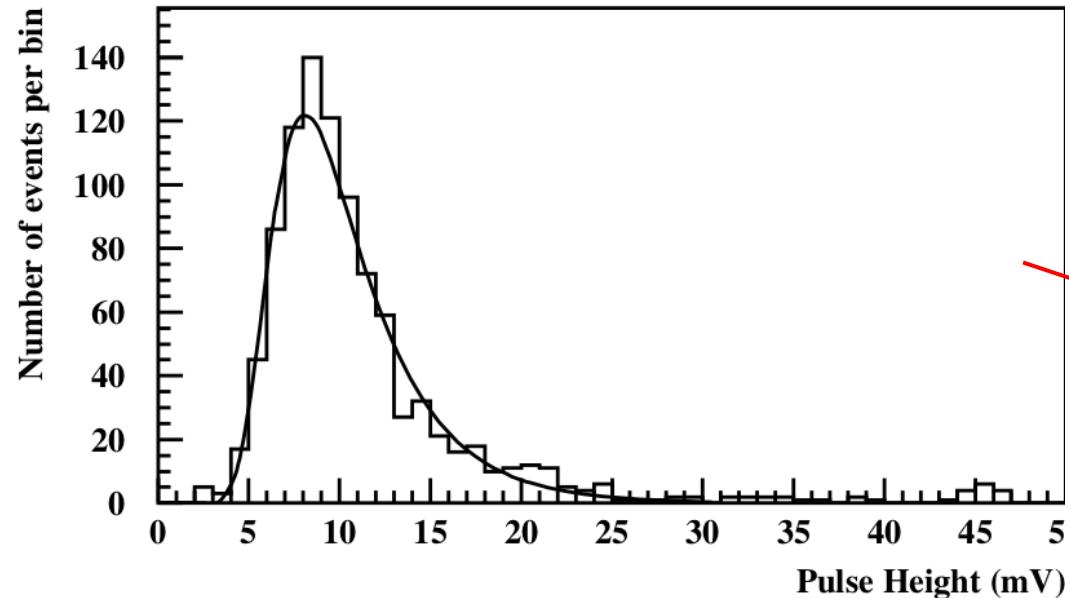


Performance – Pulse Height (PH) distribution vs HV

Mean PH is not exactly linear

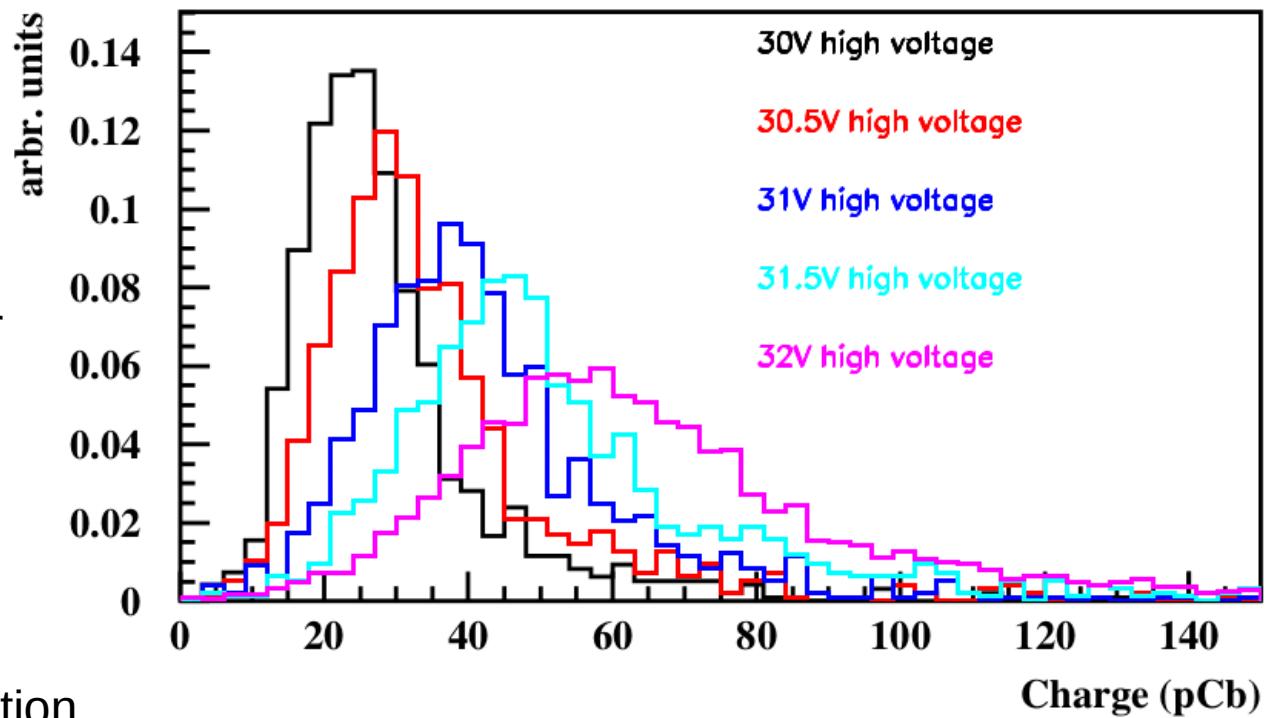


Fit with Landau distribution

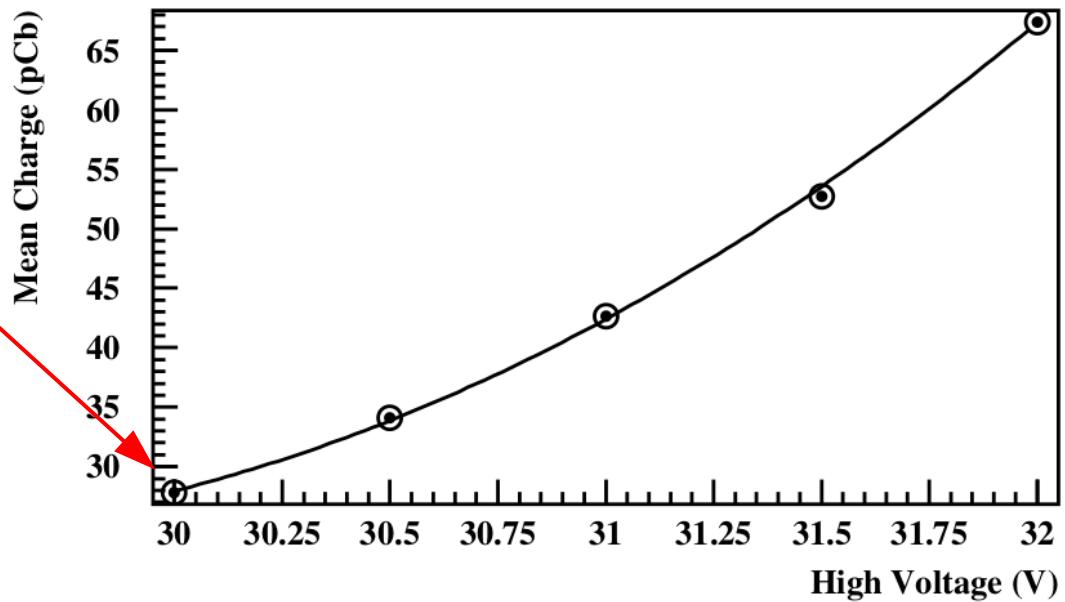
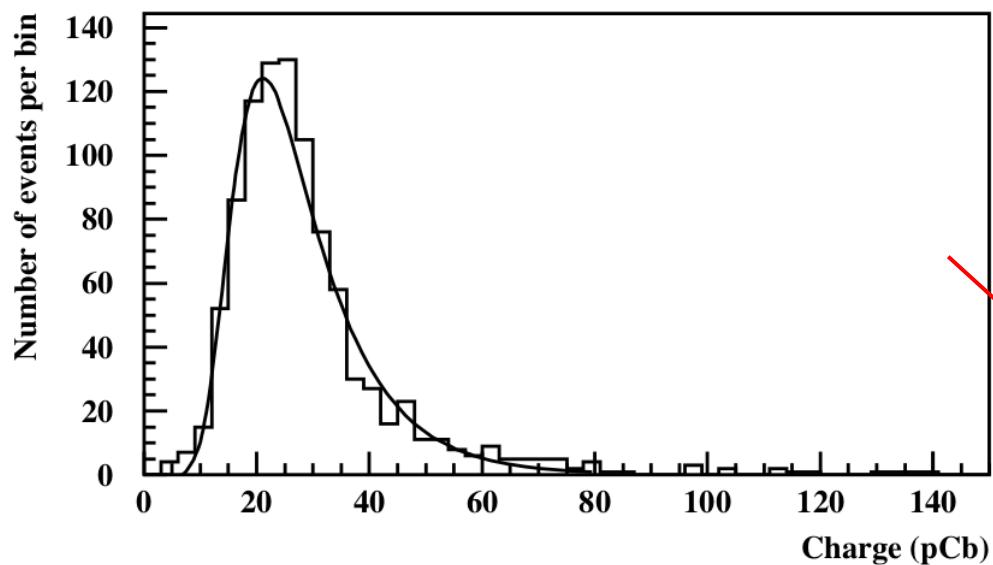


Performance – Charge distribution vs HV

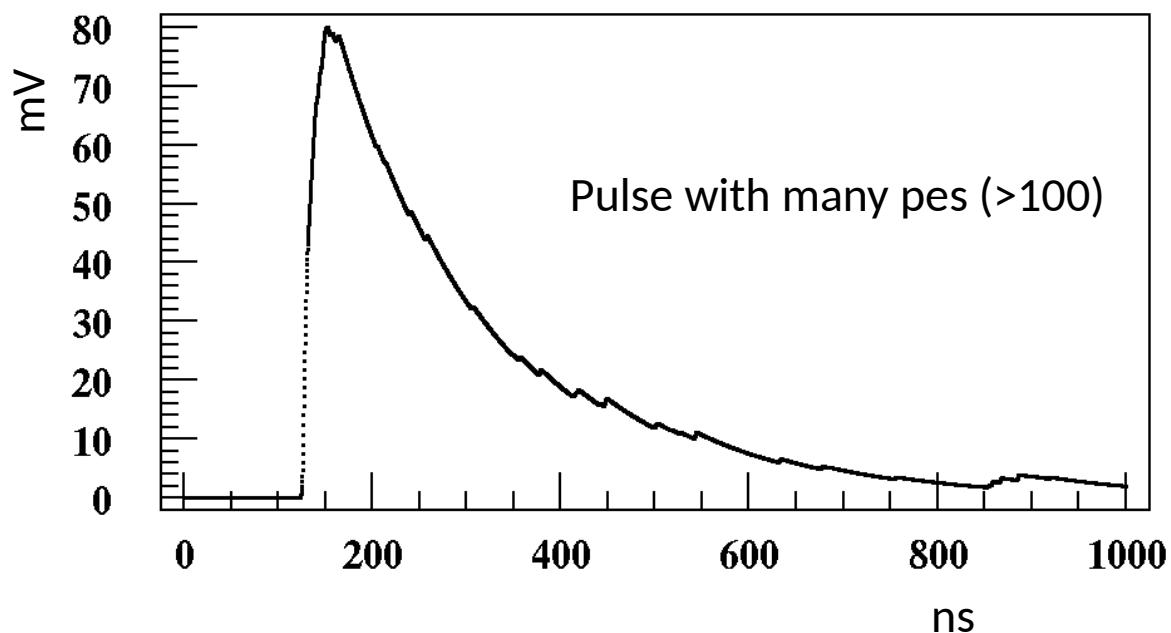
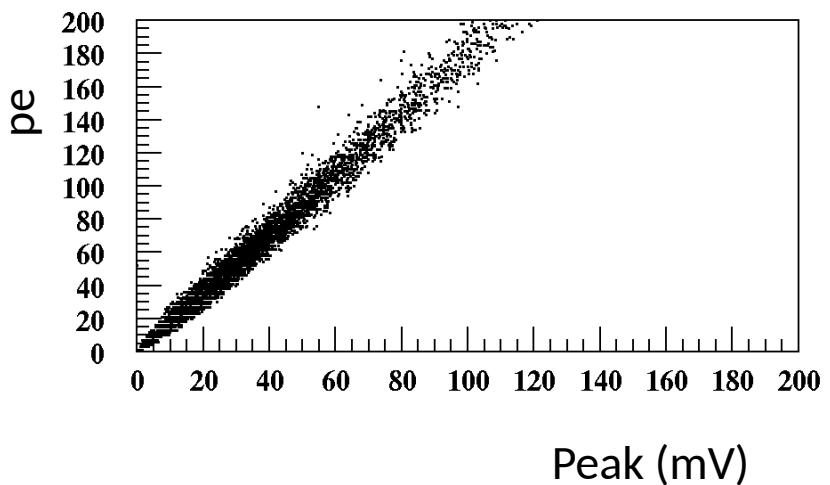
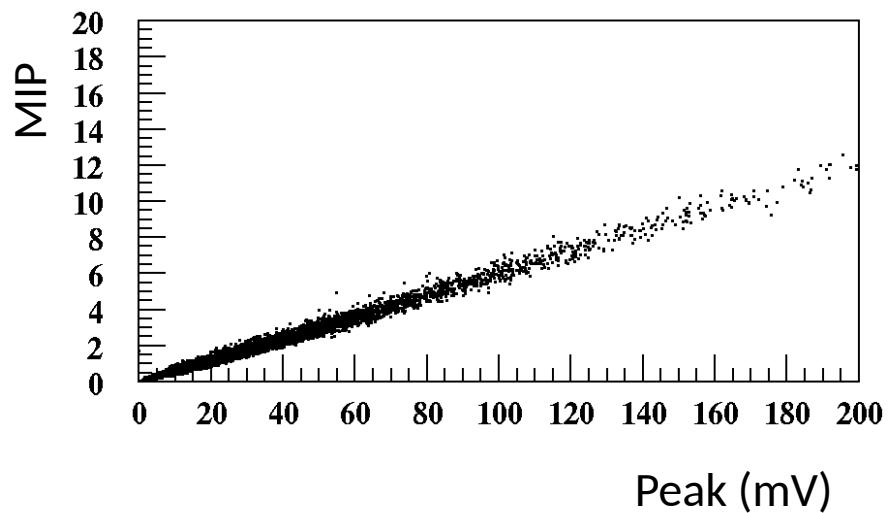
Mean charge is not exactly linear



Fit with Landau distribution

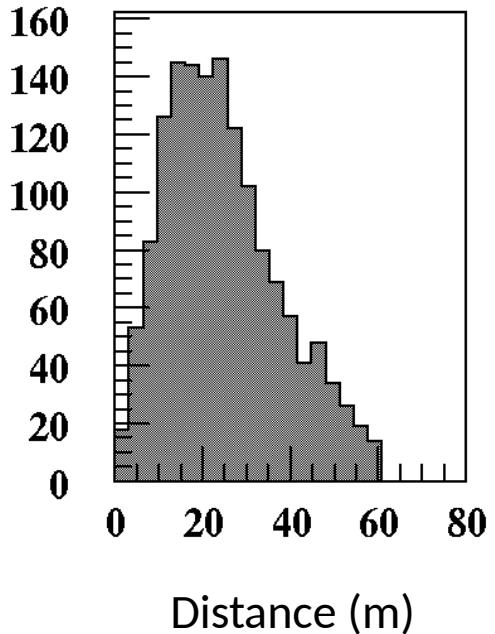


Performance – MC studies of a station with 4 detectors – Pulse characteristics

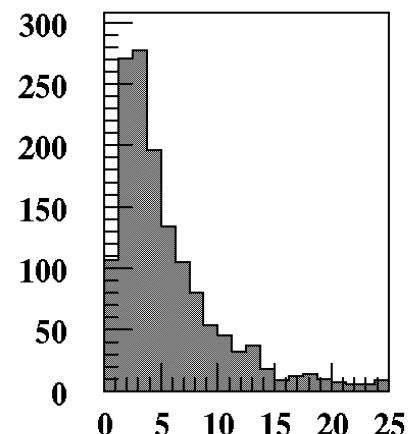
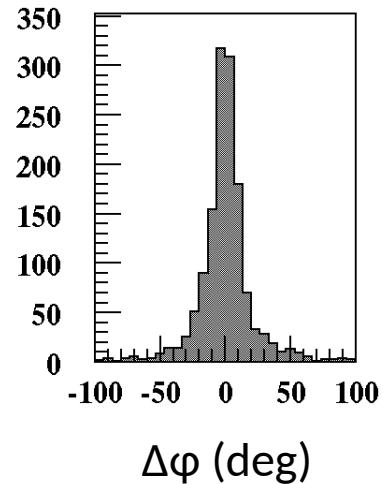
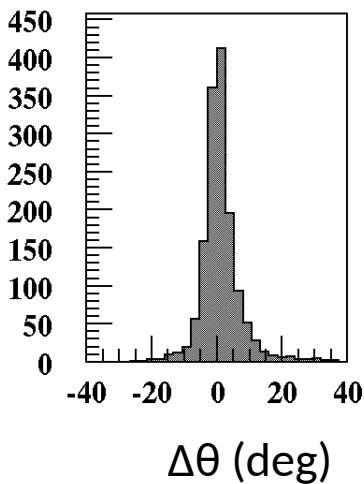
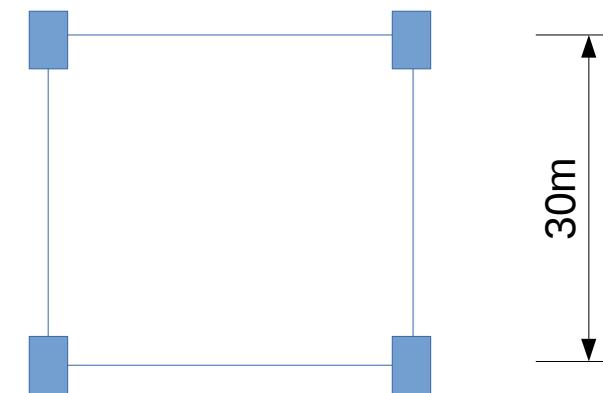


Performance – MC studies of a station with 4 detectors – Resolution and event rate – I

Threshold 20 mV (1MIP)
Timing @ 6 mV
Median 4.1deg
146 per day, 6 per hour



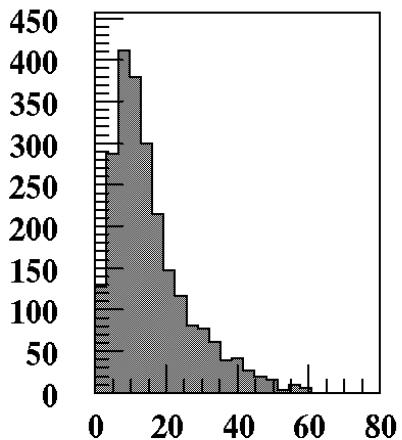
Square 30x30



3d angle (deg)

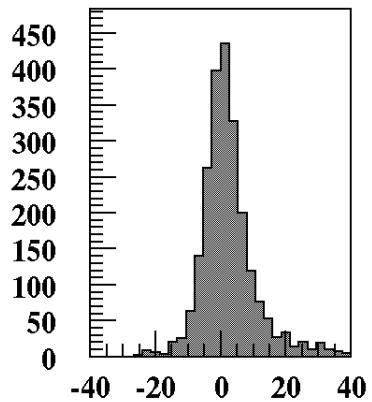
Performance – MC studies of a station with 4 detectors – Resolution and event rate – II

Threshold 20 mV (1 MIP)
Timing @ 6 mV
Median 6.5 deg
236 per day, 10 per hour

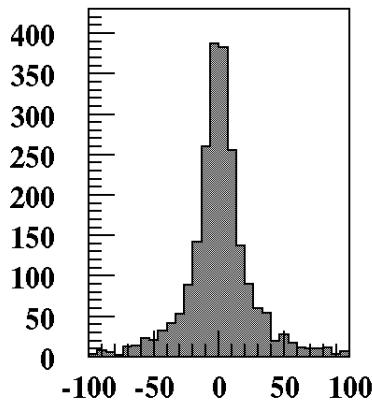


Distance (m)

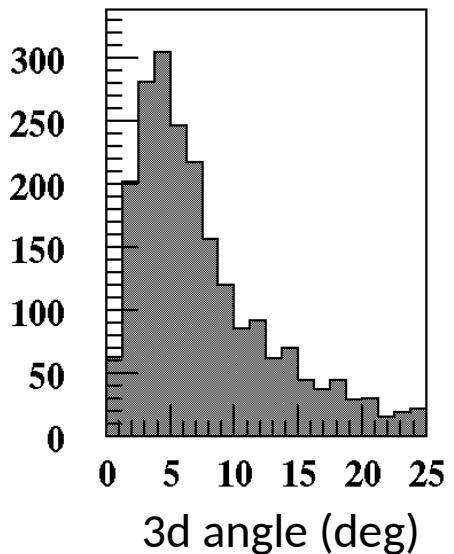
Square 10x10



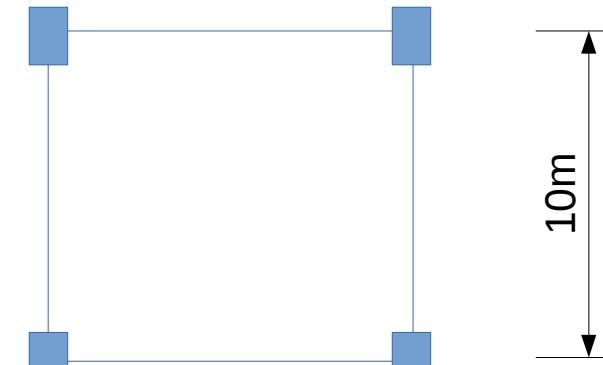
$\Delta\theta$ (deg)



$\Delta\phi$ (deg)



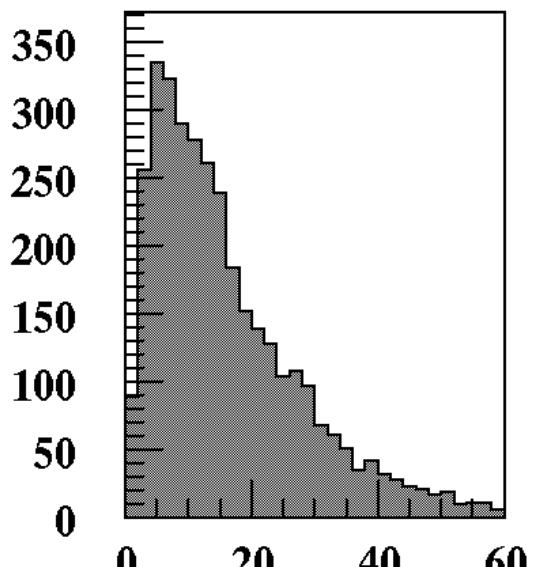
3d angle (deg)



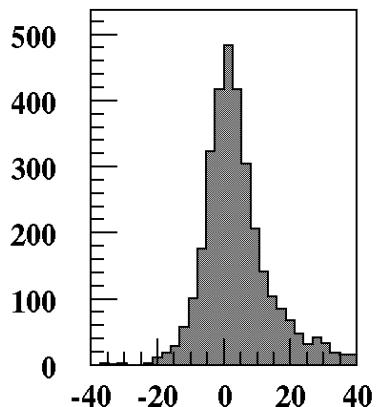
Performance – MC studies of a station with 4 detectors – Resolution and event rate – III

Threshold 20 mV (1 MIP)
Timing @ 6 mV
Median 8.7deg
341 per day, 14 per hour

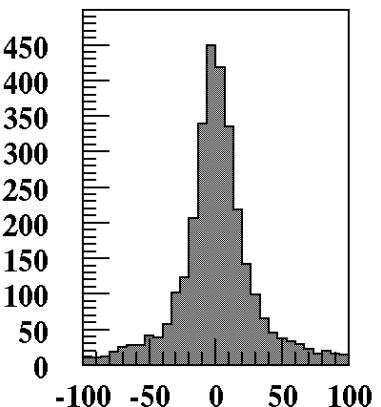
6x6



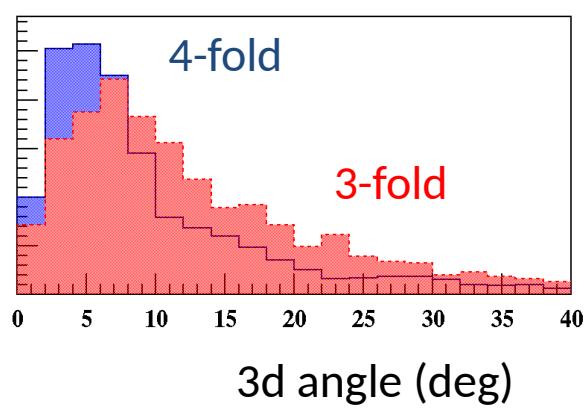
Distance (m)



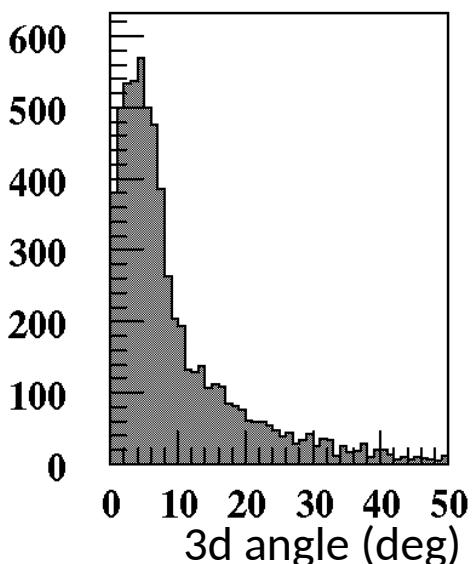
$\Delta\theta$ (deg)



$\Delta\varphi$ (deg)



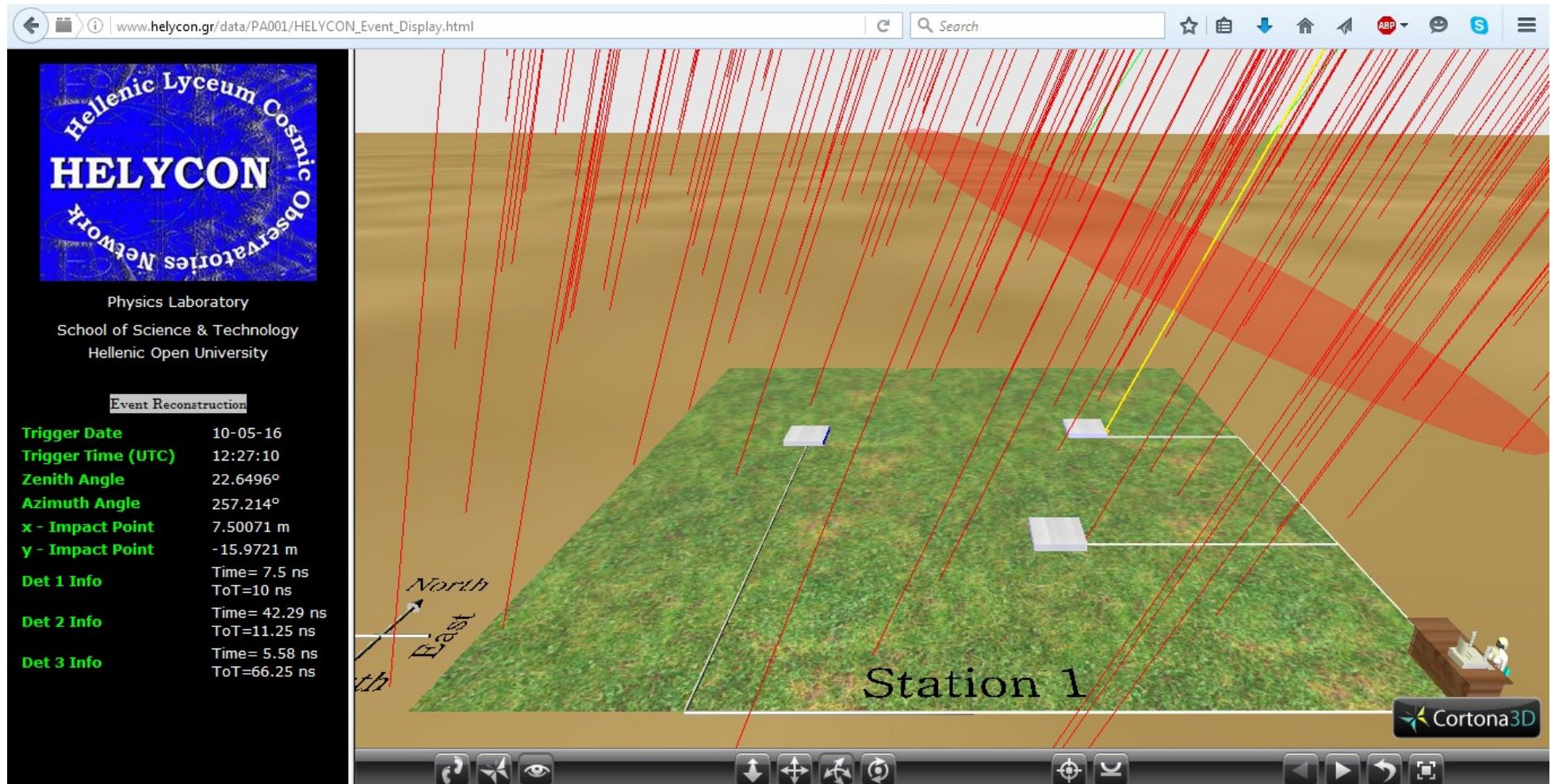
3d angle (deg)



3d angle (deg)

MiCos Telescope

Example Educational Activity: Reconstruction



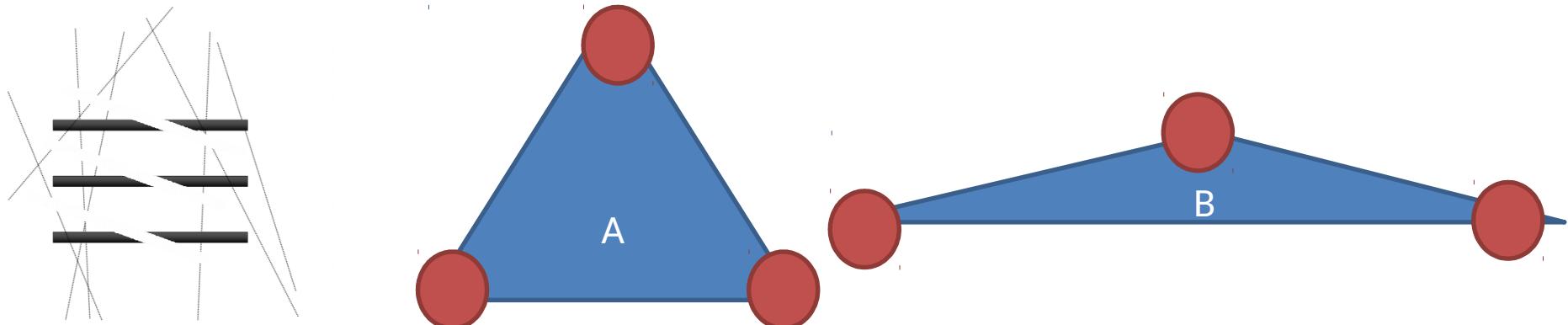
You can find a real - time representation of the last detected shower on:
http://www.helycon.gr/data/PA001/HELYCON_Event_Display.html

MiCos Telescope

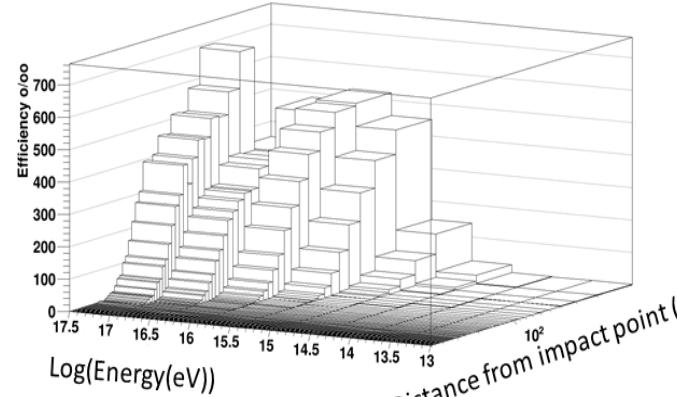
Example Educational Activity:

MC studies

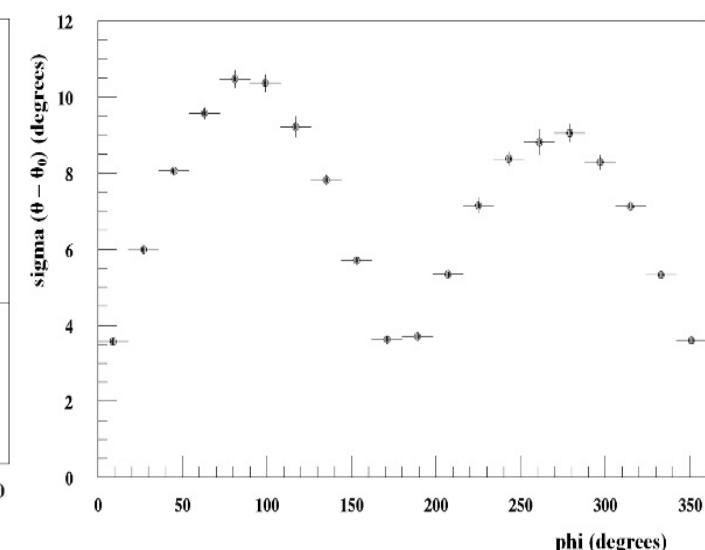
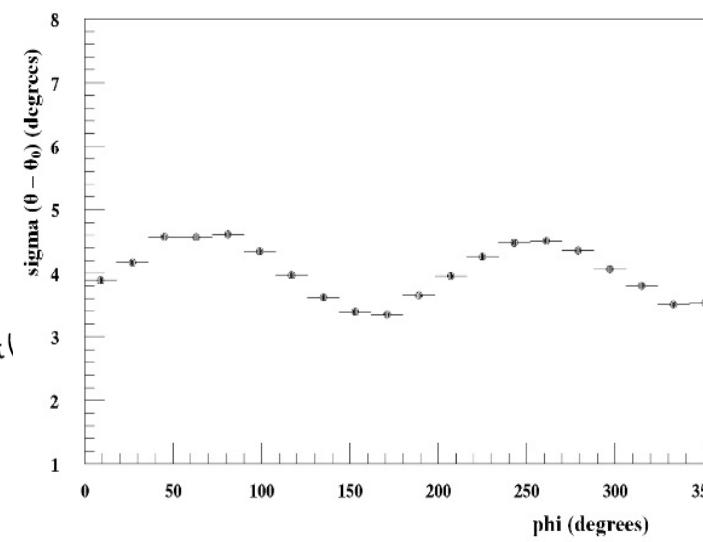
Geometries Studies



Full Monte Carlo



Toy Monte Carlo



MiCos Telescope Future Plans

- Adjustment of the HELYCON online software for the MiCos detector stations
 - More user friendly
 - To be used by teachers and high school students without the intervention of highly qualified personnel
- Some high schools are already interested in acquiring a MiCos detector station
 - Proposal has been submitted for the construction of more MiCos detector stations