The Hellenic Open University Cosmic Ray Telescope: Research and Educational Activities

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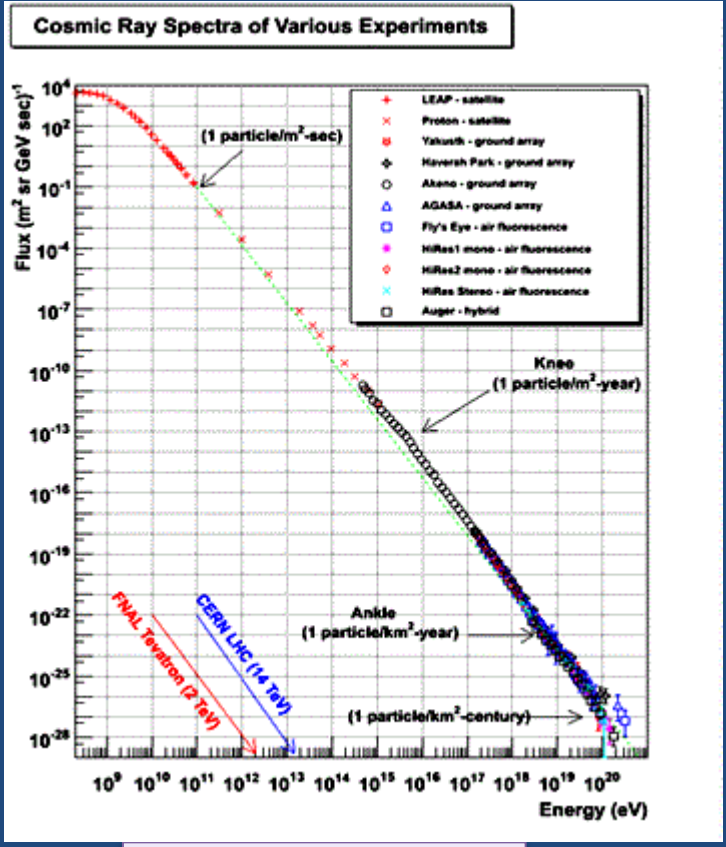
Outline

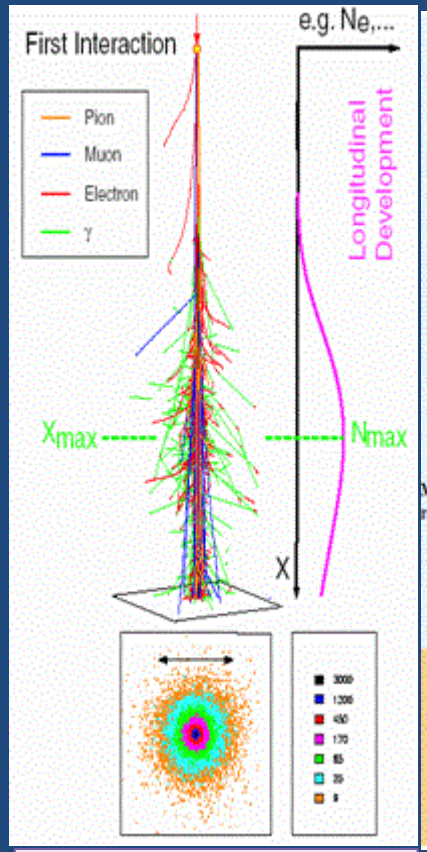
- Introduction to Extensive Air Showers and Educational Cosmic Rays Telescopes
- The Hellenic Open University Telescope Array
  - Construction
  - Testing
  - Performance
- Educational Activities
- Plans

Cosmic Rays and Detection

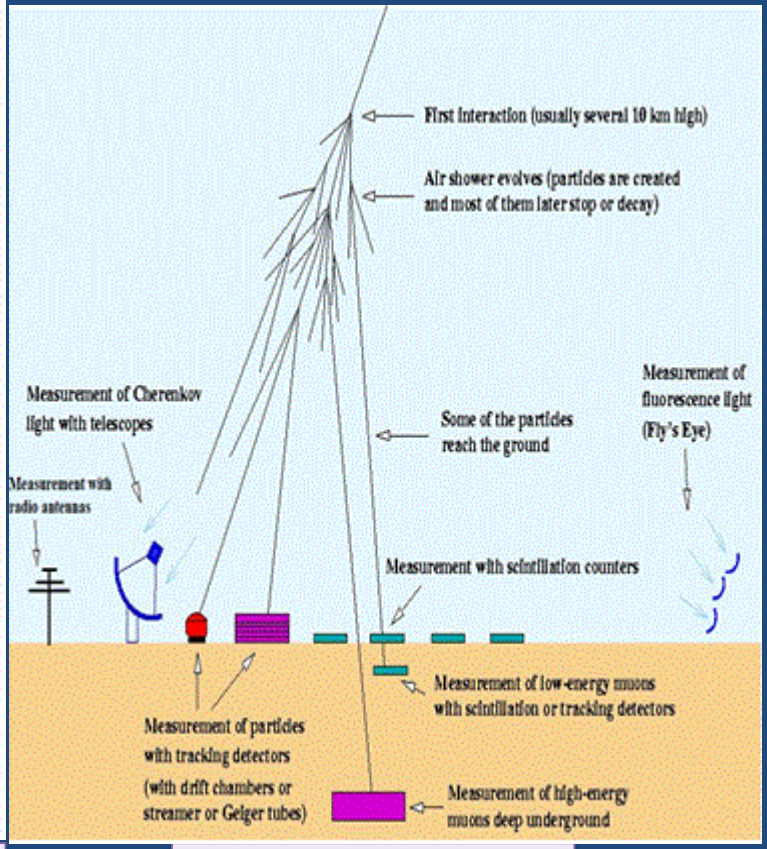
- Cosmic Rays and Elementary Particles
- Scientific Interest (the wide energy spectrum, the unknown origin of high energy cosmic rays, the acceleration mechanisms, the composition of the primary particles, detection techniques etc



Energy Spectrum



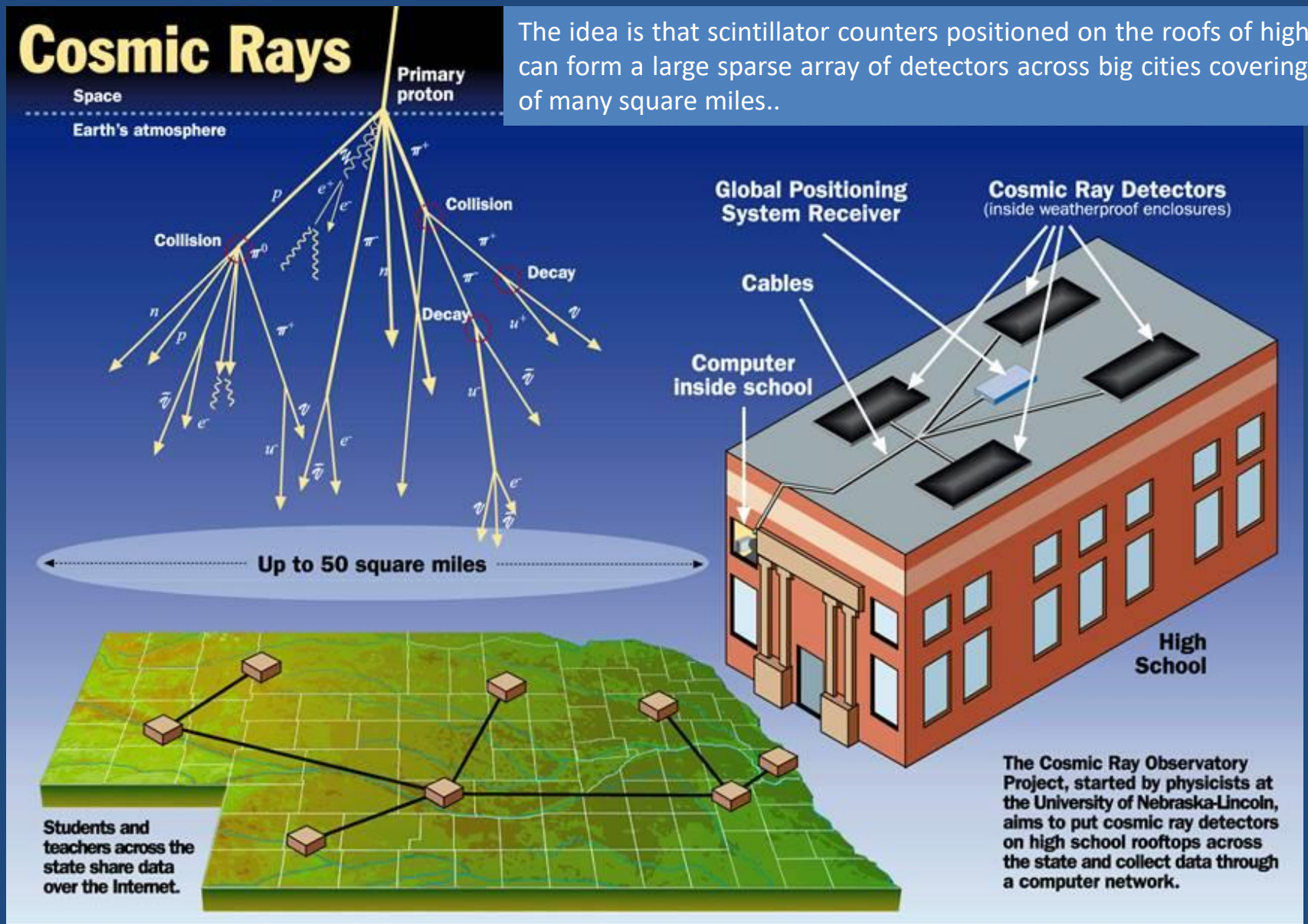
EAS



Detection

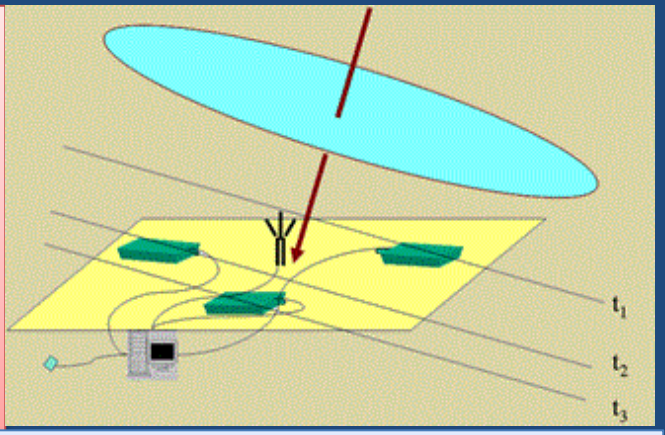
Educational Cosmic Ray Telescope

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..



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

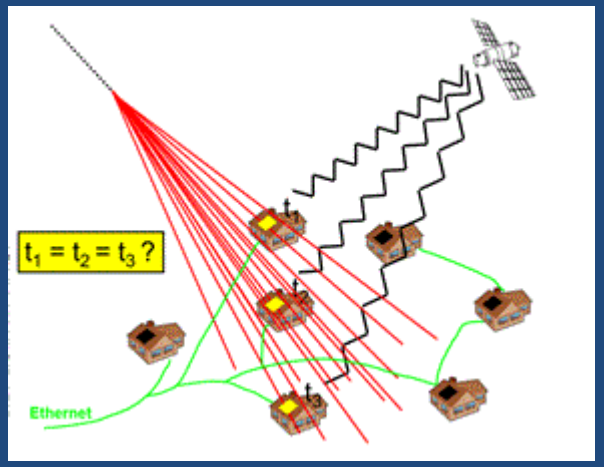
- Classroom lessons for the history of Cosmic rays, the detection techniques, Instrumentation, statistical techniques, MC simulation etc
- The Assembly of the station (polishing and cleaning of the scintillator, connecting high-voltage supply, gluing PMT, wrapping the scintillator)
- Calibration and 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

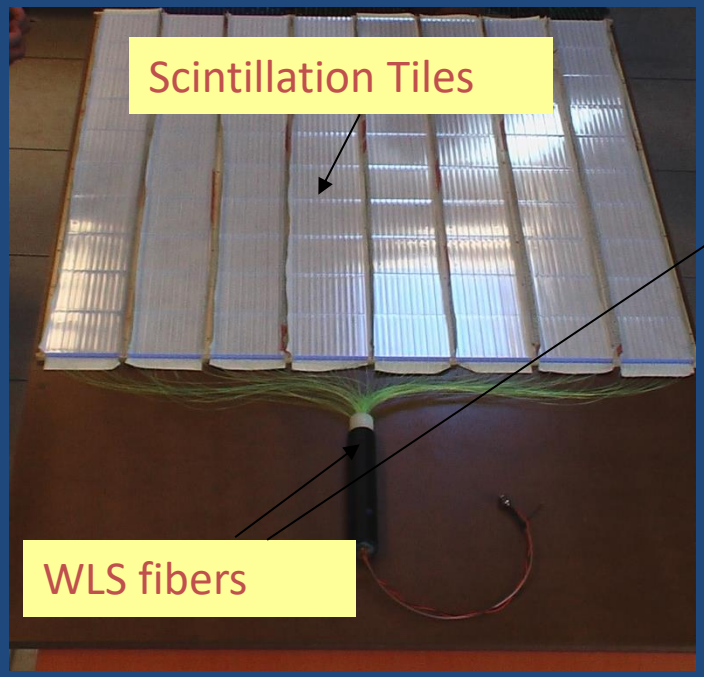
POLAND
MAZE ,CREDO
RUSSIA
Showers of Knowledge
SPAIN
Cazadores de Rayos Gamma
FINLAND
Callio Lab
CZECH Republic
CZELTA
ITALY
Extreme Energy Events
Romania
ROCOSMICS
Slovakia
SKALTA
GREECE
HELYCON

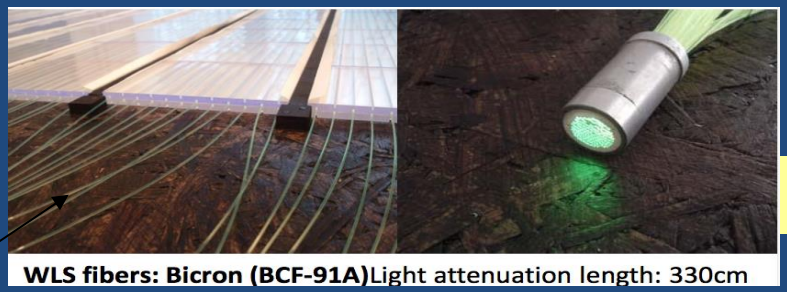
The Hellenic Open University Educational Cosmic Ray Telescope

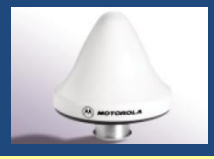


S. Tzamarias, A. Leisos, A. Tsirigotis, G. Bourlis

The HELYCON Detector Module

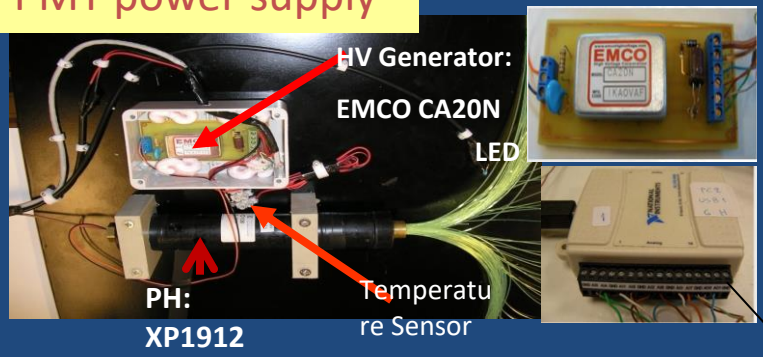




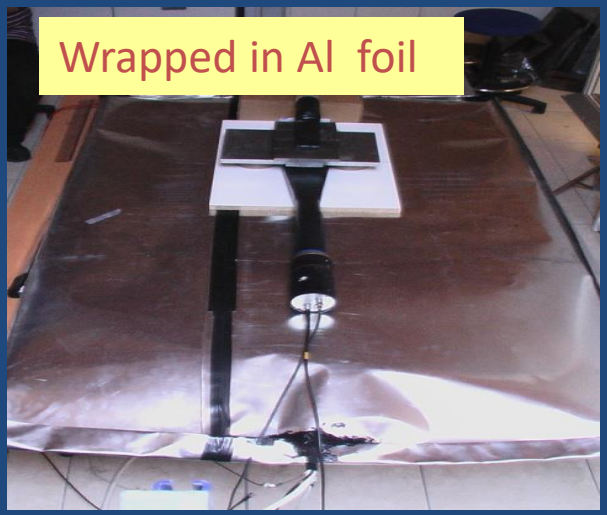


GPS timestamp

PMT power supply



Quarknet Card



Station Server

(Control, Monitoring and DAQ software)

Astroneu Collaboration

AUTH, DEMOKRITOS, Univ. of AEGEAN and TEI PIRAEUS, Univ. Of ATHENS, HOU and Univ. of PATRAS

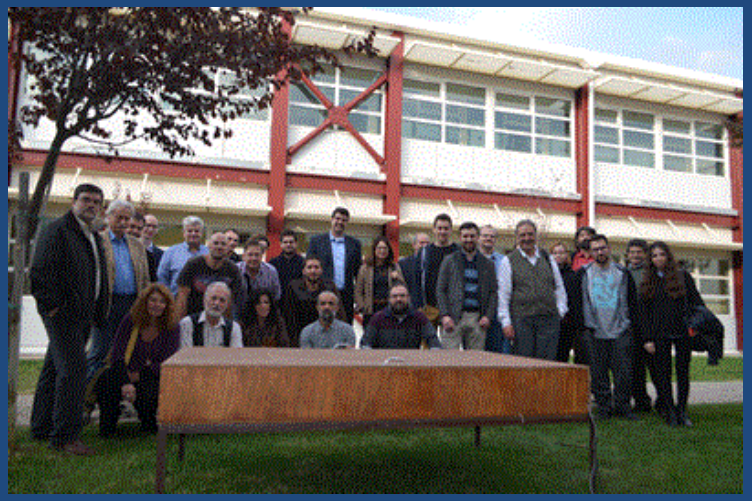
Research Team: S.Tzamarias, A.Leisos, A.Liolios, E.Savvidis, I.Katsioulas, D.Sampsonidis, Ch.Elefteriadis, Ch.Petridou, I.Maznas, G.Bourlis, A.Tsirigotis, G.Georgis, N.Giokaris, A.Manousakis-Katsikakis, E.P.Christopoulou, A.Birbas, I.Gkialas, K.Zachariadou, I.Manthos, K.Prekas, G.Fanourakis, C.Papadopoylos, D.Lenis, A.Papaoikonomou, P.Razis

External Collaborators: J.Vergados, I.Giomataris, Jean-Pierre Ernenwein, Ch.Nicolaou, Dr.J.Moussa, S.Pnevmaticos, E.Pierri, K.Siori, G.Zisimopoulo

«THALIS - HOU - Development and Applications of Novel Instrumentation and Experimental Methods in Astroparticle Physics».

High Energy Neutrino Telescopy

Extensive Air Shower Instrumentation



EAS Telescopy: Operation & Reconstruction

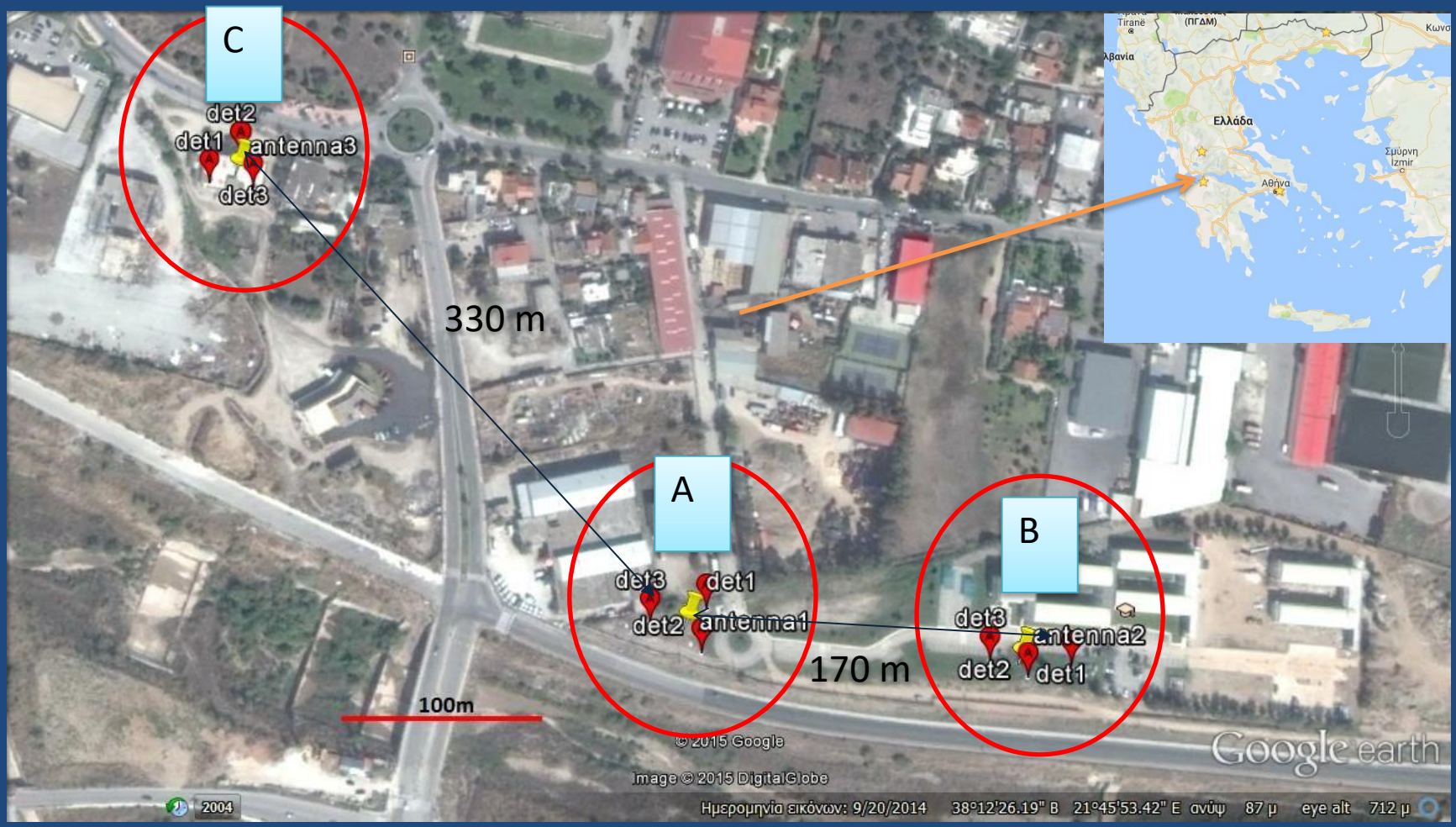
Low Energy Neutrino Detection

In 2014 3 autonomous stations where installed and are still operated at the University Campus in Patras (Greece)

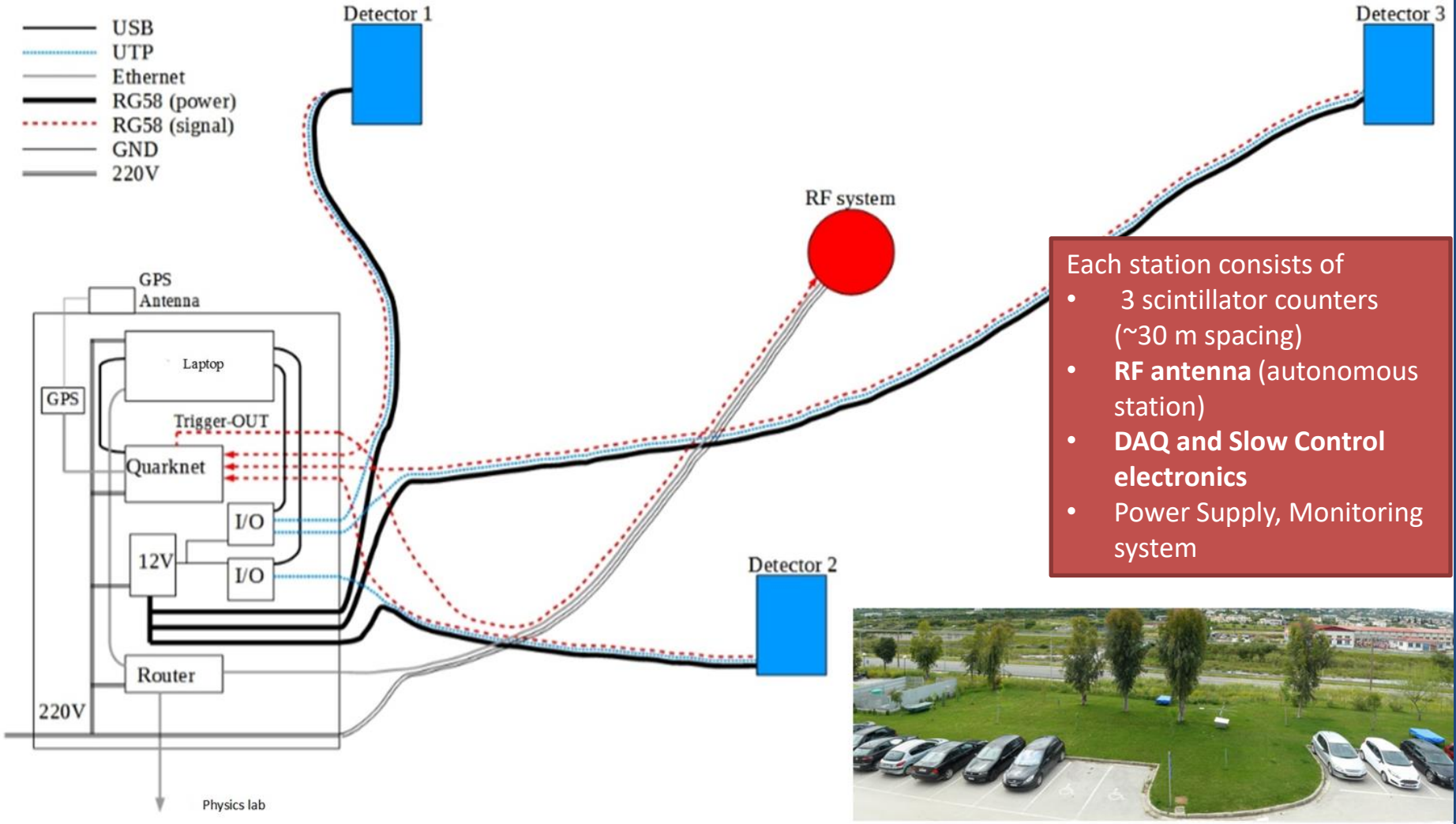
The HOU Cosmic Ray Telescope

3 stations at the University Campus

And one more station deployed in the Physics Lab (3.5 km apart)



HOU Cosmic Ray Telescope Station Schematic



Each station consists of

- 3 scintillator counters (~30 m spacing)
- **RF antenna** (autonomous station)
- **DAQ and Slow Control electronics**
- Power Supply, Monitoring system

HOU Cosmic Ray Telescope Control Box and DAQ

For showers wih E>10^{17} eV

CODALEMA Antenna

Detectors data acquisition with the Quarknet card based on the Time over Threshold technique

Designed at Fermilab

- 4 input channels
- 10x amplification of the input signals
- Performs time tagging of the crossings of the pulses with one adjustable threshold (set through the acquisition software)
- Time resolution 1.25ns
- Adjustable trigger criteria (majority, time window)
- NIM trigger out signal
- USB connection to hosting computer
- External GPS receiver provides the absolute time of the event

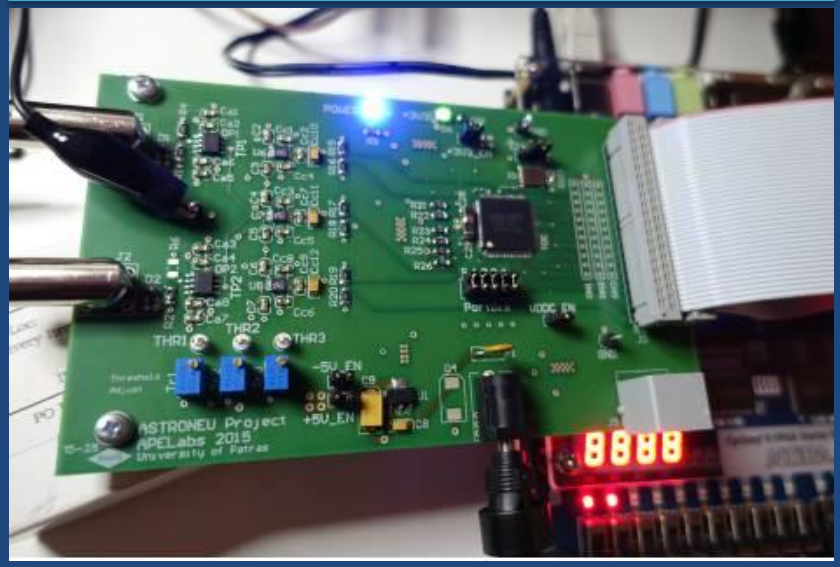
Antenna Electronics

HOU Cosmic Ray Telescope New electronics

The prototype

- Includes 2 input channels 3 thresholds for channel 1, 1 threshold for channel 2
- It is Based on the TMC-GPS ultra-high performance time to digital converter for the time tagging of the pulse crossings of the adjustable thresholds
- The Time resolution is 0.1ns
- There is a USB connection to hosting computer, and
- External GPS receiver for timing of the events

Designed by the collaboration, developed at the Applied Electronics Lab of Patras Univ (Prof .A. Birbas)



arXiv:1702.0106

A 100-ps Multi-Time over Threshold Data Acquisition System for Cosmic Ray Detection

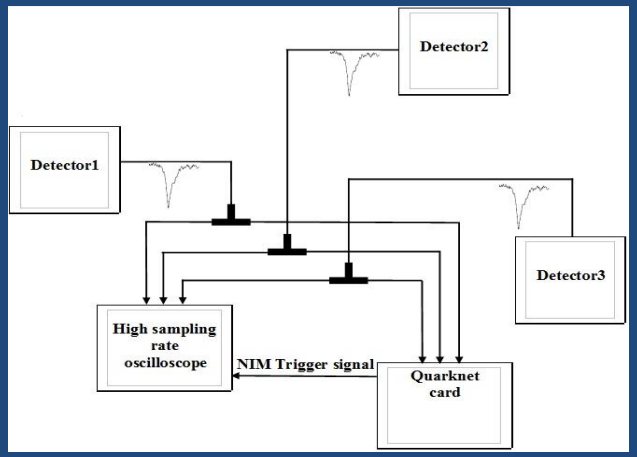
HOU Cosmic Ray Telescope Preparation before Deployment

PMT calibration
(gain, single pe level and dark count rate)

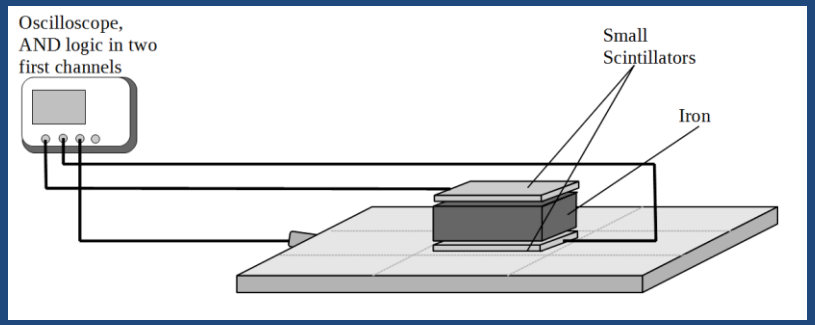
Particle detectors calibration
(uniformity, timing and MIP response)

Tests of the Quarknet cards (DAQ cards)
(thresholds, timing accuracy, trigger logic)

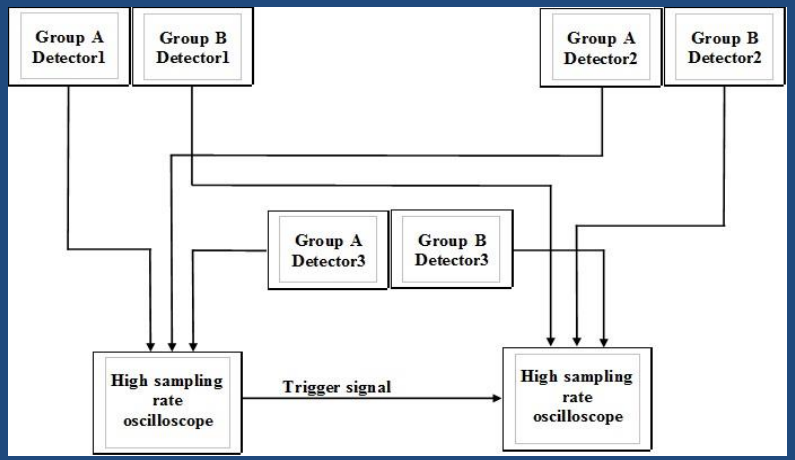
Calibration of the whole detector array
(Angular offsets, charge collection, waveform shapes etc)



DAQ card calibration



Counter Calibration



Station Calibration and testing

HOU Cosmic Ray Telescope SW

HOURS-EAS

Hellenic Open University Reconstruction and Simulation of Extended Air Showers

Raw Data Creation

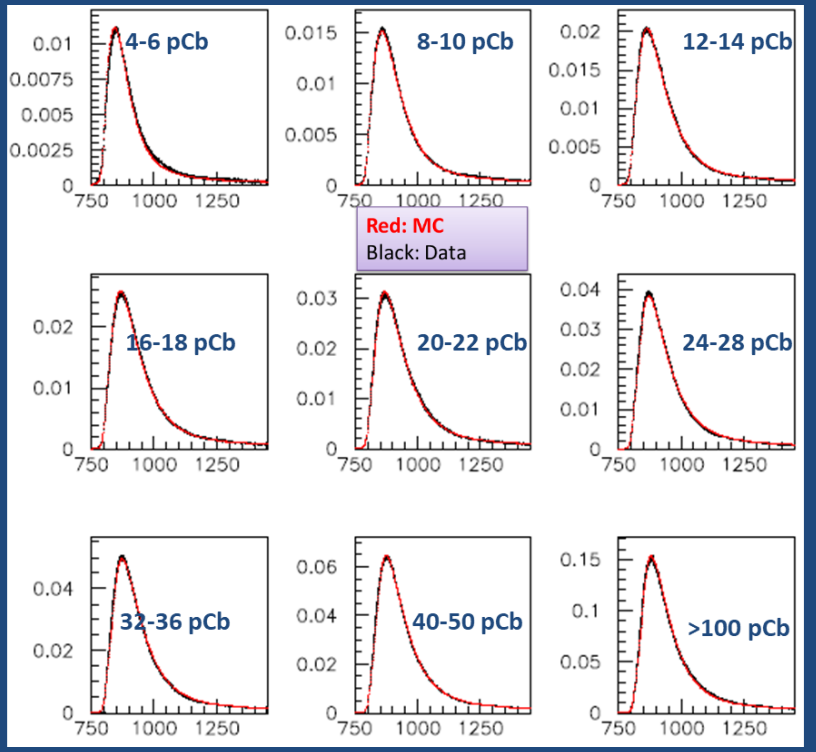
- Initialization
- CORSIKA Particle Information on the Detector Level
- Fast Simulation of Scintillation & WLS Processes
- Generation Of PMT Photoelectrons
- PMT Response Pulse
- Signal Transmission and Digitization

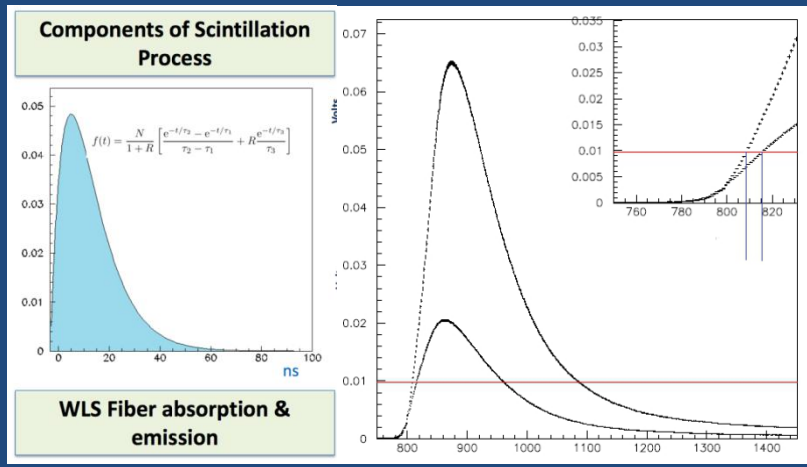
Detector Database

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

Performance Plots

- Initialization
- Signal Processing
- Data Quality
- Shower Reconstruction



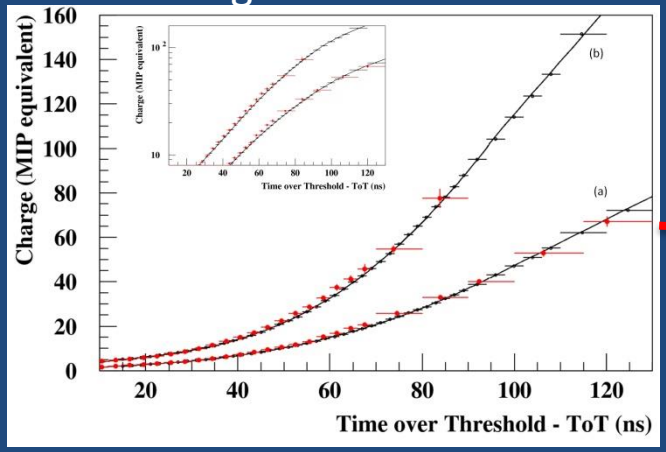


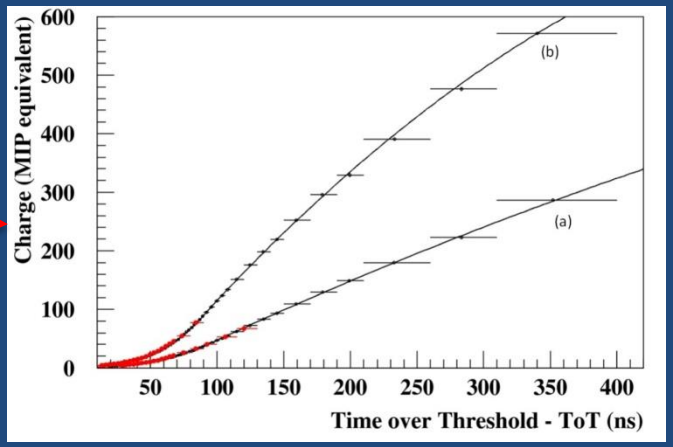
- Parameterizations using Geant4 full simulation
- Slewing correction
- Digitization DAQ functionality
- Signal processing
- Reconstruction Studies

arXiv:1702.00945

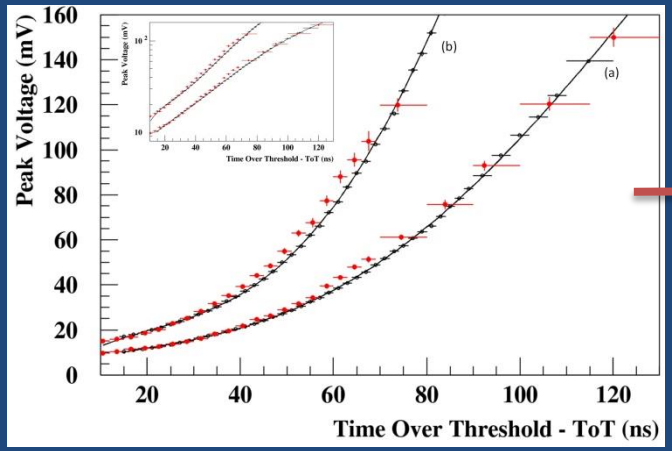
HOU Cosmic Ray Telescope ToT parametrizations

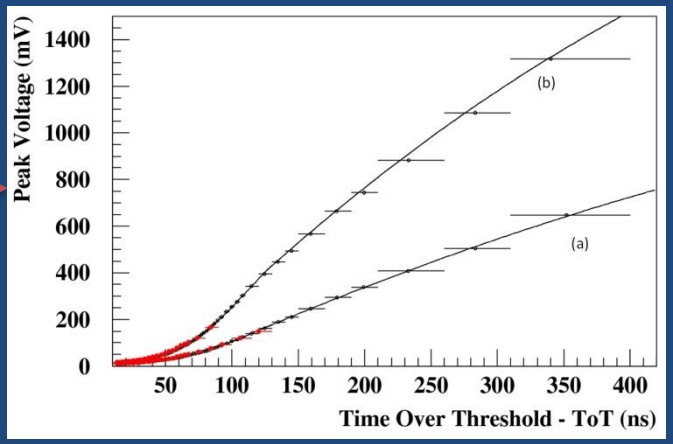
- Charge vs ToT





- Peak Voltage vs ToT





Fit functions

✓ ToT: 0 - 95 ns
4th grade polynomial

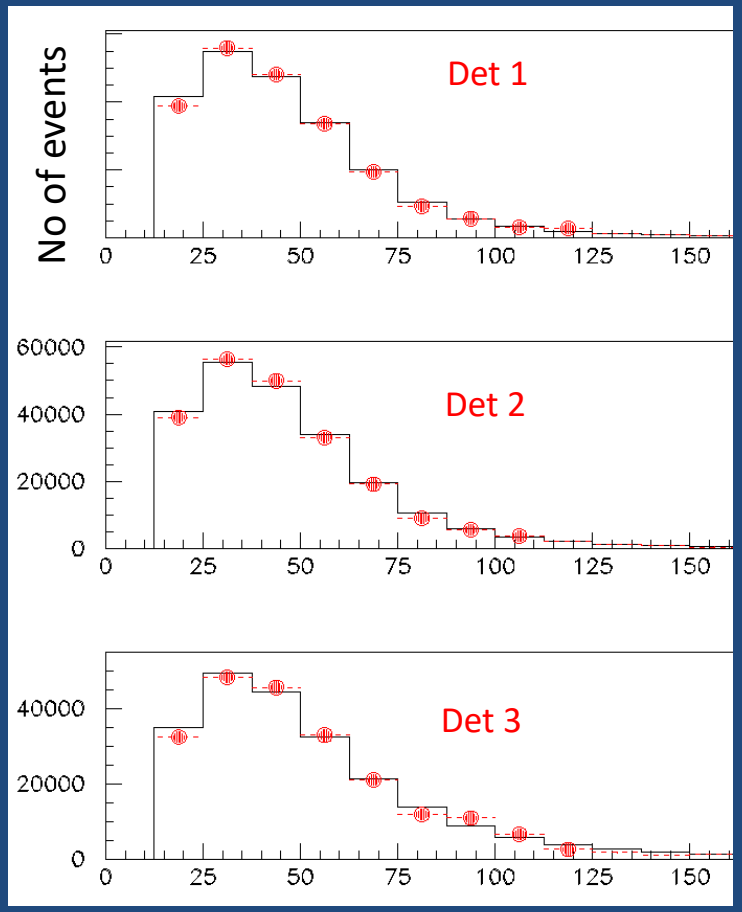
✓ ToT: 95 - … ns
2nd grade polynomial

Red: Data
Black: MC

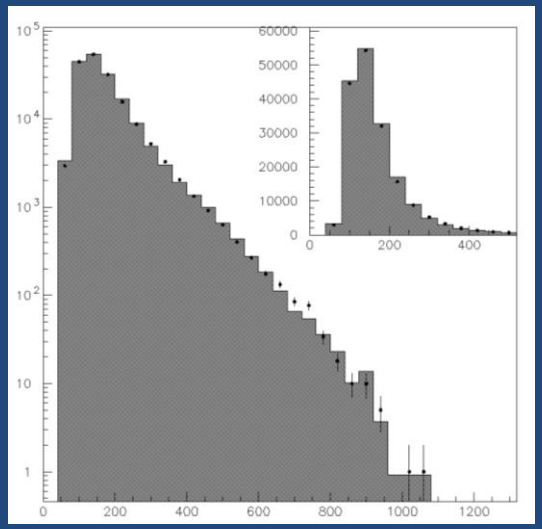
a: ToT@4.7mV threshold

b: ToT@9.7mV threshold

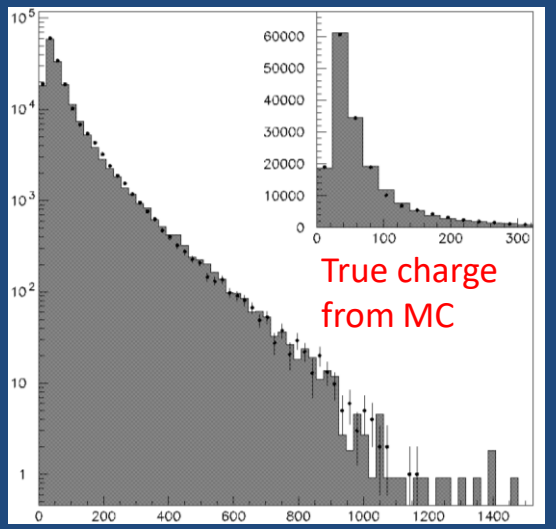
HOU Cosmic Ray Telescope Single Station Performance



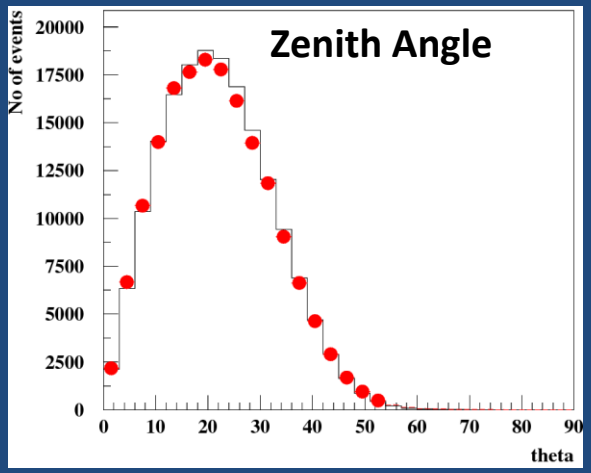
Time over Threshold (ns)



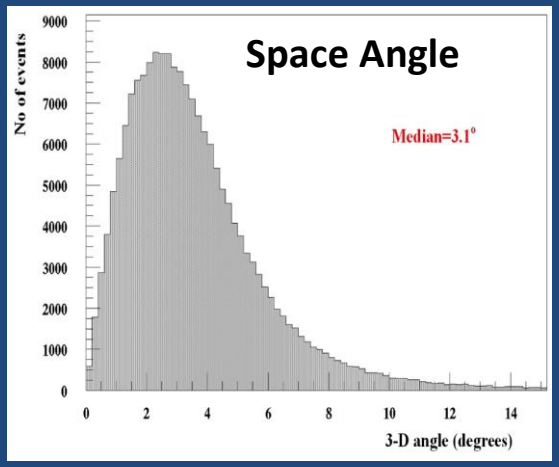
Sum of ToT (ns)



Sum of charge (MIP equivalent)



Degrees



Degrees

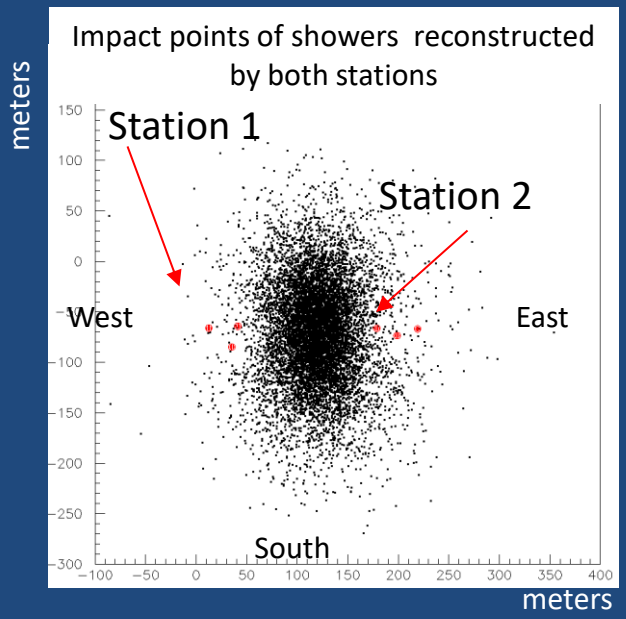
Histos: MC
Dots: Data

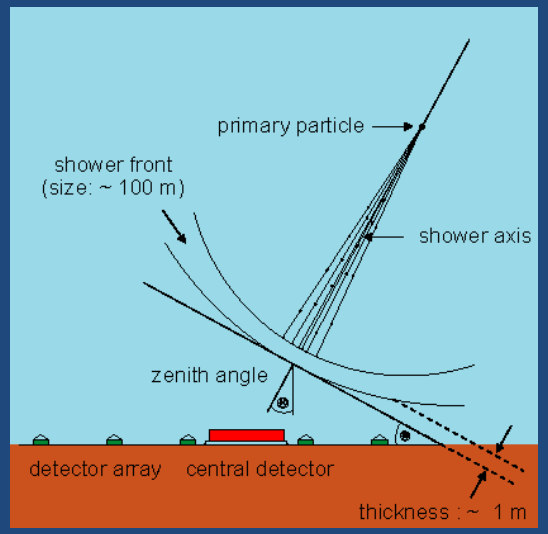
HOU Cosmic Ray Telescope Stations in Coincidence

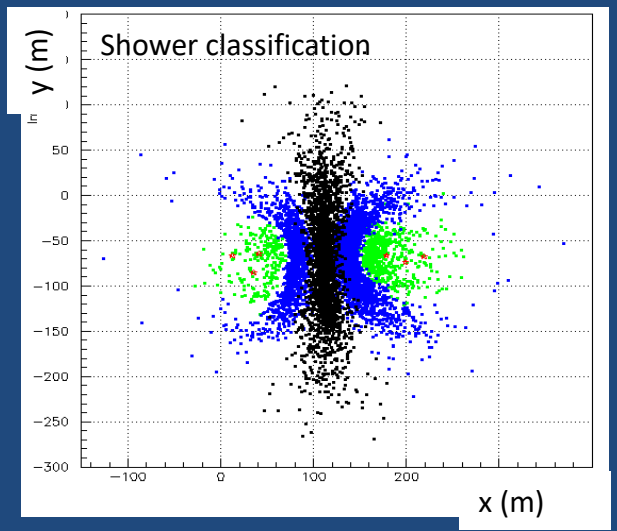
Showers that trigger both stations have energy $E>10^{16}$ eV

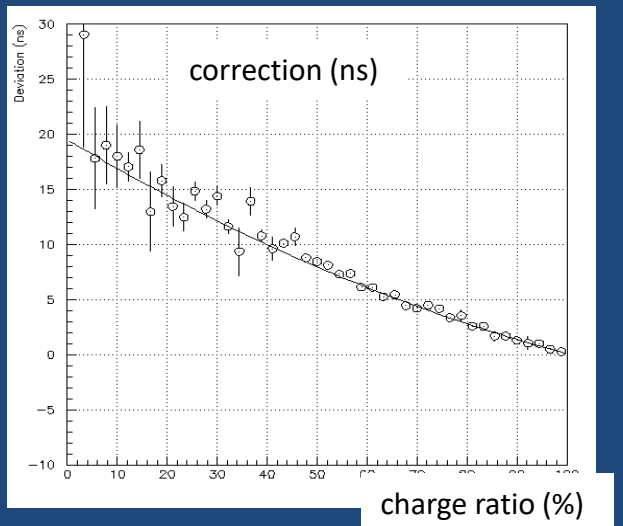
Shower front curvature (extra delay) must be taken into account

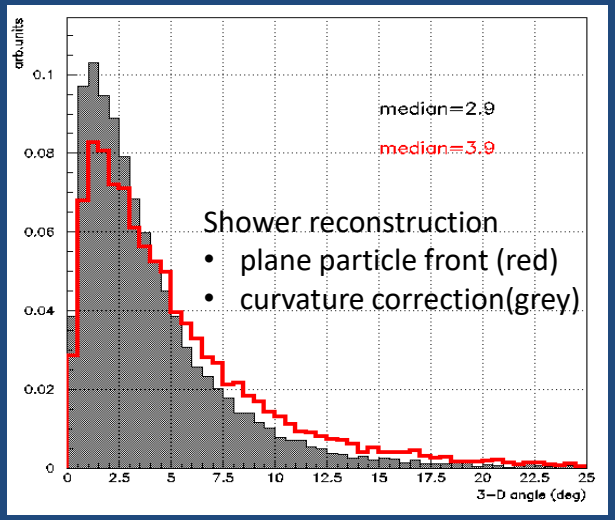
The charge ratio of the most energetic counters of the two arrays can be used to classify the showers and apply corrections





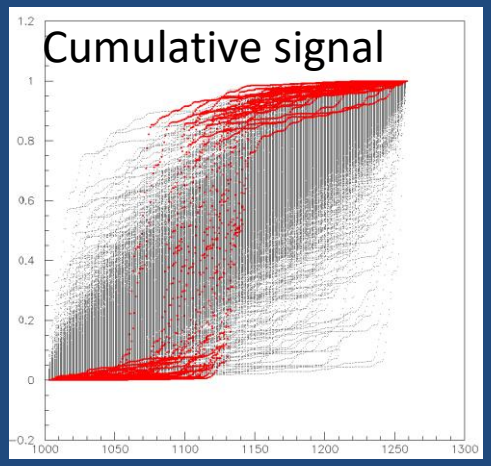


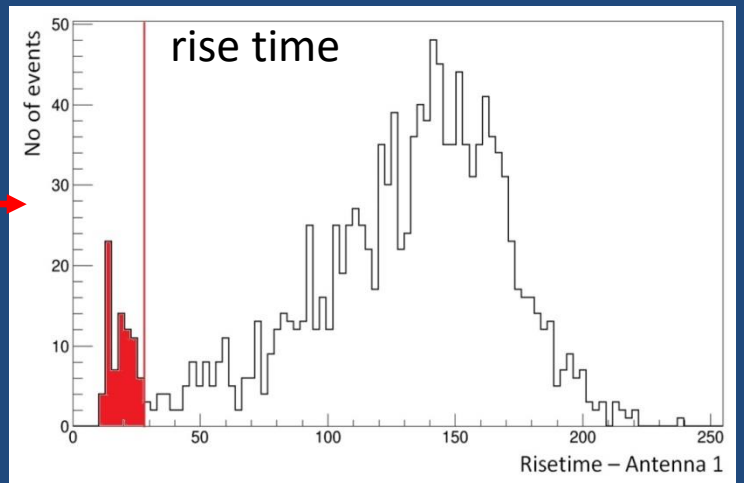


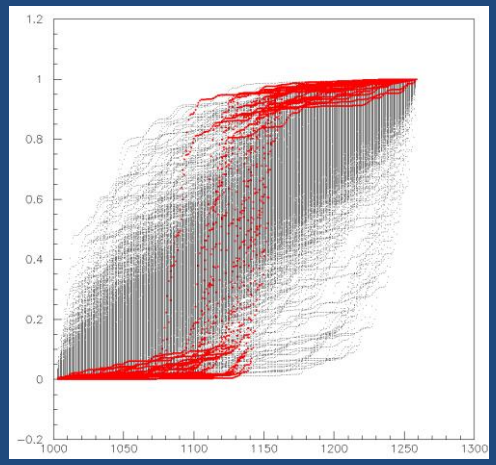


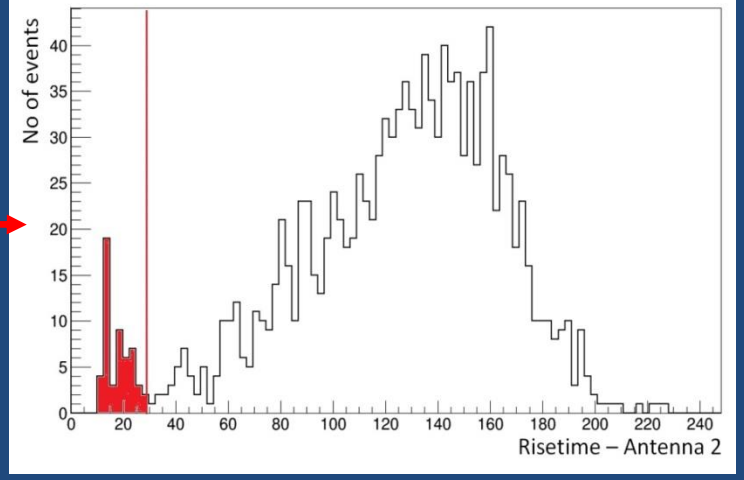
HOU Cosmic Ray Telescope
RF Detection of Coincidence Events

Focus on events in coincidence from station 1 and station 2 particle detectors









Red: Cosmic events in both antennas

Black: Background events

arXiv:1702.05794

Already deployed 3 more antennas on Station 1 in order to reconstruct EAS from antennas' data only

HOU Cosmic Ray Telescope & Secondary Education

Getting high school students and teachers involved

HOU Post Graduate Programme: Master's in Teaching Natural Sciences MSc

- **Master Thesis of Athina Charalambous (Introducing shower reconstruction in secondary education)**
- **Master Thesis of Leonidas Xiros (PMT calibration guide for high school students)**
- **Phd (in prep) of Michalis Petropoulos (Educational activities for Particle and Astroparticle Physics)**

Summer School in Kardamili (2017): Lectures and Experimentation with a simple PMT Hodoscope

Patras Science Festival (2017): Special Session for the HOU Telescope at the University Campus

Special sessions with “hands on” in collaboration with the Association of Greek Physicists

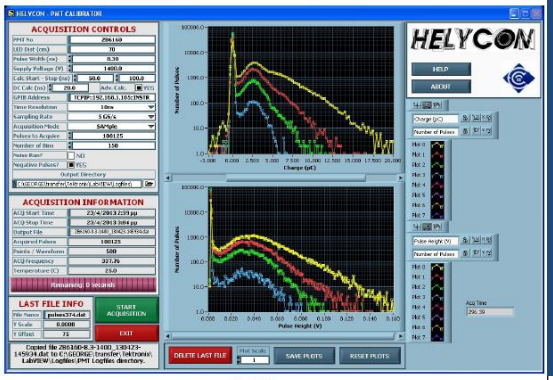
HOU Cosmic Ray Telescope Activities for High School students

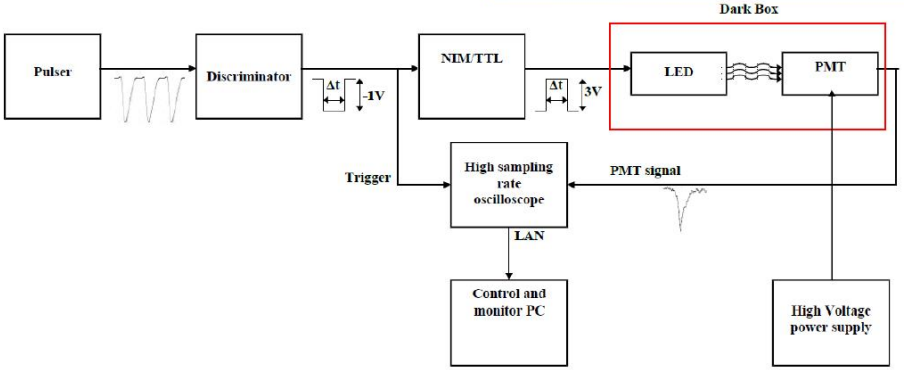
- Visits of high school students to the HOU Telescope (University Campus in Patras)
- Lectures for the Cosmic rays and the detection techniques
- Hands on experimentation in:
  - PMT calibration
  - Scintillator Counter uniformity and response to mip
  - Timing studies
  - Coincidence studies
  - DAQ 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

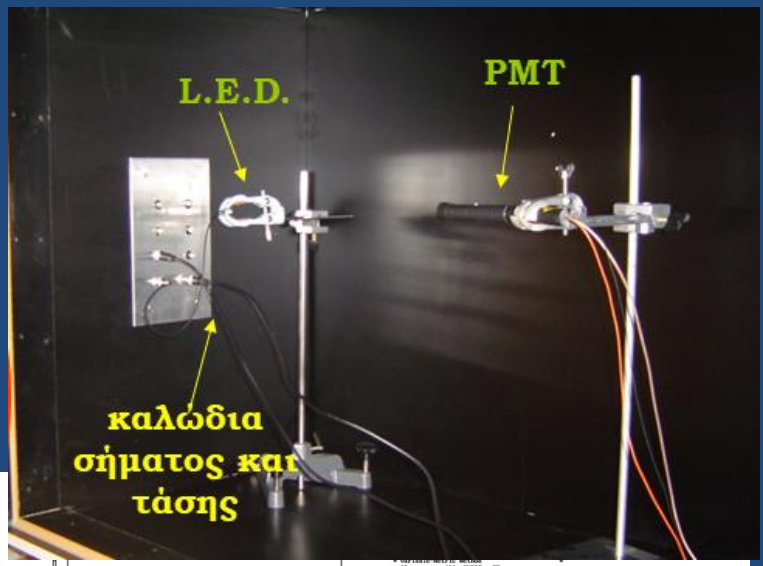
HOU Cosmic Ray Telescope Educational Activity: PMT Calibration

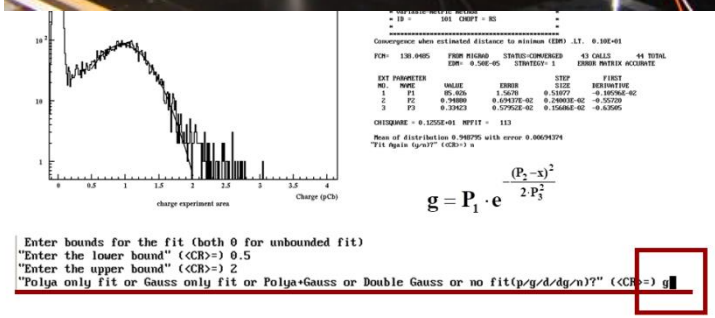
HOU PMT Calibration Setup

- 5GS/s high sampling rate oscilloscope (Tektronix 5052B) with LAN connectivity
- Custom software for data acquisition (LabVIEW and C++)
- PMT stays in darkness without supply voltage for ~3h
- PMT powered with the typical voltage for ~1h before measurements begin



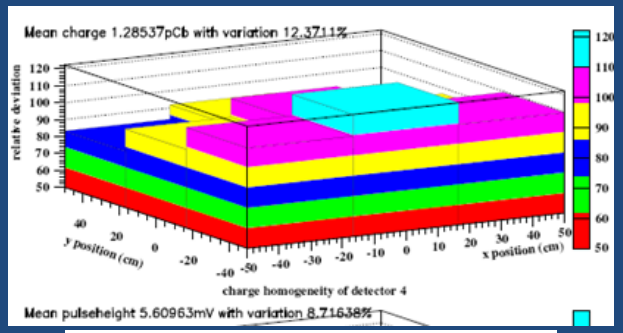


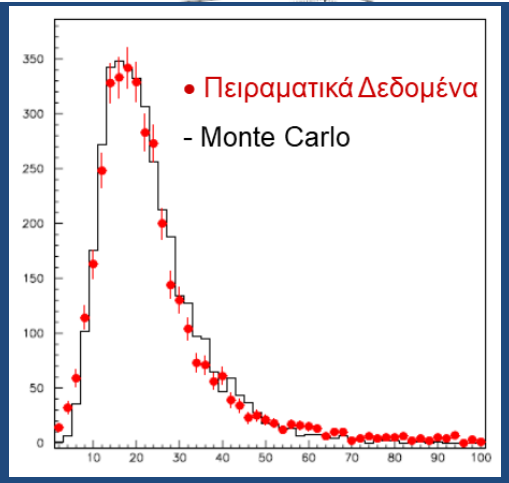


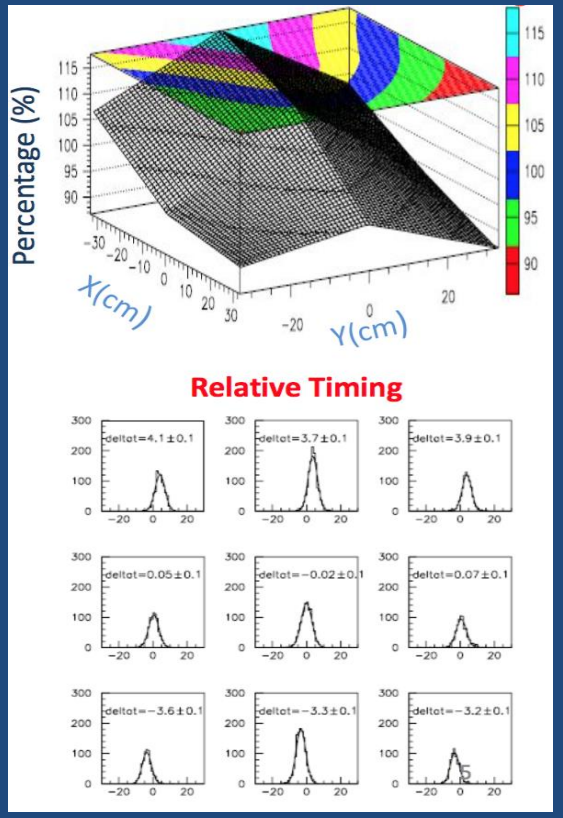


Designed as Tele-Labarotary (telephysics.eap.gr)
Webcasts & Power Point Presentations, Software packages, Step by Step instructions

HOU Cosmic Ray Telescope Educational Activity : Scintillator study







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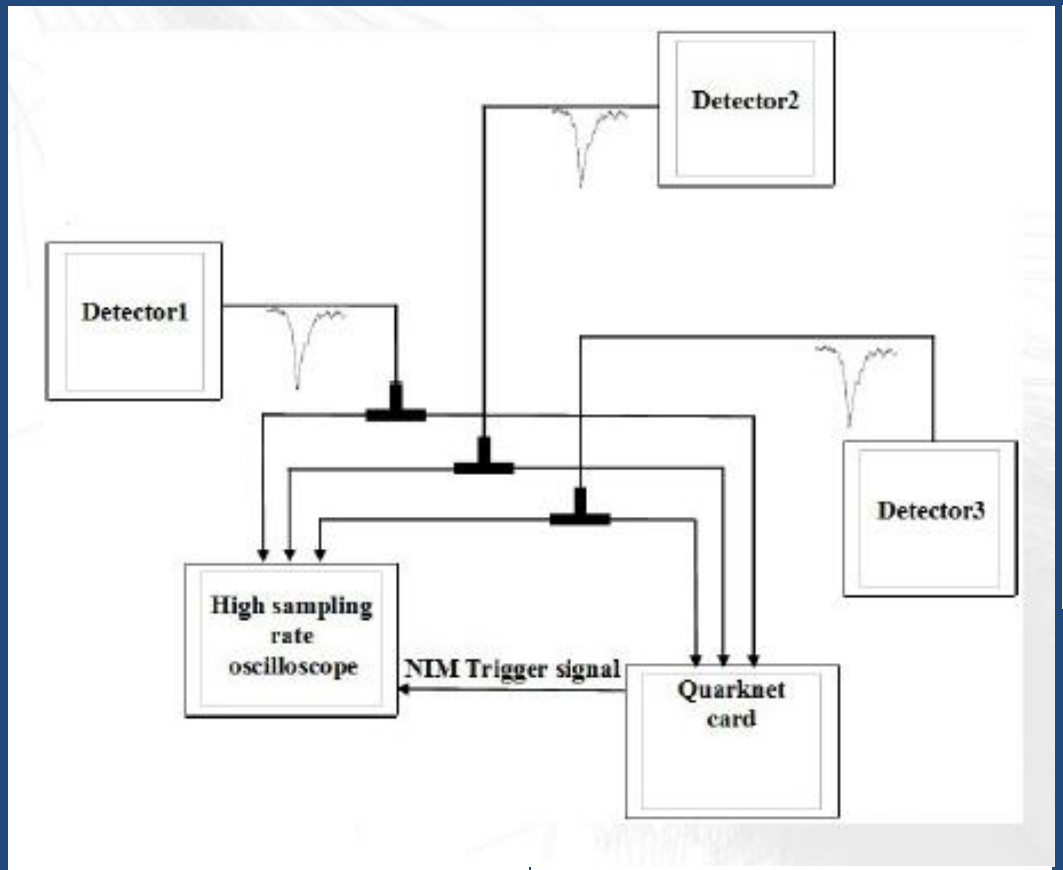
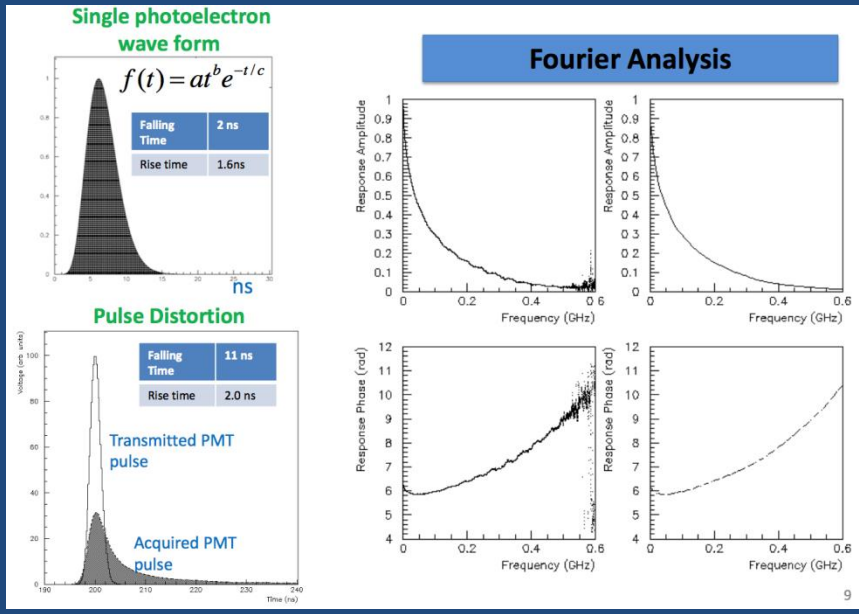
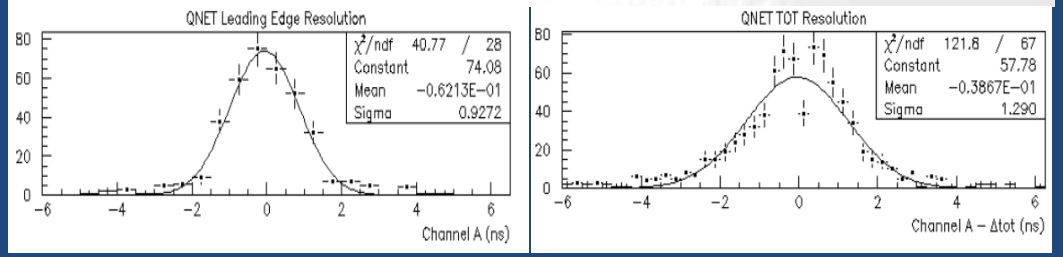
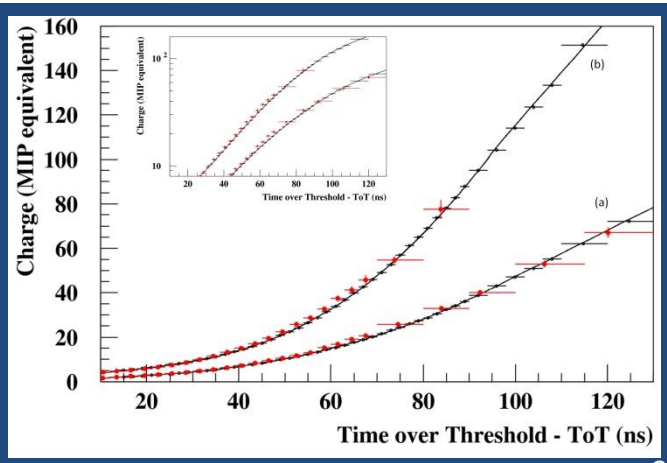
HOU Cosmic Ray Telescope Educational Activity: DAQ Performance





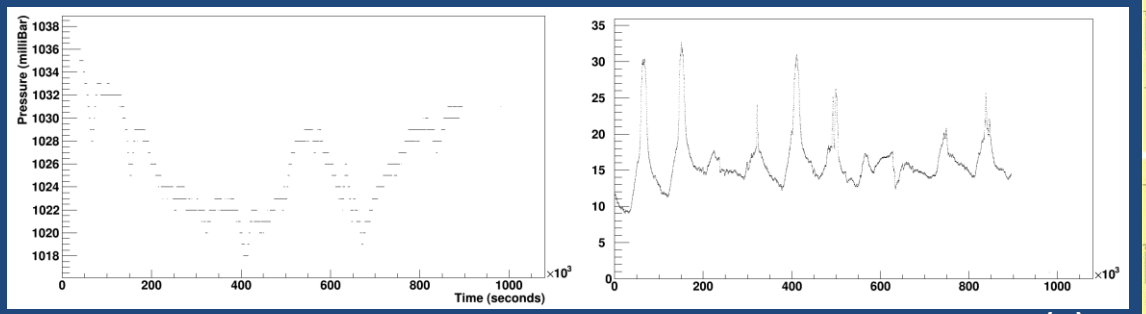


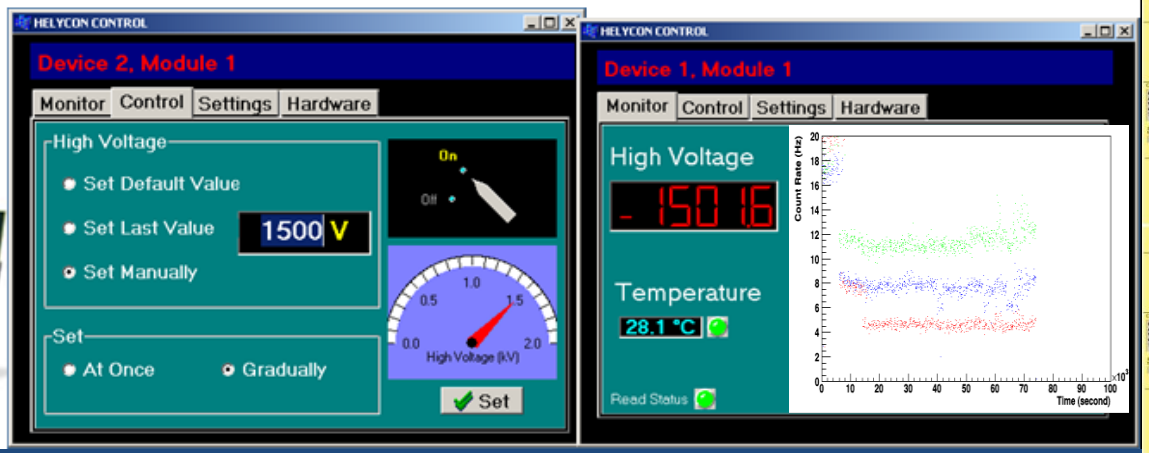


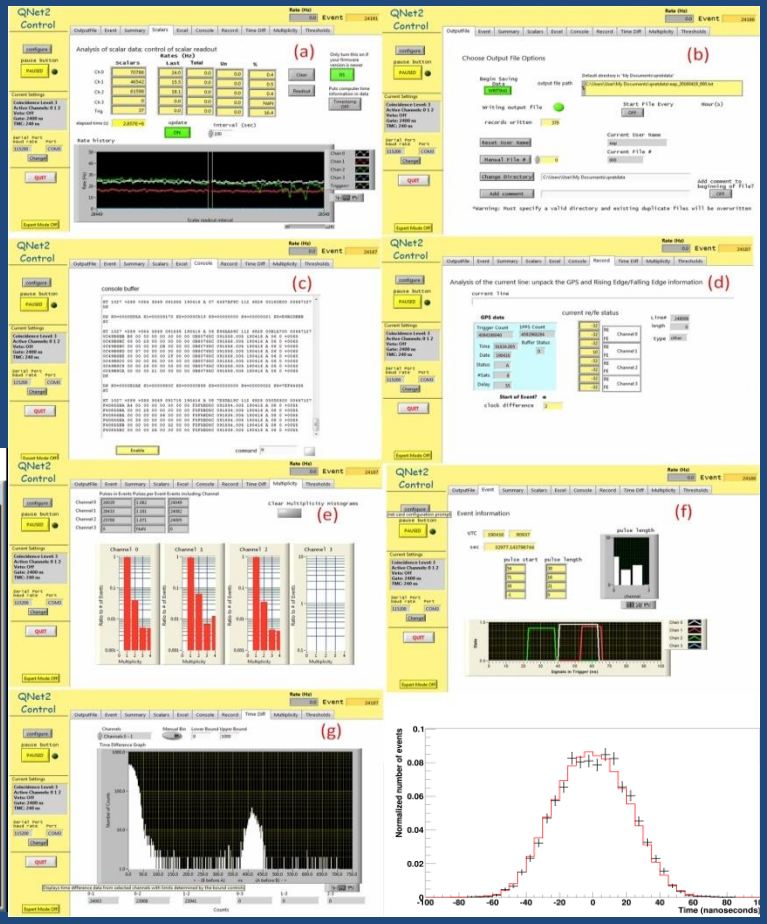
HOU Cosmic Ray Telescope Educational Activity: Control & Monitoring

Temperature (C)

Pressure (mbar)







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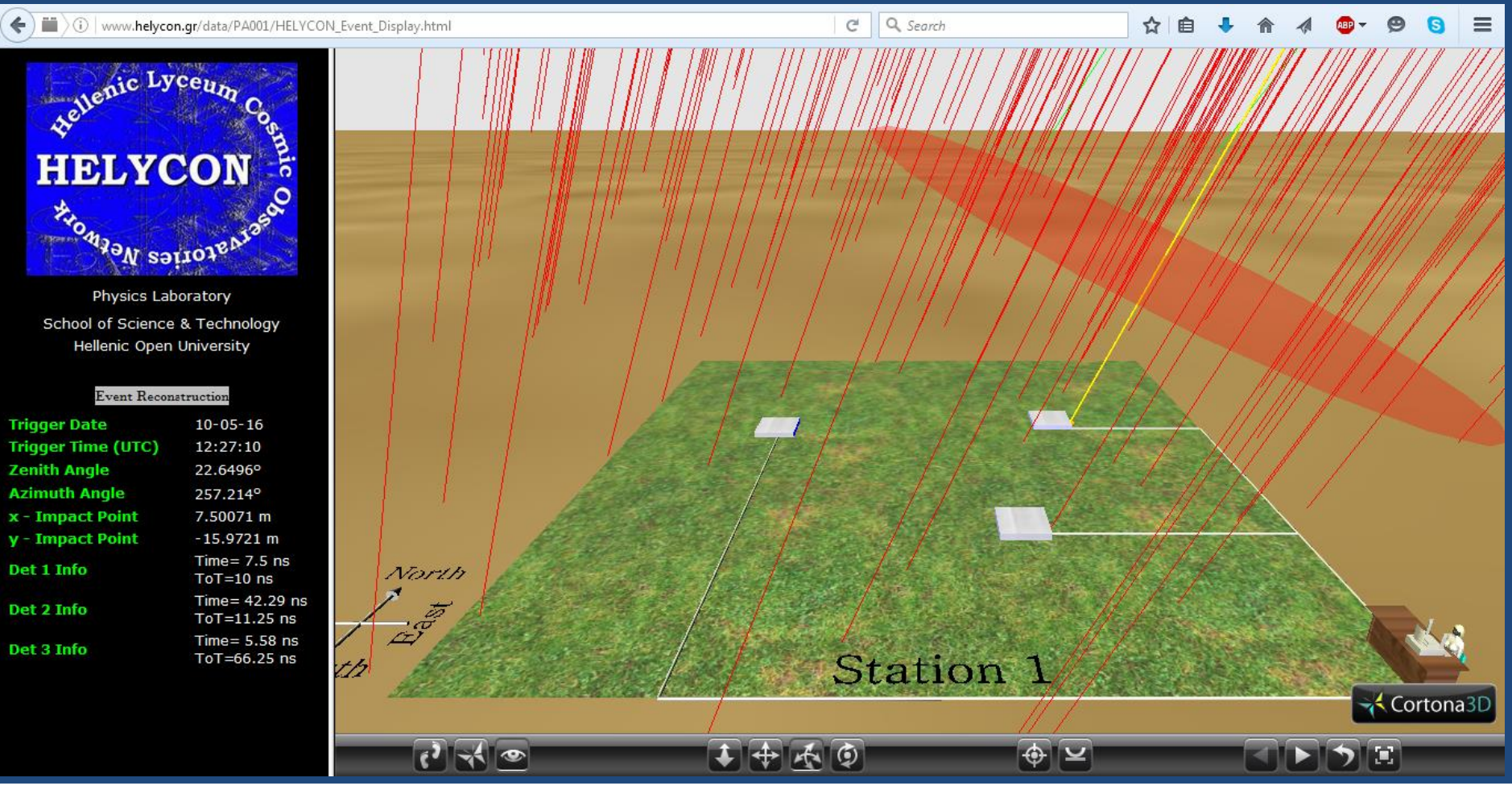
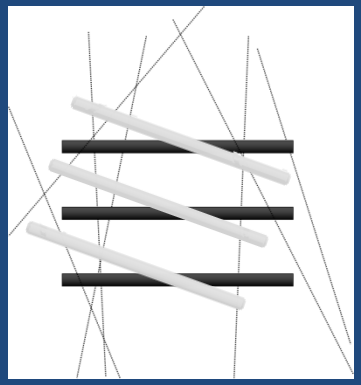
HOU Cosmic Ray Telescope Educational Activity: Reconstruction

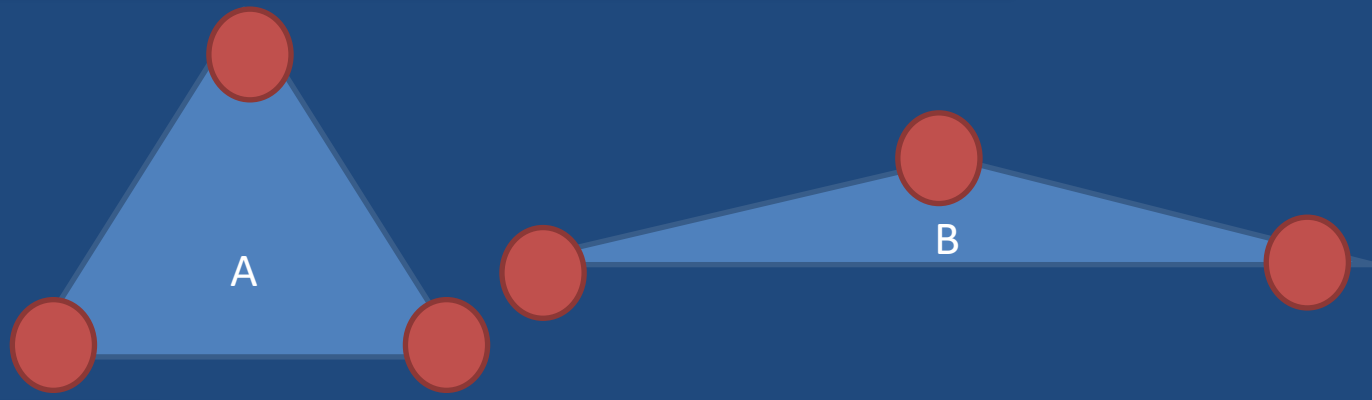


You can find a real – time representation of the last detected shower on:
http://www.helycon.gr/data/PA001/HELYCON_Event_Display.html

HOU Cosmic Ray Telescope Educational Activity: MC studies

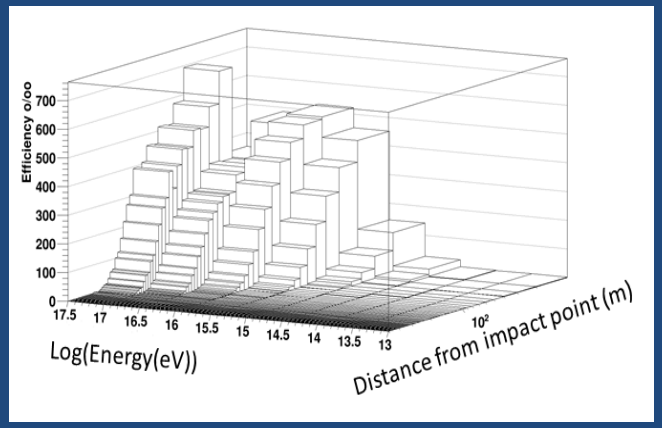
Geometries Studies

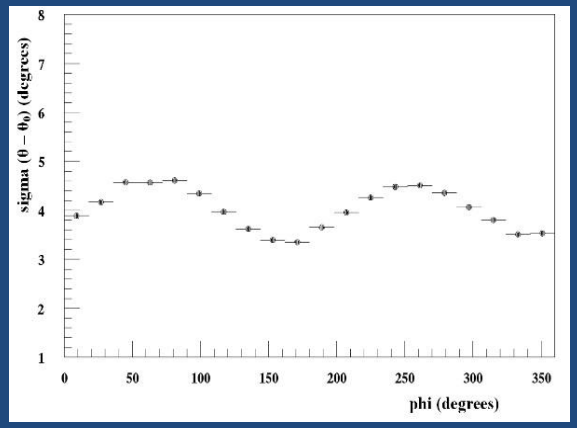


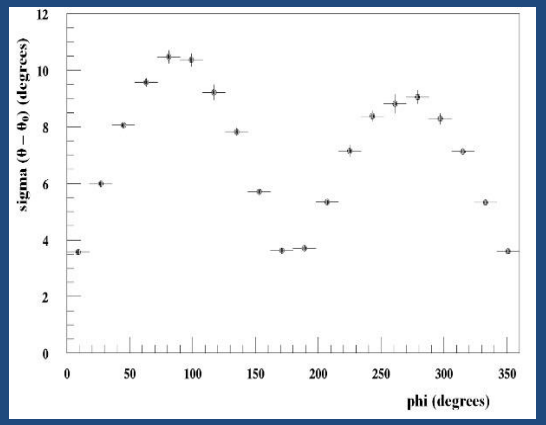


Full Monte Carlo

Toy Monte Carlo







HOU Cosmic Ray Telescope Near Future Plans

HOU Physics Lab has established Collaboration with the ministry of education in Western Greece and already contacted High Schools

Plans by the end of 2017

- In October there will be a seminar for high school students (16-18 yr old) and 15 students arranged in three groups will be trained for a week in the Physics Laboratory of HOU.
- The three groups will be responsible for:
  - 1st group: PMT calibration
  - 2nd group: Scintillator Counter response to mip and Timing studies
  - 3rd group: Operation and Monitoring of a station
- All of them will analyze real data (shower reconstruction)
- In December they will present the results in their school and (hopefully) a new group will start the training

Plans for 2018

- A Station will be deployed in a school and trained students will maintain the detector

Thank you !!!