The HELYCON detector array: Digitization Techniques and KM3NeT Calibration

Antonios Leisos

Physics Laboratory

School of Science and Technology

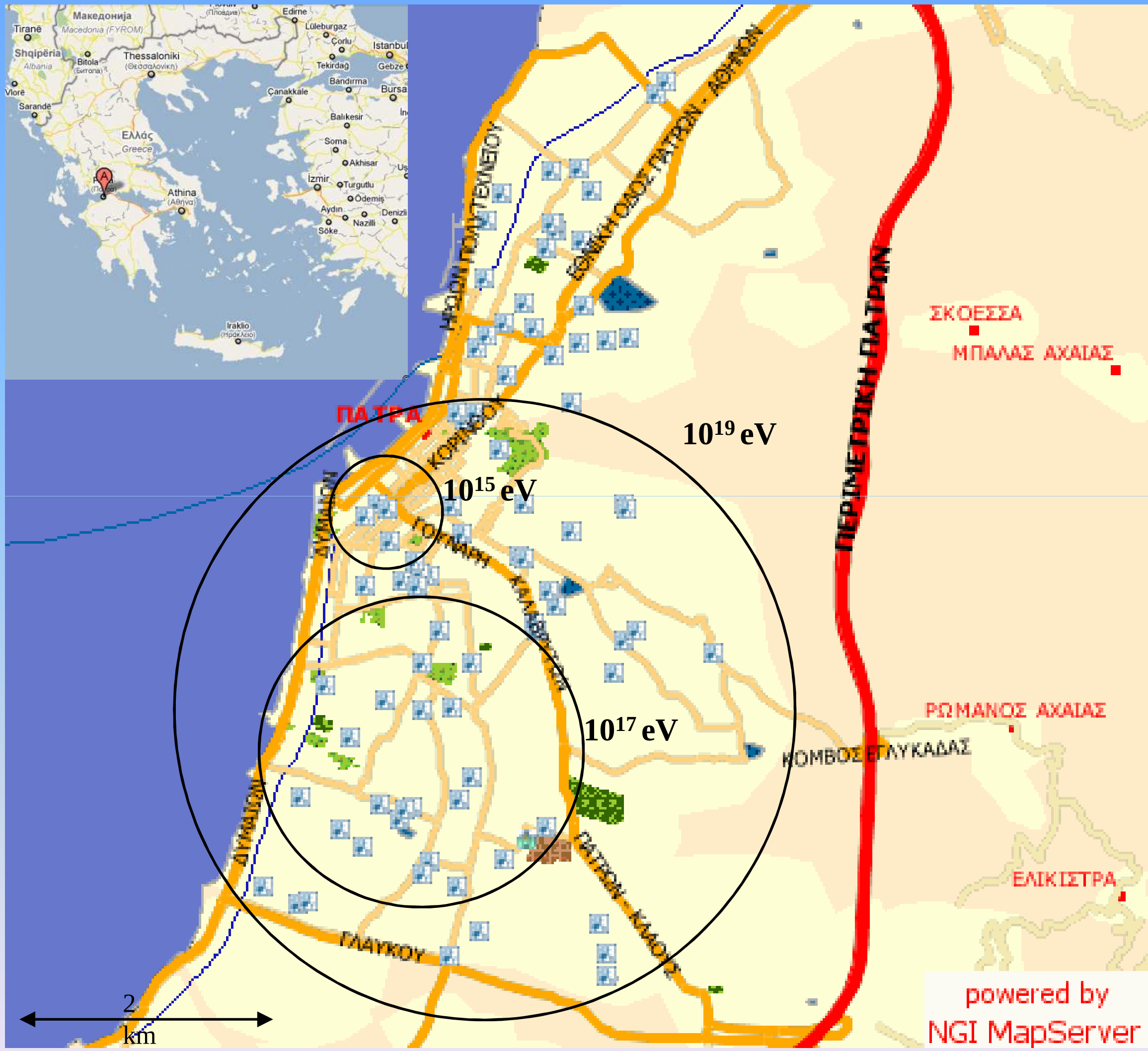
Hellenic Open University

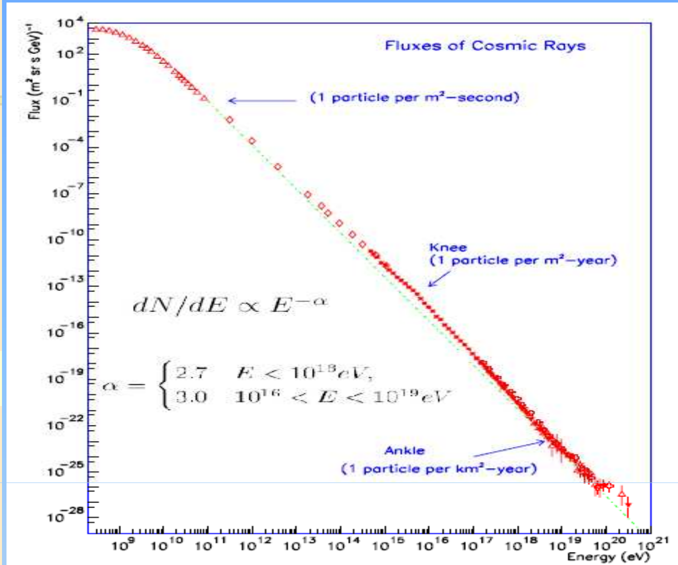
- Multi Time Over Threshold Technique
- Sea Top Calibration infrastructure of VLVNT

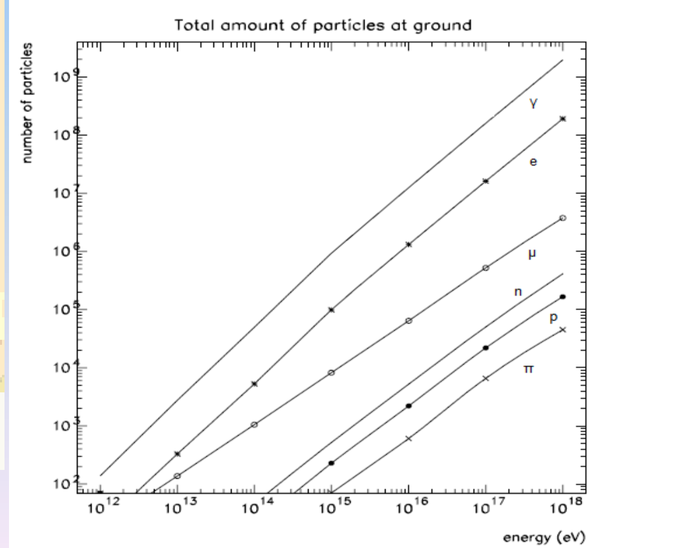
XXVIII Workshop on Recent Advances in Particle Physics and Cosmology, Aristotle University of Thessaloniki
Hellenic Society for the Study of High Energy Physics, Thessaloniki, 25-28 March 2010, Greece

HELYCON

HELLENIC LYCEUM COSMIC OBSERVATORIES NETWORK



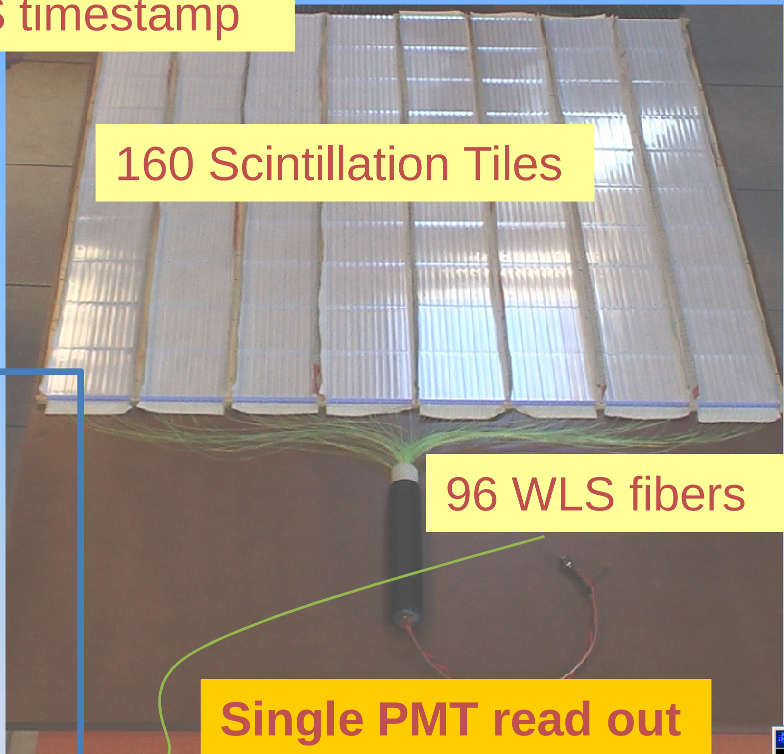




Low Energy Threshold 10^{13} eV, TR~1Hz

Detector Module

GPS timestamp



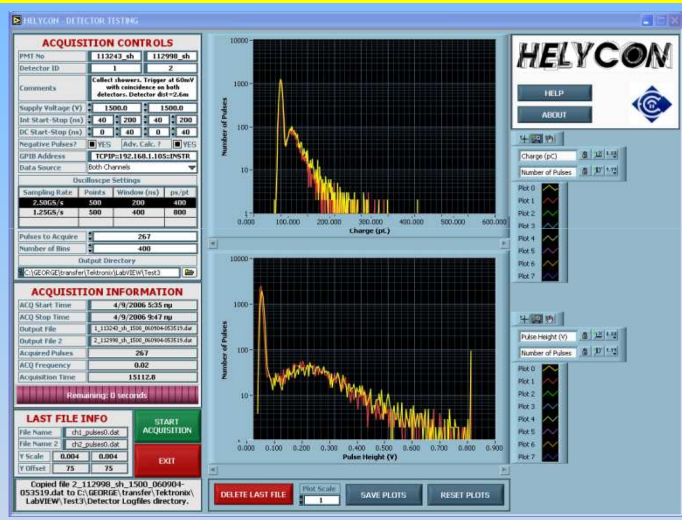
160 Scintillation Tiles

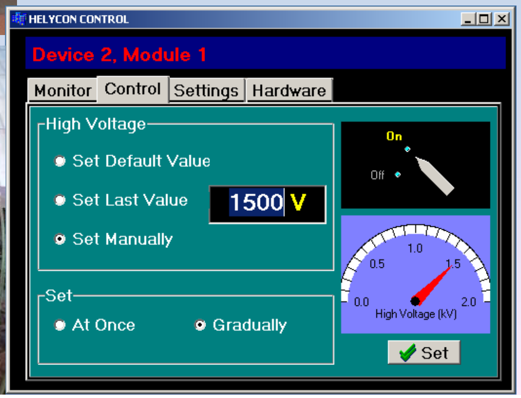
96 WLS fibers

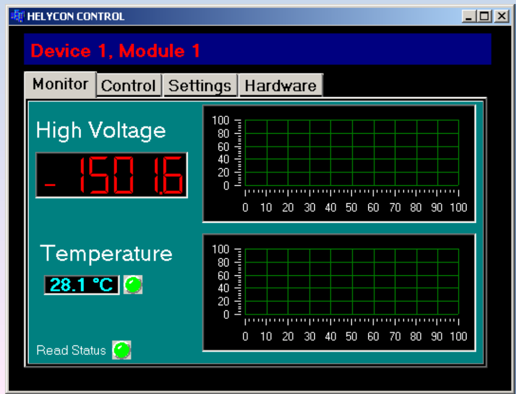
Single PMT read out

DAQ S/W based on LabView

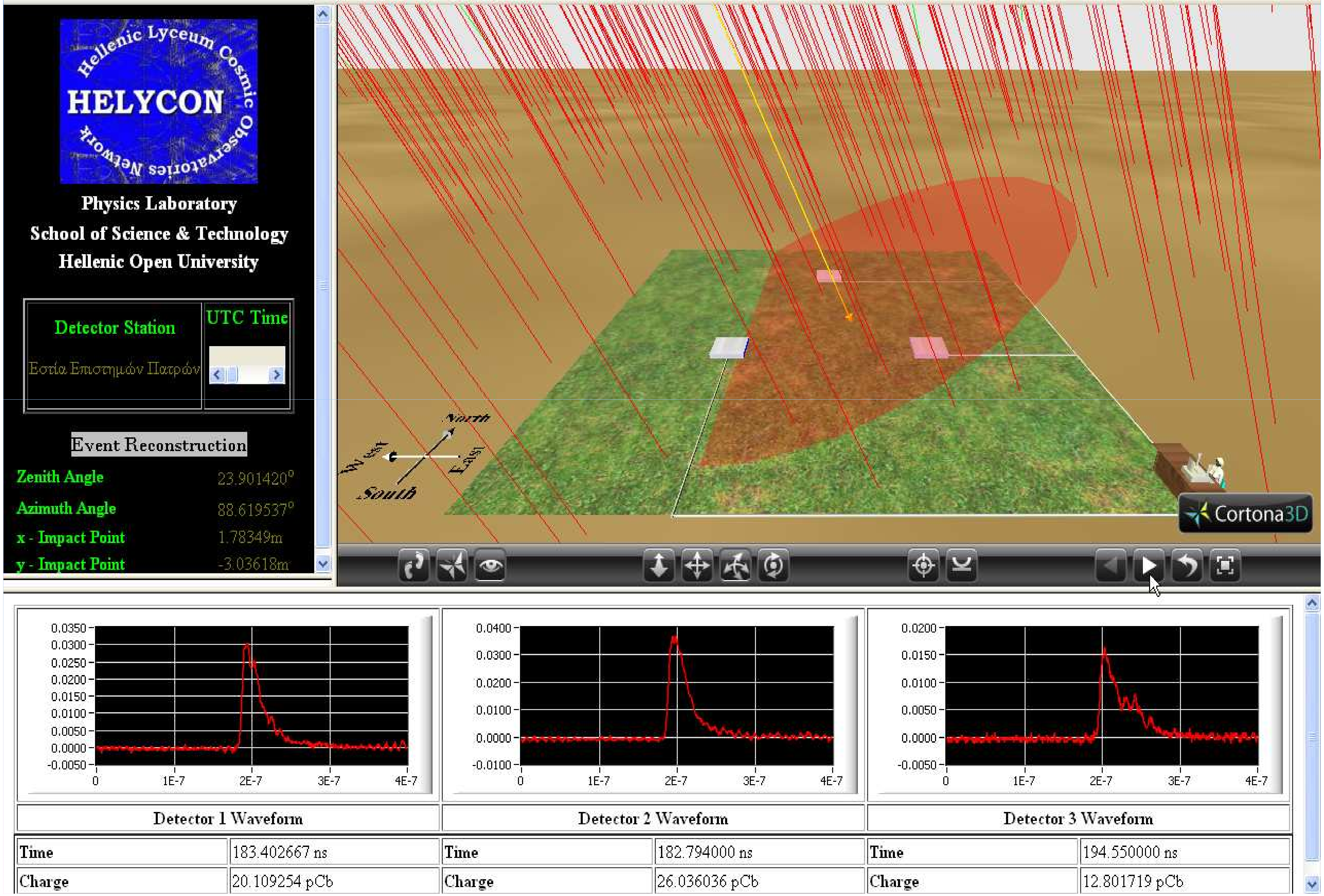
On-Line analysis - distributions







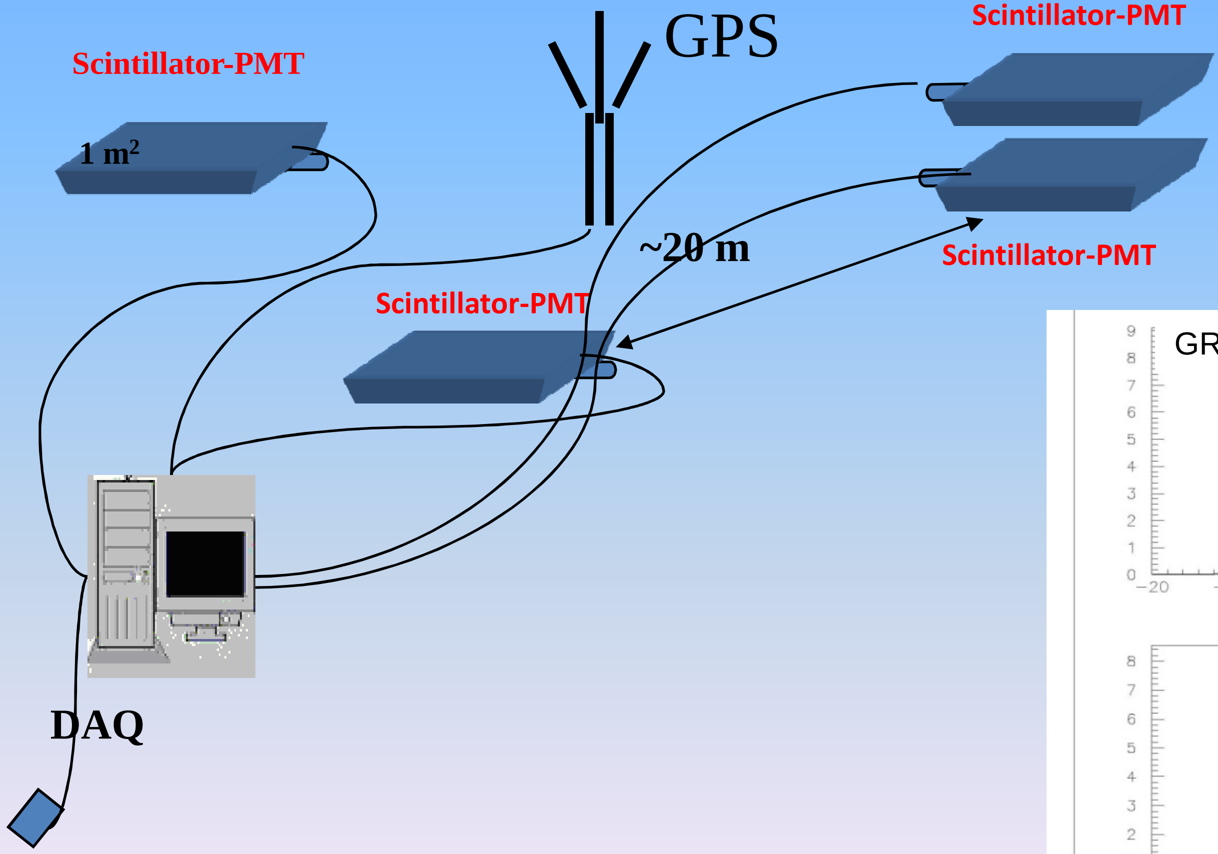
Web monitor

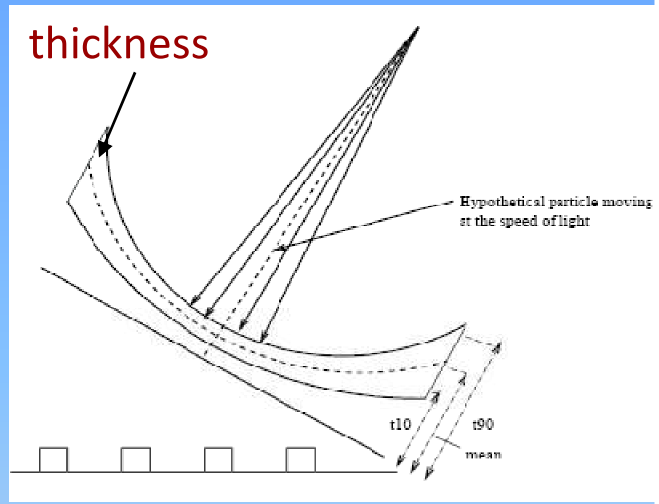


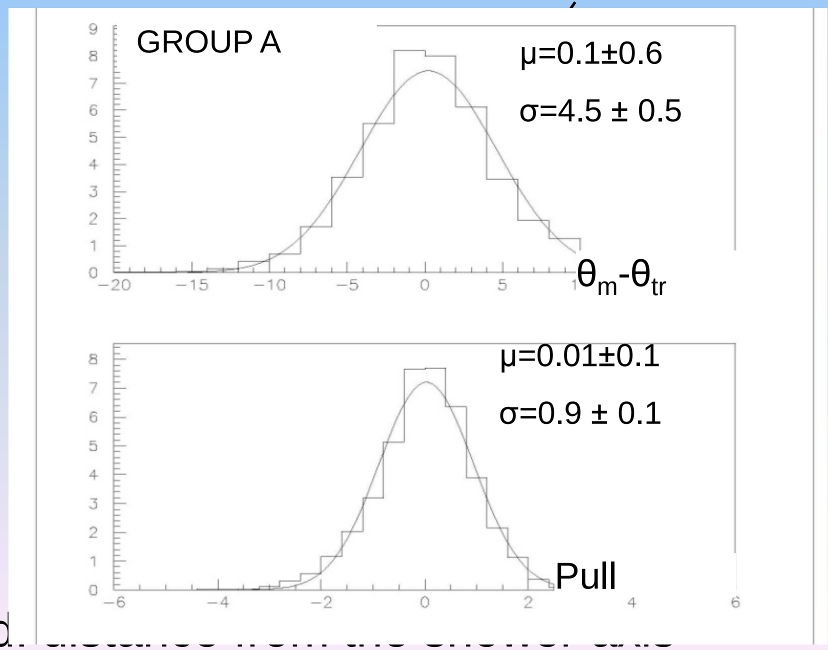
Hellenic Lyceum Cosmic Observatories Network
HELYCON
Physics Laboratory
School of Science & Technology
Hellenic Open University
Detector Station
UTC Time
Εστία Επιστημών Πατρών
Event Reconstruction
Zenith Angle 23.901420°
Azimuth Angle 88.619537°
x - Impact Point 1.78349m
y - Impact Point -3.03618m
North
West
East
South
Cortona3D
Detector 1 Waveform
Detector 2 Waveform
Detector 3 Waveform
Time 183.402667 ns
Charge 20.109254 pCb
Time 182.794000 ns
Charge 26.036036 pCb
Time 194.550000 ns
Charge 12.801719 pCb

HELYCON Station

Single Station Set-Up







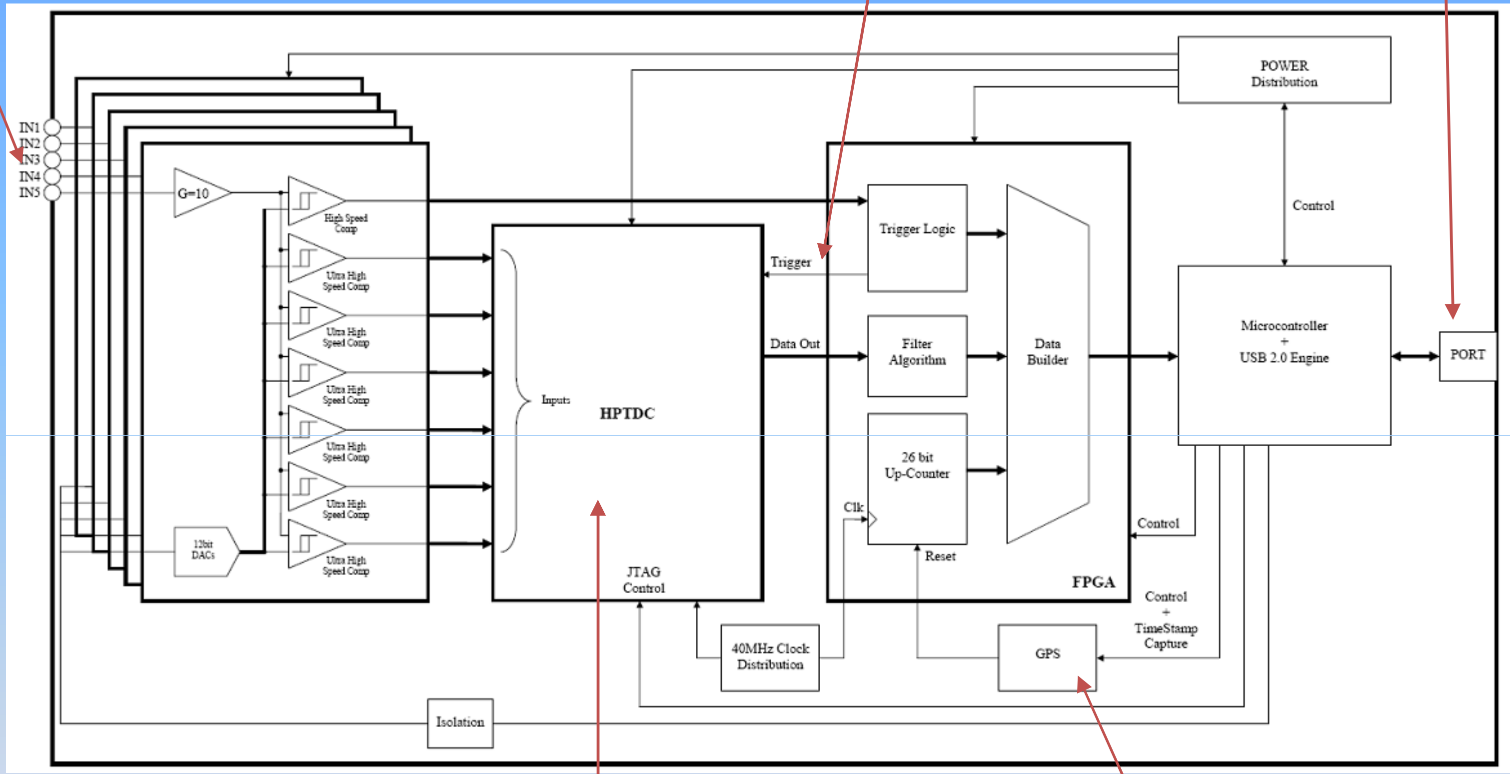
4·(1W/counter)+30W(PC+electronics)

Readout Electronics

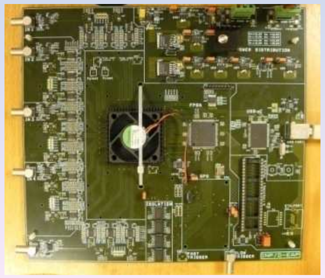
5 PMT Signal Inputs

Trigger Output

USB Port



GPS Input



NCSR Demokritos

25ps accuracy TDC

ReadOut Electronics

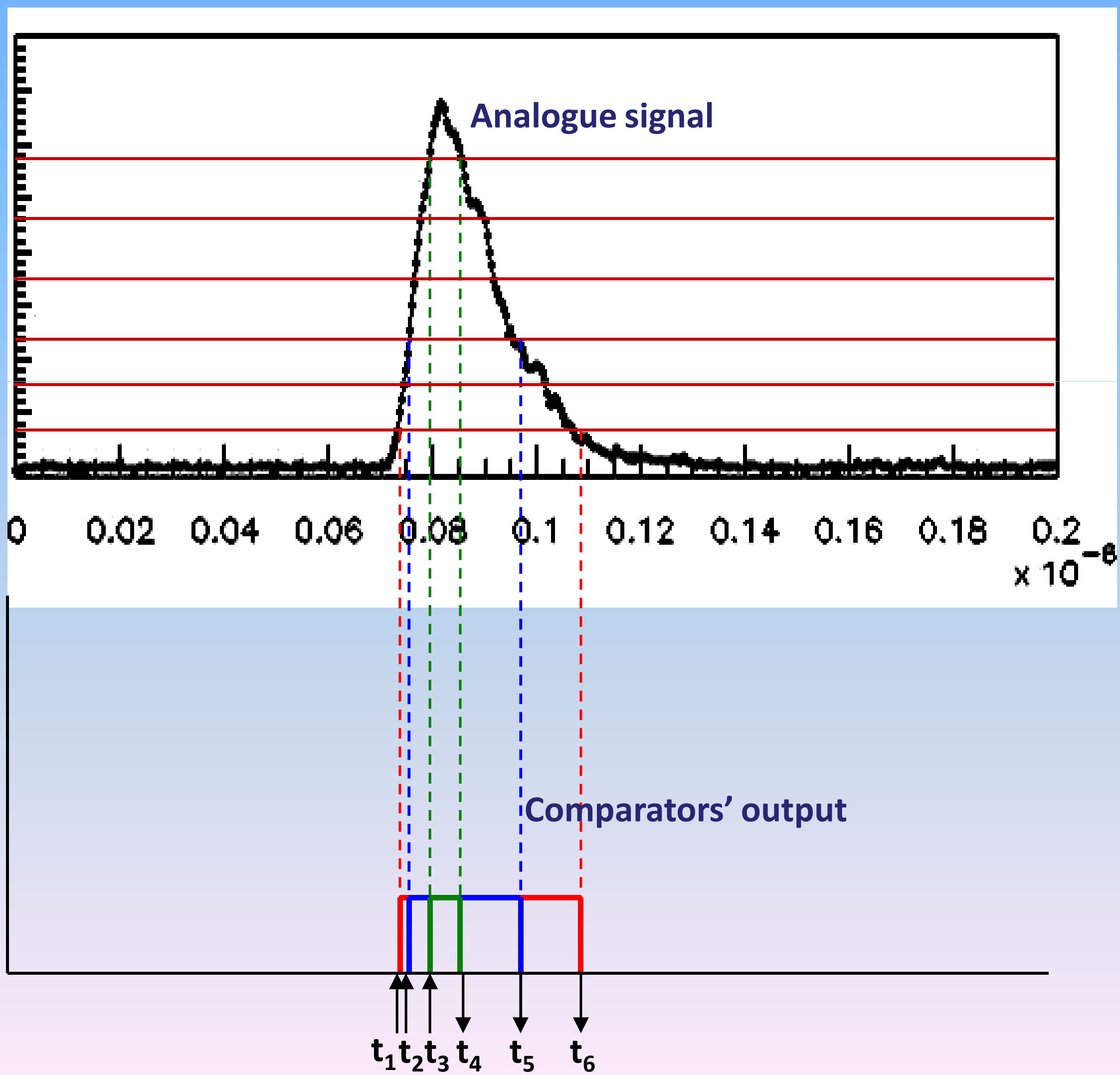
Detectors and Instrumentation Lab, NCSR Demokritos

Loukas Dimitris,
Michailakis Isidoros, Papadakis Giannis

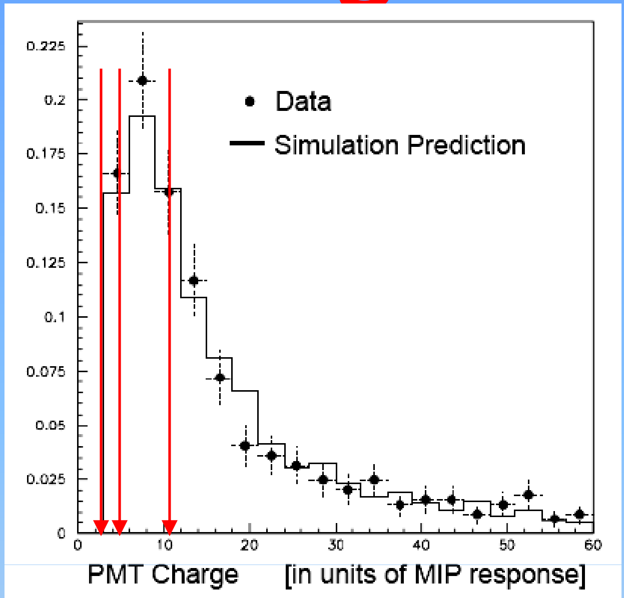
ASIC Implementation (Electronics Department, University of Patras)

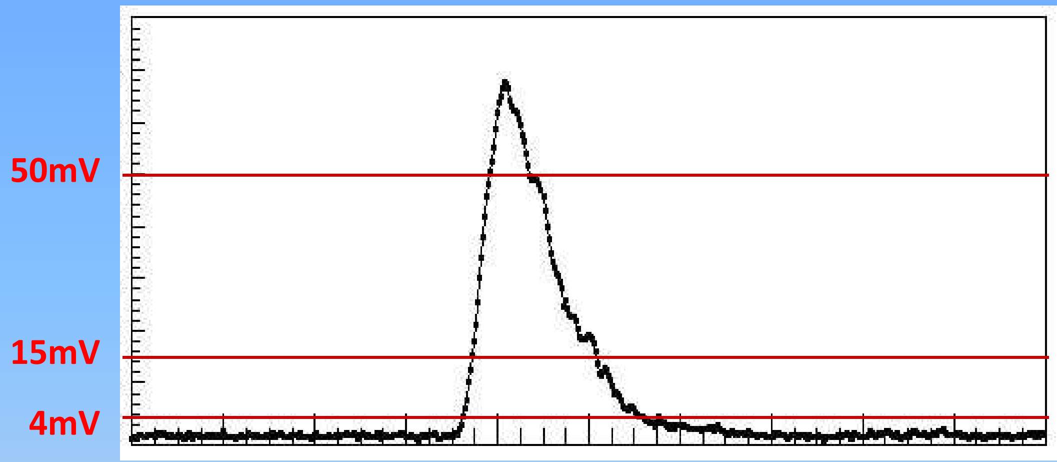
New

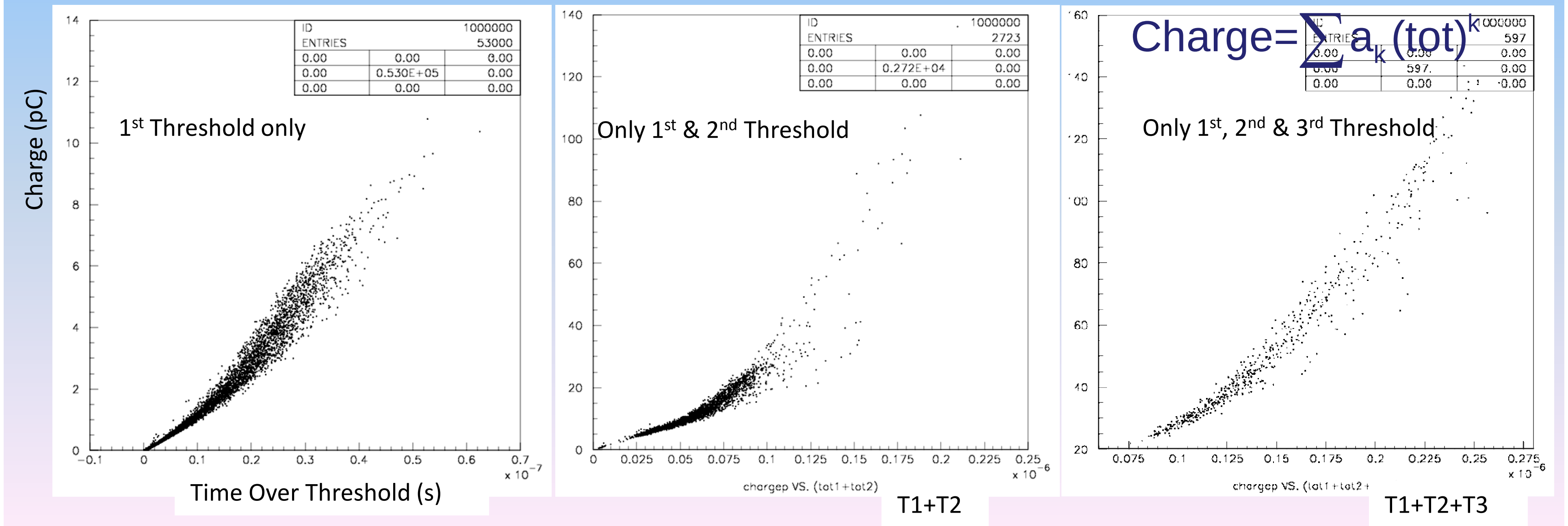
Multi-Time Over Threshold Digitization Technique



Charge vs Time over Threshold

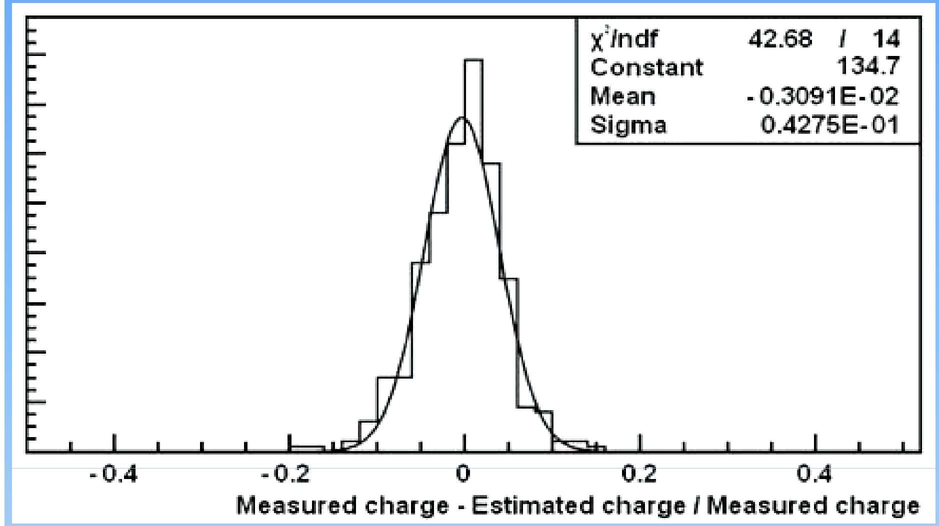


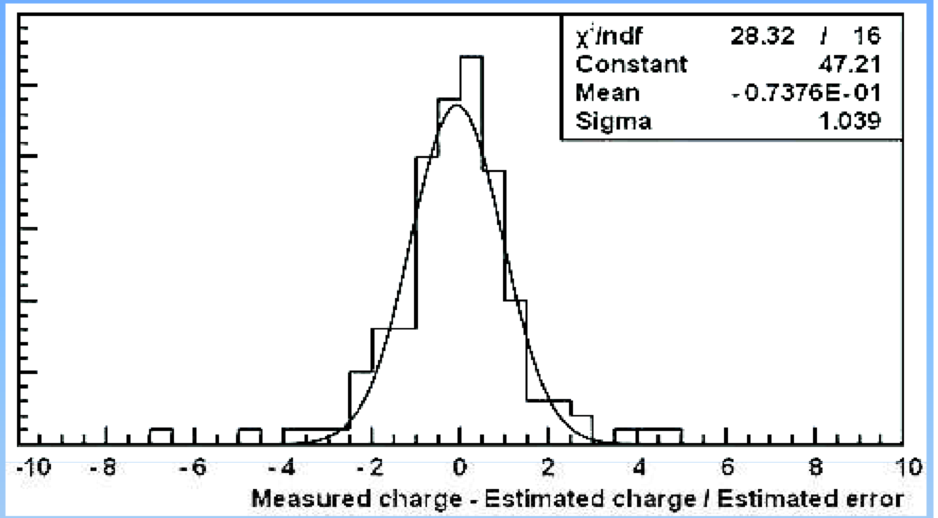




Charge Estimation

4 thresholds





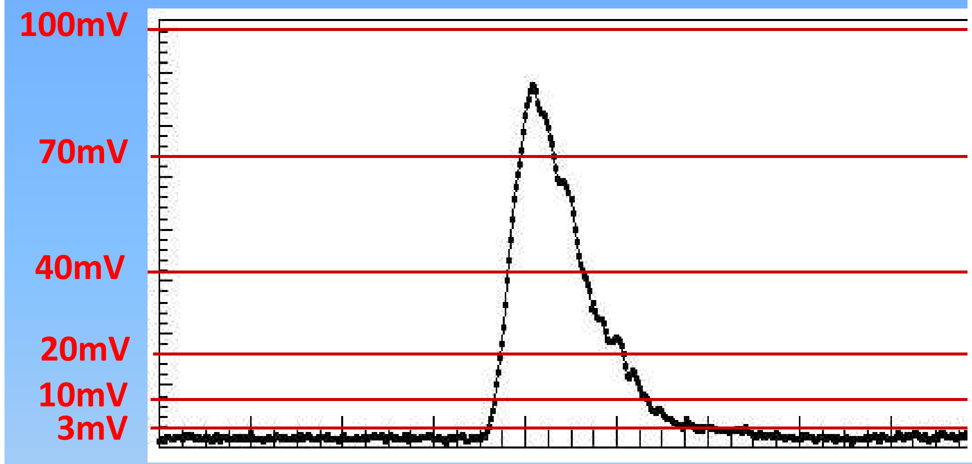
$$\frac{\text{Measured Charge} - \text{Estimated Charge}}{\text{Measured Charge}} \qquad \frac{\text{Measured Charge} - \text{Estimated Charge}}{\text{Estimated Error}}$$

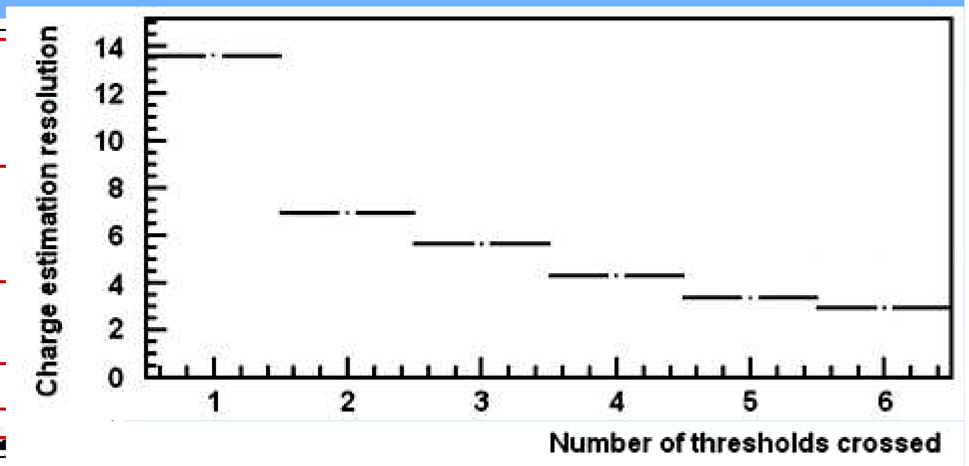
- **Estimated Resolution 4.3%**
- **Pull distribution sigma of 1.04 ± 0.07**

G. Bourlis et al,
doi:10.1109/IWASI.2009.5184796

Charge Estimation Resolution

Charge estimation resolution vs number of thresholds crossed





Thresholds crossed	1	2	3	4	5	6
Charge estimation resolution (%)	13.6	6.9	5.6	4.3	3.4	2.9

G. Bourlis et al,
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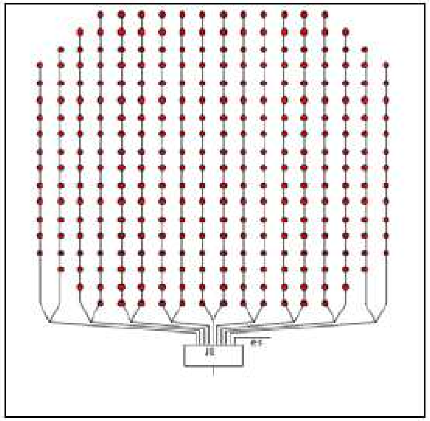
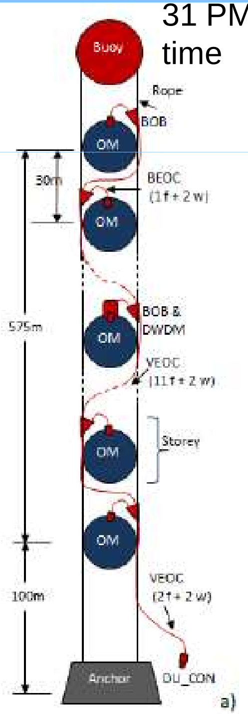
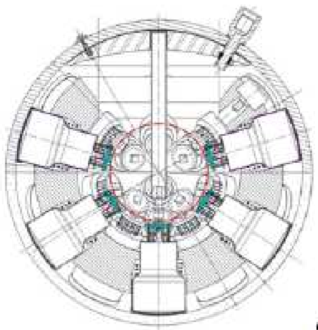
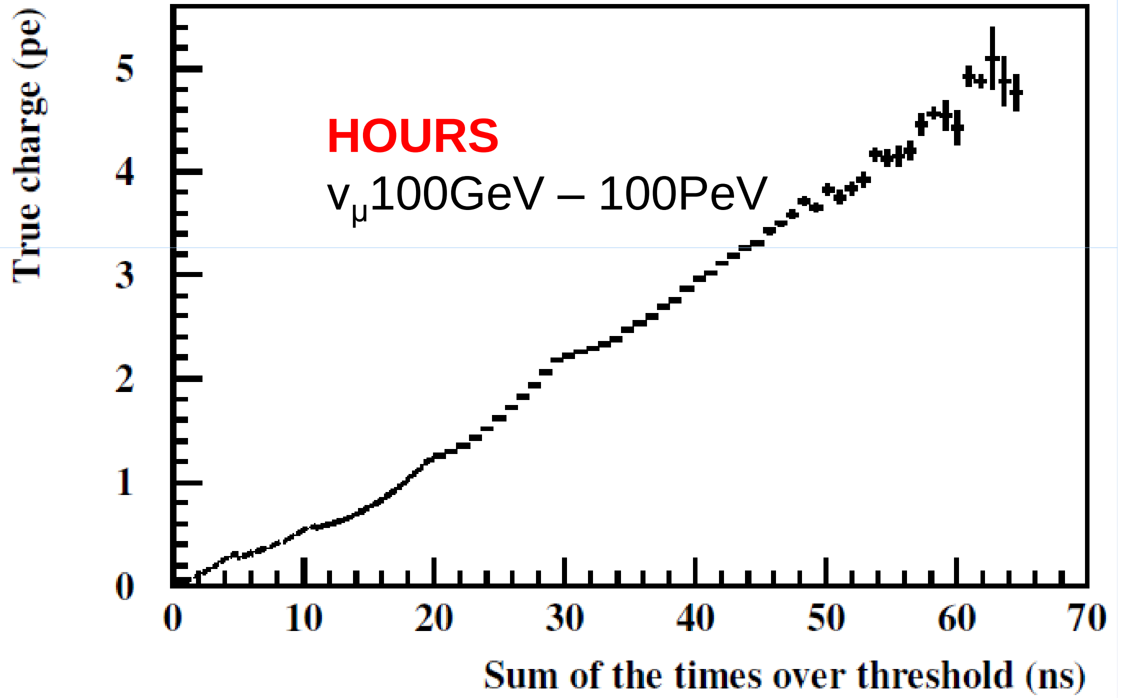
MTOT & Underwater Neutrino Telescope Data



31 PMTs 3″, 2.5 ns rise time, 4.5 ns fall time

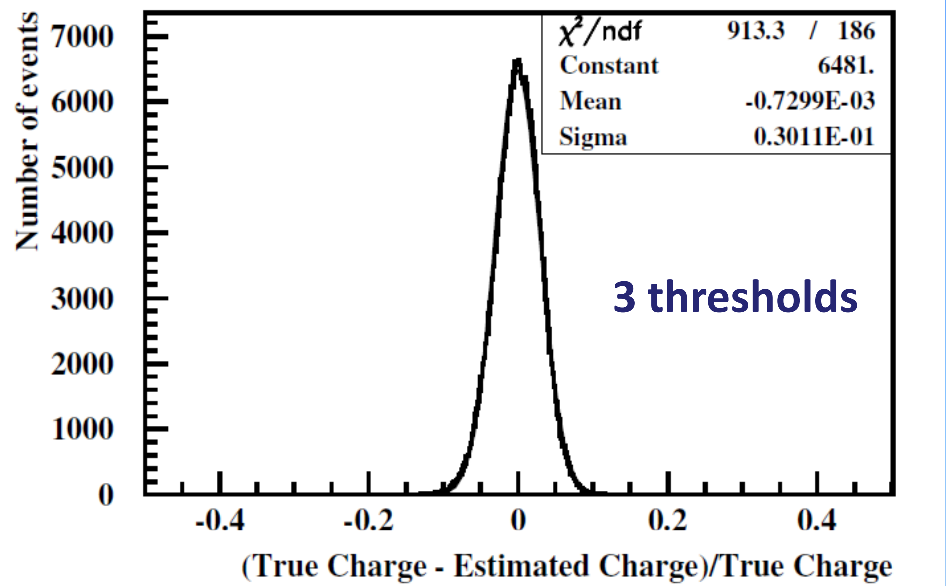


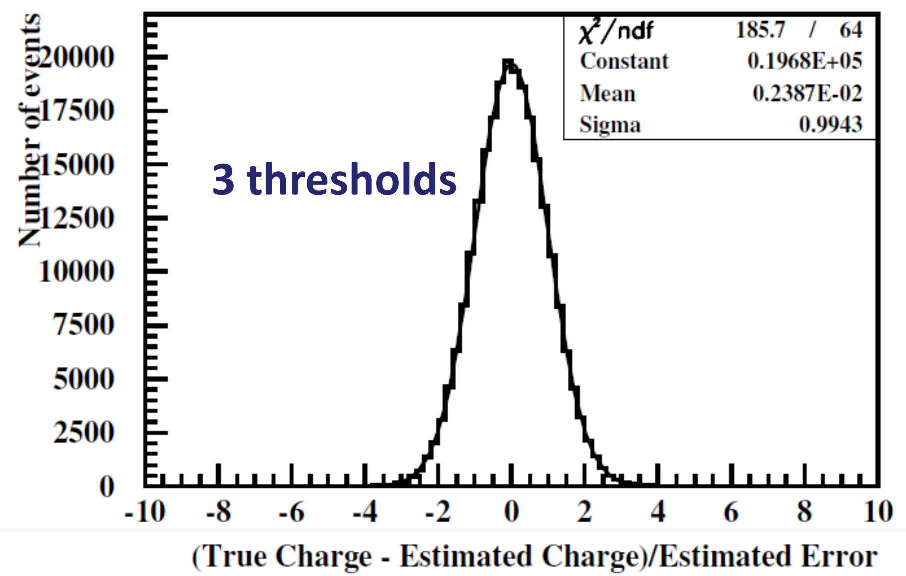


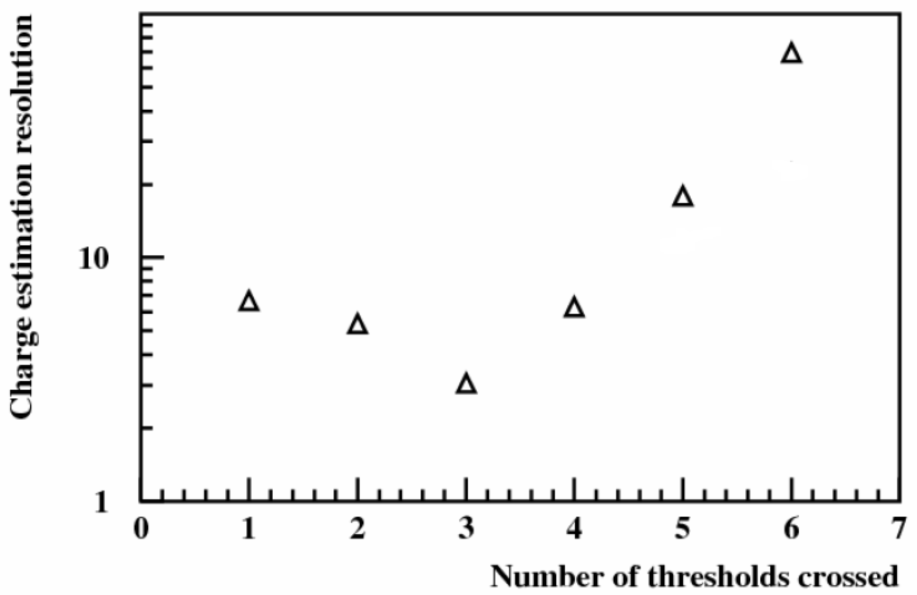


Thresholds : 0.252pe, 0.4pe, 0.635pe, 1.26pe, 2.52pe και 8.0pe

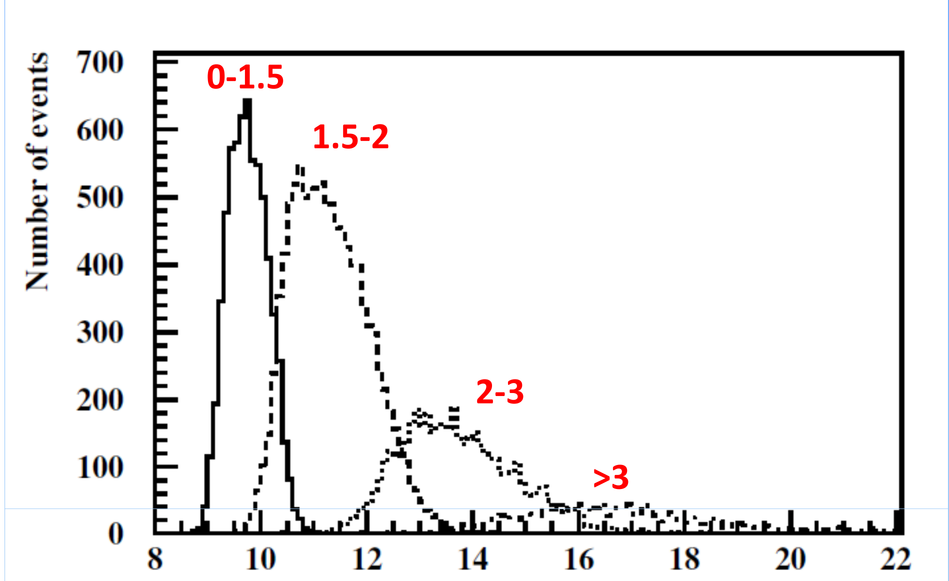
Charge Estimation Resolution



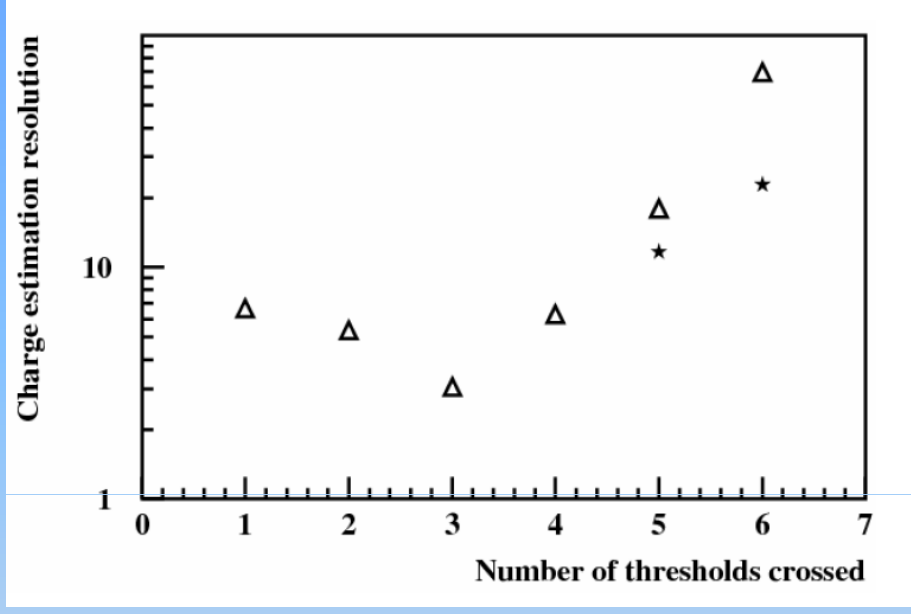


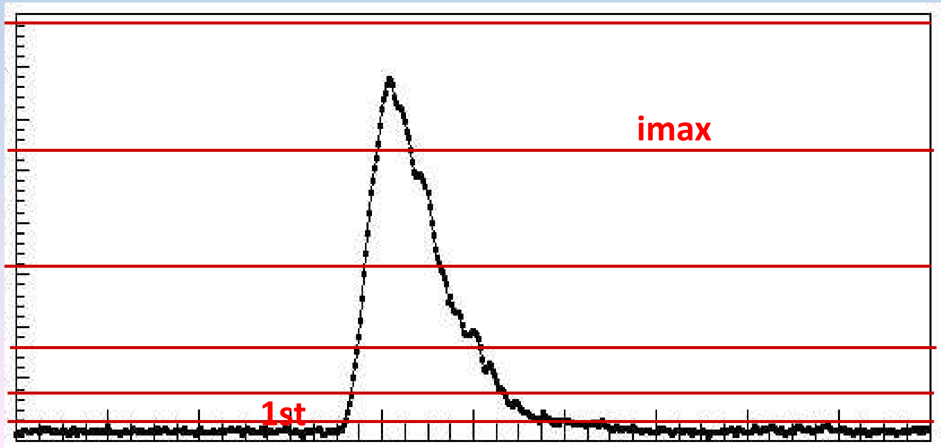


Optimization



$$Dtot = \sqrt{(tot(1))^2 - (tot(i_{max}))^2}$$





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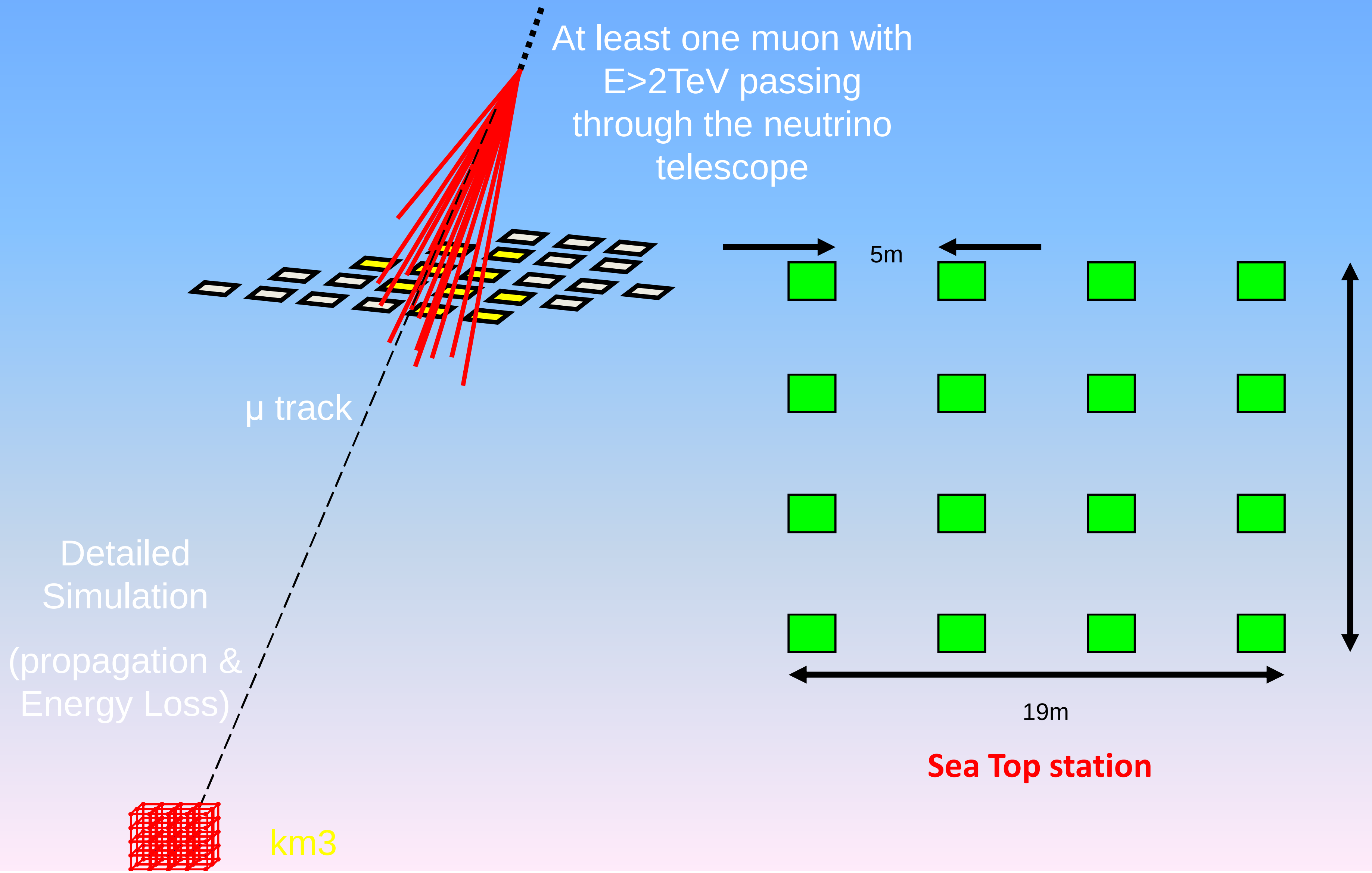
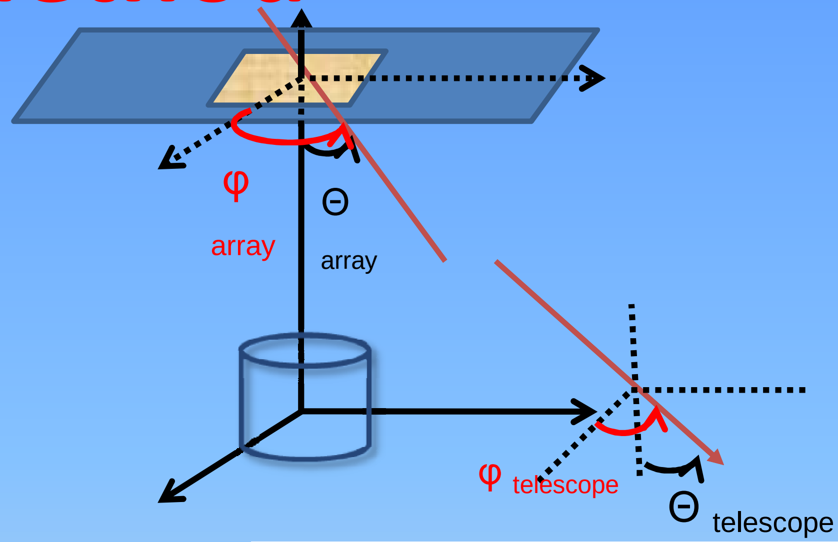
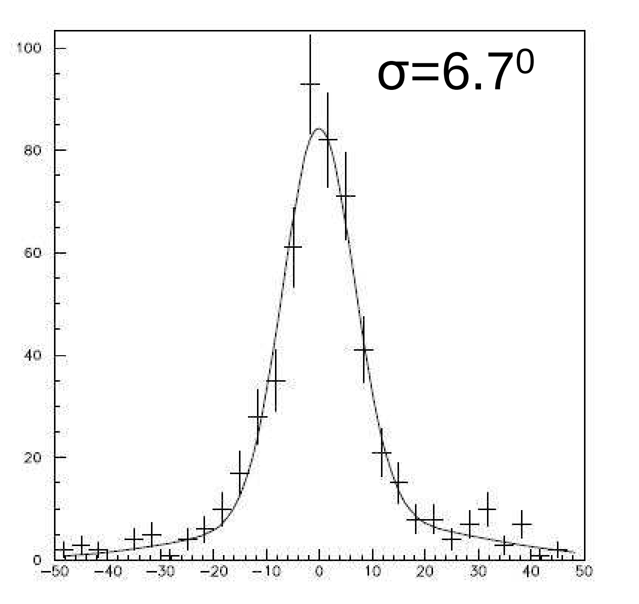
Underwater Neutrino Telescope Calibration



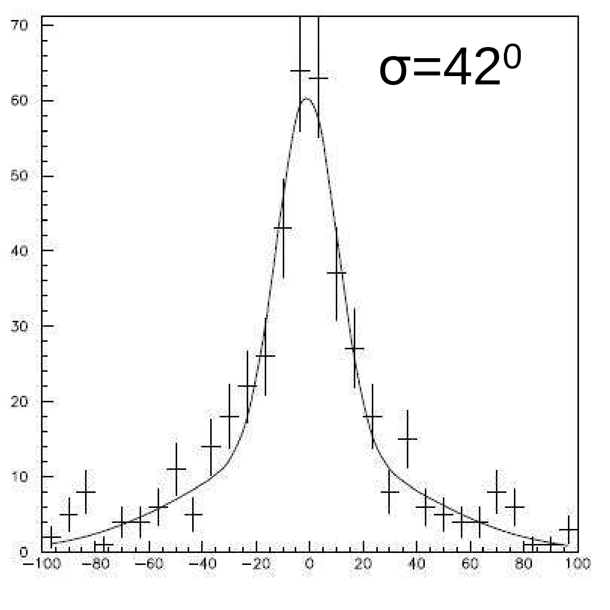
Standard Method

Detector: SeaWiet
Depth: 2500 m
Quality cuts:
- mean deposited charge in active counters >1.7
- number of PMT hits > 10.

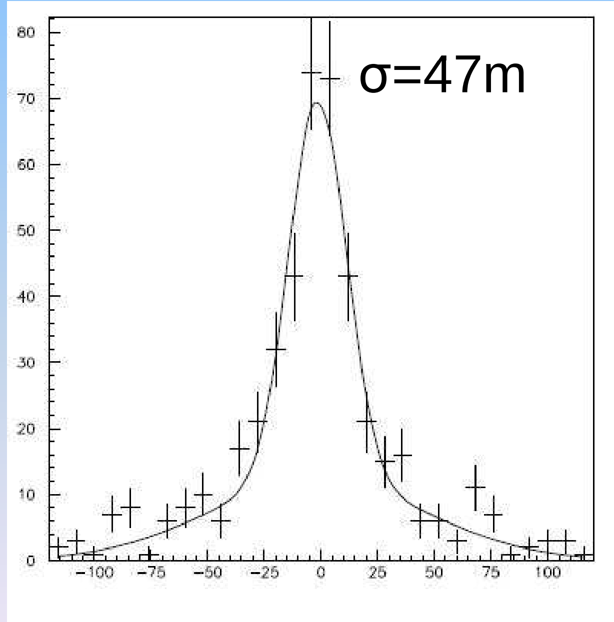




$\theta_{Telescope}-\theta_{array}$



$\varphi_{Telescope}-\varphi_{array}$

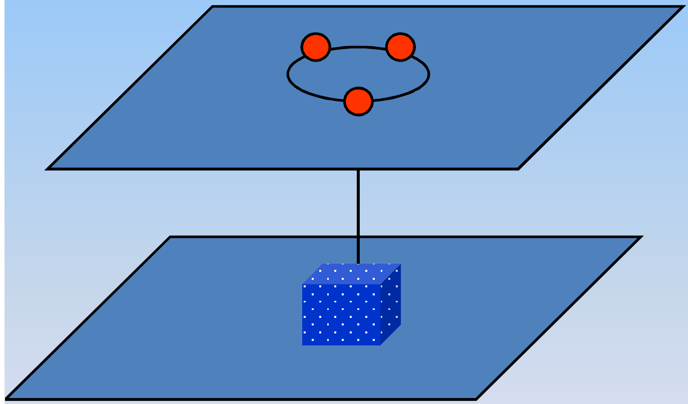


$X_{Telescope}-X_{array}$

Standard method

A. Tsirigotis et al,
Nuclear Instruments and Methods in Physics Research A 595 (2008) 80–83

3 stations for 10 days



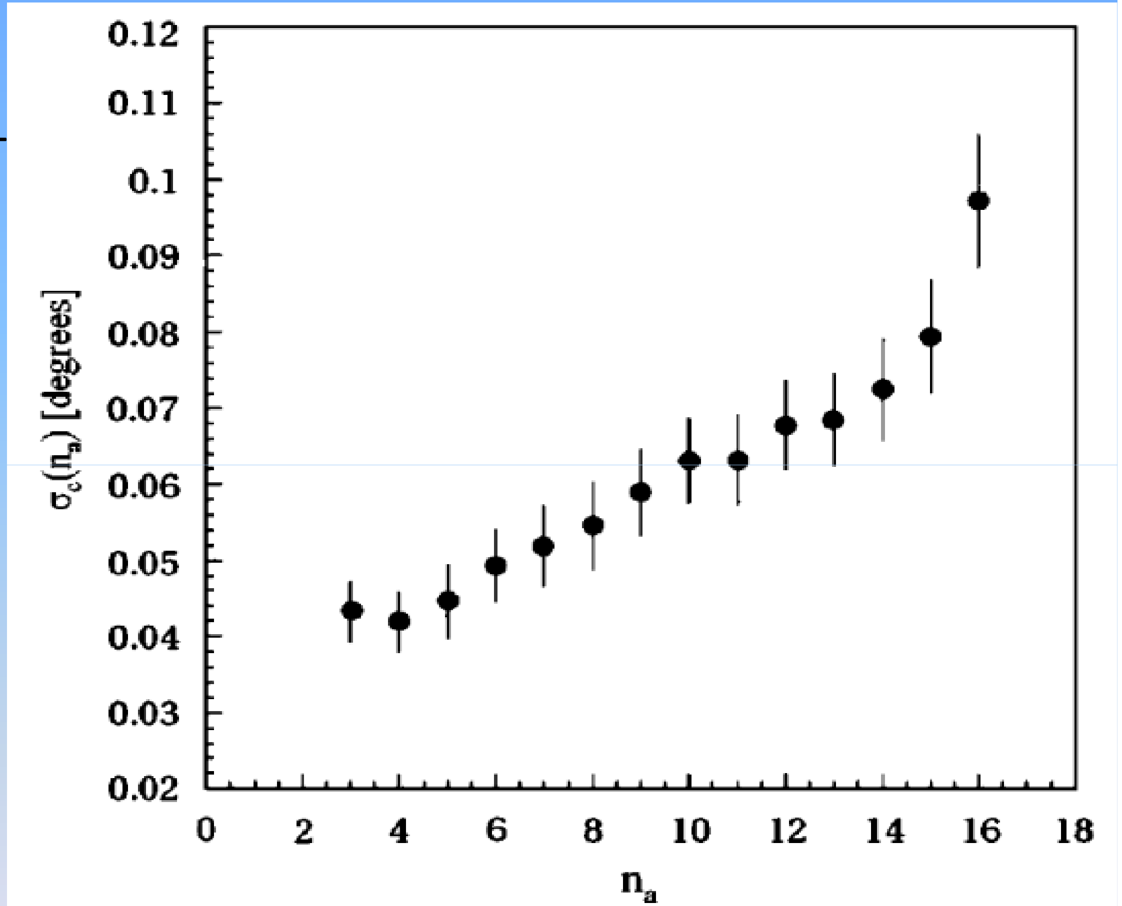
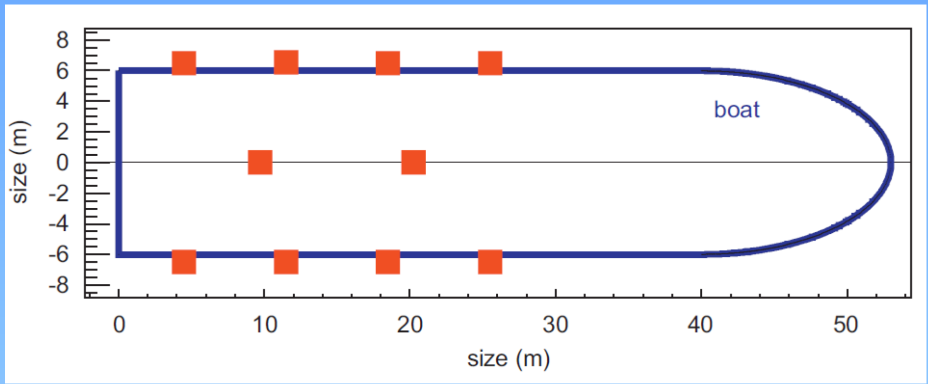


Fig. 4. The calibration resolution of three HELYCON detector arrays, for 10 days of operation, as a function of the minimum number of active detectors per event.

Calibration Study in Antares



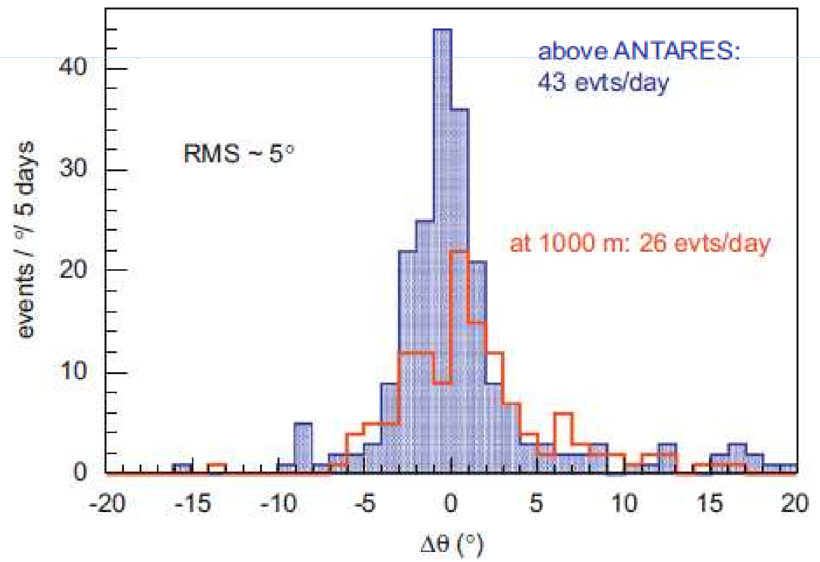
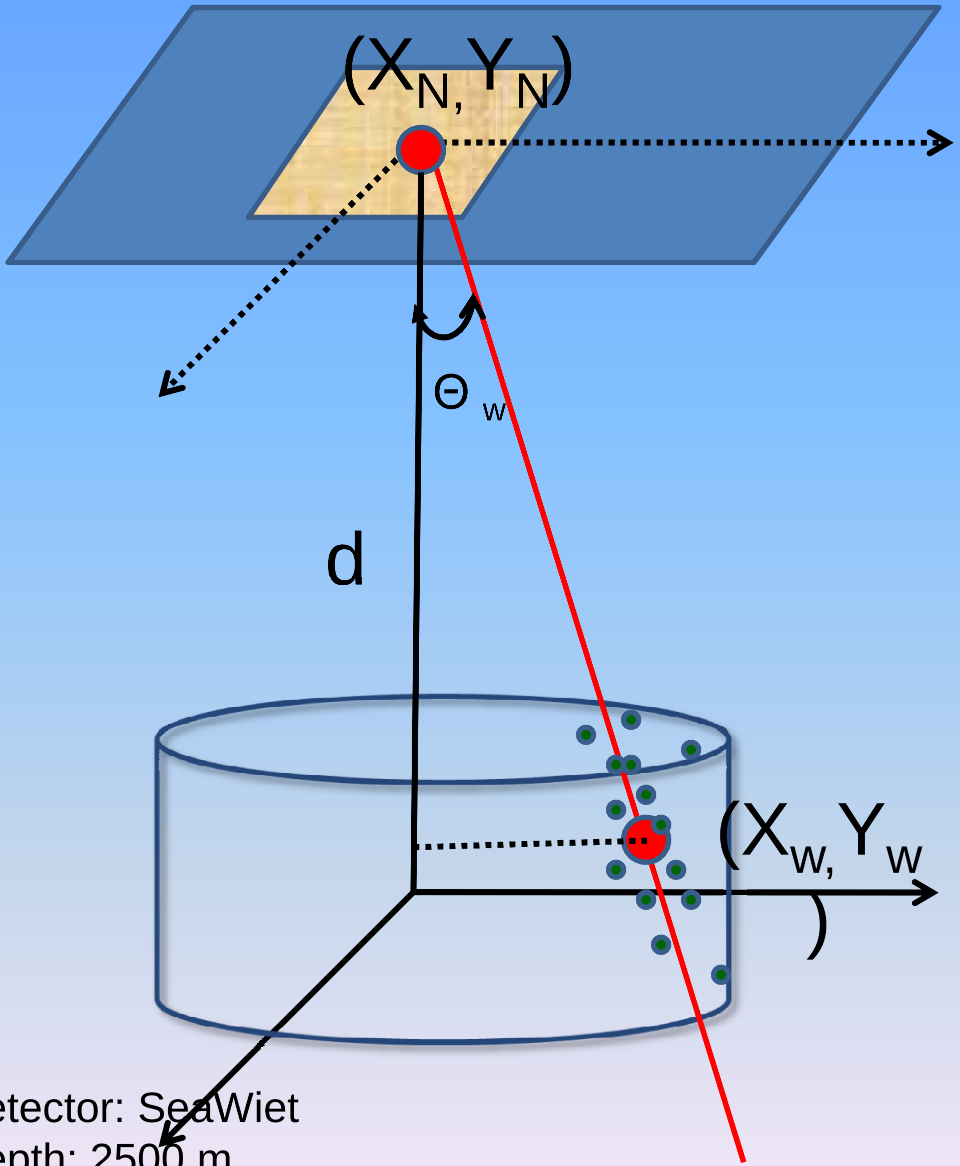


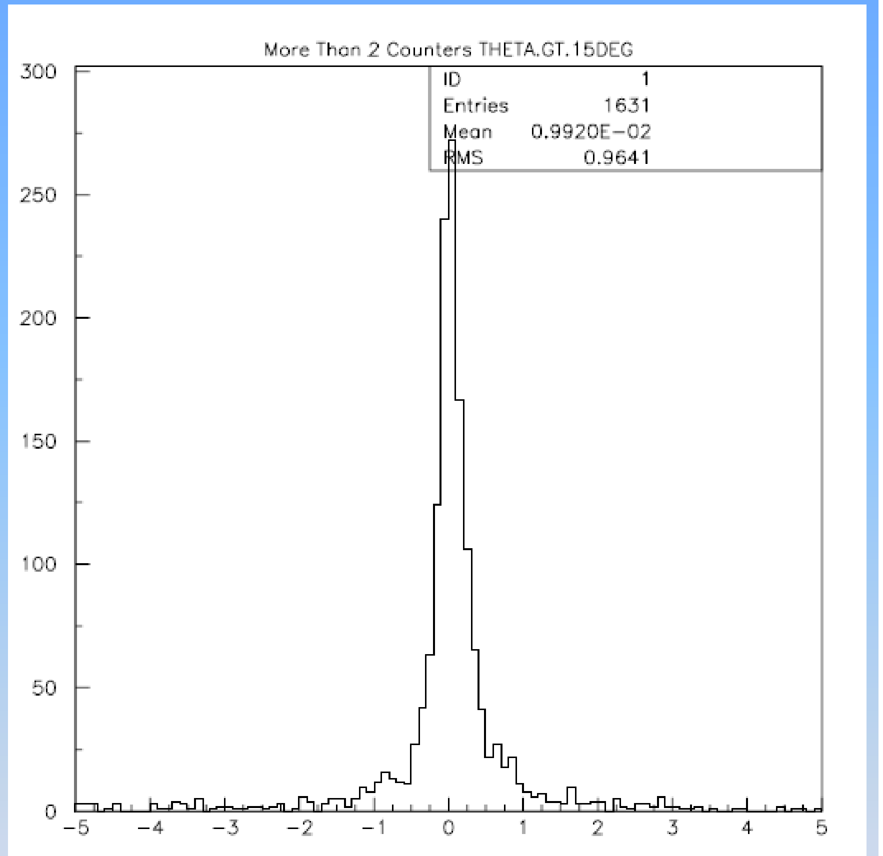
Fig. 3. Zenith angle event by event comparison between surface array shower axis measurement and reconstructed track in ANTARES, with loose quality cut. The difference of rates is mainly due to the muon absorption which is greater for zenith around 24° than for pure down-going muons. The RMS of the two distributions are similar, both being slightly better than the value of 5° indicated in the figure.

J.-P. Ernenwein, et al., Nucl. Instr. and Meth. A 602 (2009) 88–90

In this work we have estimated the potential of a floating surface array in the calibration of an underwater neutrino telescope of the size of ANTARES. Using Monte Carlo simulations (CORSIKA, HELYCON software and ANTARES software), we can conclude that a 5 day sea campaign with a surface array made of 10 scintillators distributed on an area of $13 \times 23\,m^2$ would be useful to reveal a systematic error of about 0.5° on the zenith angle reconstructed by the telescope. This constraint becomes 1.5° for the azimuth.

Improved Method

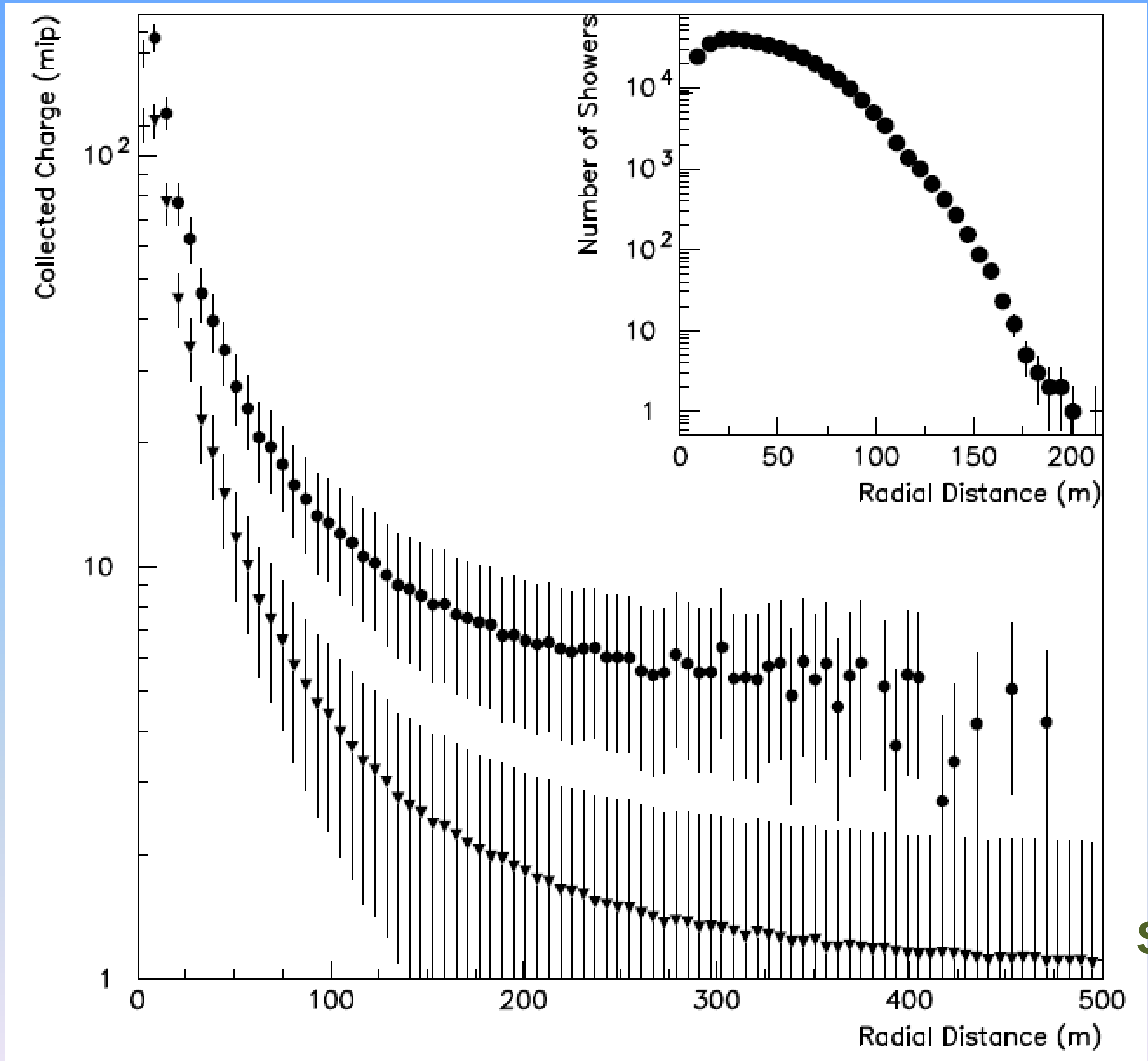




$\theta_w - \theta_{shower}$

Detector: SeaWiet
Depth: 2500 m
Quality cuts:
•number of PMT hits > 10

Improved Method



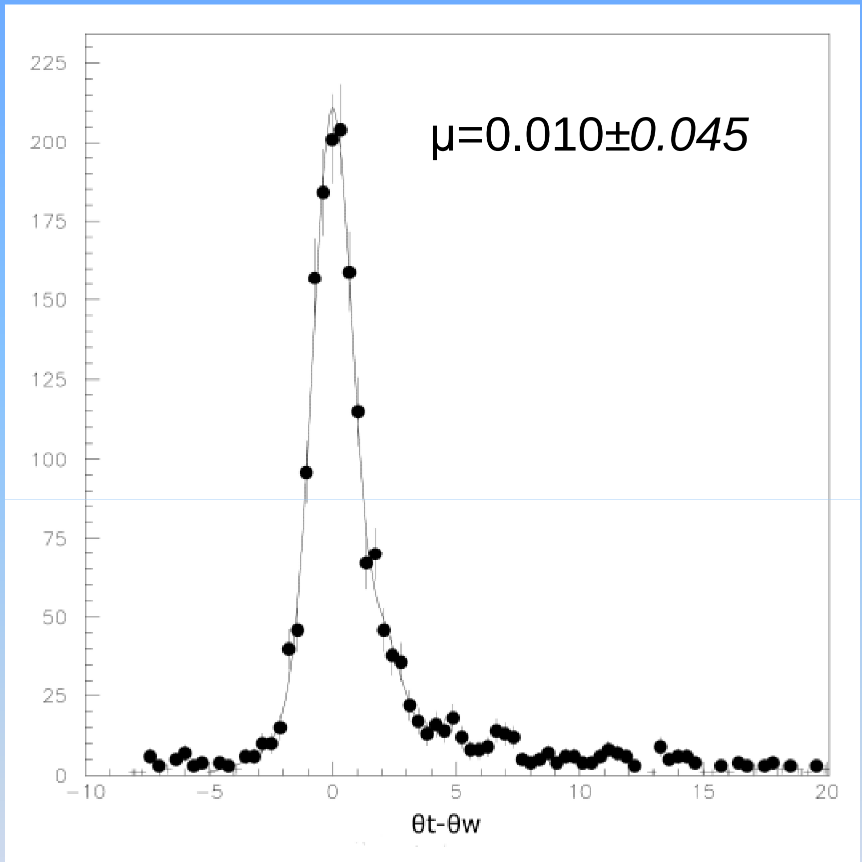
Five counters

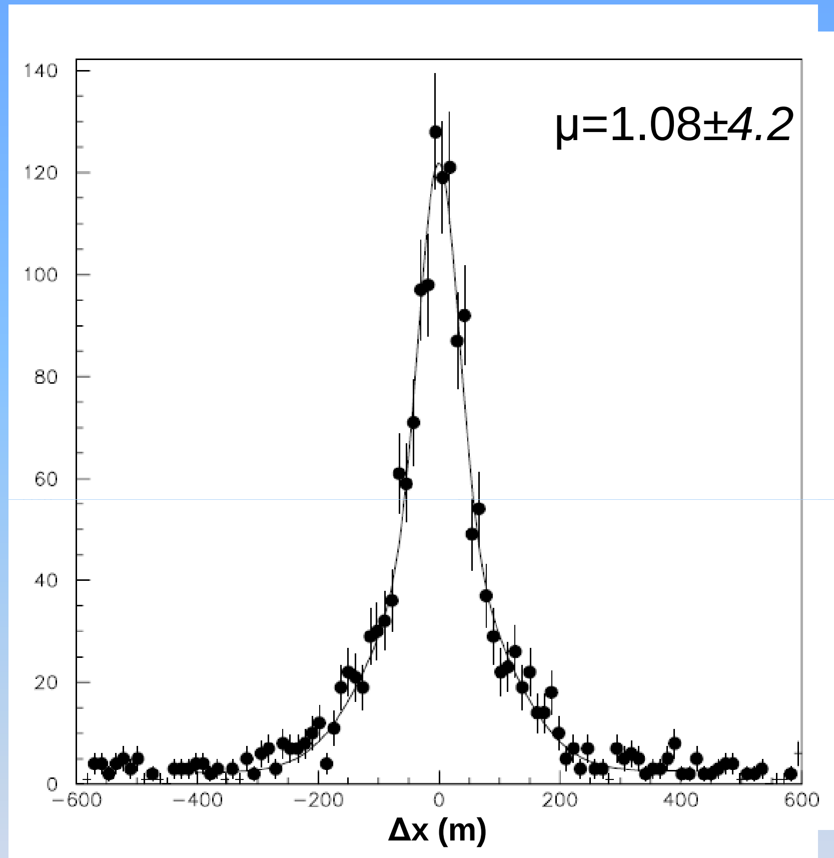
Single counter

For N_{det}>4 and $Q_{collected}$> of 25 mips,
<R>=44 m, whilst only 0.05% > 150m from the center of the platform

Improved Method

Set corresponding to
39 hours of operation





Scaled to 10 days operation with 2 stations

→ $\sigma_\theta=0.01^0$, $\sigma_\varphi=0.07^0$, $\sigma_X=1$m

Summary Of Results

Improved method

SeaWiet

Depth (m)	Offset Sensitivity (deg)	
	θ	ϕ
3500	0.014	0.07

vOne

Depth (m)	Offset Sensitivity (deg)	
	θ	ϕ
2500	0.01	0.02
3500	0.02	0.06

Standard method

SeaWiet

Depth	Offset Sensitivity	
	θ	ϕ
3500	0.045	0.34±0.07

vOne

Depth	Offset Sensitivity	
	θ	ϕ
2500	0.040±0.006	0.20±0.02
3500	0.09±0.02	0.46±0.05

Consistent Estimations when the array Is shifted in X or Y axis

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Conclusions

- The multi time over threshold technique is very promising digitization technique for PMT pulses of HELYCON detector as well as for the Neutrino telescope data

- The HELYCON station can be used as a sea top calibration infrastructure for the angular and absolute position of underwater neutrino telescopes