Performance of the μCosmics detector

A. Leisos, A. Tsirigotis, L. Xiros, M. Petropoulos, S. Nonis, A. Marantis
Physics Laboratory, Hellenic Open University, Particle and Astroparticle Physics Group

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The μCosmics Detector

The μCosmics detector is an educational air shower detector, based on the architecture of Astroneu, a hybrid array of EAS detection stations deployed at the Hellenic Open University (HOU) campus . The μCosmics detector (Figure 1,2) consists of three detection units (scintillator detectors), a PC-based oscilloscope and a PC for monitoring and storing the data. In comparison with the corresponding Astroneu detection station the μCosmics detection unit is much smaller, while the Photomultiplier Tube (PMT) is replaced with a small Silicon Photomultiplier (SiPM) that, in addition, does not require high voltage. Consequently, the μCosmics detection station is a low cost and easy to carry telescope that can be operated within the classroom or school lab, while its simplicity allows the assembly of the detection units by the students themselves.

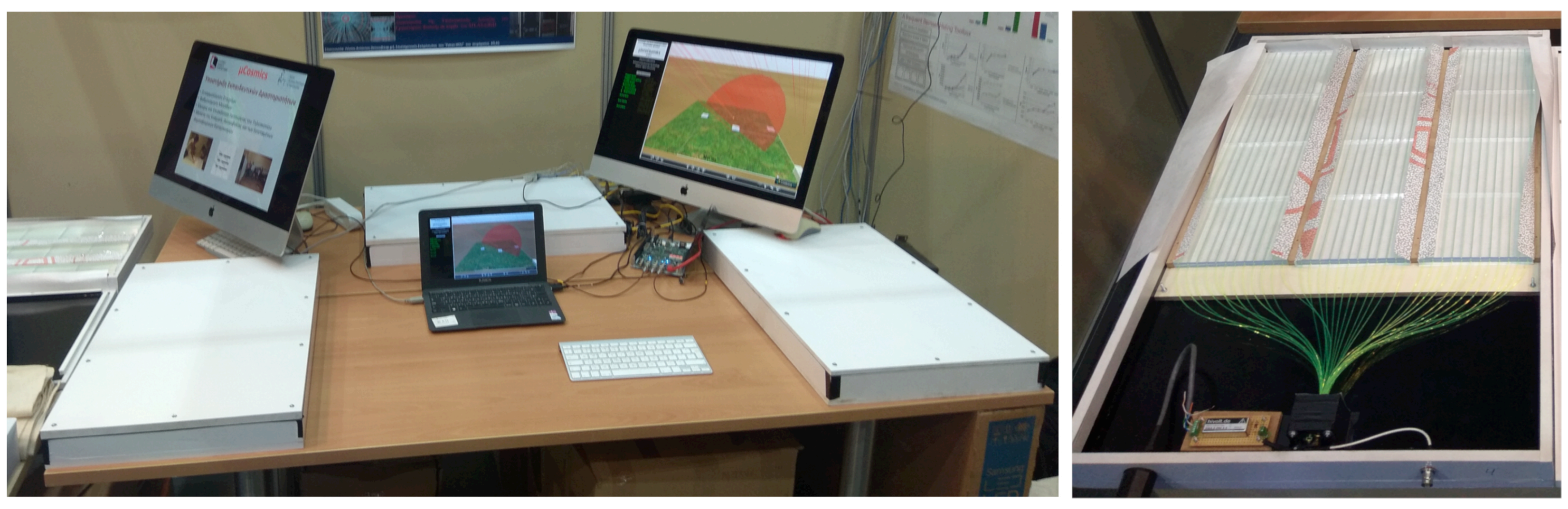
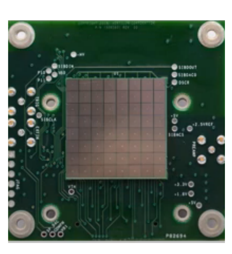
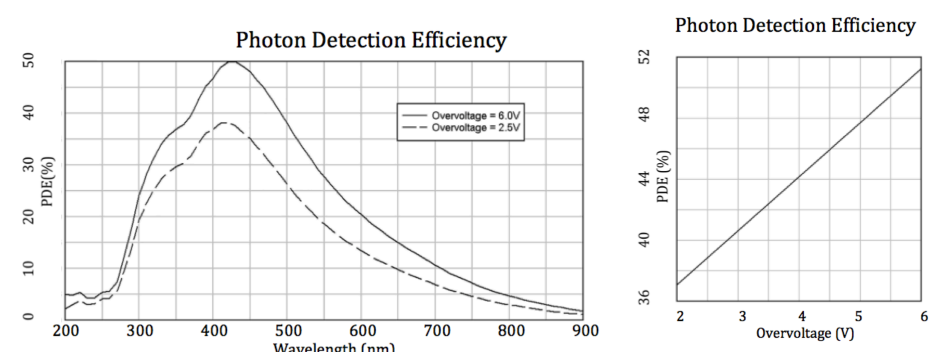


Figure 1
The μCosmics telescope (left) with 3 detection units (white boxes) and the interior of the detection unit (right).

SiPM
6x6mm
35μm micro cell size
22292 cells
45% Quantum Efficiency at 430 nm
Operation supply voltage 30V





PC-based Digital Oscilloscope
4 channels
250 MHz Analog Bandwidth
1GSa/s sampling rate
64 k memory depth

Custom Power Supply
3 outputs
0-40 V adjustable output

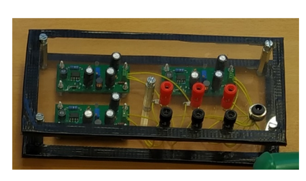


Figure 2
The main components of the μCosmics telescope.

The 3 detection units of the μCosmics detector are positioned a few meters apart inside the class or school laboratory. By requiring these three detectors to register particles in a very short period of time, one can distinguish between atmospheric muons and extensive air showers caused by high energy primaries. Measuring the relative times that the shower particle front passes through the particle detectors and using triangulation, the direction of the shower axis and consequently of the primary particle can be reconstructed with an accuracy of a few degrees.

The μNet Project

The development of the μCosmics detector along with the corresponding educational activities that were developed during summer schools gave birth to the μNet project. μNet aims at the active involvement of high school students in experimental procedures of Astroparticle physics and especially in Cosmic Ray physics. In the framework of μNet, 20 educational cosmic ray telescopes will be installed at Greek high school laboratories, while remote operated devices deployed at the HOU campus will be available to more than 30 schools per year. The schools equipped with μCosmics detectors as well as the schools participating in distance education activities, will constitute the μNet network (see Figure 3), the 1st Greek school network of educational cosmic ray telescopes

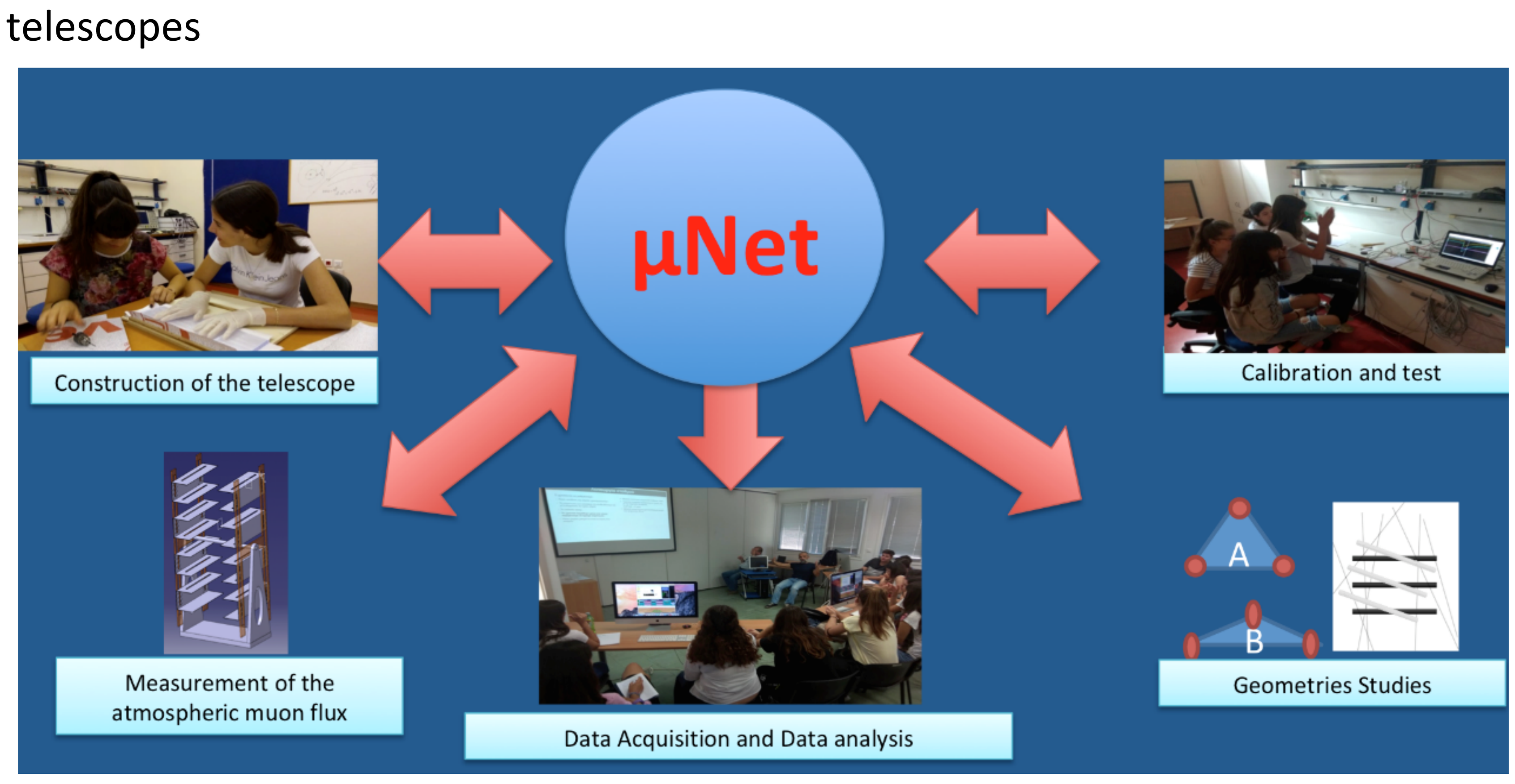


Figure 3
Educational activities with the μCosmics detector

Characterization of the μCosmics Detection Units

During the calibration procedure of the telescope the three detection units are positioned on top of each other (Figure 4). This way single atmospheric muons penetrate all three detector units almost simultaneously (atmospheric muons travel almost with the speed of light). The outer units are operated in coincidence, while the middle detector is under test.

If for example a shower passes through the detector units simultaneously (i.e. a shower comes directly from above and perpendicular to the ground) the three pulses should appear simultaneously. This is not always case due to the different cables' lengths that produce different delays to the signal propagation.

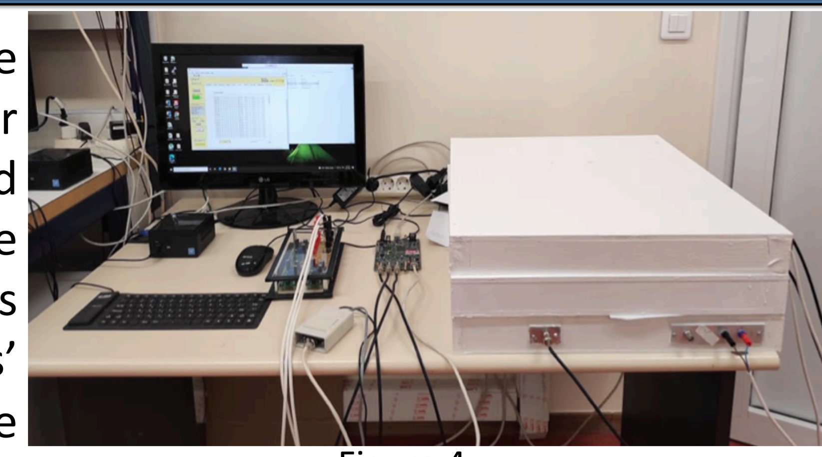


Figure 4
The experimental setup for the calibration procedure

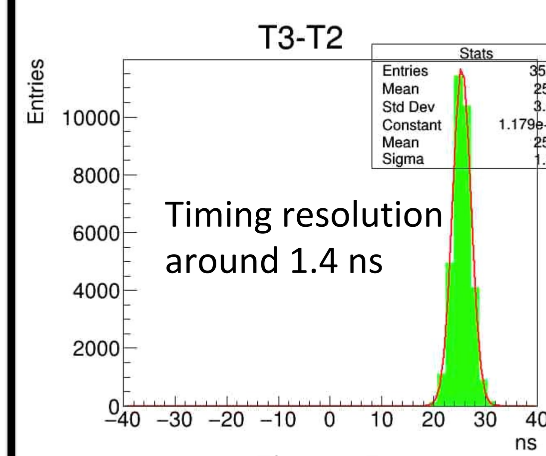


Figure 5
The time difference of a pair of detectors

The cable offsets were determined from the distributions of the time differences of the pulses when a muon penetrated the devices. The mean values of the histograms (see Figure 5) are used for the offset estimation, while the rms of the distribution is used to estimate the timing resolution of each detector unit.

The characterization of each detector unit included also the measurement of the mean pulse shape and the pulse height distribution when a minimum ioinising particle passes through the detection unit. All calibration procedures are automatized and deployed by a web application that is used also for the online telescope operation, data quality inspection and shower reconstruction (Figure 6).

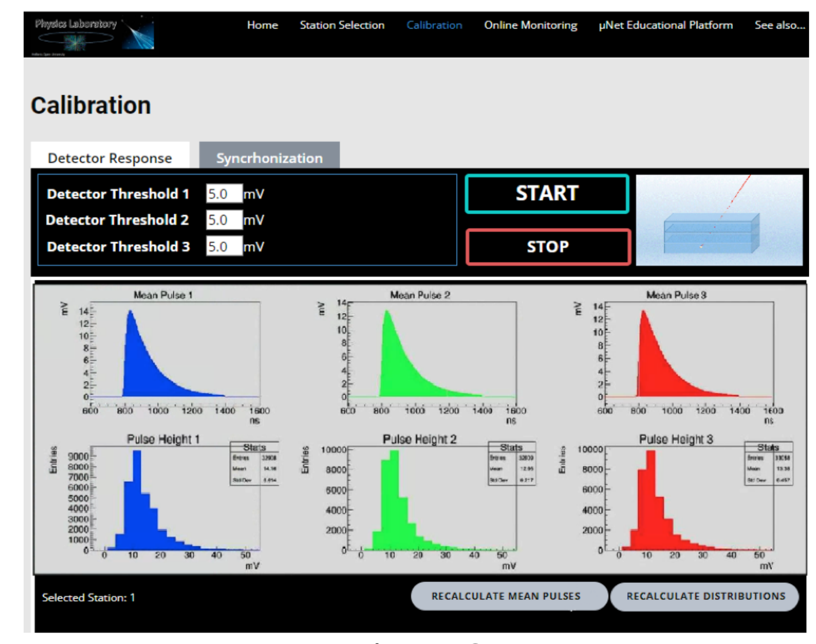
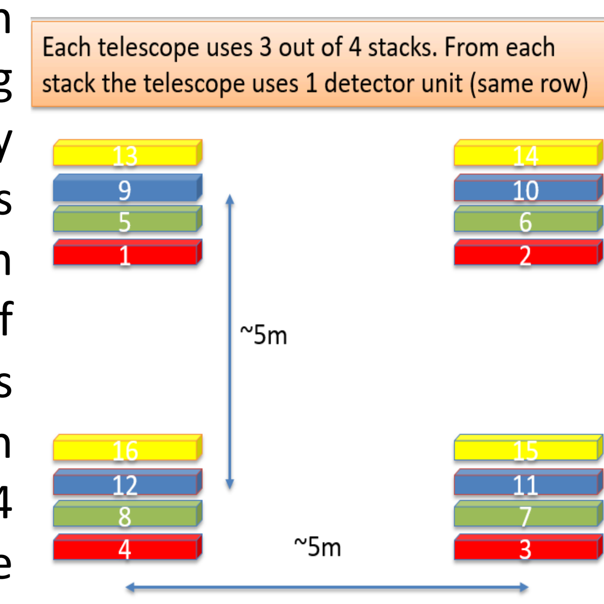


Figure 6
The characterization of the detection units using the online web application

Performance

In order to study the resolution of the telescope in estimating the direction of the primary cosmic ray, 16 detection units were arranged as shown in Figure 7, left. Four stacks of detectors were placed at the tips of a square of side ~5 meters. In each stack there were 4 detectors one on top of the other. That way 16 different telescopes were formed following 4 different geometries (Figure 7, right).



Telescope	Detector Units
1	2,3,4
2	1,3,4
3	1,2,4
4	1,2,3
5	6,7,8
6	5,7,8
7	5,6,8
8	5,6,7
9	10,11,12
10	9,11,12
11	9,10,12
12	9,10,11
13	14,15,16
14	13,15,16
15	13,14,16
16	13,14,15

Figure 7
The experimental setup for the determination of the telescope's resolution. The combination of the detection units for each telescope is shown on the table.

The reconstruction rate was calculated by the distribution of time between consecutive reconstructed events. The distribution is exponential and the rate is calculated from the mean value (see Figure 8, left). The telescopes reconstruction rates is shown on the right of Figure 8, where the color coding is the same as in Figure 7.

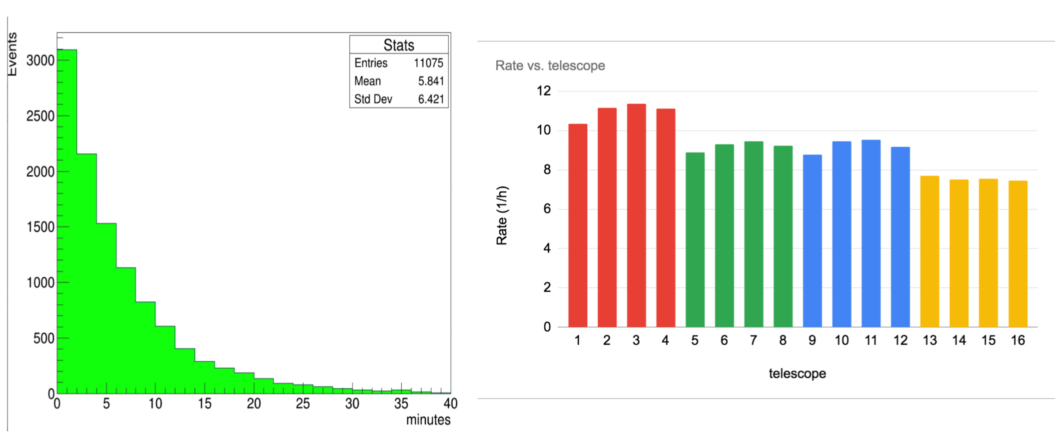


Figure 8
The distribution of the time between consecutive events (left). The reconstruction rates of the 16 telescopes (right).

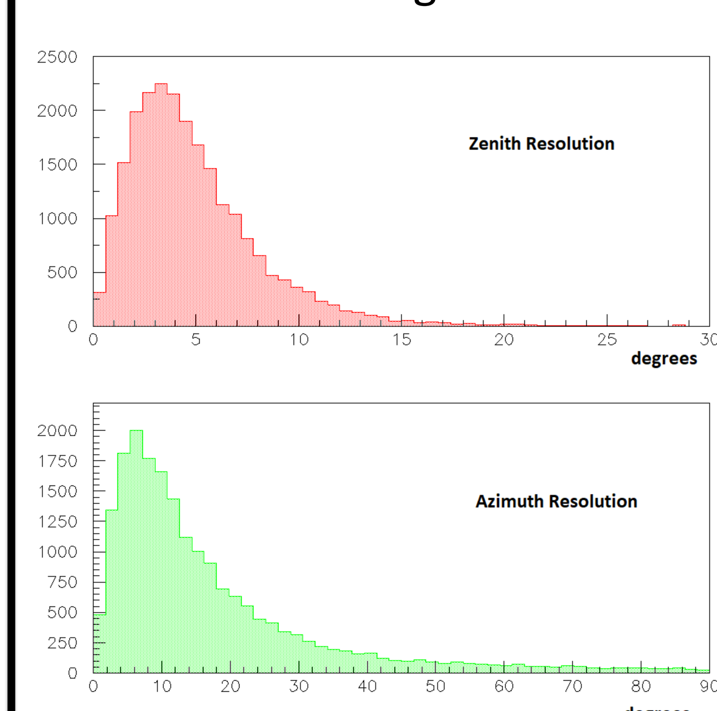


Figure 9
The distributions of zenith (top) and azimuth (bottom) resolution.

By comparing the reconstructed direction of a shower using different telescopes the corresponding resolution is estimated. Showers that are reconstructed simultaneously by more than one telescope are analyzed to estimate the overall performance (i.e. without applying any quality criteria cuts). The zenith and azimuth resolutions are expressed as the variances of the corresponding measurements. The distributions of the resolutions are shown in Figure 9.

A new experimental setup has been deployed in order to investigate the effect of the geometrical layout of a μCosmics station, as well as for the comparison with the Monte Carlo simulation. Eight detection units were arranged as it is shown in Figure 10, offering 56 different μCosmics telescopes (3 out of 8 combinations). The 56 telescopes will be available for high school students that participate to μNet as remote users, by assigning one telescope for each school.

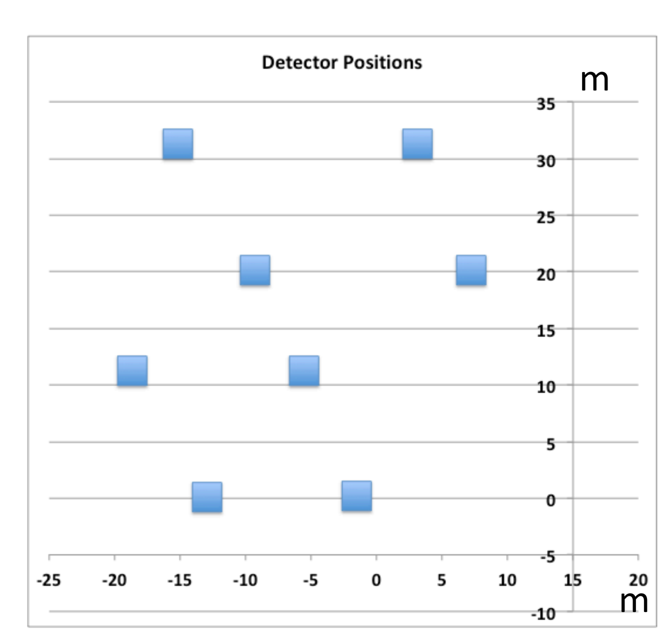


Figure 10
The arrangement of eight detection units that is used for the study of the geometrical layout of a μCosmics telescope

Acknowledgments
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