15TH TOPICAL SEMINAR ON INNOVATIVE PARTICLE AND RADIATION DETECTORS (IPRD19)

Siena, 14 - 17 October 2019

MONITORING THE LONG-TERM STABILITY OF CIVIL BUILDINGS THROUGH THE MRPC TELESCOPES OF THE EEE PROJECT

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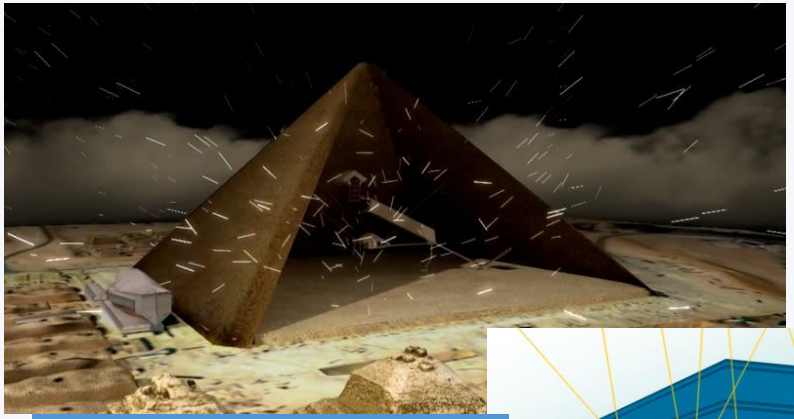
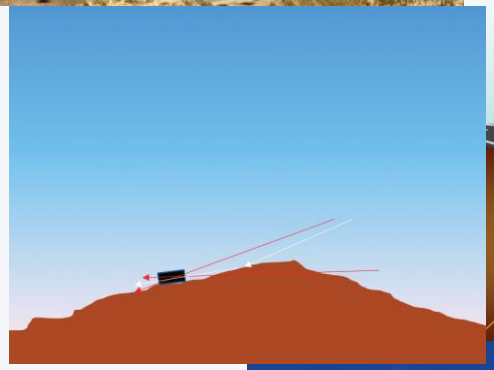
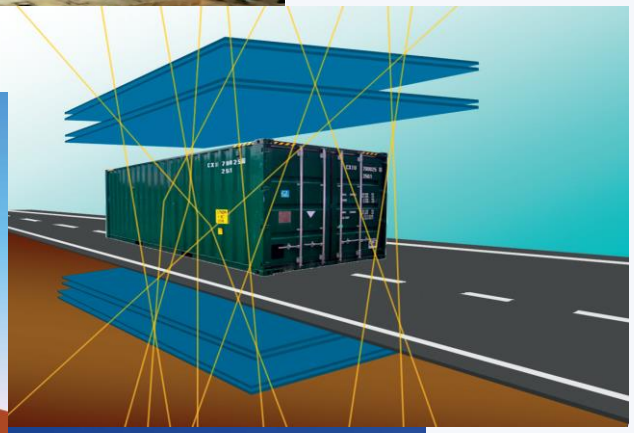
Applications of secondary cosmic rays

APPLICATIONS:

- Vulcanology
- Underground measurements
- Archaeology
- Homeland security
- Muon tomography
- …



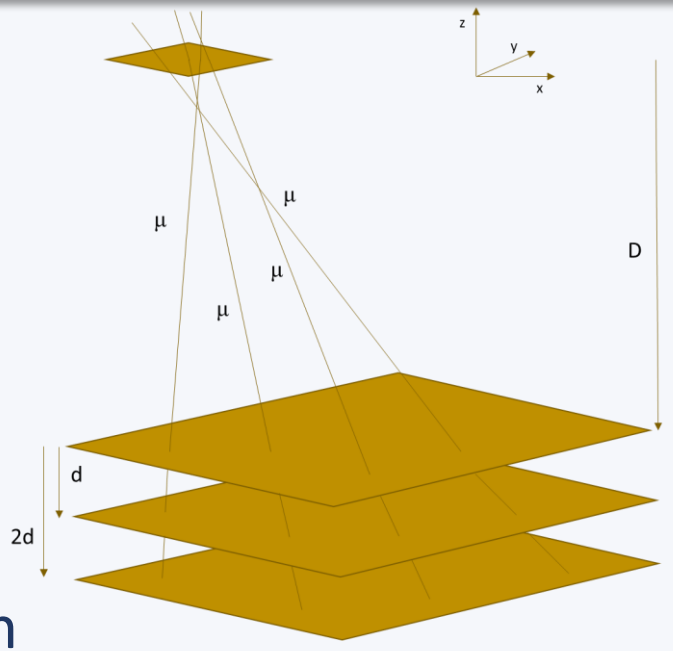




→ Long-term building stability monitoring

Cosmic muons as a tool to monitor the stability of civil structures on a long-time scale

Muons passing through a tracking detector and additional detectors are used as a tool to monitor small (mm) shifts of parts of the structure over long time periods.



- limited invasiveness
- use of a free natural source of radiation
- μ are highly penetrating walls and floors are easily traversed
- no need of visibility or empty spaces (VS optical systems)
- possibility to design a global monitoring system
- low rate of cosmic muons (relatively) long data taking

Cosmic muons as a tool to monitor the stability of civil structures on a long-time scale

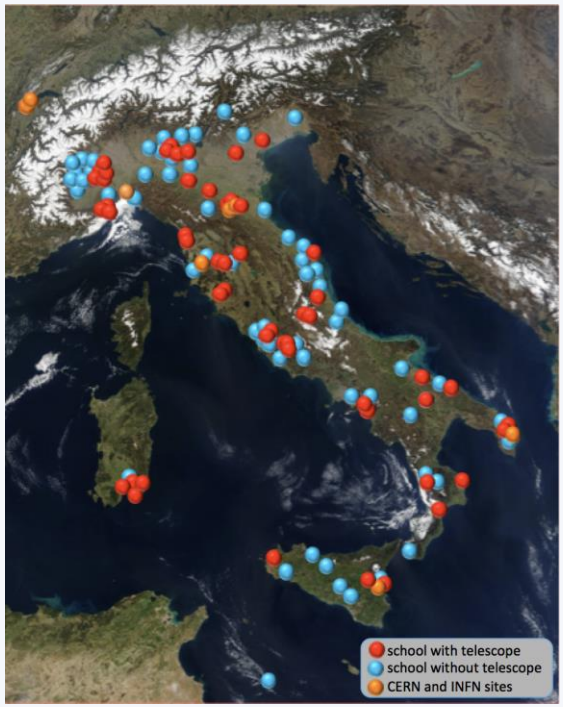
- Extensive simulations and prototype detectors being implemented by Brescia-Pavia groups in Italy (G.Bonomi et al.).
- Technique applied to “Palazzo della Loggia” in Brescia as a case study.

Performances of the method depend on: capability of the main tracking detector, geometry and position of the additional detectors, measurement stability, acquisition time,..

→ Coincidence measurements with a tracking detector of the EEE Project and an additional detector carried out in Catania to test such a possibility

EEE Telescopes

Extreme Energy Events Project: collaboration of Centro Fermi, INFN, CERN & MIUR.



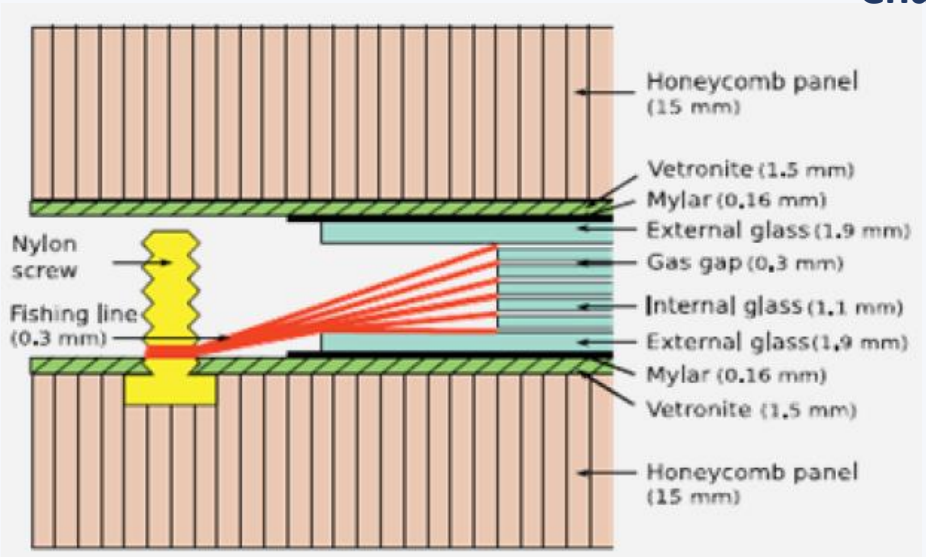
It aims at the detection of cosmic ray muons by means of a *sparse array of telescopes*, distributed all over the Italian territory.

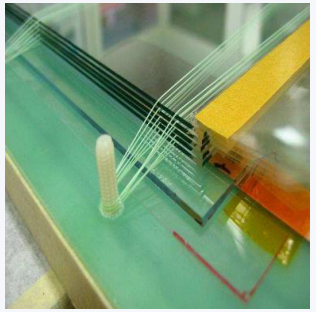
- 56 telescopes in high schools
- 2 telescopes at CERN
- 4 at INFN Sections

Total: 62 telescopes

(+50 institutes on the waiting list)

Network of telescopes based on Multi-gap Resistive Plate Chambers (MRPC)



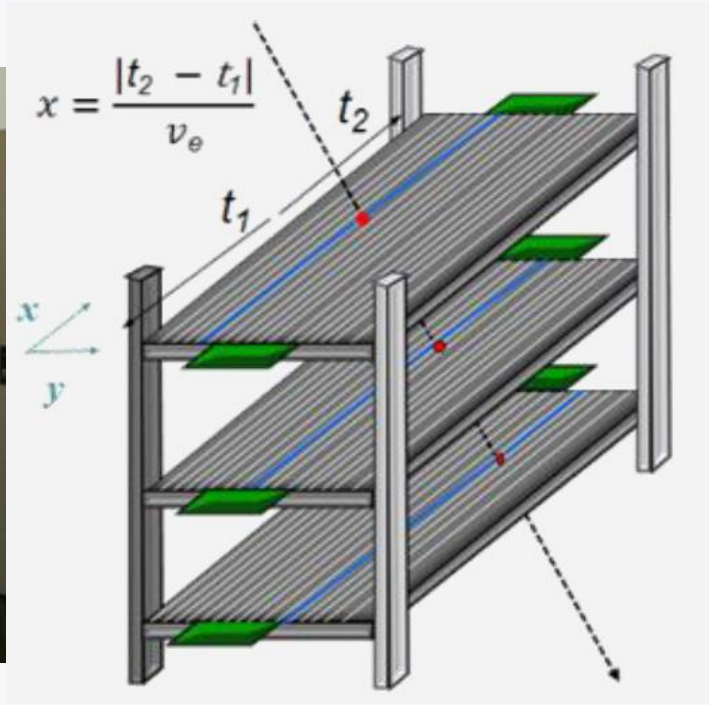


EEE Telescopes

- Reasonable cost
- Long term operation required
- Reconstruction of muon orientation
- TOF measurements
- Chambers built by students and teachers at CERN

Performance of the MRPCs:

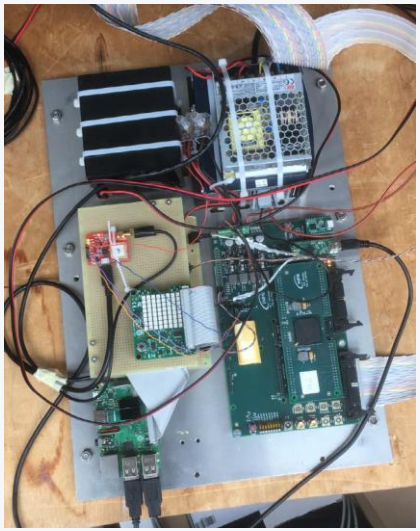
- Time Resolution ~ 240 ps
- Longitudinal Spatial Resolution ~ 1.5 cm
- Transverse Spatial Resolution ~ 1 cm
- Efficiency ~ 93 %



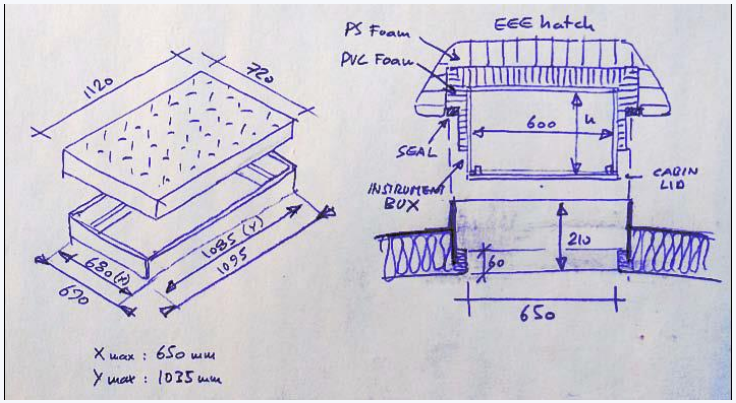
POLAR detector

Polar is one of the three detectors of the PolarquEEEst project by Centro Fermi

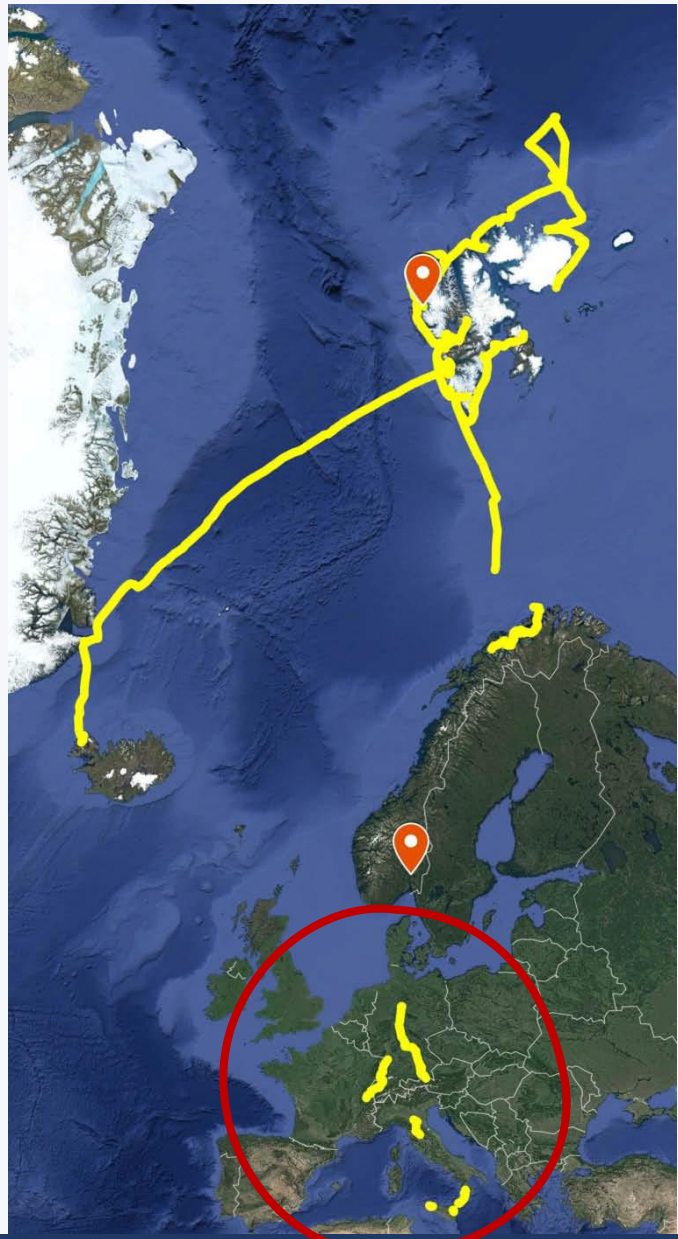
Assembled at CERN by high school students



- 2 Plastic scintillator planes
- Distance between planes: 11 cm
- 4 Tiles for each plane: 30 cm x 20 cm
- 2 SiPMs per tile (16 SiPMs in total)

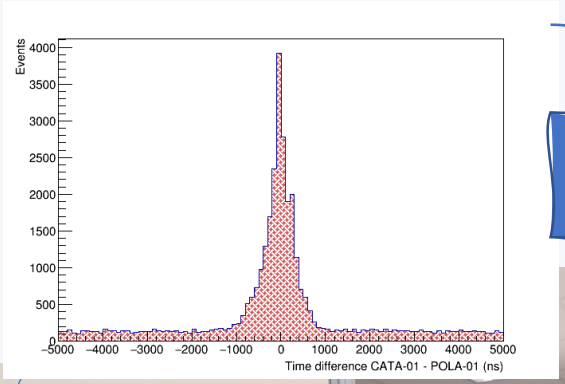


- ✓ Nanuq
- ✓ Genova
- ✓ Vigna di Valle (Rome)
- ✓ Cosenza
- ✓ Messina
- ✓ Cefalù (Palermo)
- ✓ Erice (Trapani)
- ✓ Catania-Etna
- ✓ Lampedusa
- ✓ Bologna
- ✓ Munich
- ✓ Hannover
- ✓ Frankfurt am Main
- ✓ CERN



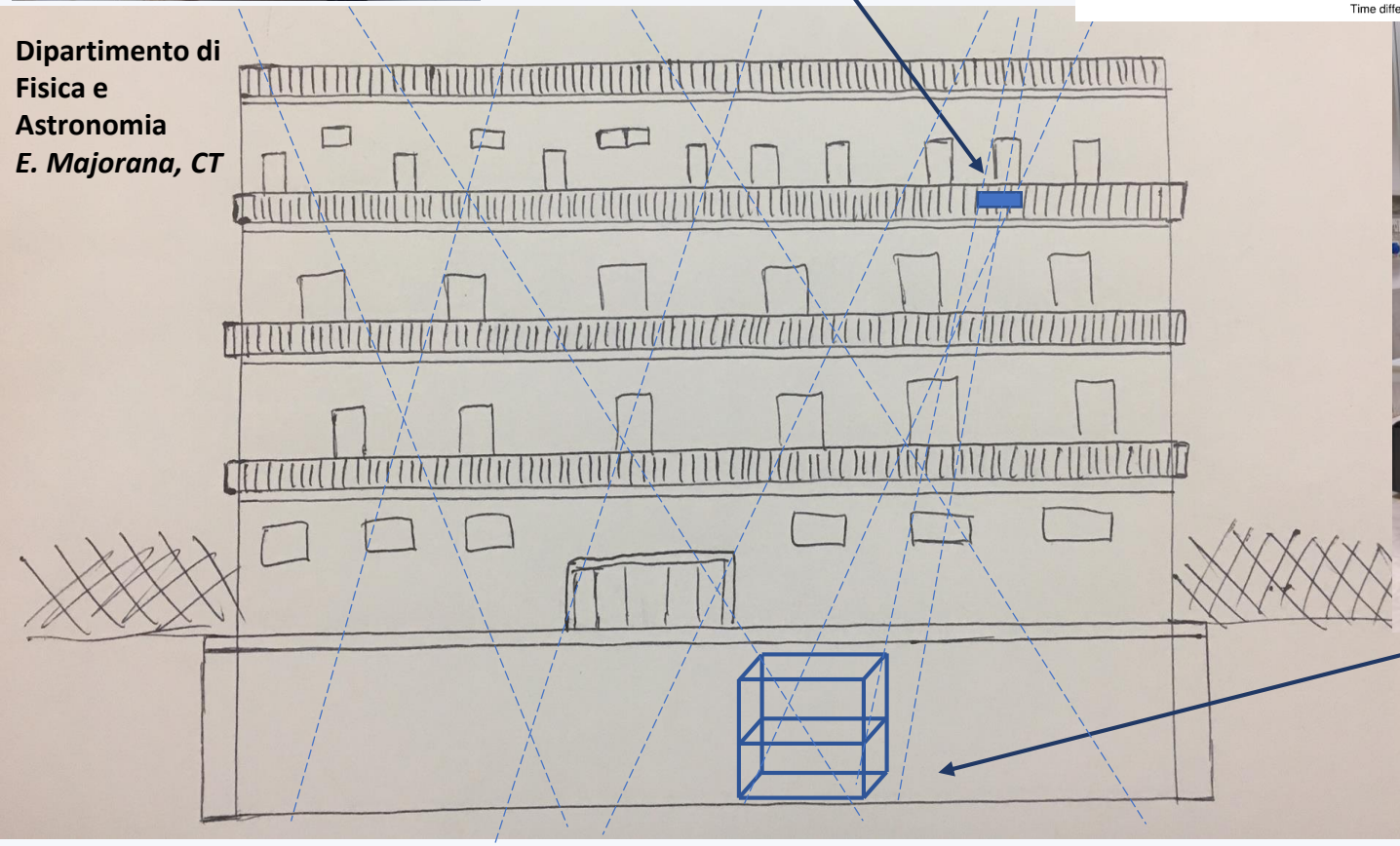
Experimental setup @ DFA- UniCT

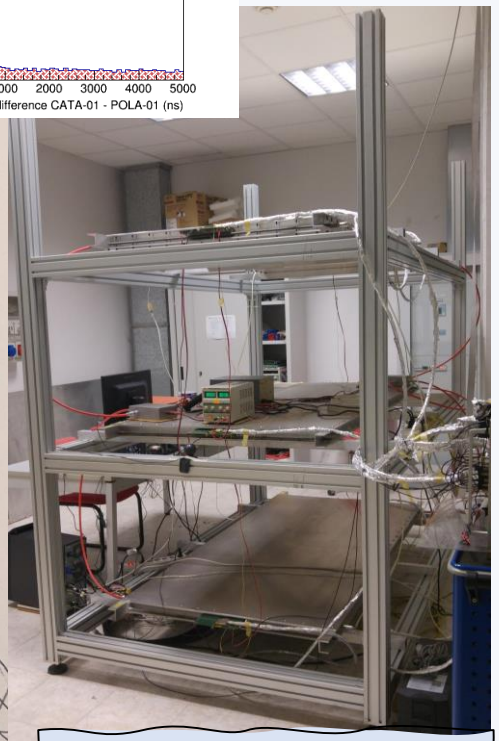
- GPS time tagging of events (20 ns time resolution)
- Average count rate a.s.l. ~30 Hz



Coincidence: 600 ns time window

Dipartimento di Fisica e Astronomia *E. Majorana, CT*



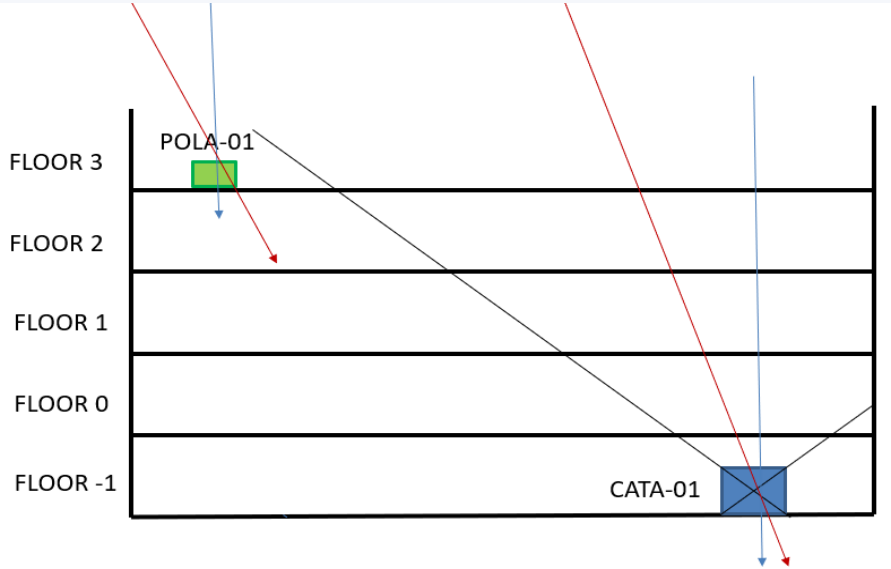


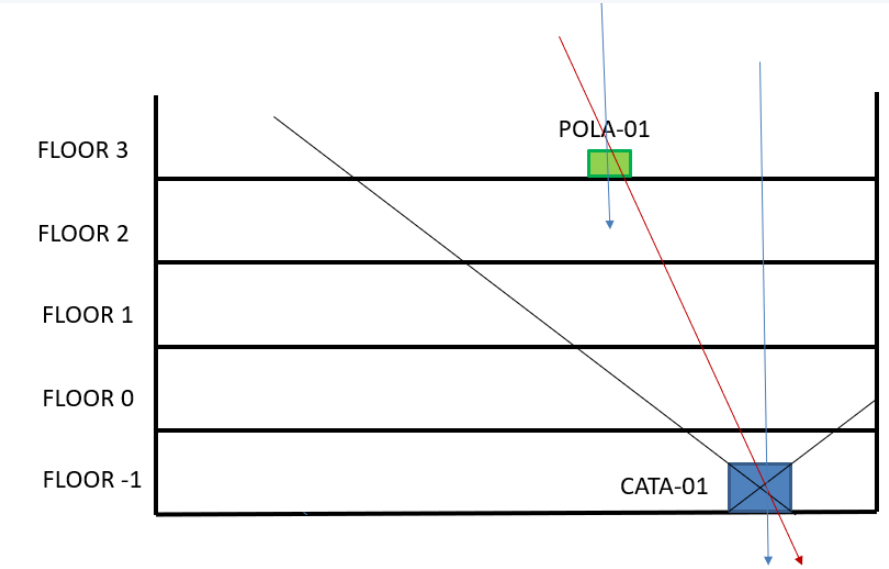
- GPS information (40 ns time resolution)
- Detection efficiency >90%

Measurements

Measure 1 – **outside** the acceptance cone:
two independent muons.
~ **13 days** DAQ

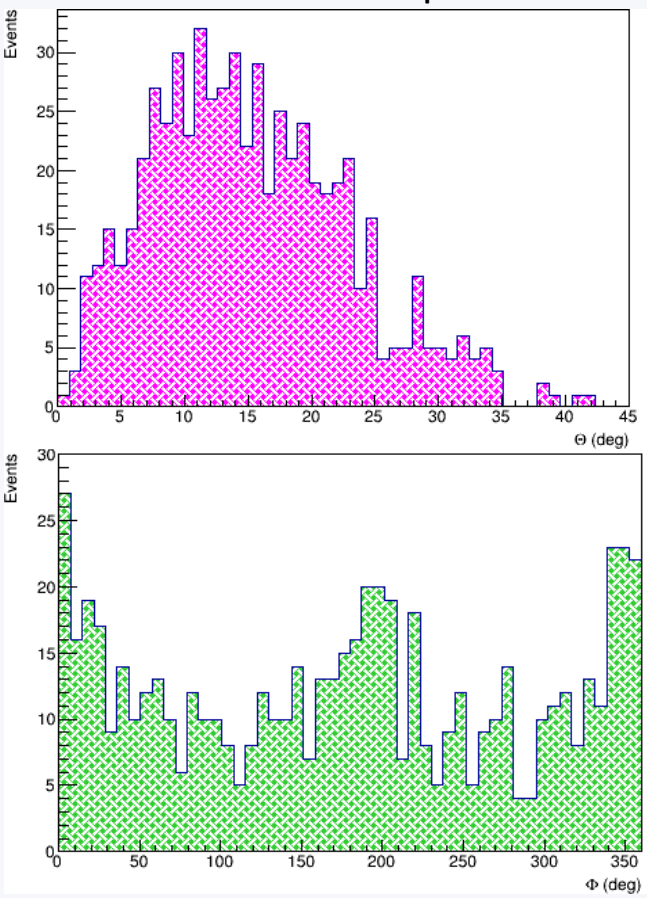
Measure 2 – **inside** the acceptance cone:
also muons passing through both detectors.
Narrow acceptance cone.
~ **47 days** DAQ



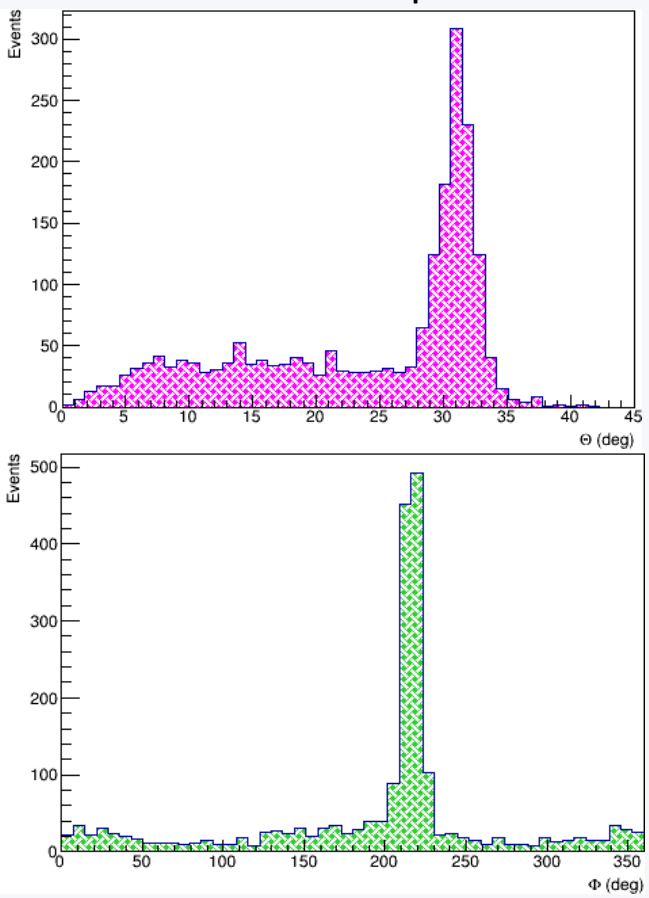


Zenithal and azimuthal distributions

Outside CATA-01 acceptance cone



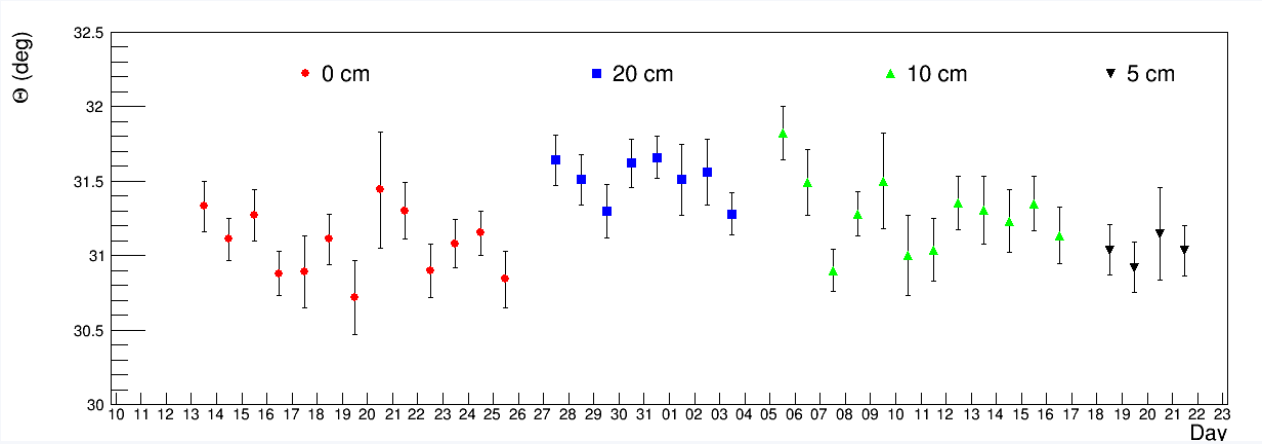
Inside CATA-01 acceptance cone



Broad distributions → two individual, time correlated muons from the same shower

Main peak → same muon track intersecting both detectors

Daily variation of the average value of θ

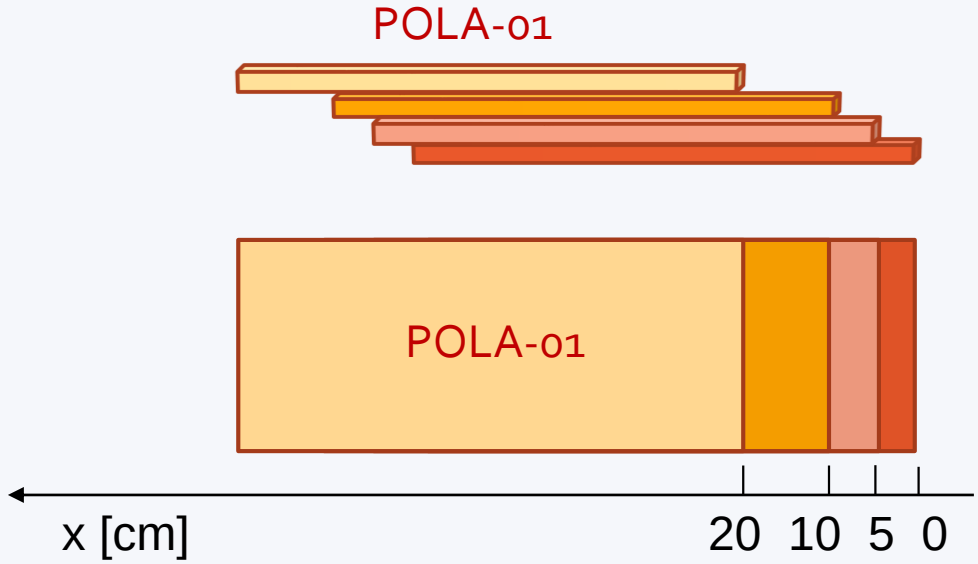


Four sets of measurements:

- Reference -> 0 cm
- First shift -> 20 cm
- Second shift -> 10 cm
- Third shift -> 5 cm

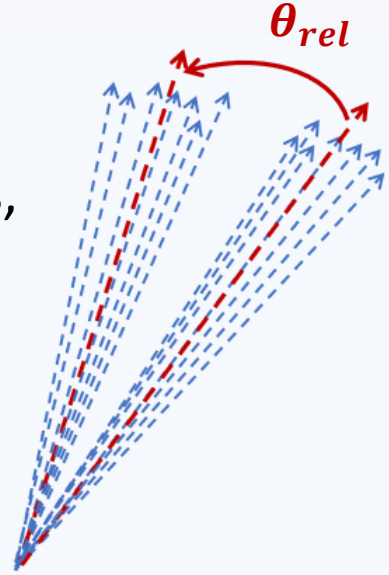
Mean values for θ and ϕ angles, estimated with a Gaussian fit.

Gaussian fit		
x [cm]	**< θ > ± Δ<θ>**	**< ϕ > ± Δ<ϕ>**
0	31.03° ± 0.05°	216.39° ± 0.16°
+5	31.18° ± 0.07°	215.88° ± 0.33°
+10	31.36° ± 0.08°	215.98° ± 0.30°
+20	31.45° ± 0.06°	215,67° ± 0.20°



Shift of the average direction in space

Estimation of the average direction in space, summing on all the tracks, in 3 configurations (5 cm, 10 cm, 20 cm).

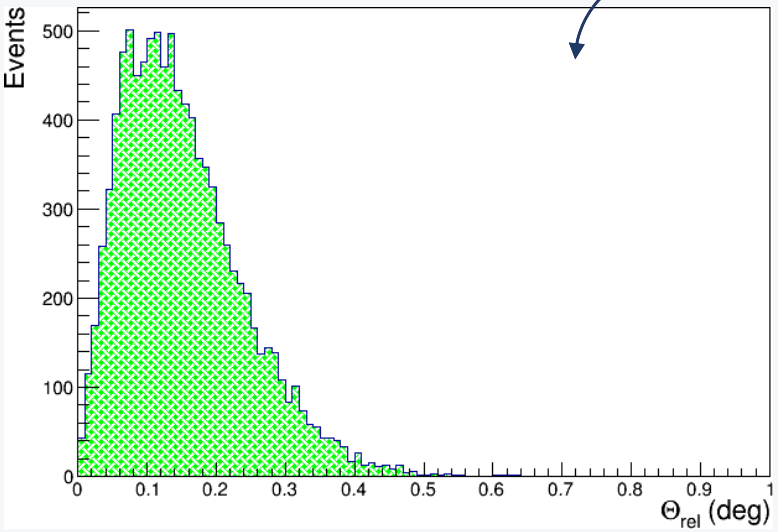


To estimate the ***uncertainty in the relative angle***:

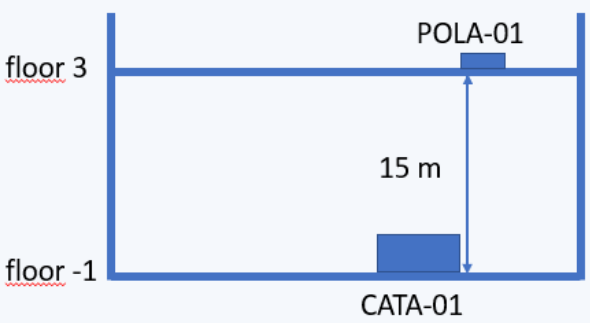
- split the overall set of tracks in 2 subsets
- evaluate their average direction
- generate a large number of subsets
- distribution of these differences

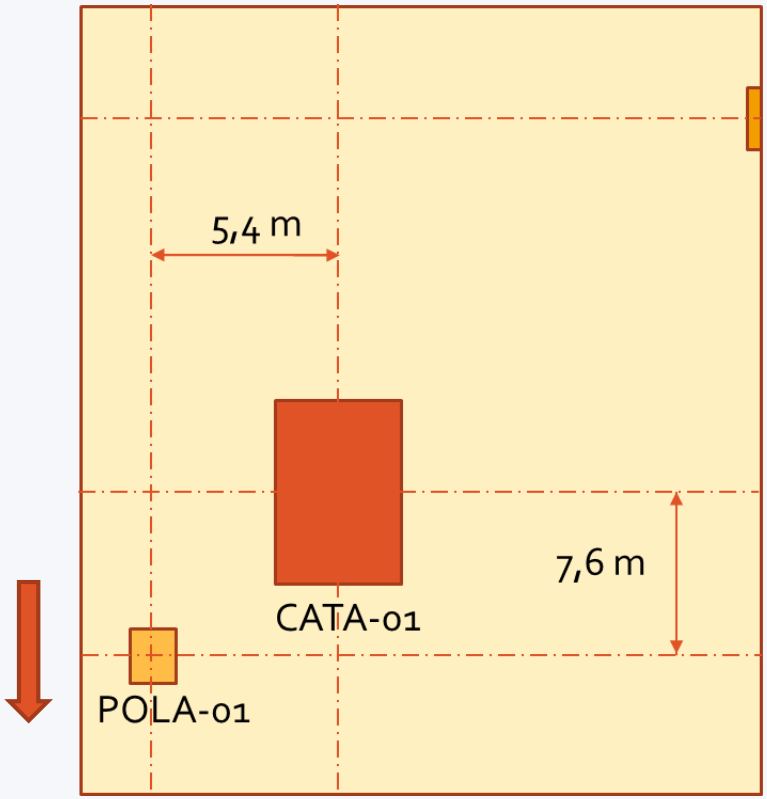
Relative distance	Relative angle shift
20 cm	0.44°
10 cm	0.24°
5 cm	0.31°

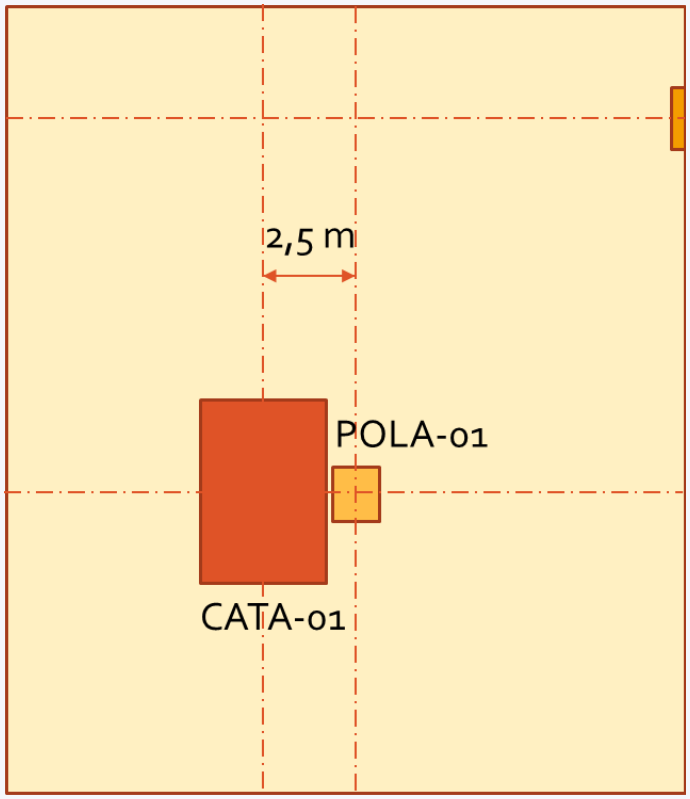
5 cm measurement has a very short statistics – just 4 days



Position of detectors







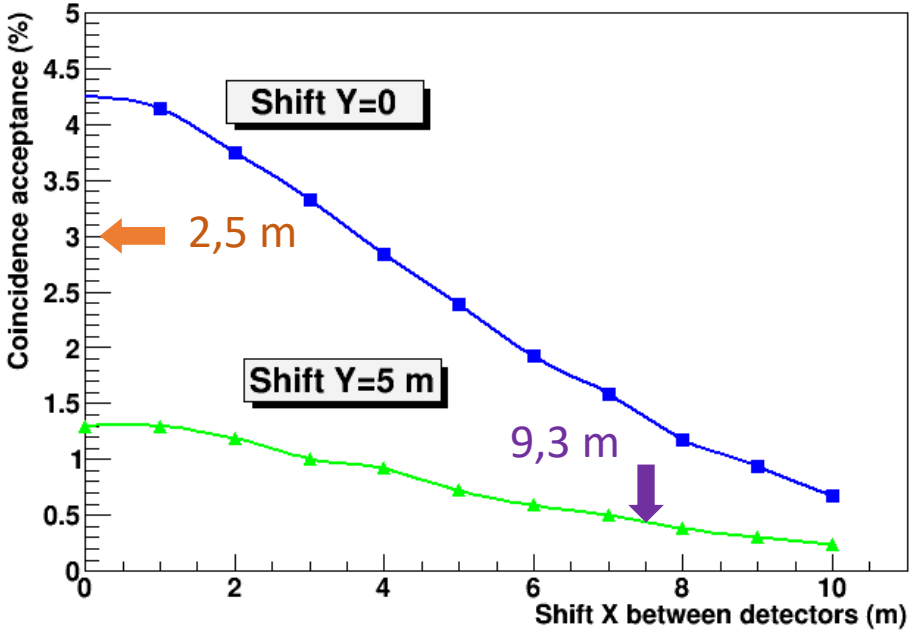
POLA-01 was moved closer to the vertical of CATA-01

Effect of relative position

Relative horizontal distance between detectors	Acquisition time	# events
9,3 m	~ $7 \cdot 10^5$ s	757
2,5 m	~ $6 \cdot 10^5$ s	4305

Sensitivity at 2.5 m:
- *few **cm** in 1 day data taking*
- *few **mm** in few months data taking*

- POLA-01 was moved closer to the vertical of CATA-01
- Statistics increased by a factor ~ 7, in agreement with MC simulations.

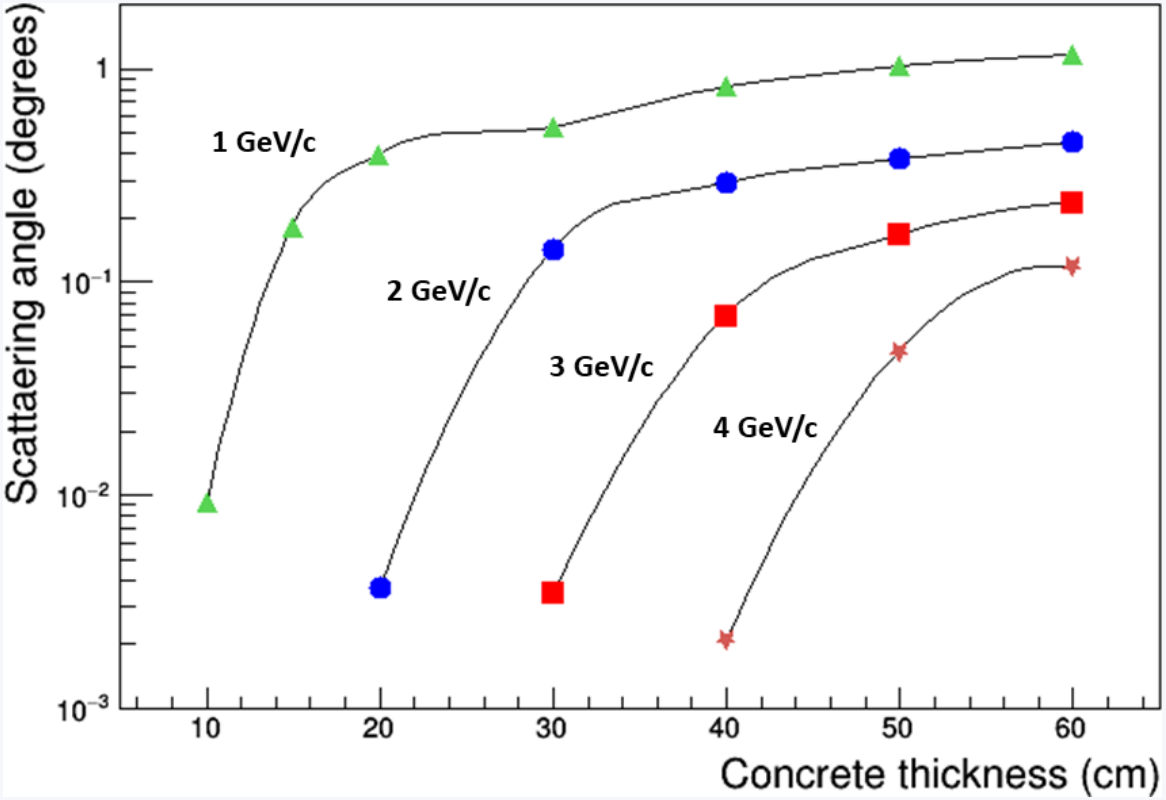


GEANT3 Simulations

→Evaluation of multiple scattering effect due to the interposed material between the two detectors

→60 cm of concrete-equivalent solid for the 4 layers

→For *p* around 3-4 GeV/c → 0.1°-0.2° comparable to the observed uncertainty

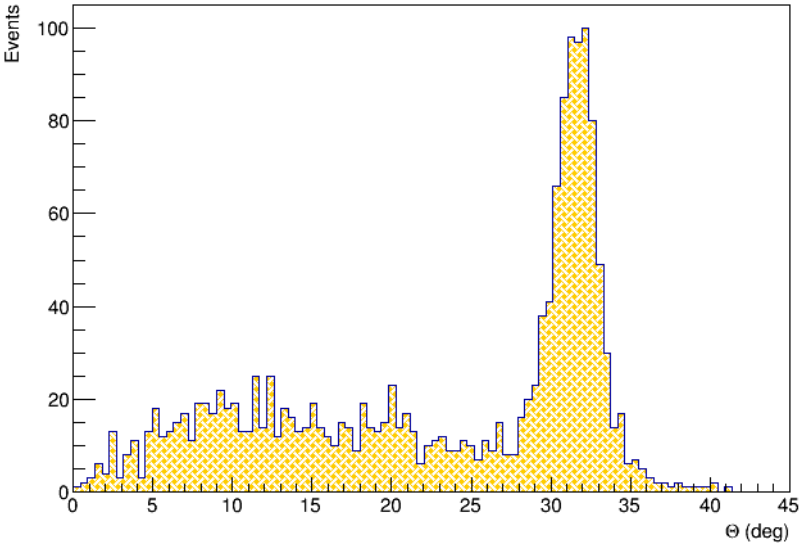


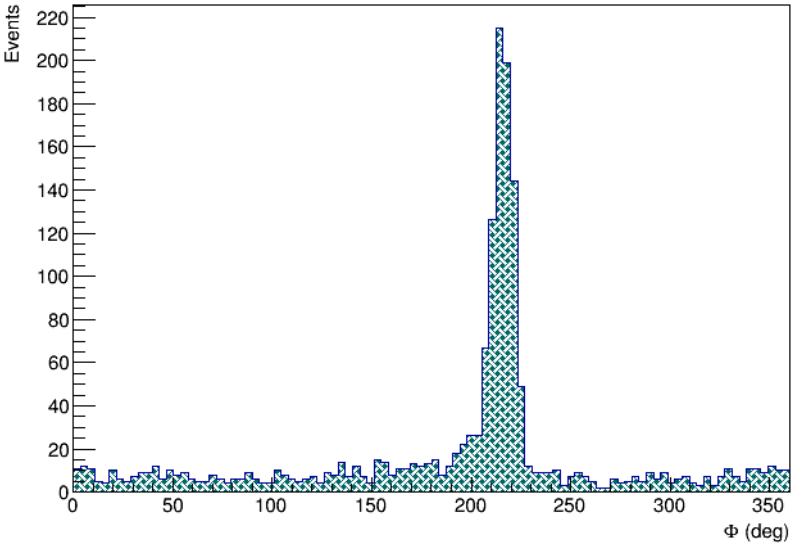
Conclusions & Outlook

- Coincidence measurements between MRPC EEE telescope & POLA-01 were carried out to test the possibility of monitoring the long-term building stability
- The sensitivity of the method may be roughly estimated of the order of **few mm** for a data taking period of **several weeks** (in the optimal relative distance)
- Most of the EEE telescopes are presently located inside school buildings → the addition of one or several small scintillators with good capabilities in the same building could offer a further contribution to the EEE activities in the schools

BACKUP

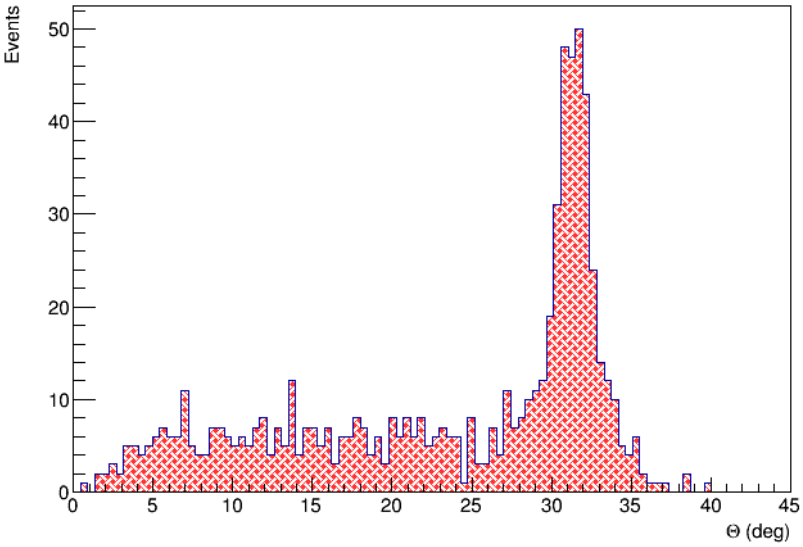
20 cm shift

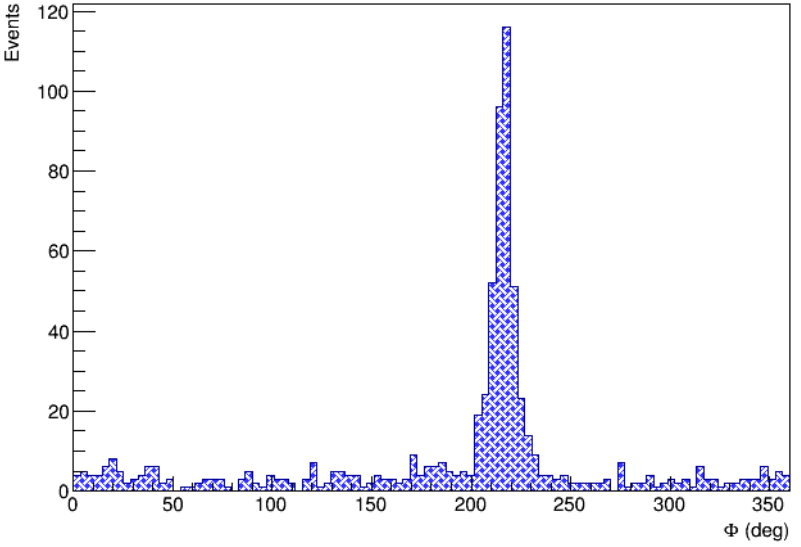




x [cm]	< θ > ± Δ<θ>	< ϕ > ± Δ<ϕ>
0	31.03° ± 0.05°	216.43° ± 0.20°
+20	31.45° ± 0.06°	216.23° ± 0.32°

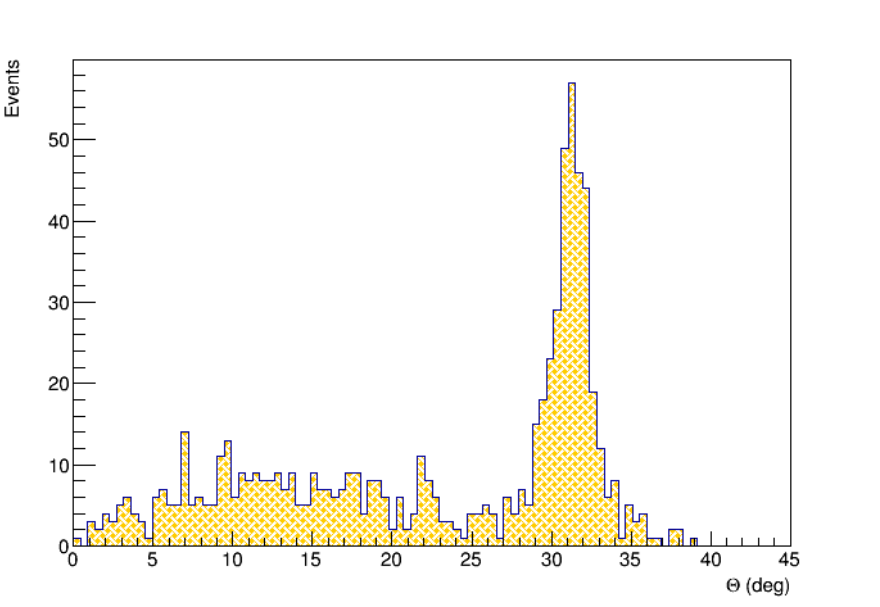
10 cm shift

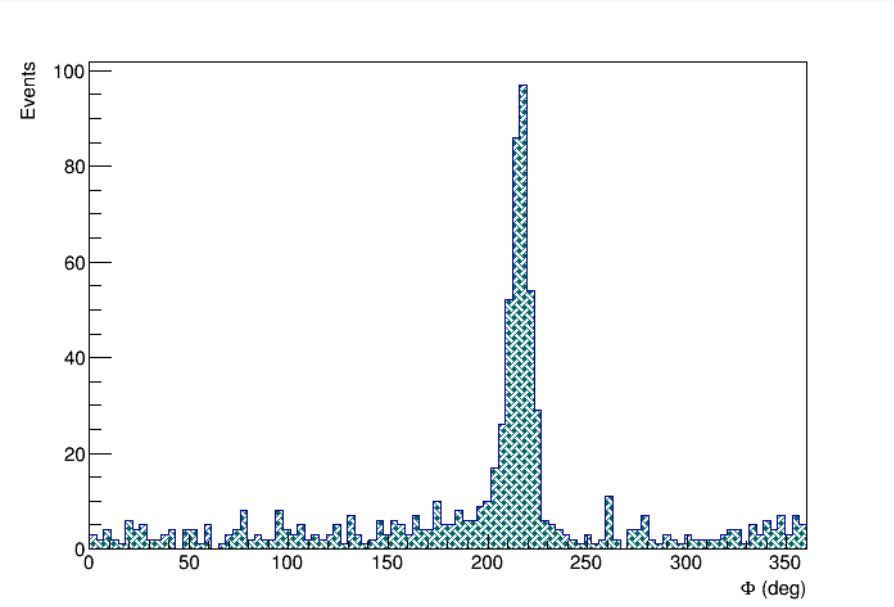




x [cm]	< θ > ± Δ<θ>	< ϕ > ± Δ<ϕ>
0	31.03° ± 0.05°	216.43° ± 0.20°
+10	31.36° ± 0.08°	216.15° ± 0.29°

5 cm shift





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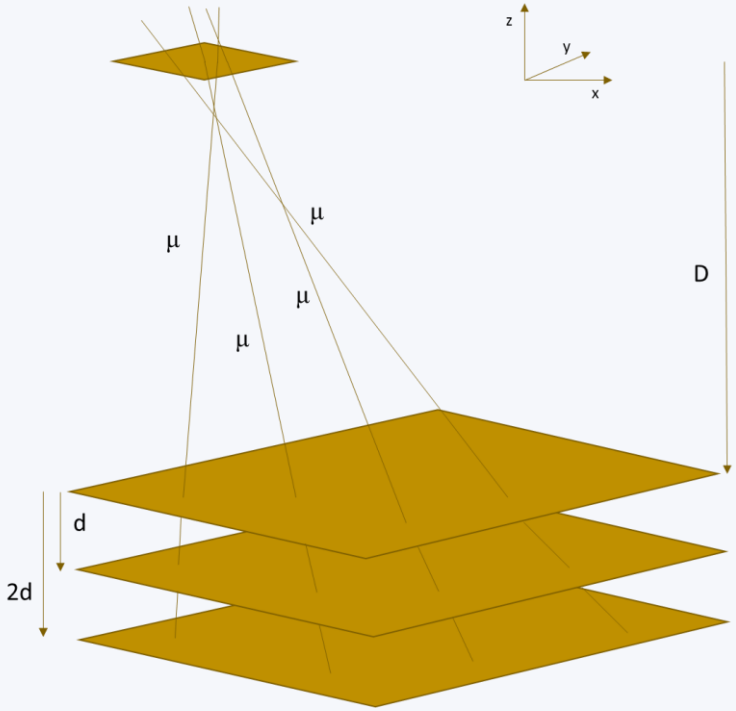
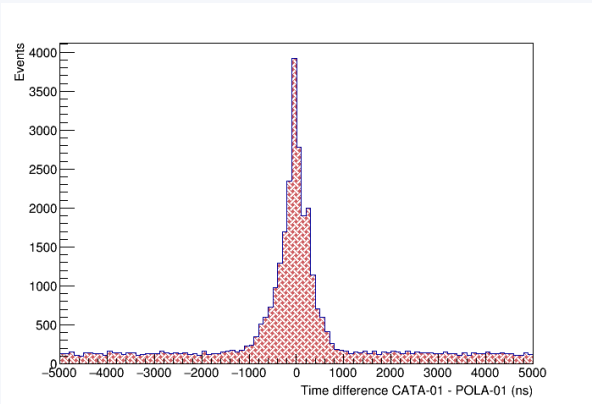
0	31.03° ± 0.05°	216.43° ± 0.20°
+5	31.18° ± 0.07°	215.88° ± 0.33°

Coincidence measurements

Coincidence window
$\lvert(\Delta t + (t\text{-}int(t)) \cdot 2500 - 1500) - 140\rvert < 600$ ns
Quality cuts
$\chi^2 < 10$
-2 ns < ToF < 10 ns
Number of satellites POLA-01 ≥ 3
Number of satellites CATA-01 ≥ 3
Number of tracks POLA-01 = 1
Number of tracks CATA-01 = 1





→Two detectors working separately

→Coincidence measurement selected using the GPS information in a 600 ns time interval

Detectors

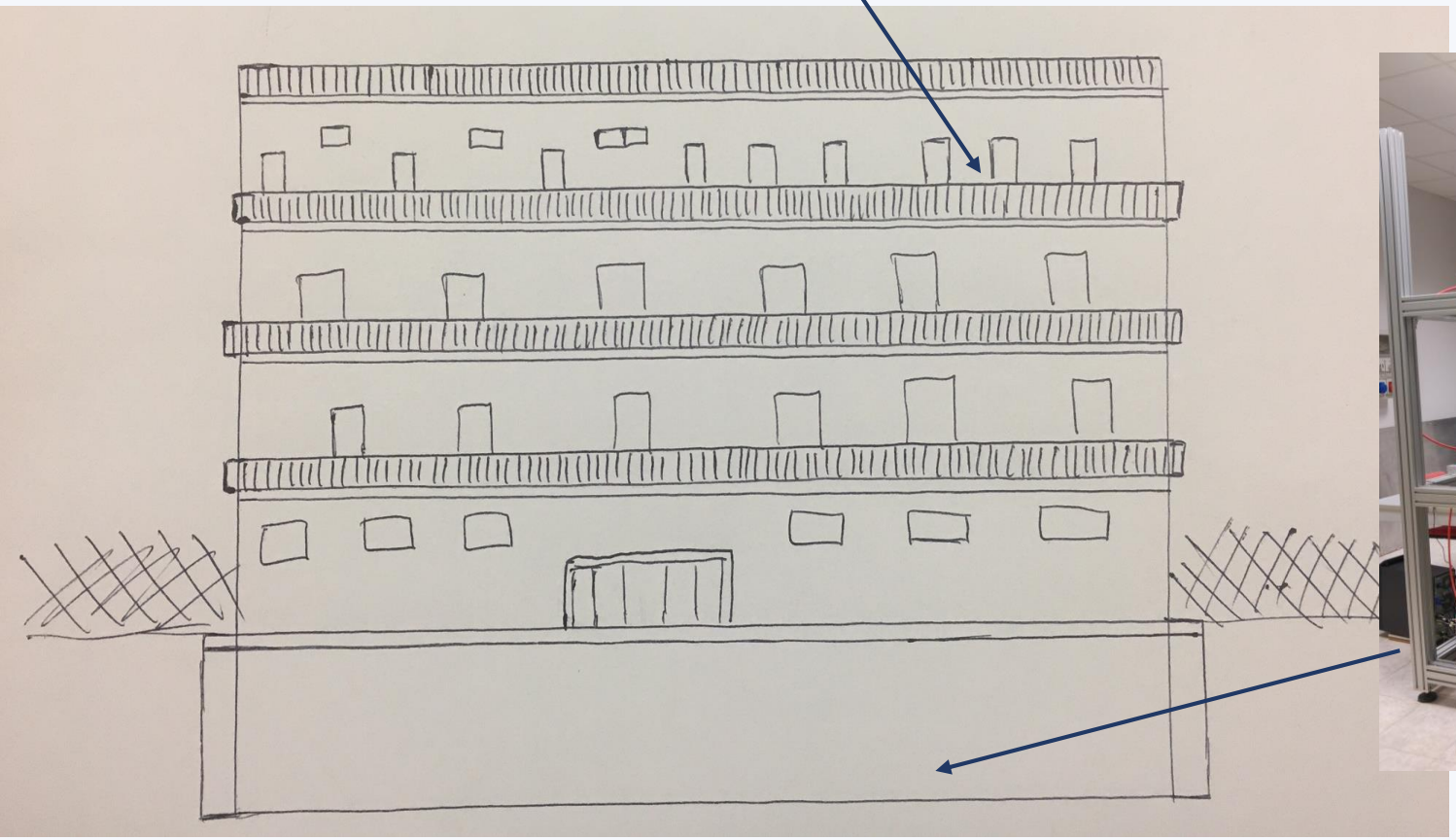
POLA-01

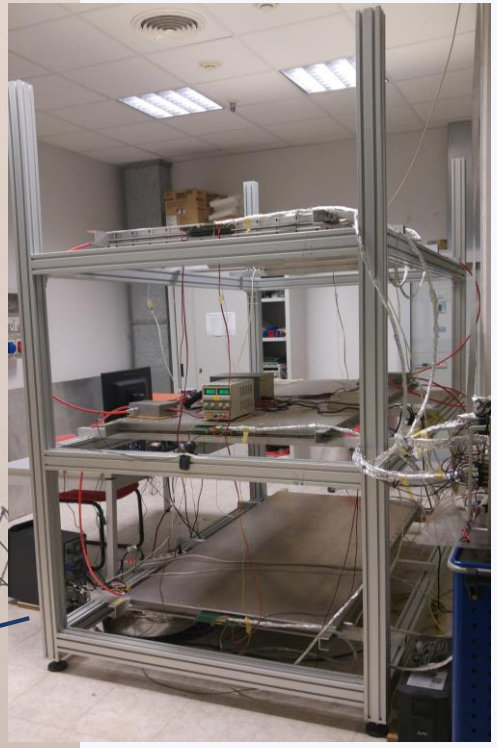
- Scintillator-based technology
- 56 x 78 x 19.5 cm^3
- GPS time tagging of events (20 ns time resolution)
- Average count rate a.s.l. ~30 Hz

CATA-01

- Gas-based technology
- 3 MRPC 158 x 82 cm^2
- GPS information (40 ns time resolution)
- Detection efficiency >90%

Detectors





Track Selection

Coincidence window
$\lvert(\Delta t + (t\text{-}int(t)) \cdot 2500 - 1500) - 140\rvert < 600$ ns
Quality cuts
$\chi^2 < 10$
-2 ns < ToF < 10 ns
Number of satellites POLA-01 ≥ 3
Number of satellites CATA-01 ≥ 3
Number of tracks POLA-01 = 1
Number of tracks CATA-01 = 1

Corrected time difference spectrum