XV Workshop on Resistive Plate Chambers and Related Detectors RPC2020

Use of the EEE MRPC telescopes to investigate possible instabilities of civil structures on a long time-scale

Chiara Pinto* for the EEE Collaboration

*Centro Fermi, Rome; University and INFN, Catania

Istituto Nazionale di Fisica Nucleare

Dipartimento di Fisica e Astronomia "Ettore Majorana"

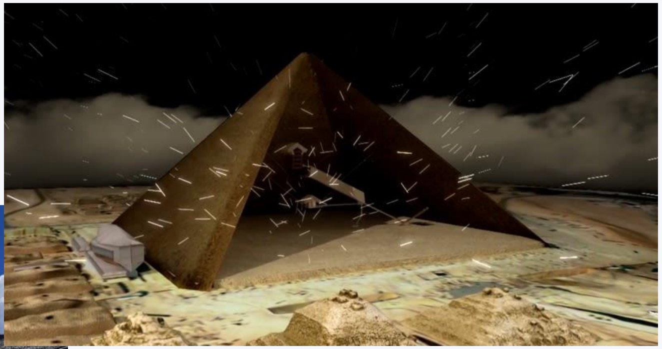
Centro Fermi – Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi

Extreme Energy Events – Science inside Schools

Applications of secondary cosmic rays

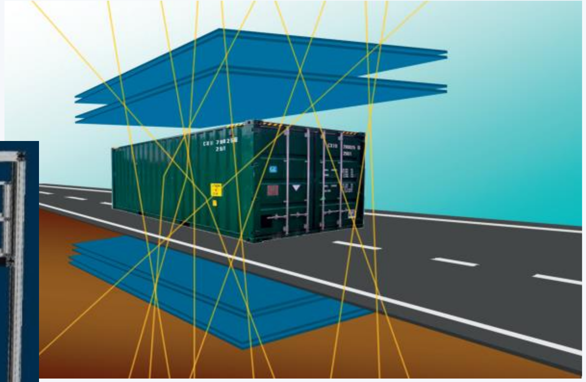
MUON ABSORPTION

- *Vulcanology*
- *Underground measurements*
- *Archaelogy*



MUON SCATTERING

- *Homeland security*
- *Safety – Nuclear reactor and waste*

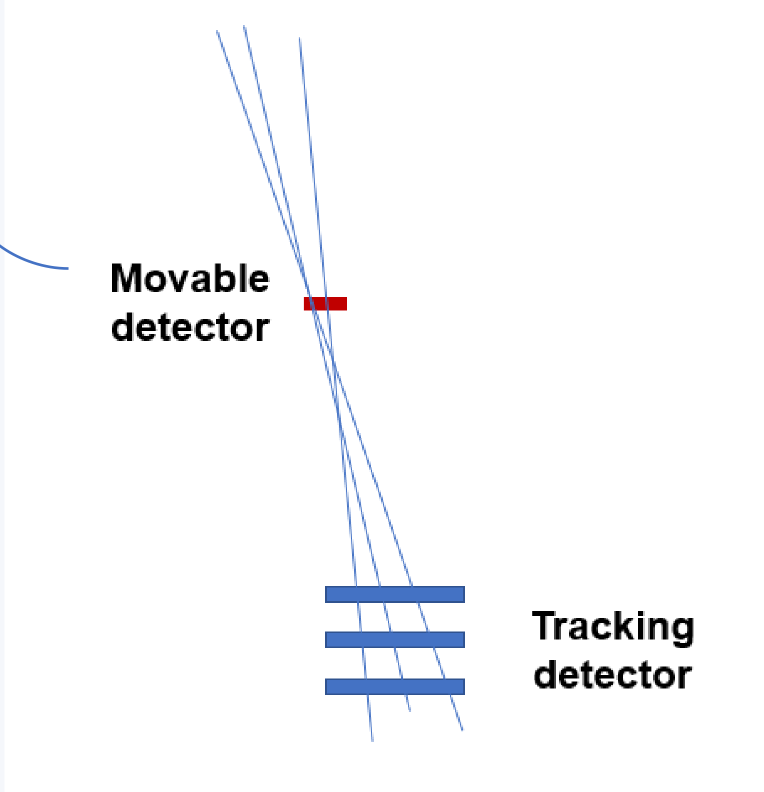


→ Long term building stability monitoring

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

THE IDEA → **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.**

Moved to mimic possible deformations of the building



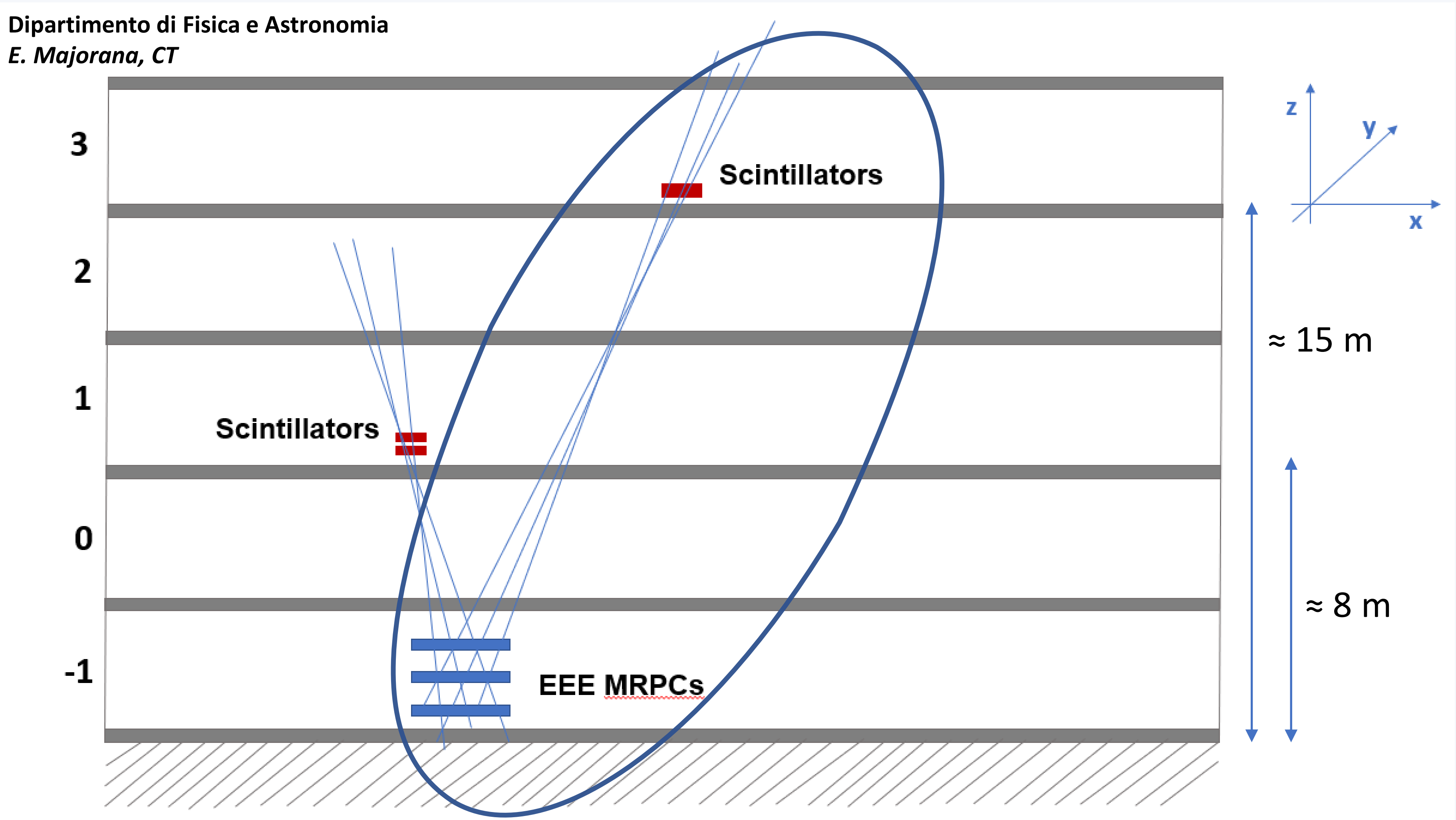
Extensive simulations and prototype detectors by Brescia Pavia groups (G.Bonomi et al.)

Technique applied to “Palazzo della Loggia” in Brescia as a case study.

Depend on: capability of the main tracking detector, geometry and position of the additional detectors, constant response of detectors, acquisition time,.. ← **PERFORMANCE**

Experimental setup to monitor the building stability

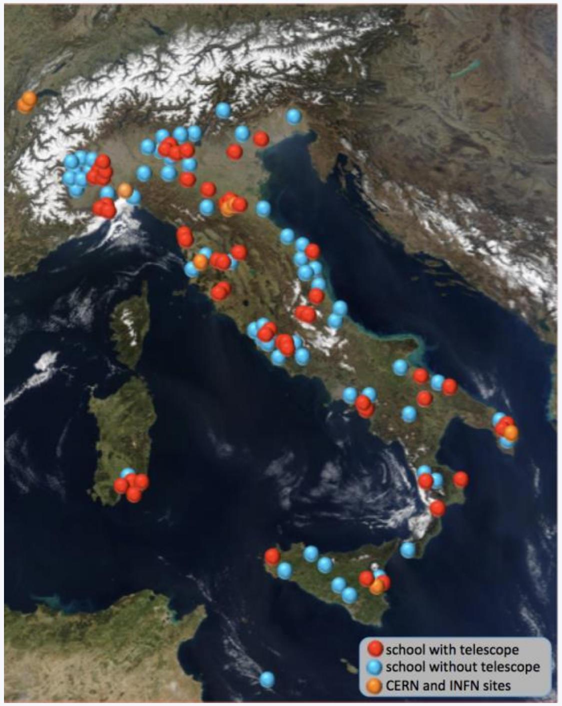
In Catania → 2 experimental setup to test the possibility of monitoring the long term building stability



EEE Telescopes

See talks by F. Coccetti, G. Mandaglio & M.P. Panetta

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.

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

Total: 59 telescopes

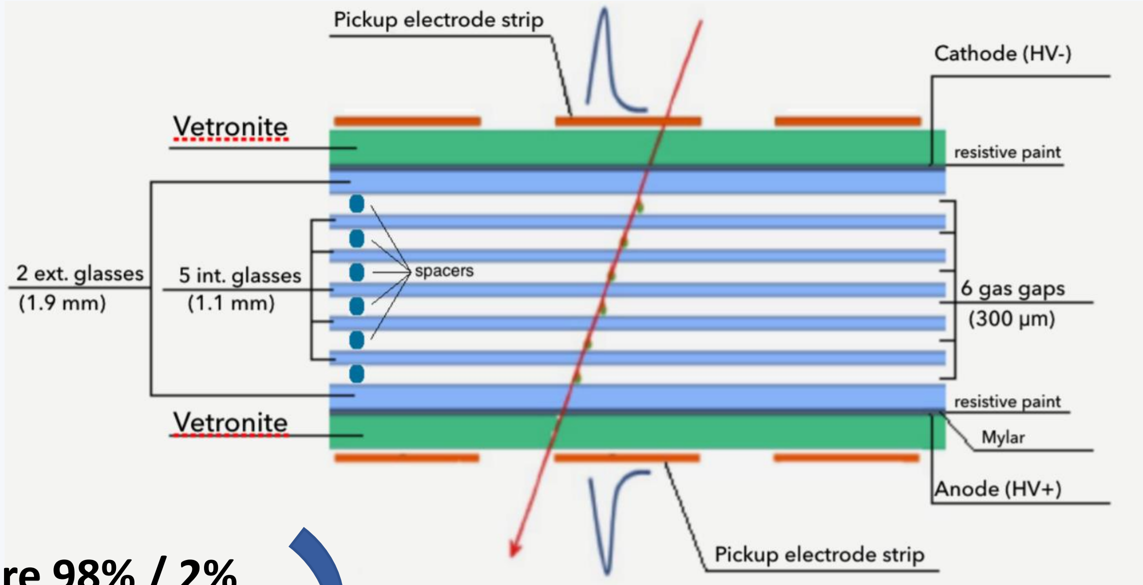
(+50 institutes on the waiting list)

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

EEE Telescopes

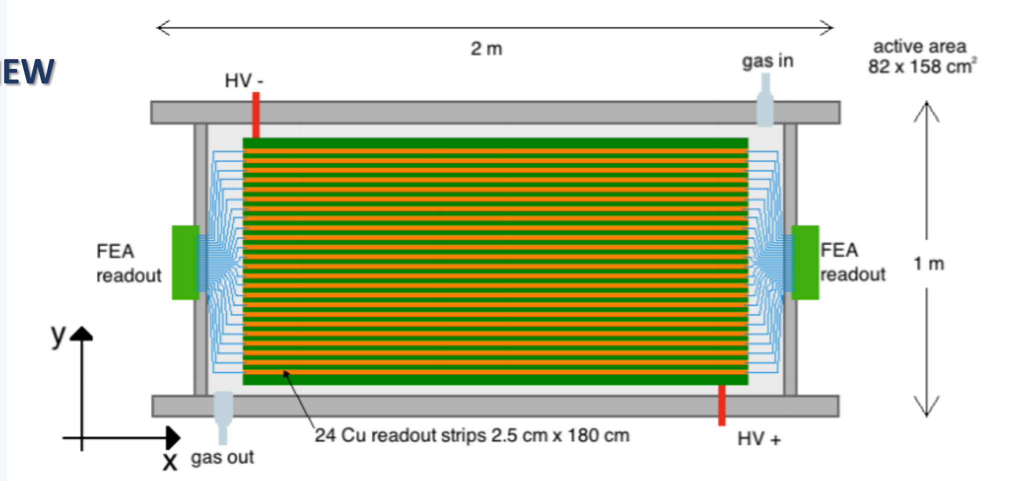
- Chambers built by students and teachers at CERN
- Reasonable cost
- Long term operation required
- Reconstruction of muon orientation
- TOF measurements

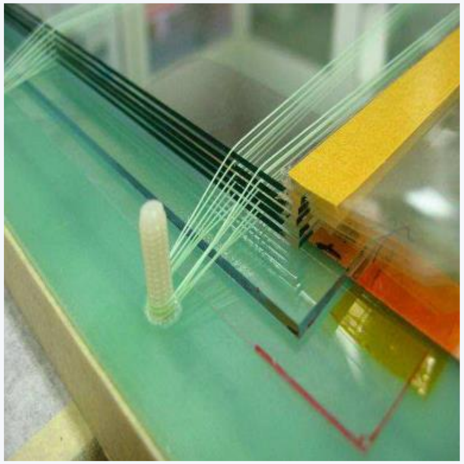
Inner structure



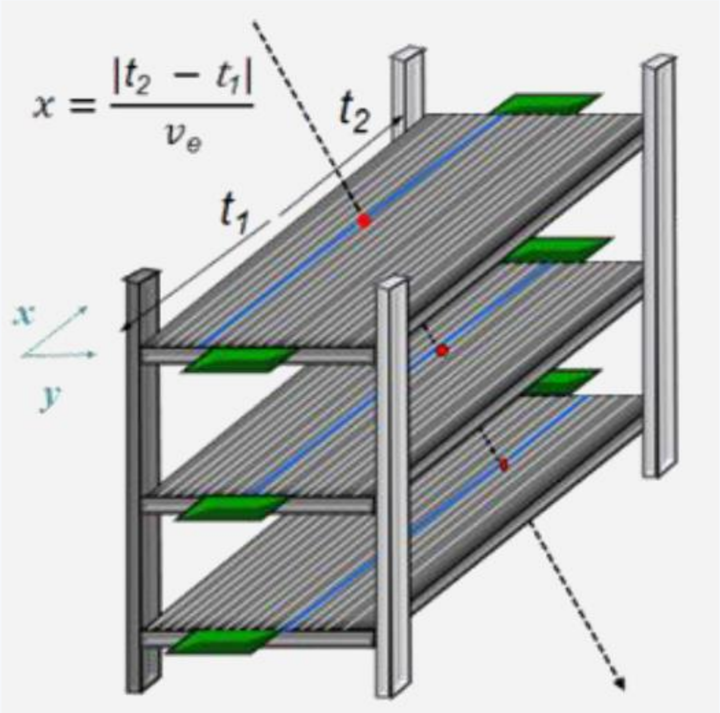
Chambers filled with a gas mixture 98% / 2% of Freon and SF_6, at a continuous flow of 1-2 l/h and atmospheric pressure

Top view





EEE Telescopes



Performance of the MRPCs:

- Time Resolution ~ 240 ps
- Longitudinal Spatial Resolution ~ 1.5 cm
- Transverse Spatial Resolution ~ 0.9 cm
- Average efficiency telescope network ~ 93 %

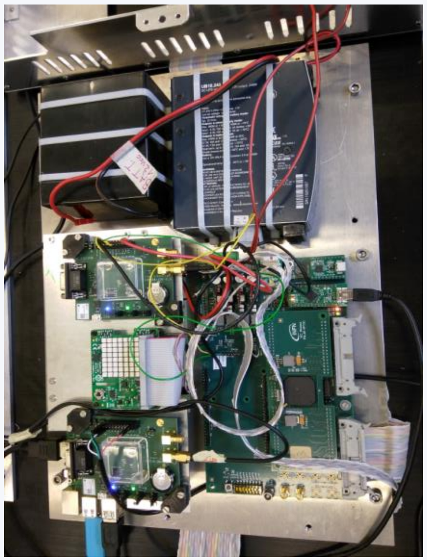
- Trigger logic: six-fold coincidence of the OR signals from the FEA cards (→ triple coincidence of both ends of the chambers)
- Synchronization guaranteed by a GPS unit that provides the event time stamp with precision of ≈ 40 ns

M. Abbrescia *et al* 2018 *JINST* **13** P08026

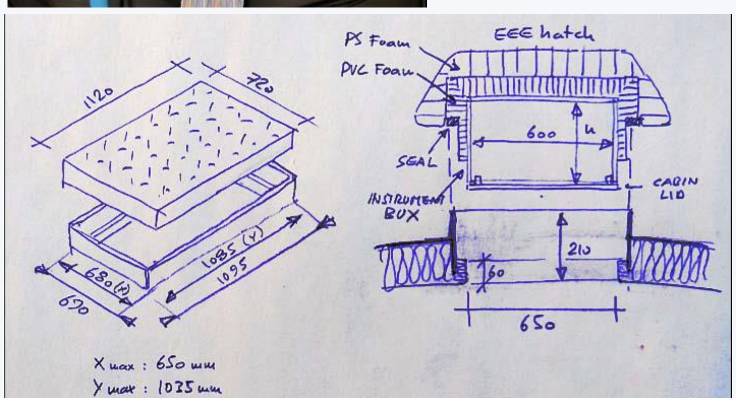
POLAR detector

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

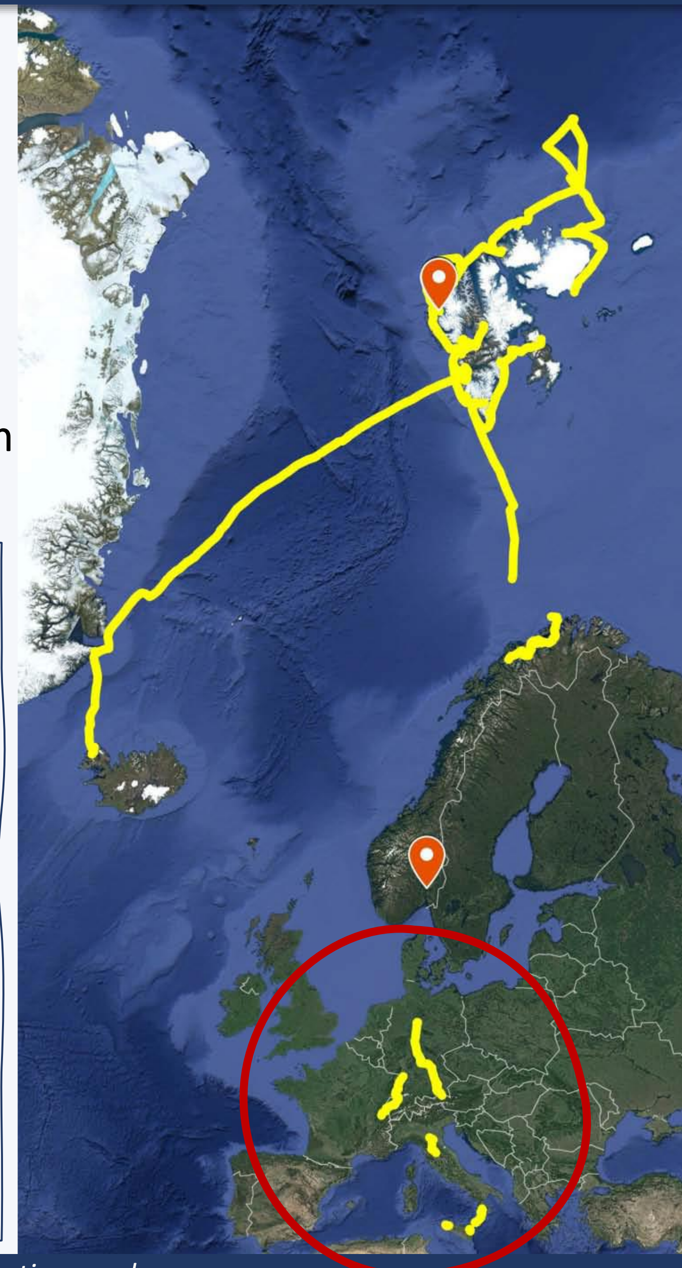
Assembled at CERN by high school students



- 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



POLAR detector

- ✓ Nanuq
- ✓ Genova
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- ✓ Lampedusa
- ✓ Bologna
- ✓ Munich
- ✓ Hannover
- ✓ Frankfurt am Main
- ✓ CERN

Ny Alesund

POLAR started its trip in Ny Alesund and for some time stopped in Catania

Catania

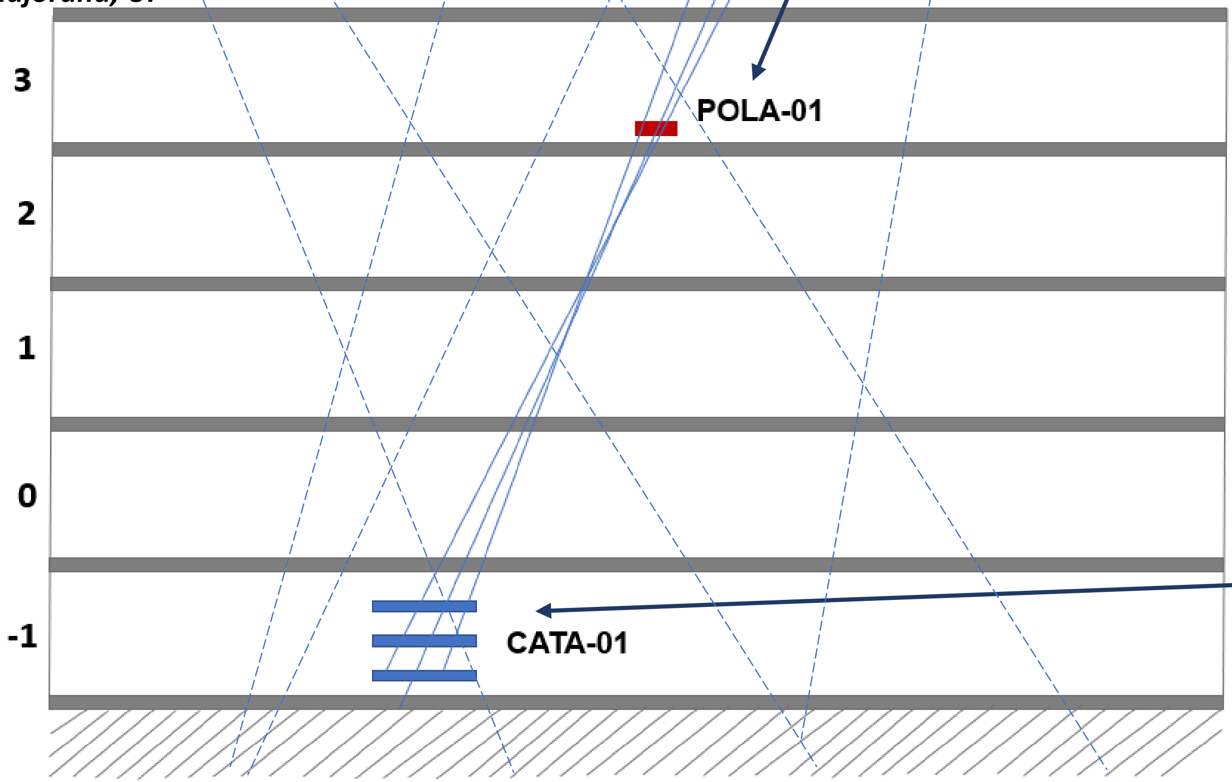
1st experimental setup @ DFA- UniCT

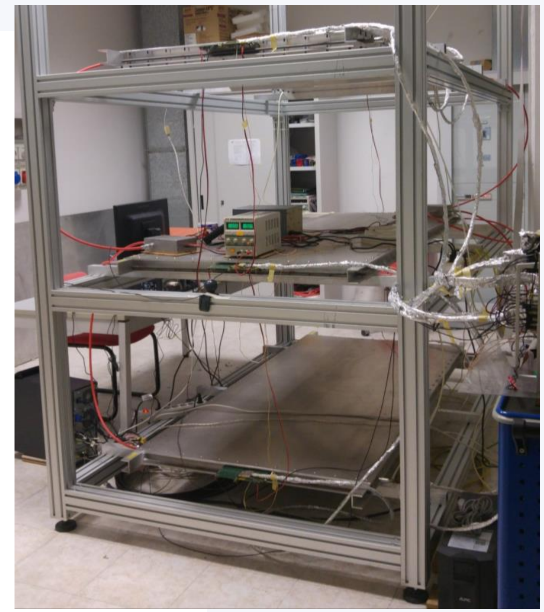
Dipartimento di Fisica e Astronomia
E. Majorana, CT

NO VISIBILITY BETWEEN DETECTORS (4 LAYERS OF CONCRETE)

- GPS time tagging of events
- Average count rate a.s.l. ~30 Hz

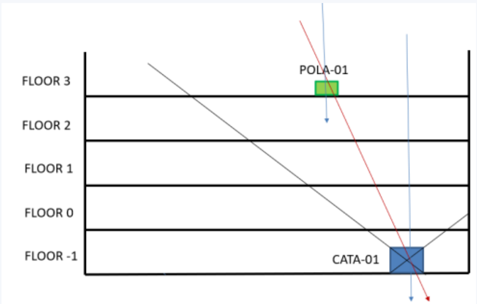
Detectors take data independently, then correlated by GPS information





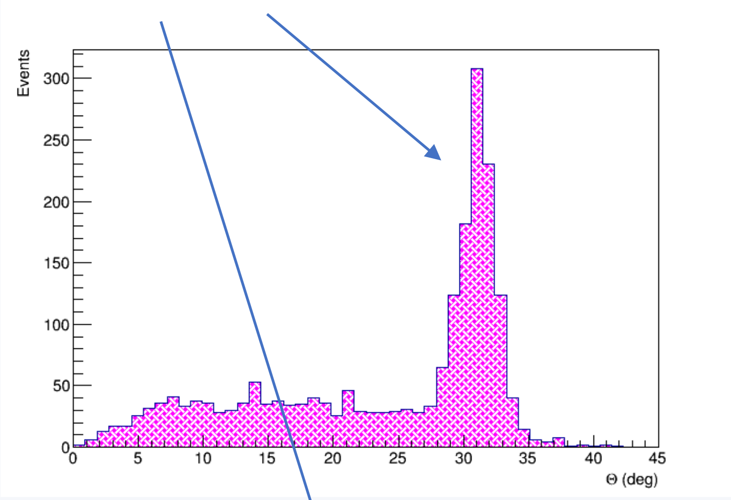
- GPS information

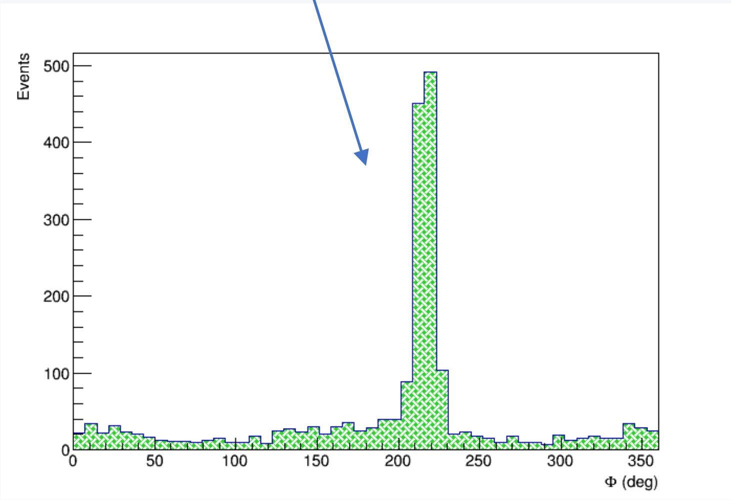
Commissioning measurements



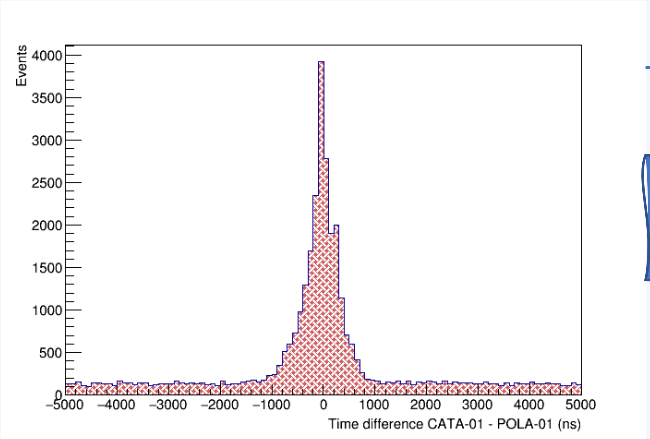
Same muons passing through both detectors.

Inside the acceptance cone: ~ **47 days** data acquisition in total





- The track orientation (θ,ϕ) — as reconstructed by the MRPC EEE telescope — is considered
- These distributions depend on the relative position of the movable scintillator w.r.t. the EEE telescope



Coincidence: 600 ns time window

M. Abbrescia *et al* 2019 *JINST* **14** P06035

«Simulating» the building shifts

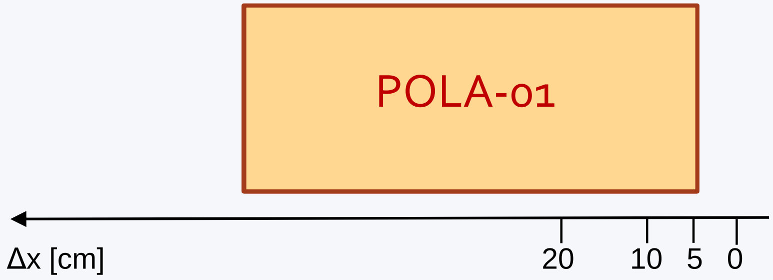
The scintillator was moved to mimic the building shift

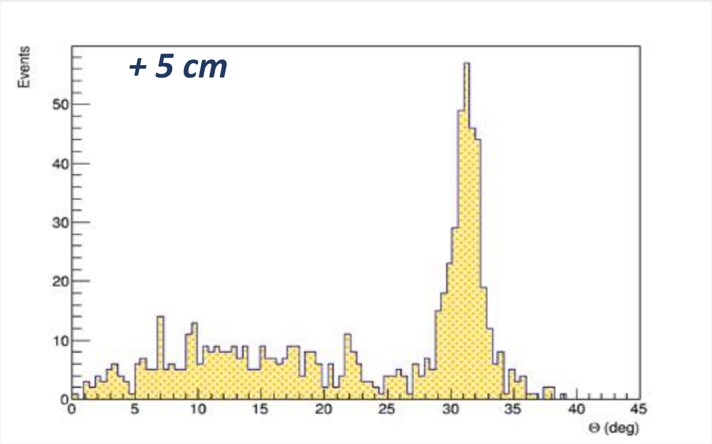
Four sets of measurements:

- Reference -> 0 cm

«Simulating» the building shifts

The scintillator was moved to mimic the building shift



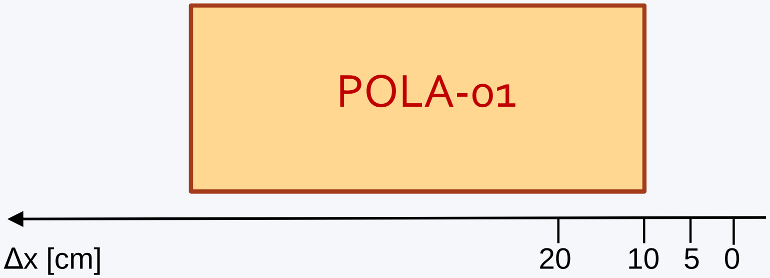


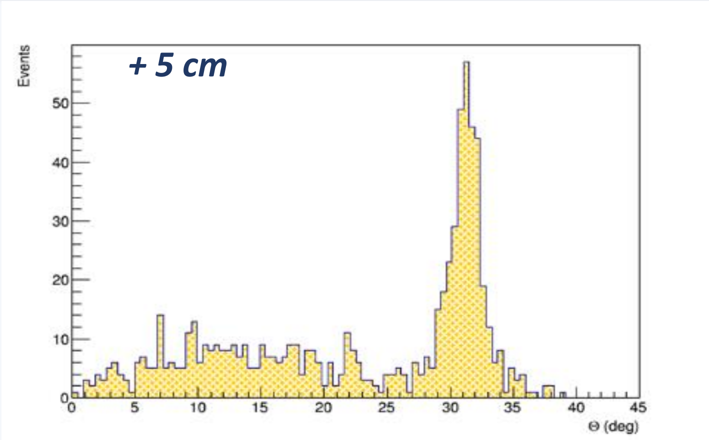
Four sets of measurements:

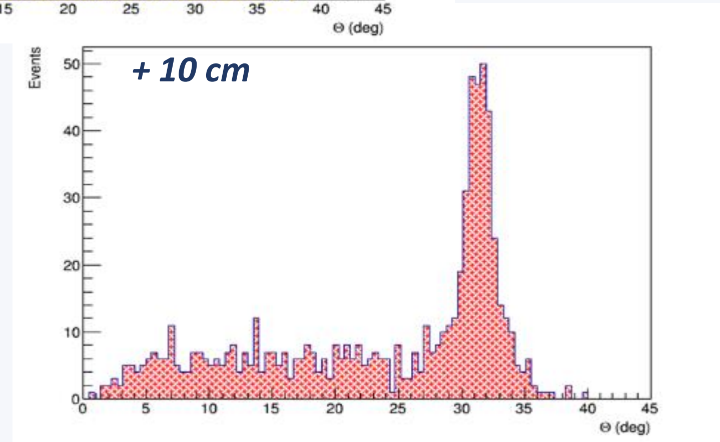
- Reference -> 0 cm
- First shift -> 5 cm

«Simulating» the building shifts

The scintillator was moved to mimic the building shift





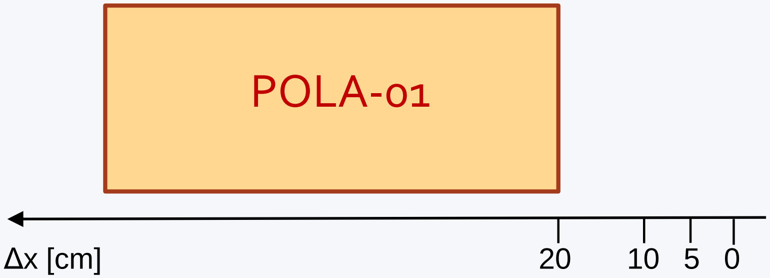


Four sets of measurements:

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

«Simulating» the building shifts

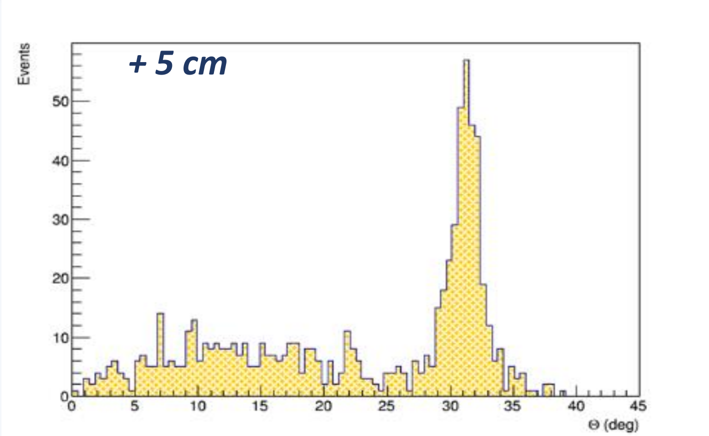
The scintillator was moved to mimic the building shift

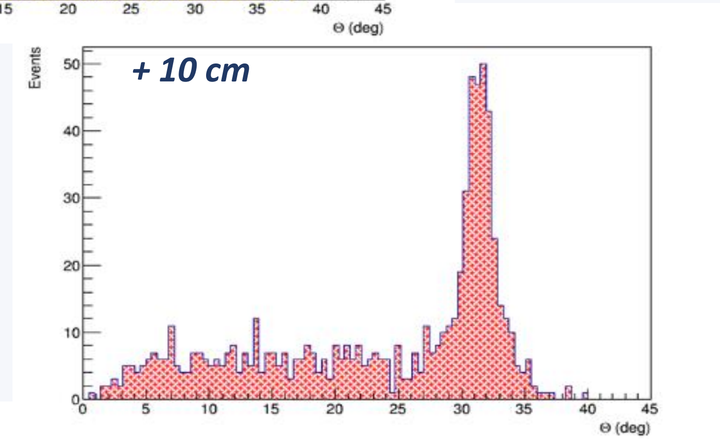


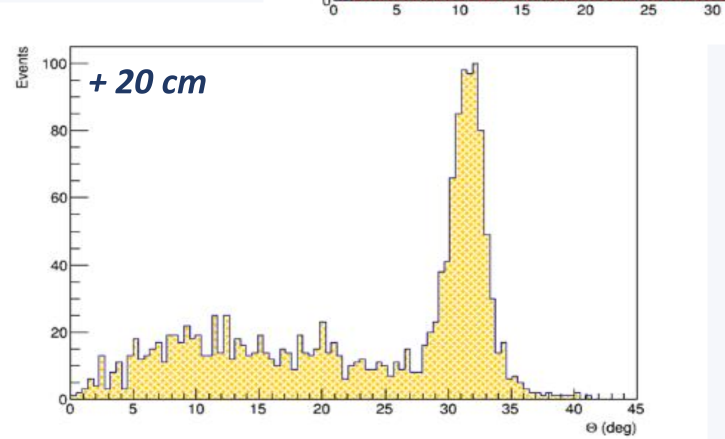
Four sets of measurements:

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

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°

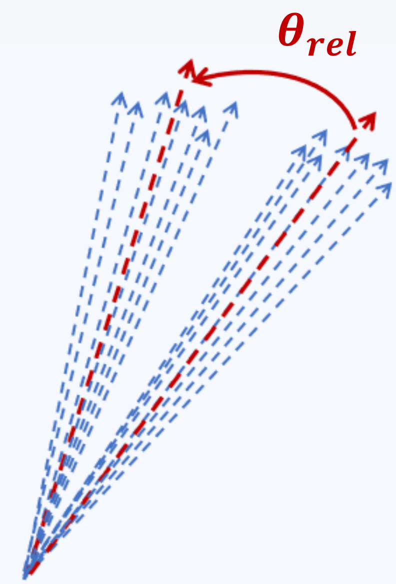






Shift of the average direction in space

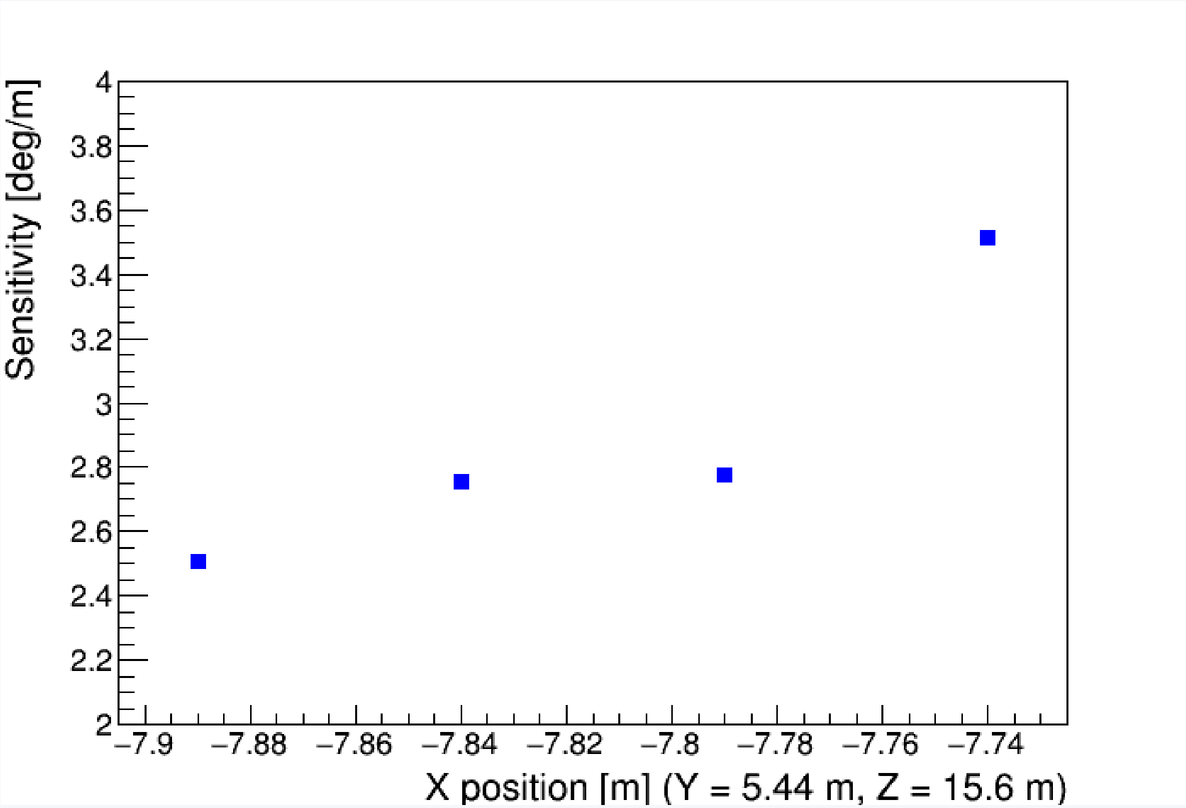
Estimation of the average direction in space, summing on all the tracks, in 3 configurations (5 cm, 10 cm, 20 cm).



Relative distance	Relative angle shift
20 cm	0.44°± 0.12
10 cm	0.24°± 0.12
5 cm	0.31° ± 0.16

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

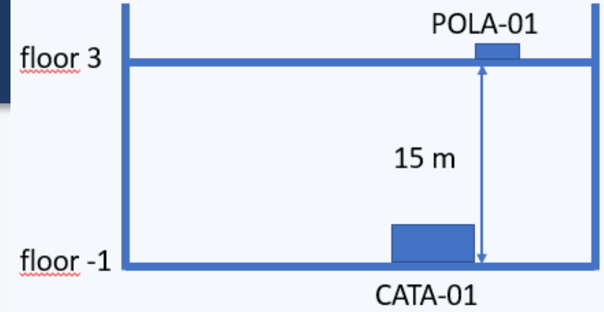
Geometrical simulations

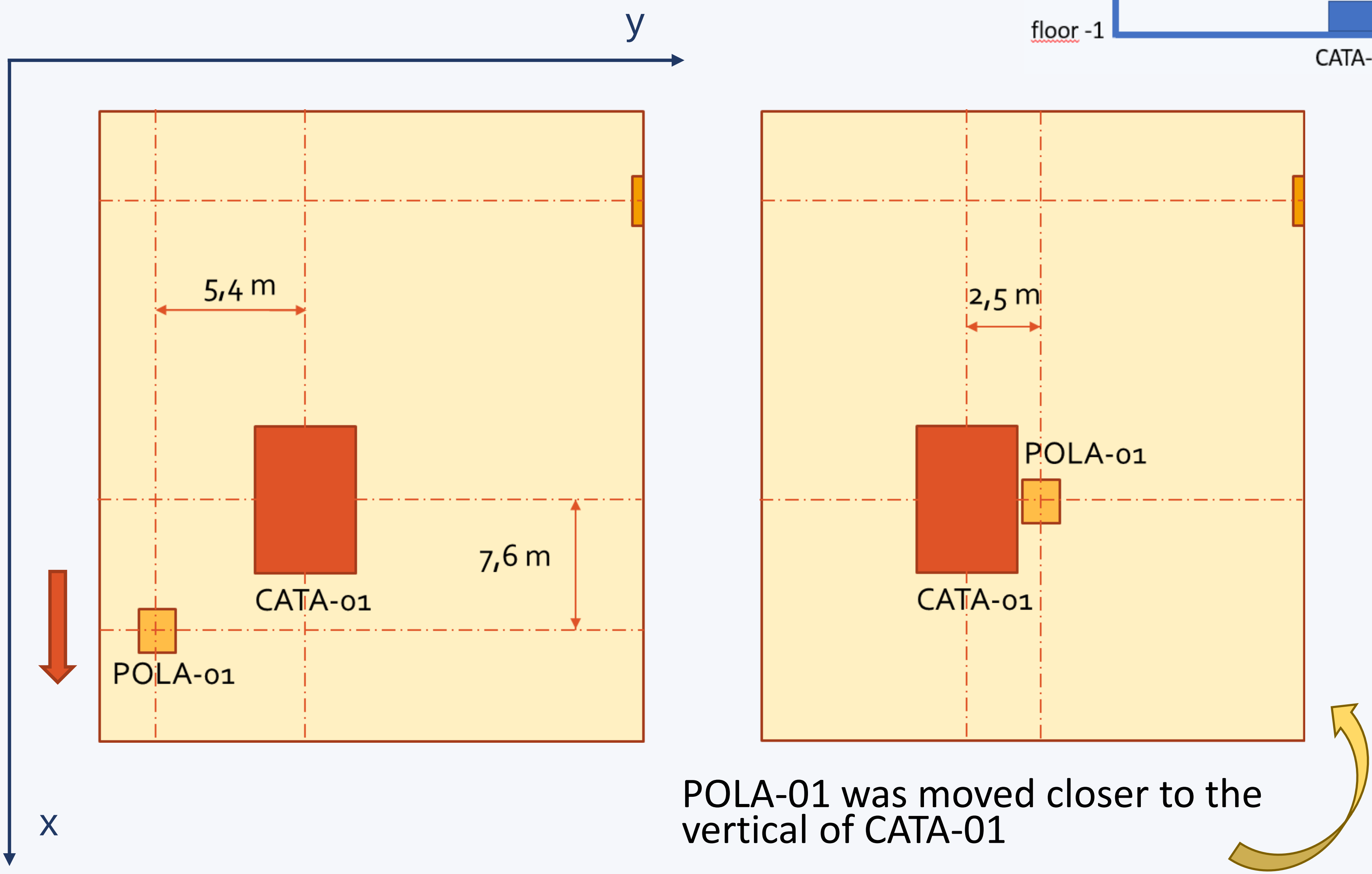


Going closer to the vertical of the reference detector the sensitivity increases

Sensitivity = $\frac{\Delta\theta}{\Delta s}$

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	$\sim 7 \cdot 10^5$ s	757
2,5 m	$\sim 6 \cdot 10^5$ s	4305

Performance of the method at 2.5 m:
- *few **cm** in 1 week data taking*

More commissioning measurements were performed

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

To further investigate this possibility we arranged a second experimental setup, along the vertical direction of the EEE MRPC telescope

2nd experimental setup @ DFA- UniCT

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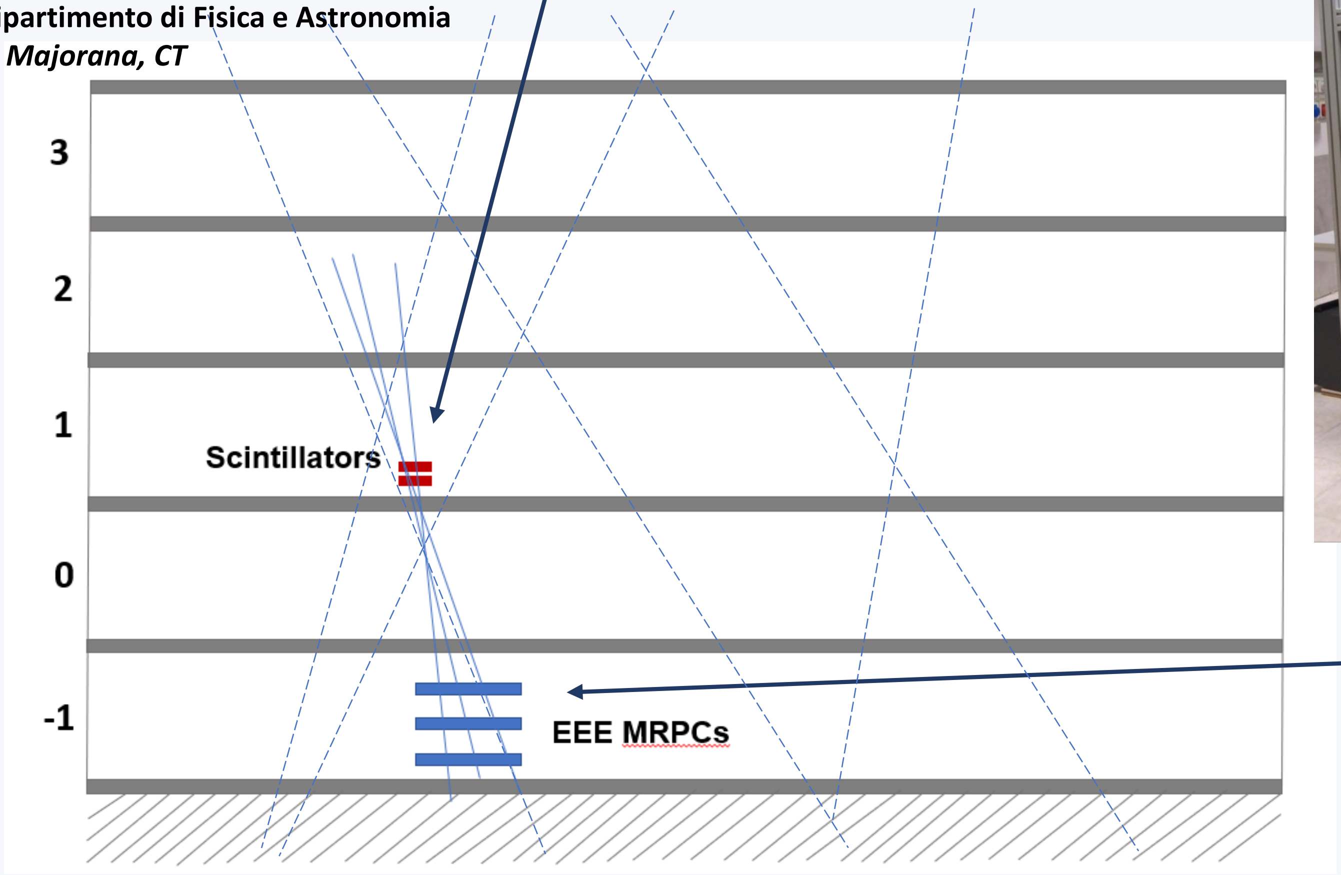
- GPS time tagging of events
- Detector efficiency > 95%

NO VISIBILITY BETWEEN DETECTORS
(2 LAYERS OF CONCRETE)

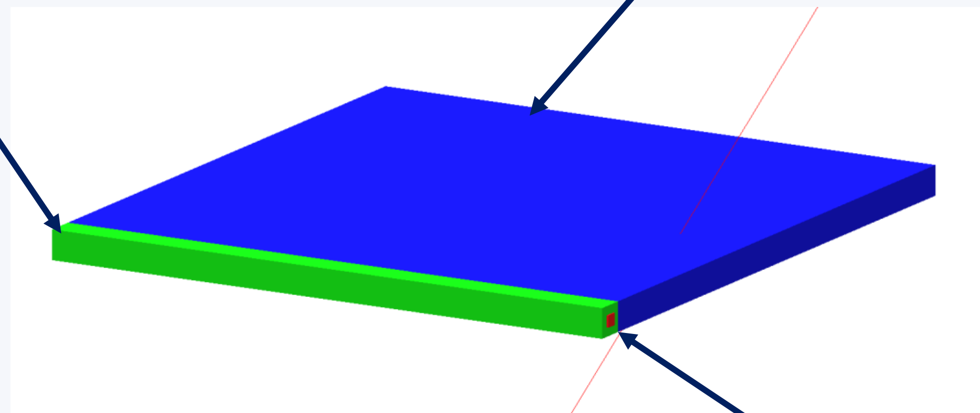


- GPS information

Scintillator module

1 x 1 x 20 cm^3 WLS bar

Extruded scintillator tile
20 x 20 x 1 cm^3



SiPM Hamamatsu 6x6 mm^2

GOALS:
- Low dark rate count
- High threshold
- High efficiency

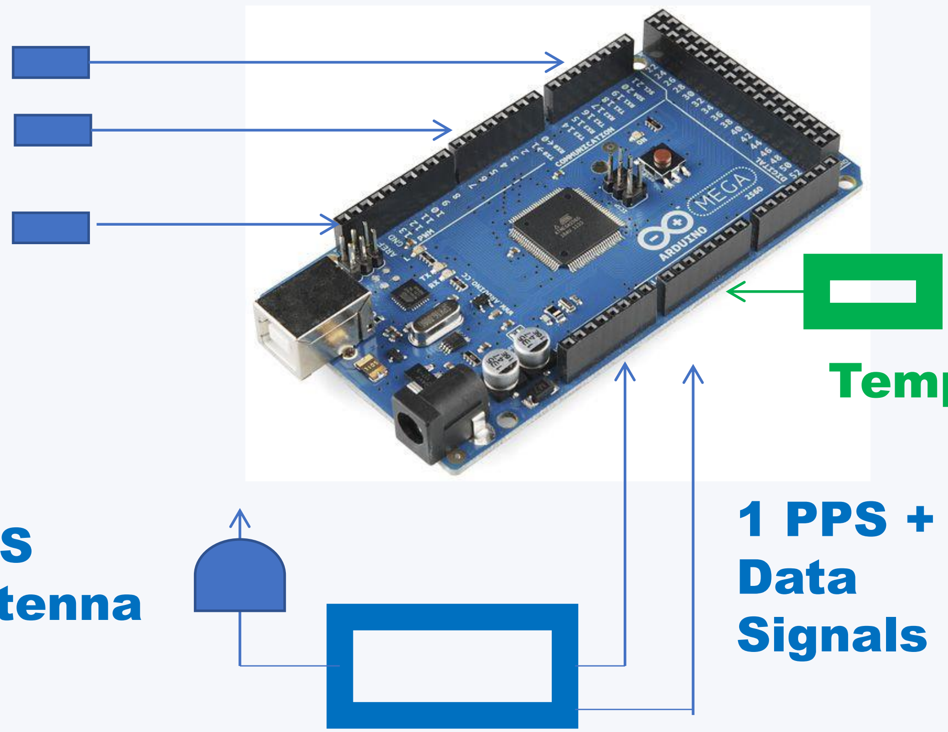
Light-tight box with:
- **Fast front-end amplifier**
- **Discriminator/ TTL shaper**
- **Power supply**

P. La Rocca et al., 2019 JINST 14 T01003

Electronics and data acquisition

TTL signals from each module are sent to the digital inputs of an Arduino MEGA board.

Fast digital readout → ≈ 800 ns per channel

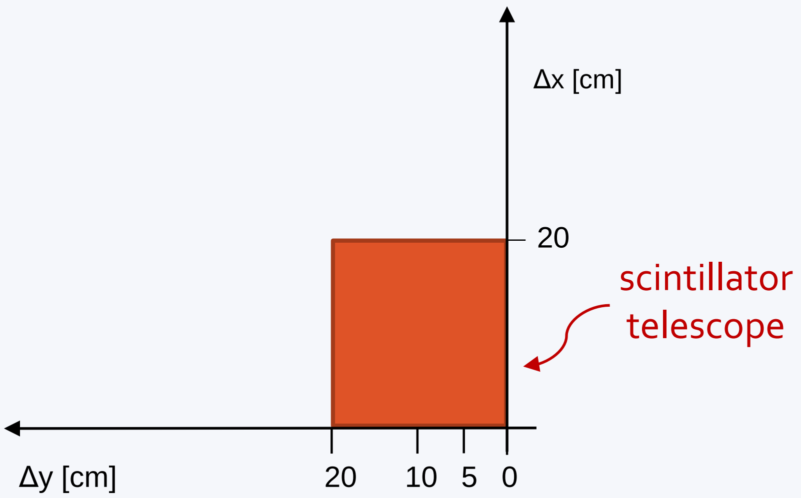


GPS Time Stamping Information: 1 PPS + internal 16 MHz Arduino clock.

«Simulating» the building shifts

Four sets of measurements:

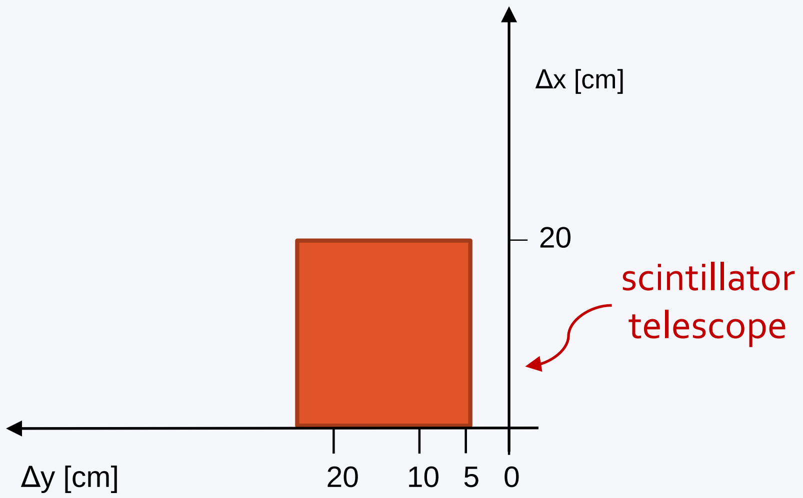
- Reference -> 0 cm



«Simulating» the building shifts

Four sets of measurements:

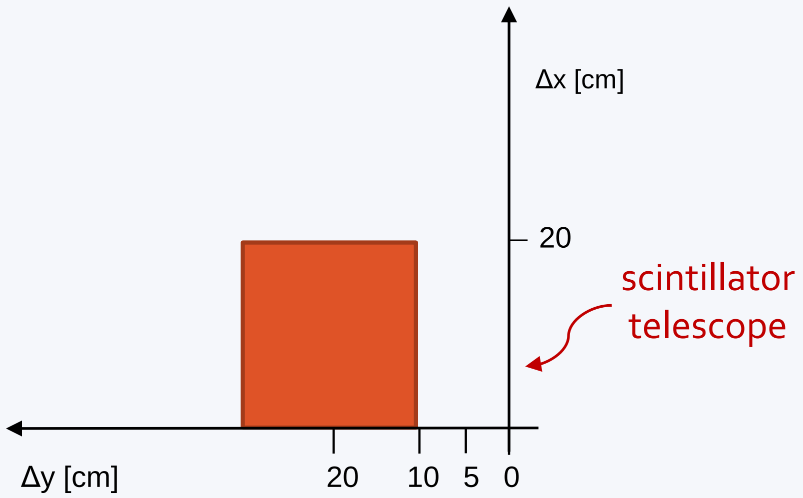
- Reference -> 0 cm
- First shift -> 5 cm



«Simulating» the building shifts

Four sets of measurements:

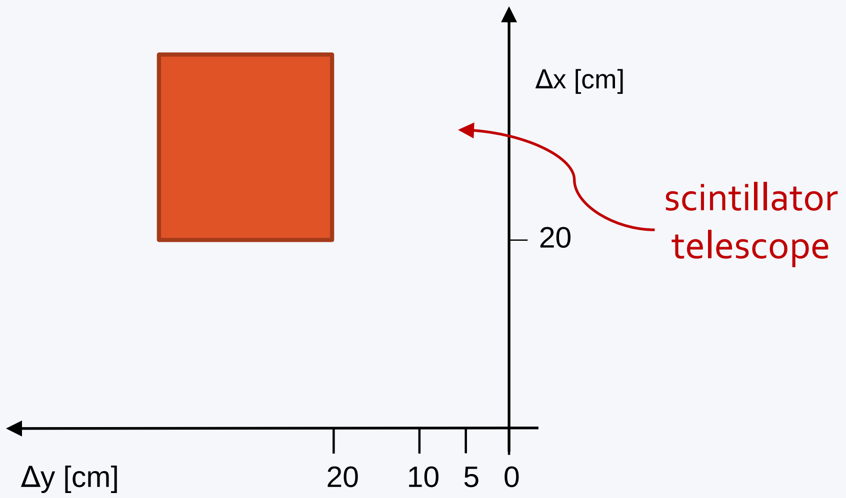
- Reference -> 0 cm
- First shift -> 5 cm
- Second shift -> 10 cm



«Simulating» the building shifts

Four sets of measurements:

- Reference -> 0 cm
- First shift -> 5 cm
- Second shift -> 10 cm
- Third shift (2D) -> (20 cm, 20 cm)



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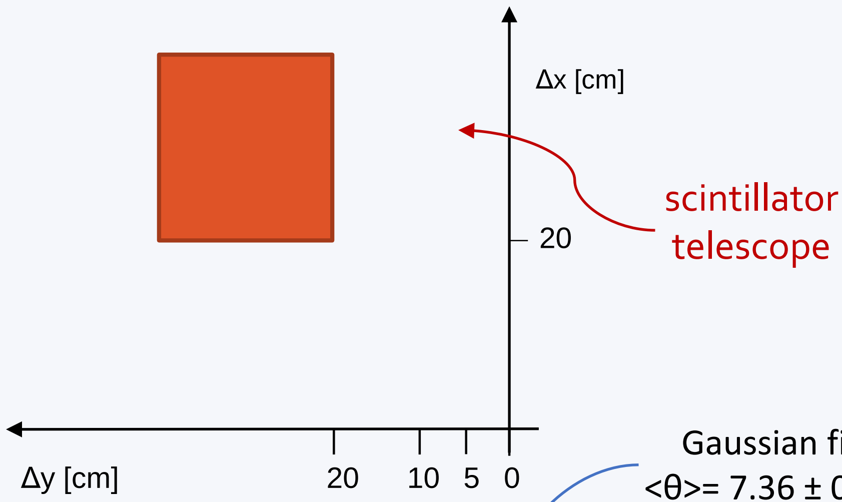
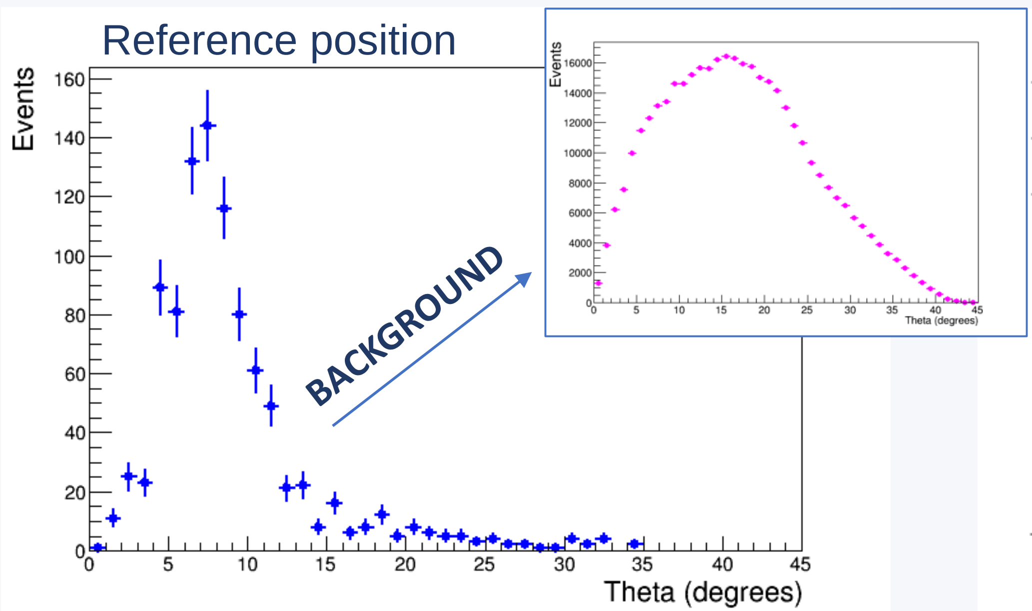
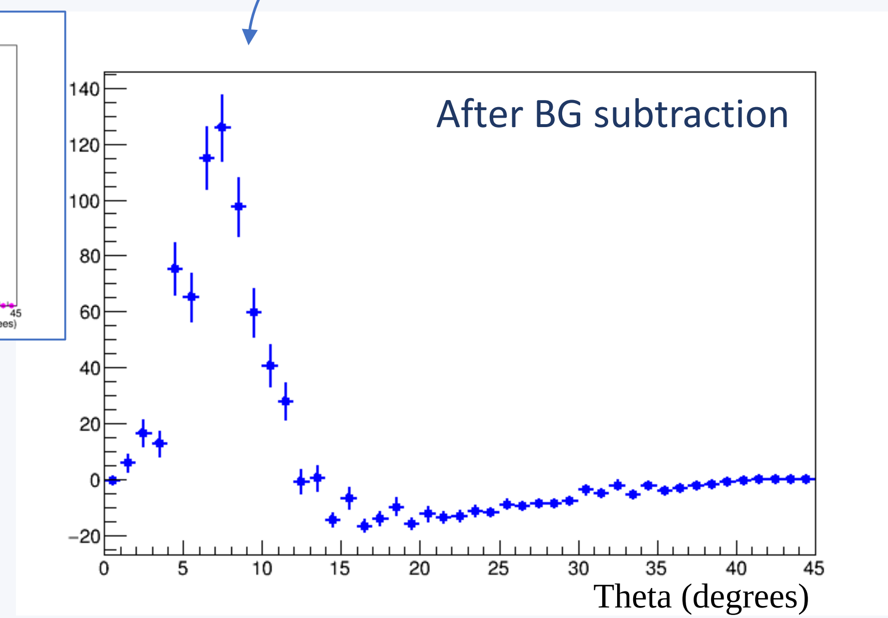


Gaussian fit
<θ>= 7.36 ± 0.11

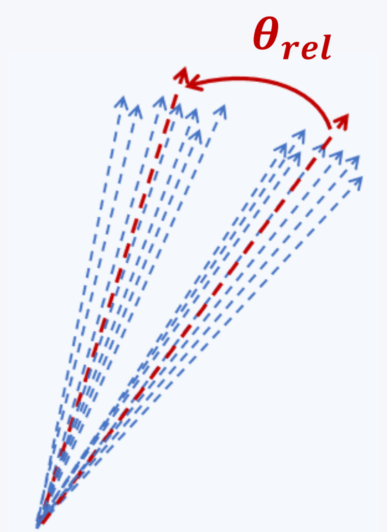




3D shifts

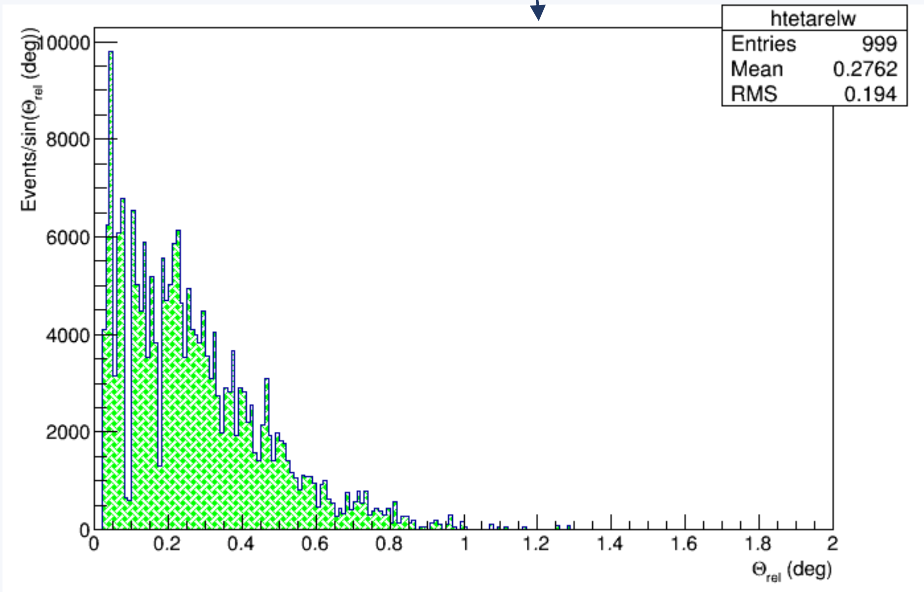
Each of the three shifts allows to get closer to the vertical of the reference detector

Position (x,y)	3D shift
(0 cm, 5 cm)	0.334° ± 0.21°
(0 cm, 10 cm)	0.523° ± 0.22°
(20 cm, 20 cm)	2.060° ± 0.21°



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

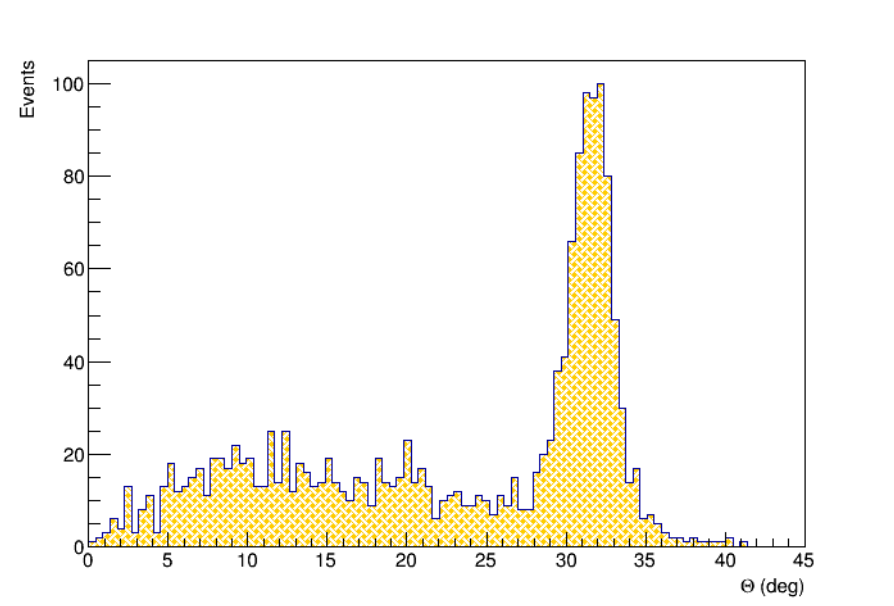


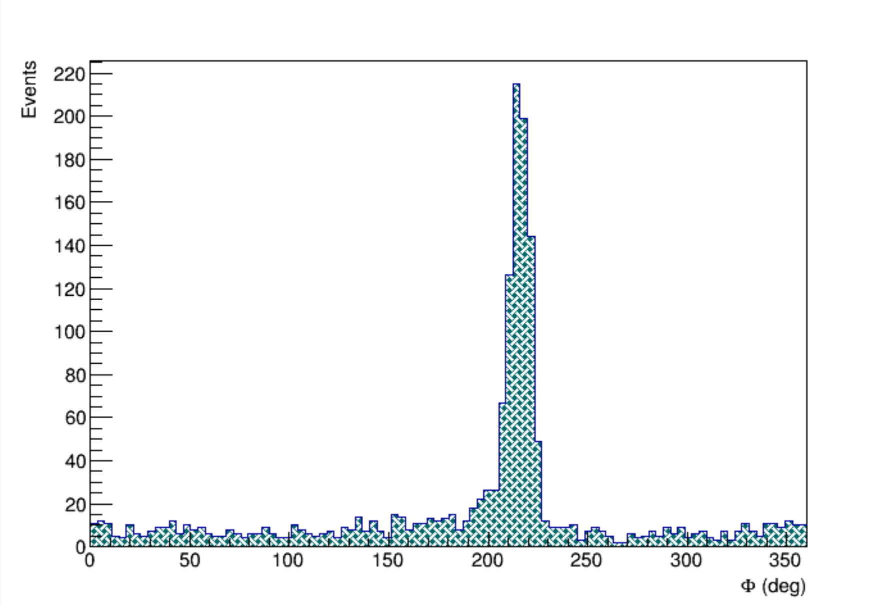
Conclusions & Outlook

- Coincidence measurements between MRPC EEE telescope & additional detectors were carried out to test the possibility of monitoring the long term building stability
- The additional detector is moved in order to mimic possible deformations of the building
- The sensitivity of the method depends on: capabilities of the main tracking detector, geometry and position of the additional detectors, uniformity over time of detectors response, acquisition time, ...
- Performance of the method can be estimated of the order of few cm in 1 week data taking

BACKUP

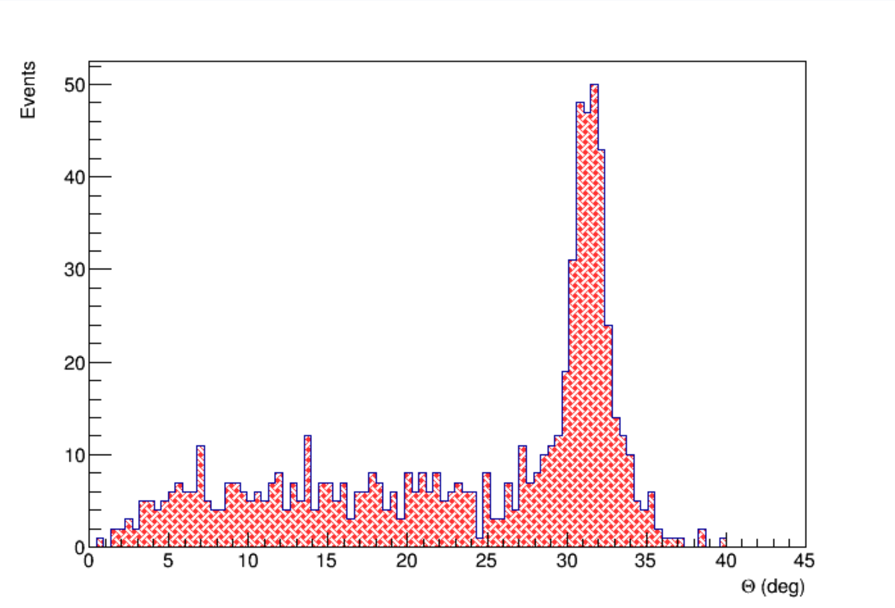
20 cm shift

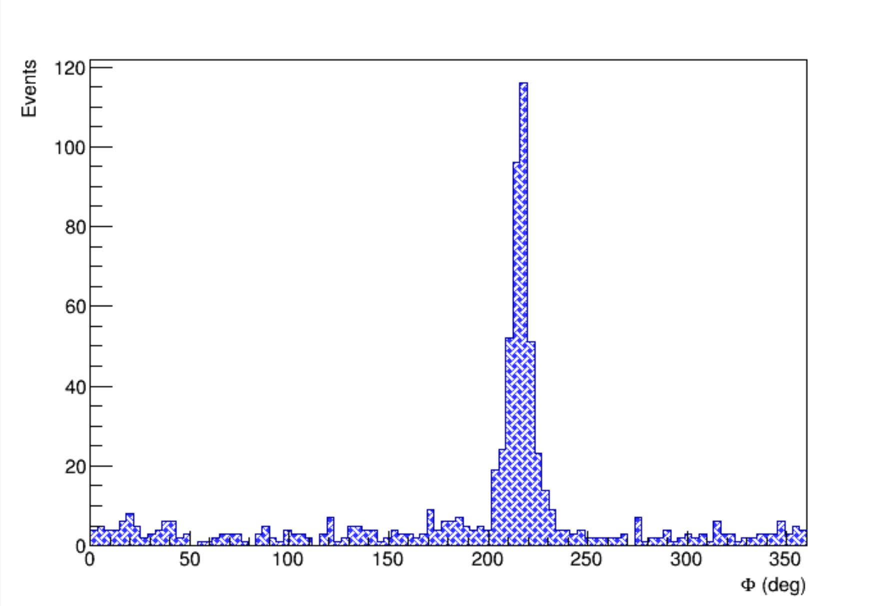




x [cm]	< θ > ± Δ<θ>	< ϕ > ± Δ<ϕ>
0	31.03° ± 0.05°	216.43° ± 0.20°
+20	31.45° ± 0.06°	216.23° ± 0.32°

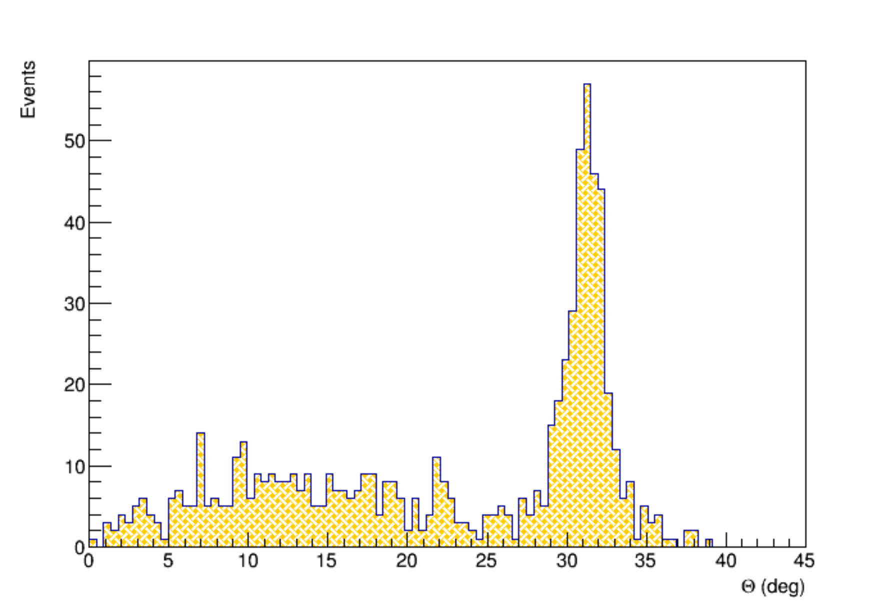
10 cm shift

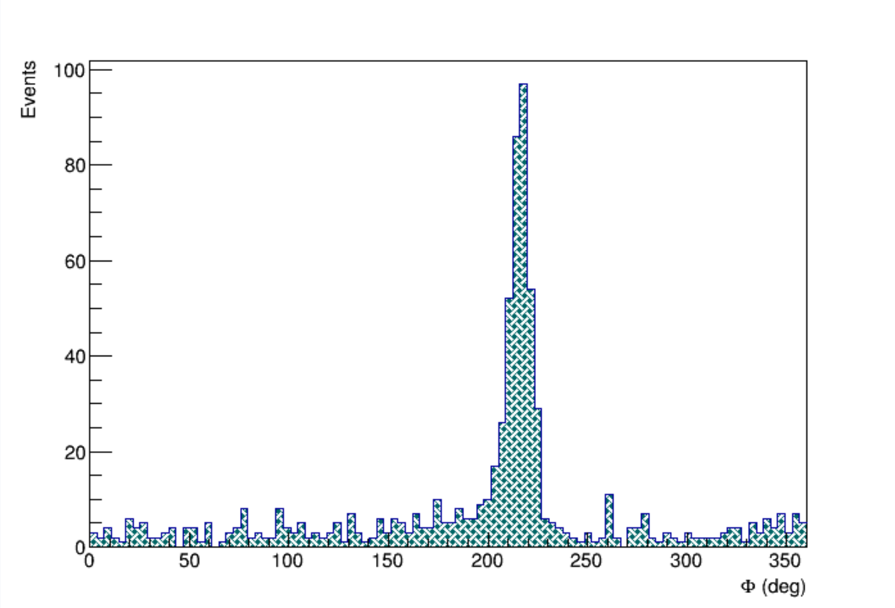




x [cm]	< θ > ± Δ<θ>	< ϕ > ± Δ<ϕ>
0	31.03° ± 0.05°	216.43° ± 0.20°
+10	31.36° ± 0.08°	216.15° ± 0.29°

5 cm shift





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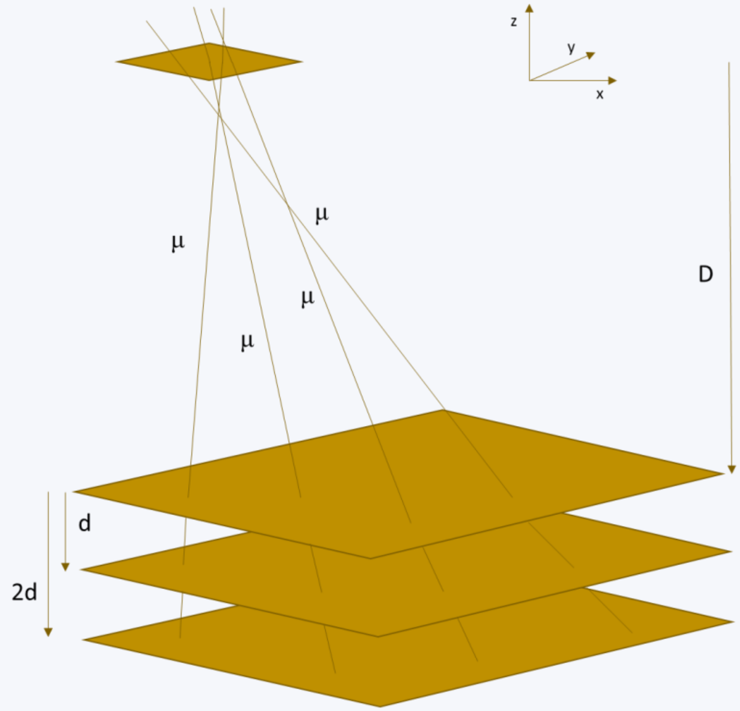
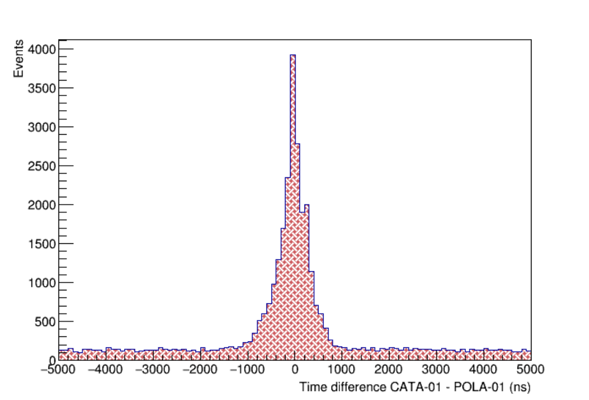
0	31.03° ± 0.05°	216.43° ± 0.20°
+5	31.18° ± 0.07°	215.88° ± 0.33°

Use of the EEE MRPC telescopes to investigate possible instabilities of civil structures on a long time-scale

Coincidence measurements

Coincidence window
$\lvert(\Delta t + (t - \mathrm{int}(t)) \cdot 2500 - 1500) - 140\rvert < 600$ 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





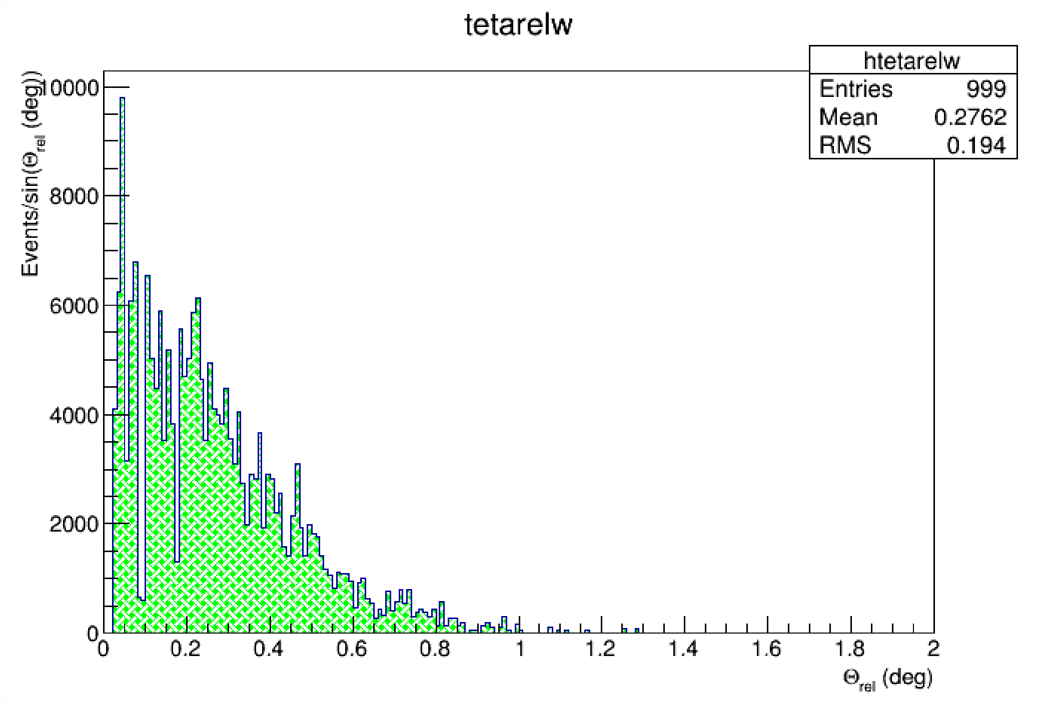
→Two detectors working separately

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

3D shifts error estimation

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



3D shifts

Position (x,y)	3D θ	3D ϕ	3D error
(0 cm, 0 cm)	5.926	47.892	0.16
(0 cm, 5 cm)	5.638	49.564	0.13
(0 cm, 10 cm)	5.635	43.573	0.16
(20 cm, 20 cm)	3.901	52.422	0.13

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