DETECTING EEE-CORRELATED MUONS WITH POLA-01 IN CATANIA: POSSIBLE APPLICATIONS IN THE MONITORING OF CIVIL STRUCTURES?

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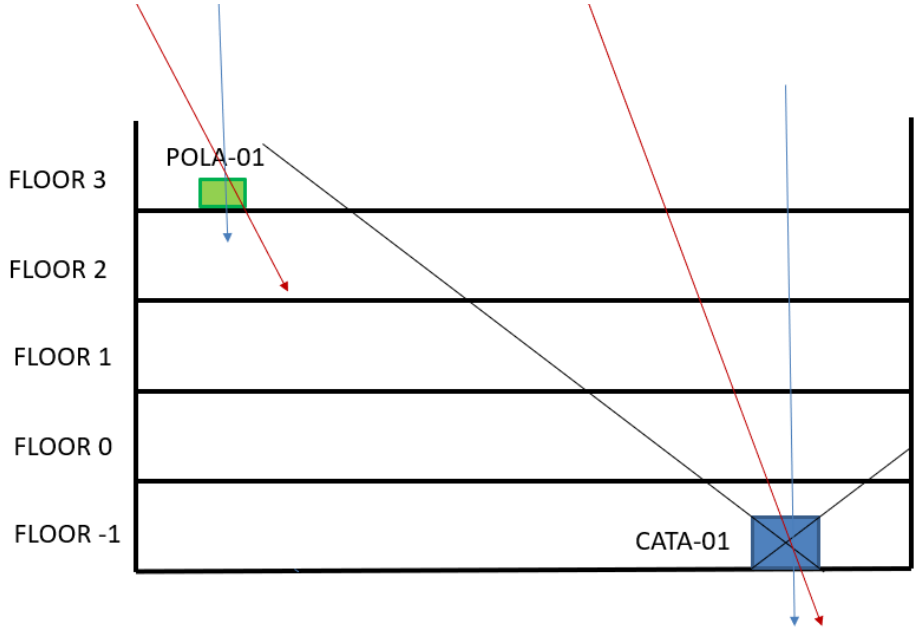
Outline

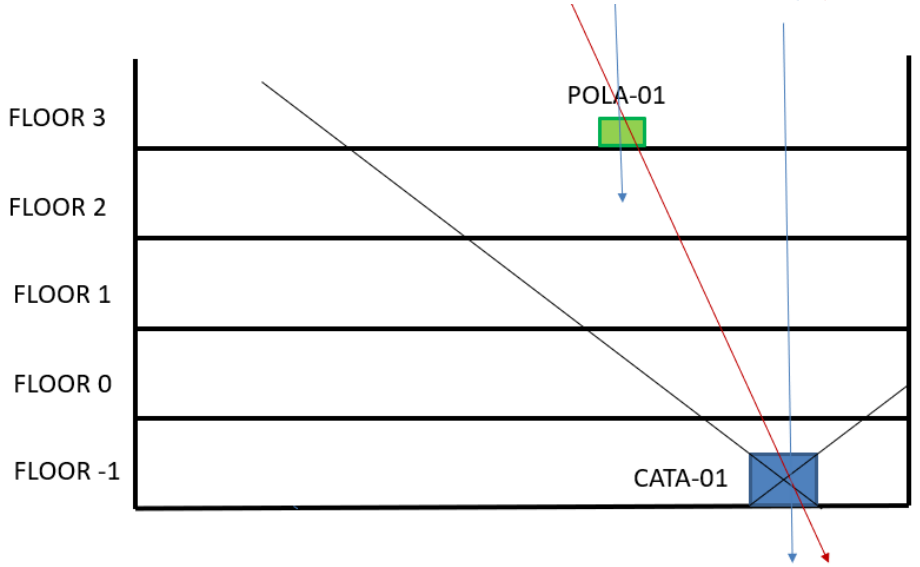
- POLA-01 – CATA-01 coincidence measurements, inside and outside CATA-01 acceptance;
- Preliminary results on angular distributions;
- Project of measurements to monitor civil structures stability;
- Preliminary tests on the sensitivity of such a measurement using CATA-01 – POLA-01 detectors.

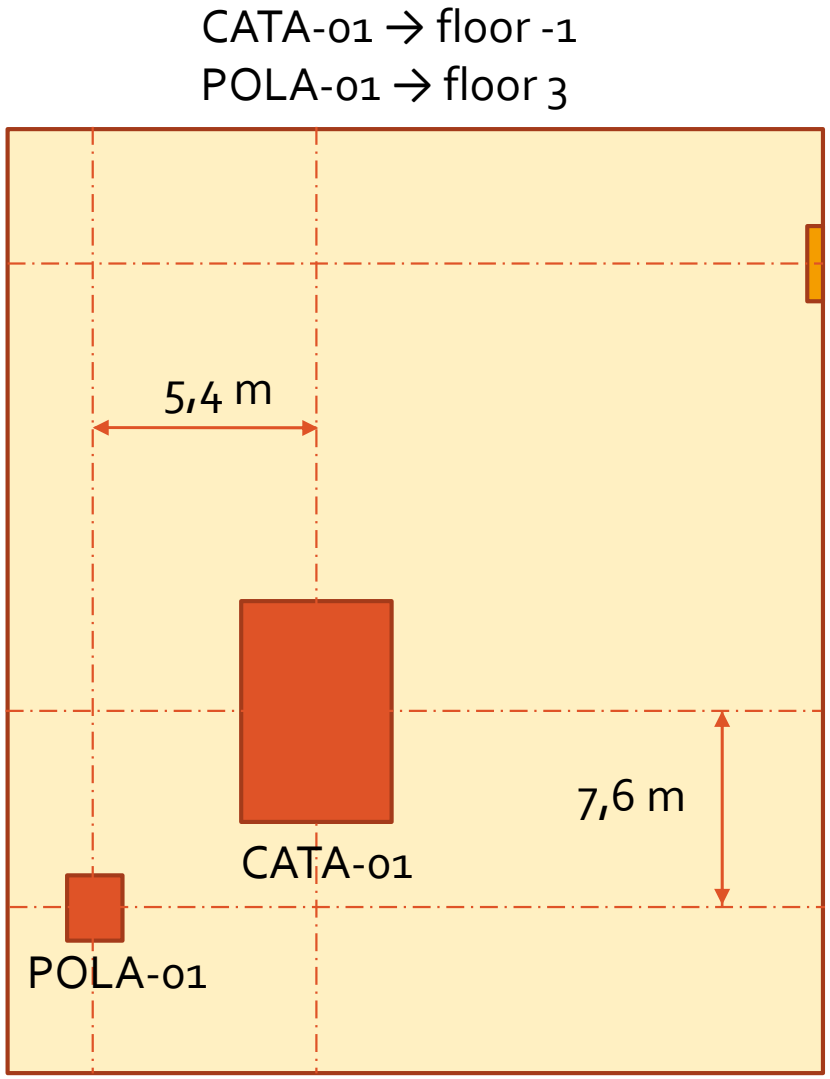
Measurements

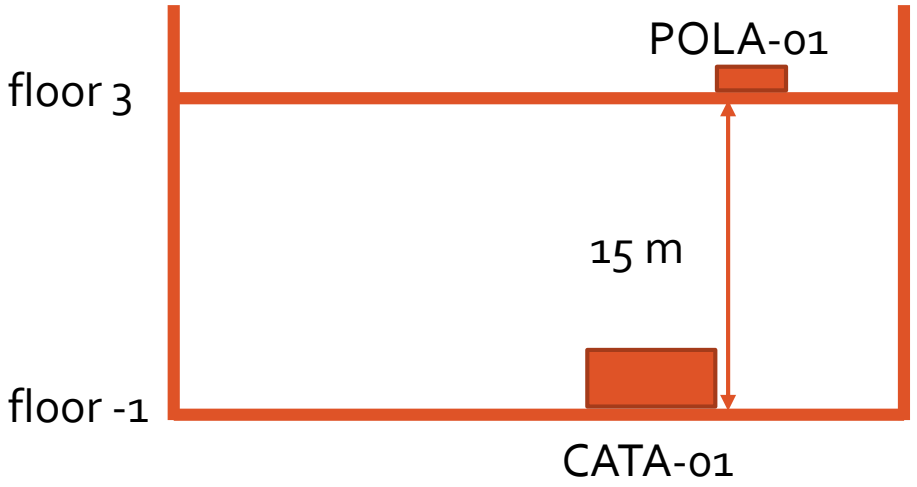
- Measure 1 – outside the acceptance interval of CATA-01, in order to detect two independent muons coming from the same shower.
  About 3 days acquisition time.

- Measure 2 – inside the acceptance interval of CATA-01, in order to detect also muons passing through both detectors. Detectors geometry select a narrow acceptance cone (POLA-01: 40 cm x 60 cm).
  About 26 days acquisition time, but still running.





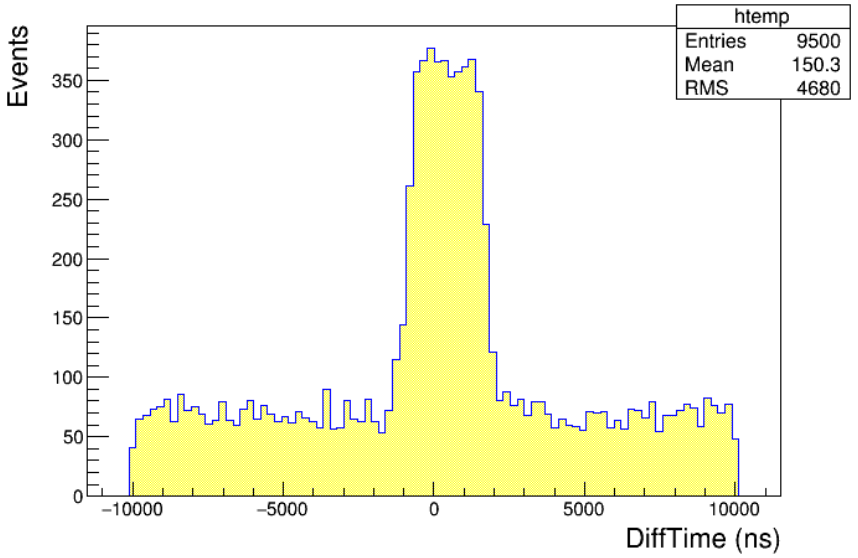


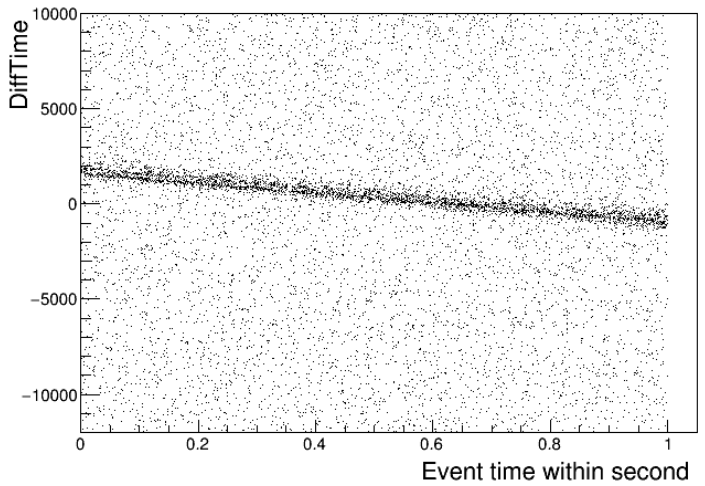


Geometrical disposition of the two detectors in Catania Physics department.

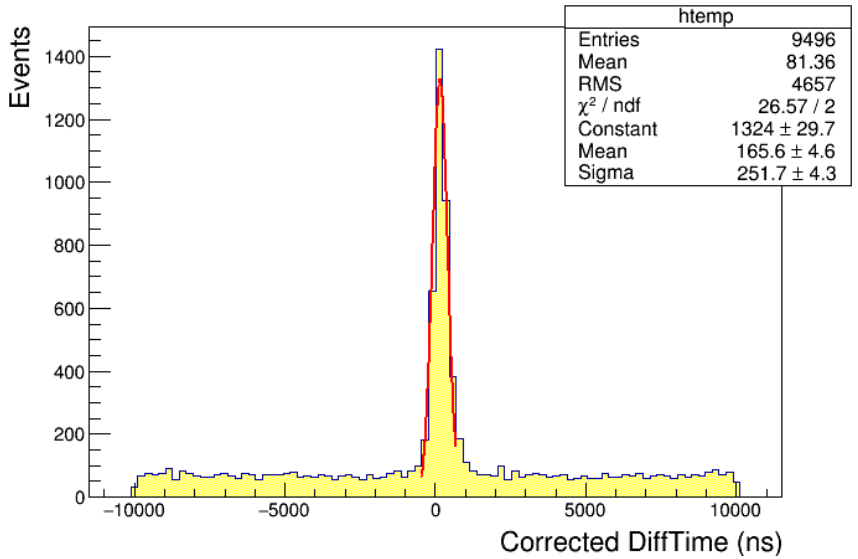
Time difference

Uncorrected time difference spectrum





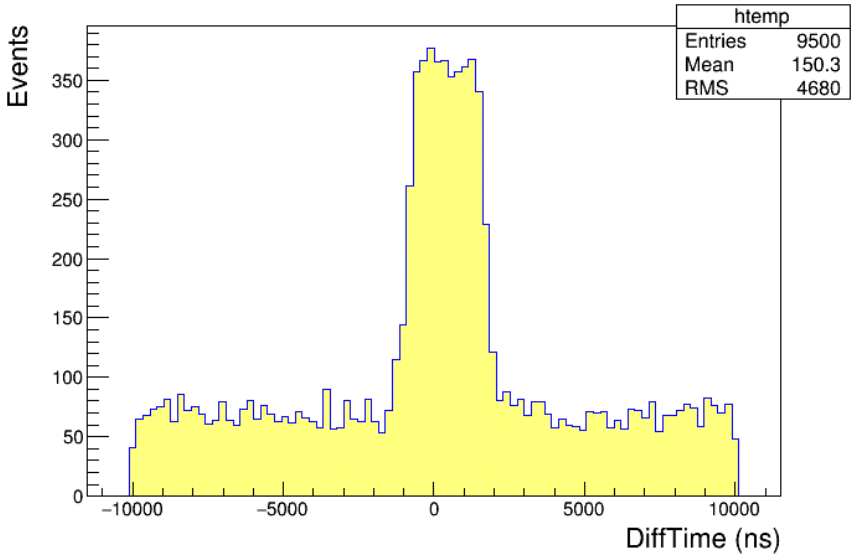
Corrected time difference spectrum



- Time difference between CATA-01 and POLA-01 data
- Corrected by a factor depending on clock drift (line's slope)

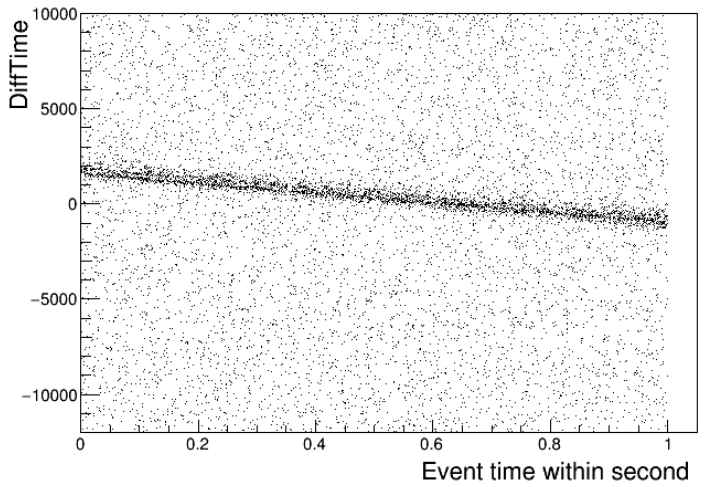
Time difference

Uncorrected time difference spectrum

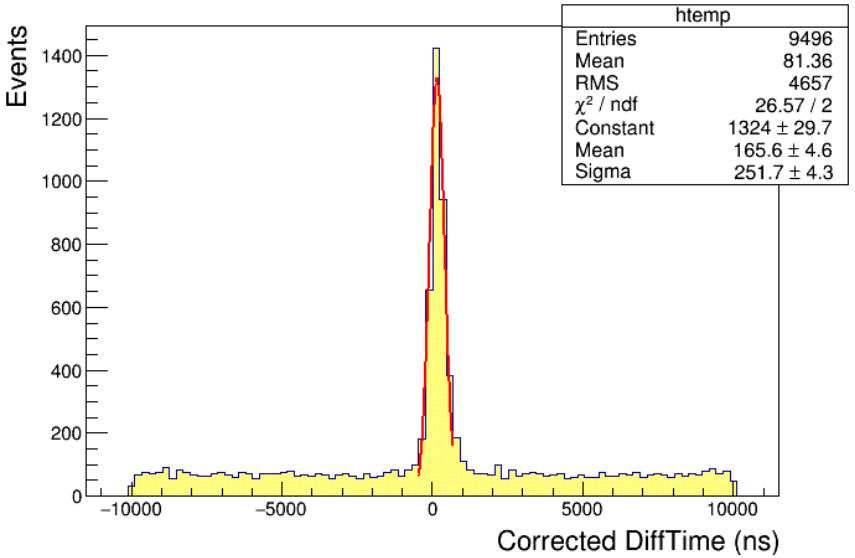


Drift formula:

$\Delta t_{corrected} = \Delta t + (t\text{-int}(t)) \cdot 2500 - 1500$



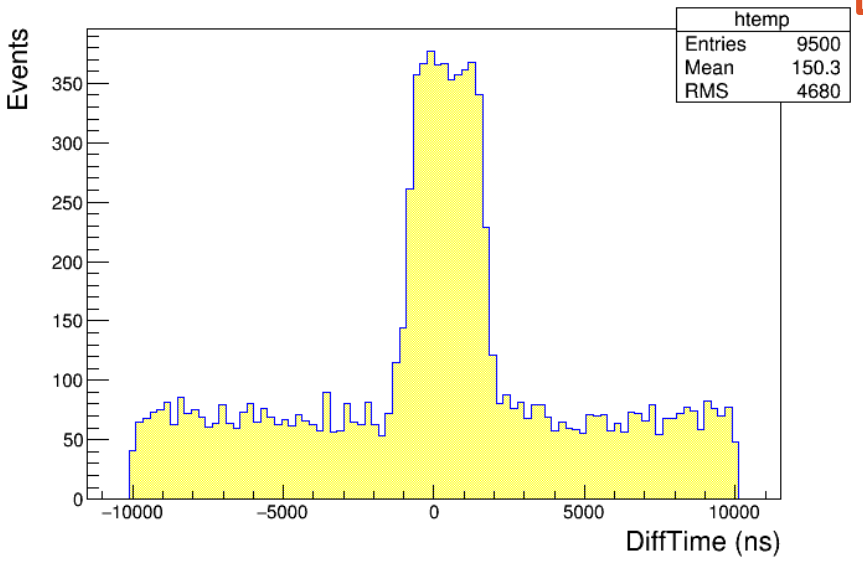
Corrected time difference spectrum



- Time difference between CATA-01 and POLA-01 data
- Corrected by a factor depending on clock drift (line's slope)

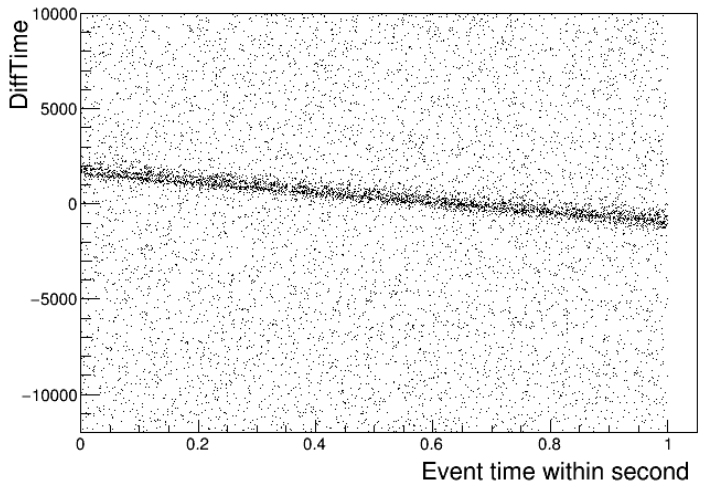
Time difference

Uncorrected time difference spectrum

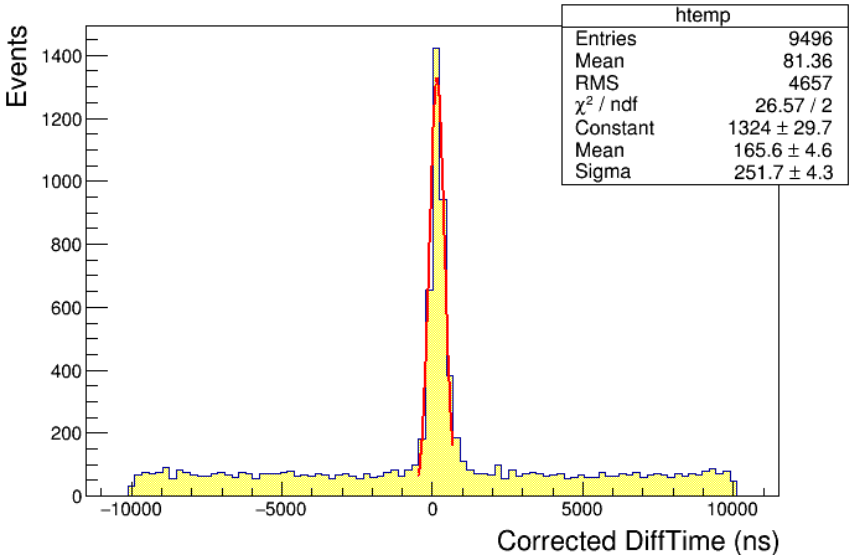


Drift formula:

$\Delta t_{corrected} = \Delta t + (t\text{-int}(t)) \cdot 2500 - 1500$



Corrected time difference spectrum



- Time difference between CATA-01 and POLA-01 data
- Corrected by a factor depending on clock drift (line's slope)

	Uncorrected	Corrected
Peak width	~ 3 μs	~ 250 ns

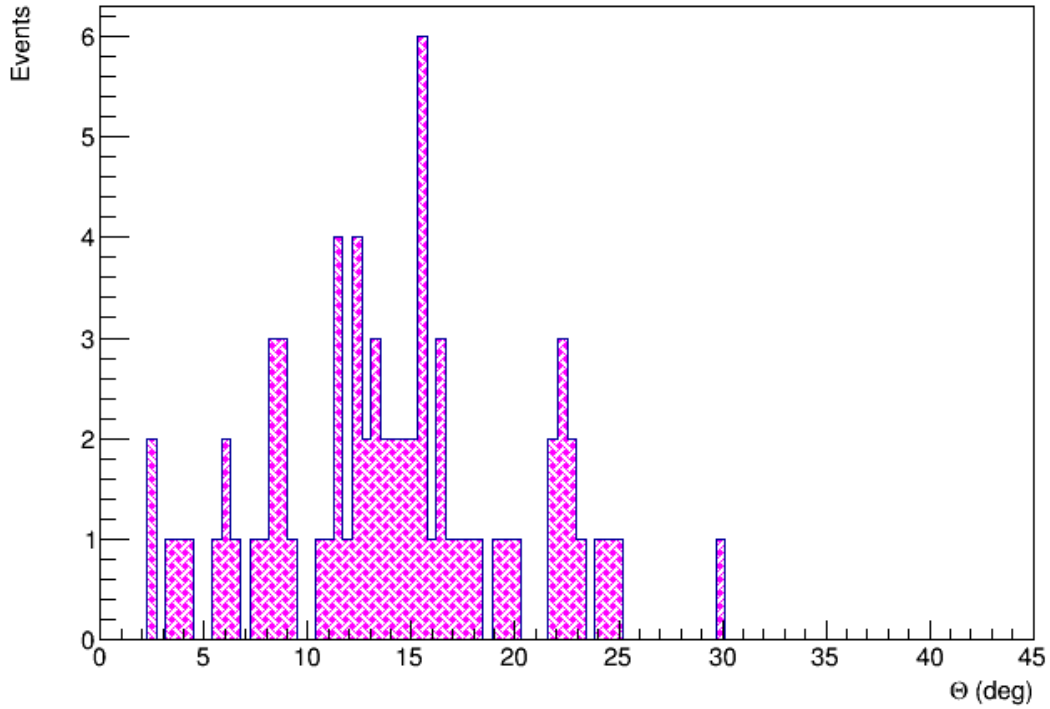
Track selection

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

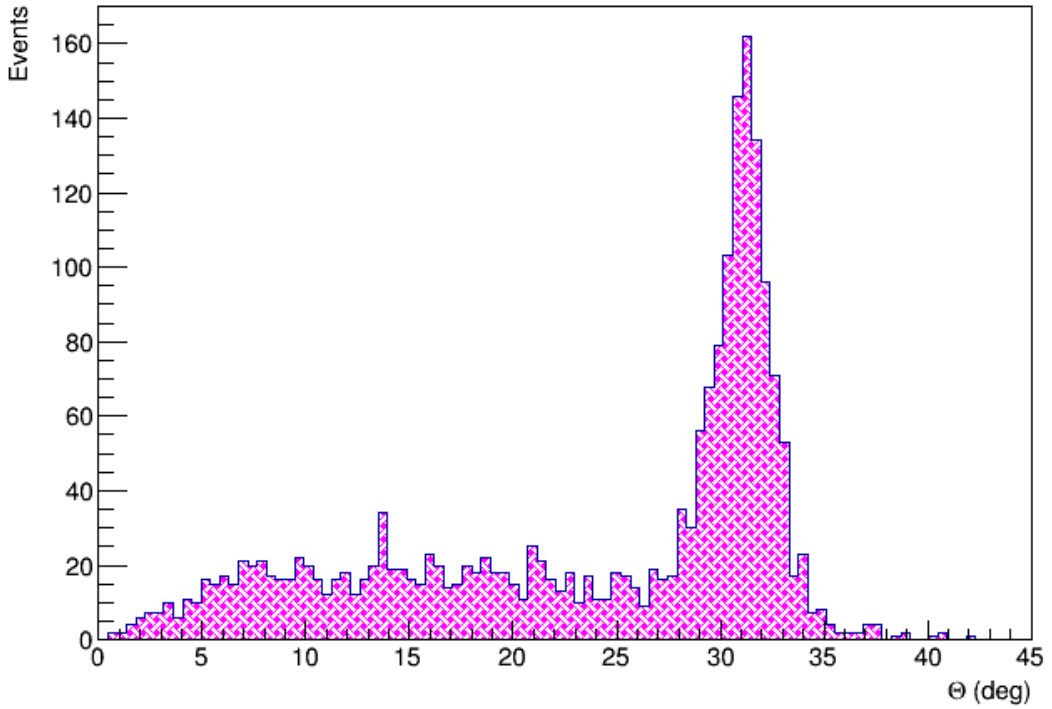
- Measurements OUTSIDE CATA-01 acceptance cone: 3 days data taking.
- Measurements INSIDE CATA-01 acceptance cone: 13 days data taking.

Theta distribution

POLA-01 outside CATA-01 acceptance



POLA-01 inside CATA-01 acceptance

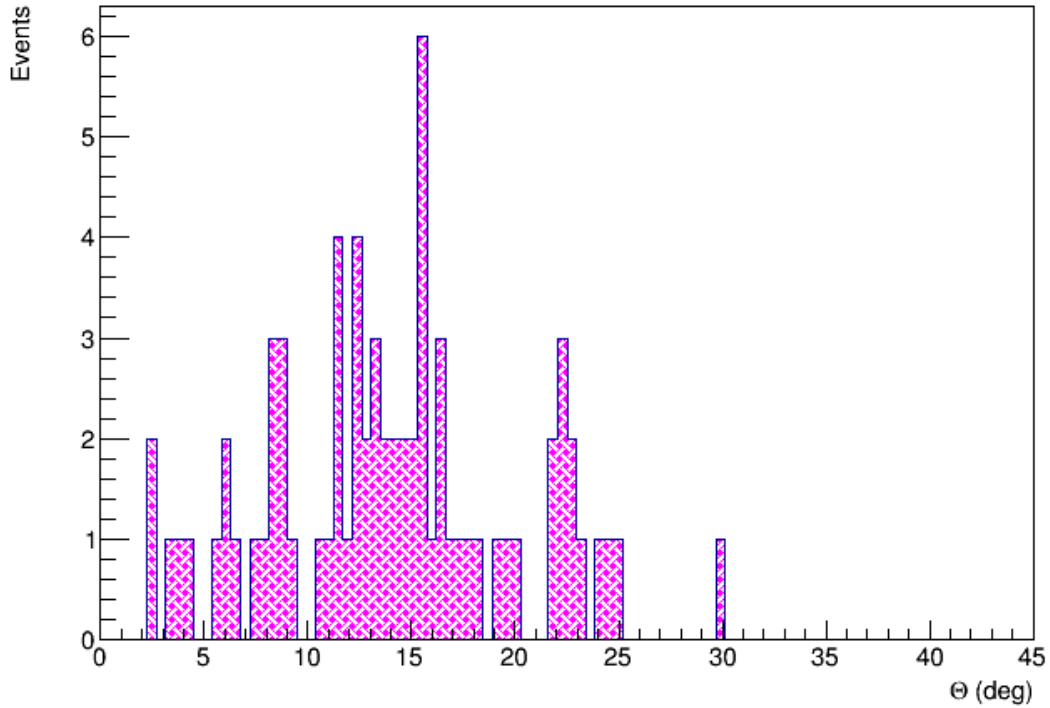


On the left panel the **background** due to independent muons is shown.
On the right there is a **peak** in a selected region of θ, corresponding to muons passing through both detectors, **superimposed on the background**.

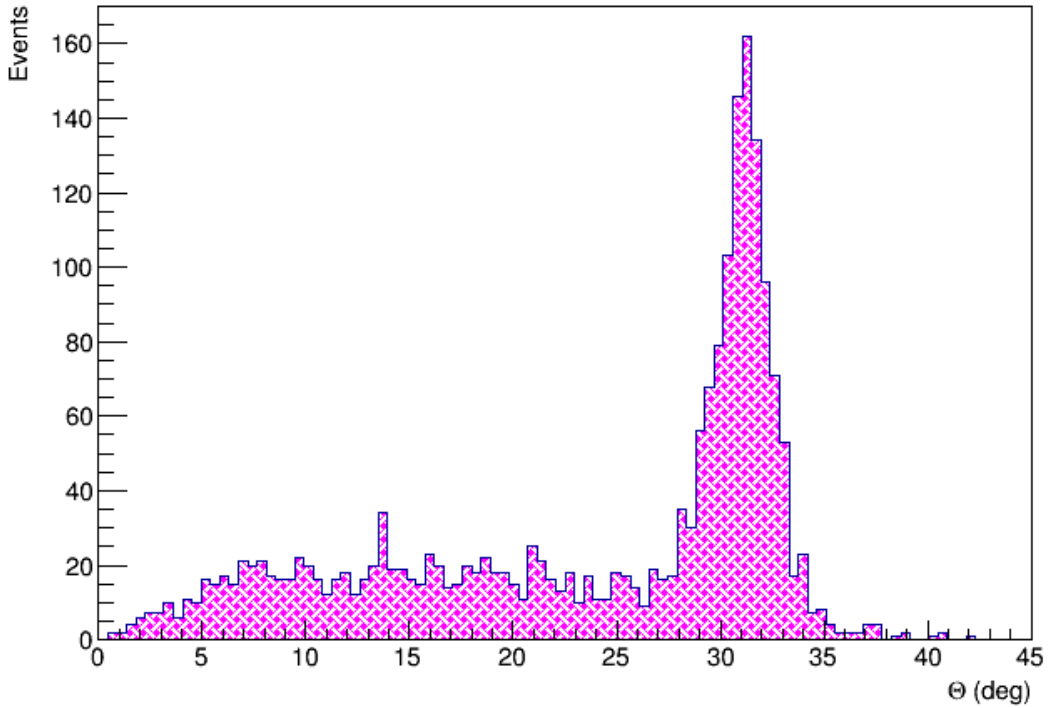
Theta distribution

< θ >	Δ<θ>
31.03°	0.05°

POLA-01 outside CATA-01 acceptance



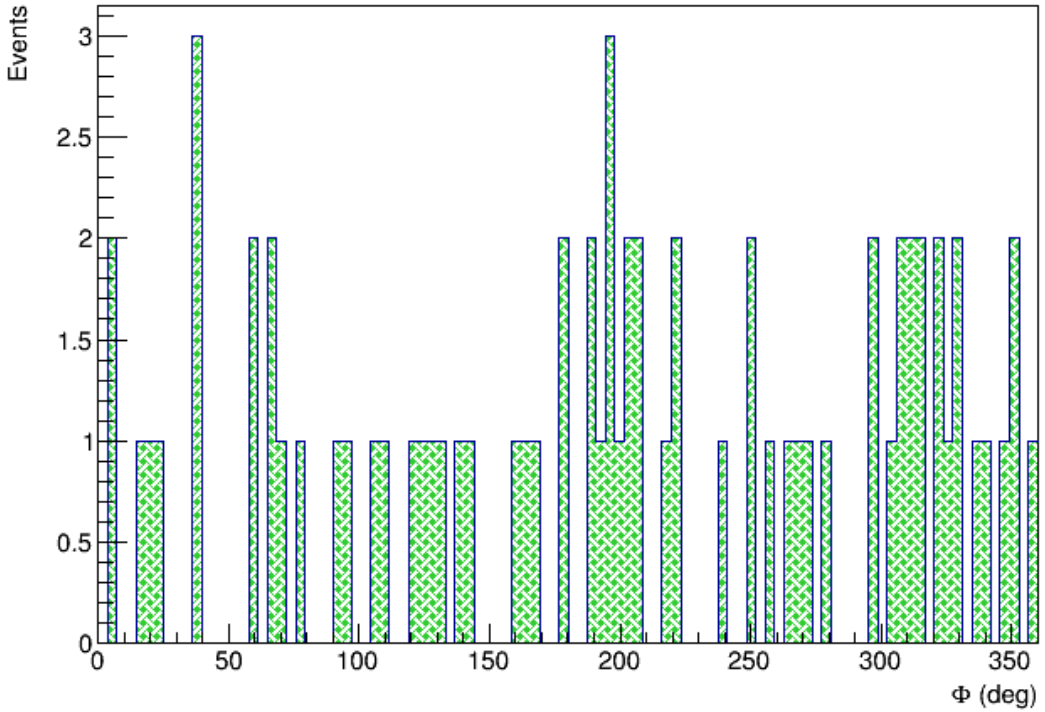
POLA-01 inside CATA-01 acceptance



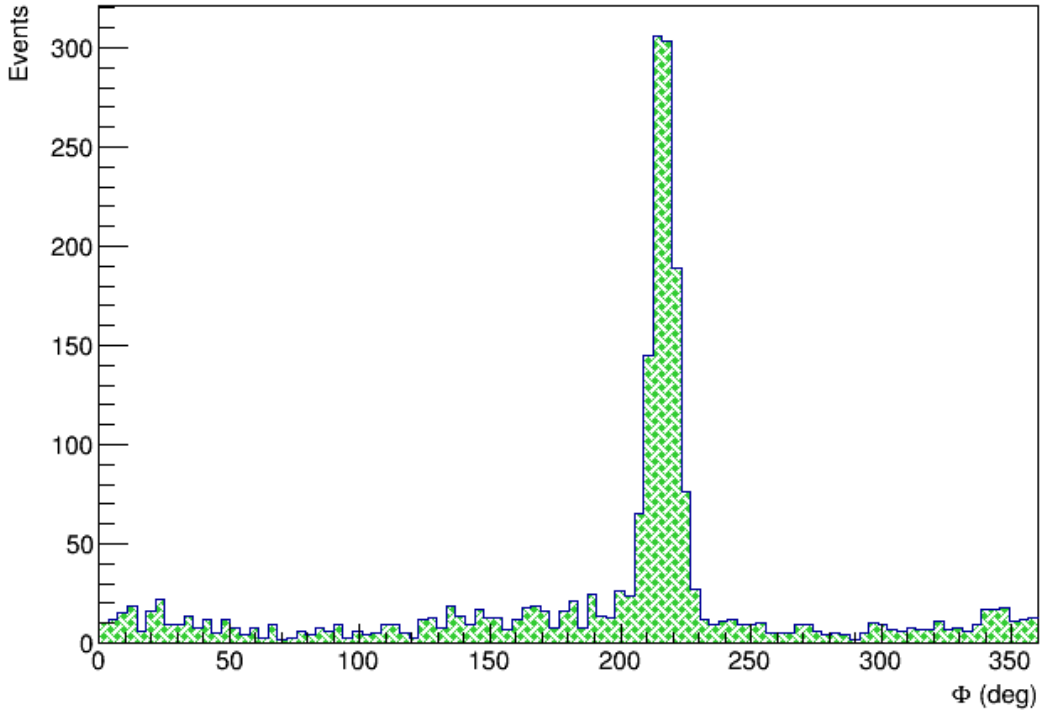
On the left panel the **background** due to independent muons is shown.
On the right there is a **peak** in a selected region of θ, corresponding to muons passing through both detectors, **superimposed on the background**.

Phi distribution

POLA-01 outside CATA-01 acceptance



POLA-01 inside CATA-01 acceptance

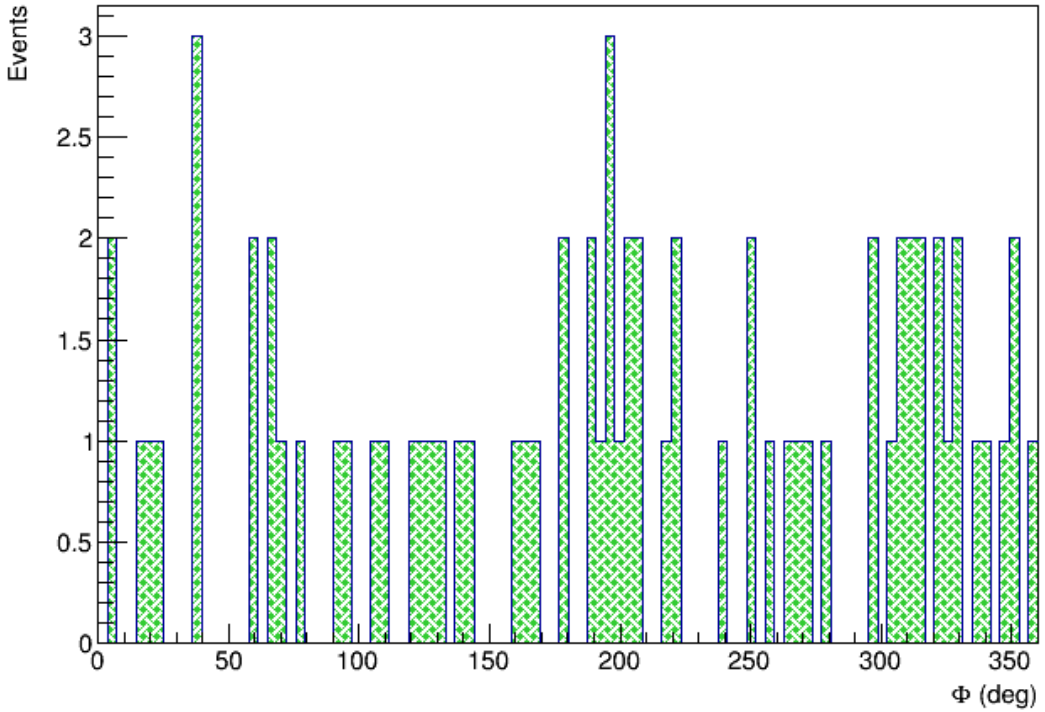


As before, for the ϕ distribution.

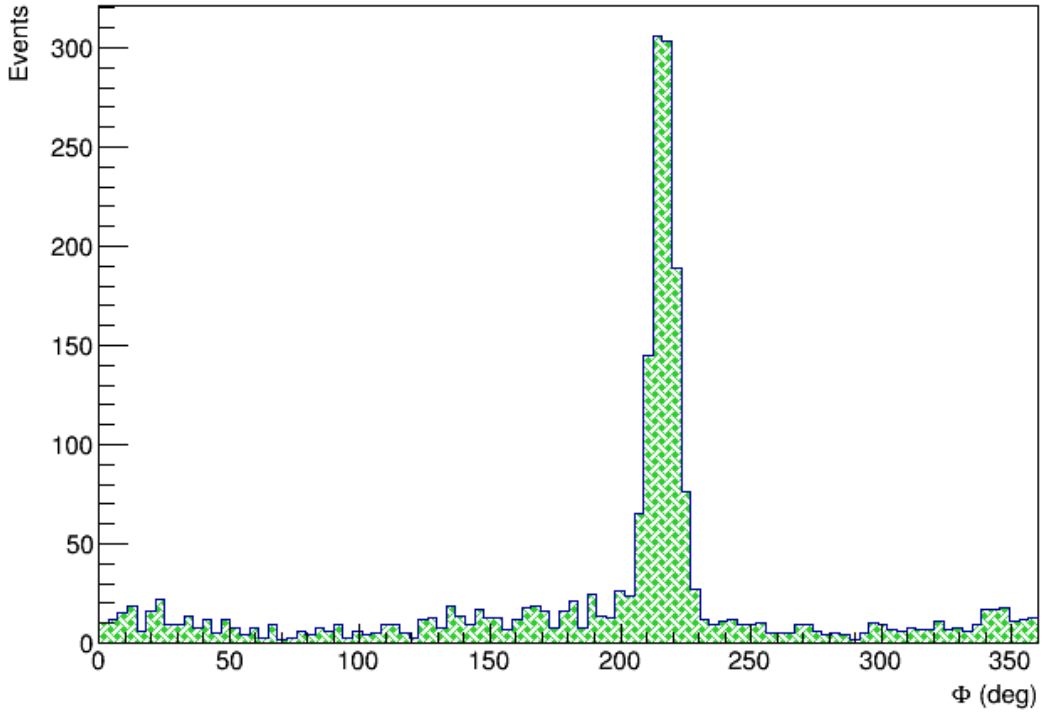
Phi distribution

< ϕ >	Δ<ϕ>
216.43°	0.20°

POLA-01 outside CATA-01 acceptance

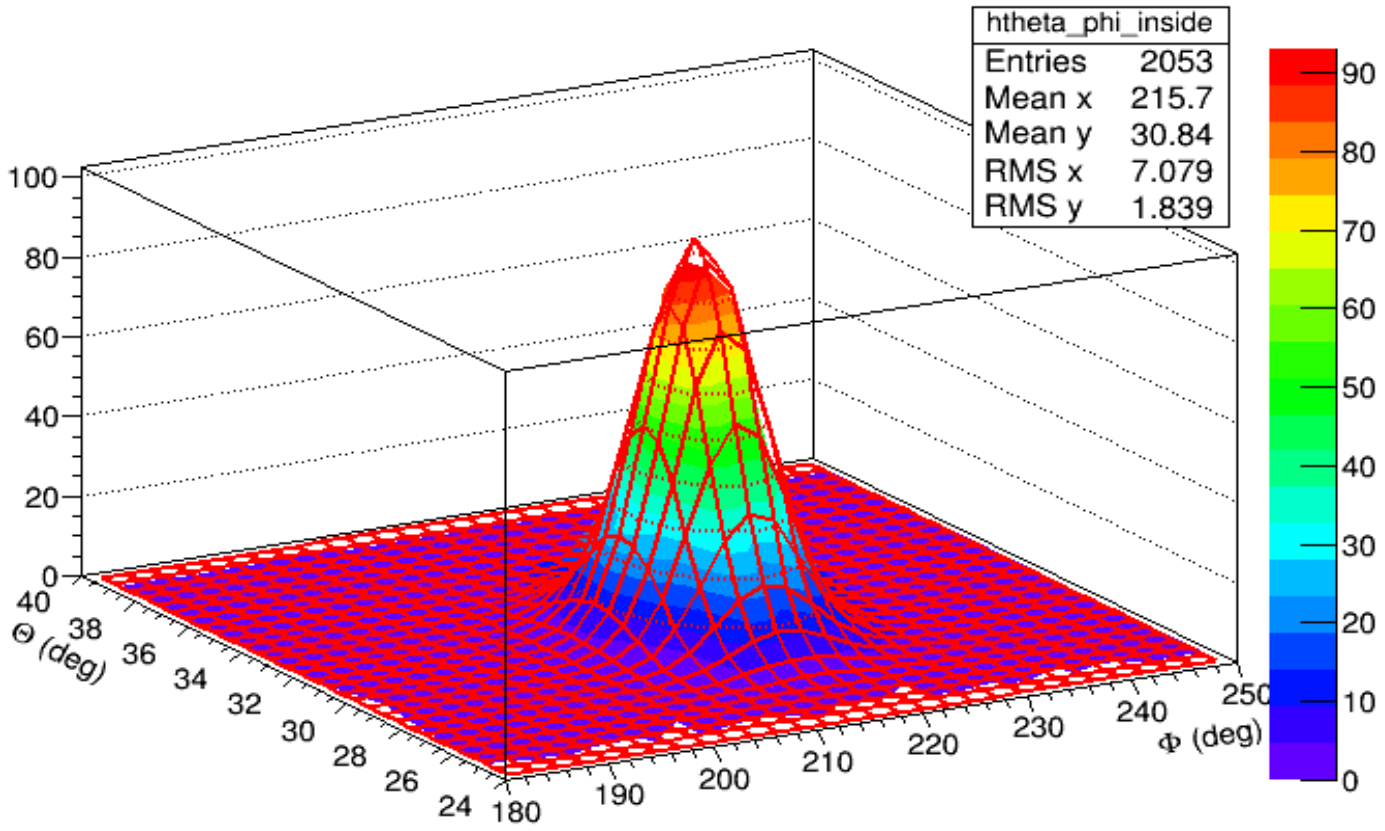


POLA-01 inside CATA-01 acceptance



As before, for the ϕ distribution.

Theta-Phi correlation



< θ >	Δ<θ>
31.11°	0.05°

< ϕ >	Δ<ϕ>
216.63°	0.16°

Comparable results are obtained by a combined fit over the two variables.

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

- A few years ago, measurements of cosmic muons passing through a tracking detector and additional detectors mechanically coupled to the structure of large buildings was suggested as a tool to monitor small (mm) shifts of parts of the structure over long time periods.

👍 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)

👍 limited invasiveness

👍 possibility to design a global monitoring system

👎 low rate of cosmic muons (relatively) long data taking

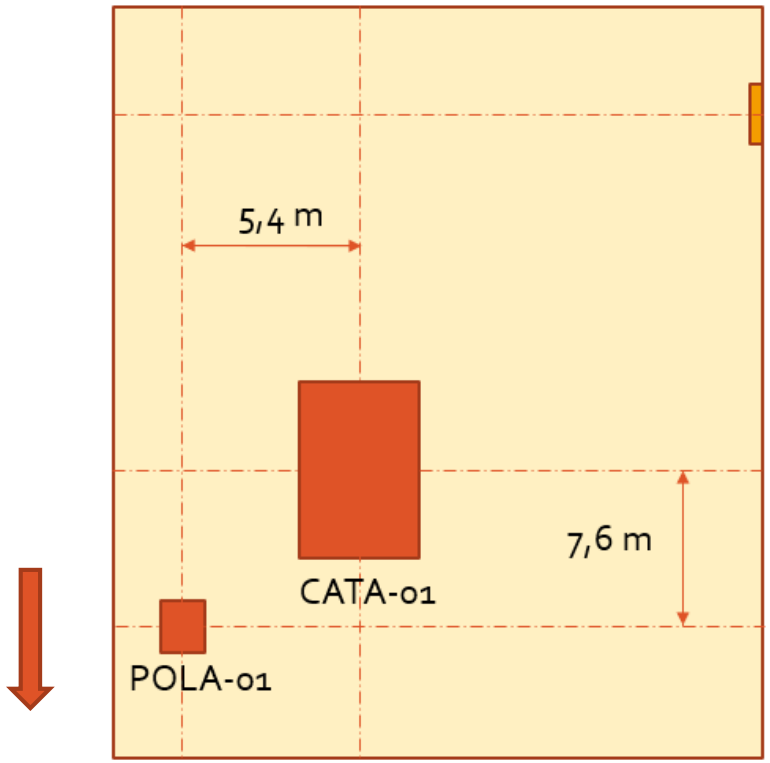
Cosmic muons as a tool to monitor the stability of civil structures on a long time scale

- Extensive simulations and prototype detectors being implemented by Brescia-Pavia groups in Italy (G.Bonomi et al.). The technique was applied to a realistic scenario, using the "Palazzo della Loggia" in Brescia as a case study.
- Performances of the method depend on the capability of the main tracking detector, geometry and position of the additional detectors , measurement stability, acquisition time,..

Are EEE telescopes able to provide a tool even for this new application?

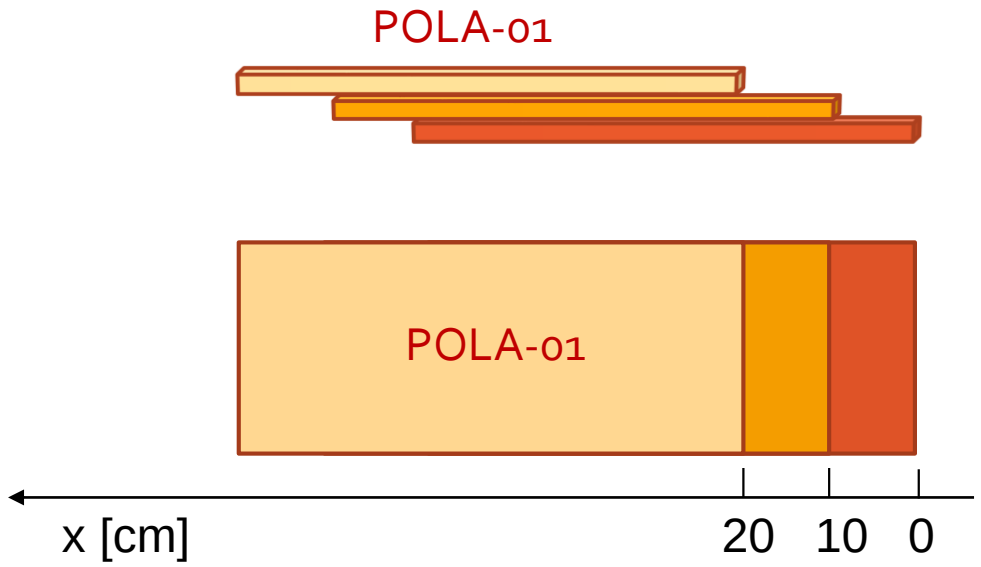
→ Preliminary measurements with CATA-01 as a tracking detector and POLA-01 as an additional detector carried out to test such a possibility

Measurements

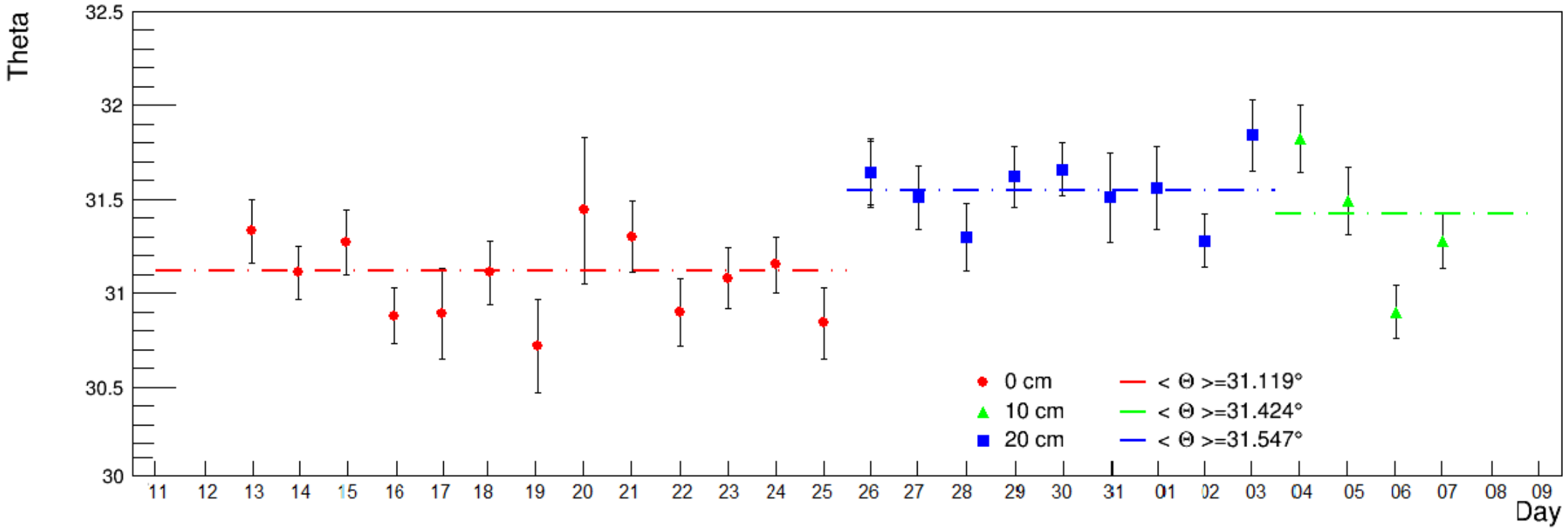


Three sets of measurements:

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



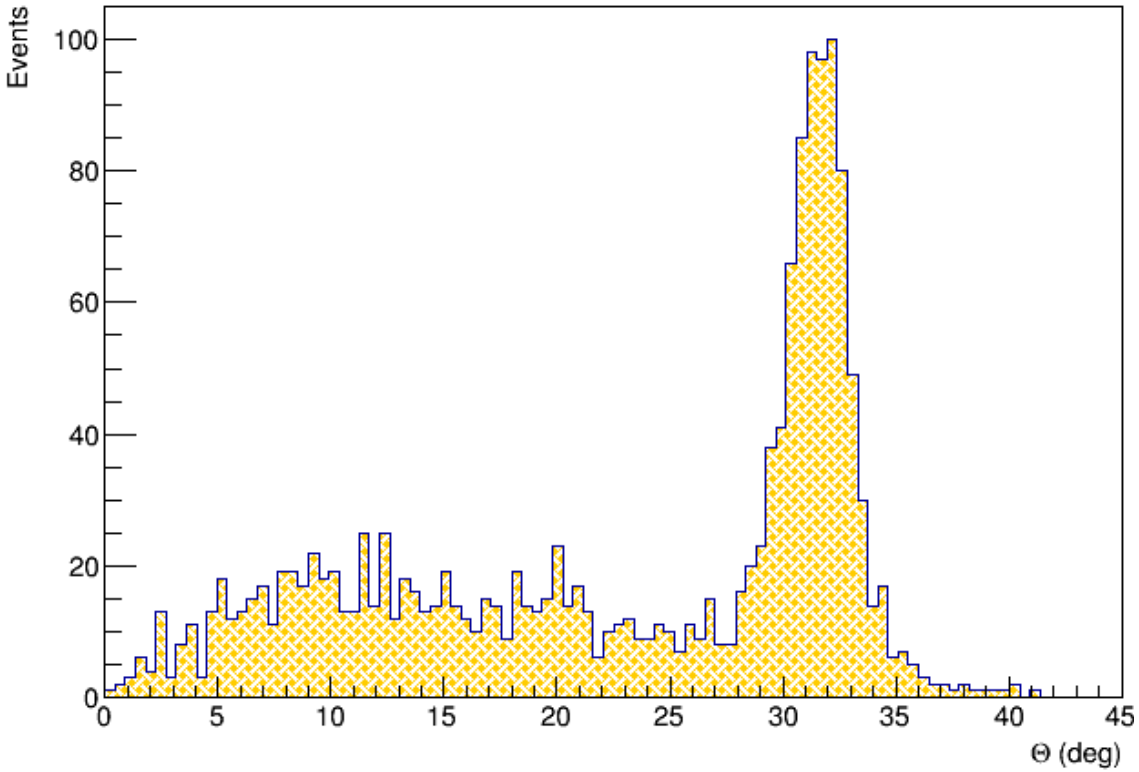
Theta variation per day



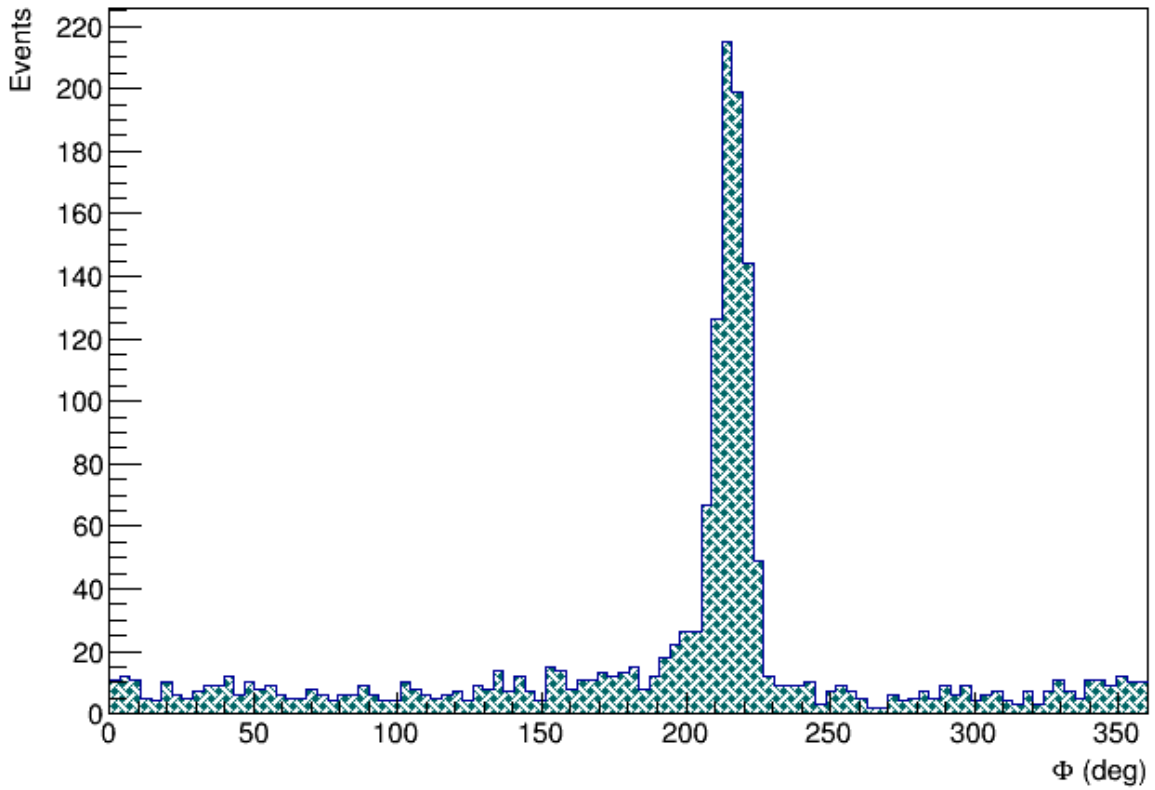
Extracting θ centroids day by day one can see that in average there is a shift.

20 cm shift

POLA-01 inside CATA-01 acceptance



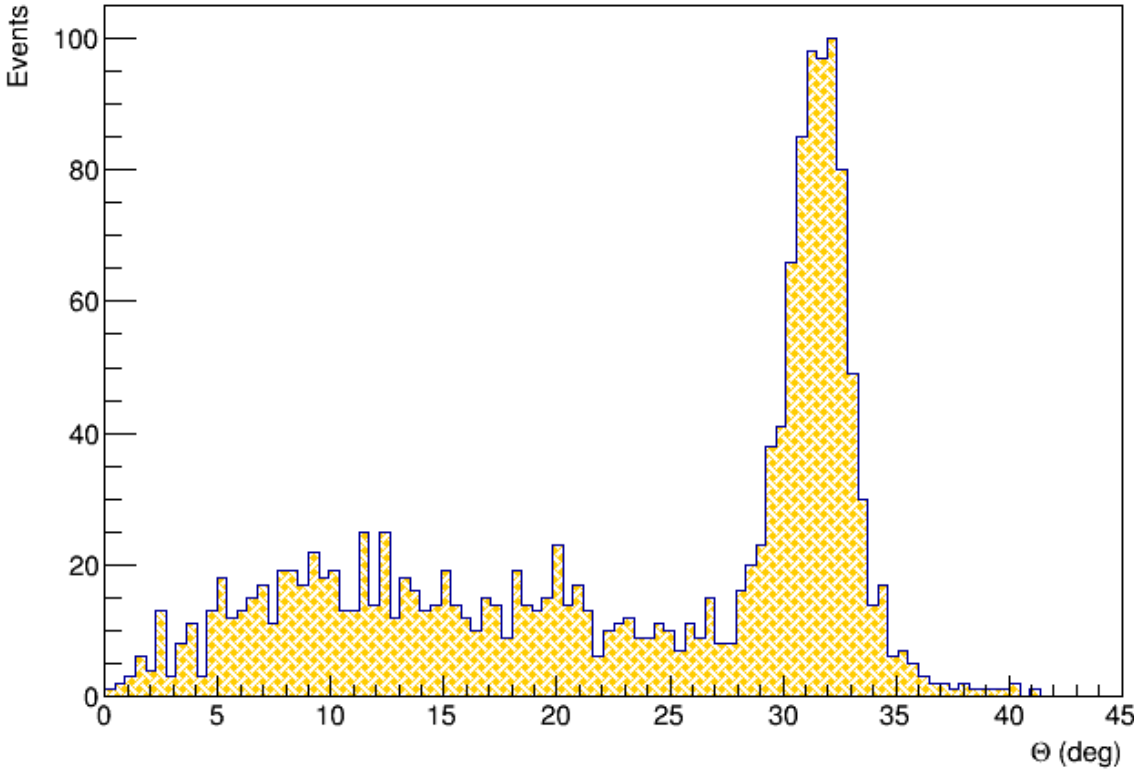
POLA-01 inside CATA-01 acceptance



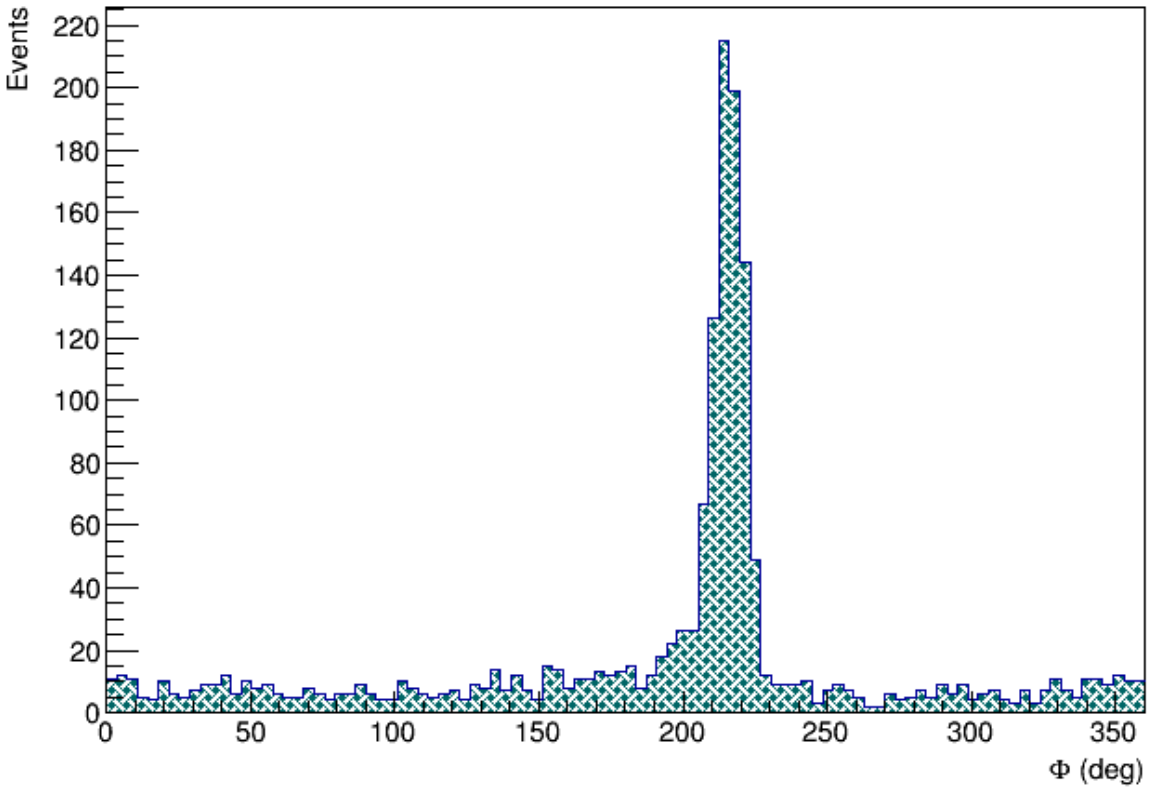
20 cm shift

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°

POLA-01 inside CATA-01 acceptance

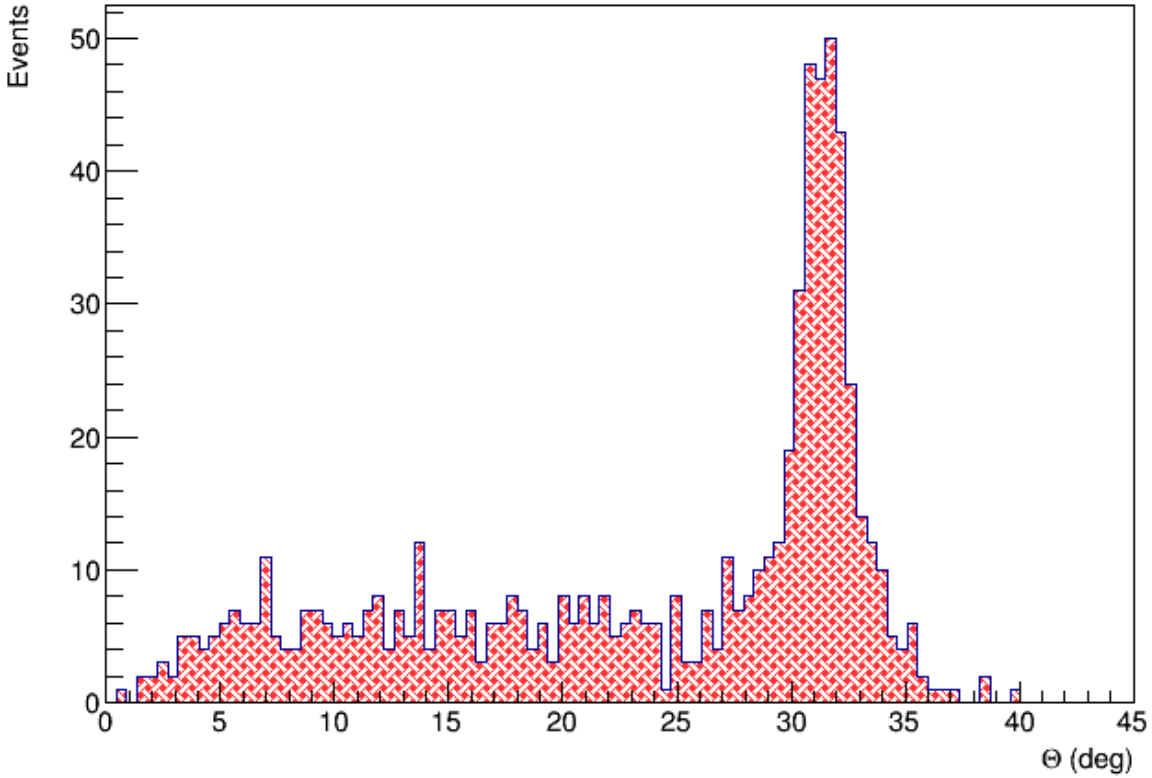


POLA-01 inside CATA-01 acceptance

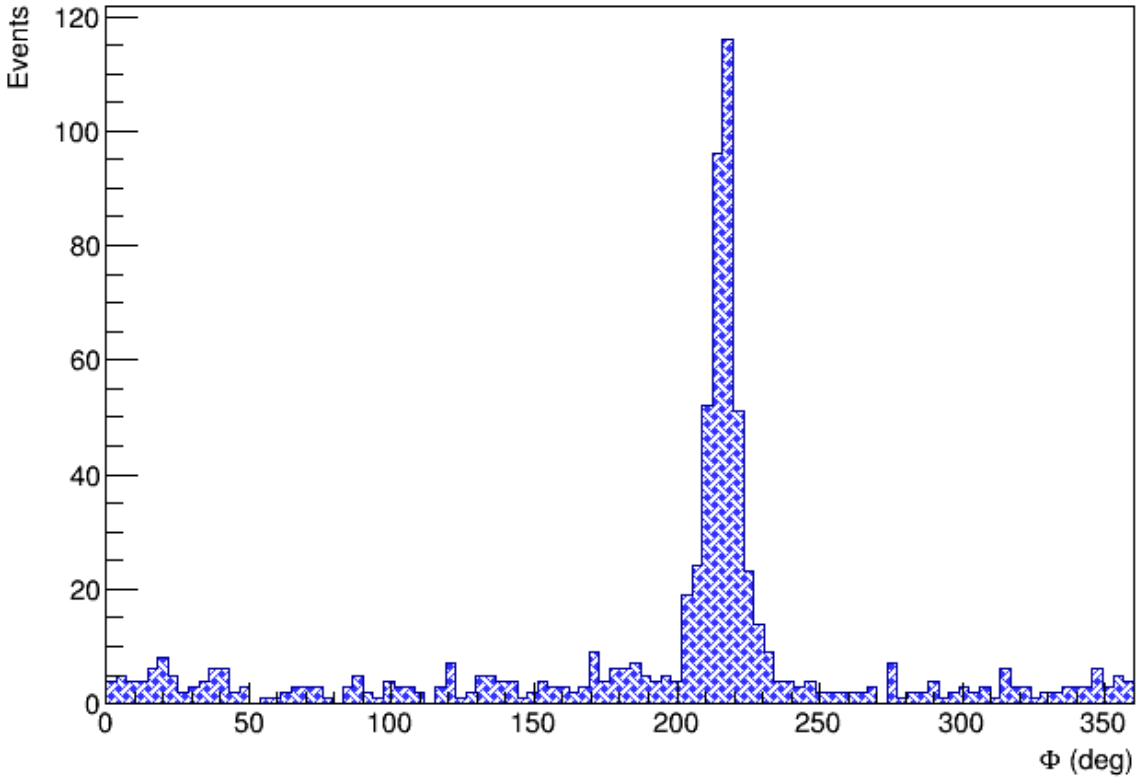


10 cm shift

POLA-01 inside CATA-01 acceptance



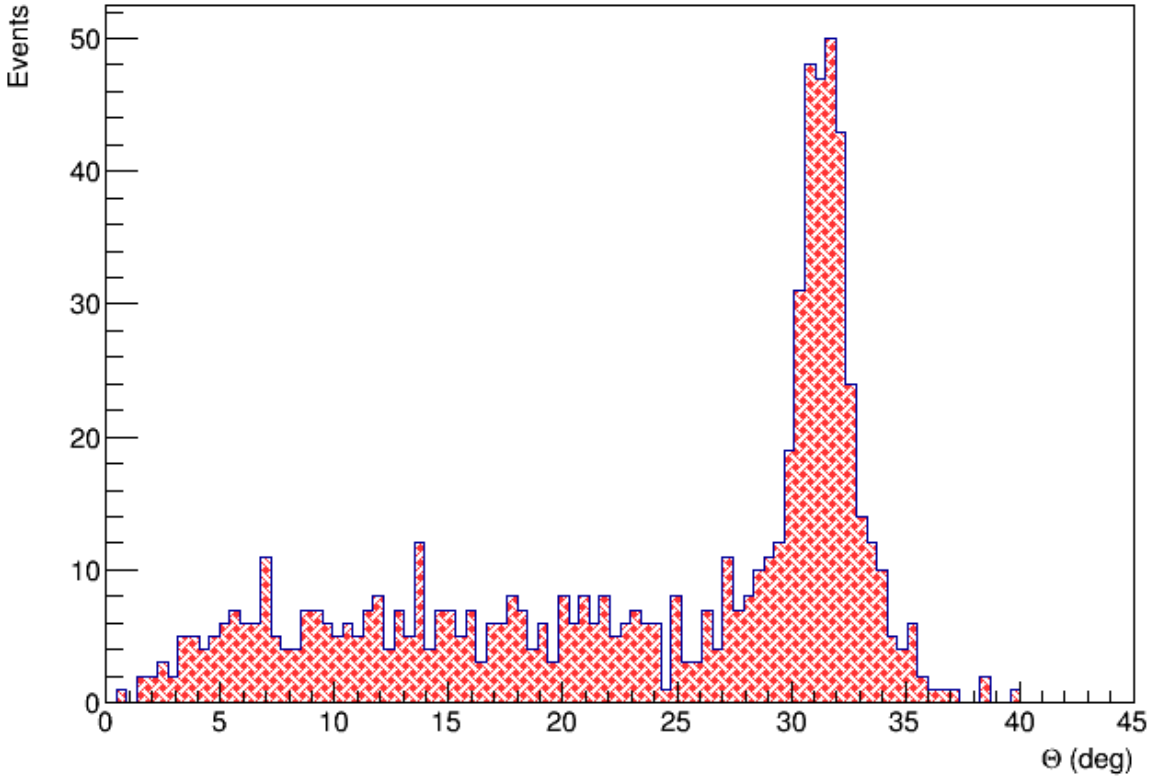
POLA-01 inside CATA-01 acceptance



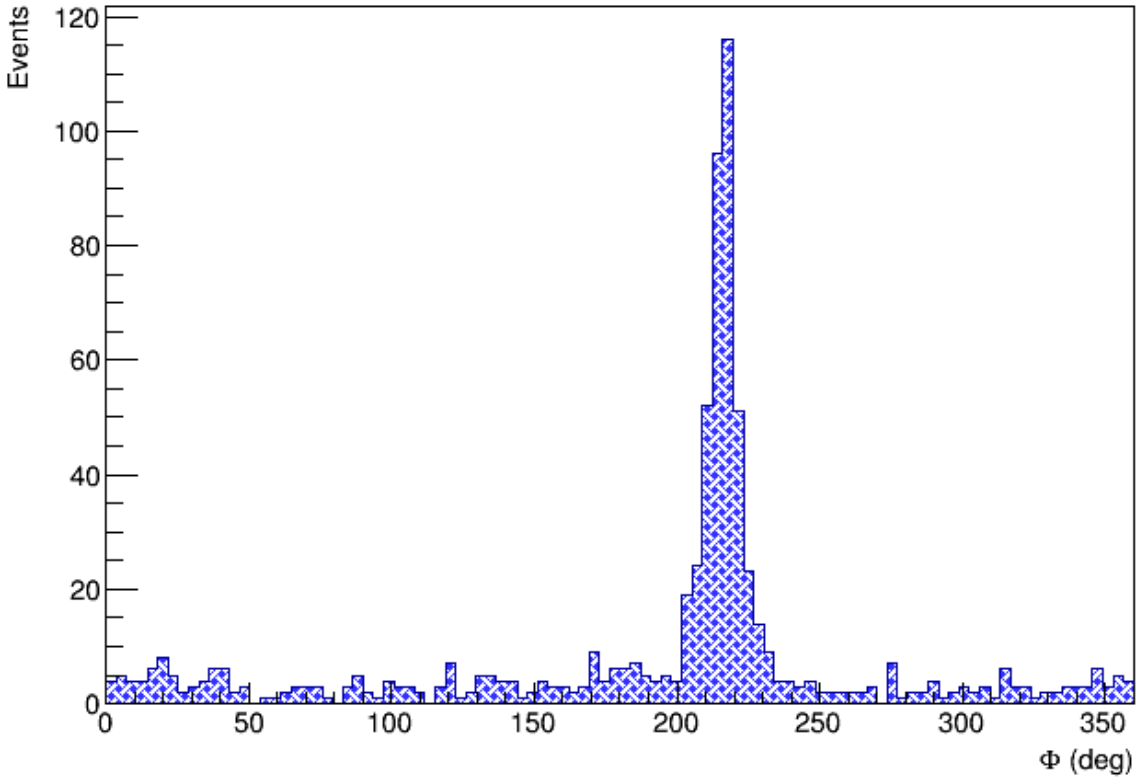
10 cm shift

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°

POLA-01 inside CATA-01 acceptance



POLA-01 inside CATA-01 acceptance



Measurements

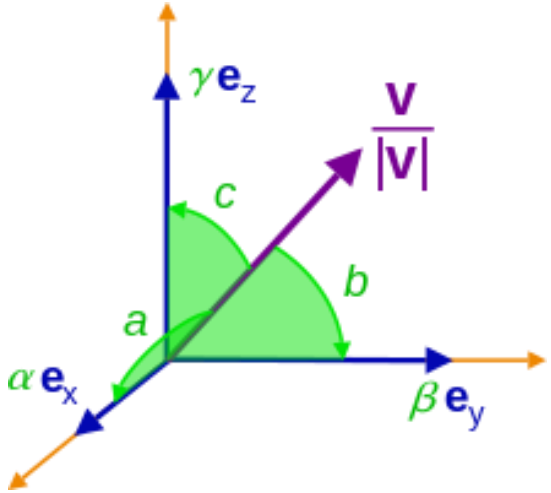
- Mean values for θ and ϕ angles, estimated with a gaussian fit.

Gaussian fit		
x [cm]	**$< \theta > \pm \Delta<\theta>$**	**$< \phi > \pm \Delta<\phi>$**
0	31.03° ± 0.05°	216.39° ± 0.16°
+10	31.36° ± 0.08°	215.98° ± 0.30°
+20	31.45° ± 0.06°	215,67° ± 0.20°

Distribution of average direction in space

- Estimation of the average direction in space, summing on all the tracks, in 3 configurations (0 cm, 10 cm, 20 cm).
- Each average direction is individuated by a couple (θ, ϕ).
- The difference between such average directions indicate the relative angle shift.

Relative distance	Relative angle shift
20 cm	0.44°
10 cm	0.30°



Conclusions and outlook

- Measurements still running during January 2019;
- Present sensitivity of the method may be roughly estimated of the order of 1 cm for a data taking period of 1 week;
- Better estimation of sensitivity and systematic errors in progress;
- Monte Carlo simulations in progress to better understand the results and improve operational conditions.