

CENTRO  
FERMI

*Enrico Fermi*

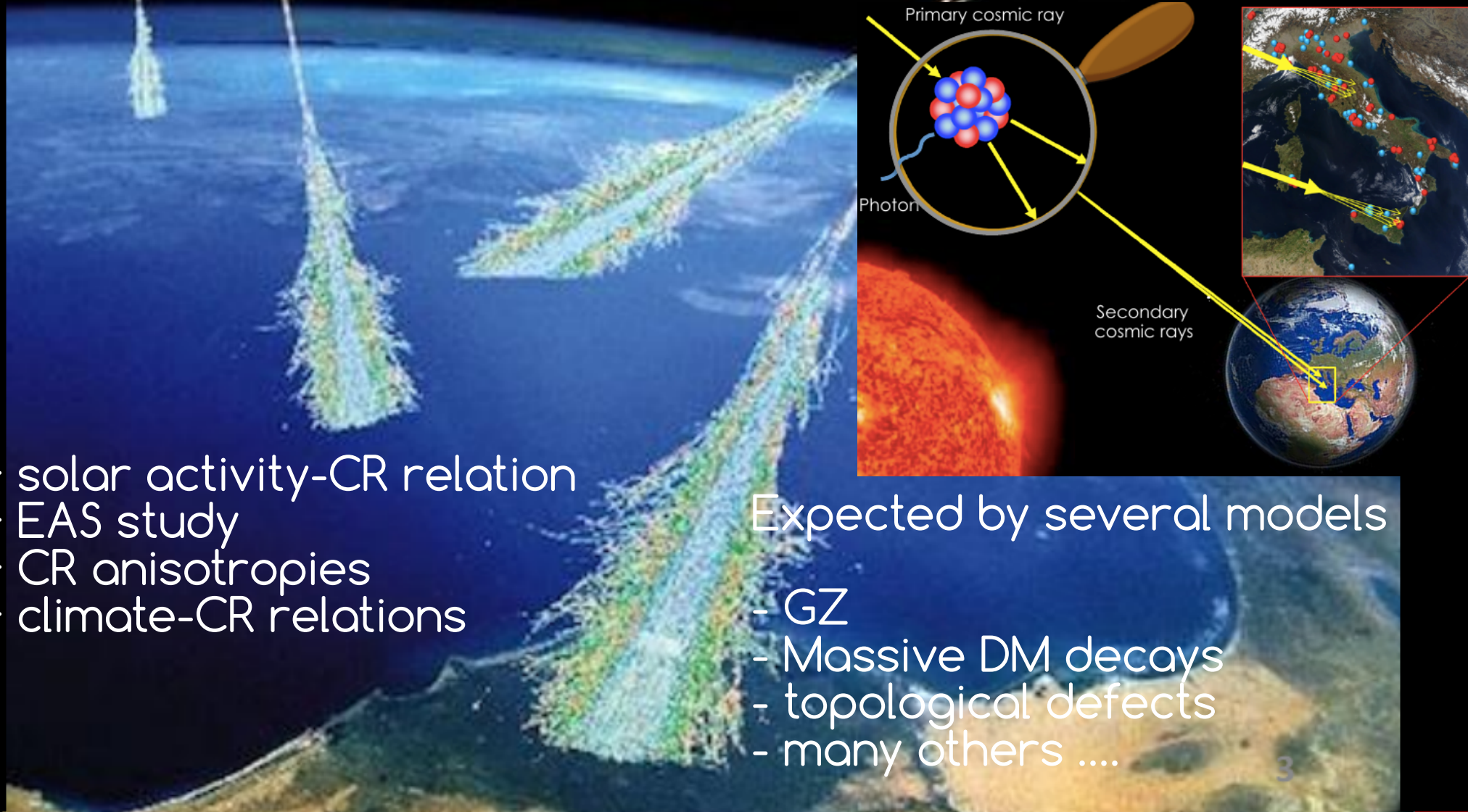
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ENRICO FERMI



# The Extreme Energy Event network Status and Perspectives

Ivan Gnesi for the EEE Collaboration

EEE is an extended and inhomogeneous array  
for the search of  
Long Distance Correlations among EAS



- + solar activity-CR relation
- + EAS study
- + CR anisotropies
- + climate-CR relations

Expected by several models

- GZ
- Massive DM decays
- topological defects
- many others ....

Present status:

Total 53 telescopes

47 inside high schools buildings

2 at CERN

4 inside INFN and Universities

49 sites selected for the upgrade

6 new telescopes in 2017

over a surface of  $3 \cdot 10^5 \text{ km}^2$

covering  $10^\circ$  in latitude and longitude



Mostly organized  
In **12 clusters**  
for EAS detection



# The Multigap Resistive Plate Chamber (see M.P. Panetta talk)

Same technology used for the Time Of Flight (TOF) measurement at ALICE (LHC)

6 gas gaps 250-300  $\mu\text{m}$

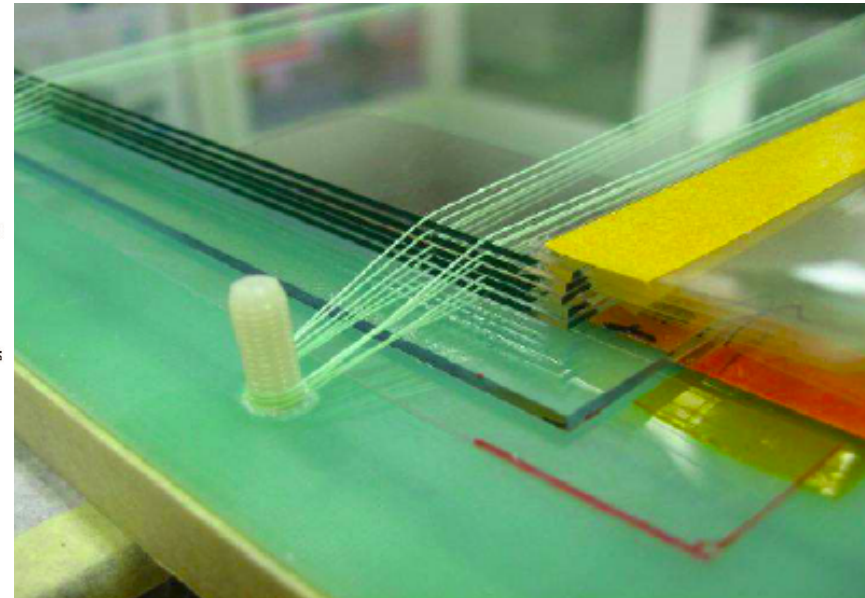
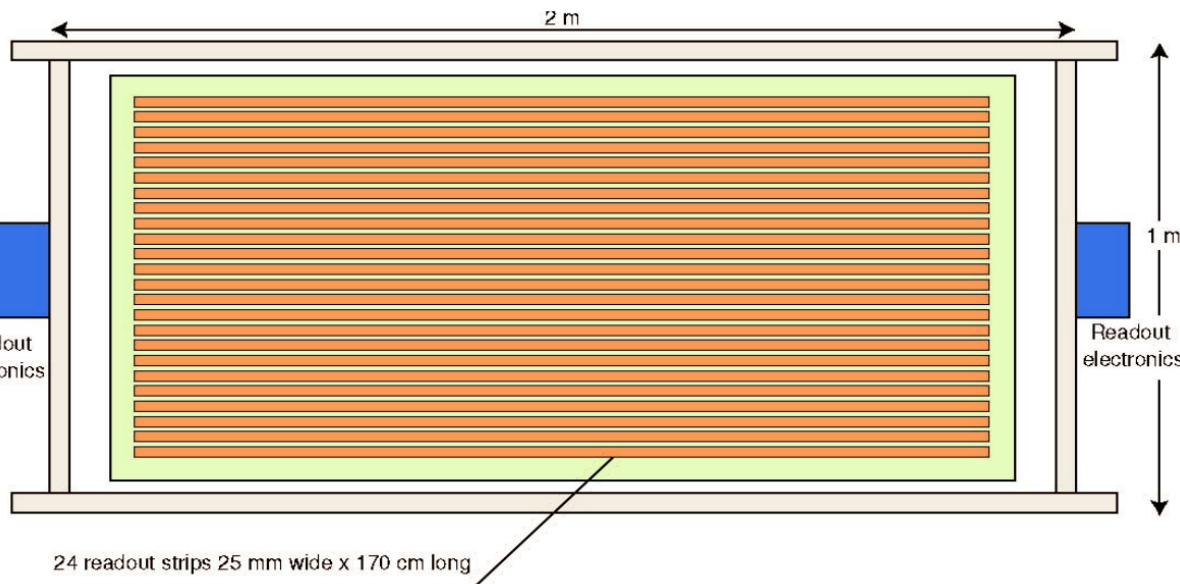
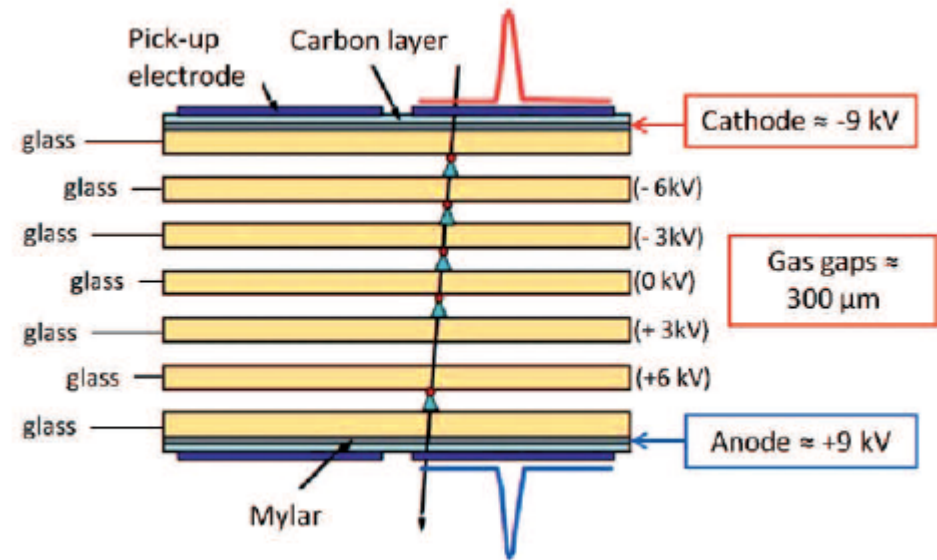
$\text{C}_2\text{H}_2\text{F}_4$  (98%) /  $\text{SF}_6$  (2%) mixture

18-20 kV working voltage

24 strips per chamber, 2.5 cm pitch

The signal induced on the strips is the **sum of the 6 gaps signals**

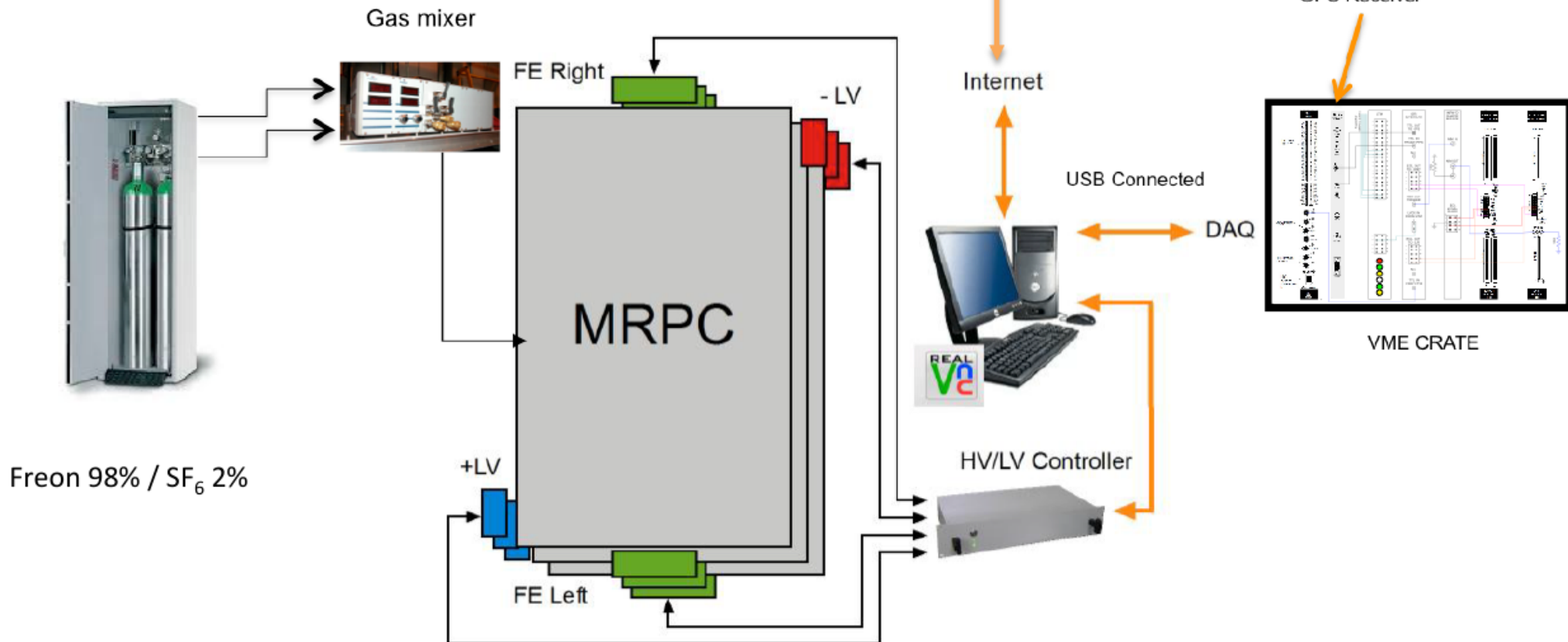
The **avalanche time is very short**  $\rightarrow$  time resolution



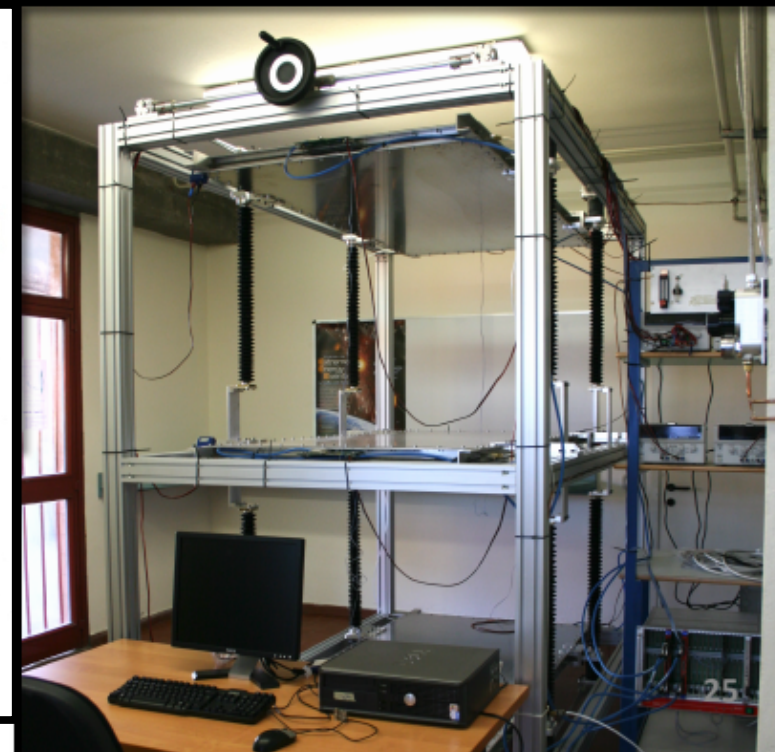
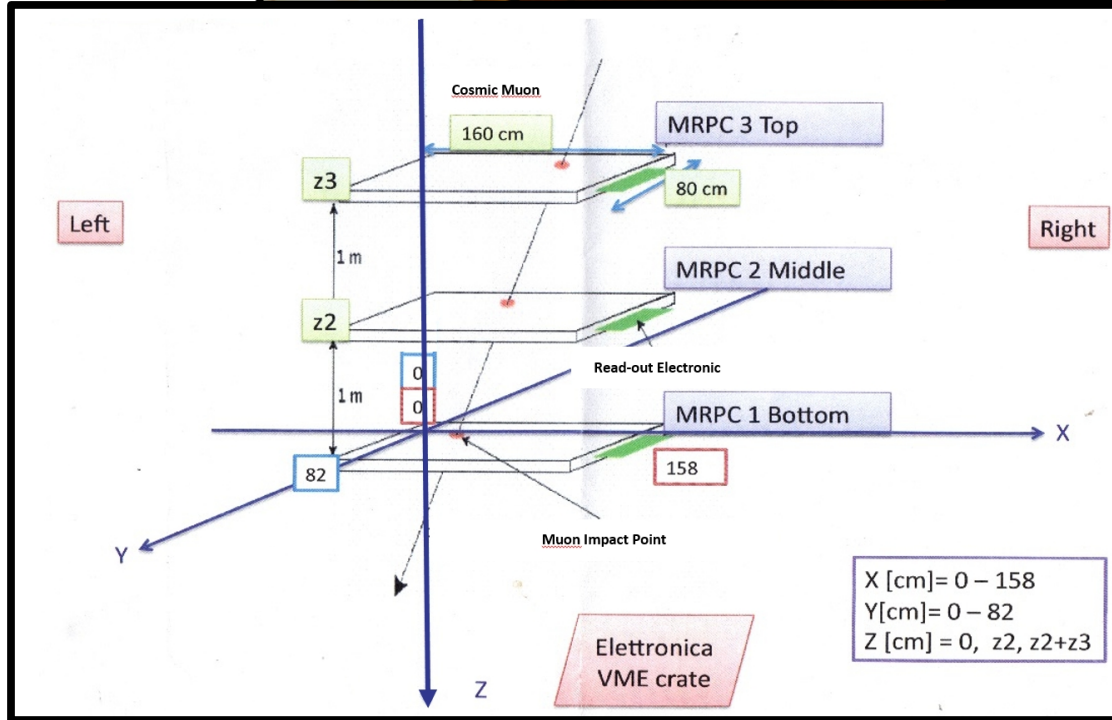
144 readout channels

TDCs @ 100 ps (can be operated to 25 ps)

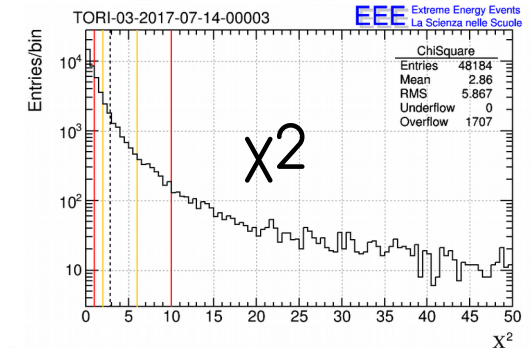
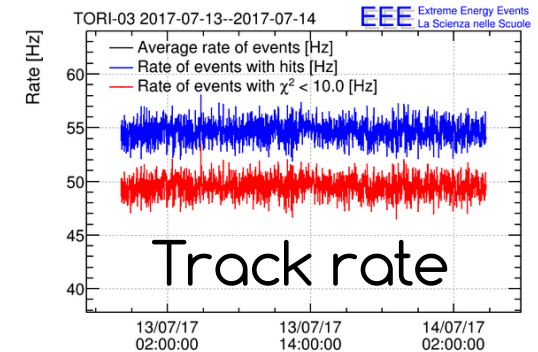
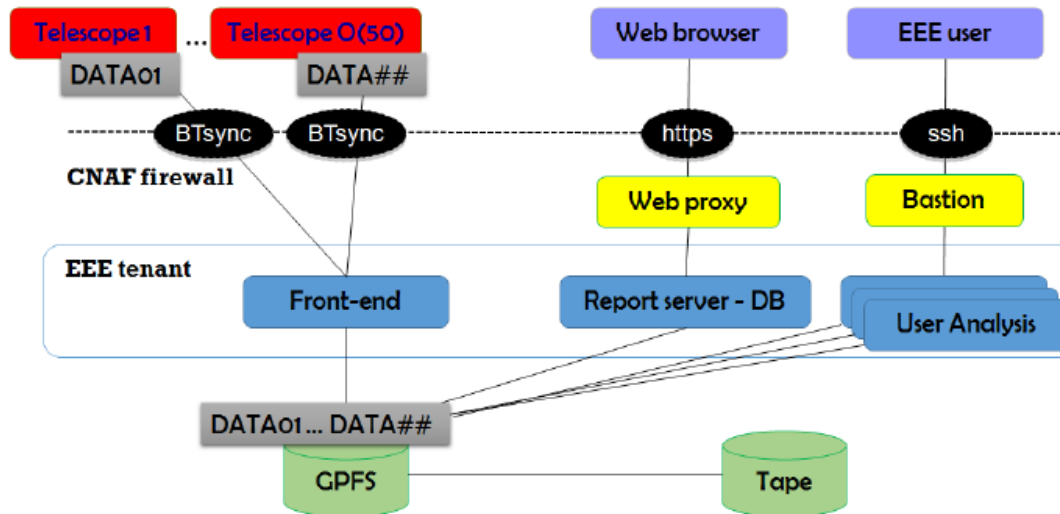
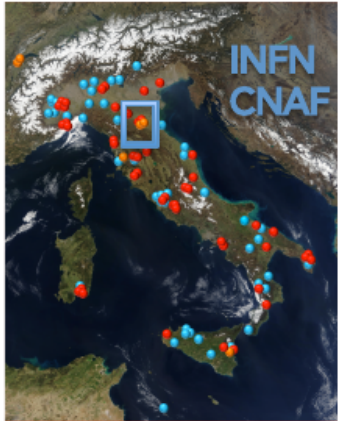
GPS @ 10-20 ns resolution



Some EEE telescope installations



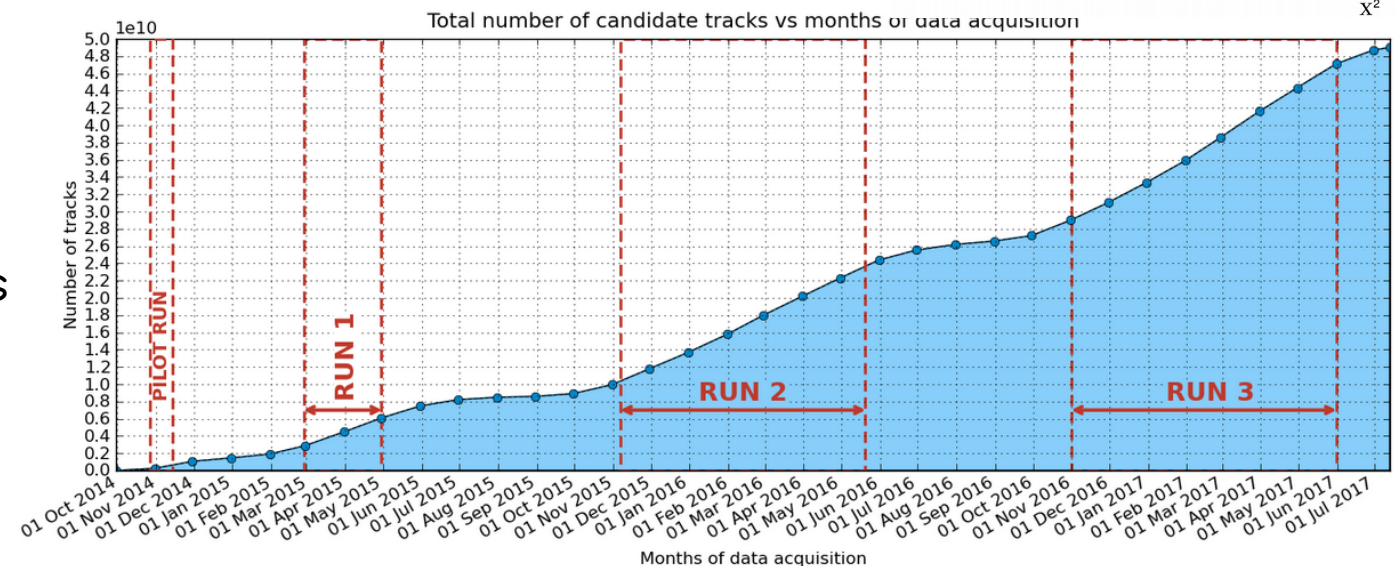
Data are automatically sent to INFN CNAF, reconstructed and processed by DQM



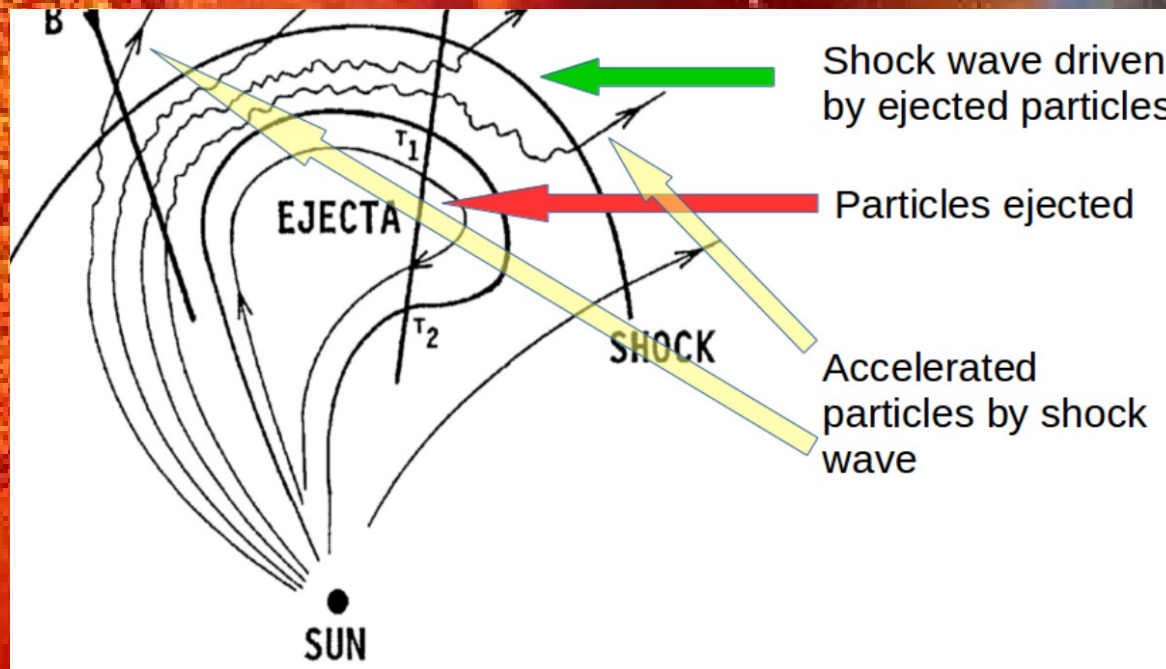
> 50 billions tracks  
with  $\chi^2 < 10$   
have been collected  
for analysis

The data collection rate is  
at present  
25 billions/y → increasing

RUN-4 starting on  
October 2nd



# Forbush Decreases and solar activity

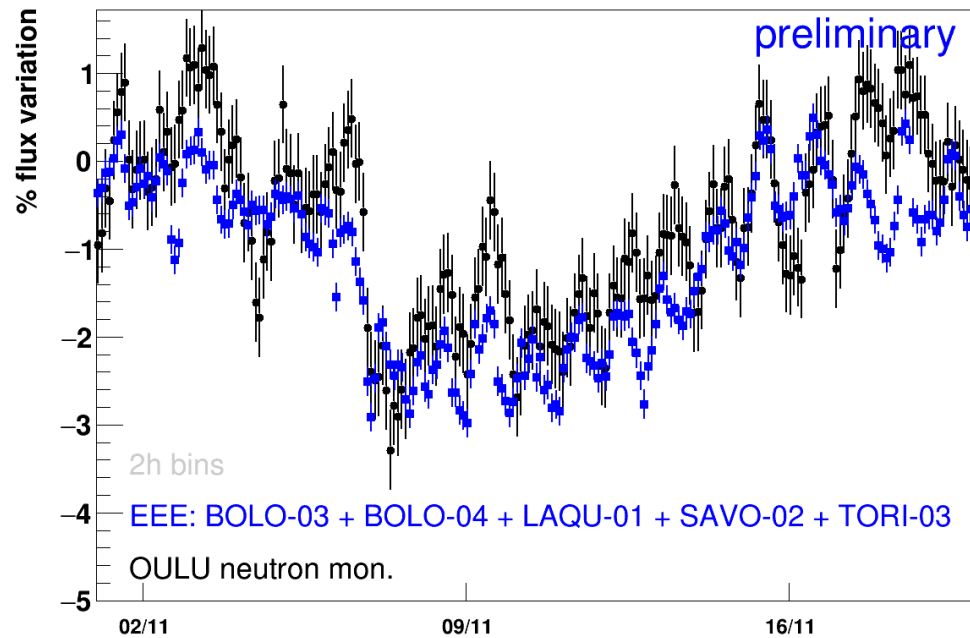




# Results – Forbush Decreases

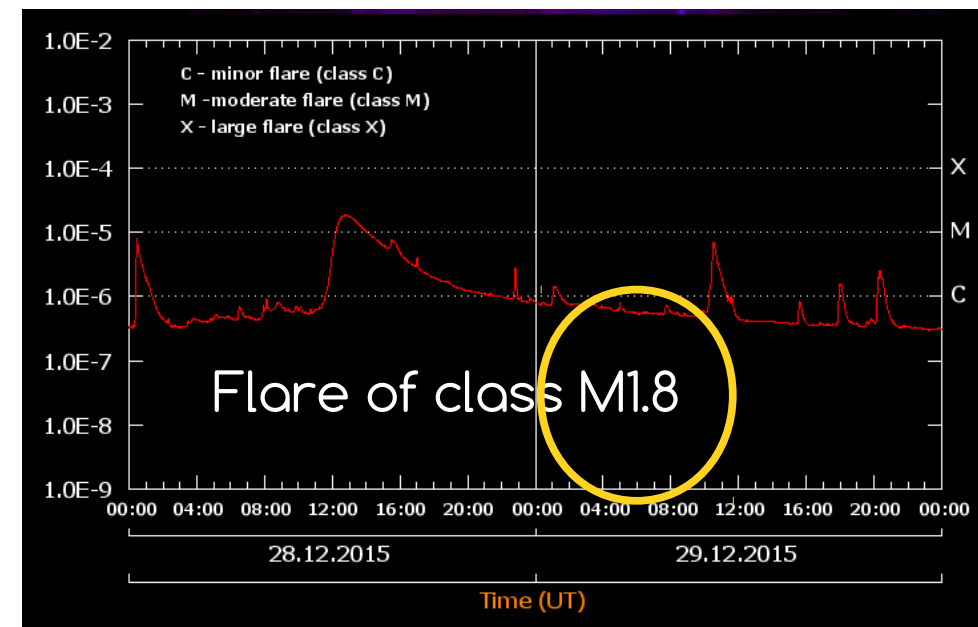
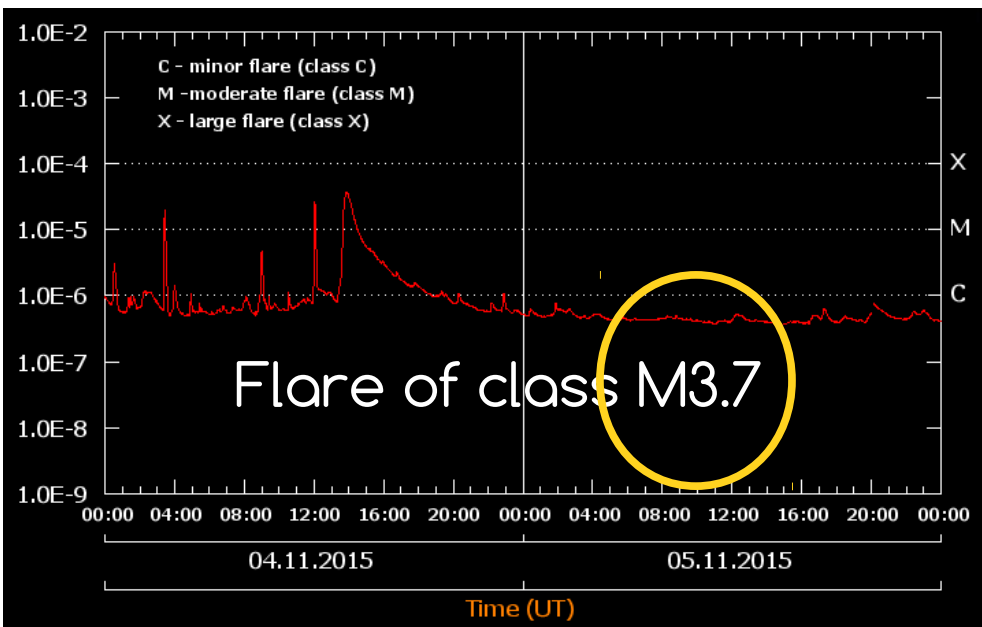
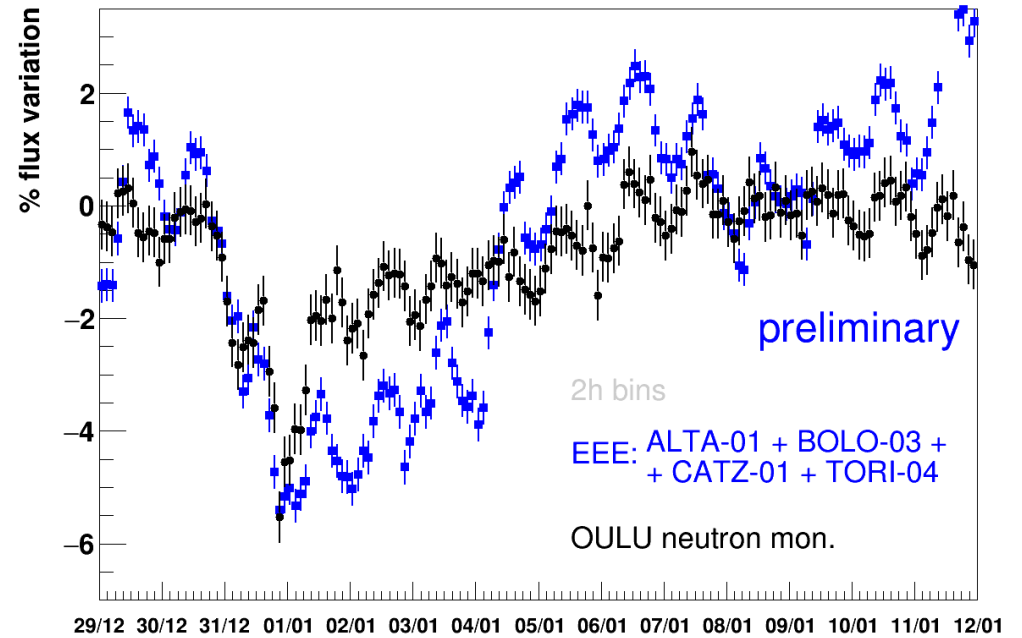
GCRD 2015-11-07

EEE Extreme Energy Events  
La Scienza nelle Scuole



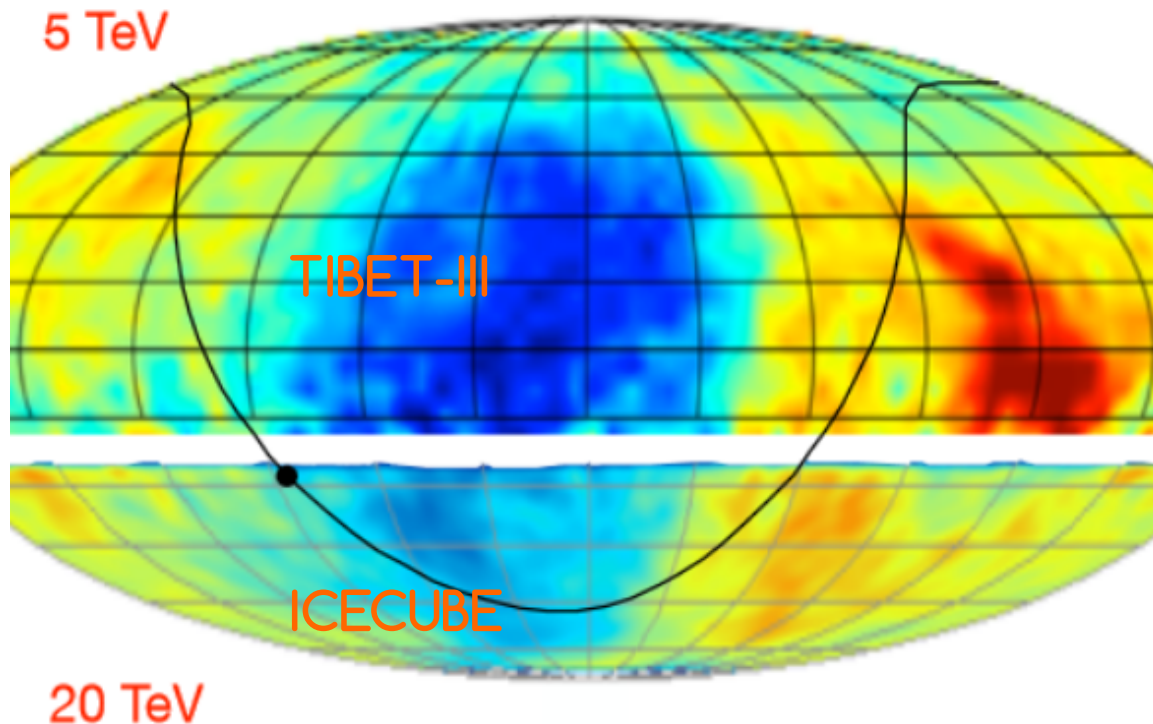
GCRD 2015-12-31: EEE-OULU fluxs

EEE Extreme Energy Events  
La Scienza nelle Scuole

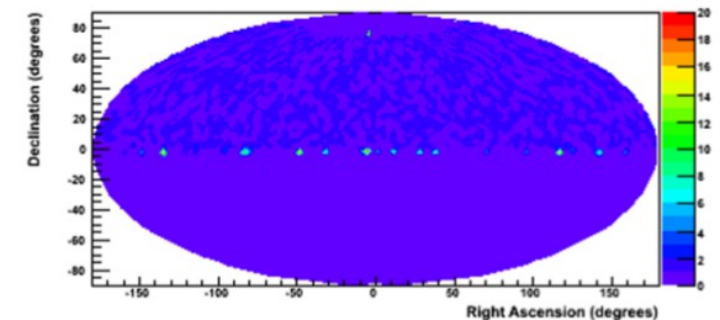
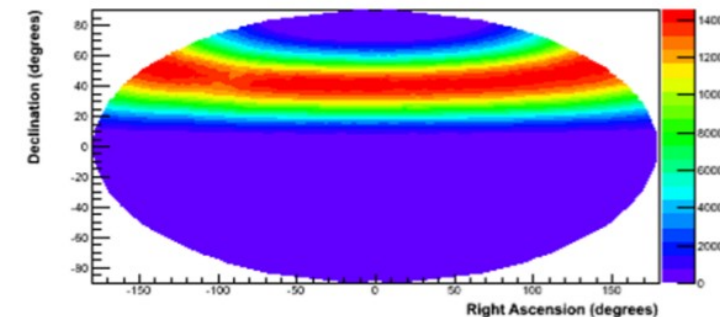
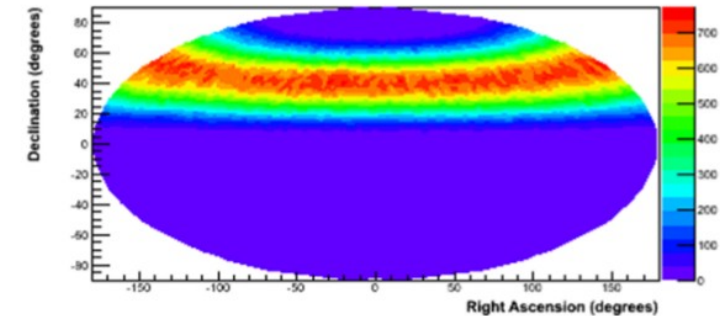


# CR anisotropies @ TeV scale

- + Dipole ( $10^{-3}$ ) : relative motion/well defined sources?
- + Multipole ( $<10^{-4}$ ): local turbulent magnetic field component ?



EEE

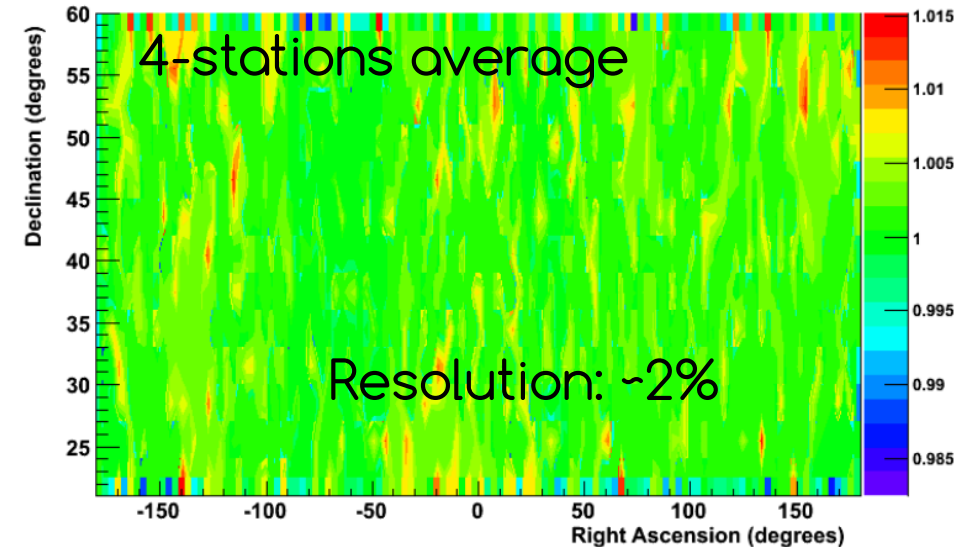
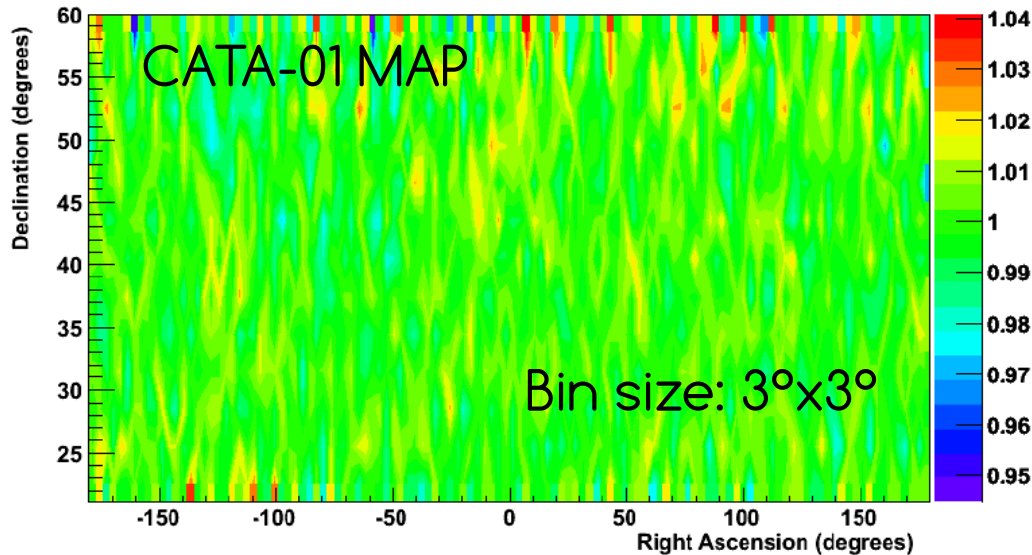


EEE stations are suitable for studying **TeV CR anisotropies**

- local IMF features
- Compton Getting

→ already observed effects to be  $10^{-3}$ - $10^{-5}$

EEE Site (Location)	Geographical location	Number
SAVO-01 (Savona)	44° 18.366' N, 8° 28.078' E	48.6 M
CAGL-01 (Cagliari)	39° 13.767' N, 9° 7.084' E	16.6 M
TRIN-01 (Trinitapoli)	41° 21.167' N, 16° 5.004' E	20.2 M
CATA-01 (Catania)	37° 31.501' N, 15° 4.046' E	19.3 M



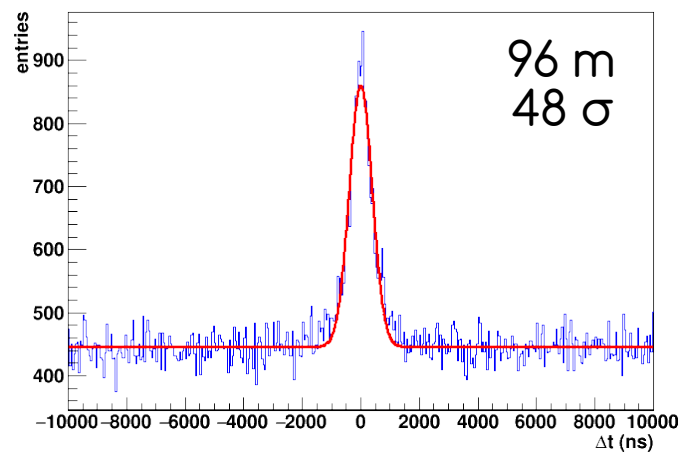
With the present preliminary dataset **no evidences of anisotropies** at the level of the available **2%** resolution

with the **whole statistics**, at least factor 100 → **0.2%** resolution expected



## Studies on EAS

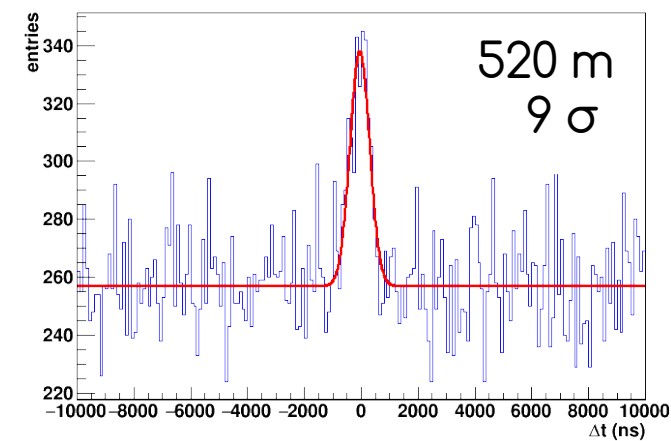
# Results – Studies on EAS (see F. Coccetti talk)



Coincidences observed up to 1500 m for all telescopes pairs

Coincidence time is corrected according to the  $\mu$  arrival directions.

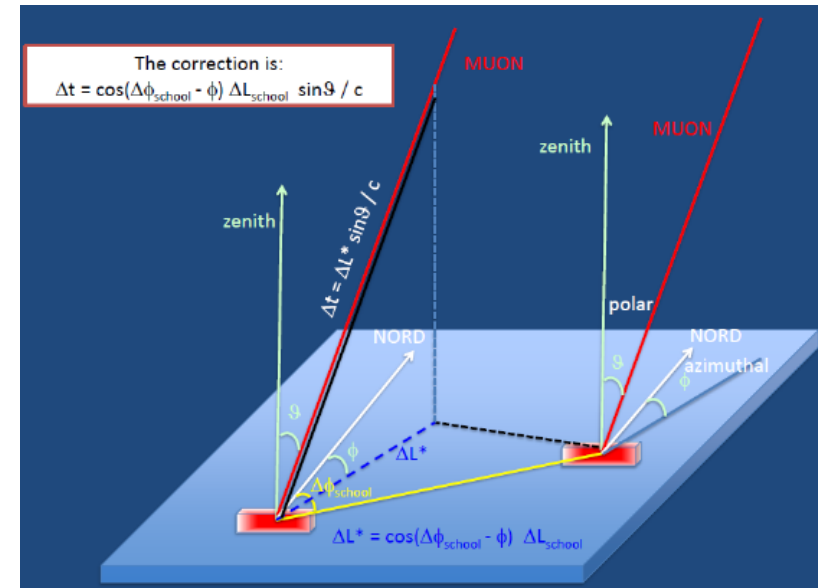
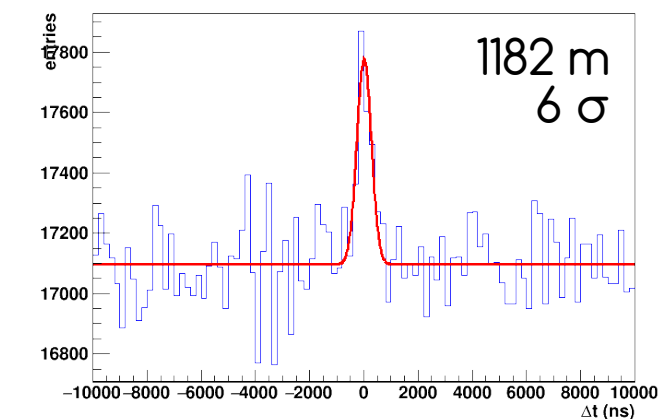
This enhance S/B ratio.



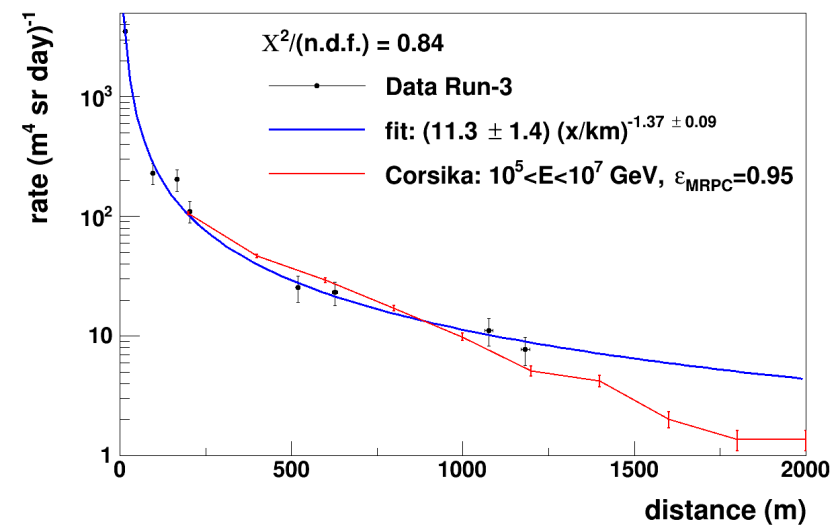
Corsika simulation confirms the observed coincidence rate for all the telescope pairs.

Better efficiency corrections to be evaluated.

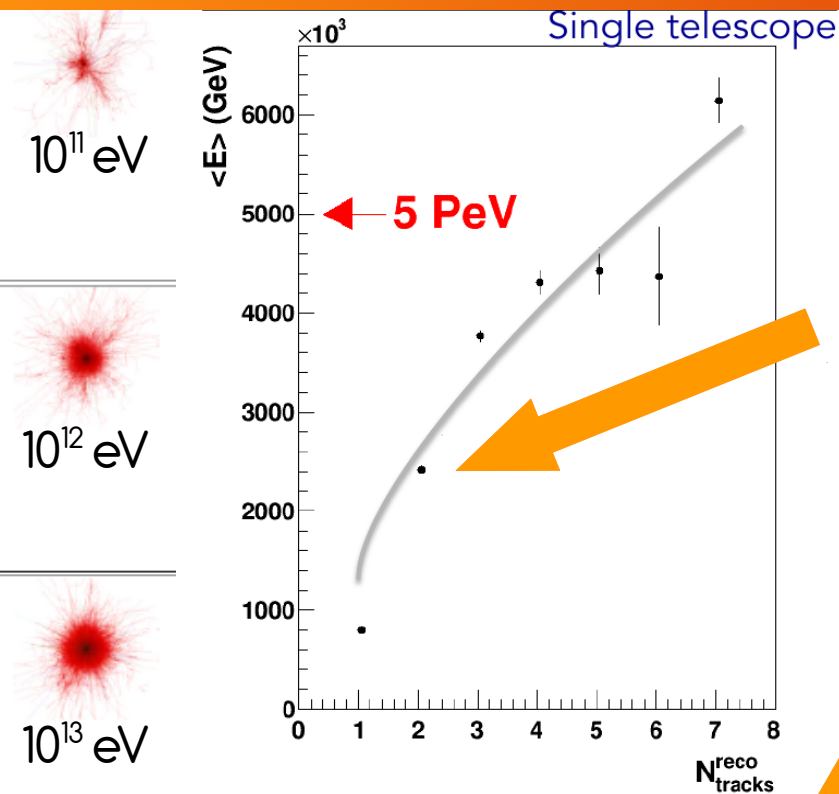
Acceptance taken into account



Rates not corrected for efficiency



# Results – Studies on EAS (see F. Coccetti talk)



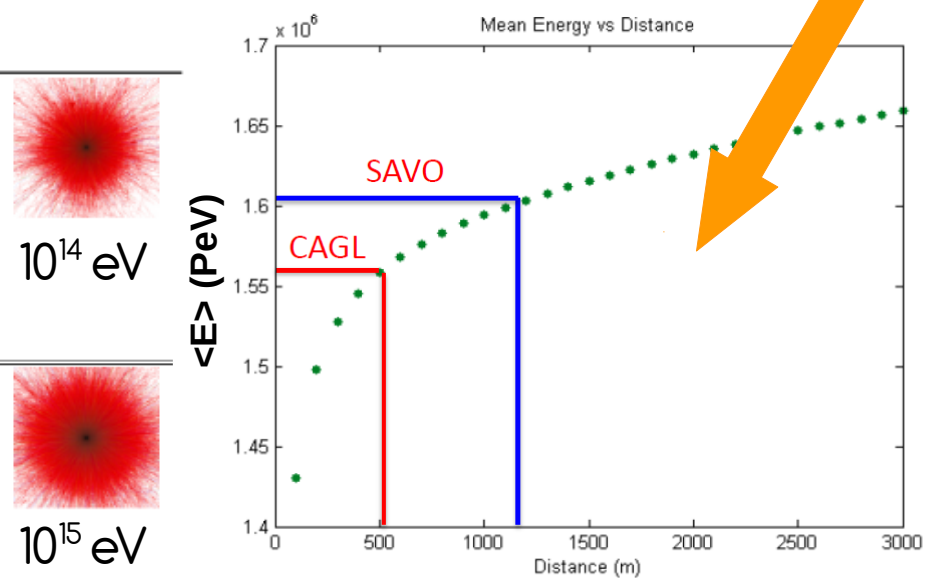
Track multiplicity on single telescopes is sensitive for primary energy in PeV region

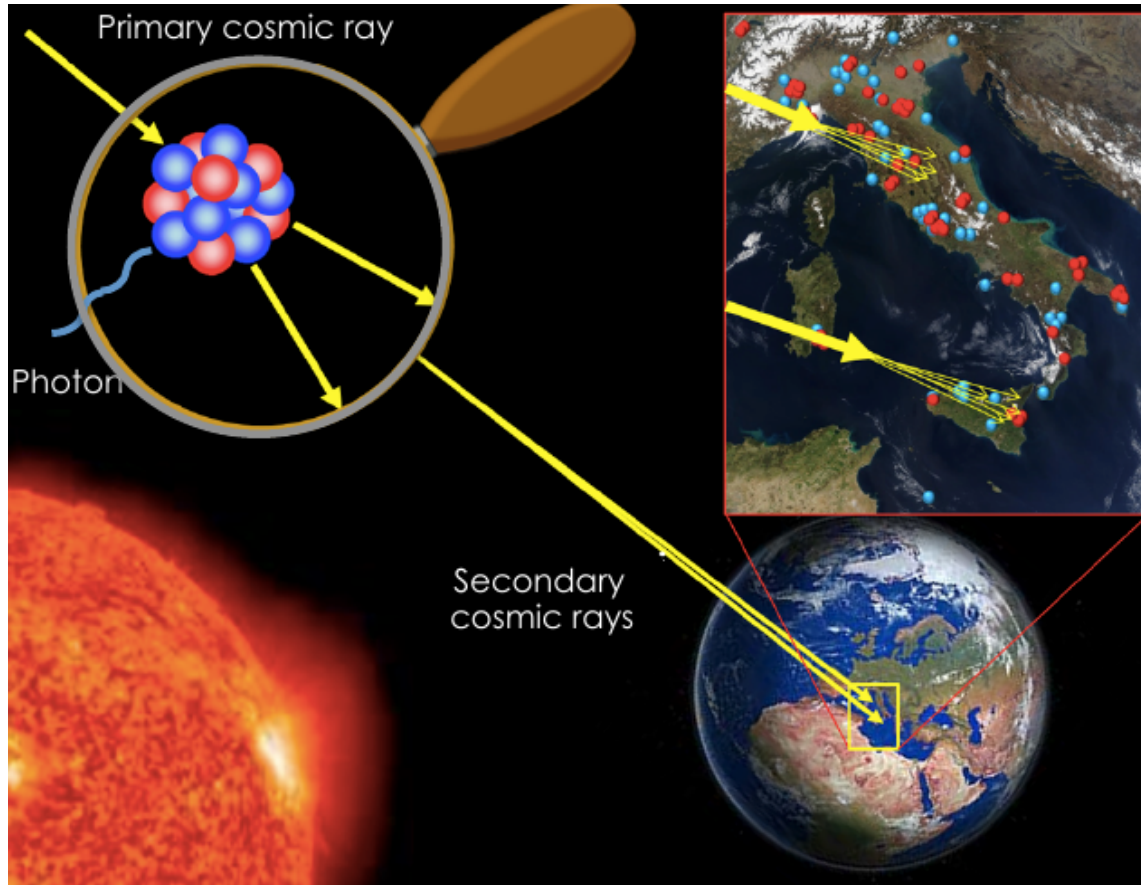
Telescope distance is a good parameter at lower energies but saturates at PeV



Super-clusters (4-6) telescopes are being installed by extending the 3-telescopes clusters in order to address higher energy EAS.

TORI cluster is being extended to 4 telescopes in autumn





## EAS Long Distance Correlation

# Results – Long Distance EAS Correlations

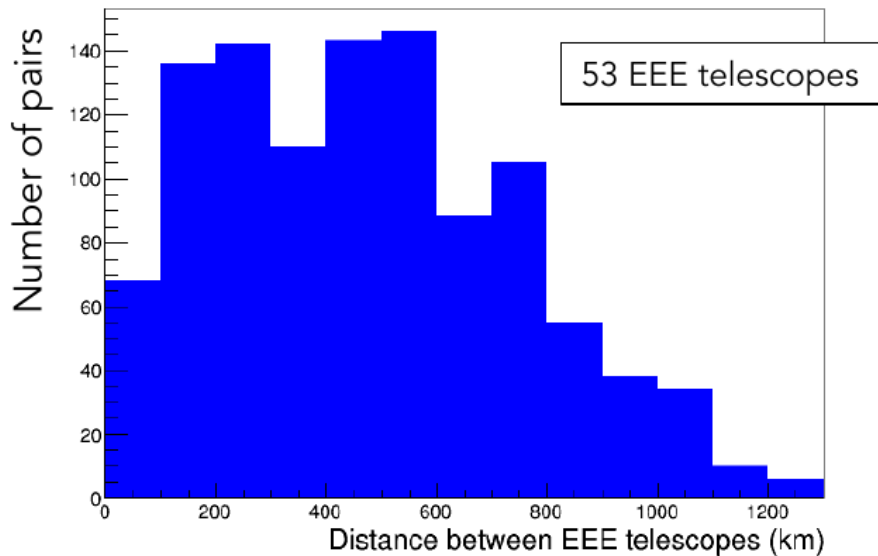
Long Distance Correlated EAS (LDC EAS) have **not yet been observed**

only hints from LAAS collaboration

N.Ochi et al., J.Phys. G: Nucl.Part.Phys. 29(2003)1169.

Y.Fujiwara et al., Nucl.Phys. B (Proc.Suppl.) 151(2006)481.

A.Iyono et al., 32nd ICRC 2011, doi:10.7529/ICRC2011/V01/0063.



EEE array:

**12** clusters

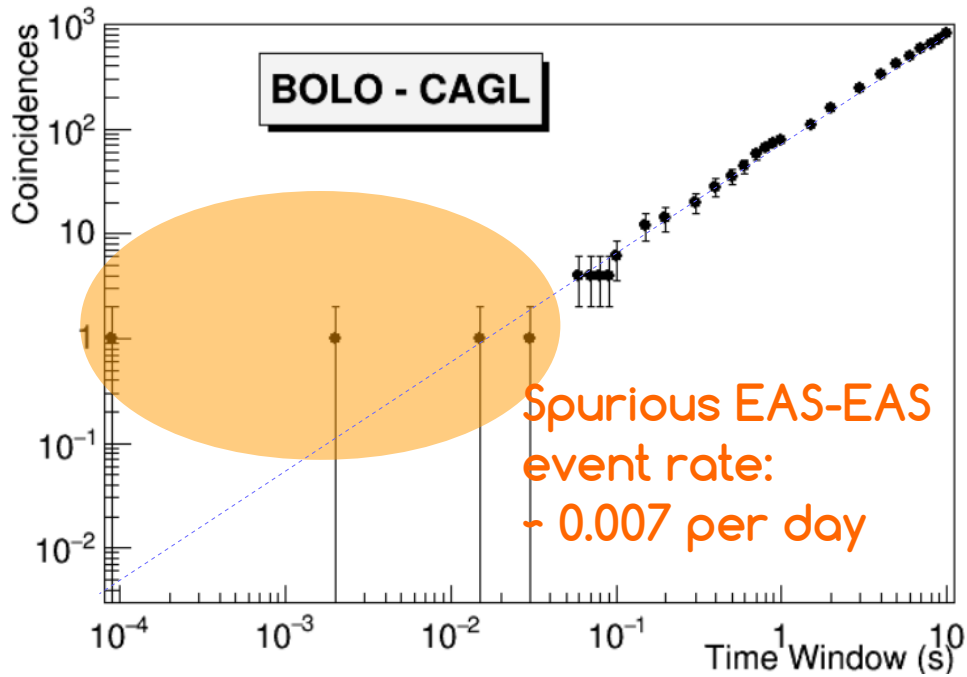
**66** cluster pairs

distances from **100 to 1200 km**





# Results – Long Distance EAS Correlations



## Analysis approach:

- each cluster identify EAS
- searching for time coincidences among EAS observed at the various clusters for decreasing time windows
- measuring the background of spurious coincidences at the shortest time window
- testing residual events probability to belong to background distribution ( $p$ -value)



# Results – Long Distance EAS Correlations

Few events observed with

$P_{\text{value}} < 0.05$

with time differences and opening angles compatible with a LDC-like event topology

Event	EEE pairs	Distance (km)	$\Delta t$ ( $\mu\text{s}$ )	$\vartheta_{\text{rel}}$ (deg)	Expected events	p-value	UTC Time
(A)	BOLO - CAGL	614	86	27.1	$0.0069 \pm 0.0002$	0.007	26.11.2015 19h 07' 16"
(B)	BOLO - LAQU	290	740	9.1	$0.014 \pm 0.001$	0.014	25.03.2016 18h 31' 05"
(C)	CATA - TORI	1040	88	9.2	$0.0265 \pm 0.0005$	0.026	09.01.2016 06h 42' 15"
(D)	GROS - TORI	377	297	14.4	$0.032 \pm 0.001$	0.031	04.06.2016 02h 31' 08"
(E)	CERN - CATA	1200	248	9.3	$0.049 \pm 0.001$	0.048	15.02.2016 01h 28' 29"
(F)	CAGL - CERN	817	690	8.7	$0.073 \pm 0.002$	0.070	26.02.2016 09h 21' 58"
(G)	CERN - SAVO	285	99	6.1	$0.108 \pm 0.001$	0.102	24.11.2015 12h 35' 47"
(H)	CAGL - SAVO	566	99	19.9	$0.115 \pm 0.001$	0.109	08.04.2015 00h 02' 50"
(I)	BOLO - CERN	450	73	19.4	$0.1194 \pm 0.0001$	0.112	03.05.2016 06h 46' 35"
(L)	LAQU - SAVO	453	760	10.9	$0.142 \pm 0.003$	0.132	13.12.2015 21h 43' 00"

The EEE network is being extended and optimized in order to increased the total exposure of one order of magnitude within the next RUNs

- EEE is a **non-homogeneous array** of high **time resolution tracking telescopes** (MRPCs)
- Main scope is the observation or limit extraction for **EAS Long Distance Correlations**

Present situation:

- **53 telescopes** (increasing at roughly 10% rate per year)
- **10 degrees** lat/long coverage
- **12 clusters** / 66 cluster pairs
- **10°** lat/long span
- **50 billion tracks** in 2 years of data taking

Items under study

- **Solar activity survey** via CR flux (FD mainly)
- Sub-TeV **anisotropies** (no observation at 2% level → next RUN below 1%)
- **Upward muon flux**
- EAS Long Distance Correlation → **few events with low  $p$ -value observed:** increased statistics with the next RUN

Upgrade activities:

- Array extension
- EAS **energy identifications** (sw)
- **Super-clusters**

Thanks to the installation of telescopes in High Schools EEE has a **strong outreach impact**. Didactic activities on CR at schools and students involvement in the experiment!

BACKUP SLIDES

# The Multigap Resistive Plate Chamber (see M.P. Panetta talk)

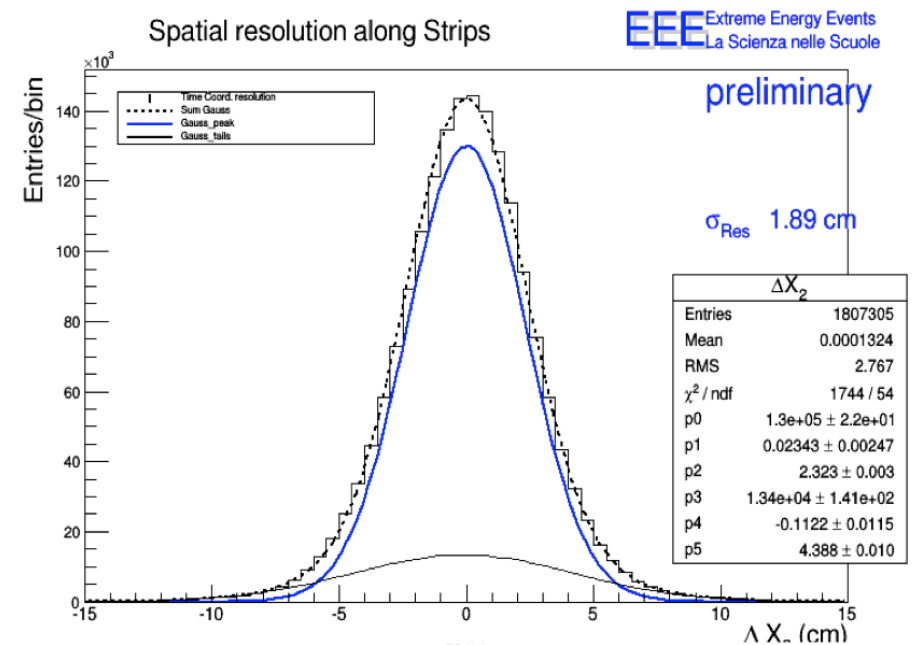
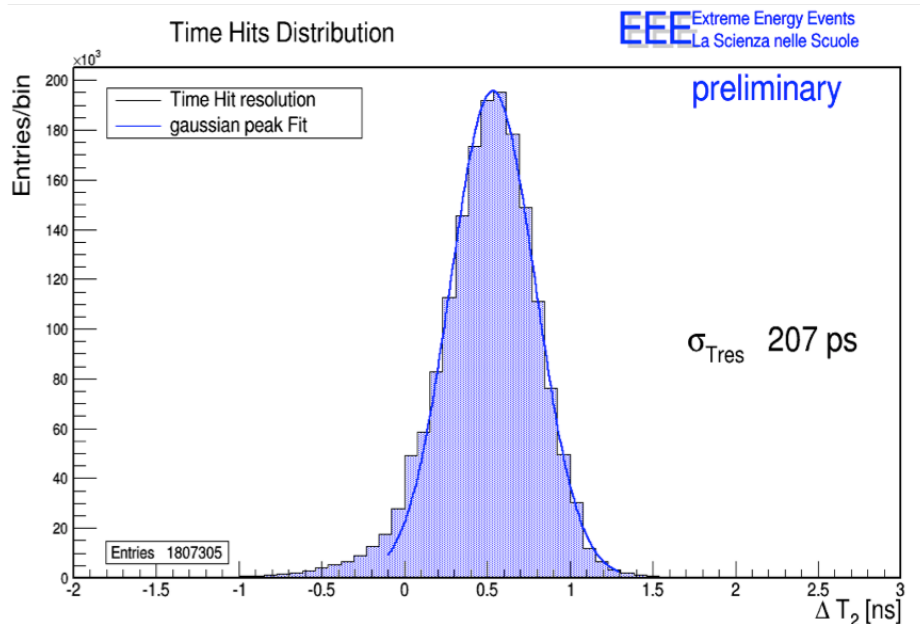
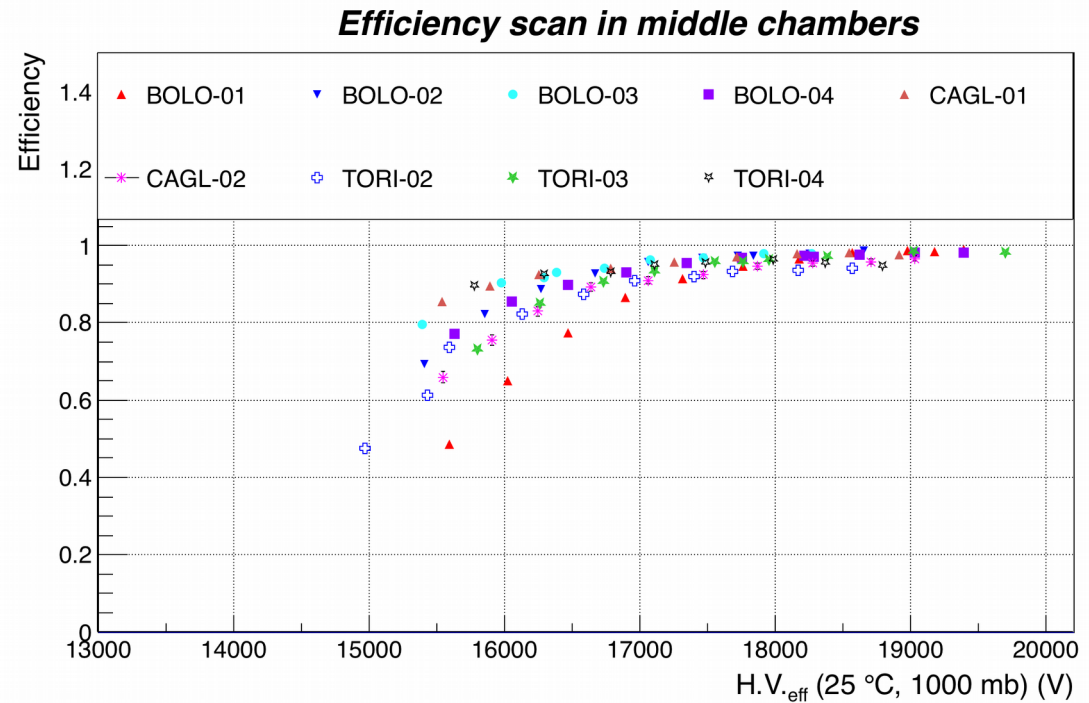
Extended **plateau at 100% efficiency**

→ important for rare event search

Time resolution **200 ps**  
( $<100$  ps for vertical muons)

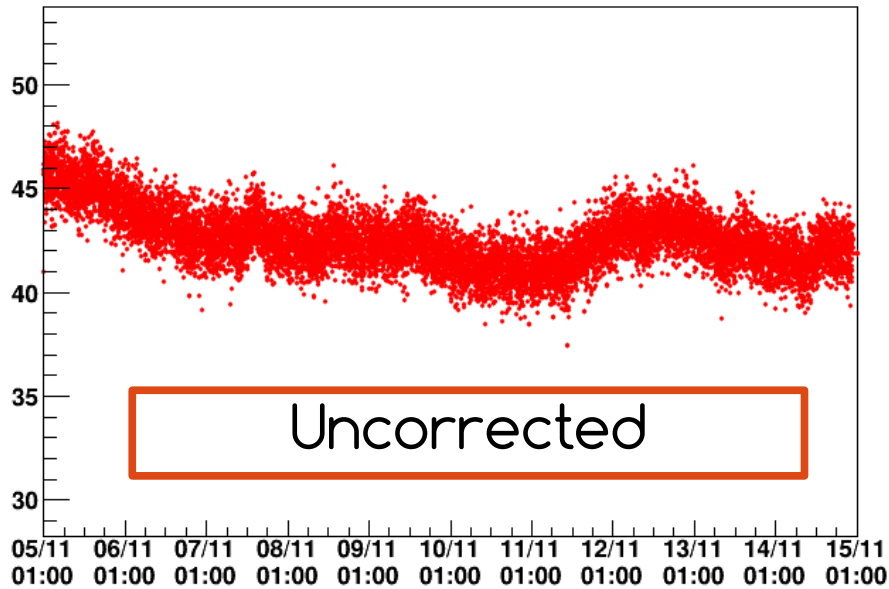
Spatial resolution  $< 2$  cm

→  **$< 1^\circ$  angular resolution** for a  
EEE telescope

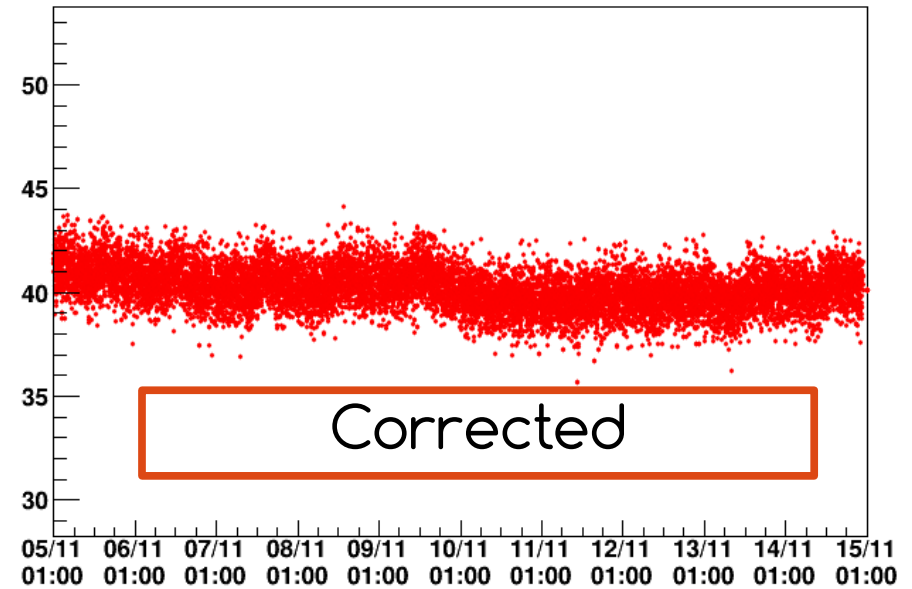


# Results - Forbush Decreases

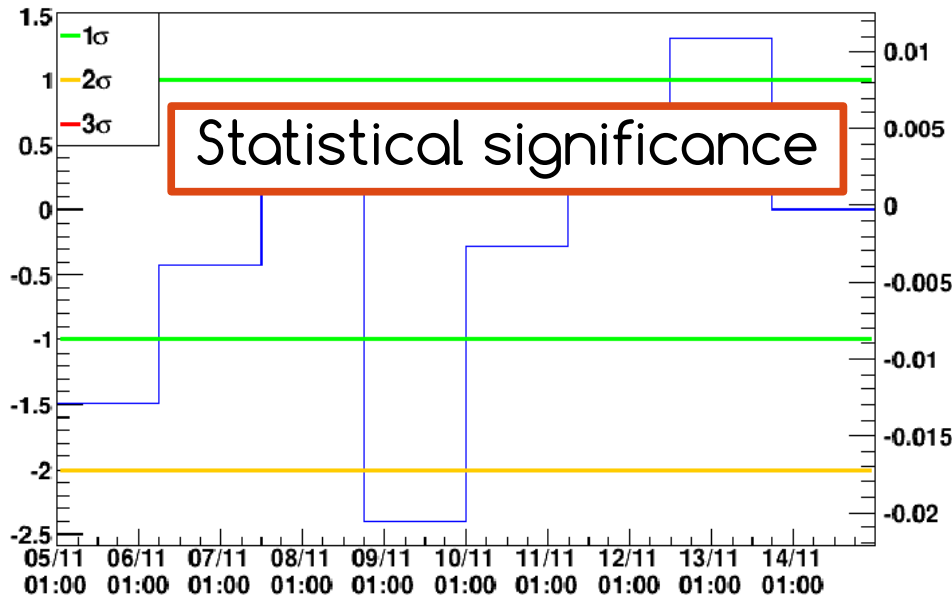
Track Rate time trending( $\chi^2 < 10$ )



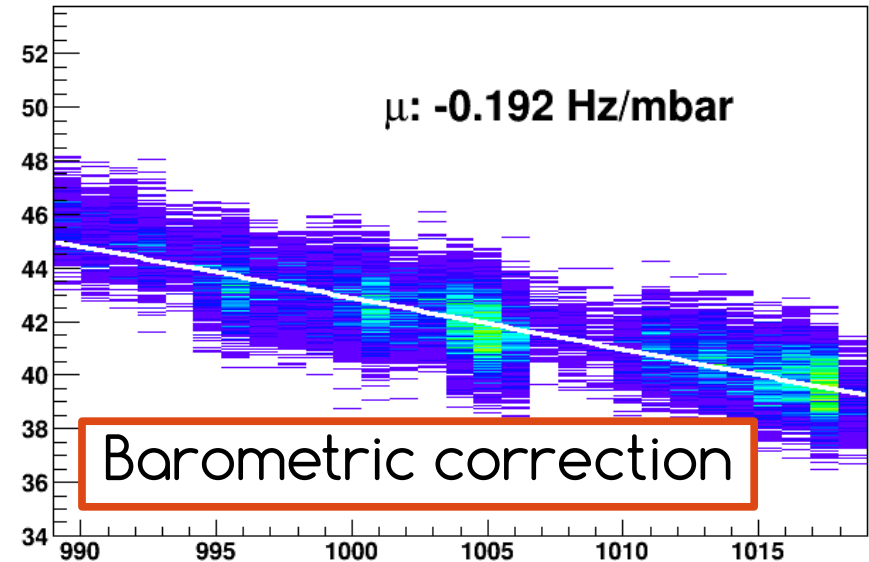
Track Rate time trending ( $\chi^2 < 10$ ) corrected



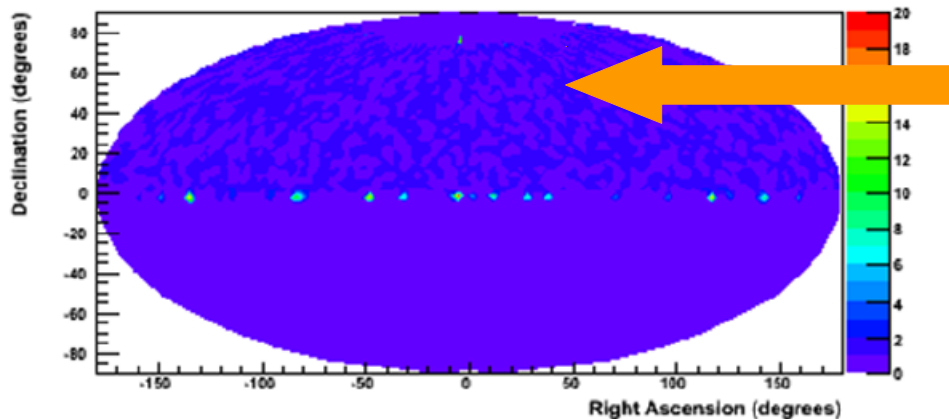
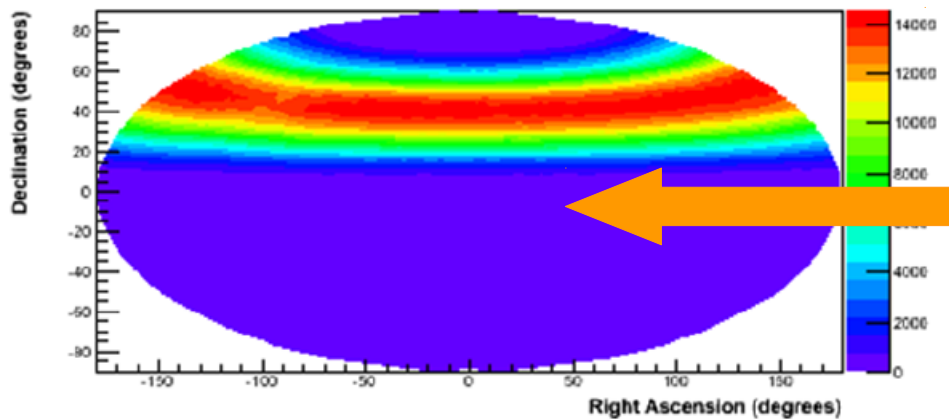
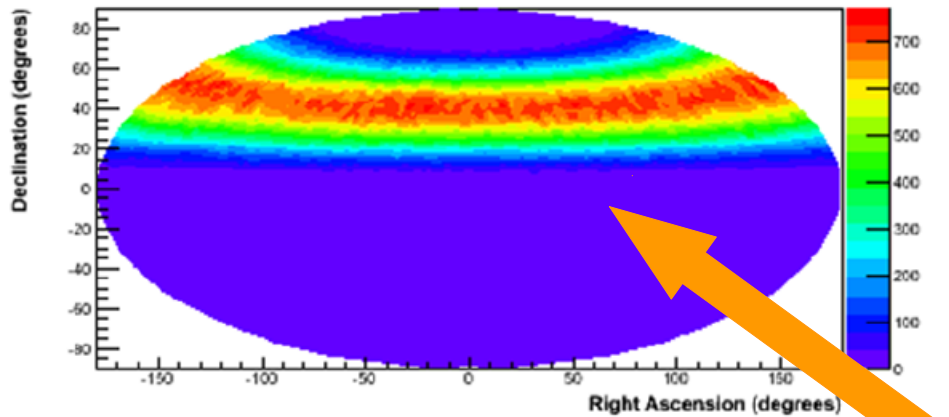
n- $\sigma$  flux variation - %flux variation



Pressure (mbar) vs Rate (Hz) correlation



# Results – subTeV anisotropies



EEE stations are suitable for studying  
**TeV CR anisotropies**  
→ local IMF features  
→ relative motion (Compton Getting)  
already observed effects to be  $10^{-3}$ - $10^{-5}$   
(e.g. ICECUBE @ 100 TeV max)

Aitoff map for a EEE telescope  
→ **sky coverage ~40 degrees** )

Correction map → **scrambling method**

20 randomly generated tracks per each real track over 24 h

**Corrected Map**  
Its the ratio between the raw data and correction map

A preliminary analysis using **110 Mevs** (now 50 billions available) have been performed