

Observations of cosmic ray flux decreases with the Extreme Energy Events telescope array

Extreme Energy Events

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Bologna, Roma Tor Vergata, Salerno

CNAF (Bologna)

ICSC World Laboratory (Geneva)

CERN (Geneva)

102° Congresso SIF, 2016, September 26-30, Padova (Italy)

The Experiment

The Extreme Energy Events is a net of 52 telescopes (growing)



for studying
Low and High ECR
and related phenomena
with a broad
scientific program.

Telescopes are installed in **italian High Schools** (and Research Centers)
thus EEE keeps also
an **educational** and **outreach** parallel mission

EEE telescope array - displacement

Telescopes are arranged in **clusters** with typical distances

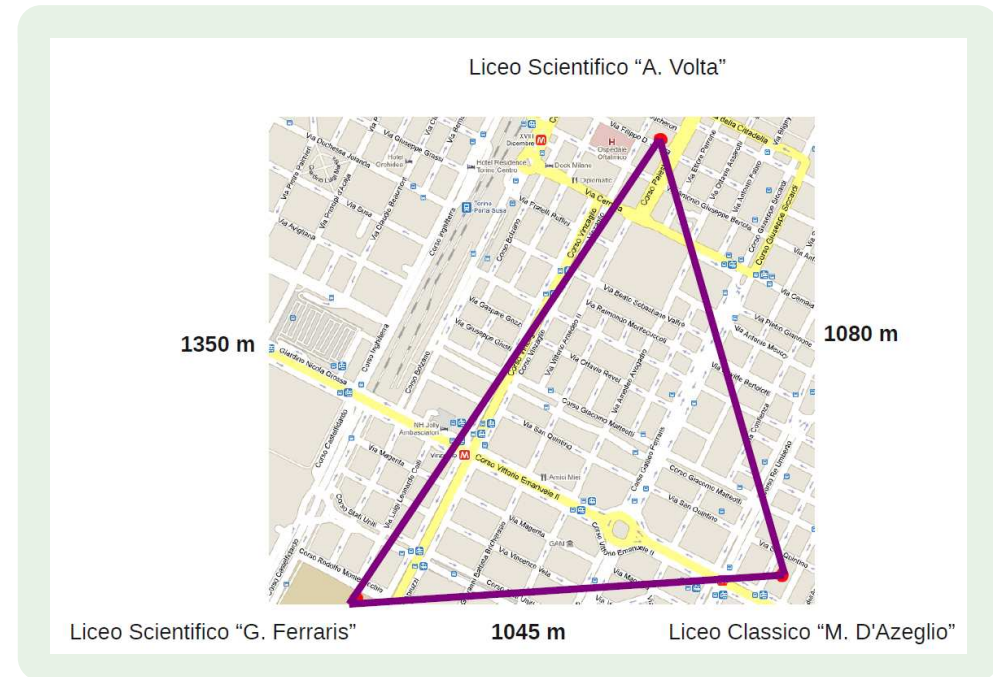
30 m to 6 km.

Each cluster size allows for different **energy thresholds**:

i.e. 3 station - 1 km clusters

$$E_{th} \sim 10^{17} \text{ eV.}$$

Clusters are up to **1000 km** far away.



this allows for both studying **Extended Air Showers** and exotics
+ **climate** and **interplanetary CR** related issues

EEE telescope array - Scientific Program

Single Telescope

- Local Anisotropies
⇒ La Rocca talk
- Upward particles (ν physics?)
⇒ Panetta talk
- long term solar activity correlation
- prompt solar events
⇒ this talk
- atmosphere/climate effects

Long baseline

- GZK and GZK-like effect
 - γ disintegration (e.g. Sun)
 - interstellar medium inter.
 -
- astronomy? to be investigated

Short baseline

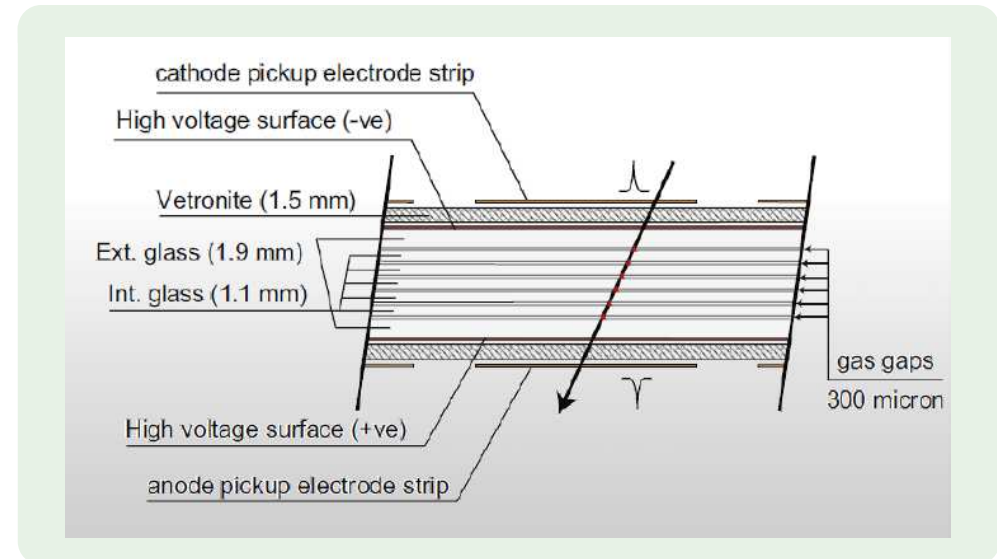
HECR around the knee
⇒ Cicalò talk

The Telescopes

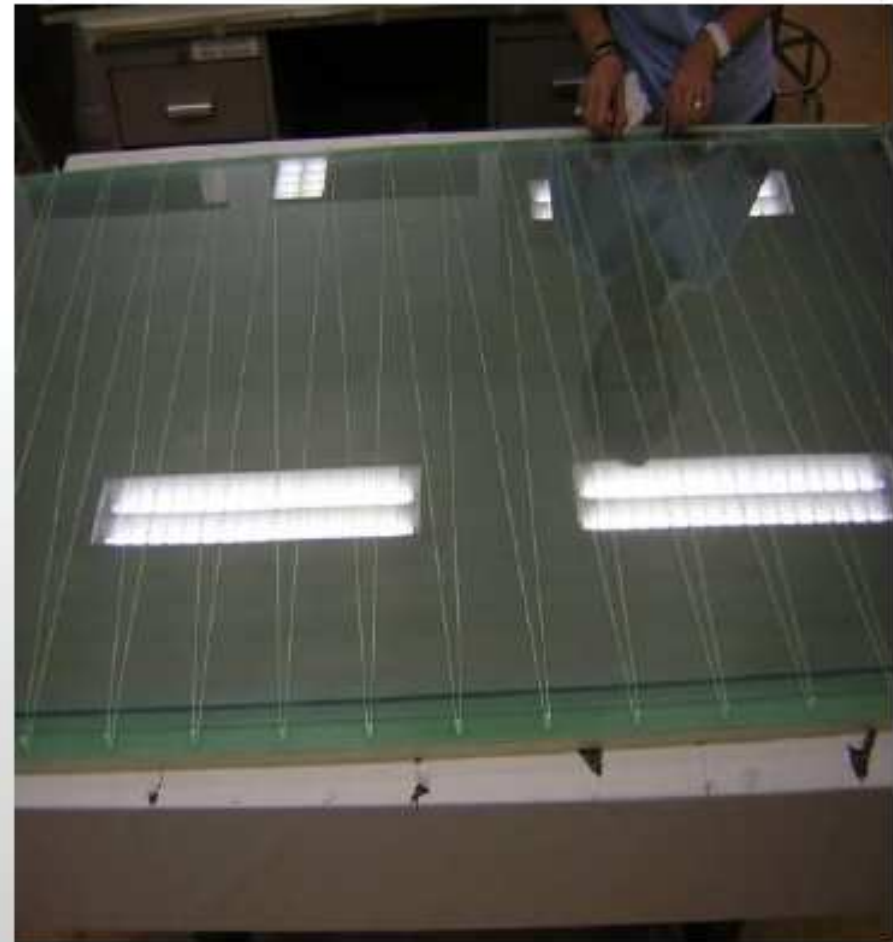
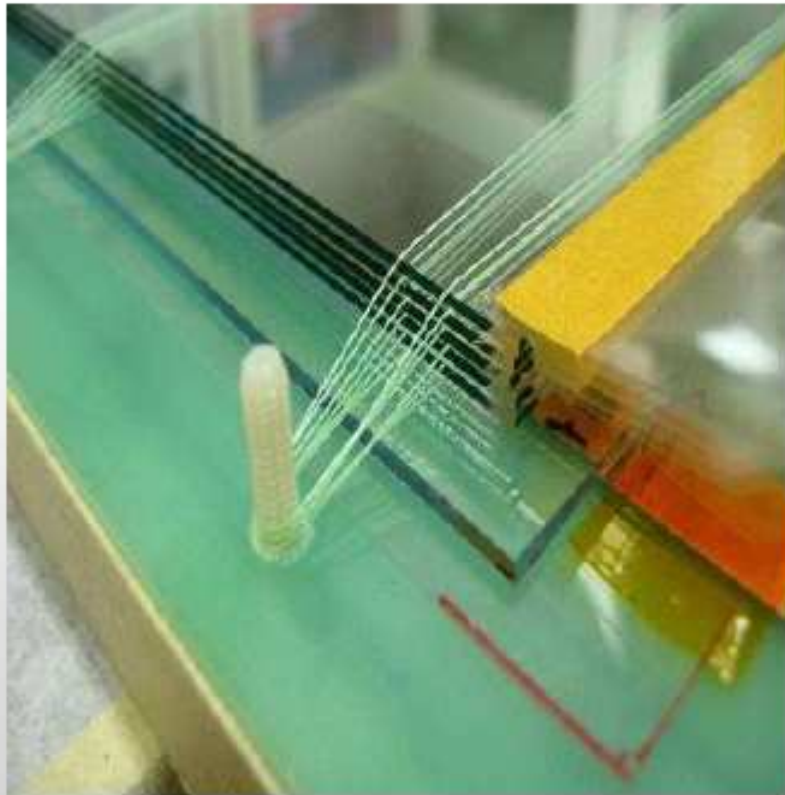
The Multigap Resistive Plate Chambers

EEE chamber is an extended version of
ALICE TimeOfFlight modules

- 6 gas gaps: 2 glass plates with their external surfaces painted with resistive paint; 5 floating glass plates (spaced by 300 μm)
- $\text{C}_2\text{H}_2\text{F}_4$ (98%) and SF_6 (2%) continuously fluxed by (3l/h)

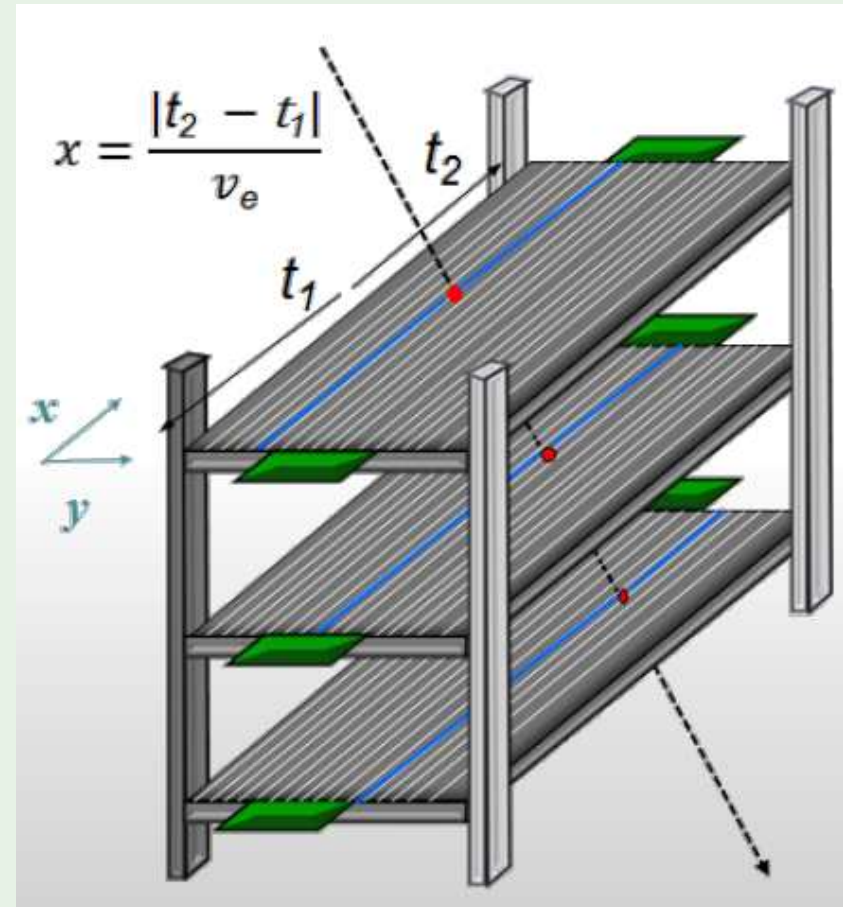


The Fishing line is used as a simple spacer ($300\ \mu\text{m}$) between glasses

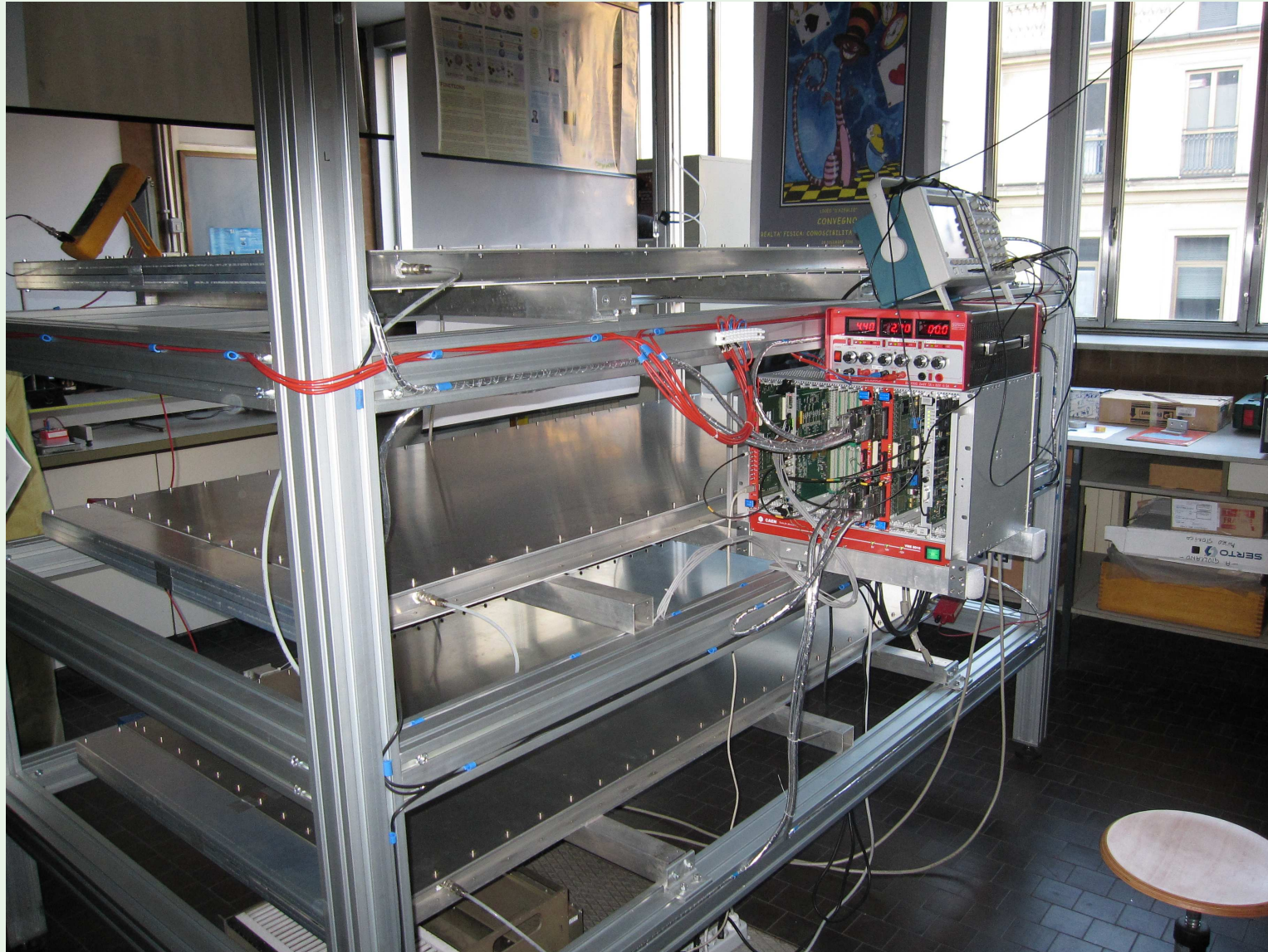


The Telescope

- Each telescope: 3 MRPC, 160 x 80 cm, 24 strips
- operated at 20 kV
- 6 Fast amplifier/discriminator NINO ASIC
- GPS
- VME-based data acquisition
2 Multi-hit TDCs
(100 ps resolution)
- Weather Station



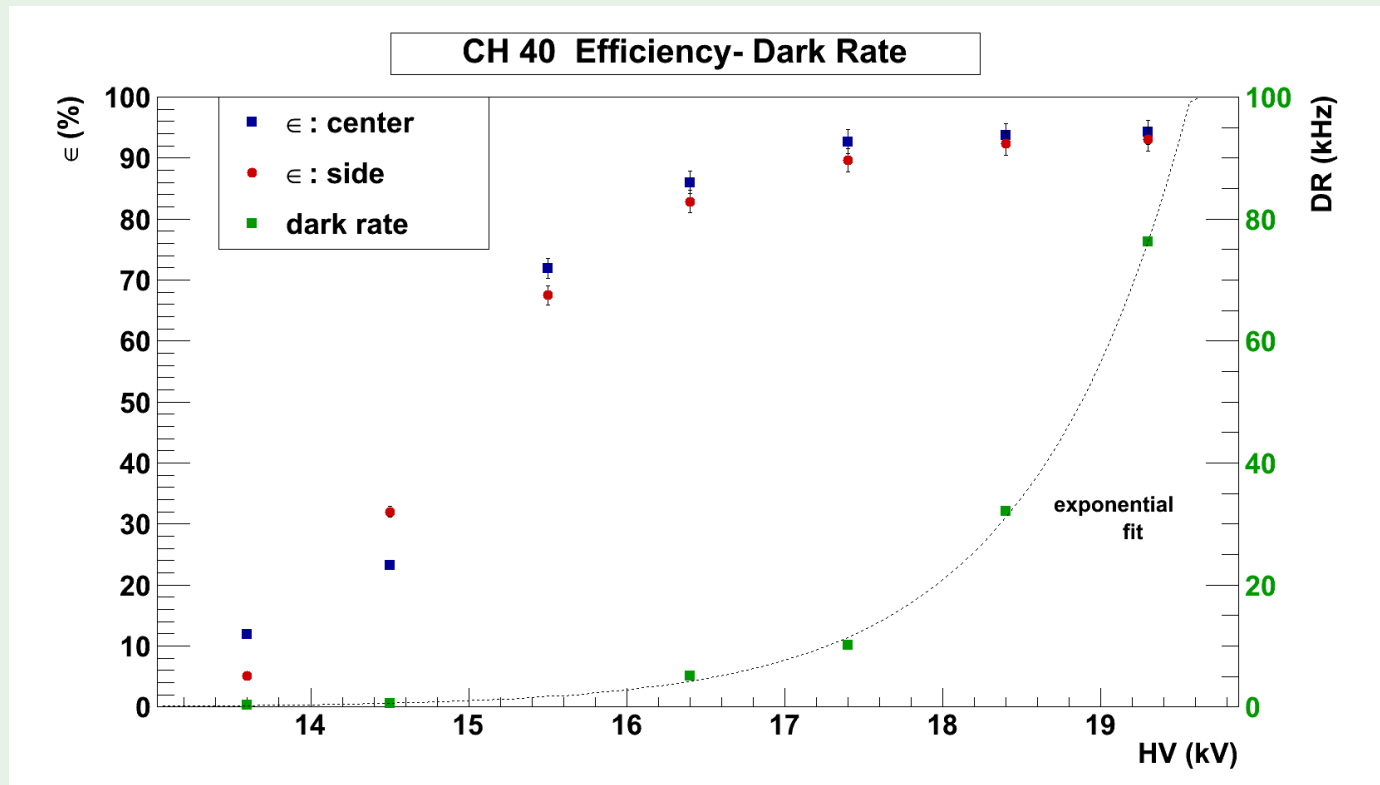
The telescope equipment



The Station Performances

⇒ De Gruttola talk

Chamber Efficiencies and Dark Count

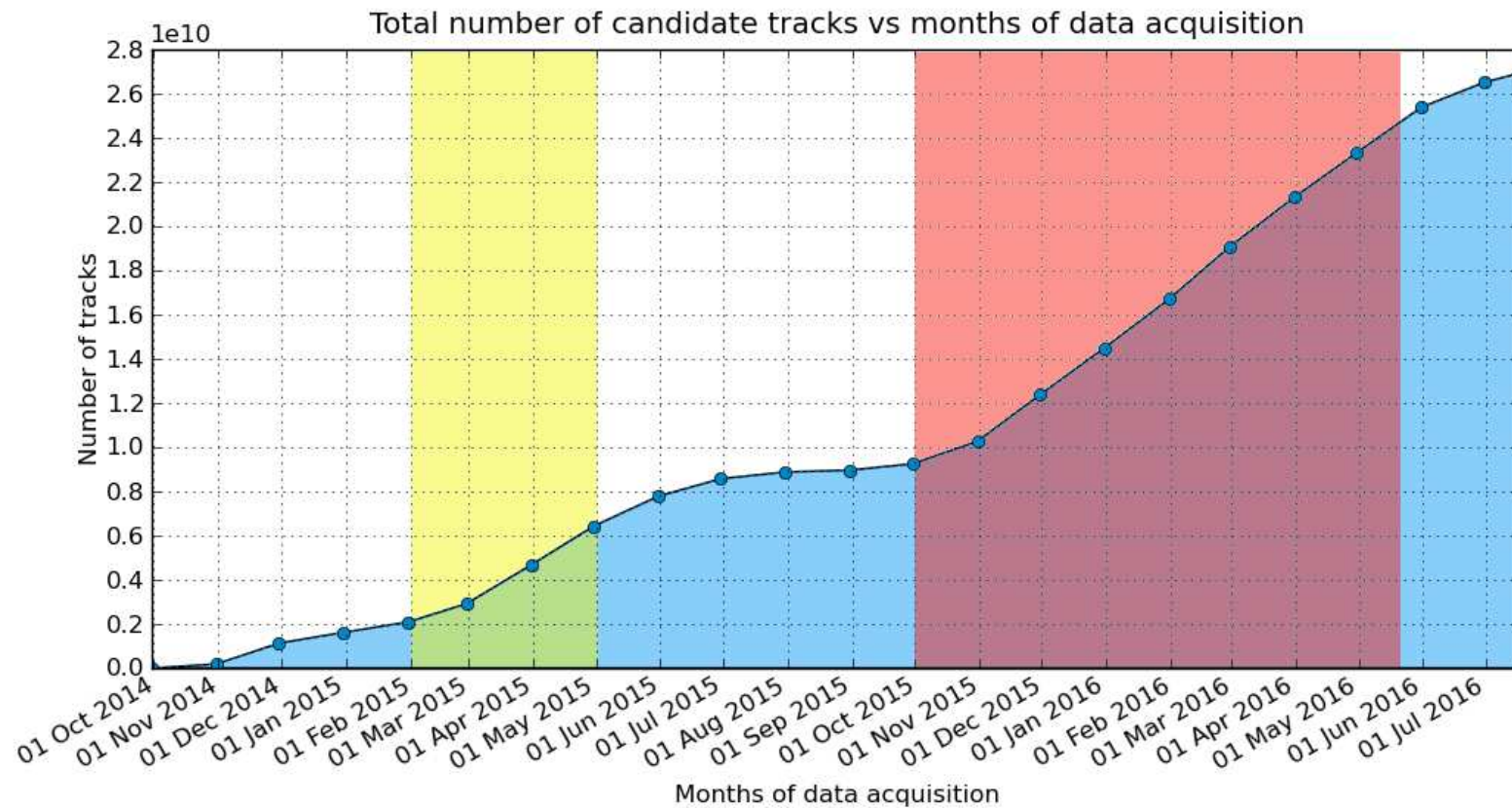


+ 200 ps time res. and tracking

The Data Taking, Concentration, Reconstruction Philosophy

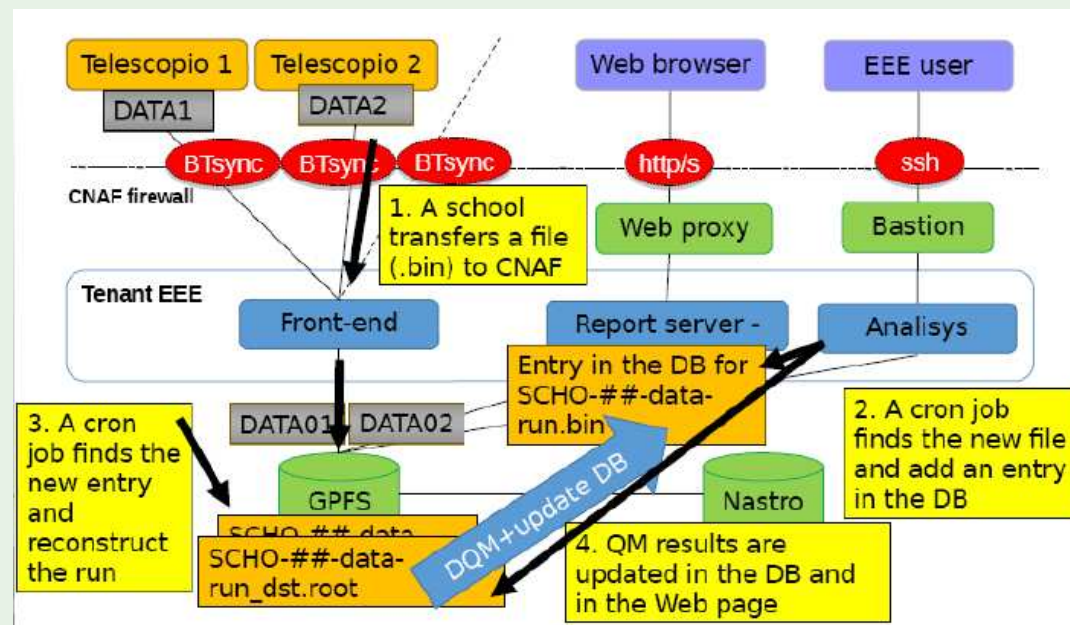
Data Taking and Coordinated Runs

⇒ Cicalò talk



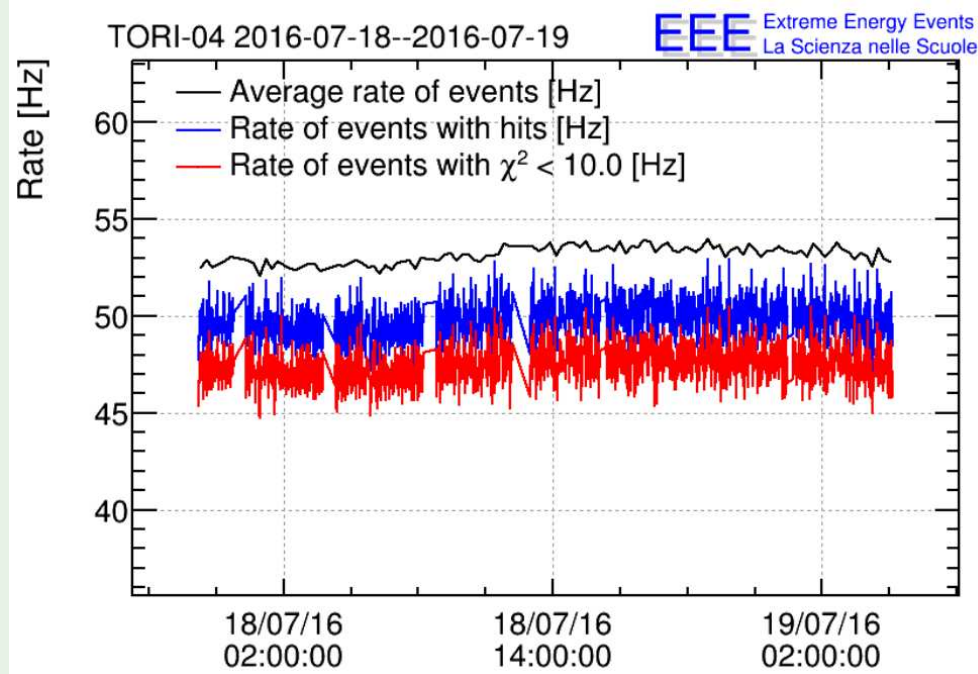
Data Transfer and automatic reconstruction @ CNAF ⇒ Coccetti+Bossini talks

- Data are stored at the INFN-CNAF computer centre of Bologna
- A complex software architecture has been set-up to reconstruct the data and provide **quasi-online** (few hours) Data Quality checks on the web for monitoring purposes.



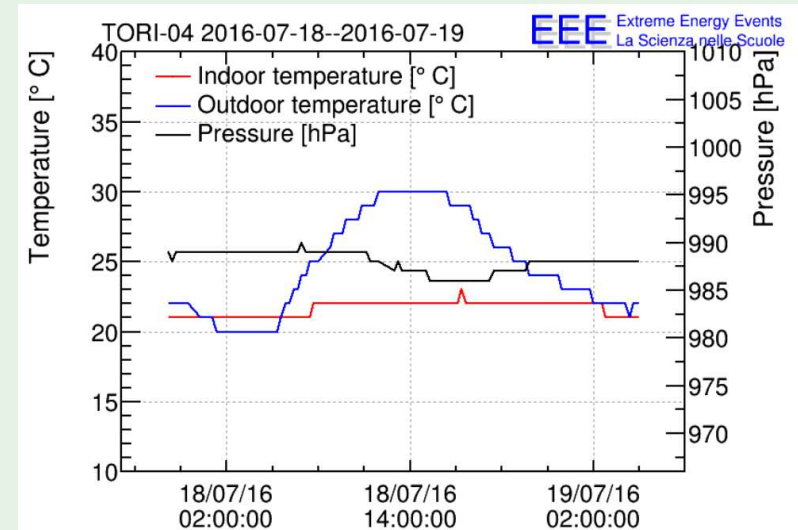
Data Quality Monitor

Rate Monitor



Daily and Run by Run based trending fluxes are provided in a few hours and published online

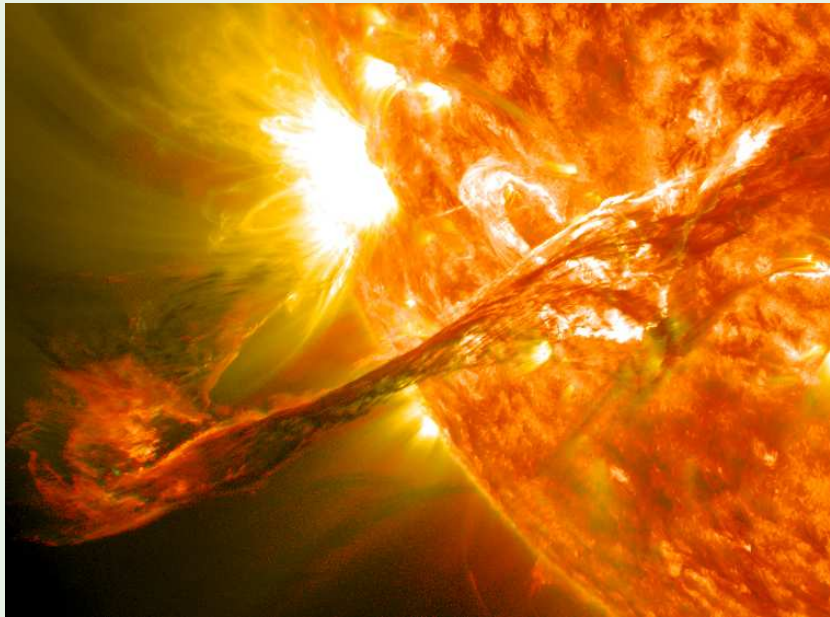
Environment



Pressure, Temperature and Humidity Data are also collected and made available for corrections and analysis.

*Cosmic Rays flux modulation
by prompt solar events*

Forbush decreases and sun-related phenomena



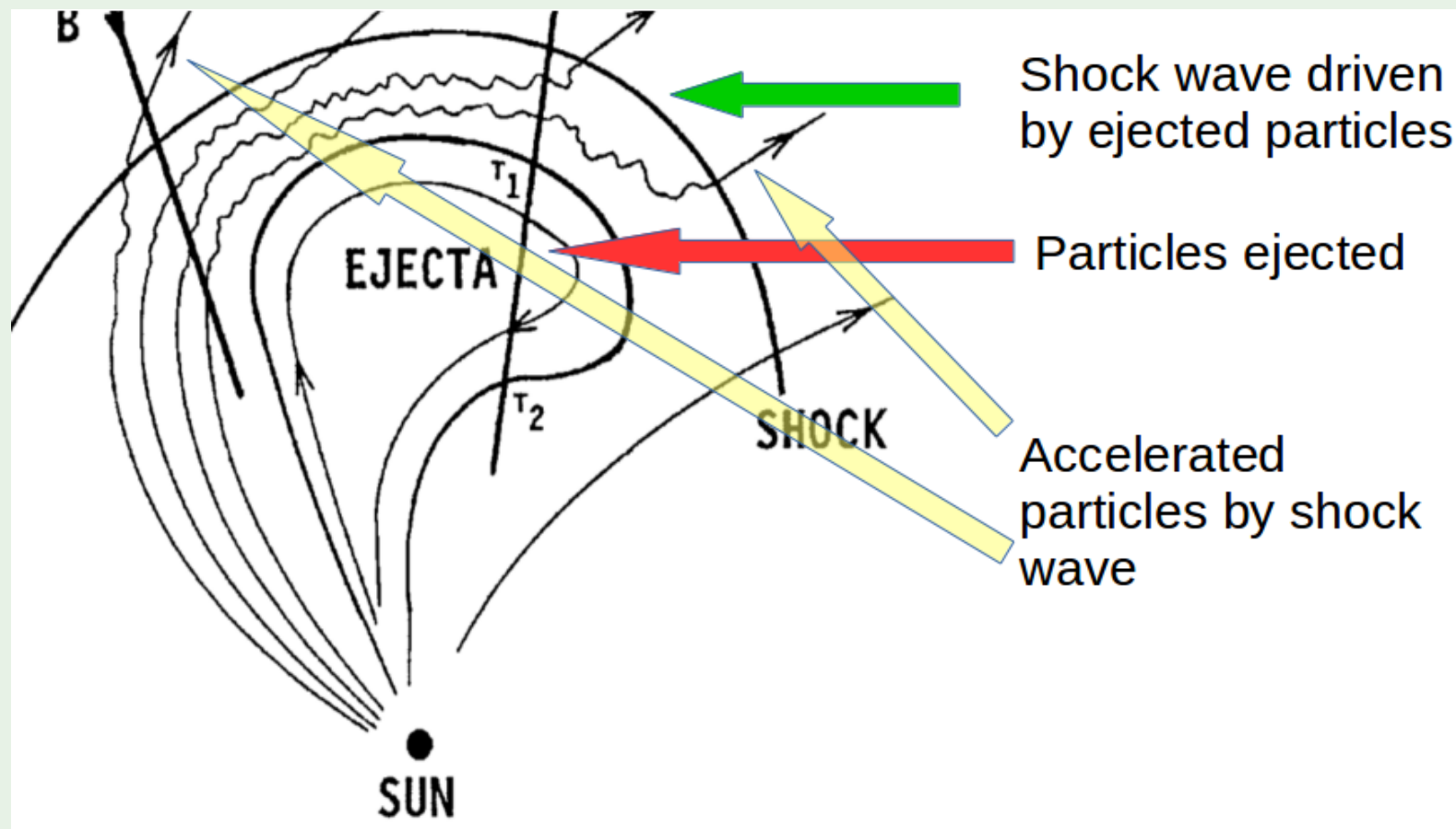
Forbush decreases are prompt CR flux decrease correlated to CME and Flares on Sun.

Flares are prompt e.m. flashes at $\sim 10^{25}$ J ($P_{sun} \sim 10^{26}$ W).

Coronal Mass Ejections are proton burst at $\sim 10^{23-24}$ J with speed 20-2000 km/s.

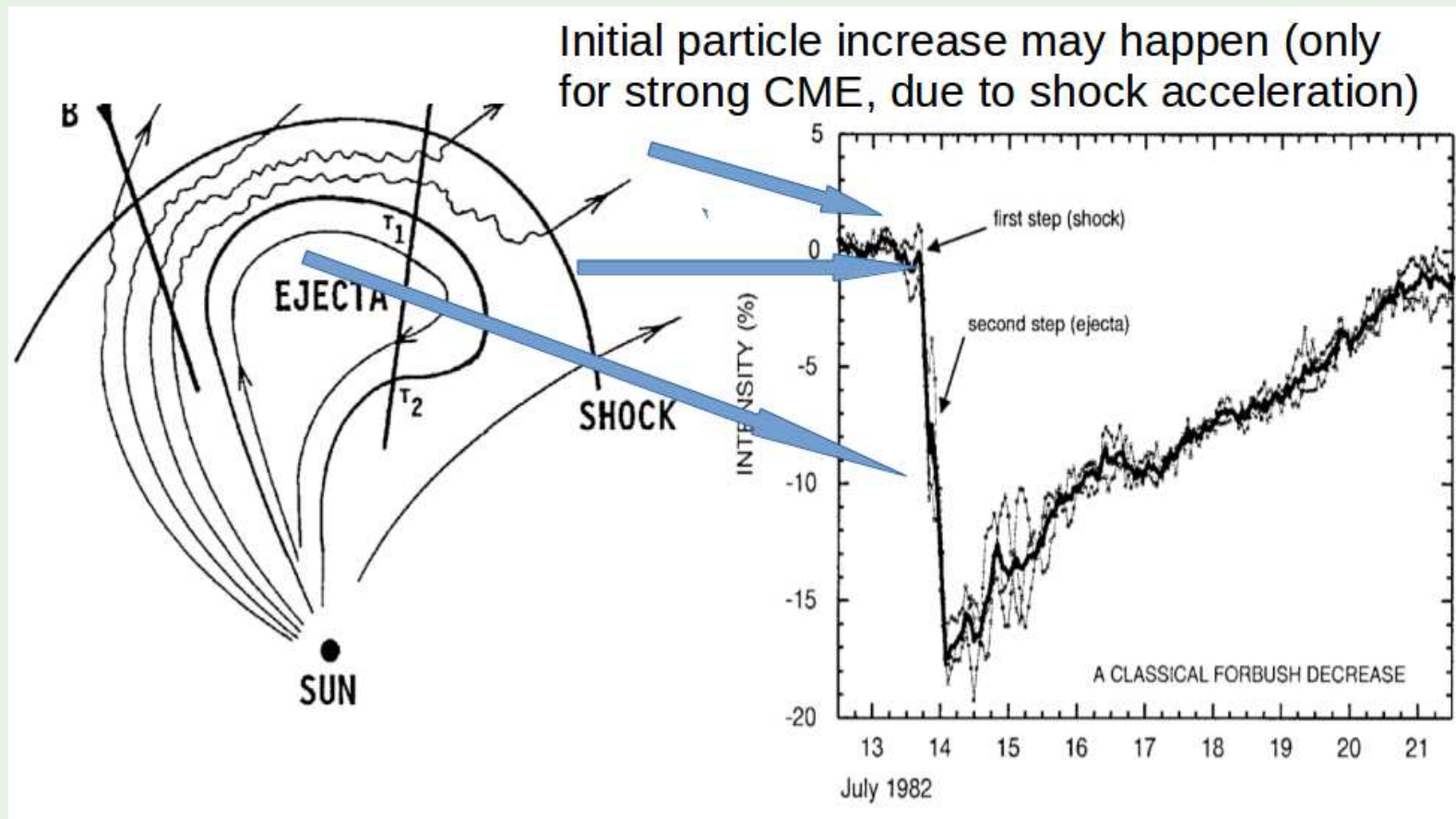
A complete understanding of both Flares, CME and Forbush is not yet available.

- The most reliable scenario is a **two step mechanism** which involves
- the **magnetic line disruption** via plasma thermal pressure, with a **proton burst emission**
 - **magnetic line reconnection** and reheating with a **flare emission**

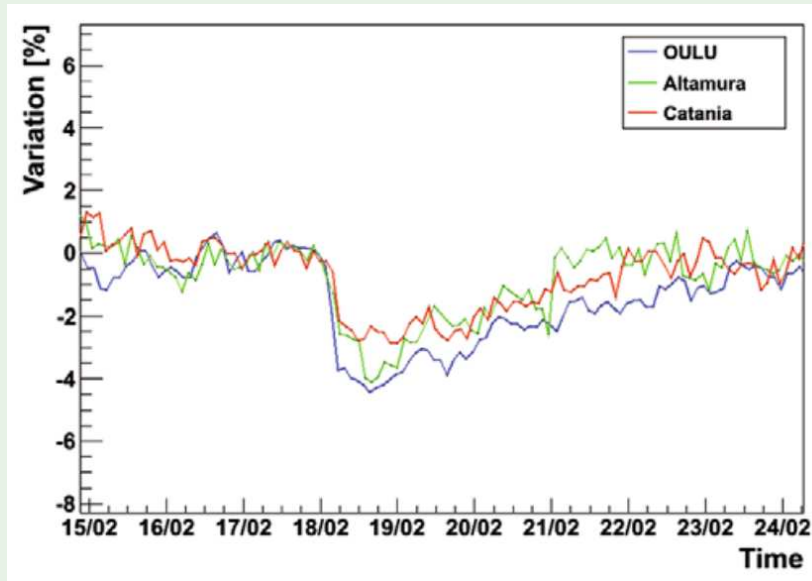


Interplanetary magnetic field and low energy CR are

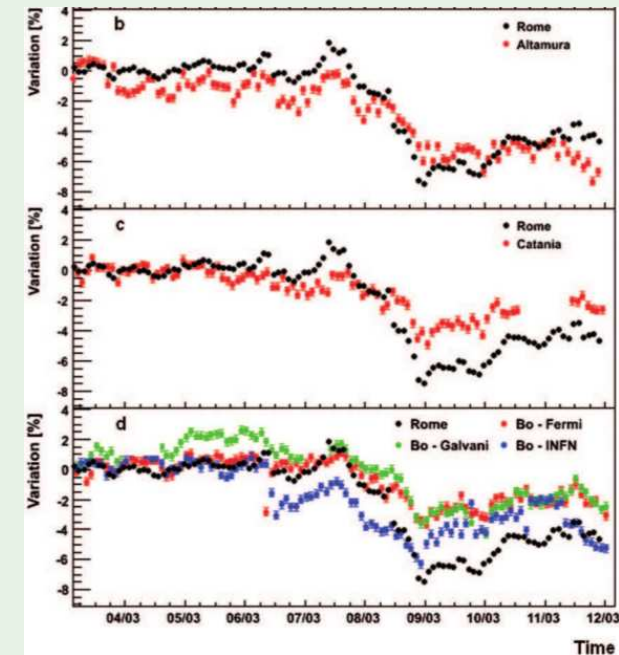
- first swept and compressed by the **shock wave**
- then again disturbed by the **proton burst**



Events observed before coordinated runs:

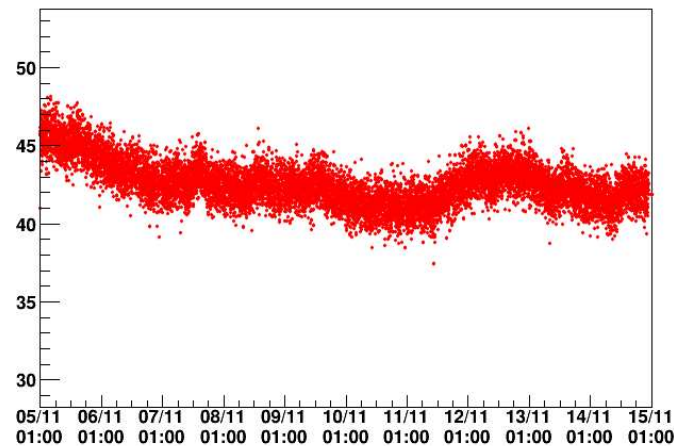
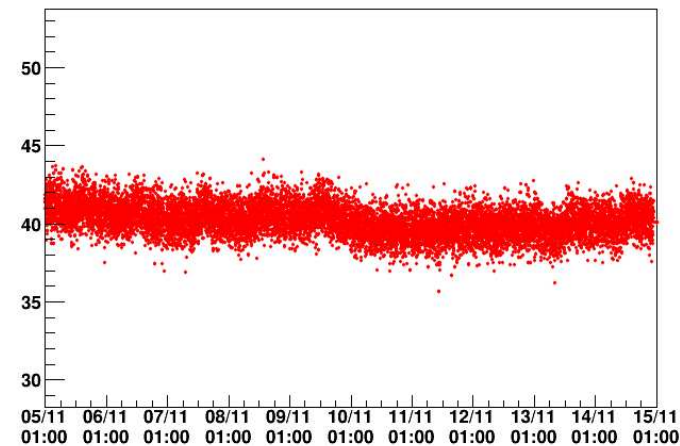
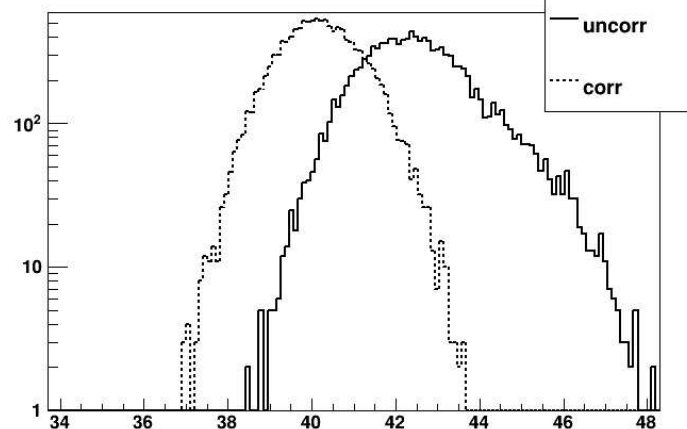


Scale X2 flare
 $2 \times 10^{-4} \text{Wm}^{-2}$
 on Earth

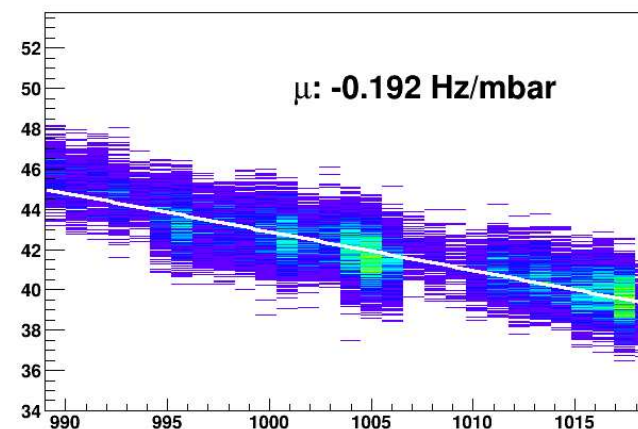


Scale X5.4 flare
 2nd in magnitude
 since last solar minimum

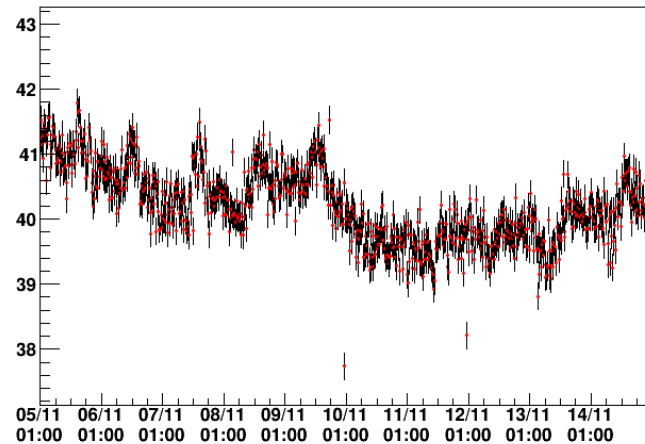
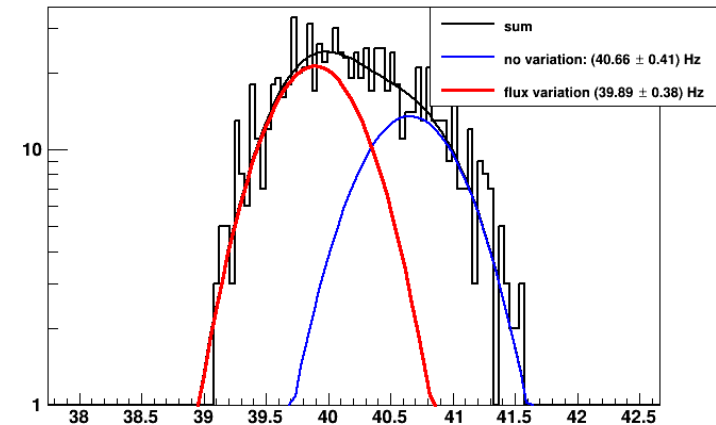
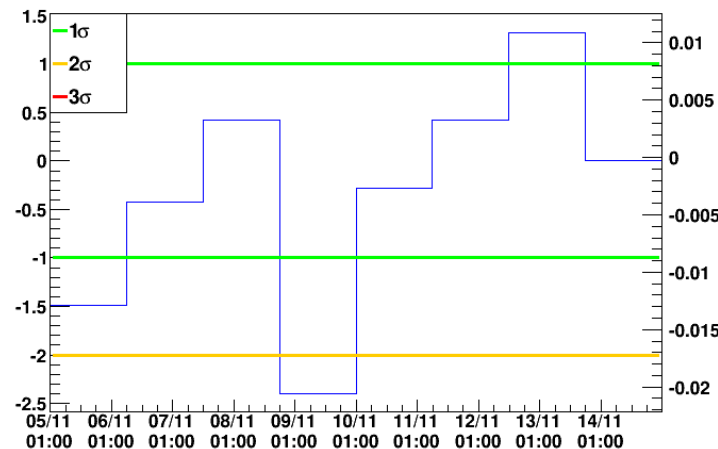
the **Corrections**: Atmospheric Pressure
 \Rightarrow fluctuations of pressure modify the **material depth**
 above telescopes, and mimic **flux variation**

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

Pressure (mbar) vs Rate (Hz) correlation



after corrections and time integration
the amplitude and significance
of the decrease is measured

Track Rate time trending ($\chi^2 < 10$) correctedTrack Rate ($\chi^2 < 10$) corrected and integratedn- σ flux variation - %flux variation

Search parameters

Required stat. sign.: 0.5 %

Averaging on 0.26 h

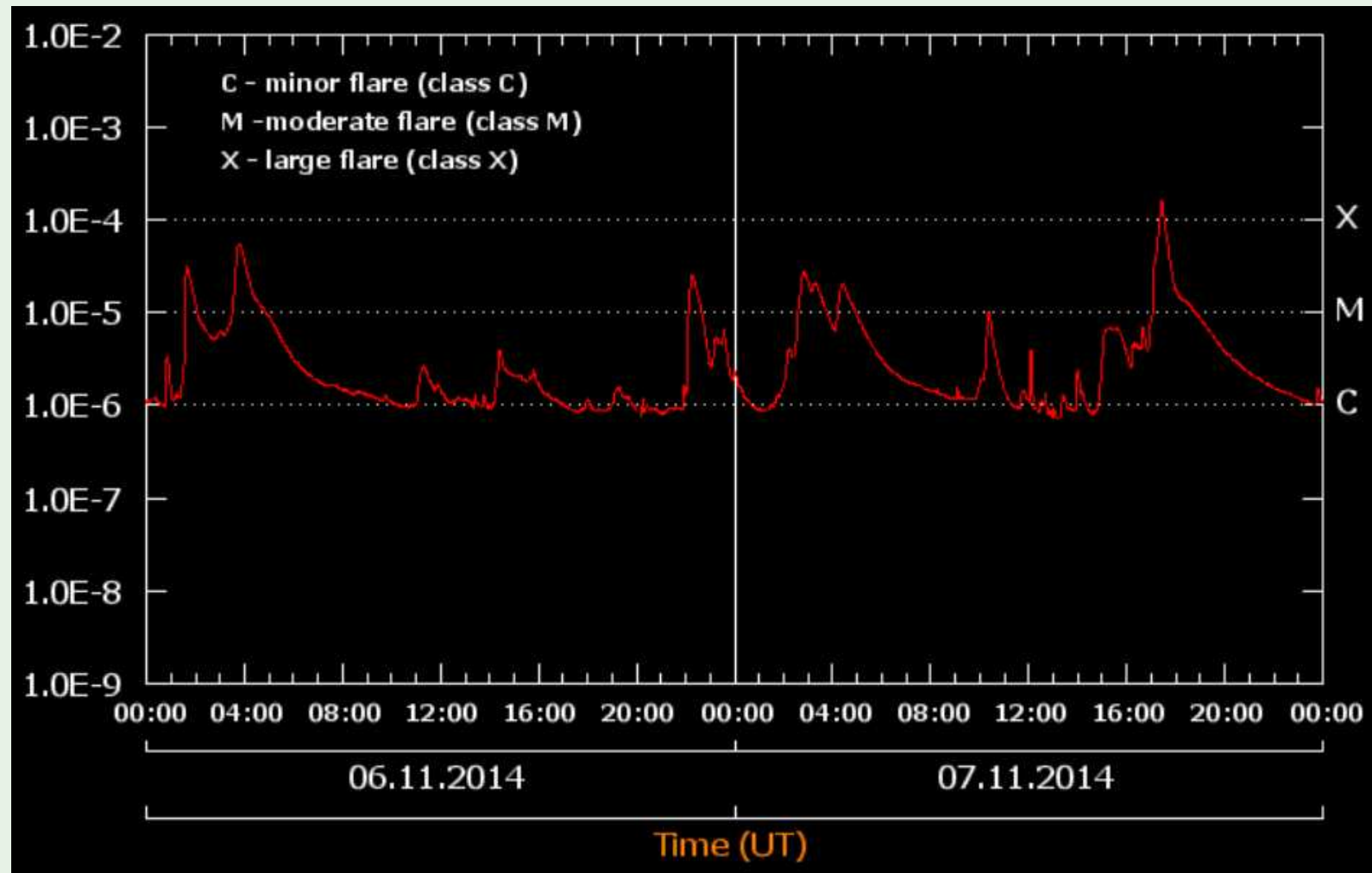
Fit time windows: 24.0 h

Search time step: 24.0 h

Max/Min n- σ fluct. 1.3 / -2.4 σ

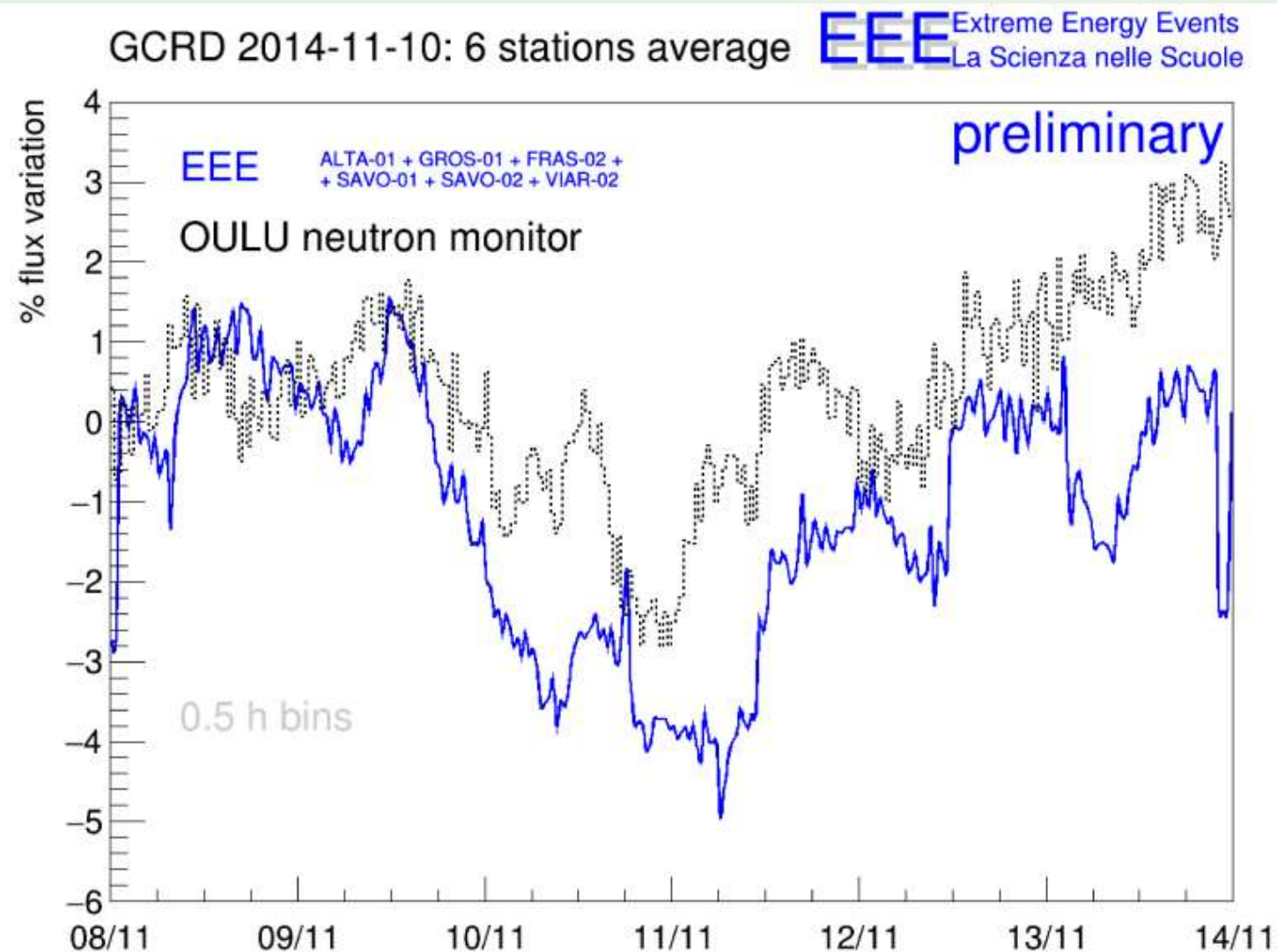
Max/Min % fluct. 1.1 / -2.0 %

Flare 2014-11: X1.6 Class
from Tesis-CORONAS-PHOTON experiment
...few days waiting for the effects on Earth...

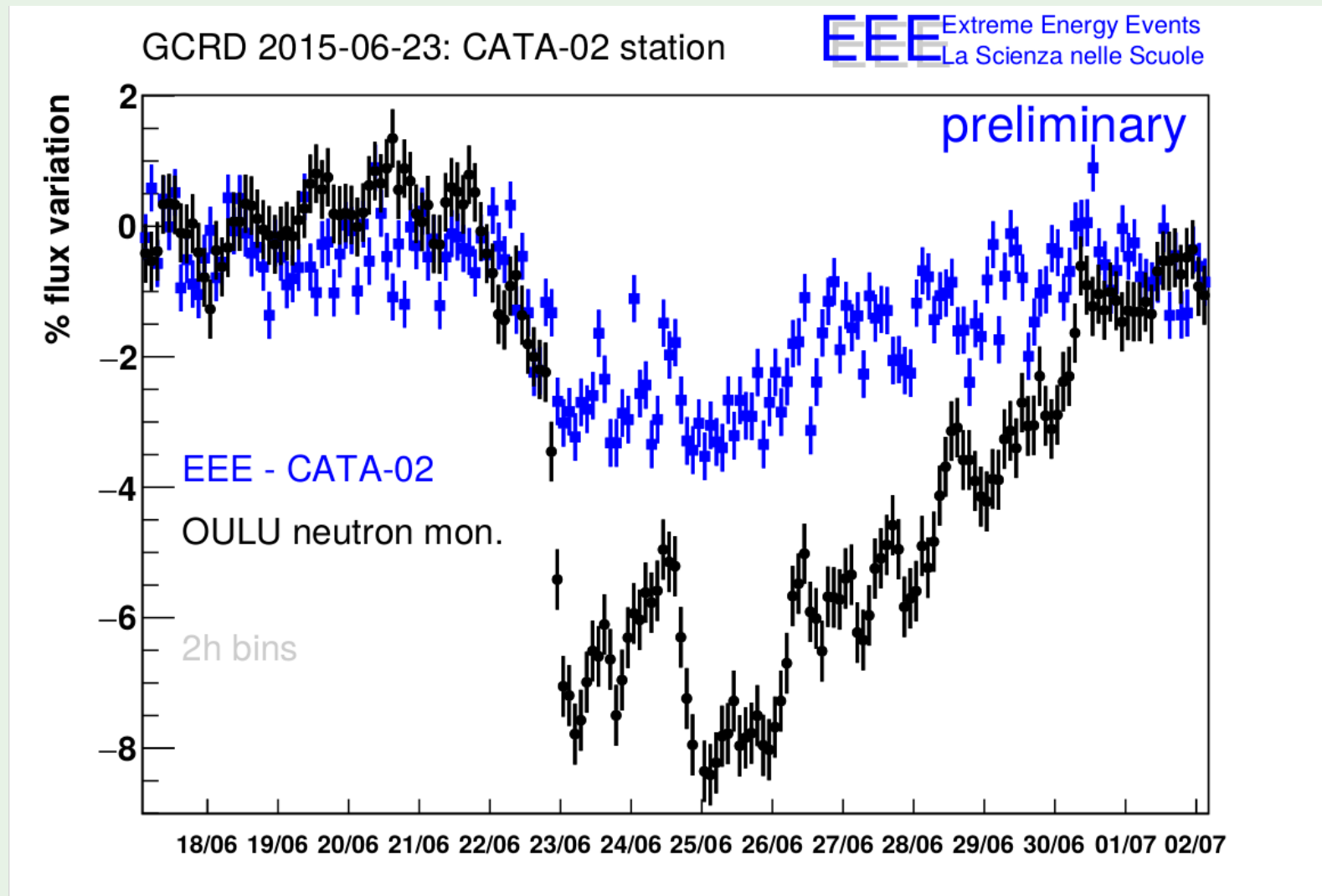


Forbush 2014-11

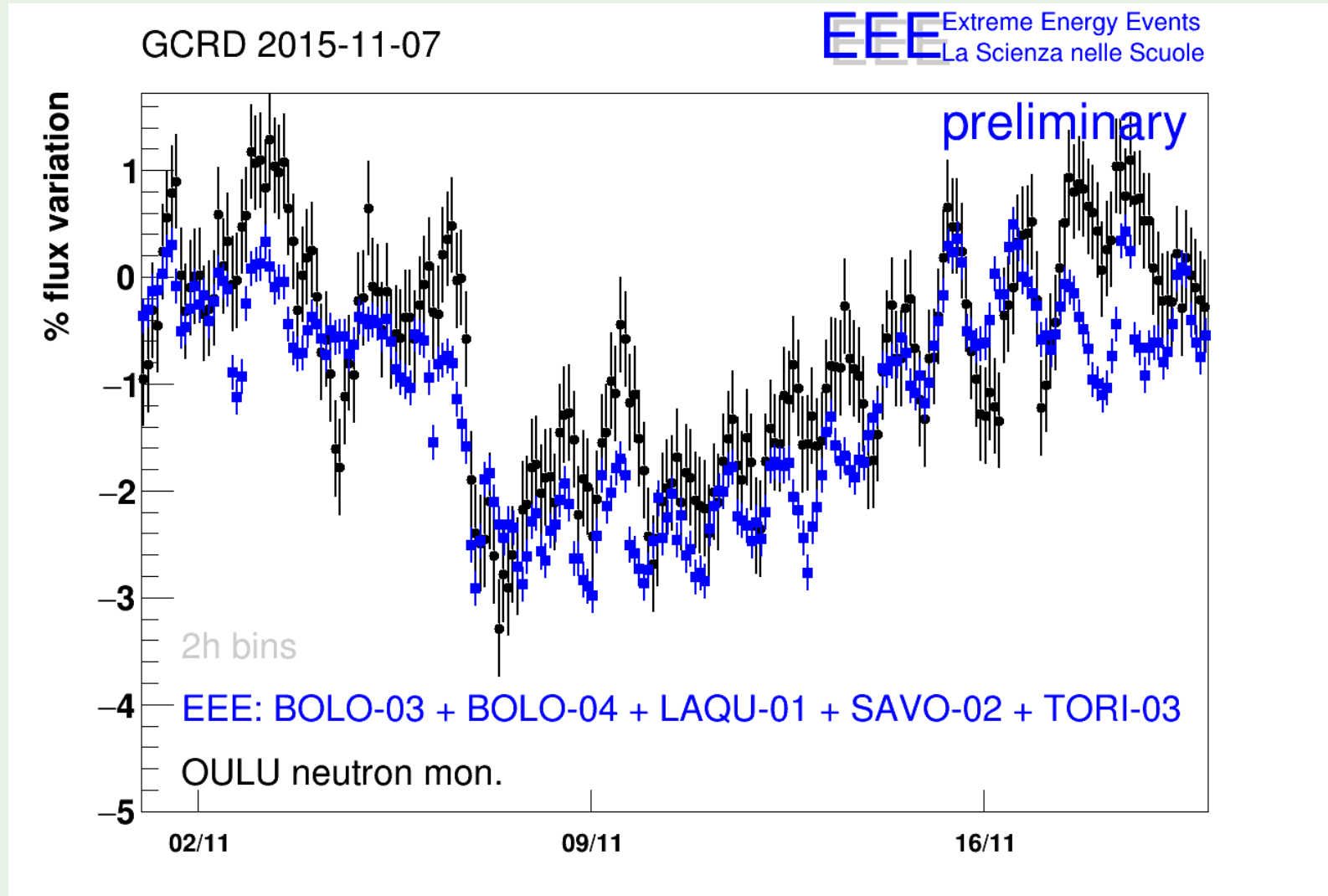
good correlations with Neutron Monitors
but muon amplitude a factor ~ 2 higher



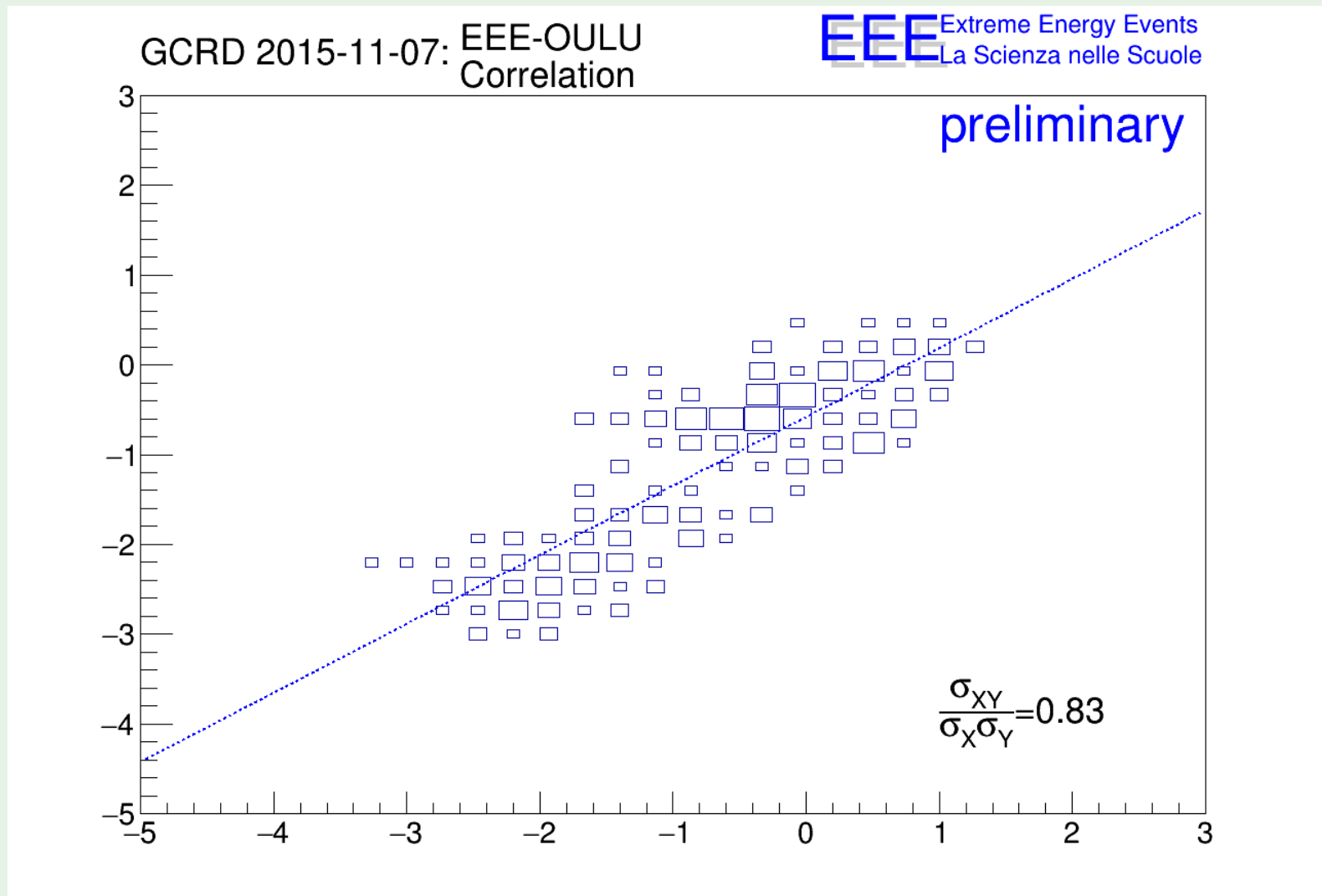
Forbush 2015-06: M3.8-M6.5 flares
good correlations with Neutron Monitors
but **muon amplitude a factor ~ 2 lower**



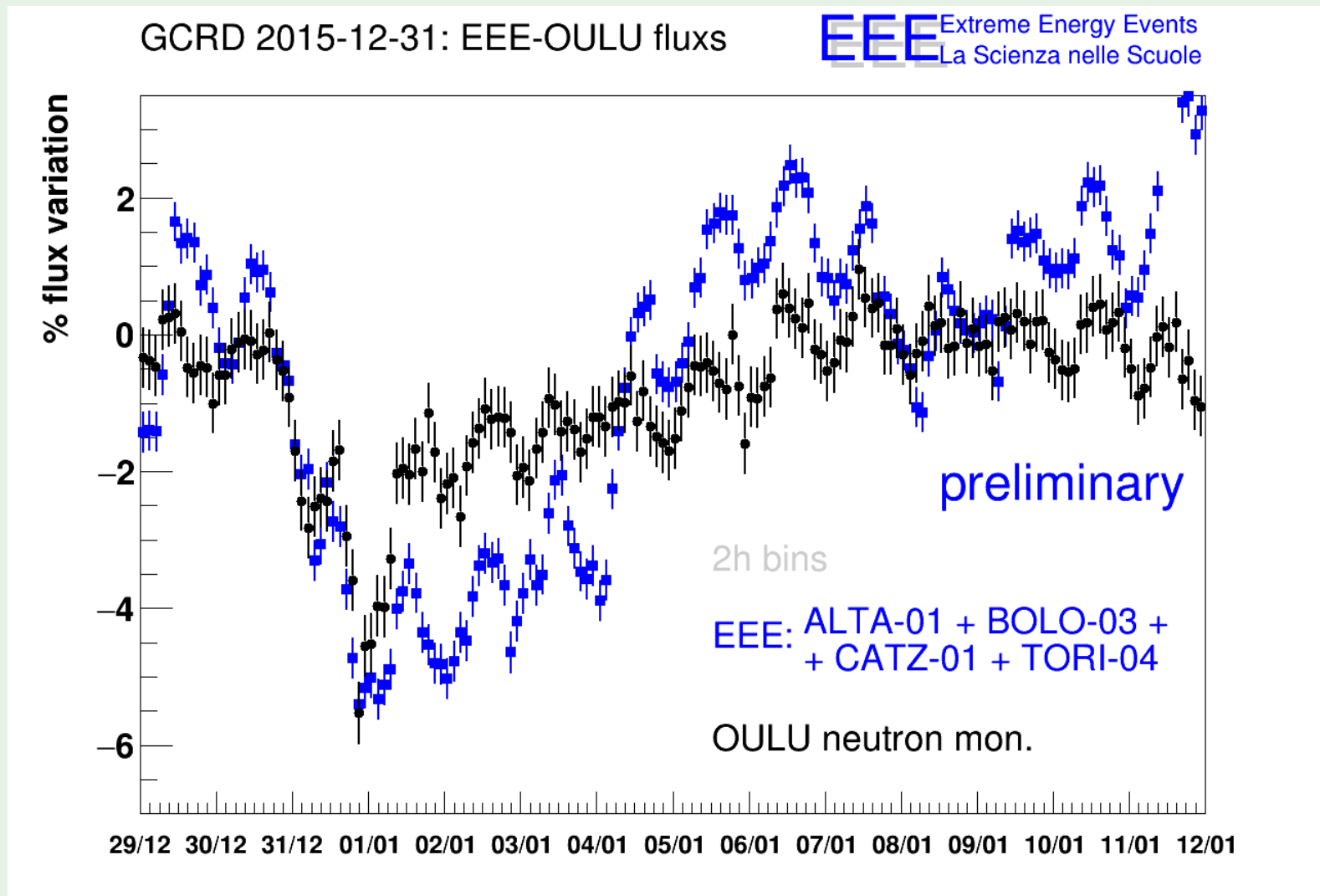
Forbush 2015-11: M3.7 flare very good correlations with Neutron Monitors



Forbush 2015-11: M3.7 flare very good correlations with Neutron Monitors

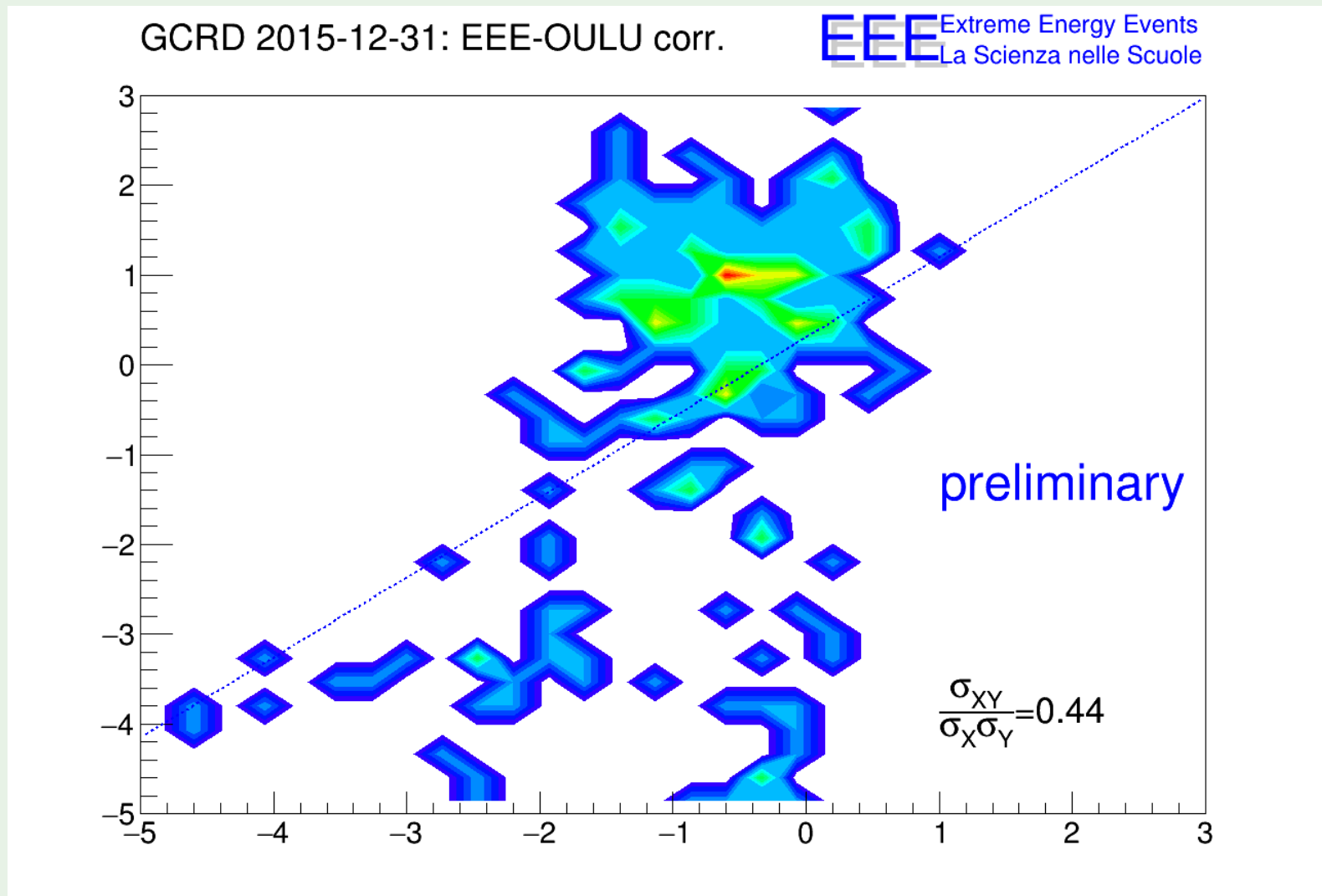


Forbush 2015-12: M1.8 flare

low correlations with Neutron Monitors and **two-step** recovery mechanisms

Forbush 2015-12: M1.8 flare

low correlations with Neutron Monitors and two-step recovery mechanisms



- the different CR Forbush effects on muon and neutron component is not understood (and not confirmed)
- Pressure, Temperature corrections have to be deeply studied in order to perform a robust correction to the non-CR related modulation effects
- Latitude and Longitude dependence studies are possible also with the EEE detectors (10 degrees in lat and long coverage)
- crossing the data with NM net is on the way
- ...
- after stabilizing the telescopes, long term studies on solar cycle survey are feasible.

Summary and Conclusions

The Educational and Outreach activities

- Telescopes are built at CERN
- by students and teachers
- installed in high schools
- monitored by students
- > 500 students involved
- ...growing



- Masterclasses
- Lectures
- Trainings on detectors
- Analysis
- Schools
- Events

Conclusions

- EEE is a wide tracking telescope array
 - 52 telescope already working
 - > 25 in construction
- high time resolution
- tracking capabilities
- 10 degrees in latitude and longitude coverage
- suitable both for studies at energies below and above the knee
- multipurpose array
 - HECR
 - CR flux modulation
 - local anisotropies (with coincidences also higher energies available)
 - studying the feasibility of upward flux identification
- Environmental Studies
- + educational purposes

> 2015 Articles

- EEE coll.: Looking at the sub-TeV sky by cosmic muons detected in the EEE MRPC telescopes”
 - EPJ-Plus (2015), 130:187
- EEE coll.: A study on upward going particles with the Extreme Energy Events telescopes
 - Nucl. Instr. and Meth. A 816 (2016) 142:148
- ... and preparing
- ”The EEE Telescope performances”
- ”An extended study of subTeV anisotropies with the EEE array”
- ”A study of multistation coincidences at the km scale with the EEE array”
- ”A Forbush decrease survey with the EEE telescopes”