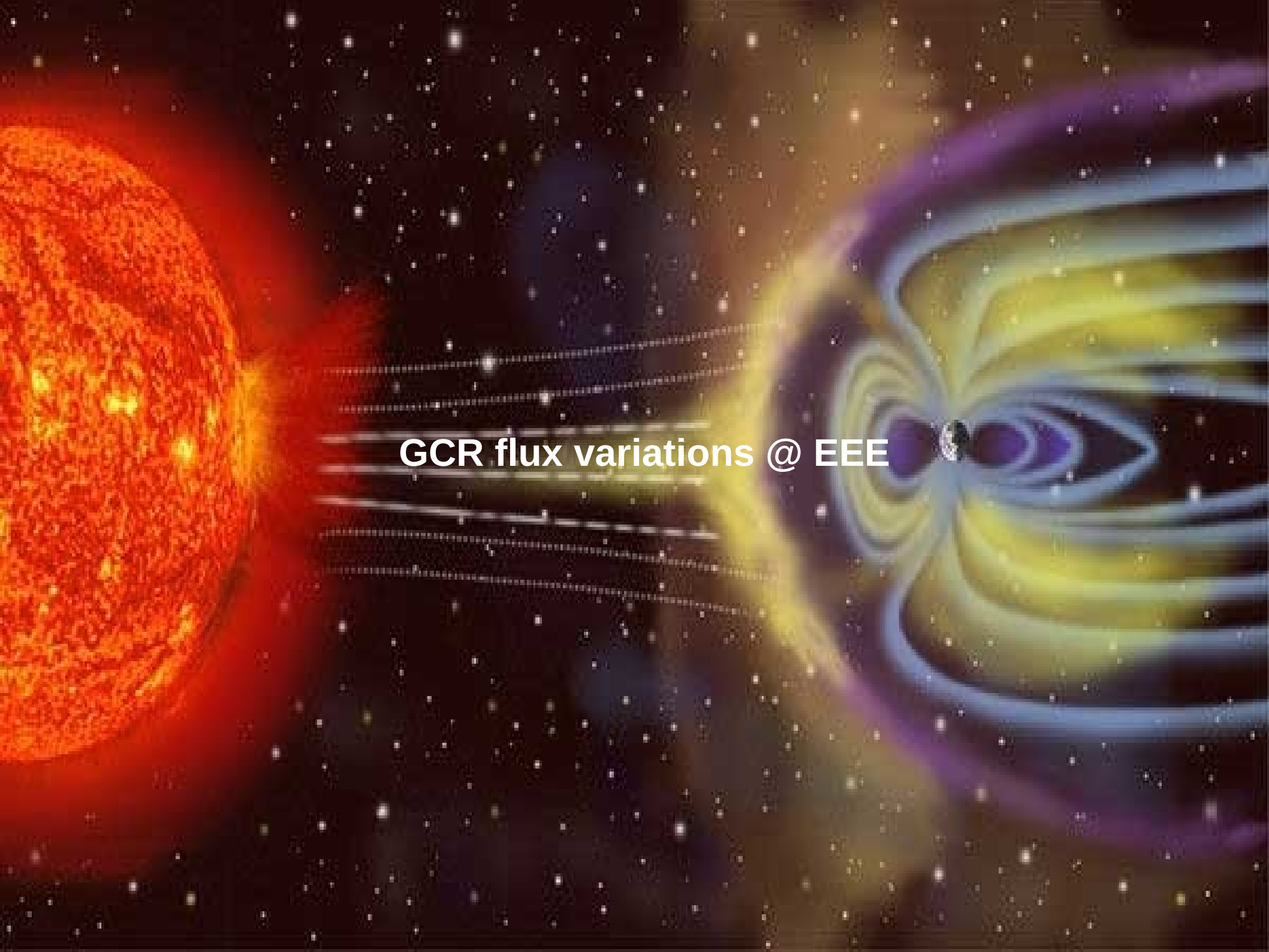

GCR flux variations @ EEE

Forbush and GCRDs

First rigorous experimental observation of Cosmic Ray Flux Decrease was obtained by S. E. Forbush in 1937-38, after deep statisitcal analysis of data from "precision cosmic ray meter, Cheltenham, Maryland"

fects.

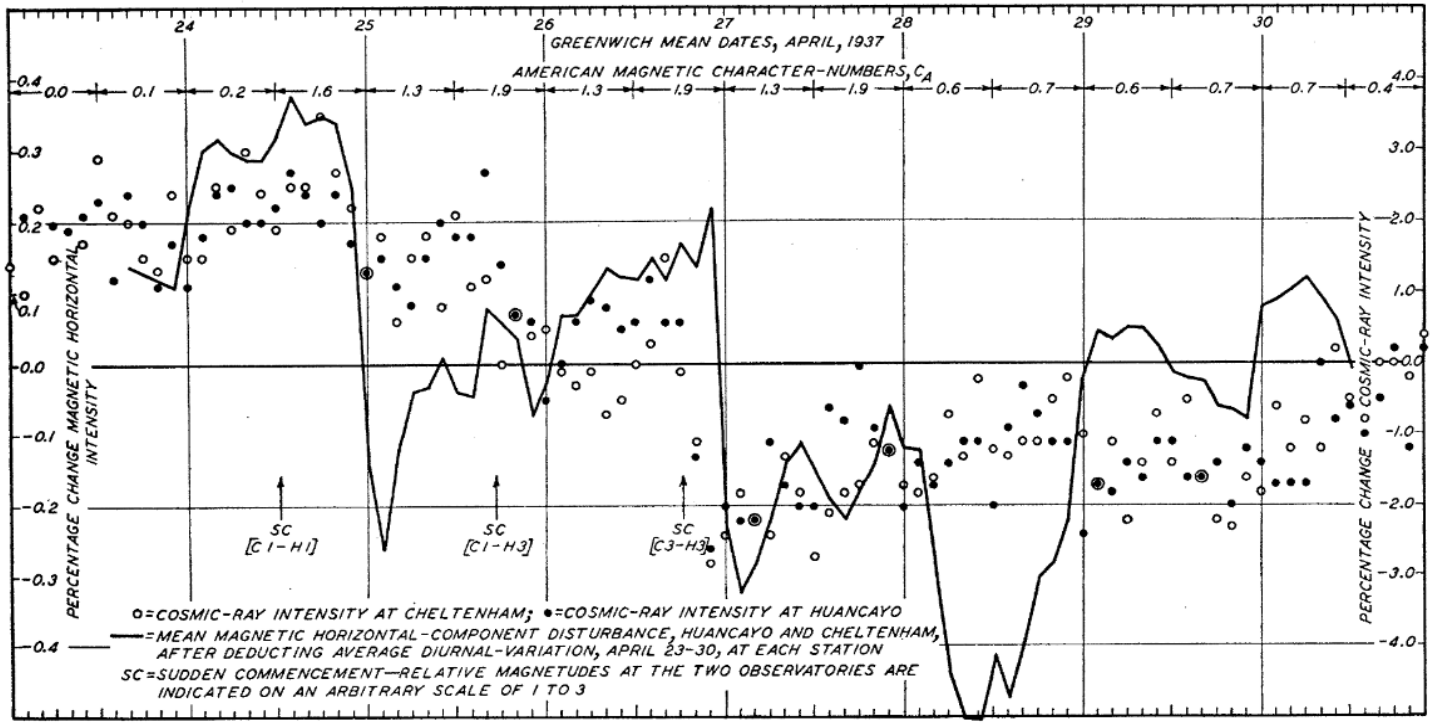


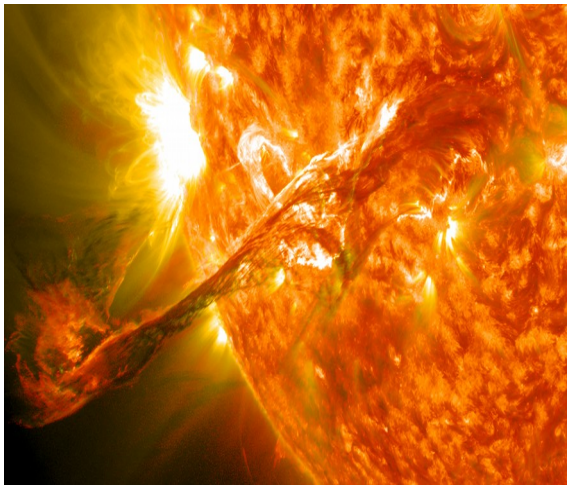
FIG. 1. Bi-hourly departures expressed in percentage of absolute values for component April 23–30, 1937, Huancayo and

While the evidence here presented cannot be regarded in itself as conclusive proof that the observed changes in cosmic-ray intensity are due to the external field of the magnetic storm, this hypothesis seems to be the most reasonable one.

GCRD sources: Energetic events on Sun Corona

Coronal Mass Ejections

- Ejection of particles from Sun Corona (protons, electrons)
- Particles are accelerated from 20 to 2000 km/s
  - Average 400 km/s
- Accelerated by the heating of underlying sun layers, confined by magnetic field
- $E_{tot} \approx 10^{23\text{-}24}$ J
  (Sun power P ≈ 4 10^{26} W)
- Rate of occurrence:
  - 0.25 day^{-1} (solar minimum)
  - 4 day^{-1} (solar maximum)

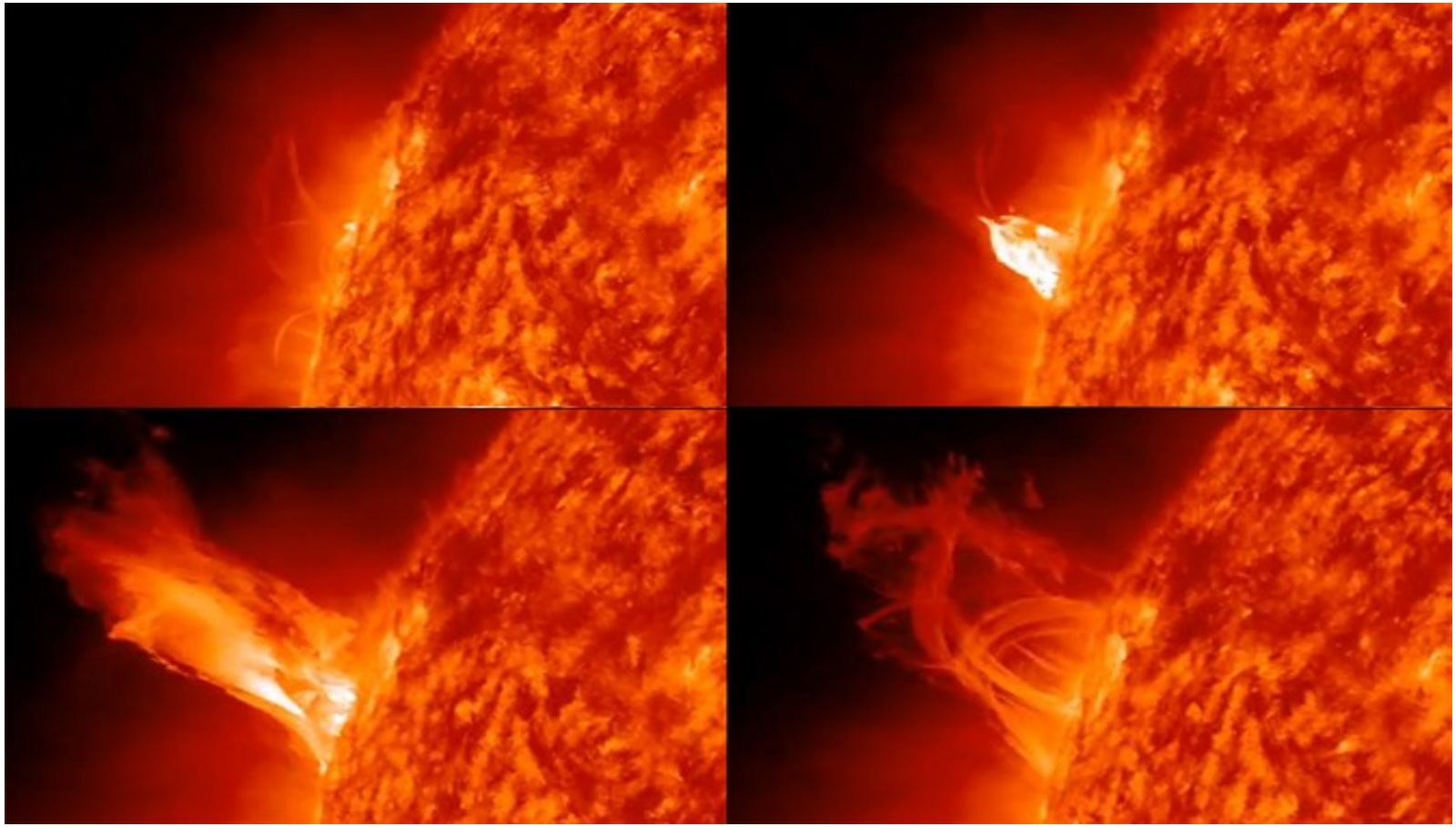


Flares

- Sudden increase in brightness
- Occurring in Sun Corona a belt confined along sun equator by magnetic fields
- Lasting secs to hour
- $E_{tot} \approx 10^{25}$ J
  (Sun power P ≈ 4 10^{26} W)
- Observable in

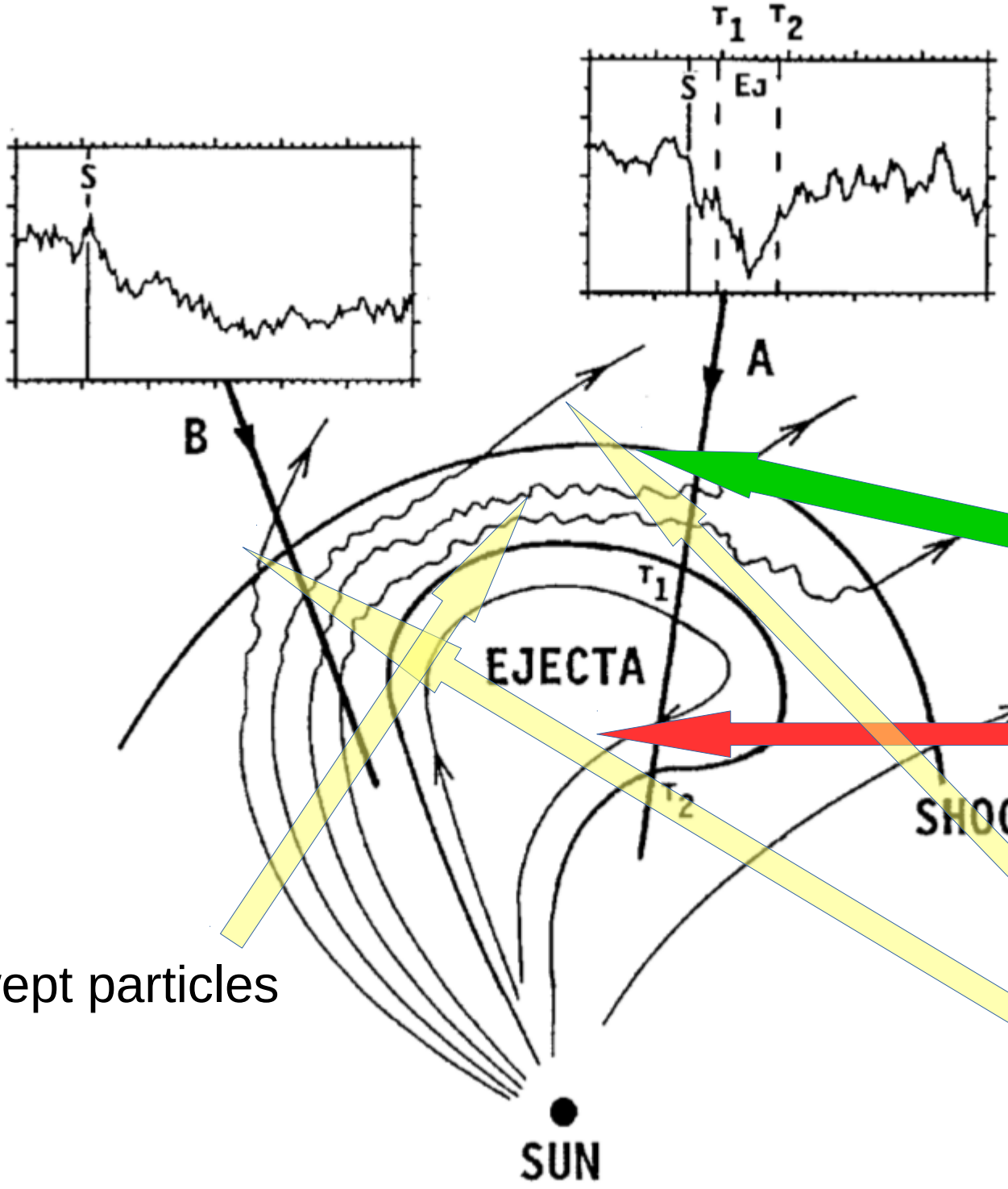
  visible
  x-ray
  Gamma-ray

Flare – CME connection



Flares are believed to be the results of **re-heating due to manetic lined reconnection** after a CME. However Flares and CME are **not always associated**, even if this happens in case of the **strongest events**.

GCRDs occurs in interplanetary medium



Shock wave driven by ejected particles

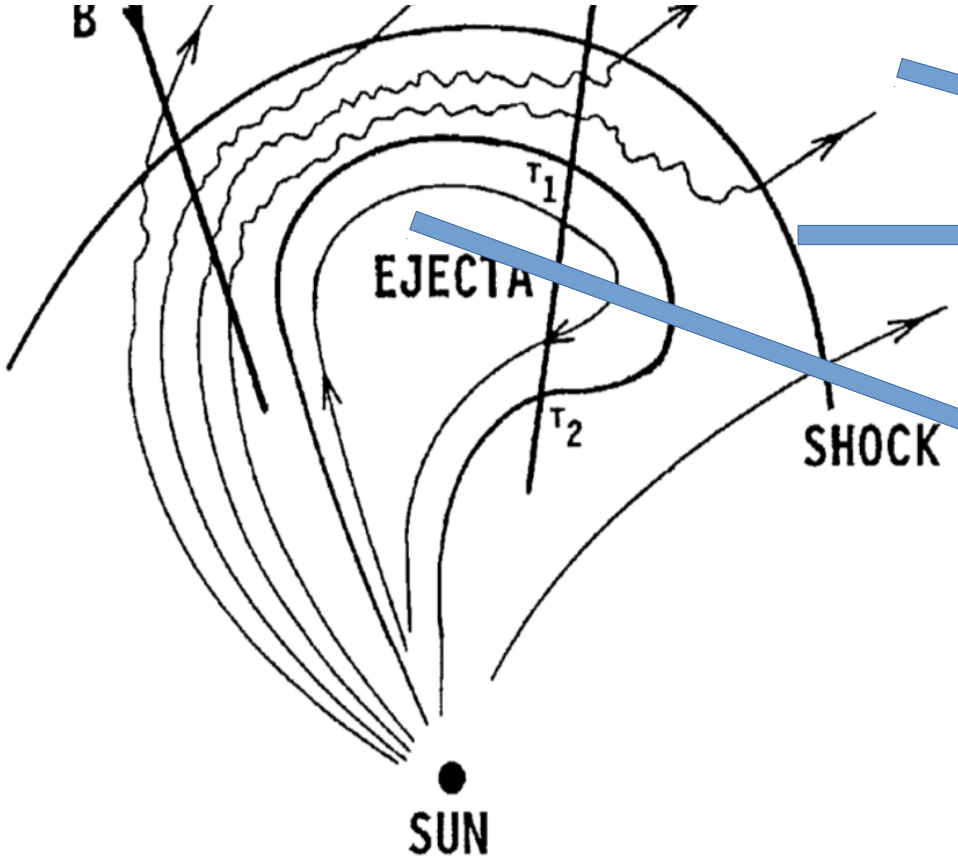
Particles ejected

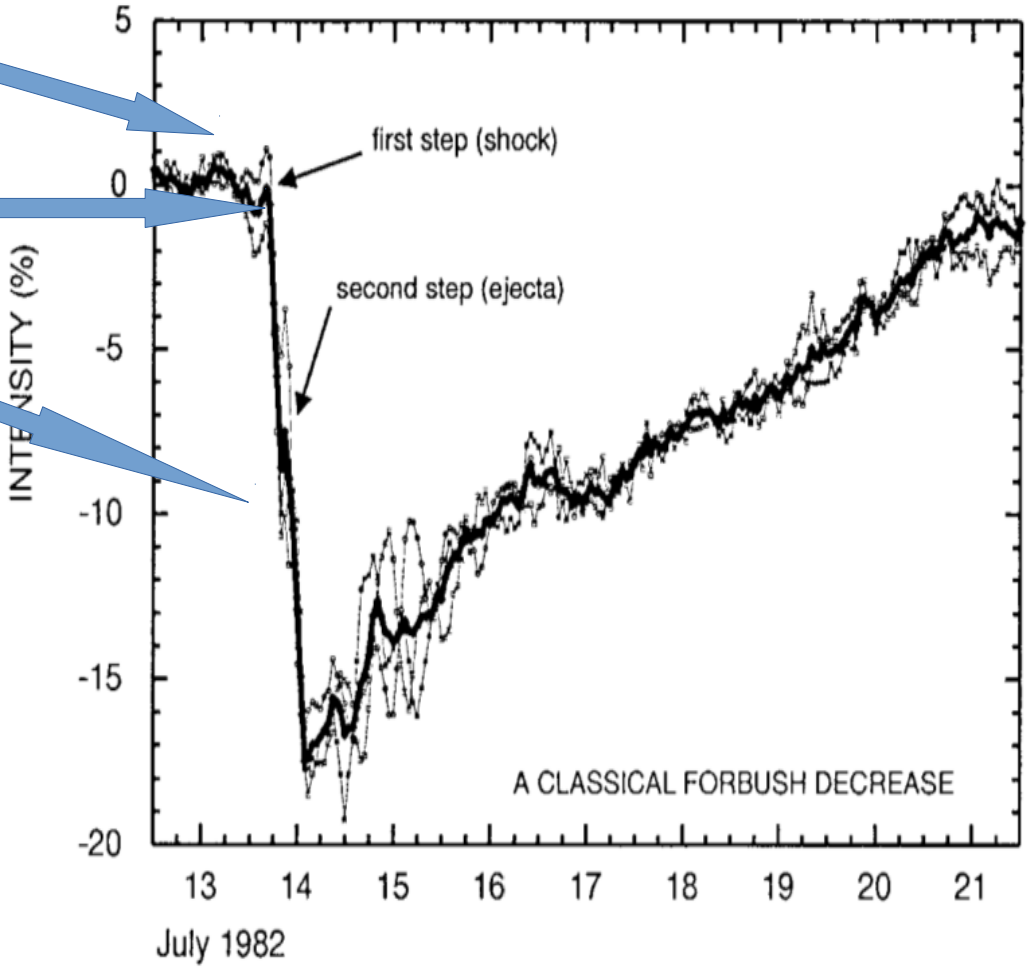
Accelerated particles by shock wave

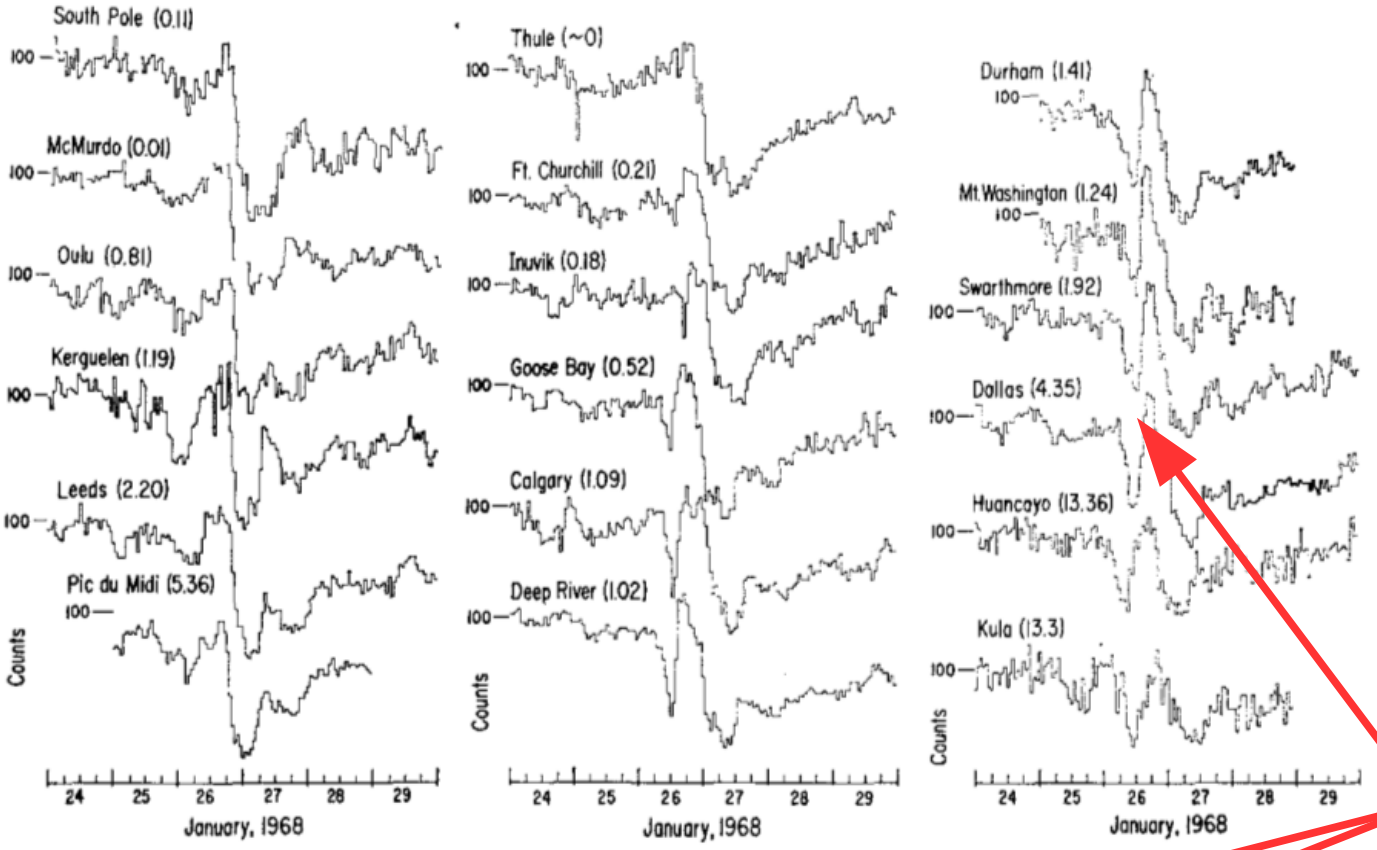
Swept particles

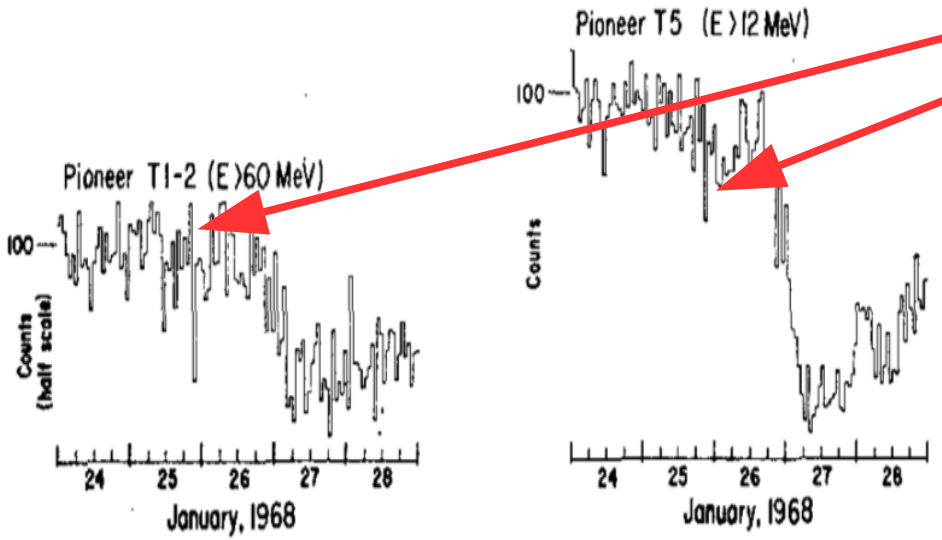
Effects on Earth: two-step mechanism

Initial particle increase may happen (only for strong CME, due to shock acceleration)









Neutron Monitors

Pioneer satellites

Complex phenomenon:

Energy threshold effects e.g . on two-step mechanism

Magnetic Field

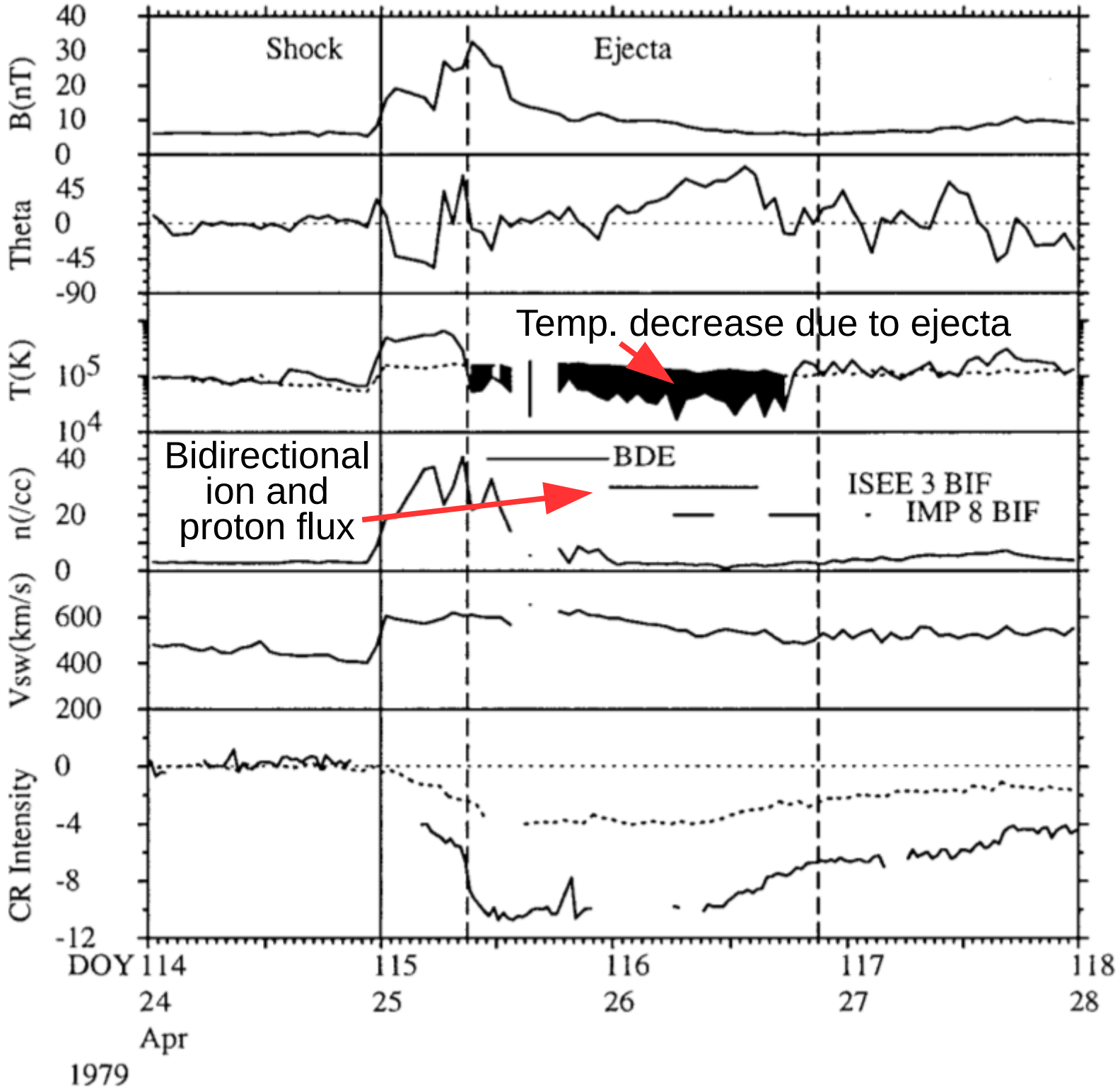
Magnetic field out of ecliptic

Proton Temp

Wind particle density

Wind speed

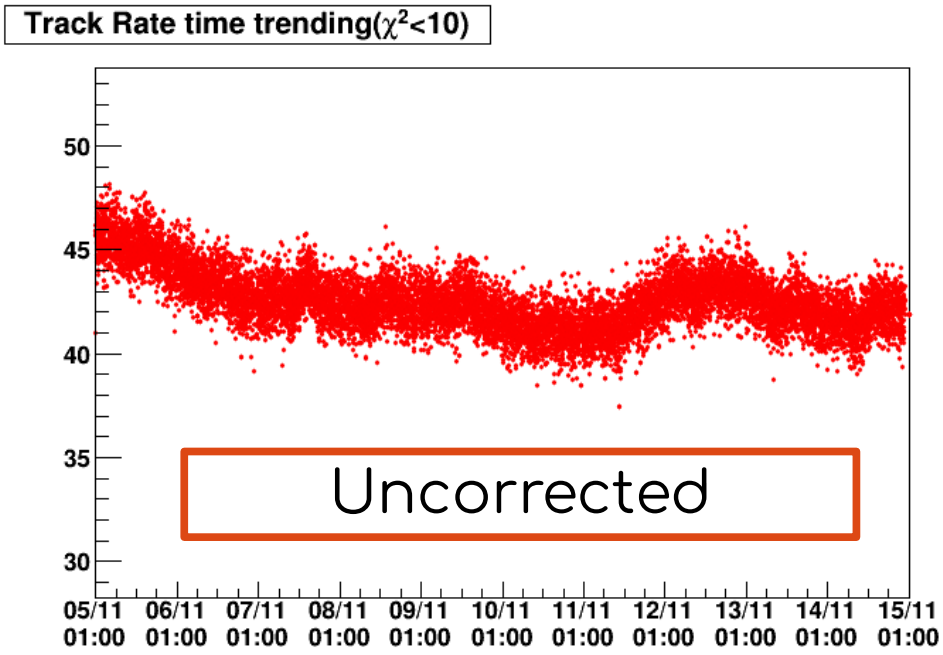
Forbush effect

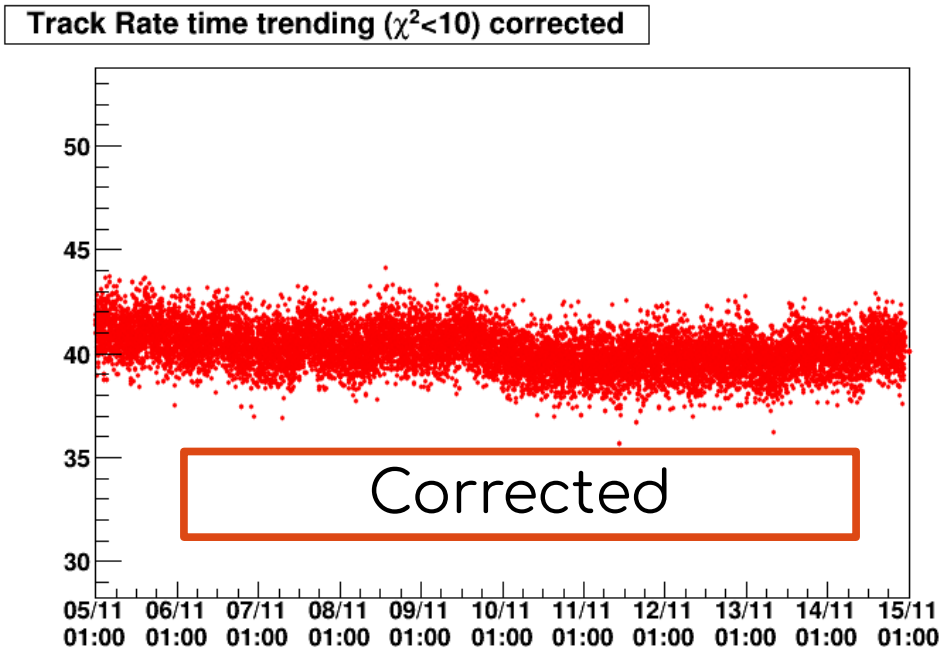


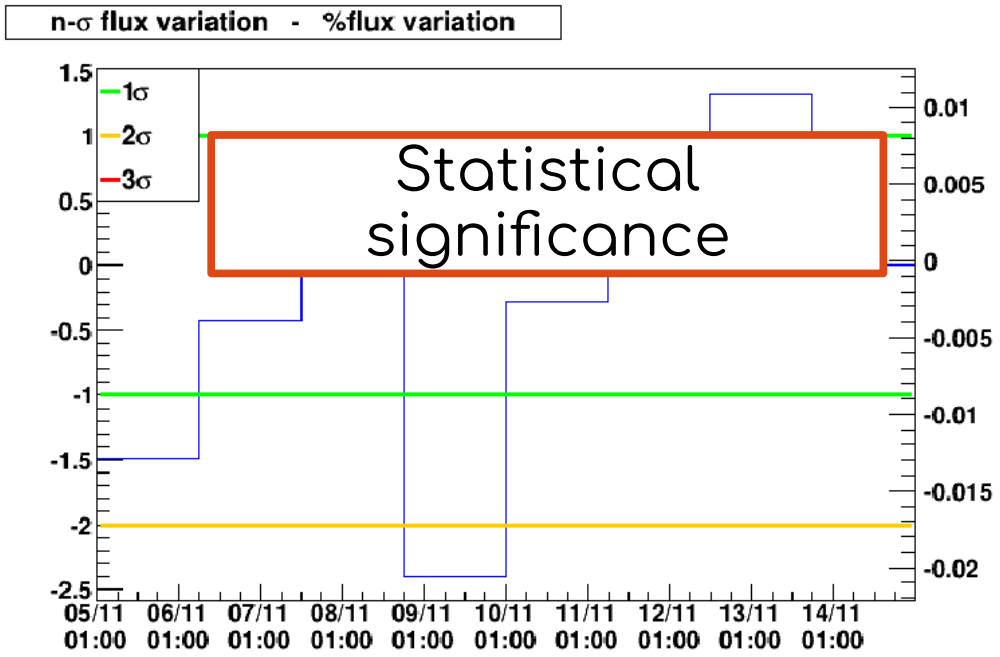
GCRDs
occurred since the beginning of coordinated data taking

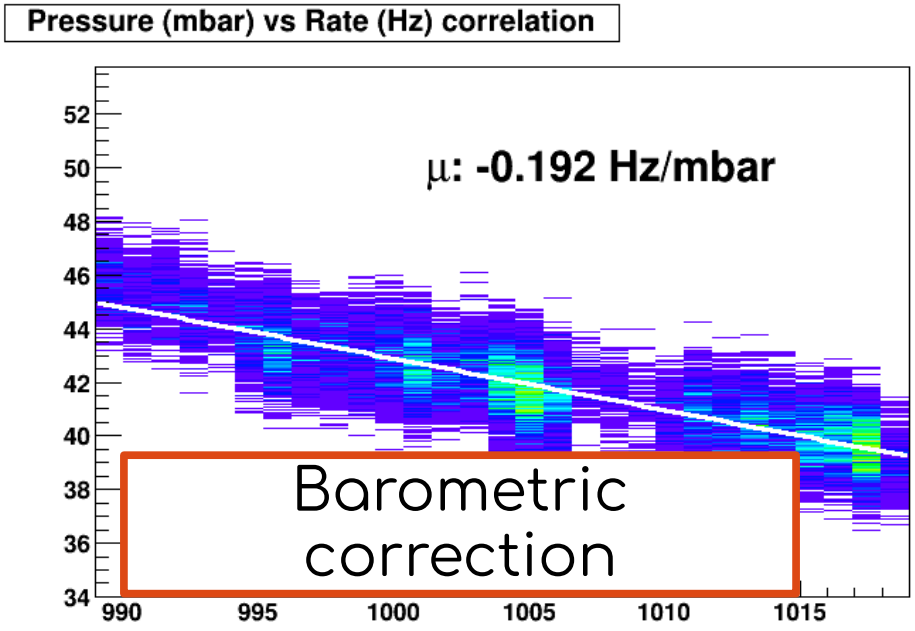
The analysis and Forbush identification approach

Corrections and Forbush identification

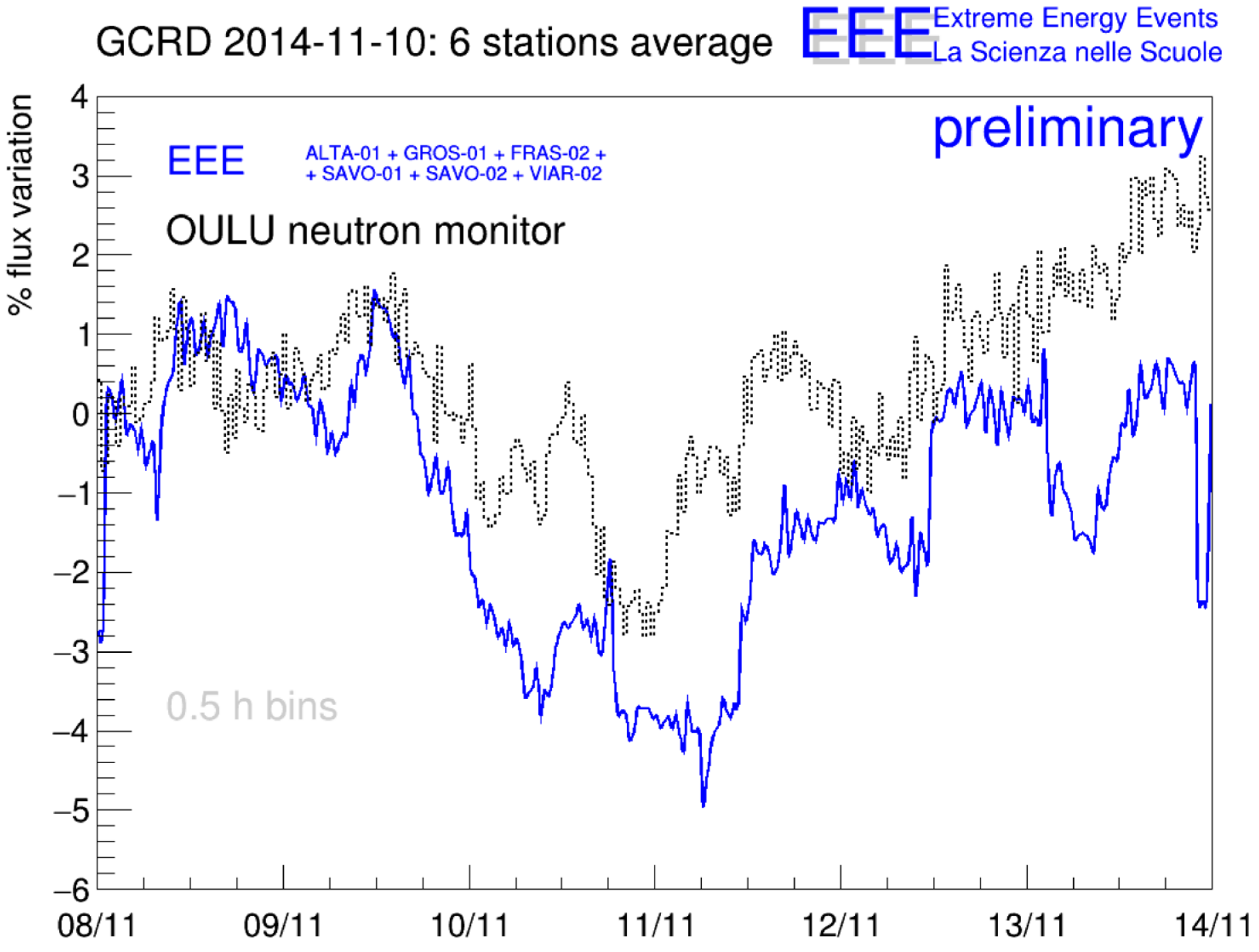




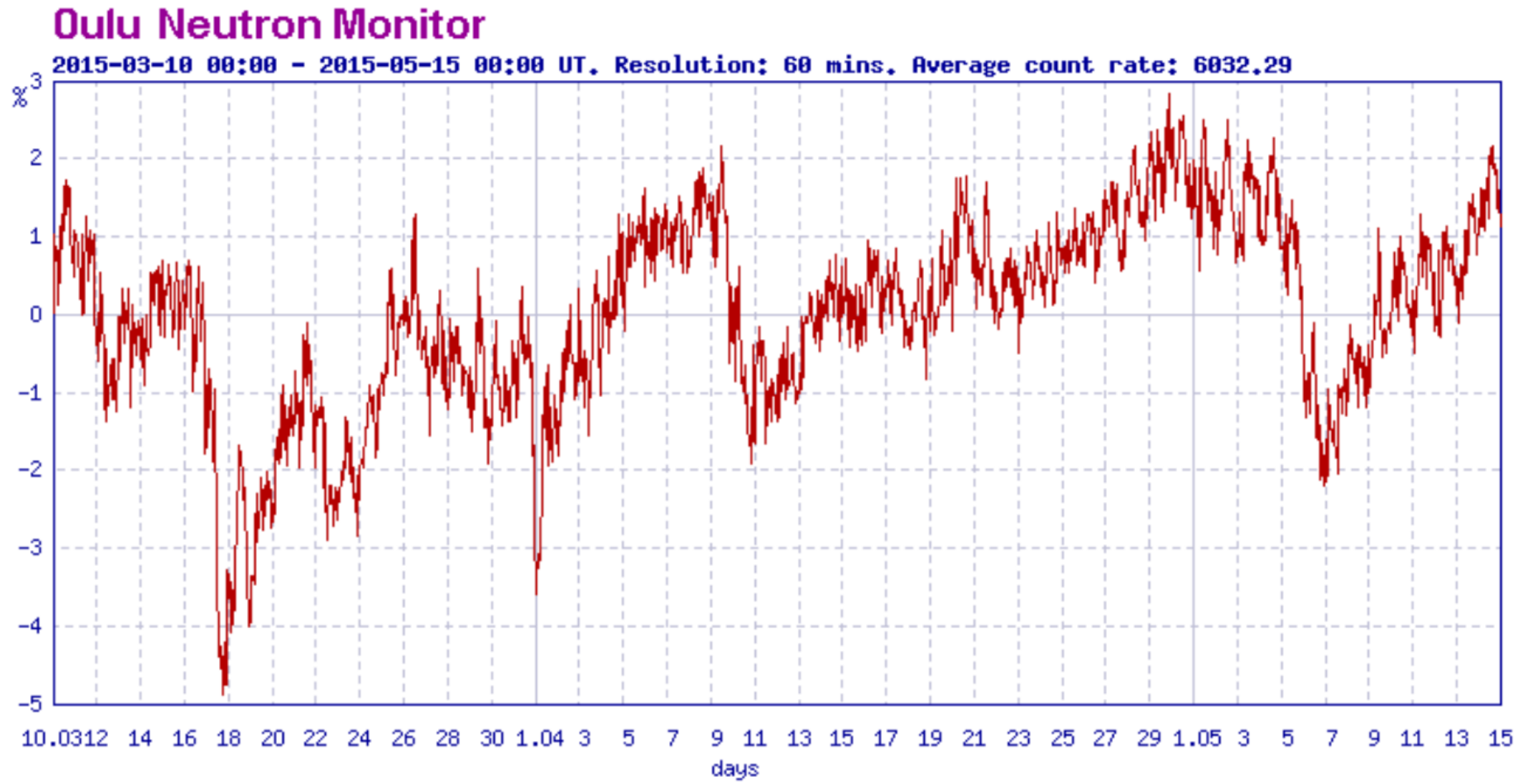


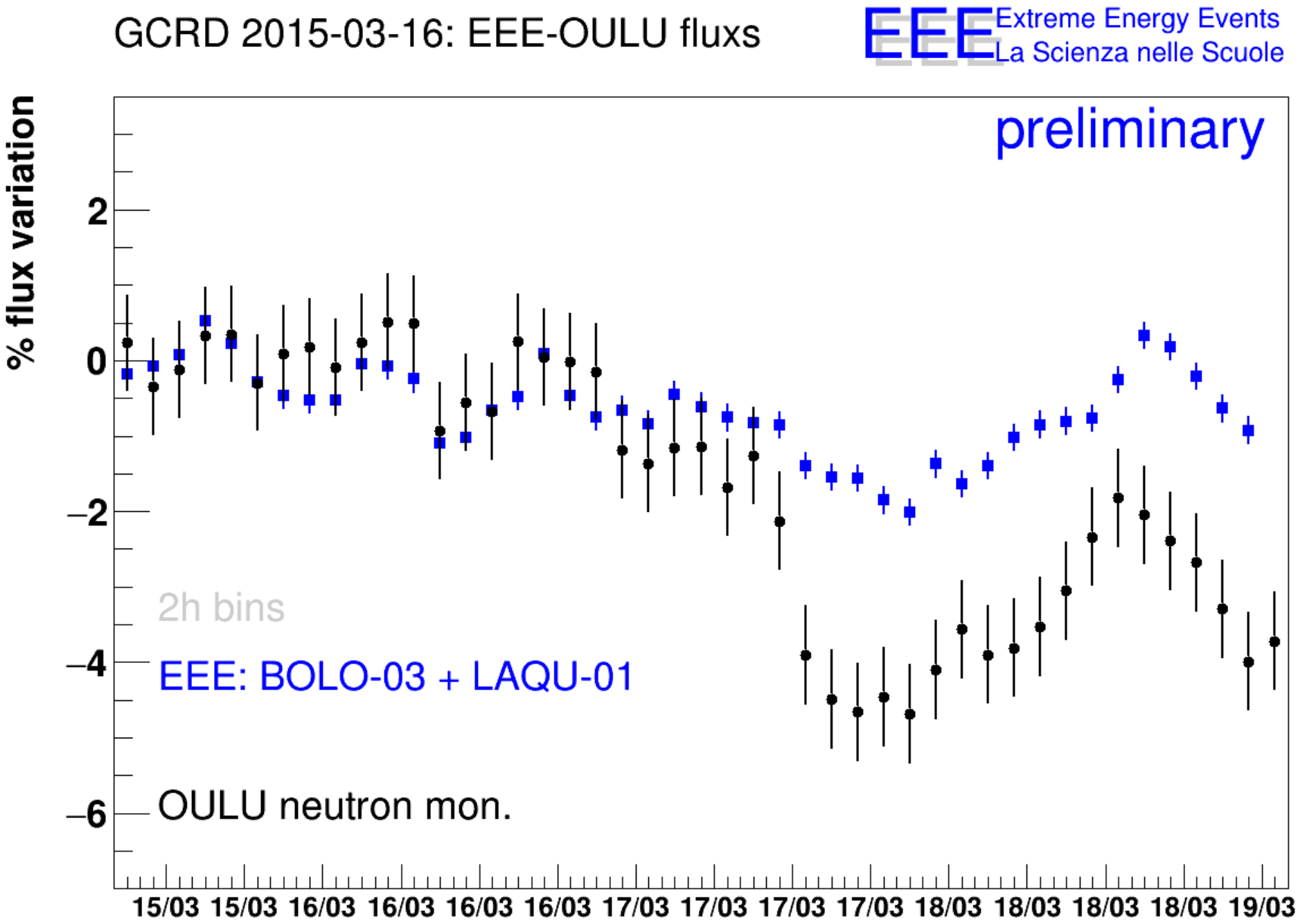


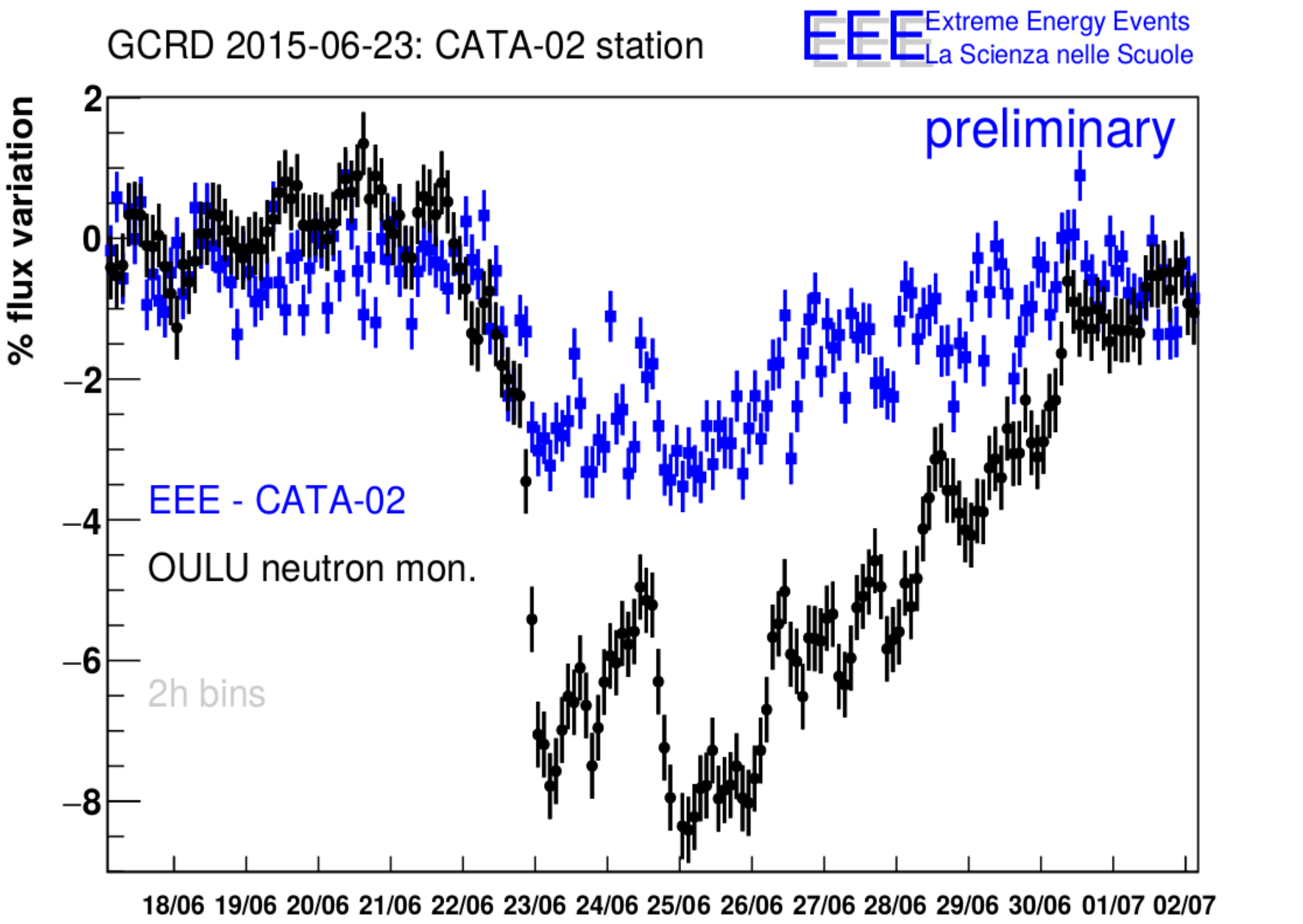
The observed events

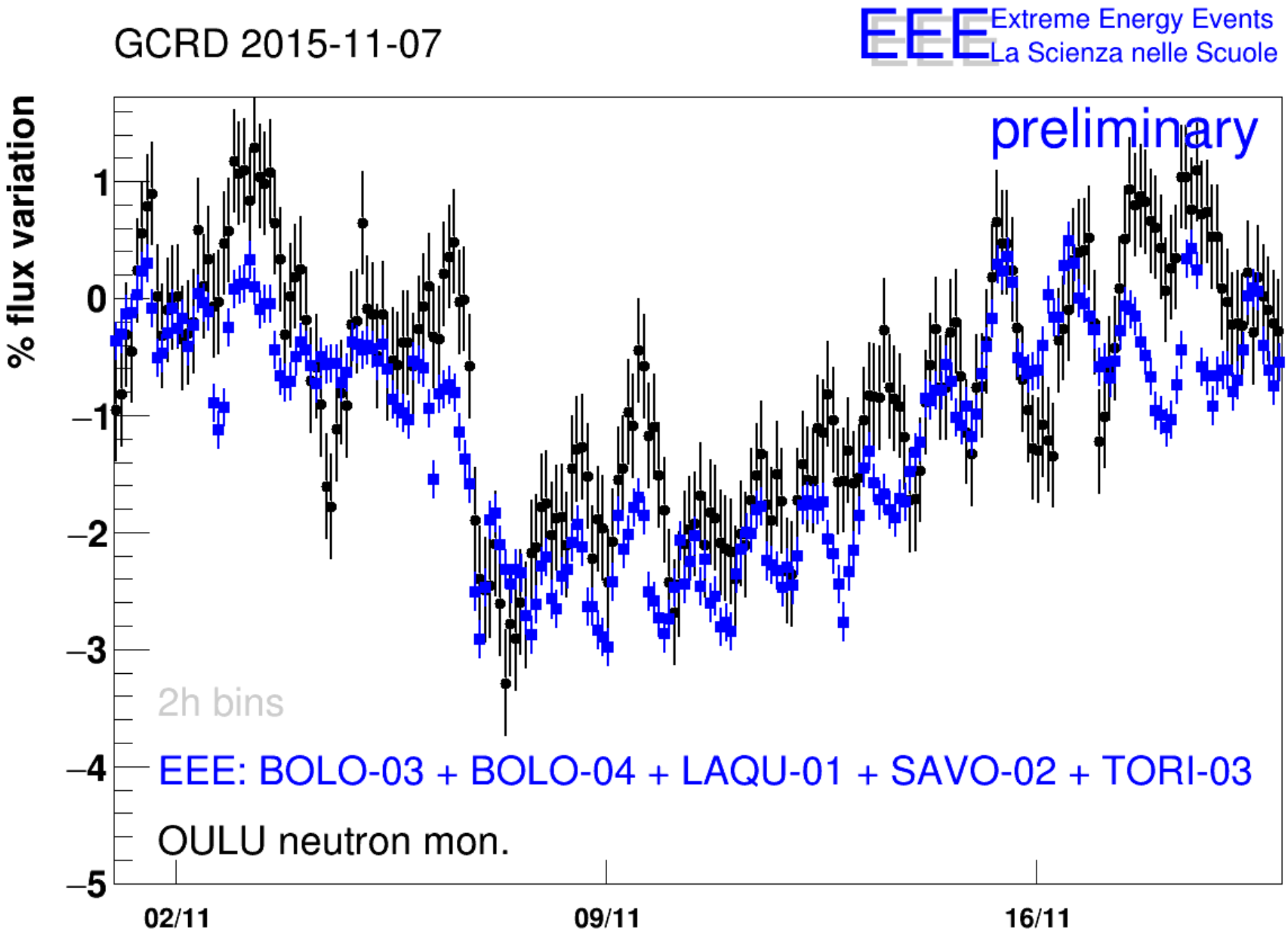

GCRD 2014-11-10: 6 stations average
EEE Extreme Energy Events
La Scienza nelle Scuole
preliminary
EEE
ALTA-01 + GROS-01 + FRAS-02 +
+ SAVO-01 + SAVO-02 + VIAR-02
OULU neutron monitor
0.5 h bins
% flux variation
4
3
2
1
0
−1
−2
−3
−4
−5
−6
08/11
09/11
10/11
11/11
12/11
13/11
14/11

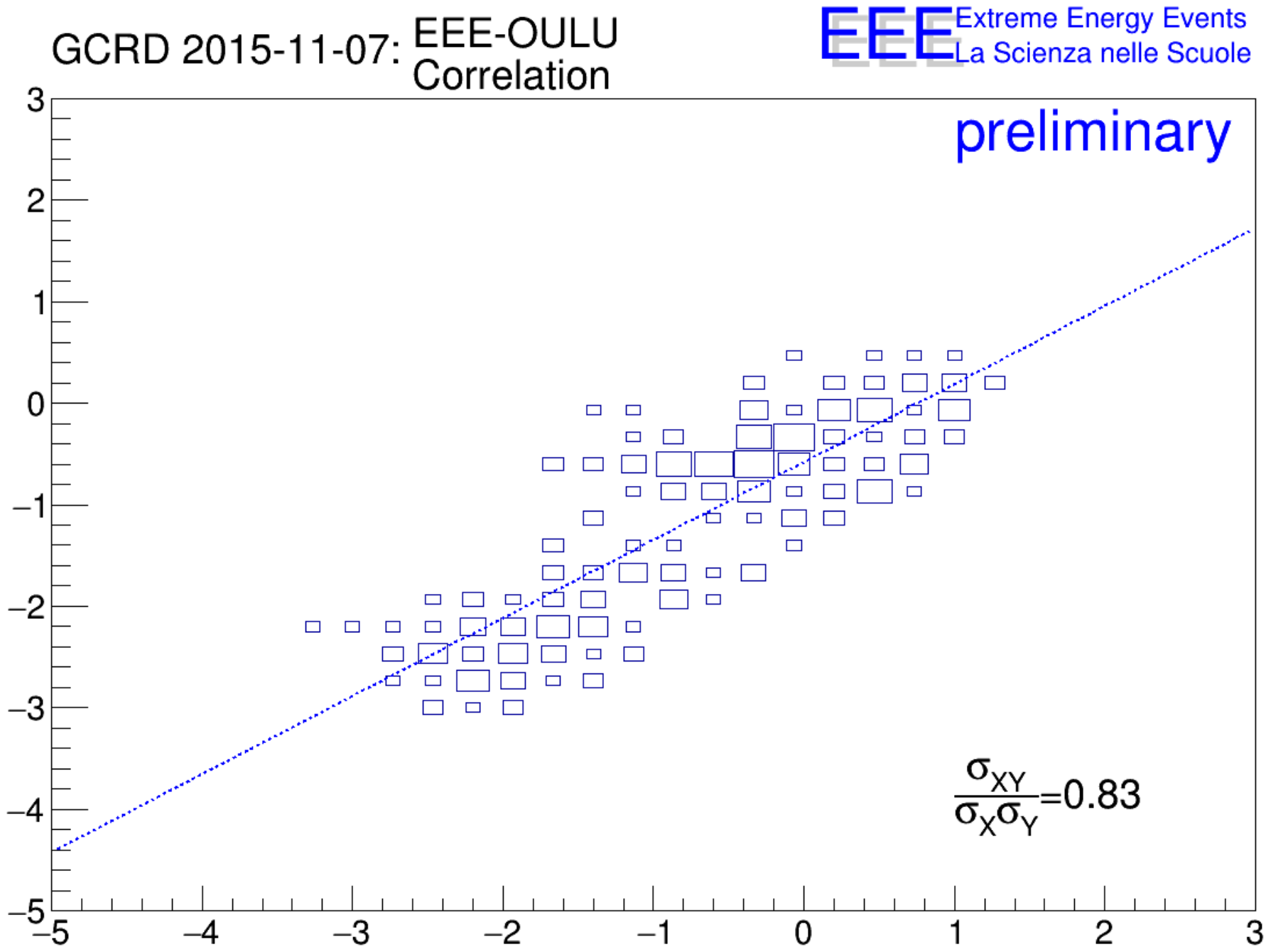
GCRD: 2015 March – May, an active season

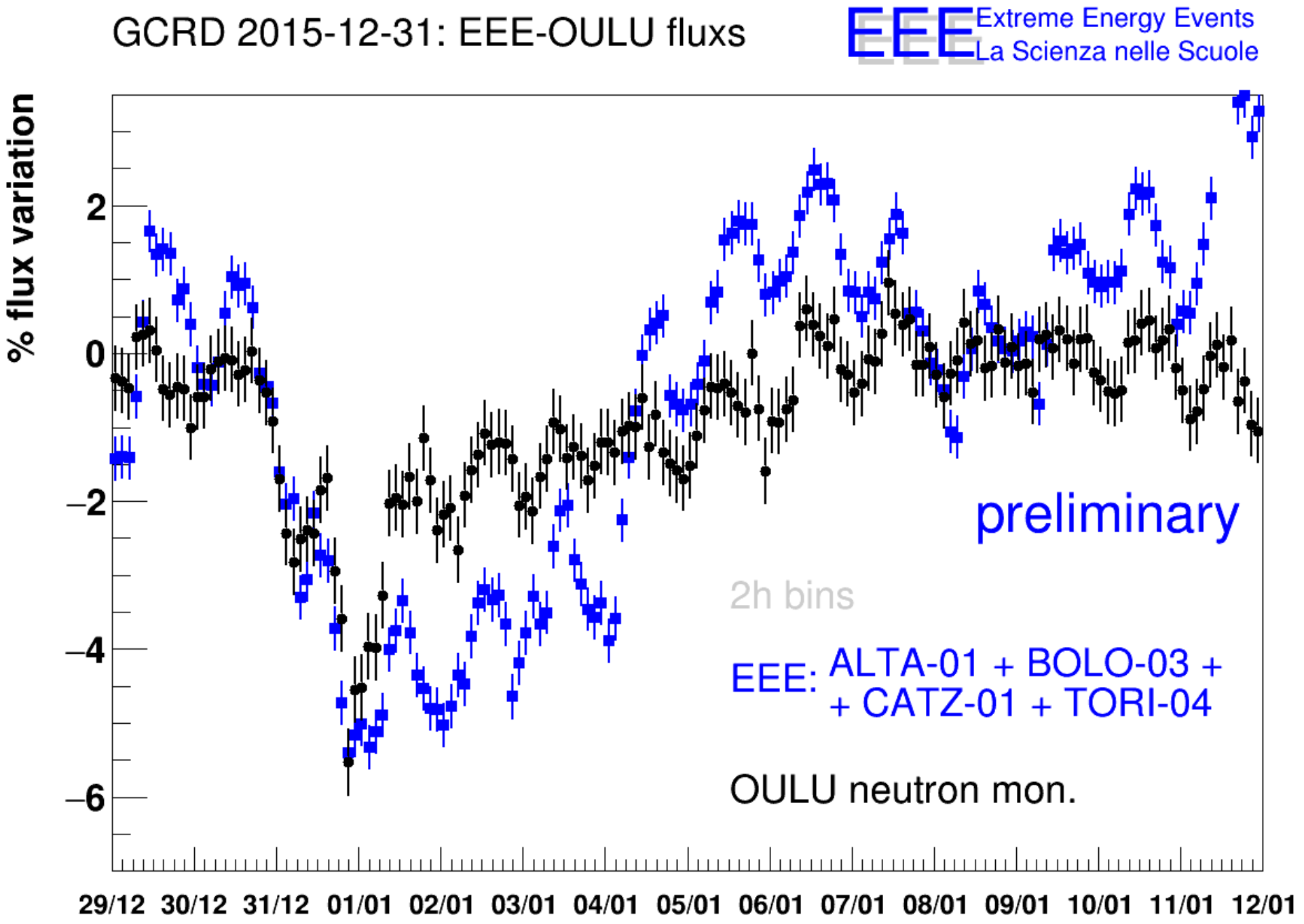



GCRD 2015-03-16: EEE-OULU fluxs
EEE Extreme Energy Events
La Scienza nelle Scuole
preliminary
% flux variation
2
0
−2
−4
−6
2h bins
EEE: BOLO-03 + LAQU-01
OULU neutron mon.
15/03 15/03 16/03 16/03 16/03 16/03 17/03 17/03 17/03 17/03 18/03 18/03 18/03 18/03 19/03


GCRD 2015-06-23: CATA-02 station
EEE Extreme Energy Events
La Scienza nelle Scuole
preliminary
% flux variation
2
0
−2
−4
−6
−8
EEE - CATA-02
OULU neutron mon.
2h bins
18/06 19/06 20/06 21/06 22/06 23/06 24/06 25/06 26/06 27/06 28/06 29/06 30/06 01/07 02/07

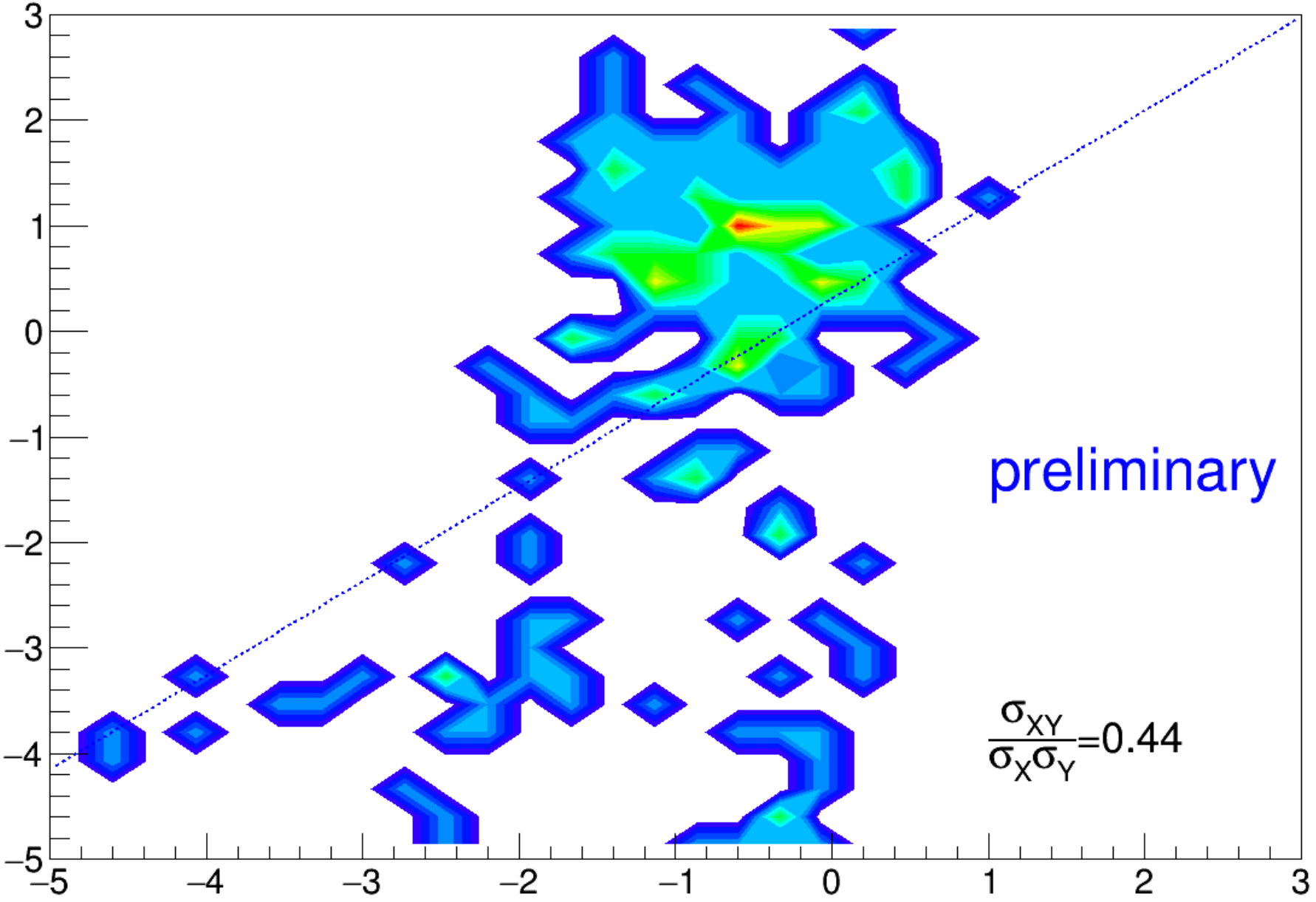

GCRD 2015-11-07
EEE Extreme Energy Events
La Scienza nelle Scuole
preliminary
% flux variation
1
0
−1
−2
−3
−4
−5
2h bins
EEE: BOLO-03 + BOLO-04 + LAQU-01 + SAVO-02 + TORI-03
OULU neutron mon.
02/11
09/11
16/11


GCRD 2015-11-07: EEE-OULU Correlation
EEE Extreme Energy Events
La Scienza nelle Scuole
preliminary
$\frac{\sigma_{XY}}{\sigma_X \sigma_Y}$=0.83
3
2
1
0
−1
−2
−3
−4
−5
−5
−4
−3
−2
−1
0
1
2
3

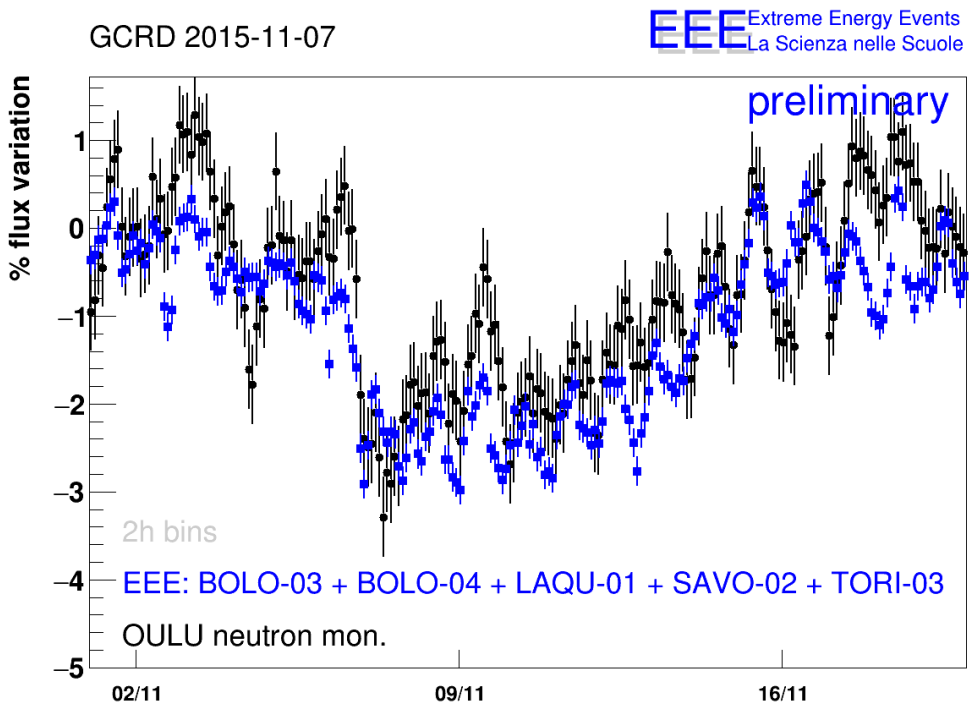

GCRD 2015-12-31: EEE-OULU fluxs
EEE Extreme Energy Events
La Scienza nelle Scuole
% flux variation
2
0
−2
−4
−6
preliminary
2h bins
EEE: ALTA-01 + BOLO-03 +
+ CATZ-01 + TORI-04
OULU neutron mon.
29/12
30/12
31/12
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01

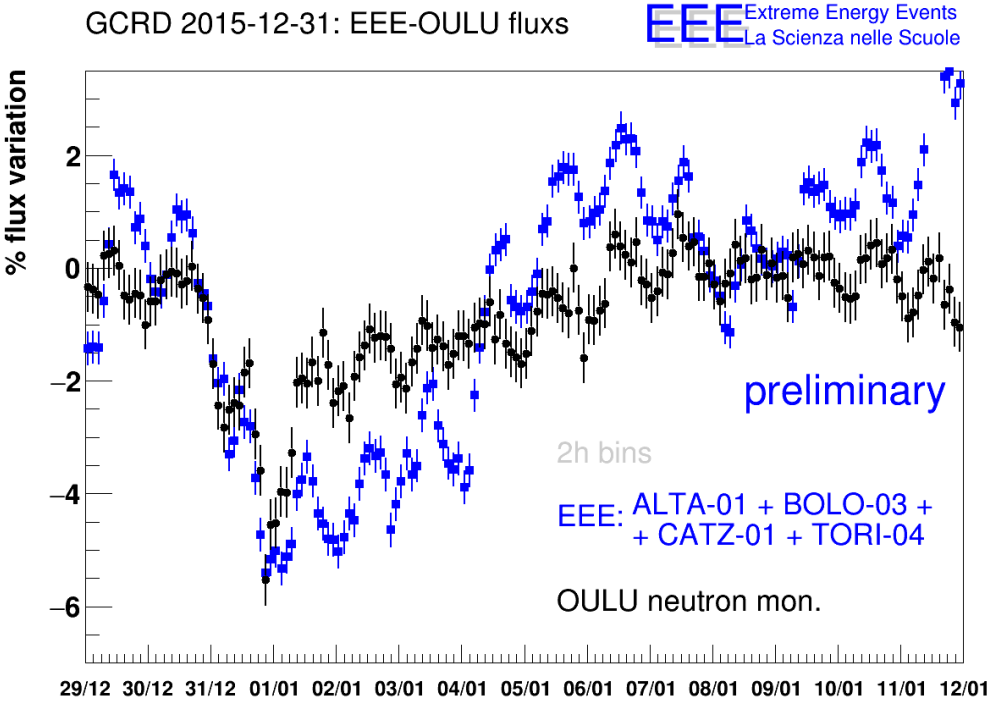
GCRD 2015-12-31: EEE-OULU corr.

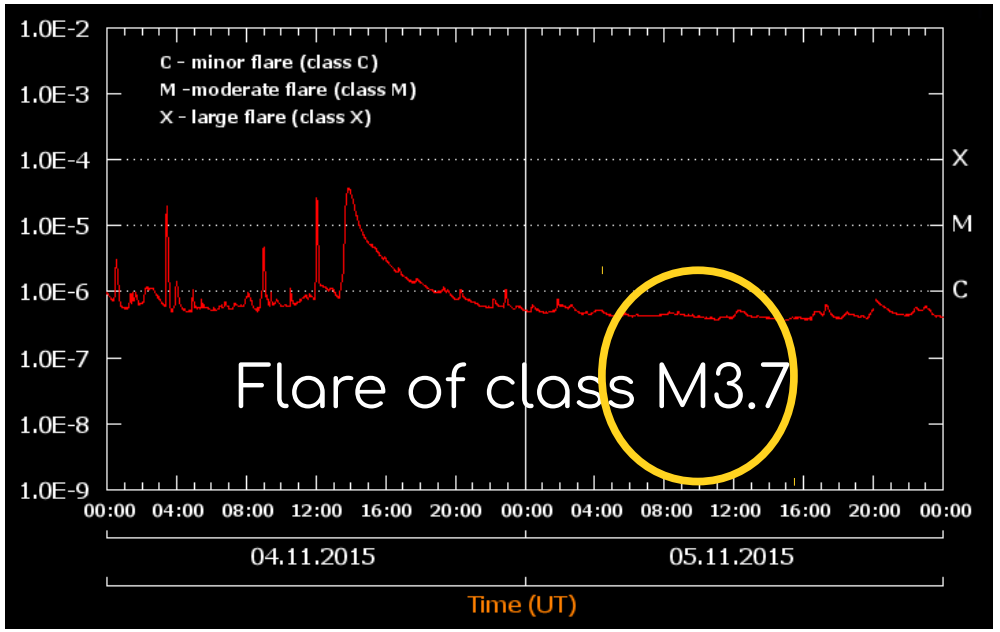
EEE Extreme Energy Events
La Scienza nelle Scuole

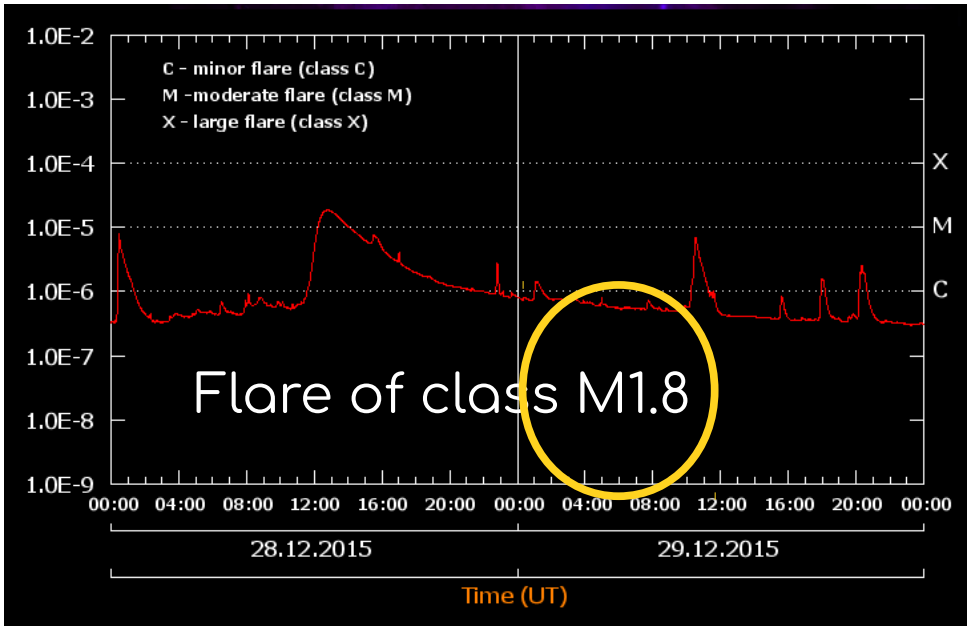


Forbush-Flares correlation

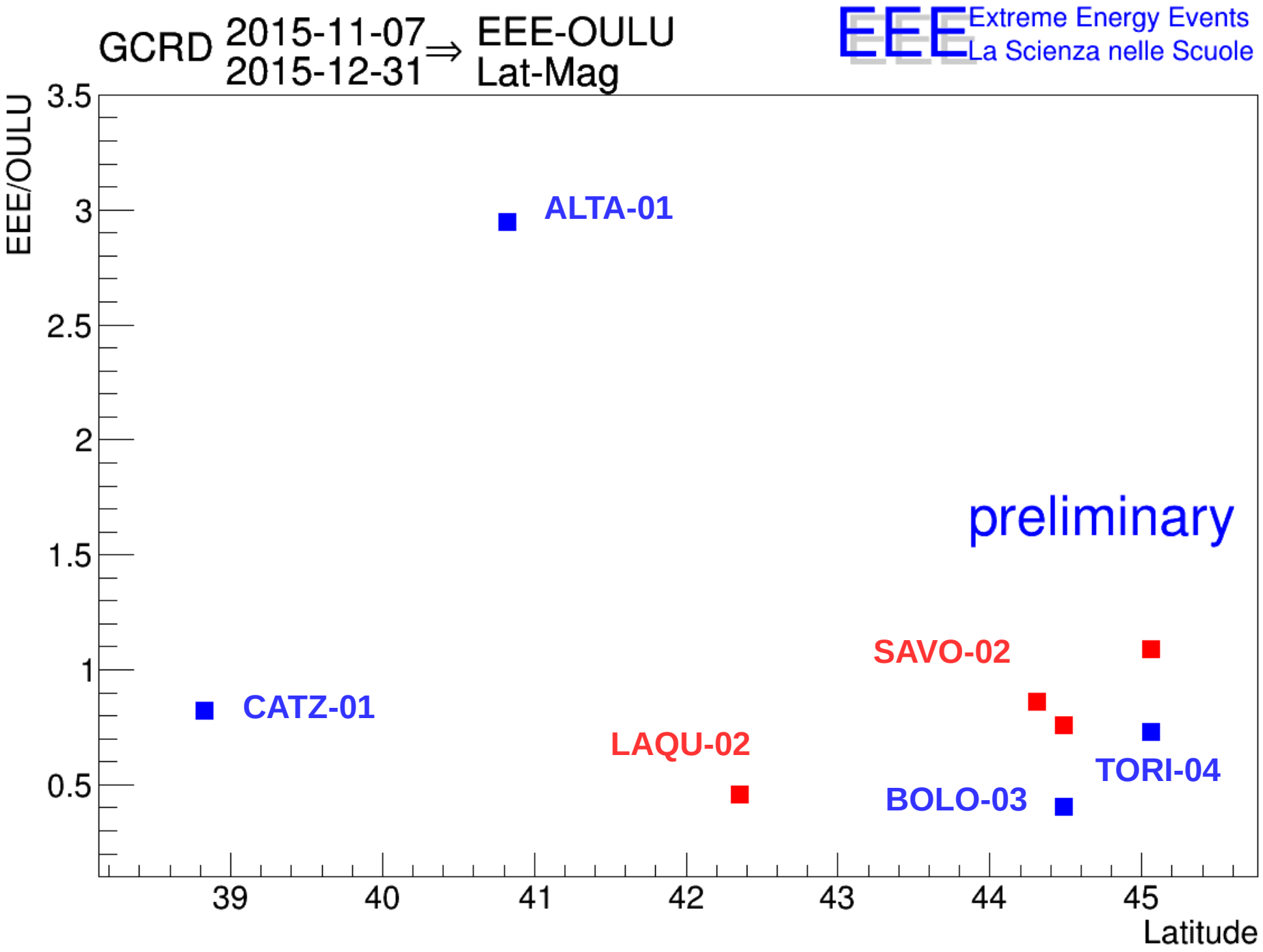

GCRD 2015-11-07
EEE Extreme Energy Events
La Scienza nelle Scuole
preliminary
% flux variation
2h bins
EEE: BOLO-03 + BOLO-04 + LAQU-01 + SAVO-02 + TORI-03
OULU neutron mon.
02/11
09/11
16/11


GCRD 2015-12-31: EEE-OULU fluxs
EEE Extreme Energy Events
La Scienza nelle Scuole
% flux variation
preliminary
2h bins
EEE: ALTA-01 + BOLO-03 +
+ CATZ-01 + TORI-04
OULU neutron mon.
29/12 30/12 31/12 01/01 02/01 03/01 04/01 05/01 06/01 07/01 08/01 09/01 10/01 11/01 12/01


C - minor flare (class C)
M -moderate flare (class M)
X - large flare (class X)
Flare of class M3.7
04.11.2015
05.11.2015
Time (UT)


C - minor flare (class C)
M -moderate flare (class M)
X - large flare (class X)
Flare of class M1.8
28.12.2015
29.12.2015
Time (UT)

Latitude correlation search


GCRD 2015-11-07 ⇒ 2015-12-31 EEE-OULU Lat-Mag
EEE Extreme Energy Events
La Scienza nelle Scuole
EEE/OULU
3.5
3
2.5
2
1.5
1
0.5
39
40
41
42
43
44
45
Latitude
ALTA-01
CATZ-01
LAQU-02
SAVO-02
BOLO-03
TORI-04
preliminary