



# GCR flux variations @ EEE

Introduction

Already available results

Lesson learned and Upgrades

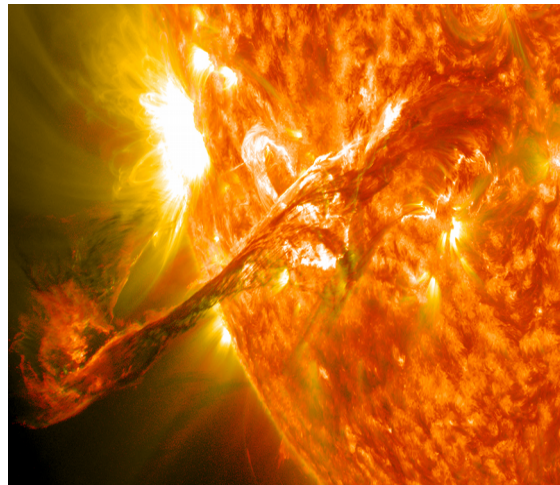
Timeline and Paper

Ivan Gnesi

# 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
- $E_{\text{tot}} \approx 10^{23-24} \text{ J}$   
(Sun power  $P \approx 4 \cdot 10^{26} \text{ W}$ )
- Rate of occurrence:
  - $0.25 \text{ day}^{-1}$  (solar minimum)
  - $4 \text{ day}^{-1}$  (solar maximum)

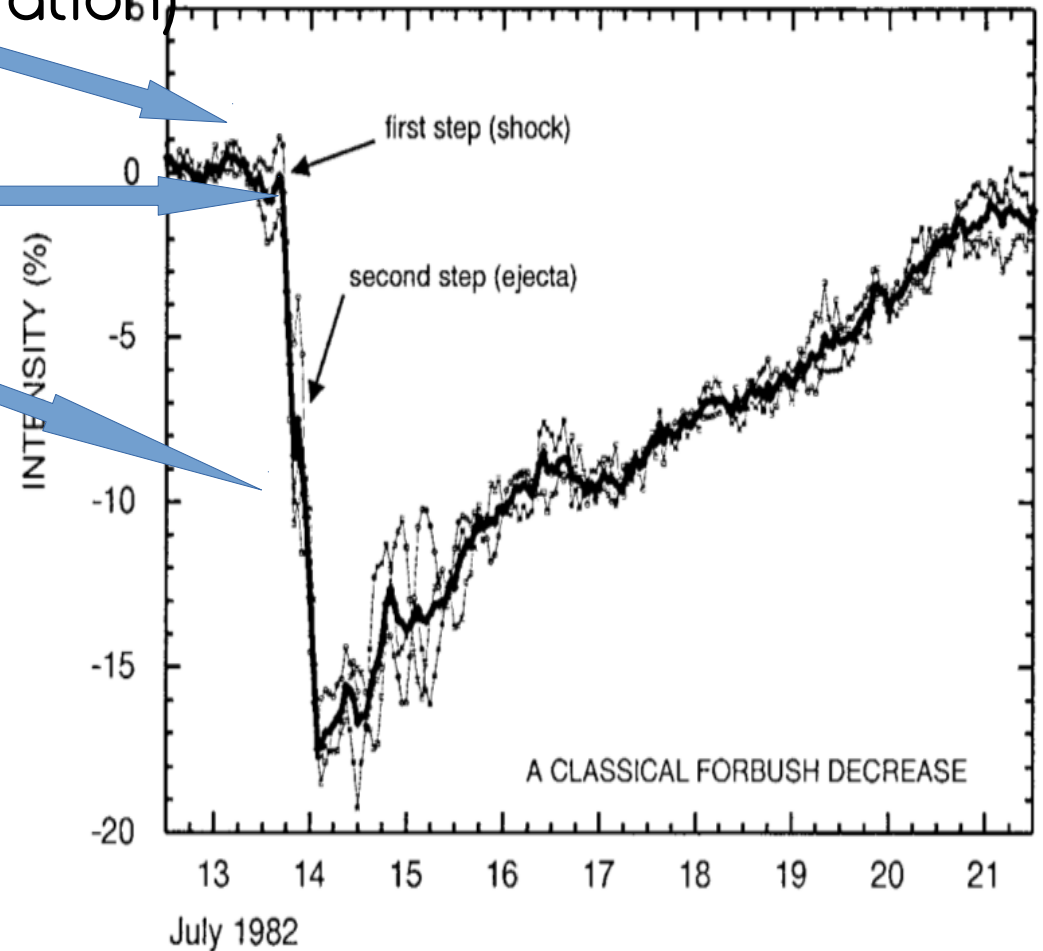
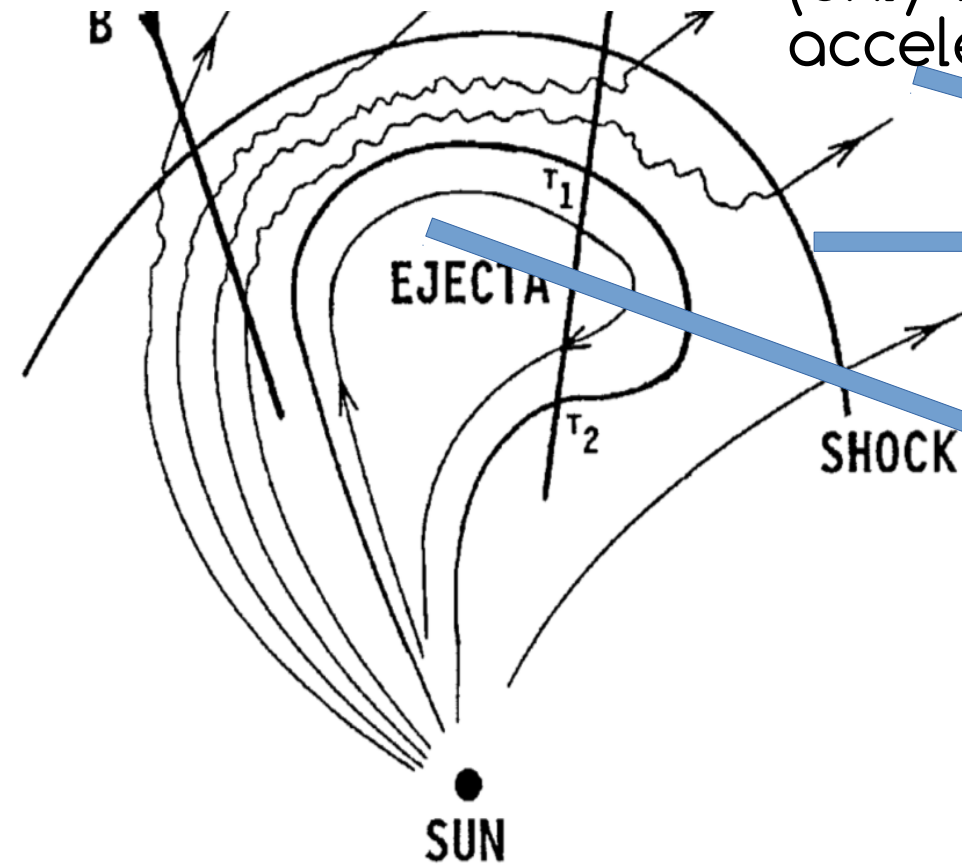


## Flares

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

# Effects on Earth: two-step mechanism

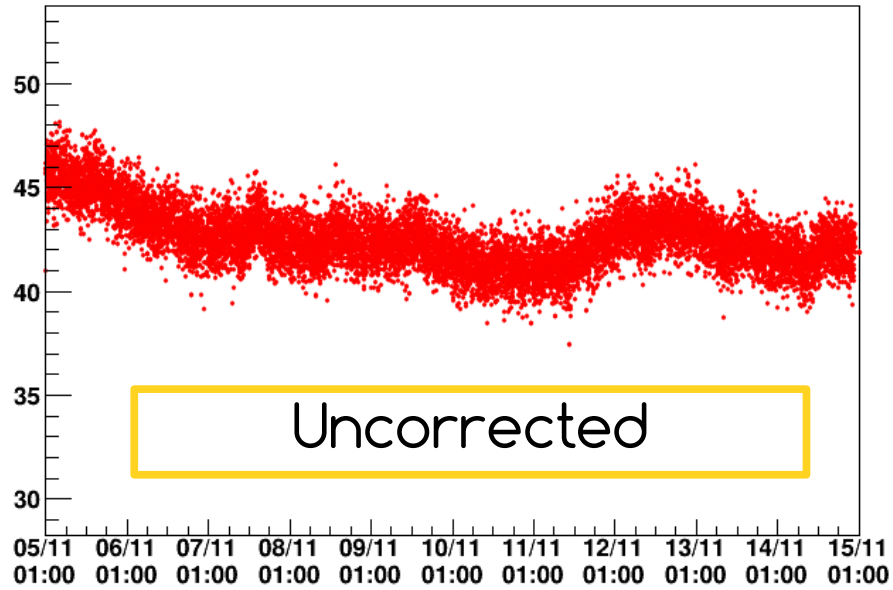
Initial particle increase may happen (only for strong CME, due to shock acceleration)



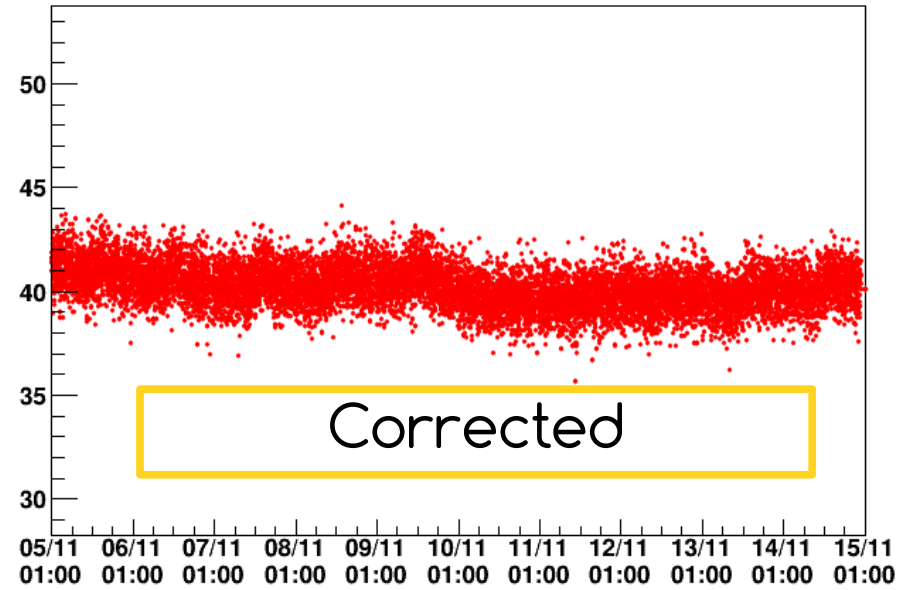
GCRDs  
occurred since the beginning of  
coordinated data taking

# Analysis chain 1/2

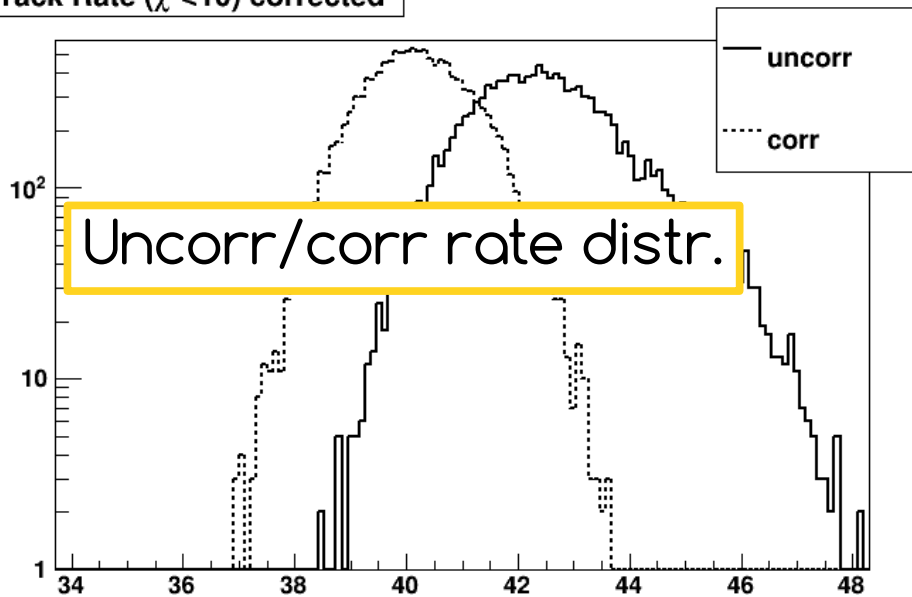
Track Rate time trending ( $\chi^2 < 10$ )



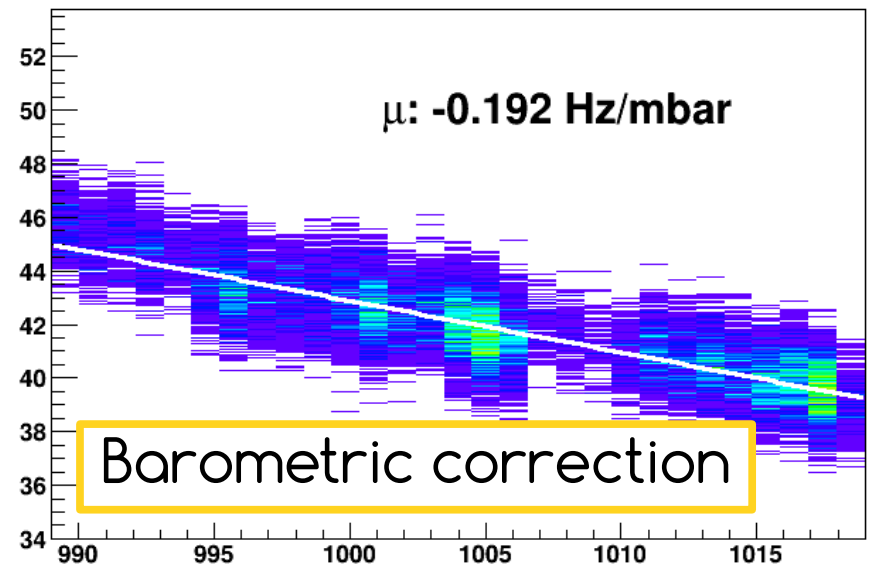
Track Rate time trending ( $\chi^2 < 10$ ) corrected



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

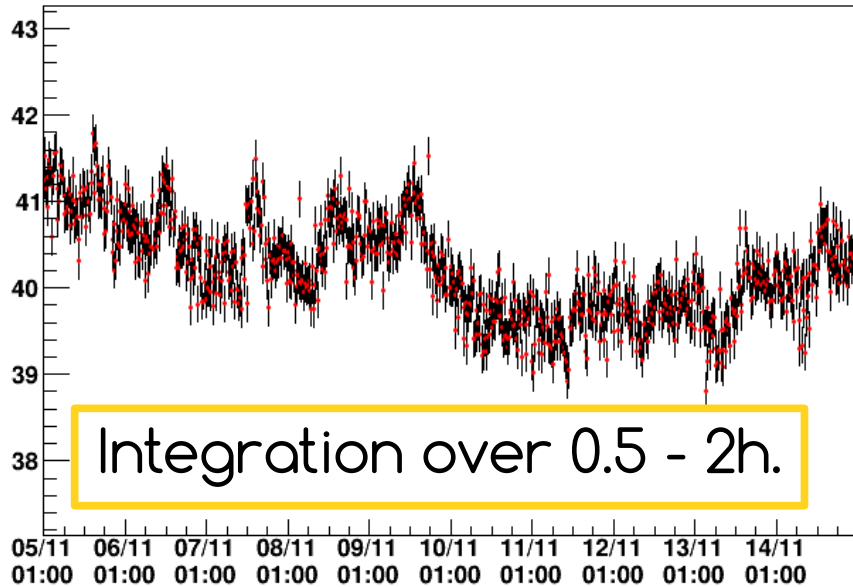


Pressure (mbar) vs Rate (Hz) correlation

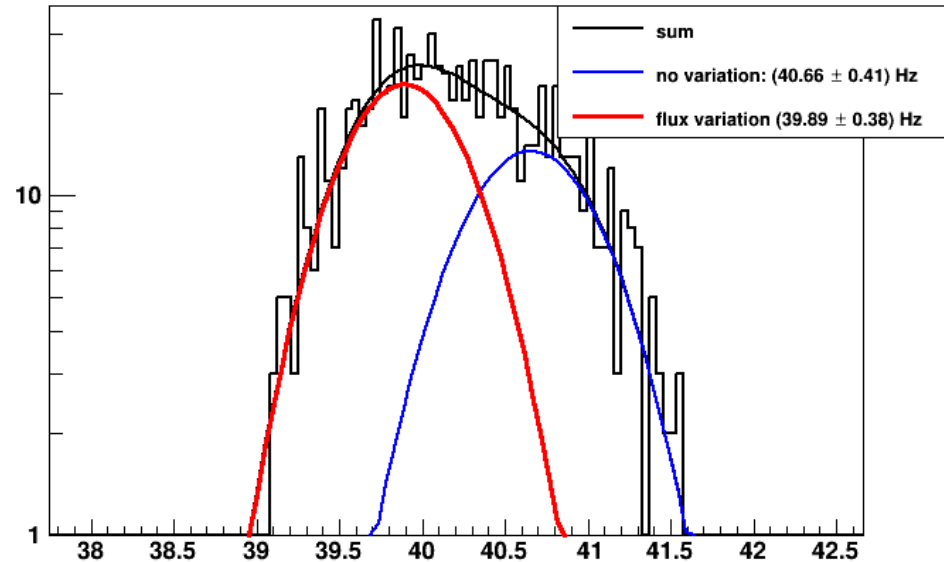


# Analysis chain 2/2

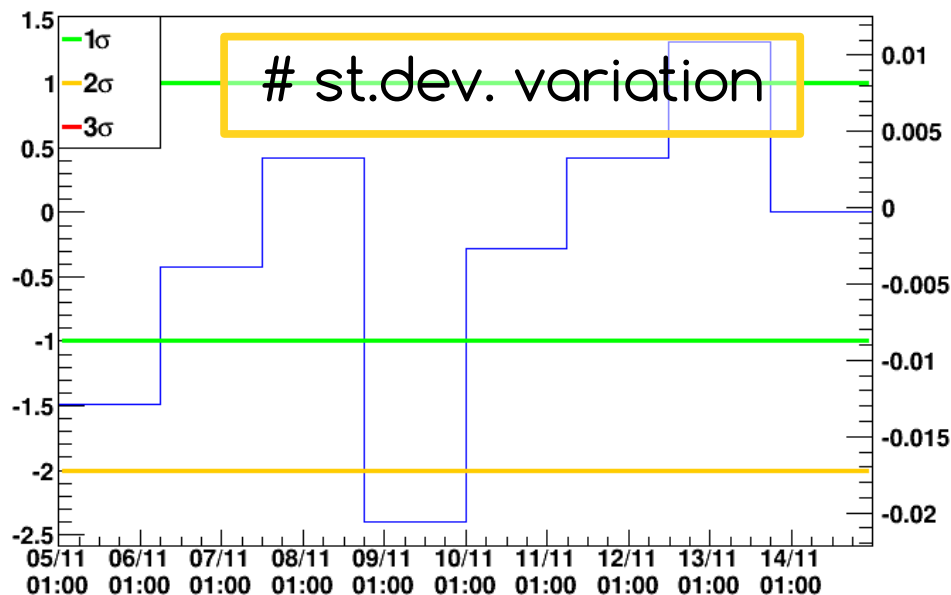
Track Rate time trending ( $\chi^2 < 10$ ) corrected



Track Rate ( $\chi^2 < 10$ ) corrected and integrated



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



## Search parameters

Required stat. sign.: 0.5 %

Averaging on 0.26 h

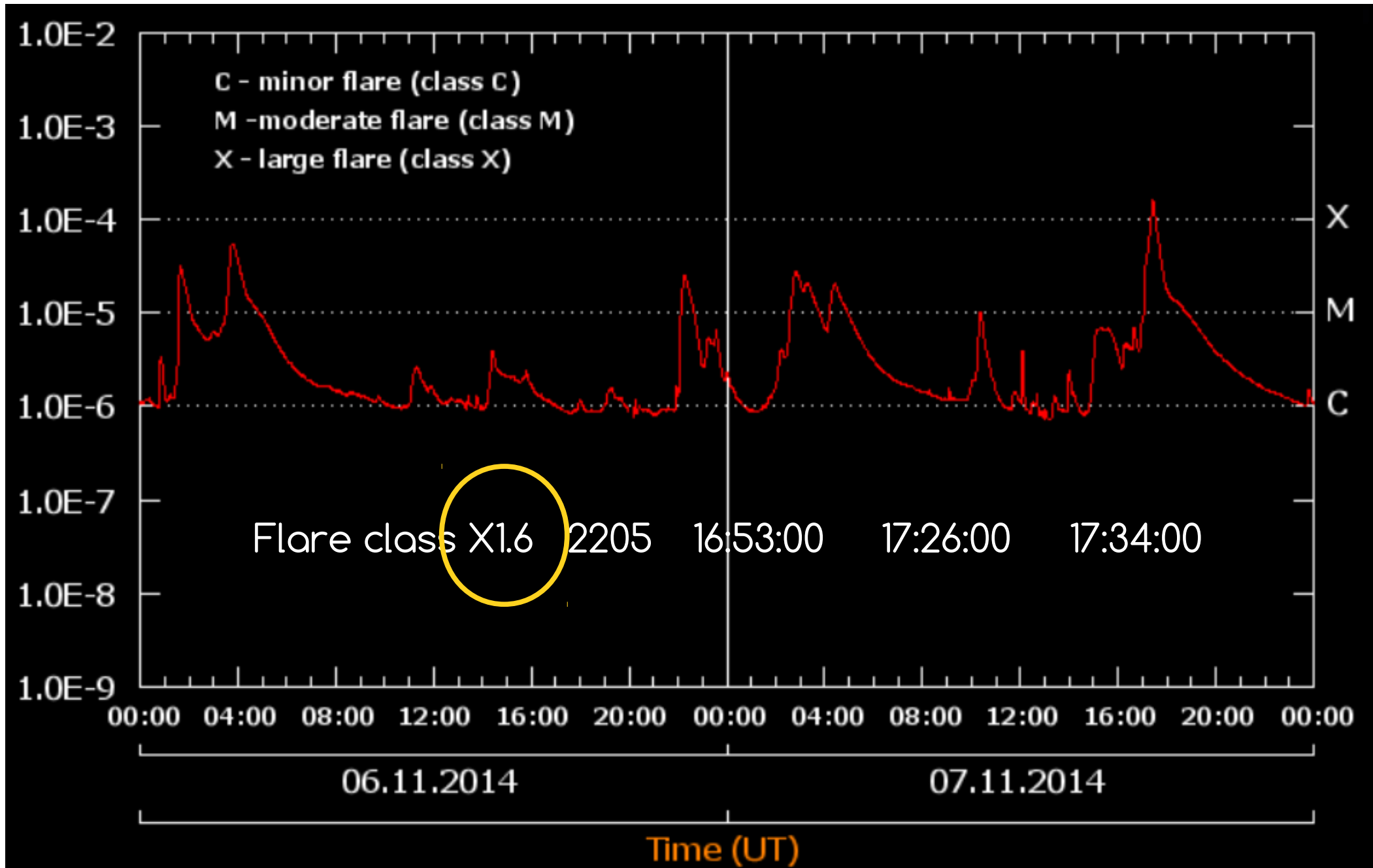
Fit time windows: 24.0 h

Search time step: 24.0 h

Max/Min n- $\sigma$  fluct. 1.3 / -2.4  $\sigma$

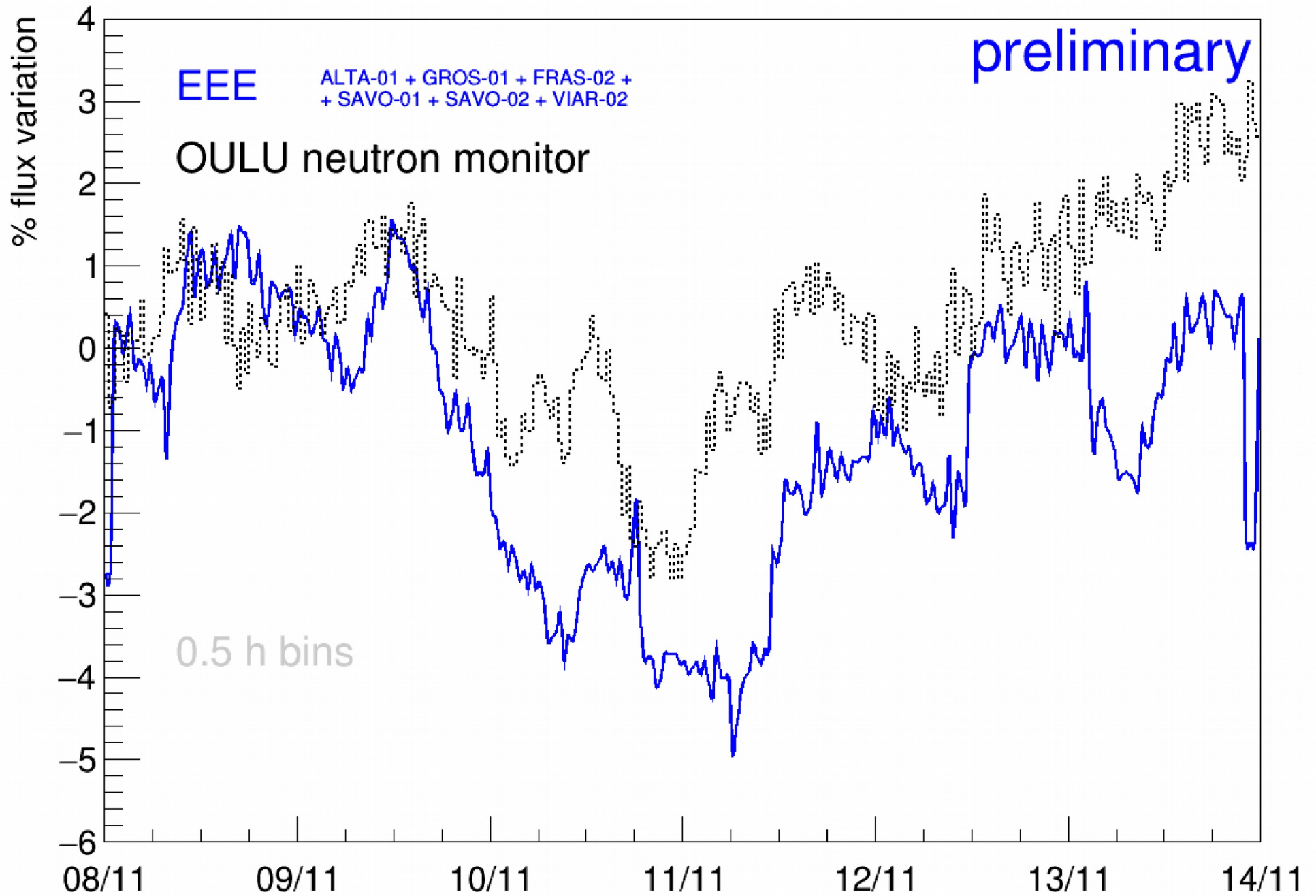
Max/Min % fluct. 1.1 / -2.0 %

# GCRD 2014-11-10



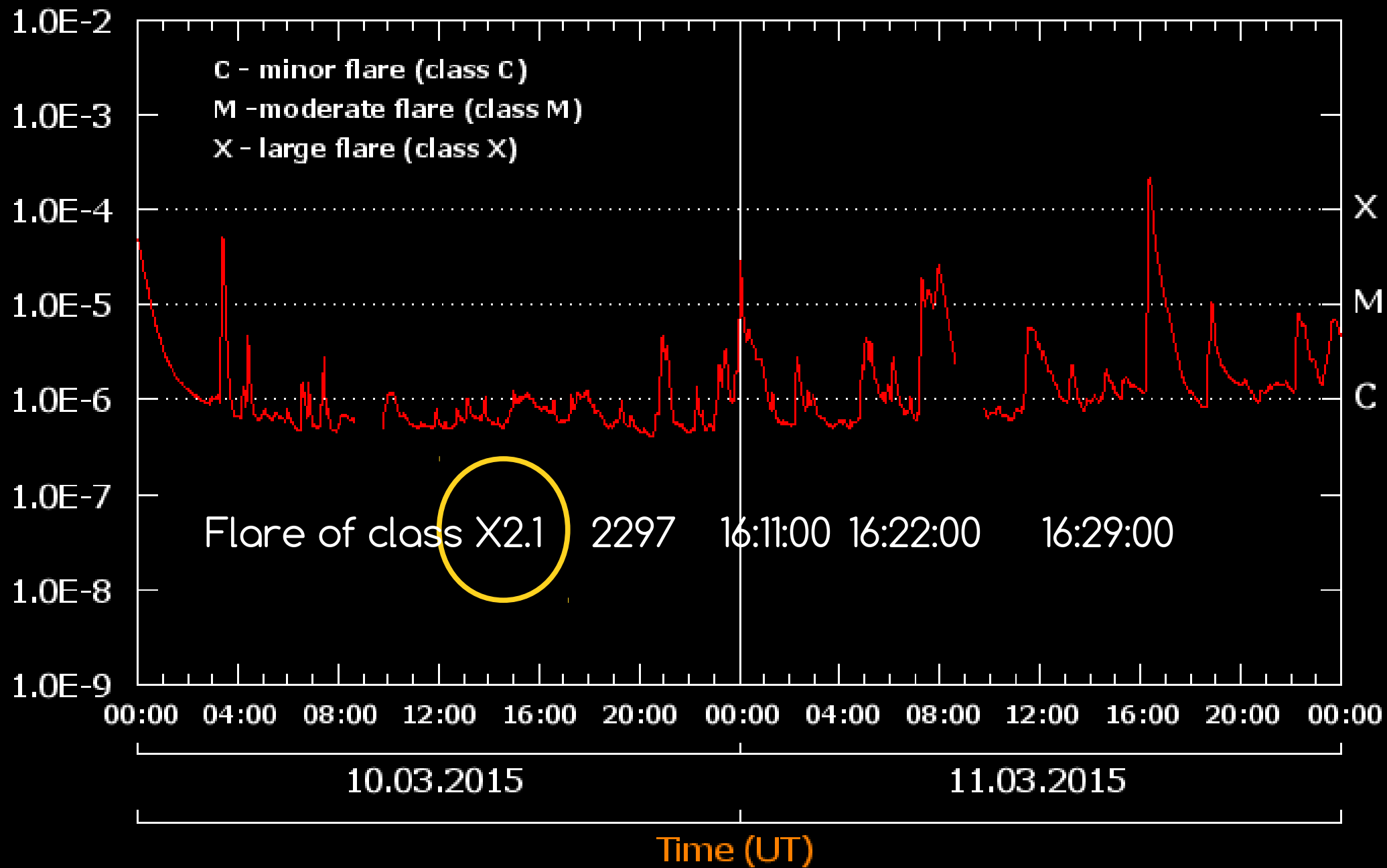


# GCRD 2014-11-10: 6 stations average

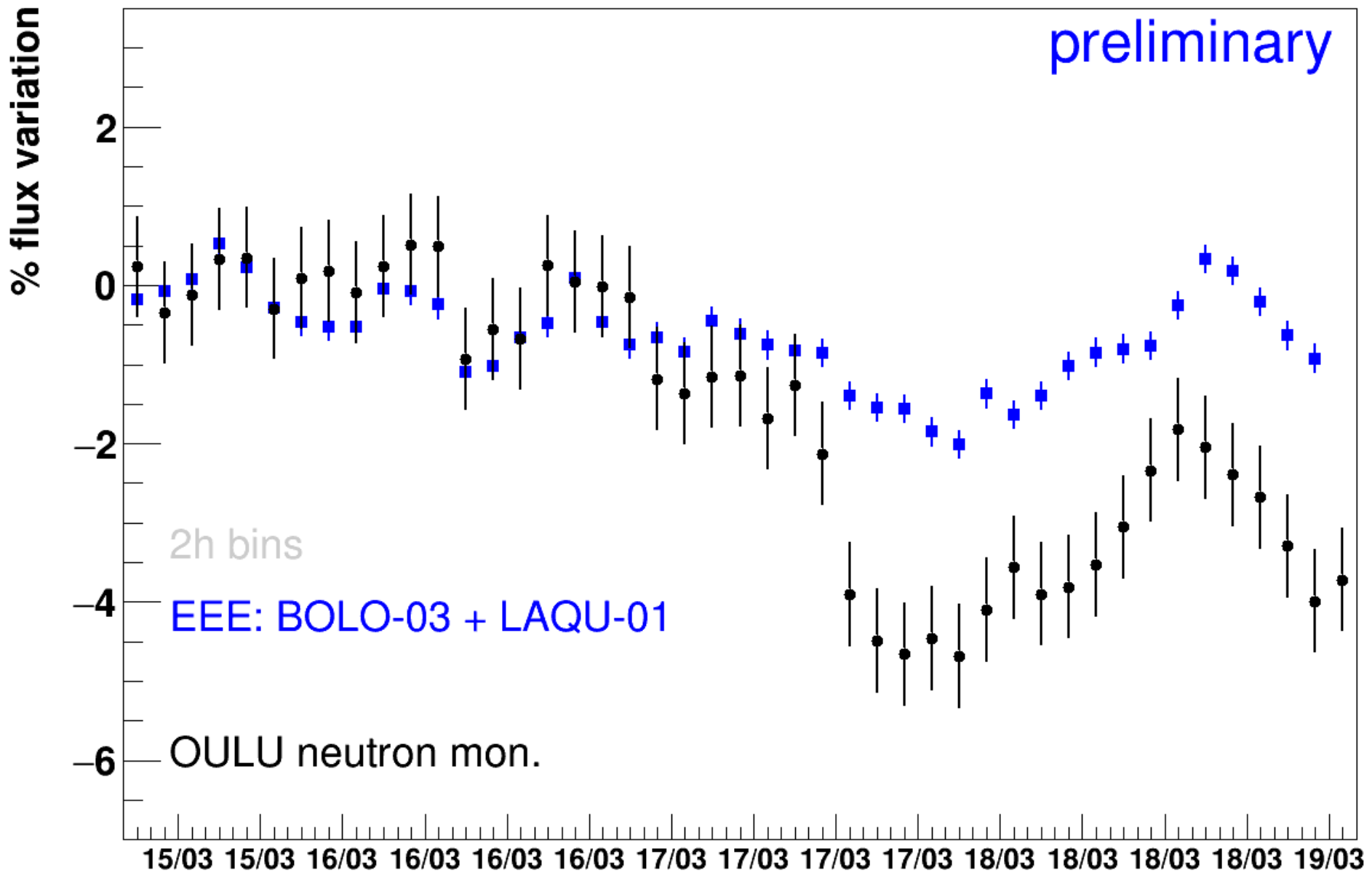




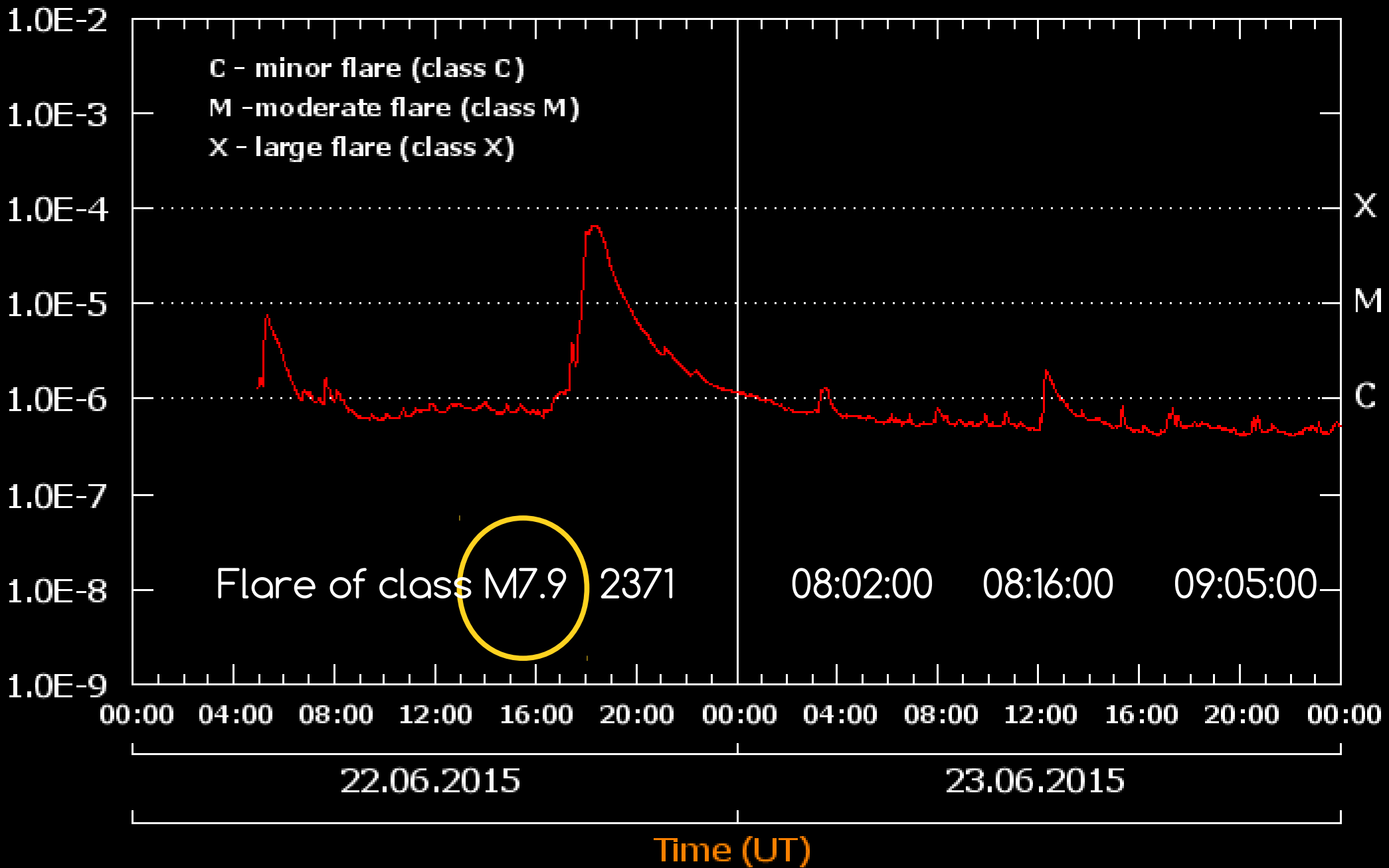
# GCRD 2015-03-16



# GCRD 2015-03-16: EEE-OULU fluxs

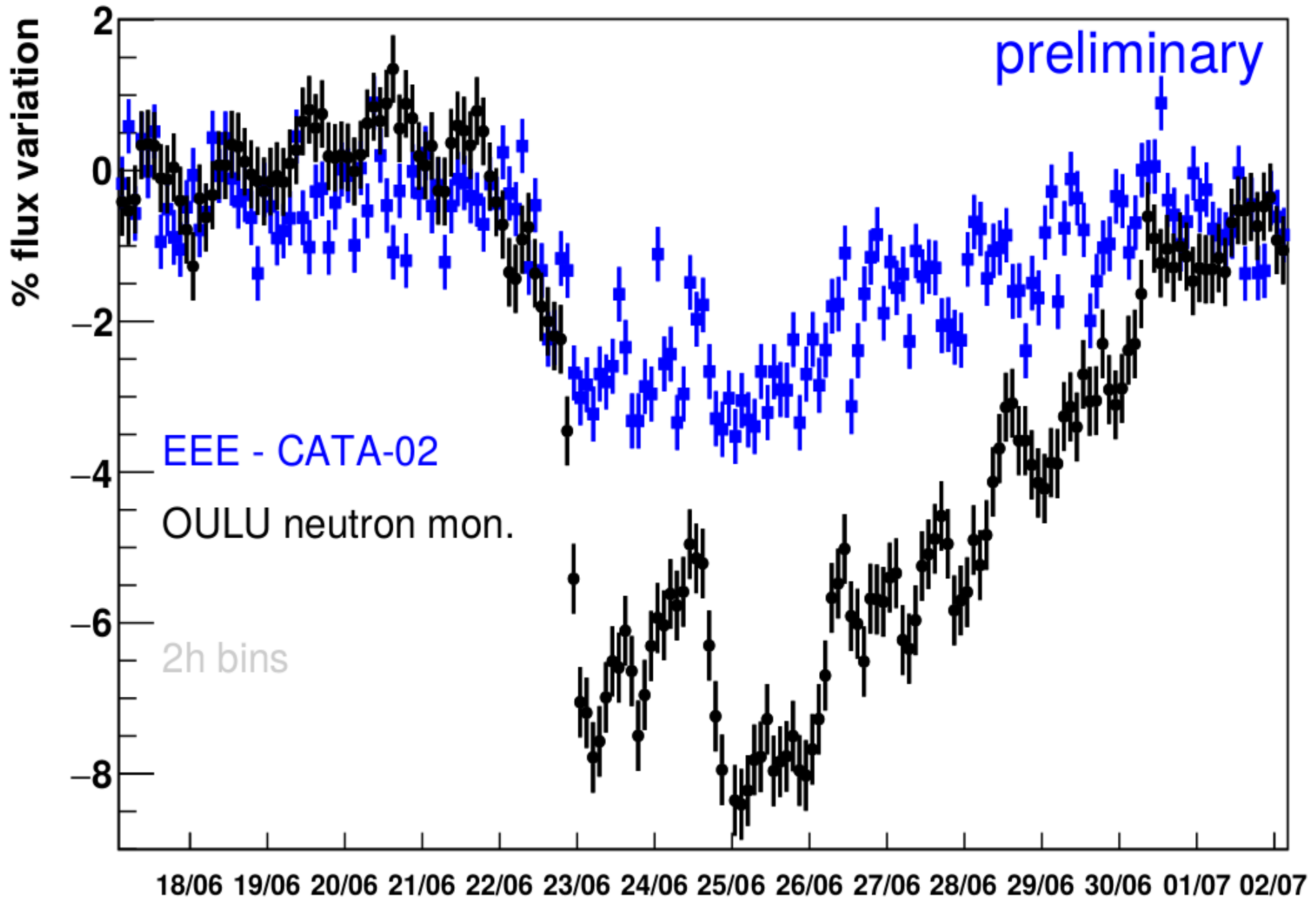


# GCRD 2015-06-23

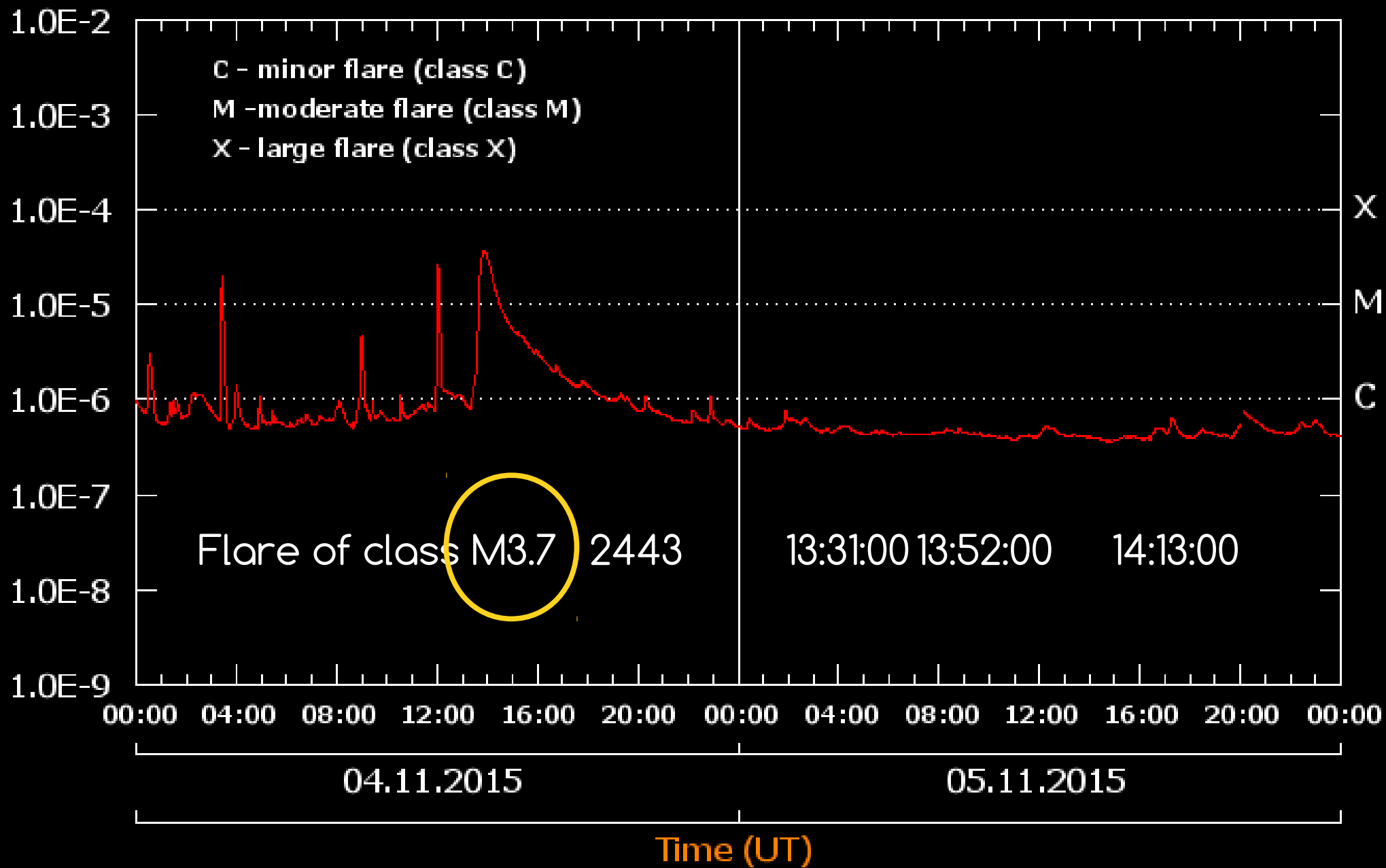


4-8 h time difference between flare and GCRD !

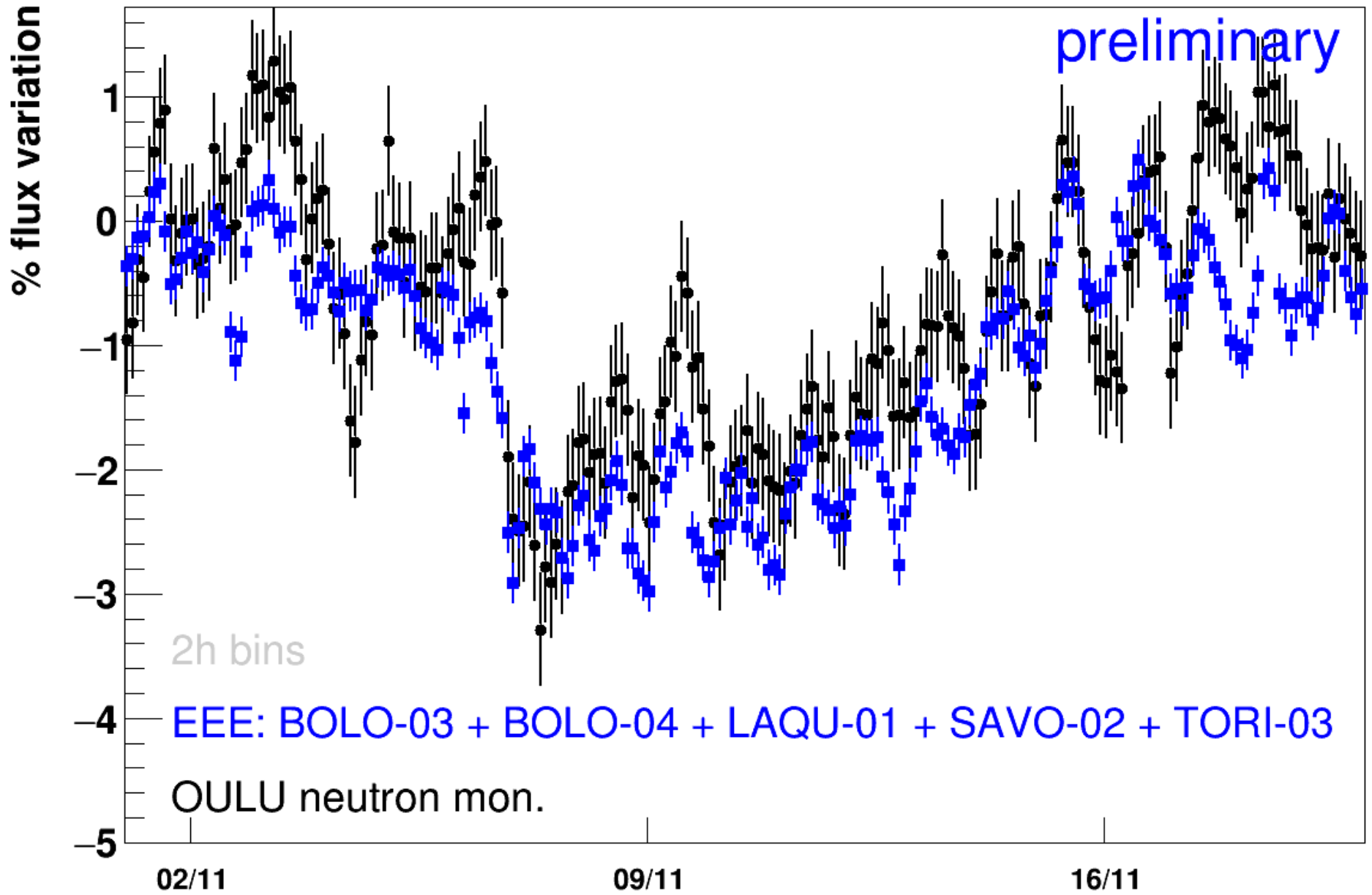
GCRD 2015-06-23: CATA-02 station



# GCRD 2015-11-07

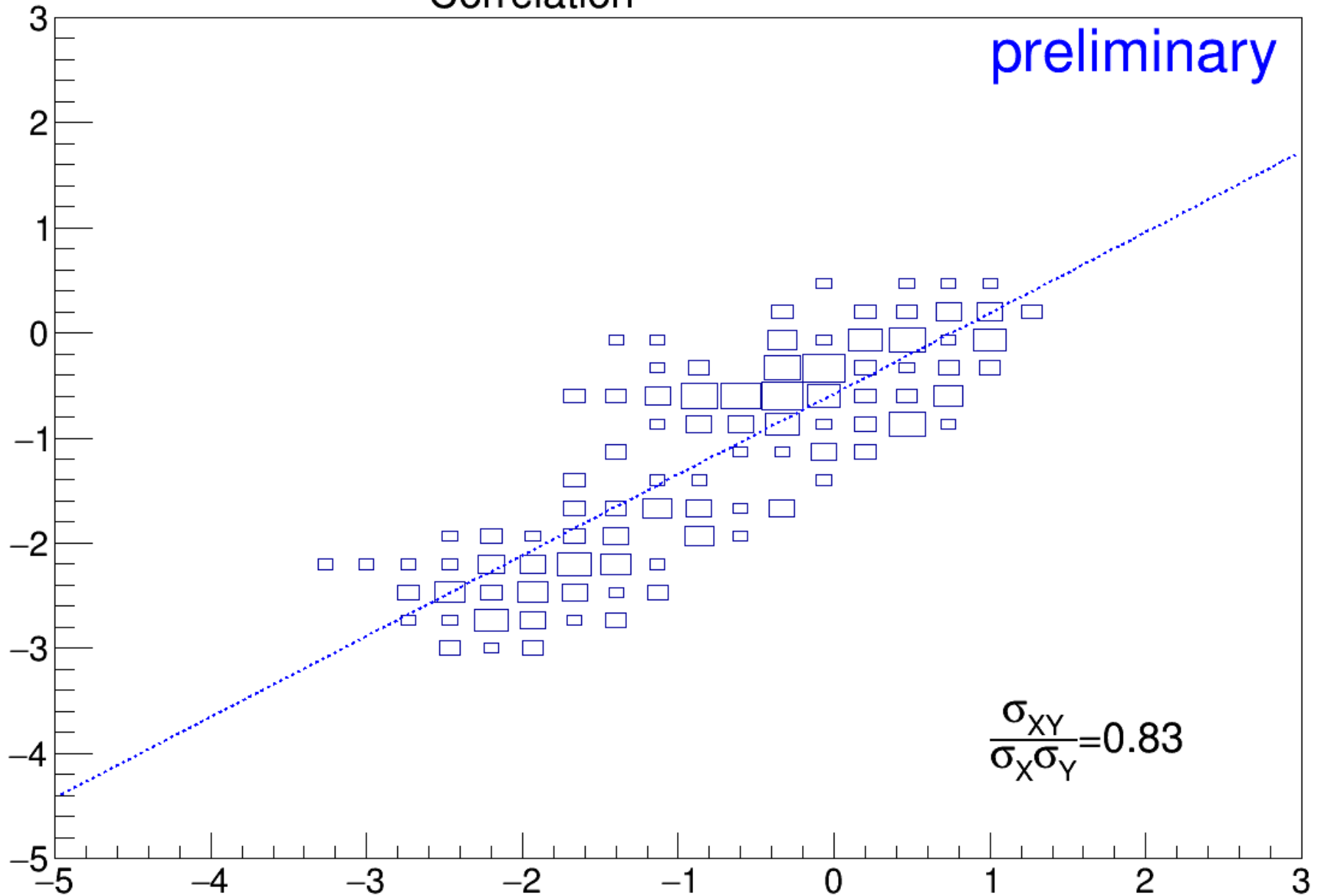


GCRD 2015-11-07



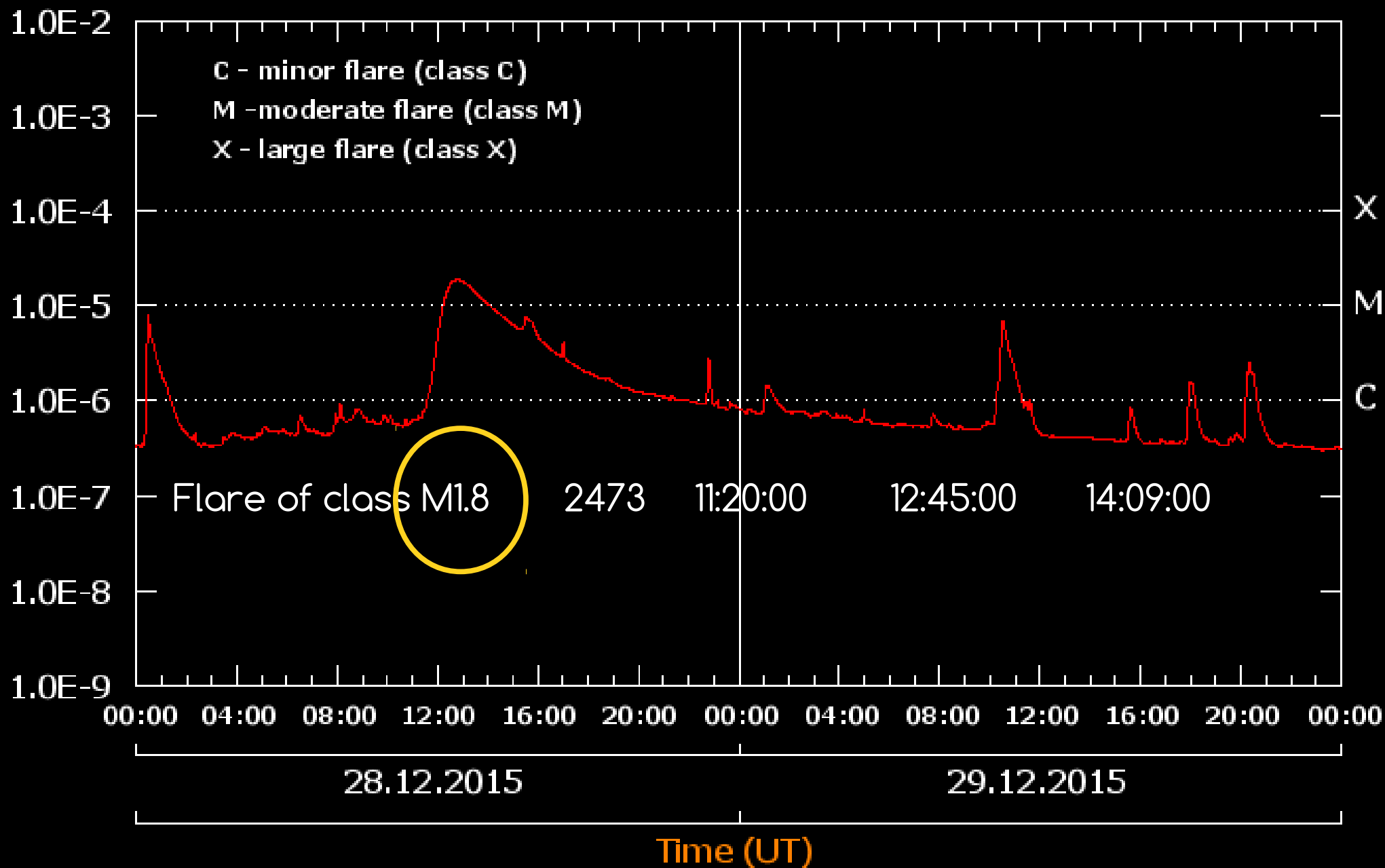
GCRD 2015-11-07: EEE-OULU  
Correlation

preliminary

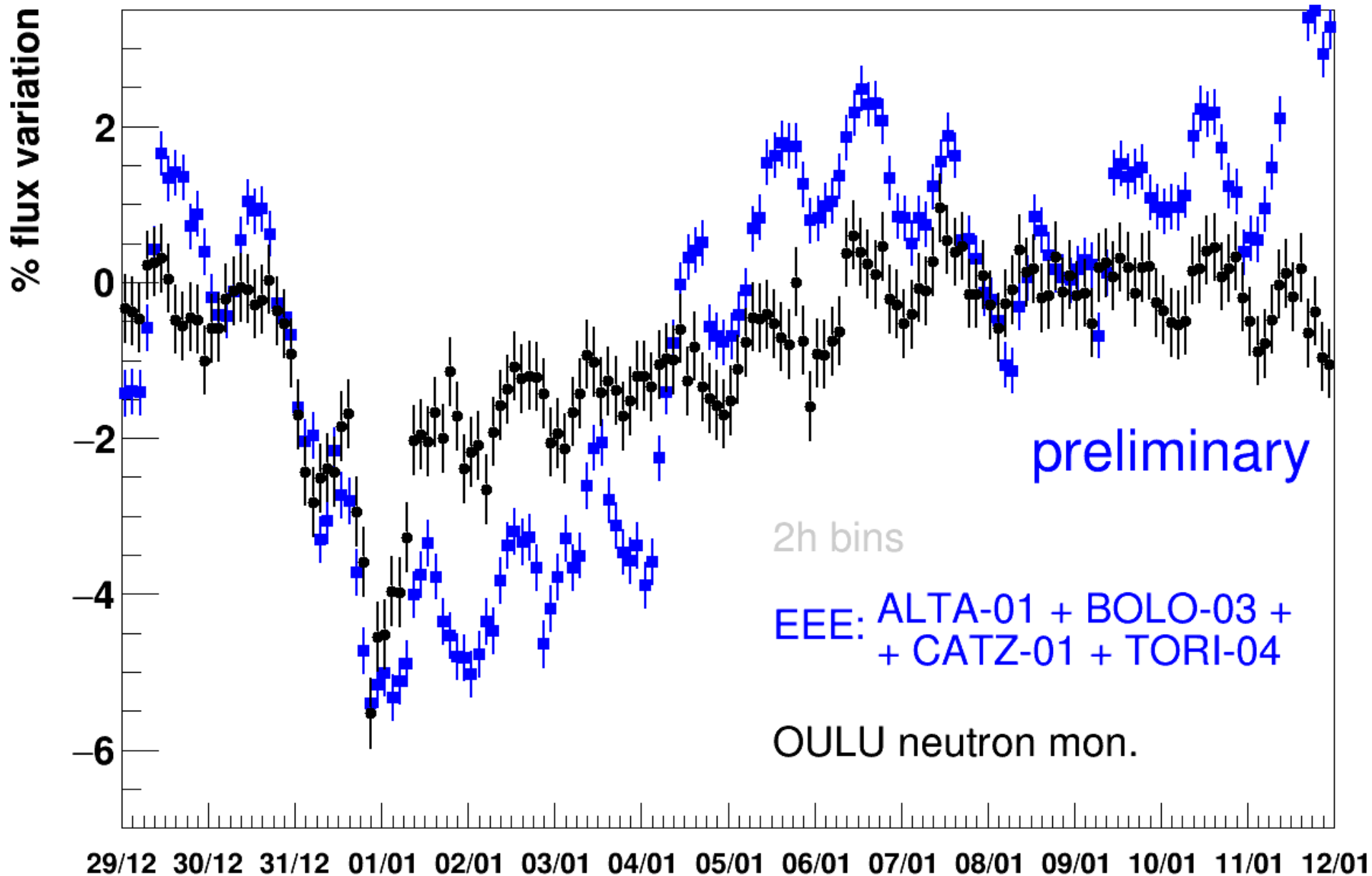


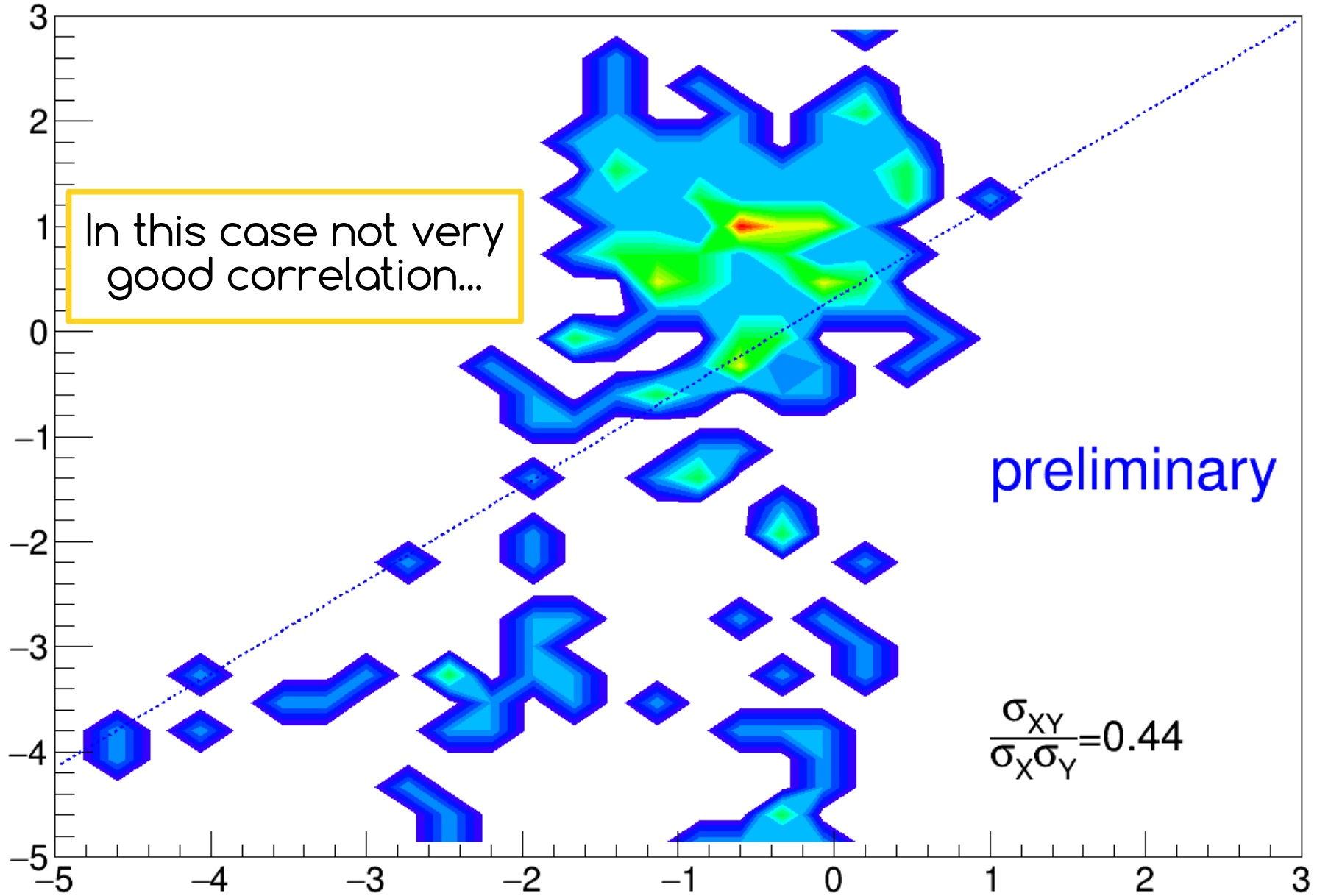


# GCRD 2015-12-31

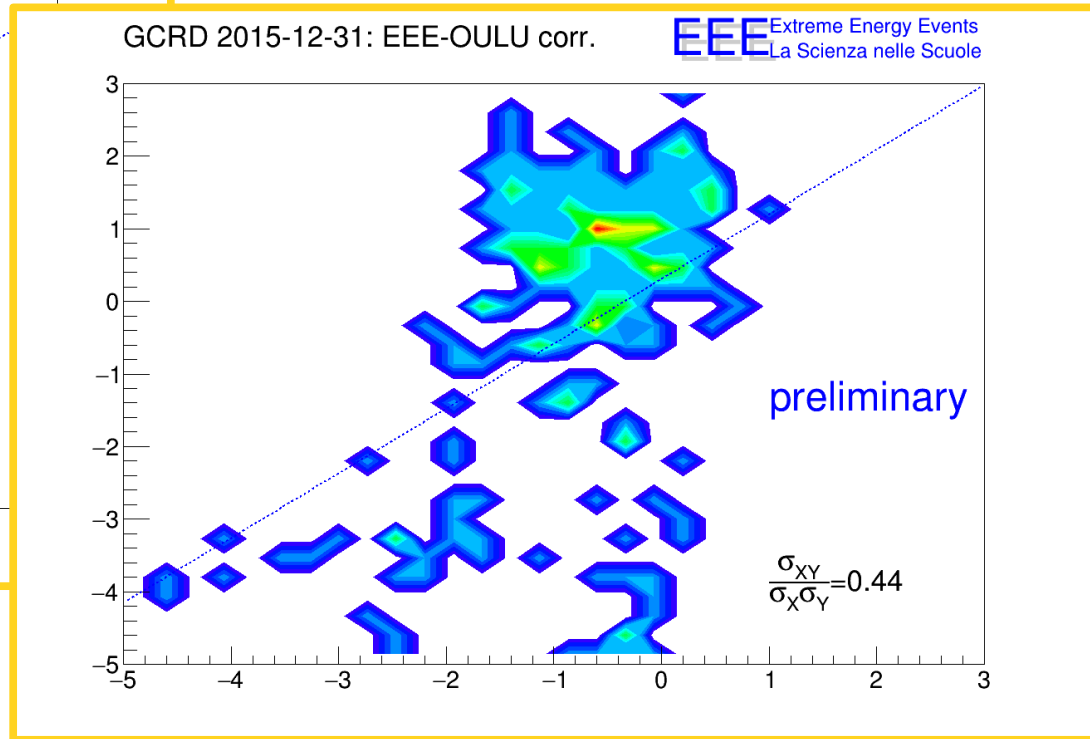
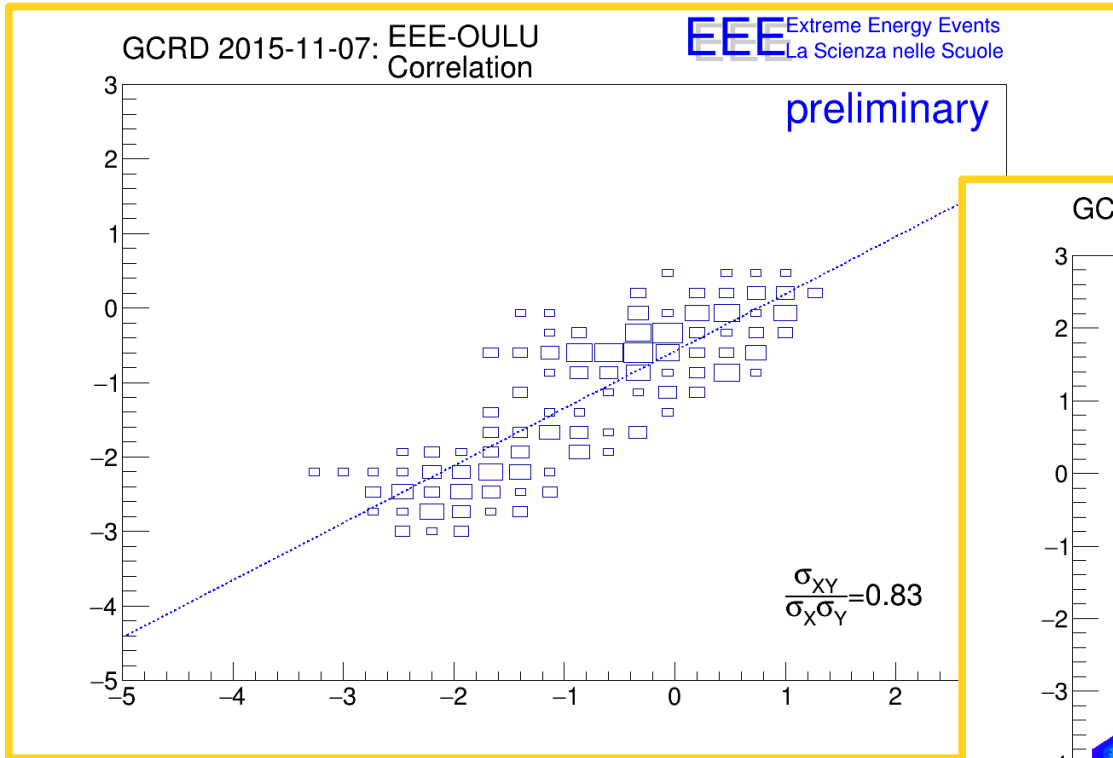


# GCRD 2015-12-31: EEE-OULU fluxs



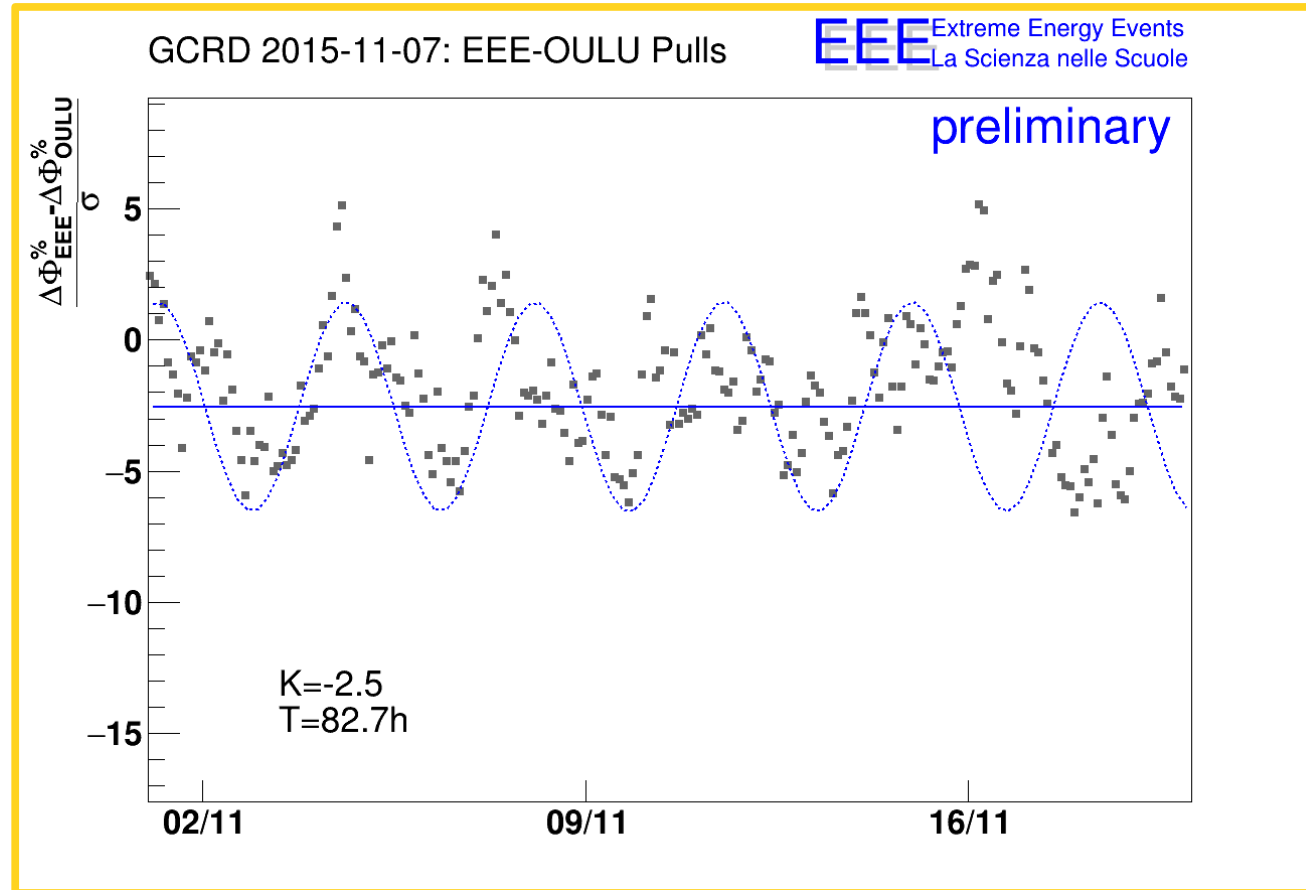


Thus there are unclear features:



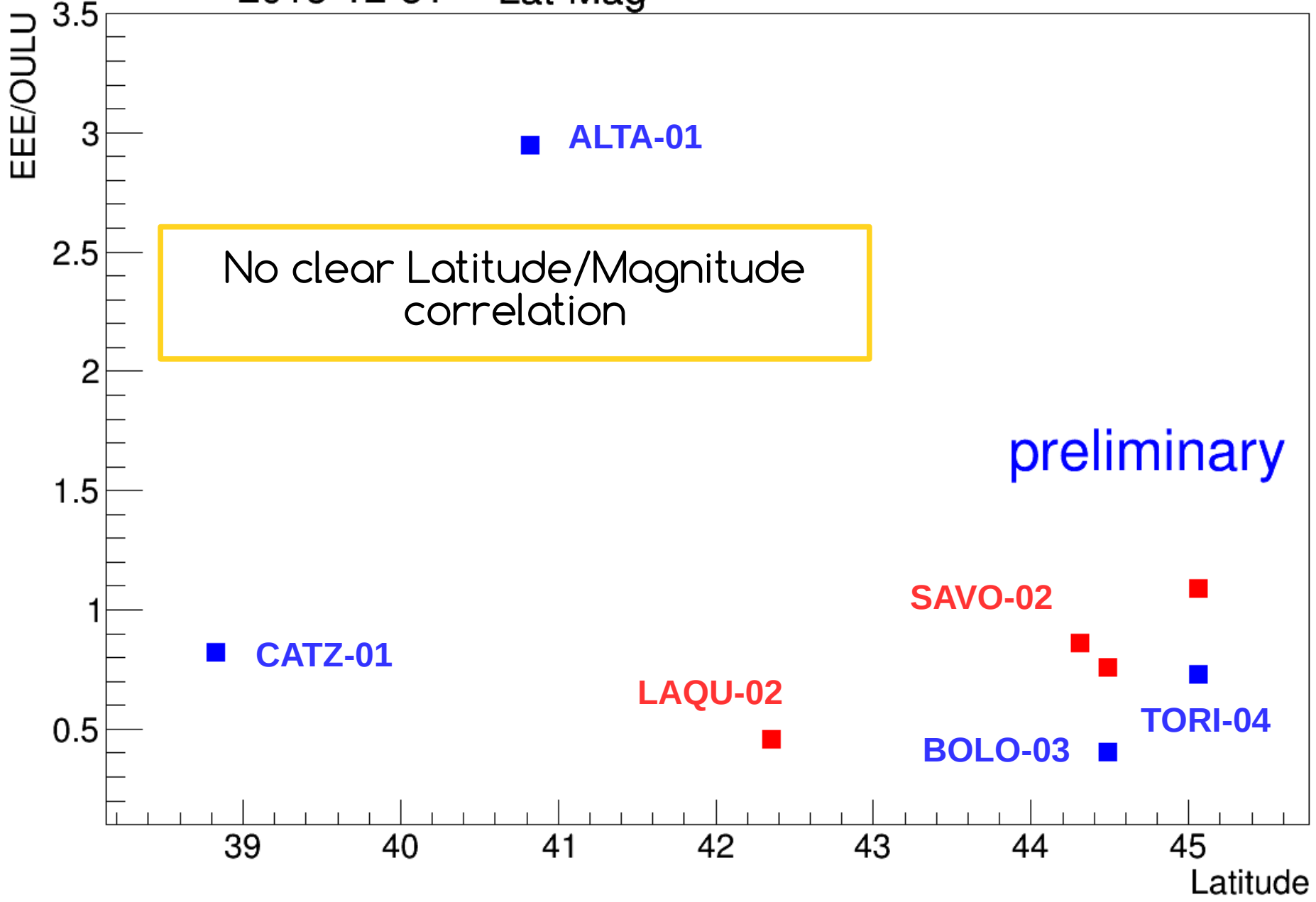
Low NM-EEE correlation is some case

There are unclear features:



NM-EEE time displacement  
well beyond longitude effects (83 hours)

GCRD 2015-11-07 →  
2015-12-31 → EEE-OULU  
Lat-Mag



# Several parameters involved in instabilities: 1/2

1. Barometric correction stability
2.  $H_{\text{Veff}}$  temperature dependance

These two parameters have to be corrected for reaching better confidence on the 5 GCRD already observed



Using data on the long period  
2016-01 -----> 2017-01  
We systematically extracted  
Barometric correction  
on the whole period

Asking for:

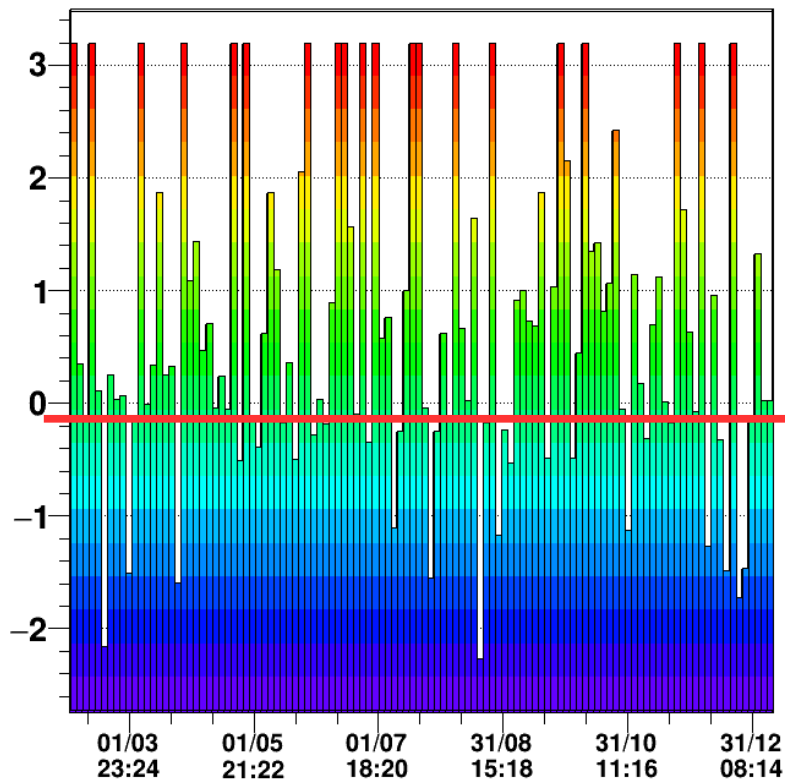
>1000 Pressure-Rate measurements per  
extraction

> 10 mbar pressure variation

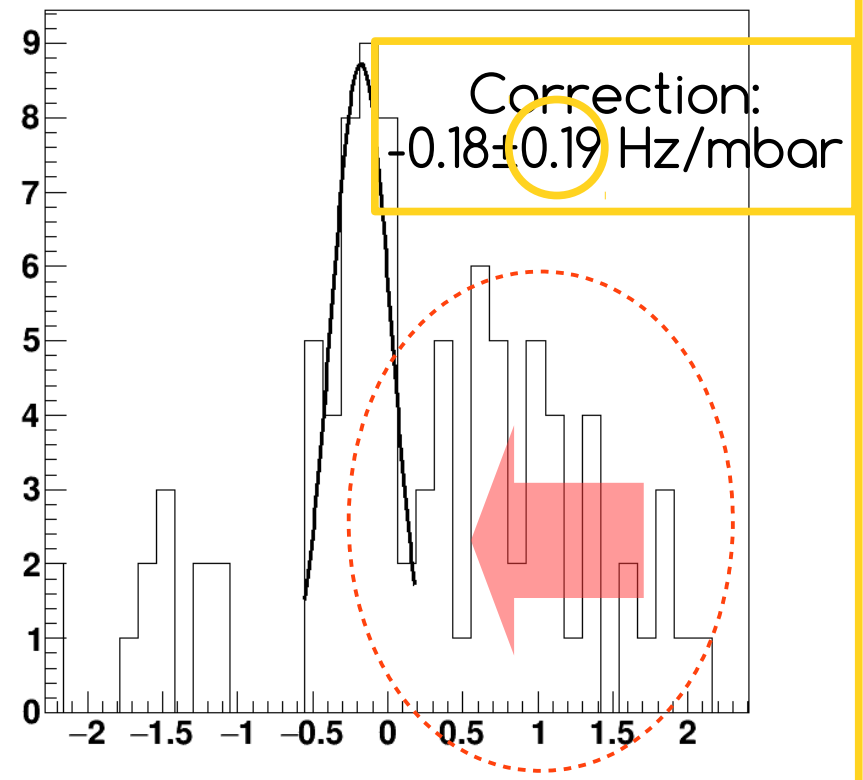
5 Hz < track rate < 70 Hz

# On stations involved in 2016-01-01 GCRD: CATZ-01

Barometric correction trending



Barometric correction



Measurement clearly uncorrelated  
(Temperature dependence or HV instability?)

# Manually searched for all telescopes in 2016:

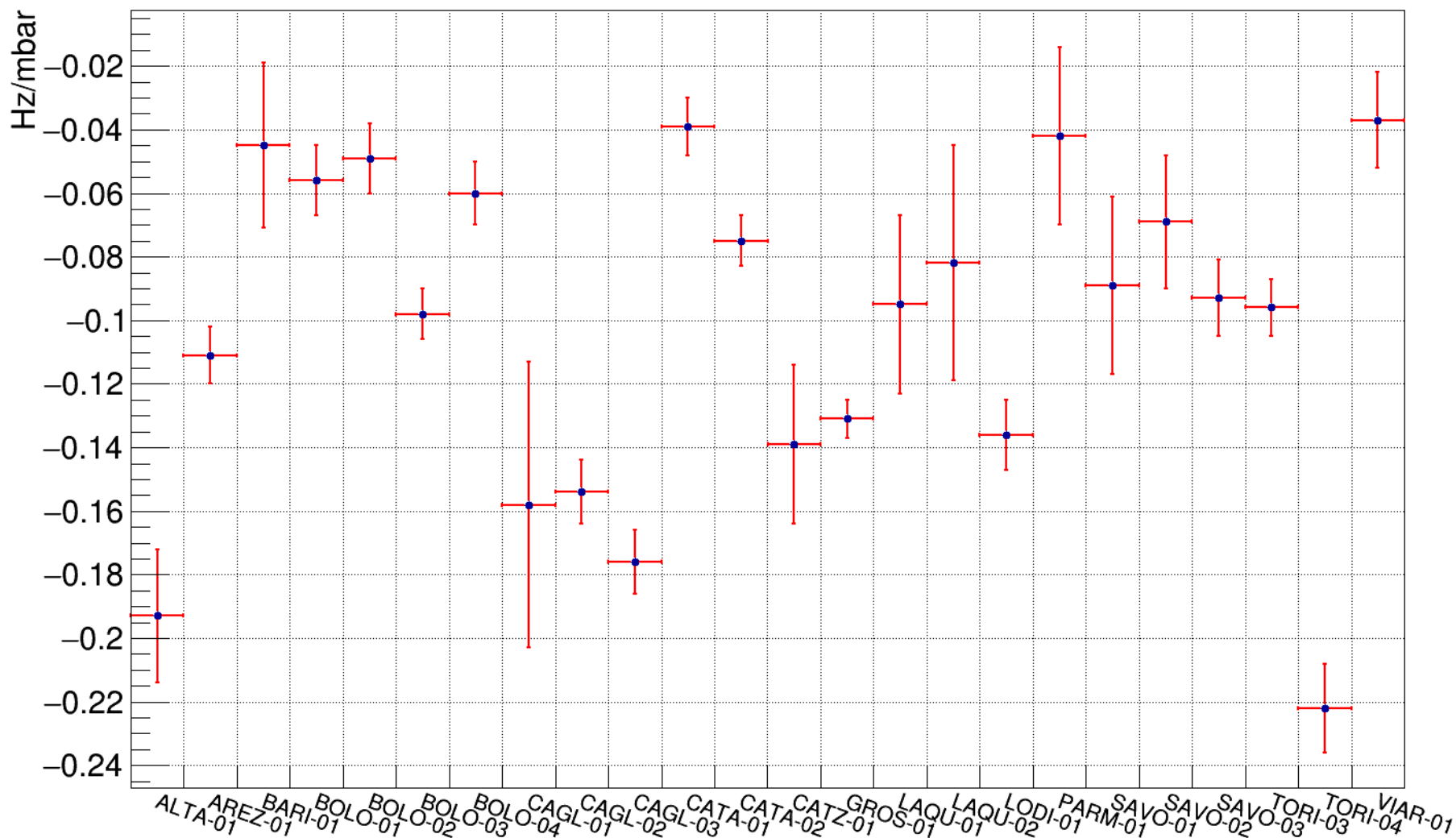
Day by day search for several instability sources

- DAQ instabilities
  - noisy strips
- prompt noise variations (strips in and out)
  - power shutdown (only GPS trigger)
  - HV modifications

Etc.

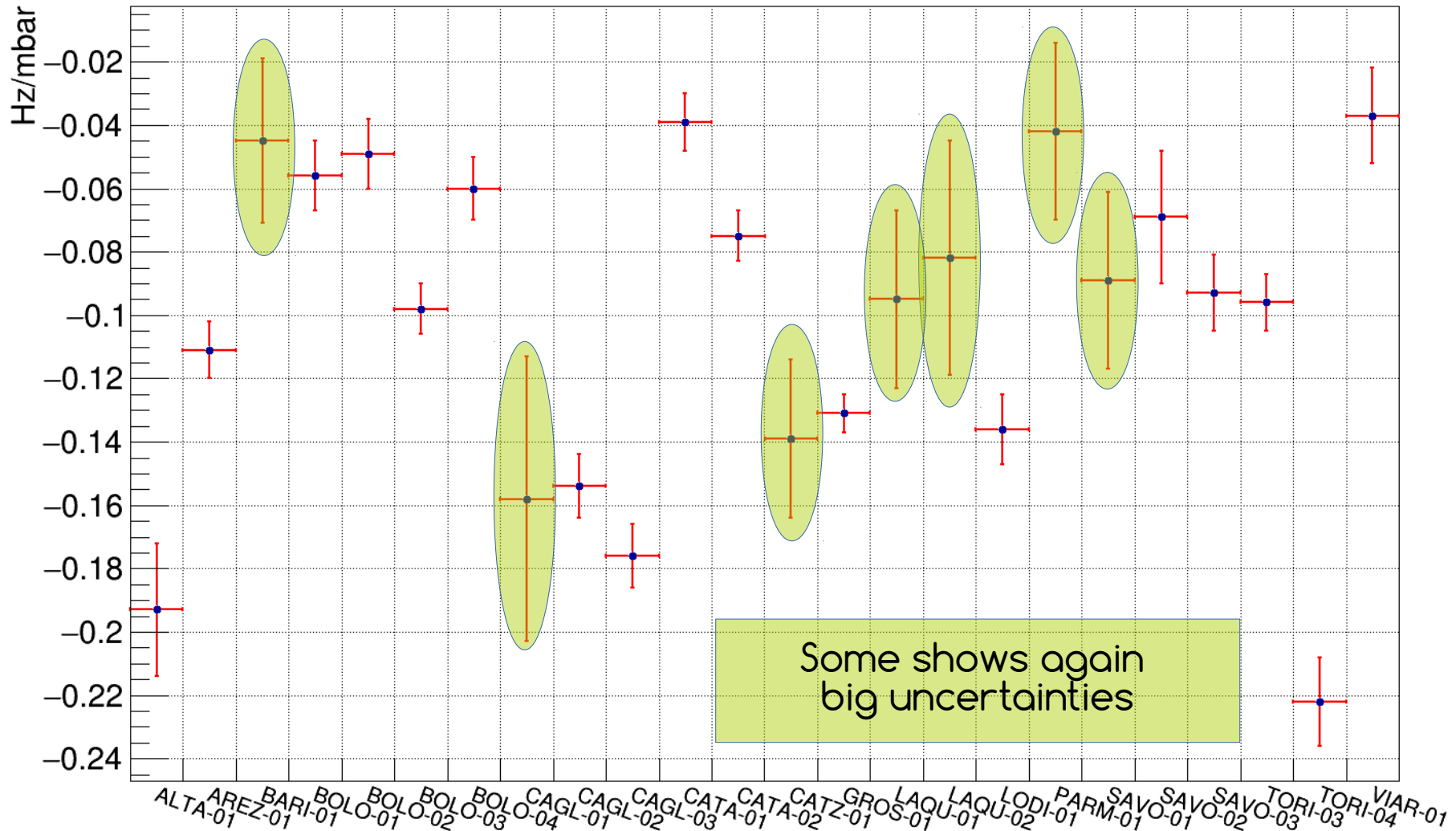
For ~ 50% of telescopes  
a “stable” barometric correction  
has been found

### Barometric Corrections

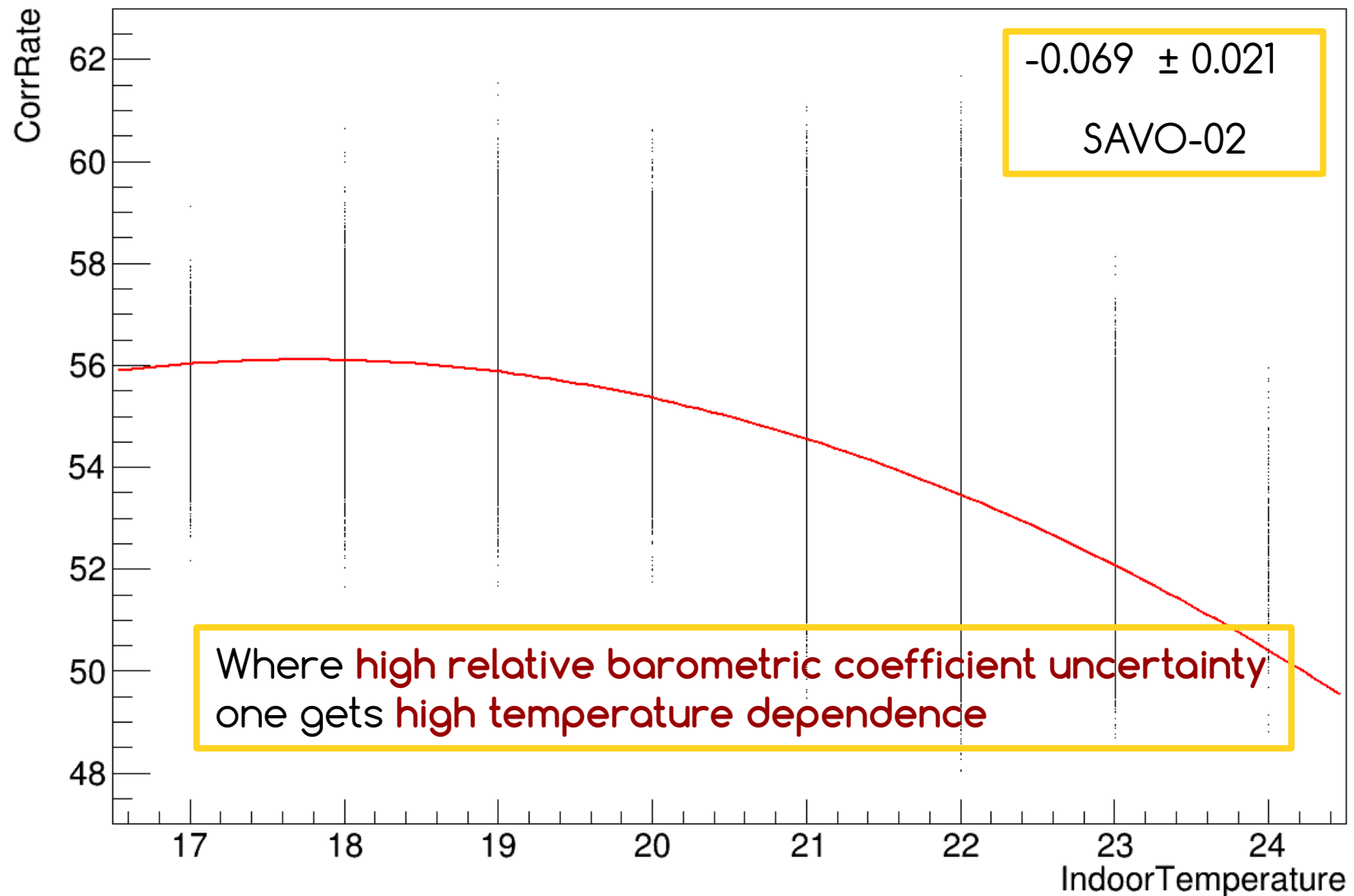


For ~ 50% of telescopes  
a stable barometric correction  
has been found

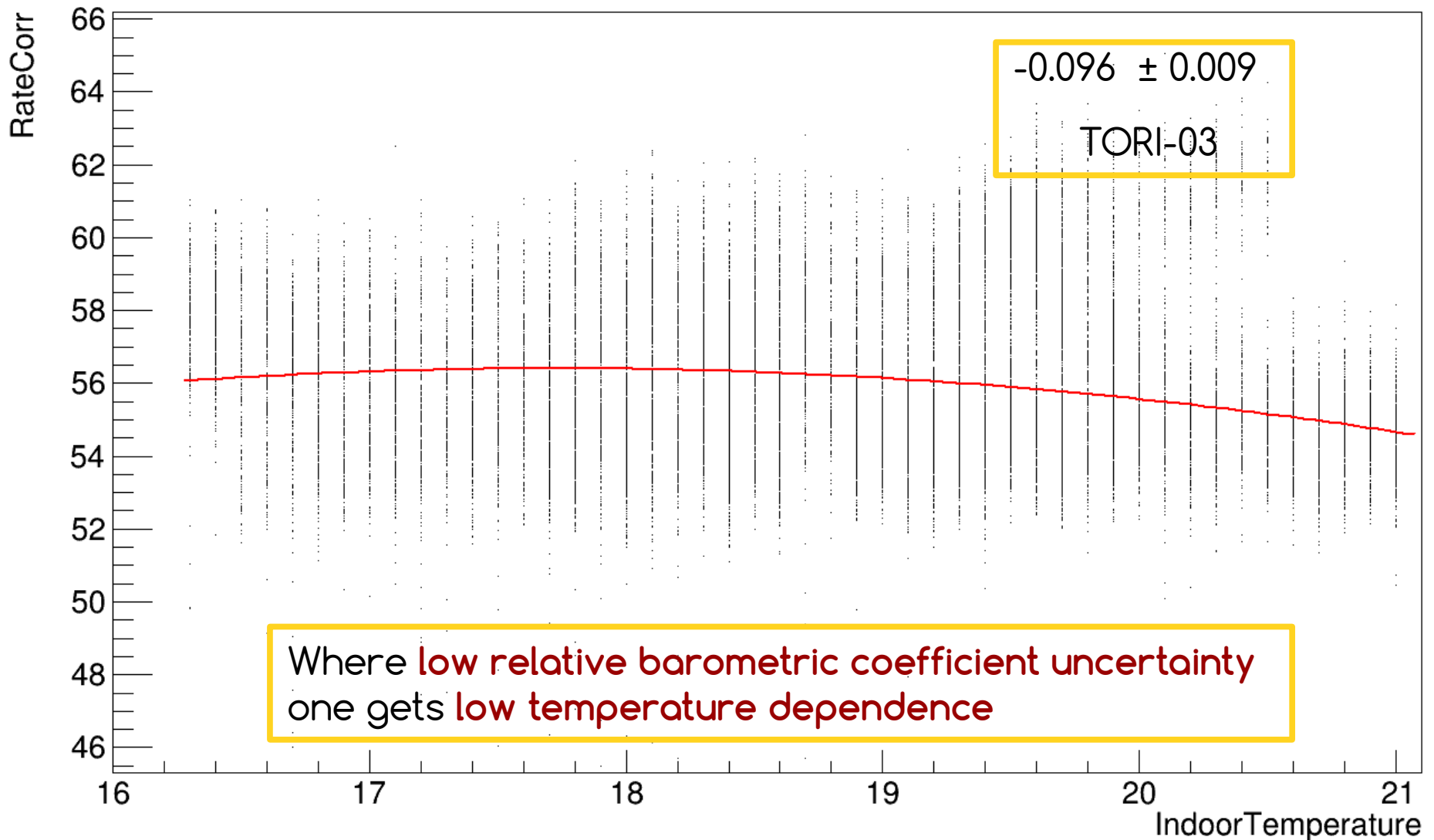
### Barometric Corrections



Big uncertainties in barometric corrections  
related also to absence  
of temperature correction: this is the **temperature  
dependence after barometric corrections**



# Big uncertainties in barometric corrections related also to absence of temperature correction





## Next step

Performing

temperature/pressure  
simultaneous corrections extraction

Using starting values already extracted

Reprocess data with new corrections

Other parameters involved in instabilities:

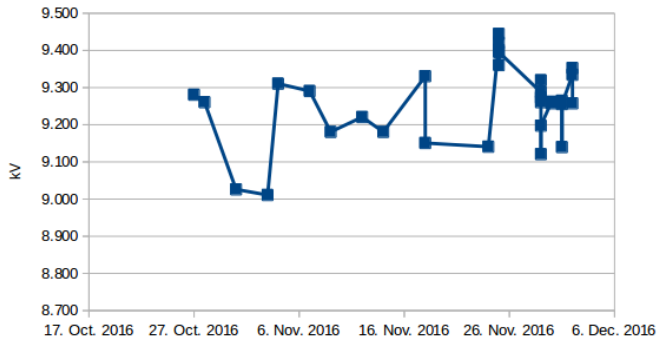
HV fluctuations:

Marco S. is working on stabilizing CATZ-01  
and soon TORI-01

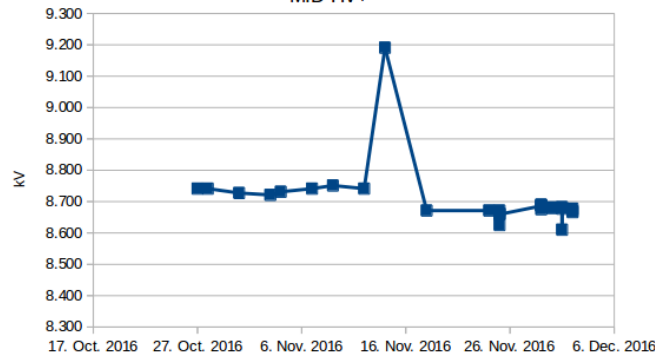
This item is not related to the  
5 GCRD we want to publish  
but it's fundamental for extensive GCRD  
measurements in future

# HV fluctuations as measured by students at TORI-01 (same by Marco S. at CATZ-01)

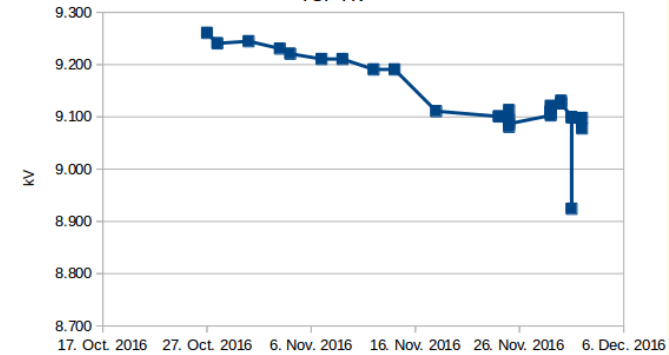
BOT HV+



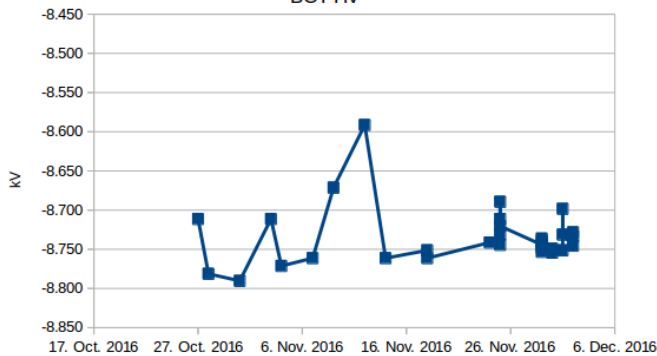
MID HV+



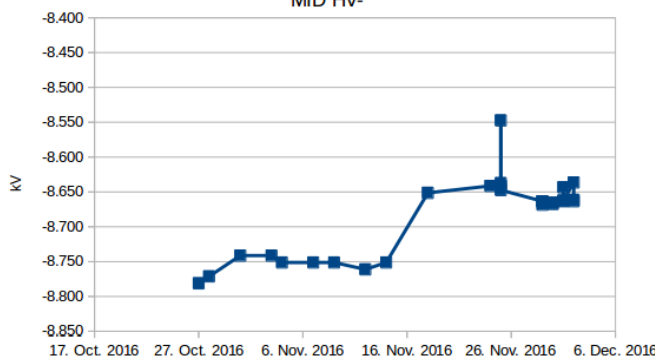
TOP HV+



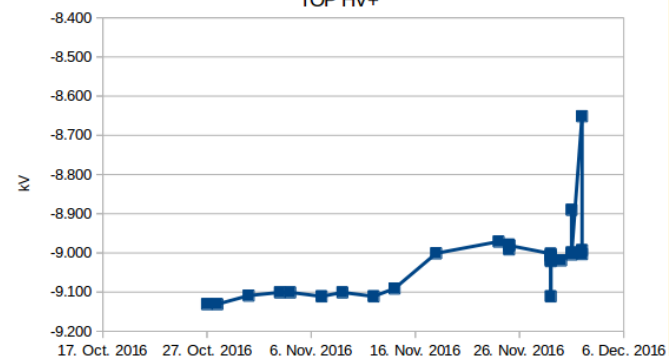
BOT HV-



MID HV-



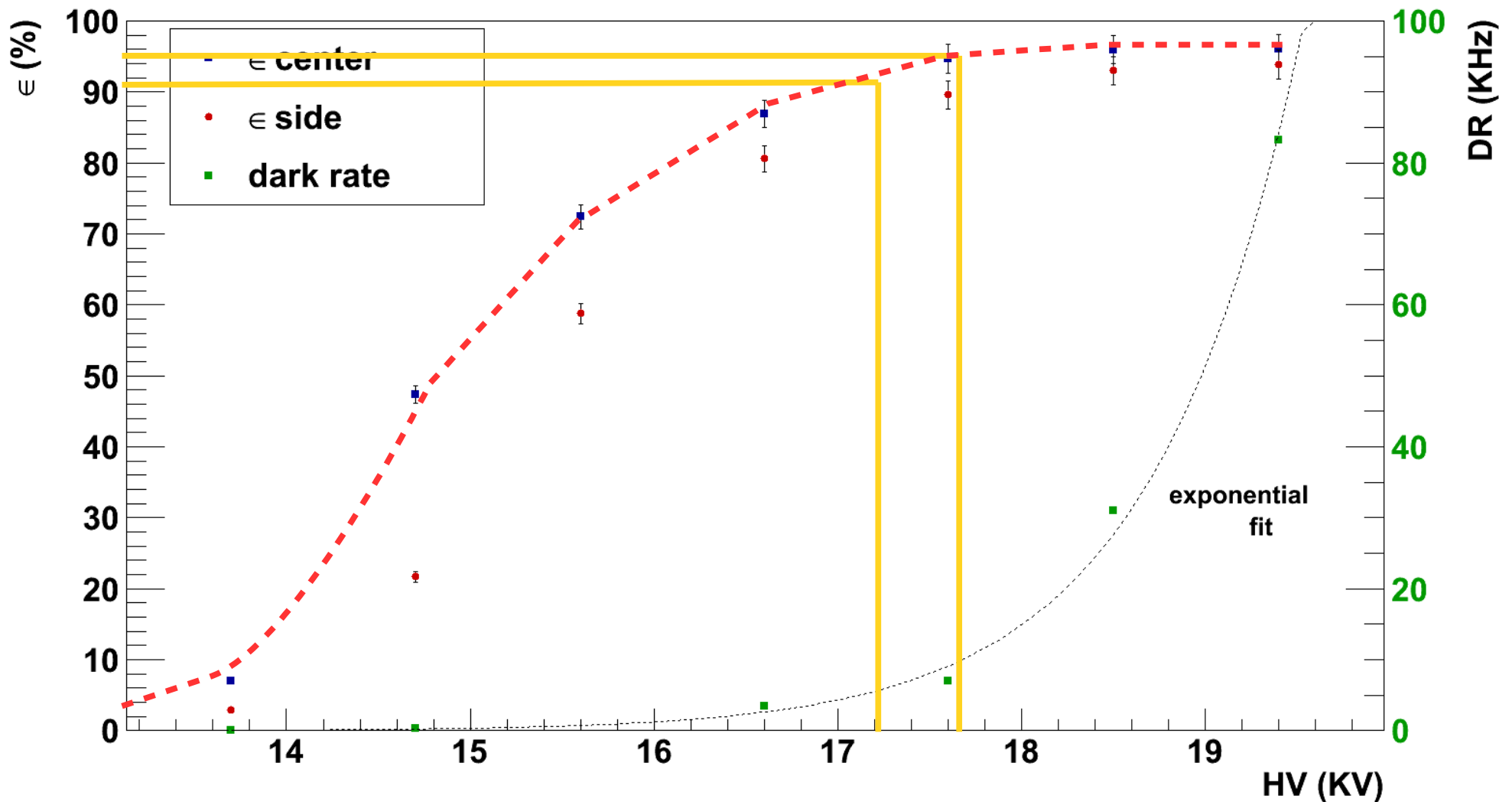
TOP HV-



HV fluctuation and working point:  
100-400 V fluctuations

It could bring efficiency fluctuation of few %  
If not at plateau, same as a GCRD...

CH 41 Efficiency-Dark Rate



## Next steps for the array stability:

Marco S. is working on a **feedback on HV + MRPCs Press/Temp/HV read out** which should be working in the autumn  
The system is already working as a Press/Temp/HV read out at CATZ-01

unfortunately a lot of telescope are equipped by stand-alone LV power supplies anyhow they can be read out

- **TORI-03 feedback system activity ongoing** -

Lecce group is also studying a solution **on the EEE power supply units**



## Possible structure:

1. Introduction to GCRD and past EEE observation
2. The network and the detector
3. Data selection criteria
4. Corrections
5. Results
  - 5.1 – 5.5 The 5 GCRD
    - 5.1.1 The flux decreases (averaged and single telescopes)
    - 5.1.2 Comparison with NM
    - 5.1.3 Directional information
    - 5.1.4 CME-GCRD correlation

Backup



# Forbush and GCRDs

First rigorous experimental observation of Cosmic Ray Flux Decrease was obtained by S. E. Forbush in 1937-38, after deep statistical analysis of data from

“precision cosmic ray meter, Cheltenham, Maryland”  
and after studies on barometric and temperature effects.

LETTERS TO THE EDITOR

1109

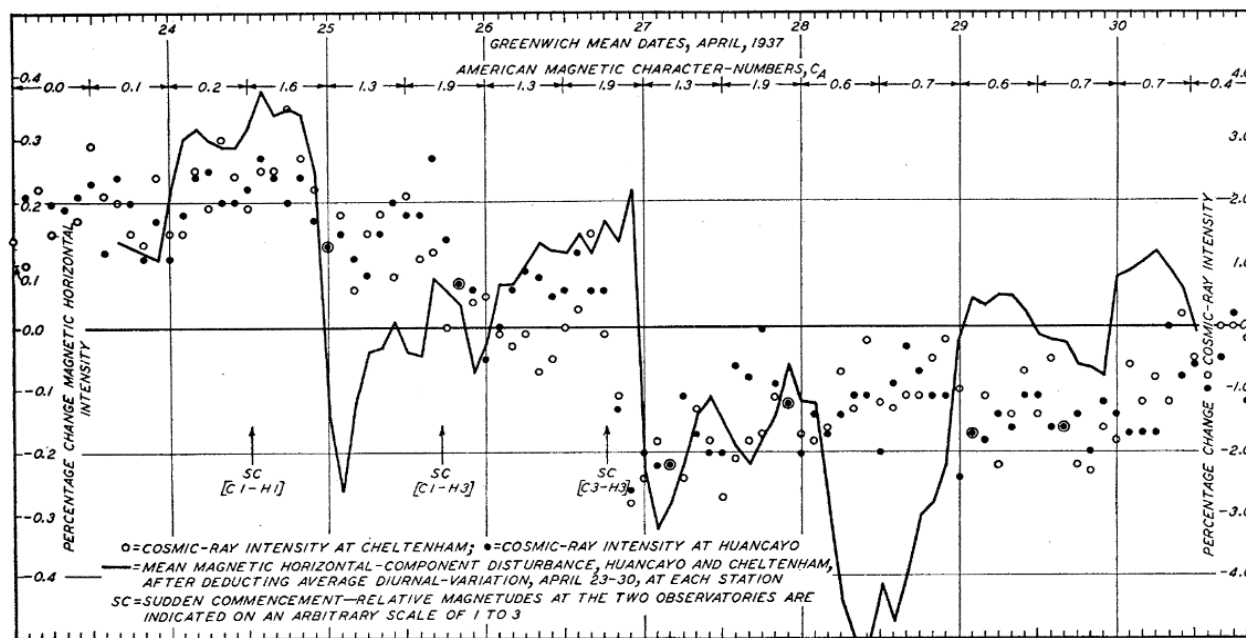
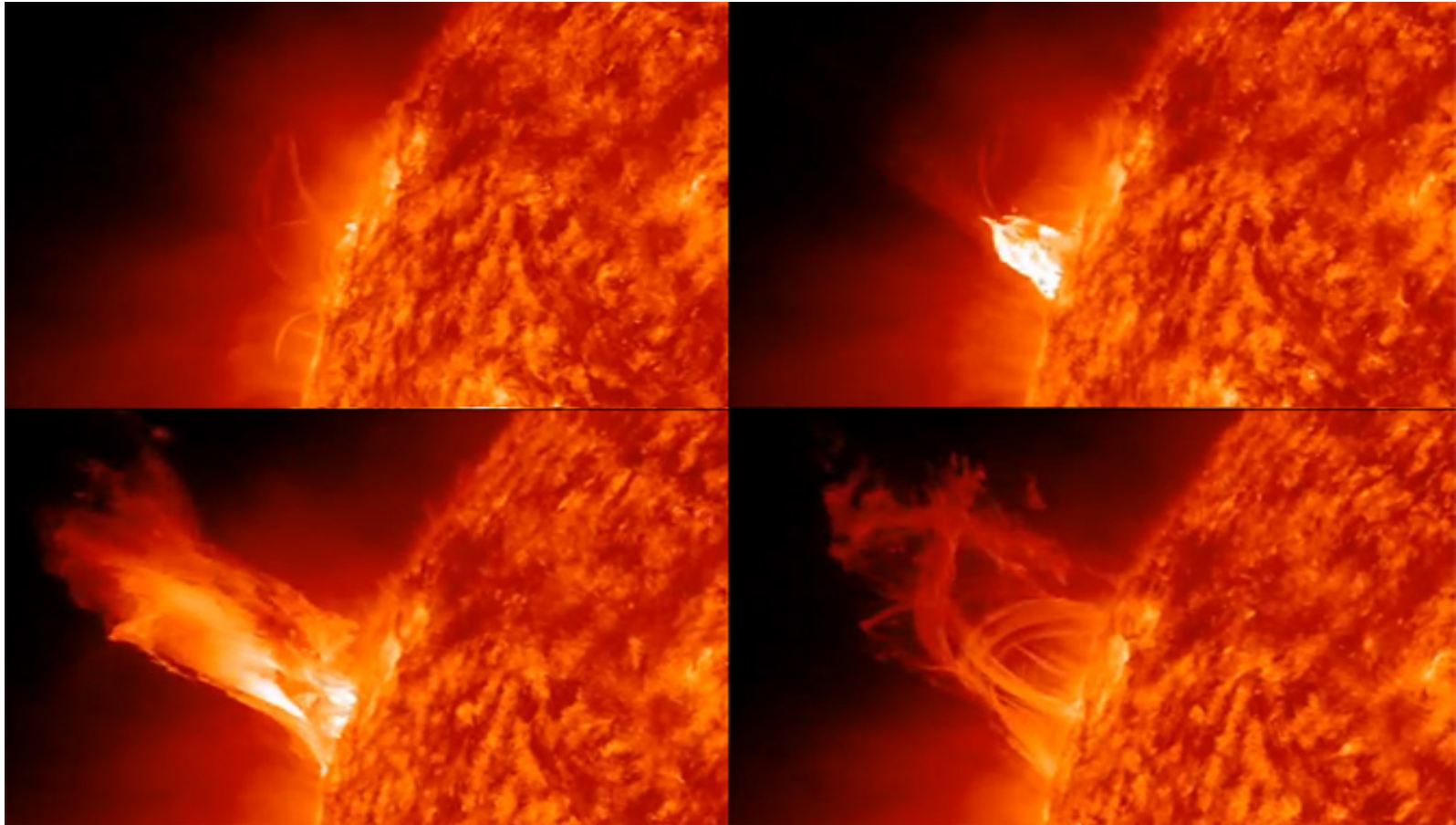


FIG. 1. Bi-hourly departures expressed in percentage of absolute values for cosmic-ray intensity and for disturbance of horizontal magnetic component April 23-30, 1937, Huancayo and Cheltenham magnetic observatories.

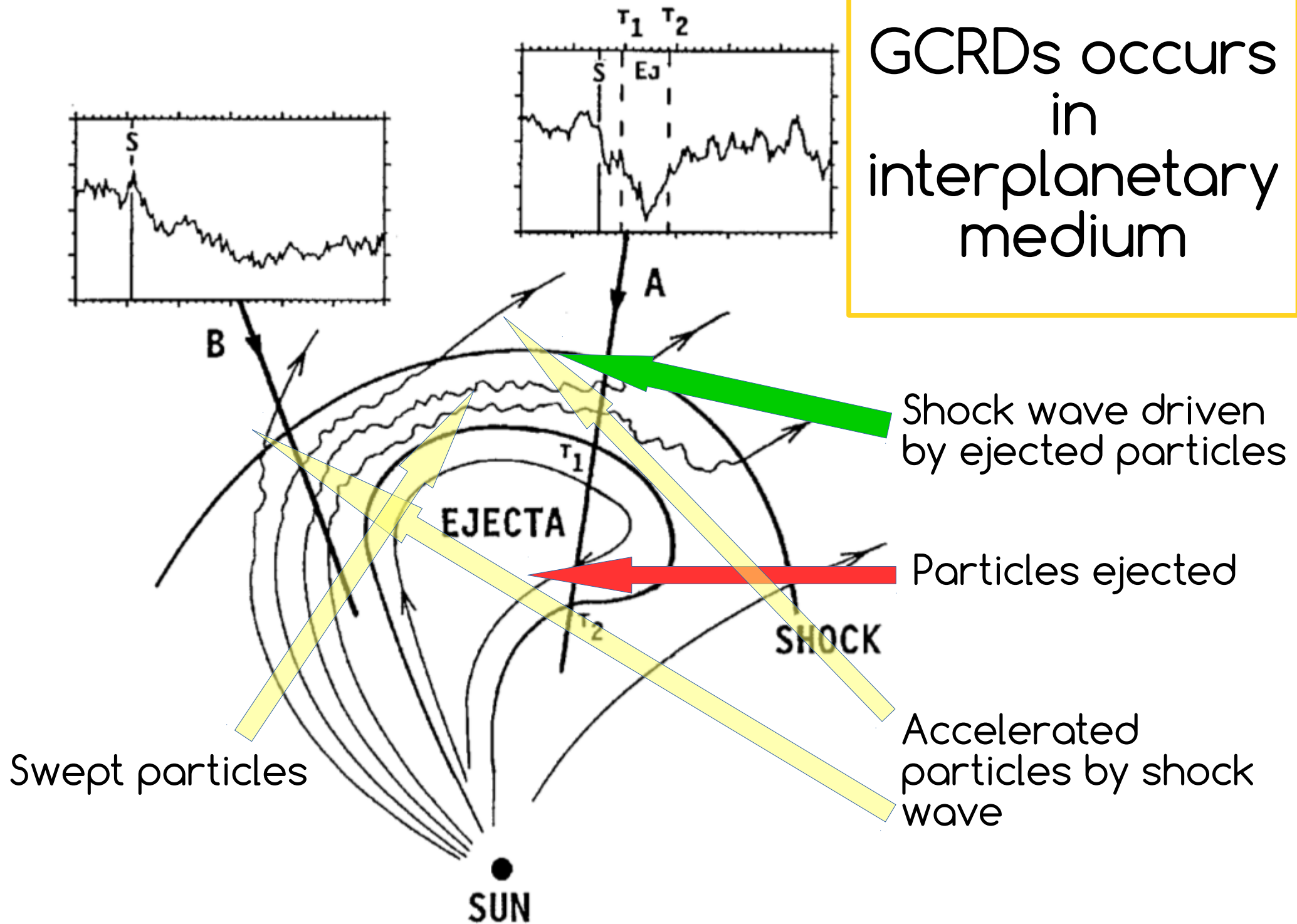
While the evidence here presented cannot be regarded in itself as conclusive proof that the observed changes in cosmic-ray intensity are due to the external field of the magnetic storm, this hypothesis seems to be the most reasonable one.

# Flare – CME connection



Flares are believed to be the results of re-heating due to magnetic 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

SUN

EJECTA

SHOCK

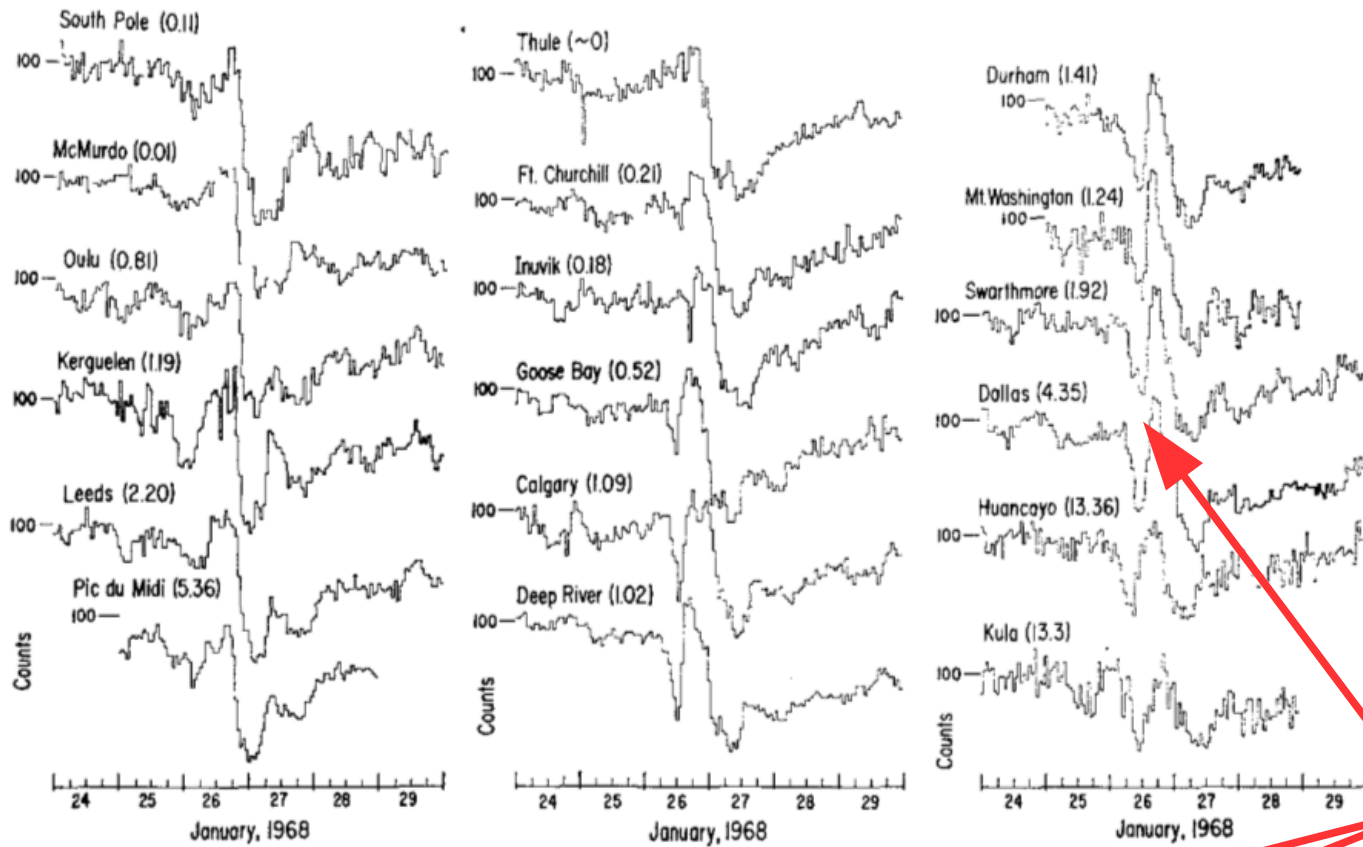
$\tau_1$   $\tau_2$

S Ej

B

A

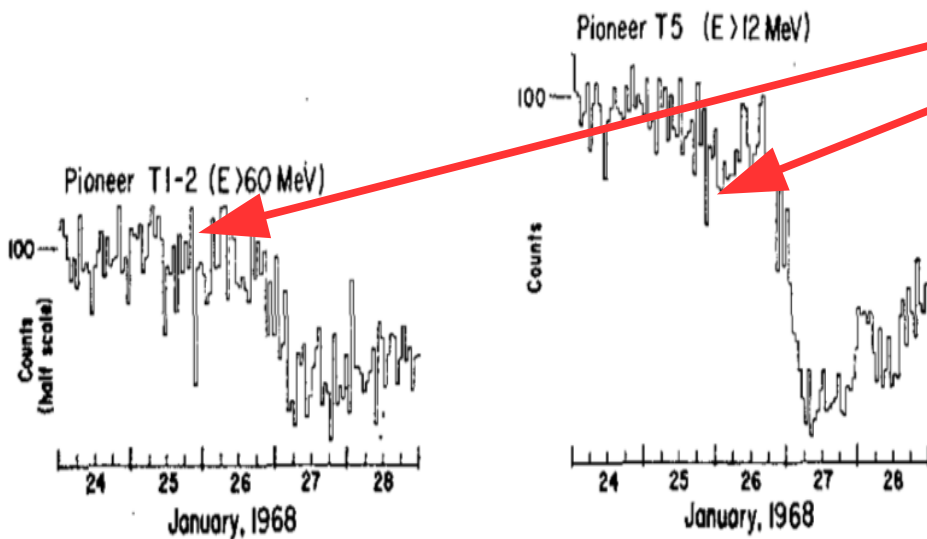
# Neutron Monitors



Complex phenomenon:

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

# Pioneer satellites



Magnetic Field

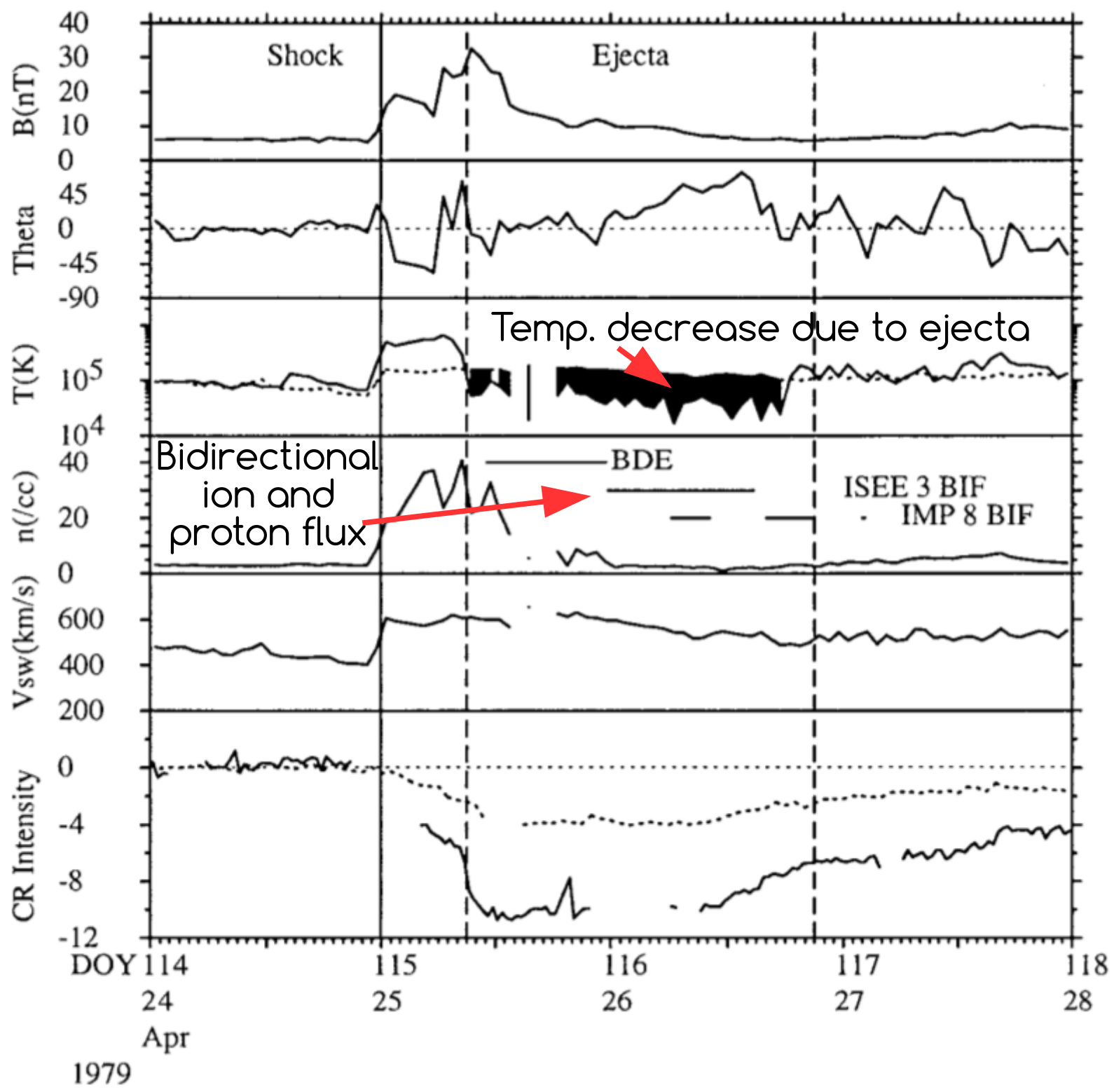
Magnetic field out of ecliptic

Proton Temp

Wind particle density

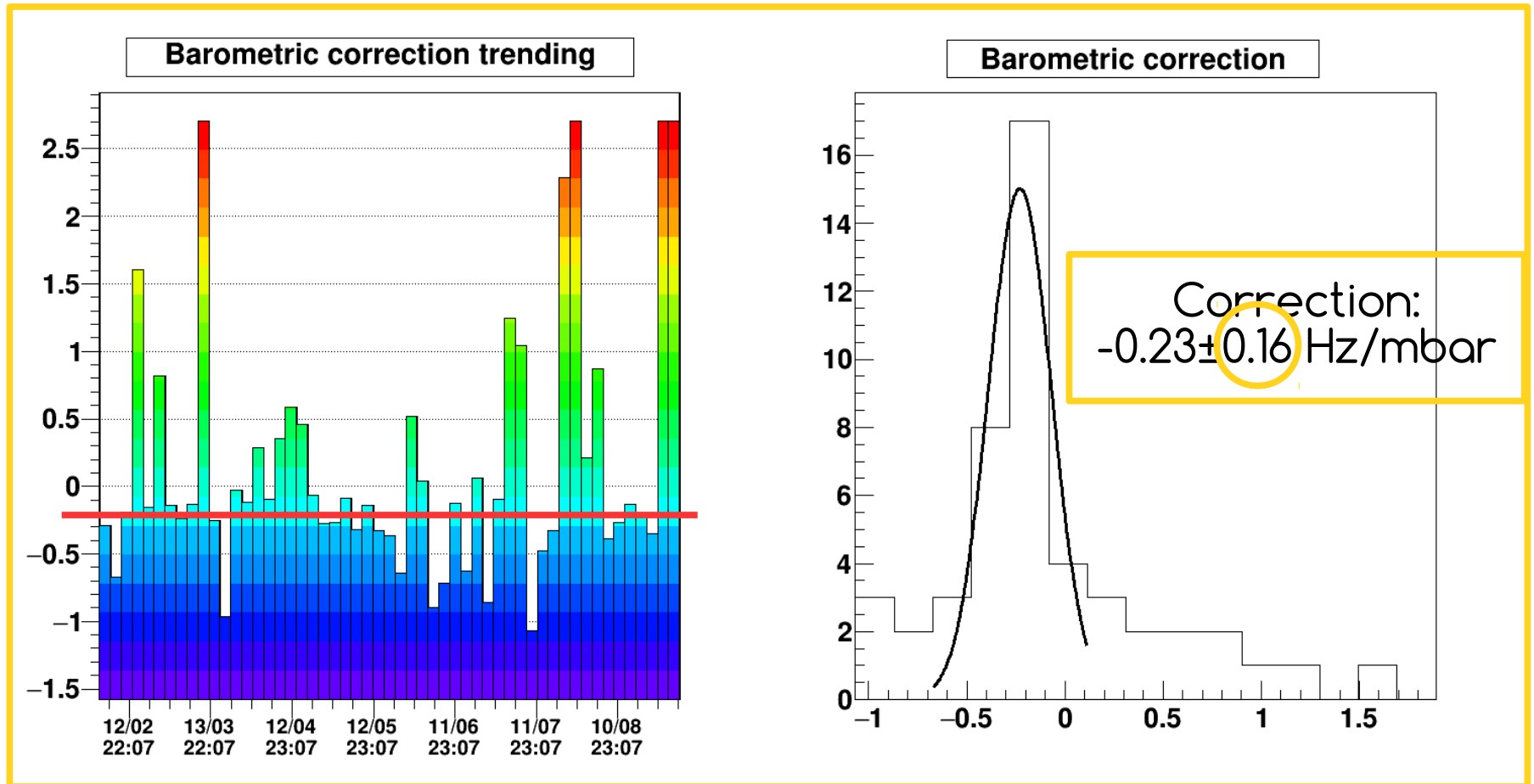
Wind speed

Forbush effect



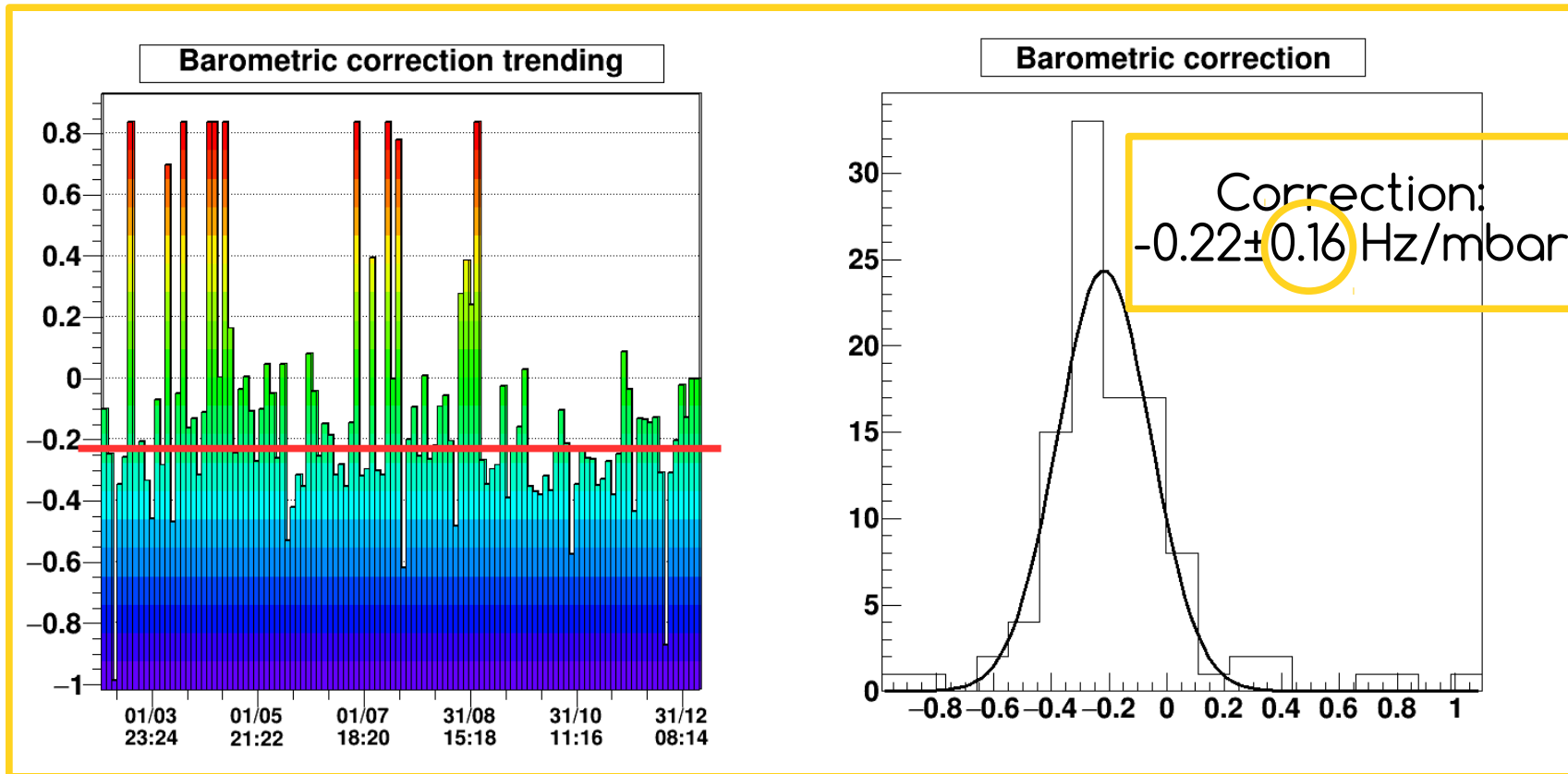


# On stations involved in 2016-01-01 GCRD: ALTA-01



Uncertainty on Barom. Corr. very high  
Corrections of the **same magnitude as GCRD**

# On stations involved in 2016-01-01 GCRD: TORI-04



Uncertainty on Bar. Corr. very high  
Corrections of the same magnitude as GCRD

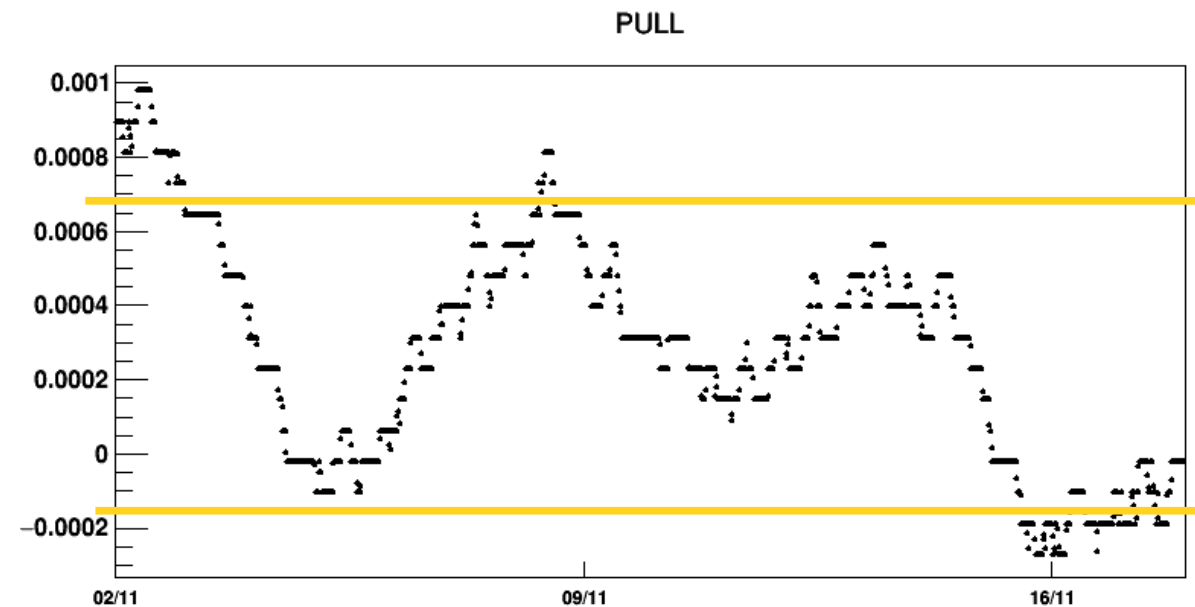
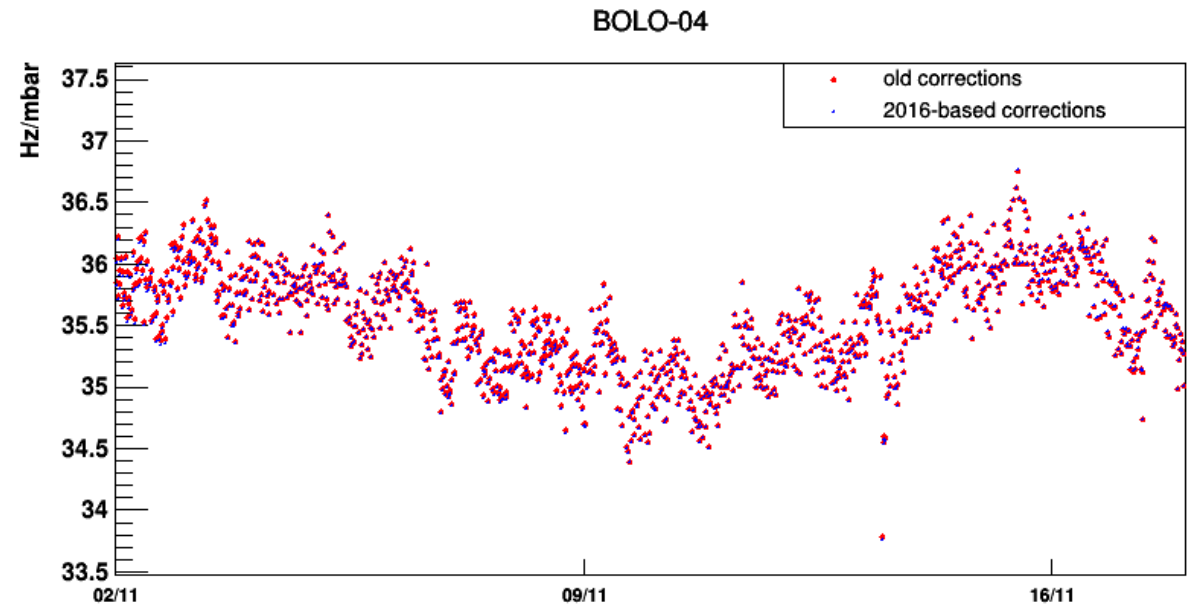
Examples of corrections with barometric coefficient extracted in

1. a short period (red)
2. over the whole 2016 with manual search (blue)

Forbush 2015-11

-0.057

$-0.060 \pm 0.010$



This is the difference between the two corrections normalized to the average rate

This allows to extract the systematics ~ few ‰ (binning + ..)



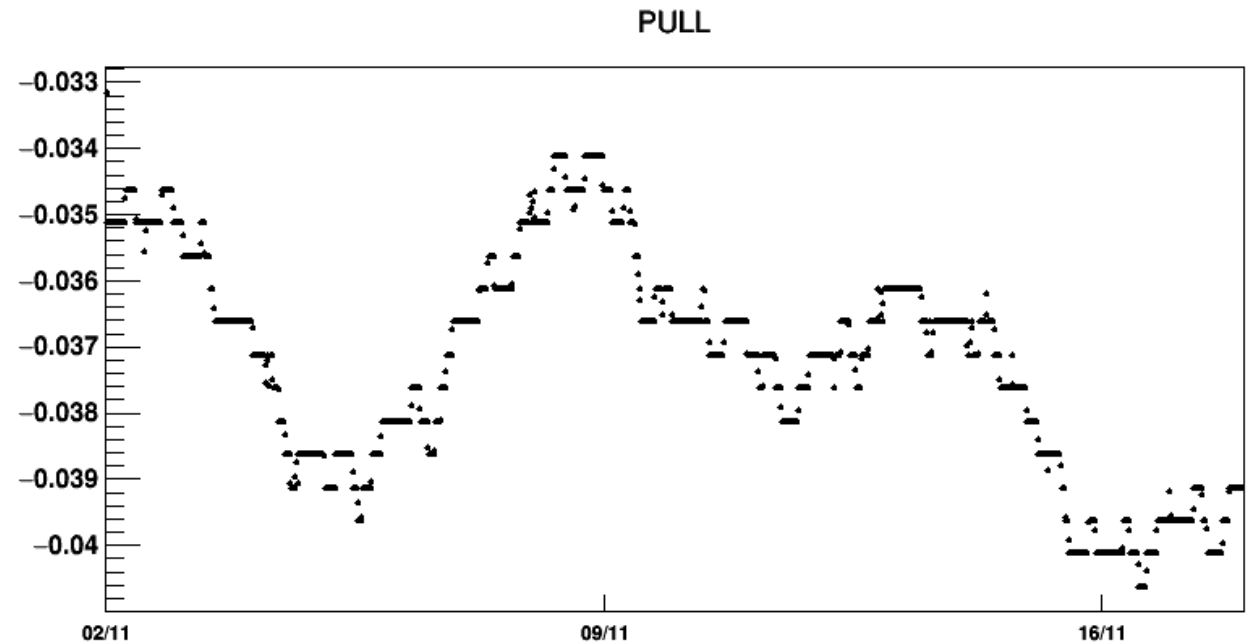
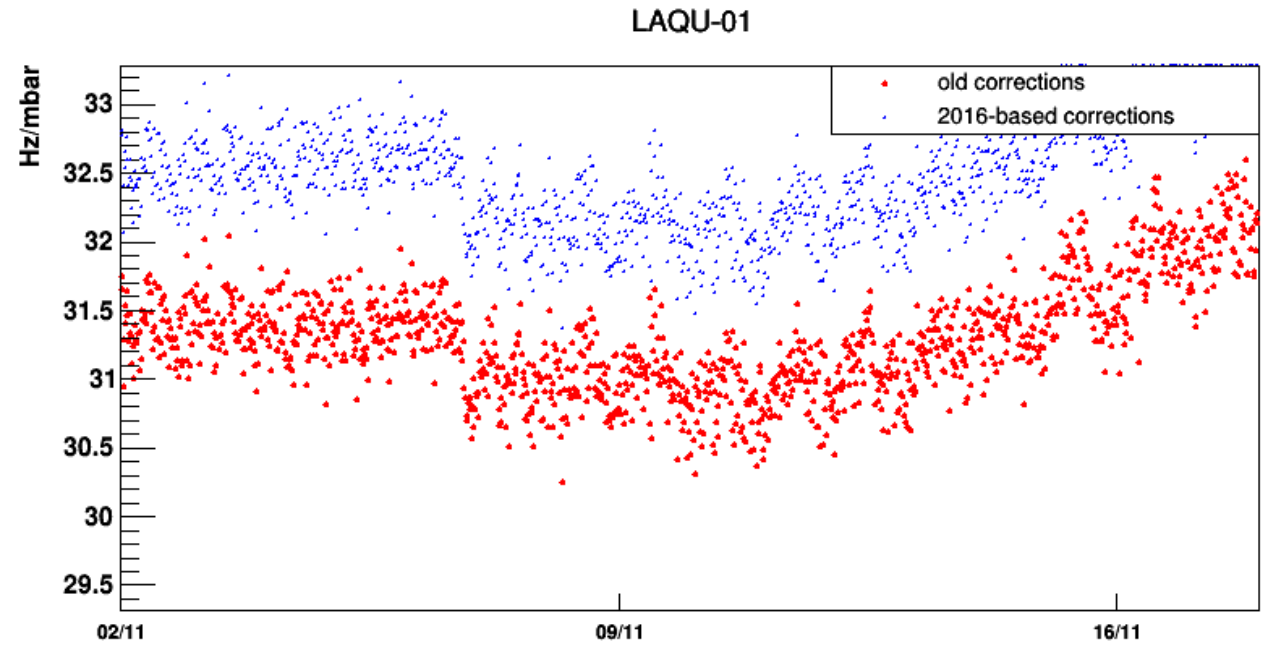
Examples of  
correction  
variation w.r.t.  
short period  
extraction

Forbush 2015-11

-0.079



$-0.095 \pm 0.028$



Examples of  
correction  
variation w.r.t.  
short period  
extraction

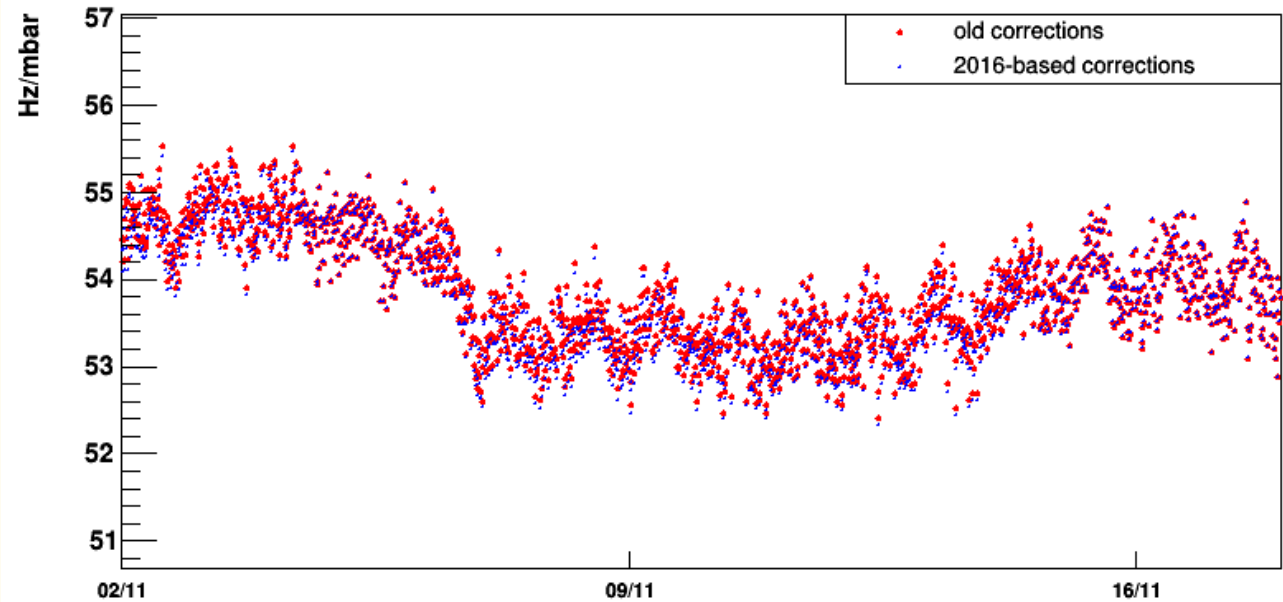
Forbush 2015-11

-0.057

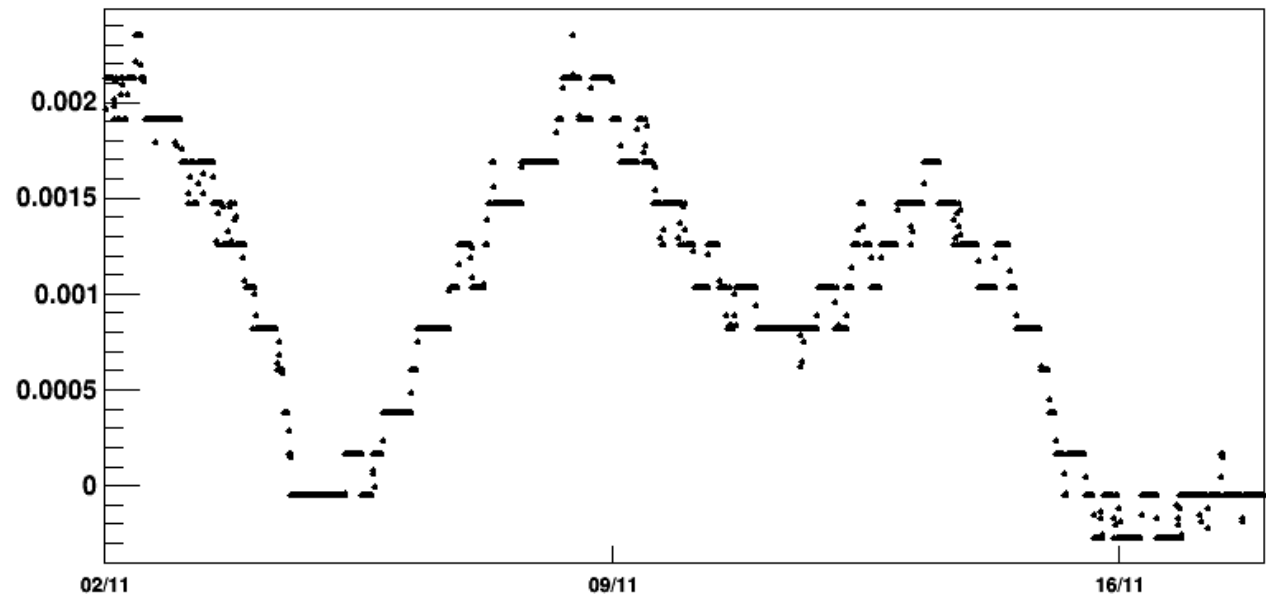


$-0.069 \pm 0.021$

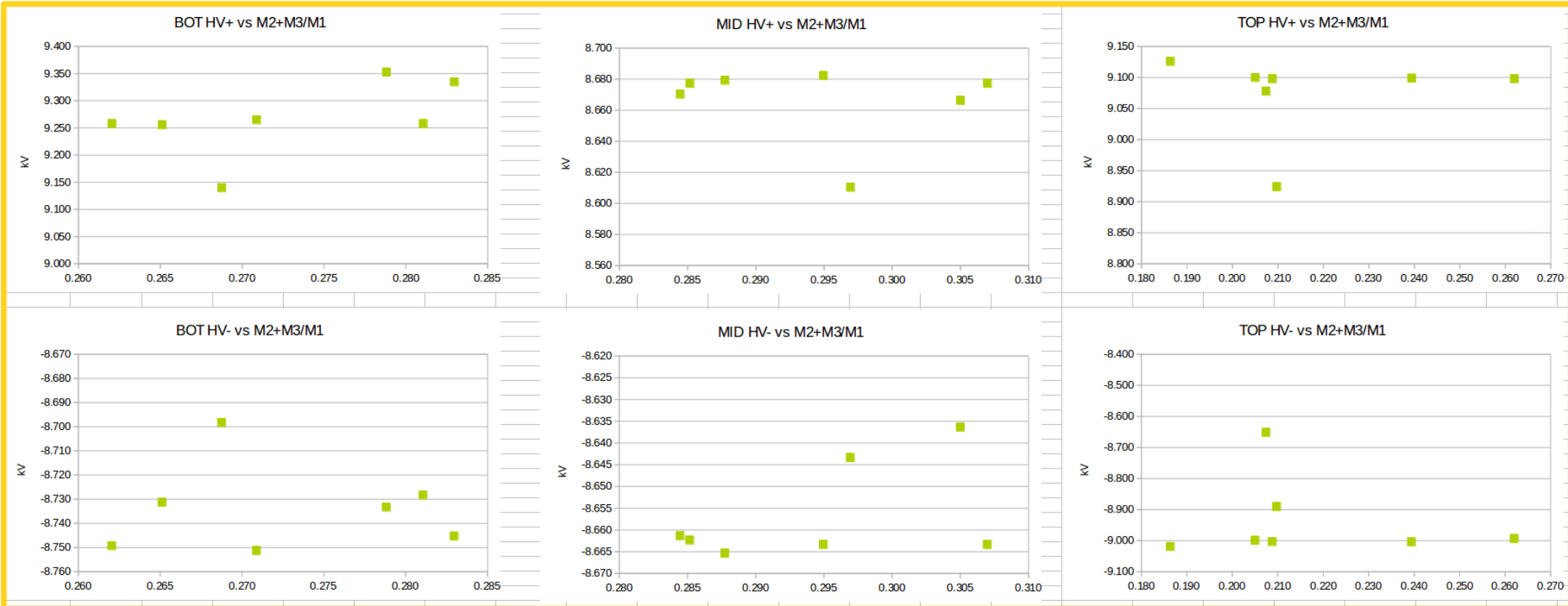
SAVO-02



PULL

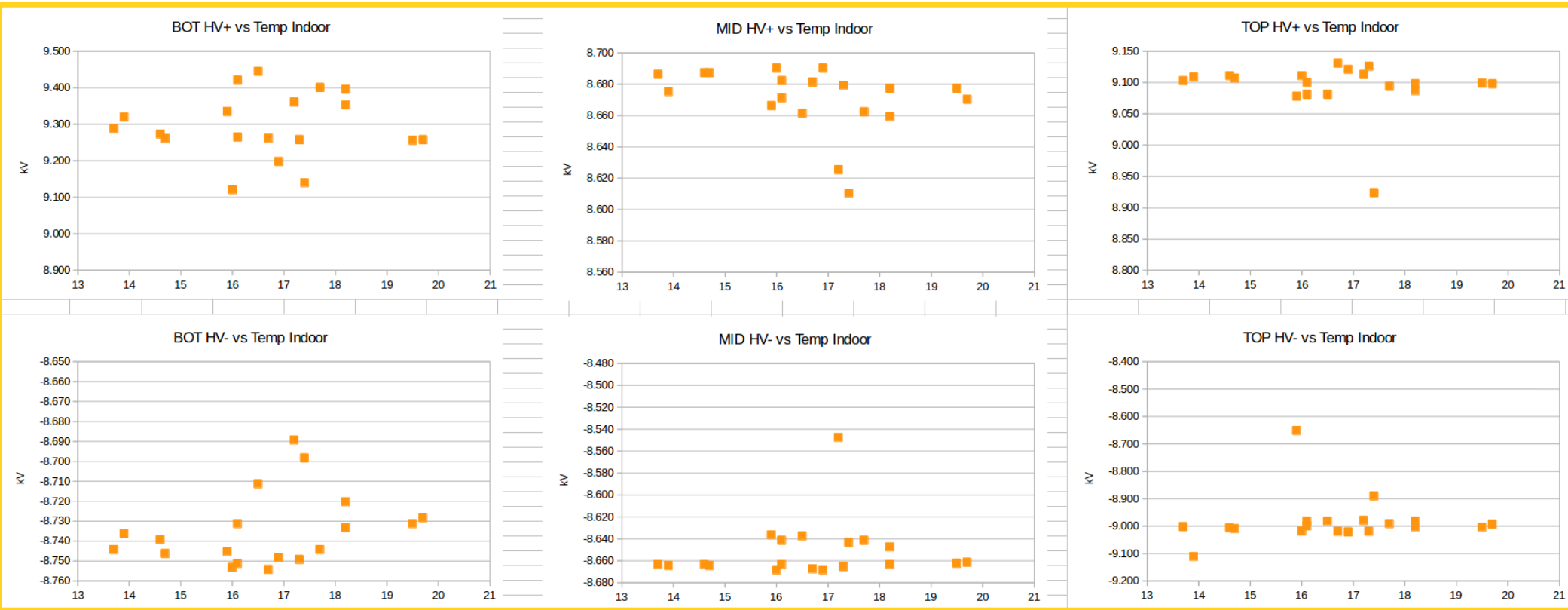


# Multiplicity vs HV

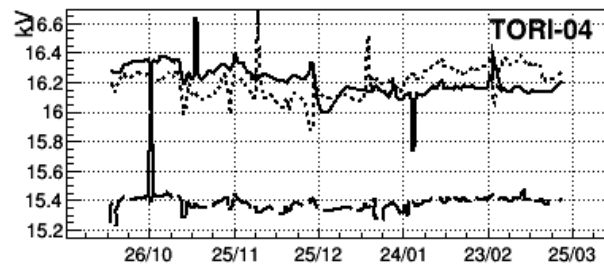
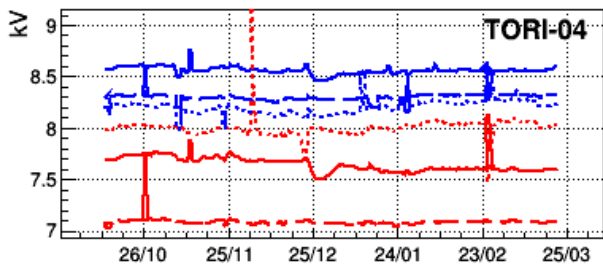
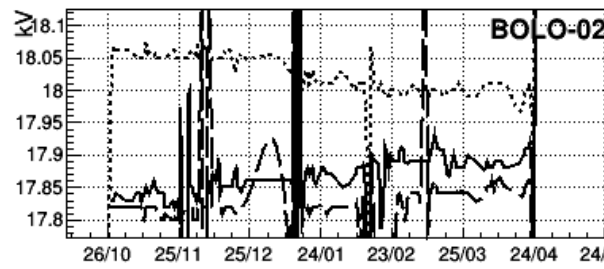
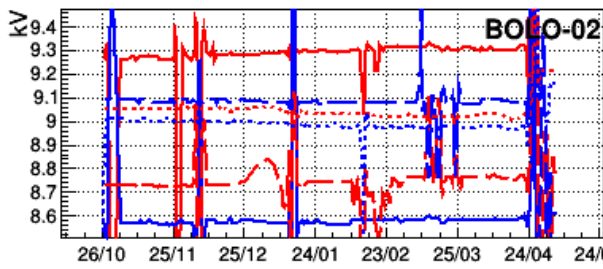
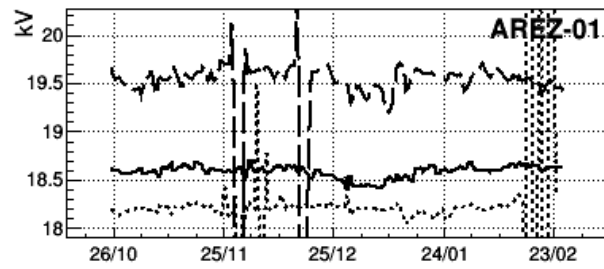
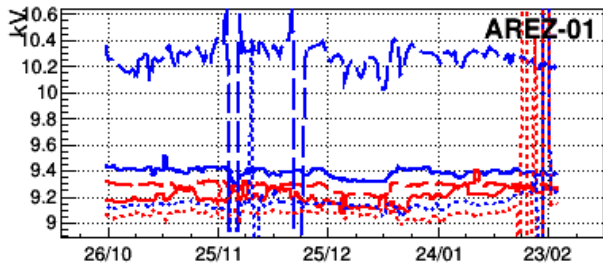
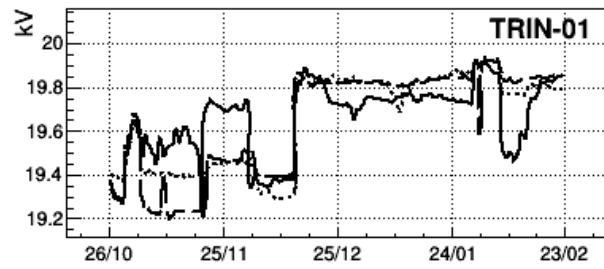
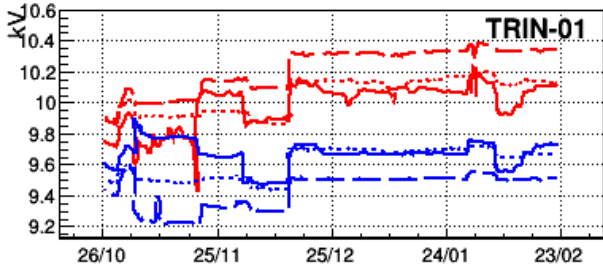
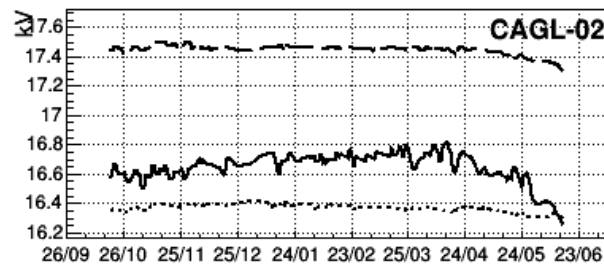
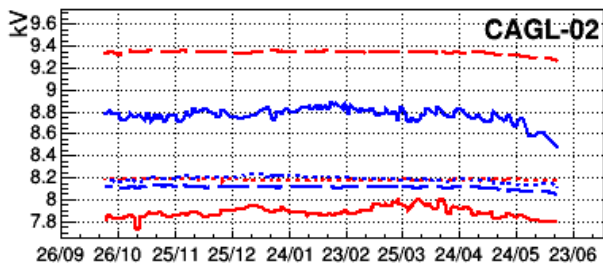


... no correlation with multiplicities

# HV vs Temperature



...no clear Temperature correlation



HV instability is a real problem, also connected to efficiency curve →