2013 Roma International Conference
on AstroParticle Physics , Roma (Italy),

May 22-24 2013

UNIVERSITA' degli STUDI di ROMA TOR VERGATA

INFN Istituto Nazionale di Fisica Nucleare

PAMELA a Payload for Antimatter Matter Exploration and Light–nuclei Astrophysics

H and He production during the 2012 March 7 solar particle event with the PAMELA experiment

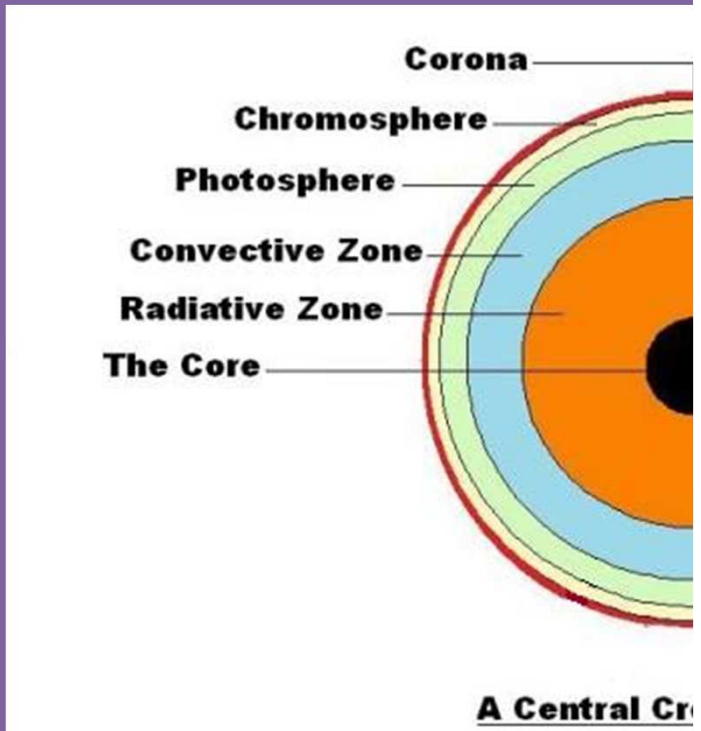
Martucci Matteo
Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati (RM)
Mergè Matteo
Istituto Nazionale di Fisica Nucleare, Sezione di Roma ''Tor Vergata''
Sotgiu Alessandro
Università degli Studi di Roma ''Tor Vergata''

WHAT IS A SOLAR FLARE?

- A solar flare is a **sudden brightening** of a part of the Chromosphere and/or Corona

- Flare shows enhanced emission in almost all wavelength, from radio to γ-rays

- Flare emissions are caused by thermal **plasma heating**, and non-thermal **particle acceleration**

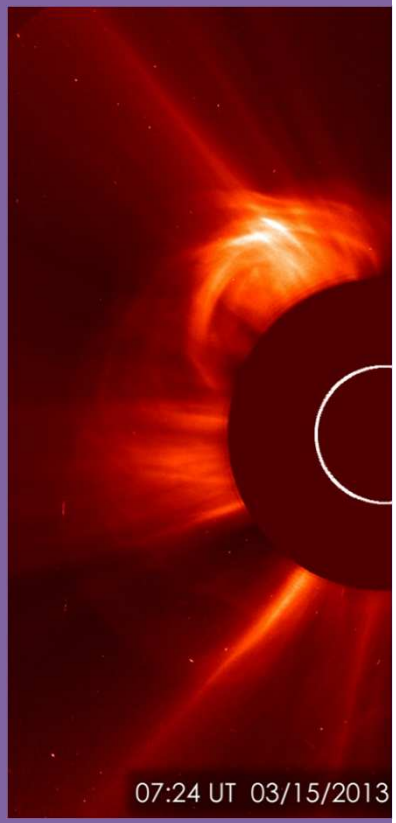


A Central Cr

- **Heating and particle acceleration** are believed to be caused by **magnetic reconnection in the Corona**

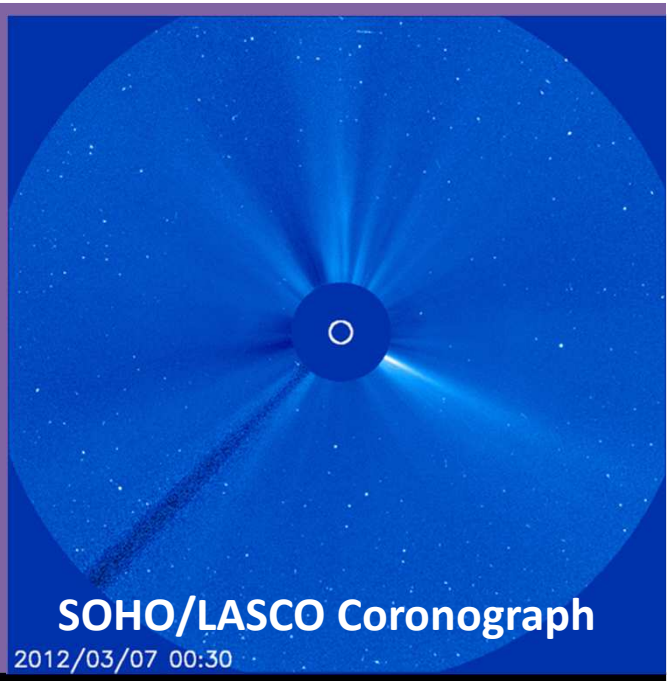
CORONAL MASS EJECTIONS (CMEs)

- A CME is a large scale coronal plasma (and magnetic field) structure ejected from the Sun, as seen by a coronagraph
- A CME propagates into IS.
- A CME disturbs the solar wind, drives shock in interplanetary space, and produce energetic particles at the shock front.

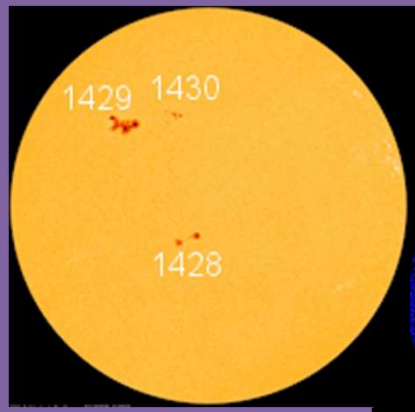


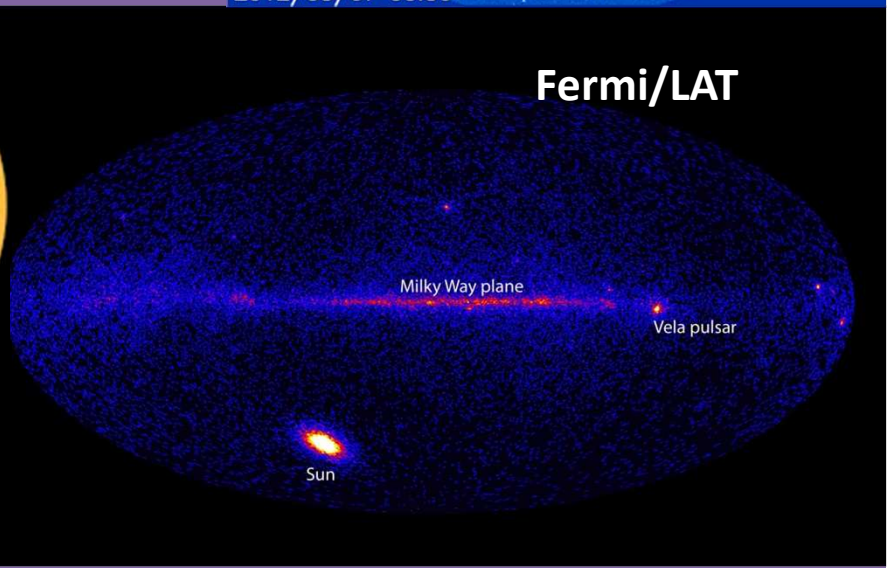
THE 2012 MARCH 7th SOLAR ENERGETIC PARTICLE EVENT

- X 5.4 flare: strongest of 2012 (diffusive event). Occurred after 9 M-flares in one day
- A CME hit Earth's magnetic field on March 8th around 1100 UT. The impact was weaker than expected, sparking only a mild (Kp=5) geomagnetic storm



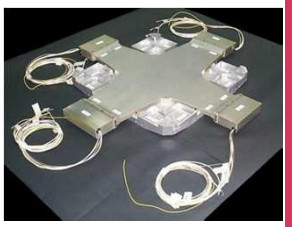
- AR 1429 (N18E31)
- Start: March 7, 00:02
- Peak: March 8, 11:55
- End: March 11, 02:14





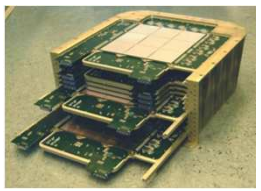
PAMELA

Time-Of-Flight
plastic scintillators + PMT:
- Trigger
- Albedo rejection;
- Mass identification up to 1 GeV;
- Charge identification from dE/dX.

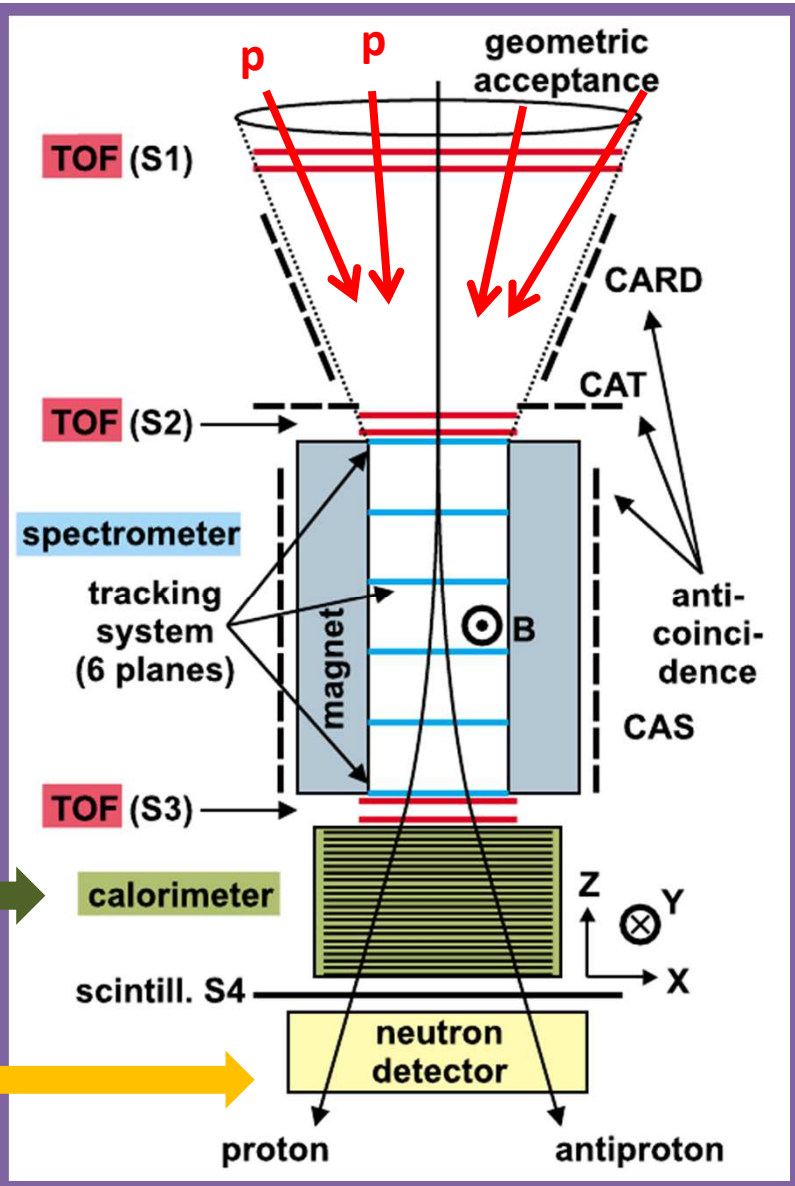


Spectrometer
microstrip silicon tracking system
- *Magnetic rigidity → R = pc/Ze*
– *Charge sign*
– *Charge value from dE/dx*
+ permanent magnet

Electromagnetic calorimeter
W/Si sampling (16.3 X_0, 0.6 λ_I)
- Discrimination e+ / p, anti-p / e- (shower topology)
- Direct E measurement for e-

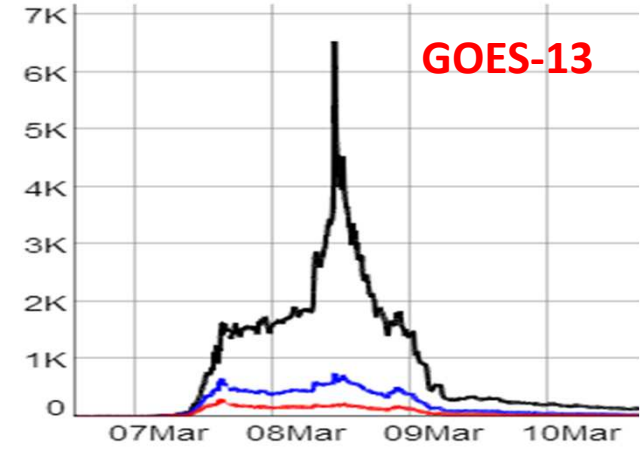


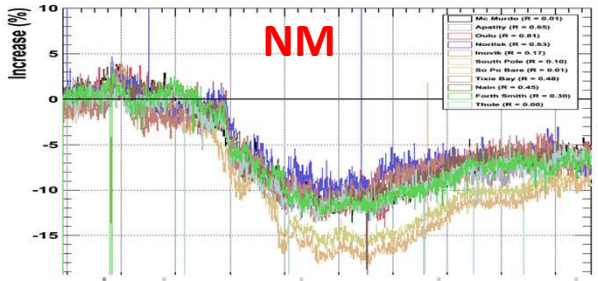
Neutron detector
3He tubes + PMT:
- High-energy e/h discrimination

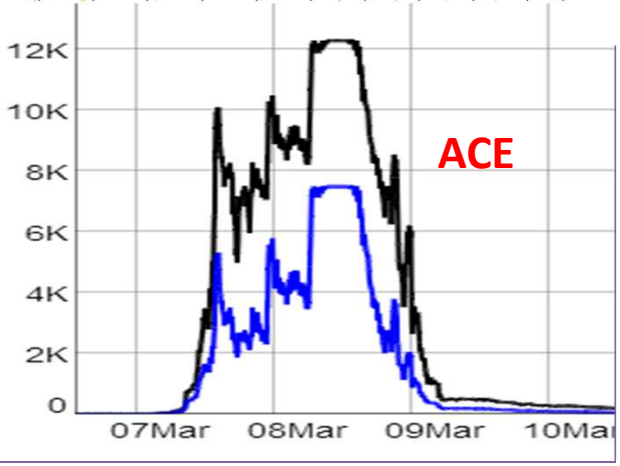


PAMELA CAPABILITIES IN SEP DETECTION

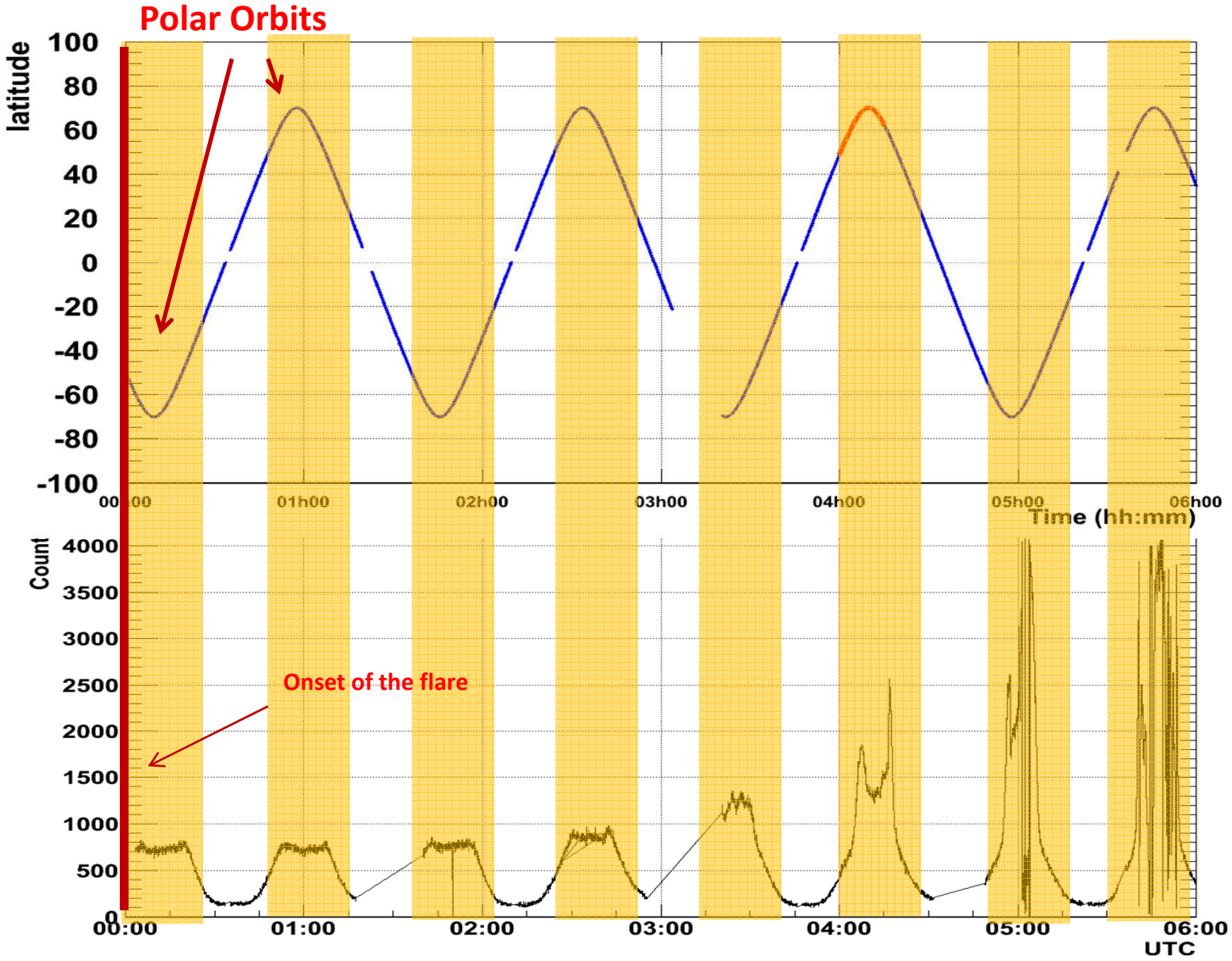
- PAMELA presents a unique opportunity to study the highest energy SEP events
- It spans the energy range between the highest data channel of ACE or GOES and NM
- PAMELA can analyse flare with associated GLE event (like the 17th May one)
- PAMELA can explore continuously a wide rigidity range
- PAMELA has the opportunity to see where the SEP spectrum rolls off → exploring the limits of the acceleration processes at play in the Sun



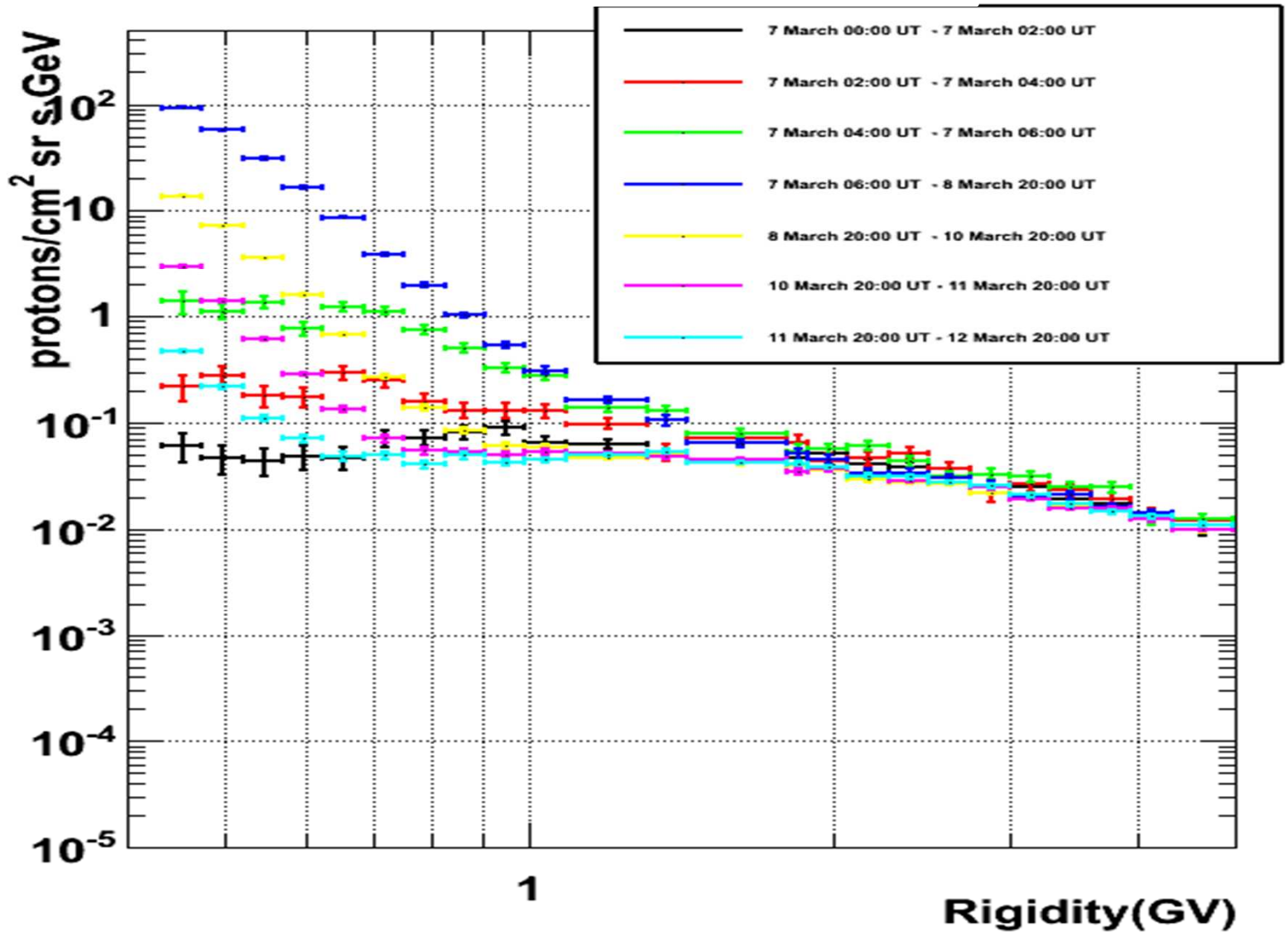




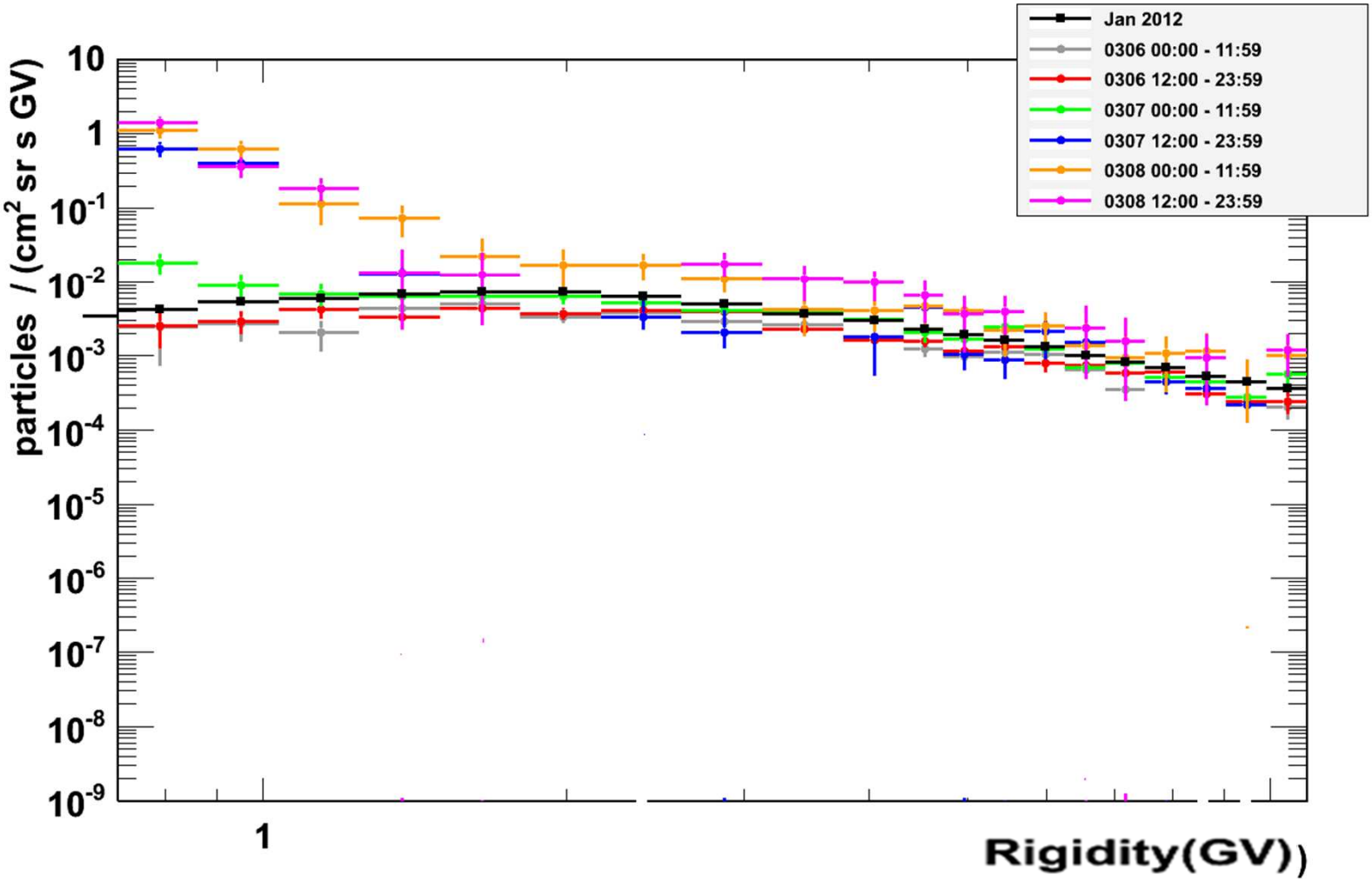
PAMELA ORBIT AND COUNTS



SOLAR PORTION OF THE DIFFERENTIAL H FLUX

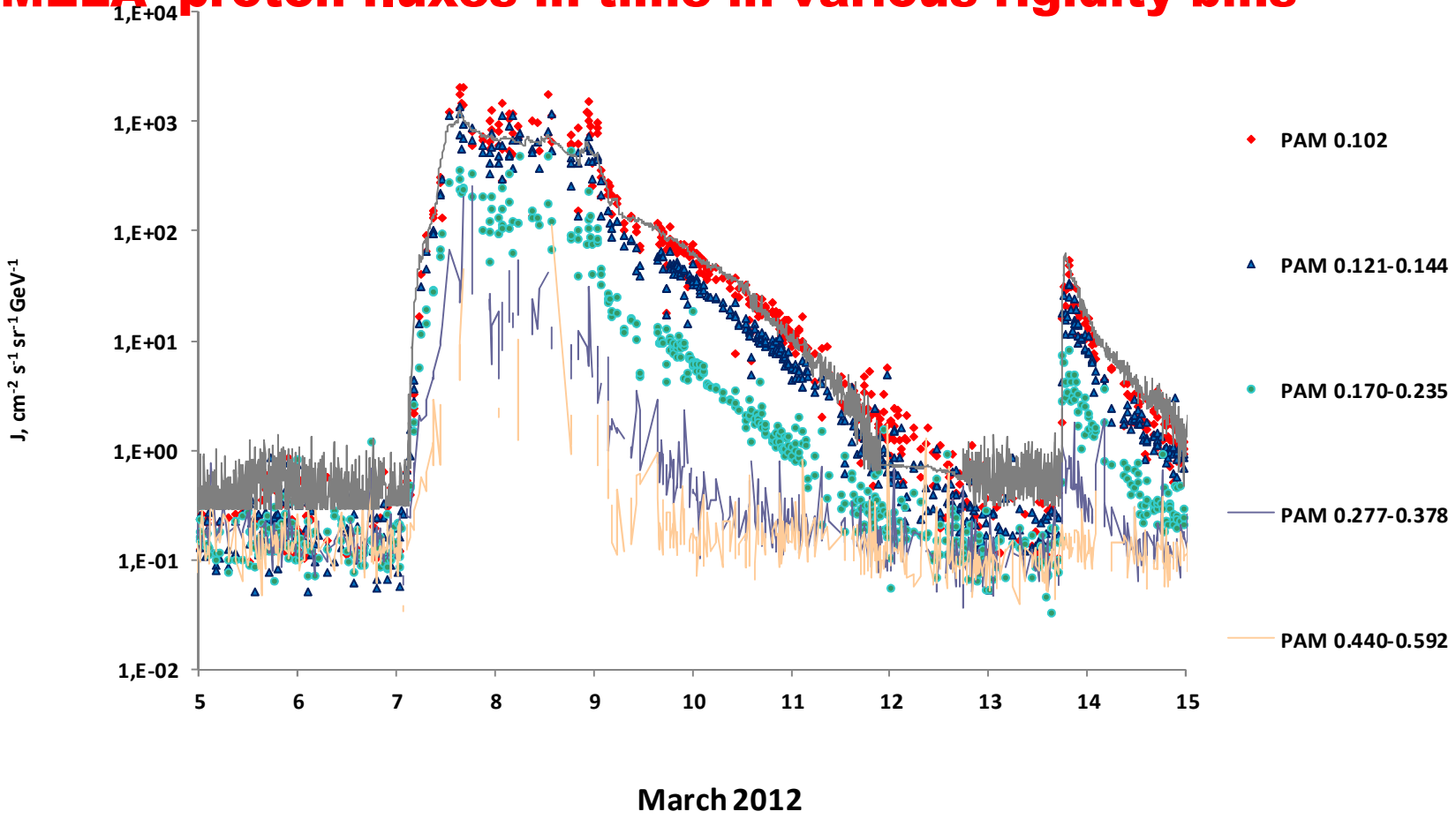


SOLAR PORTION OF THE DIFFERENTIAL He FLUX



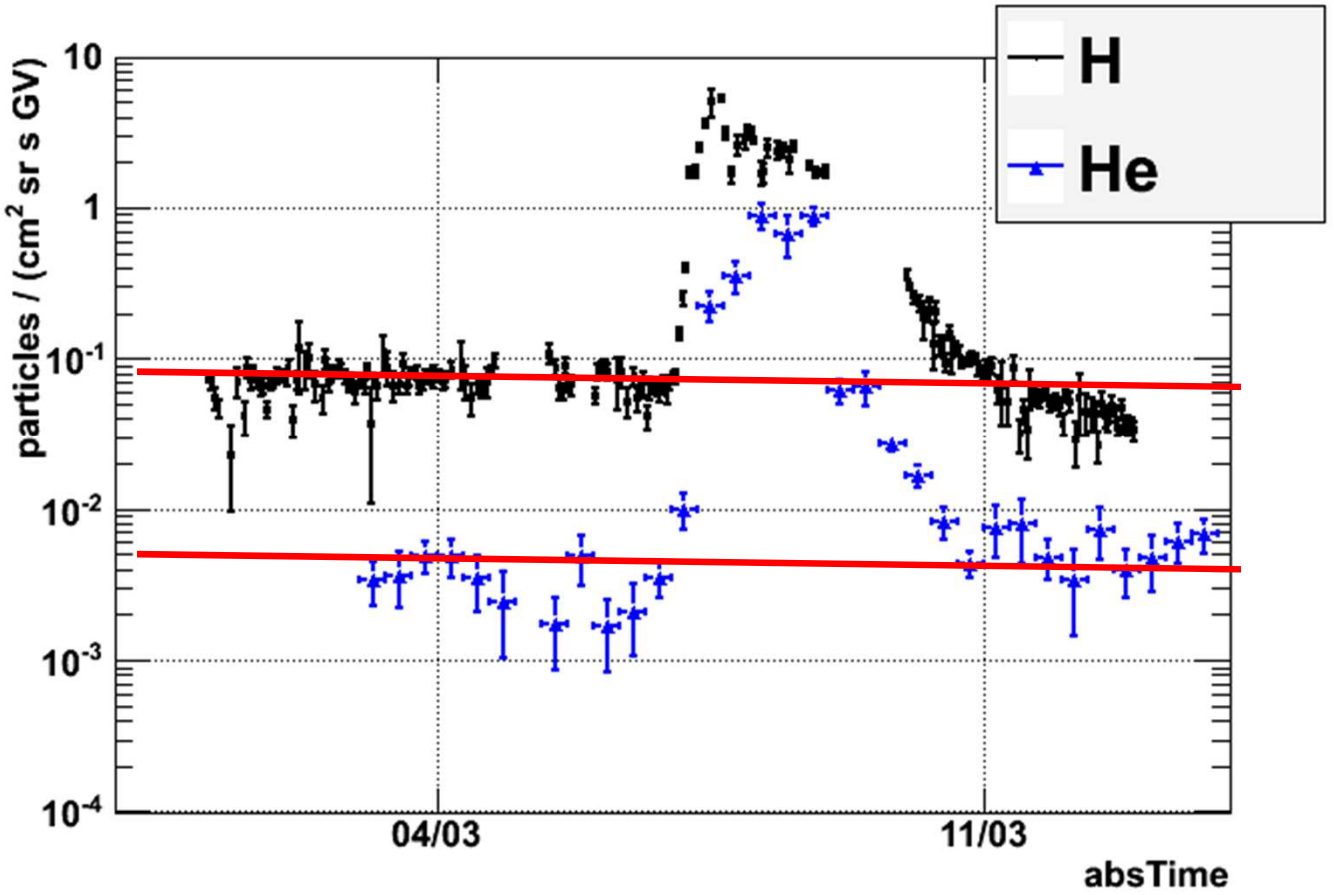
FLUXES IN TIME

PAMELA proton fluxes in time in various rigidity bins

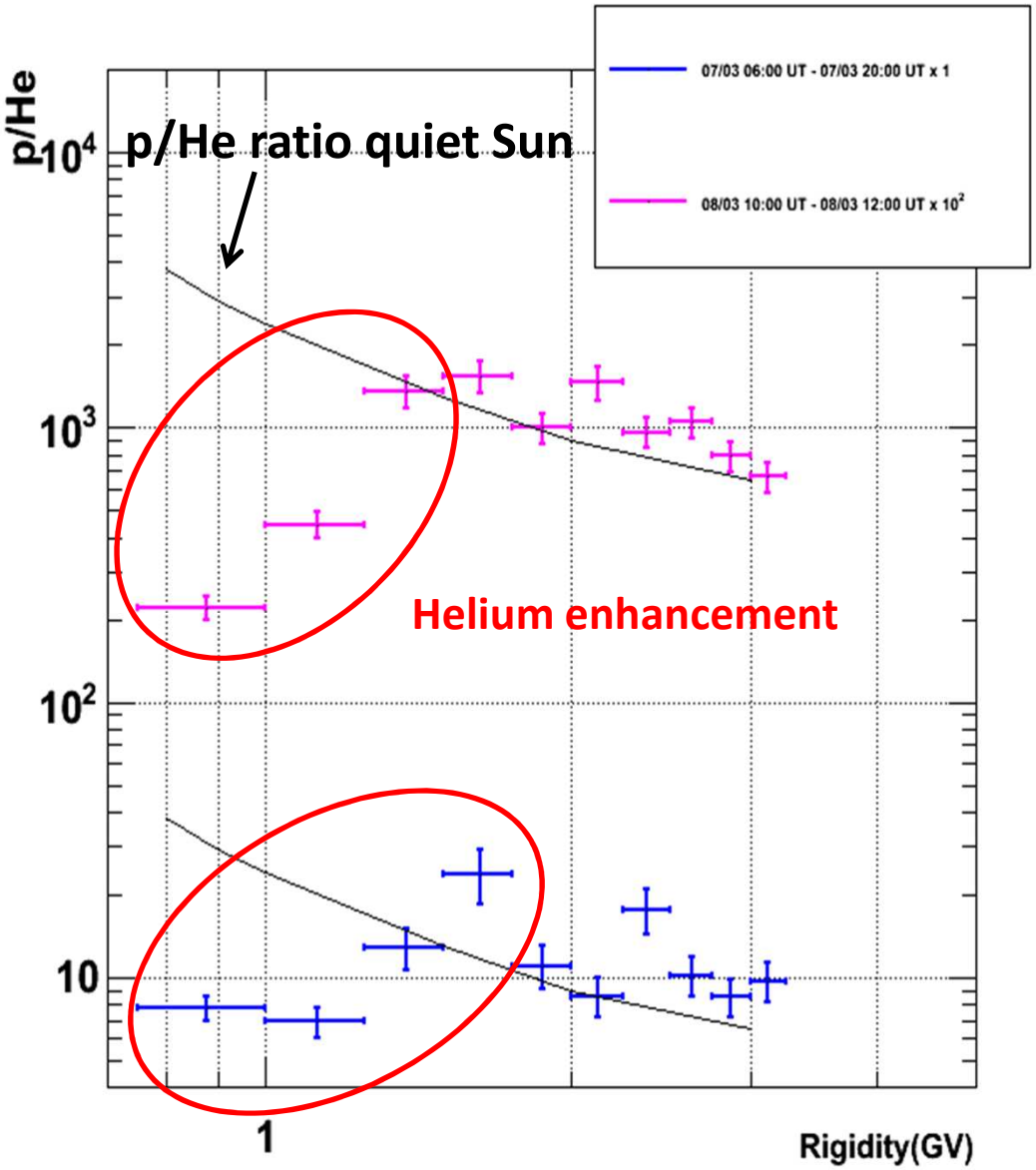


H & He FLUXES IN TIME

0.700 GV < Rigidity < 1.080 GV



p/He RATIO DURING THE MARCH 7 FLARE



A Helium enhancement is visible in the time slice from March 7 (0600 UT) to March 7 (2000 UT) and also in the slice from March 8 (1000 UT) to March 8 (1200 UT)

FIT ON SOLAR ENERGETIC PARTICLE FLUX

- 4 physical functions for the procedure (all of them can explain a single mechanism)

$$\Phi_p = A\ e^{-E/E_0}$$

$$\Phi_p = A\ e^{-R/R_0}$$

$$\Phi_p = A\ R^{-\gamma-\delta(R-R_0)/R_0}$$

$$\Phi_p = A\ R\ K_2\ (R/c\,\alpha\,T)^{1/2}$$

where K_2 is a modified Bessel function of the order 2, with αT as free parameter (α representing an acceleration rate and T the escape time from the acceleration region)

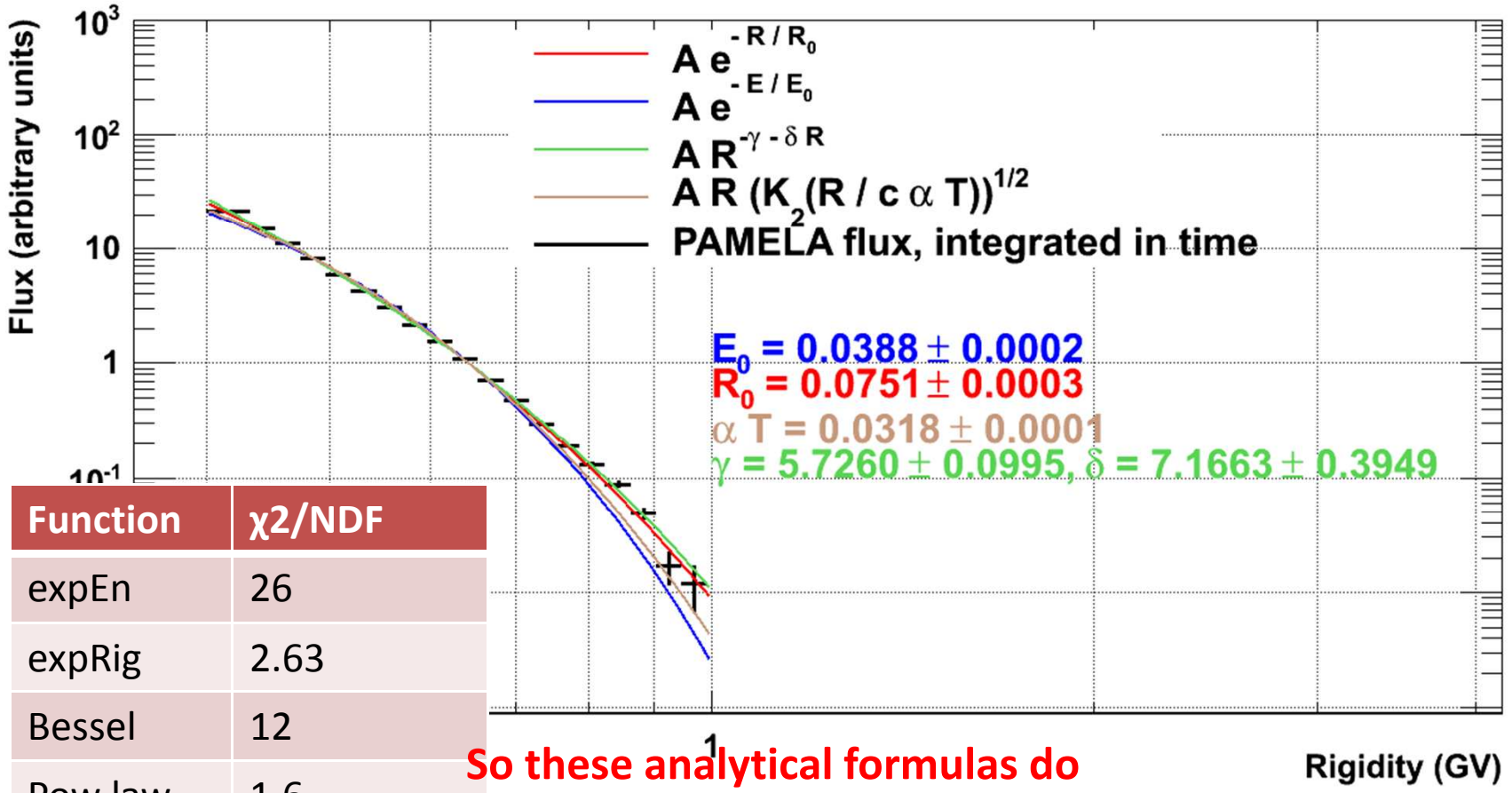
FIT ON SOLAR ENERGETIC PARTICLE FLUX

An exponential in kinetic energy or rigidity function is typical for simple models of acceleration provided by a large scale (quasi) static electric field

A power law is indicative of shock acceleration

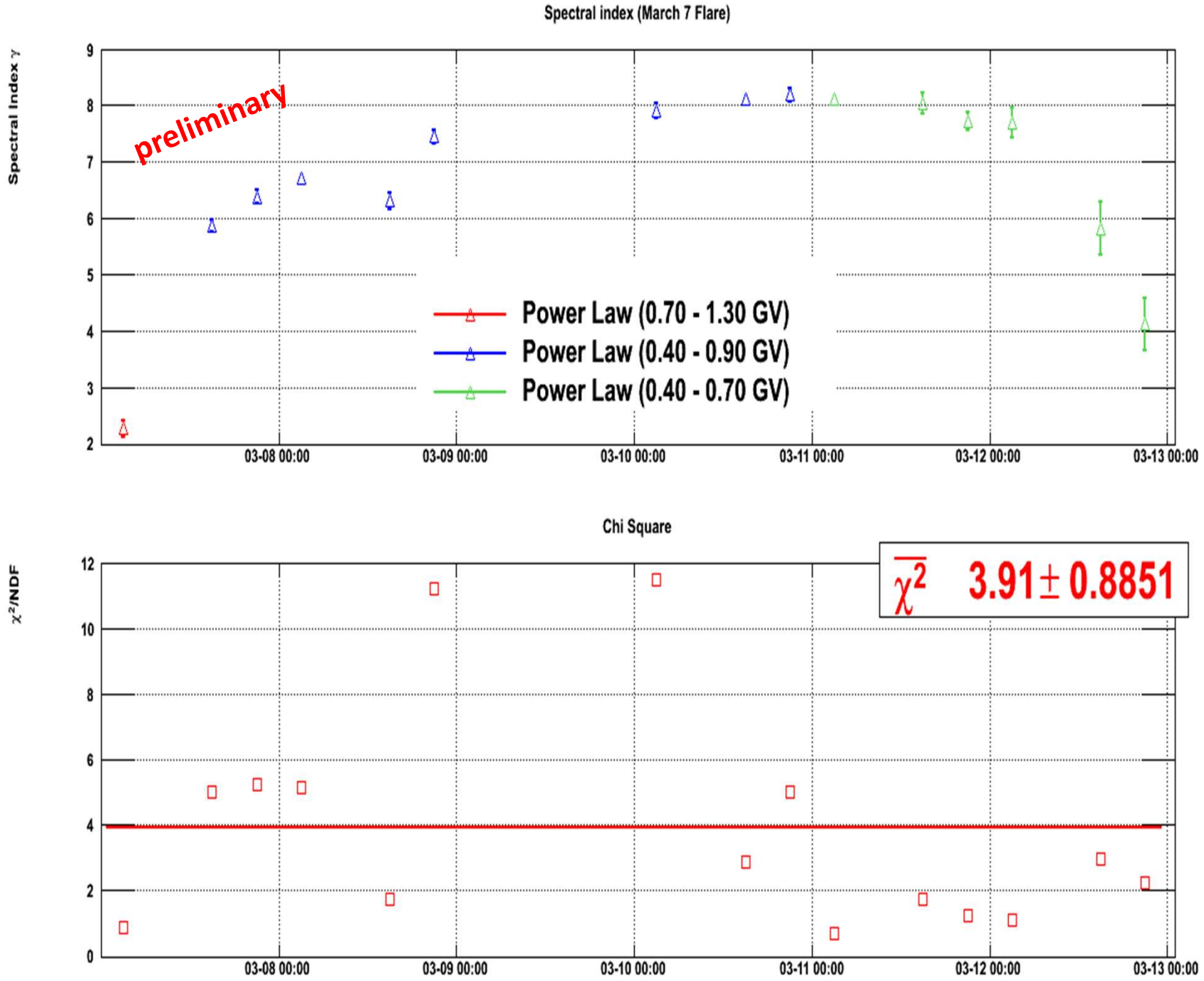
Bessel function results from stochastic acceleration

FIT RESULTS



Function	χ2/NDF
expEn	26
expRig	2.63
Bessel	12
Pow law	1.6

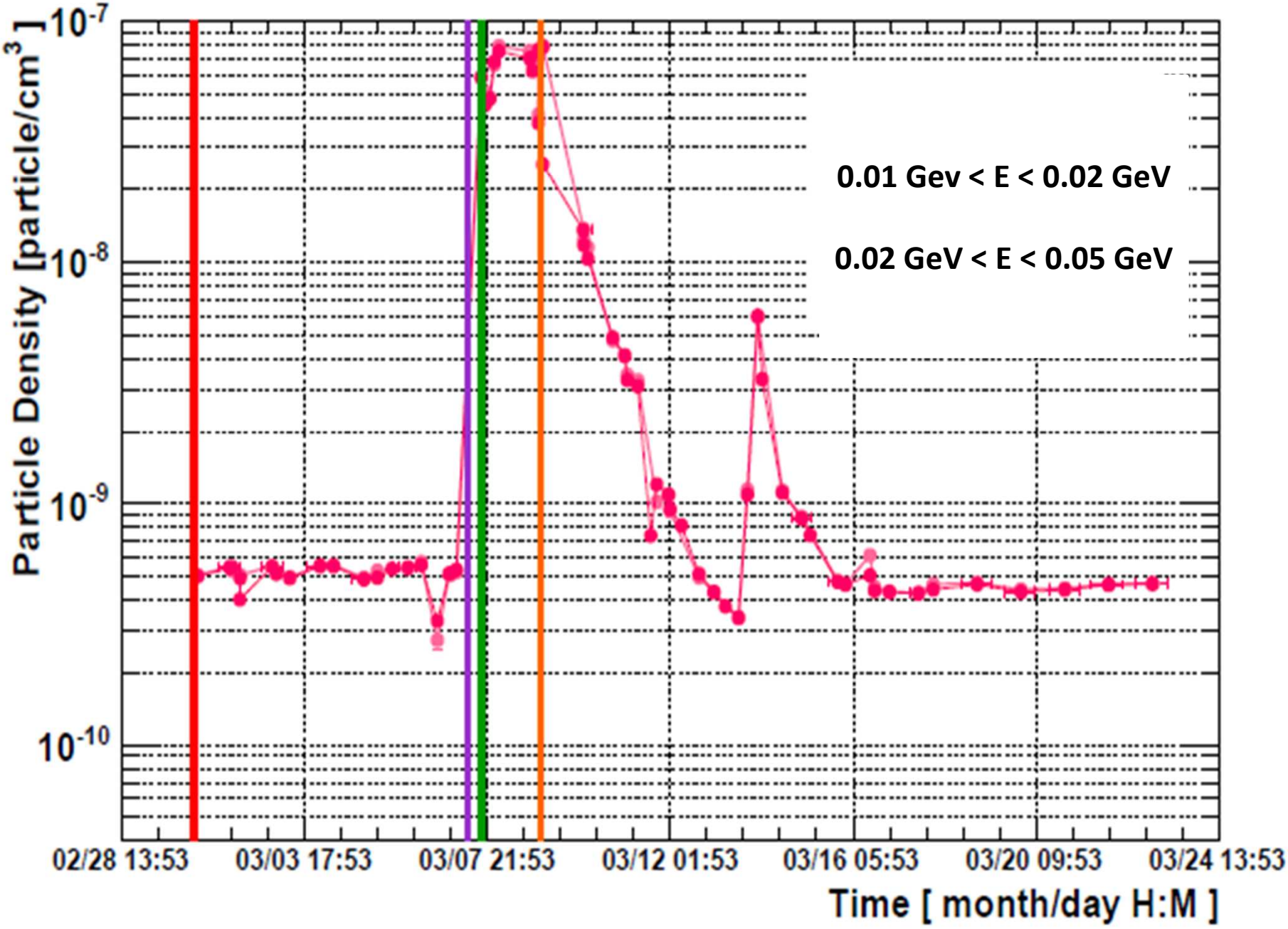
So these analytical formulas do not correctly describe the spectrum in the whole energy range.

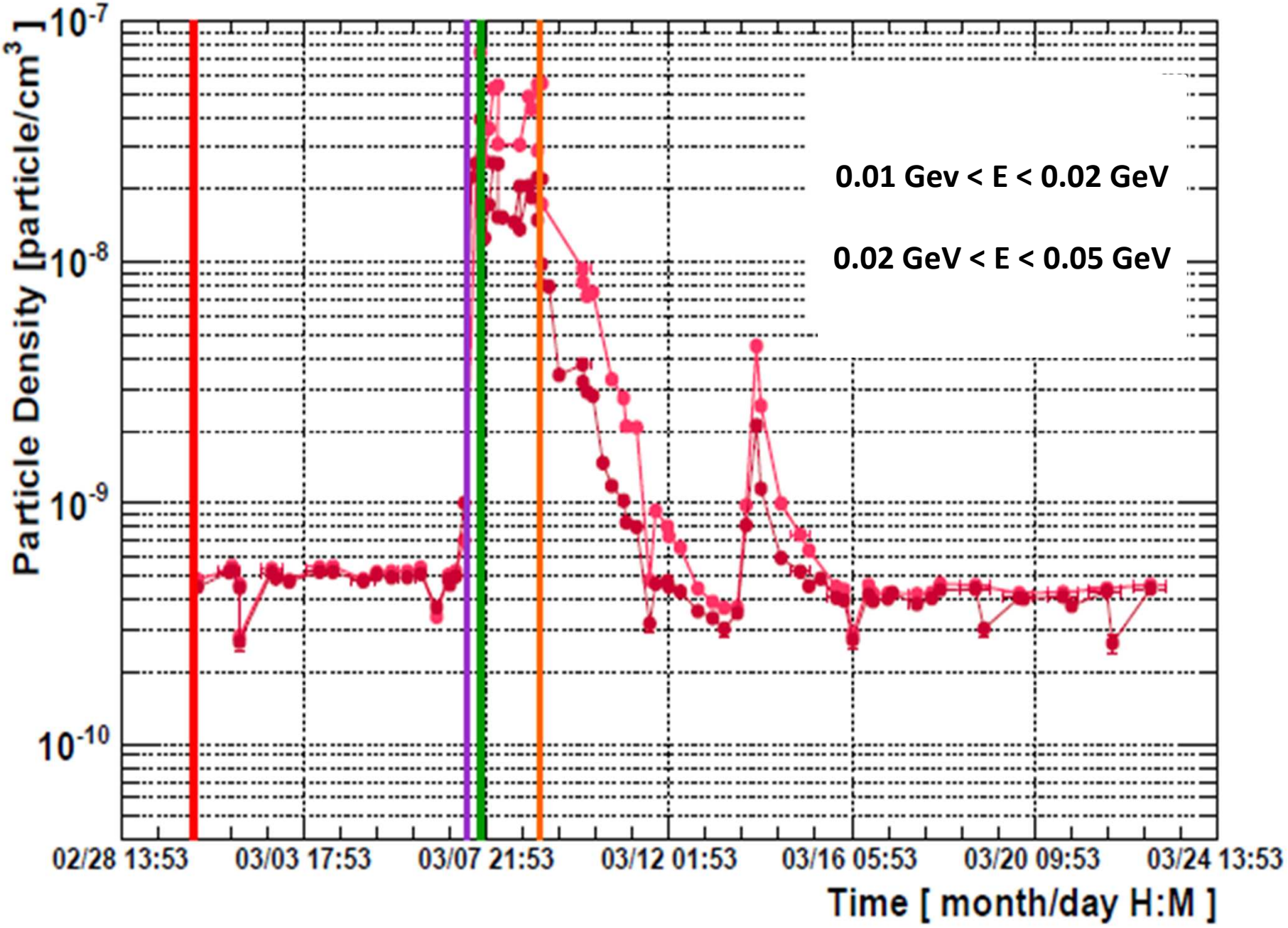

Spectral index (March 7 Flare)
Spectral Index γ
preliminary
Power Law (0.70 - 1.30 GV)
Power Law (0.40 - 0.90 GV)
Power Law (0.40 - 0.70 GV)
03-08 00:00
03-09 00:00
03-10 00:00
03-11 00:00
03-12 00:00
03-13 00:00
Chi Square
χ²/NDF
χ² 3.91 ± 0.8851

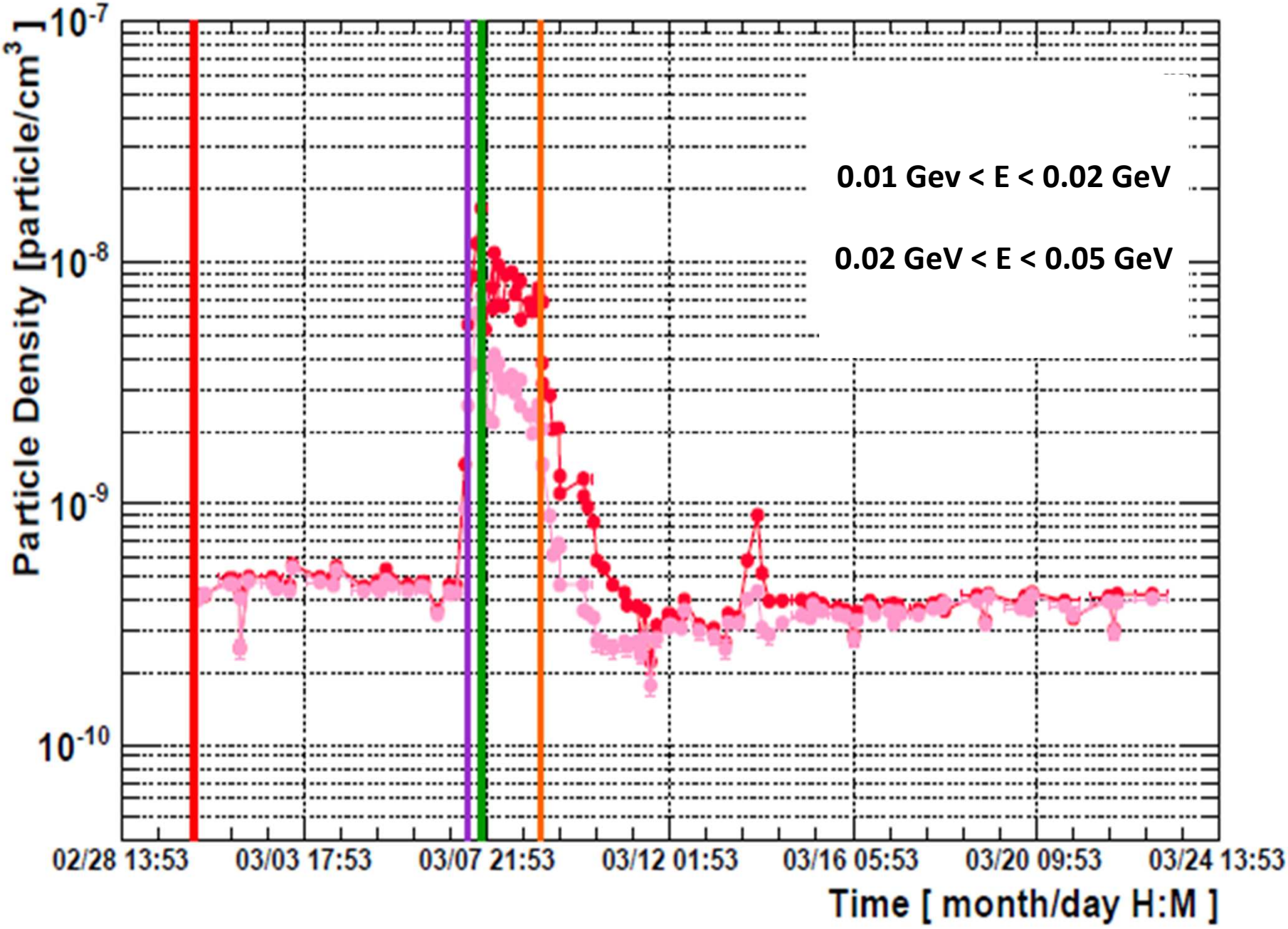
CONCLUSIONS

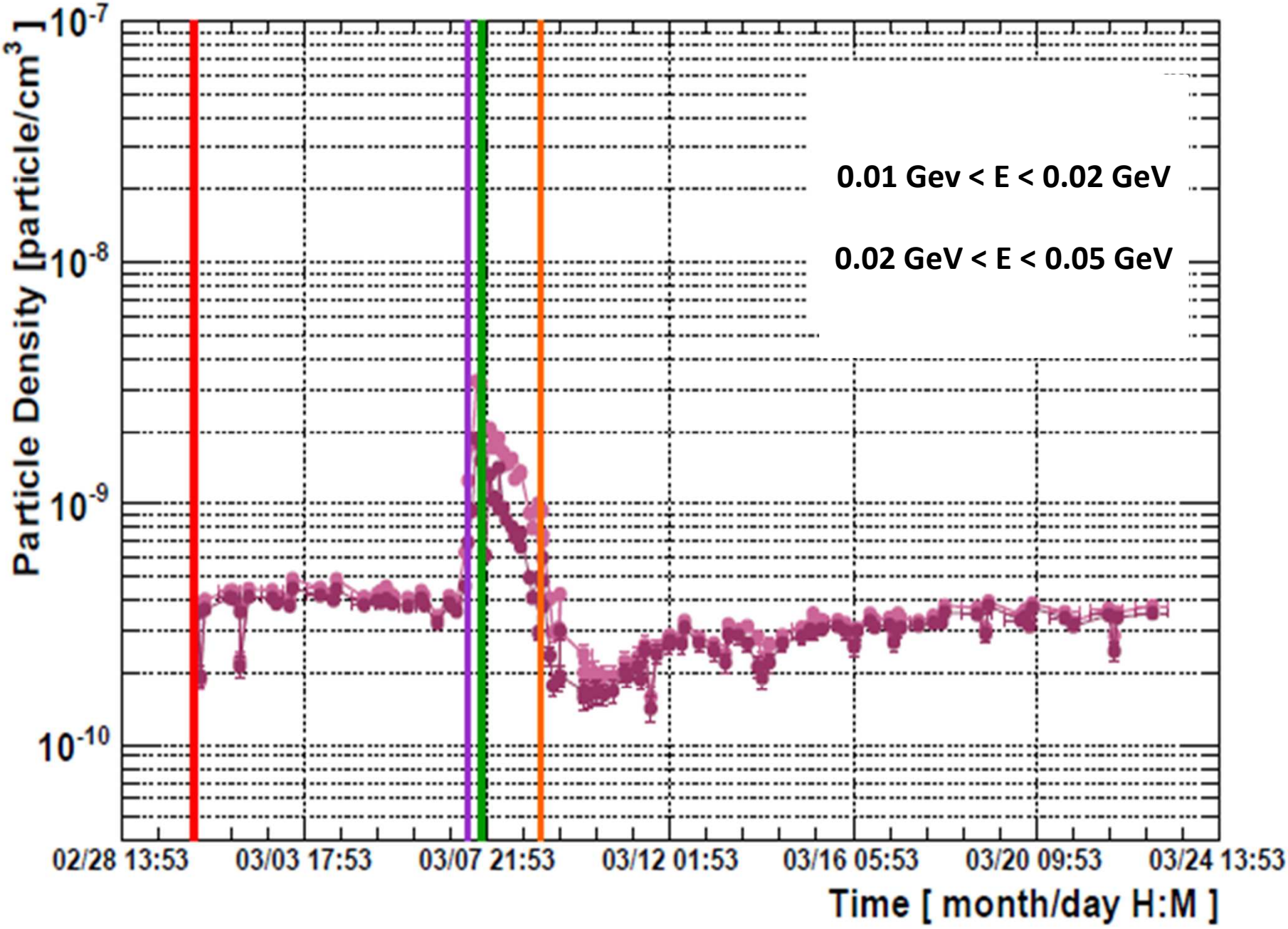
- PAMELA can study in depth the strongest flare that can be produced by the Sun, with a great energy precision
- Different types of flare could be compared to understande bettere acceleration mechanisms
- The cutoff dependence permits the detection of very low energy particle at Poles
- Due to the great precision and redundancy of PAMELA instrumentation, it could study different particle compositions during the events
- Study on acceleration mechanisms could improve our knowledge on transport mechanisms in the inner heliosphere

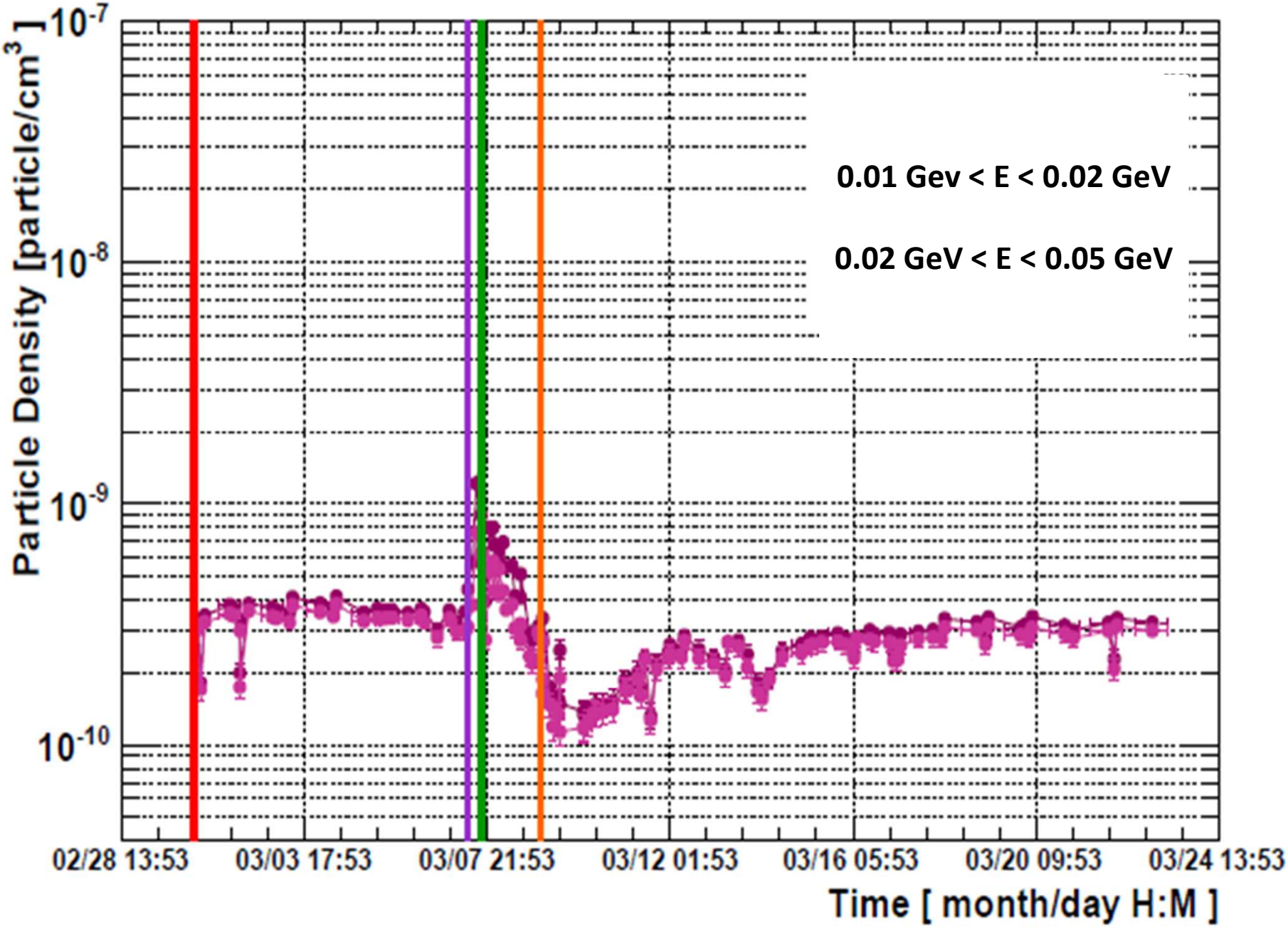
BACKUP SLIDES

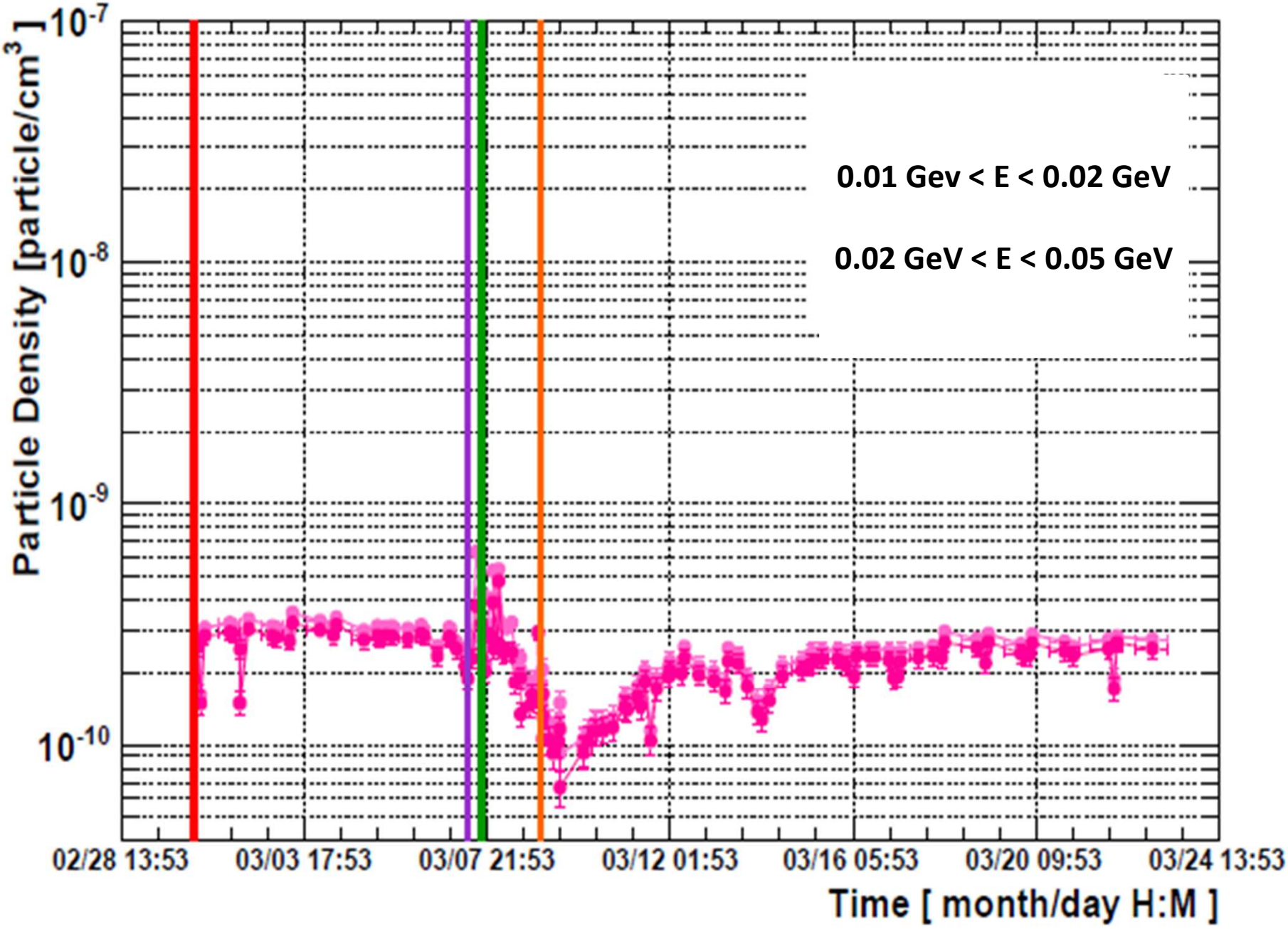

Particle Density [particle/cm^3]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.01 Gev < E < 0.02 GeV
0.02 GeV < E < 0.05 GeV
02/28 13:53
03/03 17:53
03/07 21:53
03/12 01:53
03/16 05:53
03/20 09:53
03/24 13:53
Time [month/day H:M]


Particle Density [particle/cm^3]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.01 Gev < E < 0.02 GeV
0.02 GeV < E < 0.05 GeV
02/28 13:53
03/03 17:53
03/07 21:53
03/12 01:53
03/16 05:53
03/20 09:53
03/24 13:53
Time [month/day H:M]


Particle Density [particle/cm^3]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.01 Gev < E < 0.02 GeV
0.02 GeV < E < 0.05 GeV
02/28 13:53
03/03 17:53
03/07 21:53
03/12 01:53
03/16 05:53
03/20 09:53
03/24 13:53
Time [month/day H:M]


Particle Density [particle/cm^3]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.01 Gev < E < 0.02 GeV
0.02 GeV < E < 0.05 GeV
02/28 13:53
03/03 17:53
03/07 21:53
03/12 01:53
03/16 05:53
03/20 09:53
03/24 13:53
Time [month/day H:M]


Particle Density [particle/cm^3]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.01 Gev < E < 0.02 GeV
0.02 GeV < E < 0.05 GeV
02/28 13:53
03/03 17:53
03/07 21:53
03/12 01:53
03/16 05:53
03/20 09:53
03/24 13:53
Time [month/day H:M]


Particle Density [particle/cm^3]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
0.01 Gev < E < 0.02 GeV
0.02 GeV < E < 0.05 GeV
02/28 13:53
03/03 17:53
03/07 21:53
03/12 01:53
03/16 05:53
03/20 09:53
03/24 13:53
Time [month/day H:M]