

RICAP 2013
Università degli Studi di Roma La Sapienza
22-24 May 2

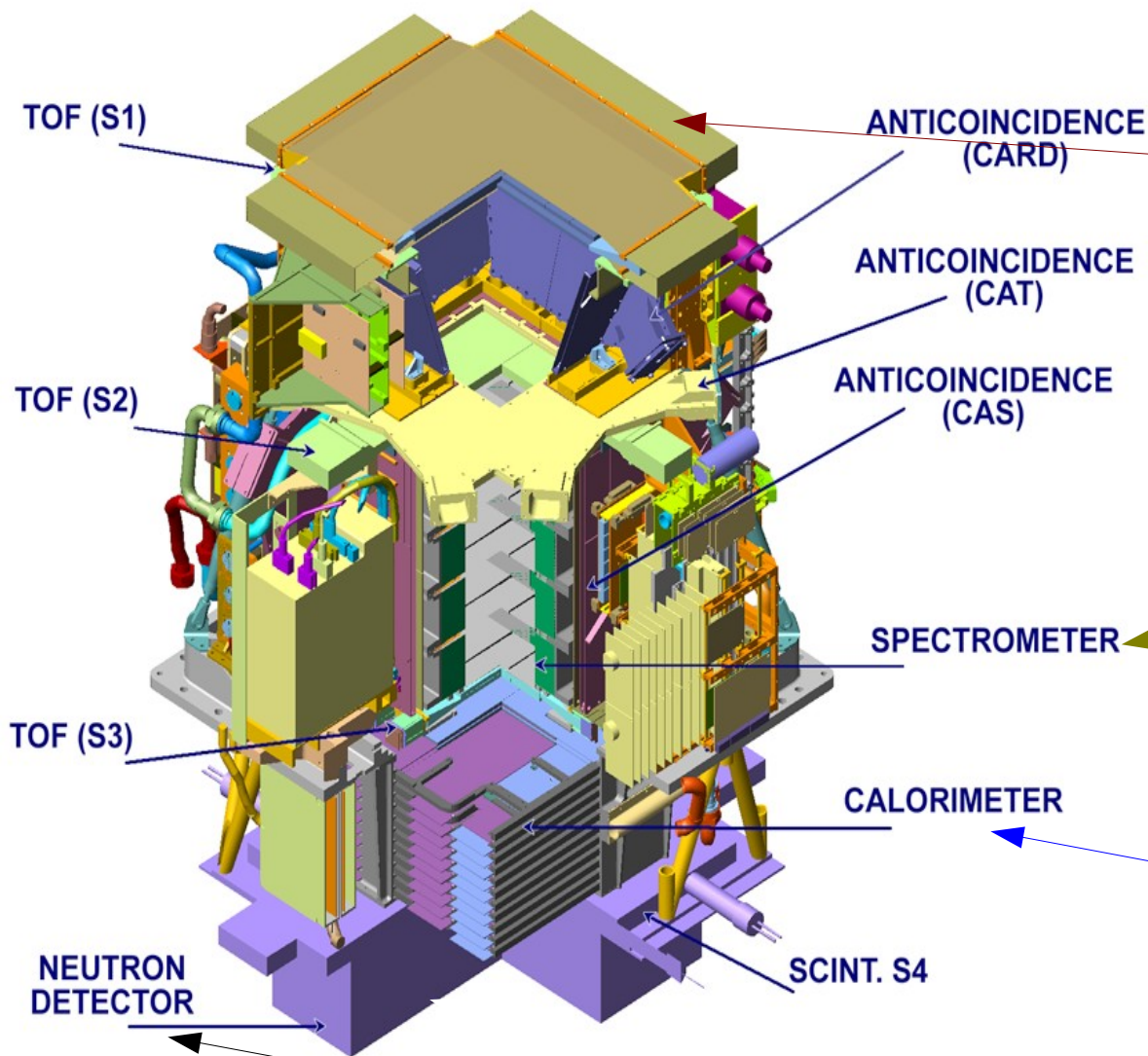
Multiparticle Analysis of Forbush Decrease of the 13th December 2006 Solar Event with the PAMELA Experiment



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PAMELA Apparatus



- S1, S2, S3; double layers, x-y
- plastic scintillator (8mm)
- ToF resolution ~ 300 ps (S1-3 ToF > 3 ns)
- lepton-hadron separation < 1 GeV/c
- S1.S2.S3 (low rate) / S2.S3 (high rate)

- Permanent magnet, 0.43 T
- $21.5 \text{ cm}^2 \text{ sr}$
- 6 planes double-sided silicon strip detectors ($300 \mu\text{m}$)
- $3 \mu\text{m}$ resolution in bending view
MDR $\sim 1.2 \text{ TV}$

- 44 Si-x / W / Si-y planes (380)
- $16.3 \text{ X0} / 0.6 \text{ L}$
- $dE/E \sim 5.5 \%$ (10 - 300 GeV)
- Self trigger $> 300 \text{ GeV} / 600 \text{ cm}^2 \text{ sr}$

- 36 ^3He counters
- $^3\text{He}(n,p)\text{T}$; $E_p = 780 \text{ keV}$
- 1 cm thick poly + Cd moderator
- $200 \mu\text{s}$ collection

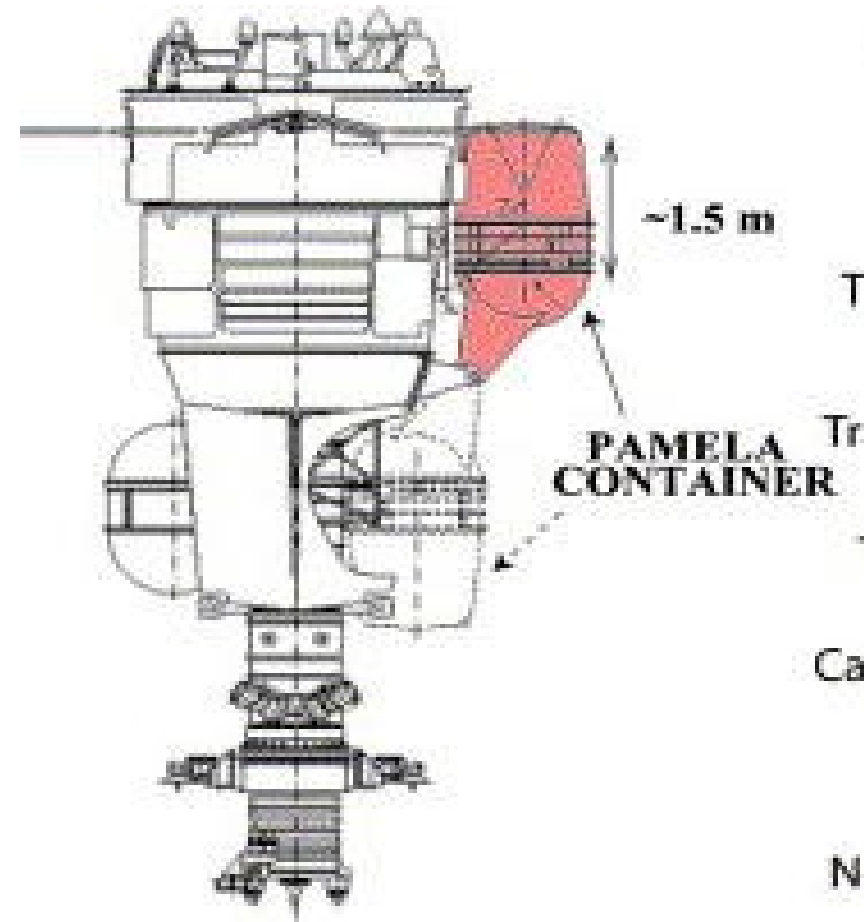
More info on the apparatus:

Astropart. Phys. 27 (2007) 296

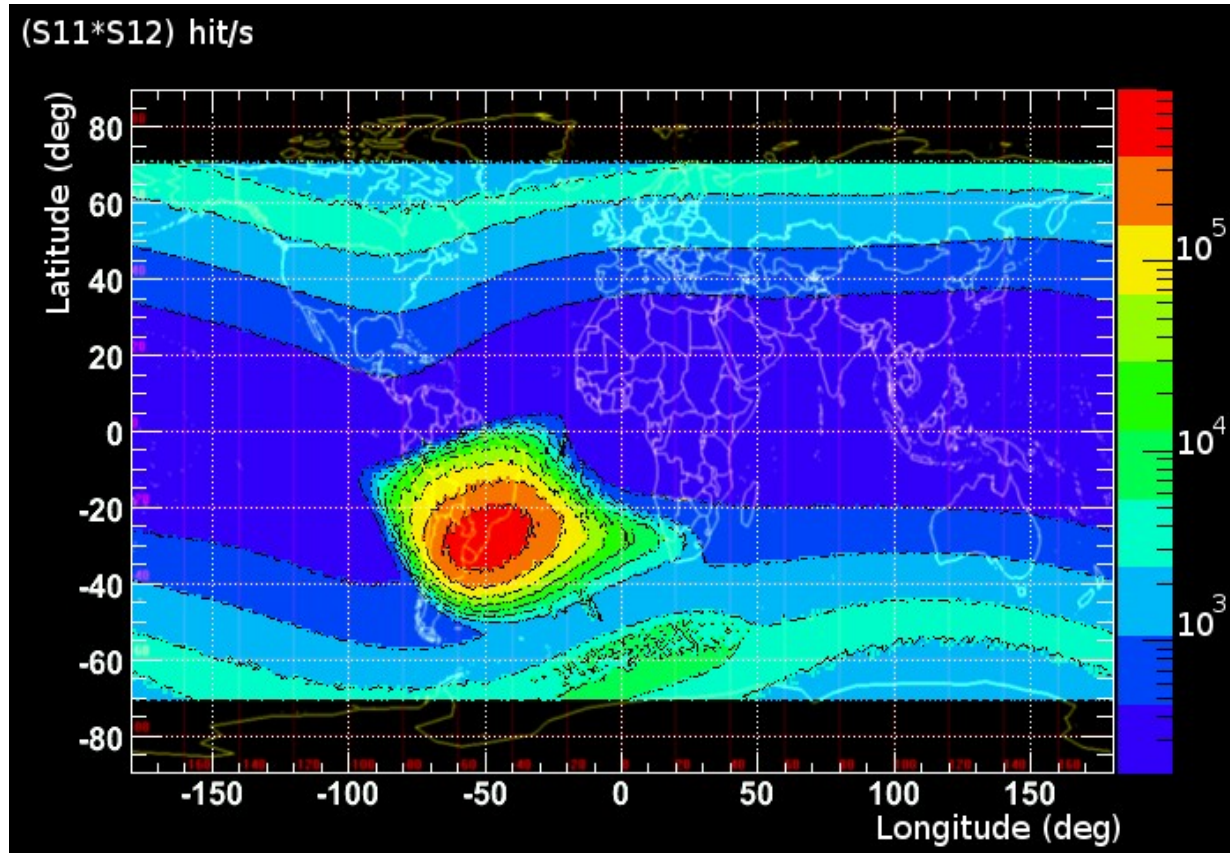
PAMELA Orbit

- Low Orbit: 350 – 610 km
 - (now circular with $\sim 570\text{km}$)
- Inclination: 70°
- Duration: $\sim 90'$

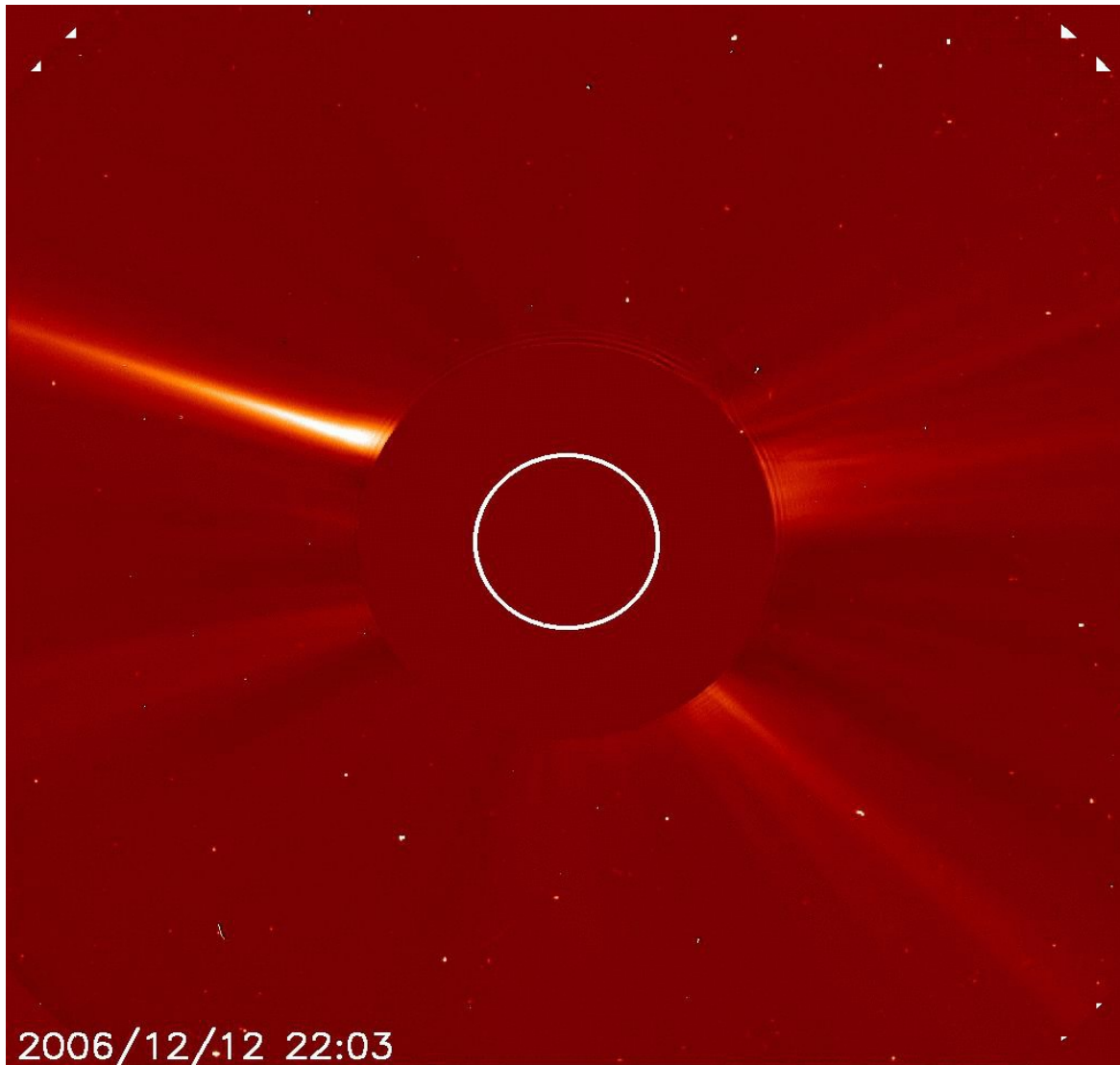
Geomagnetic cutoff $< 50\text{ MV}$ at poles
The orbit does not limit the lowest detectable energy.



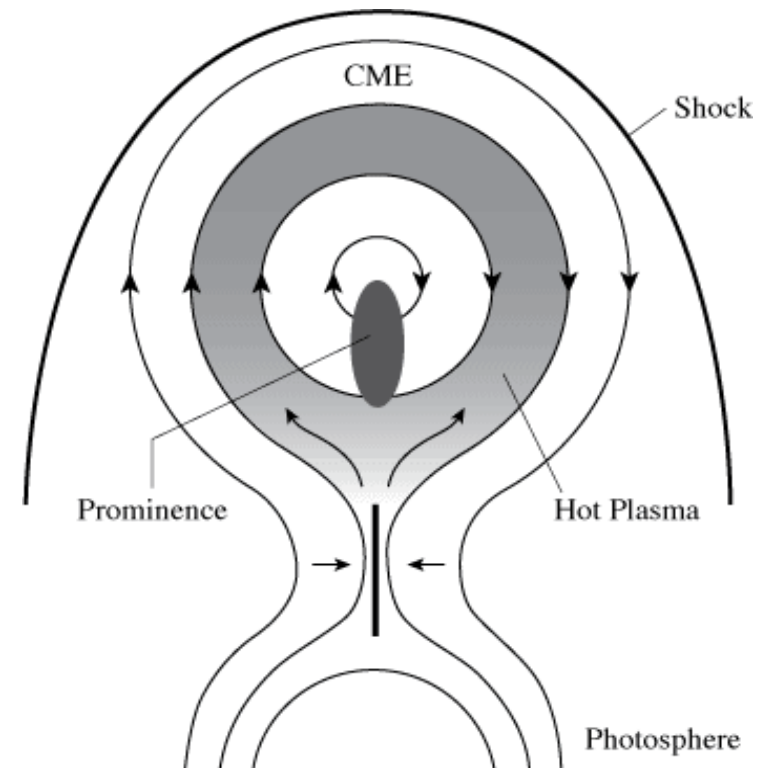
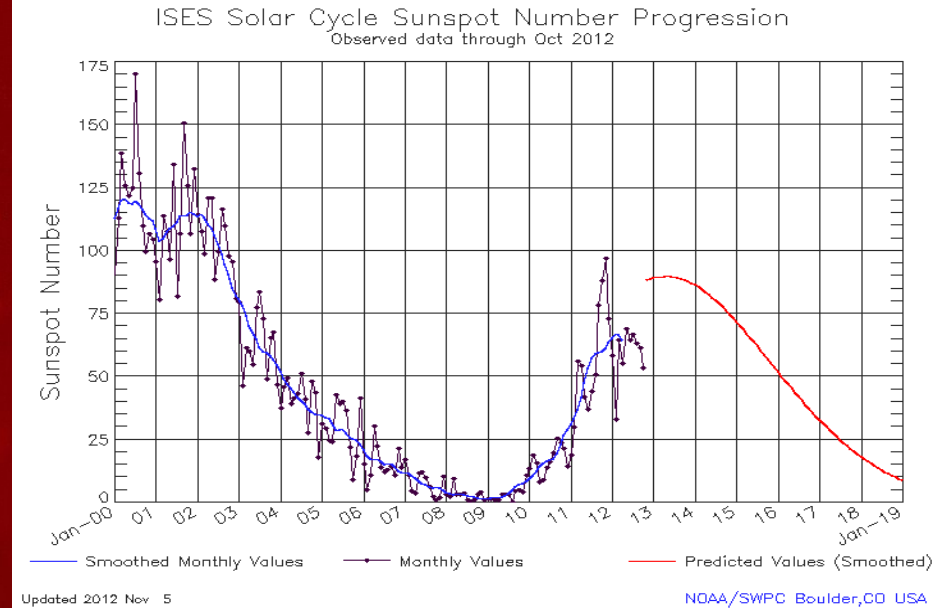
- Geom. Factor: $\sim 21.5\text{ cm}^2\text{ sr}$
- Mass: 470 kg
- Dimensions: $130 \times 70 \times 70\text{ cm}^3$
- Days in orbit: ~ 2600



Dec 2006 Solar Event



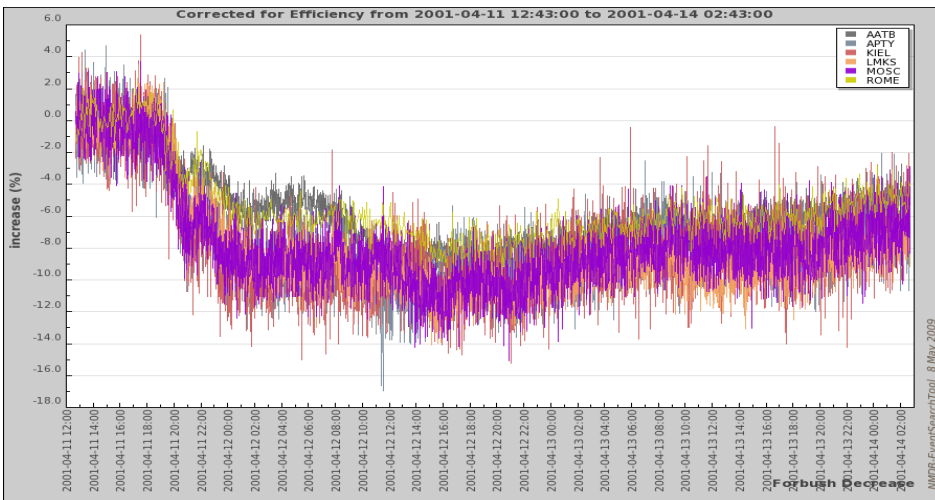
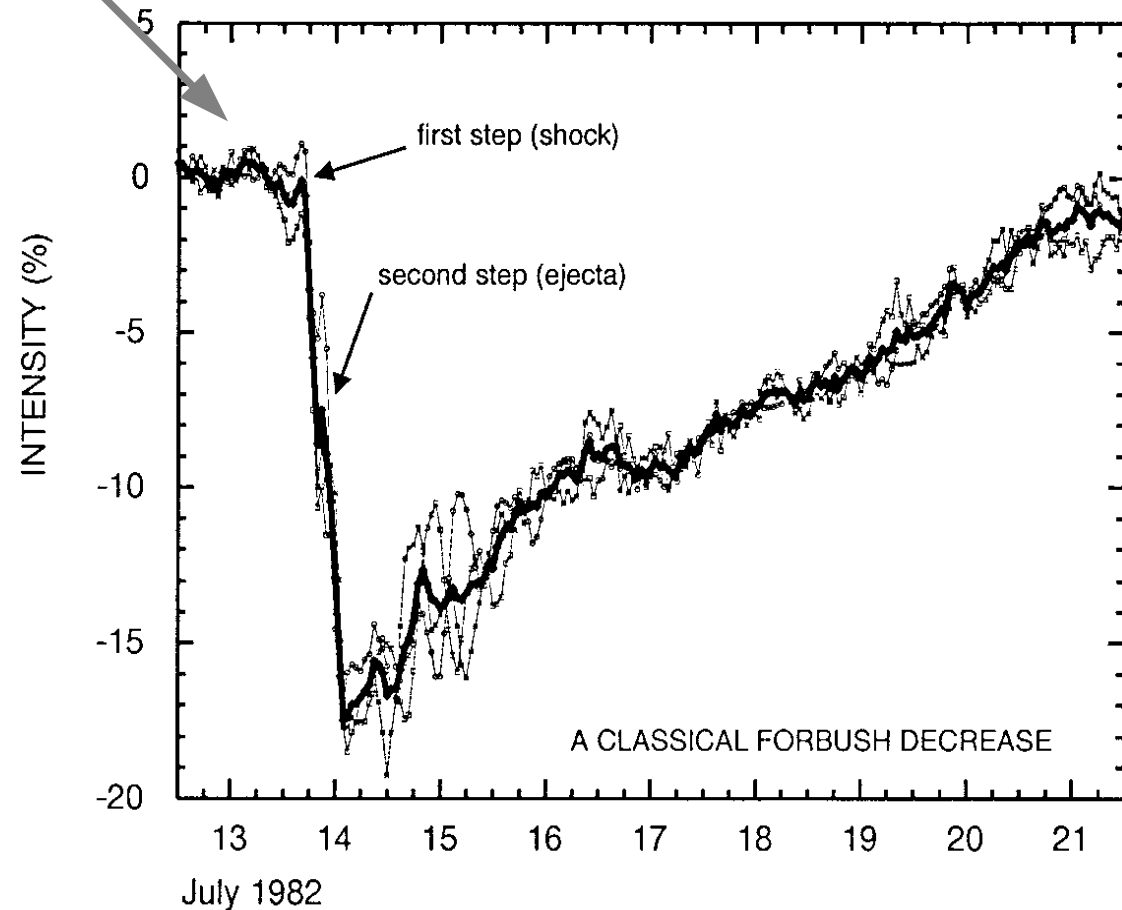
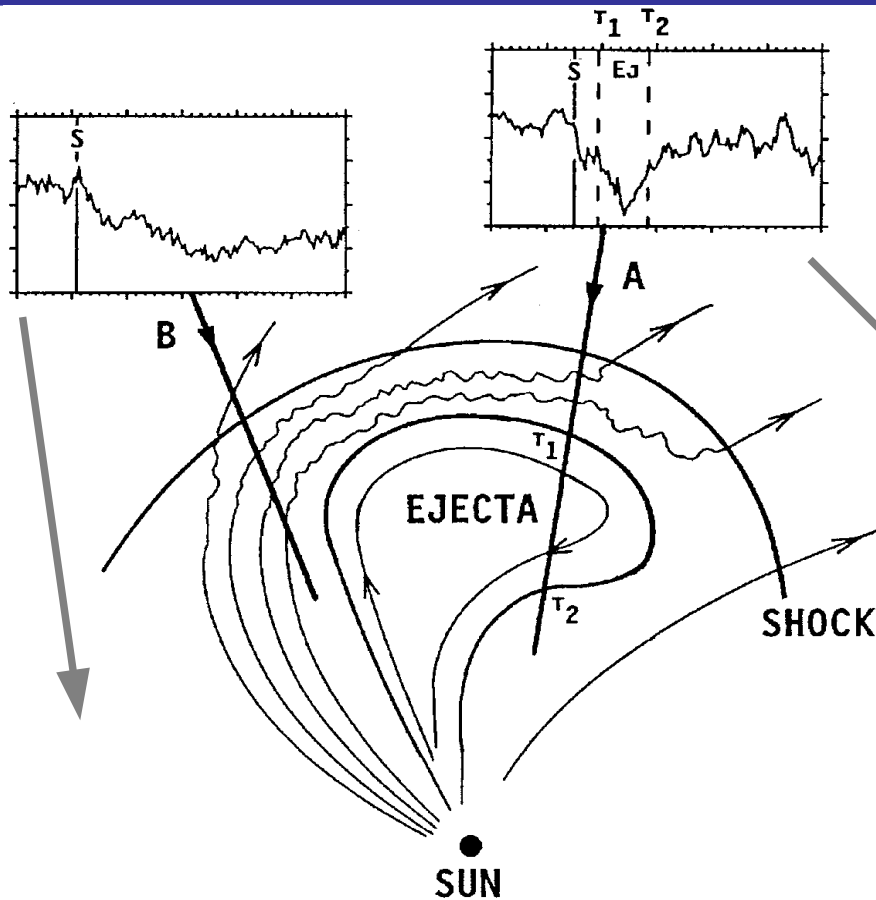
- X3.4 flare and CME → GLE
- Broad event:
 - observed by probes separated 74° in latitude and 119° in longitude



Forbush Effect

Proposed by Scott E. Forbush

Sudden decrease of Galactic Cosmic Rays flux after an intense solar event.

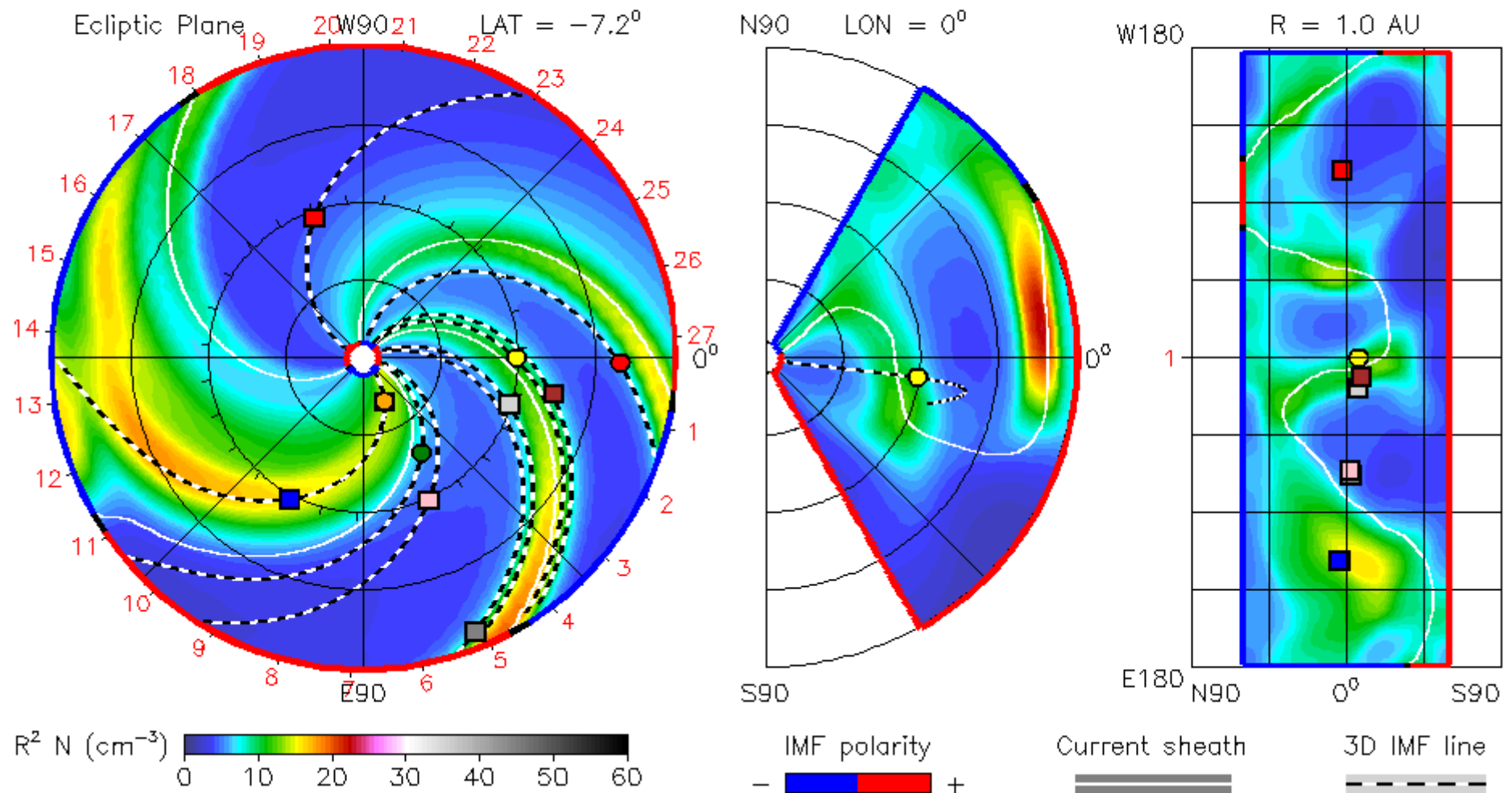


CME Propagation

2012-03-06T00:00

2012-03-06T00 +0.00 day

● Earth ● Mars ● Mercury ● Venus ■ Juno ■ Kepler ■ Messenger ■ MSL
■ Spitzer ■ Stereo_A ■ Stereo_B

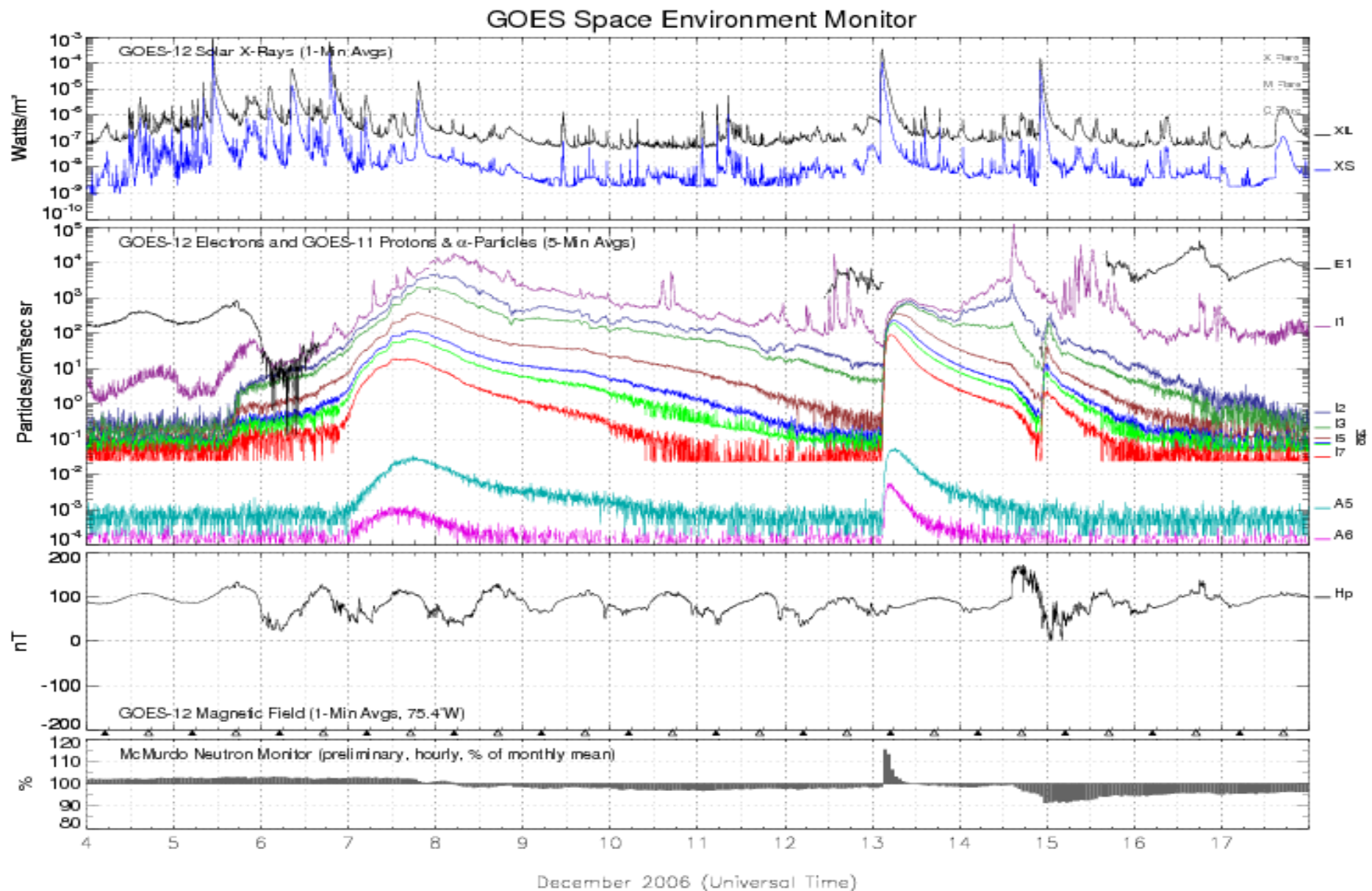


ENUL-2.7 lowres-2121-a3b1f WSA_V2.2 GONG-2121

ccmc/weafr-cld/256x30x90x1.2121-a3b1f.16-mcp1umn1cd-1.q53q5d2.gong-2012-03-06T00 2012-03-07

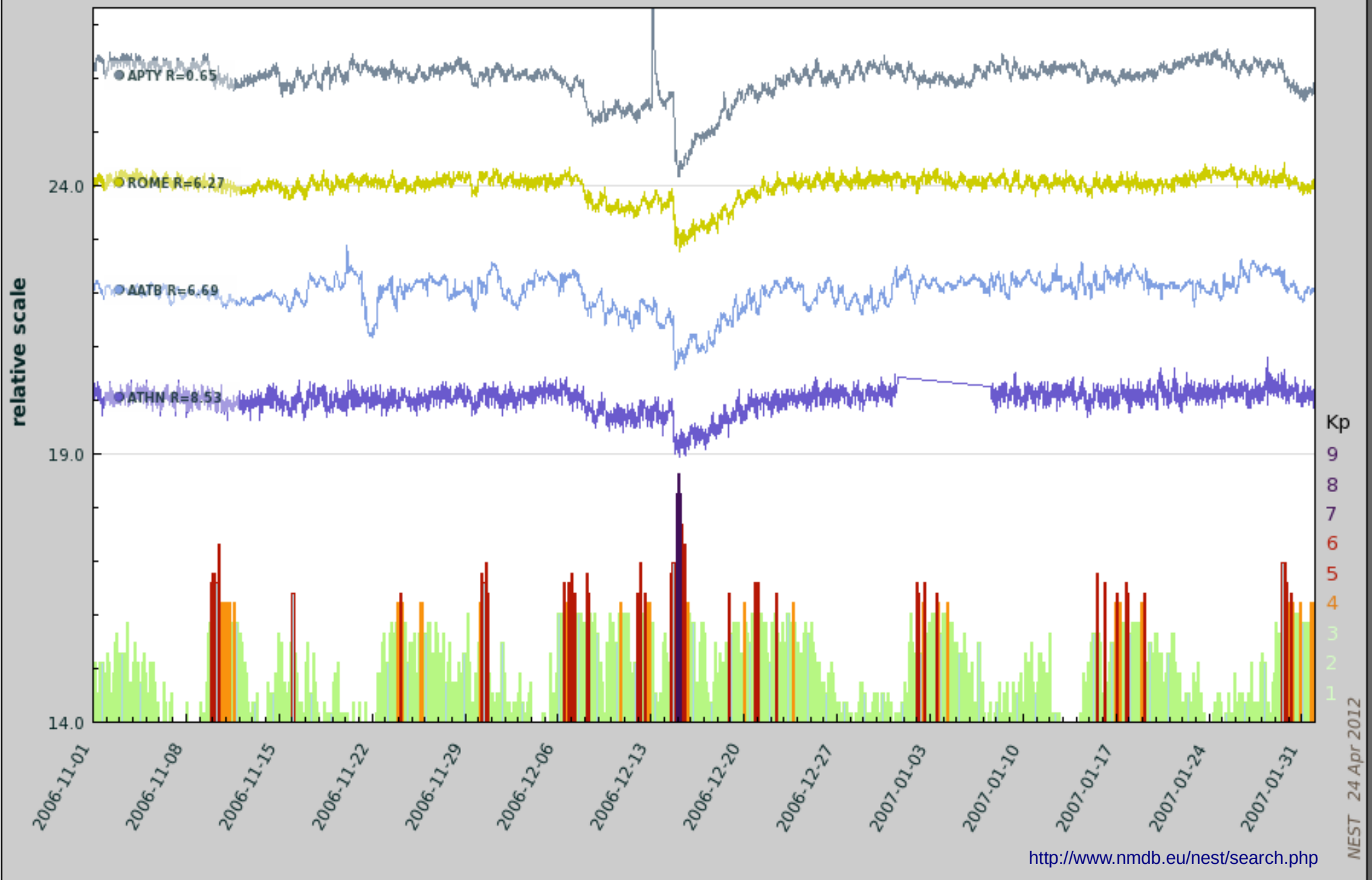
[2]<http://iswa.gsfc.nasa.gov/iswa/iSWA.html>

Space Weather

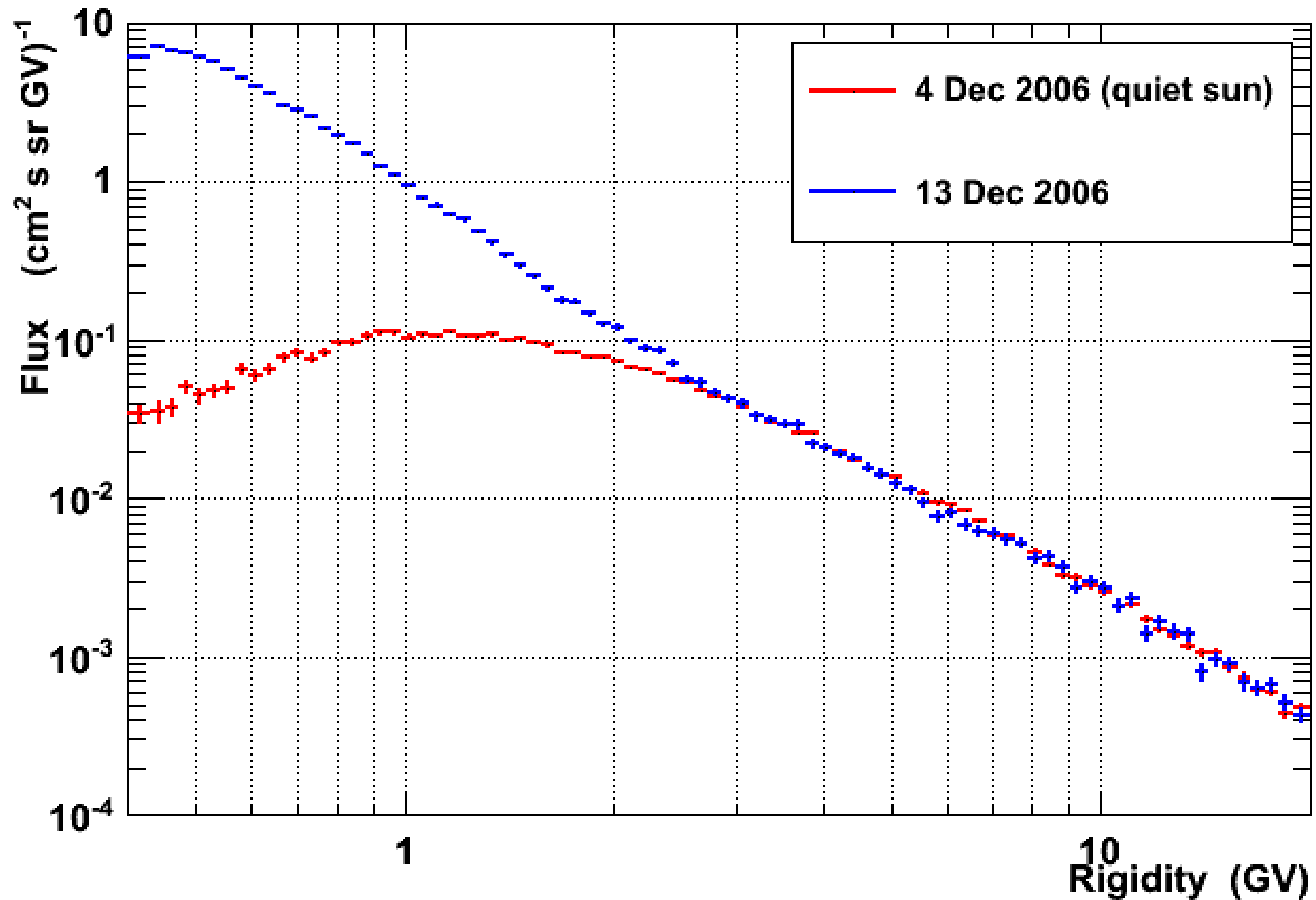


Nmdb

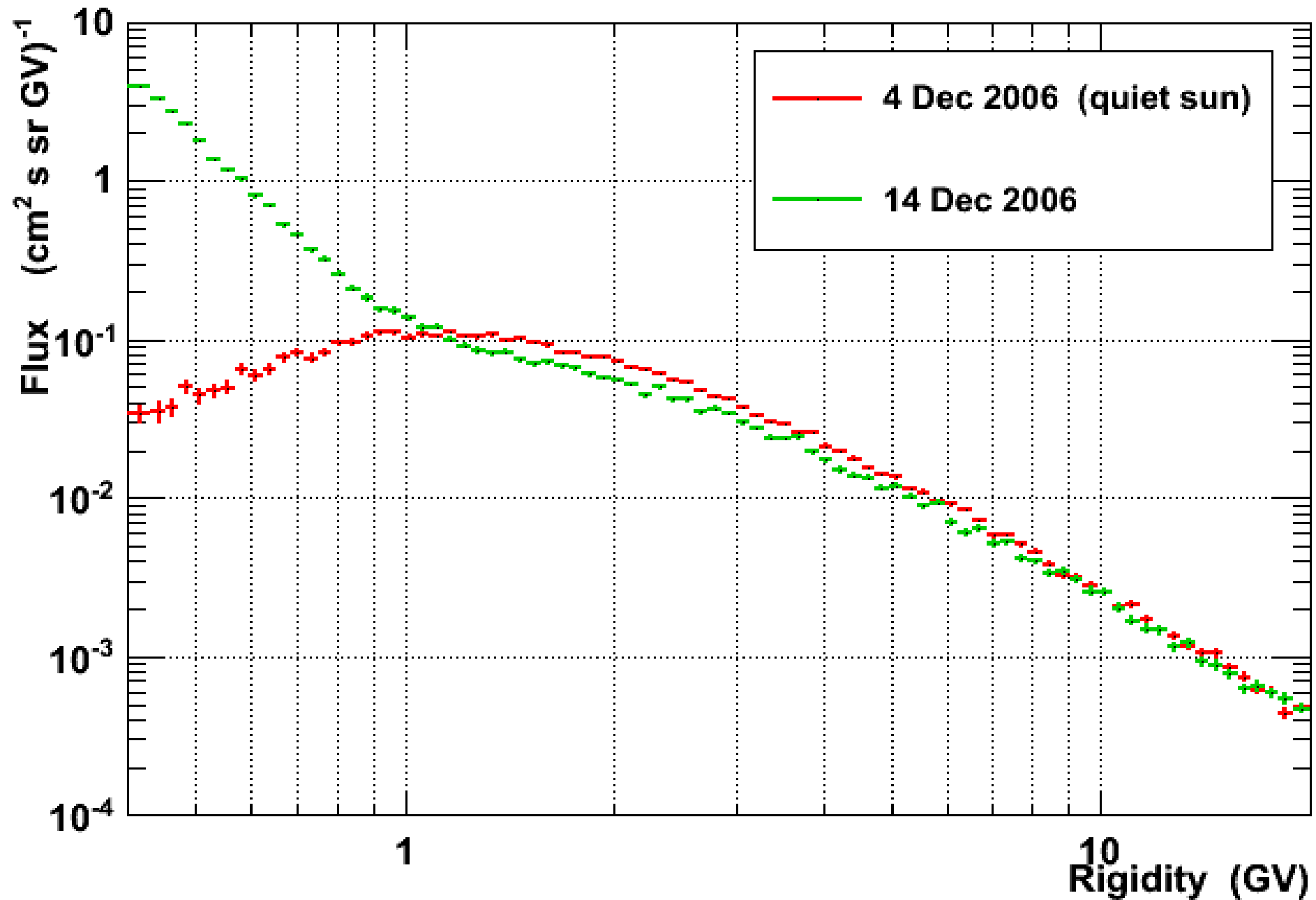
revised corr_for_efficiency values averaged to 30 min from 2006-11-01 00:00:00 to 2007-01-31 23:30:00



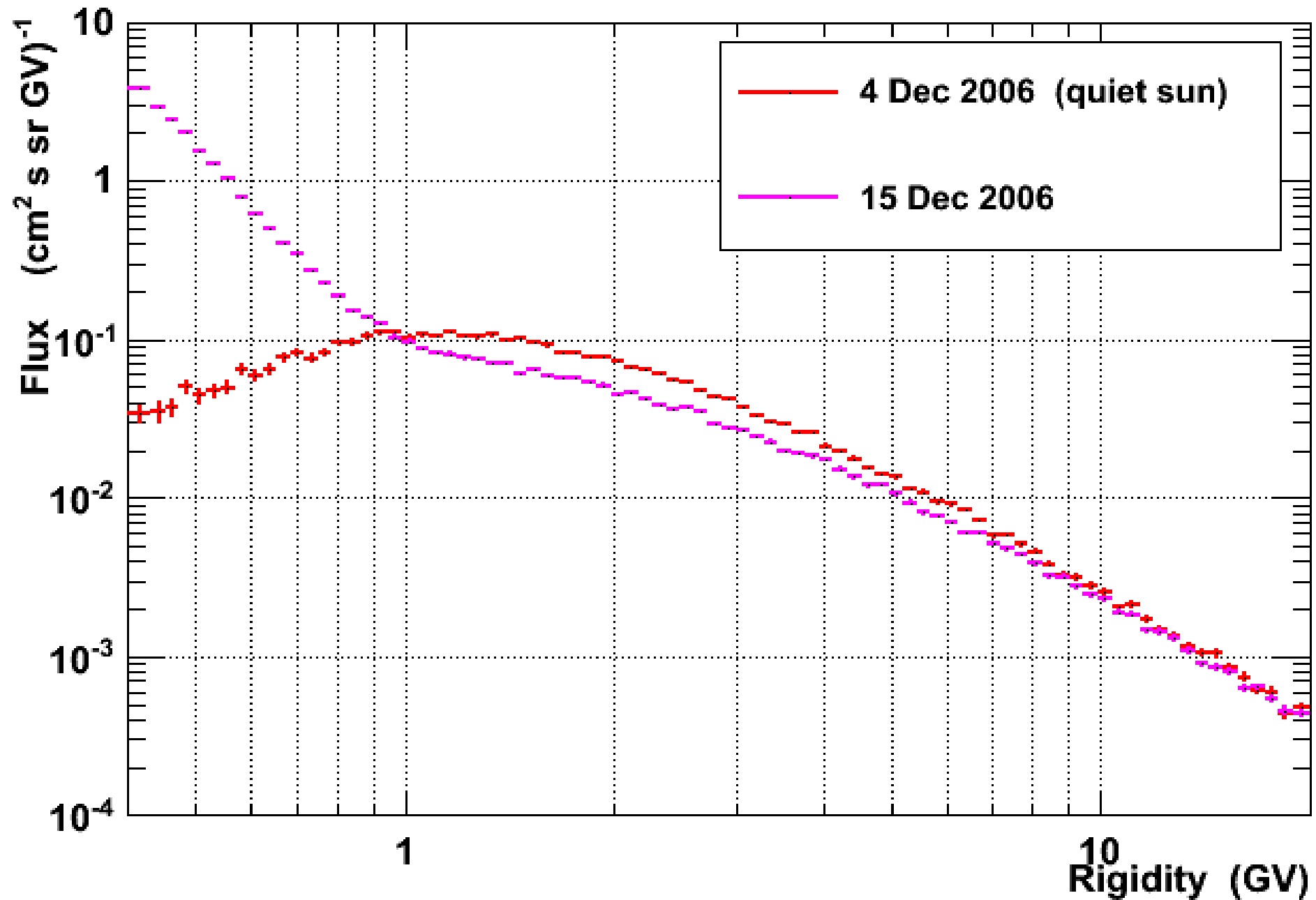
Evolution of the event



Evolution of the event

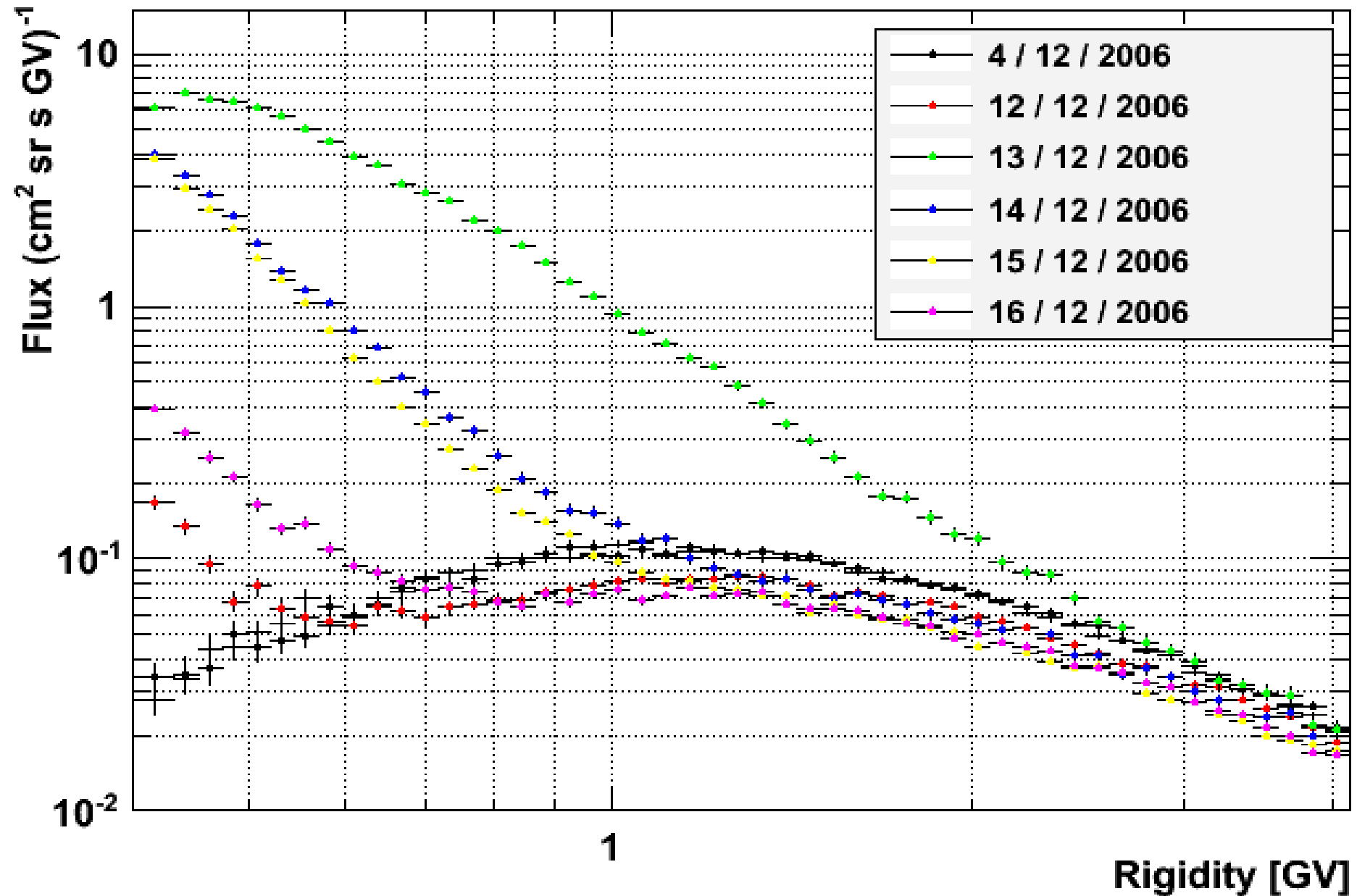


Evolution of the event

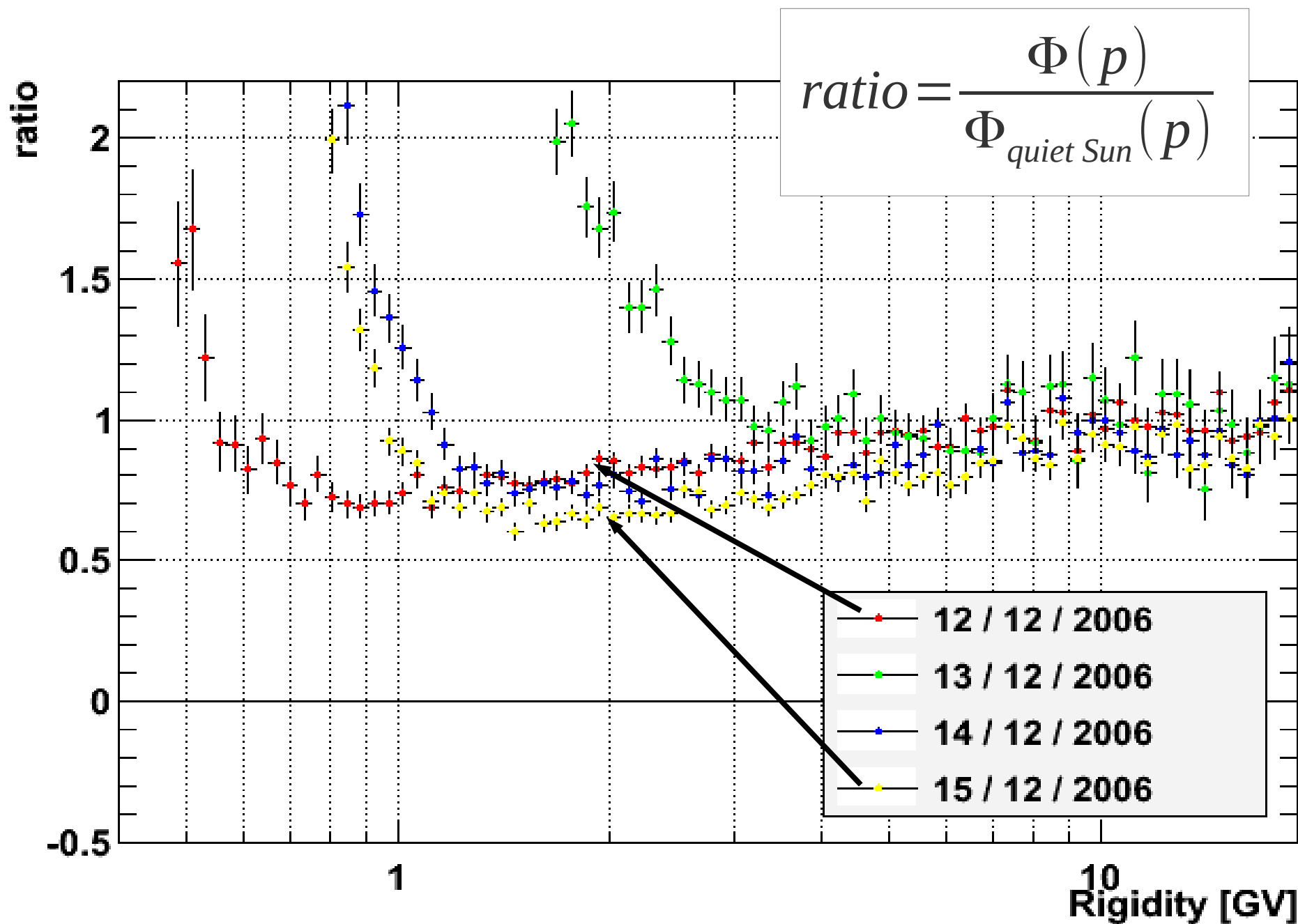


2006 Solar Event

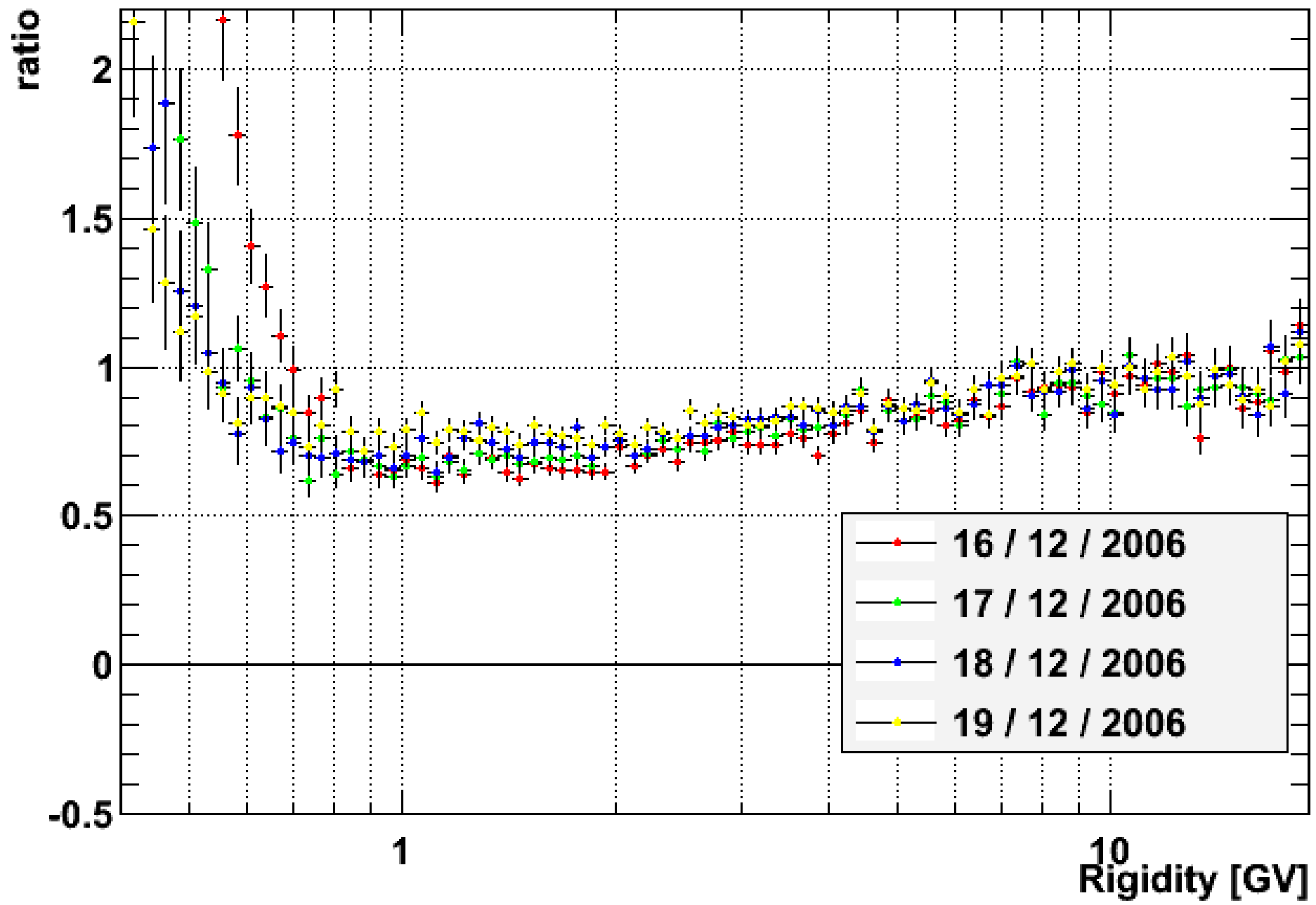
dec 13th solar event



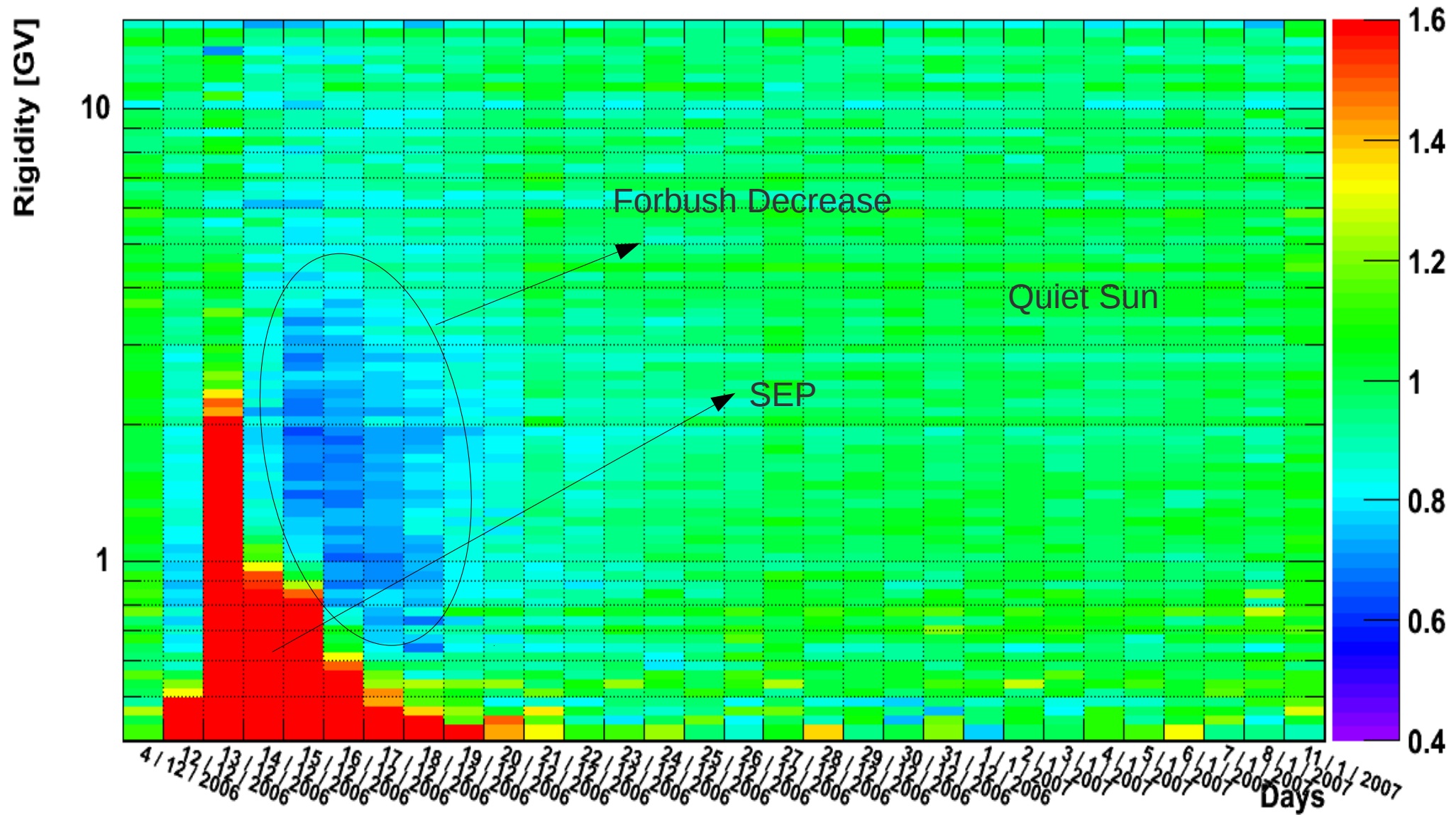
Relative Decrease



Relative Decrease

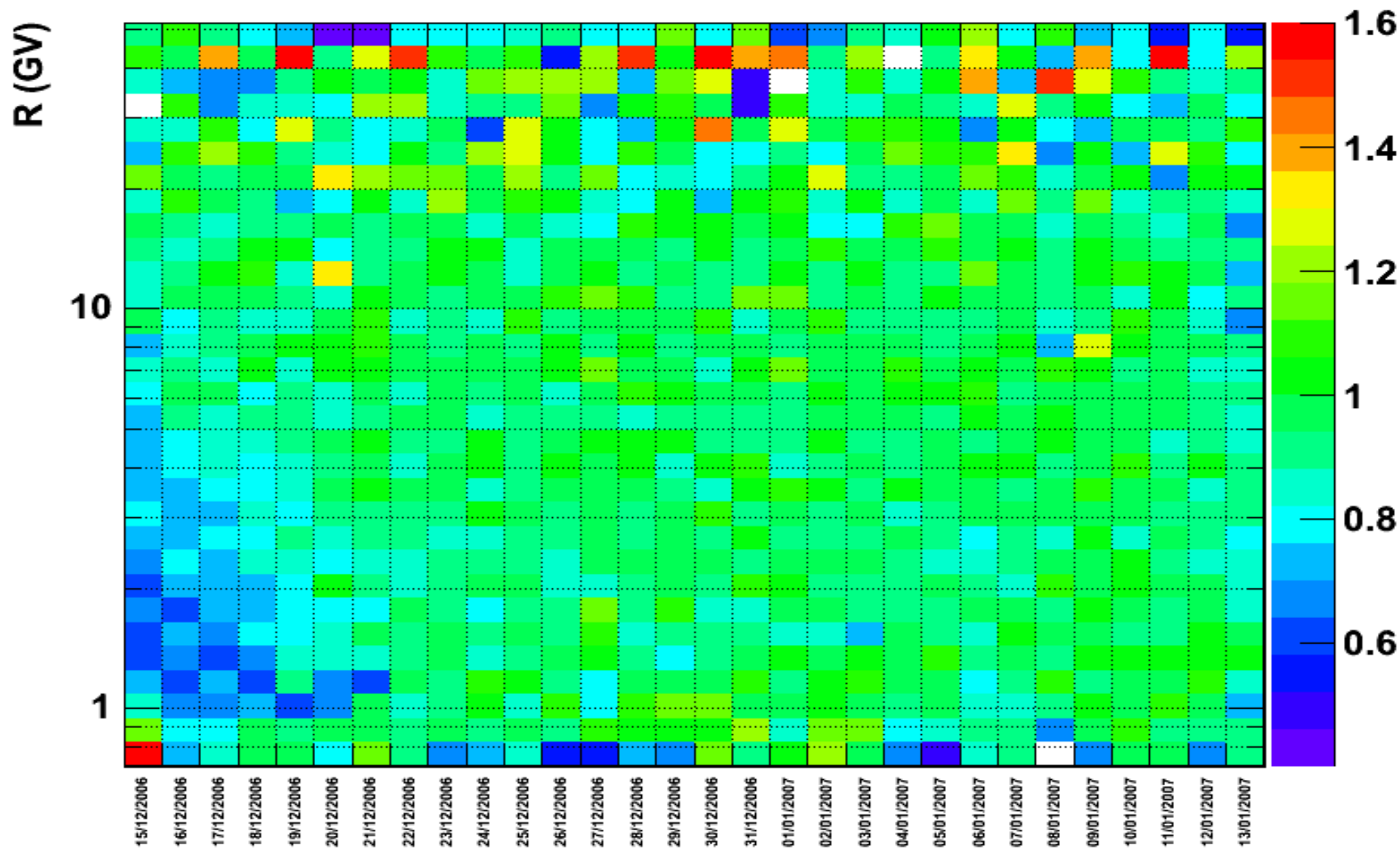


Protons



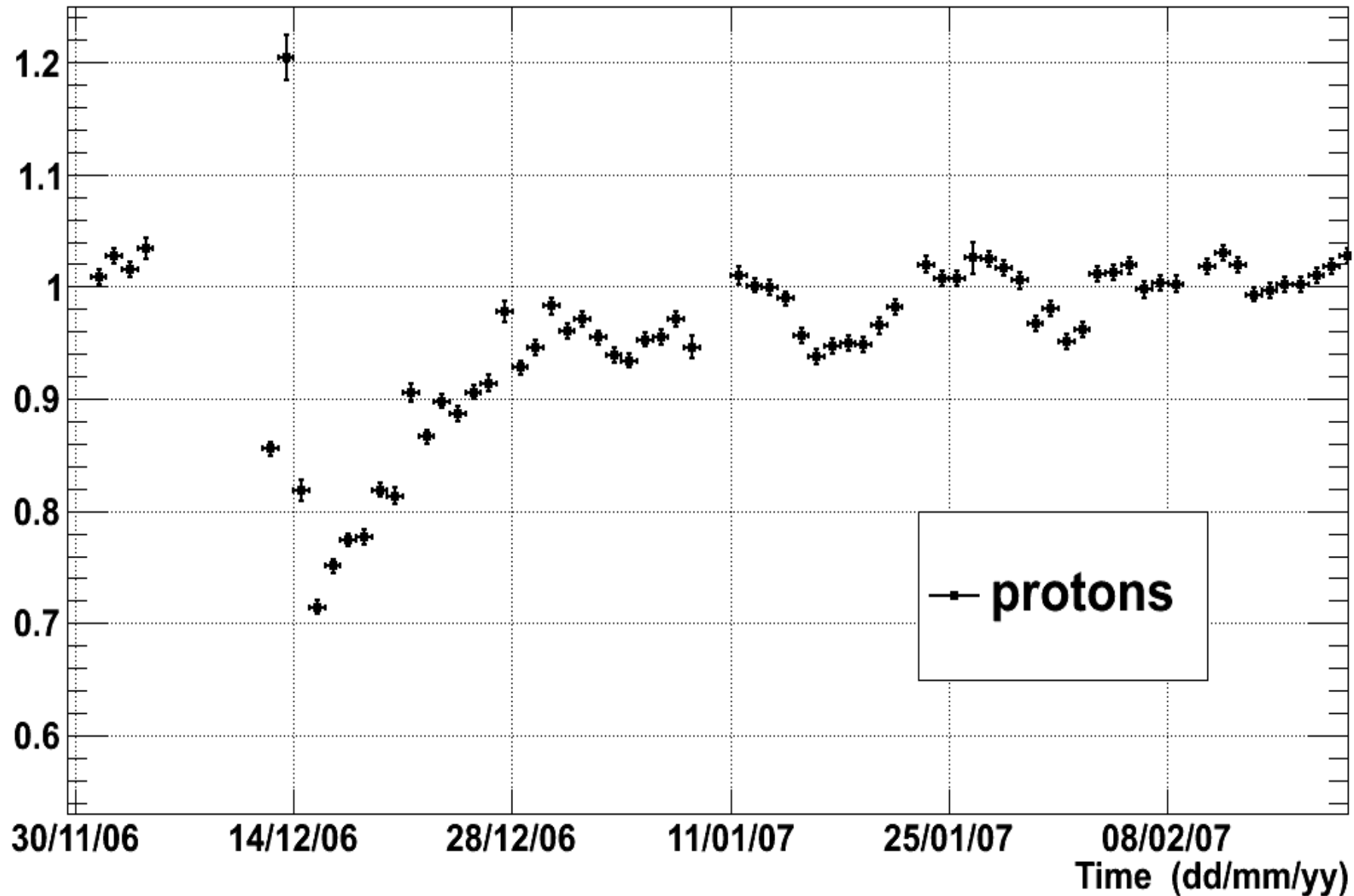
Helium

helium



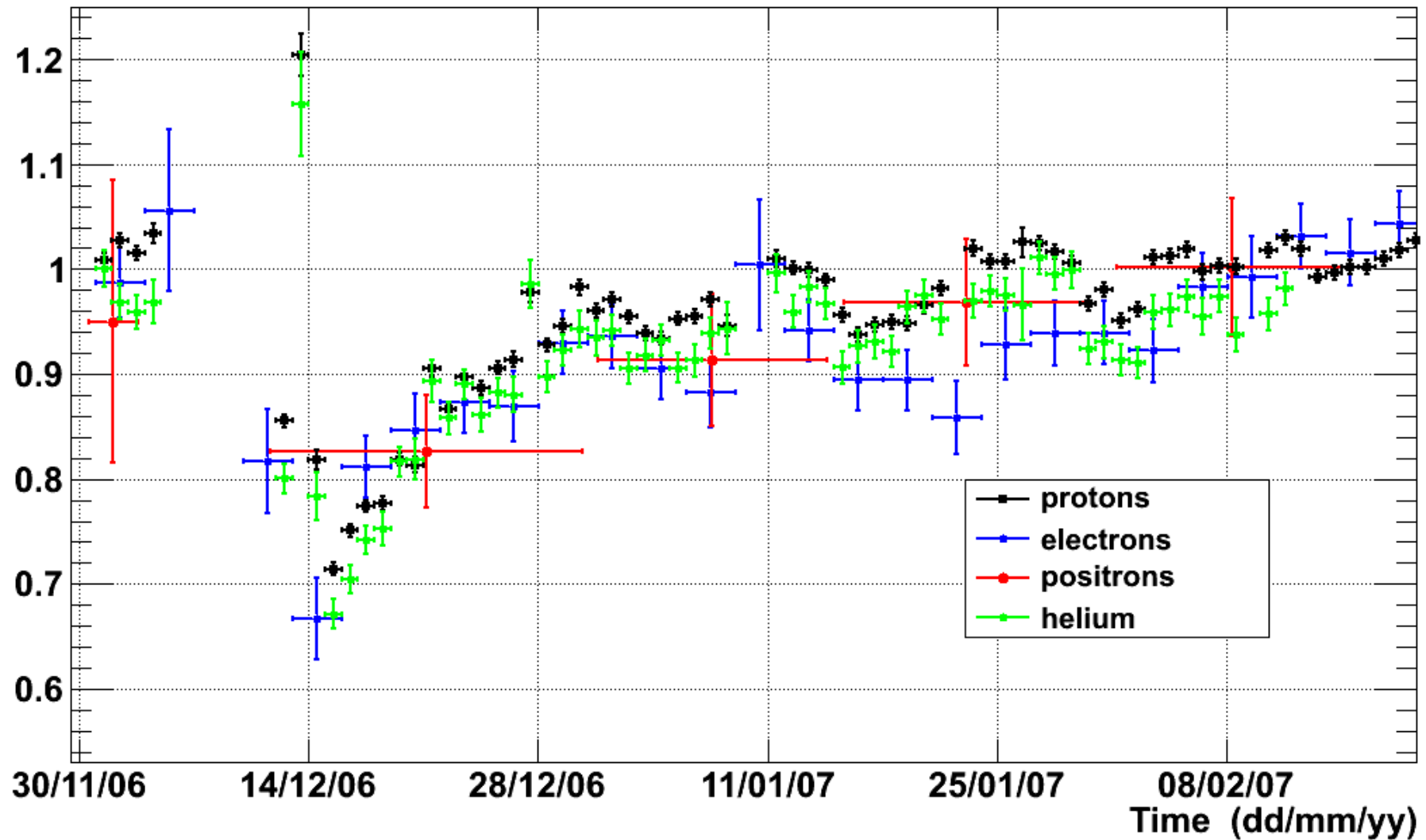
Time Development

Rigidity from 1.57 to 5.70 GV



Multiparticle Comparison

Rigidity from 1.57 to 5.70 GV



Maximum Decrease

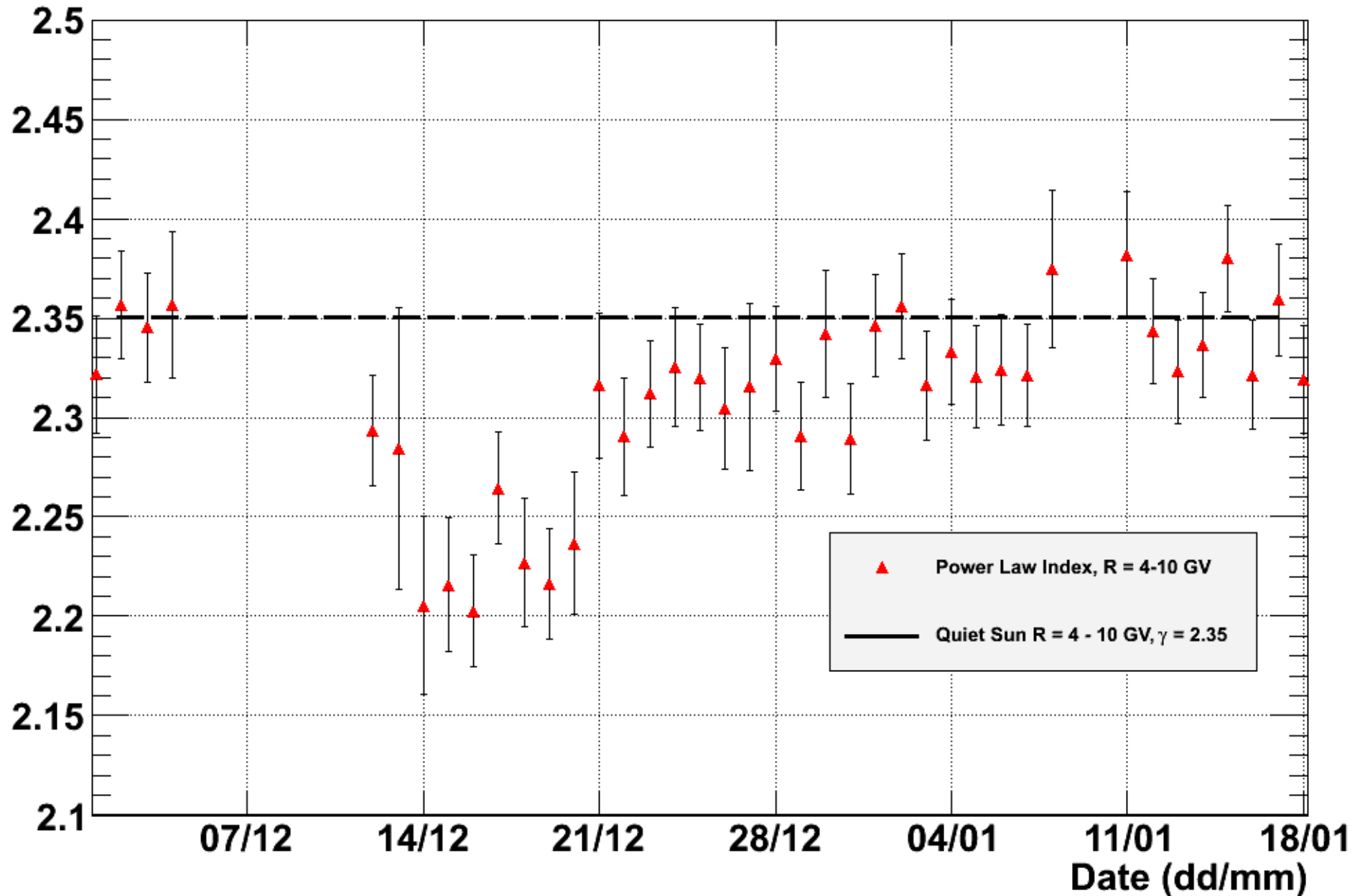
- For the first time in space we have measured the rigidity dependence of the effect. Also for the first time it was possible to measure the effect for different particles.
- During the 13/12/2006 solar event we have measured a peak decrease in the 1.57 – 5.70 GV rigidity range for 4 different components of the galactic cosmic rays:

species	Decrease:
Protons	$(28.5 \pm 0.6)\%$
Electrons	$(33 \pm 4)\%$
Positrons	$(45 \pm 15)\%$
Helium	$(33 \pm 2)\%$

- No evidence of charge/mass dependence. (Broad event)
- PAMELA experiment allows to observe the full rigidity extension of the effect

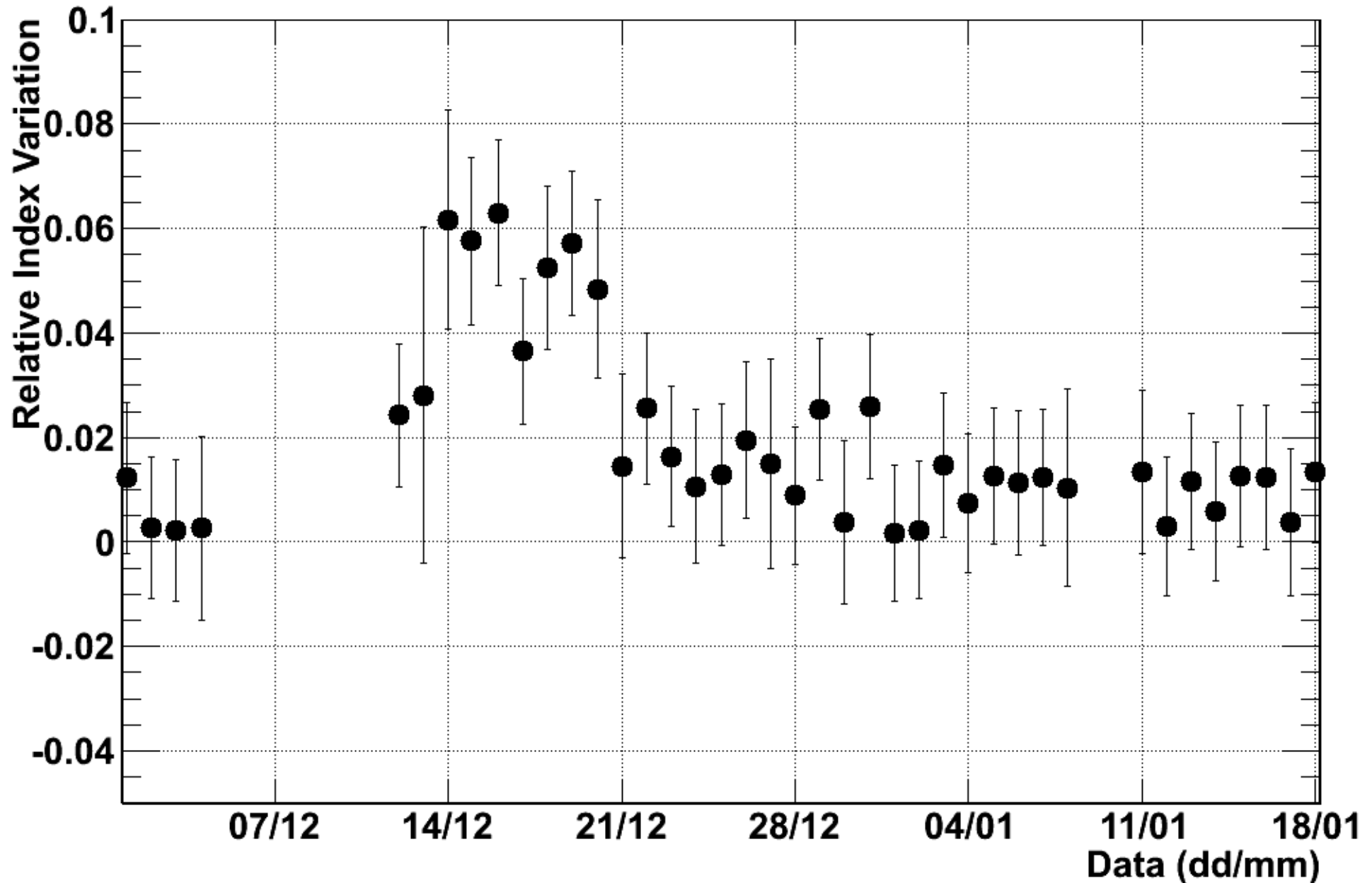
Spectral Index Hardening

Gamma Index quiet Sun comparison



Spectral Index Hardening

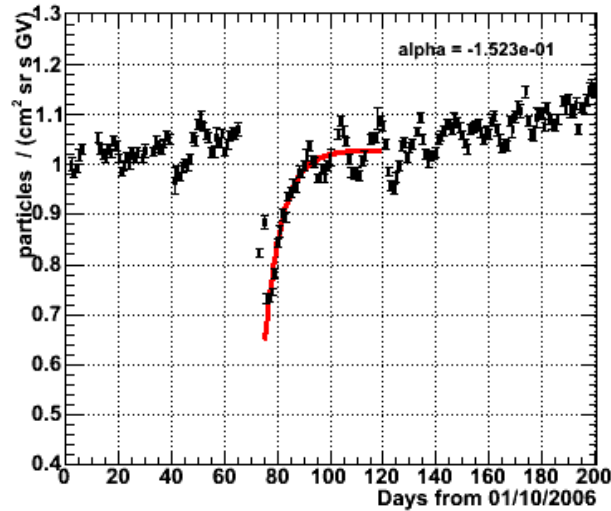
Graph



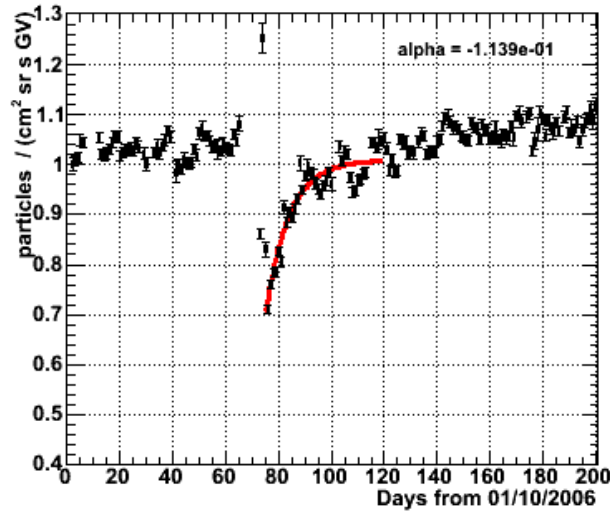
Recovery Time Rigidity Dependence

$$I(t) = I_0(t) - A(R) e^{-t/\tau(R)} \quad [3]$$

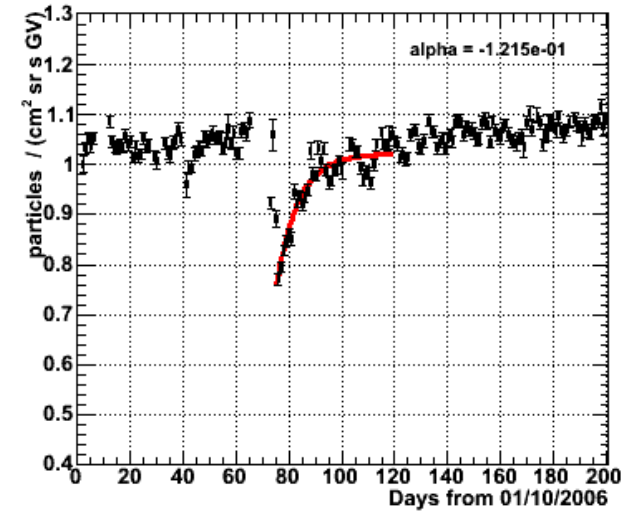
from 1 to 2 GV



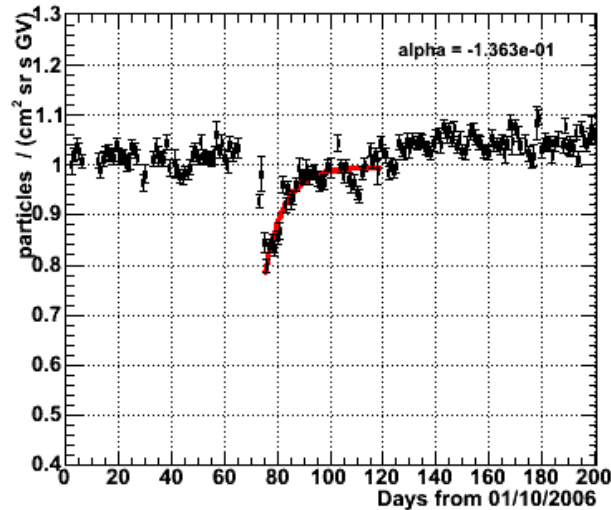
from 2 to 3 GV



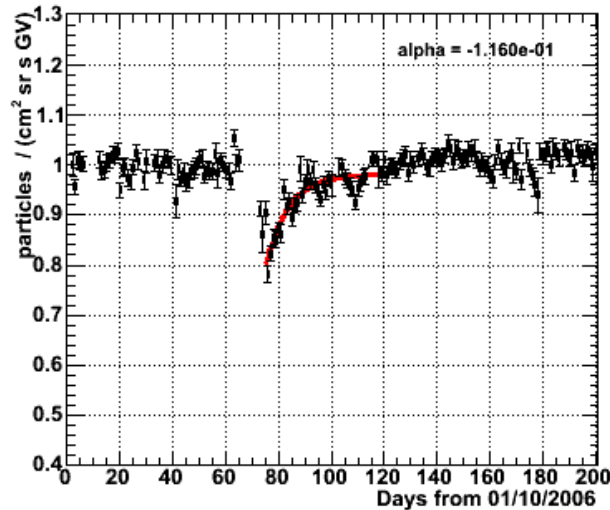
from 3 to 4 GV



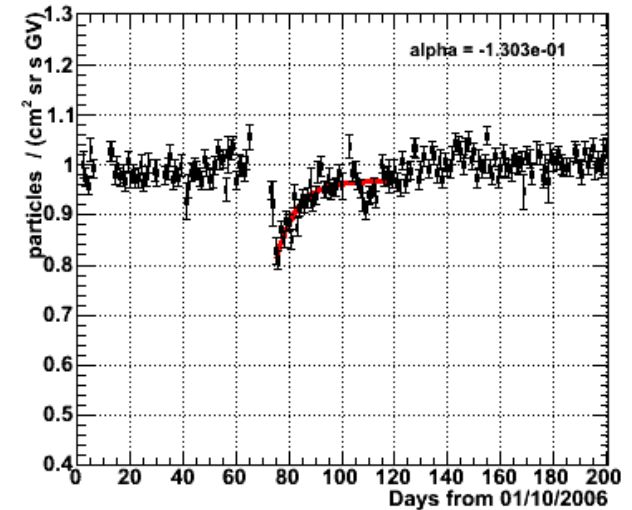
from 4 to 5 GV



from 5 to 6 GV

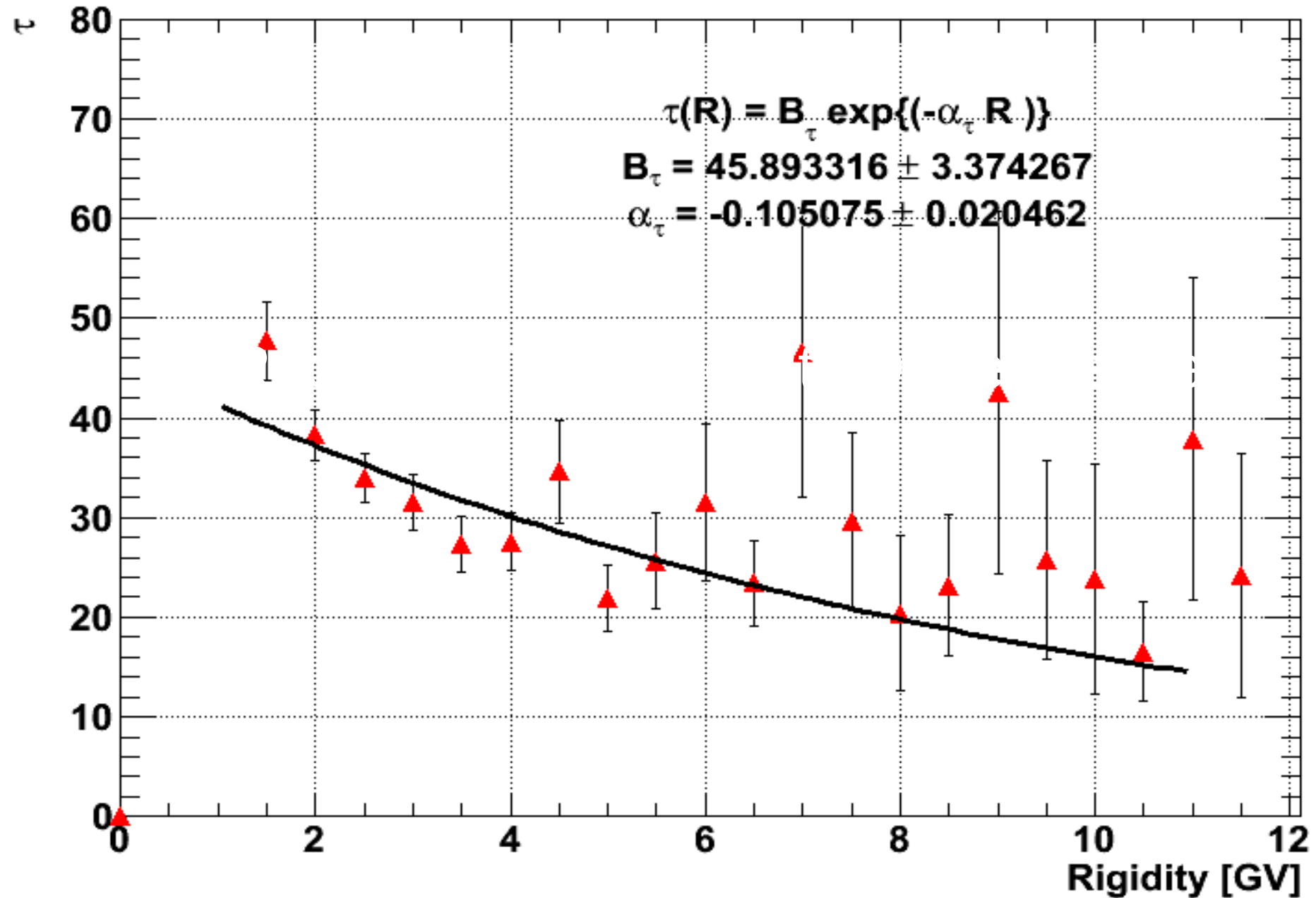


from 6 to 7 GV



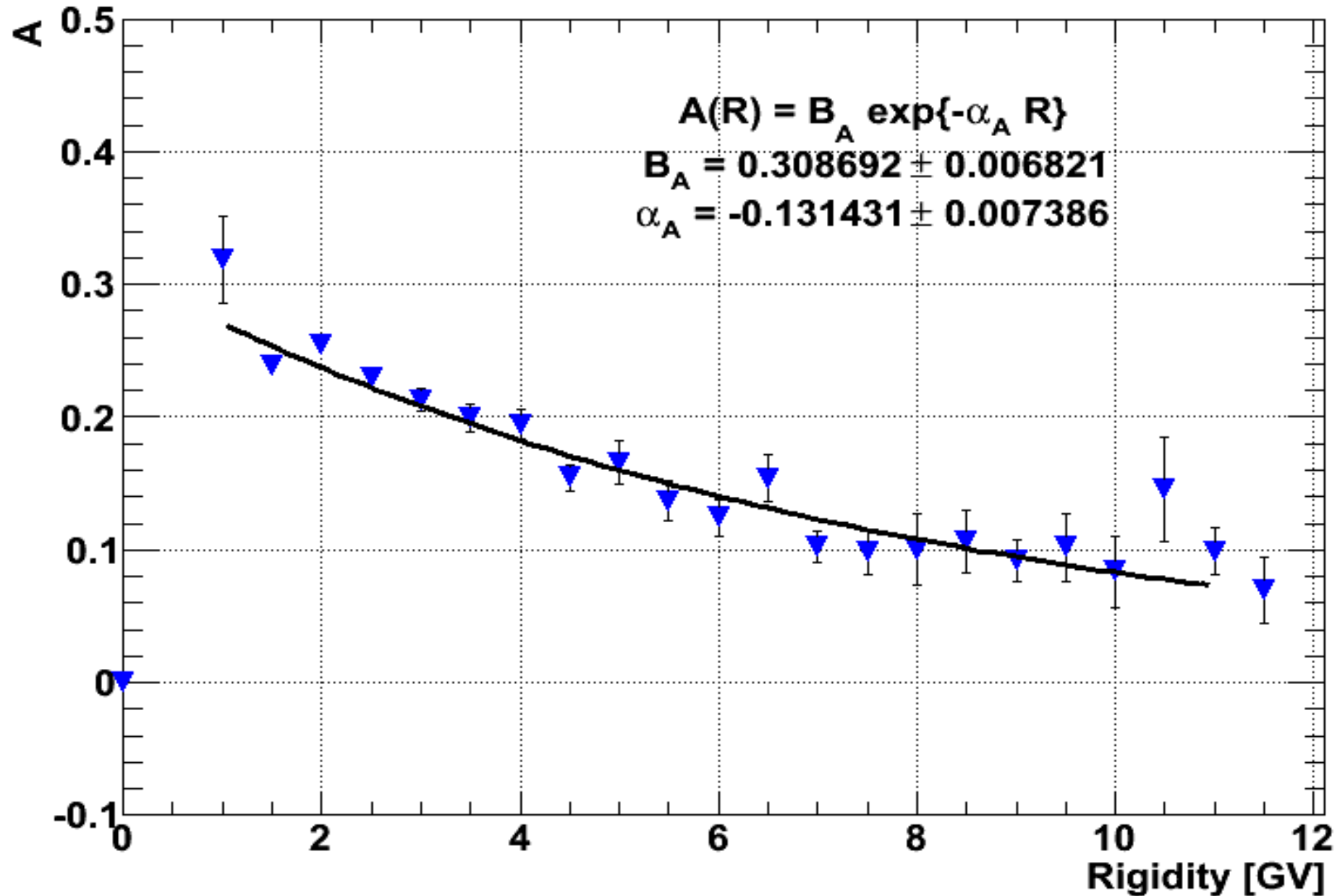
Recovery Time Rigidity Dependence

Graph



Recovery Time Rigidity Dependence

Graph



Conclusions

- For the first time in space has been observed in the full extension of the Forbush Effect
 - The effect has been observed in the proton component up to 20 GV for this event
- For the first time in space has been observed a Forbush decrease for electrons and positron components of galactic cosmic rays
 - The Dec 13th 2006 solar event showed a comparable decrease and recovery for protons, helium, electron and positrons
- Studying the charge and mass dependence of the effect allows to obtain detailed information on the interaction between the CME magnetic field and GCR constraining several parameters of GCR propagation models
- PAMELA spectrometer challenges the previous analysis of FDs made with Neutron Monitors allowing an unprecedented precision in energy dependence of the effect
- The 24th solar cycle will give (and already have... march 7th 2012) us the chance to observe many major events