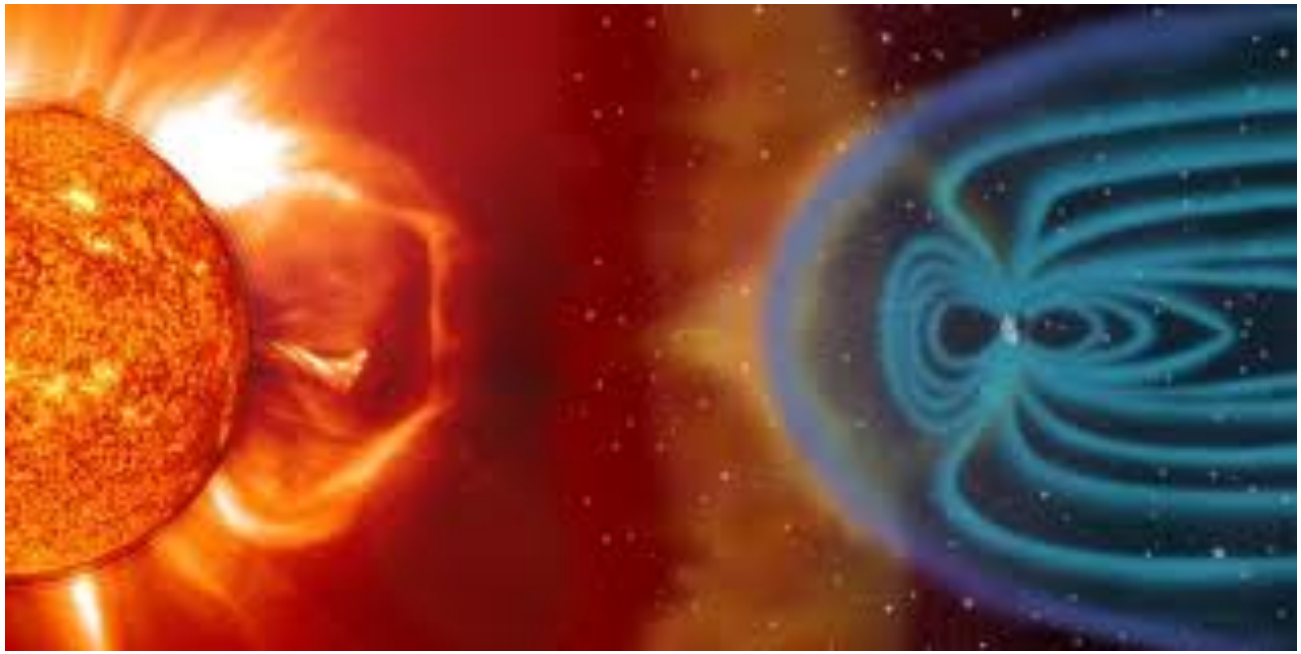
The LISA Pathfinder environment and mission performance



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In collaboration with
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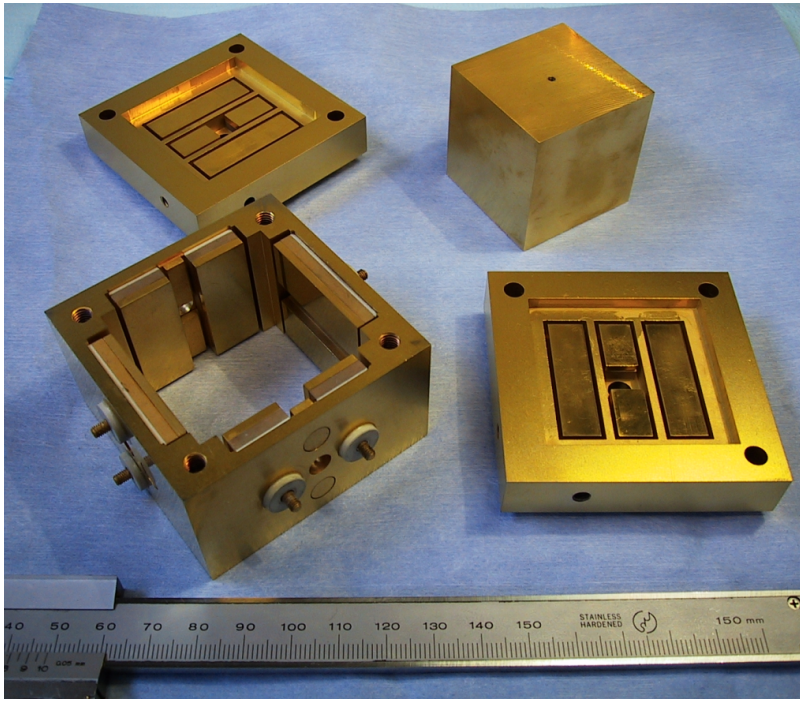
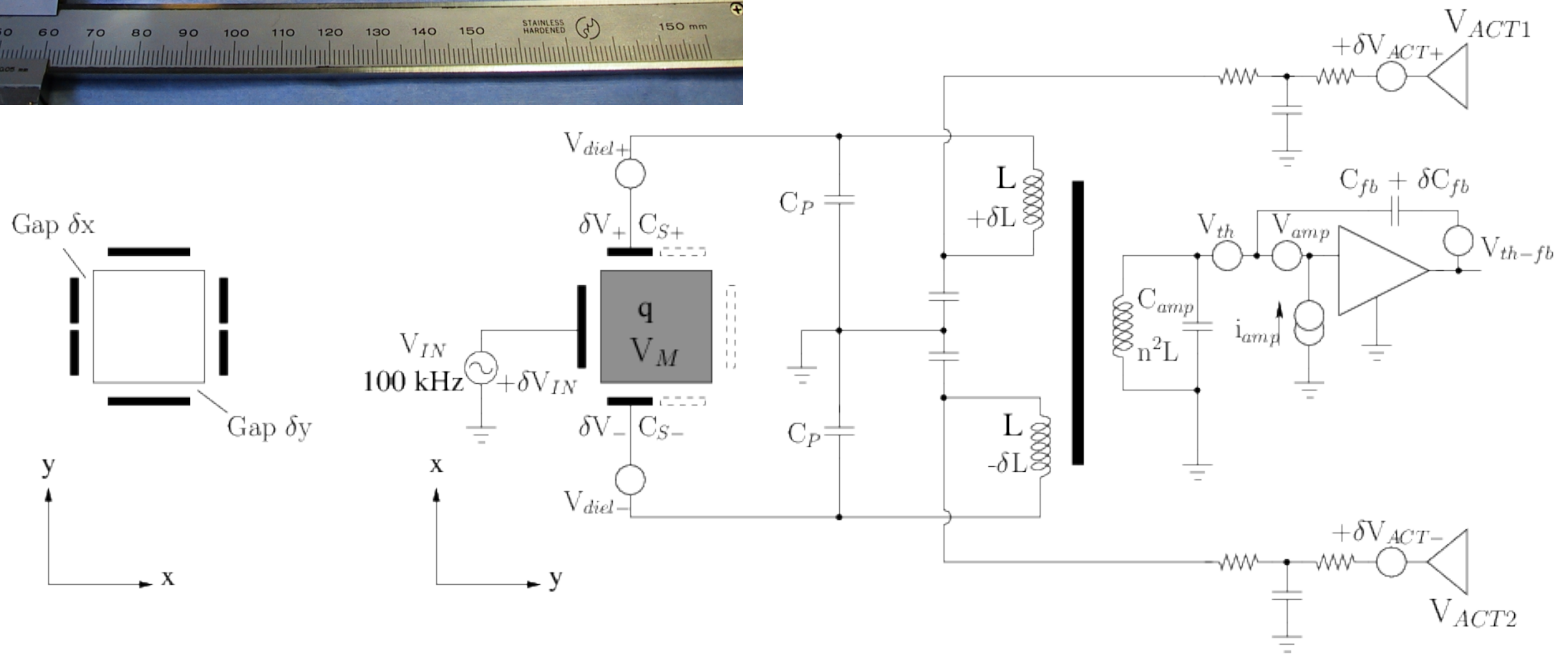
OUTLOOK

- Test-mass charging on LISA-PF
- Solar activity in 2015
- GCR energy spectra and SEP event occurrence at the time of LISA-PF operations
- GCR short-term variations
- Test-mass charging (Fluka simulation results)
- Conclusions

LISA-PF inertial sensor and test mass

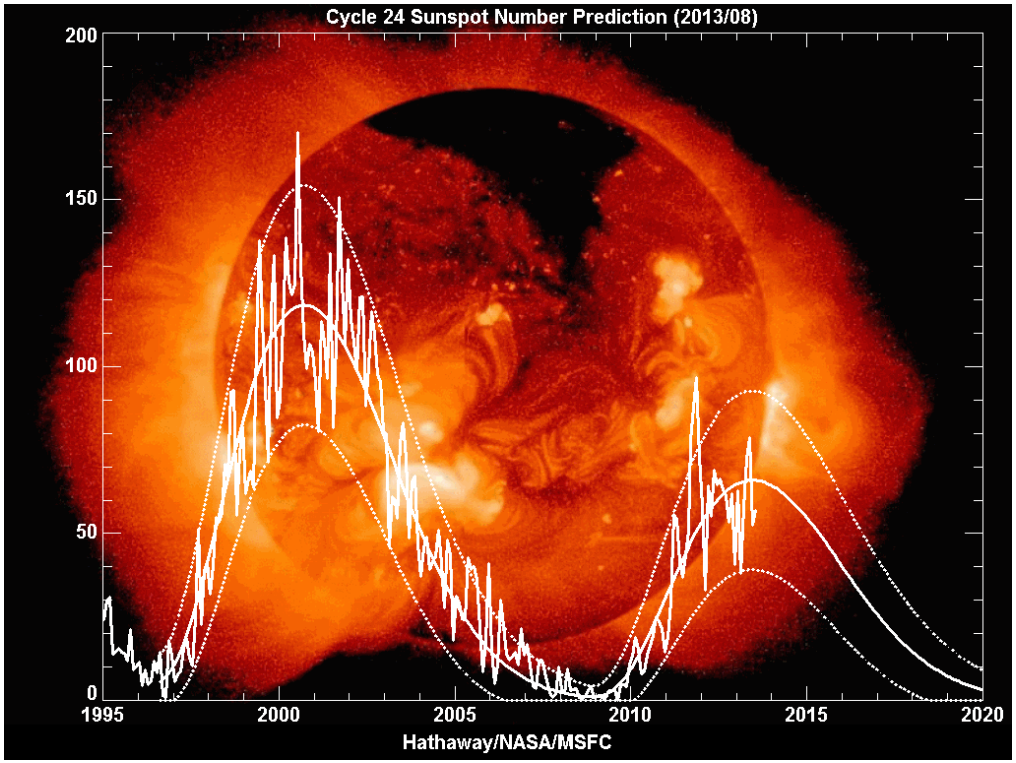


Particles with energies > 100 MeV/n penetrate the spacecraft and charge the test-masses



Solar activity in 2015

Predictions of both GCR fluxes and SEP occurrence were carried out on the basis of the expected level of solar activity



Last polarity change from – to + occurred in December 2013. The next from + to - possibly around 2025.

SUNSPOTs in 2015 (N_{SS}) min-avg-max:

29.9 – 54.1 – 78.4

Expected number of SEP events (N_{SEPs}) in 2015 (6 months)

min – avg – max: $N_{SEPs}=0.0694\ N_{SS}$

1.1 – 1.9 – 2.7

http://solarscience.msfc.nasa.gov/images/ssn_predict.txt

Nymmik R.A. 1999 Proc. 26° ICRC, Salt Lake City, 6, 268-71
Nymmik R.A. 1999 Proc. 26° ICRC, Salt Lake City, 6, 280-3
C. Grimani et al., CQG, 31, 045018 (14pp), 2014

Solar Modulation of Galactic Cosmic Rays

$$\frac{J(r,E,t)}{E^2-E_o^2} = \frac{J(\infty,E+\Phi)}{(E+\Phi)^2-E_o^2}$$

NO SOLAR POLARITY CORRECTION NEEDED

J: particle energy spectrum

r: distance from the Sun

E: particle total energy

t: time

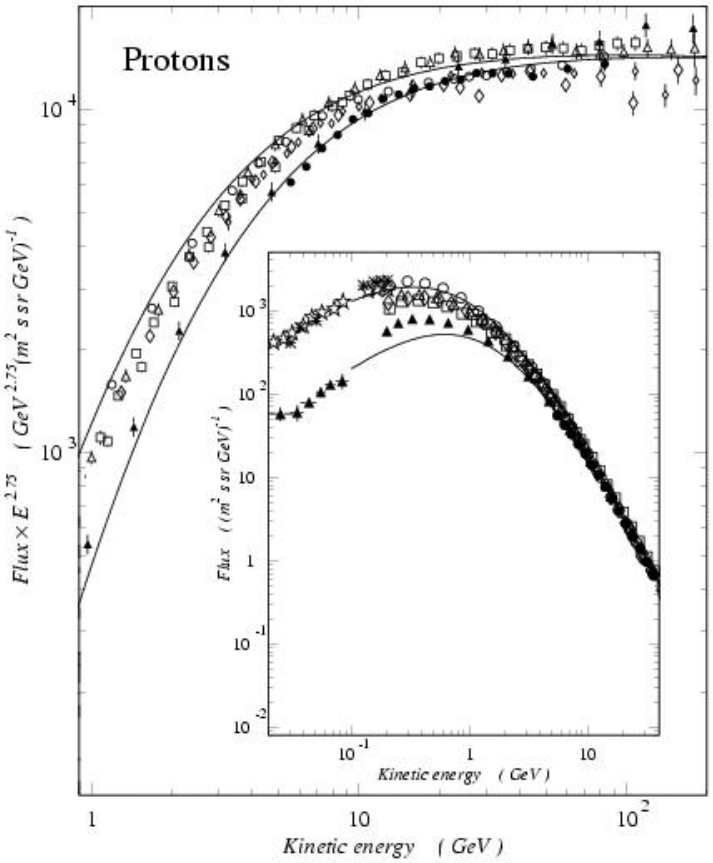
E_o= particle rest mass

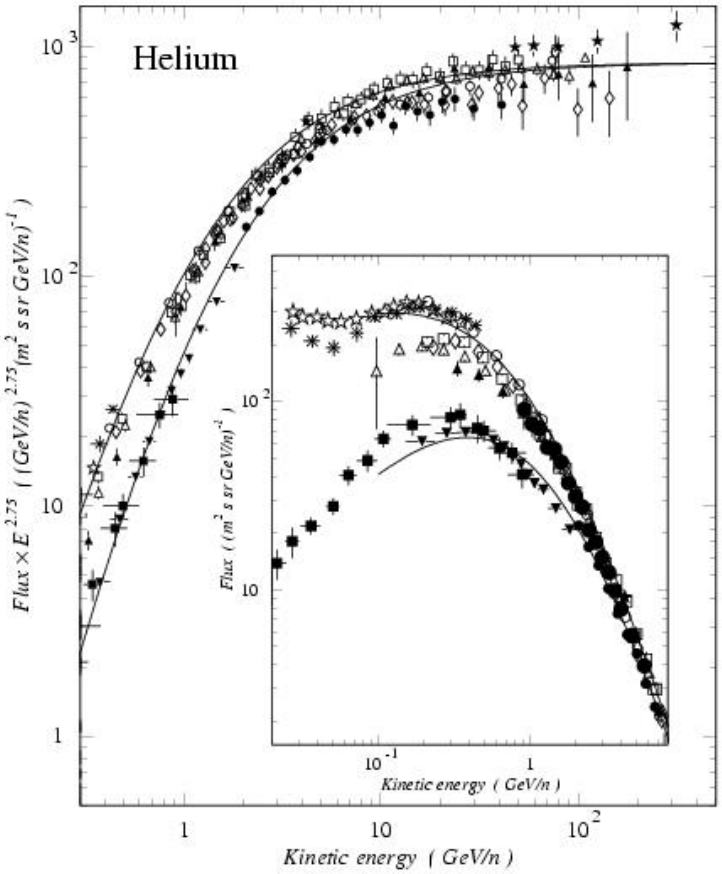
Φ= particle energy loss from ISM (different for each particle species)

Gleeson and Axford, Ap. J., 154, 1011, 1968

GCR at solar minimum and maximum

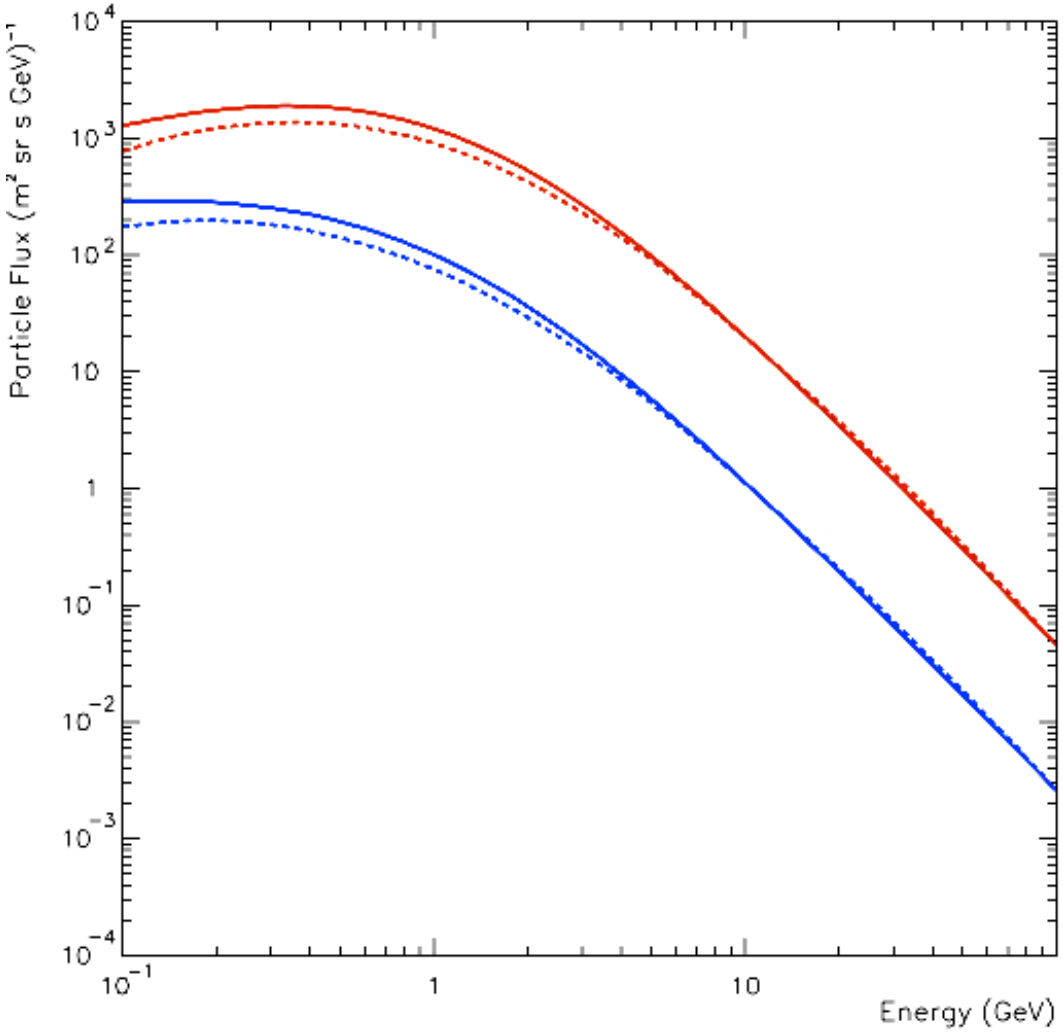
p , He 98% composition GCRs





Papini, Grimani, Stephens, 1996

SOLAR POLARITY and cosmic-ray intensity



Maximum reduction of incident p and He fluxes during a negative GSMF polarity epoch

Boella et al., JGR, 106, 29,355,2001

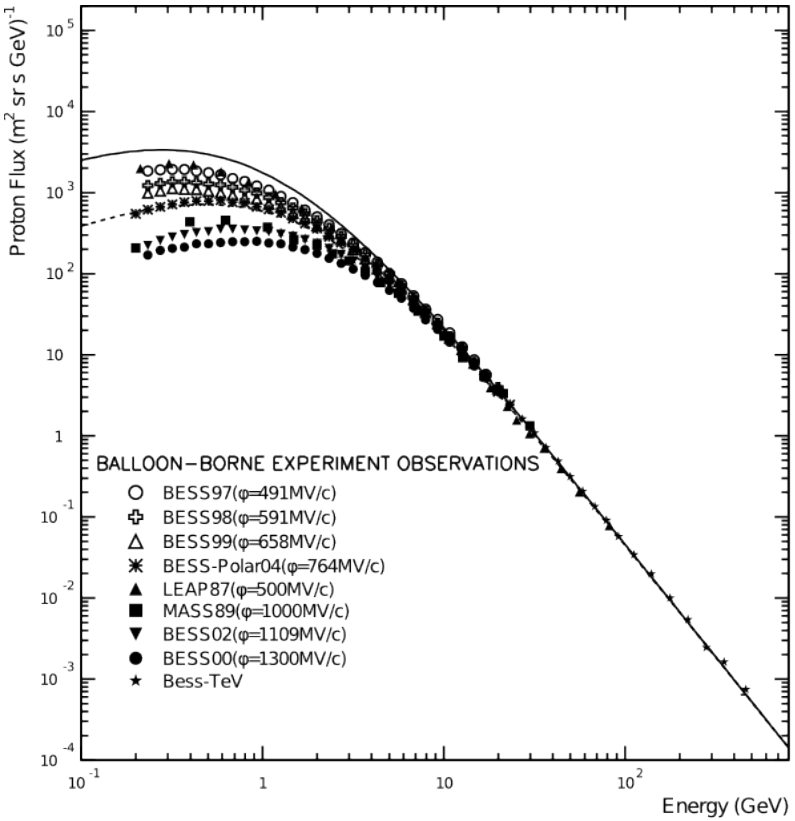
GCR-flux variations in the inner heliosphere (Ulysses/Pamela experiment between 1 and 5 AU)

- Radial distance: 3%/AU
- Latitude: 0.33%/deg

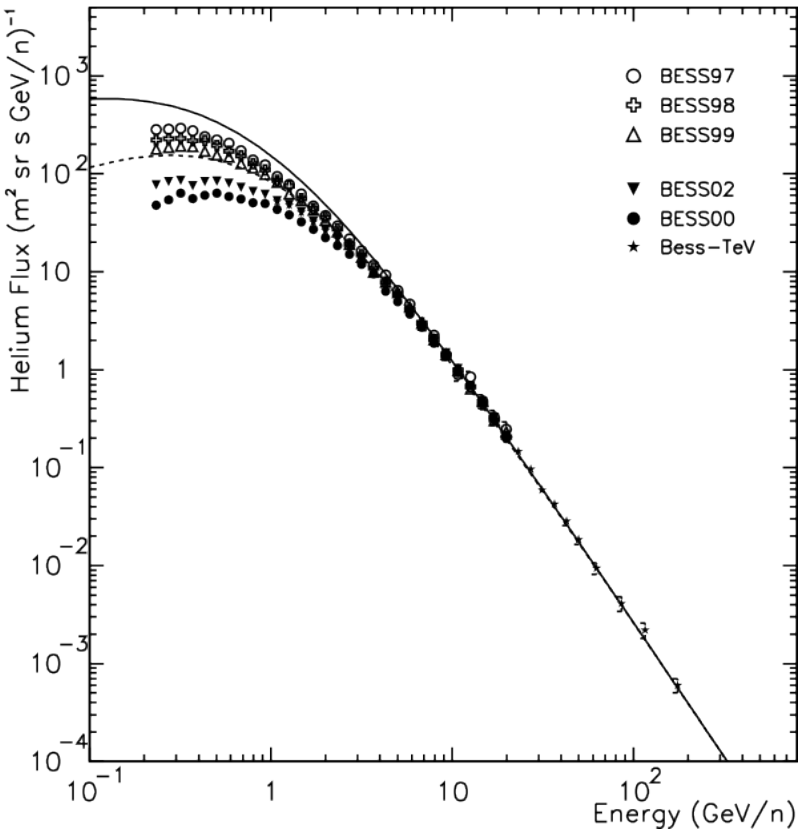
GCR near-Earth data can be used for LISA-PF test-mass projections

Heber et al., ApJ, 699, 1956, 2009
De Simone et al., Astrophys. Sp. Sc. Trans., 7, 425, 2011

GCR projections 2015



ϕ= 350 MV/c - 800 MV/c

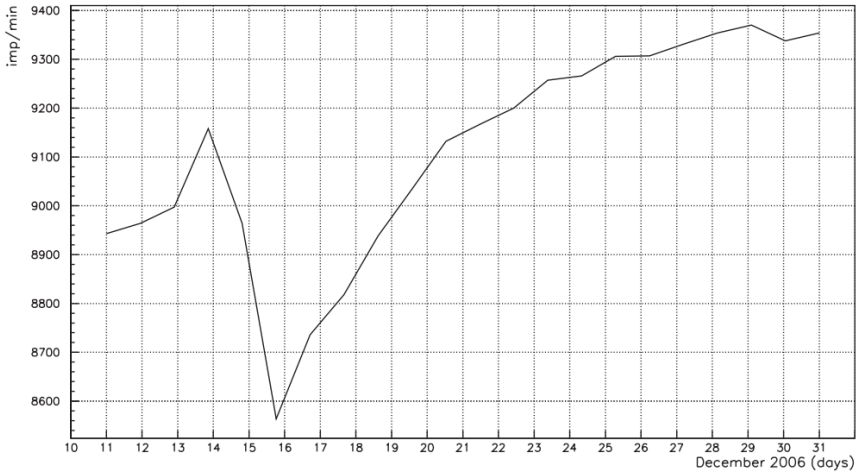


CG et al., CQG, 29, 105001 (13 pp), 2012 and references therein

GCR short-term variations

- Forbush decreases
- GCR 27-day variations
- GCR variations and fluctuations in the LISA-PF bandwidth

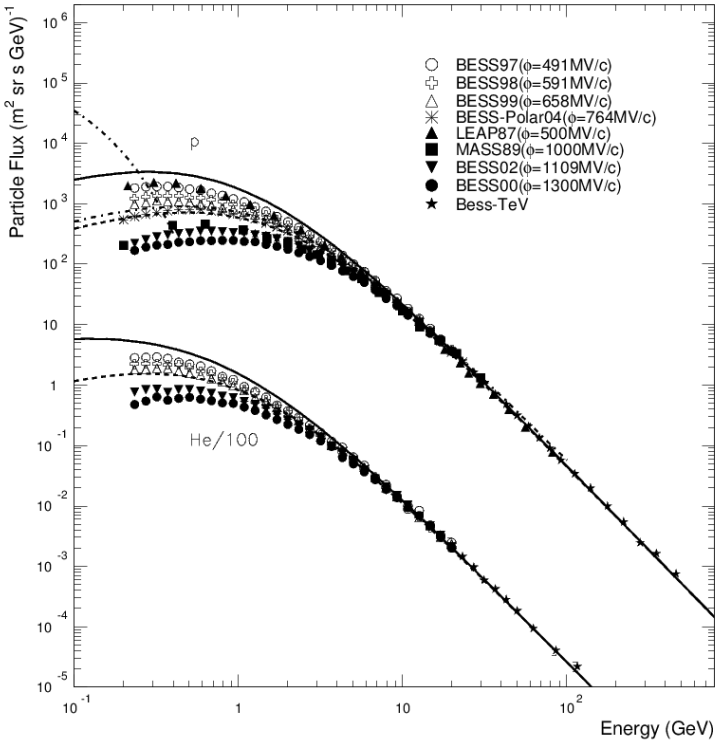
Classical Forbush decreases



Moskow neutron monitor

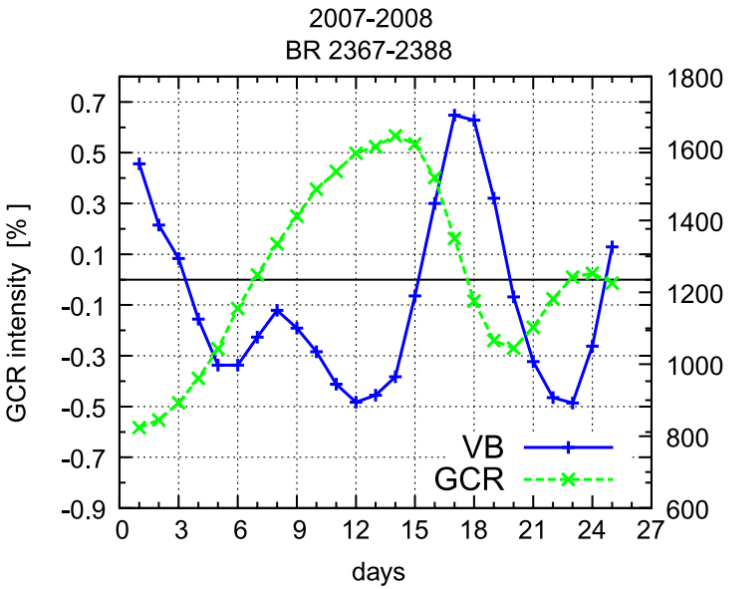
14 December 2006
observed for the first time
in space by the PAMELA
experiment

Adriani et al., Ap. J., 742, 102, 2011

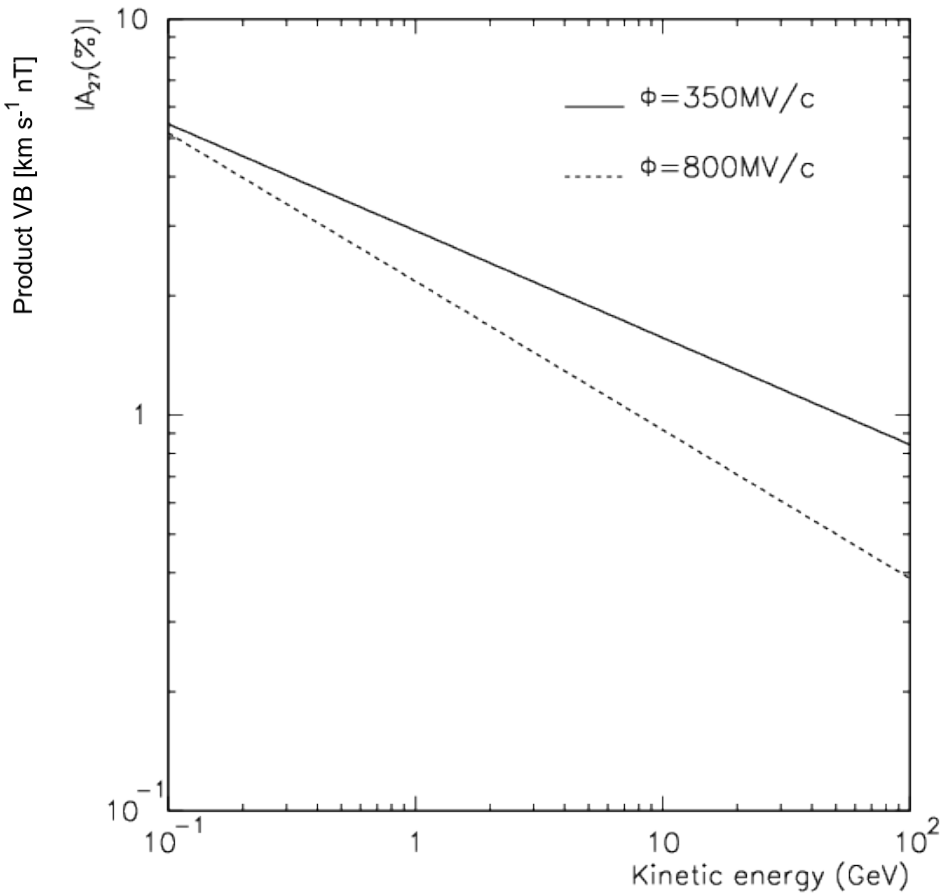


C. Grimani et al., CQG, 28, 094005 (10pp), 2011
C. Grimani et al., to be submitted to CQG

GCR 27-day variations

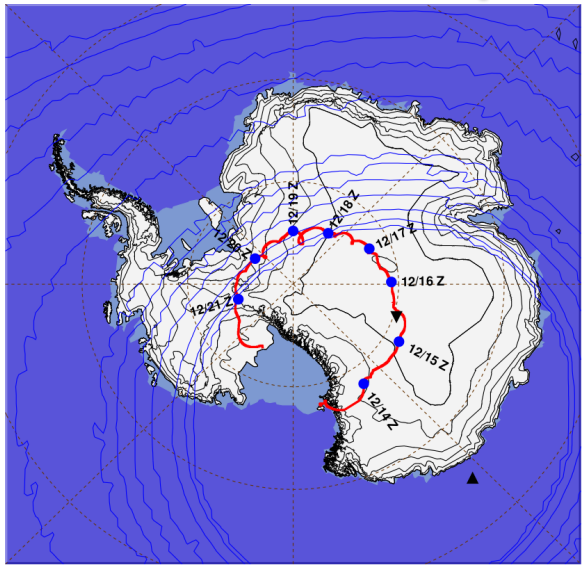


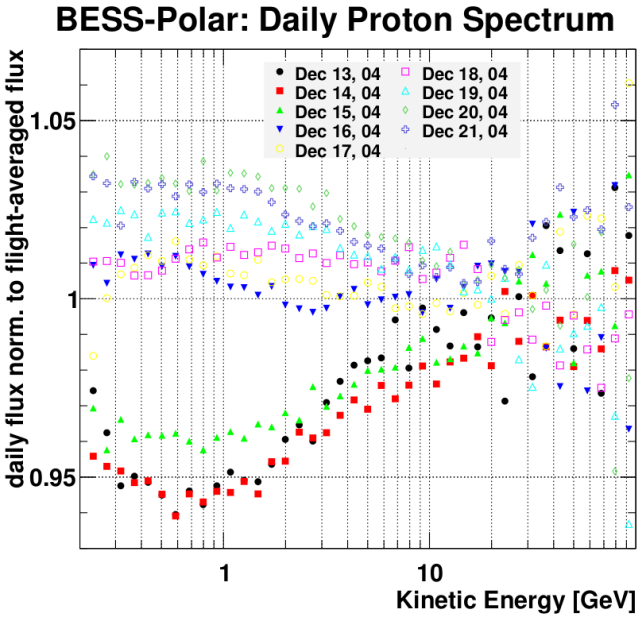
Positive and negative variations observed near Earth with respect to steady-state GCR observations

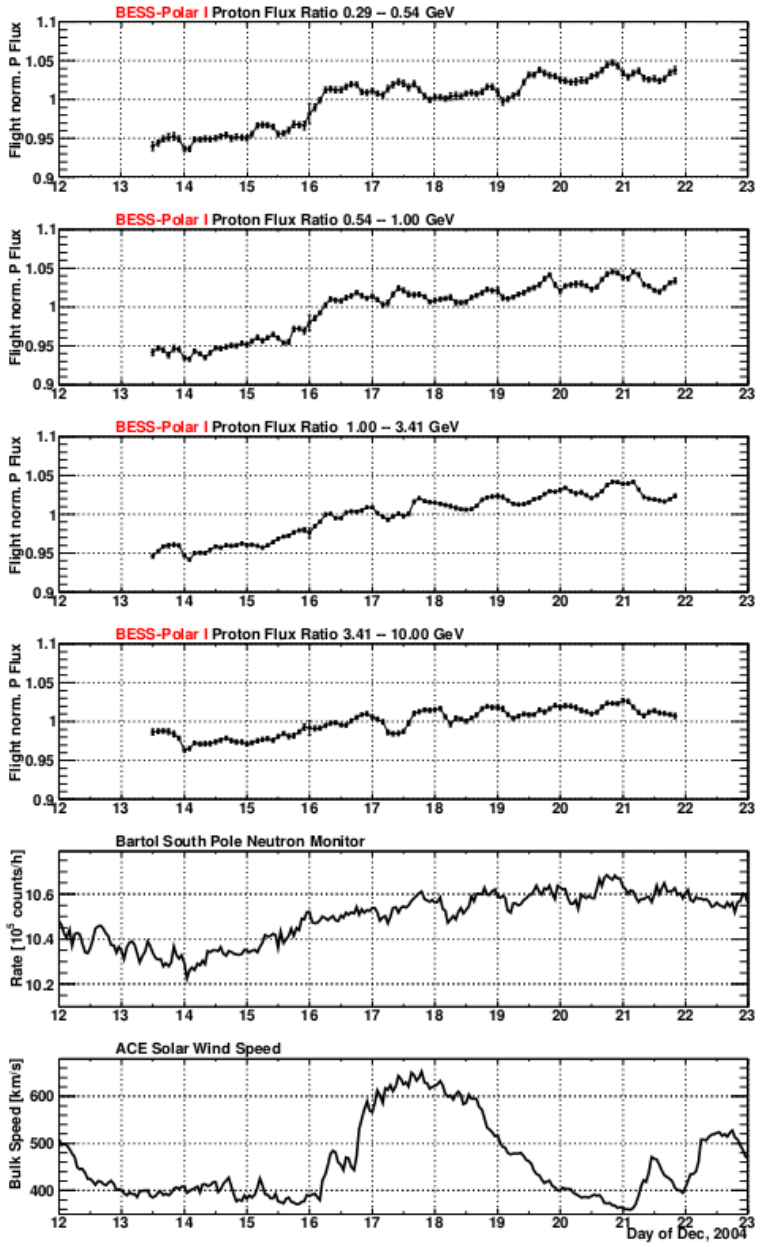


Alania, Gil and Modzelewska, Astrophys. Sp. Sc. Trans., 4, 31, 2013

GCR variations in the LISA-PF bandwidth – BESS-Polar I experiment

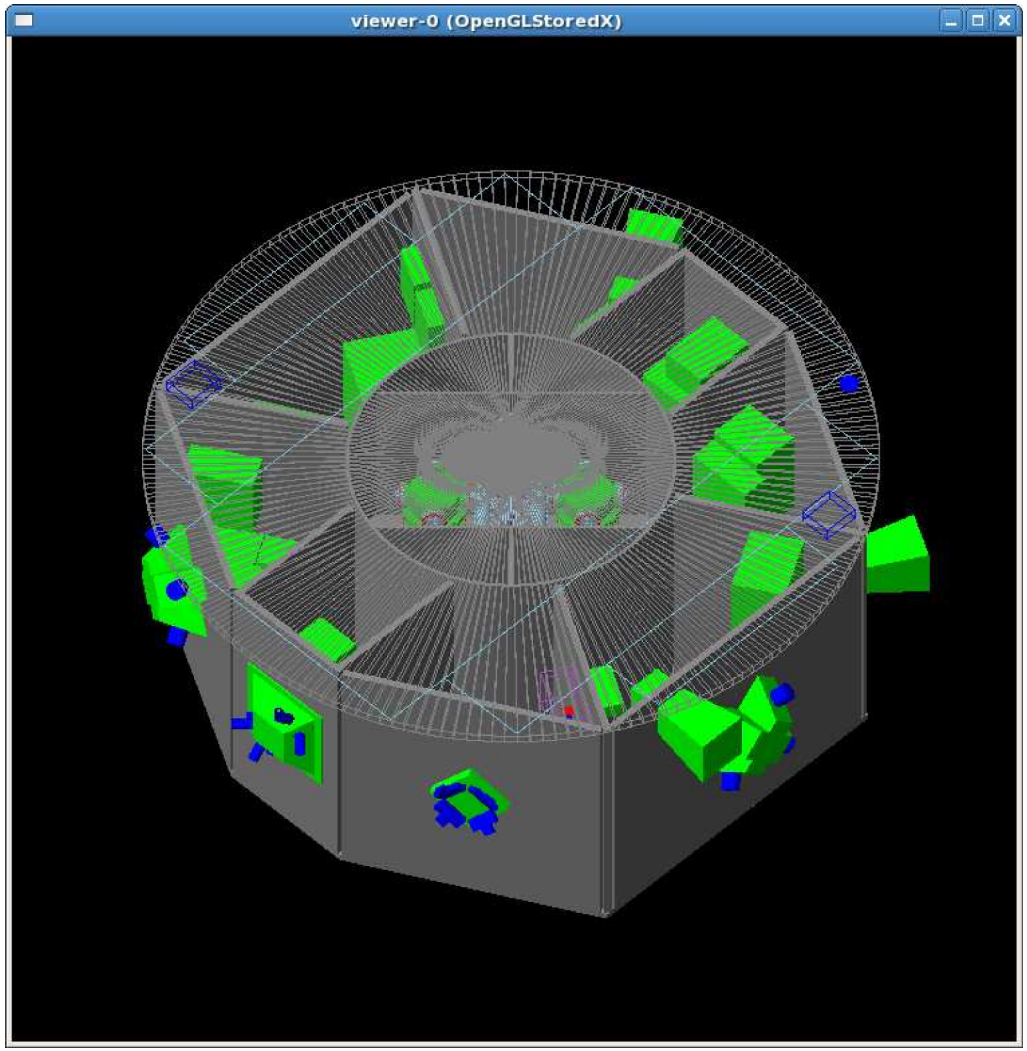






Hams T. et al. Proc. 31° Int. Cosm. Ray Conf., Lodz, 2008

LISA-PF 2005 geometry



Geant4 geometry
kindly provided
by P. Wass

Wass et al., CQG, 22, 2005, S311-S317

Test-mass charging

Net and effective charging estimated with the **Fluka MC** Program

2x10^6 events in each run In order to limit the uncertainty on λ_{eff} <2%

$$\lambda_{NET} = \sum_{j=-\infty}^{+\infty} j\lambda_j$$

$$\lambda_{EFF} = \sum_{j=-\infty}^{+\infty} j^2\lambda_j$$

Ferrari et al., 2005-10 (Geneva:CERN)
Battistoni et al.,
AIP Conf. Proc. 896,
M. Albrow and R. Raja, 31-49

Where: j is the amplitude of the charge released by each event and λ_j is rate of occurrence of that event.

$$S_Q(\omega) = \frac{S}{\omega} = \frac{\sqrt{2e^2\lambda_{eff}}}{\omega}$$

$$S = \sqrt{2e^2\lambda_{eff}} \quad e\ s^{-1}\ Hz^{-1/2}$$

LISA-PF test-mass charging

Particle	λ_{net} (e^+/s)	λ_{eff} (e/s)	S (e $s^{-1}Hz^{-1/2}$)
p_{min}	14.1	168.9	18.4
p_{max}	32.5	295.5	24.3
He^3_{min}	0.22	0.92	1.4
He^3_{max}	1.9	5.6	3.4
He^4_{min}	0.81	1.9	2.0
He^4_{max}	3.8	10.7	4.6
$p_{11/2006}$	31.2	312.6	25.0
$p_{FD14/12/2006}$	19.4	213.1	20.6
$p_{27-day+;min}$	16.6	176.2	18.8
$p_{27-day-;min}$	10.9	173.7	18.6
$p_{27-day+;max}$	35.8	250.0	22.4
$p_{27-day-;max}$	27.1	239.7	21.9
$p_{2h\ min}$	11.5	176.6	18.8
$p_{2h\ max}$	30.0	231.1	21.5

24.9 e s^{-1} $Hz^{-1/2}$
Wass et al., 2005
@ solar minimum

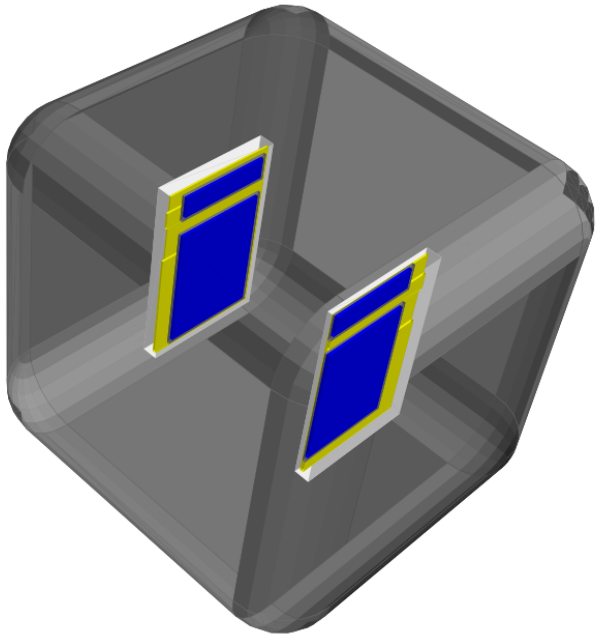
We find:

25.0 e s^{-1} $Hz^{-1/2}$
(p_{max},He_{max})

18.6 e s^{-1} $Hz^{-1/2}$
(p_{min},He_{min})

LISA-PF performance (test-mass charging and RM observations)

$$\frac{S}{N} \simeq \frac{A}{\sigma}\sqrt{N_{TB}}$$



N_{TB}= Number of RM time bin (10 minutes) measurements

GCR variations of the order of 1% will be observed using RM count-rates if those short-term variations last for more than one hour for minimum GCR projections and for half an hour for maximum GCR projections.

2 silicon wafers inside a shielding copper box 6.4 mm thick

P. Cañizares et al., CQG, 28, 094004, 2011

Conclusions

- We have studied the LISA-PF test-mass charging induced by GCRs at the time of mission operation with Fluka
- A very good agreement was found with Geant4 simulation
- Hourly GCR short-term variations can be monitored with radiation monitors
- Next: electrons and nuclei Z>3