Charge-sign dependent solar modulation as observed by the PAMELA experiment.

Riccardo Munini
on behalf of the PAMELA collaboration
and Potgieter M., Raath J.L.

INFN Trieste Italy

Solar Energetic Particles,Solar Modulation and Space Radiation, Arlington, 24-27 April 2017

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

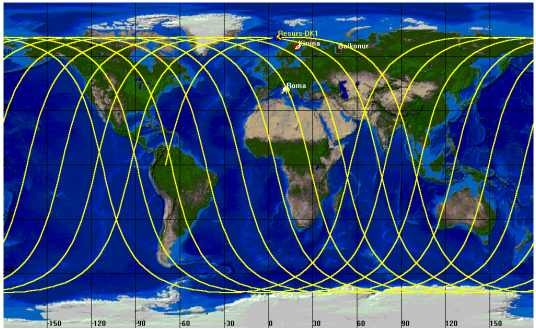
INFN Istituto Nazionale di Fisica Nucleare

PAMELA and solar modulation

Solar Modulation with PAMELA

- Long flight duration: 2006 - 2015;
- Low energies (70 MeV electron);
- Particles antiparticles, charge-sign dependence;

PAMELA and solar modulation



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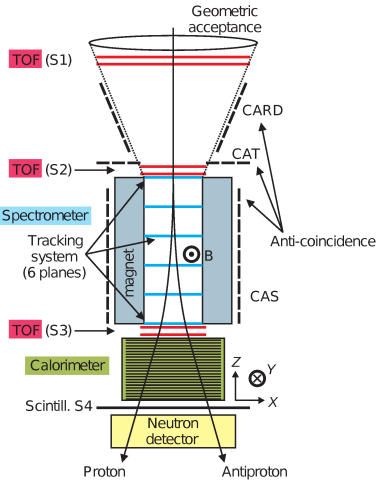

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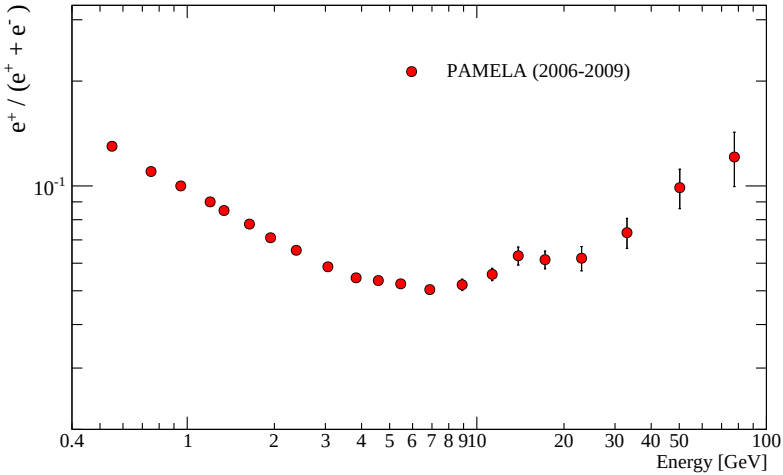
Cosmic-ray positron fraction high energy excess



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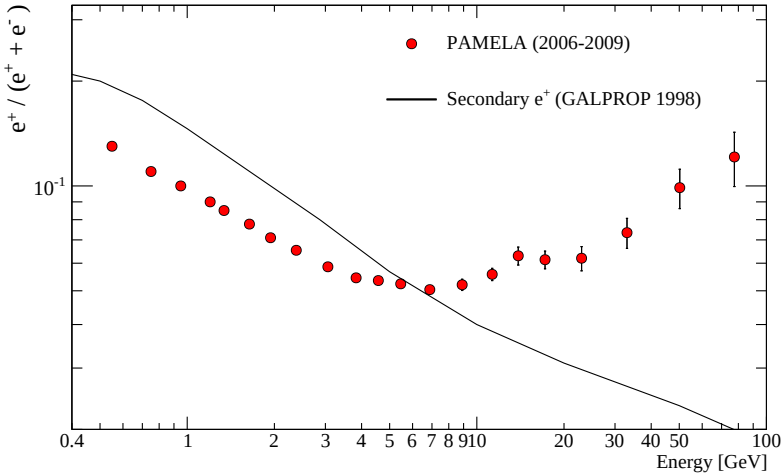

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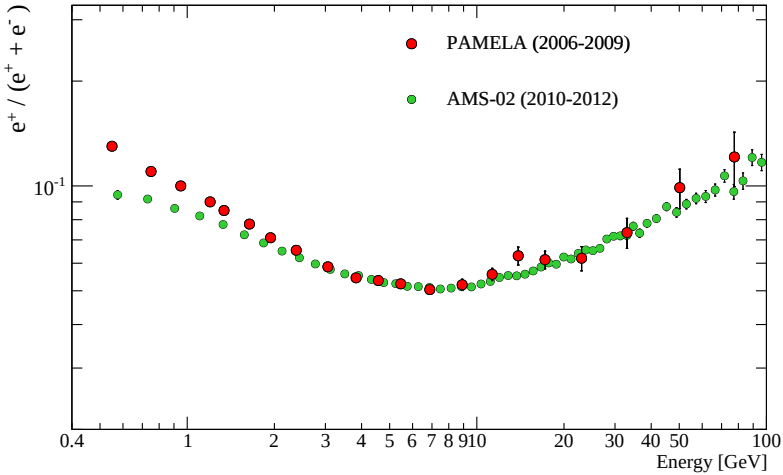
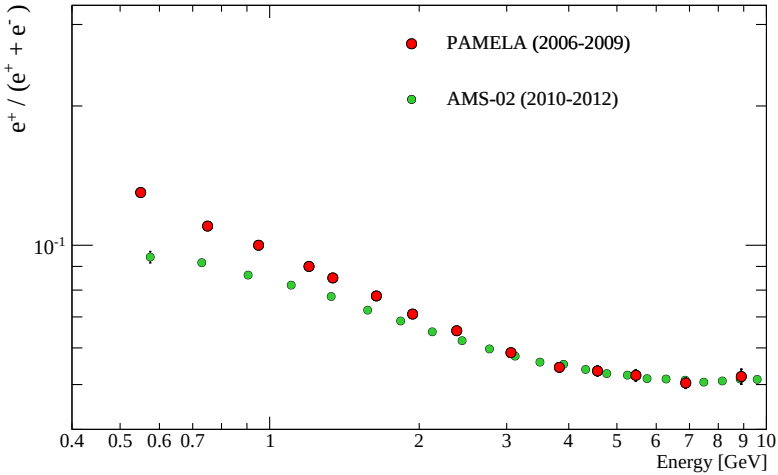
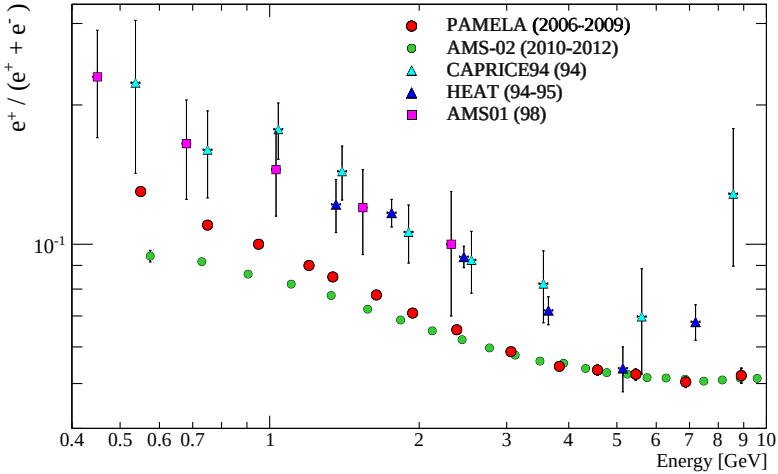


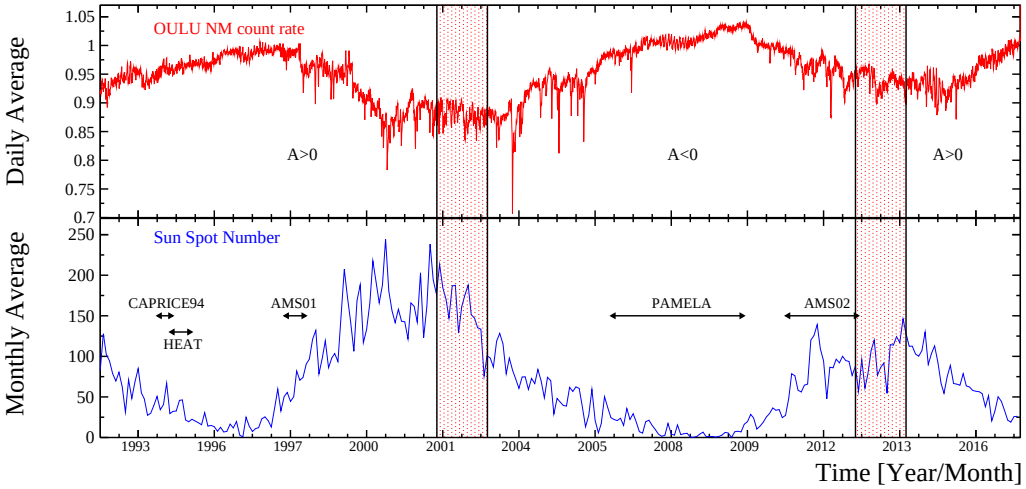
Cosmic-ray positron fraction low energy differences



Cosmic-ray positron fraction low energy differences



Positron fraction vs. solar activity



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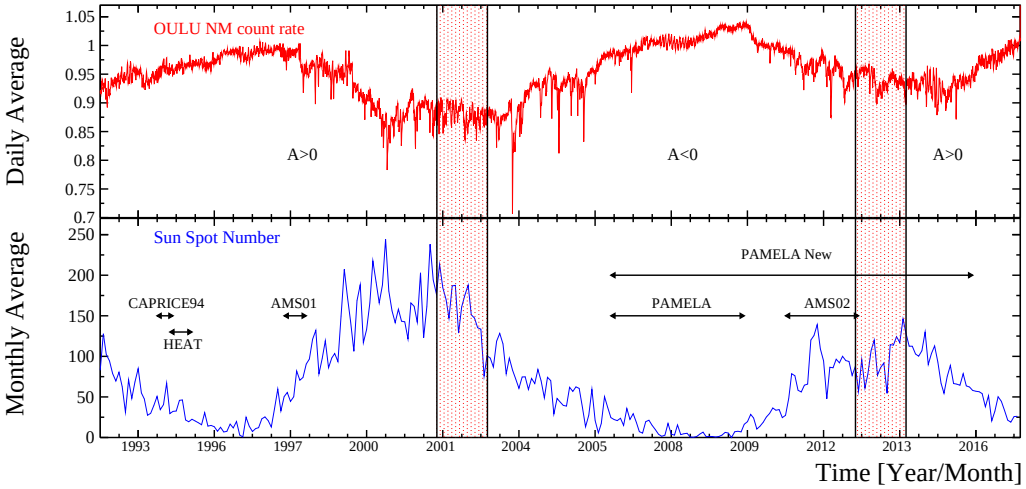
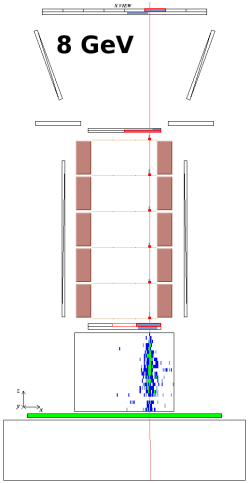


Electrons and Protons inside PAMELA

- Electron
- Proton
- Proton



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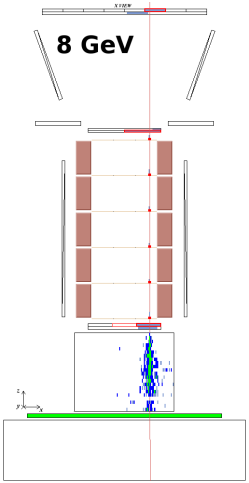

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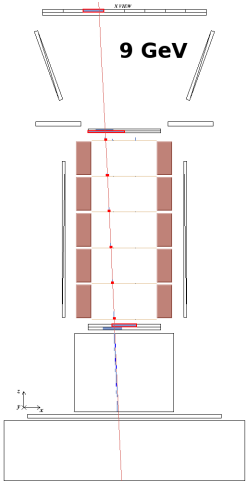

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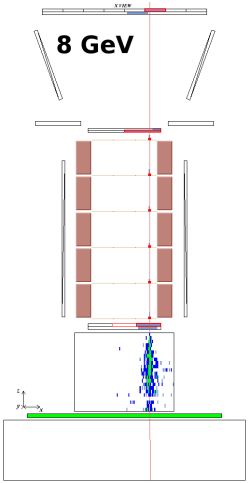

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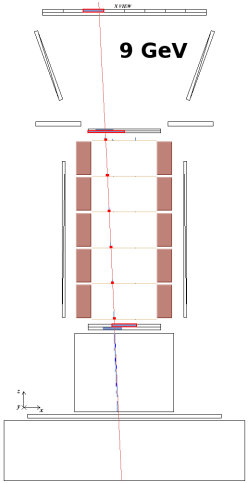

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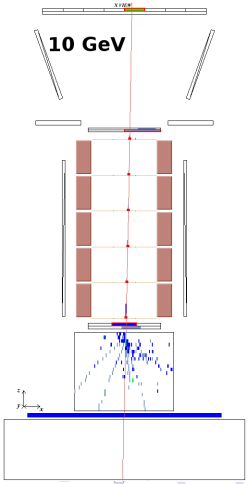
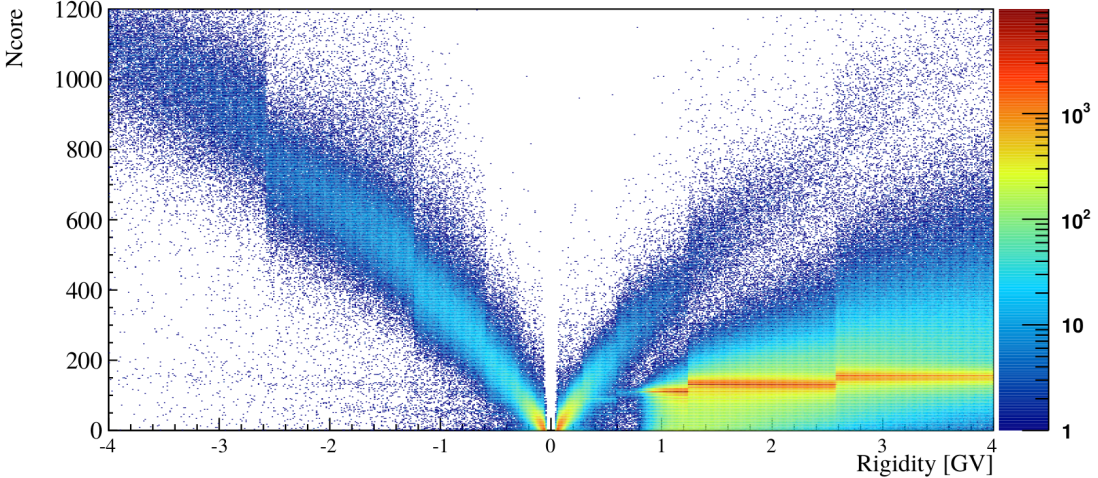


Calorimeter Selection



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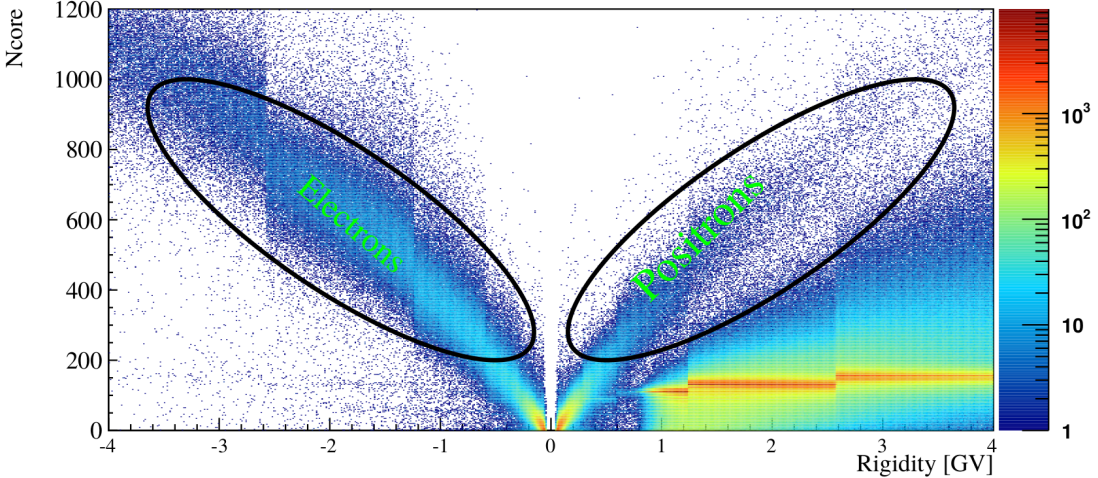

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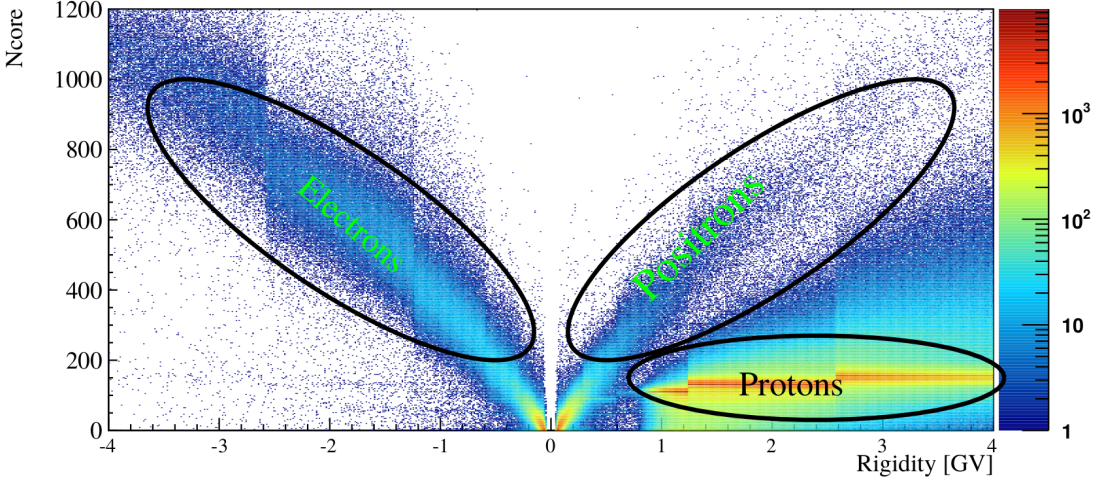

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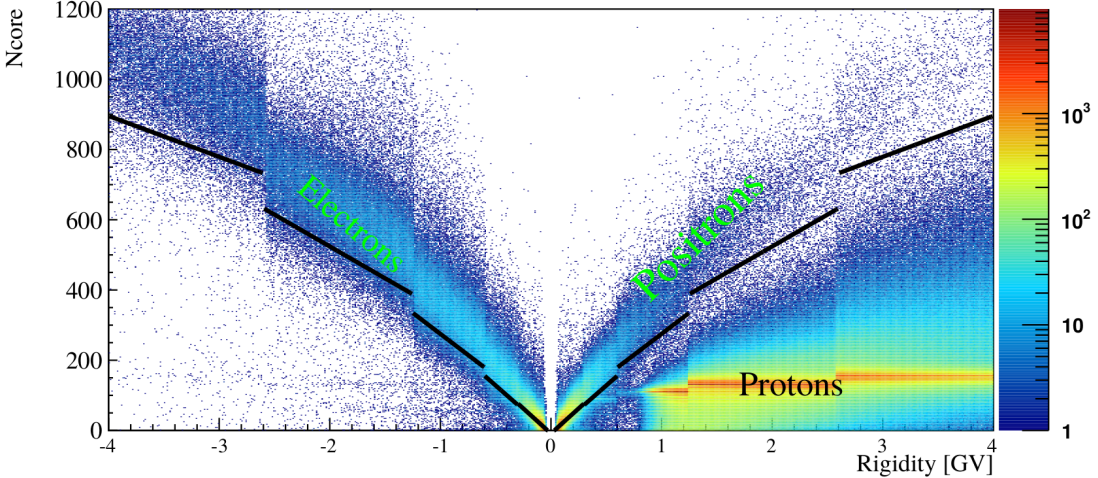
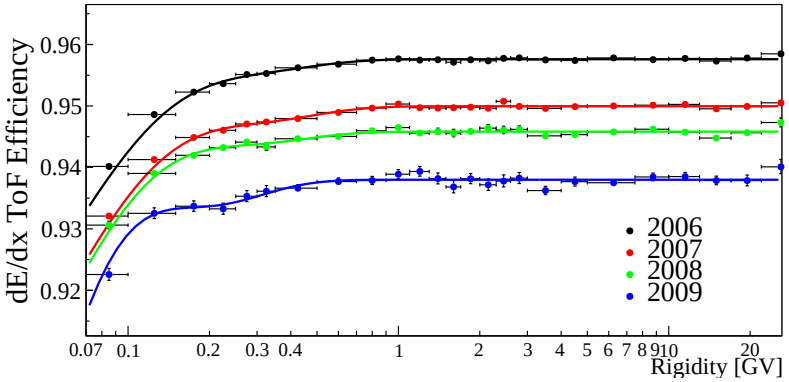
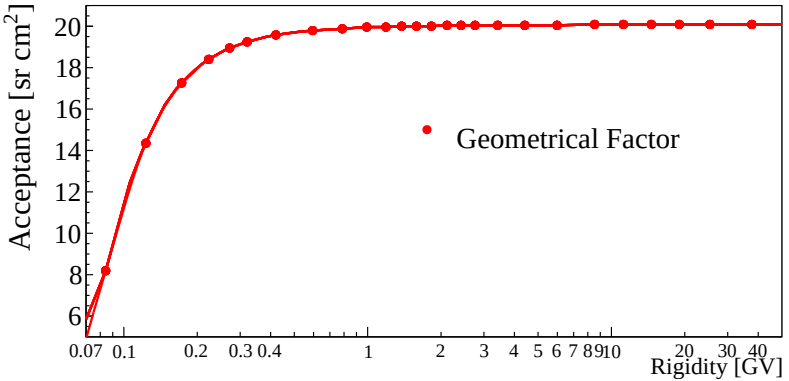


Time dependent Efficiencies



Acceptance


Acceptance [sr cm^2]
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16
14
12
10
8
6
Geometrical Factor
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0.1
0.2
0.3
0.4
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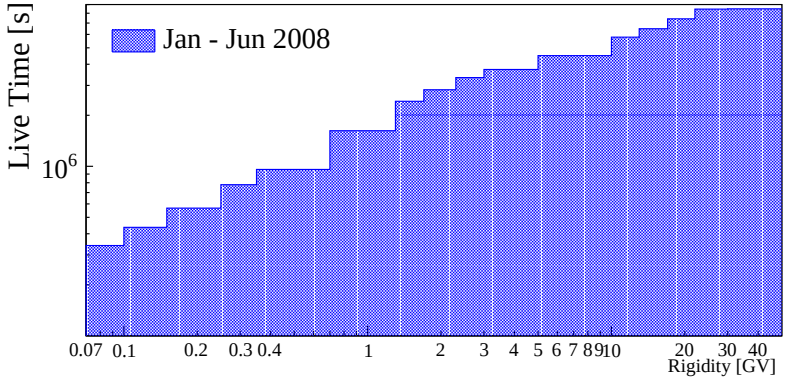
2
3
4
5
6
7
8
9
10
20
30
40
Rigidity [GV]

Live time


Live Time [s]
10^6
Jan - Jun 2008
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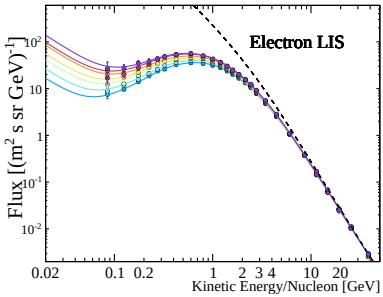
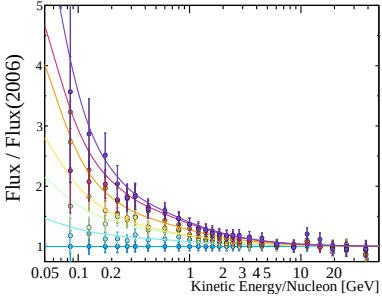
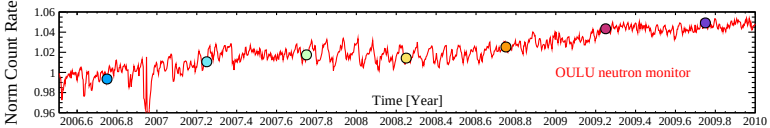
Rigidity [GV]

Published Time Dependent Electron Fluxes (Semestral 2006 - 2009)



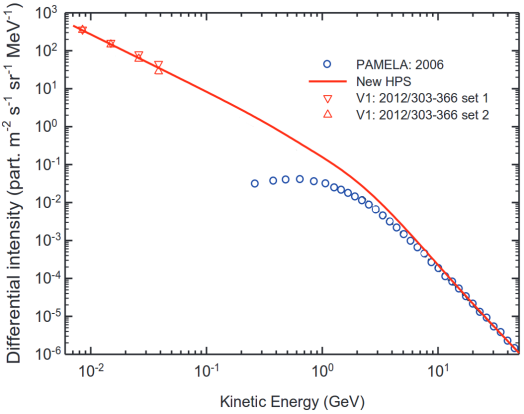




O. Adriani et al., ApJ 810 (2015) 142

Modeling

- Input spectrum LIS.
- Heliospheric magnetic field (HMF);
- LIS modulated from the HP up to Earth.



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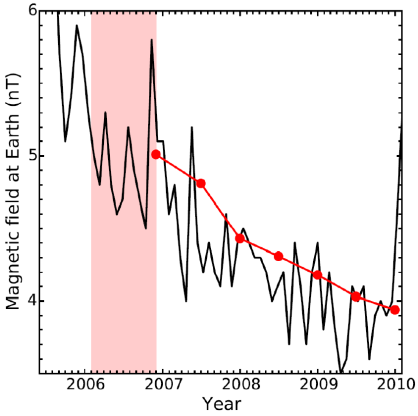

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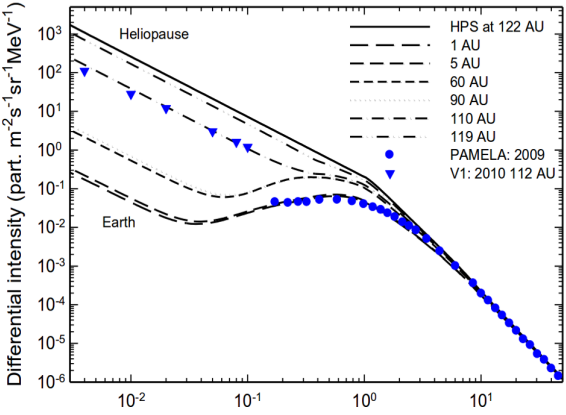
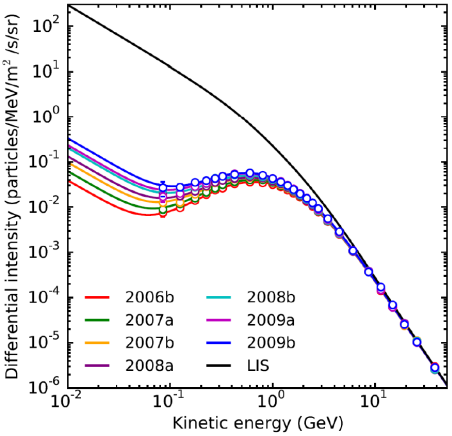


Modeling results



- Model results on time dependent electron spectra;
- The energy dependence of the diffusion coefficient K is derived by the turbulence theory;
- The values of the K components were tuned to reproduce PAMELA data;
- K is correlated to the particle mean free path $K = \frac{v}{3}\lambda$;
- Diffusion dominated $< .1$ GeV;

M. S. Potgieter and E. E. Vos and R. Munini and M. Boezio and V. Di Felice
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Astrophys.J. 810 (2015) 2, 141.

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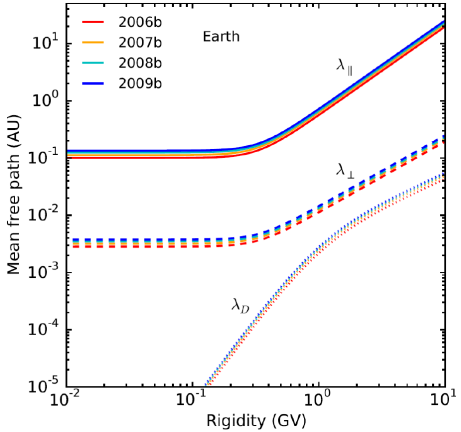

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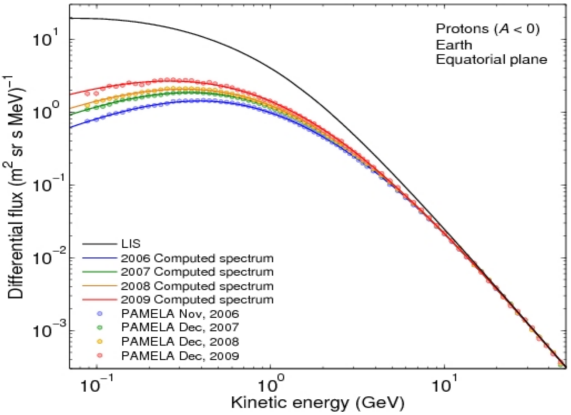

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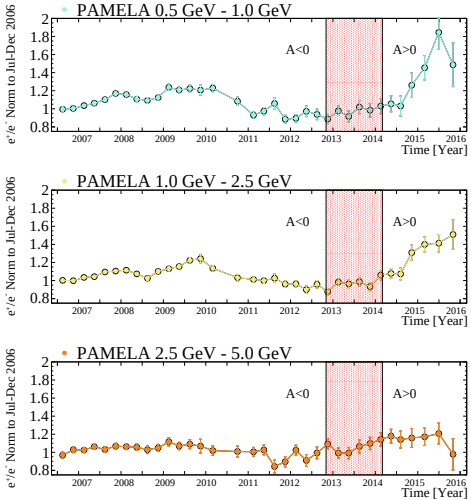
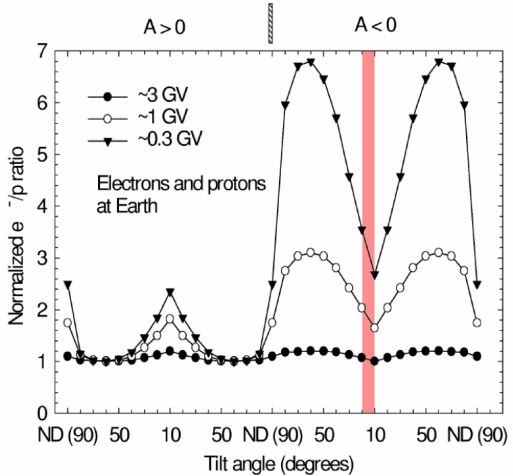
Positron - Electron Ratio



O. Adriani et al., PRL 116 (2016) 241105

Positron - Electron Ratio



E.E. Vos, PhD thesis (2016)

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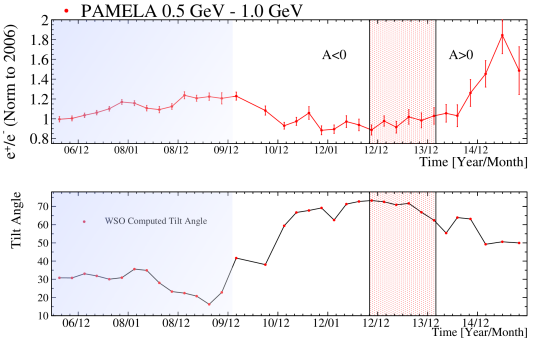

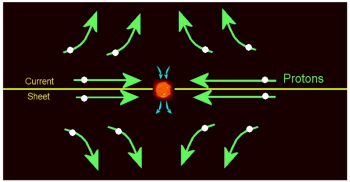

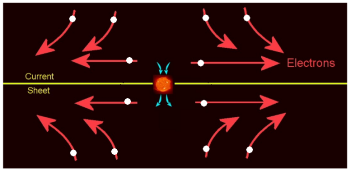

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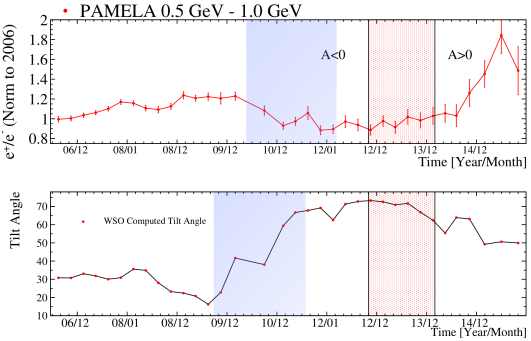

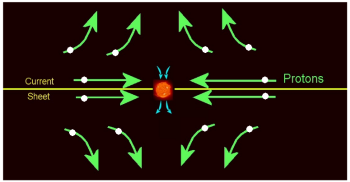

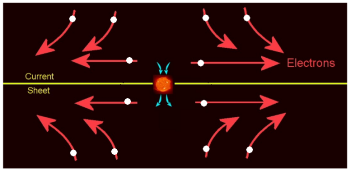

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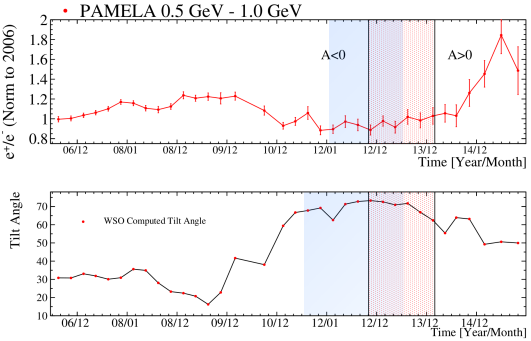

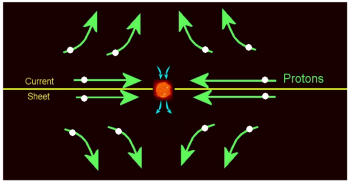

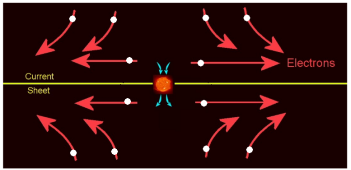

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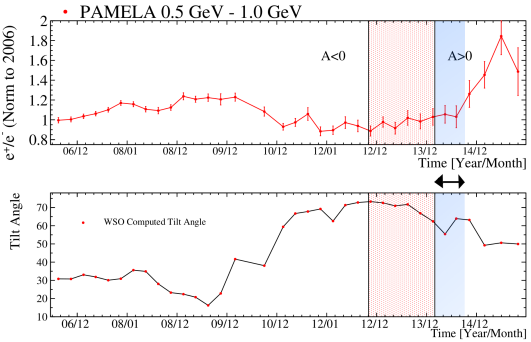

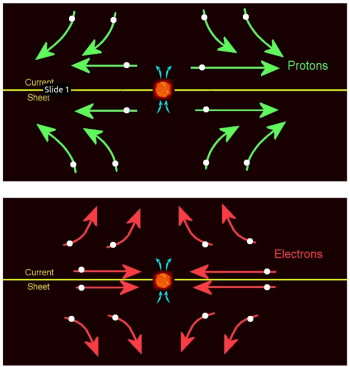

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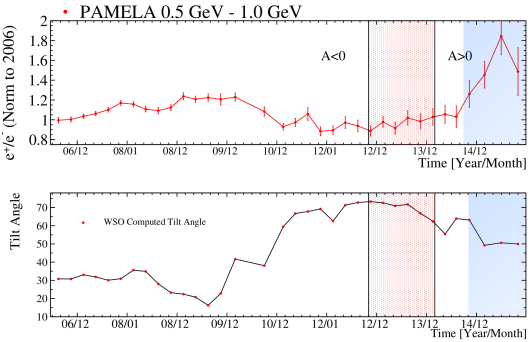

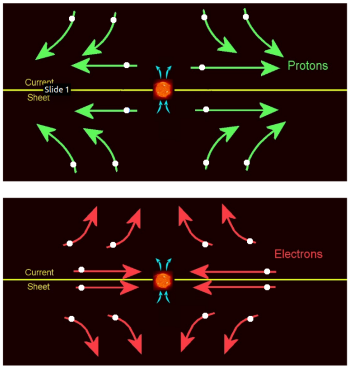

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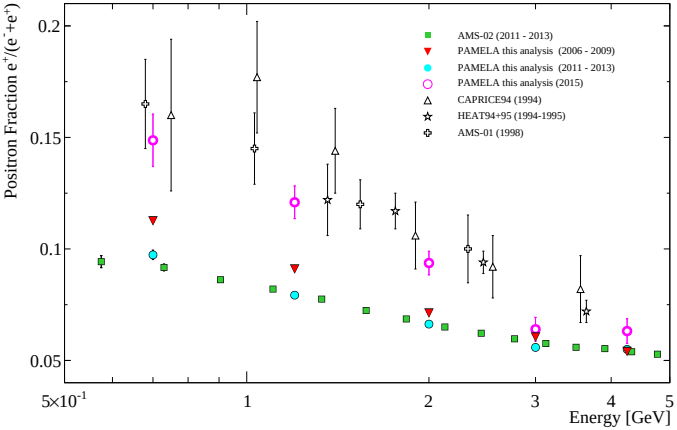
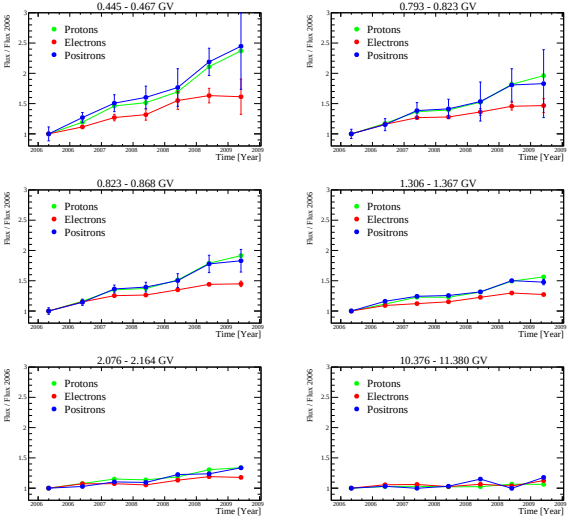
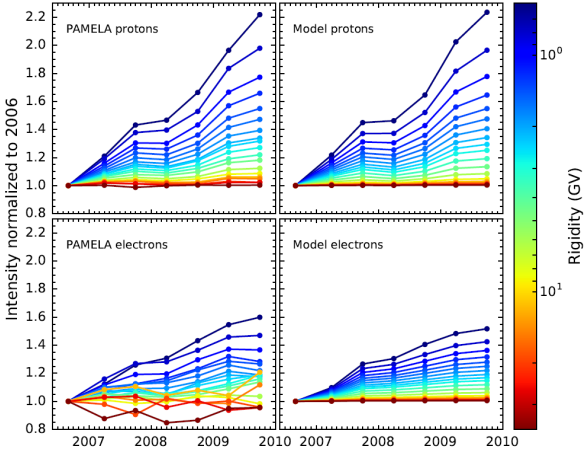


O. Adriani et al., PRL 116 (2016) 241105

Positron - Electron - Proton

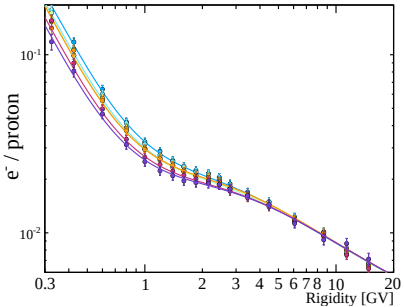


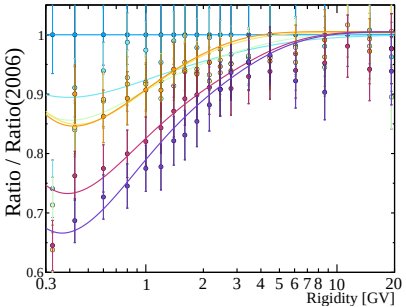
Proton - Electron

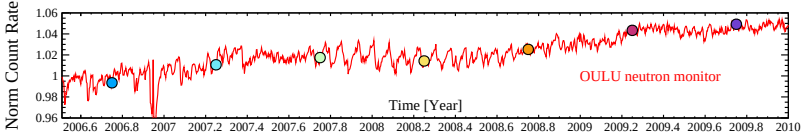


V. Di Felice et al., ApJ 834 (2017) 89

Proton Electron Ratios (Semestral 2006 - 2009)







V. Di Felice et al., ApJ 834 (2017) 89

Conclusions

- PAMELA measured electron and positron solar modulation for almost ten years;
- Electrons flux were published for the 23rd solar minimum;
- 3D numerical model was applied to reproduce PAMELA data;
- Charge sign solar modulation was studied (e^+/e^-) between 2006 and late 2015;
- (e^+/e^-) time variation introduced by drift motion was measured;
- The effect of the change of magnetic field polarity inversion was also measured;
- Electron and proton fluxes measured by PAMELA were also studied in the context of charge sing solar modulation;