New measurement on the time dependence of the cosmic-ray electrons and positrons by the PAMELA experiment between July 2006 and December 2015.

Riccardo Munini

INFN Trieste

XXV European Cosmic Ray Symposium, 4 - 9 September 2016, Torino

a Payload for Antimatter Matter Exploration and Light–nuclei Astrophysics

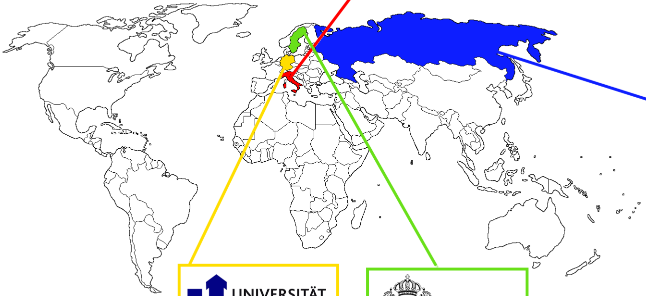
PAMELA COLLABORATION

Naples Bari Florence Frascati Rome Trieste CNR, Florence

Consiglio Nazionale delle Ricerche

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

Università di Roma Tor Vergata



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Ioffe Physical Technical Institute

Физический институт имени П.Н. Лебедева ФИАН

МИФИ

Moscow

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PAMELA collaboration and external collaboration

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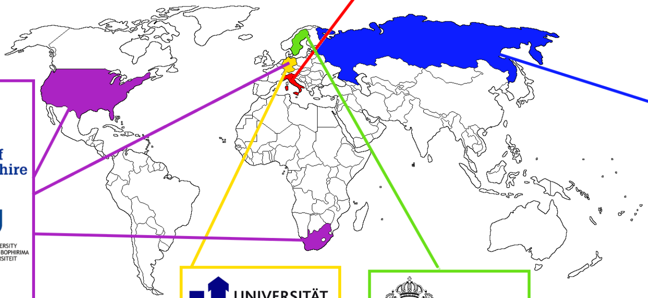

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External collaboration

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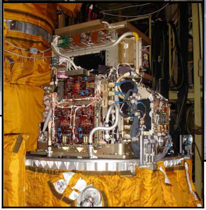
10 years of PAMELA

Launched on 15th June 2006. Recently celebrate 10 years in flight!





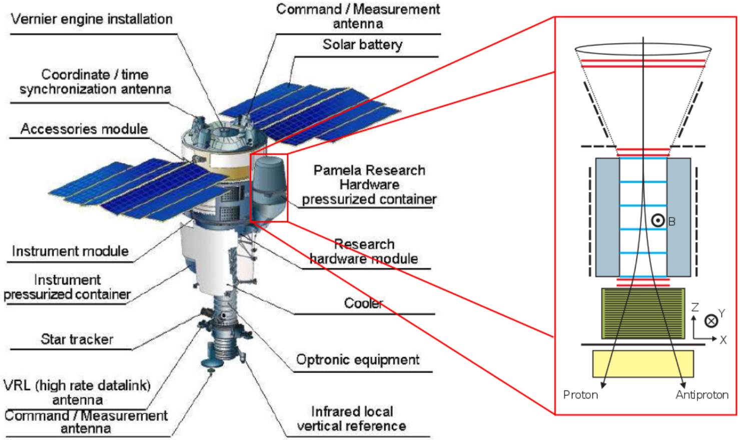
The PAMELA instrument

PAMELA

- Resurs DK1 satellite, high quality camera;
- Quasi-polar elliptical orbit 70 degree inclination → **low cutoff rigidity**.

Main goals

- Direct detection of CRs in space;
- Precise measurement of (anti)particles;
- Long flight duration → **Solar modulation**.



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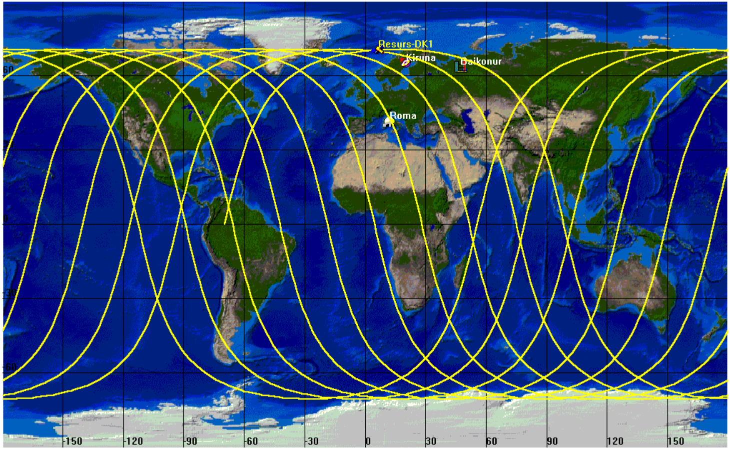

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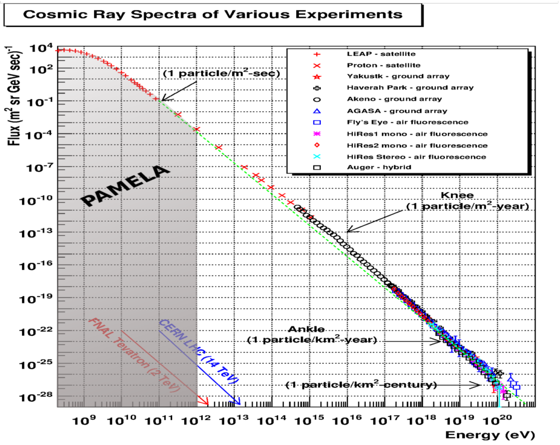

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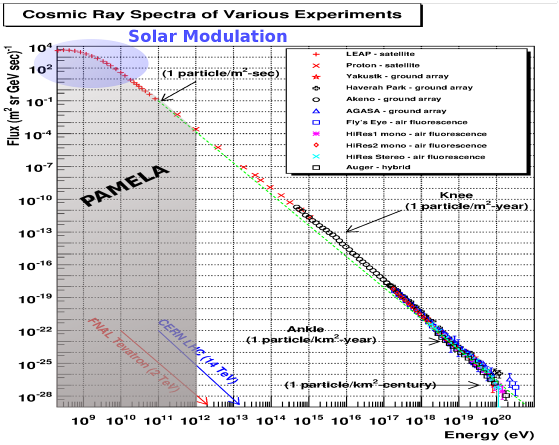


The PAMELA instrument

Time of Flight

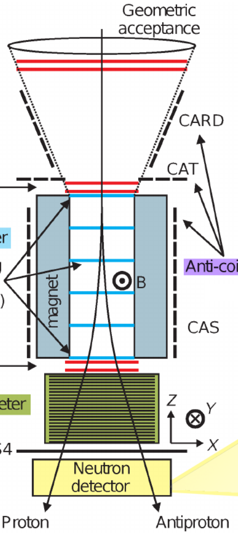
24 bars of plastic scintillator disposed on six plane, S11, S12, S21, S22, S31, S32;

Tracking system

Six plane of silicon detector inside a magnetic cavity;

Calorimeter

Calorimeter: 44 planes of Si detector interleaved with 22 tungsten planes, 16.3 radiation length;



GF: 21.5 cm² sr
Mass: 470 kg
Size: 130x70x70 cm³
Power Budget: 360W

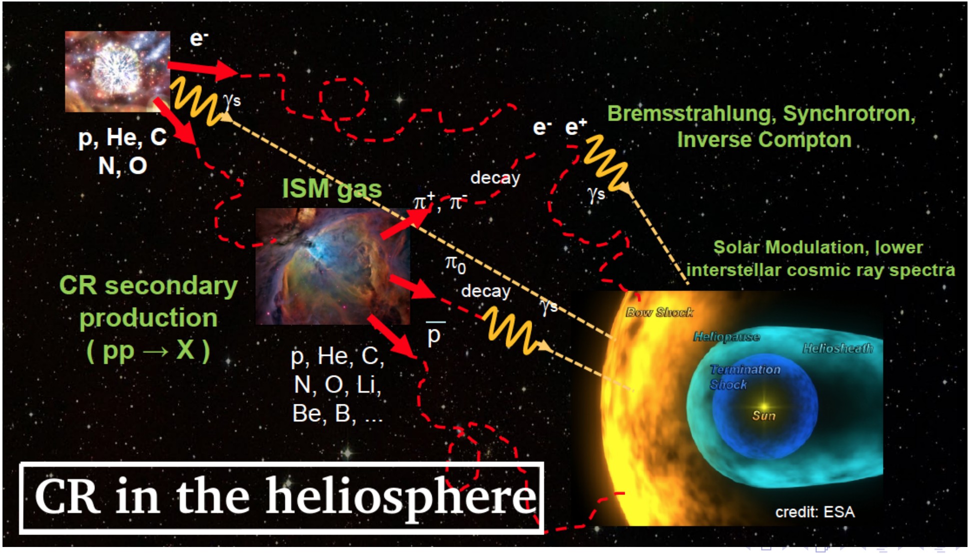
Anticoincidence

(CAS, CARD e CAT) nine plane of plastic scintillator around the apparatus;

Neutron detector

36 proportional counter filled with ^{3}He.

Cosmic Rays in the heliosphere



CRs and the heliosphere

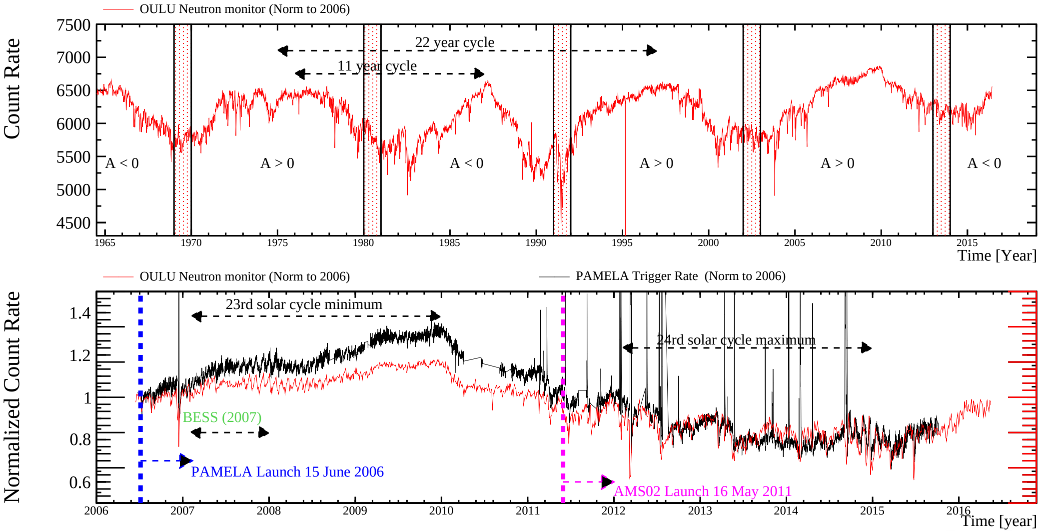
Below $\sim$ 30 GV heliosphere strongly affects CRs at Earth

$$\underbrace{\frac{\partial f}{\partial t}}_{a} = -\underbrace{\mathbf{V}\cdot\nabla f}_{b} + \underbrace{\nabla\cdot(\mathbf{K_s}\cdot\nabla f)}_{c} - \underbrace{\langle \mathbf{v_D}\rangle\cdot\nabla f}_{d} + \underbrace{\frac{1}{3}(\nabla\cdot\mathbf{V})\frac{\partial f}{\partial \ln p}}_{e} + \underbrace{Q(\mathbf{x},p,t)}_{f}$$

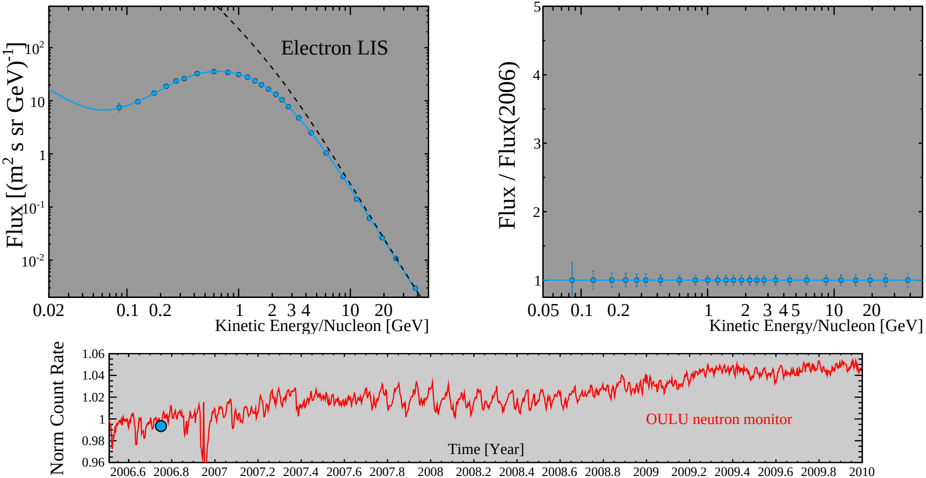
(a) $f(\mathbf{x}, p, t)$, omnidirectional function distribution of CRs; **(b)** convection with solar wind $\mathbf{V}$; **(c)** diffusion by magnetic field irregularities; **(d)** drift, curvature and gradient in magnetic field; **(e)** adiabatic energy losses; **(f)** local sources (Jovian electrons);

Heliosphere: ideal environment to test the theory for propagation of charged particles under conditions which well approximate cosmic condition.

Solar Activity and Cosmic Rays

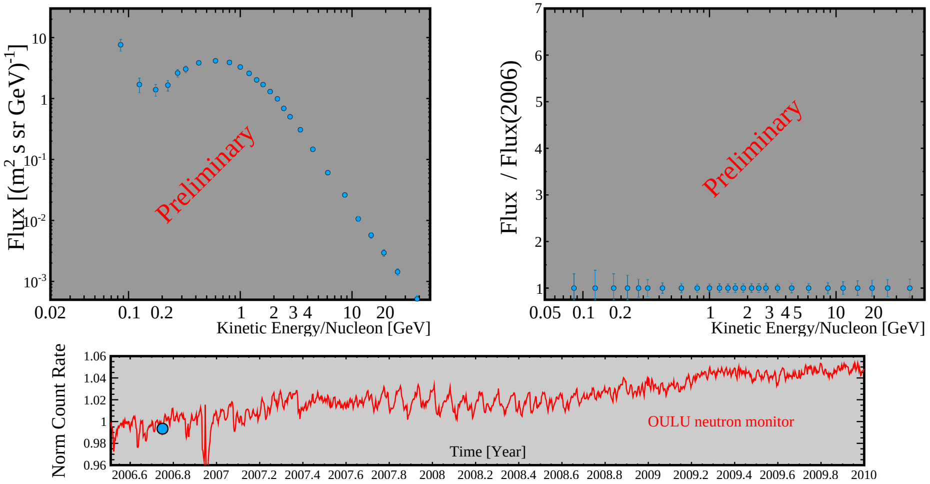


Time Dependent Electron Fluxes



O. Adriani et al., ApJ 810 (2015) 142 *M. S. Potgieter et al., ApJ 810 (2015) 2, 141*

Time Dependent Positron Fluxes

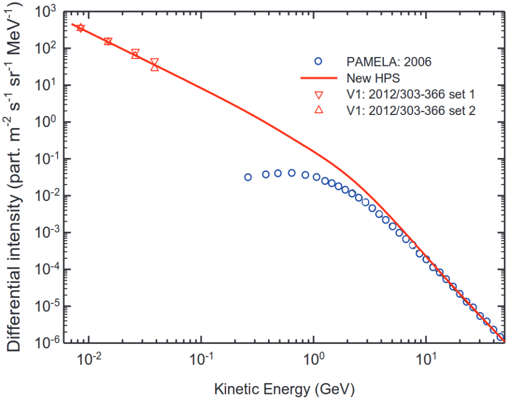


Modeling

3D numerical solution of the Parker equation

Results

- Input spectrum LIS;
- Tilt angle averaged on the preceding 16 months;
- Heliospheric magnetic field (HMF);
- LIS modulated from the HP up to Earth.
- Determination of diffusion and drift coefficients.



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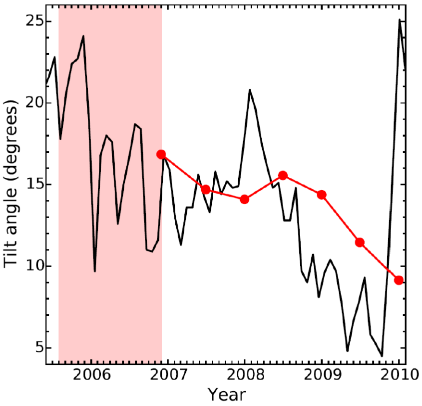

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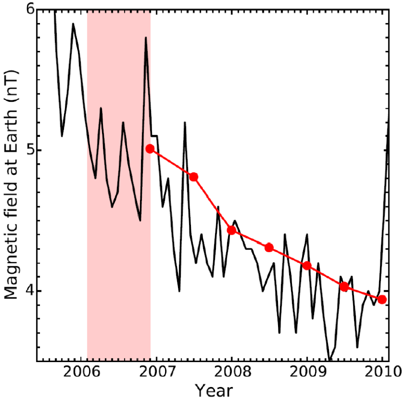

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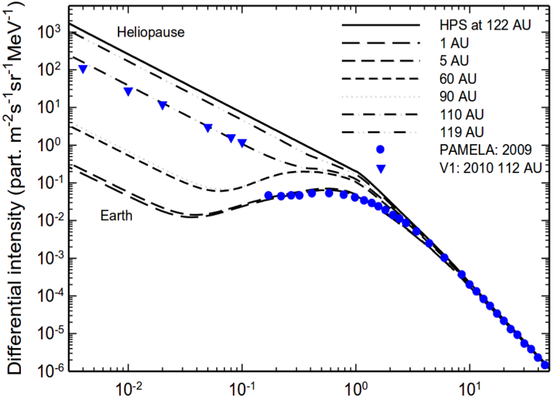

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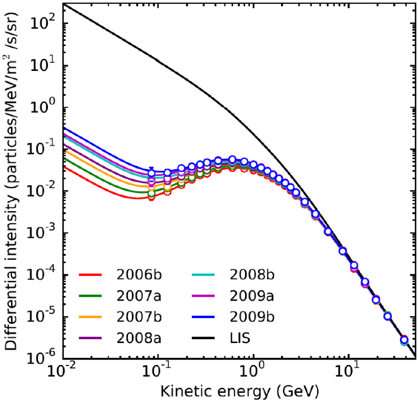

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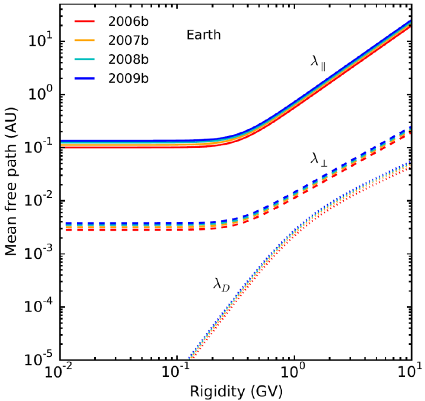
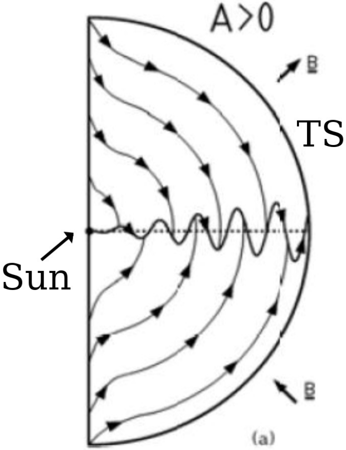
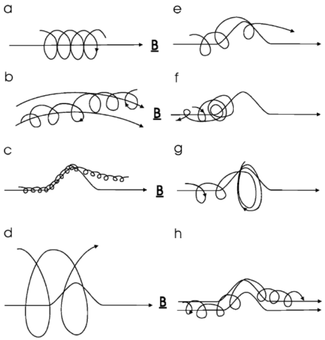


Drift Pattern (Positive charged particles)



$$\underbrace{\langle \mathbf{v_D} \rangle \cdot \nabla f}_{d}$$

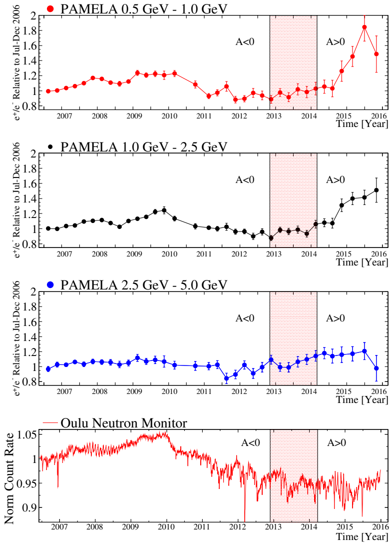


H. Moraal, Space Science Reviews 176 (2013) 299

Reversal of the Sun magnetic field polarity

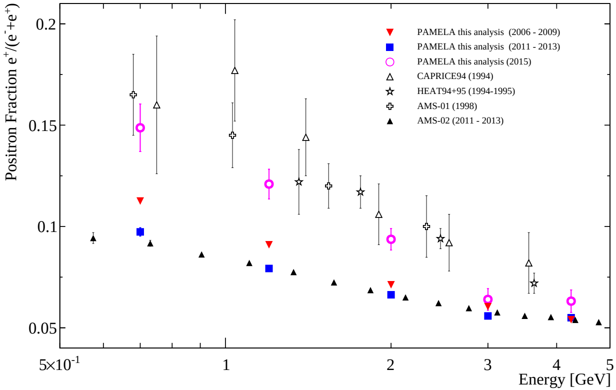
- Polarity reversal change global drift pattern for positive and negative particles;
- During the 24th solar cycle this took place between November 2012 and March 2014 (16 months apart);
- After few months the new condition "propagate" through the heliosphere and positron starts to increase abruptly.

O. Adriani et al., Phys. Rev. Lett. 116, (2016), 241105



Time dependence of the positron fraction

- Low energy "tension" between experiment explain with charge-sign dependence;
- Positron fraction in 2015 approach previous measure obtained in A $>$ 0 epochs.



Conclusion and Perspective

- Time dependent electron and positron fluxes were evaluated during 23rd solar minimum (2006-2009);
- A 3D numerical model was used to reproduce the experimental data;
- Diffusion and drift coefficents were evaluated;
- Drift effects were studied by means of the electron to positron ratio;
- Tension between measurements of the positron fraction at low energy (< 5 GeV) explanined in term of charge sign dependent solar modulation;
- Solar modulation of Helium (Carbon ?).