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

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INFN Trieste

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

PAMELA collaboration

Naples  Bari  Florence  Frascati  Rome  Trieste  CNR, Florence

Germany  Sweden

Moscow  St. Petersburg
PAMELA collaboration and external collaboration

Naples  Bari  Florence  Frascati  Rome  Trieste  CNR, Florence

External collaboration

University of New Hampshire

Northwest University

NASA

University of Siegen

Kungl Tekniska Högskolan

Moscow

St. Petersburg

Germany

Sweden
Launched on 15th June 2006. Recently celebrate 10 years in flight!
The Pamela experiment

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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**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;

**Anticoincidence**

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

**Neutron detector**

36 proportional counter filled with $^3$He.

GF: 21.5 cm$^2$ sr
Mass: 470 kg
Size: 130x70x70 cm$^3$
Power Budget: 360W
Cosmic Rays in the heliosphere

CR secondary production (pp → X)

CR in the heliosphere

Bremsstrahlung, Synchrotron, Inverse Compton

Solar Modulation, lower interstellar cosmic ray spectra
CRs and the heliosphere

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

$$\frac{\partial f}{\partial t} = -V \cdot \nabla f + \nabla \cdot (K_s \cdot \nabla f) - \langle v_D \rangle \cdot \nabla f + \frac{1}{3} (\nabla \cdot V) \frac{\partial f}{\partial \ln p} + Q(x, p, t)$$

(a) $f(x, p, t)$, omnidirectional function distribution of CRs; (b) convection with solar wind $V$; (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.
TIME DEPENDENT ELECTRON 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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Drift Pattern (Positive charged particles)

\[ \langle v_D \rangle \cdot \nabla f \]

H. Moraal, Space Science Reviews 176 (2013) 299
Cosmic Rays in the heliosphere

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.

Low energy "tension" between experiment explain with charge-sign dependence;

Positron fraction in 2015 approach previous measure obtained in $A > 0$ epochs.
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 coefficients 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) explained in term of charge sign dependent solar modulation;
Solar modulation of Helium (Carbon ? ).