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Trapped positrons and electrons observed by PAMELA

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For PAMELA collaboration

PAMELA detectors

Main requirements \rightarrow high-sensitivity antiparticle identification and precise momentum measure



The PAMELA Experiment

Resurs DK satellite built by the Space factory «TsSKB Progress» in Samara (Russia)



Trigger rate ~25Hz (outside radiation belts) Event size (compressed mode) ~ 5kB 25 Hz x 5 kB/ev \rightarrow ~ 10 GB/day



Satellite was launched 15.06.2006 on elliptical polar orbit with inclination 70⁰, altitude 350-610km. Circular orbit with altitude ~570km from September 2010

Since July 2006 till June 2015:

- ~3000 days of data taking (~90%)
- ~50 TByte of raw data downlinked
- ~8•10⁹ triggers recorded and analyzed



Spectra in different parts of magnetosphere



East-west effect



Data analysis

Spectra and ratios of positrons and electrons were published in Adriani et. al "Measurements of quasitrapped electron and positron fluxes with PAMELA" -JRG, 2009

doi:10.1029/2009JA014660

Analysis for protons based on particle tracing was published : O.Adriani et al ApJ,799, 1, L4 (2015) and arXiv:1504.06253 (submitted to JGR)

Here trajectories of positrons and electrons were reconstructed in the Earth's magnetosphere by a program based on Runge-Kutta numerical integration method. IGRF field model was used (http://nssdcftp.gsfc.nasa.gov)

Boundary of magnetosphere was chosen as

Hmin=30 km, Hmax=20000 km

Time of tracing up to 30 second

(time of drift around the Earth for particles with energy E>0.1 GeV)

The method of tracing was used previously in AMS-01 experiment



Reconstructed trajectories of electrons and positrons detected by PAMELA during several orbits

Samples of particles trajectories:

Simple reentrant albedo:



Altitude vs latitude

Trajectory of albedo positrons with rigidity R=1.24 GV, detected on altitude ~1000 km

Quasi-trapped particles:



Positron trajectory with rigidity R=1.24 GV, detected on altitude 1062 km with pitch-angle 68 °.

Positron trajectory with rigidity R=0.5 GV, detected on altitude 1062 km.

Trapped positron



Positron trajectory with rigidity R=1.24 GV, detected on altitude 1062 km with pitch-angle about 90 °.

Altitude vs longitude. Minimal trajectory altitude is in South Atlantic Anomaly region.

Quasi-trapped particle near geomagnetic cut-off



Positron trajectory with rigidity R=2.24 GV, detected on altitude 1062 km with small pitch-angle .

Cosmic ray trajectory near geomagnetic cut-off



Chaotic trajectory of non-adiabatic type .

Only particles with rigidity $R < 10 / L^3$ GV were considered to exclude chaotic trajectories

Tracing of events in AMS-01



tracing of leptons

The flight time versus energy from the The geographical origin of long-lived (a) electrons and (b) positrons.

M. Aguilar et al. / Physics Reports 366 (2002) 331-405

Tracing of events in AMS-01



electrons and (b) positrons.

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PAMELA: electron and positron flight time in magnetosphere



The flight time versus energy from the tracing of leptons.

Difference with AMS-01: More wide interval of altitudes (350-600 km), possibility to work in SAA. There is trapped component with very long flight time

Re-entrant albedo: point of origin

electrons







Quasi-trapped albedo: points of detection

positrons

electrons



Quasi-trapped albedo: points of origin

AMS-01

PAMELA



Positron to electron ratio vs energy



Positron to electron ratio vs longitude

Albedo (shortlived)

Quasitrapped (longlived)



Trapped albedo: points of detection

positrons

electrons



Space distribution of trapped particles

positrons

electrons



Space distribution of trapped particles



Geomagnetic coordinates of detected trapped particles



Trapped ratio e-/e+



Positron to electron ratio



Conclusion

From tracing of particles :

- 1. By flight time selection in geomagnetic field electrons and positrons have five distinct components:
 - cosmic rays
 - cosmic rays with chaotic trajectories
 - albedo
 - quasitrapped
 - trapped
- 2. For first time PAMELA observed high energy trapped electrons and positrons with energy ~>100 MeV
- 3. Origin (production mechanism) of trapped lepton component differs from reentrant and quasitrapped components.

SPARE SLIDES





Positron to electron ratio vs energy



Quasi-trapped albedo: point of origin

positrons

electrons

