A powerful tracking detector for cosmic rays: the magnetic spectrometer of the PAMELA satellite experiment

- INTRODUCTION
- DESCRIPTION OF THE MAGNETIC SPECTROMETER
- TESTS RESULTS
- CONCLUSIONS

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The WiZard - PAMELA experiment

**MAIN TOPICS:**
- \( e^+ / \bar{p} / \text{light nuclei} \) spectra measurement
- Search for light antinuclei

**SECONDARY TOPICS:**
- Modulation of GCR's in the Heliosphere
- Solar Energetic Particles (SEP)
- Earth Magnetosphere

\[ \bar{p} \text{ spectra} \rightarrow 80 \text{ MeV}/c \ldots 190 \text{ GeV}/c \]
\[ e^+ \text{ spectra} \rightarrow 50 \text{ MeV}/c \ldots 270 \text{ GeV}/c \]
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The PAMELA detector

MAIN SUBDETECTORS

- TOF
- TRD
- Magnetic Spectrometer
- Calorimeter
- Neutron Detector

Flight forseen for the first half of 2003
The PAMELA Magnetic Spectrometer

- **Magnetic System**
  - It produces an intense magnetic field where charged particles follow curved trajectories

- **Tracking System**
  - It allows to determine six points in the high field region to reconstruct the particle trajectory → measurement of the momentum and the charge sign

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**Momentum** \( p = m_\gamma v \)

**Charge sign** \((e^+/e^-)(\bar{p}/p)\)

- If \( B \) uniform and perpendicular to \( p \), then

\[ p = qBr \]
A glossary of magnetic spectrometers

- **Momentum** \( p = qBr \) \((r=\text{radius of curvature})\)
- **Rigidity** \( R = p/q = Br \)
- **Deflection** \( \eta = 1/R = q/p \)
- \( \Delta R/R = \Delta \eta/\eta = R \cdot \Delta \eta \) \((\Delta \eta = \text{constant } \propto \text{position's measurement error})\)
- **Maximum Detectable Rigidity (MDR)**: 
  \[
  \left( \frac{\Delta R}{R} \right)_{R=\text{MDR}} = 1 \rightarrow MDR = \frac{1}{\Delta \eta}
  \]
The PAMELA Magnetic Spectrometer

MAGNETIC SYSTEM

- 5 magnetic modules
- Permanent magnet assembled in an aluminum mechanics
  - Nd-Fe-B alloy
- Magnetic cavity sizes:
  - (132 x 162) mm² x 445 mm
- Field inside the cavity:
  - 0.48 T at the center
- Places for detector planes and electronics boards lodging
- Geometric Factor: 20.5 cm²sr
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Geometry of a magnetic block

\[ \alpha = 39.17 \, \text{deg} \]
\[ \beta = 50.83 \, \text{deg} \]
The PAMELA Magnetic System

Magnetic field measurement

- Gaussmeter F.W. Bell provided with 3-axis probe mounted on a motorized positioning device (0.1mm precision)

- Measurement of the three components in 67367 points 5mm apart from each other

- Average field along the central axis of the magnetic cavity: 0.43 T

- Good uniformity!

Main field component along the cavity axis
The PAMELA Magnetic System

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The PAMELA Tracking System

- 6 detector planes
- Each plane: composed of 3 "ladders"
- The "ladder": 2 microstrip silicon sensors + 1 hybrid circuit with front-end electronics (VA1 chip)
- Silicon sensors: double sided; double metalization; integrated decoupling capacitance
- Resolutions: $\sigma_x \approx 3\,\mu m$, $\sigma_y \approx 13\,\mu m$
- MDR > 740 (GV/c)
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The first detector plane
The test plane electronics lodging on the magnetic system
The magnetic spectrometer during the last beam test at CERN (July 2002)
July 2000: CERN SPS

- FINAL LADDERS
- FINAL ELECTRONICS
- SMALLER MAGNETIC SYSTEM

Spatial resolution
(July 2000 beam test with 5 ladder prototype MS)

\[
\langle \sigma_x \rangle = (2.77 \pm 0.04) \mu m \\
\langle s/n \rangle \approx 50
\]

\[
\langle \sigma_y \rangle = (13.1 \pm 0.2) \mu m \\
\langle s/n \rangle \approx 20
\]
July 2000: CERN SPS

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- FINAL ELECTRONICS
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\[ \eta = \frac{1}{R} = \frac{q}{p} \]
July 2000: CERN SPS

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\[ \Delta p/p \text{ versus } p \]

\[ MDR = (742 \pm 38) \text{GV} / \text{c} \]
2002: production of flight model detector planes
Performances obtained with cosmic rays in Firenze: s/n for MIP

![Graph showing S/N ratio versus percentage of bad strips for different planes.](image-url)
During the last test (July 2002) the spectrometer flight model has been tested to determine the performances.

**Signal**

### non bending view

- Entries: 500
- Entries: 500
- Entries: 500
- Entries: 500
- Entries: 500
- Entries: 500
- Entries: 500
- Entries: 500

### bending view

- Entries: 500
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**Signal/Noise**

- $s/n \approx 26$
- $s/n \approx 52$
During the last test (July 2002) the spectrometer flight model has been tested to determine the performances.

**July 2002: CERN SPS**

300 GeV/c Electron event

- **non bending view**
- **bending view**
CONCLUSIONS

- The PAMELA magnetic spectrometer is now ready for the final assembly phase

- The tracking capabilities have been accurately studied in several beam tests at CERN PS and SPS since 1998
  - \((s/n)_x \approx 52\), \((s/n)_y \approx 26\) for MIP
  - spatial resolution: \(\sigma_x \approx 3\mu m\), \(\sigma_y \approx 13\mu m\)
  - MDR > \textbf{740 (GeV/c)}

- The whole detector will be assembled starting from next week in the laboratory of Roma Tor Vergata