

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



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

Lorenzo Bonechi
INFN Sezione di Firenze - PAMELA collaboration

The WiZard - **PAMELA** experiment

MAIN TOPICS:

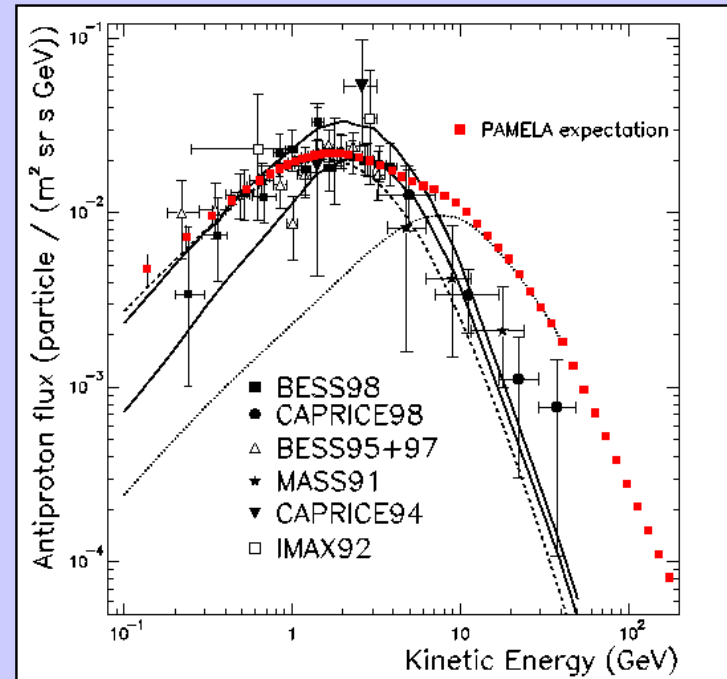
- e^+ / \bar{p} / light nuclei spectra measurement
- Search for light antinuclei

SECONDARY TOPICS:

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

\bar{p} spectra → 80 MeV/c ... 190 GeV/c
 e^+ spectra → 50 MeV/c ... 270 GeV/c

Antiproton flux



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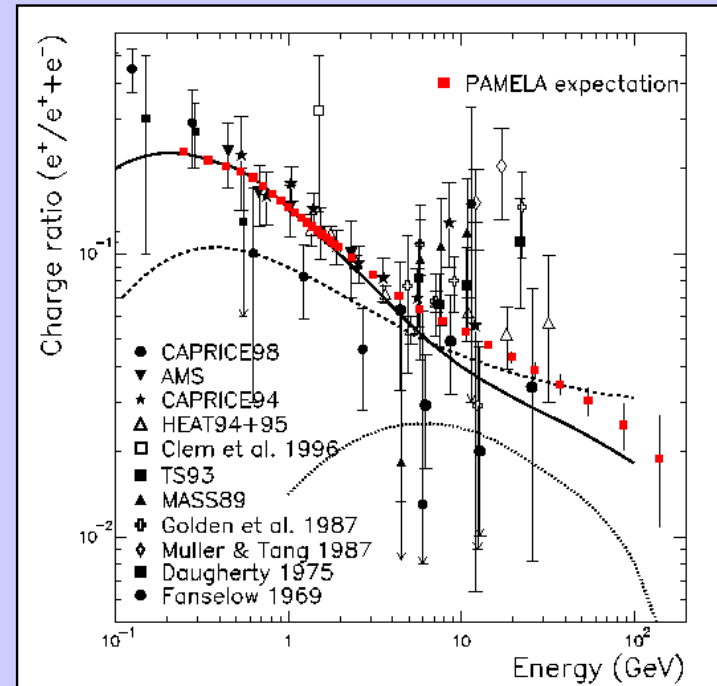
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Positron charge ratio



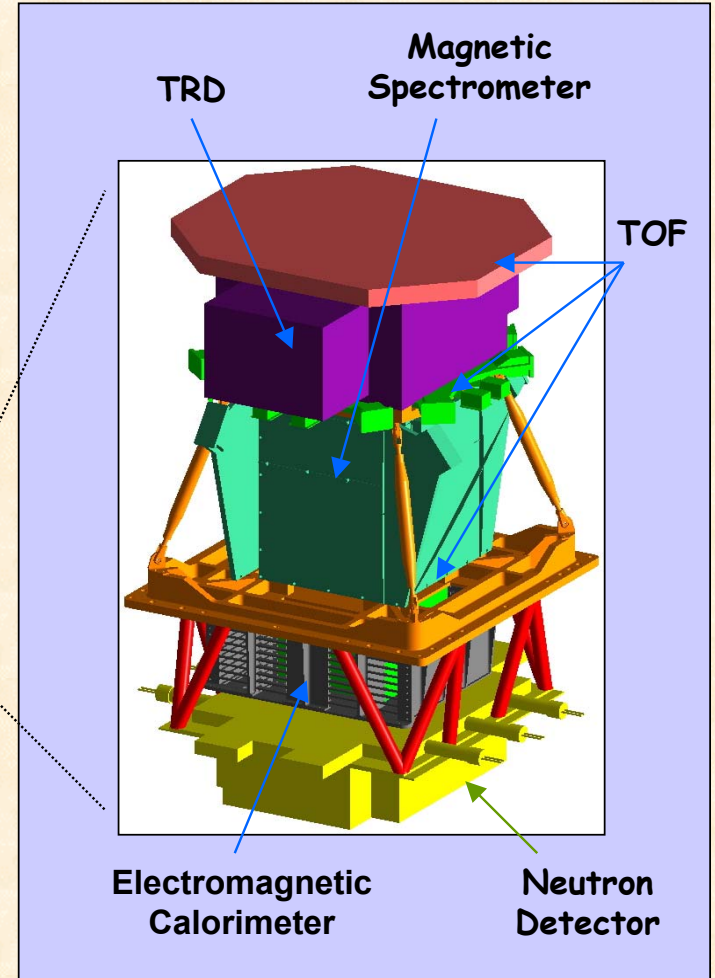
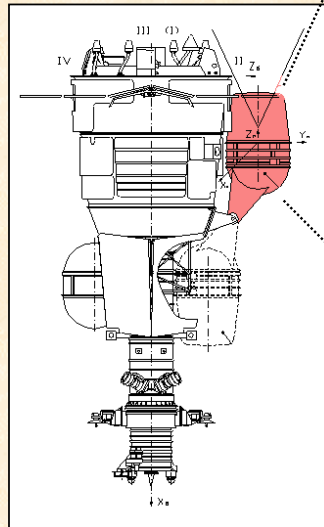
The **PAMELA** detector

MAIN SUBDETECTORS

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

Flight forseen for the first half of 2003

RESURS DK1



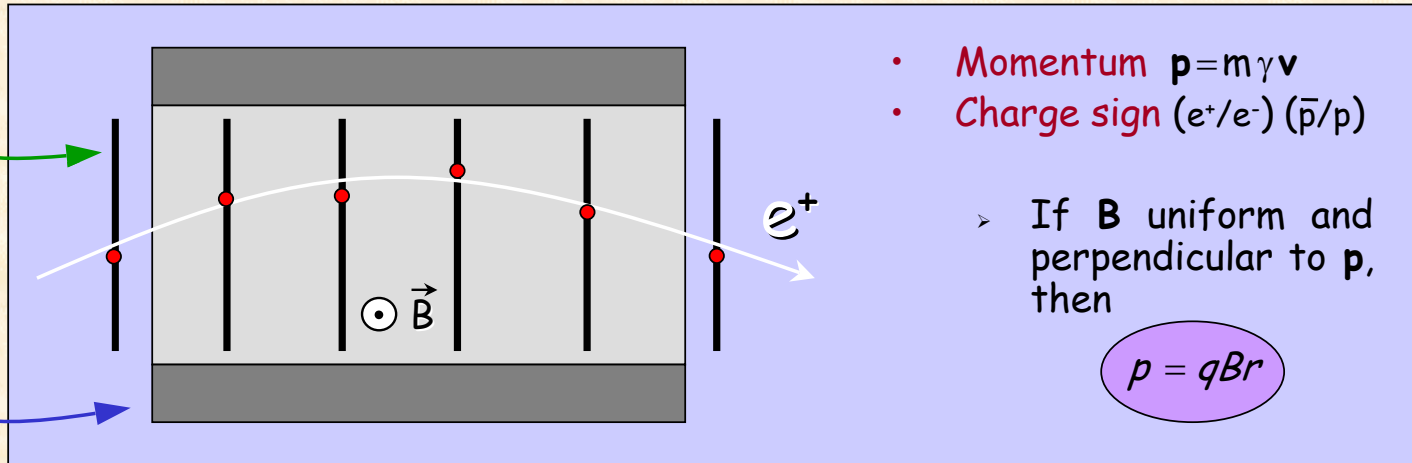
The **PAMELA** Magnetic Spectrometer

- **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

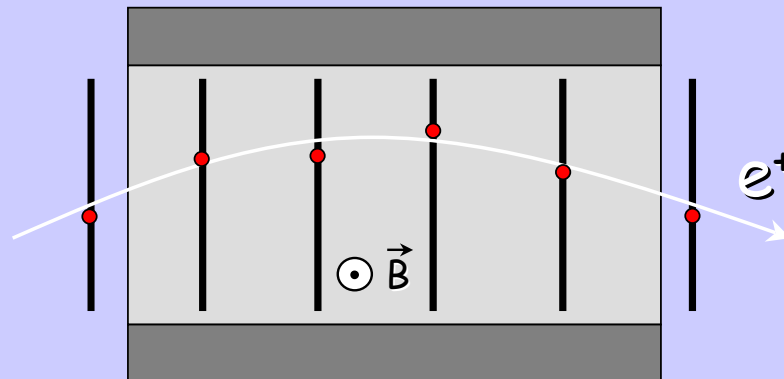


A glossary of magnetic spectrometers

- **Momentum** $p = qBr$ (r =radius of curvature)
- **Rigidity** $R = p/q = Br$
- **Deflection** $\eta = 1/R = q/p$
- $\Delta R/R = \Delta\eta/\eta = R \cdot \Delta\eta$ ($\Delta\eta = \text{constant} \propto \text{position's measurement error}$)

↳ spatial resolution

- Maximum Detectable Rigidity (**MDR**): $\left(\frac{\Delta R}{R}\right)_{R=MDR} = 1 \rightarrow MDR = \frac{1}{\Delta\eta}$

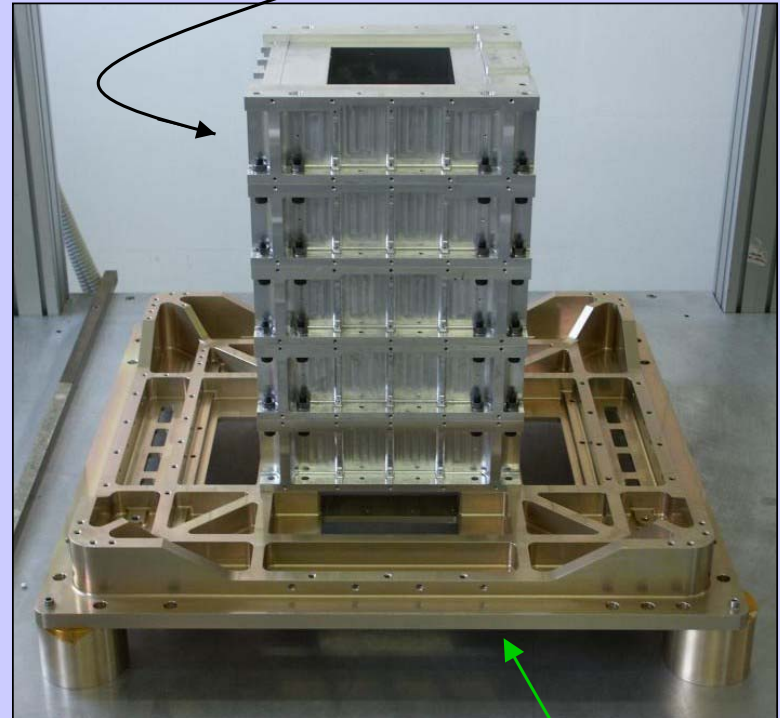


The **PAMELA** Magnetic Spectrometer

MAGNETIC SYSTEM

- 5 magnetic modules
- permanent magnet assembled in an aluminum mechanics
 - **Nd-Fe-B** alloy
- magnetic cavity sizes:
 - $(132 \times 162) \text{ mm}^2 \times 445 \text{ mm}$
- field inside the cavity:
 - **0.48 T** at the center
- places for detector planes and electronics boards lodging
- Geometric Factor: **20.5 cm²sr**

The "Magnetic Tower"



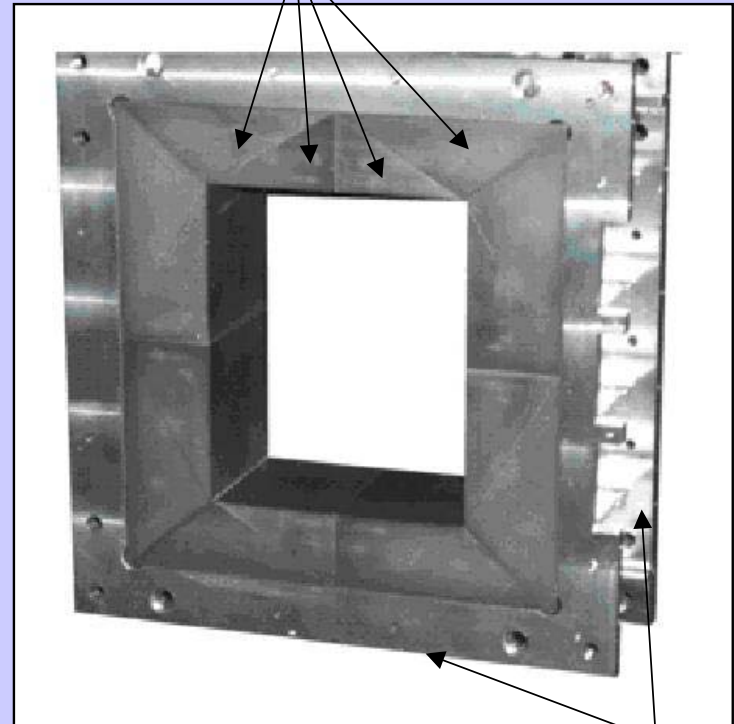
Base Plate prototype

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Permanent magnet elements



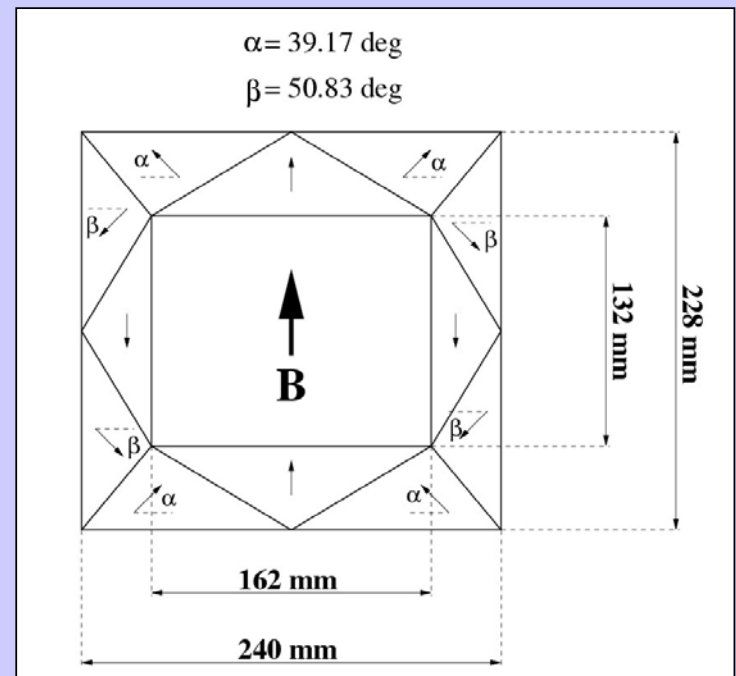
Aluminum frame

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Geometry of a magnetic block

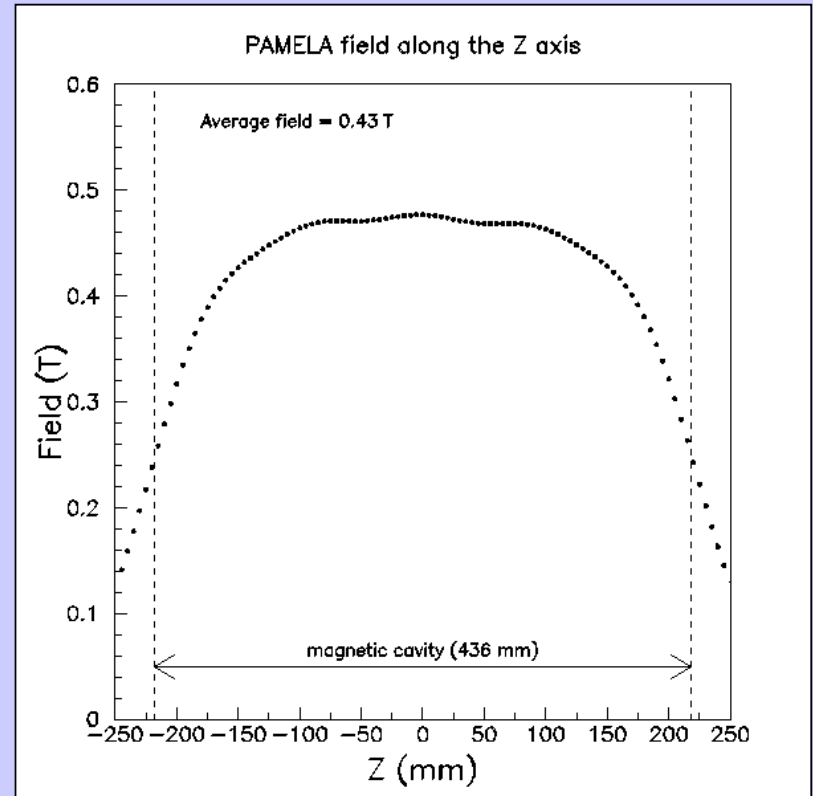


The PAMELA Magnetic System

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

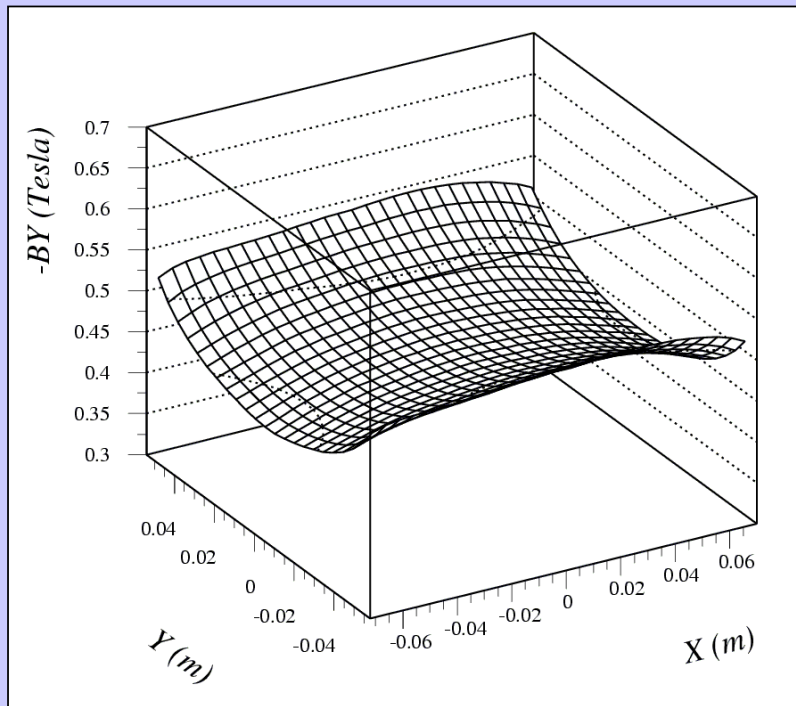


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Main field component for $z=0$ (I)

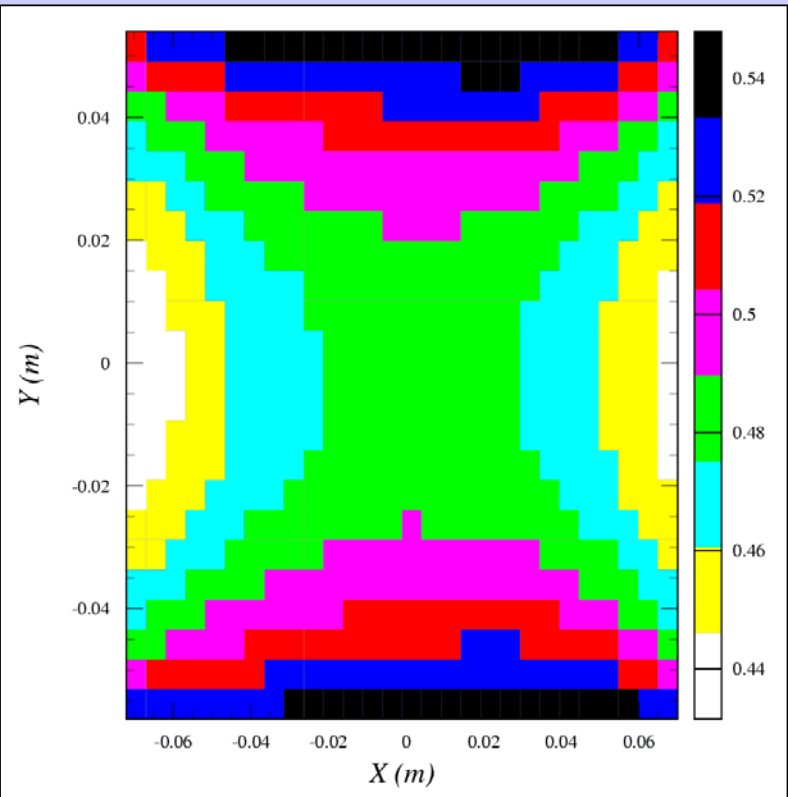


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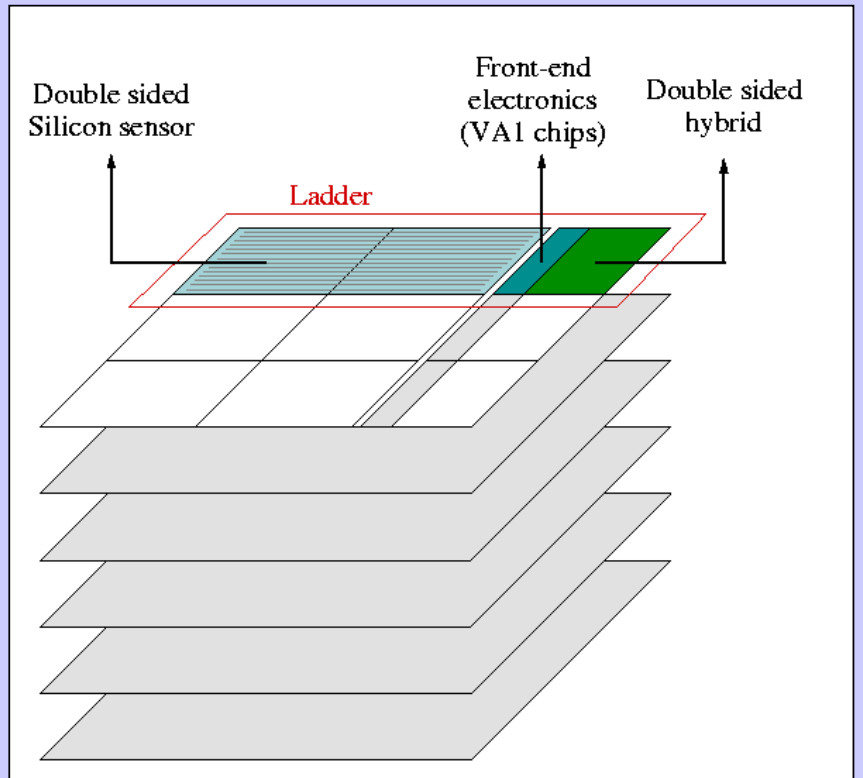


The PAMELA Tracking System

The TRACKER

- 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: $\sigma_x \approx 3\mu\text{m}$, $\sigma_y \approx 13\mu\text{m}$
- MDR > 740 (GV/c)

The detector planes

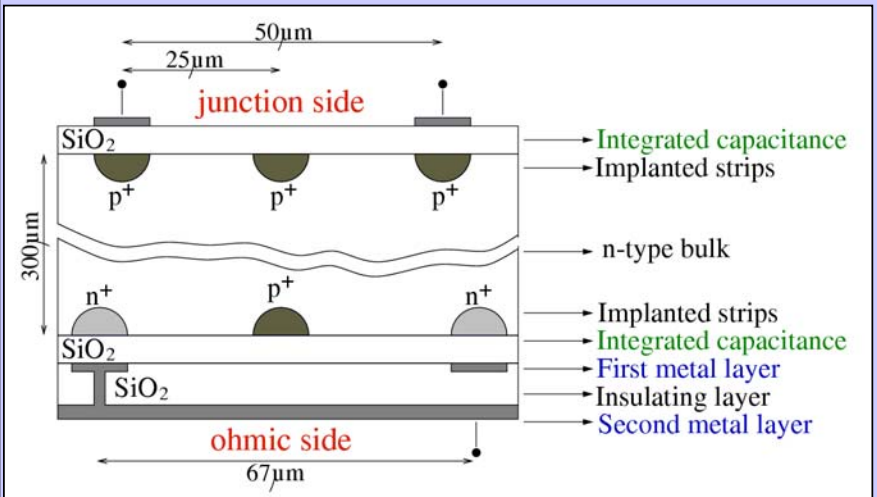


The PAMELA Tracking System

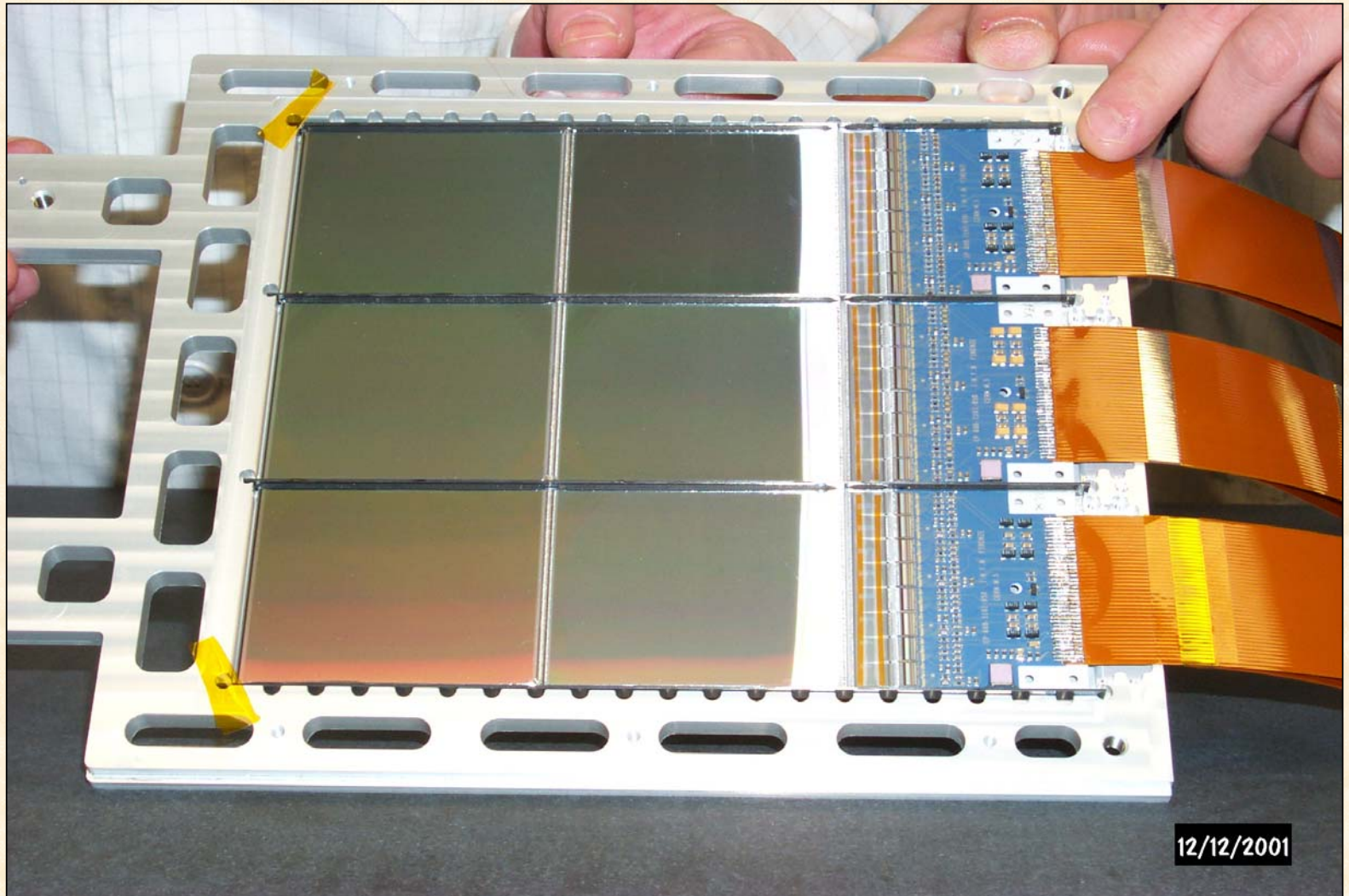
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The silicon sensor



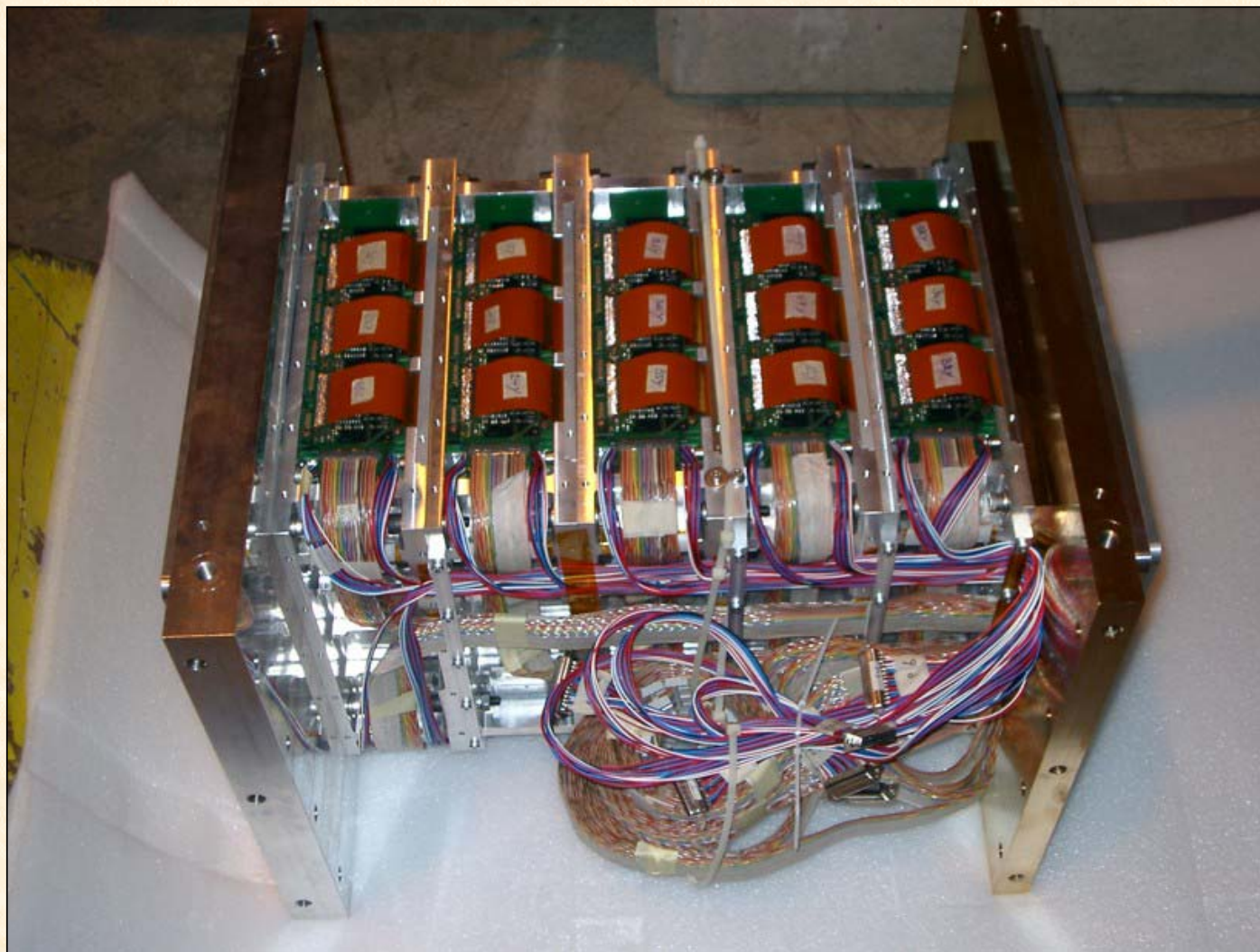
The first detector plane



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

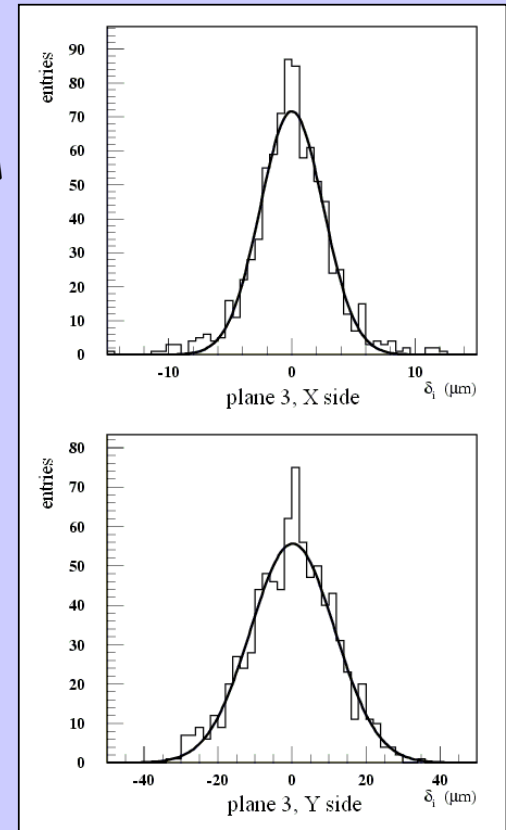
(July 2000 beam test with 5 ladder prototype MS)

$$\langle \sigma_x \rangle = (2.77 \pm 0.04) \mu\text{m}$$

$$\langle s/n \rangle \approx 50$$

$$\langle \sigma_y \rangle = (13.1 \pm 0.2) \mu\text{m}$$

$$\langle s/n \rangle \approx 20$$



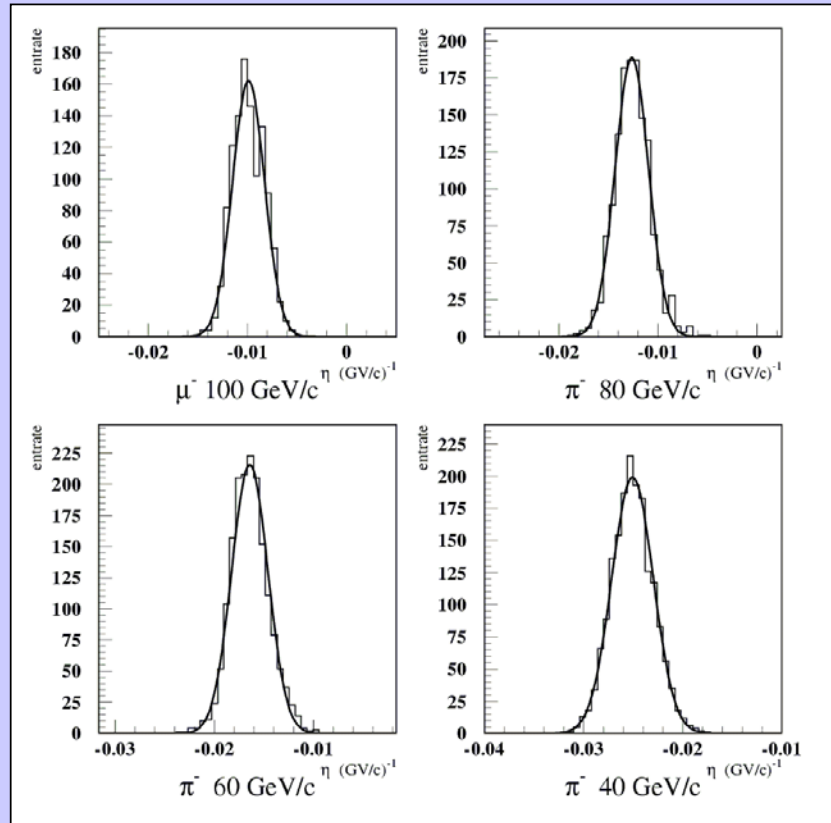
July 2000: CERN SPS

- FINAL LADDERS
- FINAL ELECTRONICS
- SMALLER MAGNETIC SYSTEM



η DISTRIBUTION

$$\eta = 1 / R = q / p$$

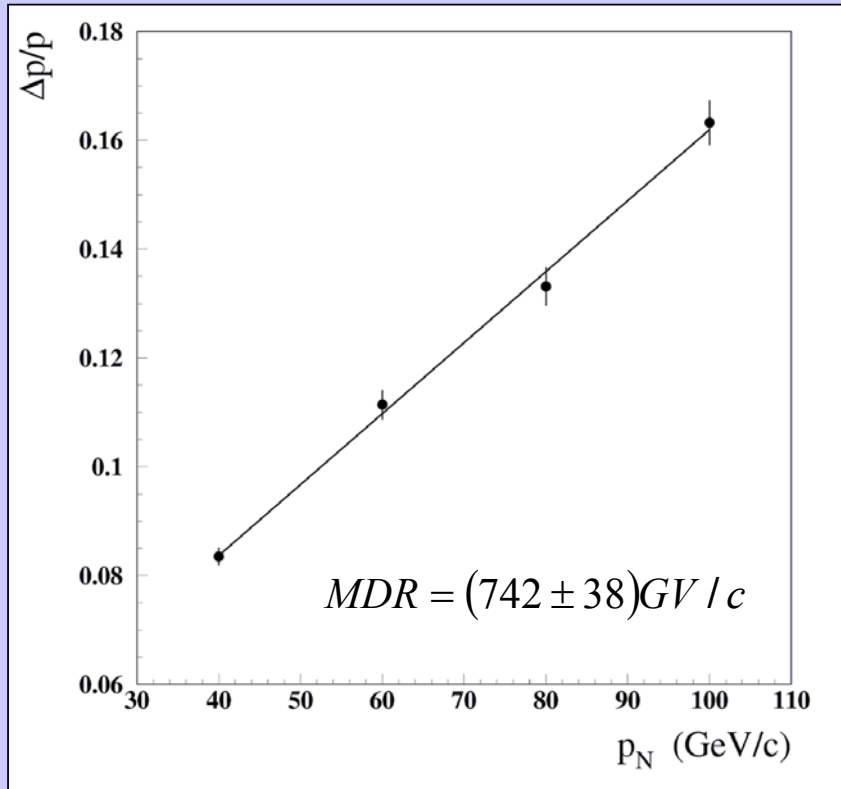


July 2000: CERN SPS

- FINAL LADDERS
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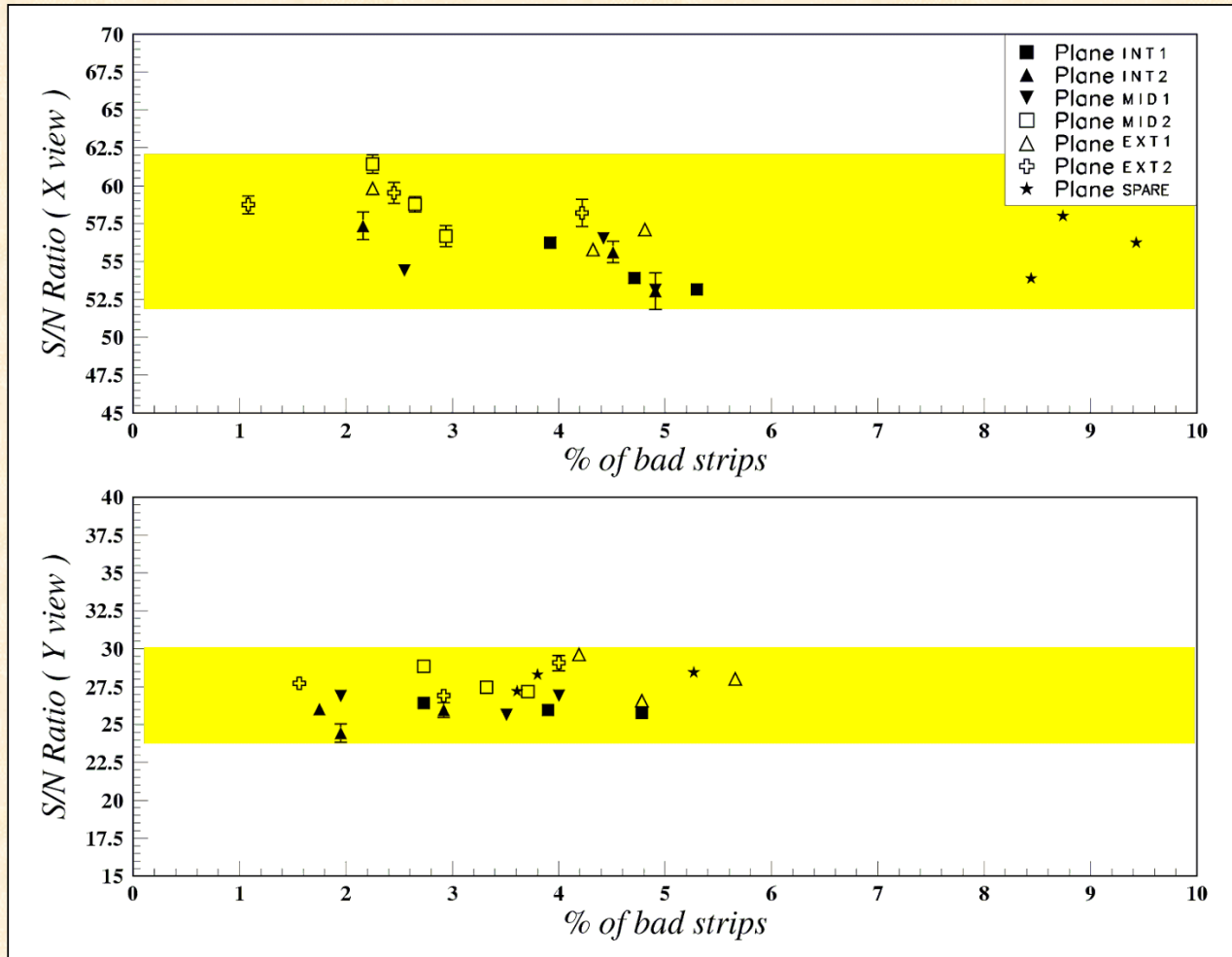


$\Delta p/p$ versus p



2002: production of flight model detector planes

Performances obtained with cosmic rays in Firenze : s/n for MIP



July 2002: CERN SPS

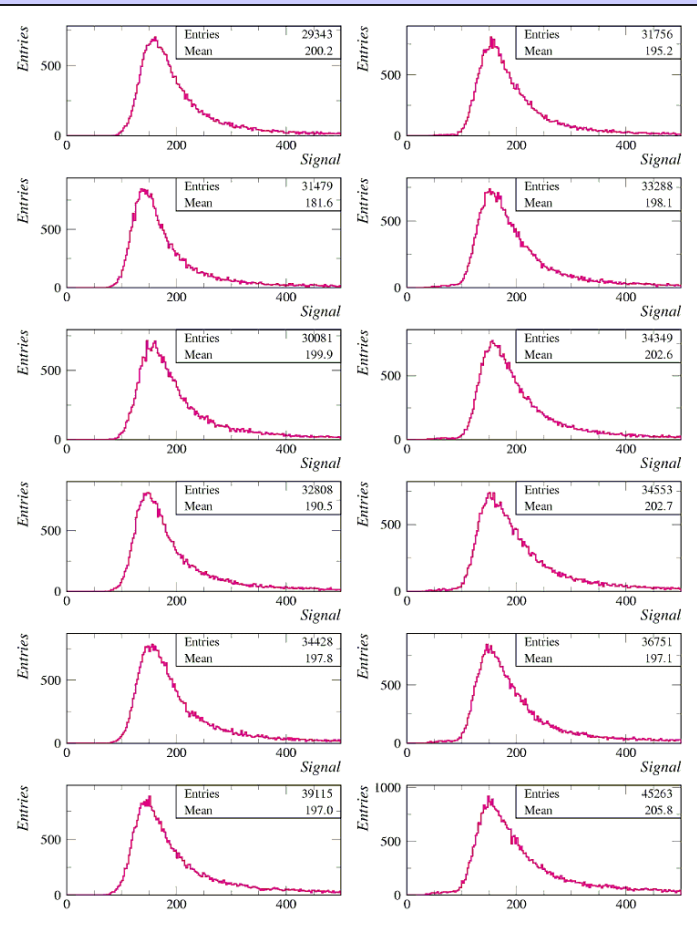
During the last test (July 2002) the spectrometer flight model has been tested to determine the performances



Signal

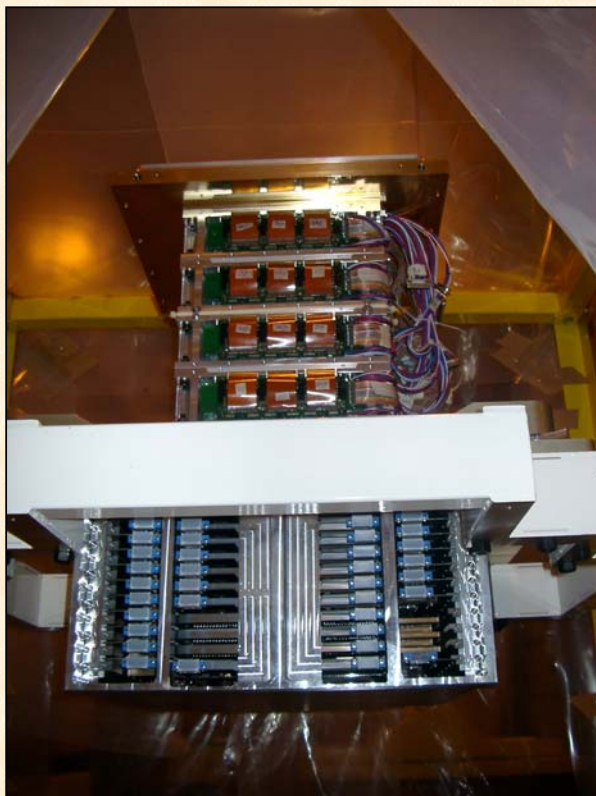
non bending view

bending view



July 2002: CERN SPS

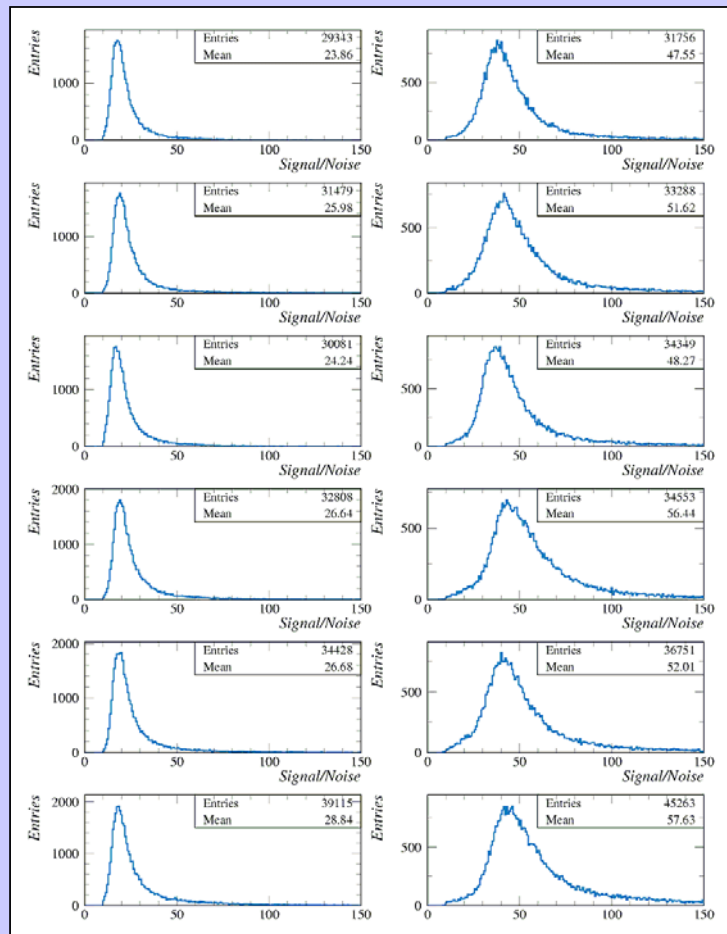
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Signal/Noise

$s/n \approx 26$

$s/n \approx 52$



July 2002: CERN SPS

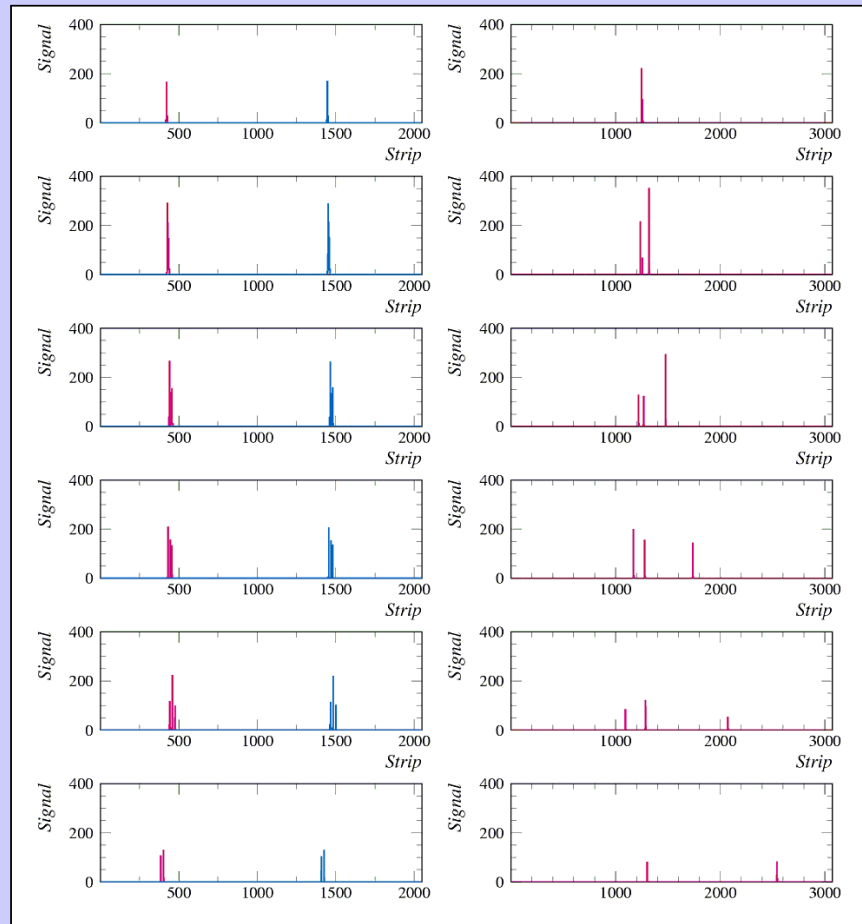
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300 GeV/c Electron event

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 : $\sigma_x \approx 3\mu\text{m}$, $\sigma_y \approx 13\mu\text{m}$
 - MDR > 740 (GV/c)
- The whole detector will be assembled starting from **next week** in the laboratory of Roma Tor Vergata