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The PAMELA silicon tracker

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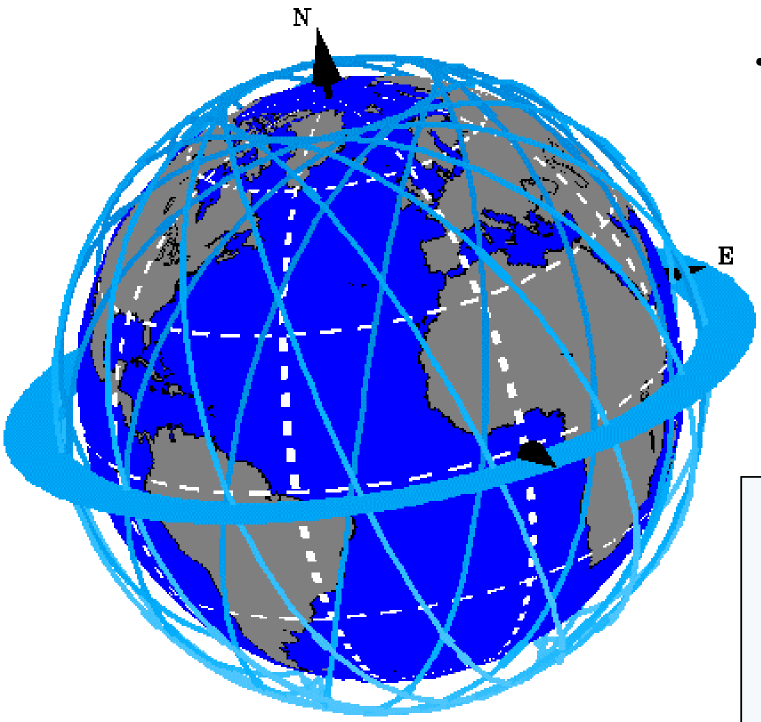
Outline

I will talk about:

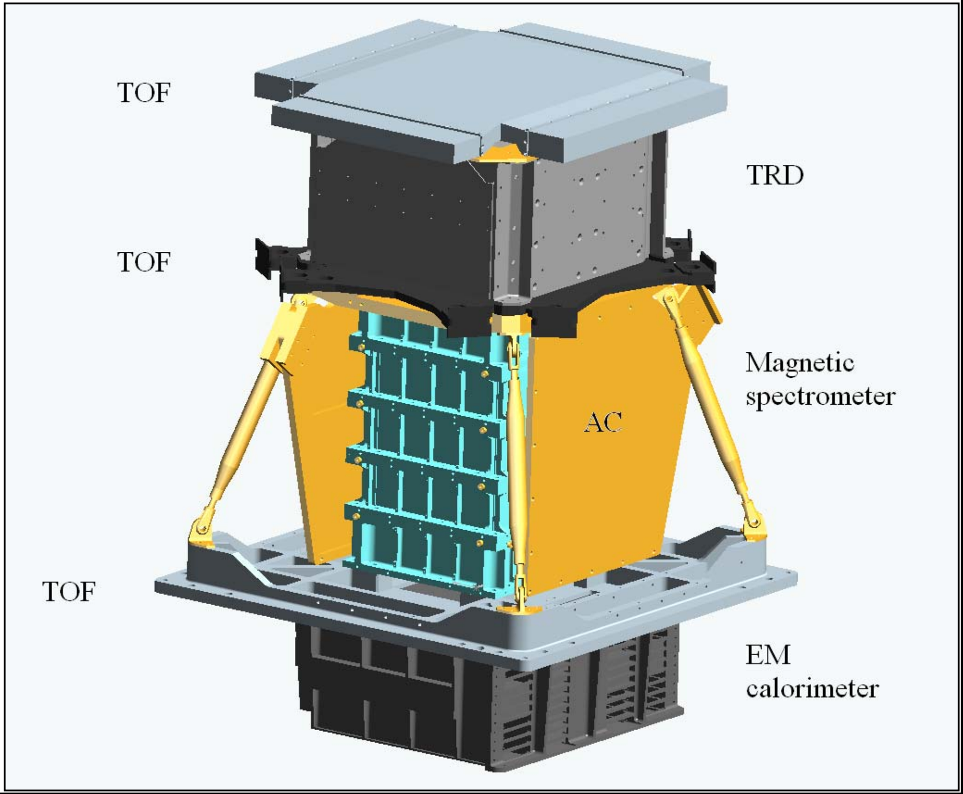
- scientific objectives of the PAMELA experiment
- tracking system's characteristics
- development of the detectors
- expected capabilities
- current status of the apparatus

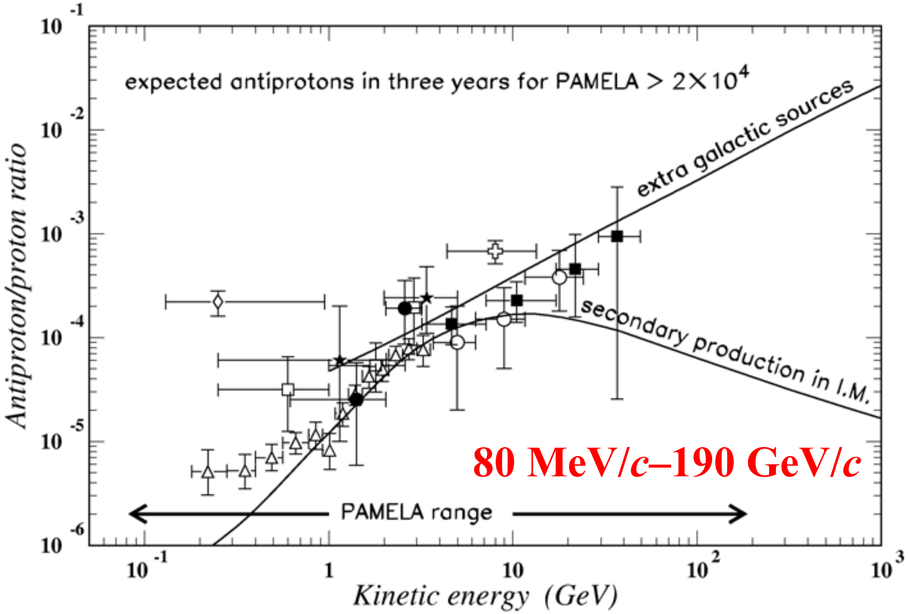


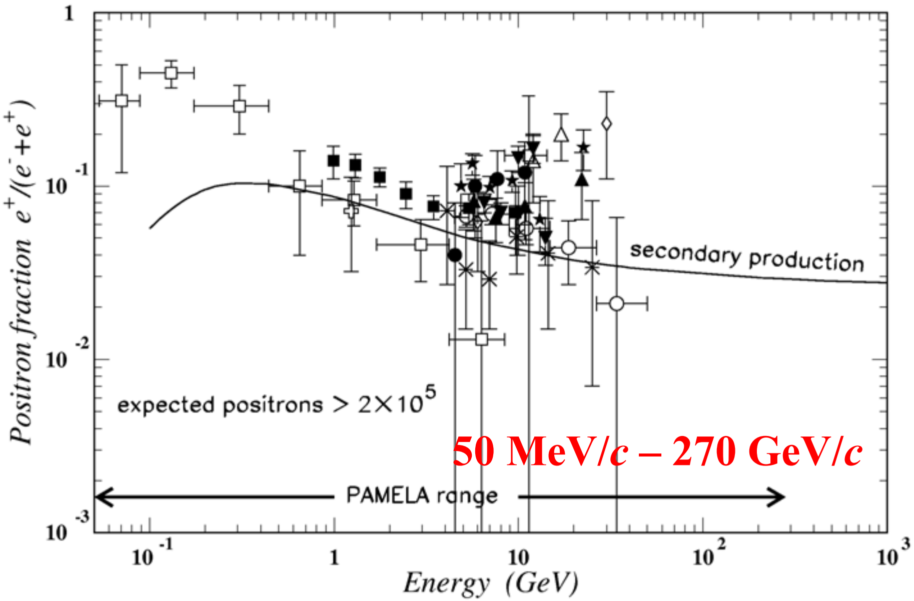
The PAMELA experiment

a Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics

The detector will be launched in orbit in 2004 onboard of the Russian satellite Resurs DK.
Quote: 350 to 600 km,
Inclination: 70.4 deg.
Main topic: search for antiparticles (antiprotons and positrons) in cosmic rays.

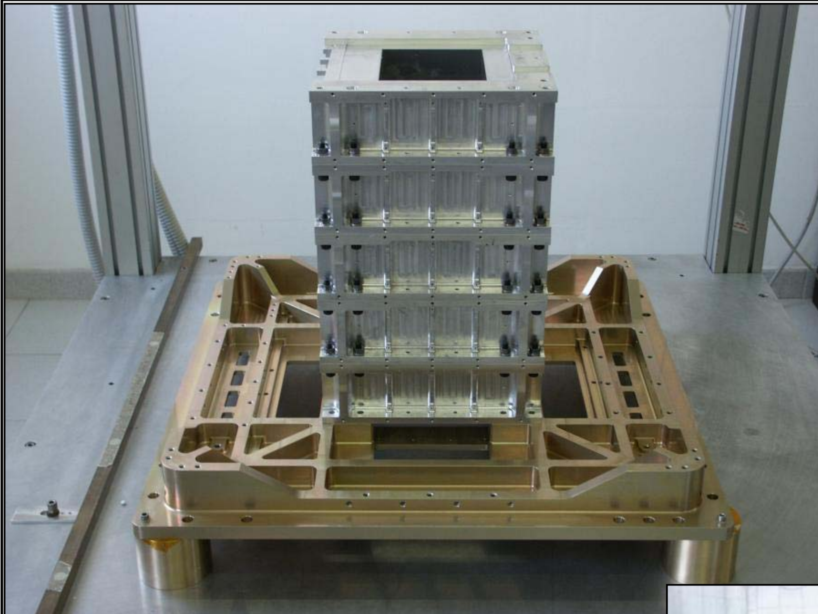






Measurements of antiprotons and positrons

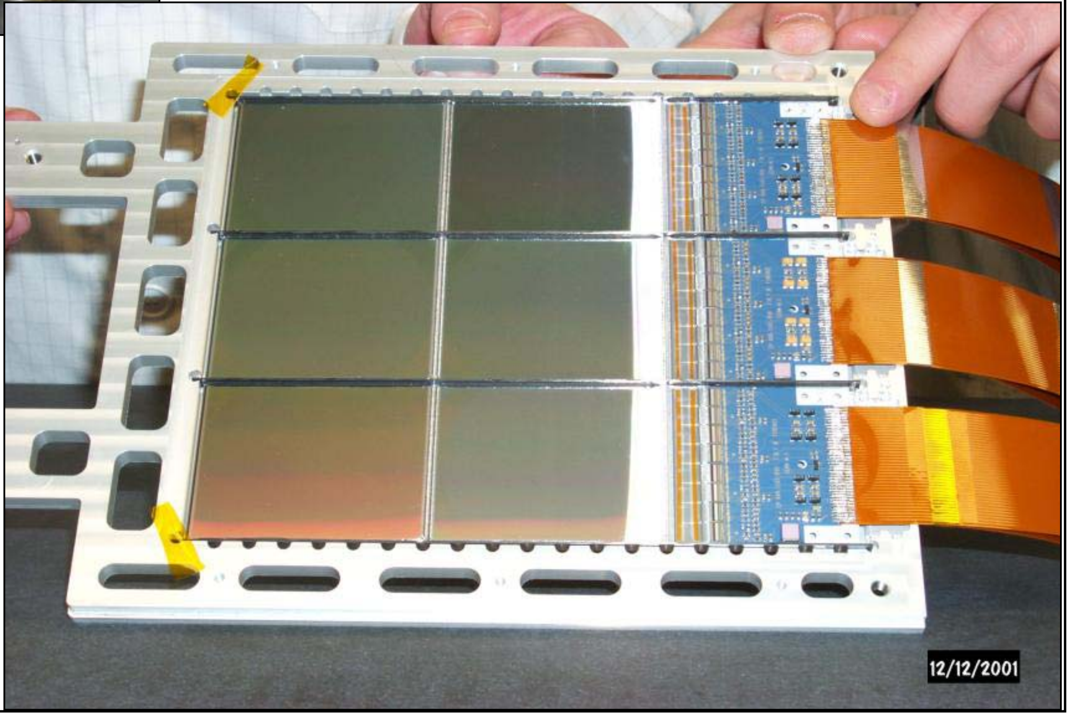
PAMELA will greatly improve the statistics (about $2{\cdot}10^4$ $\bar{p}$ and $2{\cdot}10^5$ e^+ expected in 3 years) and widen the energy range for antimatter acquisitions compared to balloon-borne missions



The tracking system

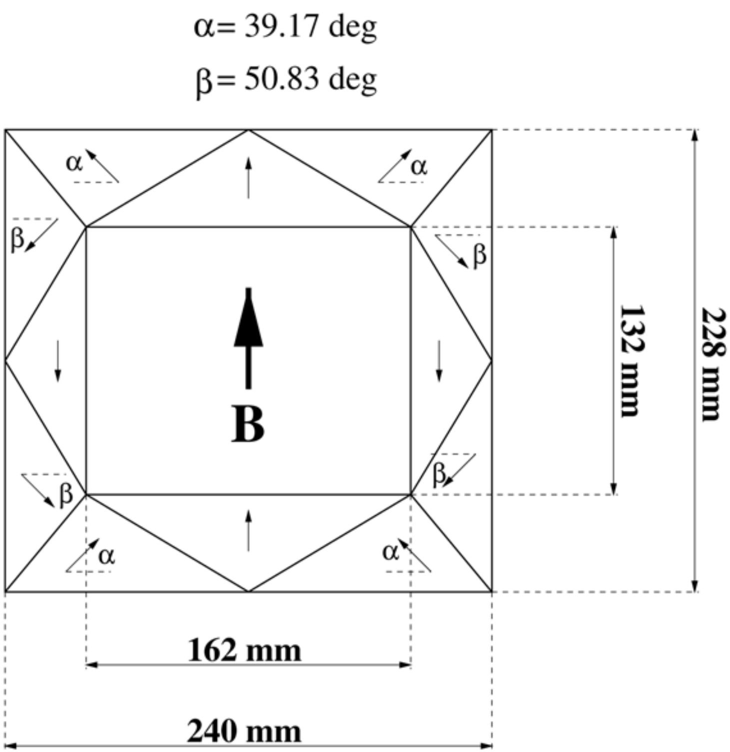
determines the particle's momentum

five modules of a permanent magnet
(a Nd-Fe-B alloy)

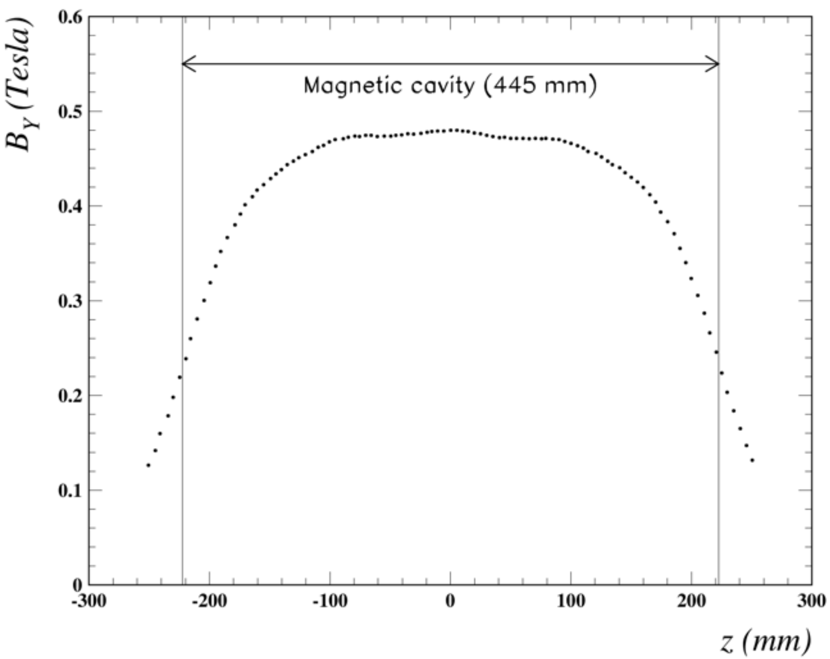


six planes of silicon microstrip detectors 300 μm thick arranged in three ladders composed of two sensors and a hybrid circuit

The magnet



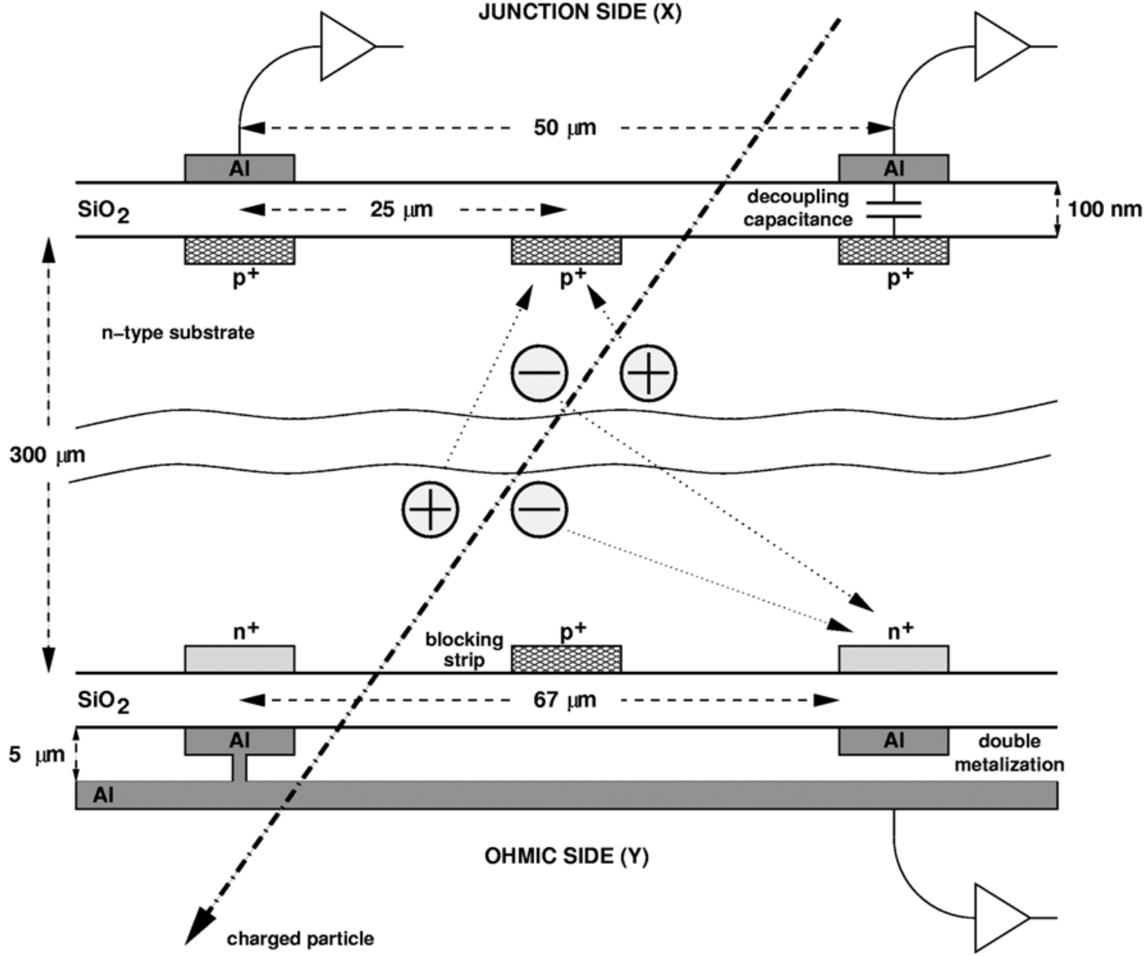
← Peculiar configuration of Nd–Fe–B blocks so to reach an almost uniform magnetic field in the cavity



The inner dimensions of the magnetic cavity define the geometrical acceptance of the apparatus: 20 cm^2sr

The silicon sensors

The silicon sensors are double sided, provided with strips implanted along mutually orthogonal directions. Junction side is used as bending view.



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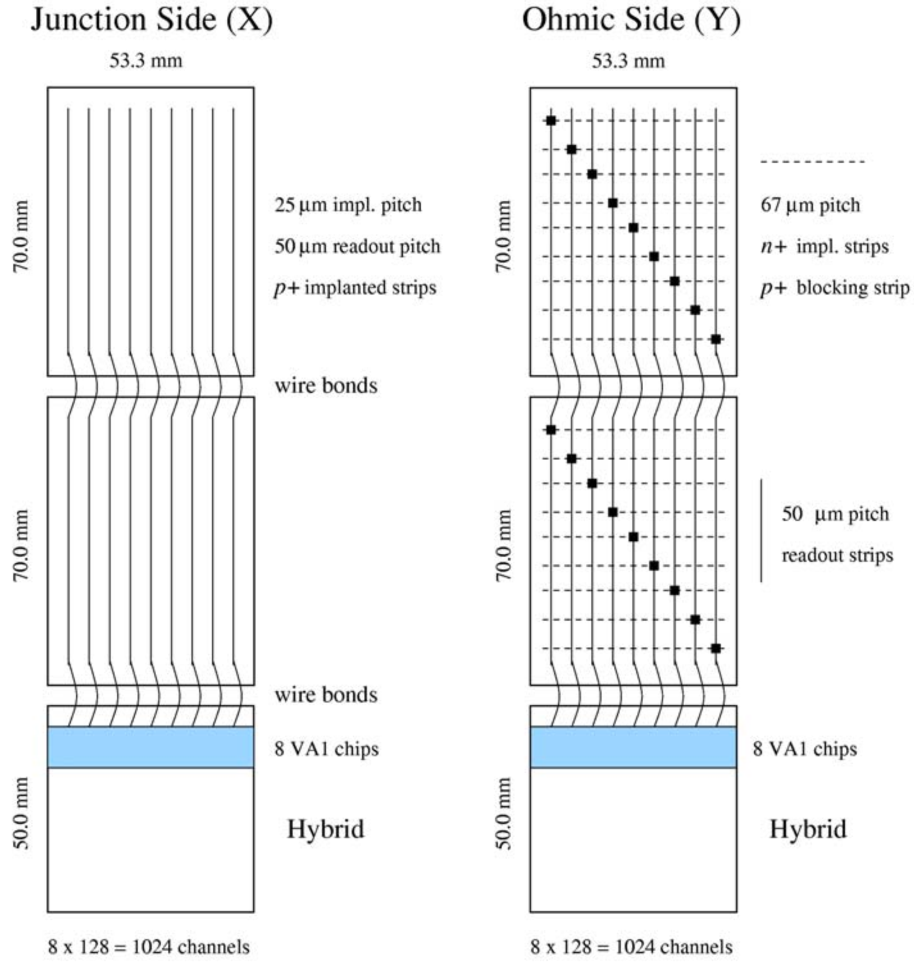
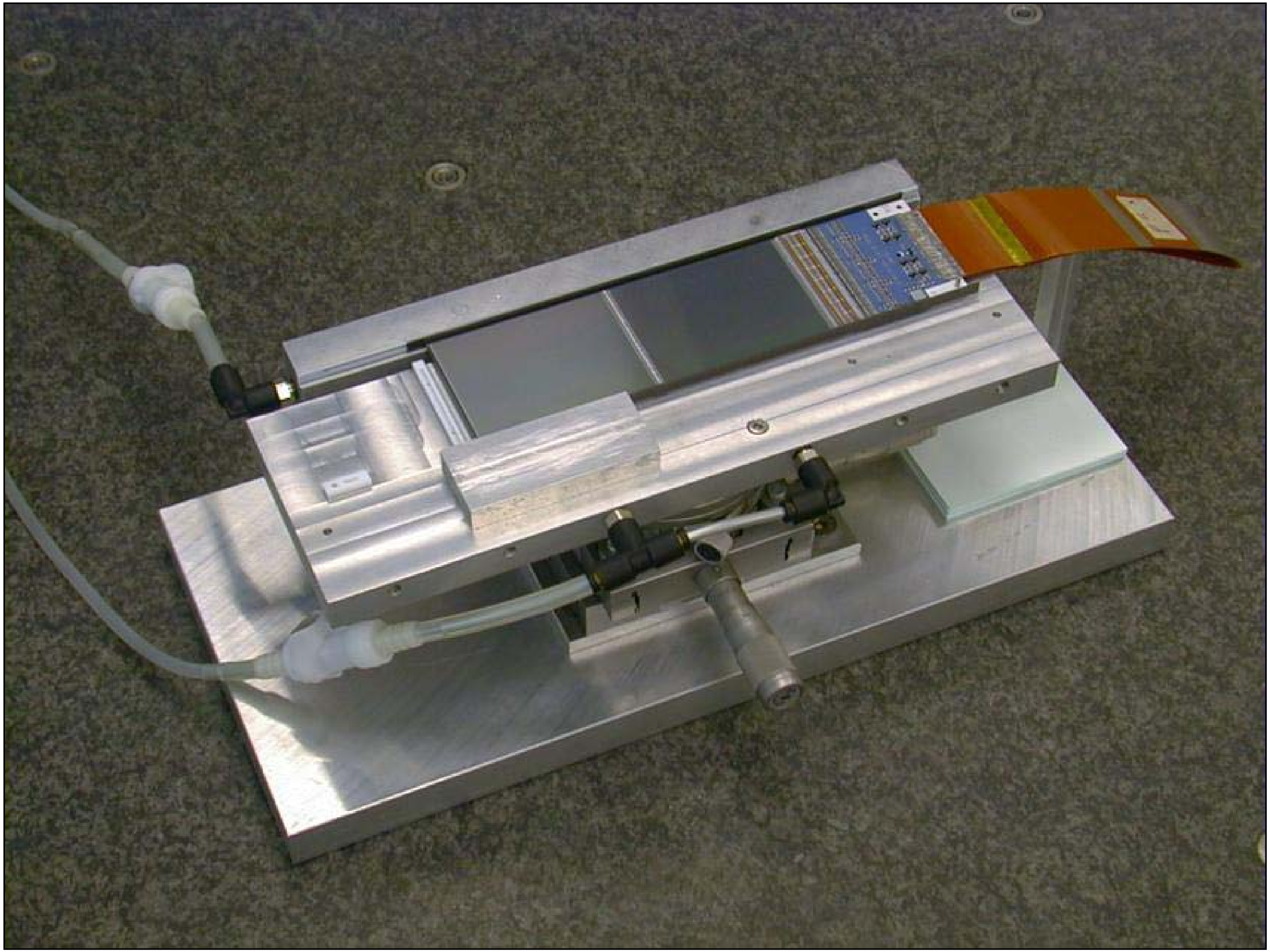


Assembling of detector planes in Firenze



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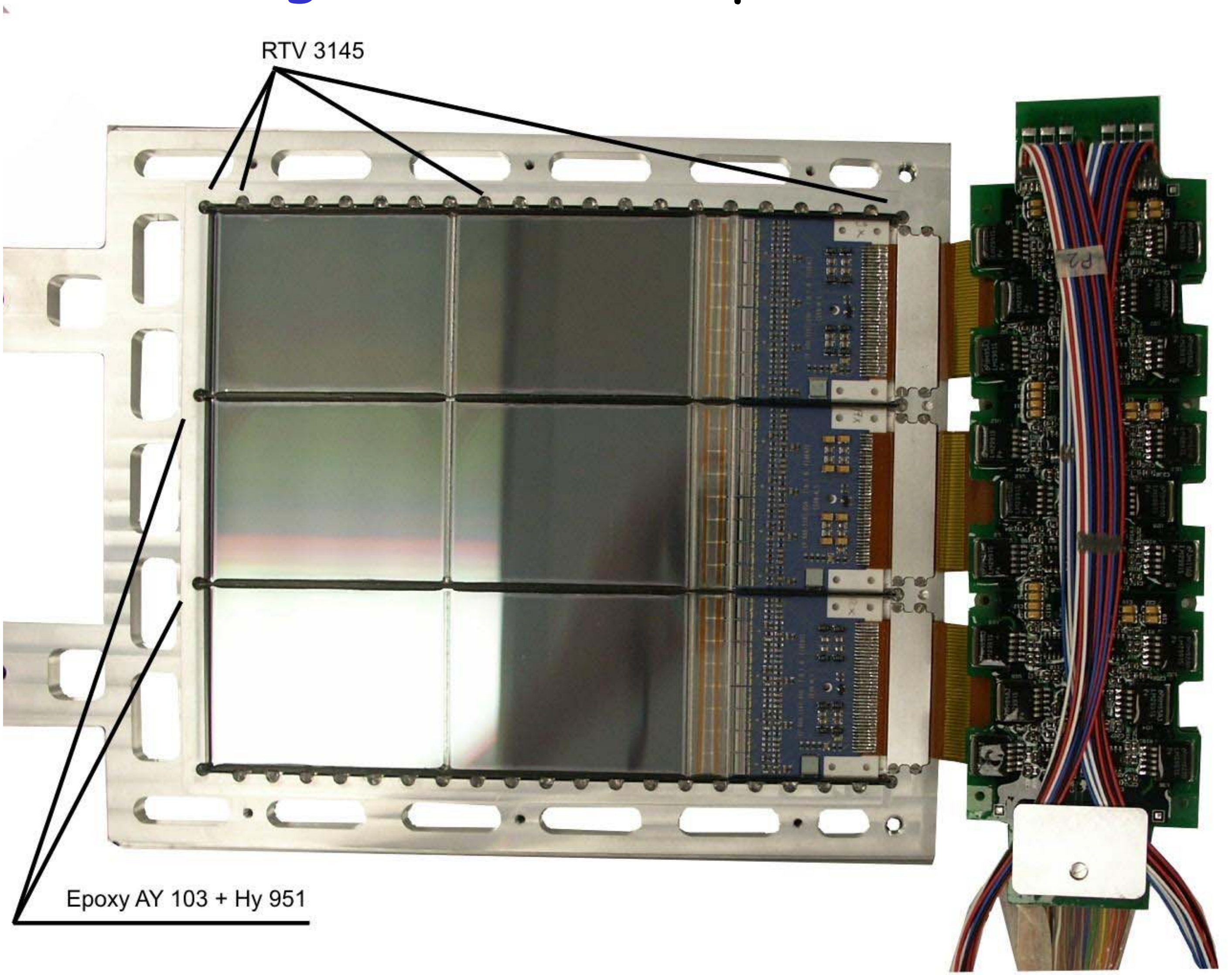

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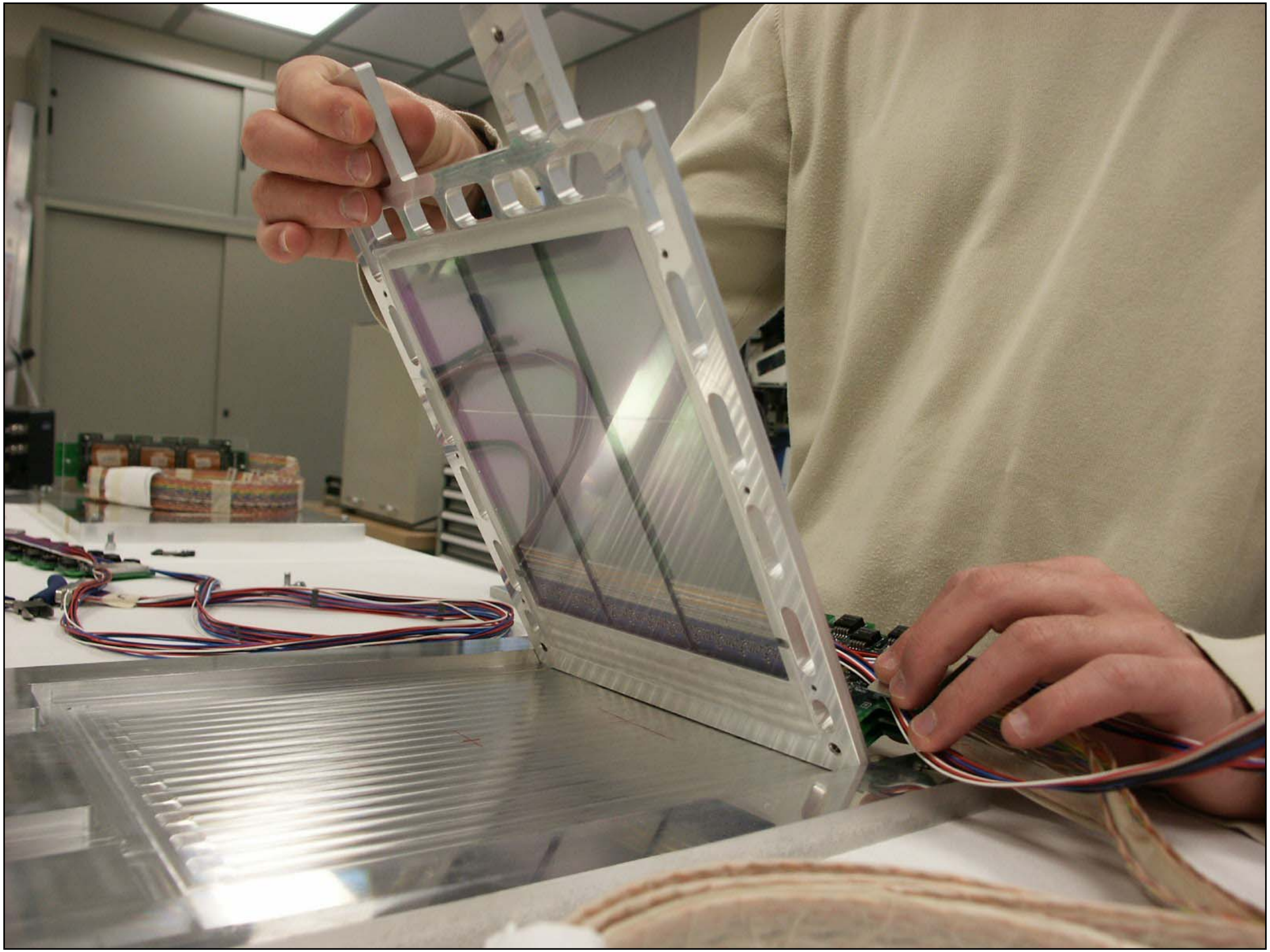


Front-end and read-out electronics

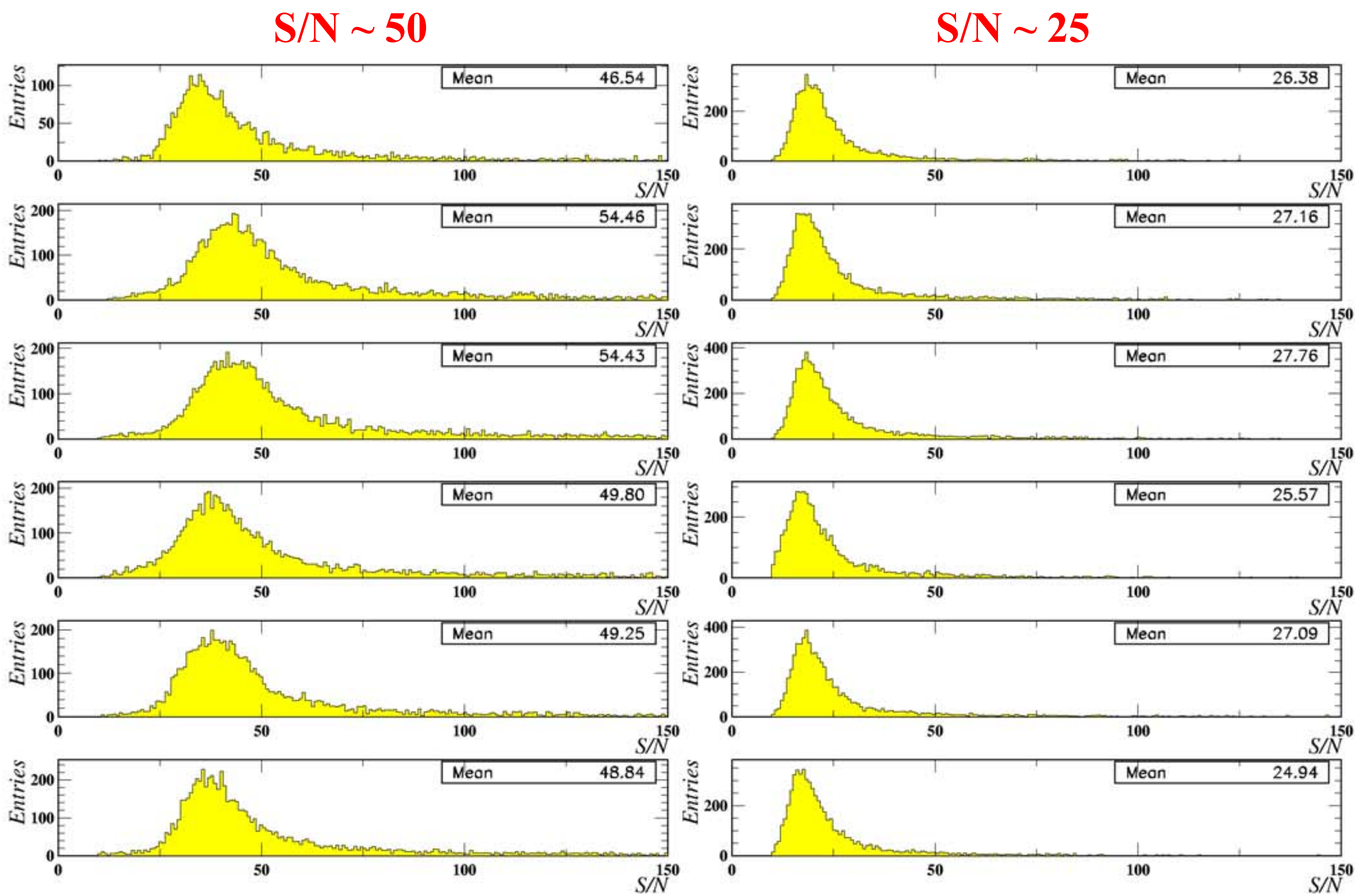
- 8 VA1 chips per ladder view:
  - low power consumption: 1 mW/channel
  - low noise: ENC = 230 e^- + 13·C_L ~ 500 e^- in our detector configuration
- 1024 strips are read-out sequentially (at 0.5 MHz frequency) and the analog signals are digitized by 36 12-bit ADCs;
- 12 DSPs control the tracker acquisition and perform on-line data compression

Radiation hardness tests

- Total dose: cumulative effect after long-term irradiation
  - 1 krad expected in three years in orbit
  - 30 krad dose reached for about 100 chips; 5 showed a failure
- SEE (single event effect): produced by a single interacting particle
  - not negligible in spite of the very low flux of heavy ions in orbit
  - test for upset and latch-up of FPGA chips on high-Z beam at GSI
  - test for latch-up of DC/DC converters at JINR
  - protection circuits (against latch-ups) and hot-cold redundancies foreseen in all the electronic boards

Performances of the detectors

observed on a test beam at Cern SPS: September 15-22, 2003



50 GeV/c protons

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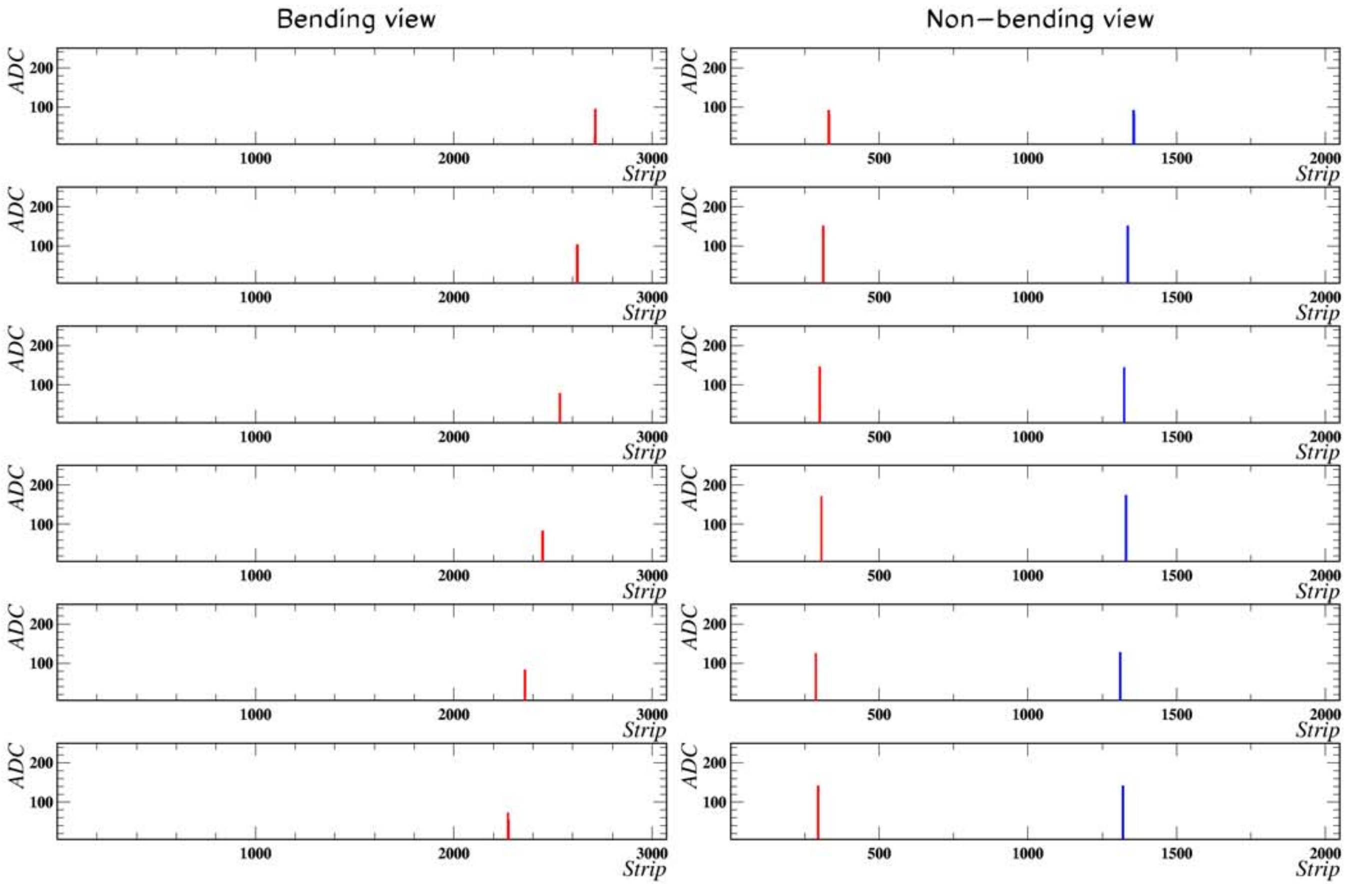


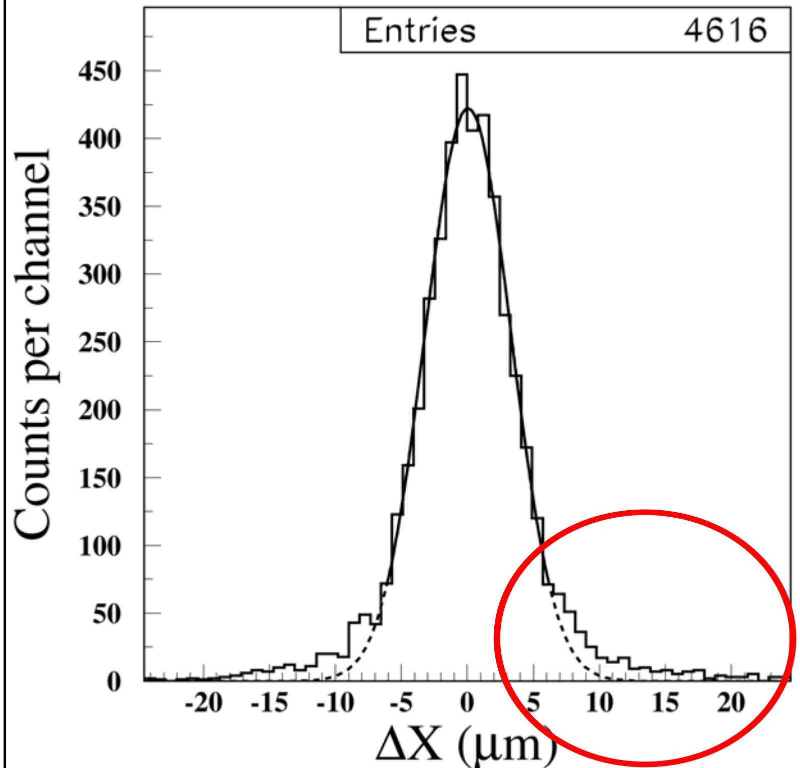
50 GeV/c protons

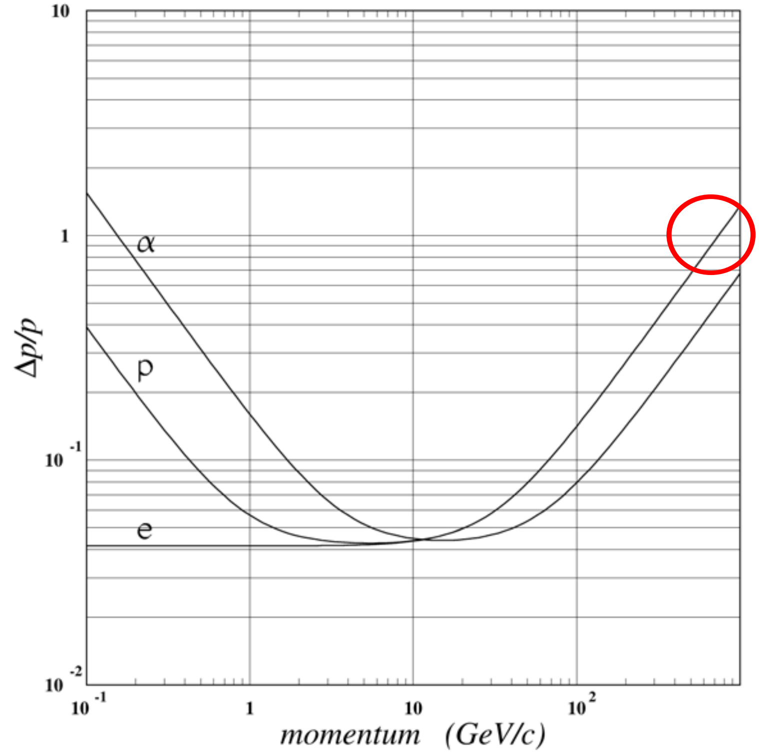
Tracker alignment

In order to reconstruct the trajectories of charged particles inside the spectrometer, the mutual positions of all the planes need to be known. An alignment procedure is thus necessary.

- preliminary alignment using data gathered in the last test beam;
- on-orbit check after the launch of the satellite.

Spatial resolution



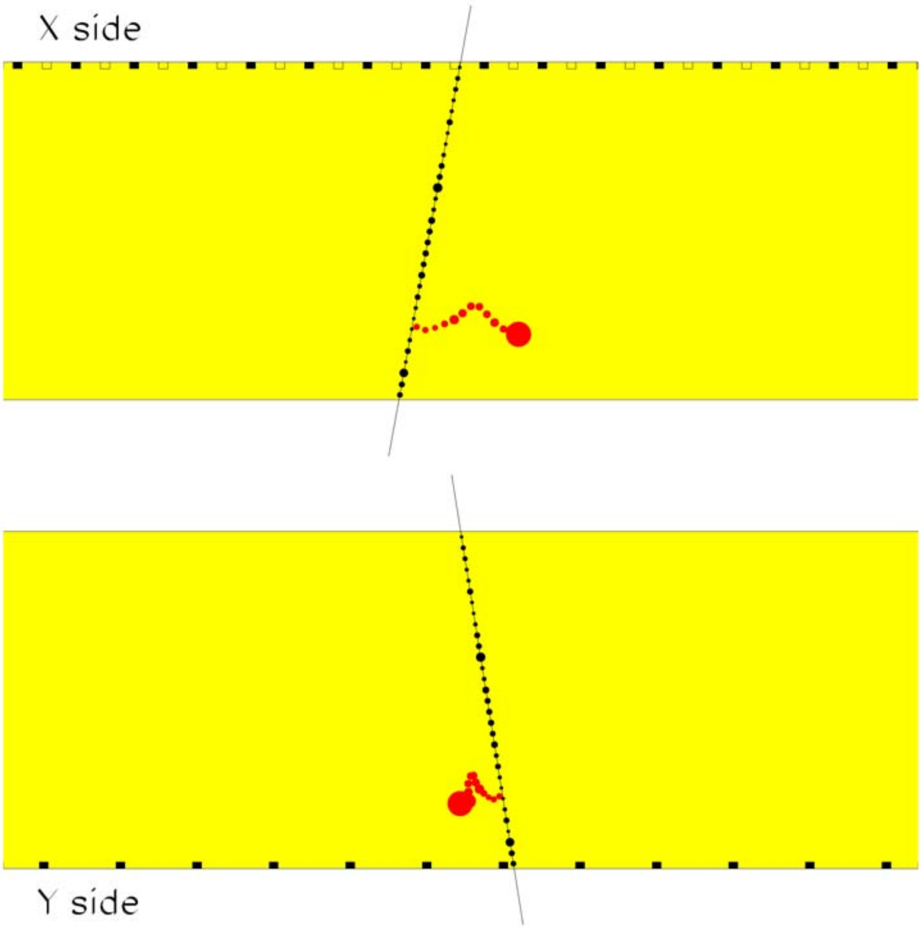


View	*S/N ratio*	*Resolution*	*MDR*
Junction	**~ 50**	**3 μm**	**> 740 GV/*c***
Ohmic	**~ 25**	**12 μm**	

Note: ***MDR=Maximum Detectable Rigidity; rigidity = momentum/charge***

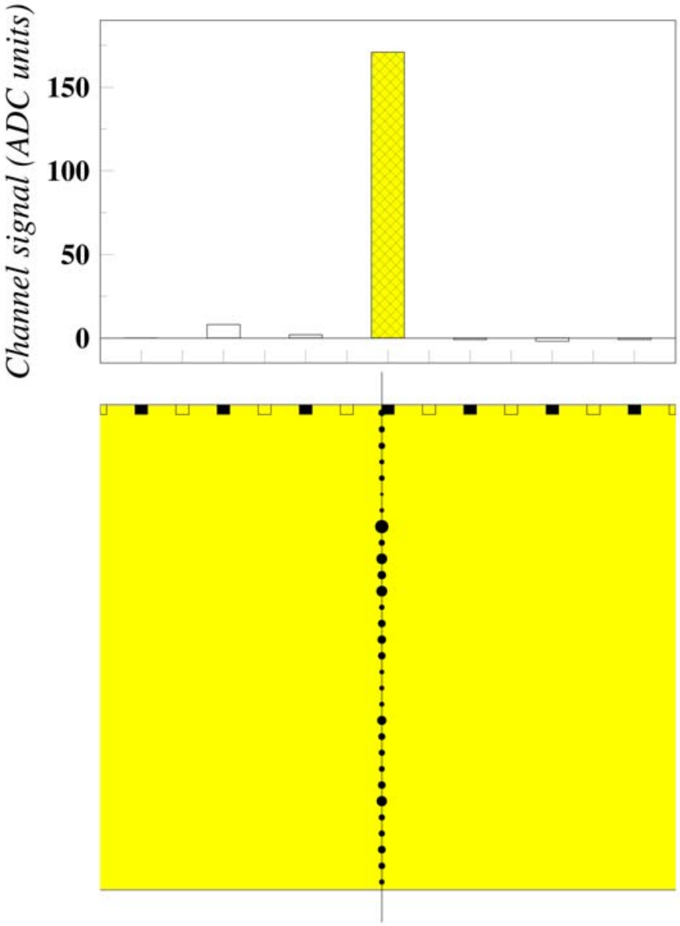
Detector simulation

GEANT-based code developed: it describes generation and collection on the strips of the charge carriers when ionizing particles cross the silicon detector.



Track by a MIP in which an energetic secondary electron is produced

Output of the simulation



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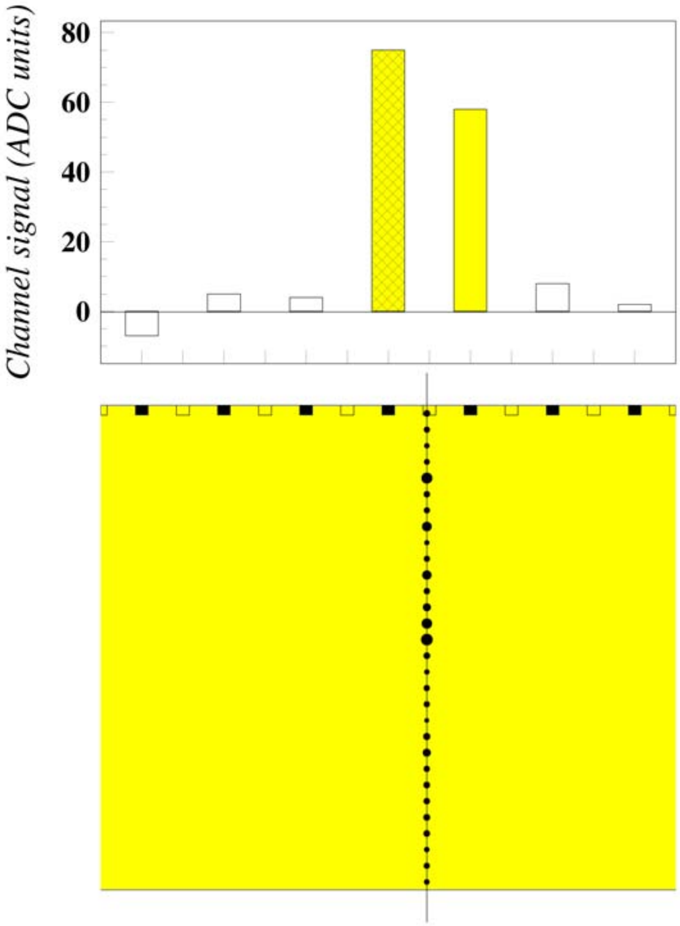

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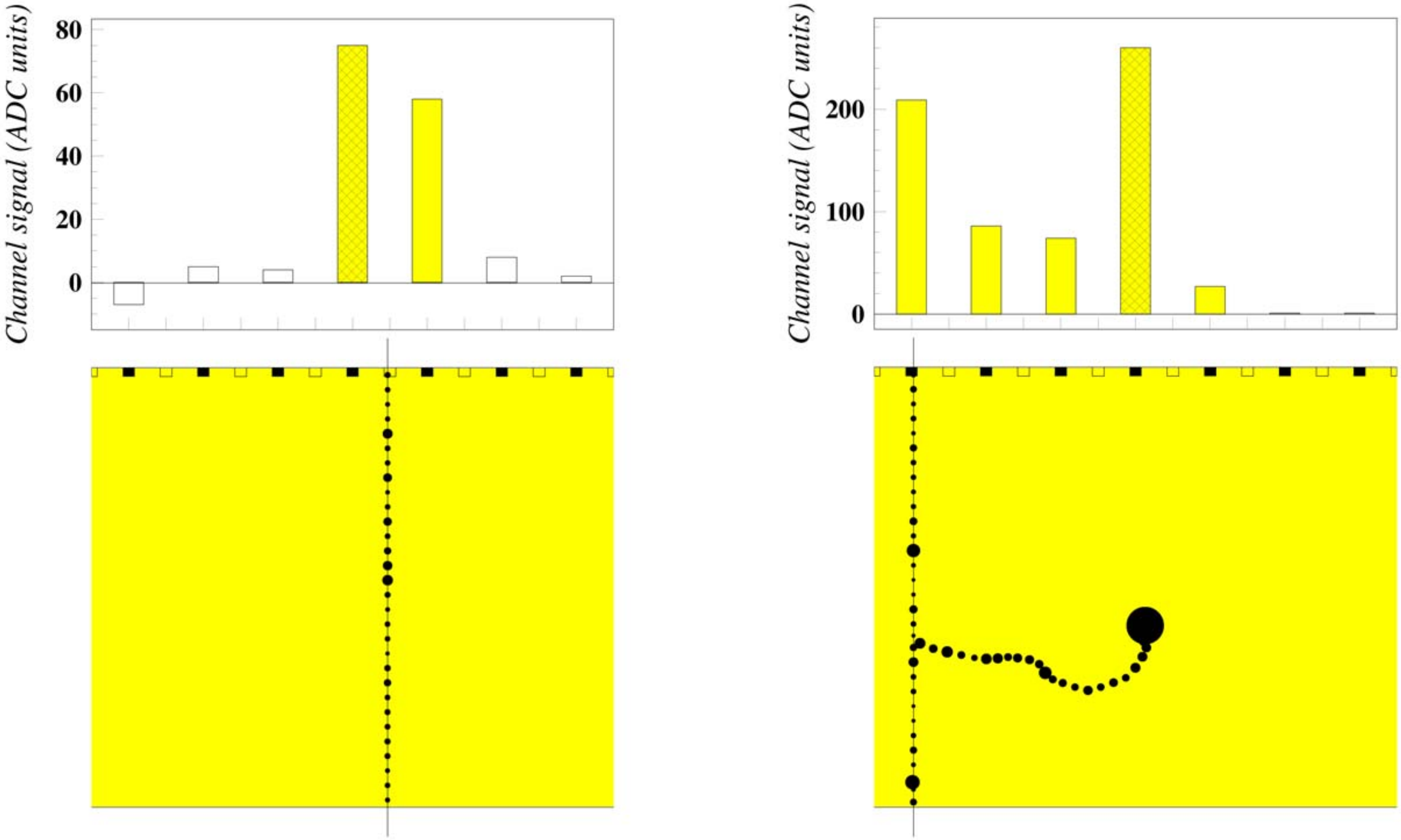
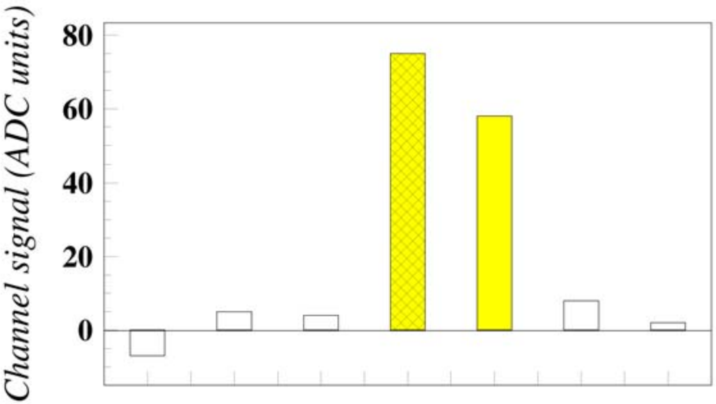


~150 μm shift !

Data analysis: the η algorithm

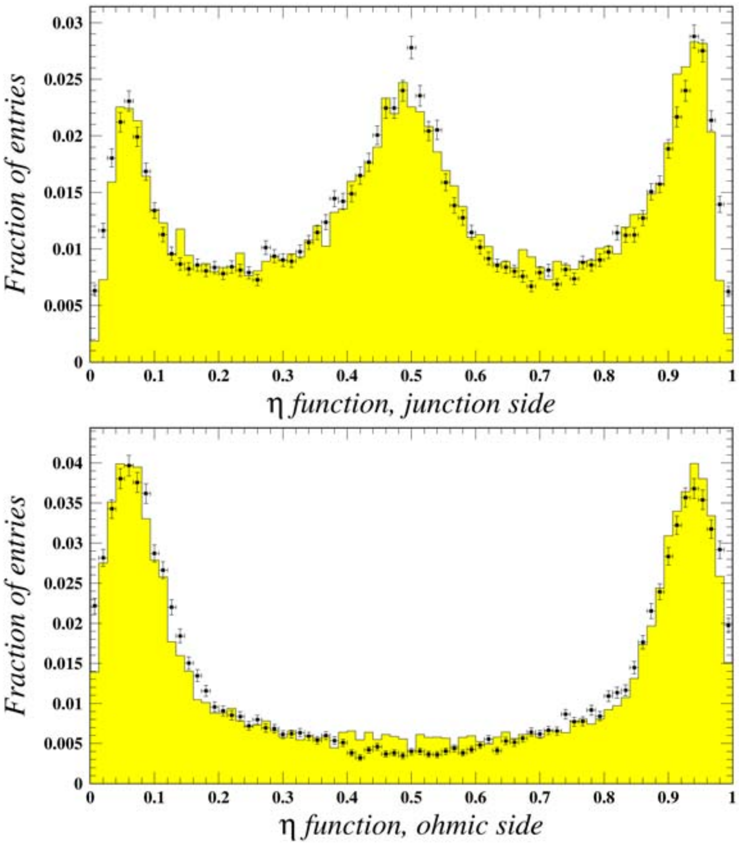


$$\eta = \frac{R}{L+R}$$

$$x = x_L + f(\eta)\cdot P$$

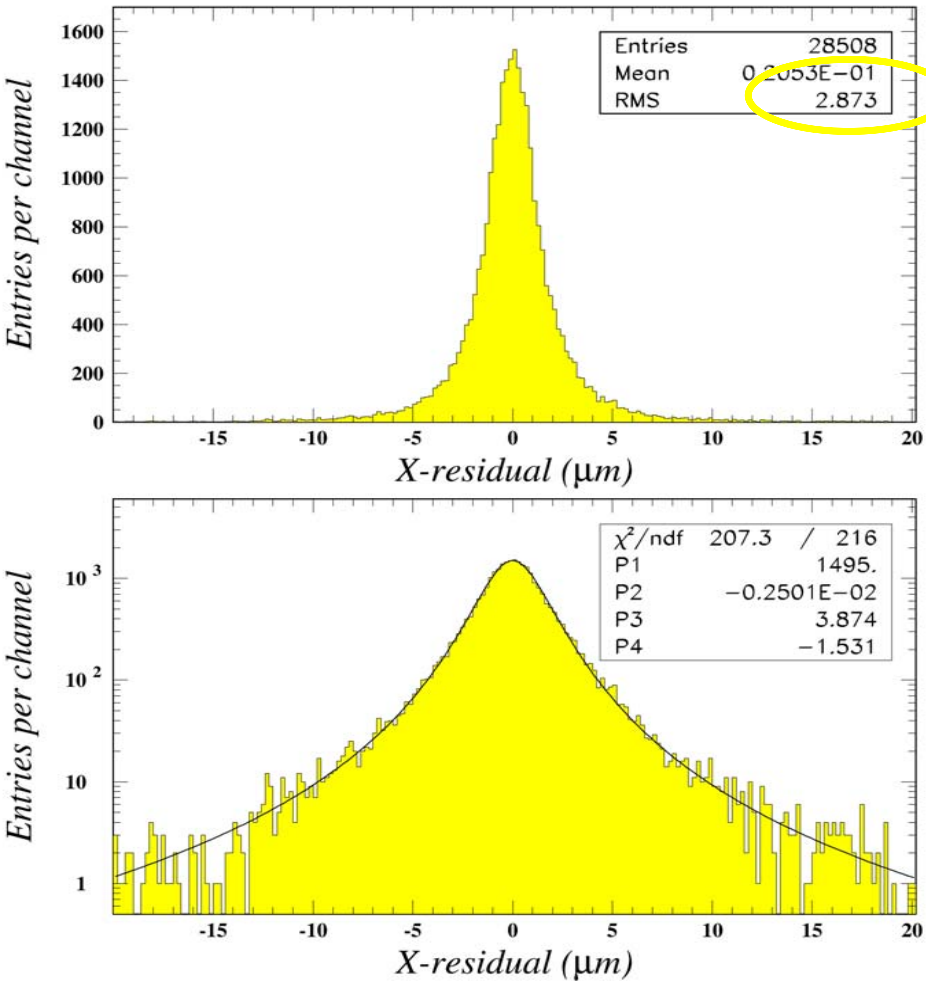
$f(\eta)$ cumulative pdf of η, estimated as:

$$f(\eta) = \frac{\int_0^{\eta} (dN/d\eta')d\eta'}{\int_0^{1} (dN/d\eta')d\eta'}$$



References for the η algorithm:
R. Turchetta, *Nucl. Instr. and Meth.* **A335,** 44 (1993)
E. Belau, *Nucl. Instr. and Meth.* **A214,** 253 (1983)

Distribution of residuals, junction side



It is not Gaussian!
Accurate fit by means of a Lorentz distribution:

$$L = p_1 \cdot \left[1 + \left(\frac{2 \cdot (x - p_2)}{p_3} \right)^2 \right]^{p_4}$$

Tails of the distribution are related to the spillover !

The spillover ...

... indicates the particle background in antiparticle measurements, due to a wrong reconstructed charge sign for small curvature, high momentum particles.

Since particles are much more abundant than antiparticles (~10^4 times), this can give rise to a mistaken flux determination.

The detailed knowledge of the distribution of spatial residuals is essential to correctly estimate the spillover background. In this case simulation provides a powerful instrument for data analysis.

Conclusions

- The flight model of the spectrometer has been already completed; the whole PAMELA apparatus will be delivered to the Russian space agency within the end of November;
- the performances of the spectrometer are very satisfying: they match the requirements of the design, needed to perform antiparticle measurements in orbit;
- the next steps of data analysis will concern the alignment of the tracker using curved tracks by test data;
- another important subject will be the simulation of the whole tracker in order to evaluate the systematic errors in the alignment procedure and to estimate the spillover background in orbit.