# The *Time-of-Flight* system of the PAMELA experiment: in-flight performances.

Rita Carbone

INFN and University of Napoli

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# The PAMELA experiment

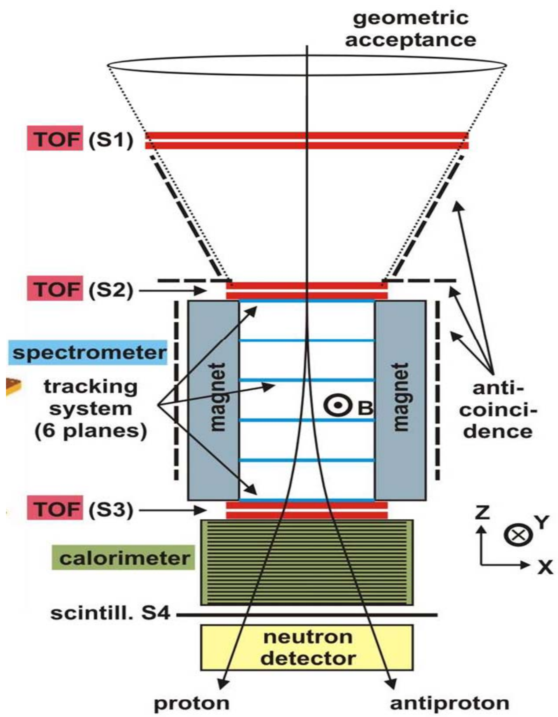
- Search for antimatter
- Search for dark matter
- Study of cosmic-ray propagation
- Study solar physics and solar modulation
- Study of electron spectrum
- Study terrestrial magnetosphere

- First switch-on on June 21th 2007
- Continuous data taking mode since 11th July 2006
- Detectors are performing nominally
- Analysis is in progress

Launched on June 15th 2006 !

# PAMELA apparatus

7 detectors combined for high-sensitivity particle identification and precise momentum measure




**Time-Of-Flight**

**plastic scintillator strips + PMT:**

⇒ trigger, albedo rejection;

⇒ mass identification up to E ~ 1 GeV;

⇒ charge identification from dE/dX.

**Magnetic spectrometer**

**with microstrip Si tracker:**

⇒ charge sign and momentum from the curvature;

⇒ charge identification from dE/dX.

**Electromagnetic calorimeter**

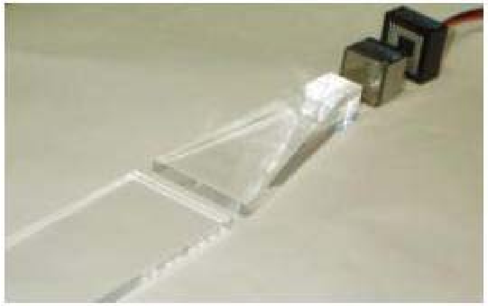
**W/Si sampling; 16.3 X0:**

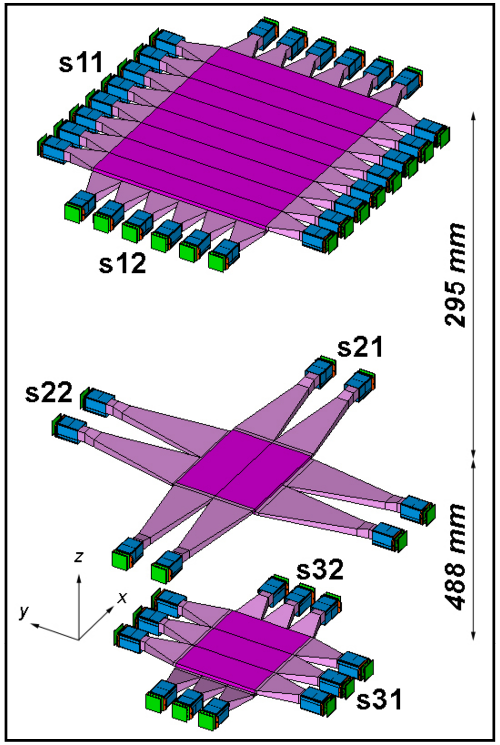
⇒ discrimination e+ / p, e- / from shower topology;

⇒ direct E measurement for e-.

# The *Time-of-Flight* system

- 6 layers (3 planes, double view)
- Several paddles (scintillator + 2 PMTs) for each layer






- provide a fast signal for triggering data acquisition in the whole instrument
- measure the flight time of particles crossing its planes; once this information is integrated with the measurement of the trajectory length through the instrument, their velocity can be derived. This feature enable also the rejection of albedo particles
- determine the absolute value of charge z of incident particles through the multiple measurement of the specic energy loss dE=dx in the scintillator counters

# Monitoring *ToF* in orbit

Main items to control:

- Gain stability

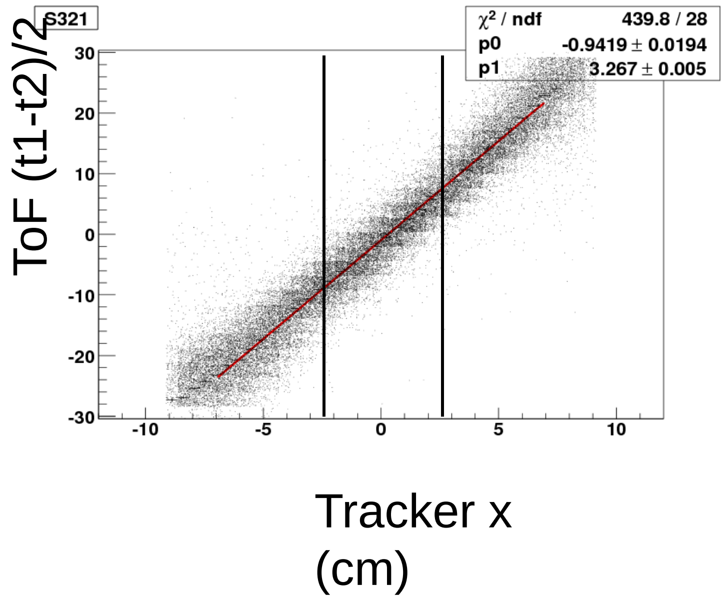
  variation of gain as function of time changes the conditions for all measurement operations and has to be taken into account in the calibration software

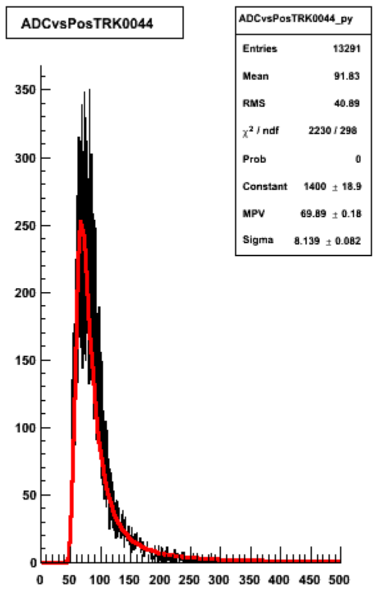
- Time resolution

  a good time resolution means, first of all, a good β measurement!

# Gain measurements

Select a clean sample of protons as reconstructed by the magnetic spectrometer with rigidity>5 GV and β>0.7 which hit ToF paddles in a window of ±2.5 cm from the centre of the paddle itself

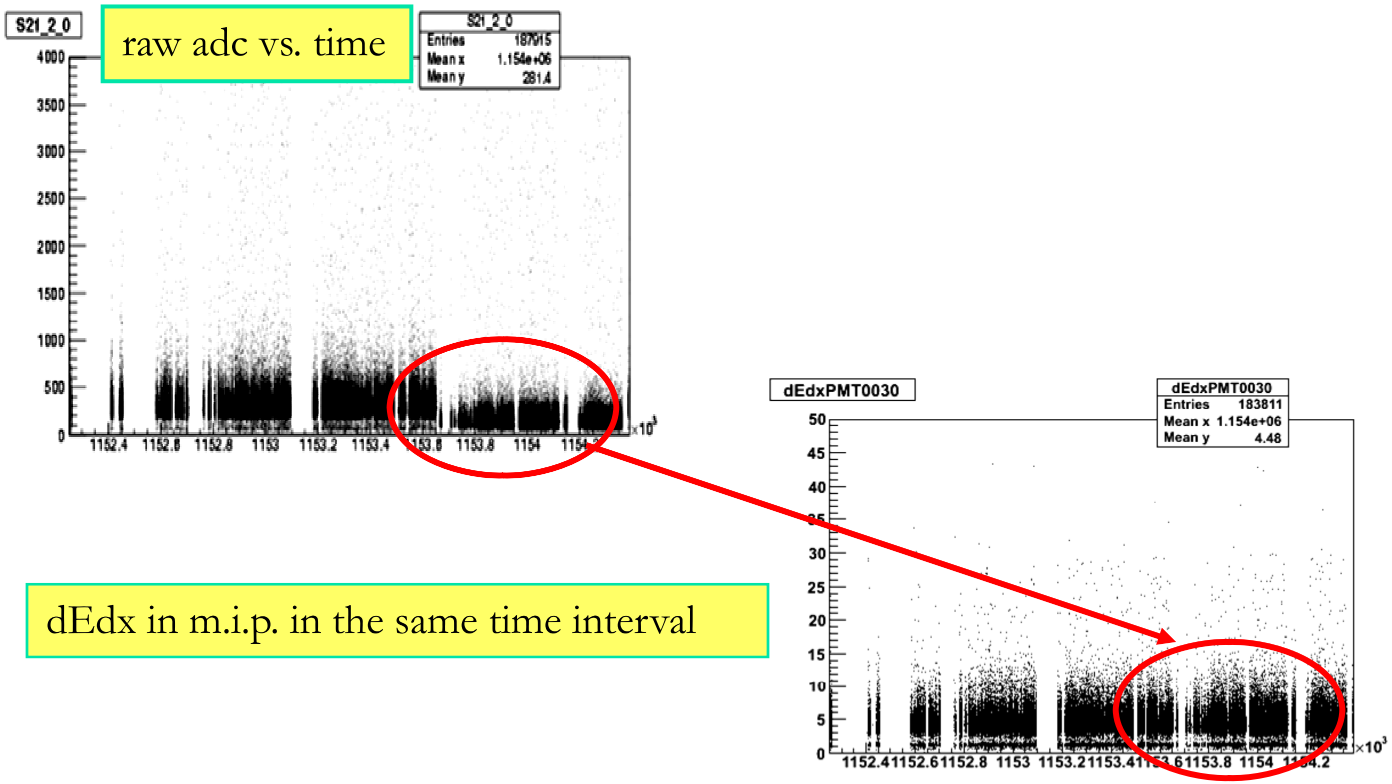



For this sample we can plot and fit the Landau distribution of the raw ADC signal: its peak value is the parameter we have to control

# Gain stability

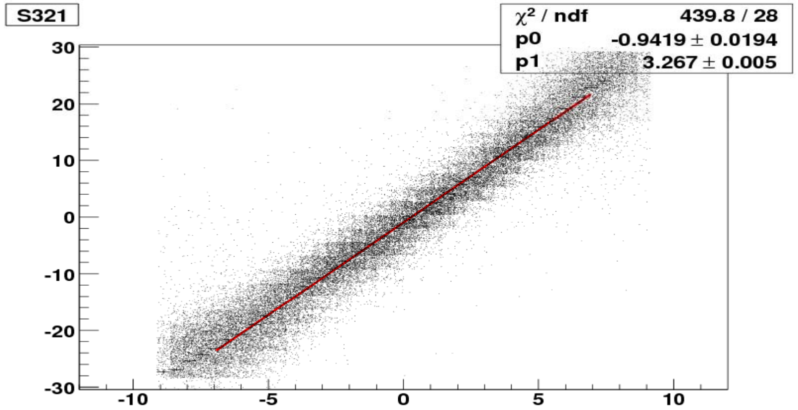
For the periods during which there is a loss of gain for some PMTs we use “ad hoc” calibration parameters to normalize the situation



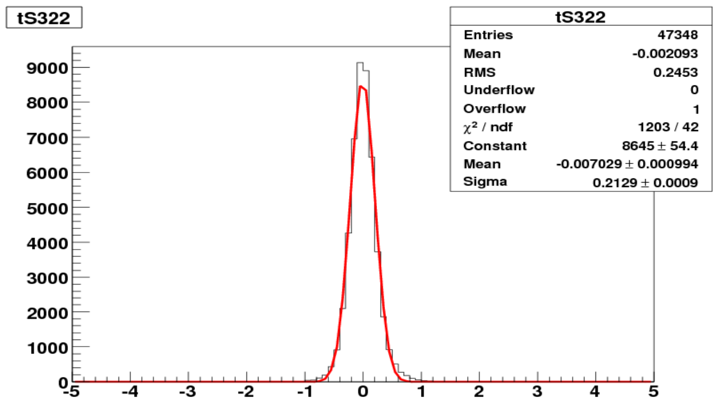
# Single paddle time resolution

The position of the hit point on a paddle as reconstructed by the ToF is proportional to the difference of the time measurements operated at both ends for that event

$$x = \frac{v_{eff}(t_1 - t_2)}{2} + cost$$




Plotting this TOF position vs. the position as reconstructed by the Tracker (assuming negligible the uncertanty in the projected position), the σ of the distribution of residuals gives us the single paddle time resolution.



# Single paddle time resolution

- At this moment the measured time resolution is ~200 ps for S1 and S3 paddles and ~150 ps for S2 paddles for Z=1 particles

- For higher Z the time resolution improves: preliminary result for Z=2 is ~105 ps

- This results are in agreement with some results from a beam test of February 2006 (in this case time resolution reached a value of 48 ps for Carbon ions)

- We expect improvement for Z≤3 from *Time-Walk effect* correction (work in progress)

# β resolution

The resolution on measurements of time of flight within two paddles of two different planes is the composition of the single paddle time resolution:

$$\Delta t_{ij} = \sqrt{(\delta t_i)^2 + (\delta t_j)^2}$$

Remembering that time of flight and β are related by:

$$T_{tof} = K_1 + K_2 \frac{1}{\beta}$$

We can easy derive β resolution according to:

$$\Delta T_{tof} = \frac{d \cdot \sigma_\beta}{c\beta^2}$$

Preliminary β resolution: ~14% for Z=1 (single measurement)

Also this result improves for higher Z and can be improved considering multiple measurements for the same event (6 layers allow several 2 paddles combinations…)

# Conclusions

- The system is working well!
- Preliminary results are encouraging
- Several improvements are possible
- Work is in progress!

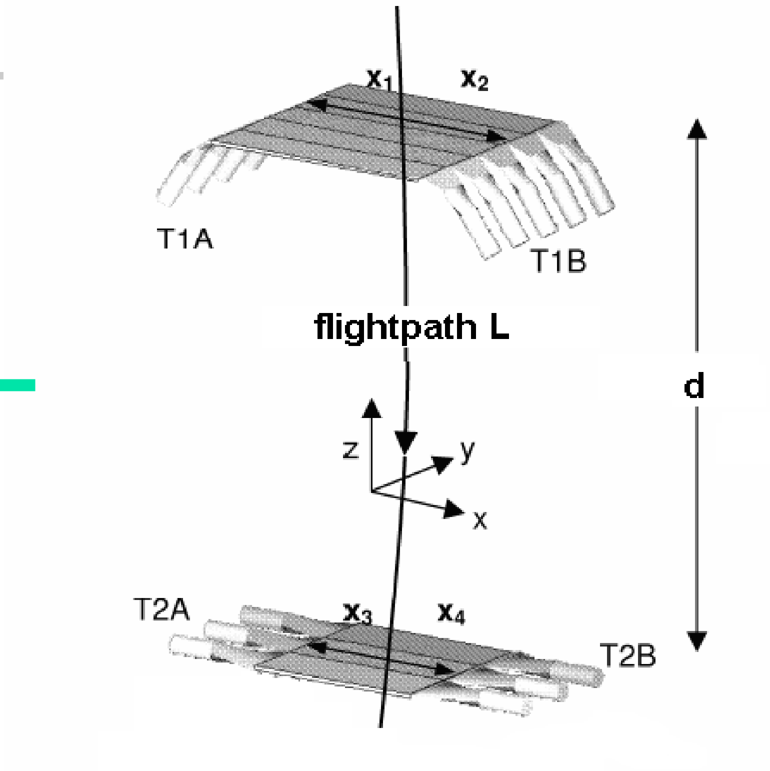
# $\beta$ measurement with *ToF*

$$t_1 = C_1 + \frac{x_1}{v_{eff}}$$

$$t_2 = C_2 + \frac{x_2}{v_{eff}}$$

$$t_3 = C_3 + \frac{x_3}{v_{eff}} + \frac{L}{c\beta}$$

$$t_4 = C_4 + \frac{x_3}{v_{eff}} + \frac{L}{c\beta}$$




$$t_{S1} = (t_1 + t_2)/2$$

$$t_{S2} = (t_3 + t_4)/2$$

$$\Delta T = t_{S2} - t_{S1} = a + b/\beta$$

Calibration constants