The magnetic spectrometer of PAMELA

8th International Conference on Large Scale Applications and Radiation Hardness of Semiconductor Detectors

David Fedele

on behalf of the PAMELA-Tracker Collaboration

June 27-29, 2007 (Florence)

Outline

- **Introduction**
  - ✓ The PAMELA experiment
- **The magnetic spectrometer**
- **Examples of flight data**
- **Tracker performances**
  - ✓ Preliminary analysis of a sample of flight data

PAMELA a Payload for Antimatter Matter Exploration and Light–nuclei Astrophysics

ITALY:

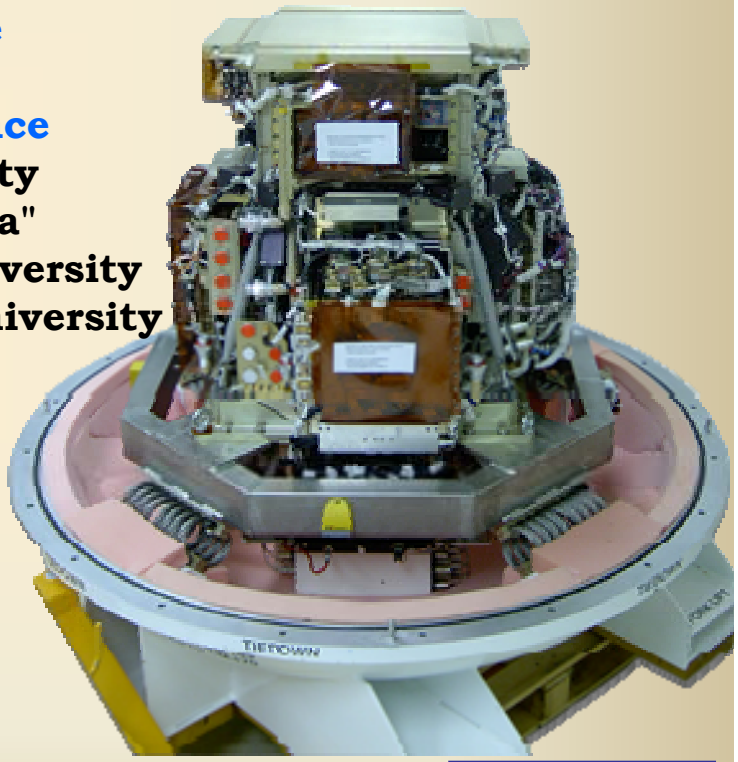
- **INFN Florence and Physics Department of Florence University**
- **Institute of Applied Physics "Nello Carrara", Florence**
- **INFN Bari and Physics Department of Bari University**
- **INFN and Physics Department of Rome "Tor Vergata"**
- **INFN Naples and Physics Department of Naples University**
- **INFN Trieste and Physics Department of Trieste University**
- **INFN National Laboratories, Frascati**

GERMANY: Physics Department of Siegen University

SWEDEN: Royal Institute of Technology, Stockholm

RUSSIA:

- **Ioffe Physico-Technical Institute, St Petersburg**
- **Cosmic Rays Laboratory, Moscow Engineering and Physics Institute, Moscow**
- **Lab. of Solar and Cosmic Ray Physics, P.N. Lebedev Physical Institute, Moscow**

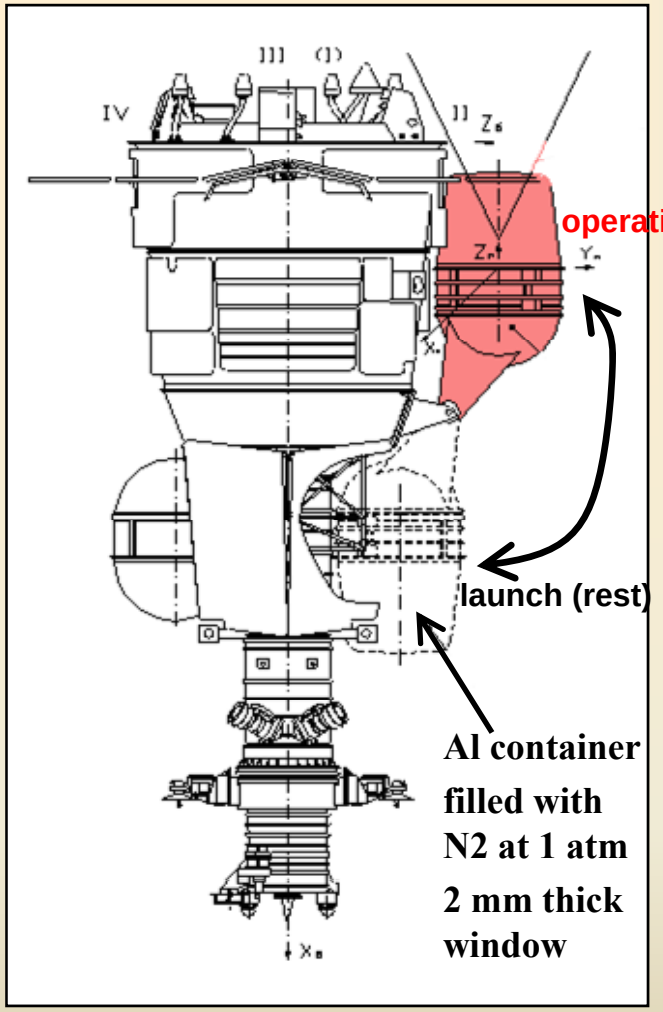


PAMELA experiment

Mission overview:

- ✓ on-board Resurs-DK1 Russian satellite;
- ✓ quasi-polar orbit 70 inclination, elliptical orbit 350-600 km altitude;
- ✓ long expected duration (> 3 years);

- no atmospheric background;
- high statistics, also at lower energies (geomagnetic effect).



PAMELA experiment

➢ Design goals for PAMELA performance:

	energy range	particles in 3 years
➢ Antiproton flux	80 MeV - 190 GeV	~ 10^4
➢ Positron flux	50 MeV – 270 GeV	~ 10^5
➢ Electron flux	up to 400 GeV	~ 10^6
➢ Proton flux	up to 700 GeV	~ 10^8
➢ Electron/positron flux	up to 2 TeV (from calorimeter)	
➢ Light Nuclei	up to 200 GeV/n He/Be/C:	~$10^{7/4/5}$
➢ AntiNuclei search	sensitivity of 3×10^{-8} in $\overline{He}/He$	

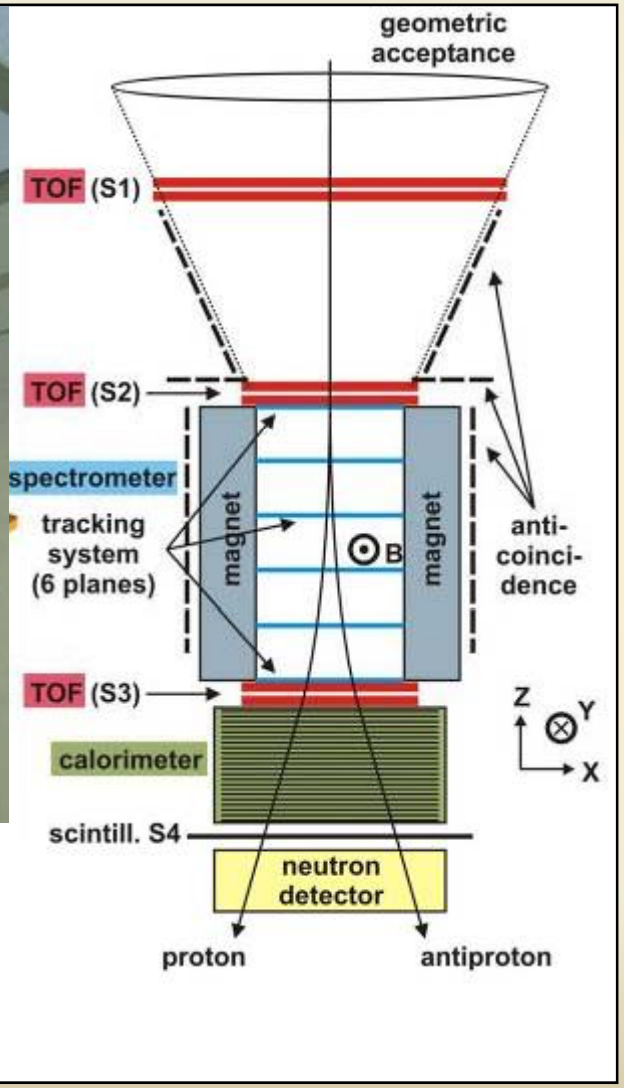
Taking into account live time and geometrical factor:

1 HEAT-PBAR balloon-flight ~ 22.4 days PAMELA data

1 CAPRICE98 balloon-flight ~ 3.9 days PAMELA data

PAMELA apparatus

➢ **Main requirements:** high-sensitivity antiparticle identification, precise momentum measure.



max diameter: 102 cm
height: 130 cm
weight: 470 kg
power: 355 W

➢ Magnetic spectrometer

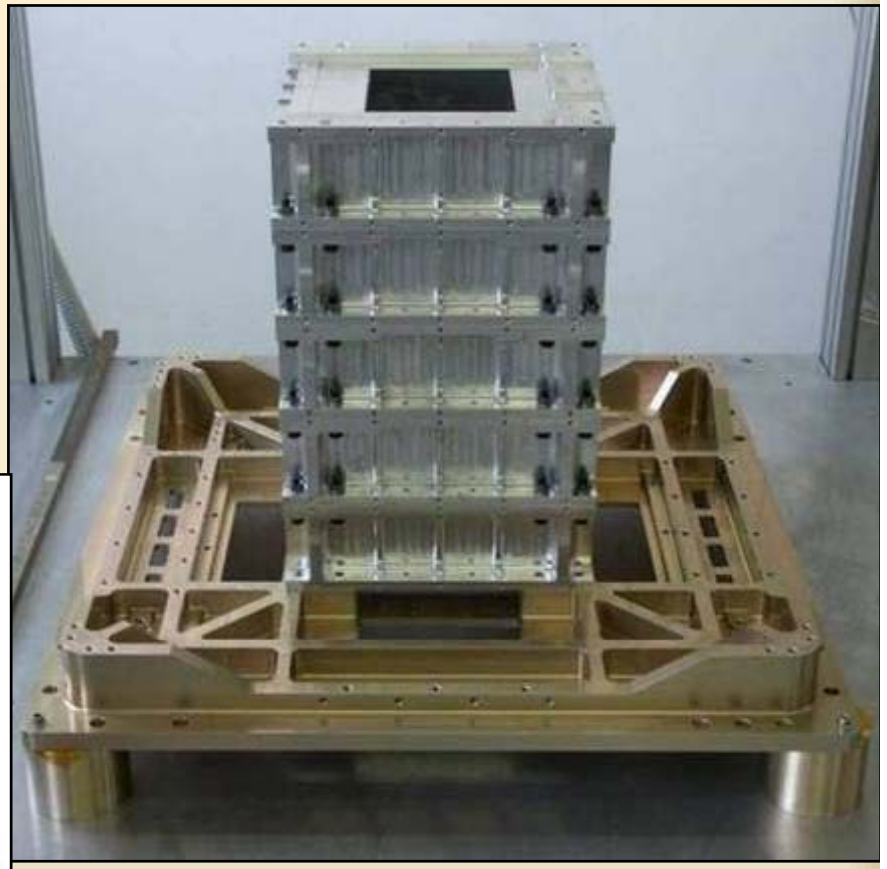
- with microstrip Si tracker

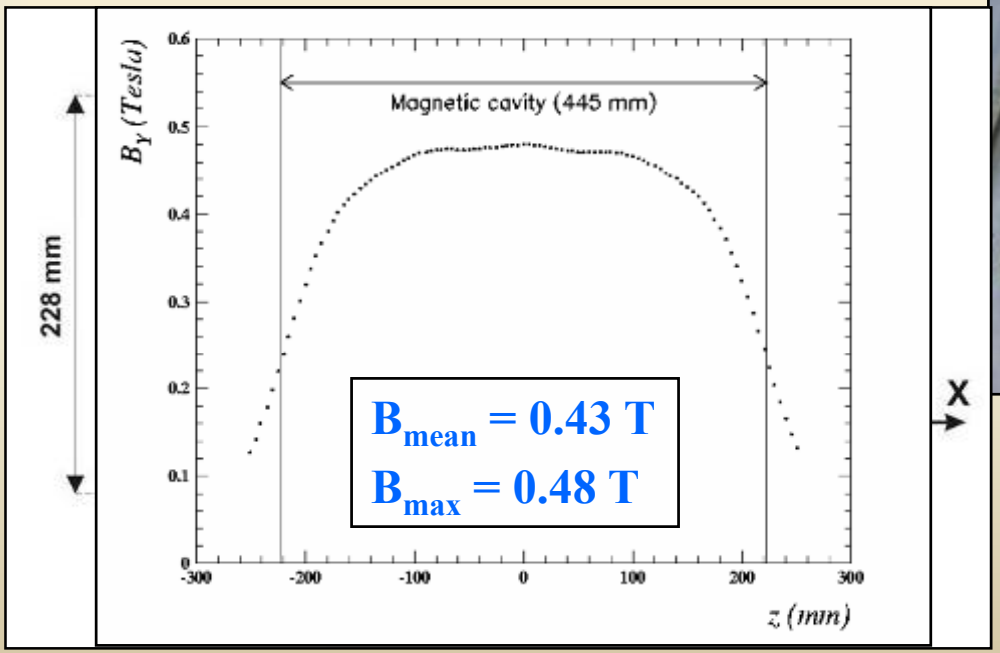
⇒ **charge sign and momentum from the curvature;**

⇒ **charge identification from dE/dX.**

Magnetic spectrometer

- Permanent magnet (5 modules):
  - ✓ Nd-Fe-B alloy elements, residual magnetization 1.3 T;
  - ✓ Al frames, tower height 43.6 cm;
  - ✓ geometric factor 21.6 $cm^2 \cdot sr$;
  - ✓ 3-axis map: 70000 points, 5 mm pitch;
  - ✓ $B_x \sim B_z < 0.1\, B_y$.

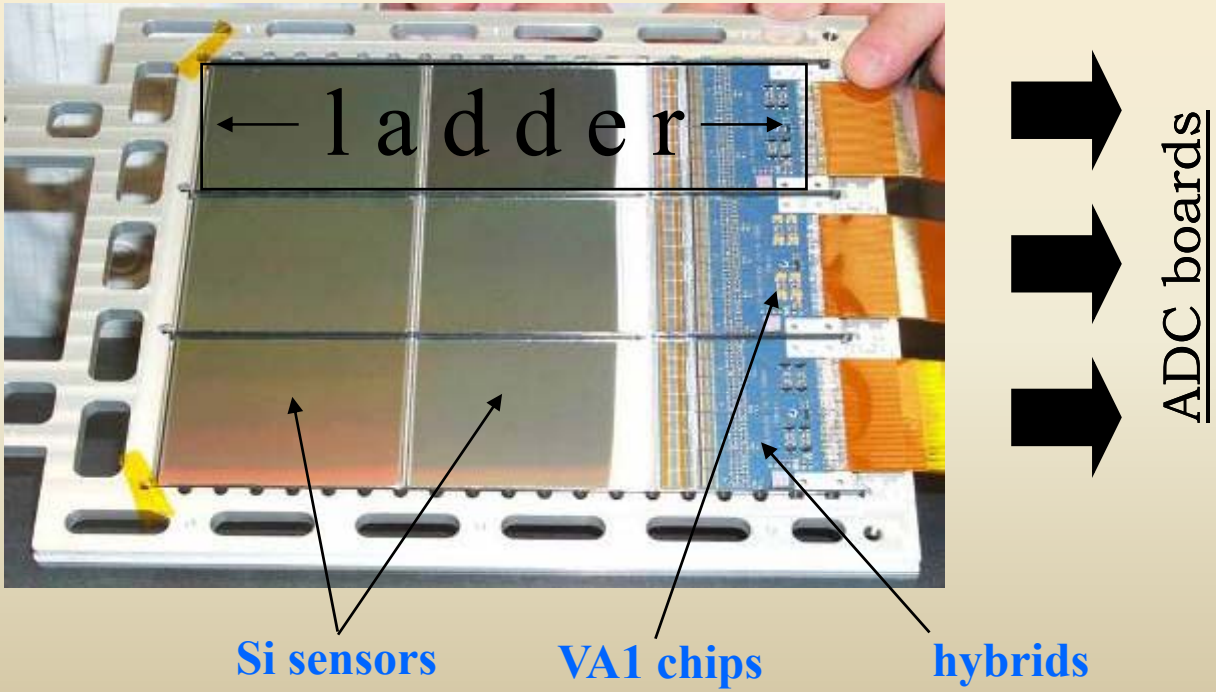




$$\frac{\sigma\left(\int Bd\ell\right)}{\left\langle\int Bd\ell\right\rangle} < 0.05$$

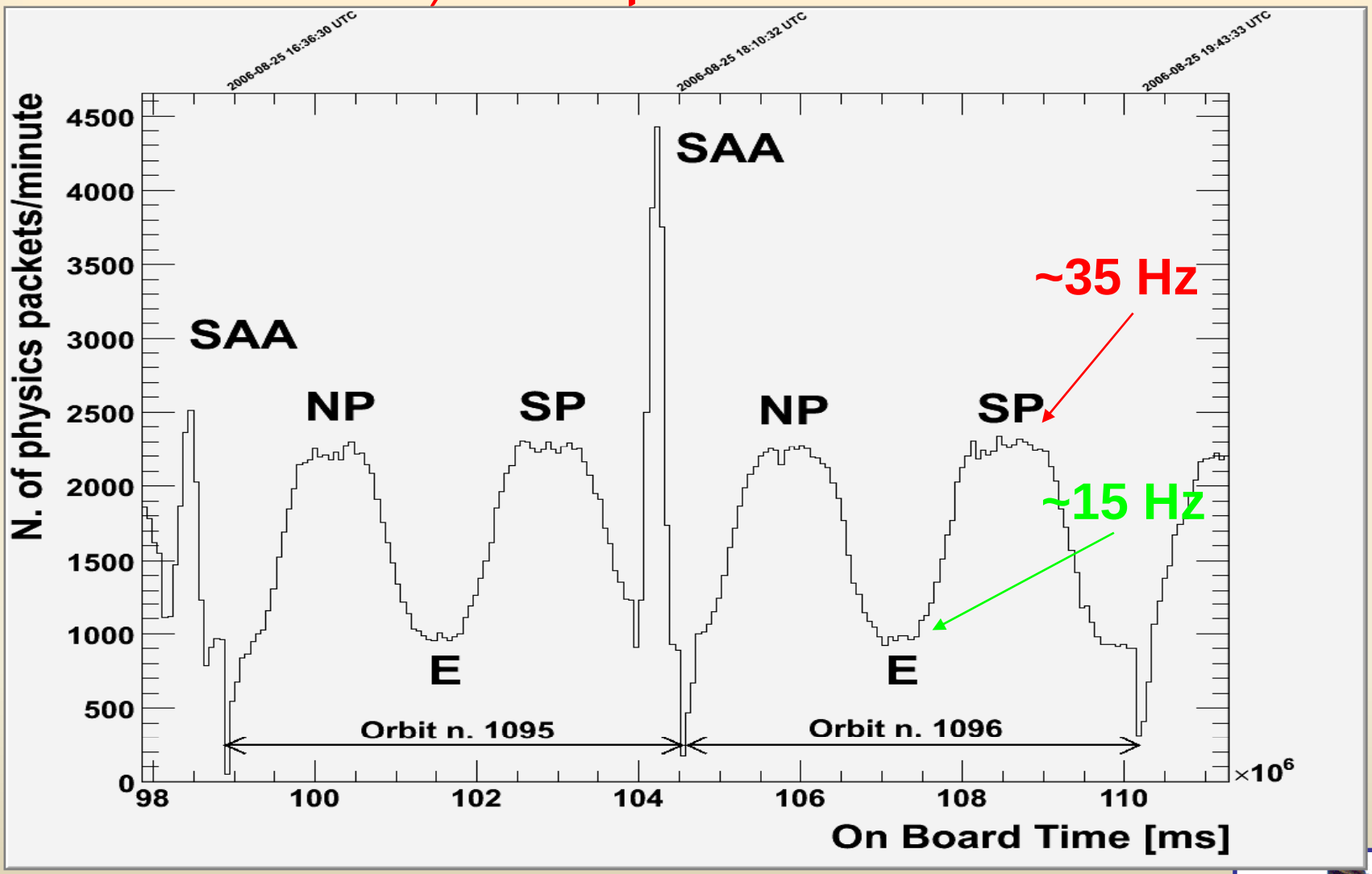
Magnetic spectrometer

- **Tracking system (6 planes, 8.9 cm apart):**
- ✓ 3 independent ladders per plane:
- ✓ 2 Si microstrip sensors per ladder:
- ✓ **double sided, with double metallization on ohmic view;**
- ✓ **integrated capacitive coupling;**
- ✓ FE electronics (VA1 chips) integrated on hybrid boards.



The Launch: 15th June 2006

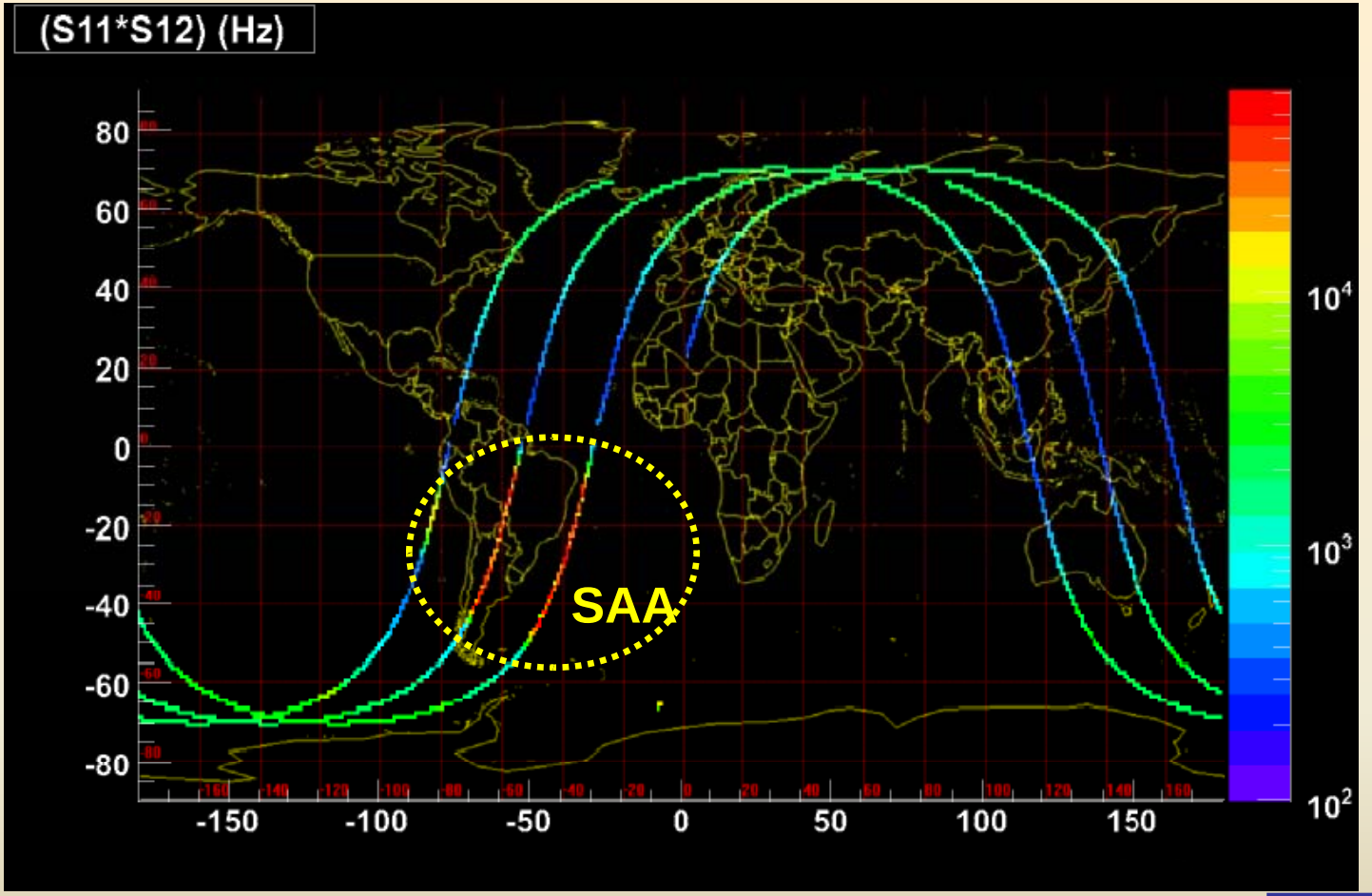
Physics packets rate



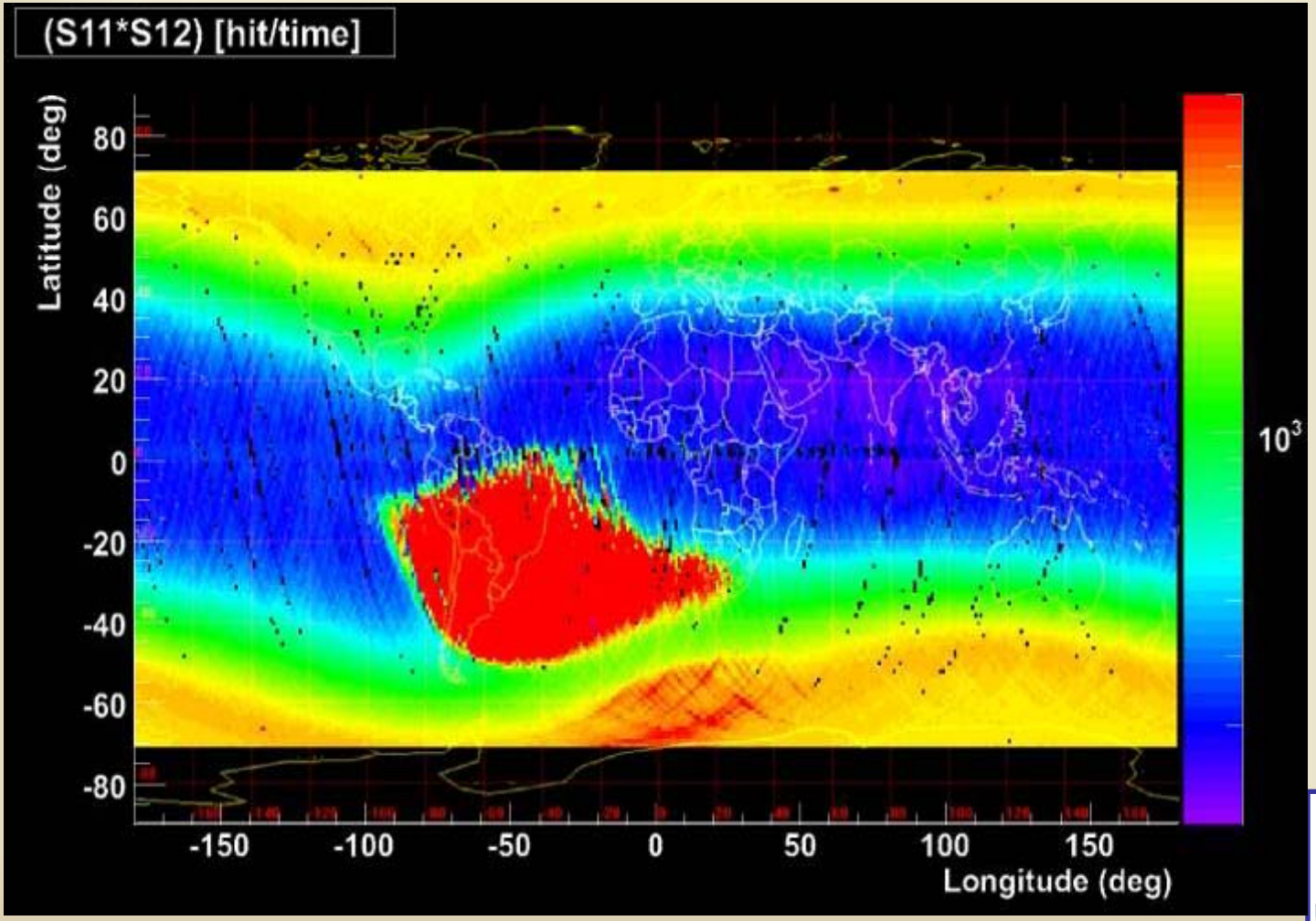
Data rate consistent with the position along the orbit

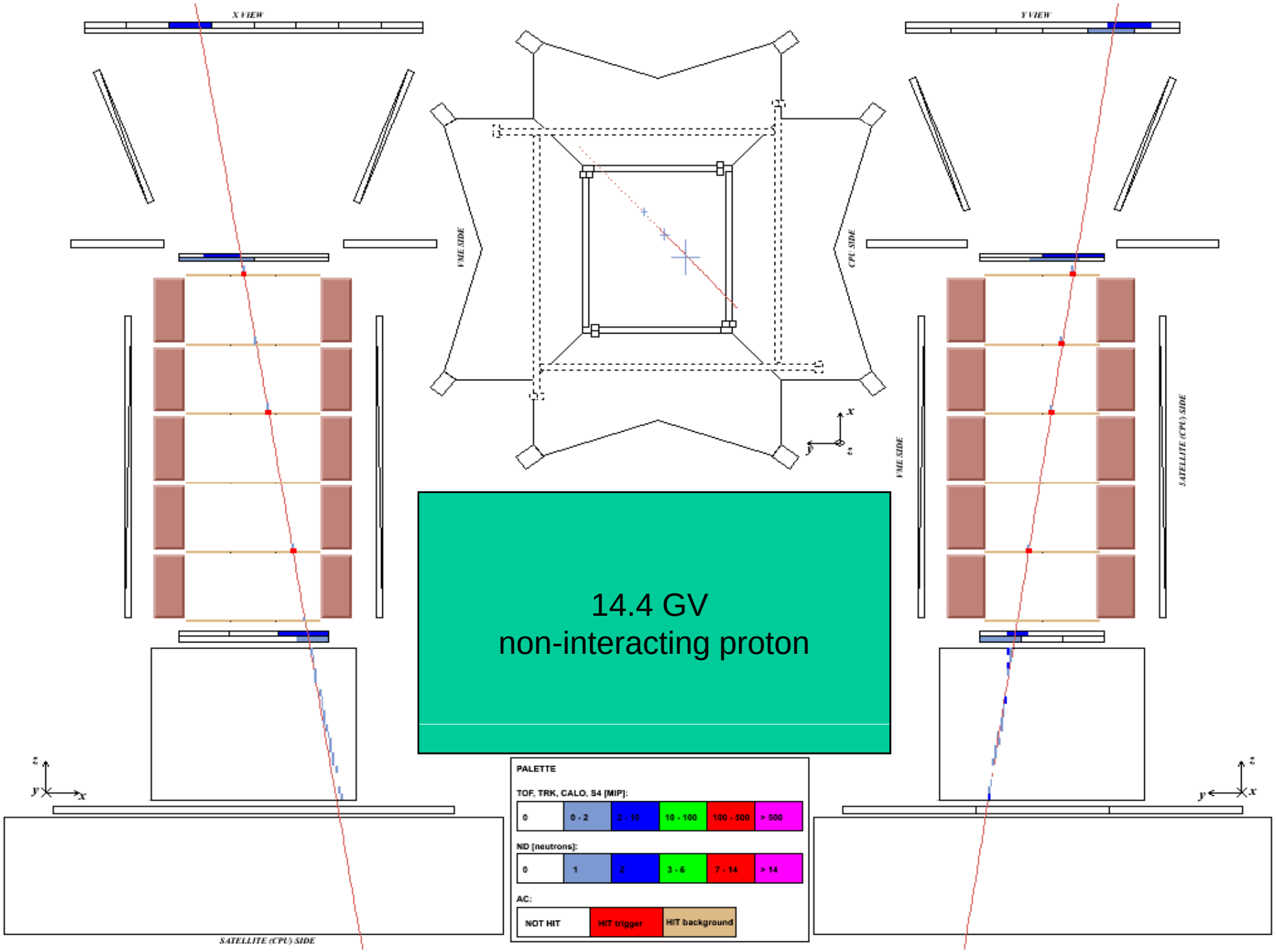
Counting rate in S1

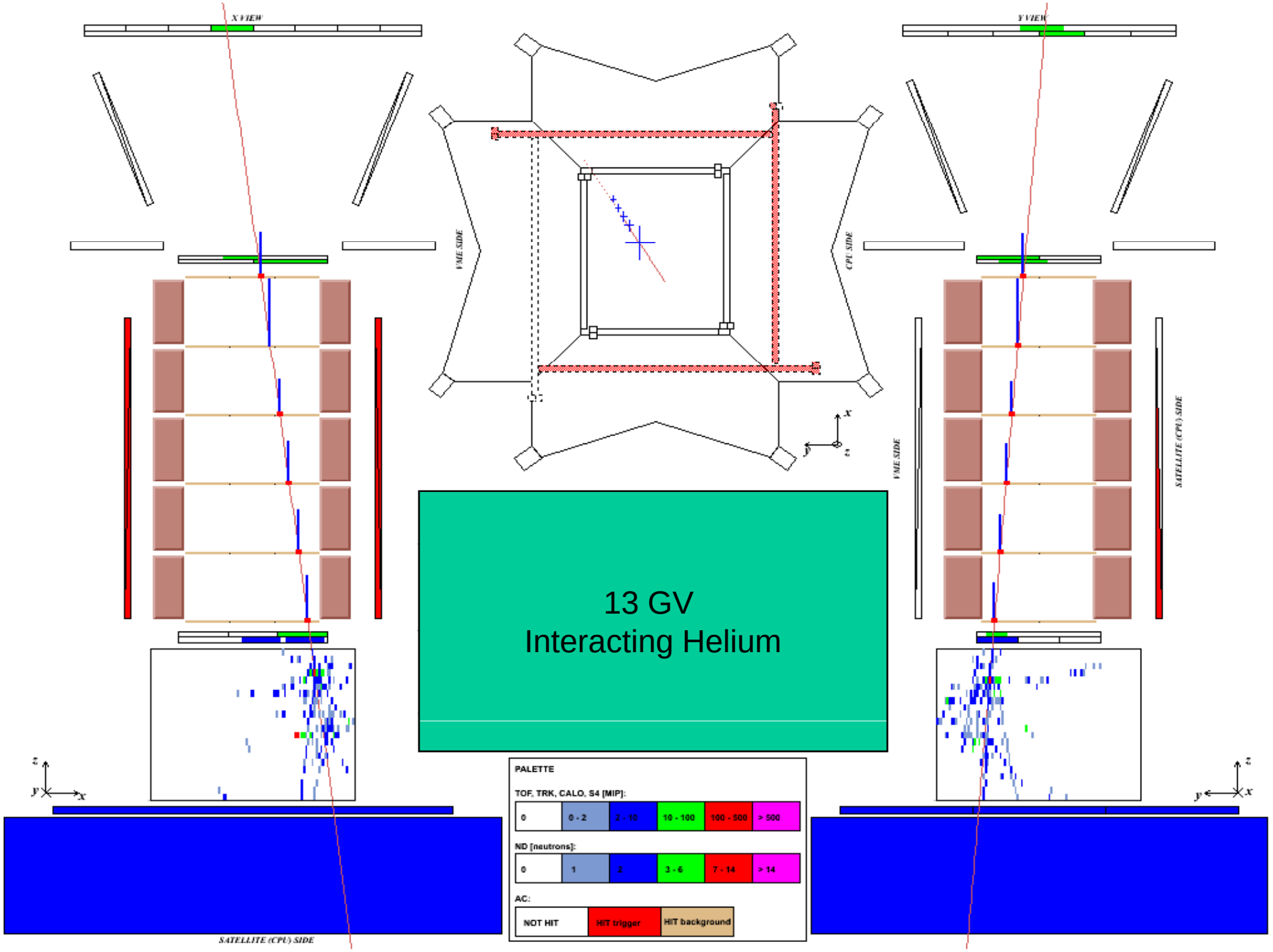
Download @orbit 3754 – 15/02/2007 07:35:00 MWT

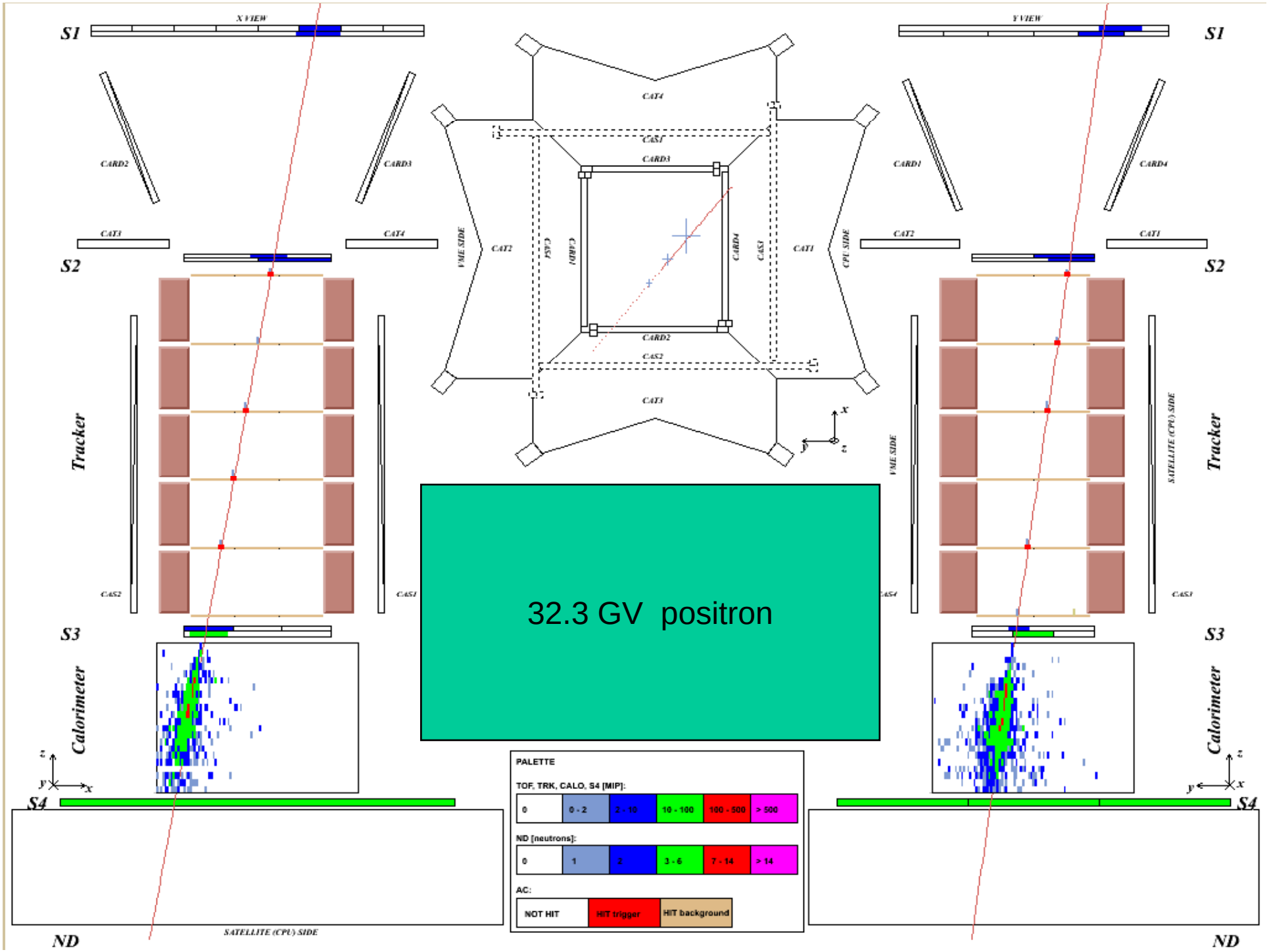


SAA and electron belts seen by S1 counts

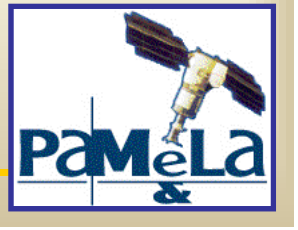



X VIEW
Y VIEW
VME SIDE
CPE SIDE
VME SIDE
SATELLITE (CPE) SIDE
14.4 GV
non-interacting proton
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background
SATELLITE (CPE) SIDE


X VIEW
Y VIEW
VME SIDE
CPU SIDE
VME SIDE
SATELLITE (CPU) SIDE
13 GV
Interacting Helium
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background
SATELLITE (CPU) SIDE

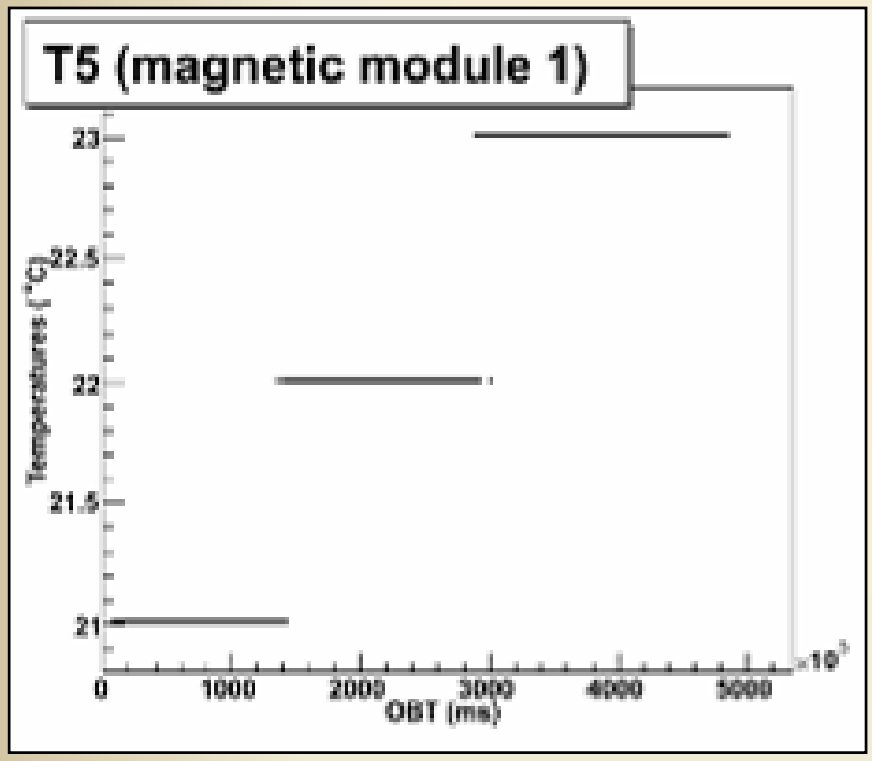

S1
X VIEW
Y VIEW
S2
S3
S4
Tracker
Calorimeter
ND
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
32.3 GV positron
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background

Tracker Performances

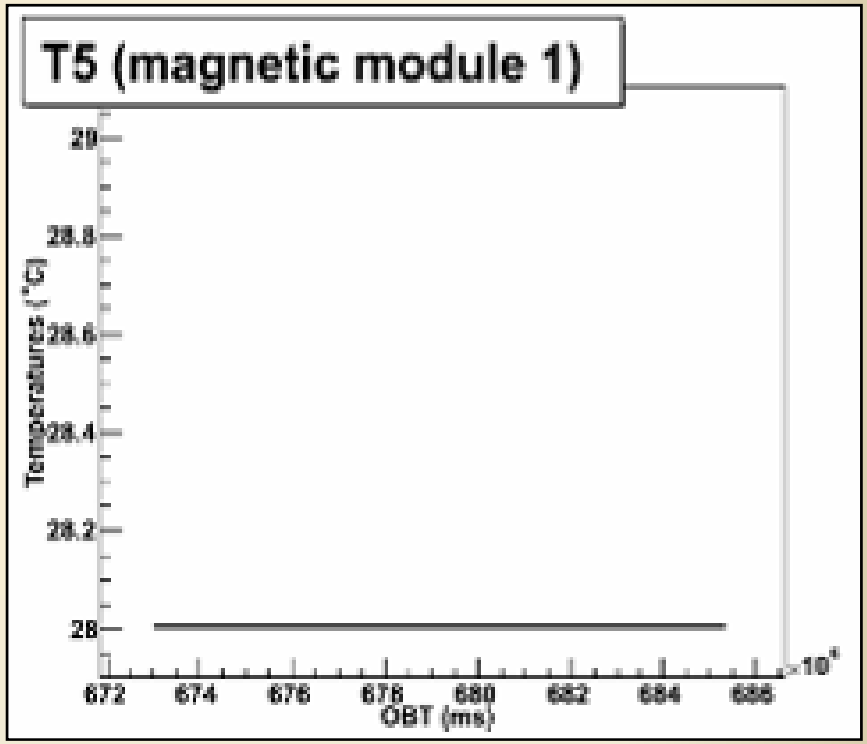


Temperatures in flight

- After power-up temperature remains stable:
  - **< 1° C variations along orbit;**
  - **< 10° C difference between PAMELA off and on.**

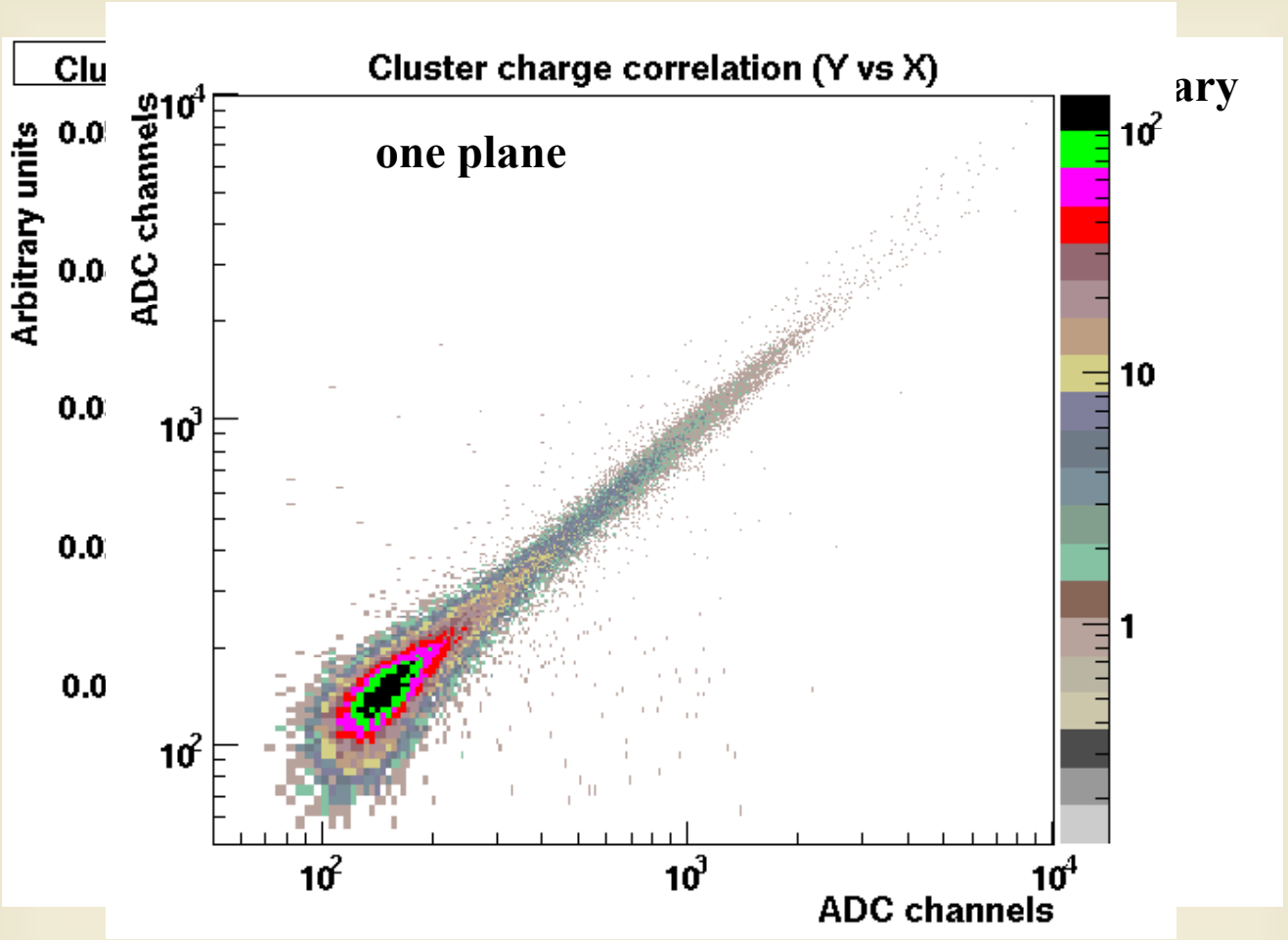


At power-up: 21° C
(5000 s ~ 0.9 orbits)



8 days after power-up: 28° C
(10000 s ~ 1.8 orbits)

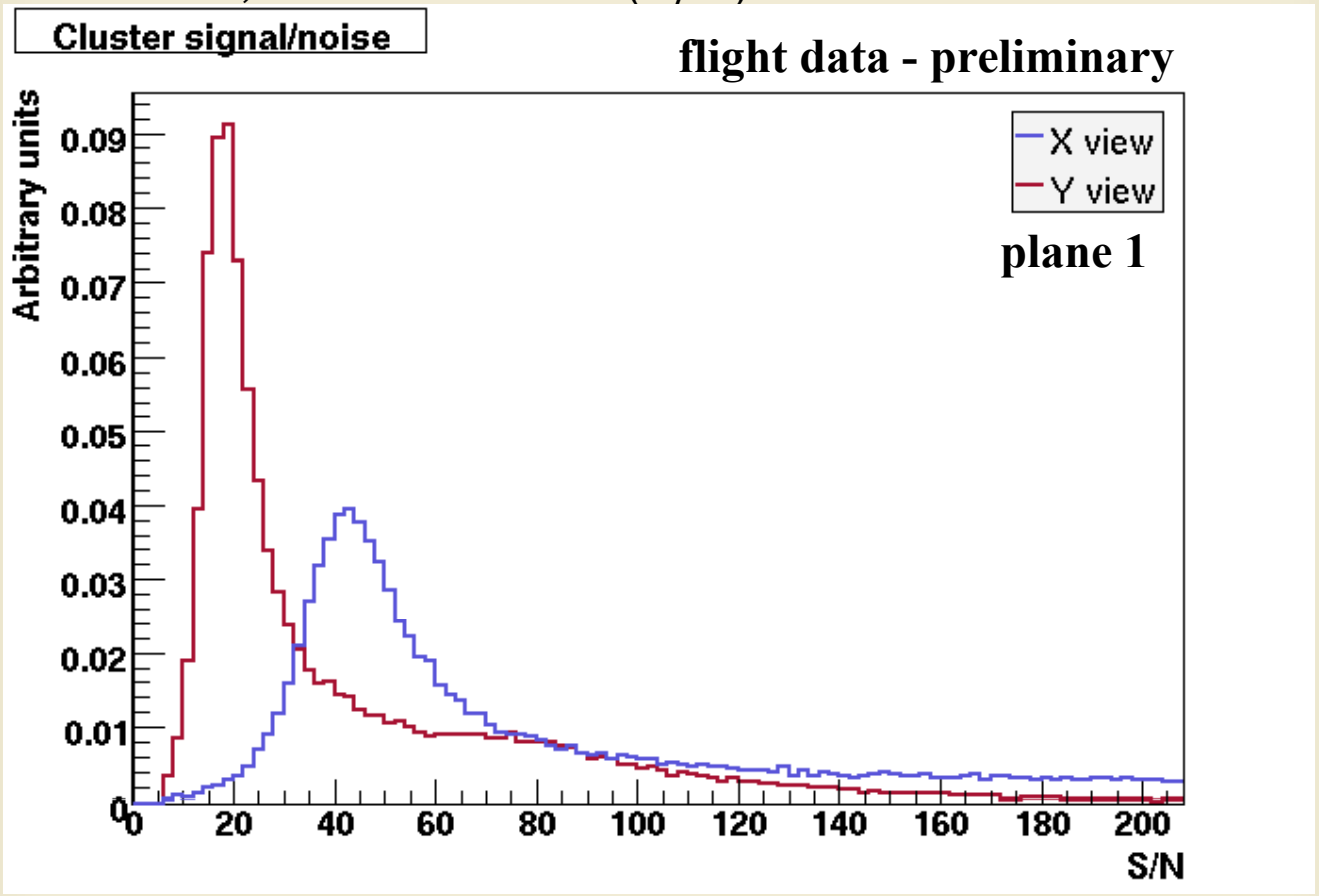
Signal characteristics



- Cluster inclusion cuts: S > 7 N (seed), S > 4 N (neighbours).

Signal/Noise ratio

- Signal/Noise ratio, calculated as Σ(S/N) over the cluster channels.

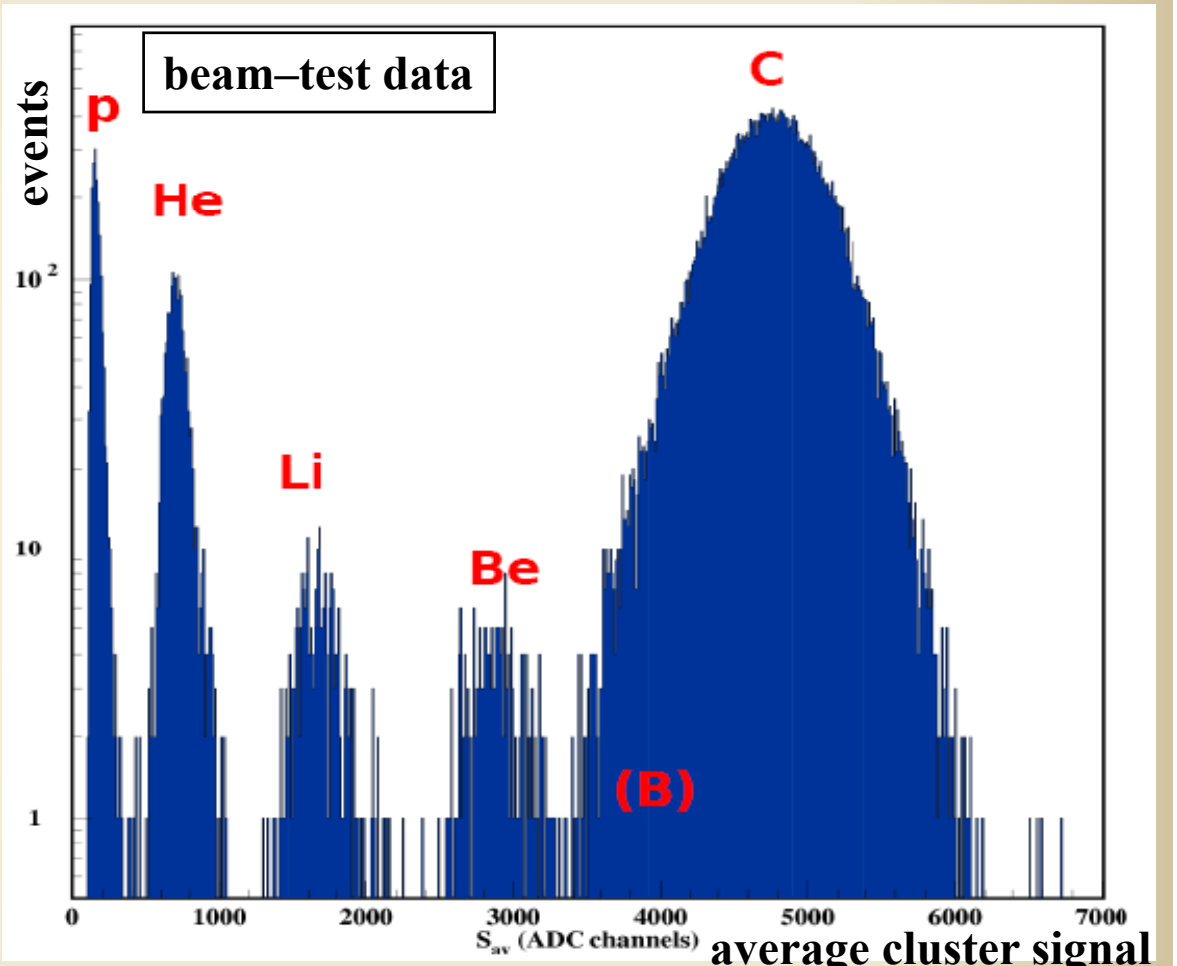


This sample contains also non-MIP cosmic rays (He etc.).

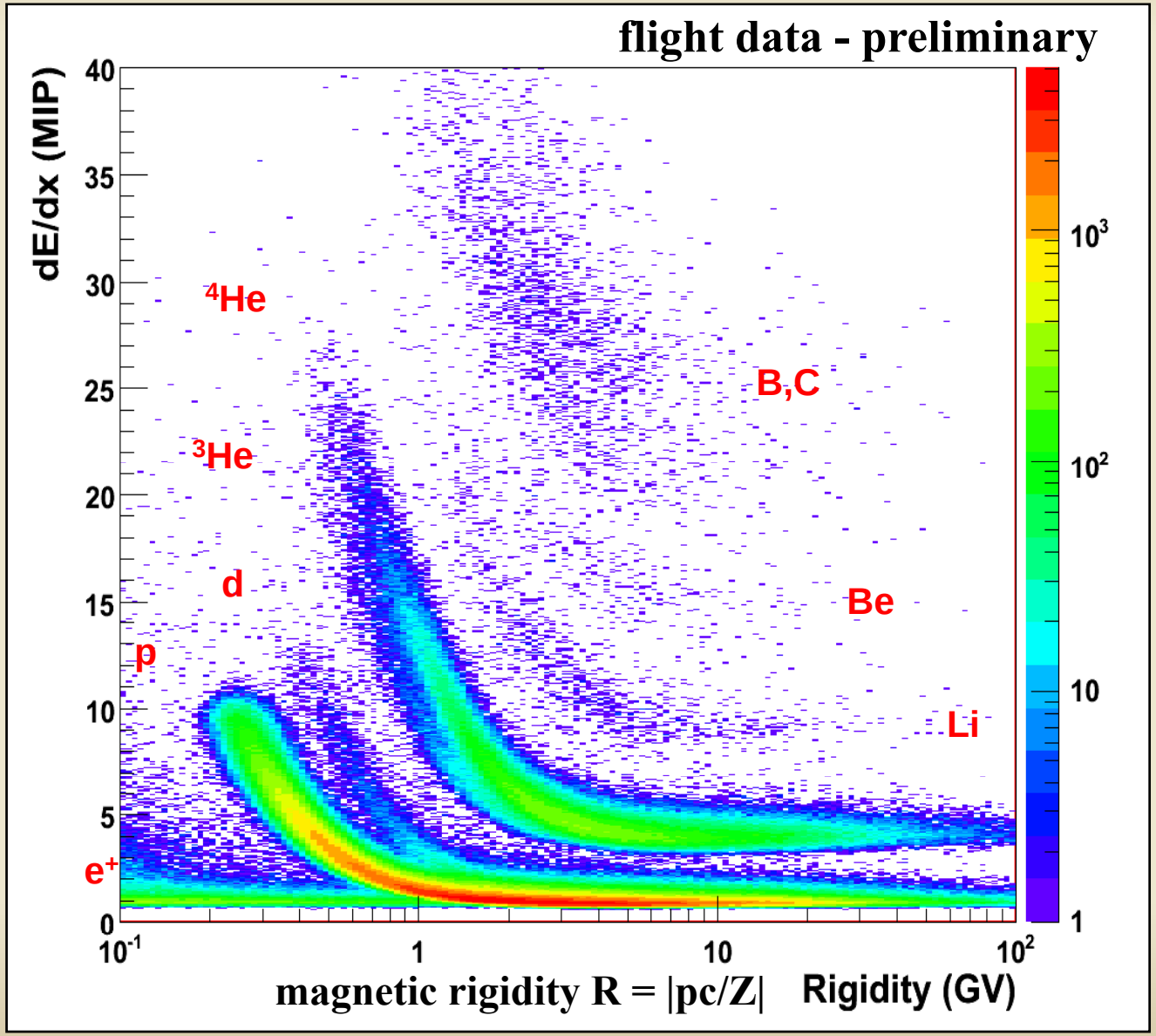
Typical average signal/noise measured at beam-test for orthogonally incident MIP: 56 (X view) 26 (Y view)

Charge discrimination

- Full charge discrimination capabilities studied with beam-test data (GSI Darmstadt, 2006).
  - Fragmentation of ^{12}C projectiles on different targets (Al, polyethylene).
- Single-channel saturation at ~ 10 MIP affects B-C discrimination.



Charge discrimination



Spatial resolution

- Critically depends on the signal/noise ratio.
- Resolution for junction (X, bending) view determines the momentum measurement.
- Depends on the Position Finding Algorithm:

  the simplest is the center-of-gravity (COG), not affected by systematic error…but

  due to discretization effect, the center-of-gravity is not the best estimator of the impact position

  (Landi G. - NIM A 485 (2002) 698 mathematic treatment)

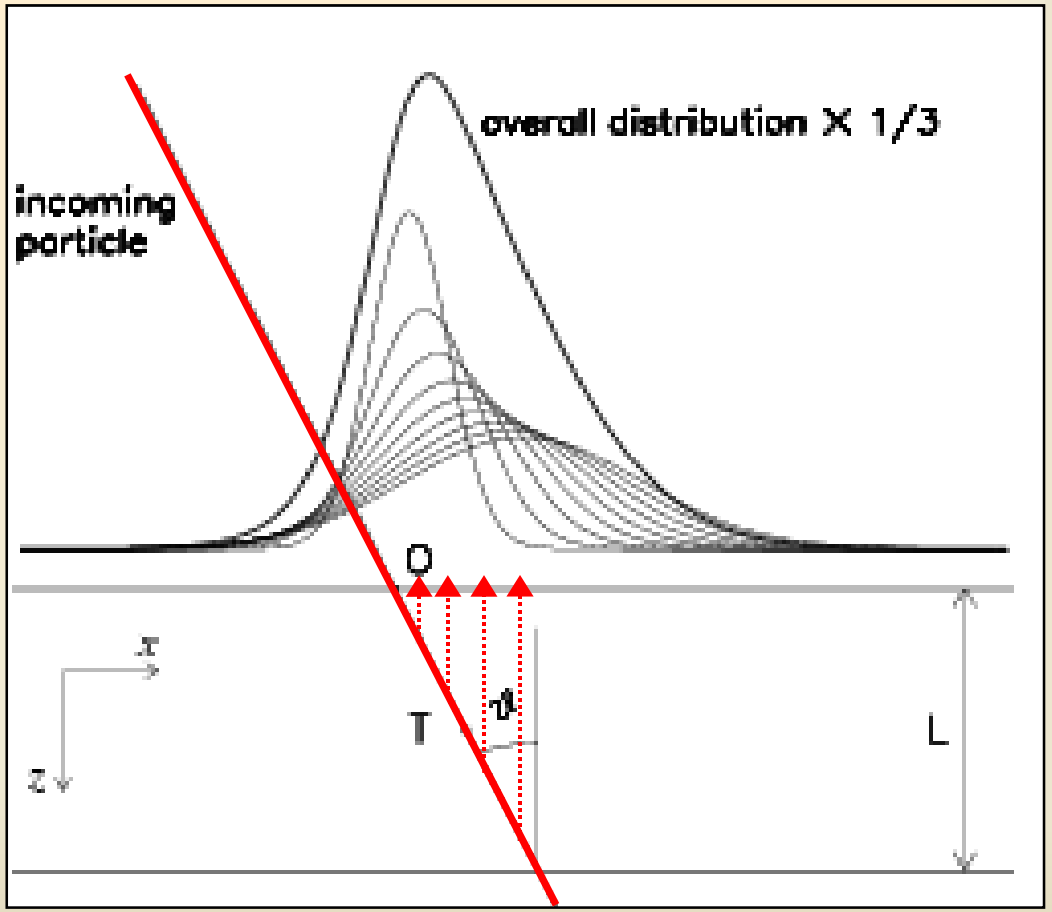
  → resolution ~ 5μm

- Best spatial resolution obtained with non-linear η algorithm.

  → resolution ~ 3μm

Signal distribution

- Non-linear η-algorithm is based on the assumption that the signal distribution is symmetric
- Signal distribution is asymmetric in case of inclined tracks
- Non-linear η-algorithm is affected by systematic error depending on the angle



The "Landi Effect"

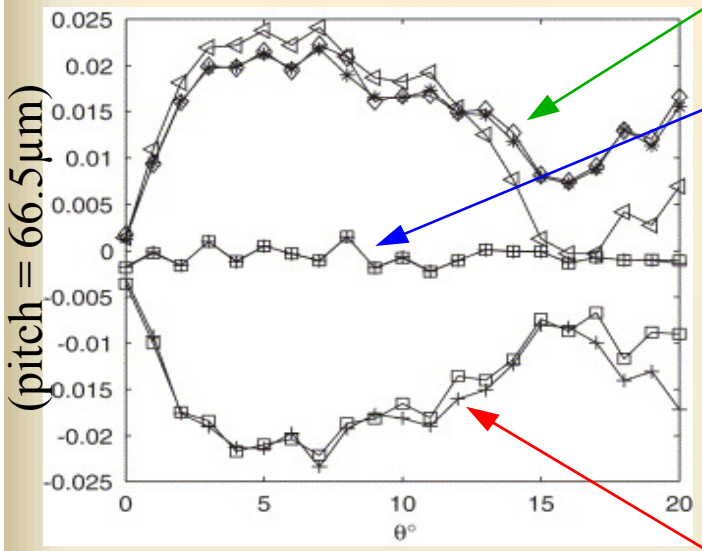
Landi G.

NIM A 554 (2005) 226

$$\Delta = \langle cog_4 - cog_1 \rangle$$

Correction

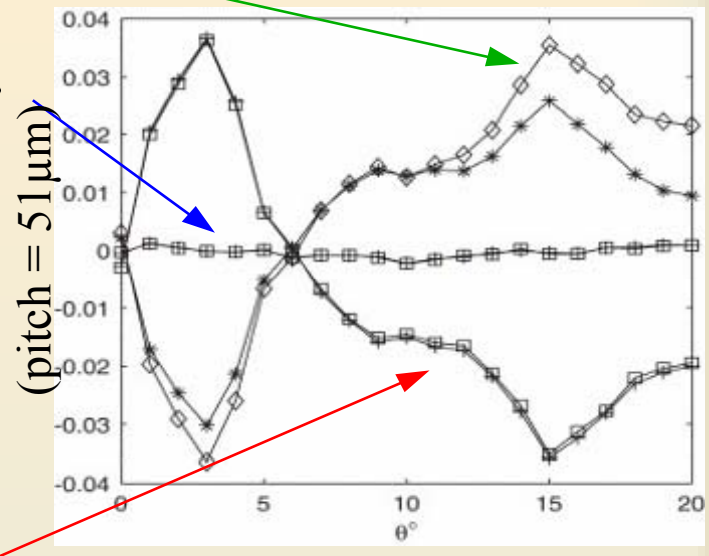
$$\langle \tilde{x}(\eta_{2,3}) - \Delta - x \rangle$$



Sensor without floating strip

$$\langle \tilde{x}(\eta_{2,3}) - x \rangle$$

Systematic error

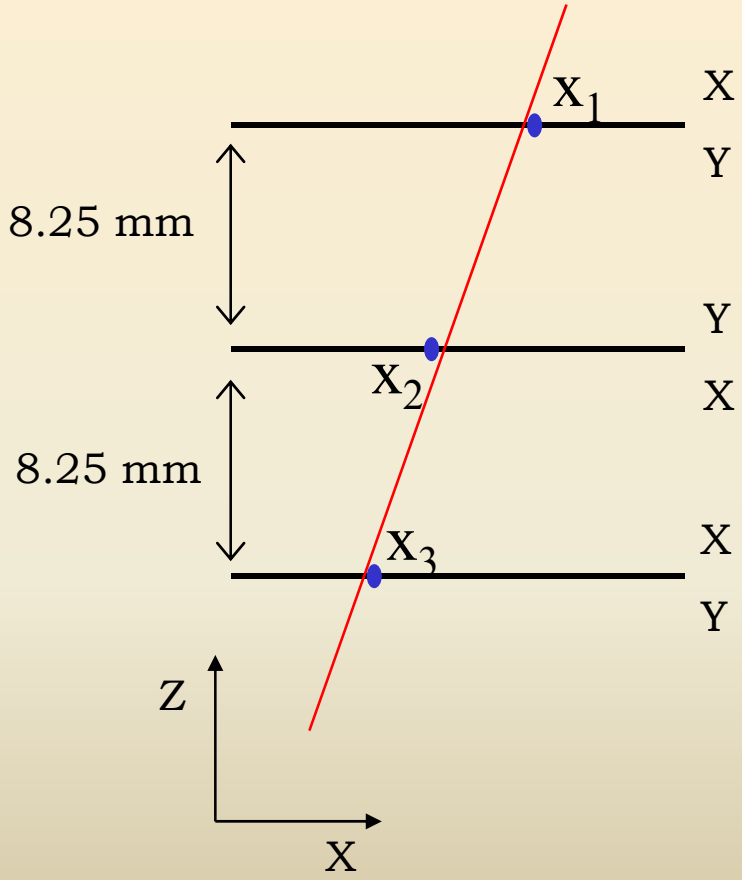


Sensor with floating strip

- cog_4 no systematics, but worse resolution
- non-linear $\eta_{2,3}$-algorithm better resolution, but angle-dependent systematic

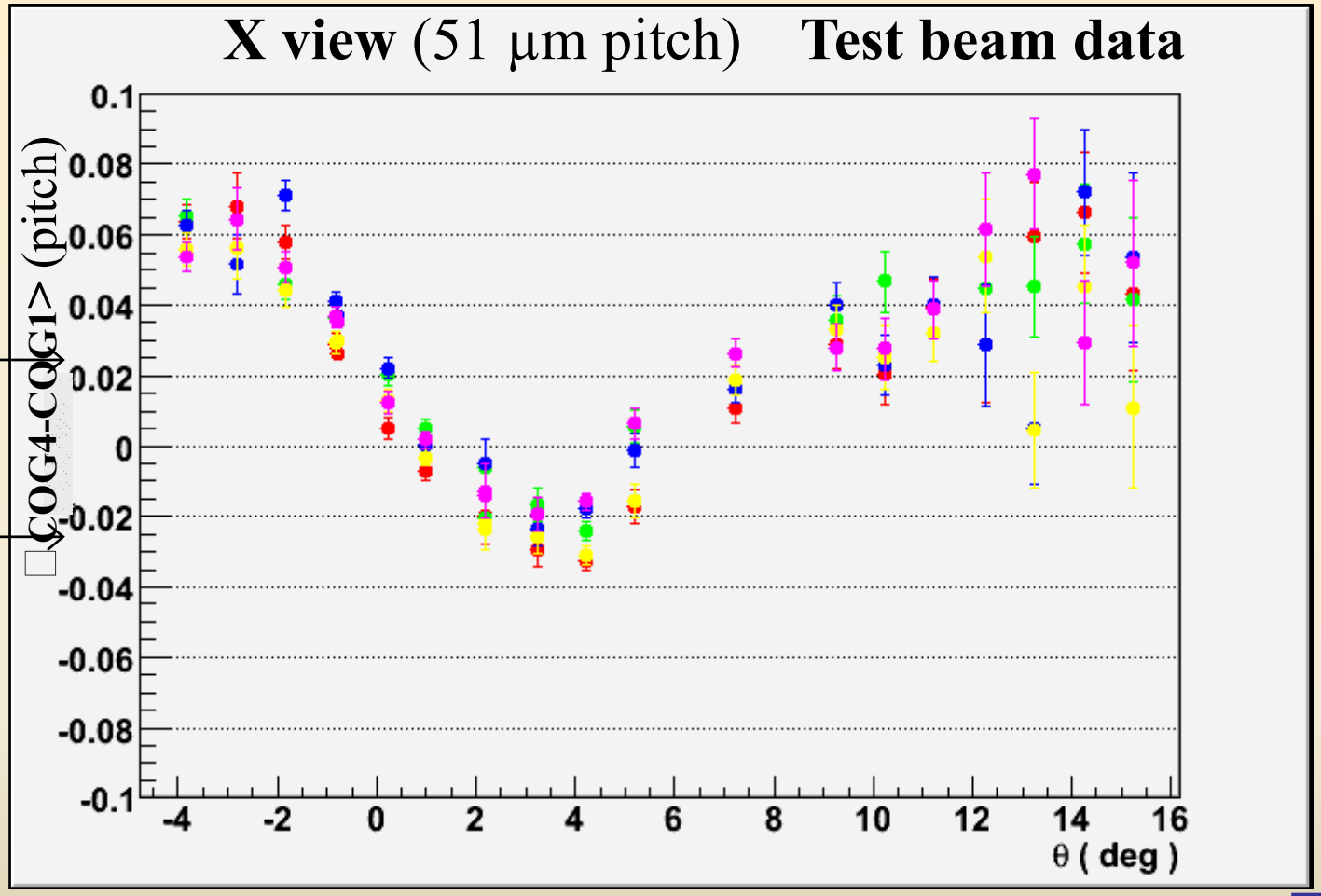
The "Landi Effect"

- We are investigating this effect by studying the spatial residuals for the data taken at test beam in this sperimental configuration



2nd plane upside down to emphasize the effect

The "Landi effect"

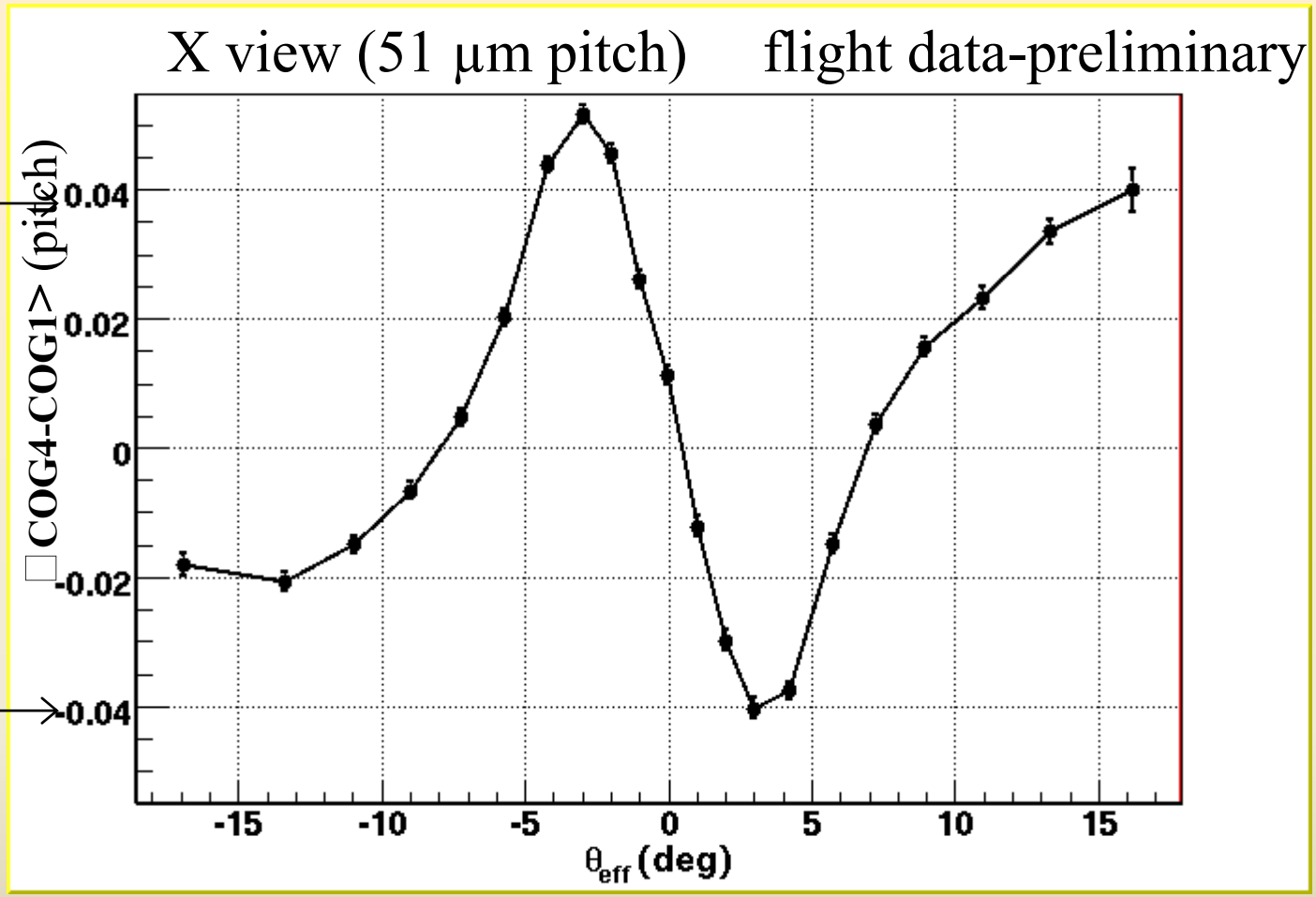


+2μm

-2μm

residuals $\delta = \frac{x_1 + x_3}{2} - x_2$

The "Landi effect"



Analysis is in progress

Conclusions

- PAMELA is taking data since 11 July 2006.
  - **Up to now the amount of data collected is ~4.7 TB.**
  - **Corresponding to more than 570 · 10^6 events.**
- Magnetic spectrometer on-flight performances are nominal.
- Data analysis is in progress.
  - Precise determination of detector characteristics.
  - Application to physics research items.

→ PAMELA will be able to achieve the scientific goals of the mission!!!