In-Flight performances of the PAMELA satellite experiment

Paolo Papini

on behalf of the PAMELA collaboration

June 20-22, 2007

PAMELA science

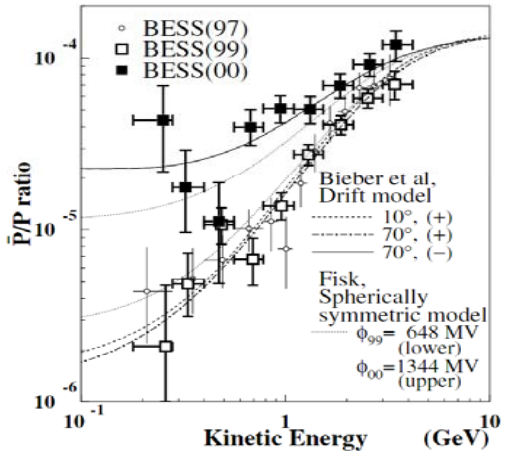
- Search for antimatter
- Search for dark matter
- Study of cosmic-ray propagation
- Study solar physics and solar modulation
- Study of electron spectrum (local sources?)
- Study terrestrial magnetosphere

Antiprotons

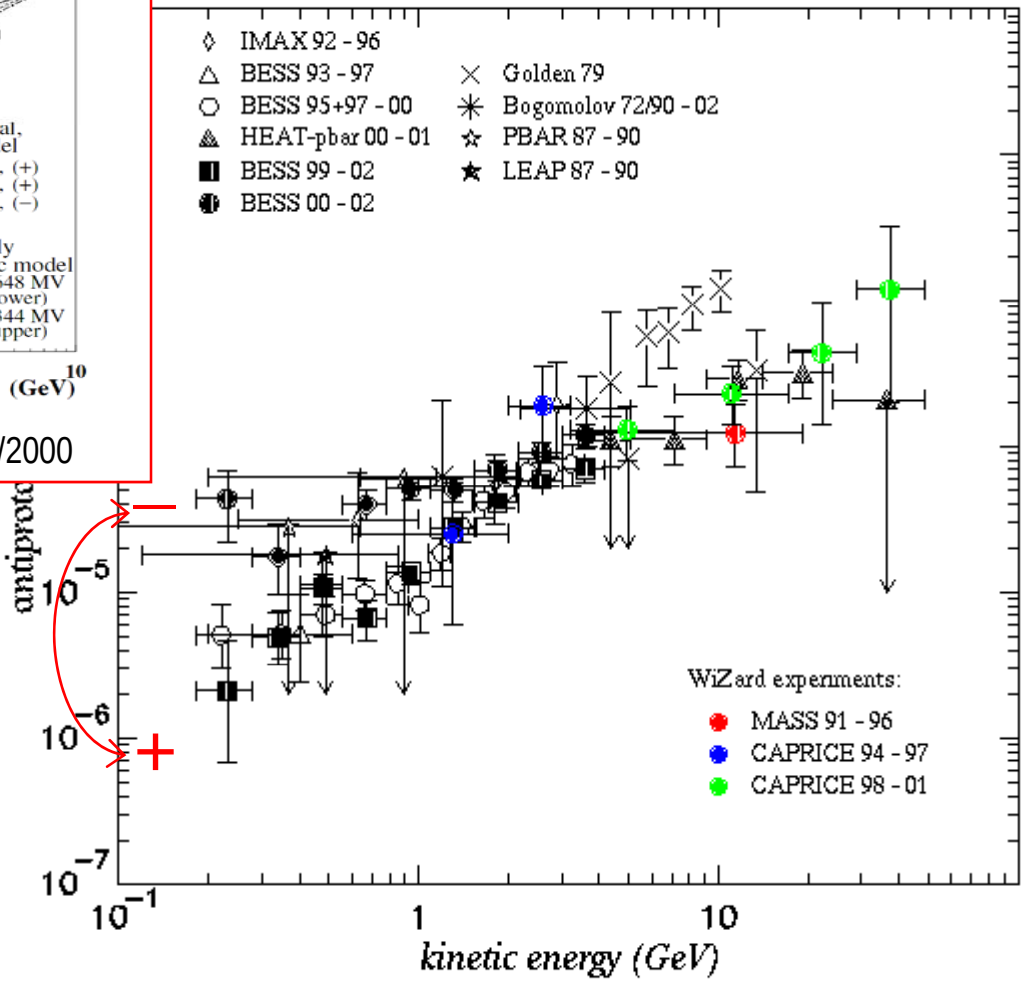
Experimental scenario during 90s

Charge-dependent solar modulation

Asaoka Y. Et al. 2002

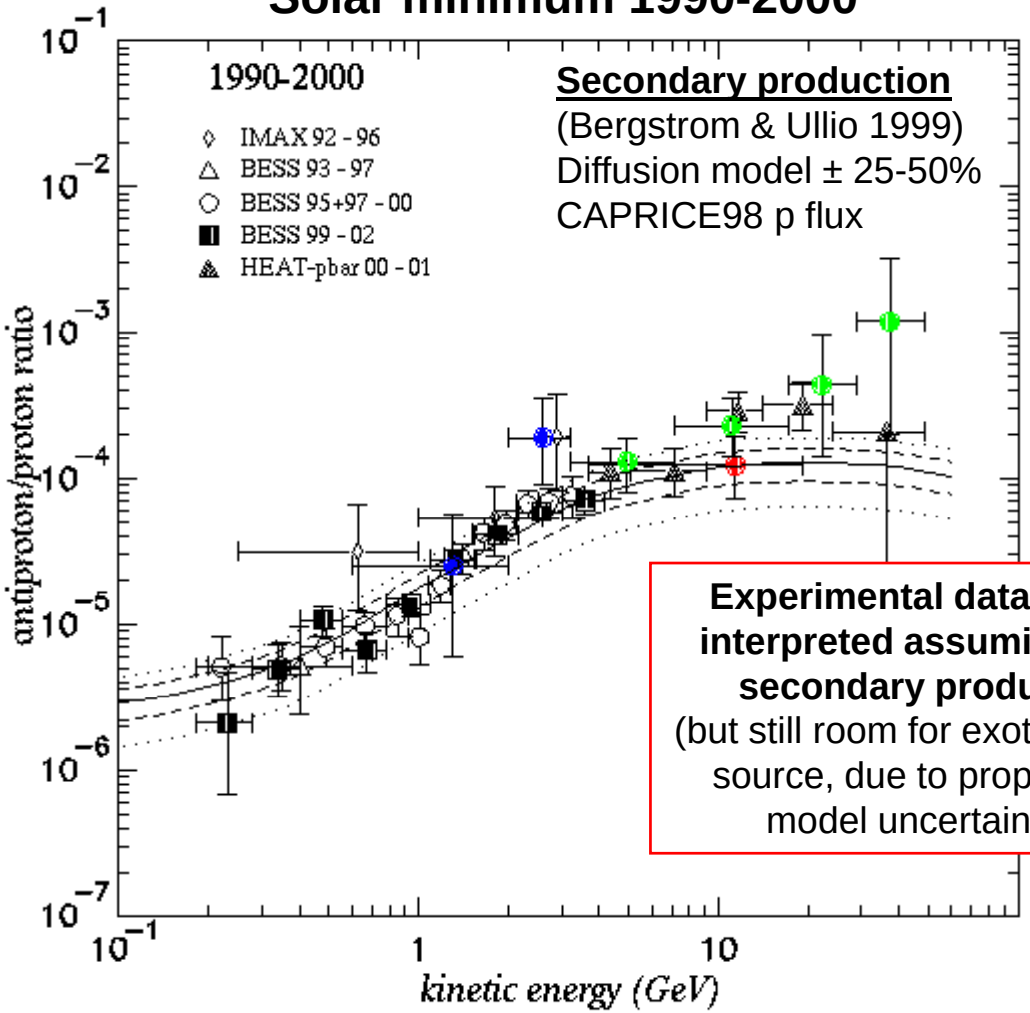


Solar polarity reversal 1999/2000



Antiprotons

Solar minimum 1990-2000



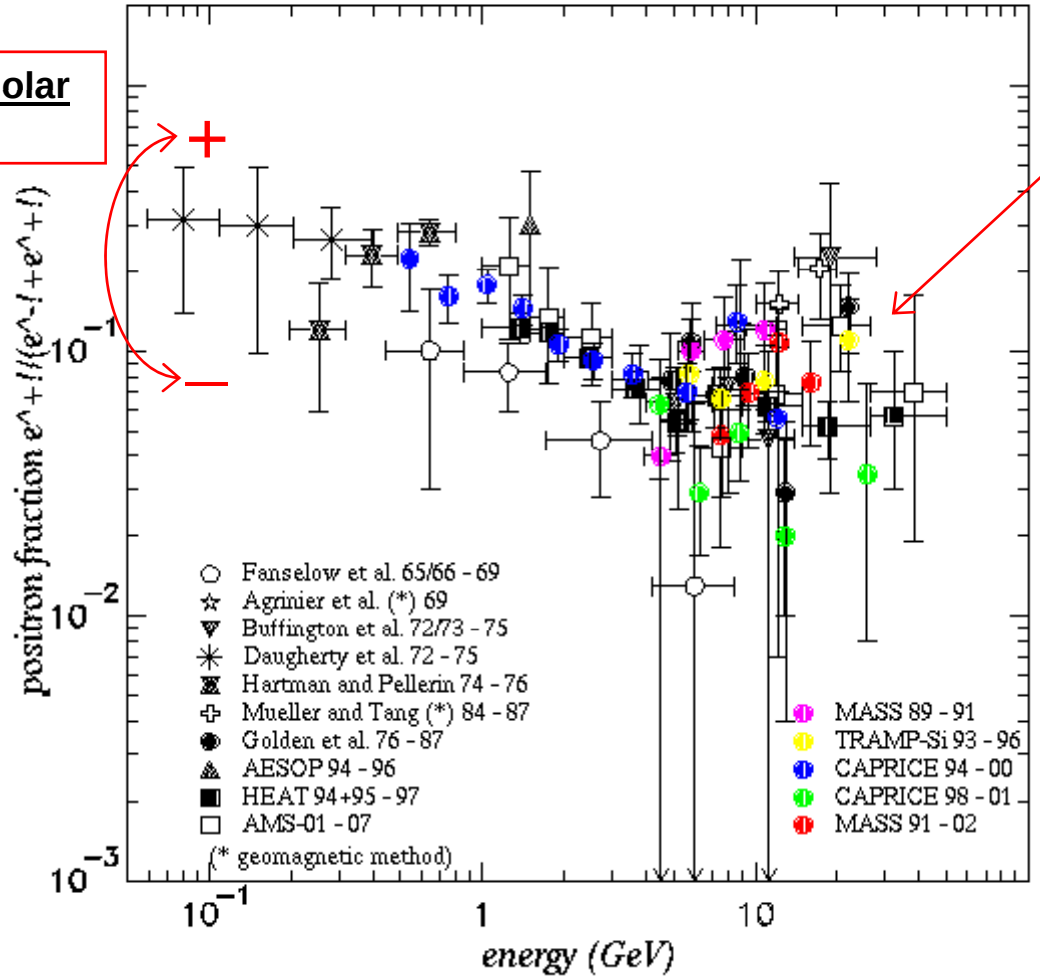
Secondary production
(Bergstrom & Ullio 1999)
Diffusion model ± 25-50%
CAPRICE98 p flux

Experimental data can be interpreted assuming pure secondary production
(but still room for exotic primary source, due to propagation model uncertainties)

Positrons

Experimental scenario until 90s

Charge-dependent solar modulation

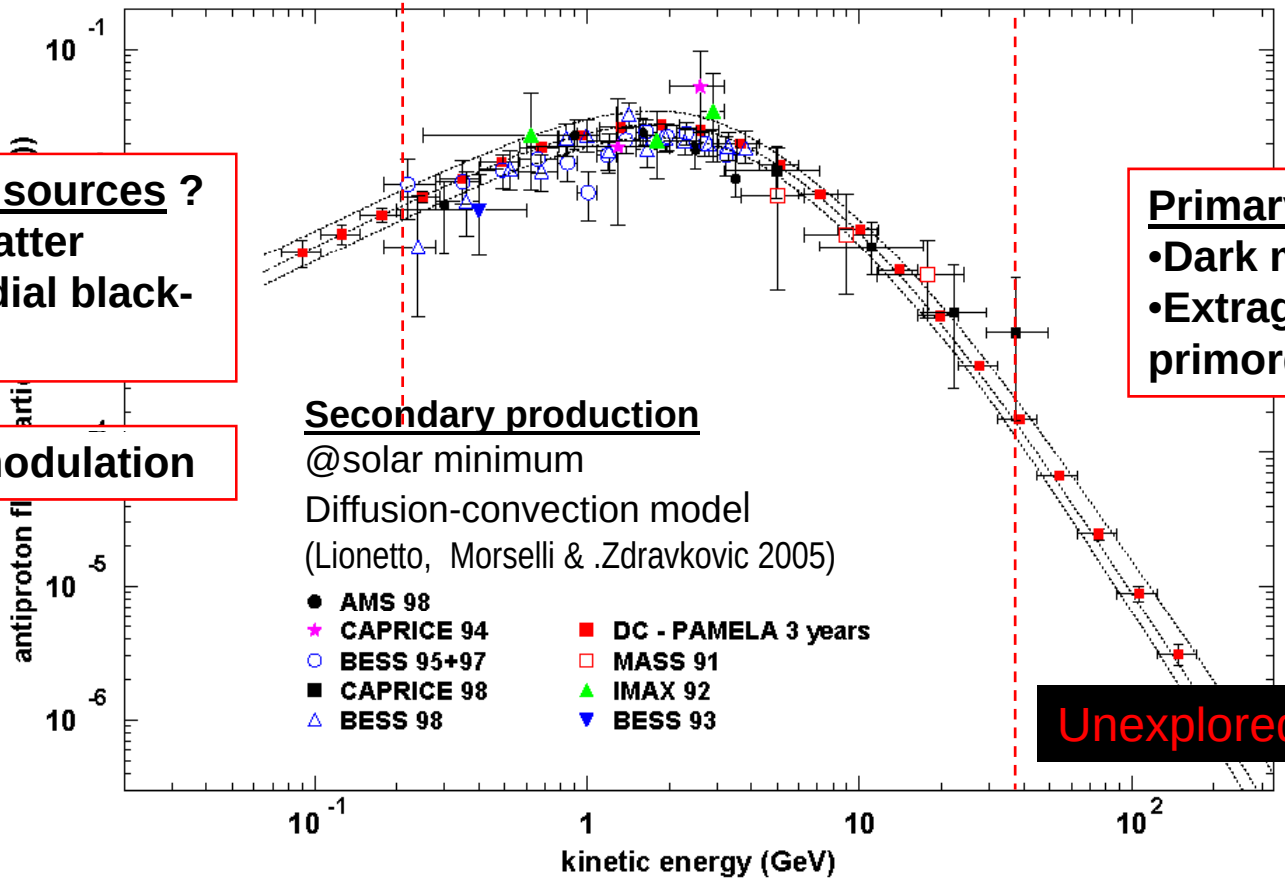


…?…

Difficult interpretation due to large uncertainties in propagation models

Antiprotons

PAMELA expectation in 3 years



Primary sources ?
- **Dark matter**
- **Primordial black-holes**

- **Solar modulation**

Secondary production
@solar minimum
Diffusion-convection model
(Lionetto, Morselli & .Zdravkovic 2005)

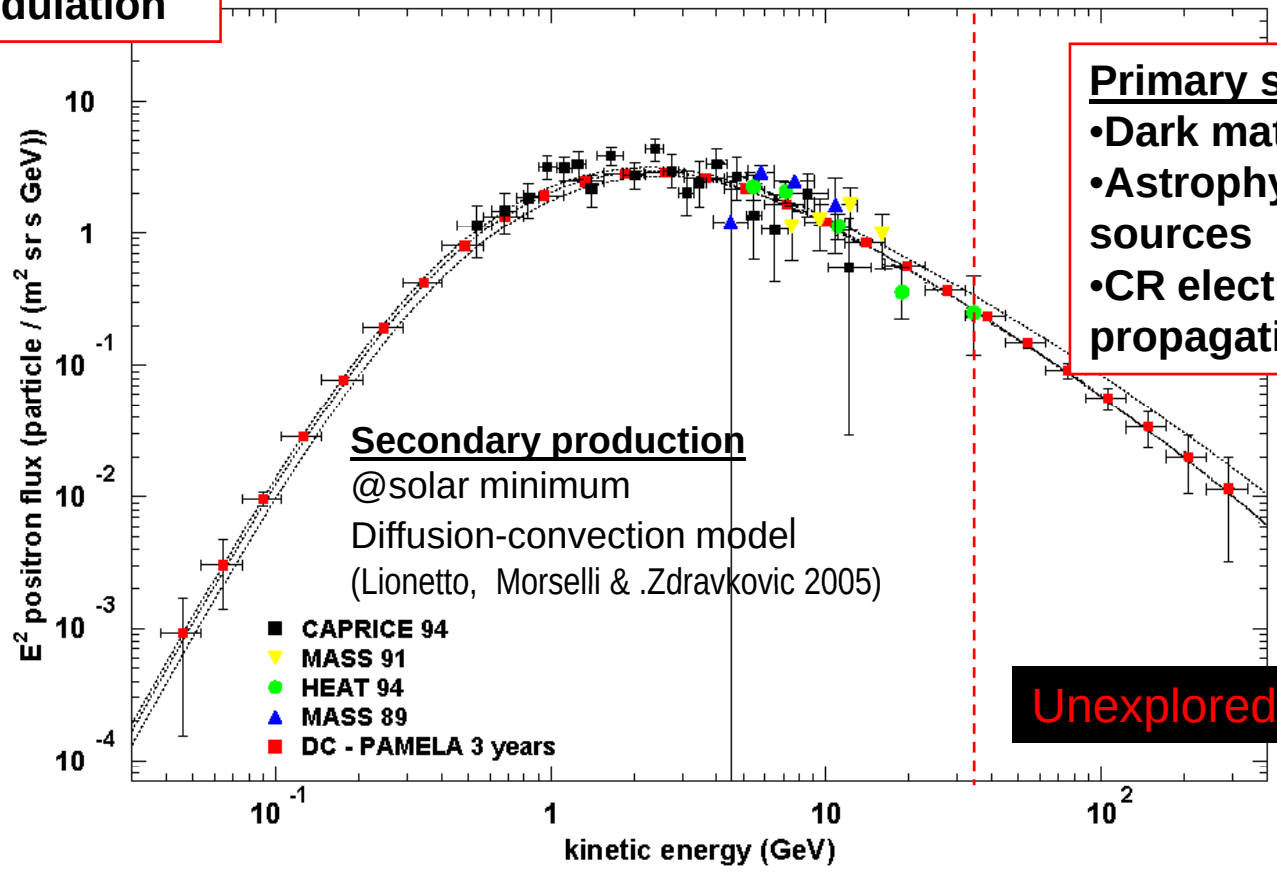
Primary sources ?
- **Dark matter**
- **Extragalactic primordial p-par**

Unexplored Region

Positrons

PAMELA expectation in 3 years

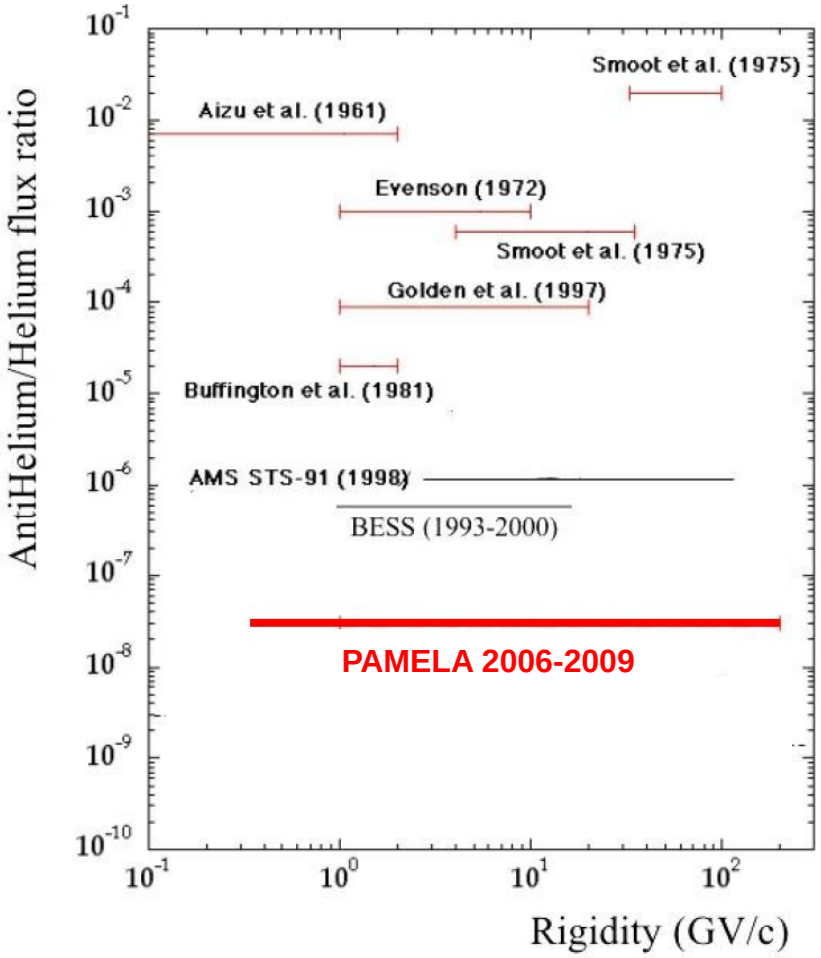
• **Solar modulation**



Primary sources ?
- **Dark matter**
- **Astrophysical sources**
- **CR electron propagation**

Extragalactic Cosmic-ray Antimatter Search

Unequivocal signature of large-scale antimatter structures



Cosmic-ray Antimatter from Dark Matter annihilation

A plausible dark matter candidate is neutralino (χ), the lightest SUSY particle.

Annihilation of relic χ gravitationally confined in the galactic halo

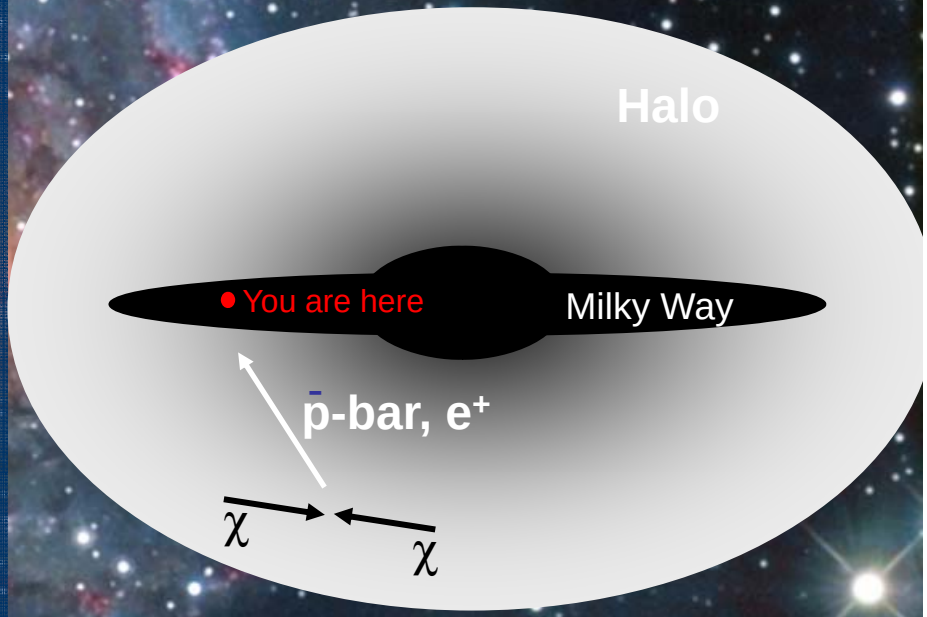
→ Distortion of antiproton and positron spectra from purely secondary production

Most likely processes:

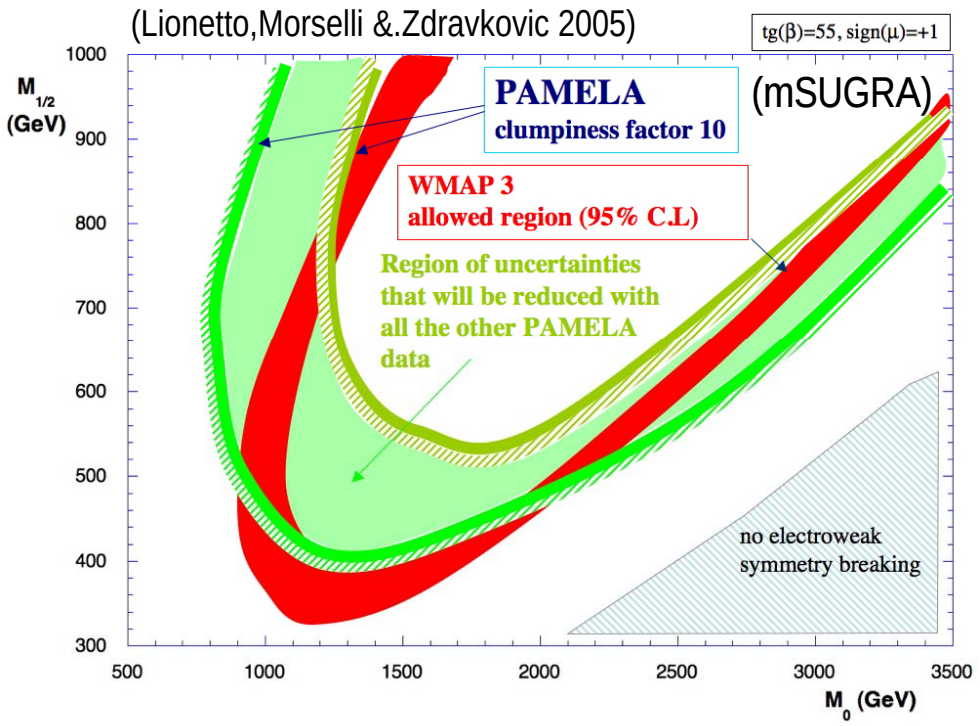
- $\chi\chi \rightarrow qq \rightarrow$ hadrons$\rightarrow$ anti-p, e^+,…
- $\chi\chi \rightarrow W^+W^-, Z^0Z^0, \ldots \rightarrow e^+, \ldots$

  direct dicay $\Rightarrow$ positron peak $Ee+ \sim M\chi/2$

  other processed $\Rightarrow$ positron continuum $Ee+ \sim M\chi/20$

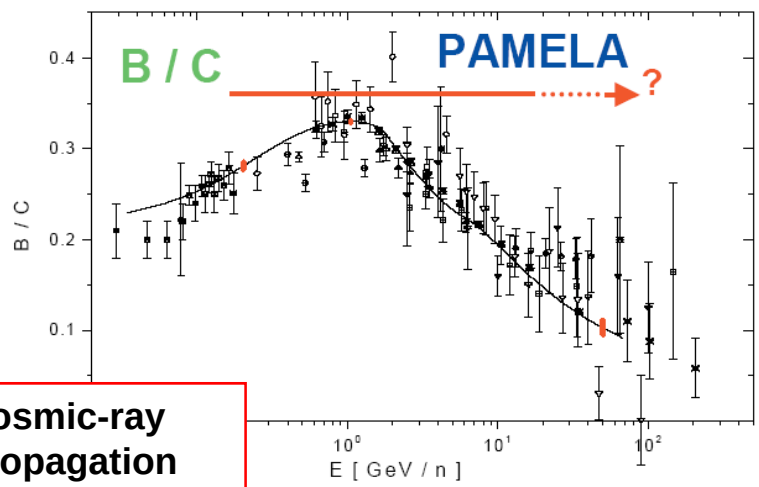


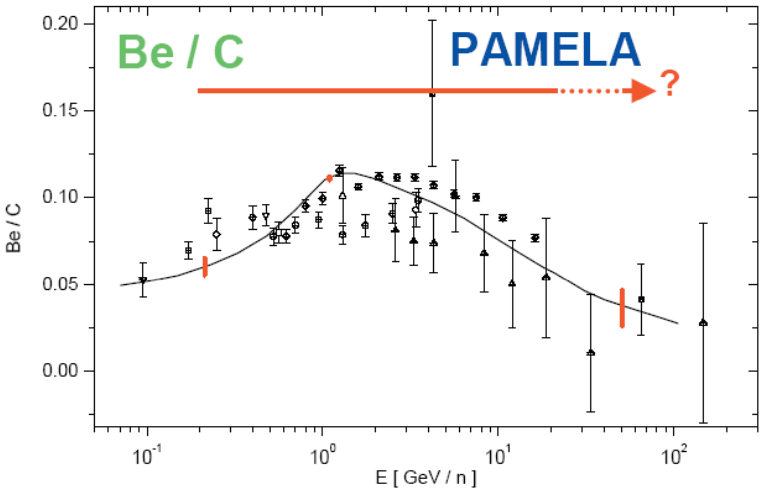
Antiprotons



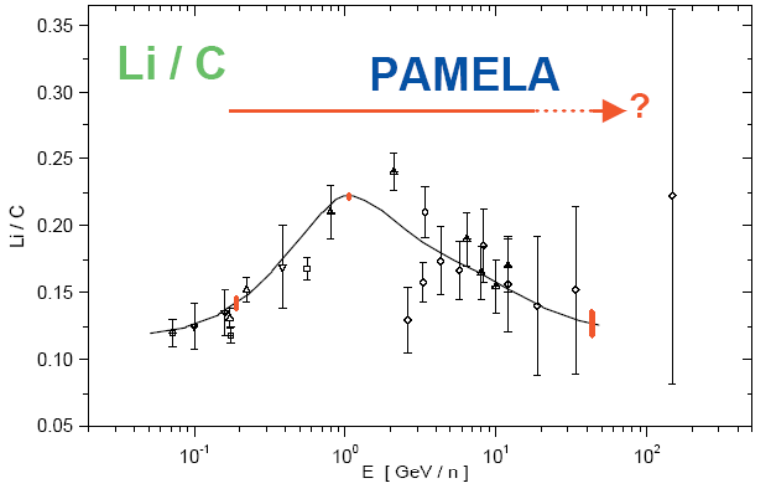
Unambiguous interpretation of exotic matter signature requires a clear understanding of the secondary spectra and their sources.

Secondary-to-primary ratio

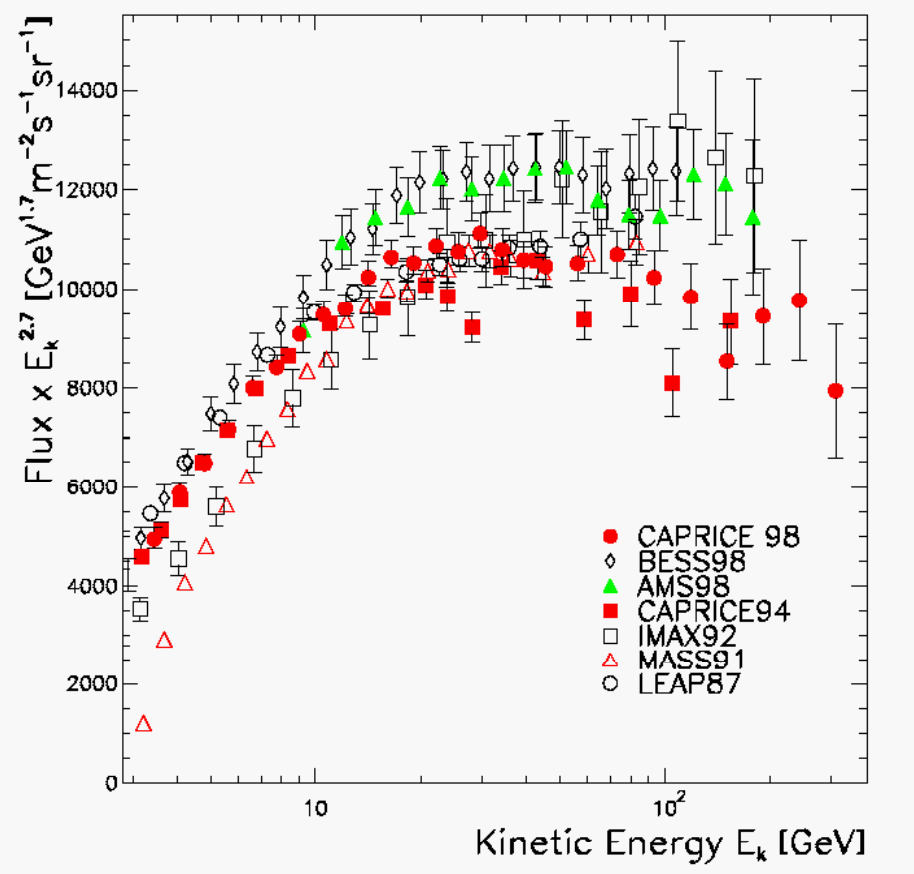


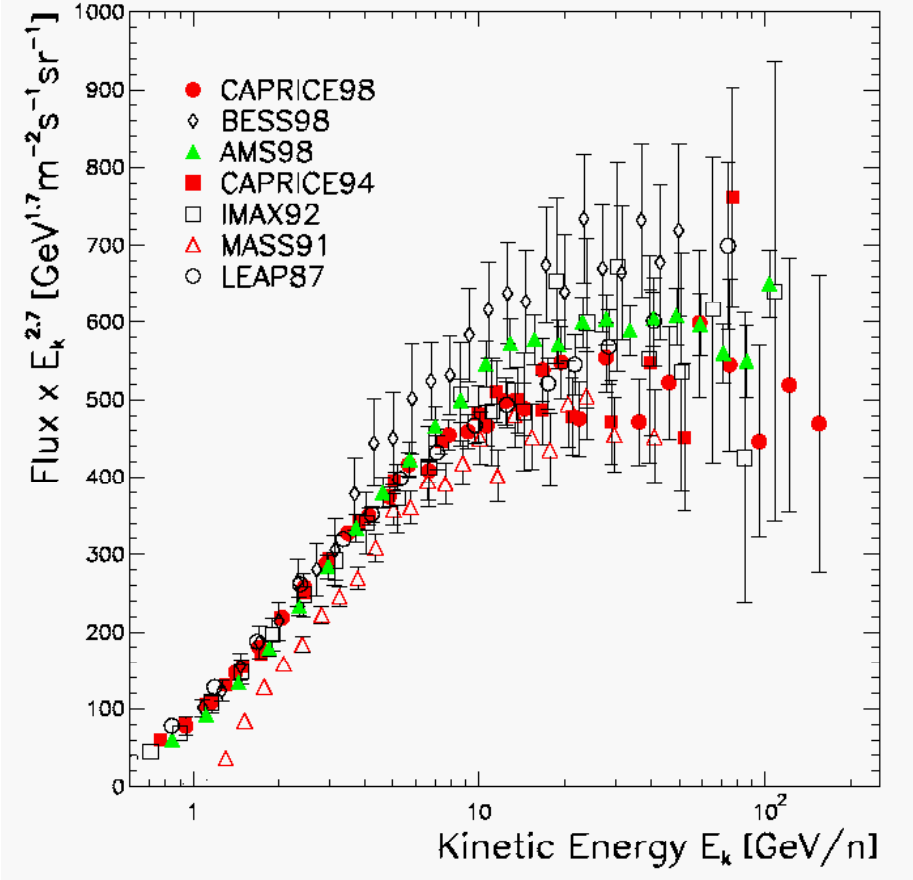


Cosmic-ray propagation parameters often tuned on B/C data



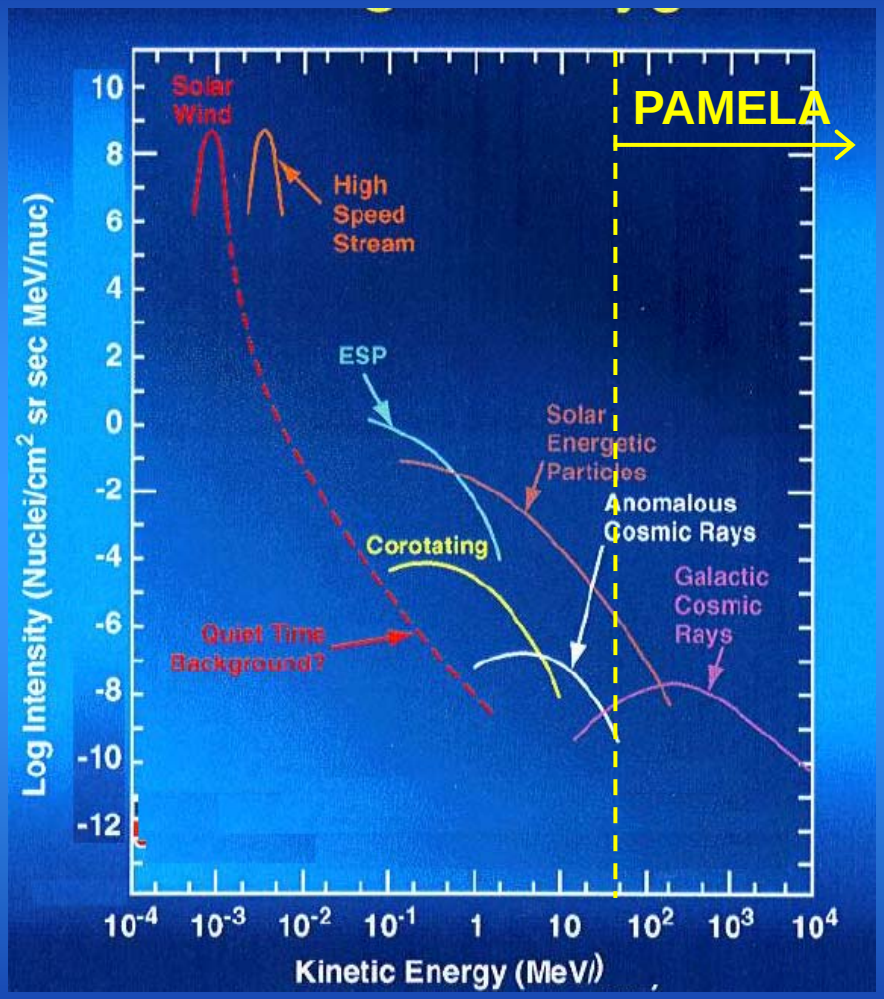
Primary spectra: H and He





Cosmic-ray propagation calculations affected by uncertainty on primary flux.

Solar physics



- Solar Modulation effects
- High energy component of Solar Proton Events
  - Proton (>80MeV)
  - Electrons and positrons (>50MeV)
- Nuclear composition of Gradual and Impulsive events
- 3He and 4He isotopic composition in Impulsive events
- Electrons of Jovian origin
- Anomalous cosmic-rays

(3 Solar events beetween 6/12/2006 and 18/12/2006; see "Solar and heliospheric cosmic ray observations with PAMELA experiment" – Marco Casolino)

PAMELA nominal capabilities

	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 He/He	

→ Simultaneous measurement of many cosmic-ray species

→ New energy range

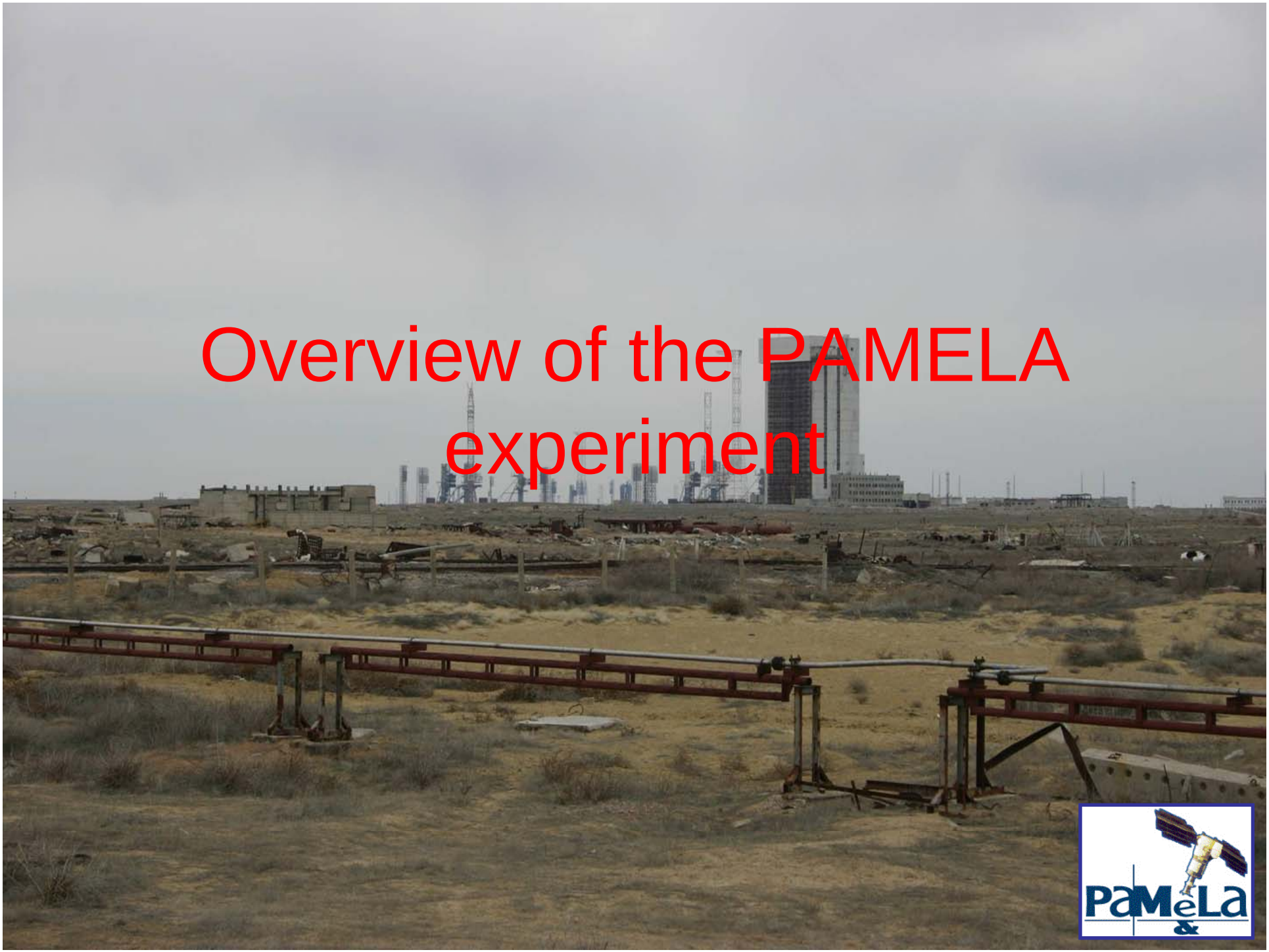
→ Unprecedented statistics

Taking into account live time and geometrical factor:

1 HEAT-PBAR flight ~ 22.4 days PAMELA data

1 CAPRICE98 flight ~ 3.9 days PAMELA data

Overview of the PAMELA experiment



PAMELA collaboration

Italy




Bari **Florence** **Frascati** **Naples** **Rome** **Trieste**

Russia

Moscow **St. Petersburg**

Sweden

Stockholm

Germany

Siegen

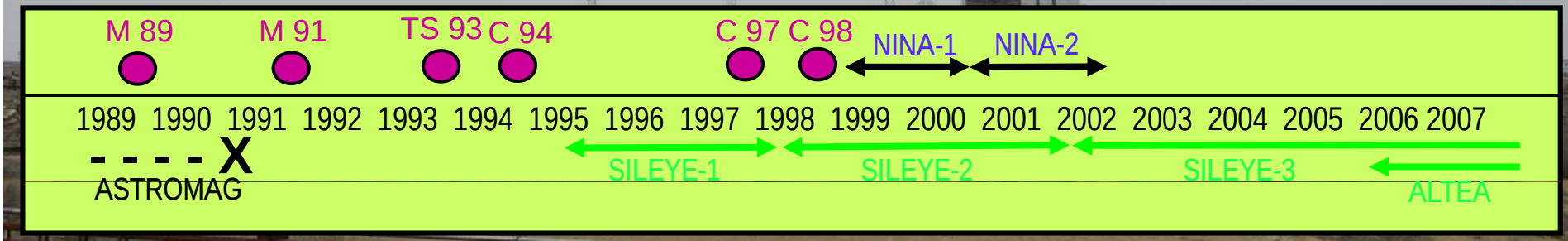
P. Picozza a, A.M. Galperb, G. Castellini d, O. Adriani c, F. Altamura a,
M. Ambriola j, G.C. Barbarino g, A. Basili a,
G.A. Bazilevskaja , R. Bencardino a, M. Boezio e,
E.A. Bogomolov k, L. Bonechi c, M. Bongi c, L. Bongiorno i,
V. Bonvicini e, F. Cafagna j, D. Campanag, P. Carlson f,
M. Casolino a, C. De Marzoj, *, M.P. De Pascale a, G. De Rosag,
D. Fedele c, P. Hofverbergf, S.V. Koldashovb, S.Yu. Krutkov k,
A.N. Kvashnin , J. Lund f , J. Lundquist e, O. Maksumov,
V. Malvezzi a, L. Marcelli a, W. Mennh, V.V. Mikhailov b,
M. Minori a, S. Misin , E. Mocchiutti e, A. Morselli a,
N.N. Nikonov k, S. Orsi f , G. Osteria g, P. Papini c,
M. Pearce f, **, M. Ricci i, S.B. Ricciarini c, M.F. Runtso b,
S. Russo g, M. Simonh, R. Sparvoli a, ***, P. Spillantini c,
Yu.I. Stozhkov , E. Taddei c, A. Vacchi e, E. Vannuccini c,
S.A. Voronov b, Y.T. Yurkinb, G. Zampa e, N. Zampa e, V.G. Zverev b

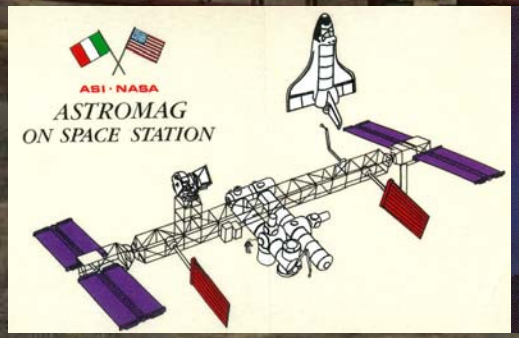
A-INFN, Structure of Rome "Tor Vergata" and Physics Department of University of Rome "Tor Vergata" Rome, Italy
B-Moscow Engineering and Physics Institute, Moscow, Russia
C-INFN, Structure of Florence and Physics Department of University of Florence, Florence, Italy
D-IFAC, Florence, Italy
E-INFN, Structure of Trieste and Physics Department of University of Trieste, Via A. Valerio 2, I-34127 Trieste, Italy
F-KTH, Department of Physics, Stockholm,Sweden
G-INFN, Structure of Naples and Physics Department of University of Naples Naples, Italy
H-Universit¨at Siegen, Siegen, Germany
iI-NFN, Laboratori Nazionali di Frascati, Frascati, Italy
J-INFN, Structure of Bari and Physics Department of University, Bari, Italy
K-Ioffe Physical Technical Institute, St. Petersburg, Russia
L-ebedev Physical Institute, Moscow, Russia

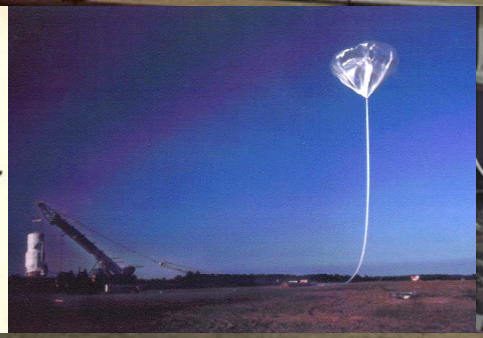
PAMELA prehistory

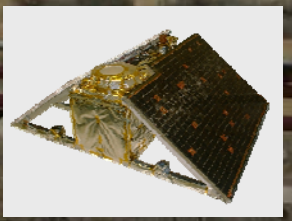
- Astromag/WiZard project (PAMELA precursor) on board of the Space Station Freedom →CANCELED
- Balloon-borne experiments: MASS-89,91 TS-93 CAPRICE-94,97,98
- Space experiments*: NINA-1,2 SILEYE-1,2,3 ALTEA

(*study of low energy nuclei and space radiation environment)









PAMELA history

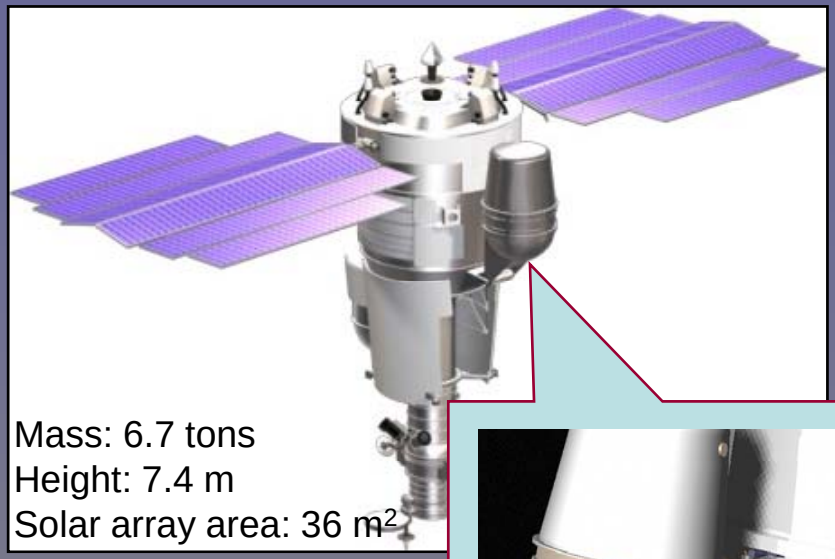
- 1996: PAMELA proposal
- 22.12.1998: agreement between RSA (Russian Space Agency) and INFN to build and launch PAMELA.

  Three models required by the RSA:
  - Mass-Dimensional and Thermal Model (MDTM)
  - Technological Model (TM)
  - Flight Model (FM)

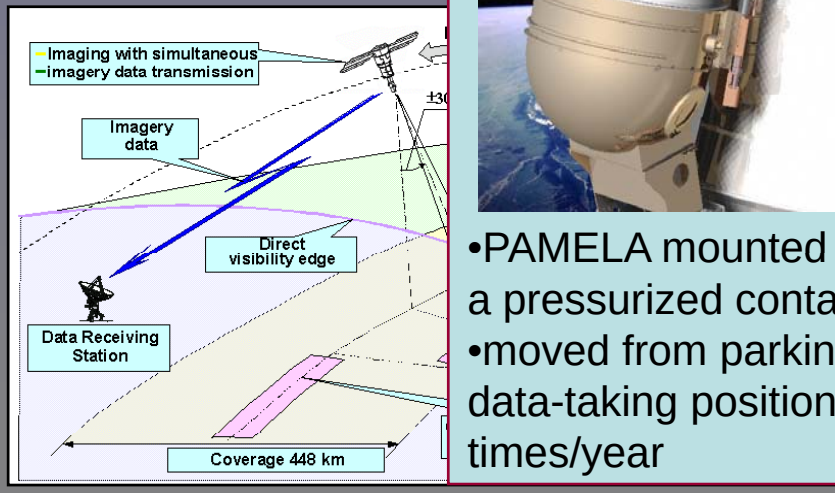
  → ***Starts PAMELA construction***
- 2001: change of the satellite → ***complete redefinition of mechanics***
- 2006: flight!!!

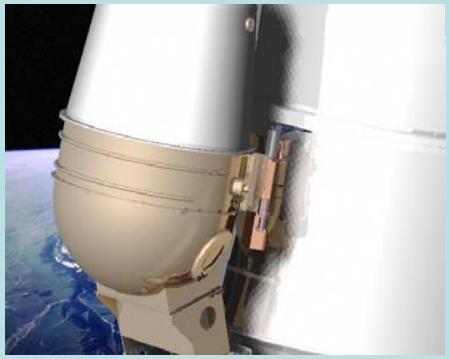
1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007

The Resurs DK-1 spacecraft



Mass: 6.7 tons
Height: 7.4 m
Solar array area: 36 m^2





•PAMELA mounted inside a pressurized container
•moved from parking to data-taking position few times/year

- Multi-spectral remote sensing of earth's surface
  → near-real-time high-quality images
- Built by the Space factory TsSKB Progress in Samara (Russia)

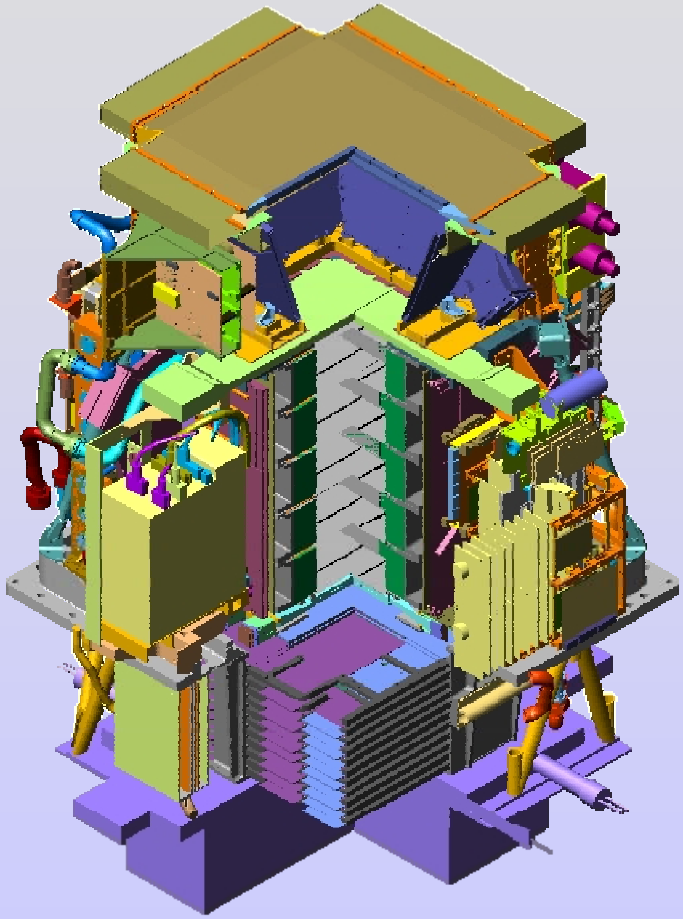
Operational orbit parameters:

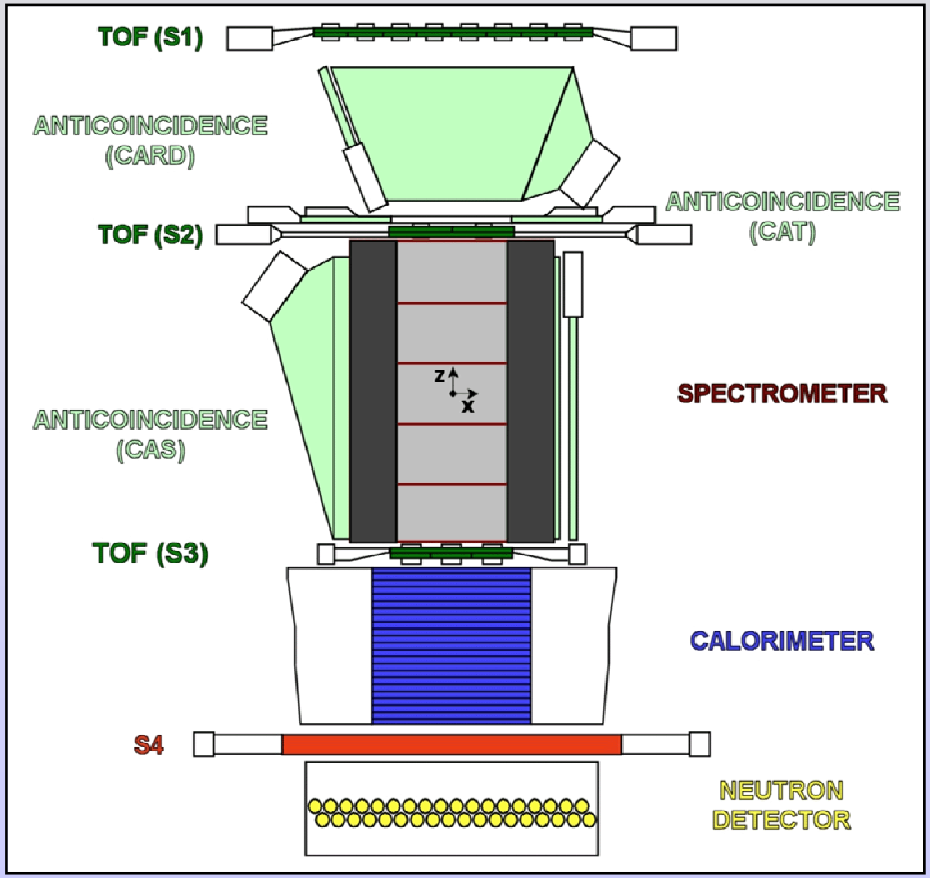
- inclination ~70^o
- altitude ~ 360-600 km (elliptical)

Active life >3 years

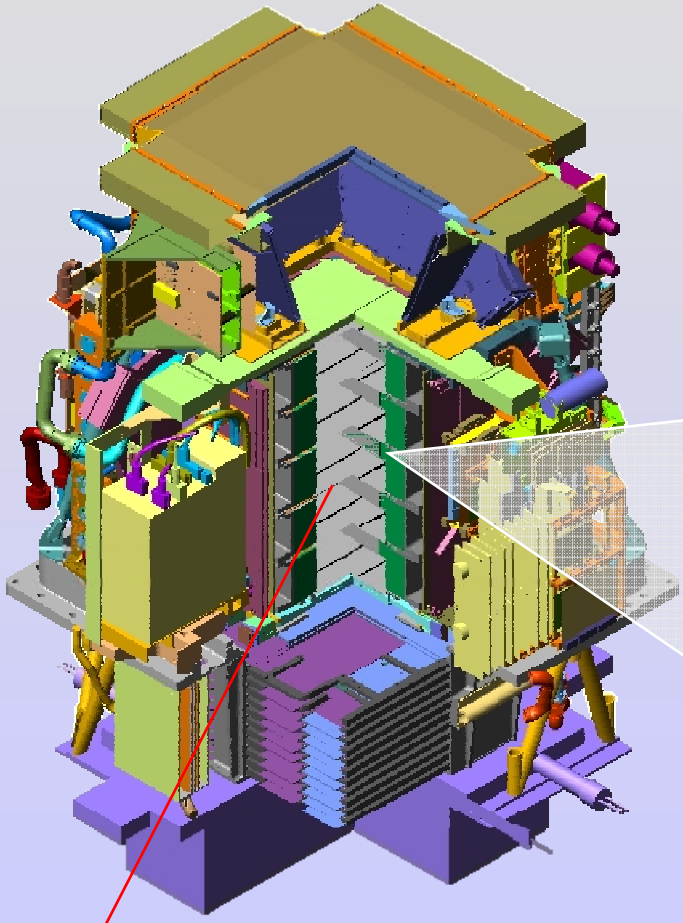
Data transmitted via Very high-speed Radio Link (VRL)

PAMELA apparatus

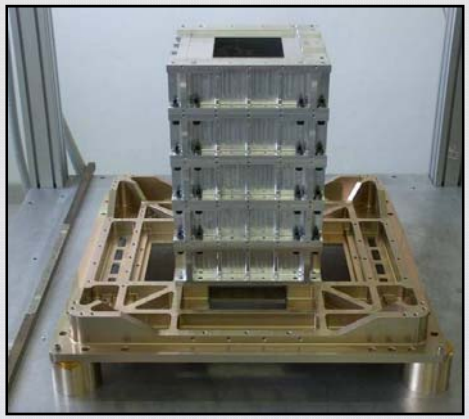


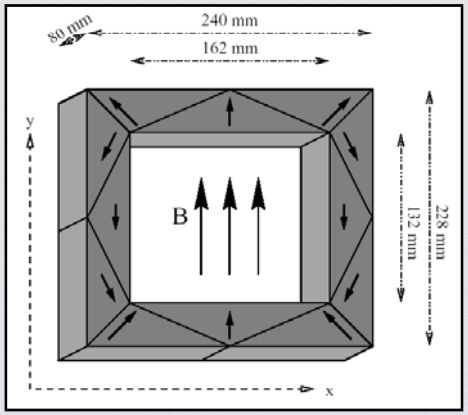


GF: 21.5 cm^2 sr
Mass: 470 kg
Size: 130x70x70 cm^3
Power Budget: 360W



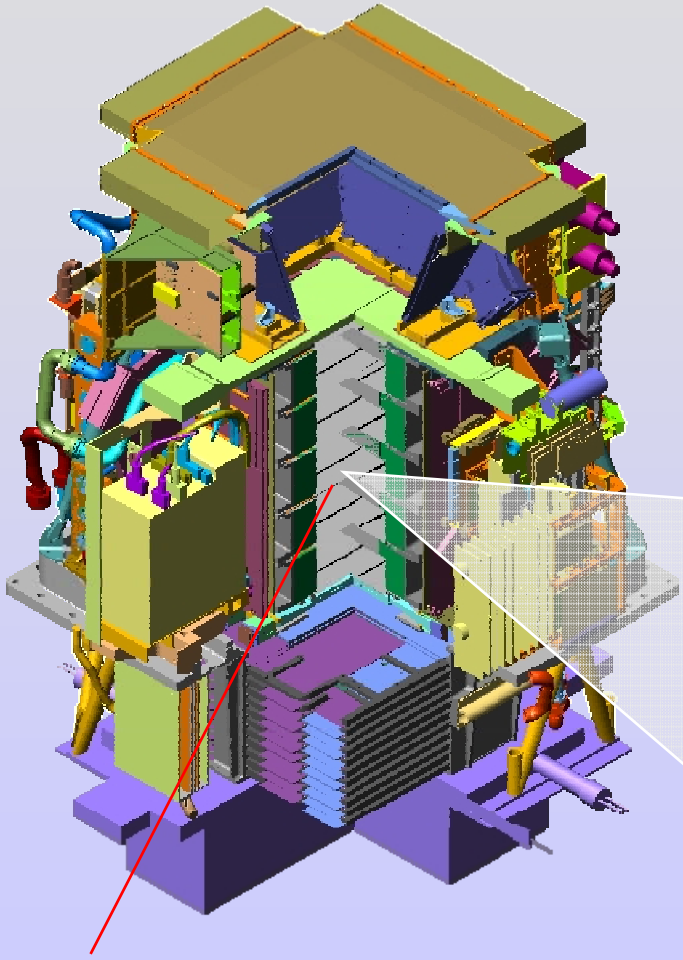
The magnet





Characteristics:

- 5 modules of permanent magnet (Nd-B-Fe alloy) in aluminum mechanics
- Cavity dimensions 162x132x445 cm^3
  → GF 21.5 cm^2sr
- Magnetic shields
- 5mm-step field-map
- B=0.43 T (average along axis), B=0.48 T (@center)



The tracking system

Main tasks:

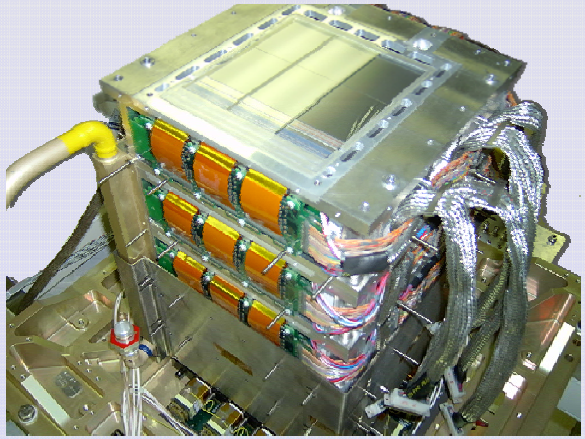
- Rigidity measurement
- Sign of electric charge
- dE/dx

Characteristics:

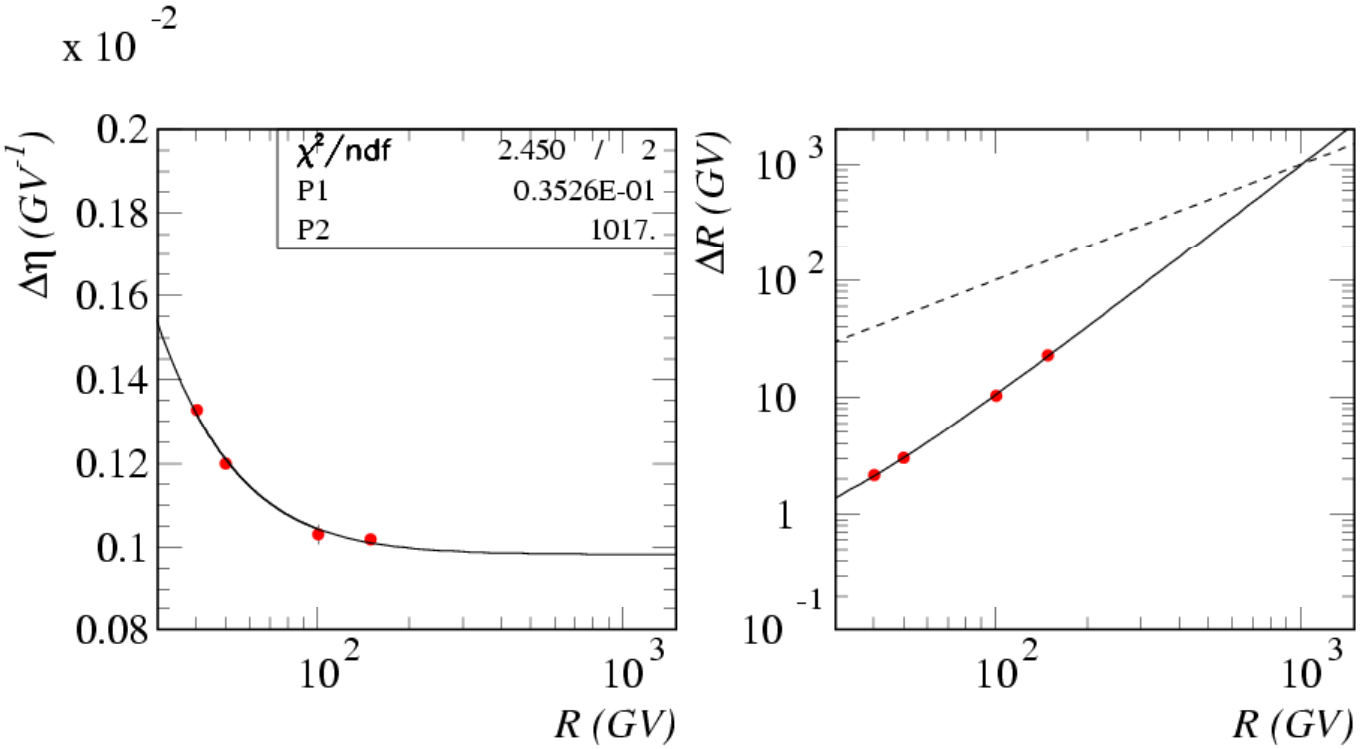
- 6 planes double-side (x&y view) microstrip Si sensors
- 36864 channels
- Dynamic range 10 MIP

Performances:

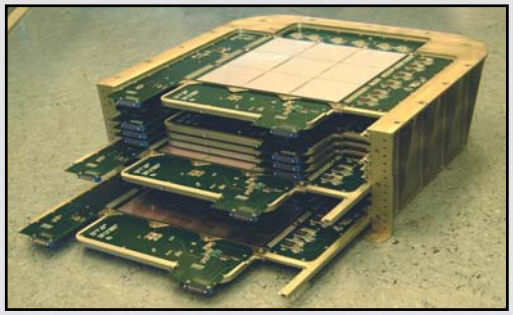
- Spatial resolution: 3-4μm
- MDR ~1T (from test beam data)

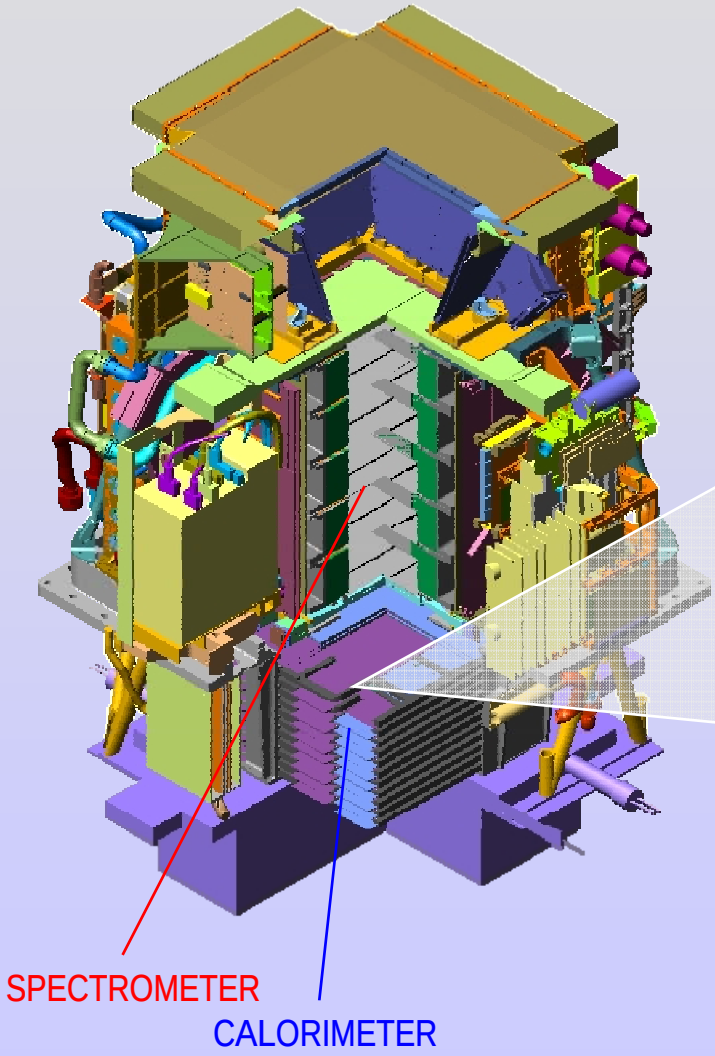


Maximum detectable rigidity



The electromagnetic calorimeter





Main tasks:

- e/h discrimination
- $e^{+/-}$ energy measurement

Characteristics:

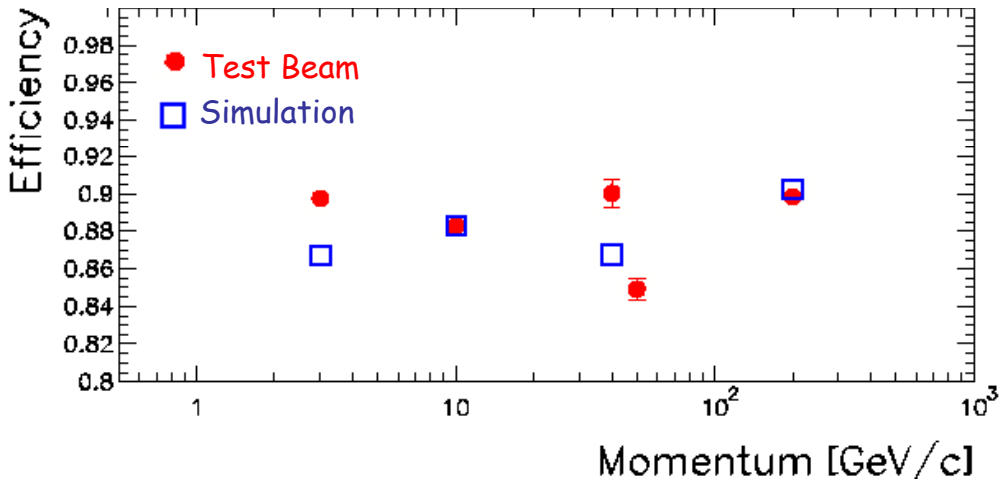
- 44 Si layers (X/Y) +22 W planes
- 16.3 X_o / 0.6 I_0
- 4224 channels
- Dynamic range 1400 mip
- Self-trigger mode (> 300 GeV GF~600 cm^2 sr)

Performances:

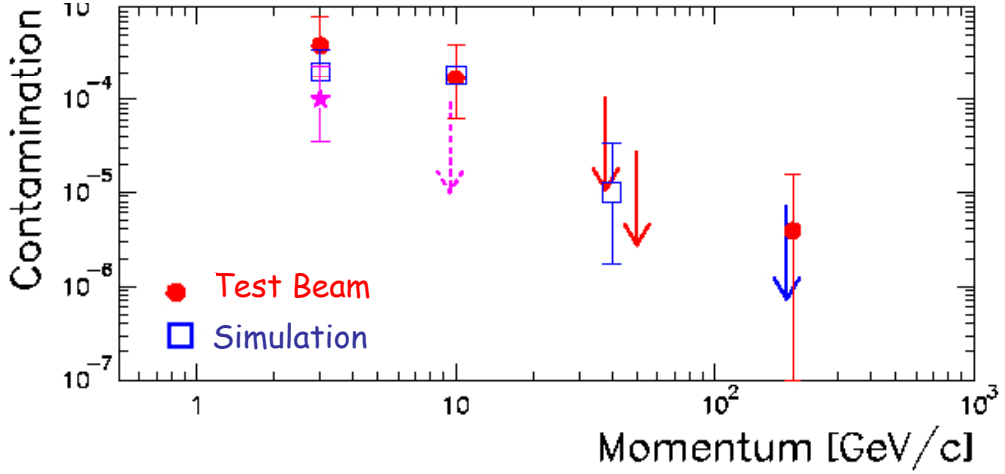
- p-bar and e^+ selection efficienecy ~ 90%
- p rejection factor $>10^5$
- e^- rejection factor > 10^4
- Energy resolution ~5% @200GeV

Electron identification

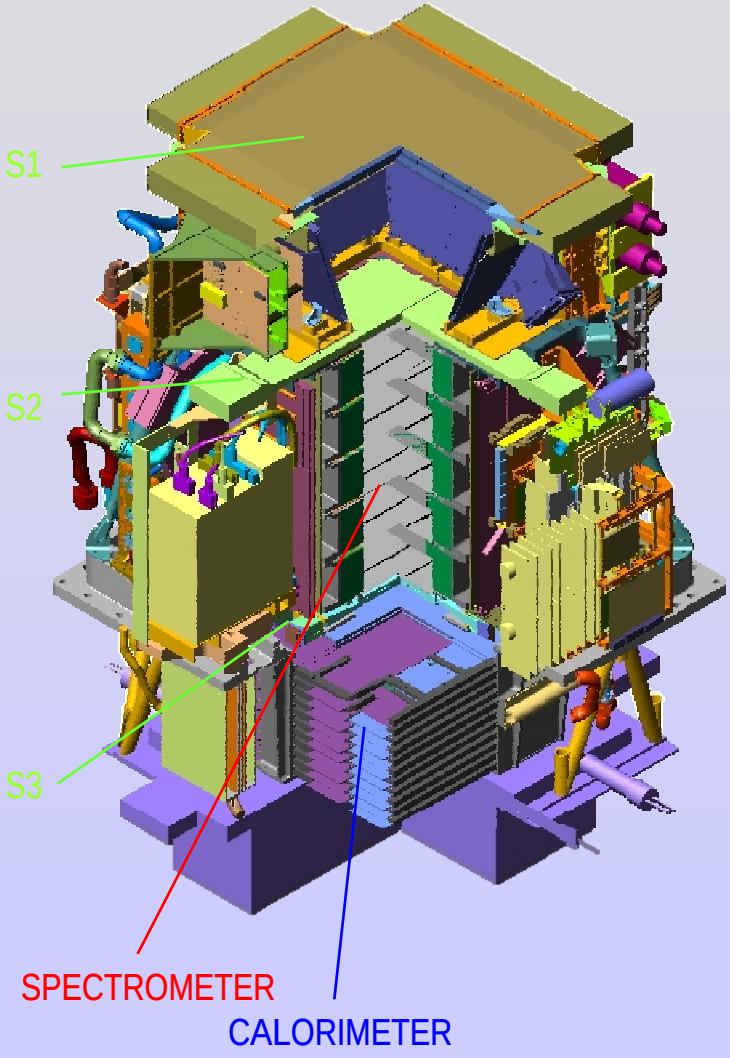
Electron identification efficiency

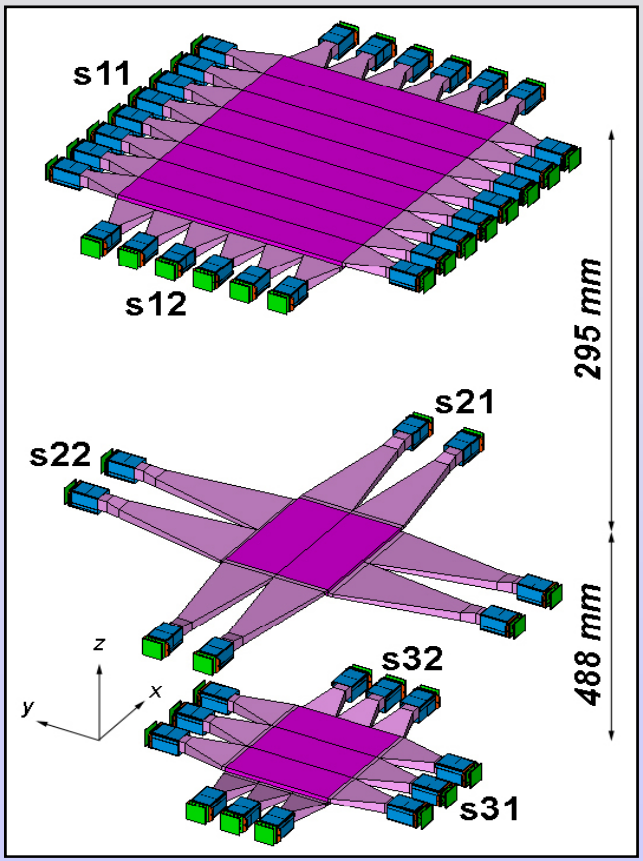


Proton contamination in the electron sample

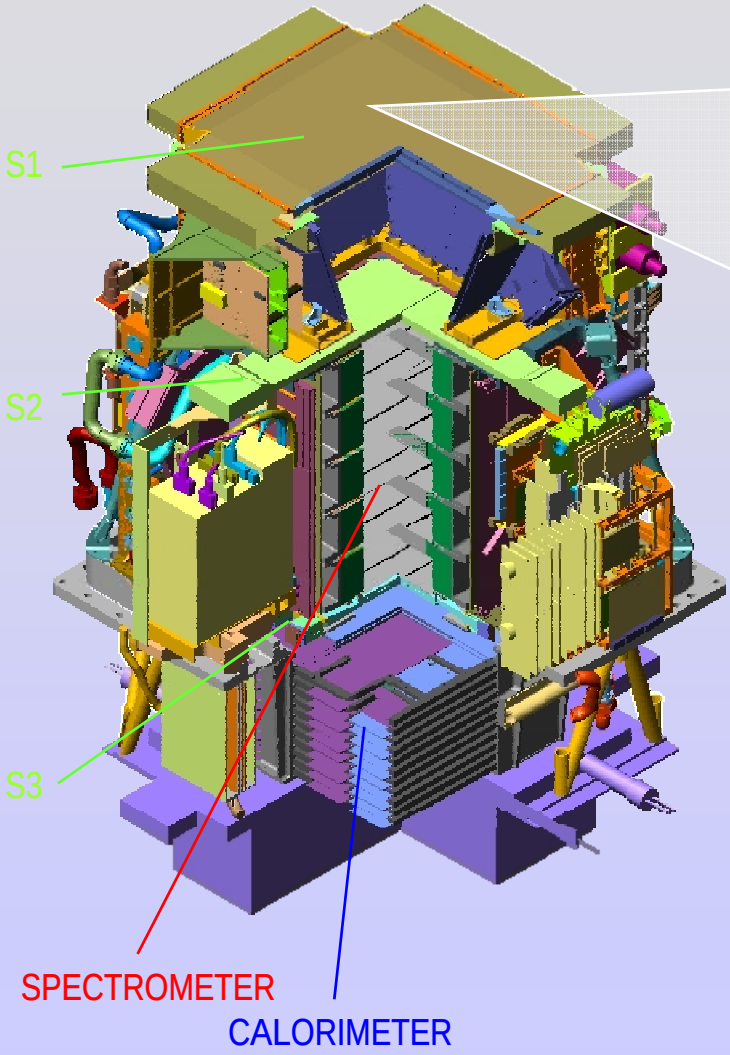


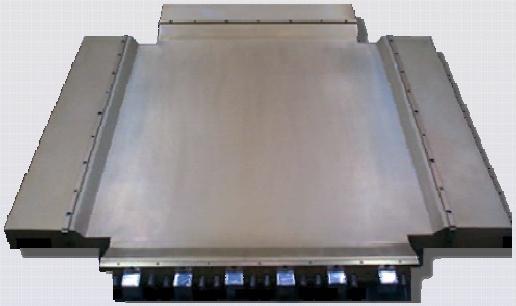
PaMeLa


S1
S2
S3
SPECTROMETER
CALORIMETER


s11
s12
295 mm
s21
s22
z
y
x
s32
s31
488 mm

The time-of-flight system



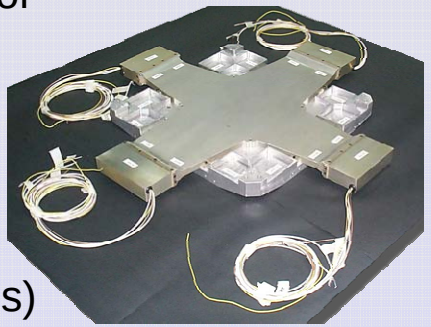


Main tasks:

- First-level trigger
- Albedo rejection
- dE/dx
- Particle identification (<1GeV/c)

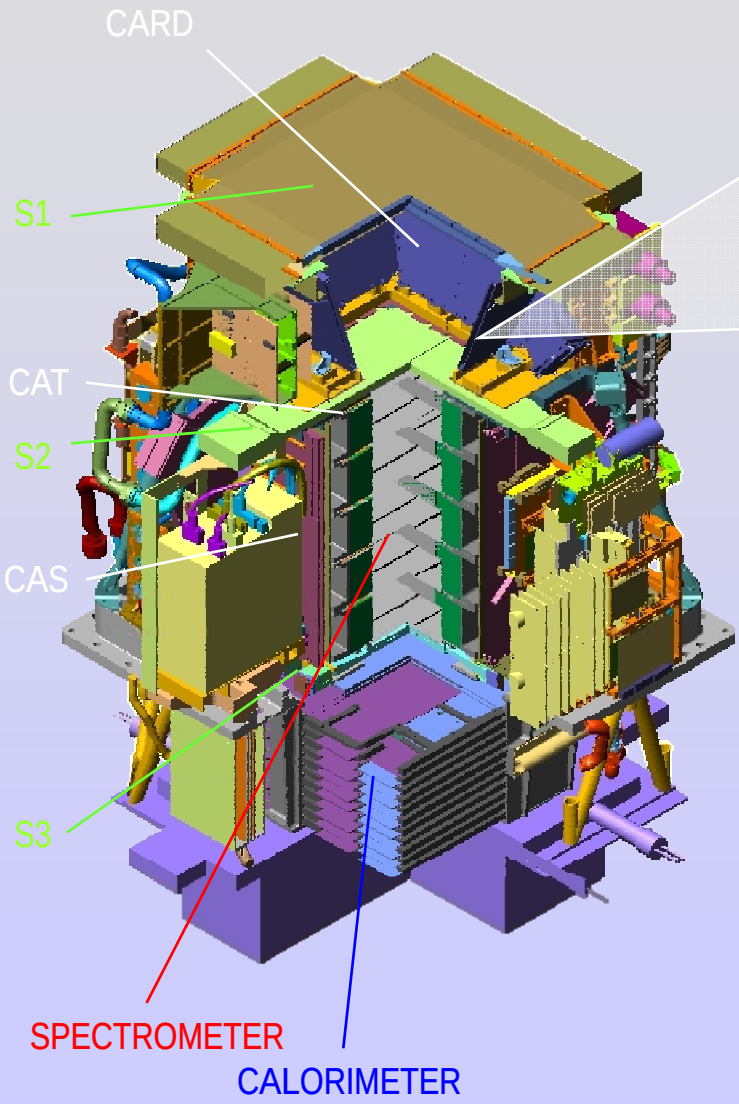
Characteristics:

- 3 double-layer scintillator paddles
- X/Y segmentation
- Total: 48 Channels



Performances:

- σpaddle ~ 110ps
- σTOF ~ 330ps (for MIPs)



The anticounter shields

Main tasks:

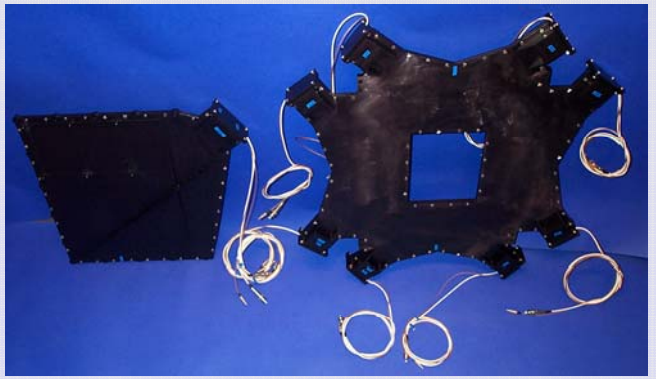
- Rejection of events with particles interacting with the apparatus (off-line and second-level trigger)

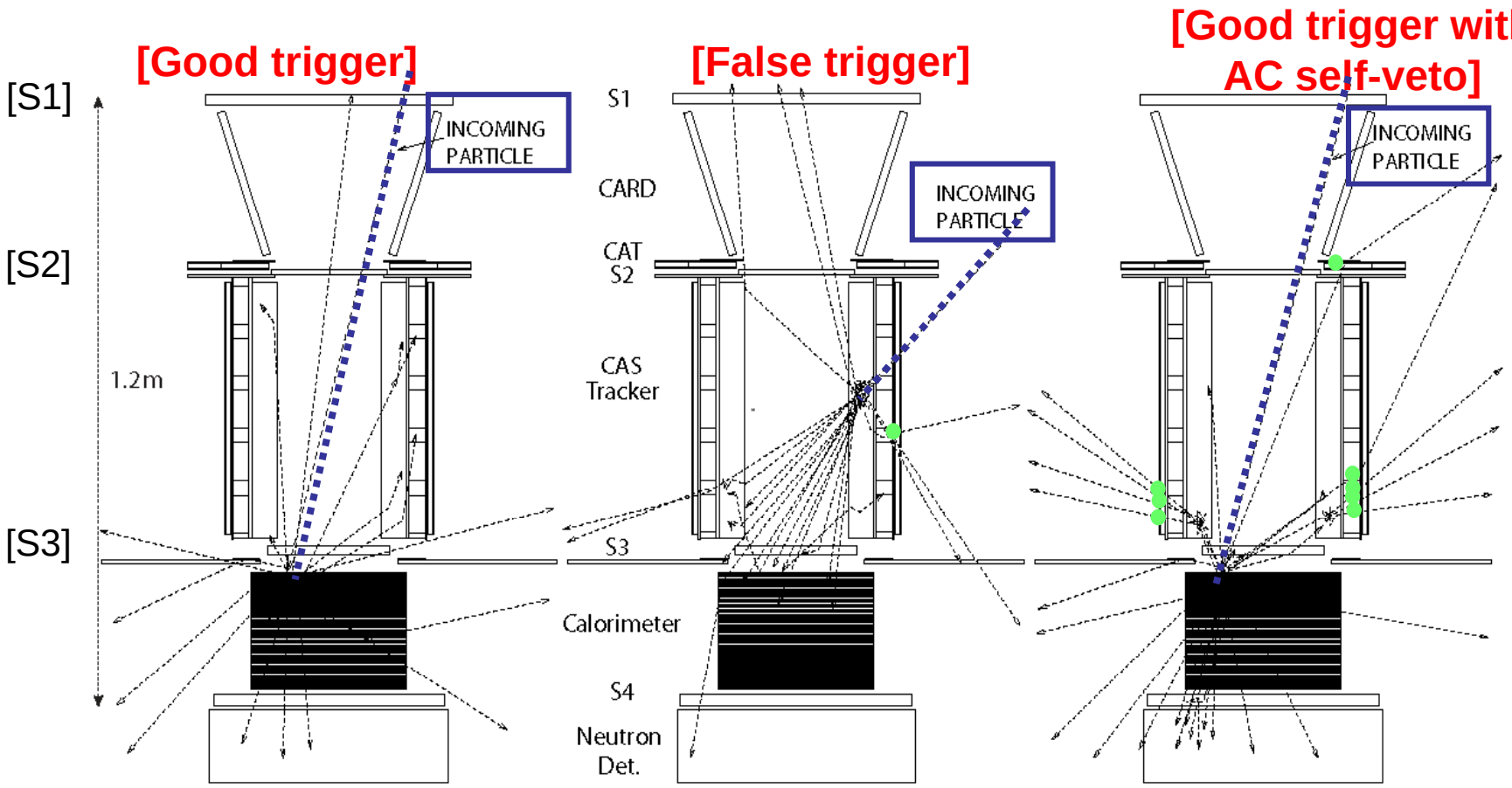
Characteristics:

- scintillator paddles 10mm thick
- 4 up (CARD), 1 top (CAT), 4 side (CAS)

Performances:

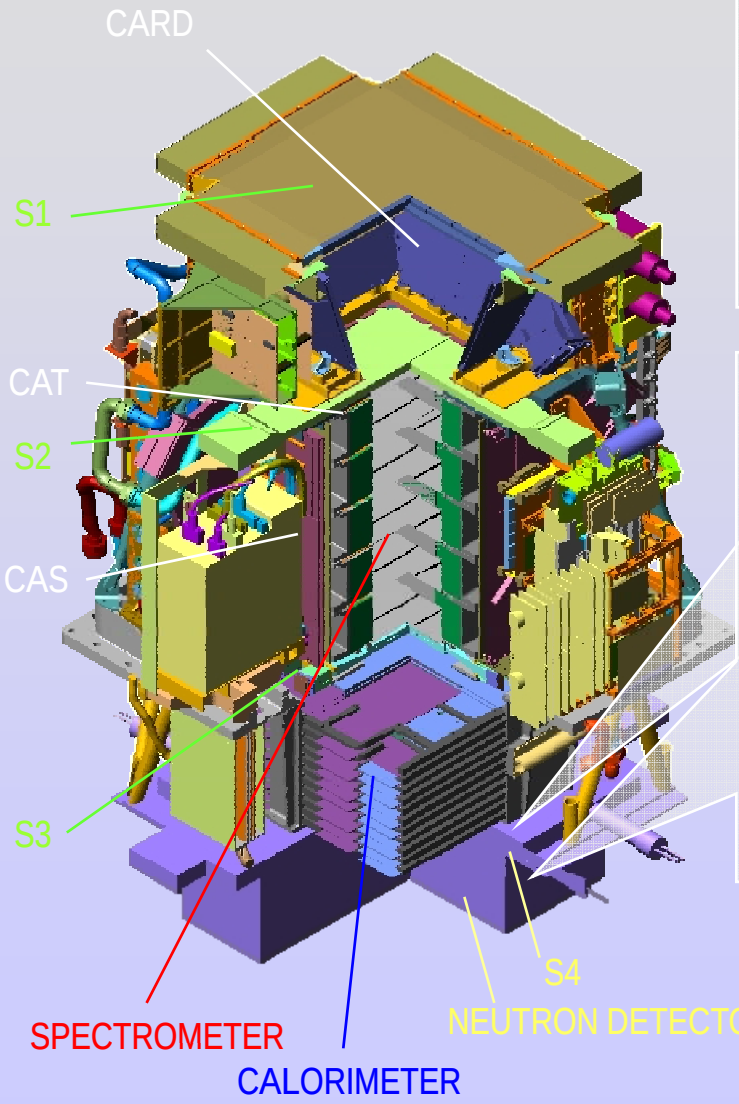
- Efficiency > 99.9%





Main trigger = S1 AND S2 AND S3

Use AC offline or in L2 trigger to reduce false triggers



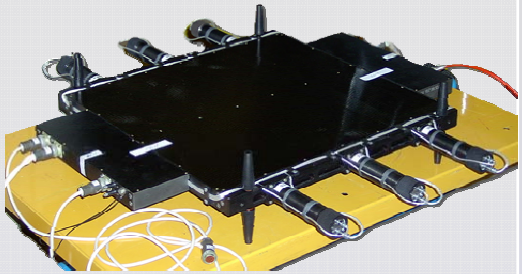
Shower-tail catcher (S4)

Main tasks:

- ND trigger

Characteristics:

- 1 scintillator paddle 10mm thick



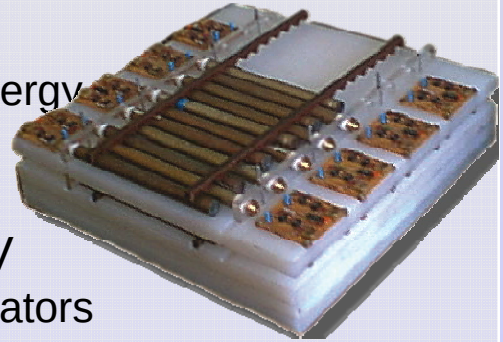
Neutron detector

Main tasks:

- e/h discrimination @high-energy

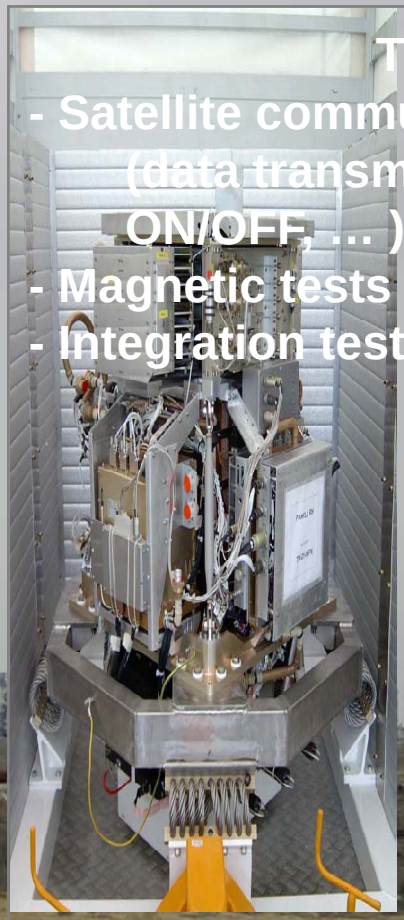
Characteristics:

- 36 ^{3}He counters: ^{3}He(n,p)T → Ep=780 keV
- 1cm thick polyetilene moderators
- n collected within 200 μs time-window



MDTM
- Vibration/shock/transport tests
- Thermal tests

TM
- Satellite communication tests (data transmission, power ON/OFF, …)
- Magnetic tests
- Integration tests



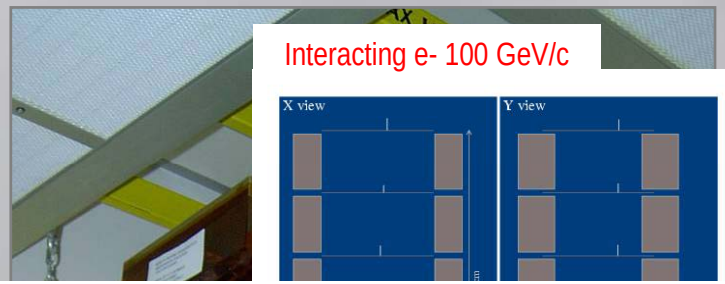
MDTM & TM

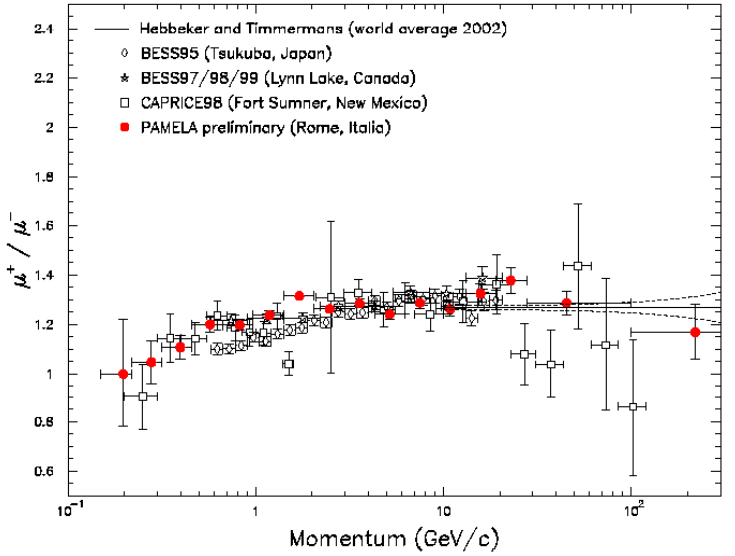
1998 1999 2000 2001 2002 2003 2004 2005 2006 2007

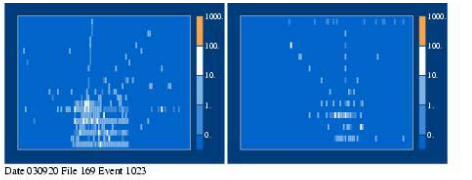
PaMeLa

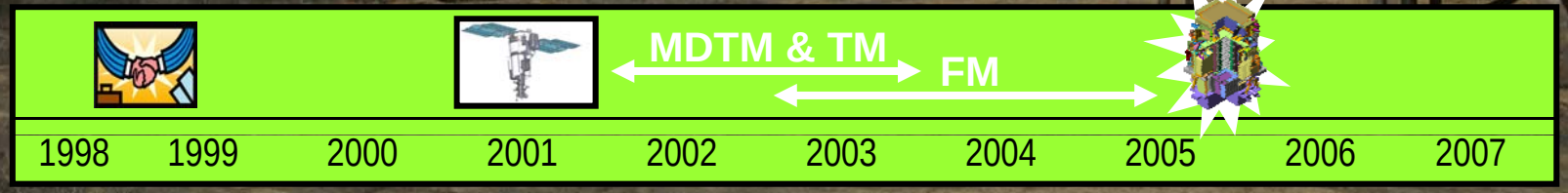
FM

- End 2002: start FM integration!
- Bean tests:
  - **Jun 2002 @ SPS**
    Test of preliminary setup with
    p (200-300GeV) e (40-300GeV)
  - **Sep 2003 @ SPS**
    Test with p (50-150GeV)
- Jan 2005 @ IABG
  - Full vibration/shock test at minimal load
- Feb-Mar 2005 @ INFN Rome
  - **Test with atmospheric cosmic rays**
- Apr 2005 →shipping to TsSKB-Progress Factory



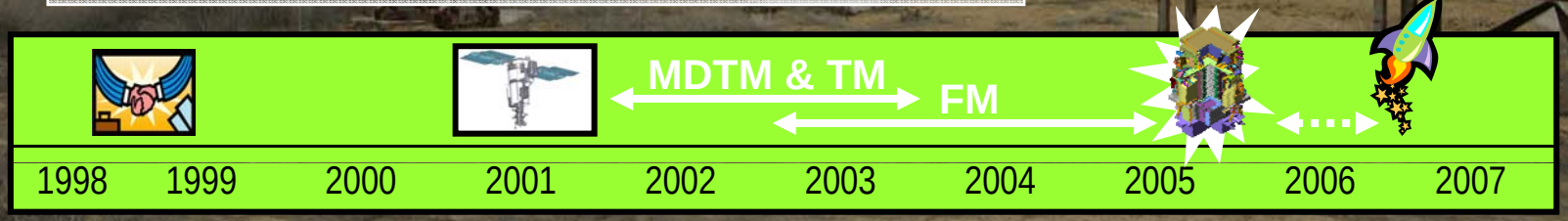






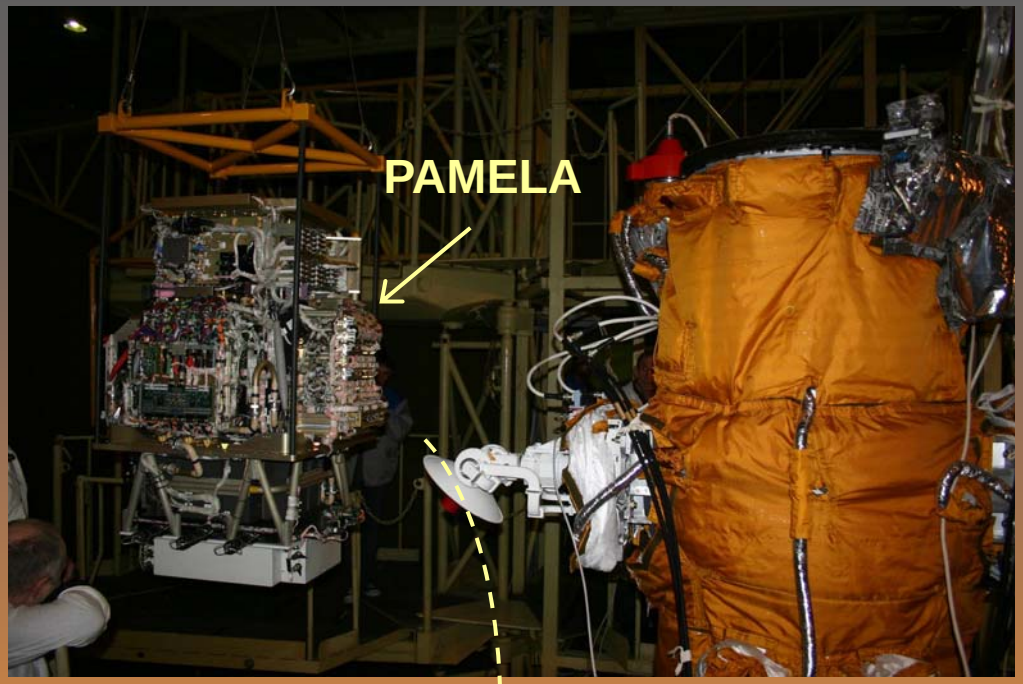
Launch preparation

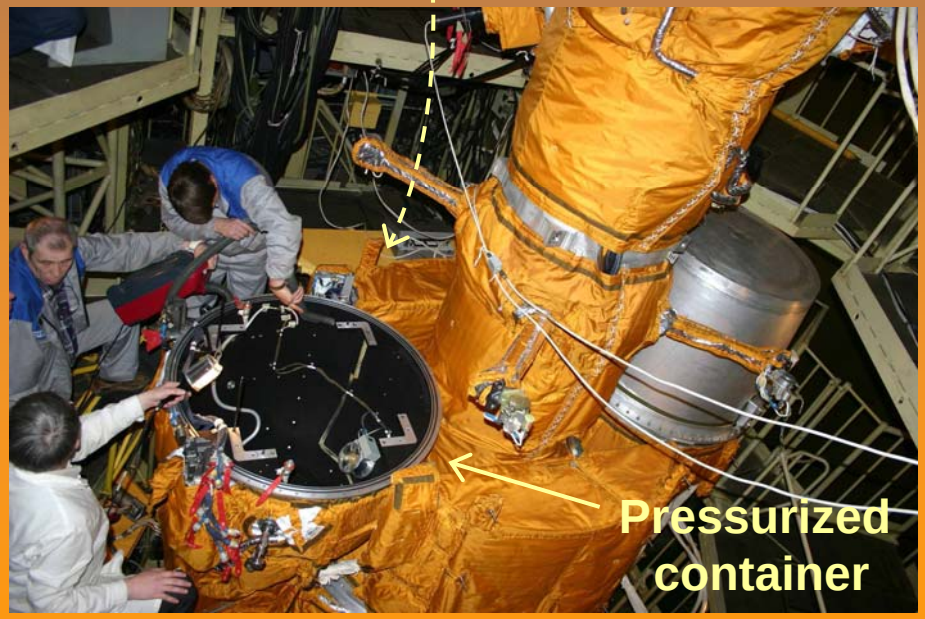
- May 2005 – March 2006 @TsSKB-Progress Factory
  - Full qualification tests
    - Mechanical interfaces
    - Cooling loop
    - Power supply tests
    - Interface with VRL
    - Electrical tests
- March 2006 @ Baykonur
  - 60 days work before launch
    - Standalone tests
    - Insertion into pressurized container
    - Electrical tests with satellite
    - Test of the downlink

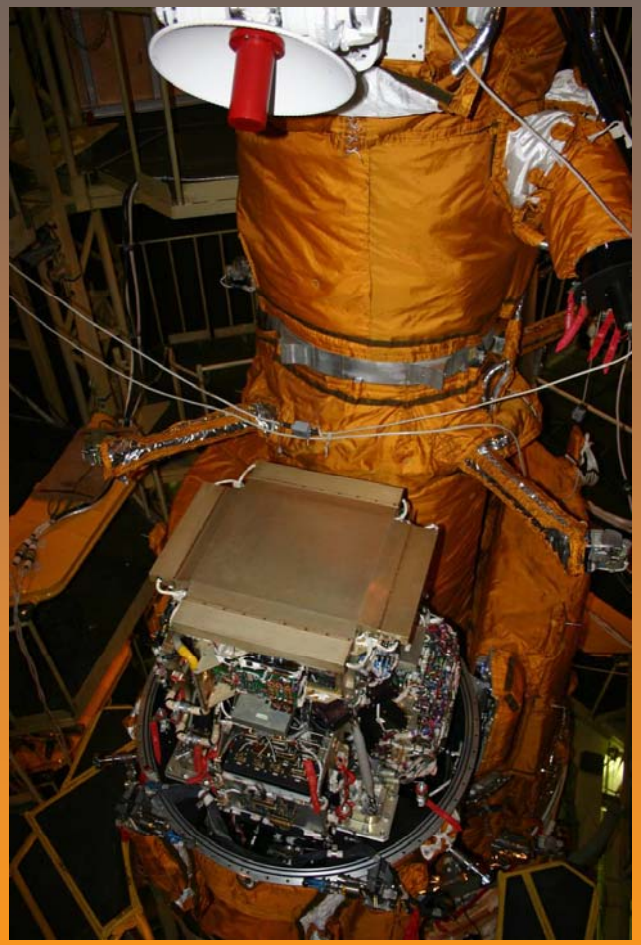


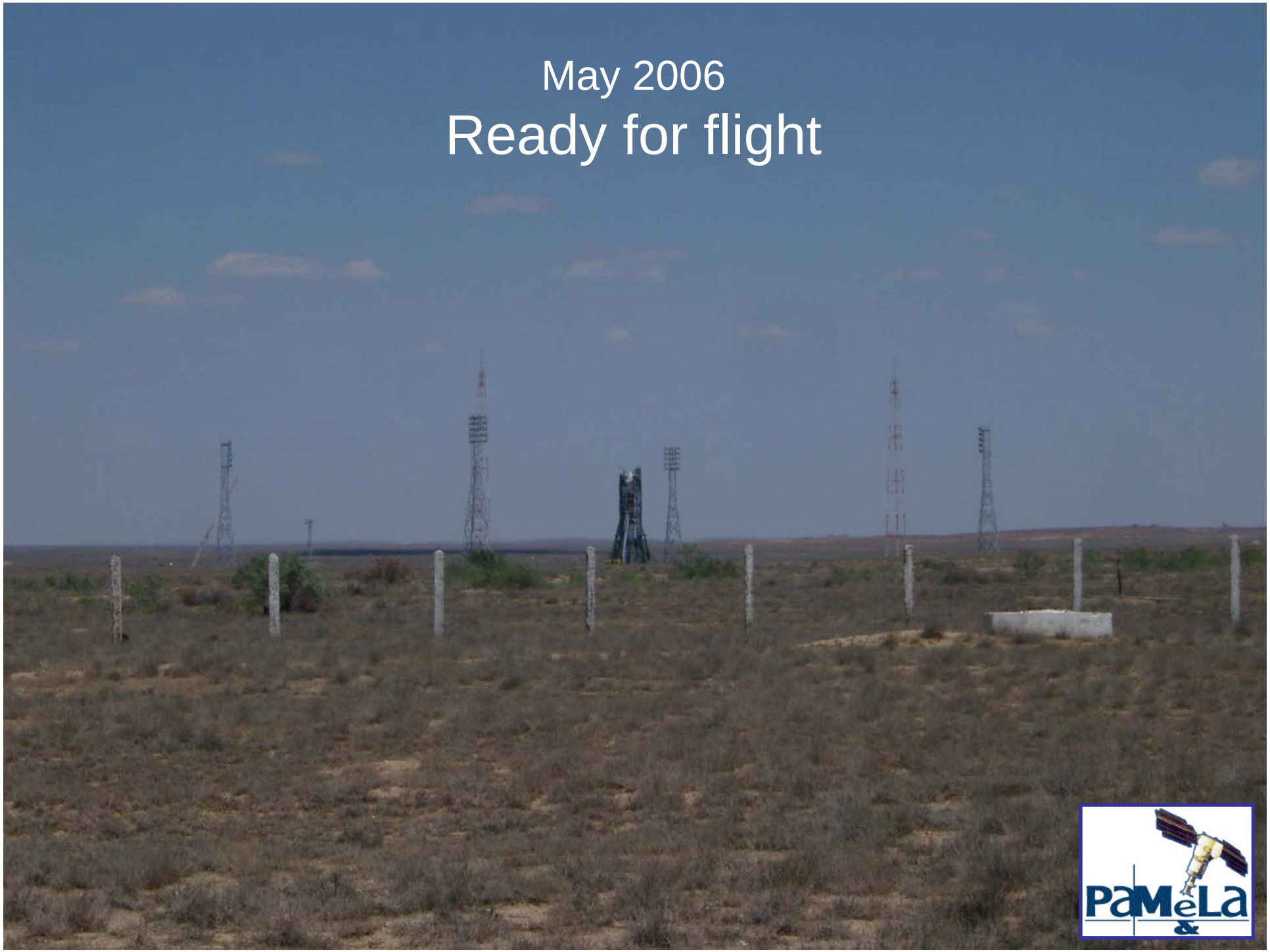
PaMeLa

March 2006 @Baykonur
Integration with satellite








May 2006
Ready for flight
PaMeLa

The Launch: 15th June 2006

PAMELA status

First switch-on on June 21st 2006

- Detectors in nominal conditions (no problems due to the launch)
- Tested different trigger and hardware configurations
- Commissioning phase successfully ended on September 15th 2006

→ PAMELA in continuous data-taking mode

At April 30th 2007:

- PAMELA ON for **291 days**
- 34251 acquisition runs
- 4.7 TB of raw data
- **~570 millions of triggers recorded**
- 23341009 s (~ **270 days**) of total acquisition time

Data acquisition

- Trigger configurations

  High-radiation environment

  → (S21 AND S22) AND (S31 AND S32) OR CALORIMETER

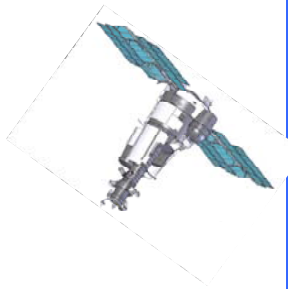
  Low-radiation environment

  → (S11 OR S12) AND (S21 OR S22) AND (S31 OR S32) OR CALORIMETER
- Trigger rate* **~25Hz**
- Fraction of live time* ~ 75%
- Event size (compressed mode) ~ 5kB

  → 25 Hz x 5 kB/ev ~ 10 GB/day

(*outside radiation belts)

Data transmission



- Collected data stored in PAMELA mass-memory (2GB)
- Download (PAMELA → satellite)
  7-8 per day → 14-16 GB
- Downlink (satellite→ ground)
  2-3 sessions per day
- Error rate $<10^{-9}$

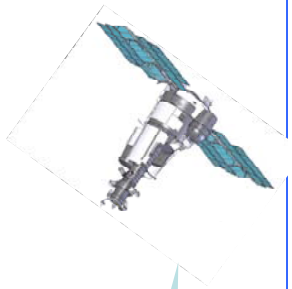
Main downlink station:

Research Centre for Earth operative monitoring“NtsOMZ” (Moscow, Russia)

Spare downlink station:

Khanty-Mansiysk West Siberia

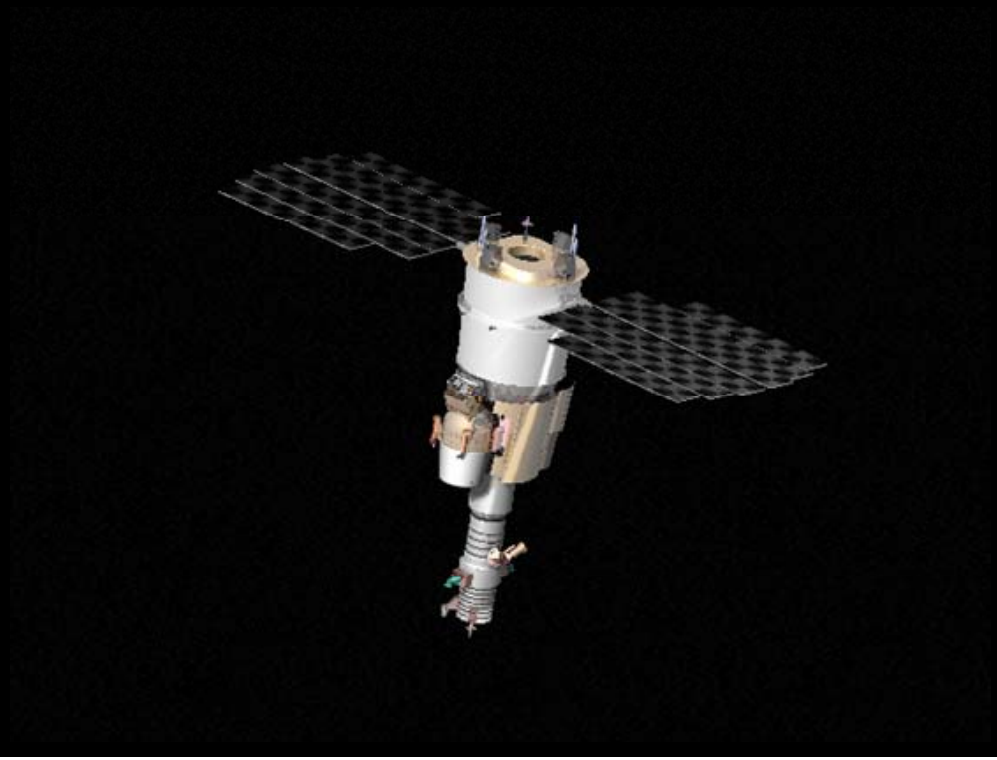
Remote control



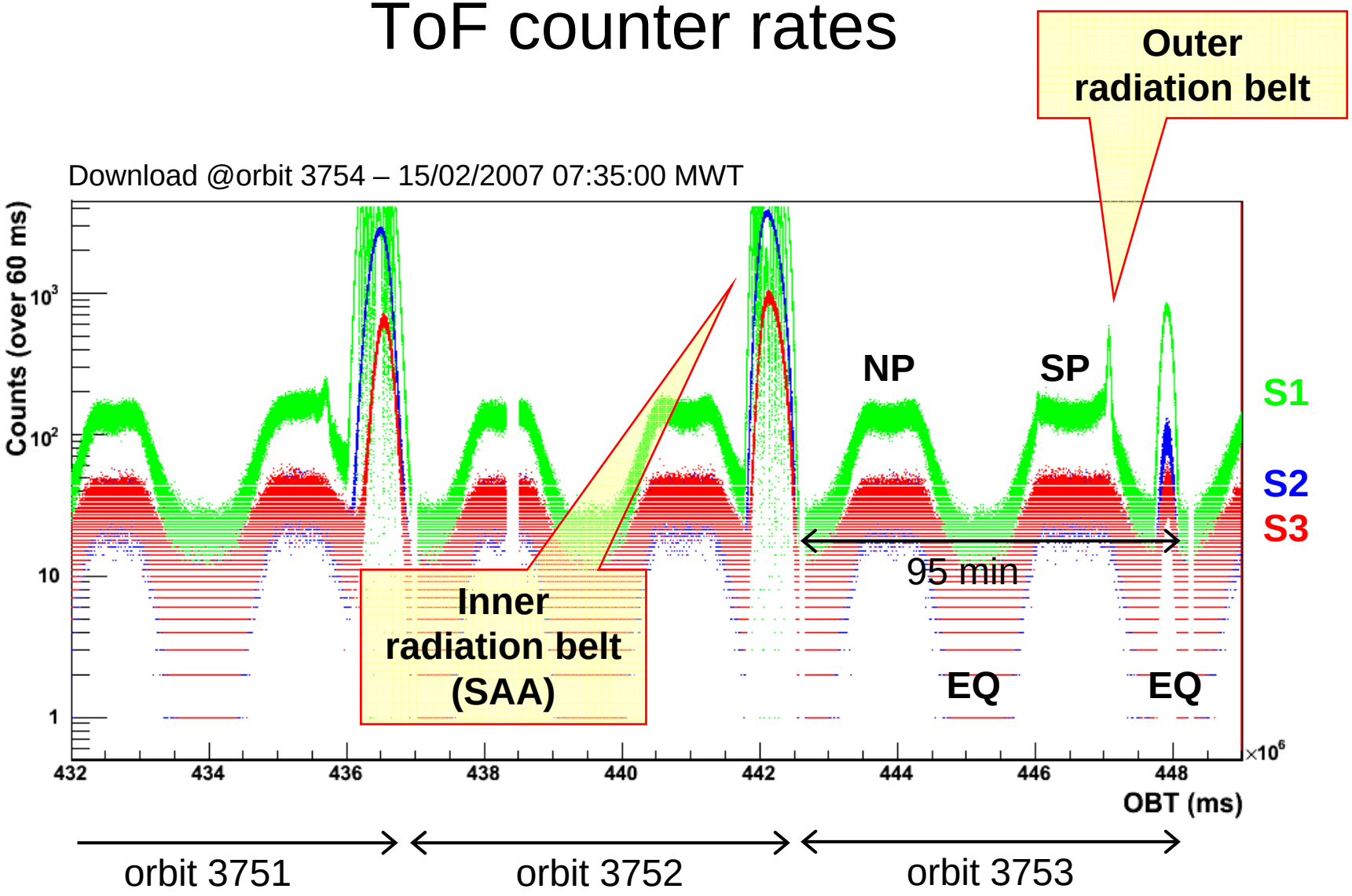
- Macrocommands: commands to PAMELA cpu
  - System configuration (hundreds of modifiable parameters):
  - Calibration (ascending node)
  - Download to satellite mass memory
  - …
- Telecommands: hardware lines to handle power modules

→ Extremely flexible system, designed to be easily adapted to space (unknown) conditions.

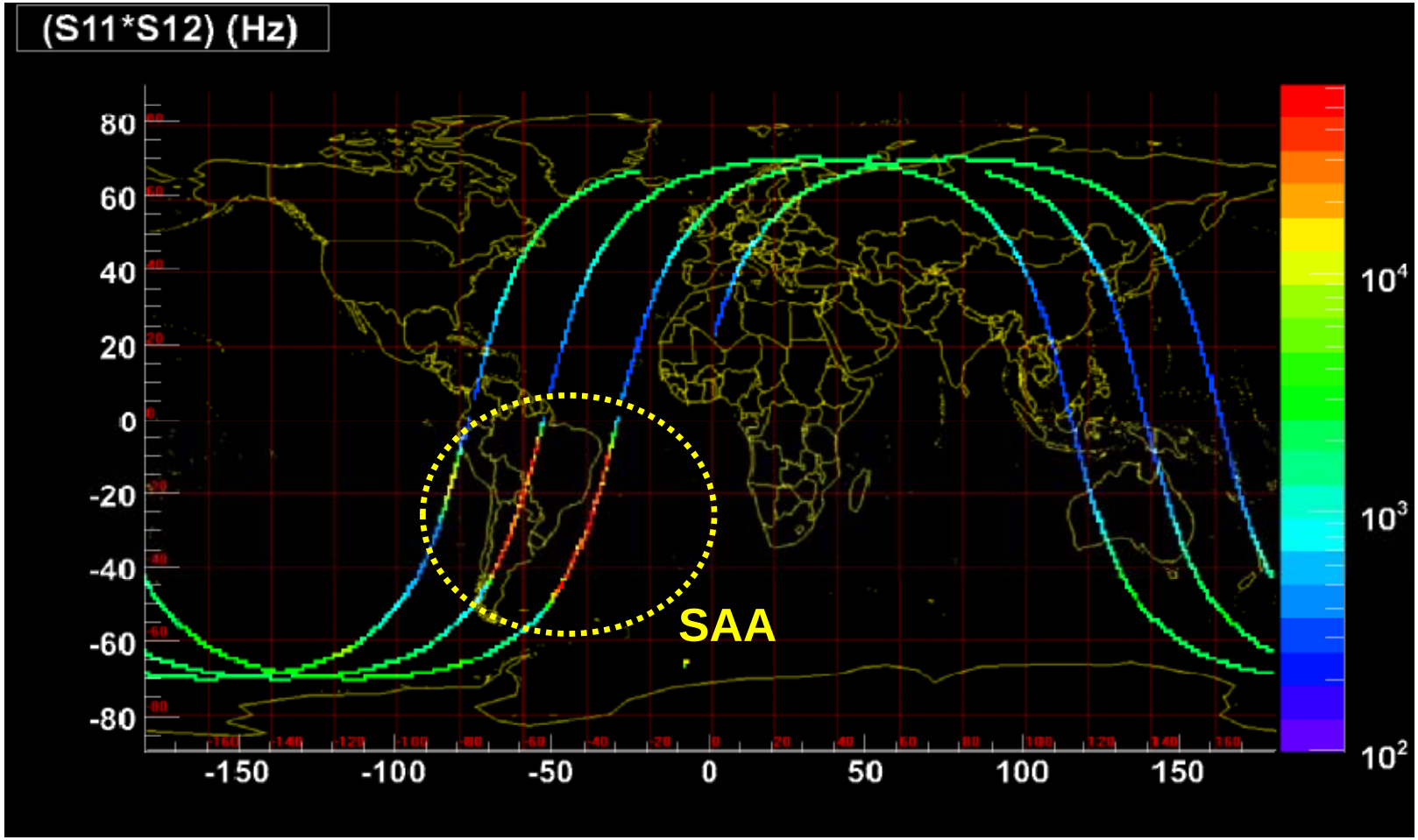
Orbital environment

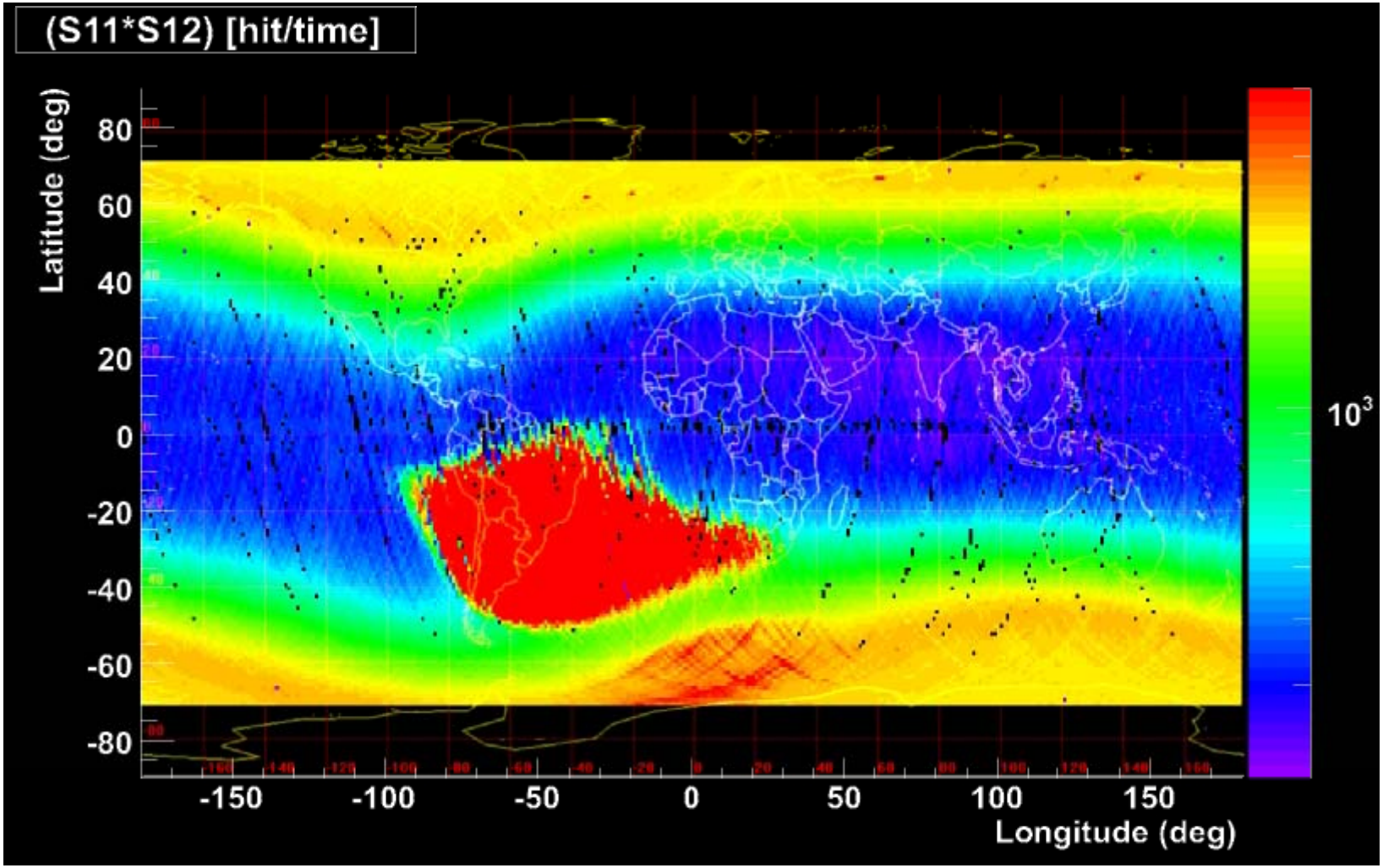


ToF counter rates

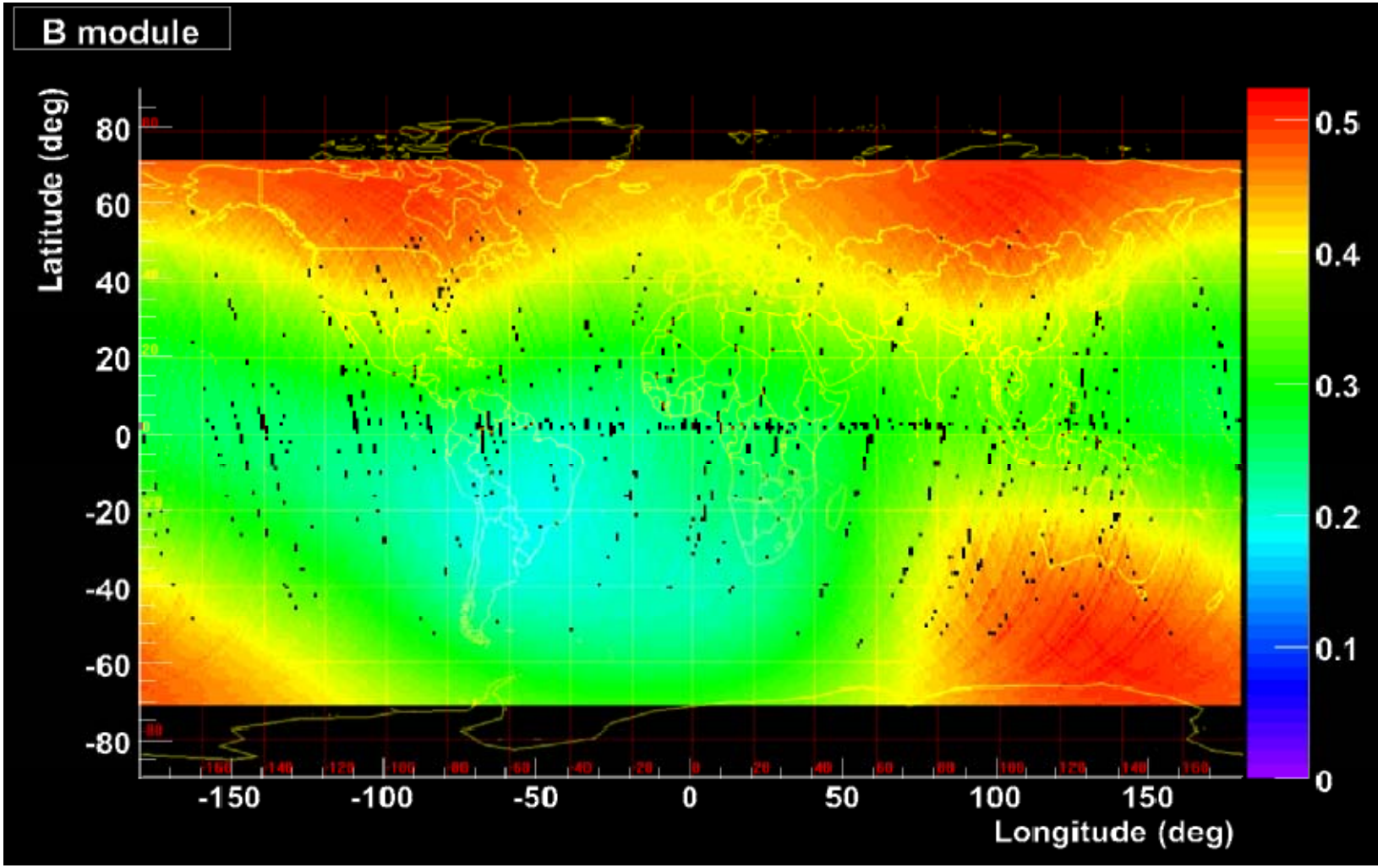


Download @orbit 3754 – 15/02/2007 07:35:00 MWT

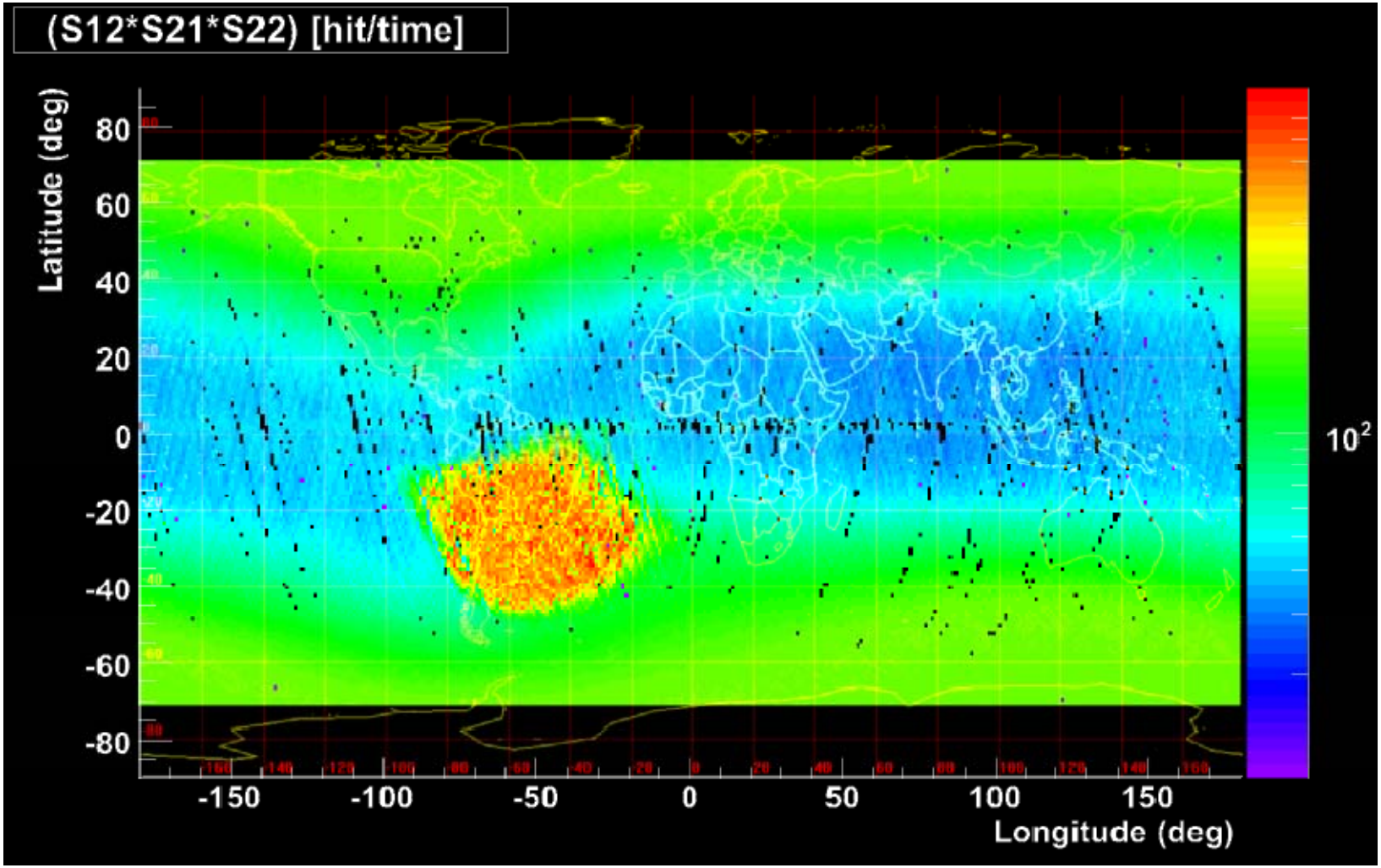


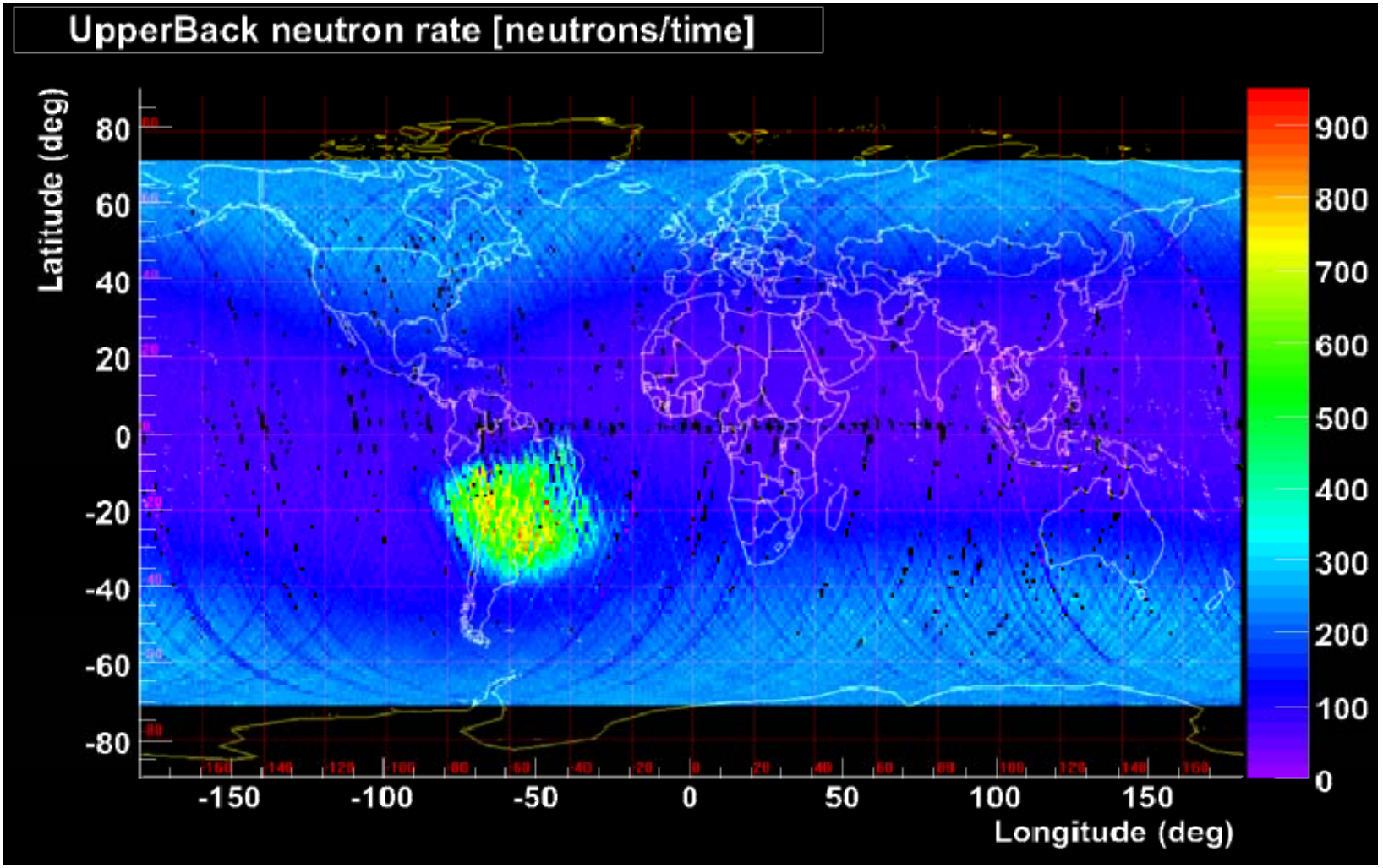

(S11*S12) [hit/time]
Latitude (deg)
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
Longitude (deg)
10^3

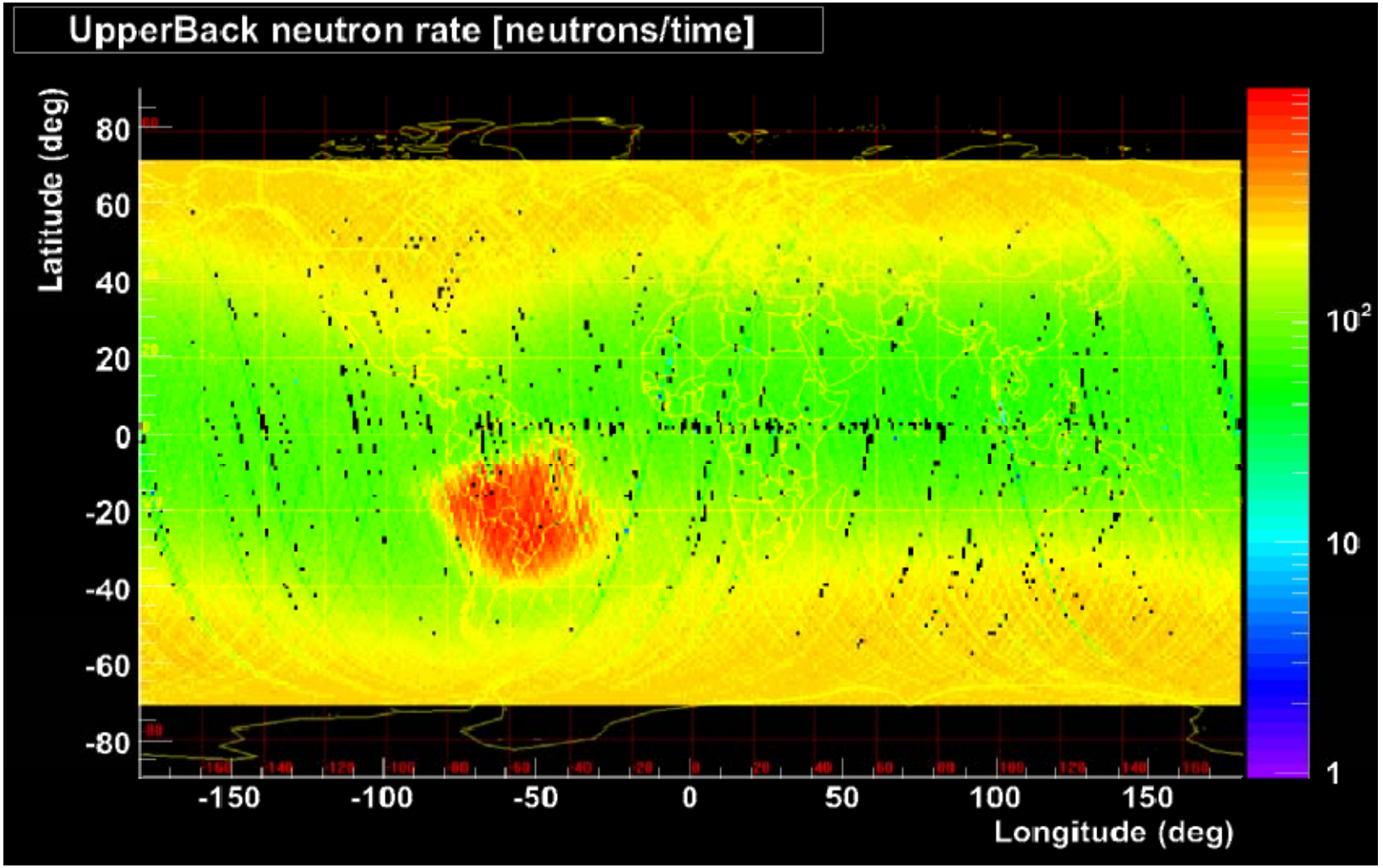
Magnetic Field (IGRF)



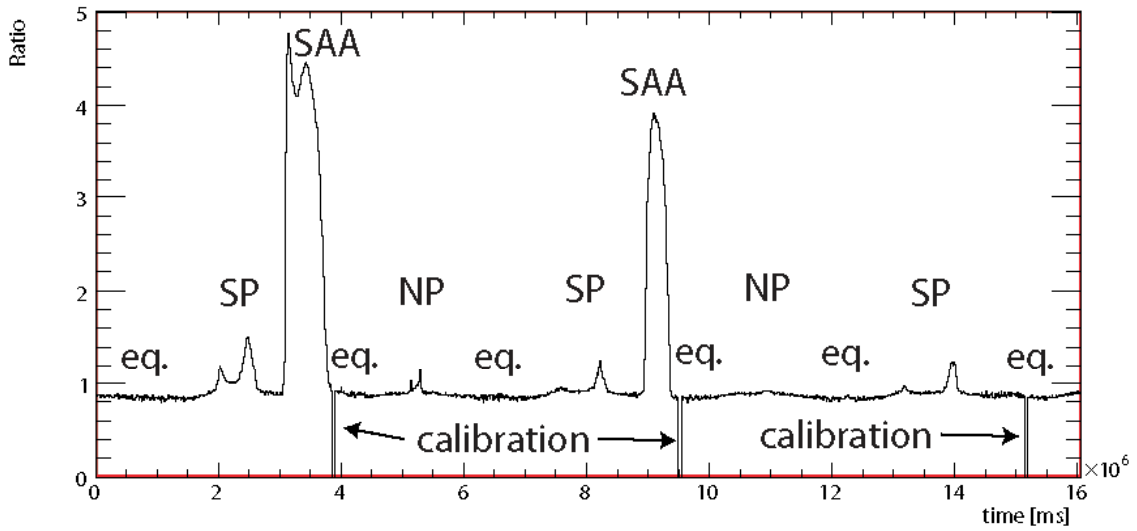
(→ see poster session)


(S12*S21*S22) [hit/time]
Latitude (deg)
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
Longitude (deg)
10^2

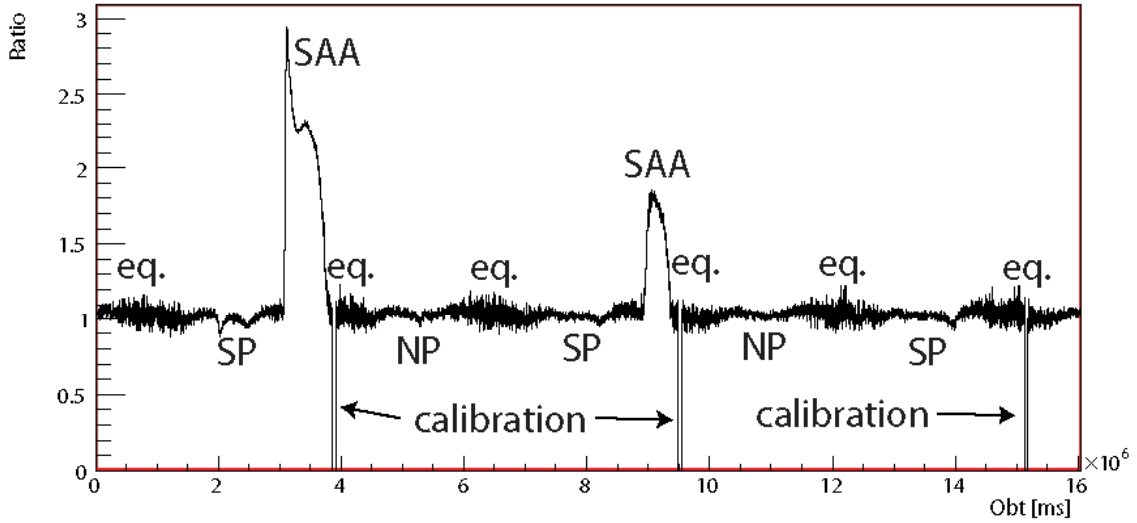

UpperBack neutron rate [neutrons/time]
Latitude (deg)
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
Longitude (deg)
900
800
700
600
500
400
300
200
100
0


UpperBack neutron rate [neutrons/time]
Latitude (deg)
80
60
40
20
0
-20
-40
-60
-80
-150
-100
-50
0
50
100
150
Longitude (deg)
10^2
10
1

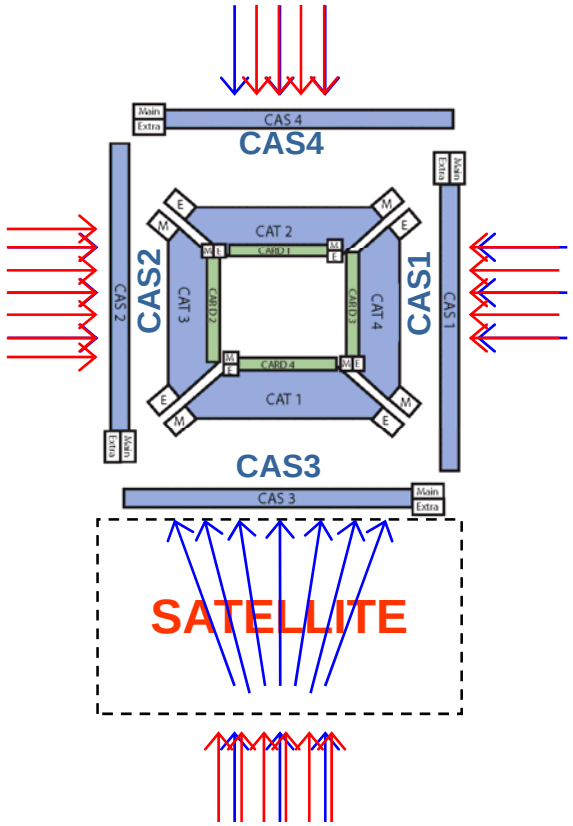
Ratio singles rates CAS4/CAS3



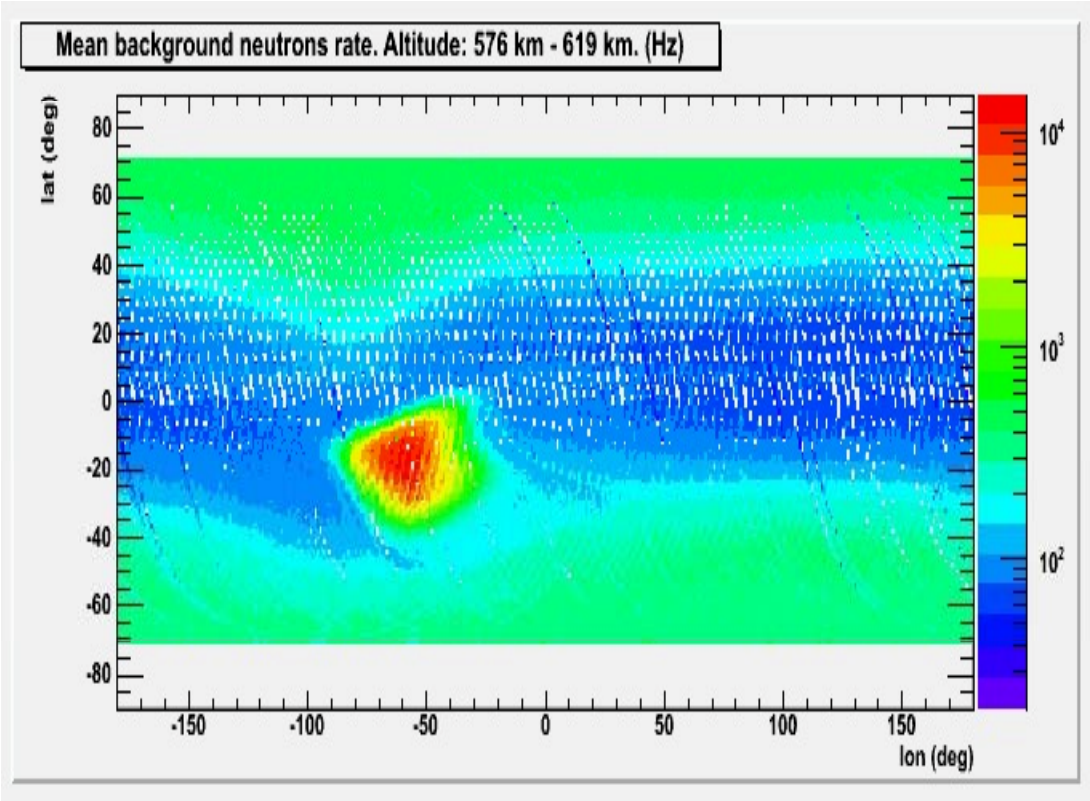
Ratio singles rates CAS2/CAS1

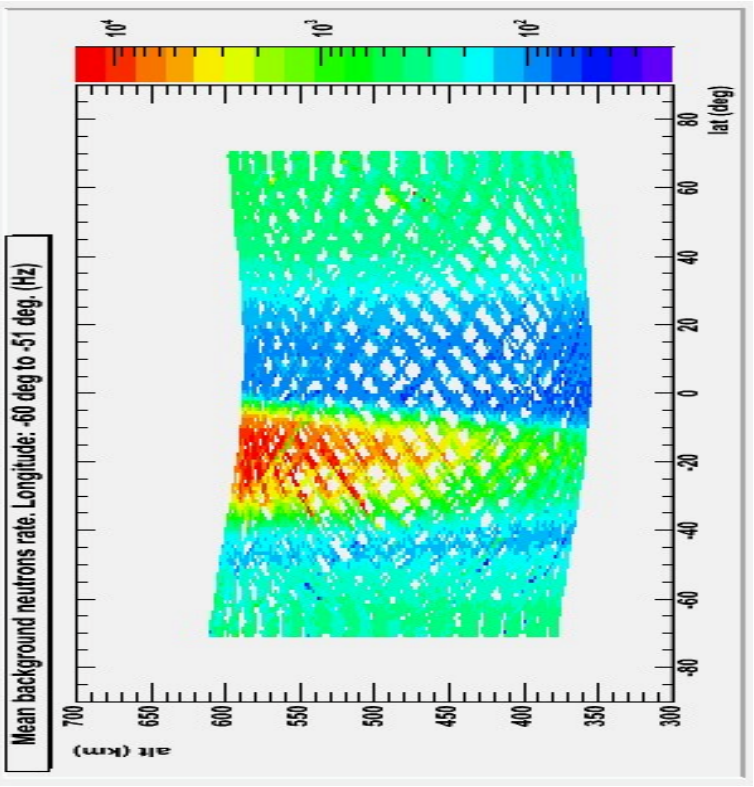


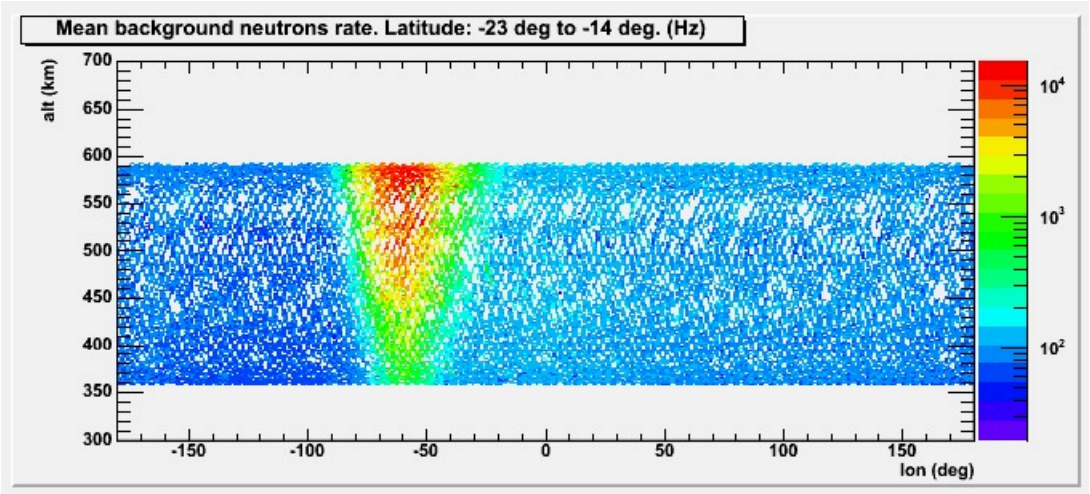
Outside the Radiation belts



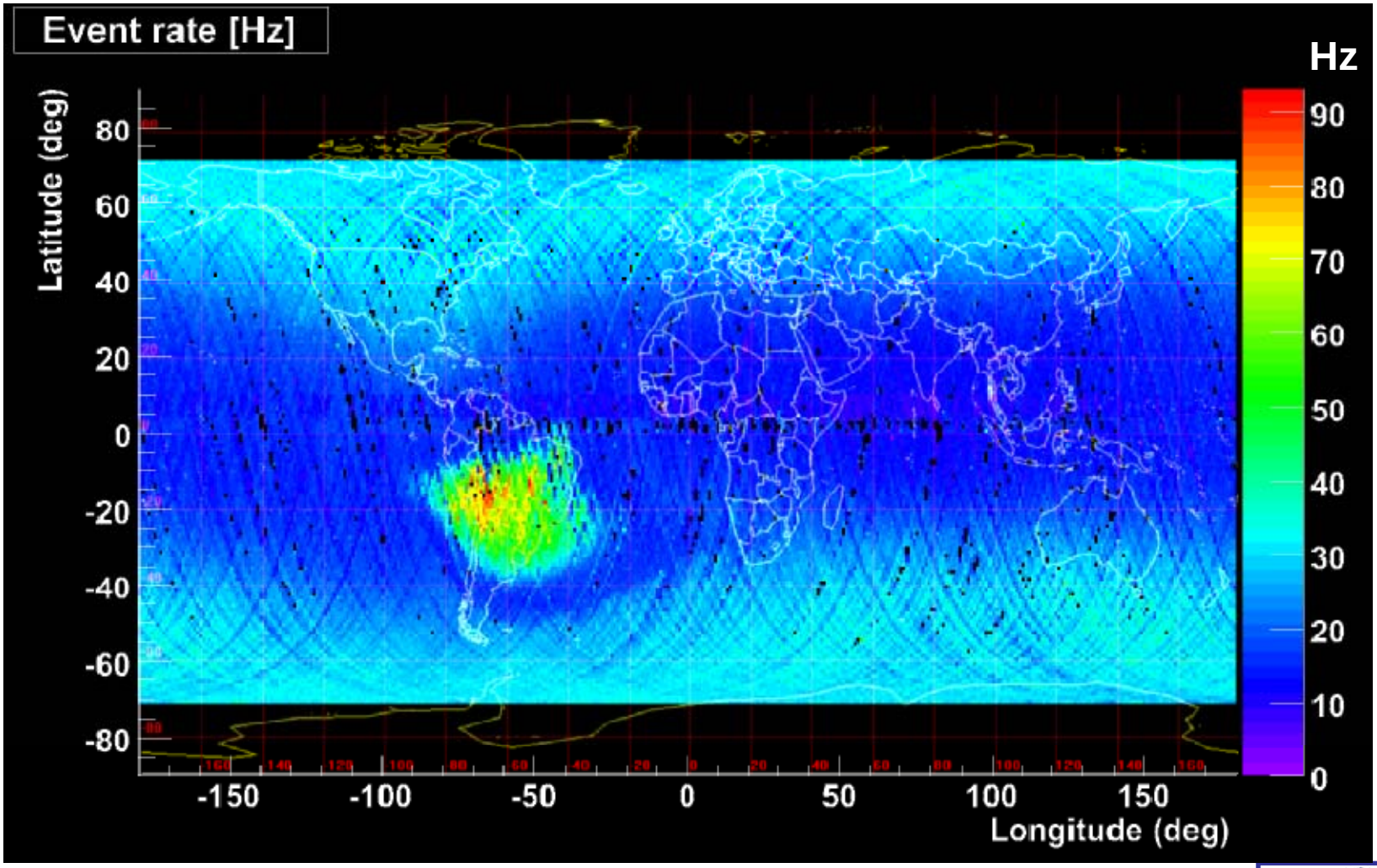
Neutron Tomography. Orthogonal projections



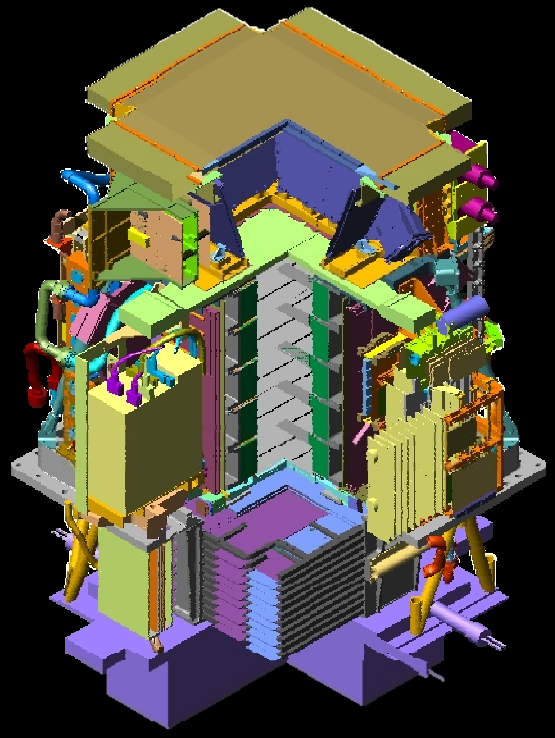


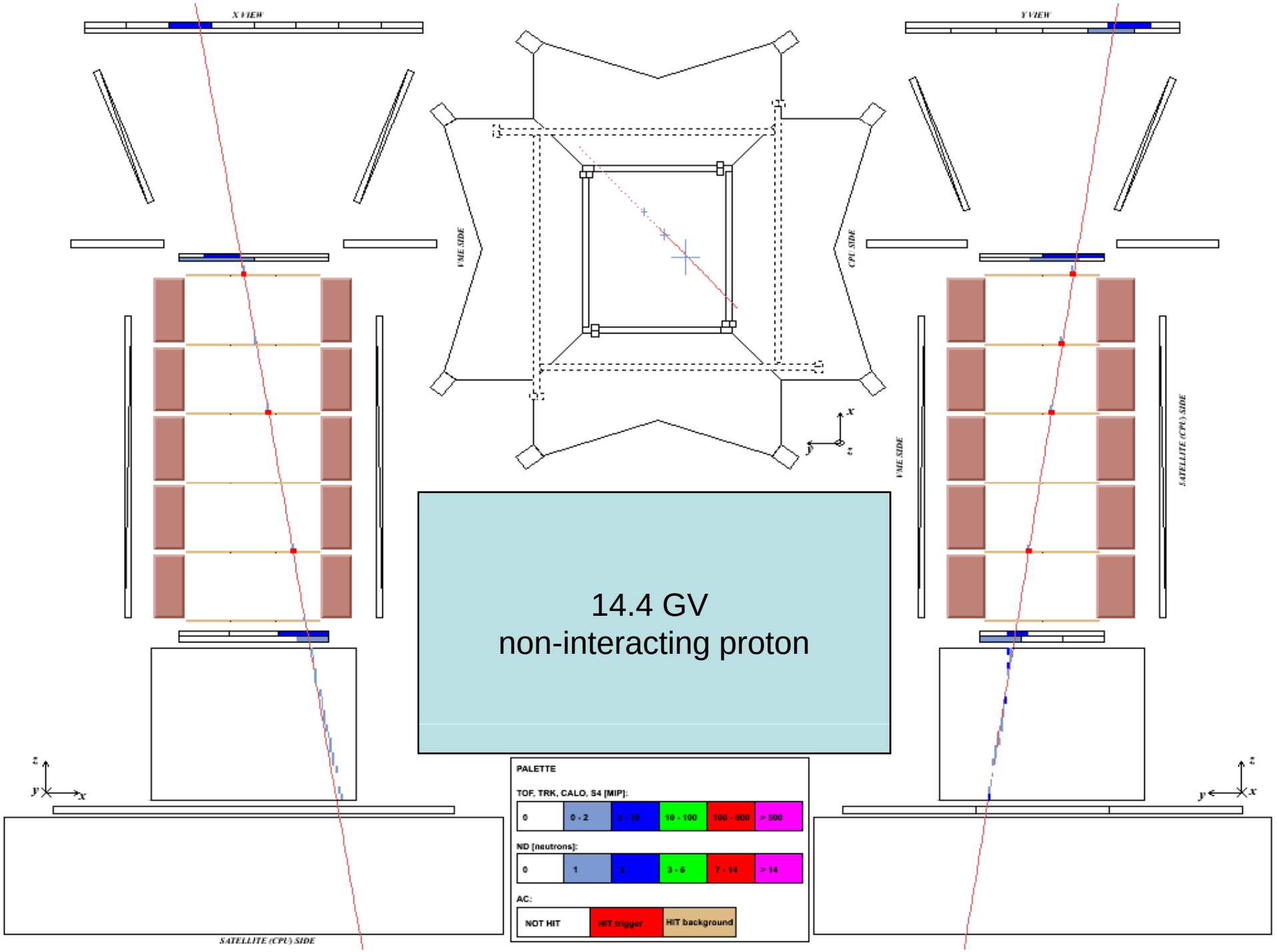


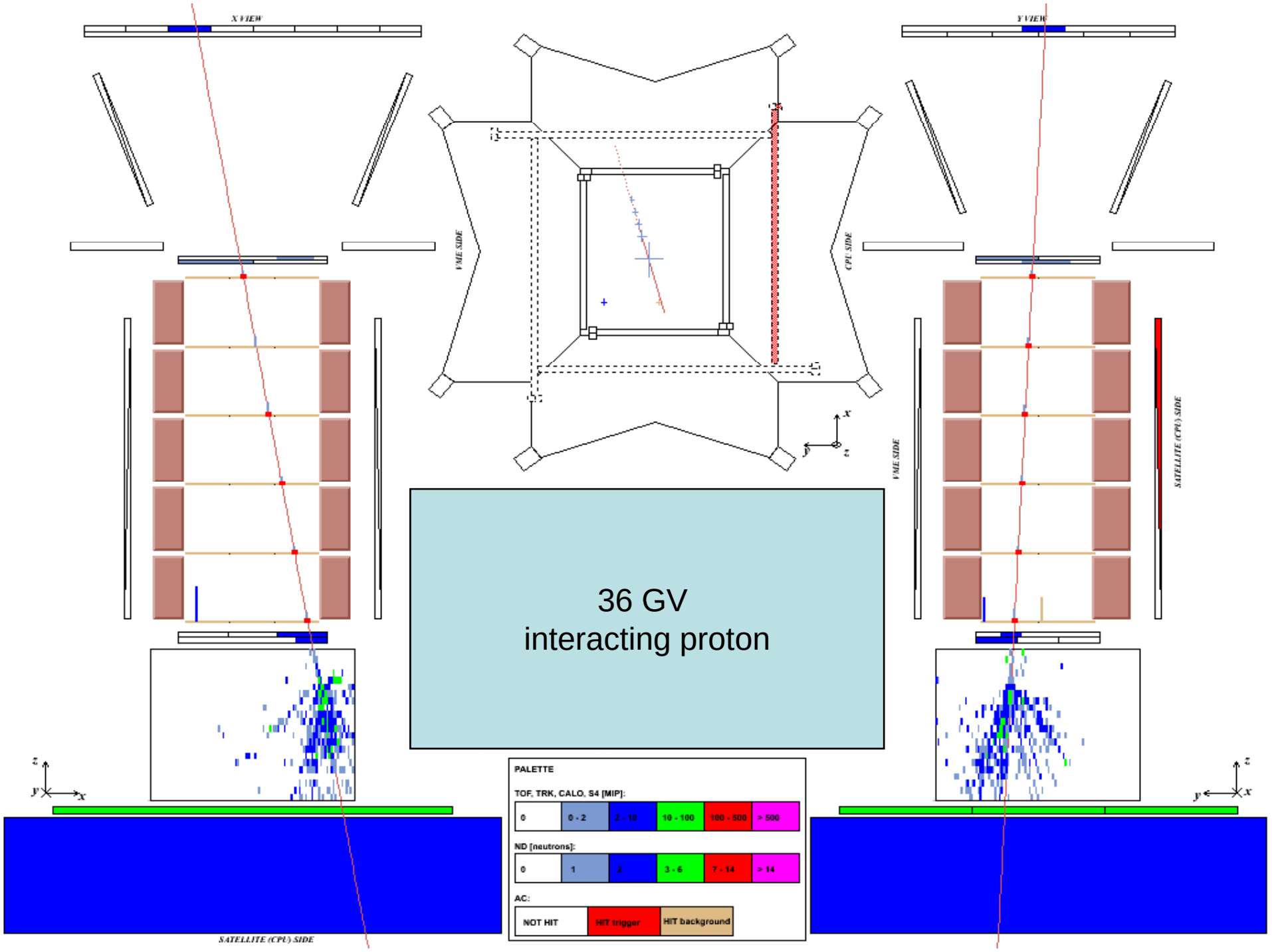
Trigger rate

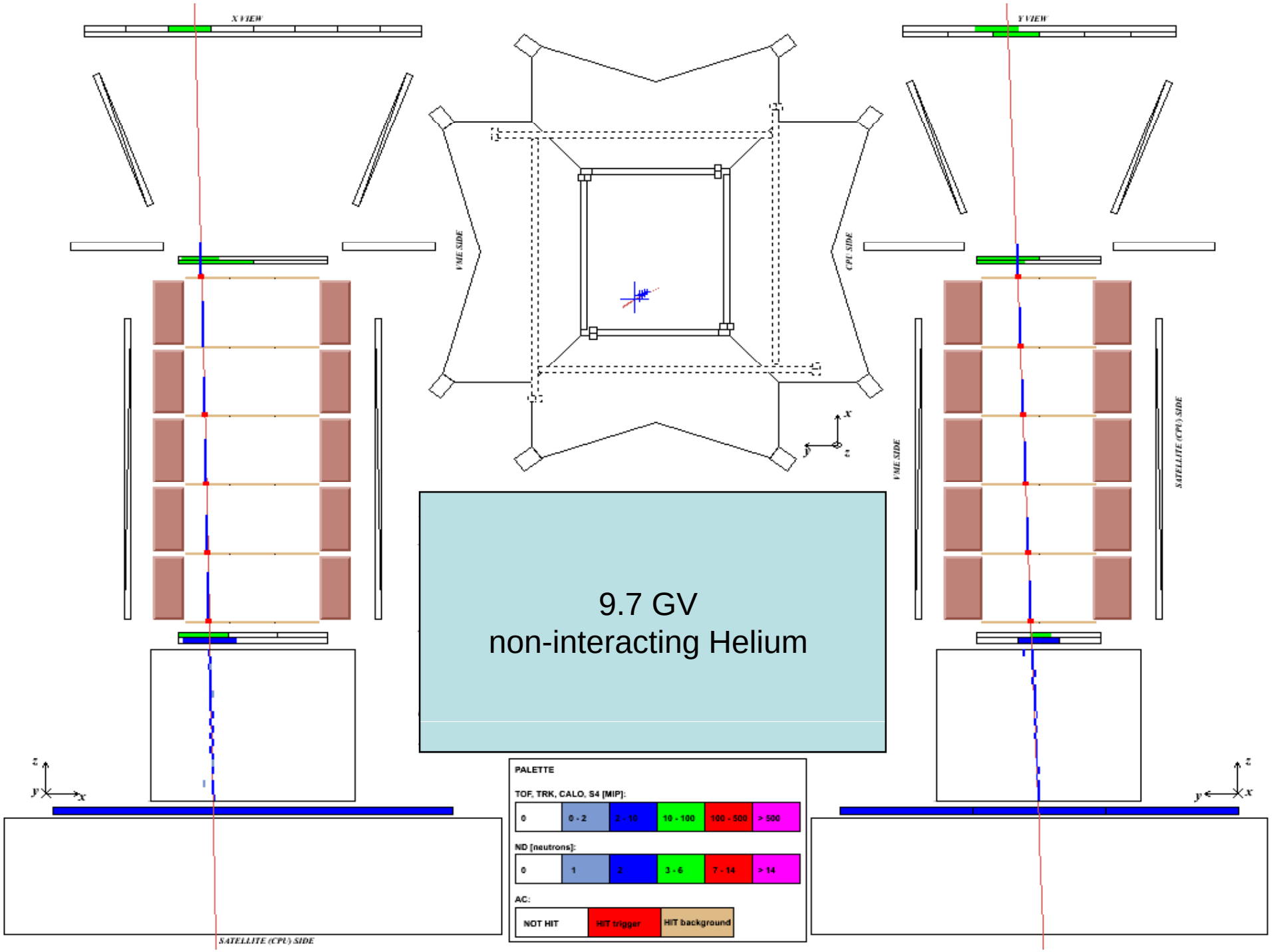


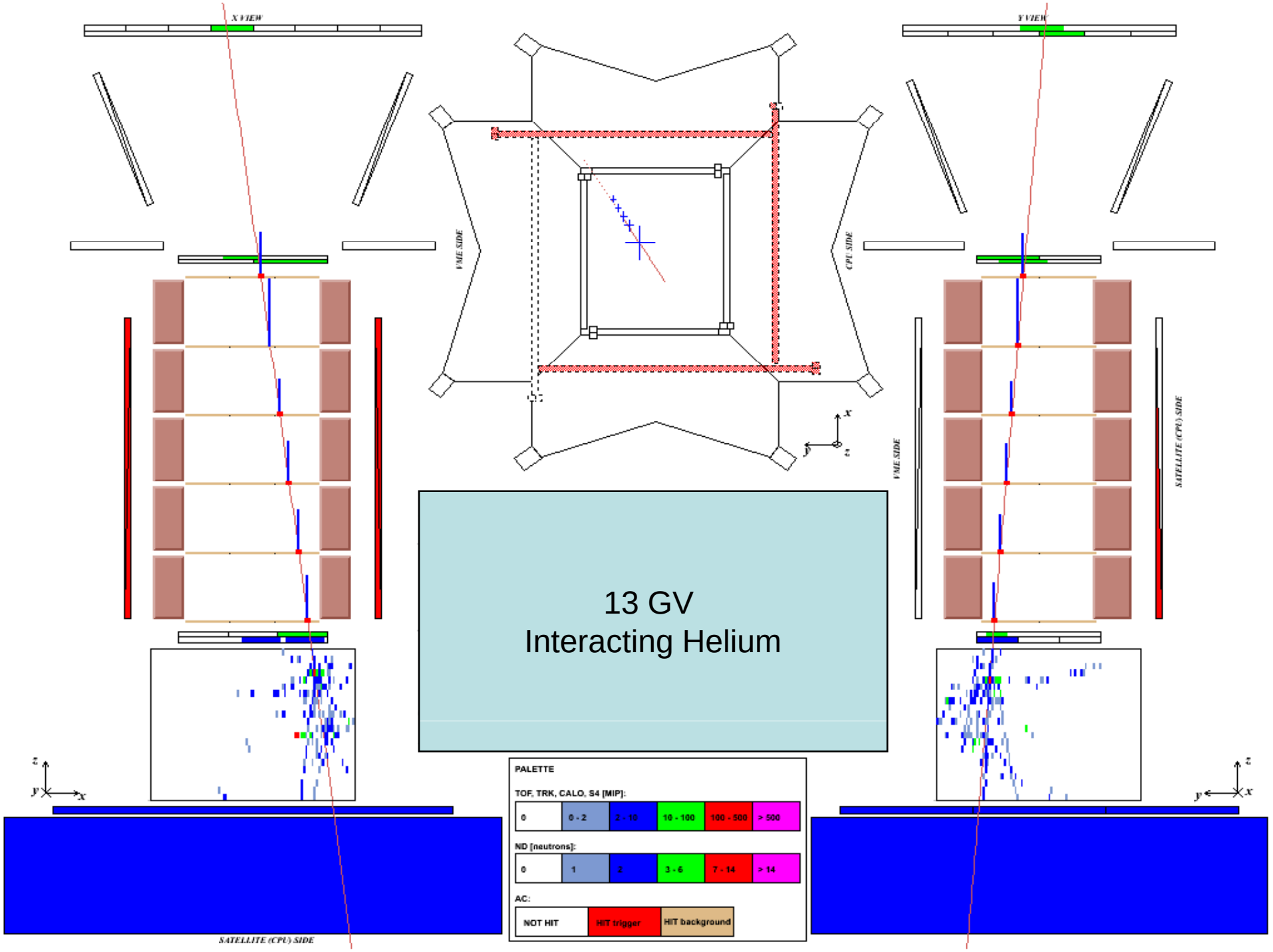
Detector performances

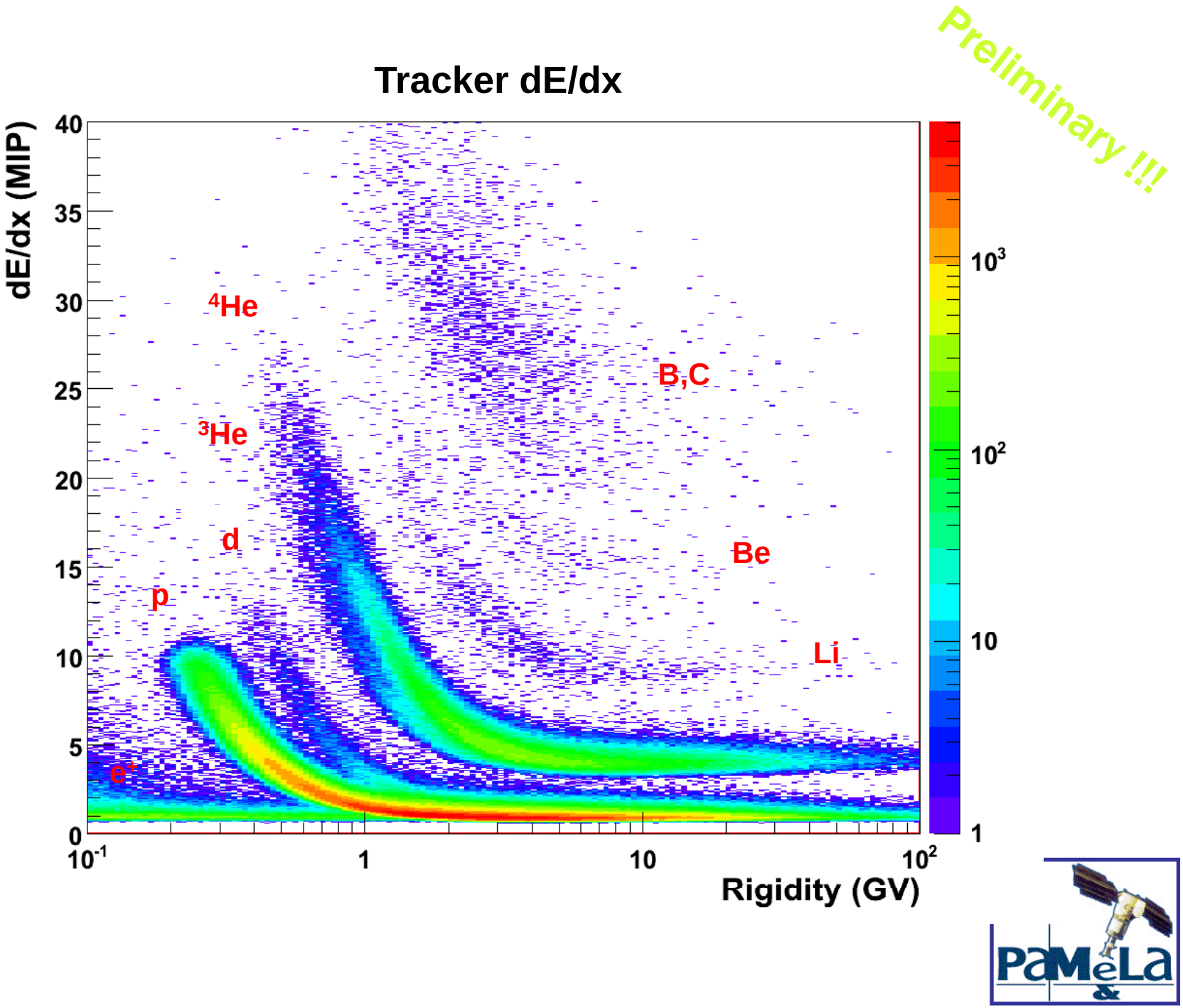



X VIEW
Y VIEW
VME SIDE
CPE SIDE
VME SIDE
SATELLITE (CPE) SIDE
14.4 GV
non-interacting proton
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background
SATELLITE (CPE) SIDE


X VIEW
Y VIEW
VME SIDE
CPU SIDE
VME SIDE
SATELLITE (CPU) SIDE
SATELLITE (CPU) SIDE
36 GV
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

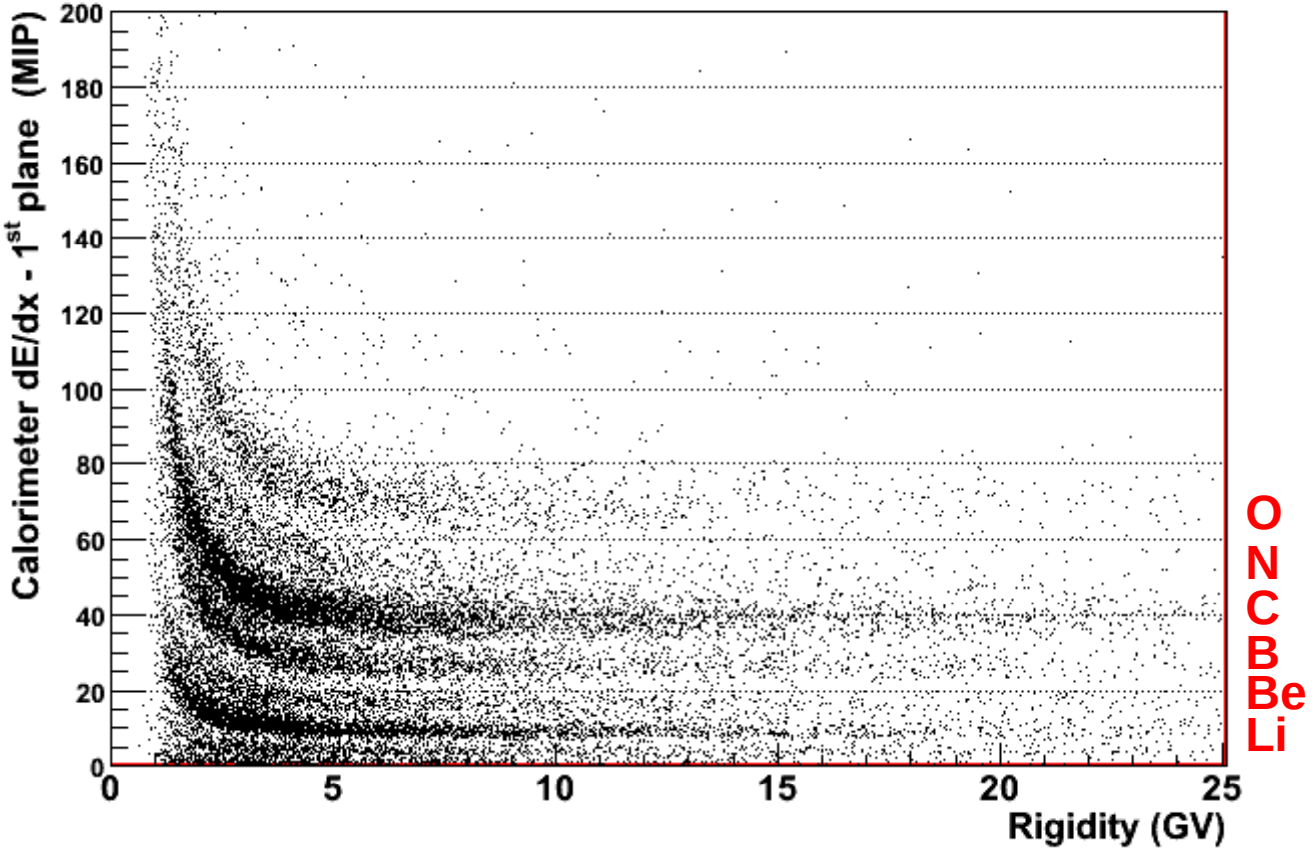

X VIEW
Y VIEW
VME SIDE
CPU SIDE
VME SIDE
SATELLITE (CPU) SIDE
SATELLITE (CPU) SIDE
9.7 GV
non-interacting Helium
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background


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

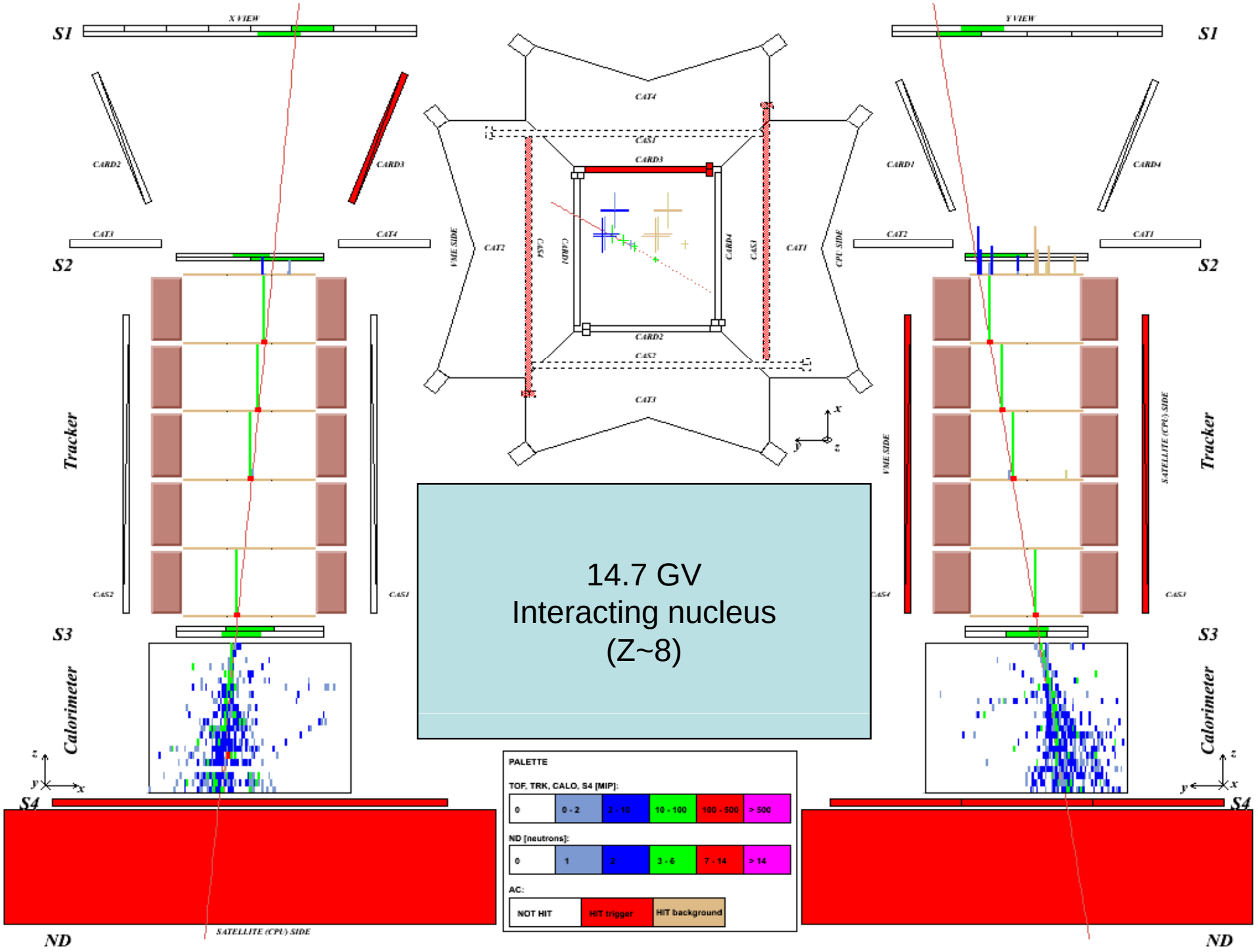

Tracker dE/dx
Preliminary !!!
dE/dx (MIP)
Rigidity (GV)
^{4}He
^{3}He
d
p
e$^+$
B,C
Be
Li
0
5
10
15
20
25
30
35
40
10^{-1}
1
10
10^2
1
10
10^2
10^3
PaMeLa

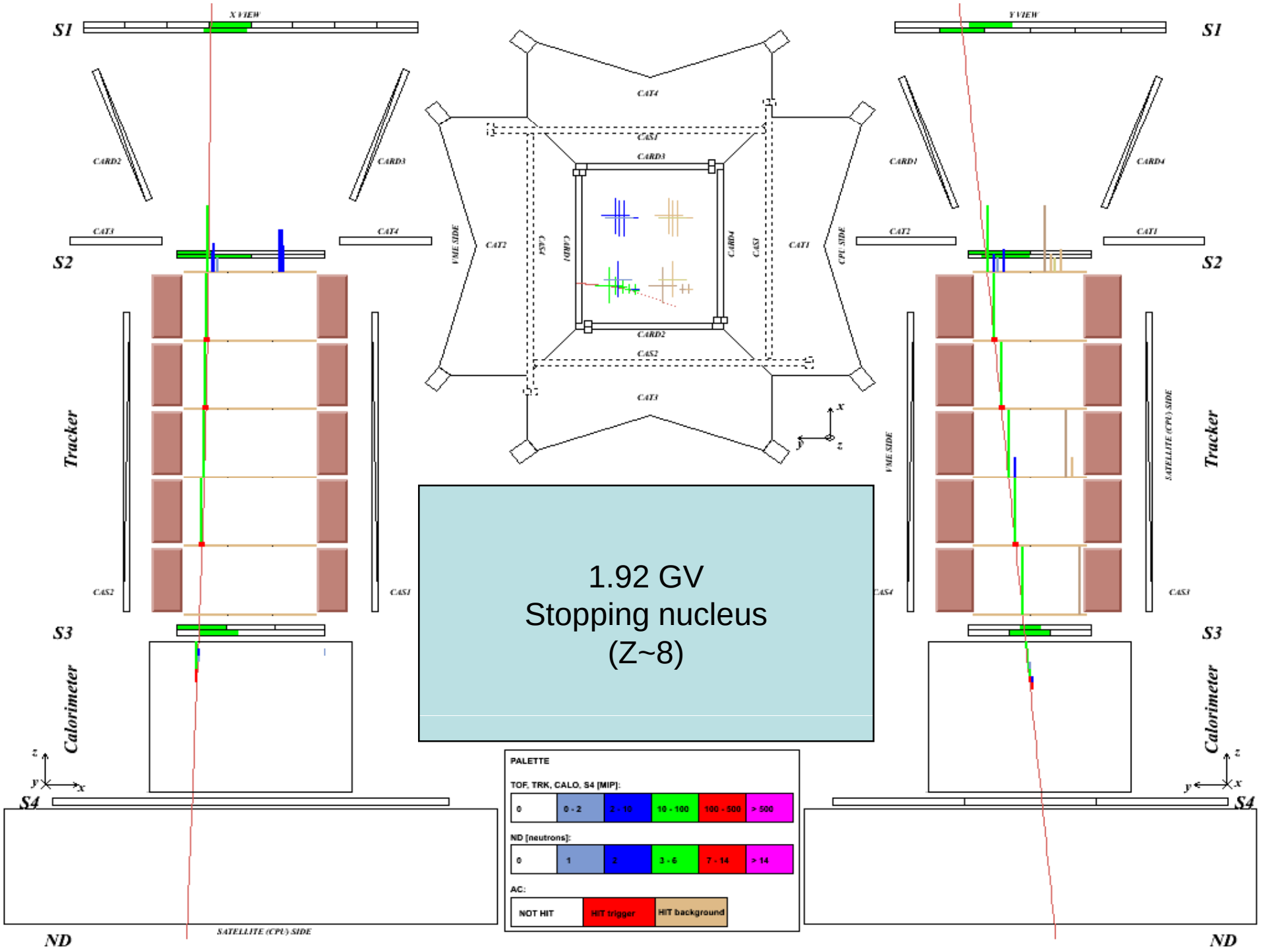
Preliminary !!!

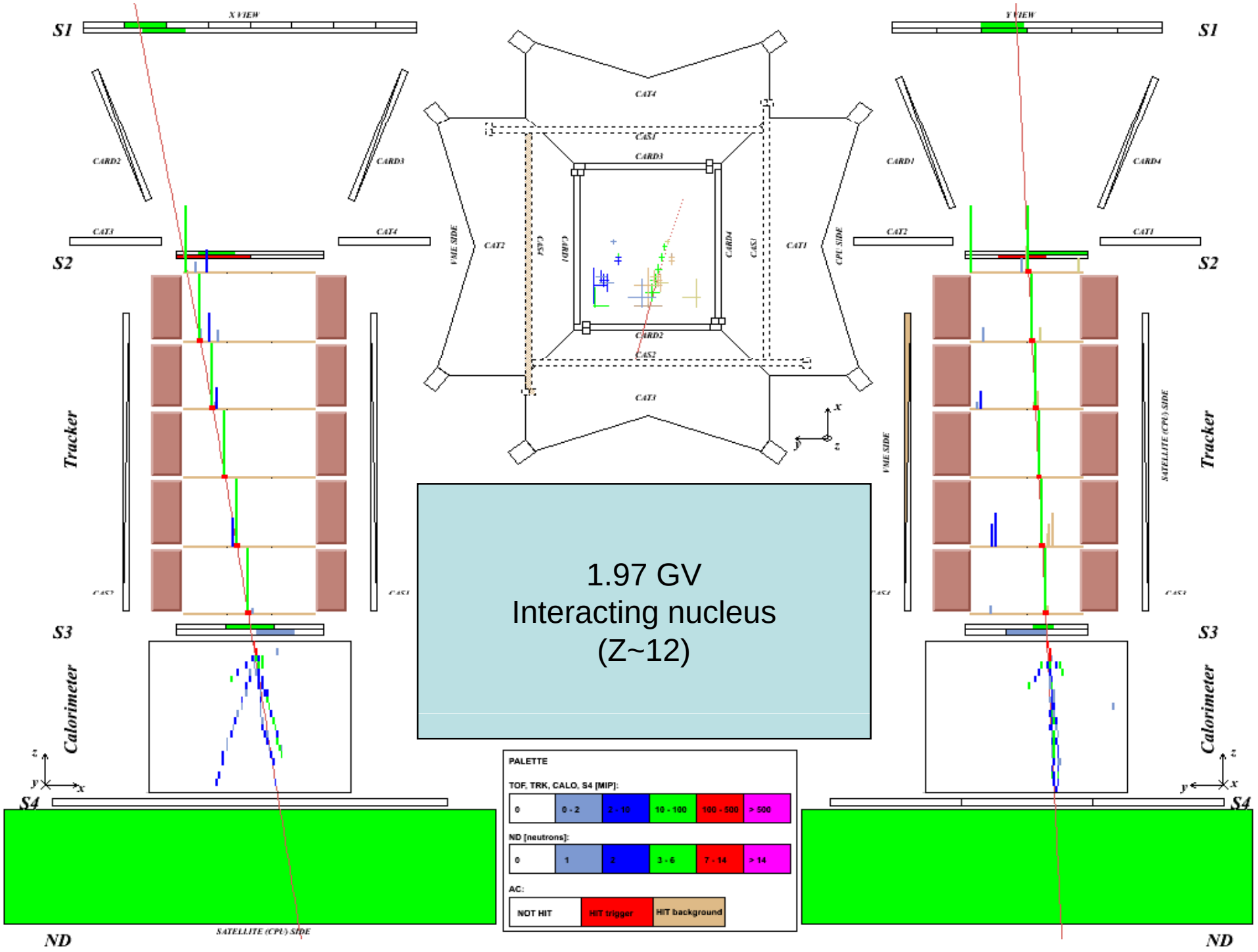
Calorimeter dE/dx (first Si-layer)

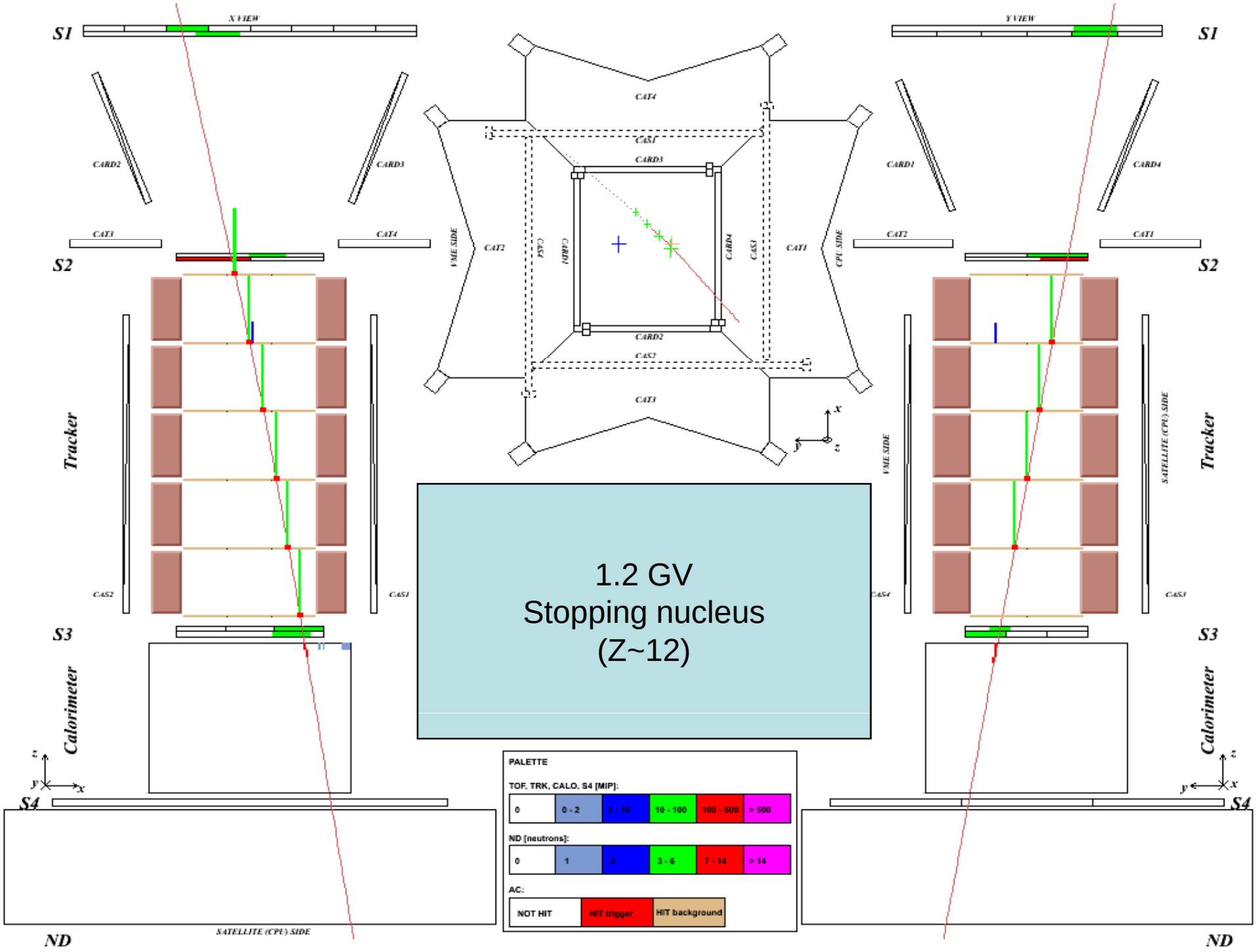


PaMeLa


X VIEW
Y VIEW
S1
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
14.7 GV
Interacting nucleus
(Z~8)
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

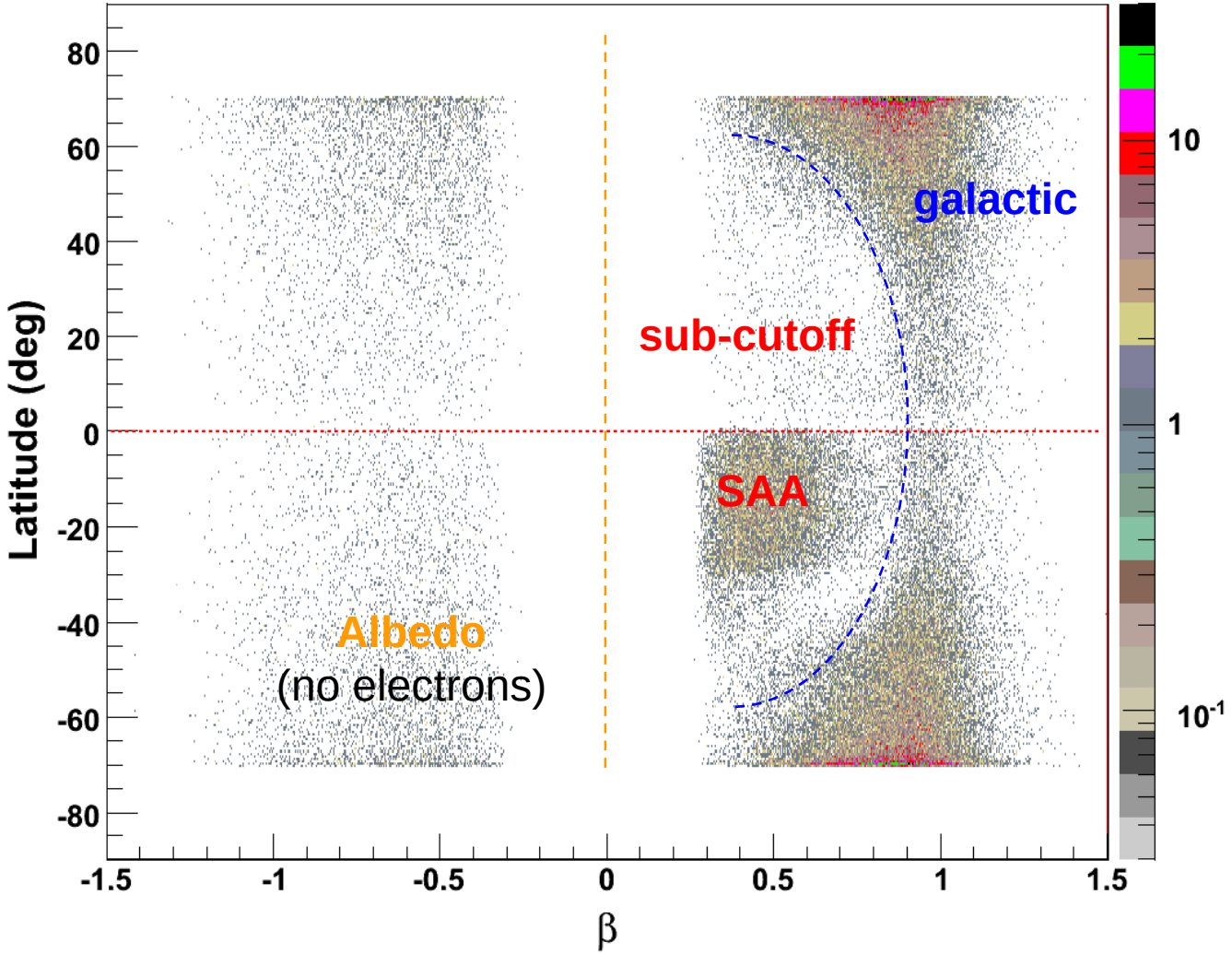

X VIEW
Y VIEW
S1
S2
S3
S4
ND
Tracker
Calorimeter
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
1.92 GV
Stopping nucleus
(Z~8)
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC:
NOT HIT
HIT trigger
HIT background


X VIEW
Y VIEW
S1
S2
S3
S4
ND
Tracker
Calorimeter
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
1.97 GV
Interacting nucleus
(Z~12)
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


S1
X VIEW
CARD2
CARD3
CAT3
CAT4
S2
Tracker
CAS2
CAS1
S3
Calorimeter
S4
ND
SATELLITE (CPU) SIDE
CAT4
CAS1
CARD3
VME SIDE
CAT2
CAS4
CARD1
CARD4
CAS3
CAT1
CPU SIDE
CARD2
CAS2
CAT3
Y VIEW
CARD1
CARD4
CAT2
CAT1
VME SIDE
SATELLITE (CPU) SIDE
CAS4
CAS3
1.2 GV
Stopping nucleus
(Z~12)
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

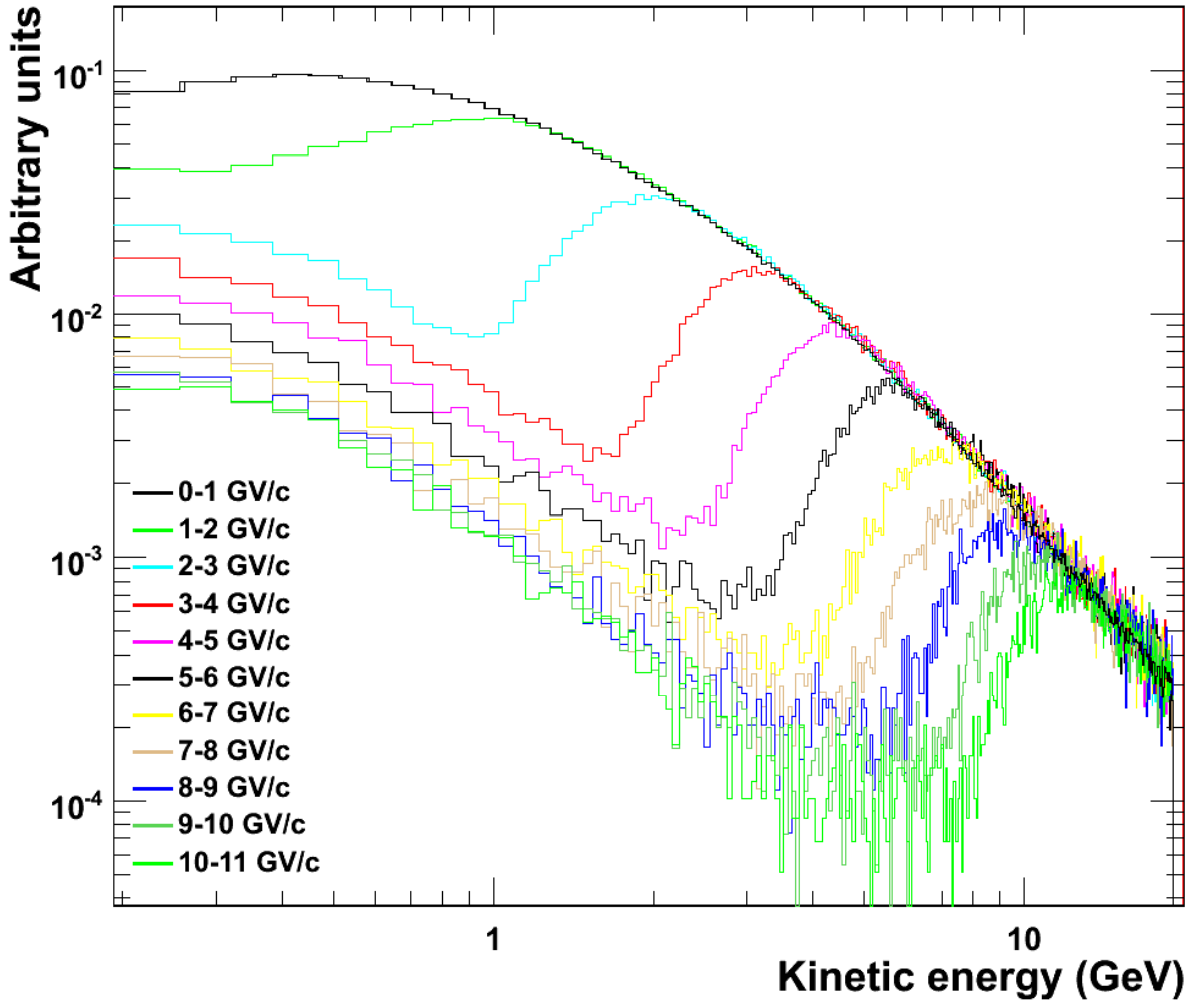
Preliminary !!!

Latitude vs beta (Z=1)



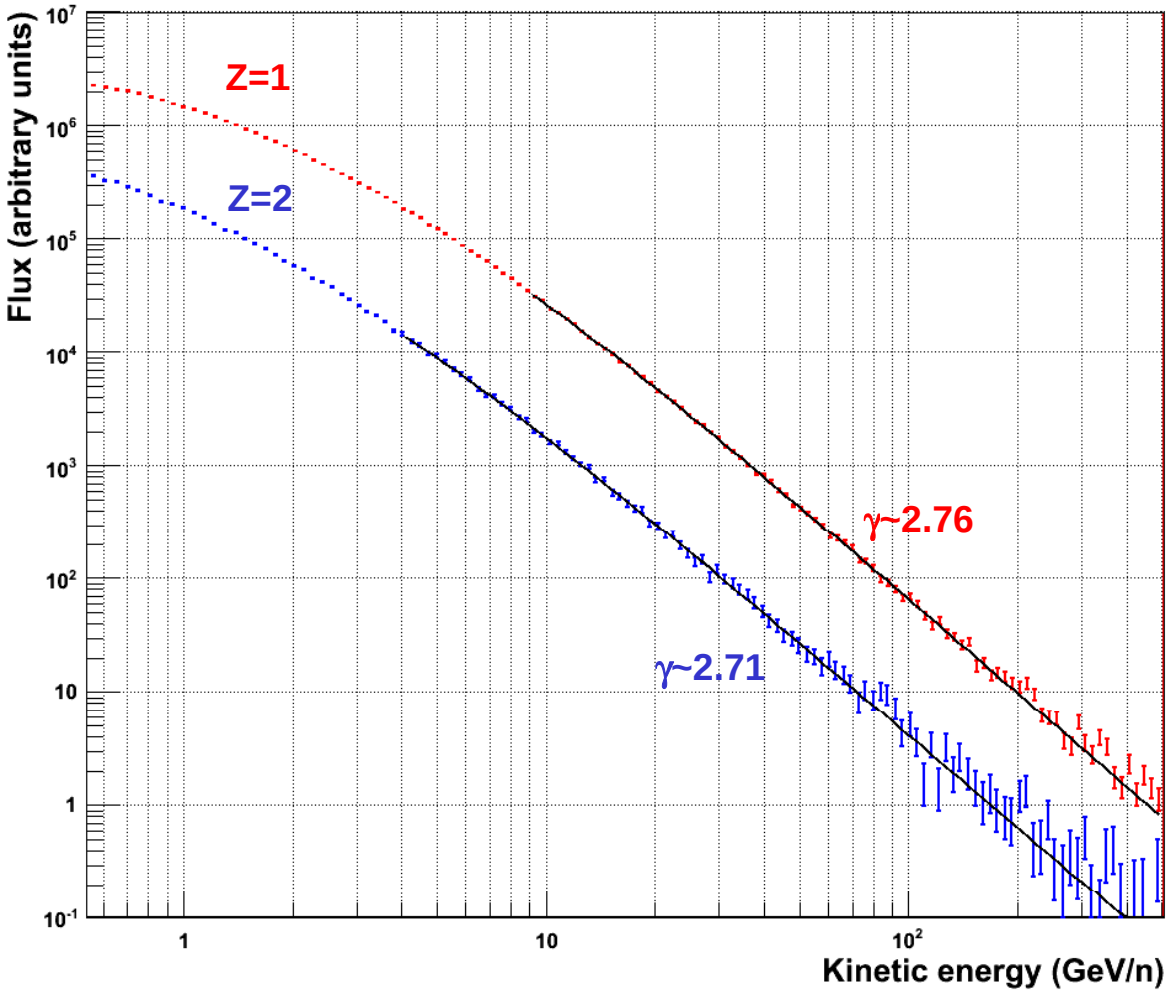
H spectra @ different cutoff rigidities

Preliminary !!!

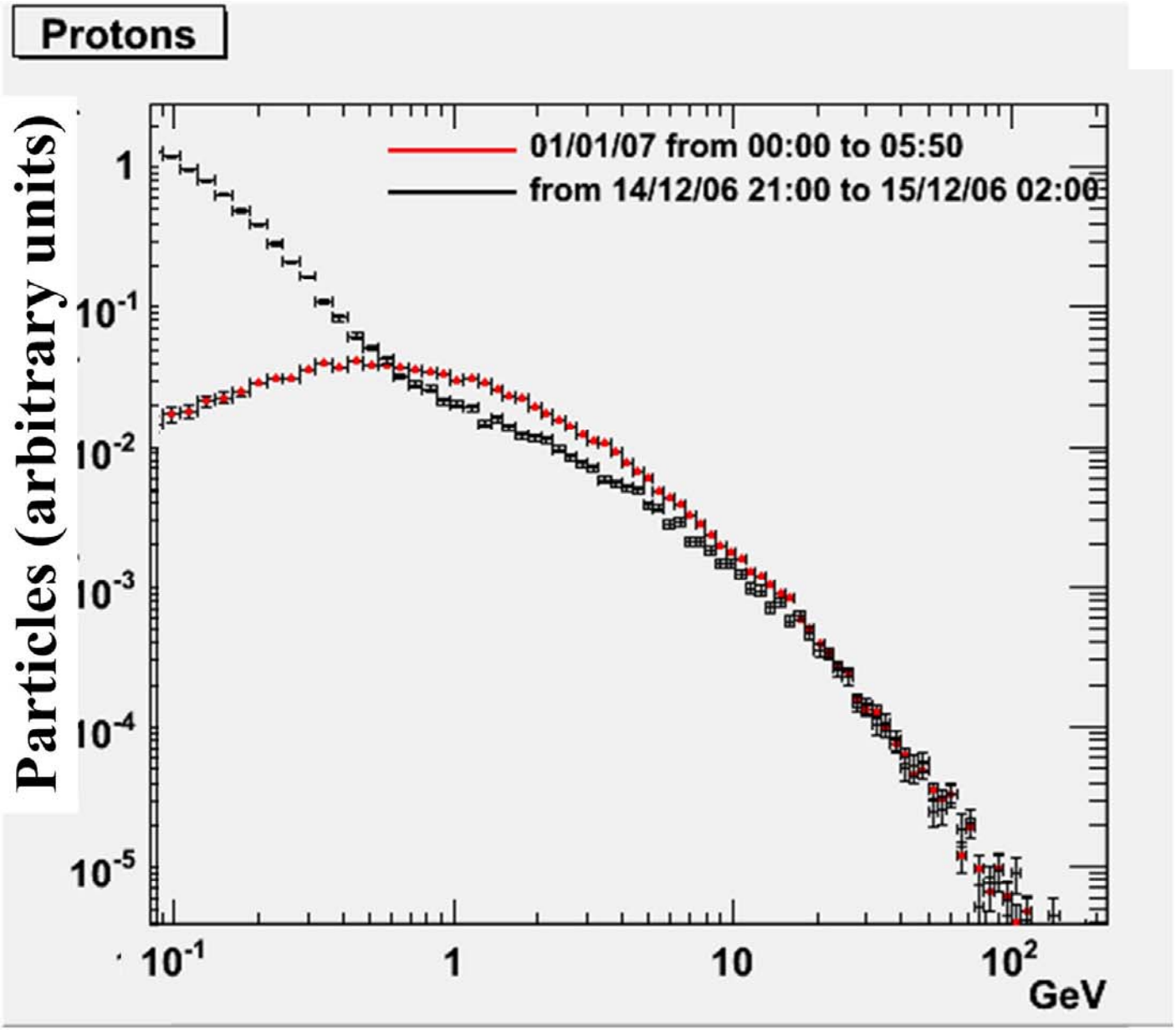


Galactic H and He spectra

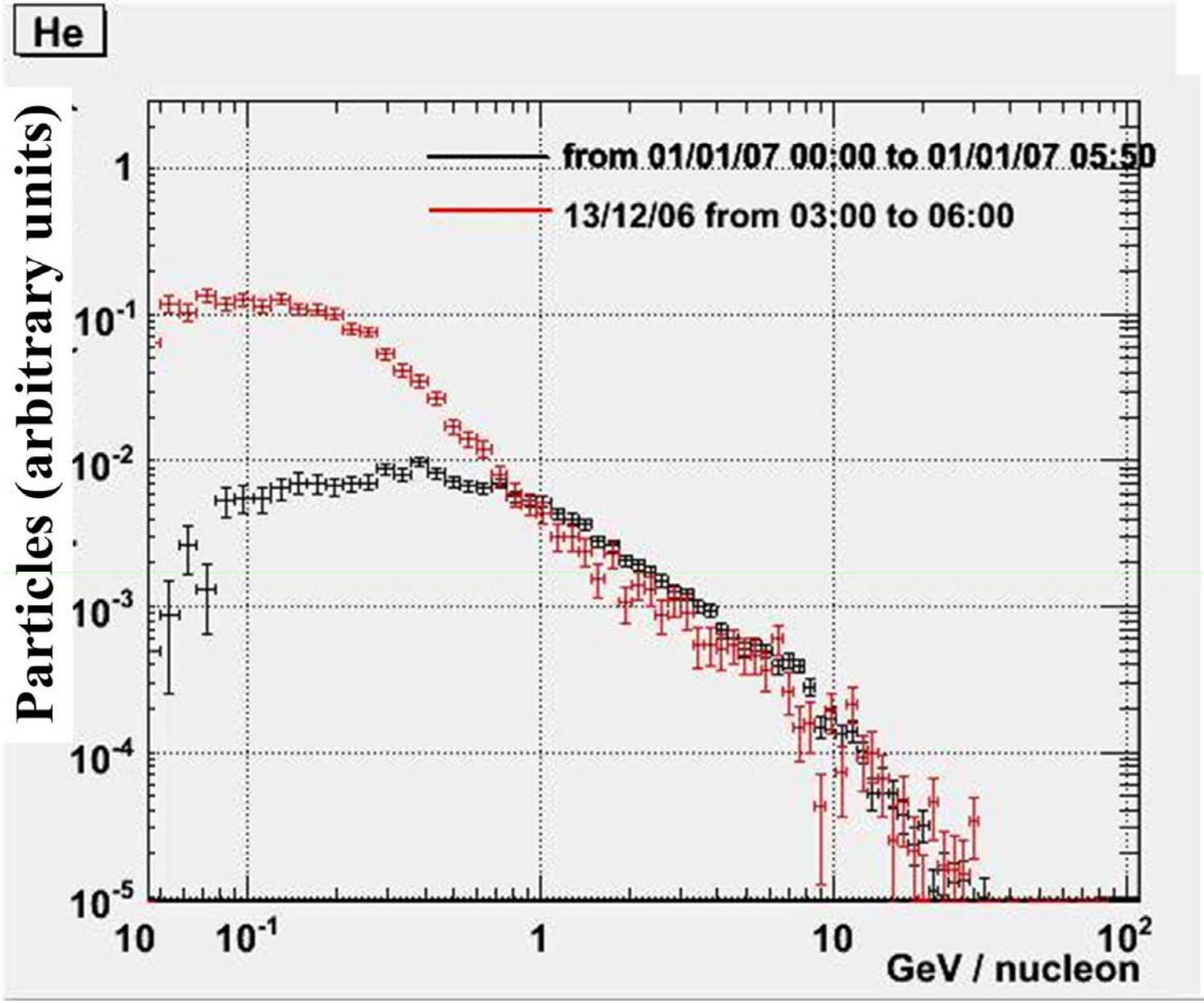
Preliminary !!!



Solar flare


Protons
Particles (arbitrary units)
01/01/07 from 00:00 to 05:50
from 14/12/06 21:00 to 15/12/06 02:00
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-1}
1
10
10^{2}
GeV

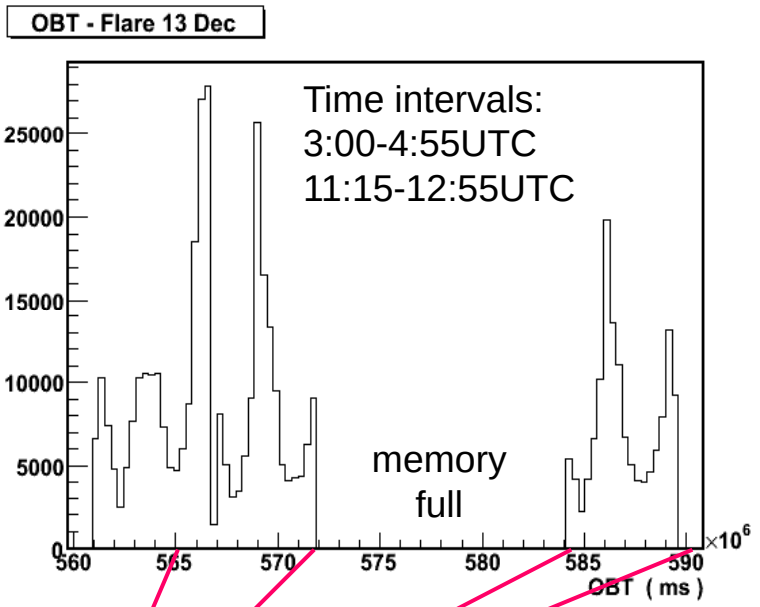
Solar flare

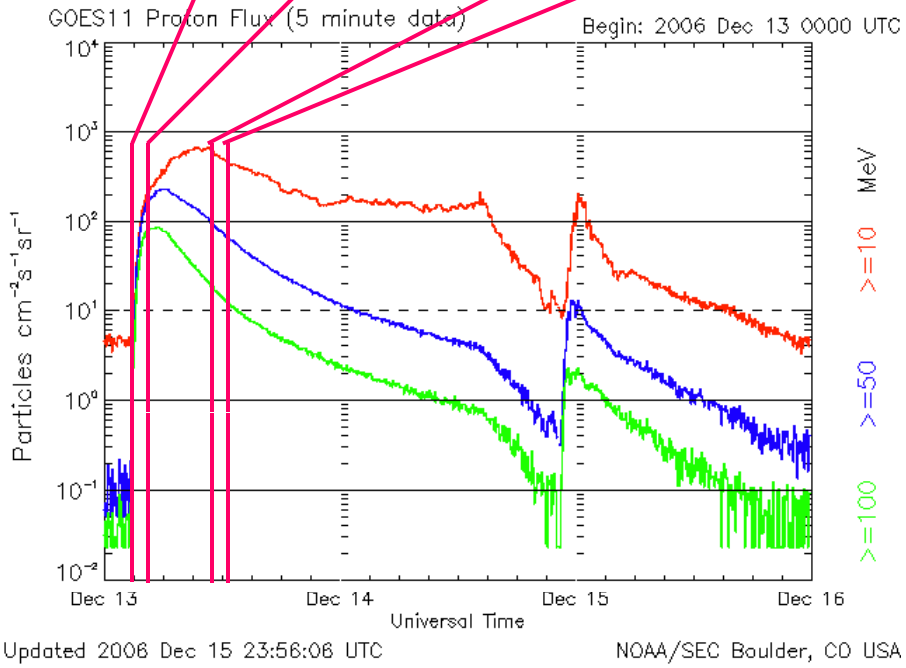

He
from 01/01/07 00:00 to 01/01/07 05:50
13/12/06 from 03:00 to 06:00
Particles (arbitrary units)
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10
10^{-1}
1
10
10^{2}
GeV / nucleon

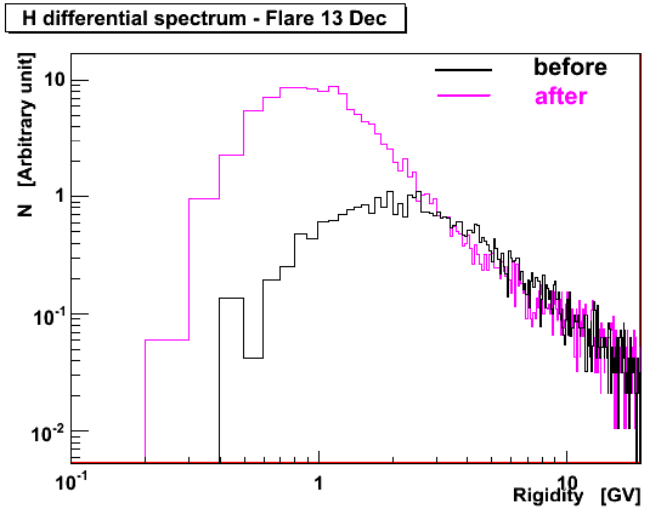
Solar Impulsive event 13/12/2006

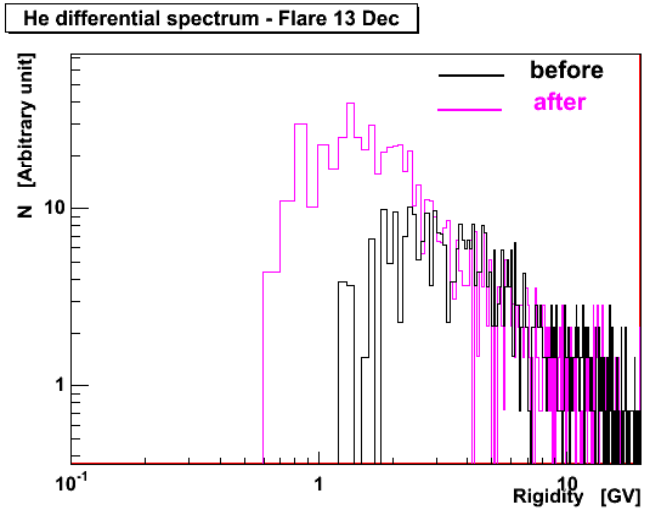
(CME already on 6/12)

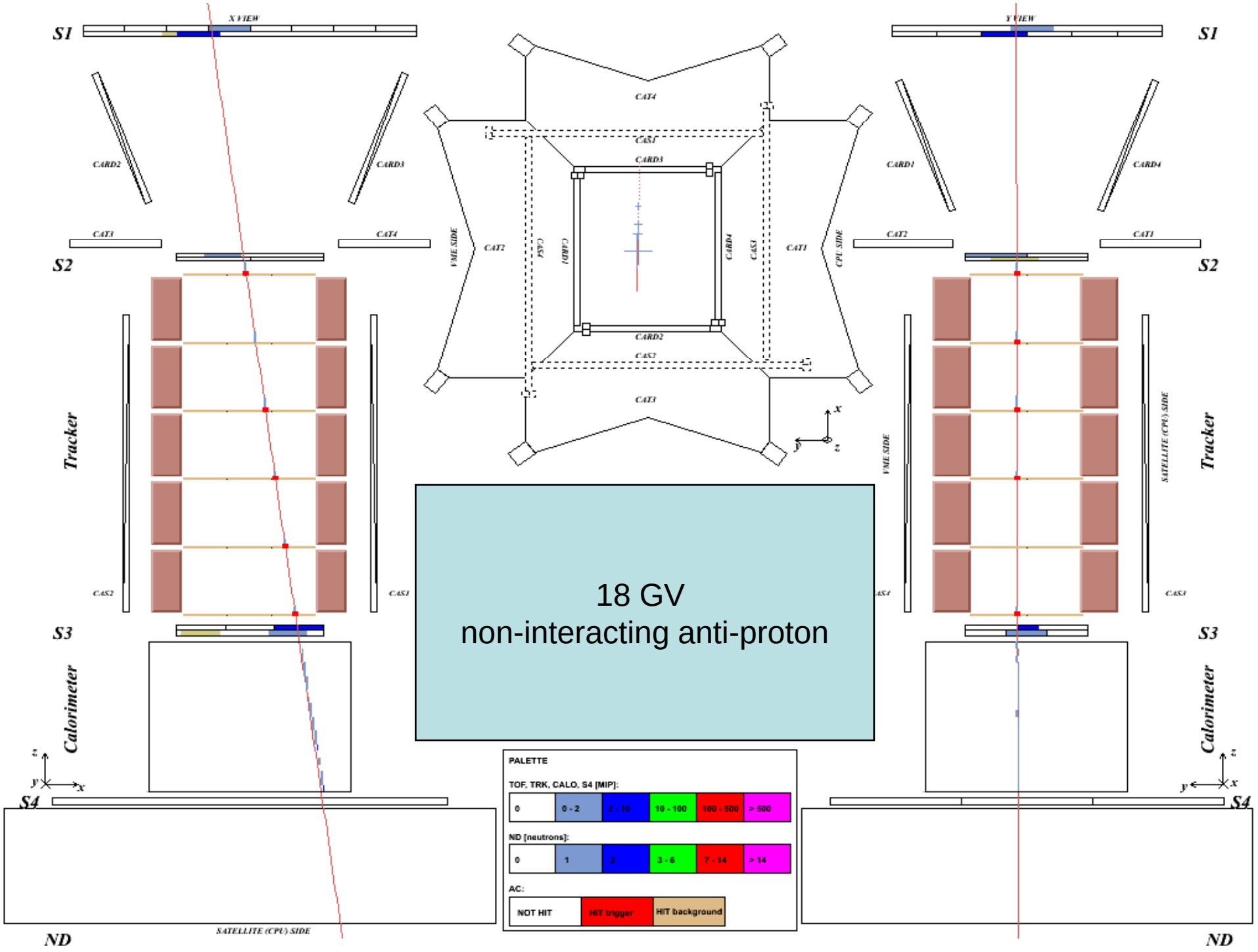
Preliminary !!!

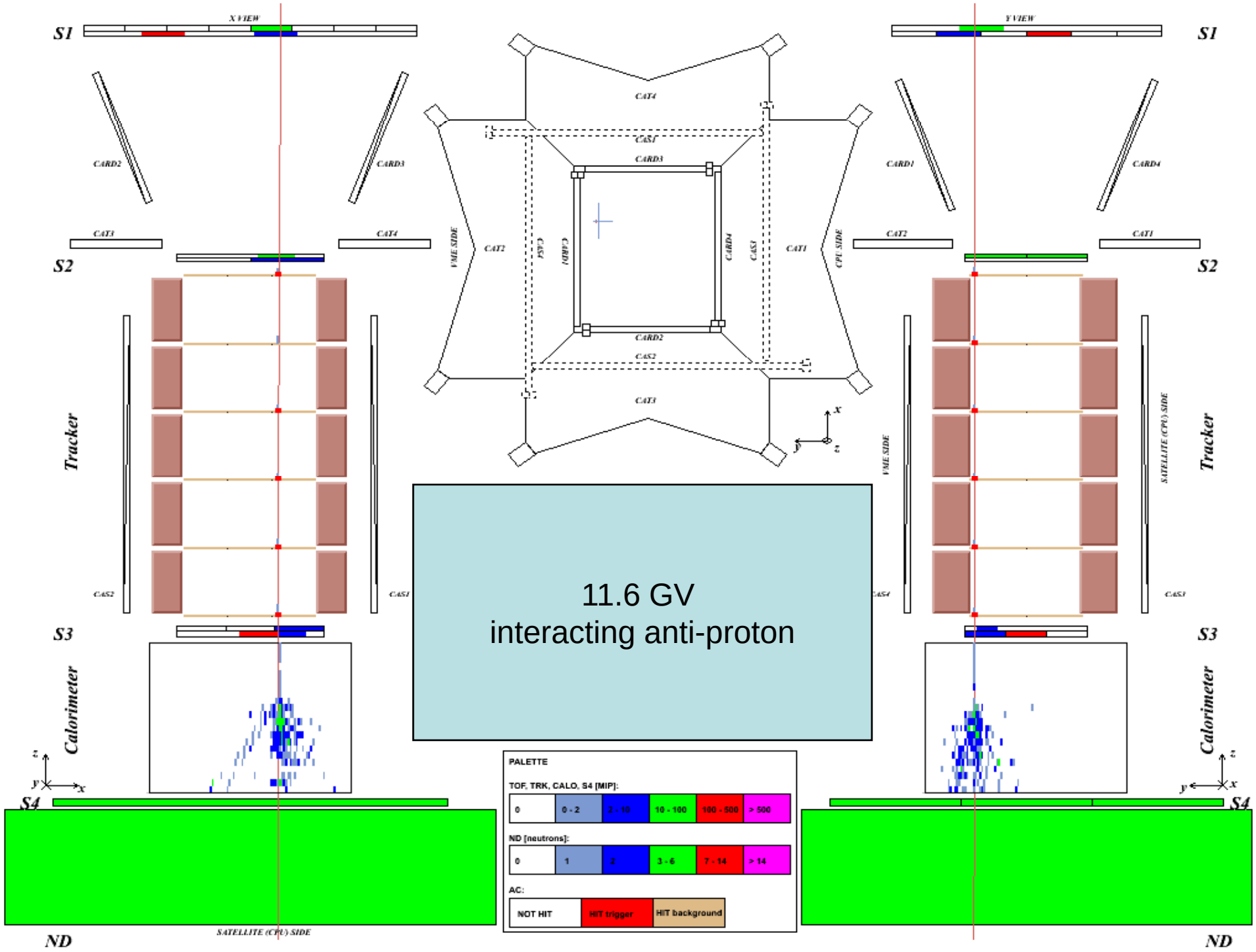


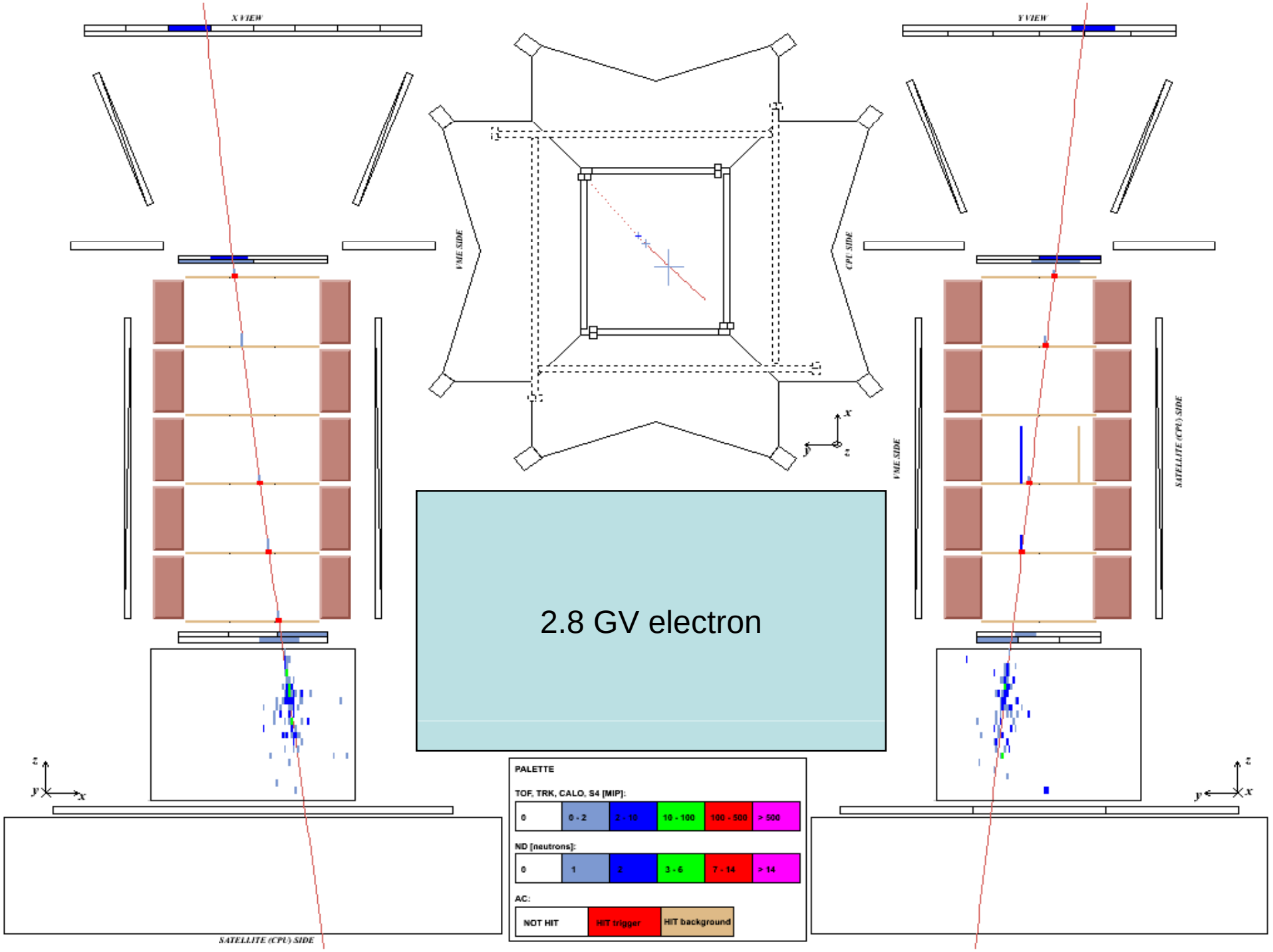


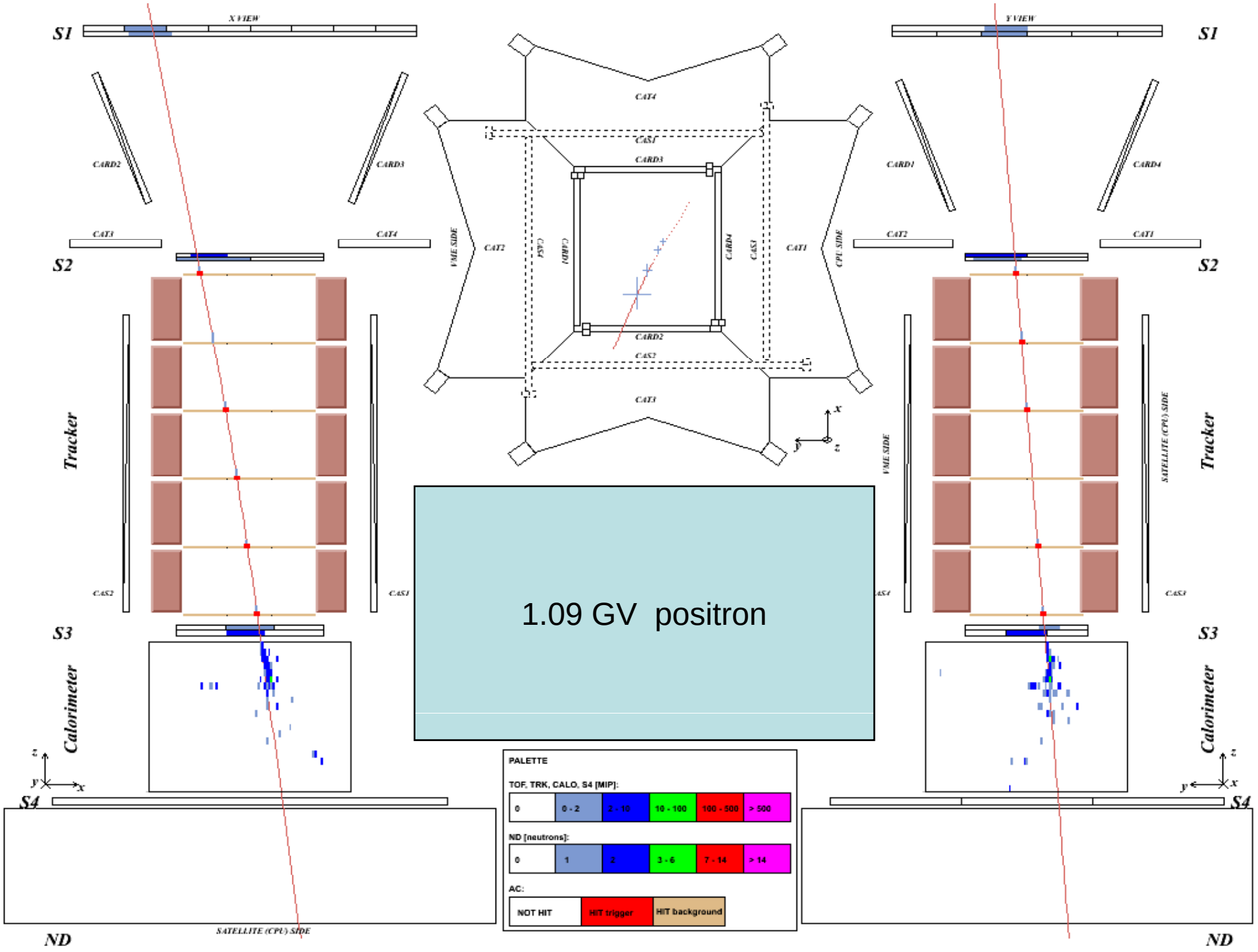


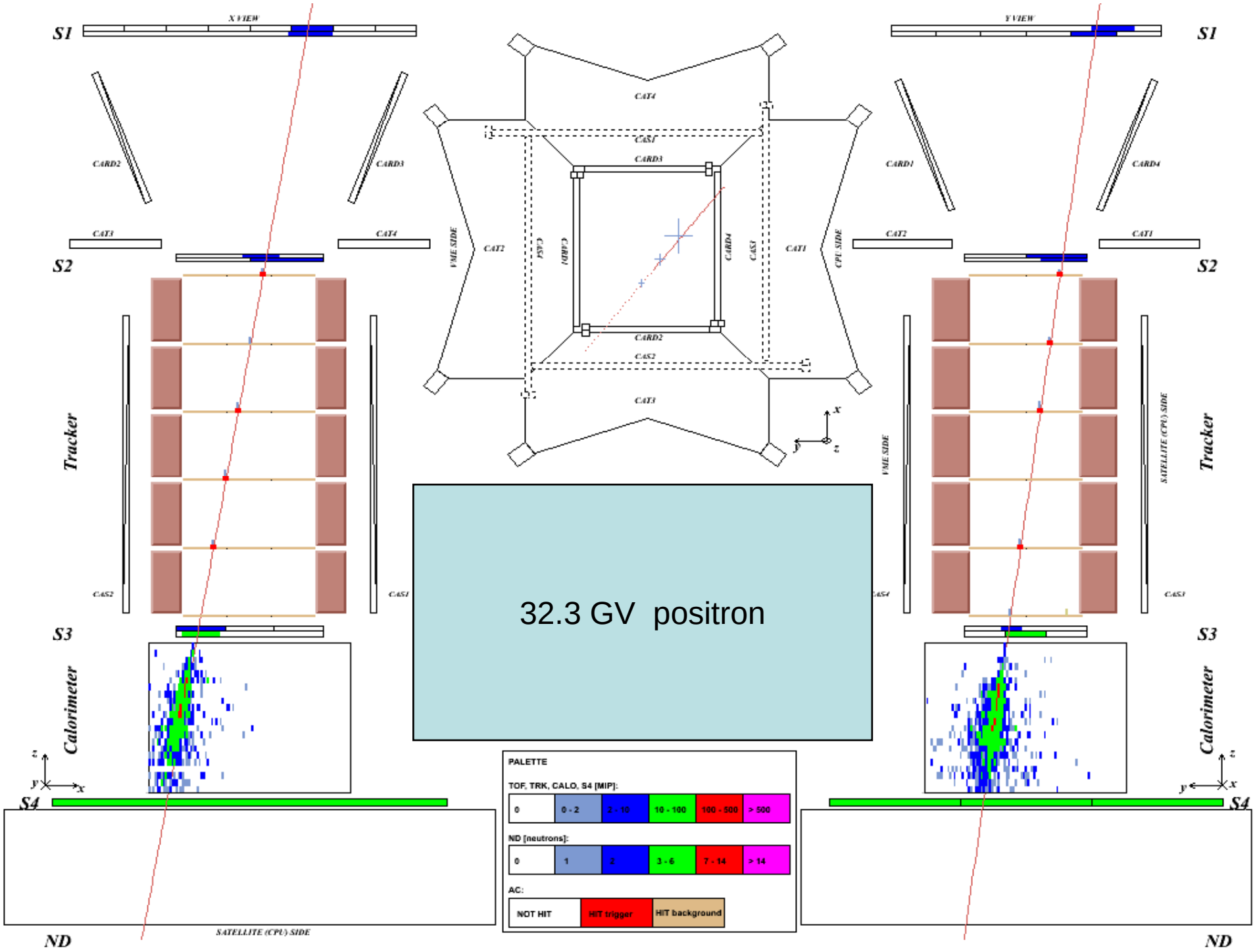



X VIEW
Y VIEW
S1
S2
S3
S4
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
Tracker
Calorimeter
ND
18 GV
non-interacting anti-proton
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC: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

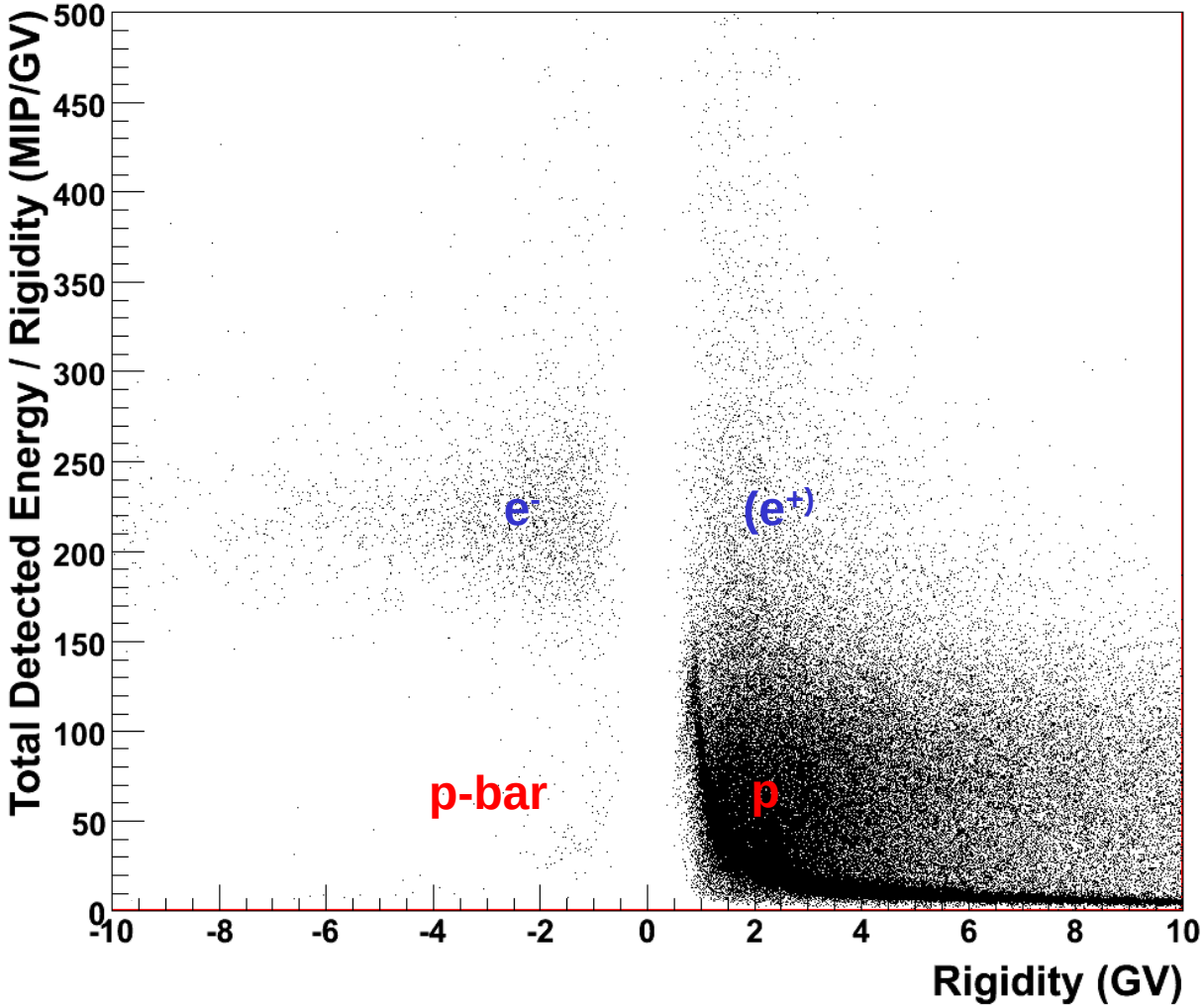

X VIEW
Y VIEW
S1
S2
S3
S4
Tracker
Calorimeter
ND
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPE SIDE
SATELLITE (CPE) SIDE
11.6 GV
interacting anti-proton
PALETTE
TOF, TRK, CALO, S4 [MIP]:
0
0 - 2
2 - 10
10 - 100
100 - 500
> 500
ND [neutrons]:
0
1
2
3 - 6
7 - 14
> 14
AC: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


X VIEW
Y VIEW
VME SIDE
CPU SIDE
VME SIDE
SATELLITE (CPU) SIDE
SATELLITE (CPU) SIDE
2.8 GV electron
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


X VIEW
Y VIEW
S1
S2
S3
S4
ND
Tracker
Calorimeter
CARD1
CARD2
CARD3
CARD4
CAT1
CAT2
CAT3
CAT4
CAS1
CAS2
CAS3
CAS4
VME SIDE
CPU SIDE
SATELLITE (CPU) SIDE
1.09 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


S1
X VIEW
CARD2
CARD3
CAT3
CAT4
S2
Tracker
CAS2
CAS1
S3
Calorimeter
S4
ND
SATELLITE (CPU) SIDE
CAT4
CAS1
CARD3
VME SIDE
CAT2
PSCD
CMPC
CARD4
CAS3
CAT1
CPU SIDE
CARD2
CAS2
CAT3
x
y
z
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
Y VIEW
CARD1
CARD4
CAT2
CAT1
VME SIDE
SATELLITE (CPU) SIDE
CAS4
CAS3

Preliminary !!!

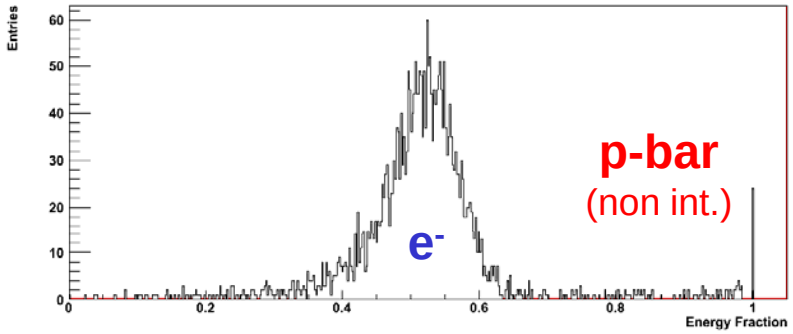


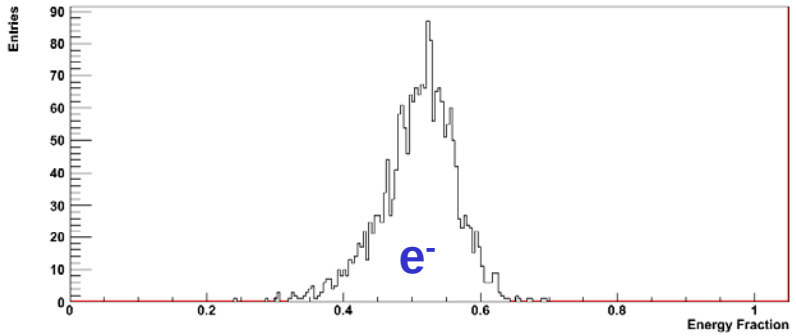
PaMeLa

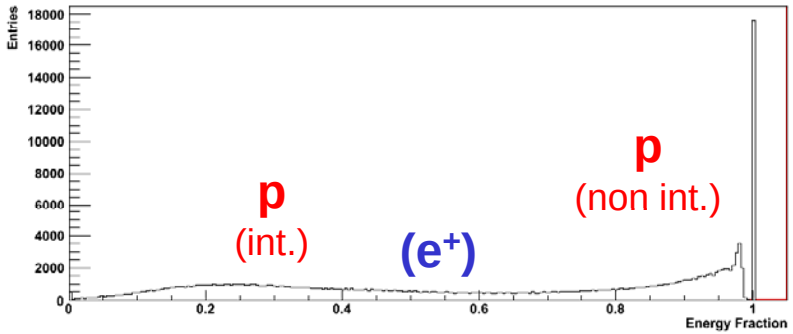
Positron selection

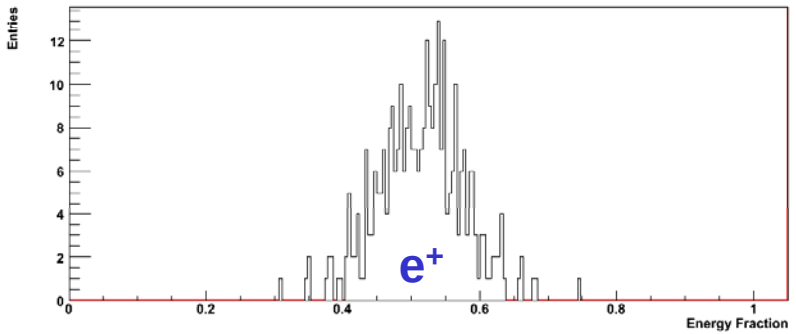
Preliminary !!!

Fraction of charge released along the track



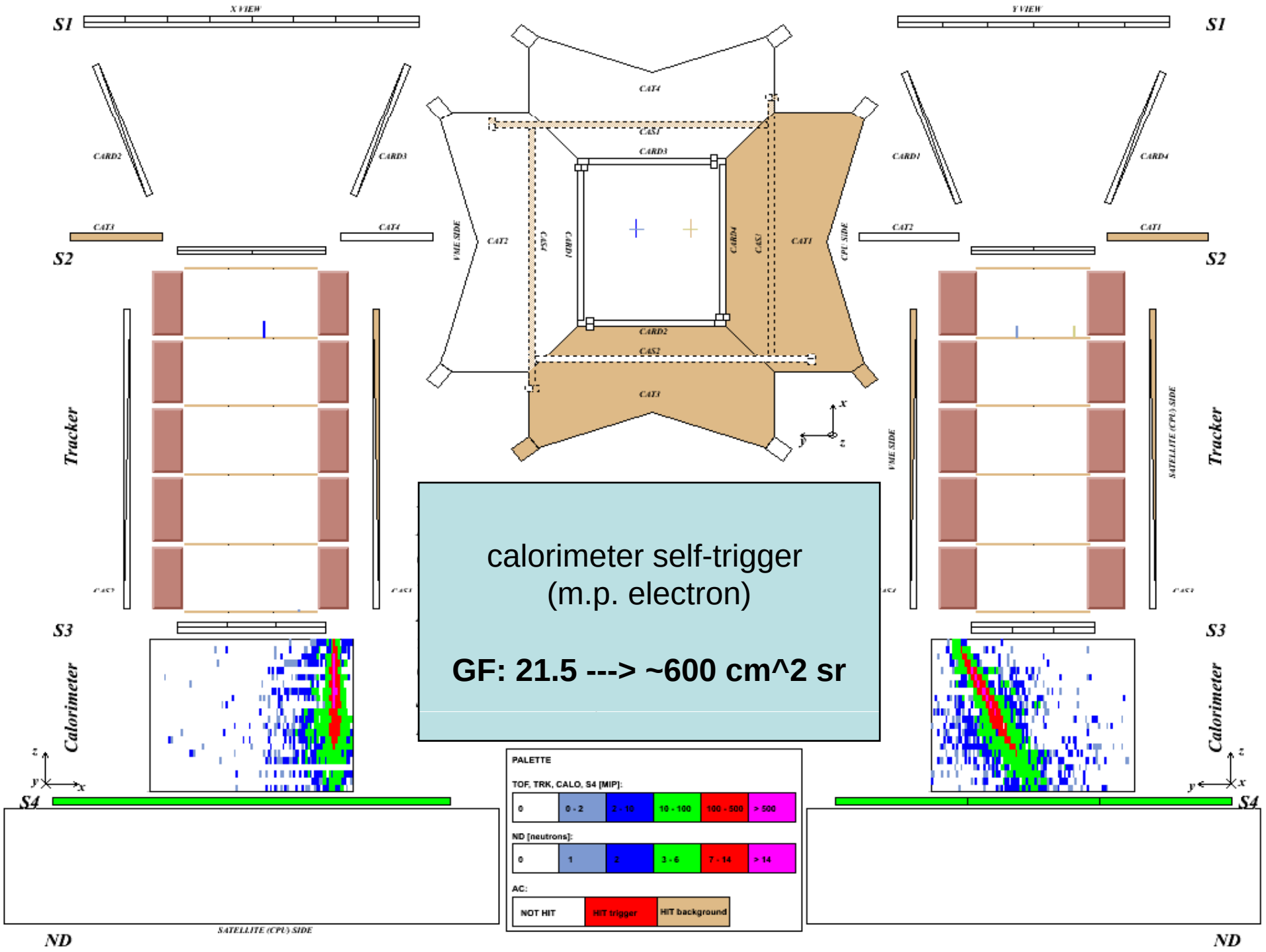






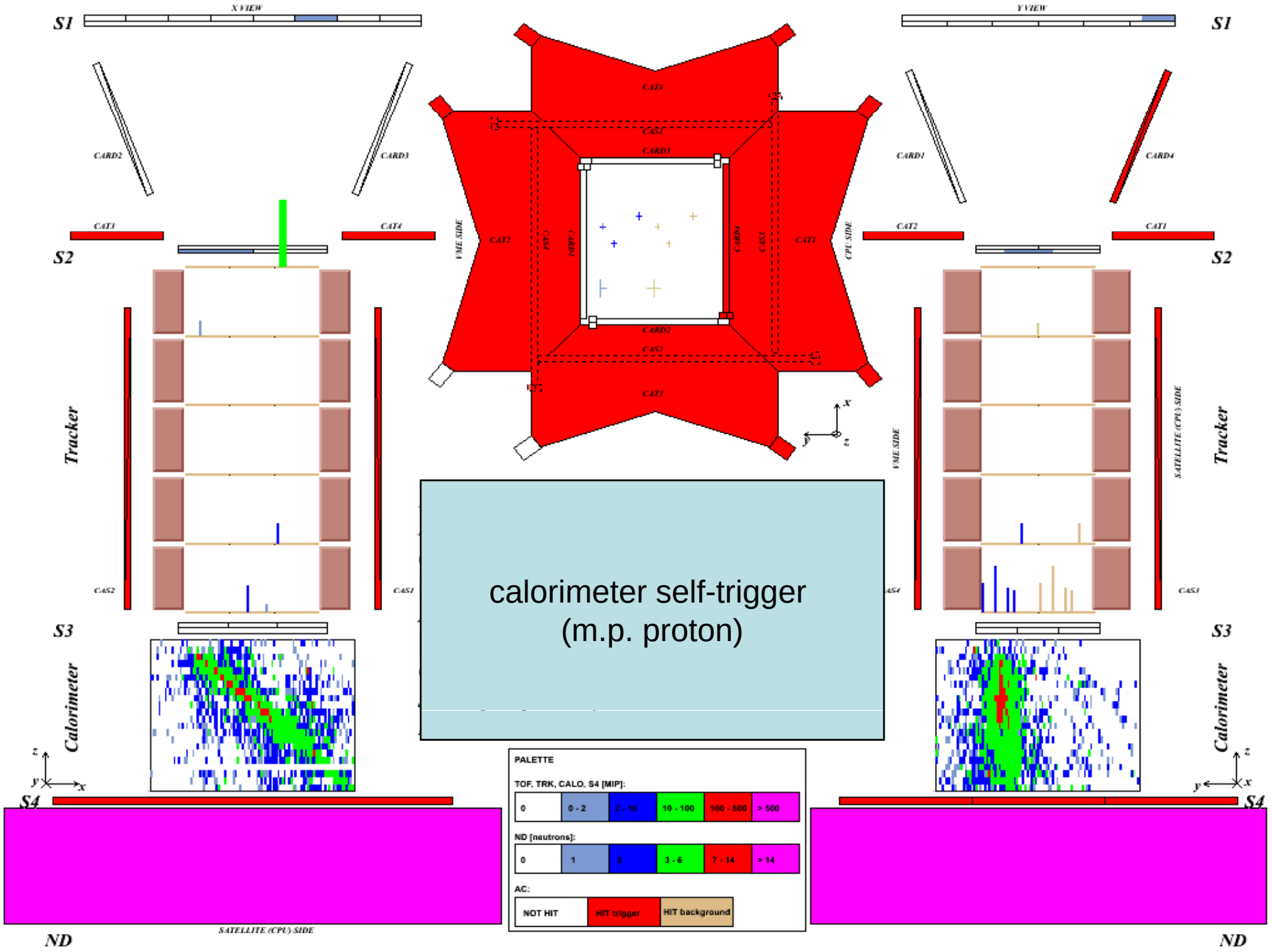
Many selection criteria provided by the calorimeter:

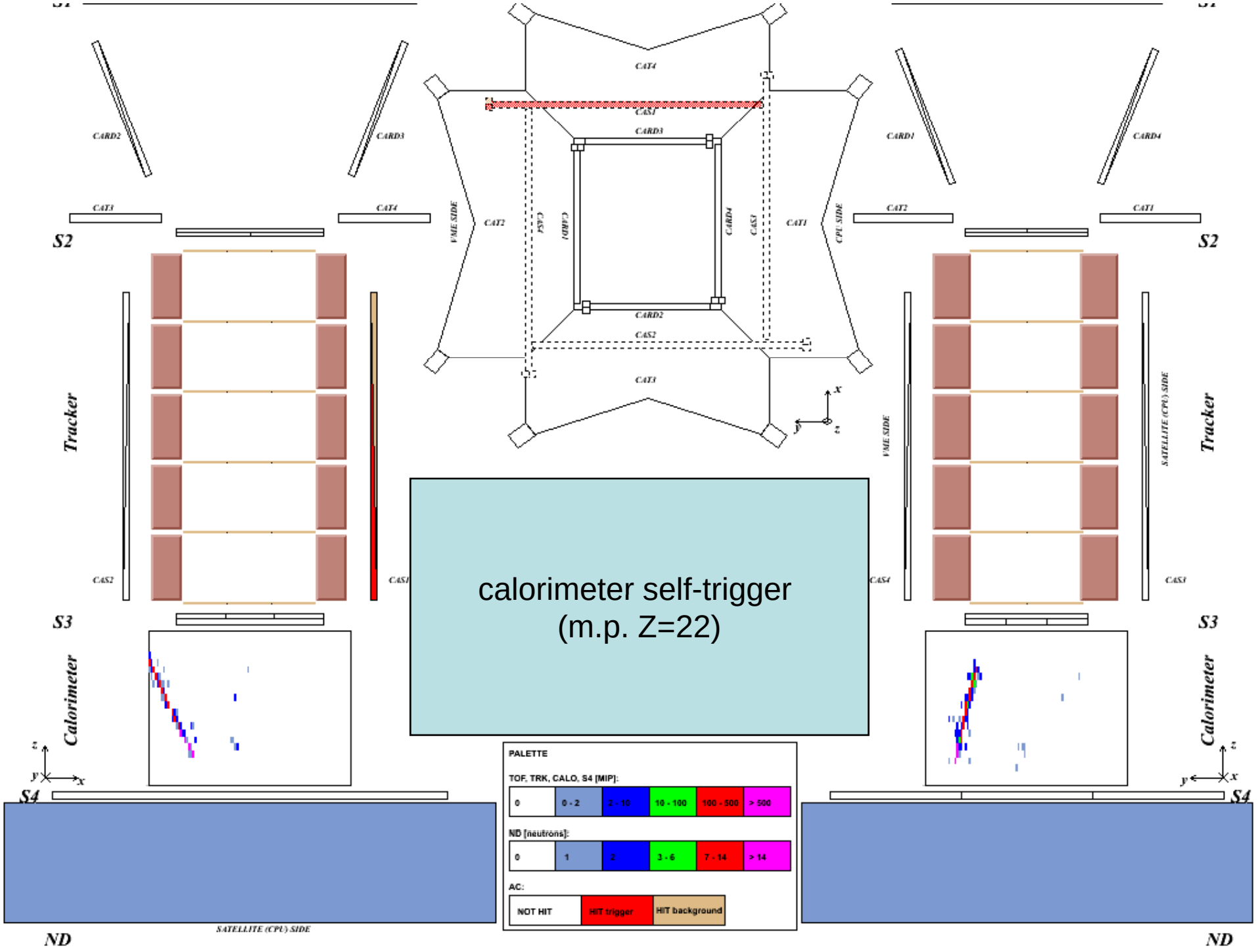
- total energy release
- longitudinal and later shower development
- shower topology
- …



calorimeter self-trigger
(m.p. electron)

GF: 21.5 ---> ~600 cm^2 sr


S1
X VIEW
Y VIEW
S1
CARD2
CARD3
CARD1
CARD4
CAT3
CAT4
CAT2
CAT1
S2
S2
VME SIDE
CPU SIDE
CAT4
CAS1
CARD3
CAT2
CARD1
CARD4
CAS4
CAS3
CAT1
CARD2
CAS2
CAT1
Tracker
Tracker
CAS2
CAS1
CAS4
CAS3
SATELLITE (CPU) SIDE
VME SIDE
S3
S3
Calorimeter
Calorimeter
S4
S4
ND
ND
SATELLITE (CPU) SIDE
calorimeter self-trigger
(m.p. 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


CAT4
CAS1
CARD3
CARD2
CAT3
CAT4
CAT2
CAT1
CARD1
CARD4
VME SIDE
CPU SIDE
CARD4
CAS3
CARD1
CAS4
CARD2
CAS2
S2
S3
S4
Tracker
Calorimeter
SATELLITE (CPU) SIDE
ND
calorimeter self-trigger
(m.p. Z=22)
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

Conclusions

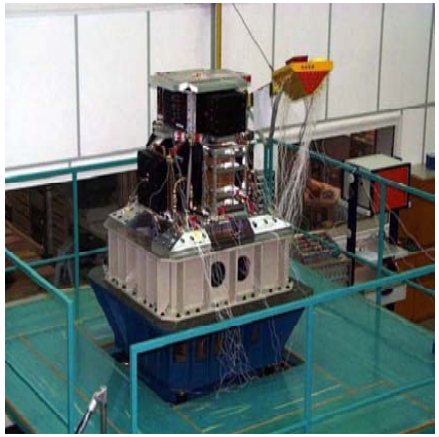
- PAMELA is in continuous data taking mode since 11th July 2006
- Detectors are performing nominally
- Analysis is in progress

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

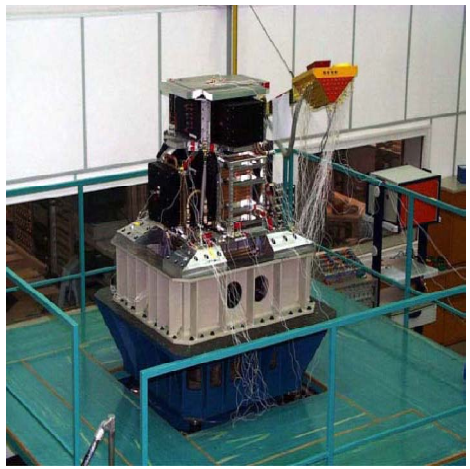
Spares

Mechanical Model

- Same geometry of FM (dimensions, mass, spacecraft attachment points, etc.)
- Mechanical qualification test:
  - Aug 2002 @ IABG Laboratories
    - Same vibration spectra and mechanical loads during rocket launch (amplified)
  - May 2003 @ TsSKB-Progress Testing Center.
    - transport, vibration and shock test whilst integrated into pressurized container



Mechanical Model

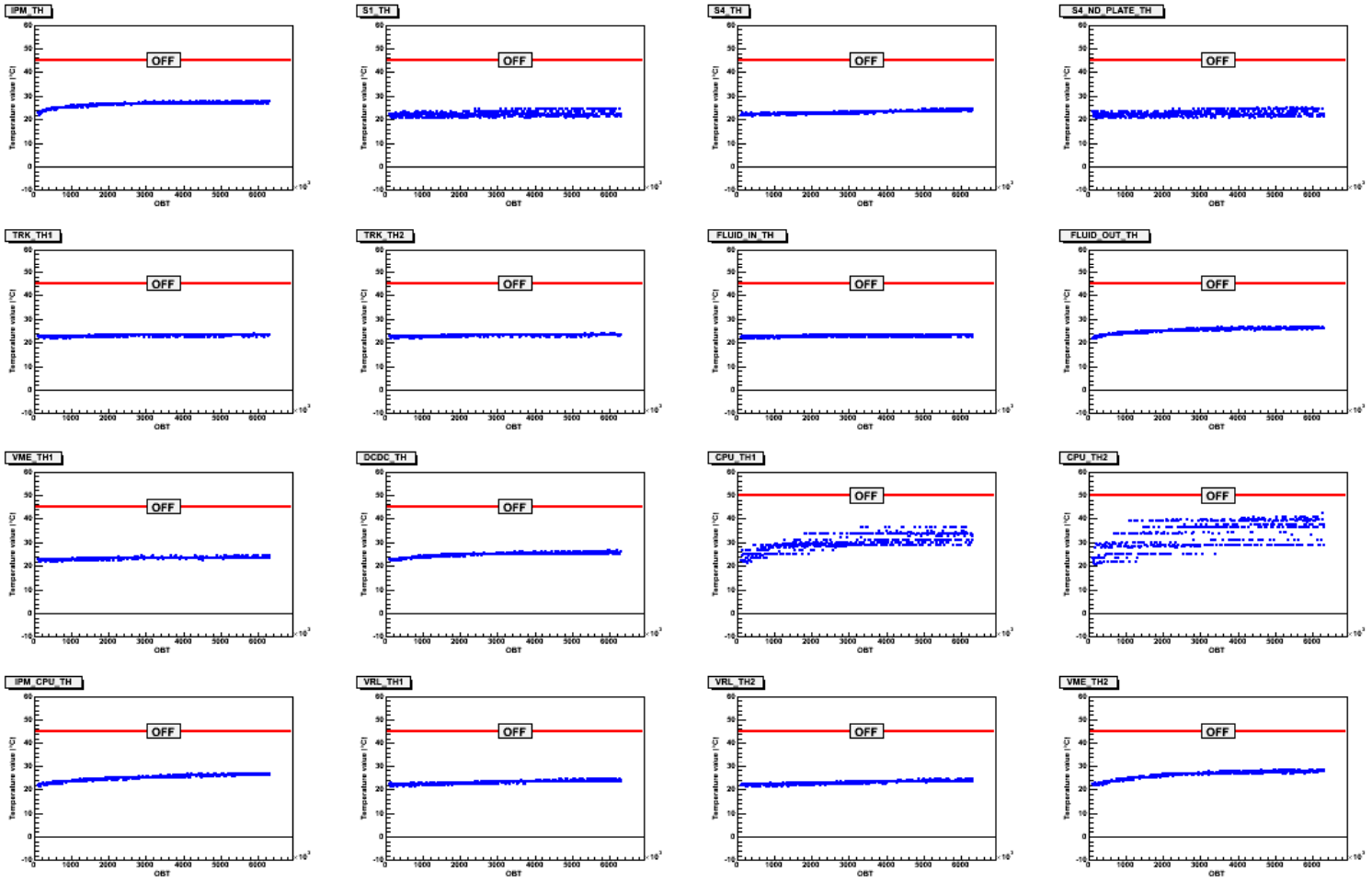


- Same thermal behavior of FM (surface characteristics, heat releases, etc.)
- Design limits: 5°C ÷ 40°C
- Thermal qualification test:
  - May 2003 @ TsSKB-Progress Testing Center.
    - over-heating, over-cooling and transient modes

Technological Model

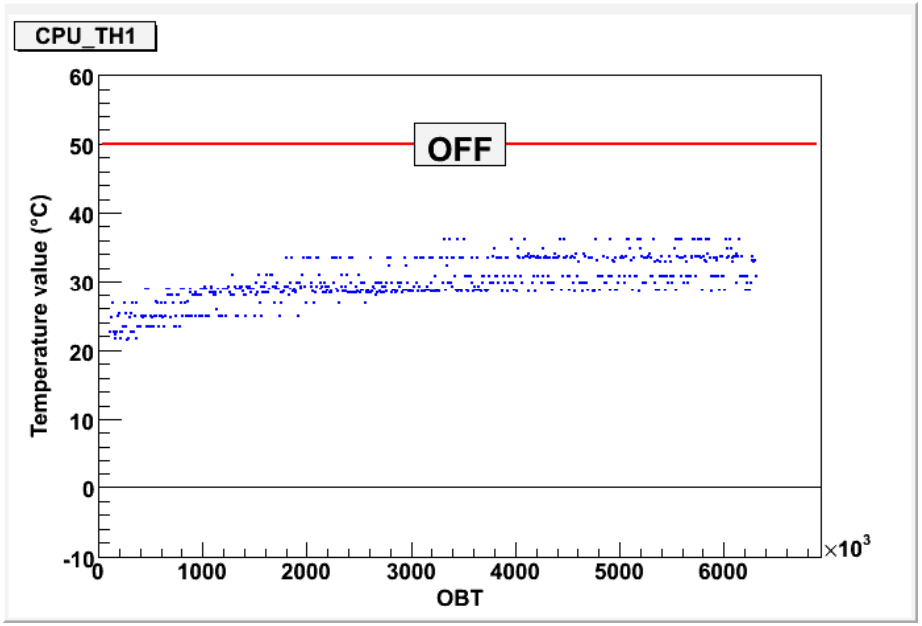
- Same as FM (electrical connections, electronics boards, magnetic field, etc.) but dummy detectors
- Electrical tests:
  - Dec 2003 @ INFN Rome
    - (emulated-) satellite communication interface through adapter
    - powering procedures
  - May-Oct 2004 @ TsSKB-Progress Testing Center.
    - full integration into the satellite

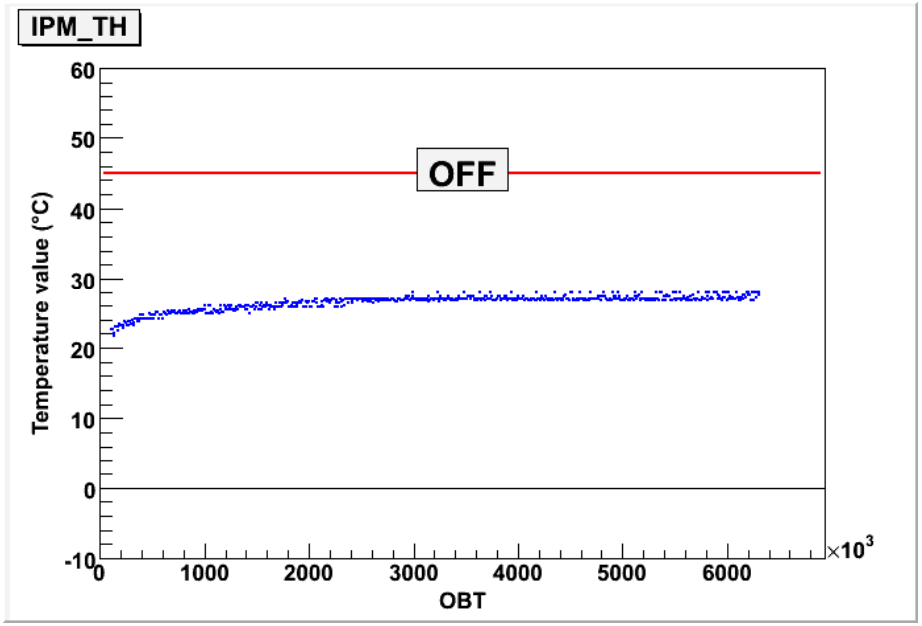
Temperature



First PAMELA power ON in space

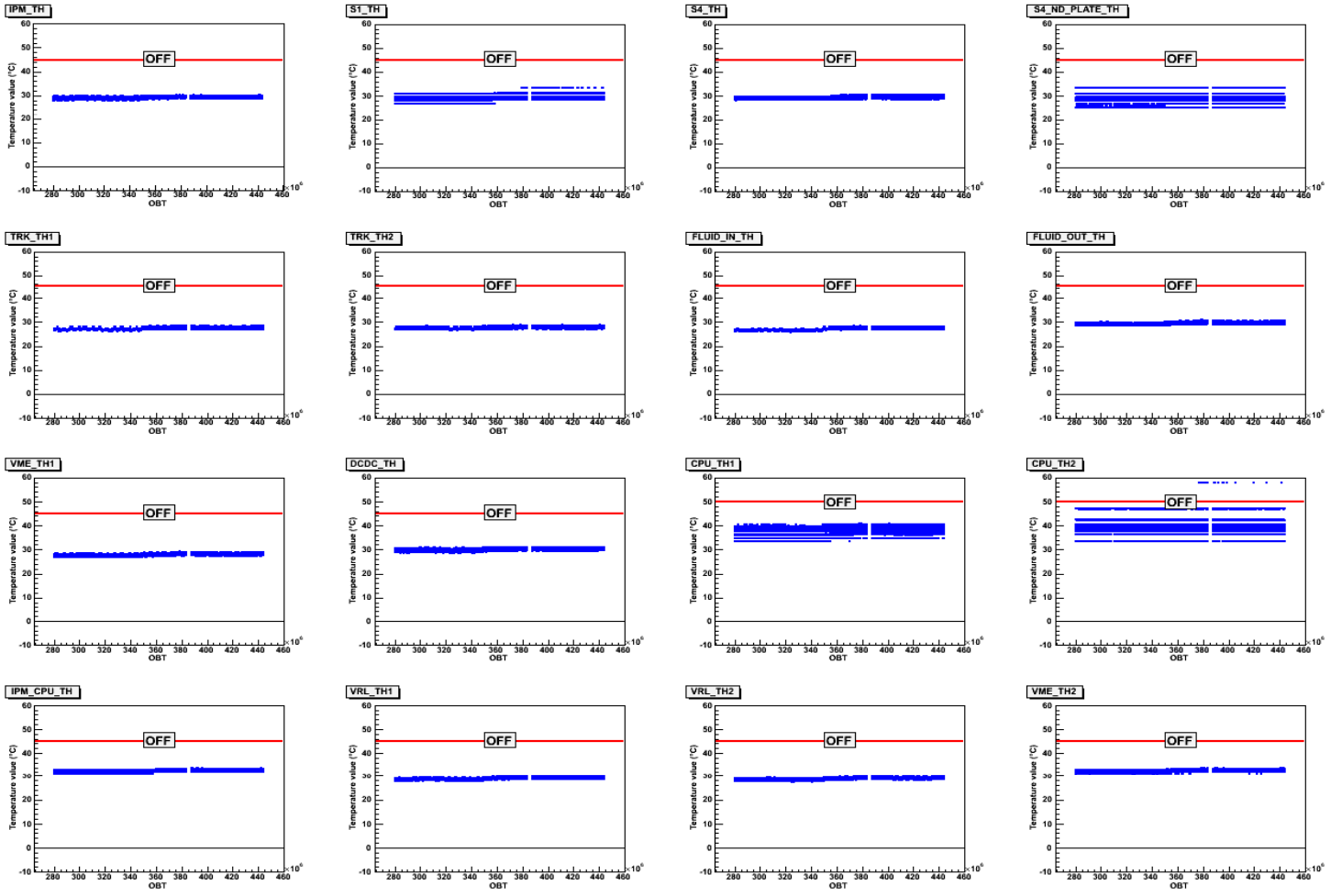
Temperature





First PAMELA power ON in space

Temperature



Orbits 1720÷1749 (~44h) - 5÷7 Oct 2006

On-line operations

- Running operations (scientific functionality)
  - Detector initialization, calibration and acquisition
- Slow Controls (housekeeping)
  - Cyclic checks of alarms, voltage and temperature sensors, status of the electronic boards
- Alarms

  On-line operations can lead to error/alarm conditions (over-temperature, FE alarms eg. lacth-up etc..)
- Recovery
  - System reset
  - Power OFF/ON
- Download to satellite mass memory

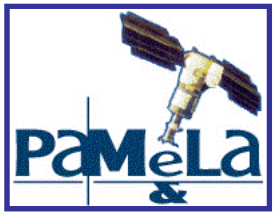
Remote control

- Macrocommands: commands to PAMELA cpu (MCMDs) sent either by the satellite or from ground
  - System configuration (hundreds of modifiable parameters):
    - Acquisition (operative mode, trigger configuration…)
    - Detectors (compression parameters, PMT thresholds…)
    - Reaction to alarm
  - Calibration (ascending node)
  - Download to satellite mass memory
  - Boot/Shutdown
  - Patch to program
  - …
- Telecommands: hardware lines to handle power modules

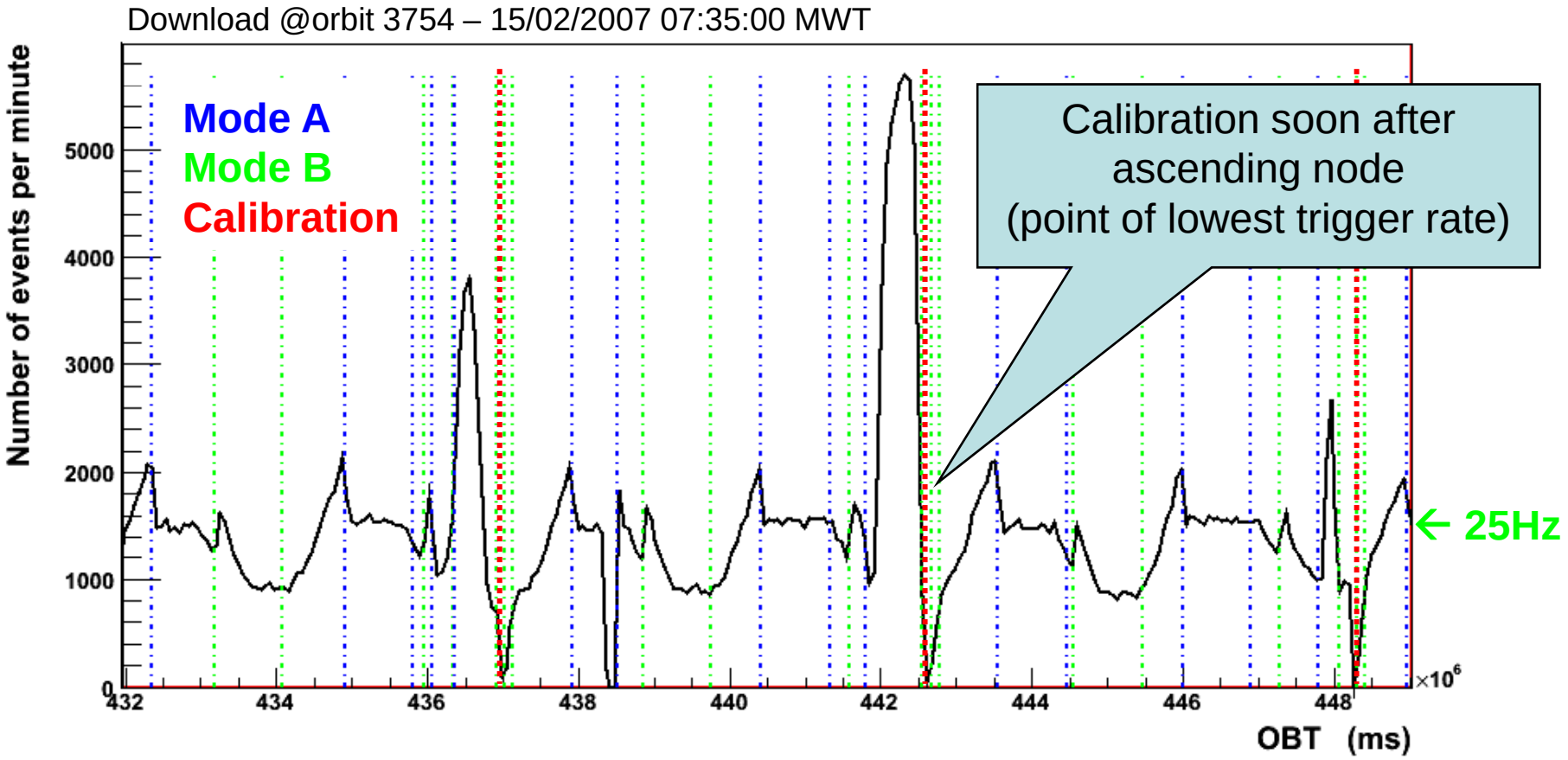
→ Extremely flexible system, designed to be easily adapted to space (unknown) conditions.

Acquisition

- Acquisition segmented in runs of fixed configuration.
  - Two ***acquisition modes***:
    - Mode A → high radiation environment
    - Mode B → low radiation environment
- Run duration and acquisition mode defined by the ***working schedule***.
  - Four working schedules
    - A→B when S1 counting rate exceed a given threshold
    - A→B at fixed time (relative to ascending node)
    - A→B according to a time table provided from ground
    - Always B and fixed time duration (default)

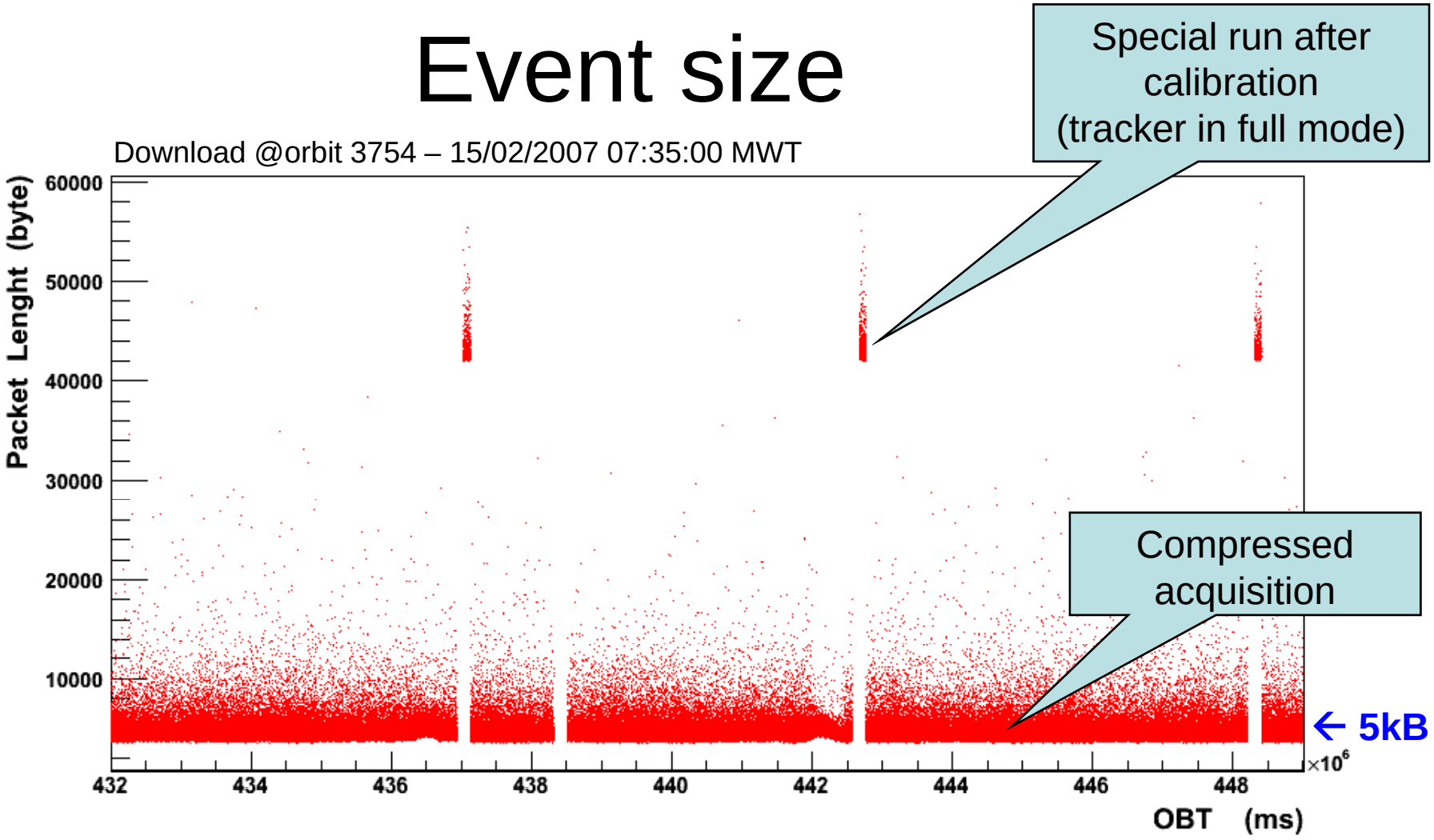


Trigger rate



- Mode A → (**S21** AND **S22**) AND (**S31** AND S**32**) + CALORIMETER
- Mode B → (**S11** OR **S12**) AND (**S21** OR **S22**) AND (**S31** OR S**32**) + CALORIMETER

Event size



25 Hz x 5 kB/ev ~ 10 GB/day

Dead/Live time