

# Antimatter and Dark Matter research with PAMELA Space Mission

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(on behalf of Pamela collaboration)

DISCRETE'08

Valencia, 15 December 2008

Our present understanding  
does not forbid a  
Baryon Symmetric Universe

$\text{antiM}/\text{M} < 10^{-5}$  in  $10^{-8}$  of the Universe  
(if well mixed in the gas systems)



The observed M-antiM asymmetry  
is a LOCAL phenomenon

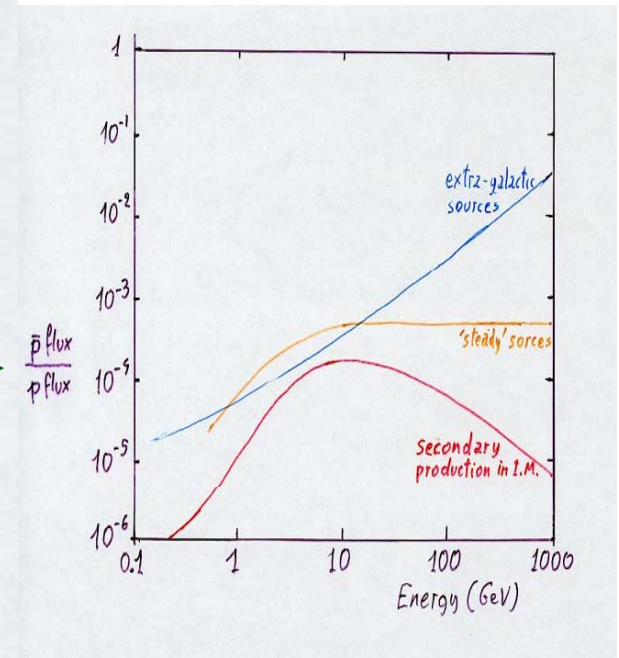
# Antimatter in the Cosmic Radiation

$e^+$  • Large background from many secondary sources

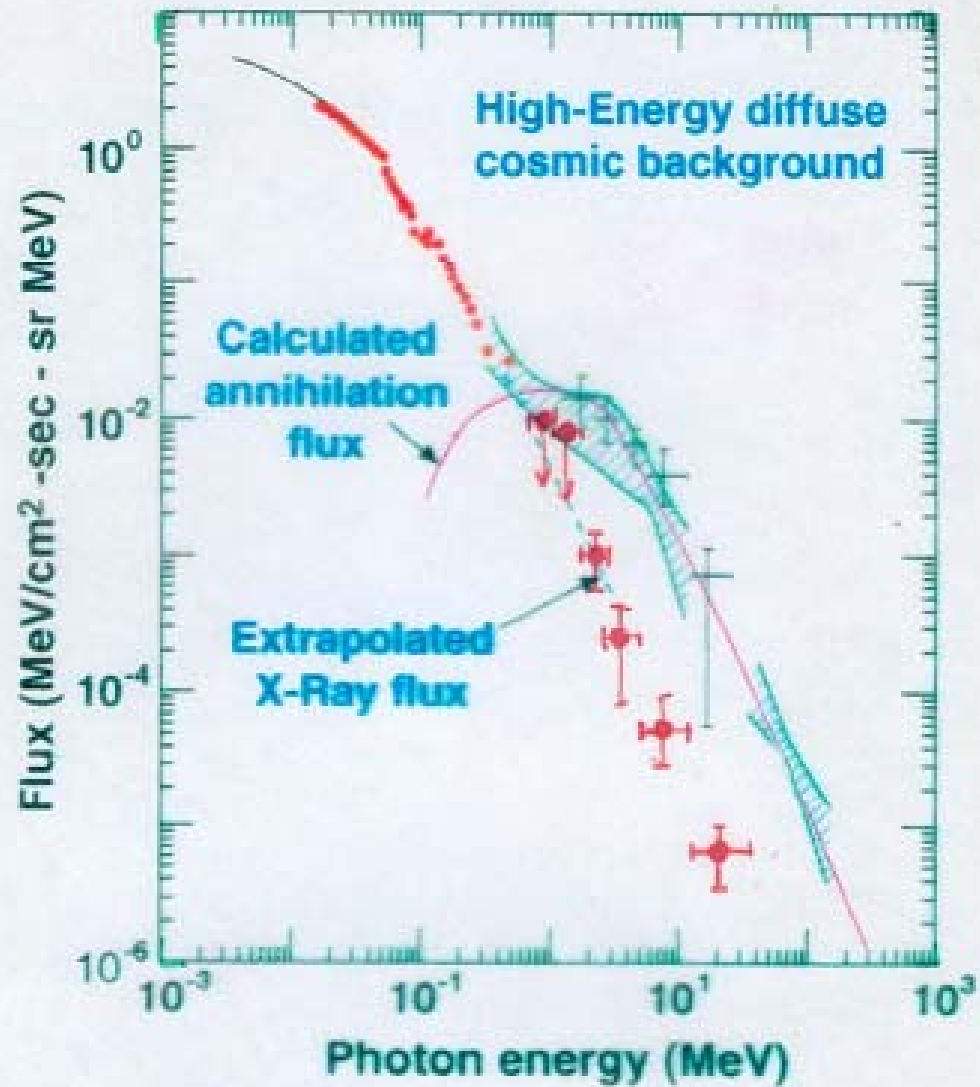
$\bar{p}$  • Relatively abundant  
• Large background (from  $p+ISM$ ) up to  $\sim 10$  GeV  
• Sensible probe at very high energies ( $\gtrsim 100$  GeV)

$\bar{n}$  • NO idea of their abundance  
• NO background  
• however

• 'diffusive' long travel  
• Galactic modulation



high energy  
( $\rightarrow 100$  GeV/n)



COMPTEL experiment (ICRC 1995)

--- Experimental summary:

- The “MeV bump” disappeared (in 1995)
- The  $p^-$  and  $e^+$  measured fluxes can be justified by production on ISM
- The search for  $N^-$  gave only upper limits

--- AT PRESENT:

**NO EXPERIMENTAL INDICATIONS  
FOR COSMOLOGICAL ANTIMATTER**

--- NEEDED:

**HIGHER ENERGIES (for  $p^-$ ,  $e^+$ ,  $N^-$ )  
CLEANER ENVIRONMENT ( $p^-$ ,  $e^+$  in space)**

--- WHAT FOR THE NEXT FUTURE?? :

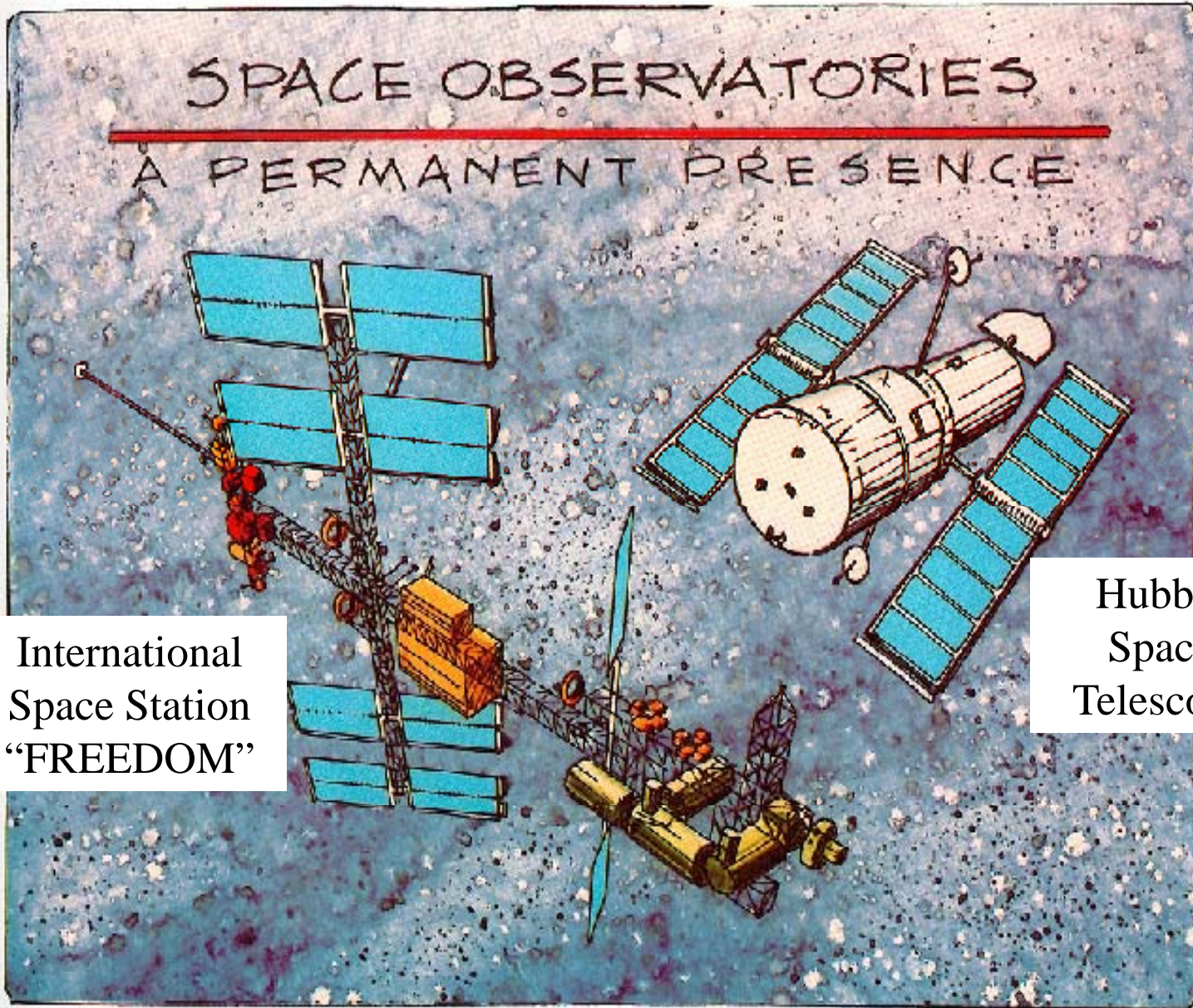
BESS by LDB flights ( $p^-$  exotic,  $N^-$ )  
PAMELA on satellite ( $p^-$ ,  $e^+$ ,  $N^-$ )  
AMS-02 on ISS ( $N^-$ ,  $p^-$ ,  $e^+$ )

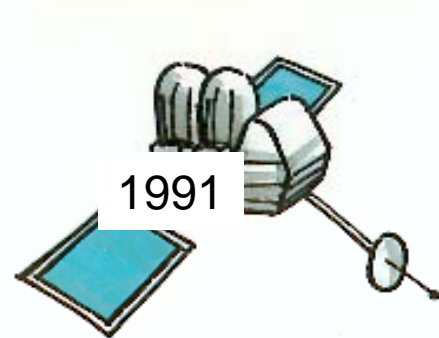
# SPACE OBSERVATORIES

A PERMANENT PRESENCE

International  
Space Station  
"FREEDOM"

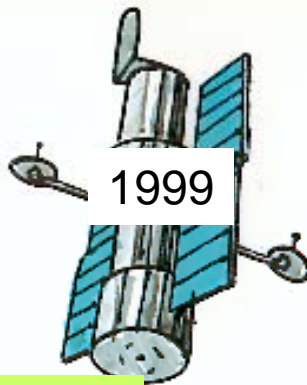
Hubble  
Space  
Telescope





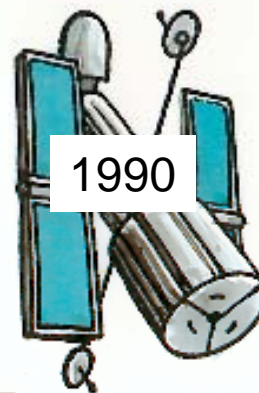
1991

**CGRO**



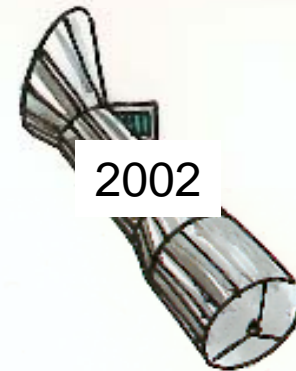
1999

**AXAF  
(CXO+  
XMM)**



1990

**HST**



2002

**SIRTF**

# THE GREAT OBSERVATORIES

FOR SPACE ASTROPHYSICS

1999

**Advanced  
Composition  
Explorer  
(ACE)**

**Heavy Nuclei Collector (HNC)**

and

**Particle-Accelerator  
Superconducting Magnet  
(SAMAG)**

**CANCELLED**

facilities

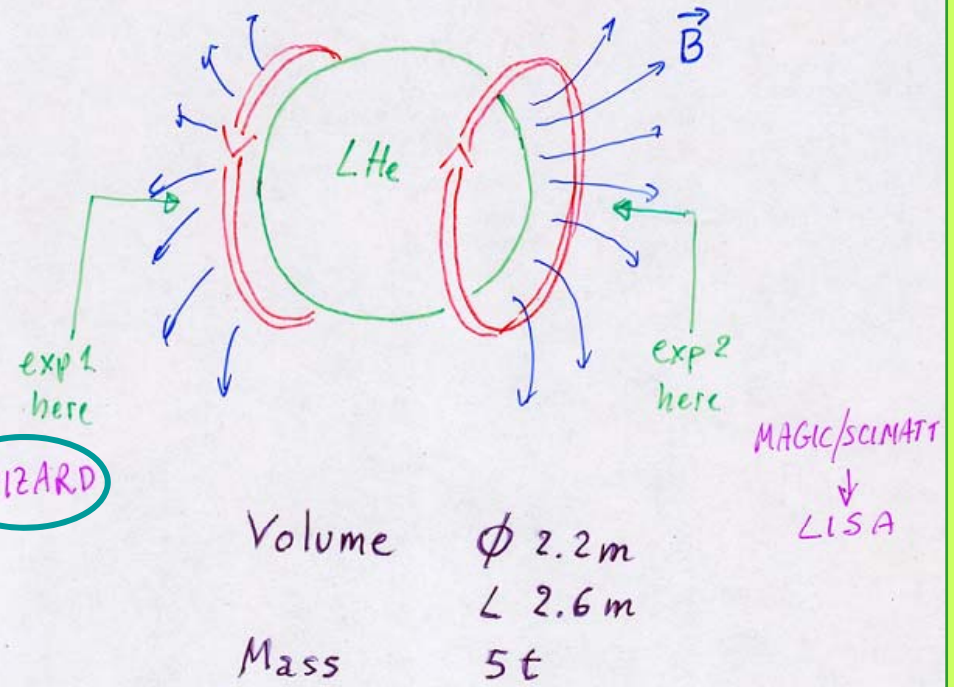
on board of the Freedom SS

+

**Very Long Base  
Interferometer  
(VLBI)**

**Experiments approved for the first phase of the ASTROMAG facility**

ASTROMAG:  
Magnetic system concept



main Physics objectives:

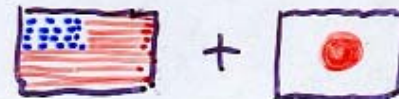
1)- Antimatter component in CR



2)- Isotopic spectra

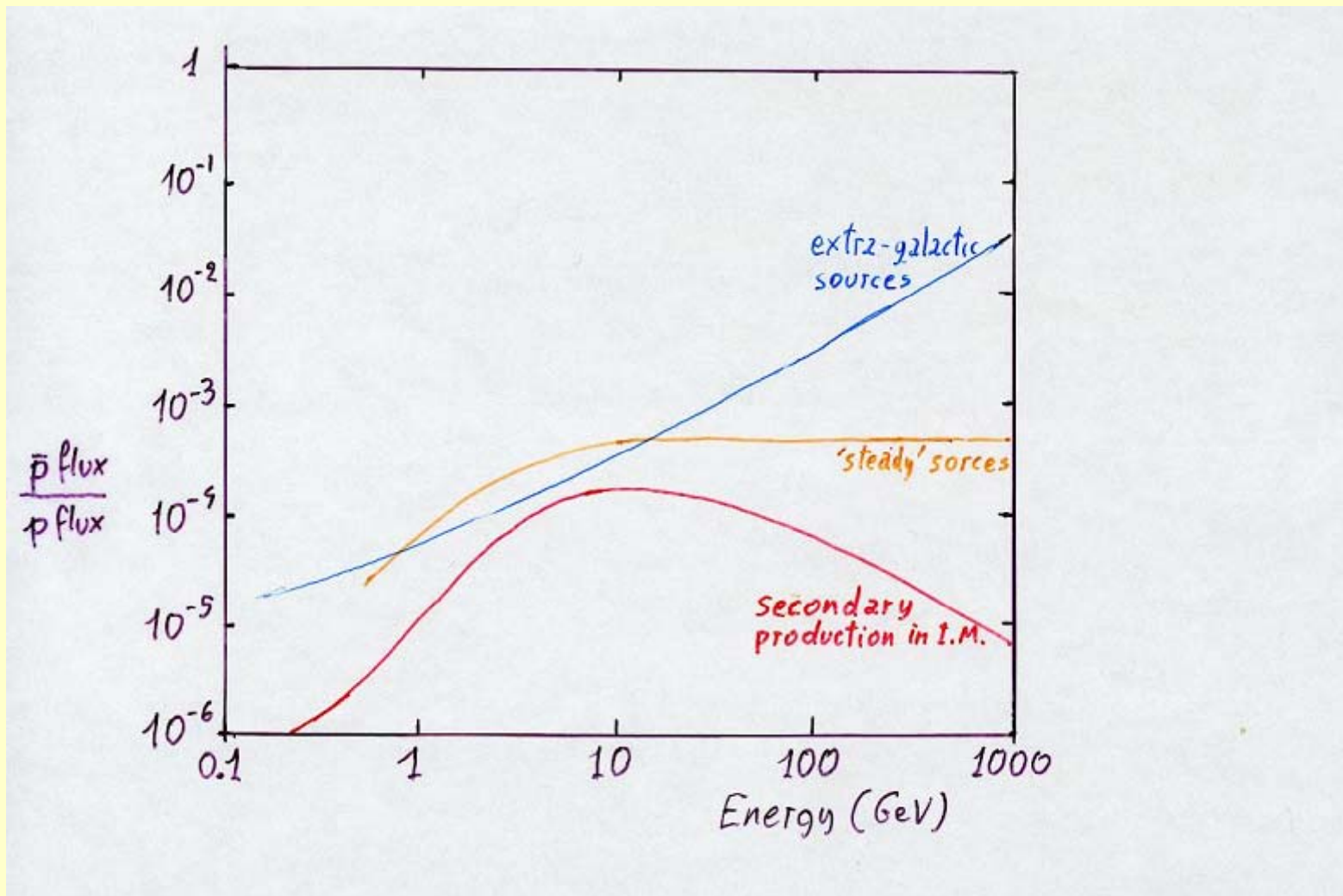


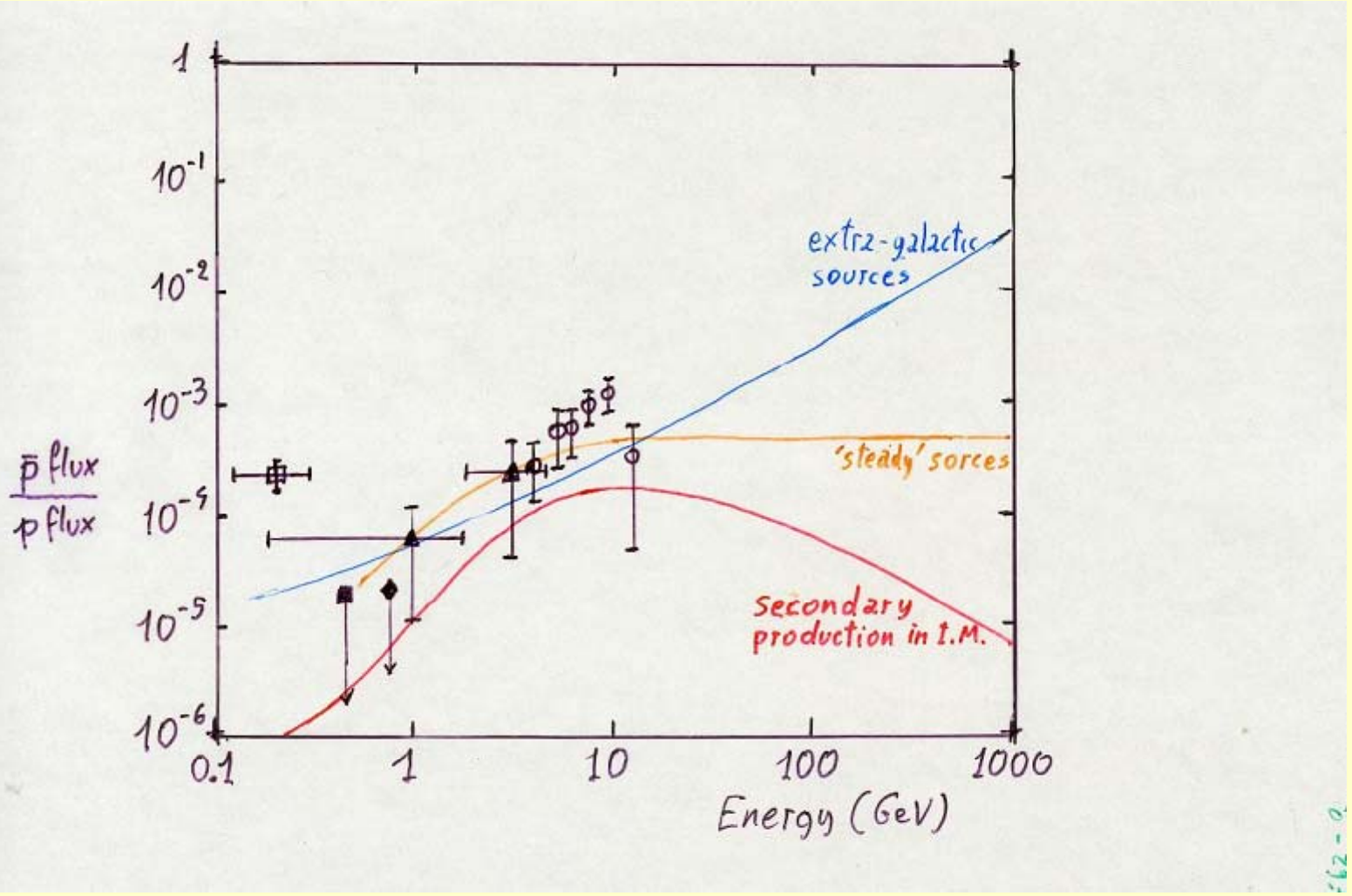
3)- Compositness up to  $10^{16}$  eV

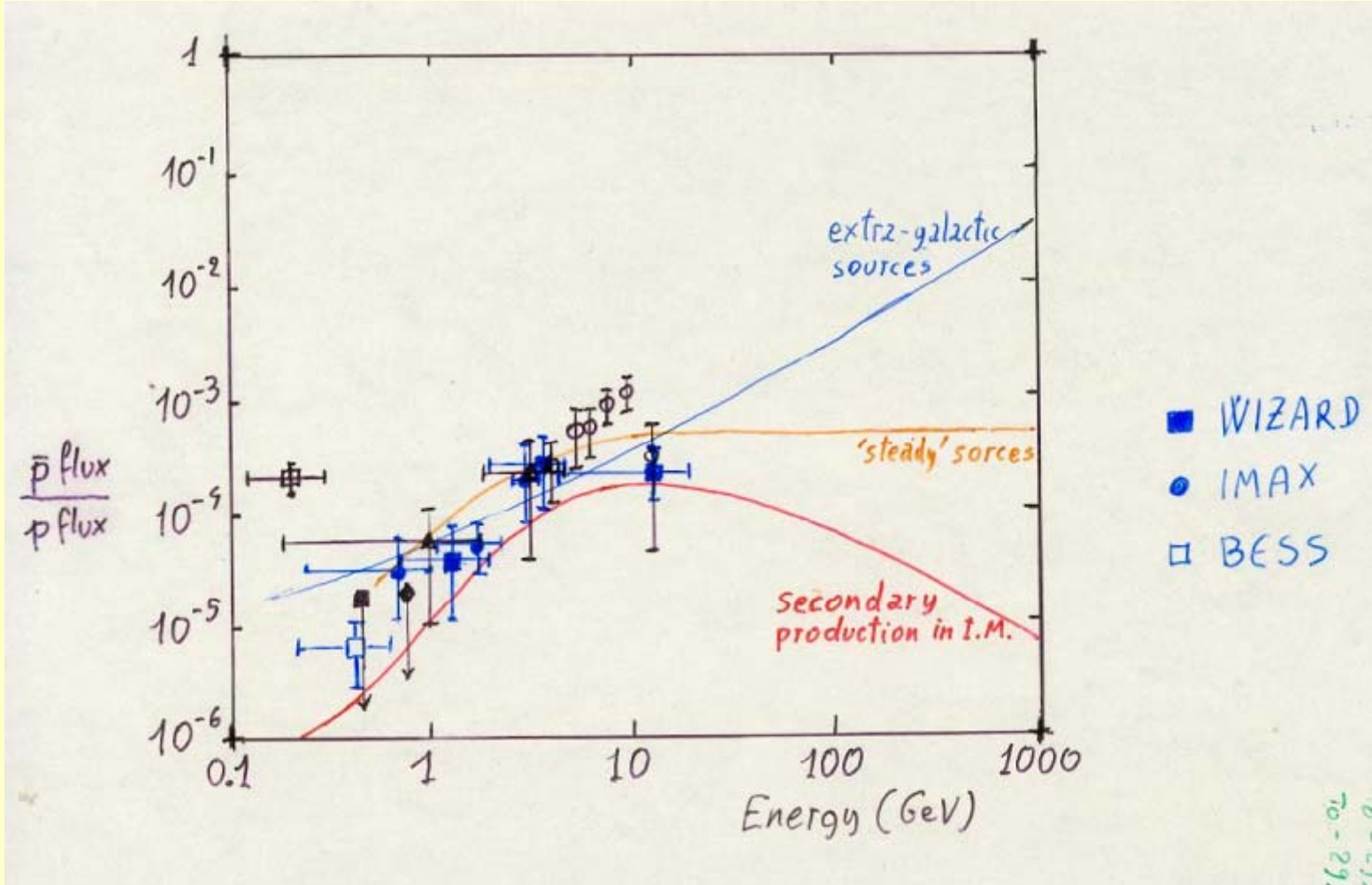


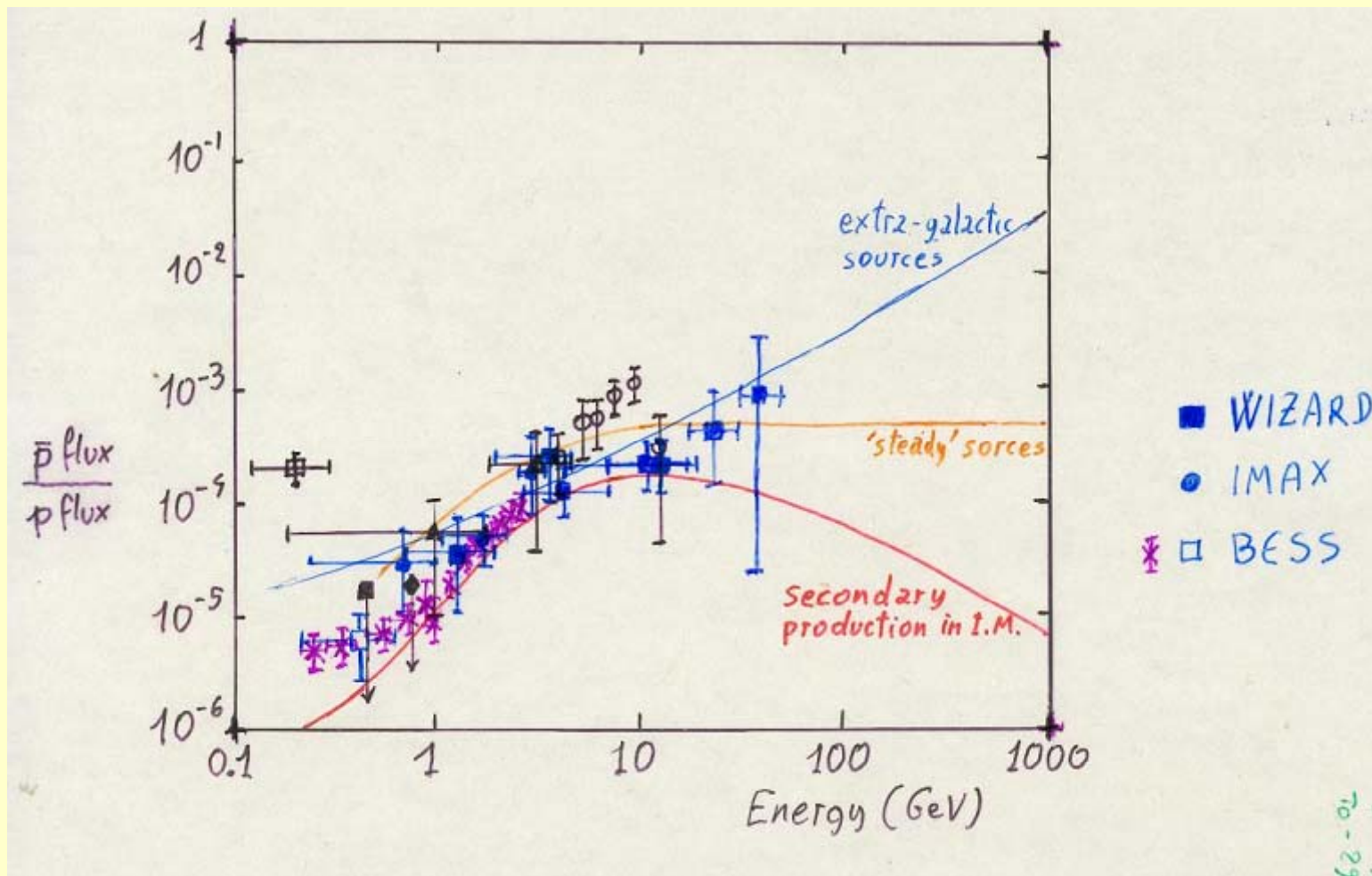
SCINATT LISA WIZARD



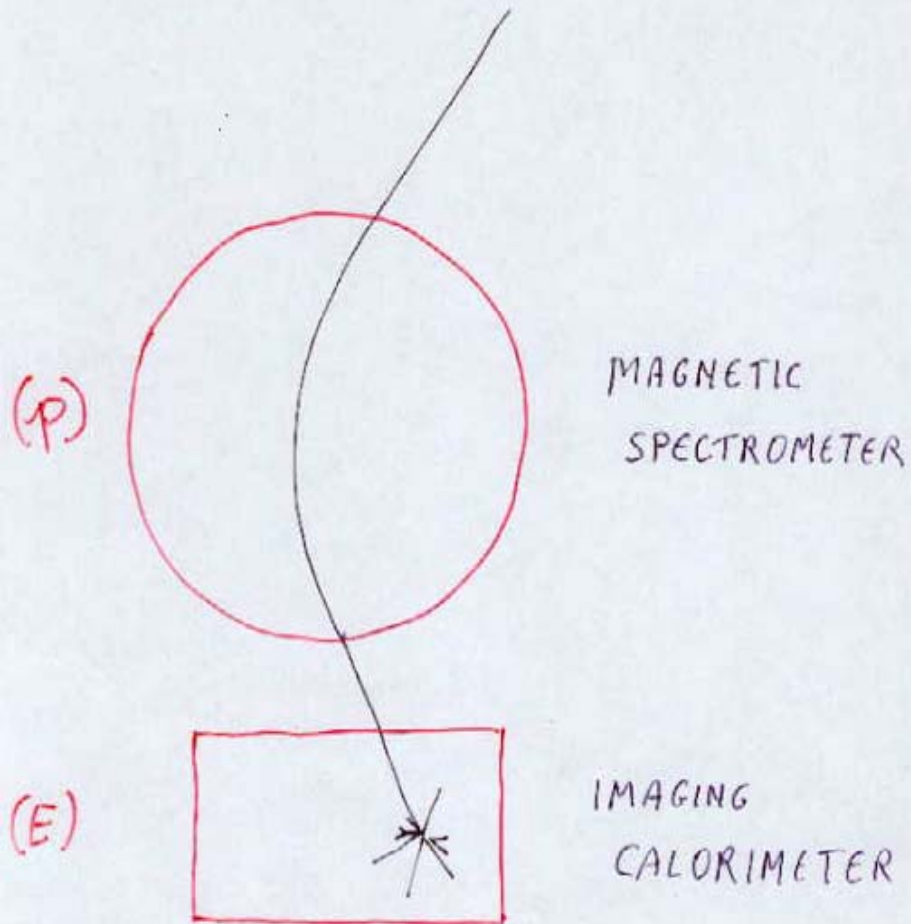




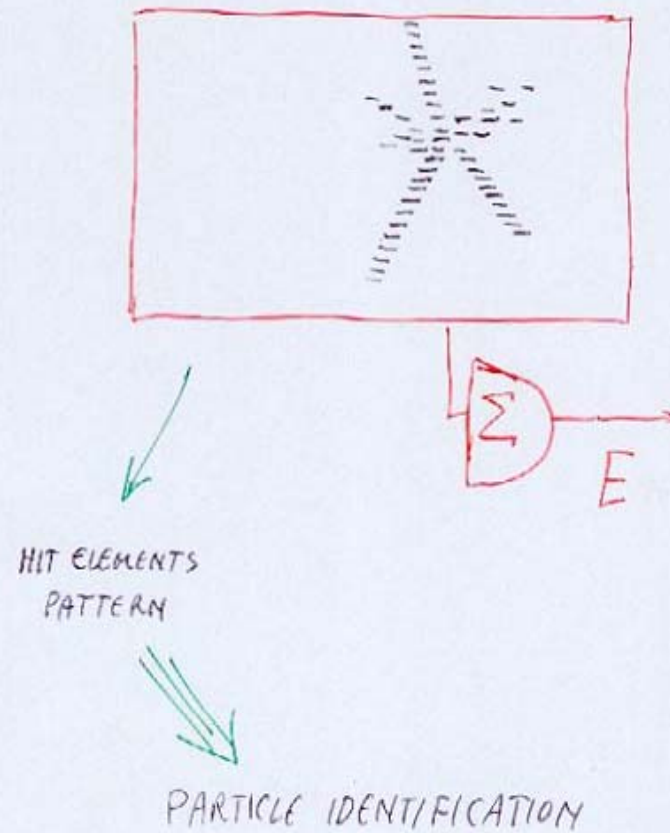




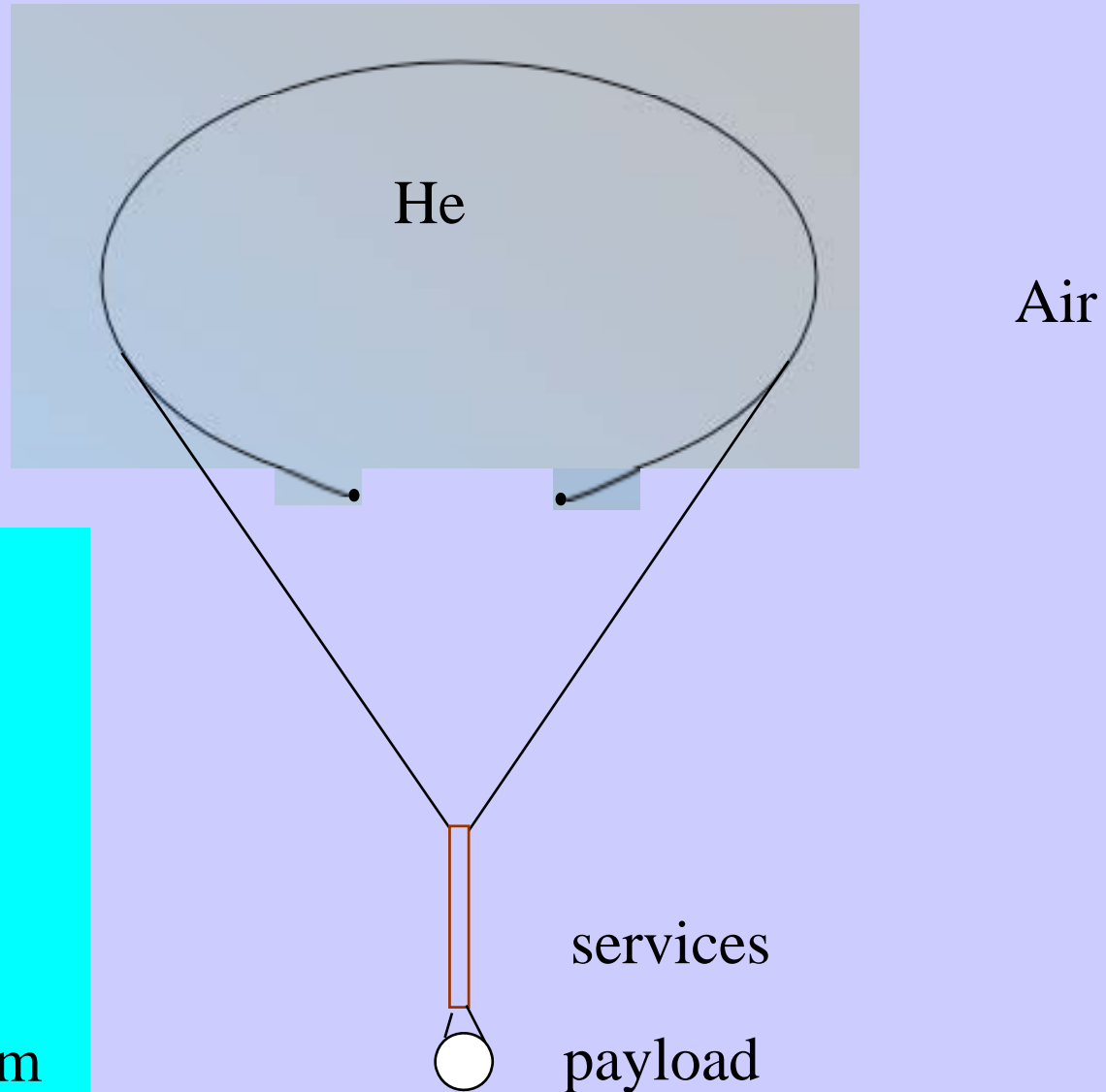
"IDEAL" SCHEME FOR HUNTING ANTIMATTER



IMAGING CALORIMETER



# Open balloons



## Class A balloons

2.8 Mm<sup>3</sup> @ 5 g/cm<sup>2</sup>

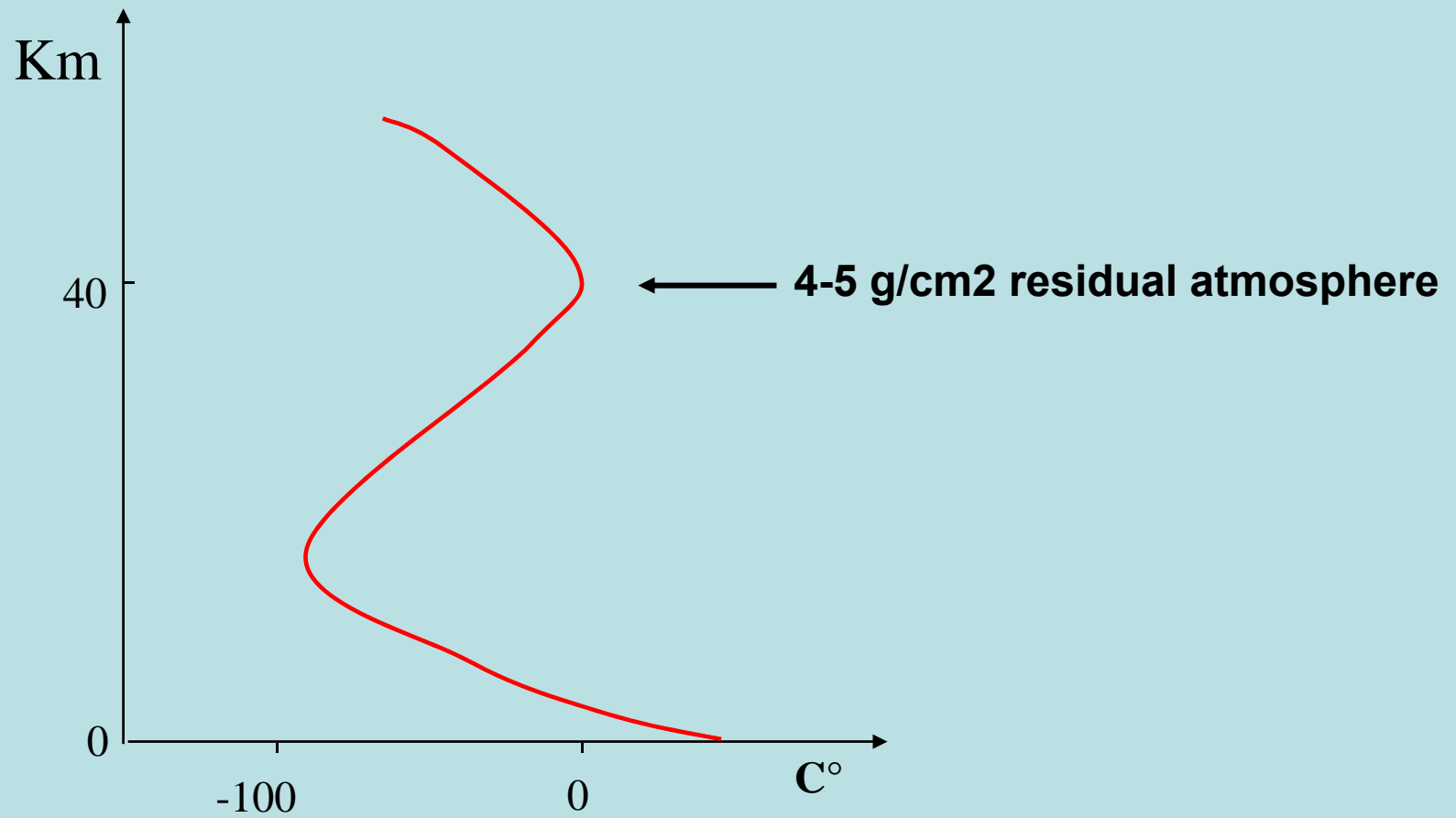
Lifting power ~ 11t

Balloon 5 t

services 3 t

payload 3 t @ 38÷40km  
(5g/cm<sup>2</sup> residual atm.)

# Atmospheric temperature versus Altitude



**‘open’ balloons:**

Volume @  $5\text{g/cm}^2 > 1 \text{ Mm}^3$

Very thin material ( $20\mu\text{m}$ ),

does not support pressure differences

Maximum load  $\approx 3 \text{ t}$

Line of sight (LOS)  $\approx 800 \text{ km}$

Typical duration of the flight 20 hours



It is necessary a:

# New Generation of Antimatter Researches in Cosmic Rays

[BESS + PAMELA + AMS]

# WiZard: → Russian Italian Missions (RIM)

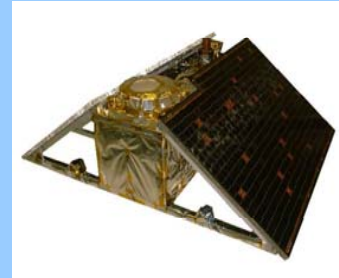
MASS-89, 91, TS-93,  
CAPRICE 94-97-98



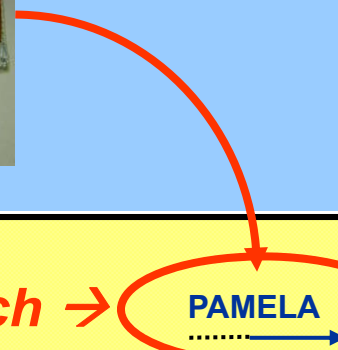
NINA-1



NINA-2



PAMELA



M 89

M 91

TS 93

C 94

C 97

C 98

← Antimatter search →

PAMELA

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

*Life Science*  
*Solar physics*

SILEYE-1

NINA-1

NINA-2

Alteino-SILEYE-3

LAZIO-SIRAD

SILEYE-2

ALTEA-SILEYE-4



SILEYE-1



SILEYE-2



ALTEINO:  
SILEYE-3



LAZIO  
SIRAD



ALTEA:  
SILEYE-4

# Wizard Collaboration



KUNGL  
TEKNISKA  
HÖGSKOLAN



## for PAMELA expt

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<sup>9</sup> II University and INFN, Roma-Tor Vergata (Italy)

<sup>10</sup> [Ioffe Physical Technical Institute \(Russia\)](#)

<sup>11</sup> [Moscow Engineering and Physics Institute, Moscow \(Russia\)](#)

<sup>12</sup> Siegen University, Physics Department, Siegen (Germany)

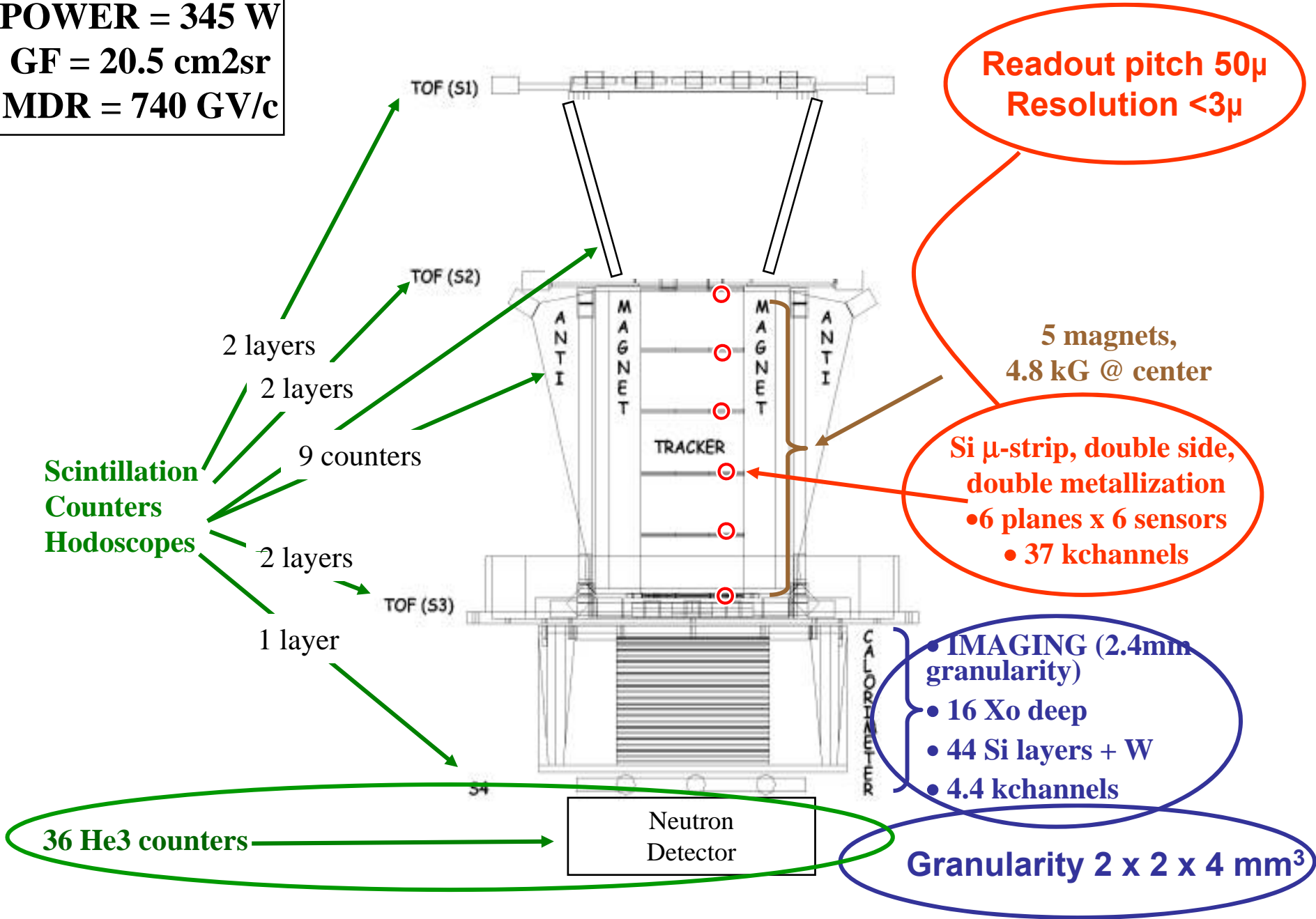
<sup>13</sup> Tata Institute of Fundamental Research, Bombay (India)

<sup>14</sup> Particle Astrophysics Laboratory, NMSU, Las Cruces (USA)

<sup>15</sup> Istituto di Ricerca Onde Elettromagnetiche CNR, Firenze (Italy)

<sup>16</sup> [University and INFN, Napoli \(Italy\)](#)

**MASS = 480 kg**  
**POWER = 345 W**  
**GF = 20.5 cm<sup>2</sup>sr**  
**MDR = 740 GV/c**



# PAMELA



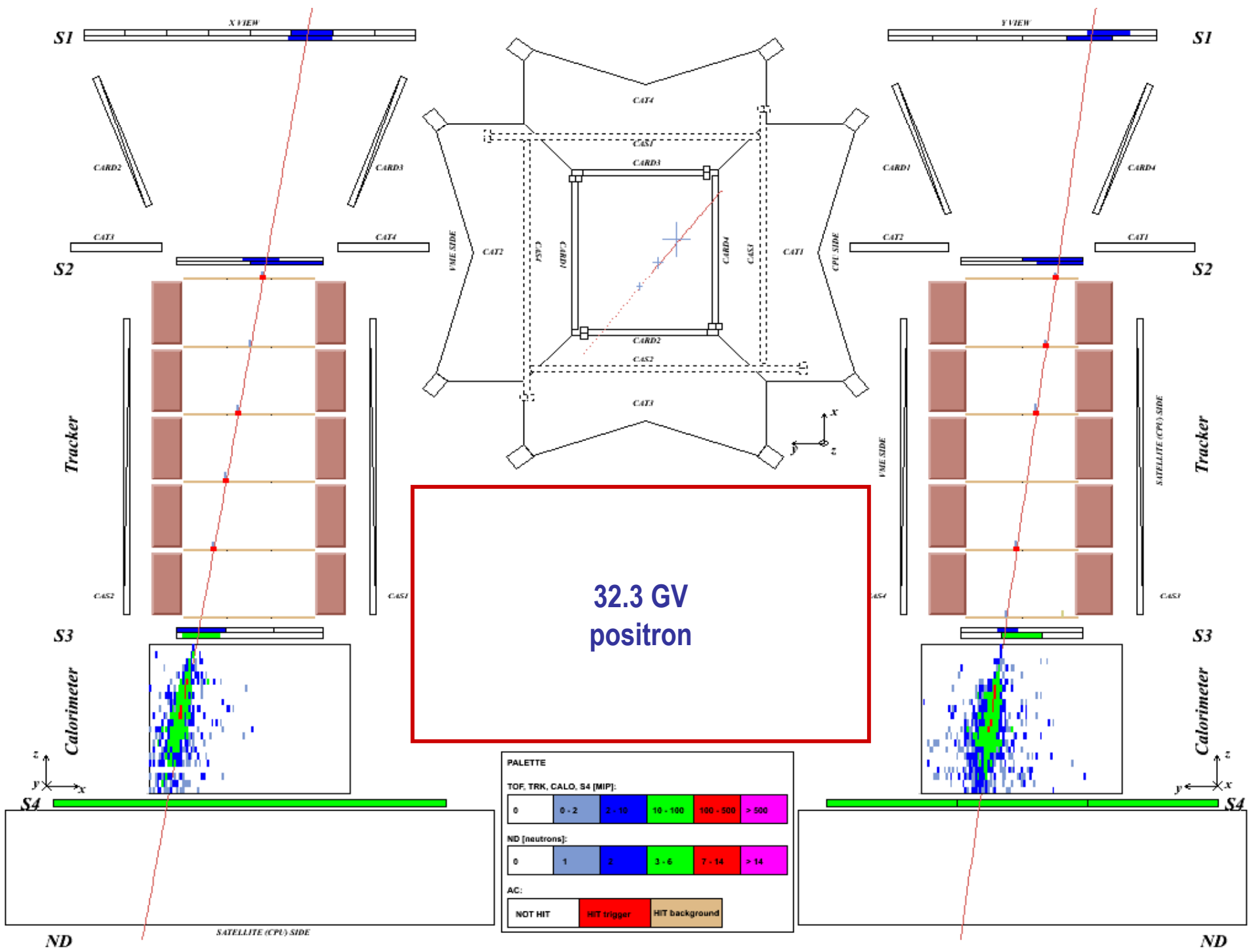
GF	20.5 cm <sup>2</sup> sr
Mass	480 Kg
Dimensions	120 x 40x45 cm <sup>3</sup>
Power Budget	345W

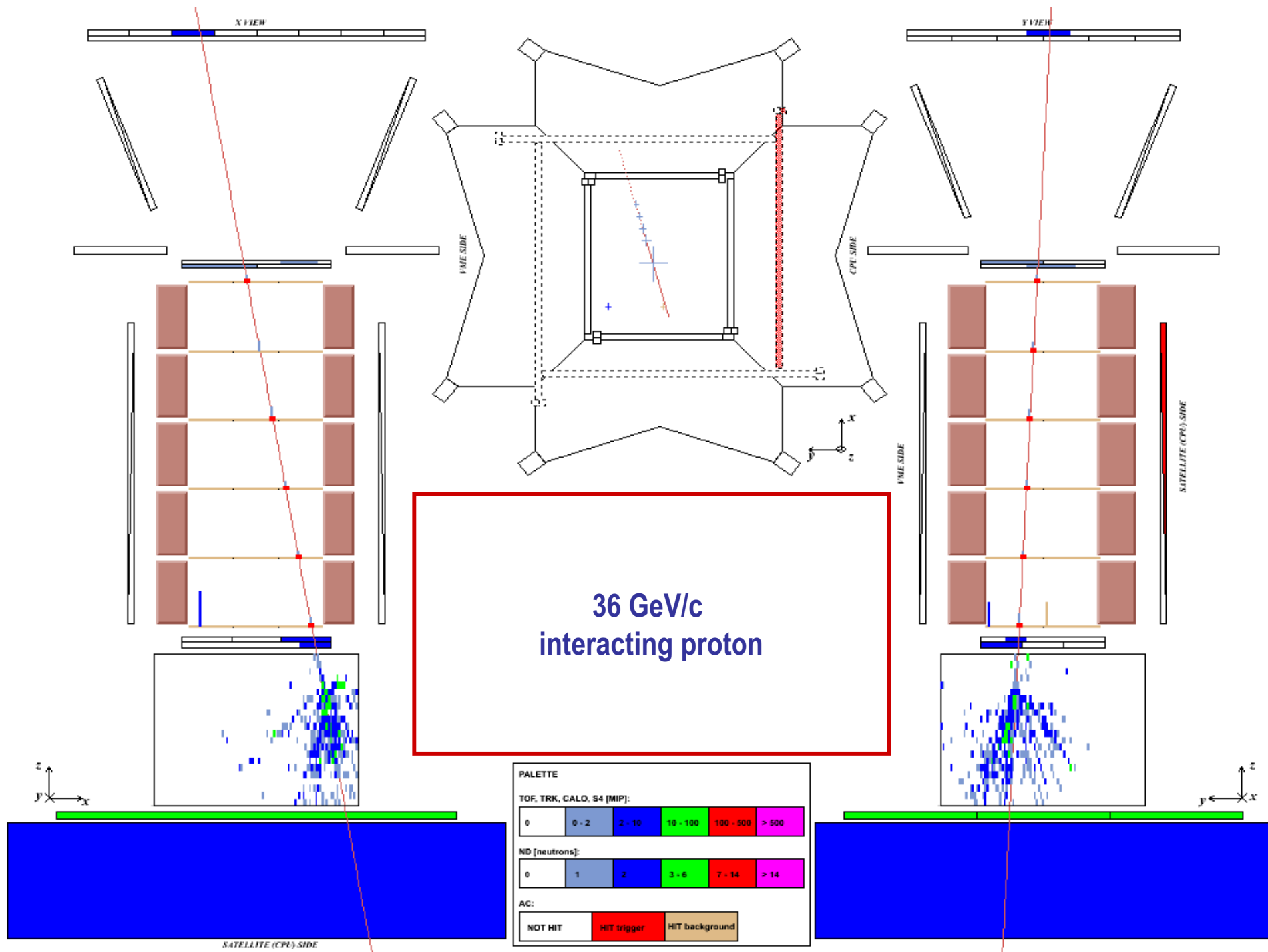
- Positrons 50 MeV - 270 GeV
- Antiprotons 80 MeV - 190 GeV
- Limit on antinuclei  $\sim 7 \cdot 10^{-8}$  (He /He)
  
- Electrons 50 MeV - 2TeV
- Protons 80 MeV - 700 GeV
- Nuclei  $< 300$  GeV/n ( $Z \leq 8$ )
  
- study of the solar modulation after the 23<sup>rd</sup> solar cycle maximum.

# PAMELA milestones

- **Launch from Baikonur: June 15<sup>th</sup> 2006, 0800 UTC.**
- **Power On: June 21<sup>st</sup> 2006, 0300 UTC.**
- **Detectors operated as expected after launch**
  
- **PAMELA in continuous data-taking mode since commissioning phase ended on July 11<sup>th</sup> 2006**
  
- **As of ~ now:**
  - **~600 days of data taking (~73% live-time)**
  - **~10 TByte of raw data downlinked**
  - **>10<sup>9</sup> triggers recorded and under analysis**







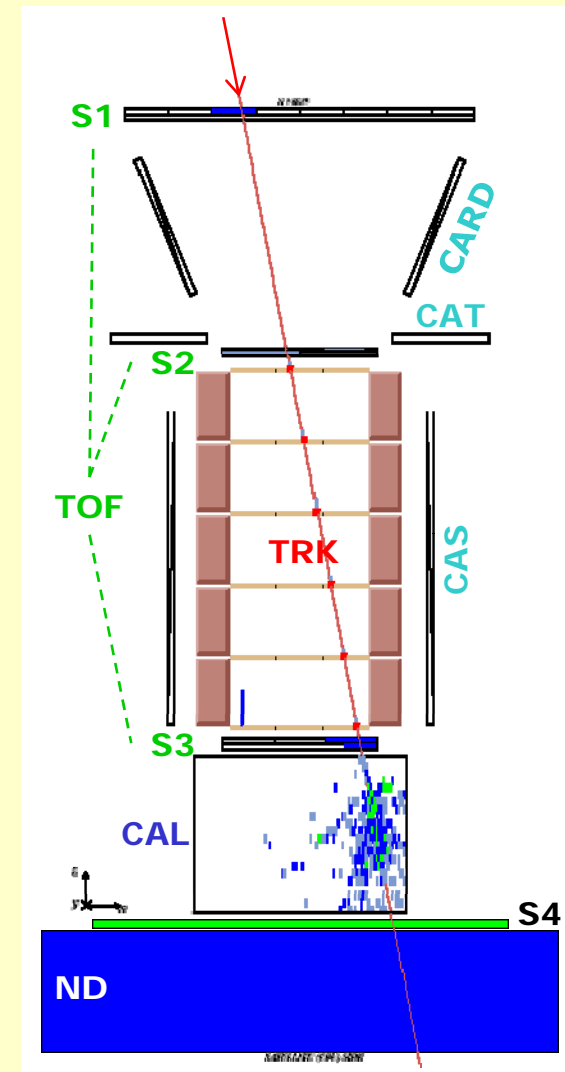


# High-energy antiproton analysis

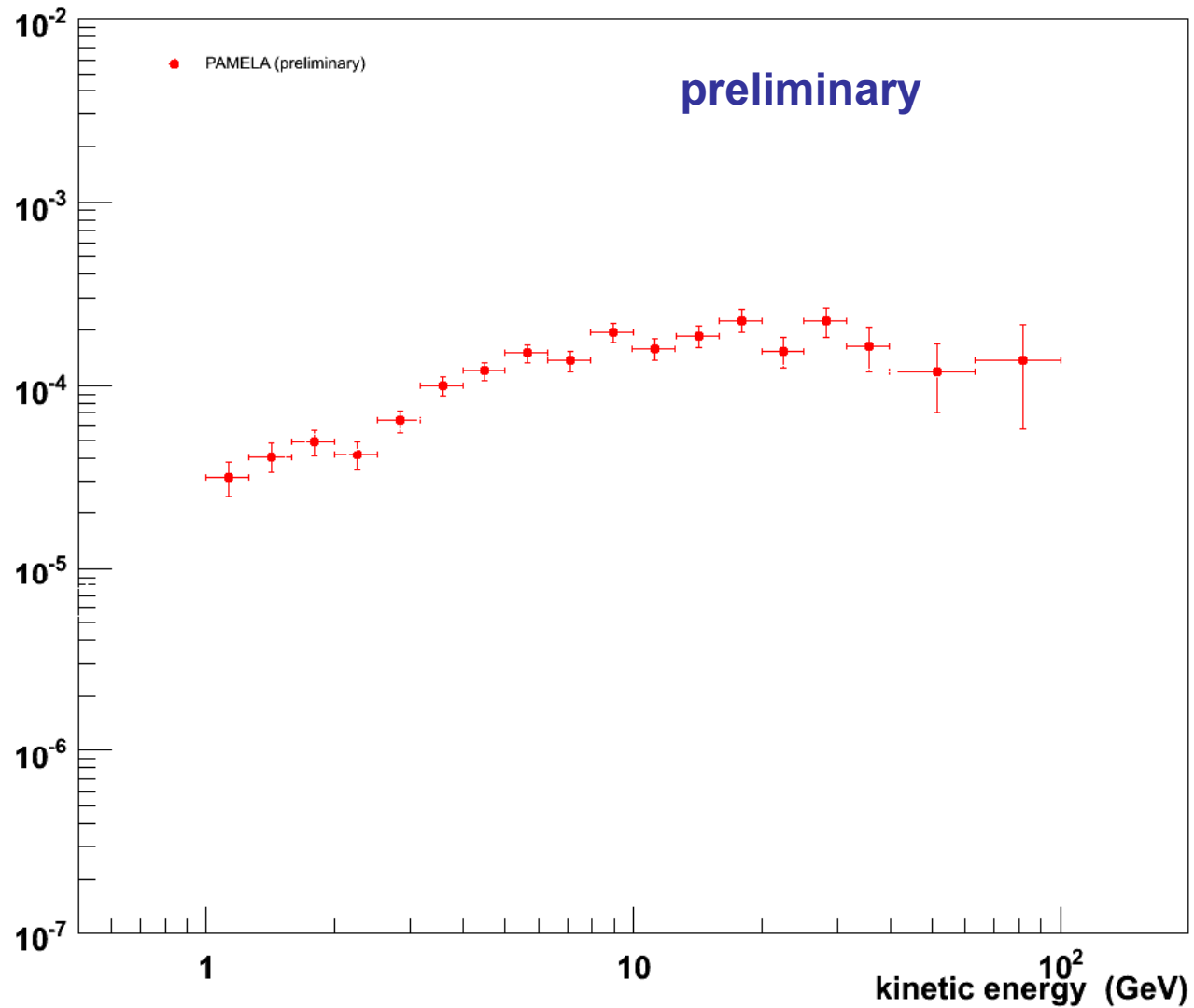
Event selected from 590 days of data

Basic requirements:

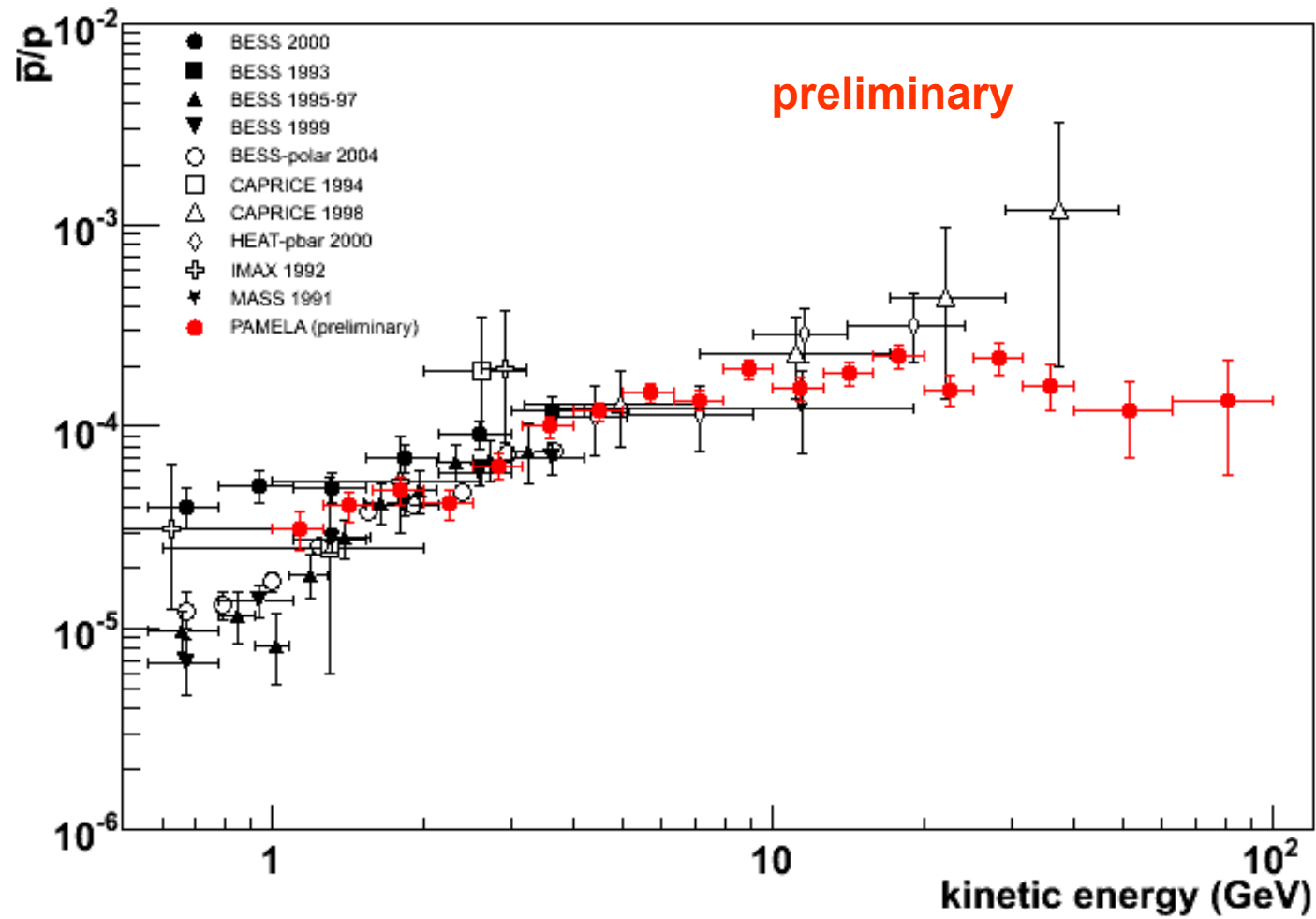
- **Clean pattern inside the apparatus**
  - single track inside TRK
  - no multiple hits in S1+S2
  - no activity in CARD+CAT
- **Minimal track requirements**
  - energy-dependent cut on track  $\chi^2$  (~95% efficiency)
  - consistency among TRK, TOF and CAL spatial information
- **Galactic particle**
  - measured rigidity above geomagnetic cutoff
  - Down-ward going particle (no albedo)



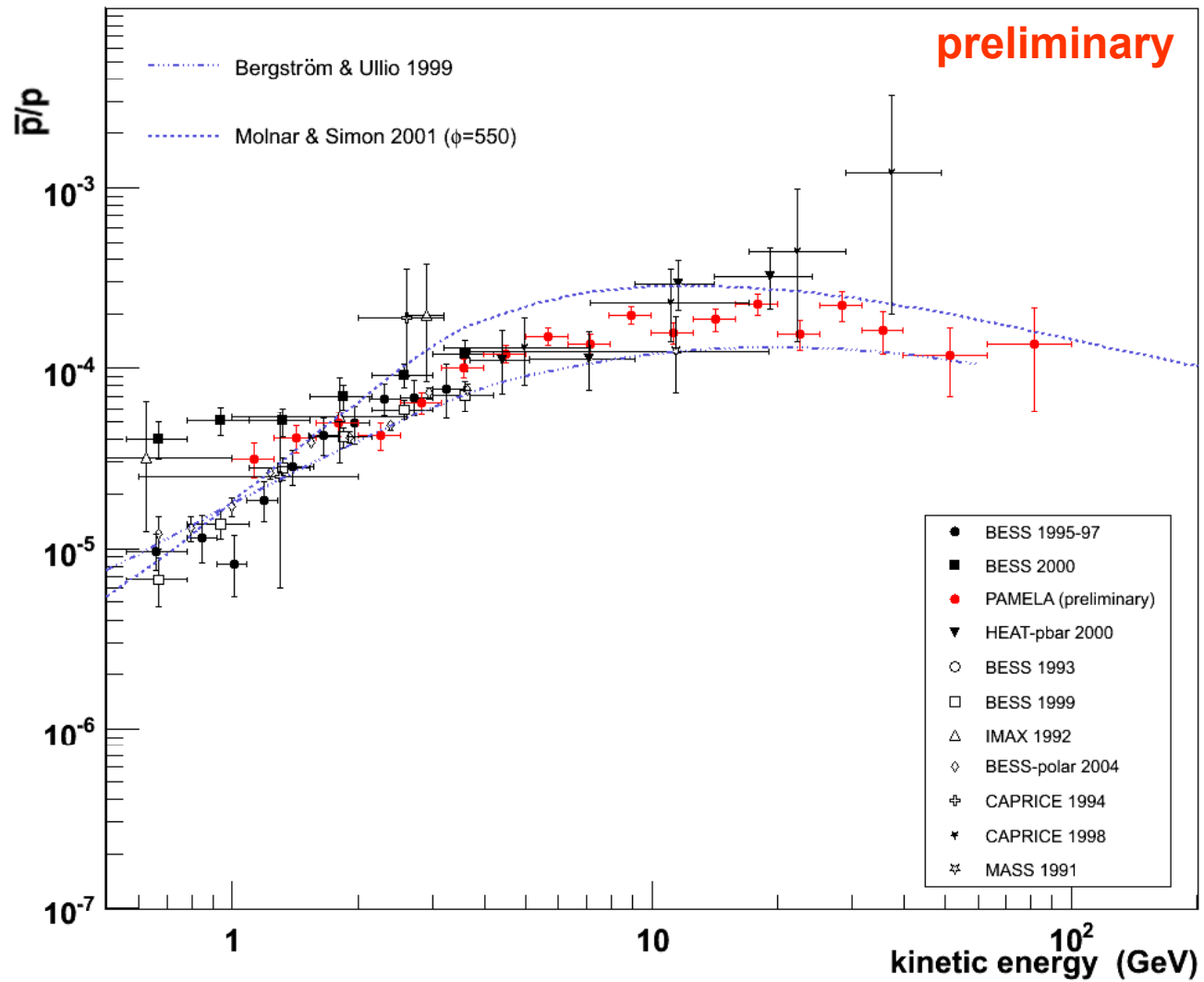
# PAMELA: Antiproton-Proton Ratio



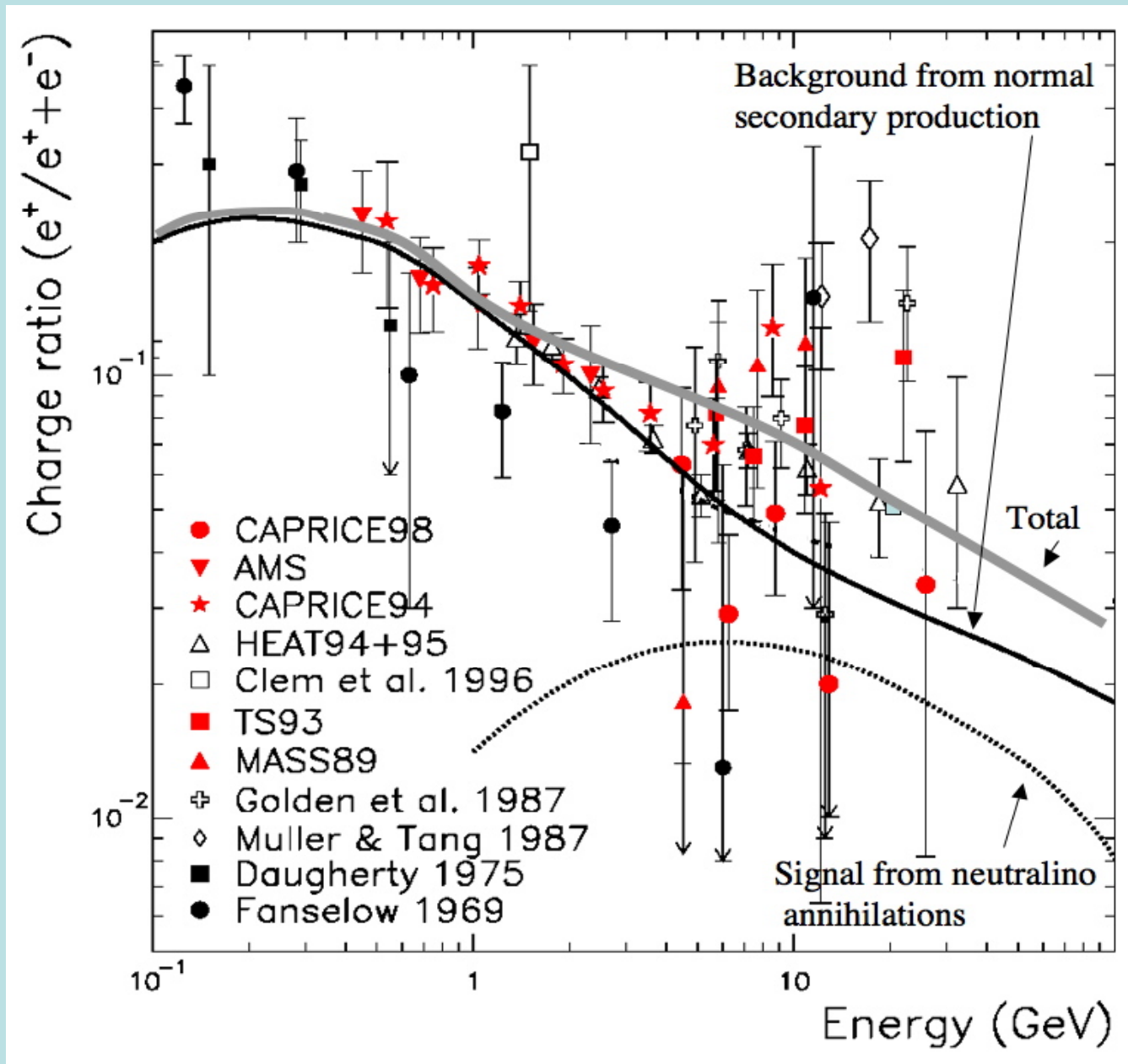
# PAMELA: Antiproton-Proton Ratio



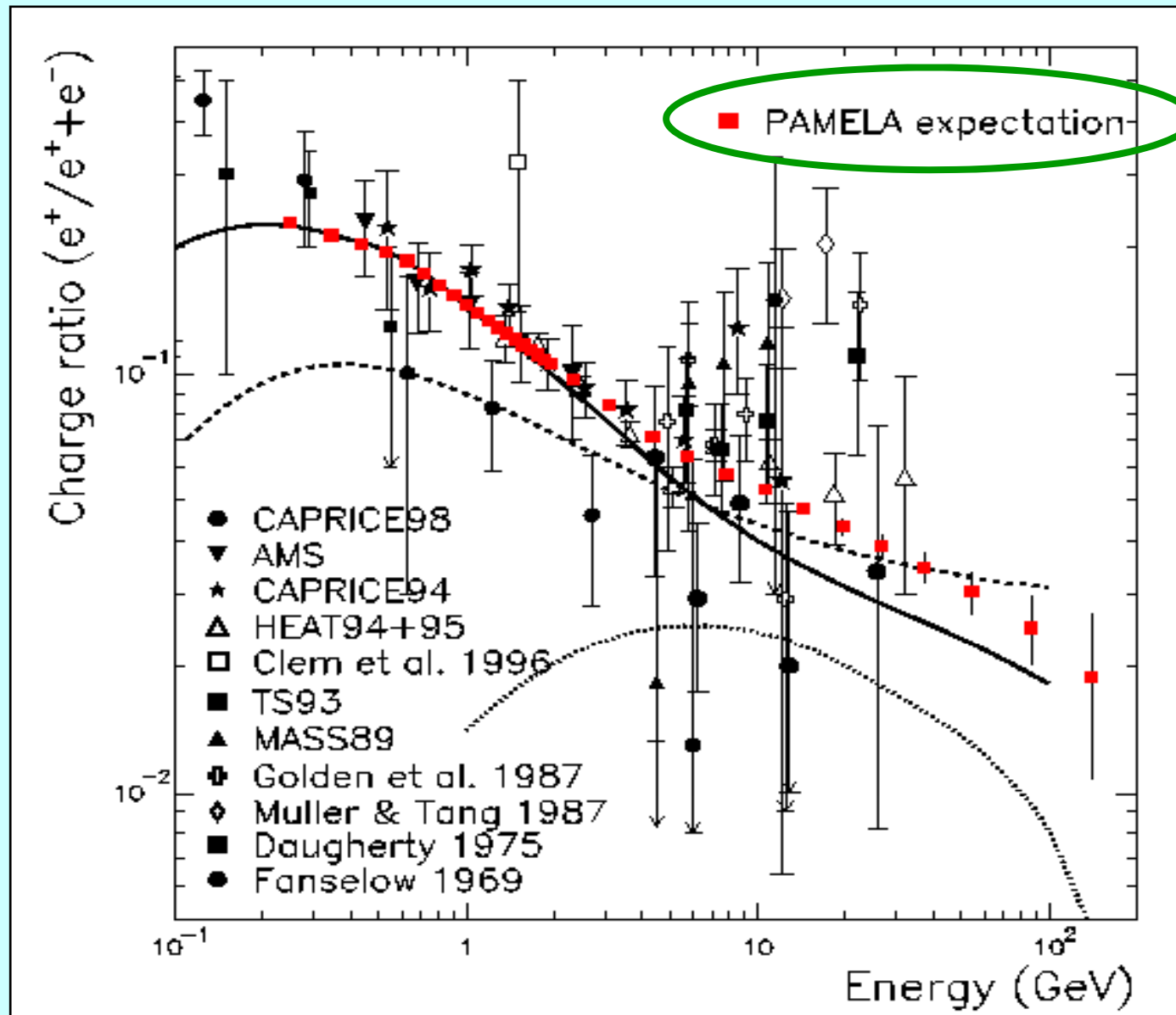
# PAMELA: Antiproton-Proton Ratio



# Positron - Electron ratio



# Positron charge ratio

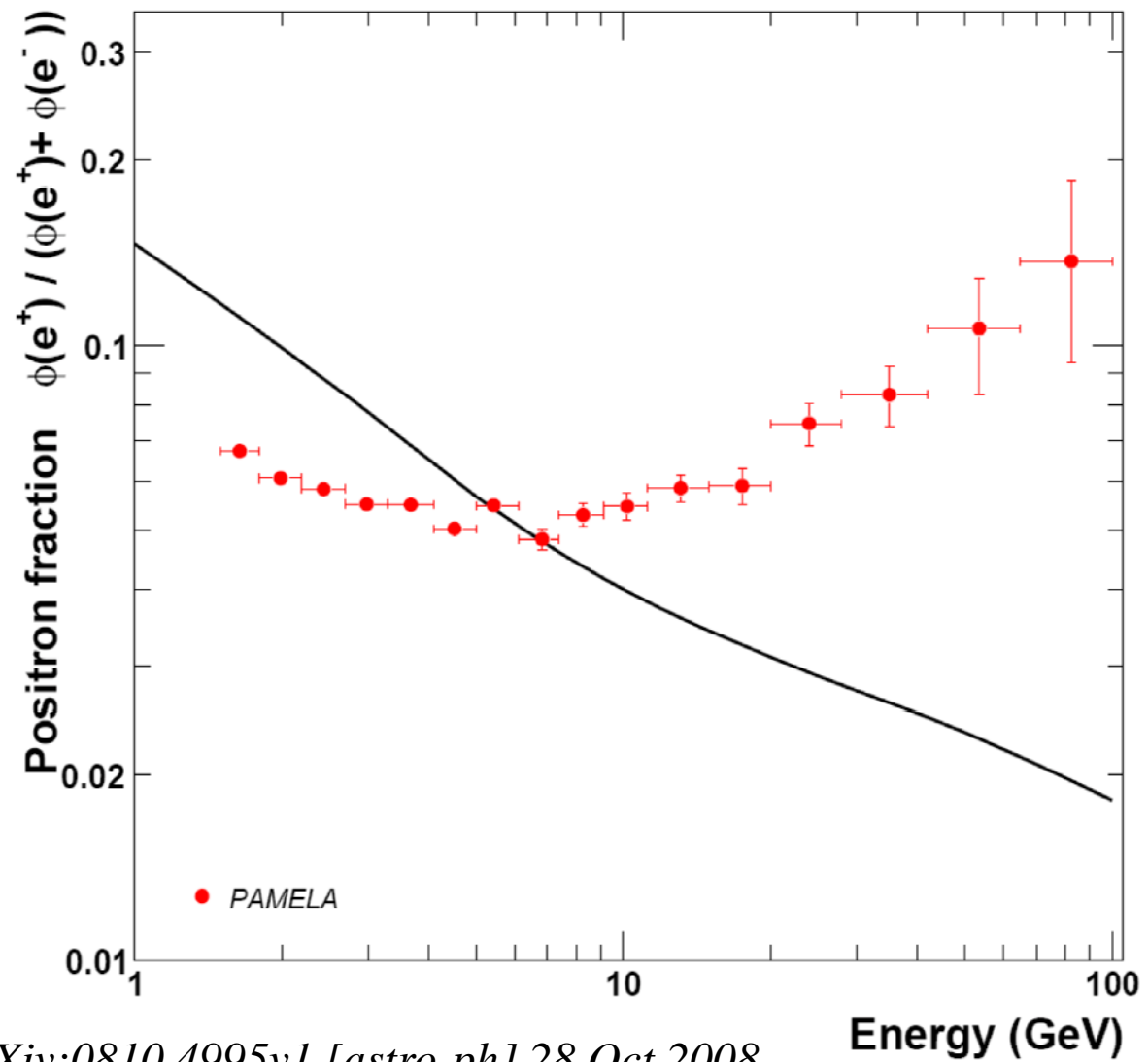


# Pamela e+ results

- Till August 30<sup>th</sup> about 20000 positrons from 200 MeV up to 200 GeV have been analyzed

- More than 15000 positrons over 1 GeV

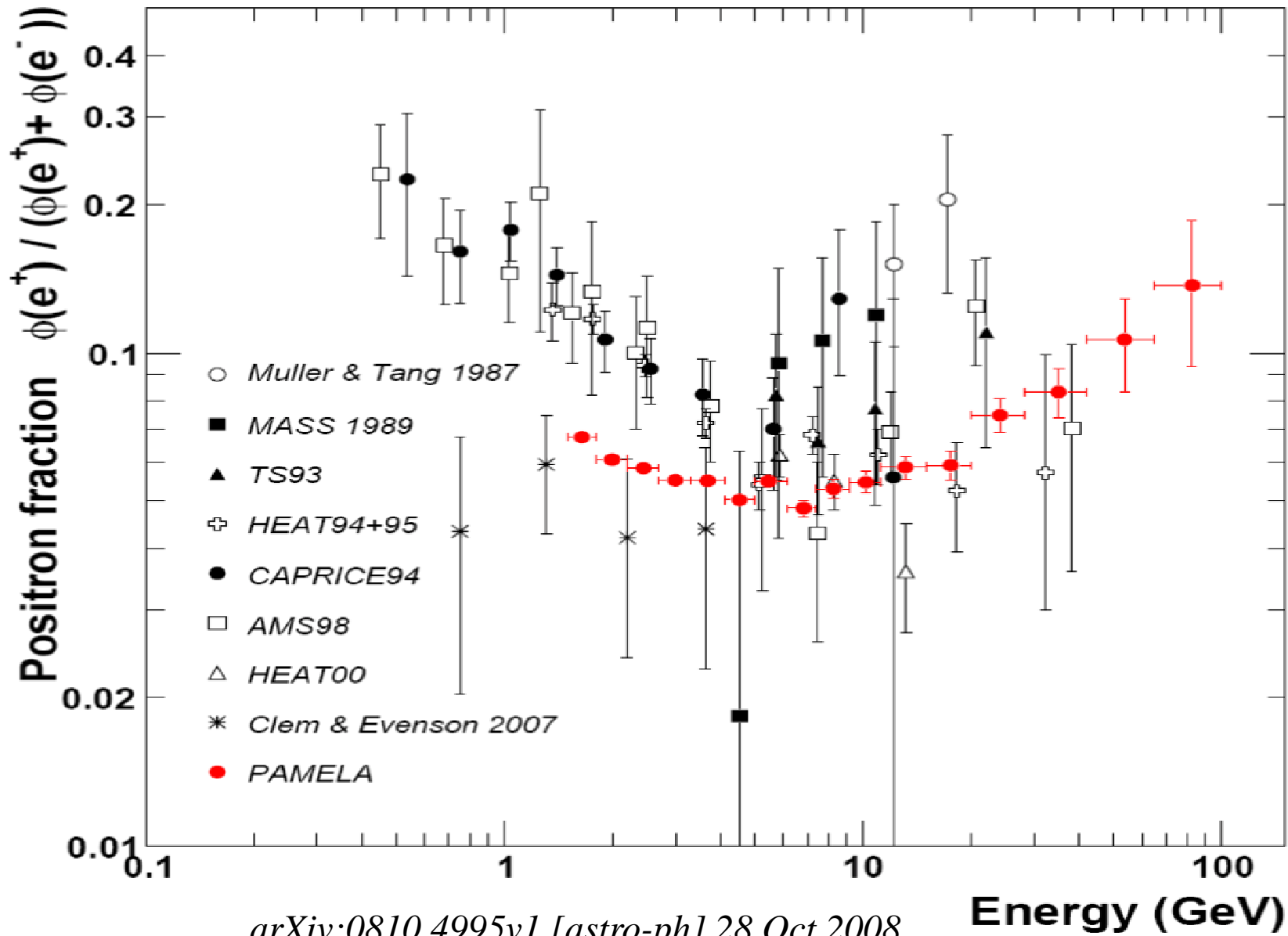
- Other eight months data to be analyzed



*arXiv:0810.4995v1 [astro-ph] 28 Oct 2008*

*Accepted on Nature*

# Pamela e+ results



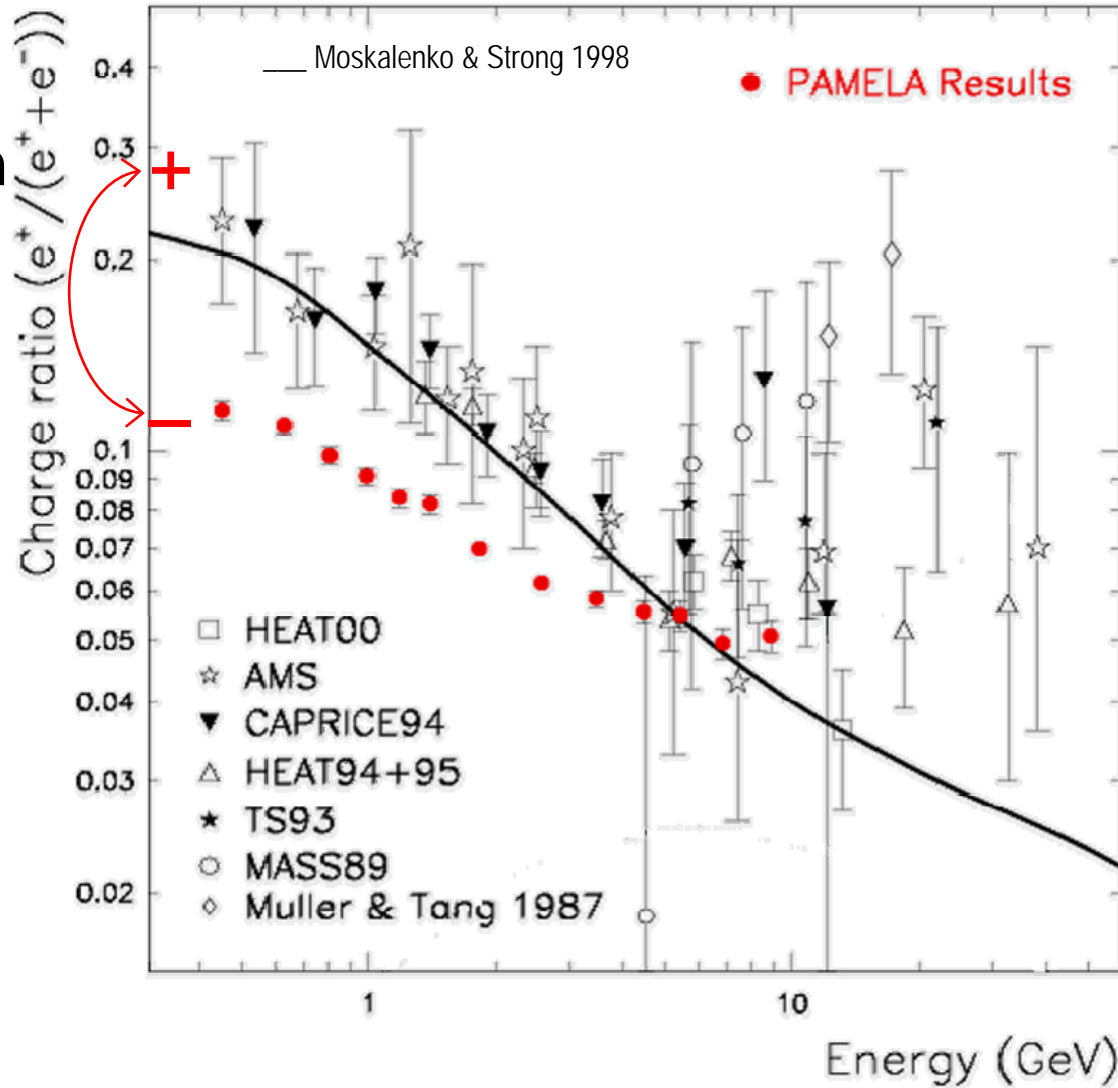
Accepted on Nature



# Positrons to Electrons ratio

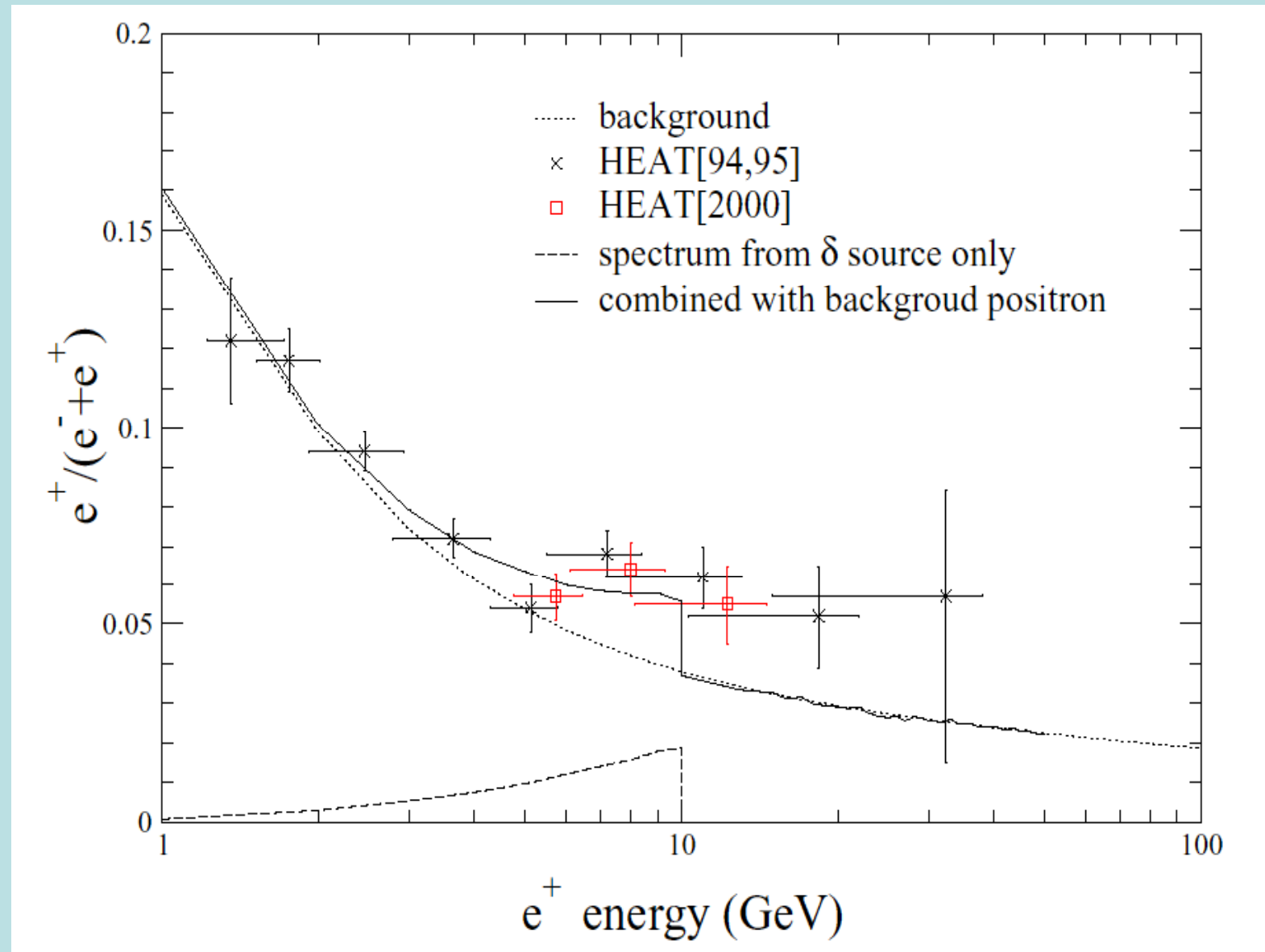
Preliminary

Charge sign  
dependent  
solar  
modulation



statistical errors only

# Positrons with HEAT



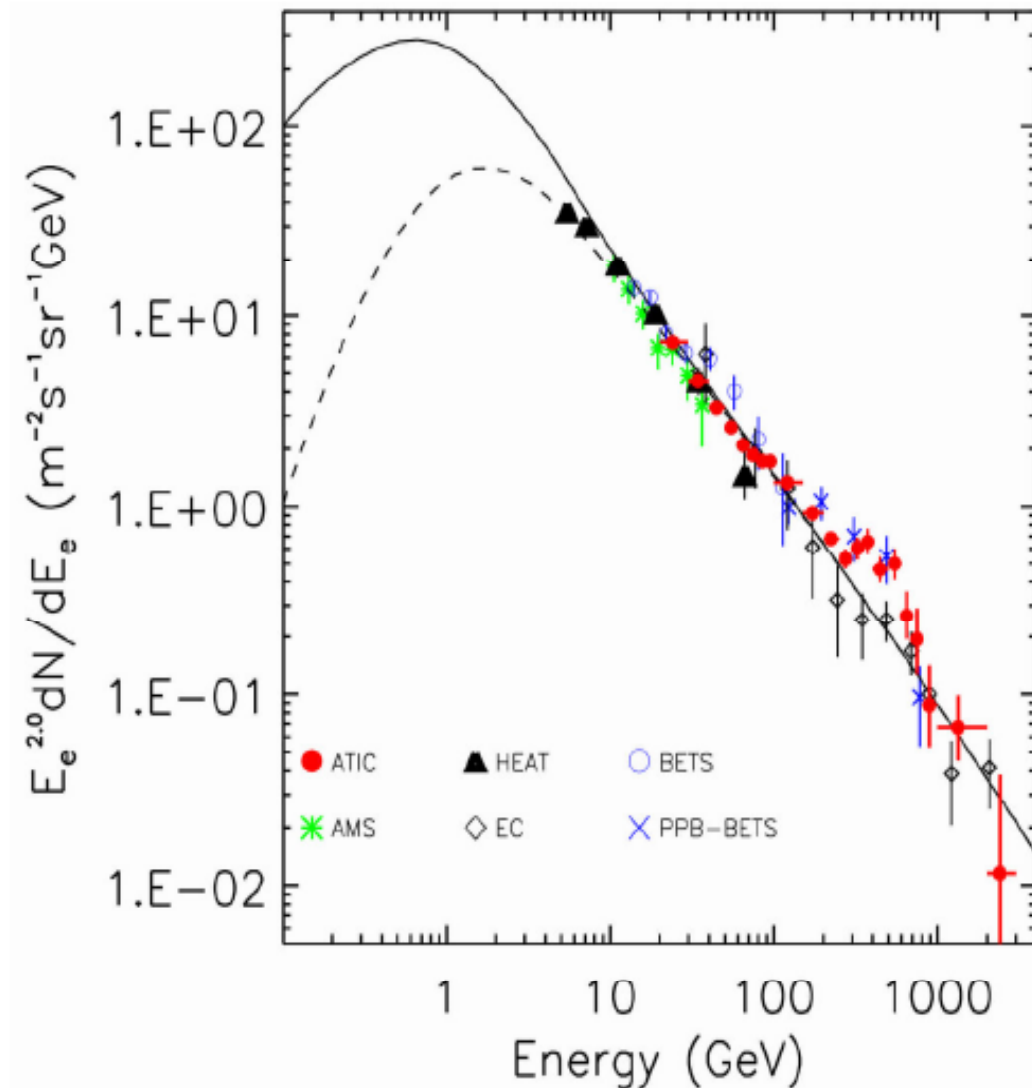
# The ATIC electron results exhibits a feature

Curves are from GALPROP  
diffusion propagation  
simulation code

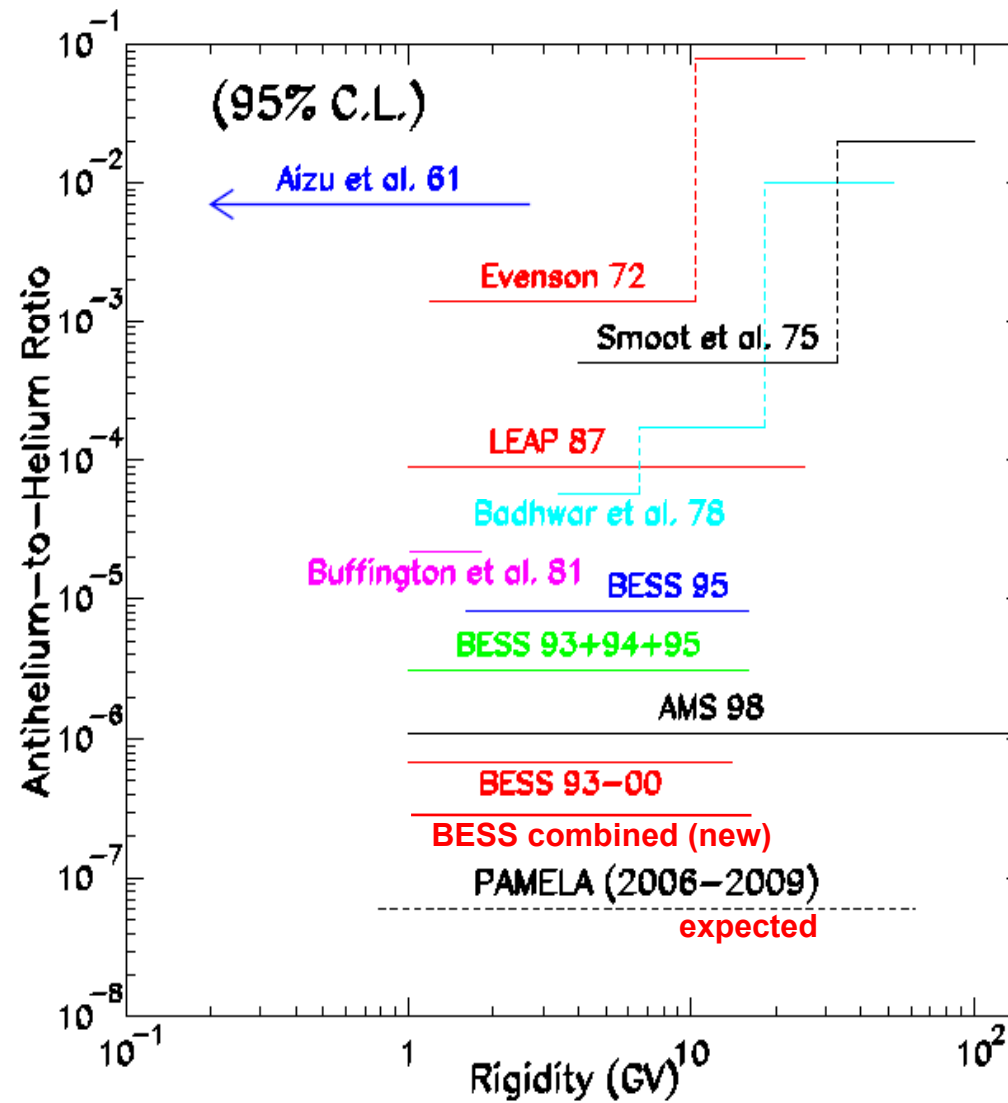
- Solid curve is local interstellar space
- Dashed curve is with solar modulation (500 MV)

“Excess” at about 300 – 600 GeV

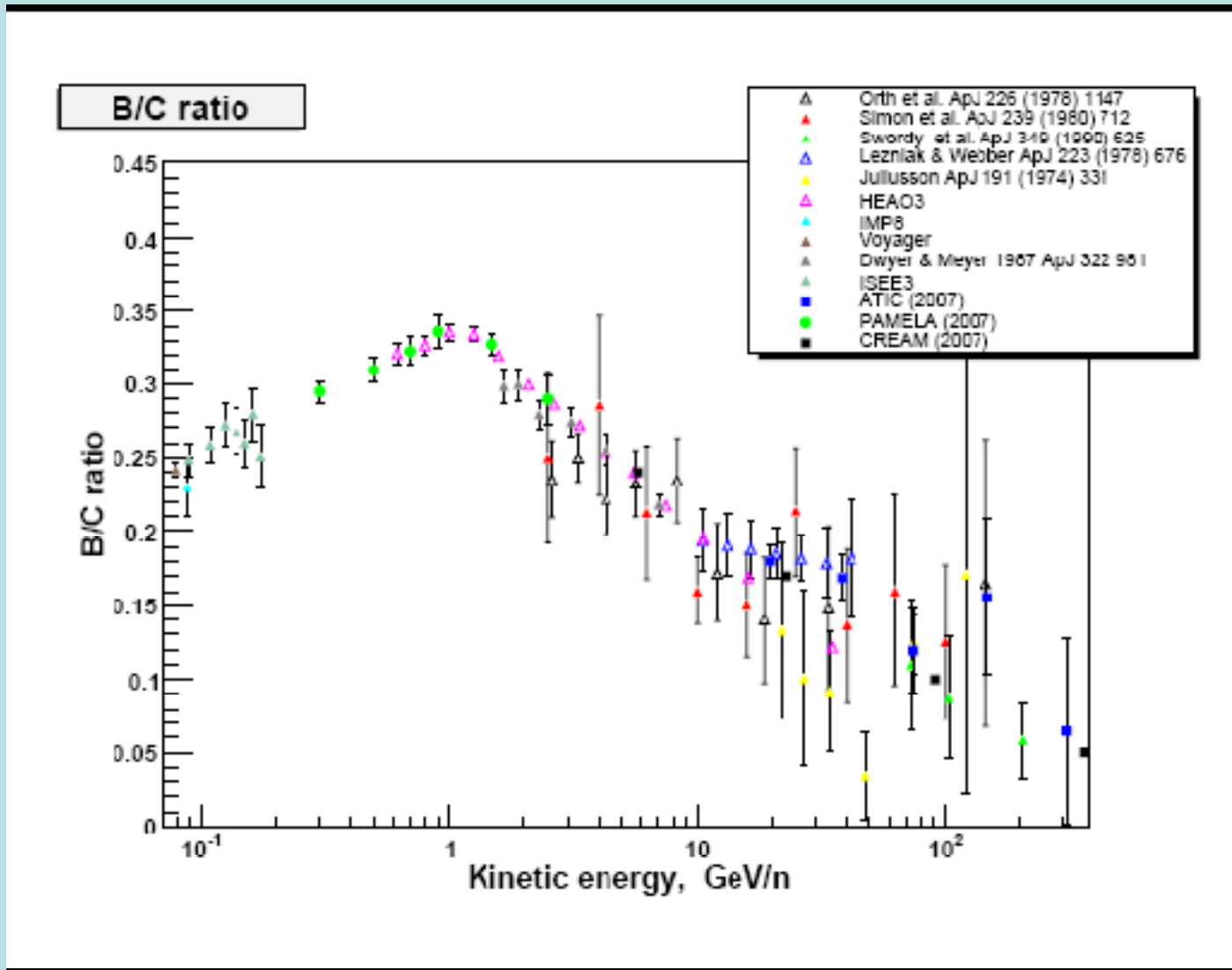
Also seen by recent PPB-BETS



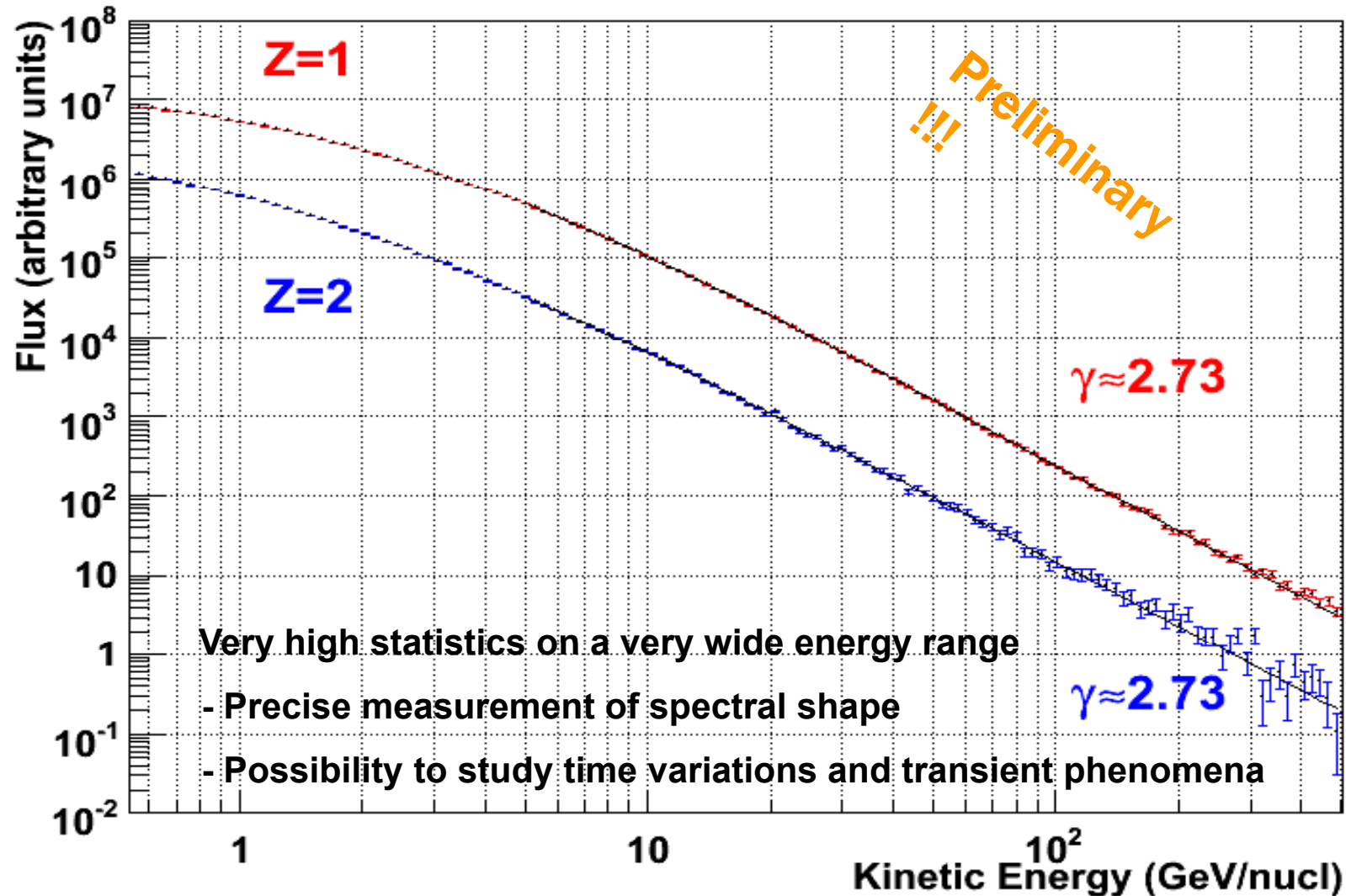
# Cosmic-ray antimatter search



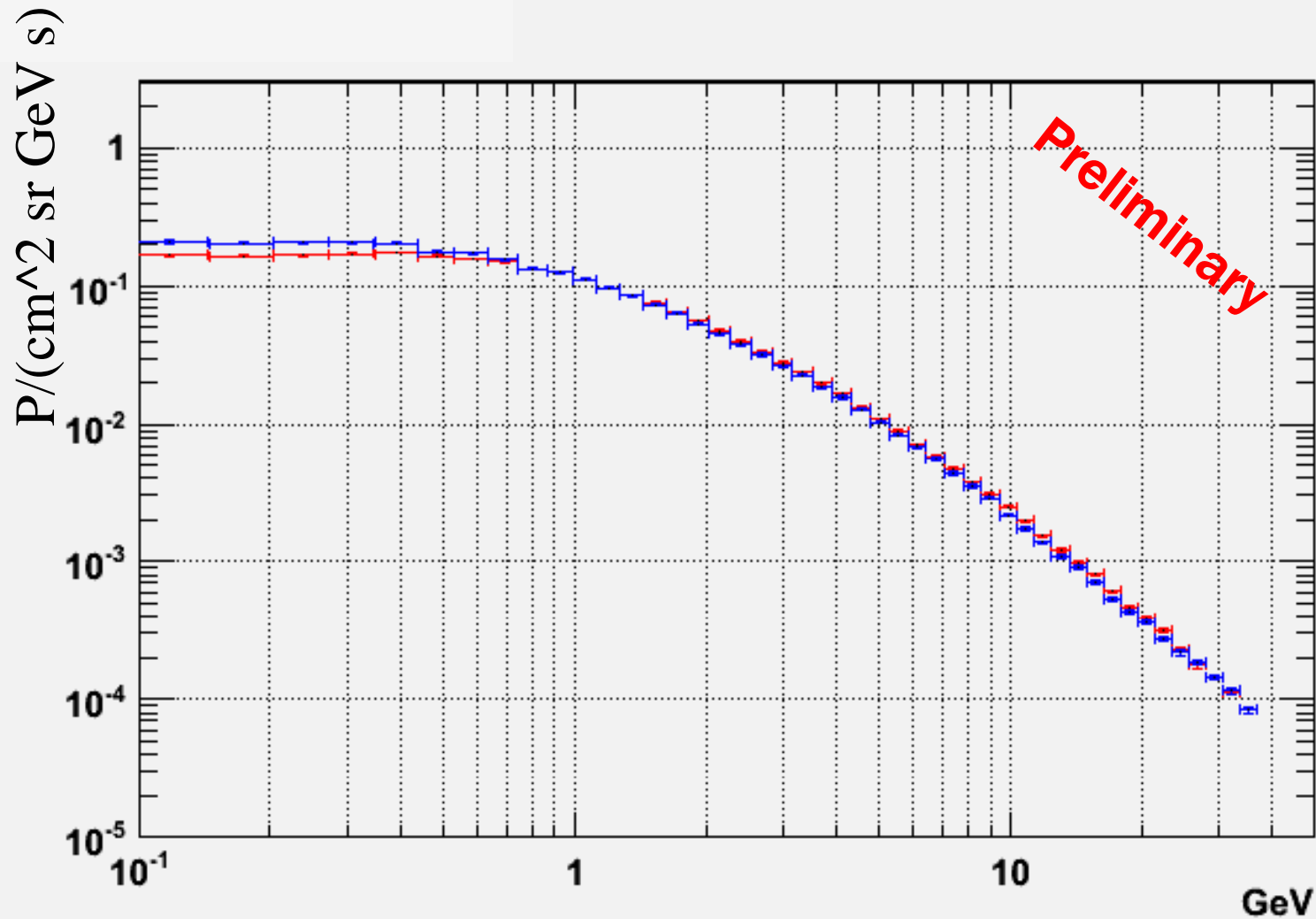
# PAMELA: Preliminary Results B/C



# PAMELA: Galactic H and He spectra



# PAMELA: Proton Spectra

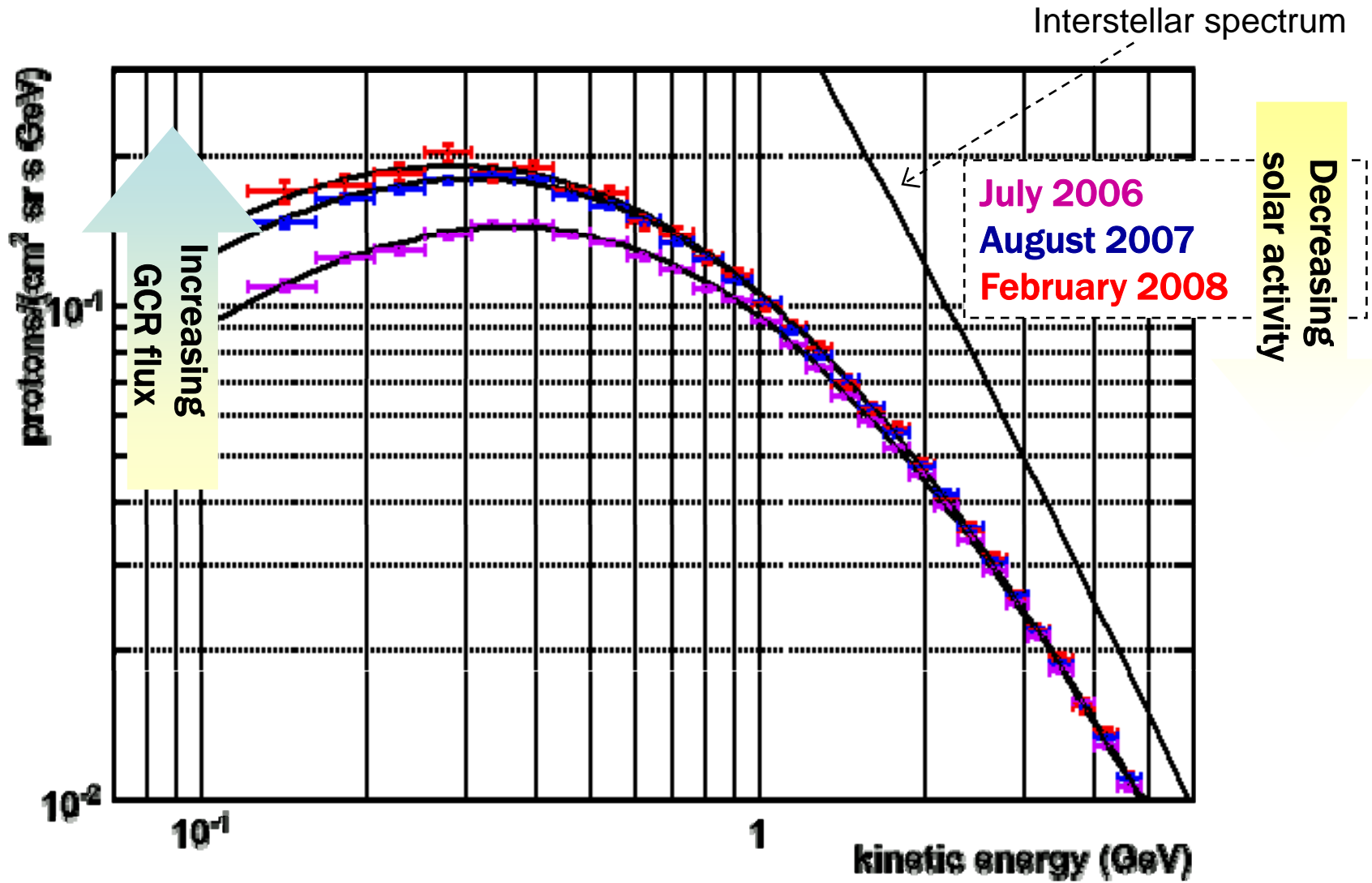


**RED: JULY 2006**

**BLUE: AUGUST 2007**

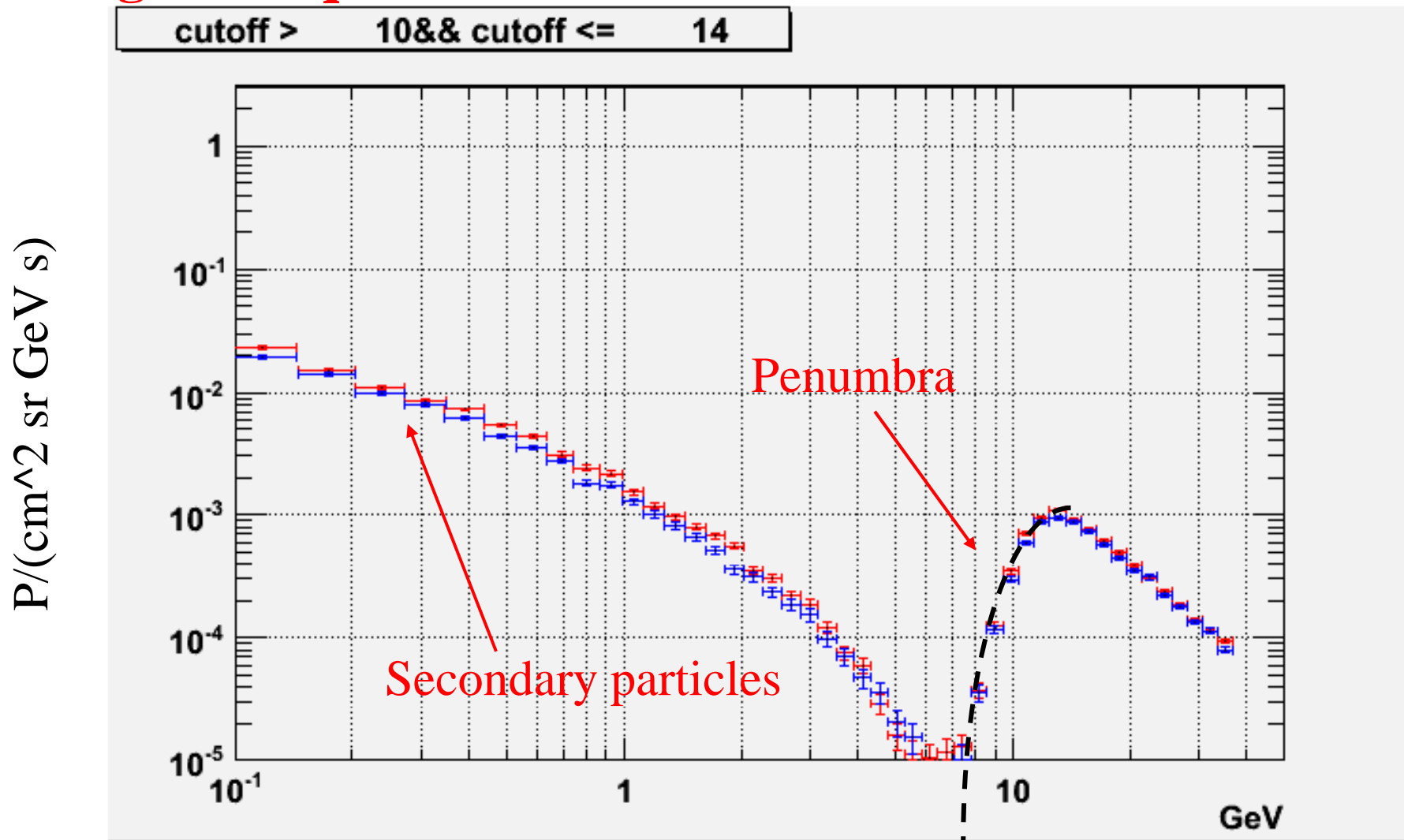
# Solar modulation

(statistical errors only)





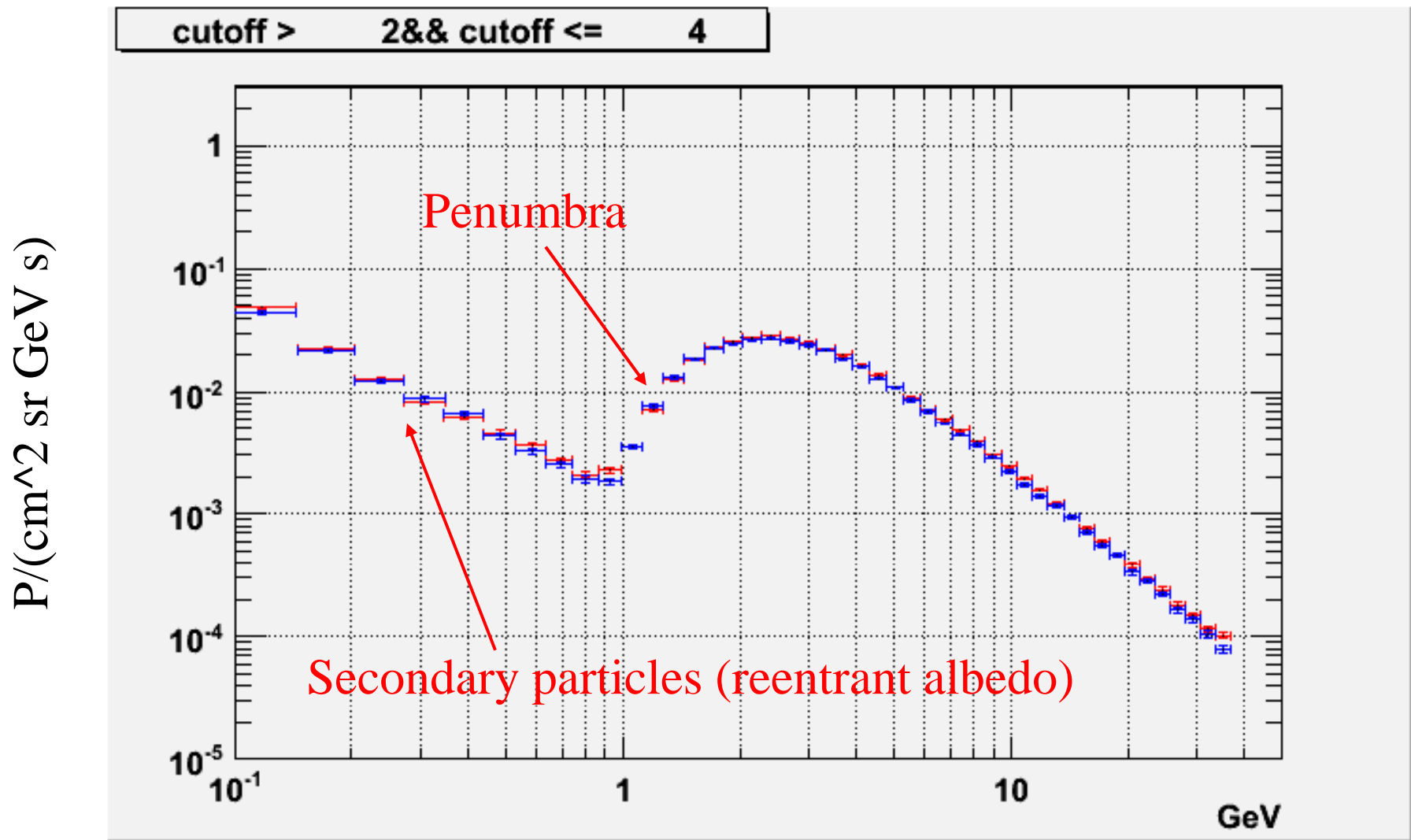
# Primary and secondary spectra: Magnetic equator



**RED: JULY 2006**

**BLUE: AUGUST 2007**

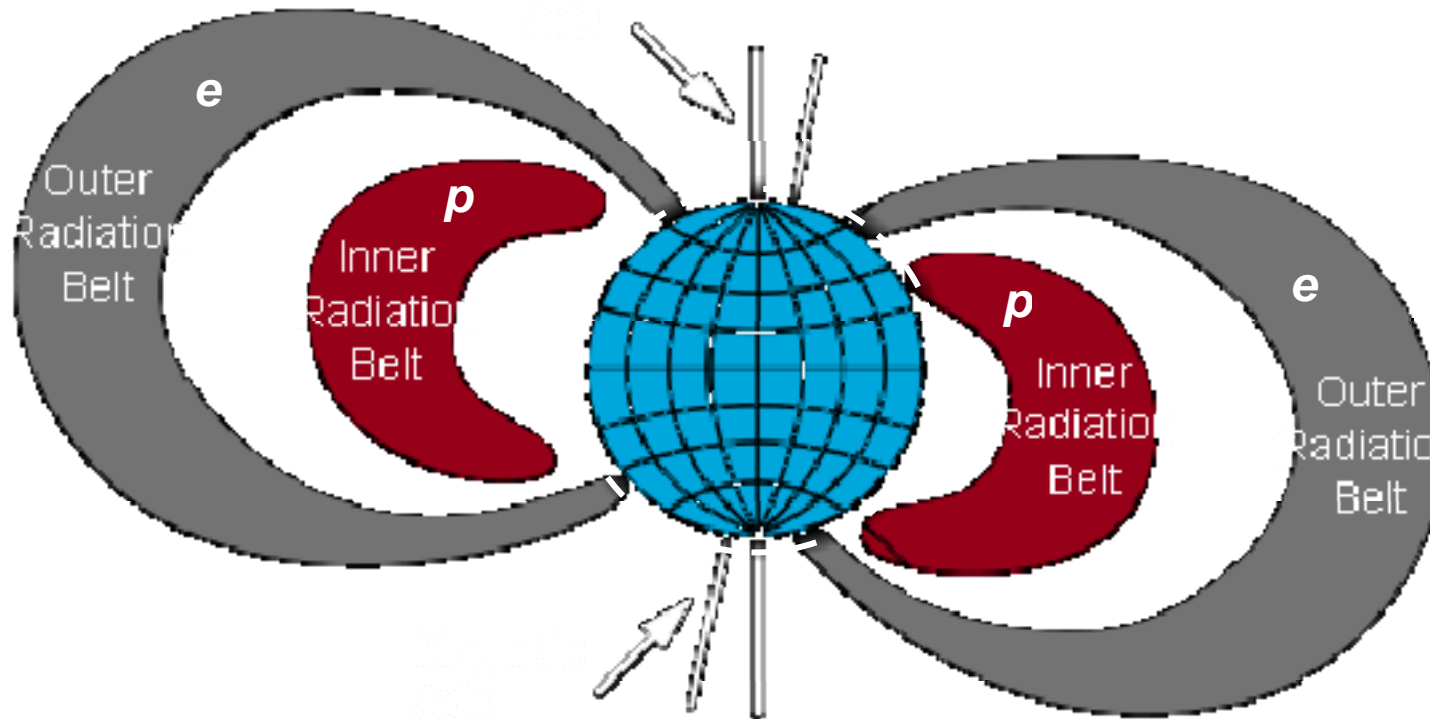
# Primary and secondary spectra: Intermediate latitudes

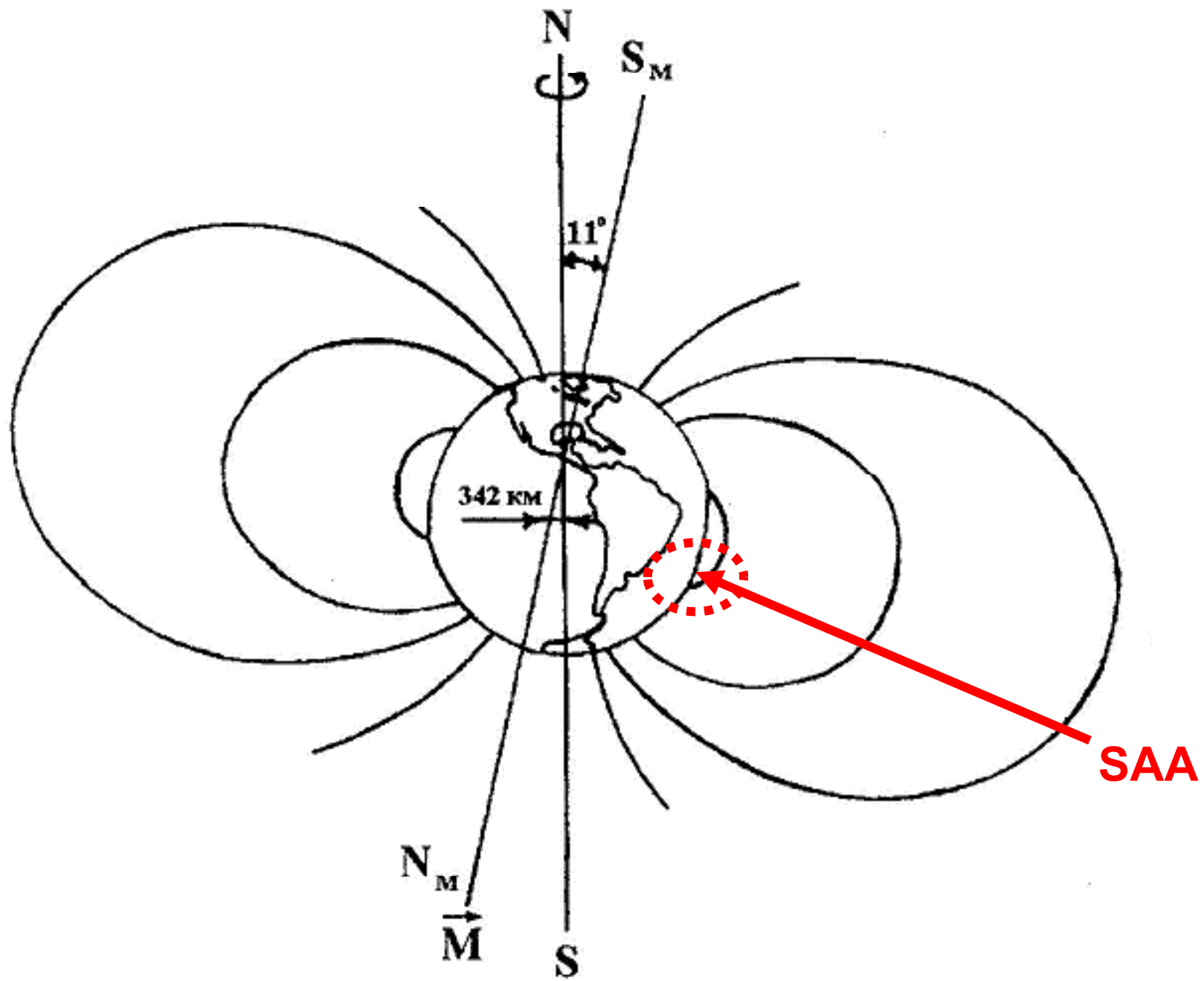


**RED: JULY 2006**

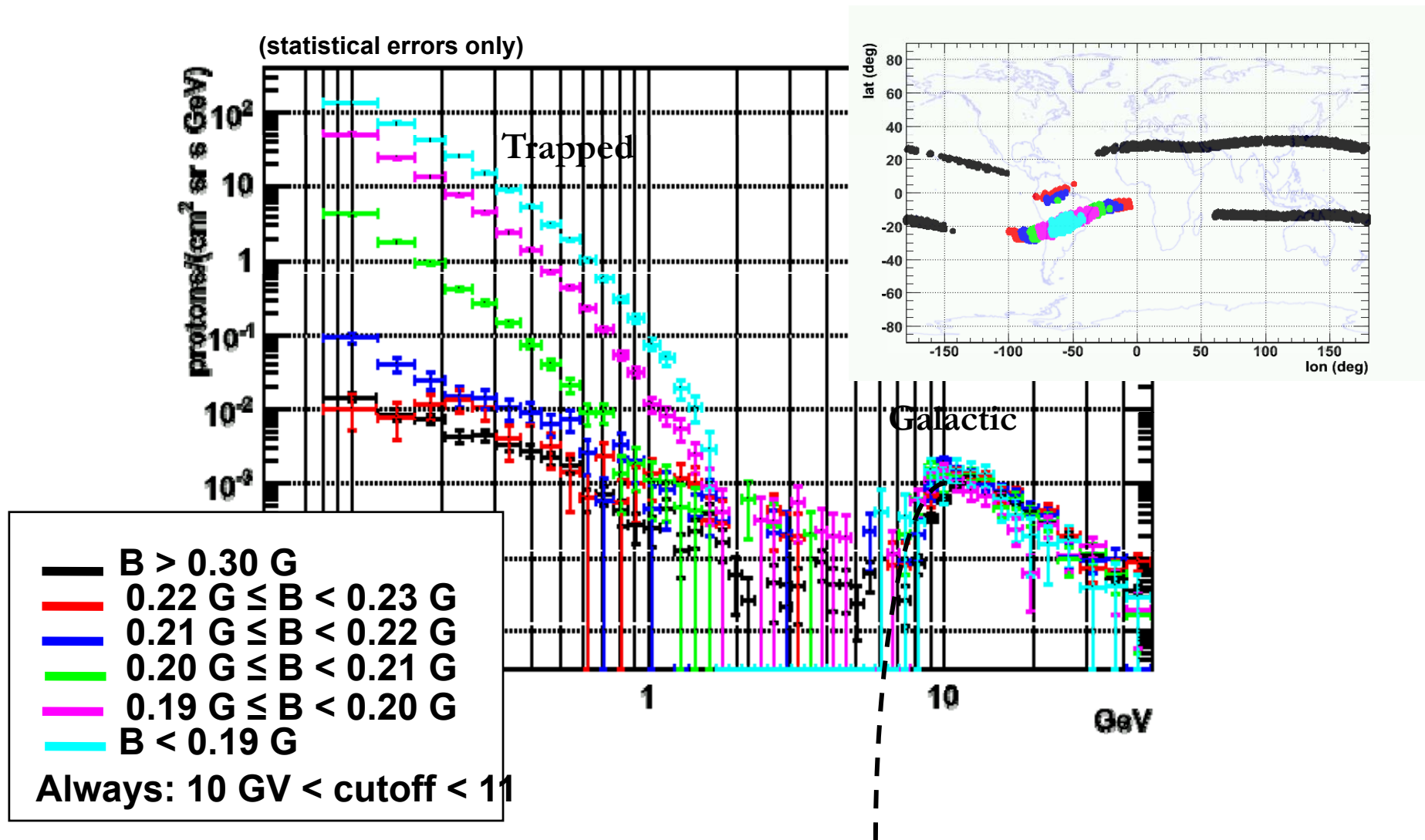
**BLUE: AUGUST 2007**

# A look at Earth: the geomagnetic field

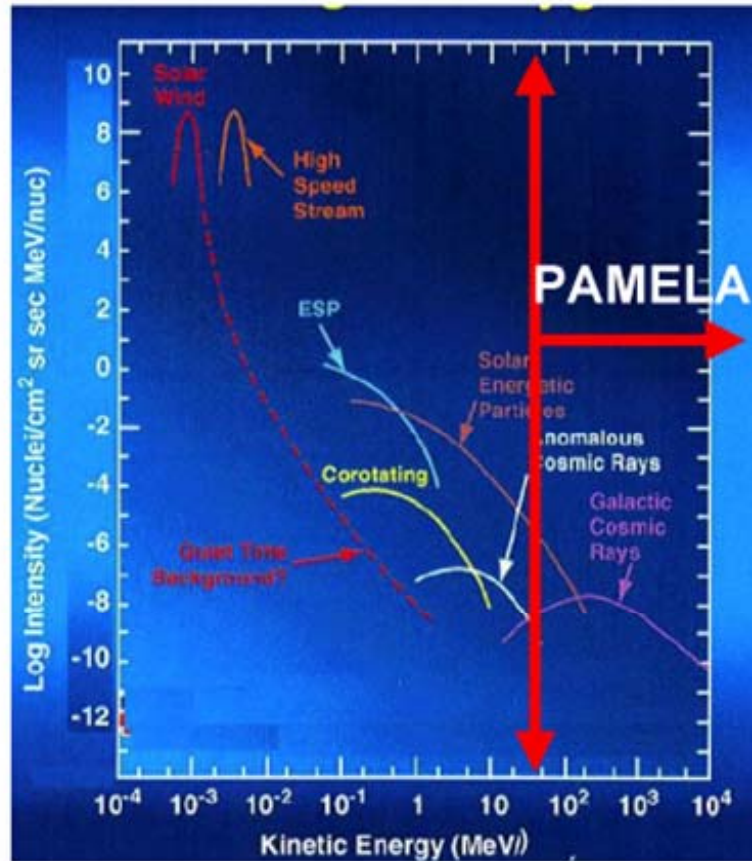




# Spectrum of proton radiation belt inside the SAA



# Solar Physics with PAMELA



- Solar Modulation effects

- High energy component of Solar Proton Events (from 80 MeV to 10 GeV)

**80 MeV**

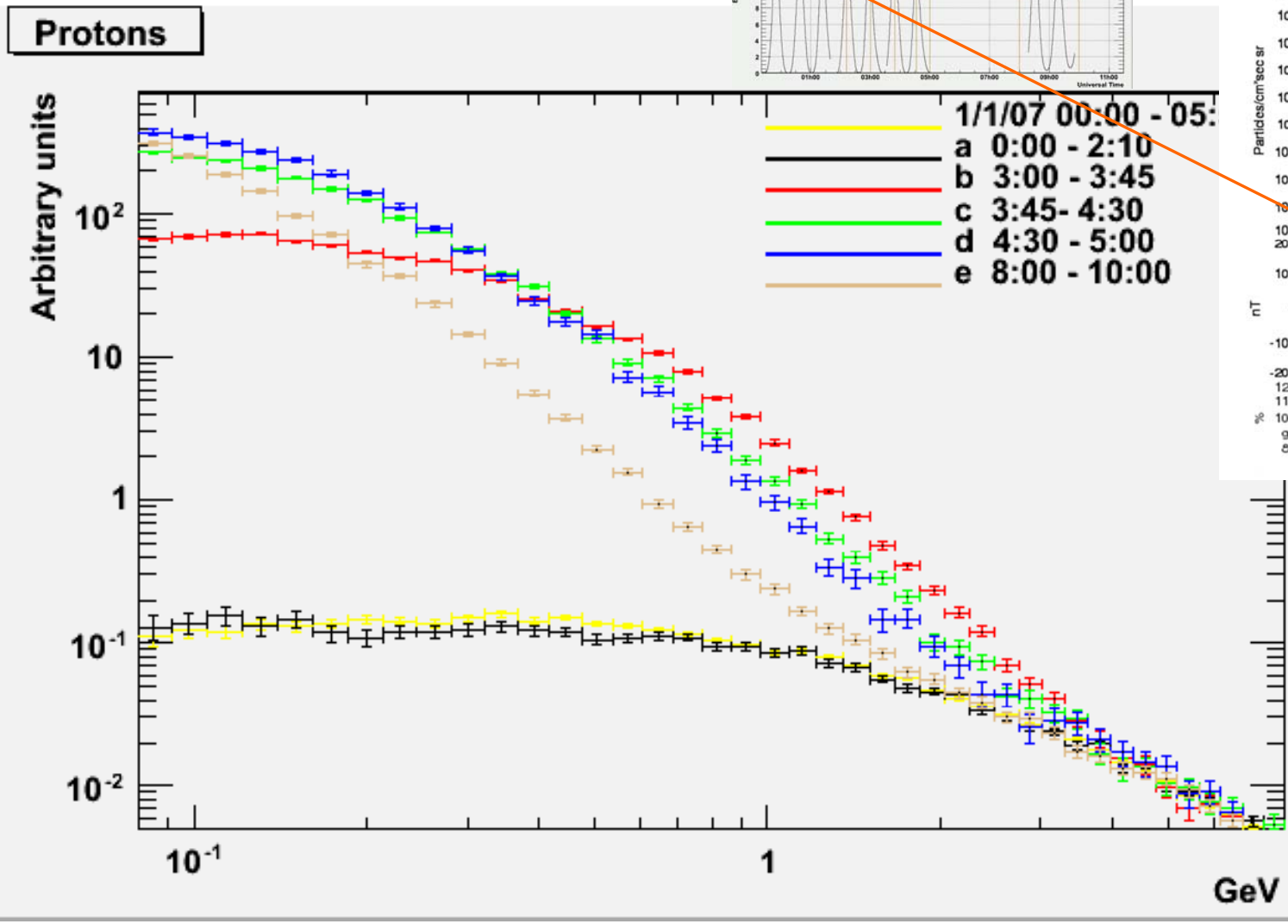
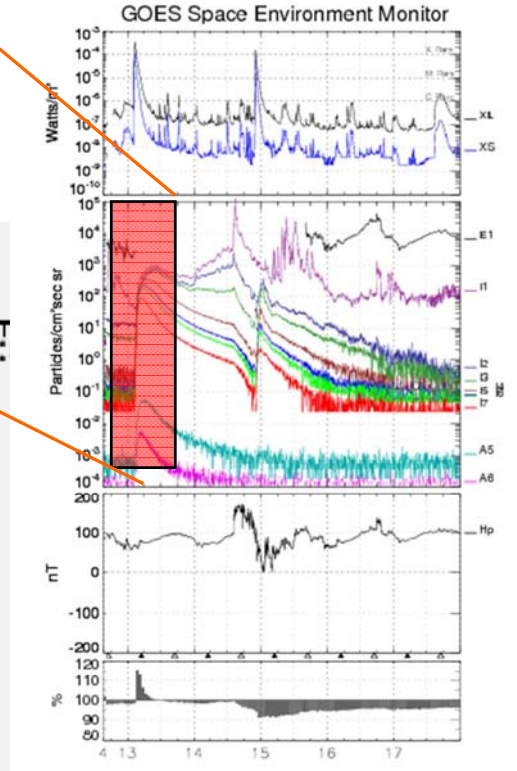
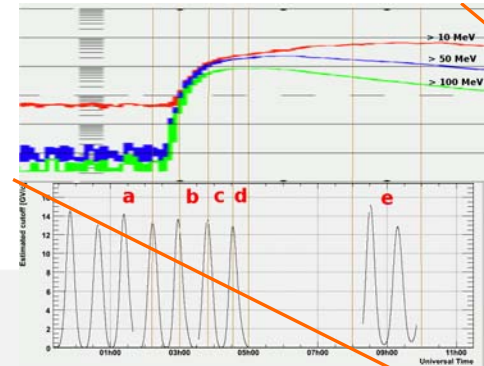
- High energy component of electrons and positrons in Solar Proton Events (from 50 MeV)

**50 MeV**

- Nuclear composition of Gradual and Impulsive events

- <sup>3</sup>He and <sup>4</sup>He isotopic composition

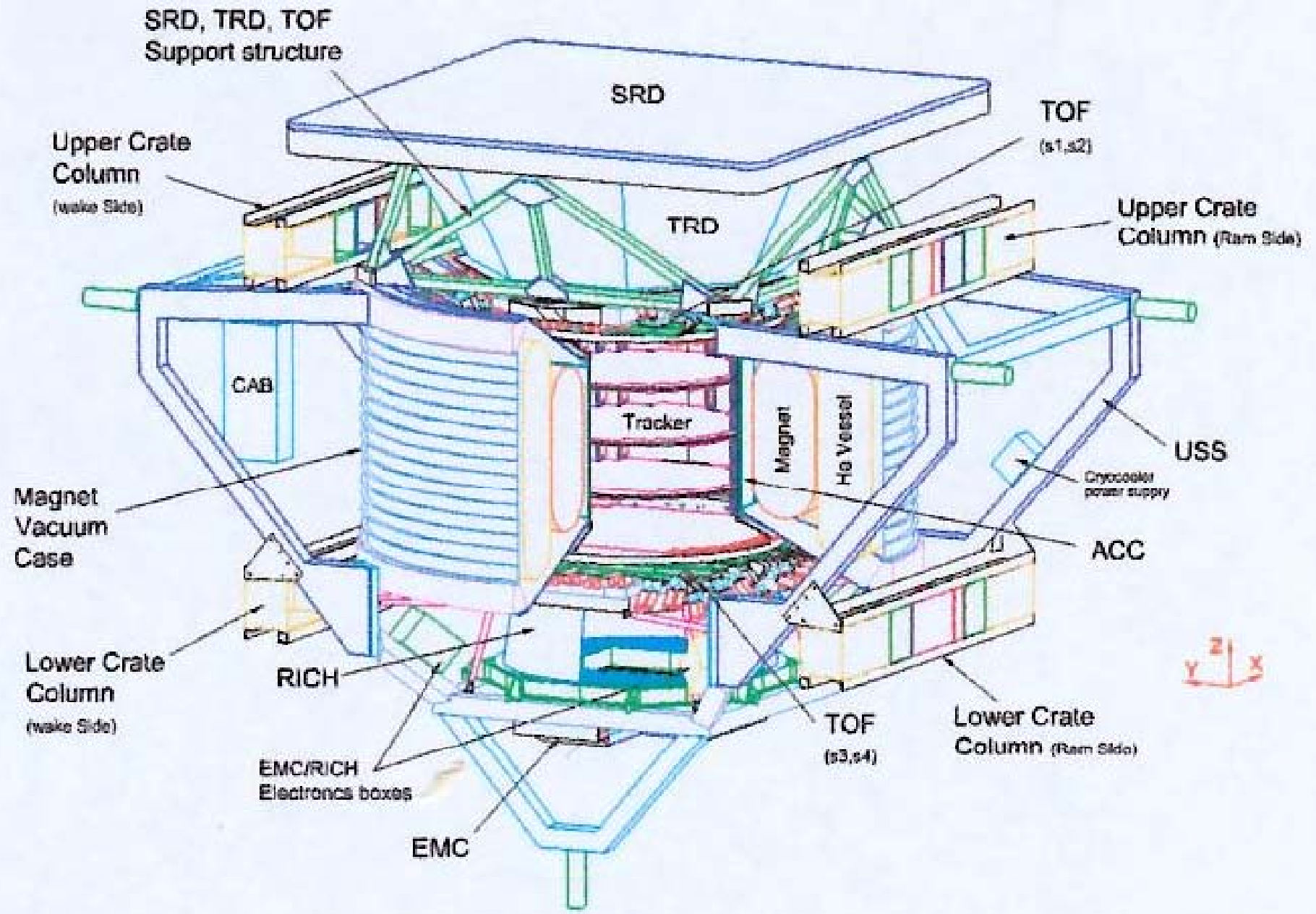
# December 13th 2006 event



**Preliminary!**

- PAMELA is the first space experiment which is measuring the Antiprotons and Positrons to the high energies ( $> 150\text{GeV}$ ) with an unprecedented statistical precision
- PAMELA is setting a new lower limit for finding Antihelium
- PAMELA is looking for Dark Matter candidates
- PAMELA is providing measurements on elemental spectra and low mass isotopes with an unprecedented statistical precision and is helping to improve the understanding of particle propagation in the interstellar medium
- PAMELA is able to measure the high energy tail of solar particles.





# AMS-02 on the International Space Station



AMS-2

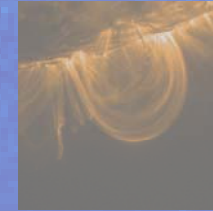
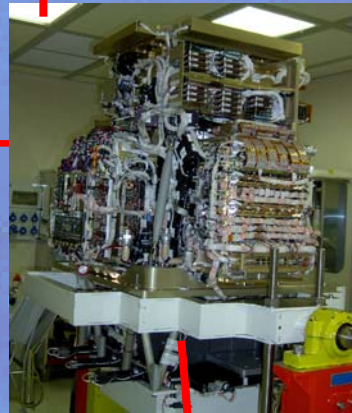
2009-2012

# Pamela and AMS-02 Space Observatories at 1AU

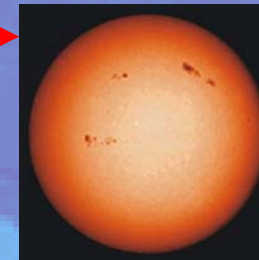
*Matter : Antimatter  
PBH · Dark Matter  
Galactic cosmic rays*

*Solar Energetic particles*

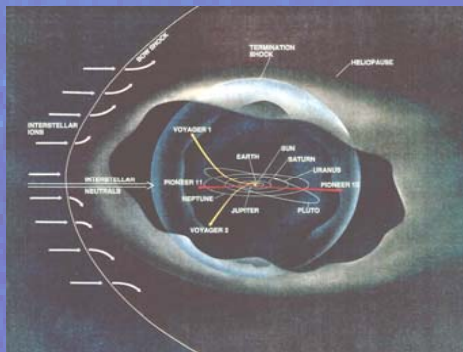
*Jovian electrons*



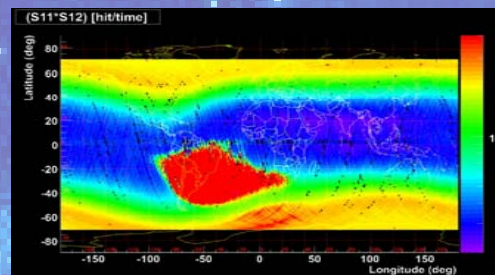
*Solar Modulation*



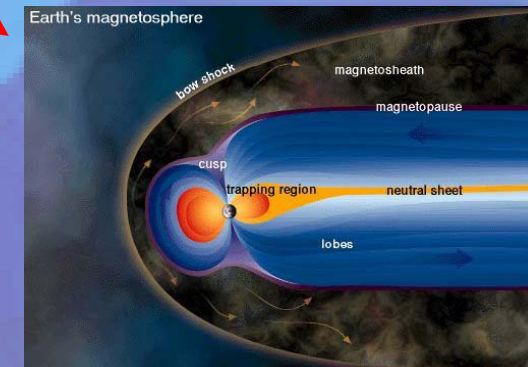
*Anomalous Nuclei  
Nearby e<sup>-</sup> Sources*



*R. B., SAA, Albedo,  
secondary particle*



*Magnetospheric physics*



Thank you for your attention