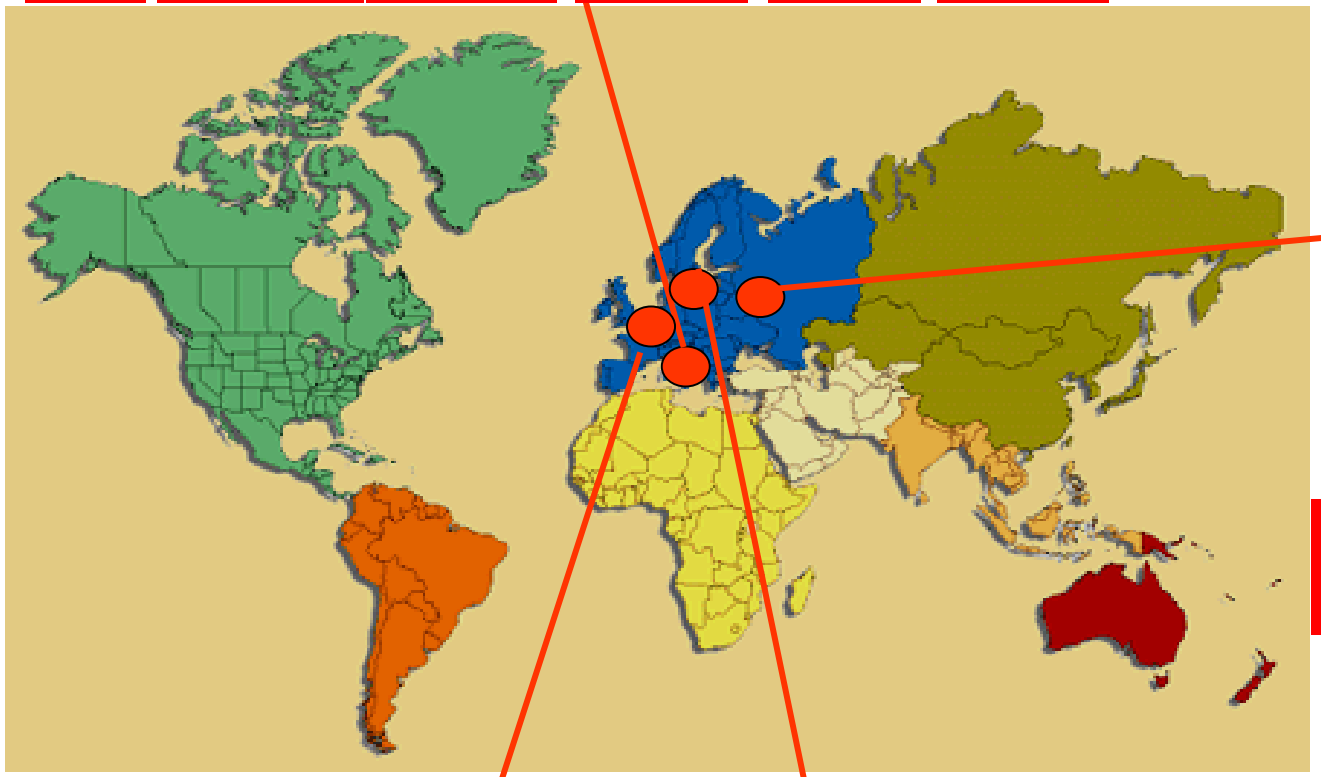
Dark Matter Search with PAMELA Space Mission

F.S. Cafagna, INFN Bari
for the PAMELA Collaboration

PAMELA Collaboration

Italy:

Bari, Florence, Frascati, Naples, Rome, Trieste, CNR, Florence



Russia:

Moscow
St. Petersburg

Germany:

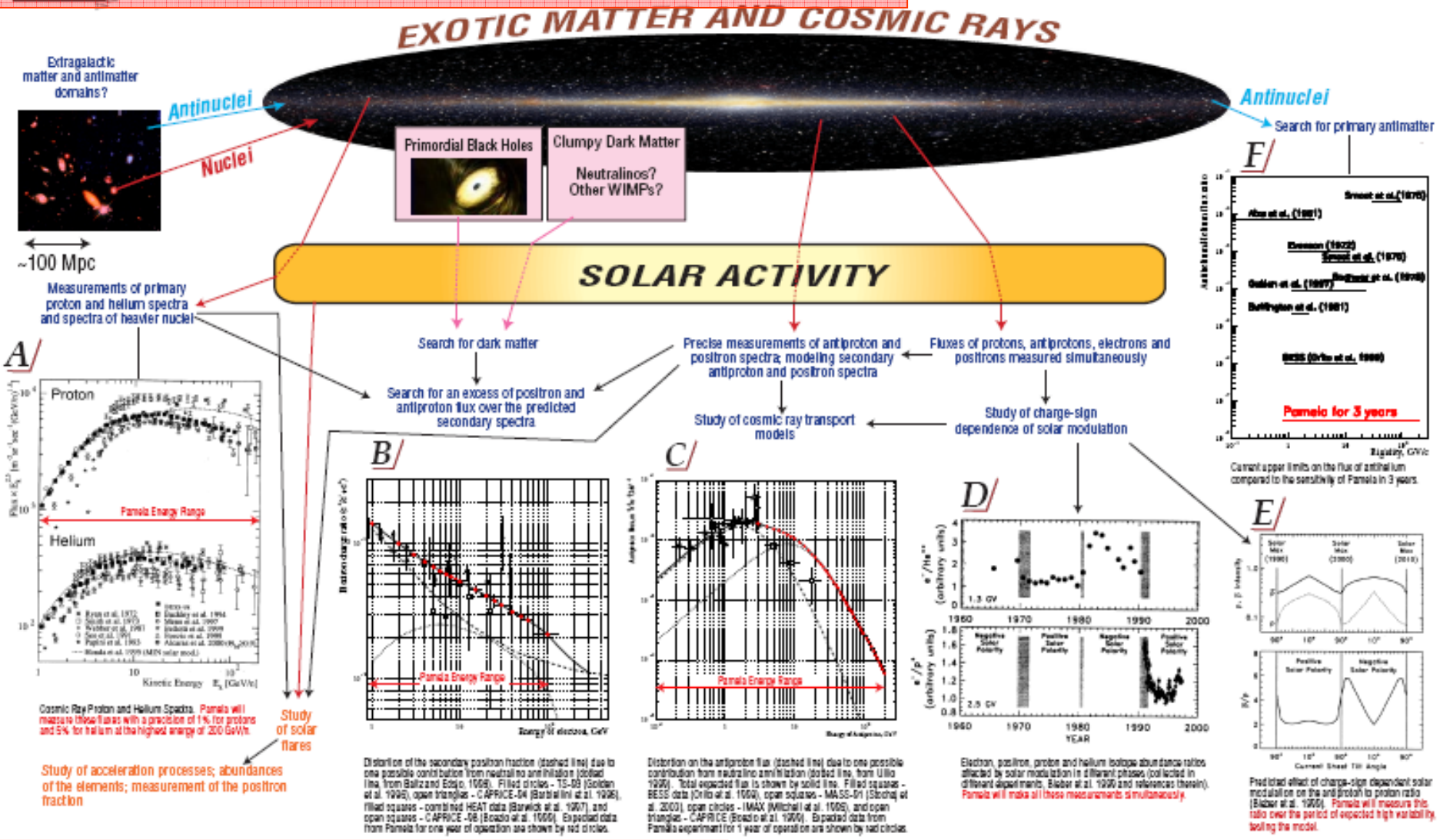
Siegen

Sweden:

KTH, Stockholm

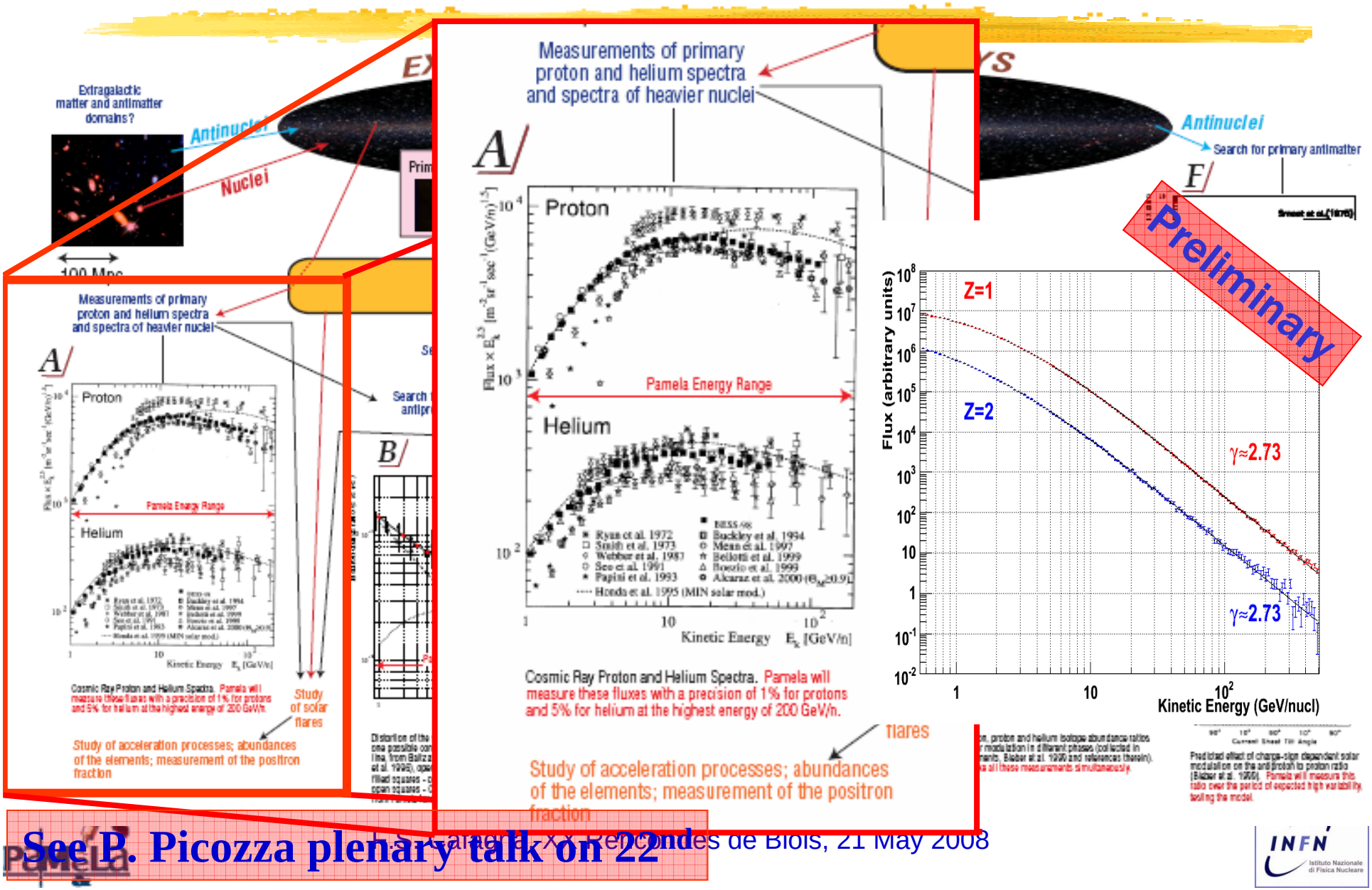
PAMELA Science

PAMELA as a Space Observatory @ 1AU



See P. Picozza plenary talk on 22

PAMELA Science



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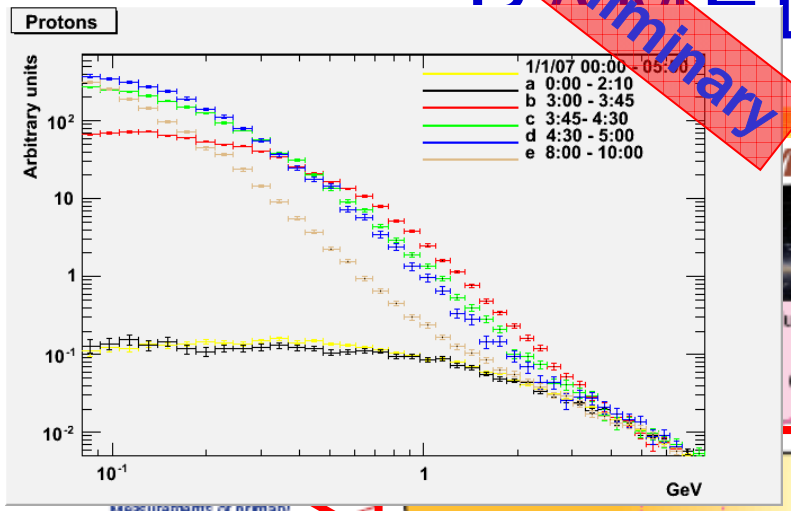
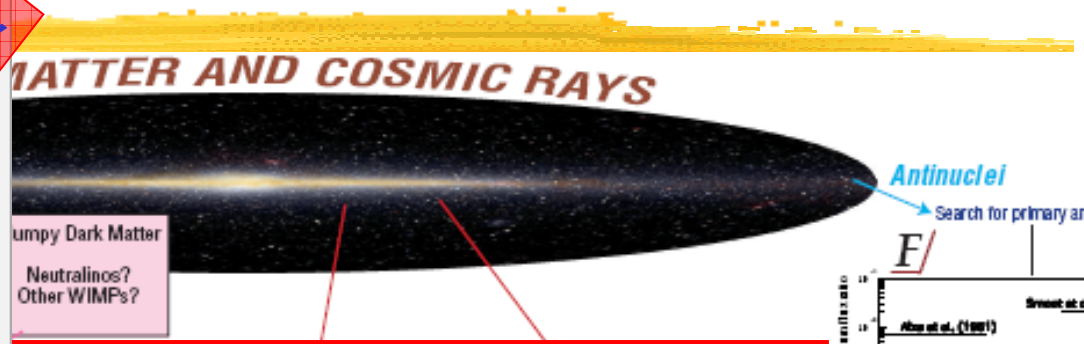
PAMELA Science



Preliminary



Antinuclei

Search for primary antimatter

F

SOLAR ACTIVITY

Measurements of primary proton and helium spectra and spectra of heavier nuclei

A

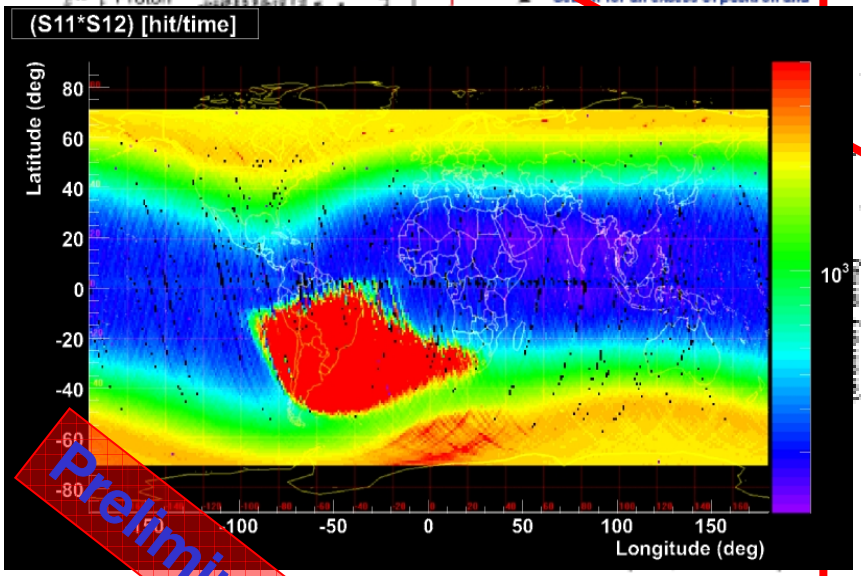
Search for dark matter

Search for an excess of positron and

Precise measurements of antiproton and

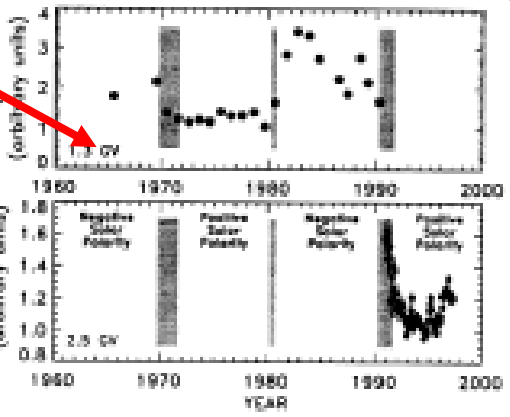
Fluxes of protons, antiprotons, electrons and

Current upper limits on the flux of antihelium compared to the sensitivity of Pamela in 3 years.



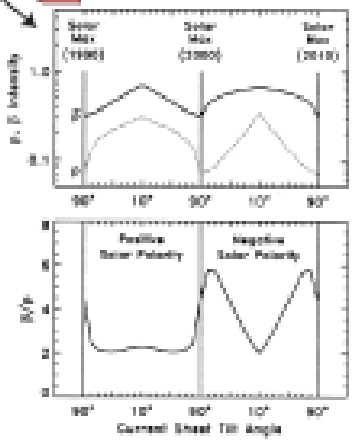
Preliminary

D



Electron, positron, proton and helium leakage abundance ratios attracted by solar modulation in different phases (collected in different experiments, Bieber et al. 1999 and references therein). Pamela will make all these measurements simultaneously.

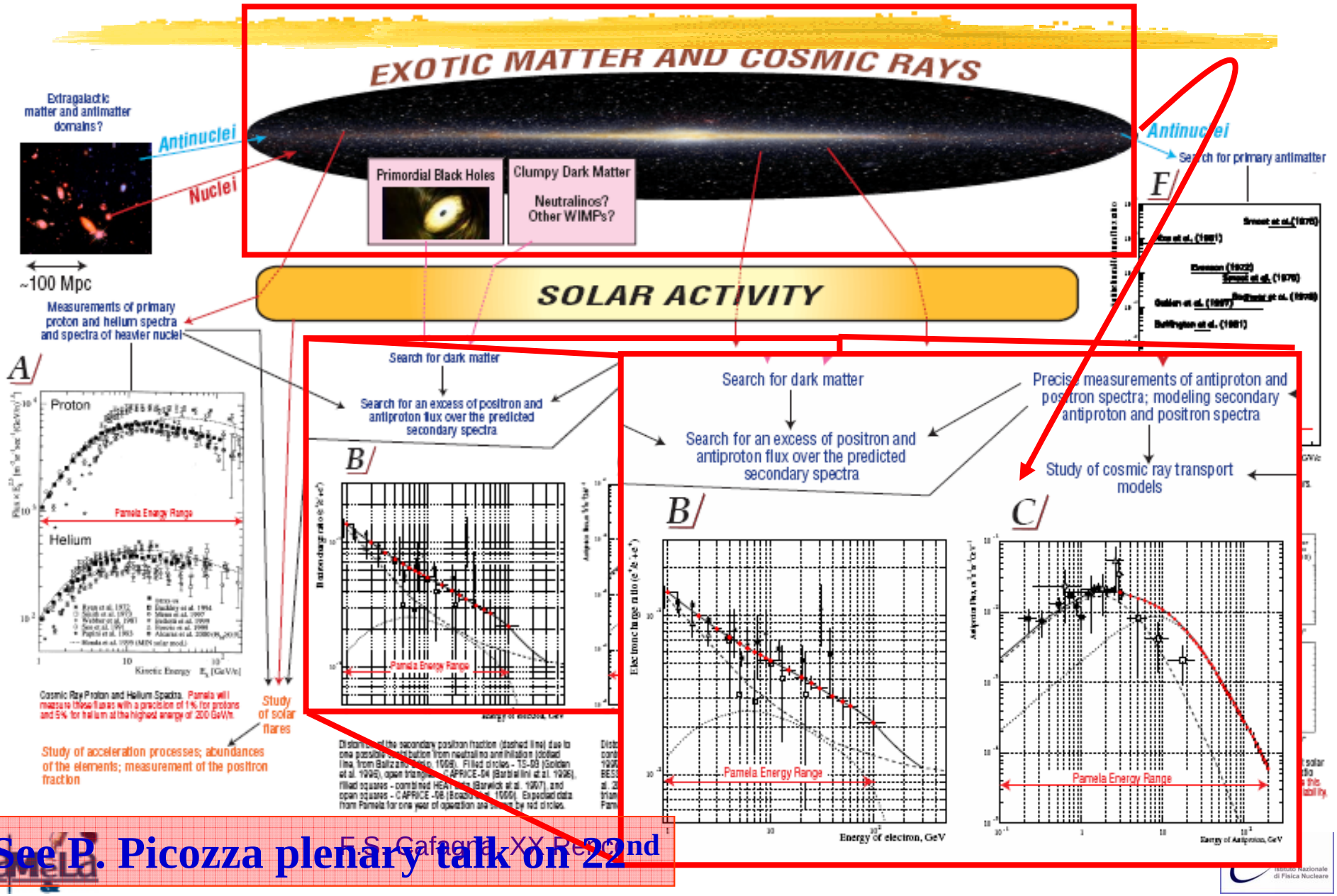
E



Predicted effect of charge-sign dependent solar modulation on the antiproton to proton ratio (Bieber et al. 1999). Pamela will measure this ratio over the period of expected high variability, testing the model.

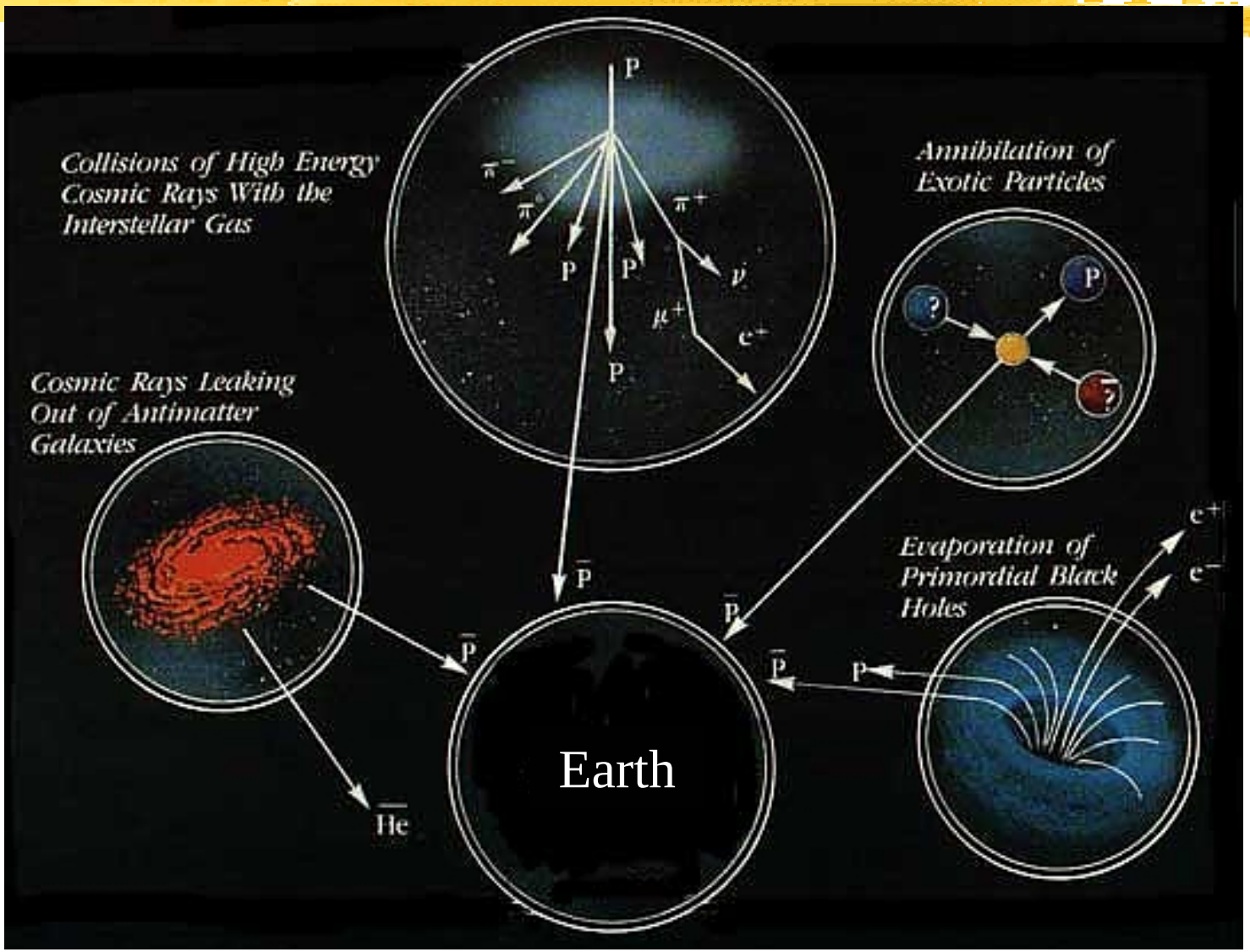
See P. Picozza plenary talk on 22nd

PAMELA Science



See P. Picozza plenary talk on 22nd

Why Anti(particle)matter matters?



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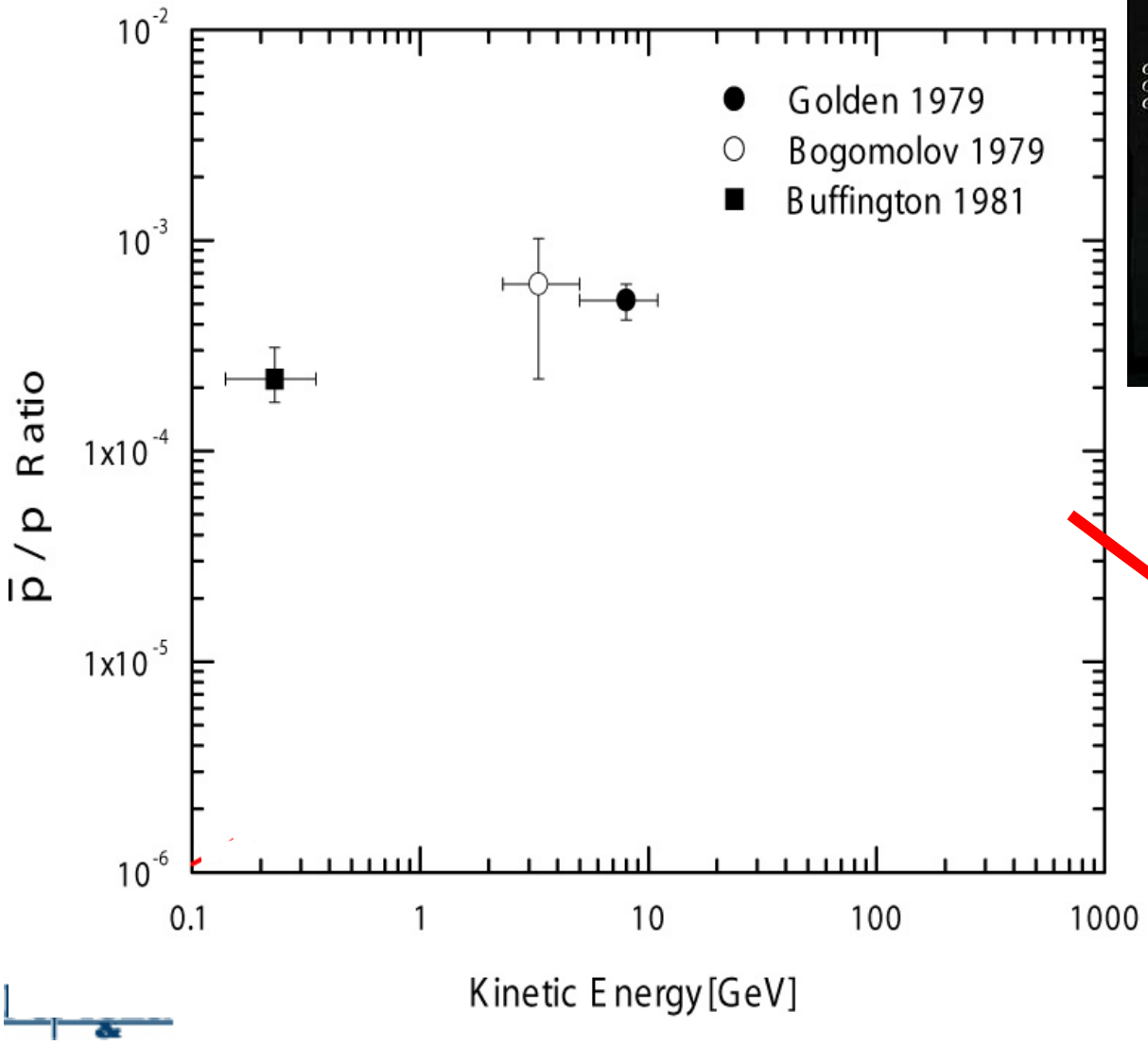
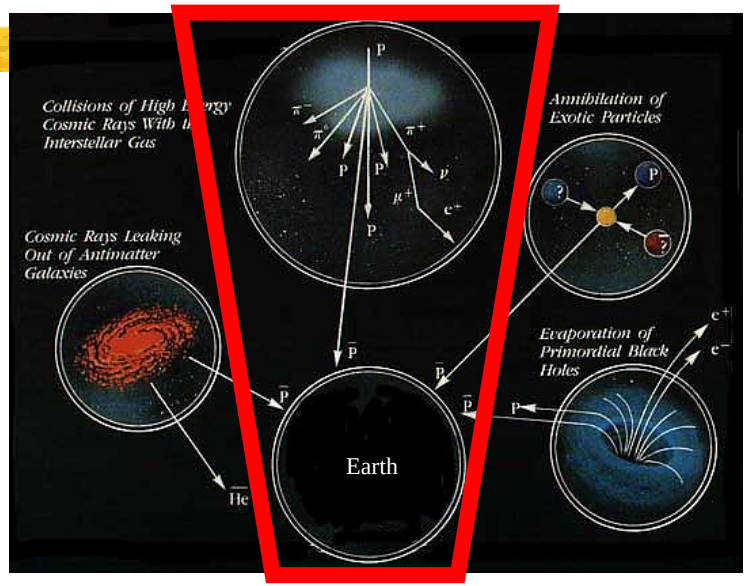
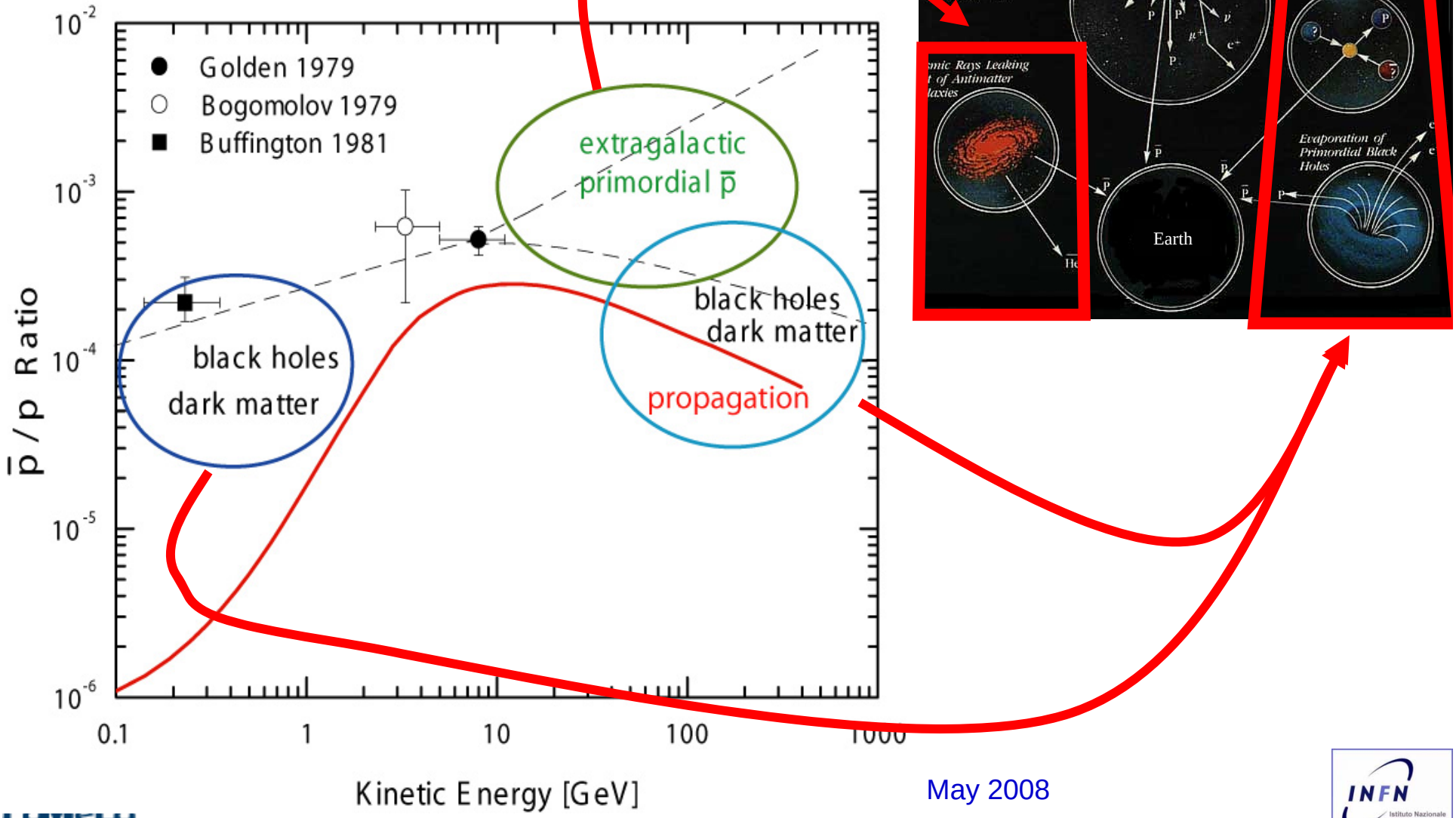




May 2008

Why Anti(particle)matter matters?



May 2008

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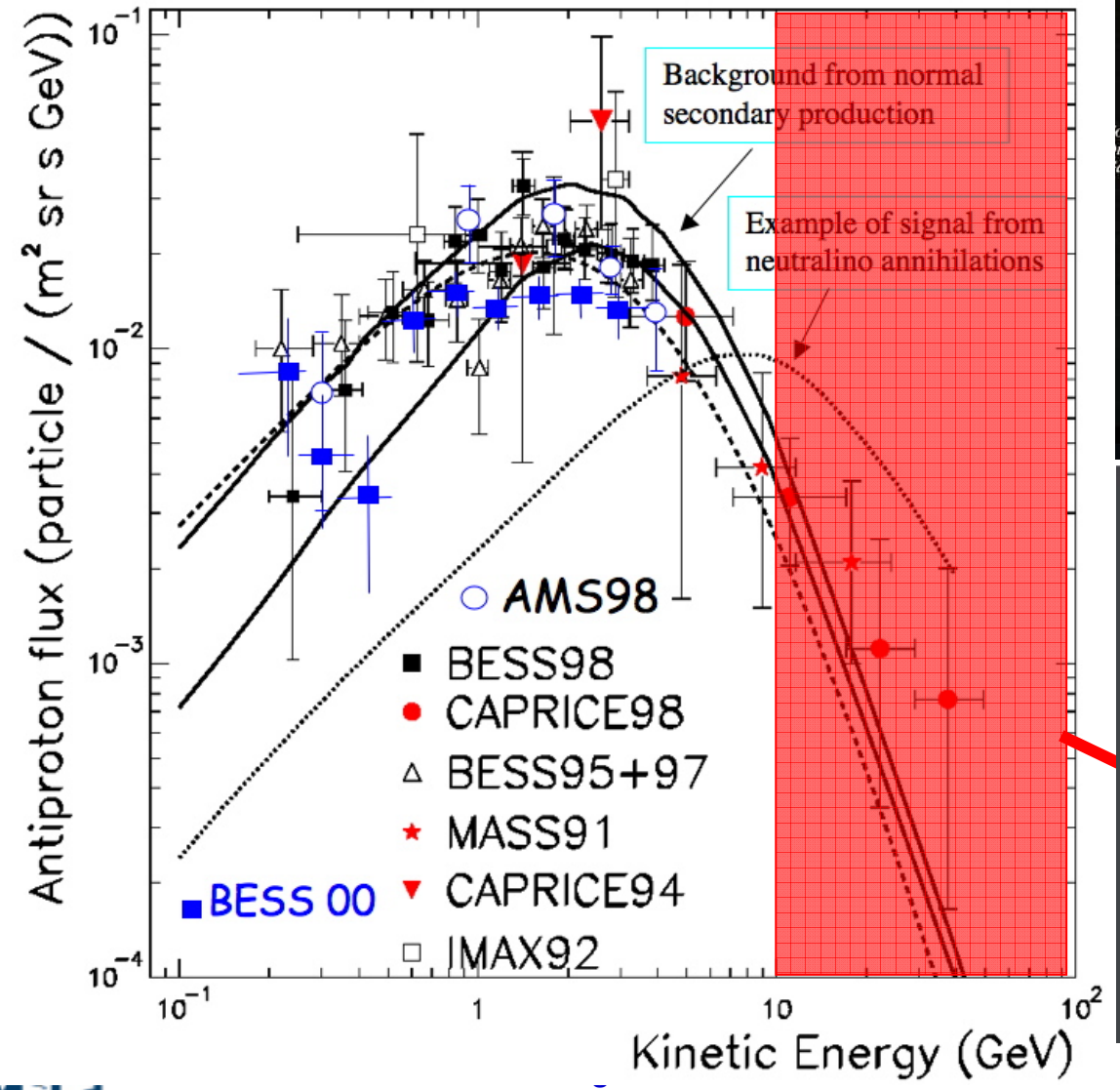
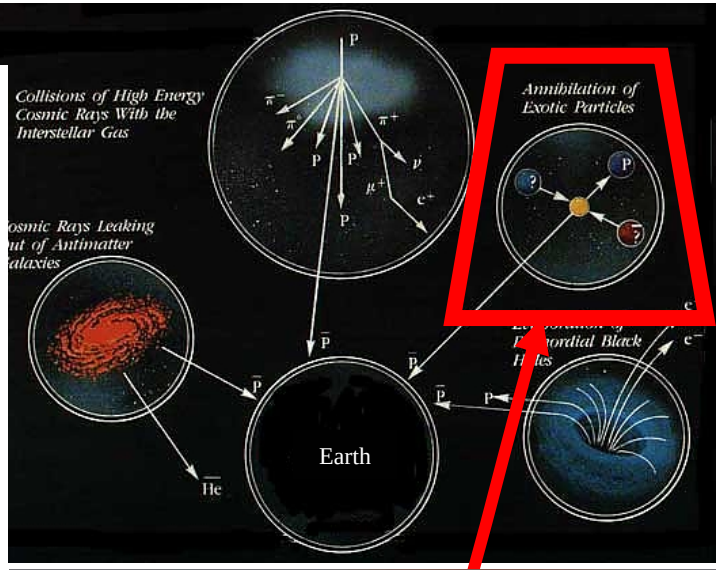
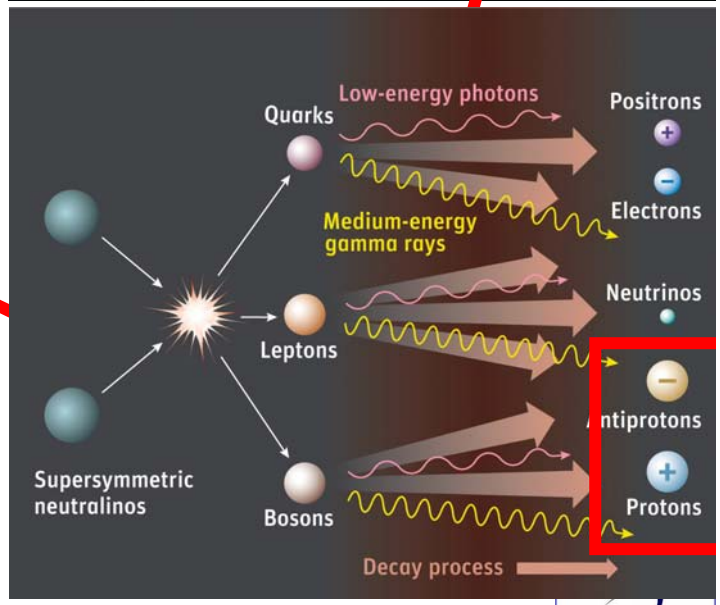




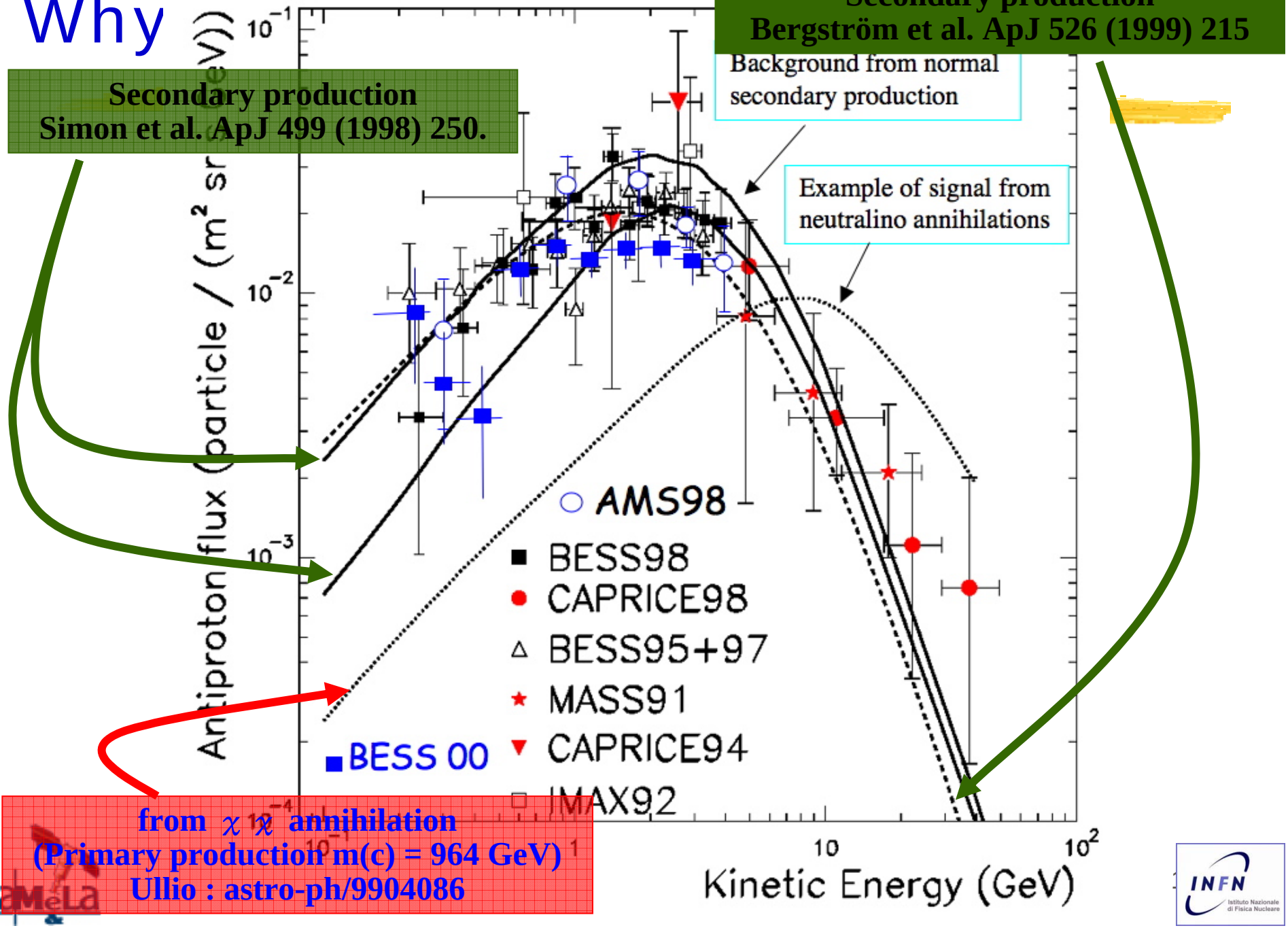


May 2008

Why

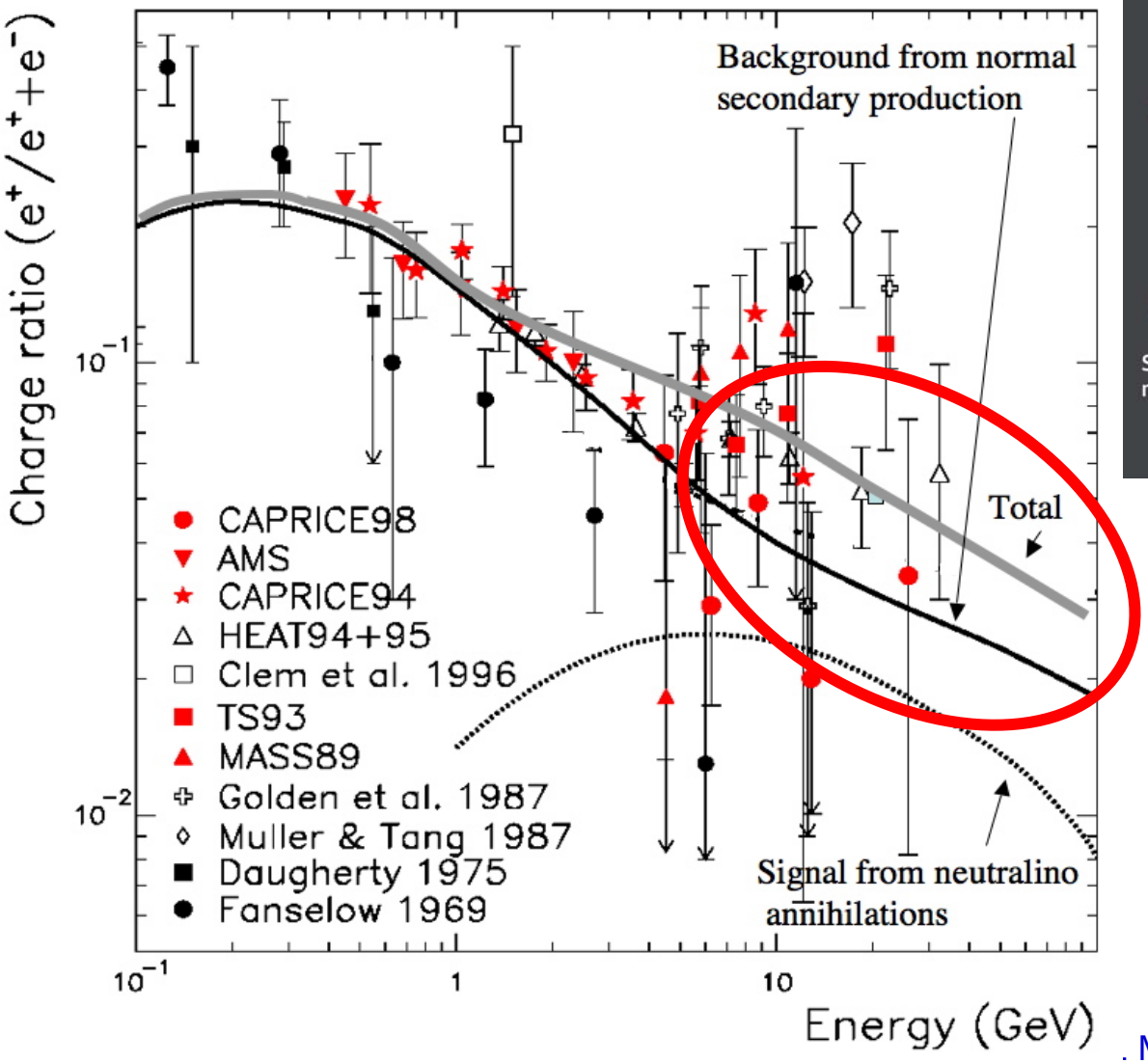
Secondary production
Simon et al. ApJ 499 (1998) 250.

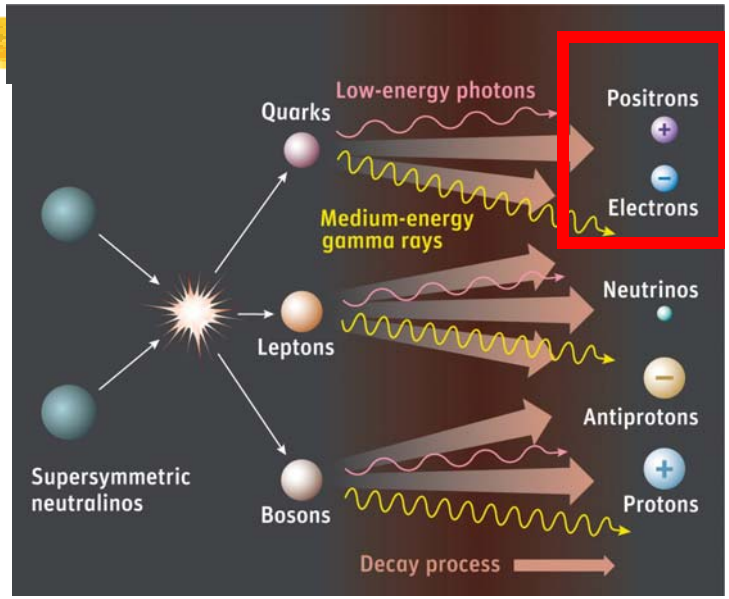
Secondary production
Bergström et al. ApJ 526 (1999) 215



from $\chi\chi$ annihilation
(Primary production m(c) = 964 GeV)
Ullio : astro-ph/9904086

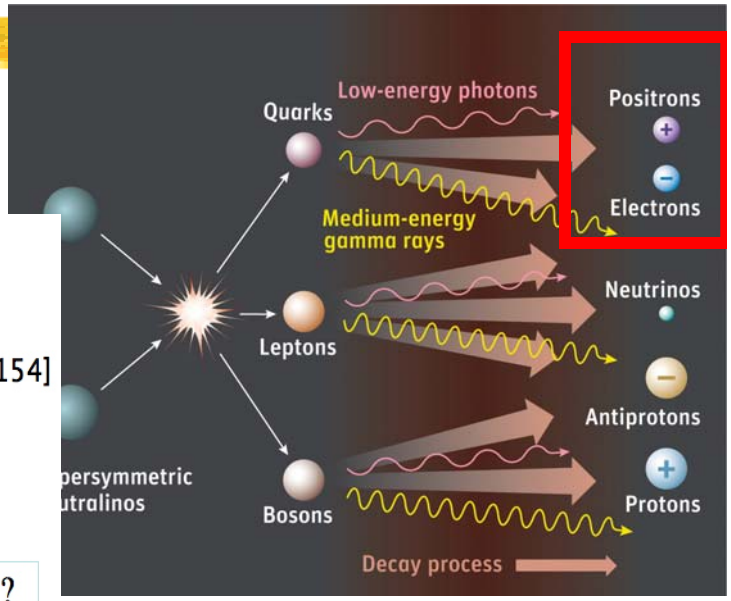
Why Anti(particle)matter matters?

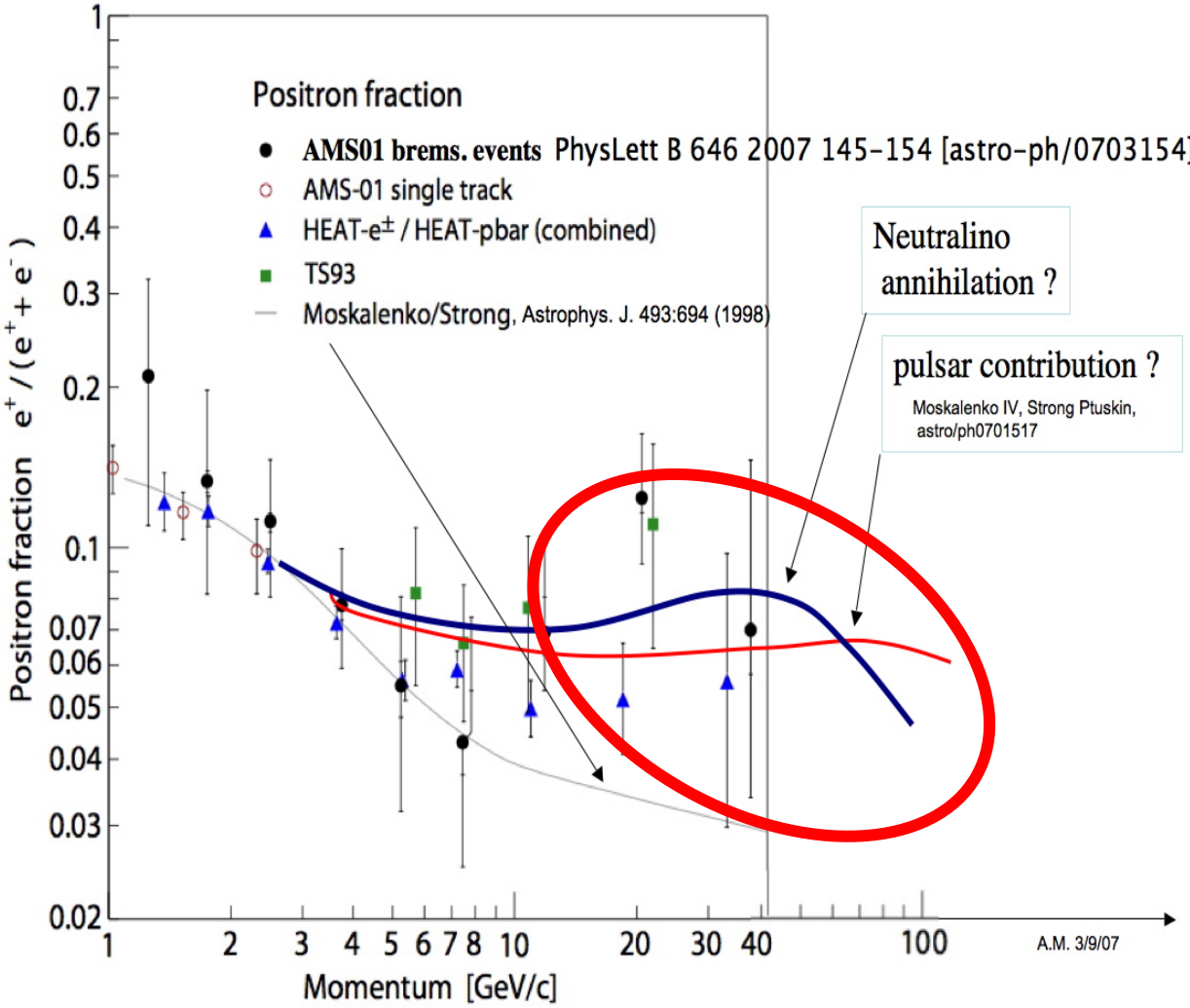




. May 2008

Why Anti(particle)matter matters?





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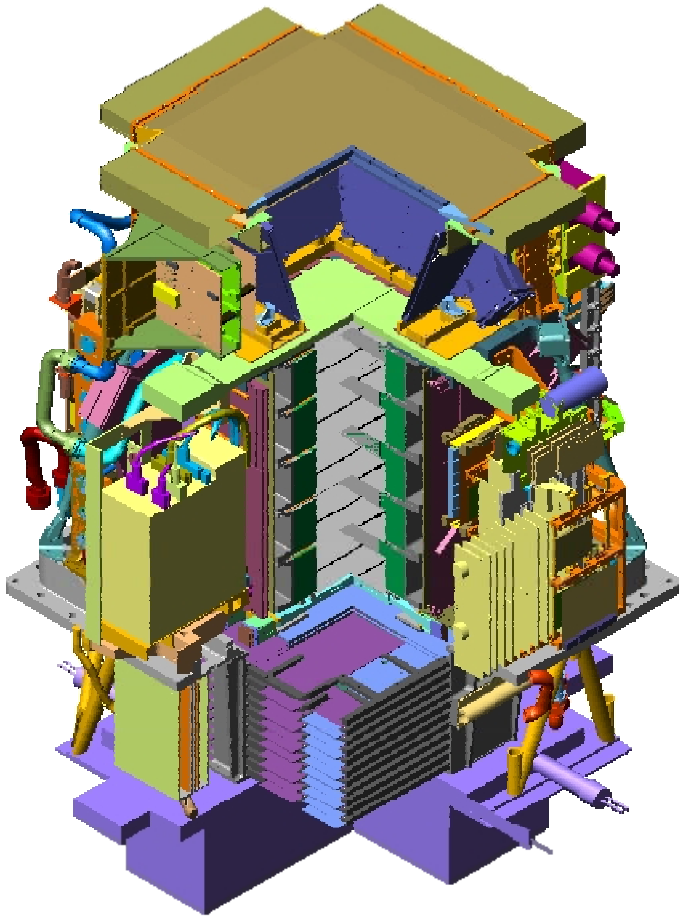
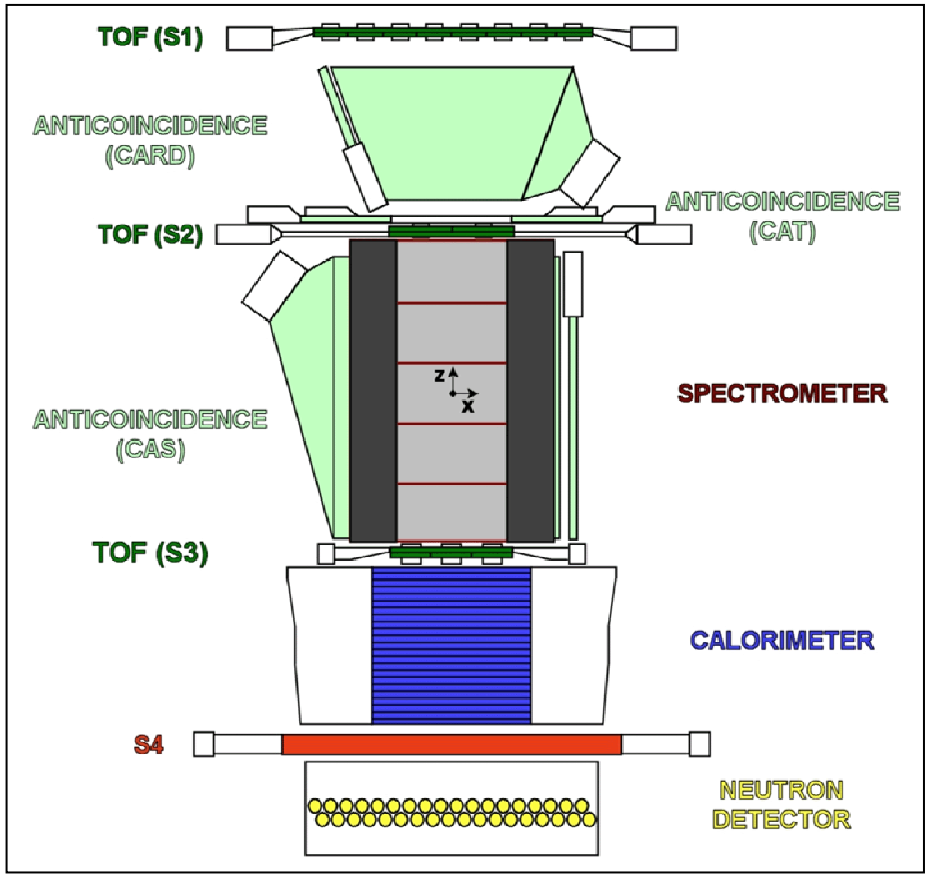
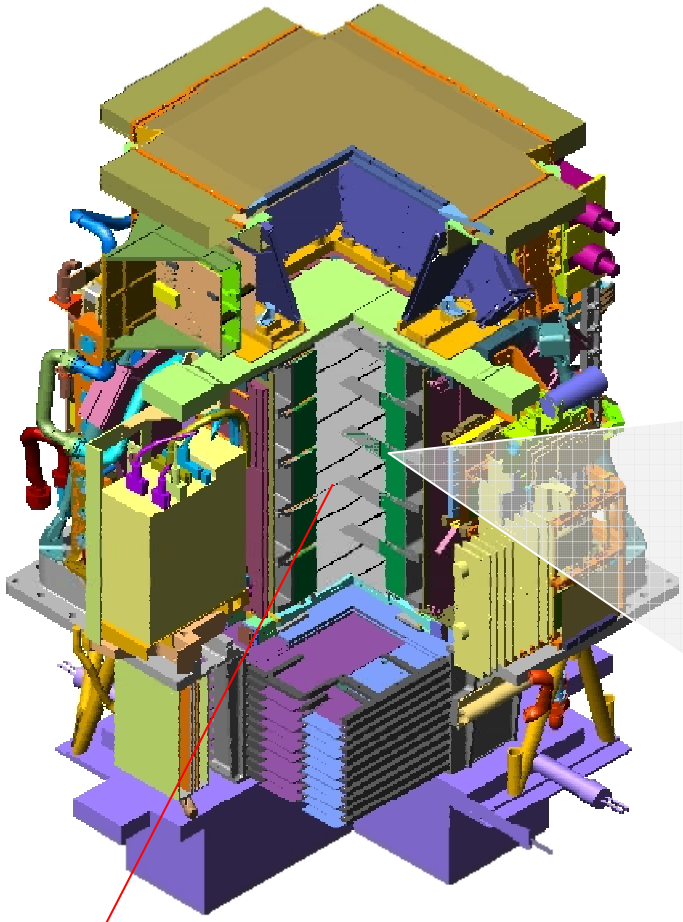
PAMELA apparatus





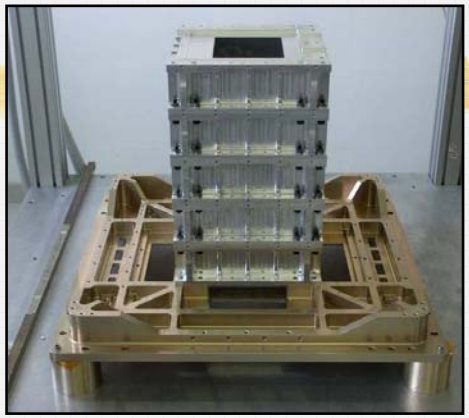
GF: 21.5 cm² sr
Mass: 470 kg
Size: 130x70x70 cm³
Power Budget: 360W

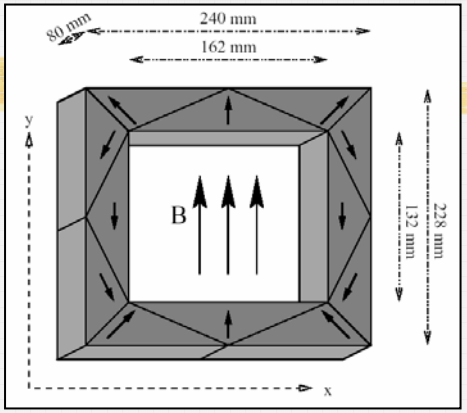
PAMELA



SPECTROMETER

The magnet

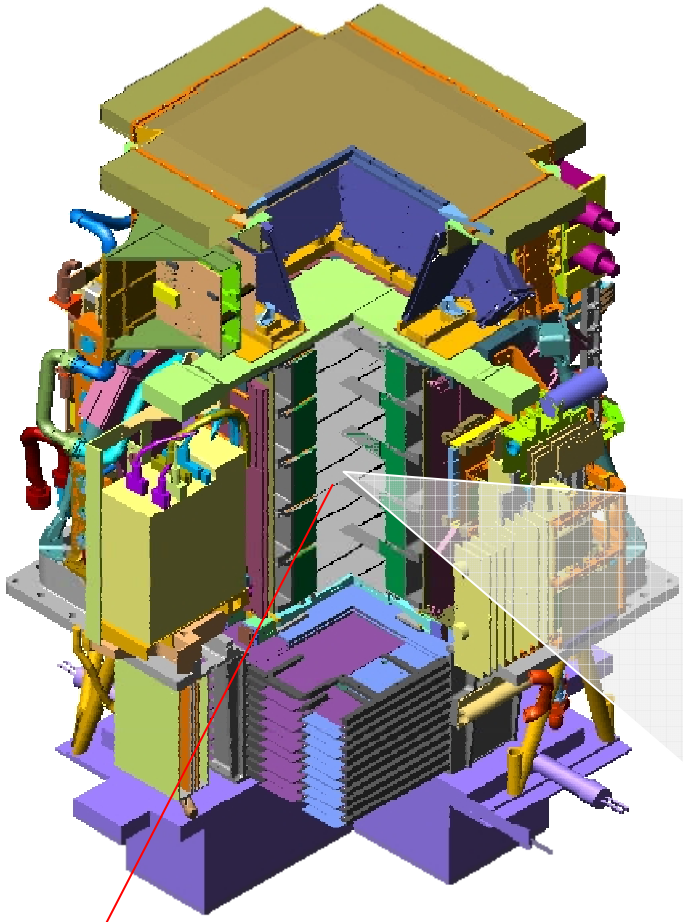




Characteristics:

- 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)

PAMELA



SPECTROMETER

The tracking system

Main tasks:

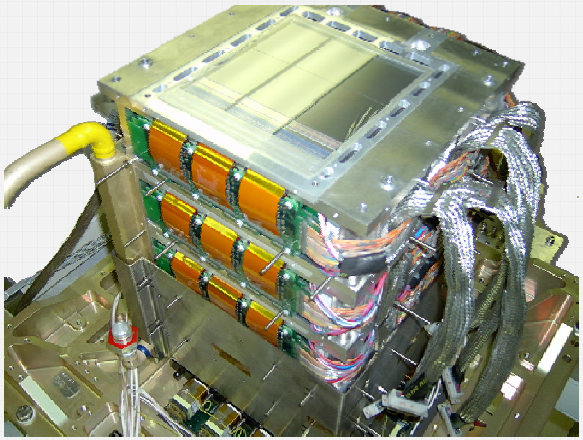
- Rigidity measurement
- Sign of electric charge
- dE/dx

Characteristics:

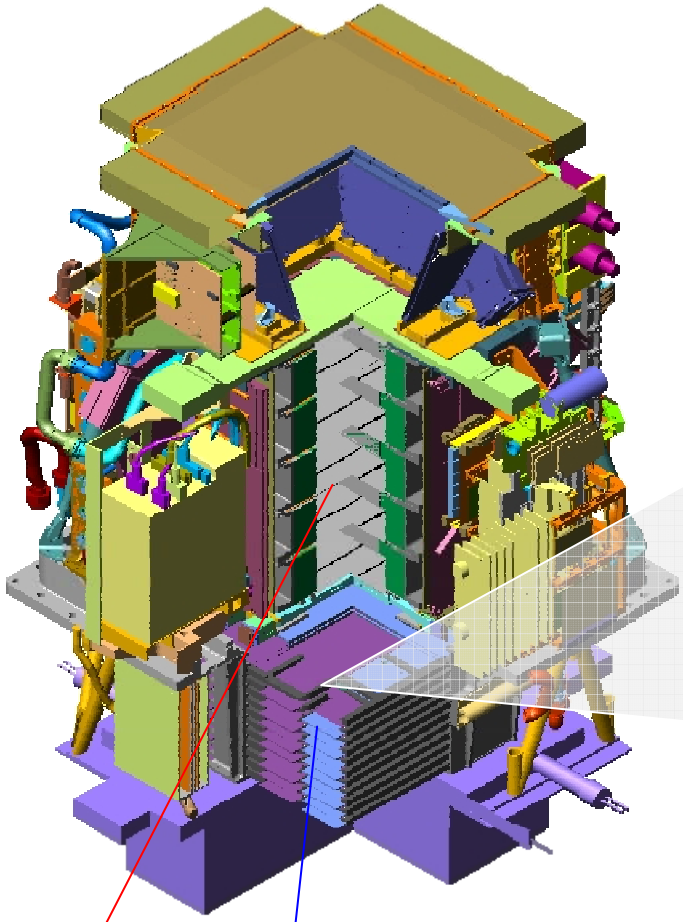
- 6 planes double-side (x&y view) microstrip Si sensors
- 36864 channels
- Dynamic range 10 MIP

Performances:

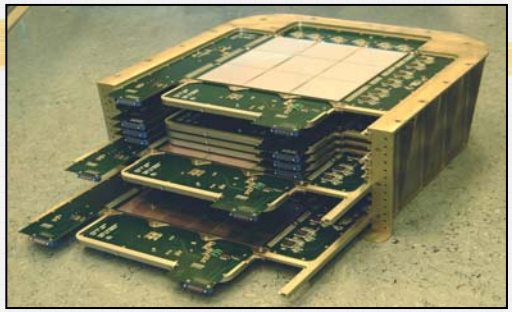
- Spatial resolution: 3-4μm
- MDR ~1T (from test beam data)



PAMELA



The electromagnetic calorimeter



Main tasks:

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

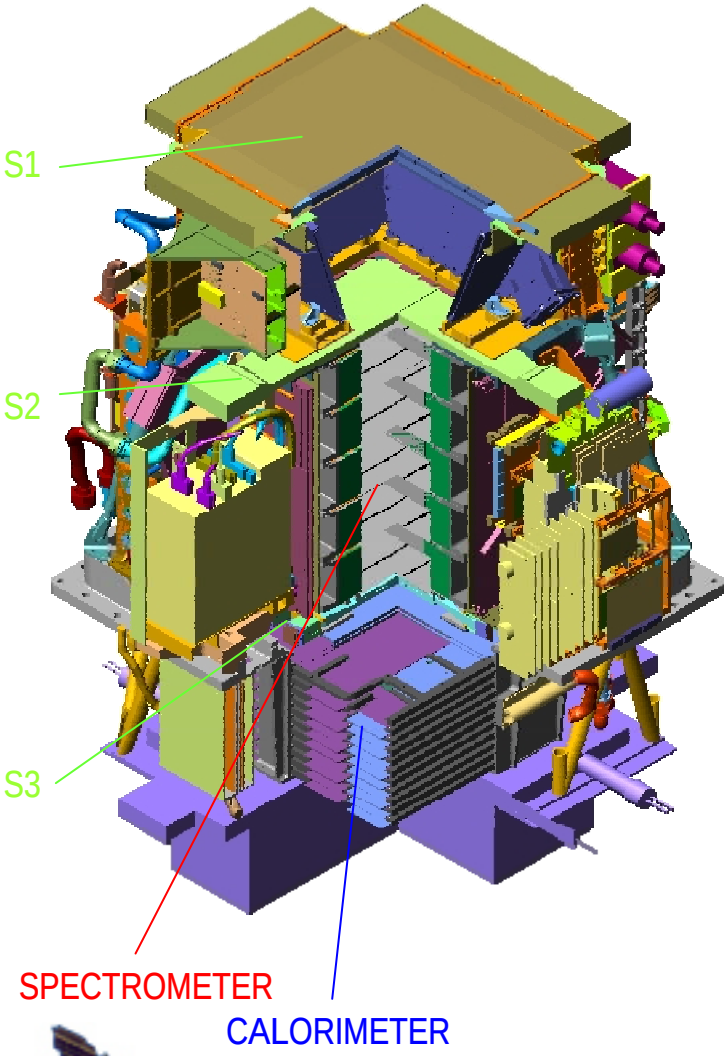
Characteristics:

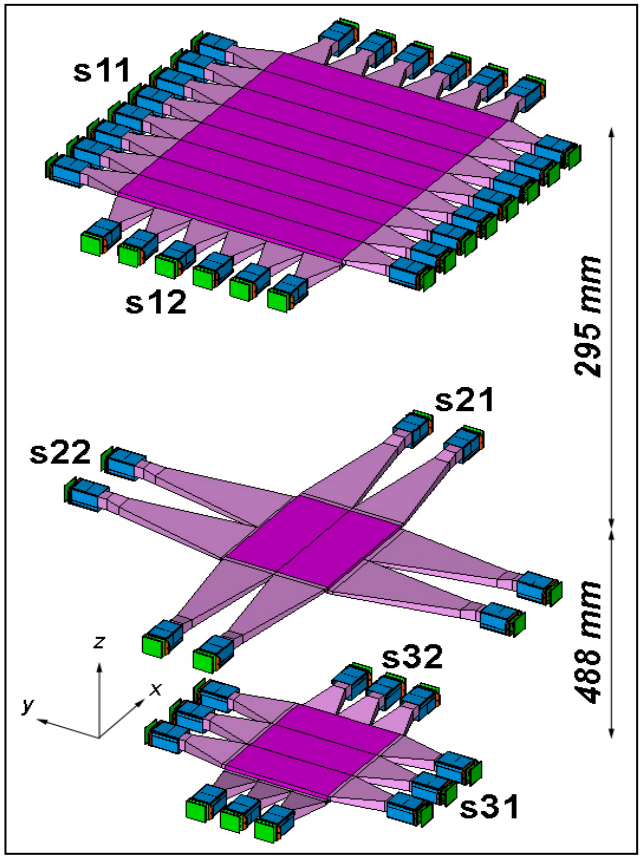
- 44 Si layers (X/Y) +22 W planes
- 16.3 X_o / 0.6 l_0
- 4224 channels
- Dynamic range 1400 mip
- Self-trigger mode (> 300 GeV GF~600 cm^2 sr)

Performances:

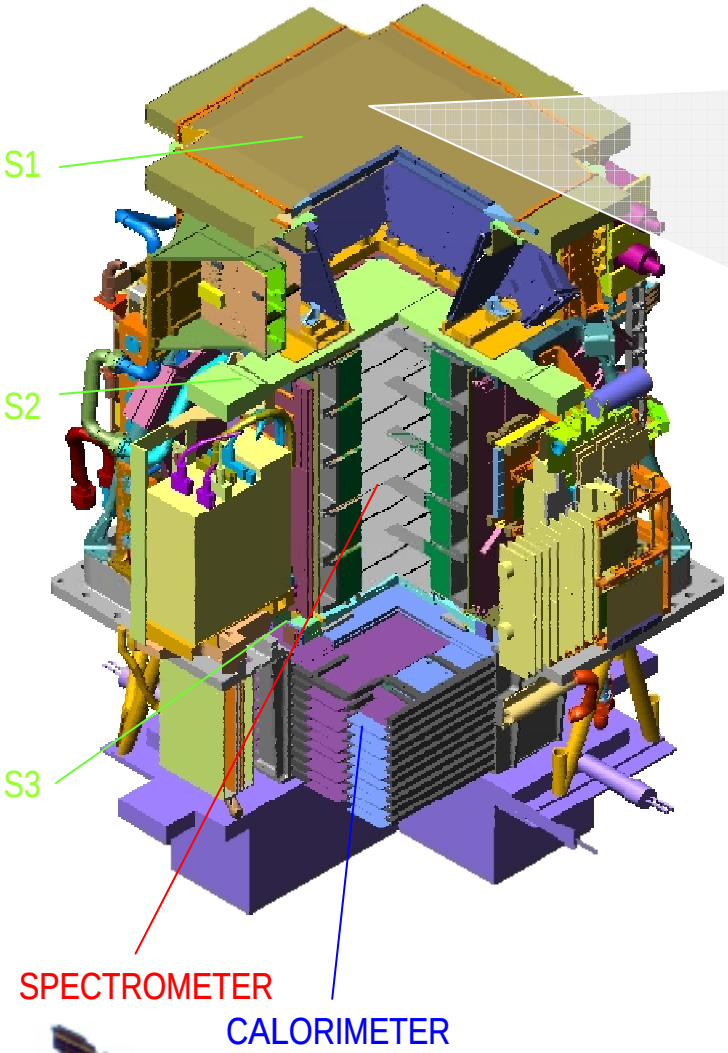
- p-bar and e^+ selection efficienecy ~ 90%
- p rejection factor $>10^5$
- e^- rejection factor > 10^4
- Energy resolution ~5% @200GeV

PAMELA

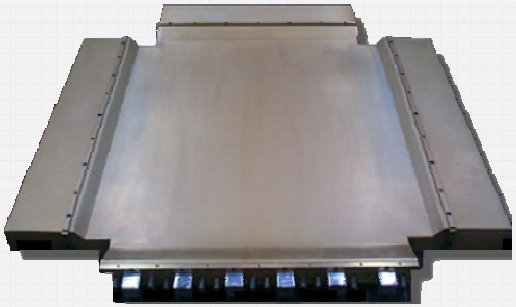

S1
S2
S3
SPECTROMETER
CALORIMETER


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

PAMELA



The time-of-flight system

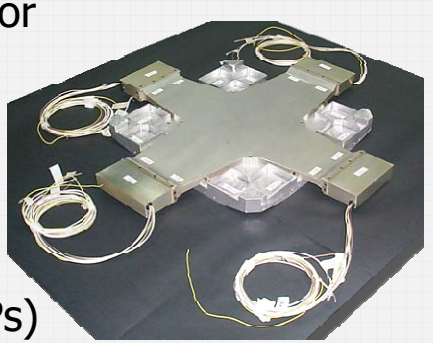


Main tasks:

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

Characteristics:

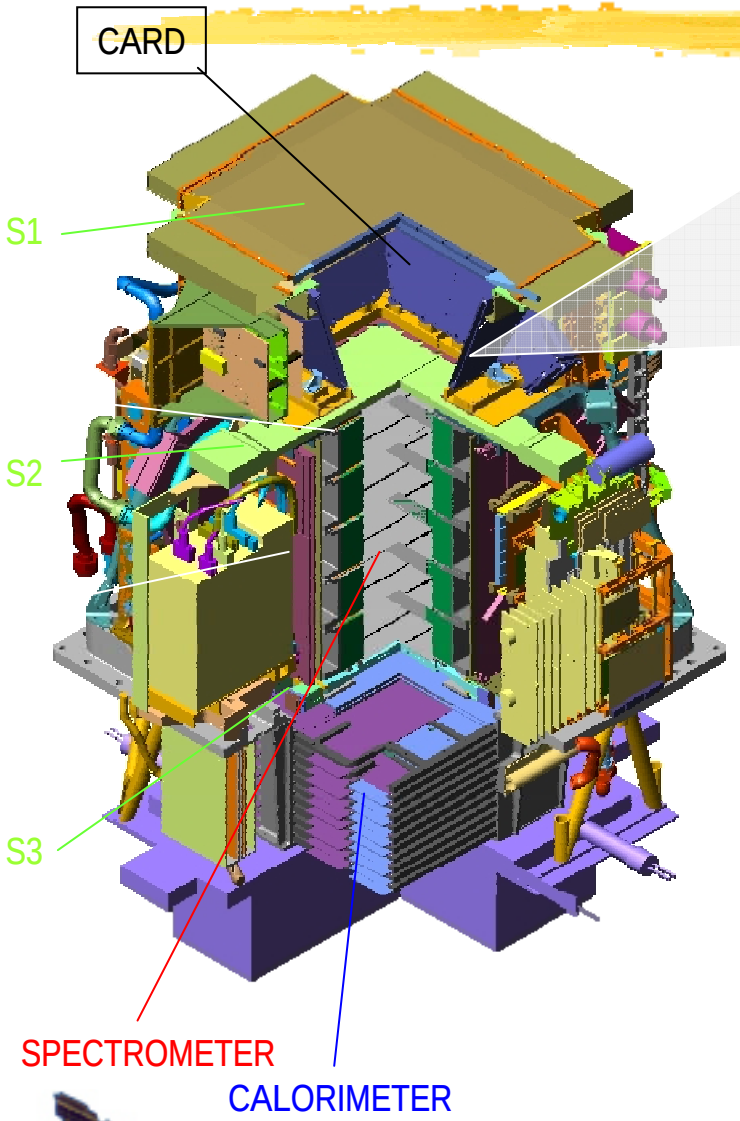
- 3 double-layer scintillator paddles
- X/Y segmentation
- Total: 48 Channels



Performances:

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

PAMELA



The anticounter shields

Main tasks:

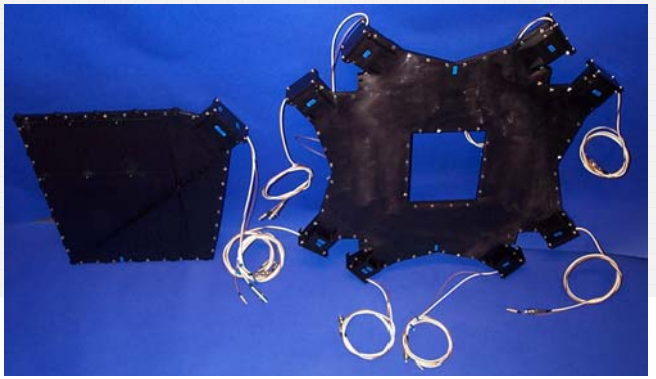
- Rejection of events with particles interacting with the apparatus (off-line and second-level trigger)

Characteristics:

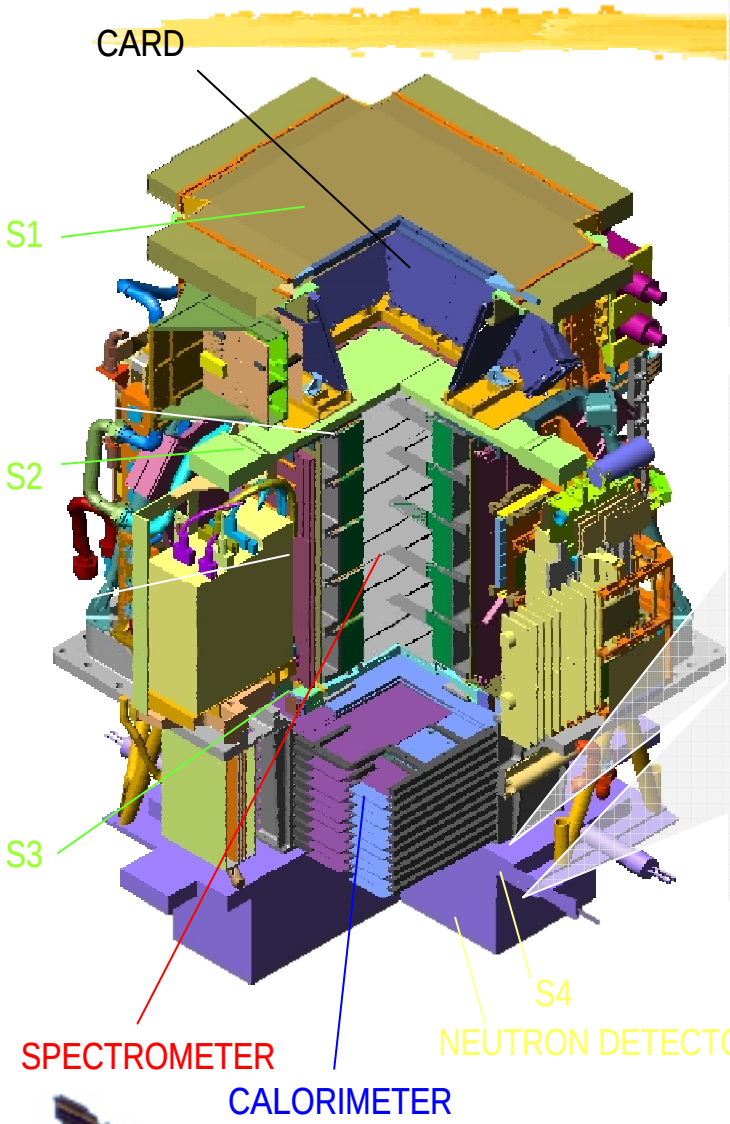
- scintillator paddles 10mm thick
- 4 up (CARD), 1 top (CAT), 4 side (CAS)

Performances:

- Efficiency > 99.9%



PAMELA



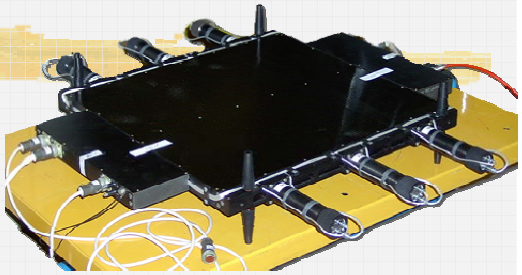
Shower-tail catcher (S4)

Main tasks:

- ND trigger

Characteristics:

- 1 scintillator paddle 10mm thick



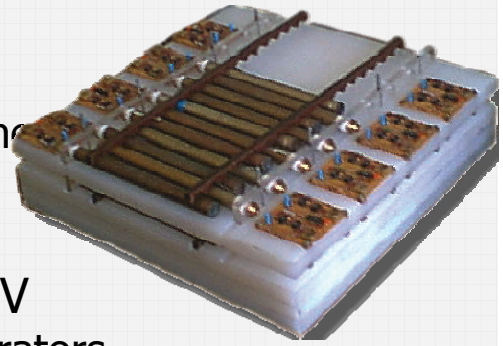
Neutron detector

Main tasks:

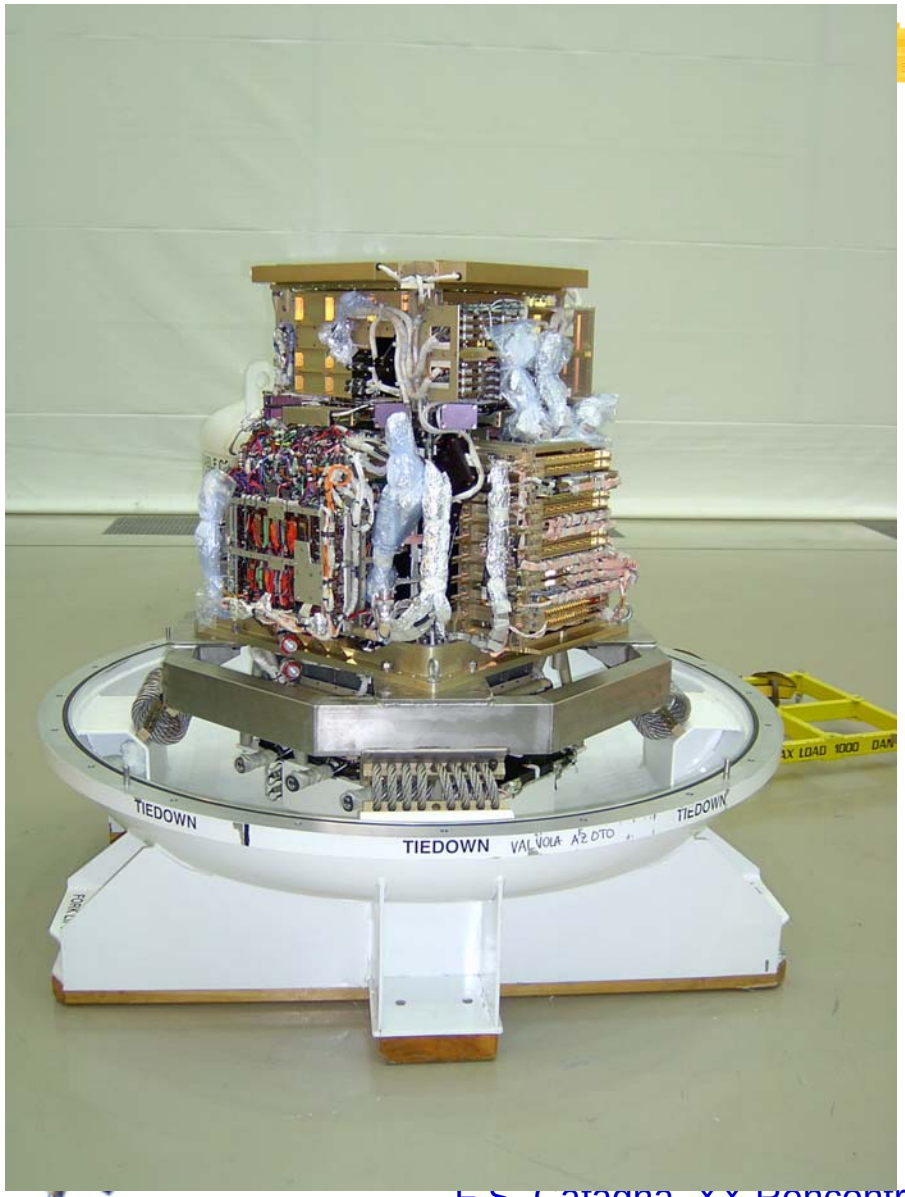
- e/h discrimination @high-en

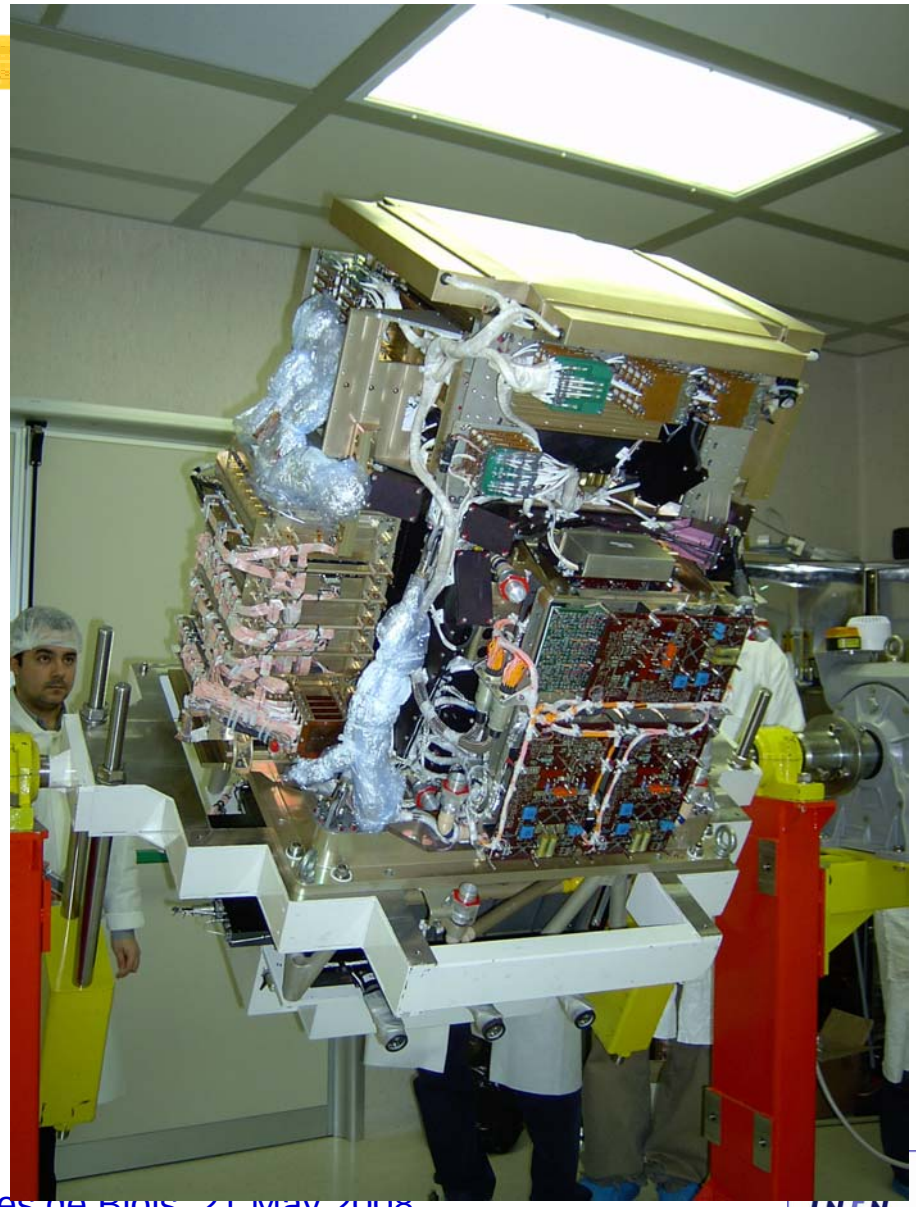
Characteristics:

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

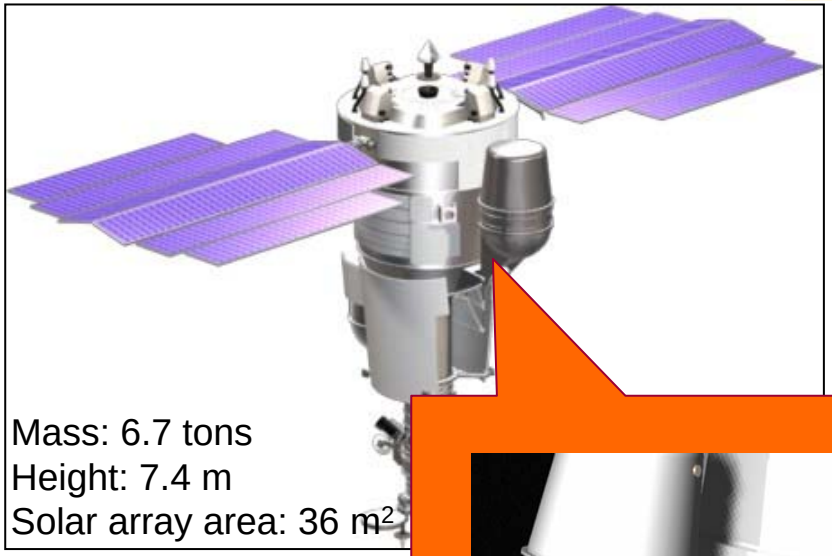


PAMELA: the integration

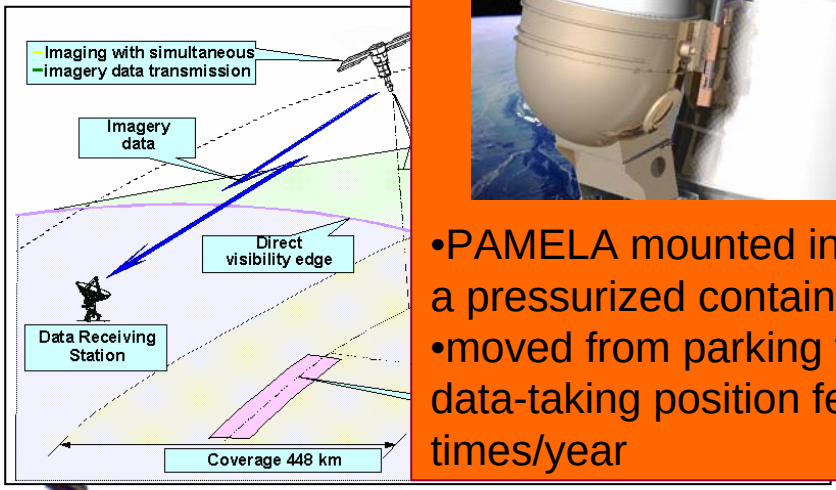




The Resurs DK-1 spacecraft



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)

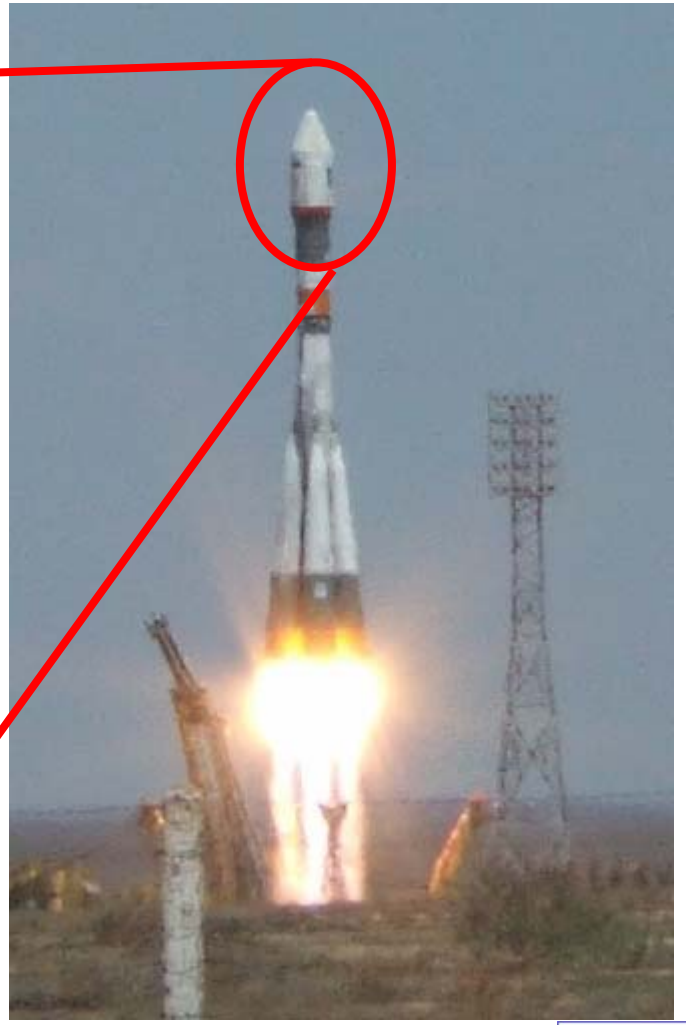
Operational orbit parameters:

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

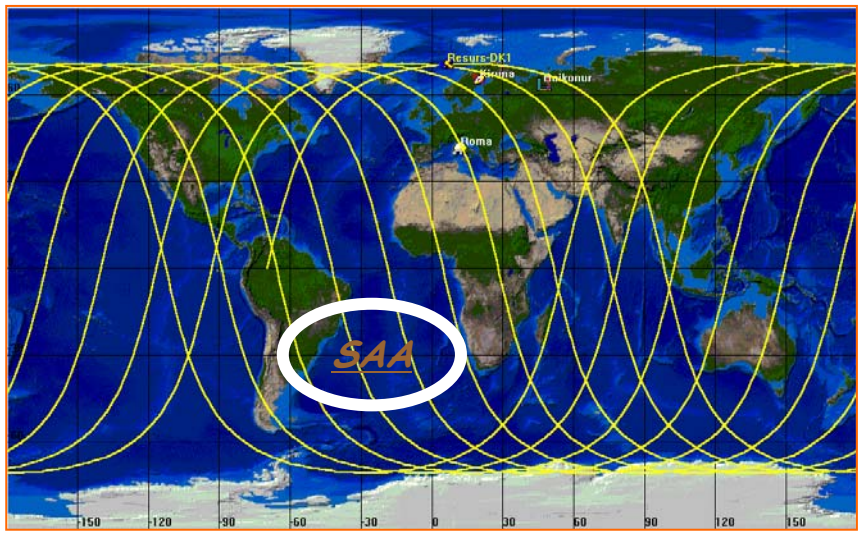
Active life >3 years

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

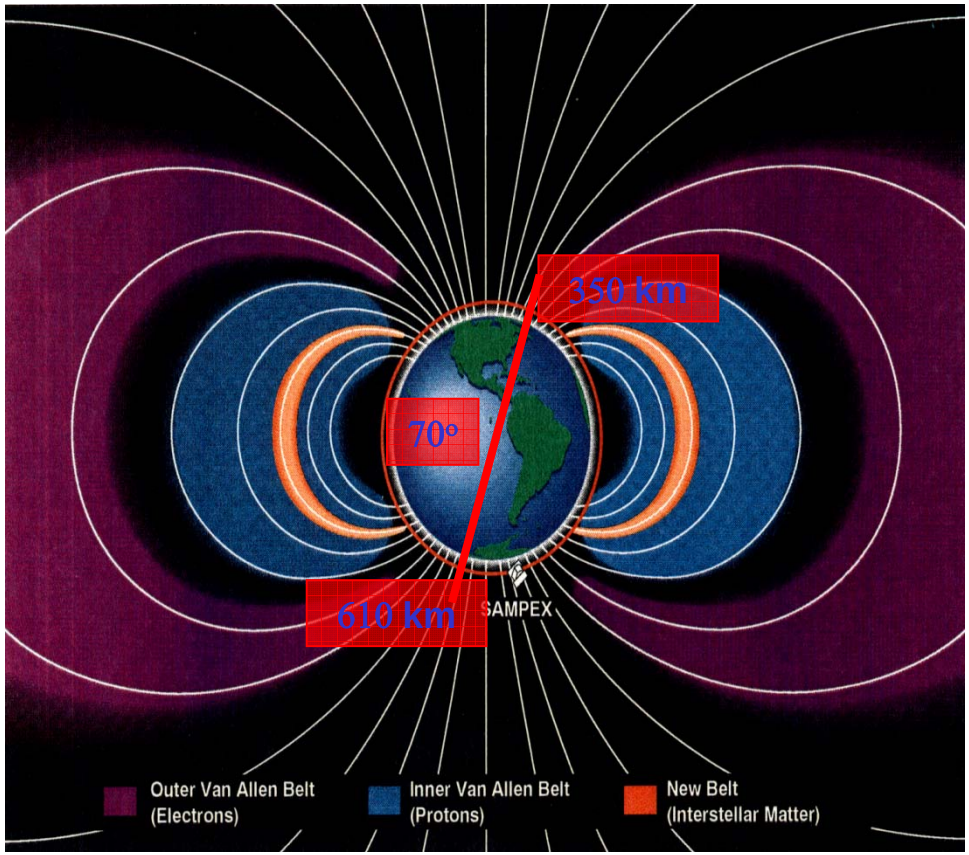
PAMELA: in the satellite & launch



Orbit Characteristics



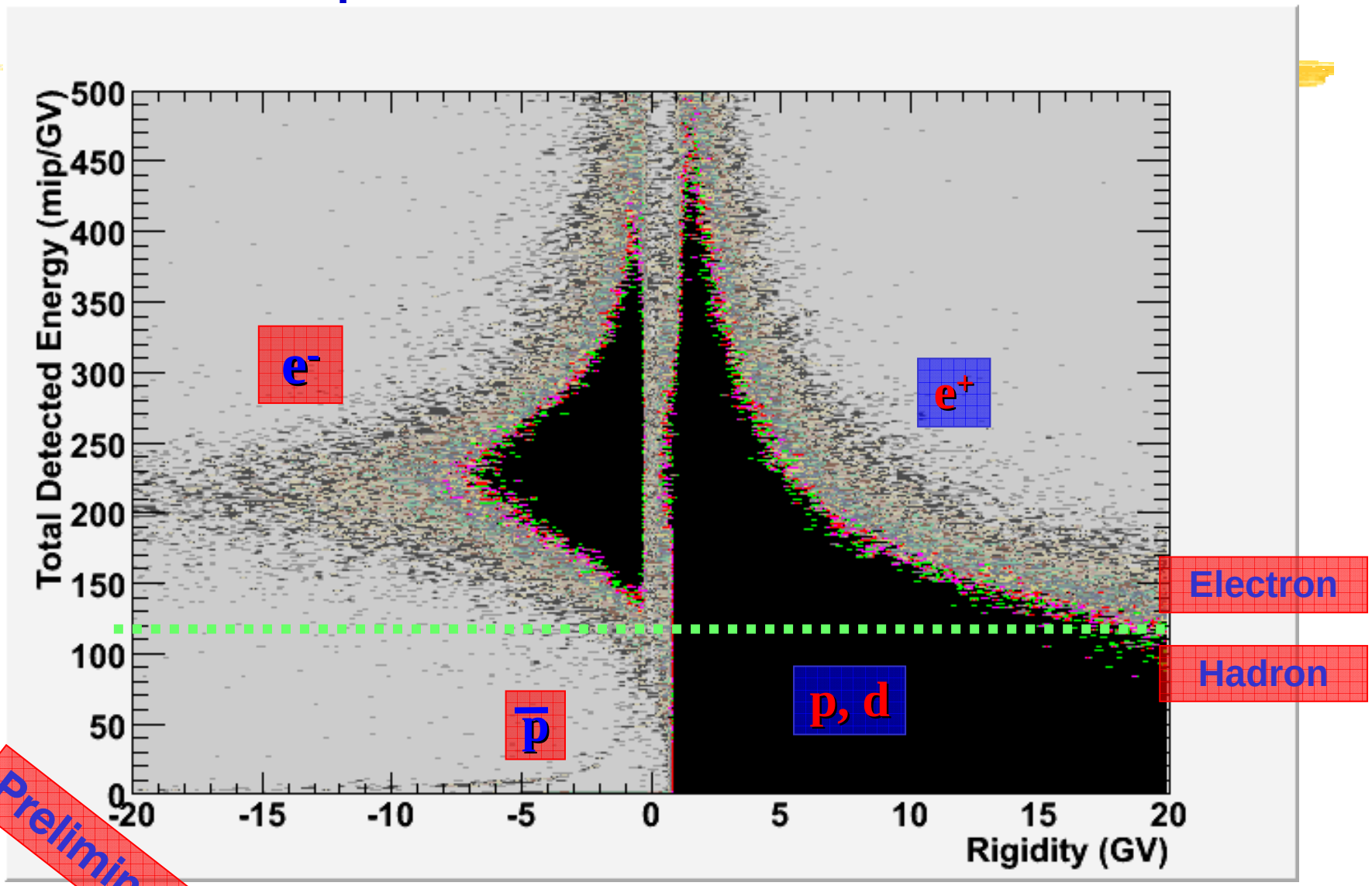
- Low-earth elliptical orbit
- 350 – 610 km
- Quasi-polar (70° inclination)
- Lifetime >3 years (assisted)



PAMELA STATUS

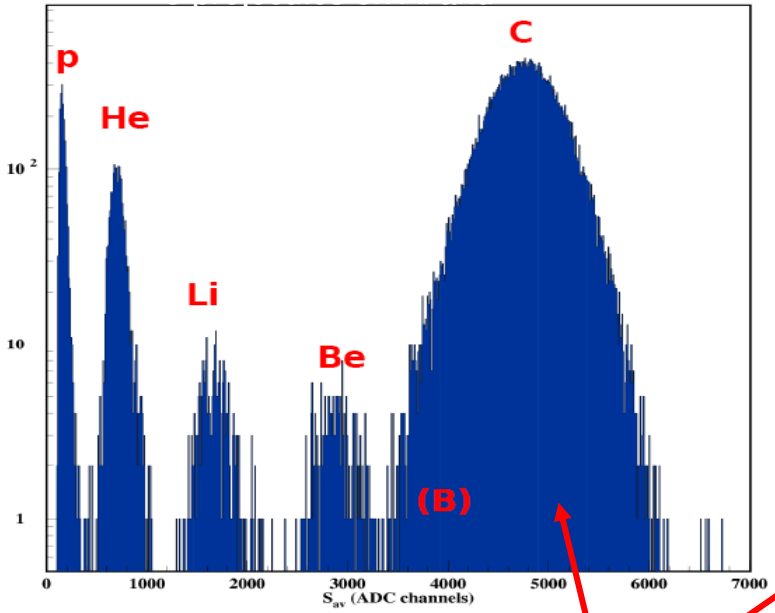
- PAMELA was launched on June the 15th 2006, from the Bajkonour Comodrome using a Soyuz rocket
- Up to February 2008 did collect ~ 8.8TB of data, corresponding to ~ $1x10^9$ triggers
- More than 10^7 p ed 800 $\bar{p}$ have been identified between 1 and 100 GeV.
- Up to August 2007 ~$2x10^5$ e^- and ~ $2x10^4$ e^+ have been identified in the range from 200 MeV to 10 GeV (~ 15000 e^+ over 1 GeV)
- Electron analysis in progress to cover the rest of the data …

Antiparticle Selection

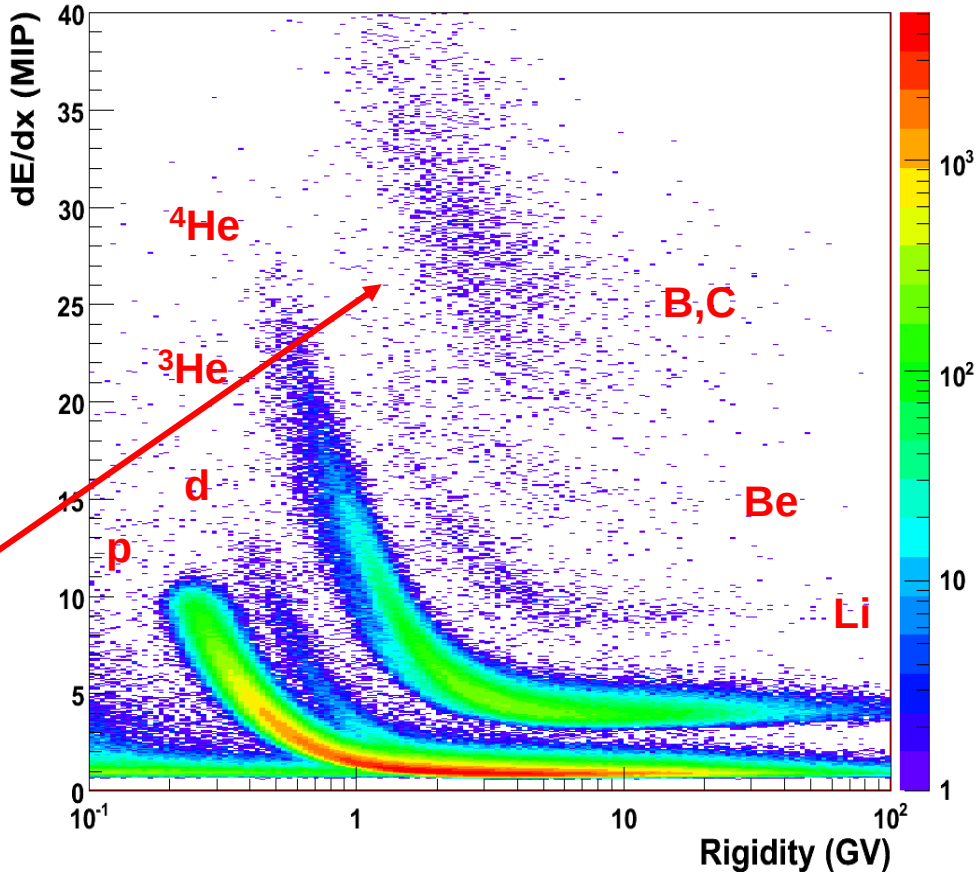


Charge identification capabilities (tracker)

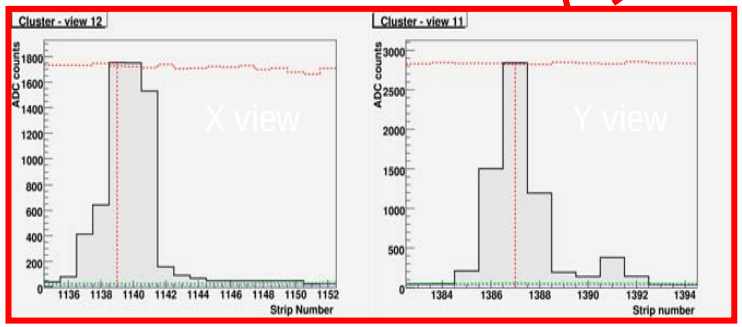
Beam-test data (@GSI 2006)



preliminary

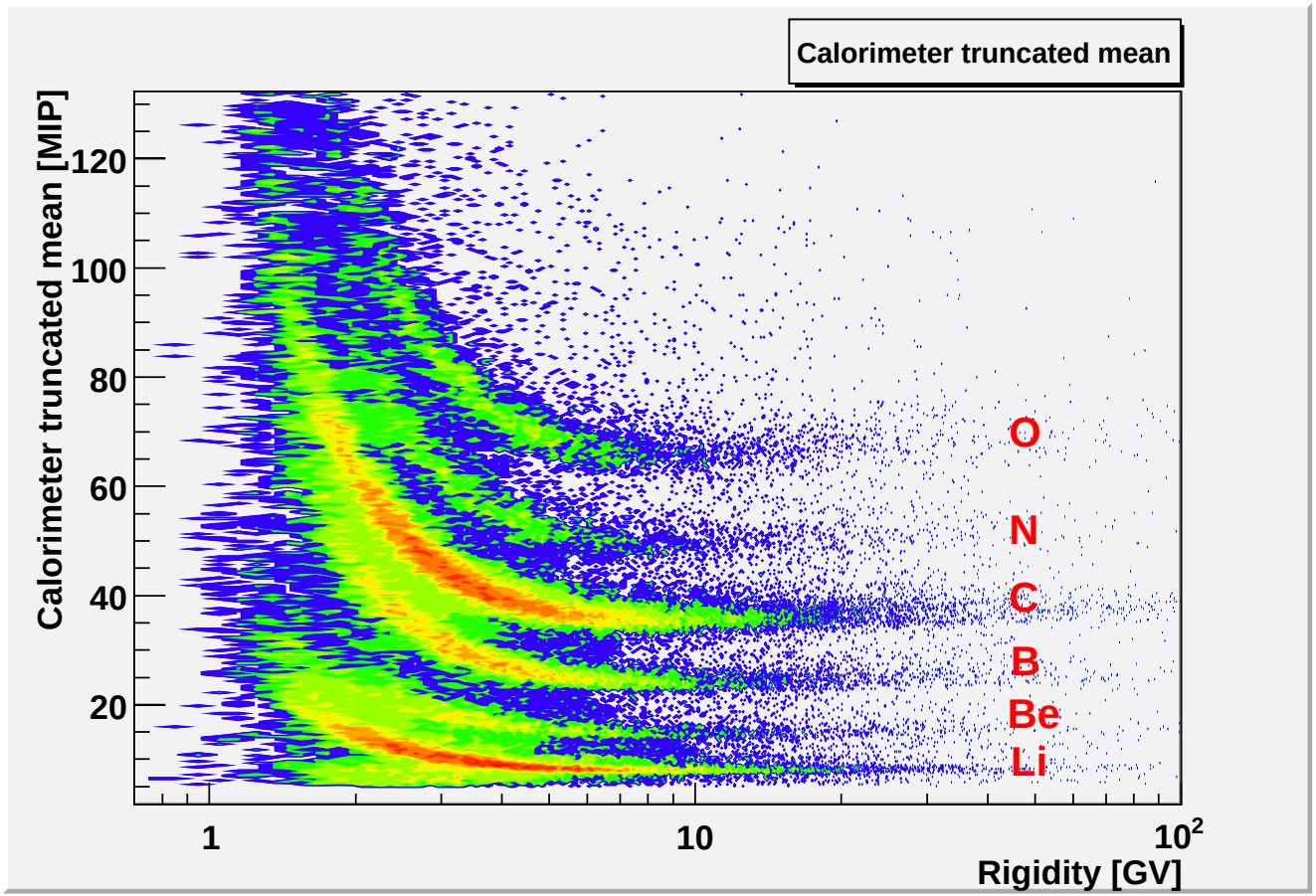


Saturated clusters



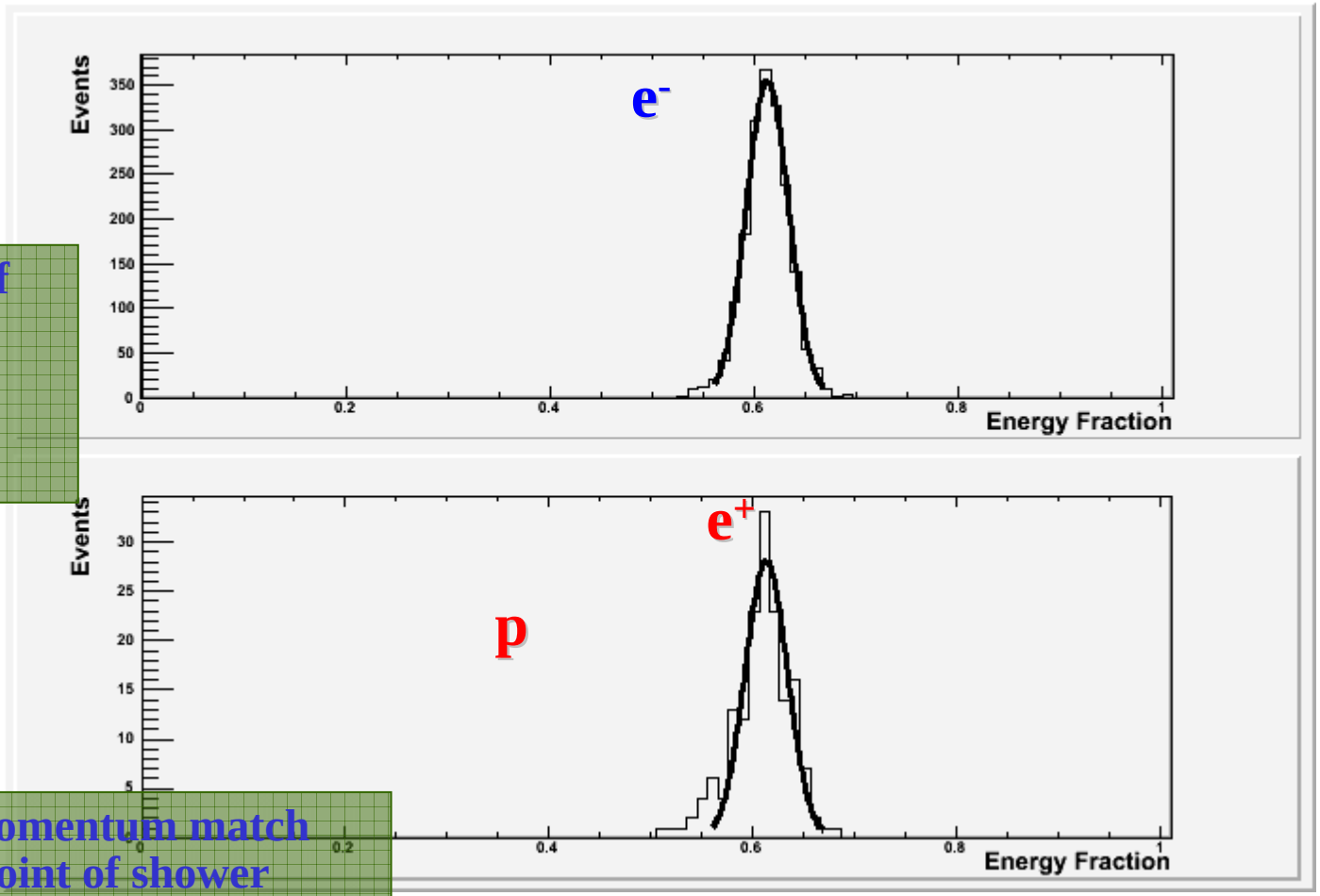
- **Good charge discrimination of H and He**
- **Single-channel saturation at ~10MIP affects B/C discrimination**

Charge identification capabilities (calo)



Positron selection with calo

Rigidity: 20-30 GV

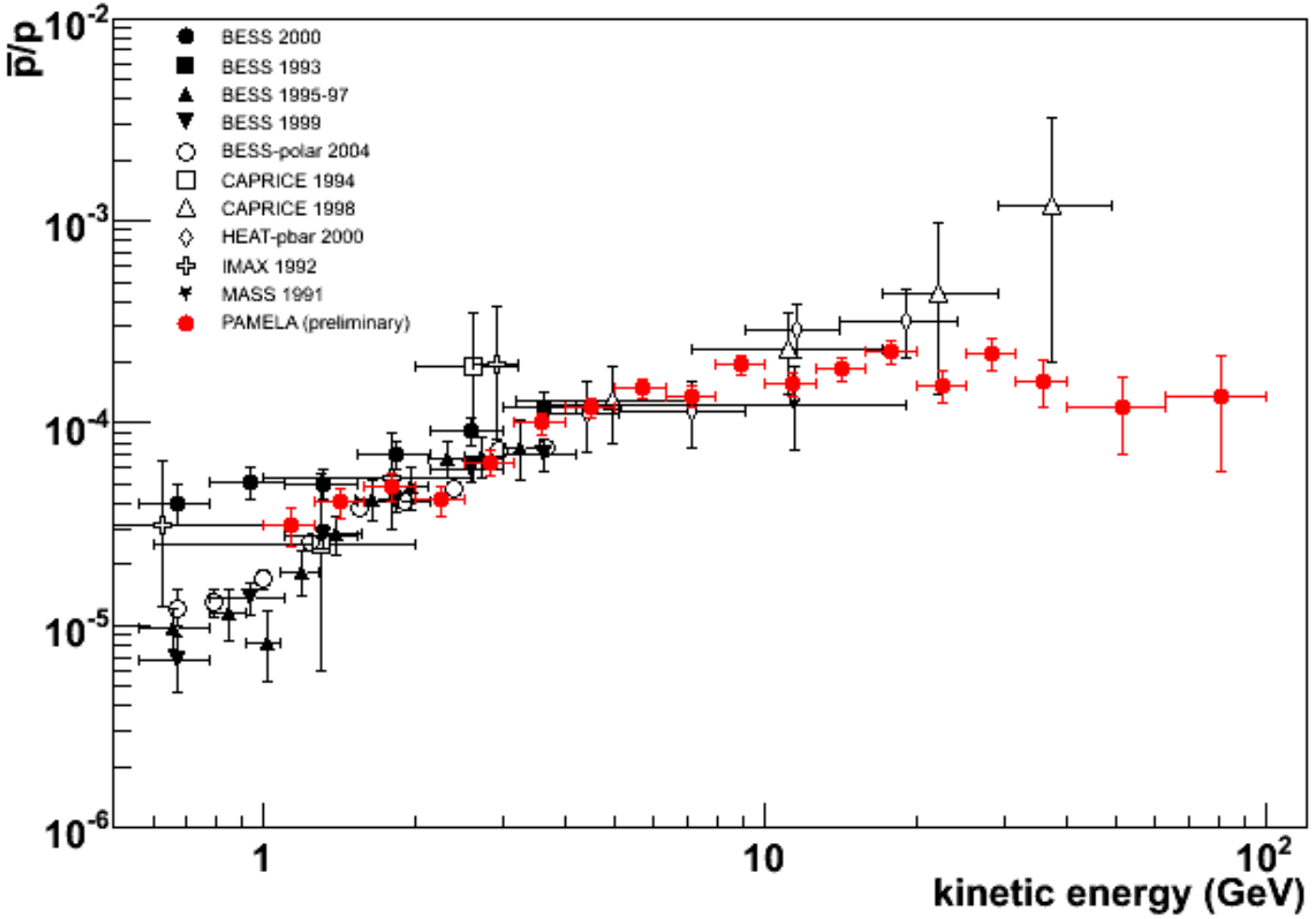


Fraction of charge released along the calo. track

- **Energy-momentum match**
- **Starting point of shower**
- **Longitudinal profile**

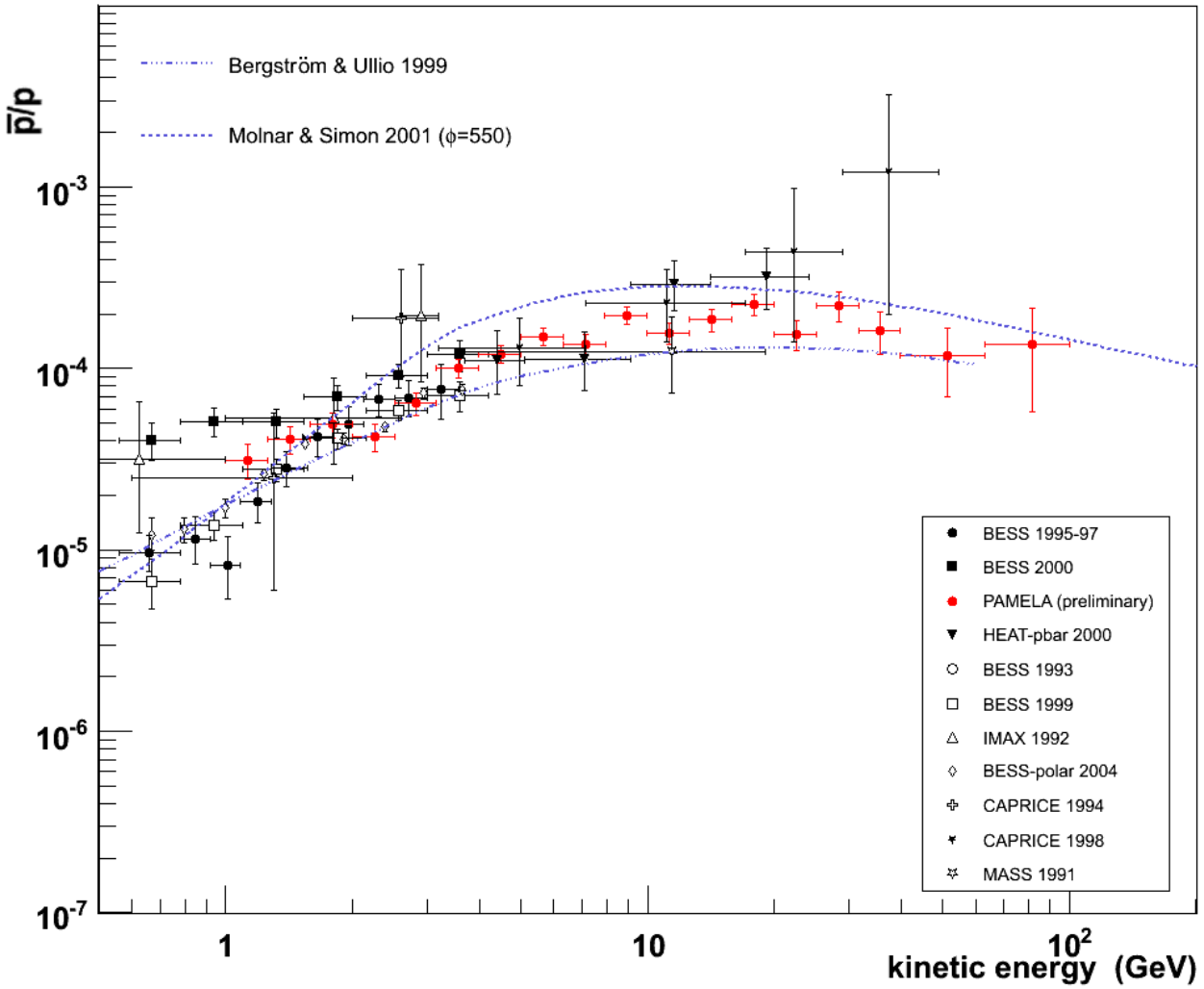
Antiproton to Proton Ratio

Preliminary

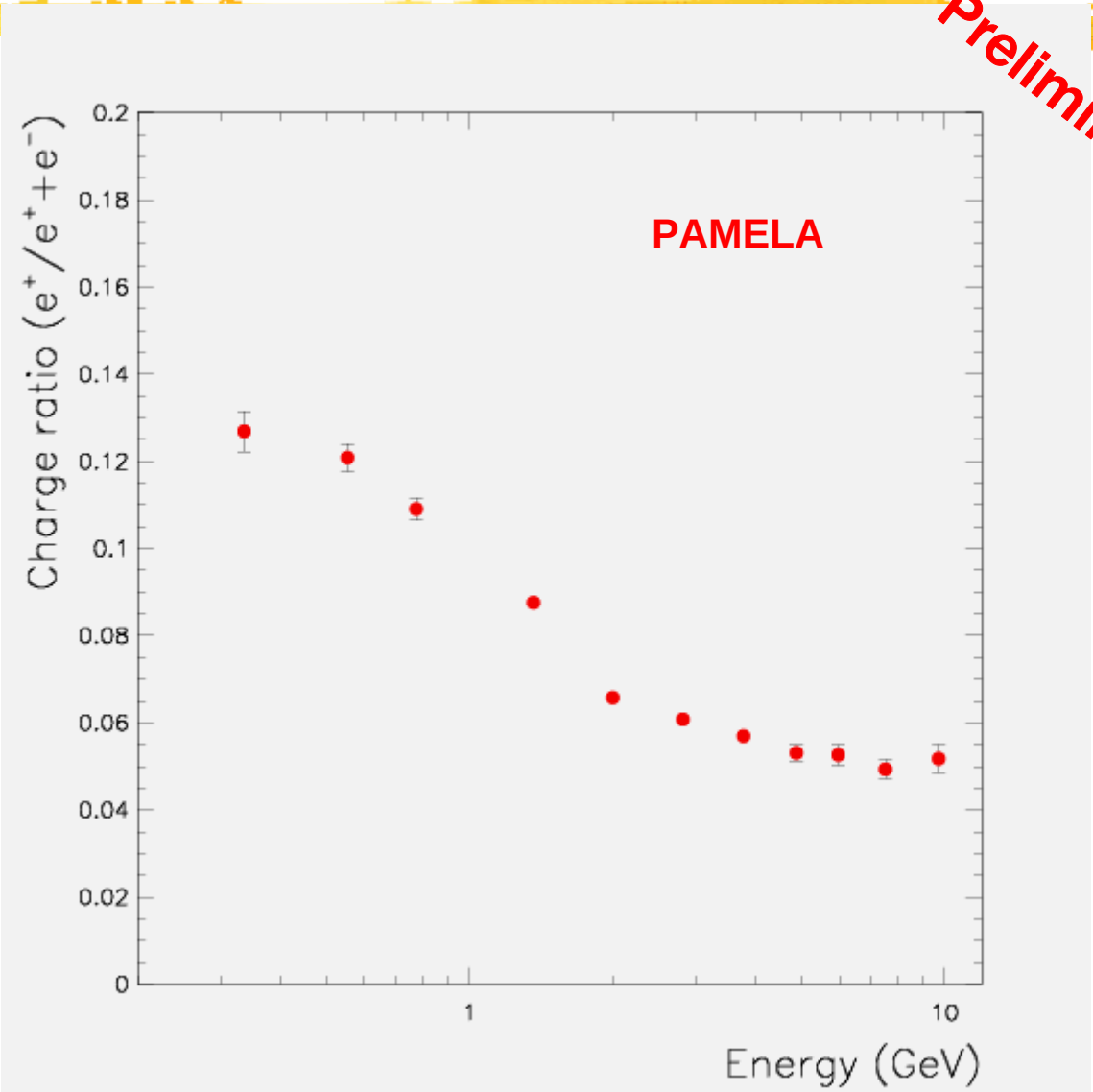


Antiproton to Proton Ratio

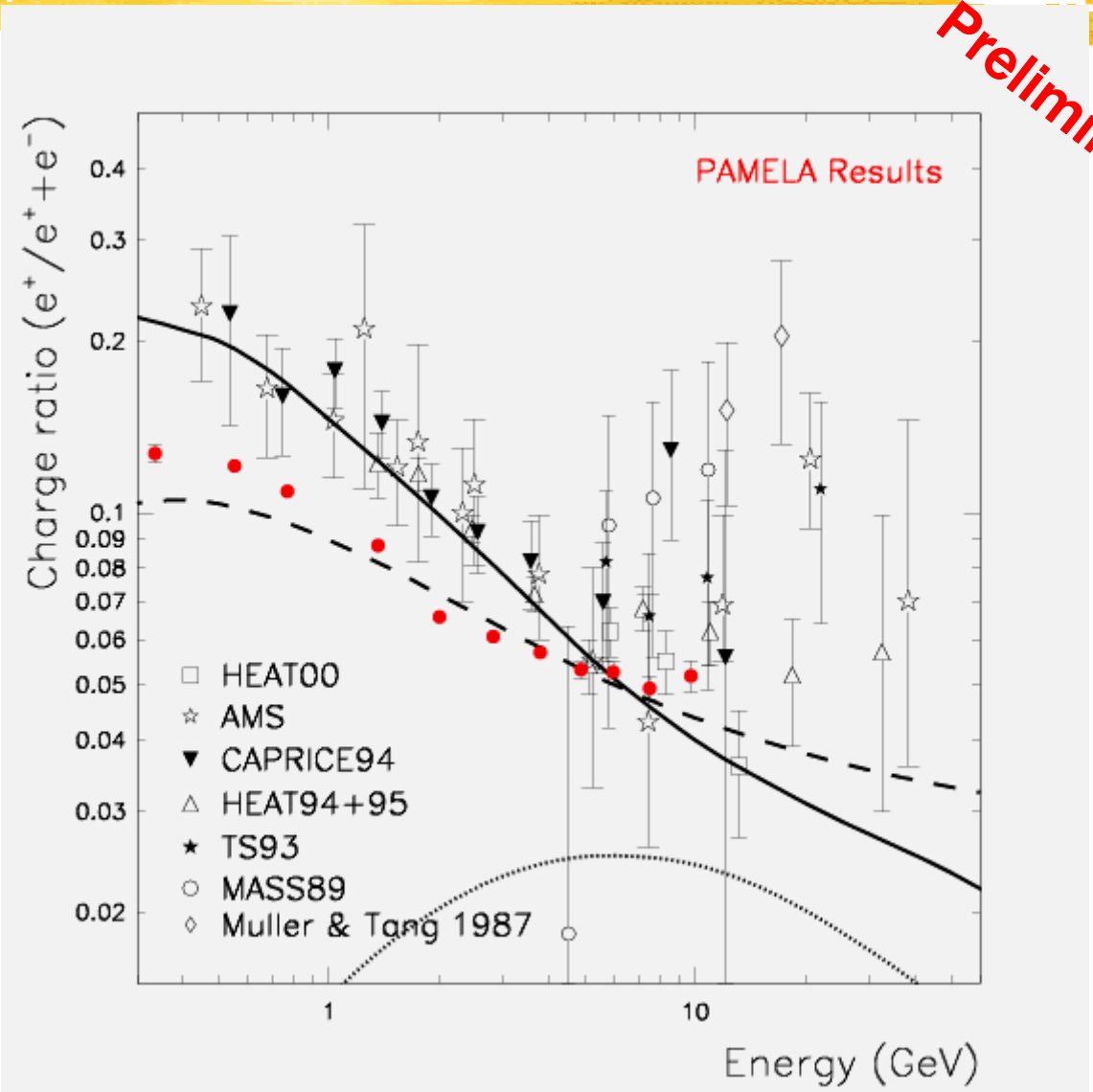
Preliminary



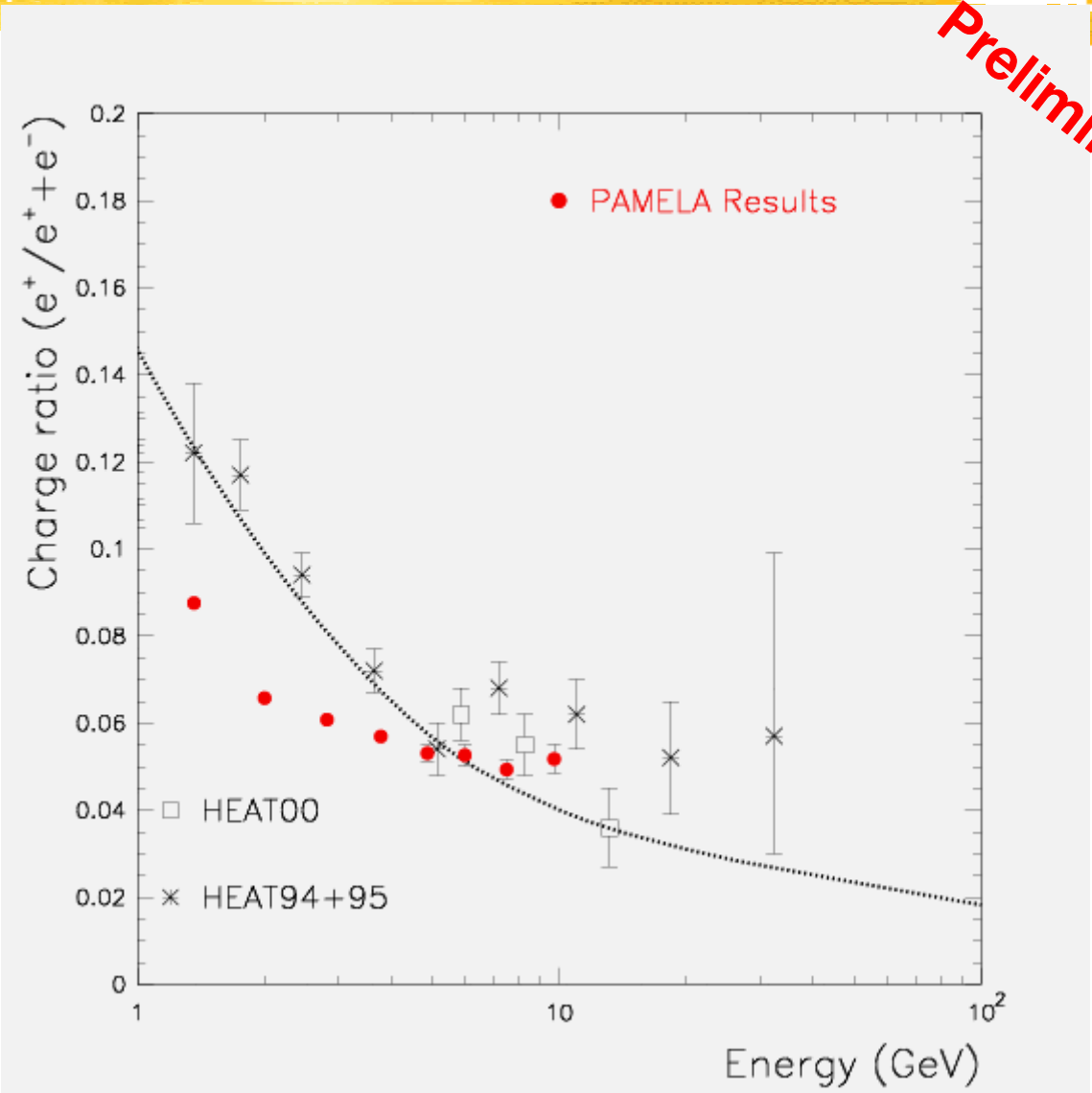
Positron - Electron ratio



Positron - Electron ratio

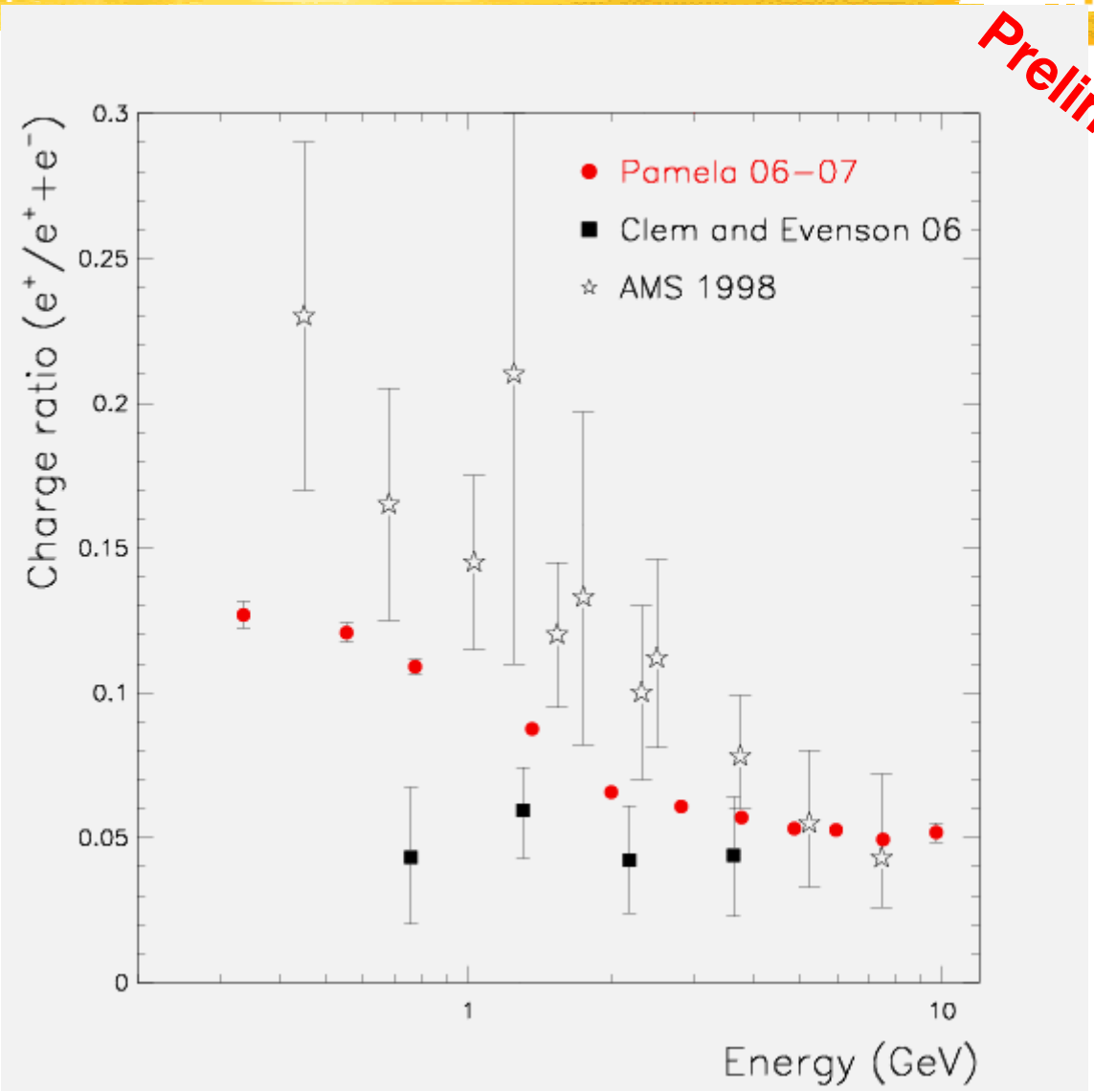


Comparison: HEAT - PAMELA



Comparison: AMS1 - PAMELA

Preliminary



Conclusions

- PAMELA is a permanent cosmic ray space laboratory
- We investigate *the p/p̄* (1 ÷ 100 GeV). Results are compatible with earlier data and do not show any clear deviation, characteristic of a dark matter neutralino contribution.
- *e+/e-* channel is under investigation as well (.2 ÷ 10GeV) … analysis in progress …