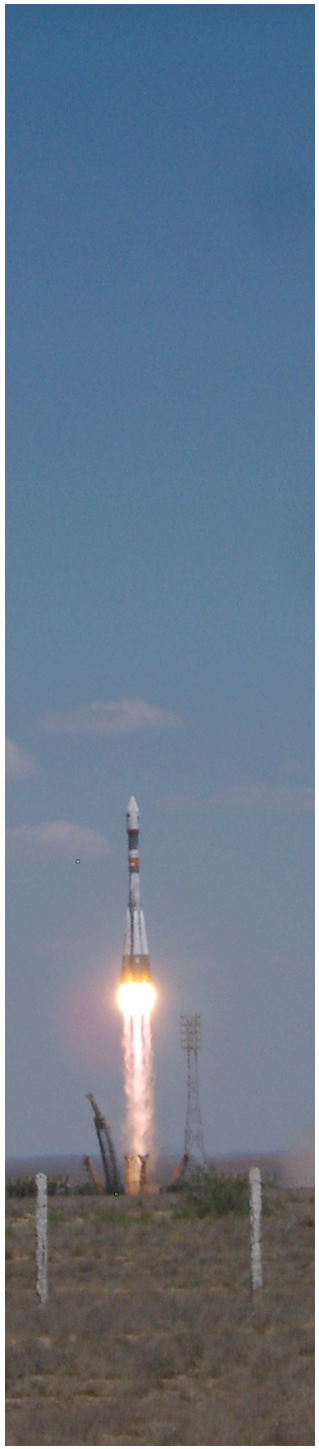


Measurements of cosmic ray antiprotons with PAMELA

Juan Wu

KTH, Stockholm

On behalf of the PAMELA collaboration

The 22nd European Cosmic Ray Symposium

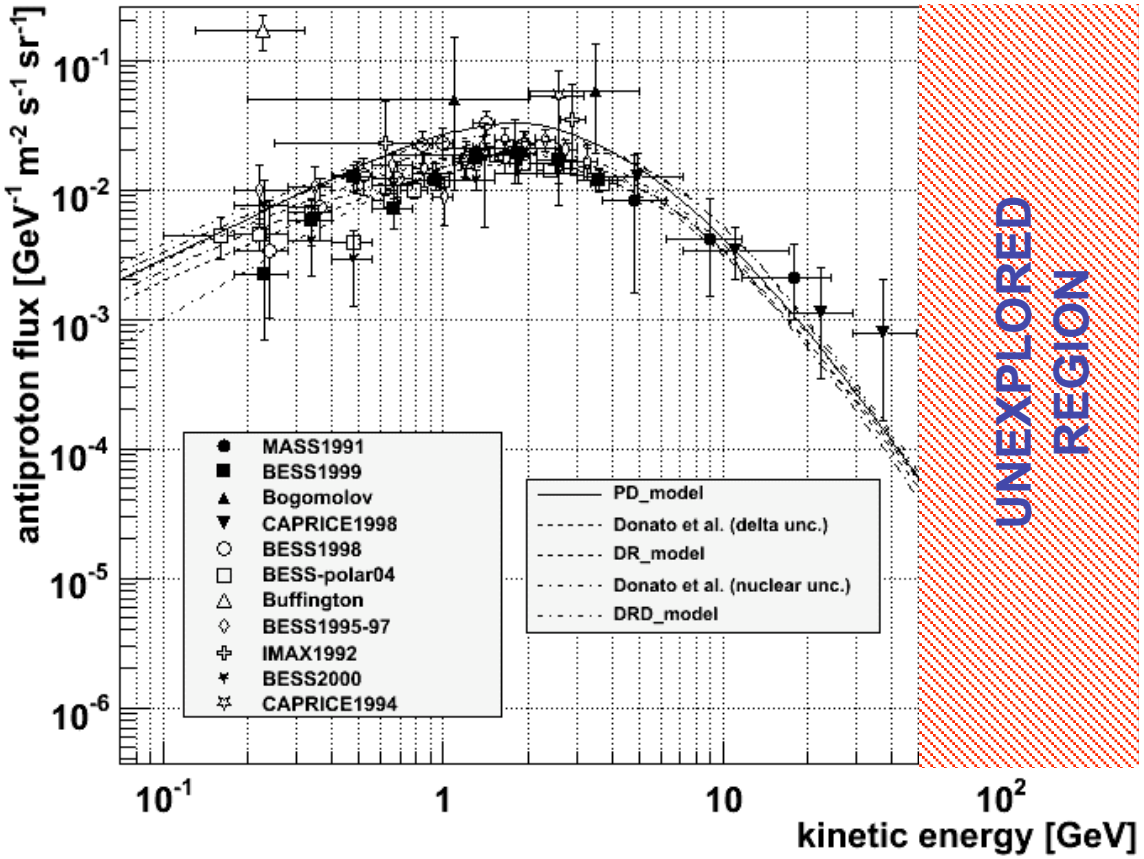
Outline

- Cosmic ray (CR) antiproton
- Antiproton identification
- Antiproton flux and antiproton-proton ratio

CR antiproton

Previous measurements of galactic antiprotons

- low statistics
- > 50 GeV: unexplored region



- standard source:

Secondary production:

CR interaction with ISM

CR + ISM → p-bar + …

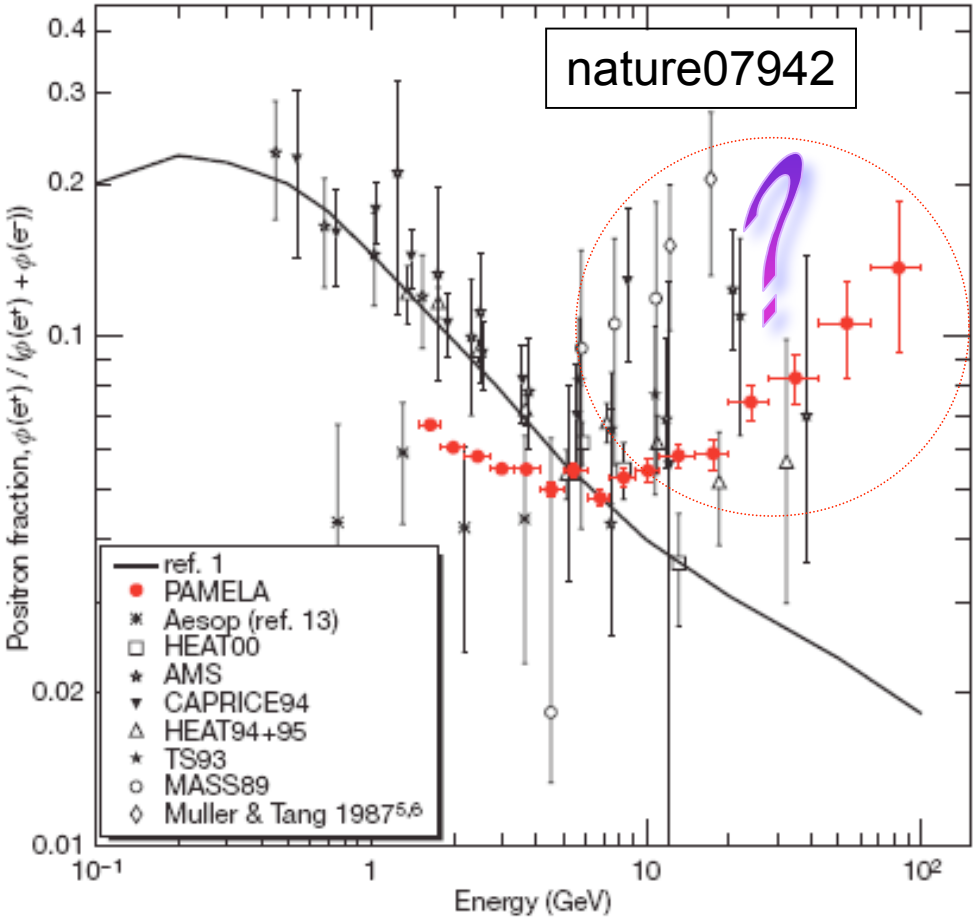
- Other possible sources :

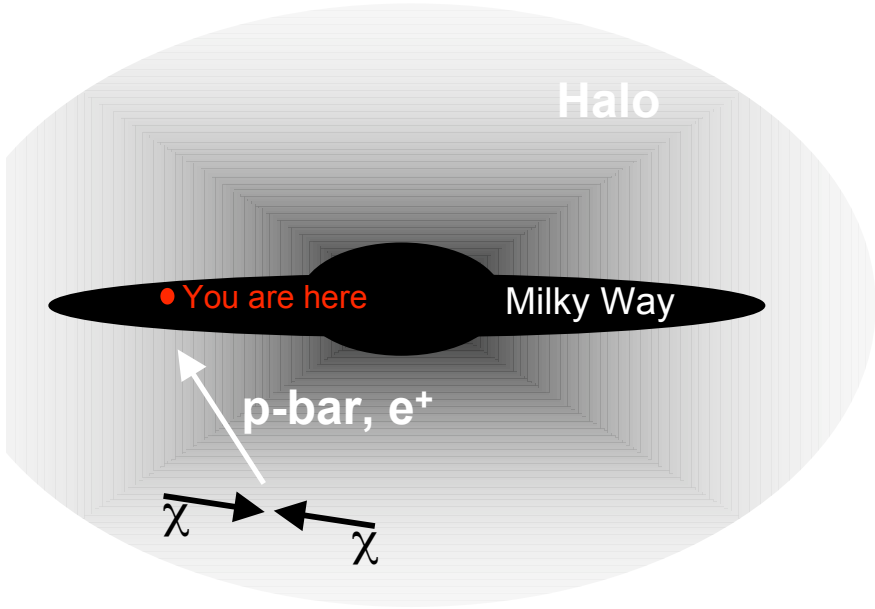
-- evaporation of primordial black holes

-- new acceleration process (old SNR)

-- dark matter annihilation

Cosmic-ray antimatter from Dark Matter annihilation





$$\chi + \chi \rightarrow X + \gamma$$
$$+ \nu$$
$$+ \bar{p}$$
$$+ e^+$$

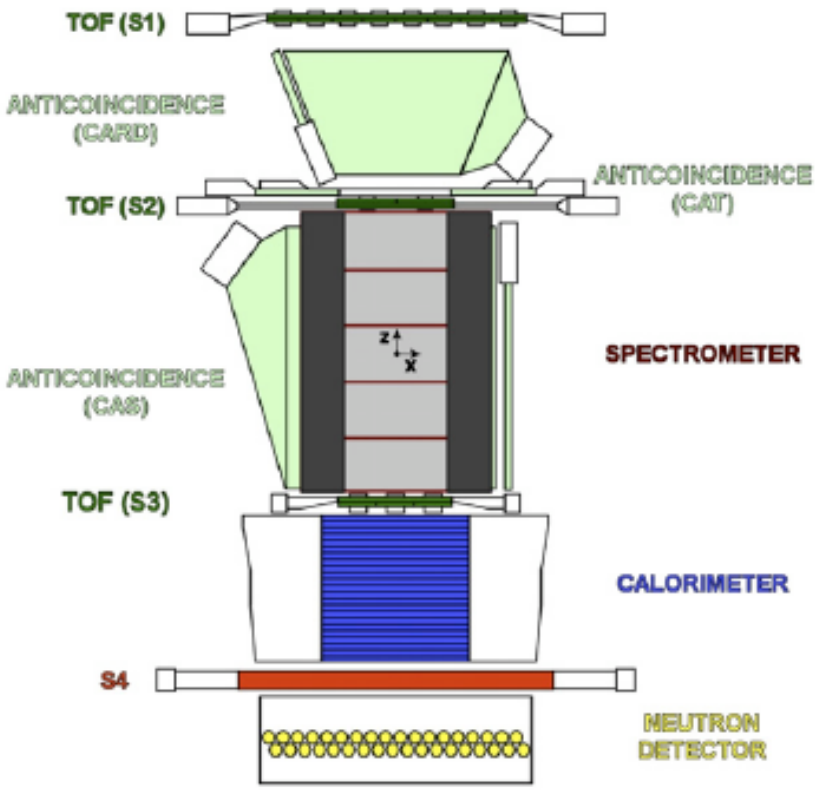
(Fermi LAT)

(AMANDA / IceCube)

PAMELA

(and Bess, HEAT, AMS etc)

PAMELA Payload for Antimatter/Matter Exploration and Light-nuclei Astrophysics



GF: 21.6 cm² sr
Mass: 470 kg
Size: 130x70x70 cm³
Power Budget: 360 W

Spectrometer (microstrip silicon tracking system + permanent magnet)

- ***Rigidity***
- ***Charge sign***
- ***dE/dx***

Time-of-Flight (plastic scintillators)

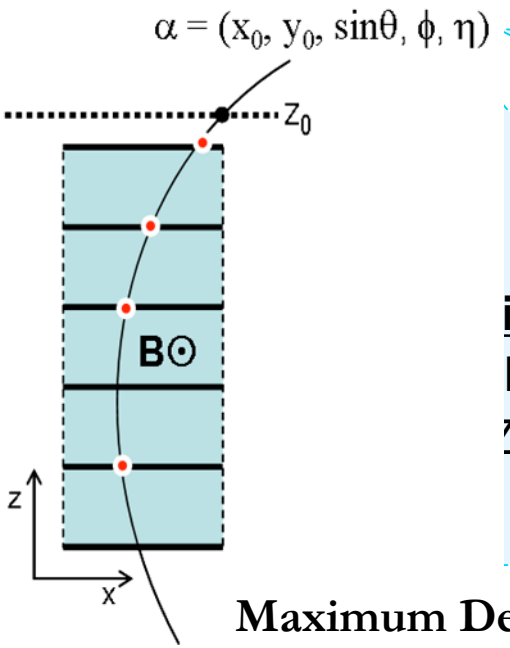
- ***Trigger***
- ***Albedo rejection***
- ***Mass identification at low energy***
- ***dE/dx***

Anticoincidence (plastic scintillators)
- ***remove "false" triggers***

Calorimeter (22 Si-x/W/Si-y planes – 16.3 X0, 0.6 λI)
- ***lepton-hadron separation***

Neutron detector (36 ^{3}He counters)
- **increase the lepton-hadron separation capability**

Track reconstruction



Iterative χ^2 minimization as a function of track state-vector components α

ic deflection

R

Ze → magnetic rigidity

σ_η/η

Maximum Detectable Rigidity (MDR)

def: @ R=MDR ⇒ $\sigma_R/R=1$

$\mathbf{MDR = 1/\sigma_\eta}$

•Measured @ground with protons of known momentum

→ **MDR ≅1080 GV**

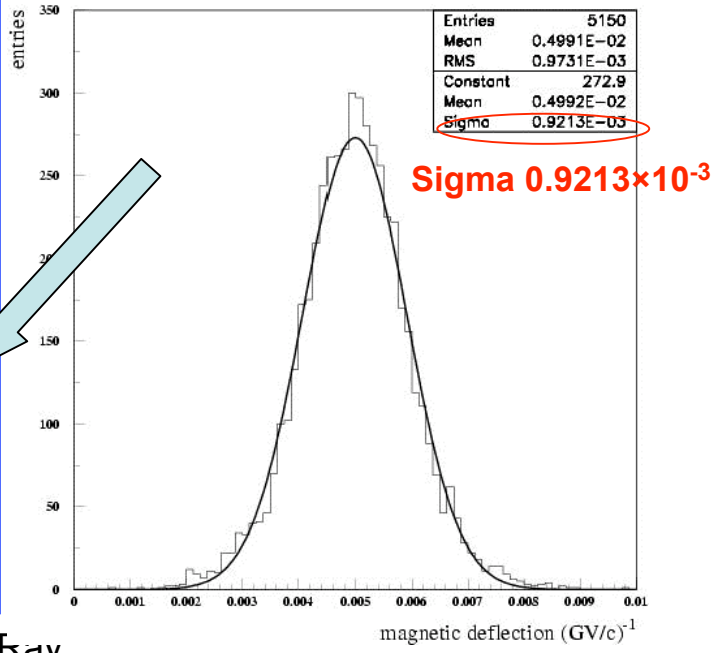
•Cross-check in flight with protons (alignment) and electrons (energy from calorimeter)

Spatial resolution with test beams

x (bending) resolution = (3.0 ±0.1)μm

y (non-bending) resolution = (11.5±0.6) μm

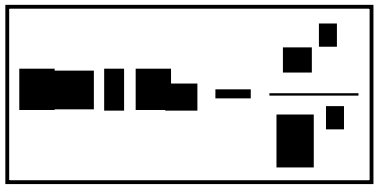
SPS test beam data: proton 200 GeV/c



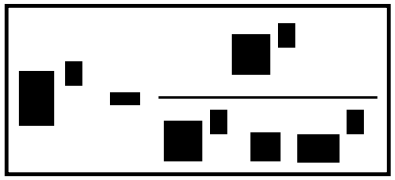
Antiproton Selection I

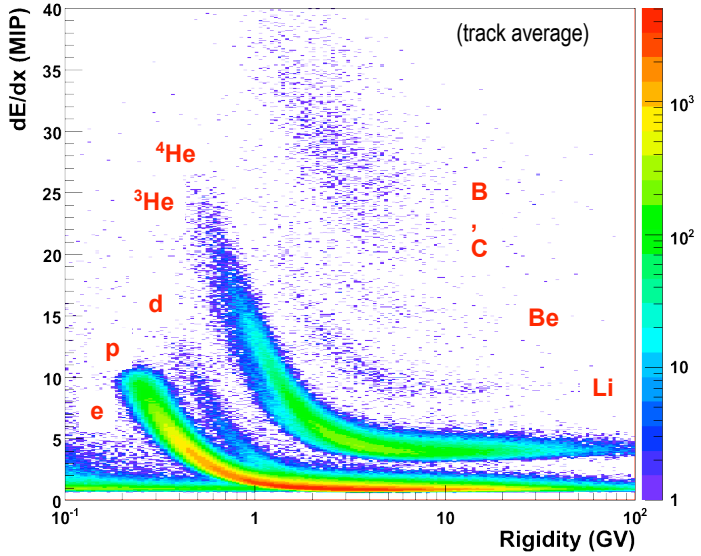
- **A proton like *dE/dx* is used in tracker + ToF**

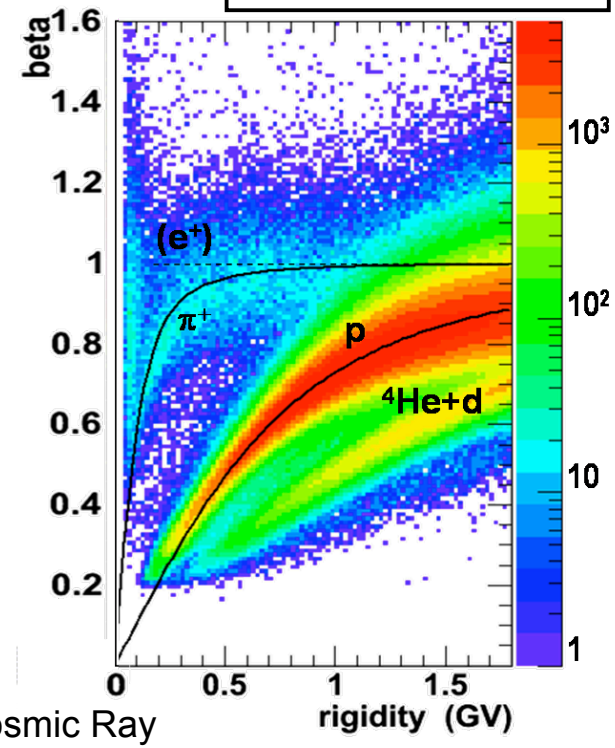
Bethe Bloch formula



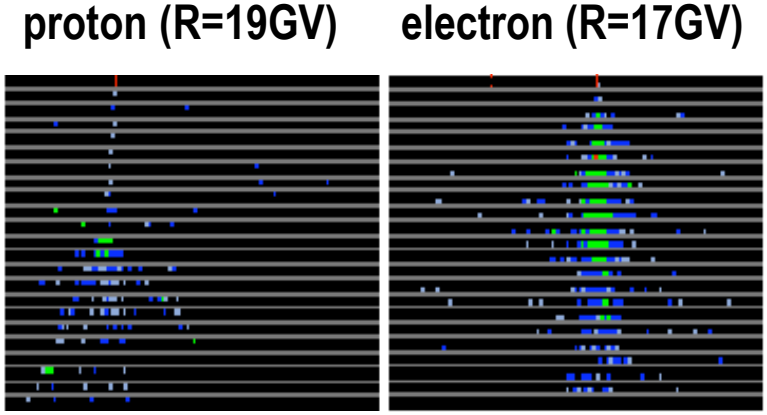
- **beta vs Rigidity consistent with mass of proton**

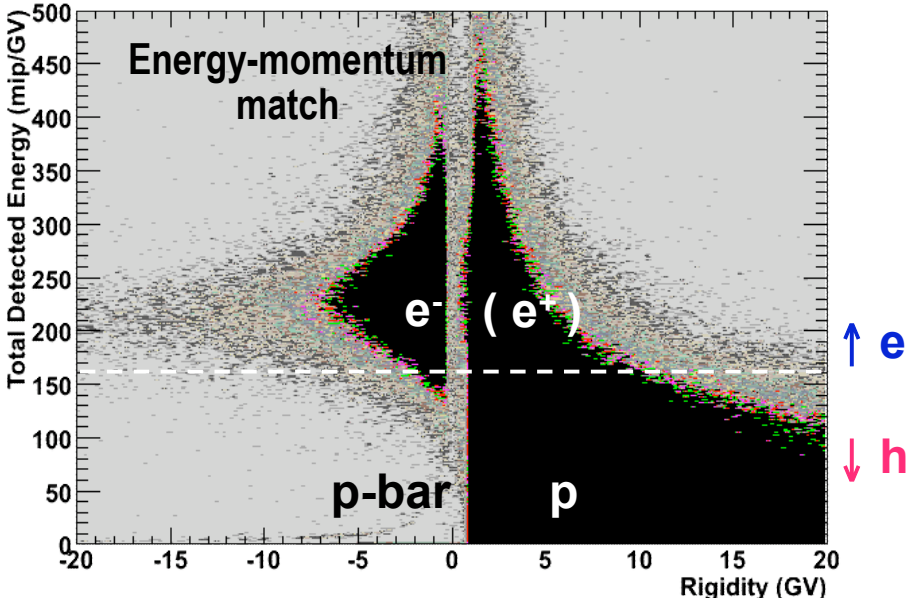


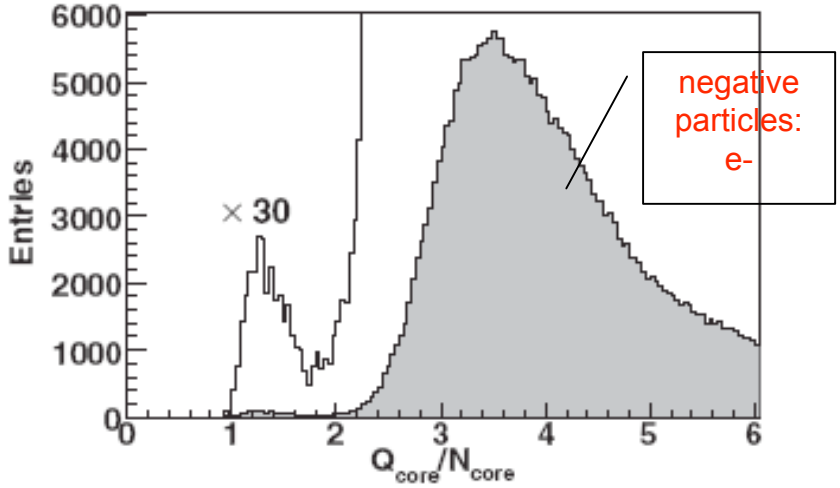


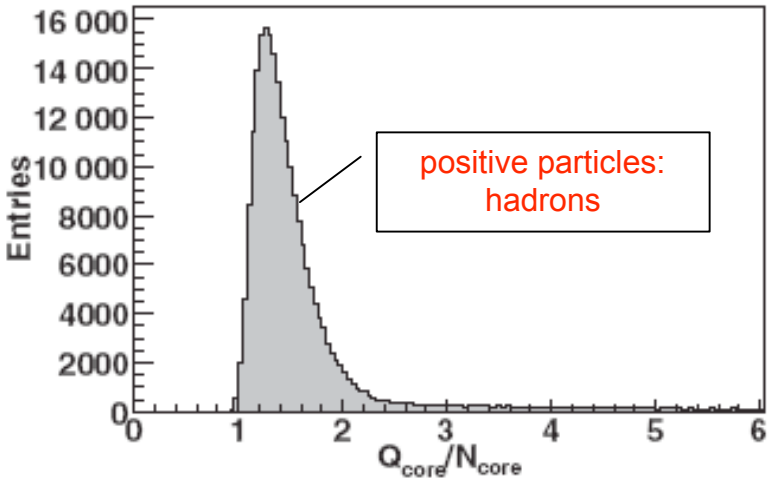


Antiproton Selection II







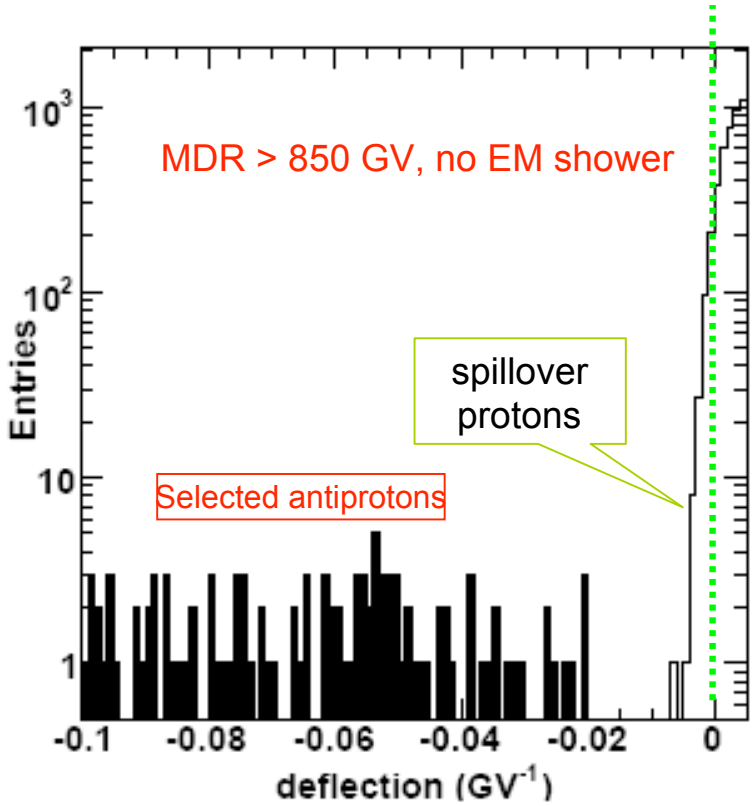


Antiproton Selection III

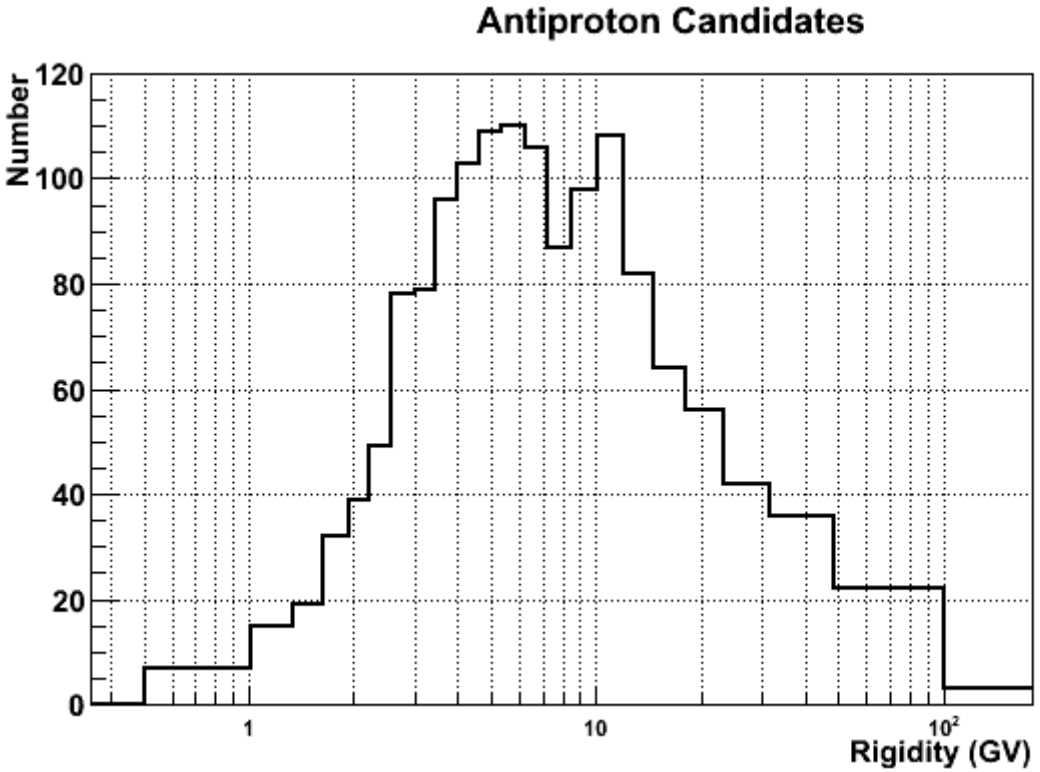
- **Spectrometer tracking information is crucial for high energy antiproton selection**

- **High rigidity protons may be assigned wrong sign-of-charge due to finite spectrometer resolution**

- **A spillover rejection requires strong track requirements:**
chi2 with ~75% efficiency, no bad strips, no δ-rays,
mdr>6 * constructed rigidity.



Seleted antirproton sample



This analysis:

- data from July 2006 to Dec 2008 (~850 days)
- Collected triggers: ~1.5 x 10^9
- Totally ~1500 antiprotons

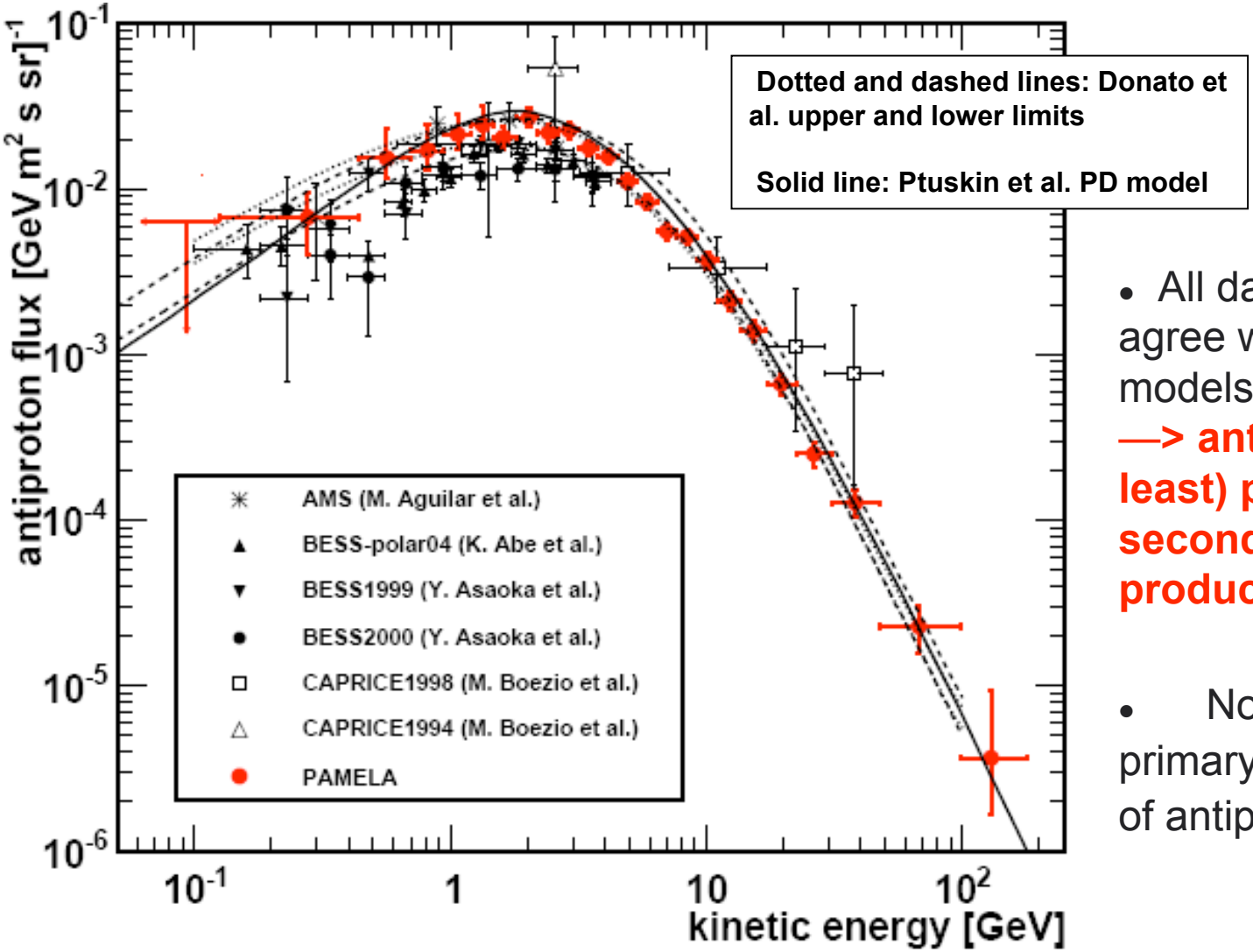
- Before PAMELA: 2 antiprotons above 30 GeV

  PAMELA: ~ 60 antiprotons above 30 GeV

- The absolute differential flux of a particle species in a given energy bin is defined as:

$$F(bin) = \frac{1}{G \times \Delta E(bin) \times LT(bin)} \times \frac{N_{sel}(bin)}{\varepsilon(bin)}$$

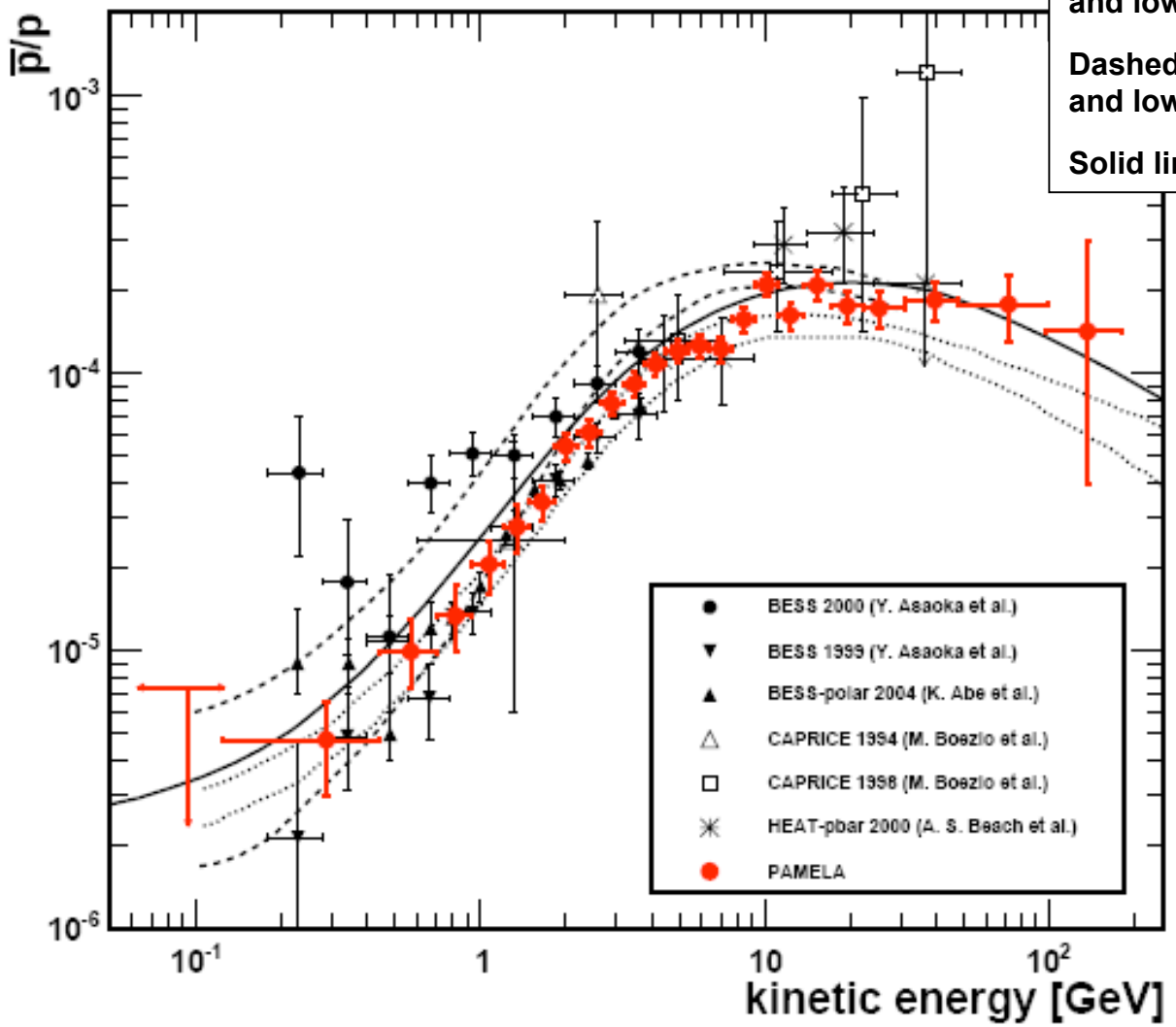
Antiproton flux



- All data generally agree with secondary models
  —> antiprotons (at least) primarily secondary production.

- No evidence of primary components of antiprotons.

Antiproton-to-proton ratio



Dotted lines: Donato et al. upper and lower limits, DRC model

Dashed lines: Simon et al. upper and lower limits, Leaky Box model

Solid line: Ptuskin et al. PD model

Confirm the ratio reported by PAMELA in PRL 102:051101,2009 which is derived from ~500 days.

Summary

- The antiproton flux and antiproton-to-proton flux ratio over the widest energy range ever achieved (60 MeV to 180 GeV) have been presented with highly improved statistics compared to previous experiments. The paper has been accepted for publication in Phy. Rev. Lett. (arXiv:astro-ph.HE:1007.0821).

- While PAMELA observed a dramatic rise in the positron fraction >10 GeV (nature07942), the measured antiproton-to-proton flux ratio and antiproton energy spectrum show no significant deviations from secondary production expectations.
  - useful parameters for secondary production calculations
  - place constraints on dark matter models

Thank you!

Spares

Antiproton Selection III