

Positron and Antiproton Measurements in the Cosmic Rays with the PAMELA Space Experiment

Emiliano Mocchiutti
INFN Trieste, Italy

On behalf of the PAMELA collaboration

*International Workshop on
Positrons in Astrophysics*

20 – 23 March, 2012
Mürren – Switzerland

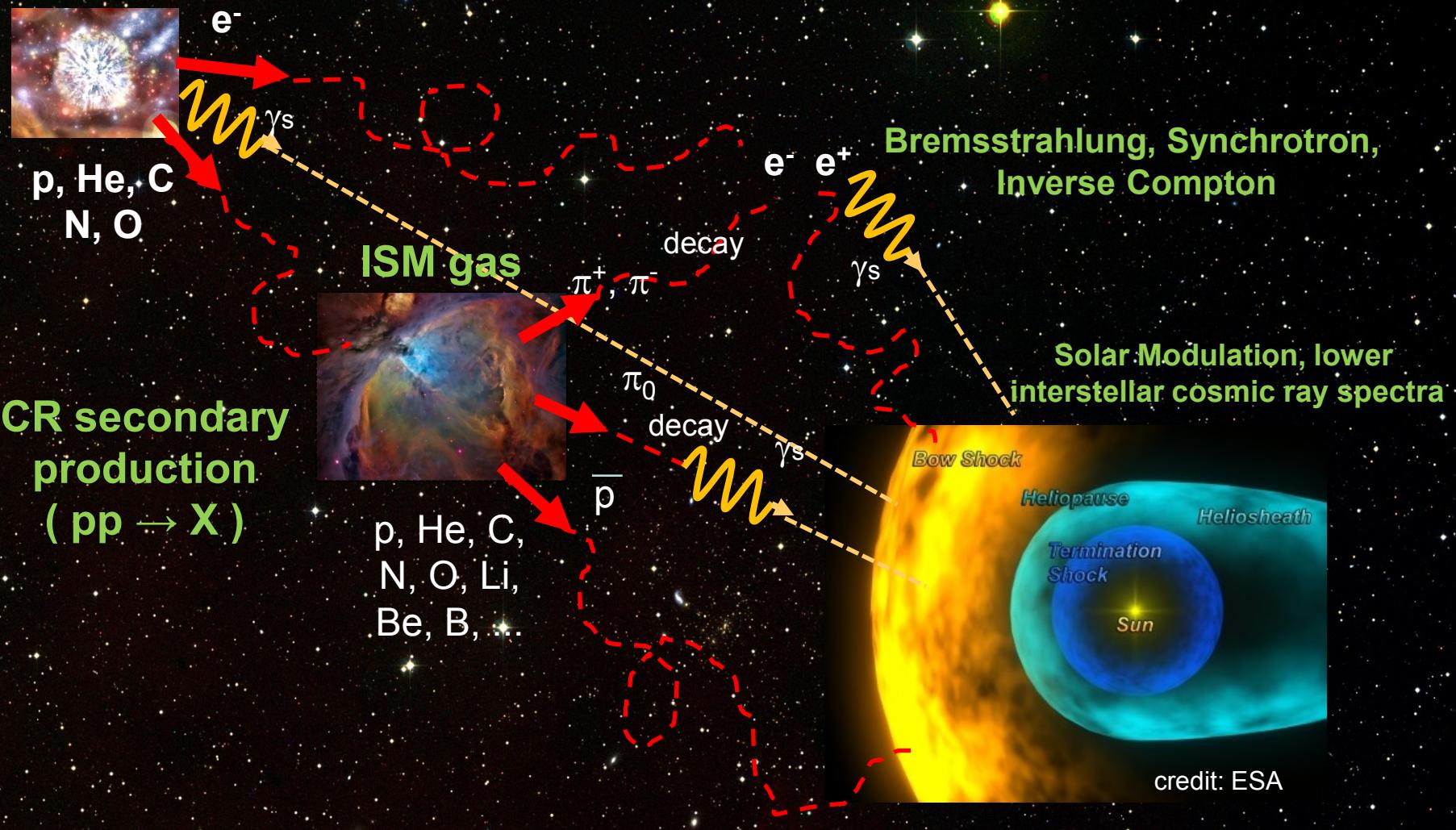


Presentation outline

- Introduction
- PAMELA apparatus
- Antiprotons and positrons (and electrons)
- Dark Matter? Astrophysical sources?
- Summary



Cosmic Rays and Anti-Particles





PAMELA

Emiliano Mocchiutti – INFN Trieste

International Workshop on Positrons in Astrophysics – Mürren, Switzerland, March 20th, 2012

PAMELA Collaboration

Italy




Bari



Florence



Frascati



Naples



Rome



Trieste



CNR, Florence



Germany:


Siegen

Sweden:

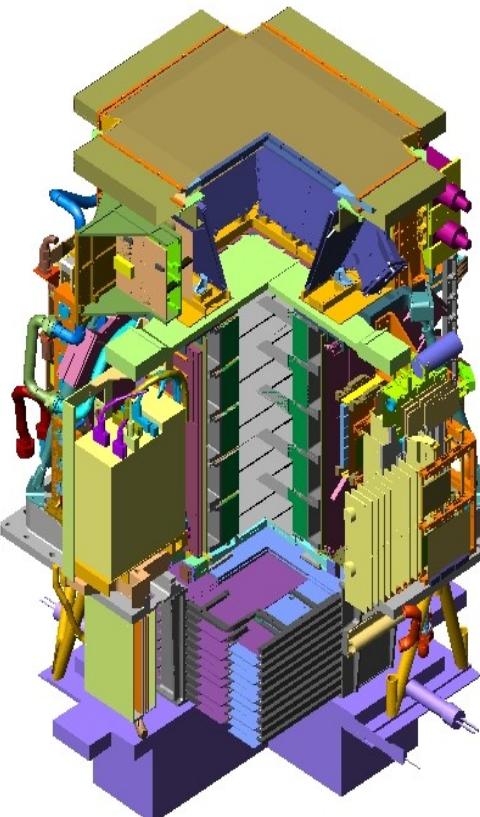

KTH, Stockholm

Russia:


Moscow / St. Petersburg



The PAMELA apparatus



Time-Of-Flight

plastic scintillators + PMT:

- Trigger
- Albedo rejection
- Mass identification up to 1 GeV
- Charge identification from dE/dX

Electromagnetic calorimeter

W/Si sampling ($16.3 X_0$, $0.6 \lambda_D$)

- Discrimination e^+ / p , $p\bar{}$ / e^- (shower topology)
- Direct E measurement for e^-

Neutron detector

3He tubes + polyethylene moderator:

- High-energy e/h discrimination

GF: $21.5 \text{ cm}^2 \text{ sr}$

Mass: 470 kg

Size: $130 \times 70 \times 70 \text{ cm}^3$

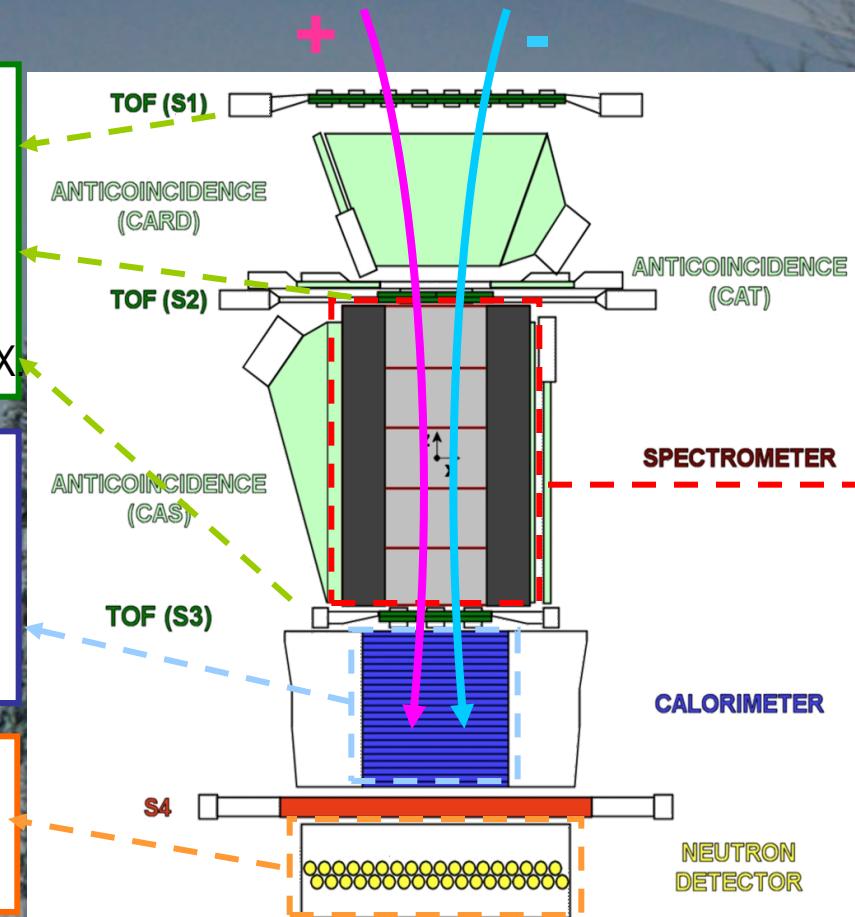
Power Budget: 360W

Spectrometer

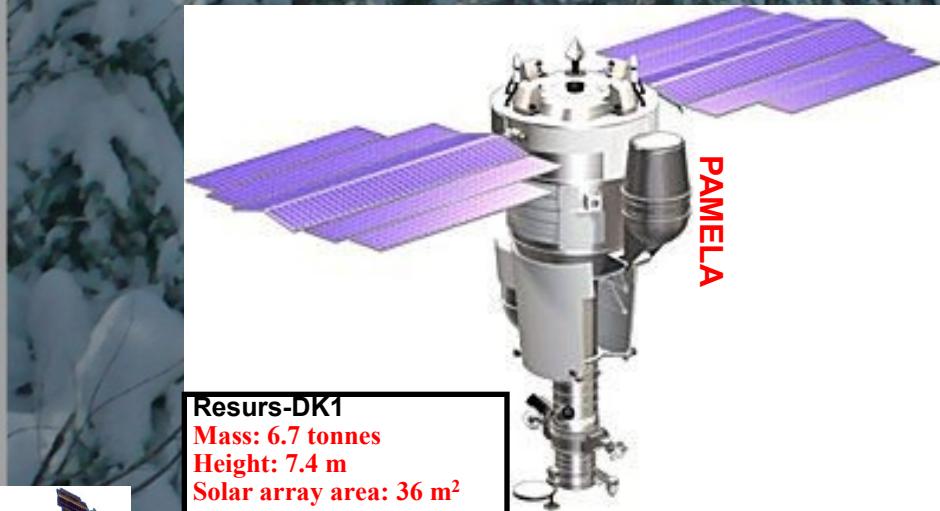
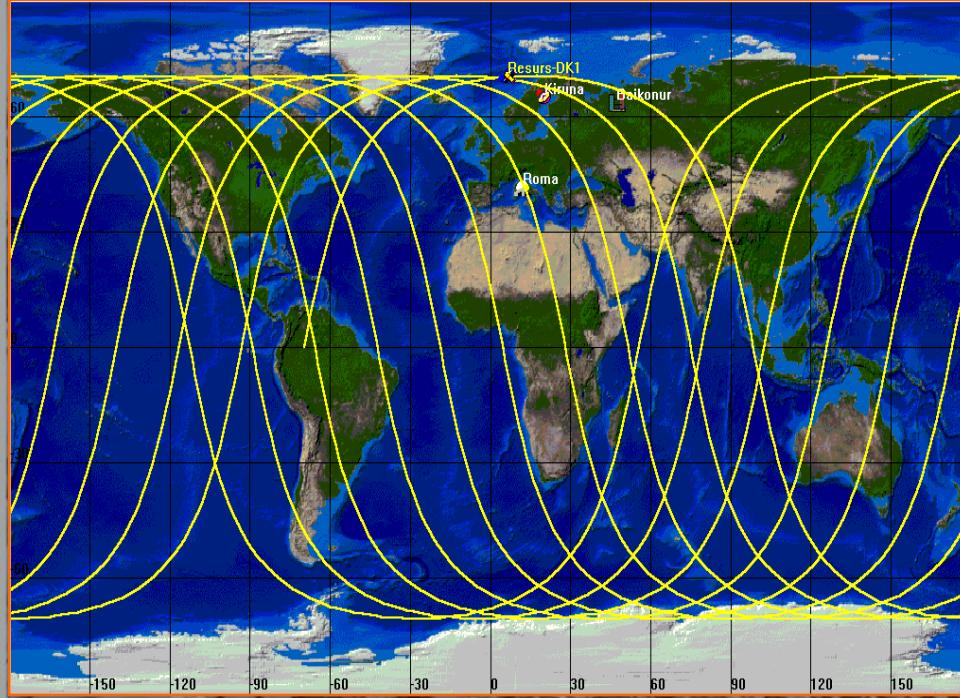
microstrip silicon tracking system + permanent magnet

It provides:

- Magnetic rigidity $\rightarrow R = pc/Ze$
- Charge sign
- Charge value from dE/dx

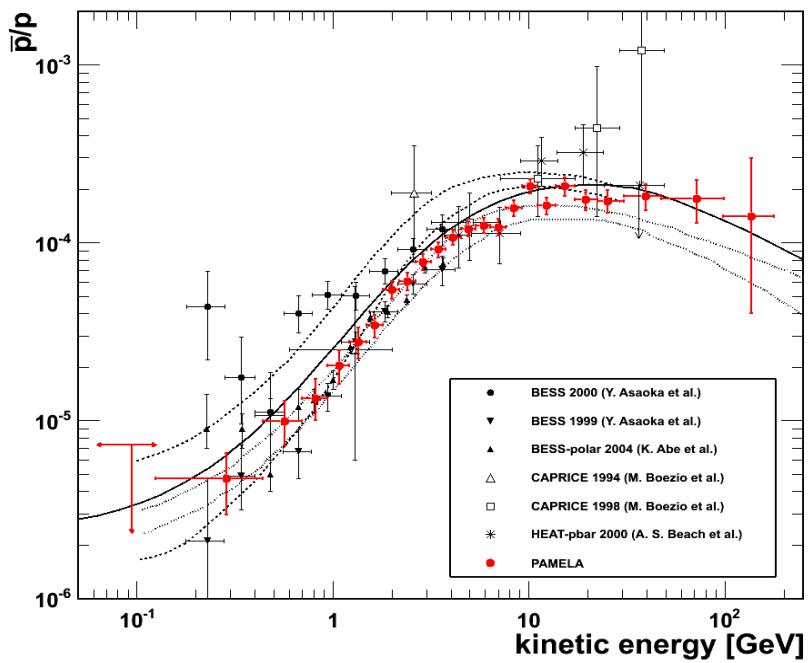


Resurs-DK1 satellite and orbit



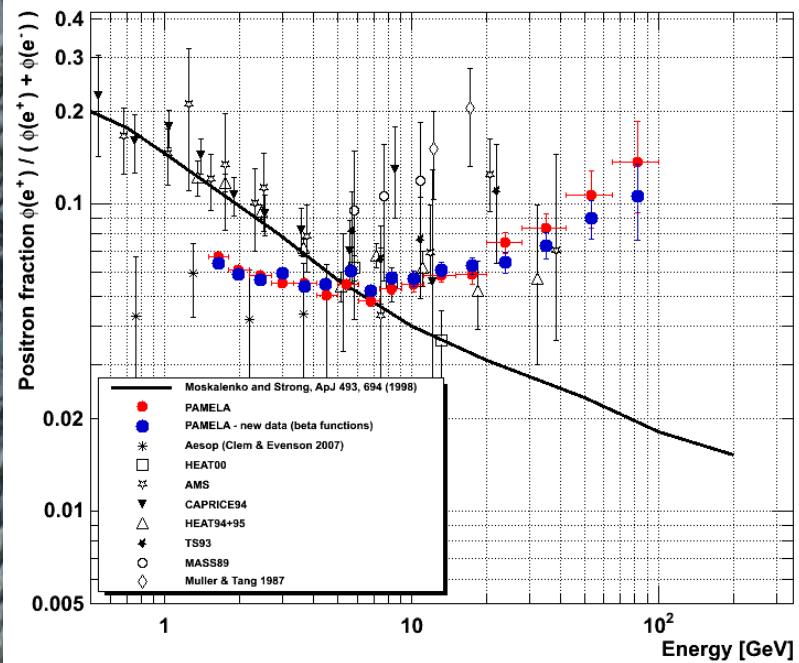
- Resurs-DK1 satellite: multi-spectral imaging of Earth's surface
- PAMELA mounted inside a pressurized container
- Launch 15/06/2006 - lifetime >3 years (assisted), extended till end of satellite operations
- Data transmitted to NTsOMZ, Moscow via high-speed radio downlink. ~16 GB per day
- Quasi-polar and elliptical orbit (70.0° , 350 km - 600 km) – from 2010 circular orbit (70.0° , 600 km)
- Traverses the South Atlantic Anomaly
- Crosses the outer (electron) Van Allen belt at south pole

PAMELA antiparticle results



Positrons
Nature 458 (2009) 607
Astropart. Phys. 34 (2010) 1

Antiprotons
PRL 102 (2009) 051101
PRL 105 (2010) 121101





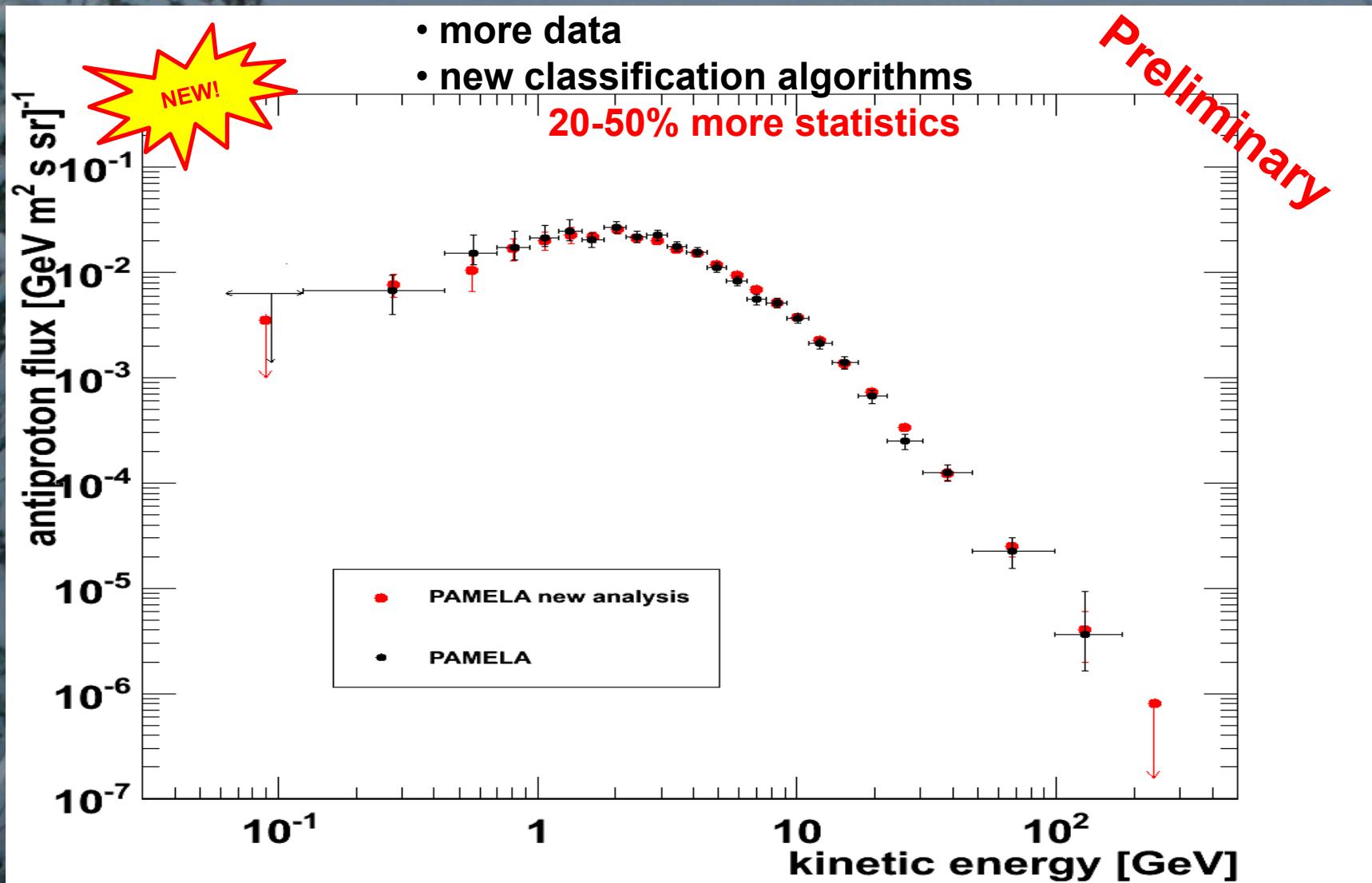
New PAMELA results



Emiliano Mocchiutti – INFN Trieste
International Workshop on Positrons in Astrophysics – Mürren, Switzerland, March 20th, 2012



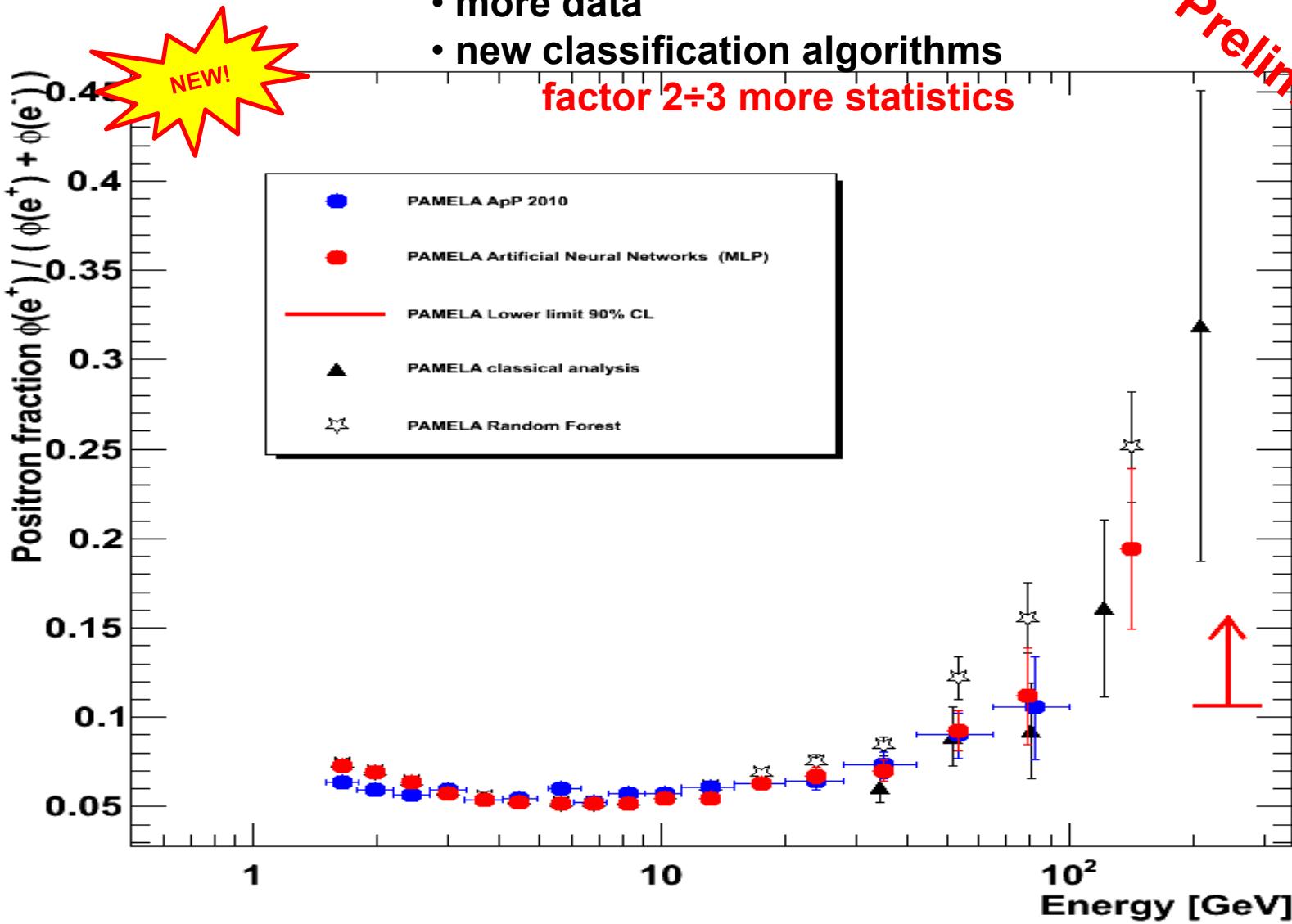
Antiprotons



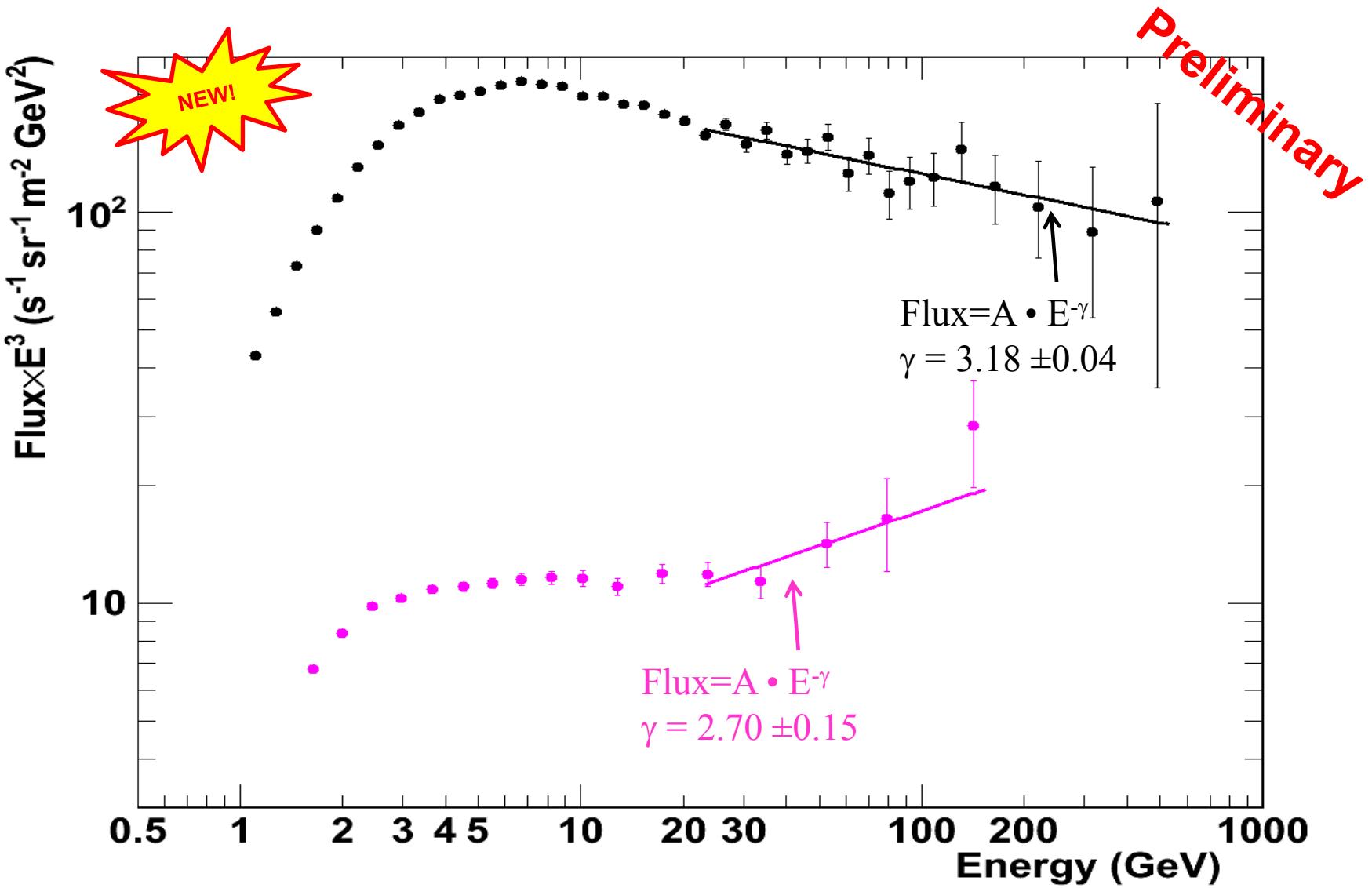
Positron fraction

- more data
 - new classification algorithms
- factor 2÷3 more statistics

Preliminary



Electrons and positrons fluxes



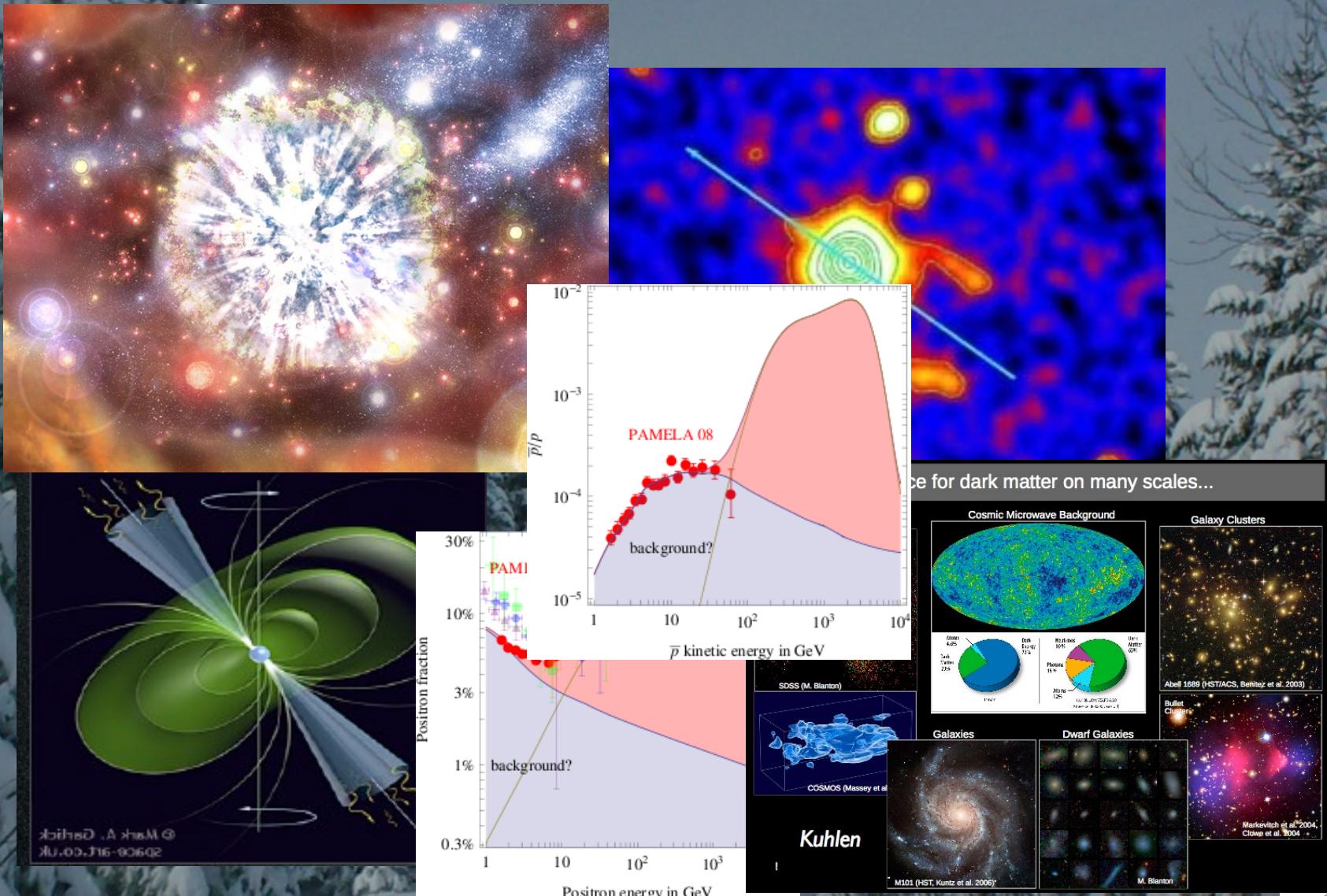


Data Interpretation

Emiliano Mocchiutti – INFN Trieste

International Workshop on Positrons in Astrophysics – Mürren, Switzerland, March 20th, 2012

A complex scenario



Emiliano Mocchiutti – INFN Trieste

International Workshop on Positrons in Astrophysics – Mürren, Switzerland, March 20th, 2012

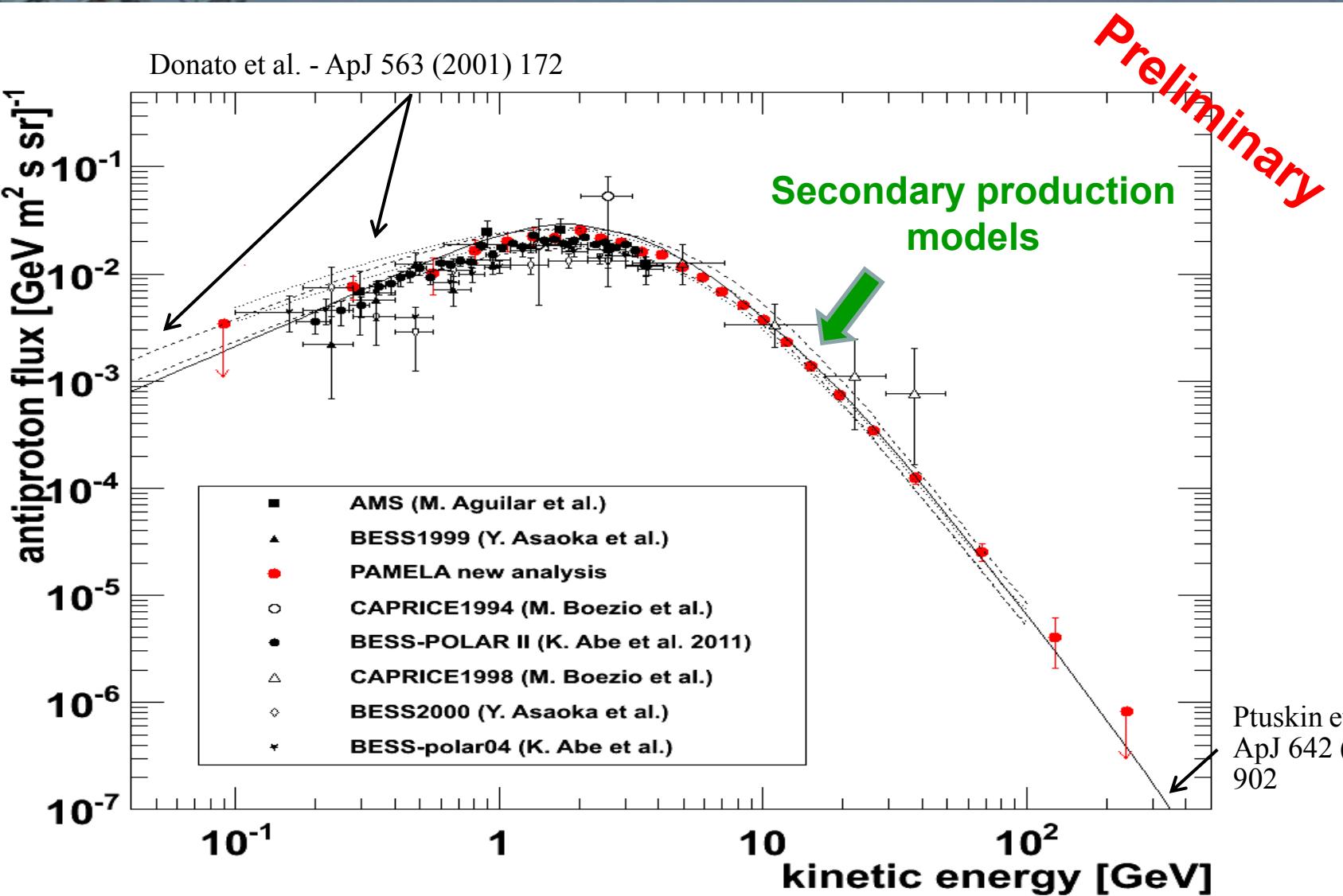
Data and models

- ❑ Antiprotons
- ❑ Positron fraction
- ❑ Electrons and positrons fluxes

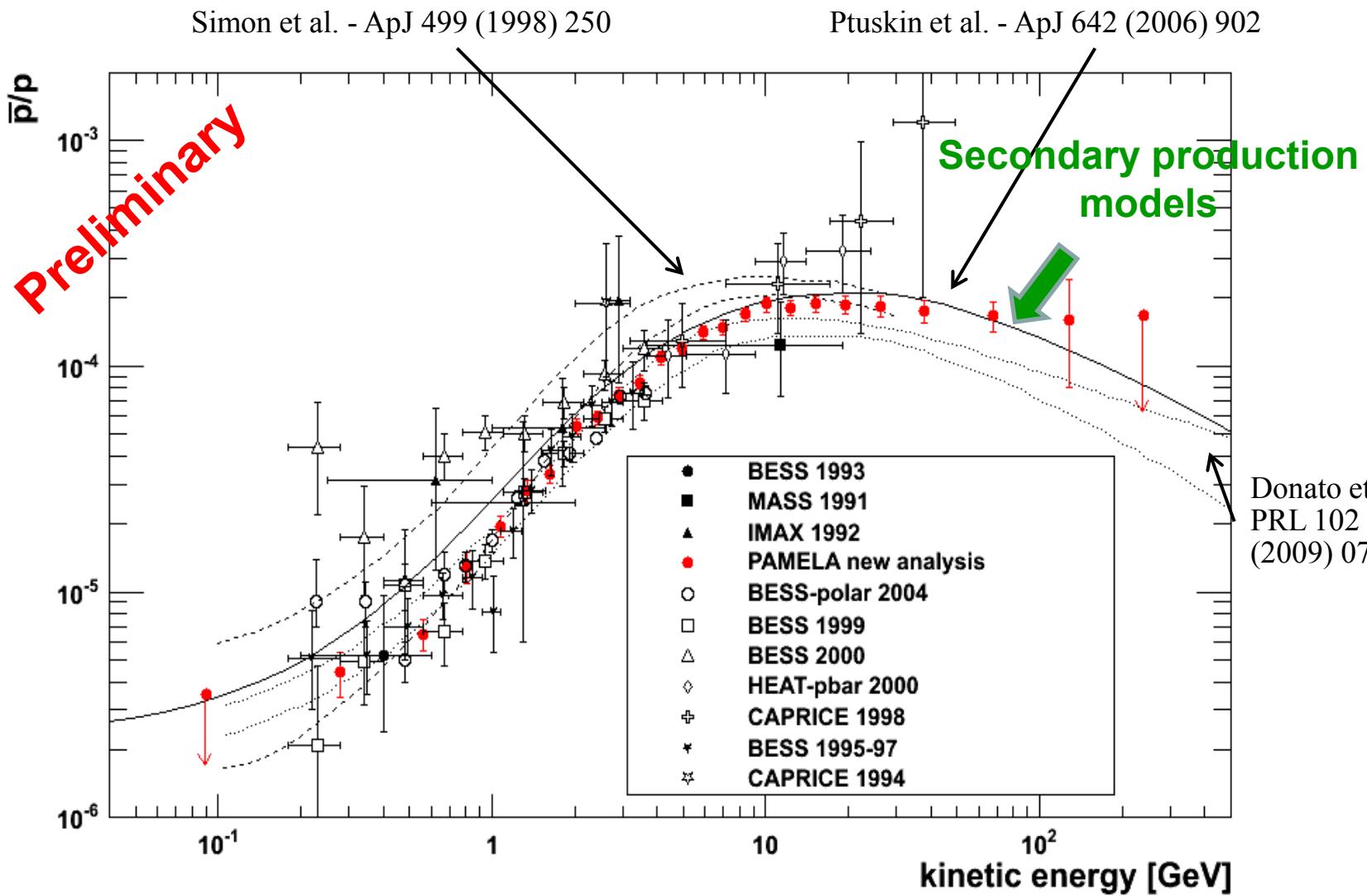


Antiprotons

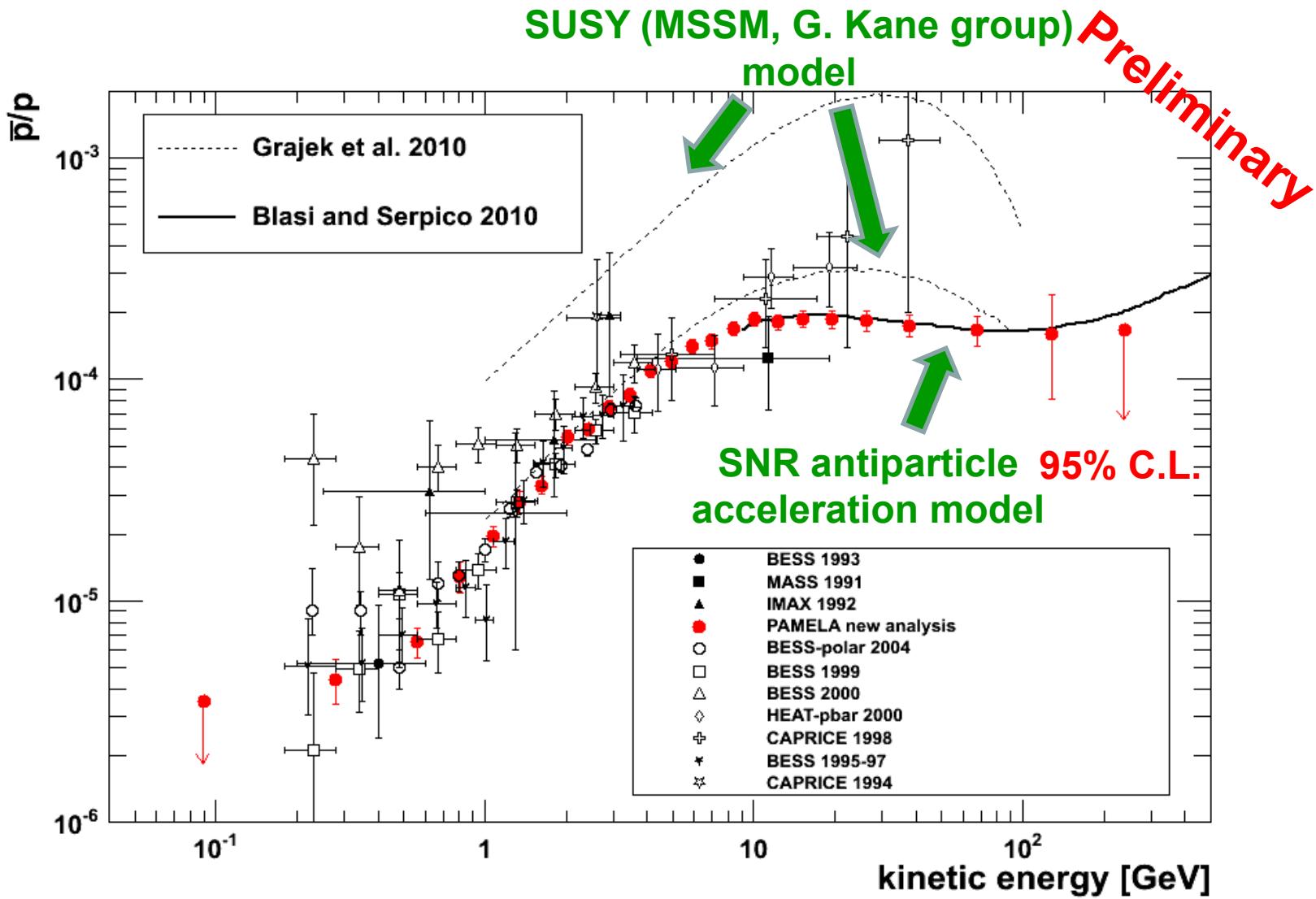
Antiprotons – secondaries?



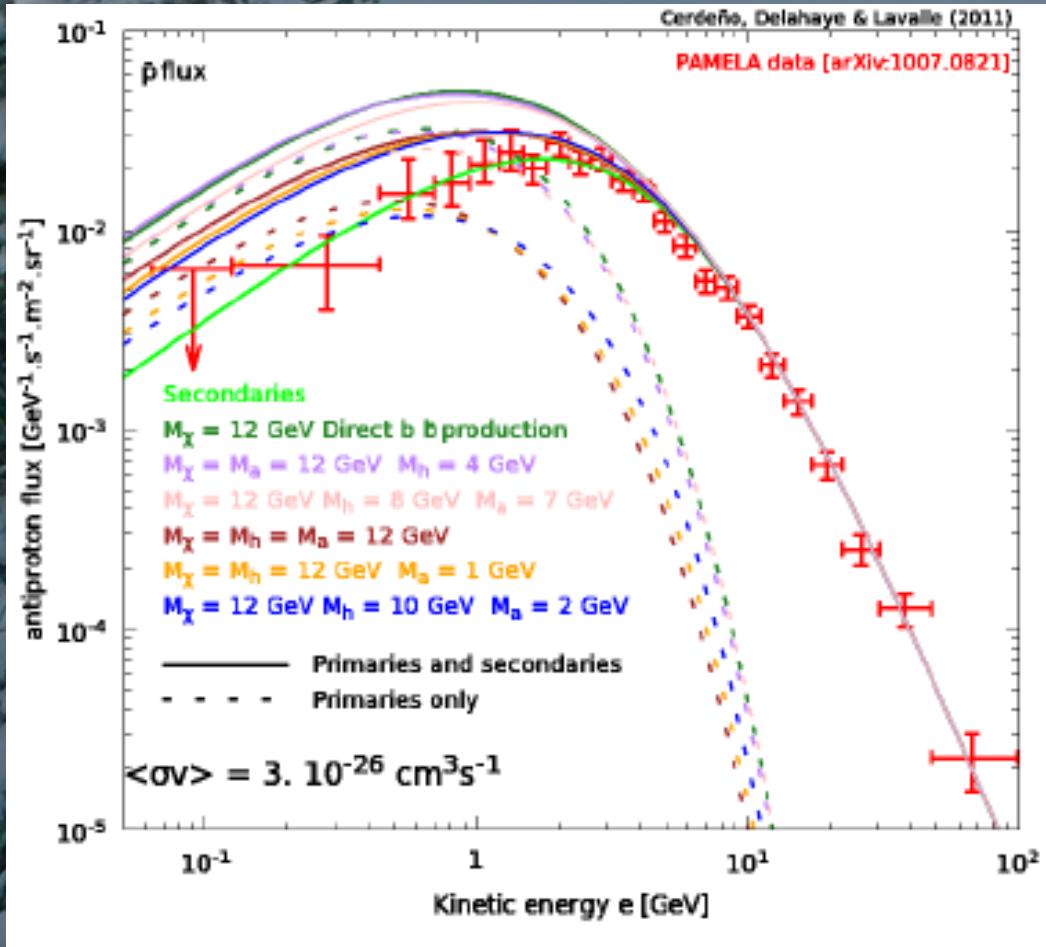
Antiprotons – secondaries?



Antiprotons – sources?



Antiprotons – sources?



D. G. Cerdeno, T. Delahaye & J. Lavalle,
arXiv: 1108:1128
Antiproton flux predictions for a 12 GeV
WIMP annihilating into different mass
combinations of an intermediate two-boson
state which further decays into quarks.

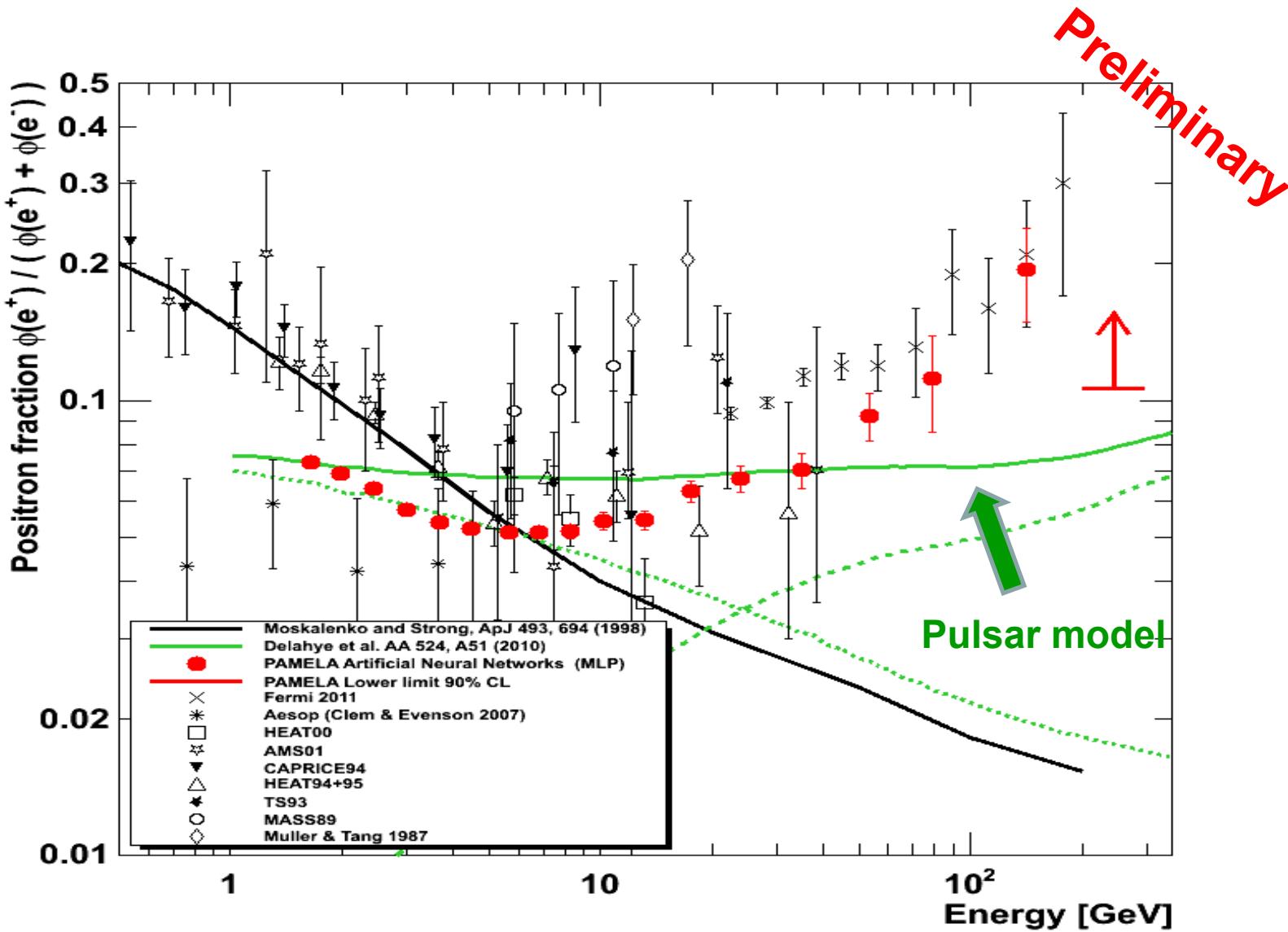
See also:

- M. Garny, A. Ibarra & S. Vogl, arXiv:1112.5155
- R. Kappl & M. W. Winkler, arXiv:1140.4376
- M. Asano , T. Bringmann & C. Weniger, arXiv:1112.5158

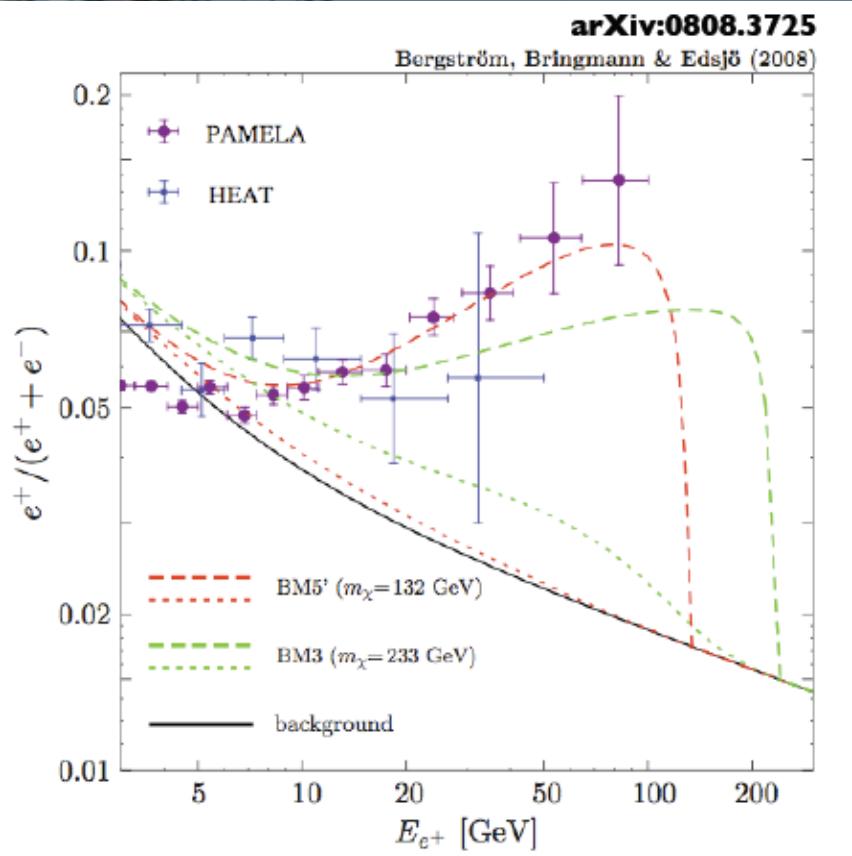


Positron fraction

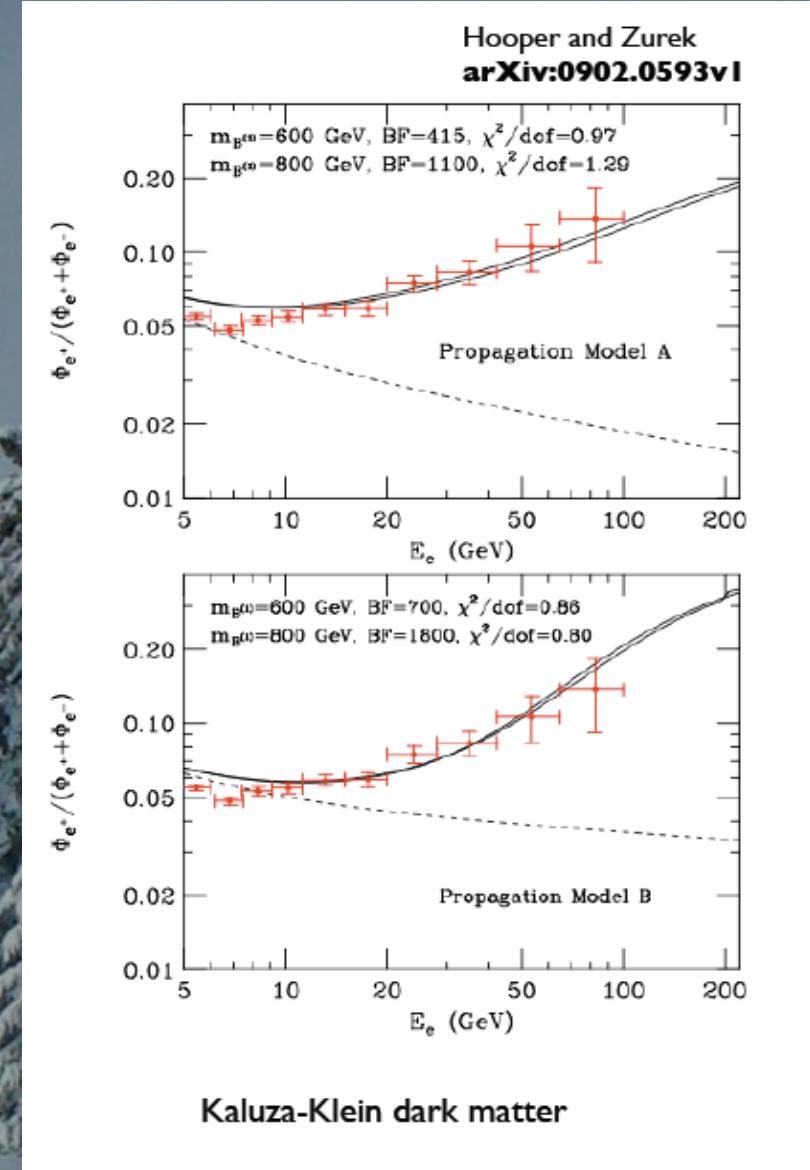
Positrons – sources?



Positrons – sources?



Majorana DM with new internal bremsstrahlung correction.
NB: requires annihilation cross-section to be “boosted” by > 1000 .

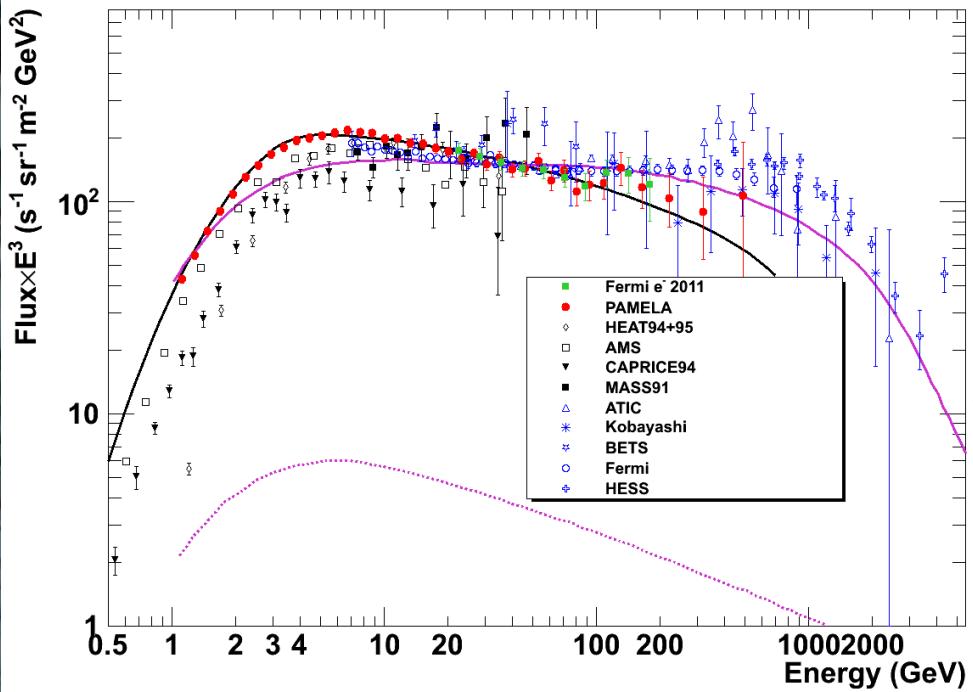




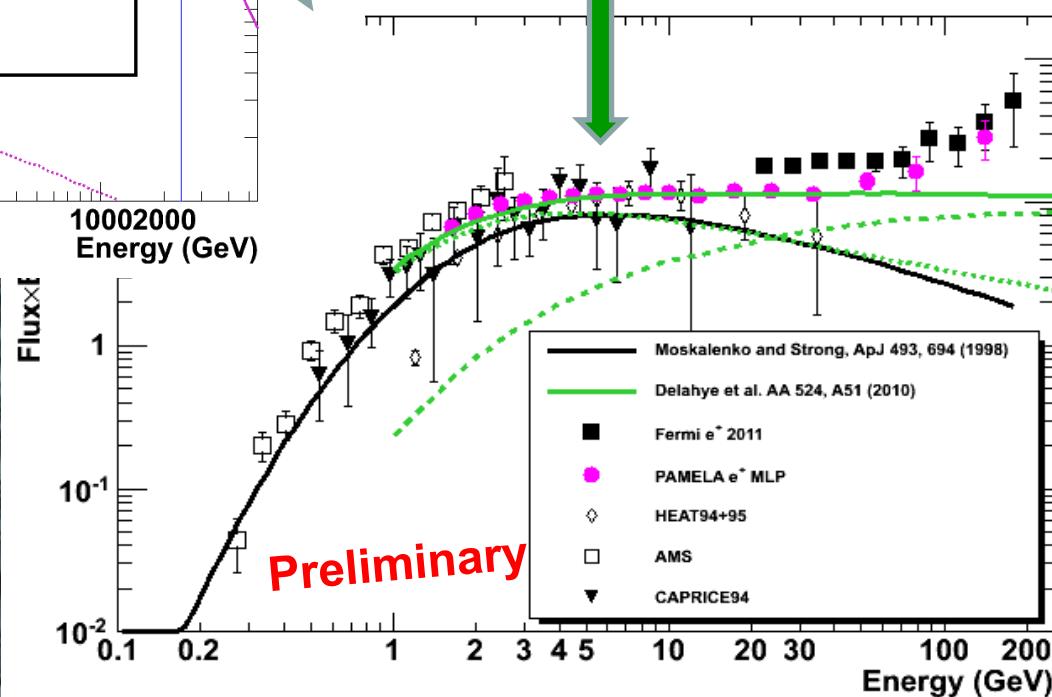
Positron and electrons fluxes

Electron and Positron fluxes

Adriani et al., Phys. Rev. Lett. 106, 201101 (2011), arXiv: 1103.2880



Delahye et al. AA
524, A51 (2010)
Pulsar model
(Primaries and
secondaries)

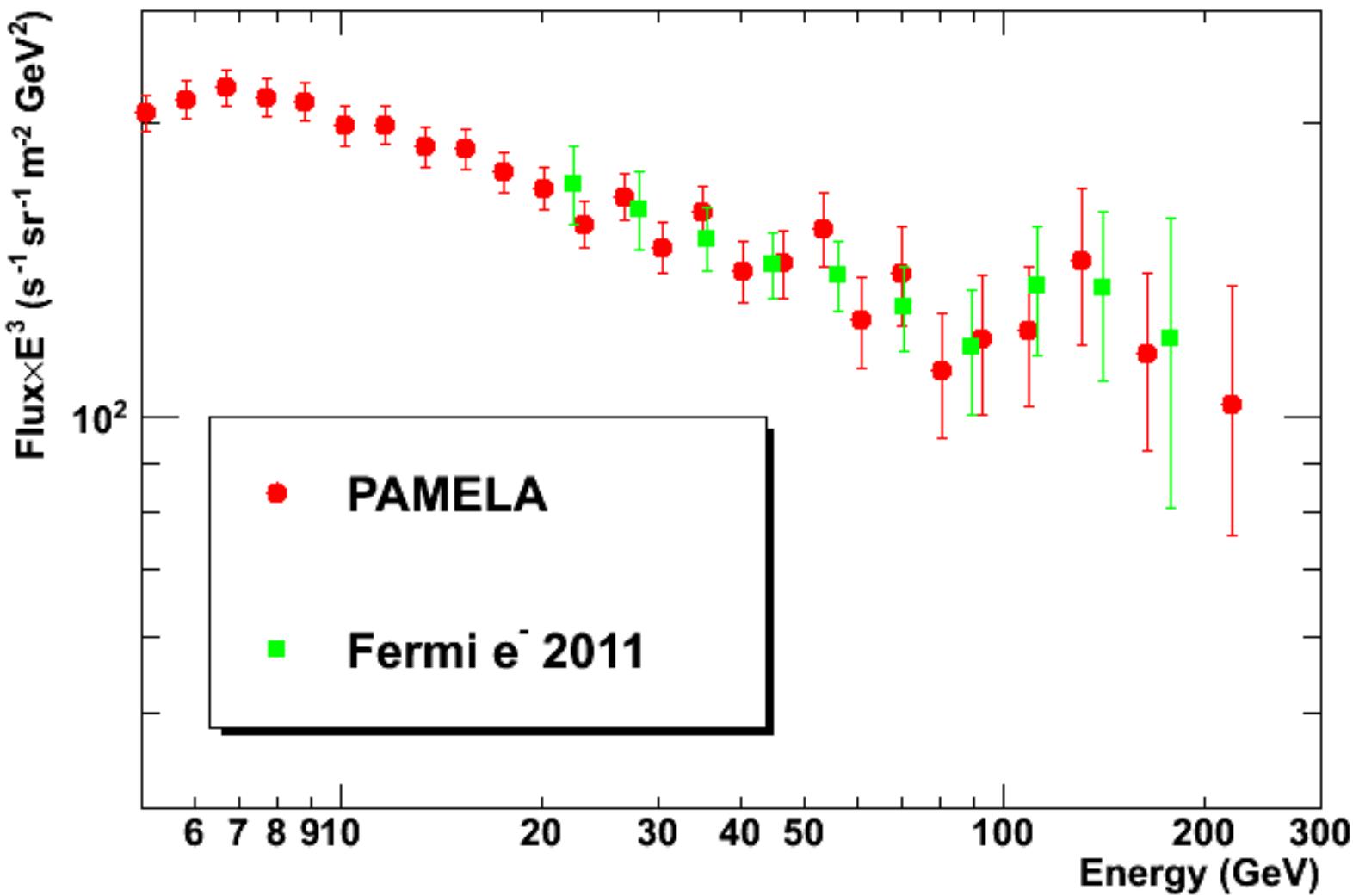


Emiliano Mocchiutti – INFN Trieste

International Workshop on Positrons in Astrophysics – Mürren, Switzerland, March 20th, 2012

Electron (e^-) spectrum

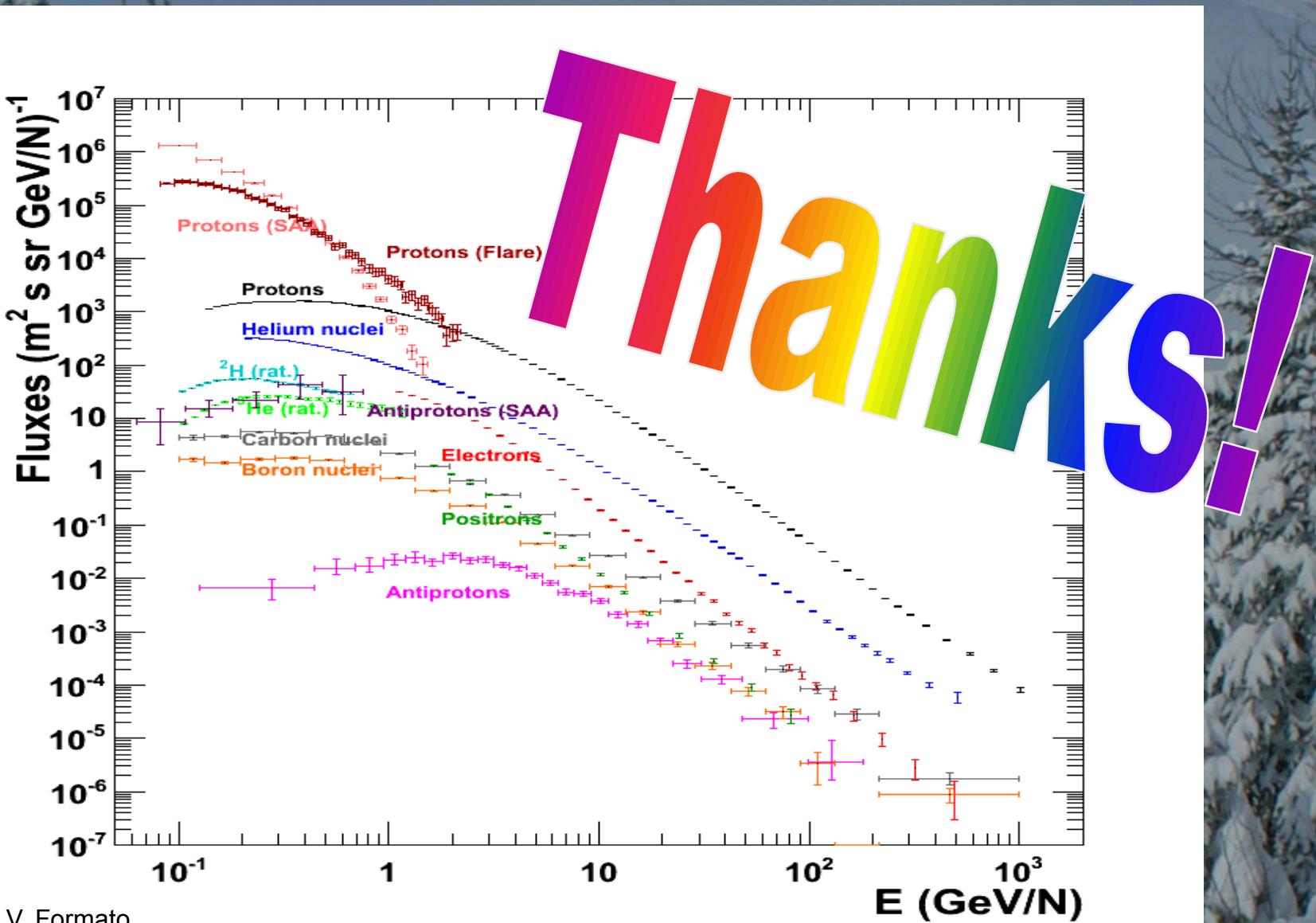
Adriani et al., Phys. Rev. Lett. 106, 201101 (2011), arXiv: 1103.2880



Summary

- PAMELA has been in orbit and studying cosmic rays for 2106 days (>5 years). > 10^9 triggers registered and >25 TB of data have been down-linked
- PAMELA lifetime extended, unlimited and depending on satellite operations
- Many very interesting measurements from PAMELA, which are challenging astroparticle physics standard model
- Analysis ongoing to finalize the antiparticle measurements (antiproton and positron flux, positron fraction), continuous study of solar modulation effects at low energy
- AMS launched! waiting for results to compare contemporary measurements

Summary of PAMELA results



V. Formato



Emiliano Mocchiutti – INFN Trieste

International Workshop on Positrons in Astrophysics – Mürren, Switzerland, March 20th, 2012