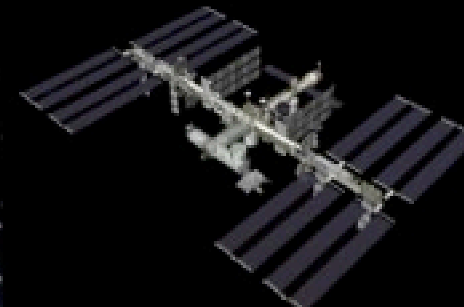
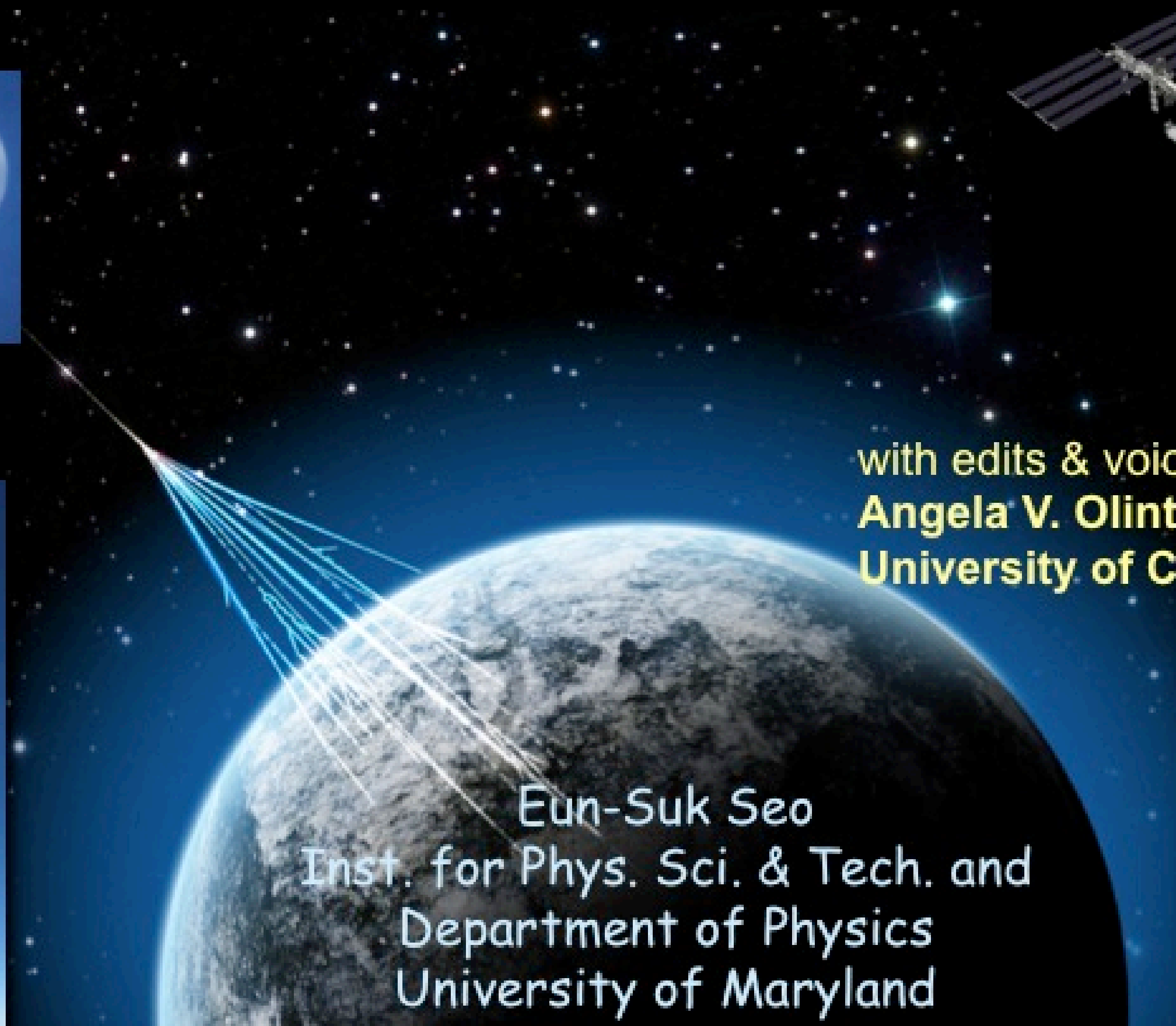
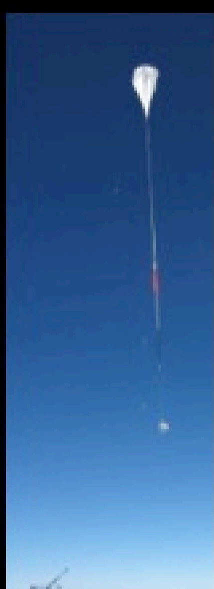
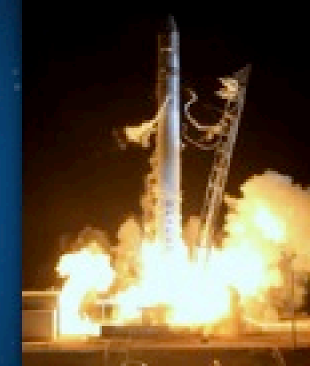
AAS HEAD meeting, Chicago, IL, 19 August 2014

AMS Discoveries Affecting Cosmic-Ray SIG Priorities









with edits & voice from
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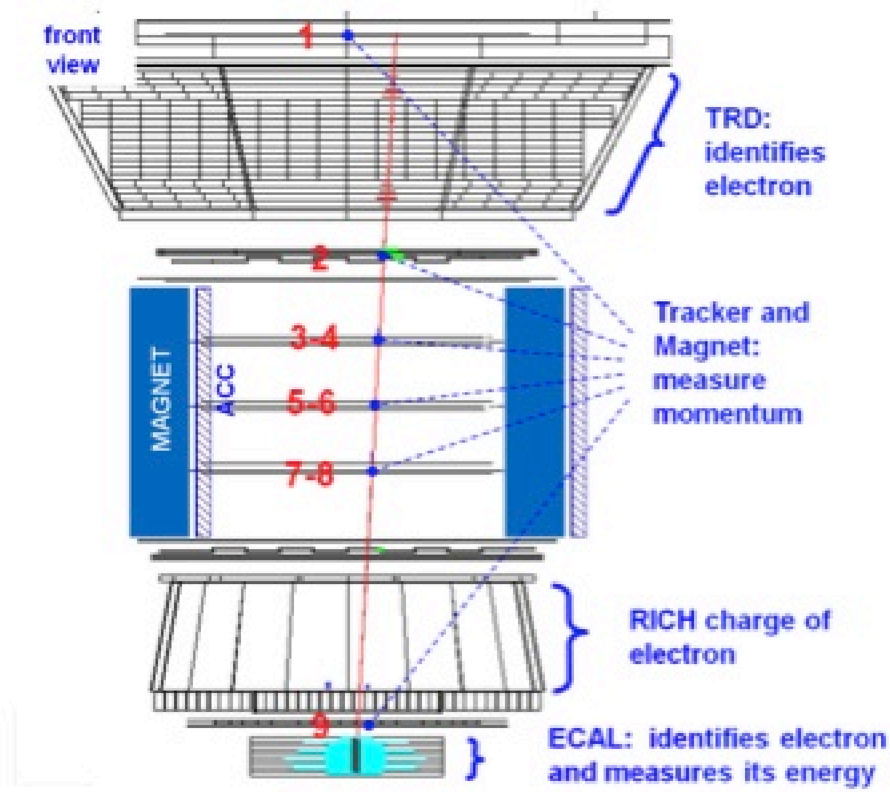
AMS

Alpha Magnet Spectrometer

Launch for ISS on May 16, 2011

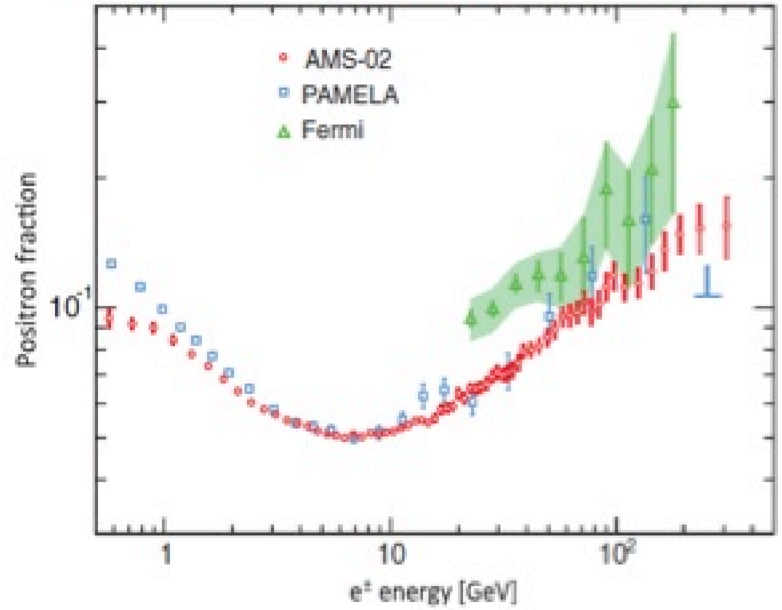
- Search for dark matter by measuring positrons, antiprotons, antideuterons and γ-rays with a single instrument
- Search for antimatter on the level of < 10^{-9}

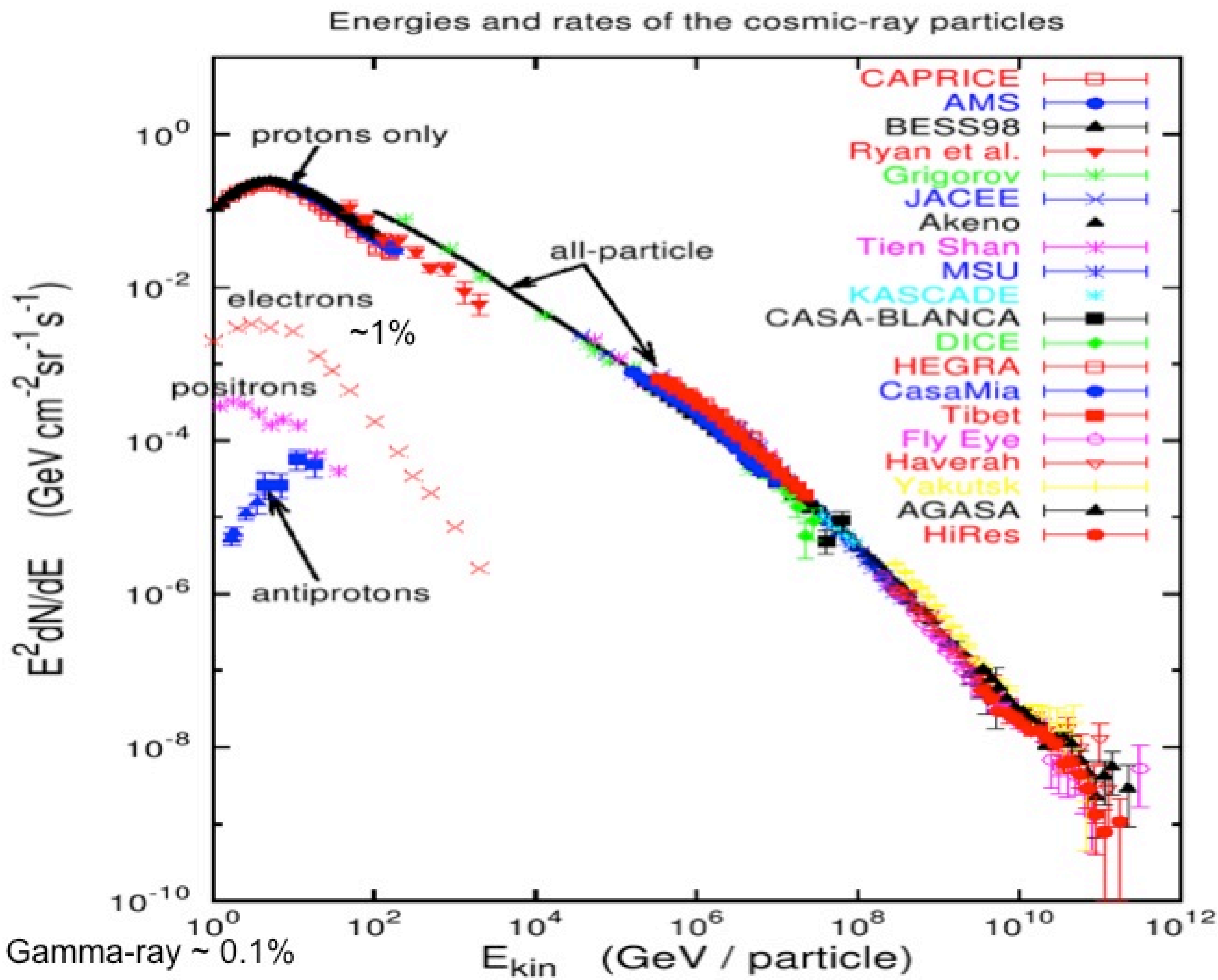


AMS data on ISS: 424 GeV positron

First Result: Precision Measurement of the Positron Fraction in Primary Cosmic Rays of 0.5-350 GeV

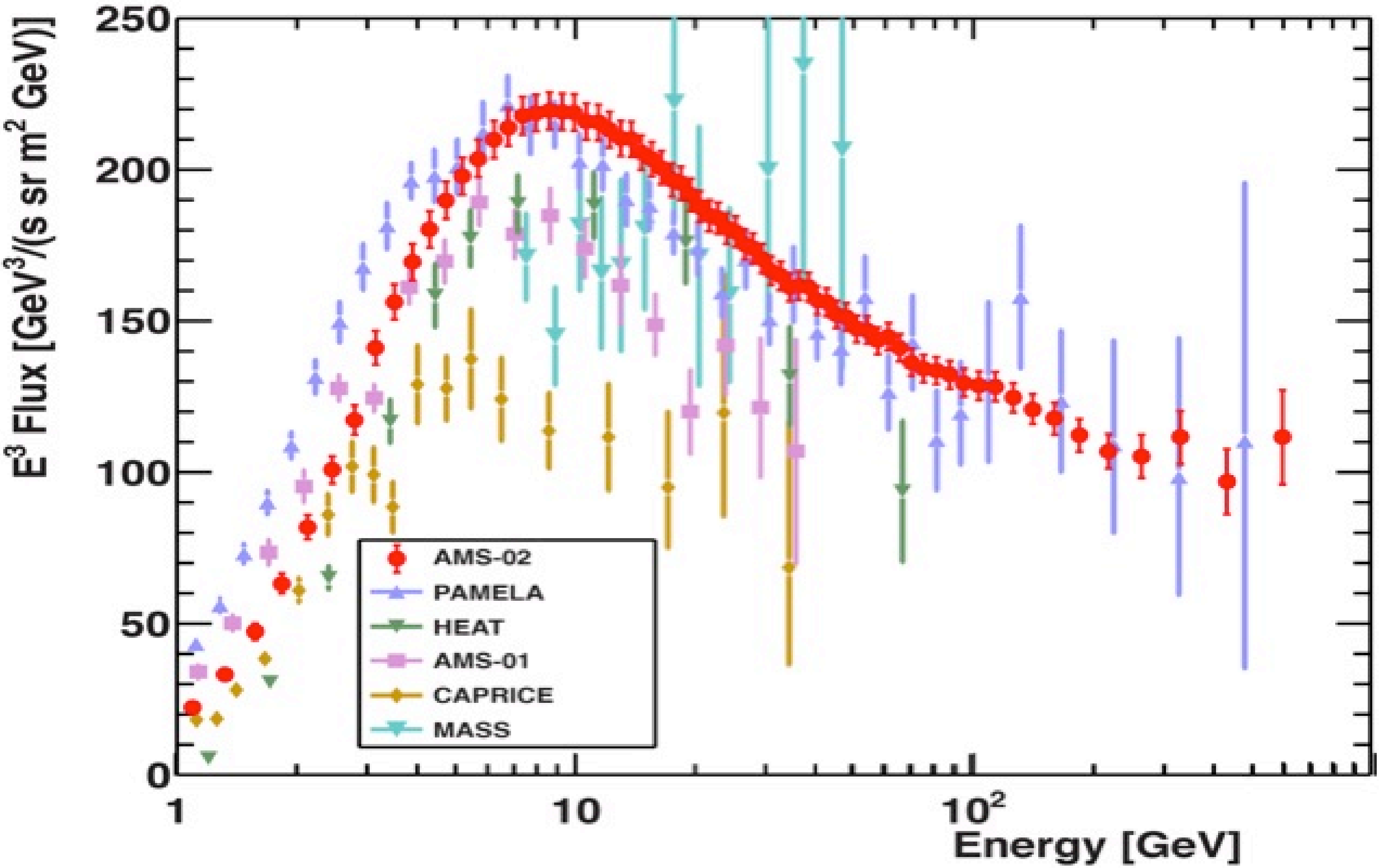
Aguilar et al., PRL 110, 141102, 2013



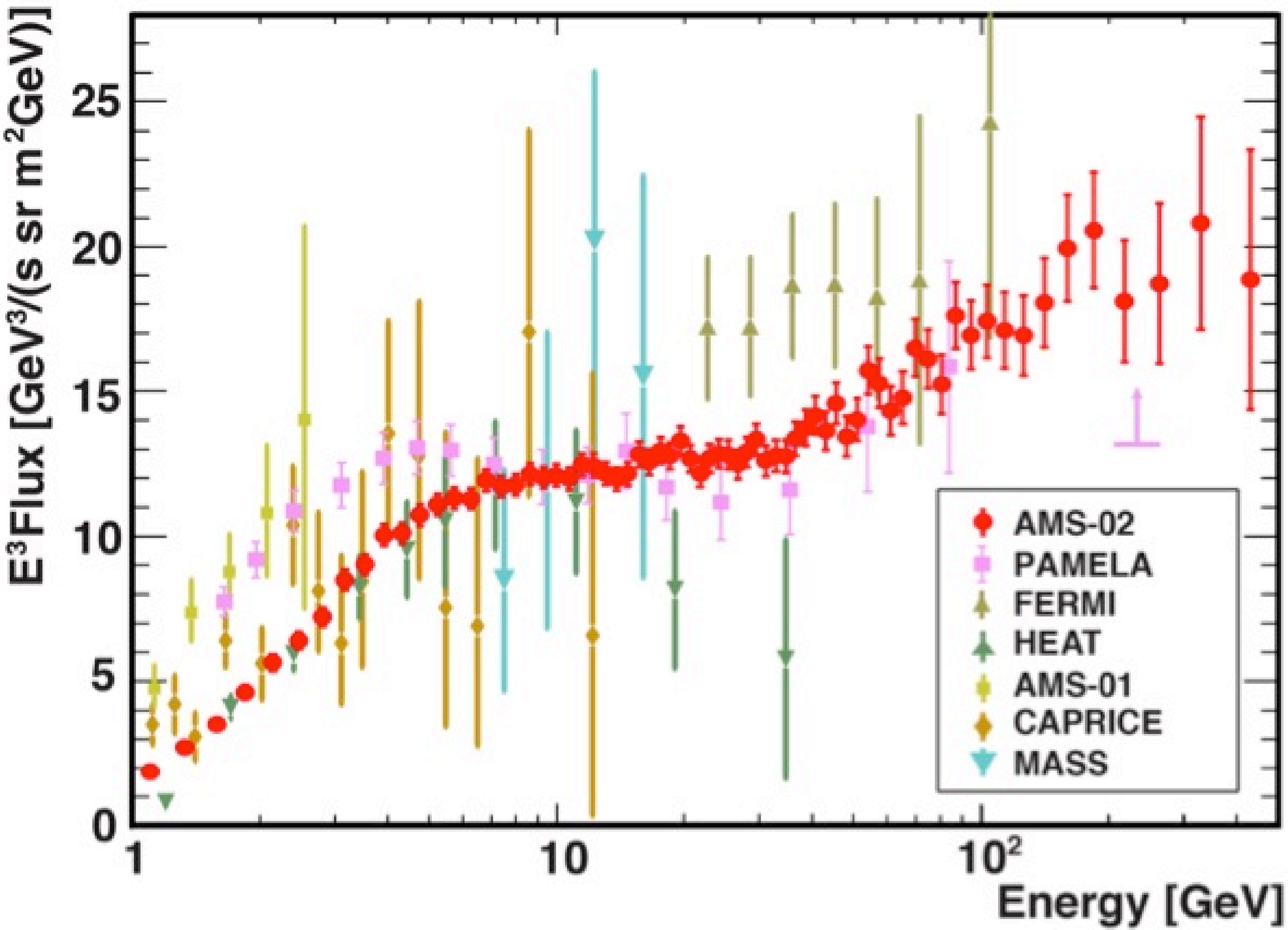


Energies and rates of the cosmic-ray particles
protons only
all-particle
electrons
~1%
positrons
antiprotons
CAPRICE
AMS
BESS98
Ryan et al.
Grigorov
JACEE
Akeno
Tien Shan
MSU
KASCADE
CASA-BLANCA
DICE
HEGRA
CasaMia
Tibet
Fly Eye
Haverah
Yakutsk
AGASA
HiRes
E^{2}dN/dE (GeV cm^{-2}sr^{-1}s^{-1})
E$_{kin}$ (GeV / particle)
Gamma-ray ~ 0.1%

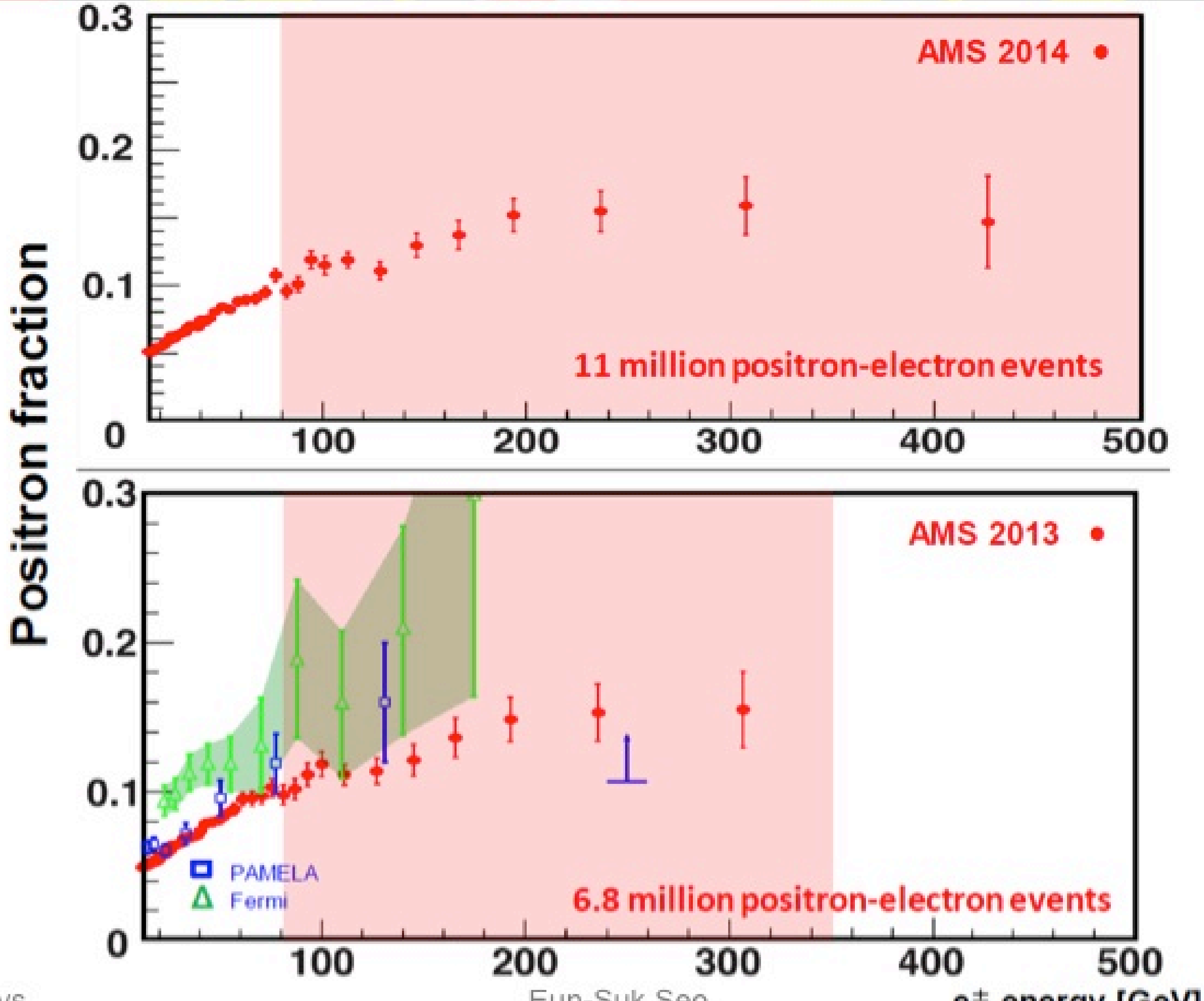
Electron Spectrum: New AMS Results



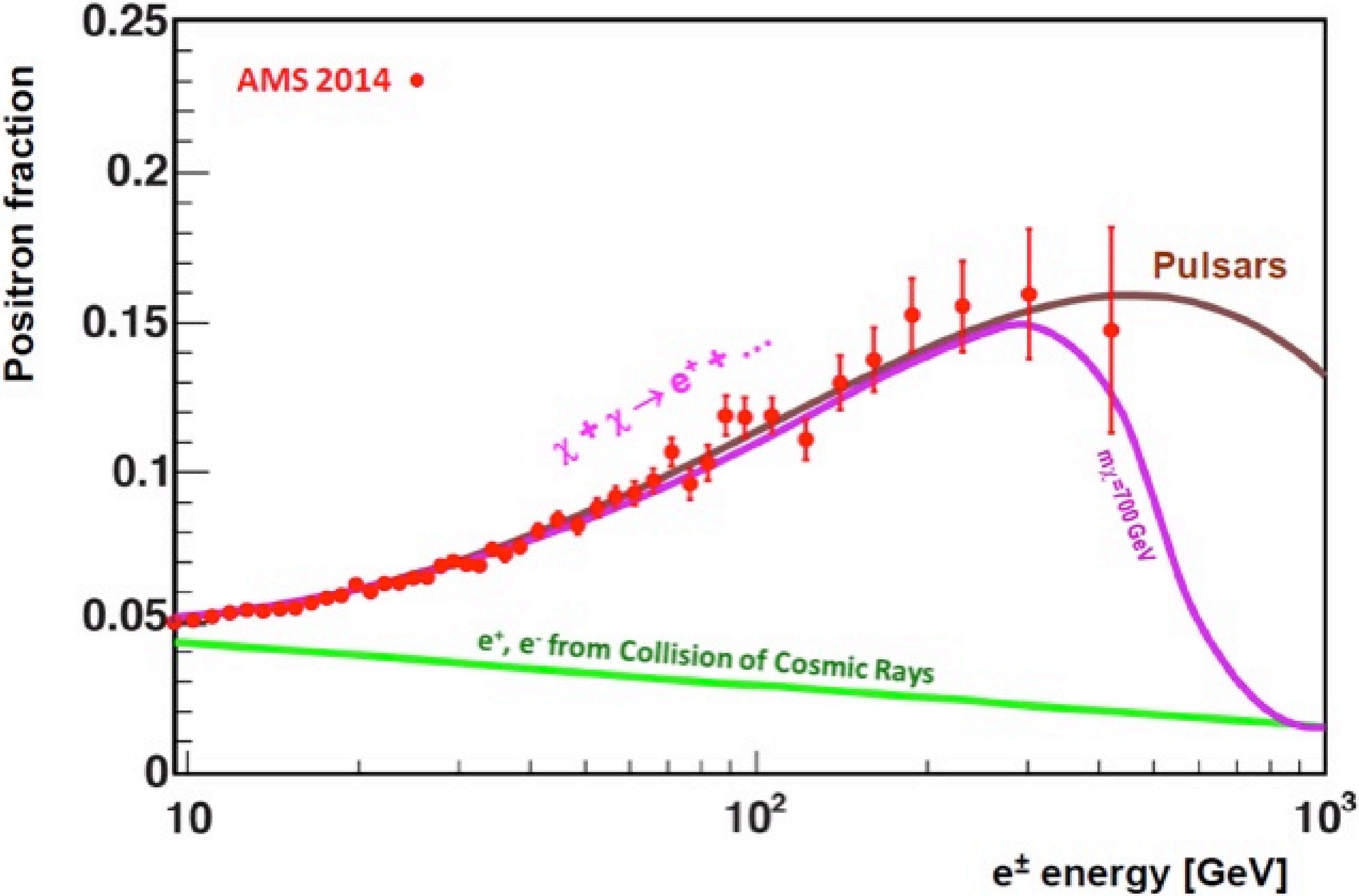
Positron Spectrum: New AMS Results



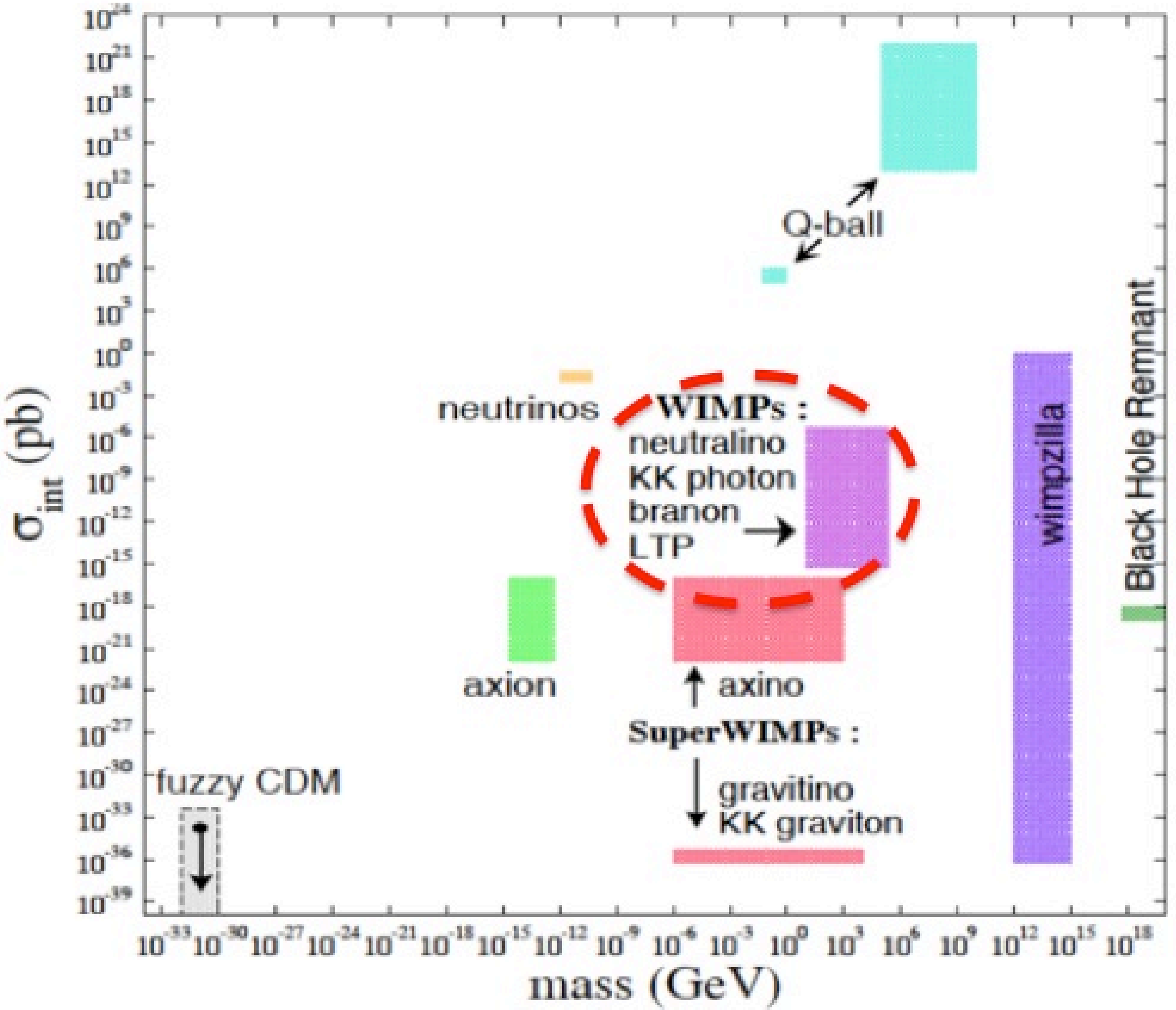
Positron Fraction: Latest AMS Results



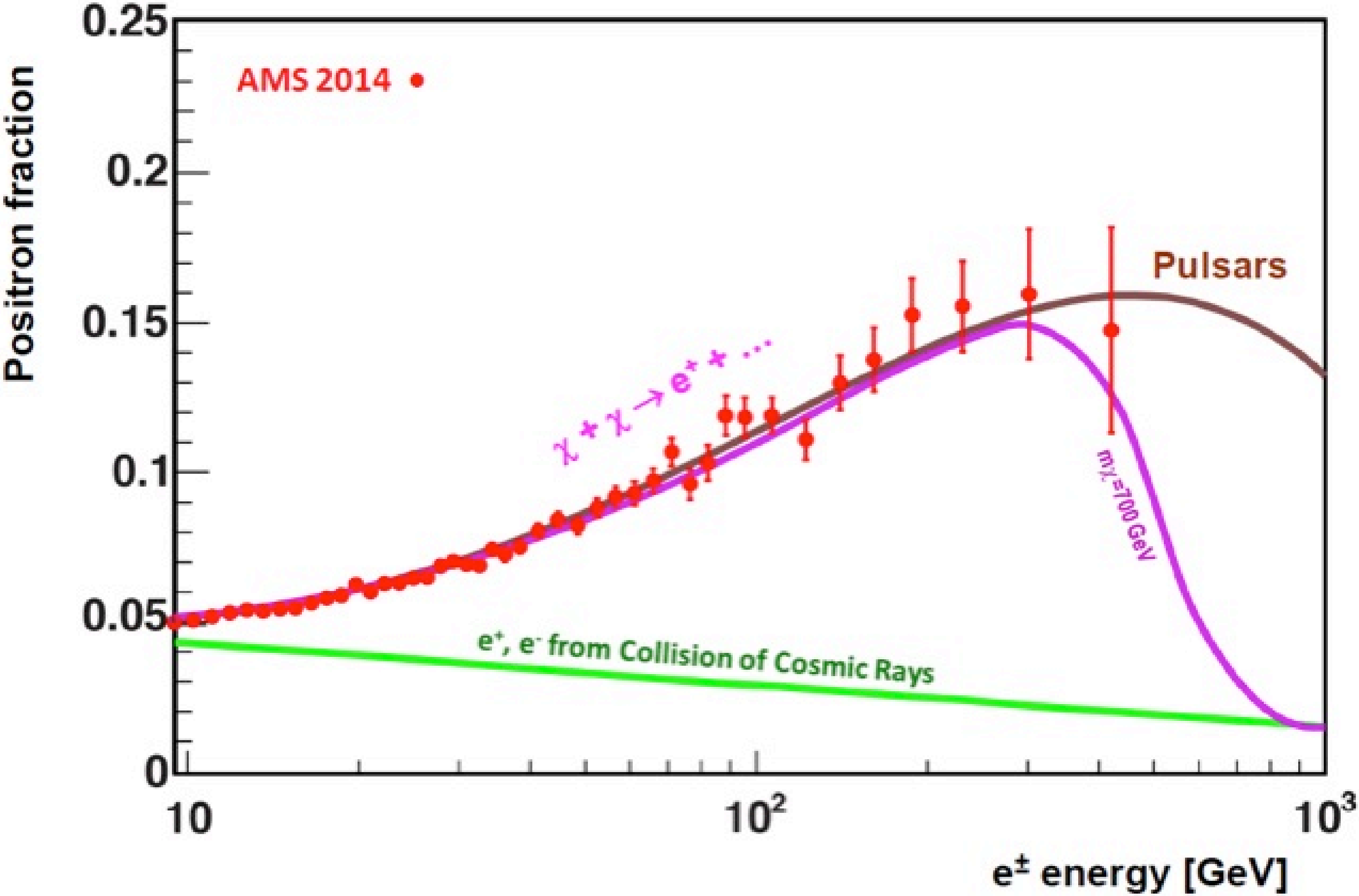
Positron Fraction: Comparison with Models



WIMP Dark Matter?



Positron Fraction: Background=CR Propagation



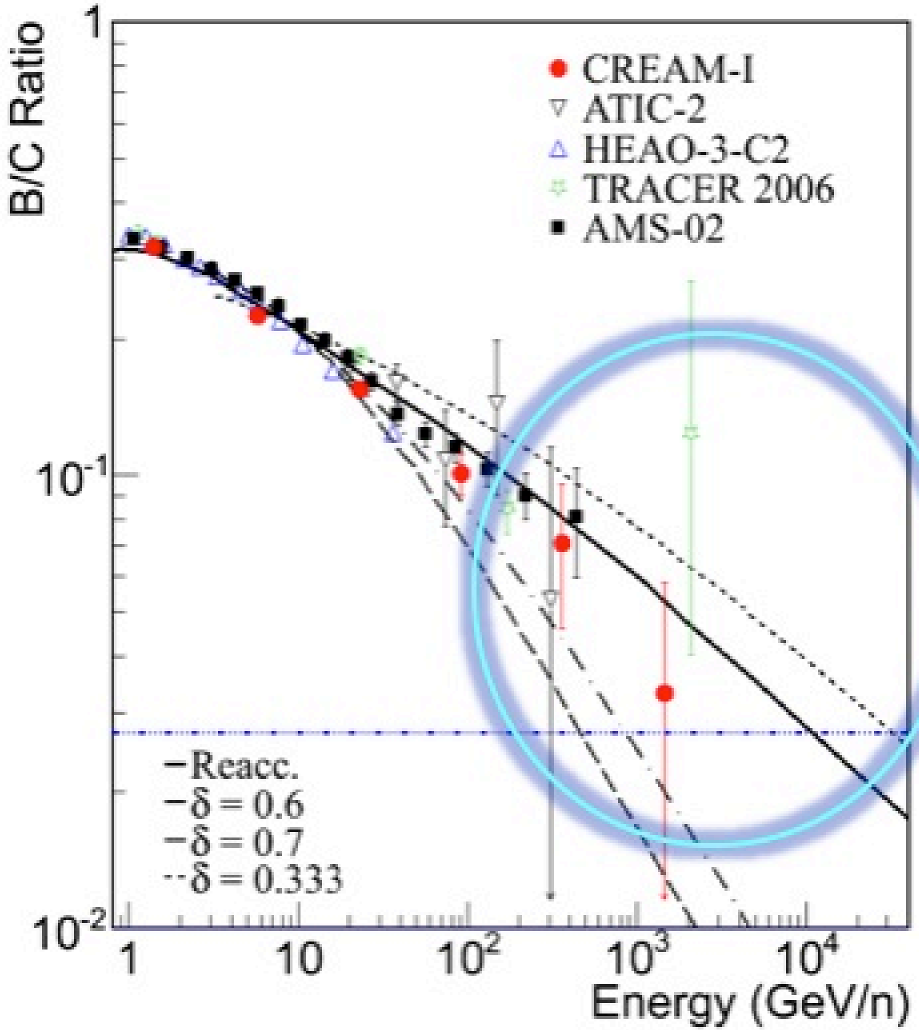
What is the history of cosmic rays in the Galaxy?

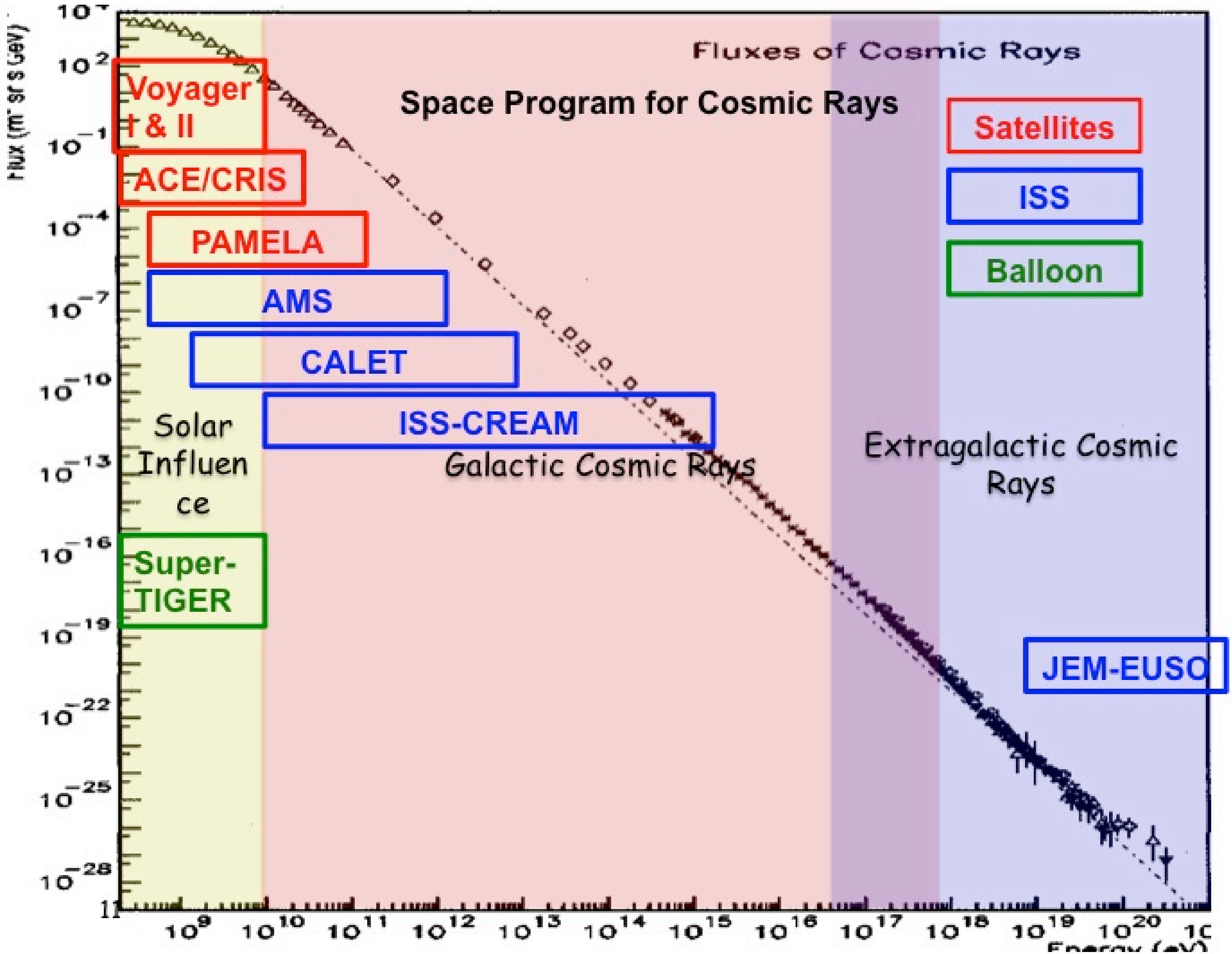
Ahn et al. (CREAM collaboration) Astropart. Phys., 30/3, 133-141, 2008

- Measurements of the relative abundances of secondary cosmic rays (e.g., B/C) in addition to the energy spectra of primary nuclei will allow determination of cosmic-ray source spectra at energies where measurements are not currently available

- First B/C ratio at these high energies to distinguish among the propagation models

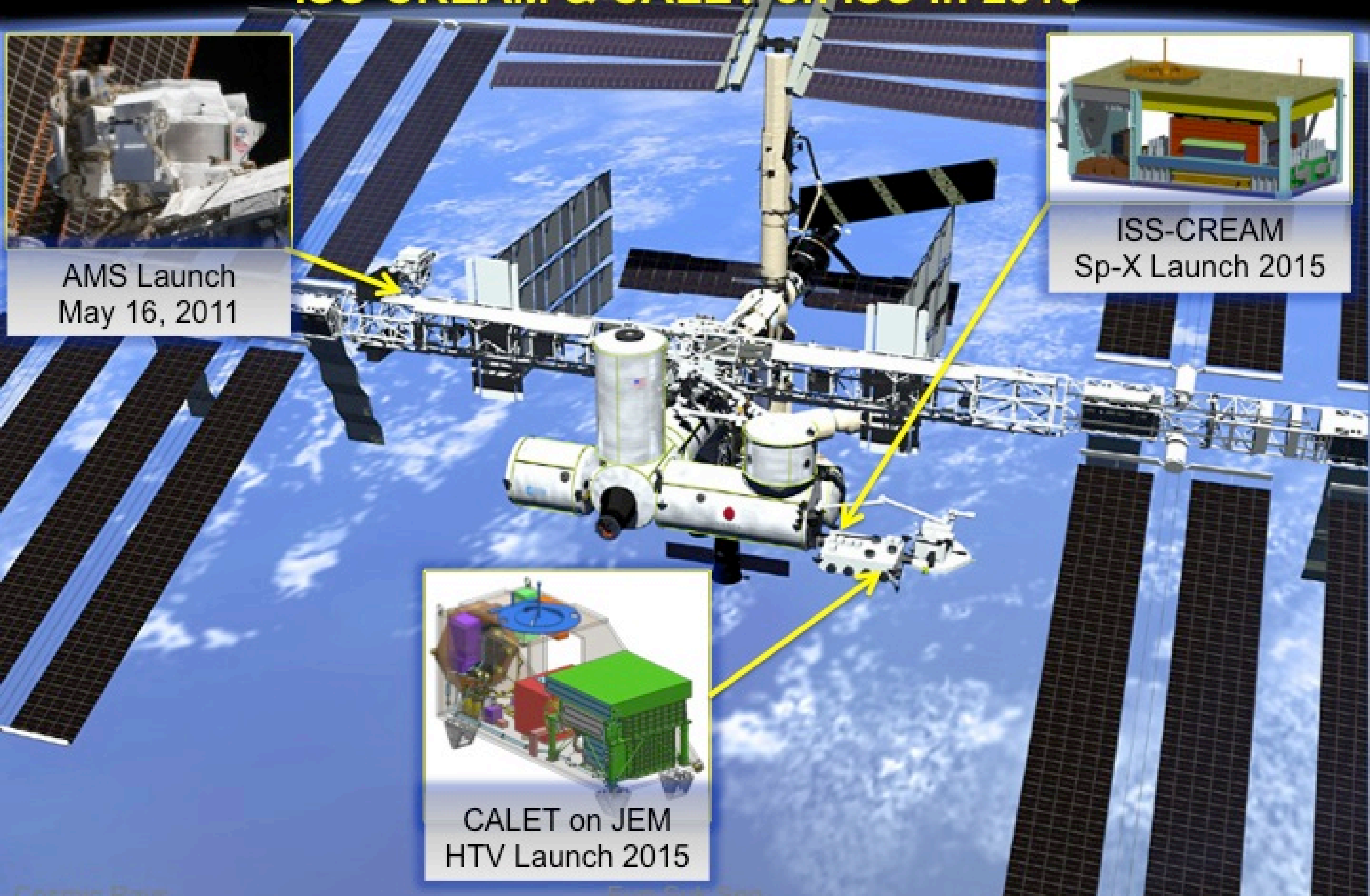
$$X_e \propto R^{-\delta}$$




Fluxes of Cosmic Rays
Space Program for Cosmic Rays
Voyager I & II
ACE/CRIS
PAMELA
AMS
CALET
ISS-CREAM
Satellites
ISS
Balloon
Solar Influence
Super-TIGER
Galactic Cosmic Rays
Extragalactic Cosmic Rays
JEM-EUSO
Flux (m² sr s GeV)
Energy (eV)

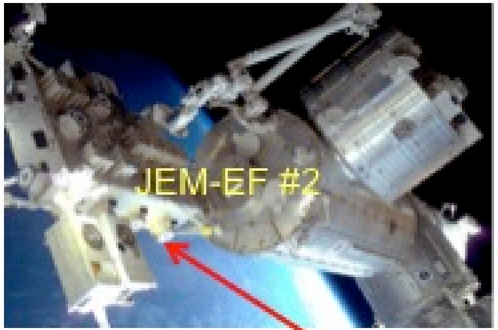
“Cosmic Ray Observatory on the ISS”

ISS-CREAM & CALET on ISS in 2015



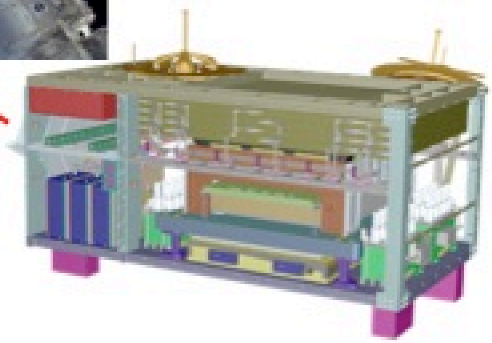
ISS-CREAM CREAM for the ISS

E. S. Seo et al, Advances in Space Research, **53**/10, *1451*, 2014

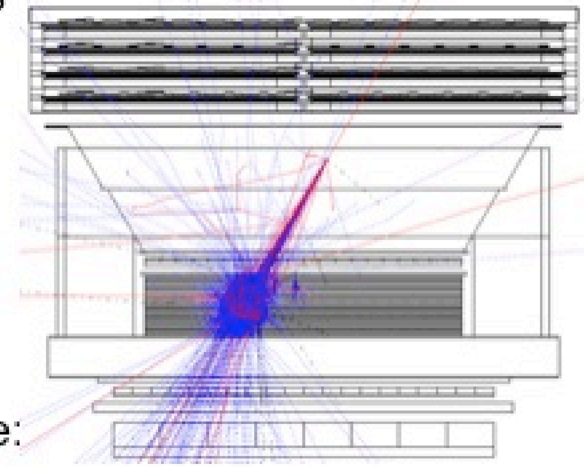


Cosmic Ray Energetics and Mass

To be installed on the ISS in February 2015 by Space X-6



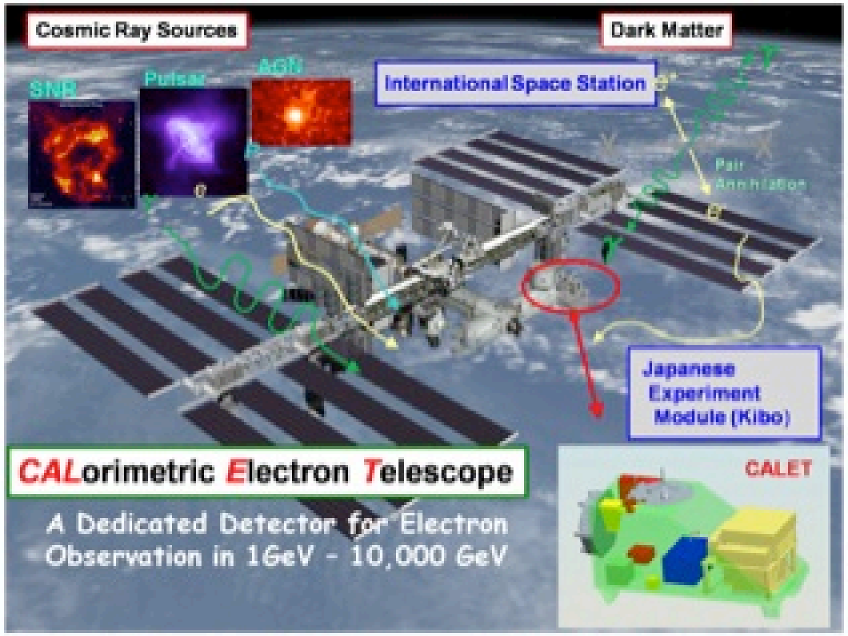
Mass: ~1400 kg
Power: ~ 550 W
Nominal data rate: ~350 kbps



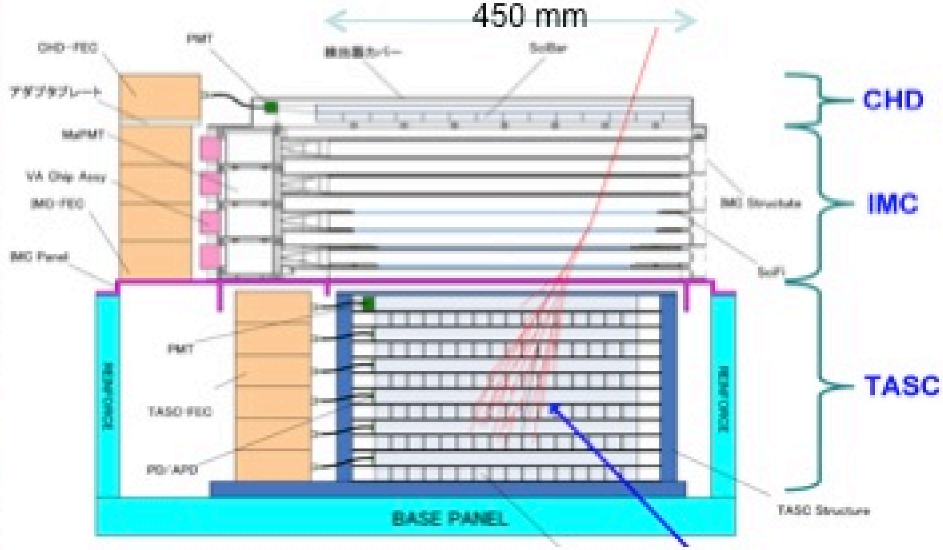
- Building on the success of the balloon flights, the payload is being transformed for accommodation on the ISS (NASA's share of JEM-EF).
  - Increase the exposure by an order of magnitude
- ISS-CREAM will measure cosmic ray energy spectra from 10^{12} to >**10^{15} eV** with individual element precision over the range from protons to iron to:
  - Probe **cosmic ray origin, acceleration and propagation**.
  - Search for spectral features from **nearby/young sources**, acceleration effects, or propagation history.

CALET CALorimetric Electron Telescope

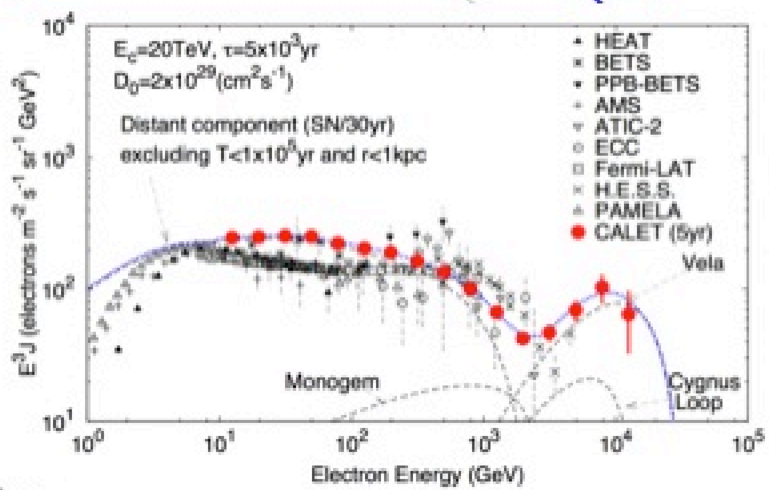
Launch target JFY 2014



electron spectrum up to > 10 TeV
anisotropies



rticles



Charge Detector (Charge Z=1-40)

1 Layer of 14 Plastic Scintillators (32 x 10 x 450 mm^3)

Imaging Calorimeter (Particle ID, Direction)

Total Thickness of Tungsten (W) : 3 X_0

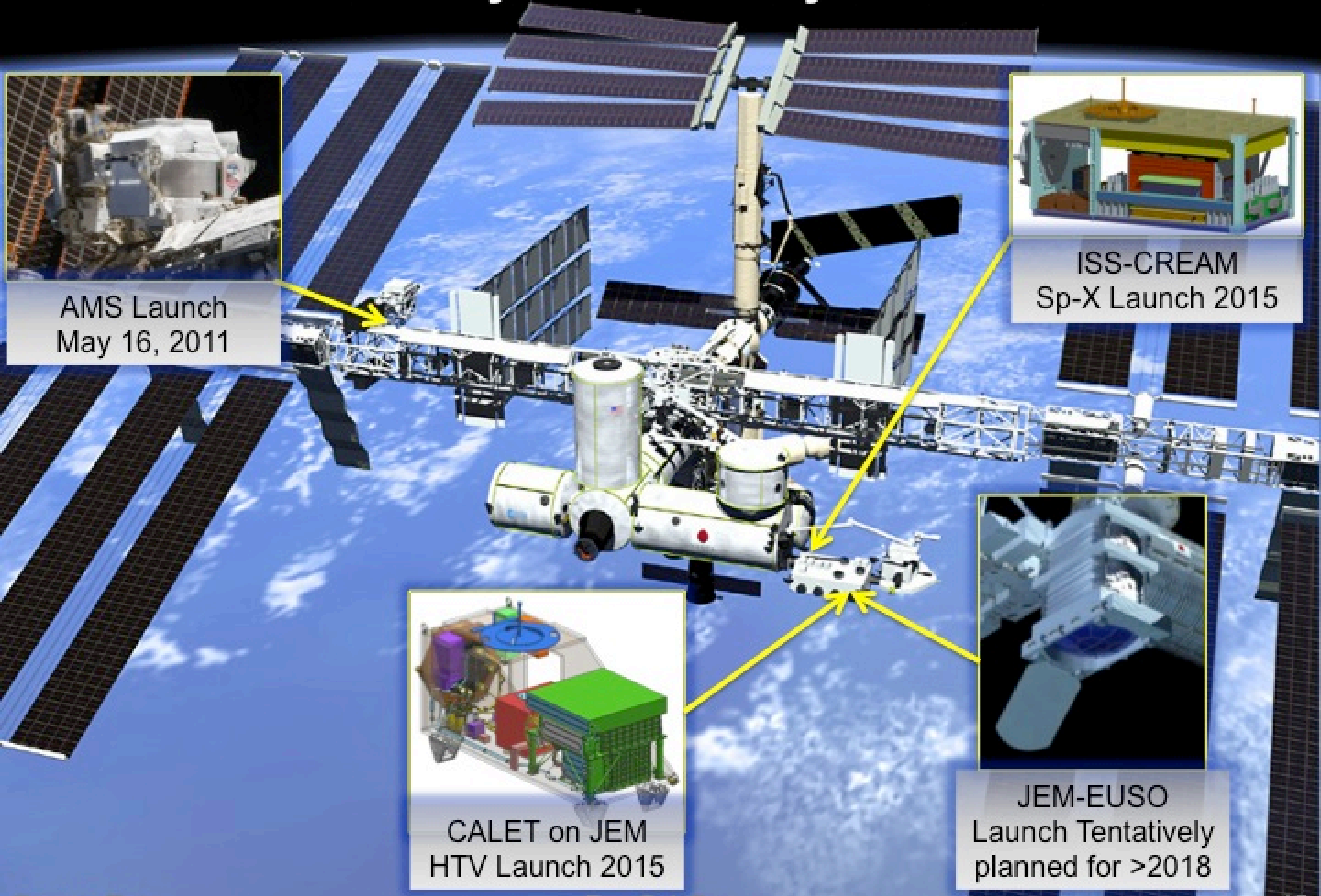
Layer Number of Scifi Belts : 8 Layers ×2(X,Y)

Total Absorption Calorimeter (Energy Measurement, Particle ID)

PWO 20 mm x 20 mm x 320 mm

Total Depth of PWO : 27 X_0 (24 cm)

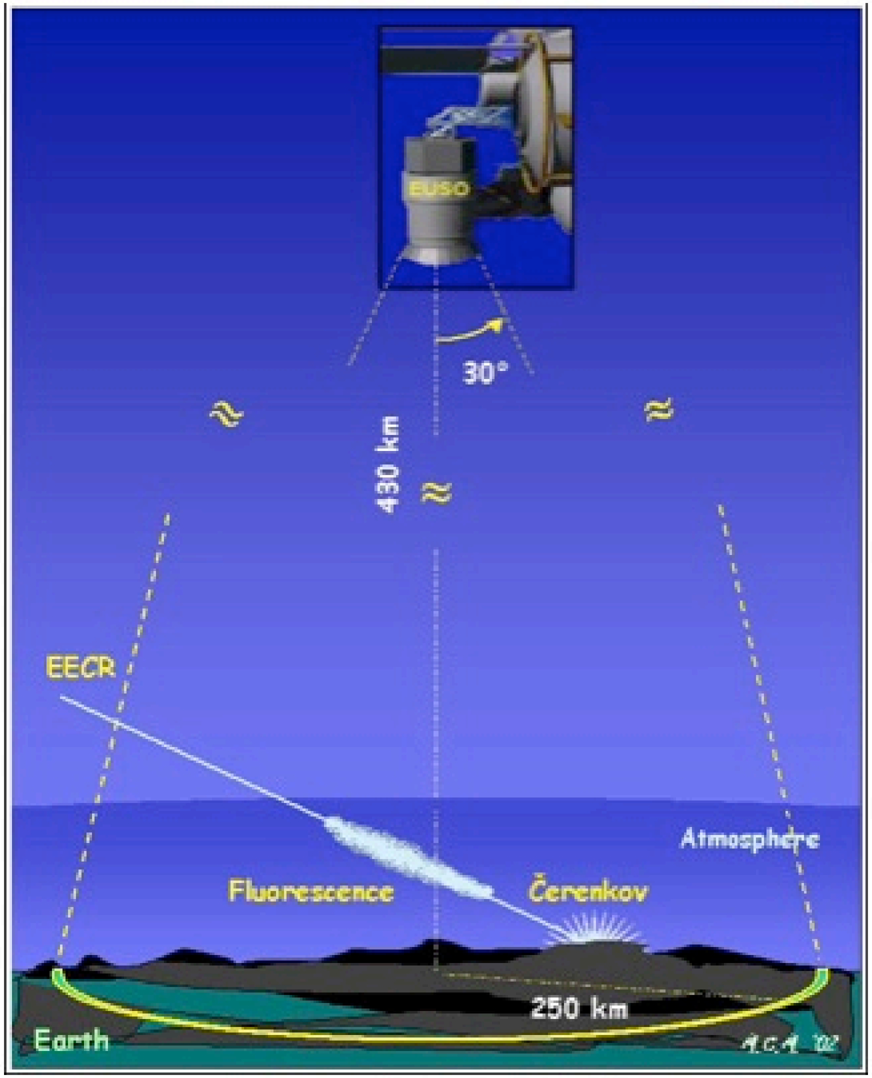
Cosmic Ray Observatory on the ISS



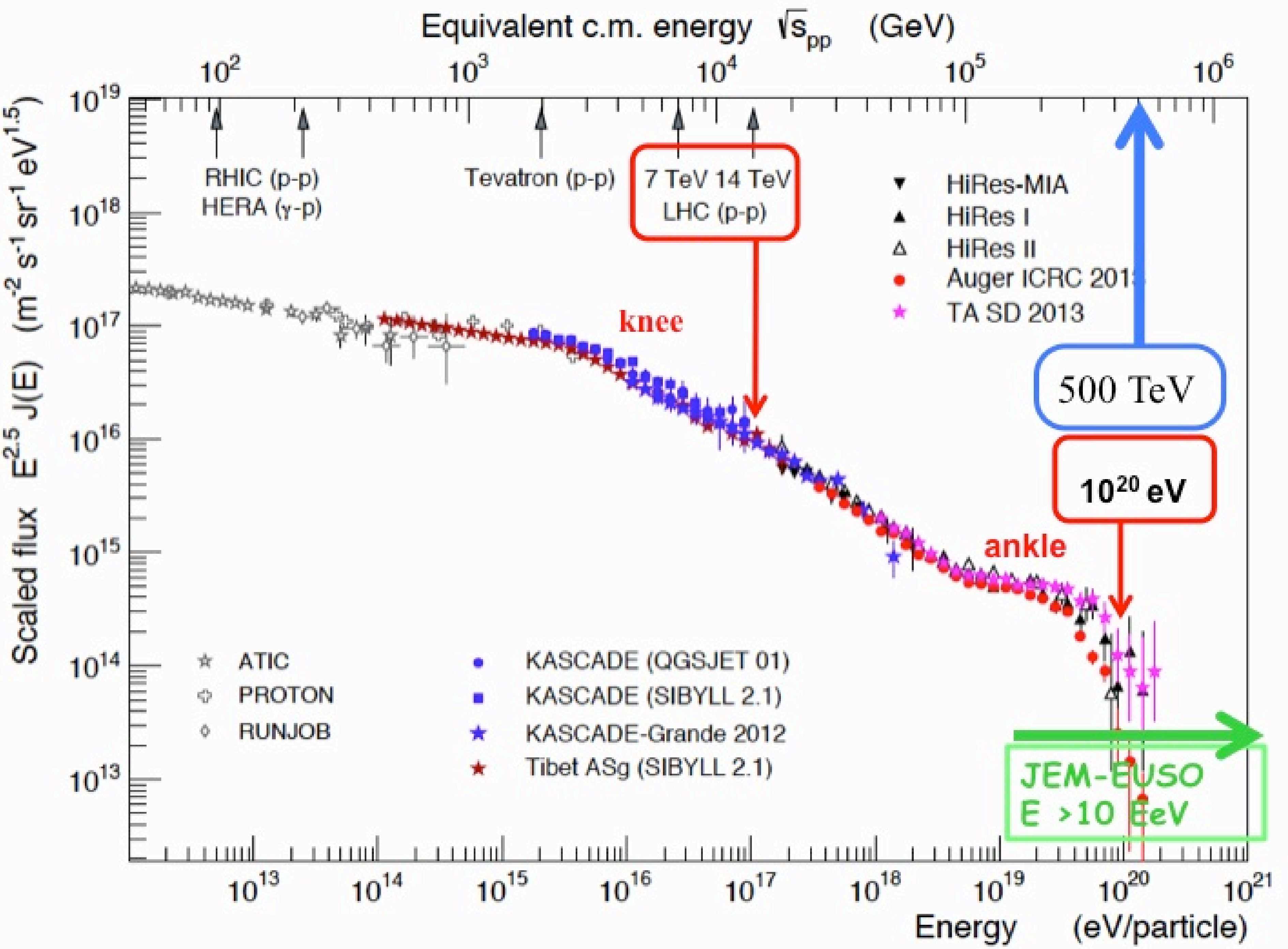
JEM-EUSO

The Extreme Universe Space Observatory on the ISS Japanese Experiment Module

- JEM-EUSO is a wide field of view UV telescope looking down on the atmosphere from the ISS. It will capture high-speed videos of extensive air-showers from extremely energetic cosmic rays striking the atmosphere.
- JEM-EUSO is an order of magnitude more sensitive than ground Observatories E>60 EeV.
- Goals:
  - **to discover the origin of Ultrahigh Energy Cosmic rays that are now known to be extragalactic.**
  - **Probe physics above LHC energies**

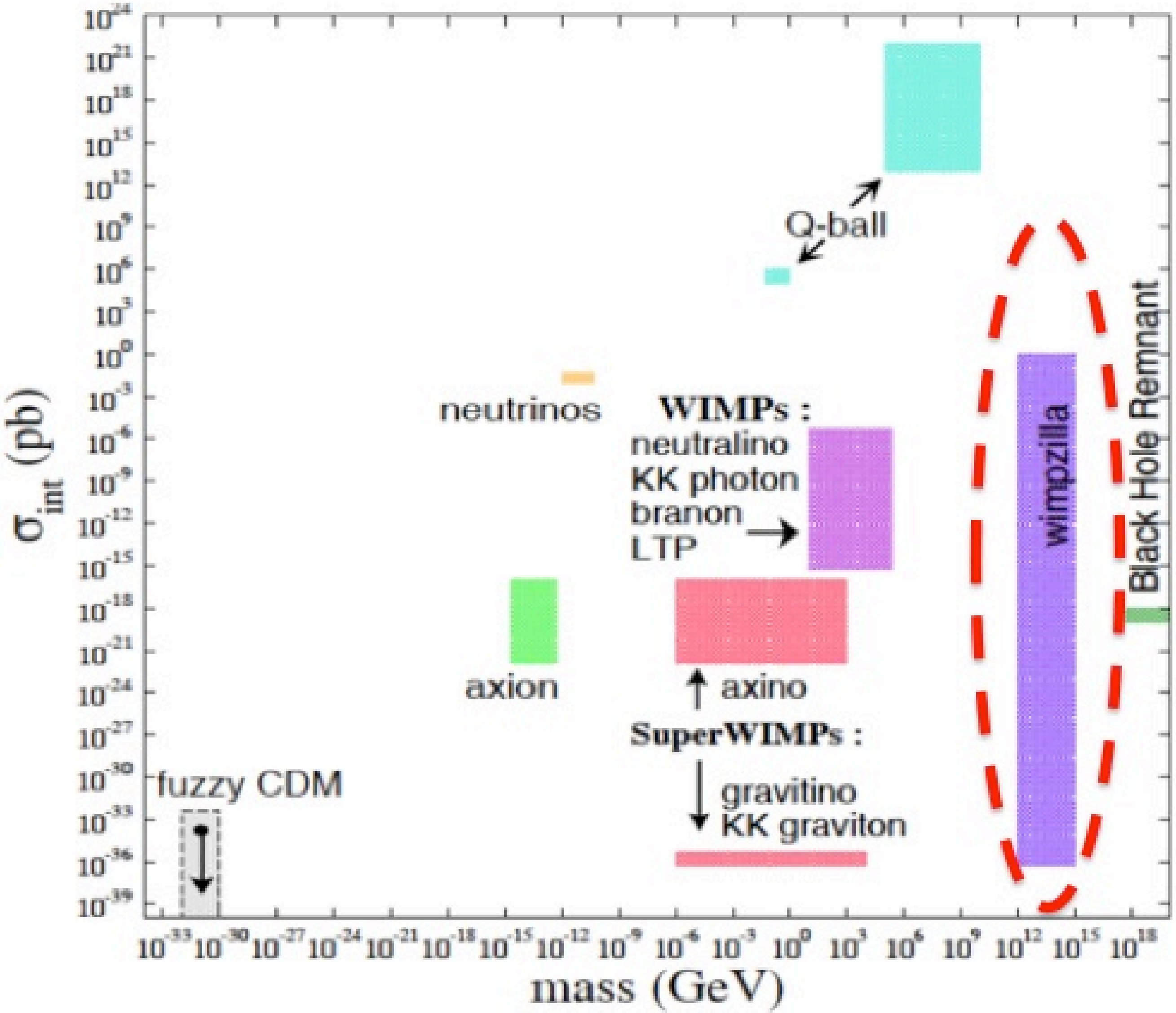


CREDIT: EUSO collaboration

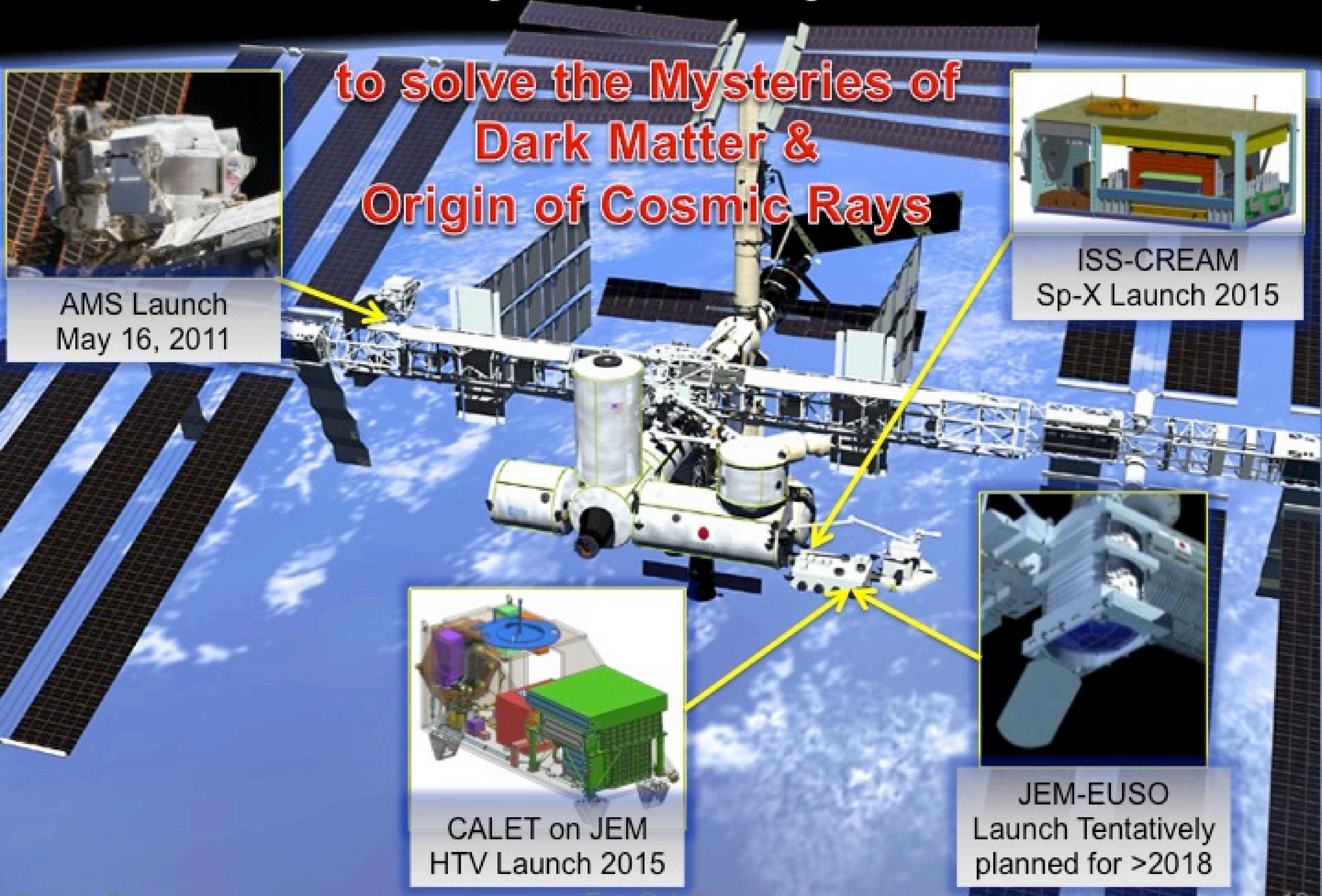


Equivalent c.m. energy $\sqrt{s_{pp}}$ (GeV)
10^2
10^3
10^4
10^5
10^6
RHIC (p-p)
HERA (γ-p)
Tevatron (p-p)
7 TeV 14 TeV
LHC (p-p)
HiRes-MIA
HiRes I
HiRes II
Auger ICRC 2013
TA SD 2013
knee
500 TeV
10^{20} eV
ankle
Scaled flux $E^{2.5}$ J(E) ($m^{-2}s^{-1}sr^{-1}eV^{1.5}$)
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
ATIC
PROTON
RUNJOB
KASCADE (QGSJET 01)
KASCADE (SIBYLL 2.1)
KASCADE-Grande 2012
Tibet ASg (SIBYLL 2.1)
JEM-EUSO
E >10 EeV
10^{13}
10^{14}
10^{15}
10^{16}
10^{17}
10^{18}
10^{19}
10^{20}
10^{21}
Energy (eV/particle)

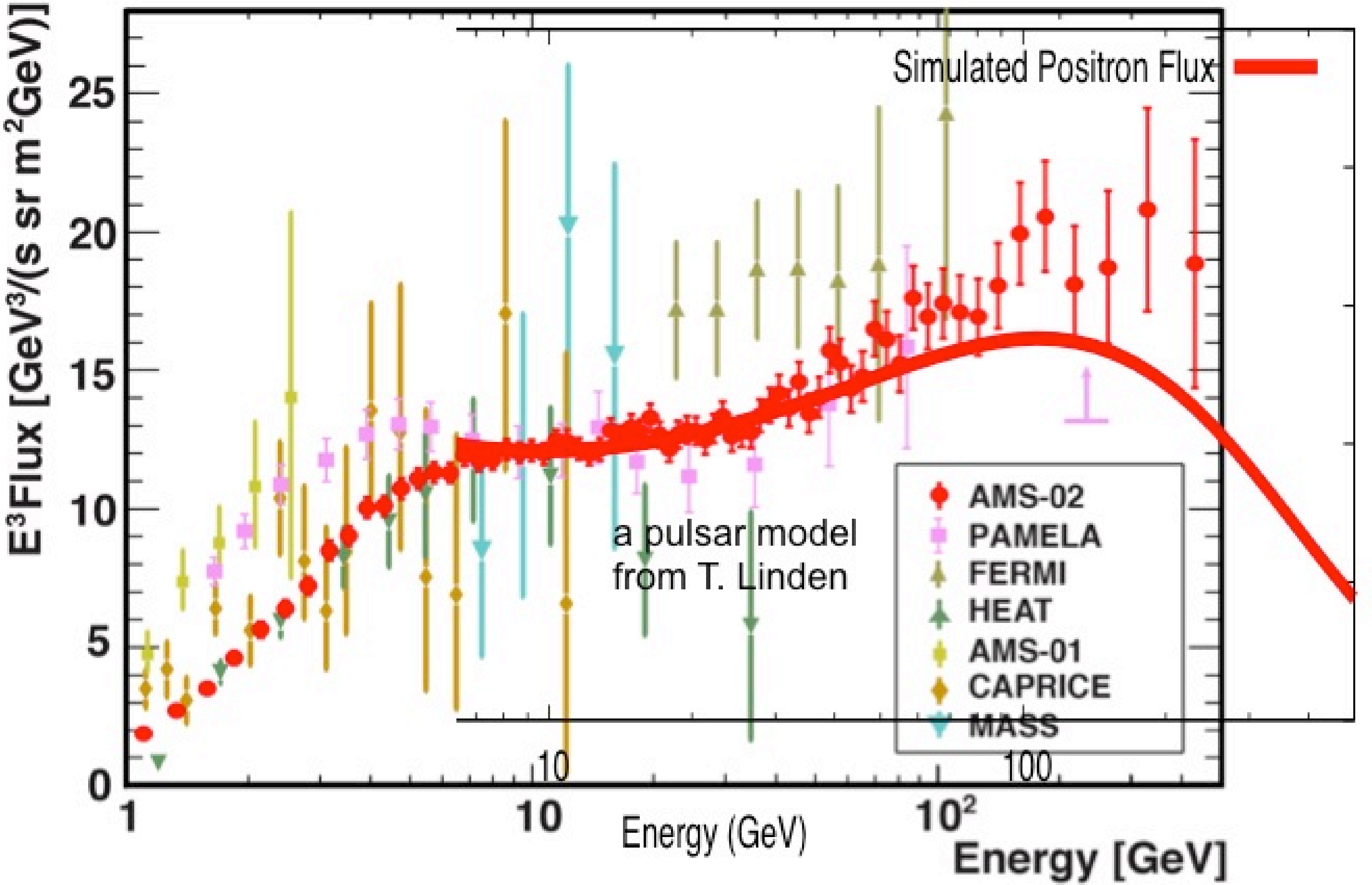
High Mass Dark Matter?



Cosmic Ray Observatory on the ISS

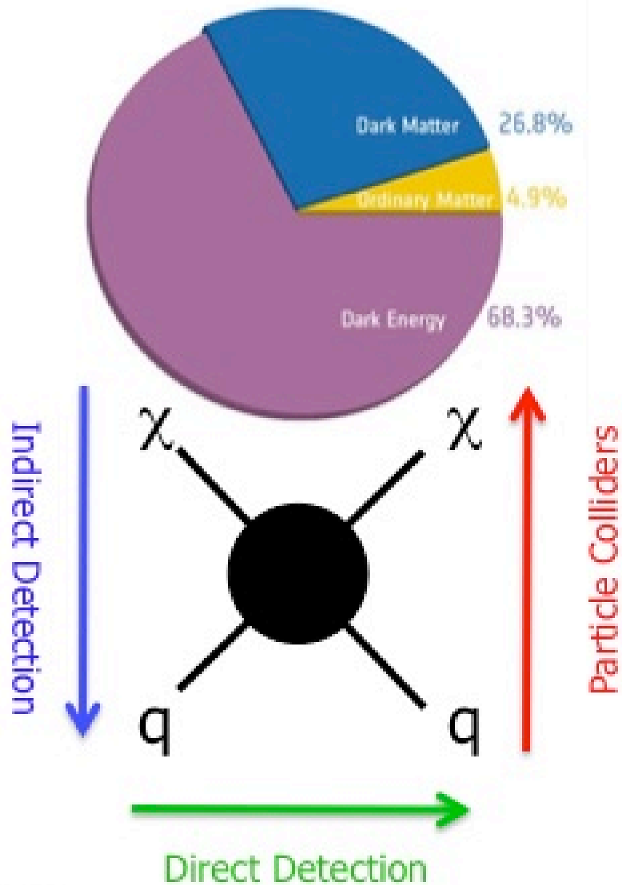


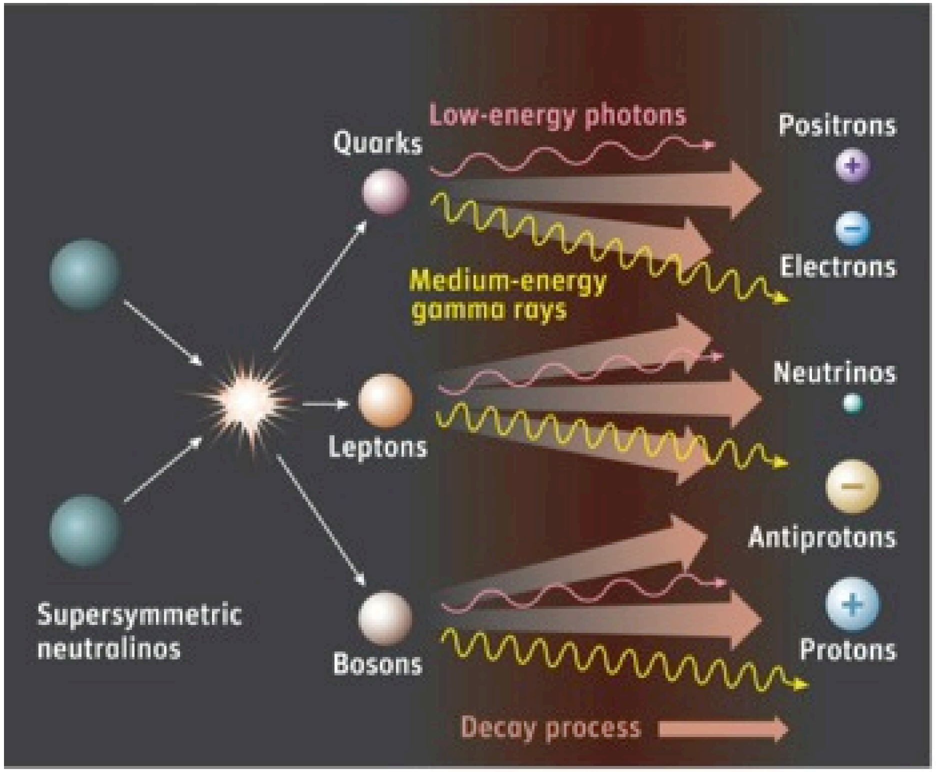
Positron Spectrum: New AMS Results



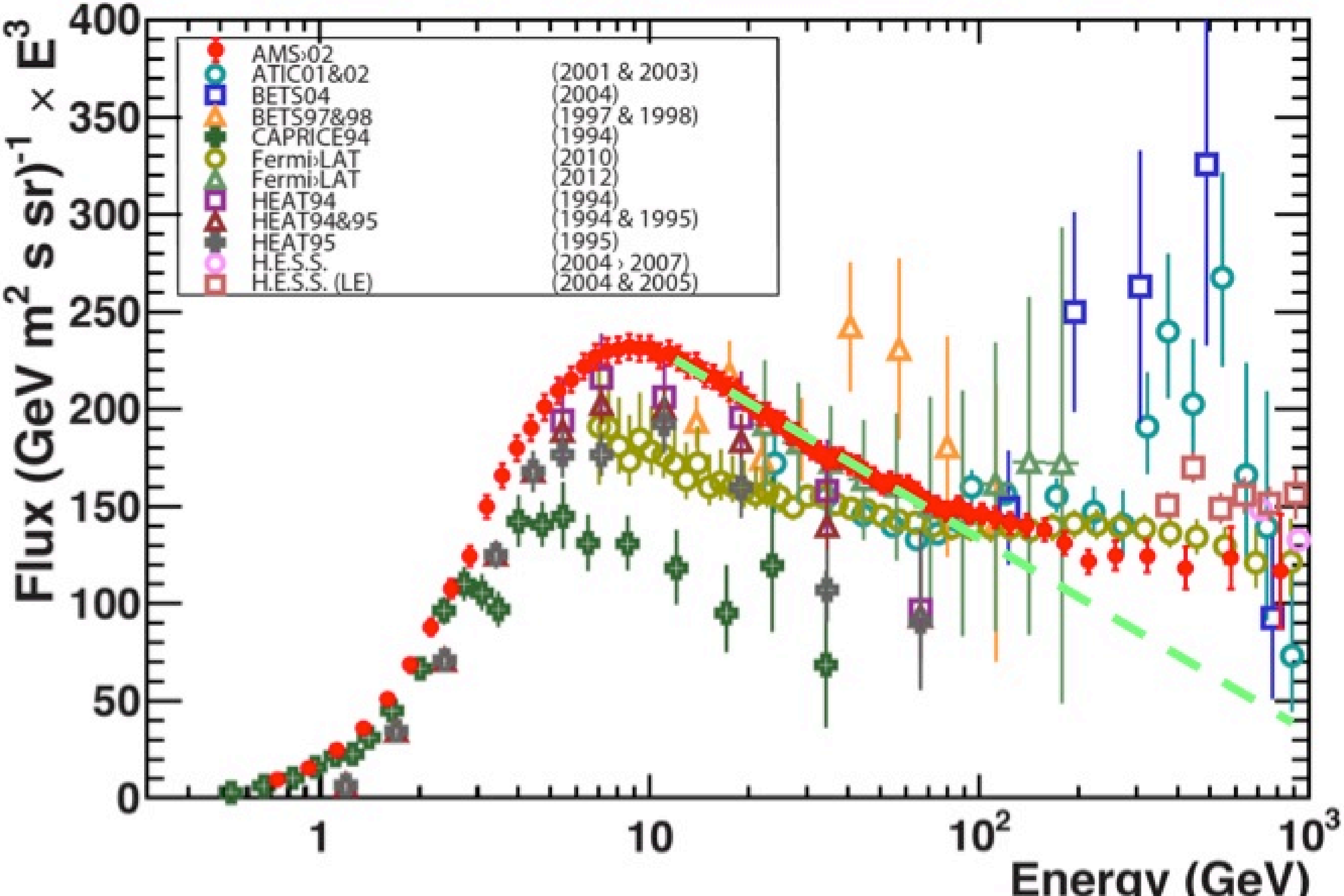
We do not know what 95% of the universe is made of!

- Weakly Interacting Massive Particles (WIMPS) could comprise dark matter.
- This can be tested by direct search for various annihilating products of WIMP's in the Galactic halo.





Total electron (e+ + e−) spectrum



Cosmic Ray Propagation

Consider propagation of CR in the interstellar medium with random hydromagnetic waves.

Steady State Transport Eq.:

$$\partial \frac{\partial}{\partial z} D_j \frac{\partial f_j}{\partial z} + \frac{\rho}{m} v\sigma f_j + \frac{1}{p^2}\frac{\partial}{\partial p} p^2 K_j \frac{\partial f_j}{\partial p} + \frac{1}{p^2}\frac{\partial}{\partial p}\left[p^2 \left(\frac{dp}{dt}\right)_{j,ion} f_j \right] = q_j + \sum_{k<j} S_{jk}$$

The momentum distribution function f is normalized as $N = \int dp\, p^2 f$

where N is CR number density, D: spatial diffusion coefficient, σ: cross section...

$$\frac{I_j}{X_e} + \frac{\sigma_j}{m} I_j + \alpha\{...\} + \frac{d}{dE}\left[\left(\frac{dE}{dx}\right)_{j,ion} I_j \right] = \frac{Q_j}{\rho_0} + \sum_{k<j} \frac{\sigma_{jk}}{m} I_k$$

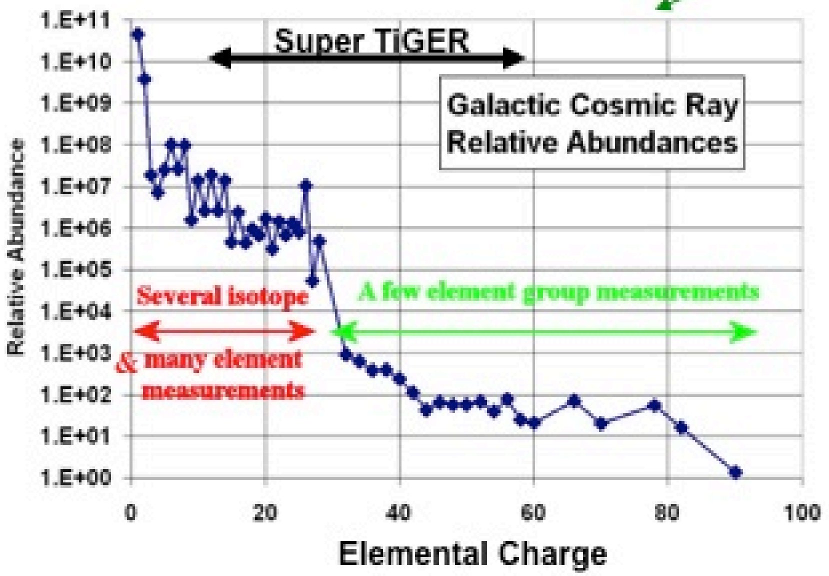
Cosmic ray intensity $I_j(E) = A_j p^2 f_{0j}(p)$

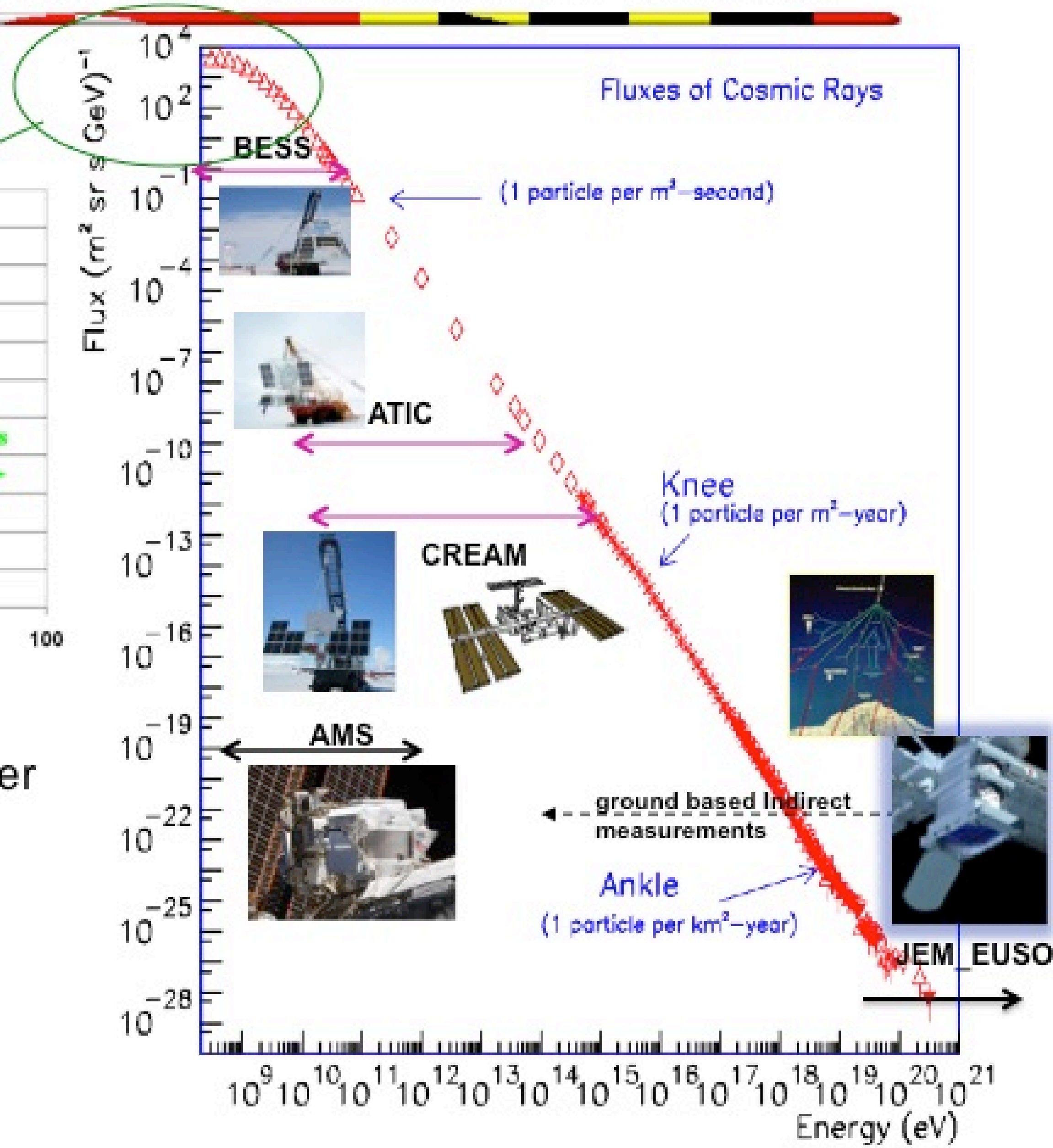
Escape length Xe

Reacceleration parameter α

E. S. Seo and V. S. Ptuskin, Astrophys. J., **431**, *705-714*, 1994.

How do cosmic accelerators work?





- Relative abundances range over 11 orders of magnitude
- Detailed composition limited to less than ~ 10 GeV/nucleon