

Cosmic Ray Anisotropy Workshop CRA2019

# Discussion topics

Oct 11, 2019

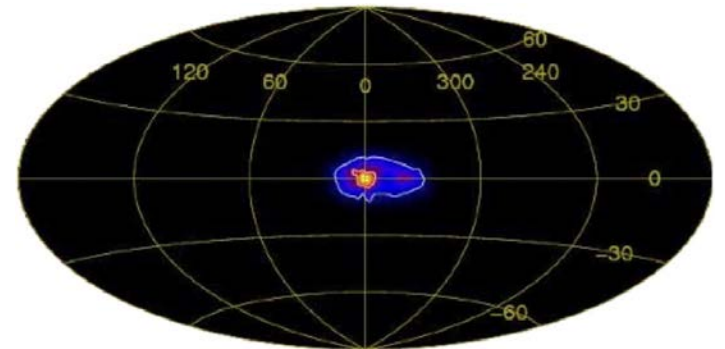
# Find the true origin

- Identification (or discrimination) of transient and (quasi-) steady-state processes
  - Hints
  - Importance
  - Examples: positron excess, breaks in the spectra of CR species, slow diffusion zones (Geminga), Fermi Bubbles
  - Historical records of CR fluxes (wood cores, ice cores, minerals...)
- Definitions of the (quasi-) steady-state
  - Timescales (?)
  - Ex.: spectrum of interstellar turbulence
- Evolution of the Galaxy
  - Effects of winds
  - Ex.: Halo expansion (e.g., P.Blasi)
- Observational consequences
  - How local is “local”?

# Expanding on particular CR issues

- Positron excess
  - Local transient event ? (a pulsar)
  - If so, all pulsars have to produce local positron excesses  
→ positron excess distribution should match the distribution of pulsars
  - The same if positrons are produced in SNR shocks, but with more fluctuations
  - DM related → clumpy/smooth positron distribution with enhancement at the Galactic center
  - 511 keV line observations (INTEGRAL) – related?

511 keV line from 5 years of observation by INTEGRAL/SPI (Weidenspointner+'2008; Prantzos+'2011)



# Uncertainties

- Interstellar medium
  - 3D gas maps (HI, H2, HII)
  - Dust distribution, properties
  - 3D Interstellar radiation field (Optical, IR - depends on gas, dust)
  - 3D Magnetic field (regular, turbulent)
  - Turbulent motions, distributions, properties, scales
- Non-uniform/anisotropic diffusion
  - Observational evidence(s)
  - Consequences
- Cross sections
  - Isotopic (e.g., Genolini+'2018)
  - particle production (antiproton excess @ 10 GV ?)
- Origin of CRs
  - Interstellar medium %
  - Stellar winds %
- Heliospheric modulation (partly solved? Tnks to Voyager 1, 2)

# Cross sections & cosmic rays

- A major source of uncertainties!
  - Systematically measured by Webber & co-workers, but accuracy is a problem (>20%-50%), limited energy range  $\sim 600$  MeV/n
  - Non-systematic measurements by different groups
  - Databases – limited information
  - Dedicated meetings:
    - [XSCRC2017: Cross sections for Cosmic Rays @ CERN](#)
    - [XSCRC2019: Cross sections for Cosmic Rays @ CERN \(13-15 Nov. 2019\)](#)
  - Genolini, Y., Maurin, D., IVM, Unger, M. 2018, “Current status and desired precision of the isotopic production cross sections relevant to astrophysics of cosmic rays: Li, Be, B, C, and N”, Phys. Rev. C **98**, 034611
  - Stimulated a proposal from NA61 collab. – CNO-projectile cross sections are measured at 13 GV
  - Doable!

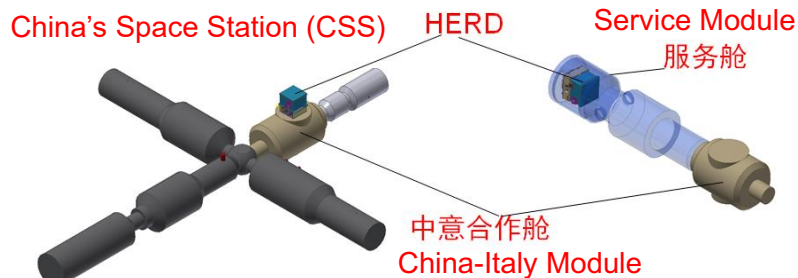
# Probes to solve current puzzles and find new ones

- CR instrumentation
  - Direct
  - Indirect
  - More accurate measurements/extension in energy
  - Antimatter in CRs (GAPS, AMS-100)
- Telescopes
  - Gamma-ray
  - X-ray
  - Radio
  - Neutrinos
  - GW
- Observations of the nearby galaxies (e.g., M31)

# Next generation instruments

## High Energy cosmic-Ray Detection (HERD)

- HERD: flagship and landmark scientific experiment onboard the China's Space Station, China-led large international collaboration
- Main Scientific Objectives:
  - **Dark matter:** dark matter search with unprecedented sensitivity
  - **Cosmic-ray:** Precise cosmic ray spectrum and composition measurements up to the knee energy
  - **Gamma-ray:** Gamma-ray monitoring and full sky survey



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## HERO

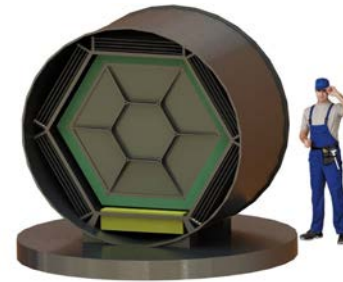
### “High Energy Rays Observatory”

### Heavy Calorimeter in Space

supported by the Russian Academy of Sciences and included in the Russian Federal Space Program

#### Main Requirements:

- **Effective exposure factor**  $>120 \text{ m}^2 \text{ sr year}$
- **Energy resolution**
  - for Protons at  $10^{15}\text{-}10^{16} \text{ eV} < 30\%$
  - at  $10^{12}\text{-}10^{15} \text{ eV} < 20\%$
  - for Nuclei at  $10^{12}\text{-}10^{16} \text{ eV} < 15\text{-}20\%$
  - for Leptons at  $3 \cdot 10^{11}\text{-}10^{13} \text{ eV} < 1\%$
- **Charge resolution**  $< 0.2 \text{ ch. u.}$  for all Nuclei at all energy range

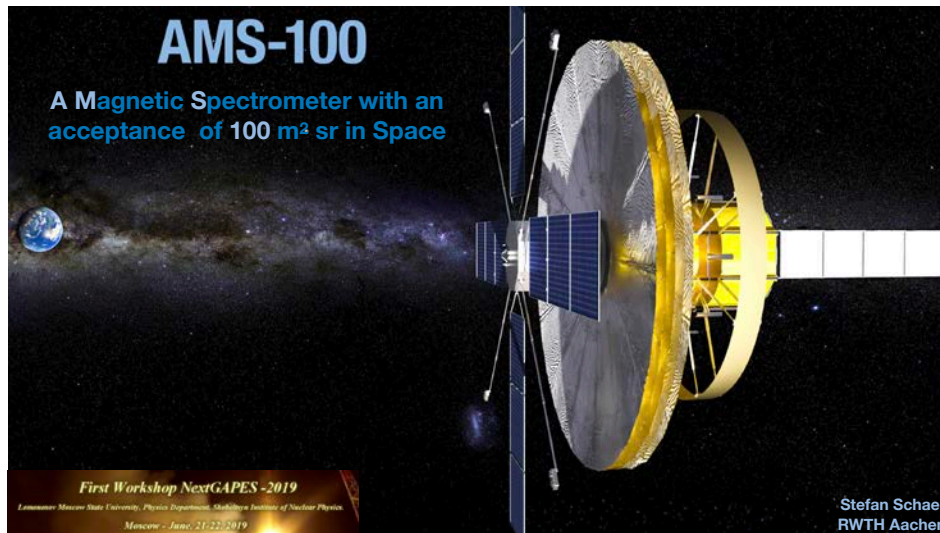


#### Timescale:

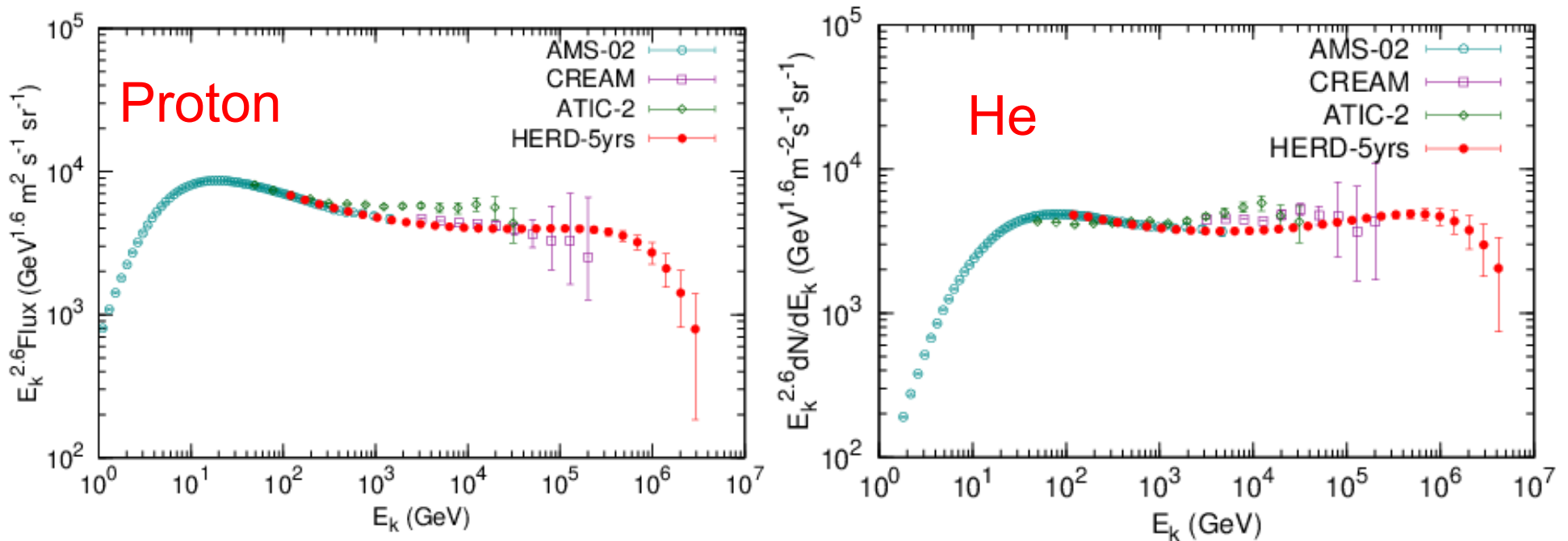
HERD – launch in 2-3 years

HERO – launch before 2030

AMS-100 – launch in 2-3 decades

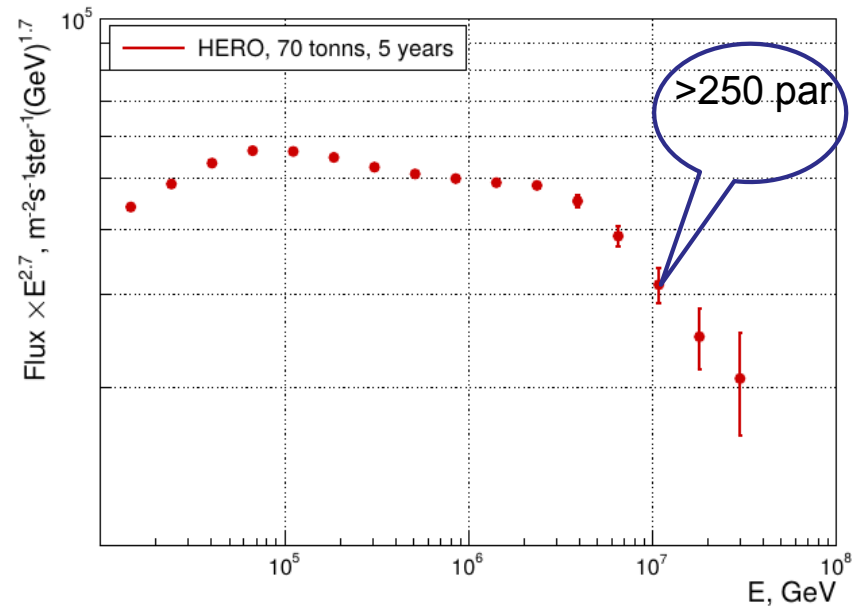
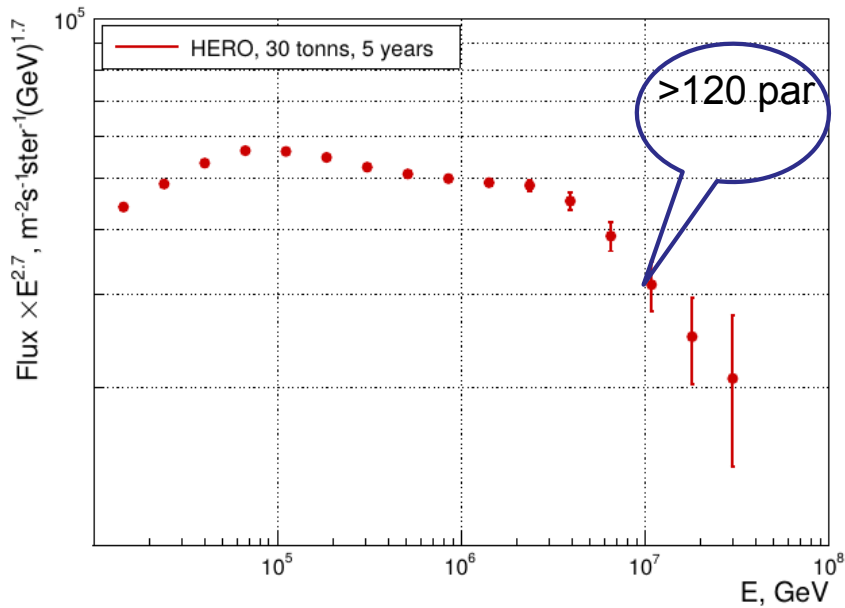
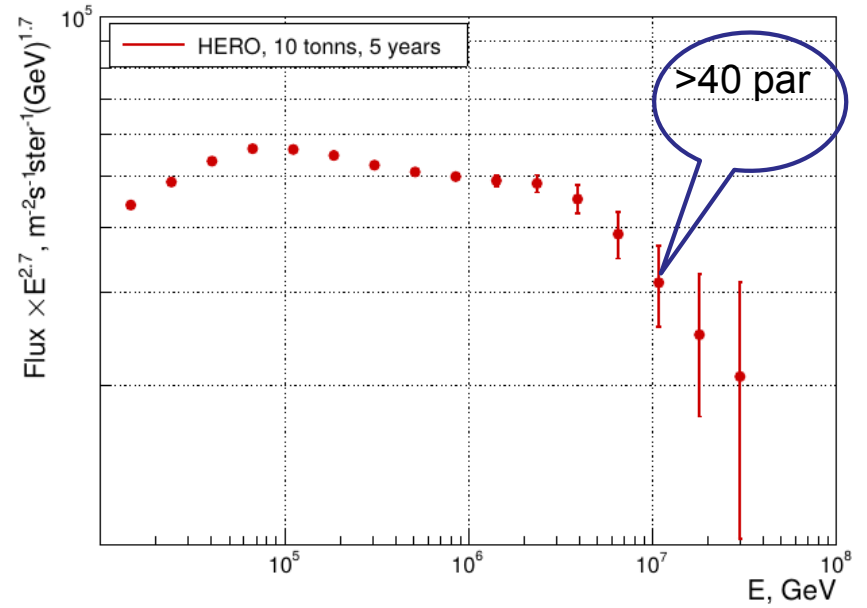
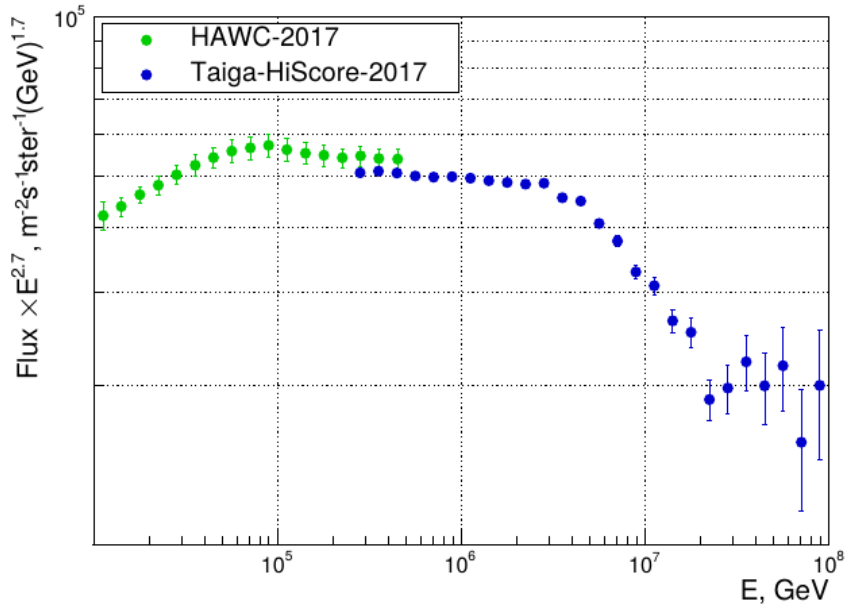


# Expected HERD Proton and He Spectra

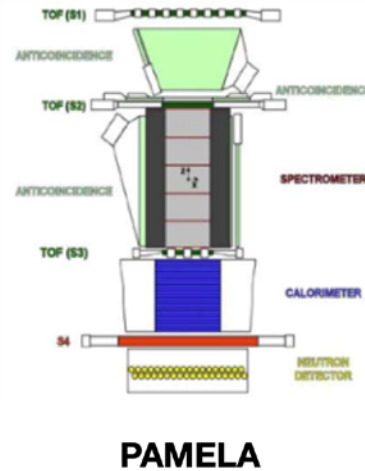
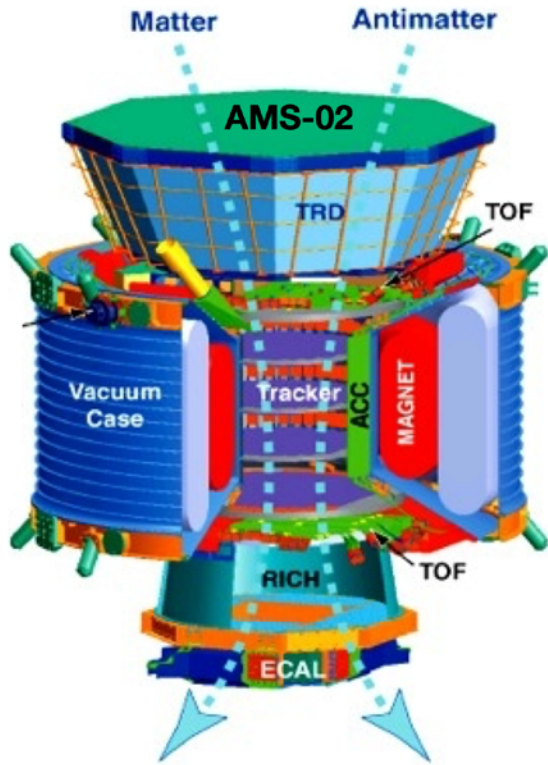


- Well extended to PeV energies
- Critically test any structures between TeV and PeV
- Clearly reveal the knee of light components (Z- or A-dependence)

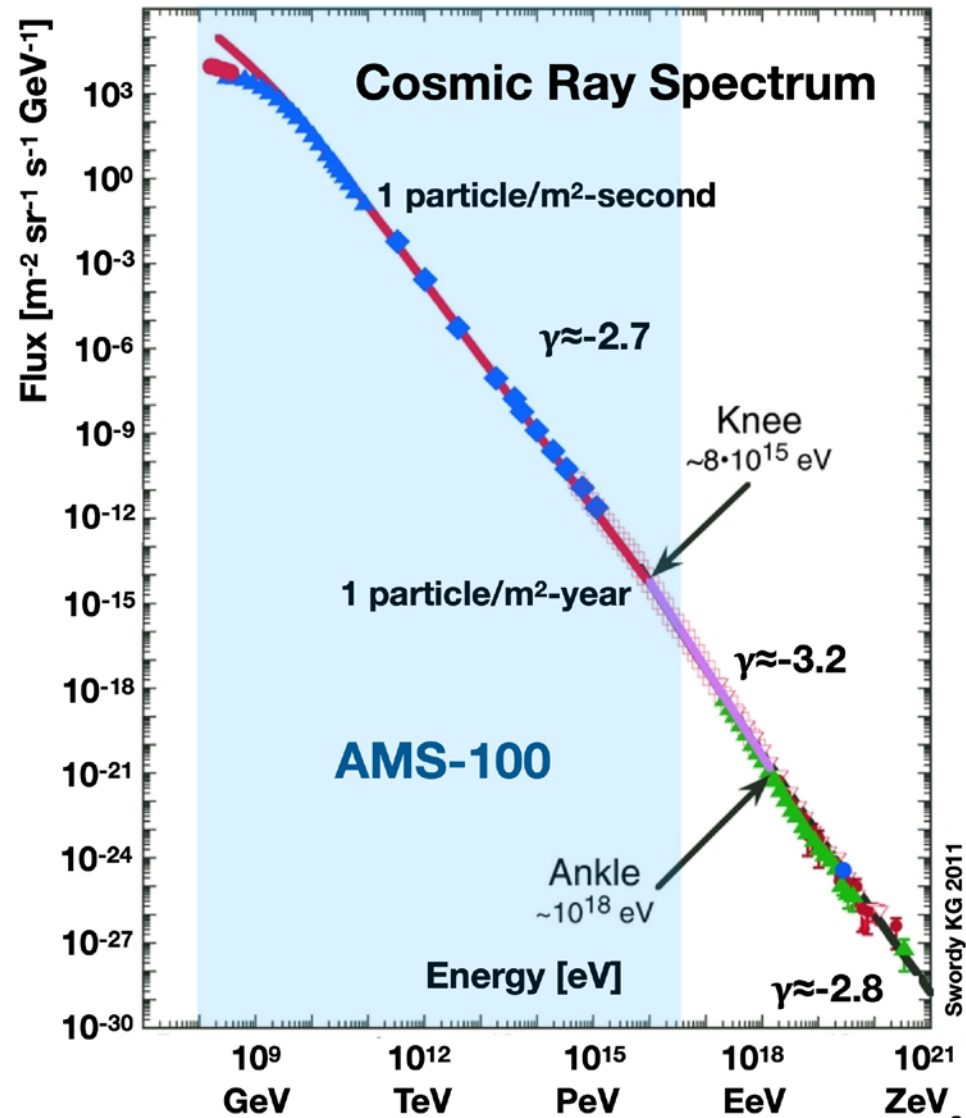
# Expected statistics for different configurations of HERO calorimeter for 5 years operation



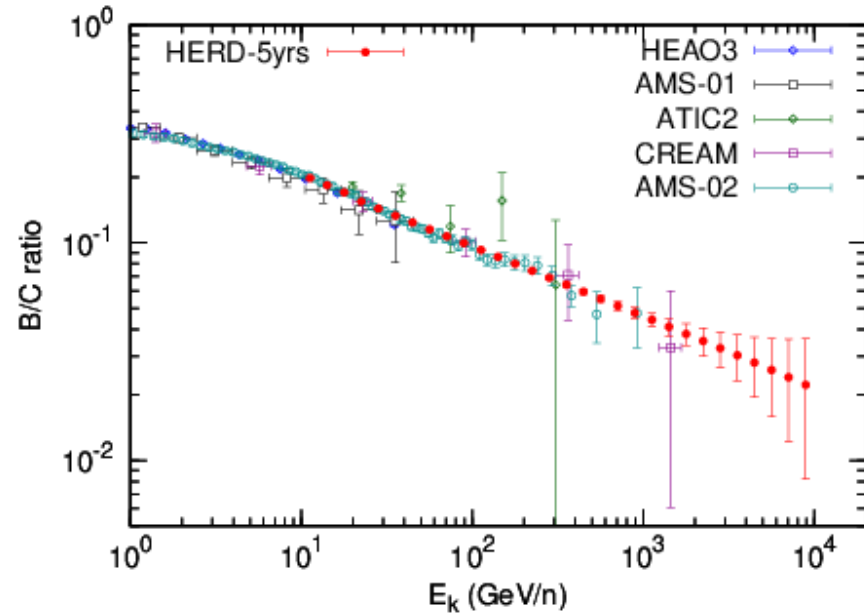
# Energy reach of AMS-100



- The cosmic ray flux follows a power law  $\Phi \approx C E^{-3}$
- An increase in energy by a factor 10 requires an increase in acceptance by 1000. AMS-02 weighs 7 tons.
- Both PAMELA and AMS-02 have a telescope like geometry.
- Just scaling such a geometry does not allow to increase the energy reach by a factor 10 and simultaneously the acceptance by a factor 1000.

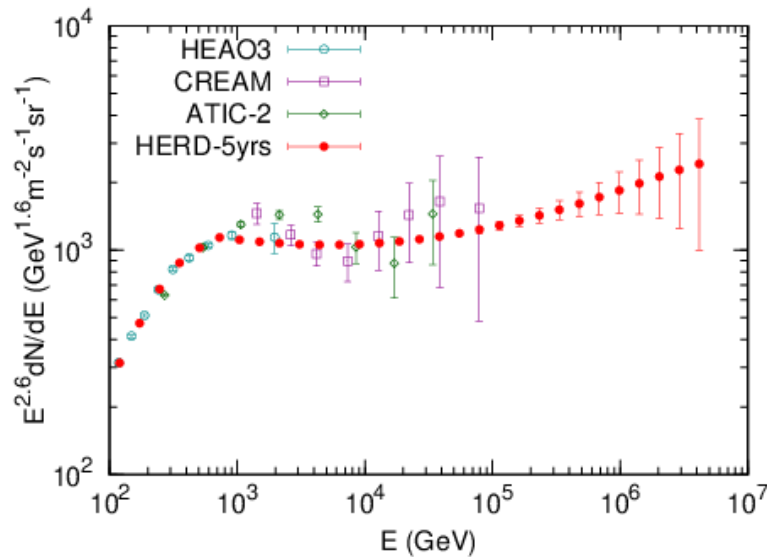


# B/C measurement with HERD



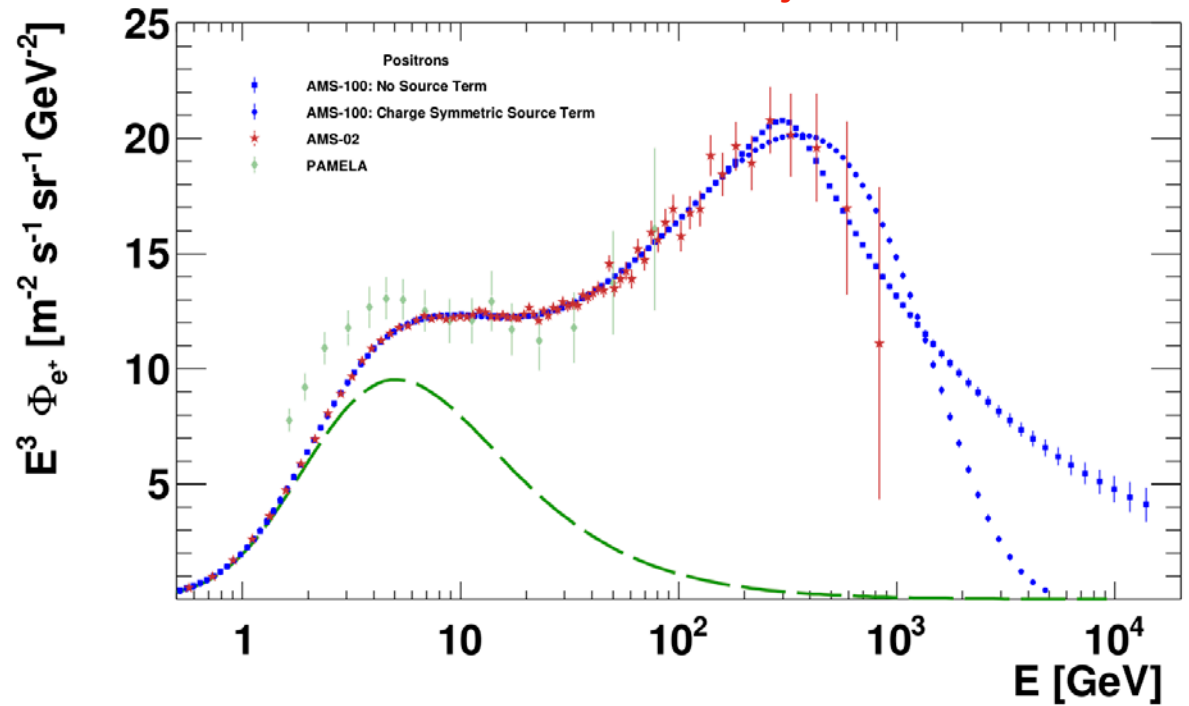
Iron nucleon and super-iron elements

mine the CR propagation  
of break at the primary nuclei spectra



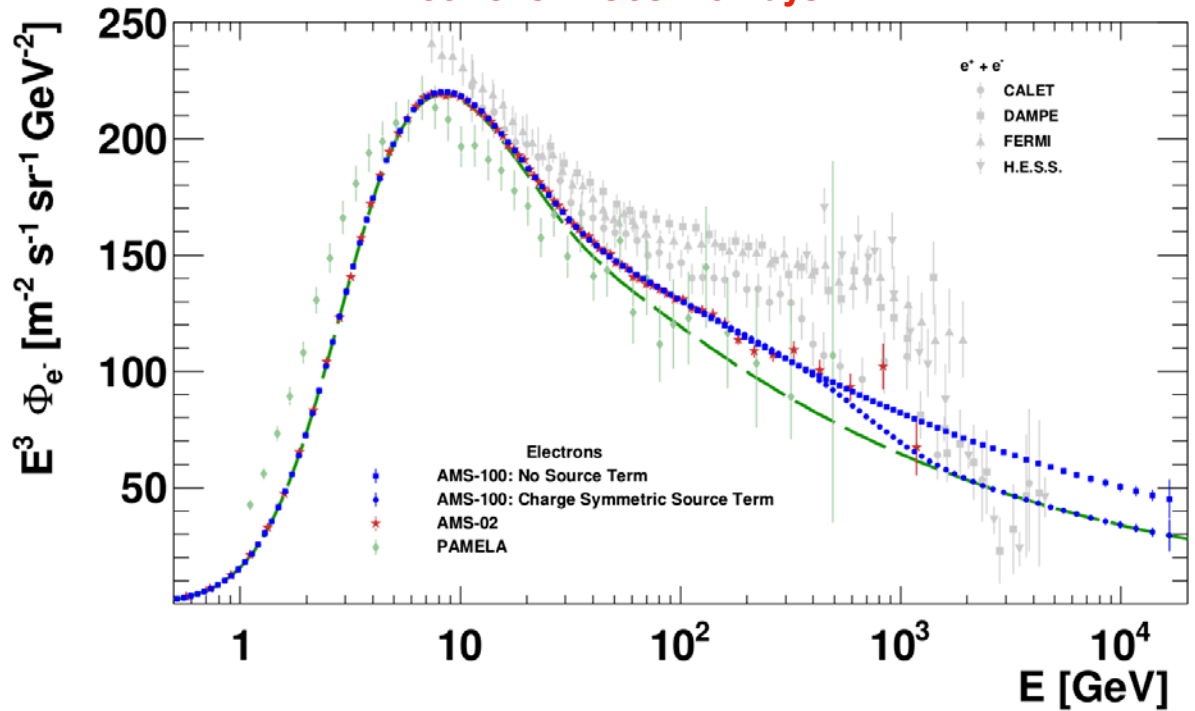
# AMS-100

## Positrons in Cosmic Rays



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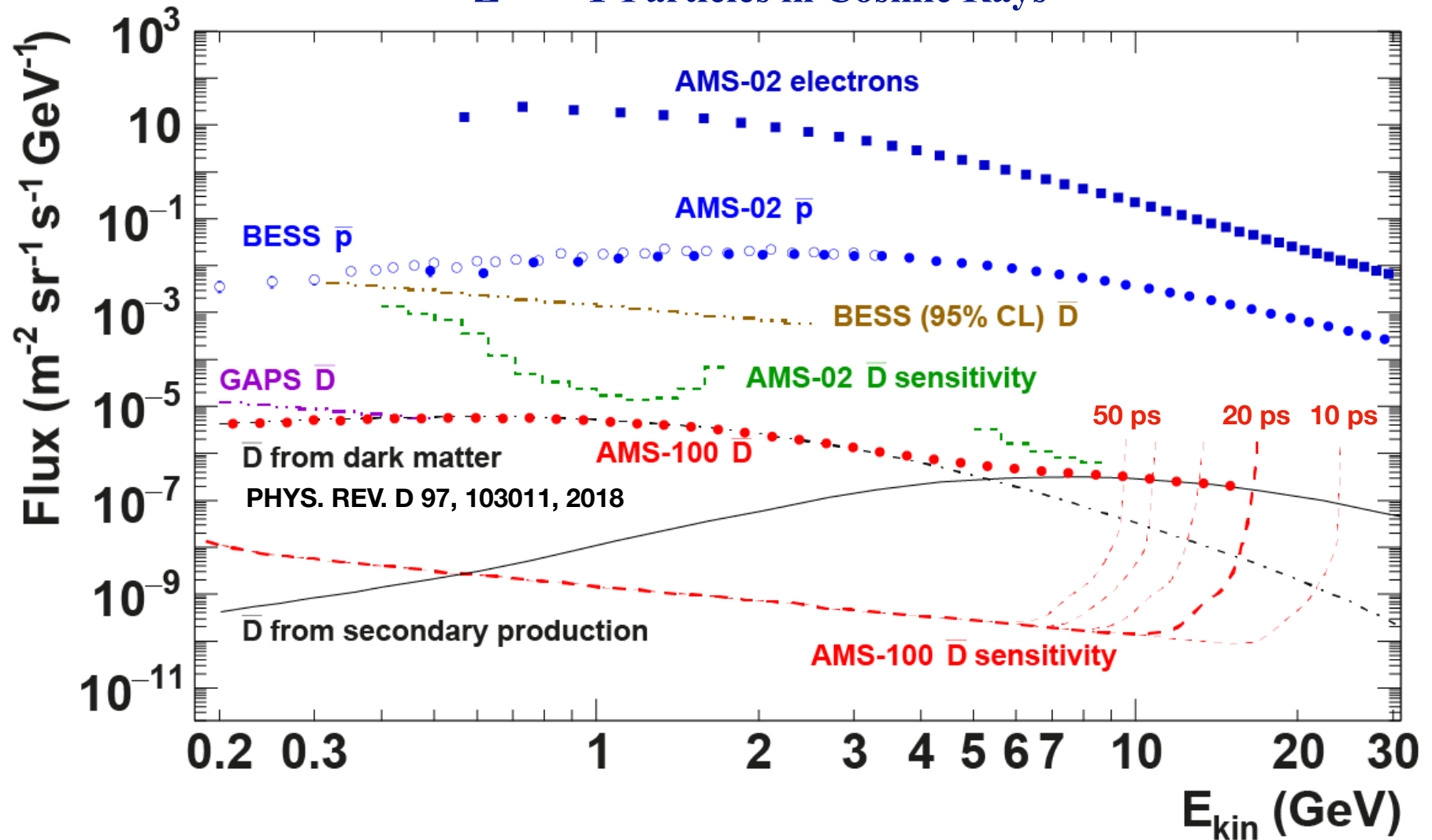
## Electrons in Cosmic Rays



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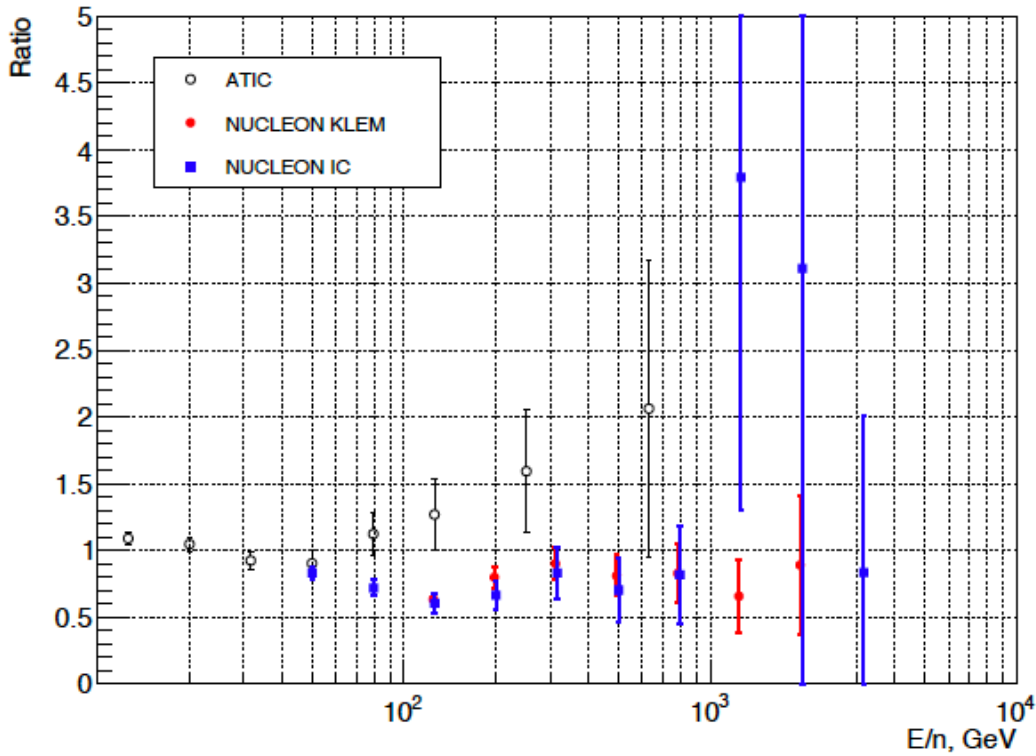
# AMS-100

## Z = -1 Particles in Cosmic Rays

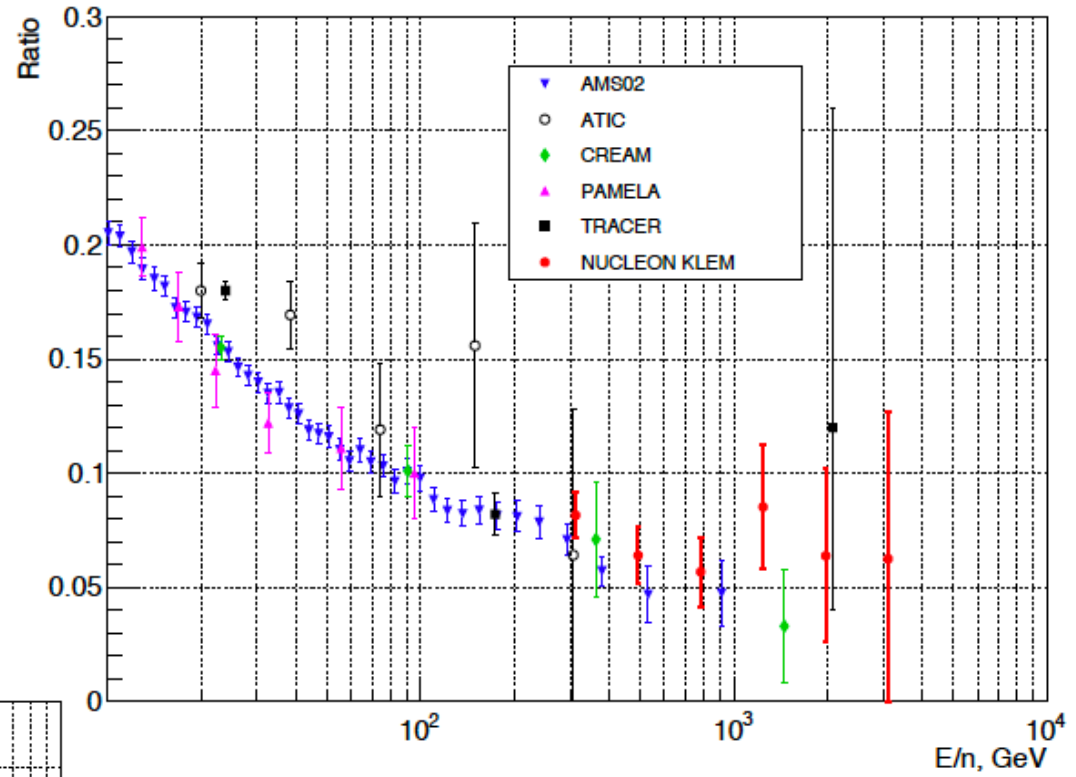


# NUCLEON

Z=16-24/Z=26 SubFe to Fe ratio



B to C ratio



Grenenyuk+'18  
Arxiv: 1809.09665

