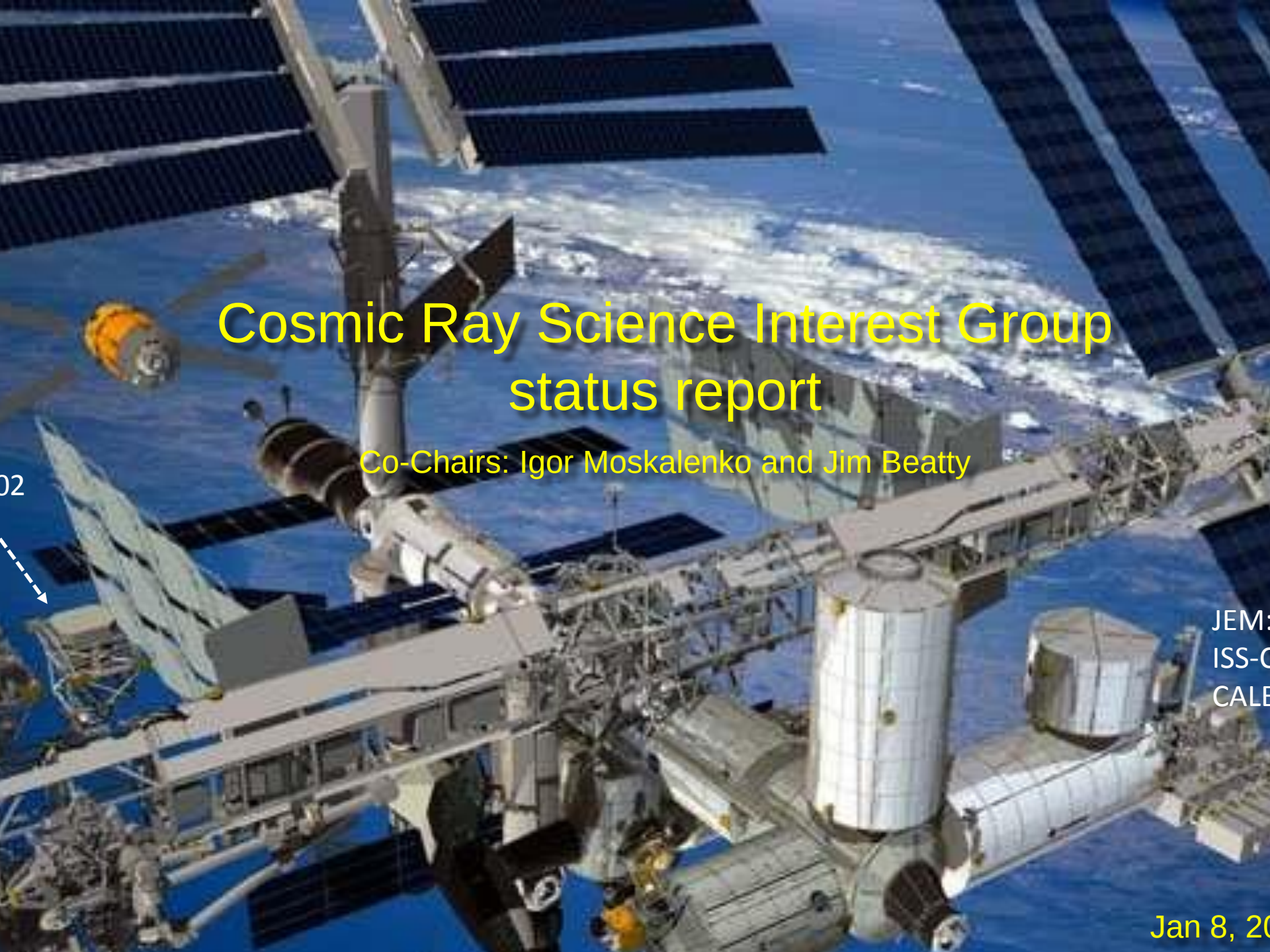

Cosmic Ray Science Interest Group
status report
Co-Chairs: Igor Moskalenko and Jim Beatty
02
JEM
ISS-C
CALE
Jan 8, 20

ISS constellation

- Alpha Magnetic Spectrometer (AMS-02), launched on on May 19, 2011
  - Cosmic ray species: elements H-Fe, electrons, positrons, antiprotons
  - Energy range: ~0.5 GeV – >1 TeV
- Calorimetric Electron Telescope (CALET), launched in August 2015
  - Cosmic ray species: elements Z=1-40 (Zr), all-electrons
  - Rigidity range: ~10 GV – 800 TV
- ISS-CREAM, launched on August 14, 2017 (mostly US mission)
  - Cosmic ray species: elements Z=1-26, all-electrons
  - Energy range: ~1 TeV – >1 PeV

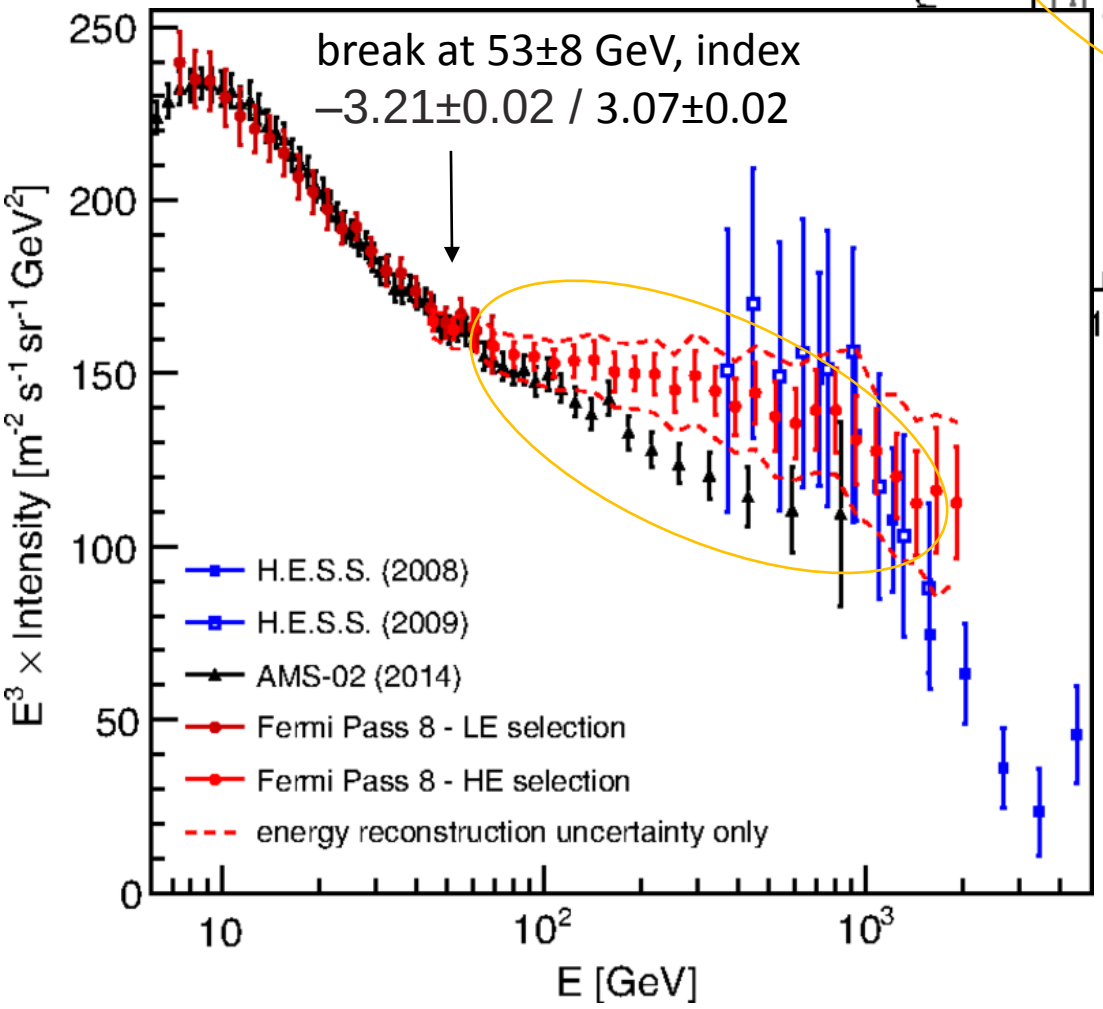
Low energies (current US missions)

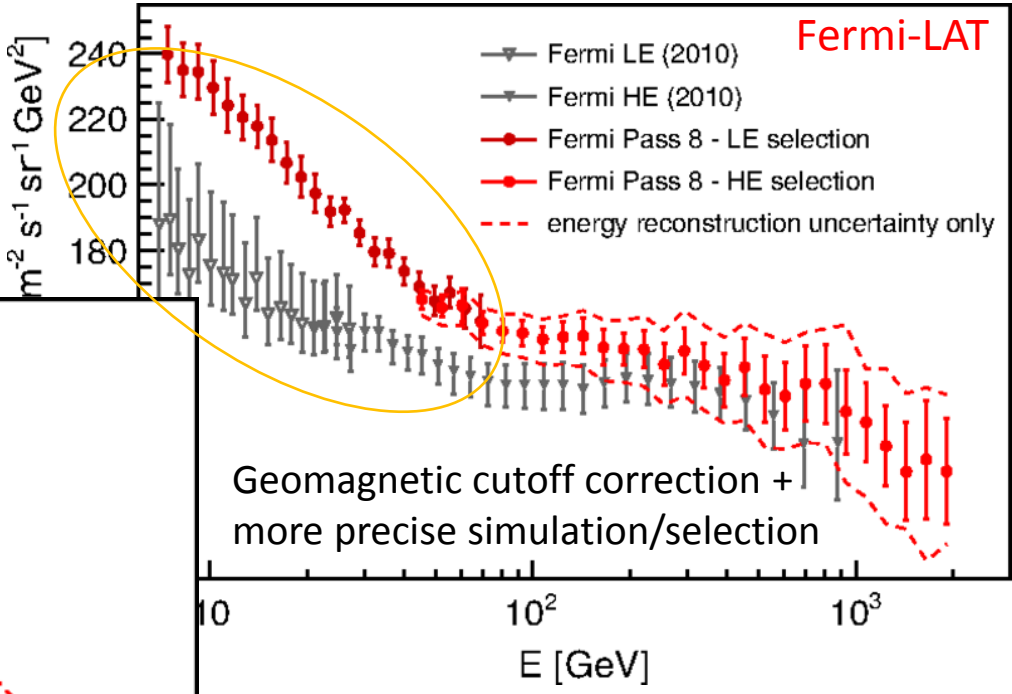
- Provide separation of individual isotopes, excellent instruments, but fairly old (ACE – 20 y.o., V1,2 – 40 y.o.!)
- Voyager 1, 2 – first heliospheric boundary/interstellar probe
  - Launched in August 1977
  - Isotopes Z=1-28, all electrons
  - Energy range: ~1 MeV/n – 200-500 MeV/n
- Advanced Composition Explorer/Cosmic Ray Isotope Spectrometer (ACE/CRIS)
  - Launched on August 25, 1997
  - Isotopes Z=28
  - Energy range 100 – 500 MeV/n

Recent scientific highlights

- Flat all-electron spectrum with sharp cutoff at ~1 TeV
- Rising positron fraction
- Flat antiproton/proton ratio
- Breaks in p, He, Li, Be, B, C, N, O spectra at the same rigidity ~300 GV (and perhaps in heavier nuclei)
- Smooth falling B/C ratio up to 2 TV
- Primary ^{60}Fe in cosmic rays (excess in ^{22}Ne/^{20}Ne ratio)
- Puzzling A-dependences of volatile and refractory elements
- All of them sparkled hot discussions in the literature
- Below are few examples from 2017

All-electron CR spectrum

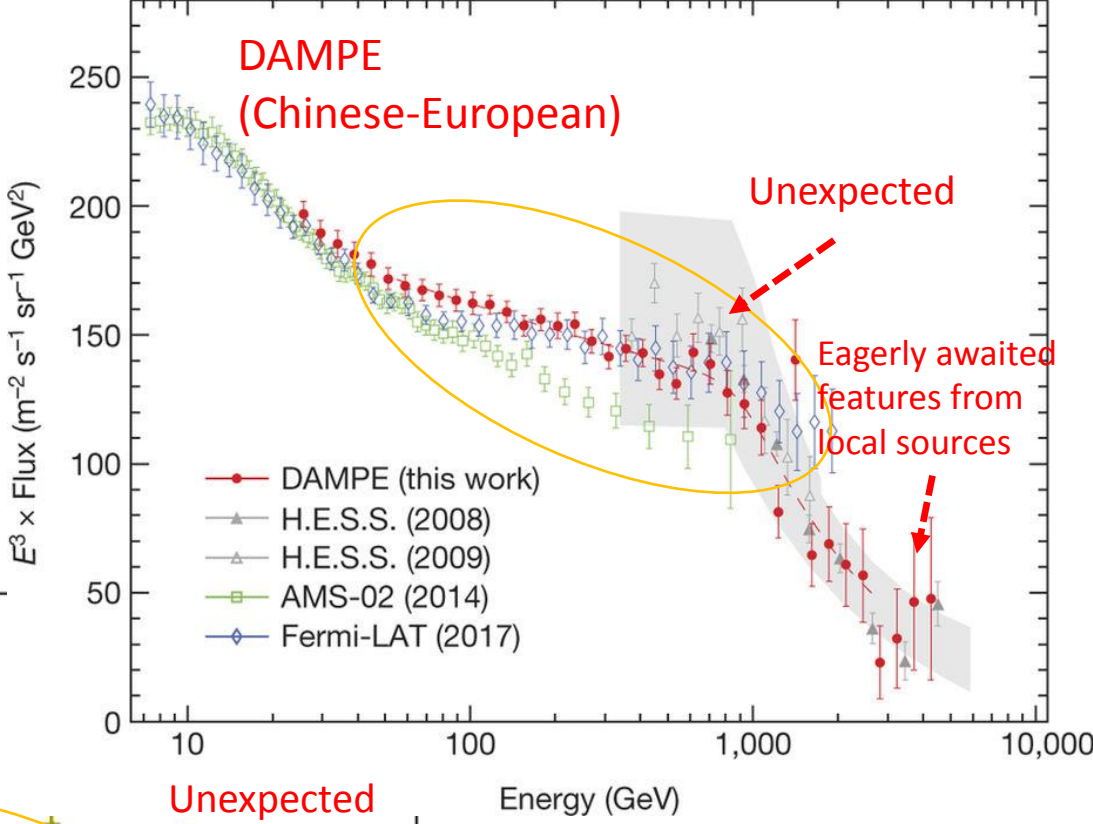


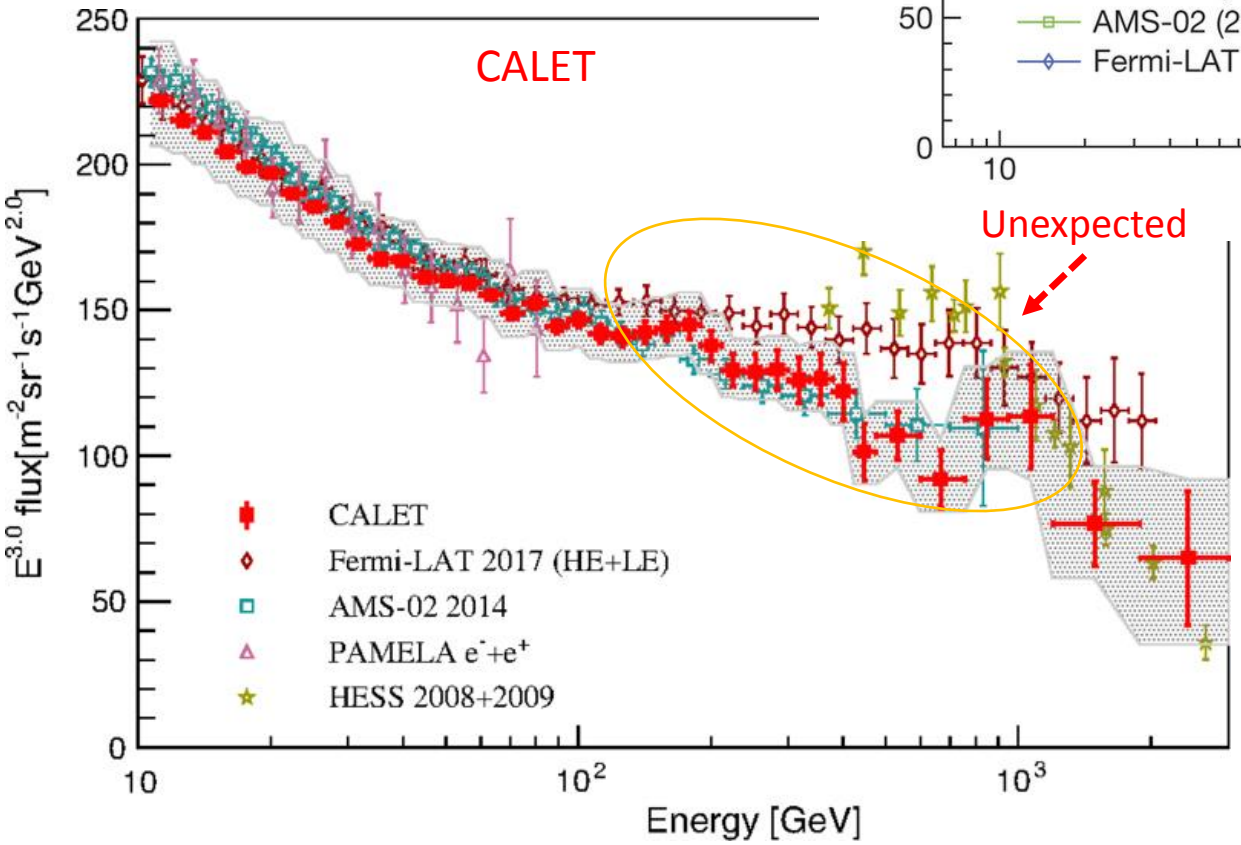


- New LAT spectrum is ~10-30% higher at LE than the old one
- Good agreement with AMS-02 data, but there is still a 1-2σ discrepancy at HE

Direct measurements of all-electron spectrum up to 5 TeV

- CALET & DAMPE are confirming the cutoff at ~1 TeV

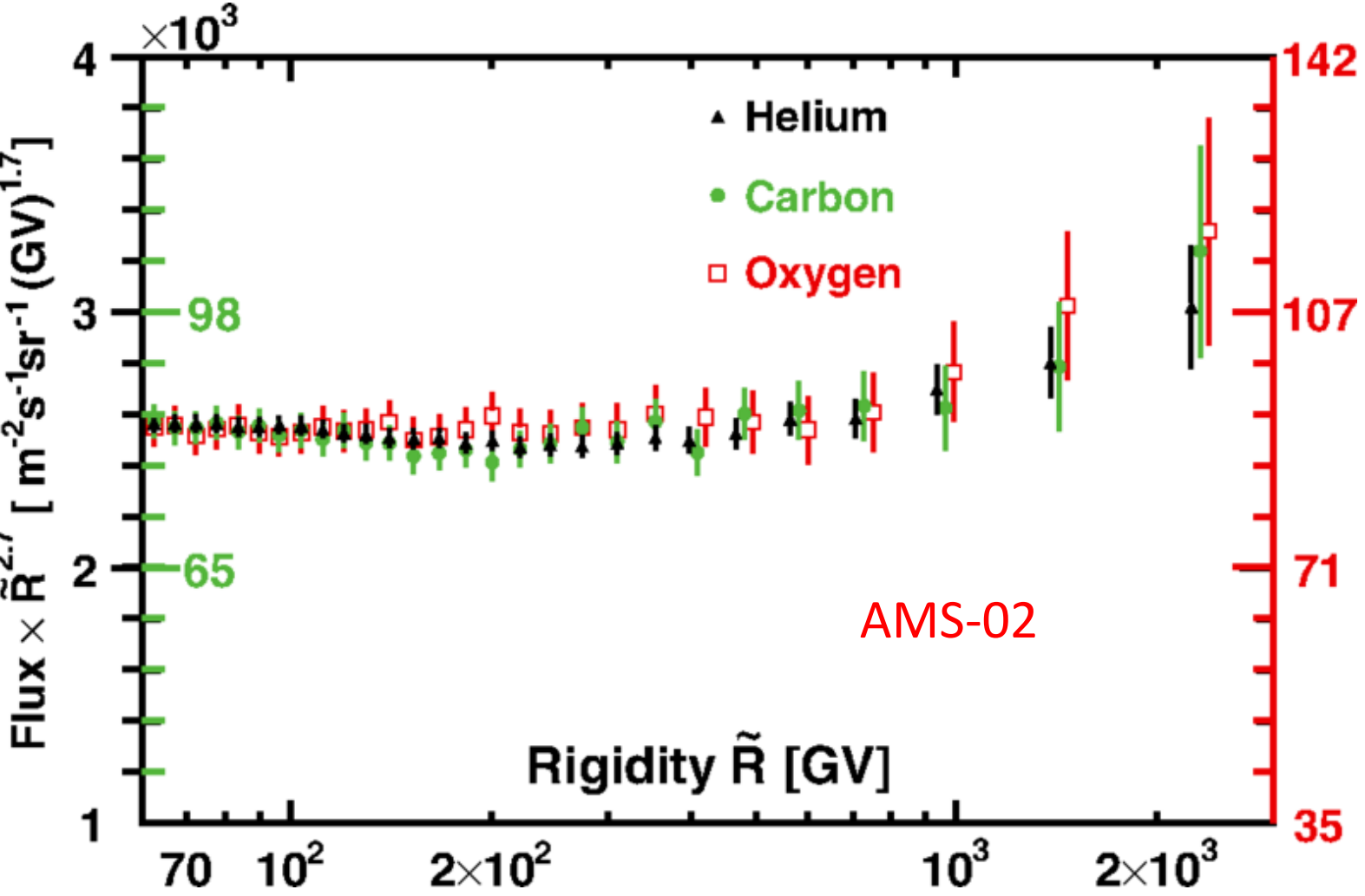




- Different behavior >100 GeV
- Hint at a spectral feature at 700-800 GeV?
- Clearly seen 2-3 components in the CRE spectrum (local sources?)
- Hint for a long-awaited feature at a few TeV?

Breaks in C, N, O

- Breaks in C, N, O found at the same rigidity as earlier in p, He
- Surprisingly similar spectral shape of `primary' nuclei!

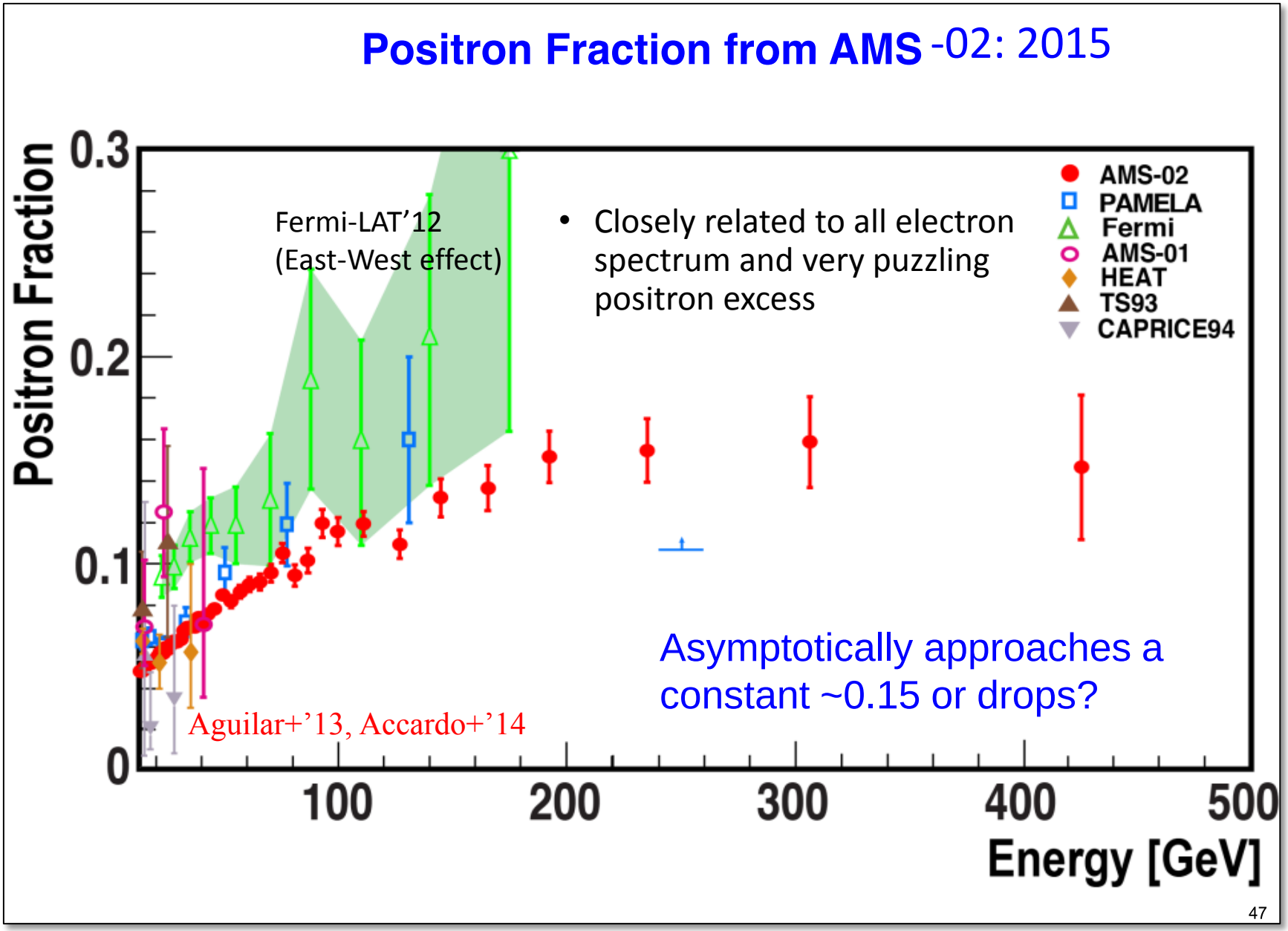


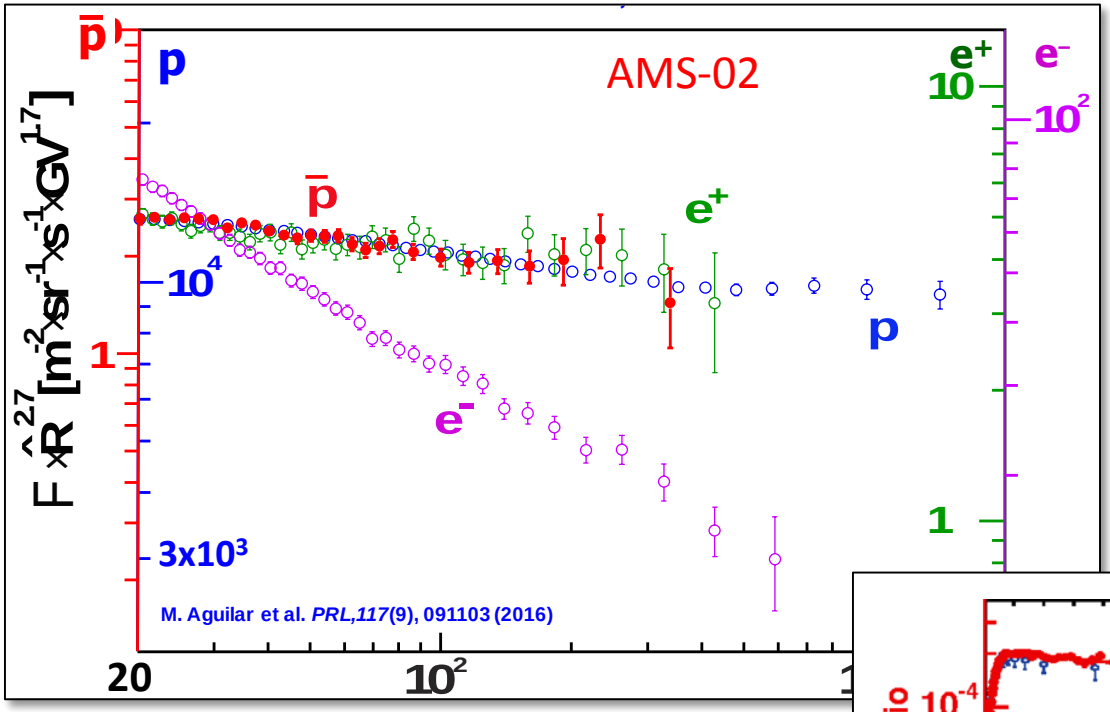
Golden age of astrophysics of cosmic rays

- Cosmic ray missions provided many breakthroughs and discoveries over the last decade
- We are not done yet!
- Hot discussions in the literature, but it is clear that some local sources are influencing CR fluxes in the neighborhood of the Solar system
- Combined effort of astrophysicists and particle physicists around the globe, but the US scientists are missing this once-in-a-lifetime discovery hunt!
- Still missing:
  - Heavy elements/isotopes through Th/U at low and high energies (probes of local sources, explosive nucleosynthesis)
  - Measurements of radioactive species ^{10}Be, ^{26}Al, ^{36}Cl, ^{54}Mn in the energy range 100 – 1000 MeV/n
  - Heavy calorimeters for PeV range
- So we have to participate!
- Precision, precision, precision! – the key to the new discoveries

BACKUP SLIDES

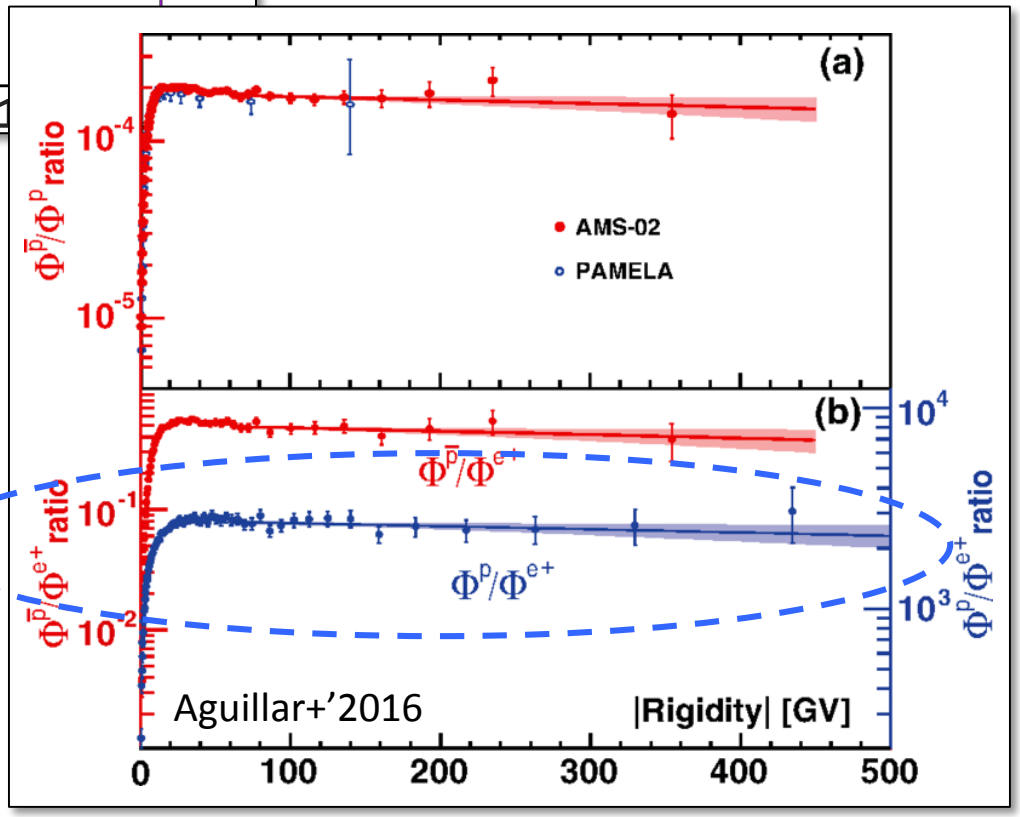
Positron fraction



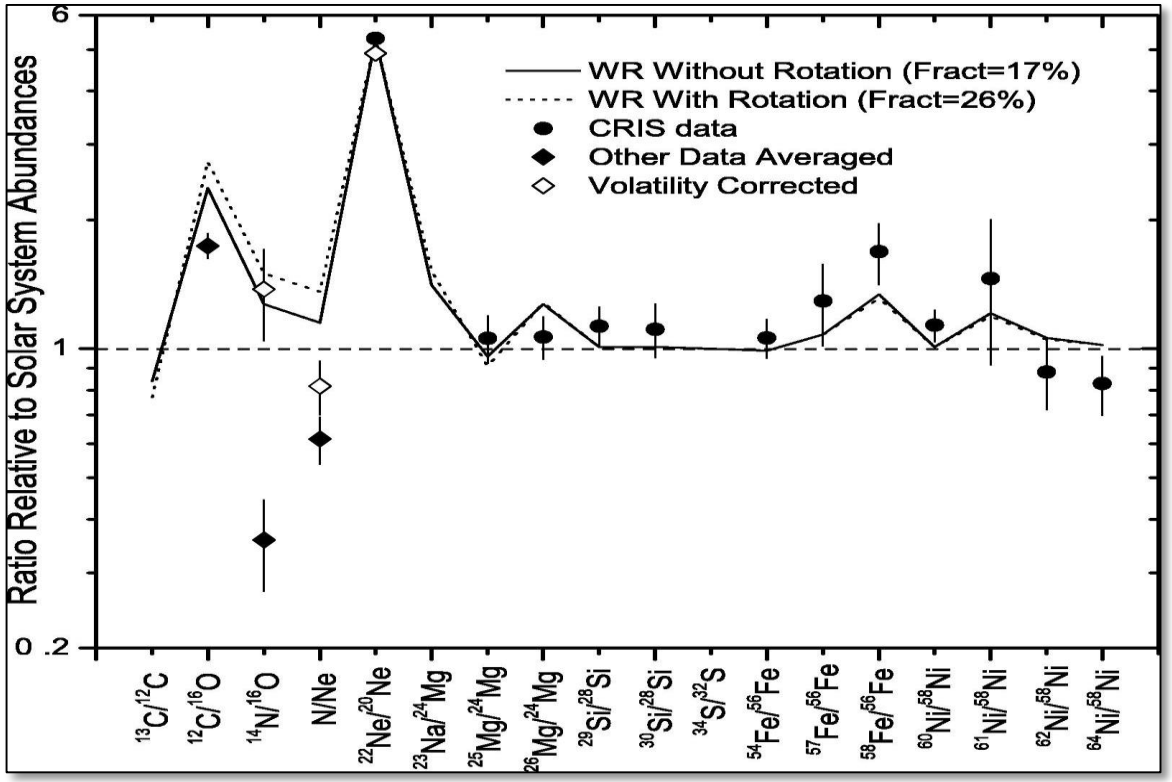


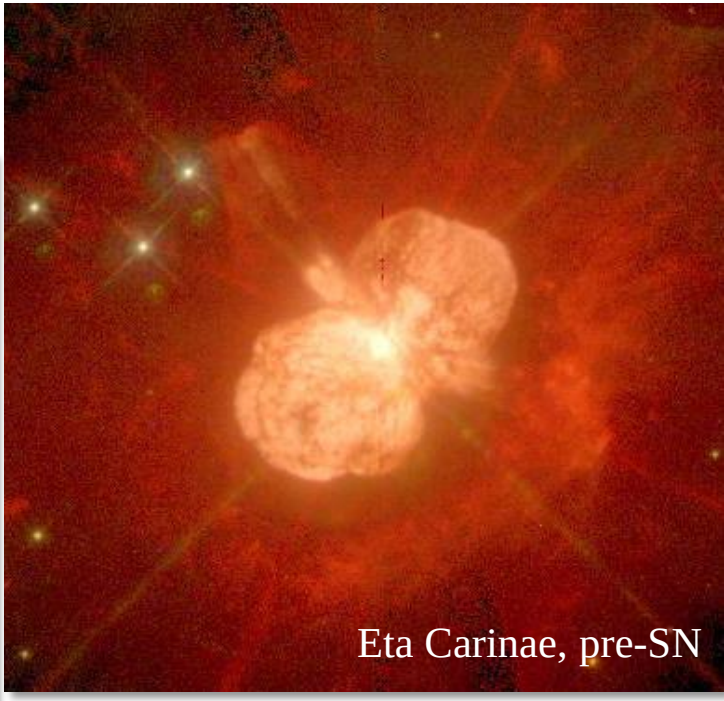
Unexpected!

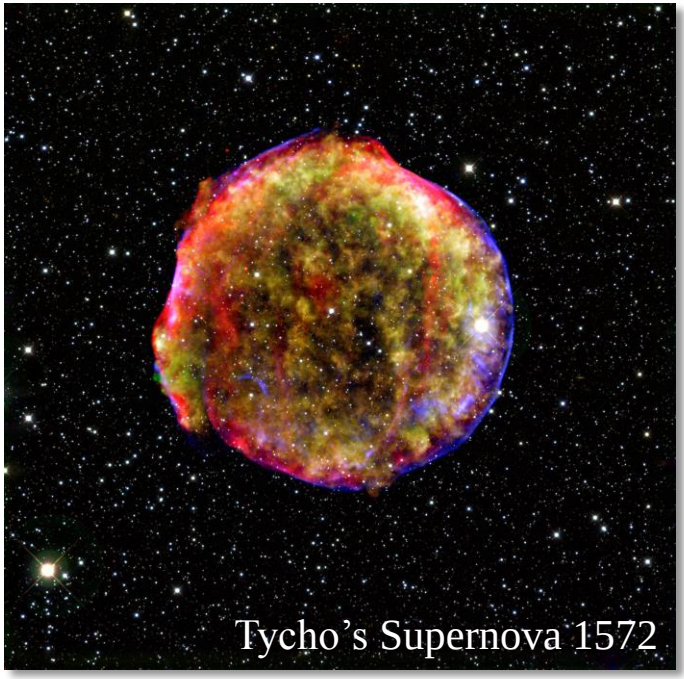
- If excess positrons are produced in pulsars or DM decays why the p/e⁺ ratio is flat?
- The flat p/e⁺ ratio perhaps indicates a common origin of p and e⁺!



Sources of CRs/Local Bubble

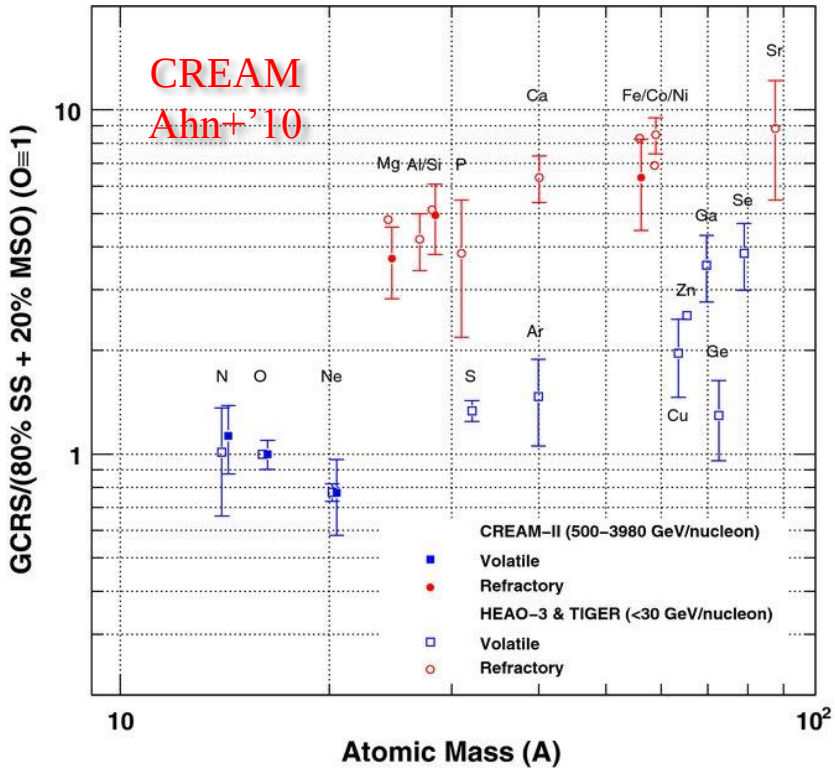


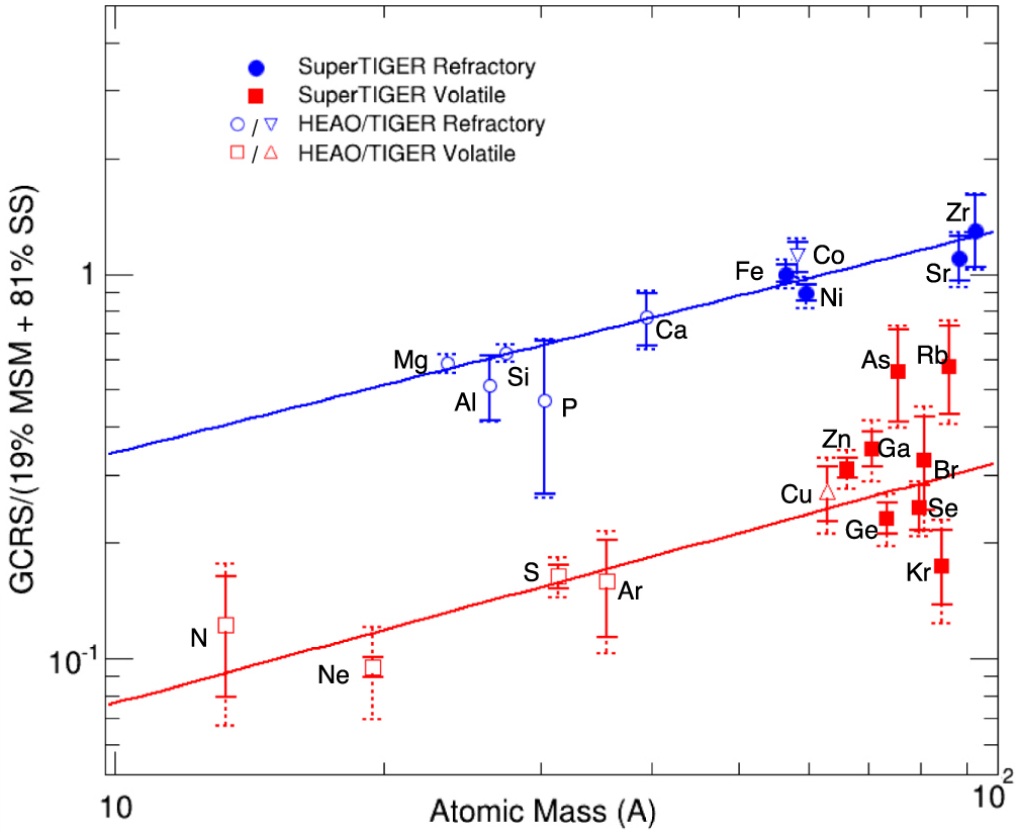




- Some isotopes have anomalous abundances in CRs vs. Solar system
- Excess in $^{22}Ne/^{20}Ne$ may indicate ~20% contribution from Wolf-Rayet winds (SN expansion in massive pre-SN stars winds)
- Primary ^{60}Fe!
- ACE/CRIS: ~200 MeV/n

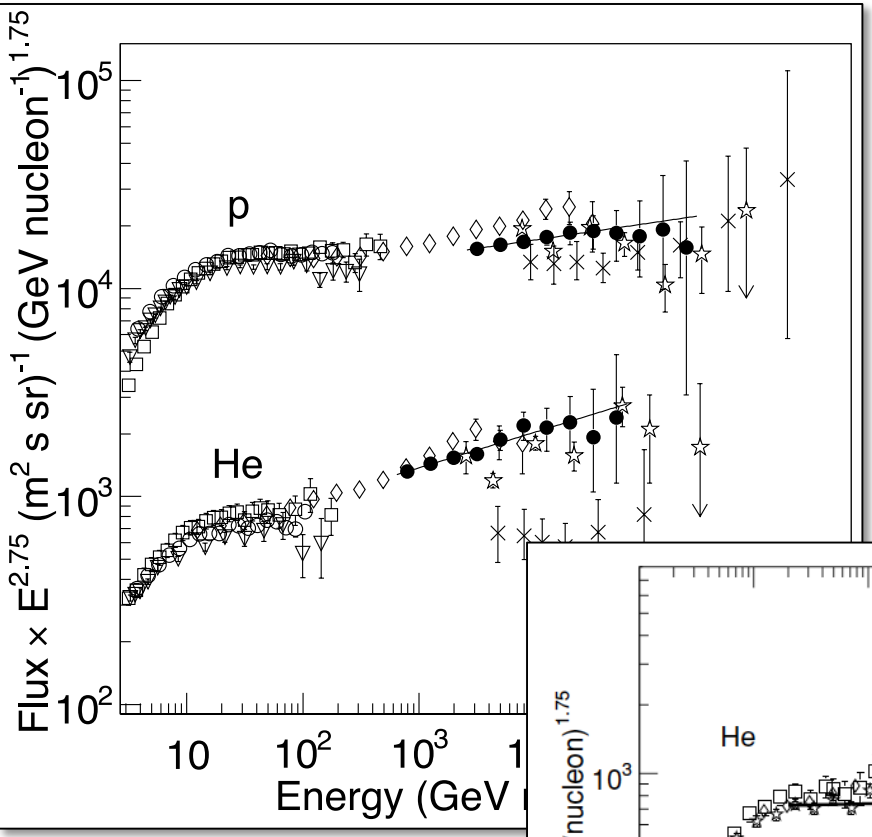
Puzzling A (Z?)-dependences



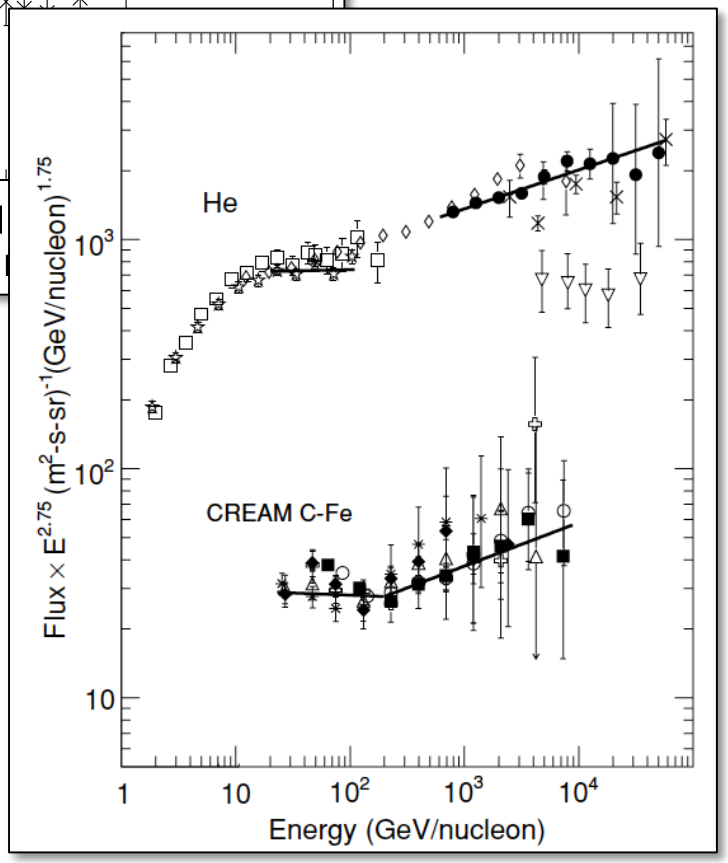


- Super-TIGER, HEAO, CREAM
- The elemental abundances are lining up forming puzzling A-dependencies of volatile and refractory elements when divided on 19% MSM + 81%SS mix
- Look similar at low and very-high energies

“Discrepant hardening” breaks in p and He spectra

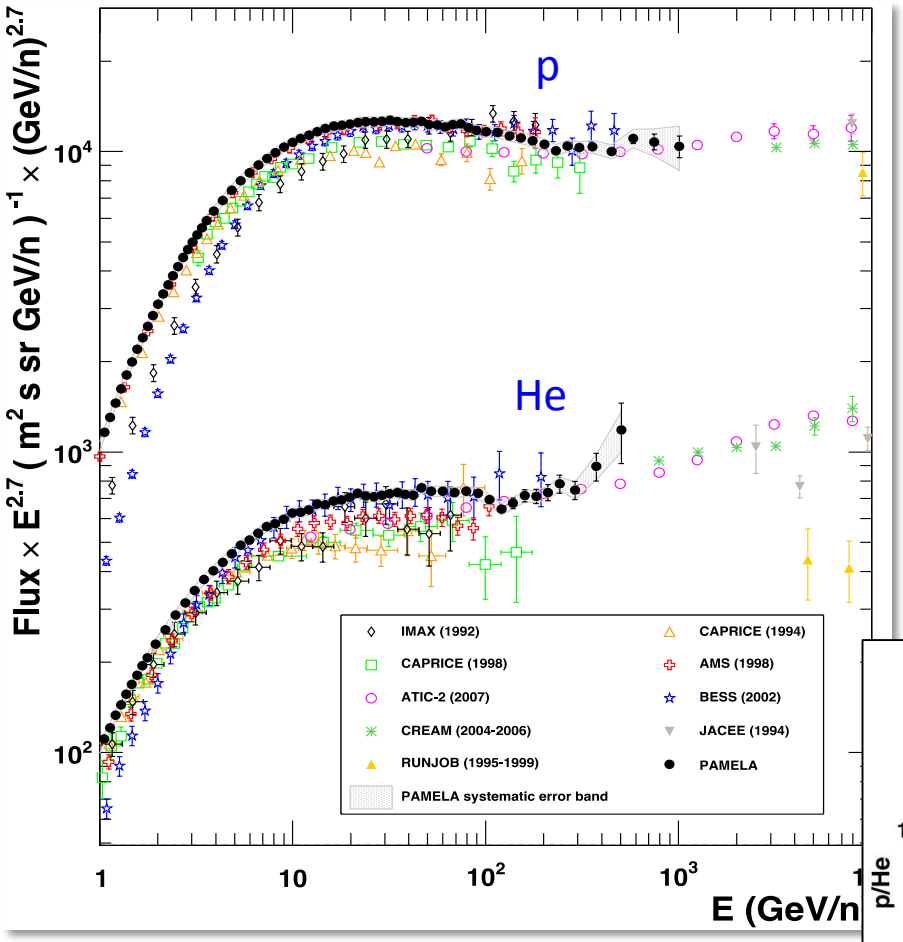


CREAM’2010

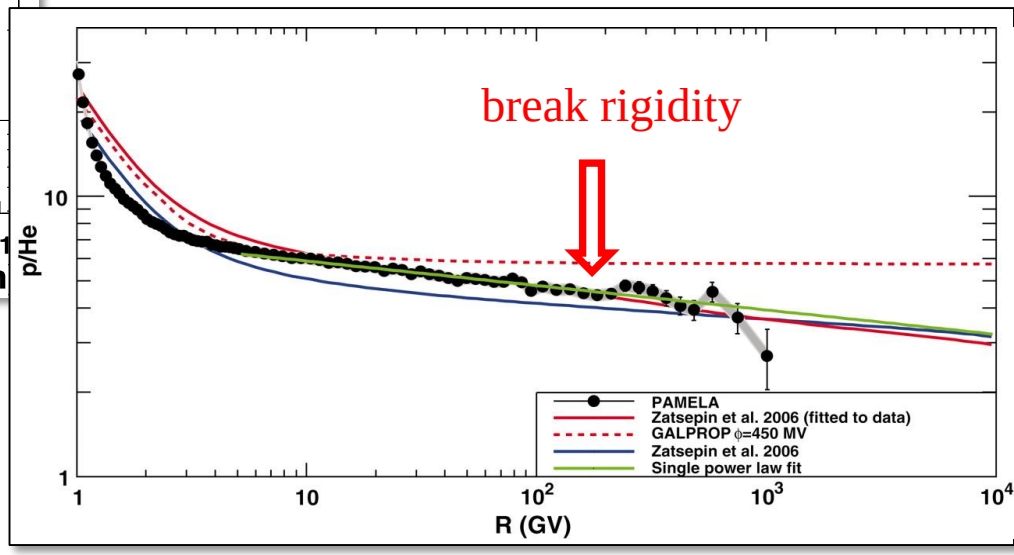


- First noticed in CREAM data, hints were present in earlier data
- Spectrum of He is flatter than spectrum of protons
- Perhaps similar breaks exist in spectra of heavier nuclei

PAMELA: definitive evidence of the breaks



- Breaks are at the same rigidity
- p/He ratio is smooth
- Points to the same origin of the breaks



B/C ratio

- Contrary to expectations, the B/C ratio is monotonically falling up to ~2 TV
- The “structure” is not significant
- The dashed red line is a fit that yields an index 0.3333
- If C has the “break”, B should also have it!
- and the breaks in C and B must be the same!
- but B is 100% secondary…