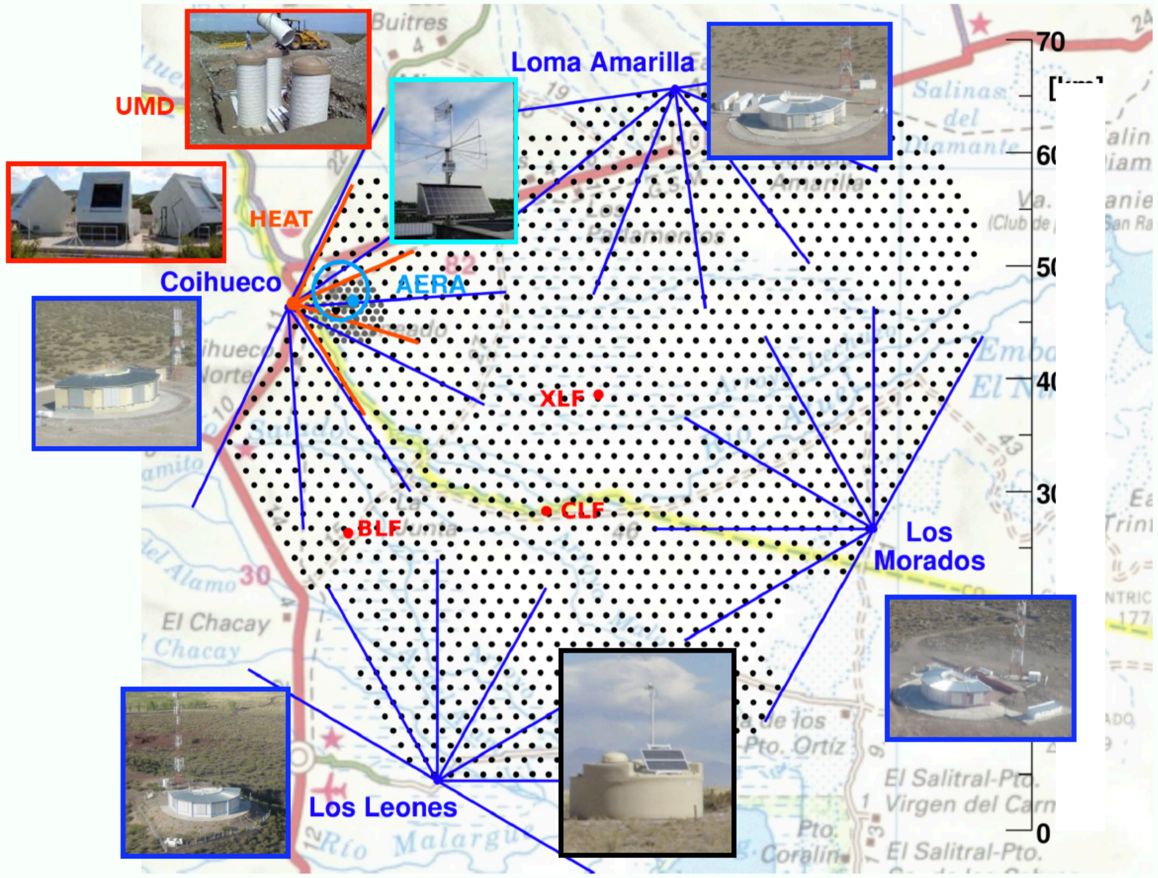
Cosmic Ray Sessions

Cosmic-Ray Indirect (CRI): 329 Contributions: 111 talks + 218 posters + 5 highlights
Cosmic-Ray Direct (CRD): 96 Contributions: 55 talks + 38 posters + 3 highlights

Auger & TA observatoires

Auger Observatory



- Water-Cherenkov stations
  - ➡SD1500 : 1600, 1.5 km grid, 3000 km²
  - ➡SD750 : 61, 0.75 km grid, 25 km²
- 4 Fluorescence Sites
  - ➡24 telescopes, 1-30⁰ FoV
- Underground Muon Detectors
  - ➡7 in engineering array phase - 61 aside the Infill stations
- HEAT
  - ➡3 high elevation FD, 30-60⁰ FoV
- AERA radio antennas
  - ➡153 graded 17 km²

+Atmospheric monitoring devices CLF, XLF, Lidars, …

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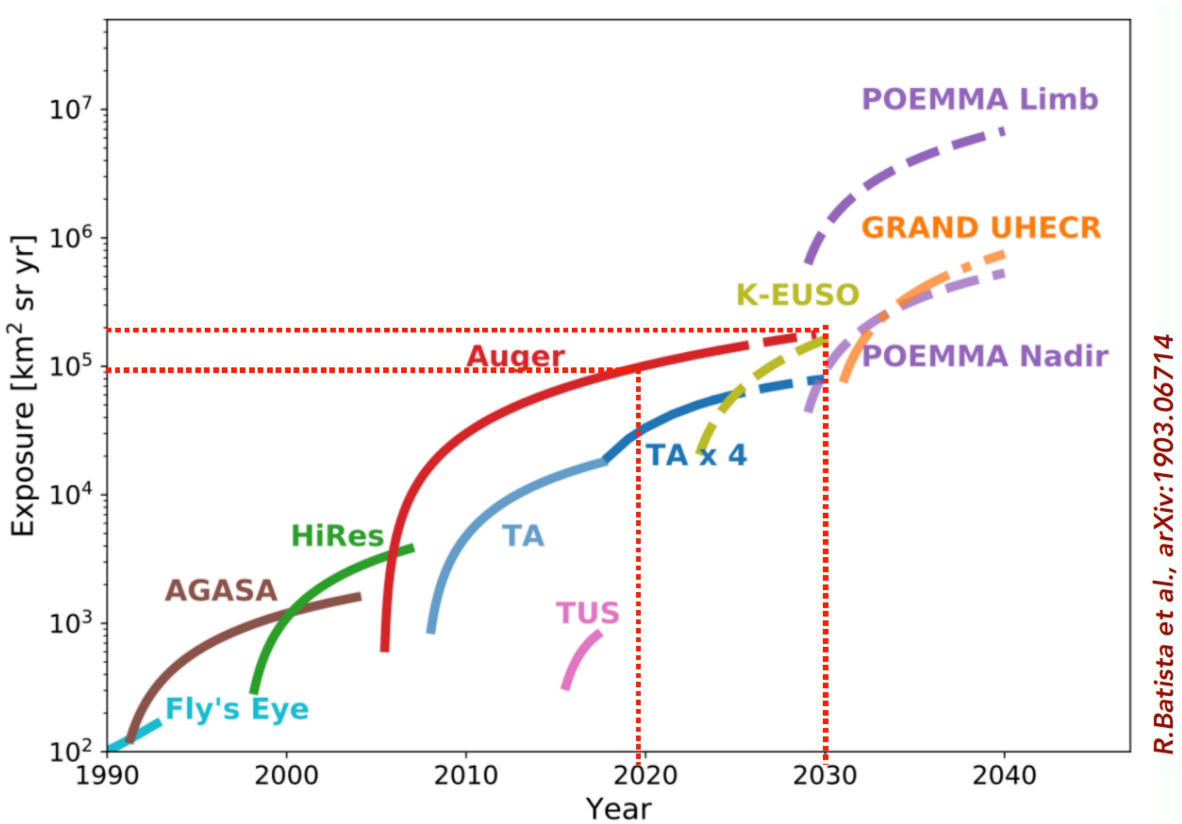
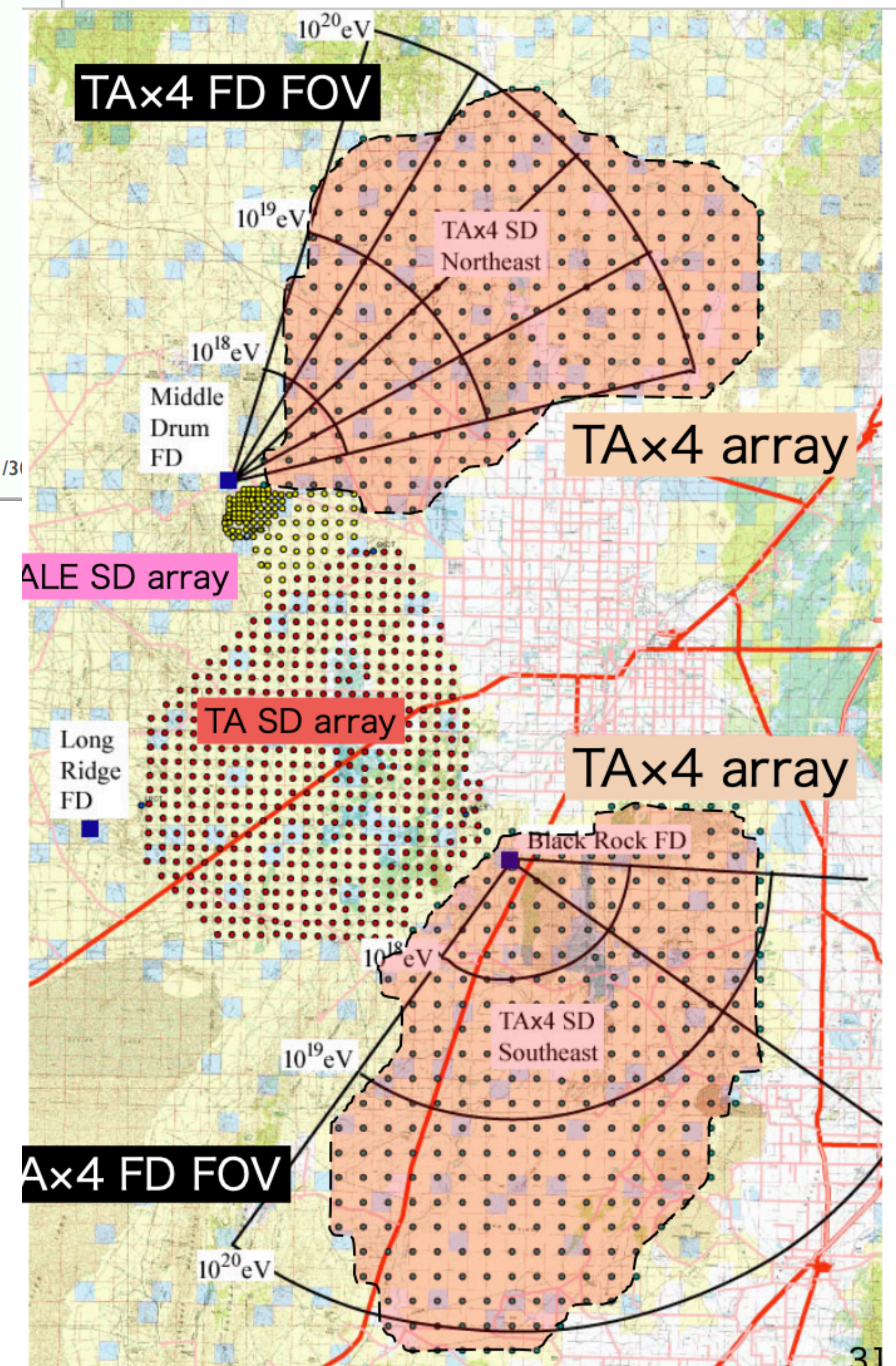
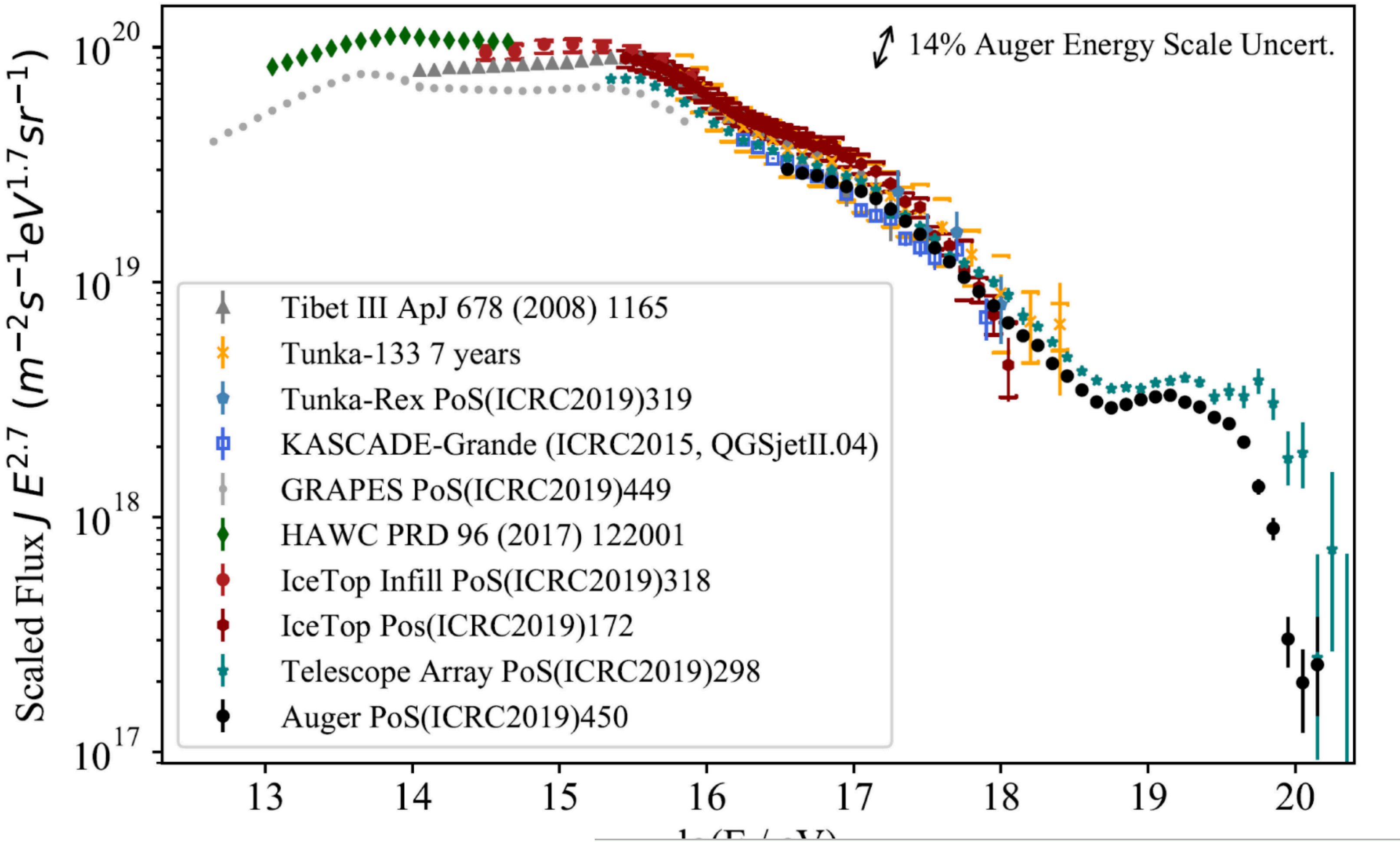




All-particle Energy Spectrum by Air-Shower Arrays

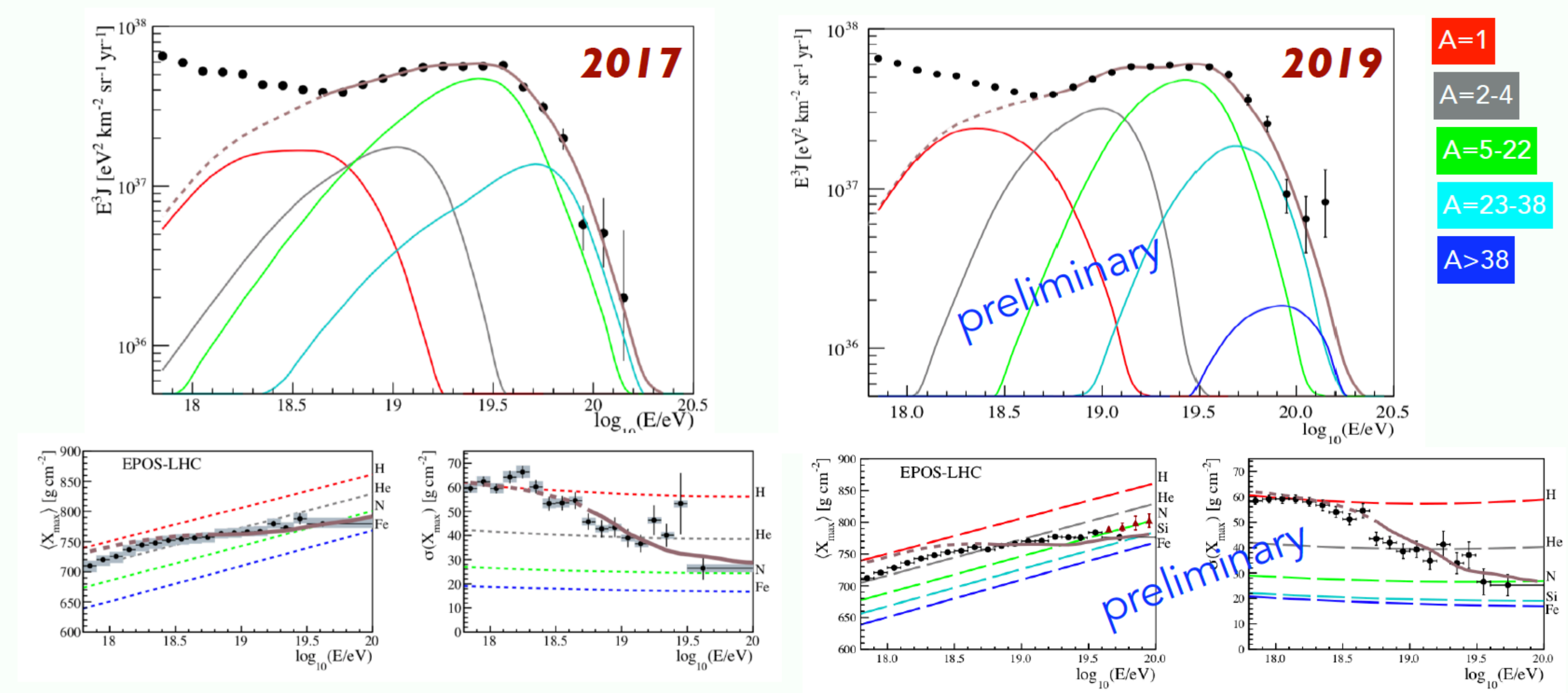
Energy spectrum



Update of the VHE to UHE CR spectrum.
⇒ Seems all consistent

within the systematics, except at UHE

Combined fit of spectrum + X_{max} distributions



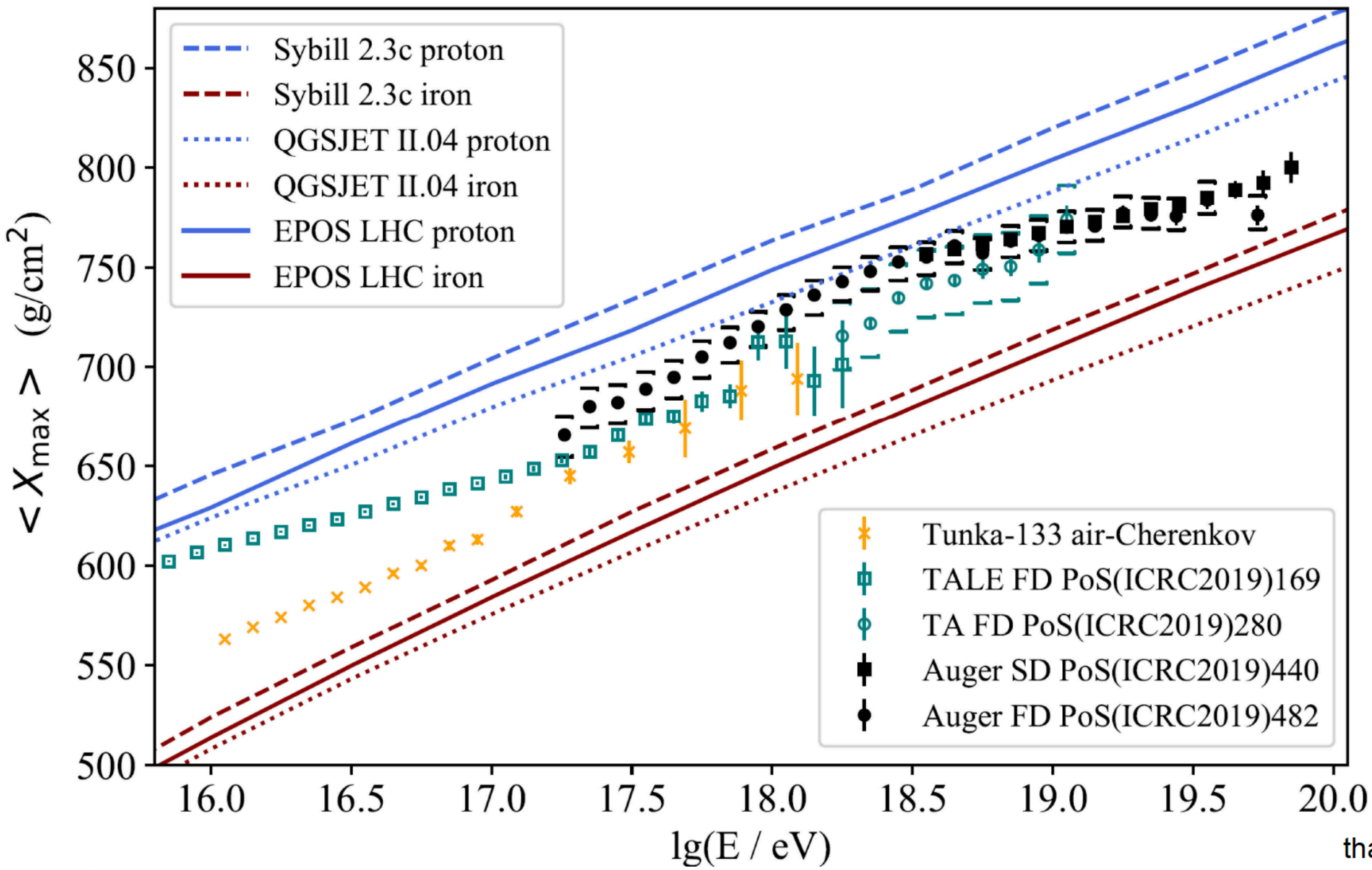
A. Aab et al. JCAP04 (2017) 038.

ICRC2019

⇒ with Auger data: global spectra+composition fit

Composition

X_{max} by traditional techniques: fluorescence, air-Cherenkov, rise time



Caveats:

energy scale uncertainties

some experiments have acceptance biases, but model lines are without bias

TA acceptance bias: 11 g/cm^2

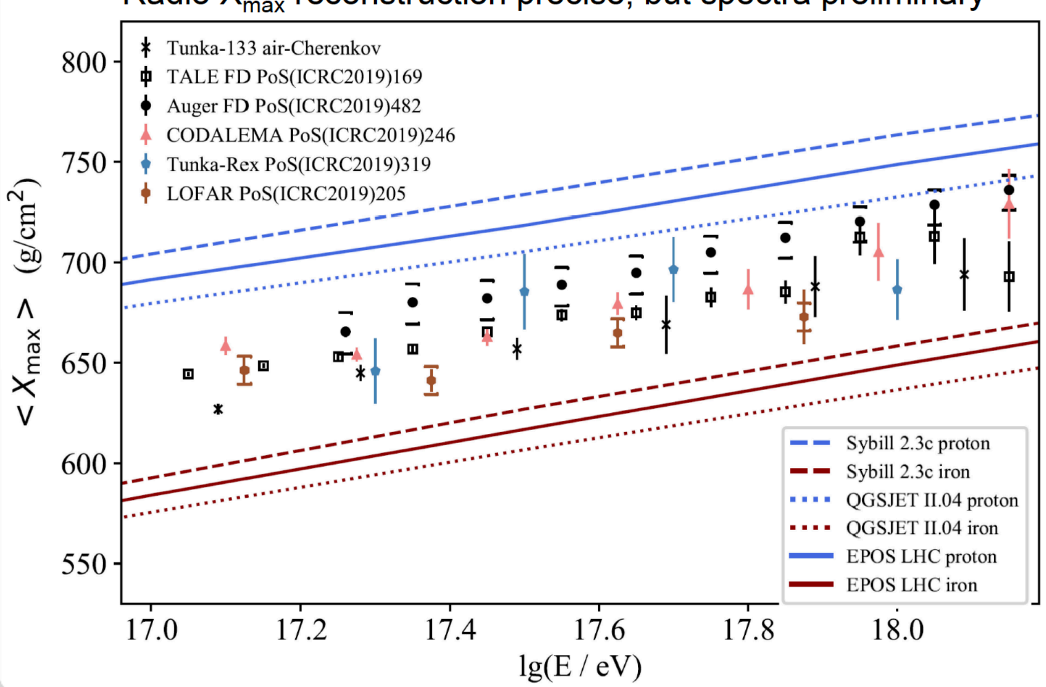
TALE bias not fully known

Tunka-133 biases and systematics not fully known

thanks to T. Pierog for model X_{max} values

X_{max} by Radio Arrays

Radio X_{max} reconstruction precise, but spectra preliminary

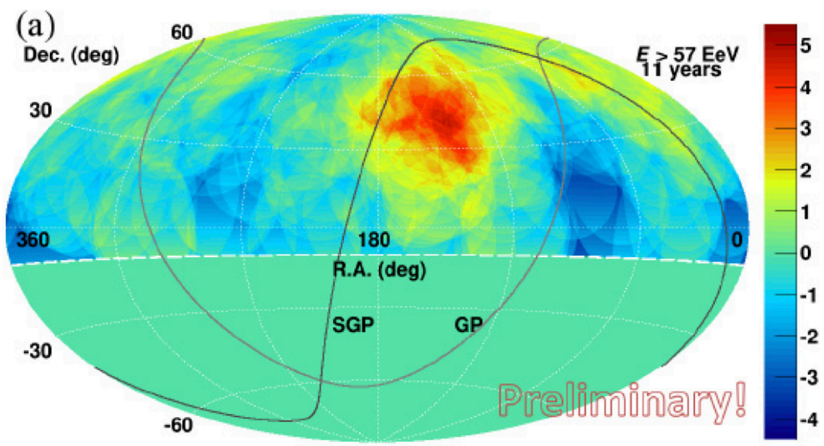


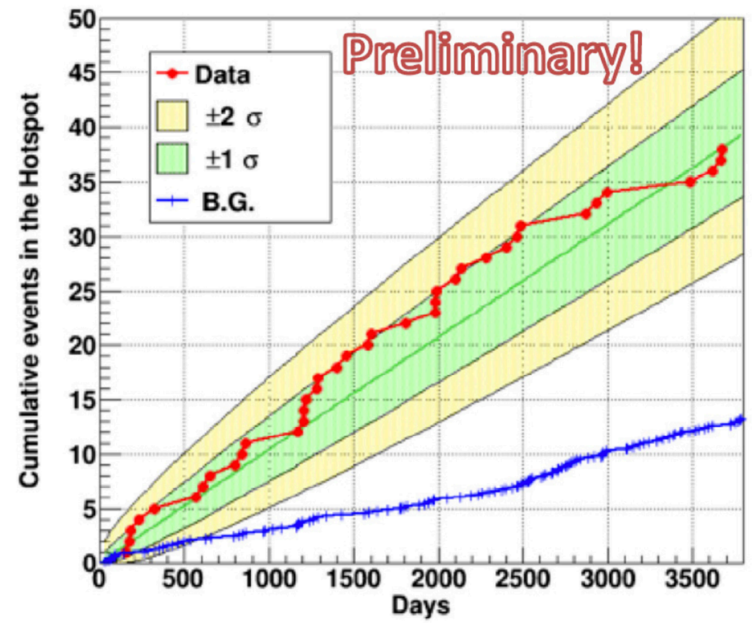
- Start to converge on the composition at UHE. We are waiting for the Auger Prime upgrade results (add scintillator + radio + better electronics) to have a better electron/muon separation.
- Very nice progress of the radio telescope array in the last few years with almost competitive results

Telescope Array - Hotspot

K. Kawata (TA Coll.)
PS3-173 - PoS 310

- number of events grows slightly slower than in the past, but still grows faster than background rate





Hotspot from 11 years of TA SD data, from May 11, 2008 to May 11, 2019

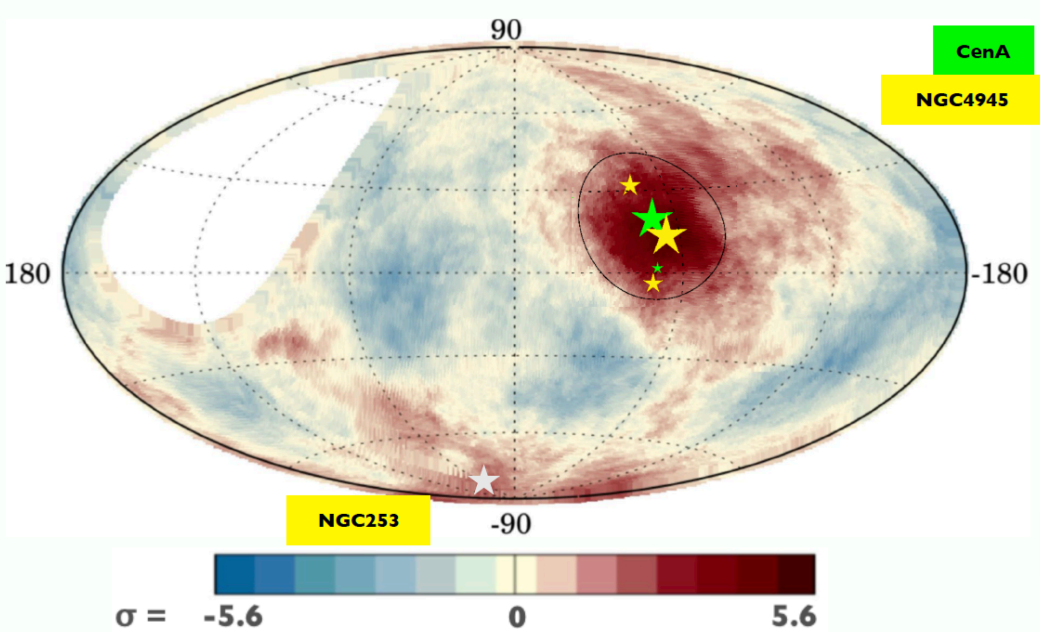
E > 57 EeV, in total 168 events
38 events fall in Hotspot (α=144.3°, δ=40.3°, 25° radius, 22° from SGP), expected=14.2 events
local significance = 5.1 σ, chance probability → 2.9σ
25° over-sampling radius shows the highest local significance (scanned 15° to 35° with 5° step)

Sources ?

* No source identified yet.
* Some hints: auger starburst galaxies, TA&Auger hotspots…

Intermediate anisotropy

Total SD events with E>32 EeV : 2157
Total exposure 101,400 km² sr yr



Blind search

Scan ranges:
32 EeV ≤ Eth ≤ 80 EeV (1 EeV steps)
1° ≤ ψ ≤ 30° (1° steps)

Most significant excess for E>38 EeV (α=202°, δ= -45°) ~2° from CenA

Centaurus A

3.9 σ effect (post-trial)
for E>37 EeV, 28° window

L.Caccianiga #206

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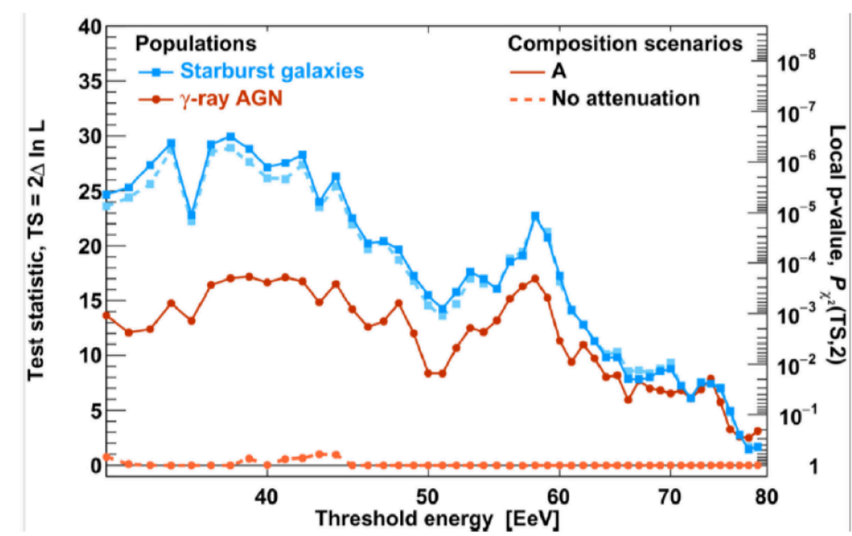
Auger: Correlations with Sour



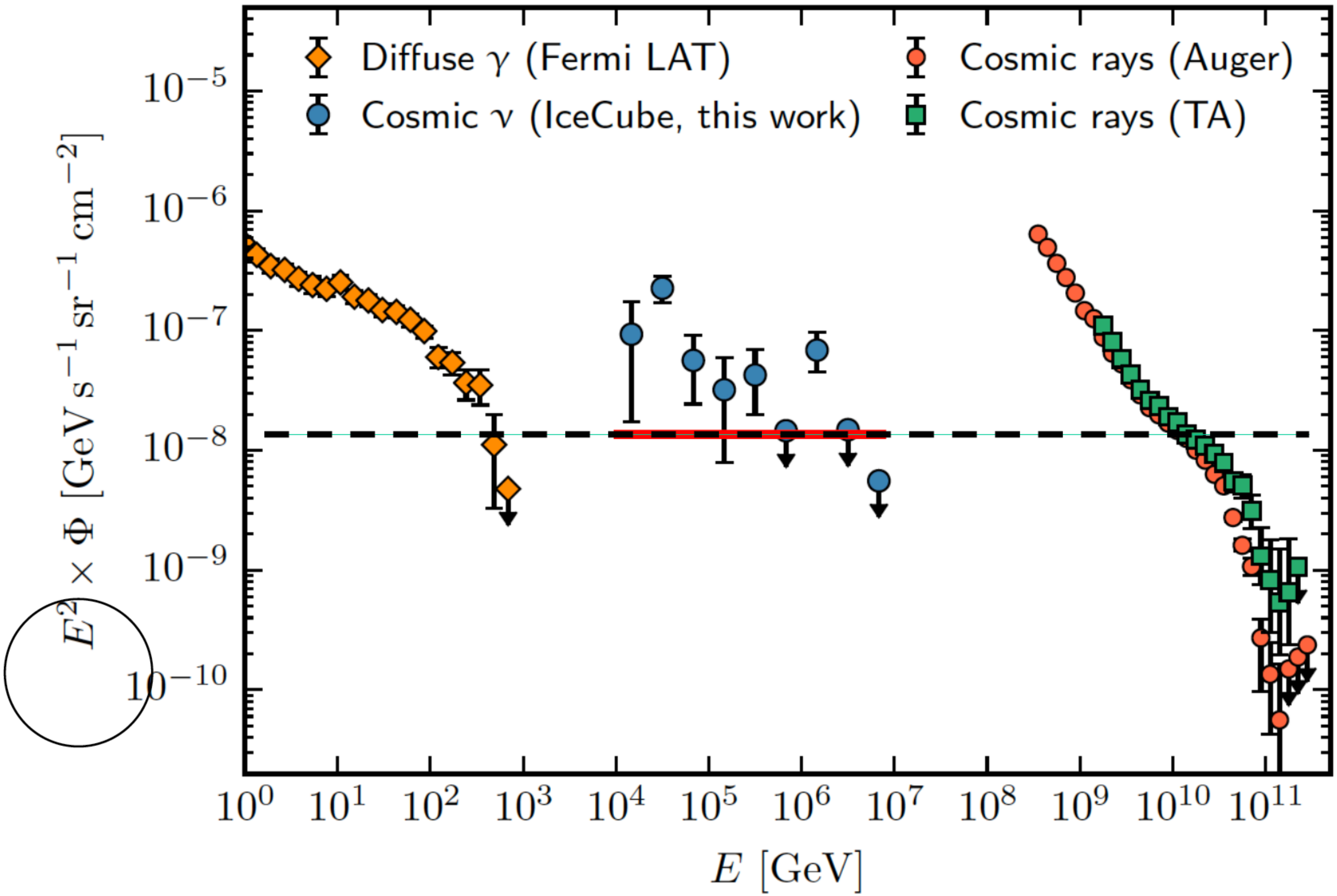
Catalog	E_{th}	θ	f_{aniso}	TS	Post-trial
Starburst	38 EeV	$15^{+5°}_{-4}$	$11^{+5}_{-4}\%$	29.5	4.5 σ
γ-AGNs	39 EeV	$14^{+6°}_{-4}$	$6^{+4}_{-3}\%$	17.8	3.1 σ
Swift-Bat	38 EeV	$15^{+6°}_{-4}$	$8^{+4}_{-3}\%$	22.2	3.7 σ
2MRS	40 EeV	$15^{+7°}_{-4}$	$19^{+10}_{-7}\%$	22.0	3.7 σ

H

All th

Note

Global multi-messenger picture

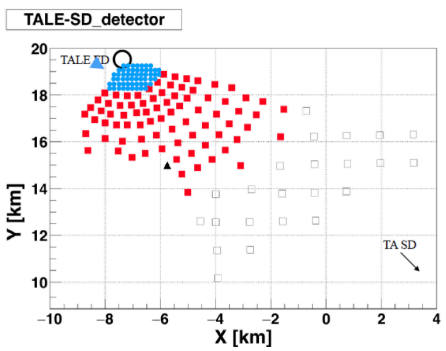


energy in the Universe in gamma rays, neutrinos and cosmic rays

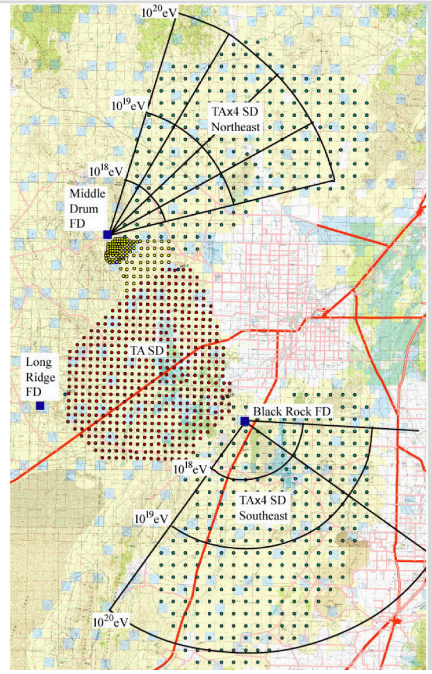
What next ?

Telescope Array: Upgrades

- Highest energies (E > $10^{19.8}$ eV)
  - TAx4 → 3000 km² scintillator array
  - new fluorescence telescopes
- Lower energies (E > $10^{15.5}$ eV):
  - TALE SD array complementing NICHE and FD



S. Ogio (Telescope Array Coll.)
H5 + CRI4g - PoS 013 + 375

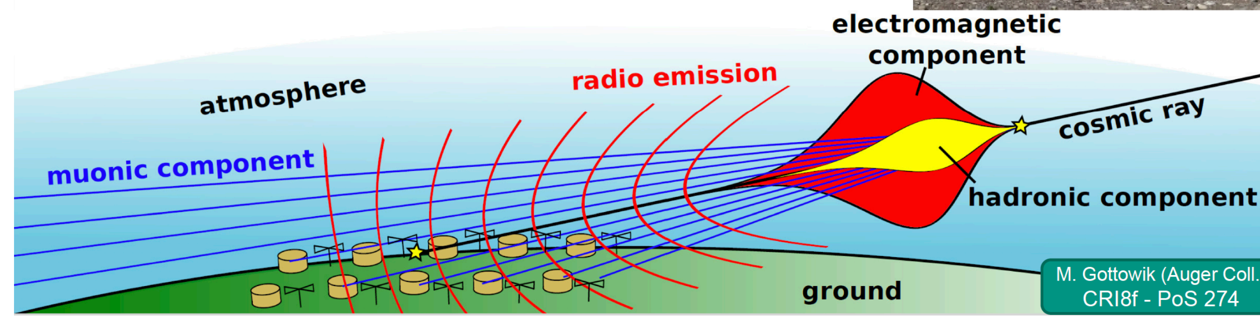


+

AugerPrime: Upgrade of the Pierre Auger Observatory

- Improved quality of surface detector:
  - scintillators + radio antennas
  - underground muon detectors
  - better electronics
- Enables per-event mass discrimination

B. Pont (Auger Coll.)
PS3-205 - PoS 395
and several more



M. Gottowik (Auger Coll.)
CRI8f - PoS 274

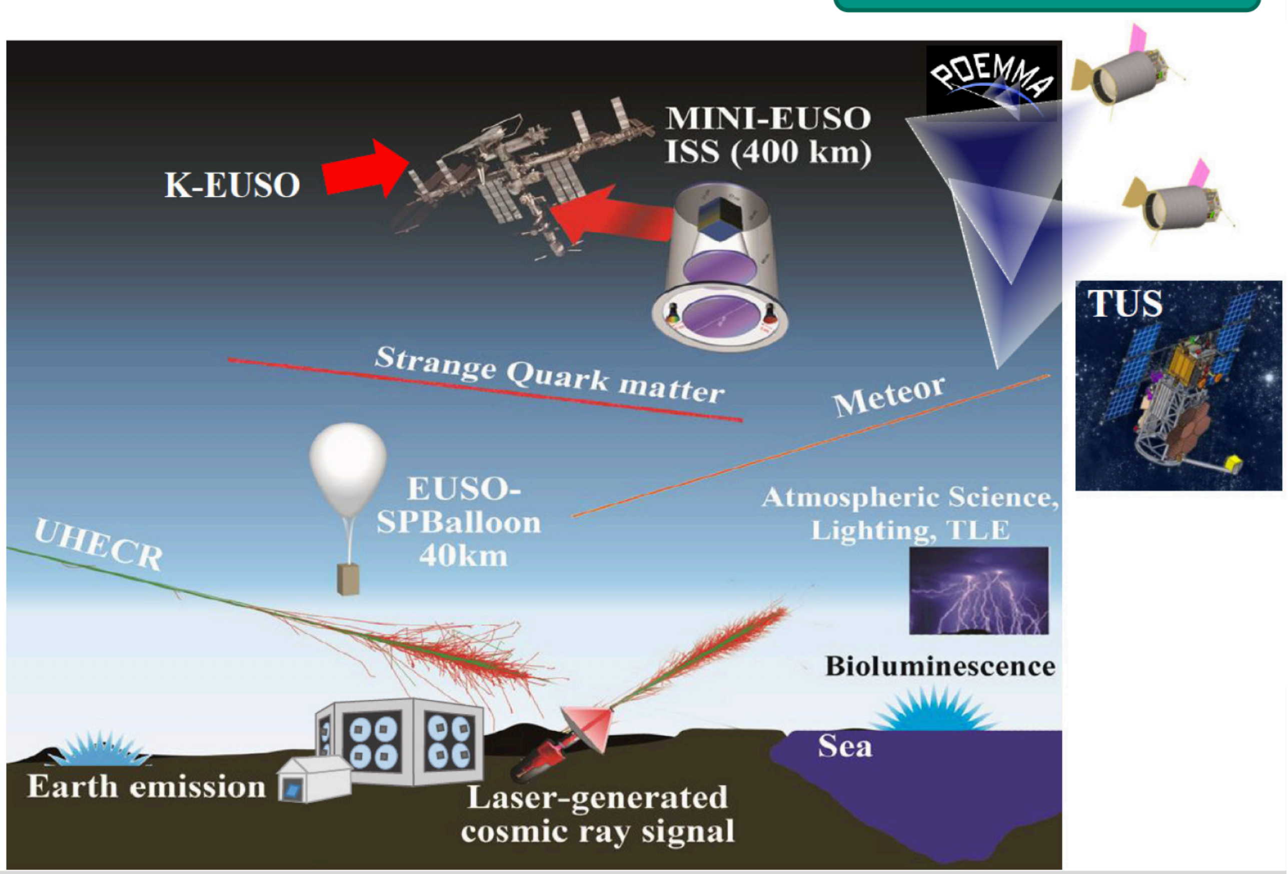
JEM-EUSO Program – towards POEMMA

M. Bertaina (JEM-EUSO Coll.)
CRI1d - PoS 192

- EUSO-TA (2013)
- EUSO-Balloon (2014)
- TUS (2016)
- EUSO-SPB (2017)
- Mini-EUSO (2019)
- EUSO-SPB2 (2022)
- K-EUSO (2023+)
- POEMMA (2029+)

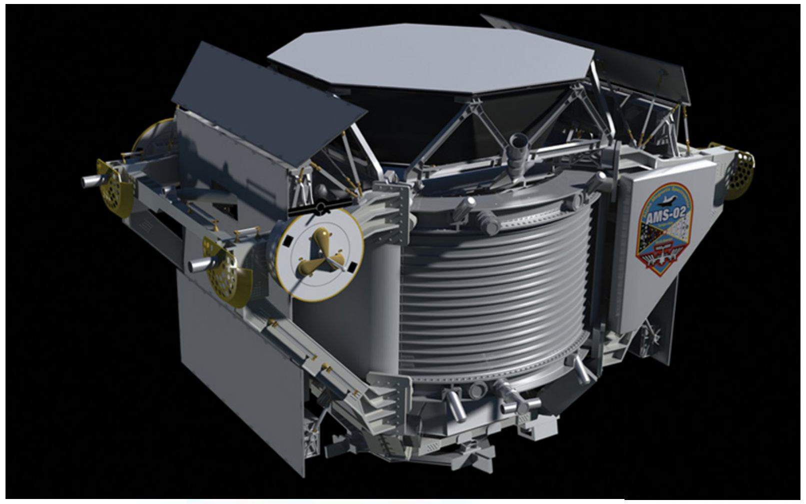
9 coincident events ~ EeV

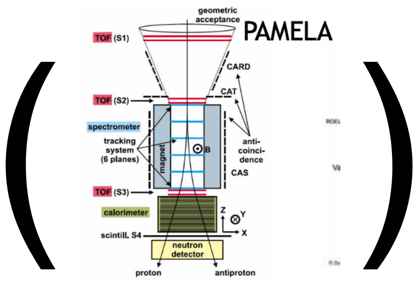
launch to ISS this month

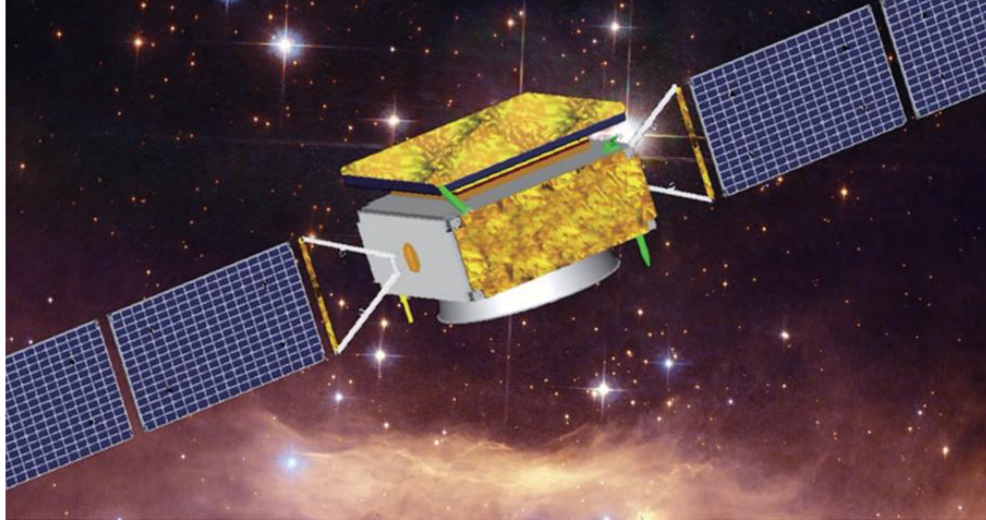


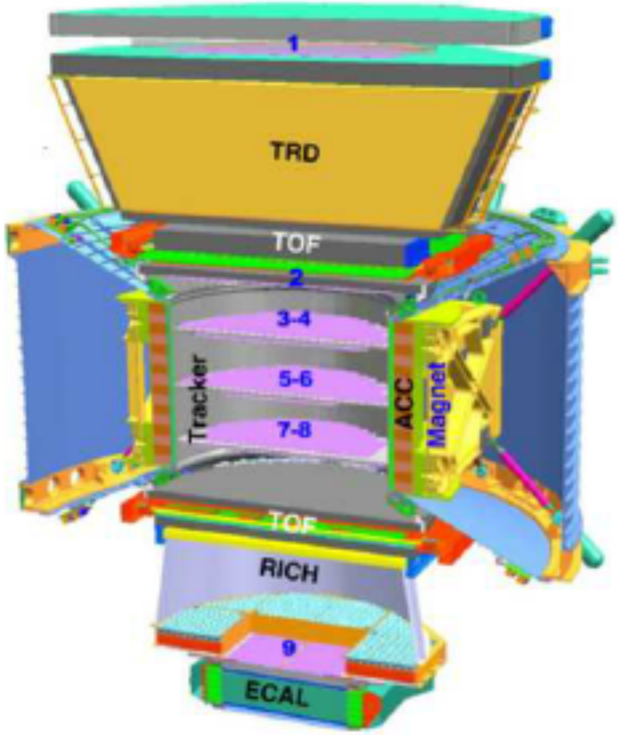
Mini-EUSO telescope has been launched on August 22 at 3:38 UTC from the Baikonur cosmodrome and docked to ISS on August 27.

Direct CR detection

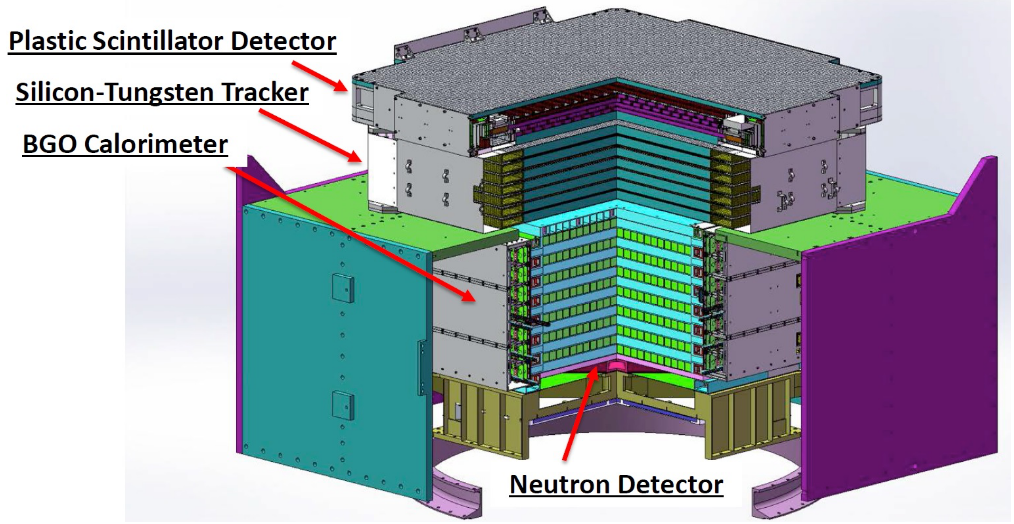




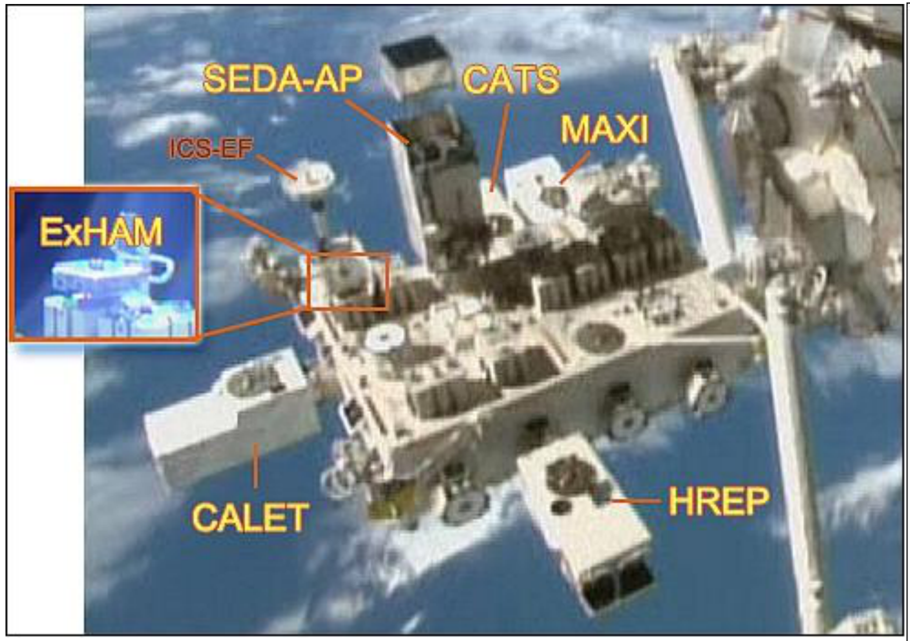


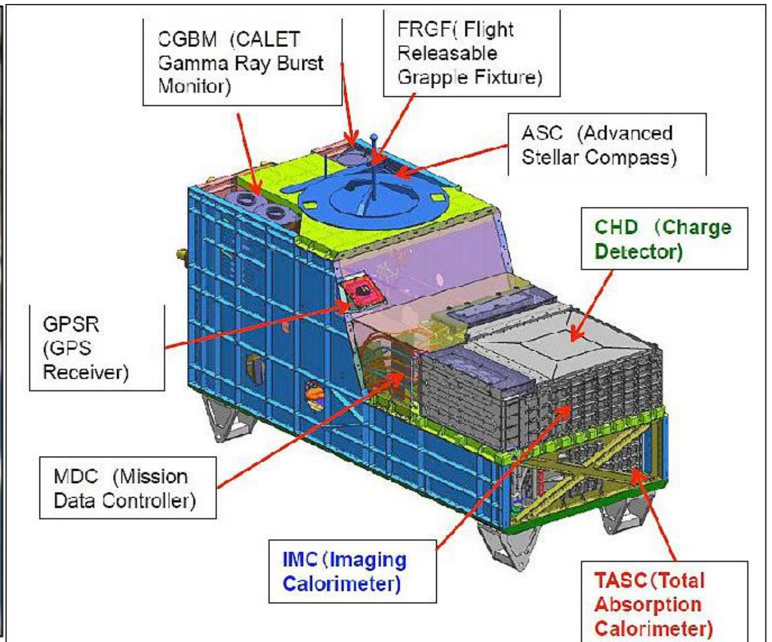


AMS-02 Installed on ISS on 19052011 (11 yrs of continuous data) collecting ~142 billion events



DAMPE satellite launched on 17122015 collecting ~6.6 billion events



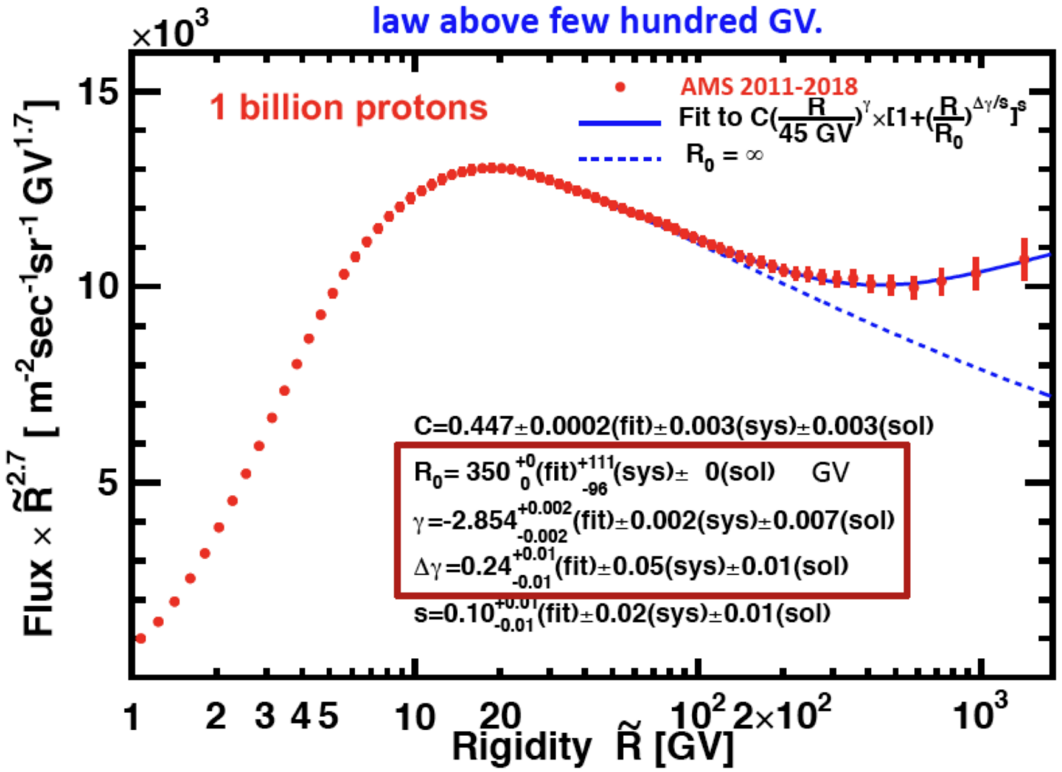


CALET installed on ISS on 13102015 collecting ~1.8 billion events

Primary CRs: p / He spectrum

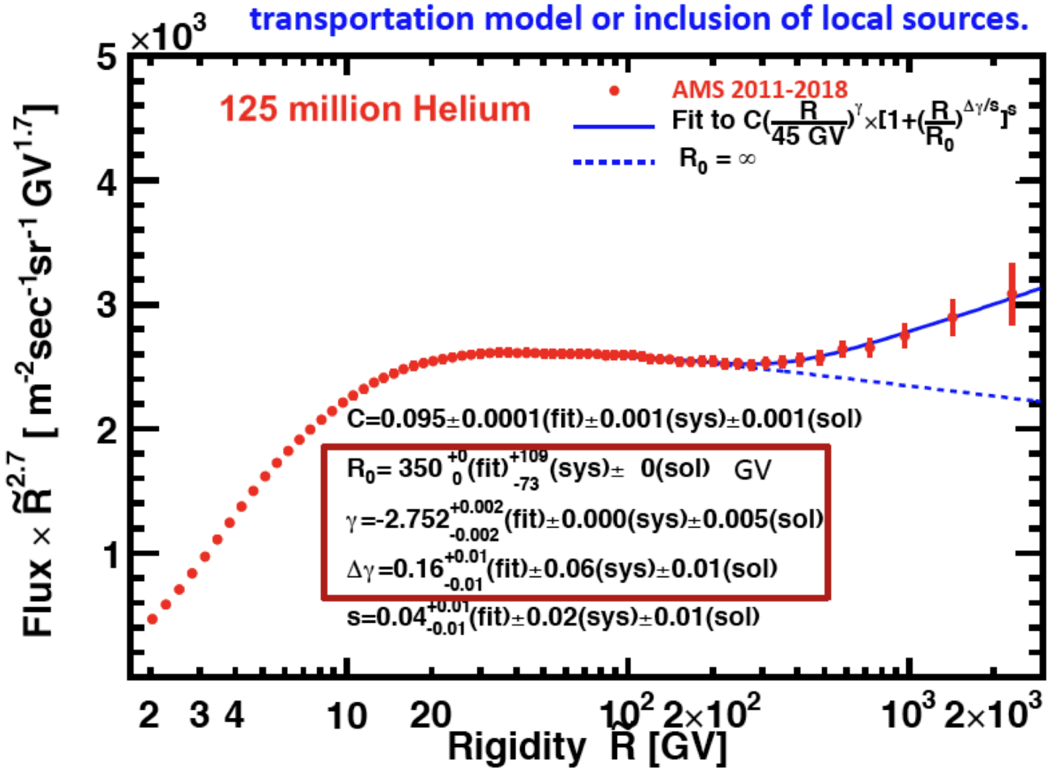
Structure in the latest proton spectrum

Proton spectrum measured by AMS shows a deviation from a single law above few hundred GV.

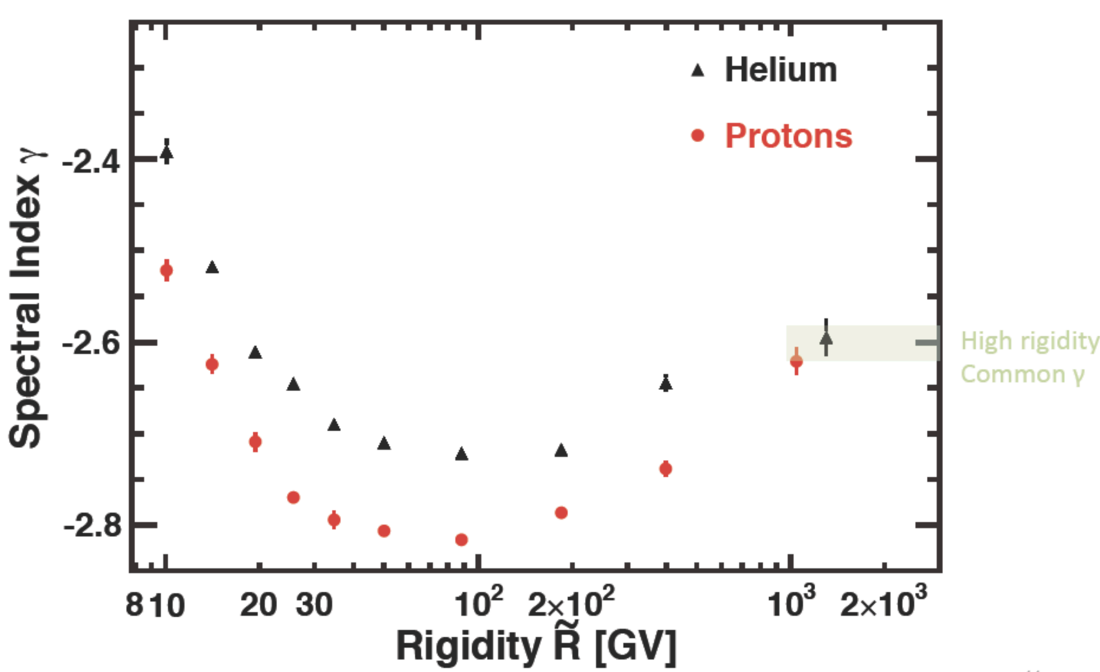


Origin of Structure in the latest helium spectrum

The structure in He (P) spectrum requires modification of cosmic ray transportation model or inclusion of local sources.



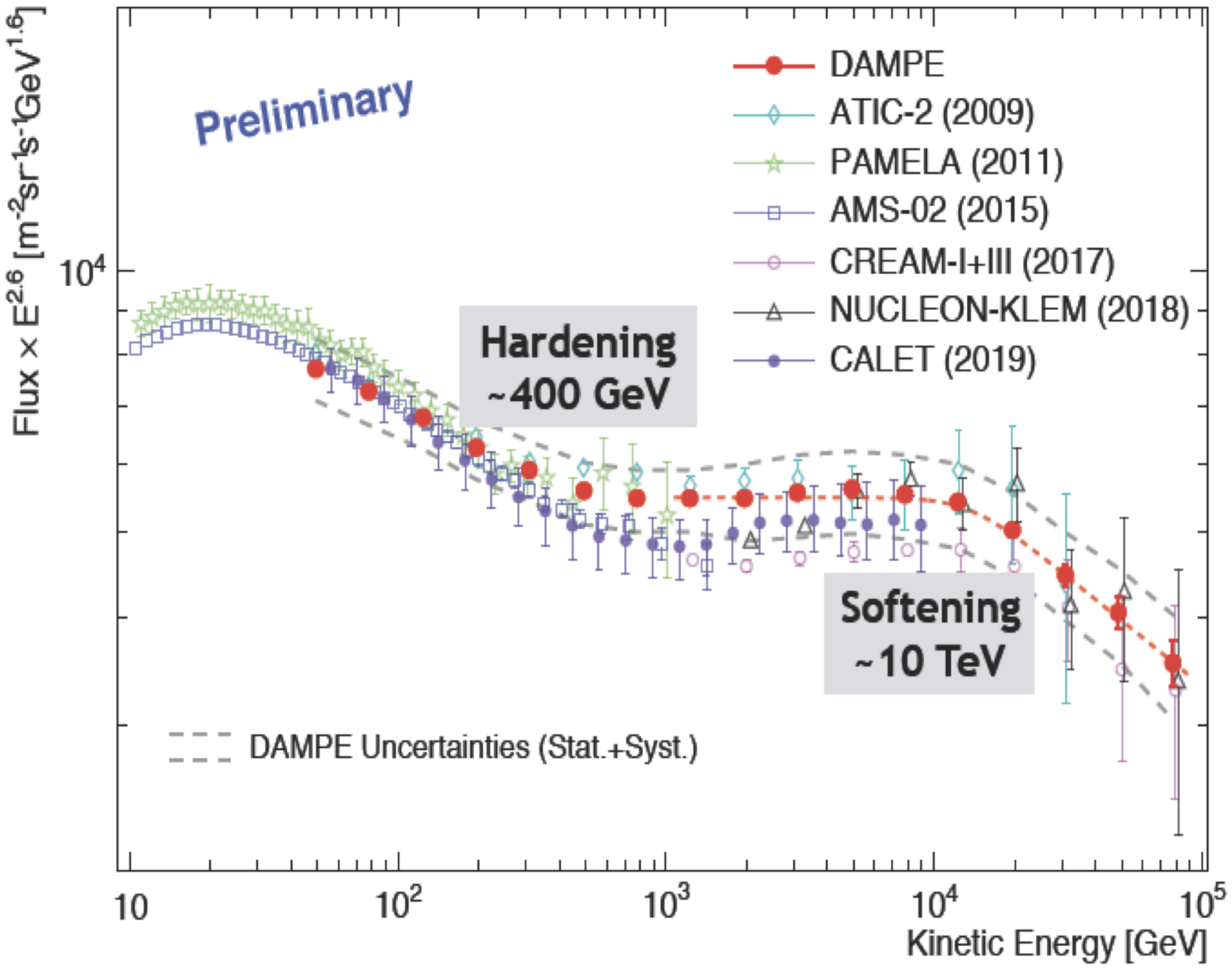
AMS Measurements of P&He Spectral Indices (2011-2018)



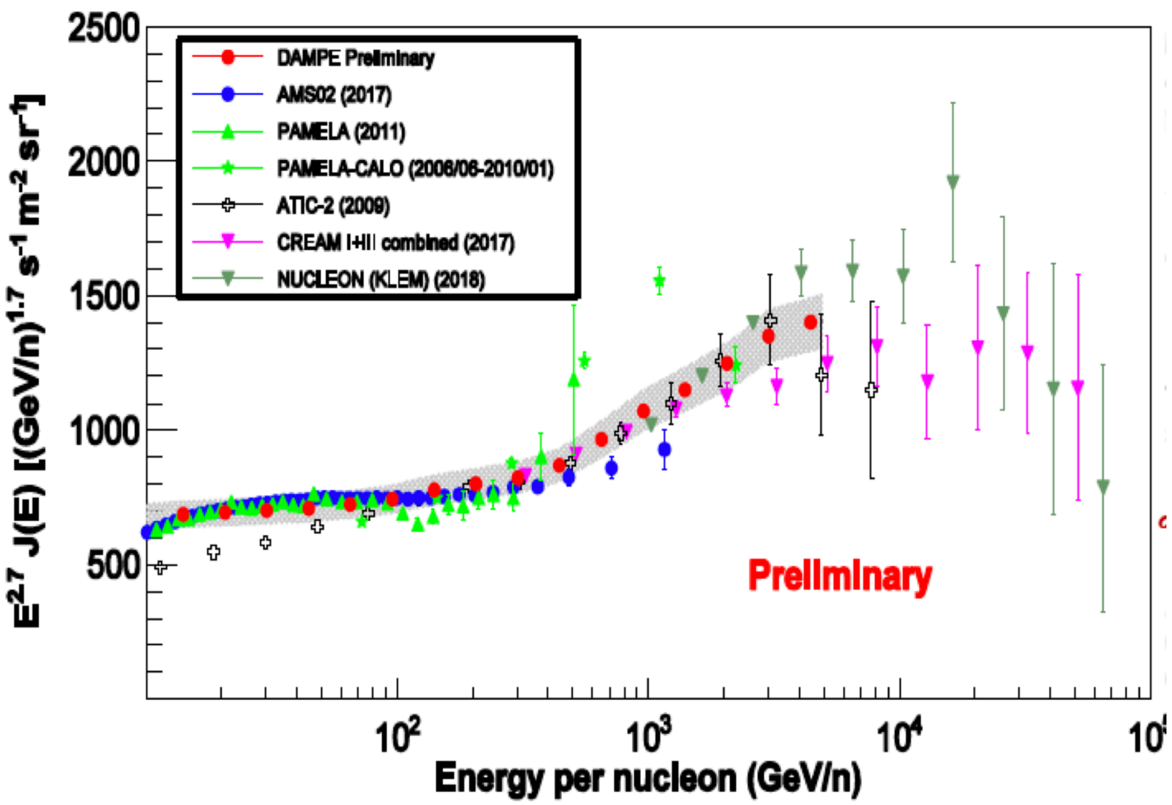
- * p/He ratio is not constant
- * As both p & He are primary CRs, it is assumed that p/He flux should be asymptotically rigidity independent.
- * Confirmation of the deviation from a single power-law in both species at roughly 200 GV

$\Longrightarrow$ May be caused by change of multiple distant sources regime to dominant local sources.

Primary CRs: p spectrum at HE



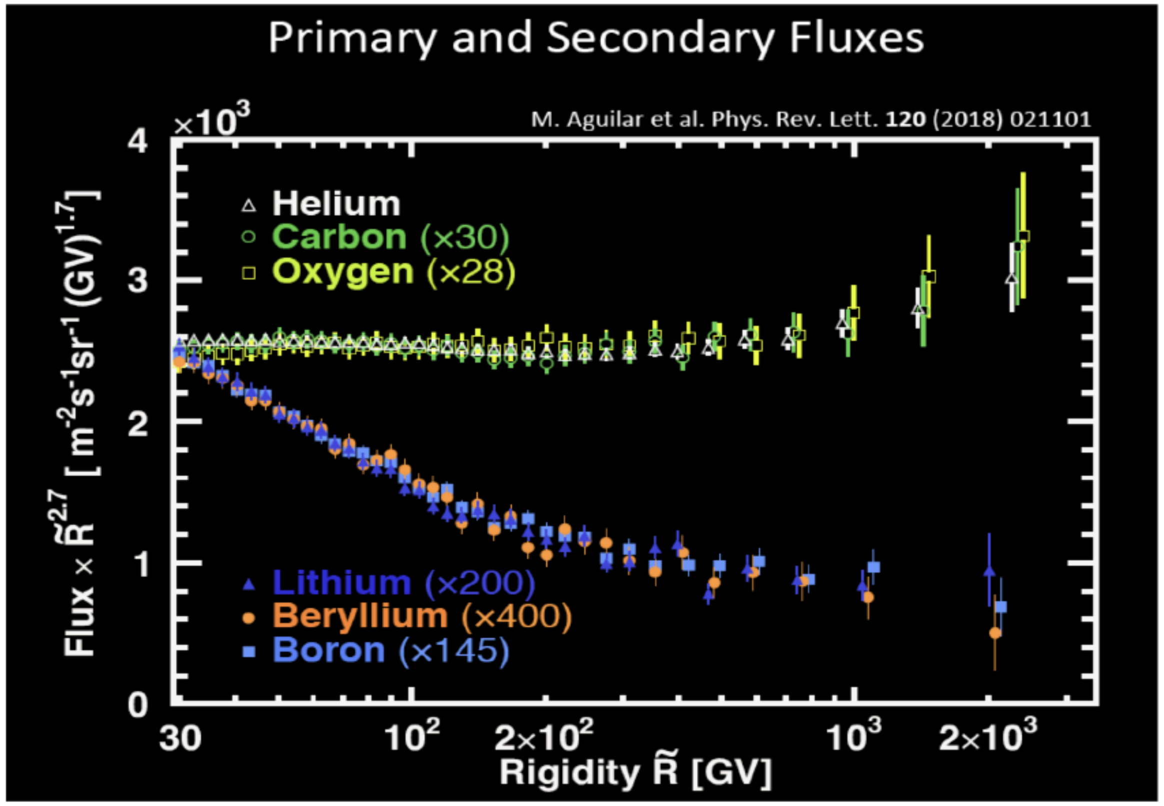
- * Confirmation of spectral hardening at ~400 GeV
- * Softening at 10 TeV
- * Universal hardening observed in heavier nuclei suggests a propagation effects ⇔ Is this picture consistent with the spectral behavior in the TeV region?

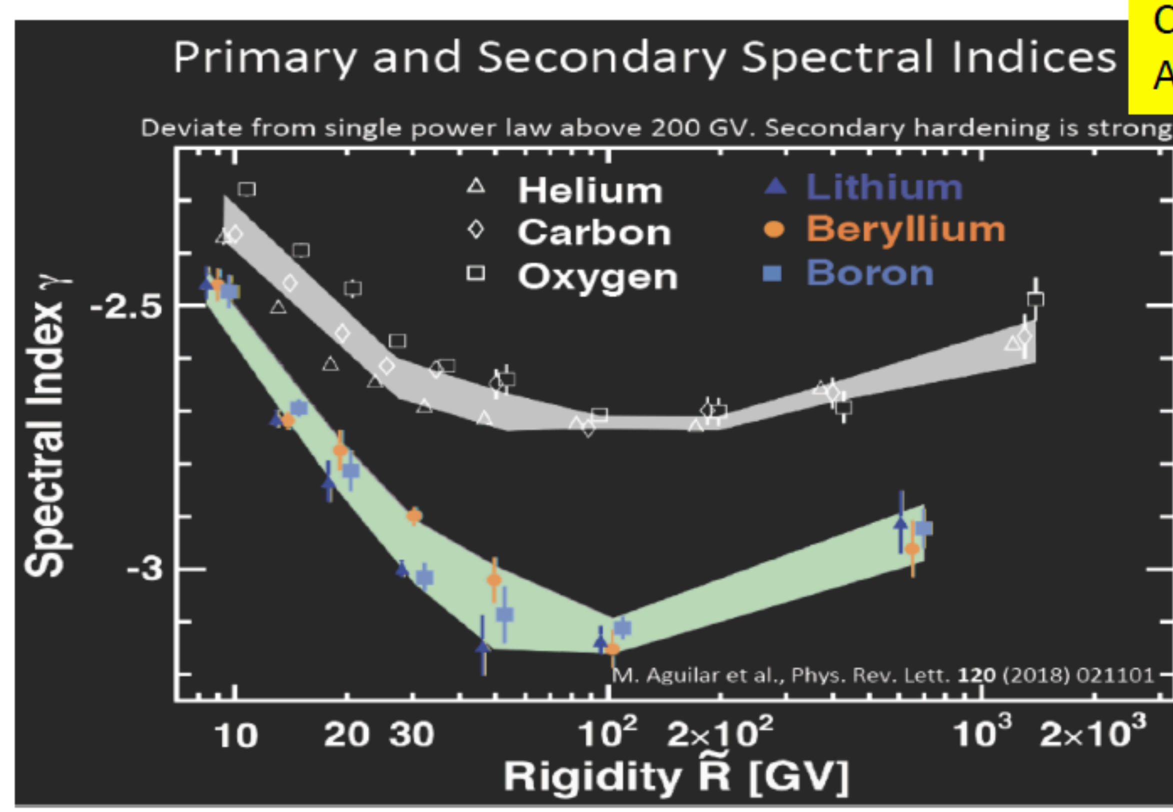


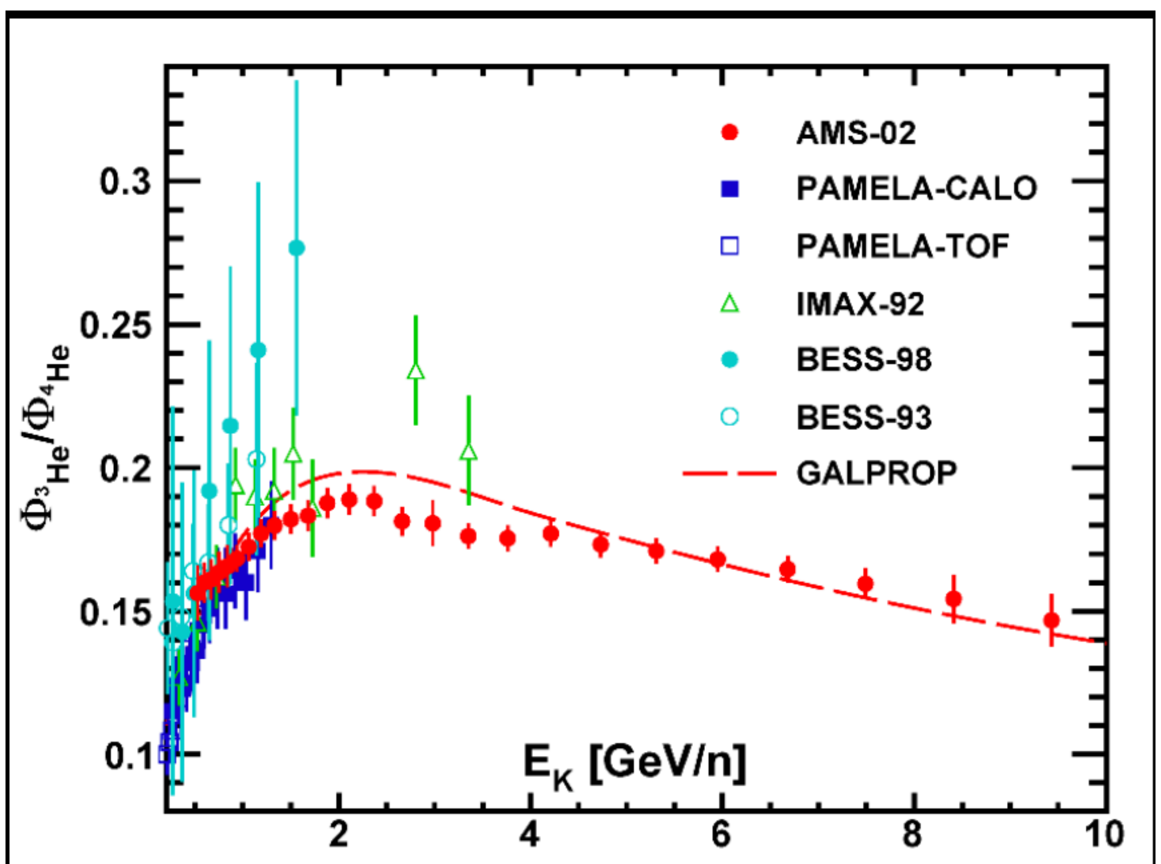
* Similar behavior for He spectrum

Secondary CRs: LiBeB & isotopes spectrum

CRD6b:
Alberto Oliva







* Important measurements to constrain the CR transport in the galaxy.

* Different hardening for He/C/O than Li/Be/B

* Secondary/primary ratios harden at 192 GV. The flux hardening seems to be a universal propagation effect.

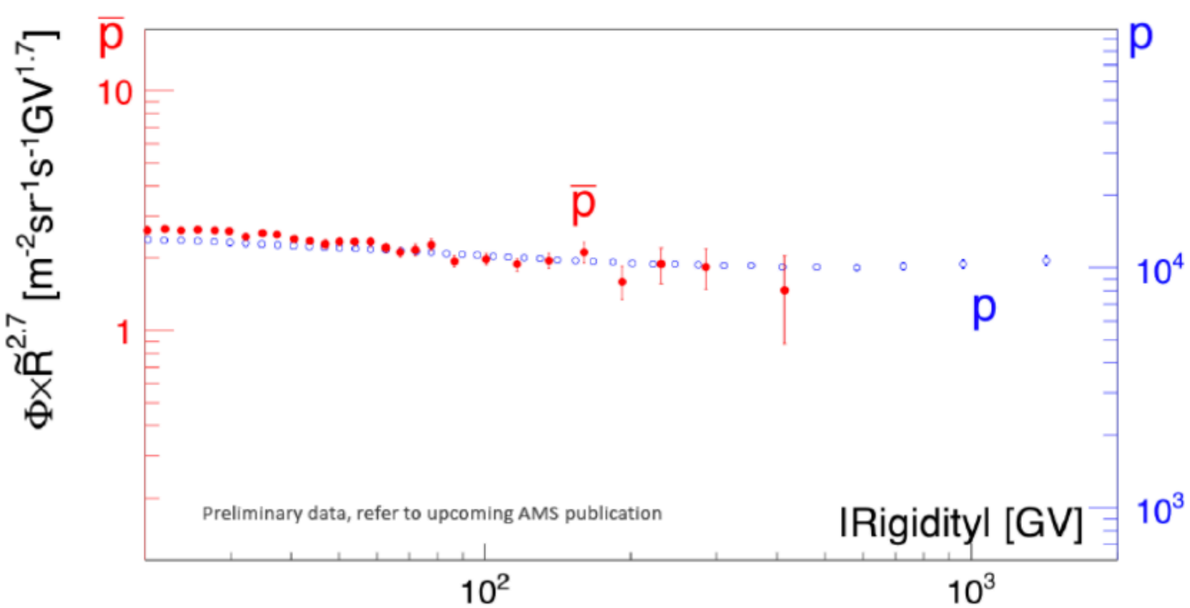
Secondary CRs: antiproton spectrum

Antiprotons in AMS-02

The Spectra of Protons and Antiprotons

If $\bar{p}$ are secondaries produced in ISM, their rigidity dependence should be different than p:

p + ISM → $\bar{p}$ + …



AMS observed for the first time that above 60 GeV, p and $\bar{p}$ have identical behavior

Flux from 1 to 450 GV

Partially extended wrt PRL 117, 091103 (2016)

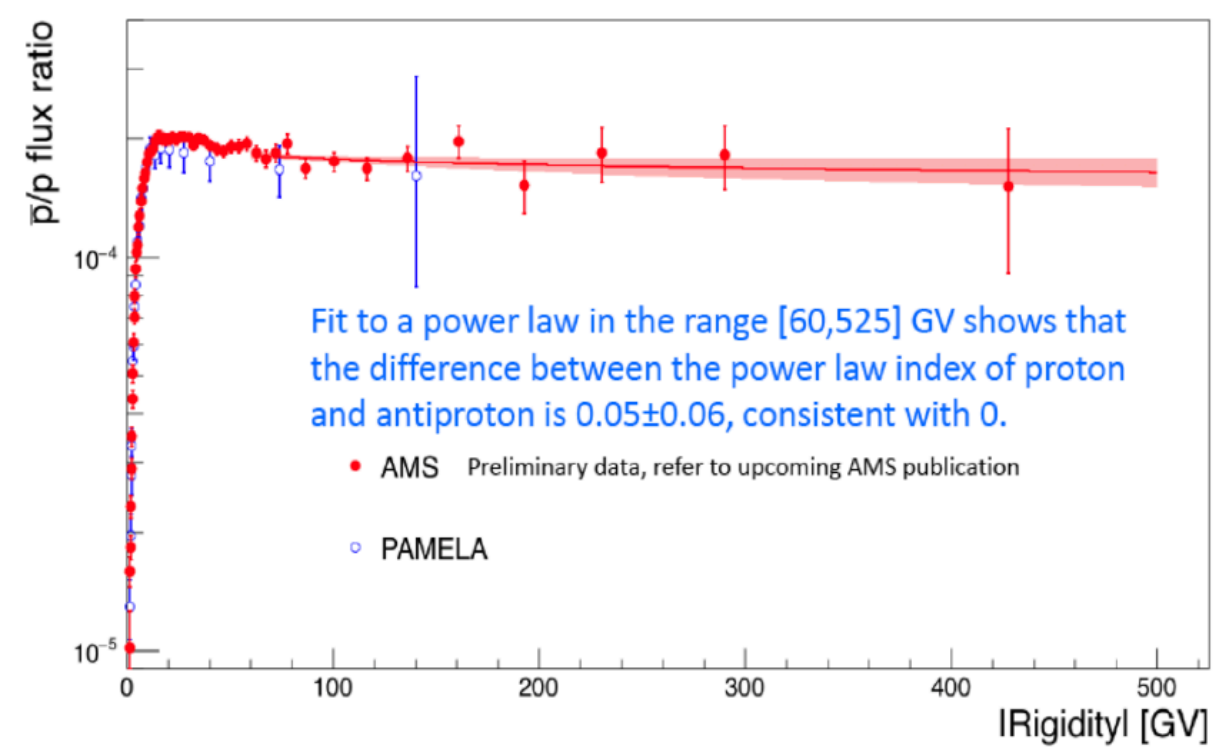
CRD1a: Cheng Zhang
H9: Bruna Bertucci

Important feature:

Antip/p flat for R>60 GeV

Antiproton-to-Proton Flux Ratio

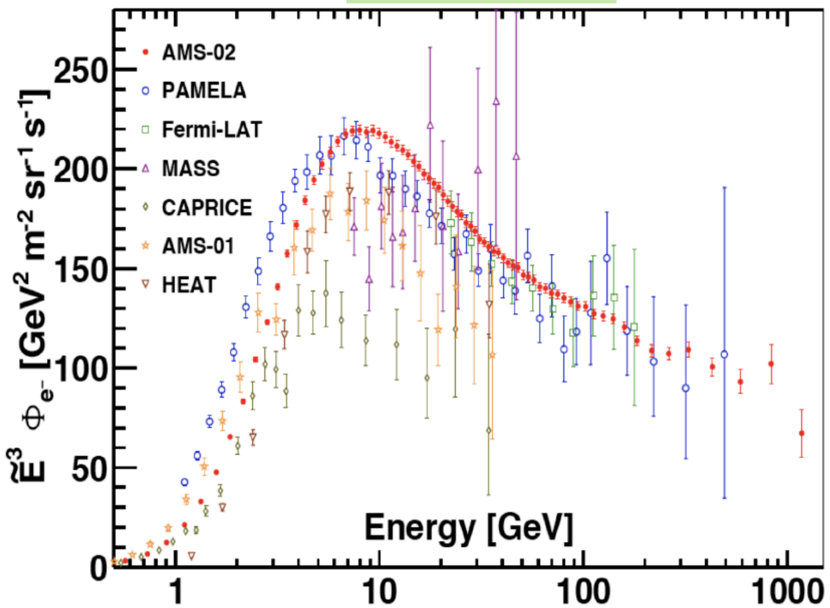
Show no rigidity dependence above 60GV



Using published AMS results for CR fluxes (p, He, C, O) and CR ratio (B/C) for the propagation constrains and the USINE code for CR transport in the galaxy, AMS-02 data are consistent with 'standard' secondary antiprotons.

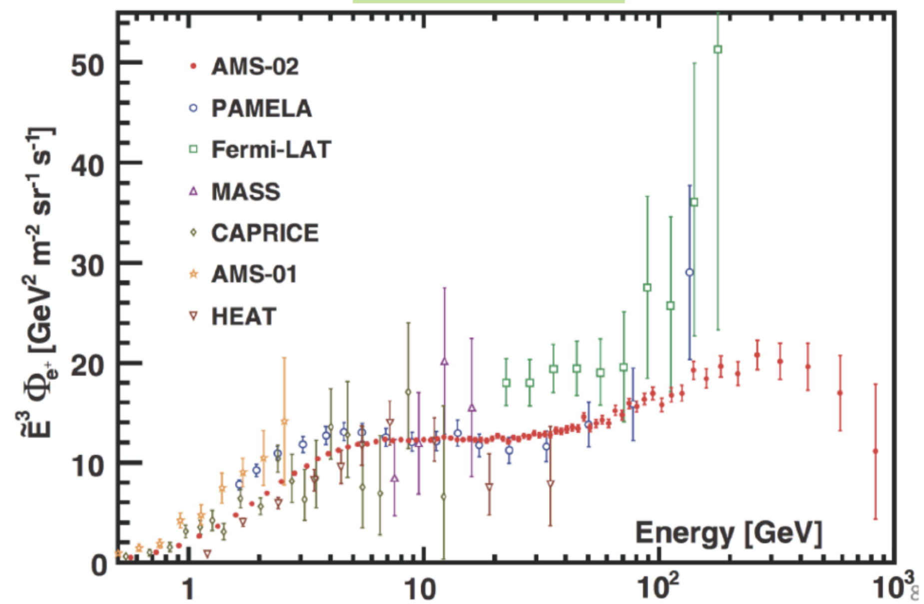
Electron / positron spectrum

Electron flux x E^3



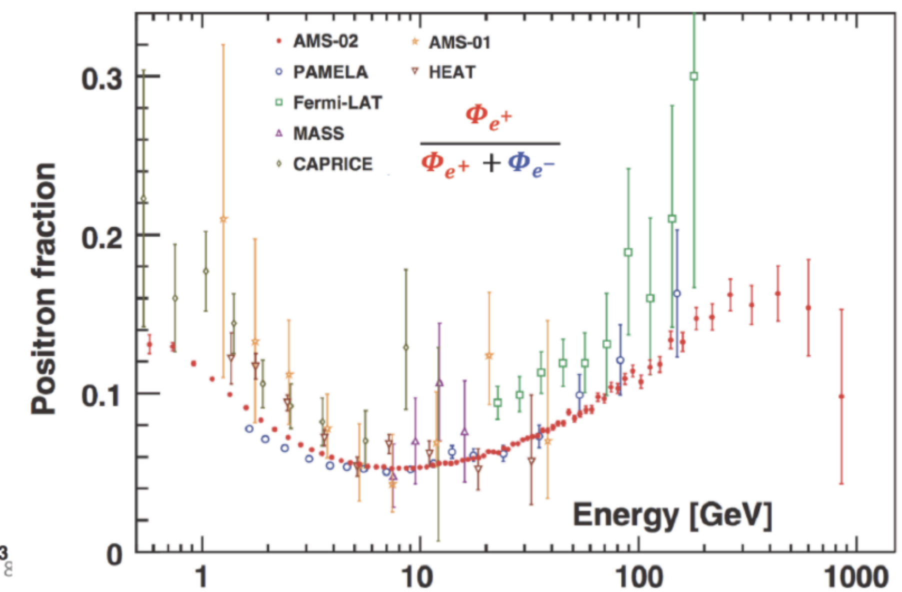
CRD2b: Weiwei Xu
H9: Bruna Bertucci

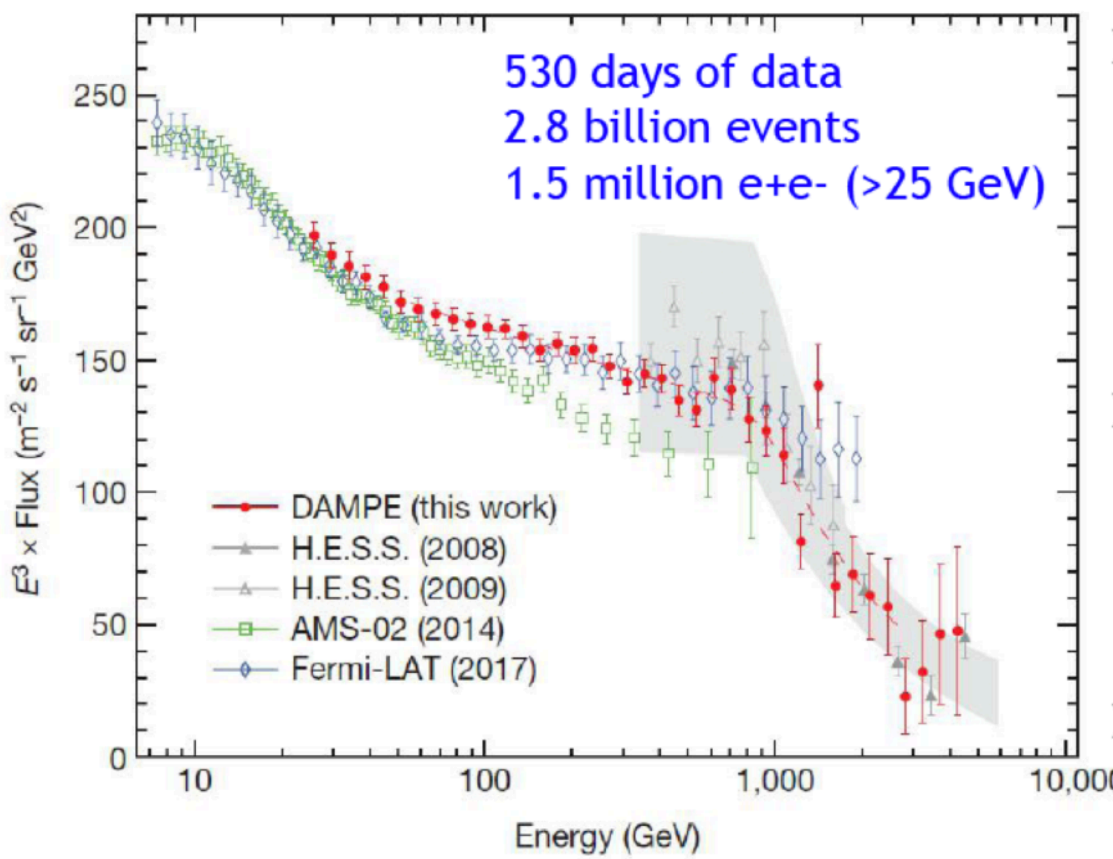
Positron flux x E^3



Phys. Rev. Lett. **122**, 041102 (2019)

CRD2h: Zuhao Weng
H9: Bruna Bertucci

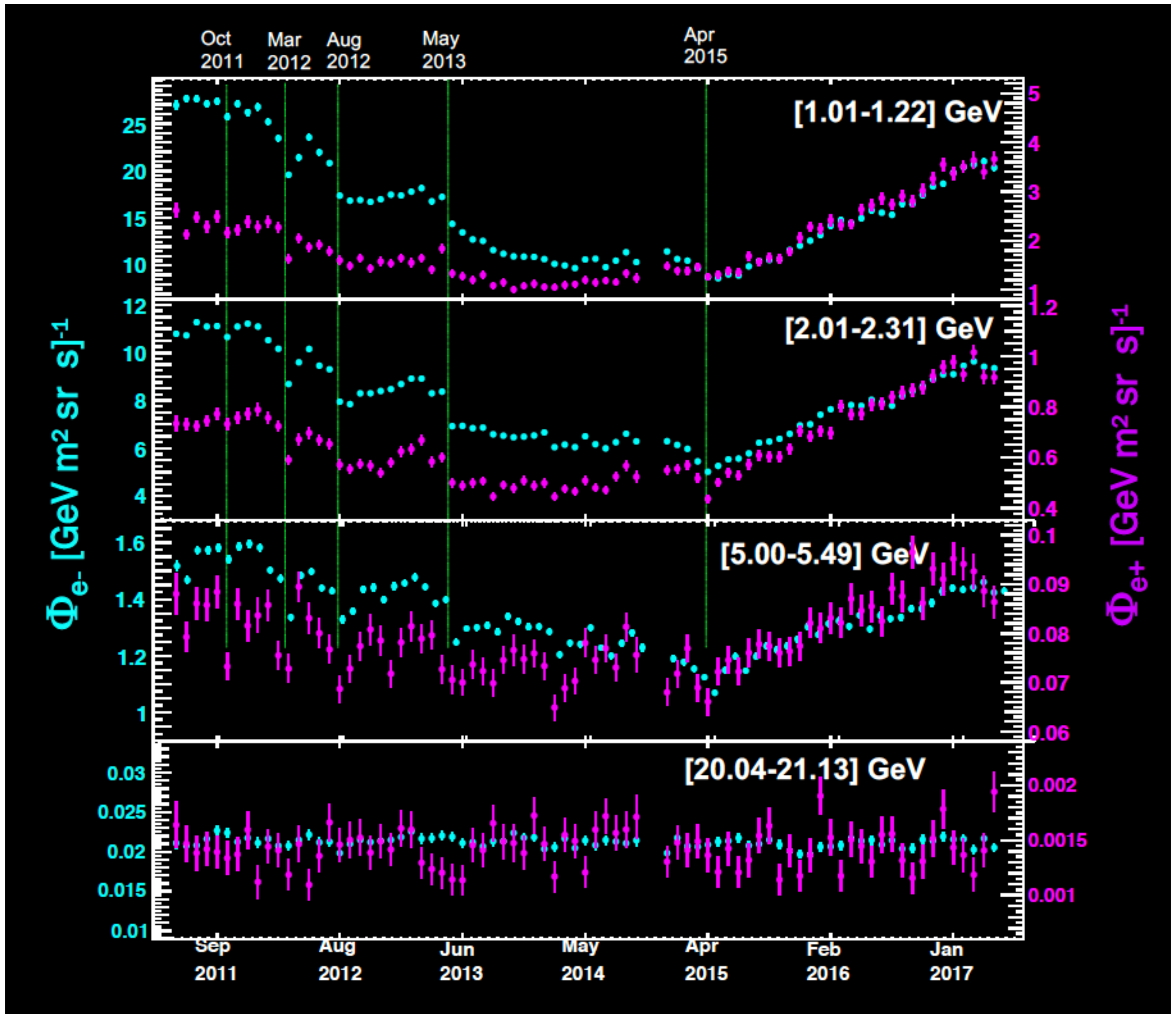


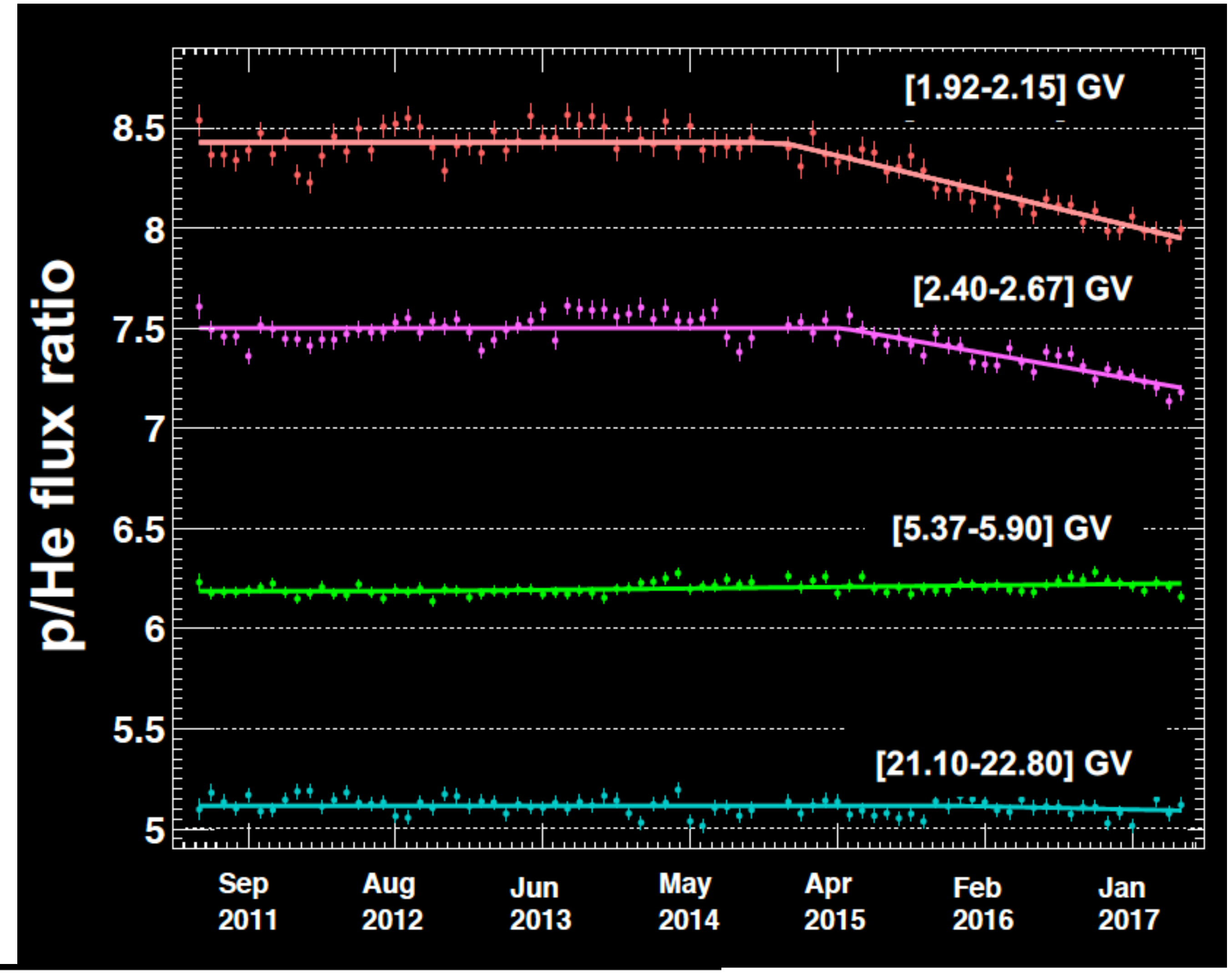


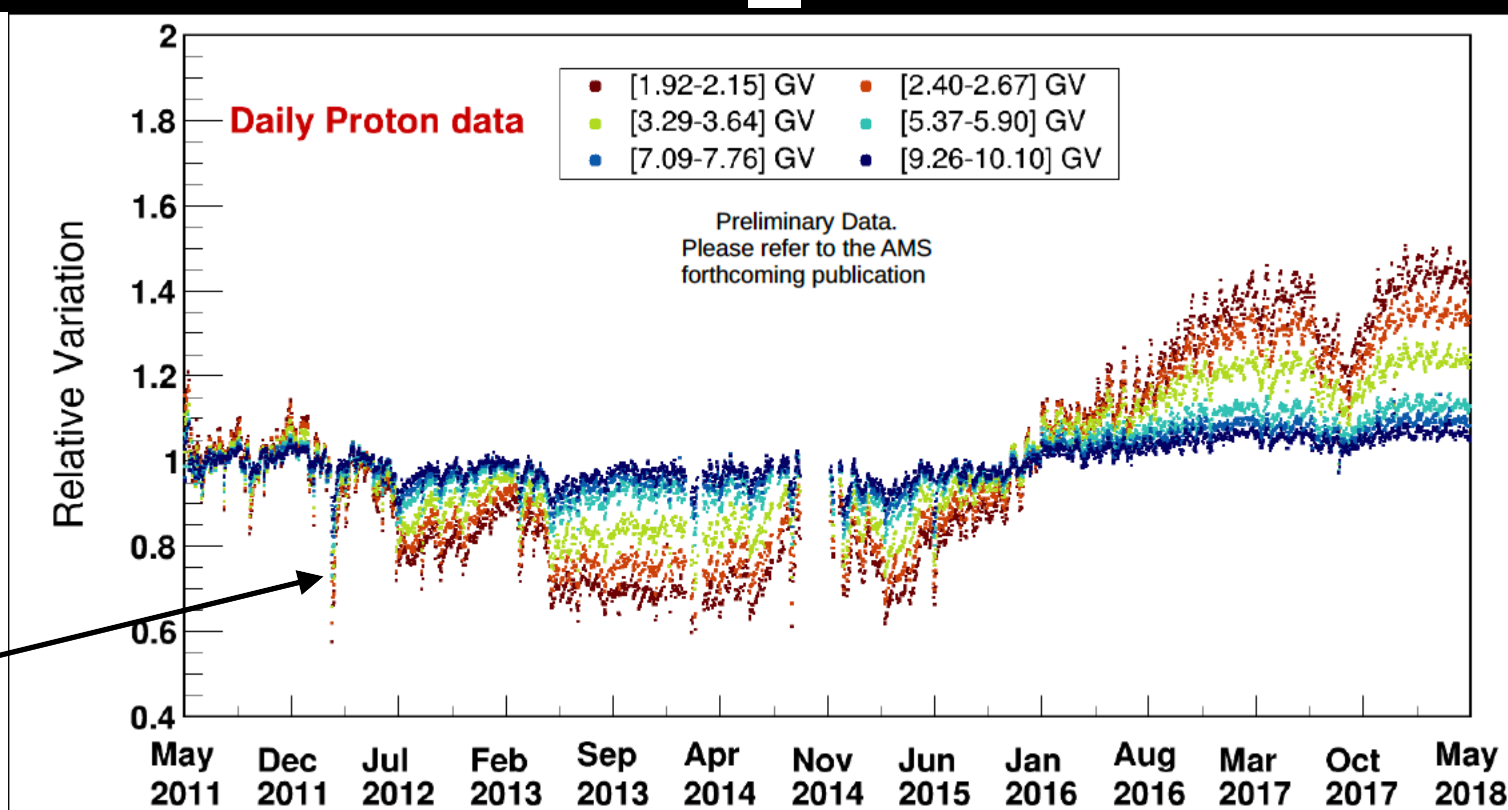
* Positron spectrum fitted with 2 components: a LE from CR interactions and a HE from new sources (pulsars? Dark matter?)

* Electron flux suppression seen by ground exps at E > 1 TeV

Time-dependent CR fluxes with AMS-02







SEP event in 07/03/2012

Summary

Classical questions still drive the evolution of the field. More data we have, more specificities we found in their properties (energy spectrum, composition, anisotropies) and more and more difficult is the interpretation.

Which classes of sources contribute to the CR flux in different energy ranges?
Are CR nuclei and electrons accelerated by the same sources?
Which sources are capable of reaching the highest particle energies?
Which are the relevant processes responsible for CR confinement in the Galaxy?
Where is the transition between Galactic and extra-Galactic CRs?
What is the origin of the difference between the chemical composition of CRs and the solar one?

With recent data, more questions arise:

What is the origin of the hardening observed in the spectra of CR nuclei at a rigidity of 300 GV?
Why is the slope of the spectrum of CR proton and helium different?
What is the origin of the prominent break observed at a particle energy of 1 TeV in the electron spectrum?
Why do the proton, positron, and antiproton spectra have roughly the same slope at particle energies larger than 10 GeV?
What is the origin of the small scale anisotropies ?
…