Observations of super-heavy nuclei of cosmic rays with DAMPE

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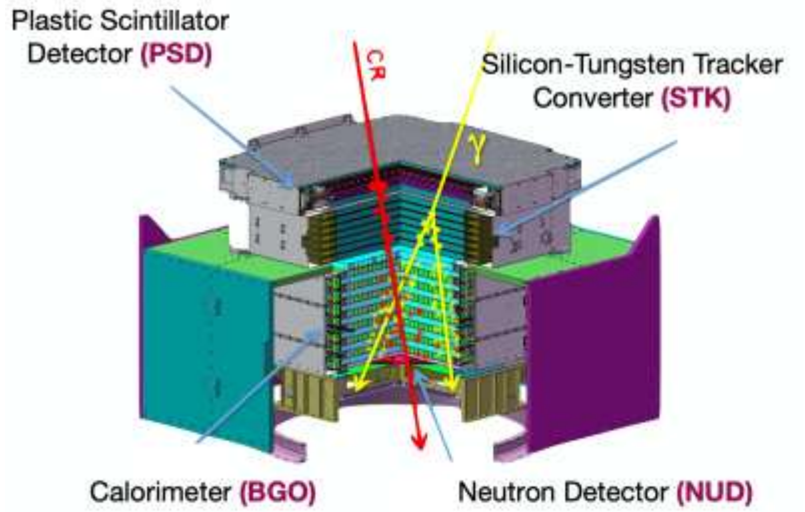
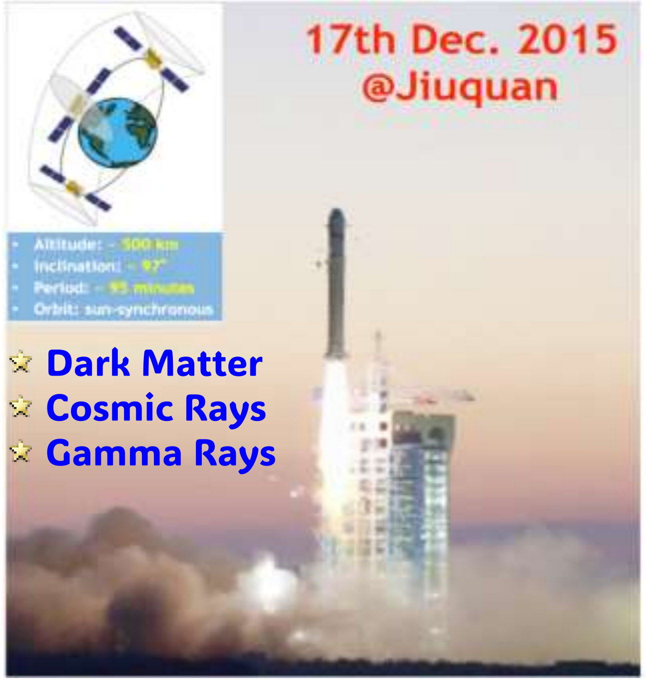
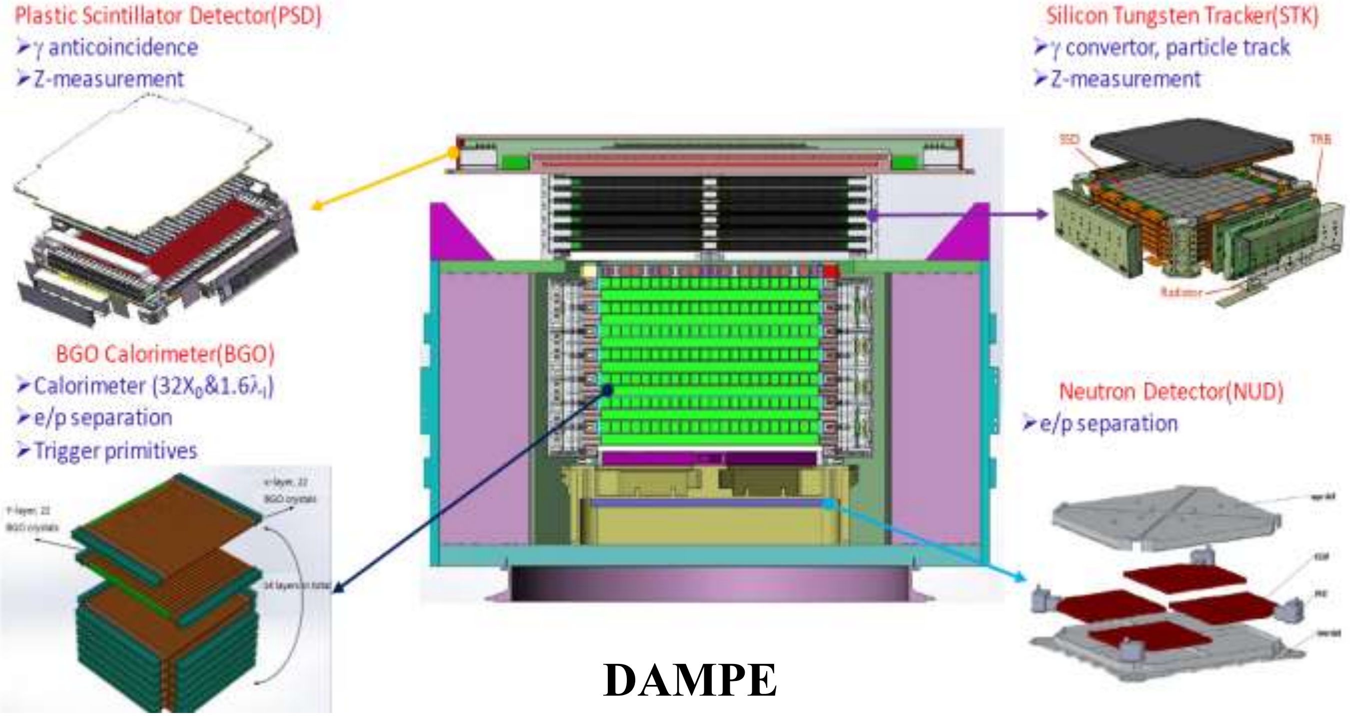
Outline

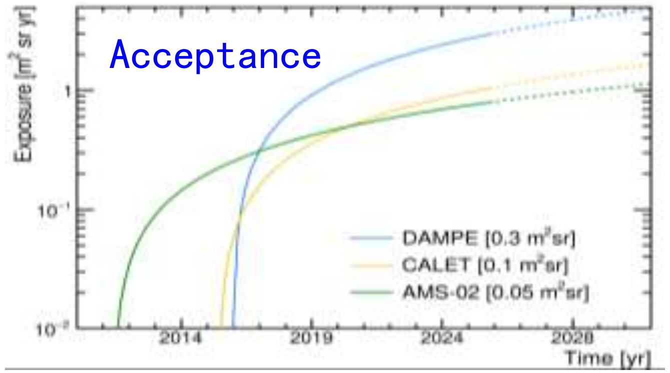
- **DAMPE**
- **Charge Reconstruction**
- **Results of DAMPE**
- **Summary**

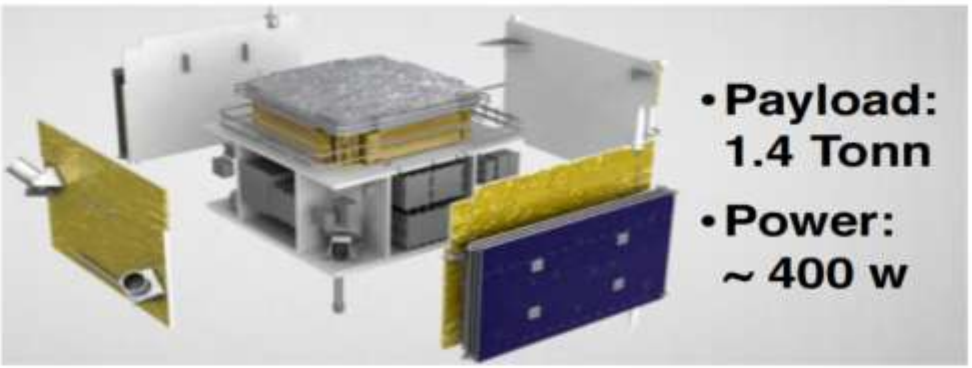


DArk Matter Particle Explorer (DAMPE)









DAMPE Charge measurement

Bethe-Bloch Equation:

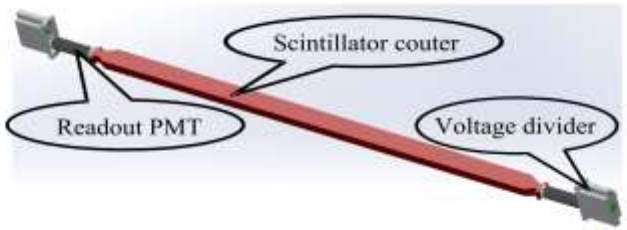
$$\left\langle \frac{dE}{dx} \right\rangle \propto z^2$$

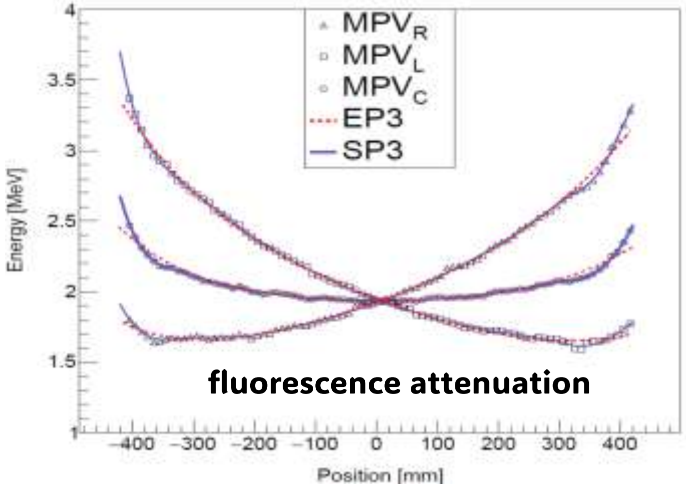
PSD Charge reconstruction:

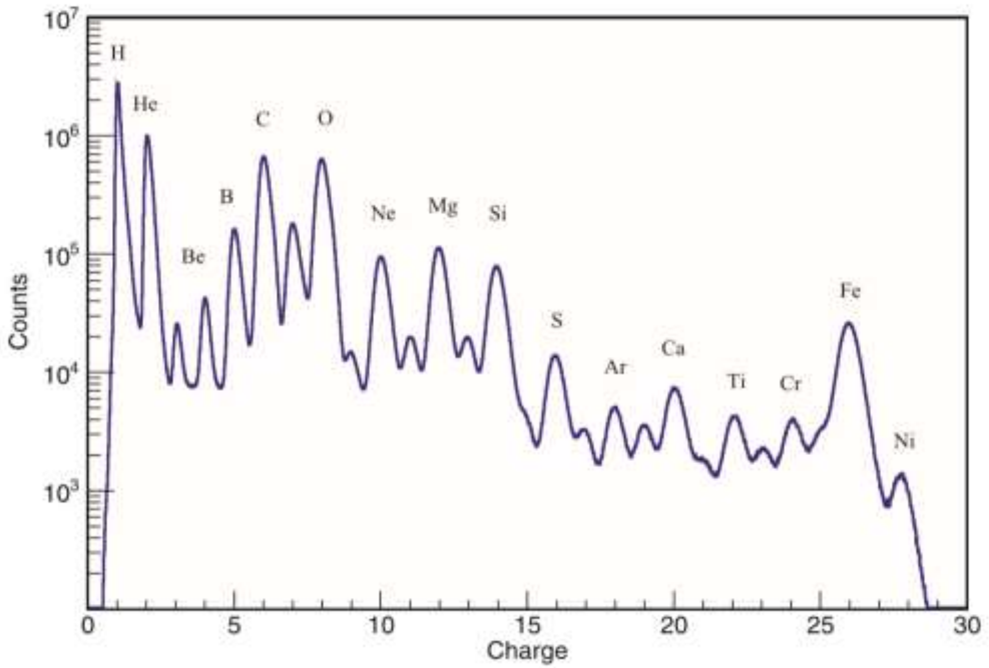
$$Q_{rec}^{L,R,C} = \sqrt{\frac{E^{L,R,C}}{A^{L,R,C}(x)} \times \frac{S}{L}}$$

Quenching Correction:

$$Q^{L,R,C} = f(Q_{rec}^{L,R,C})$$





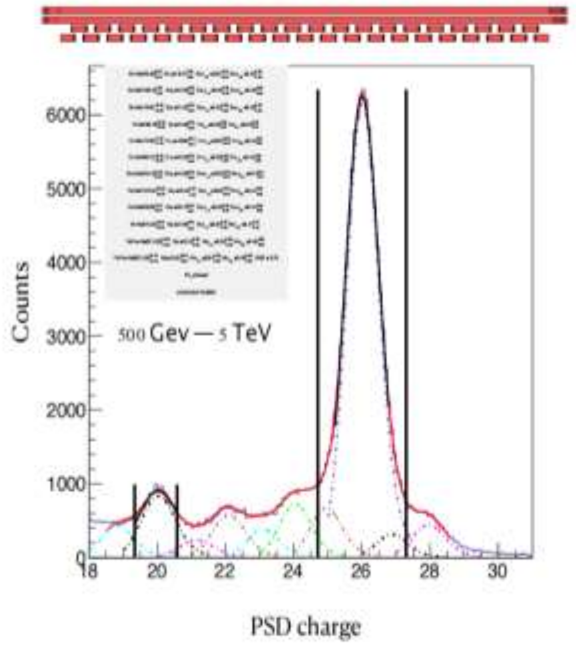


Element	σ_Z	Element	σ_Z	Element	σ_Z	Element	σ_Z
Li	0.14	C	0.18	Ne	0.21	S	0.25
Be	0.21	N	0.21	Mg	0.22	Ca	0.29
B	0.17	O	0.20	Si	0.25	Fe	0.30

M. Ding, Y.P Zhang et al, RAA 2019 Vol. 19 No. 3, 47(2019)
Dong T.K., Y.P Zhang et al. Astroparticle Physics 105, 31-36 (2019)

Charge Reconstruction

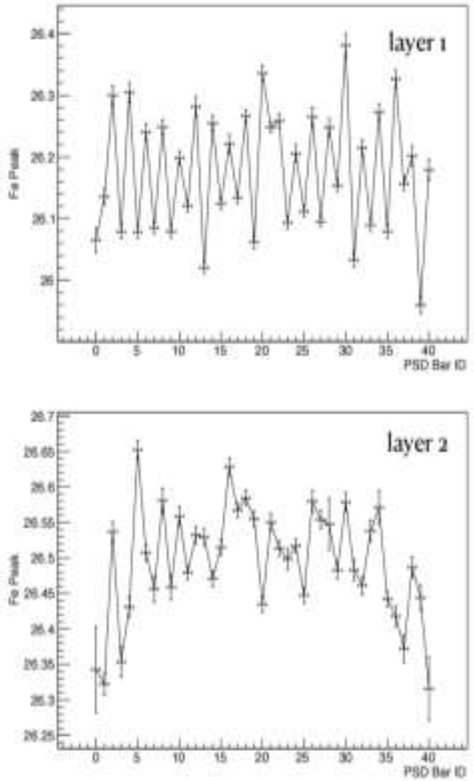
Charge Readout Correction



各PSD Bar电荷读出的偏移：$\delta_i = Fe\_P_i - 26$。

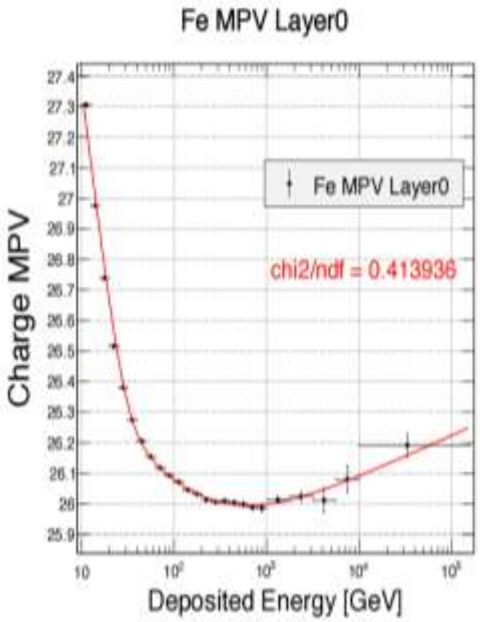
每一根PSD电荷独处的修正为：

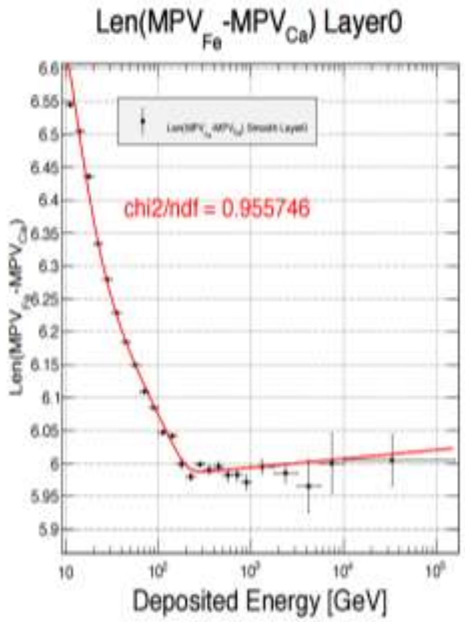
$C_i' = C_i - \delta i,\ i = 0, \cdots, 81,$



不同 PSD Bar 的拟合 Fe 峰值

Charge Vary with Energy

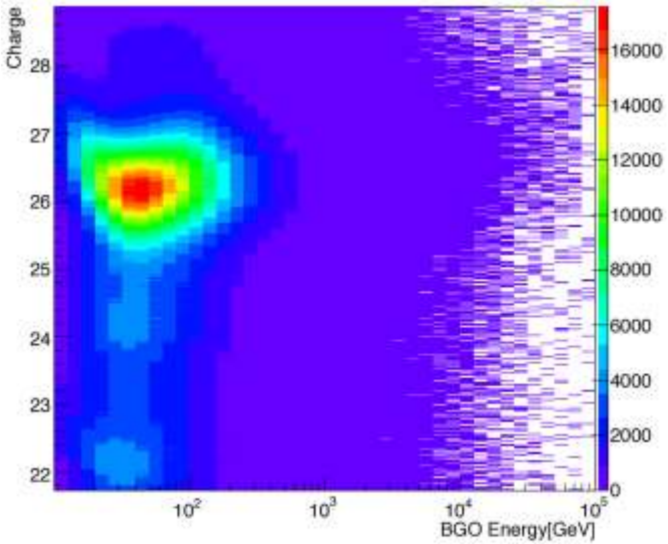


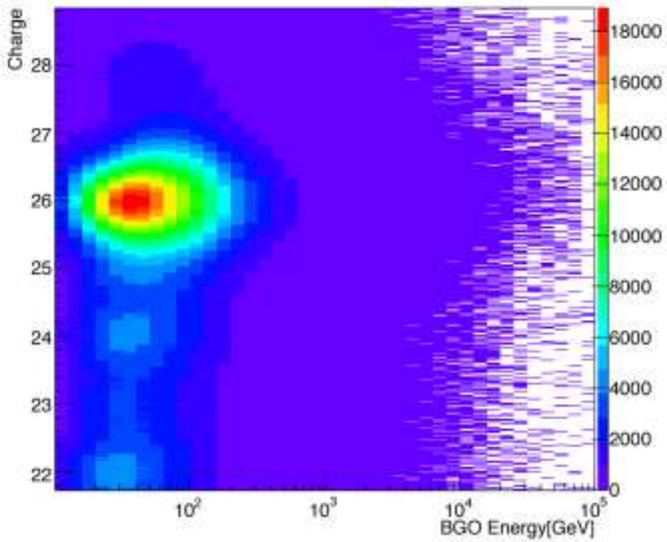


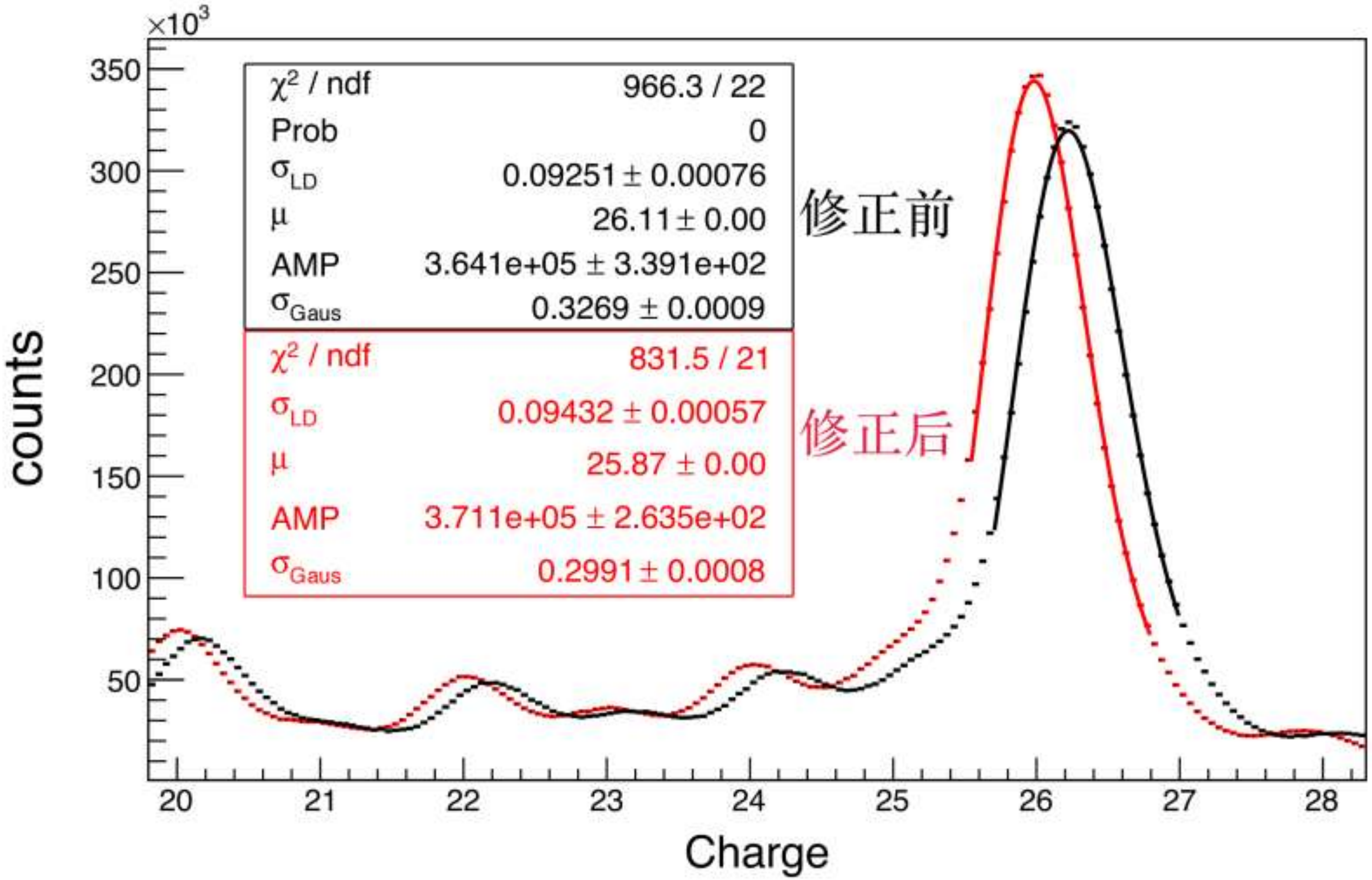
$C'' = (C_i' - Fe\_P_i) \times 6/(Fe\_P_i - Ca\_P_i) + 26,\ i = 0, \ldots, 3.$

Enhance Charge resolution and evaluate contamination

Charge Reconstruction

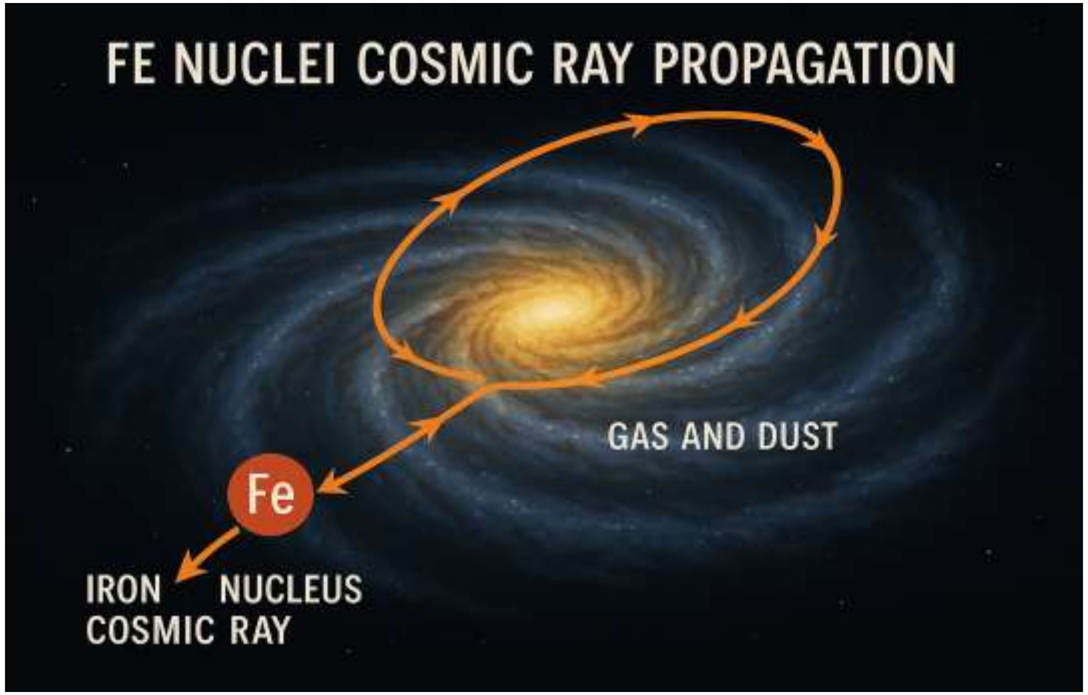


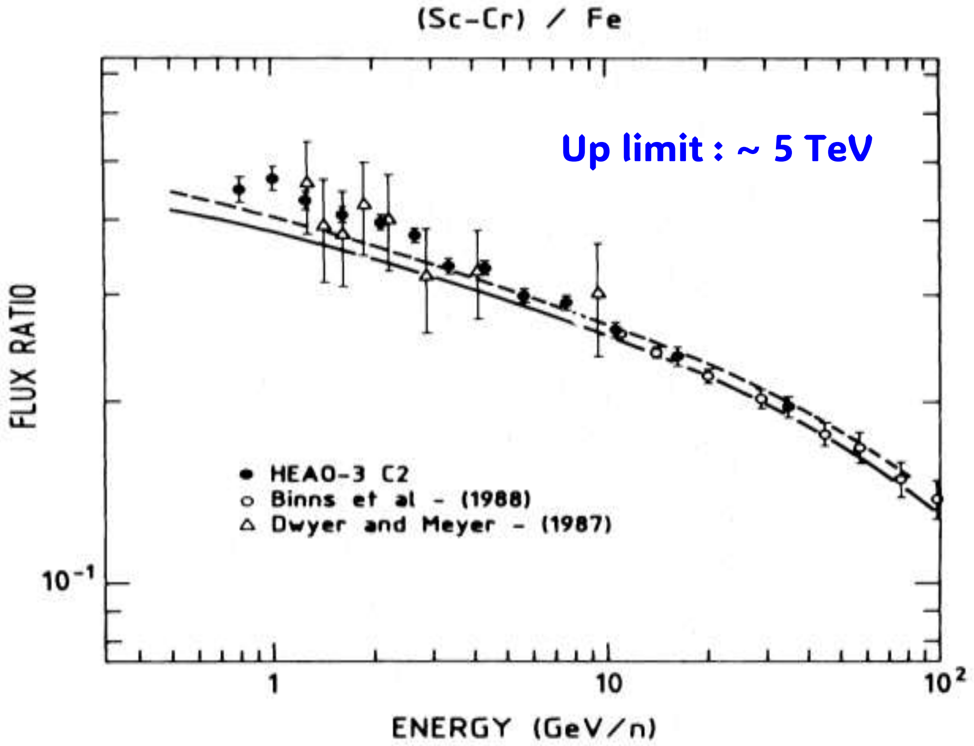




After PSD charge correction, Fe-charge value located in 26, Ca in 20.
Charge resolution improve ~10%.

Sub-Fe and Fe

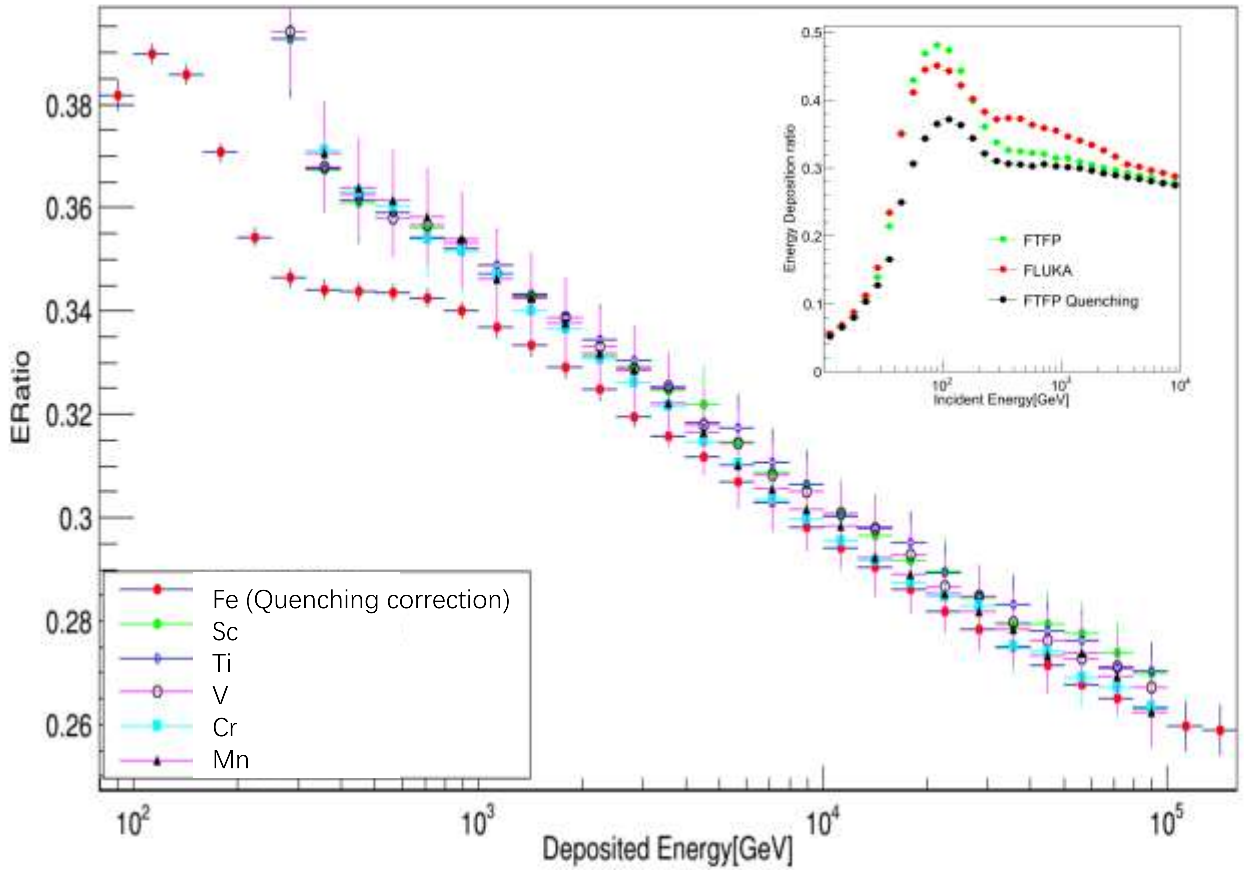


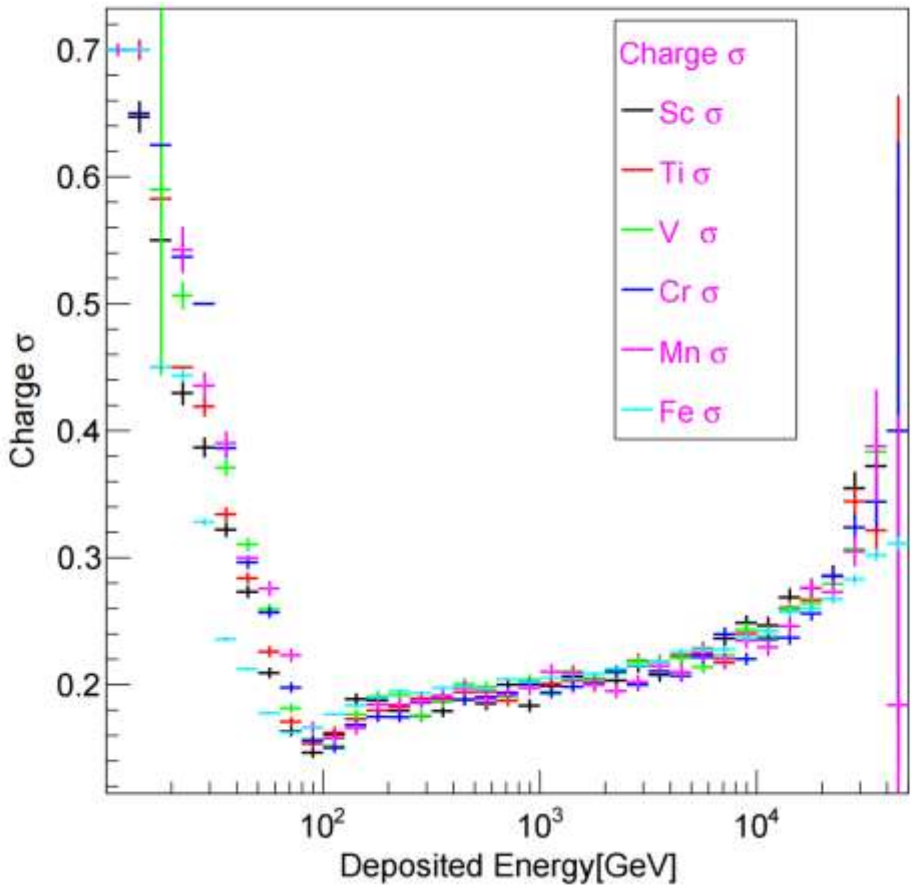


- Large Abundance and Fragment Crose section.
- The most effective probes of nearby cosmic-ray sources.
- The origin, acceleration, and propagation of heavy-nuclei cosmic rays.

No measurement the hardening of the subFe/Fe (hardening of B/C) or the bump feature of secondary nuclei.

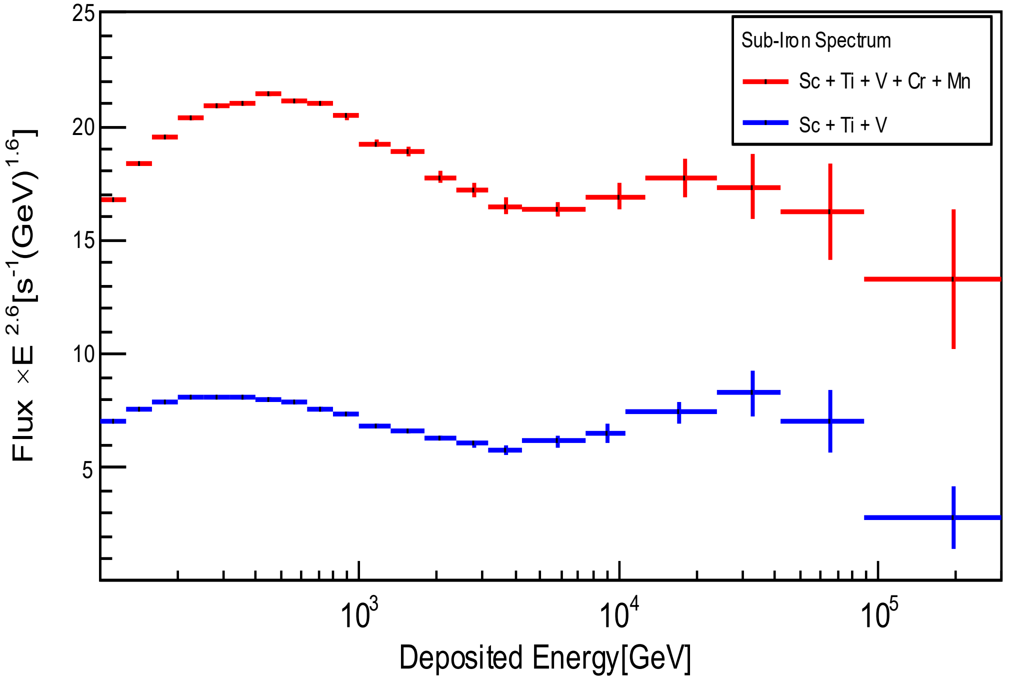
sub-Iron Energy Deposition and Charge

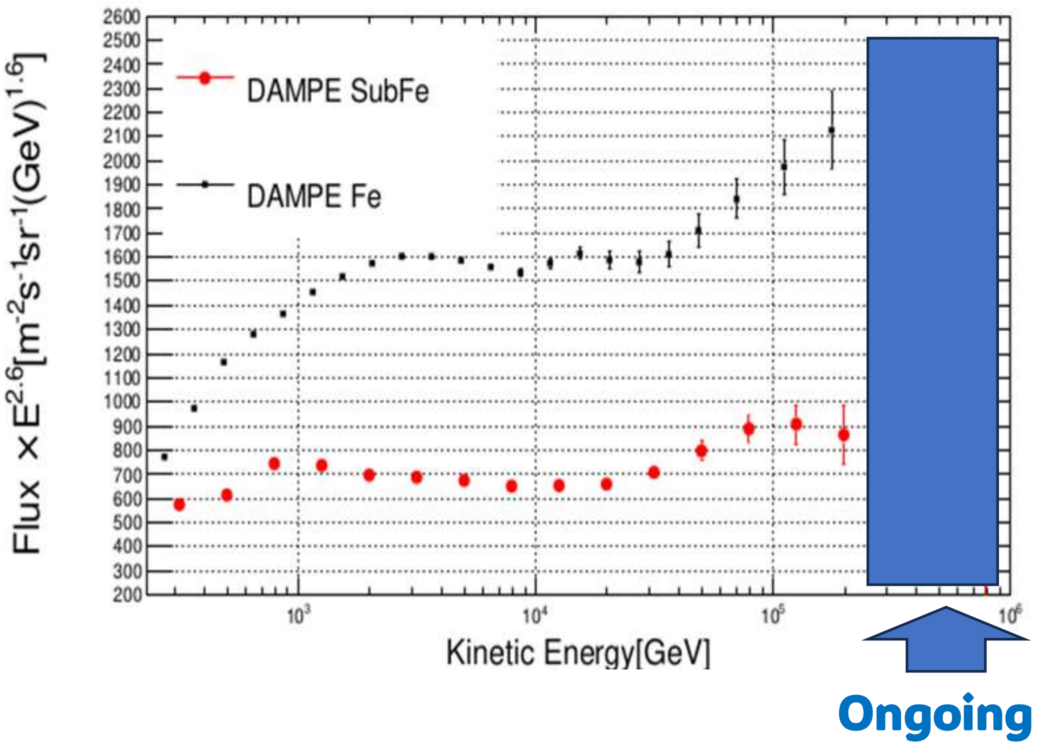




Sub-Fe and Fe has similar Energy deposition ratio and charge resolution.

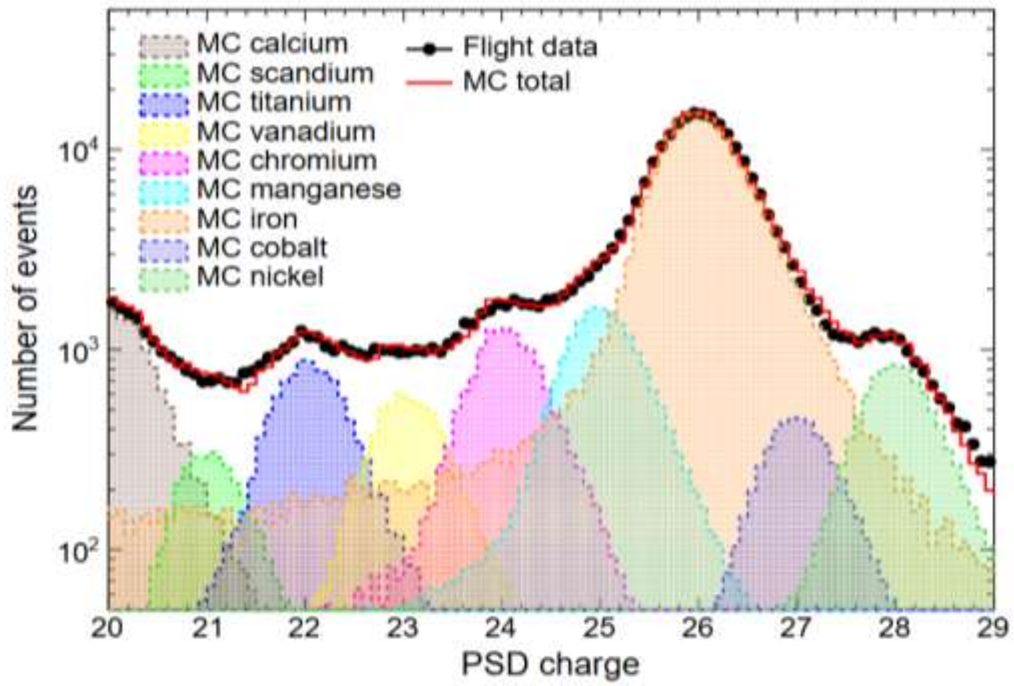
Flux of sub-Iron elements

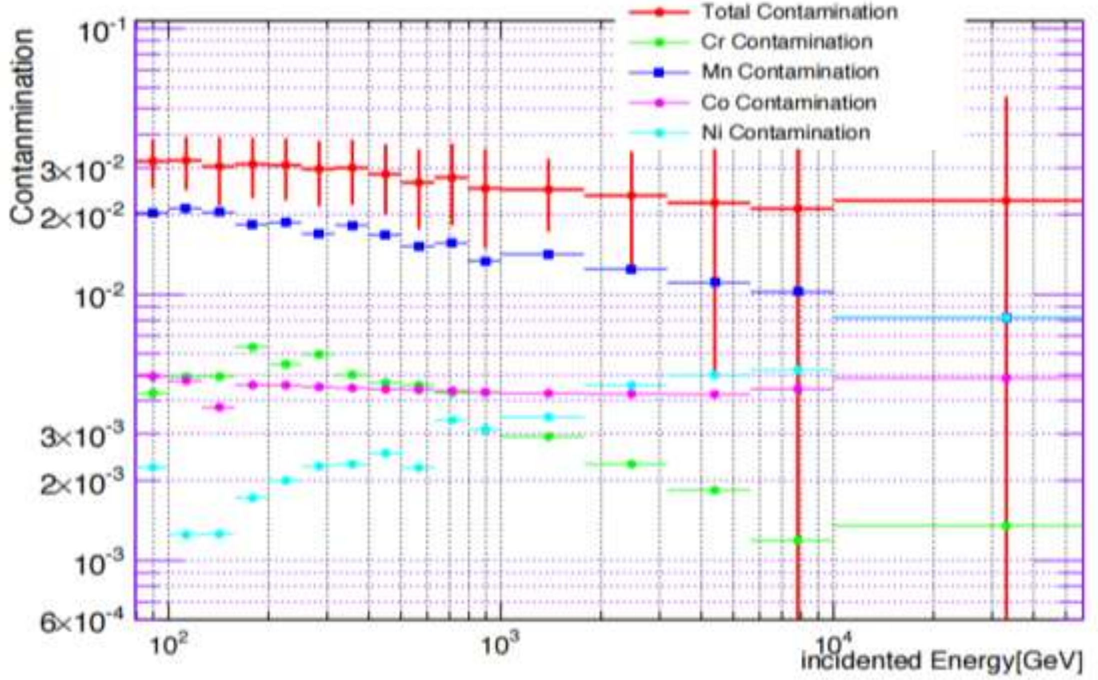




- **DAMPE sub-iron deposited spectrum find the bump structure.**
- **First-time measurement of the bump structure of secondary cosmic rays.**
- **The ratio of sub-iron and iron is the most powerful probe to investigate heavy nuclei propagation, and help us understand the origin of the bump structure.**

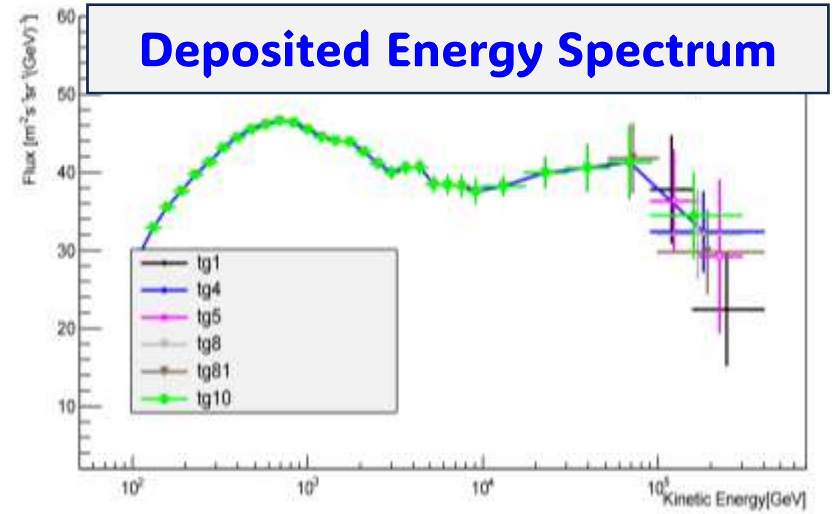
Fe Spectrum

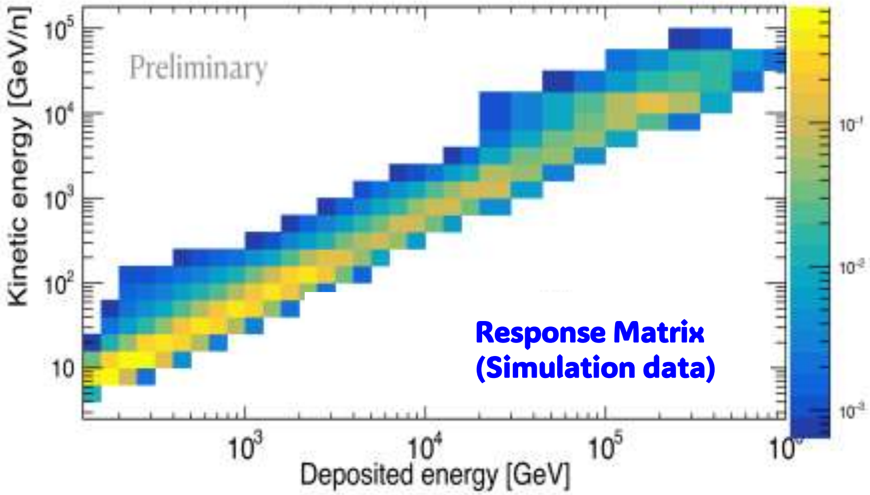




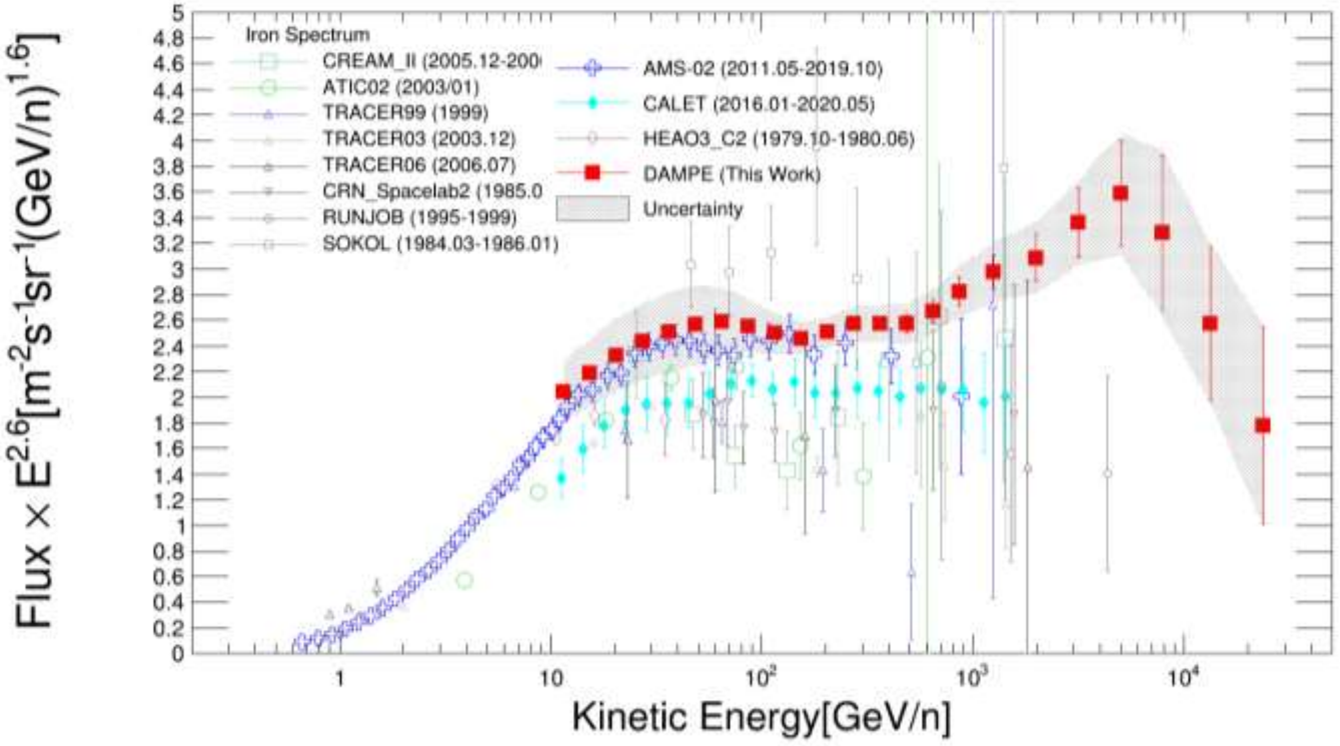
- Select Charge Range : 25.5 – 27.2
- Contamination of Fe main from Mn.
- All Contamination lower than 3.2%

Iron Spectrum



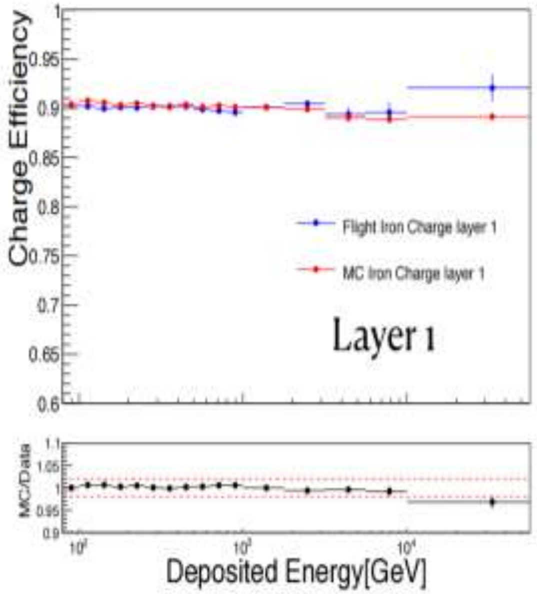


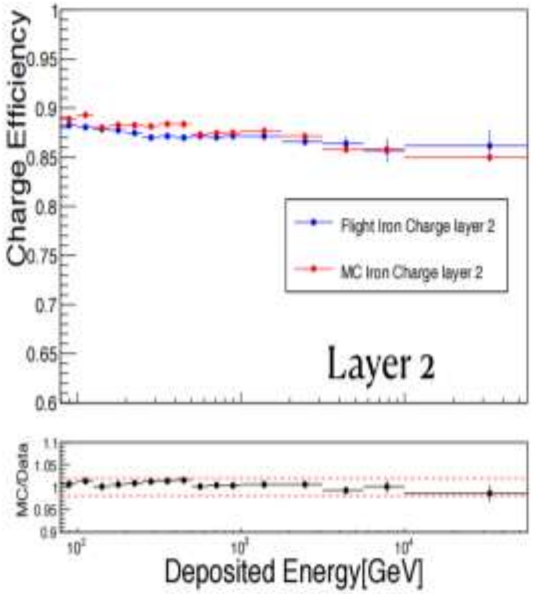
https://arxiv.org/abs/2511.05409

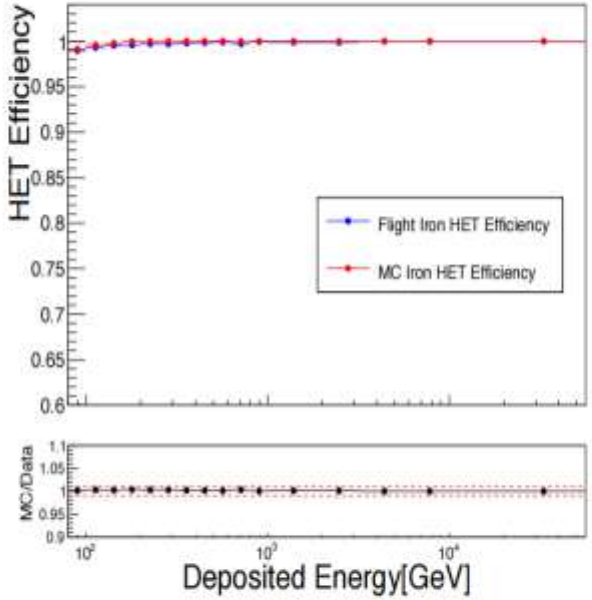


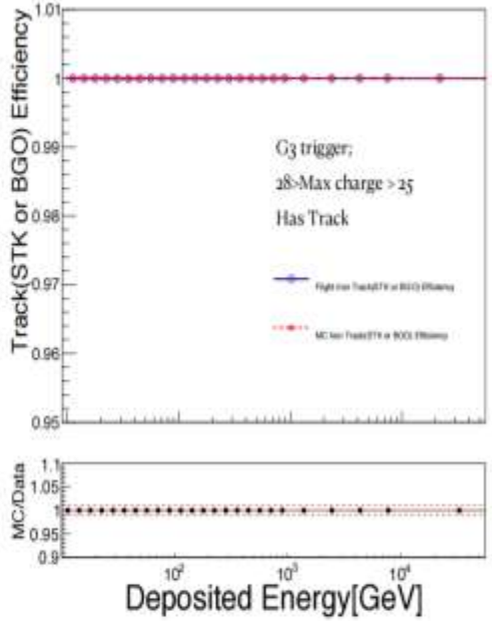
Soften: 2.4 σ, Harden: 2.7 σ.
PeV Iron Spectrum Reveals Bump at ~15 TV

Efficiency calibration









$$\varepsilon_{PSD1} = \frac{N_{PSD1|PSD2}}{N_{PSD2}}$$

$$\varepsilon_{PSD2} = \frac{N_{PSD2|PSD1}}{N_{PSD1}}$$

$$MC/Data < 2\% \, (Energy < 10TeV)$$

PSD charge Efficiency

$$MC/Data < 0.3\%$$

$$\varepsilon_{HET} = \frac{N_{HET|UNBT}}{N_{UNBT}}$$

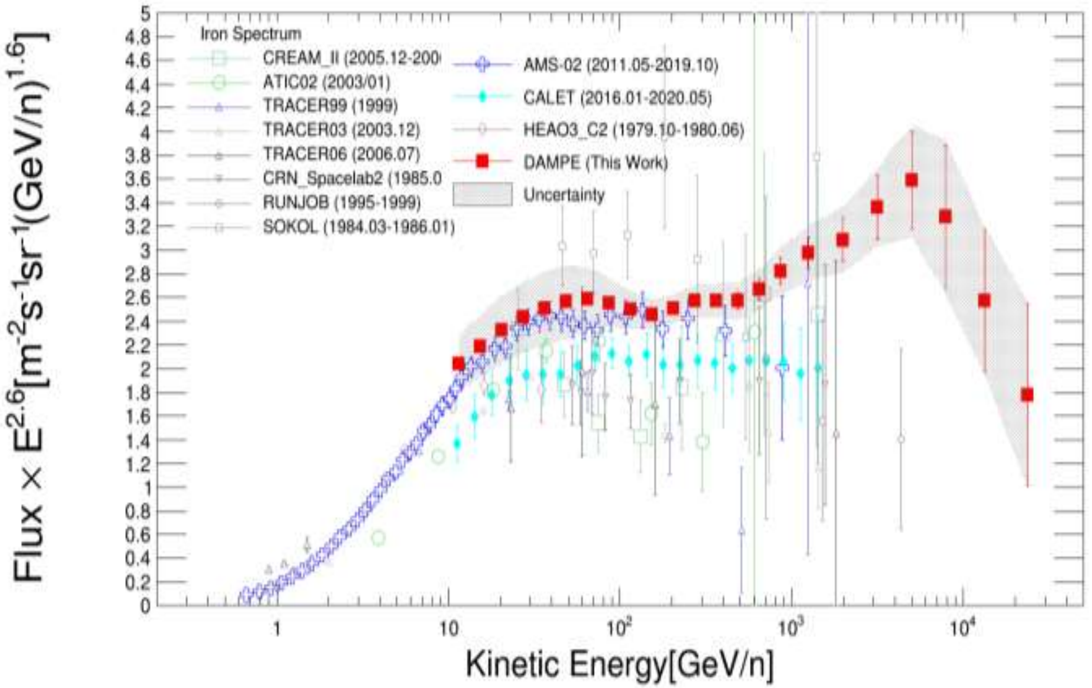
HET Efficiency

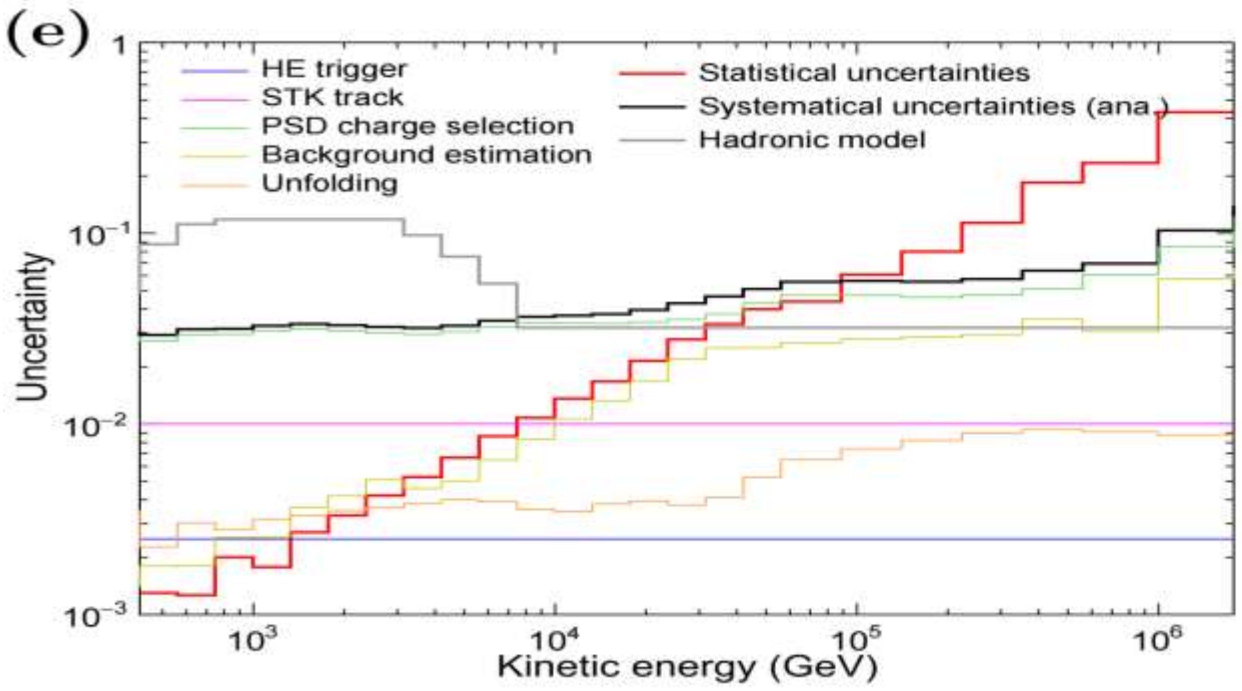
$$MC/Data < 0.01\%$$

$$Track\ Efficiency = \frac{Track(STK\ or\ BGO)}{Max\ Charge}$$

Track Efficiency

Iron Spectrum

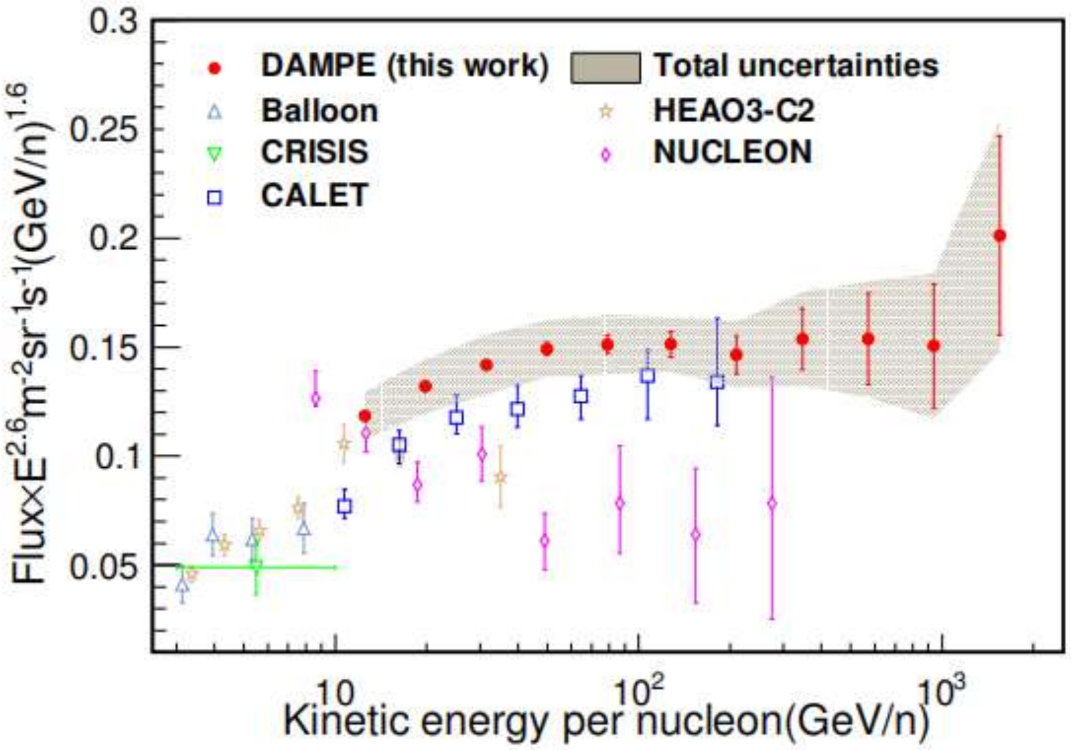


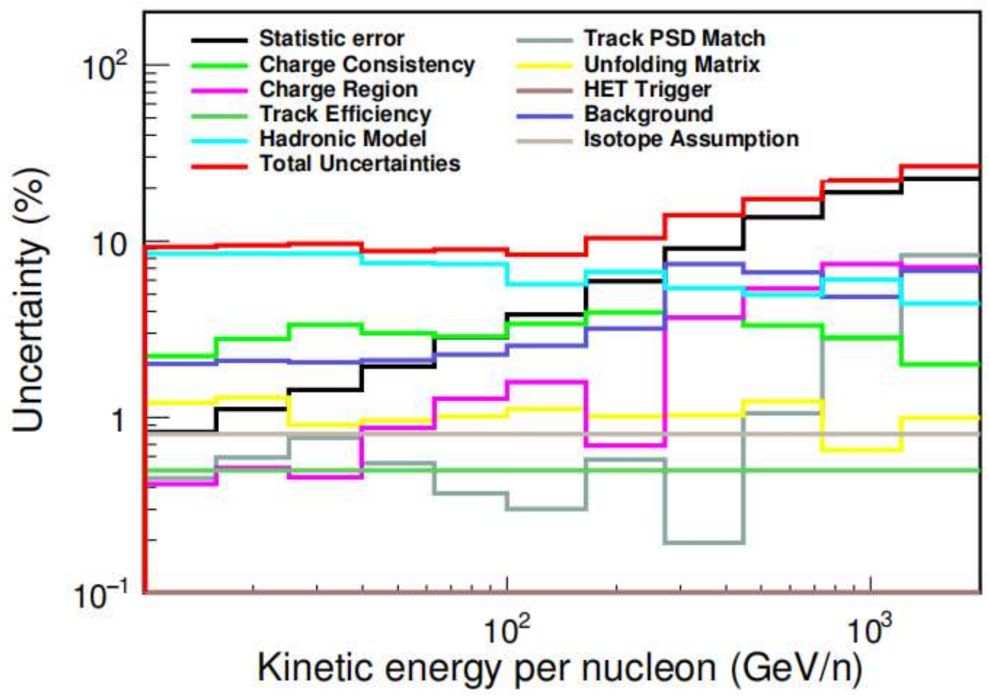


Analysis uncertainties of the iron spectrum.

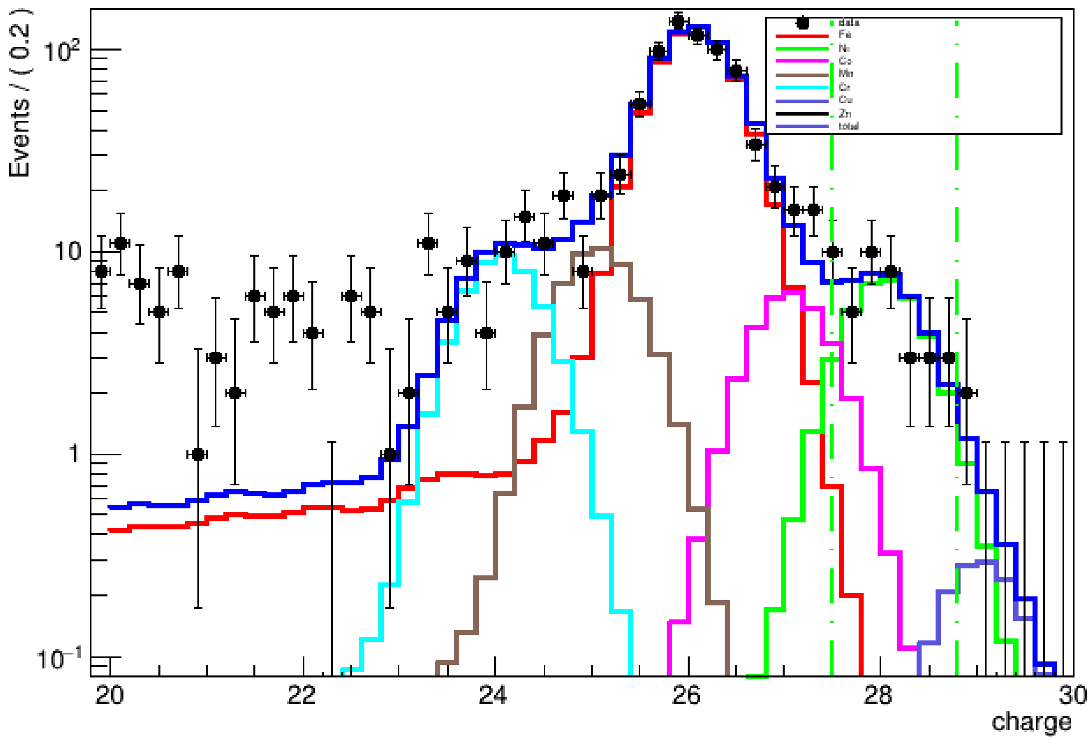
Nickel Spectrum

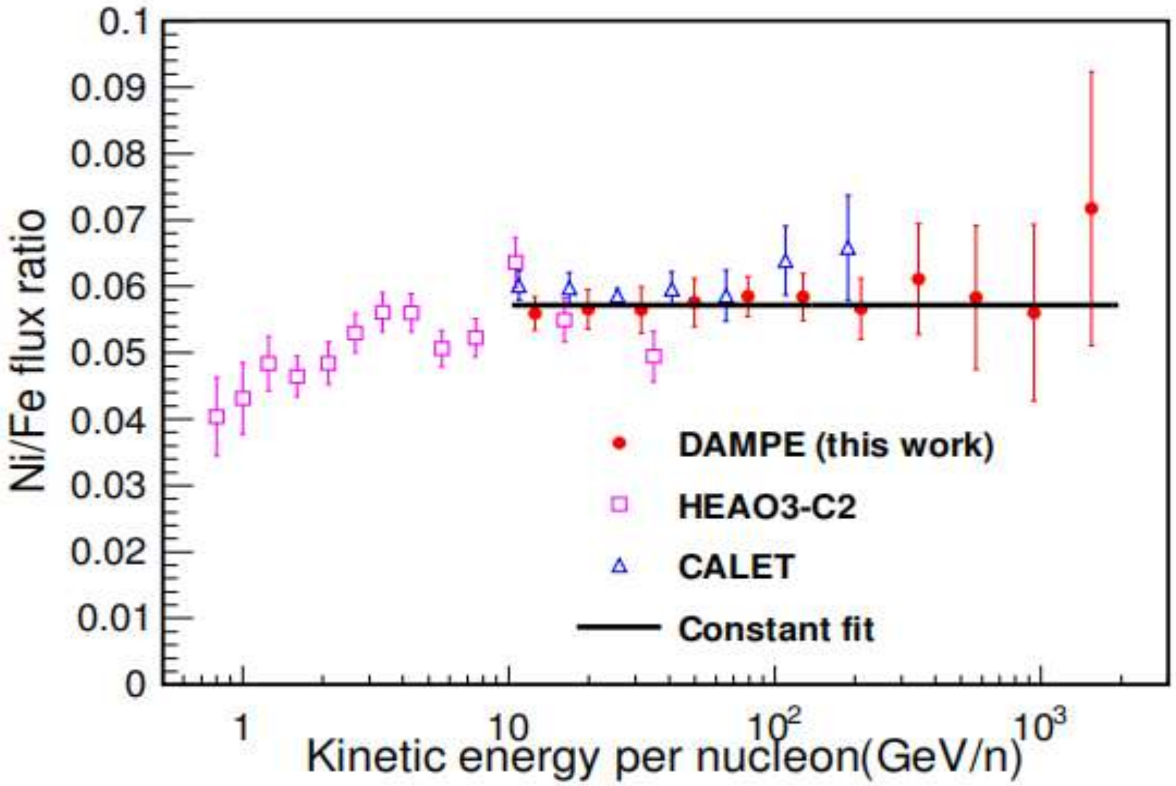
- The differential flux of nickel from 10 GeV/n to 2TeV/n was obtained.
- A similar structrue to CALET, but an absolute value shift
- A single power law is used to fit, with γ = -2.60±0.03





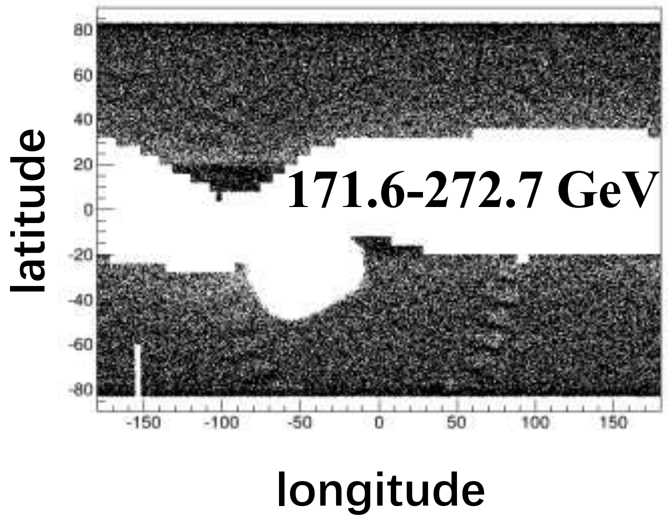
Nickel and Iron Spectrum Ratio

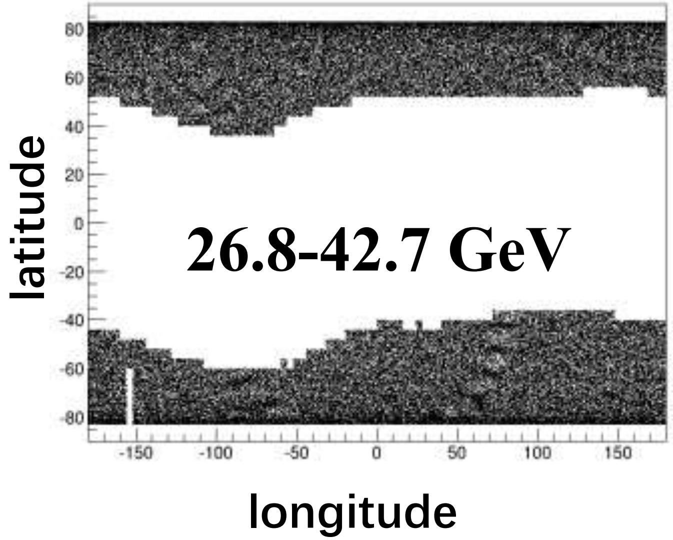


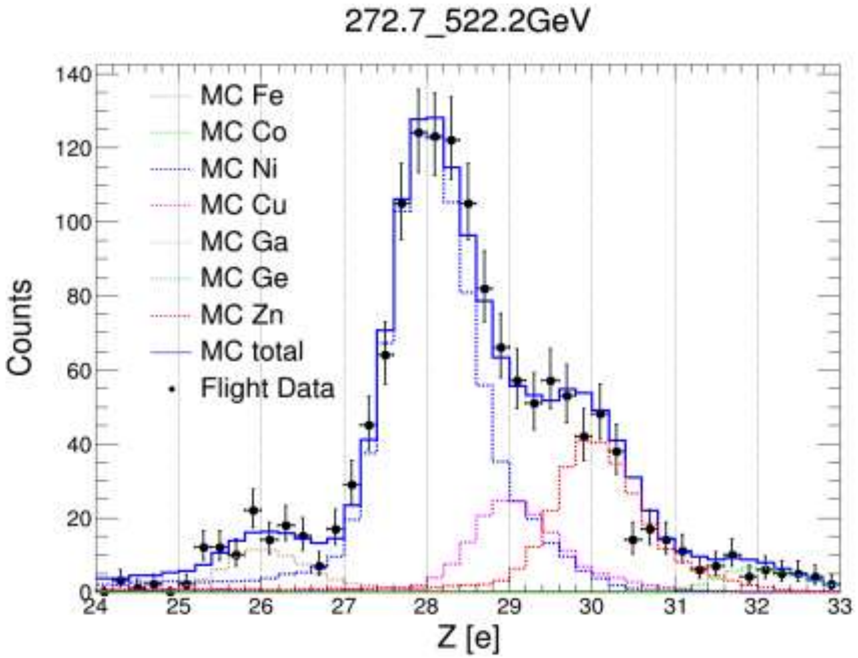


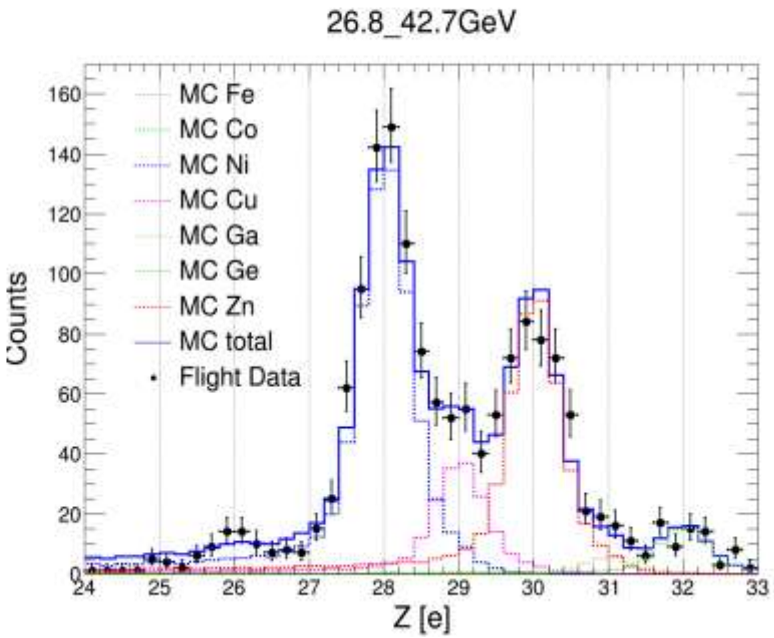
The nickel to iron ratio can be approximated by a constant fit 0.057.

Zn(Zinc) Spectrum



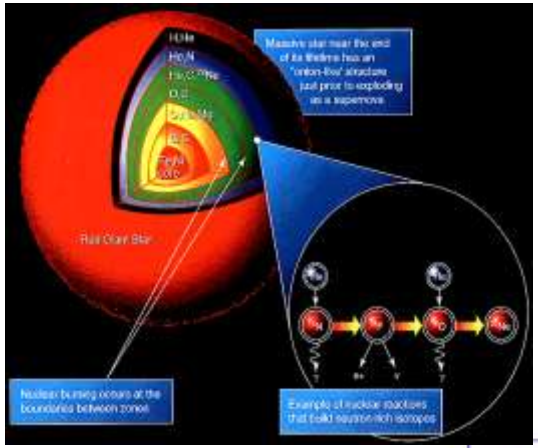




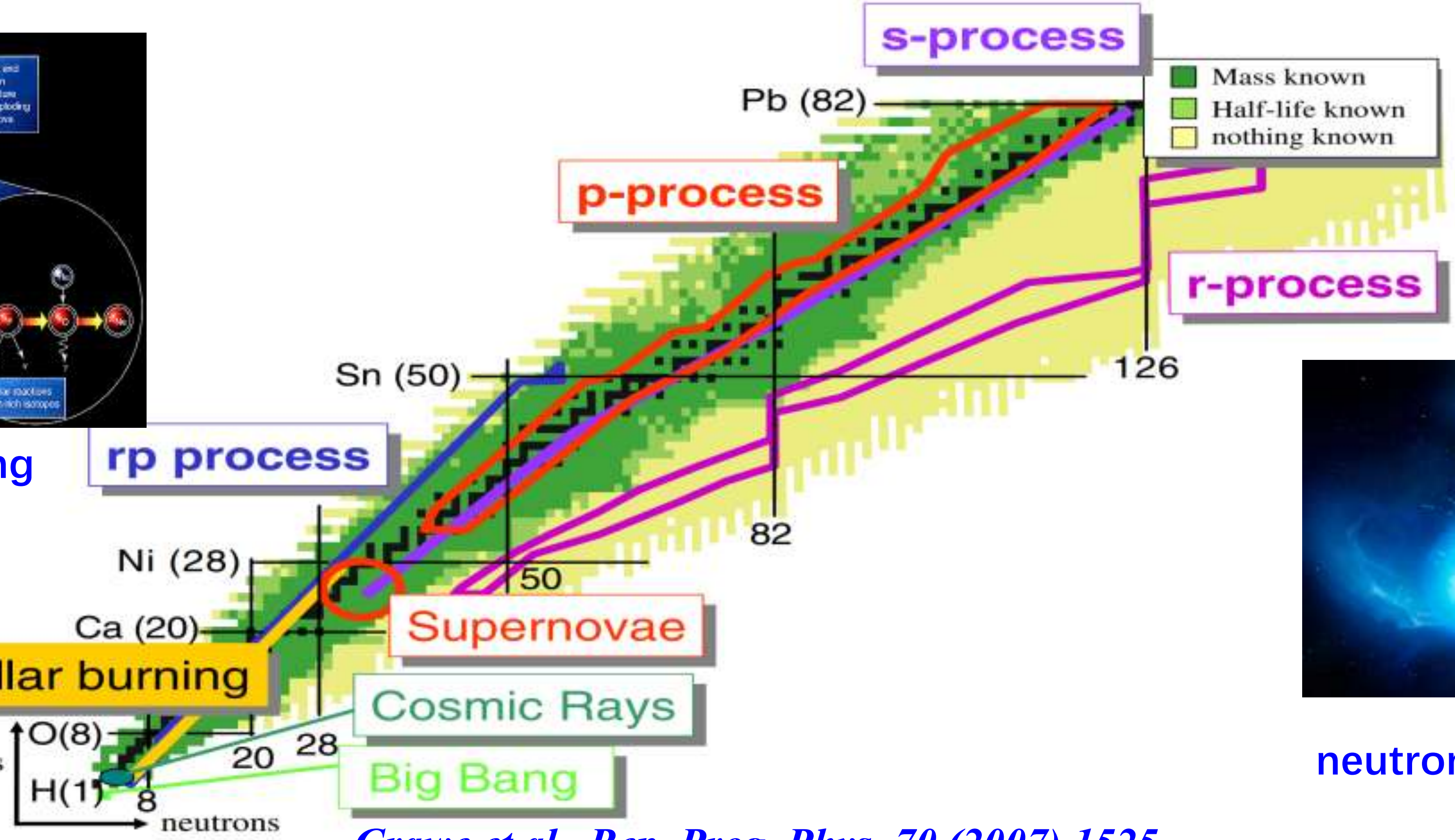


Measurement of the Zn Charge Spectrum Peak (20-500 GeV)
Enabled by DAMPE's superior charge resolution and large acceptance.

Origins of the Elements



stellar burning

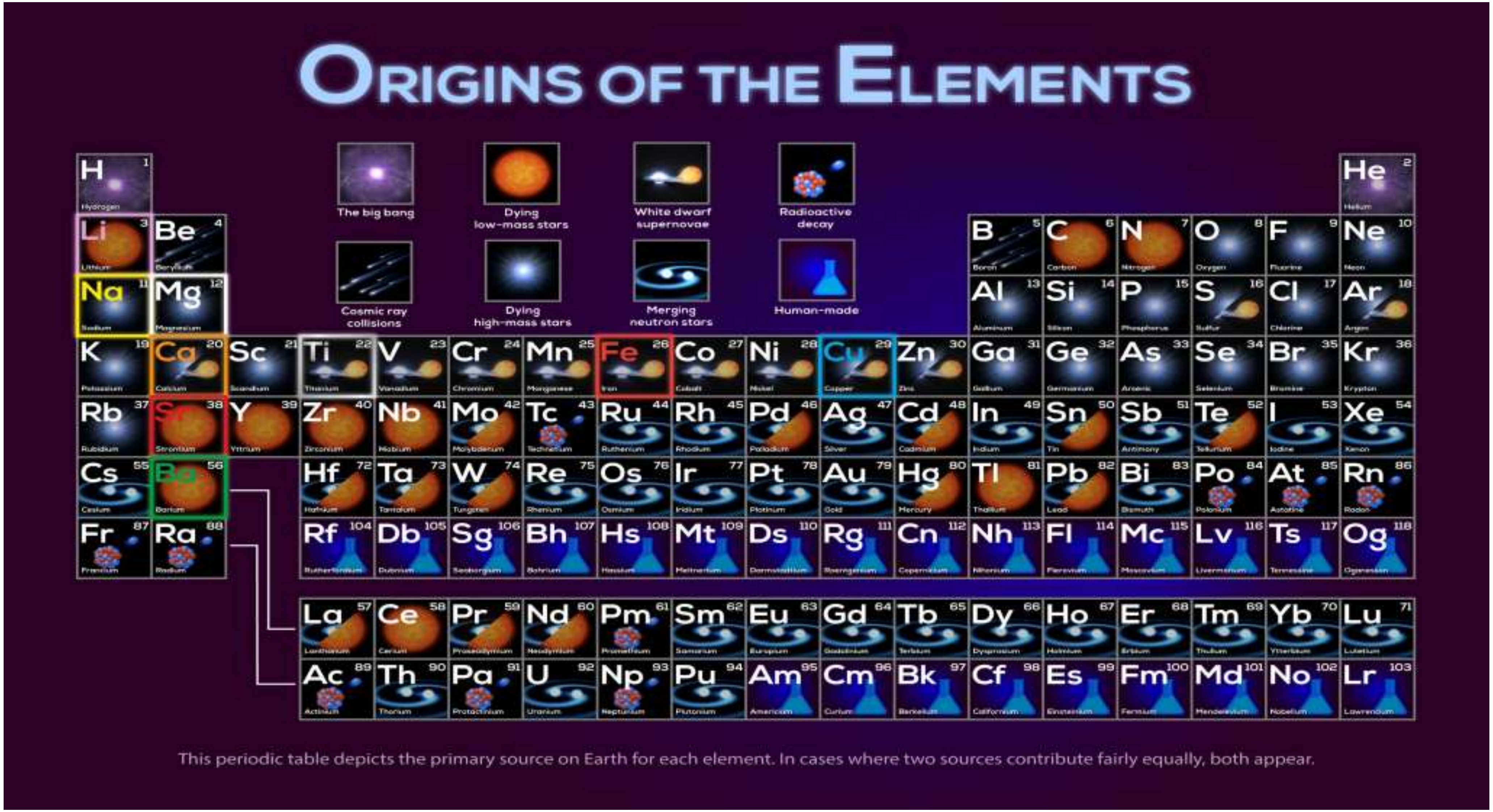


Grawe et al., Rep. Prog. Phys. 70 (2007) 1525

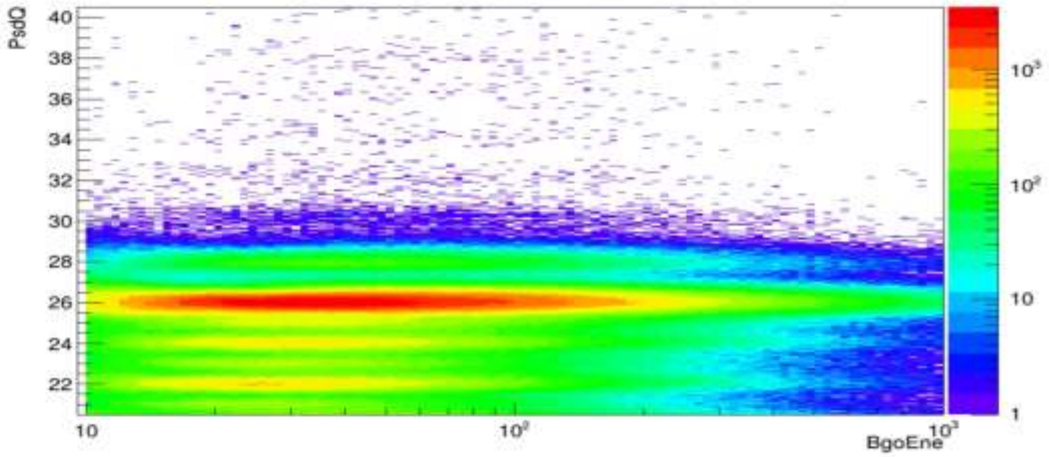
neutron star mergers

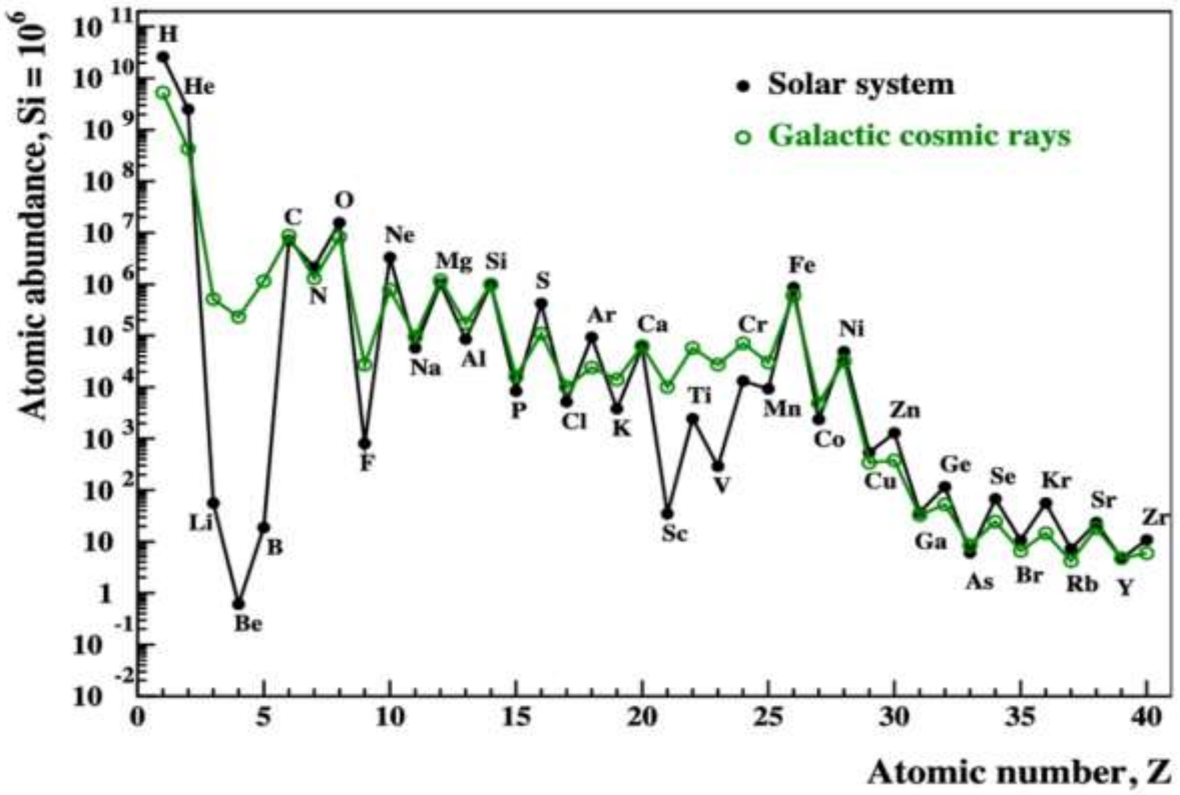
The relative abundances of Ultra-iron reveal production mechanisms (r or s process) and sources.

Origins of the Elements



Origins of the Elements



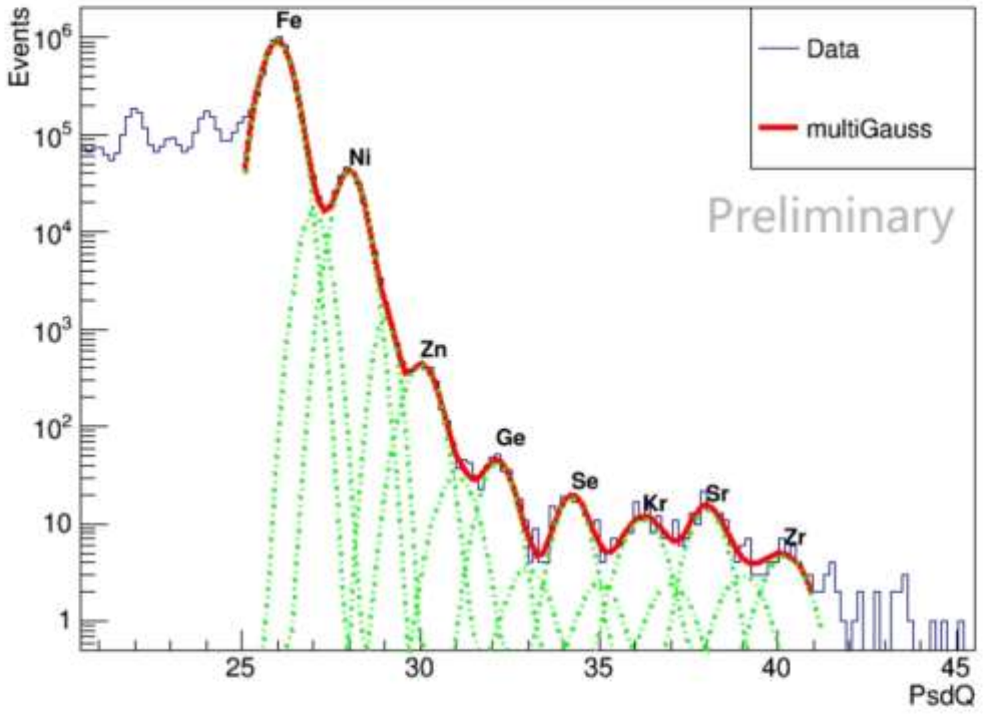


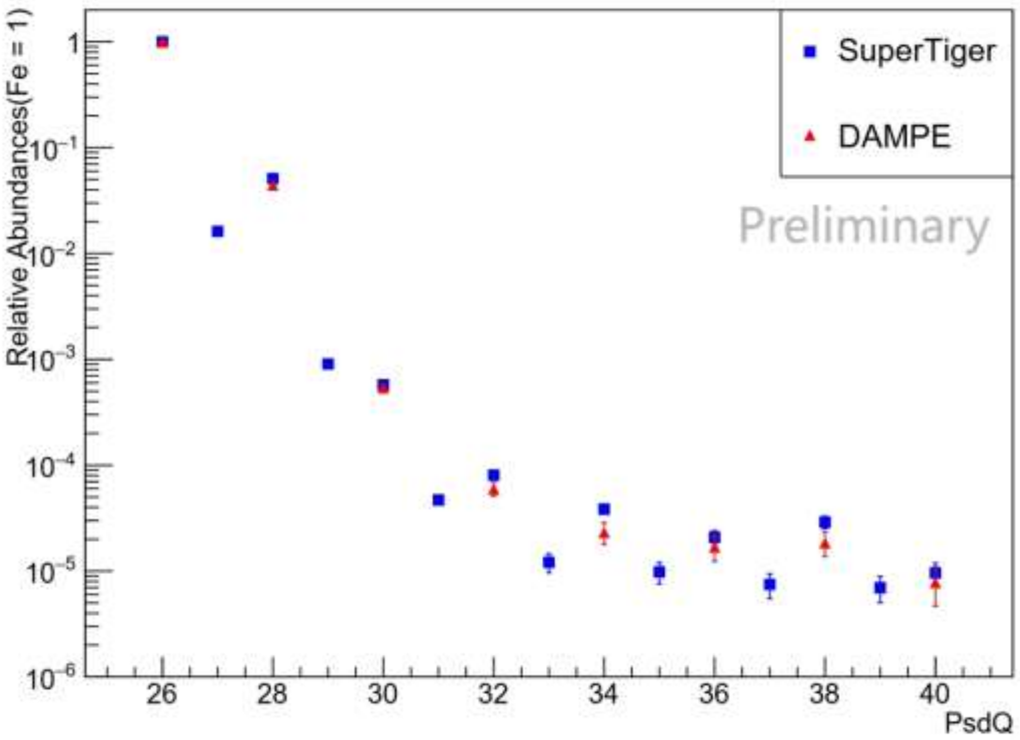
Experiment	Effective Acceptance ($m^2 \cdot sr$)	Observation Time (d)	Energy Range
CRIS	0.025	>8000	0.1–1 GeV/u
Super-TIGER	3.9	55	0.8–10 GeV/u
DAMPE	0.15	>3000	3 GeV–100 TeV

Broader energy range.
Largest event collection at high energies.

Ultra-Iron Nuclei Abundances

Relative abundance of ultra-Iron nuclei (norm. to Iron)





Summary

- We obtain a preliminary sub-Fe flux, The Energy Range bigger than previous. Need more MC data.
- Iron Spectrum show a bump structure, in low Energy Range Match Well with AMS-02.
- Ni Spectrum up to 2TeV/n was obtained, Zn Charge Peak observed in Charge Spectrum.
- Preliminary Ultra-Iron Spectrum obtained. Match wee with Super-Tiger

Thanks for your attention