Flux ratios of primary elements measured by CALET on the International Space Station

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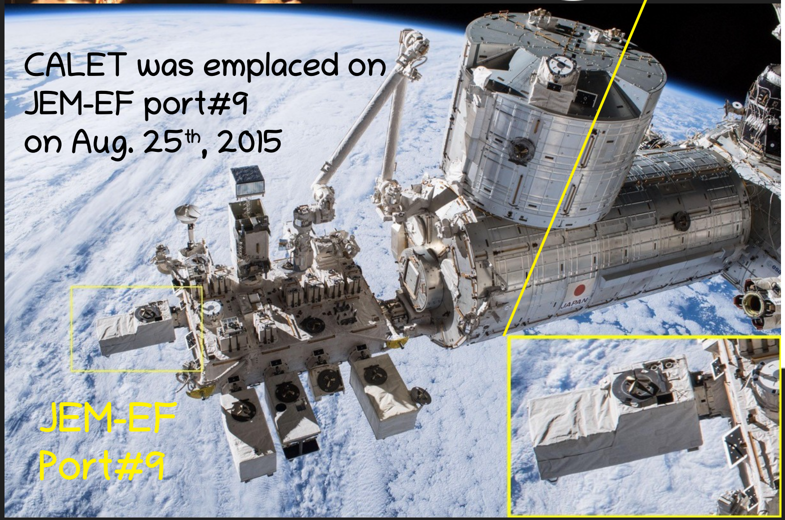
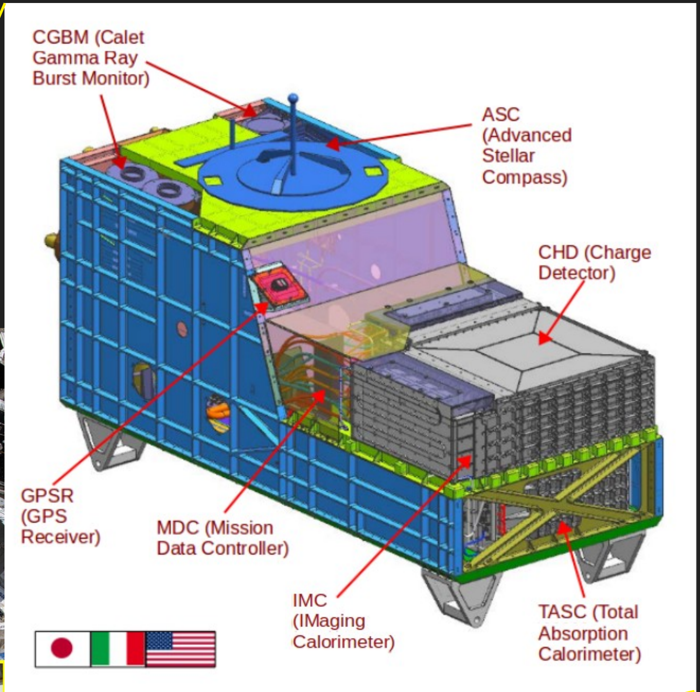
CALET Payload

CALET launch on Aug. 19th, 2015
on Japanese H2-B rocket

CALET was emplaced on
JEM-EF port#9
on Aug. 25th, 2015



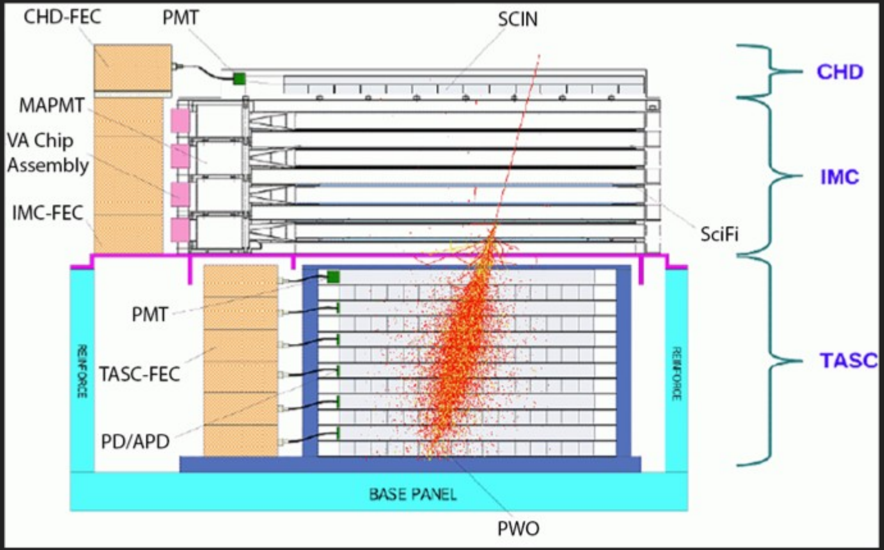


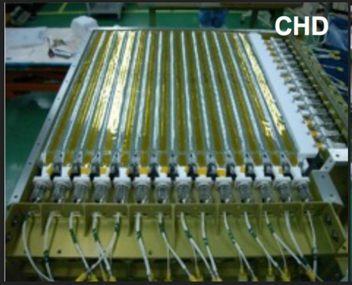
- JEM Standard Payload
- Mass: 612.8 kg
- Size: 1850 mm (L) x 800 mm (W) x 1000 mm (H)
- Power Consumption: 507 W (max)
- Telemetry: Medium (Low) 600 (50) kbps (6.5 GB/day)

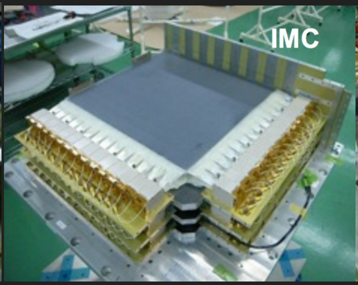
CALET started scientific observations on Oct. 13th, 2015
More than 3.8 billion events collected so far.

CALET Instrument

Field Of View: ~45° from Zenith Geometrical Factor: ~1040 cm^2sr (for e^-) Total thickness: 30 X_0 1.3 λ_I







A 30 radiation length deep calorimeter designed to detect electrons and gammas up to 20 TeV and cosmic rays up to 1 PeV

CHD (Charge Detector)

- 14x2 plastic scintillator paddles
- Single element charge ID from *p* to *Fe* and above (Z = 40)
- Charge resolution: 0.15 *e (C)*, 0.35 *e (Fe)*

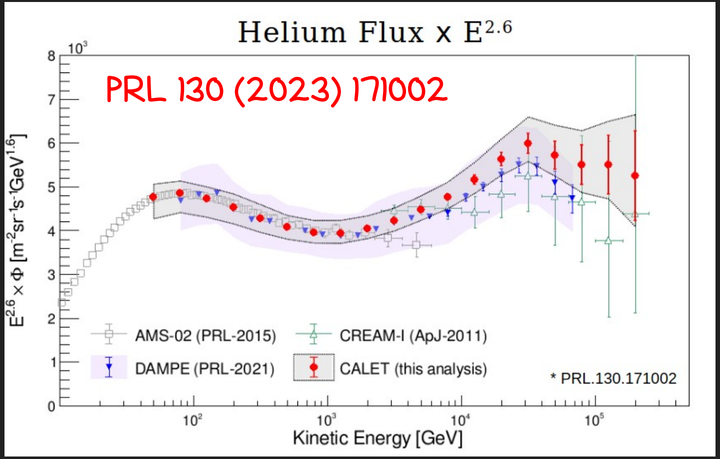
IMC (Imaging Calorimeter)

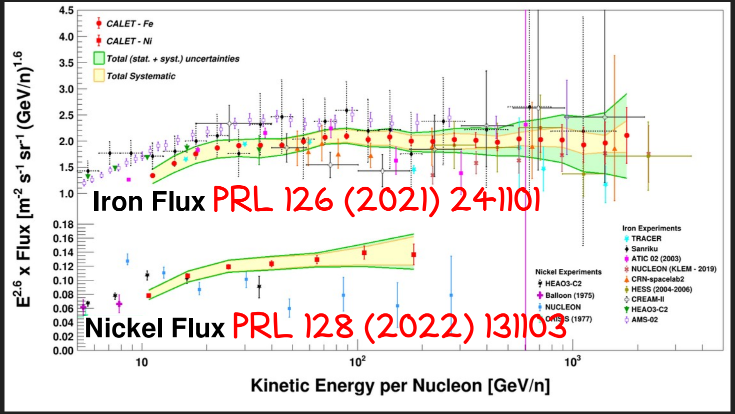
- SciFi belts (8x2x448, 1 mm^2) + Tungsten plates (7 layers: 3 X_0 = 0.2 X_0 x 5 + 1.0 X_0 x 2)
- Track reconstruction and particle ID (up to Z = 14), shower imaging
- Angular resolution: ~ 0.1°, Spatial resolution on top CHD: ~200 μm

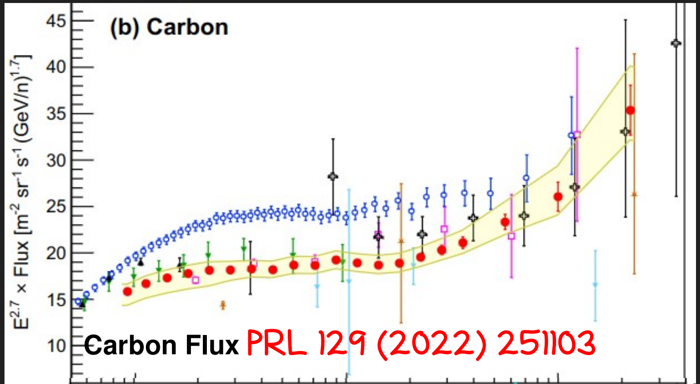
TASC (Total Absorption Calorimeter)

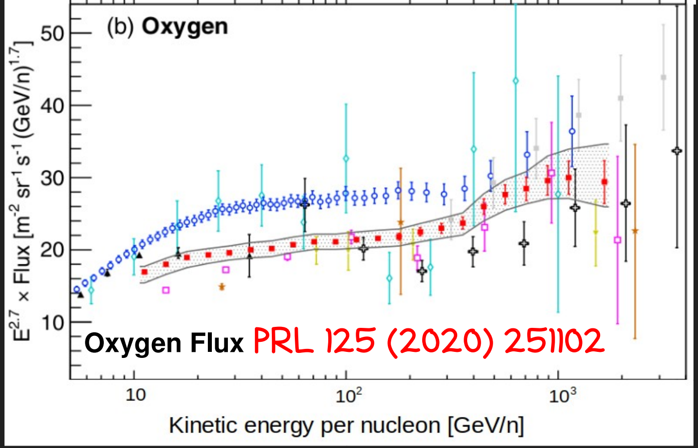
- 16 x 12 PWO logs: 27 X_0 (for e^-), 1.2 $_I$ (for p)
- Energy resolution: ~ 2% for e^- (>10 GeV), ~30-35% for p and nuclei
- e/p separation: ~10^5

Primary Nuclei Observation with CALET









Wide dynamic range (1-10^6 MIP)
Large thickness (30 X_0 , ~1.3 λ_I)
Excellent charge ID (~ 0.1 *e*)

CALET can cover the whole energy range previously investigated in separate subranges by magnetic spectrometers and calorimeters.

The flux ratio between heavy primaries (Fe and Ni) and light one (He, C and O):

- Assess the relative abundances
- Understand their propagation

Analysis procedure for primary nuclei

MC simulation of the apparatus based on EPICS (w/DPMJET-III)
Energy measurement: reconstruction of primary energy through beam test calibration
Charge reconstruction by measuring the ionization deposits in the CHD and IMC

Event selection:

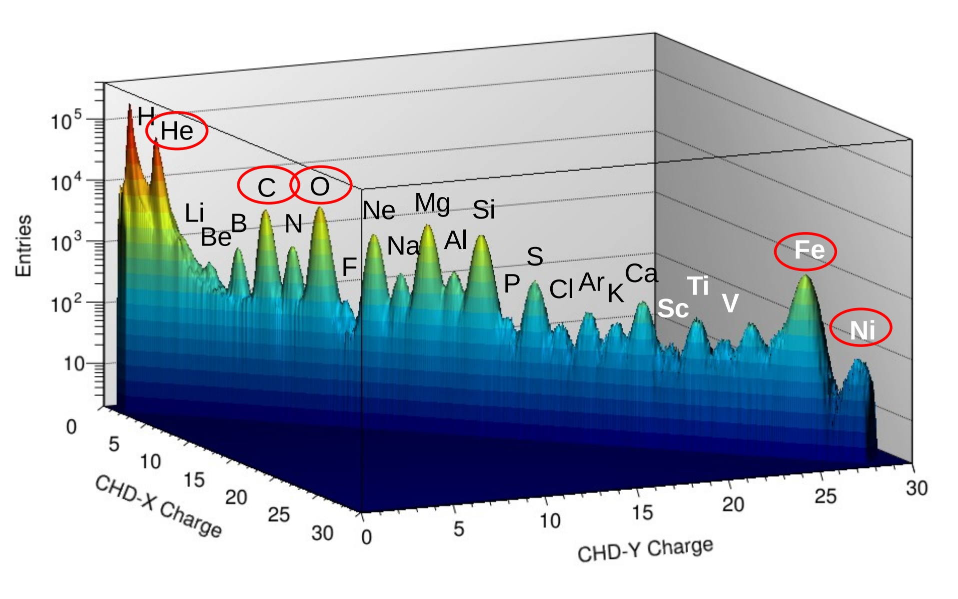
1) High energy shower trigger
1b) Off-line trigger confirmation (He, C, O)
1c) Shower event selection: selects interacting particles (Fe, Ni)
2) Rejection of events entering from lateral sides (B, C, O, He)
3) IMC reconstructed track
4) Acceptance Cut
4a) Off acceptance rejection cut (He)
5) Charge consistency Cut: removes charge-changing particles in the upper part of the detector
6) Charge selection

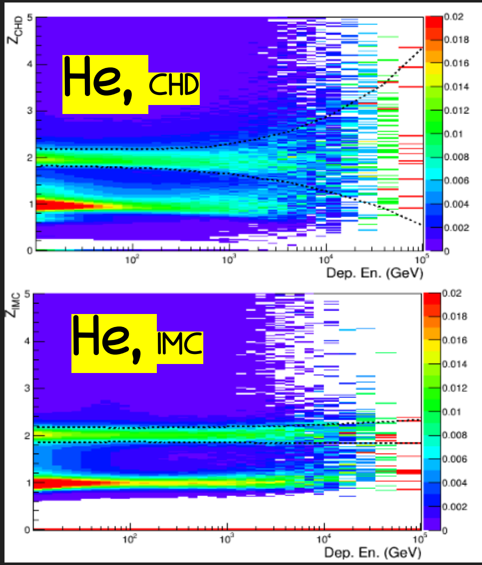
Sample used to compute the flux ratios:
86 months for C, O, Fe & Ni
78 months for He

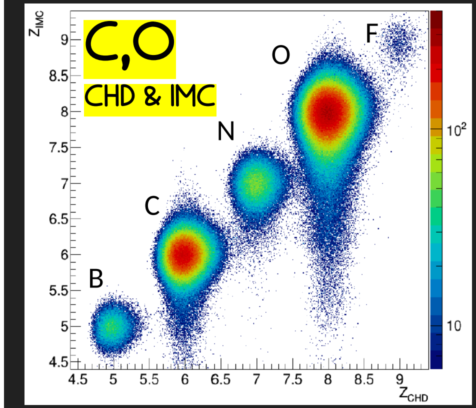
The same binning is used:
5 bins/decade

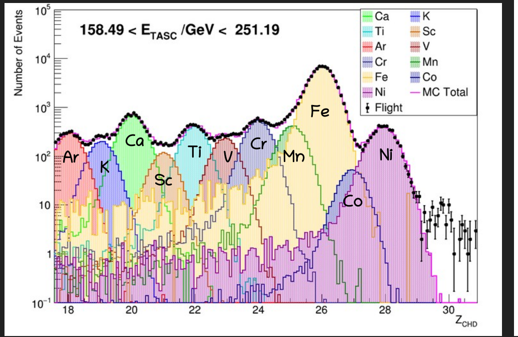
Charge Identification

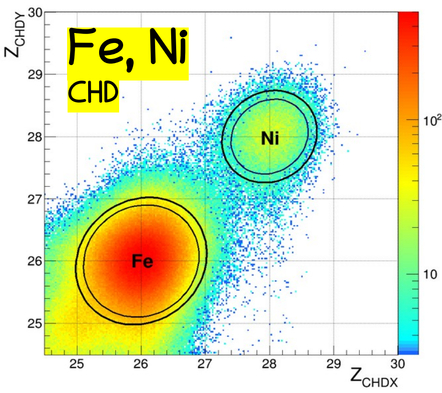
Single element identification for p, He and light nuclei is achieved by CHD+IMC charge analysis. Above Z=14 (Si) only CHD is used.









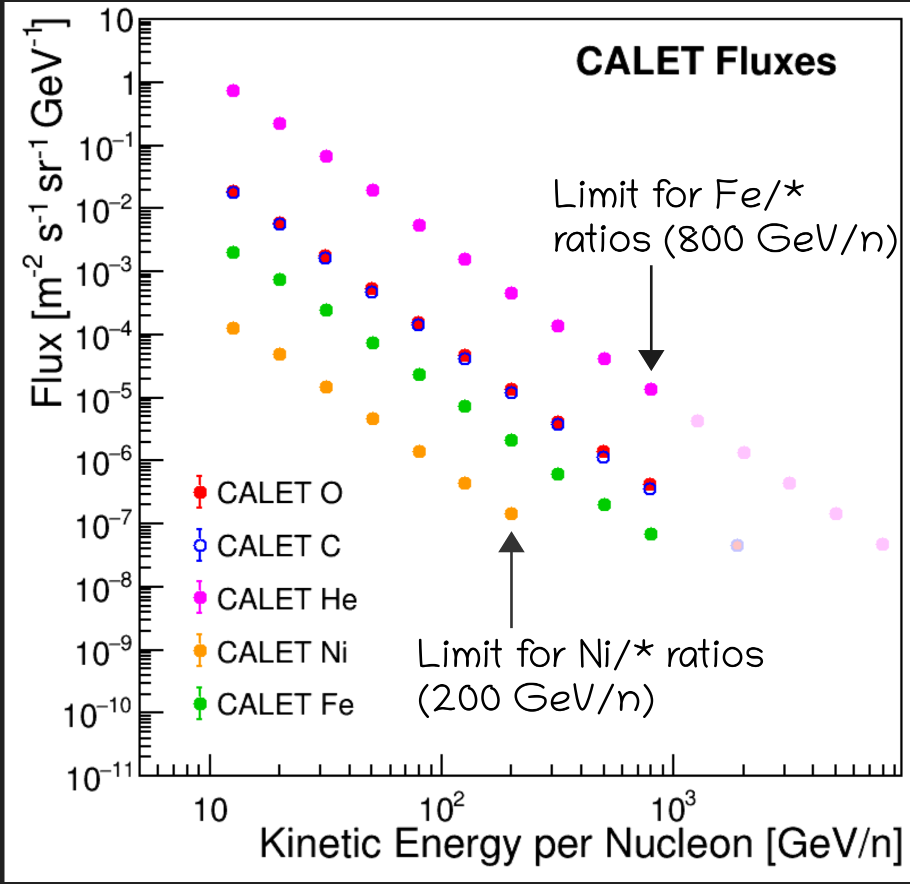


Deviation from Z^2 response is corrected both in CHD and IMC using a core + halo ionization model (Voltz)

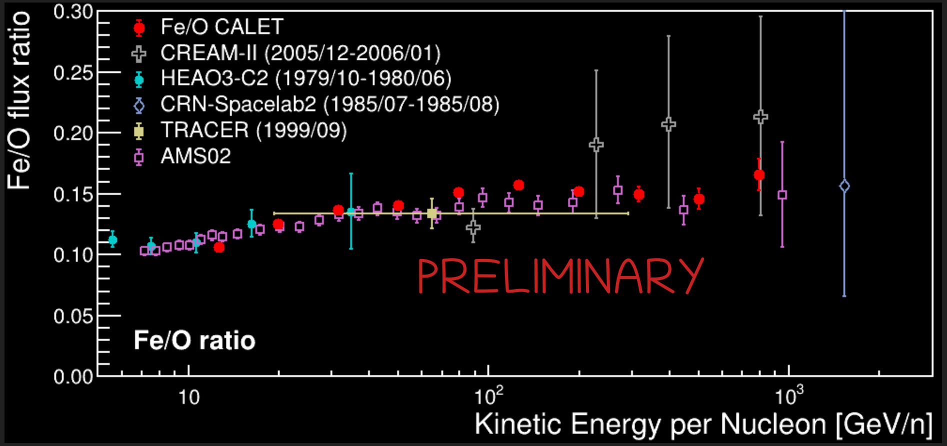
The flux measurement

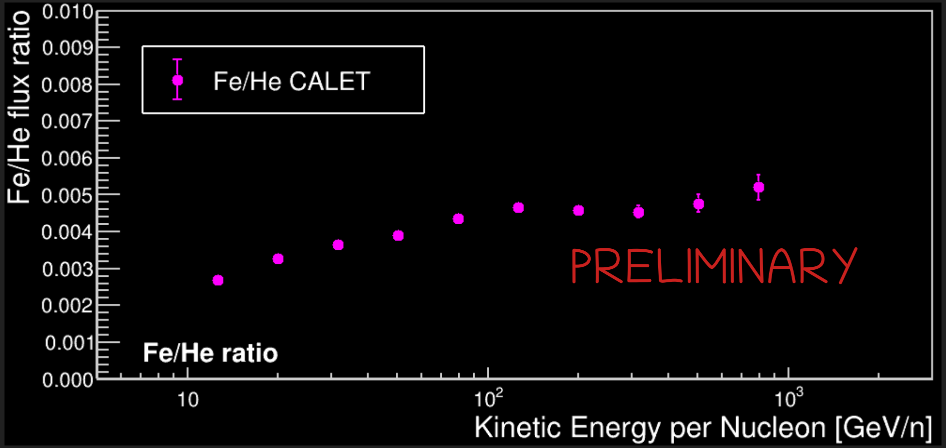
$$\Phi(E) = \frac{N(E)}{\epsilon(E)\Delta E\, S\Omega T}$$

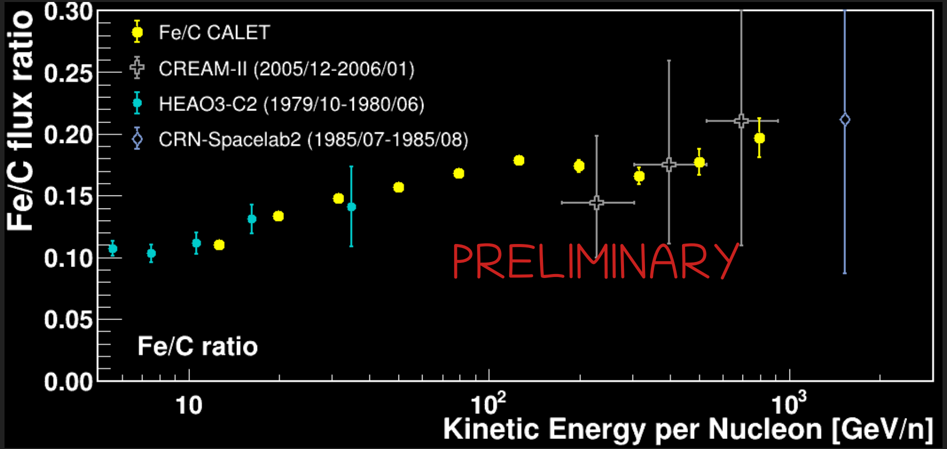
- N(E): number of events in each reconstructed energy bin
- ΔE: bin width
- ε(E): global efficiency
- SΩ: geometrical factor (~510 cm^2 sr)
- T: total live time (5.3 x 10^4 h)



The Fe/* flux ratio

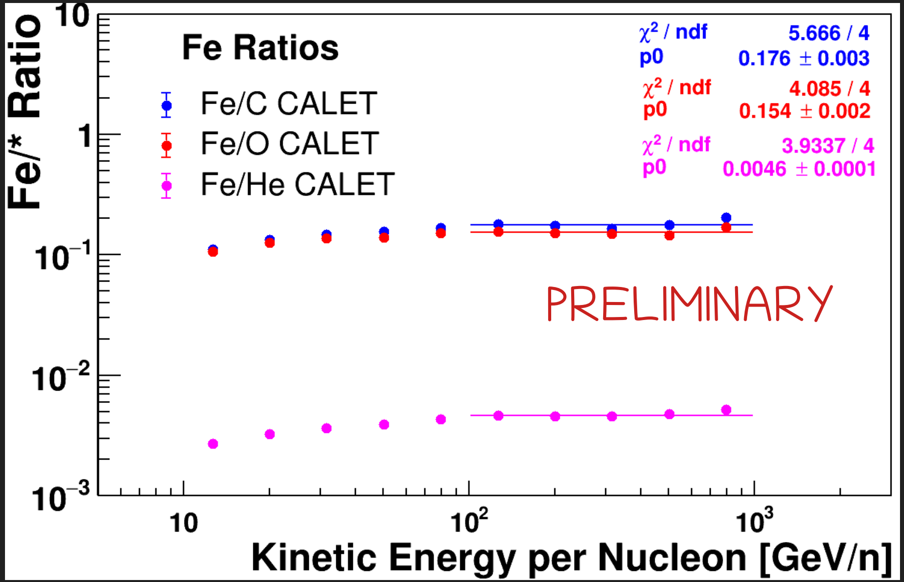


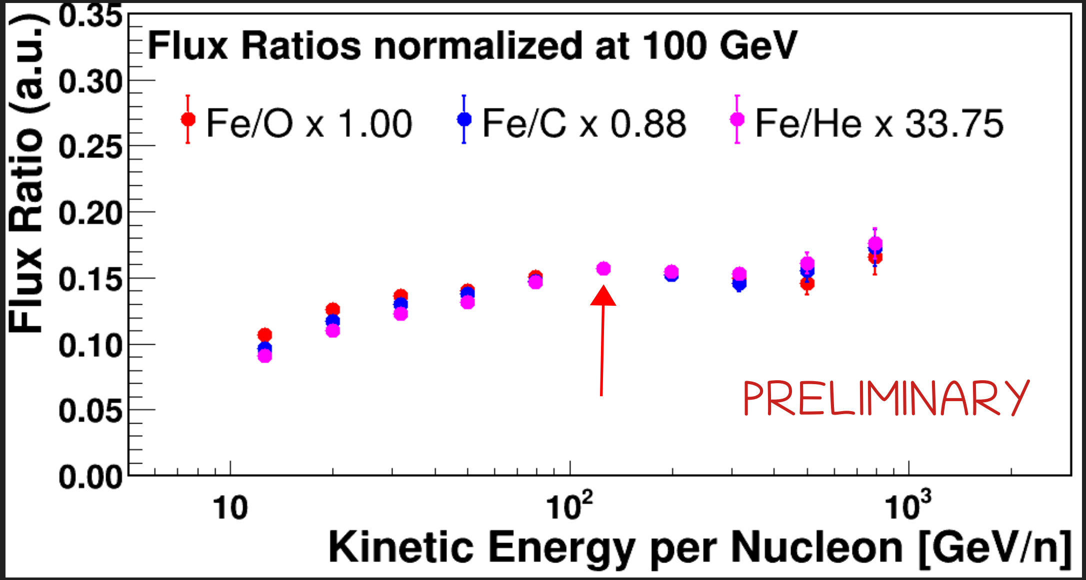




1) Only statistical errors considered
2) Comparison with AMS (in GeV/n) possible only for Fe/O ratio → similar normalization
3) CALET in good accordance with HEAO3-C2 at low energy and CREAM-II at high energy.
4) No data available for Fe/He in kinetic energy per nucleon

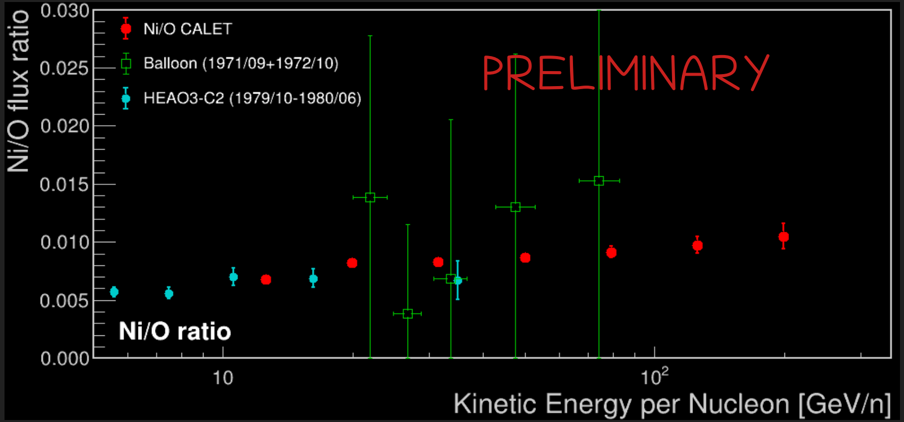
The Fe/* flux ratio

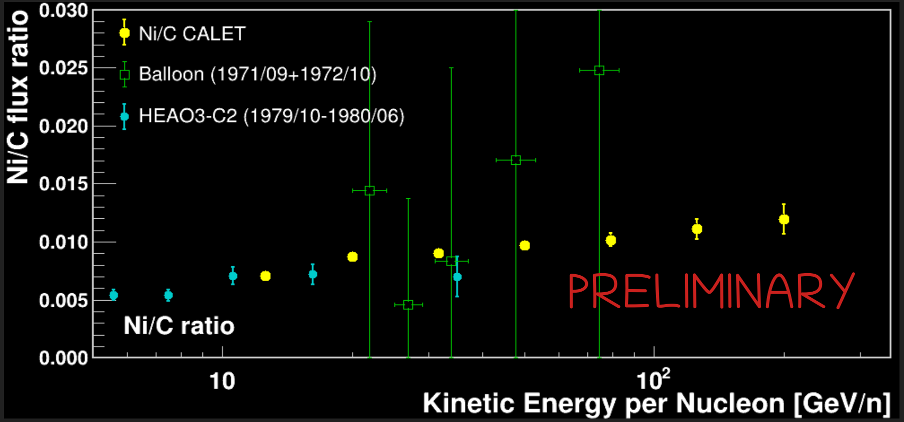


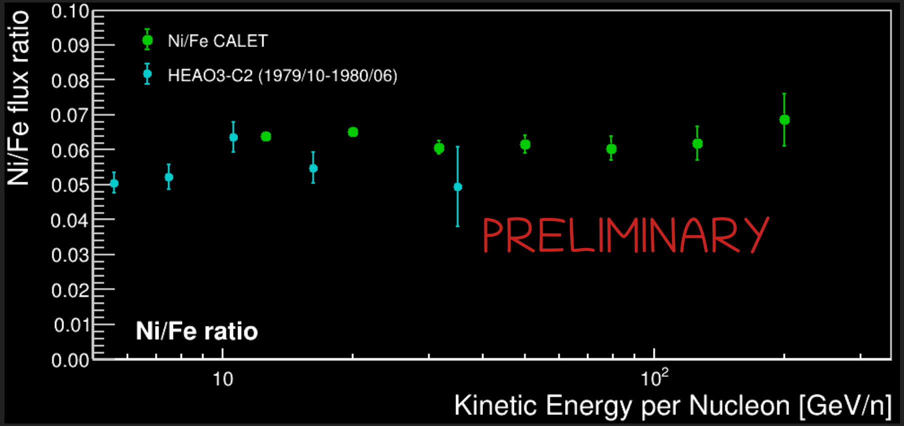


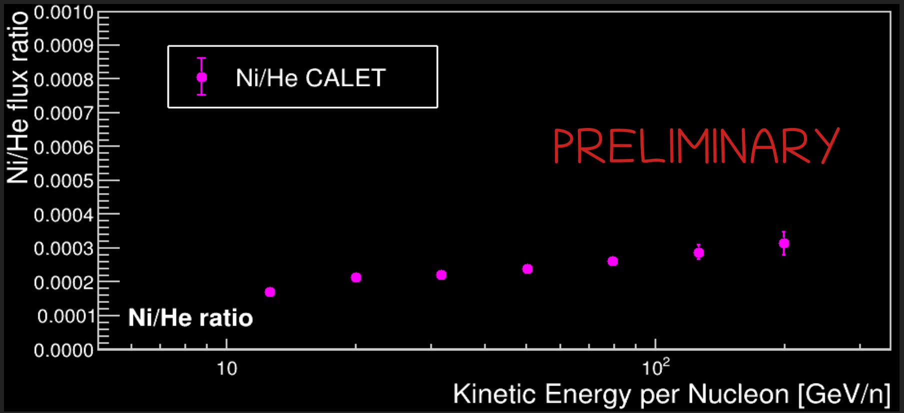
Fe/O, Fe/C and Fe/He are compatible with a constant above 100 GeV/n within errors.
→ Fe, O, C follow similar propagation

The Ni/* flux ratio



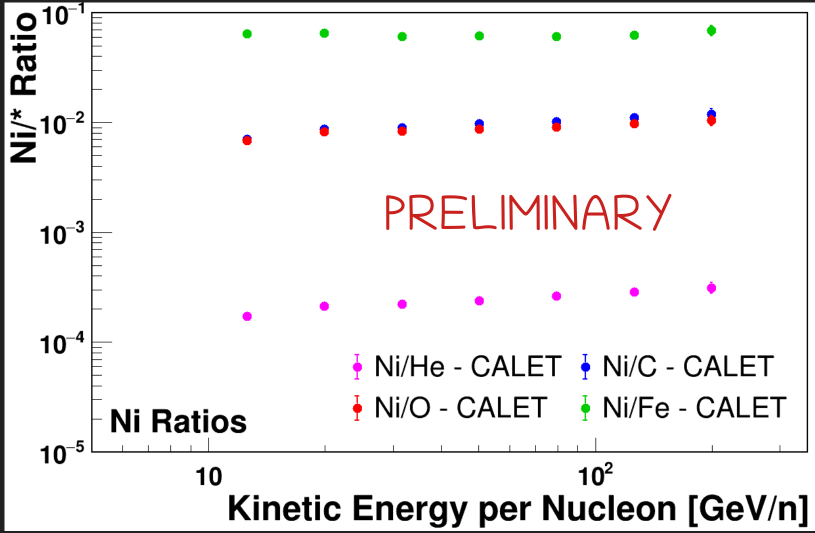


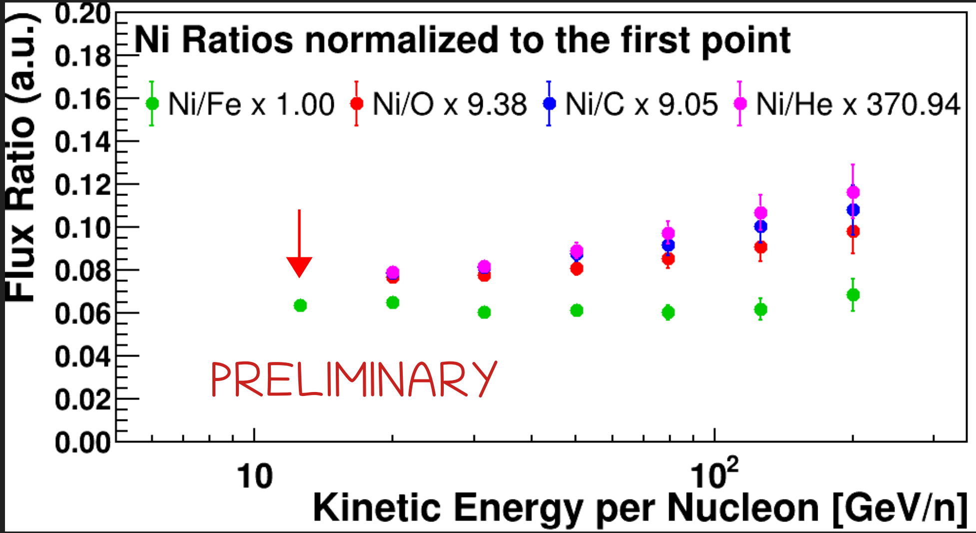


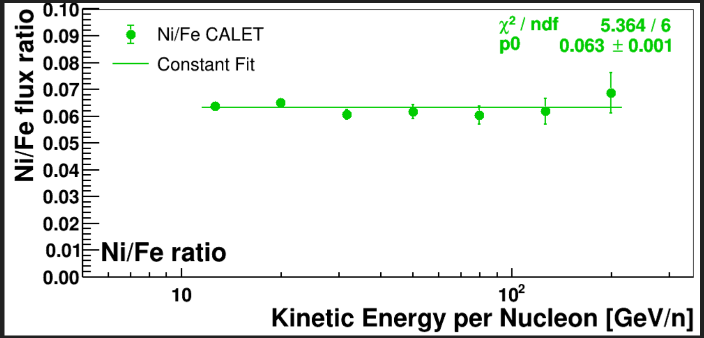


1) Only statistical errors considered
2) No data available for Ni/He in kinetic energy per nucleon
3) CALET in good accordance with HEAO3-C2

The Ni/* flux ratio

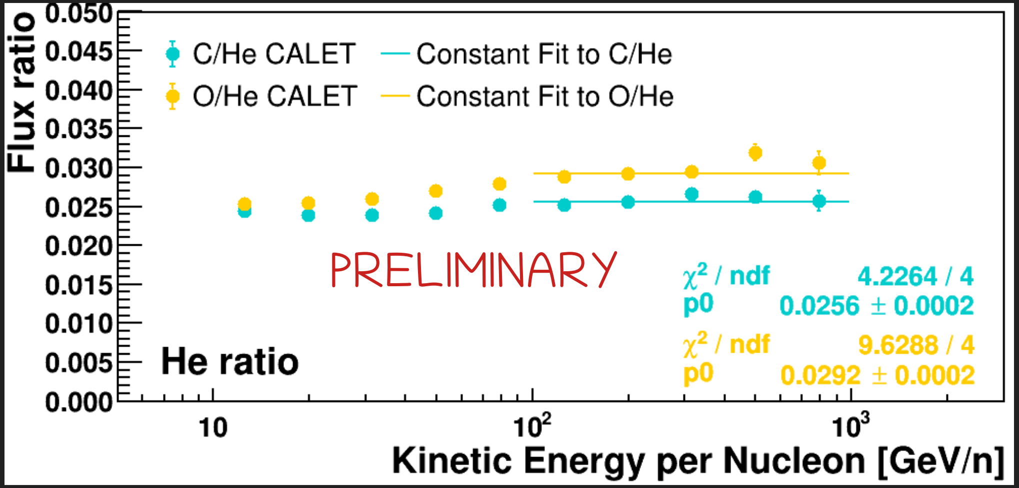


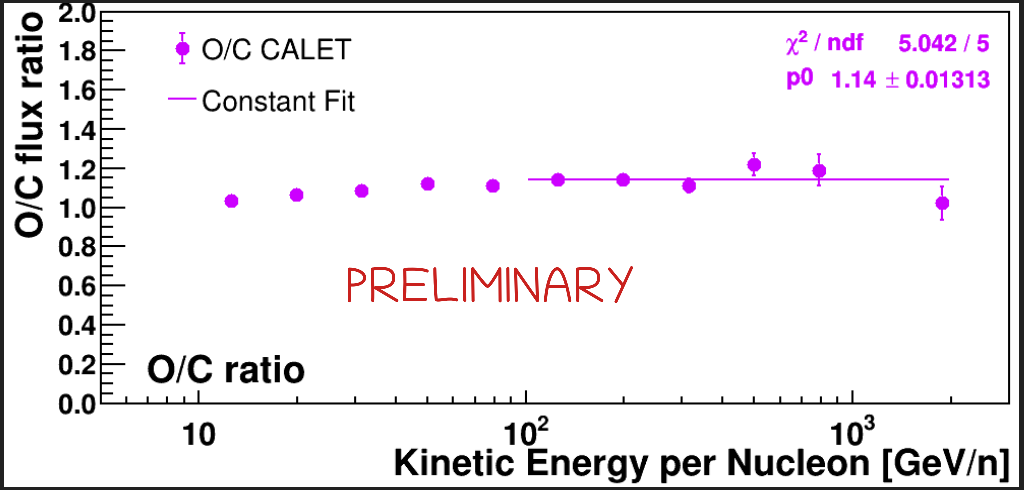




1) The Ni/Fe flux ratio is constant in all the energy range thus Ni and Fe have very similar behavior in all the energy range.
2) The present energy range of nickel flux do not allow to fit the Ni/* ratios with a constant above 100 GeV/n.
3) At low energy the Ni/O, Ni/C, Ni/He flux ratio show an increasing trend also visible in Fe/* ratios.

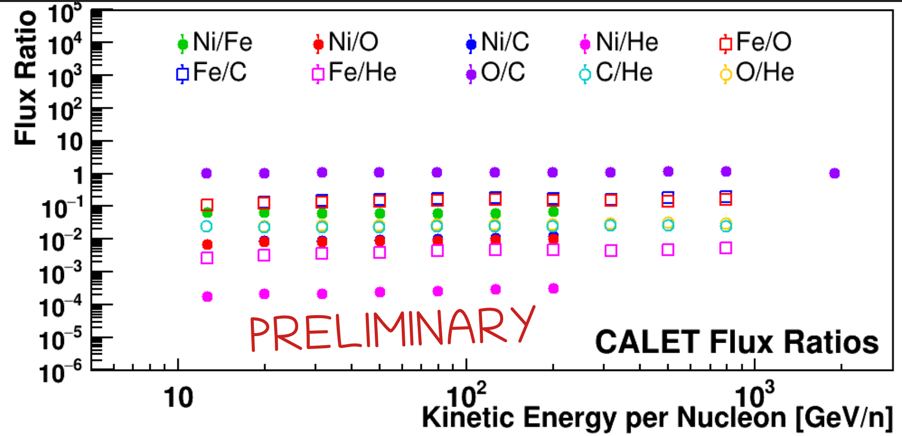
The flux ratio with light elements

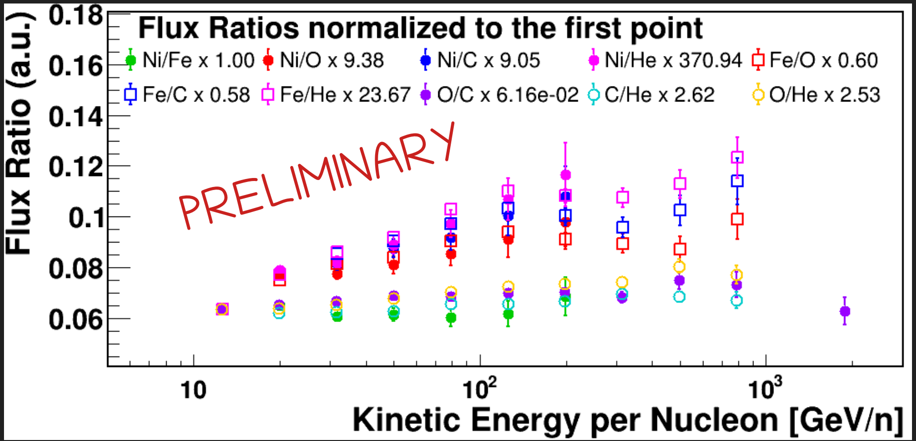




The flux ratio between light nuclei (He, C, O) is constant above 100 GeV/n

Conclusions





CALET measured the flux of primary nuclei using a larger sample with respect to our previous publications.

The flux ratios between heavy and light nuclei (Fe/C, Fe/O, Fe/He, Ni/C, Ni/O, Ni/He) have been performed in the maximum energy range available at present:

Fe/* up to 800 GeV/n

Ni/* up to 200 GeV/n

Also, the C/He, O/He and O/C ratio were performed.

Above 100 GeV/n, Fe/*, C/He, O/He and O/C show a flat behavior.

The energy region below 100 GeV/n show an increasing trend similar for all these ratios except for the Ni/Fe which is flat.

Thank you for your attention!