Precision Measurement of the Carbon Flux in Primary Cosmic Rays with AMS

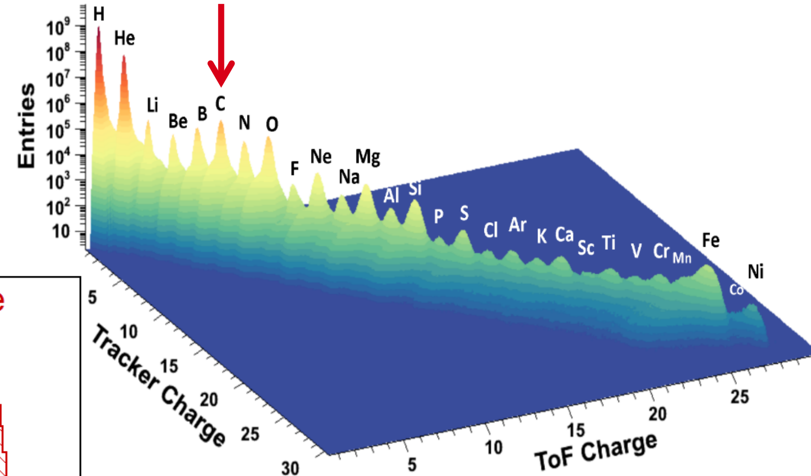
Yang Li (Université de Genève)
AMS Collaboration

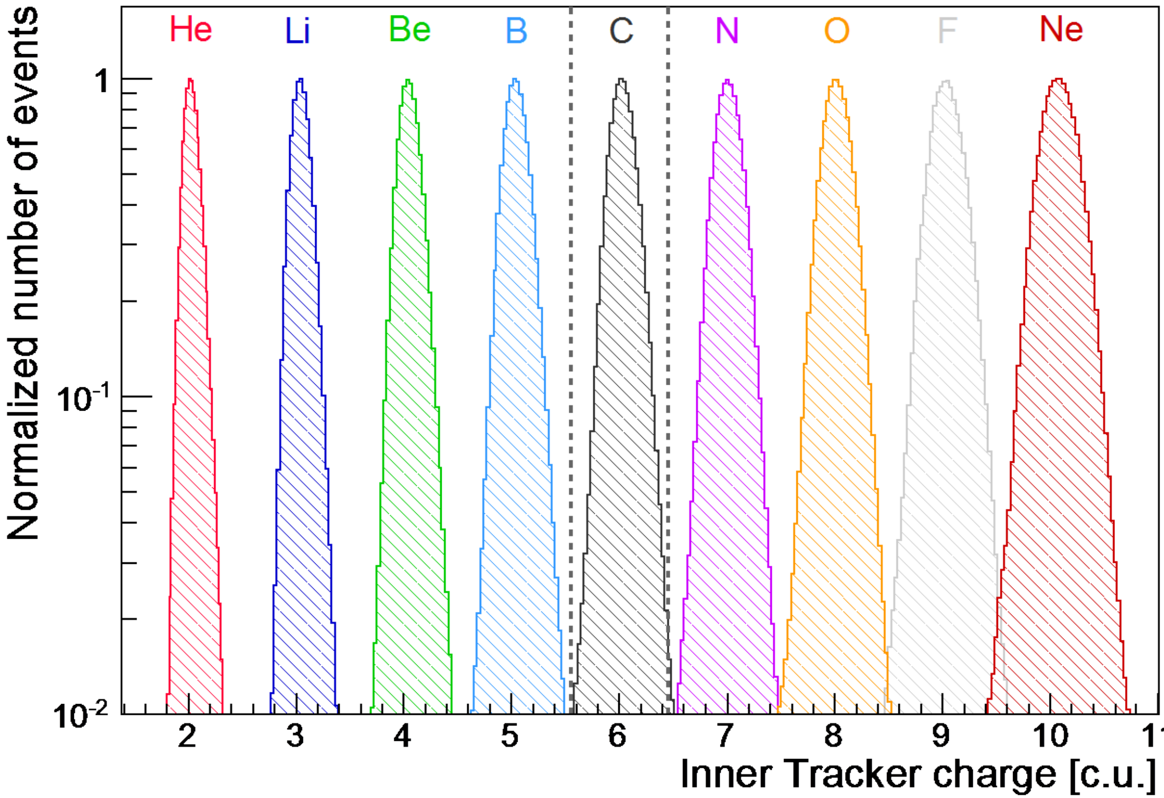
European Cosmic Ray Symposium

Torino, 5 September 2016

Carbon Nuclei in Cosmic Rays

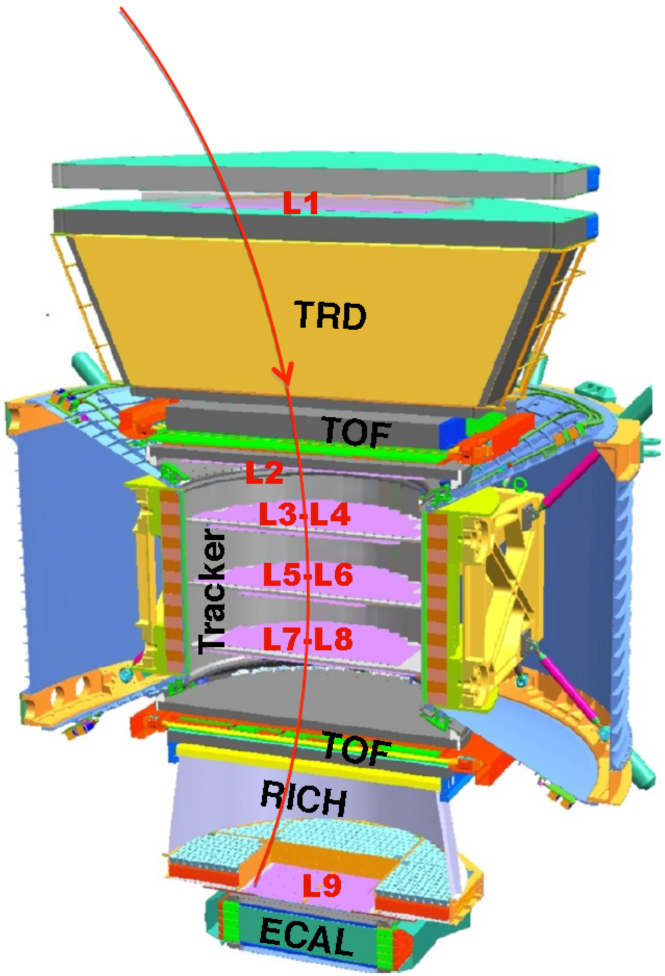
C nuclei are the 3rd most abundant charged particles in cosmic rays (CRs) [AMS C/He flux ratio ~ 1/30, (1.9 GV, 2.6 TV)] and are thought to be mainly produced and accelerated in astrophysical sources.





Nuclei identification capability of AMS is mainly provided by the Inner Tracker.

AMS Carbon Flux Measurement



Tracker (8 or 9 layers) + Magnet

Rigidity (momentum/charge) & charge magnitude

Bending coordinate resolution = 10 μm

MDR = 2.6 TV

TOF (4 layers)

Velocity and direction

$\Delta\beta/\beta^2 = 1\%$

TRD, Tracker, RICH, TOF, ECAL

consistent charge along particle trajectory

e.g., Inner Tracker $\Delta Z/Z = 2\%$

Upper TOF $\Delta Z/Z = 3\%$

Flux Measurement

The isotropic flux Φ_i for the ith rigidity bin $(R_i,\ R_i + \Delta R_i)$ is

Number of events corrected for background and for bin-to-bin migration due to tracker rigidity resolution

$$\Phi_i = \frac{N_i}{T_i\ A_i\ \epsilon_i\ \Delta R_i}$$

Bin width

Exposure Time

Trigger efficiency from data

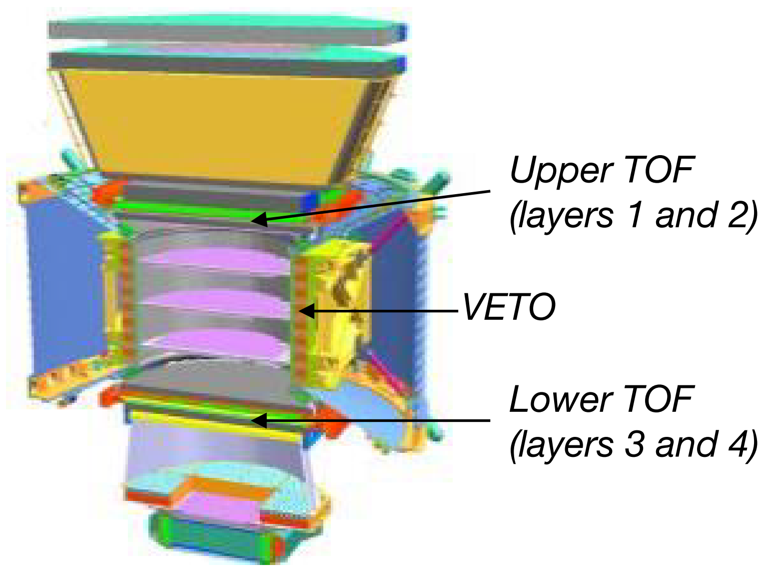
Effective acceptance from MC corrected for nuclei interactions and verified with data

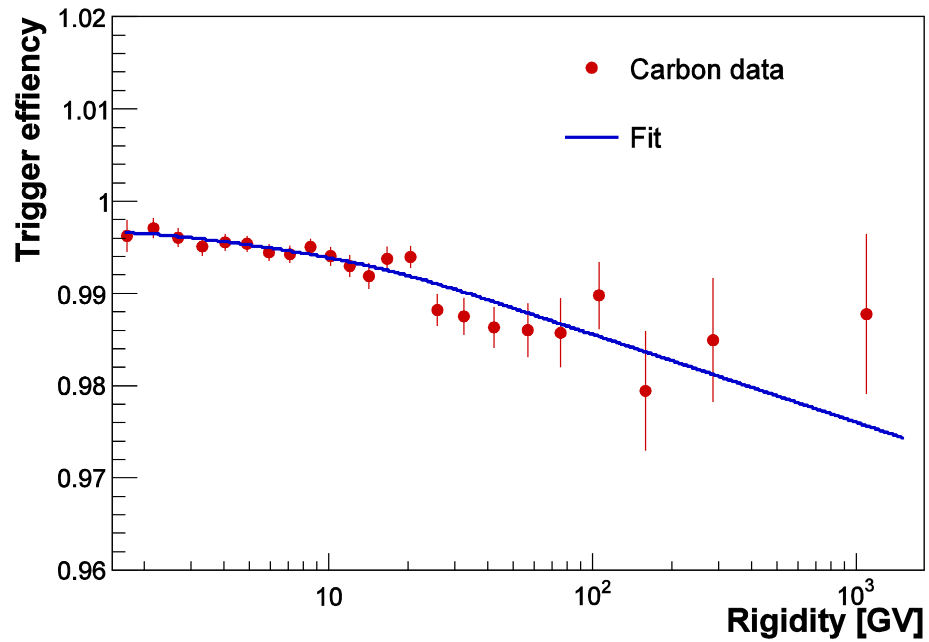
In 5 years on ISS, AMS has collected > 80 billion cosmic rays.
To match the statistics, **systematic errors studies have become important.**

Systematic Error on Trigger Efficiency

Trigger efficiency [4/4 TOF + VETO 4/8] was measured using 1% pre-scaled event sample obtained with unbiased 3 out of 4 TOF coincidence trigger.

The error is dominated by the statistics available from the unbiased trigger.



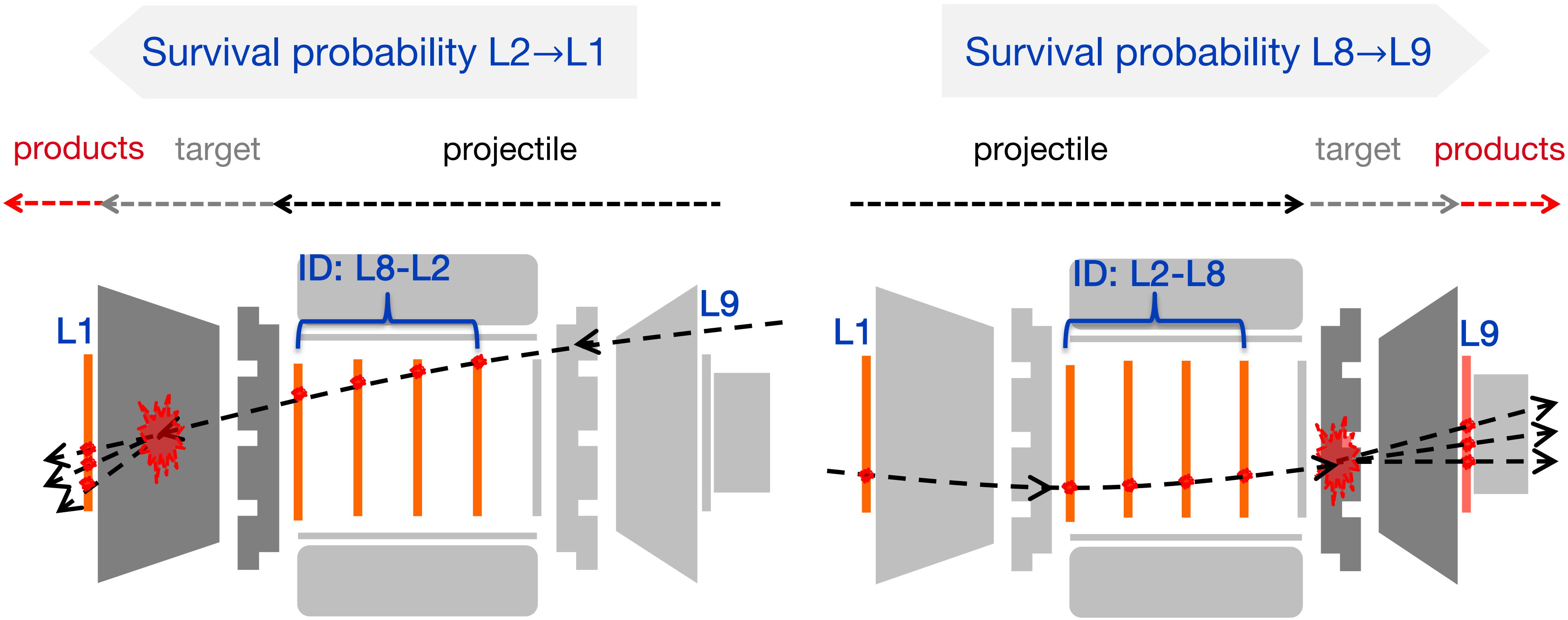


This systematic error is small (< 1%) and

the trigger efficiency is > 98% over the entire rigidity range.

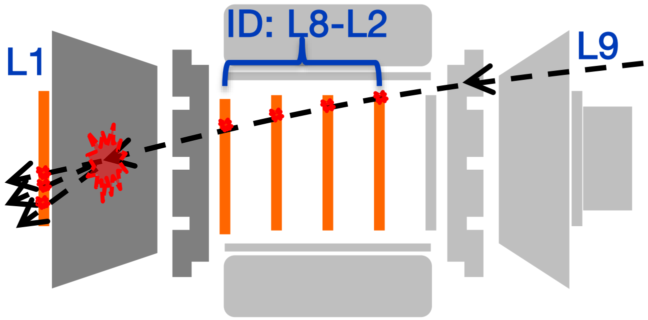
Carbon Acceptance due to Interactions

The inelastic cross sections of C+C and C+Al have only been measured below 10 GV.
We have developed a method to determine the effect on the acceptance of interactions in the detector, with AMS pointing in horizontal direction (2 days in total).

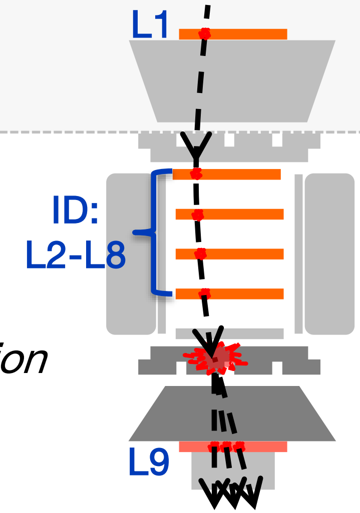


This method was verified by comparing this "horizontal" L8→L9 survival probability to the one in normal AMS orientation.

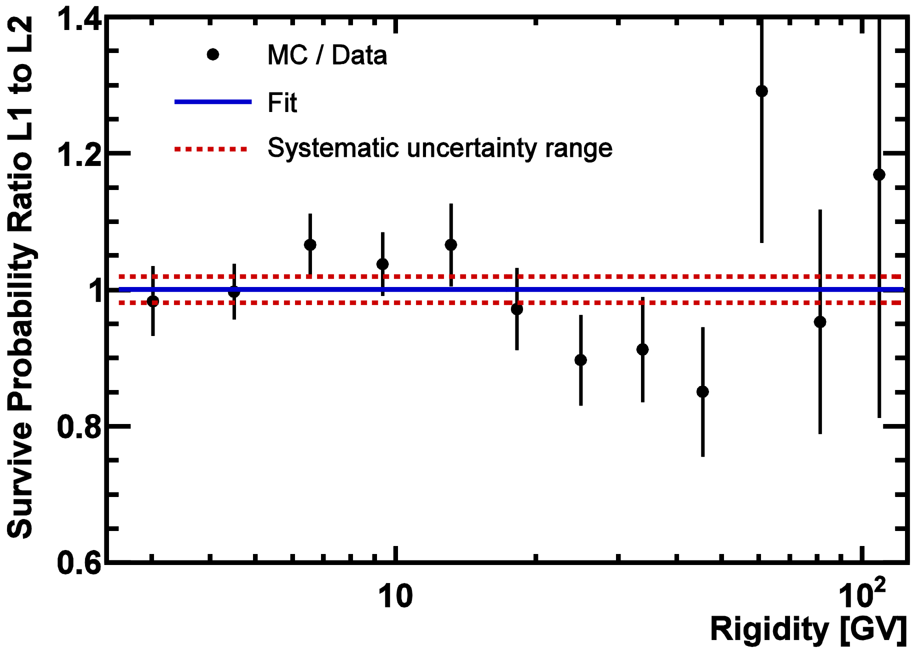
Carbon Survival Probability Data/MC Comparison



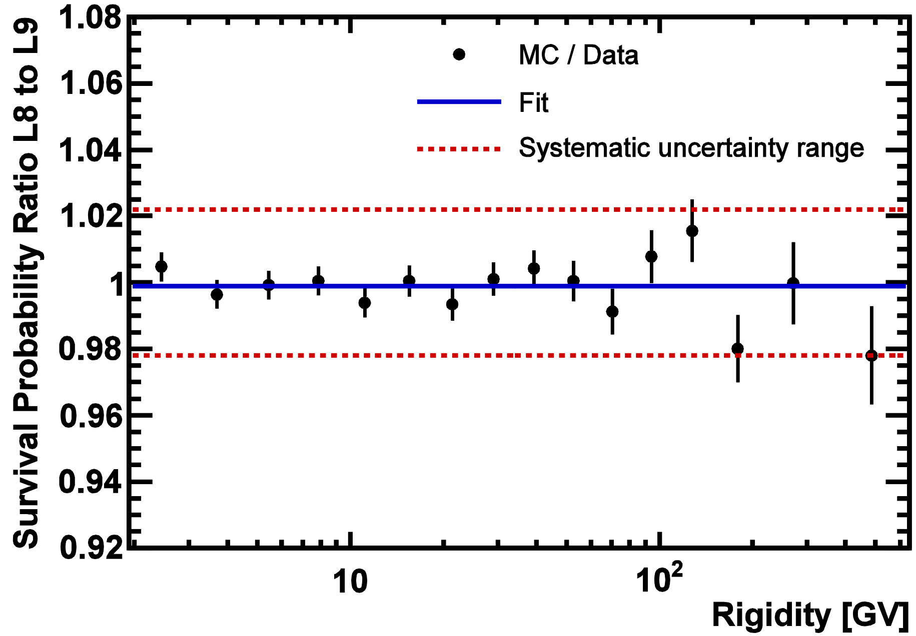
normal AMS orientation



Survival probability between L1 & L2



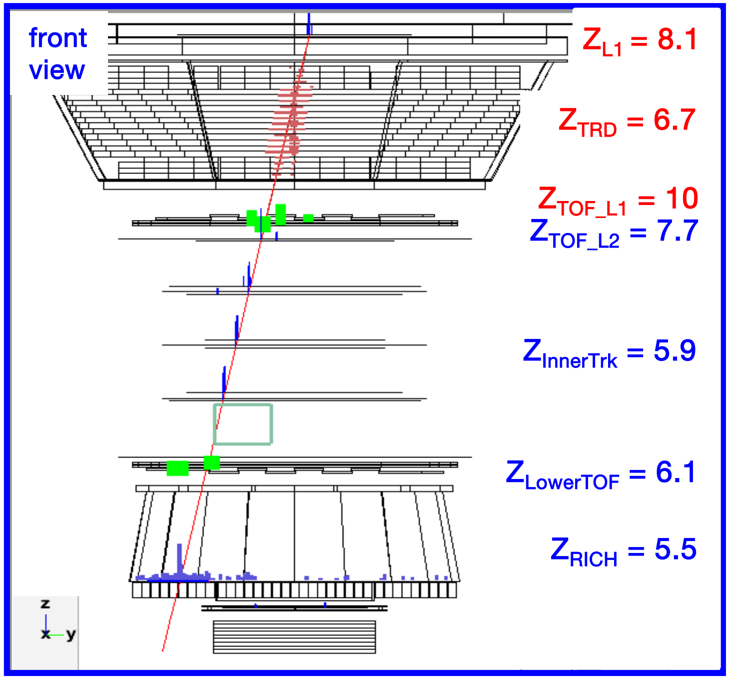
Survival probability between L8 & L9

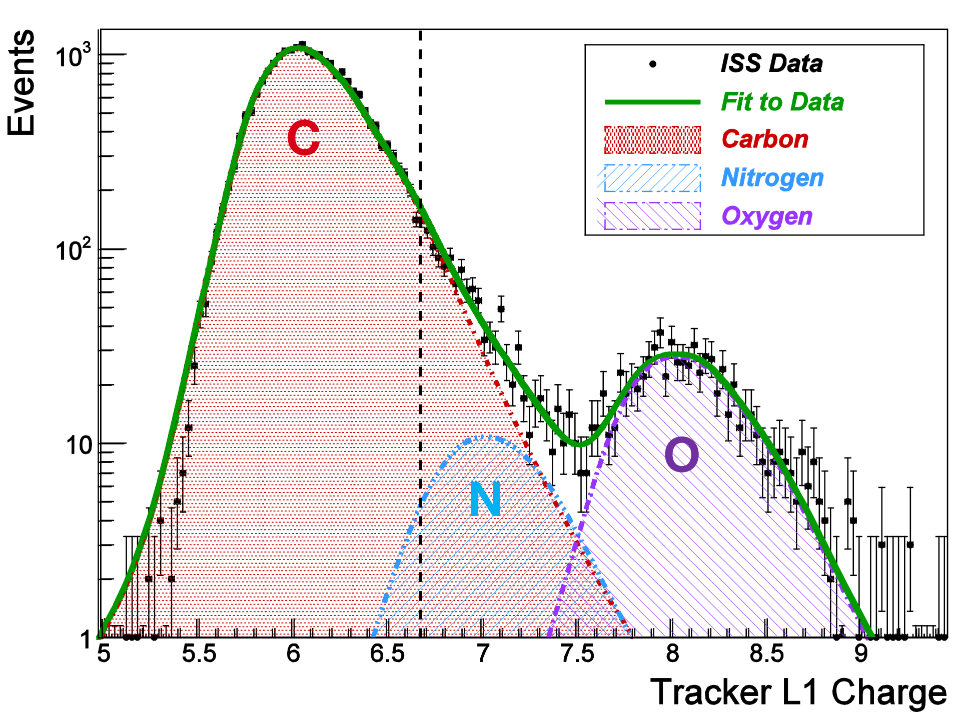


Systematic error on the carbon acceptance due to uncertainties of inelastic cross sections is ~2%.

Systematics on Background from Interactions

- There is a small background from interactions of heavier nuclei in the material (e.g., between L1 and L2), such as Oxygen → Carbon.
- The amount of residual contamination after charge selection on L1 is calculated by fitting the data with C, N and O charge distributions derived from data.
- Background contamination < 0.2%, efficiency > 95% over the entire rigidity range.



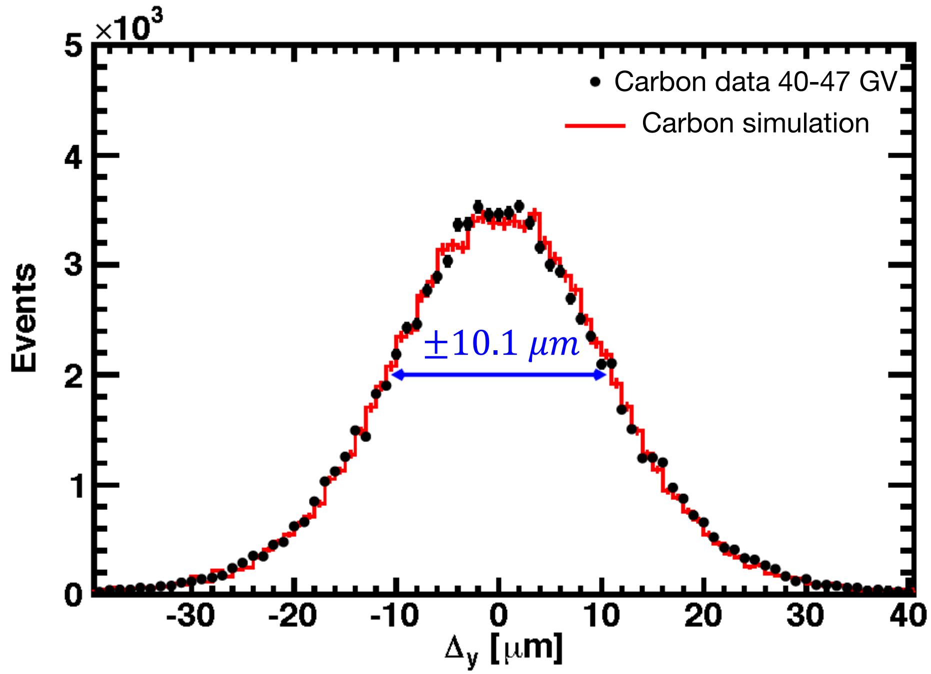


Systematic uncertainty on the knowledge of the charge templates are included in the final flux error (< 1%).

Systematic Error on Rigidity Resolution Function

Rigidity resolution function from MC simulation, verified with ISS data:

- Unbiased residuals
- Rigidity reconstruction (L1-L8) vs. (L2-L9)



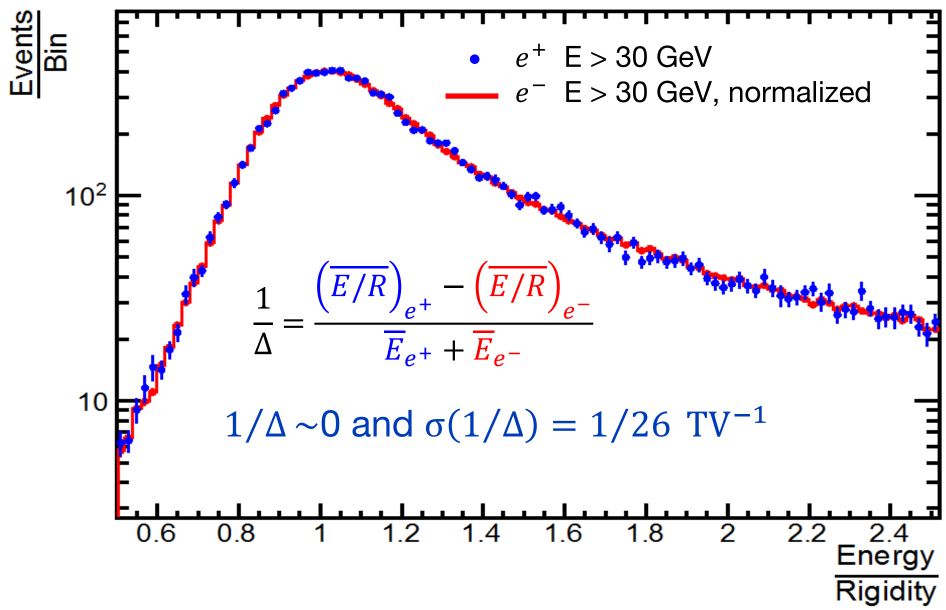
Δ_y: *Differences of the bending coordinates measured in L3 or L5 to those obtained from the track fit using measurements from the other layers.*

This systematic error was obtained by varying the width of the Gaussian core of the resolution function by 5% (due to uncertainty of 1μm of L1, L9 alignment) and the amplitudes of the non-Gaussian tails by 10% (due to uncertainty in large angle nucleus-nucleus scattering) and found to be ~1% below 200 GV and ~3% at 2.5 TV.

Systematic Error on Absolute Rigidity Scale

(1) Residual tracker misalignment

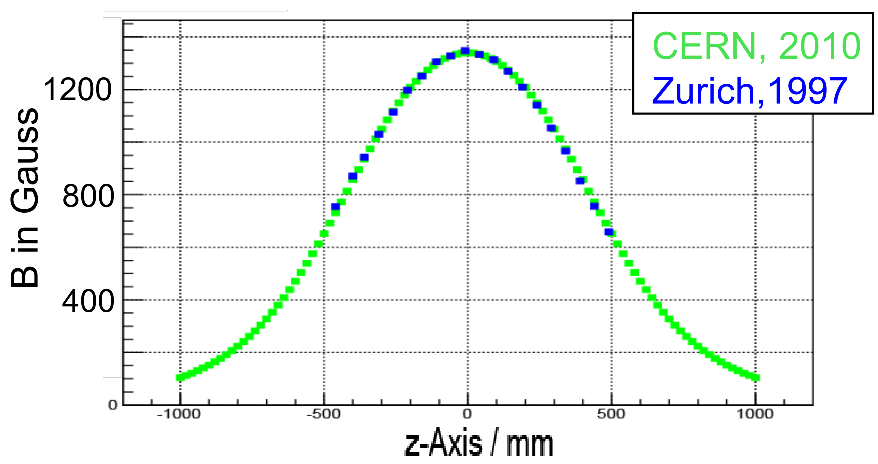
Estimated by comparing the $E_{ECAL}/R_{Tracker}$ ratio for electrons and positrons, limited by the current high energy positron statistics. The corresponding flux error is 2.5% @ 1 TV.



(2) Magnetic field

Mapping measurement (0.25%) and temperature corrections (0.1%).

This amounts to less than 0.5% systematic error on the flux.



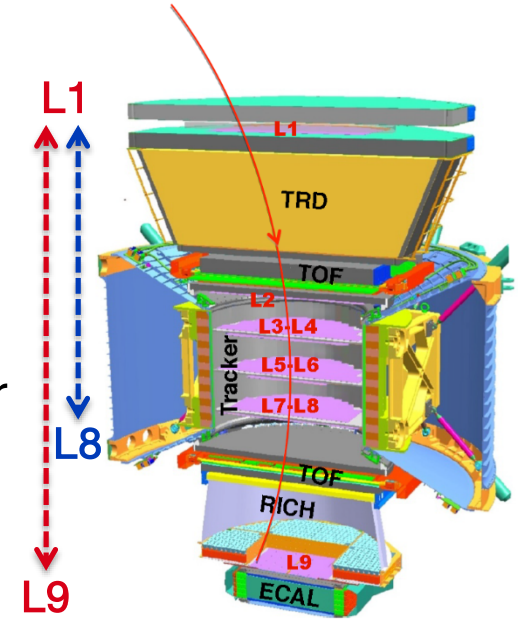
Verification of the Systematic Errors

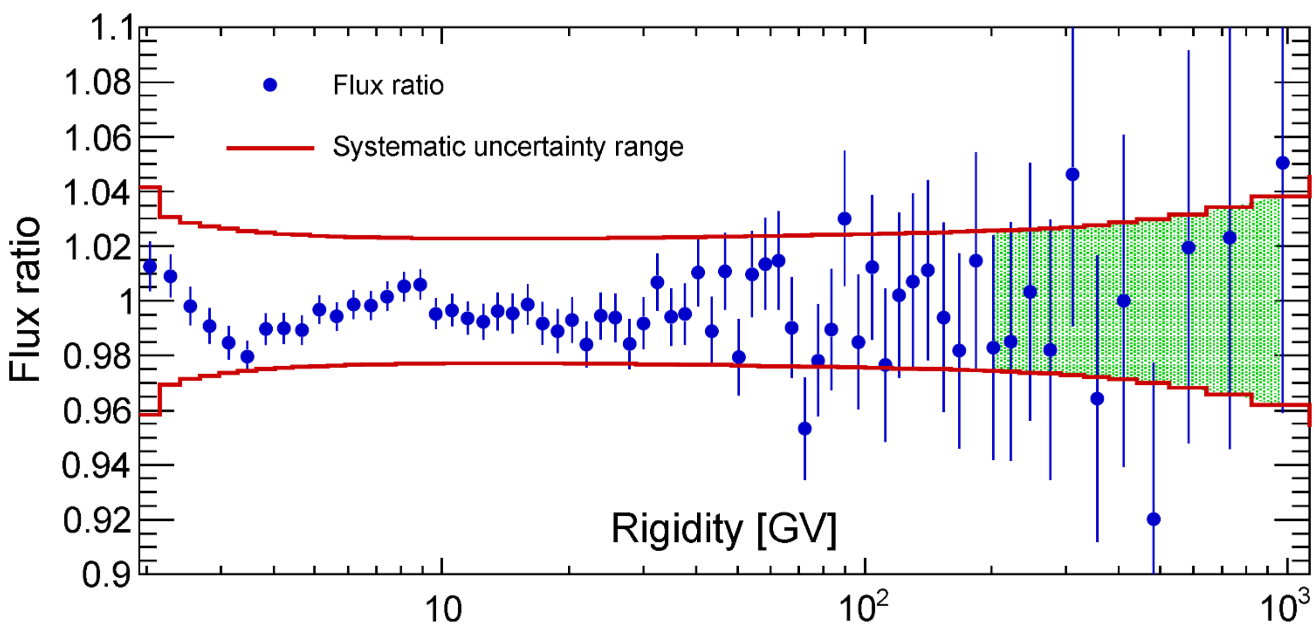
On Unfolding, Acceptance and Rigidity Resolution Function

Comparison of the C flux measured by L1 to L8 and L1 to L9:

1) At high rigidities (200 to 1000 GV), the **unfolding** effects and **resolution functions** of L1-L8 (MDR = 900 GV) and the full lever arm one (MDR = 2.6 TV) are very different.

2) L1-L8 and L1-L9 have a different geometrical acceptance and average amount of material traversed (~5 times larger effective acceptance), therefore the flux comparison also verifies the **acceptance** systematic errors.



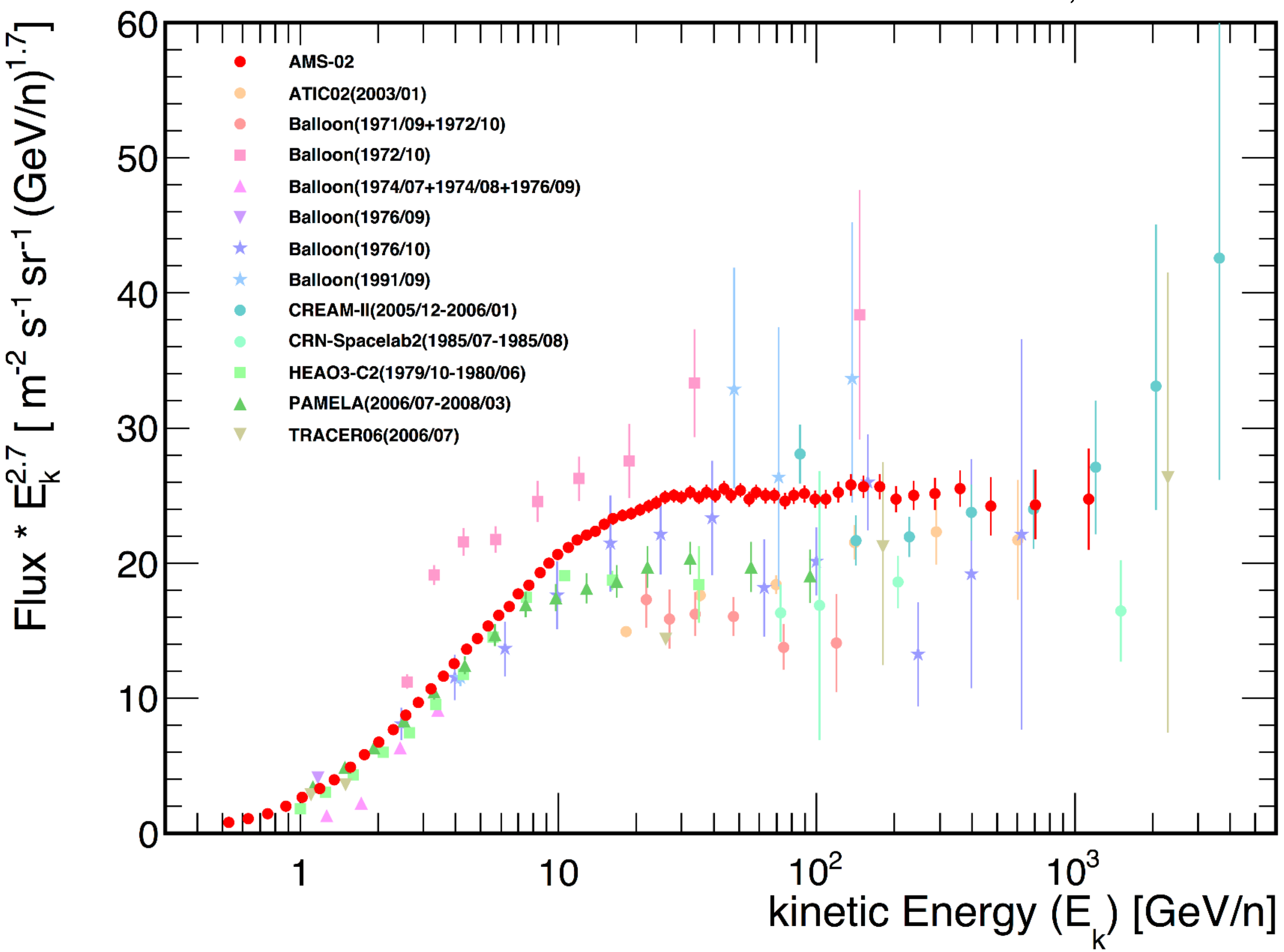


Good agreement between the flux obtained using the rigidity measured by tracker L1 to L8 and L1 to L9

AMS Carbon Flux

Current Status

M. Heil, RICAP 2016



Conclusions

- The redundancy of the charge measurement along the particle trajectory allows a very clean nuclei selection with AMS.
- The current status of the carbon flux measurement is presented.
- The detailed variations of the flux dependence with rigidity will be studied.