

Properties of Neon, Magnesium, and Silicon Primary Cosmic Rays Results from AMS



ICHEP 2020 | PRAGUE

40th INTERNATIONAL CONFERENCE
ON HIGH ENERGY PHYSICS

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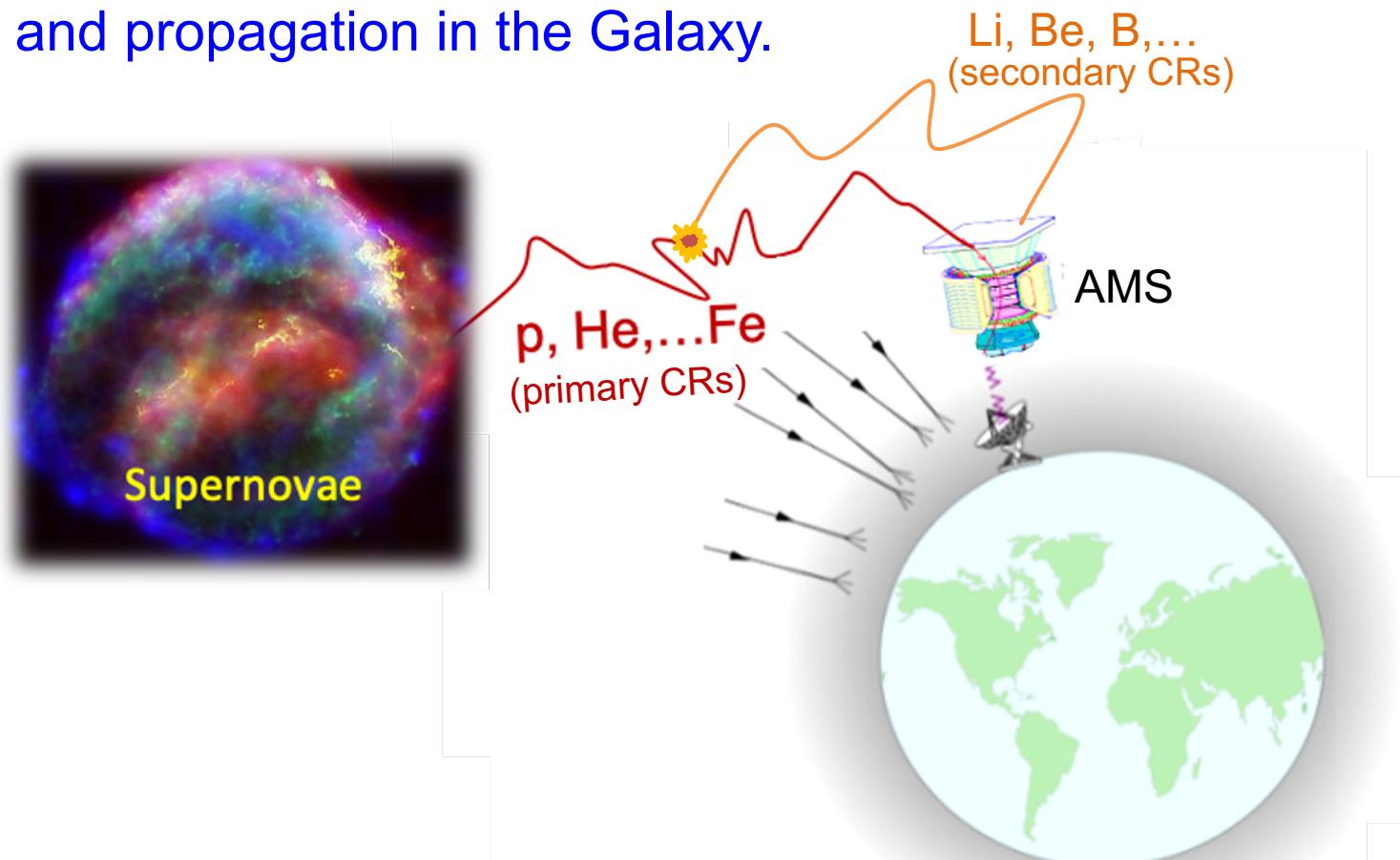
PRAGUE, CZECH REPUBLIC

Q. Yan / MIT on behalf of the AMS collaboration

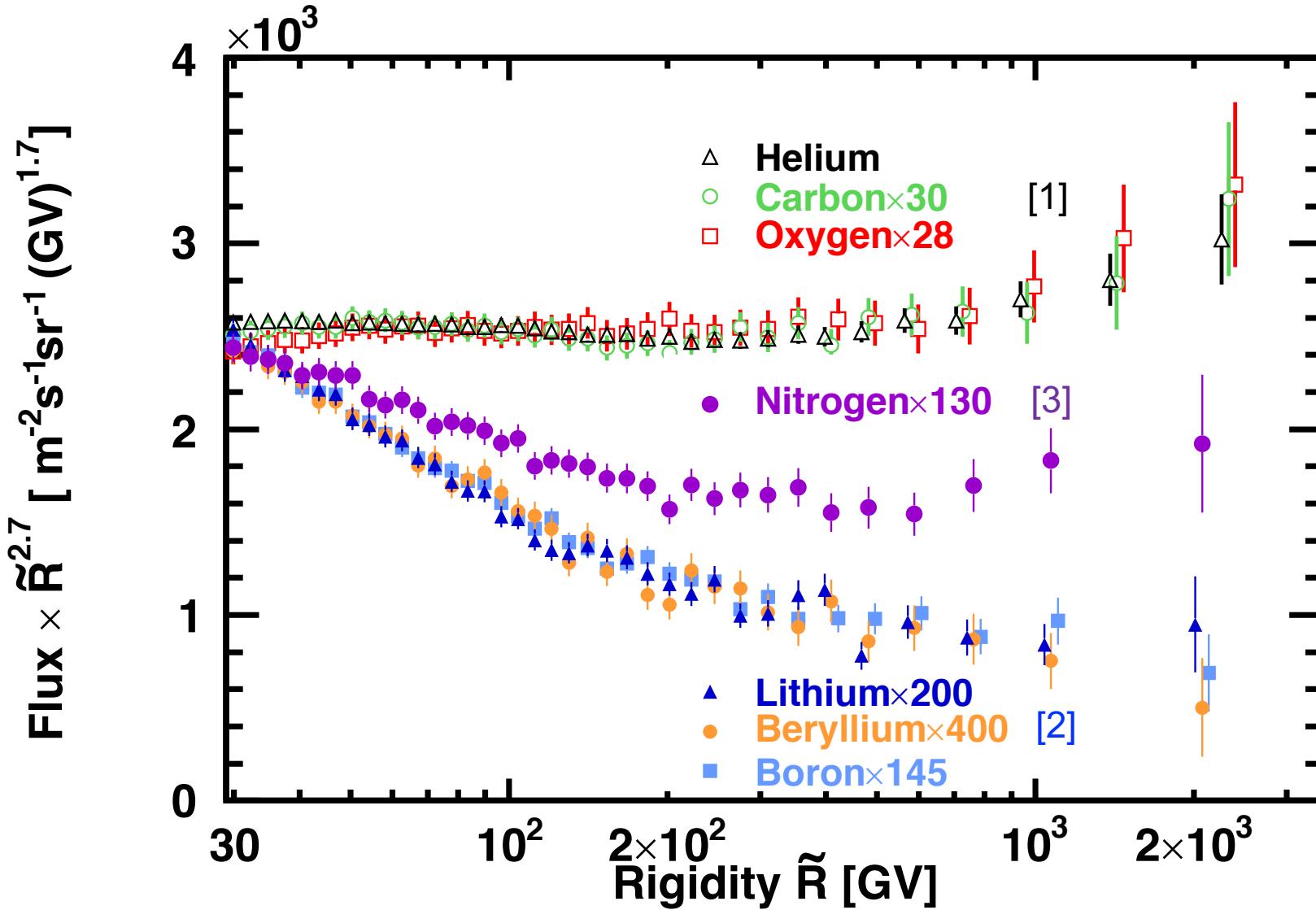
40th International Conference on High Energy Physics

Measurements of Cosmic-Ray Spectra

One of the fundamental measurements in cosmic rays (CRs) is the determination of the energy dependence of spectra of primary cosmic rays p, He, C, O, Ne, Mg, Si, ..., Fe. These are thought to be produced and accelerated in the supernova remnants in our Galaxy. Their spectra carry the information about cosmic ray acceleration in the astrophysics sources and propagation in the Galaxy.



AMS Measurements of Cosmic-Ray Light Nuclei (He-O) Spectra

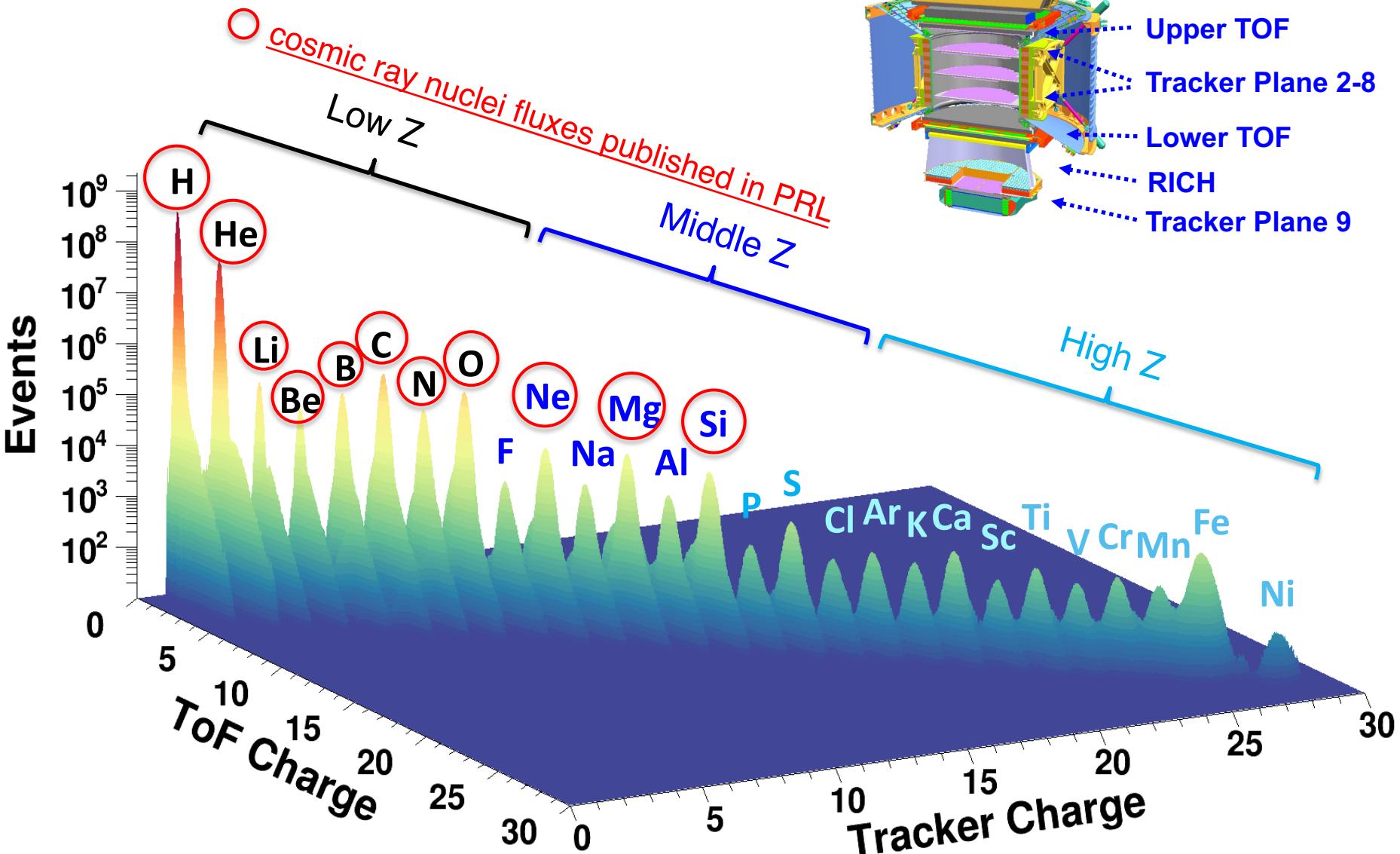


[1] M. Aguilar *et al.*, Phys. Rev. Lett. **119**, 251101 (2017).

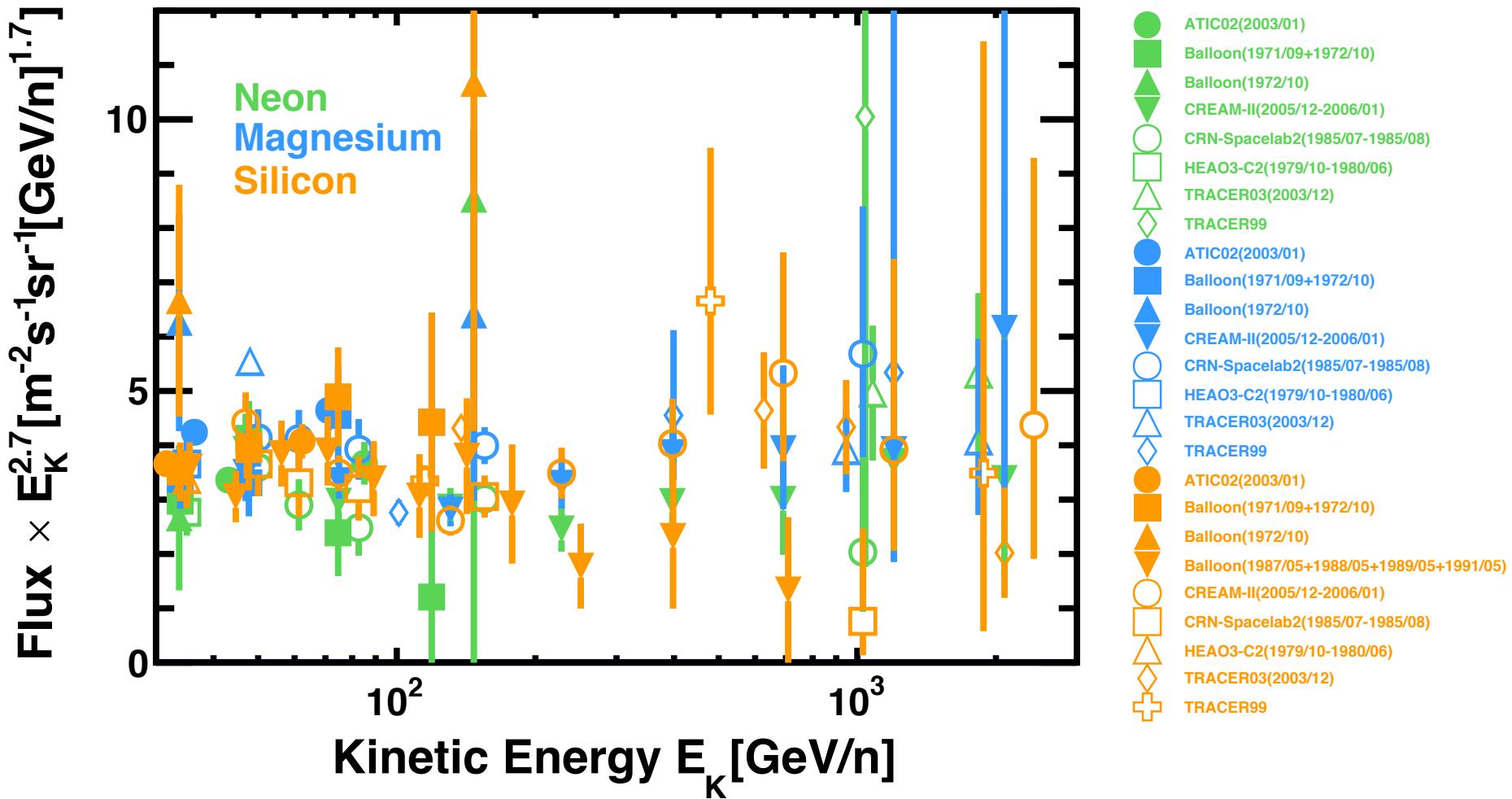
[2] M. Aguilar *et al.*, Phys. Rev. Lett. **120**, 021101 (2018).

[3] M. Aguilar *et al.*, Phys. Rev. Lett. **121**, 051103 (2018).

Primary Cosmic Rays Ne (Z=10), Mg (Z=12), and Si (Z=14)

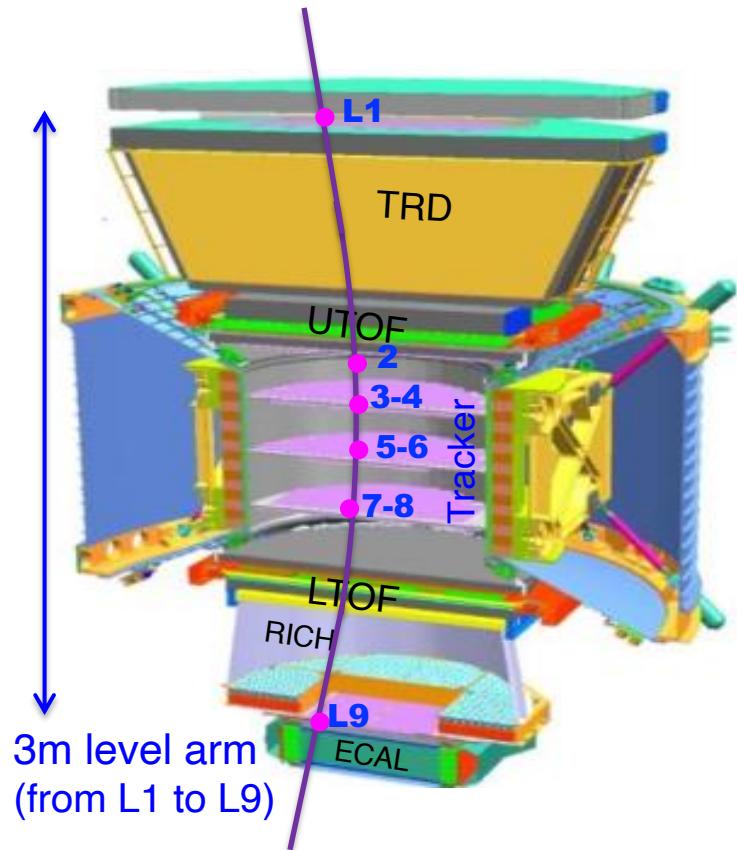


Measurements of Primary Cosmic Rays Ne, Mg, and Si Fluxes Before AMS



AMS Cosmic-Ray Nuclei Measurements ($Z=10,12,14$)

Tracker (9 Layers) + Magnet: Rigidity (Momentum/Charge)



	Coordinate Resolution	MDR
$Z = 1$	$10 \mu\text{m}$	2 TV
$2 \leq Z \leq 8$	$5-7 \mu\text{m}$	3.2-3.7 TV
$9 \leq Z \leq 14$	$6-8 \mu\text{m}$	3-3.5 TV

TOF (4 Layers): Velocity and Direction

$$\Delta\beta/\beta^2 \approx 4\% \quad (Z=1)$$

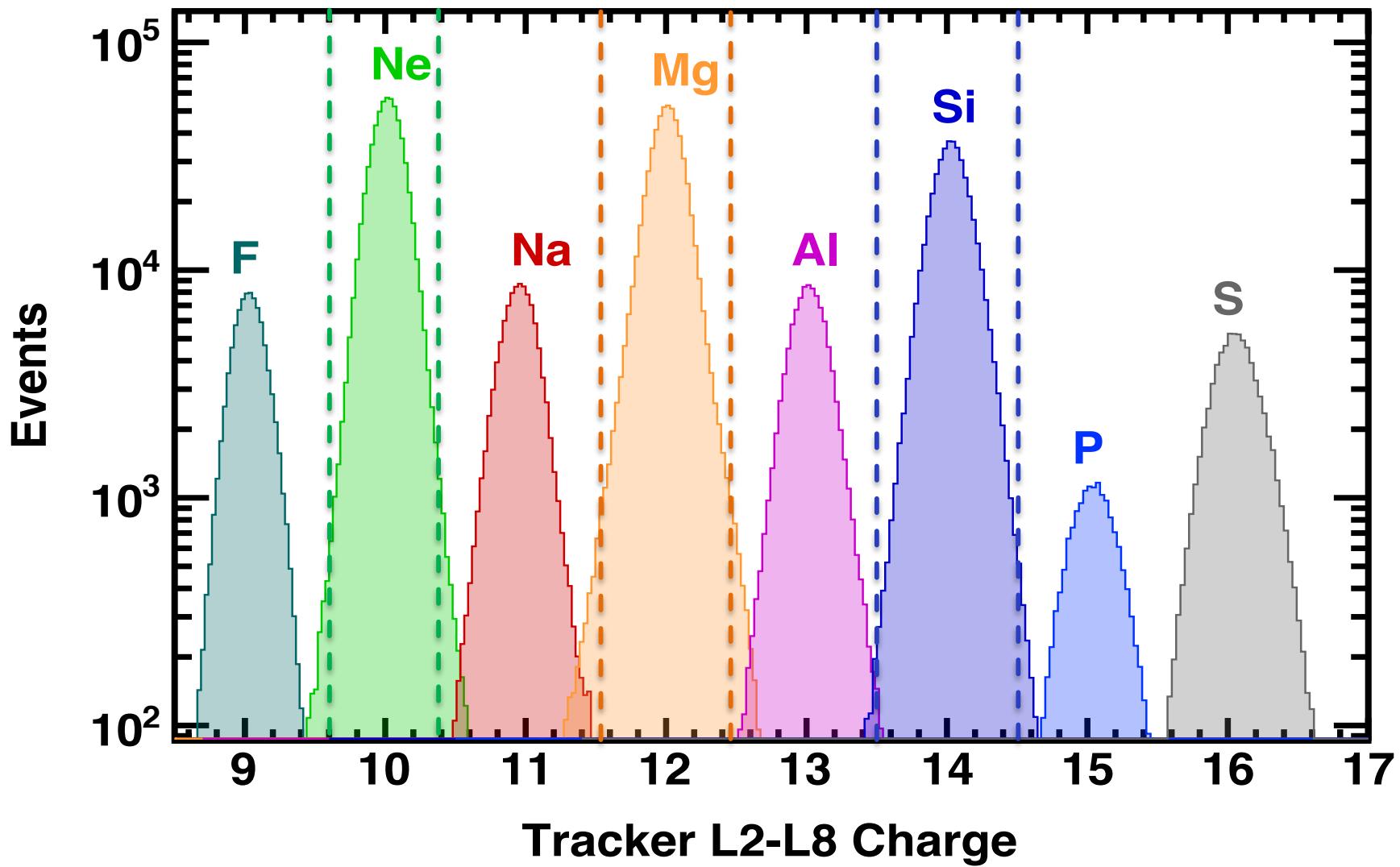
$$\Delta\beta/\beta^2 \approx 1-2\% \quad (Z \geq 2)$$

L1, UTOF, Inner Tracker (L2-L8), LTOF* and L9*

Consistent Charge Along Particle Trajectory

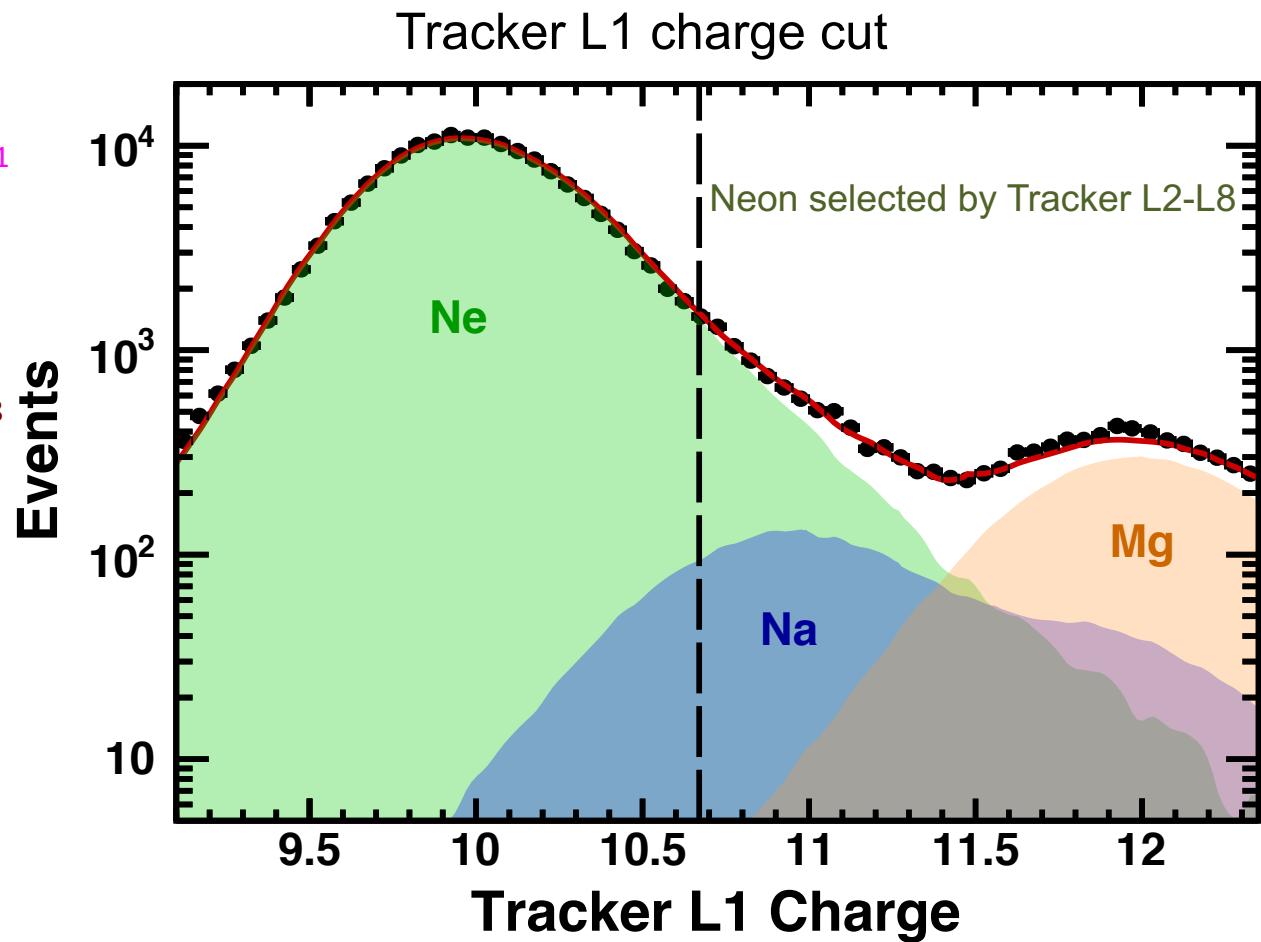
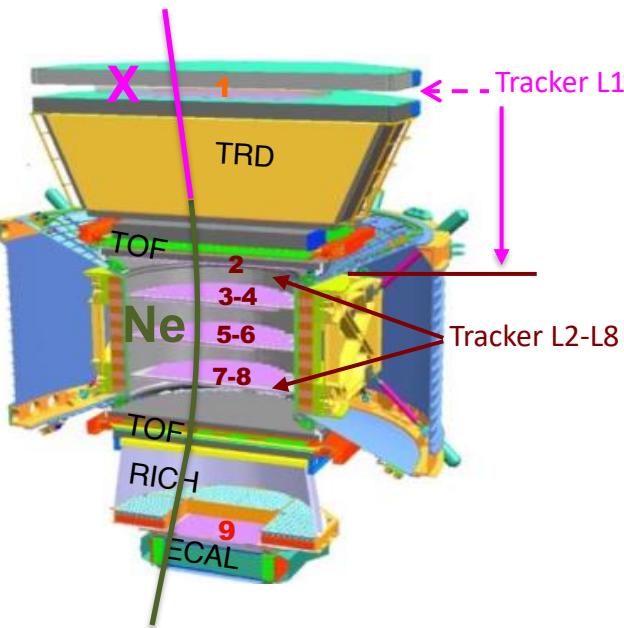
	Tracker L2-L8 Charge Resolution (c.u.)
$1 \leq Z \leq 8$	$\Delta Z \approx 0.05-0.12$
$9 \leq Z \leq 14$	$\Delta Z \approx 0.13-0.17$

Ne, Mg, and Si Event Selection

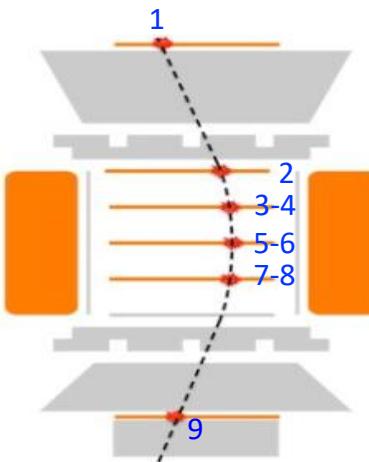
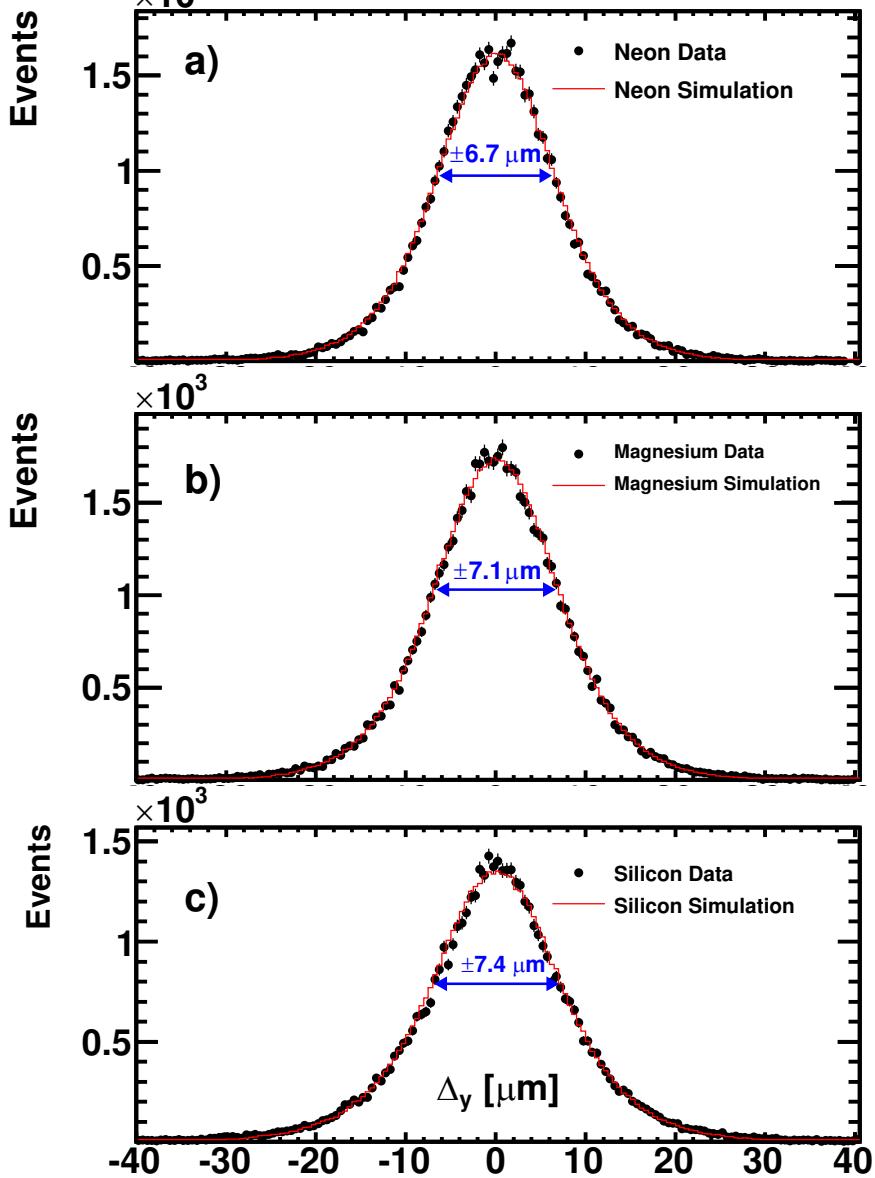


Background

The background resulting from heavier nuclei which interact between tracker L1 and L2 (for example: Mg,Na ... \rightarrow Ne) can be subtracted by L1 charge measurement. After the selection, the background is <0.2% in the entire rigidity range for Ne, Mg, and Si.



AMS Tracker Coordinate Resolution

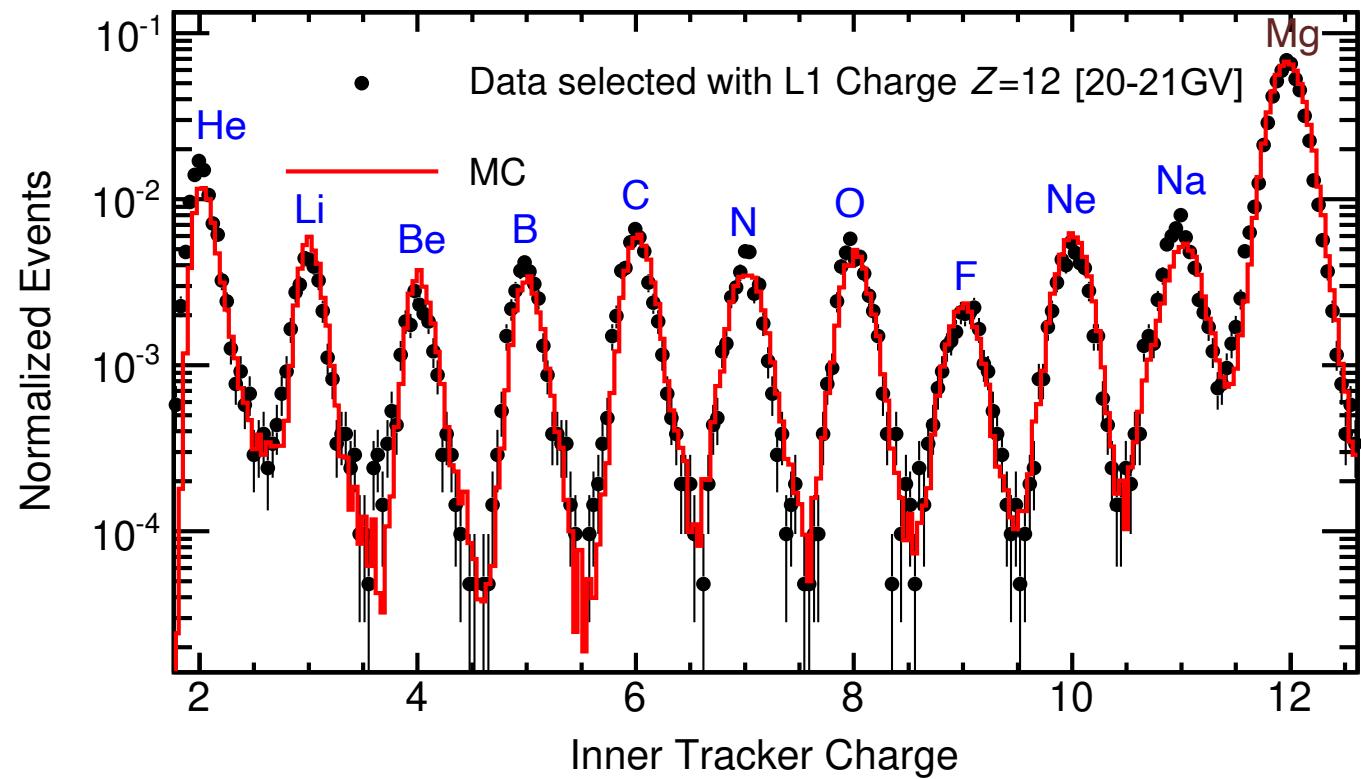
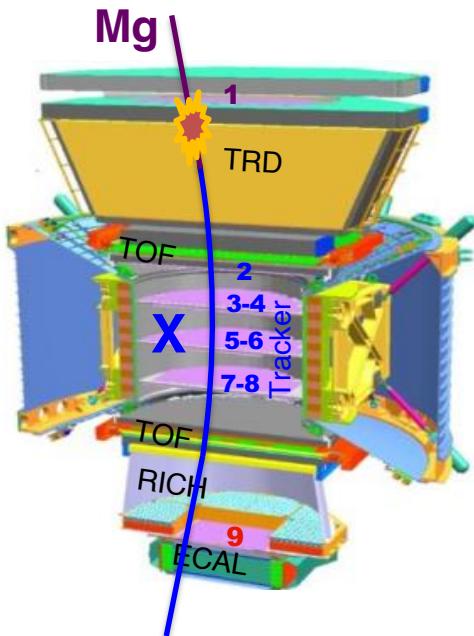


The AMS tracker together with the magnet measure the Rigidity (Momentum/Charge) of charged cosmic rays. The observed bending coordinate resolution is $6.7 \mu\text{m}$ for Ne, $7.1 \mu\text{m}$ for Mg, and $7.4 \mu\text{m}$ for Si and the corresponding Rigidity resolution is well understood. The systematic error on the fluxes is $<1\%$ below 300 GV and 2.5% at 3 TV.

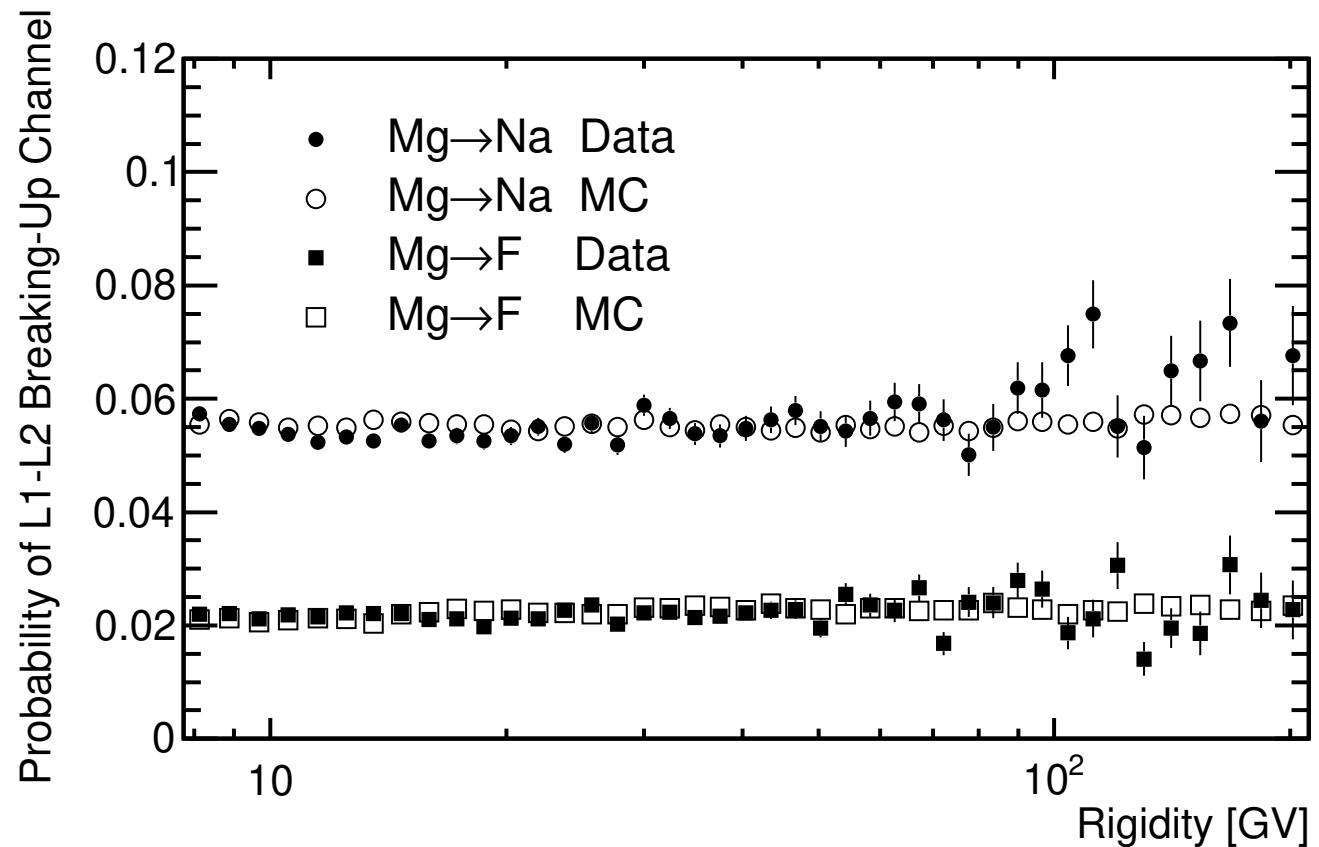
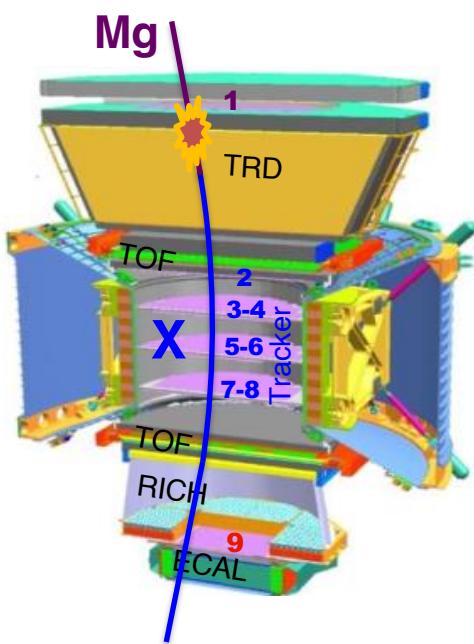
Nuclear Inelastic Interaction Measurement with AMS (Mg)

The AMS material is composed primarily of carbon and aluminum. The survival probabilities of nuclei due to inelastic interactions with the detector materials are important for determination of cosmic-ray nuclei fluxes, which were measured precisely by AMS. For high Z nuclei, the following method was used:

- Select primary nuclei by L1 charge
- Obtain survival probability by comparing charge measured with inner tracker (L2-L8)

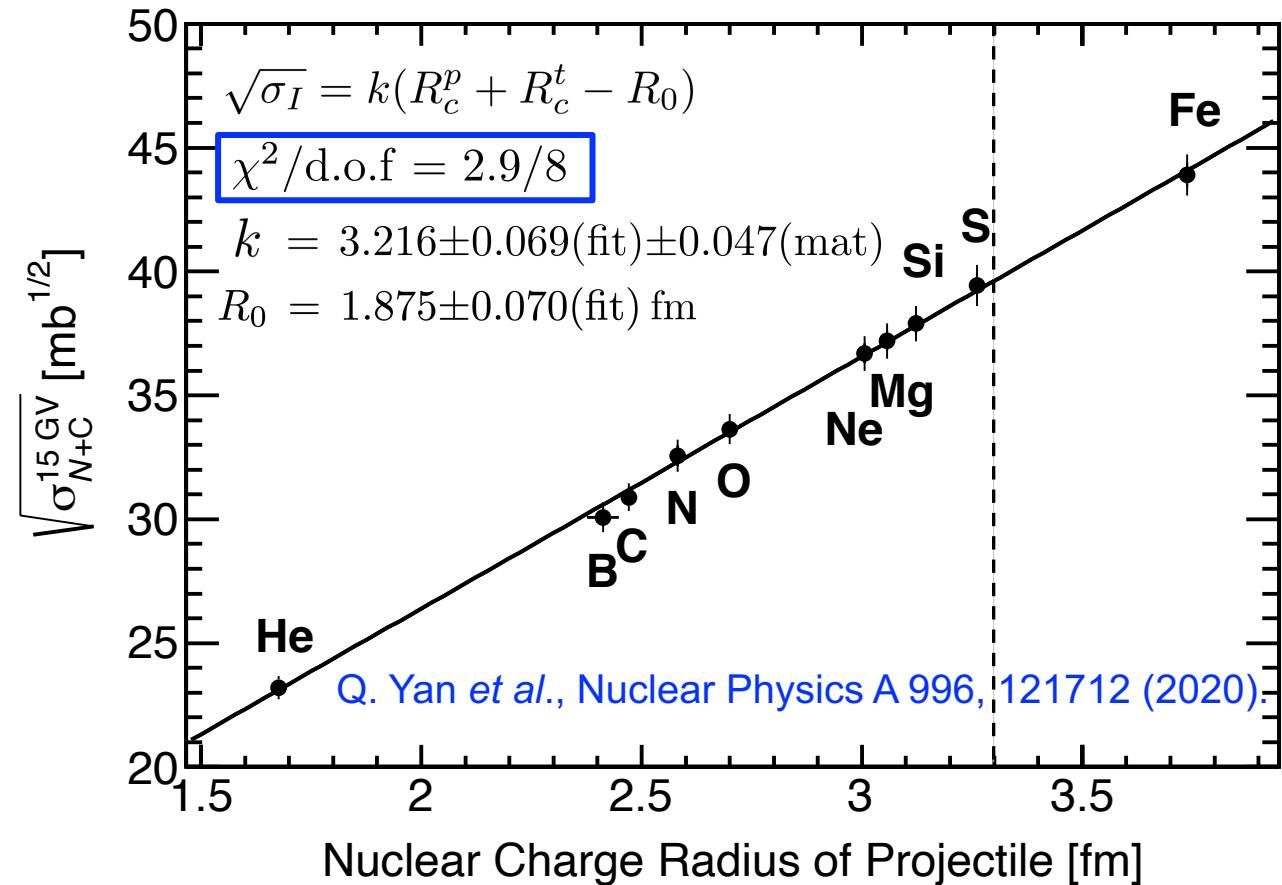


AMS Measured Nuclear Interaction Breaking-Up Probabilities Channel by Channel (Mg)



See details in “Q. Yan *et al.*, Nuclear Physics A 996, 121712 (2020)”.

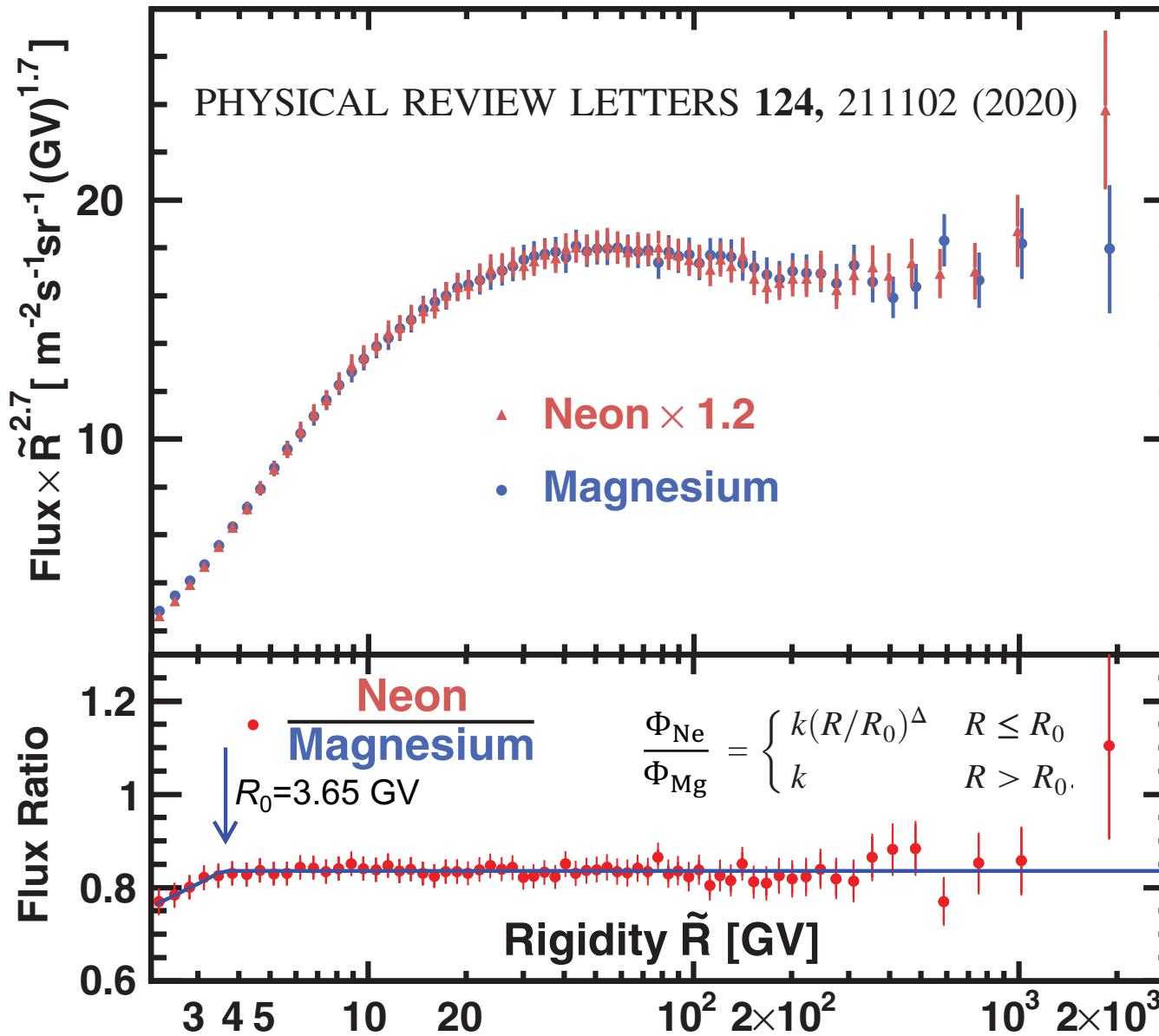
AMS Measured Nuclei+C Interaction Cross Sections



The square root of the interaction cross section on carbon target at rigidity 15 GV as a function of nuclear charge radius (R_c^p) for the projectile nuclei He, B, C, N, O, Ne, Mg, Si, S, and Fe. The nuclear charge radii are extracted from “I. Angeli and K. P. Marinova, Atomic Data and Nuclear Data Tables 99 (2013) 69-95”.

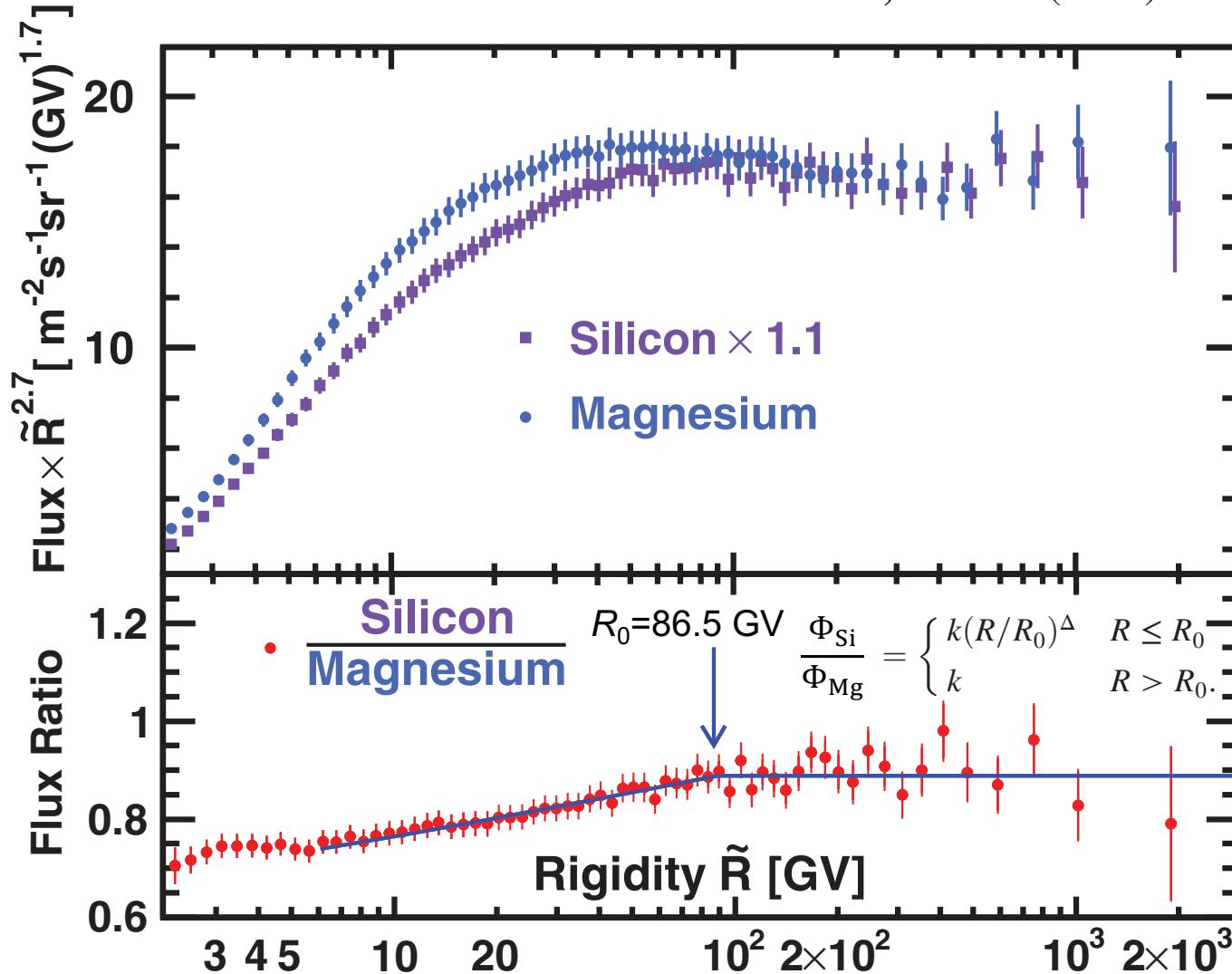
After the detailed study, the systematic error on the Ne, Mg, and Si fluxes due to uncertainties in the evaluation of the nuclear interactions is estimated to be <3.5% up to 100 GV and < 4% from 100 GV to 3 TV.

Neon and Magnesium Fluxes (AMS 2011-2018)



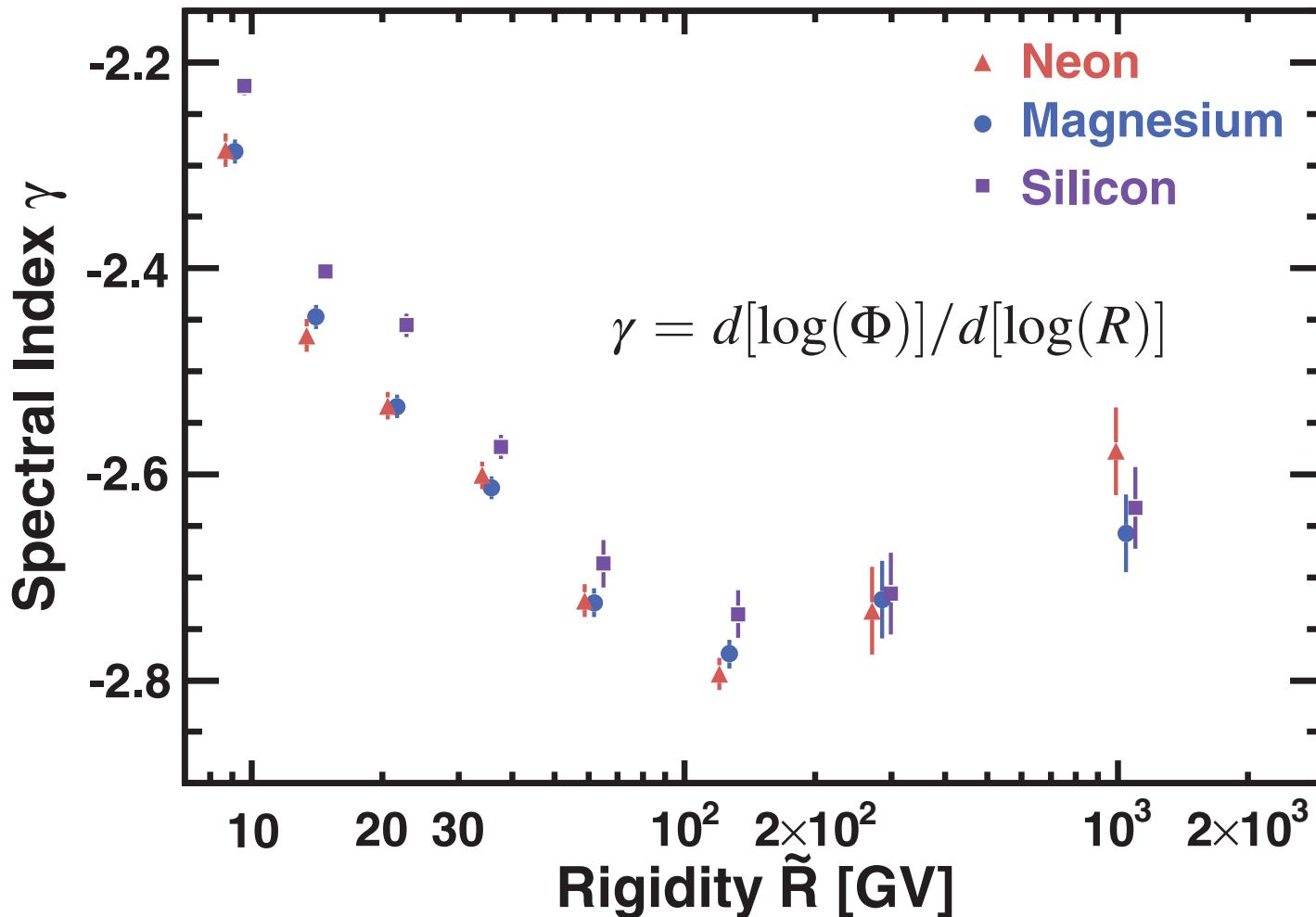
Magnesium and Silicon Fluxes (AMS 2011-2018)

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The Ne, Mg, and Si Spectral Indices

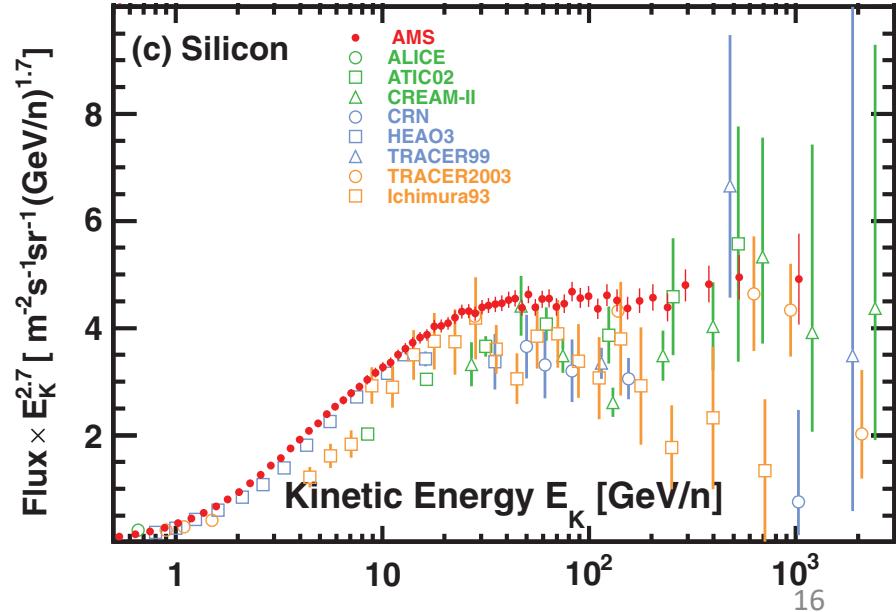
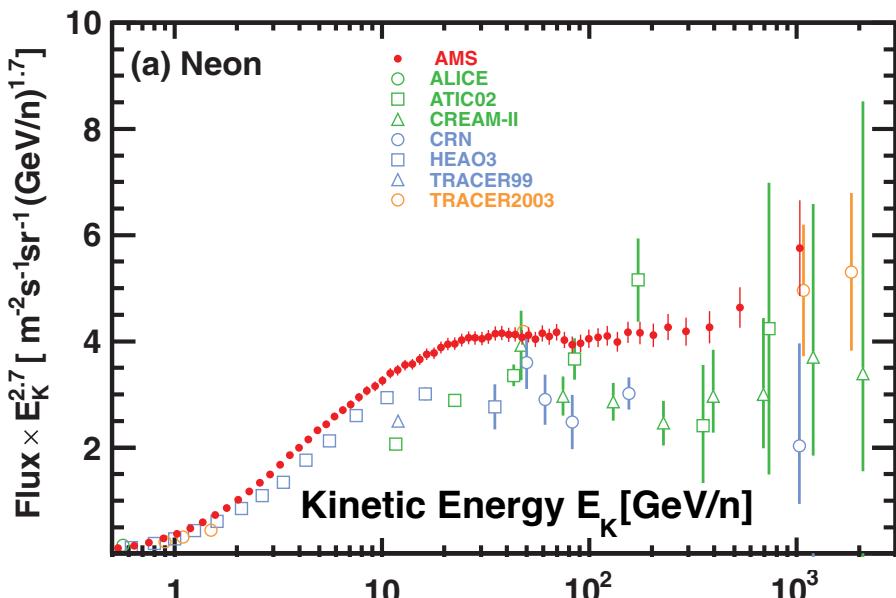
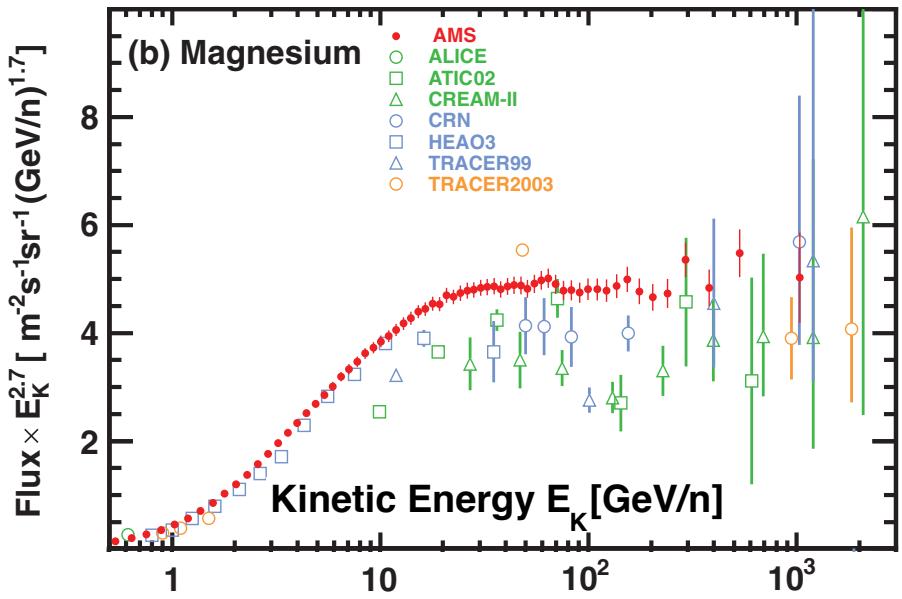
PHYSICAL REVIEW LETTERS 124, 211102 (2020)



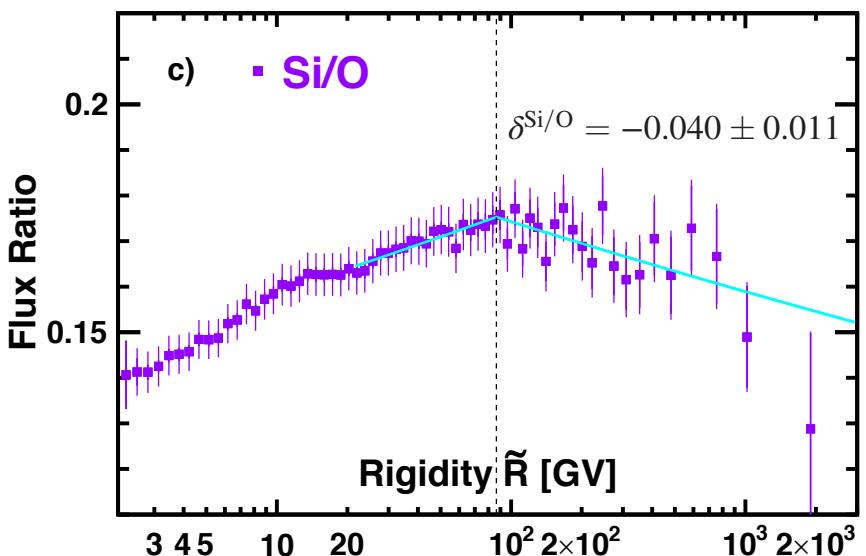
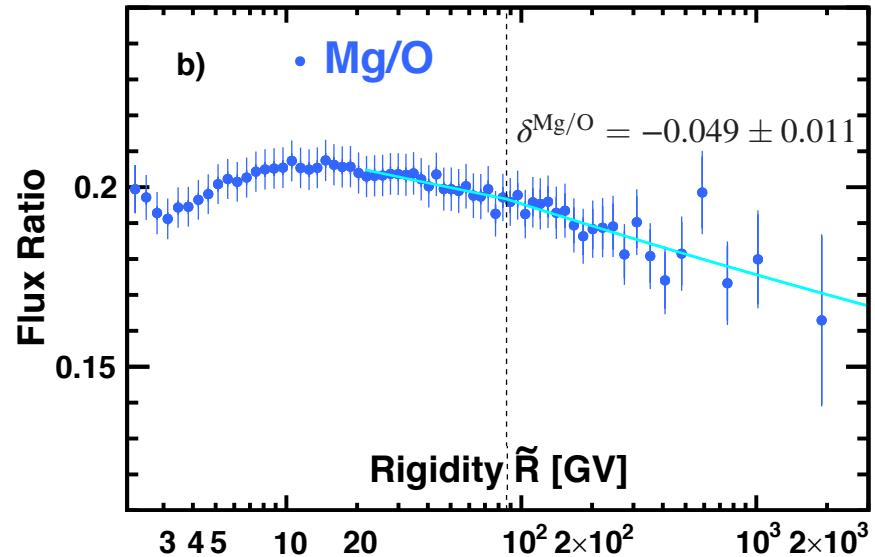
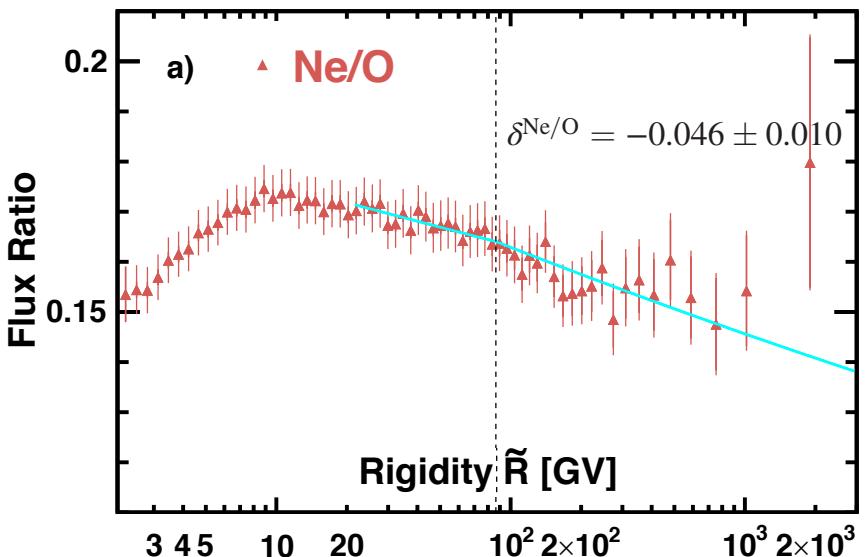
The Ne, Mg, and Si spectra have identical rigidity dependence above 86.5 GV, deviate from a single power law above 200 GV, and harden in an identical way.

AMS Results Compared with Other Experiments

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Ne, Mg, and Si Flux Ratios to Oxygen



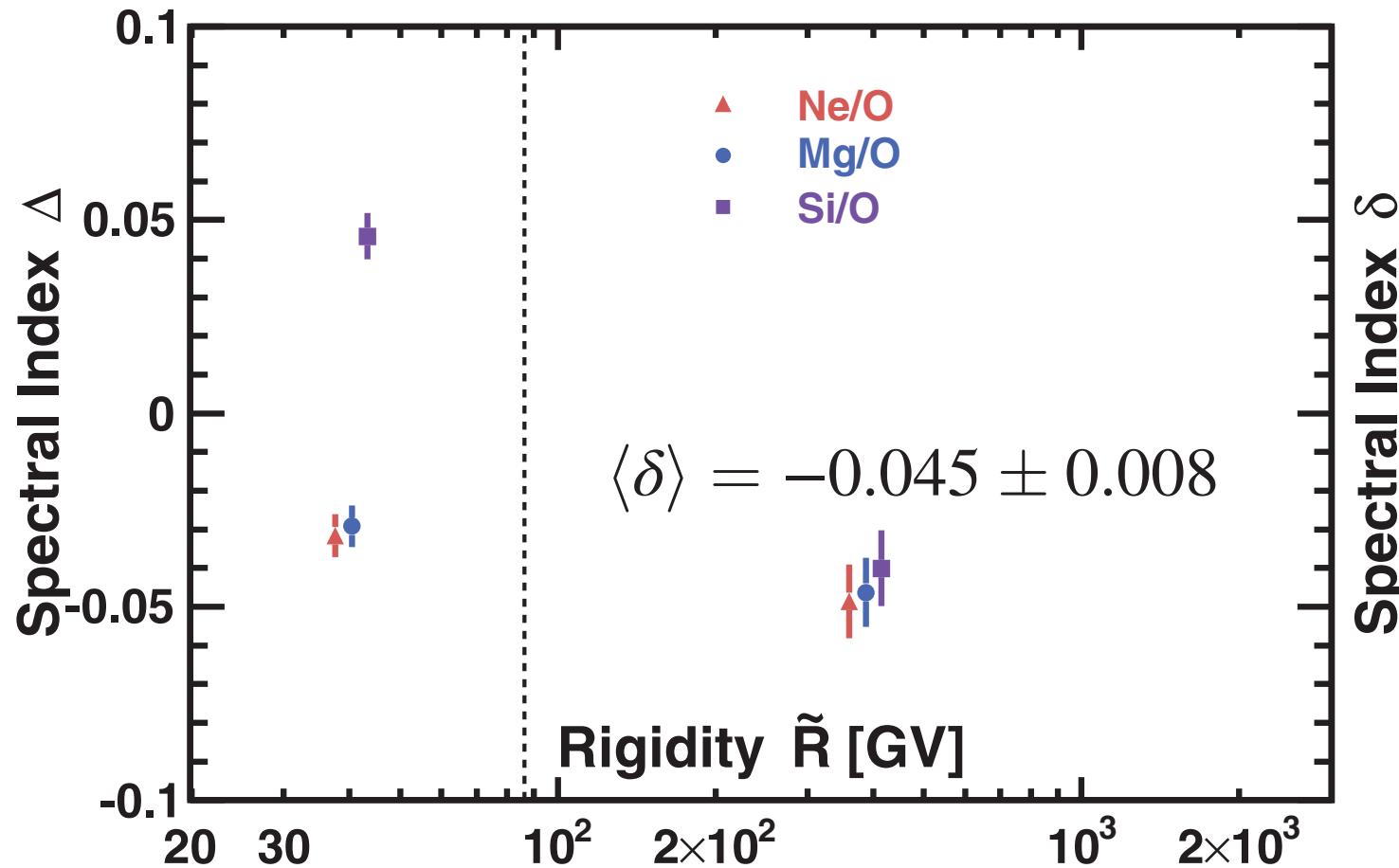
To examine the rigidity dependence difference between O and Ne-Mg-Si, Ne/O, Mg/O, and Si/O flux ratios were computed and fitted to:

$$\frac{\Phi_{\text{Ne,Mg,Si}}}{\Phi_{\text{O}}} = \begin{cases} C(R/86.5 \text{ GV})^\Delta & R \leq 86.5 \text{ GV} \\ C(R/86.5 \text{ GV})^\delta & R > 86.5 \text{ GV}, \end{cases}$$

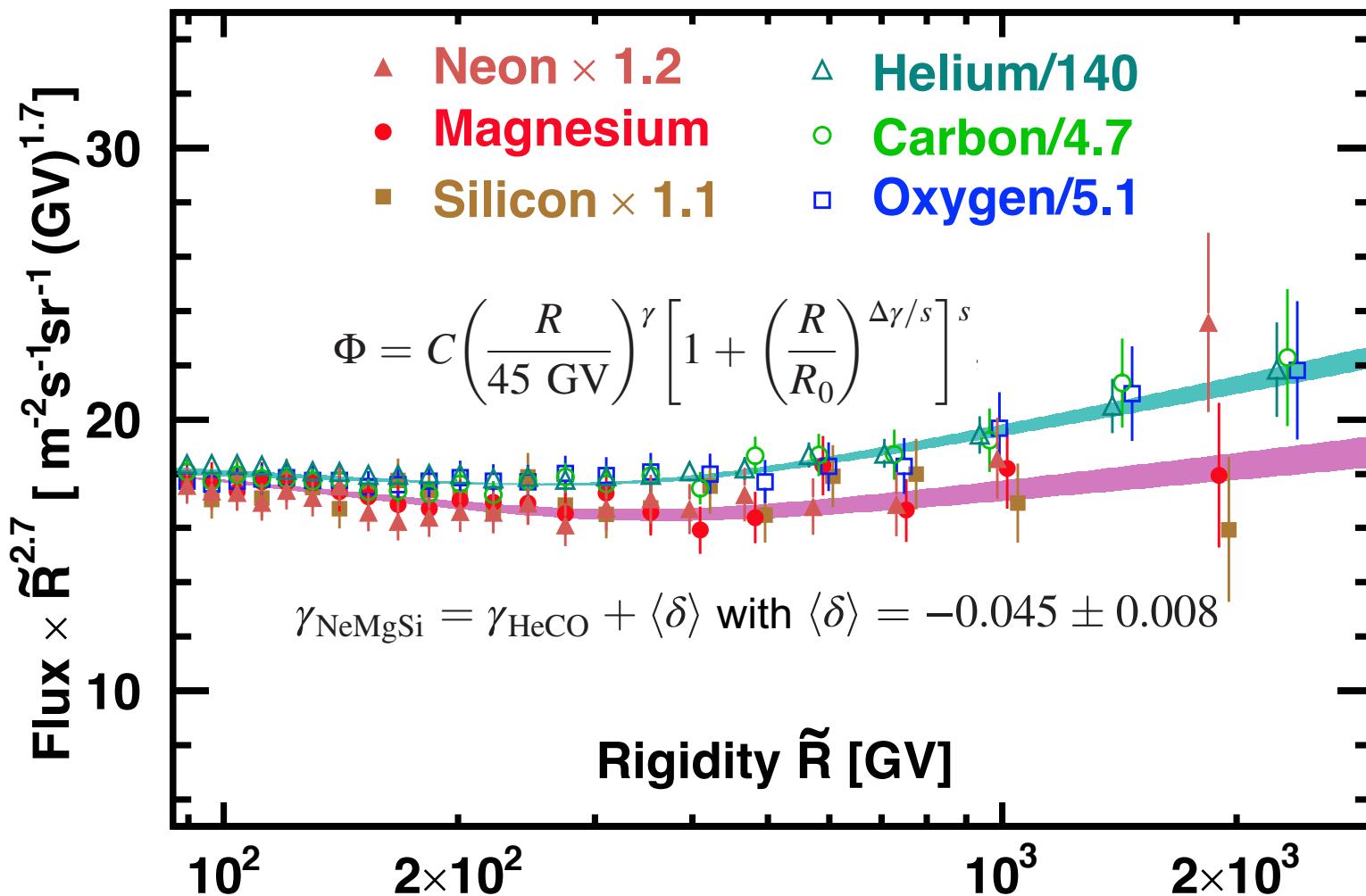
The Ne/O, Mg/O, and Si/O Flux Ratio Spectral Indices

$$\frac{\Phi_{\text{Ne,Mg,Si}}}{\Phi_{\text{O}}} = \begin{cases} C(R/86.5 \text{ GV})^{\Delta} & R \leq 86.5 \text{ GV} \\ C(R/86.5 \text{ GV})^{\delta} & R > 86.5 \text{ GV}, \end{cases}$$

The average value is $\langle \delta \rangle = -0.045 \pm 0.008$. The difference of $\langle \delta \rangle$ from zero by more than 5σ shows that the Ne, Mg, and Si is a different class of primary cosmic rays than He, C, and O.



Properties of Primary Cosmic Ray Nuclei (AMS He-Si)



Ne, Mg, Si and He, C, O are two different classes of primary cosmic rays.

Summary

- Precision measurements of primary cosmic rays Neon, Magnesium, and Silicon ($Z=10,12,14$) fluxes from 2.15 GV to 3 TV based on 7 years (2011-2018) AMS data have been presented.
- The Ne and Mg spectra have identical rigidity dependence above 3.65 GV. The three spectra have identical rigidity dependence above 86.5 GV, deviate from a single power law above 200 GV, and harden in an identical way.
- Unexpectedly, above 86.5 GV the rigidity dependence of Ne, Mg, and Si spectra is different from the rigidity dependence of primary cosmic rays He, C, and O by more than 5σ . This shows that the Ne, Mg, and Si and He, C, and O are two different classes of primary cosmic rays.

PHYSICAL REVIEW LETTERS **124**, 211102 (2020)

Editors' Suggestion

Featured in Physics

Properties of Neon, Magnesium, and Silicon Primary Cosmic Rays Results from the Alpha Magnetic Spectrometer

- The AMS precision results on other primary cosmic rays (including Iron) measurements would come soon. They are also very interesting ...