Unique Properties of the 3rd group of cosmic rays: Results from the Alpha Magnetic Spectrometer

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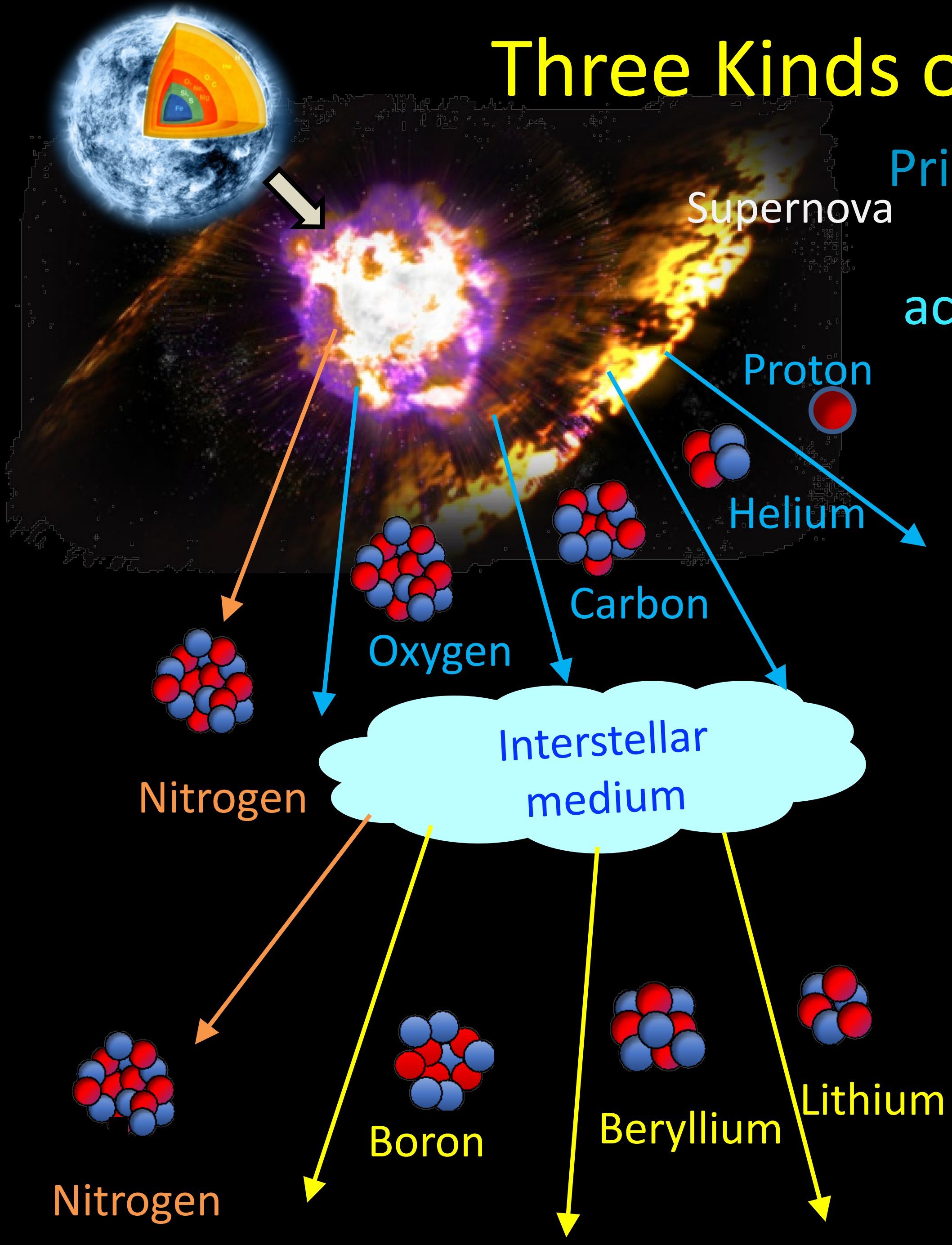
Three Kinds of Charged Cosmic Rays

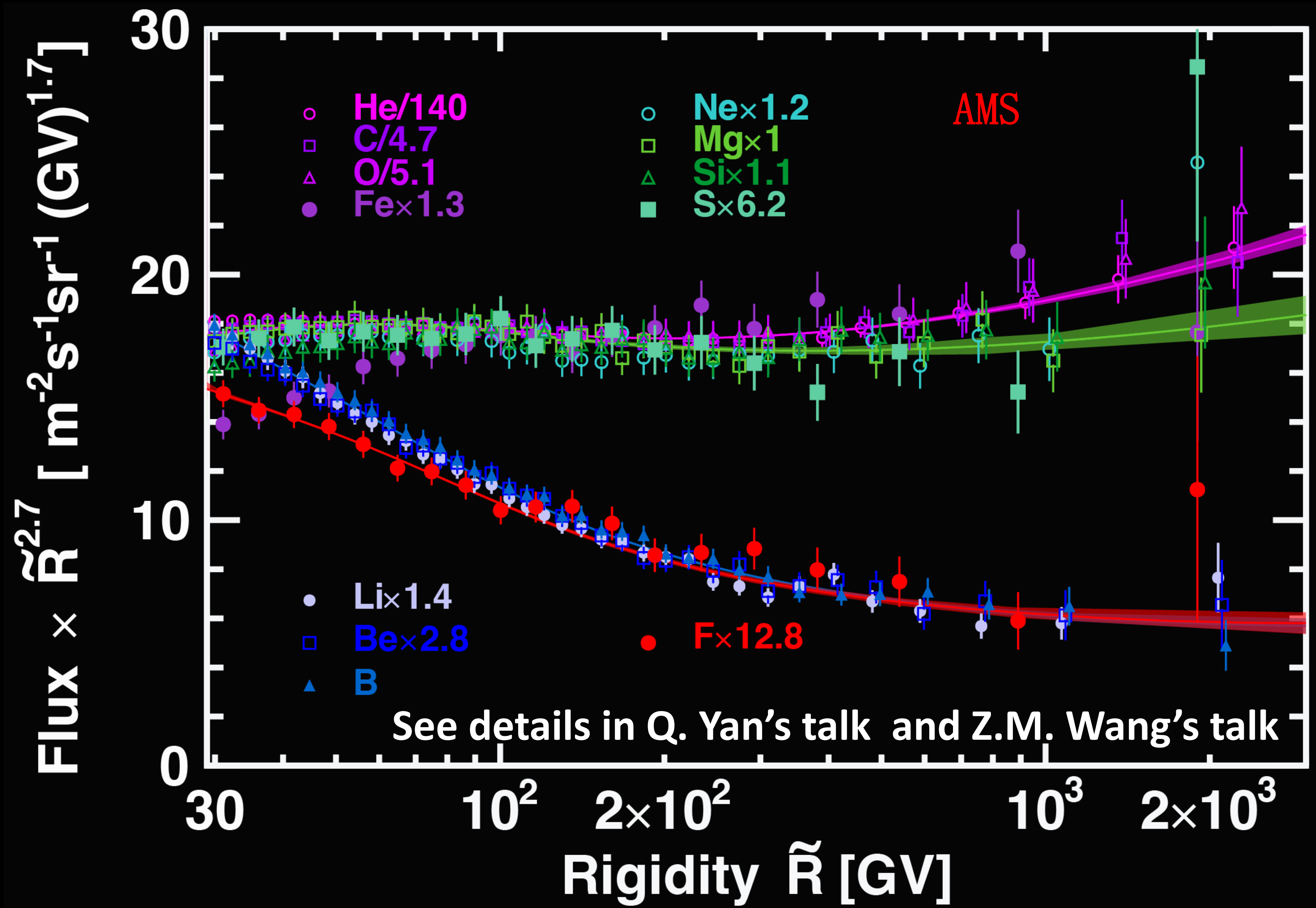


Primary cosmic rays (p, He, C, O, Ne, Mg, S ,Ar, ..., Fe) are mostly produced during the lifetime of stars and are accelerated in supernovae shocks, whose explosion rate is about 2-3 per century in our Galaxy.

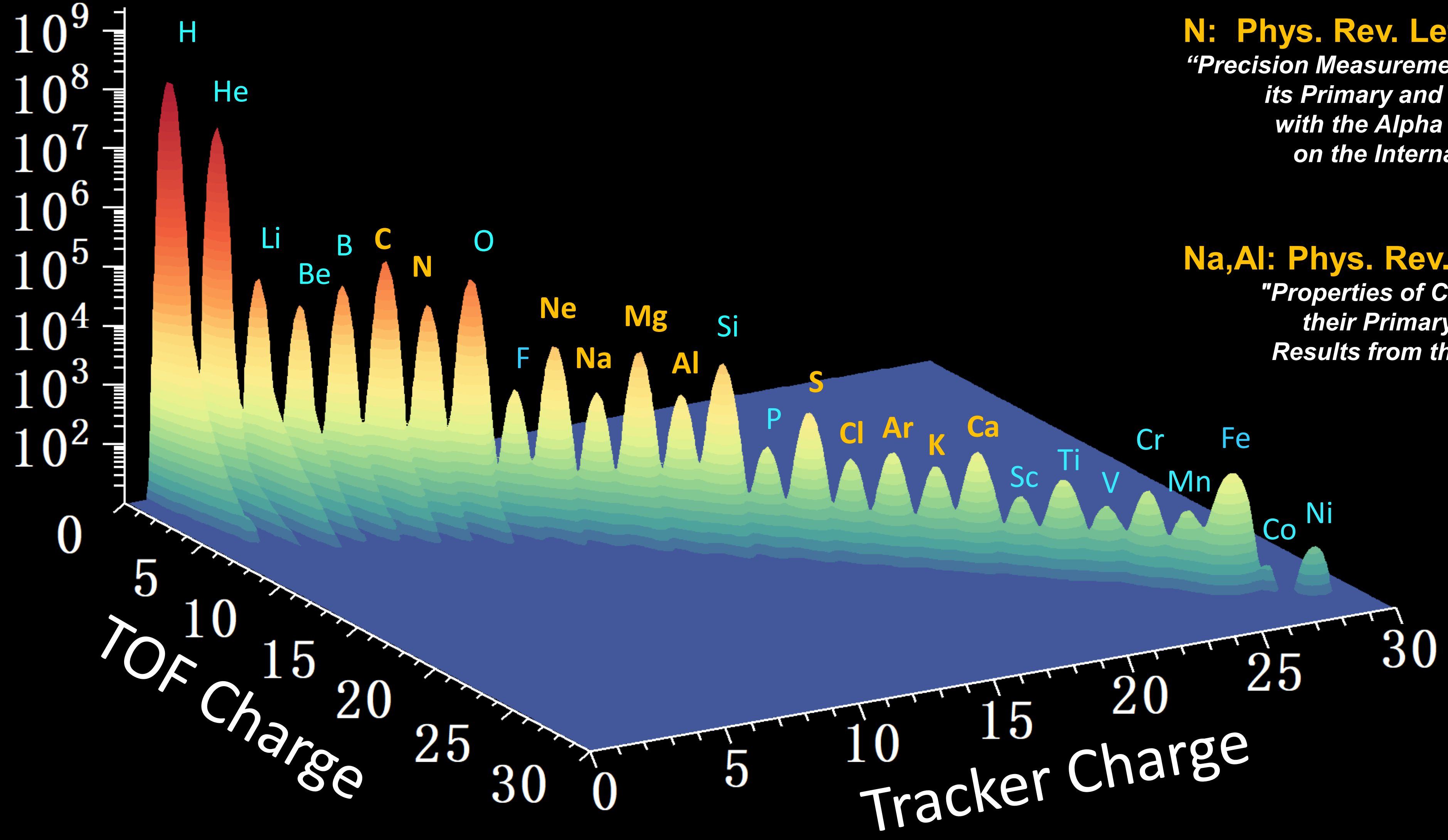
Secondary cosmic nuclei (Li, Be, B, F, …) are produced by the collisions of primary cosmic rays and interstellar medium.

Cosmic nuclei with both Primary and Secondary Components (N, Na, Al,…) . Many primary cosmic rays C, Ne, Mg, S are also expected to have sizeable secondary component.

AMS Measurement of Primary and Secondary Cosmic Rays



AMS Cosmic Rays Chemical Composition

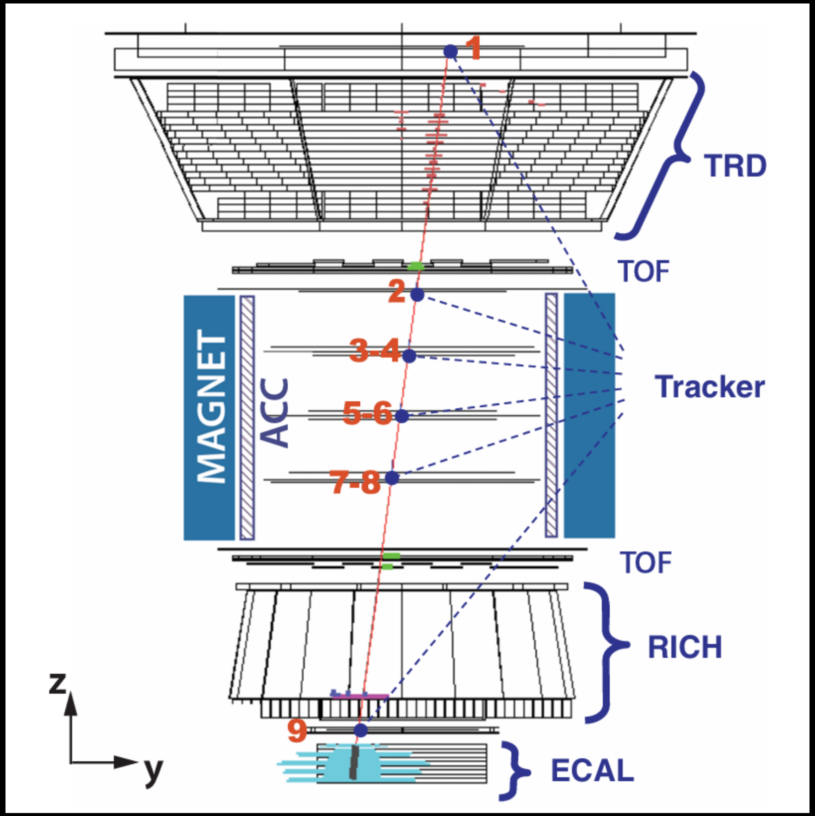


N: Phys. Rev. Lett. 121, 051103 (2018).
"Precision Measurement of Cosmic-Ray Nitrogen and its Primary and Secondary Components with the Alpha Magnetic Spectrometer on the International Space Station"

Na,Al: Phys. Rev. Lett. 127, 021101 (2021).
"Properties of Cosmic Sodium and Aluminum and their Primary and Secondary Components, Results from the Alpha Magnetic Spectrometer"

In this talk: N, Na, Al and C, Ne, Mg, S, Cl, Ar, K, Ca.

AMS Nuclei Fluxes Measurement



Tracker(9 Layers) + Magnet:
Rigidity(Momentum/Charge) with muti-TV maximal detectable rigidity (MDR)

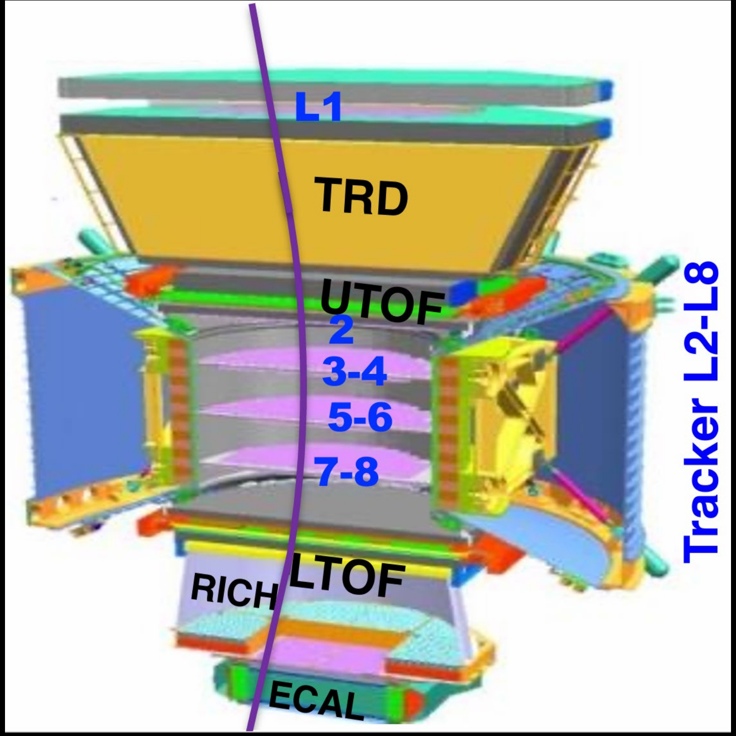
Charge Z	MDR	Coordinate Resolution
1	2TV	10μm
≥2	3.0-3.7TV	5-8μm

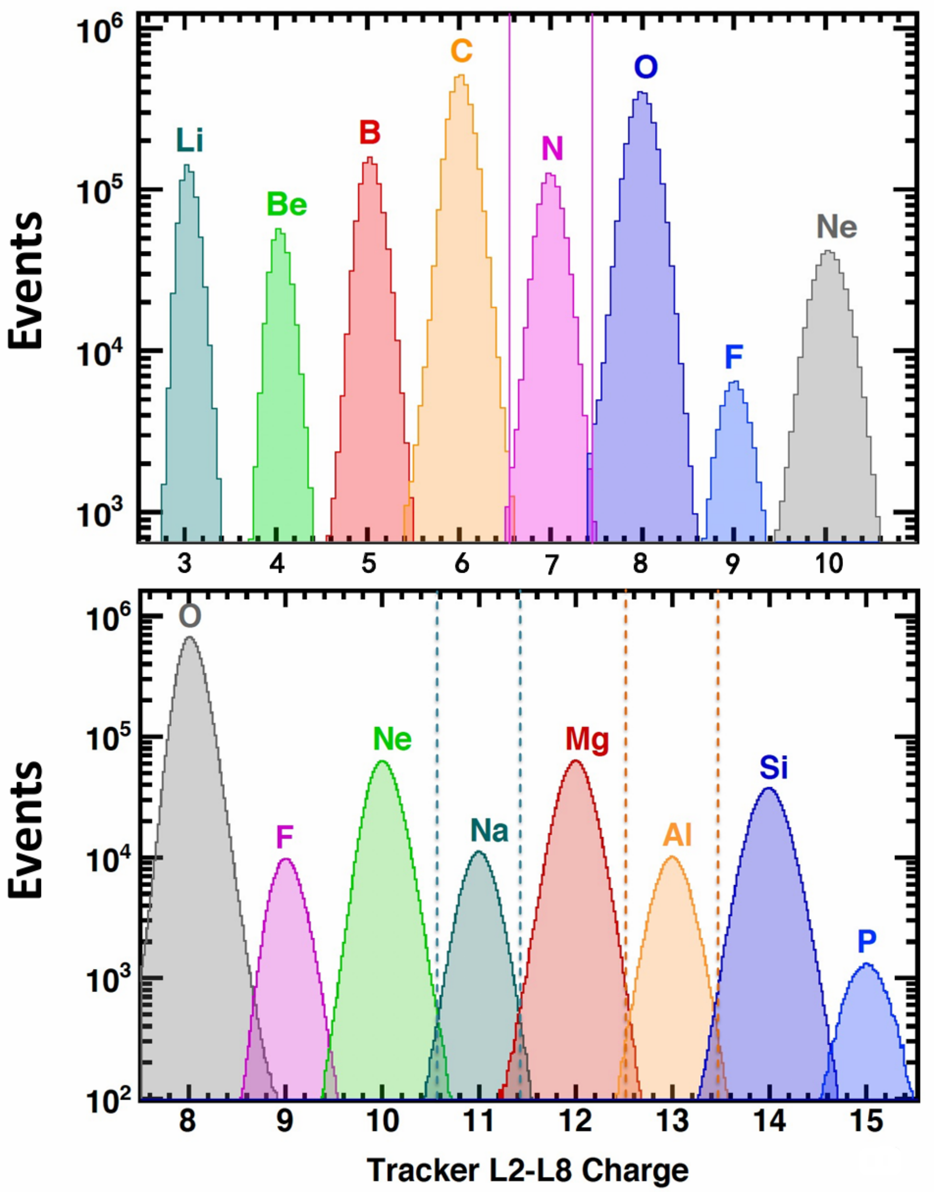
Tracker(9 Layers) + TOF(4 Layers) :
Charge measurement along the particle trajectory

Inner Tracker Charge Resolution:
$\Delta Z = 0.05 - 0.35\ (1 \leq Z \leq 28)$

AMS event selection

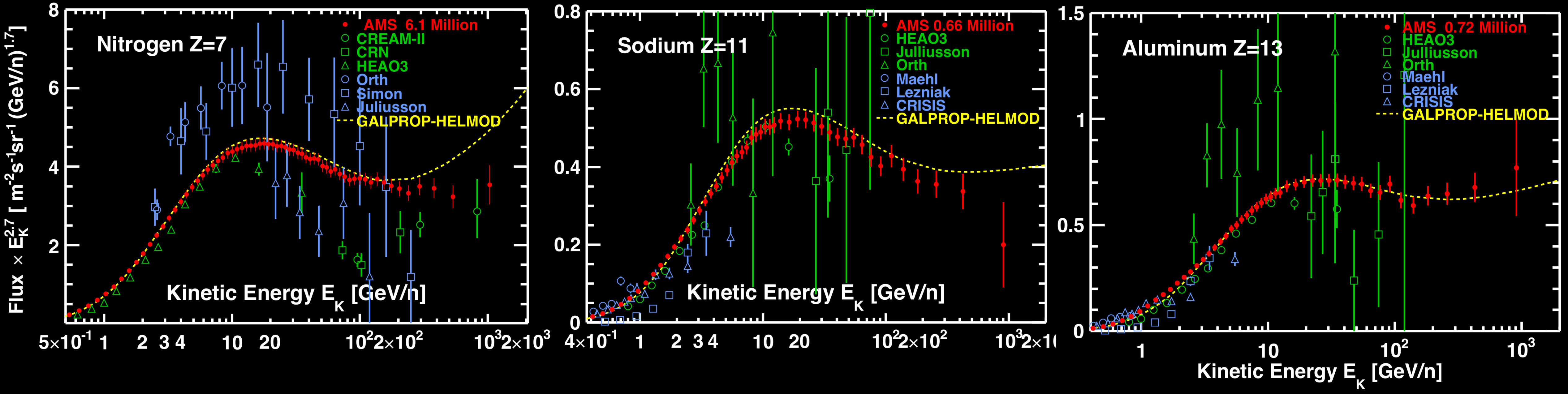
- AMS has a good charge measurement capability. Charge measured by L1, UTOF, tracker L2-L8, LTOF and L9 are required to be consistent along particle trajectory.
- The background due to finite charge resolution is negligible (N, Na and Al, <0.5% over the entire rigidity range.)





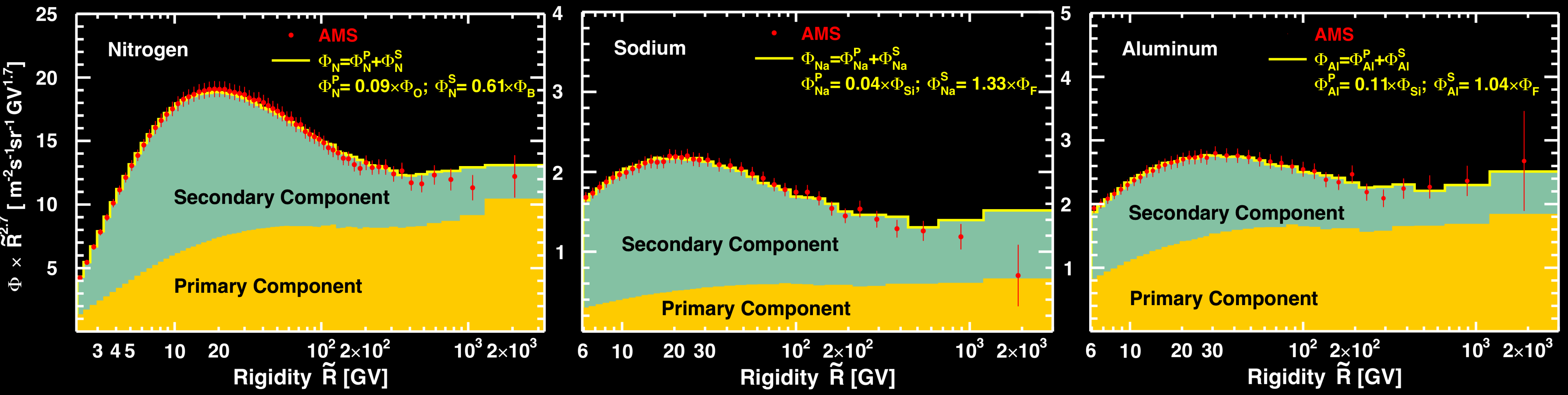
AMS N, Na, and Al Nuclei Fluxes together with earlier measurements and theory predictions.

Note that latest GALPROP-HELMOD model, based largely on AMS published data provides good agreement with AMS Na and Al measurements.

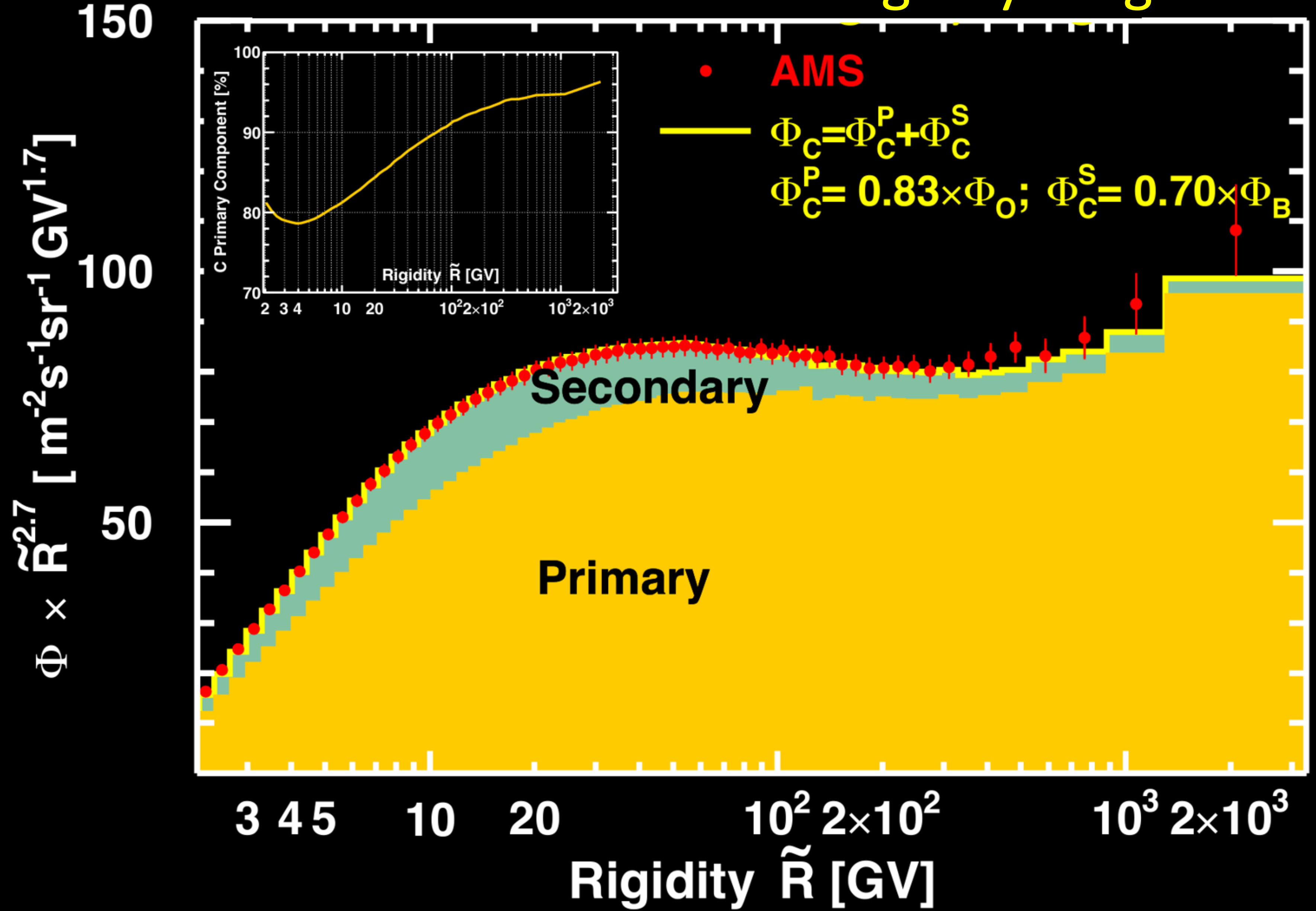


N, Na and Al fluxes can be expressed as a sum of primary (O,Si) and secondary (B,F) fluxes

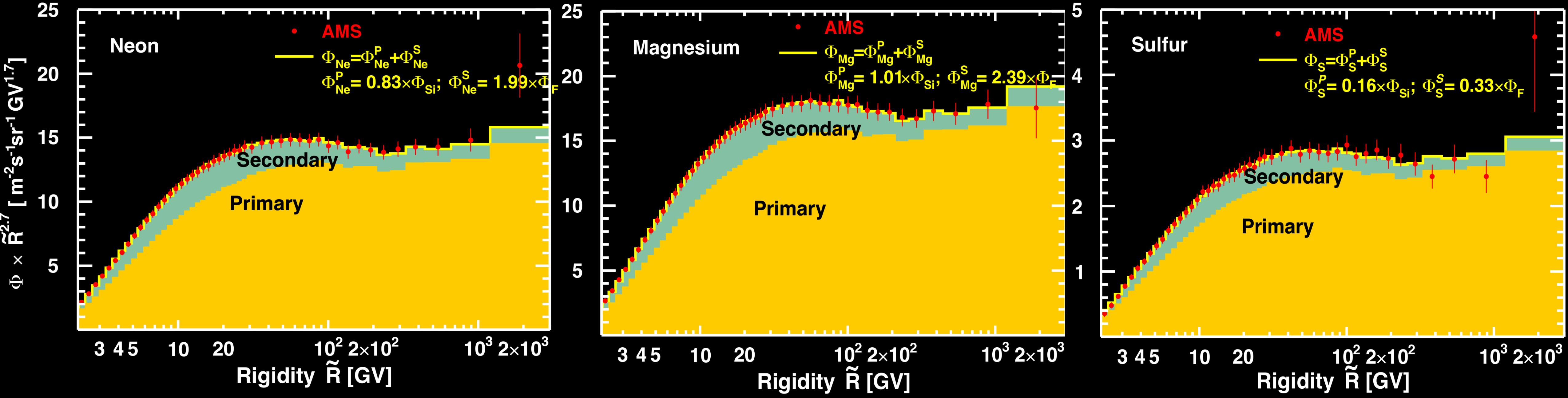
Phys. Rev. Lett. 127, 021101 (2021)



C flux can also be expressed as a sum of primary (O) and secondary (B) fluxes over the entire rigidity range

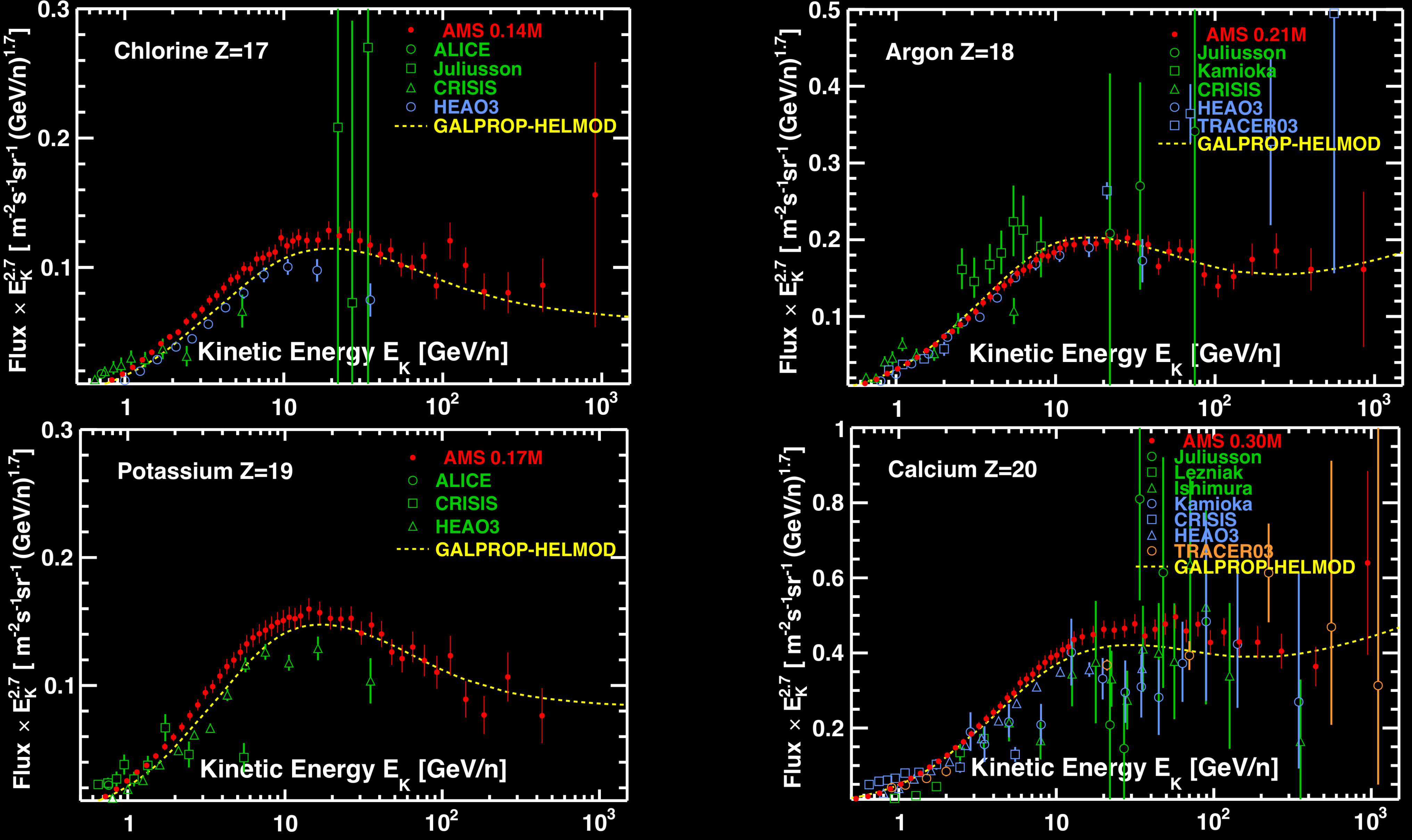


Ne, Mg, and S fluxes can also be expressed as a sum of primary (Si) and secondary (F) fluxes over the entire rigidity range

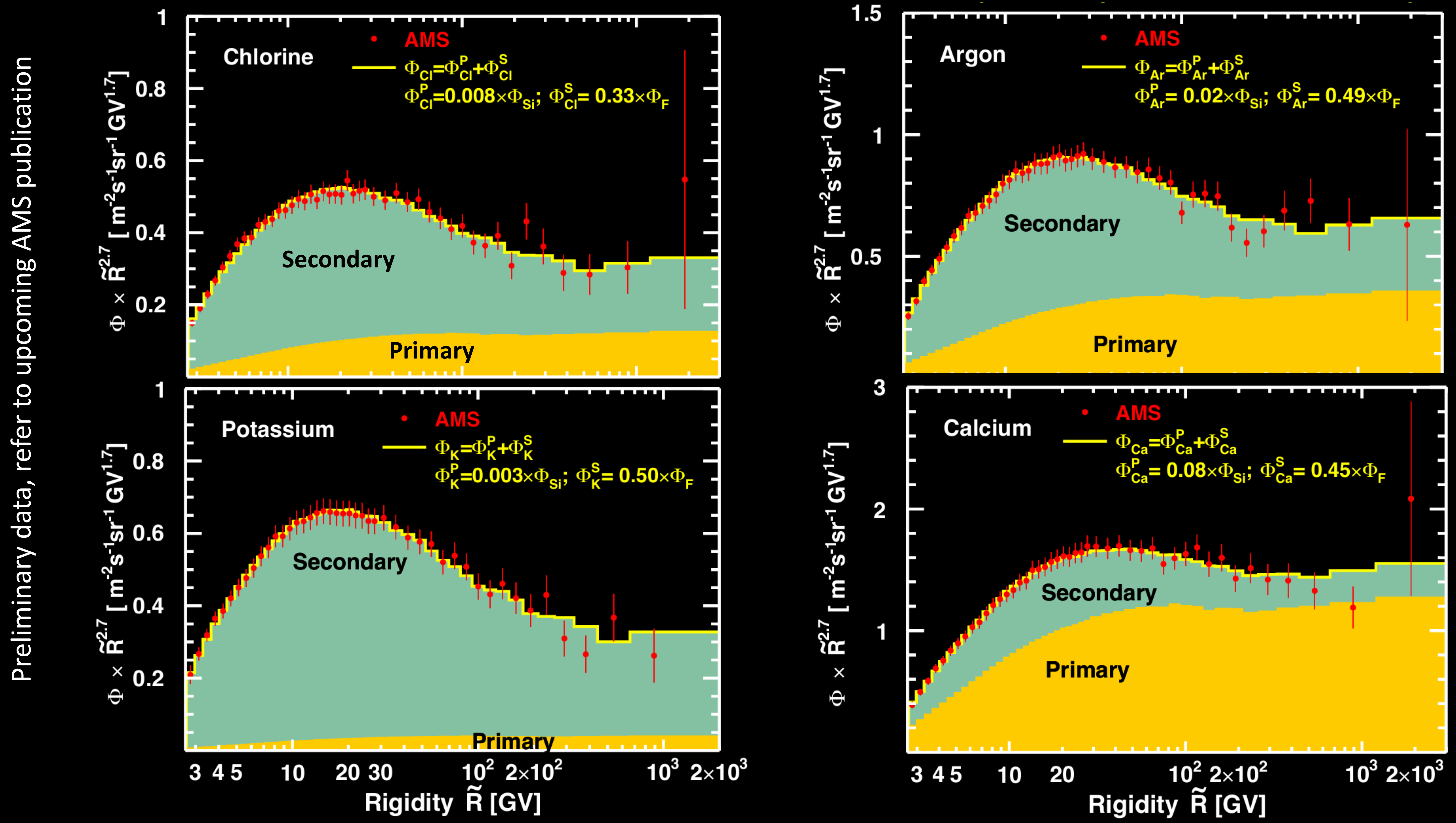


AMS Cl, Ar, K, and Ca Nuclei Fluxes together with earlier measurements and theory predictions.

Preliminary data, refer to upcoming AMS publication



Cl, Ar, K, and Ca fluxes can be expressed as a sum of primary Si and secondary F fluxes



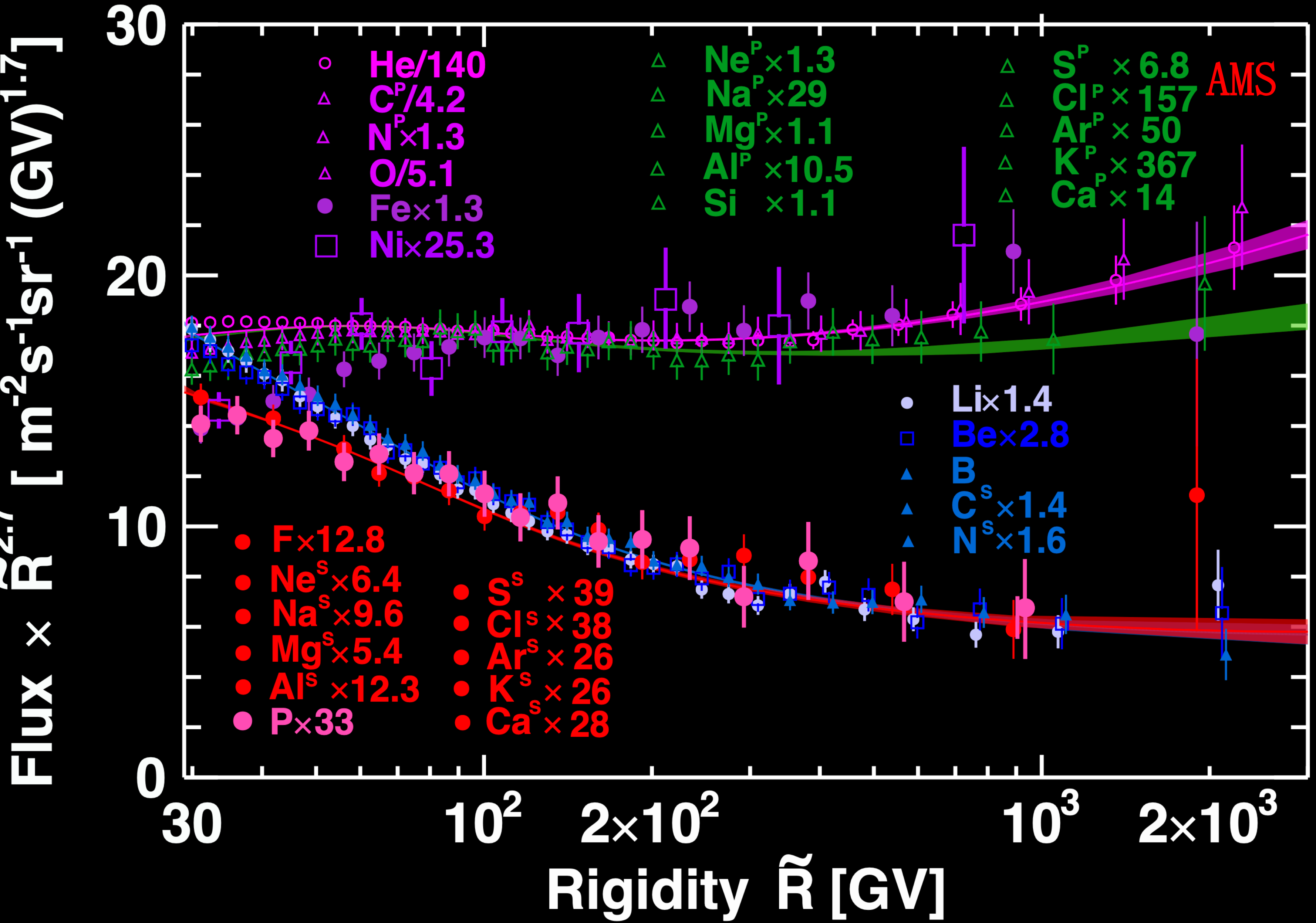
Summary Primary and Secondary Components

Nuclei Flux	Primary	Secondary	Secondary Fr,% 6 GV	Secondary Fr,% 2 TV
Φ_C	$(0.835 \pm 0.025) \times \Phi_O$	$(0.70 \pm 0.03) \times \Phi_B$	20±1	4±0.5
Φ_N	$(0.091 \pm 0.002) \times \Phi_O$	$(0.61 \pm 0.02) \times \Phi_B$	69±1	23±2
Φ_{Ne}	$(0.831 \pm 0.025) \times \Phi_{Si}$	$(1.99 \pm 0.14) \times \Phi_F$	24±1	5±0.5
Φ_{Na}	$(0.038 \pm 0.003) \times \Phi_{Si}$	$(1.33 \pm 0.04) \times \Phi_F$	81±2	38±12
Φ_{Mg}	$(1.008 \pm 0.025) \times \Phi_{Si}$	$(2.39 \pm 0.17) \times \Phi_F$	25±1	5±0.5
Φ_{Al}	$(0.105 \pm 0.004) \times \Phi_{Si}$	$(1.04 \pm 0.03) \times \Phi_F$	57±2	22±8
Φ_P	$(0.002^{+0.002}_{-0.001}) \times \Phi_{Si}$	$(0.35 \pm 0.02) \times \Phi_F$	98±2	92±2
Φ_S	$(0.162 \pm 0.005) \times \Phi_{Si}$	$(0.33 \pm 0.04) \times \Phi_F$	18±3	3±1
Φ_{Cl}	$(0.008 \pm 0.001) \times \Phi_{Si}$	$(0.33 \pm 0.01) \times \Phi_F$	86±3	63±4
Φ_{Ar}	$(0.021 \pm 0.002) \times \Phi_{Si}$	$(0.49 \pm 0.02) \times \Phi_F$	74±4	44±4
Φ_K	$(0.003 \pm 0.001) \times \Phi_{Si}$	$(0.50 \pm 0.02) \times \Phi_F$	96±3	87±3
Φ_{Ca}	$(0.076 \pm 0.003) \times \Phi_{Si}$	$(0.45 \pm 0.03) \times \Phi_F$	44±2	18±1

The C (Z=6) to Ca (Z=20) cosmic ray nuclei primary and secondary components derived as fractions of O(Si) and B(F) fluxes, respectively, and their secondary fractions at 6 GV and 2 TV.

This allows to measure relative cosmic ray abundances of C/O, N/O, Ne/Si, Na/Si, Mg/Si, Al/Si, S/Si, Cl/Si, Ar/si, K/Si, and Ca/Si at the source independently of cosmic ray propagation.

Primary and Secondary Decomposition for All Cosmic Ray Fluxes of 2≤Z≤20, Z=26, Z=28



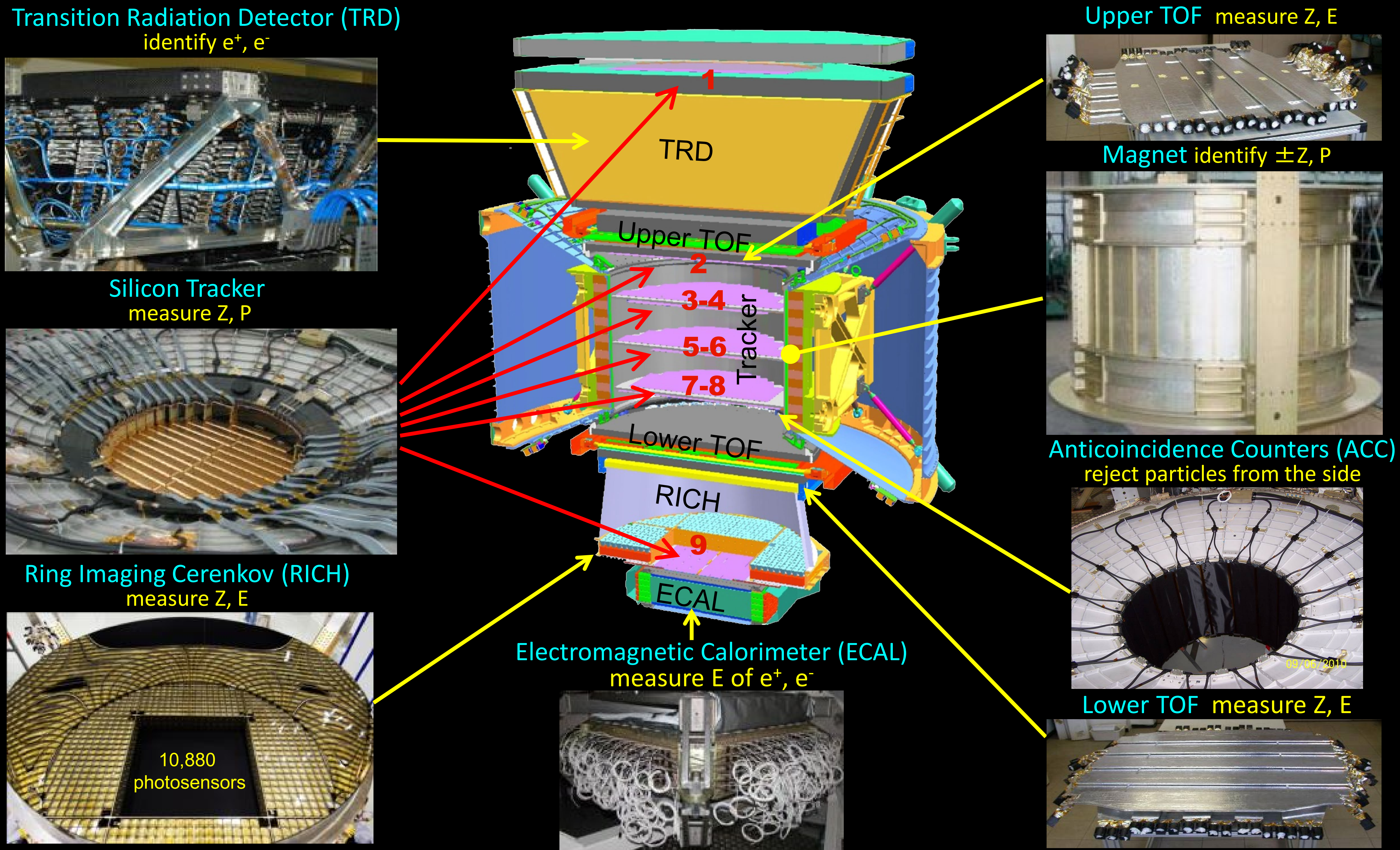
Summary

Latest results on the properties of C, N, Ne, Na, Mg, Al, S, Cl, Ar, K, and Ca cosmic rays fluxes in the rigidity range 2.5 GV to 3 TV collected by the AMS has been presented.

The unprecedented accuracy of the AMS data is revealing unique features in cosmic-ray spectra: the fluxes of C, N, Ne, Na, Mg, Al, S, Cl, Ar, K, and Ca are well described by the sums of a primary cosmic ray component and a secondary cosmic ray component.

With our measurements, the abundance ratios at the source C/O, N/O, Ne/Si, Na/Si, Mg/Si, Al/Si, S/Si, Cl/Si, Ar/Si, K/Si, and Ca/Si are determined independent of cosmic ray propagation.

AMS is a space version of a precision magnetic spectrometer



AMS Abundance Ratios at the Source

together with earlier model-dependent results from low-energy measurements.

Abundance Ratio	AMS	HEAO [ ]	ULYSSES [ ]	Voyager-1 [ ]	ACE/CRIS [ ]
Φ_{Ne}/Φ_{Si}	0.831 ± 0.025	0.580±0.030	0.580±0.061	0.581±0.004	0.511±0.058
Φ_{Na}/Φ_{Si}	0.038 ± 0.003	0.0323±0.0097	$0.0324^{+0.0130}_{-0.0077}$	0.040±0.003	0.0372±0.0256
Φ_{Mg}/Φ_{Si}	1.008 ± 0.025	1.038±0.028	1.080±0.040	1.110±0.011	1.111±0.033
Φ_{Al}/Φ_{Si}	0.105 ± 0.004	0.0778±0.012	$0.0778^{+0.0130}_{-0.0100}$	0.0966±0.0083	0.104±0.019
Φ_{P}/Φ_{Si}	$0.002^{+0.002}_{-0.001}$	0.008±0.003	$0.0033^{+0.0033}_{-0.0027}$	0.007±0.002	
Φ_{S}/Φ_{Si}	0.162 ± 0.005	0.131±0.009	0.131±0.002	0.131±0.002	0.129±0.019
Φ_{Cl}/Φ_{Si}	0.008 ± 0.001		0.001±0.001	0.003±0.002	
Φ_{Ar}/Φ_{Si}	0.021 ± 0.002	0.022±0.006	0.022±0.012	0.021±0.003	0.019±0.020
Φ_{K}/Φ_{Si}	0.003 ± 0.001	0.004±0.003	$0.003^{+0.002}_{-0.003}$	0.003±0.001	
Φ_{Ca}/Φ_{Si}	0.076 ± 0.003	0.060±0.009	0.065±0.012	0.065±0.004	0.081±0.035
Φ_{C}/Φ_{O}	0.835 ± 0.025	0.807±0.015	$0.850^{+0.066}_{-0.064}$	0.800±0.029	0.760±0.029
Φ_{N}/Φ_{O}	0.091 ± 0.002	0.048±0.012	0.065±0.006	0.072±0.004	0.053±0.037

The Fluxes of Cosmic Nuclei Measured by AMS (He-Si)