Lecture 3 101018

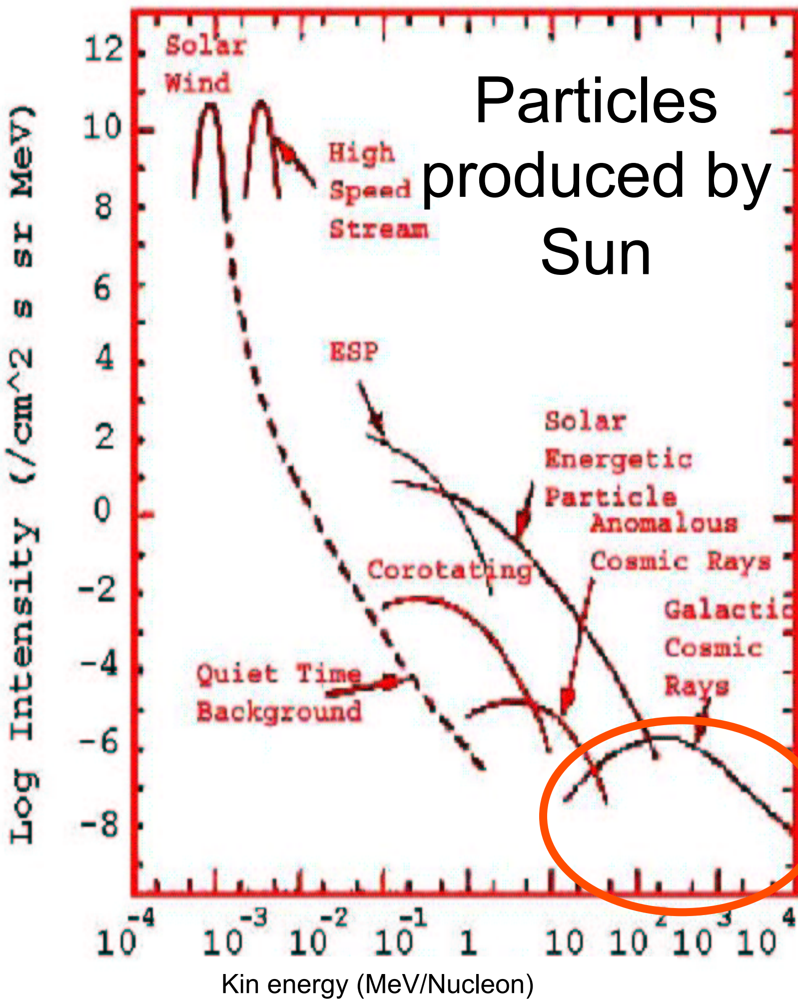
- Slides will be available at:

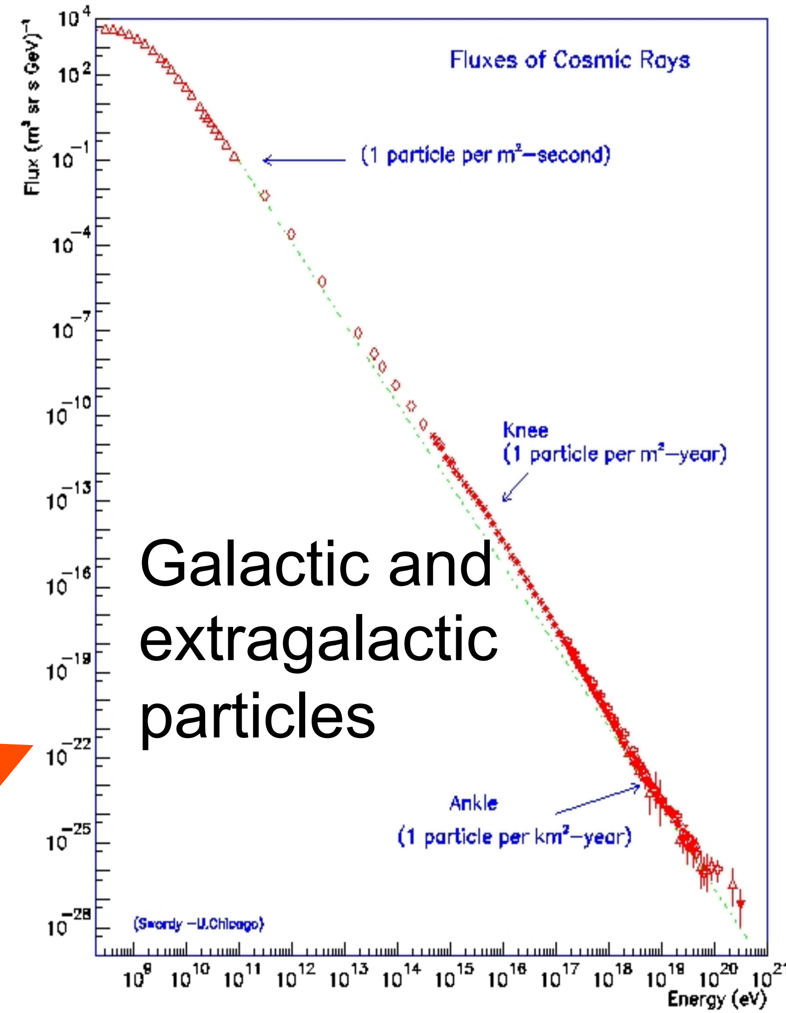
https://www.fisgeo.unipg.it/~fiandrin/didattica_fisica/cosmic_rays1819

Lo spettro energetico dei RC primari

Lo spettro differenziale e' il numero di particelle che attraversano l'unita' di superficie per unita' di tempo, di angolo solido e di energia

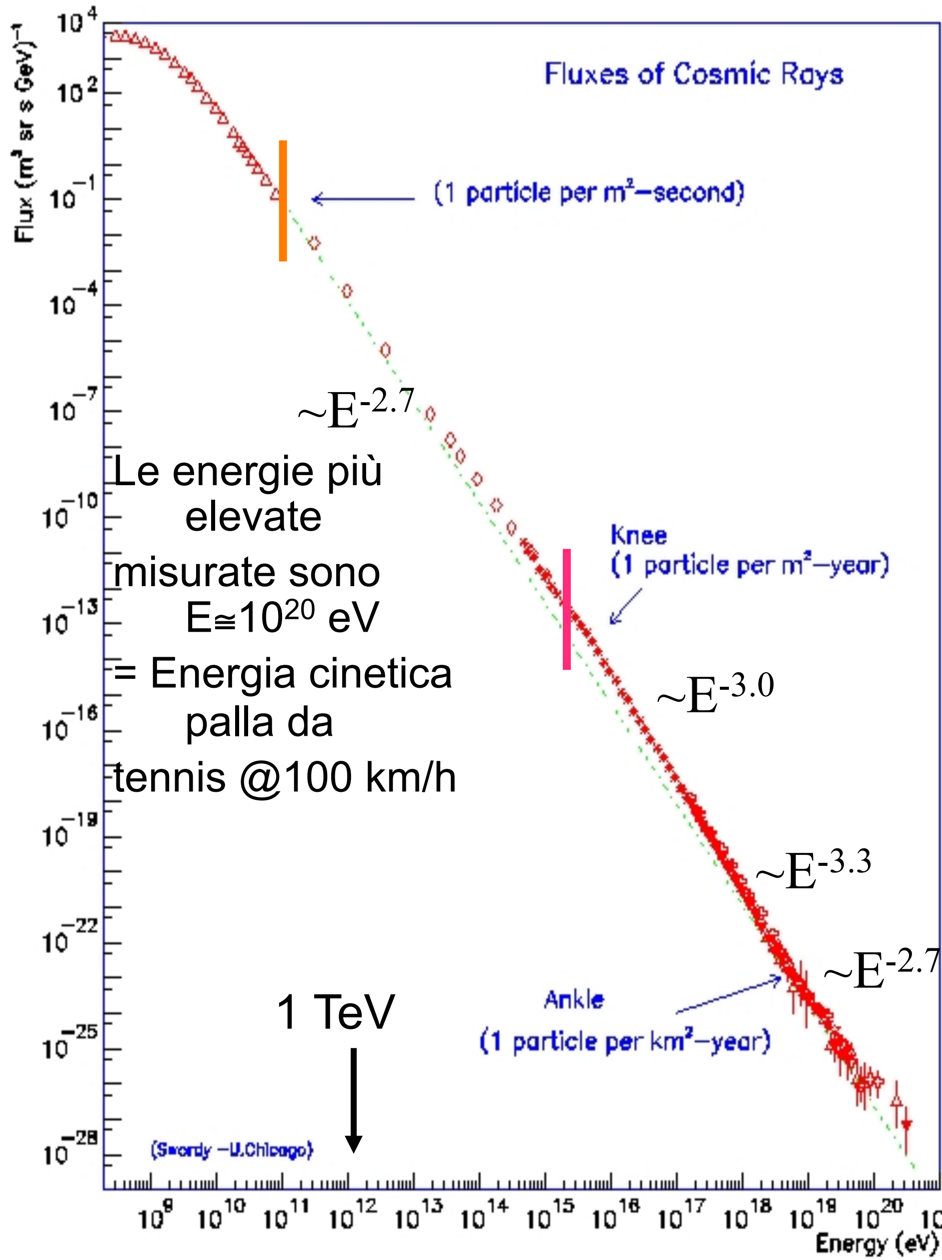
dN/dtdEdSdΩ





- Φ_{TOT}~10000 $m^{-2}s^{-1}sr^{-1}$
- Misure dirette: 85% p, 12% He, ≈1% nuclei pesanti, ≈2% $e^{\pm}$, antiprotoni + fotoni
- Si estende per 13 ordini di grandezza in energia
- Per 32 ordini di grandezza in flusso
- Legge di potenza su tutto lo spettro, con almeno due cambi di pendenza

Le energie più elevate in gioco nei RC sono irraggiungibili agli acceleratori



→ Legge di potenza

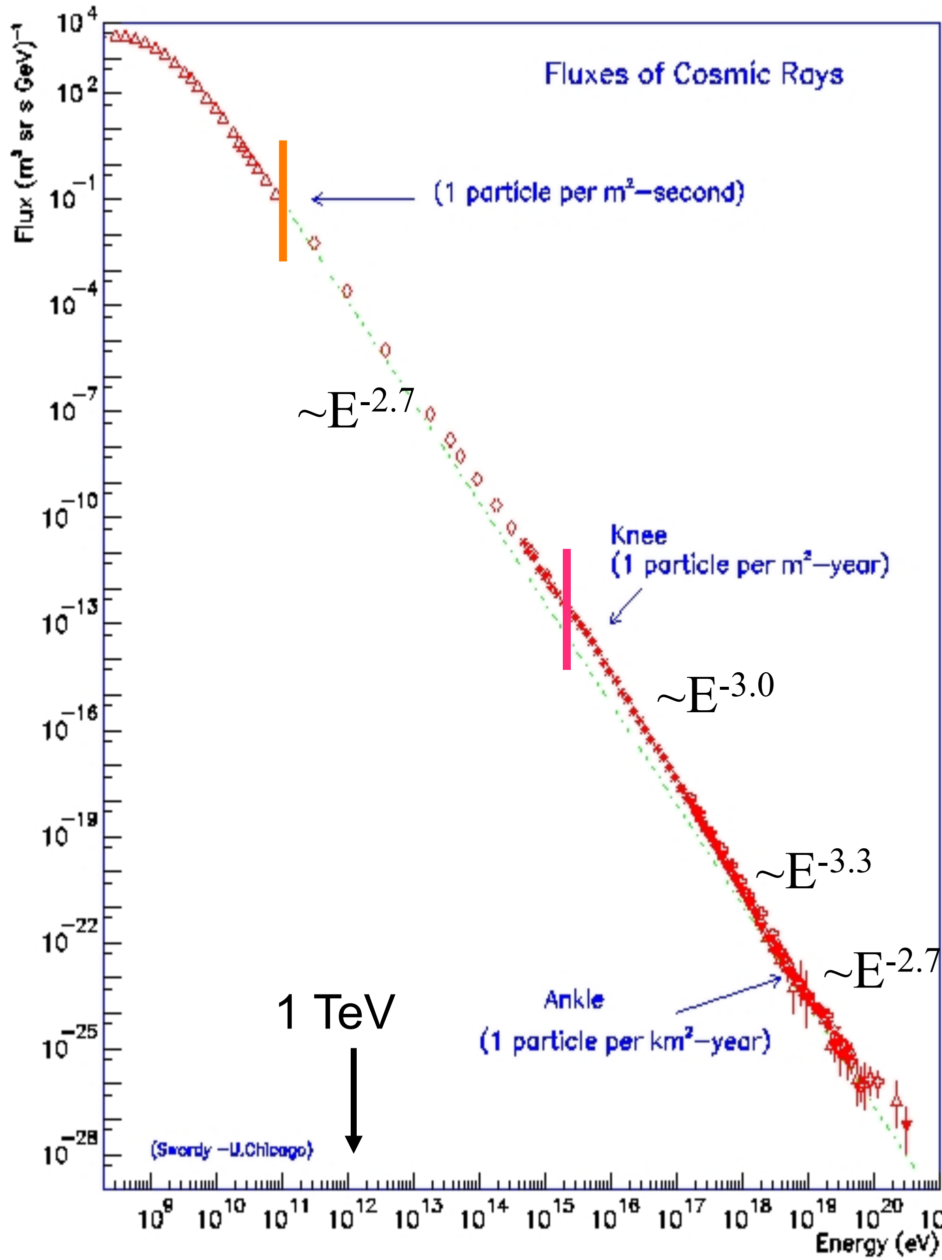
$$\Phi = K(E/GeV)^{\alpha}$$

→ Spettri non termici (quale sarebbe la distribuzione di energia di uno spettro termico?)

→ Processi di accelerazione + propagazione che producono uno spettro regolare

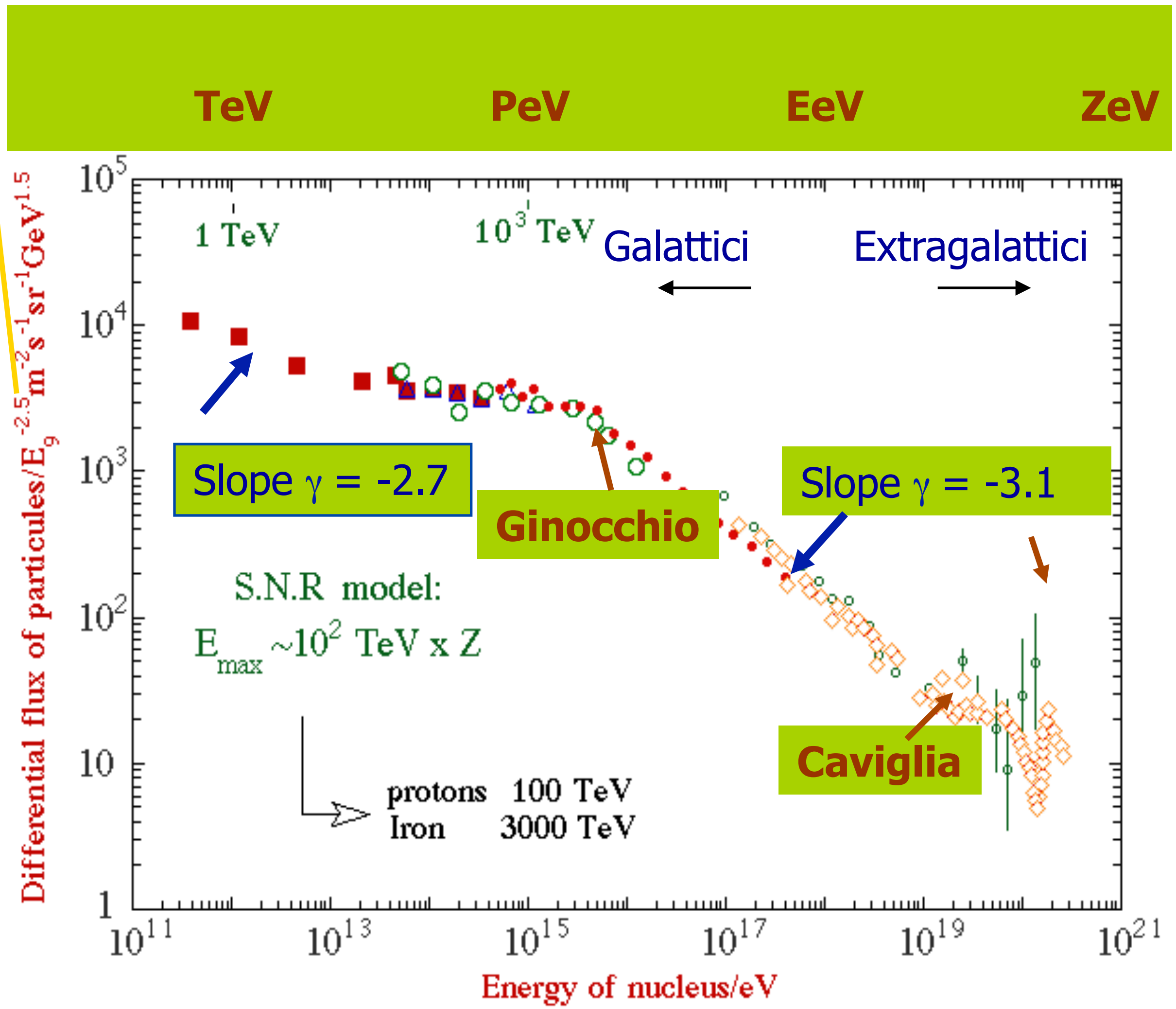
→ da informazioni sui processi di accelerazione alle sorgenti e di propagazione nel mezzo interstellare delle particelle

→ A bassa energia lo spettro e' influenzato dall'azione del vento solare



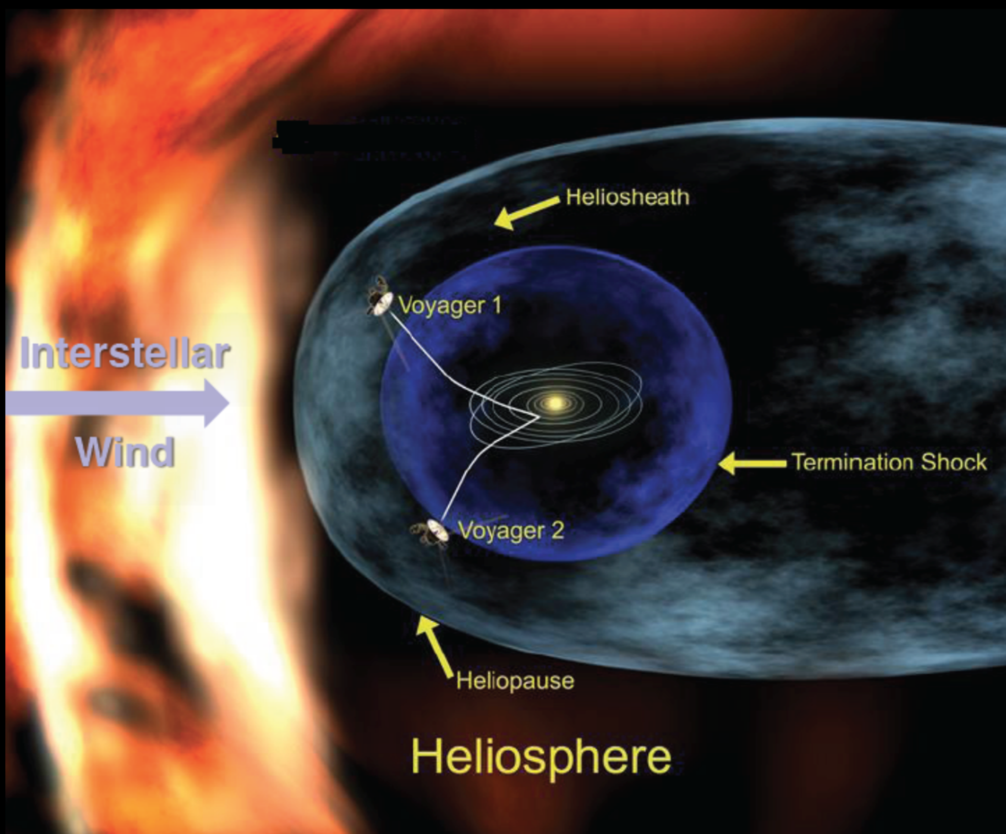
Ancora lo spettro dei RC, ma…

L'asse y viene moltiplicato per $E^{2.5}$ (o piu' in generale per una potenza di E), in modo da rendere "più piatta" la figura ed accentuare il ***cambiamento di pendenza!***



Intermezzo: Voyager data

Voyager 1 in the interstellar space



Voyager 1 131.0 AU

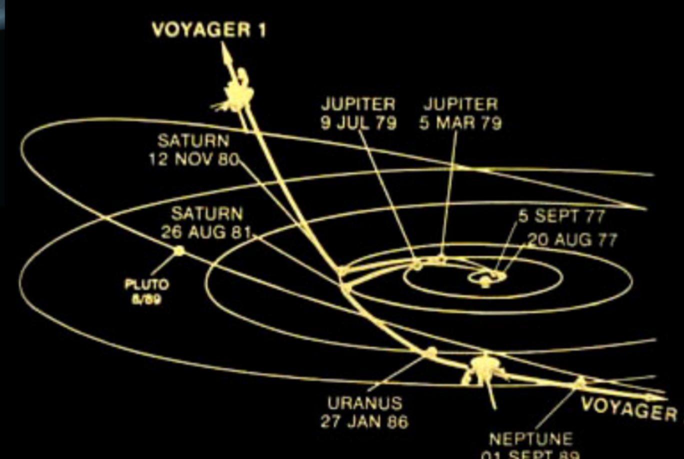
19.7 billion km

Voyager 2 107.7 AU

16.2 billion km

~2 years to interstellar space?

Launched in 1977!



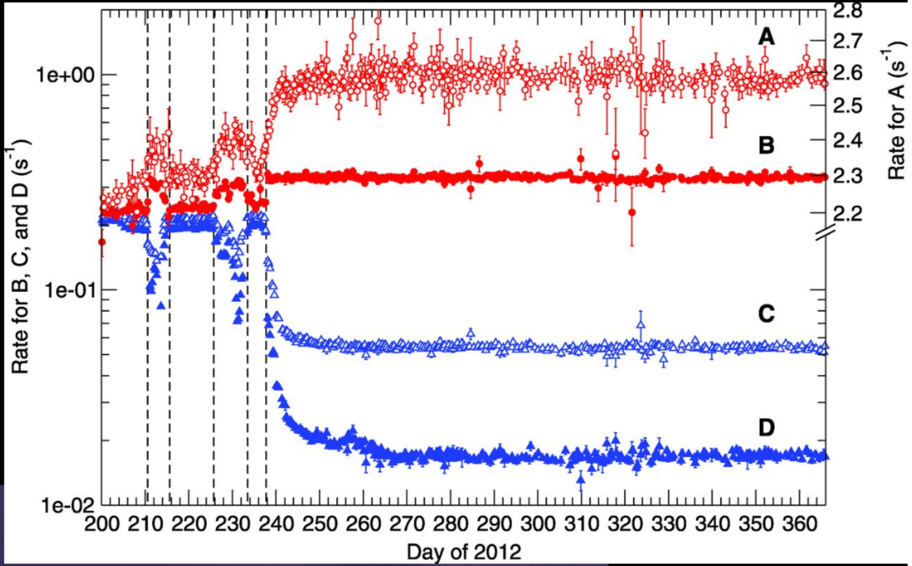
First interstellar probe!

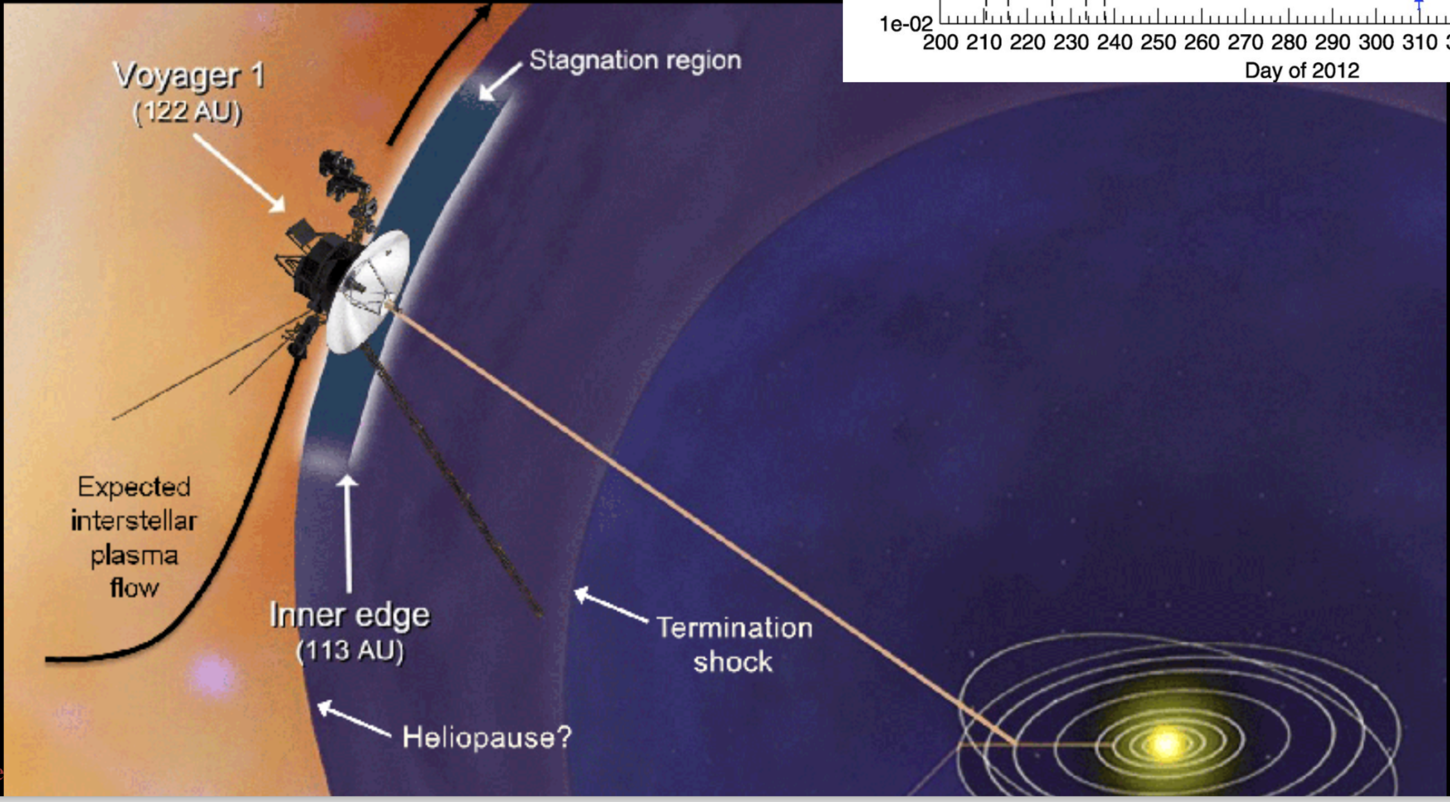
Will operate until 2026

E. Stone 2015

Interstellar probe – Voyager 1

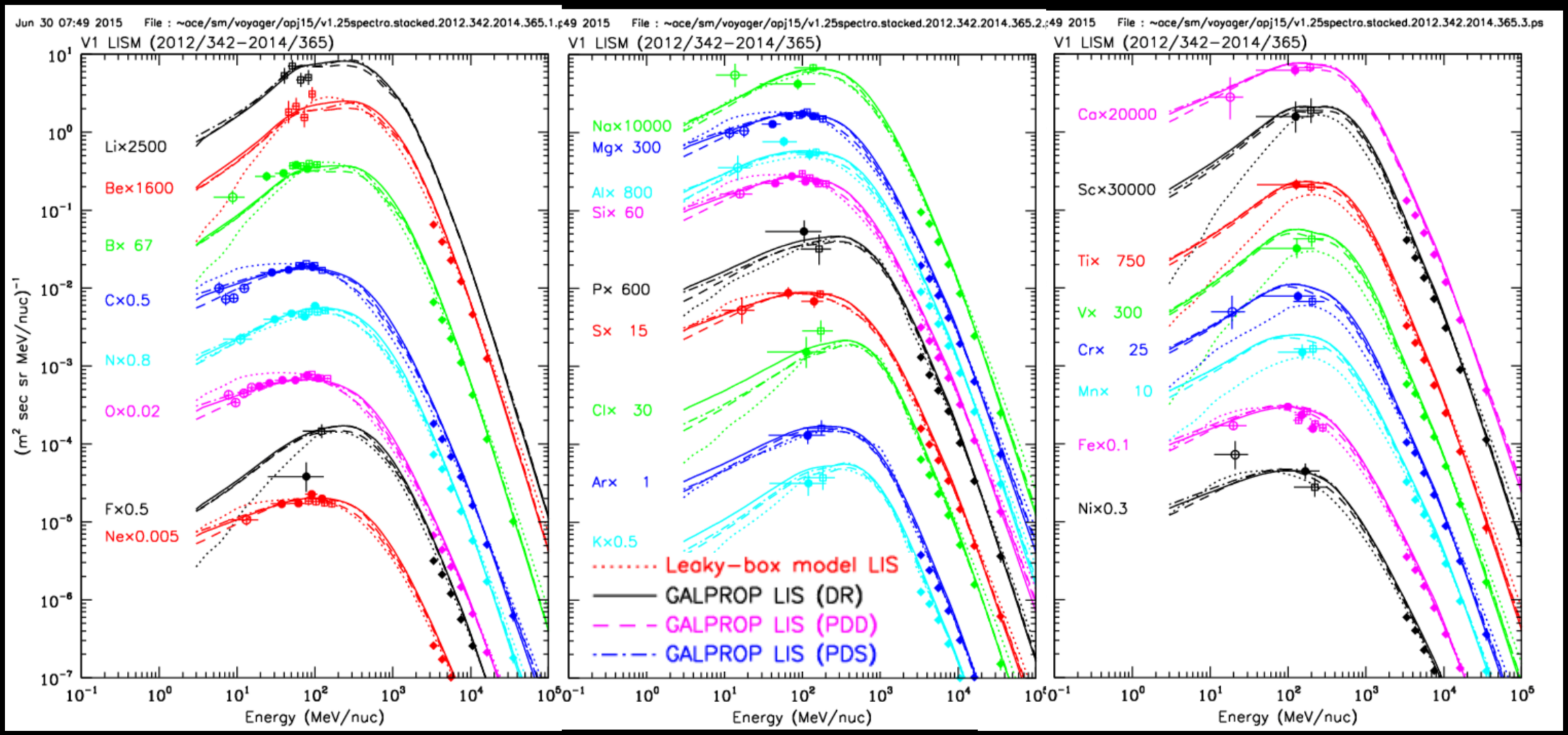
- (A) (y axis on right) GCR nuclei (E > 70 MeV) at the High Energy Telescope 1
- (B) (y axis on left) GCR electrons (6-100 MeV) observed by the Electron Telescope
- (C) (y axis on left) Protons with 7 to 60 MeV stopping in HET 1 are mainly anomalous cosmic rays before 2012/238 (25 August) and galactic cosmic rays after that
- (D) (y axis on left) Low-energy particles mainly protons with 0.5 to ~30 MeV accelerated at the termination shock and in the heliosheath





AMS-02 me

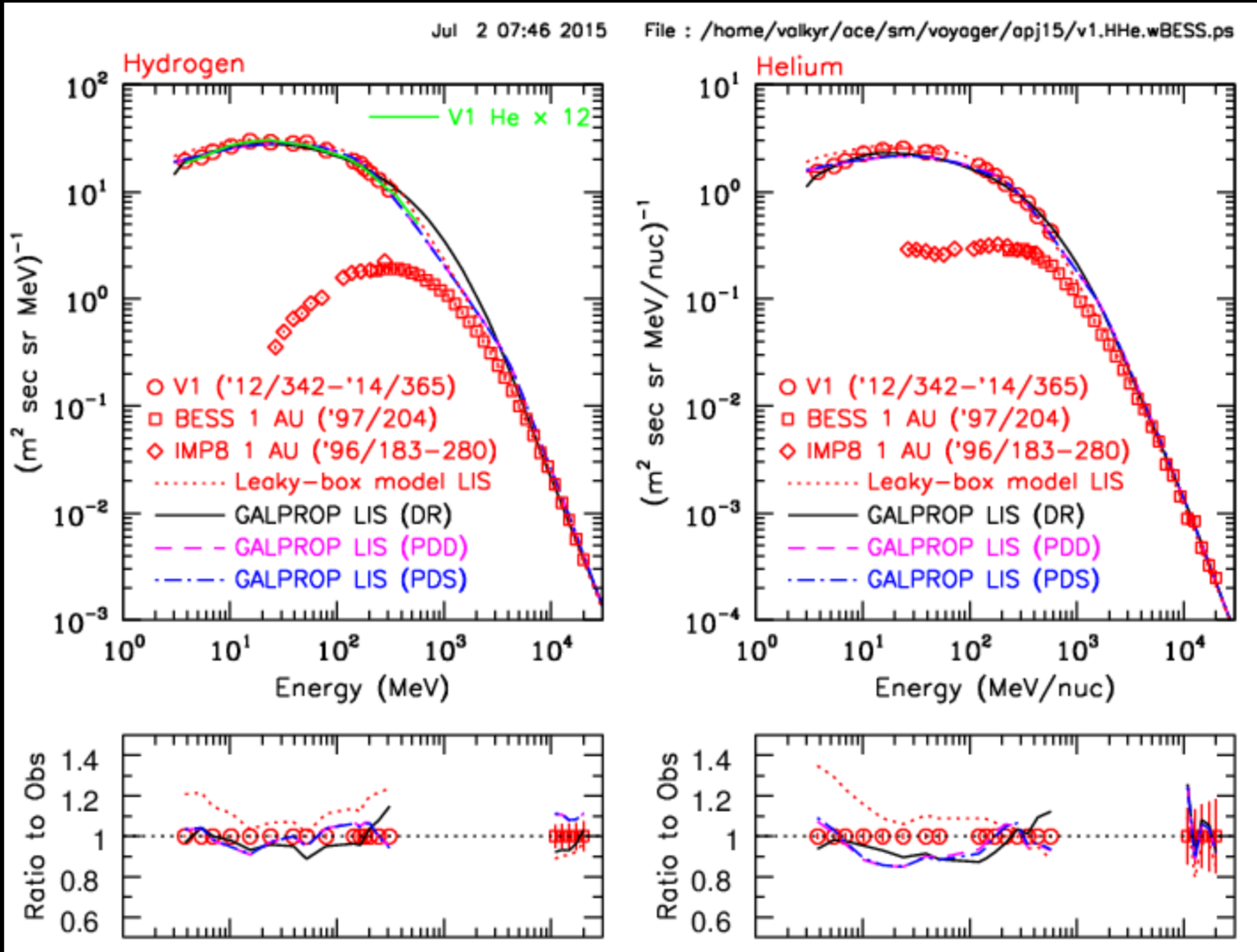
Voyager 1 spectra for 2012/342-2014/365



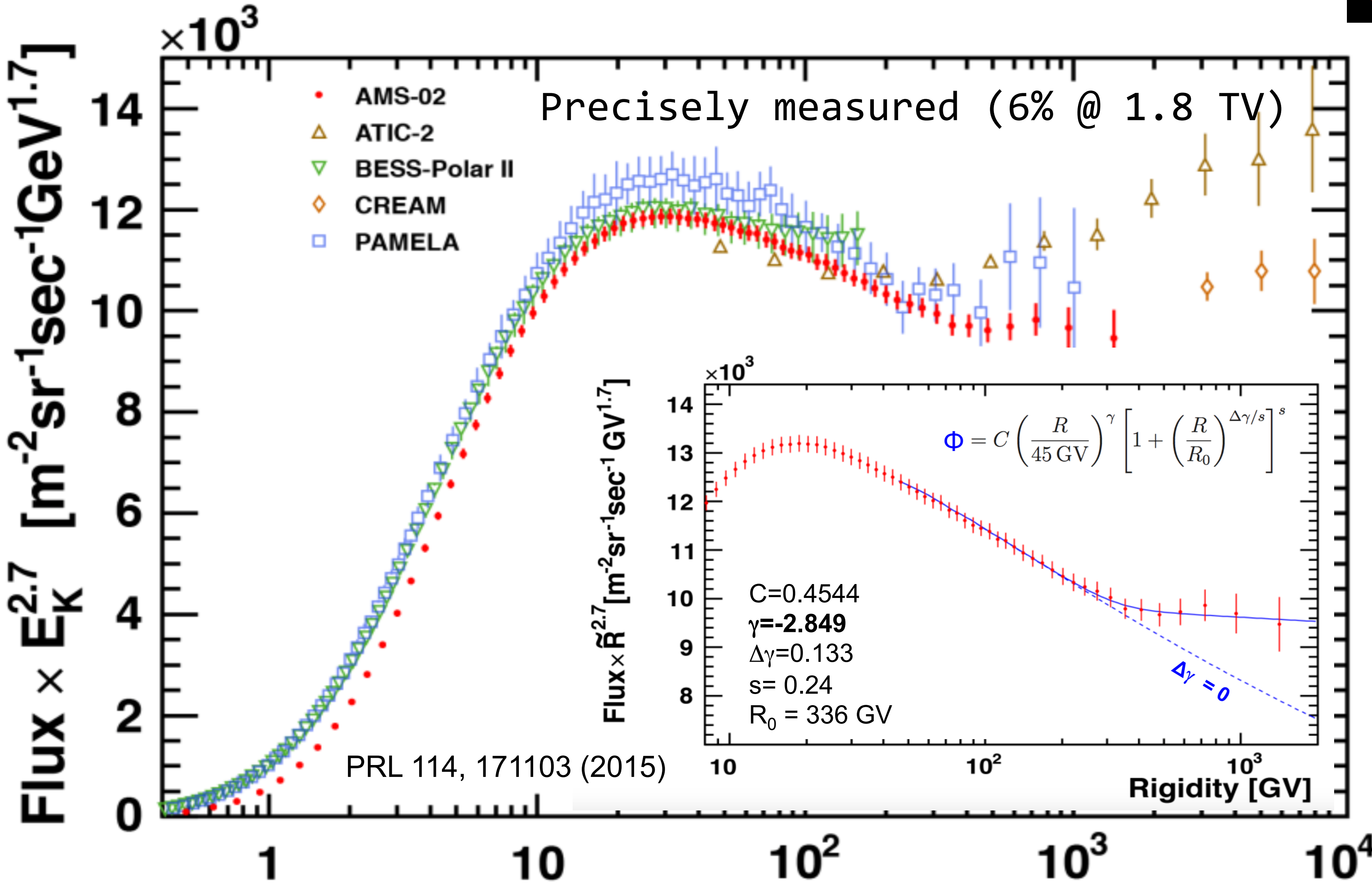
Li – Ni : V1 spectra together with HEAO-3-C2 data (≥3.35 GeV/nuc)

ApJ Paper – in progress

Voyager 1 – H and He spectra



Proton flux

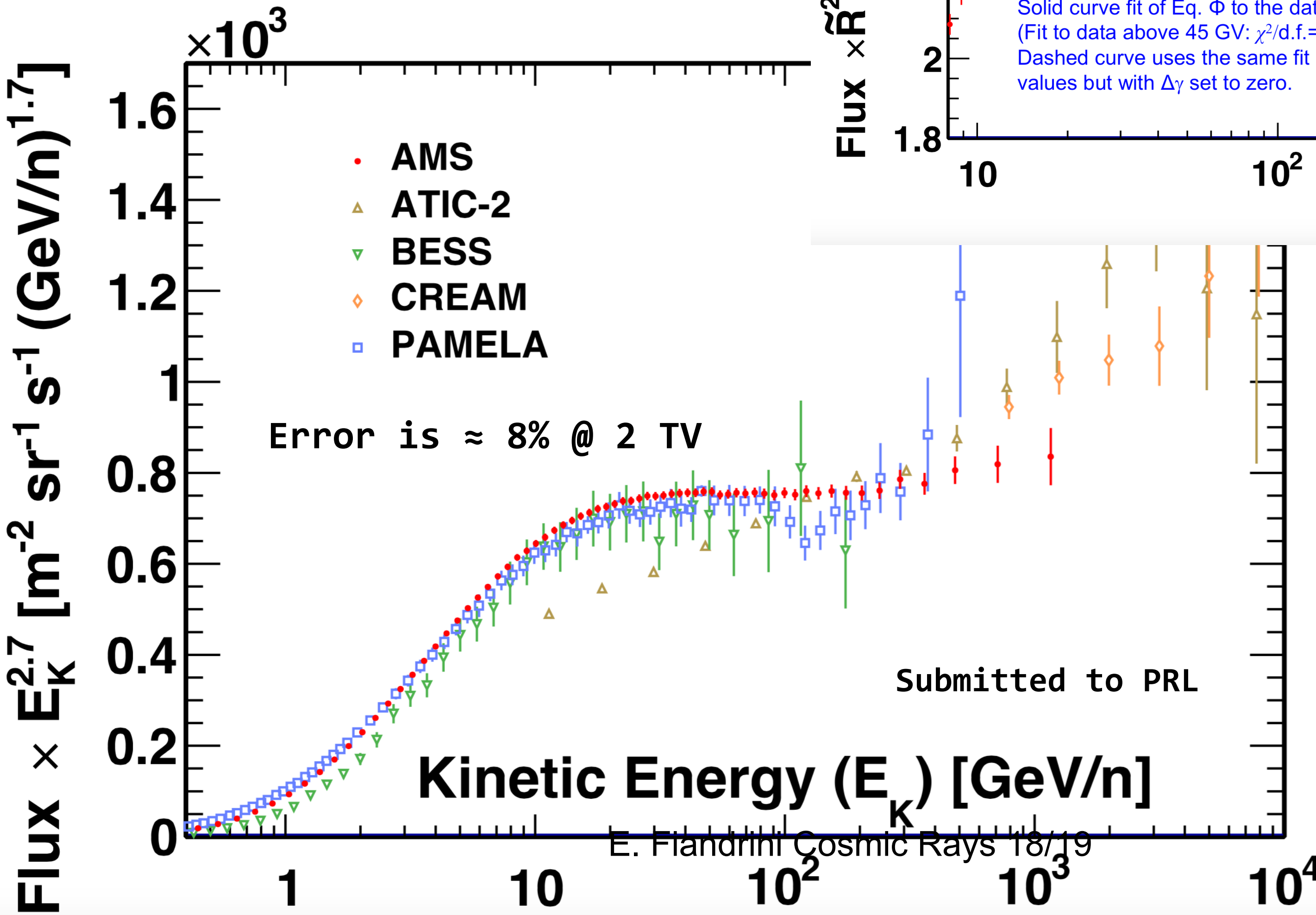


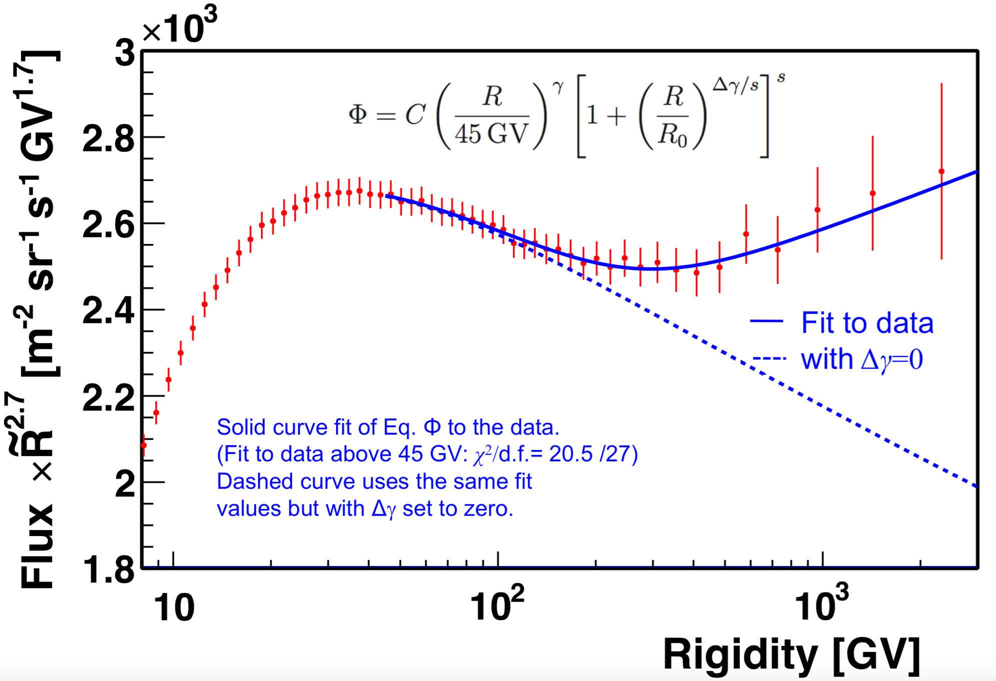
E. Fiandrini Cosmic Rays 18/19

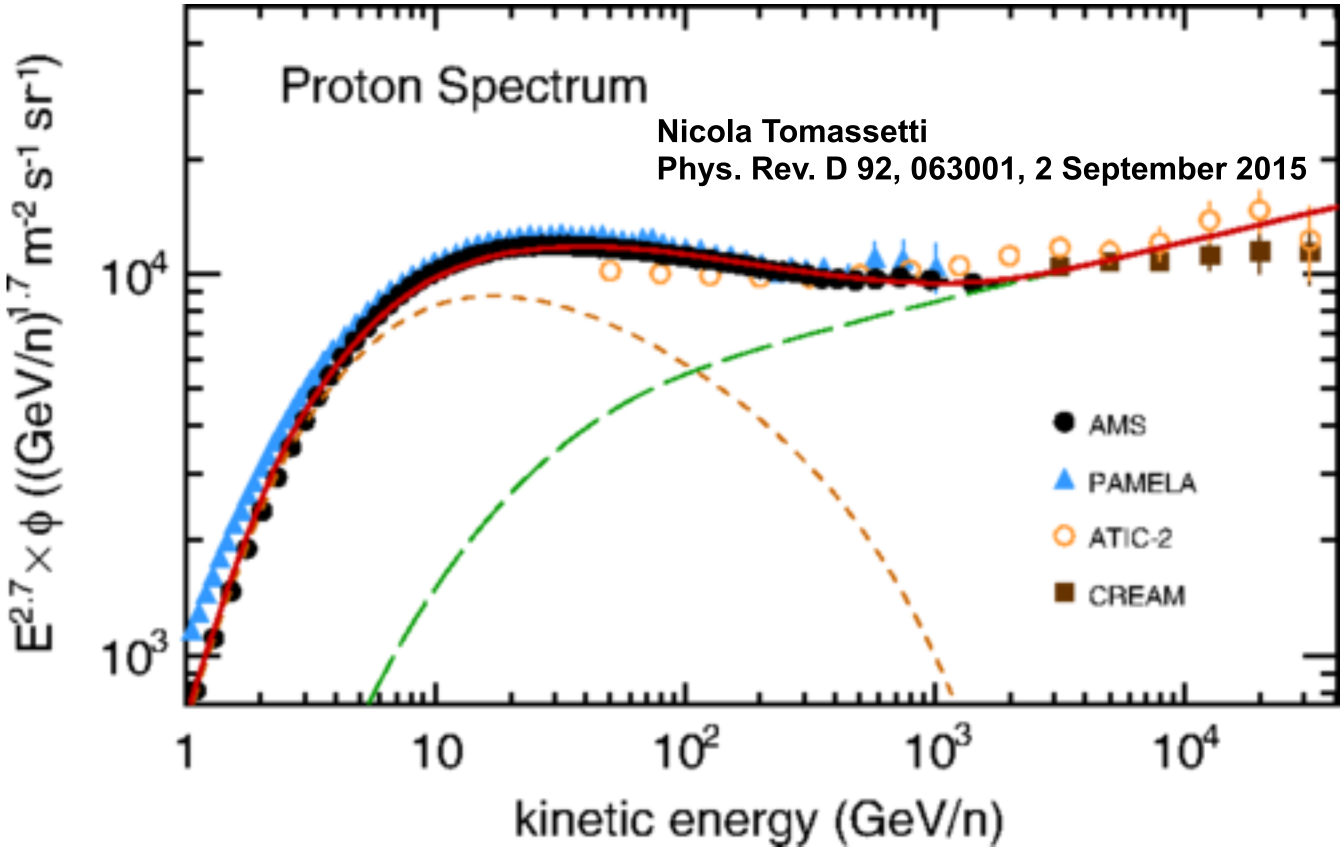
A change in the the spectral index is observed at 336 GV

He Flux

Transition energy R_0 and smoothness parameter s are the same as for protons

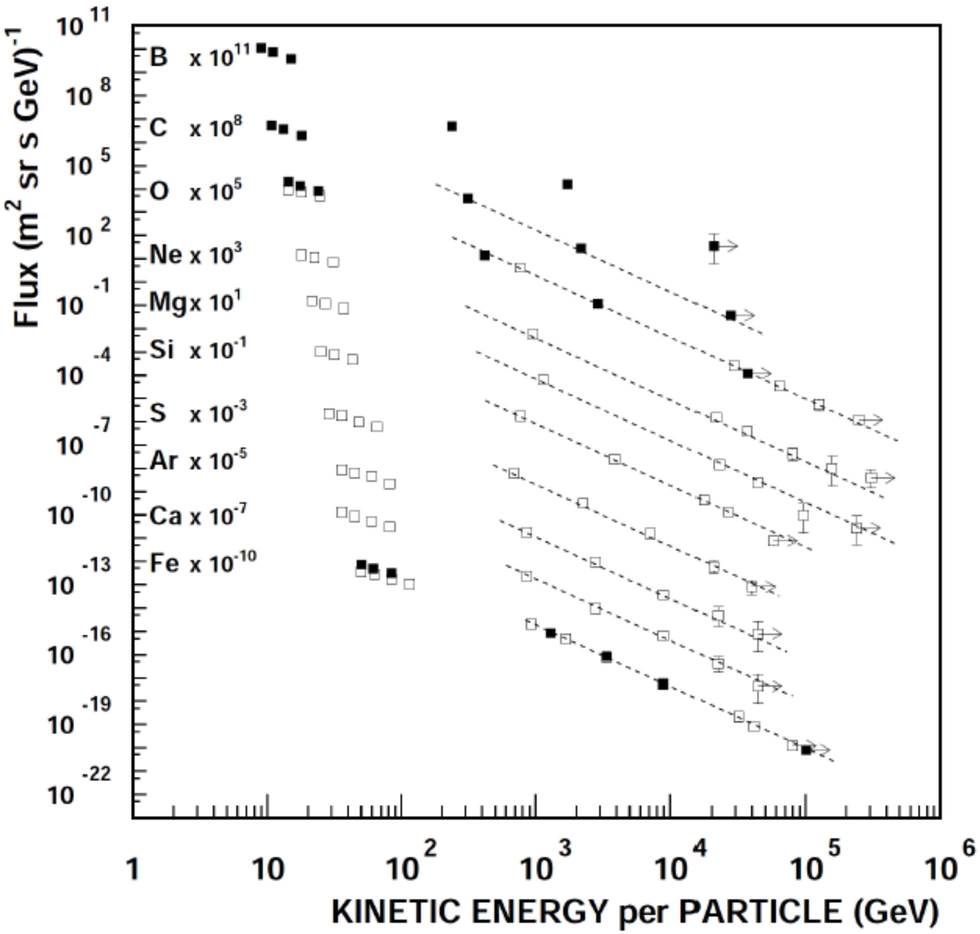






Nicola Tomassetti
Phys. Rev. D 92, 063001, 2 September 2015

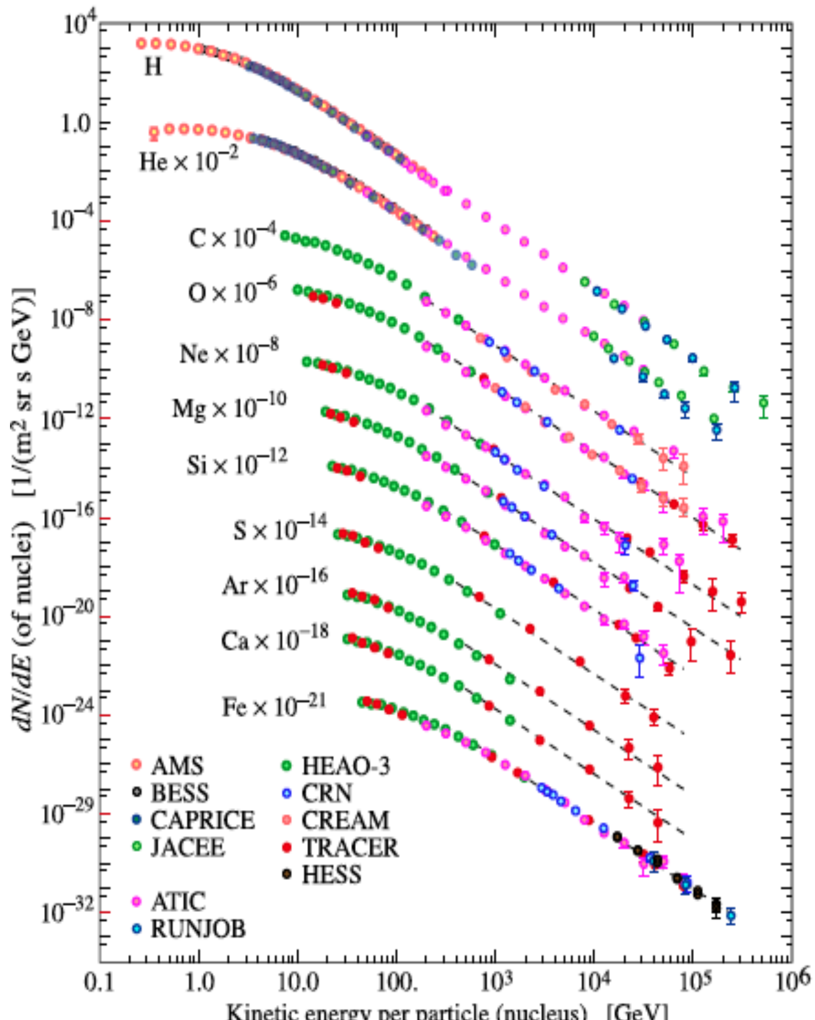
Nuclear species flux



TRACER 2 flights data:
POWER_LAW fit above 20 GeV/n:

$$\text{index } 2.65 \pm 0.05$$

Comparison between experimental results



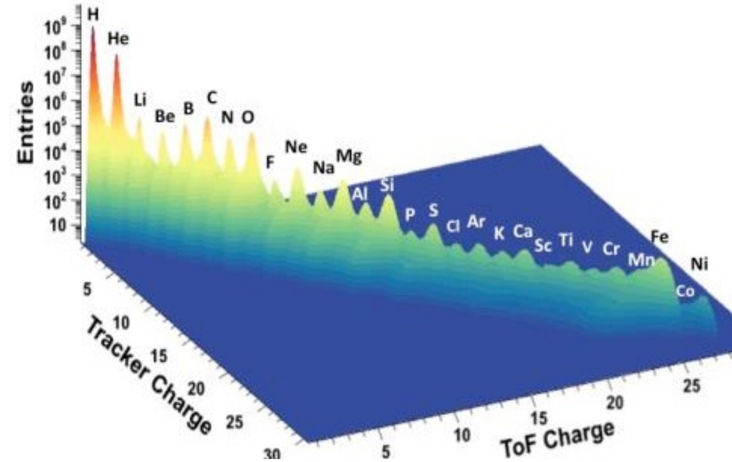
QUESTION:

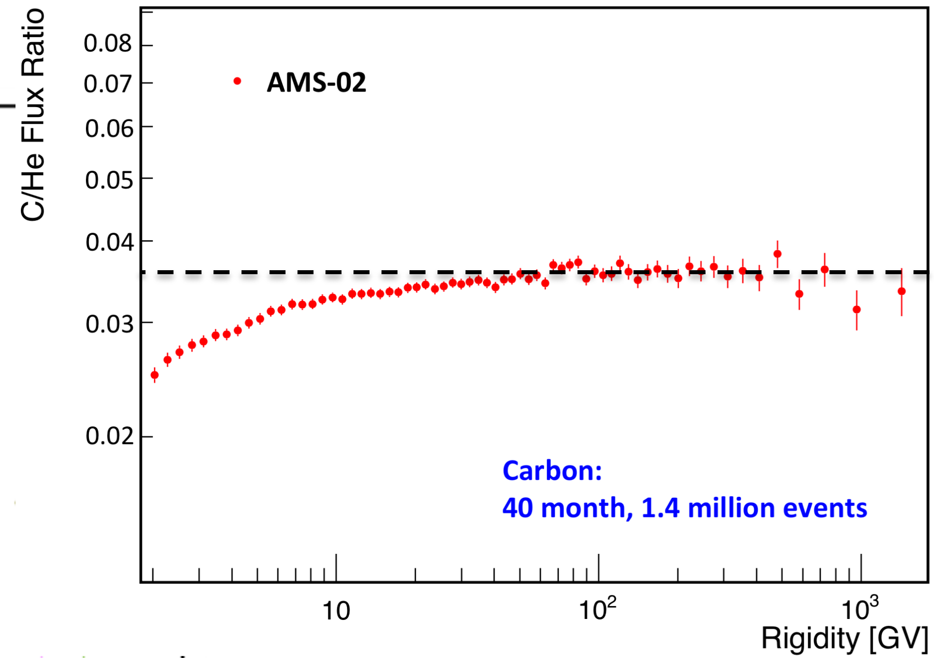
Are all the hi-Z spectra simple power laws or is there beginning to be evidence for evolution (hardening), as now seems to be the case for H and He?

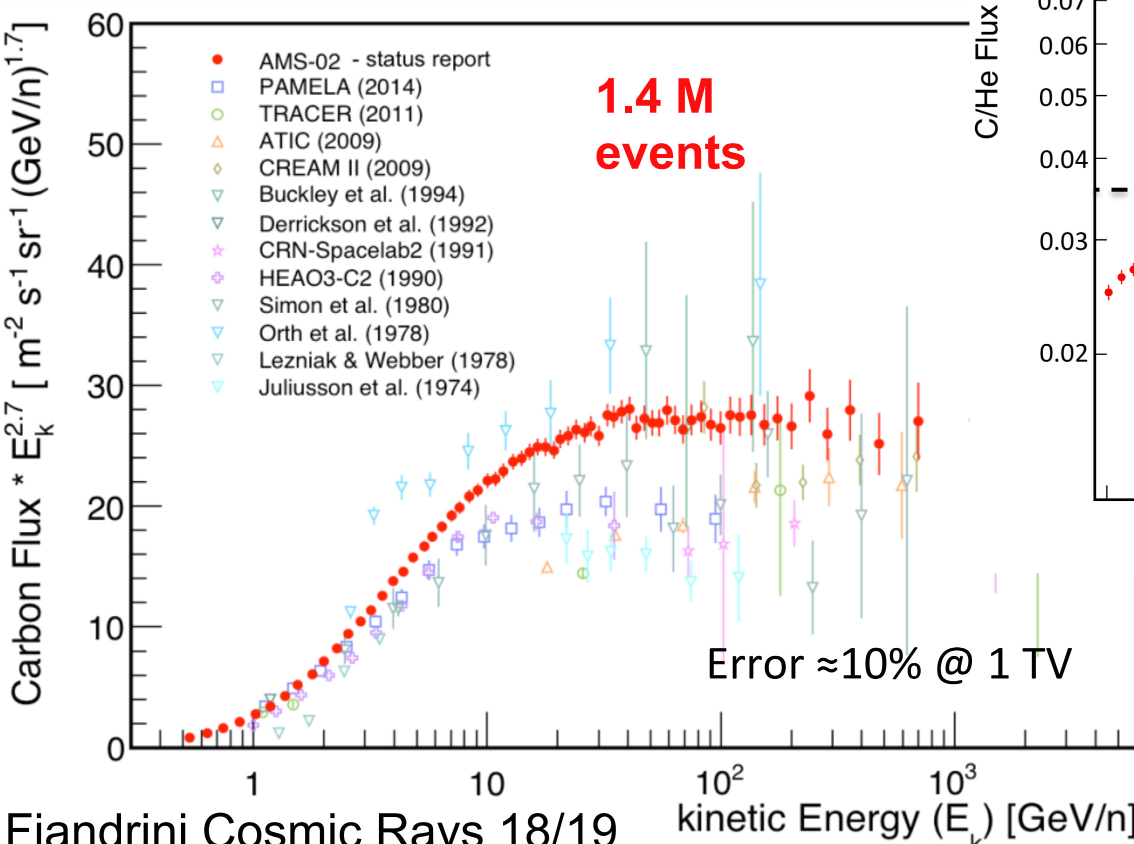
Figure courtesy of P.J. Boyle and D. Mueller

nuclear fluxes..

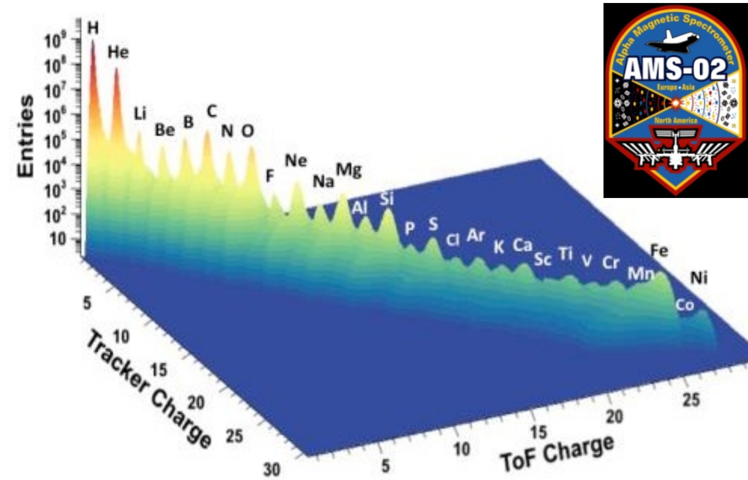
Primaries: e.g. C

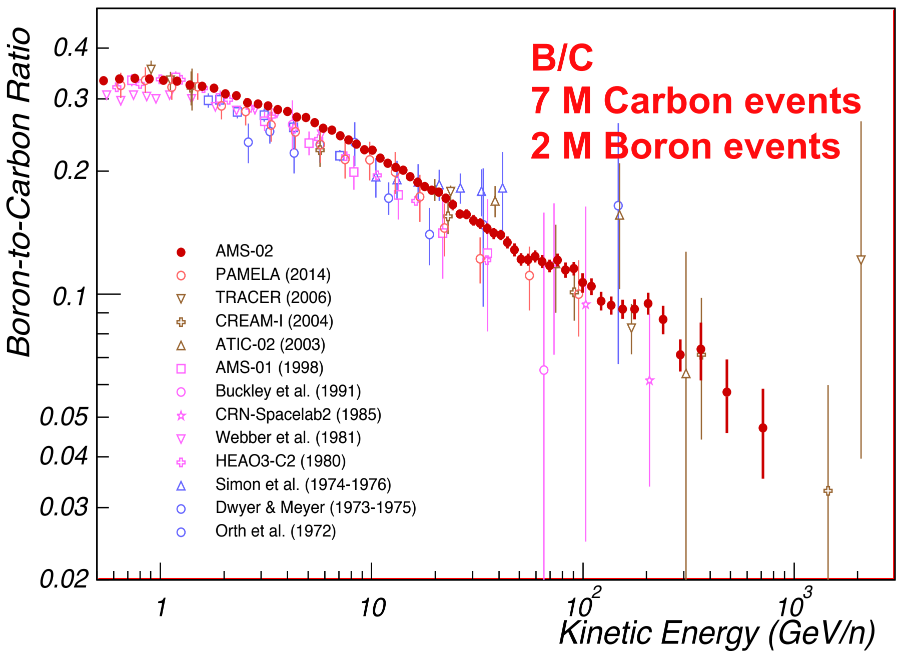


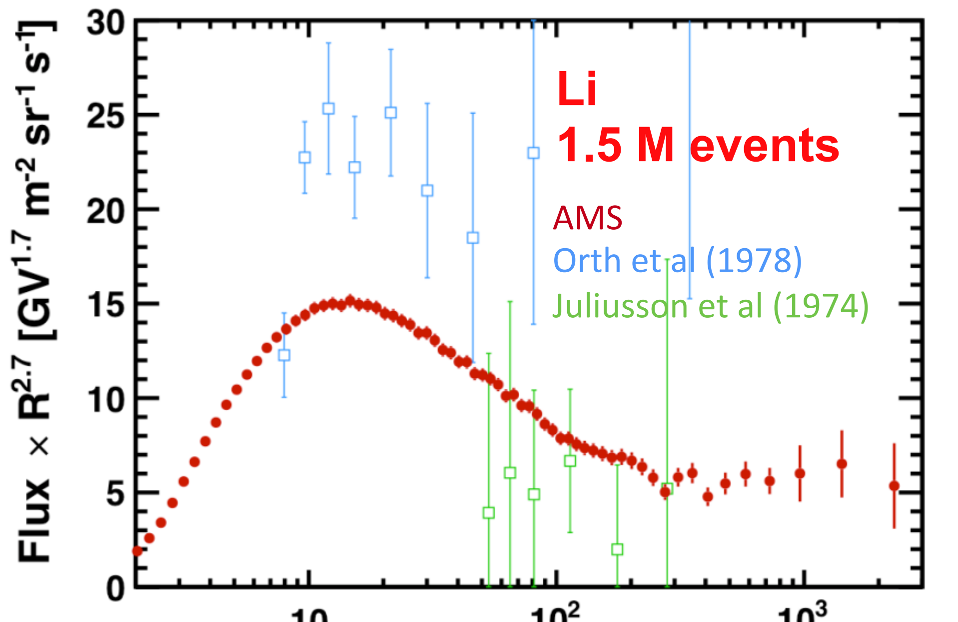




nuclear fluxes Secondaries:







Total error is 30% @ highest R

Heavier elements: hardening