

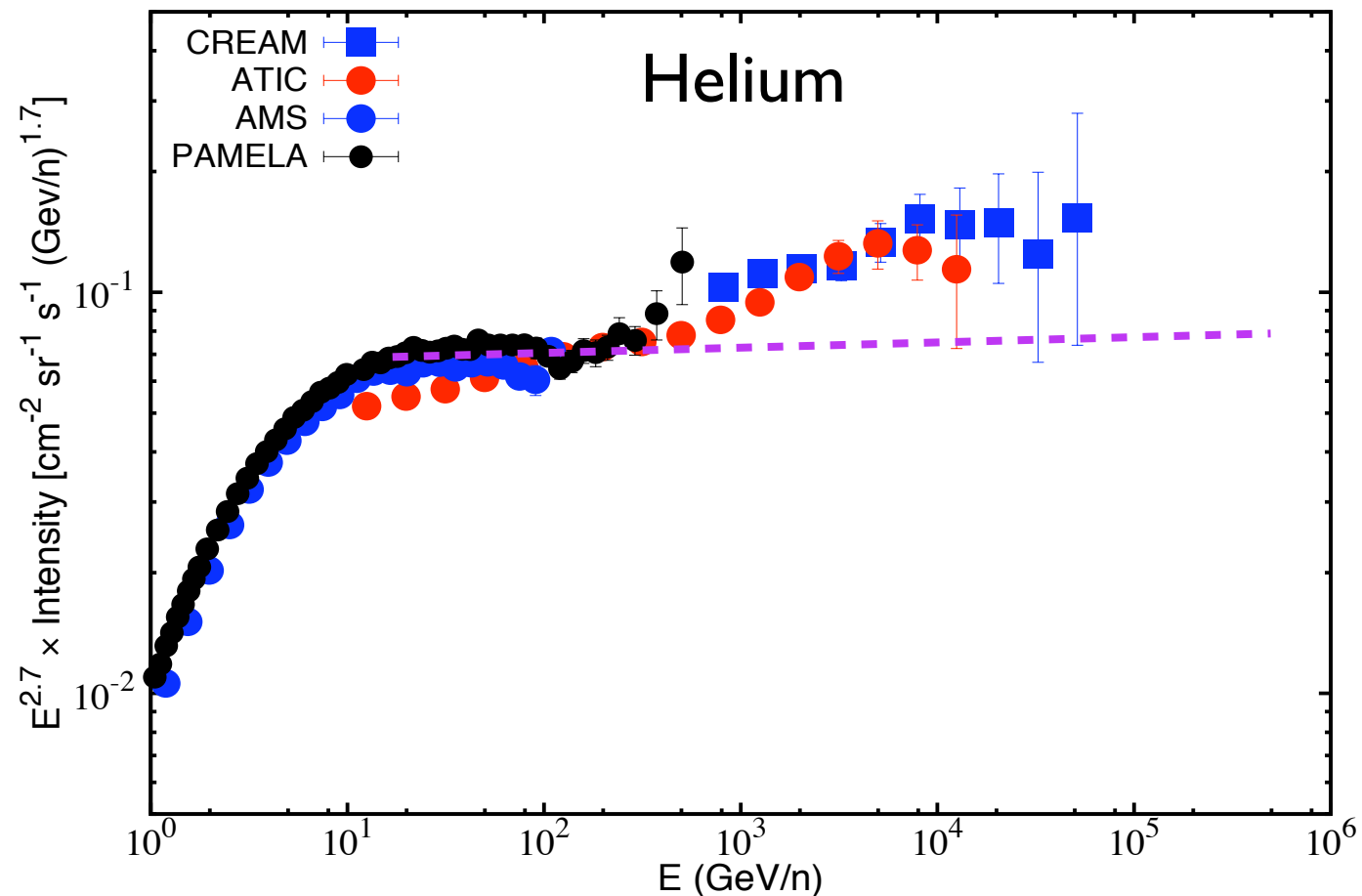
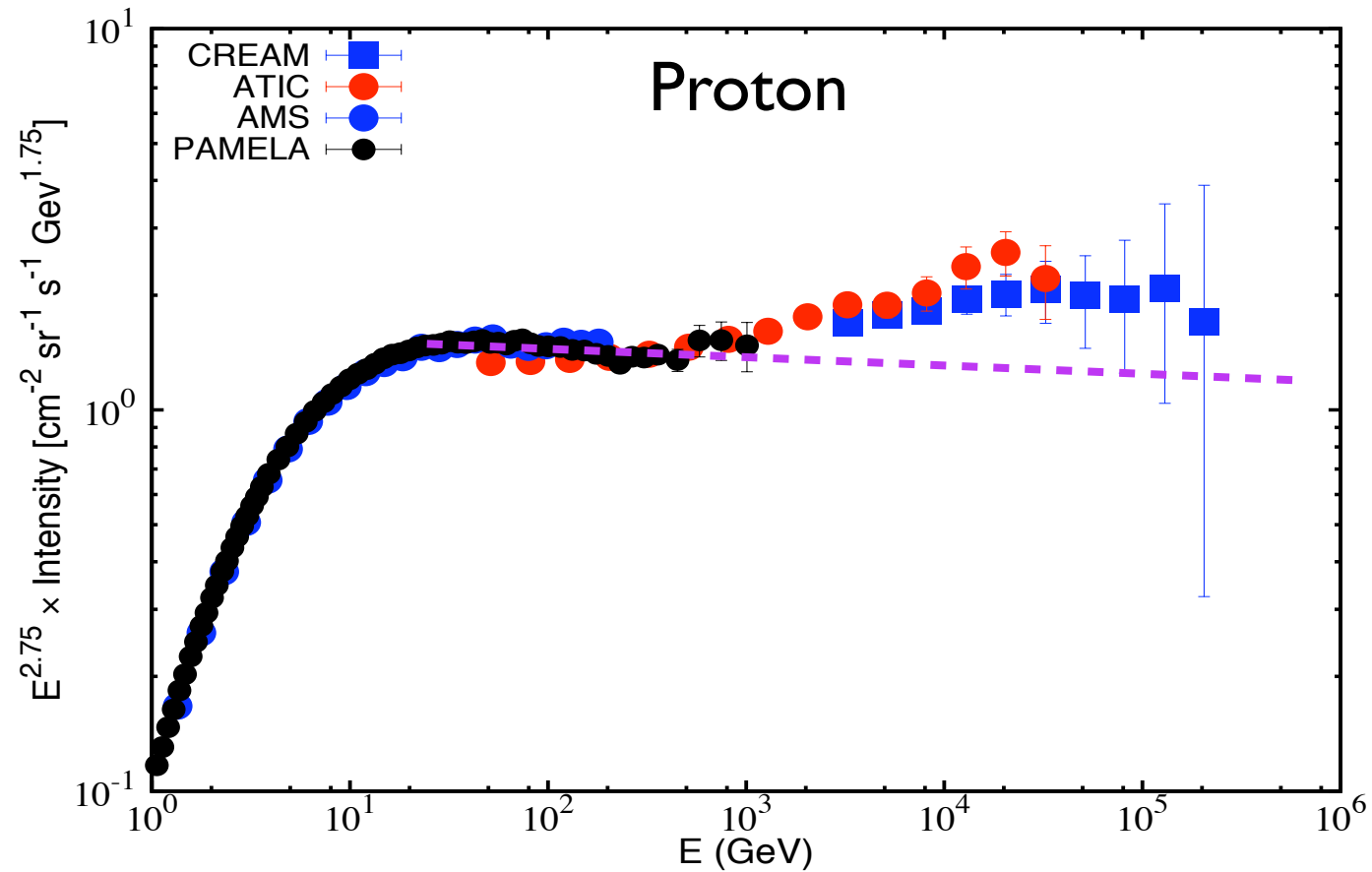
Cosmic-ray spectral anomaly at GeV-TeV energies: Re-acceleration by weak shocks

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GeV-TeV spectral anomaly

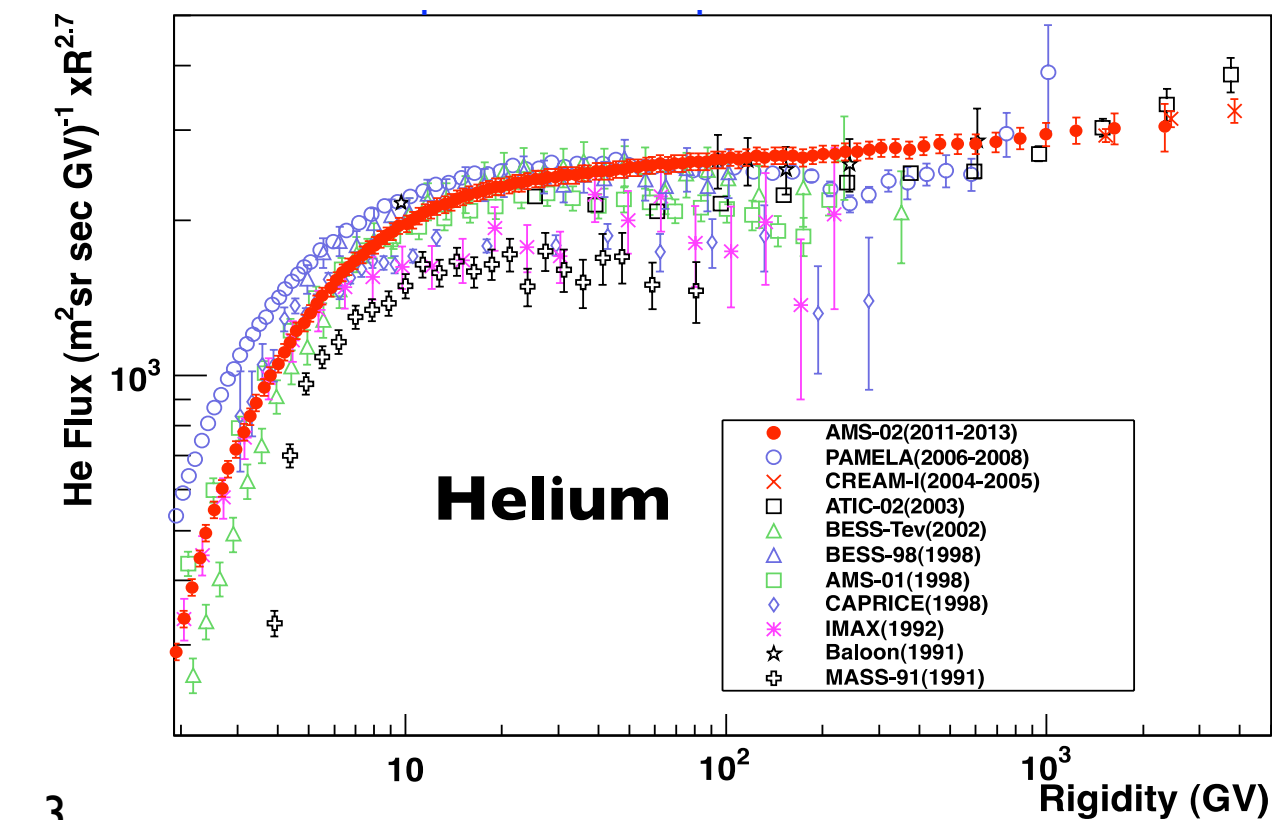
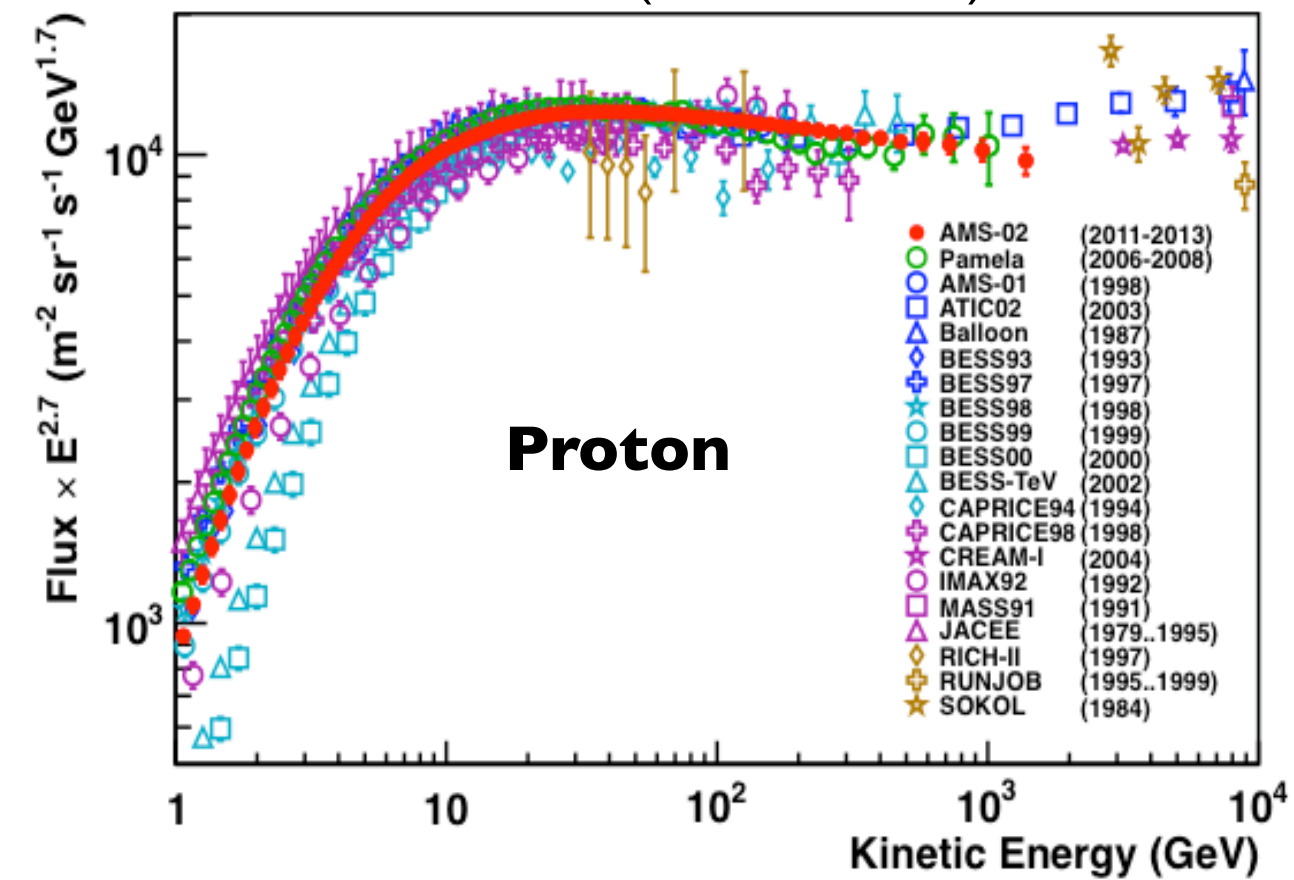


***Recent measurements by
CREAM, ATIC and PAMELA
have found cosmic-ray
spectral hardening at TeV
energies**

*(Panov+ 2007, Yoon+ 2011,
Adriani+ 2011)*

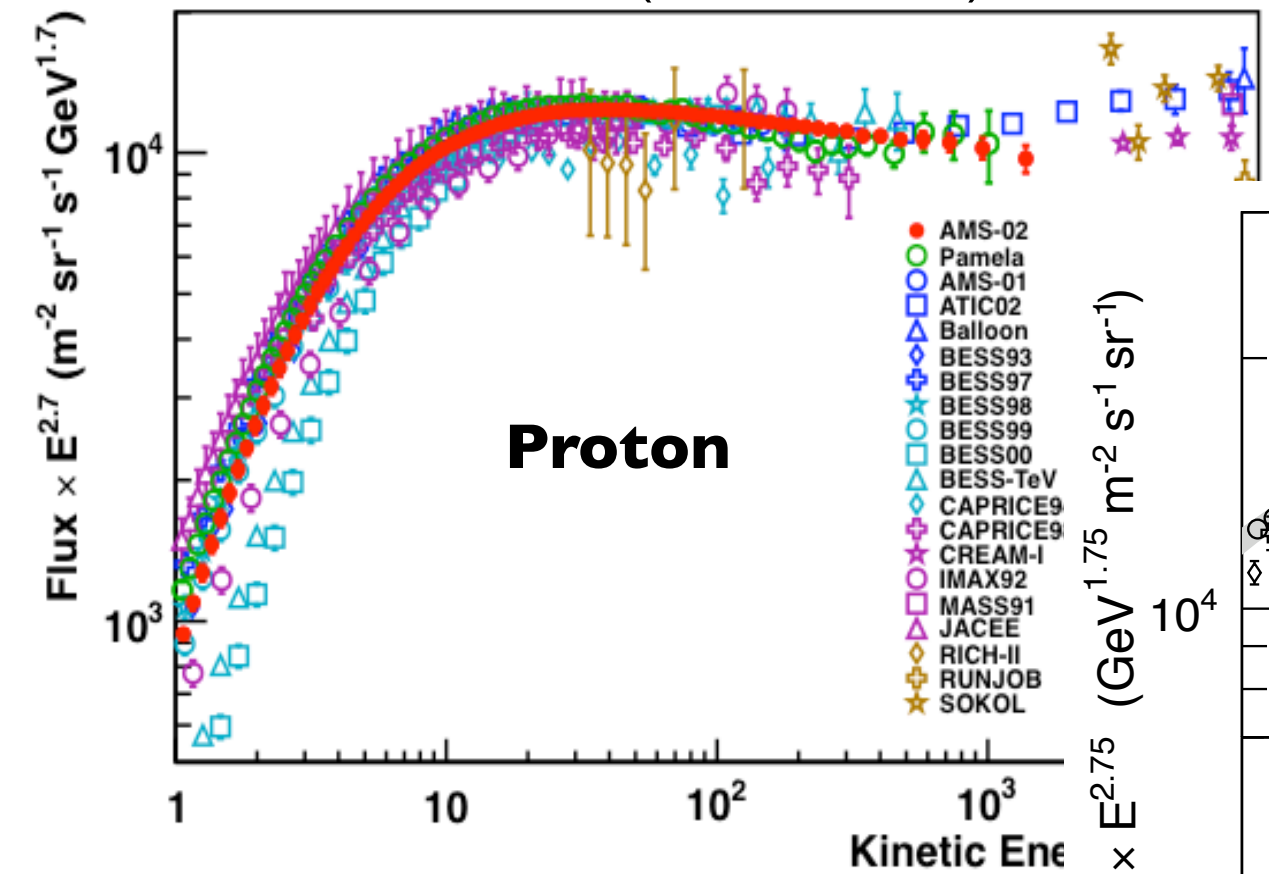
Pre. results from AMS02

AMS02 (ICRC 2013)

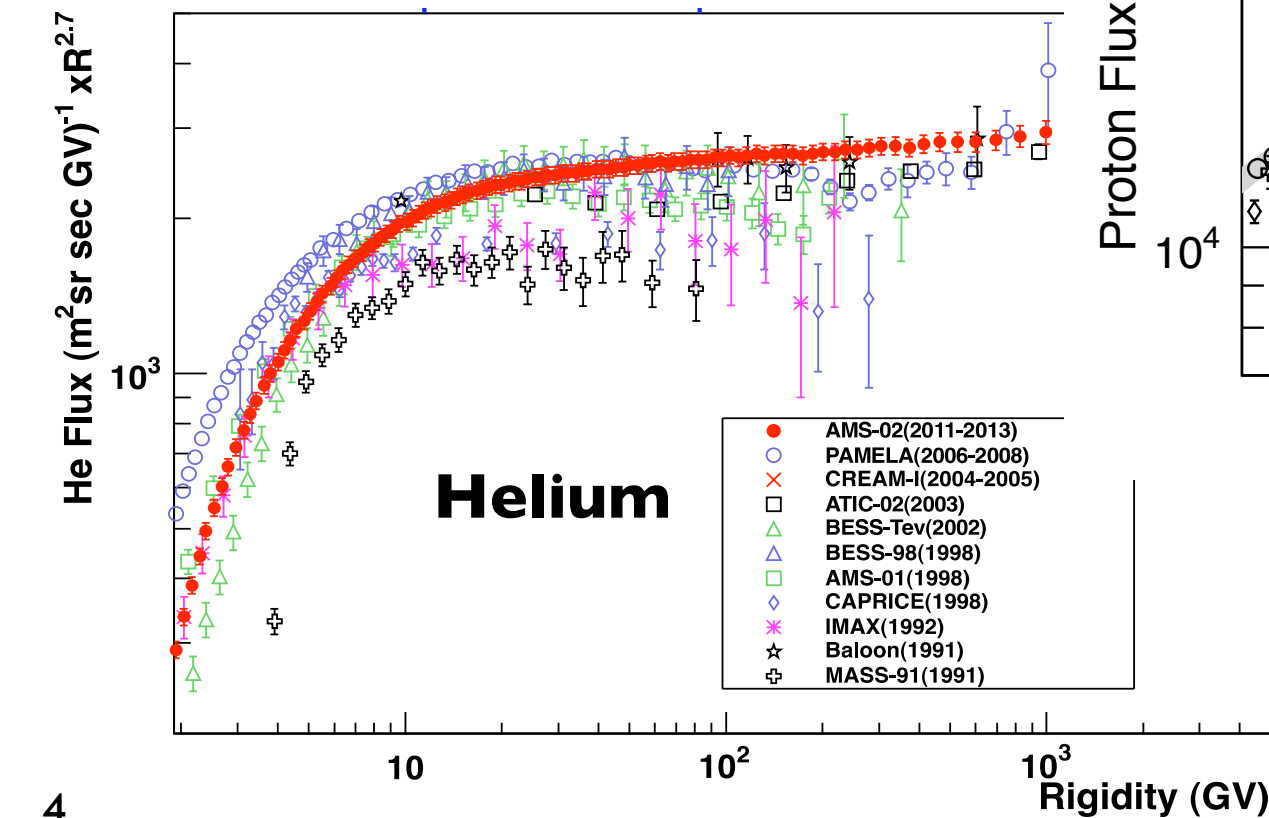
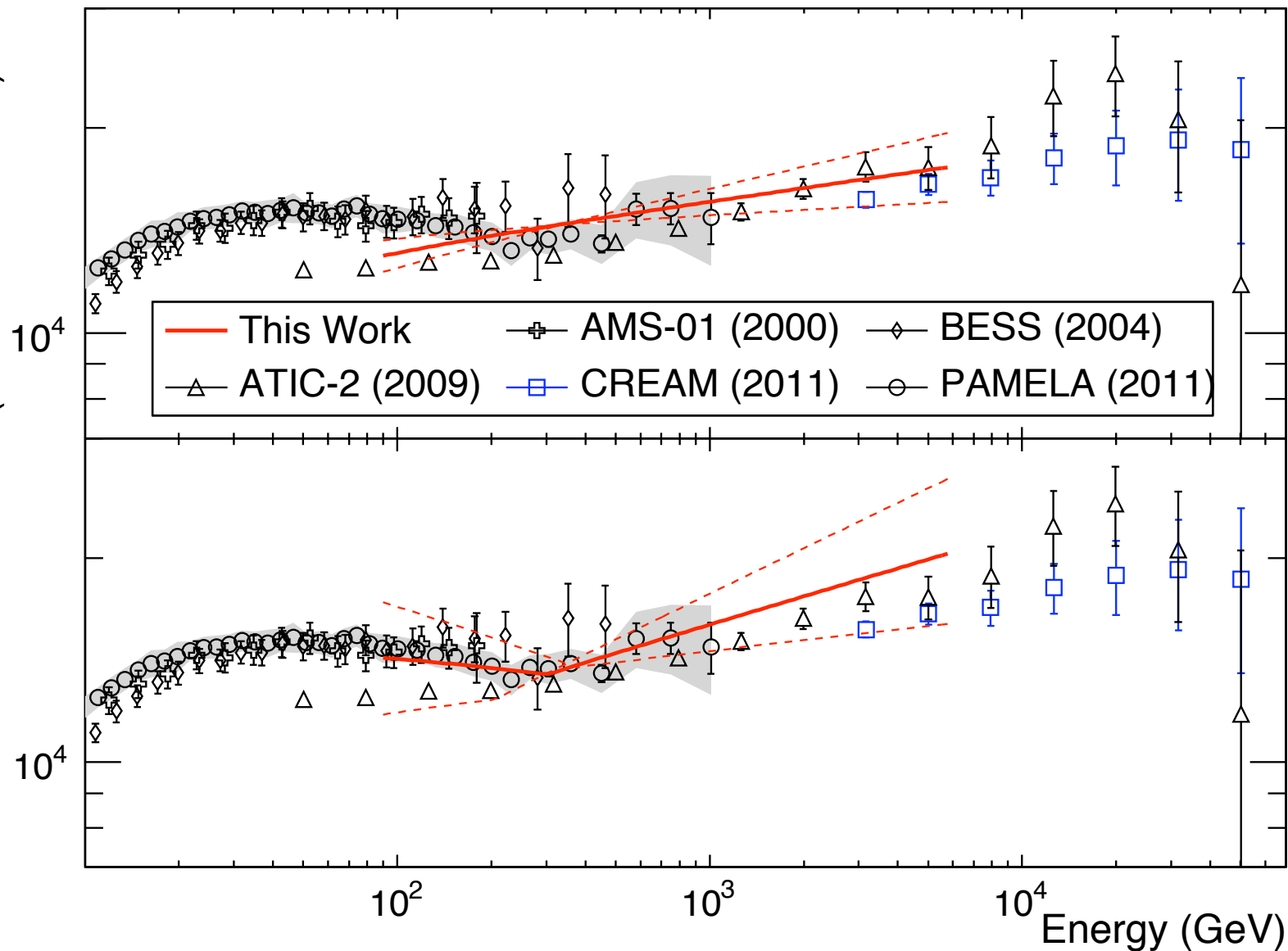


Pre. results from AMS02

AMS02 (ICRC 2013)



FERMI (arXiv:1403.5372)

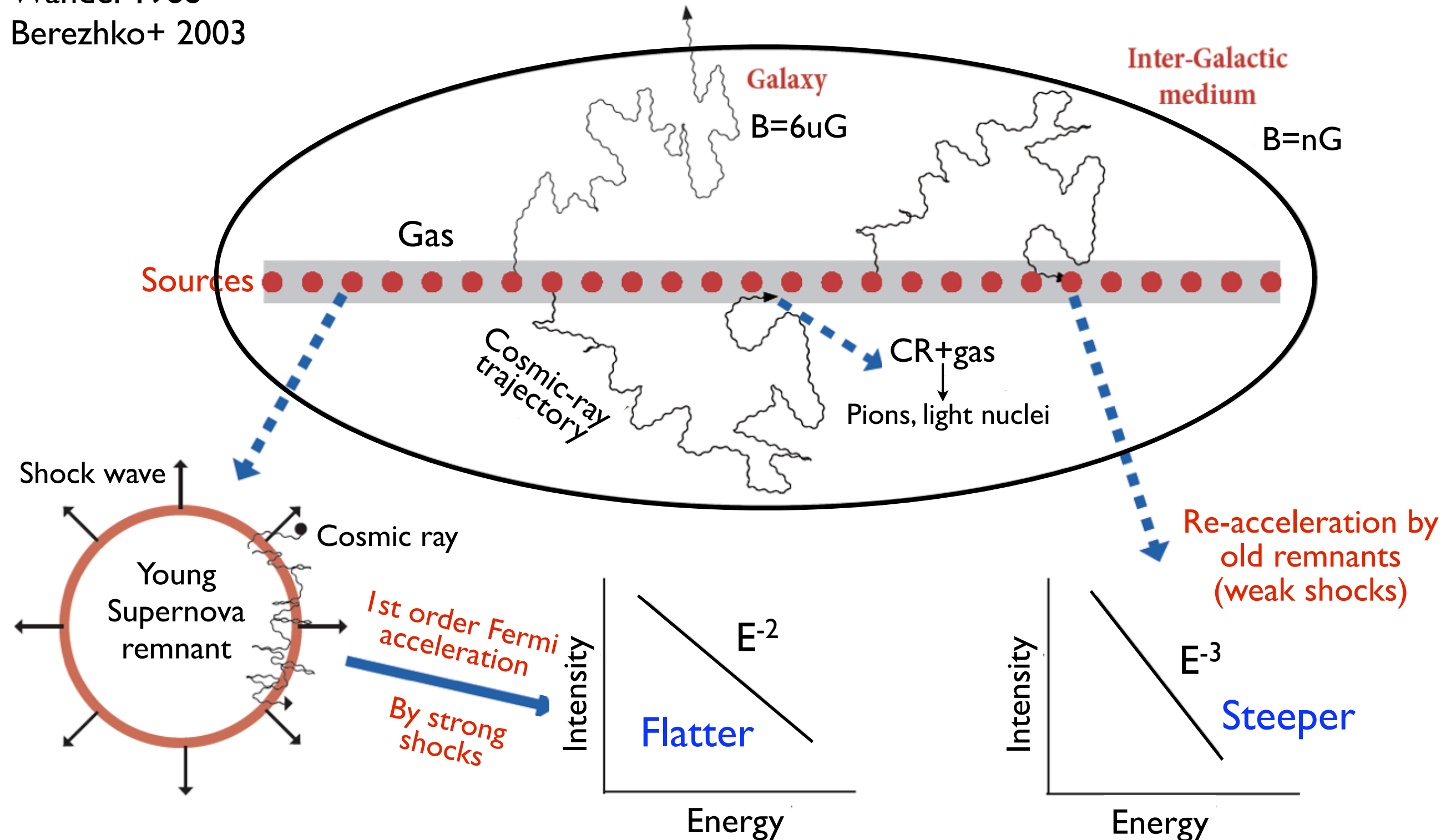


Possible explanations

- (1) Injection source spectrum** *(Biermann+ 2010; Ohira+ 2011; Yuan+ 2011; Ptuskin+ 2013)*
- (2) Propagation effect** *(Tomassetti 2012; Blasi+ 2012; Evoli & Yan 2014)*
- (3) Nearby sources** *(Thoudam & Hörandel 2012, 2013; Erlykin & Wolfendale 2012; Bernard+ 2012)*
- (4) Re-acceleration effect** *(Thoudam & Hörandel 2014; Ptuskin+ ICRC 2011)*
- (5)**

The re-acceleration model

Wandel 1988
Berezhko+ 2003



The propagation equation

(Thoudam & Hörandel, 2014, A&A, 567, A33)

$$\nabla \cdot (D \nabla N) - [\bar{n} v \sigma + \xi] \delta(z) N + \left[\xi s p^{-s} \int_{p_0}^p du N(u) u^{s-1} \right] \delta(z) = -Q \delta(z)$$

Diffusion
($D \propto p^a$)

Loss: Inelastic
+
Re-acceleration

Re-acceleration
 $\xi = \eta V_v$

Source
 $Q \propto p^{-q}$

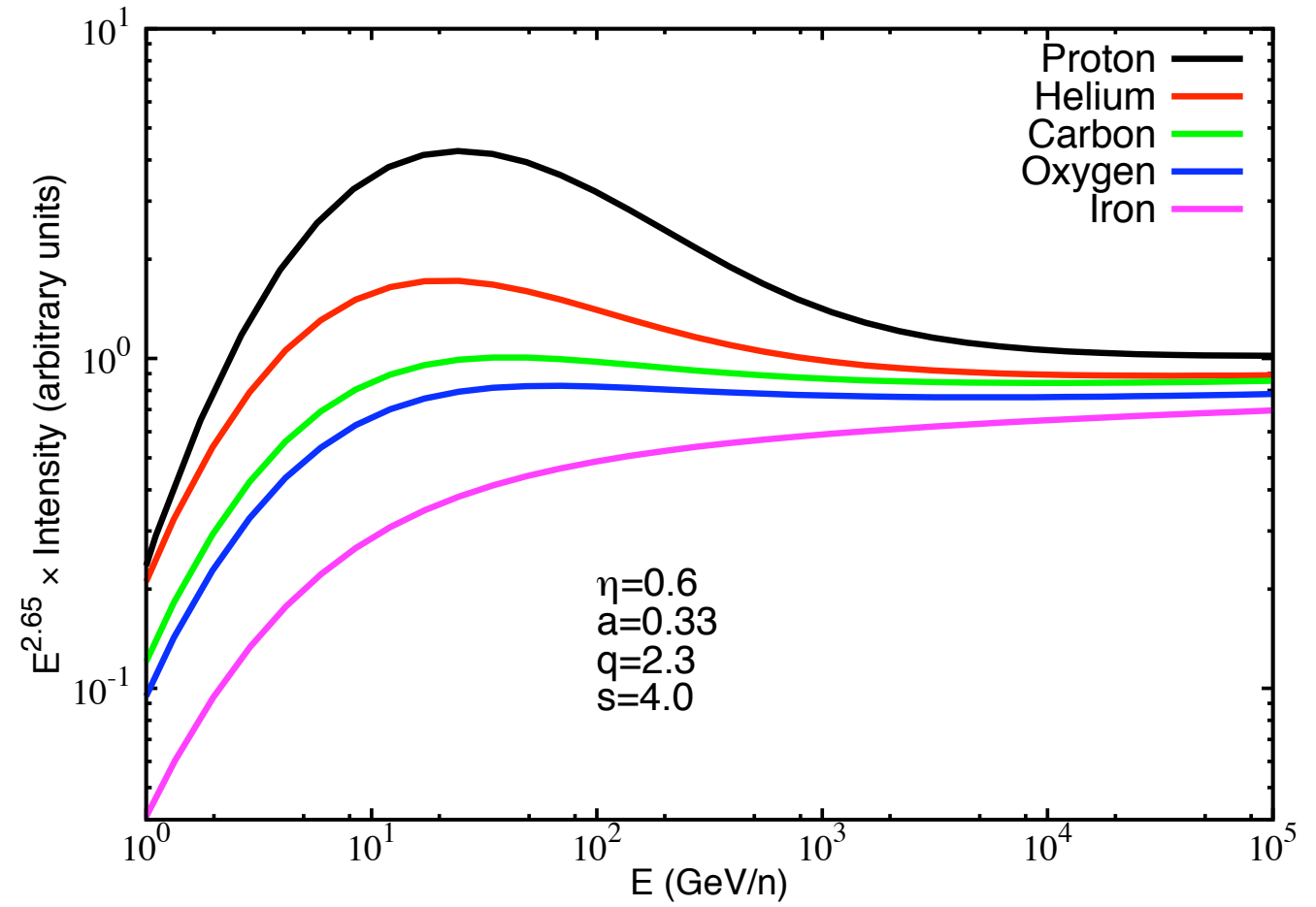
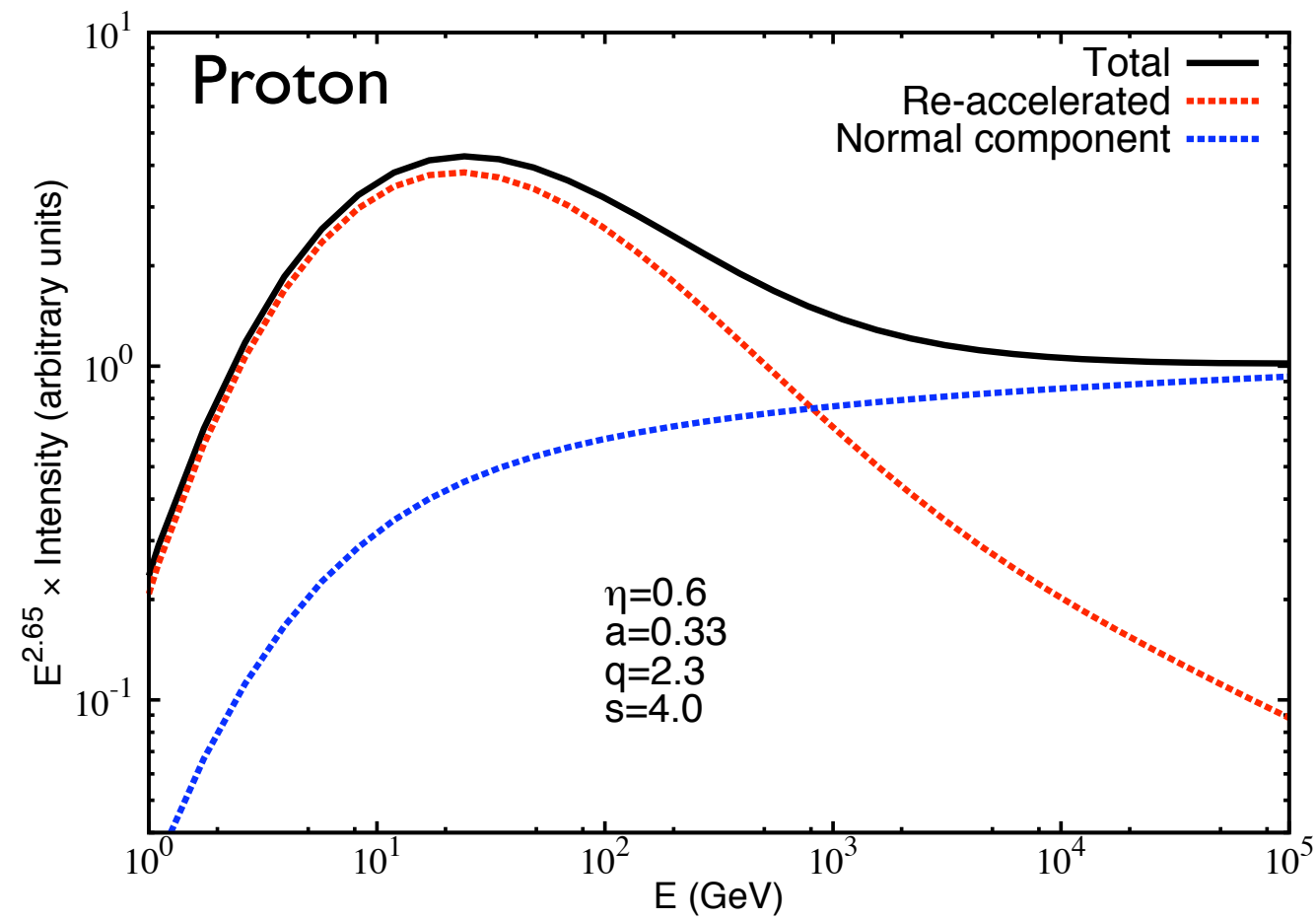
* $N(p)$: Cosmic-ray density; $p \Rightarrow$ Momentum

*Propagation parameters: (D_0, ρ_0, a)

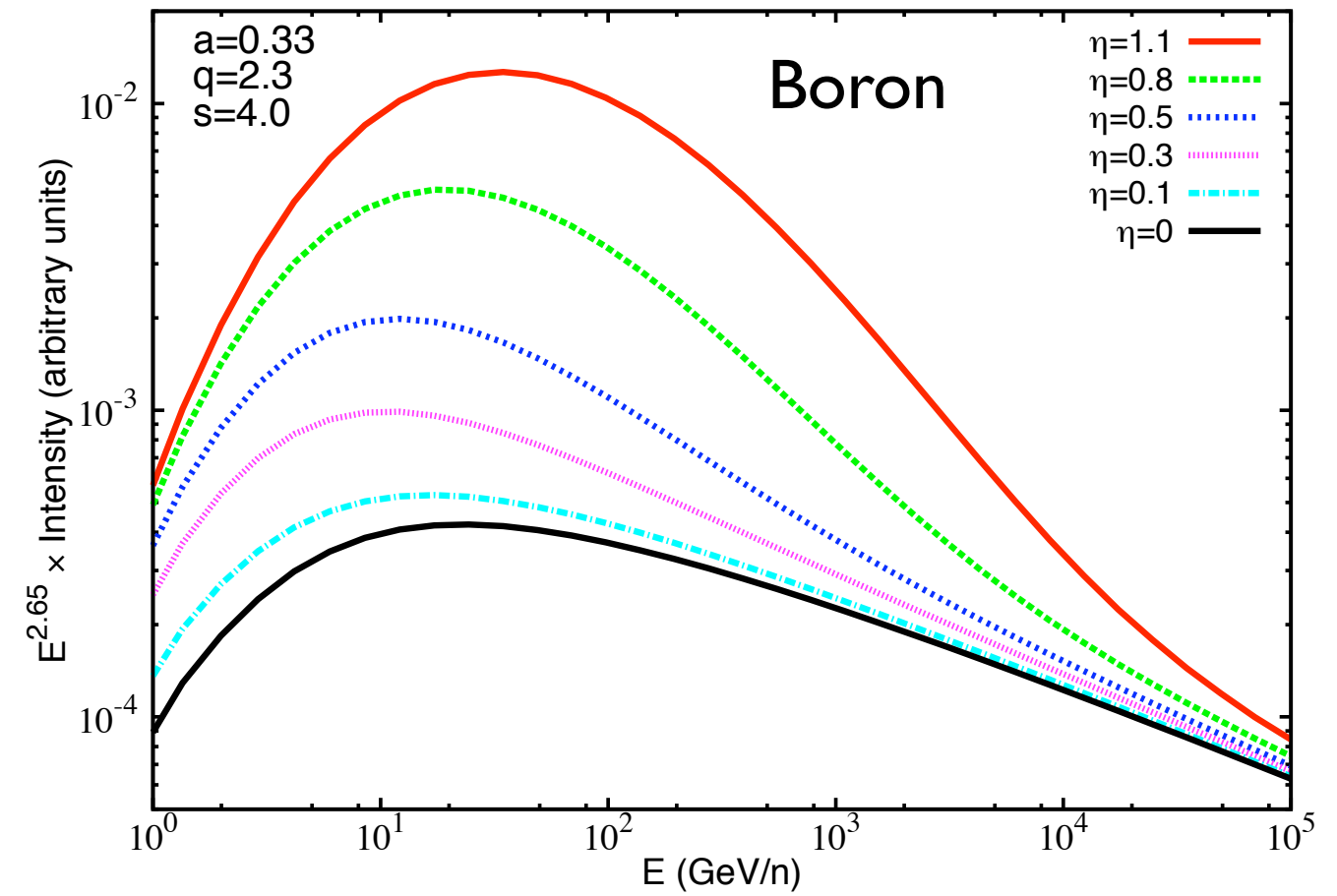
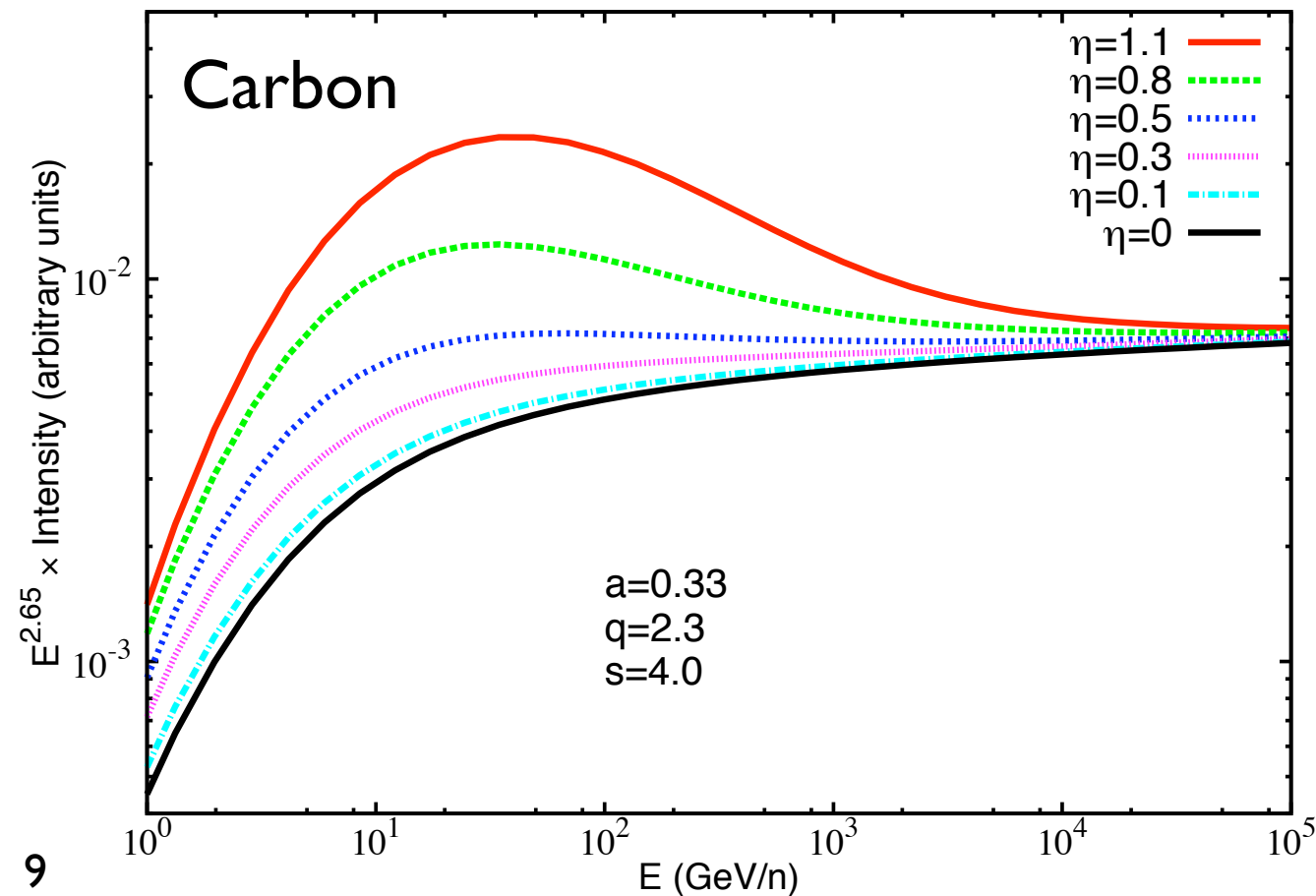
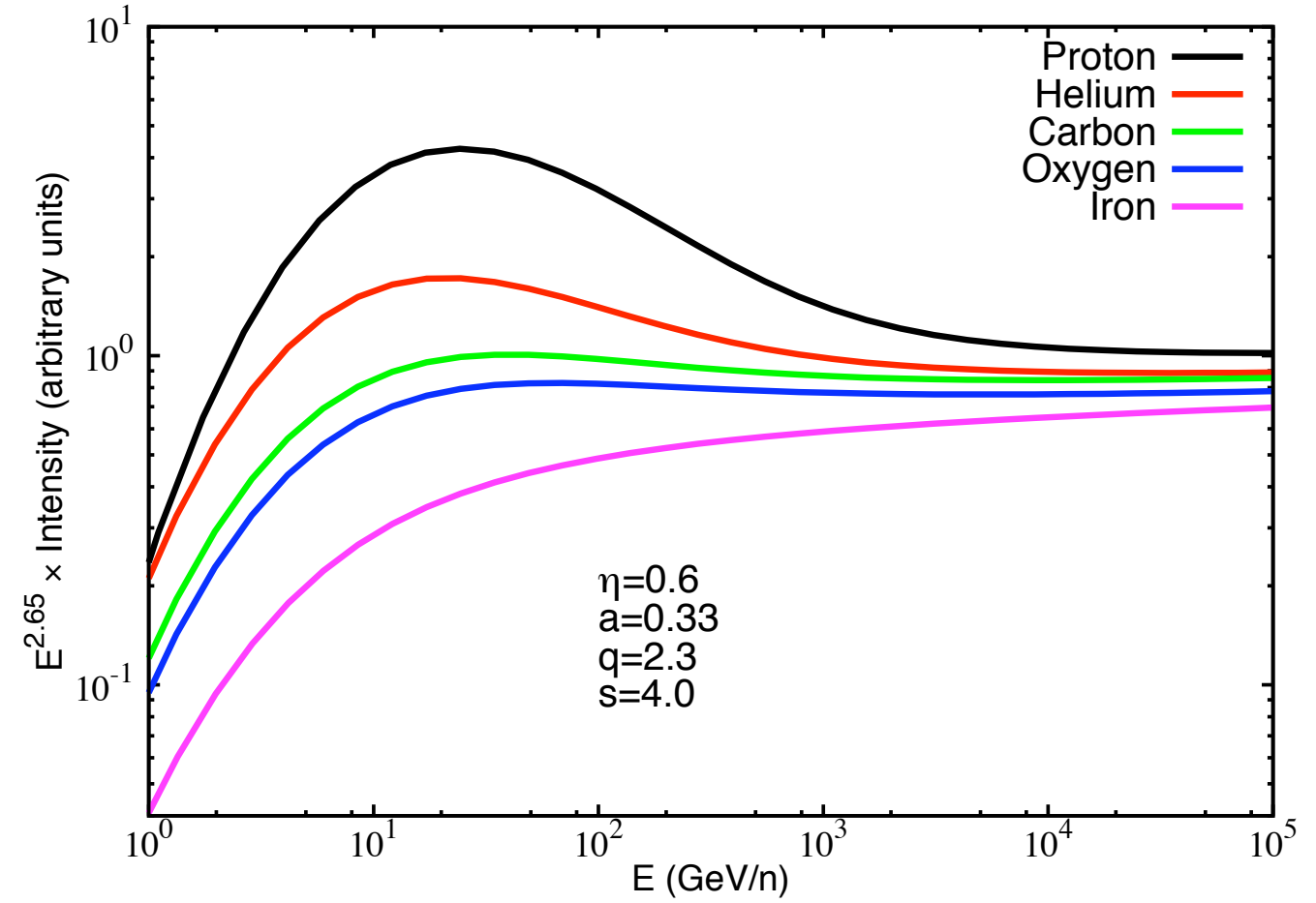
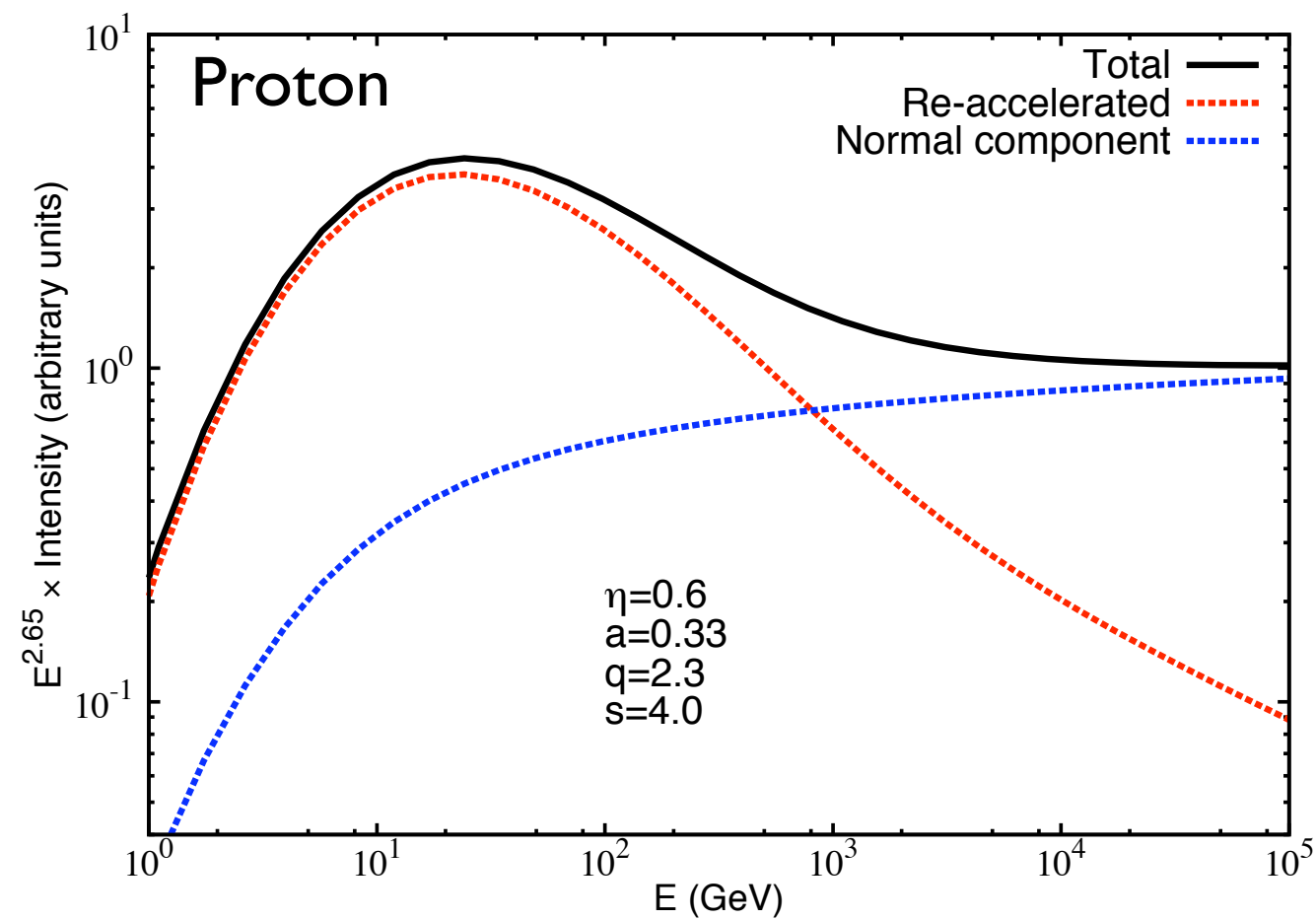
*Re-acceleration parameters: (η, s)

*Source parameters: (q, f)

Re-acceleration effect on the cosmic-ray spectrum

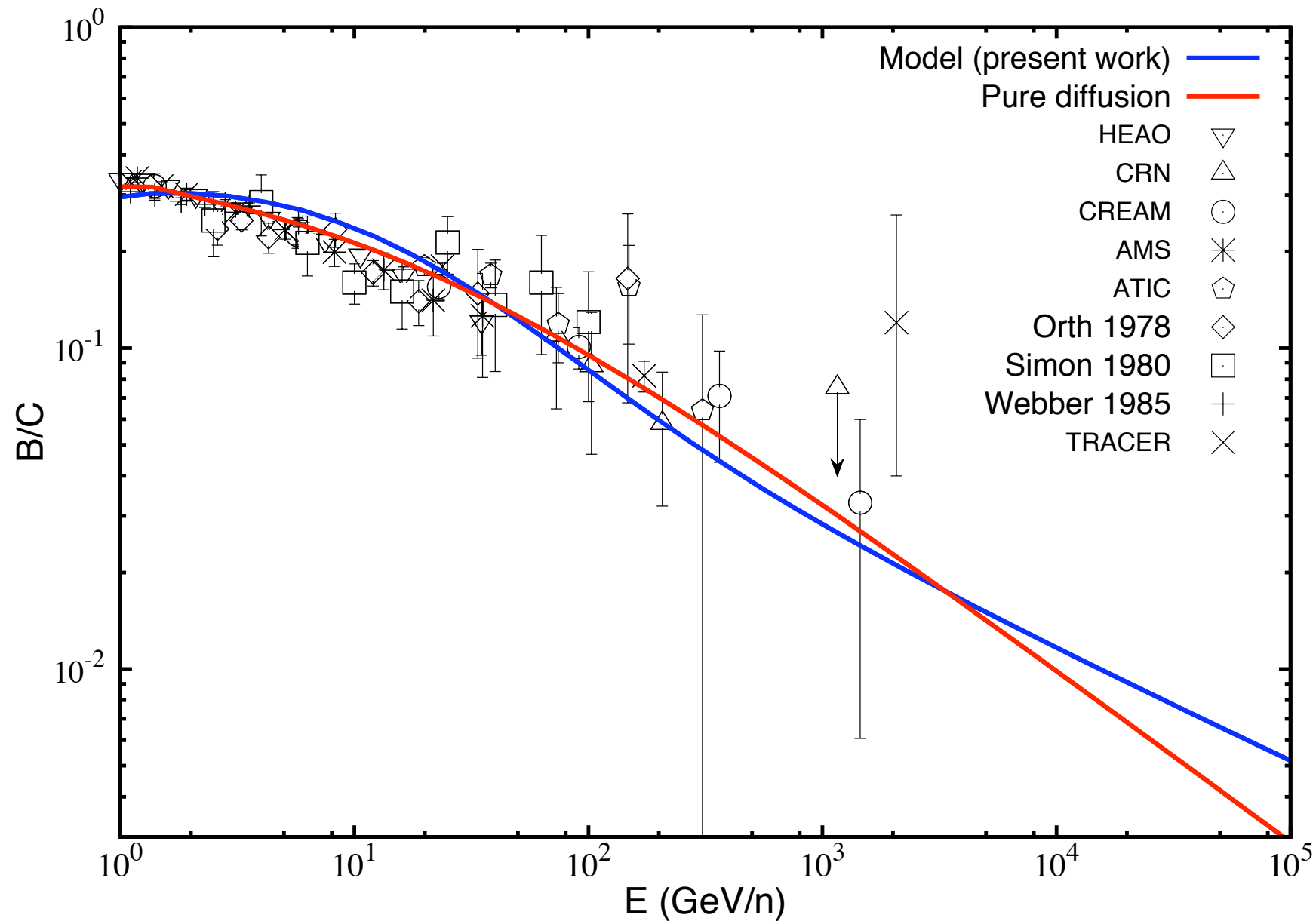


Re-acceleration effect on the cosmic-ray spectrum



Re-acceleration & propagation parameters

Boron-to-Carbon ratio



$$D_0 = 9 \times 10^{28} \text{ cm}^2 \text{ s}^{-1}$$

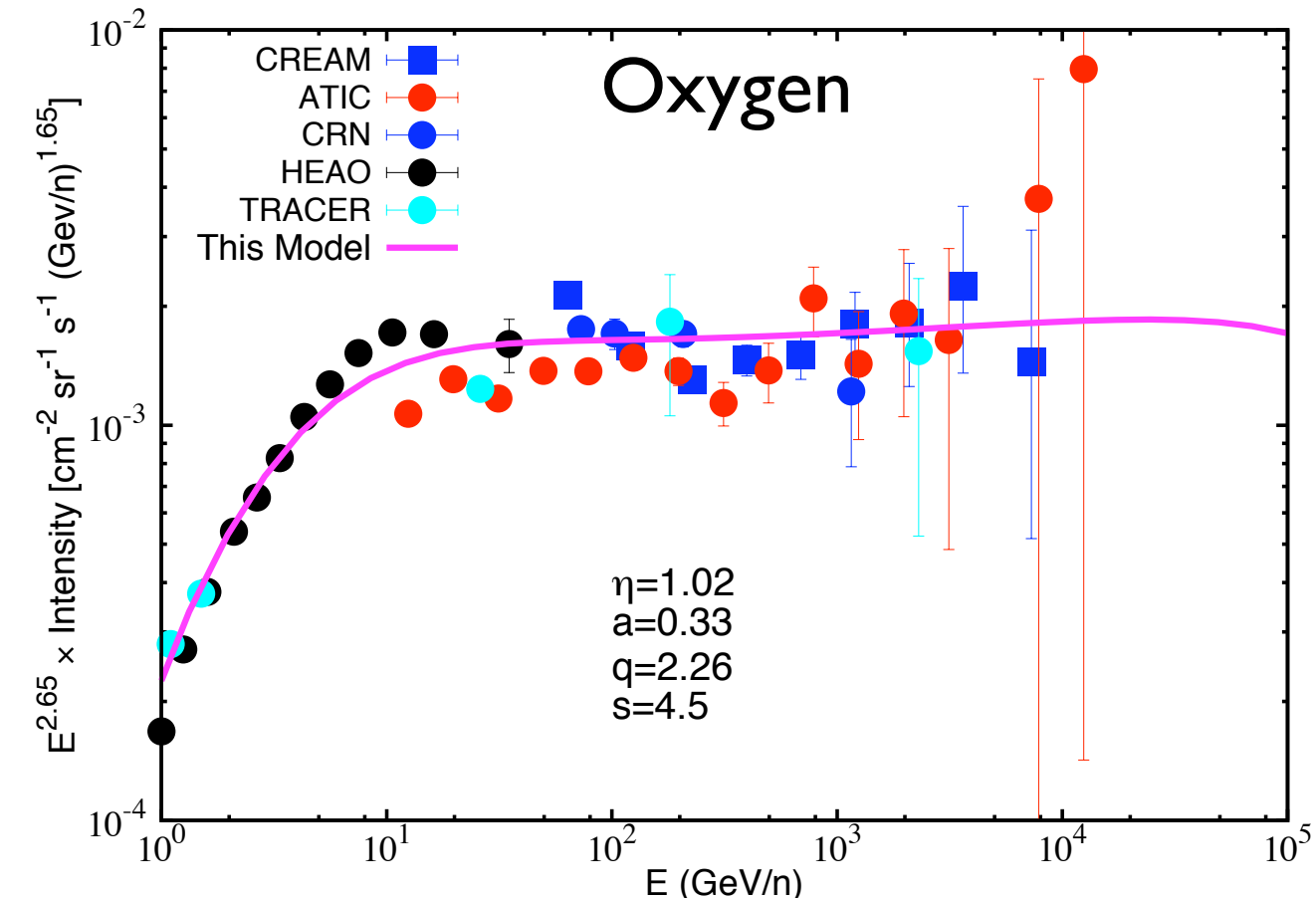
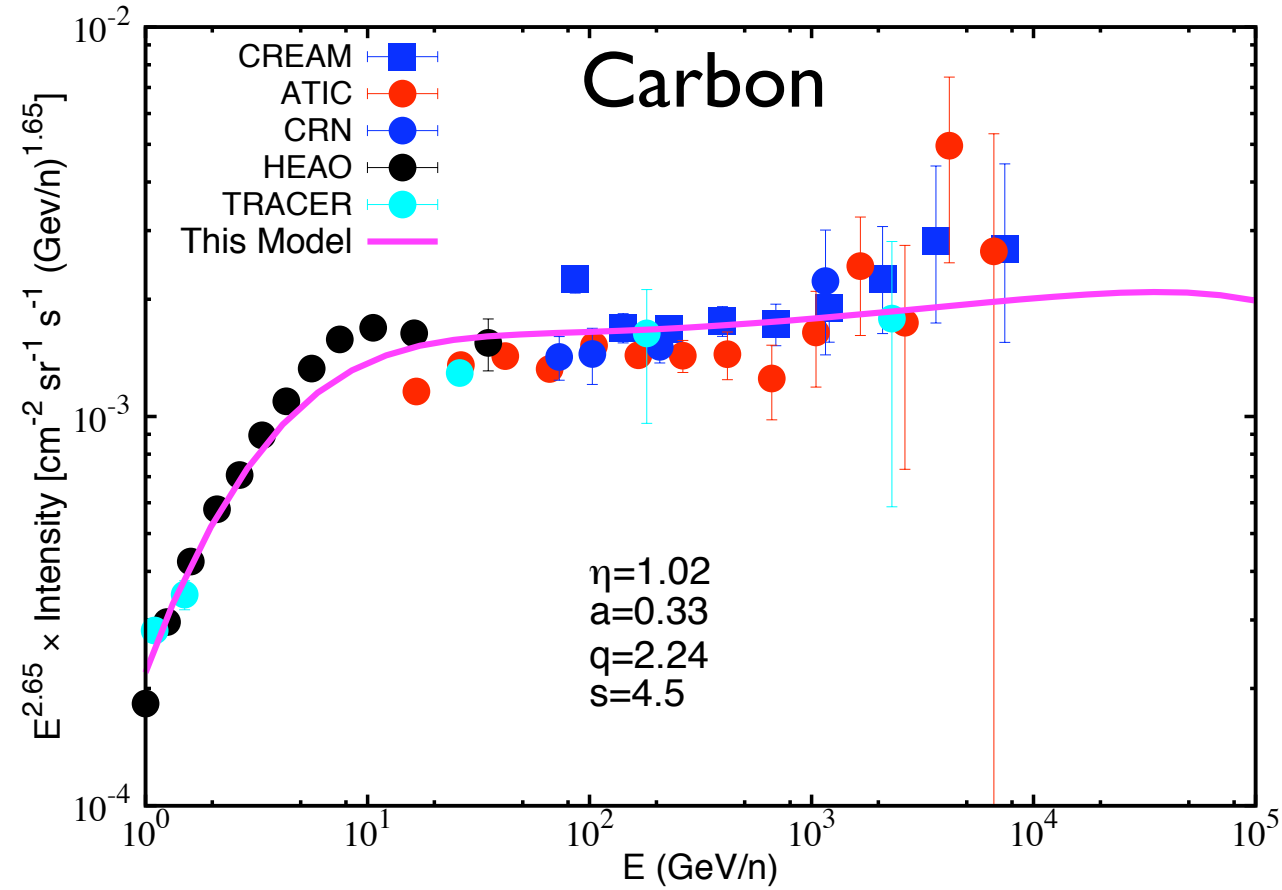
$$\rho_0 = 3 \text{ GV}$$

$$a = 0.33$$

$$\eta = 1.02$$

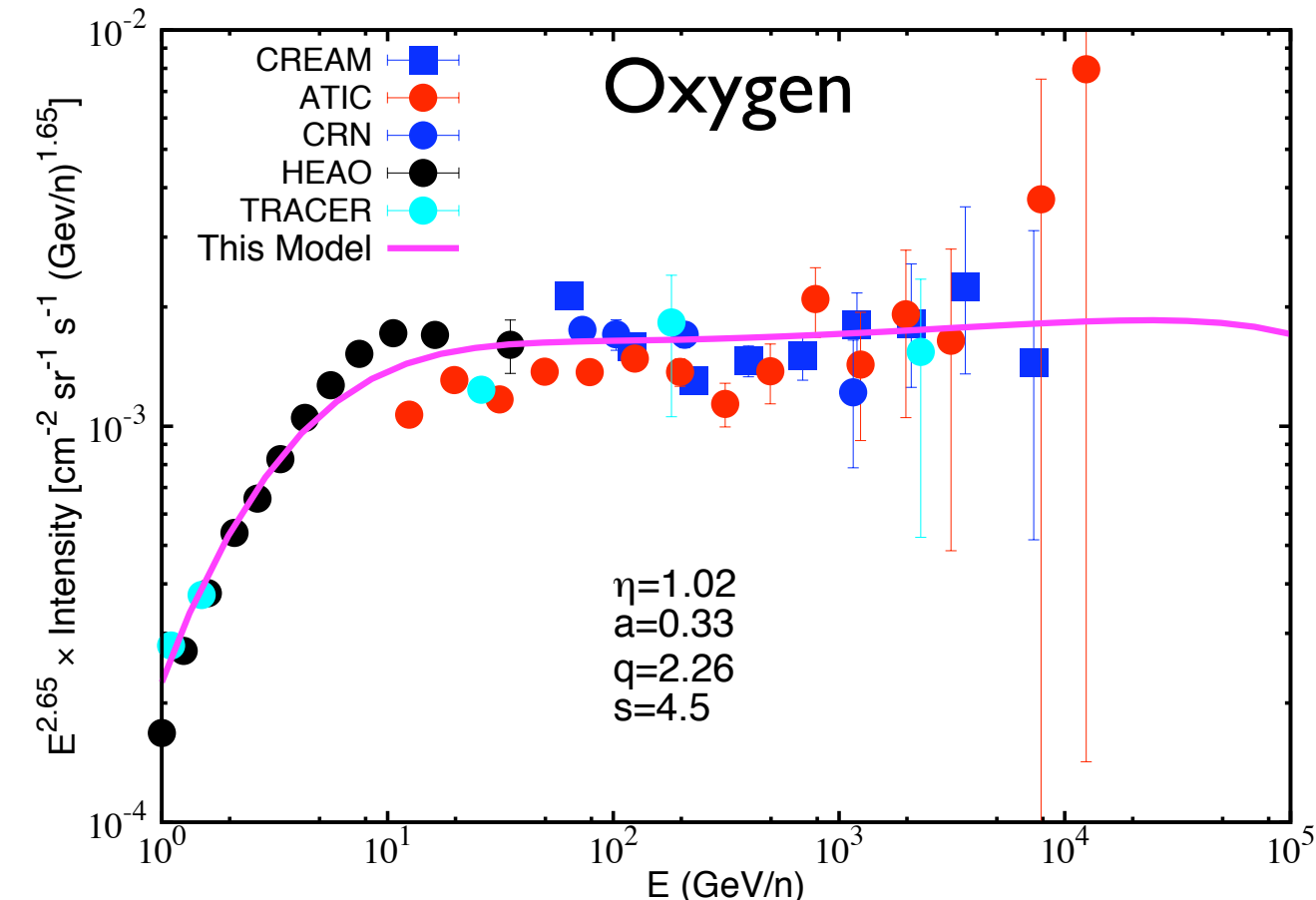
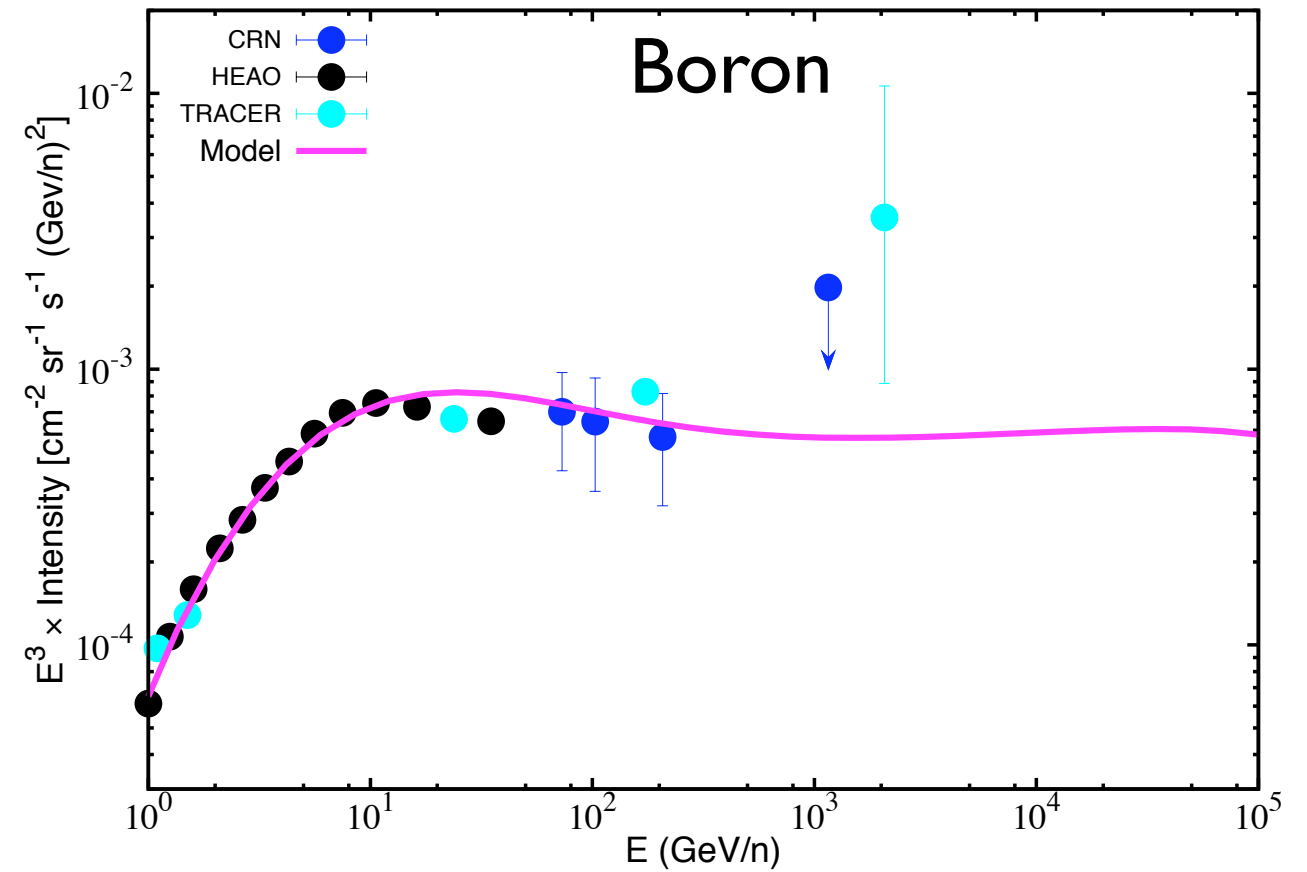
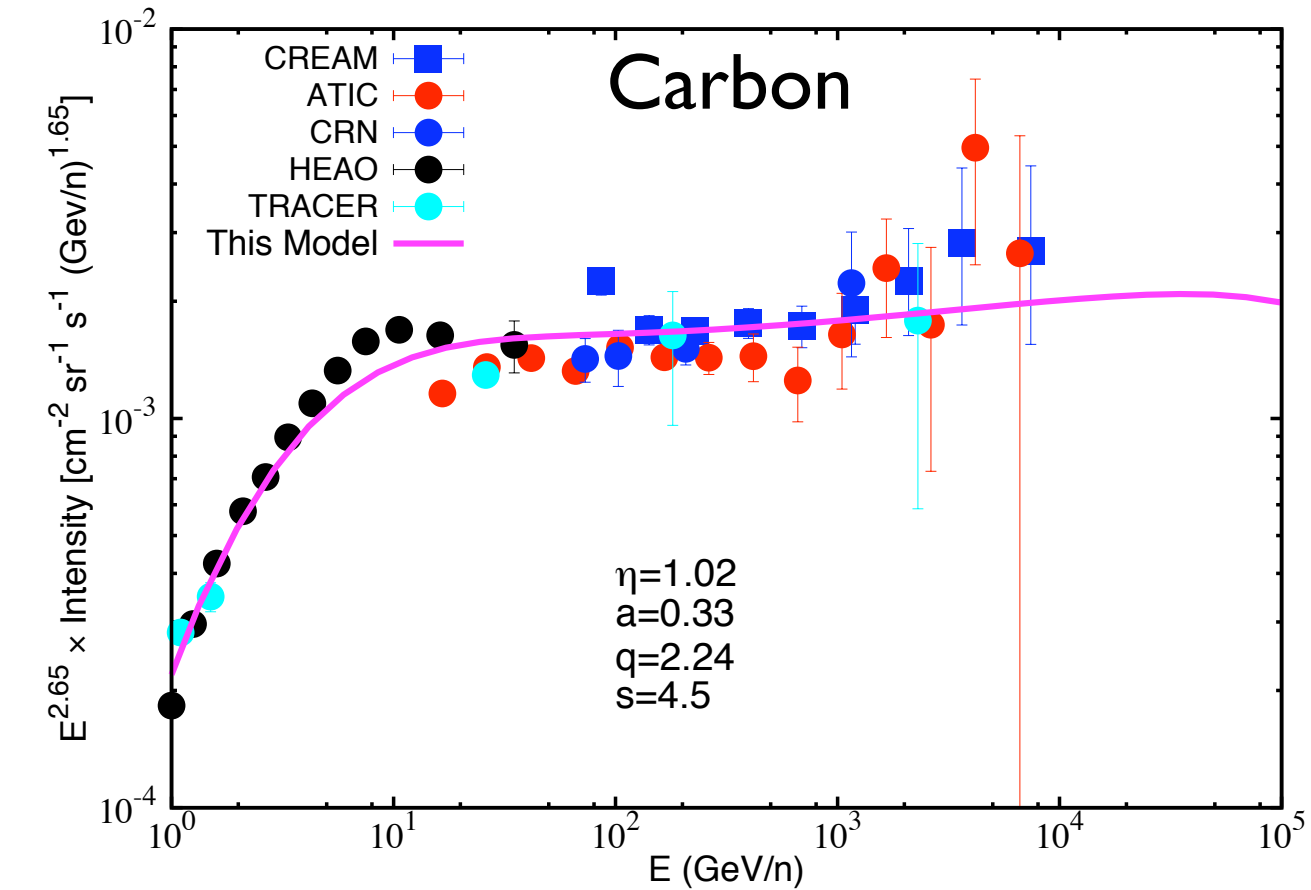
$$s = 4.5$$

Results: Carbon, Oxygen & Boron spectra



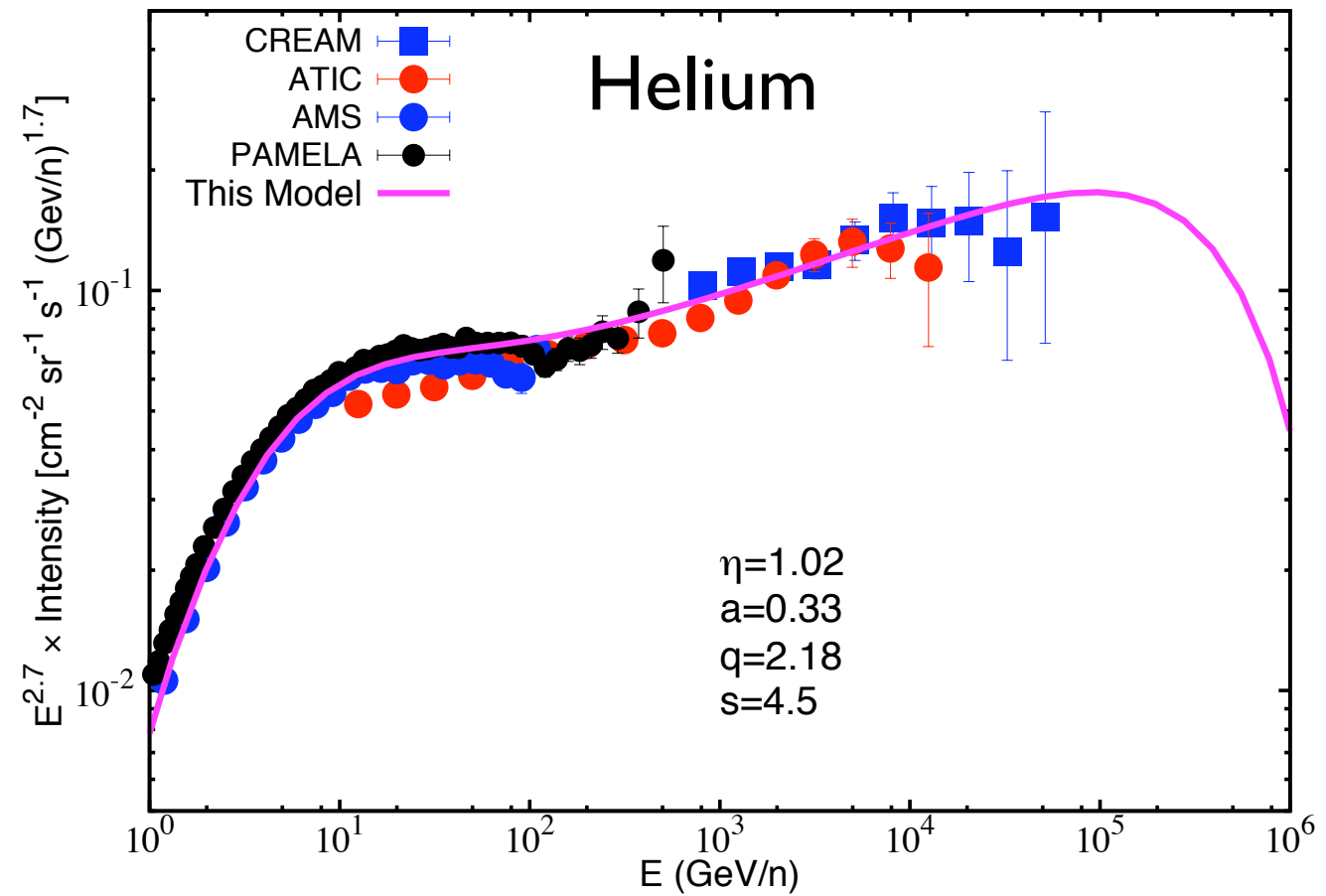
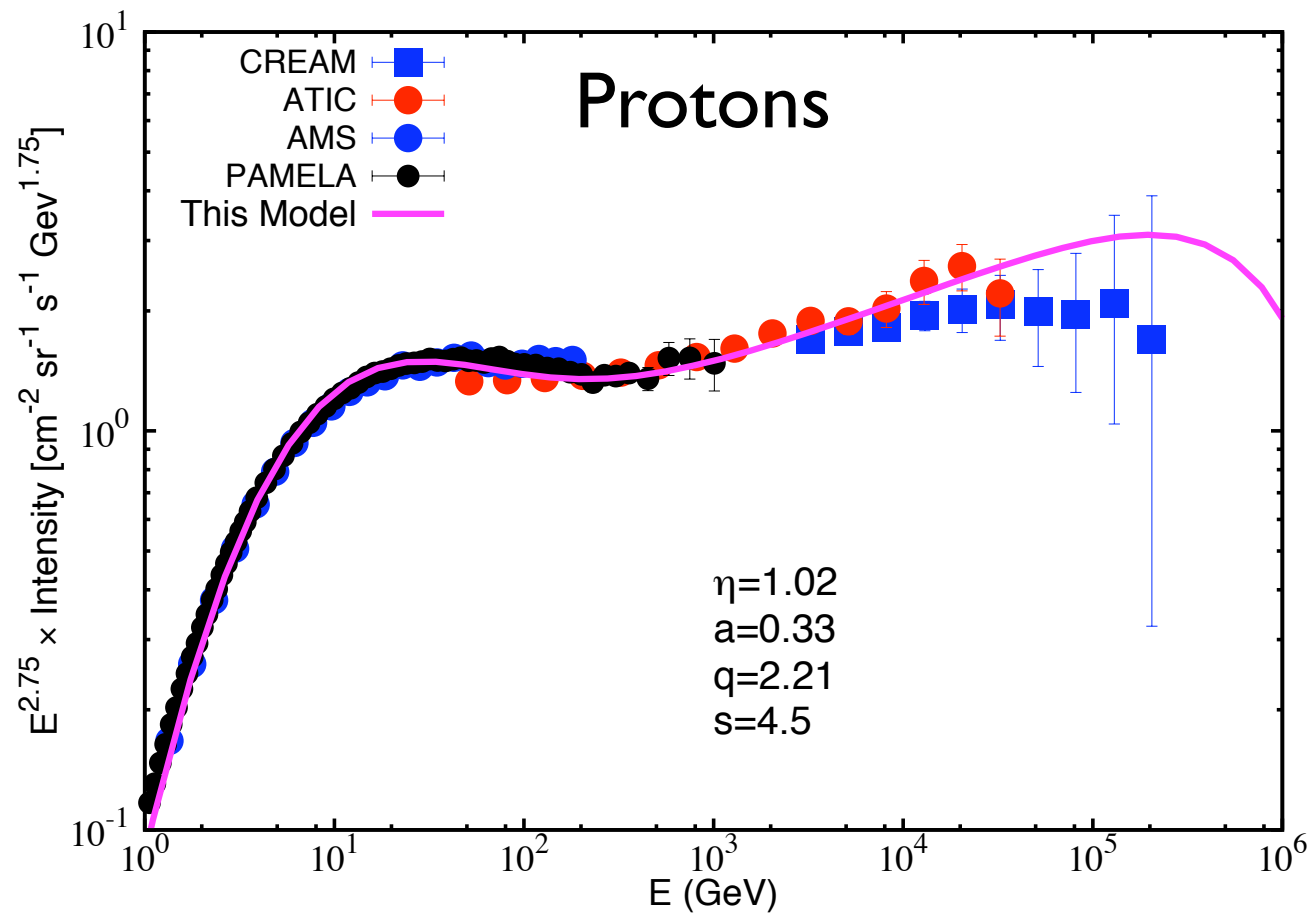
$q_C=2.24, f_C=0.024\%$
 $q_O=2.26, f_O=0.025\%$
 where f 's are in units of 10^{51} ergs

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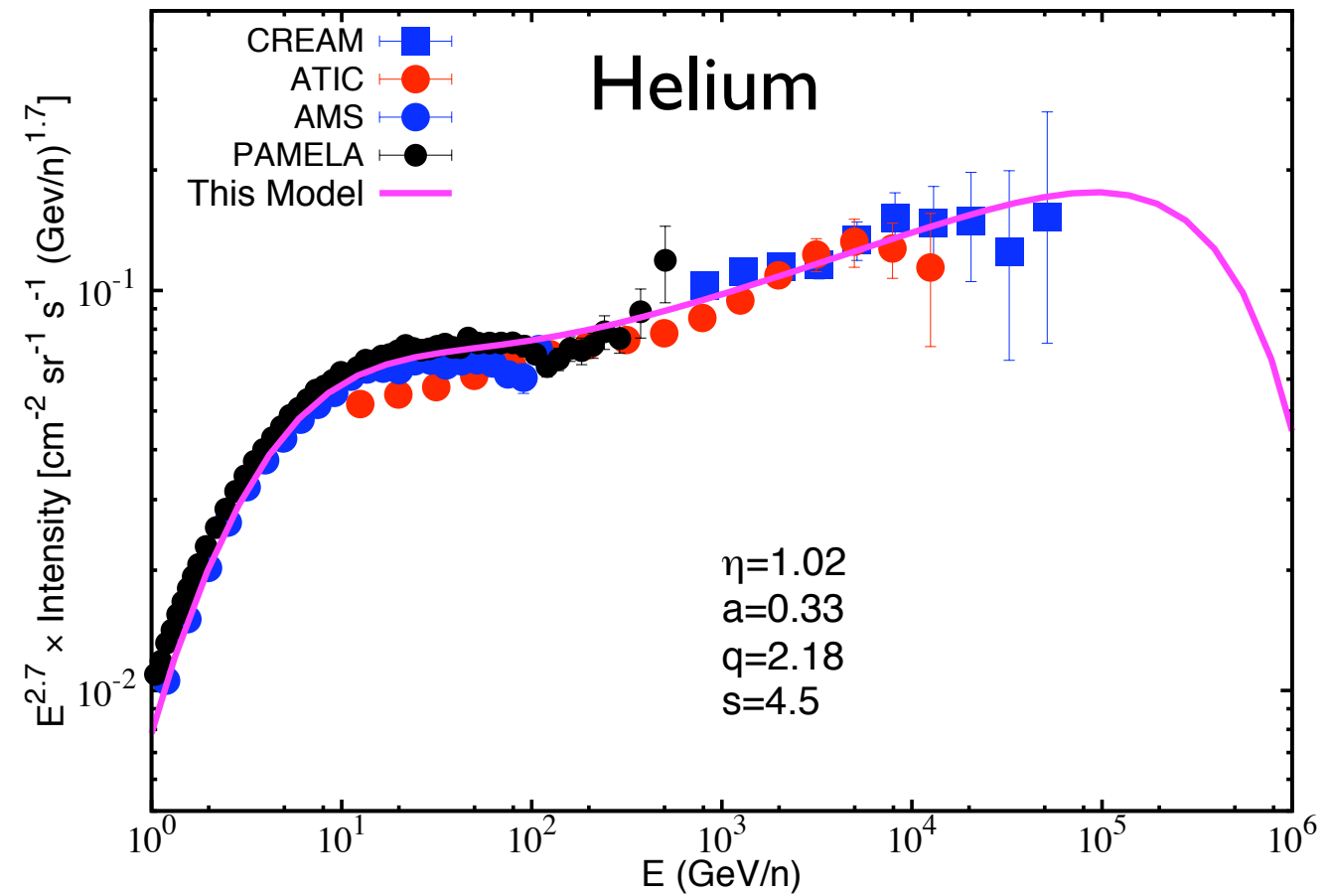
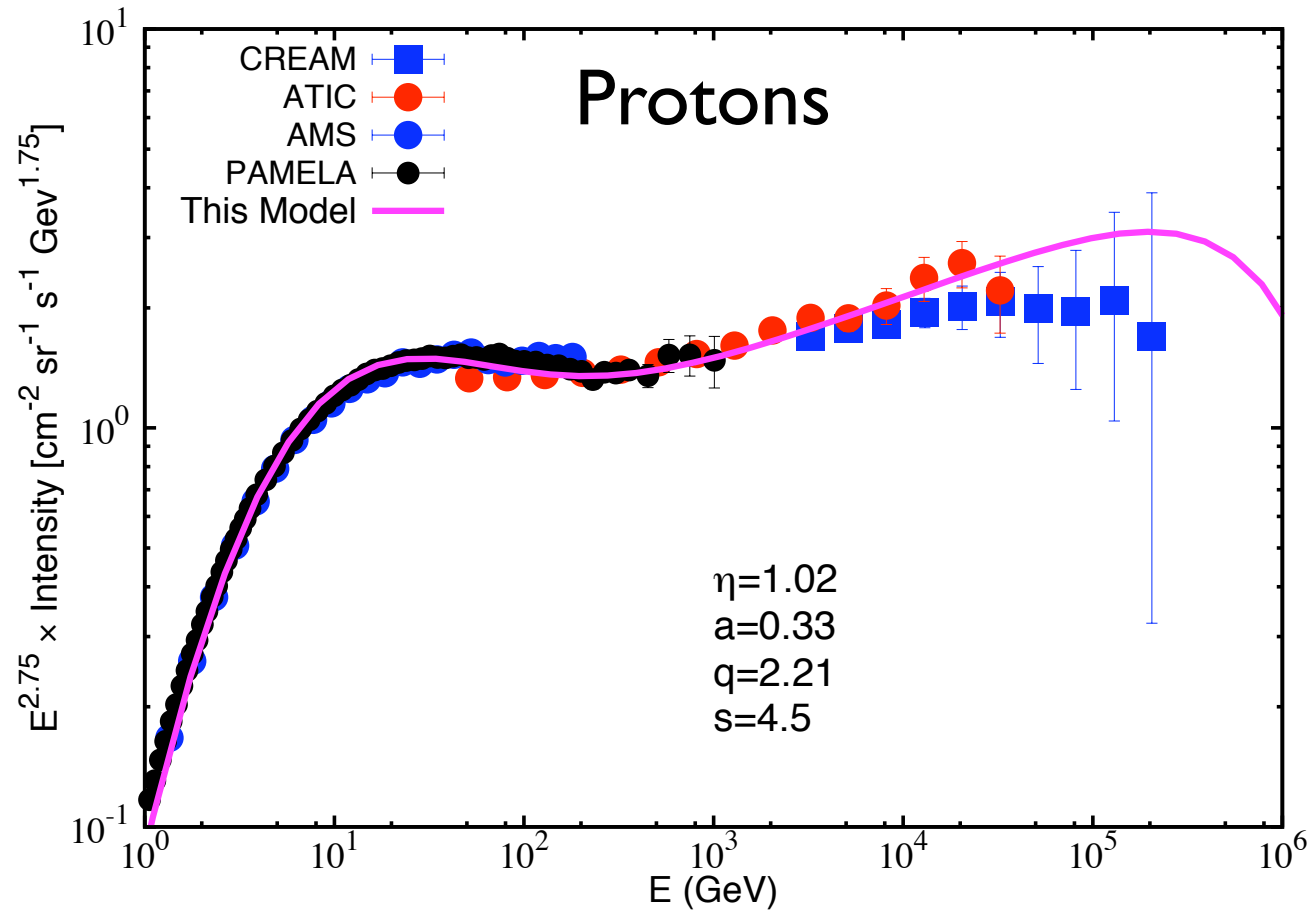
Results: Protons, Helium & Iron spectra



$$q_P=2.21, f_P=6.95\%$$

$$q_{\text{He}}=2.18, f_{\text{He}}=0.79\%$$

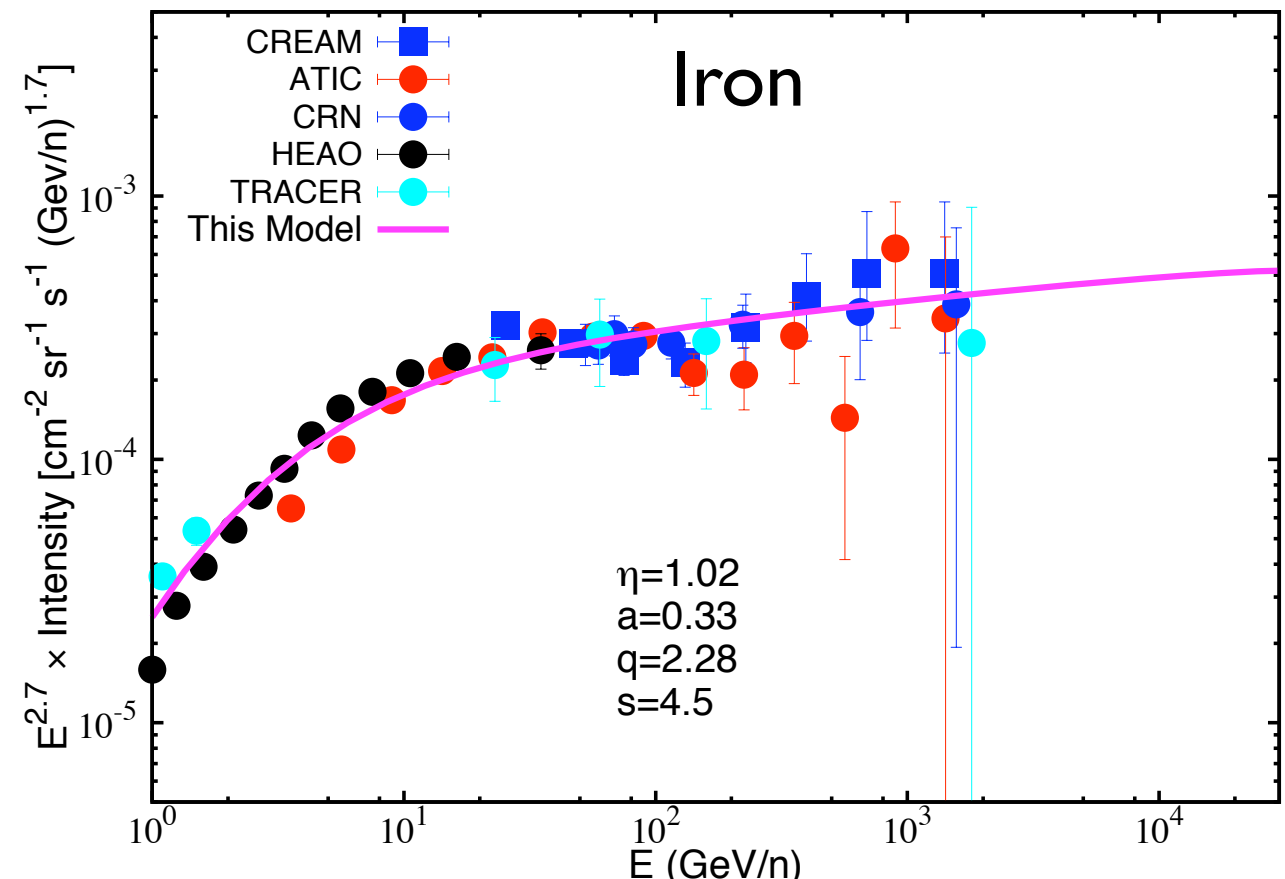
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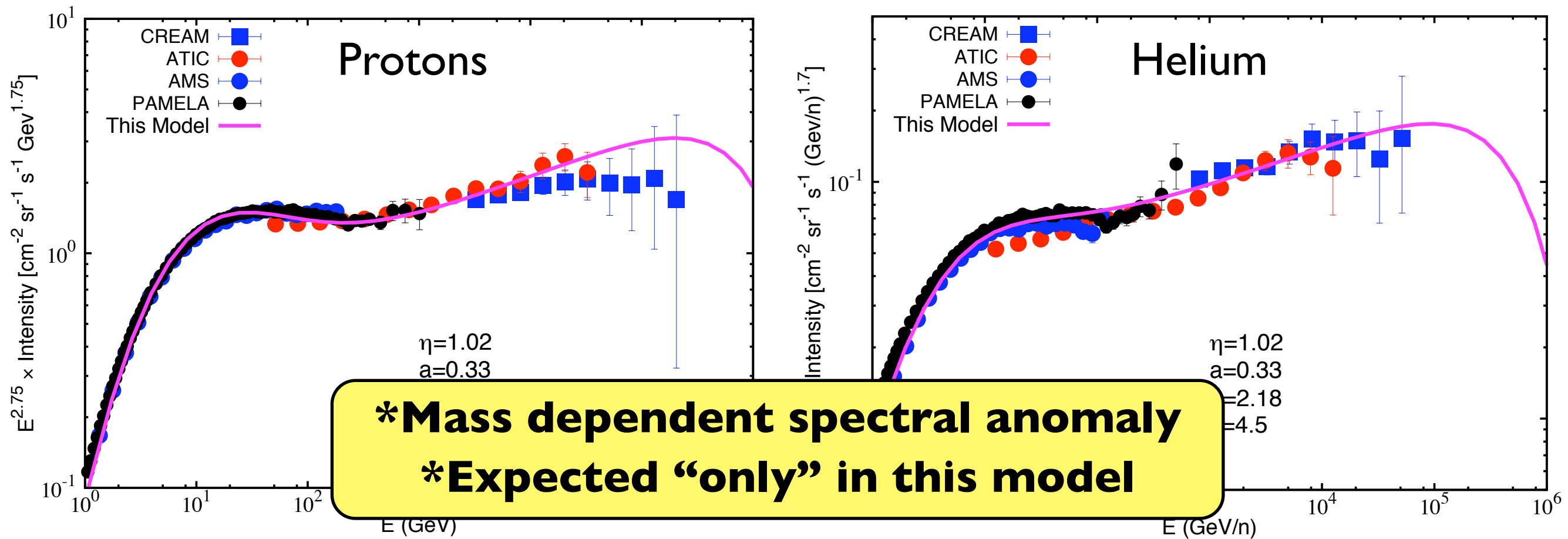
$$q_P=2.21, f_P=6.95\%$$

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$$q_{\text{Fe}}=2.28, f_{\text{Fe}}=4.9 \times 10^{-3}\%$$



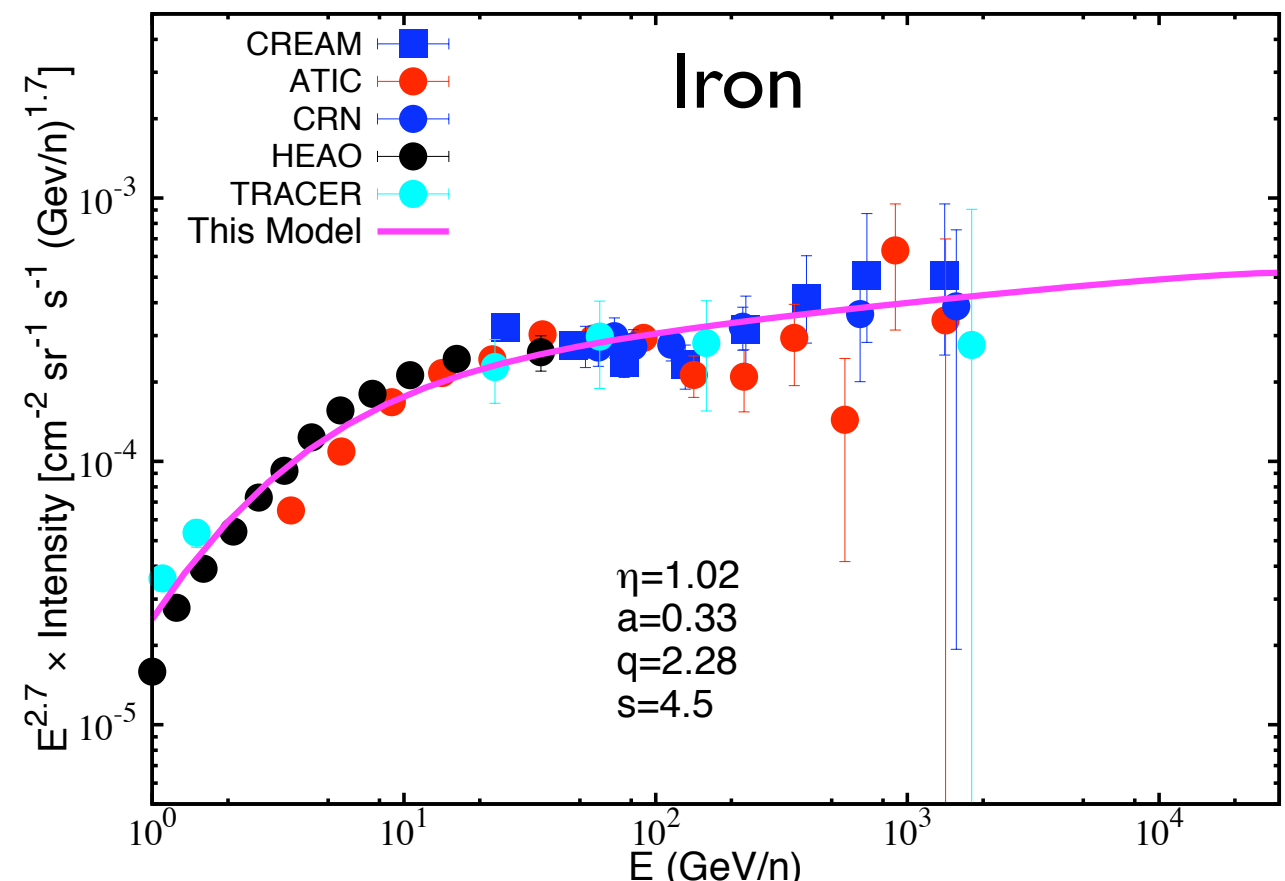
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Summary

- **The GeV-TeV spectral anomaly can be due to re-acceleration by weak shocks associated with old supernova remnants in the Galaxy**
 - **This model predicts a mass dependent spectral hardening which can be checked by sensitive measurements of heavier species**
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Thank you for your attention :)