Implications of the AMS-02 results

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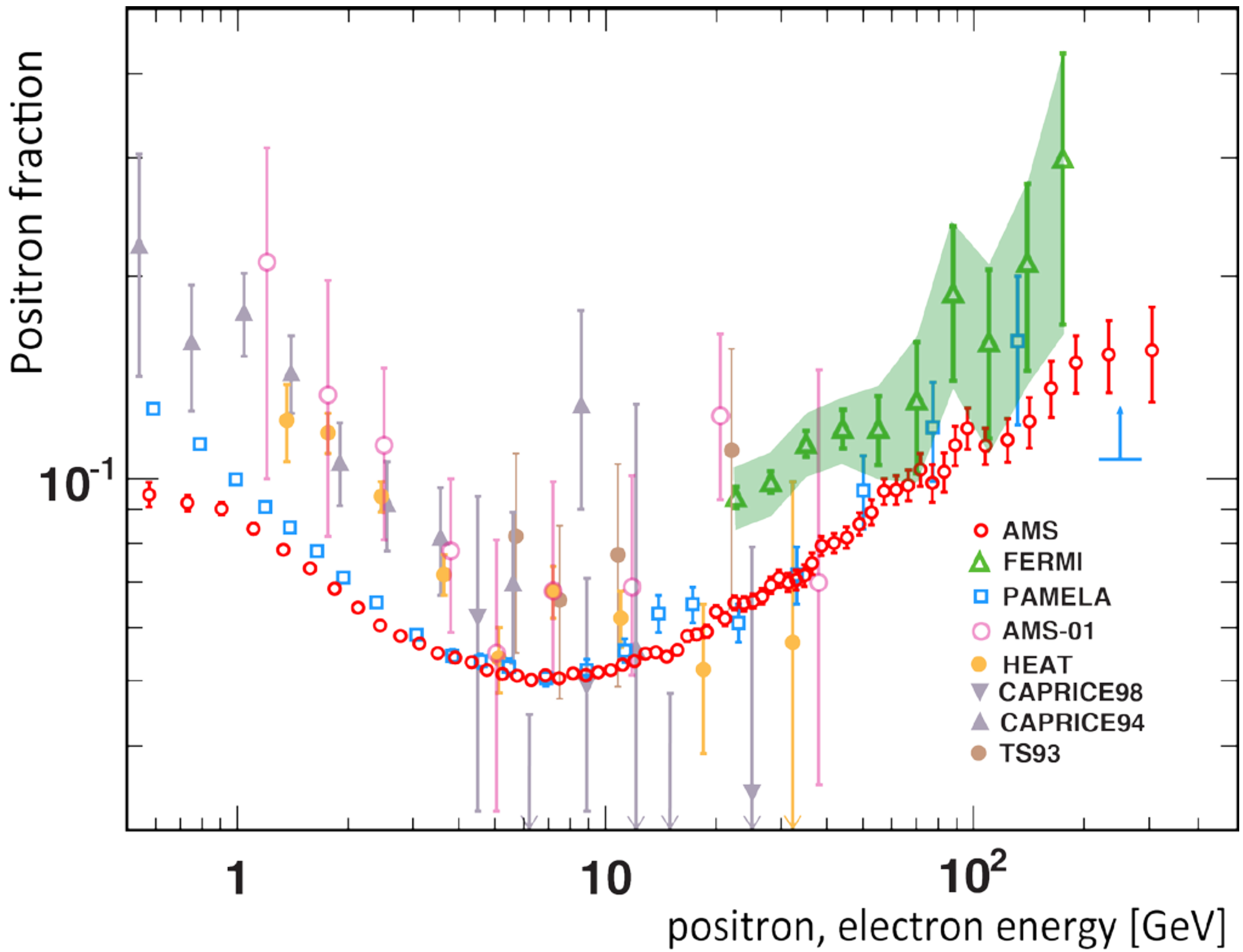
2nd Workshop of Herd. 2013-12-2



We have precise CR data → **Quantitatively study of physics behind**

Bkg+pulsar (or DM) to fit the data

$$\mathcal{P} = \begin{cases} \{A_p, \nu_1, \nu_2, p_{\rm br}^p\}, & \text{bkg protons,} \\ \{A_e, \gamma_1, \gamma_2, p_{\rm br}^e\}, & \text{bkg electrons,} \\ \underline{\{A_{\rm psr}, \alpha, E_c\} \text{ or } \{m_\chi, \langle\sigma v\rangle\}}, & \text{exotic sources,} \\ \{c_{e^+}, \phi\}, & \text{others.} \end{cases}$$

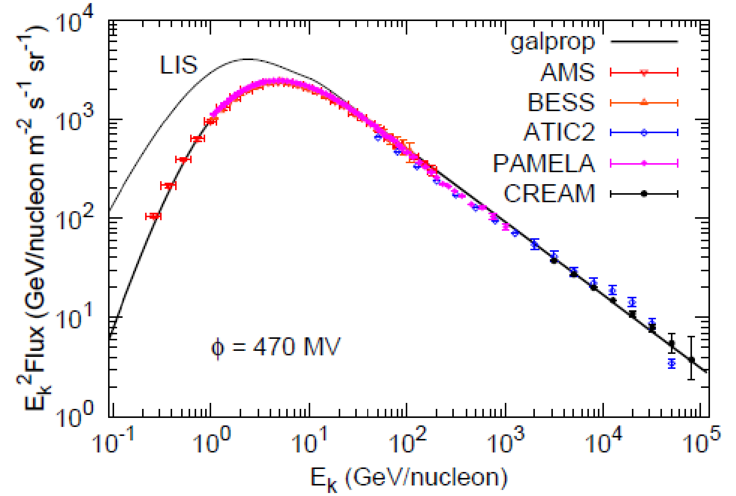
$$q(p) = A_{p,e} \left(\frac{p}{p_{\rm br}^{p,e}}\right)^{-\nu_1/\nu_2} \qquad q(p) = A_{\rm psr} p^{-\alpha} \exp(-p/p_c)$$

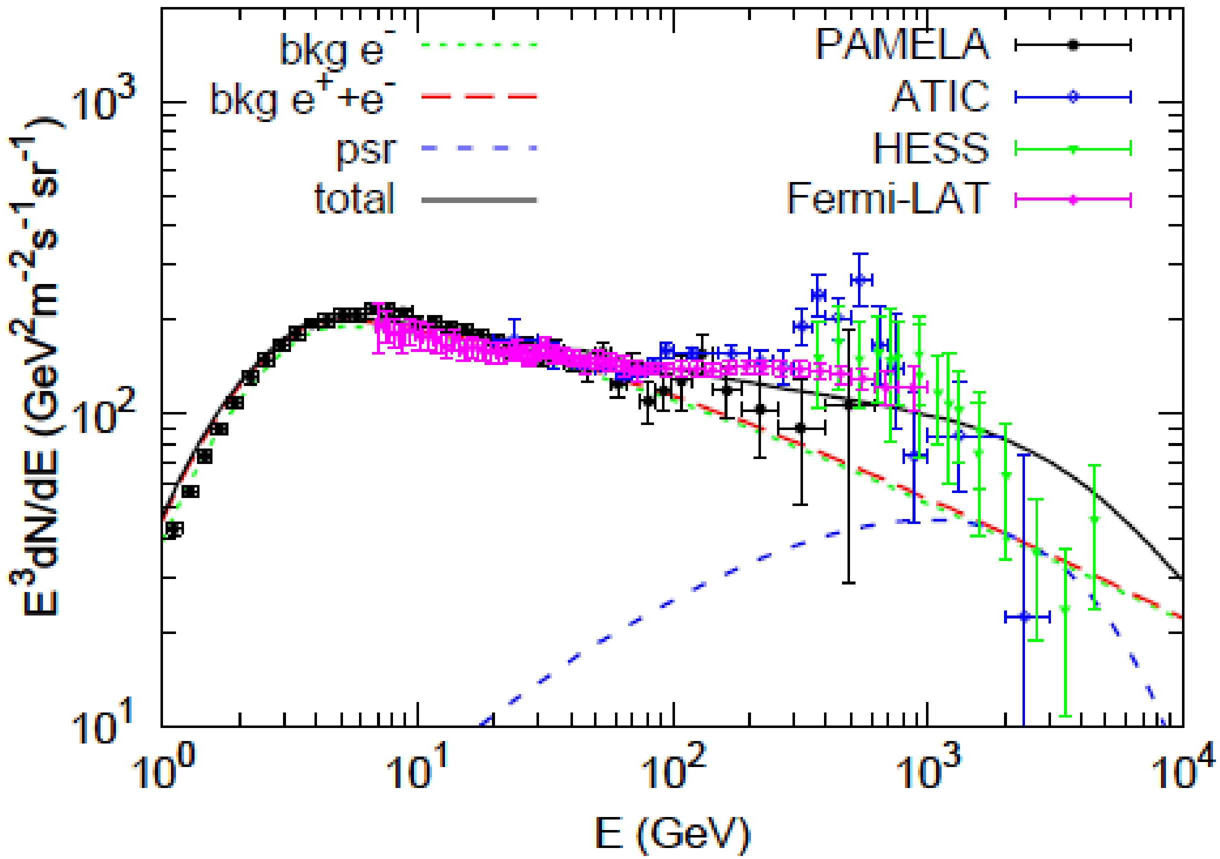
1， propagation of charged particles is treated by Galprop. We fit the parameters to data by MCMC

2, Note: propagation parameters are the best value to fit B/C, 10Be/9Be (later we discuss the uncertainties from astrophysics)

data

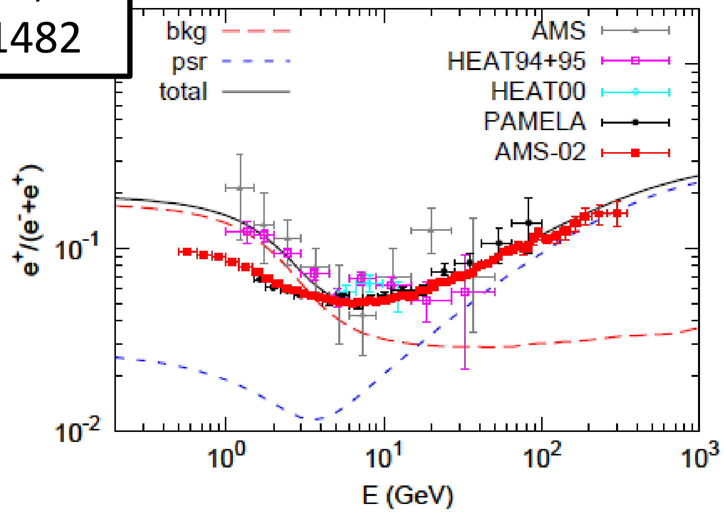
- AMS02 positron ratio
- *PAMELA electron and proton spect*
- Fermi/HESS total electron spectru

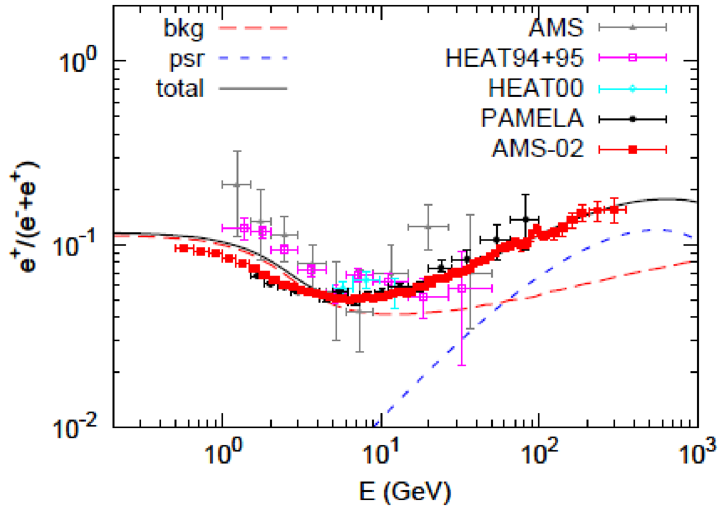


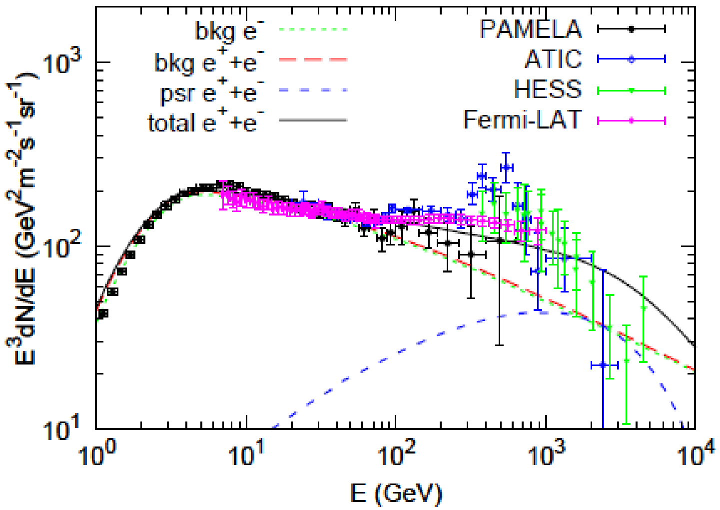


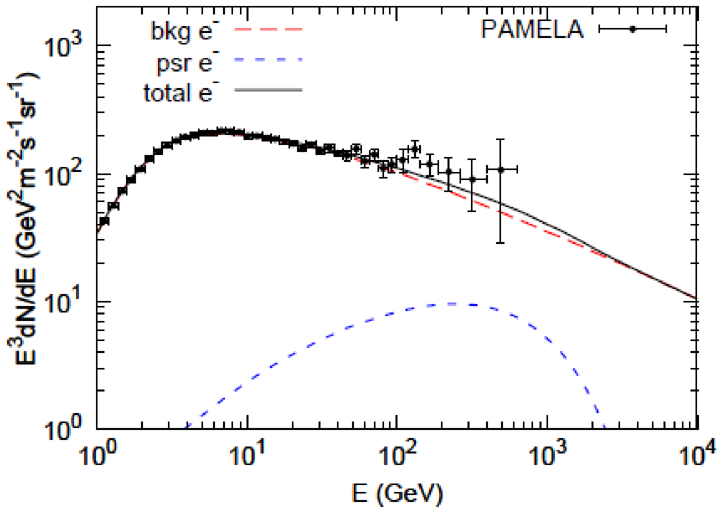
It seems pulsar can fit data roughly. However, the χ^2/dof=1.8; 6σ deviates from expectaion. ***Fermi data is not consistent with the AMS02 data***. We fit without including the Fermi data. χ^2/dof=52/80; perfect fit to data!

Yuan, Bi, Chen, Guo, Lin, Zhang, 1304.1482









Fermi data has systematic errors?

Fermi has a 5%-10% uncertainty of absolute energy scale, this induce a 10~20% in flux

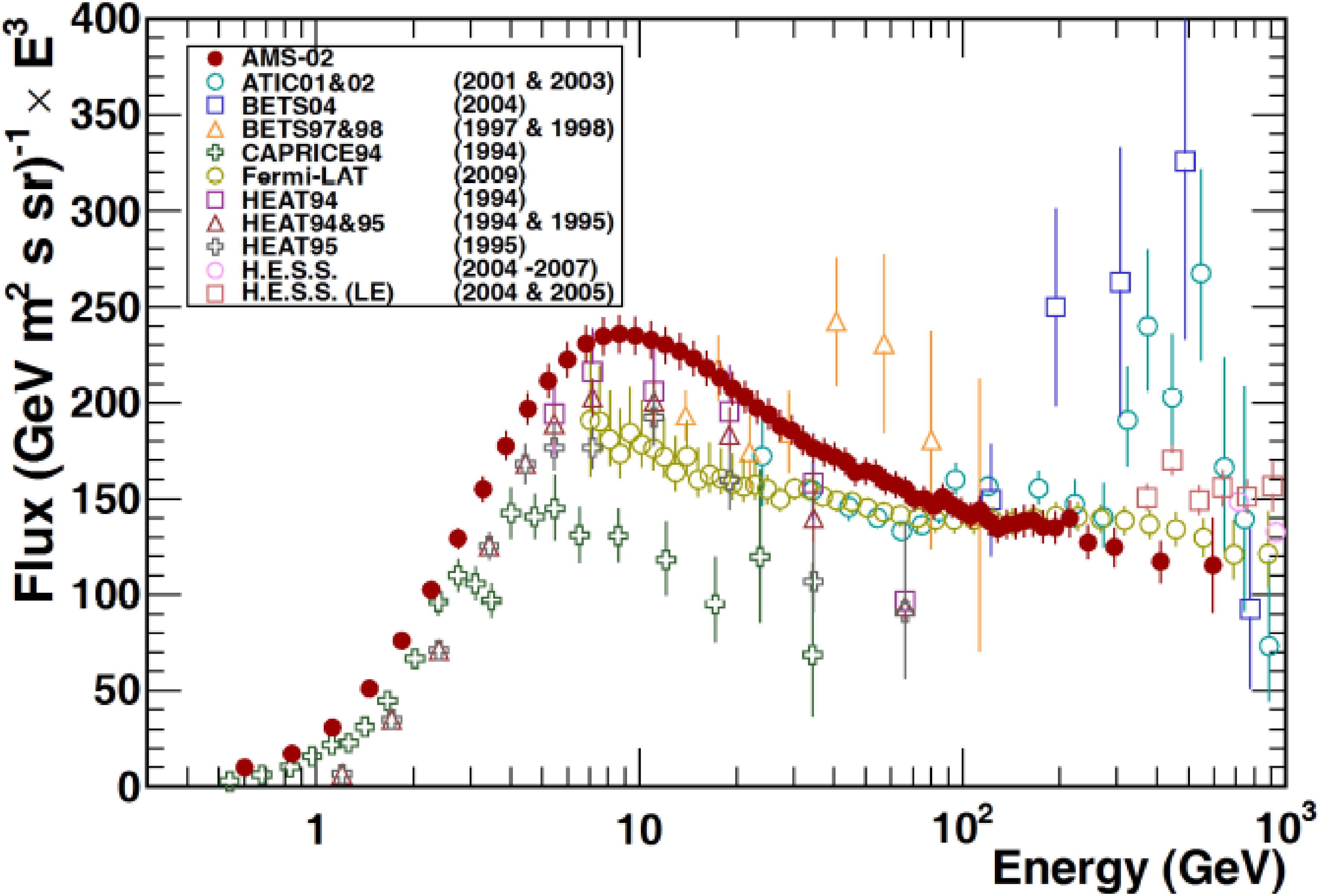
$$\Delta E/E \qquad\qquad (\Gamma - 1)\Delta E/E$$

We give other two simulations: include the Fermi/HESS systematic errors; not include Fermi data at all.

TABLE II: Definition of fitting

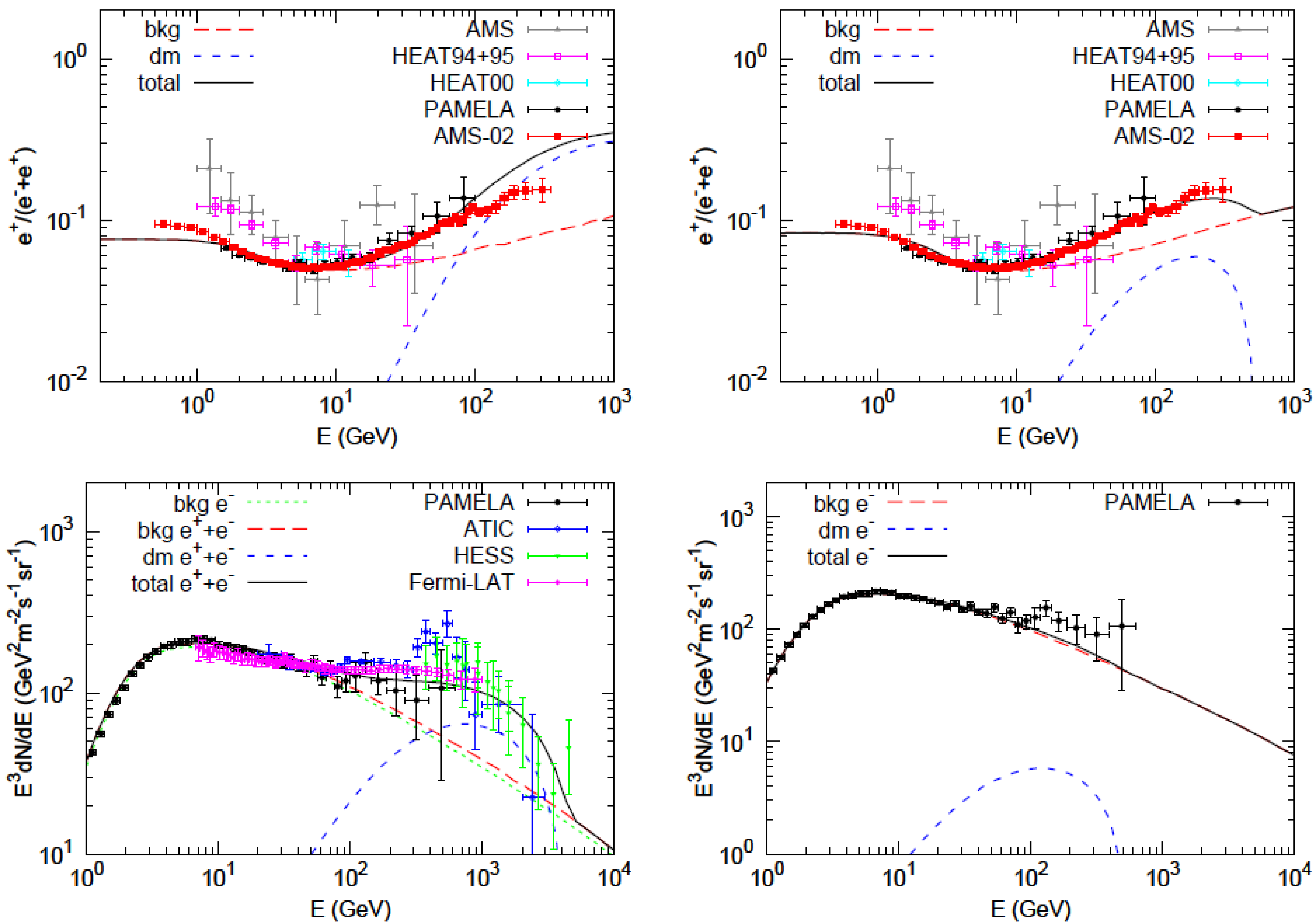
I-a	AMS $e^+/e^\pm$ + PAMELA e^- + Fermi/HESS $e^\pm$
II-a	AMS $e^+/e^\pm$ + PAMELA e^- + Fermi/HESS $e^\pm$ (enlarged error)
III-a	AMS $e^+/e^\pm$ + PAMELA e^-
I-b	AMS $e^+/e^\pm$ + PAMELA e^- + Fermi/HESS $e^\pm$ + PAMELA p
II-b	AMS $e^+/e^\pm$ + PAMELA e^- + Fermi/HESS $e^\pm$ (enlarged error) + PAMELA p
III-b	AMS $e^+/e^\pm$ + PAMELA e^- + PAMELA p

(Electron plus Positron) Spectrum



For DM the tension is stronger（AMS02-Fermi），

χ^2/dof=3.3； without Fermi, tau final state gives good fit



Fitting results of chi^2 per d.o.f

	pulsar	DM ($\mu^+\mu^-$)	DM ($\tau^+\tau^-$)
I-a	278.7/151	506.7/152	496.5/152
II-a	51.5/80	83.1/81	56.7/81
I-b	288.0/205	615.3/206	584.6/206
II-b	83.0/134	238.7/135	164.3/135

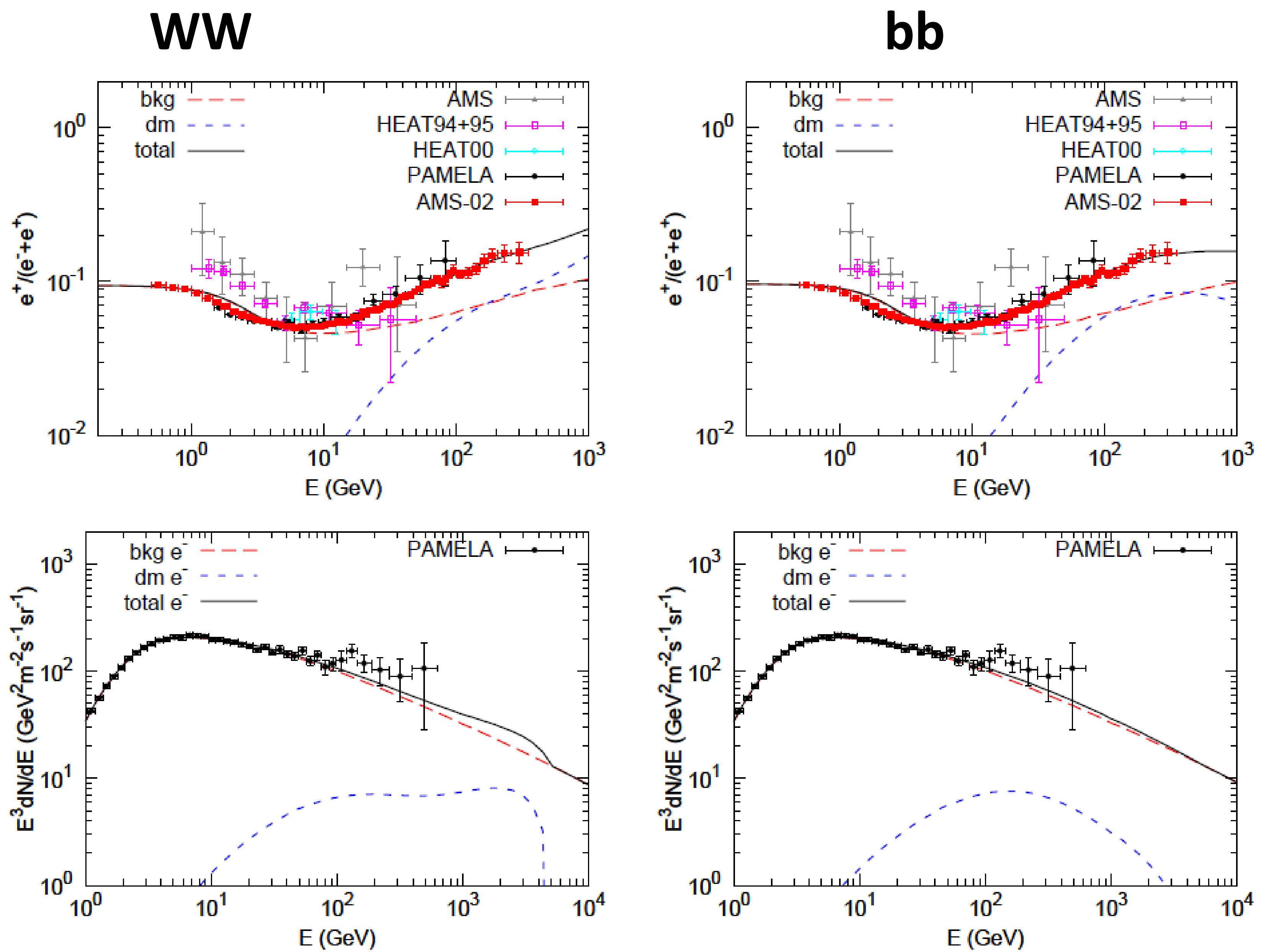
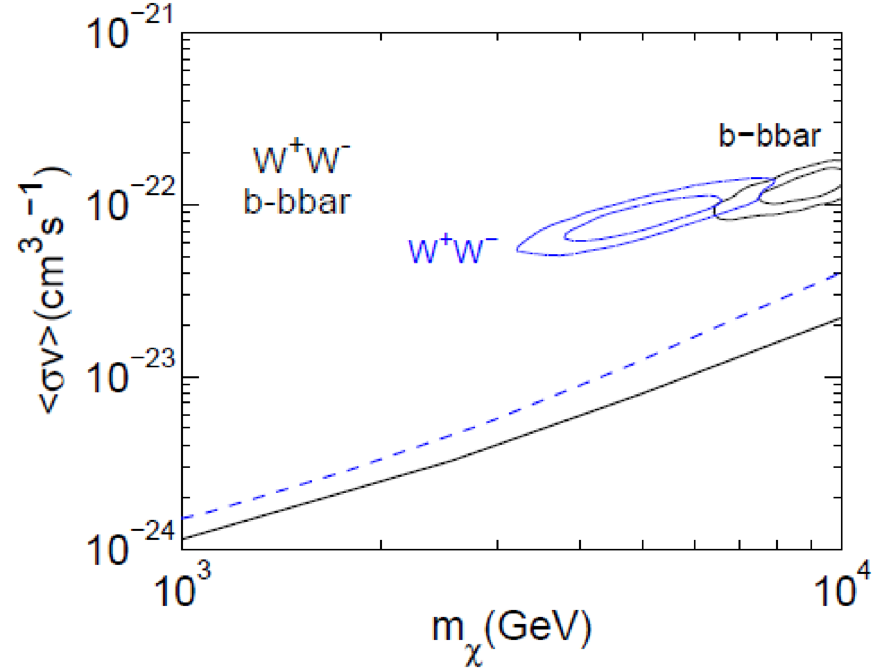
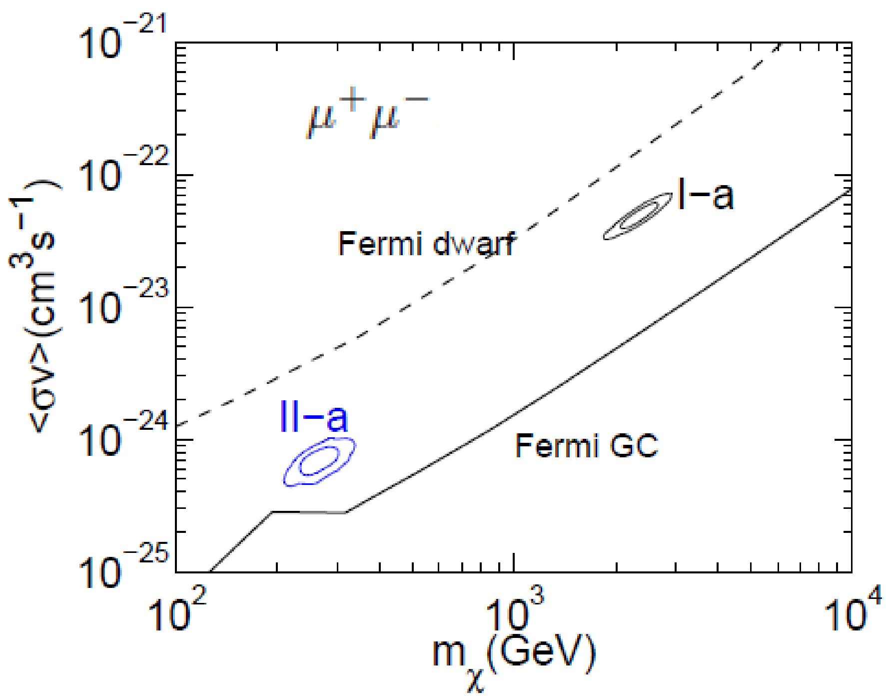


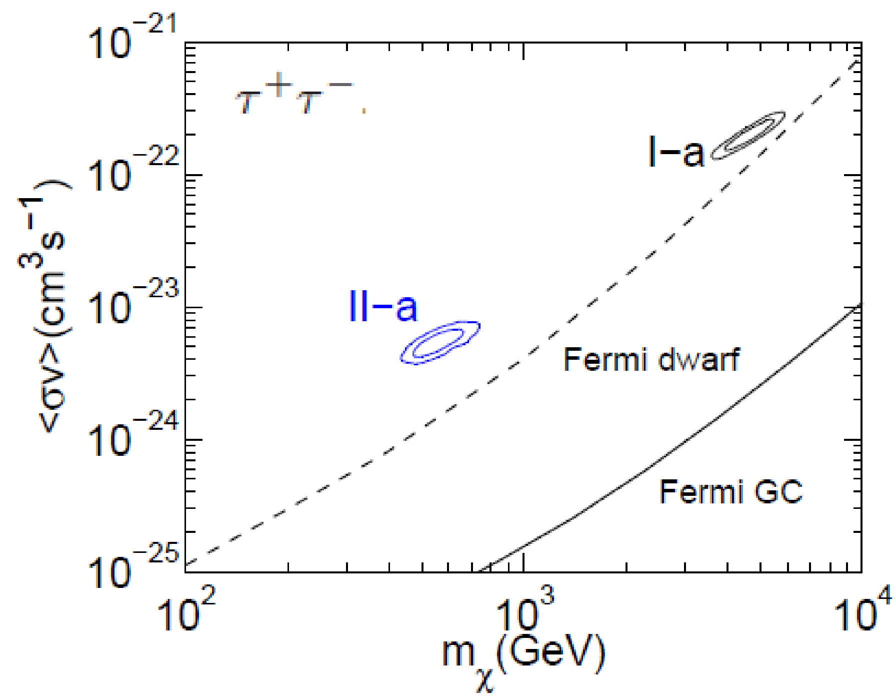
FIG. 12: The positron fraction (top) and electron spectrum (bottom) for the best fitting parameters of the fit II-a with DM annihilation into W^+W^- (left) and $b\bar{b}$ (right) channels.

Constraints from gamma

Yuan, Bi, Chen, Guo, Lin, Zhang, 1304.1482
See also, Jin, Wu, Zhou, 1304.1997
Cholis, Hooper, 1840

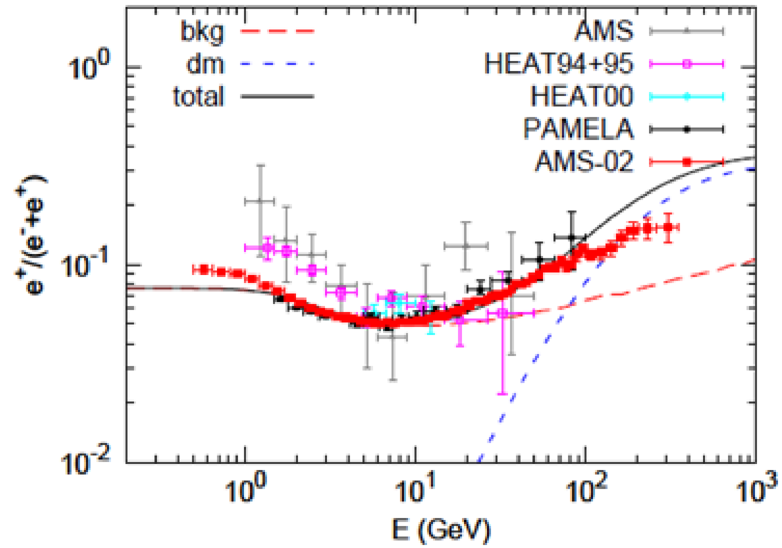


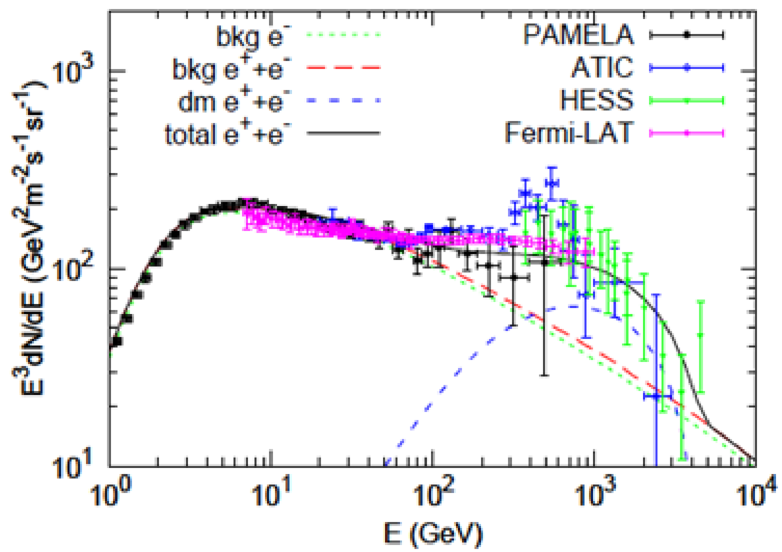




Systematic study of uncertainties of astrophysics

- Propagation
- Treatment of low energy data
- Models of strong interaction
- Galprop version

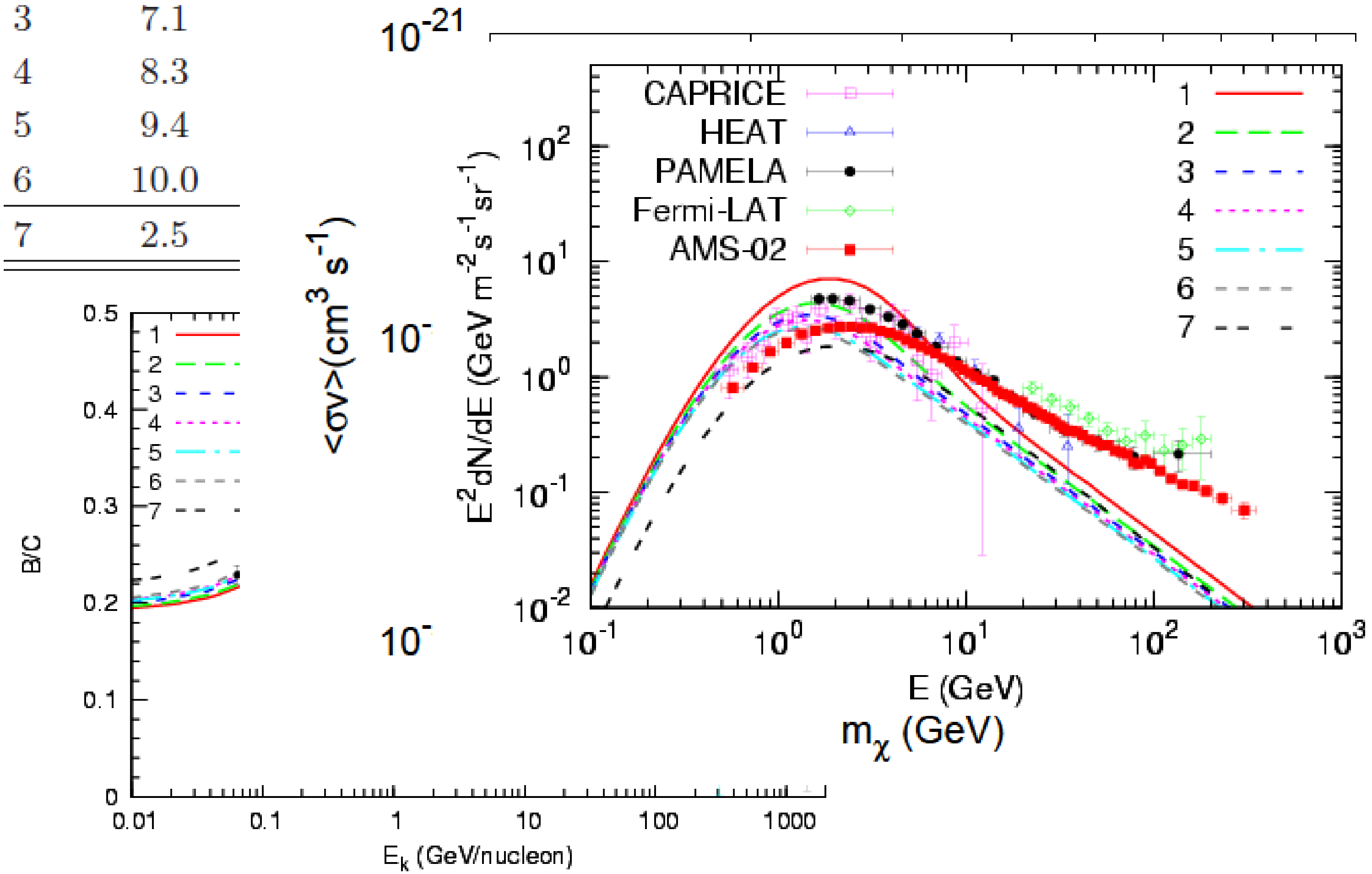




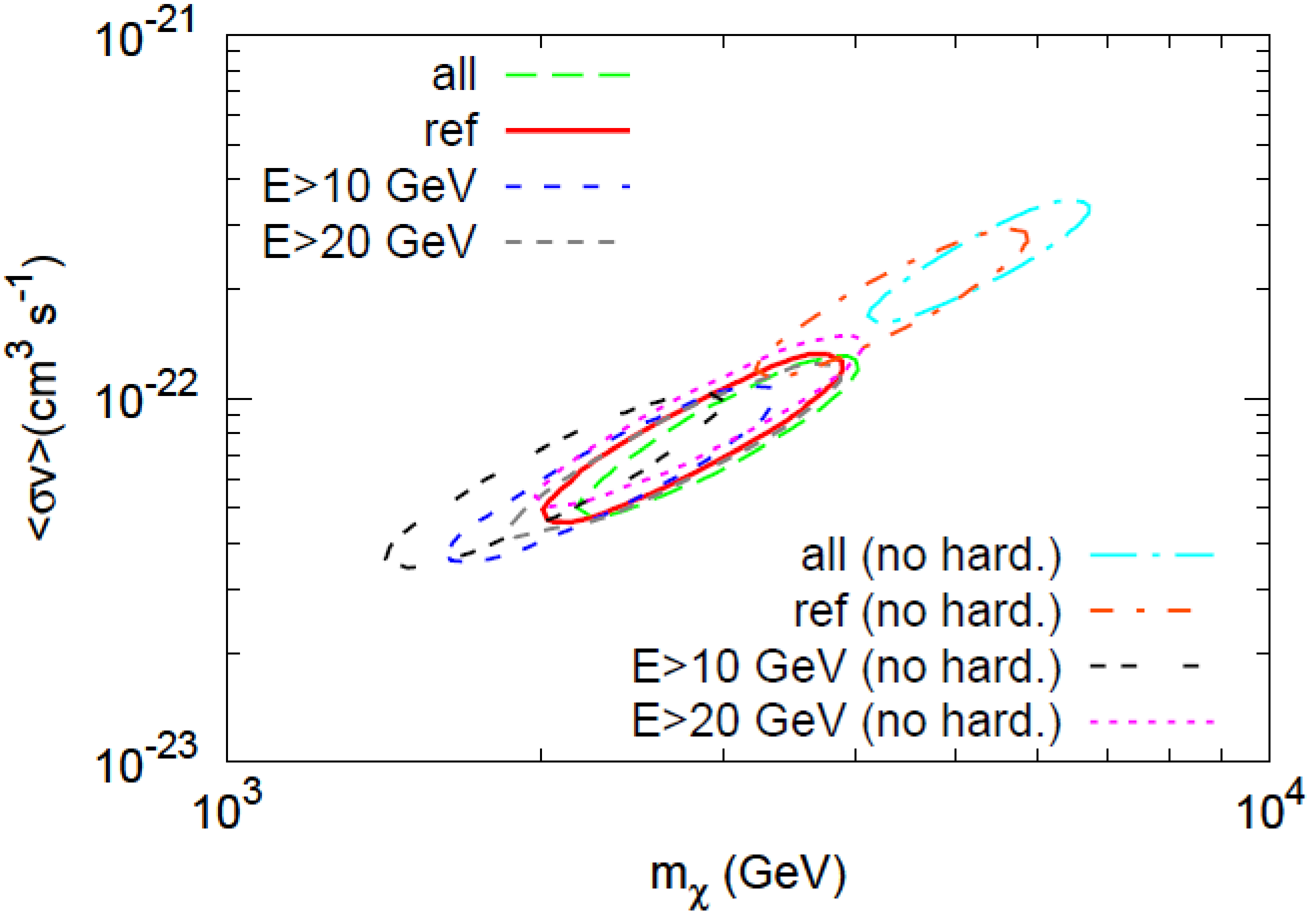
Propagation uncertainties

TABLE I: Propagation and proton injection parameters

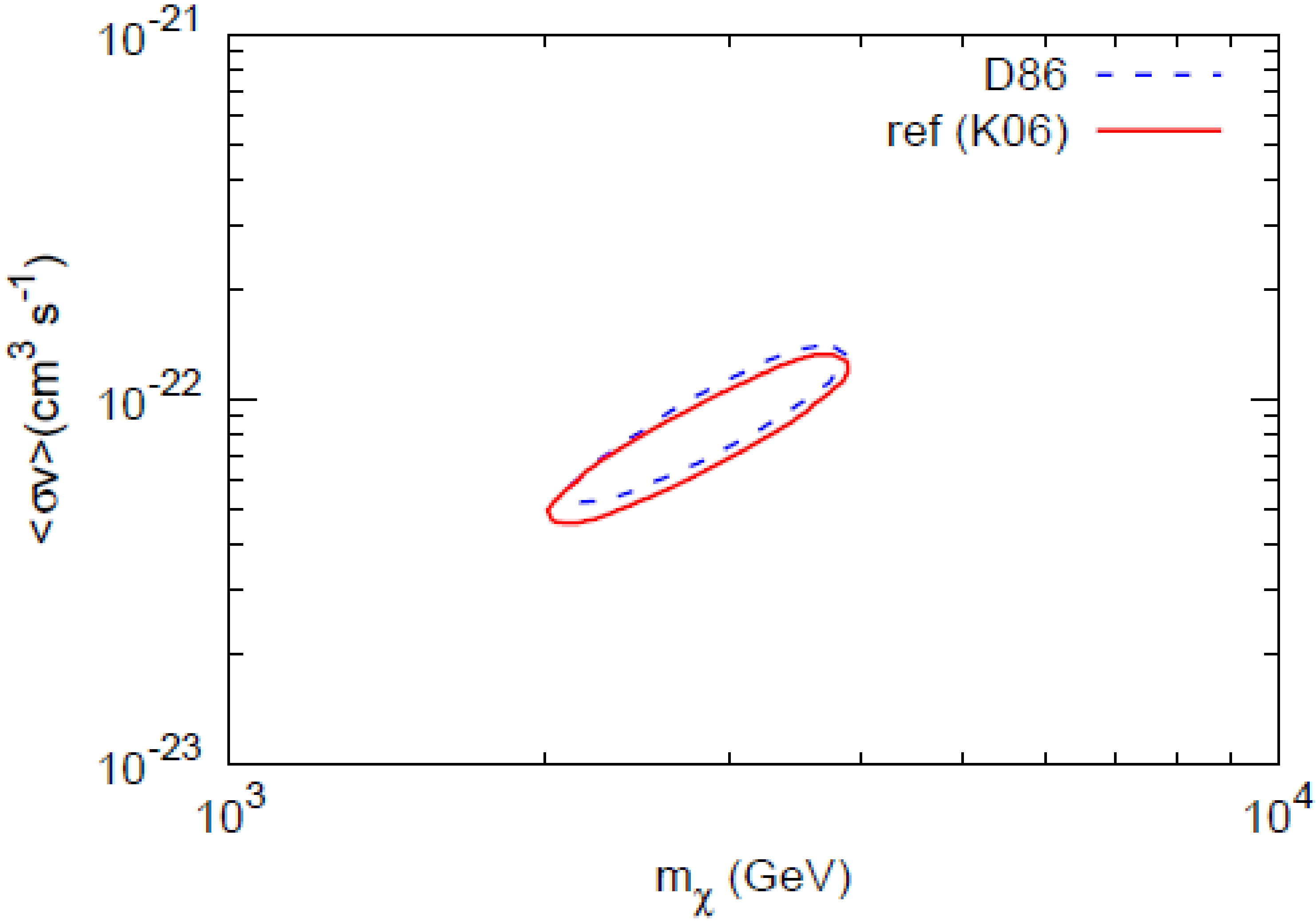
	D_0^a $(10^{28}\mathrm{cm}^2\,\mathrm{s}^{-1})$	z_h (kpc)	v_A (km s^{-1})	δ	dV_c/dz (km s^{-1} kpc^{-1})	A_p^b	γ_1	γ_2	$R_{\mathrm{br},1}$ (GV)	γ_3	Φ_p (GV)
1	2.7	2	35.0	0.33	—	4.44	1.76	2.43	15.0	2.37	0.32
2	5.3	4	33.5	0.33	—	4.49	1.79	2.44	13.2	2.37	0.34
3	7.1										0.36
4	8.3										0.36
5	9.4										0.36
6	10.0										0.33
7	2.5										0.42

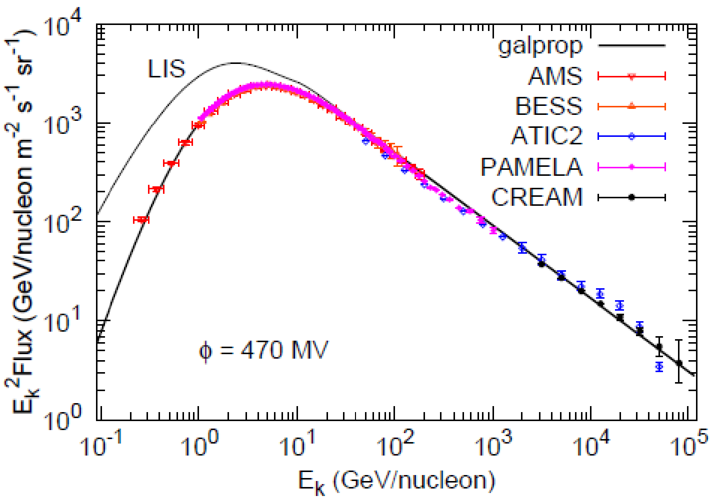


Low energy data

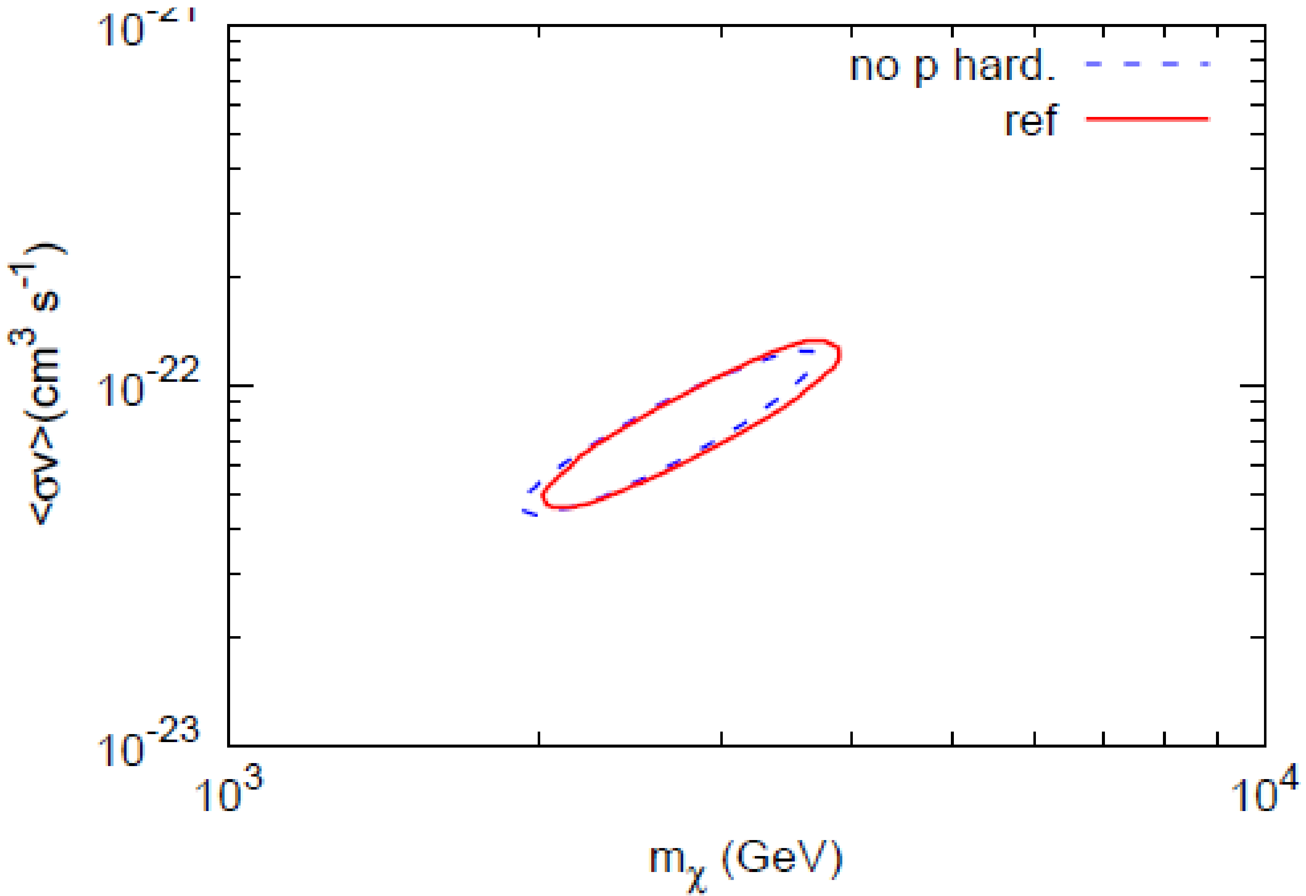


Strong interaction models




LIS
galprop
AMS
BESS
ATIC2
PAMELA
CREAM
φ = 470 MV
E_k^2Flux (GeV/nucleon m^-2 s^-1 sr^-1)
E_k (GeV/nucleon)

质子谱有（无）拐折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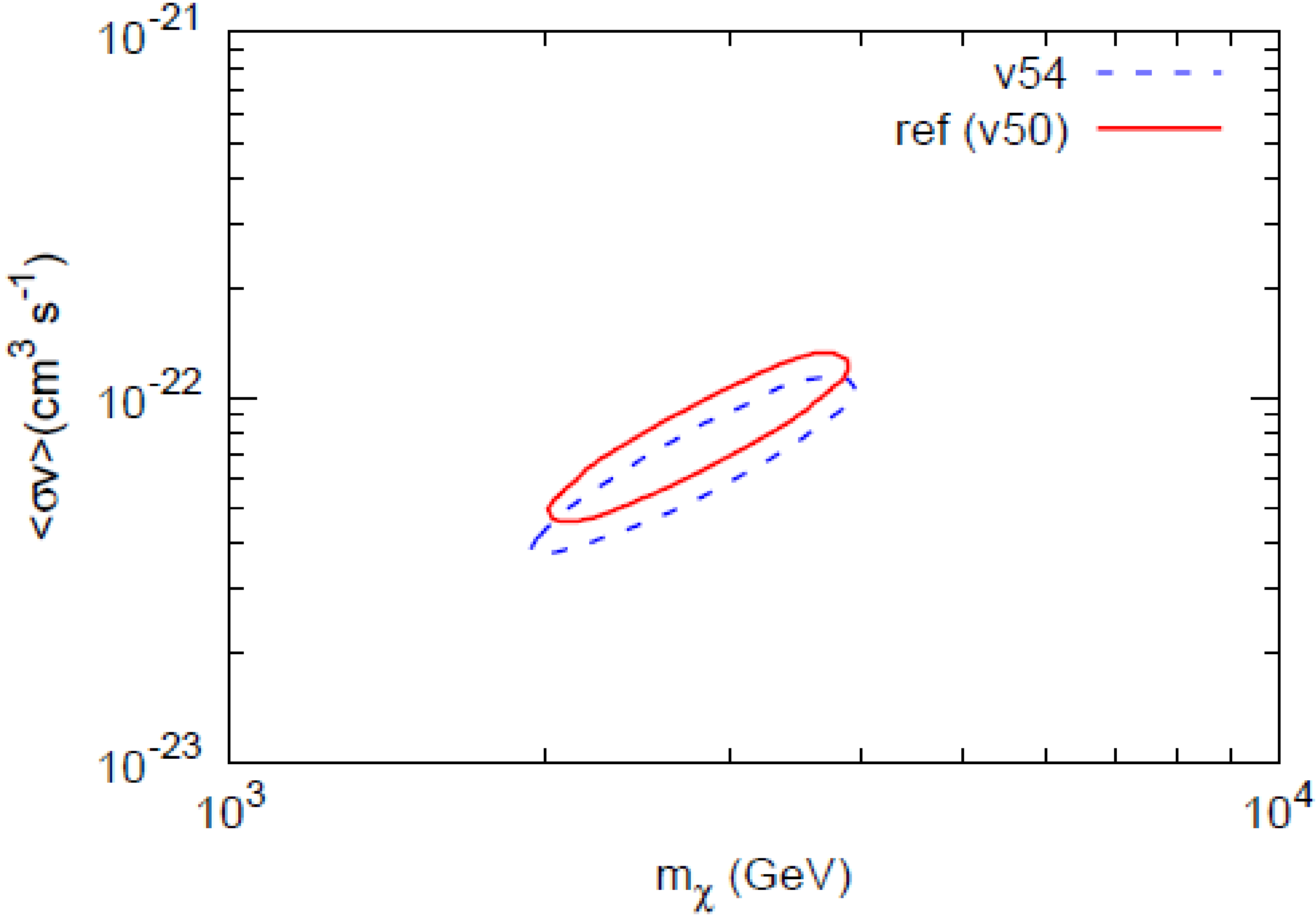
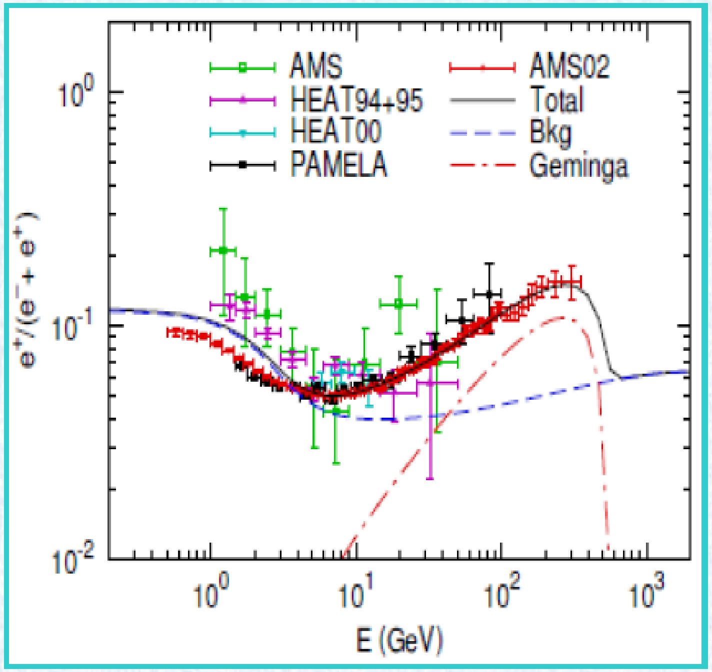
ref
<σv>(cm^3 s^-1)
m_χ (GeV)

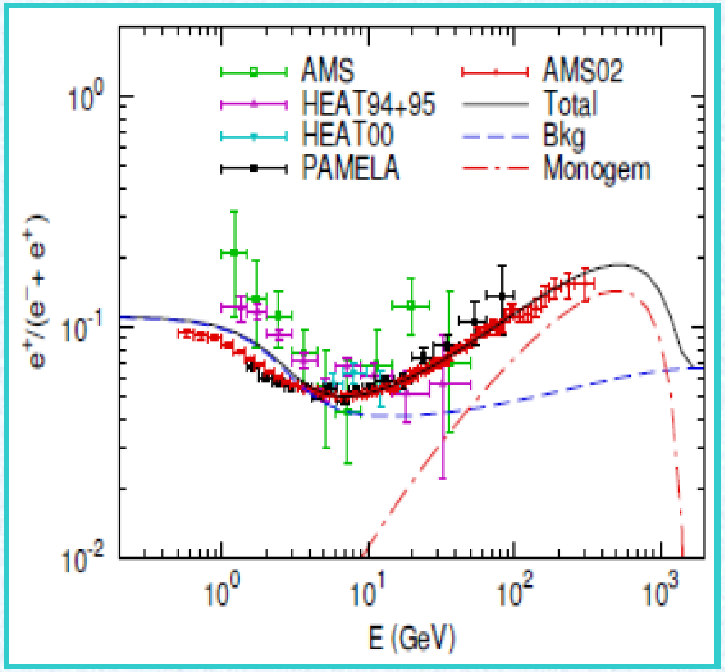
Different Galprop versions



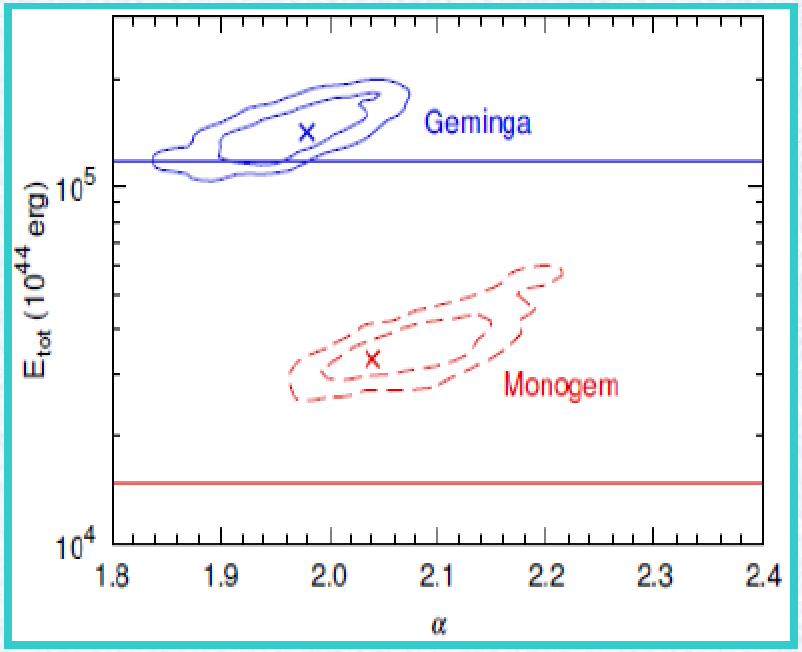
Interpret data with pulsars

Yin et al. 1304. 4128

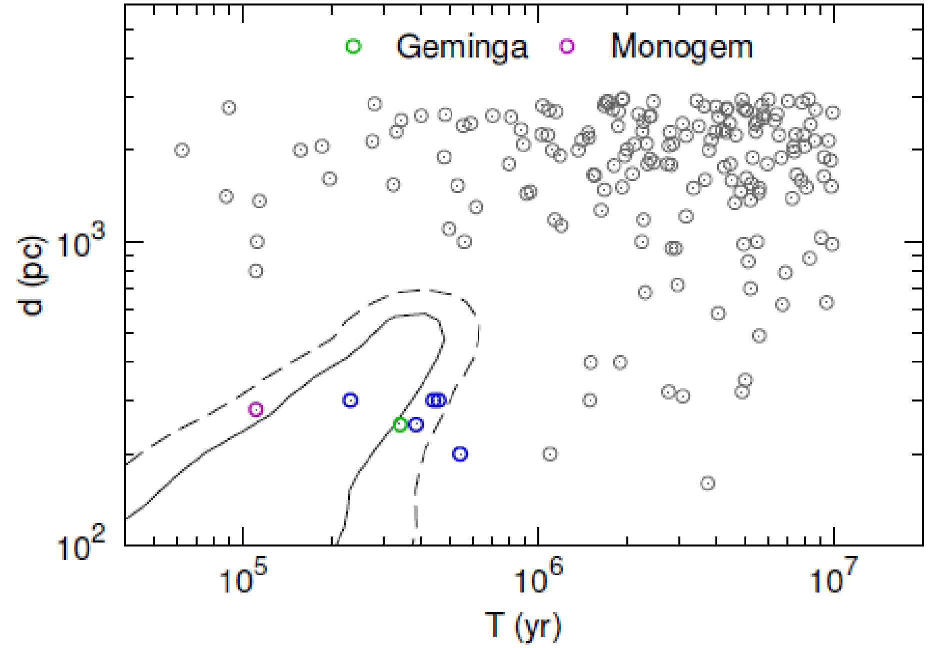


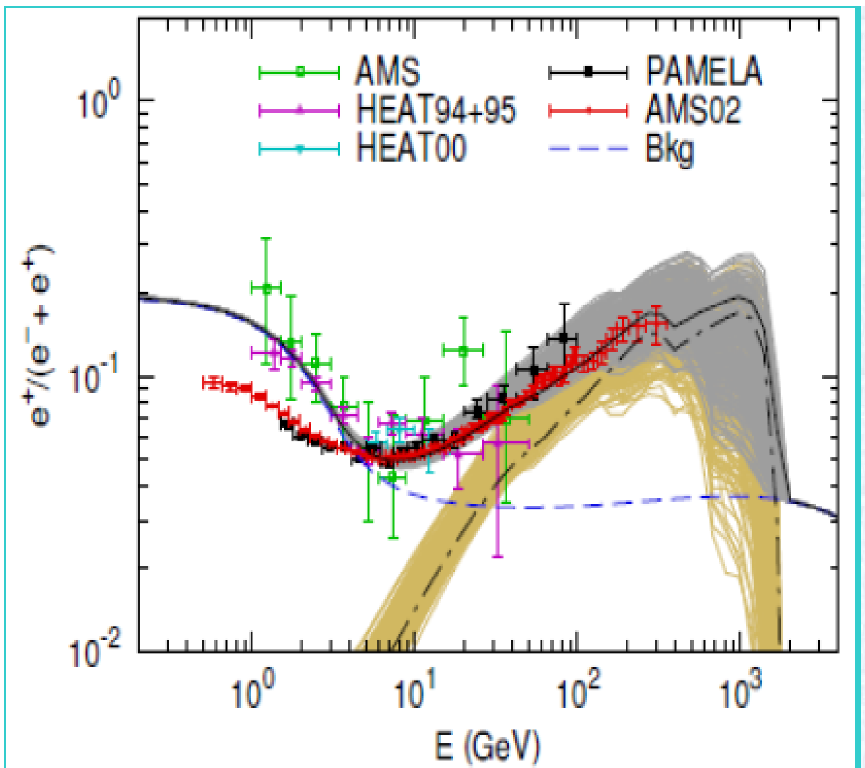


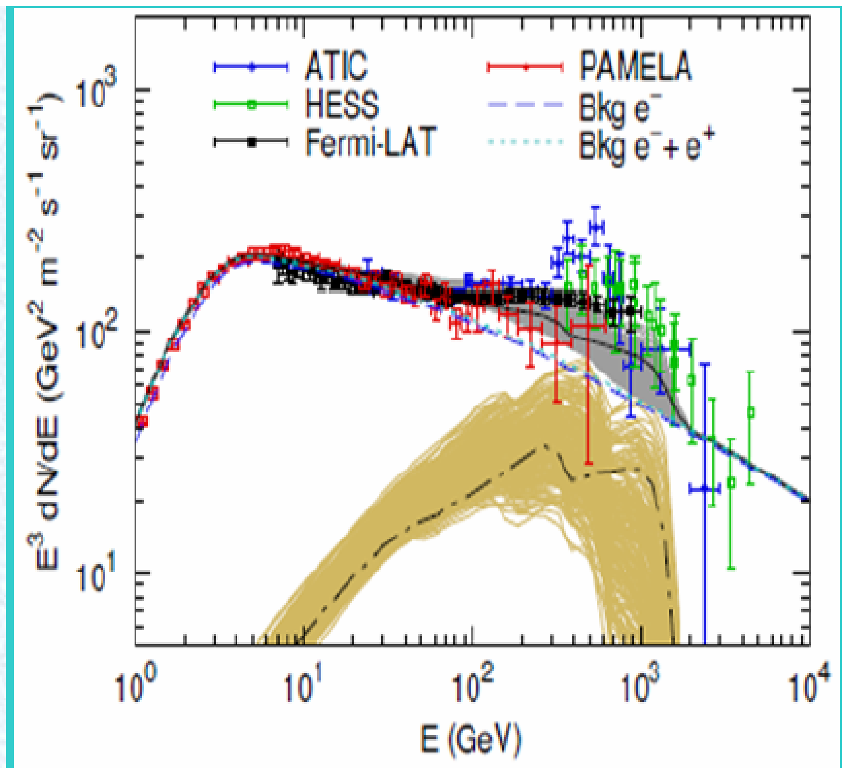
Index ~ 2, softer than before to fit PAMELA. Therefore larger total injection power.



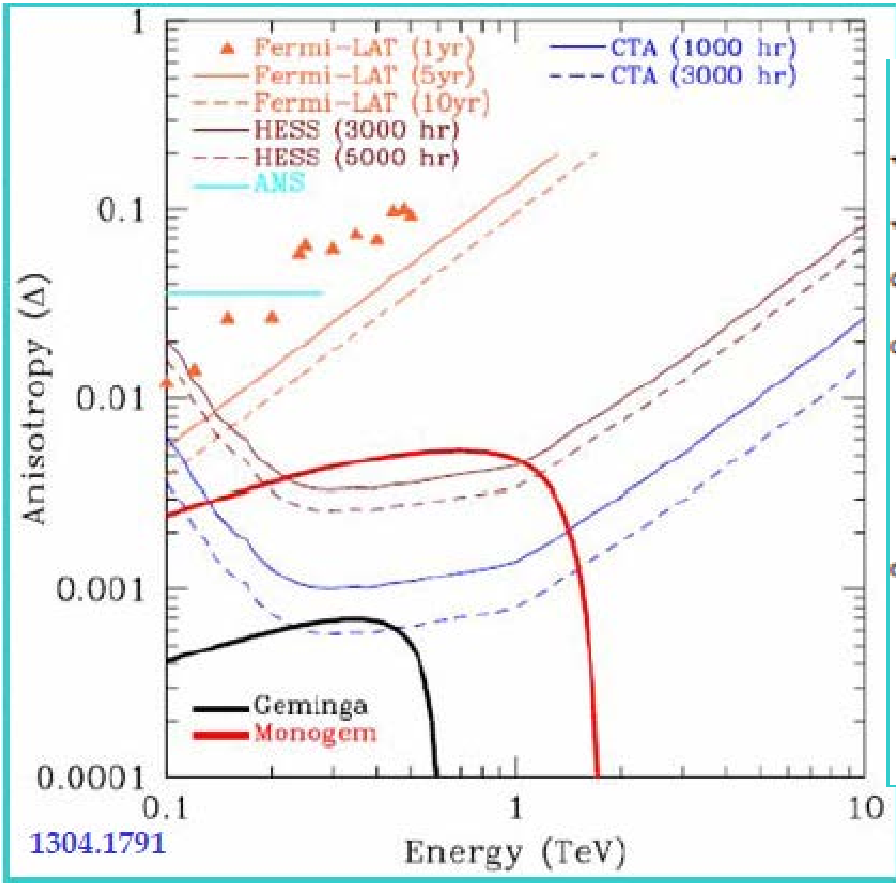
We consider contributions from nearby pulsars and add contributions from all pulsars.

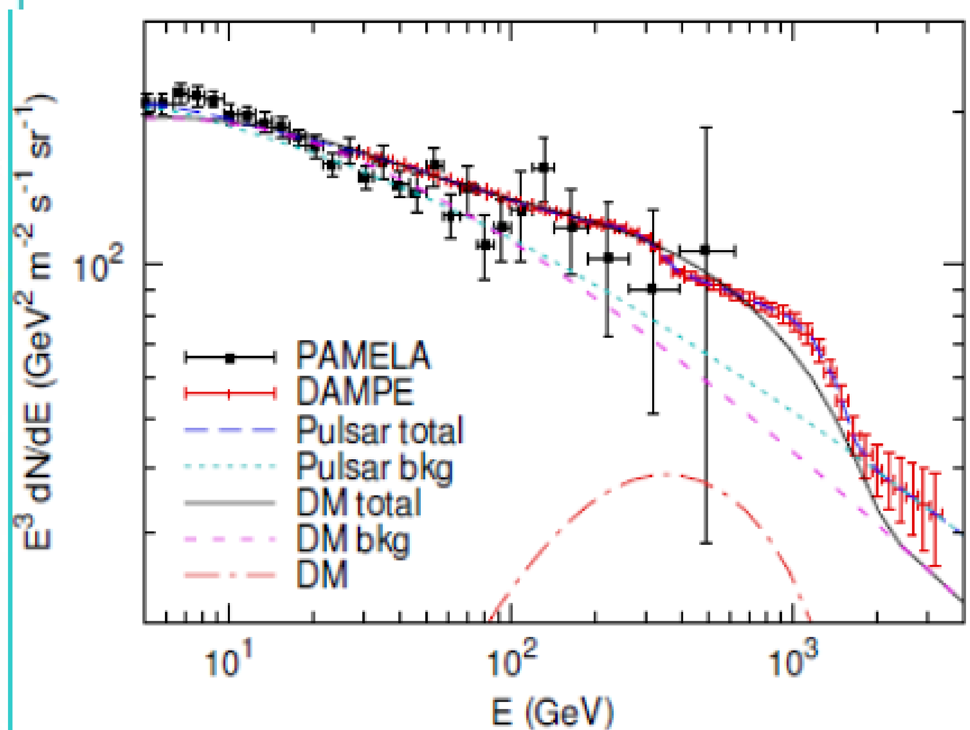






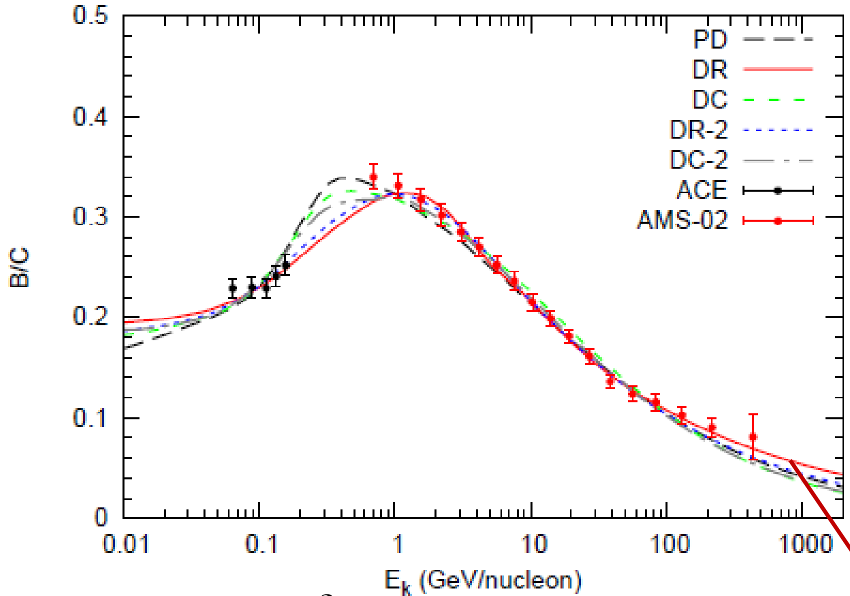
DM vs pulsar: flux anisotropy vs spectrum wiggles

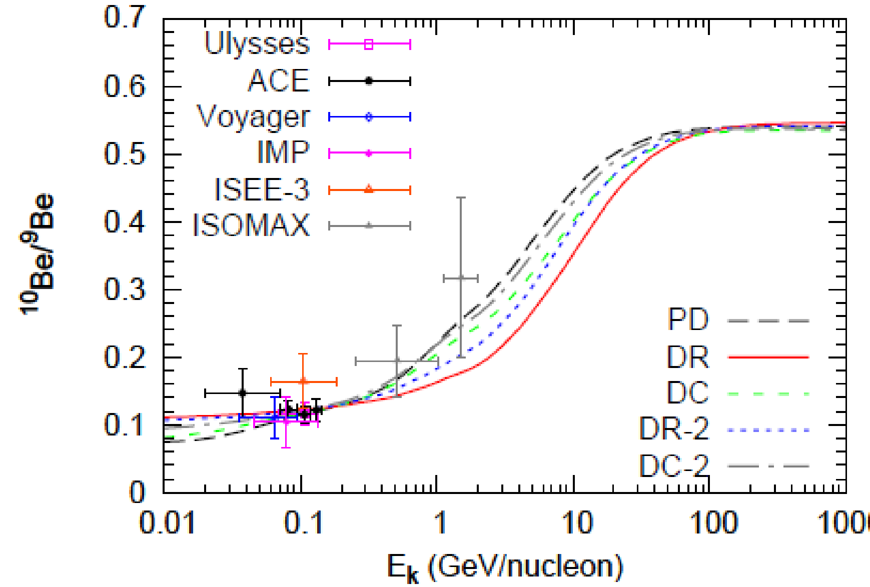




Other studies with the preliminary AMS-02 results

B/C on the CR propagation





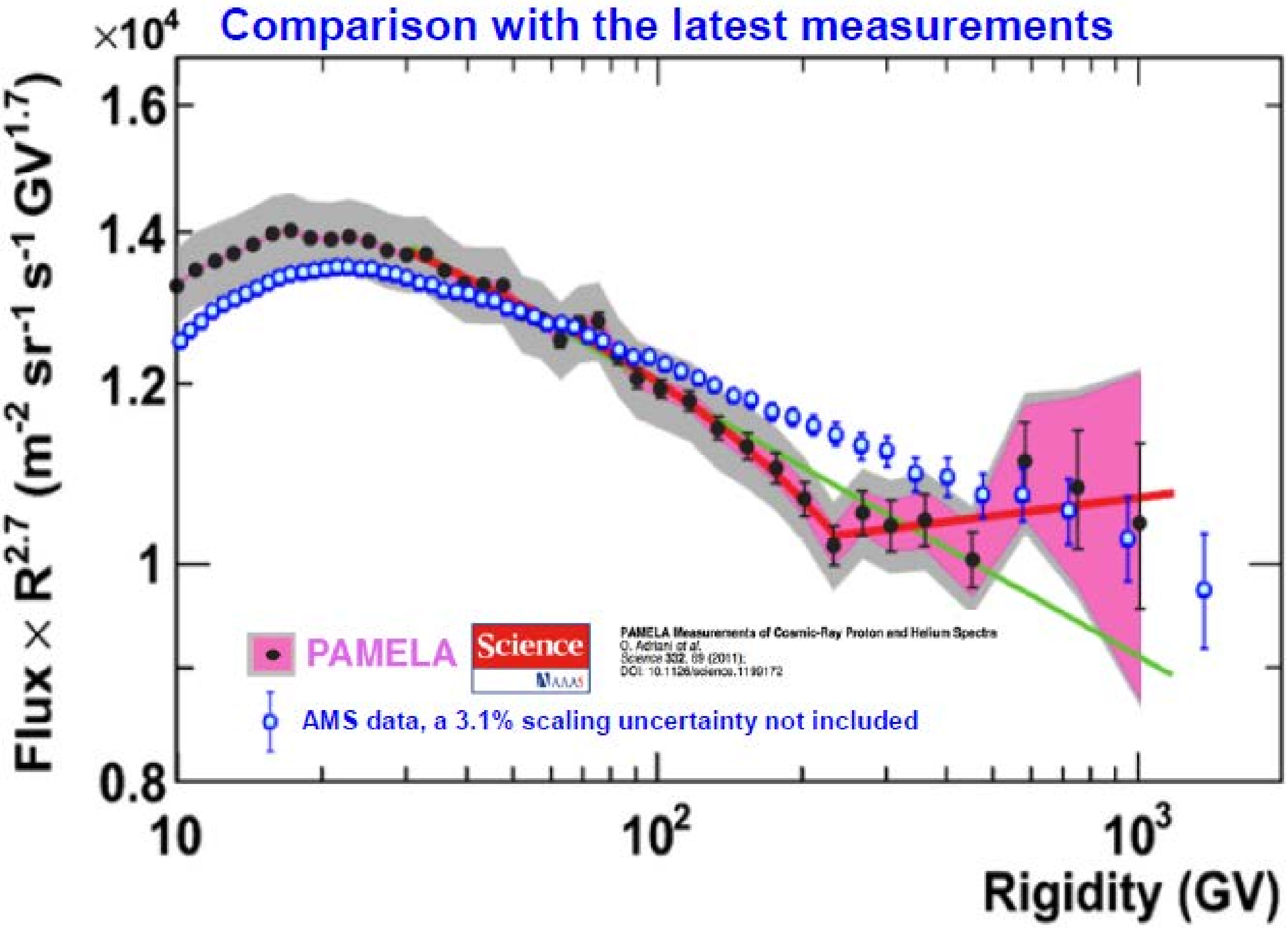
B/C at high energy is important

$$D = D_0 \left(\frac{R}{R_0} \right)^{\delta}$$

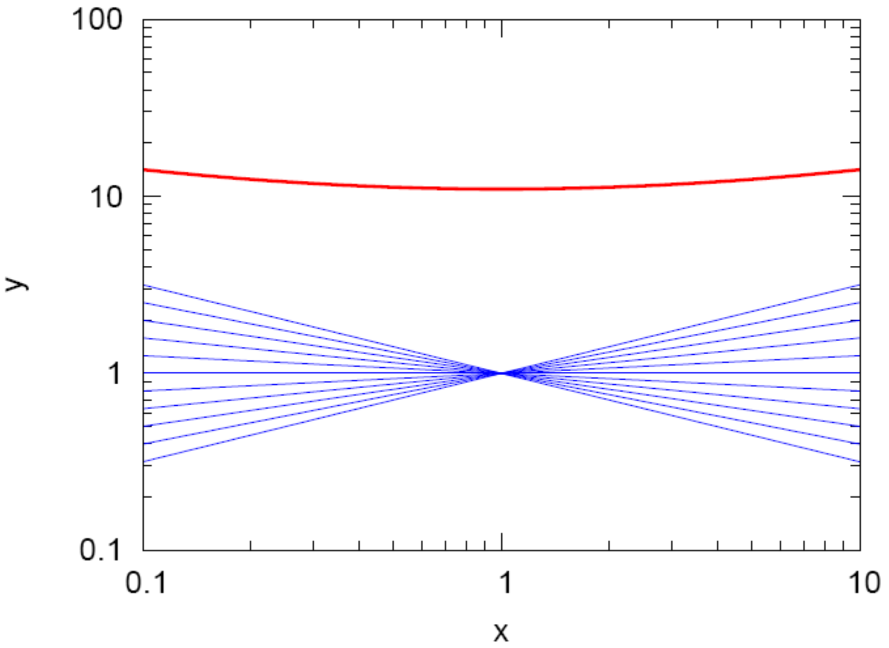
TABLE I: Fitting propagation parameters

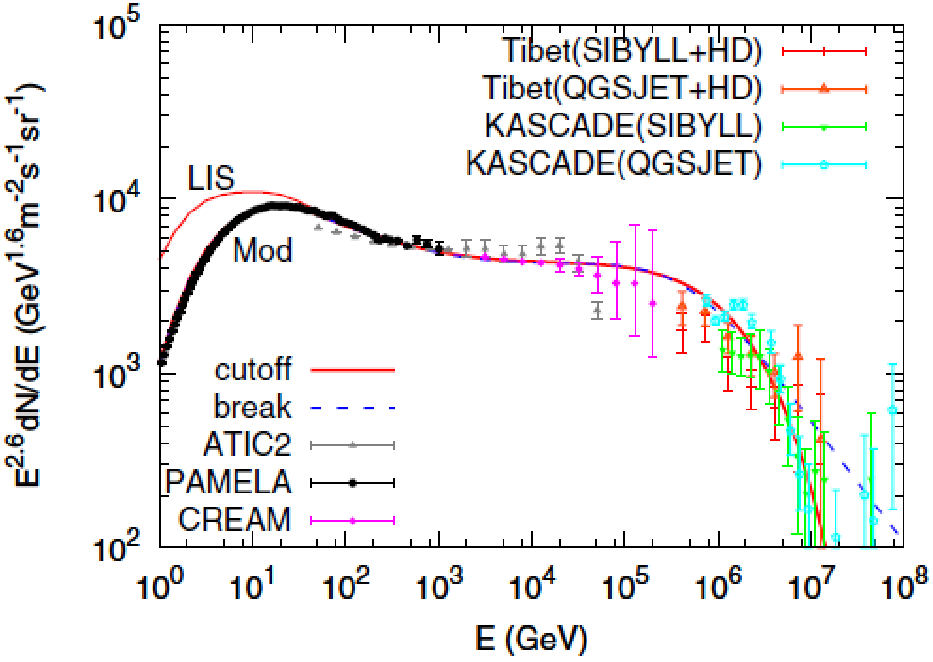
	D_0 (10^{28}cm^2 s^{-1})	δ	R_0 (GV)	η	v_A (km s^{-1})	dV_c/dz (km s^{-1} kpc^{-1})	z_h (kpc)	Φ (MV)	χ^2/dof
PD	1.62 ± 0.49	0.461 ± 0.016	4	1.0	—	—	1.9 ± 0.5	82 ± 19	51.0/29
DR	6.58 ± 1.27	0.333 ± 0.011	4	1.0	37.8 ± 2.7	—	4.7 ± 1.0	326 ± 36	14.8/28
DC	2.12 ± 0.62	0.548 ± 0.044	4	1.0	—	8.0 ± 2.5	3.8 ± 1.6	117 ± 24	49.3/28
DR-2	3.59 ± 0.88	0.423 ± 0.017	4	−0.4	22.6 ± 3.1	—	3.5 ± 0.8	334 ± 37	15.4/28
DC-2	1.95 ± 0.50	0.510 ± 0.034^a	4.71 ± 0.80	1.0	—	4.2 ± 3.2	2.5 ± 0.7	182 ± 25	33.2/27

Proton spectrum



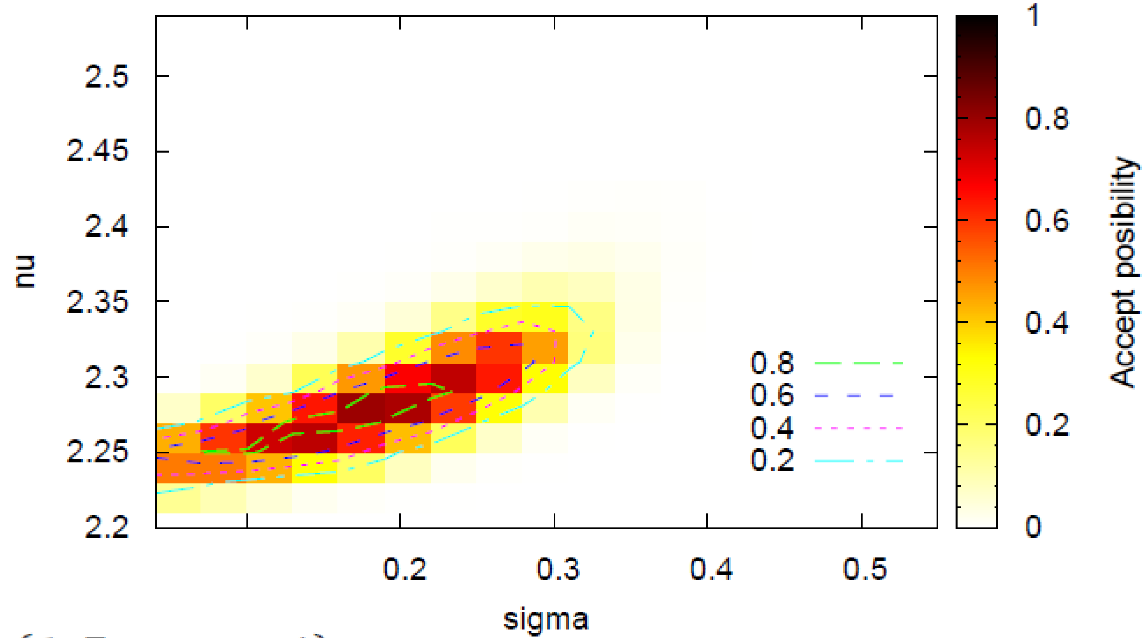
We propose a simple picture: superposition of sources with a dispersion in the source injection spectra



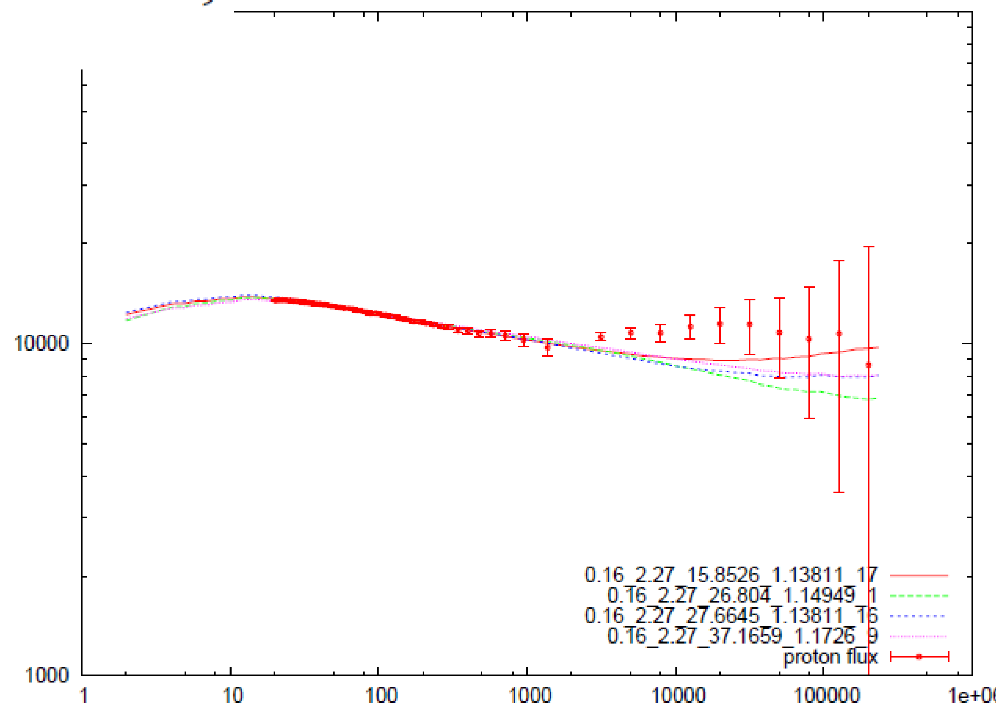


Yuan et al. (2011)

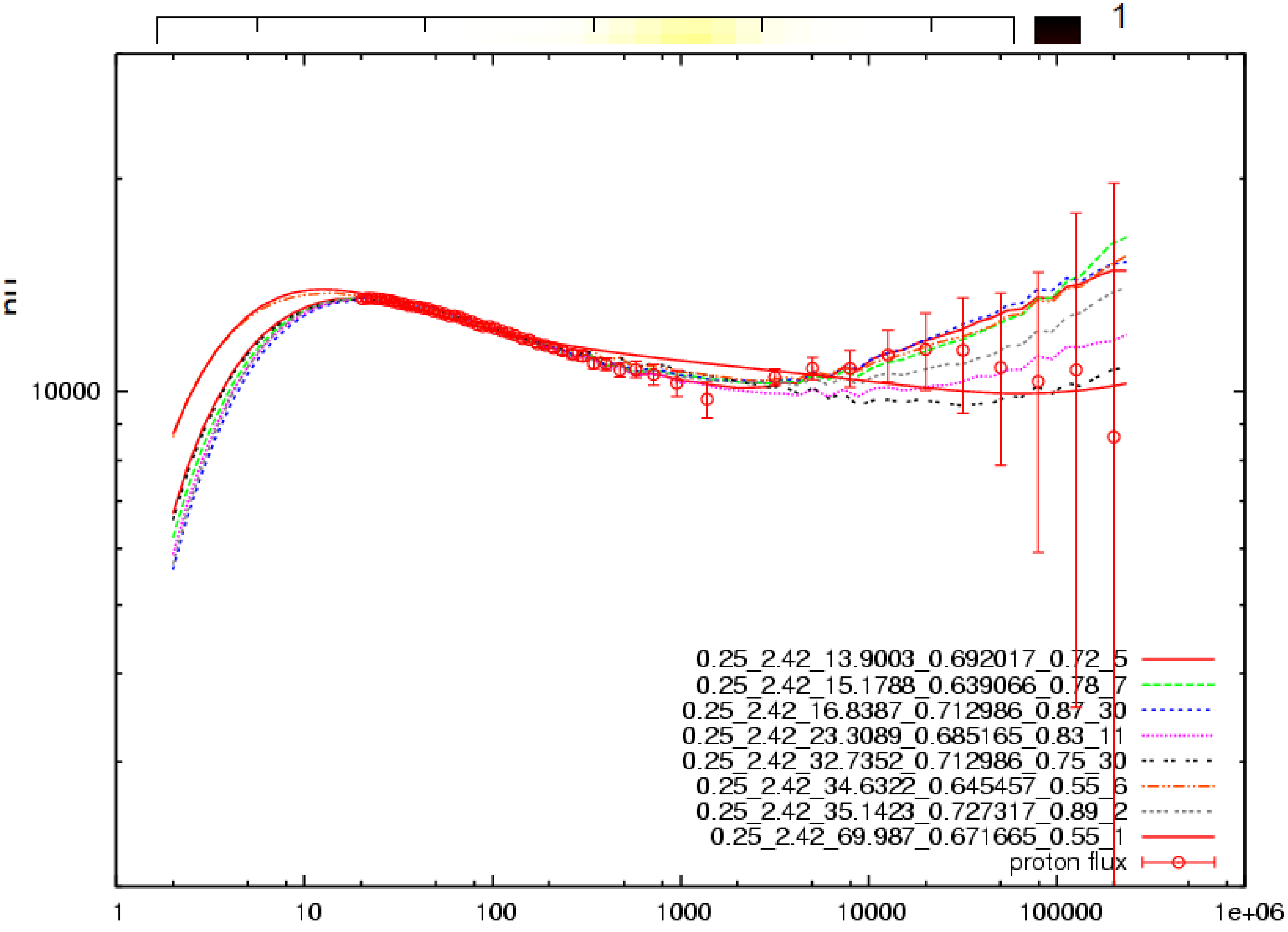
Fit the AMS02 data



$$f(\nu) = \frac{N}{\sigma_\nu * \sqrt{2\pi}} e^{-\frac{(\nu-\nu_0)^2}{2\sigma_\nu^2}} \qquad (1.5 < \nu < 4)$$



AMS02 + CREAM data



summary

- AMS-02 opens a new era of cosmic ray study. We need precise quantitative study now.

- Fermi electron spectrum shows inconsistence with AMS-02 positron ratio, by our fitting program.
- DM interpretation of AMS-02 positron ratio meets challenges from Fermi gamma observations.

- In several cases, electron spectrum (with wiggle), B/C, proton spectrum, higher energy and more precise measurement beyond the AMS-02 is required.