Dark Matter scenarios @ IceCube

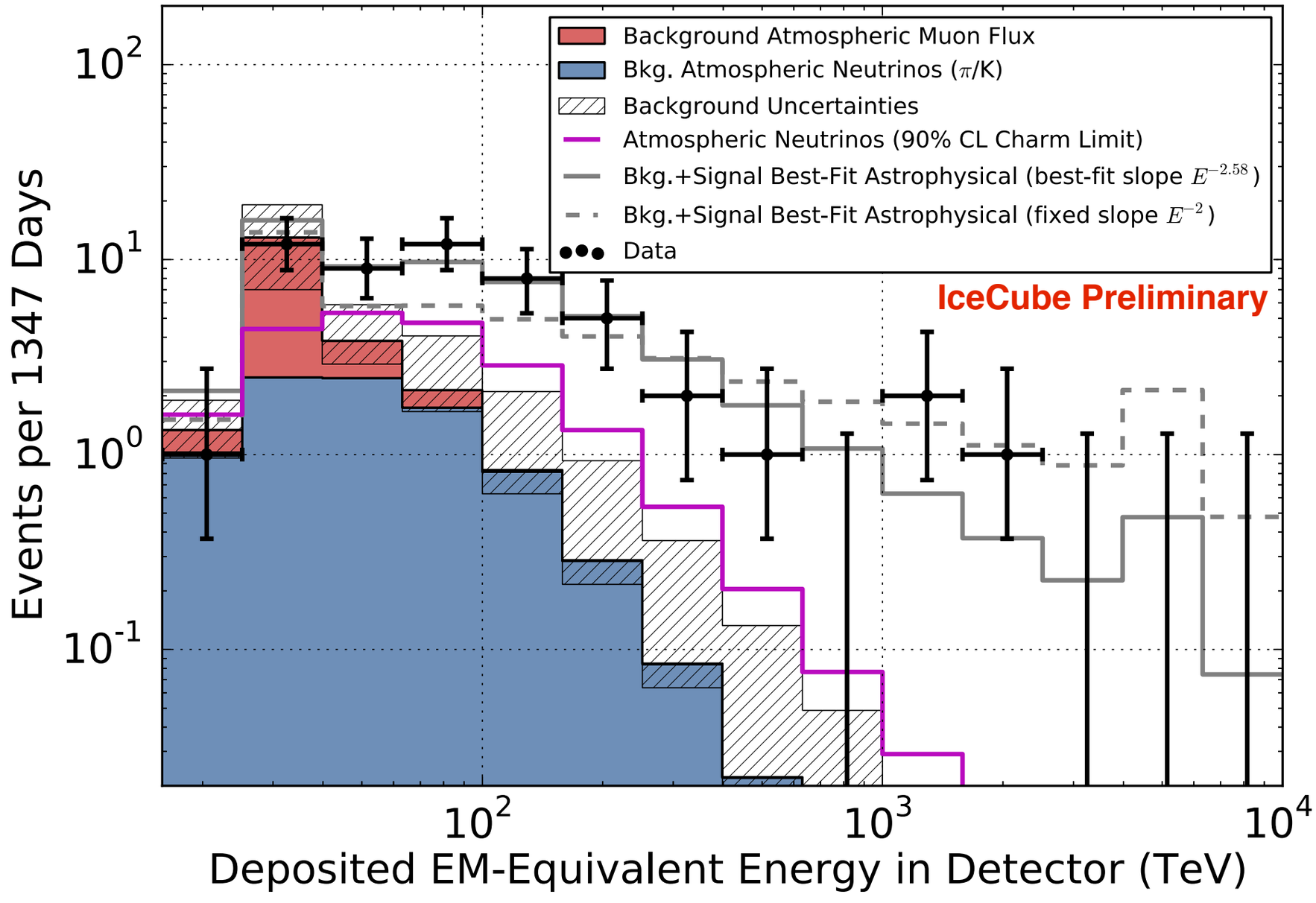
Stefano Morisi (replacing Marco Chianese)
in collaboration with Boucenna, Mangano, Miele, Pisanti, Vitagliano

Workshop on Perspectives on the Extragalactic Frontier:
from Astrophysics to Fundamental Physics

ICTP - Trieste, 2-6 May

UNIVERSITÀ DEGLI STUDI DI NAPOLI
FEDERICO II

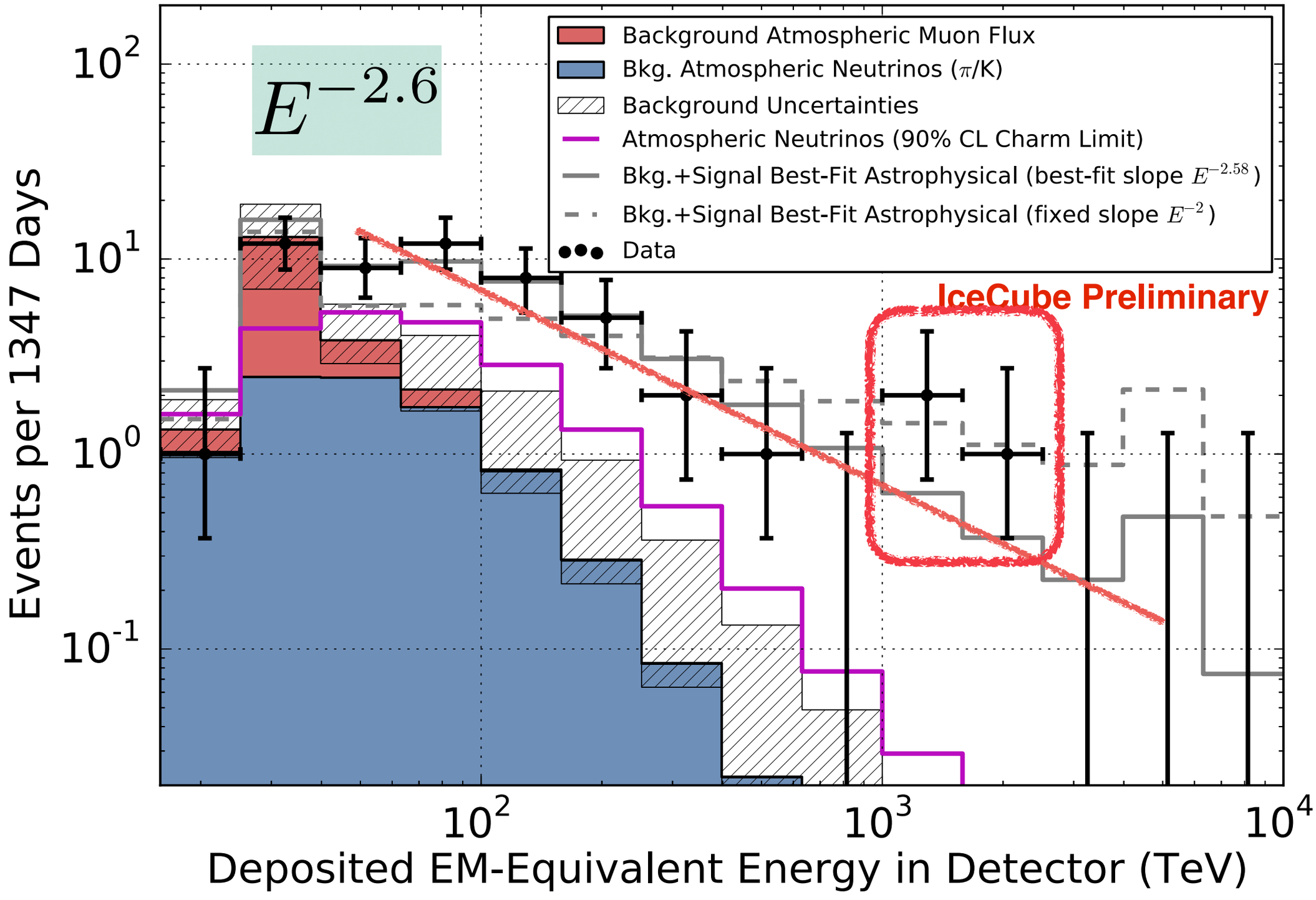
PeV *vs* 100 TeV Dark Matter @ IceCube



from Observation of Astrophysical Neutrinos in Four Years of IceCube Data
(released 21 Oct 2015) 1510.05223

see also talks of Kopper and Ahlers

PeV excess



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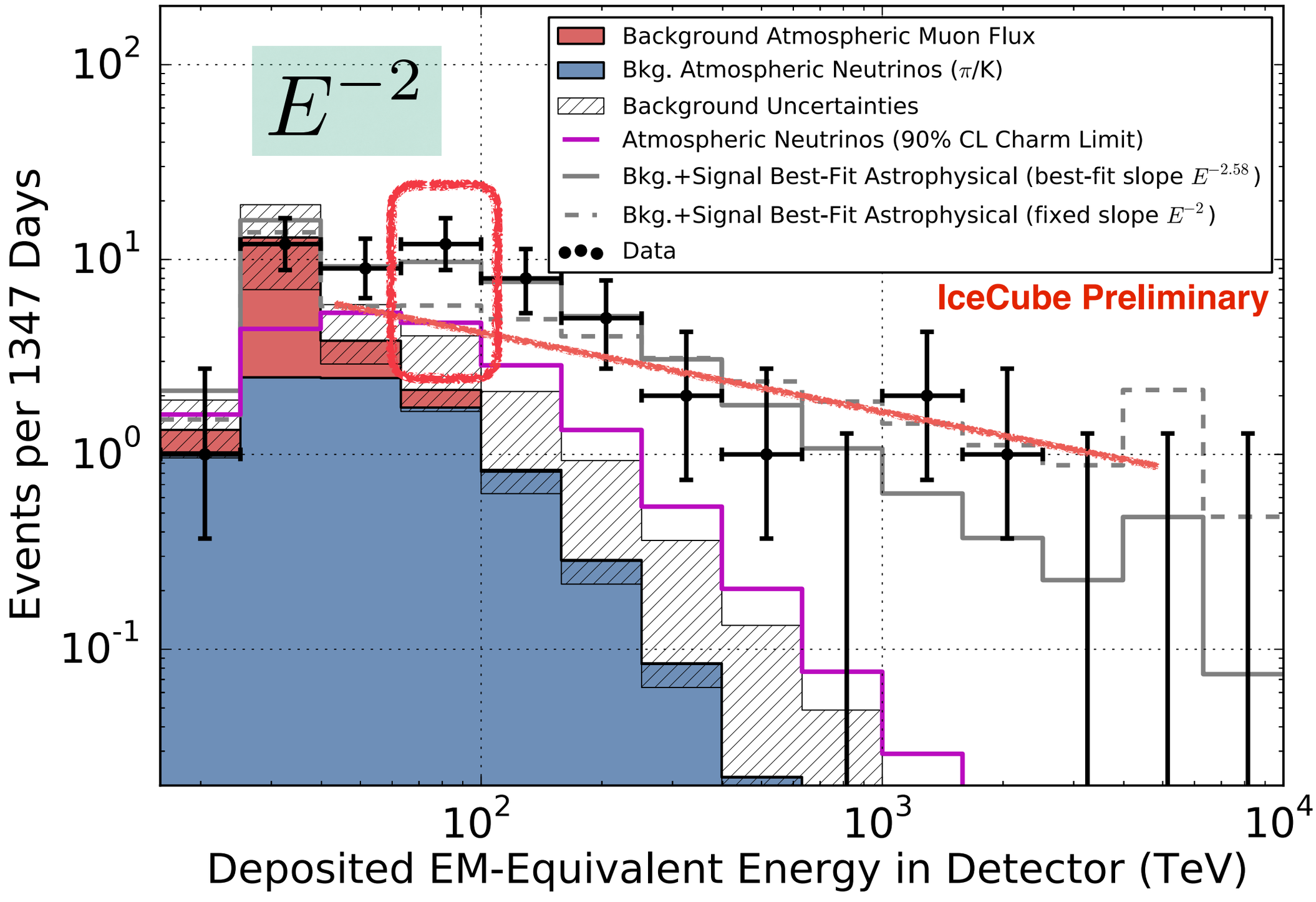
low-energy O(100) TeV excess



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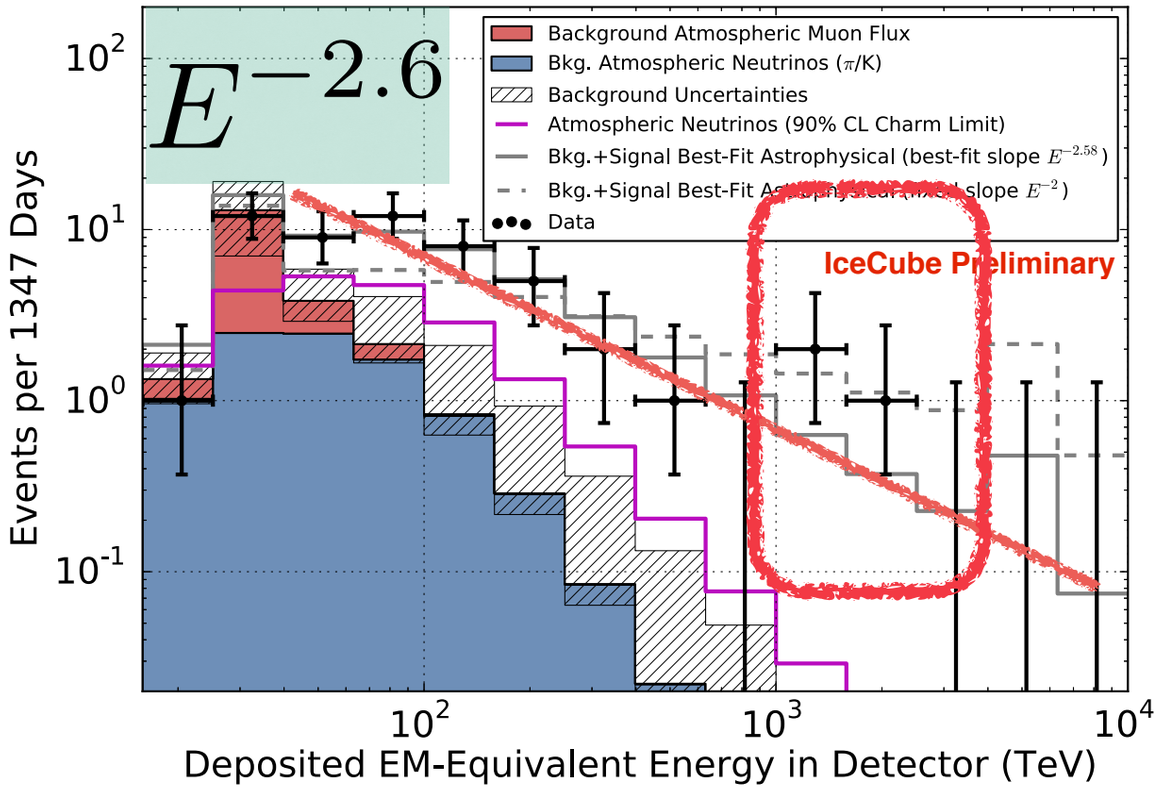
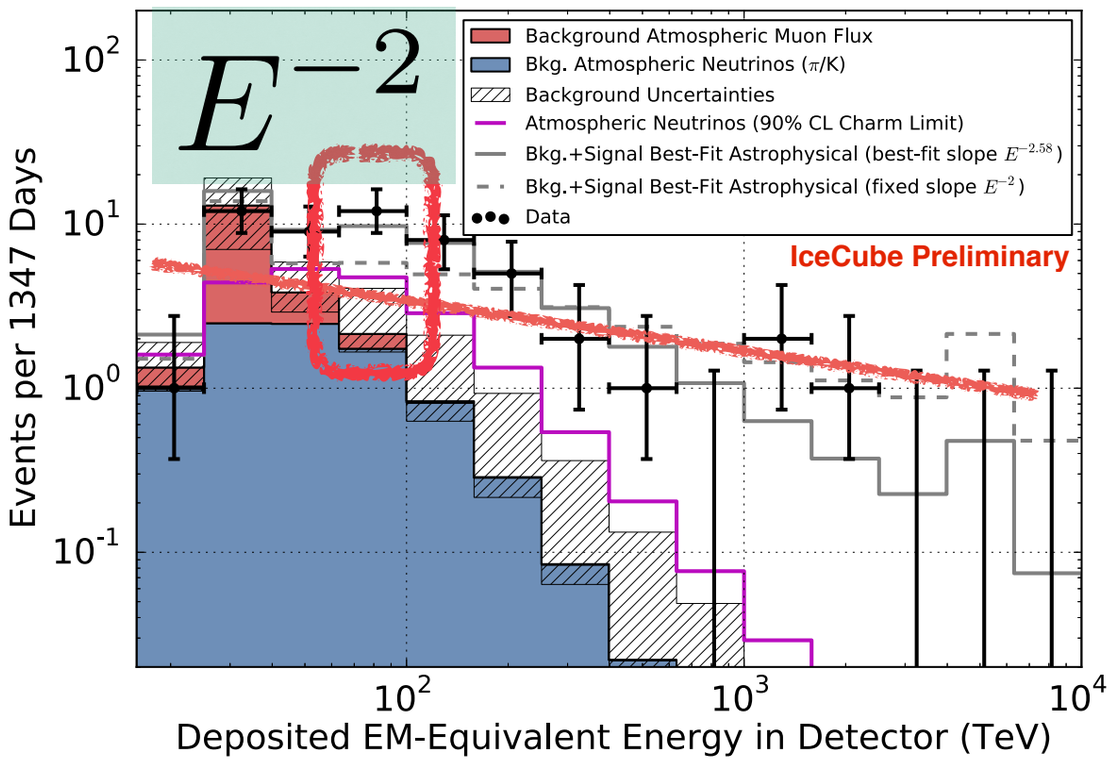
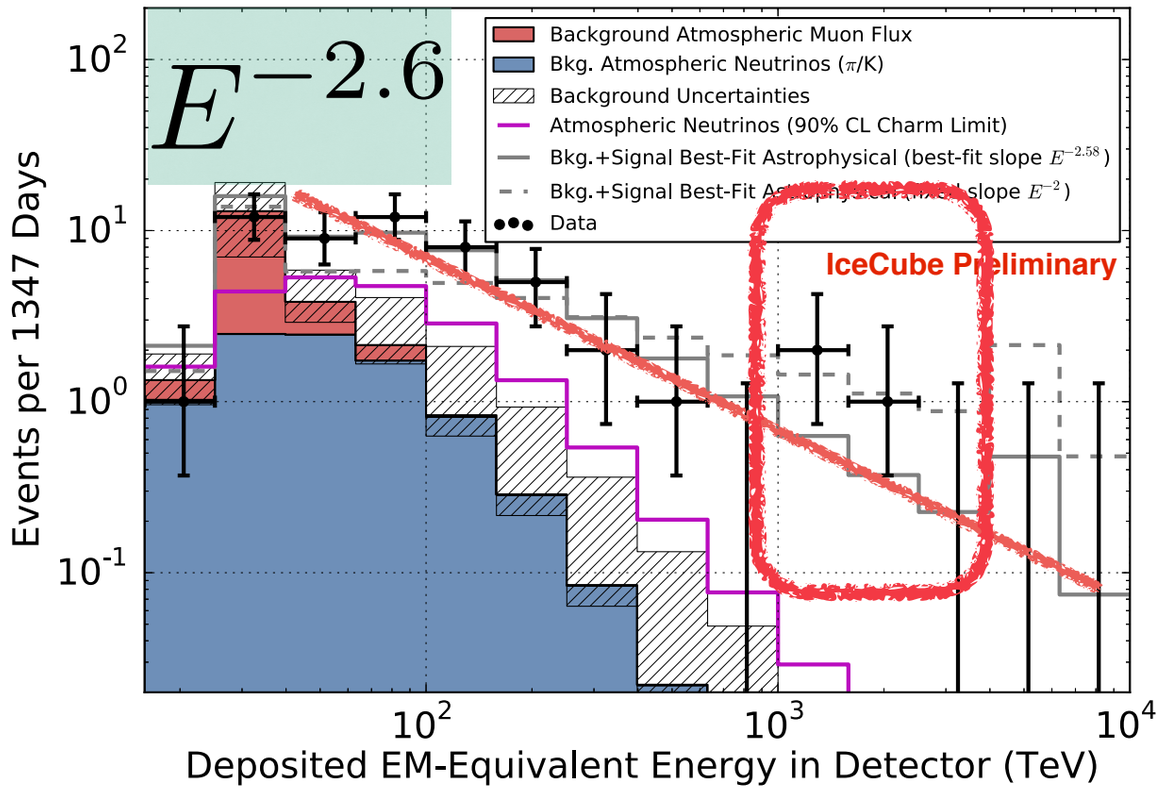


1st case
PeV excess

2nd case
O(100) TeV excess





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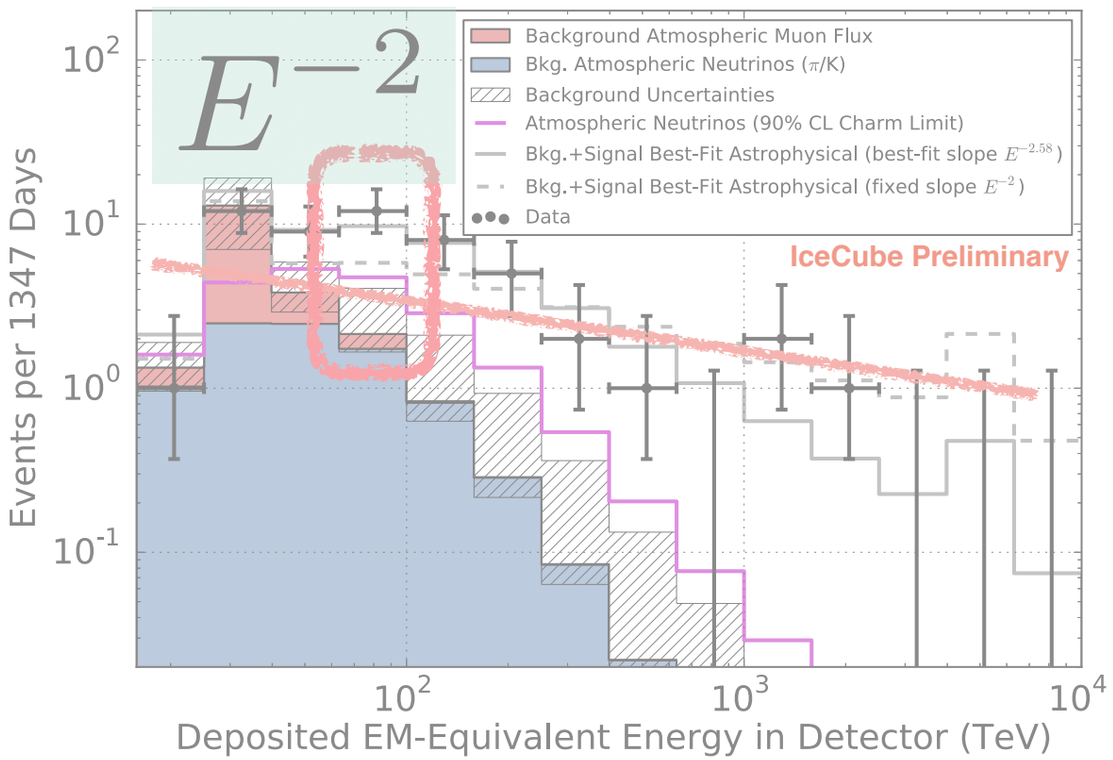
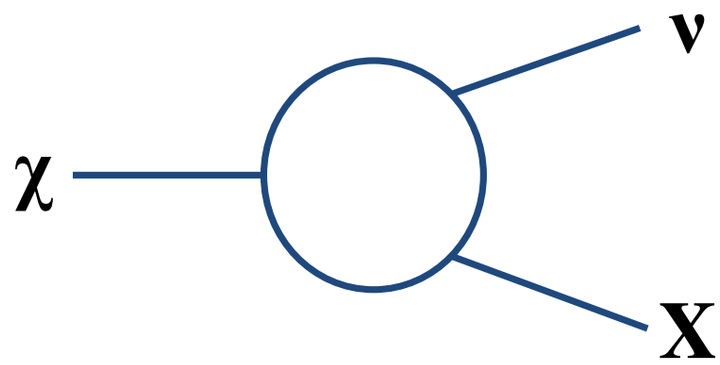


PeV decaying Dark Matter

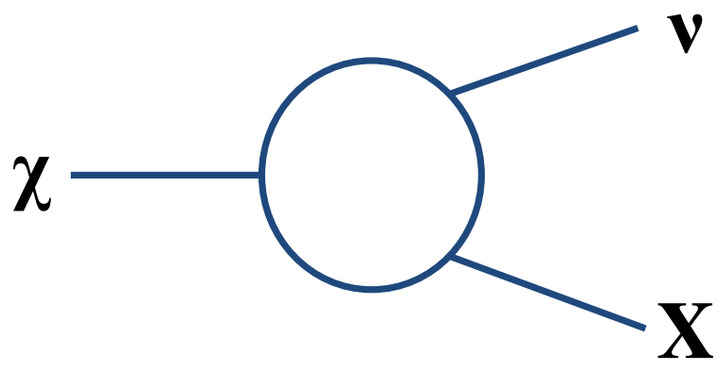


Decaying DM

Feldstein et al., PR D88 (2013)
Esmaili, Serpico, JCAP 1311
Bai et al., arXiv:1311.5864
Ema et al., PL B733 (2014)
Bhattacharya et al., JHEP 1406
Higaki et al., JHEP 1407
Ema et al., JHEP 1410
Rott et al., PR D92 (2015)
Esmaili et al., JCAP 1412
Fong et al., JHEP 1502
Dudas et al., PR D91 (2015)
Murase et al., PRL 115 (2015)
Ko, Tang, PL B751 (2015)
Aisati et al., arXiv:1510.05008

annihilating DM negligible
unless
enhancing DM density or boosted DM

PeV decaying Dark Matter



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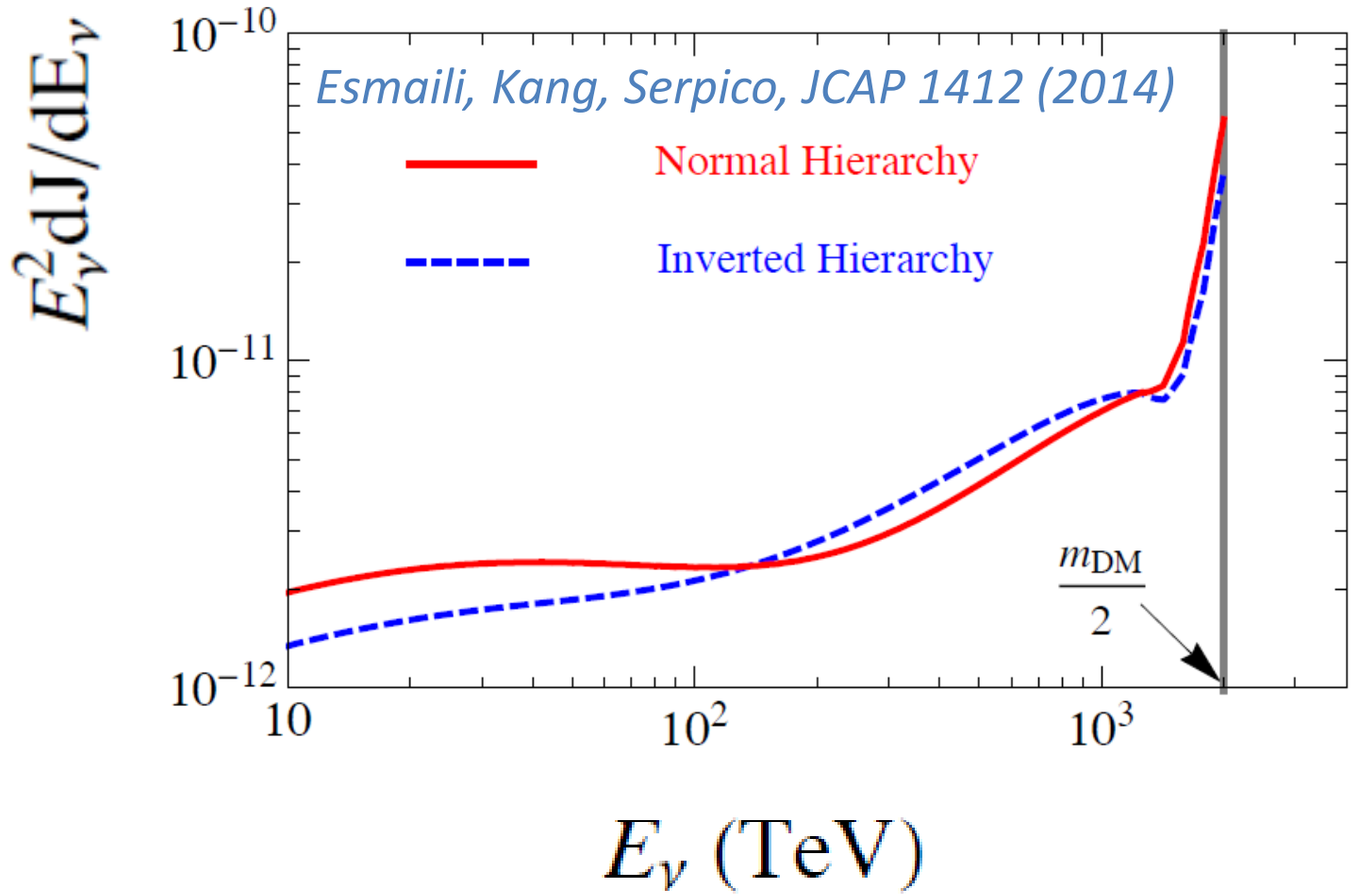
2-bodies decay

3-bodies decay

PeV decaying Dark Matter

2-bodies decay

see Esmaili talk



sharp pick! (in contrast with data)

BUT secondary neutrinos

produced by quarks allow to fit data

PeV decaying Dark Matter

3-bodies decay

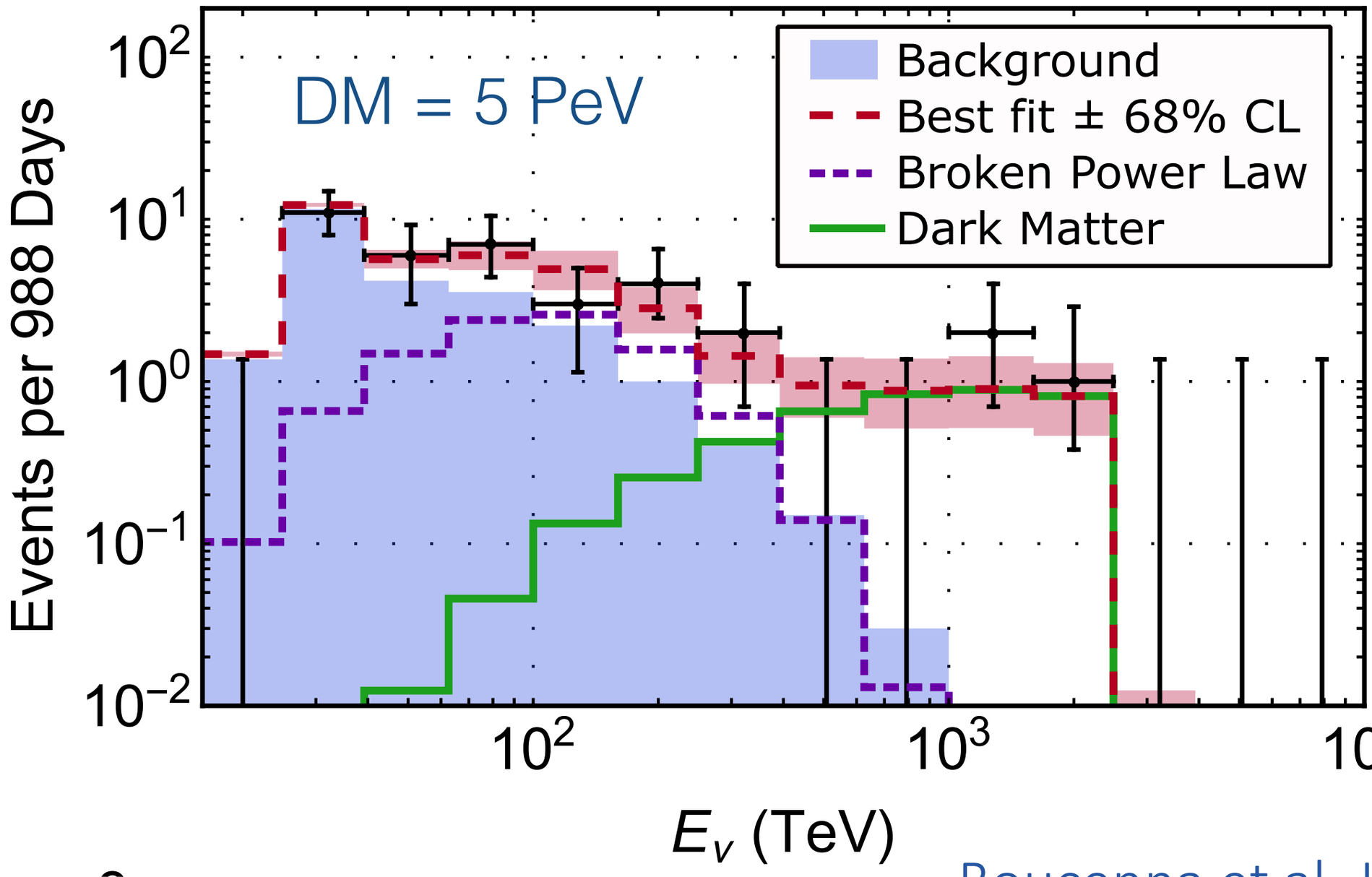
$$\chi \, \overline{L} \, \overline{L} \, e_R$$

leptophillic

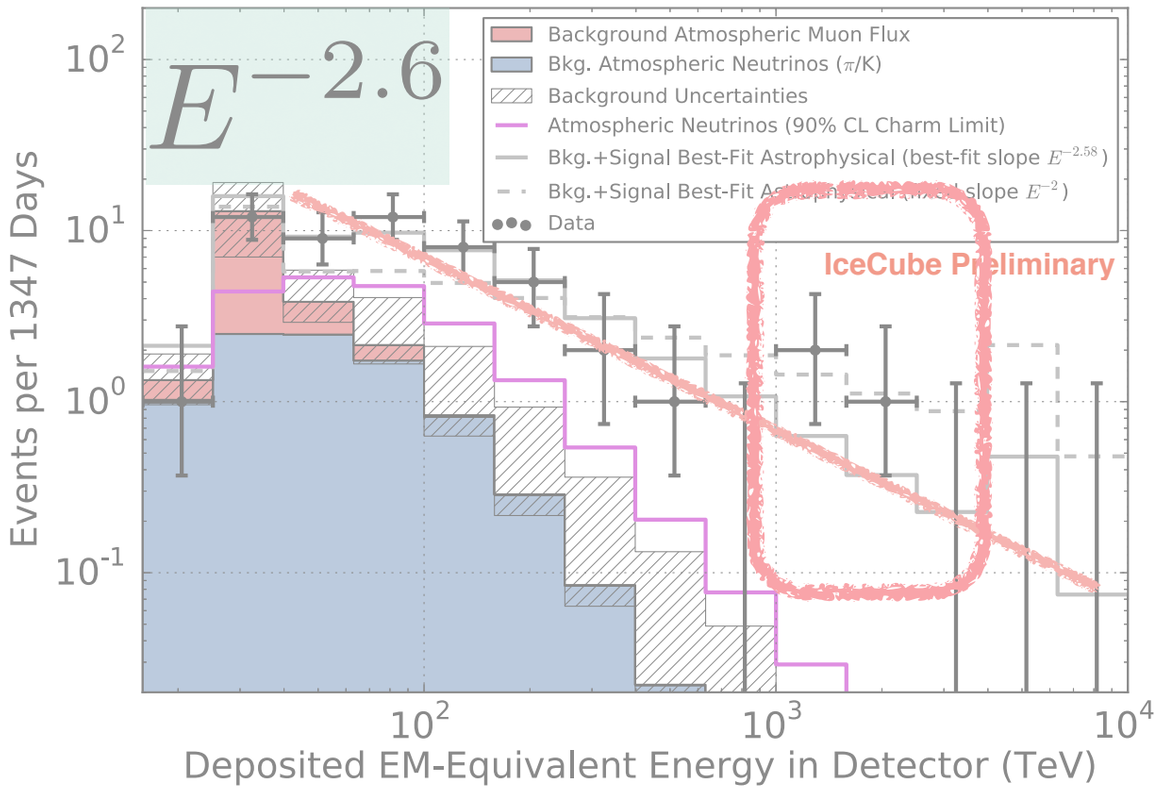
Boucenna et al, JCAP 1502

PeV decaying Dark Matter

3-bodies decay (leptophillic)

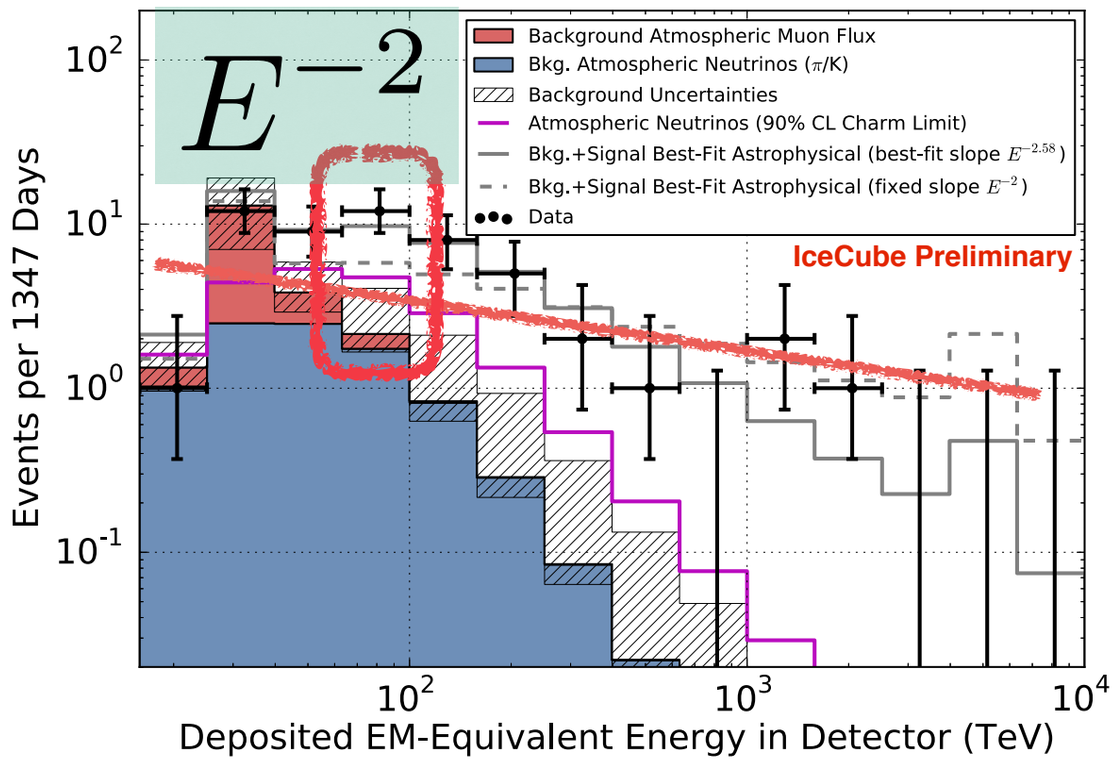


Boucenna et al, JCAP 1502

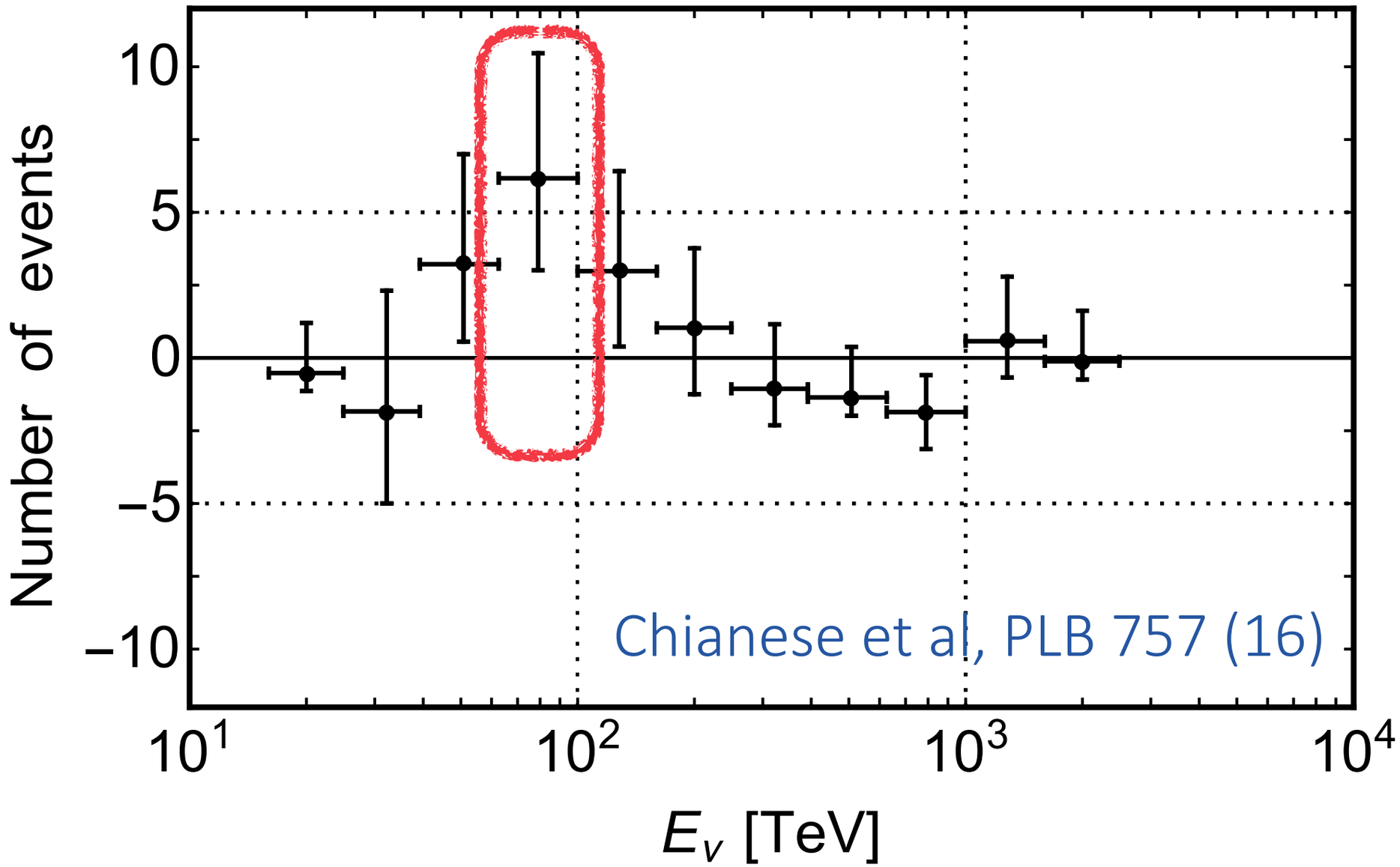


1st case
PeV excess

2nd case
O(100) TeV excess



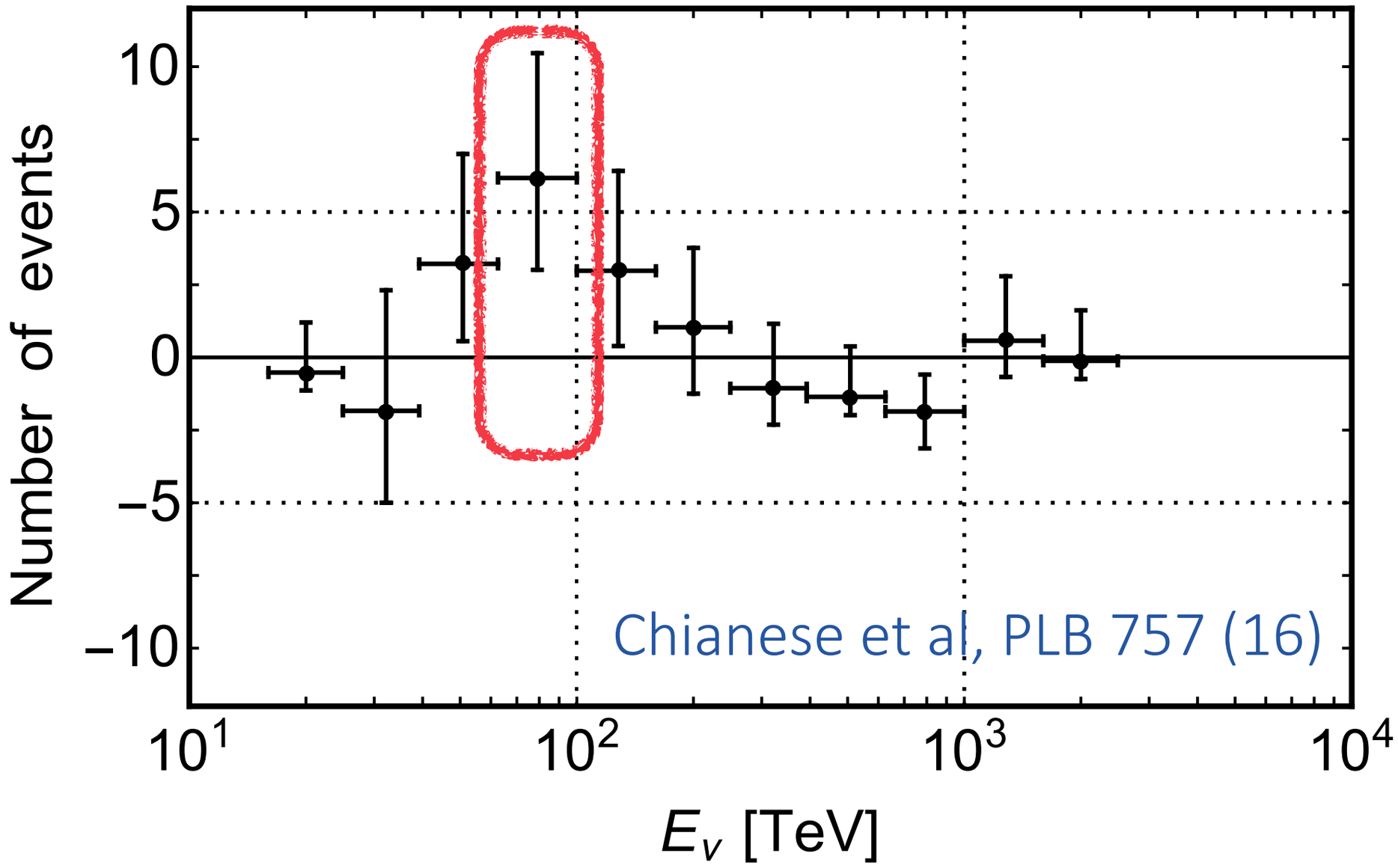
low-energy O(100) TeV excess



about 2-sigma excess with respect the sum of:

- background (atmospheric neutrino and muons)
- astrophysical component with **spectral index -2**

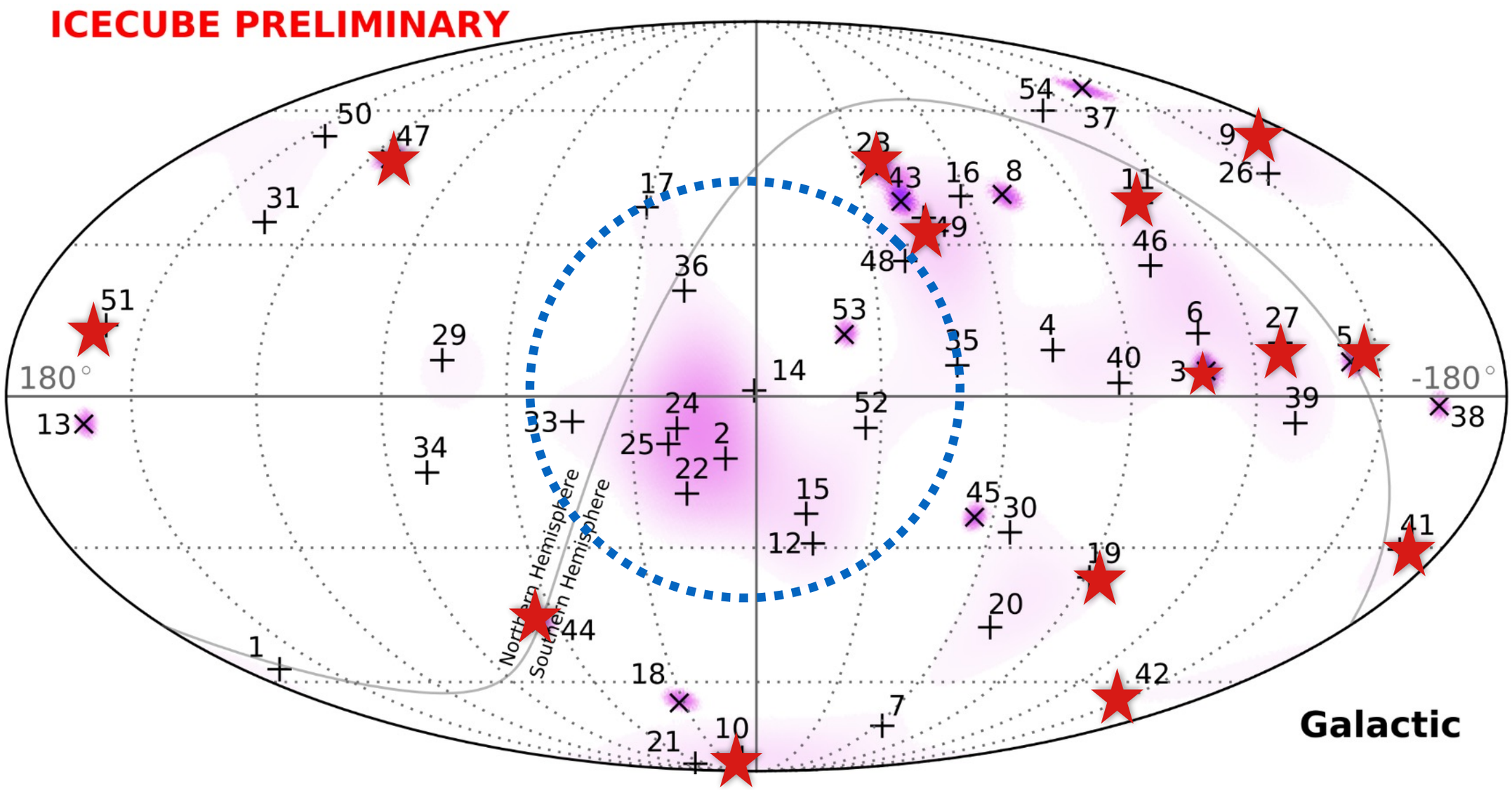
low-energy O(100) TeV excess



- we focus on the events in the energy range 60-100 TeV

- we analyze the angular distribution of these events

Where are the events in the energy range 60-100 TeV?



Statistical tests

Scenario		KS	AD
Astrophysics	Gal. plane		
	Iso. dist.		
DM decay	NFW		
	Isoth.		
DM annih. $\Delta_0^2 = 10^4$	NFW		
	Isoth.		
DM annih. $\Delta_0^2 = 10^6$	NFW		
	Isoth.		
DM annih. $\Delta_0^2 = 10^8$	NFW		
	Isoth.		

We perform two *one-dimensional* statistical tests:

- Kolmogorov Smirnov (KS)
- Anderson Darling (AD)

Astrophysical & DM scenarios

Scenario		KS	AD
Astrophysics	Gal. plane		
	Iso. dist.		
DM decay	NFW		
	Isoth.		
DM annih. $\Delta_0^2 = 10^4$	NFW		
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	Isoth.		

galactic source: galactic plane

extra-galactic source:
isotropic distribution

Astrophysical & DM scenarios

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	Isoth.		

decaying DM

annihilating DM

Δ_0^2 clumpiness factor (range 10^4 to 10^8)

$$p^{\mathrm{ann}}(\cos\theta) \propto \int_0^\infty \rho_h^2[r(s,\cos\theta)]\mathrm{d}s + (\Omega_{\mathrm{DM}}\rho_c)^2\,\Delta_0^2\,\beta_\alpha$$

Hooper, Serpico, JCAP 0706

Cirelli et al, JCAP 1103

.....

Astrophysical & DM scenarios

Scenario		KS	AD
Astrophysics	Gal. plane		
	Iso. dist.		
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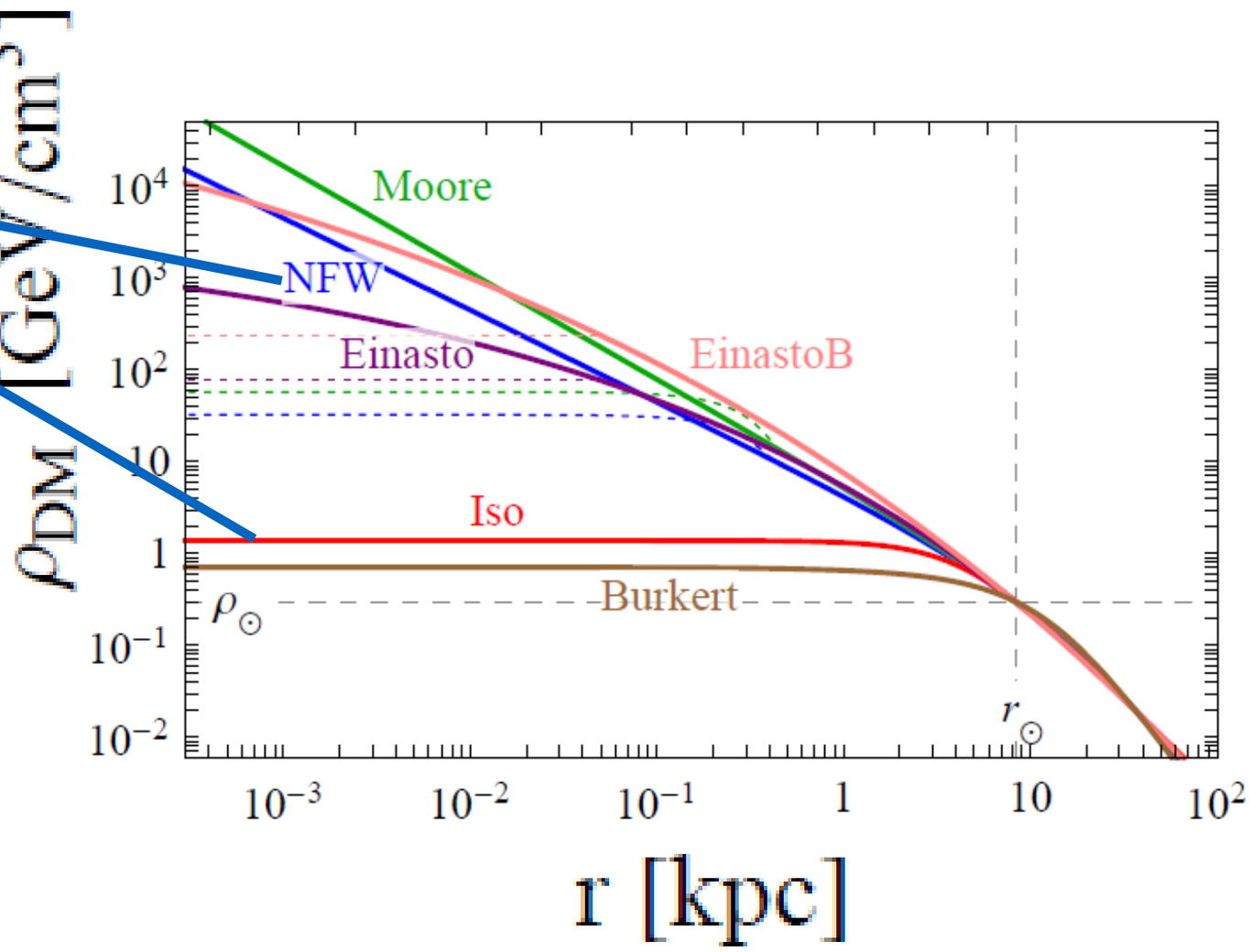


Cirelli et al., JCAP 1103 (2011)

Results: p-values

Scenario		KS	AD
Astrophysics	Gal. plane	0.007 - 0.008	not defined
	Iso. dist.	0.20 - 0.55	0.17 - 0.54
DM decay	NFW	0.06 - 0.16	0.03 - 0.14
	Isoth.	0.08 - 0.22	0.05 - 0.19
DM annih. $\Delta_0^2 = 10^4$	NFW	$(0.3 - 0.9) \times 10^{-4}$	$(0.3 - 3.8) \times 10^{-4}$
	Isoth.	$(0.9 - 2.8) \times 10^{-3}$	$(1.0 - 5.0) \times 10^{-3}$
DM annih. $\Delta_0^2 = 10^6$	NFW	0.02 - 0.05	0.02 - 0.07
	Isoth.	0.10 - 0.28	0.08 - 0.29
DM annih. $\Delta_0^2 = 10^8$	NFW	0.19 - 0.54	0.17 - 0.53
	Isoth.	0.20 - 0.55	0.17 - 0.54

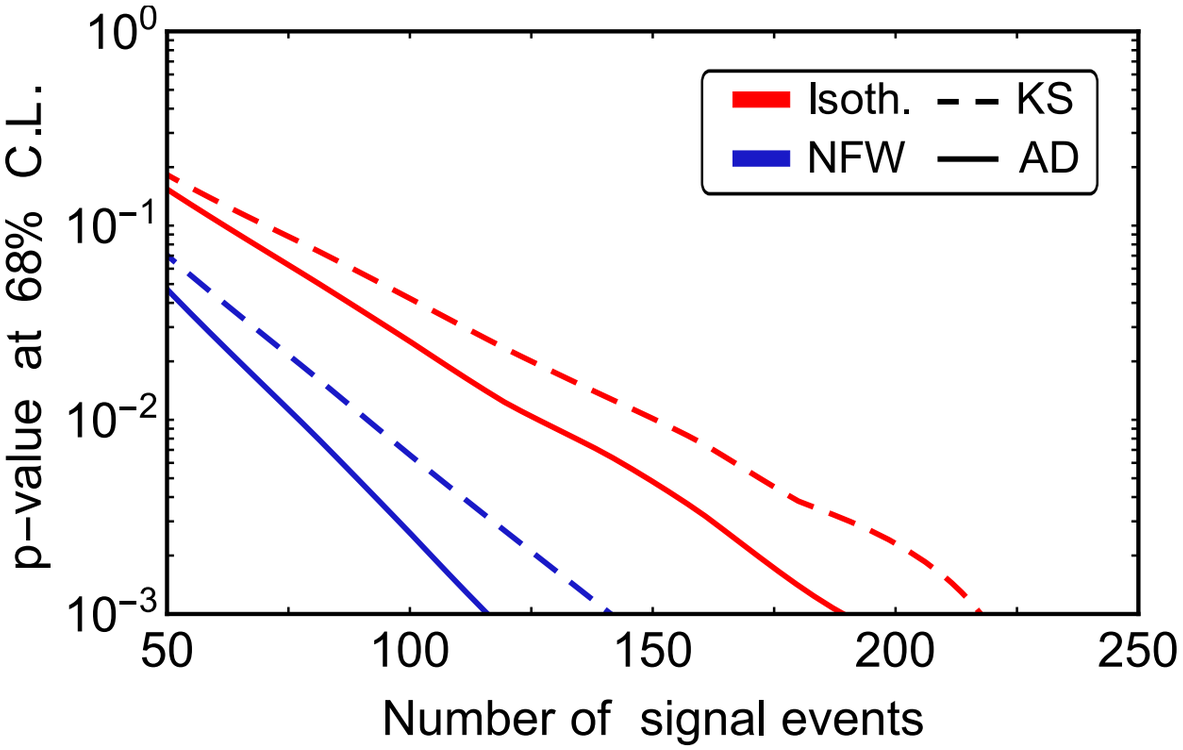
- **Disfavor** the correlation with the galactic plane

- Annihilating DM **excluded** for small clumpiness factor in both cases, NFW and Isothermal DM distributions

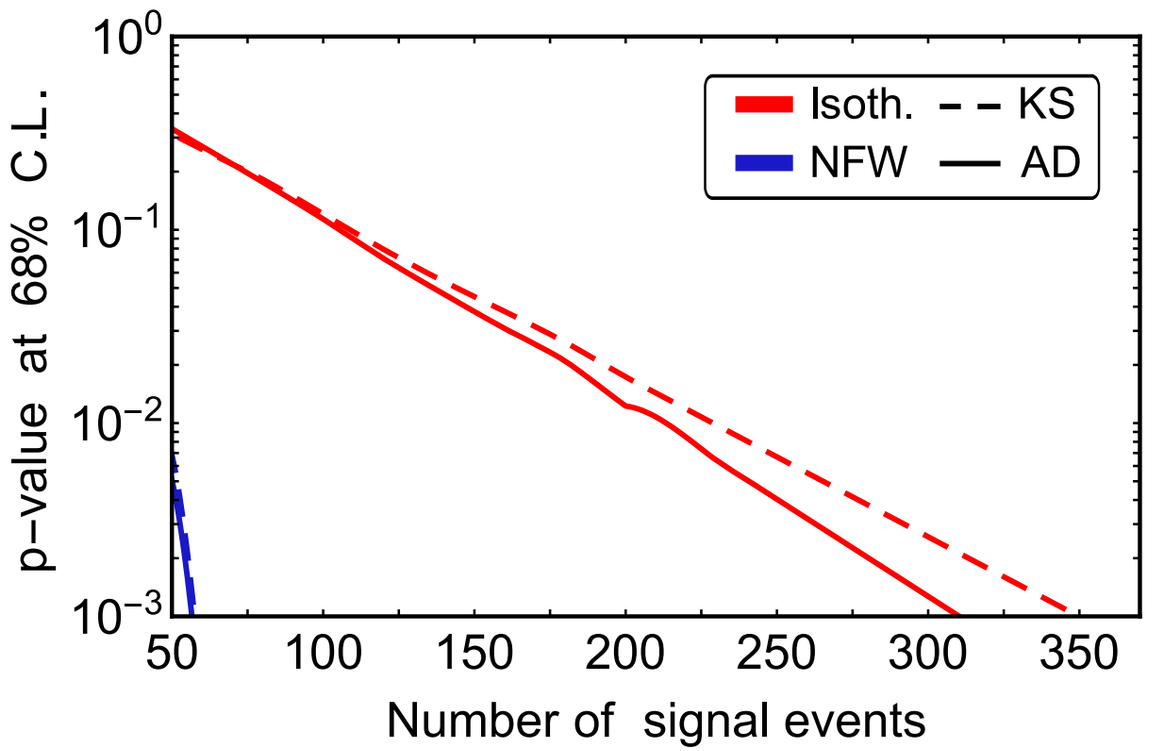
Forecast

We generate 10^5 sets of data according to the isotropic distribution

Then we perform the statistical tests under decaying or annihilating DM null hypothesis



decaying DM

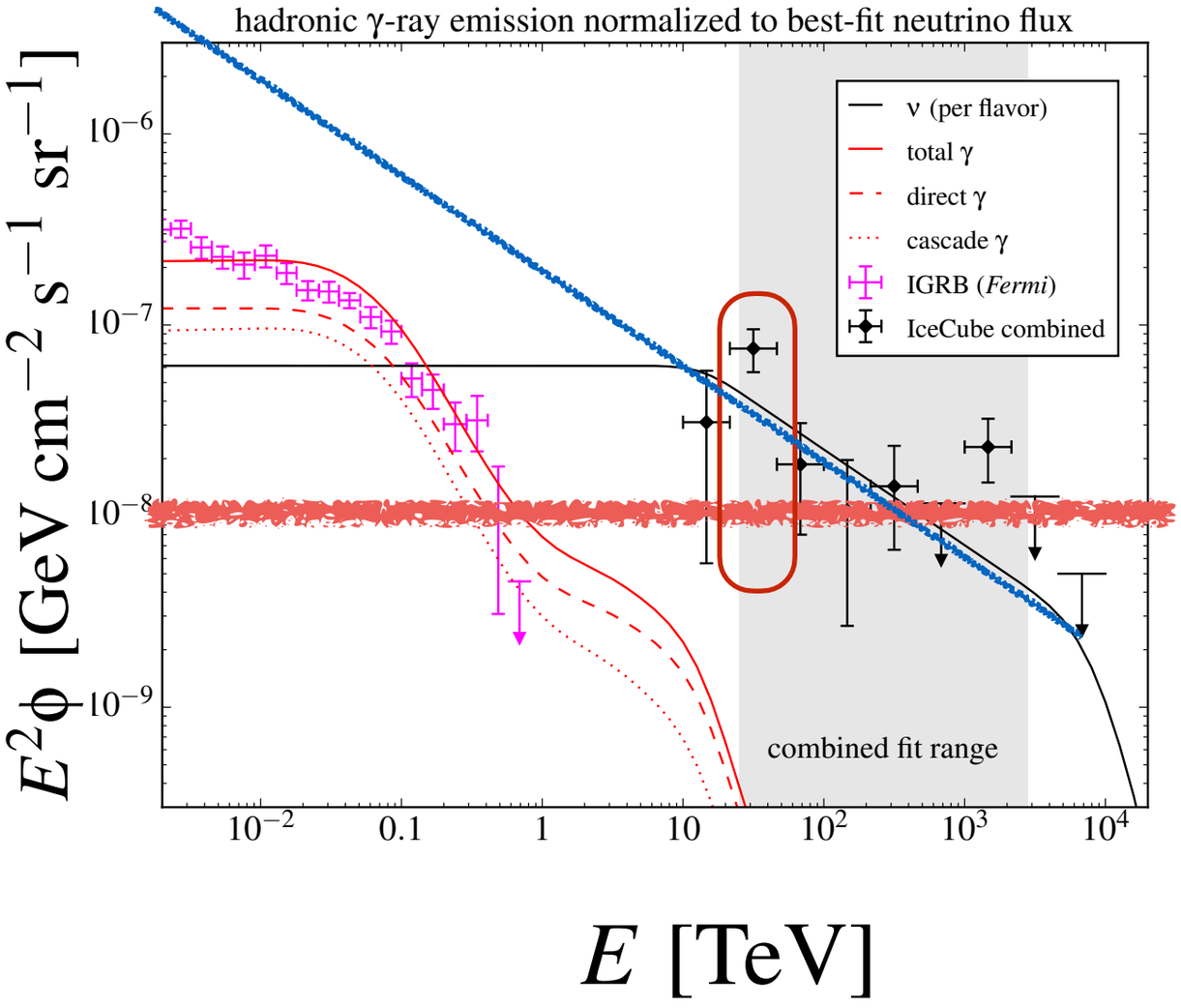


annihilating DM

has DM being seen from IceCube?

has DM being seen from IceCube?

we do not know
but can help to solve some puzzle



backup slides

Conclusions

- High-Energy and Low-Energy IceCube events could give indication about the Dark Matter

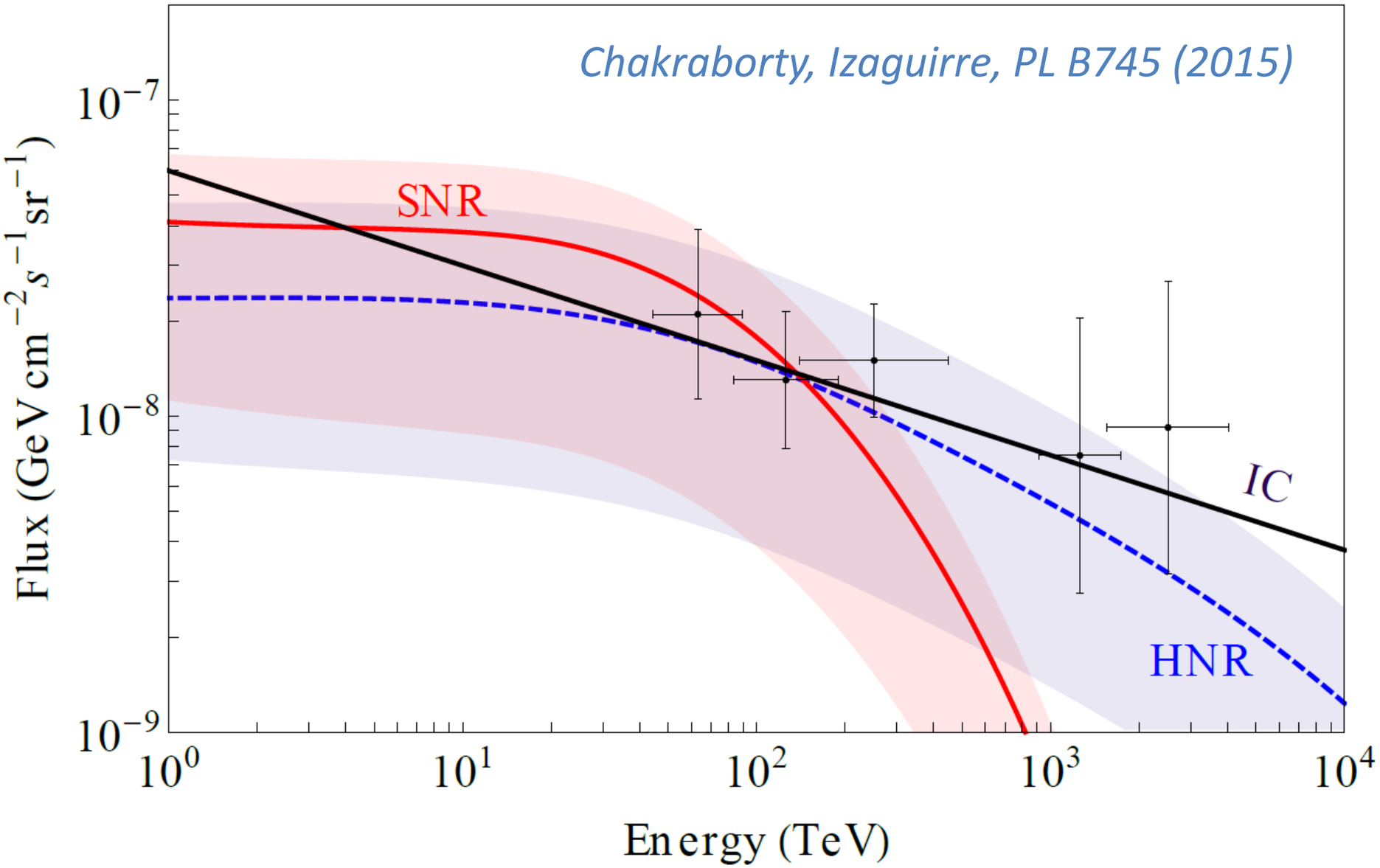
- High-Energy events can be interpreted as decaying DM

- Angular distribution analysis excludes the correlation between Low-Energy events and annihilating DM

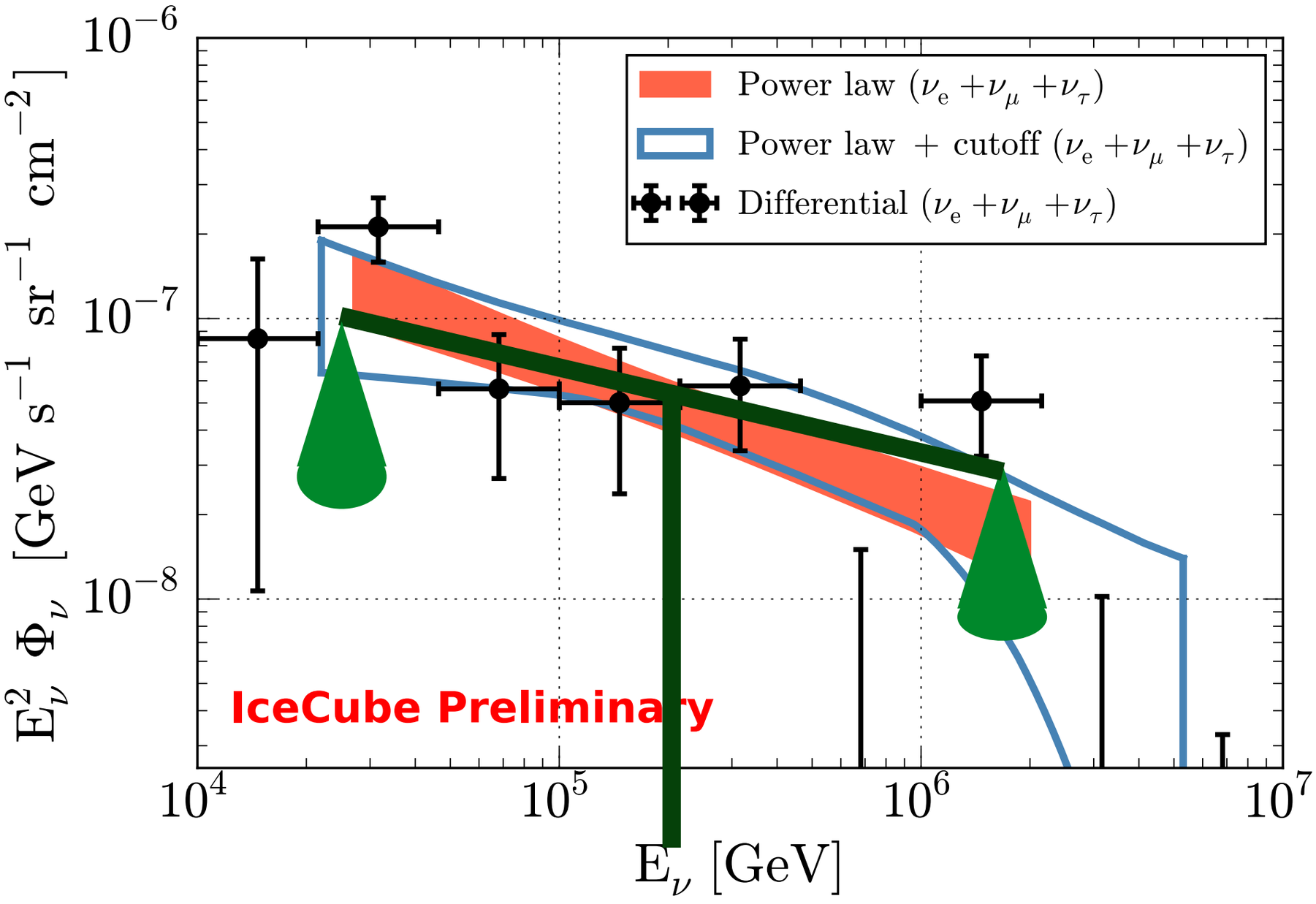
- But decaying is not yet excluded

- more statistic is required in order to completely exclude DM interpretation of IceCube data

Supernova Remnants



what is the spectral index?



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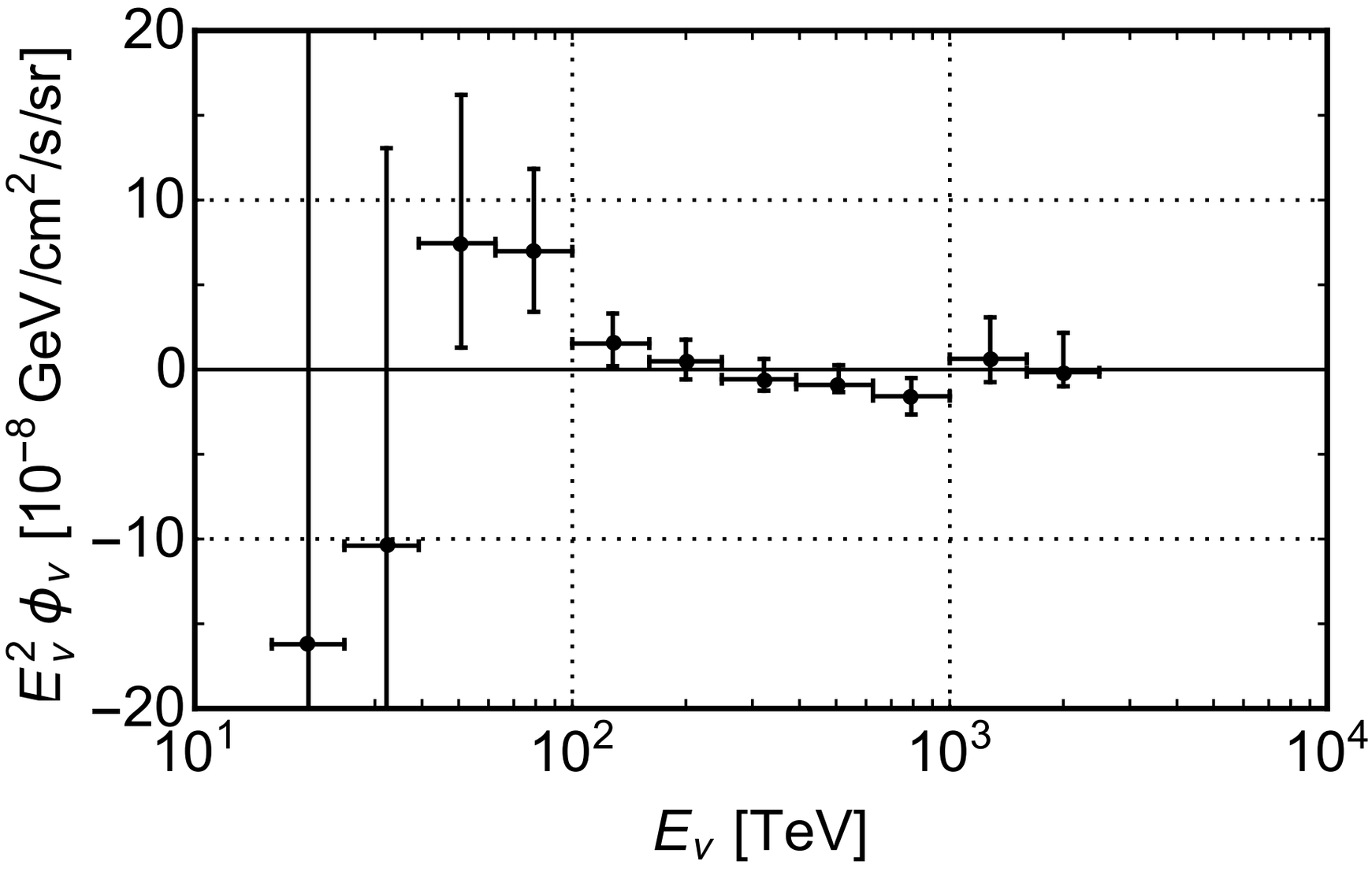

Chianese et al, PLB 757 (16)