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High-energy Neutrinos from Multi-body Decaying Dark Matter

reference:arXiv 1705.04419

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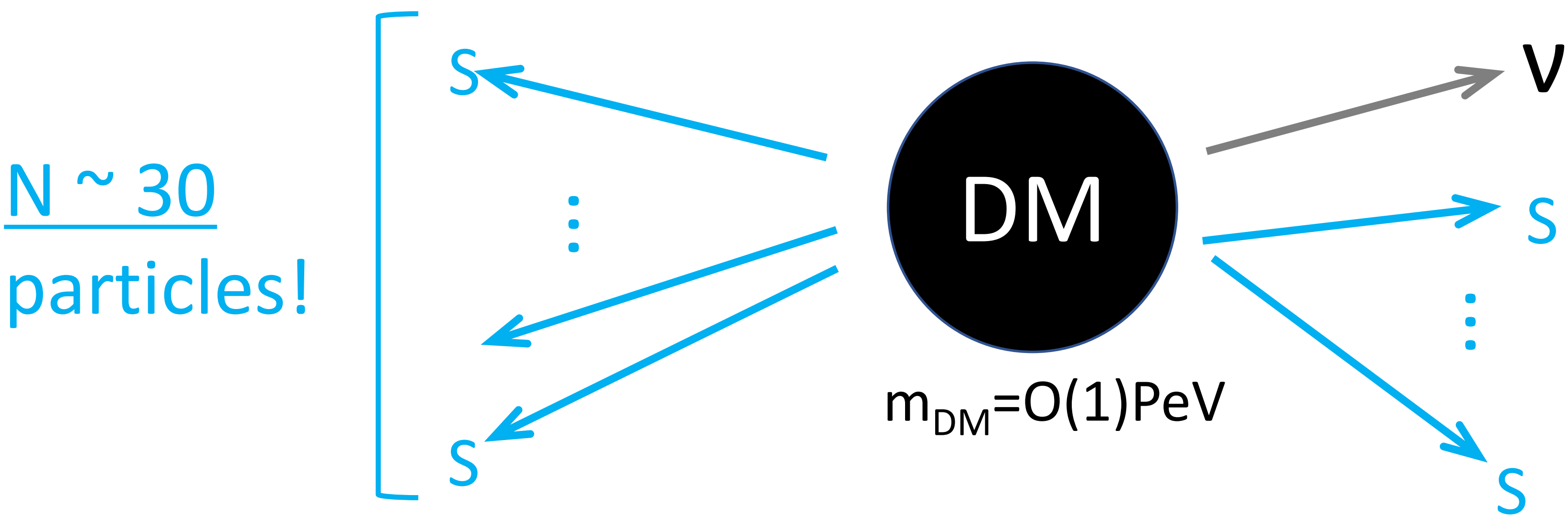
High-energy Neutrinos from Decaying Dark Matter

~30-body



Outline:

1, Introduction

2, Model

3, Result(s)

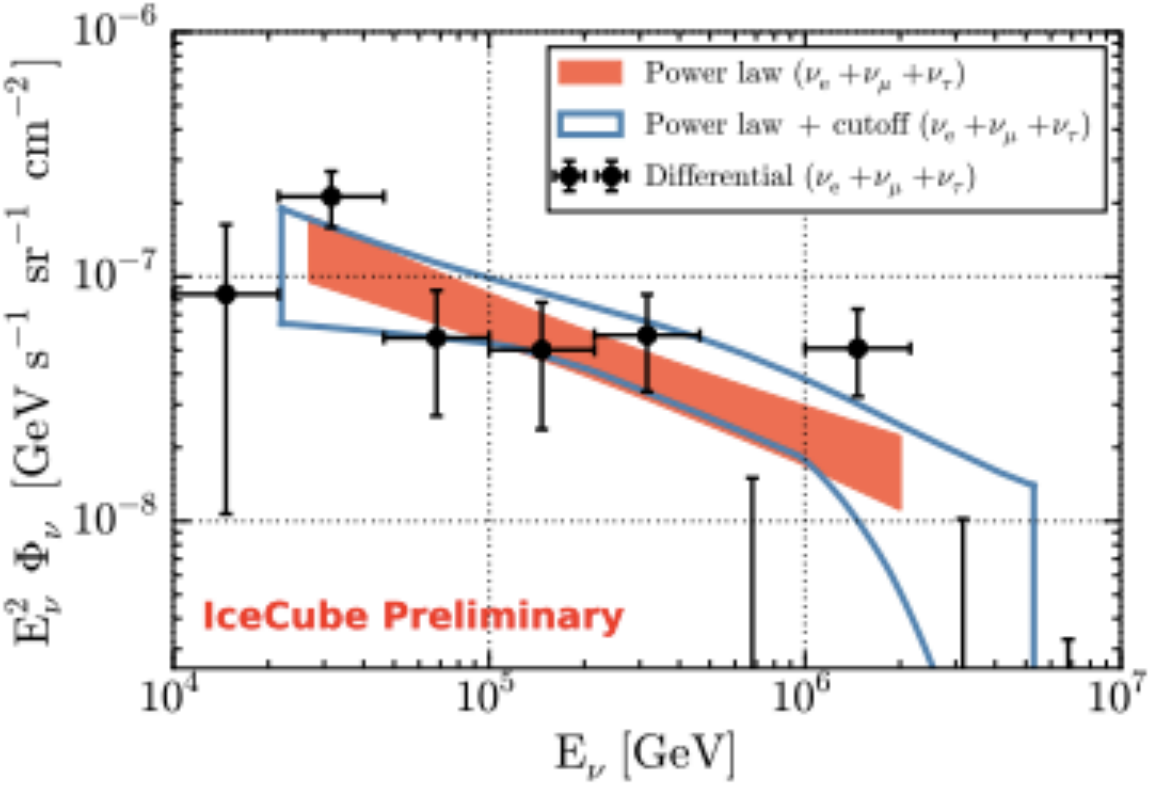
4, Summary

Introduction

What are the motivations for our multi-body decaying DM?

TeV-PeV neutrinos @IceCube

IceCube Collaboration, 1510.05223



$E^2{}_\nu \Phi_\nu \ \propto E^{-2.3}$

Origin of the TeV-PeV neutrino

1, astrophysical sources : cosmic ray proton interactions

- $p + p \to p\,,\ p\,,\ \pi^0, \pi^+, \pi^- + \ldots \to p + \nu + e^+ + e^-\,,\ \gamma, \ldots$ $E_p \sim O(10^8)$GeV

- $p + \gamma \to p, \pi^0$ or π^+ or $\pi^- + \ldots \to p + \nu + e^+ + e^-$ or $\gamma \ldots$ $E_p \sim O(10^6)$GeV

e.g. GRB, AGN, Star burst galaxies, ...

2, Dark Matter : DM -> $\nu + \ldots$

$$\begin{cases} \gamma + \ldots \\ l^+ + l^- + \ldots \to \text{inverse compton } \gamma + \ldots \\ q, \overline{q} + \ldots \to p + \overline{p} + \pi^0 + \pi^+\ \pi^- + \ldots \\ \qquad\qquad \to p + \overline{p} + \nu + e^+ + e^- + \gamma + \ldots \end{cases}$$

Origin of the TeV-PeV neutrino

1, astrophysical sources : cosmic ray proton interactions

- $p + p \to p, p, \pi^0, \pi^+, \pi^- + \ldots \to p + \nu + e^+ + e^-, \gamma, \ldots$

$E_p \sim O(10^8)$GeV

- $p + \gamma \to p, \pi^0$ or π^+ or $\pi^- + \ldots \to p + \nu + e^+ + e^-$ or $\gamma \ldots$

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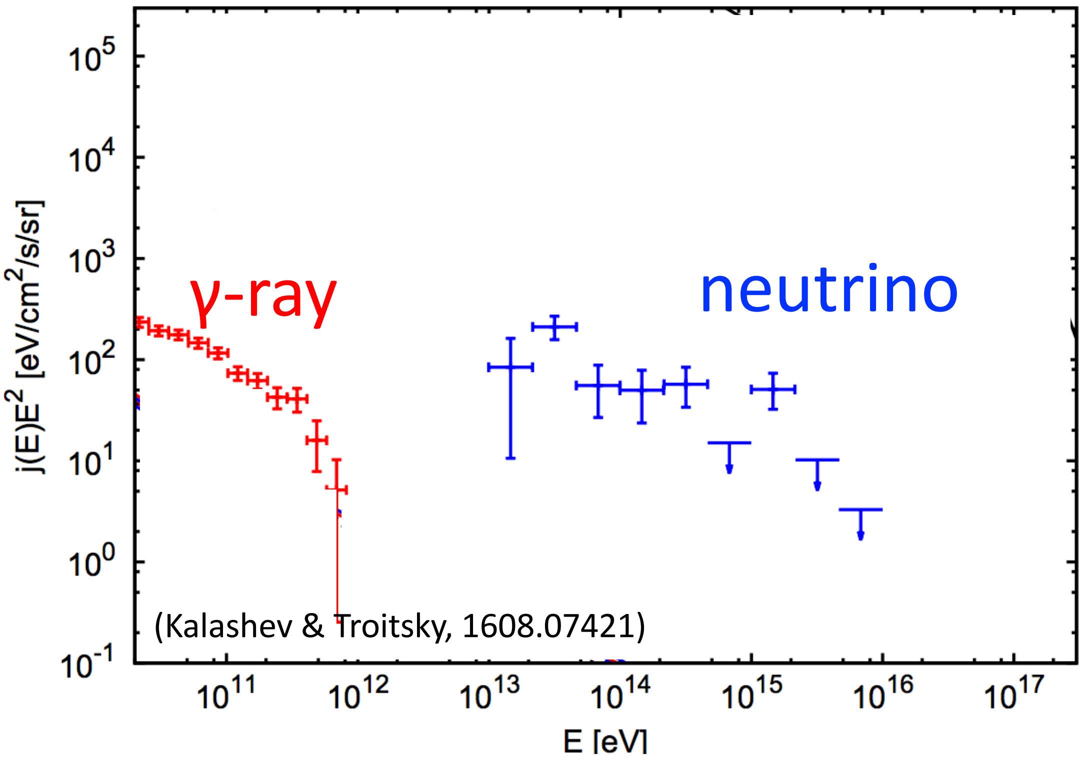
2, Dark Matter : $DM \to \nu + \ldots$

$$\begin{cases} \gamma + \ldots \\ l^+ + l^- + \ldots \to \text{inverse compton } \gamma + \ldots \\ q, \overline{q} + \ldots \to p + \overline{p} + \pi^0 + \pi^+ \ \pi^- + \ldots \\ \qquad \to p + \overline{p} + \nu + e^+ + e^- + \gamma + \ldots \end{cases}$$

Neutrinos often associate γ-rays

Problem1 : Isotropic γ-ray Background (IGRB)



$\Phi_\gamma \propto \Phi_\nu \Rightarrow$ higher γ-ray flux than the observed IGRB

Problem2 : substructures

Motivations:

- TeV – PeV neutrinos have been detected
- We do not know the origin of the TeV-PeV neutrino and structures of its spectrum
- high energy neutrino emissions often associates γ-rays which is in conflict with IGRB observations

Can we explain the TeV-PeV neutrino spectrum in consistency with the IGRB observations?

We consider the N~30 decaying DM scenario

Model

multi-body decay!

$$\boxed{\mathcal{L}_{int} = \epsilon \bar{L} l X + \frac{1}{M_*^{3n-1}} \bar{L} l S^{2n}}$$

n=15

DM

$$L = \begin{pmatrix} N_0 \\ E^- \end{pmatrix}, \qquad l = \begin{pmatrix} \nu \\ e^- \end{pmatrix}$$

S: dark fermion

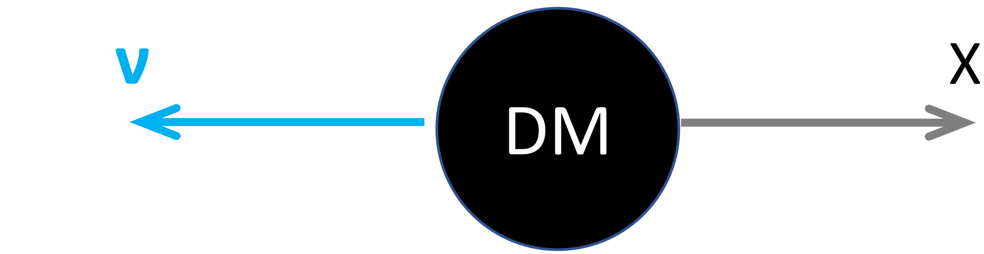
2 branches of decay modes:

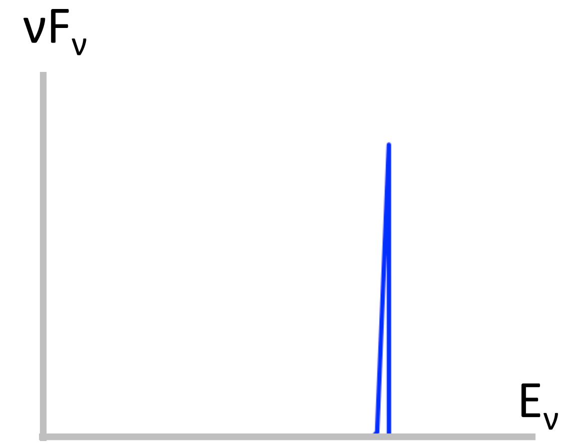
- DM -> X + ν
- DM -> 2n S + ν

We can predict 2 components in produced neutrino spectrum

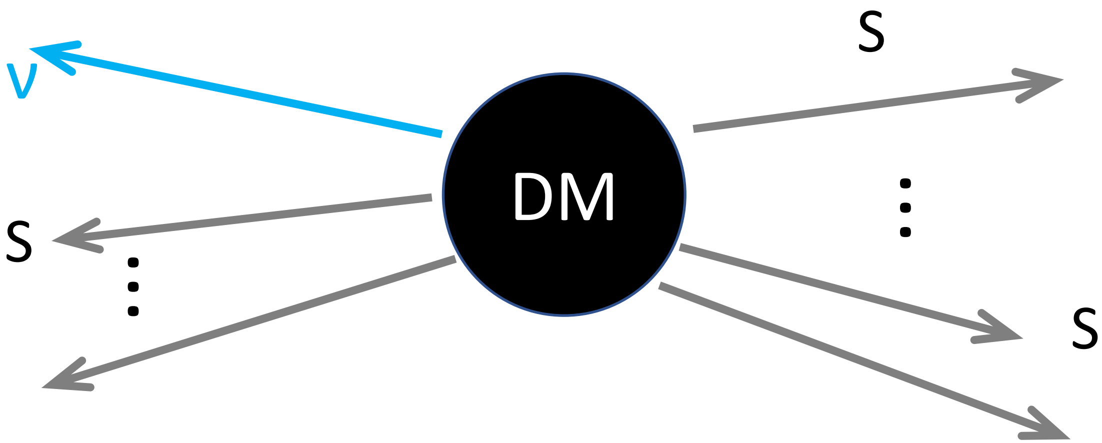
features of the neutrino spectrum

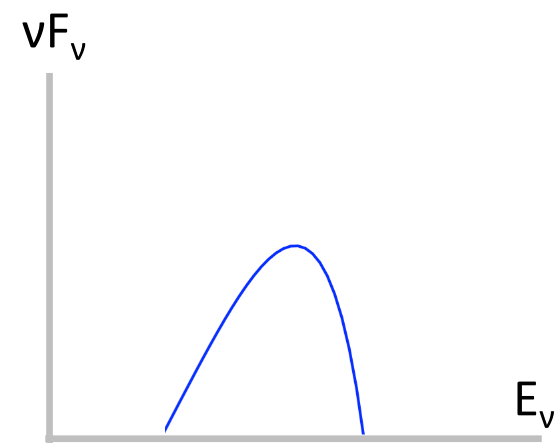
mode 1: DM -> X + ν





mode 2: DM -> 2n S + ν





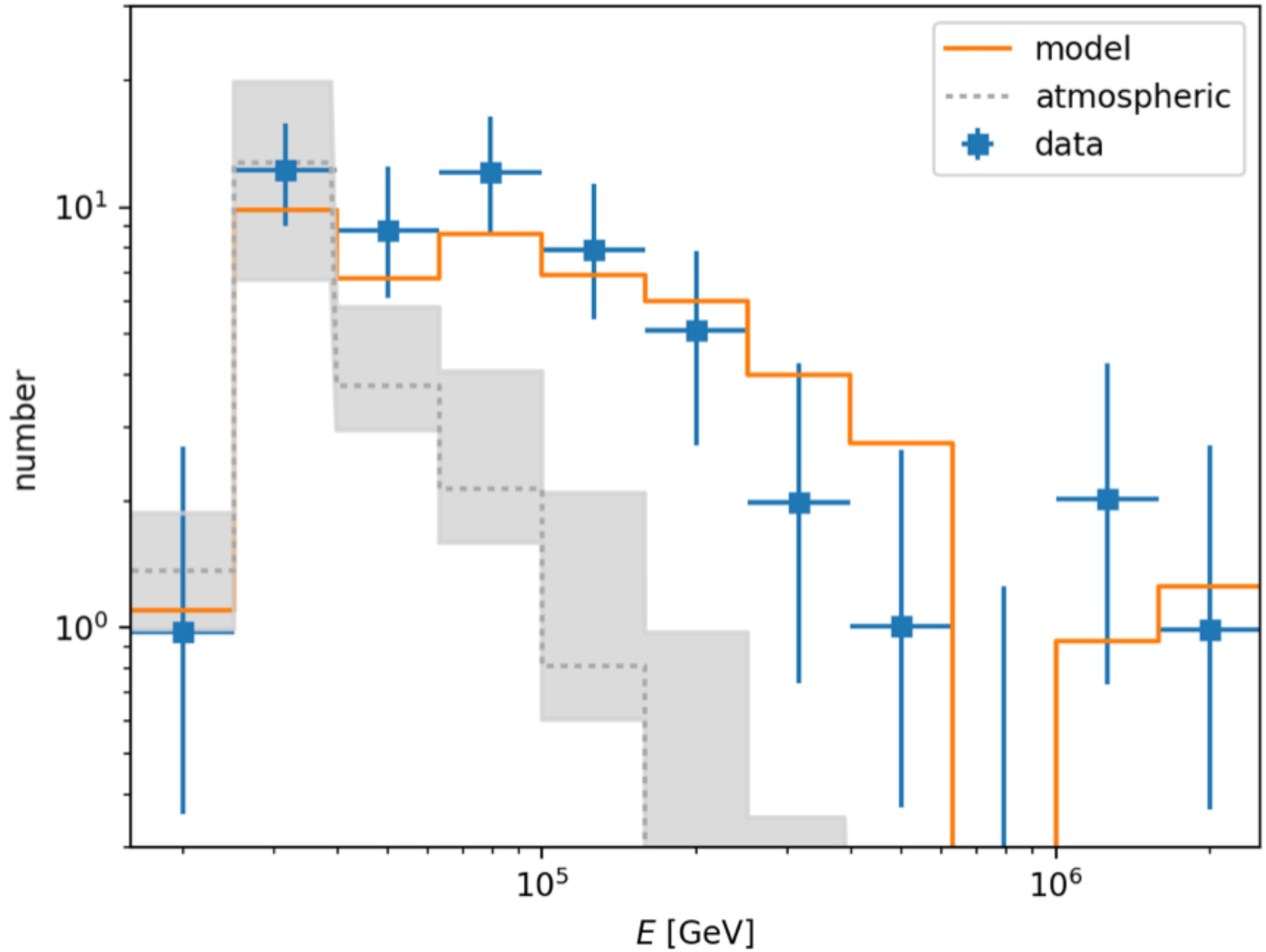
We can predict broad & line-like features in neutrino spectrum

Result

Result1: pure DM

m_{DM}=4PeV

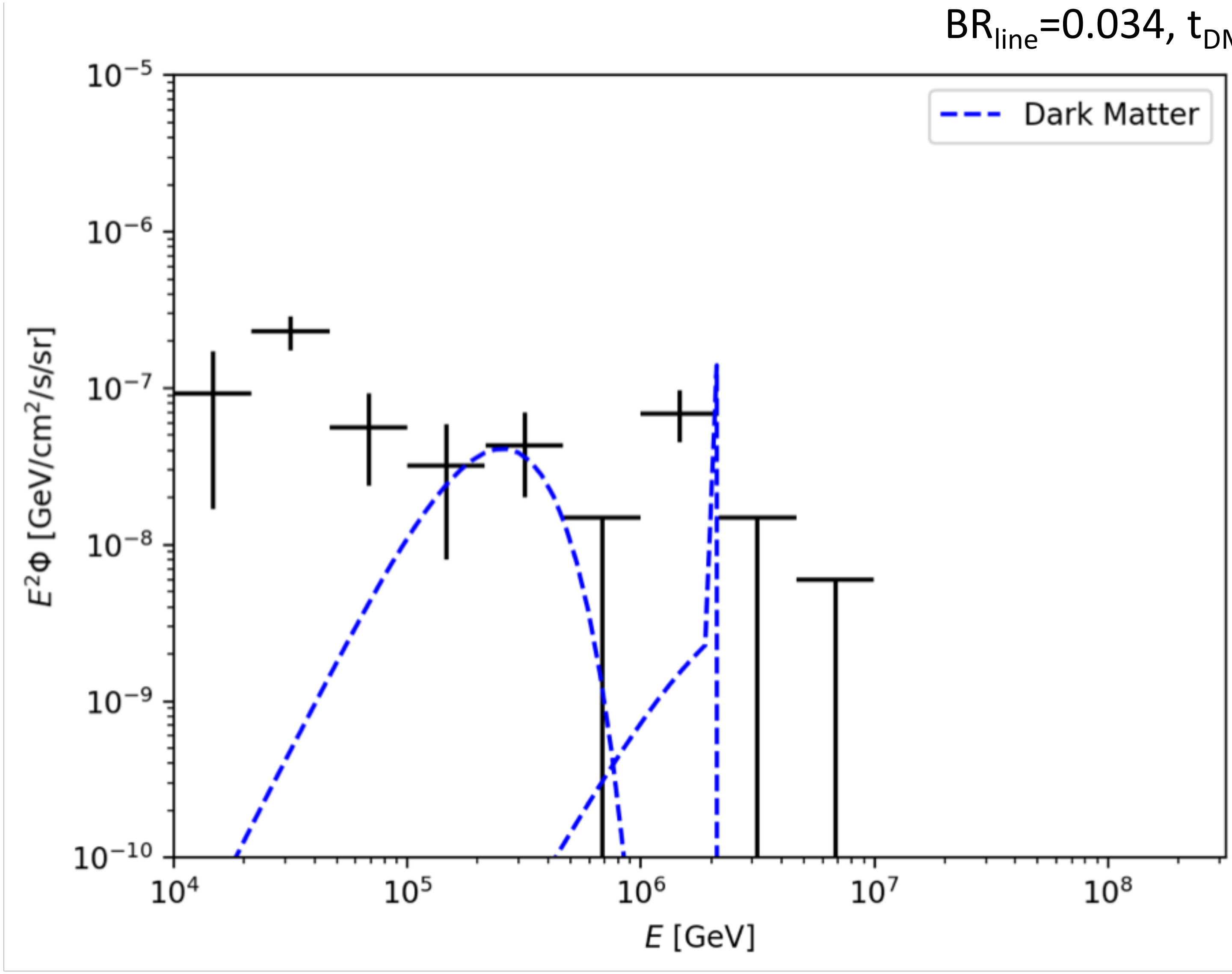
BR_{line}=0.034, t_{DM}=1.5×10^{27}s



pure DM: source spectrum

m_{DM}=4PeV

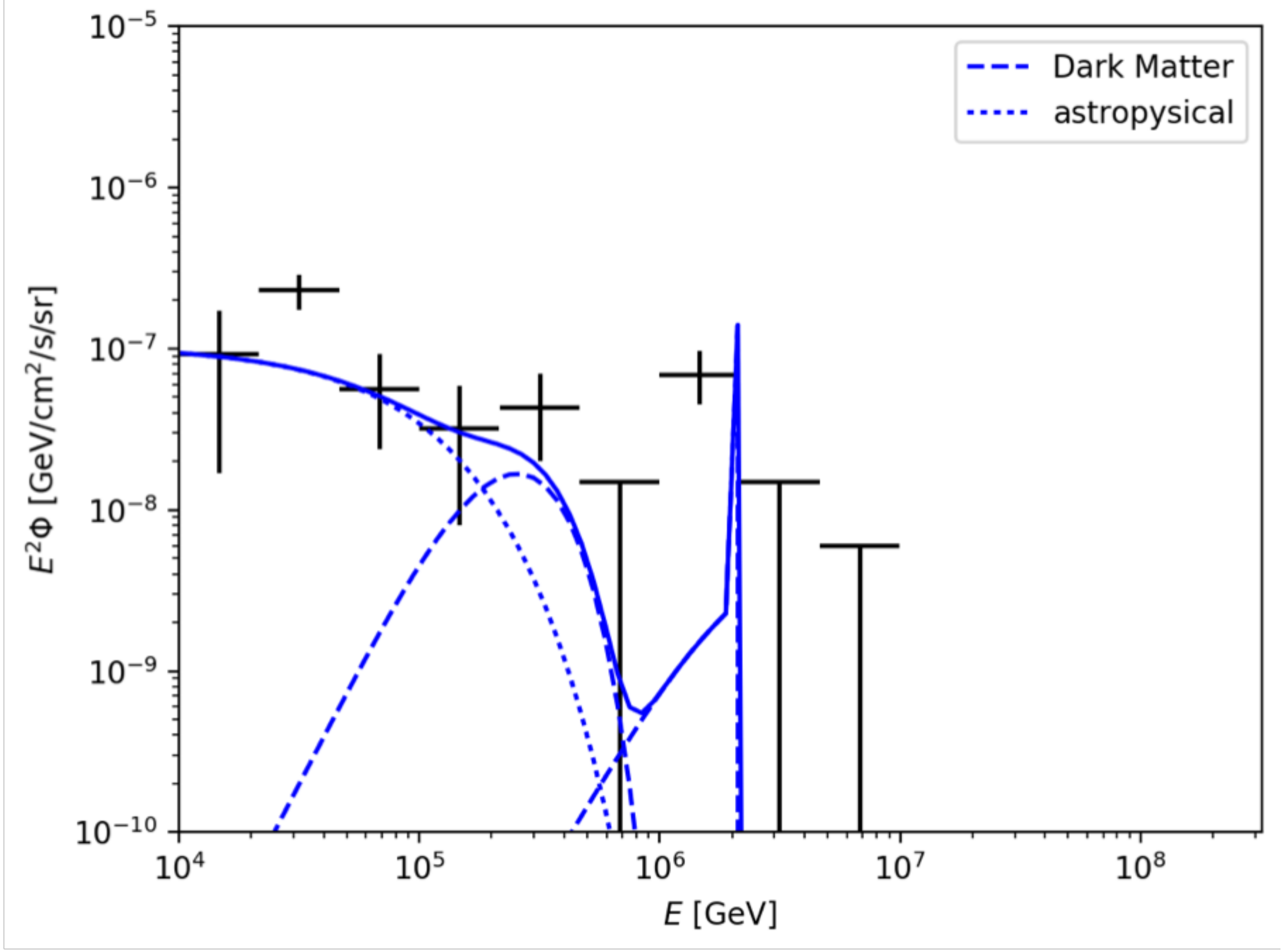
BR_{line}=0.034, t_{DM}=1.5×10^{27}s



fill the deficit:hidden accelerator?

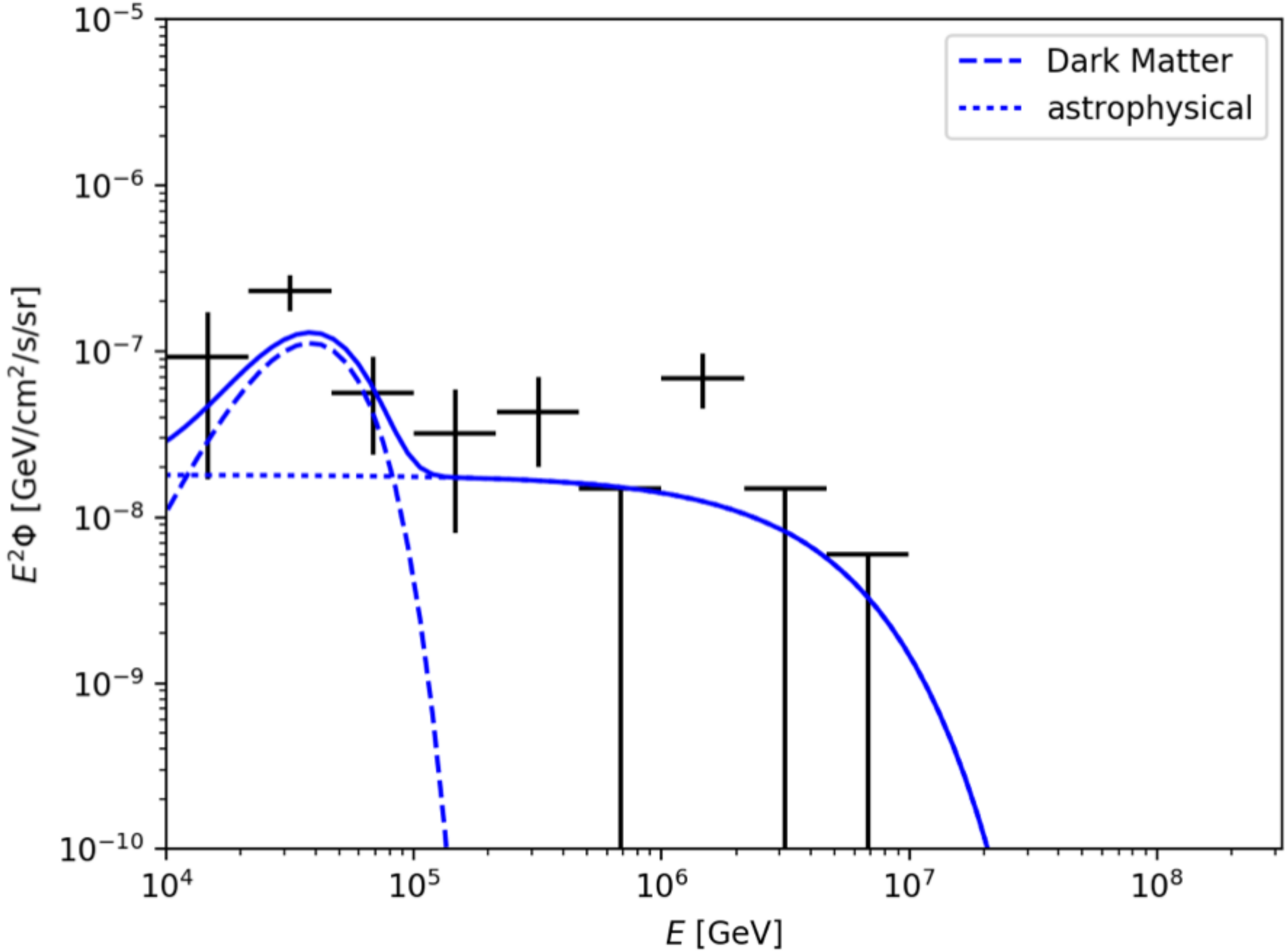
m_{DM}=4PeV

BR_{line}=0.080, t_{DM}=3.4×10^{27}s



or the grand unified scenario?

m_{DM}=600TeV
t_{DM}=2.6×10^{27}s



Summary:

Conditions:

- We do not know the origin of the TeV-PeV neutrinos @ IceCube

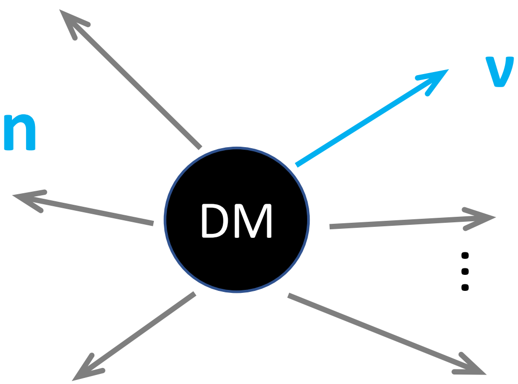
- We should be careful about the IGRB when we discuss the origin of the neutrino

Choices:

- astrophysical or dark matter (DM)?

Conclusion:

Our N~30 body decaying DM scenario can explain the observed spectrum without suffering from IGRB constraint



- 2 (or multi)- component scenario is also possible