

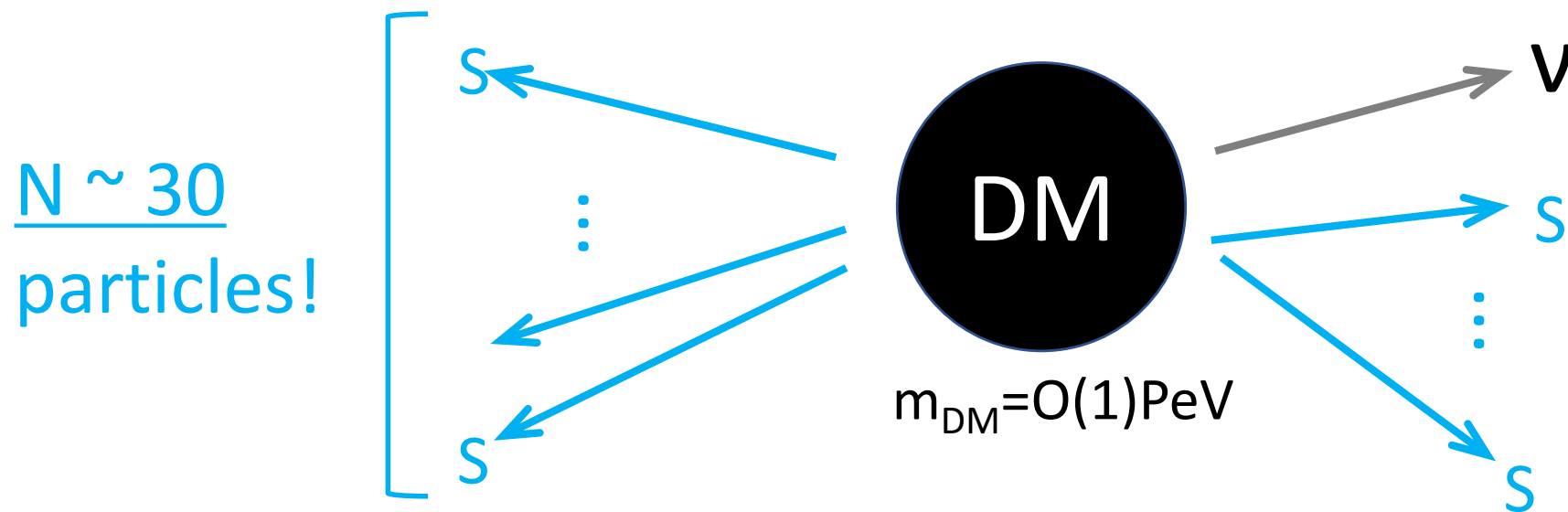
High-Energy Neutinos from Multi-body Decaying Dark Matter

reference:Phys. Rev. D., 97., 023006

Nagisa Hiroshima^{1,2}, Ryuichiro Kitano^{2,3},
Kazunori Kohri^{2,3,5}, Kohta Murase⁴

(1: ICRR, The Univ. of Tokyo, 2: IPNS, KEK, 3: SOKENDAI, 4: Penn-State Univ., 5: Univ. of Oxford)

High-Energy Neutinos from Multi-body Decaying Dark Matter



Outline:

1, Introduction

2, Model

3, Result(s)

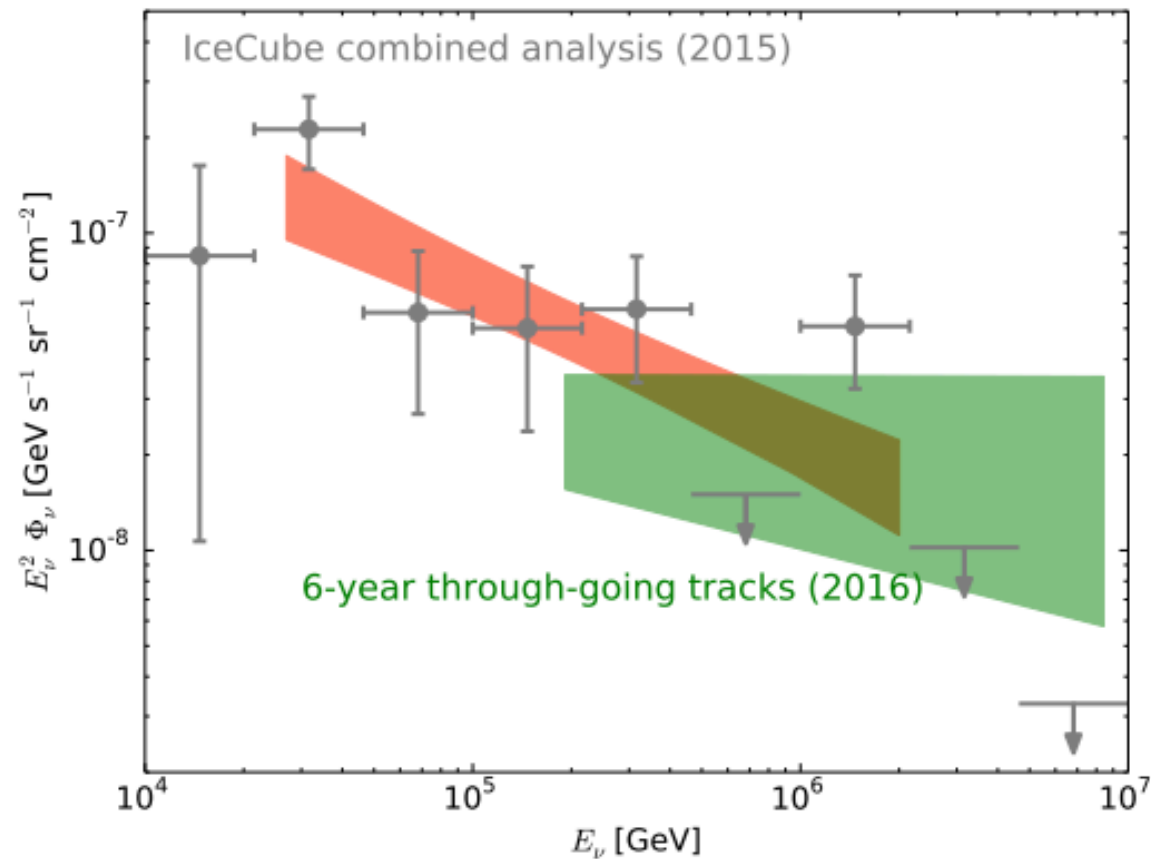
4, Summary

Introduction

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

TeV-PeV neutrinos @IceCube

IceCube Collaboration, 1701.03731



$$E_\nu^2 \Phi_\nu \propto E_\nu^{-2.5}$$

Origin of the TeV-PeV neutrino

1, **Astrophysical Sources** : cosmic ray proton interactions

- $p + p \rightarrow p, p, \pi^0, \pi^+, \pi^- + \dots$
 $\rightarrow p + \nu + e^+ + e^-, \gamma, \dots$

$$E_p \sim O(10^8) \text{ GeV}$$

- $p + \gamma \rightarrow p, \pi^0 \text{ or } \pi^+ \text{ or } \pi^- + \dots$
 $\rightarrow p + \nu + e^+ + e^- \text{ or } \gamma \dots$

$$E_p \sim O(10^6) \text{ GeV}$$

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

2, **Dark Matter** : $DM \rightarrow \nu + \dots$

$$\left\{ \begin{array}{l} \gamma + \dots \\ l^+ + l^- + \dots \rightarrow \text{inverse compton } \gamma + \dots \\ q, \bar{q} + \dots \rightarrow p + \bar{p} + \pi^0 + \pi^+ \pi^- + \dots \\ \quad \rightarrow p + \bar{p} + \nu + e^+ + e^- + \gamma + \dots \end{array} \right.$$

Origin of the TeV-PeV neutrino

1, Astrophysical Sources : cosmic ray proton interactions

- $p + p \rightarrow p, p, \pi^0, \pi^+, \pi^- + \dots$
 $\rightarrow p + \nu + e^+ + e^-, \gamma, \dots$

$$E_p \sim O(10^8) \text{ GeV}$$

- $p + \gamma \rightarrow p, \pi^0 \text{ or } \pi^+ \text{ or } \pi^- + \dots$
 $\rightarrow p + \nu + e^+ + e^- \text{ or } \gamma, \dots$

$$E_p \sim O(10^6) \text{ GeV}$$

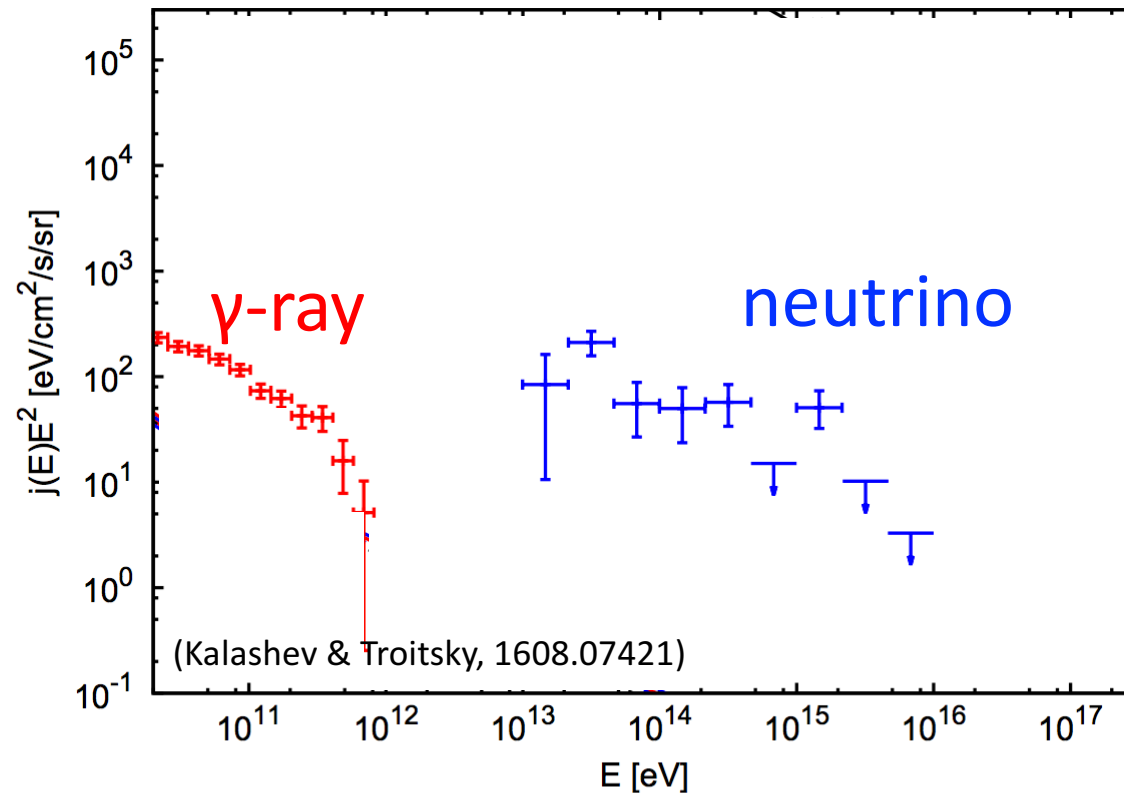
e.g. GRB, AGN, Star burst galaxies, ...

2, Dark Matter : DM $\rightarrow \nu + \dots$

$$\left\{ \begin{array}{l} \gamma + \dots \\ l^+ + l^- + \dots \rightarrow \text{inverse compton } \gamma + \dots \\ q, \bar{q} + \dots \rightarrow p + \bar{p} + \pi^0 + \pi^+ \pi^- + \dots \\ \quad \rightarrow p + \bar{p} + \nu + e^+ + e^- + \gamma + \dots \end{array} \right.$$

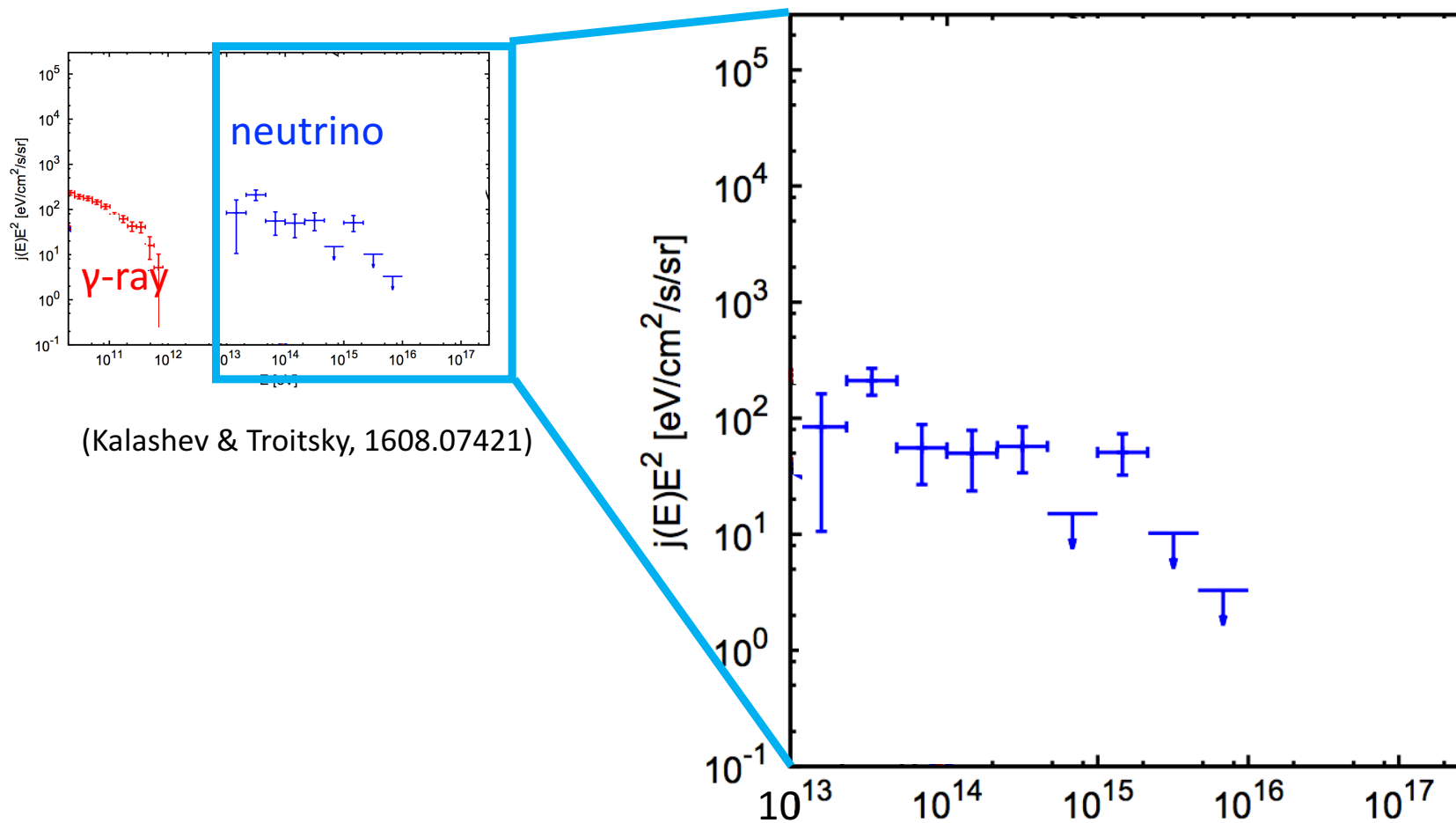
Neutrinos often associate γ -rays

Problem 1: Isotropic γ -ray Background (IGRB)



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

Problem 2: Substructures in Spectrum



Problem 3: Few Source Correlation

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 $N \sim 30$ decaying DM scenario

Model

multi-body decay!

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

n=15

$$\left[\begin{array}{l} L = \begin{pmatrix} N_0 \\ E^- \end{pmatrix}, \quad l = \begin{pmatrix} \nu \\ e^- \end{pmatrix} \\ S: \text{dark fermion} \end{array} \right. \quad \text{DM}$$

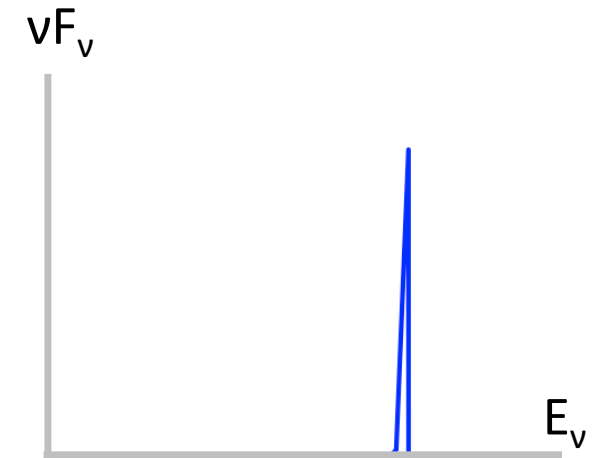
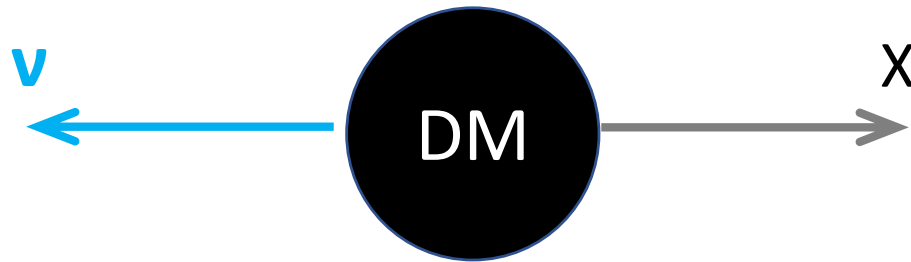
2 branches of decay modes:

- DM \rightarrow X + ν
- DM \rightarrow 2n S + ν

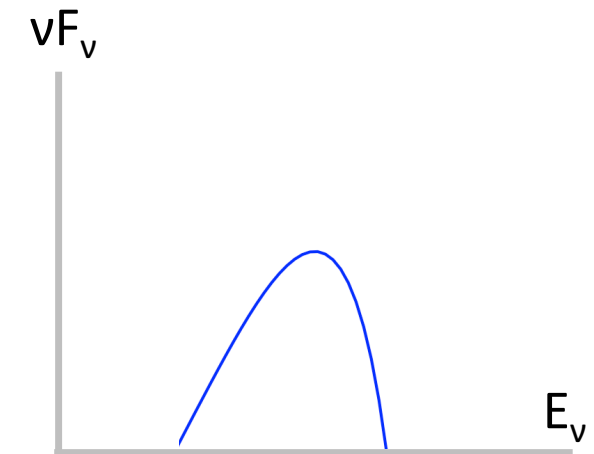
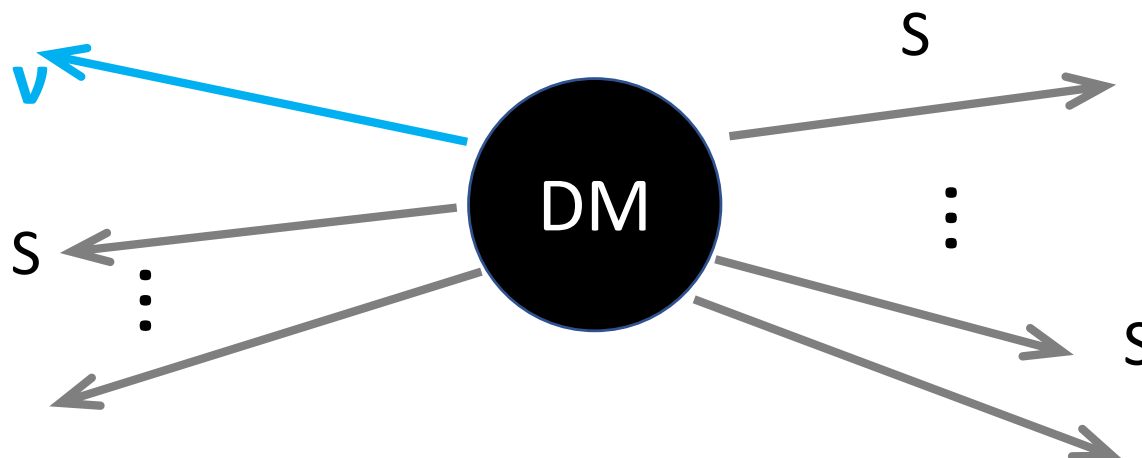
We can predict 2 components in produced neutrino spectrum

features of the neutrino spectrum

mode 1: $\text{DM} \rightarrow X + \nu$



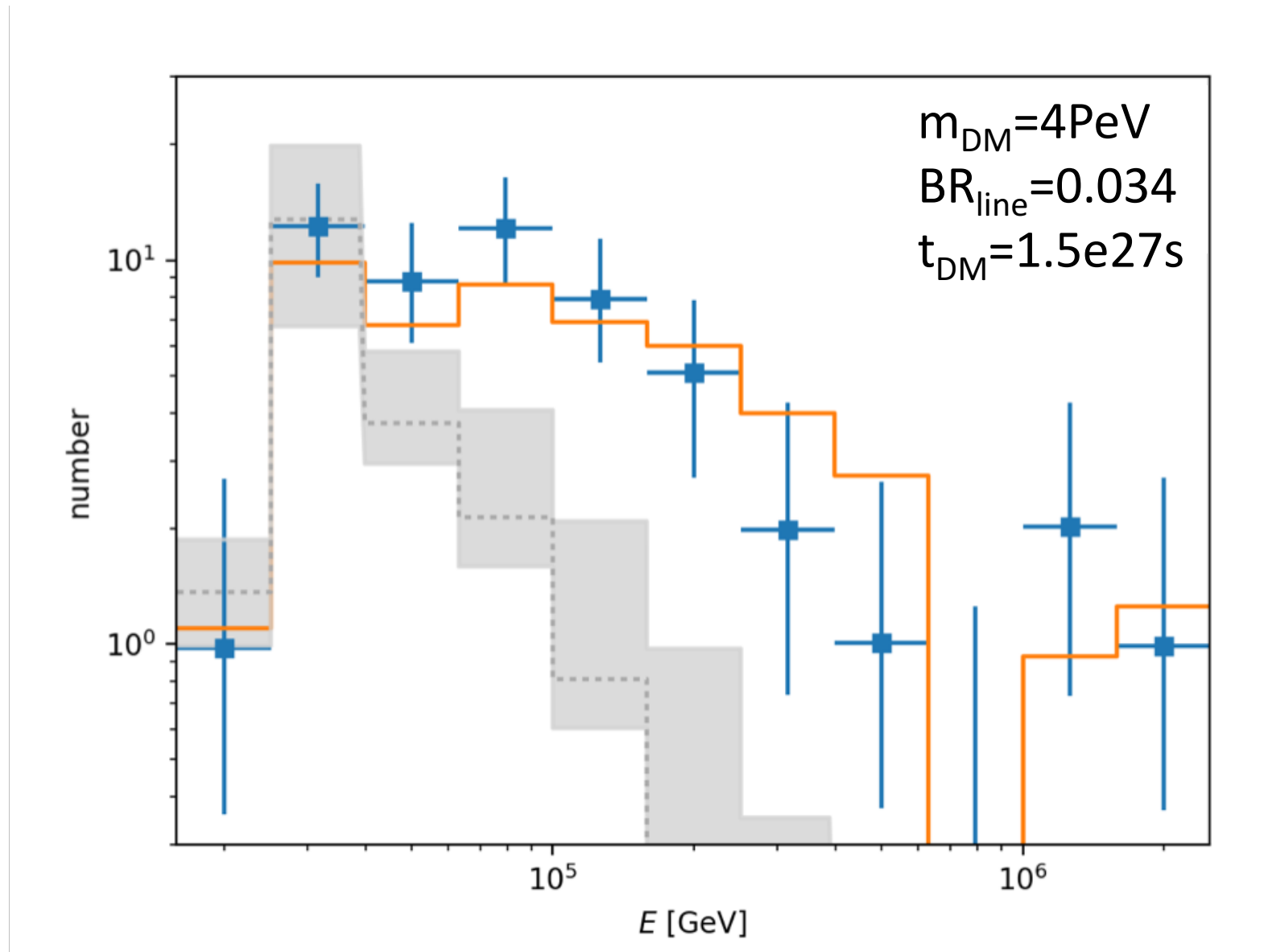
mode 2: $\text{DM} \rightarrow 2n S + \nu$



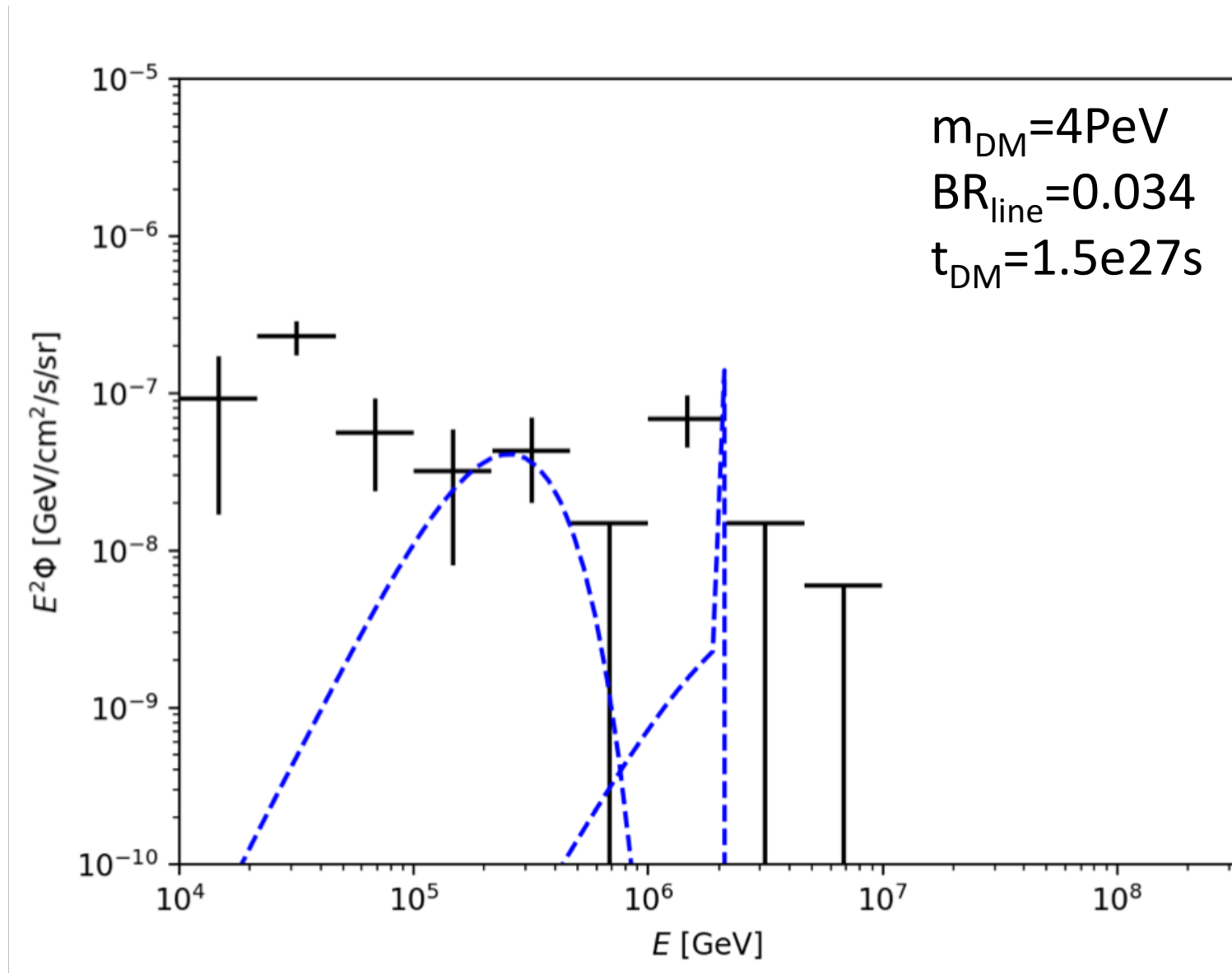
We can predict broad & line-like features in neutrino spectrum

Result

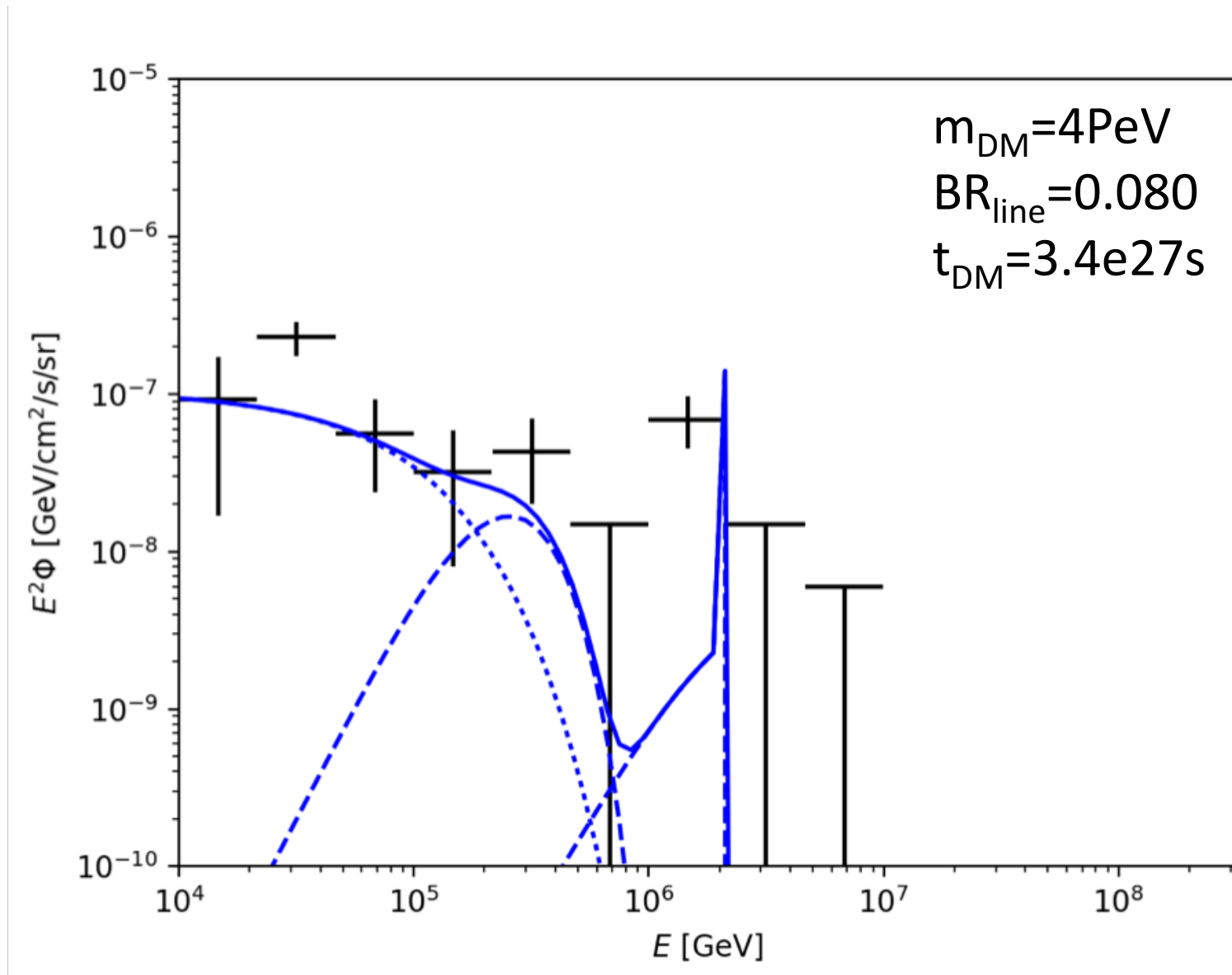
pure DM fit: ν deposited energy



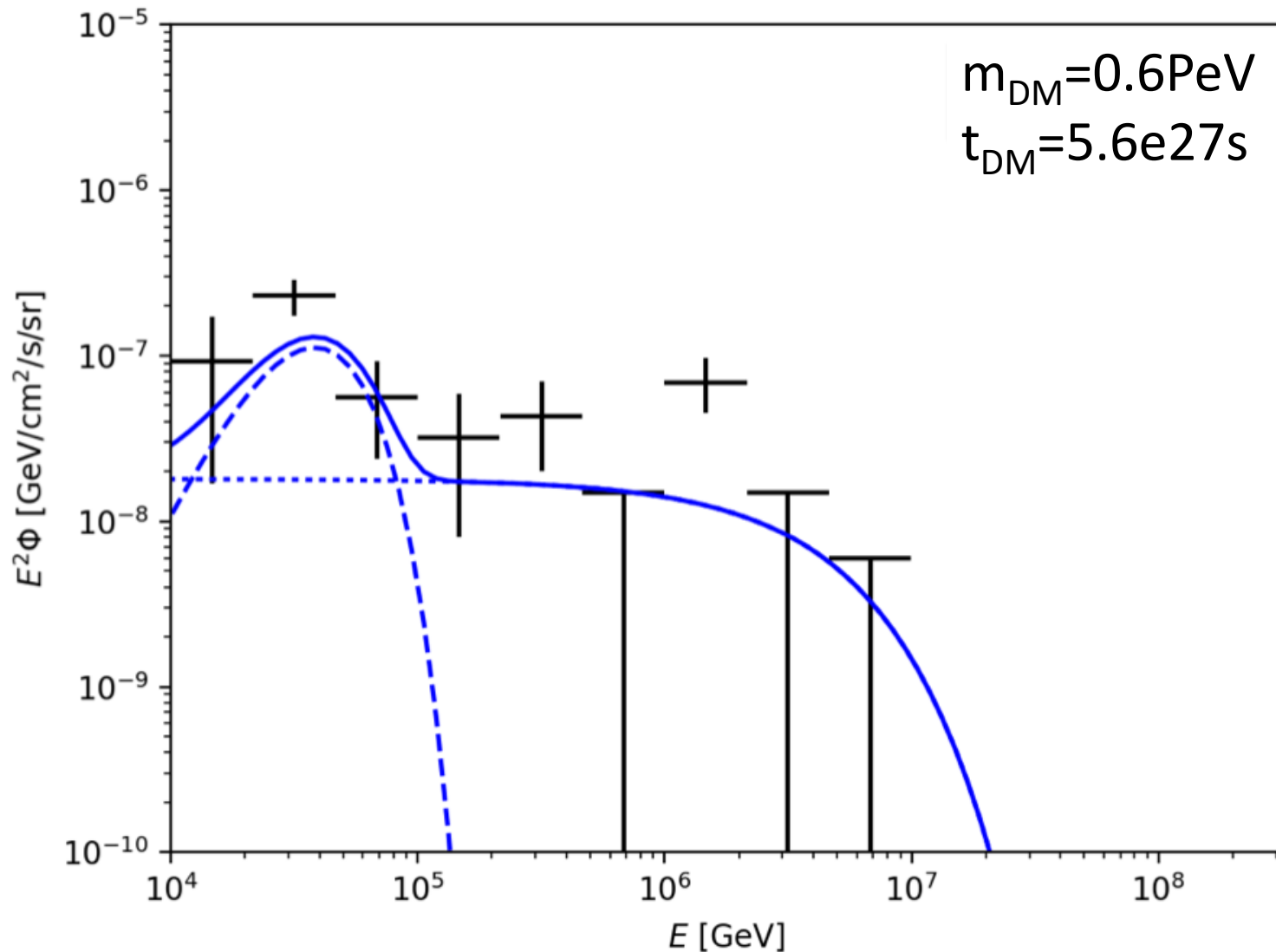
pure DM: source spectrum



DM + astrophysical hidden accelerator?



DM + ν from the proton of $E_p \sim 10^{17.5} \text{ eV}$?



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) or both of them?

Conclusion:

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

