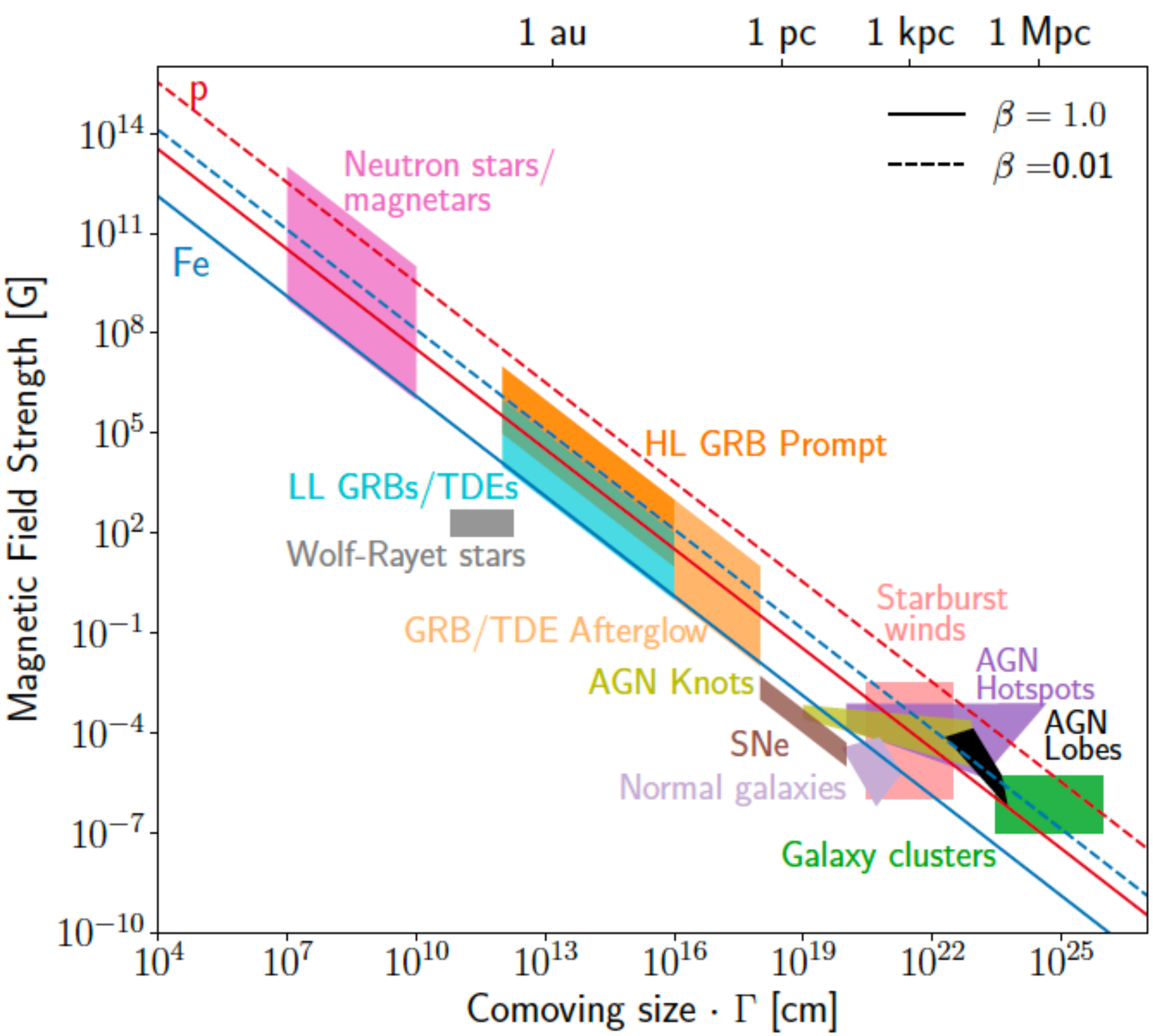
Astrophysical Diffuse models from 1 TeV to 1 EeV

Haoning He
RIKEN

Diffuse Workshop on Global Fit Sep 14, 2019

Cosmic Ray accelerators



Larmor Radius = Typical scale of sources

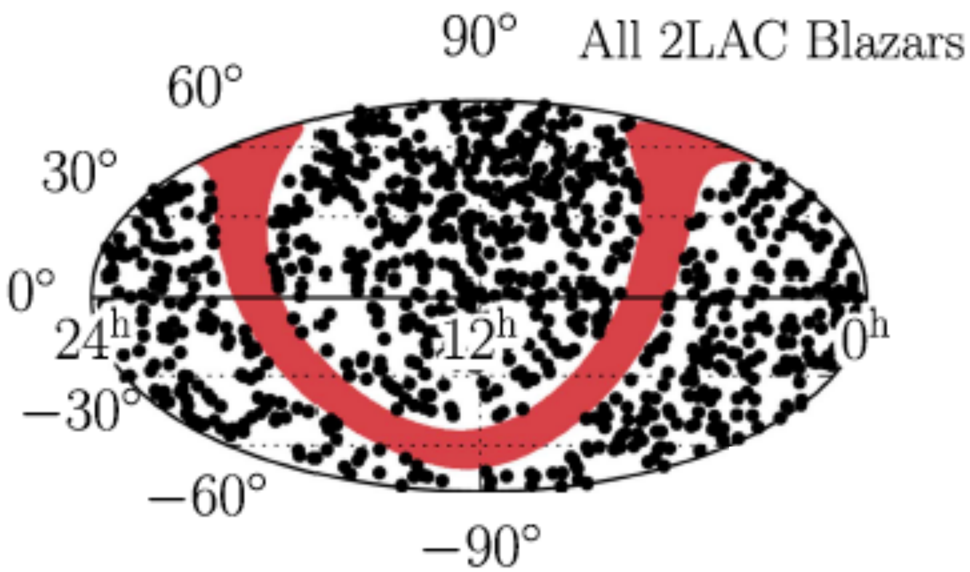
Emax=ZBL

Alves Batista et al. 2019

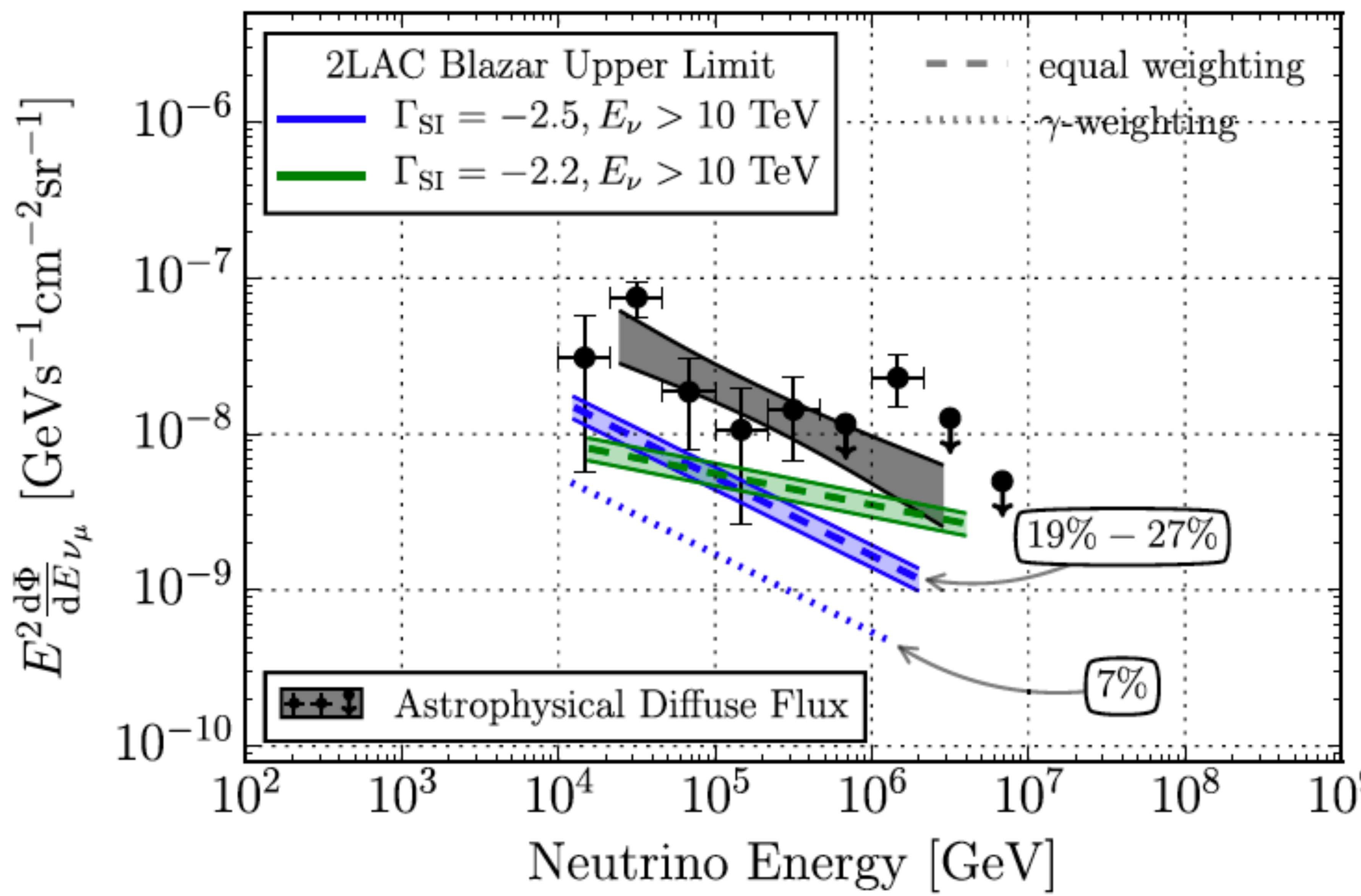
Constraints from Observations

- **Isotropy:** Galactic or Extragalactic
- **Temporal & spacial associations:** Transient or Steady sources with different event rates
- **Extragalactic Diffusive Gamma-Ray Observations:** Gamma-Ray emitters or Hidden in Gamma-Rays
- **UHECRs:** Cosmic Ray reservoirs or Cosmic Ray accelerators
- **Spectral Features:** Hadronuclear Production or Photohadronic Production
- **Flavors:** pion decay, muon-damped, neutron decay

The Contribution from Resolved Blazars



862 sources

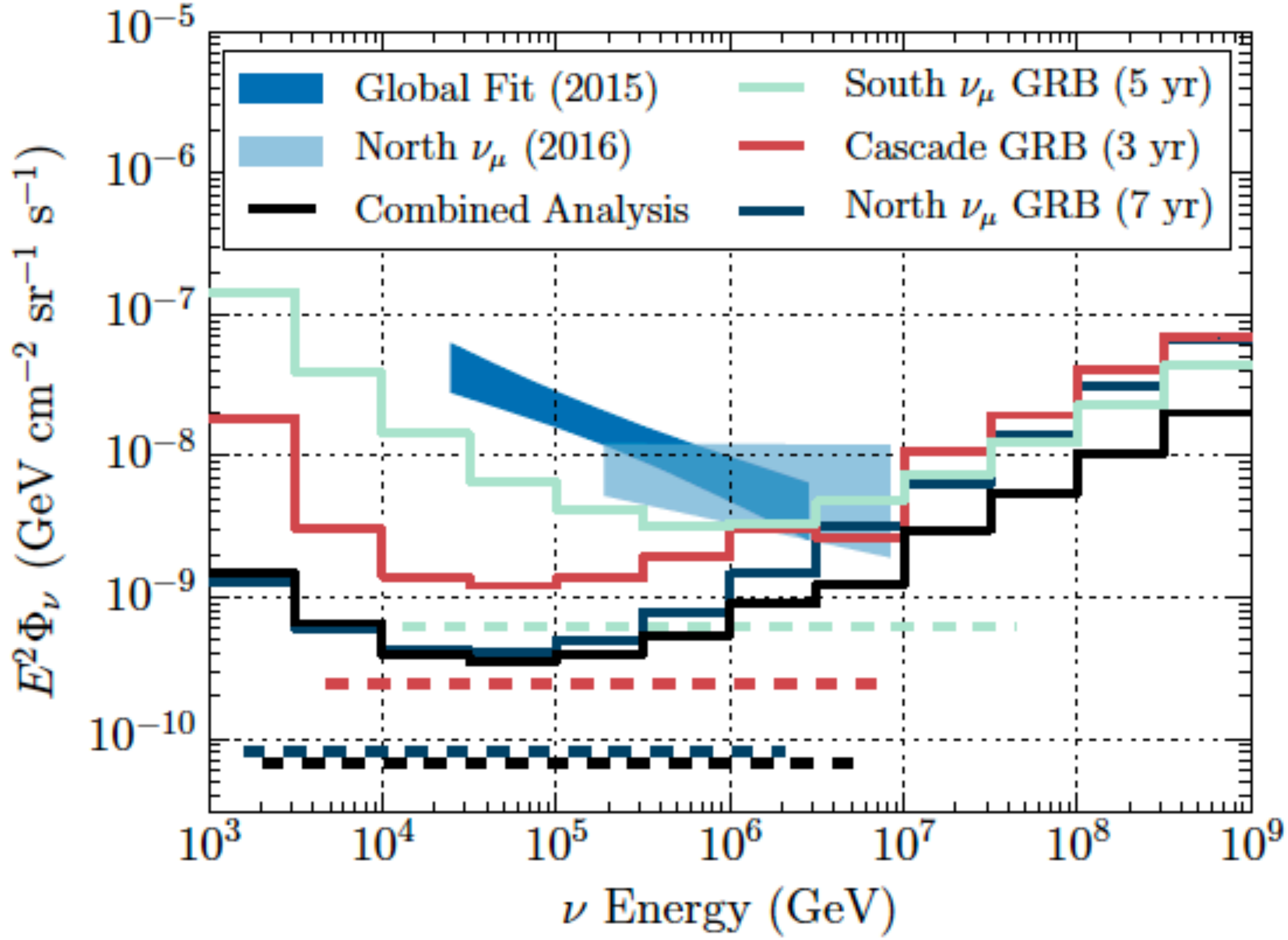


The IceCube Collaboration, 2017,ApJ,835,45A

Contribution from Prompt Observed GRBs

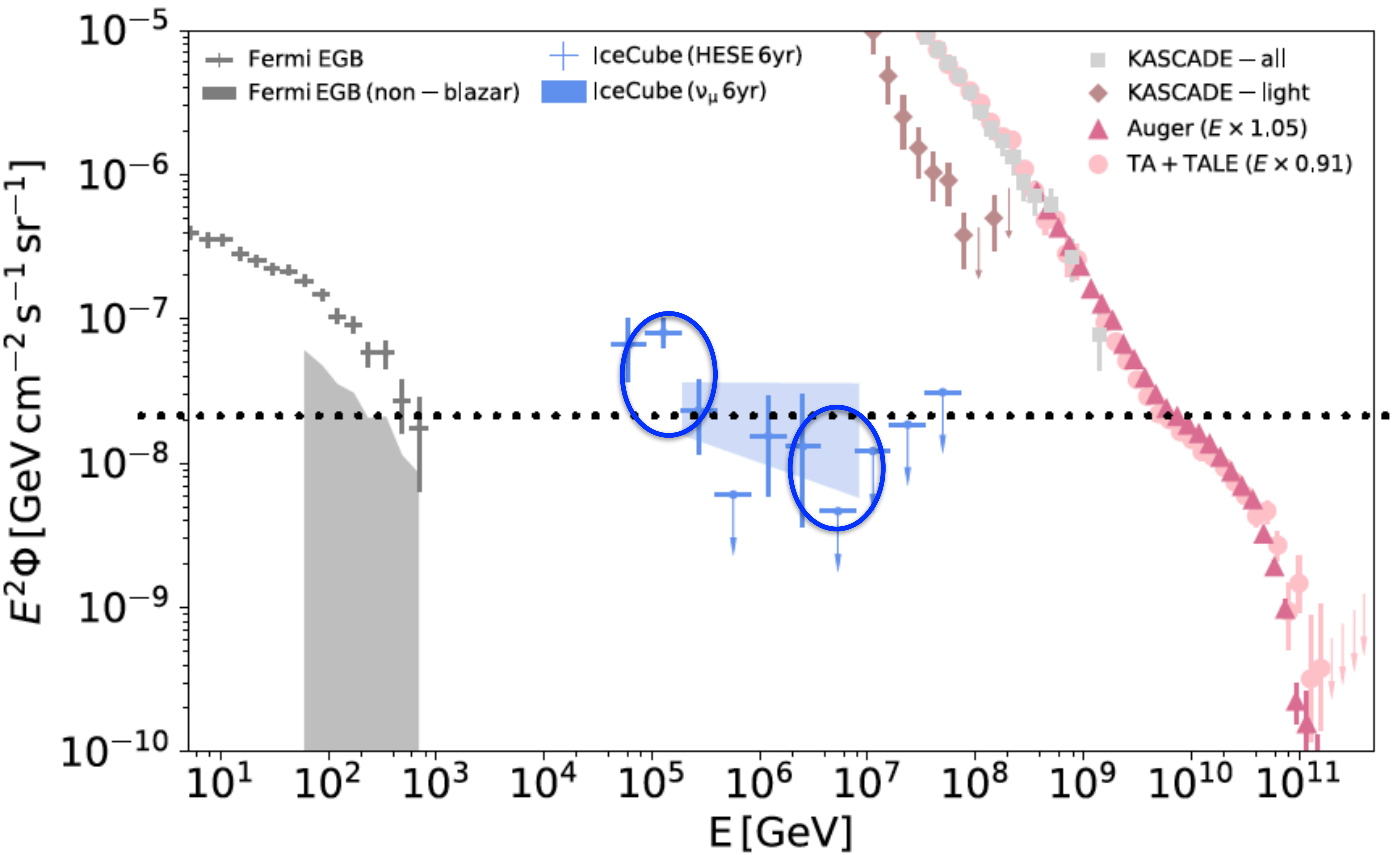
Short duration → minimal background

No neutrinos observed in coincidence with GRBs →



Prompt emission from GRBs can produce <1% of the observed neutrino flux.

arXiv:1702.06868



Fang&Murase 2018

Possible Models

1. The neutrino sources themselves are opaque to gamma rays (Hidden source) :

- choked jets in core-collapse massive stars (Meszaros & Waxman 2001; Razzaque et al.2004; Murase & Ioka 2013; Xiao & Dai 2014; Senno et al. 2016; …)
- choked jets in TDEs of supermassive black holes (Wang & Liu 2016; …)
- AGN cores (Stecker 2005; Murase et al. 2016; …)

2. The neutrino sources are distant (Chang et al. 2016;…)

- Starburst Galaxies (Chang et al. 2016; …)
- Galaxy Cluster (Fang & Murase 2018)

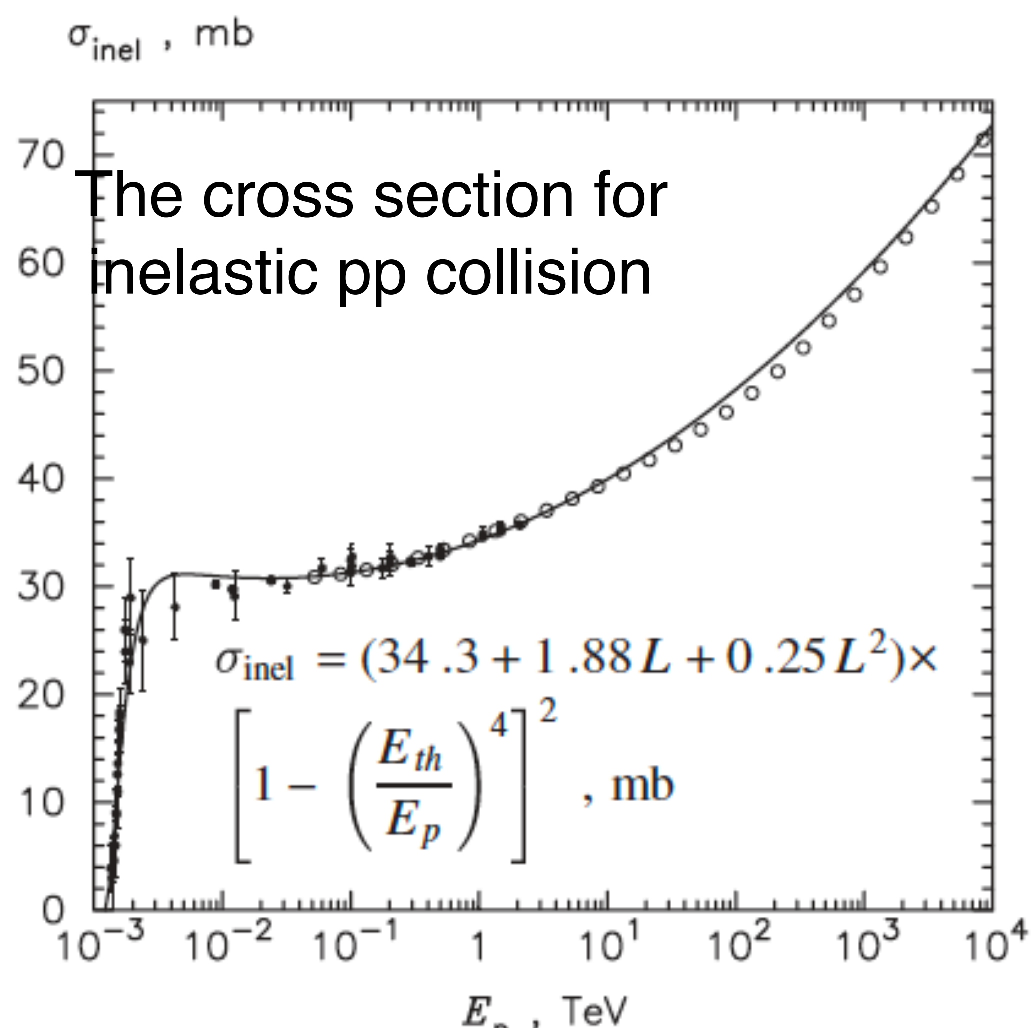
Features of Predicted Neutrino Spectra

Low energy cut off:

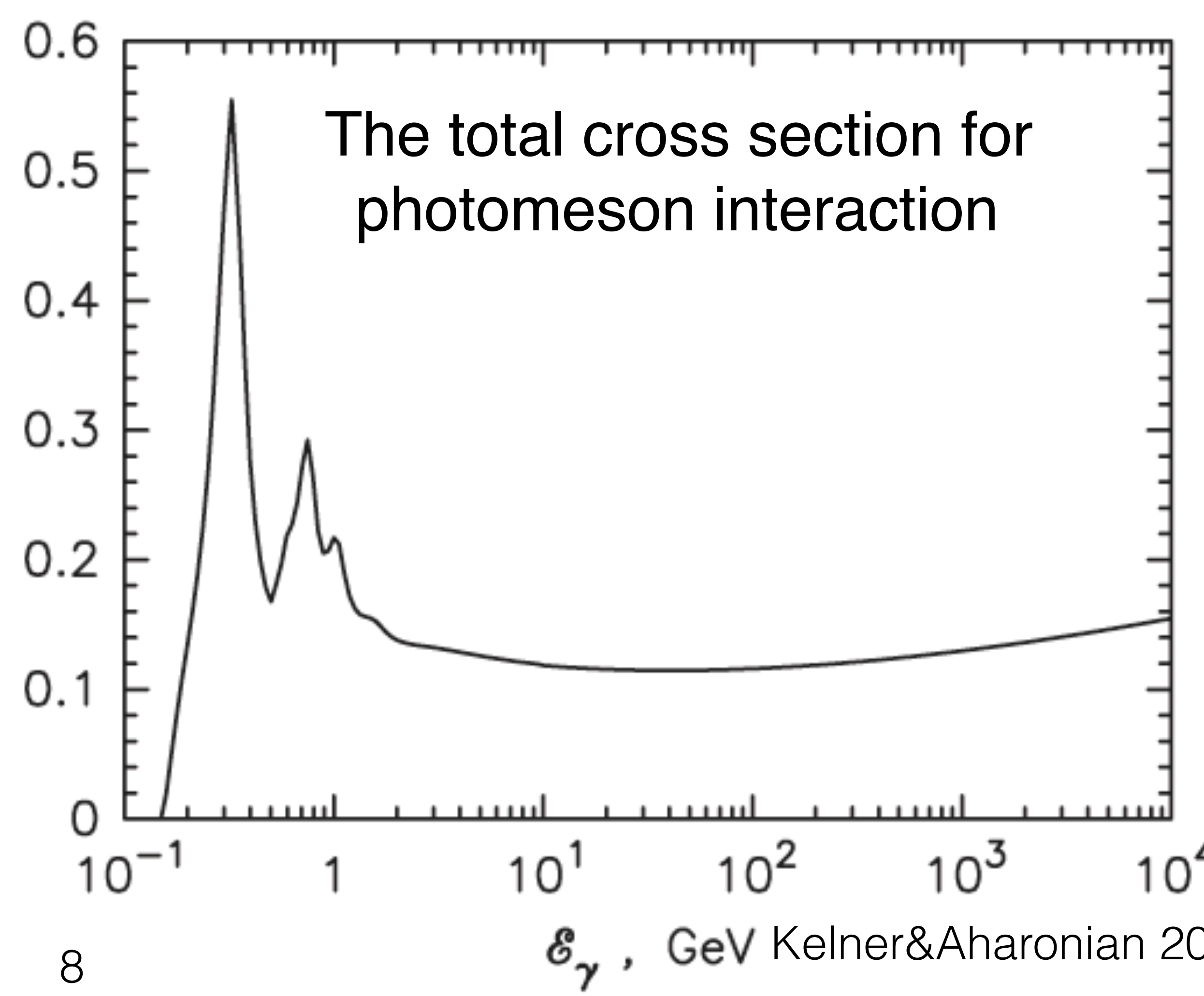
The threshold for interactions, Spectra of seed photons, Spectra of protons

High energy cut off:

1. Acceleration and cooling of protons
2. Secondary meson and muon cooling

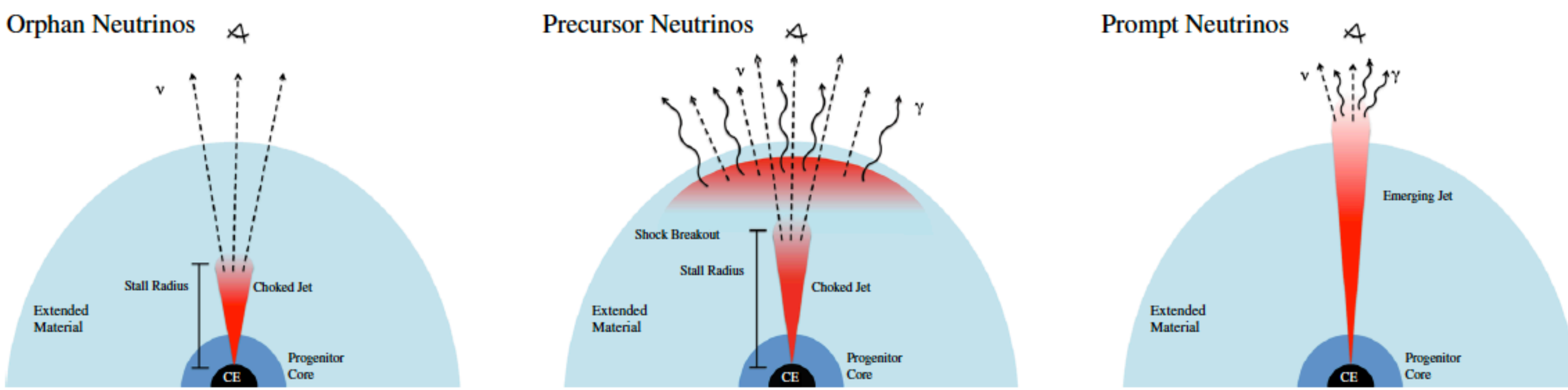


Kelner et al. 2006



Kelner&Aharonian 2008

Jets in Core-Collapse Massive Stars



Jet-driven SNe

Low luminosity GRBs (Shock breakout)

High luminosity GRBs & Low luminosity GRBs

Senno, Murase, & Meszaros 2016

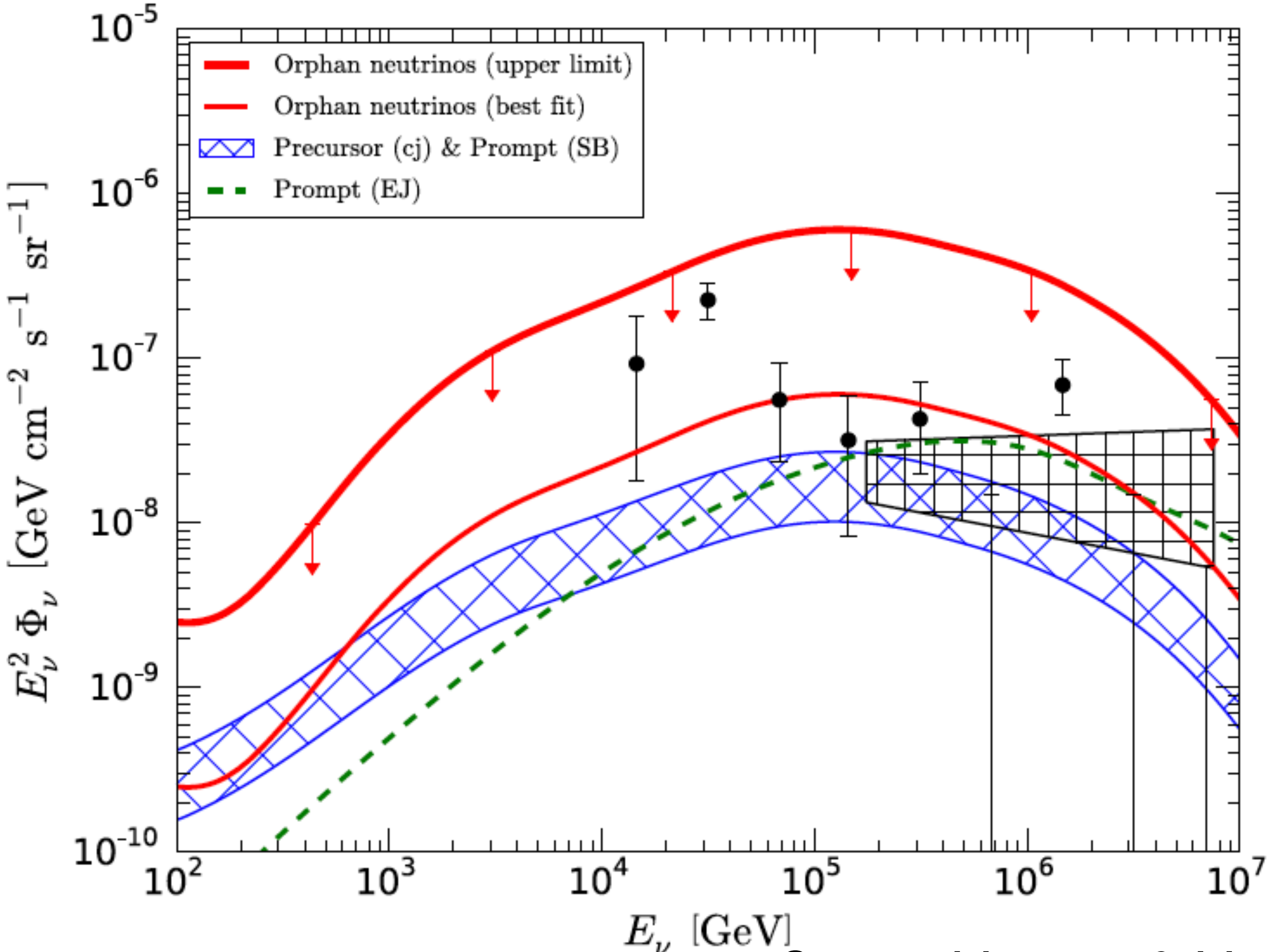
Local HL GRB rate: $0.8^{+0.1}_{-0.1}\ \mathrm{Gpc^{-3}\ yr^{-1}}$

Local LL GRB rate: $164^{+98}_{-65}\ \mathrm{Gpc^{-3}\ yr^{-1}}$

Local SNII rate: $10^5\ \mathrm{Gpc^{-3}\ yr^{-1}}$

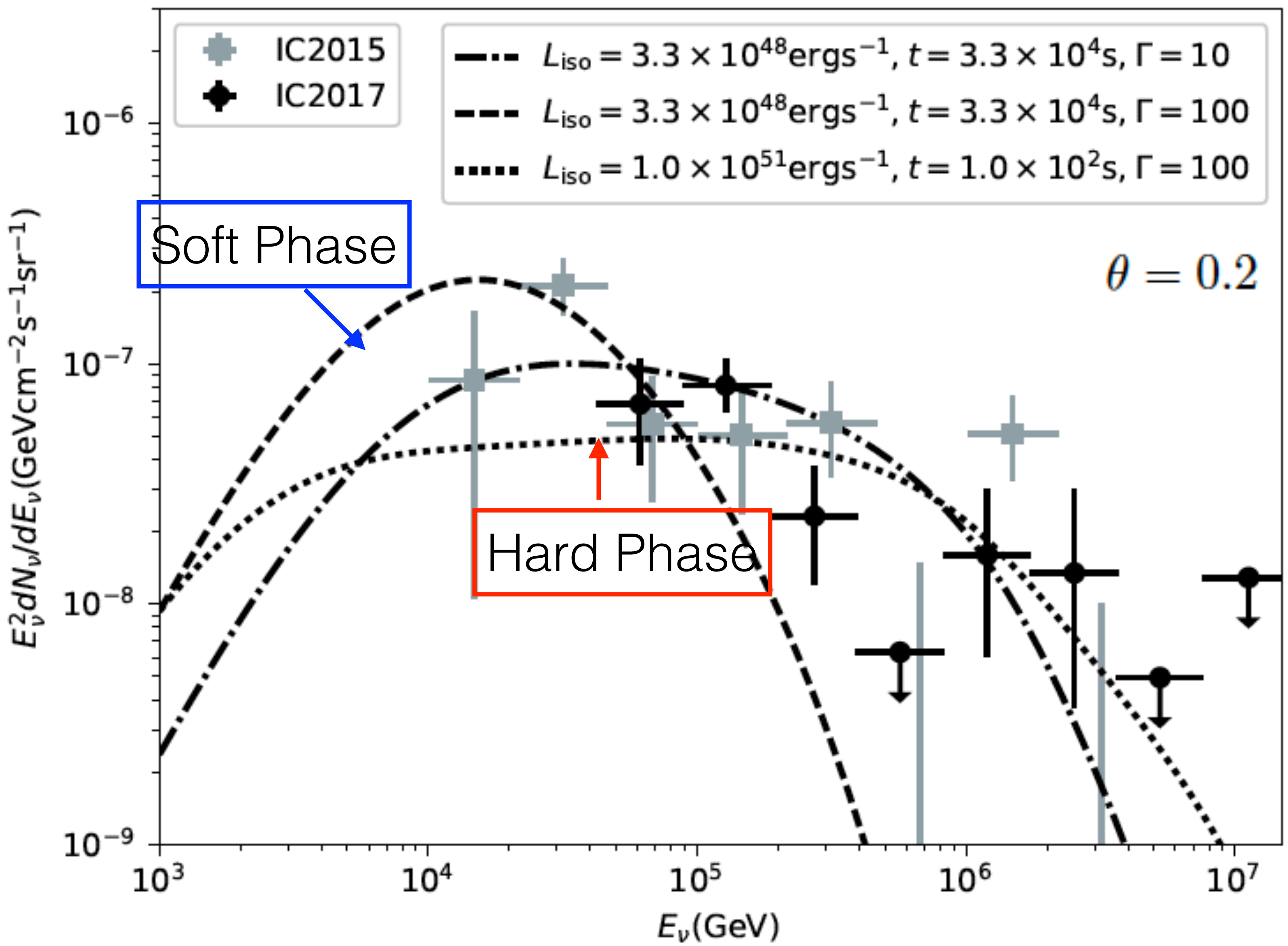
Orphan Neutrinos

CR Acceleration in jets
Target photons from jet head



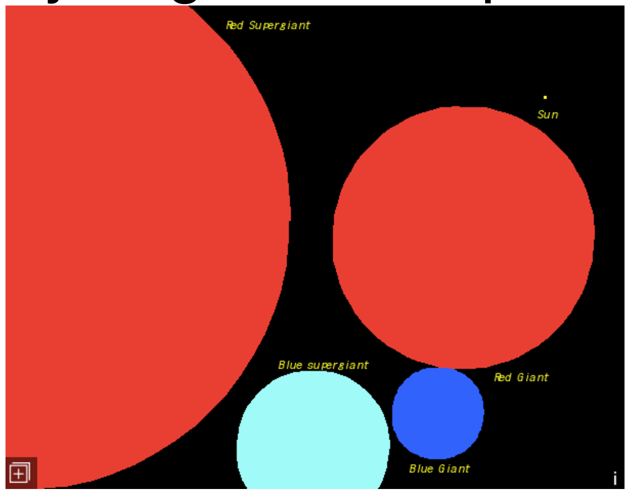
Senno, Murase, & Meszaros 2016

Choked Jets Accompanied with Type II Supernovae



He et al. (2018)

Hydrogen envelope: R $\sim 3 \times 10^{13}$ cm



Red Supergiant Stars

We assume the choked jet rate is in proportion to the star formation rate

$$R_{\mathrm{cj}} = A_{\mathrm{cj}} \rho_{\mathrm{sf}}$$

$$\rho_{\mathrm{sf}} = 0.015 \frac{(1+z)^{2.7}}{1 + [(1+z)/2.9]^{5.6}} M_\odot \mathrm{yr}^{-1} \mathrm{Mpc}^{-3}$$

Madau & Dickinson (2014)

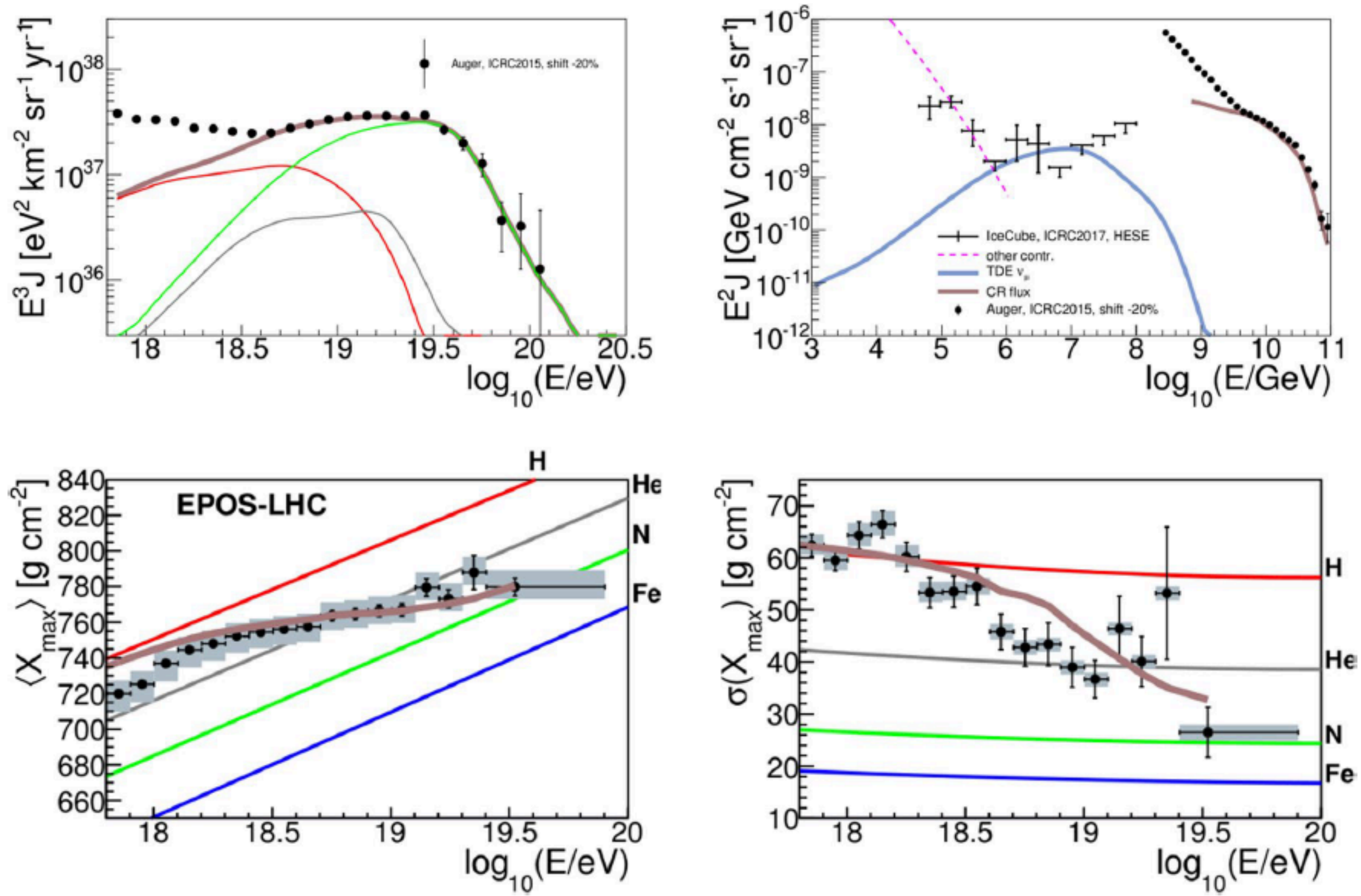
The constrained local rate of the choked jet: 1%-20% of the typical SNII rate

The rate of a muon neutrino multiplet within time window of 100-100,000 s: ~0.4/year

He et al. 2018ApJ...856..119H

Tidal Disruption Events

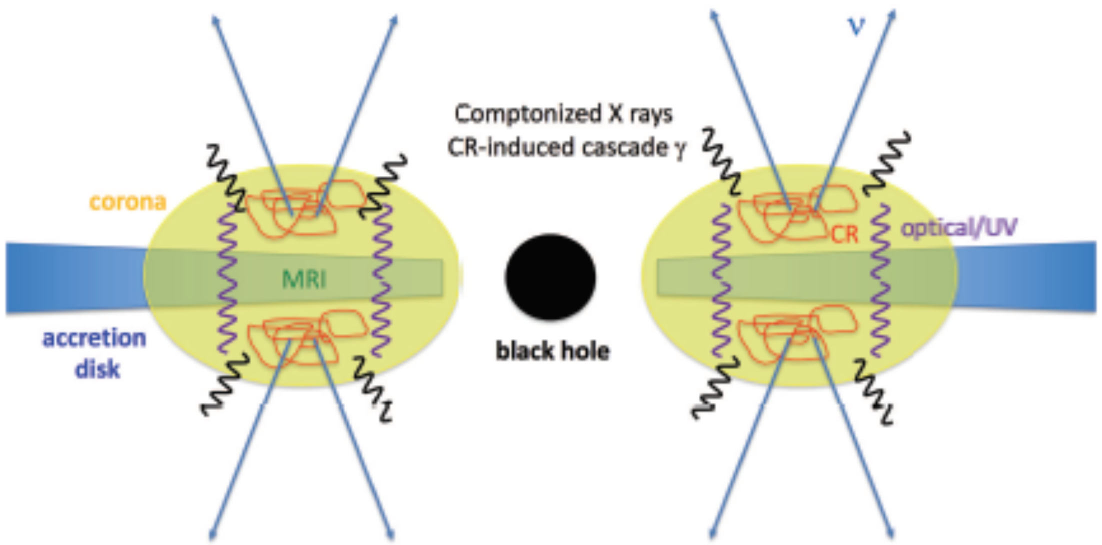
Photo-hadronic interactions both in the TDE jet and in the propagation.

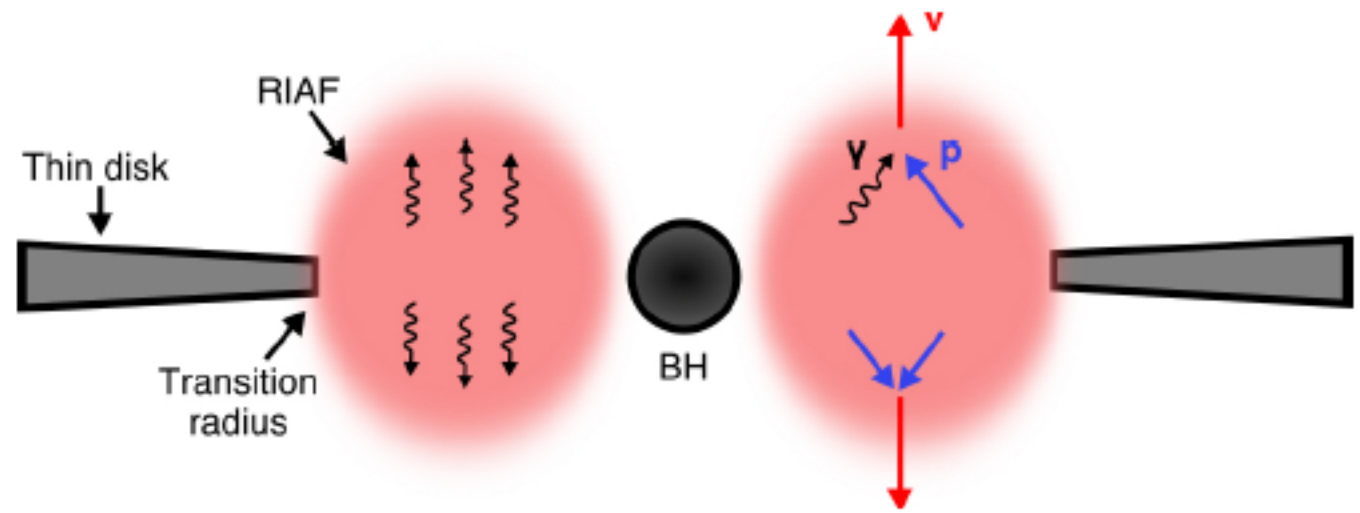


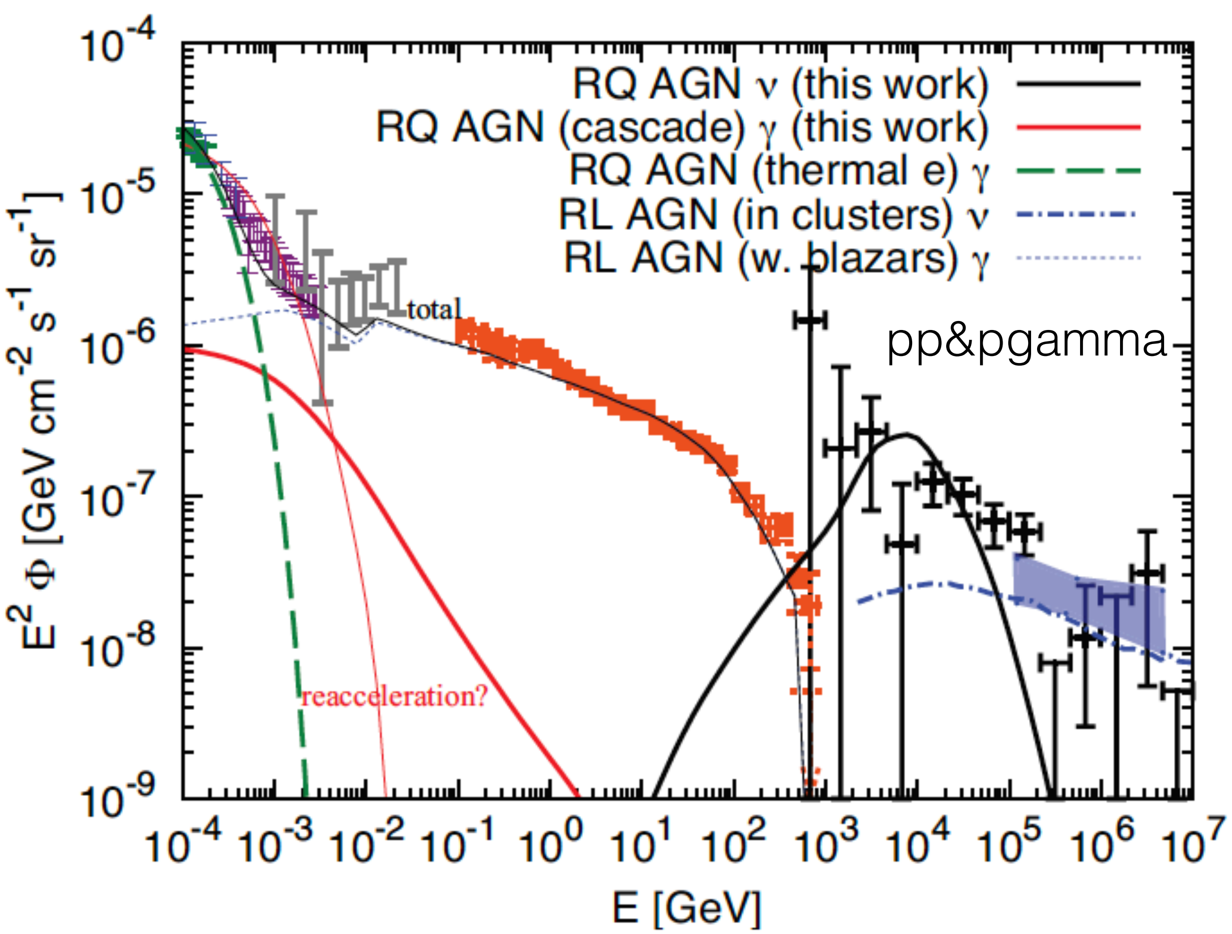
Wang&Liu 2016, Biehl et al. 2018, Guepin et al. 2018

Hidden AGN cores

CR acceleration in corona, accretion disk, or radiative inefficient accretion flows.

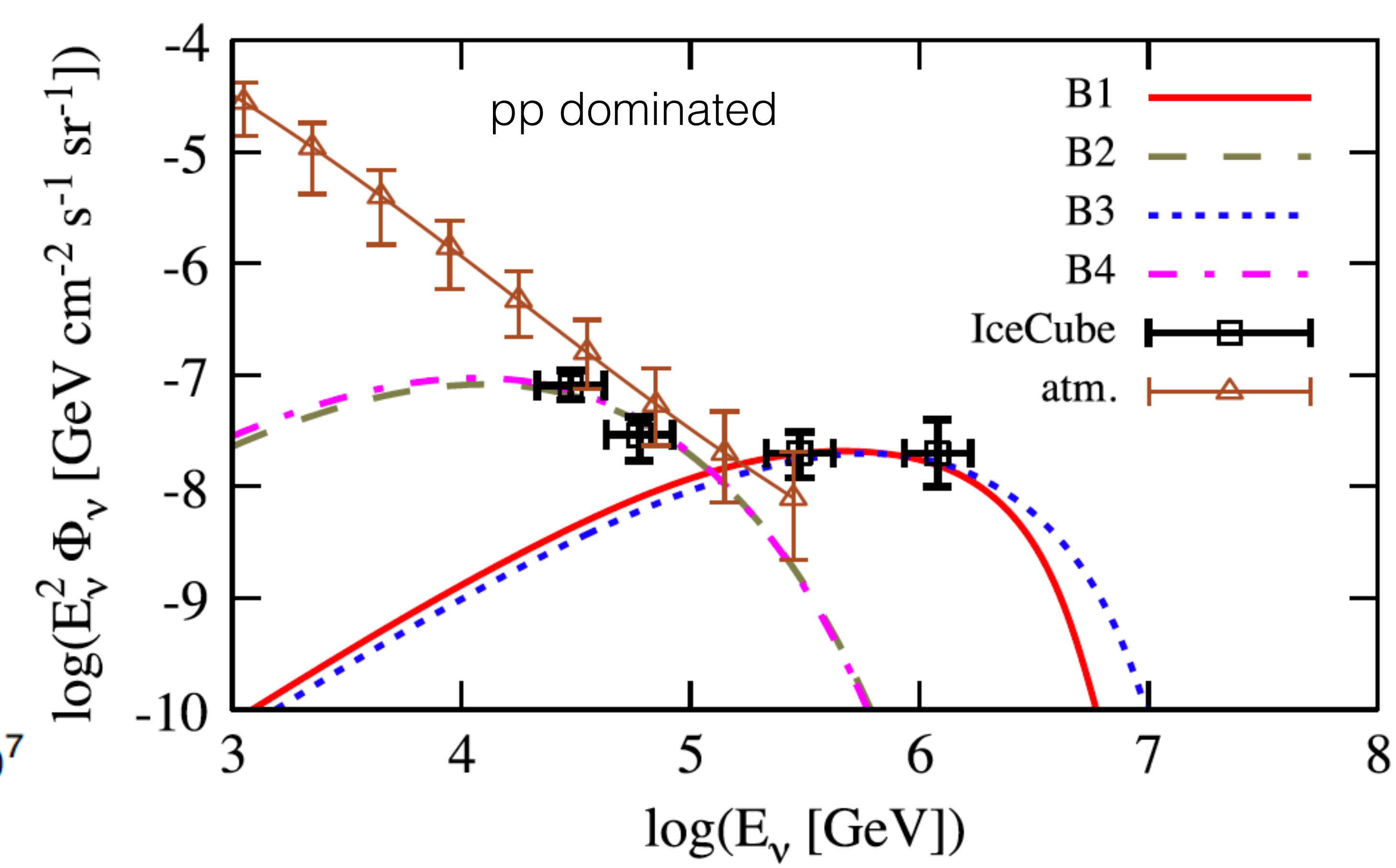






Balancing among the acceleration, cooling, and escape processes

Murase et al. 2019



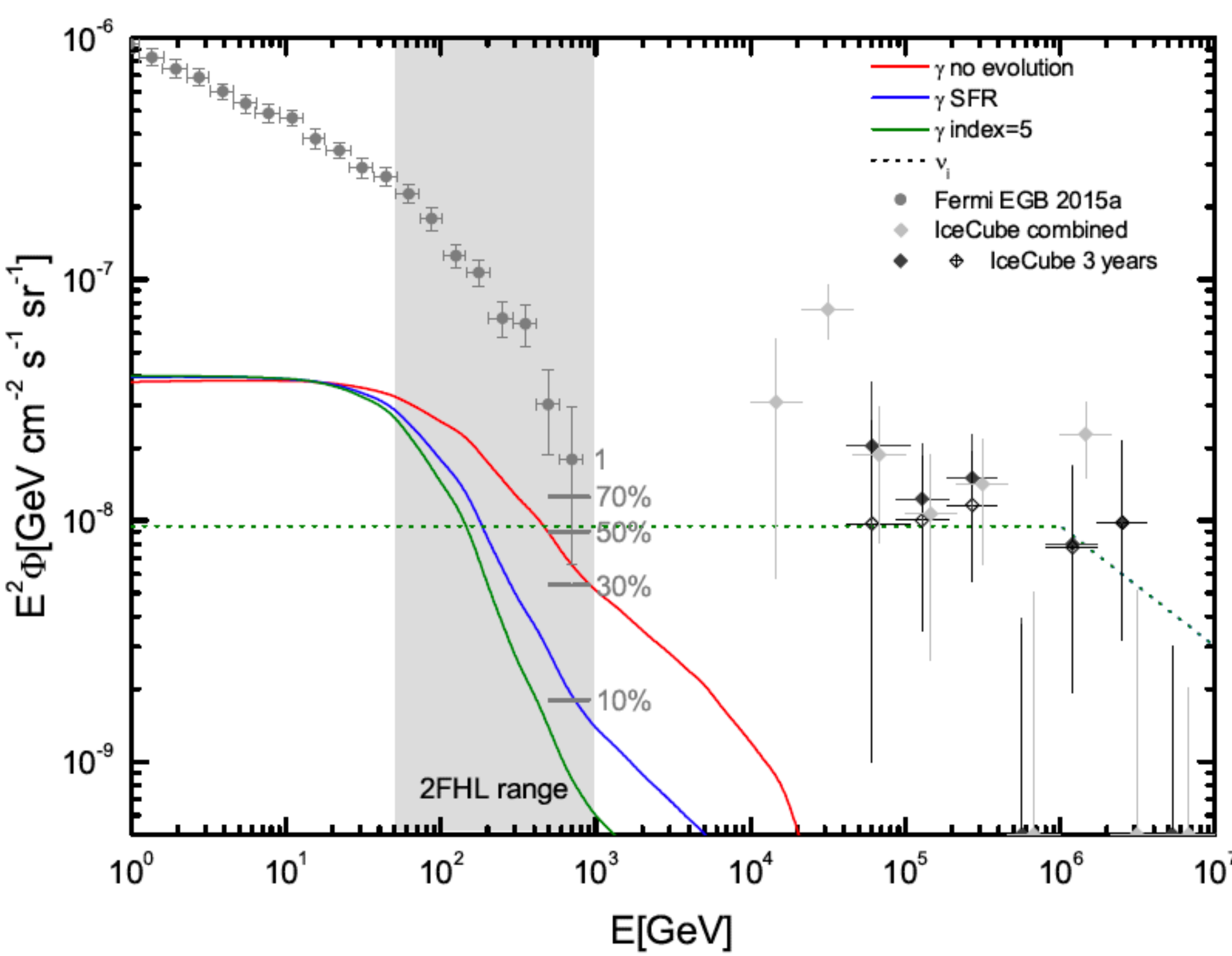
Kimura et al. 2015

Starburst Galaxies/Star-forming Galaxies

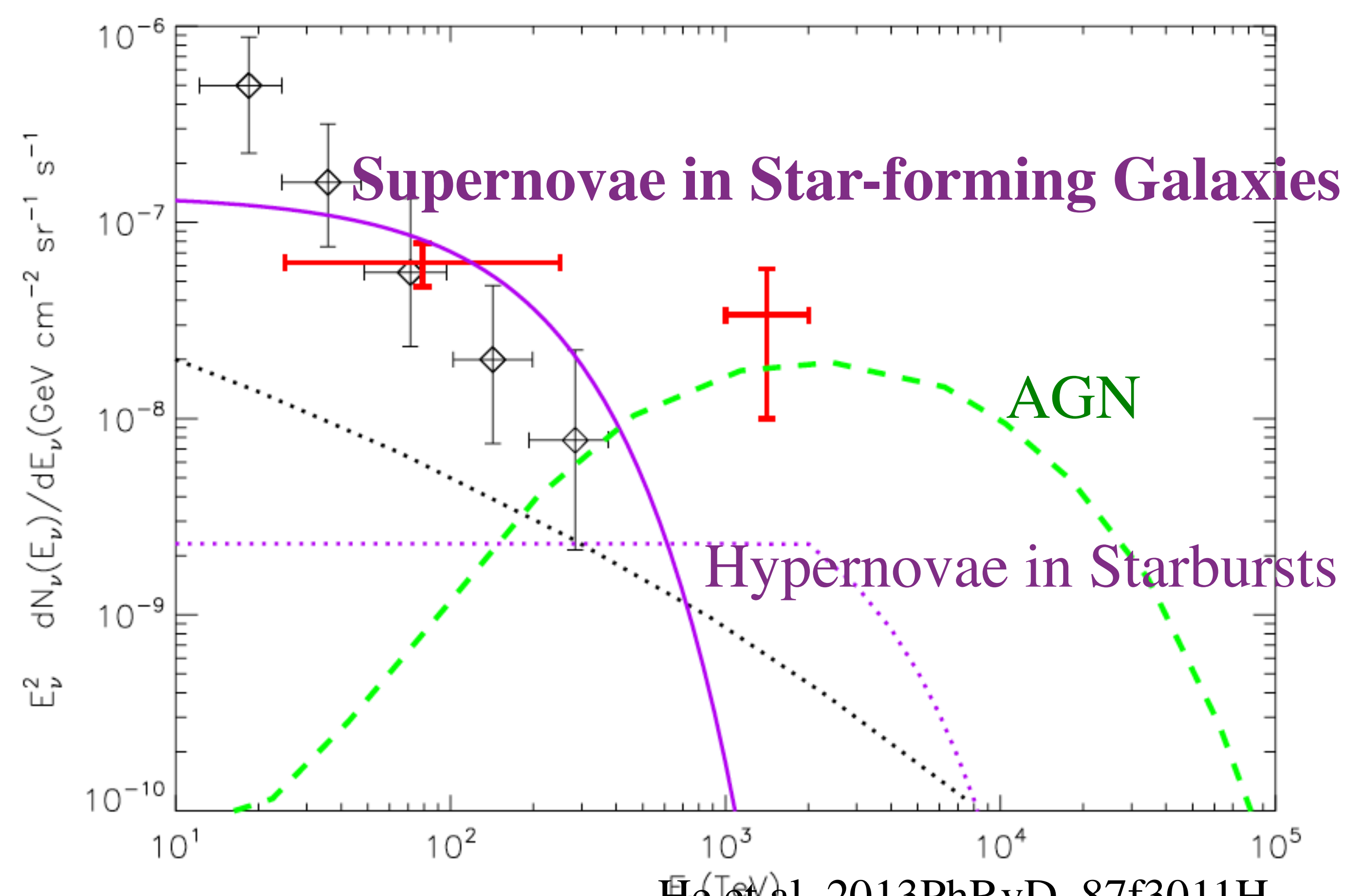
Accelerators: AGN, SNe/HNe, Starburst Wind

High star formation rate → High Supernova/Hypernova Rate

Dense ISM+ Strong Magnetic Field → $\tau_{\mathrm{conf}} \geqslant \tau_{\mathrm{loss}}$ → pp collission before escaping for <1PeV~100PeV protons



Chang et al. 2016

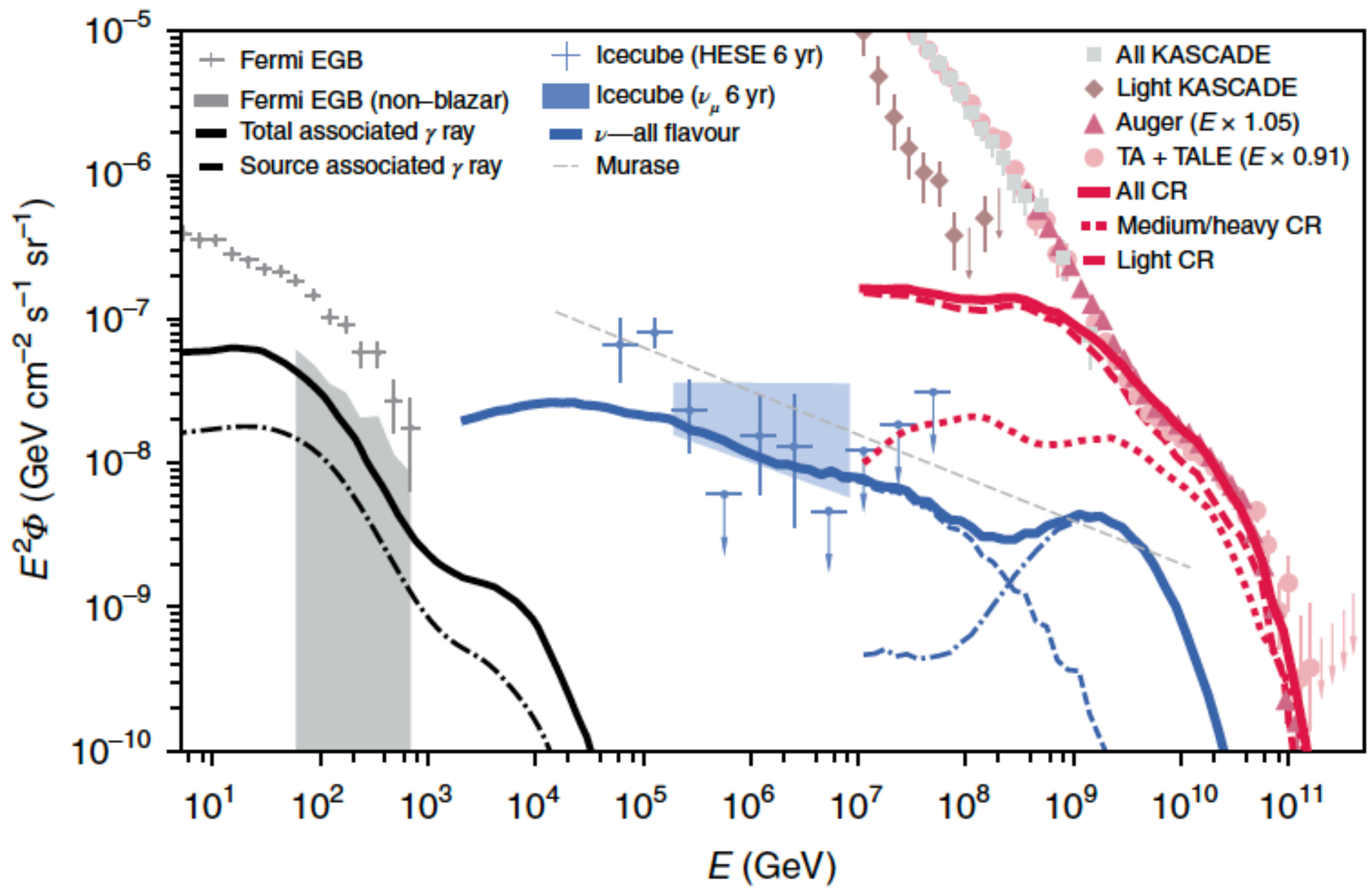


He et al. 2013PhRvD..87f3011H,
He et al., 2013arXiv1307.1450H

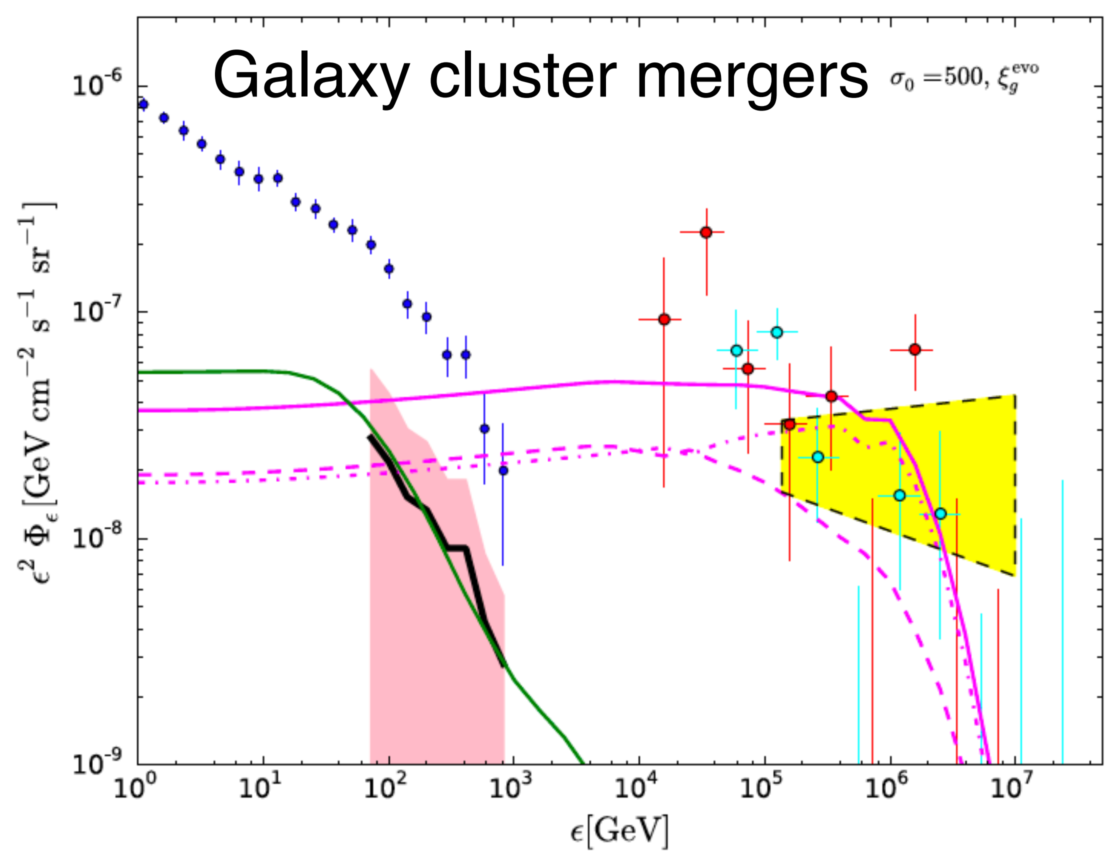
Galaxy Clusters

Cosmic Ray Accelerators in Galaxy Clusters:

1. Large scale accretion shocks (Blandford et al. 2018…)
2. Shocks produced via Galaxy cluster mergers
3. AGN jets
4. Other central sources following star formation



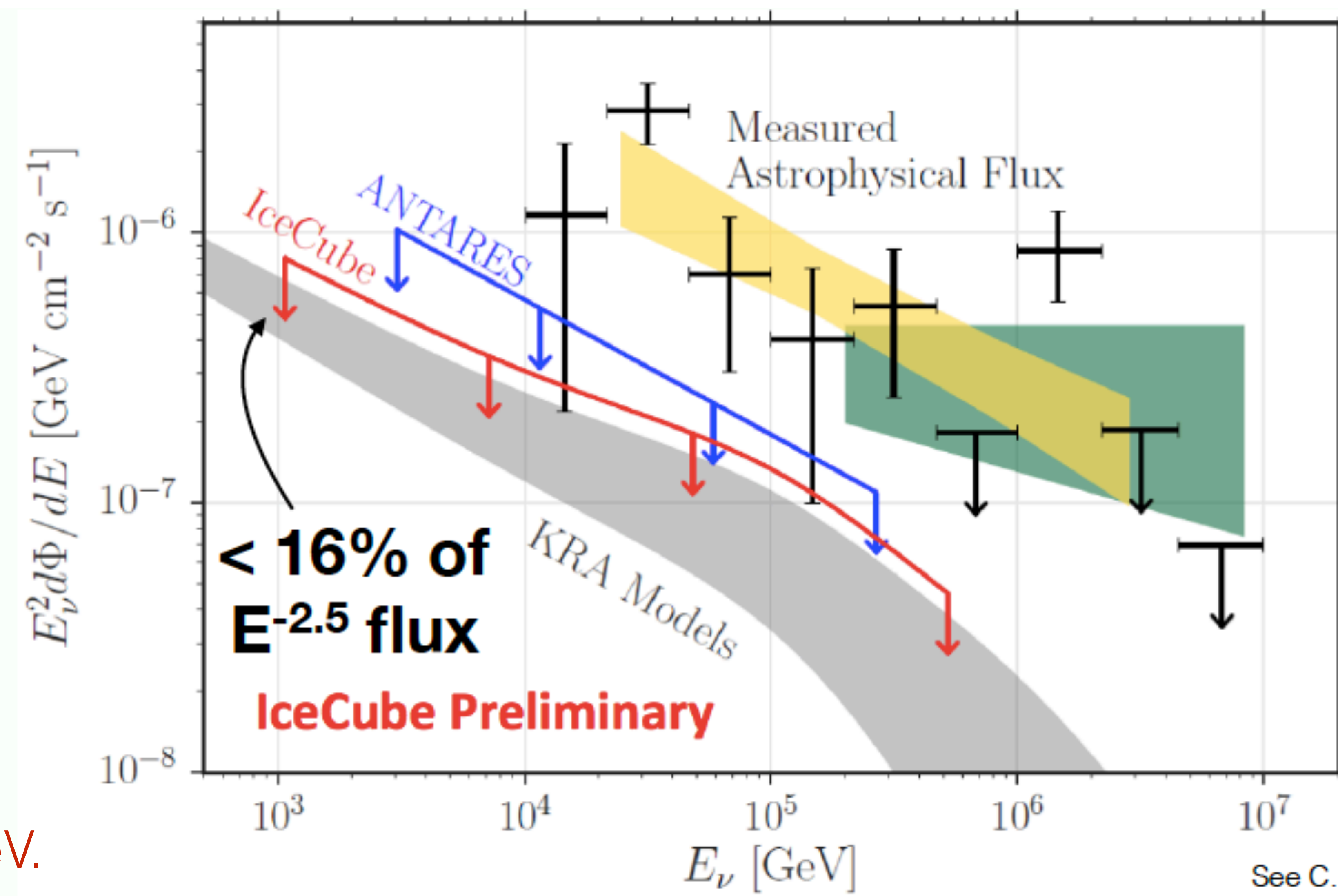
Fang & Murase 2018



Yuan et al. 2018

Galactic Sources

- SN Accompanied with Molecular Clouds
- PWN
- Fermi Bubble
- Galactic Center
- Galactic Halo
- Galactic Lobe
- Other TeV gamma-ray sources



Two Assumptions:

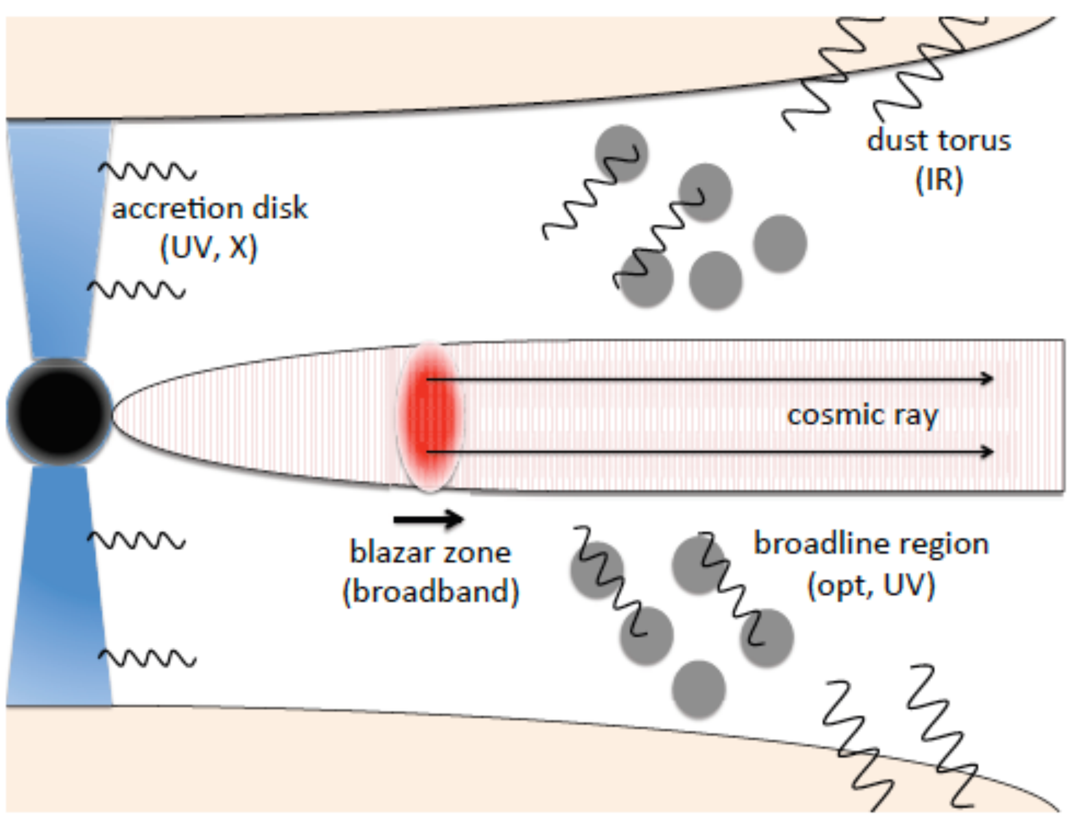
1. Hadronic Origin
2. Cosmic rays are accelerated to >PeV.

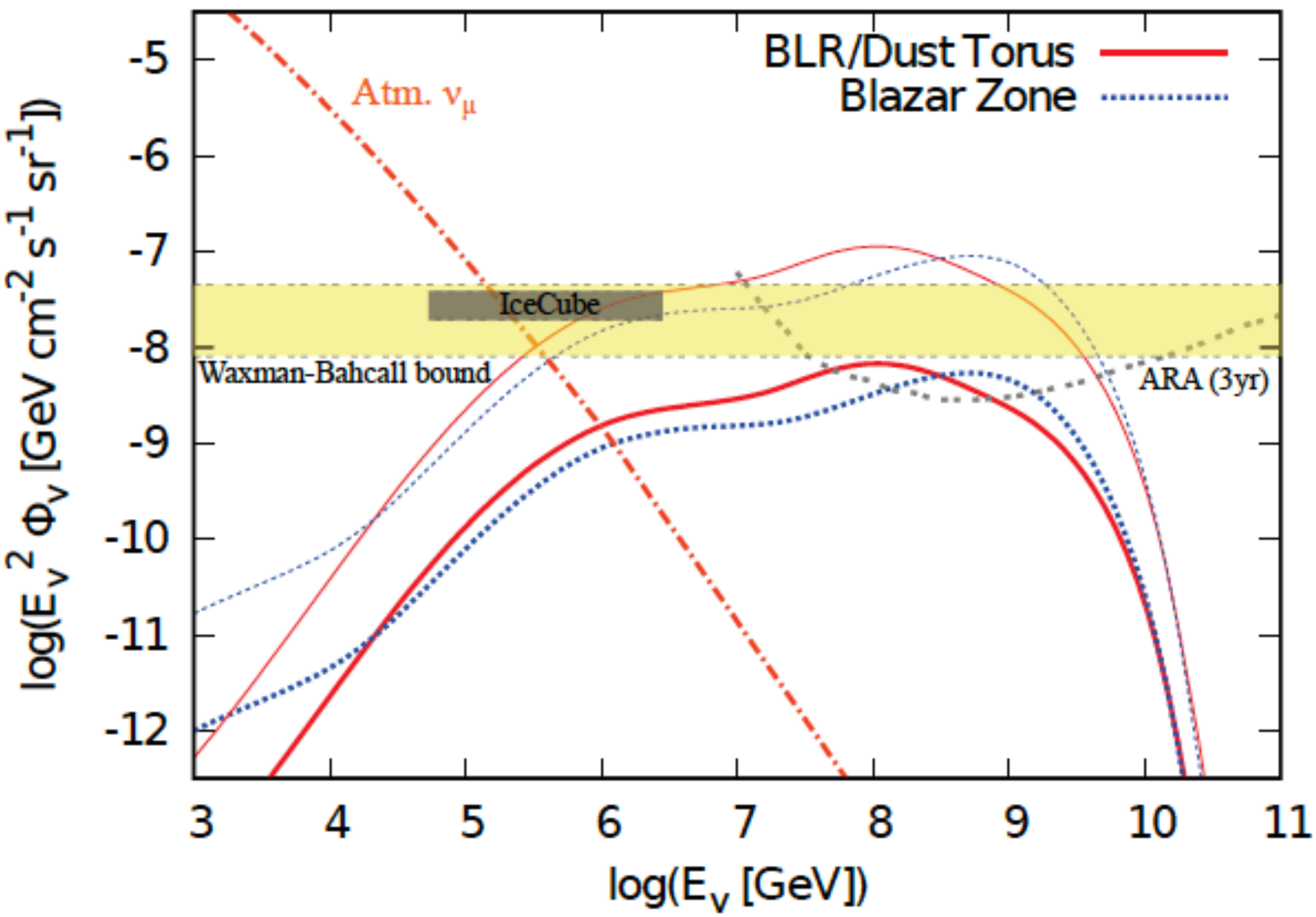
See C. Haack, NU013
arXiv:1707.03416

Models	Interaction	<100 TeV excess	HE cutoff	UHECR
Choked jets in Core Collapse Massive stars	Photohadronic	Yes	~10TeV-~PeV	No
TDEs	Photohadronic	No	~10 PeV	Yes
AGN cores	Photohadronic/ Hadronuclear	Yes	~10TeV-~PeV	No
Starburst Galaxies/ Starforming Galaxies	Hadronuclear	Yes	~100TeV-~PeV	?
Galaxy Clusters	Hadronuclear	No	~PeV-~EeV	Yes
Galactic Sources	Photohadronic/ Hadronuclear	?	~100TeV	No

Blazar Neutrinos >PeV

Acceleration in the jets.
Target photons from dust torus, BLR, blazar zone

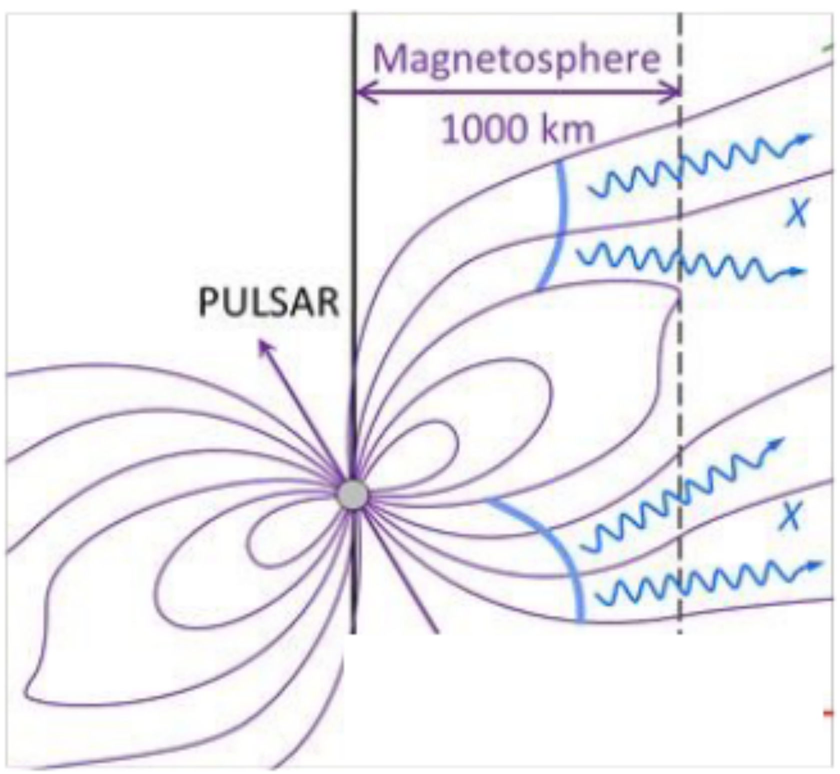


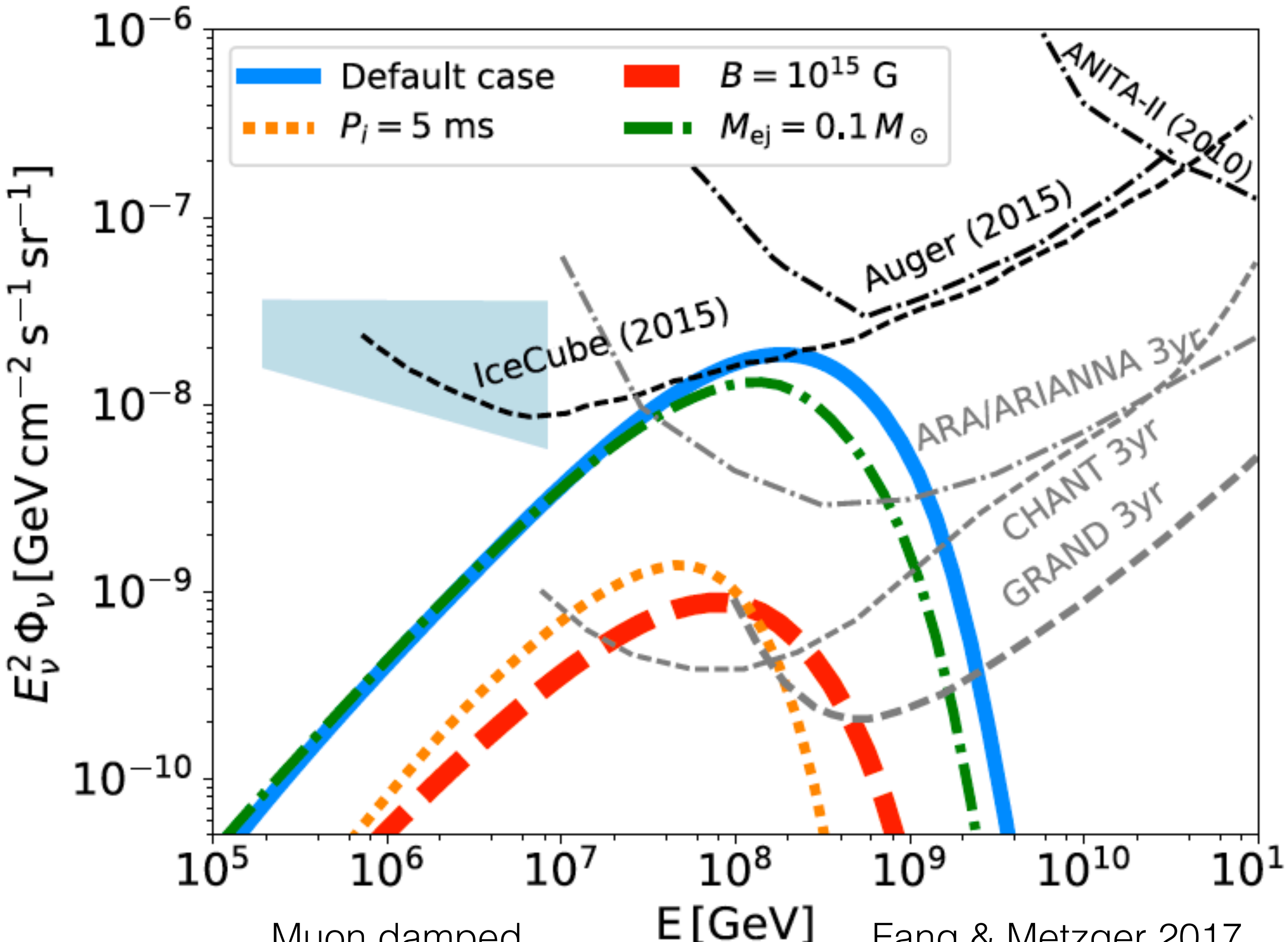


Murase et al.2014

Magnetars

Cosmic Ray Acceleration in Pulsar magnetosphere.
Target photons from nebula: Optical/UV/X-ray



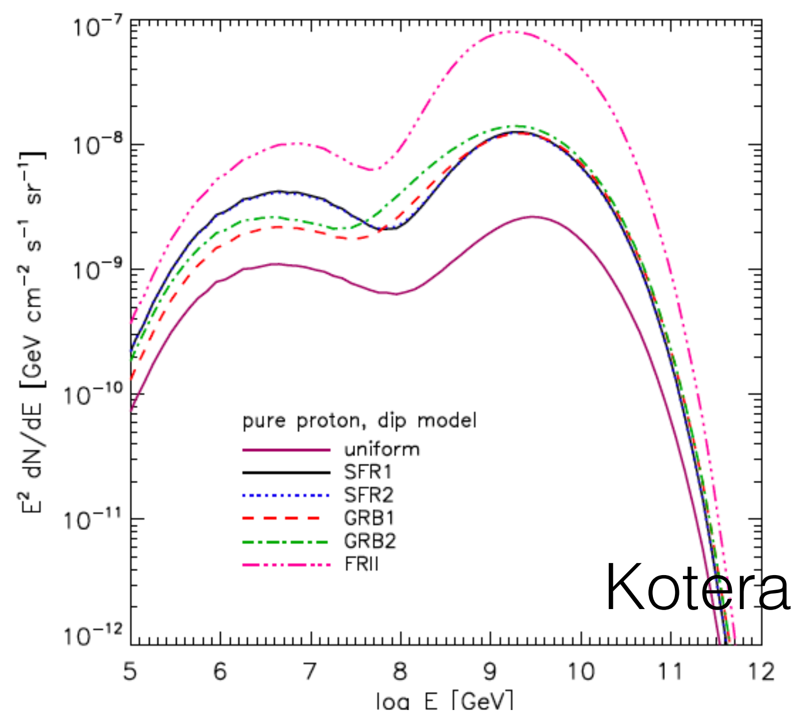


Muon damped

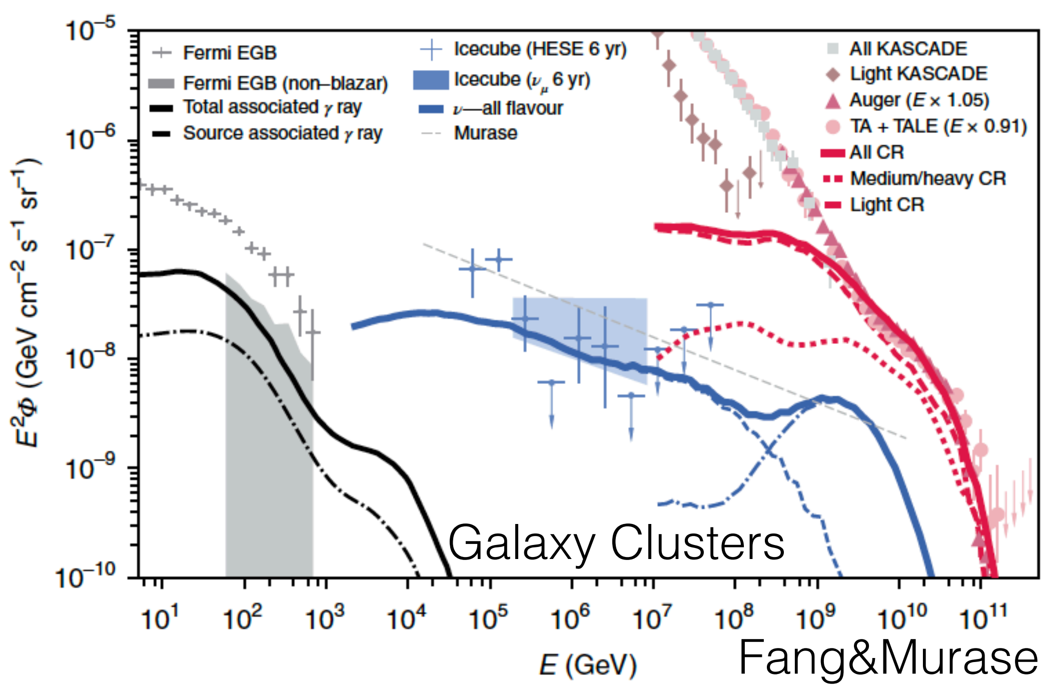
Fang & Metzger 2017

Cosmogenic neutrinos

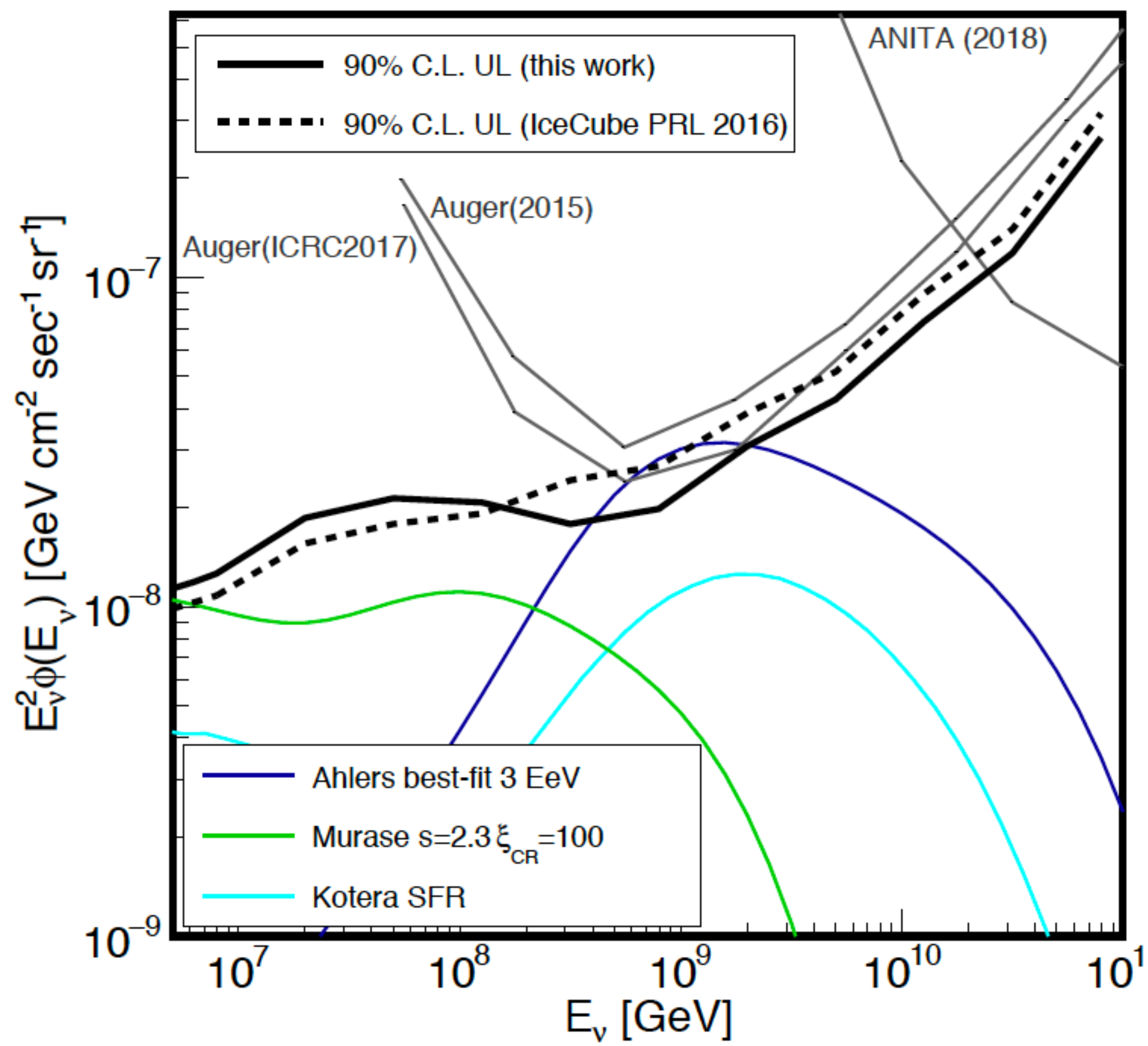
UHECRs accelerated by GRBs or young magnetars, AGNs, or Galaxy Clusters
Target photons:EBL,CMB
IceCube & Auger constrain on source evolutions



Kotera et al. 2010



Fang&Murase 2018



The IceCube, 2018

Summary

- Diffuse extragalactic gamma-ray observations & UHECRs constrain neutrino source models.
- <100 TeV excess? Chocked jets accompanied with SNII, Hidden AGN cores, Galactic Sources
- High Energy cutoff
- EeV neutrinos: Blazars, young magnetars, cosmogenic neutrinos from AGN, GRB, and galaxy clusters