ICECUBE NON-DETECTION OF GRBS: CONSTRAINTS ON THE FIREBALL COMPOSITION AND IMPLICATIONS FOR UHECRS &DIFFUSE PEV NEUTRINO EMISSION FROM ULTRA-LUMINOUS INFRARED GALAXIES

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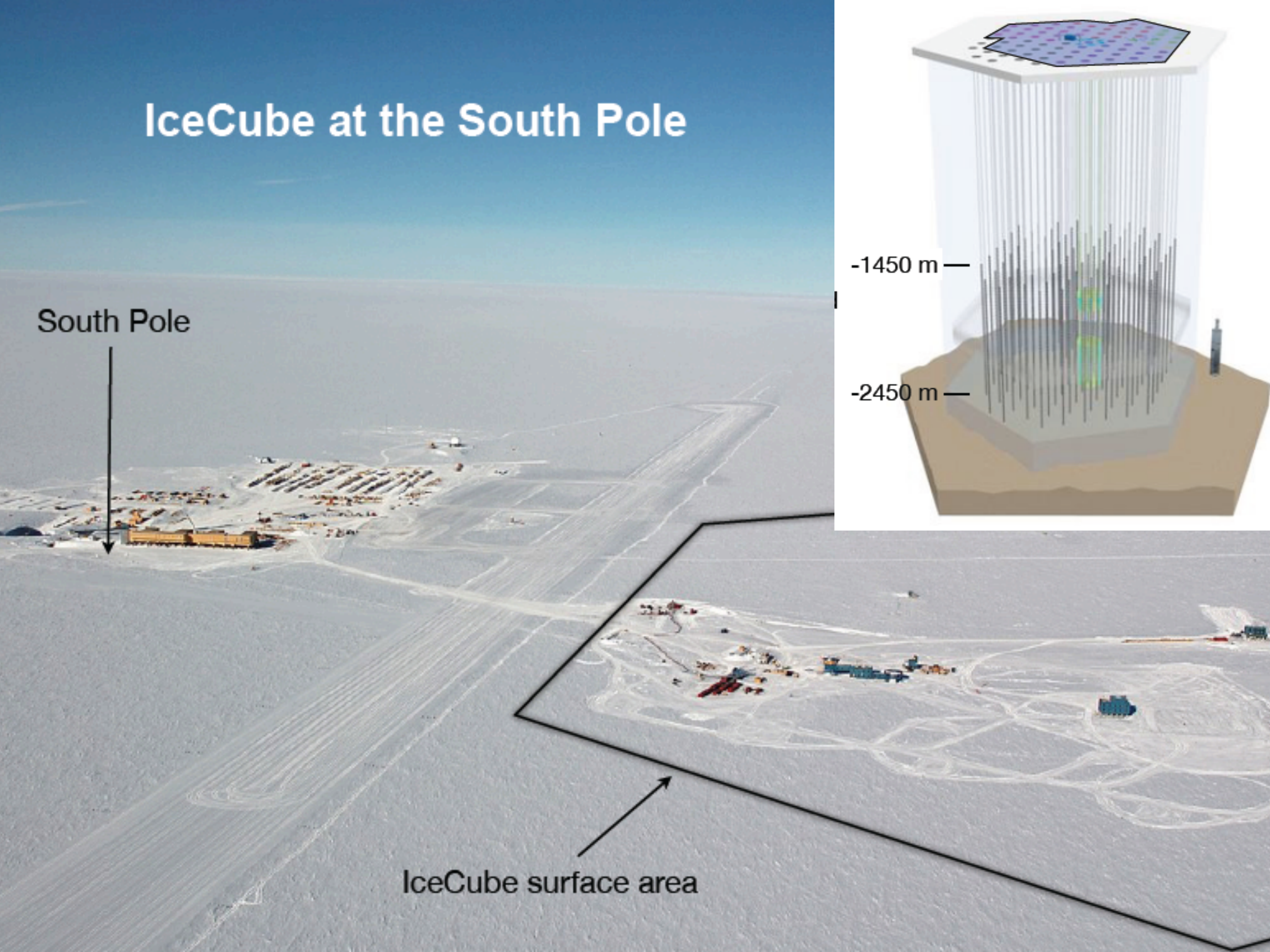
Purple Mountain Observatory

Lewes, Delaware,2013.06.01

IceCube at the South Pole



IceCube non-detection of GRBs: Constraints on the fireball composition and implications for UHECRs

He et al. 2012 ApJ, V752-29

- Haoning He
- Coauthors: Ruoyu Liu, Xiangyu Wang, Shigehiro Nagataki, Kohta Murase, Zigao Dai

GRB neutrinos

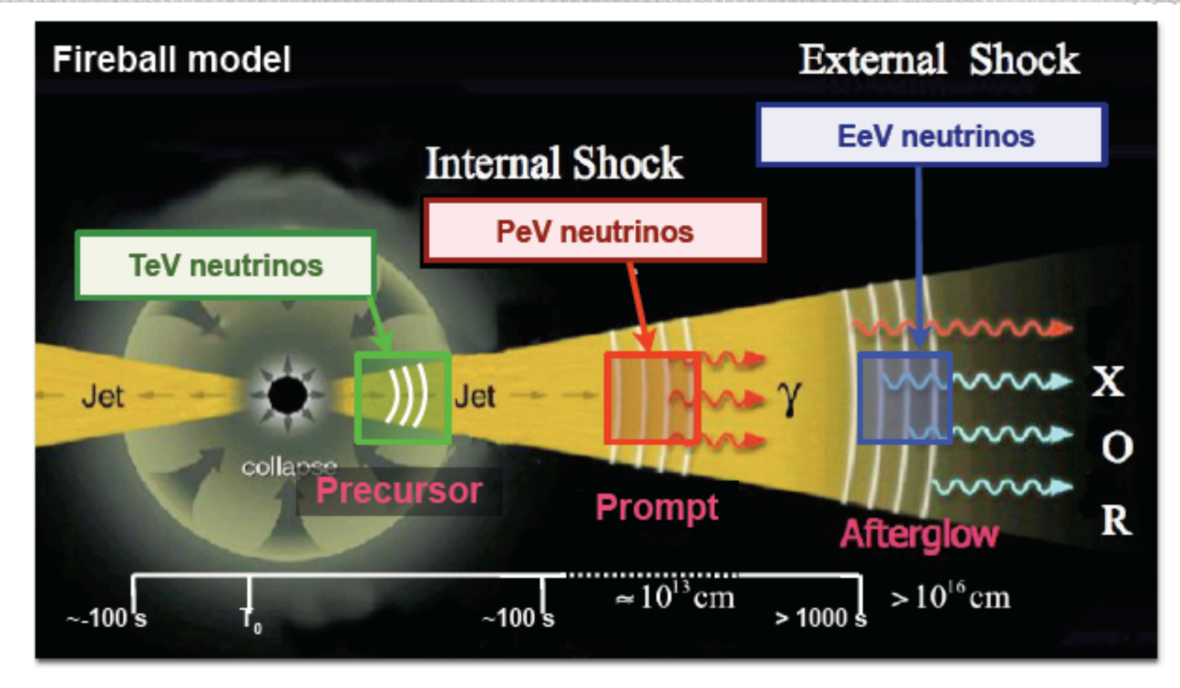
Assumptions:

Protons and electrons are accelerated in GRB fireball.
GRB is the major source of UHECRs.
Waxman & Bahcall 1997

$$p\gamma \to \Delta \to n\pi^+$$

$$\pi^+ \to \nu_\mu \mu^+ \to \nu_\mu e^+ \nu_e \bar{\nu}_\mu$$

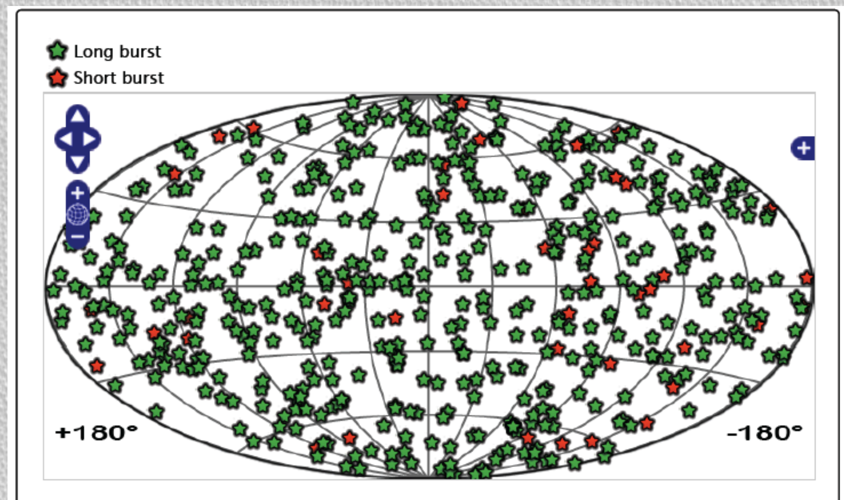
$$p\gamma \to \Delta \to p\pi^0$$



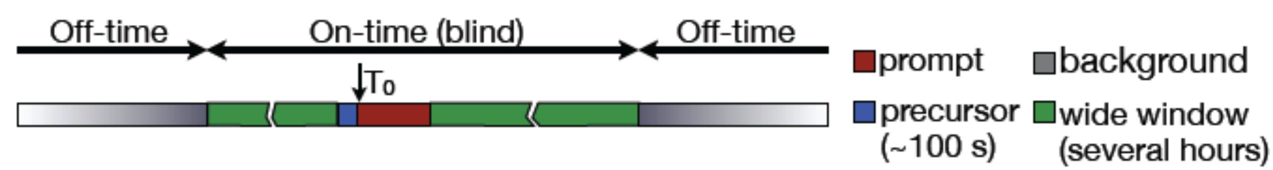
kappes' talk in kyoto, 2010

IceCube Data Analysis

GRBs Sky Map (2008.04.05-2010.05.30 during the operations of IceCube 40-string and 59-string configuration from North sky)



http://grbweb.icecube.wisconsin.edu

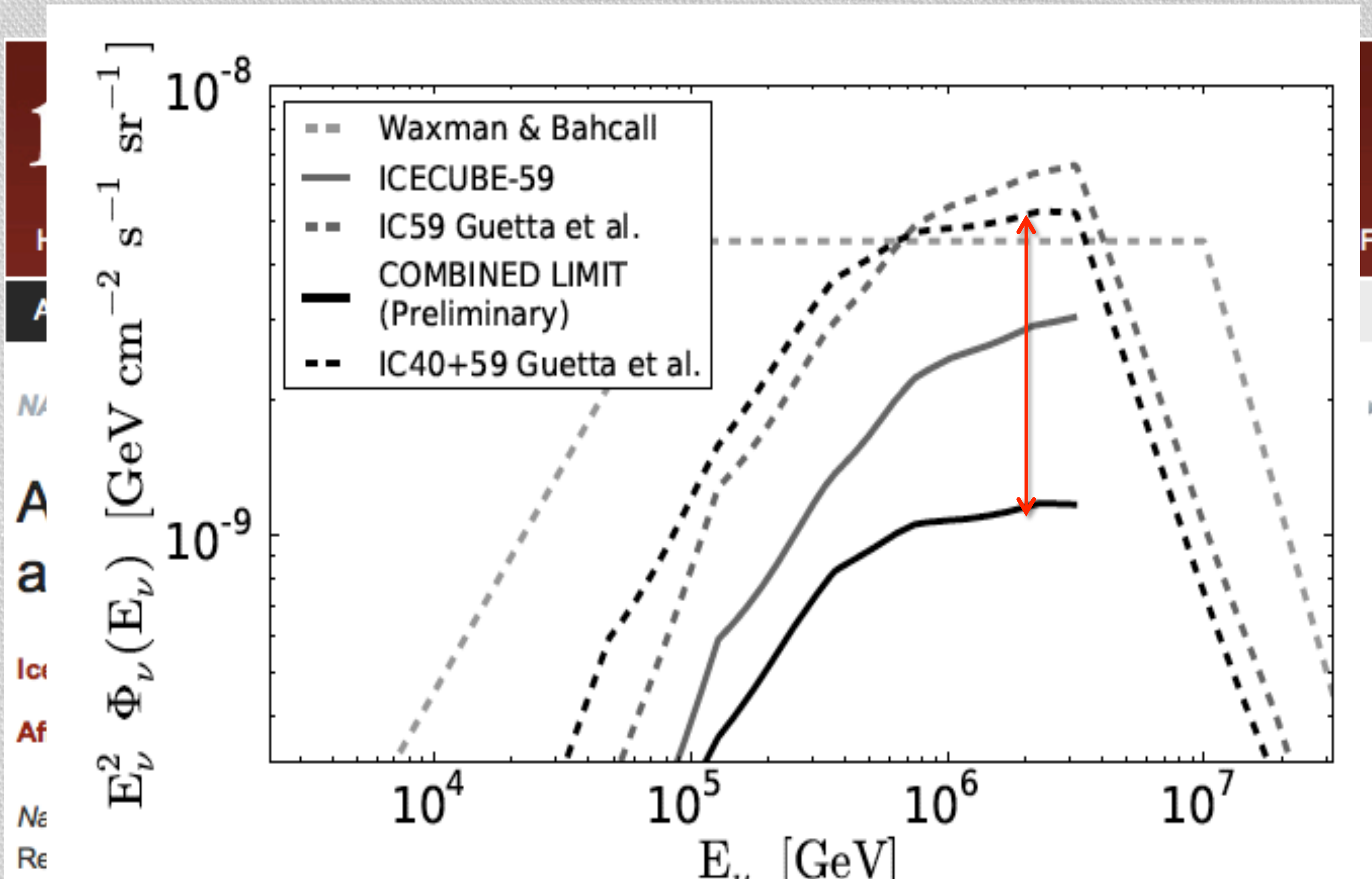


very low background → 1 event can be significant !

Kappes' talk in kyoto, 2010

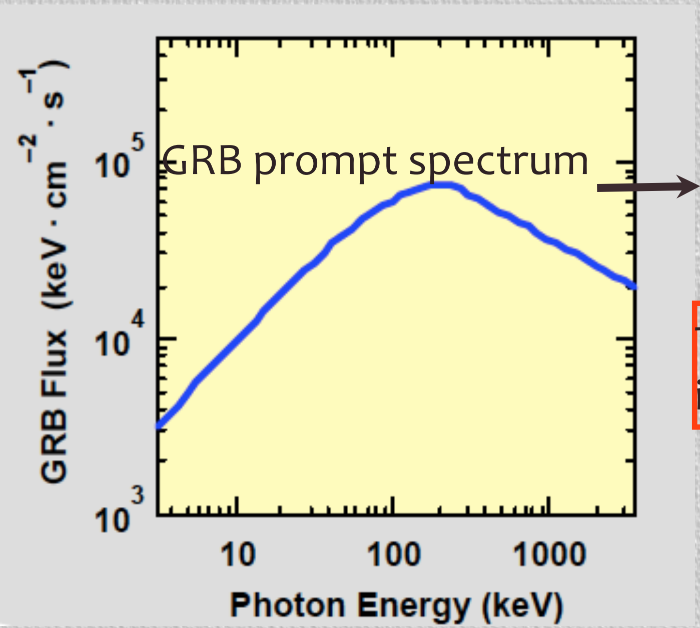
No events are detected for Ic40 and Ic59 data analysis.

IceCube Collaborator



IceCube group suggests that the assumption of GRBs as the major source of UHECR is highly chanllenged.

One of the mistakes of IceCube's calculation



photon density is a function of energy.

The fraction of energy that proton converted into pions is a function of energy.

$$\epsilon_{\nu_\mu}\frac{dn_{\nu_\mu}}{d\epsilon_{\nu_\mu}}\mathrm{d}\epsilon_{\nu_\mu} = \frac{1}{8}f_{p\gamma}(\epsilon_p)\zeta(\epsilon_p)\epsilon_p\frac{dn_p}{d\epsilon_p}\mathrm{d}\epsilon_p$$

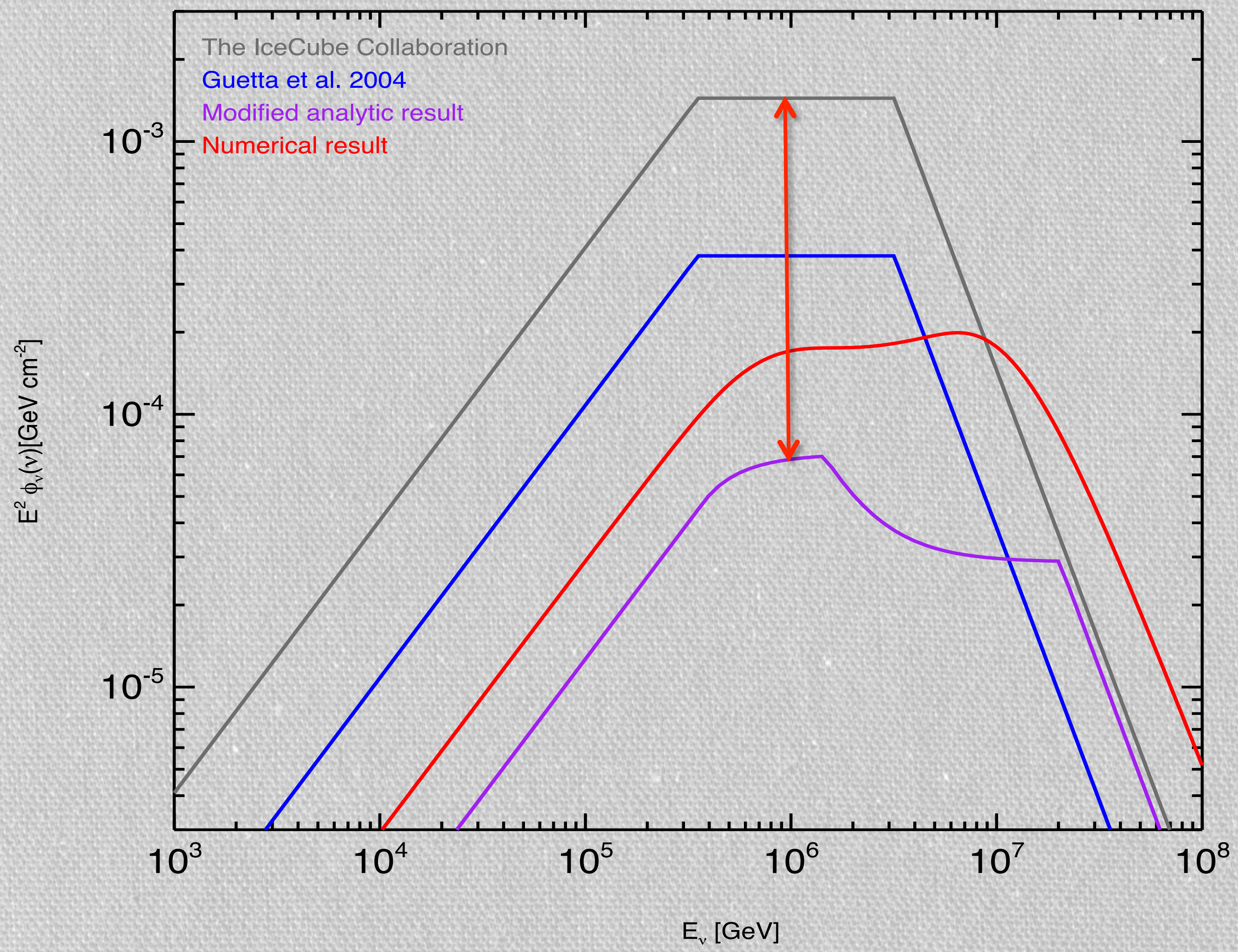
IceCube overestimate the neutrino flux by a factor of 4 due to adopting a constant energy converted fraction.

$$\int_0^\infty dE_\nu E_\nu F_\nu(E_\nu) = \frac{1}{8}\frac{1}{f_e}(1-(1-\langle x_{p\to\pi}\rangle)^{\Delta R/\lambda_{p\gamma}}) \times \int_{1\,\mathrm{keV}}^{10\,\mathrm{MeV}} dE_\gamma\ E_\gamma F_\gamma(E_\gamma)$$

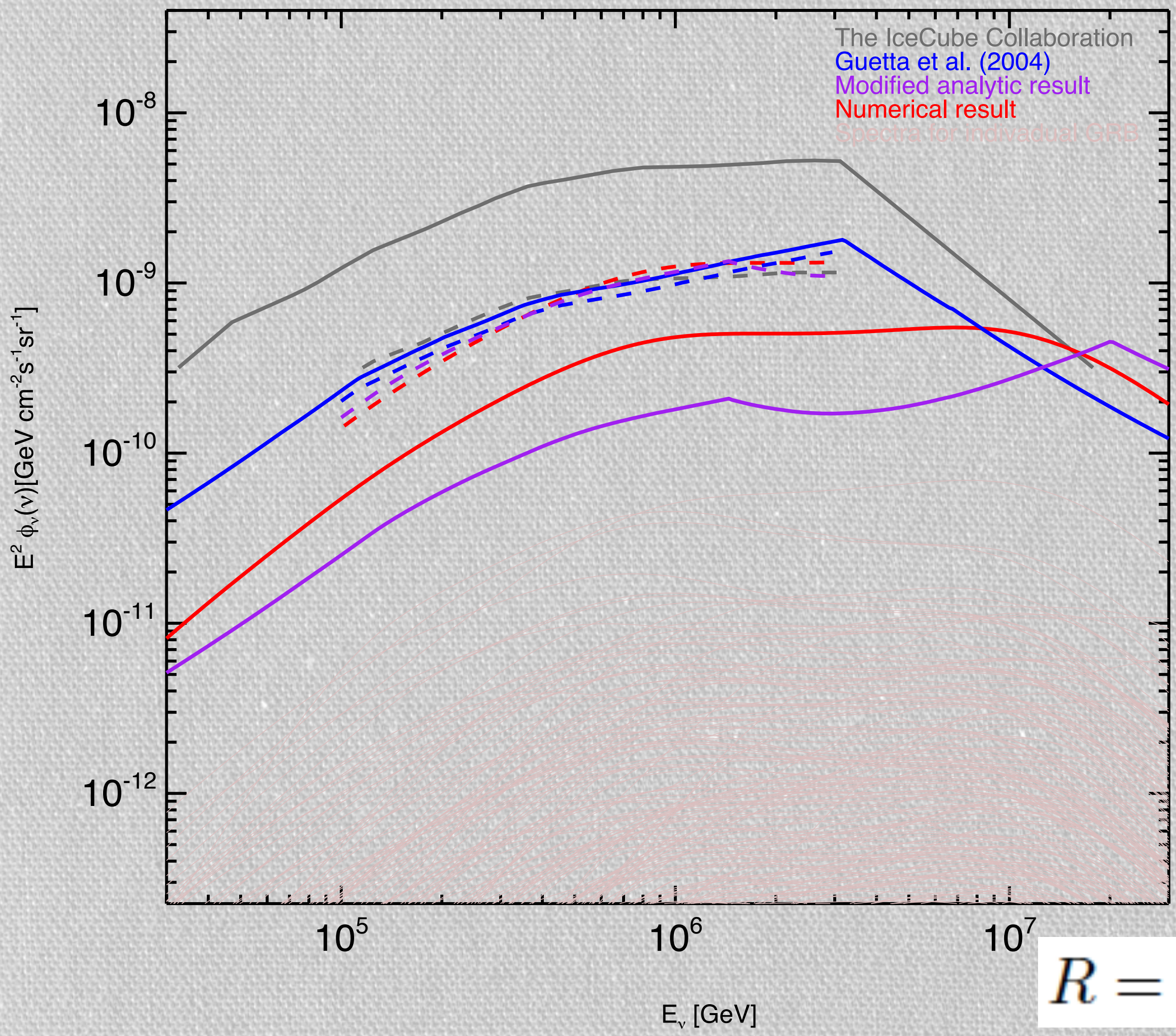
The IceCube collaborator overestimates the flux of neutrinos by a factor of 5 due to adopting a constant energy density of photons.

Li 2011, Hummer et al. 2011, Kohta et al. 2011, He,Liu,Wang,Nagataki +,2012.

Neutrino spectra for individual GRB



Neutrino Spectra for 215 GRBs



$E_p = \eta_p E_{\rm iso}$

$\eta_p = 10$

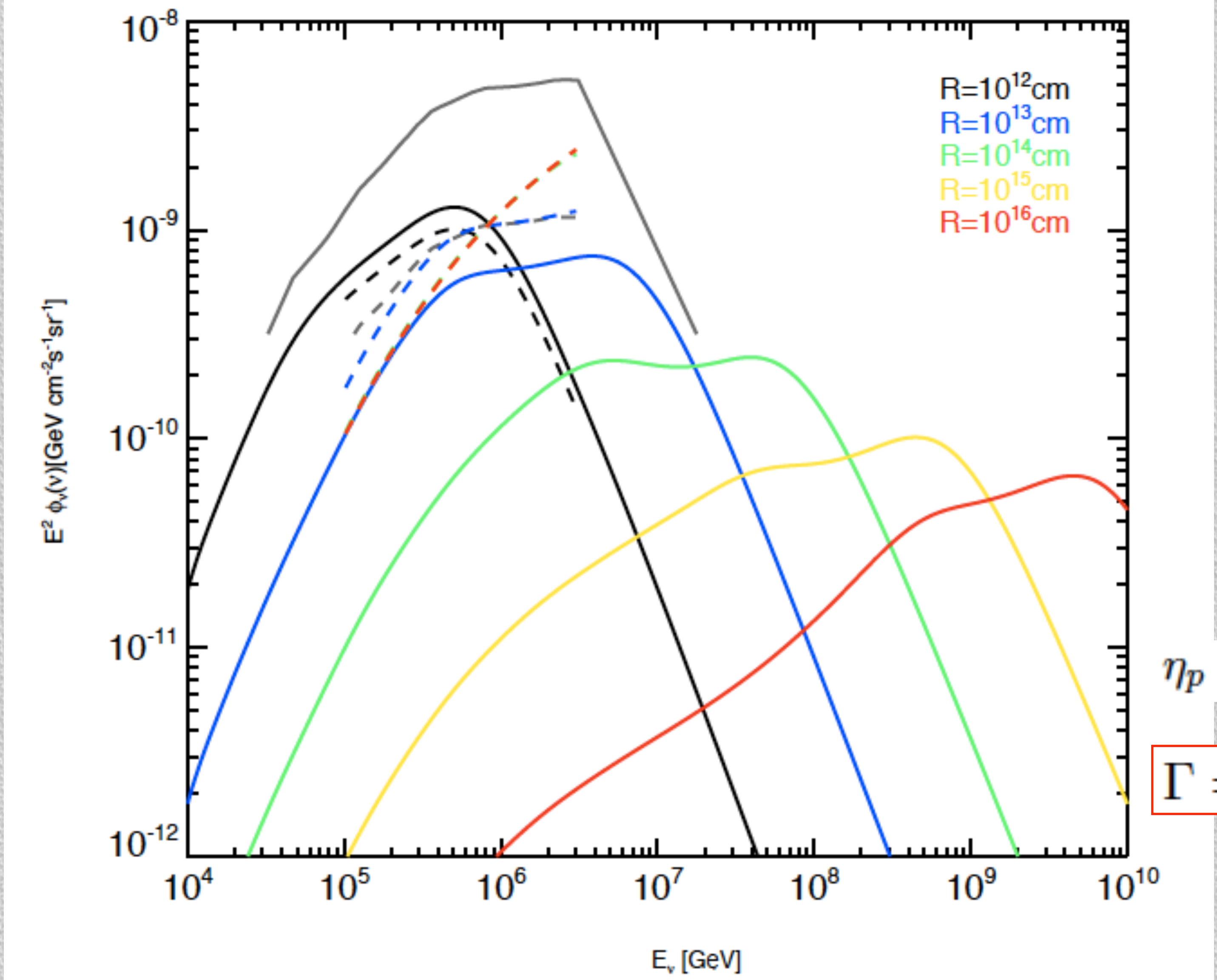
Internal shock model

$\Gamma = 10^{2.5}$

$t_{\rm v}^{\rm ob} = 0.01{\rm s}$

$R = 2\Gamma^2 c t_{\rm v}^{\rm ob}/(1+z)$

Neutrino Spectra for different dissipation Radius

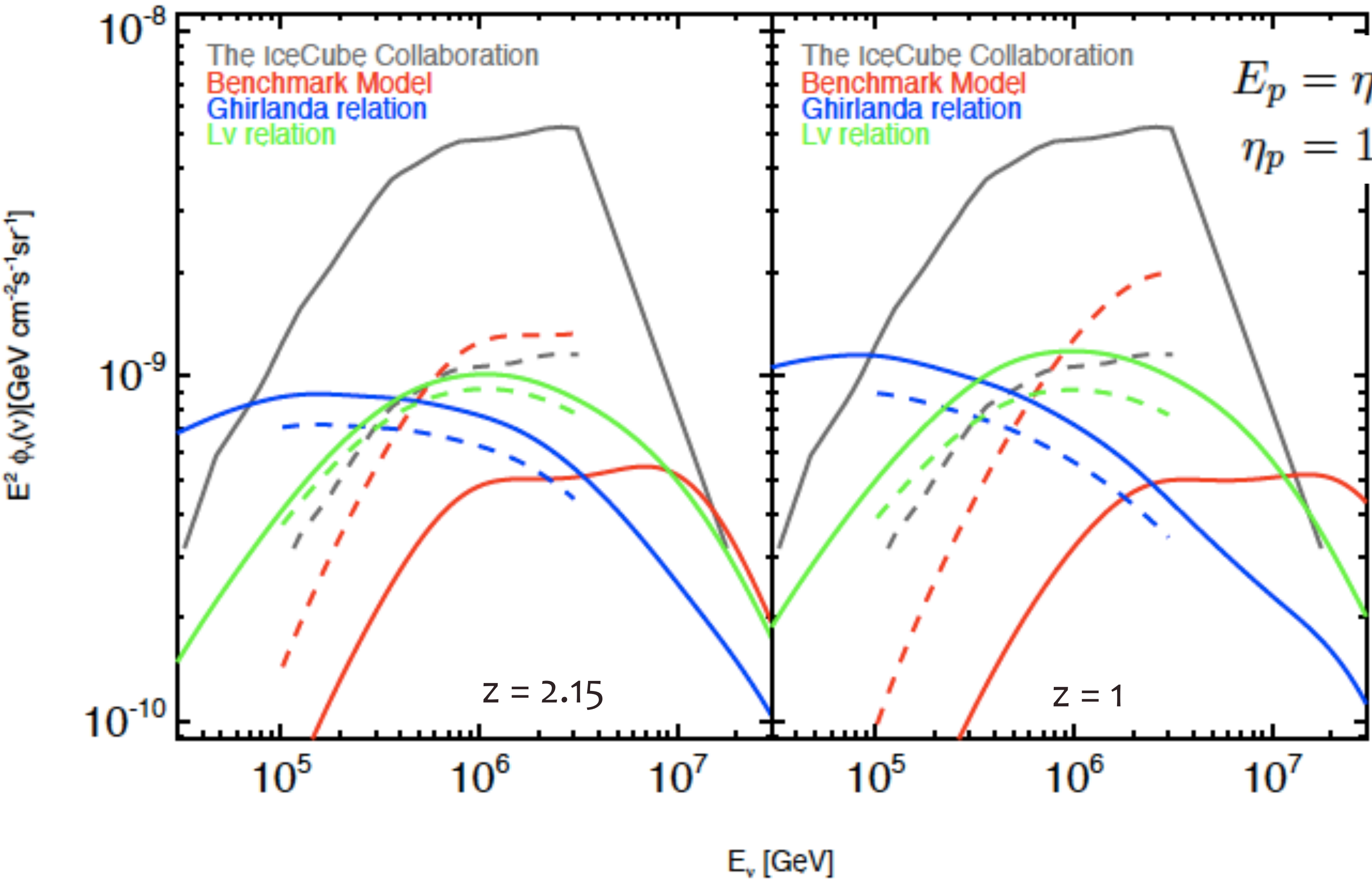


$\eta_p = 10$

$\Gamma = 10^{2.5}$

Neutrino Spectra by adopting Inherent Correlation

$\Gamma = 10^{2.5}$ $\Gamma_G = 29.8 E_{\mathrm{iso},52}^{0.51}$ $\Gamma_L = 118 E_{\mathrm{iso},52}^{0.26}$



$E_p = \eta_p E_{\mathrm{iso}}$

$\eta_p = 10$

Summary I

- Our modified numerical calculation predict GRB neutrinos whose flux is a factor of ~20 lower than that predicted by IceCube group.
- For the null result of IceCube, we can constrain the GRB model and the flux of protons.
- We cannot exclude the proposal that GRBs are the major sources of UHECRs so far.

$L_\gamma\,(\mathrm{erg\,s^{-1}})$	Γ	z	$\eta_{p,c}$
10^{52}	$10^{2.5}$	2.15	26.0
		1	39.9
$L_{\gamma\mathrm{G}}$	Γ_G	2.15	8.16
		1	7.79
$L_{\gamma\mathrm{G}}$	Γ_L	2.15	9.07
		1	7.72

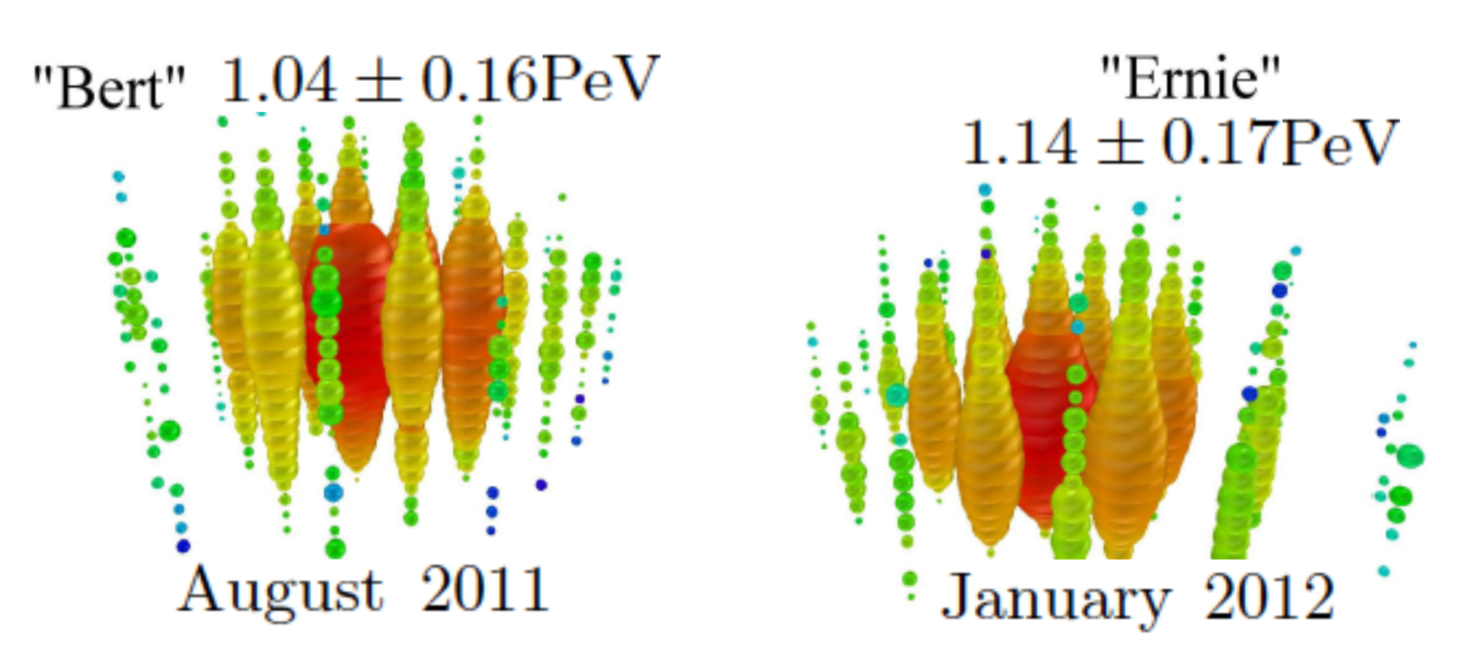
Diffuse PeV neutrino emission from Ultra-Luminous Infrared Galaxies

He et al., 2013,PRD, vol. 87, Issue 6, id. 063011

- **Hao-Ning He**
- Collaborators: Tao Wang, Yi-Zhong Fan, Si-Ming Liu, Da-Ming Wei

First observation of PeV-energy neutrinos with IceCube

- A. Ishihara, “IceCube: Ultra-High Energy Neutrinos,” Talk at Neutrino 2012, Kyoto, Japan, June 2012
- **IceCube Collaboration,2013**
- Data were collected between May 2010 and May 2012, an effective livetime of 615.9 days excluding 54.2 days used for the optimization of the analysis.



- **Origins Excluded by IceCube Collaboration:**
- 1. instrumental artifacts
- 2. atomospheric background
- 3. Glashow Resonanse
- **Possible origins:**
- Astrophysics neutrinos from GRBs, Hypernova, AGNs,ULIRGS, Cluster of Galaxies,…
- GZK neutrinos

Liu &Wang
He+
Roulet+
Bhattacharya+
Barger+
Cholis & Hooper
Kalashev+
……

Properties of ULIRGs

Ultra-Luminous Infrared emisison $L_{8-1000\mu m} > 10^{12} L_{\odot}$

High star-formation rate → Dense ISM $\Sigma_{\rm gas} \gtrsim 1.0 \ {\rm g \ cm^{-2}}$

High star-formation rate ↓ High supernova rate ↓ High hypernova rate

Dense ISM ↓ Strong megnetic field

Thompson et al. (2006)

Hypernova

SN 1997ef, SN 1997dq, SN 1998bw and SN 2002ap

Larger kinetic energy

$$E_k \sim 0.5 - 5 \times 10^{52} \ \mathrm{erg}$$

+

Larger velocity of the outflow

$$V \sim 10^9 \ \mathrm{cm\ s^{-1}} (E_k / 10^{52} \ \mathrm{erg})^{1/2} (M_{SN} / 10 M_\odot)^{-1/2}$$

↓

Be able to accelerate particles to high energy

$$\varepsilon'_{p,max} \approx 10^{17} \mathrm{eV} \left(\frac{V}{10^9 \ \mathrm{cm\ s^{-1}}}\right)^2 \left(\frac{n}{10^3 \mathrm{cm^{-3}}}\right)^{1/6} \left(\frac{M_{SN}}{10 M_\odot}\right)^{1/3}$$

p-p collision

$$\pi^+ \to \mu^+ + \nu_\mu \to e^+ + \nu_e + \bar{\nu}_\mu + \nu_\mu$$

- Energy loss time scale

$$\tau_{\rm loss} = 1.4 \times 10^4 {\rm yr} \frac{l}{100{\rm pc}} \left(\frac{\Sigma_{\rm gas}}{1.0 \ {\rm g \ cm^{-2}}} \right)^{-1}$$

- The comfinement time scale

$$\tau_{\rm conf} \approx 2 \times 10^5 {\rm yr} \left(\frac{\varepsilon'_{\rm p}}{10{\rm PeV}} \right)^{-0.5} \left(\frac{\Sigma_{\rm gas}}{1.0{\rm gcm^{-2}}} \right)^{0.5}$$

$$\tau_{\rm conf} \geqslant \tau_{\rm loss}$$

↓

$$\Sigma_{\rm gas} \gtrsim \Sigma_{\rm crit} = 0.17 \ {\rm g \ cm^{-2}} \left(\frac{\varepsilon'_{\rm p}}{10{\rm PeV}} \right)^{1/3} \left(\frac{l}{100{\rm pc}} \right)^{2/3}$$

The Diffused Neutrino flux

The total energy of PeV neutrinos from an individual hypernova in ULIRG

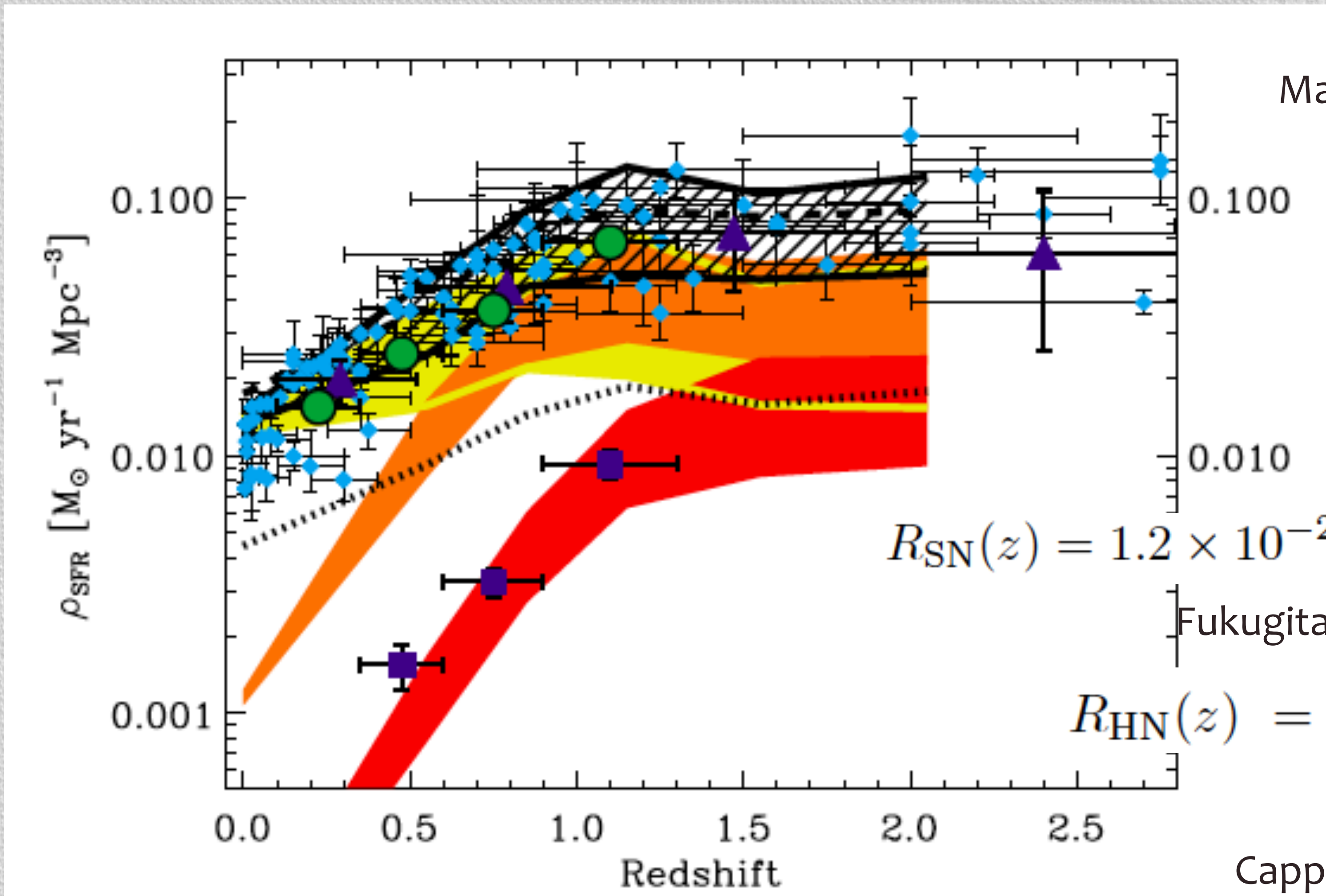
$$E_\nu \approx 4\times10^{48}\mathrm{erg}\frac{E_{\mathrm{HN}}}{2\times10^{52}\mathrm{erg}}\frac{\eta}{0.1}\frac{\epsilon_{\mathrm{dec}}}{0.07}\left(\frac{\epsilon_\nu}{0.05}\right)^{\alpha-1}\left(\frac{1+z}{3}\right)^{2-\alpha}$$

The diffused neutrino flux

$$F_\nu(\varepsilon_\nu) = \frac{1}{4\pi}\frac{c}{H_0}\int_0^z dz\frac{4\pi D_{\mathrm{c}}(z)^2 R_{\mathrm{HN}}(z) N_{\mathrm{c}}\varepsilon_\nu^{2-\alpha}}{4\pi D_{\mathrm{L}}(z)^2\sqrt{\Omega_{\mathrm{M}}(1+z)^3+\Omega_\Lambda}}(1$$

$$\frac{dN'_p}{d\varepsilon'_p} \propto \varepsilon_p'^{-\alpha}$$

The Hypernova Rate



Magnelli et al. 2011

$$R_{\rm SN}(z) = 1.2 \times 10^{-2} \rho_{\rm SFR}(z)/M_{\odot}$$

Fukugita&kawasasi 2007

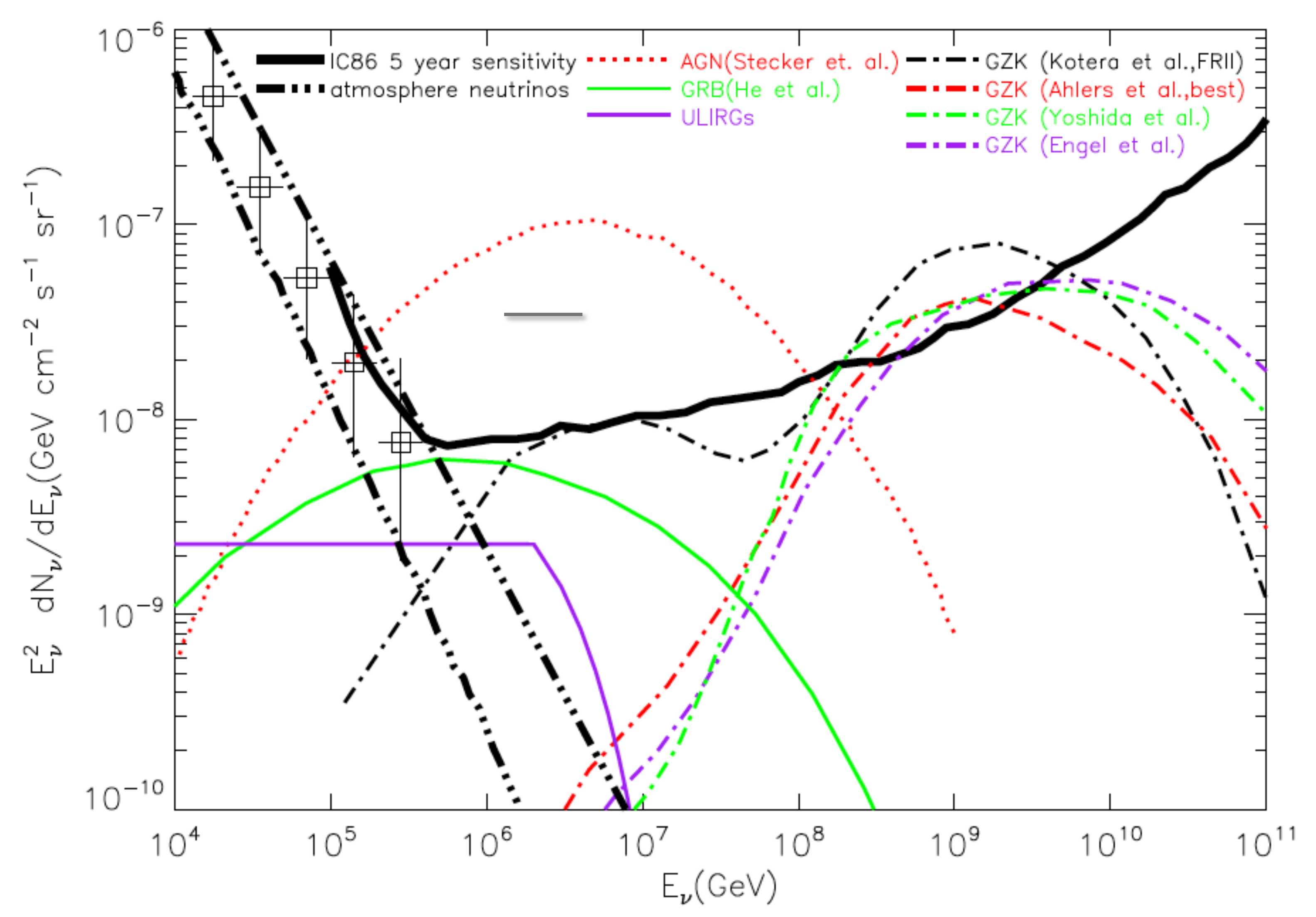
$$R_{\rm HN}(z) \;=\; f_{\rm HS} R_{\rm SN}(z)$$

$$f_{\rm HS} \simeq 0.01$$

Cappelaro et al. 1999

Guetta& Della Valle, 2007

The Neutrino Spectrum



Summary II

- 0.1 event can be obserbed for 1 year observations by IceCube full configurations, plays importan role on contributing to diffuse neutrinos.
- The ULIRG neutrino component is likely characterized by a cut off (or break) at a few PeV.

Disscusion

Other possible origins :

- GRBs
- Crashes of AGN ejecta with dense media in ULIRG/LIRG
- Crashes of supernova ejecta with other dense media (e.g., massive circumstellar material shells, Murase et al. 2011)
- clusters of galaxies (Murase et al. 2008)
- GZK neutrinos（Kalashev et al. 2013... ）

Thank you!