GRAN SASSO SCIENCE INSTITUTE
SCHOOL OF ADVANCED STUDIES
Scuola Universitaria Superiore

Istituto Nazionale di Fisica Nucleare

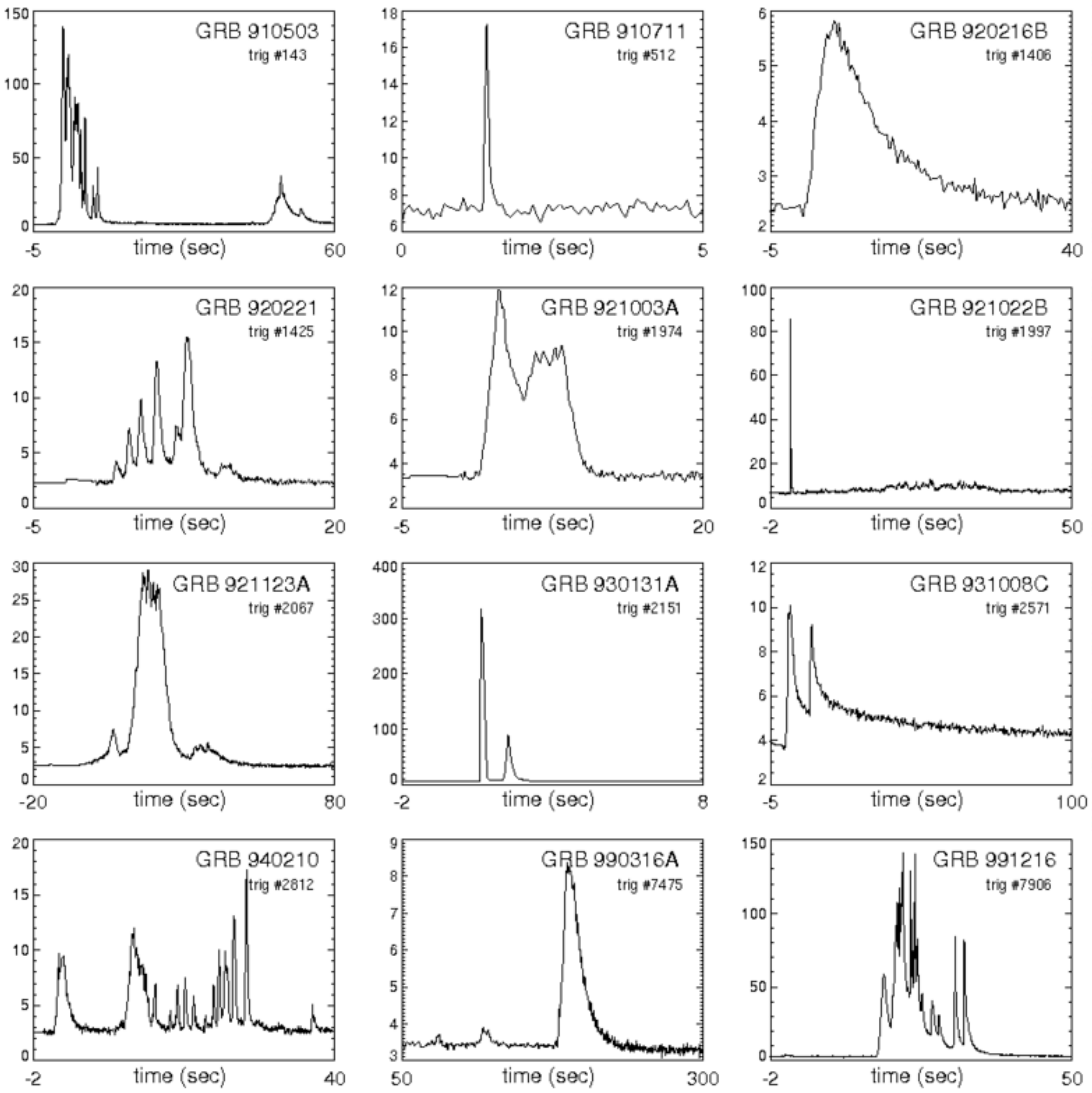
High energy neutrinos from GRBs

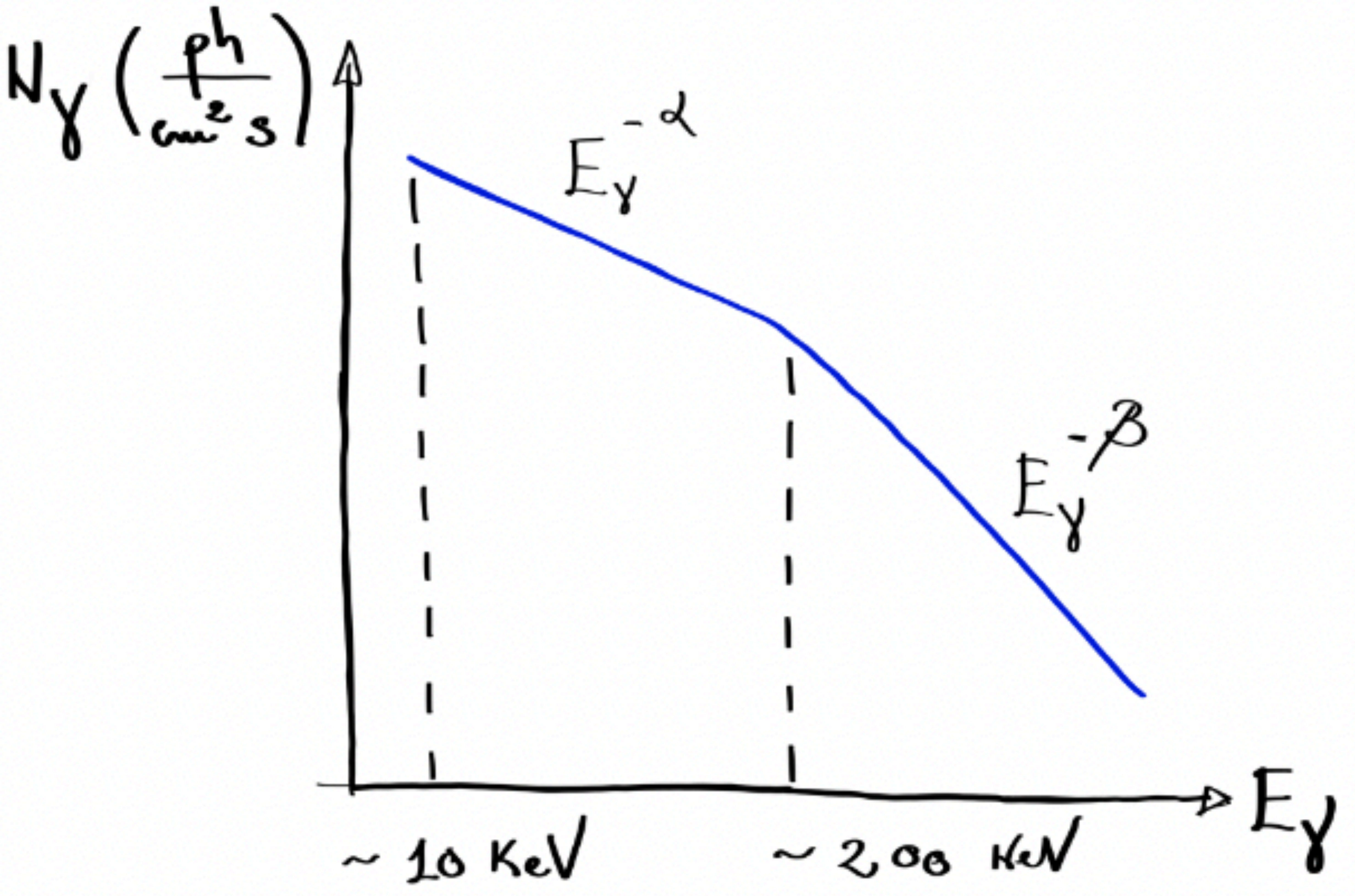
Gor Oganesyan

Francesco Lucarelli, T. Montaruli, M. Branchesi, F. Brighenti, A. Mei, S. Ronchini

All drawings by S. Ronchini

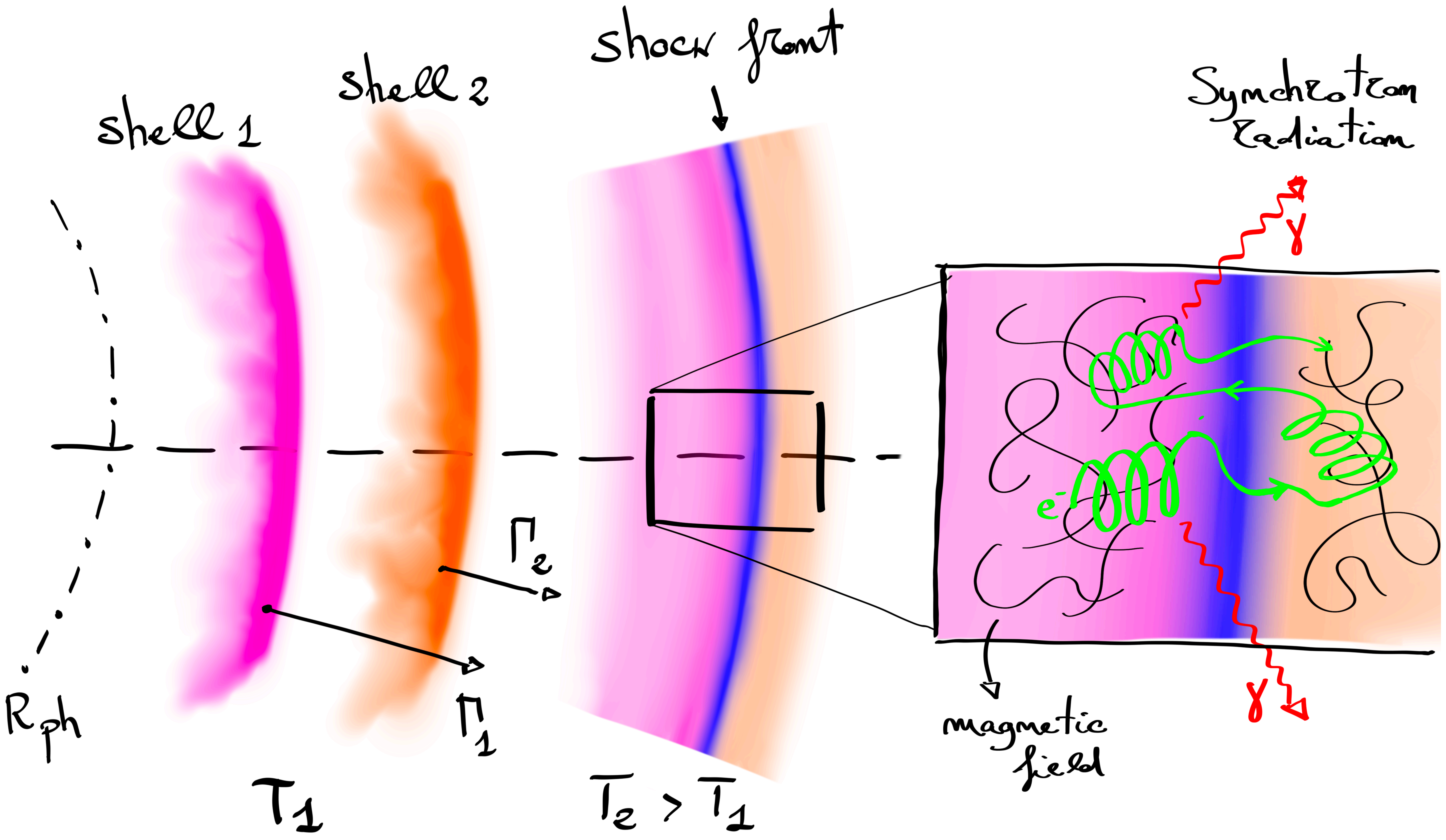
Prompt emission





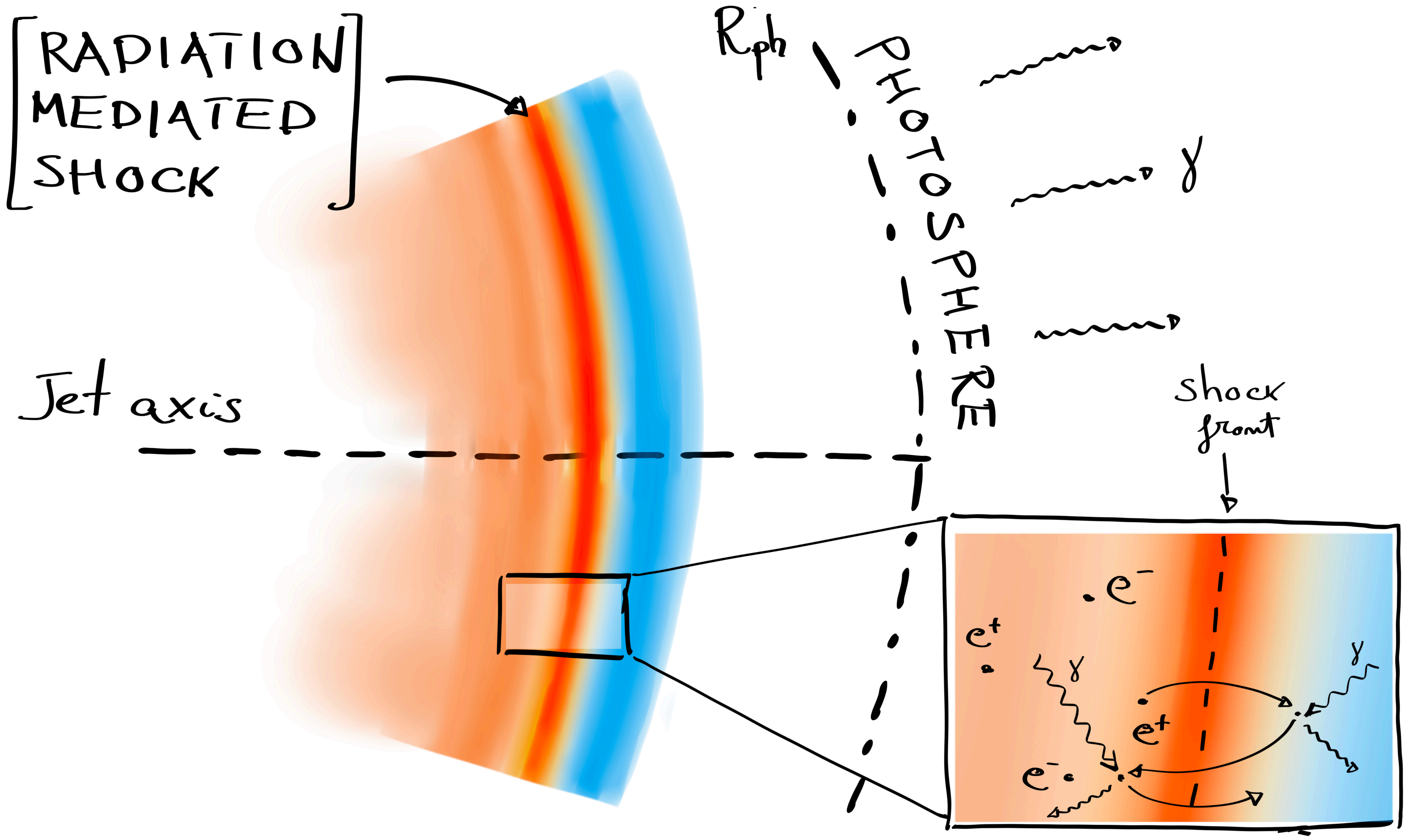
$\alpha \approx 1$ $\beta \approx 2.3$

Internal shocks



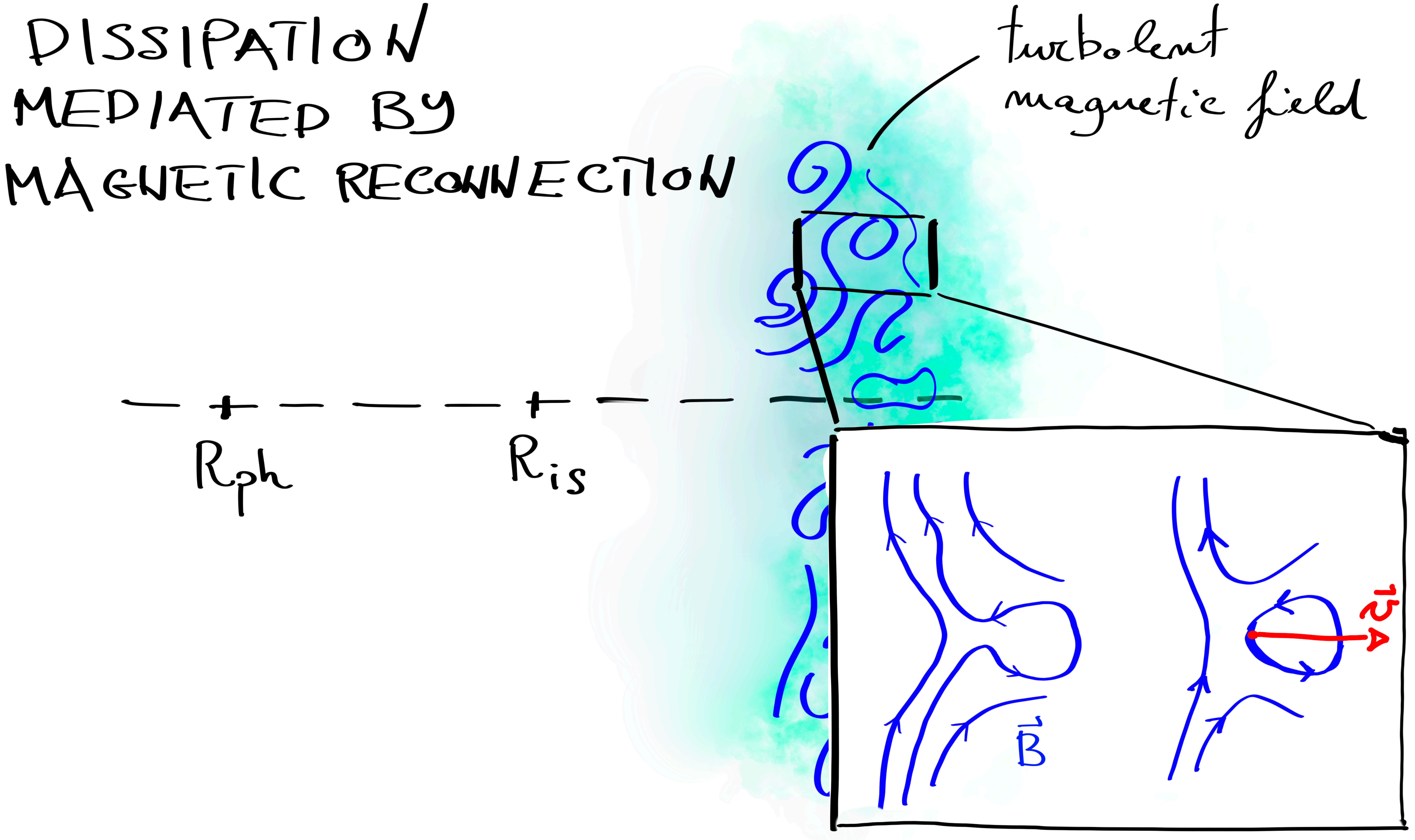
Narayan et al. 1992, Rees & Mészáros 1994

Radiation mediated shocks



Mészáros & Rees 2000, see review by Levinson & Nakar 2019

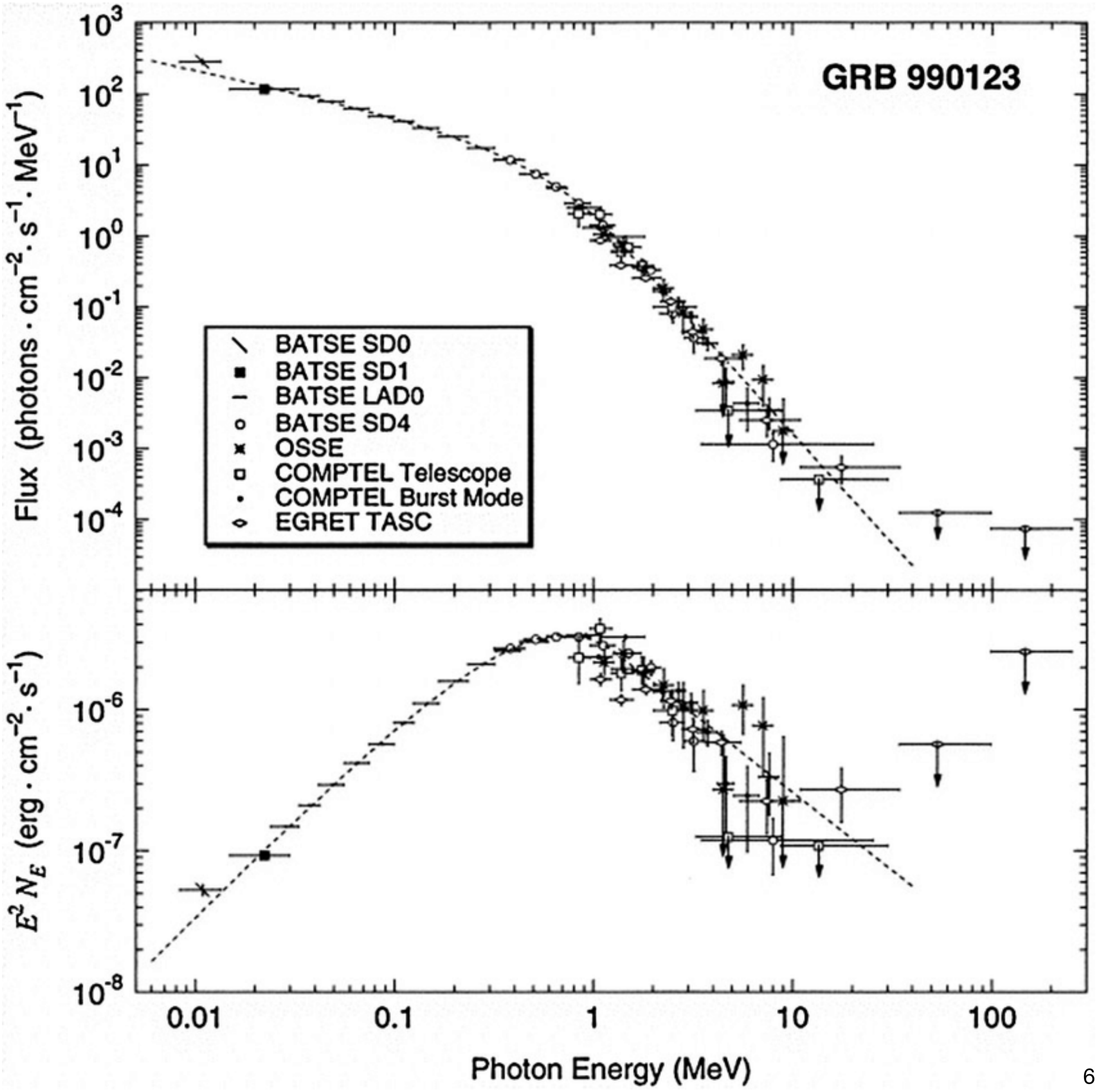
Reconnection



Lyutikov & Blandford 2003

GRB spectrum

Briggs et al. 1999



Waxman and Bahcall 1997

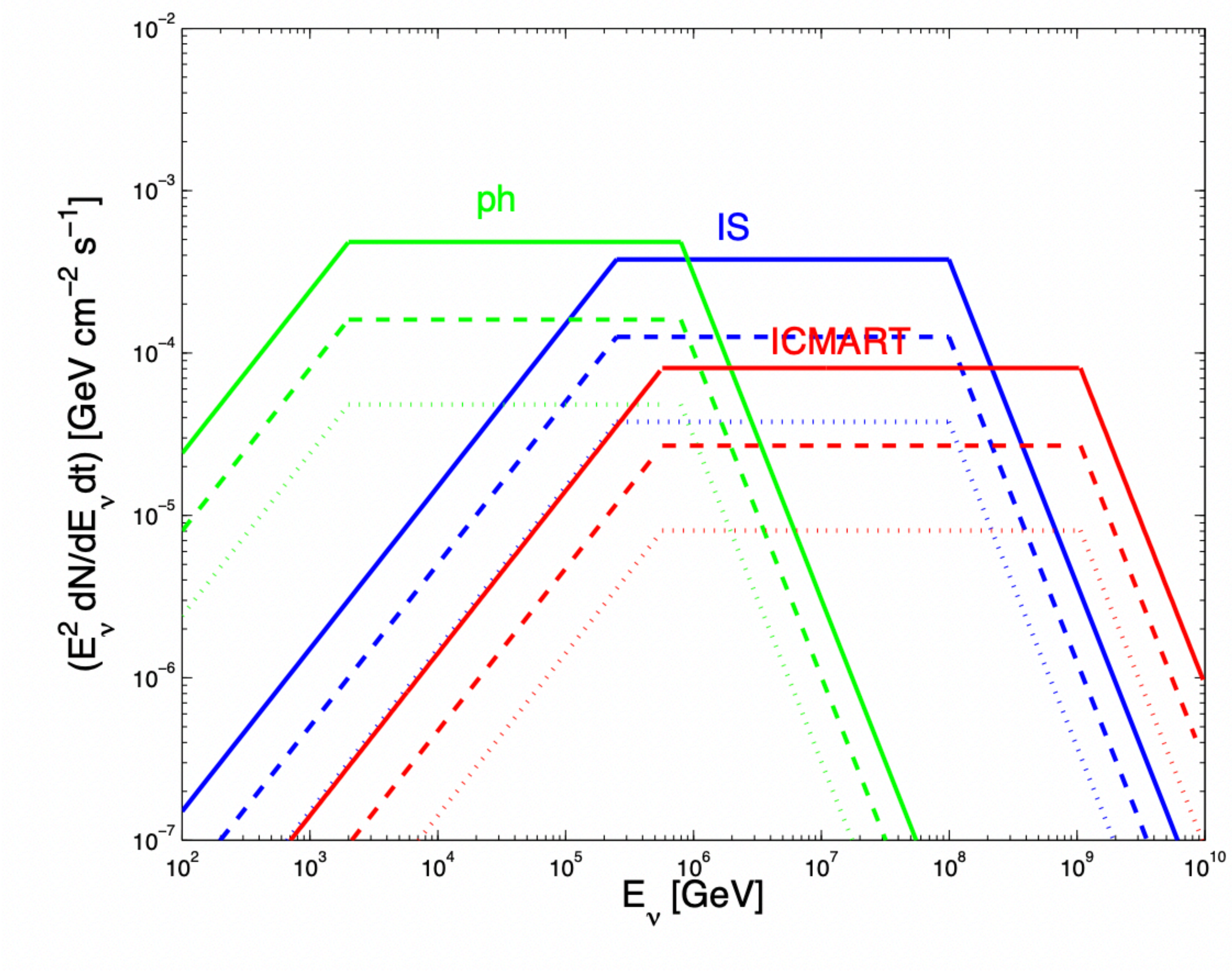
$$p + \gamma \to \Delta(1232) \to \pi^+ + n$$

$$\pi^+ \to \mu^+ + \nu_\mu$$

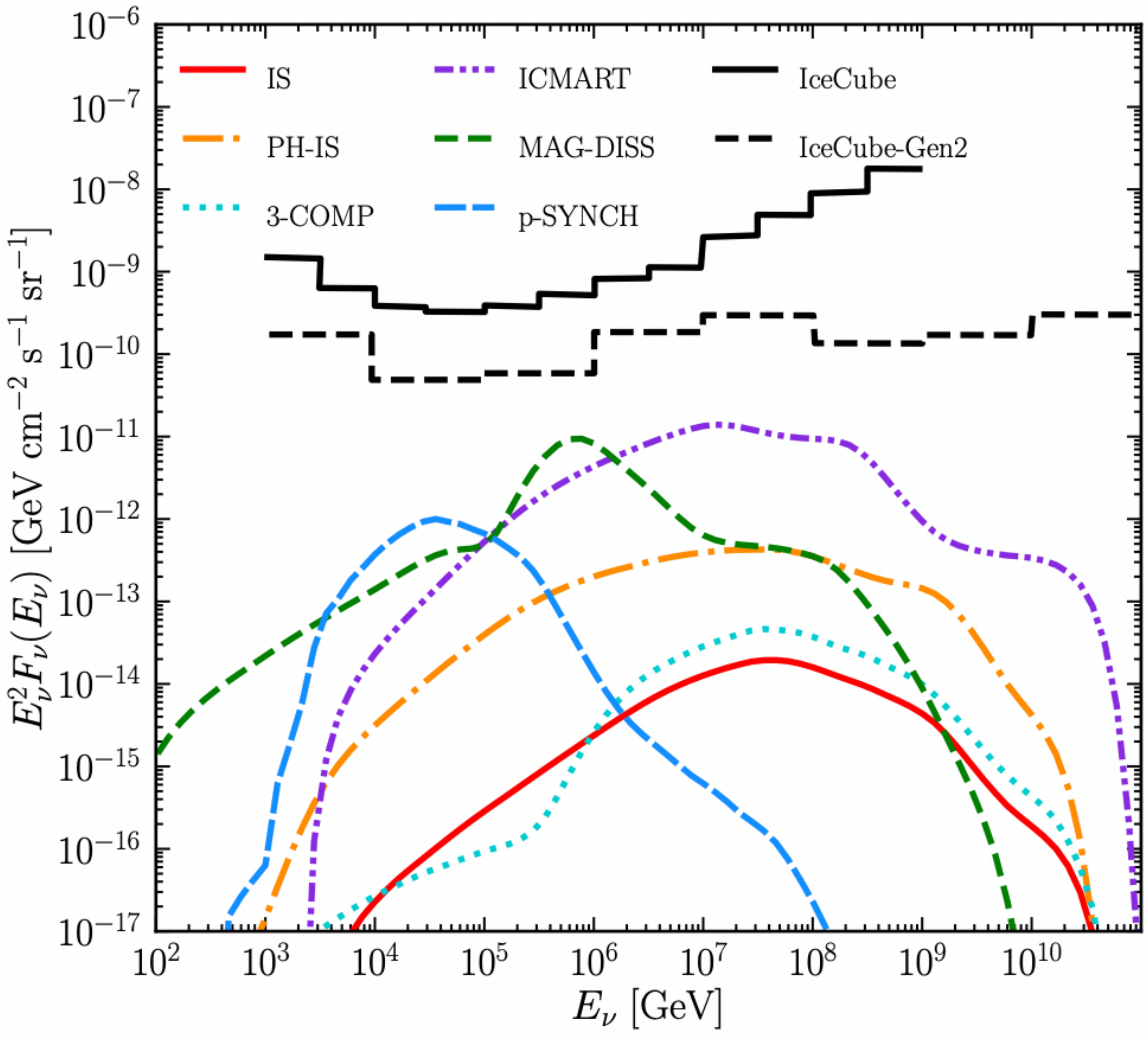
$$\mu^+ \to e^+ + \nu_e + \bar{\nu}_\mu$$

see review by Kimura 2022

$$E_{\nu,b} \approx 60\,\mathrm{TeV}\,\Gamma_2^2 \mathrm{E}_{\gamma,\mathrm{peak},300}^{-1} \left(\frac{2}{1+\mathrm{z}}\right)^2$$

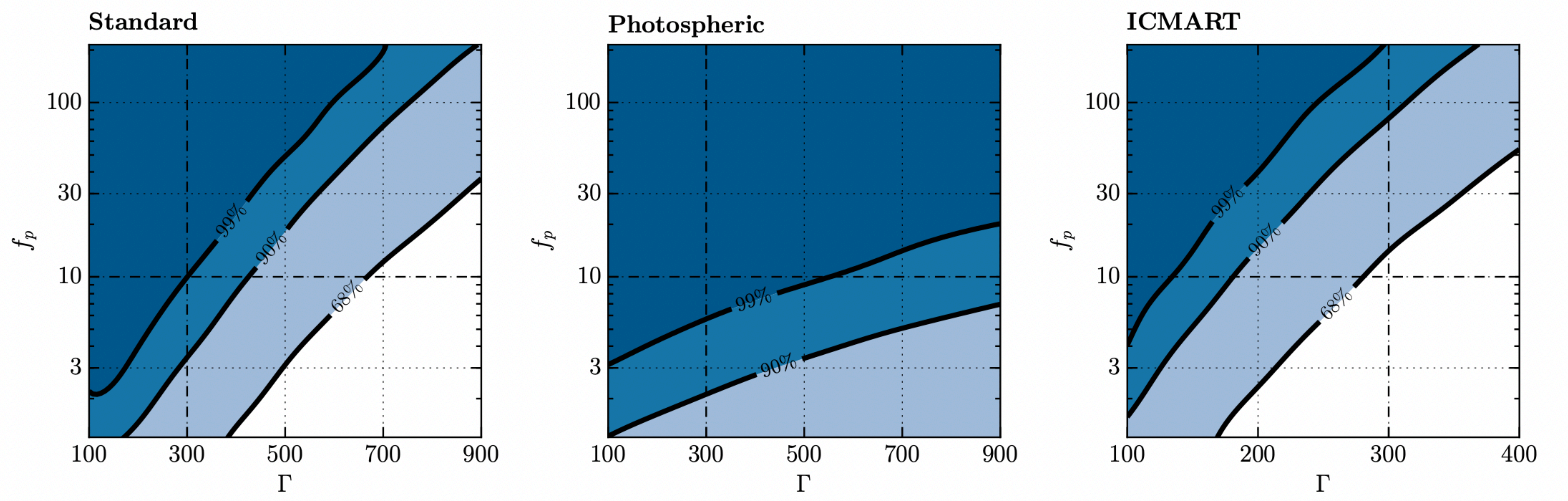


Zhang and Kumar 2013



Pitik, Tamborra, Petropoulou 2021

IceCube results



Aarsten et al. 2017

+

Abbasi et al. 2022 (stacking analysis)

Our approach

(A) Prompt emission: stacking search with physical weights

(B) X-ray flares

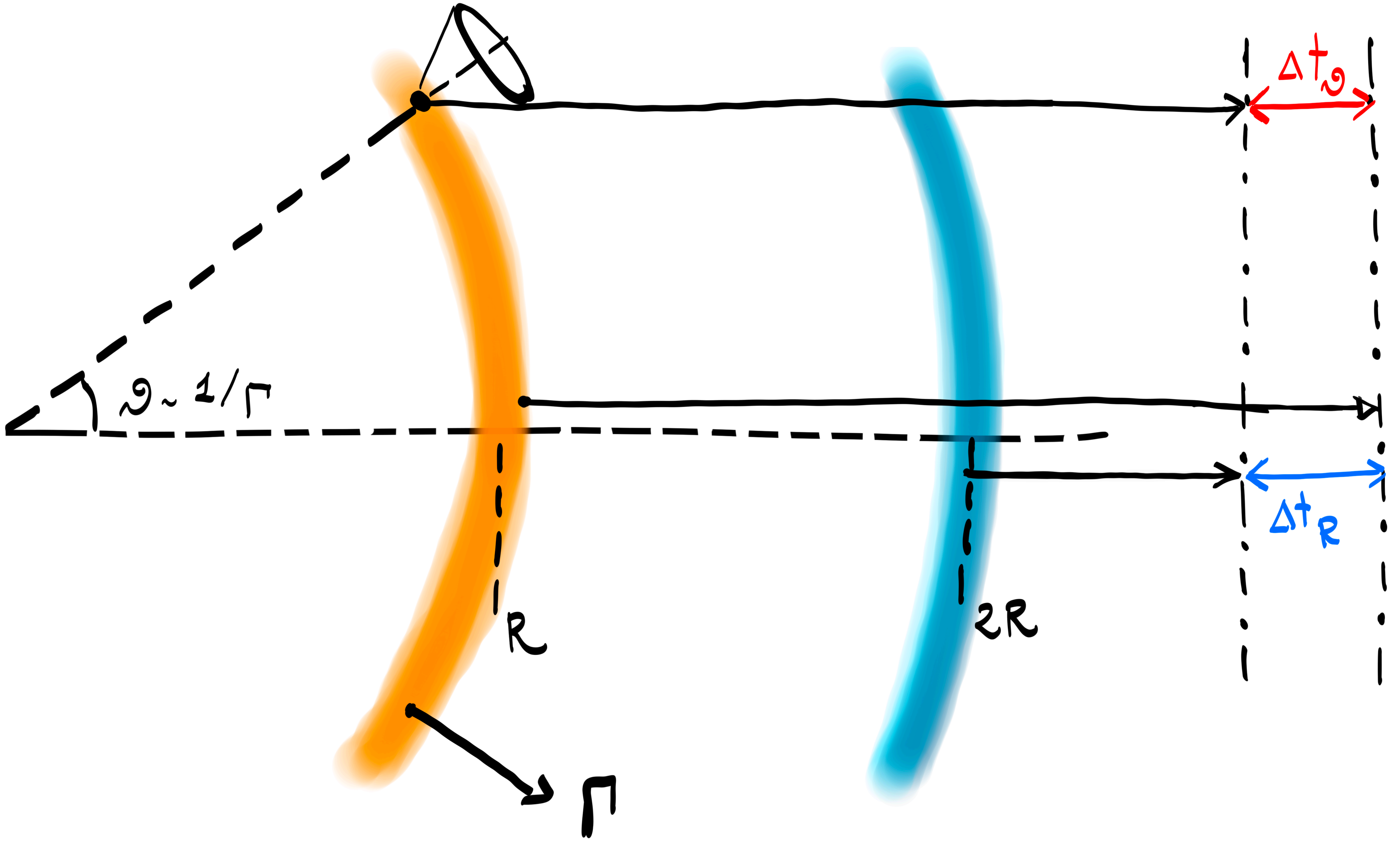
(C) X-ray plateau emission

(A) Prompt emission: stacking search with physical weights

$$E^2_{\nu_\mu}\phi_{\nu_\mu} = \frac{1}{8}\xi_p f_p f_{p\gamma} f_\pi^{syn} f_\mu^{syn} S_{iso}$$

$$f_{p\gamma} \approx 2\chi(\alpha,\beta)\left(\frac{2}{1+z}\right)\frac{L_{iso,52}}{\Gamma_2^2 R_{14}} E^{-1}_{\gamma,peak,300\mathrm{keV}}$$

(A) Prompt emission: stacking search with physical weights



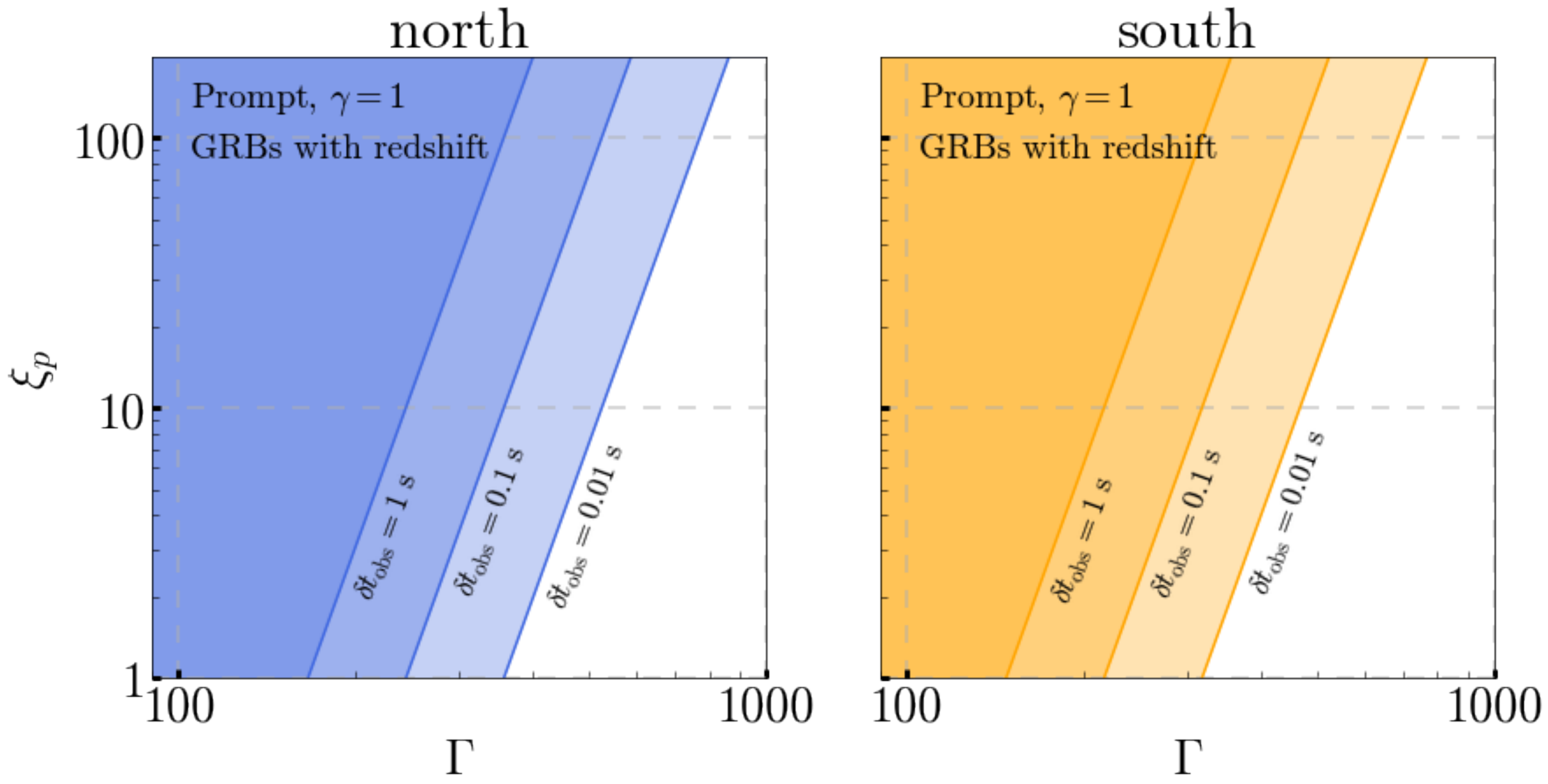
$$R \approx 2c\Gamma^2 \frac{\delta t_{obs}}{1+z}$$

$$E^2_{\nu_\mu}\phi_{\nu_\mu} \approx \frac{1}{8}\xi_p f_p f_{p\gamma} S_{iso} \approx \frac{1}{12}\chi(\alpha,\beta)\frac{L_{iso,52}S_{iso}}{E_{\gamma,peak,300}}\left(\frac{1}{\Gamma_2^4}\right)\left(\frac{1\ \mathrm{s}}{\delta t_{obs}}\right)\left[\frac{\xi_p}{ln(E_{p,max}/E_{p,min})}\right]$$

(A) Prompt emission: stacking search with physical weights

(sources with known z)

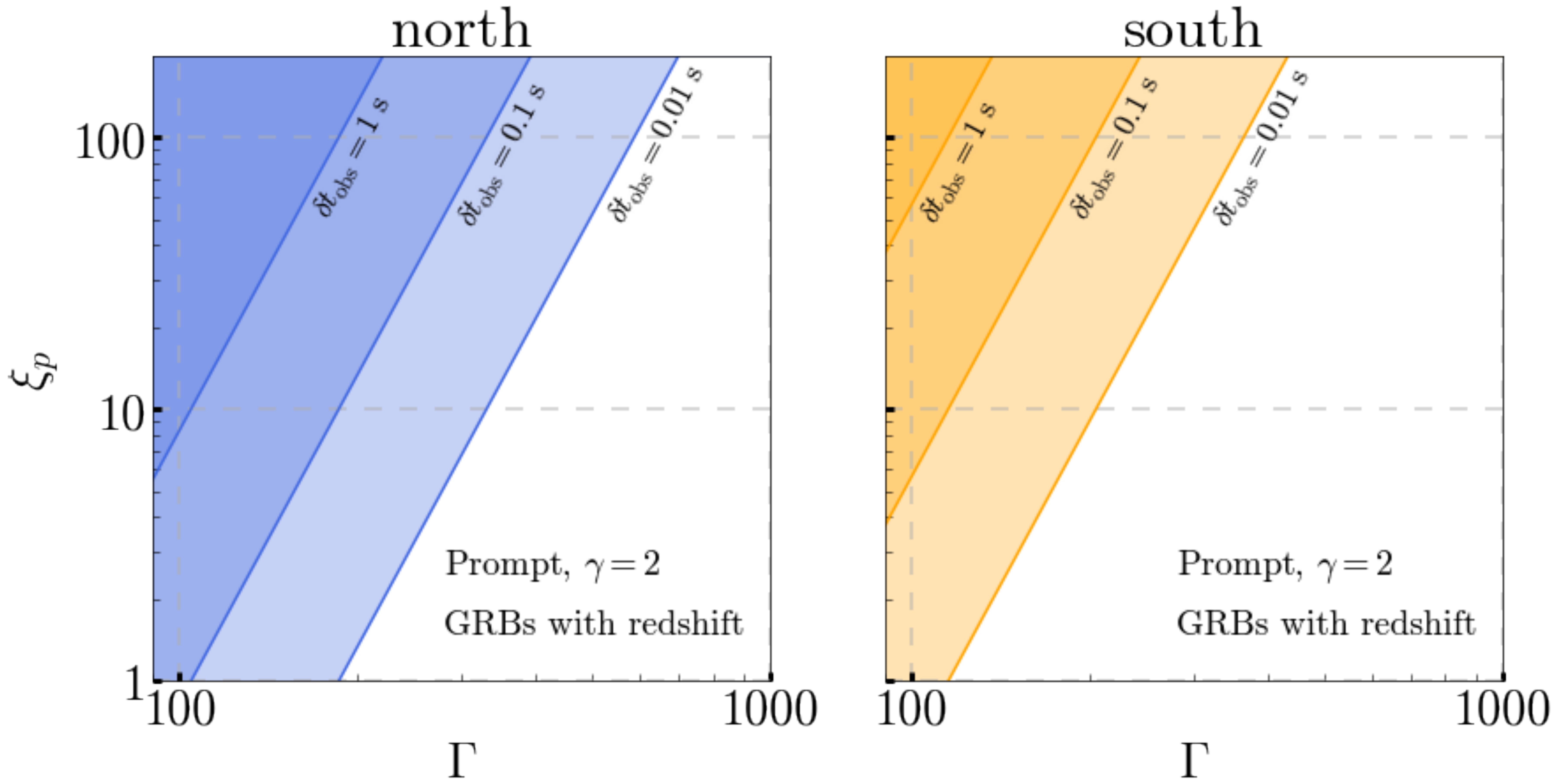
$$\xi_p = \frac{E_p}{E_{iso}}$$



(A) Prompt emission: stacking search with physical weights

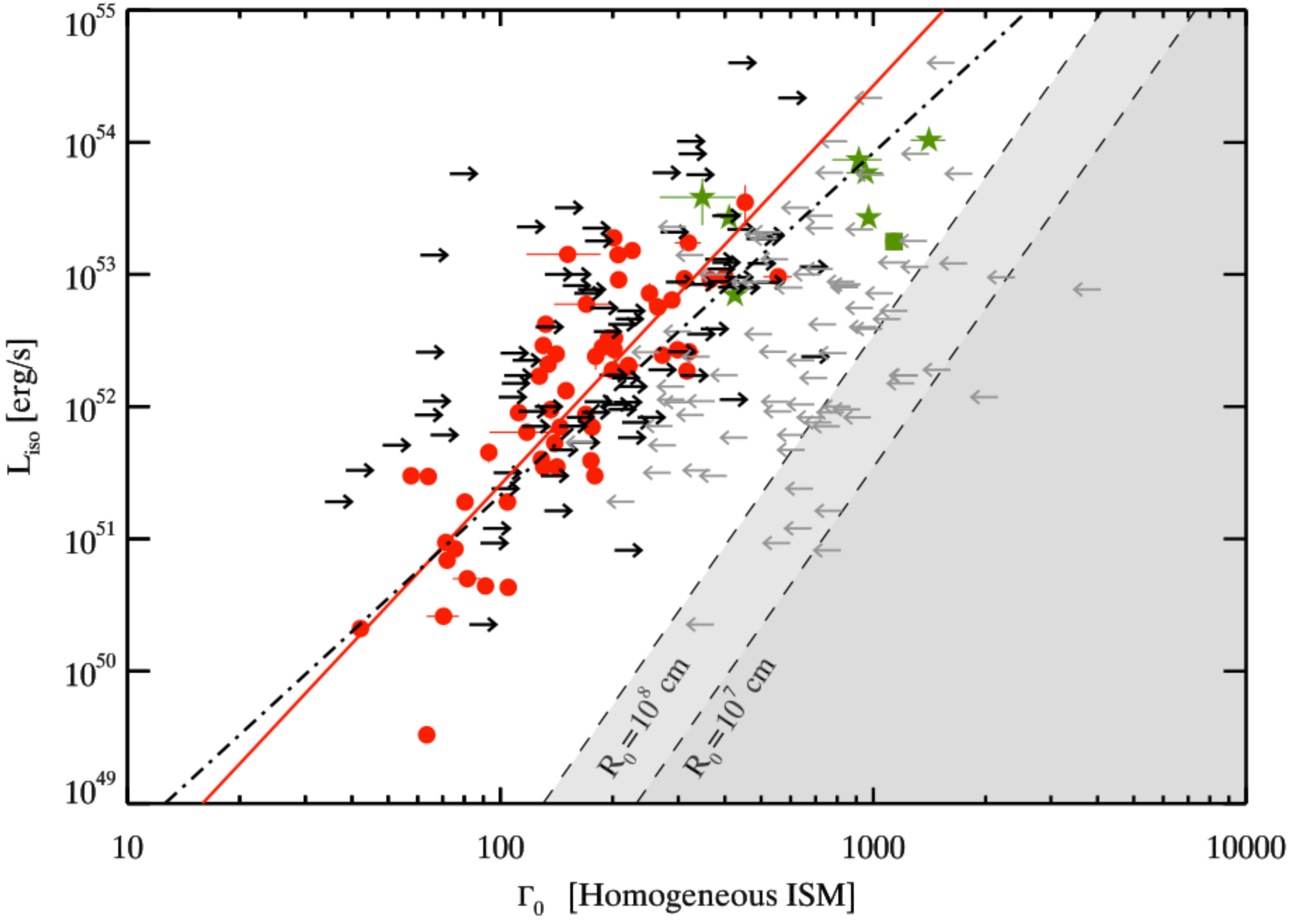
(sources with known z)

$$\xi_p = \frac{E_p}{E_{iso}}$$



(A) Prompt emission: stacking search with physical weights

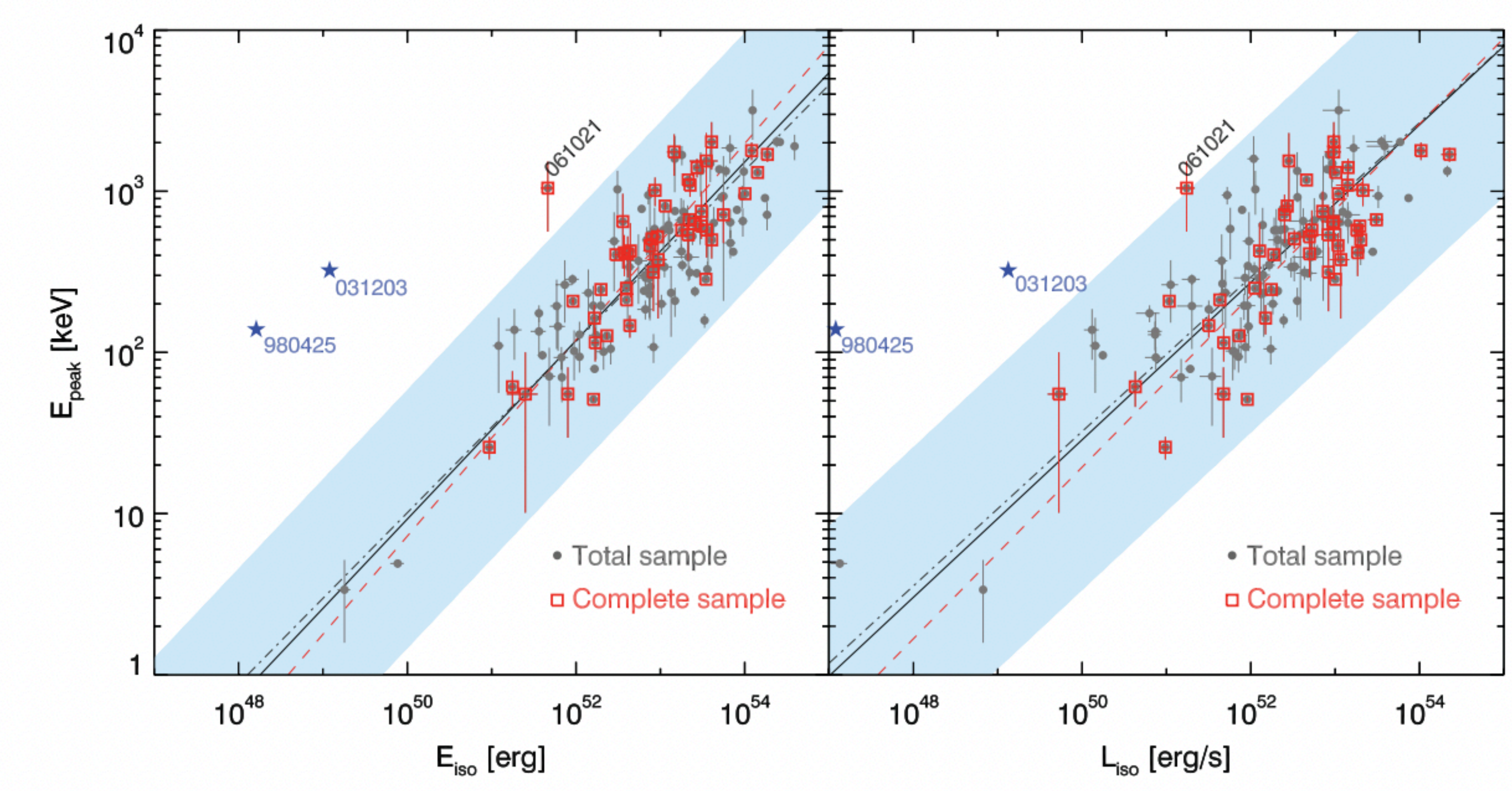
(Considering all sources)



Ghirlanda et al. 2017

(A) Prompt emission: stacking search with physical weights

(Considering all sources)

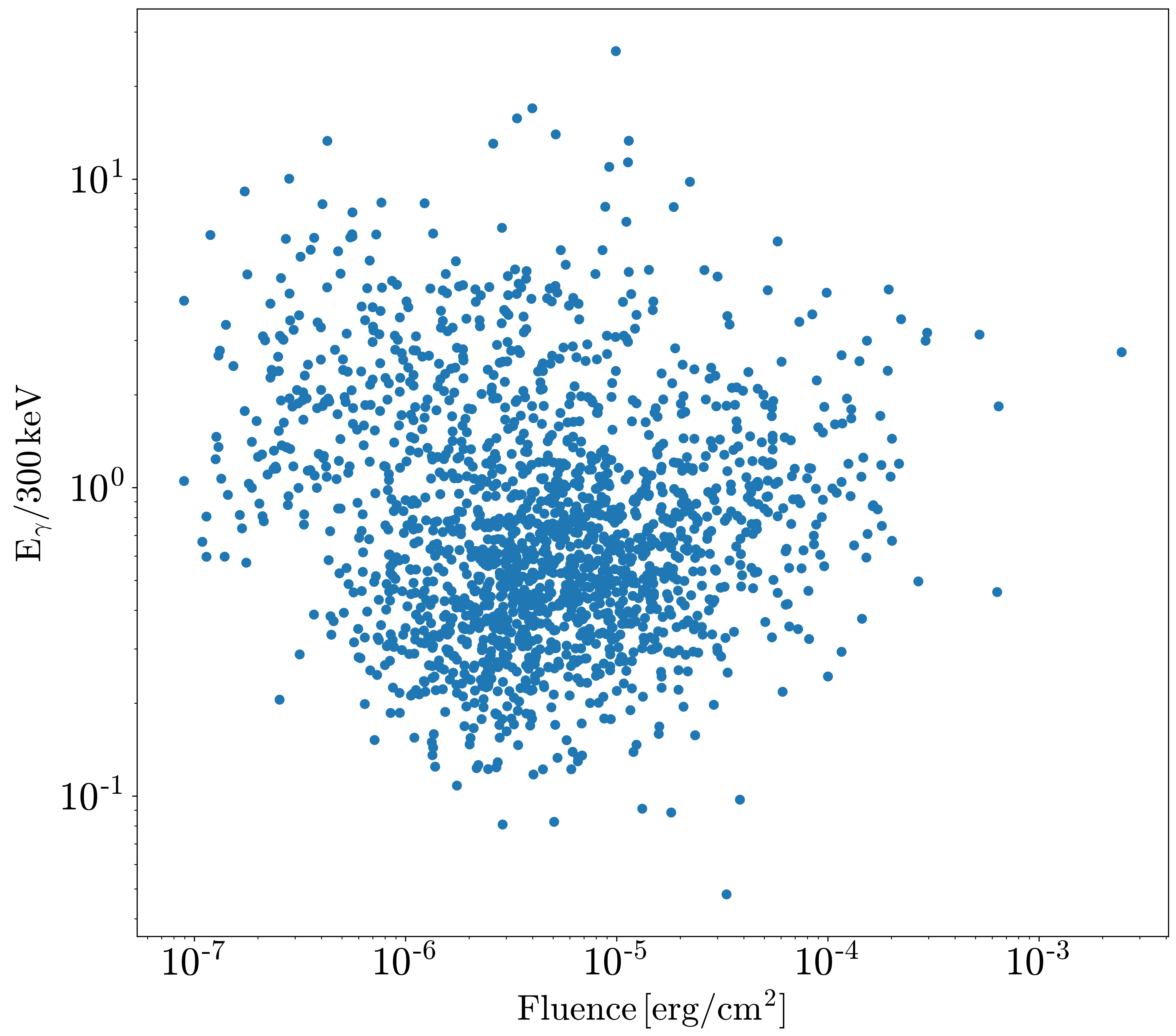


Nava et al. 2012

(A) Prompt emission: stacking search with physical weights

(Considering all sources)

$$E^2_{\nu_\mu}\phi_{\nu_\mu} \approx 0.04\chi(\alpha,\beta)\frac{S_{iso}}{E^{1.6}_{\gamma,peak,300}}\frac{1s}{\delta t_{obs}}\frac{1}{(1+z)^{0.6}}\left[\frac{\xi_p}{ln(E_{p,max}/E_{p,min})}\right]$$

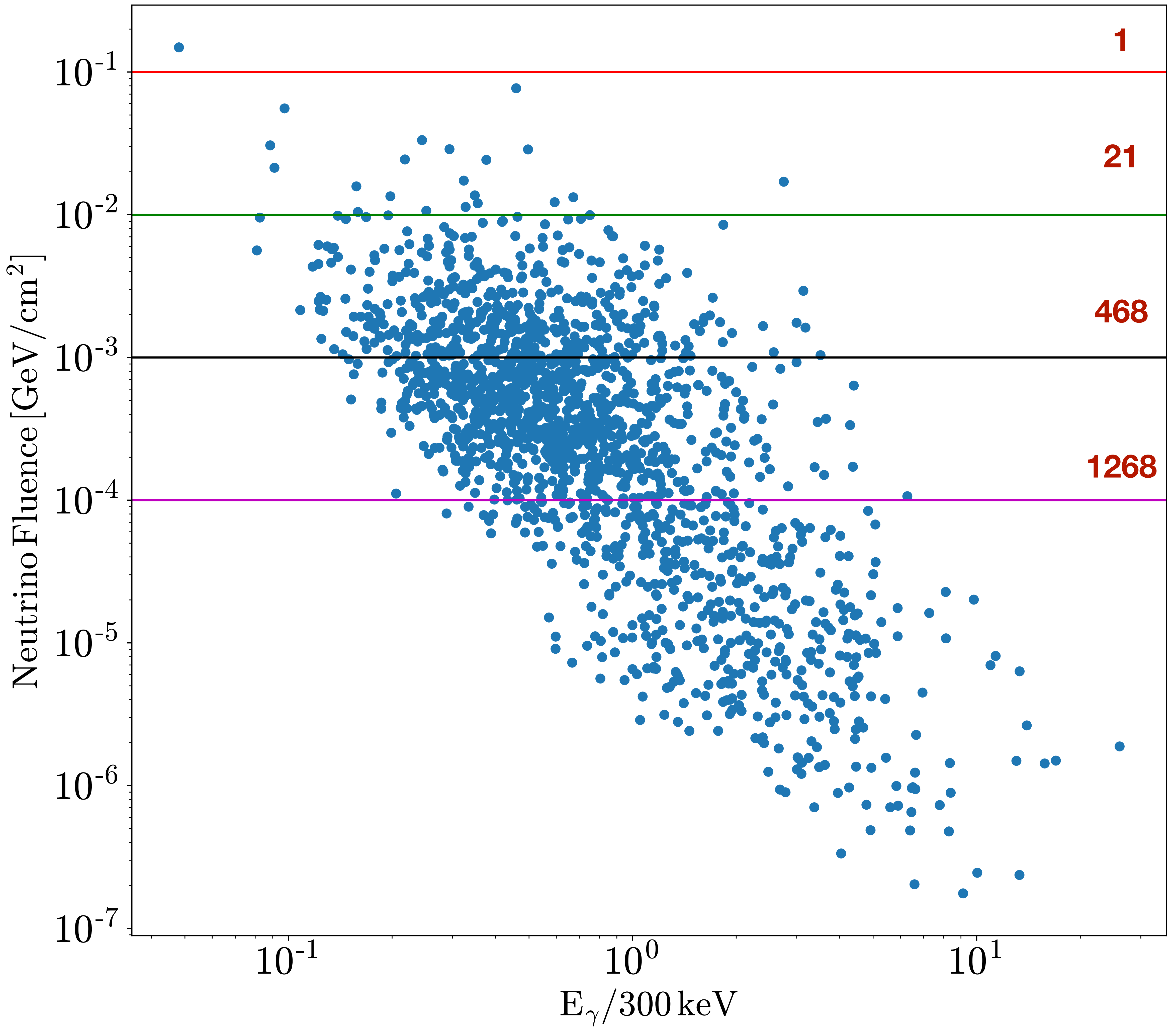


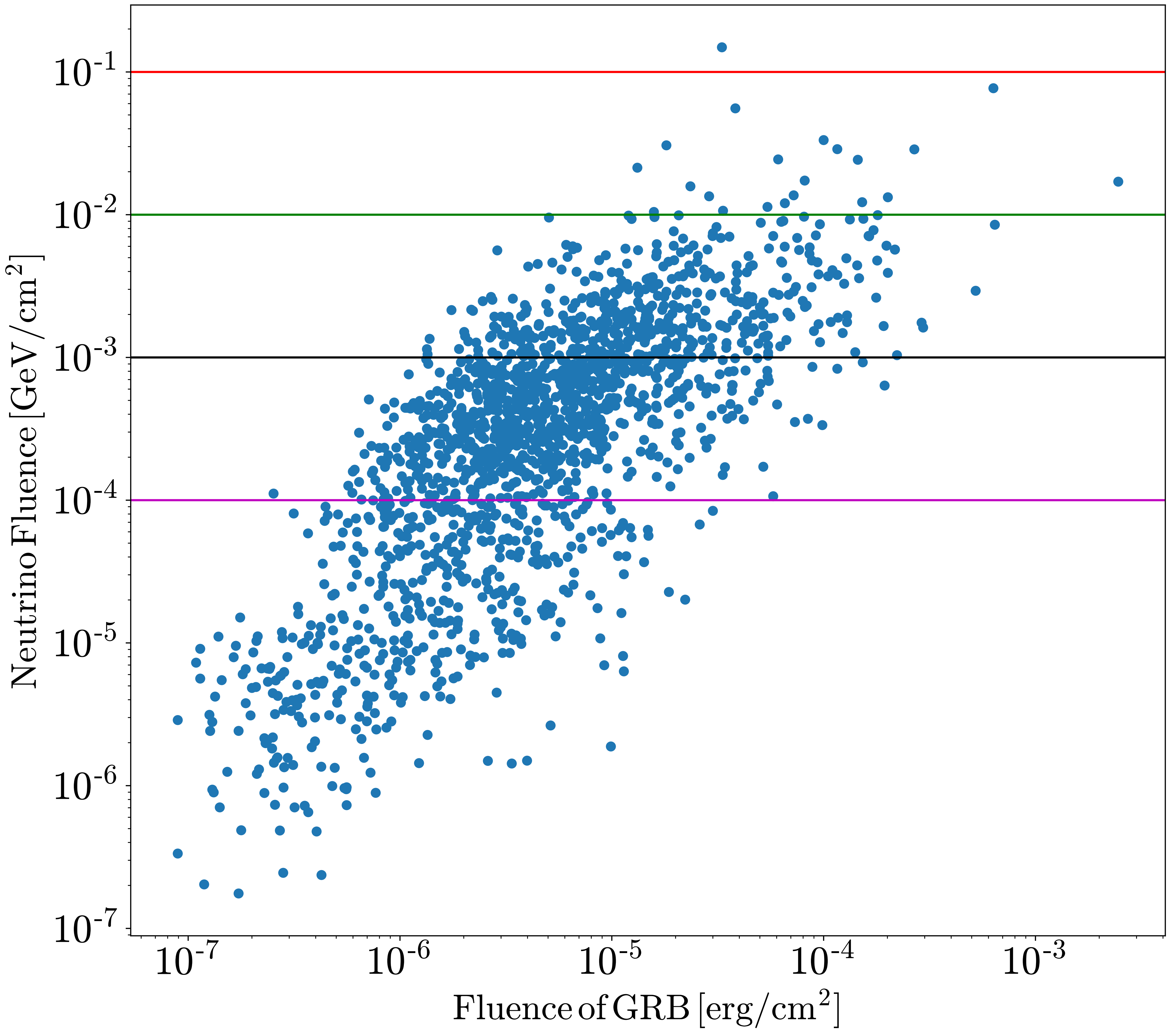
Fermi/GBM sample

(A) Prompt emission: stacking search with physical weights

(Considering all sources)

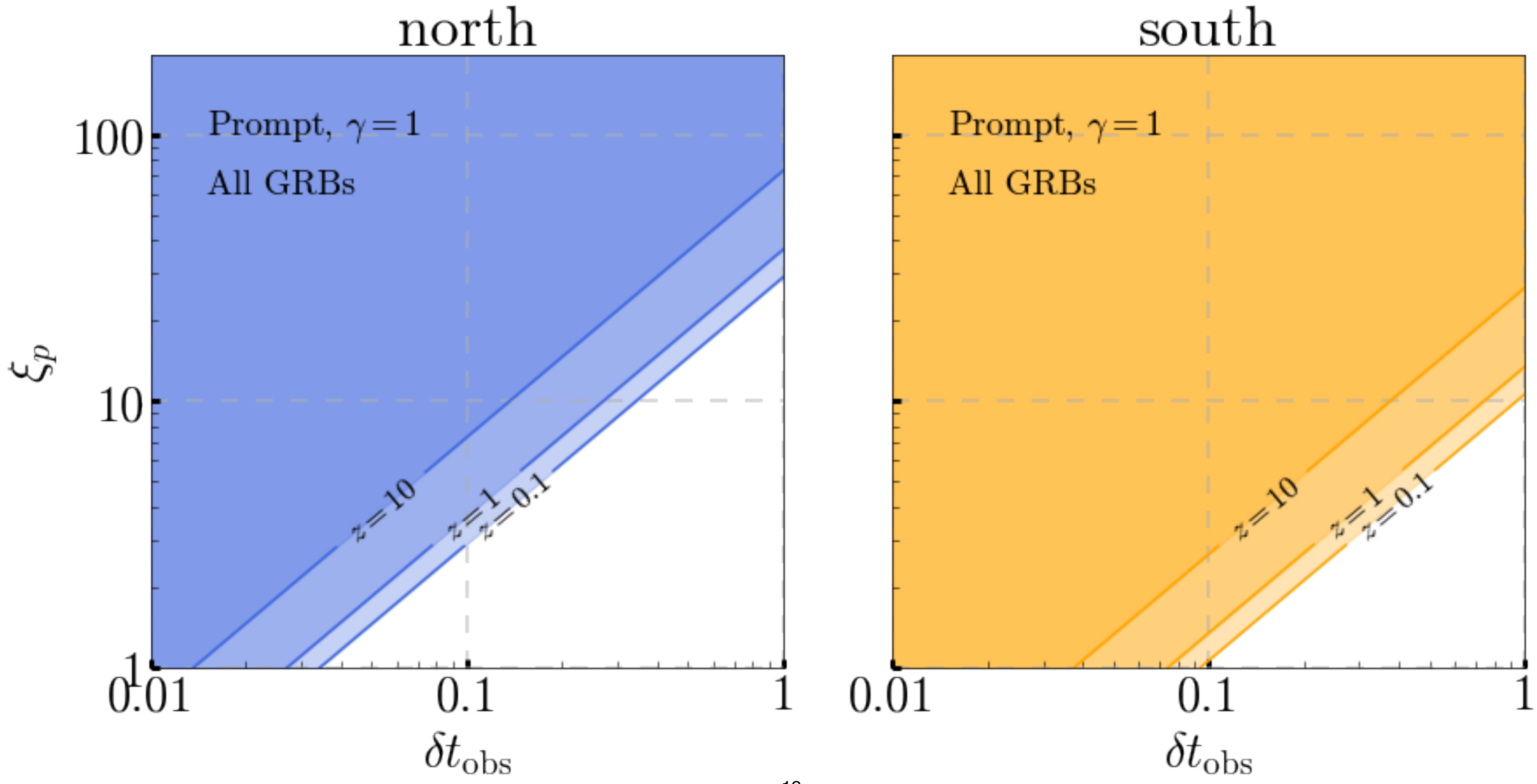
$$\xi_p = ln(E_{p,max}/E_{p,min}) \qquad \delta t_{obs} = 0.1s \qquad z = 1$$





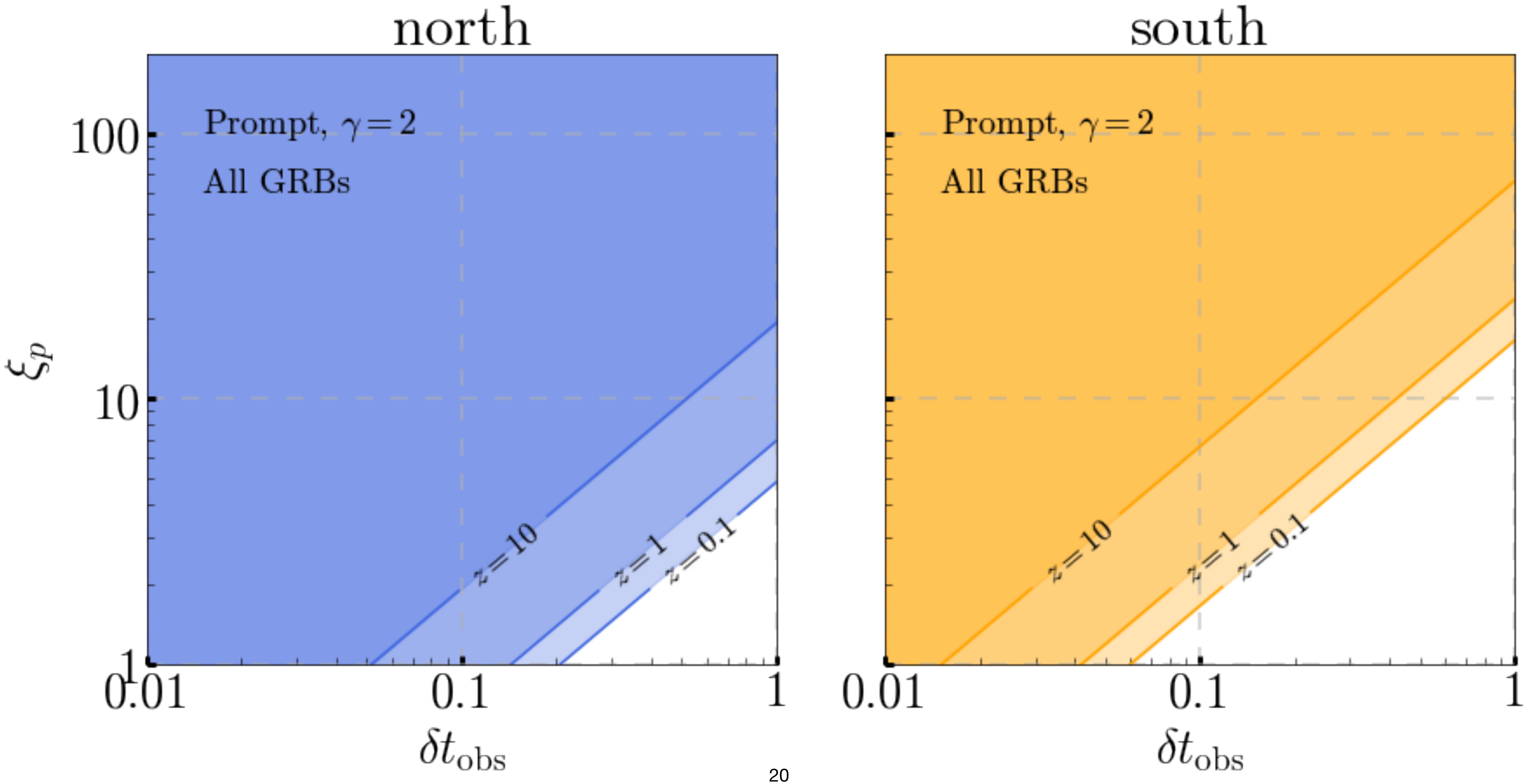
(A) Prompt emission: stacking search with physical weights

(Considering all sources)



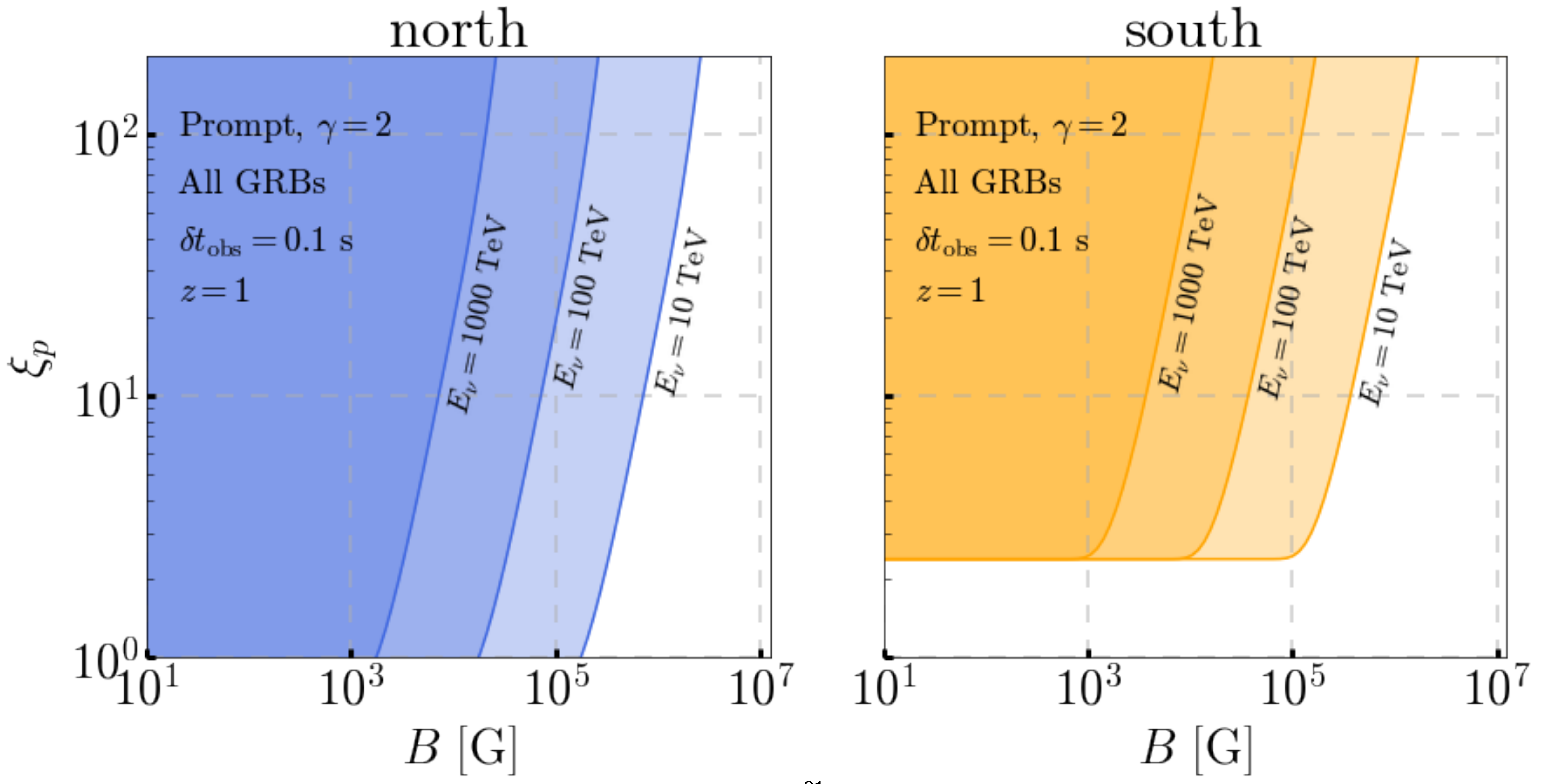
(A) Prompt emission: stacking search with physical weights

(Considering all sources)

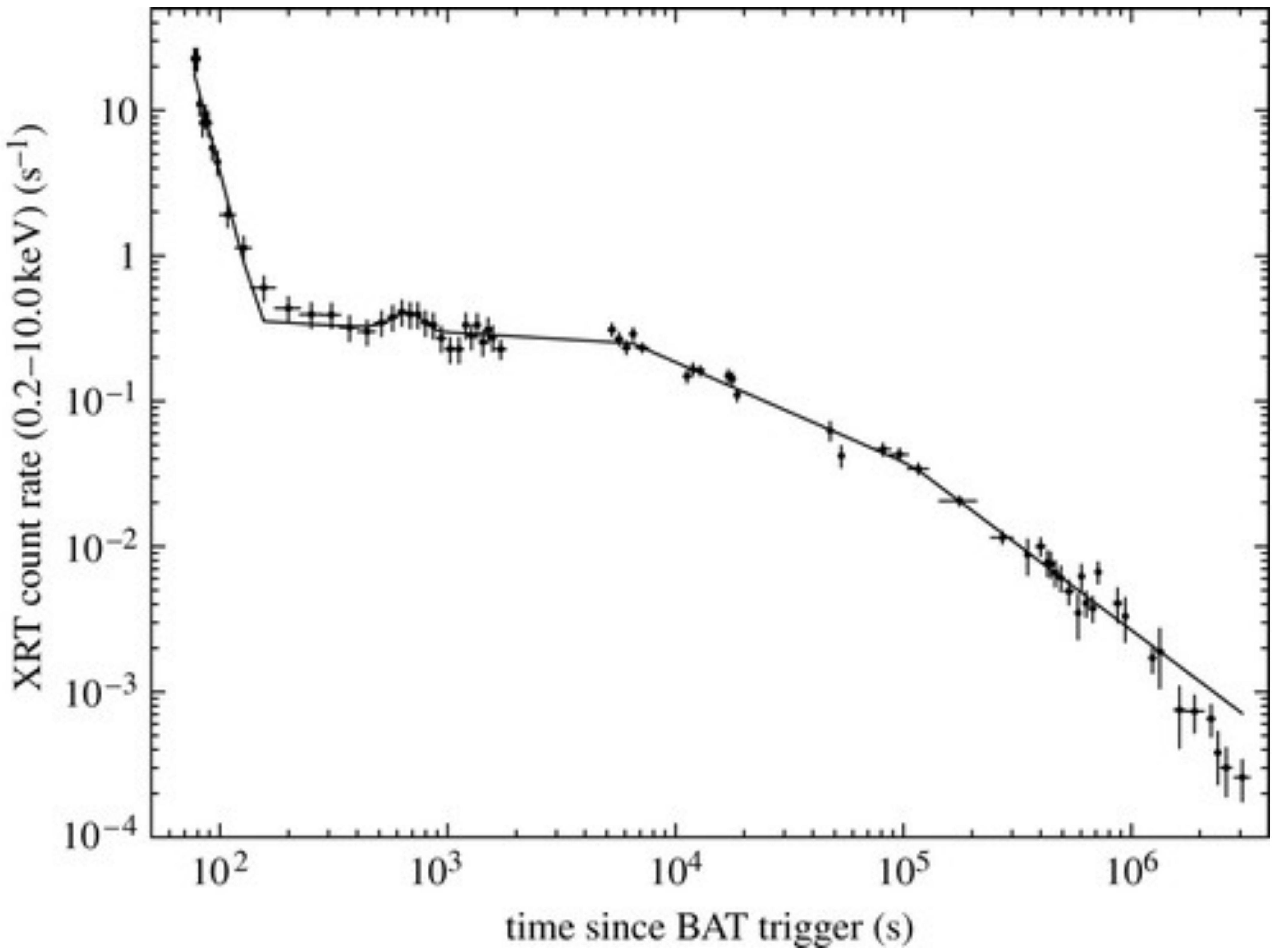


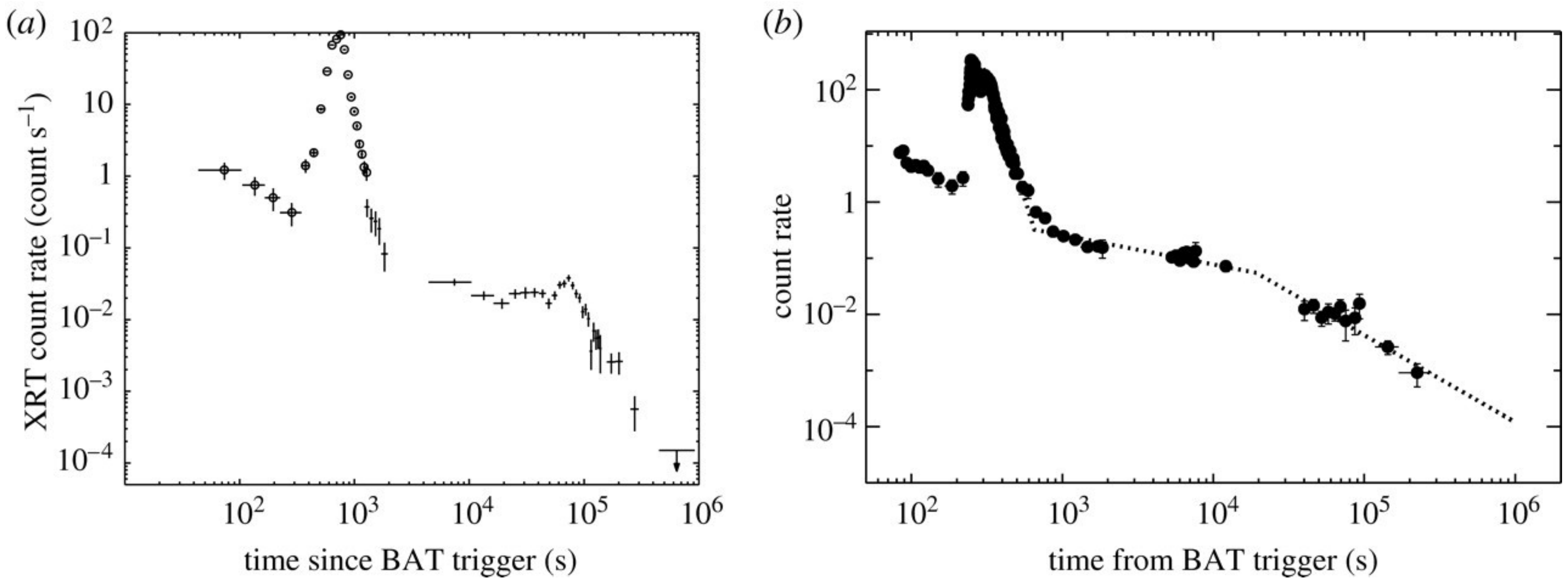
(A) Prompt emission: stacking search with physical weights

(Considering all sources)



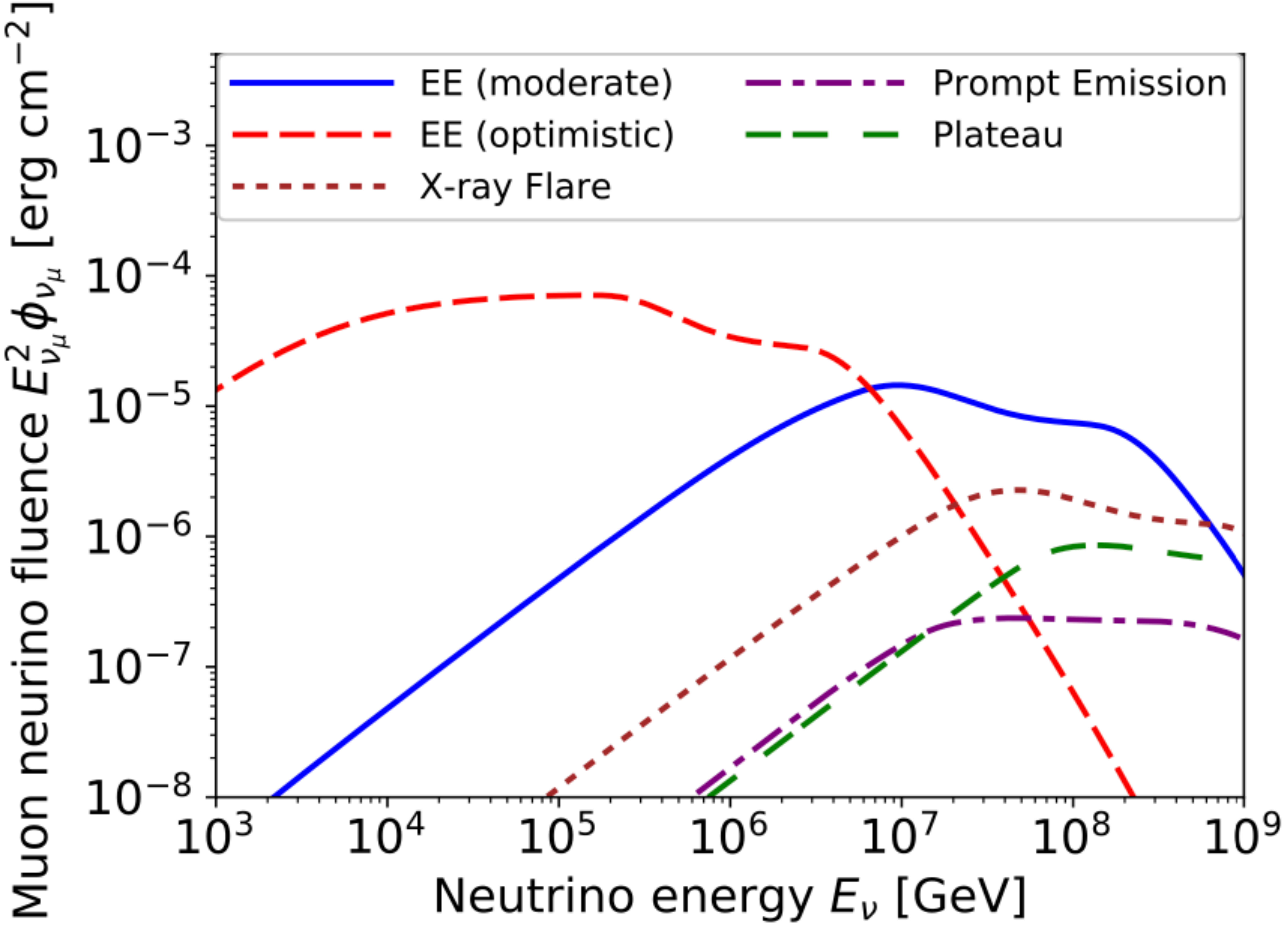
(B)-(C) X-ray plateau and X-ray flares



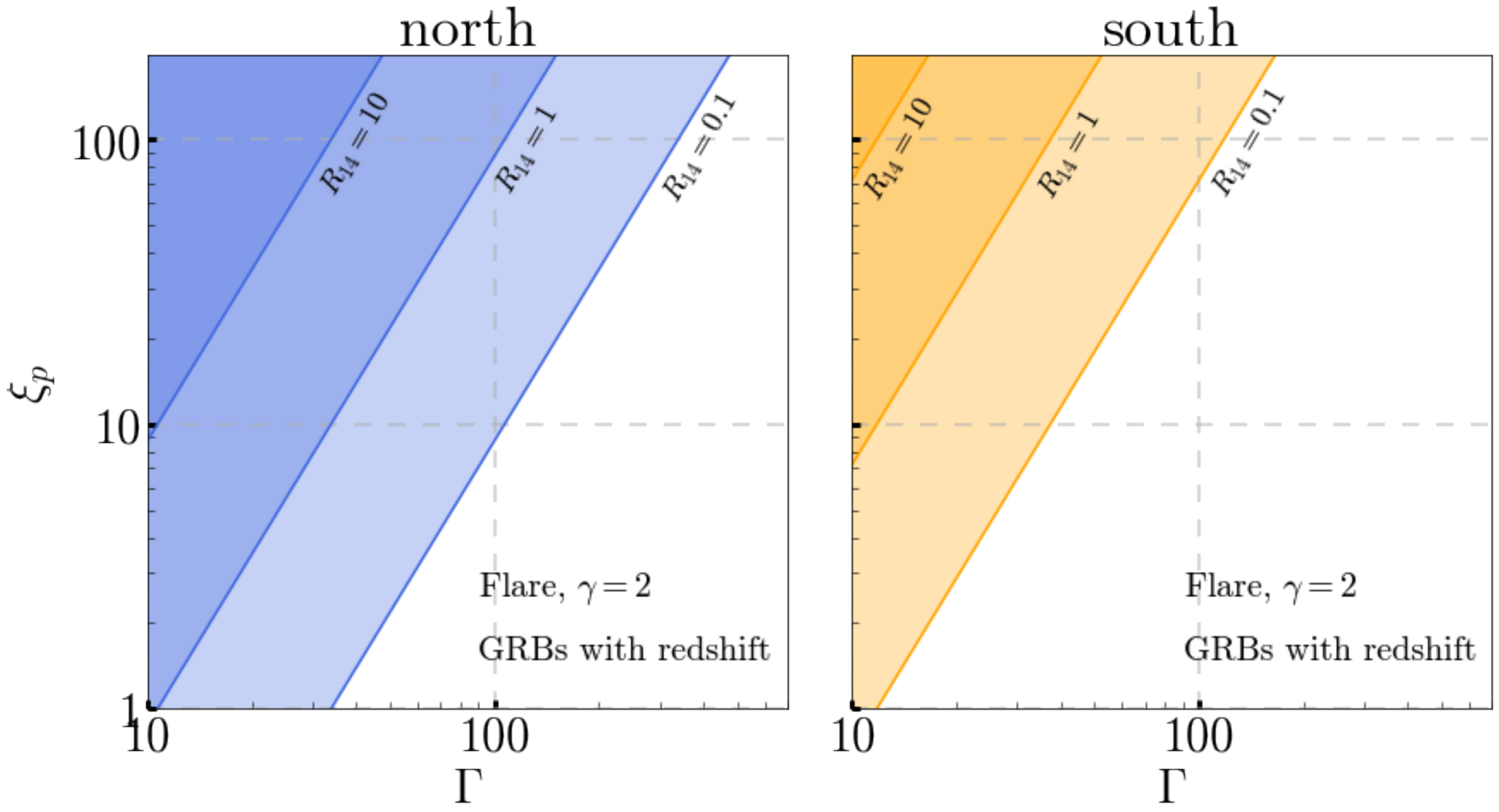


High-energy Neutrino Emission from Short Gamma-Ray Bursts: Prospects for Coincident Detection with Gravitational Waves

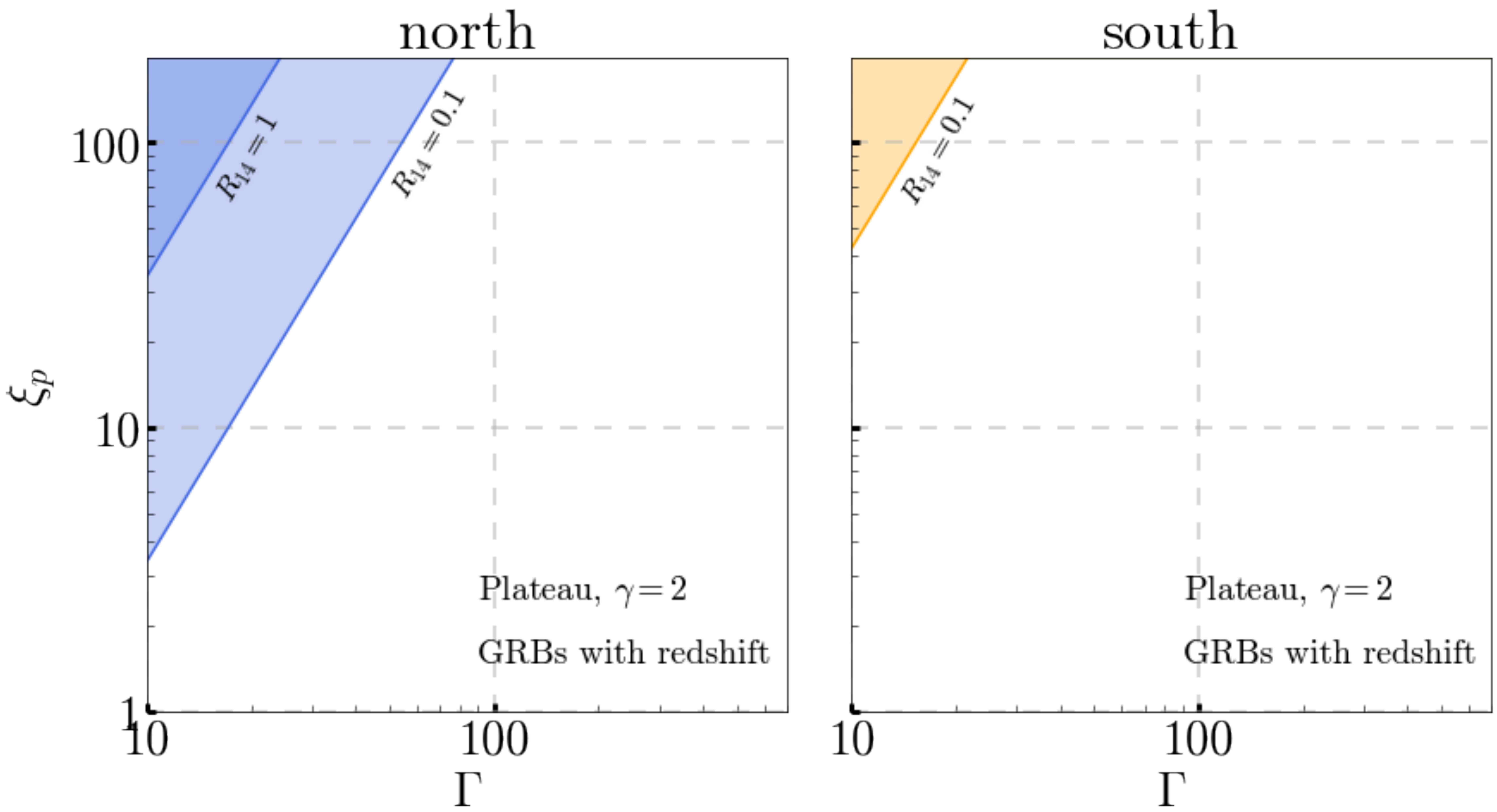
Shigeo S. Kimura[1,2,3], Kohta Murase[1,2,3,4], Peter Mészáros[1,2,3], and Kenta Kiuchi[4]



(B) X-ray flares



(C) X-ray plateaux



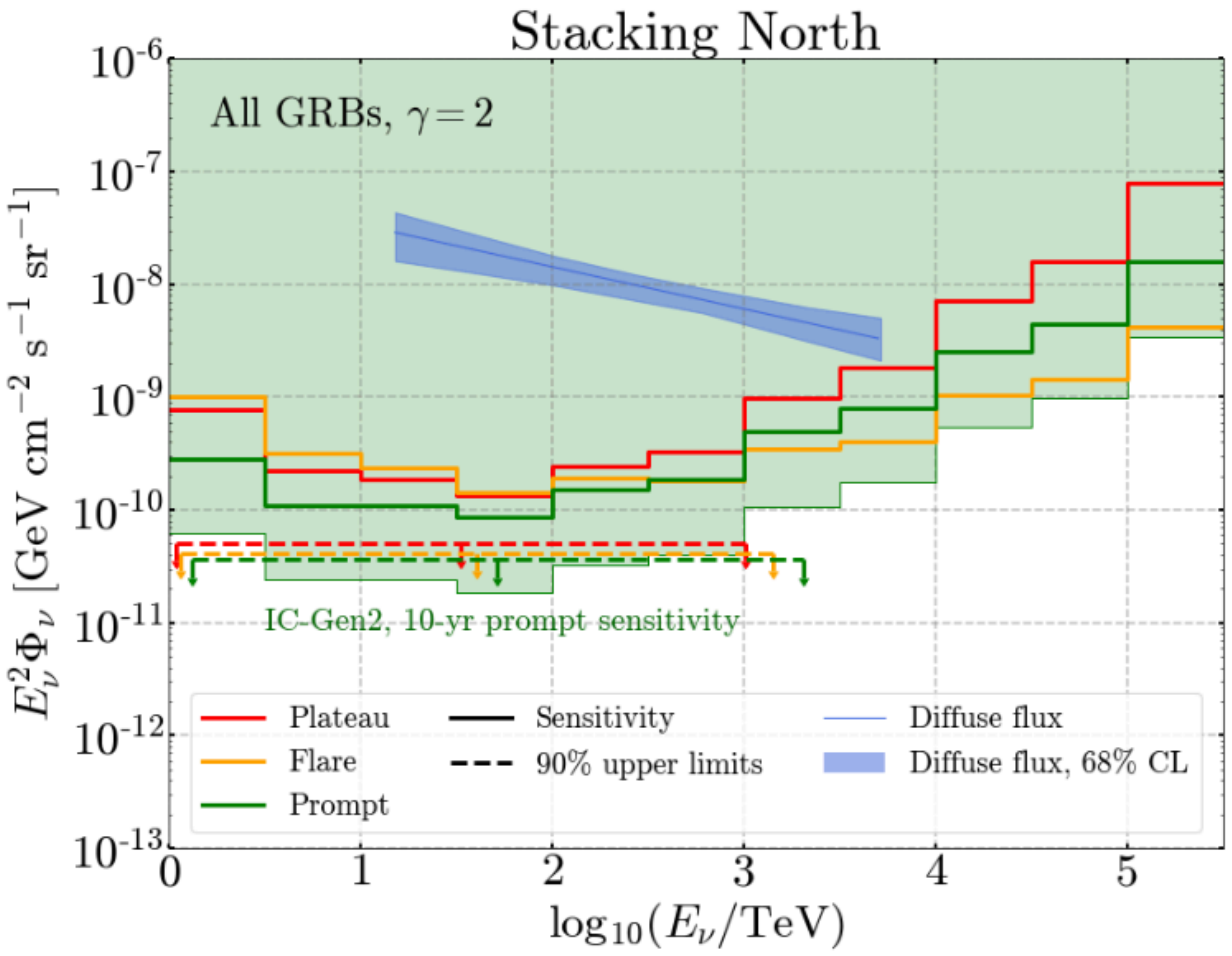
Summary

Stacking Search, all GRBs

Catalog	Hemisphere	$\gamma = 1$			$\gamma = 2$		
		$\hat{n}_s$	p_{loc}	$\phi^{\text{Stack}}_{90\%}$ [GeV cm^{-2} s^{-1} sr^{-1}]	$\hat{n}_s$	p_{loc}	$\phi^{\text{Stack}}_{90\%}$ [GeV cm^{-2} s^{-1} sr^{-1}]
Prompt	North	–	–	2.2×10^{-14}	0.9	3.7×10^{-2}	3.5×10^{-11}
	South	–	–	8.0×10^{-15}	–	–	1.2×10^{-10}
Plateau	North	–	–	8.6×10^{-14}	–	–	5.1×10^{-11}
	South	–	–	2.0×10^{-14}	–	–	4.1×10^{-10}
Flare	North	–	–	7.0×10^{-15}	–	–	4.1×10^{-11}
	South	–	–	1.7×10^{-14}	–	–	3.5×10^{-10}

F. Lucarelli et al., in preparation

Future



F. Lucarelli et al., in preparation

Some remarks

- Weighting GRBs is important
- X-ray flares/ Soft EE are promising
- GRB jets either are highly magnetised and/or are not able to accelerate protons to HEs
- GeV neutrinos (difficult) or TeV with IceCube 2