Search for 10 – 1000 GeV neutrinos from Gamma Ray Bursts, including GRB 221009A, using IceCube-DeepCore

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Abstract

We have searched for 10 – 1000 GeV neutrinos from 2268 gamma-ray bursts (GRBs) in IceCube-DeepCore data collected between April 2012, and May 2020. In addition, we conducted the same search for the ”Brightest Of All Time" (BOAT) GRB 221009A. We find no evidence of neutrino emission from these GRBs. We present model-independent limits on neutrino emission from these GRBs for various time scales that overlap with prompt, precursor and early afterglow phases. If the fireball is baryon loaded, this leads to subphotospheric neutron-proton collisions. We find that GRB 221009A provides the most constraining limit on the baryon loading. Assuming a jet Lorentz factor of 300 (800), the baryon loading on GRB 221009A is lower than 3.85 (2.13) at a 90% confidence level. The canonical value of baryon loading in models is 5.

Gamma Ray Bursts (GRBs)

- GRBs modeled as a plasma **fireball** of coupled photons, EM fields, e+/e- pairs and baryons emitted in relativist jets with Γ~300.
- Fireball is transparent to photons at the **photosphere**
- **Prompt** phase: 0.1 – 1000 s. Observed in keV – MeV γ-rays
- **Short GRBs** prompt $\lesssim$2 s. **Long GRBs** prompt $\gtrsim$2 s

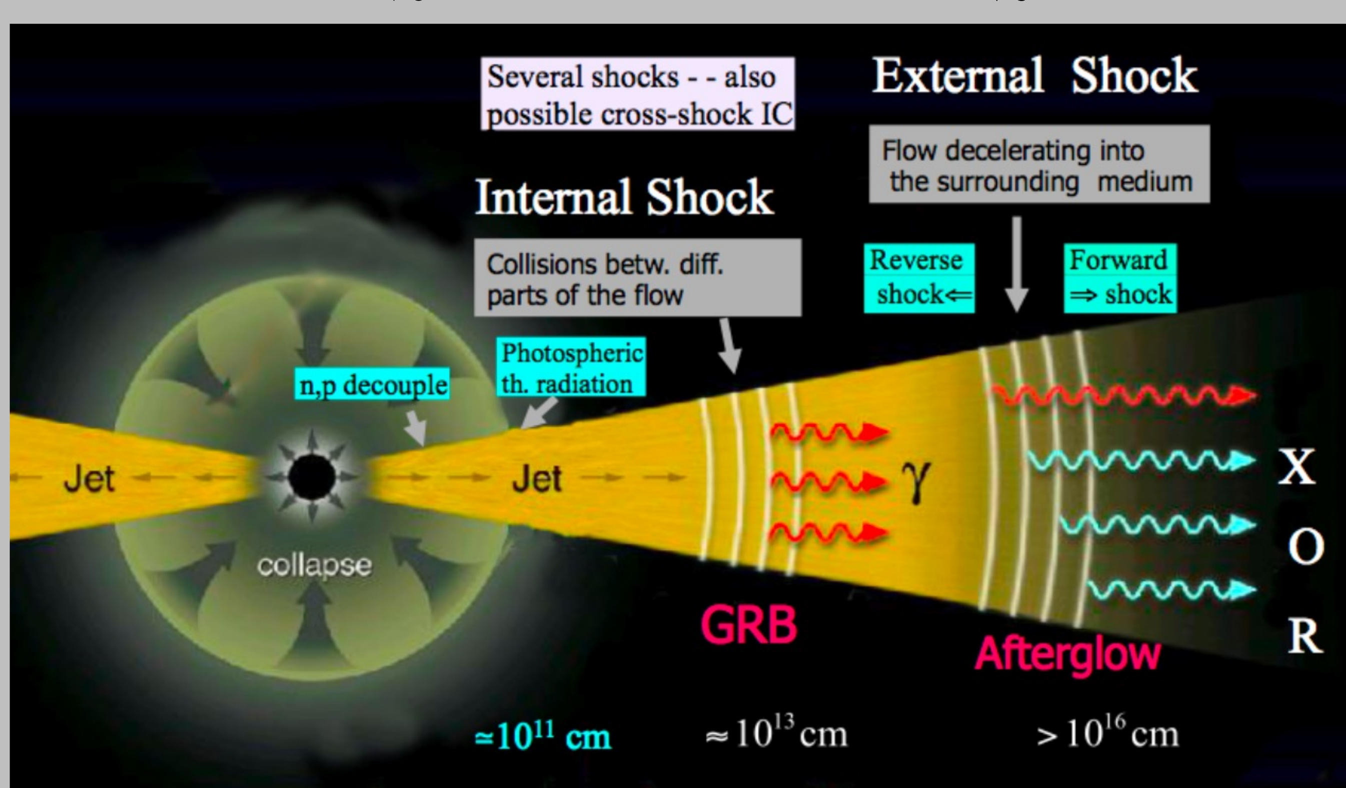

Fig 1. GRB Jets. Figure taken from Ref. [1]

GRB 2210009A – The BOAT

- Rate of GRBs above this energy fluence: once per 10000 years
- Prompt **energy fluence**: f_γ = 0.22 erg/cm^2 [2]
- **Equivalent isotropic energy** in γ-rays: $E_{iso,\gamma}$ = 1.2 x 10^{55} erg
- Redshift, z = 0.151 [3]

E_{iso}

Subphotospheric neutrinos from GRBs

- Subphotospheric (before prompt) neutrons decouple from protons
- Free streaming neutrons collide with protons → neutrinos [4,5,6]
- Neutrino emission depends on baryon loading: $\xi_N = E_{iso,N}/E_{iso,\gamma}$, the ratio of isotropic equivalent energy in nucleons to photons.

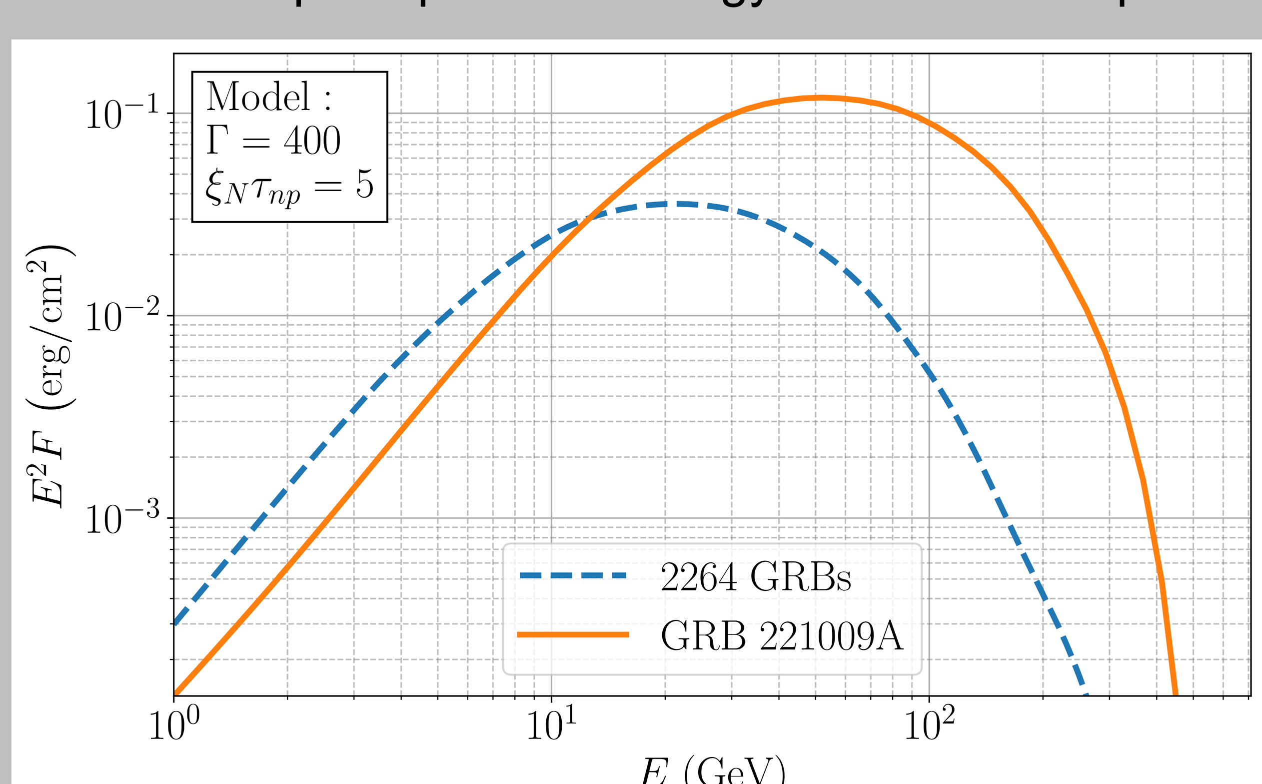

Fig 2. Neutrinos from subphotospheric neutron-proton collisions from GRB 221009A and 2264 GRBs observed in 2012 – 2020. [5,6,7]

IceCube and DeepCore

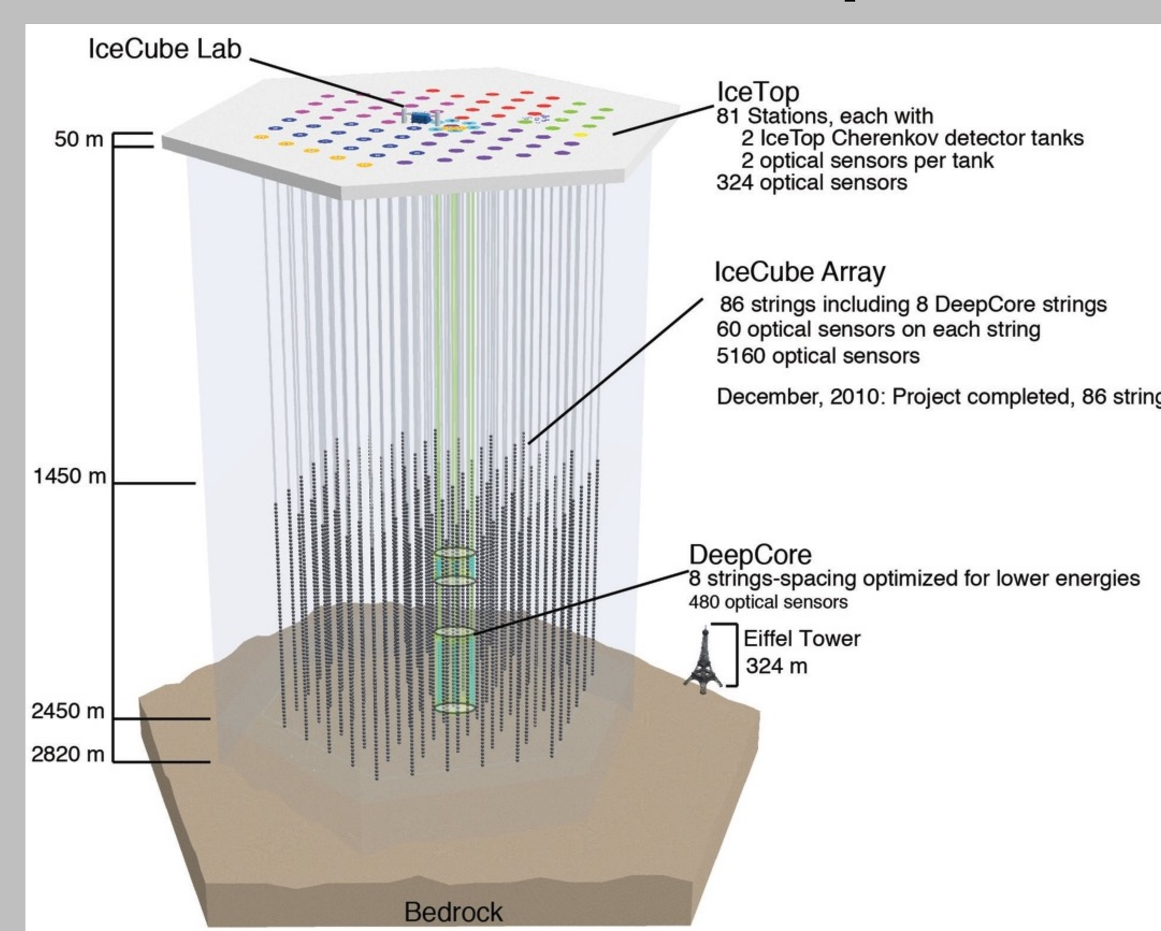

Fig 3. The IceCube neutrino observatory, including DeepCore

10 – 1000 GeV neutrino limits from GRBs

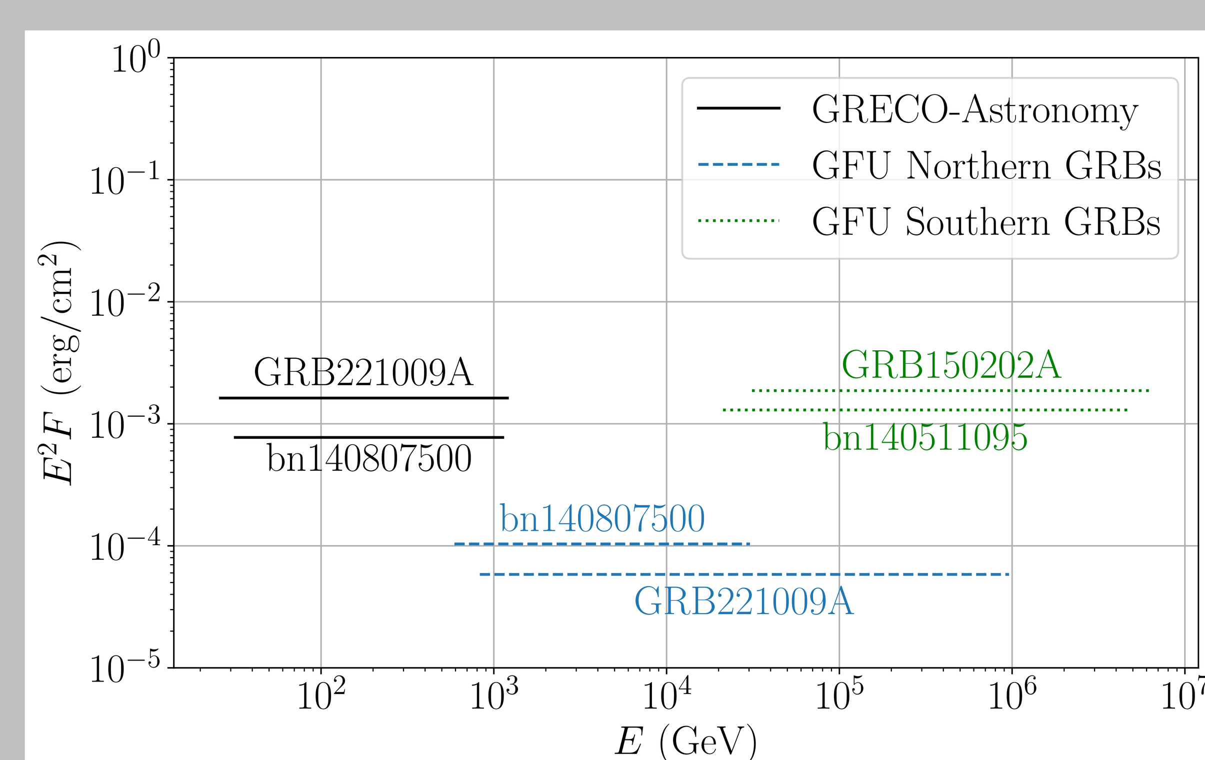

Fig 4. DeepCore (GRECO) limits on GRBs [7,8] and IceCube (GFU) limits [9]. DeepCore has approximate equal sensitivity all-sky.

Baryon loading ξ_N limit for GRB 221009A

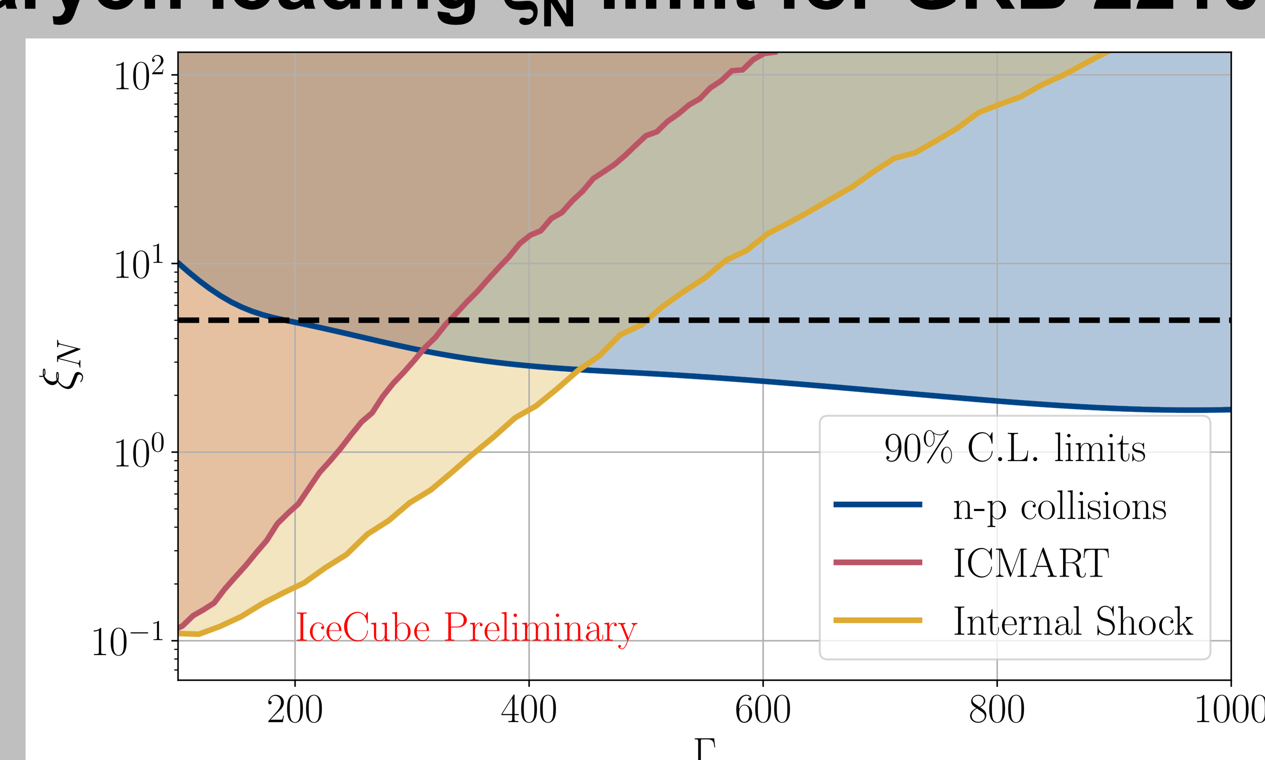

Fig 5. Canonical ξ_N=5 [6]. n-p subphostospheric collisions limit (GRECO) [7]. Internal shock & ICMART limits (GFU) [10]. **Baryon loading limit with 10 – 1000 GeV does not depend on internal shock modeling.**

References

[1] P. Mészáros. Neutrino Astronomy, pp 1-14 (2017) doi:10.1142/9789814759410_0001
[2] D. Frederiks, et al. 2023, ApJL, 949, L7, doi:10.3847/2041-821
[3] A. de Ugarte Postigo, et al. 2022, GRB Coordinates Network, 32648
[4] P. Mészáros and E. Waxman 2001, PhRvL, 87, 171102, doi: 10.1103/PhysRevLett.87.1
[5] K. Murase and K. Ioka, 2013, PhRvL, 111, 121102, doi: 10.1103/PhysRevLett.111.1
[6] K. Murase, et al. 2022, ApJL, 941, L10, doi: 10.3847/2041-8213/a
[7] R. Abbasi (IceCube collaboration). arXiv:2312.11515
[8] R. Abbasi et al. (IceCube collaboration). ApJL, 946, L26, doi: 10.3847/2041-8213/acc077
[9] R. Abbasi et al. (IceCube collaboration) ApJ, 939, 116, doi: 10.3847/1538-4357/ac9785
[10] R. Abbasi et al. (IceCube collaboration). PoS, ICRC2023, 1511, doi: 10.22323/1.444.1511