Recent Results in the Search for Muon Neutrinos from Gamma-Ray Bursts with AMANDA-II

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UC, Riverside

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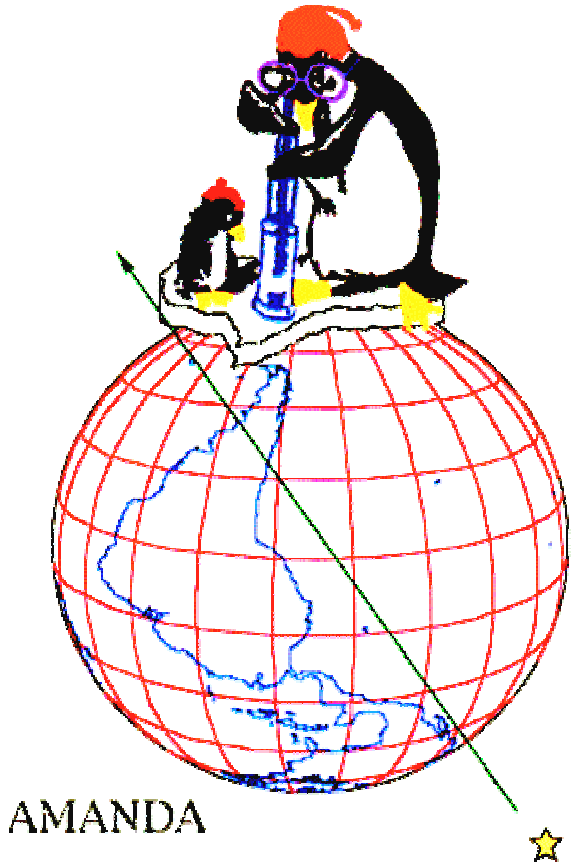


Observation Procedure

Burst location and timing provided by:

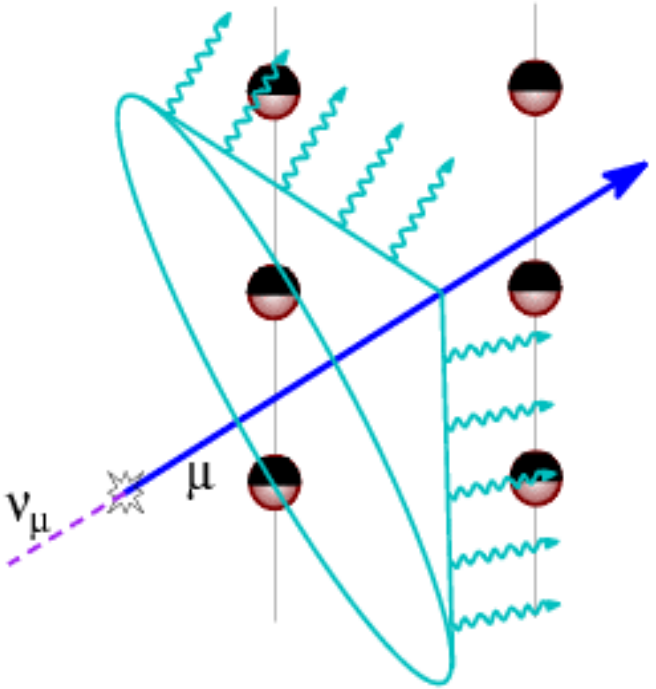
BATSE

- **Burst Catalogs**
- **Stern, Kommers**
- **GUSBAD**

IPN3

- **GCN Circulars**
- **Archival search**

(K. Hurley *et al.*)



$\nu_\mu + N \rightarrow \mu + X$

μ emits Cherenkov radiation; direction reconstructed from correlations between PMTs

Previous Observations

(Preliminary—Publication in Progress)

97-00 flux limit at Earth for 312 BATSE triggered bursts:

$$E_\nu^2 \Phi_\nu < 4 \times 10^{-8} \text{ GeV cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$$

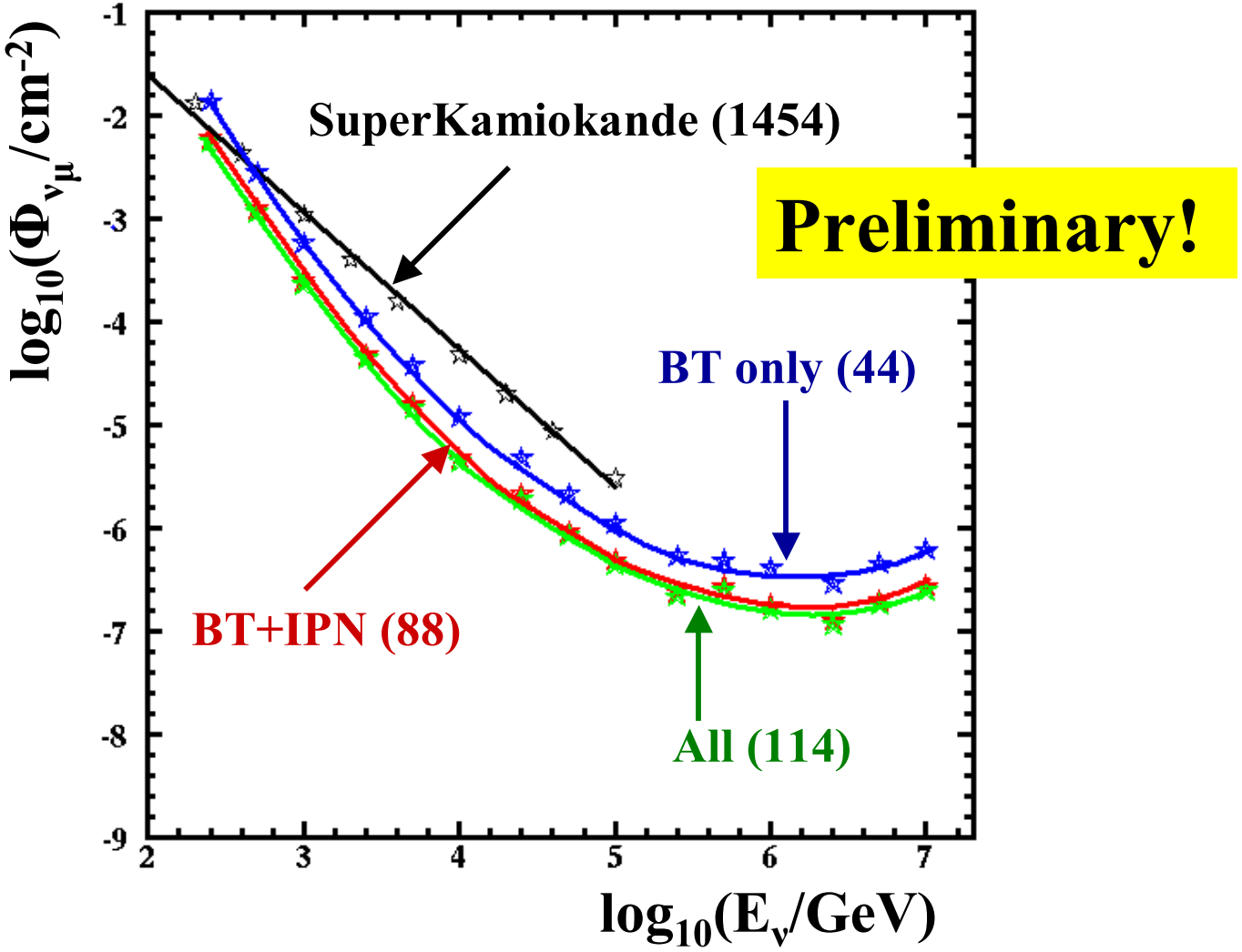
for Waxman-Bahcall-type spectrum with E_{break}=100 TeV, Γ = 300

Year	N_{Bursts}	$N_{BG, Exp}$	N_{Obs}	Event U.L.
2000	44 (BT)	0.41	0	2.05
2000	26 (BNT)	0.24	0	2.19
2000	44 (IPN)	0.60	0	2.01
2000	88 (BT+IPN)	1.02	0	1.61
2000	114 (All)	1.25	0	1.47

BT = BATSE Triggered BNT = BATSE Non-Triggered IPN = InterPlanetary Network

Green's Function Fluence Limit

following Super-Kamiokande method (*2002ApJ, 578:317F*)



Current Analysis: 2001-2003

Bursts with localization error < AMANDA searchbin size:

- 9 bursts in GCN Archives for 2001

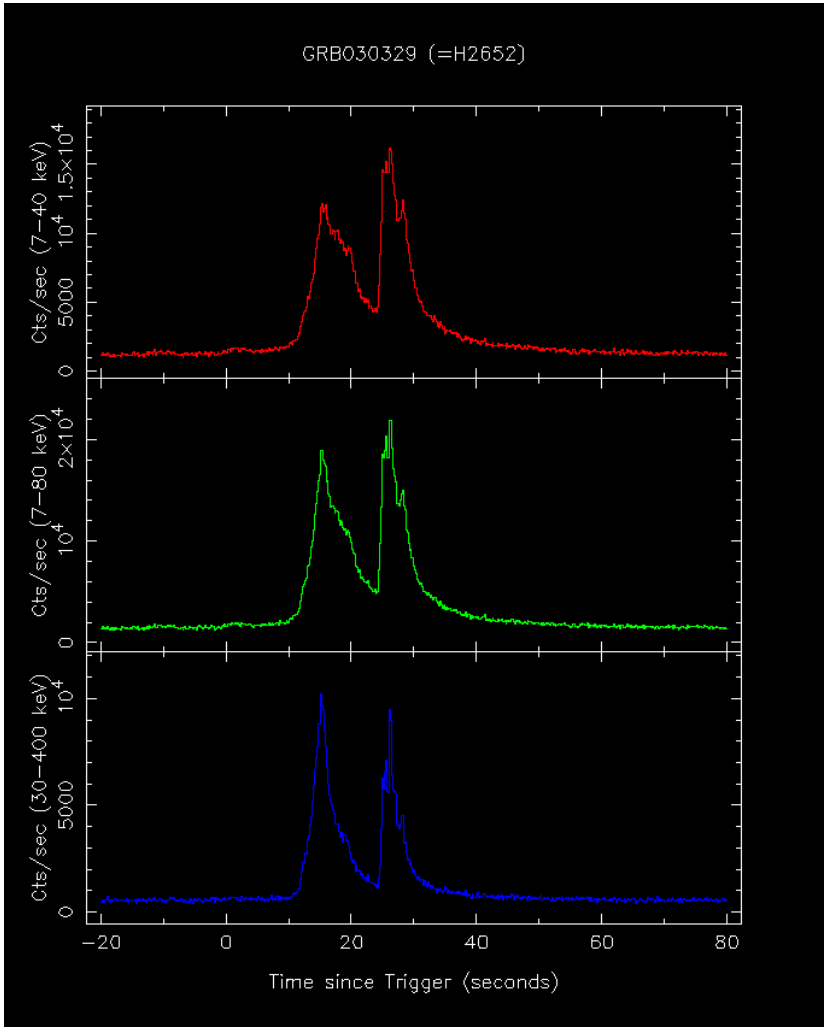
  +8 localized by K. Hurley *et al.*
- 15 bursts in GCN Archives for 2002

  +3 localized by K. Hurley *et al*.
- 26 bursts in GCN Archives for 2003

  31 bursts w/accurate timing already analyzed

+ 30 bursts to be analyzed after timing issues resolved

GRB 030329



Closest GRB observed: $z \sim 0.17$

Bright: 10^{-4} erg/cm^2 (30-400 keV)

Peak flux: 7×10^{-6} erg cm^{-2} s^{-1}

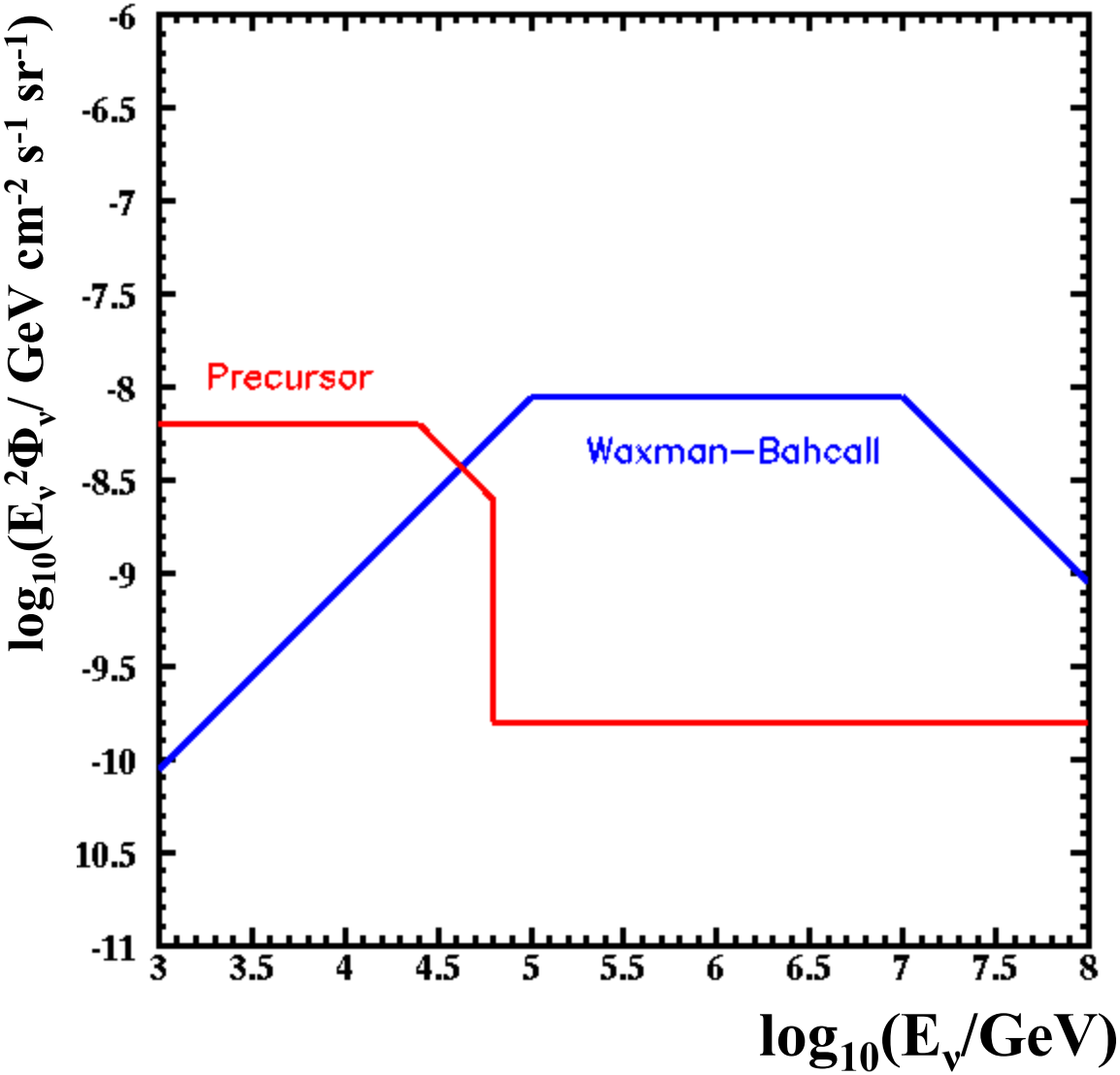
TeV-PeV ν_μ's expected from

- **burst: 1.8 events/km^2**
- afterglow: 0.03 events/km^2
- supranova: 12.4 events/km^2
- precursor: 4.1 events/km^2

[Razzaque *et al.*, PRD **69** 023001 (2004)]

This research has made use of data obtained from the HETE science team via the website http://space.mit.edu/HETE/Bursts/Data. HETE is an international mission of the NASA Explorer program, run by the Massachusetts Institute of Technology.

Model Neutrino Spectra



•Waxman, E.,
Nuc. Phys. B 118 (2003)

† Razzaque et al.,
*PRD **68** 083001 (2003);*
see also
*PRL **90** 241103 (2003)*

Cut Selection

Cuts to separate signal from background based on:

- *event time*: (t_0 - 110 s) to (t_0 – 10 s) for precursor search
  (t_0 - 10 s) to (t_0 + duration + 1 s) for coincident search
- *reconstructed track direction* relative to burst position
- *uniformity* of hits along reconstructed track
- *event-wise angular resolution* of reconstructed track

Goal is to minimize Model Rejection Factor*:

$$\textbf{MRF} = \frac{\textbf{Event Upper Limit (= FC}^{\dagger}\textbf{[90\%])}}{\textbf{Expected Signal (from MC simulations)}}$$

•Hill, G., and K. Rawlins, *Astropart. Phys.* **19** (2003) 393-402

† Feldman, G., and R. Cousins, PRD **57** (7) 3873

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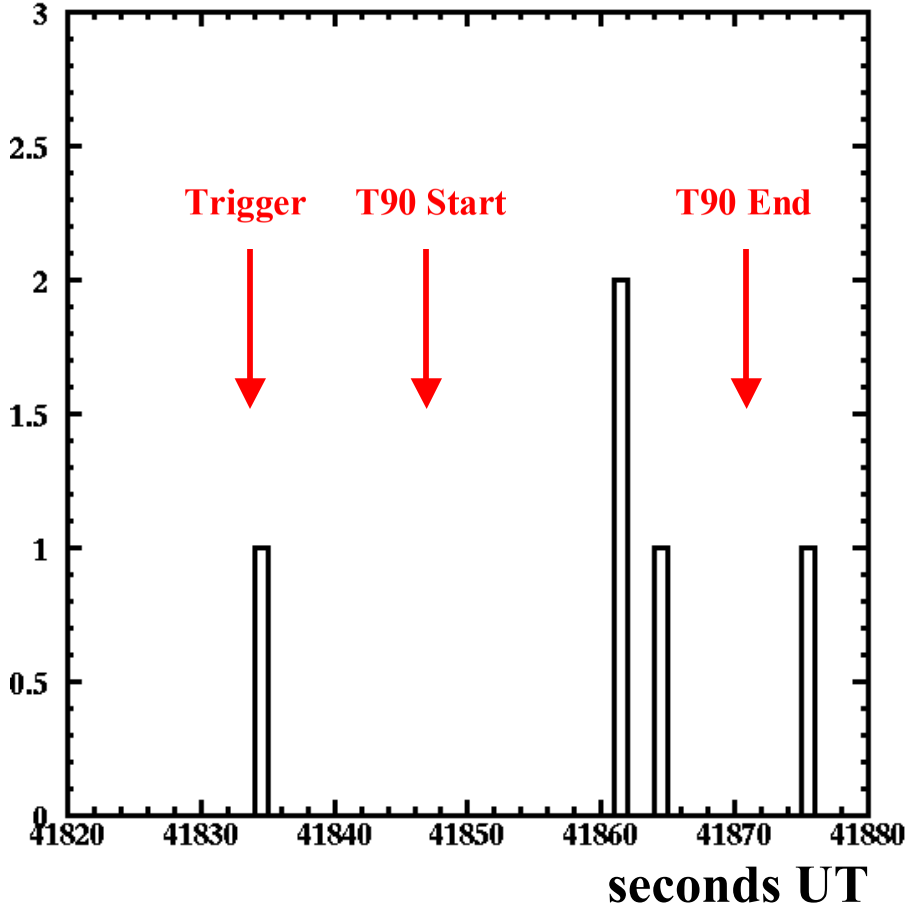
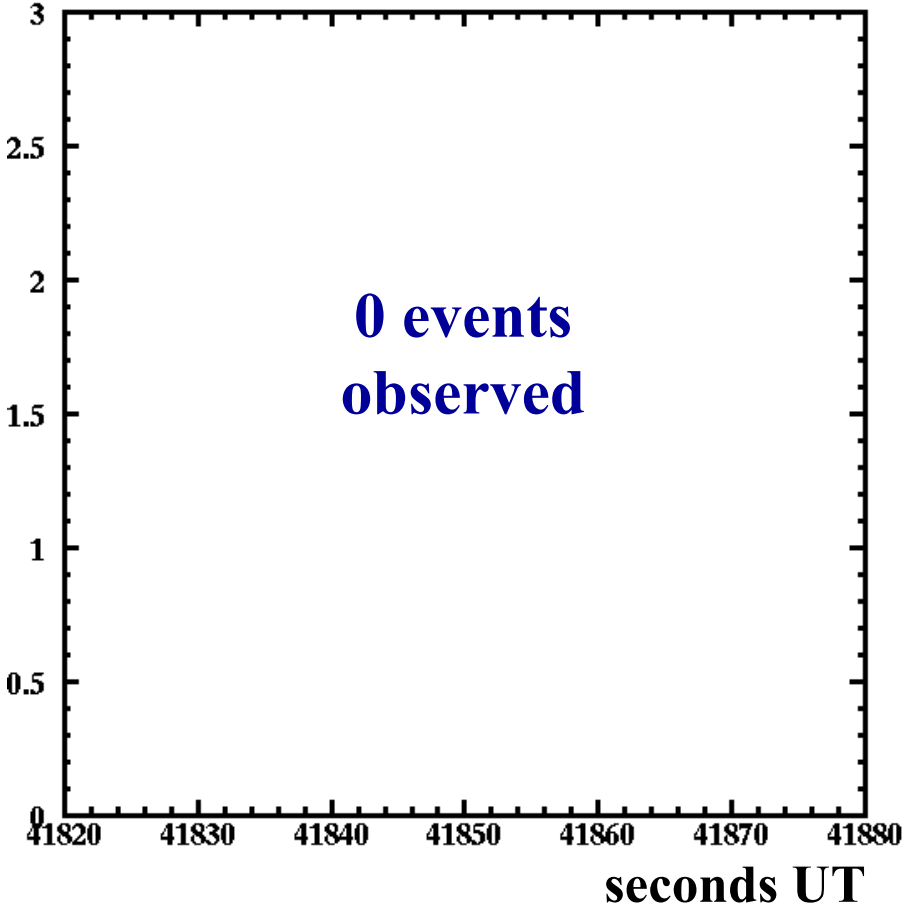
Before Final Cuts



After Final Cuts



Preliminary Results of Current Analysis

Year	N_{bursts}	$N_{BG, Exp}$	N_{Obs}	Event U.L.	MRF
2001	13	0.05	0	2.39	37
Precursor	13	0.04	0	2.40	
2002	9	0.04	0	2.40	52
Precursor	9	0.03	0	2.41	
2003	9	0.05	0	2.39	53
Precursor	8	0.03	0	2.41	
01-03	31	0.14	0	2.30	14
Precursor	30	0.09	0	2.32	
00-03	119	1.16	0	1.52	3

Observations consistent with background expectations

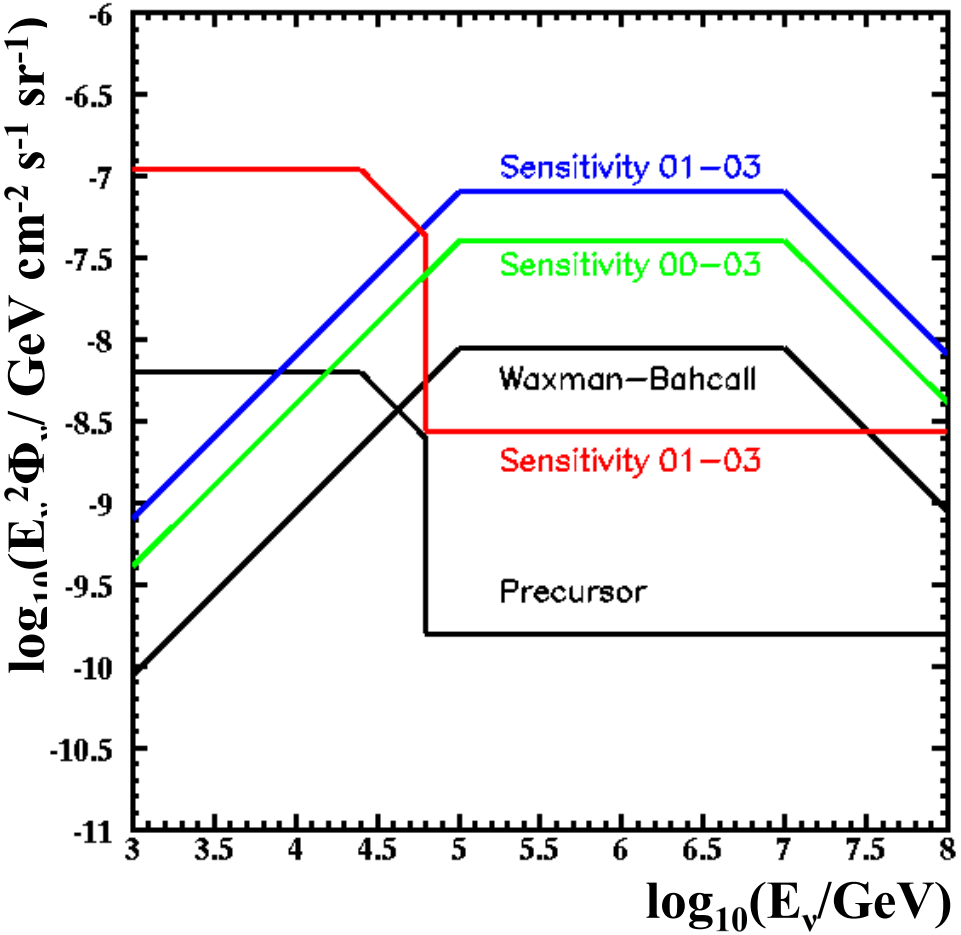
Outlook for Current Analysis

Year	N_{bursts}	$N_{BG, Exp}$	Event U.L.	MRF (Sensitivity)
2001	17	0.07	2.50	29
Precursor	17	0.05	2.48	
2002	18	0.08	2.50	27
Precursor	18	0.05	2.48	
2003	26	0.13	2.55	20
Precursor	25	0.08	2.50	
01-03	61	0.28	2.68	9
Precursor	60	0.18	2.59	
00-03	149	1.30	3.48	5

00-03 sensitivity comparable to current limit (with <½ N_{bursts})

Precursor search is completely new

Outlook for Current Analysis



W-B Flux Sensitivity at Earth:

$N = 8 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}

$N = 4 \times 10^{-8}$ GeV cm^{-2} s^{-1} sr^{-1}

For 61 bursts w/ Broken Power-Law Spectrum (E_{break} = 100 TeV, Γ=300)

Precursor Sensitivity at Earth:

$N \sim 10^{-7}$ GeV cm^{-2} s^{-1} sr^{-1}

For 60 bursts w/ E^{-2} Spectrum (E_{break} = 25 TeV)

Conclusions

- Analysis completed for 97-00, parallel 00
  - Limit set for 312 BATSE triggered bursts
  - Burst search expanded to include IPN, non-triggered
- Analysis of IPN bursts for 2001-2003 *in progress*:
  - **0 events observed**
  - Waxman-Bahcall broken power-law flux sensitivity
  - Razzaque *et al*. precursor flux sensitivity
- More GRBs on the way...
  - 100 *additional* bursts with less accurate localizations
  - Further burst localizations for 2002-2003 in progress