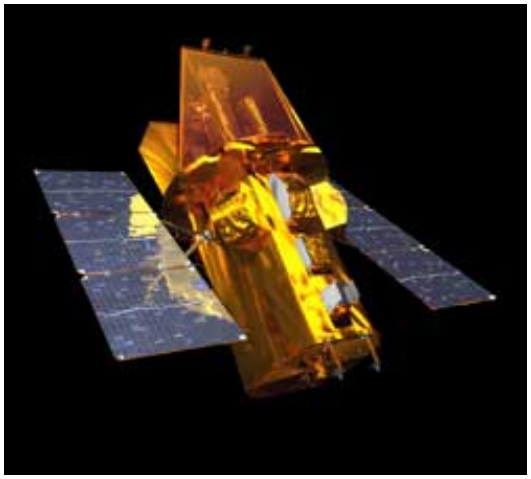
Multi-messenger observations of Gamma Ray Bursts

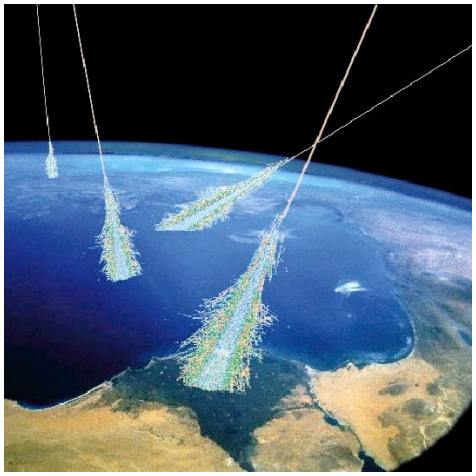
Ignacio Taboada

Astronomical messengers

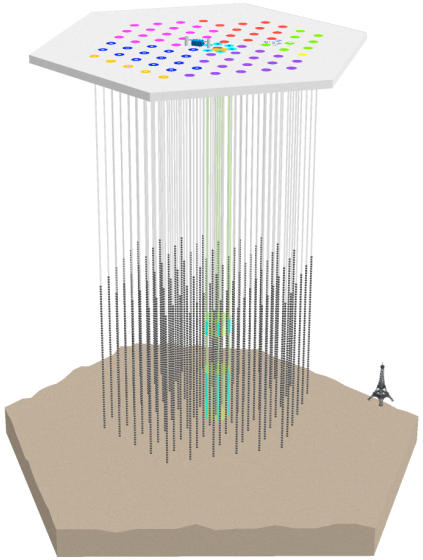
Photons



Cosmic Rays



Neutrinos



Gravitational Waves

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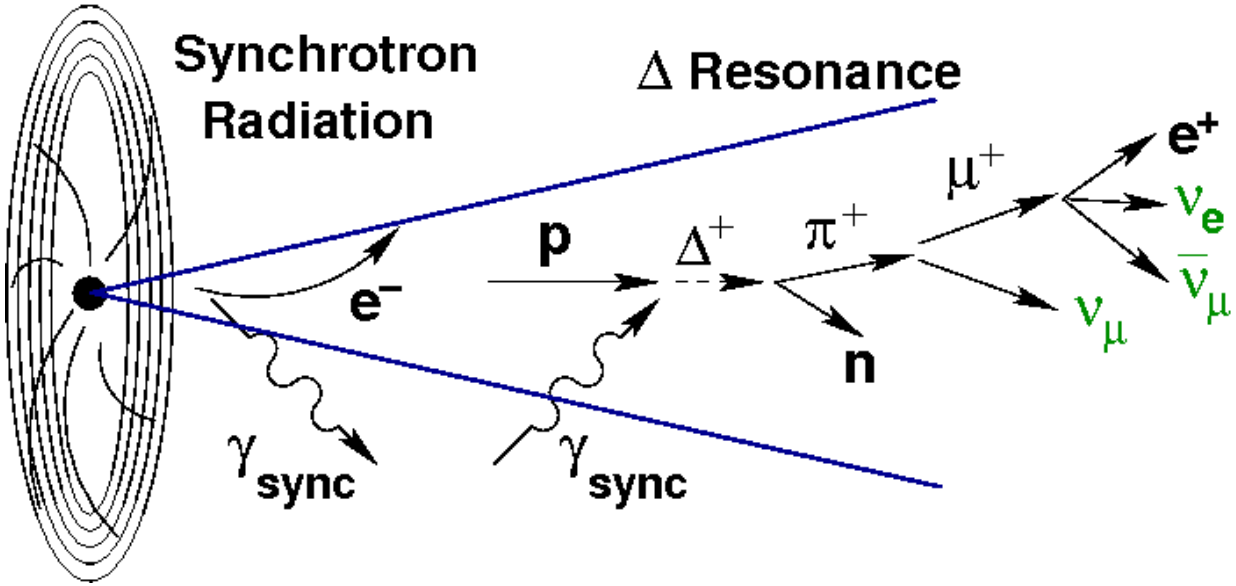
Big questions for neutrino astrophysics

- What are the sources of (galactic + extra galactic) cosmic rays?
  - GRBs are a plausible candidate source for extra galactic cosmic rays
    (but also AGNs, Galaxy clusters, etc …)
- Are there dark sources of neutrinos?
  - Choked GRBs?

(not a complete list)

Neutrinos from GRBs

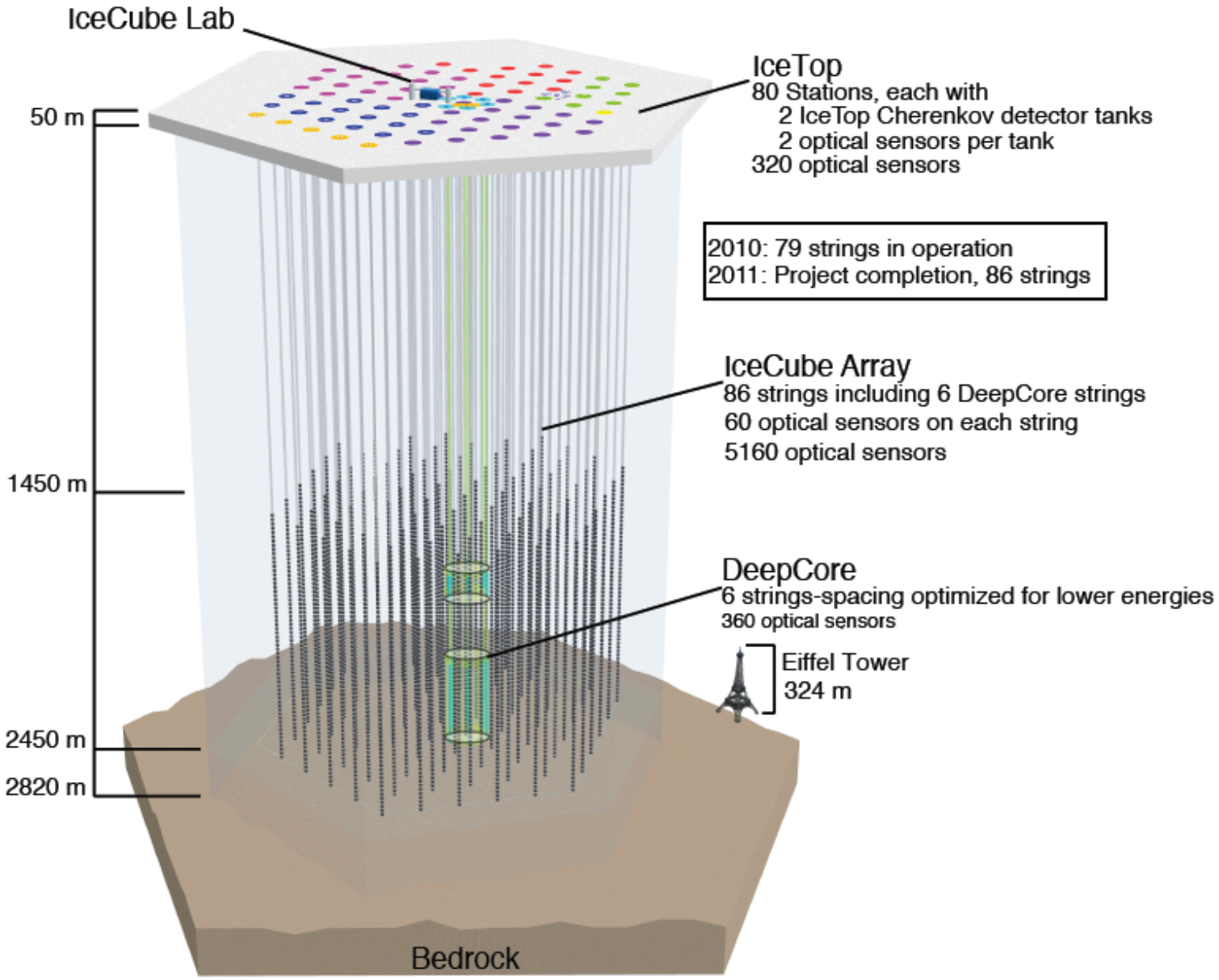


Also possible: p–p neutrino production

Precursor neutrinos and choked GRBs
Burst neutrinos
Afterglow neutrinos

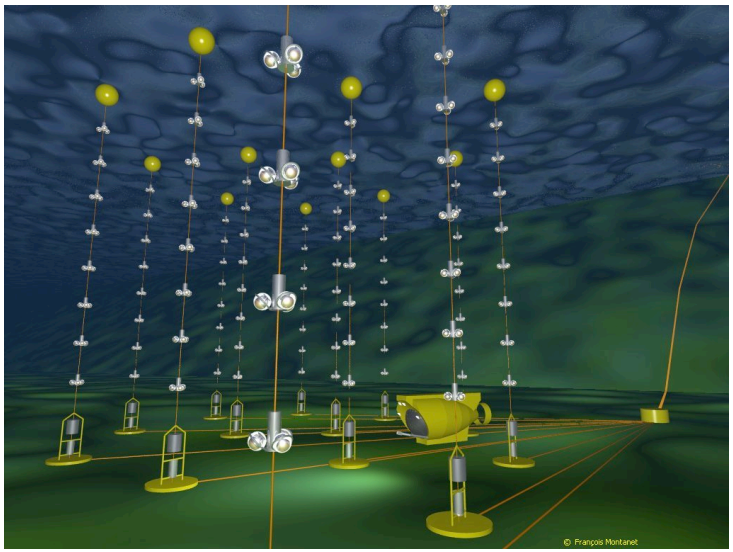
GRBs: Candidate sources for the highest energy cosmic-rays

IceCube: a one gigaton detector



Antares & KM3Net

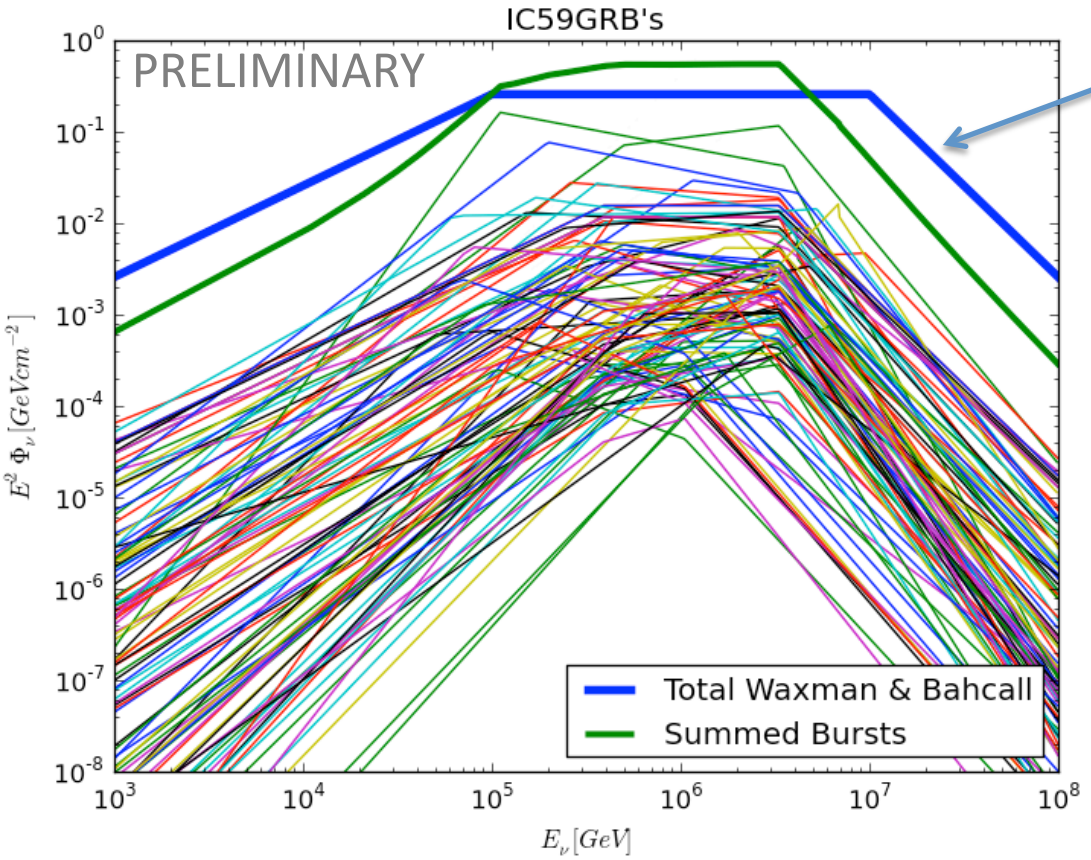
French coast on the Mediterranean (2.5 km depth)
12 lines – 1000 PMTs – 15 Mtons
In full operation since 2008
KM3Net proposed – Mediterranean
At least as big as IceCube
(with better view of the Galactic Center)



See Poster 11.04
E. Presani et al

By shear size, IceCube is more currently interesting for GRBs

IceCube search for neutrinos from GRBs



For average BATSE parameters of 109 bursts

Modeling following:
Guetta et al, Astropart Phys, 2004)

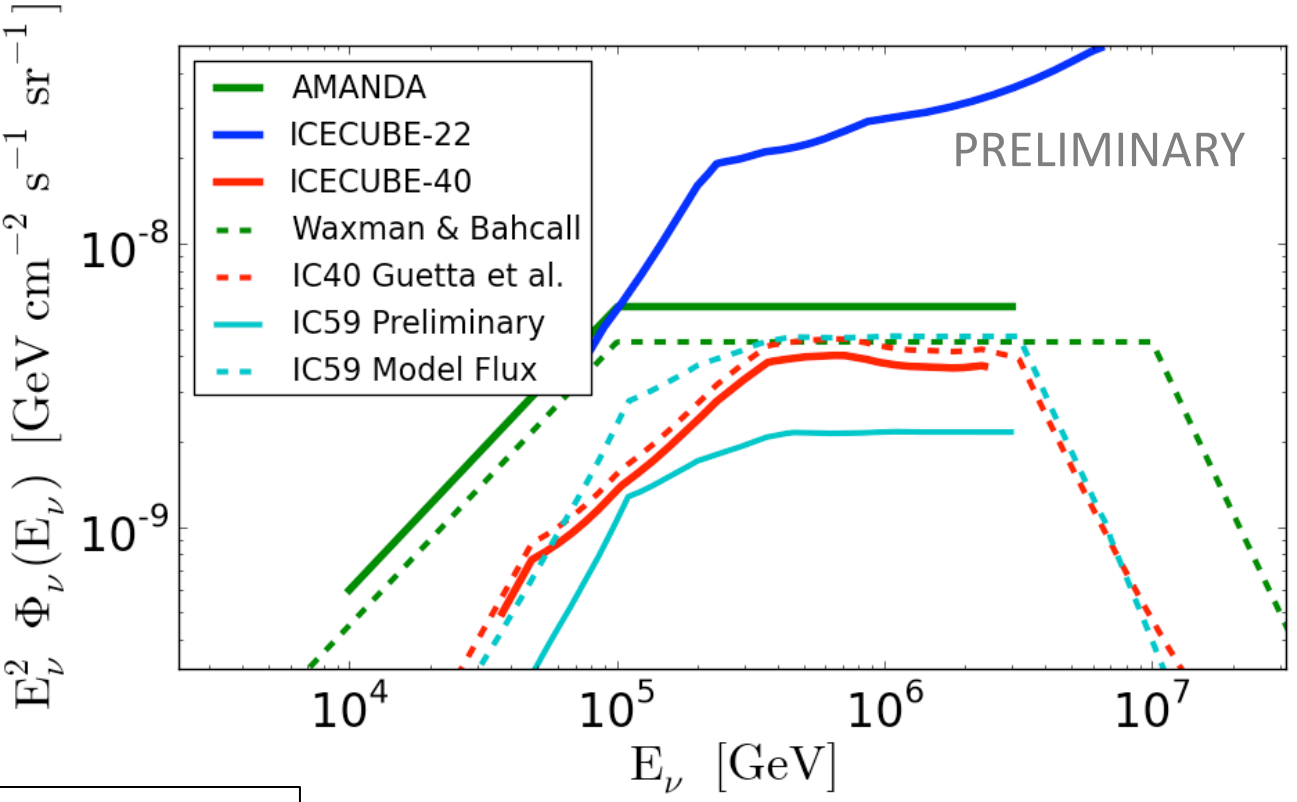
109 Northern GRBs
IceCube 59-string
May 2009 – May 2010)

Delta Resonance: Neutrino spectrum traces photon spectrum
Nuetrino fluence proportional to photon fluence

Achterberg A. et al. ApJ v664 p397, 2007
Abbasi R., et al. ApJ v710 p346, 2010
Abbasi R., et al. In preparation

Achterberg A. *et al.* ApJ v674 p357, 2008
Abbasi R., et al. ApJ 701 p1721, 2009

IceCube search for neutrinos from GRBs



See Poster 11.02
E. Blaufuss et al.
for details on IceCube searches

IceCube 59-string limit 2.2 below (default) prediction.
Combined IceCube 40- and 59-string limit not available yet
In 2-3 years, full IceCube sensitivity is one order of magnitude below model

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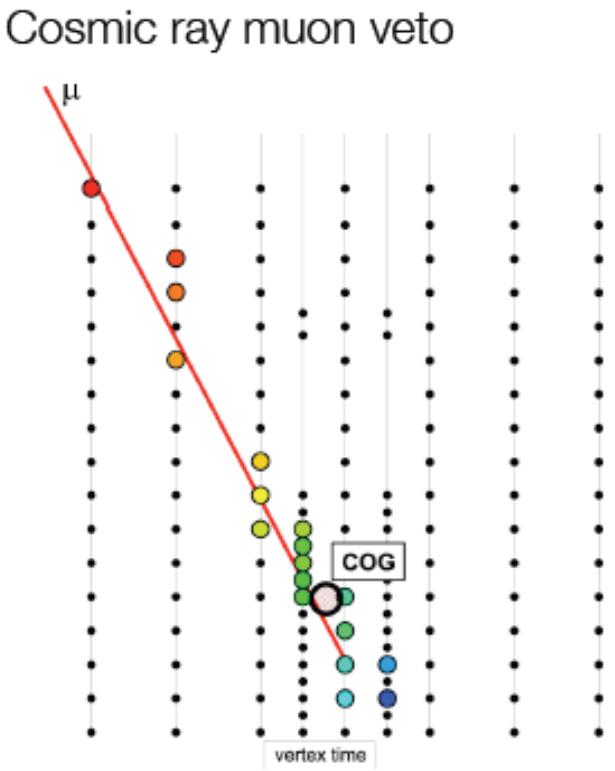
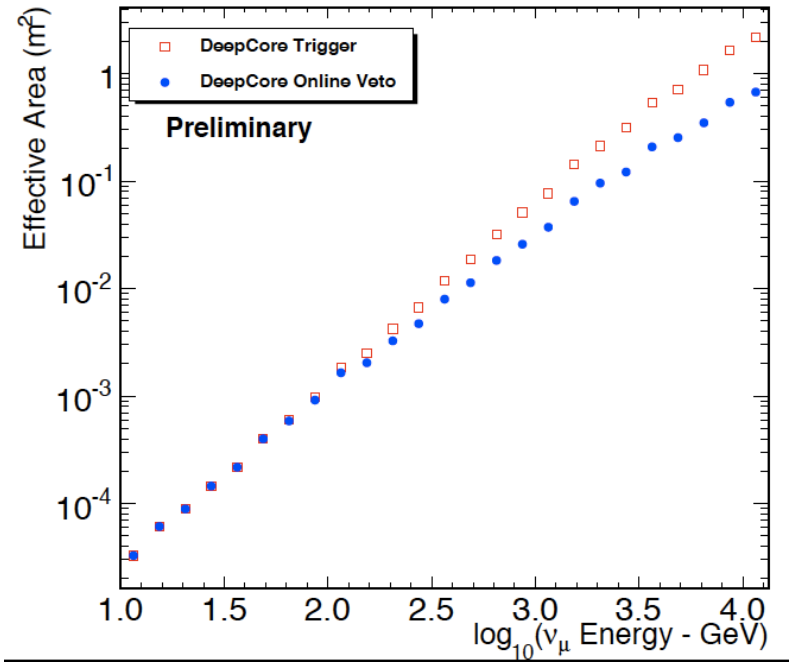
DeepCore and Choked GRBs

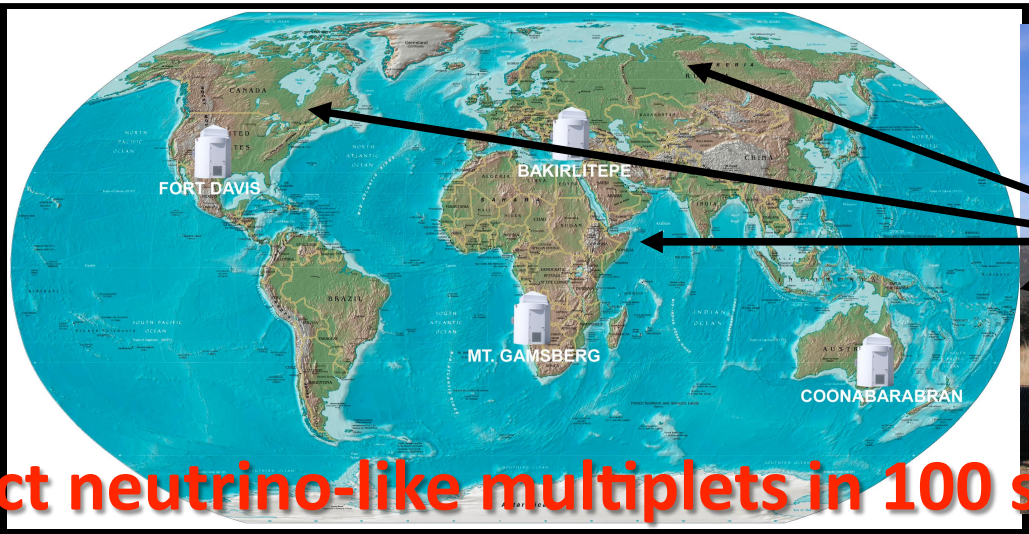




Ando & Beacom reference SN @ 10 Mpc:
4 neutrinos (all flavors) in DeepCore
Similar event rate in Antares

Taboada PRD 2010

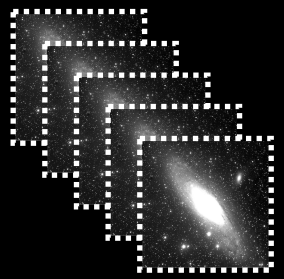
Optical Follow-Up with ROTSE & PTF



Select neutrino-like multiplets in 100 s and 3.5° coincidence

Iridium satellites

SN/GRB



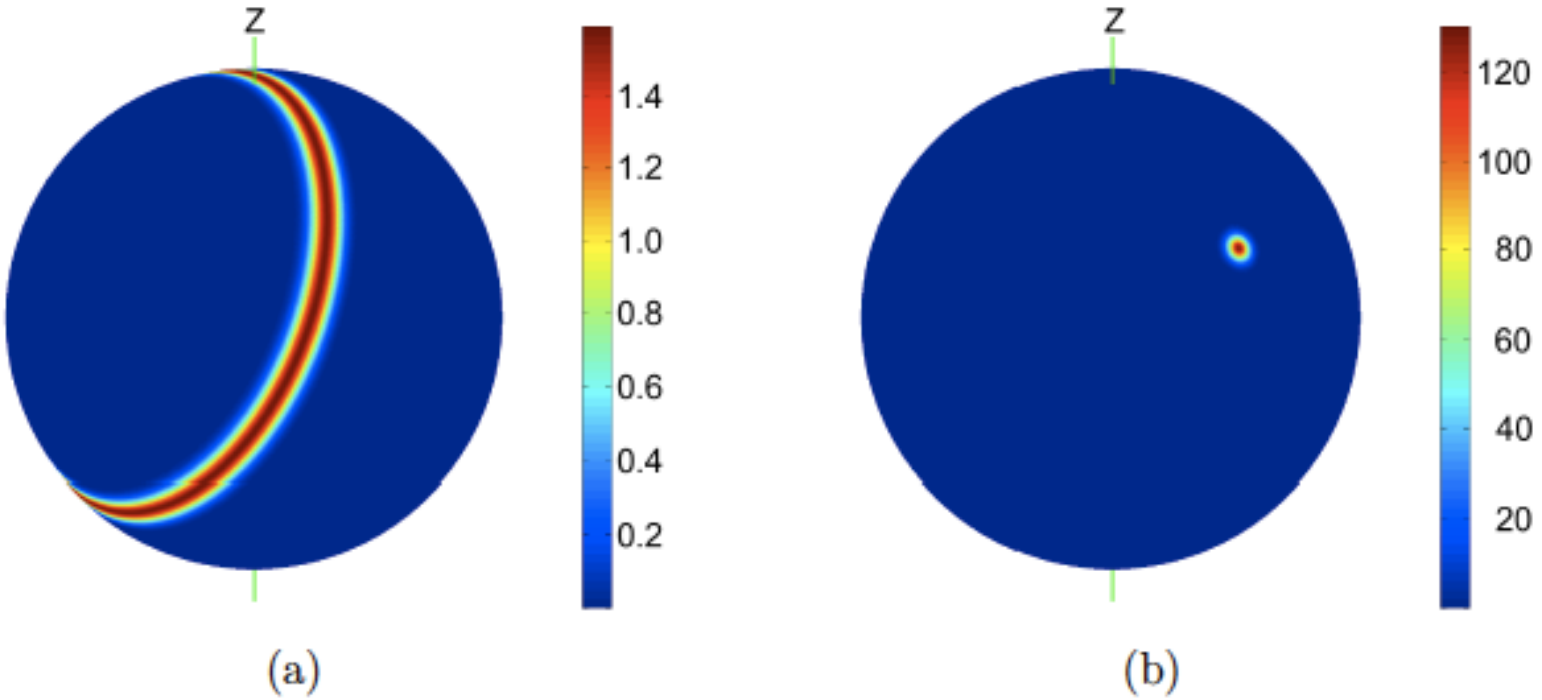
Fast reaction to GRB alerts

IceCube

Northern Hemisphere IceCube CPU

ROTSE III

Joint LIGO - IceCube search



Spatial PDF for LIGO (a) and IceCube (b)

See Poster 11.01
I. Bartos et al.
for details on
LIGO + IceCube

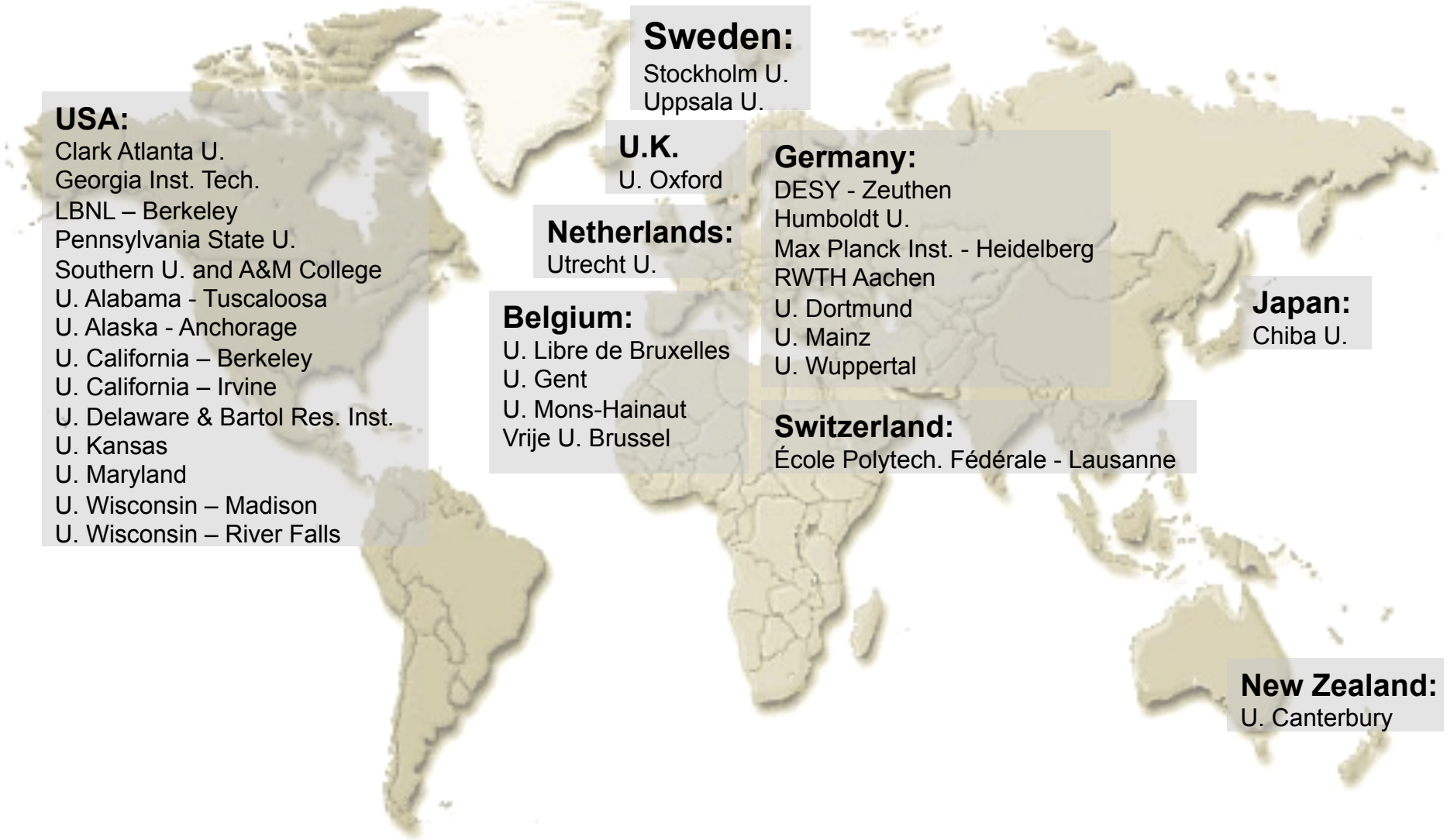
Search will proceed on archival data for LIGO science run 5 in coincidence with IceCube

Aso Y et al. Class & Quant Grav, 2008

Conclusions

- Neutrinos can test whether GRBs are the sources of extragalactic cosmic rays
- IceCube is already below the default model prediction
- In 2-3 years IceCube's sensitivity will be an order of magnitude below default model prediction
- Choked GRBs can be searched by IceCube / DeepCore / Antares
- Multi-messenger programs in place with LIGO, ROTSE and PTF
- Upcoming program with Swift (XRT) follow up.

The IceCube Collaboration



USA:
Clark Atlanta U.
Georgia Inst. Tech.
LBNL – Berkeley
Pennsylvania State U.
Southern U. and A&M College
U. Alabama - Tuscaloosa
U. Alaska - Anchorage
U. California – Berkeley
U. California – Irvine
U. Delaware & Bartol Res. Inst.
U. Kansas
U. Maryland
U. Wisconsin – Madison
U. Wisconsin – River Falls

Sweden:
Stockholm U.
Uppsala U.

U.K.
U. Oxford

Netherlands:
Utrecht U.

Belgium:
U. Libre de Bruxelles
U. Gent
U. Mons-Hainaut
Vrije U. Brussel

Germany:
DESY - Zeuthen
Humboldt U.
Max Planck Inst. - Heidelberg
RWTH Aachen
U. Dortmund
U. Mainz
U. Wuppertal

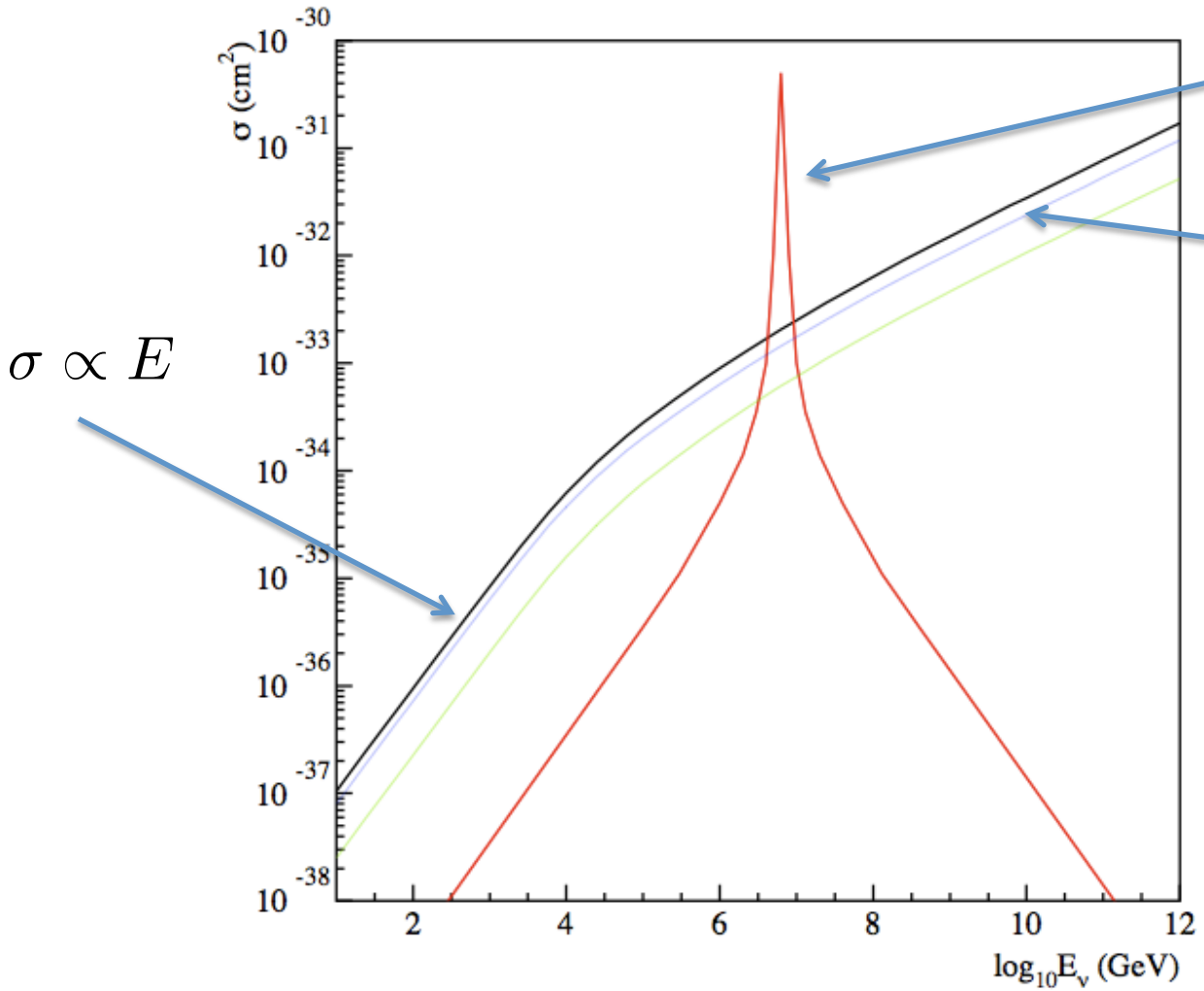
Switzerland:
École Polytech. Fédérale - Lausanne

Japan:
Chiba U.

New Zealand:
U. Canterbury

Antarctica:
Amundsen-Scott Station

Detecting neutrinos at cosmological distances



For MeV scale the cross section is 14 orders of magnitude? below that of PeV scale

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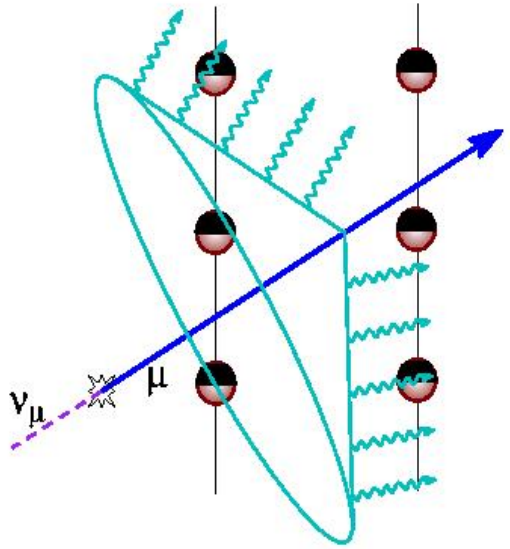
Neutrino detection

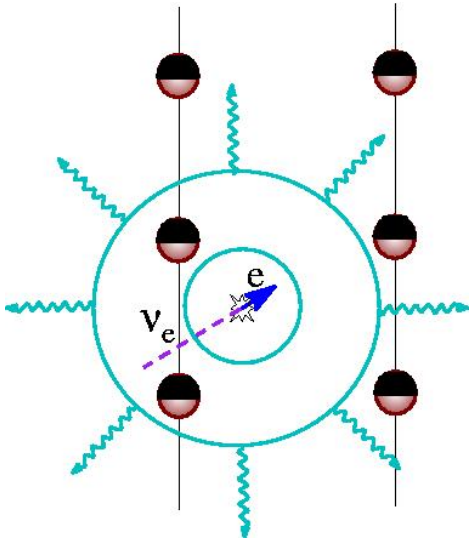
Tracks



O(km) muon tracks

- ✓ Good angular resolution
  IceCube: 1°
  Antares: 0.1°
- ✓ ν_μ sensitivity

Cascades

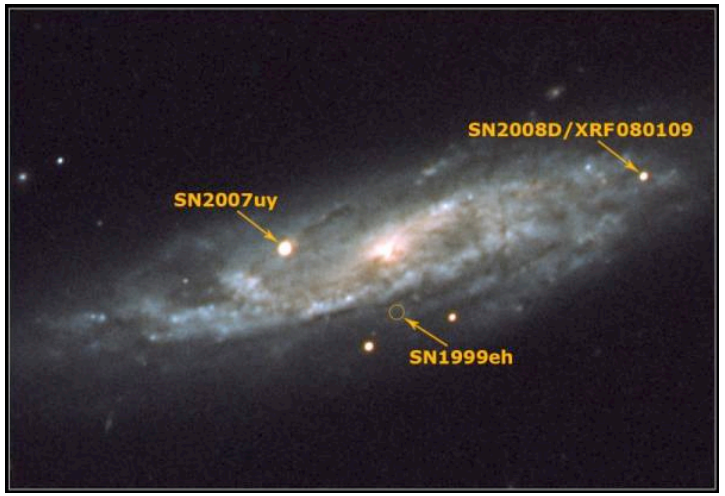


Light point sources

- ✓ Good energy resolution
- ✓ No directionality
- ✓ 4π sensitivity
- ✓ All flavor sensitivity

Neutrinos from SN 2008D

✓ X-ray flash provides (more) precise SN time



✓ Slow Jet model

Razzaque et al. PRD, 2003

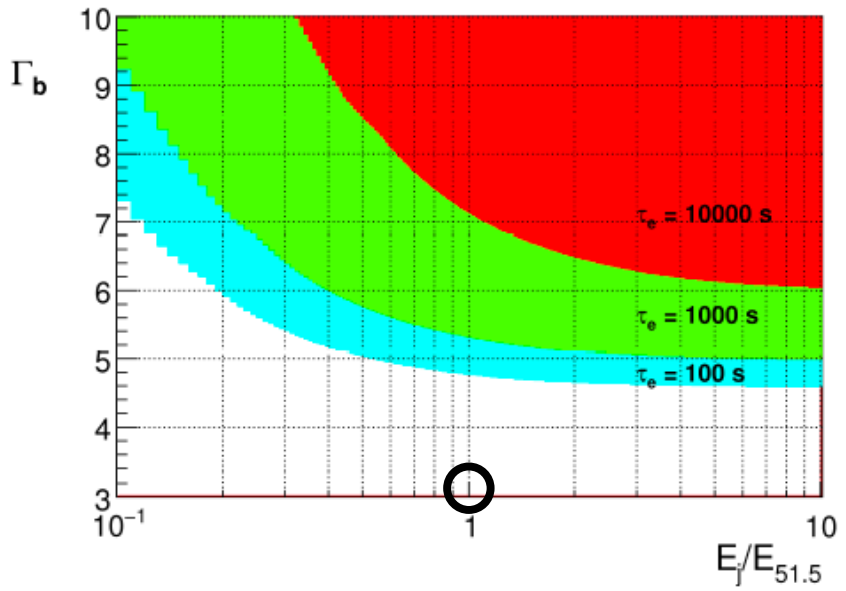
Ando and Beacom, PRL 2005

✓ Proof of principle

✓ 0.1 evts in IceCube 22-strings if jet points to Earth

✓ $\Gamma_b = 3$, $E_j = 3 \times 10^{51}$ erg

✓ No signal found



Abbasi R. et al. Submitted to A&A

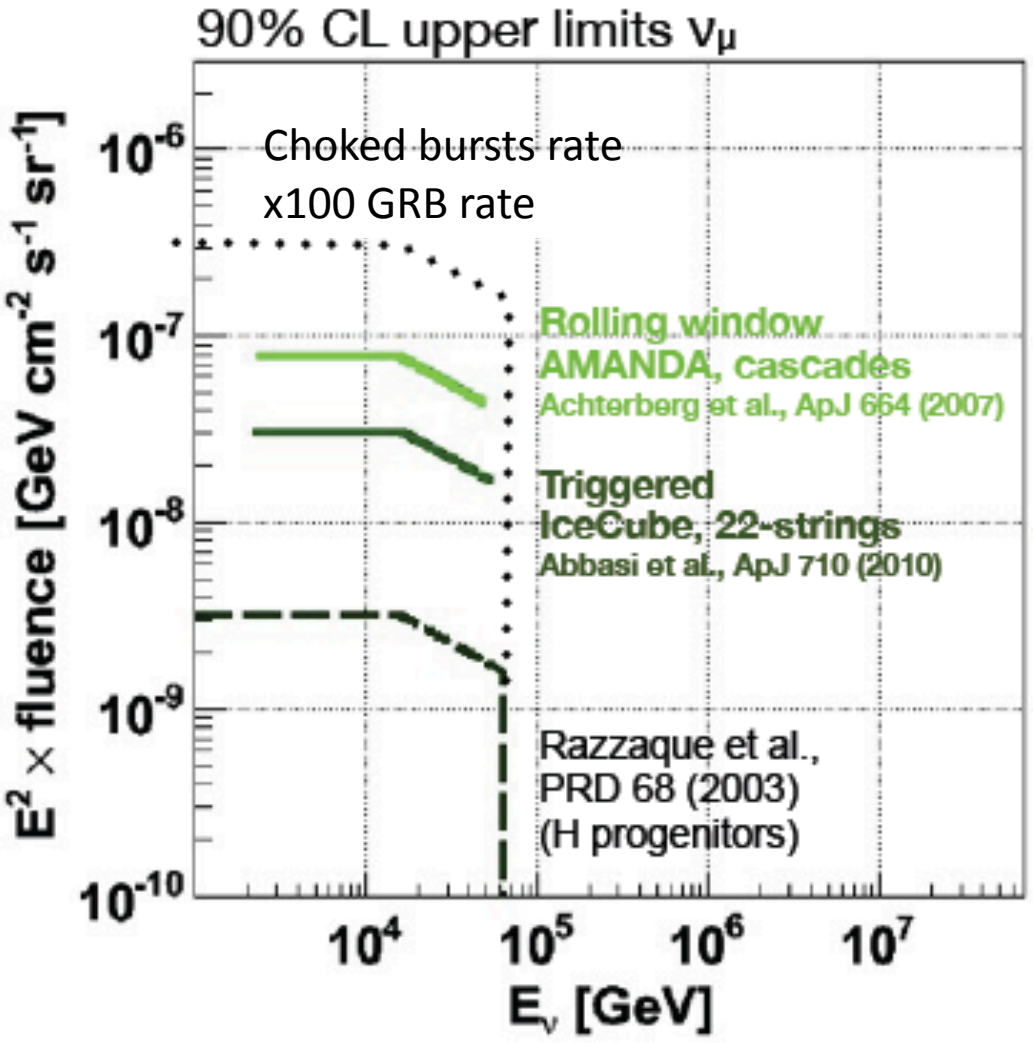
Choked GRBs and precursor neutrinos

- Jets with low Γ still inside progenitor star

  → TeV neutrinos

- Possibly large fraction of "choked" bursts

  → only detectable with "rolling window"



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