High-energy neutrino astronomy with IceCube

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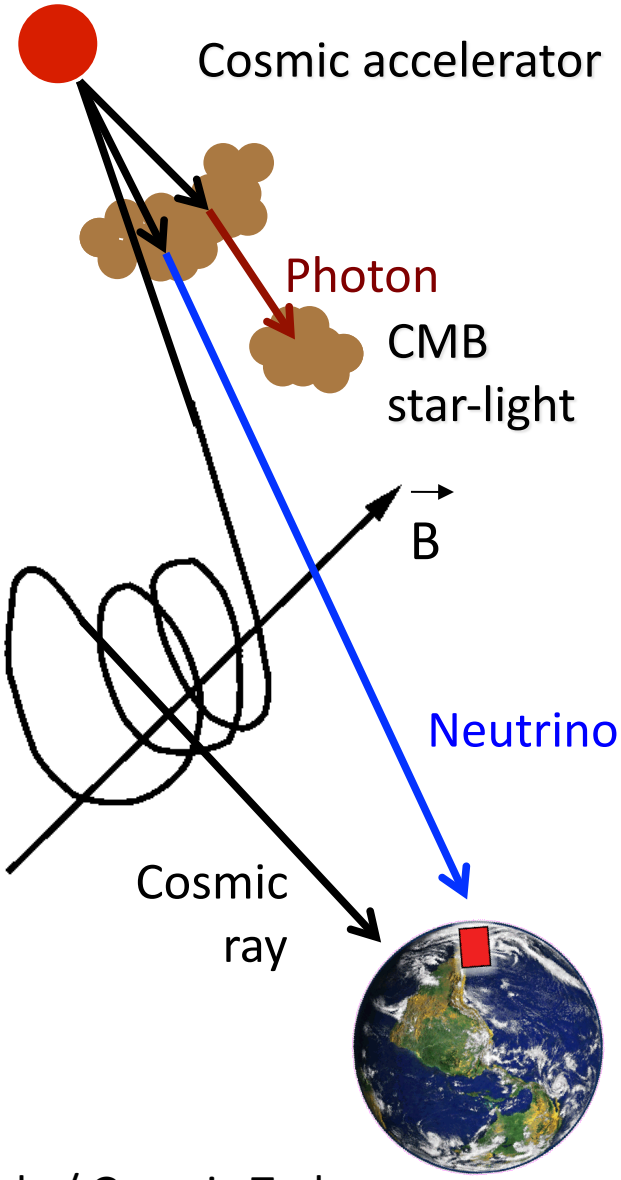
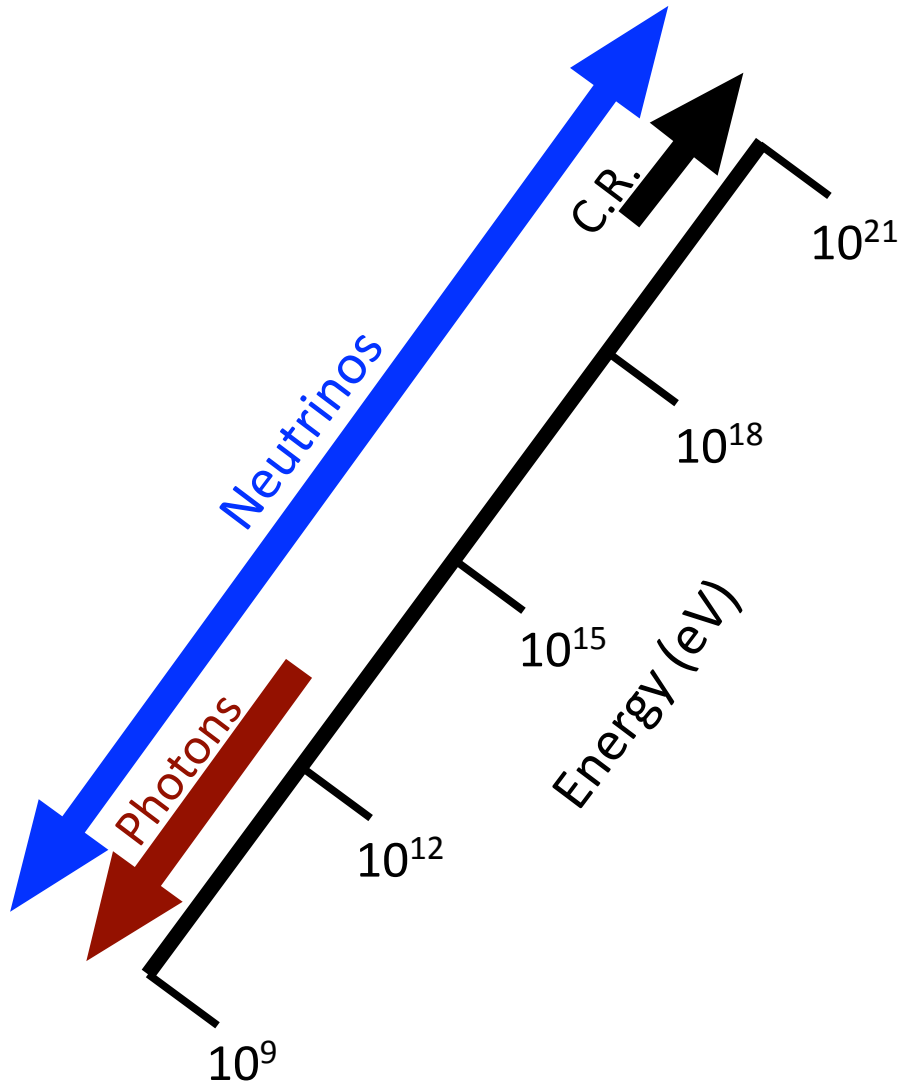
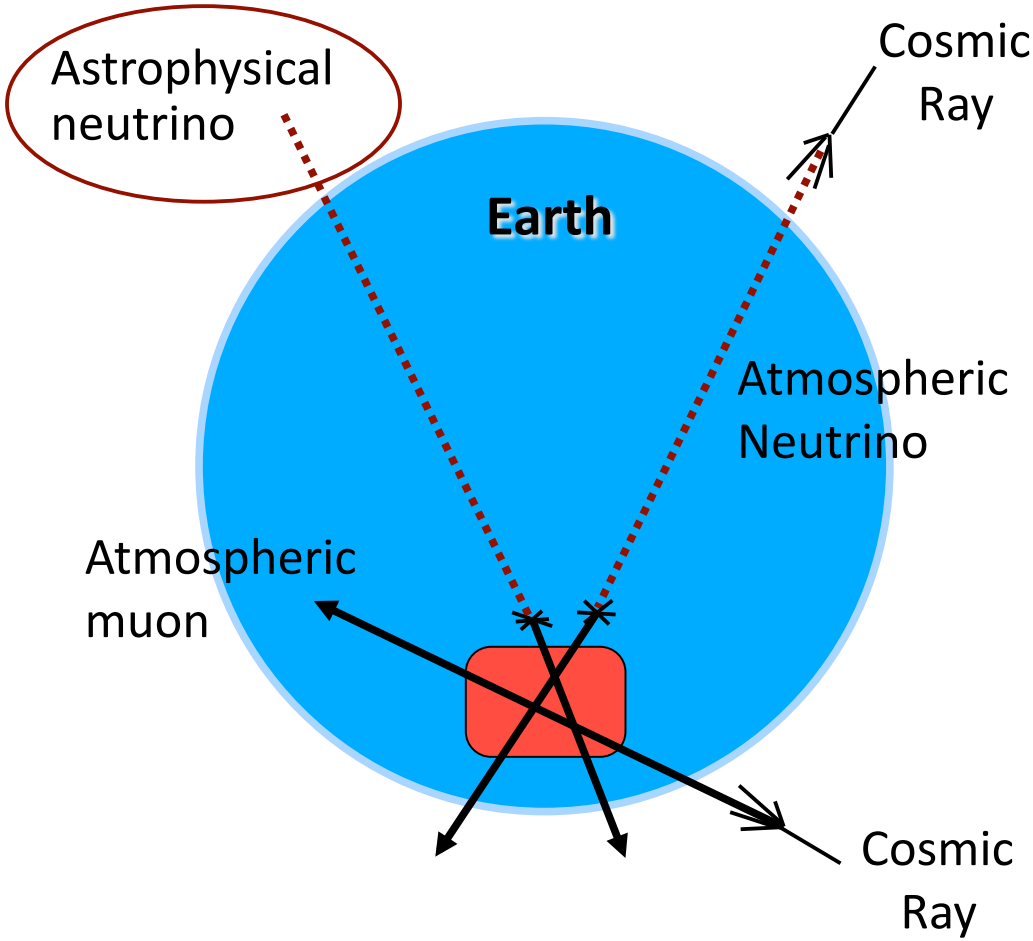
SLAC Summer Institute 2010

Neutrinos as astronomical messengers



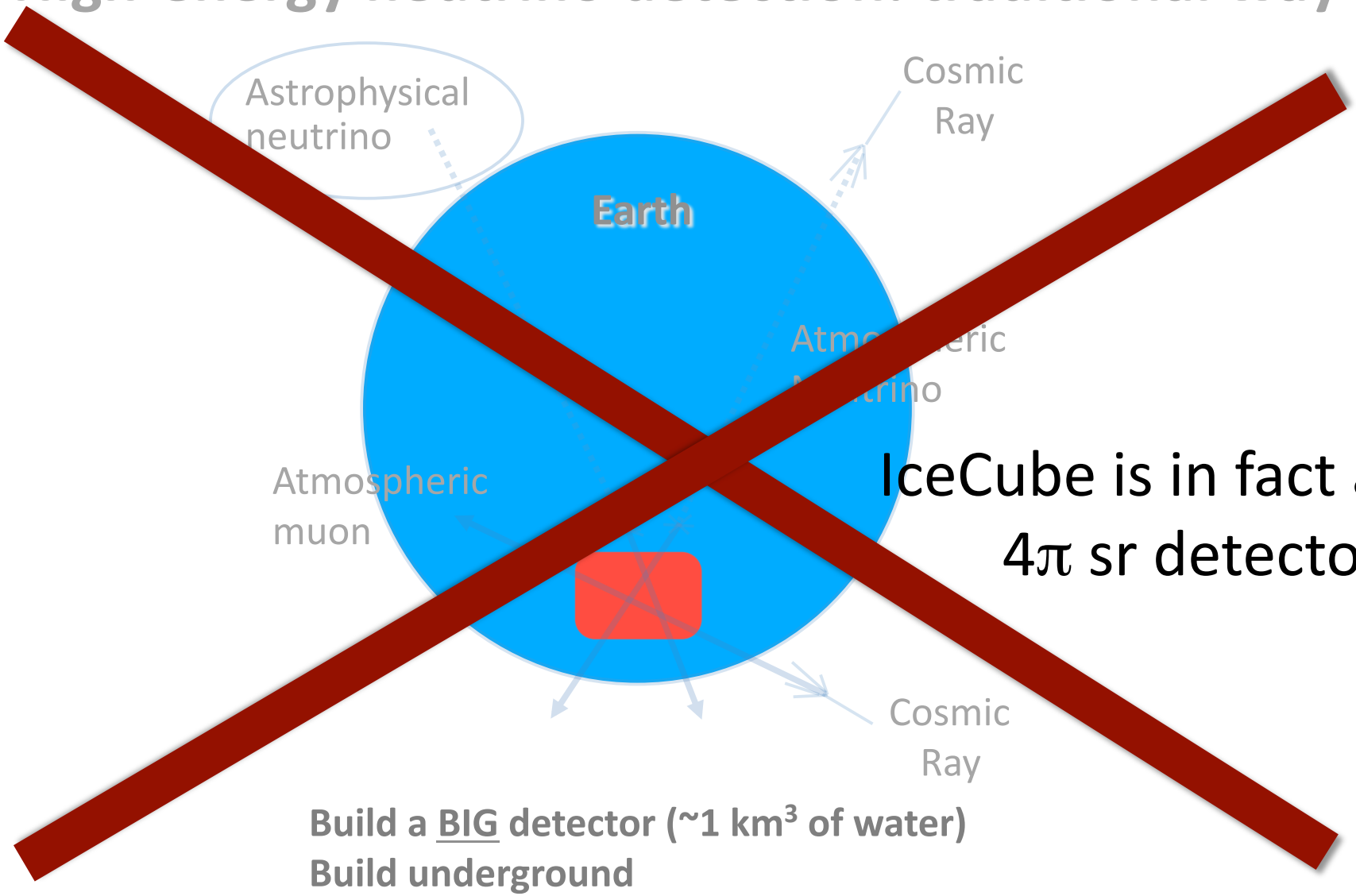


High-energy neutrino detection: traditional way



Build a <u>BIG</u> detector (~1 km^3 of water)
Build underground
Use Earth as a filter
Cherenkov Detection

High-energy neutrino detection: traditional way



IceCube is in fact a 4π sr detector

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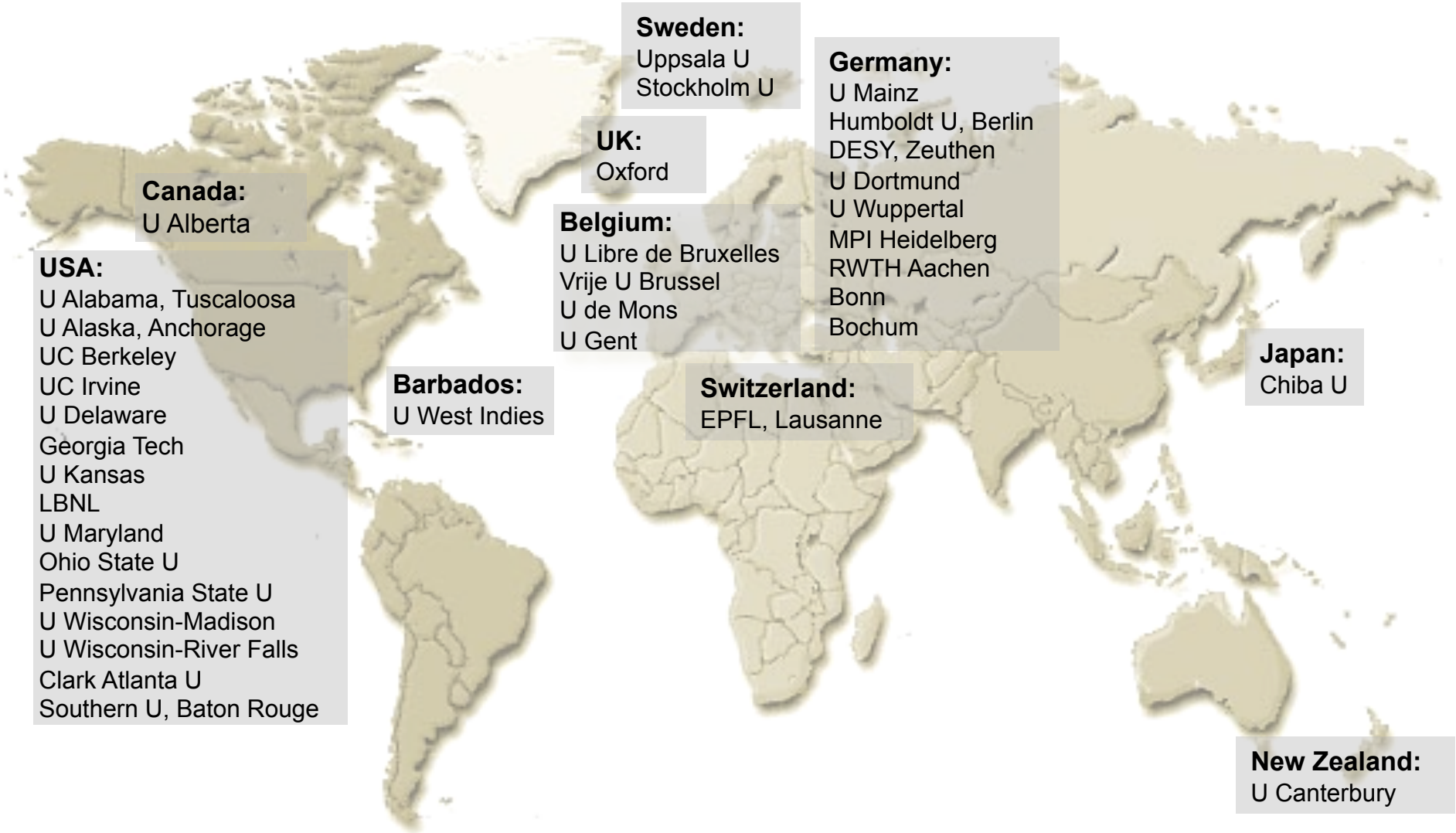
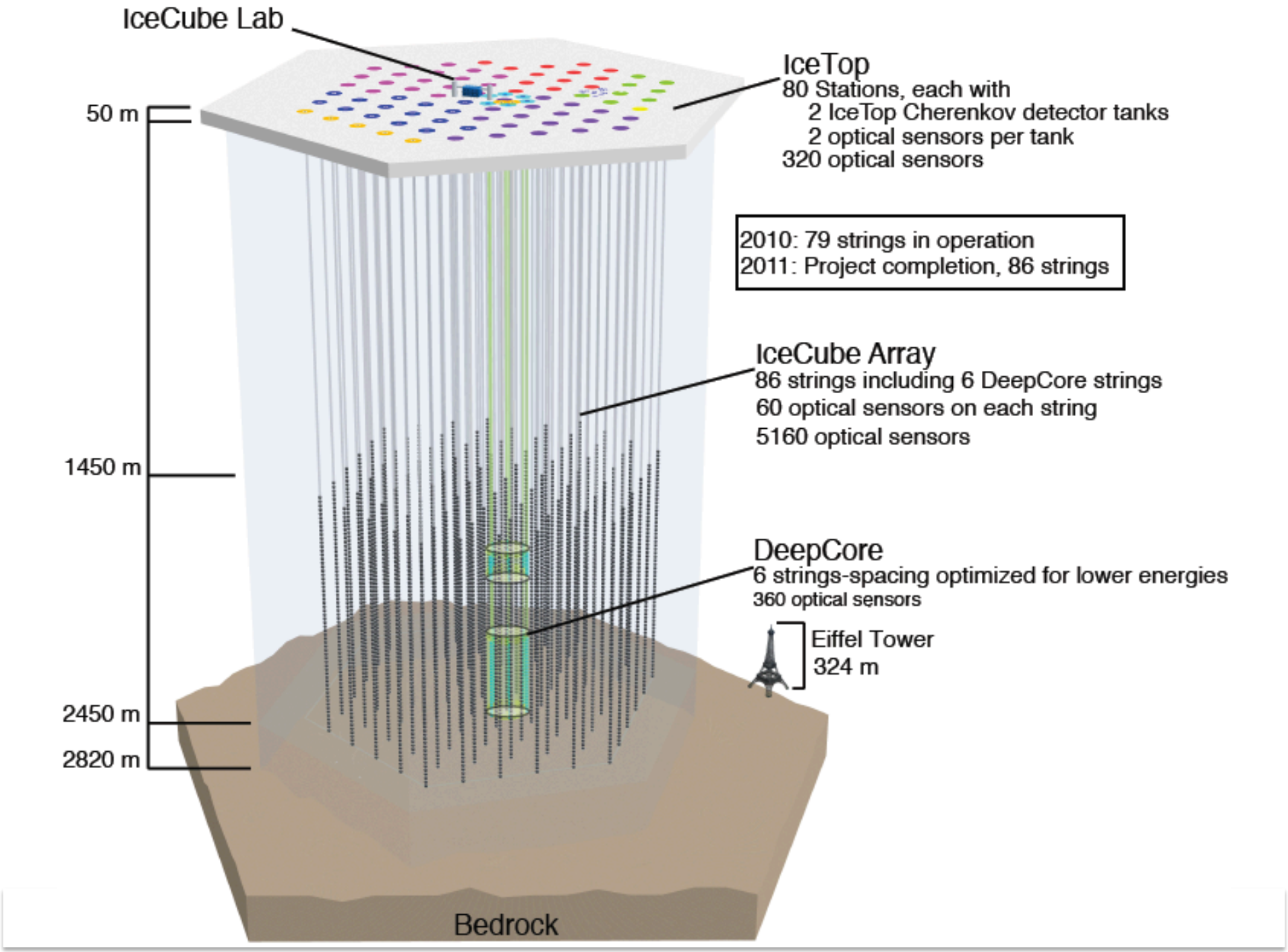
Use Earth as a filter
Cherenkov Detection

The IceCube collaboration. Approximately 250 people



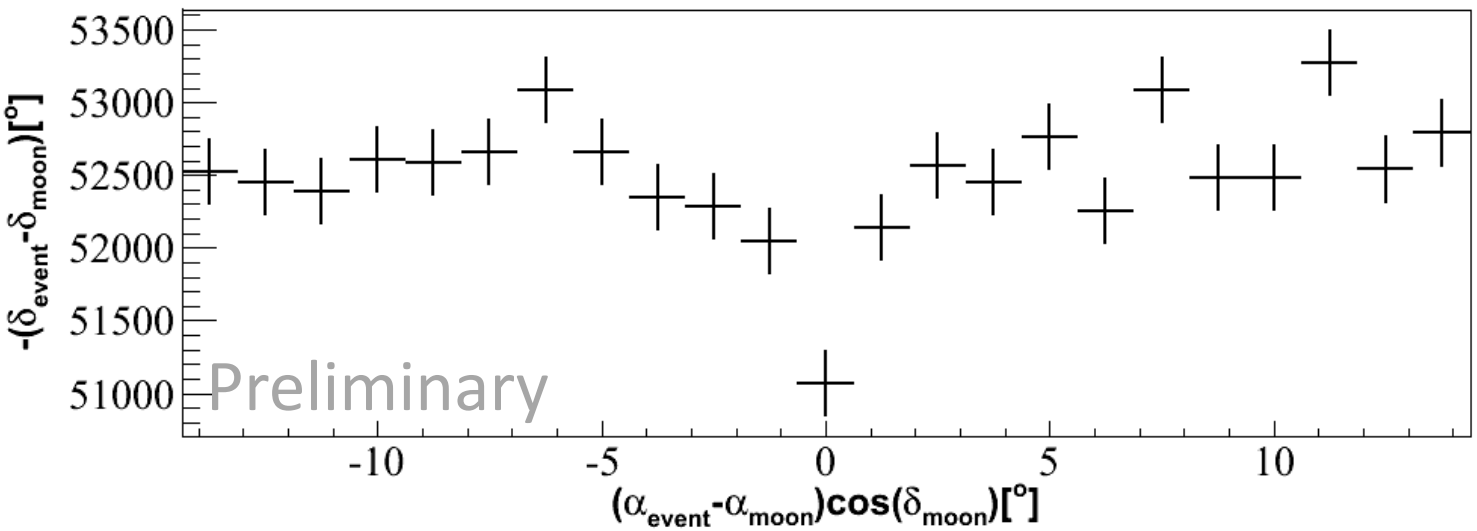

IceCube Lab
IceTop
80 Stations, each with
2 IceTop Cherenkov detector tanks
2 optical sensors per tank
320 optical sensors
50 m
2010: 79 strings in operation
2011: Project completion, 86 strings
IceCube Array
86 strings including 6 DeepCore strings
60 optical sensors on each string
5160 optical sensors
1450 m
DeepCore
6 strings-spacing optimized for lower energies
360 optical sensors
Eiffel Tower
324 m
2450 m
2820 m
Bedrock

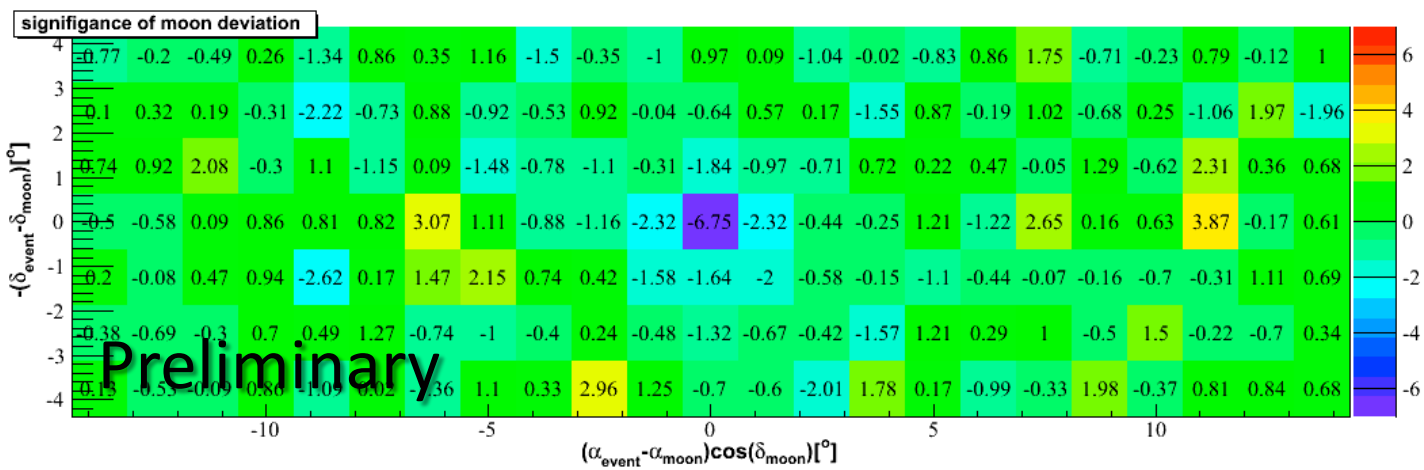
IceCube performance

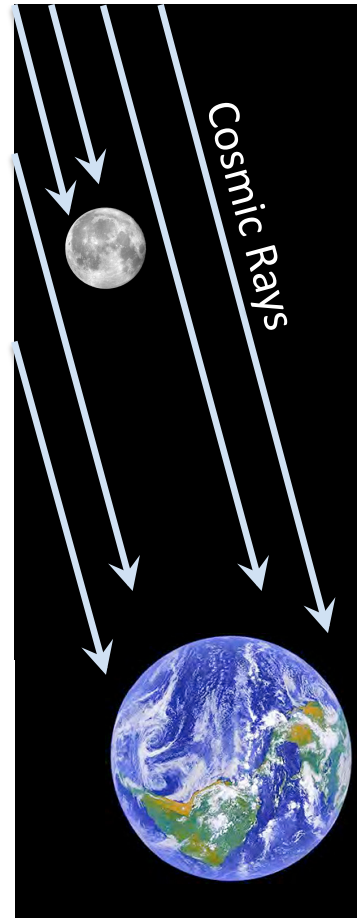
- ✓ Low noise rates: ~300Hz (SPE/sec)
  - Rate with correlated pulses ~500Hz
  - Supernova MeV ν detection!
- ✓ High duty cycle: >97%
- ✓ 32 / 4790 DOMs dead (0.7%)
- ✓ Event rates (79 strings)
  - Muons: ~1.8 kHz
  - Neutrinos: ~220/day

Observation of the Moon shadow

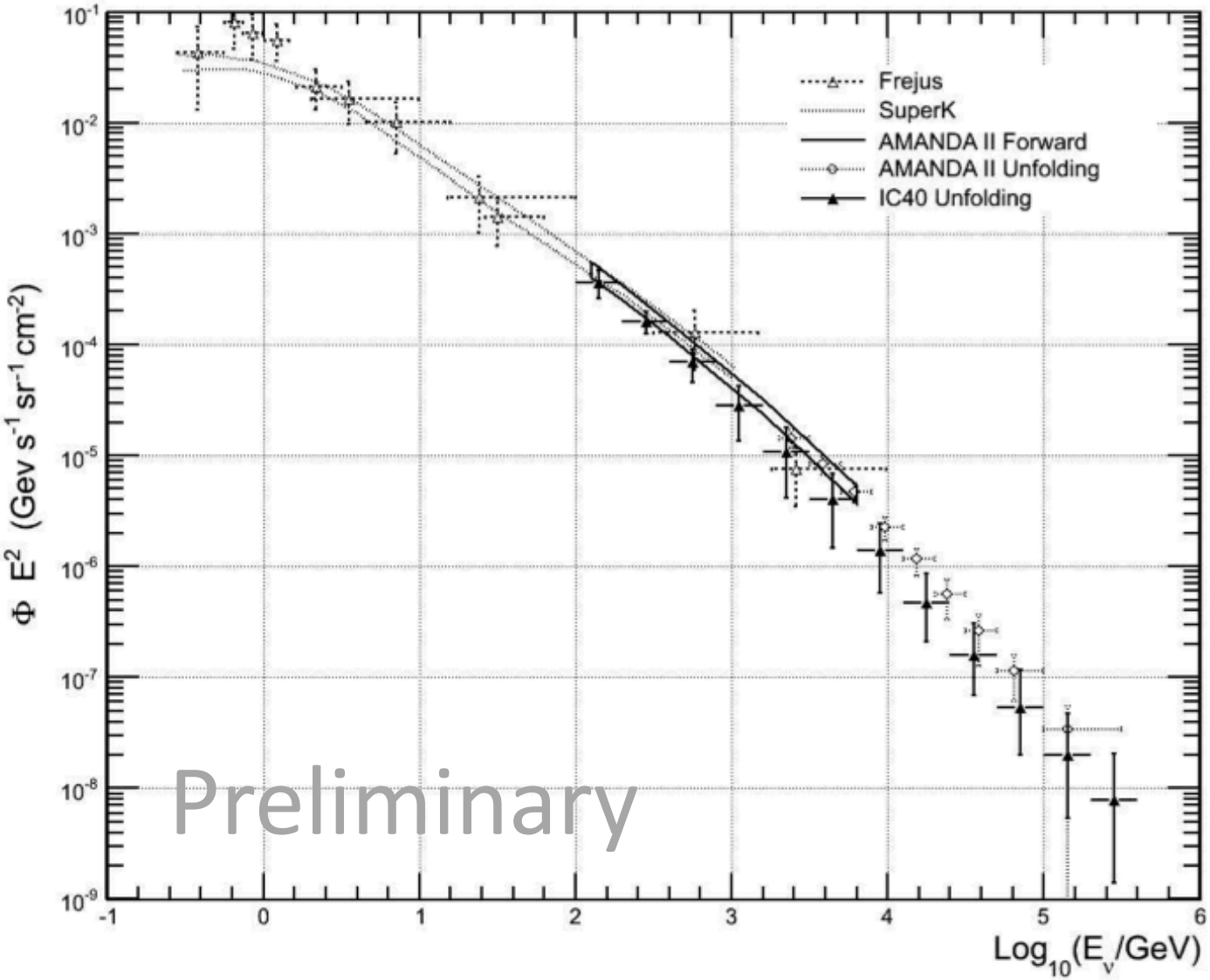
(14 Moon cycles – IC40)



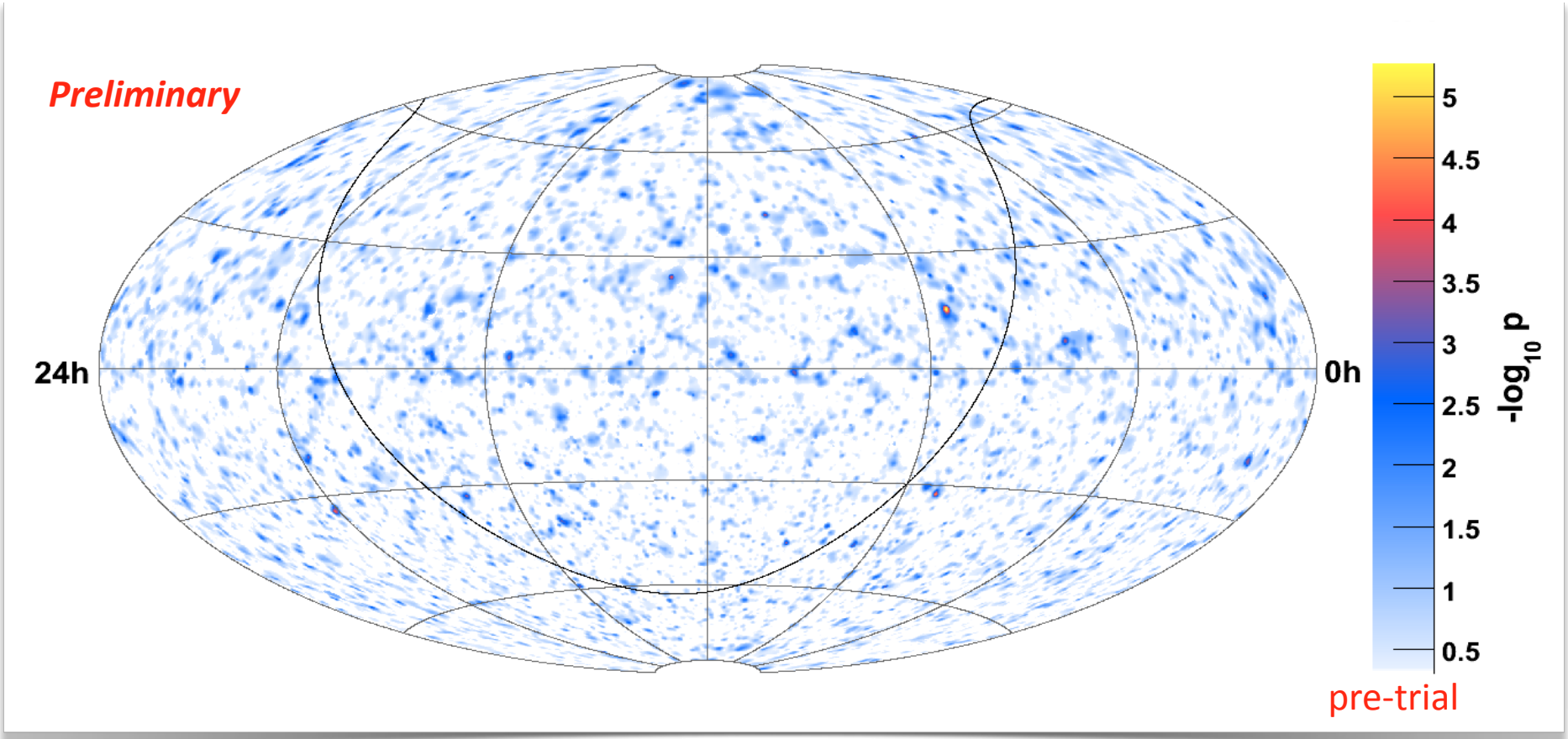




Atmospheric muon neutrinos



All Sky Point Source Search. IC40



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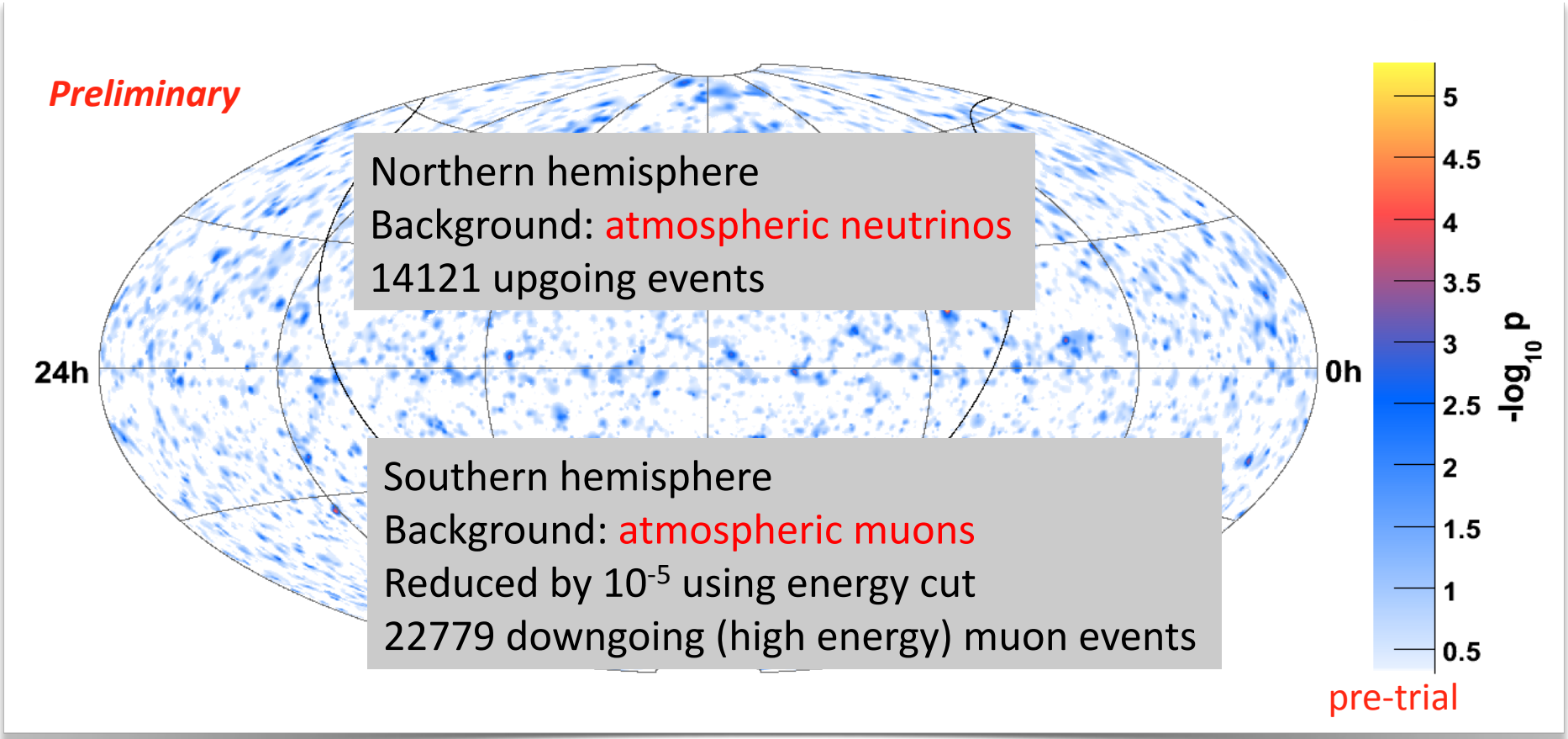
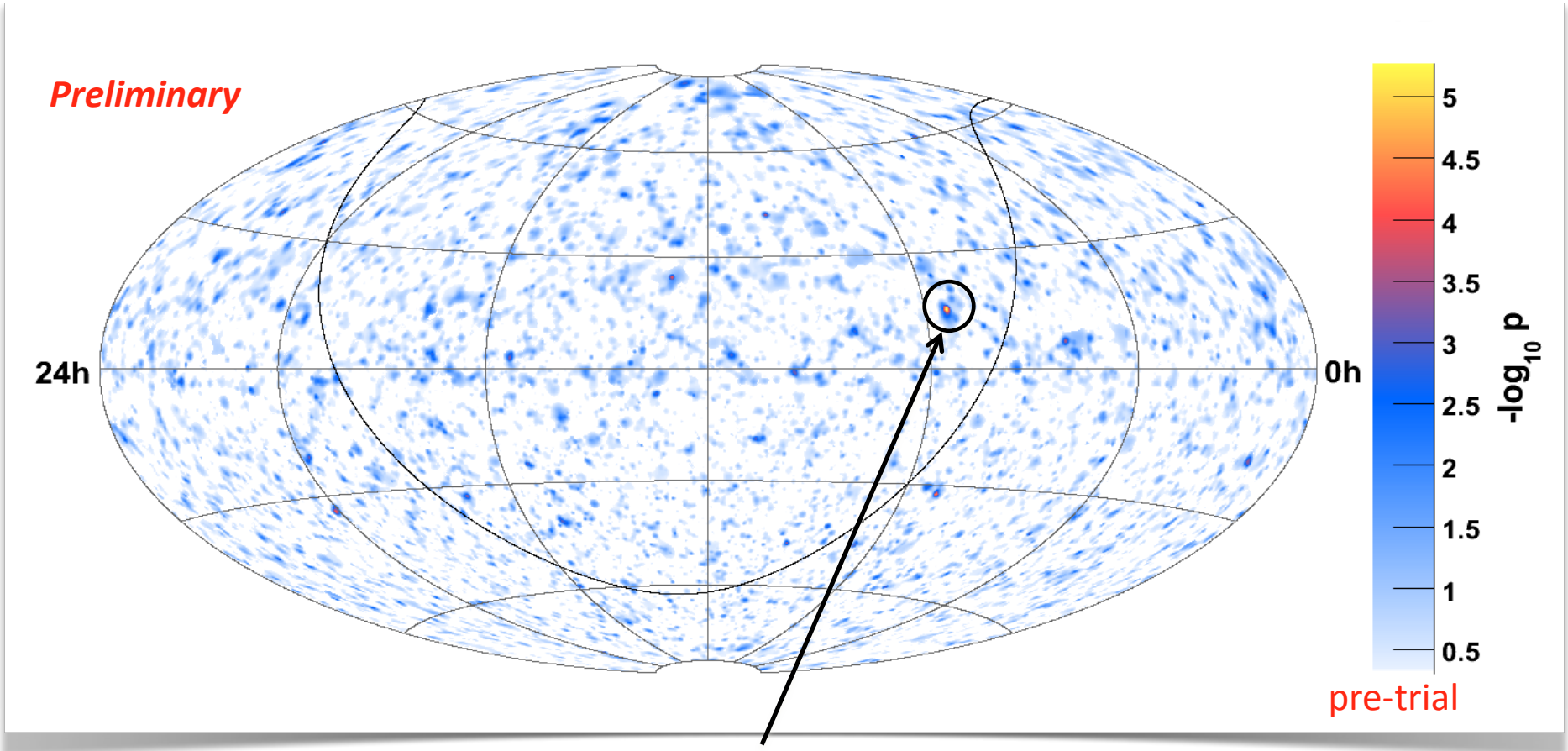


Livetime = 375.5 days

All Sky Point Source Search. IC40



Hottest location in the all-sky search is:
Ra=113.75, Dec=15.15

All-sky p-value = 18%
not significant, no evidence for neutrino source

Stacked Source Search

Catalog	# Sources	Model	p-value	N_s	γ	$\nu_\mu + \nu_\tau$ upper limit
Milagro	17	E^{-2} uniform	0.32	7.6	-2.6	Φ_{90} = 24.5
Milagro	6 (SNR)	Halzen et al (2008)	0.02 (*)	15.2	-2.9	SF = 7.2
Starburst Galaxies	127	E^{-2} prop to FIR flux	1.0	0.0		Φ_{90} = 58.6
Clusters of Galaxies	5	Model A	0.78	0.0		SF = 2.6
		Model B		1.8	-3.9	SF = 4.0
		Isobaric		0.0		SF = 4.4
		Central AGN		0.0		SF = 2.0

Likelihood method provides signal normalization and spectral index consistent with the data

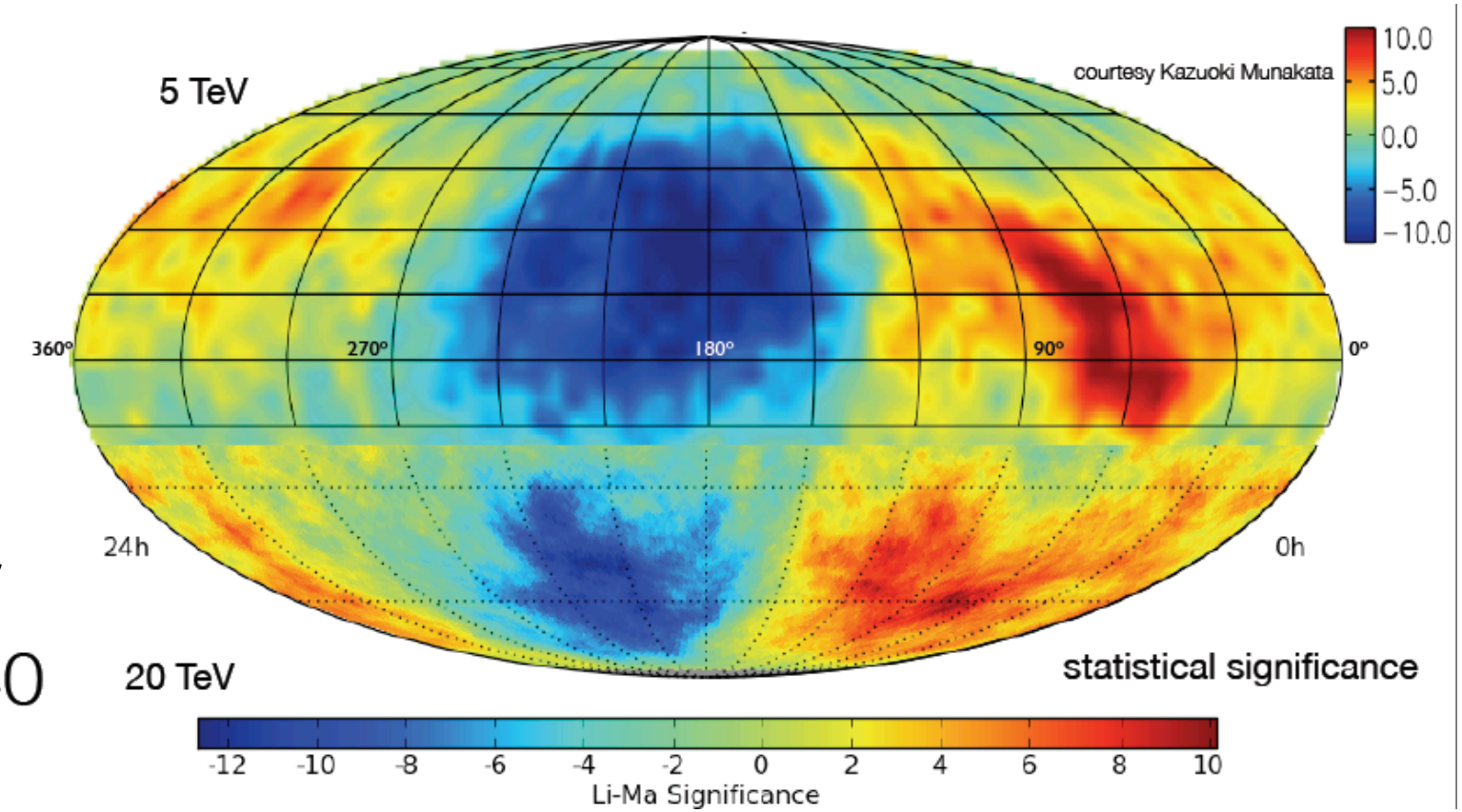
(*) A posteriori source selection
Φ_{90} in units of 10^{-12} $TeV^{-1}.cm^{-2}.s^{-1}$
SF: model scaling factor

Cosmic Ray Anisotropy

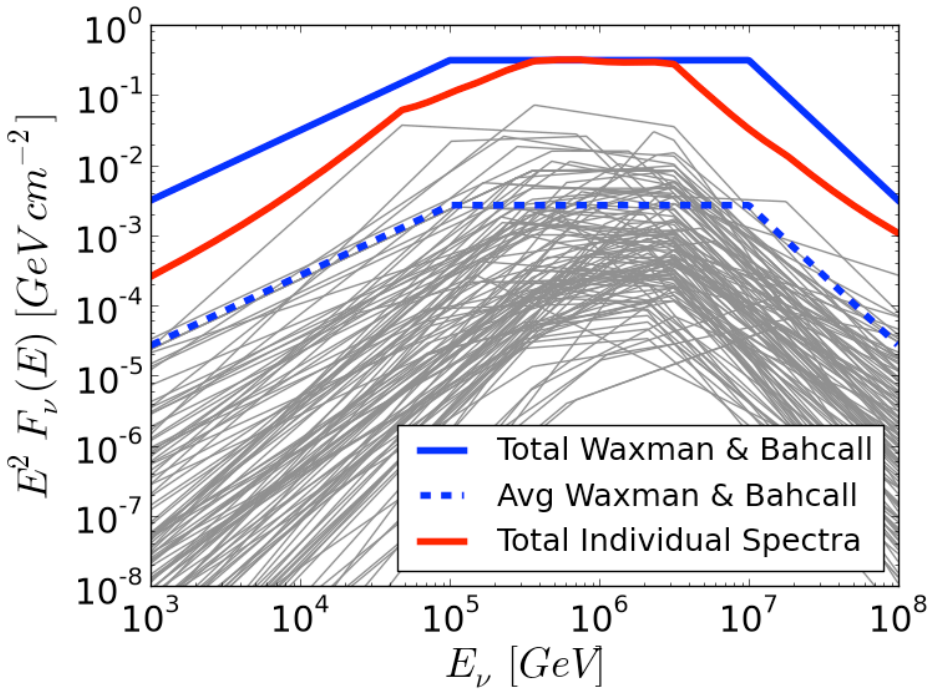
Tibet-III
(5° smoothing)

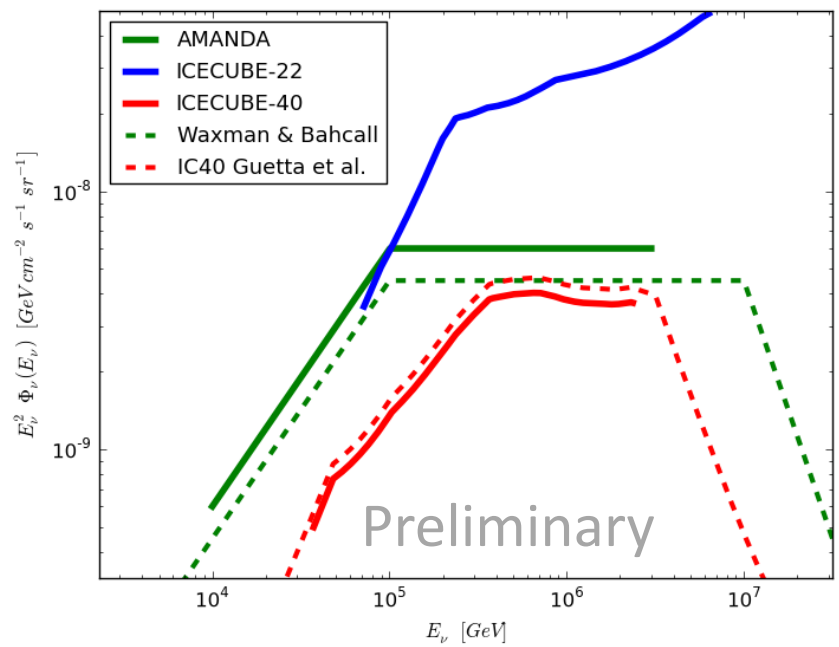
Preliminary

IceCube-40
(3° smoothing)



Neutrinos from GRBs

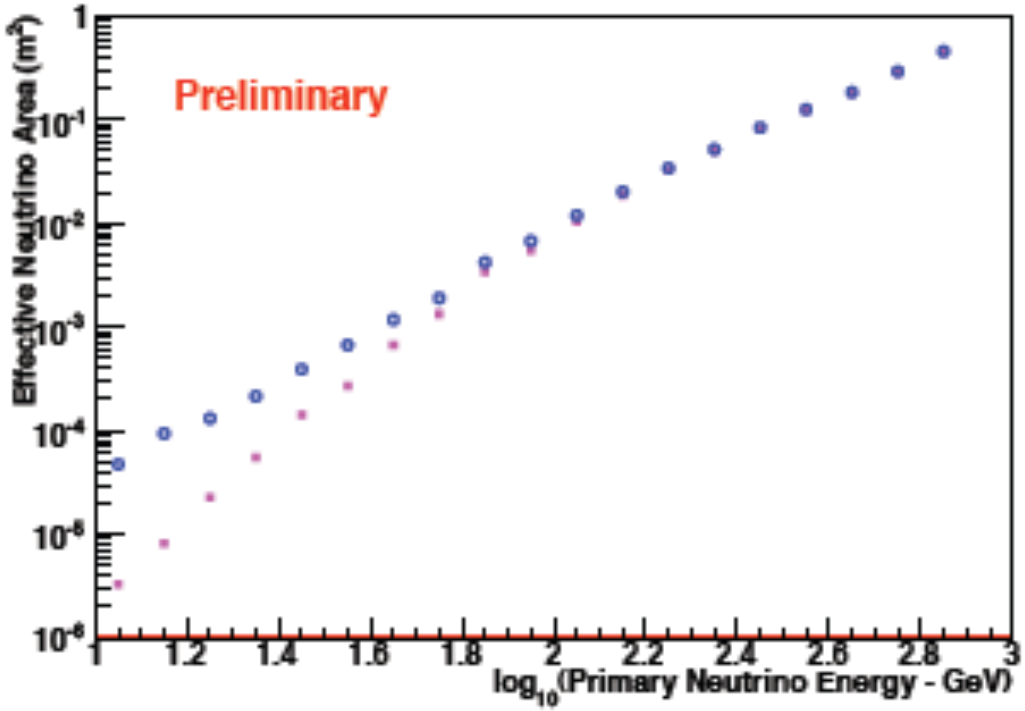


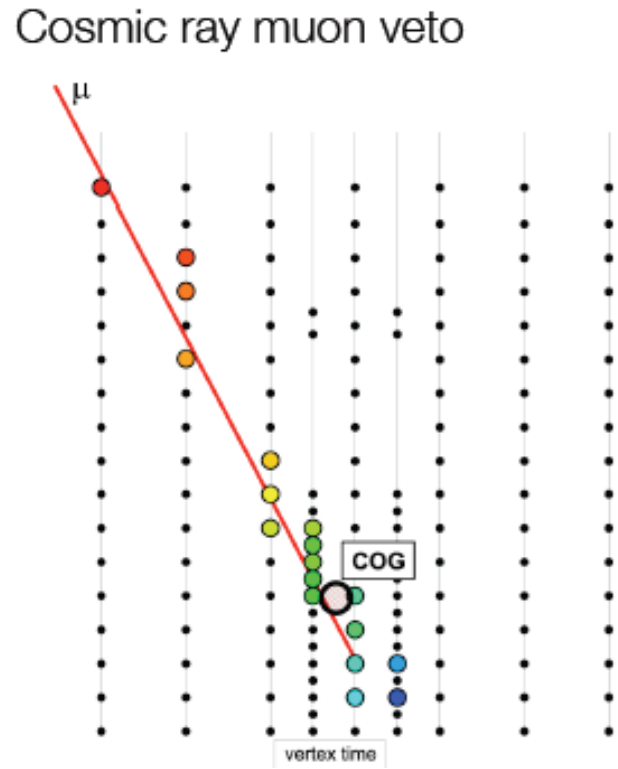


IceCube in coincidence with Fermi/GBM has a 95% of detection potential of Waxman-Bahcall model at 5 σ in one year. Within 5 years, IceCube will extensively sample the allowed parameter space of the Waxman-Bahcall model.

117 Northern hemisphere GRBs, reported mostly by Fermi.

DeepCore Science Potential





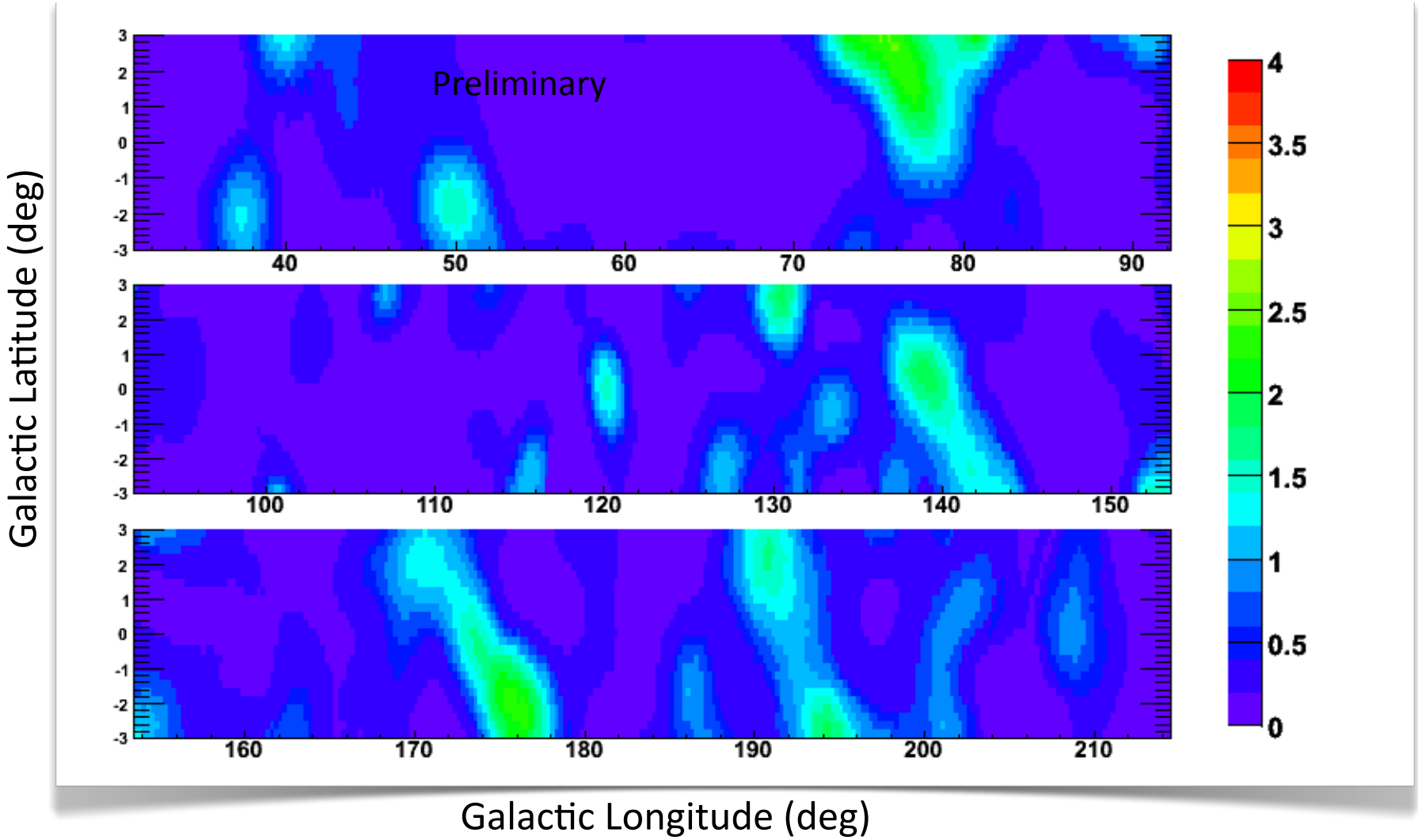
Indirect dark matter search (Sun, Center of galaxy)
4π sr neutrino astronomy (>10 GeV)
Neutrino oscillations

Conclusions and outlook

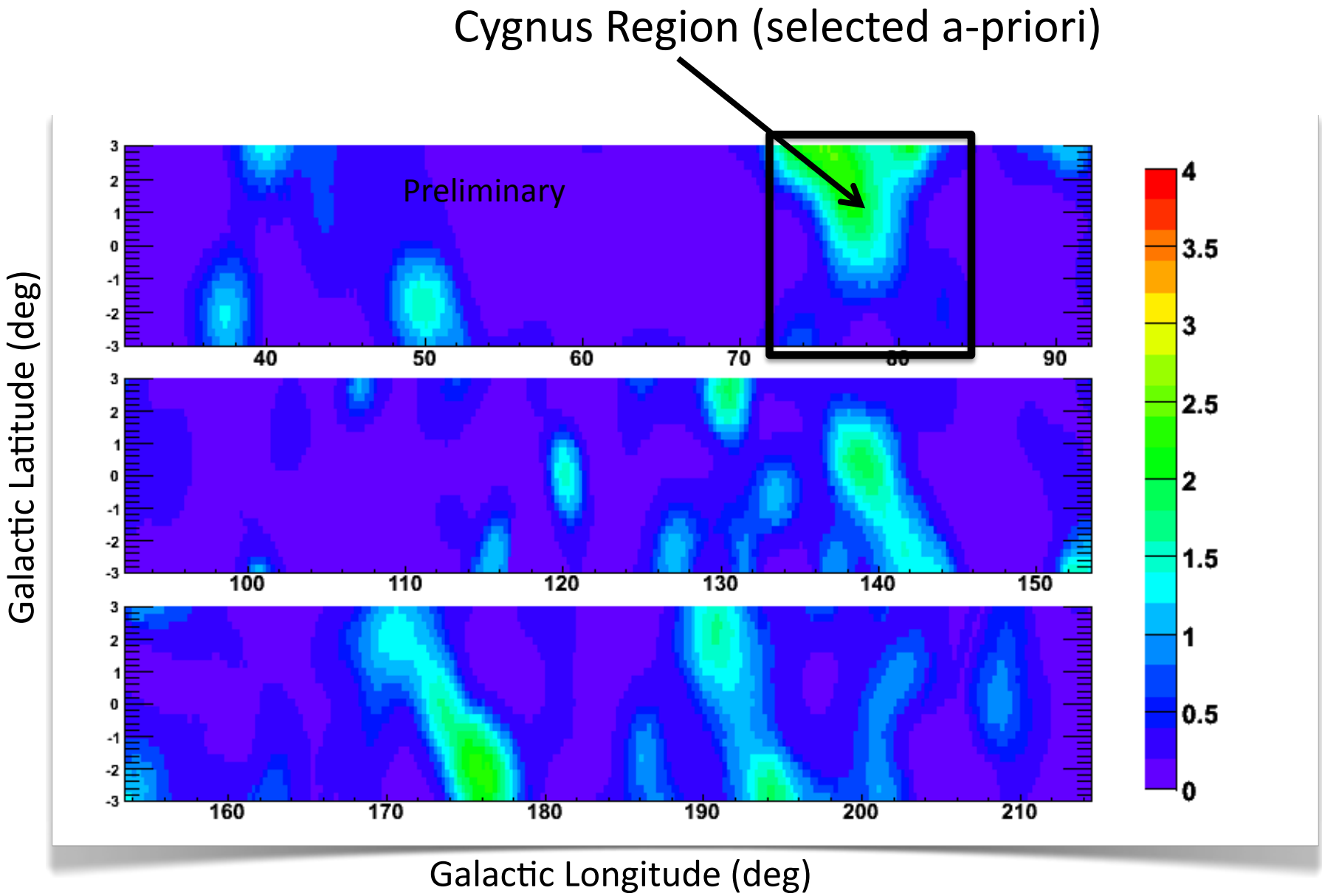
- ✓ IceCube construction almost completed
- ✓ IceCube meeting or exceeding its design requirements
- ✓ IceCube is a 4π sr detector
- ✓ IceCube already producing scientific results.
  - Point sources, diffuse, GRBs, Atmospheric neutrinos, cosmic rays, Target of opportunity programs, indirect Dark Matter search, etc …

IC22+AMANDA, optimized for soft spectra sources

Galactic Plane Scan

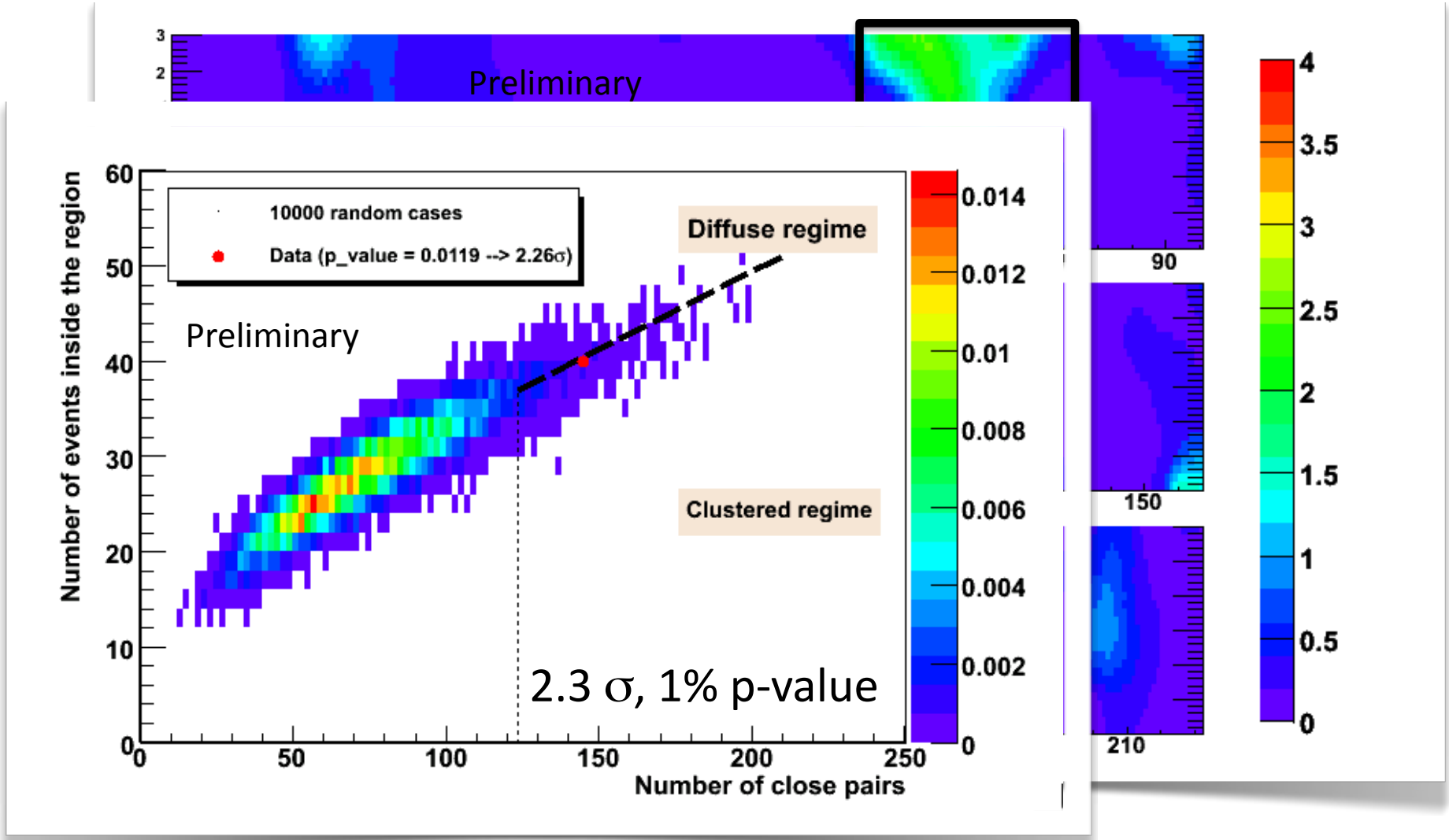


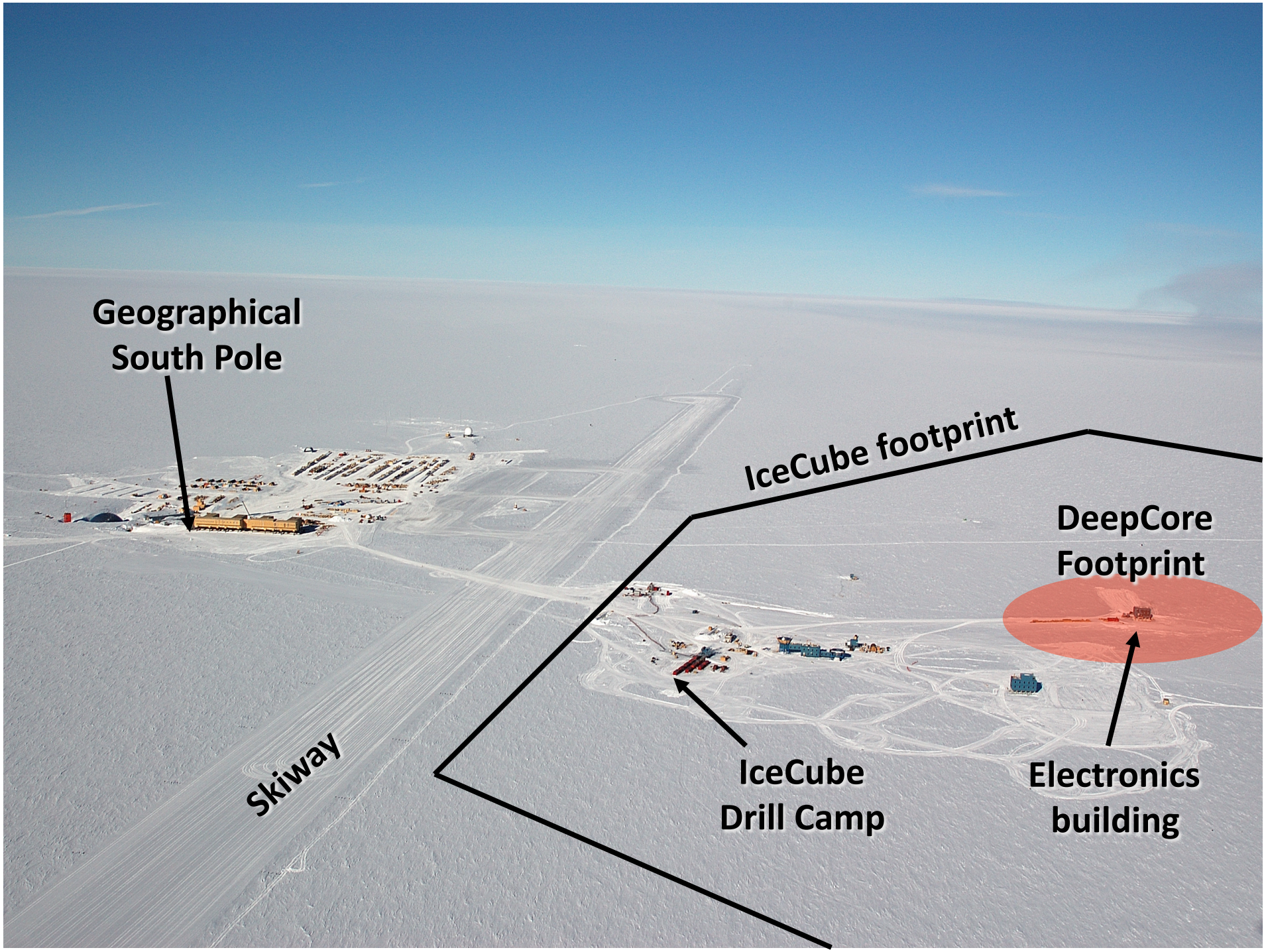
IC22+AMANDA, optimized for soft spectra sources



IC22+AMANDA, optimized for soft spectra sources

Cygnus region




Geographical
South Pole
IceCube footprint
DeepCore
Footprint
Skiway
IceCube
Drill Camp
Electronics
building

Optical Follow-Up