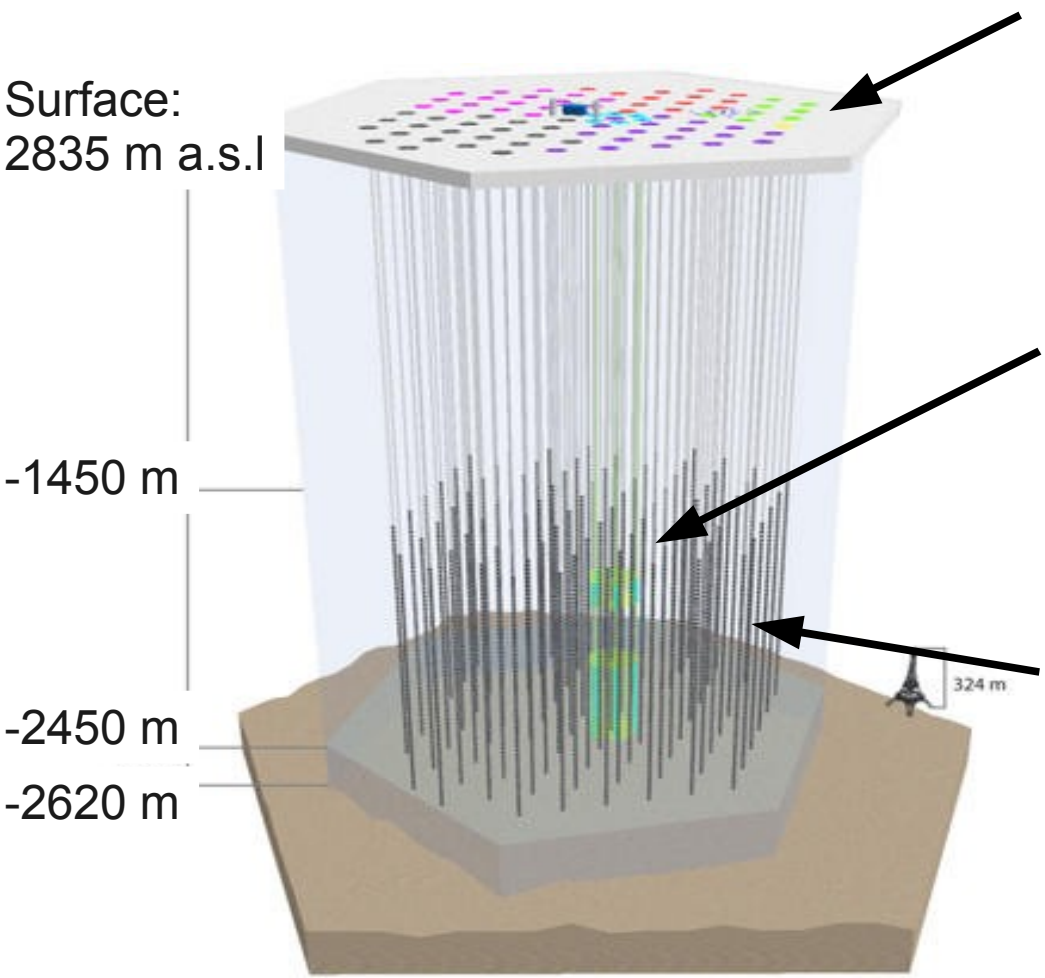
Results from IceCube

Patrick Berghaus
University of Delaware

IceCube Collaboration: > 250 People

IceCube: 3 Components



IceTop (Surface Array):

- 2 Surface Tanks per InIce String
- 2 DOMs per Tank
- 2010: **2x73** Tanks Installed

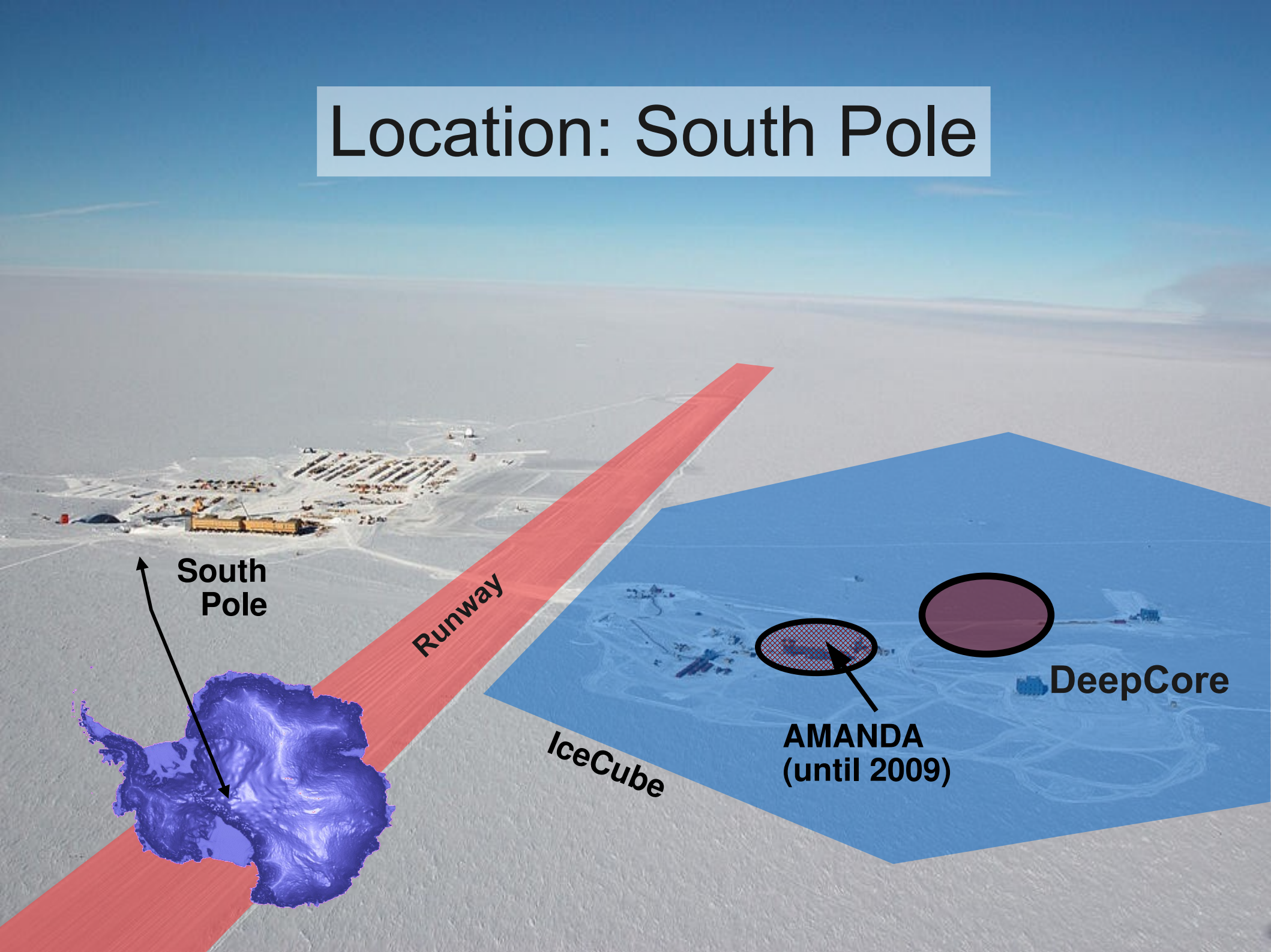
DeepCore (Low Energy):

- 6 Strings
- DOMs have 50% higher q.e. (34%)
- DOM Spacing 7 meters

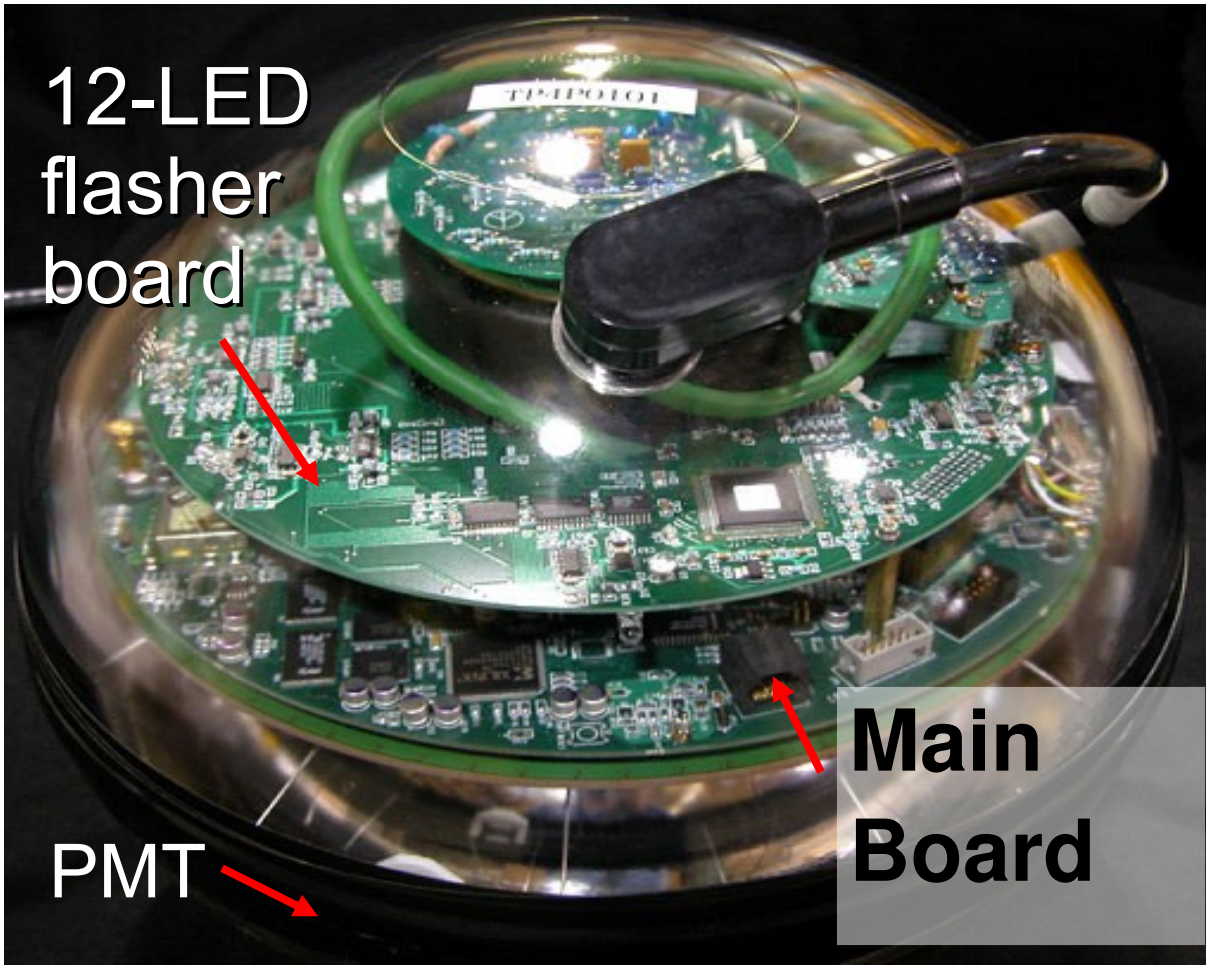
InIce:

- 1 km^3 instrumented
- 4800 DOMs, 17 meter spacing
- 80 strings
- 2010: **73** Strings deployed

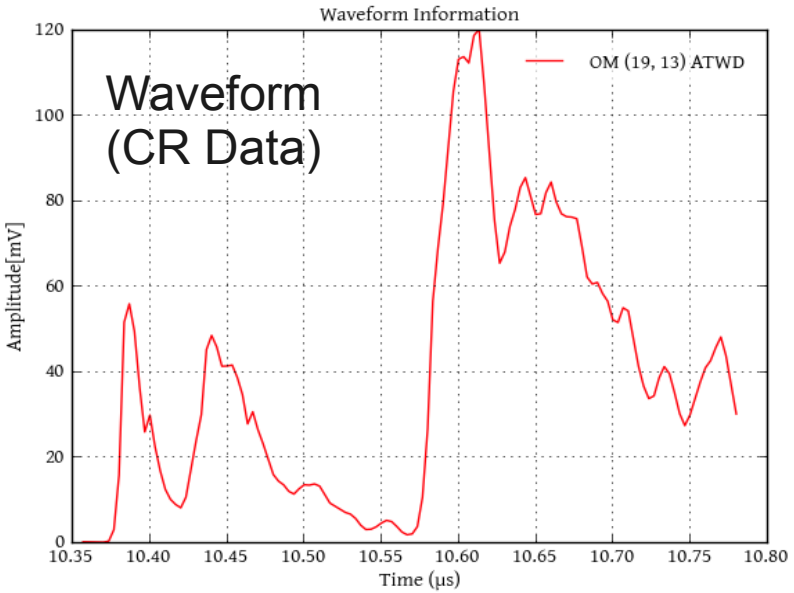
Location: South Pole



Digital Optical Module (DOM)

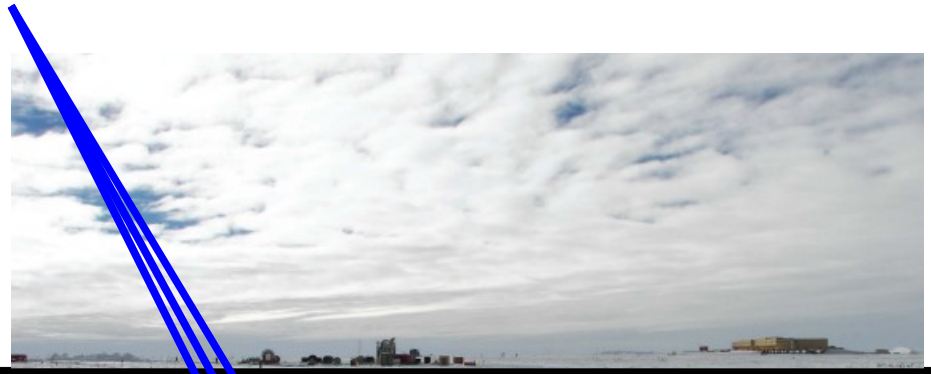


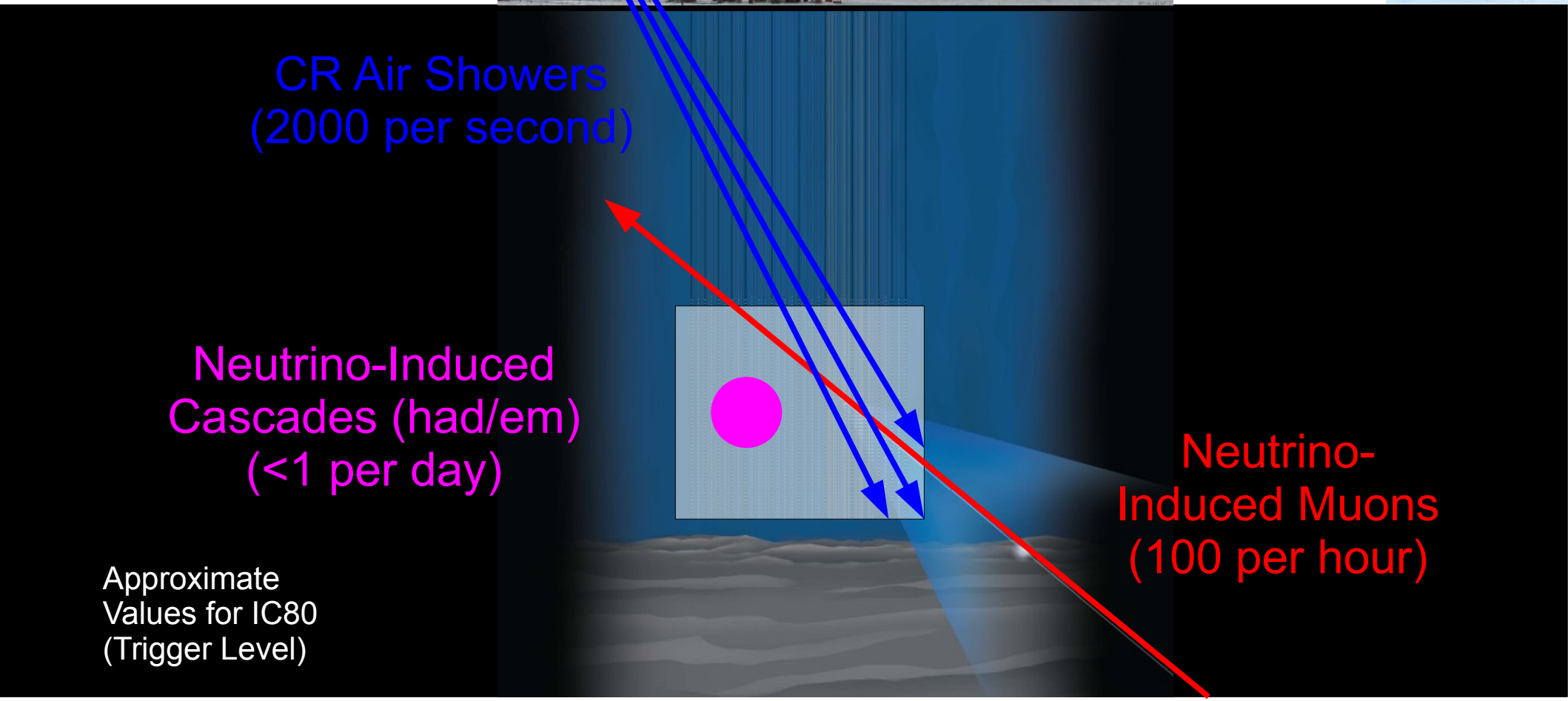
PMT:	10” Hamamatsu
Digitization:	
ATWD (custom):	300 Mhz / 400ns
FADC:	40MHz / 6,400ns
Noise Rate:	650Hz



400 ns

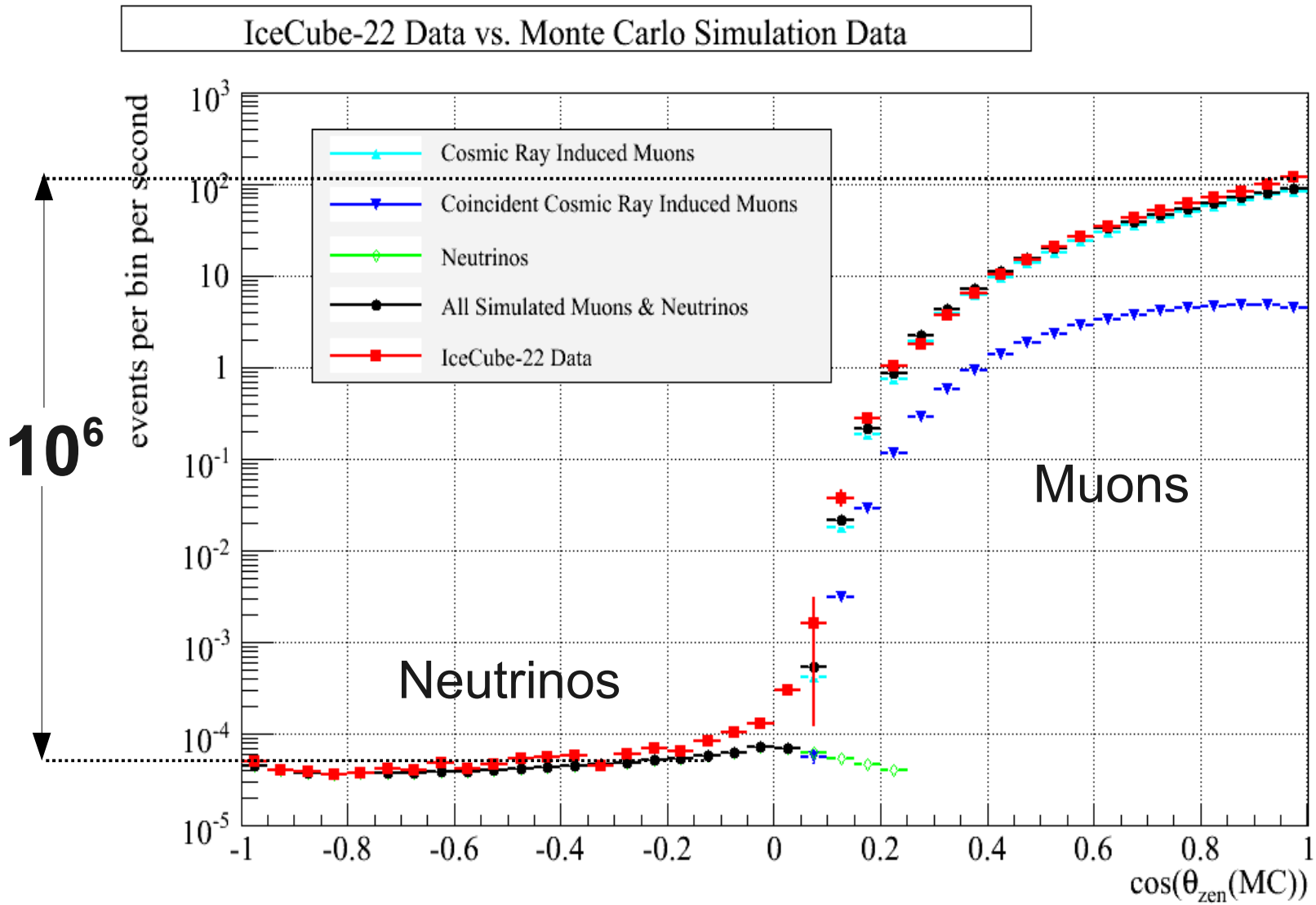
Event Types





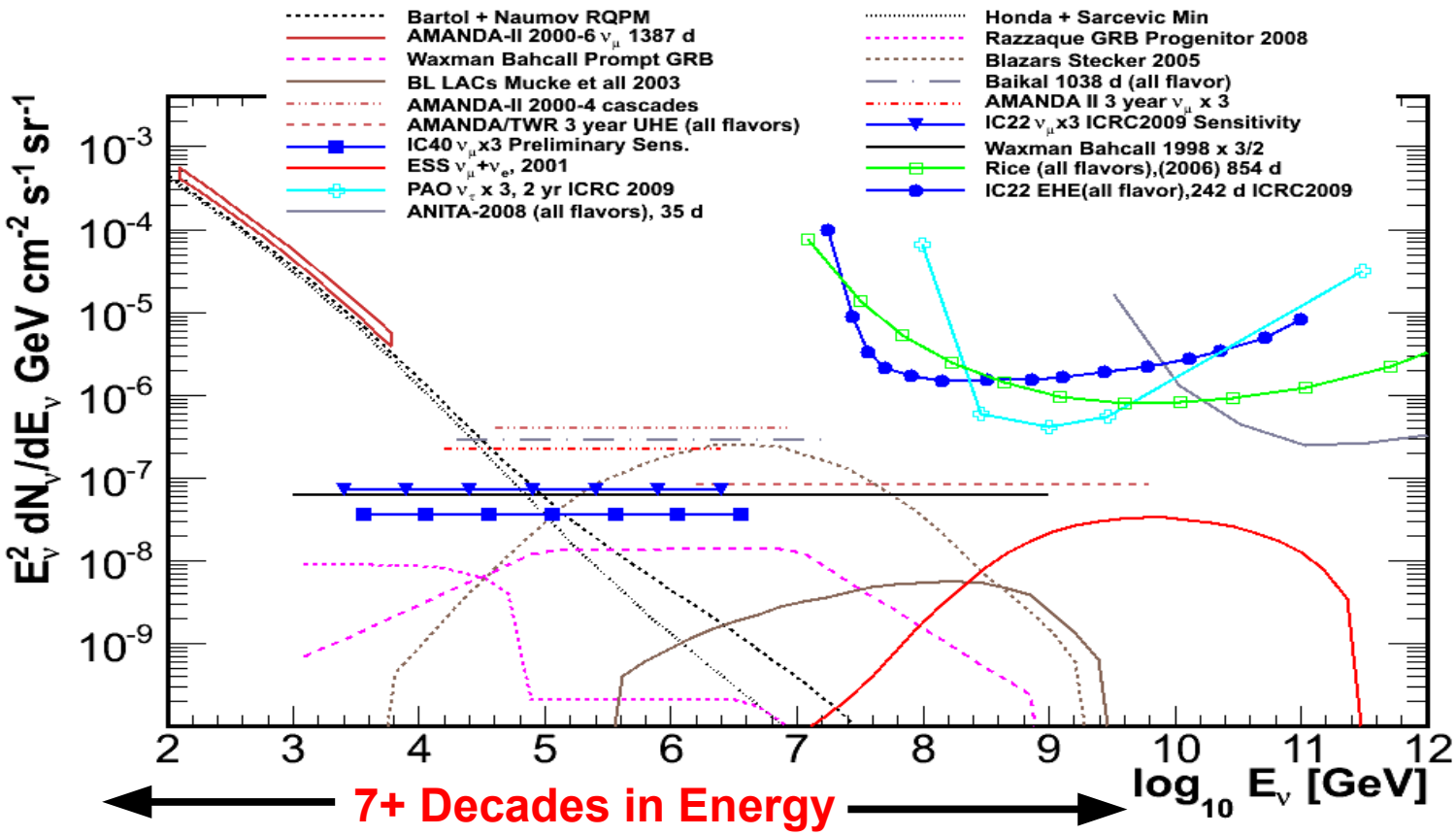
Approximate
Values for IC80
(Trigger Level)

All Sky Muon Flux (IC22, 2008)



arXiv:0902.0021

IceCube Neutrino Physics



Oscillations

Atmospheric Charm Production

Gamma-Ray Bursts

Dark Matter

QG

Active Galactic Nuclei

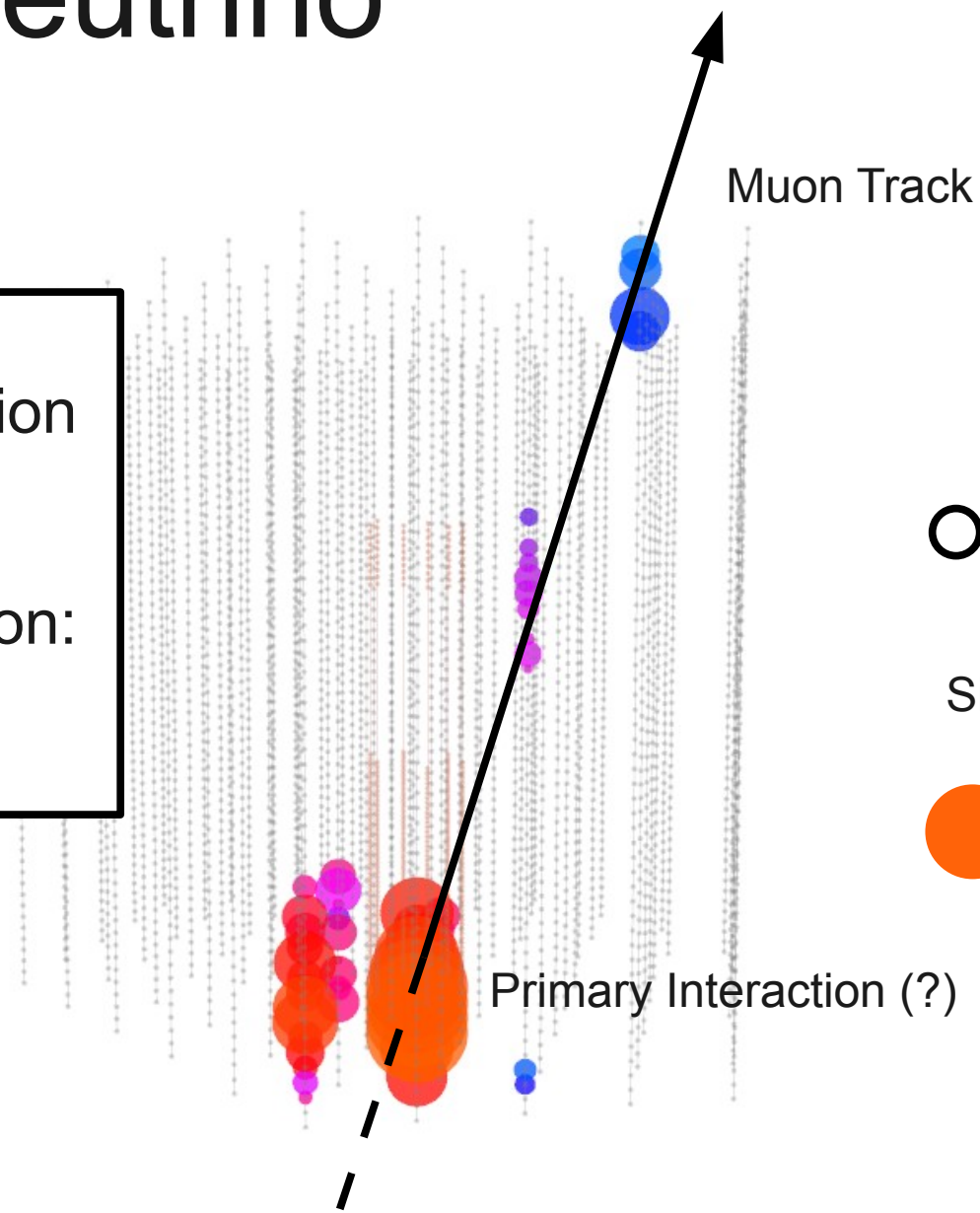
GZK Neutrinos (CMB Interactions)

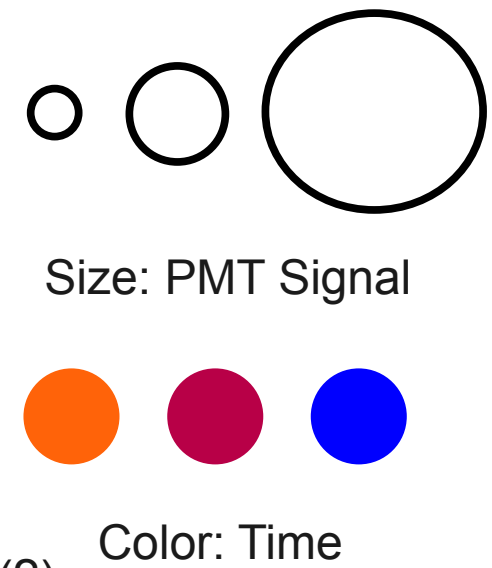
Galactic Sources (Supernova Remnants?)

Muon Neutrino

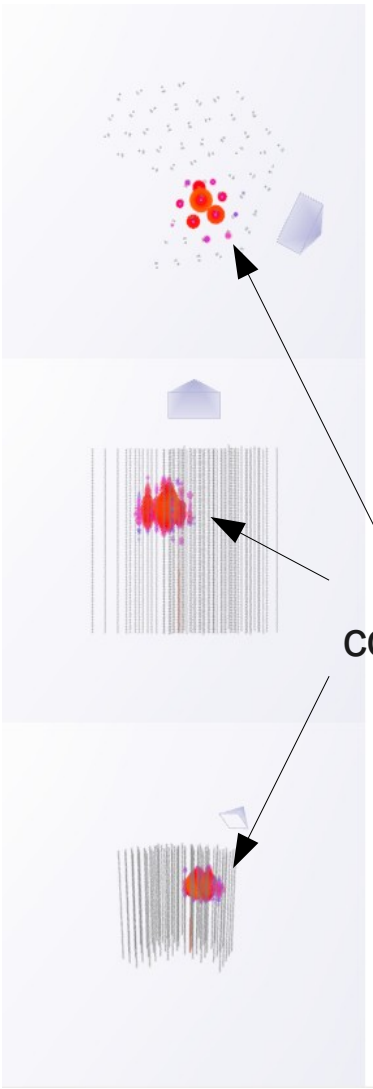
Angular Resolution
< 1°

Energy Resolution:
0.3 in $\log_{10}E$

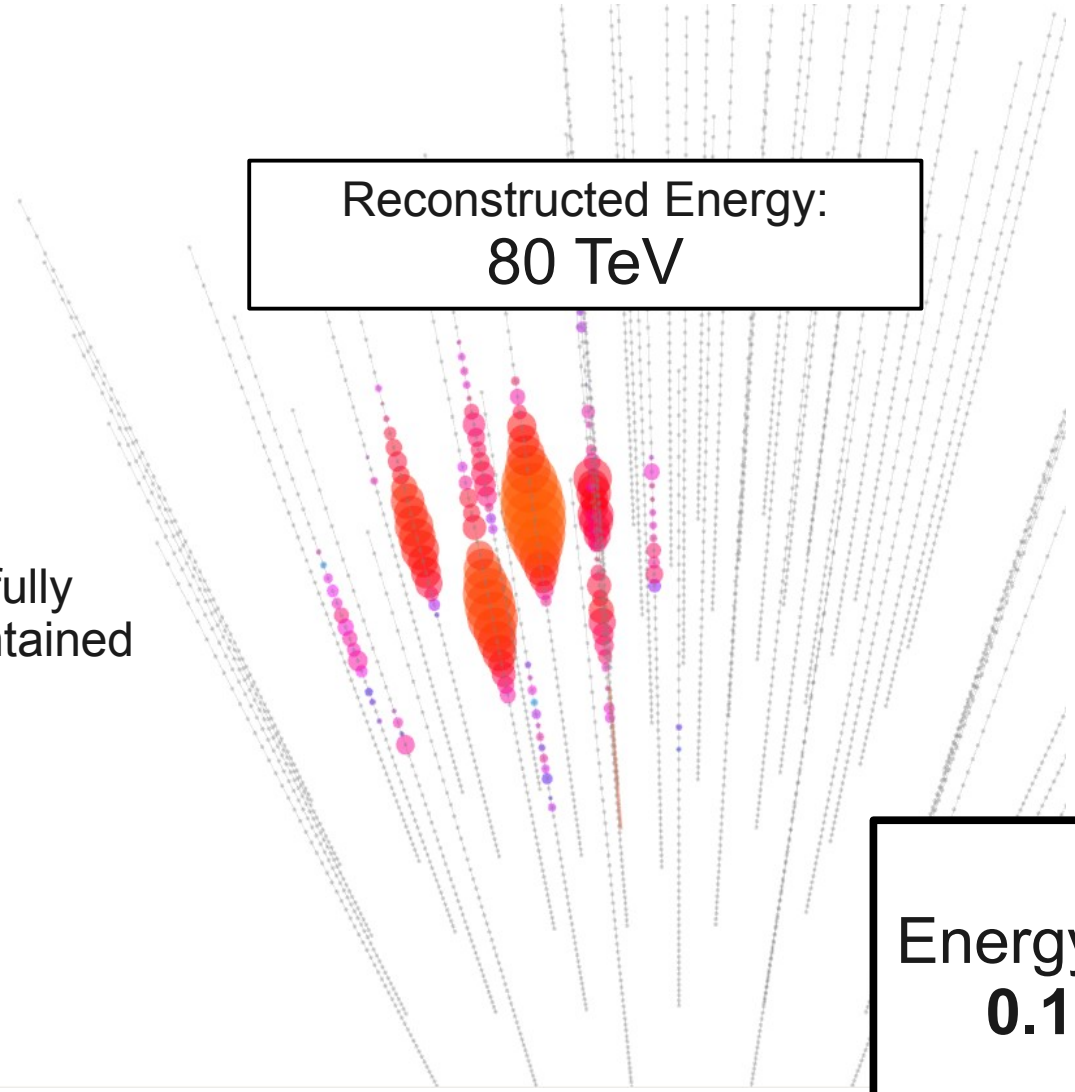




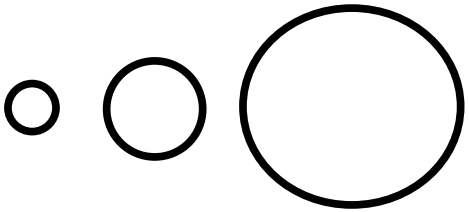
Neutrino-Induced Cascade



fully contained



Reconstructed Energy:
80 TeV



Size: PMT Signal

Color: Time

Energy Resolution:
0.1 in $\log_{10}E$

Neutrino Point Sources

Astrophysical Hadron Accelerator

$$p + X \rightarrow \pi^0 + \pi^+ + \pi^-$$

$$\pi^0 \rightarrow \gamma\gamma$$

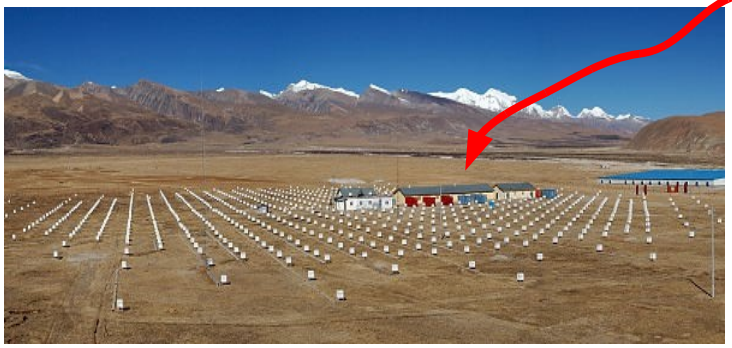
$$\pi^+ \rightarrow \mu\nu_\mu$$

$$\pi^- \rightarrow e + 2\nu_\mu + \nu_e$$

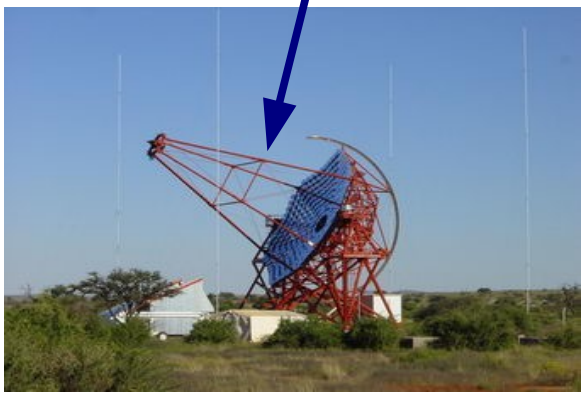
direction scrambled by interstellar/-galactic magnetic field

ambiguity with purely electromagnetic processes

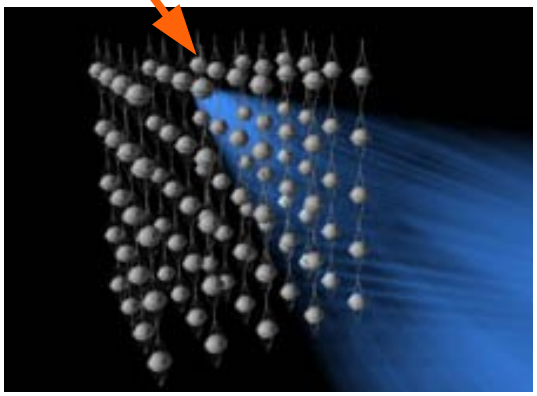
"Smoking Gun" for hadronic acceleration



CR Air Shower Array

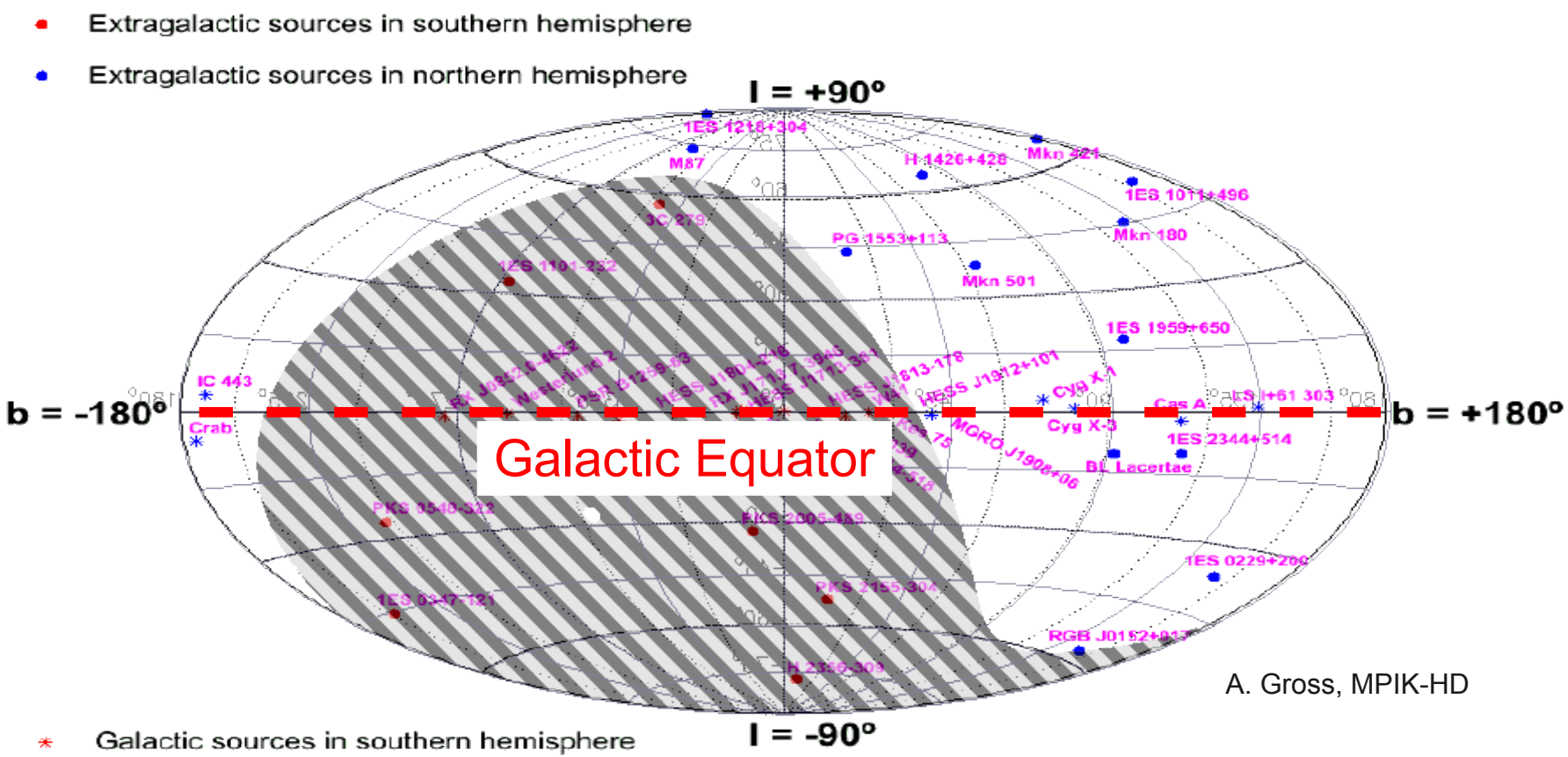


Cherenkov Telescope



Neutrino Telescope

Sky Coverage

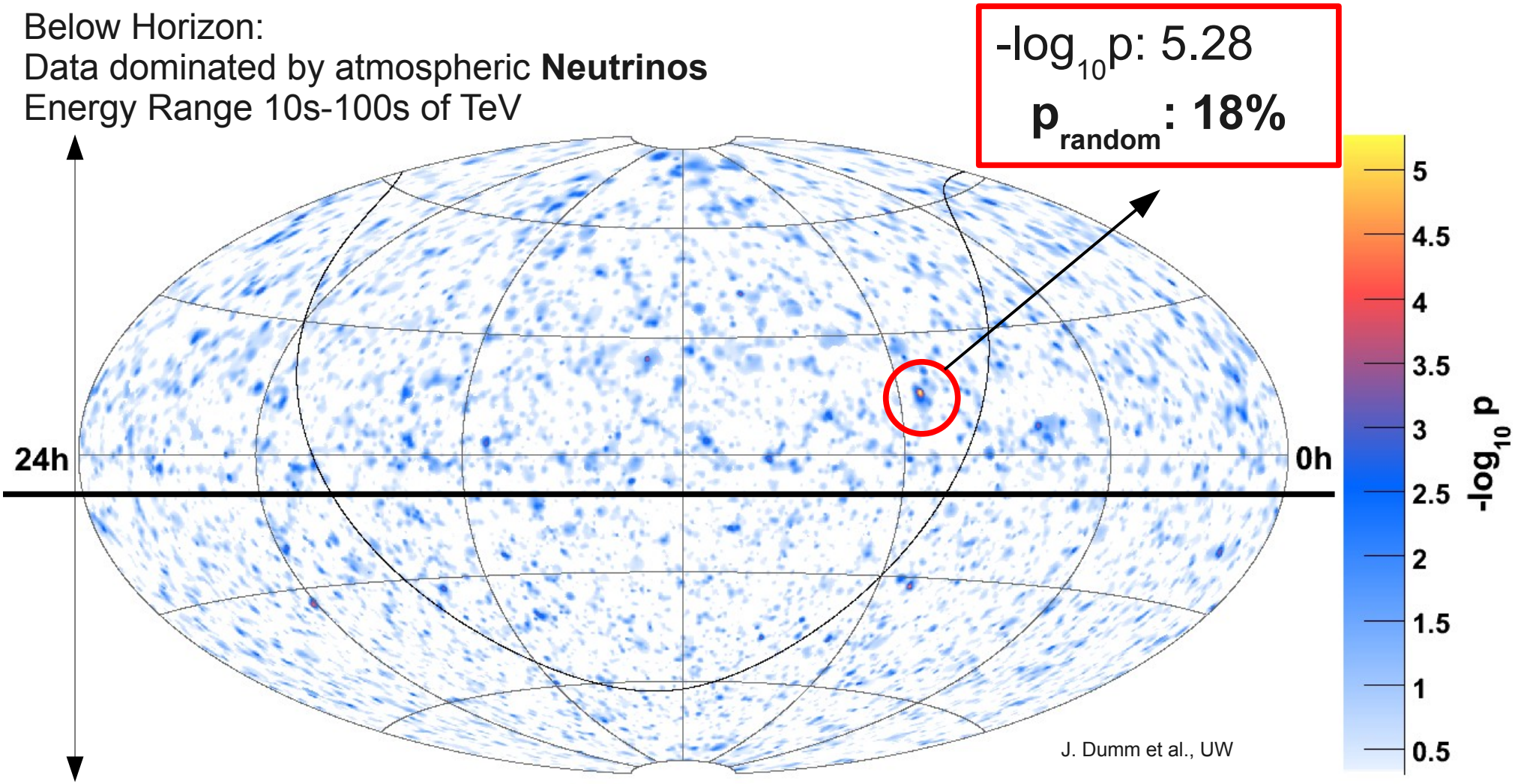


A. Gross, MPIK-HD

- not directly accessible for IceCube
- directly accessible for IceCube

IC40 Point Source Search

Below Horizon:
Data dominated by atmospheric **Neutrinos**
Energy Range 10s-100s of TeV



Above Horizon:
Data dominated by atmospheric **Muons**
Energy Range >PeV, increasing with angle

Neutrino Point Source Flux Limits

Further Analyses:

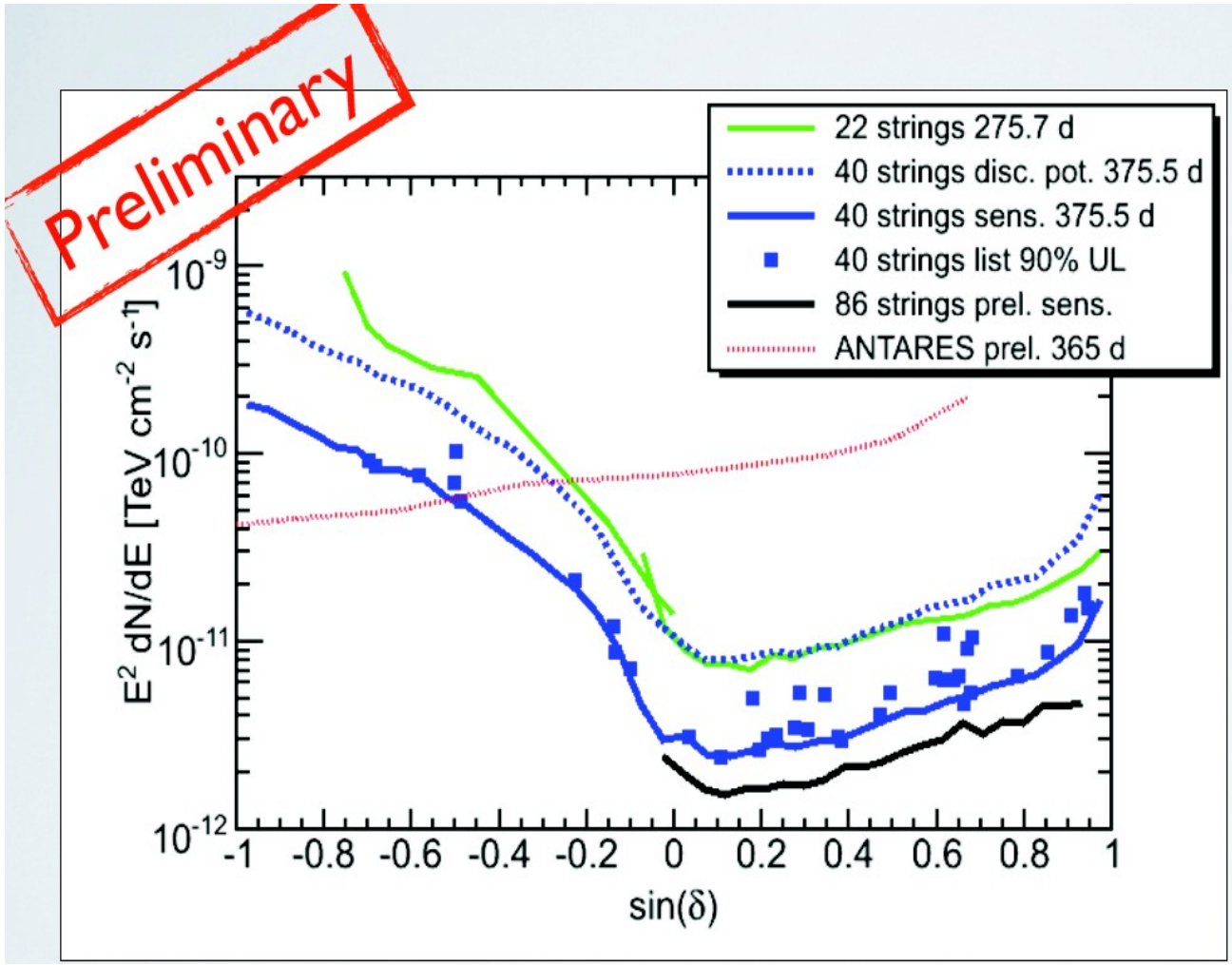
Flare Searches

Multi-Wavelength

Target-of-Opportunity

Optical Follow-Up

Source Stacking



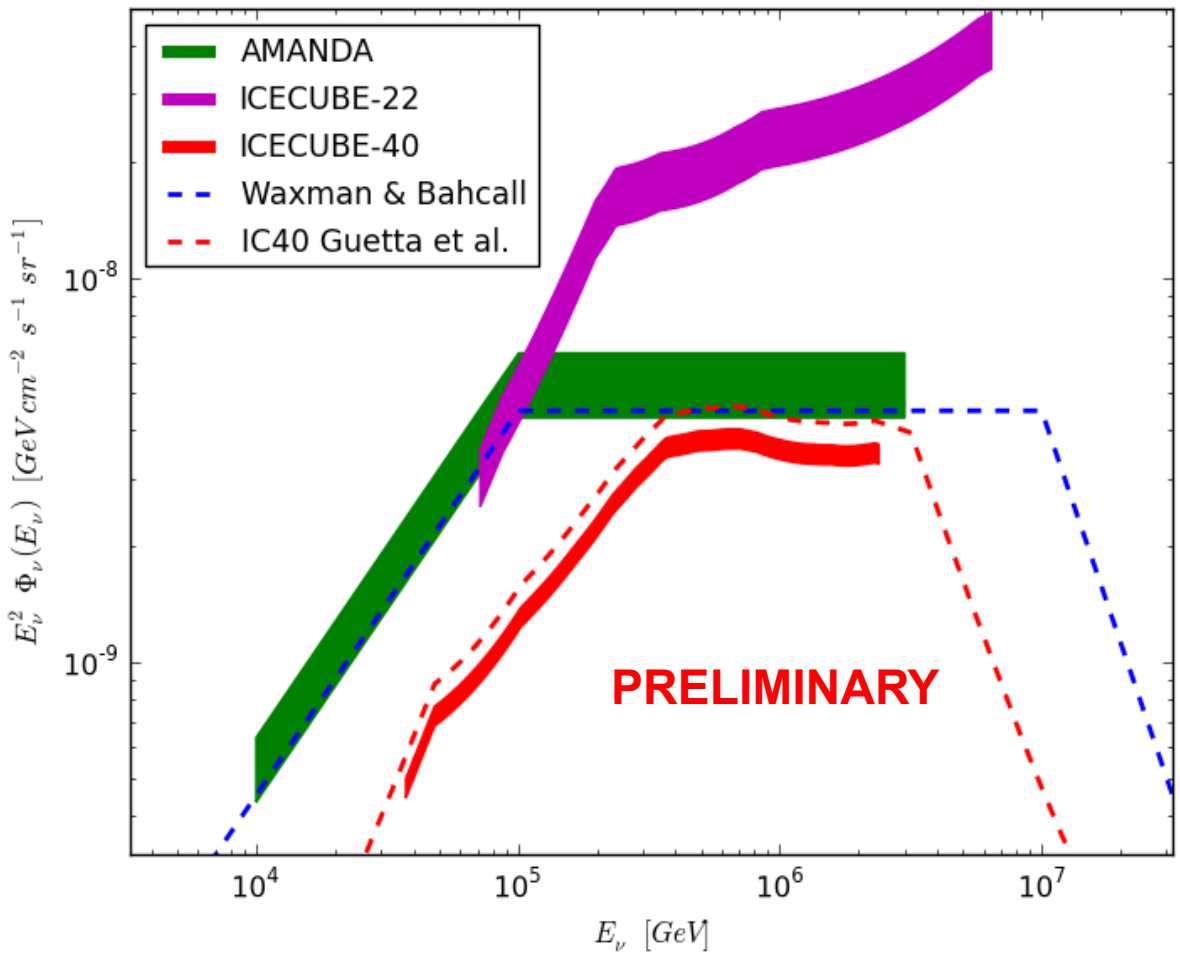
Triggered GRB Search

Based on 117 satellite-detected
Gamma-Ray Bursts

Search for coincident neutrino events

Burst parameters individually modeled

IceCube limit approaches "standard" Waxman-Bahcall neutrino emission model

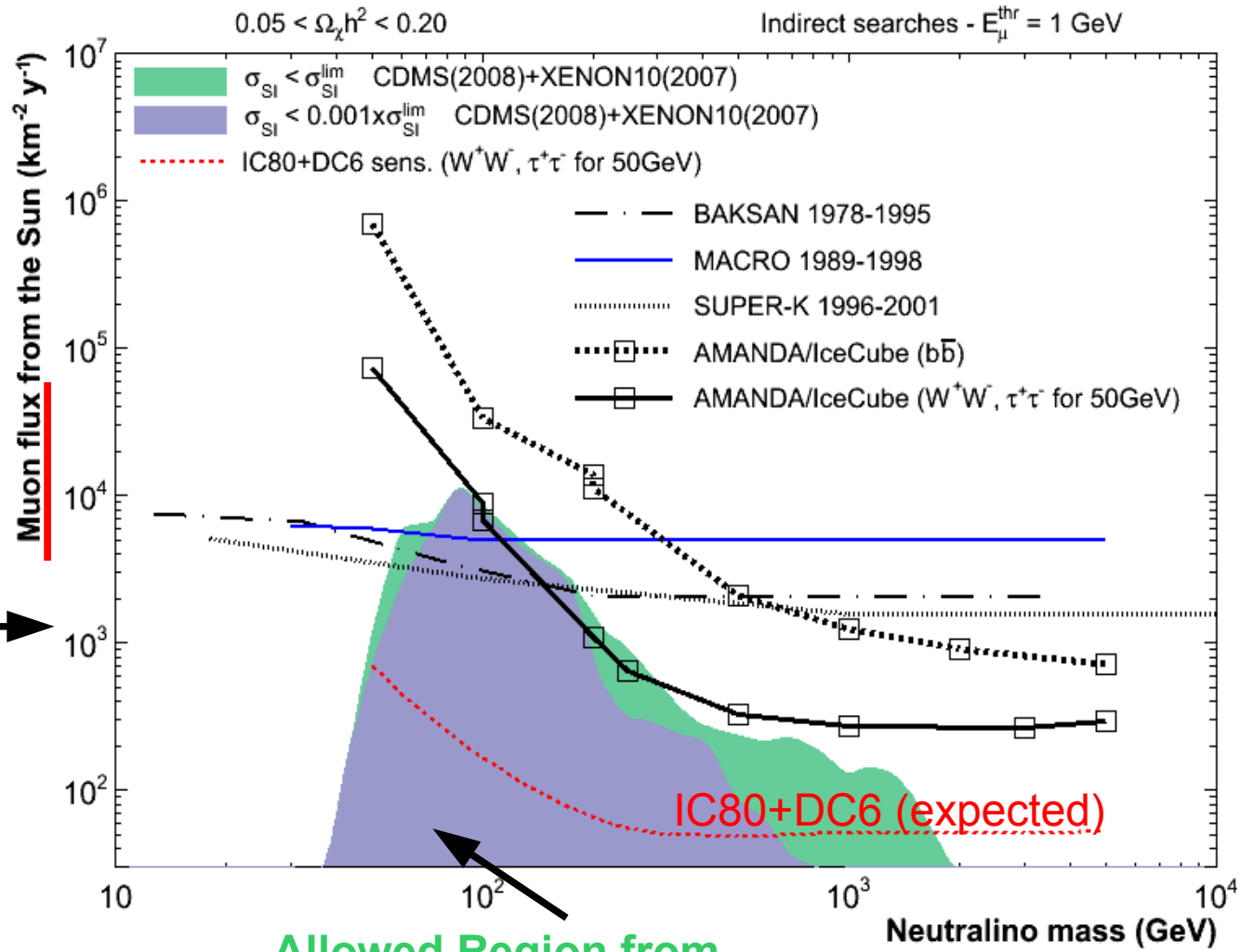


Indirect Dark Matter Searches

Neutralino
(Kaluza-Klein)
Pair Annihilation

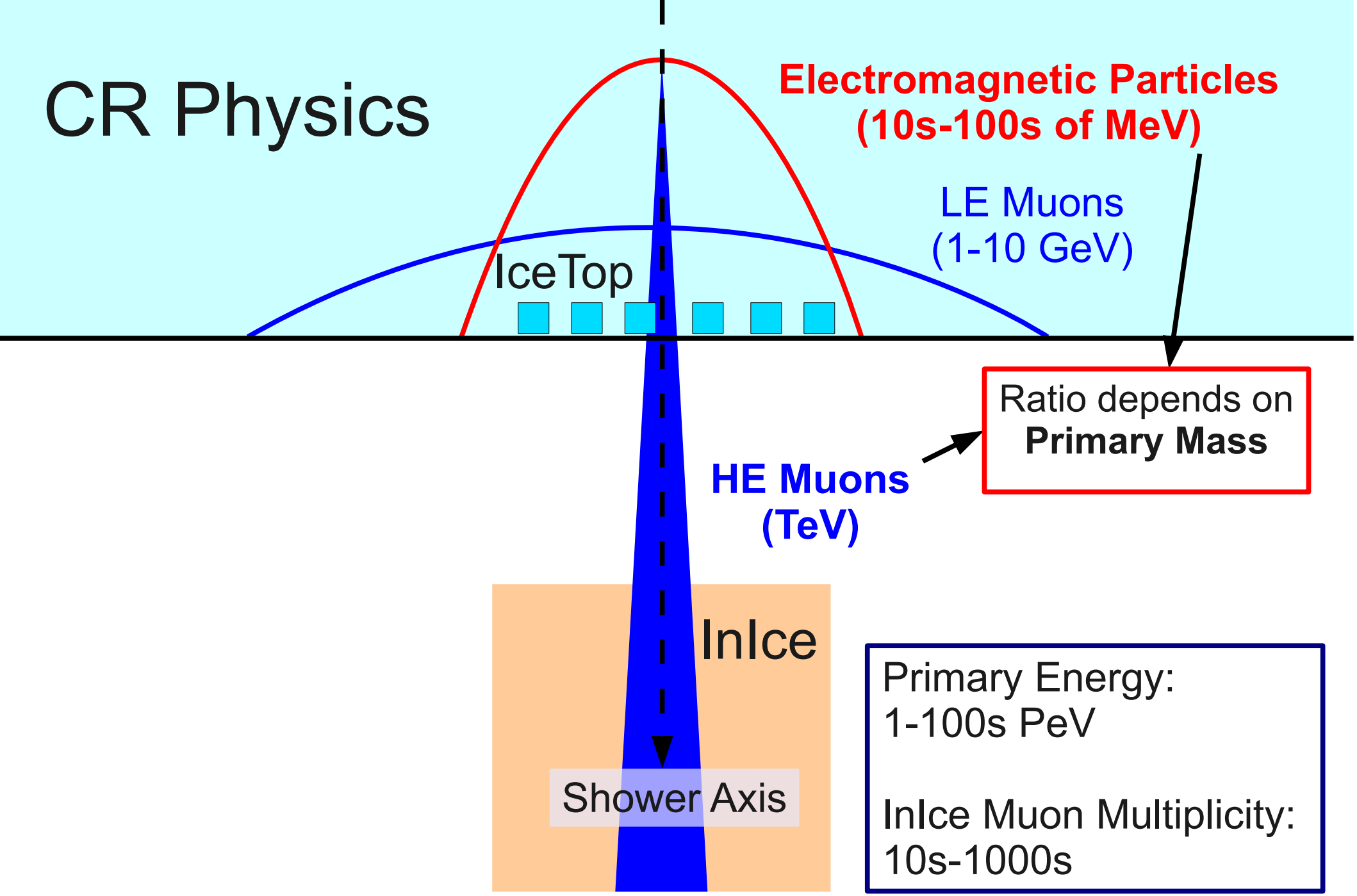
in

Sun
(Earth,
Galactic Center,
Galactic Halo)



Allowed Region from Direct Measurements (Cryogenic)

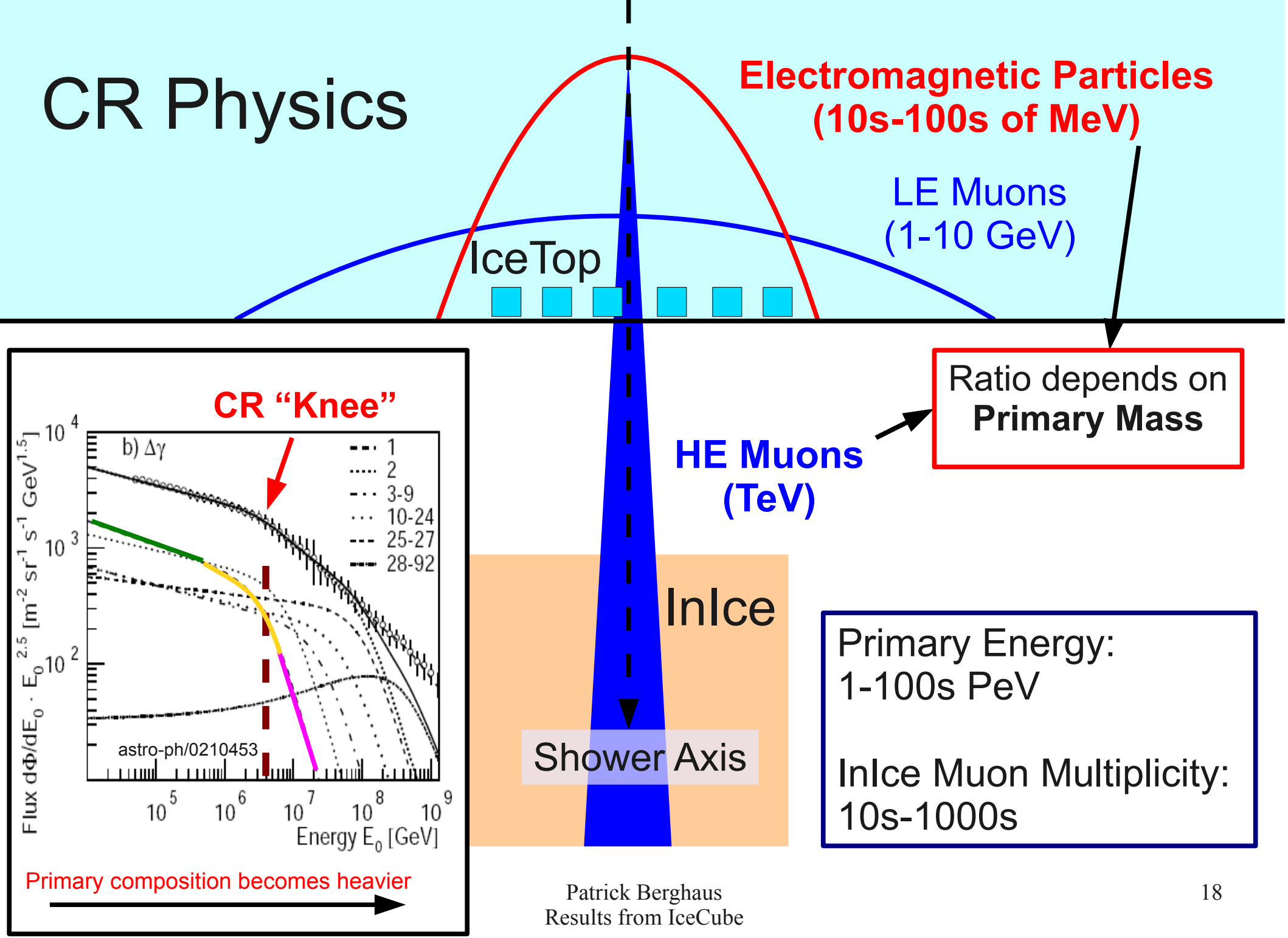
CR Physics



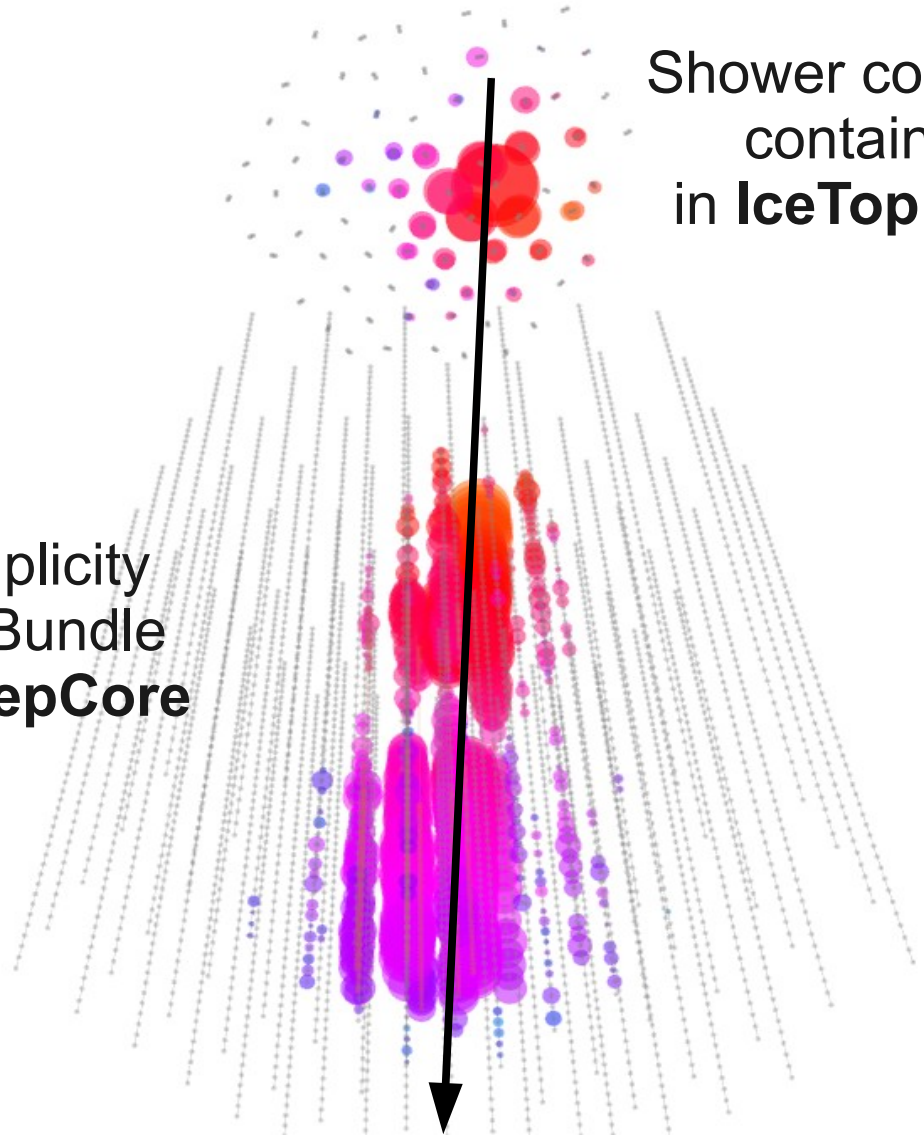
Primary Energy:
1-100s PeV

InIce Muon Multiplicity:
10s-1000s

CR Physics

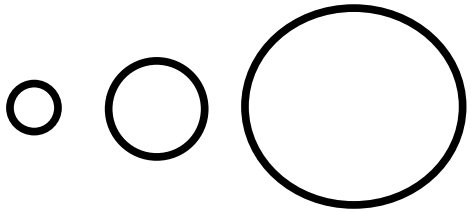

Electromagnetic Particles
(10s-100s of MeV)
LE Muons
(1-10 GeV)
IceTop
Ratio depends on
Primary Mass
HE Muons
(TeV)
InIce
Shower Axis
CR "Knee"
b) Δγ
1
2
3-9
10-24
25-27
28-92
astro-ph/0210453
Flux dΦ/dE0 · E0 2.5 [m-2 sr-1 s-1 GeV1.5]
Energy E0 [GeV]
Primary composition becomes heavier
Primary Energy:
1-100s PeV
InIce Muon Multiplicity:
10s-1000s

IC79 CR Shower



Shower core fully contained in **IceTop** array

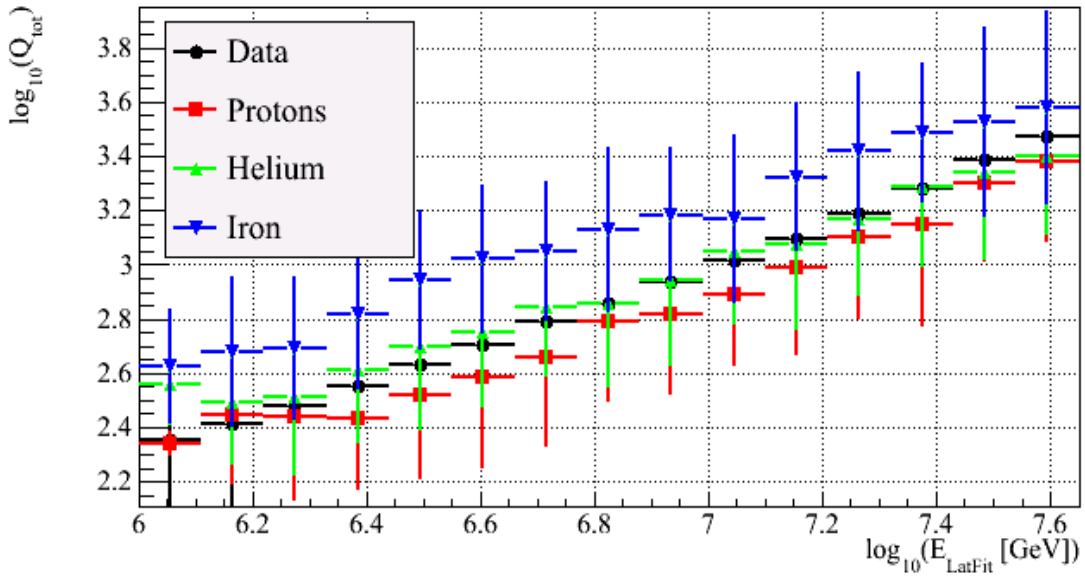
High-Multiplicity HE Muon Bundle In **InIce/DeepCore**



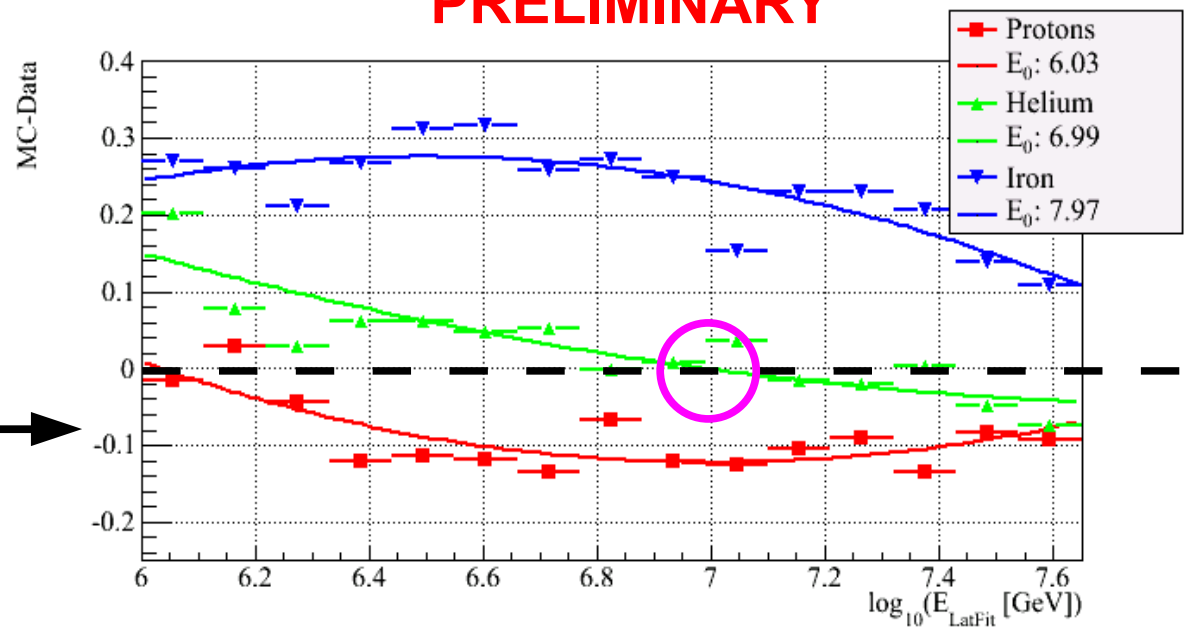
Size: PMT Signal

Color: Time

IceTop/InIce Energy Correlation



PRELIMINARY



InIce
(HE muons)

IceTop (EM)

<log A> = He
at
$E_{prim} \approx 10$PeV

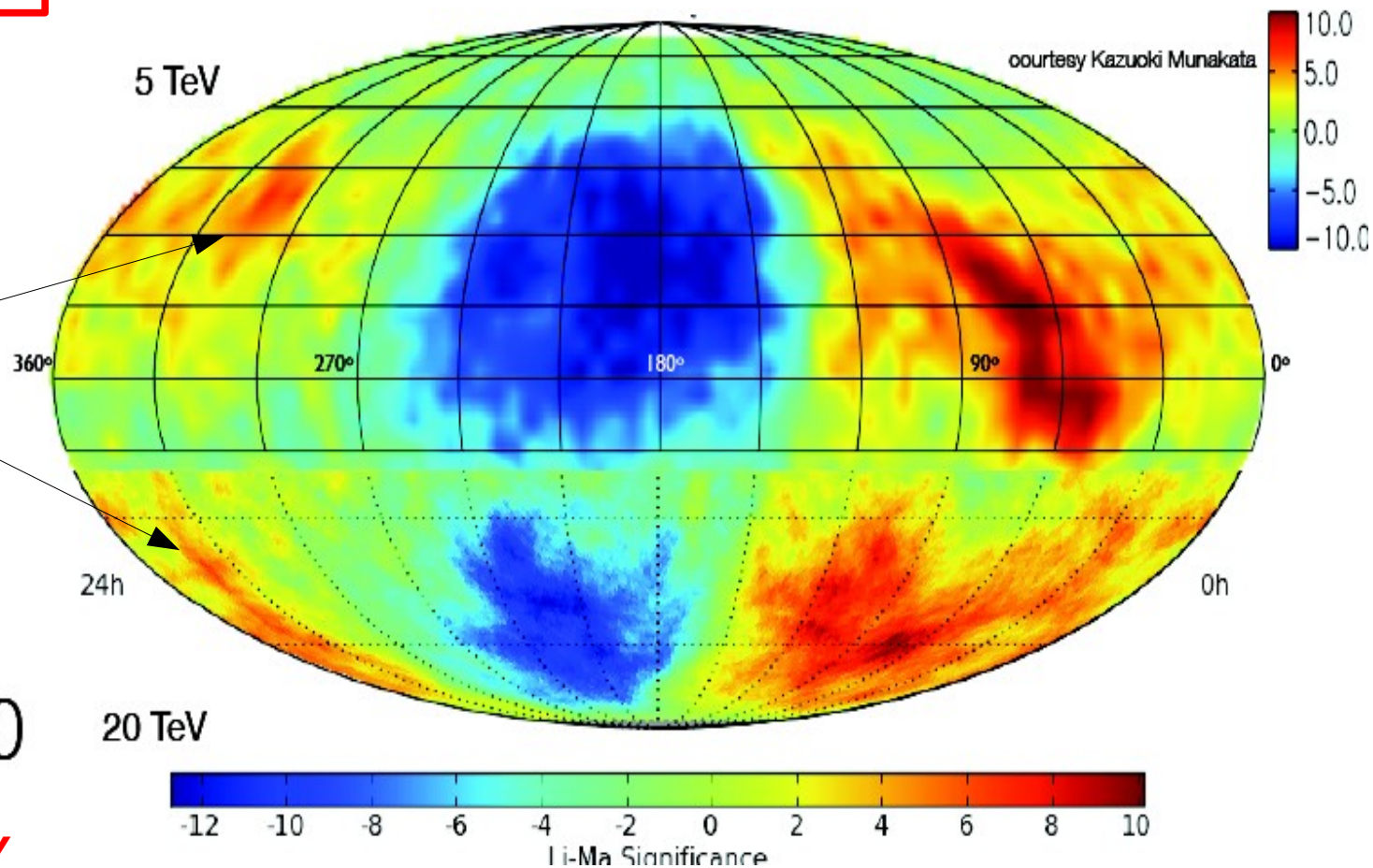
$\langle Q_{MC}(A)\rangle$
=
$\langle Q_{data}\rangle$

CR Anisotropy

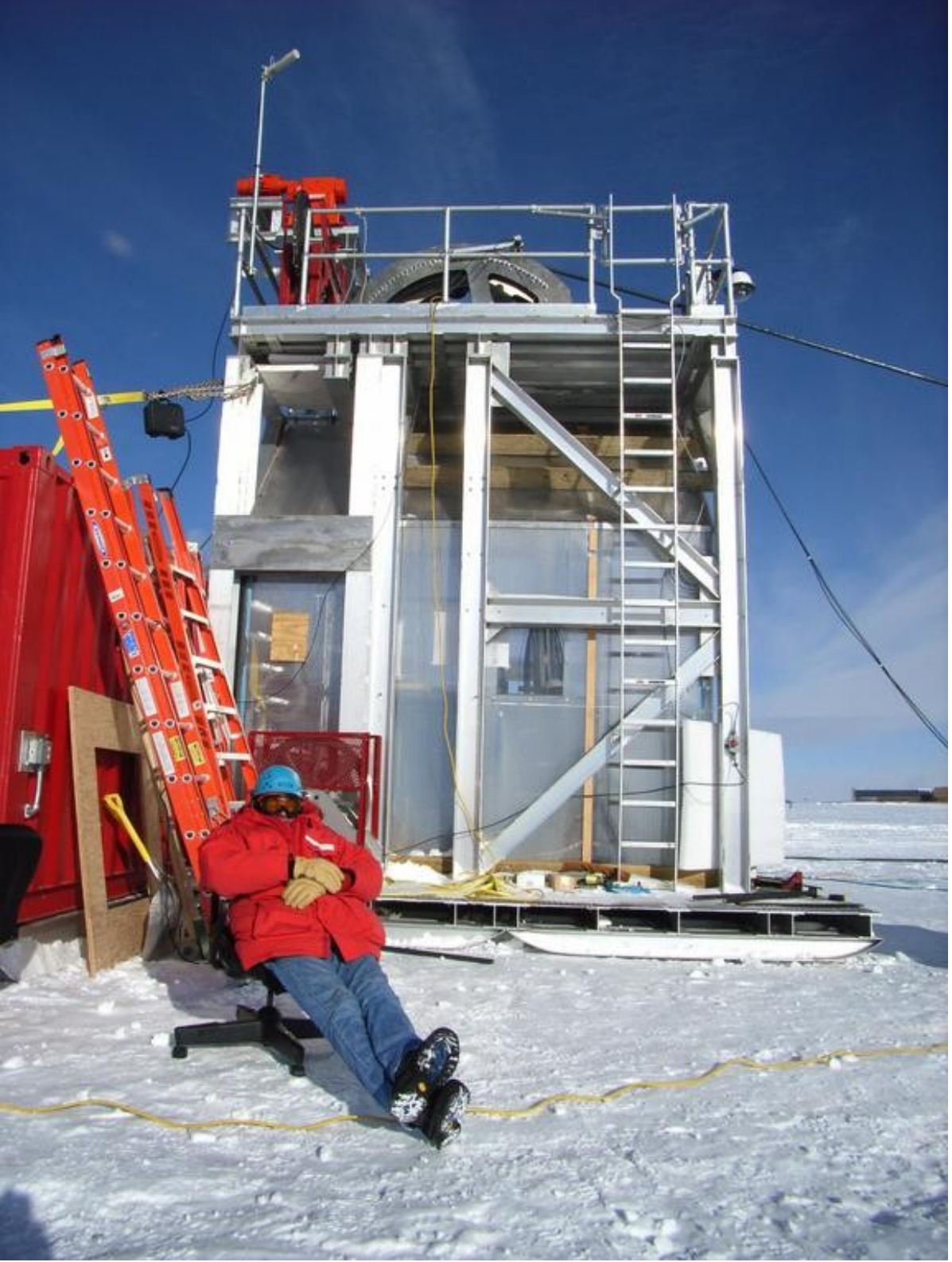
First measurement in the southern hemisphere, consistent with northern results

Tibet-III
(5° smoothing)

"Hot Spots" from nearby Sources?



IceCube-40
(3° smoothing)
PRELIMINARY

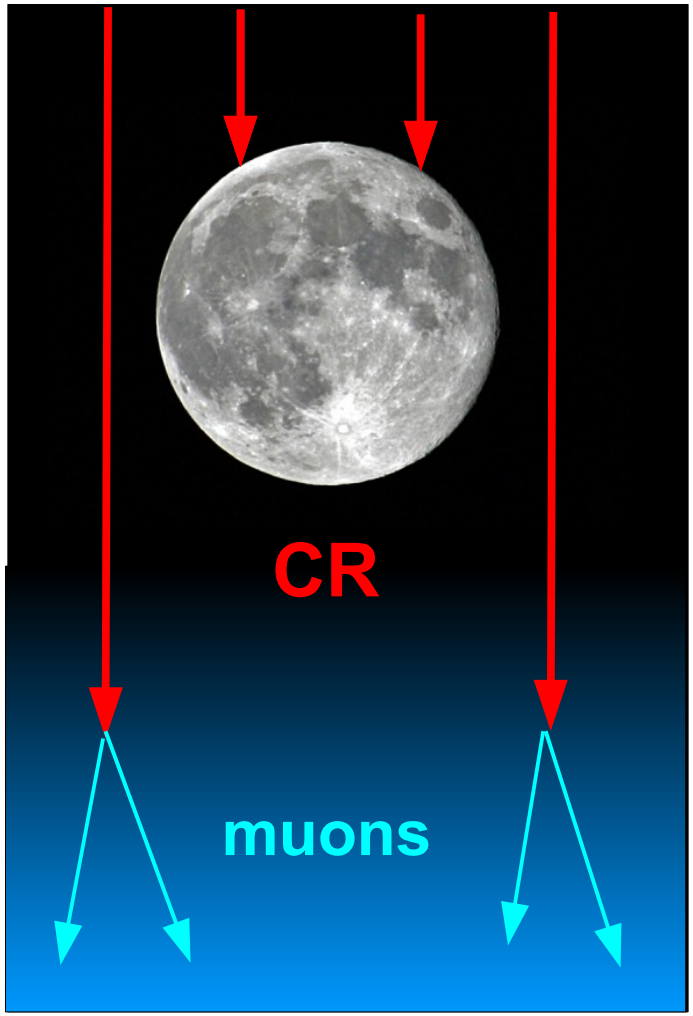


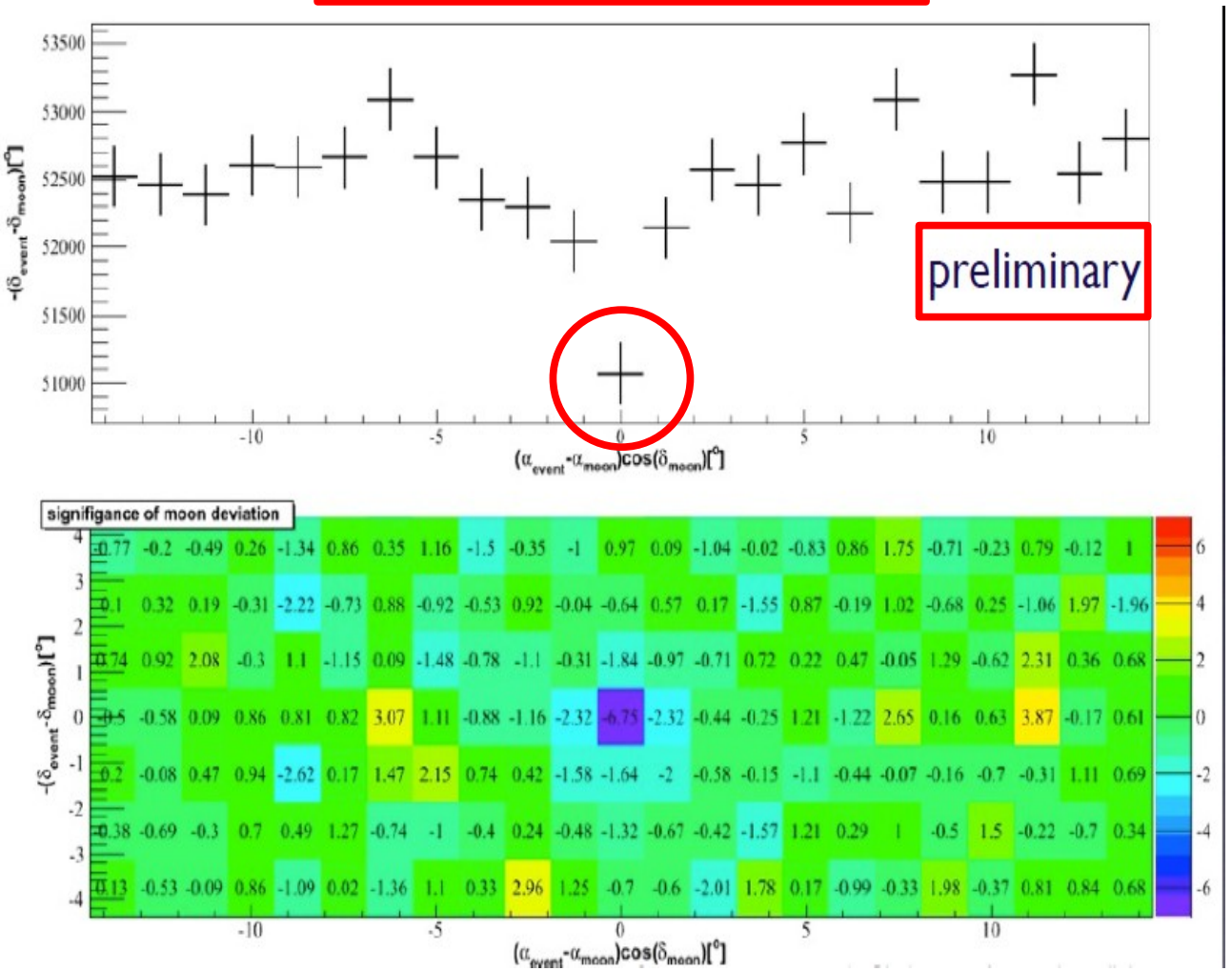
Thank you for your attention!

backup

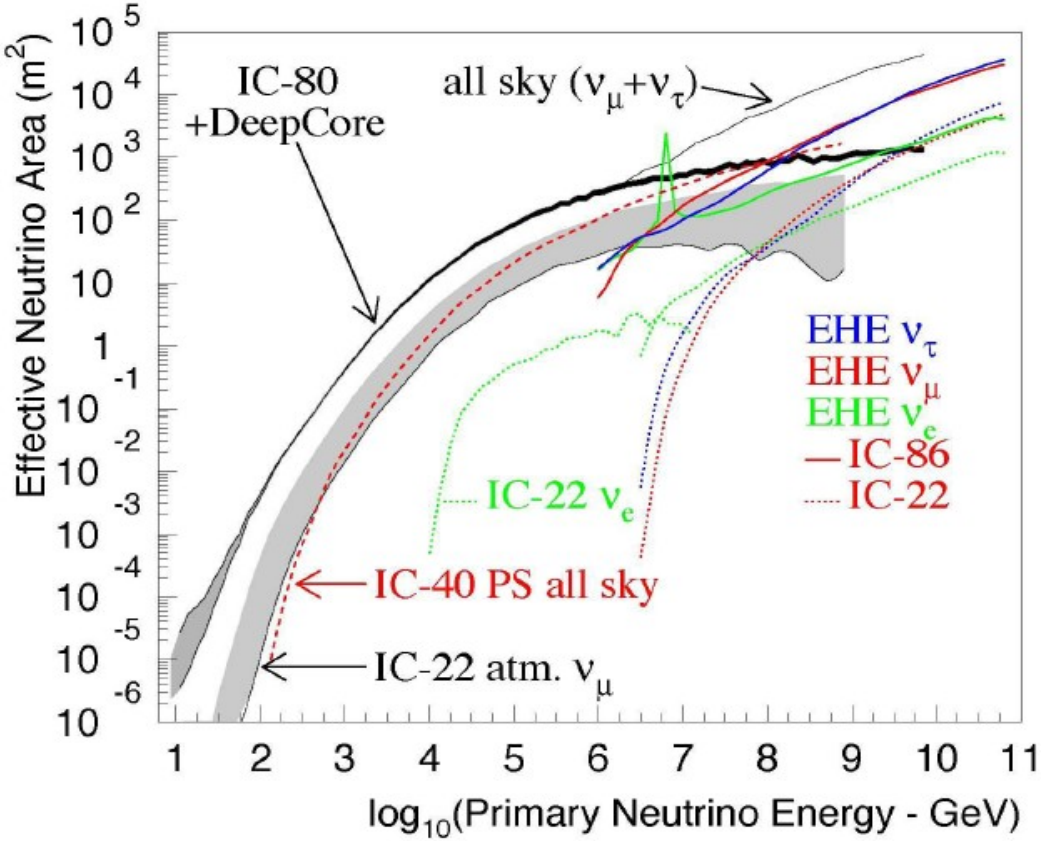
Moon Shadow

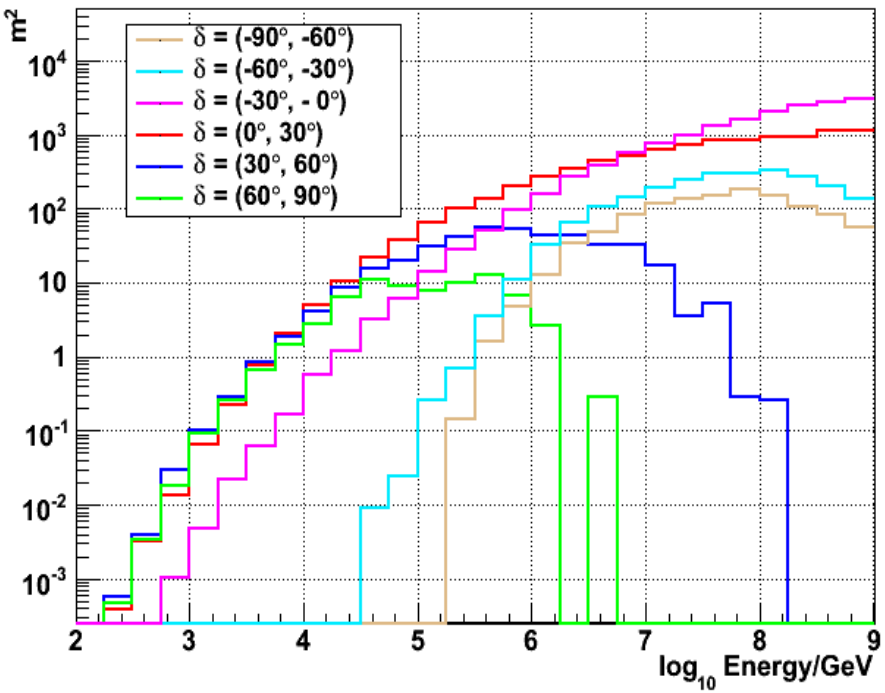
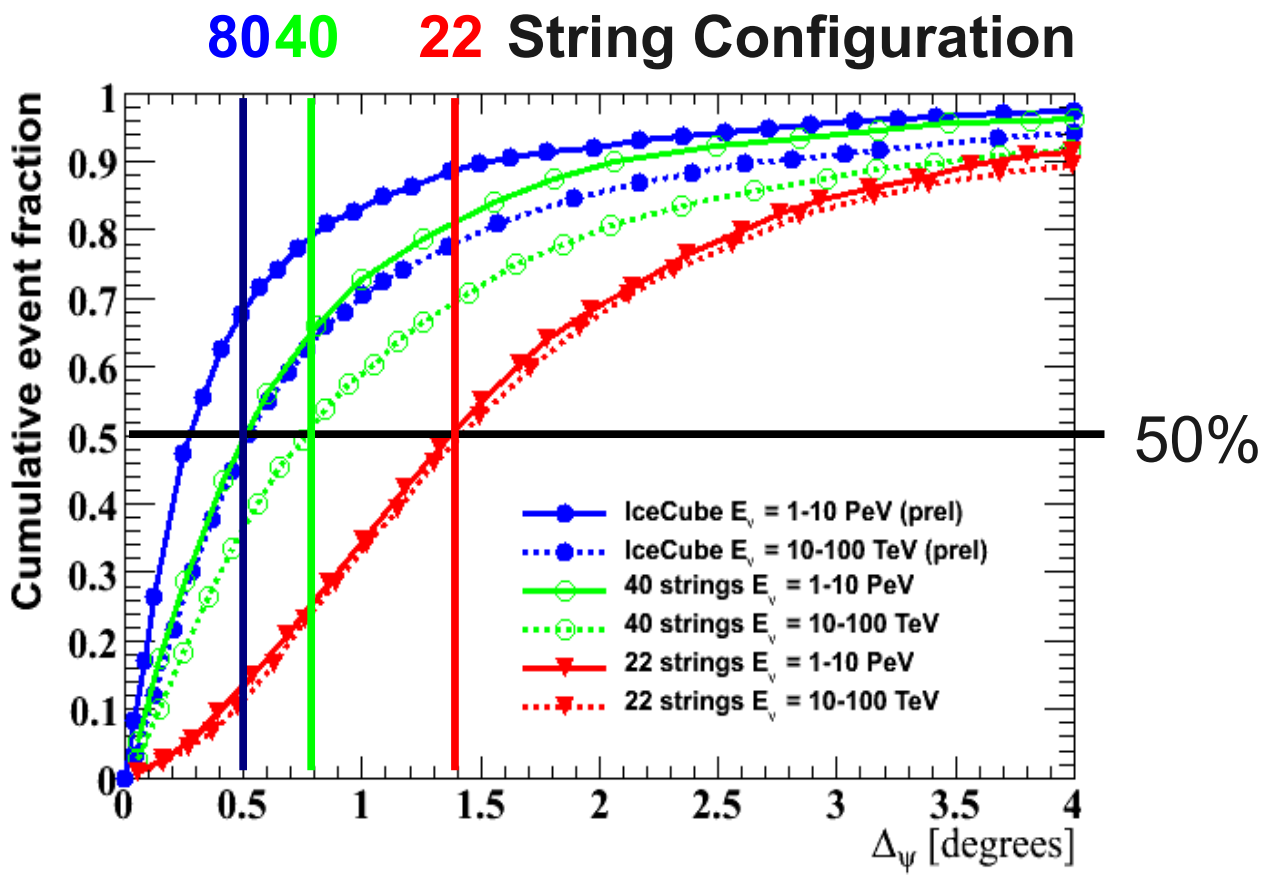
Moon Shadow seen with >6σ significance





Neutrino Effective Area





Angular Resolution (Muon Neutrinos)