IceCube and Deep Core

selected results and perspectives

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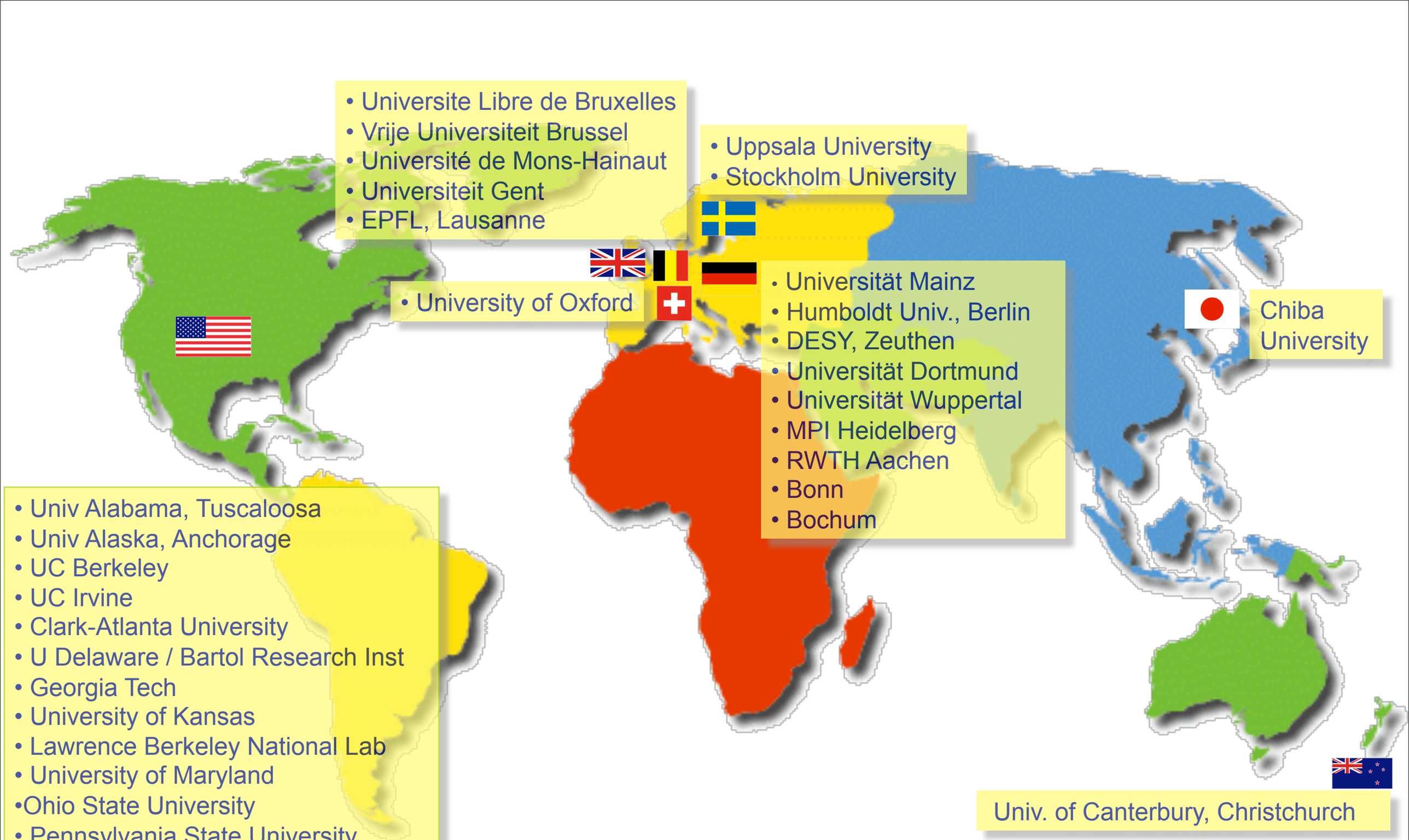
October 8-11, 2009

University of Wisconsin - Madison

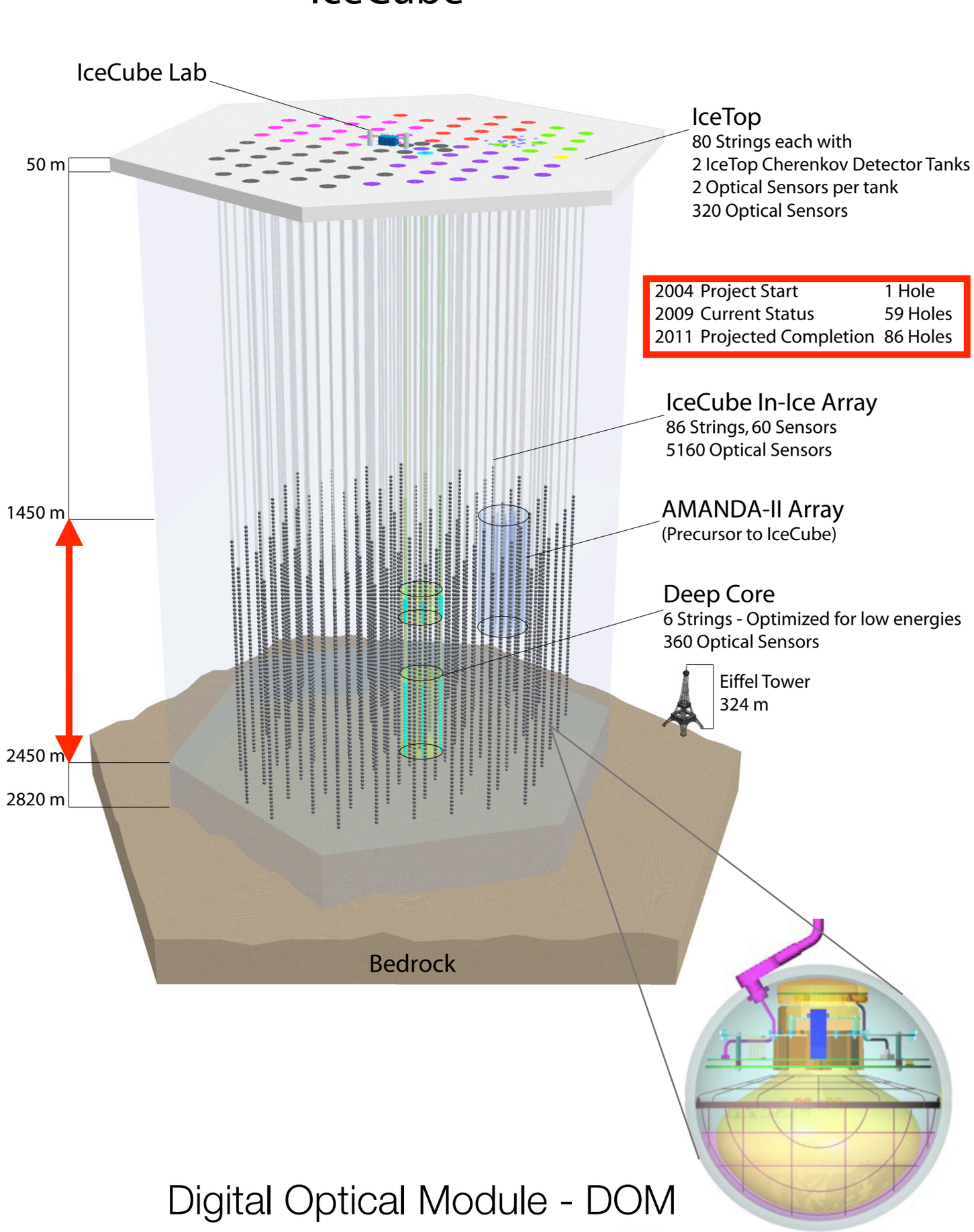


the IceCube Collaboration

34 institutions in 4 continents

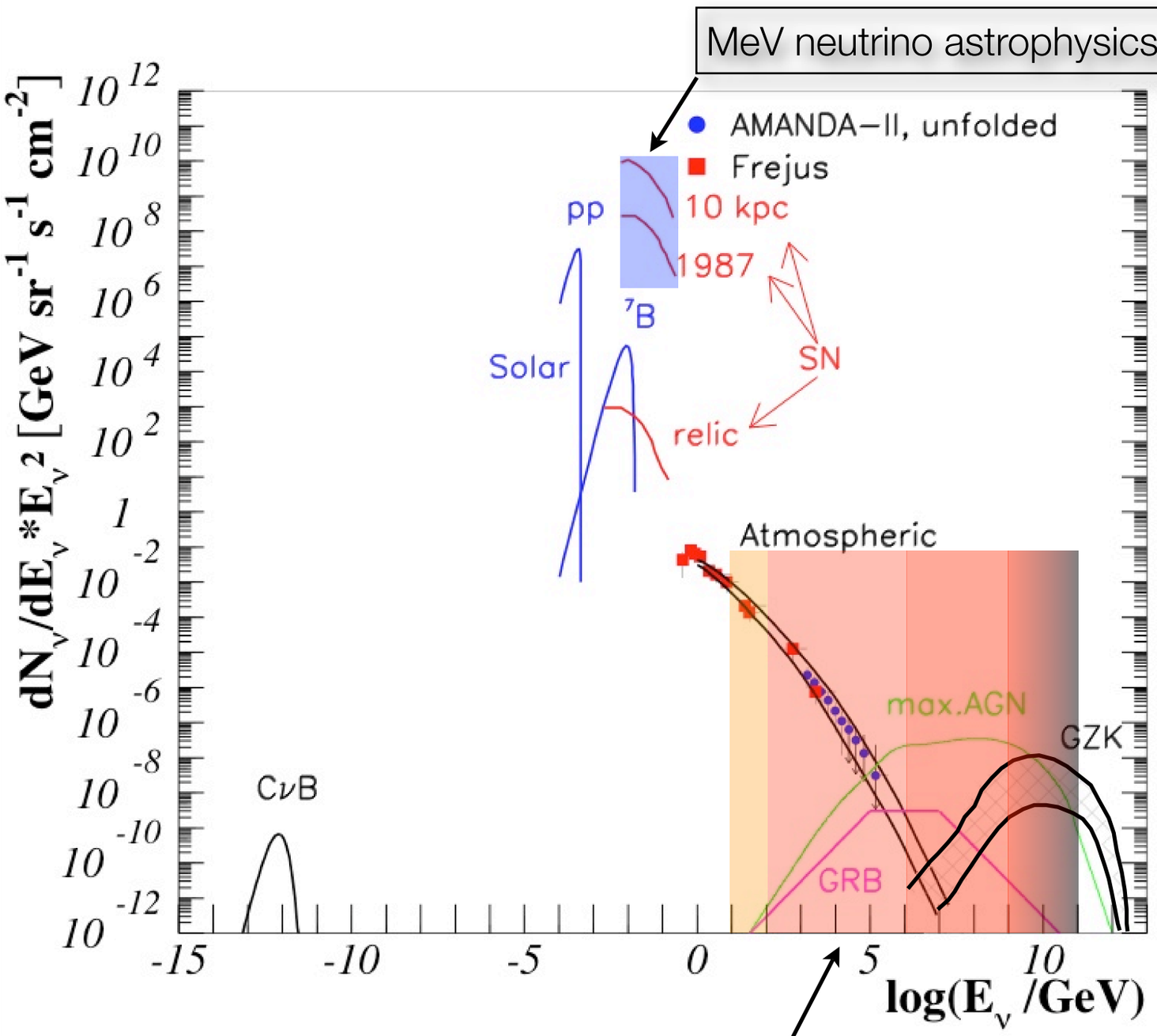
IceCube Observatory

- IceCube
  - currently 59 strings
  - 80 strings in 2011
  - 125m inter-string spacing
  - 17m DOM distance
- taking data during construction
- AMANDA decommissioned on May 11, 2009
- Deep Core currently with 1 string
- Deep Core 6 strings in 2010

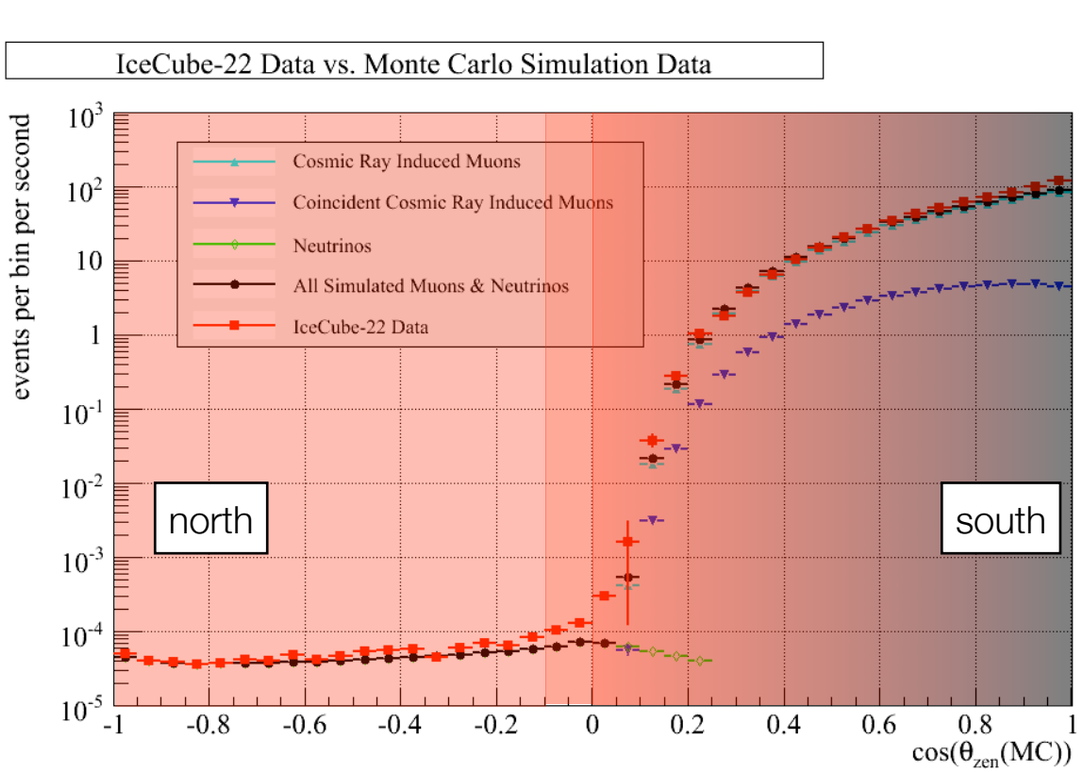



125 m

high energy neutrino astronomy



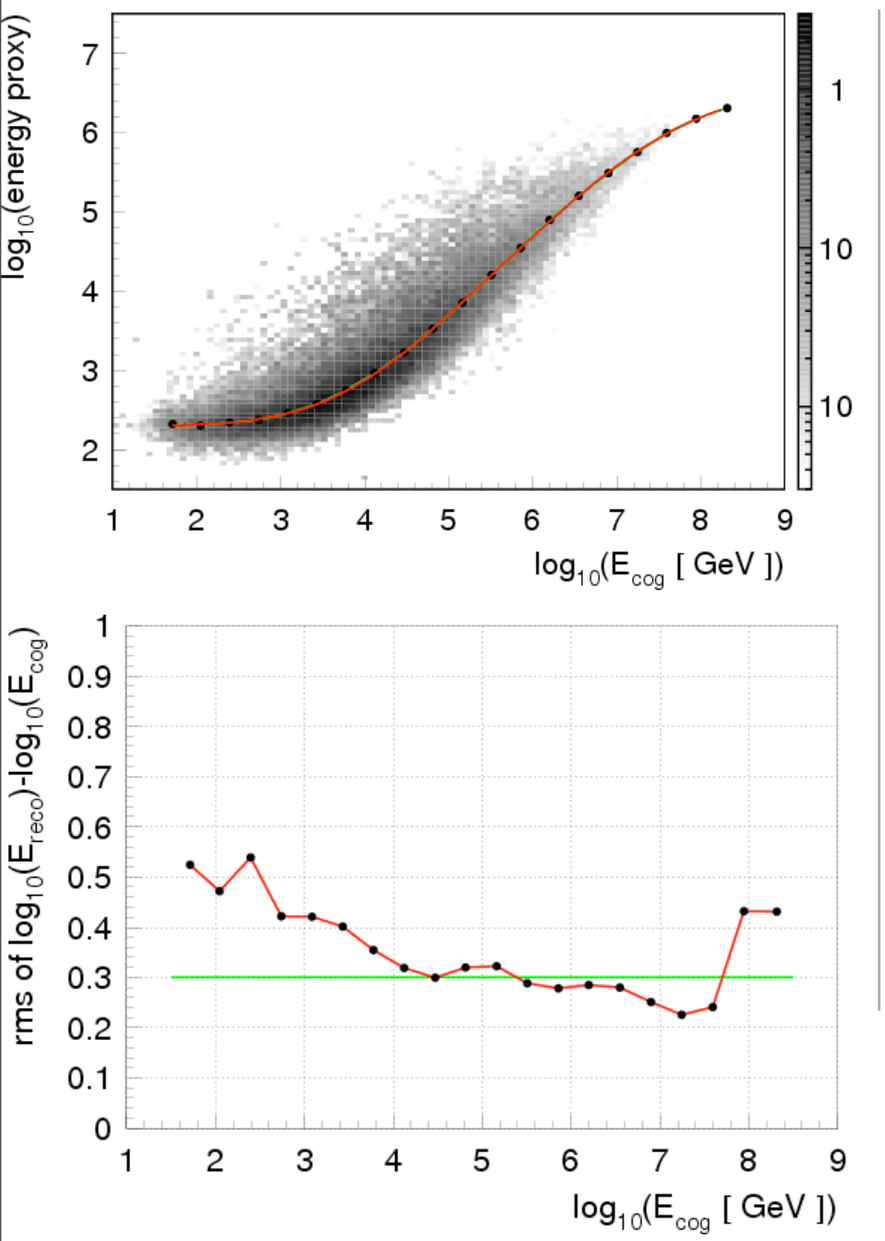
- search whole sky
- high background from south
  - high energy selection



Patrick Berghaus, Kristin Rosenau

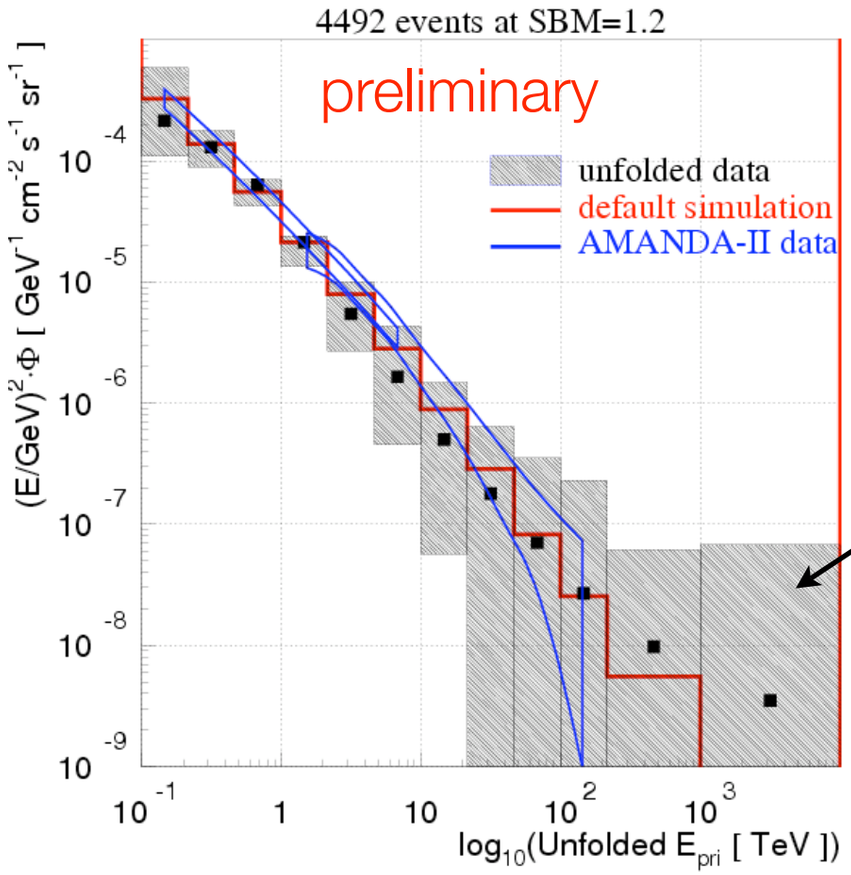
high energy neutrino astronomy

atmospheric neutrinos



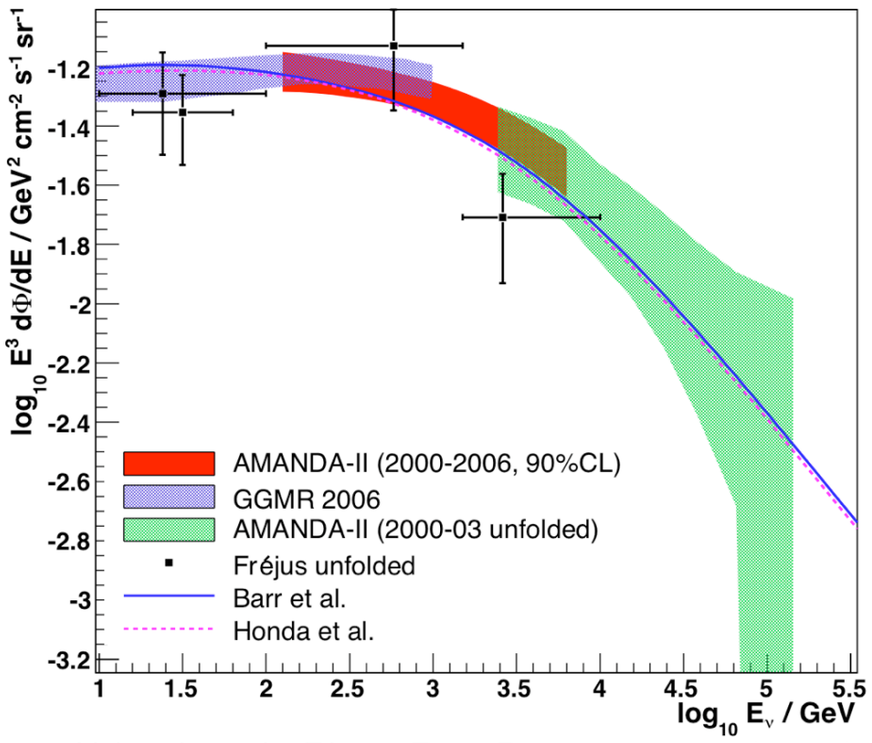
energy estimation resolution

IceCube 22 strings (2007)
unfolded atmospheric ν_μ spectrum



statistical & systematic uncertainties

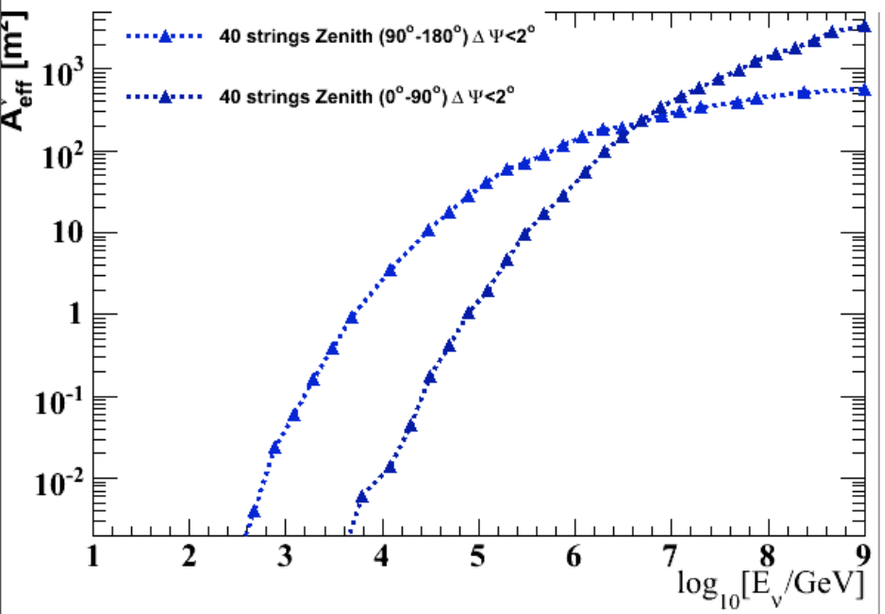
Dimitry Chirkin



Abbasi et al., Phys. Rev. D 79, 102005 (2009), arXiv:0902.0675

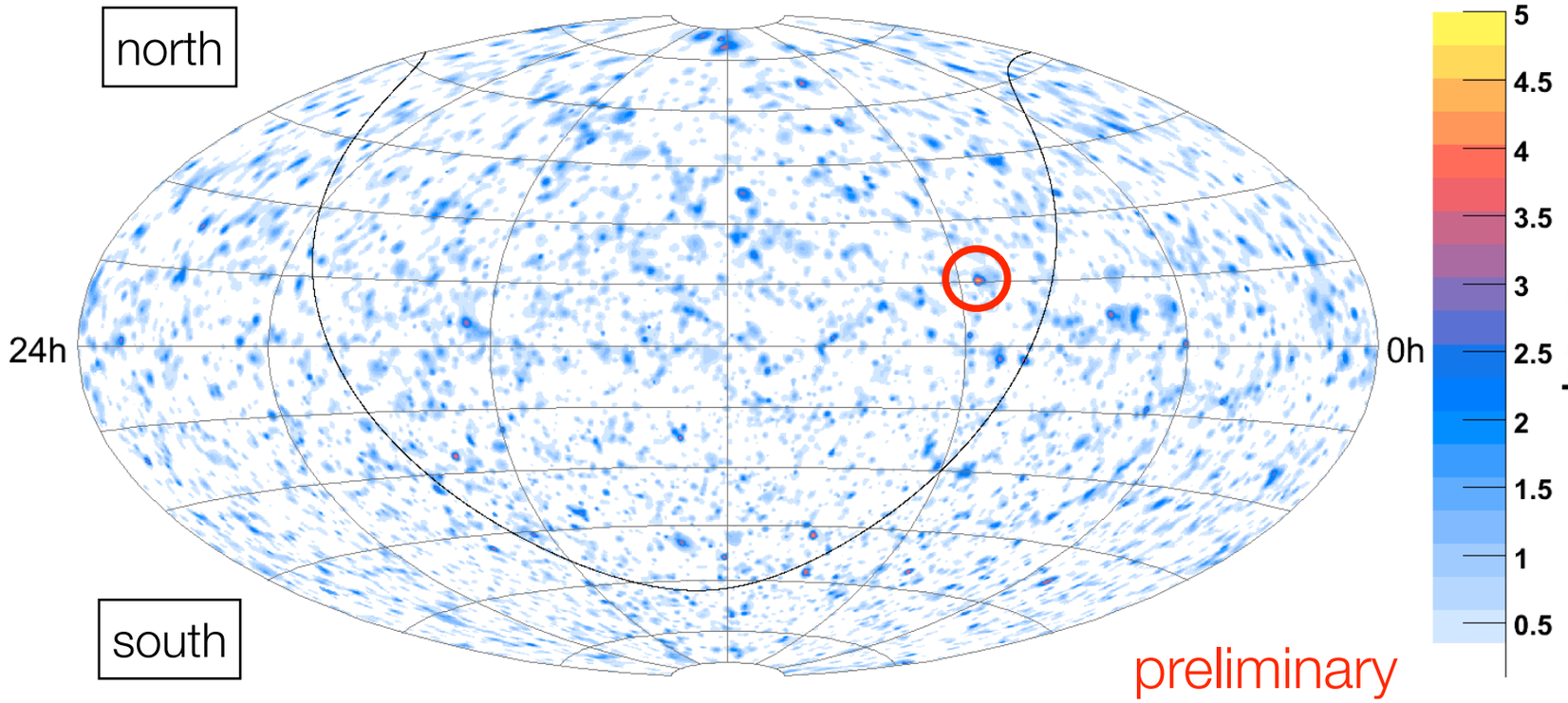
point sources

IceCube 40 strings (6 months of 2008)
search for points of HE neutrinos



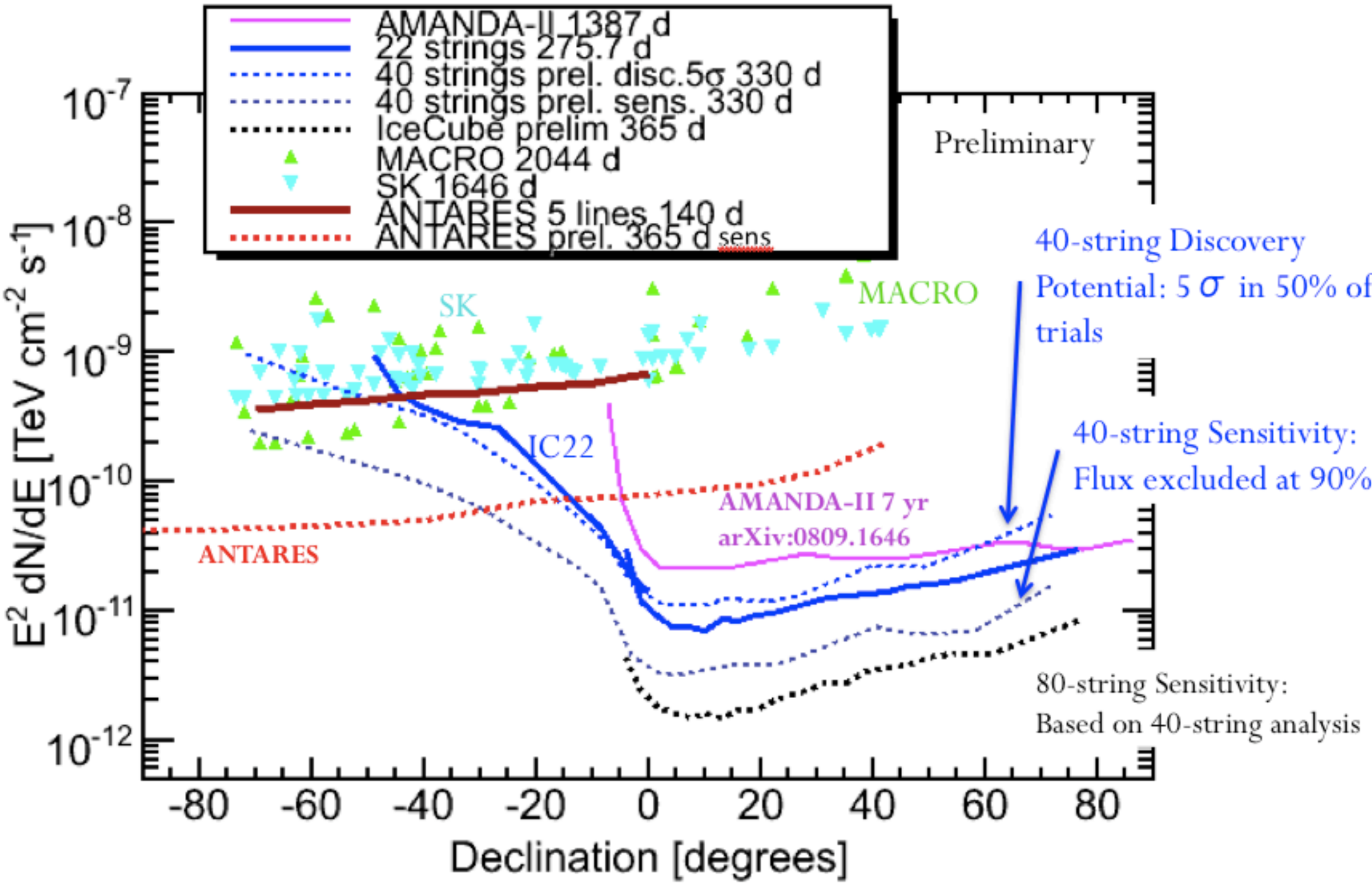
neutrino effective area

J Dumm, C Finley, T Montaruli

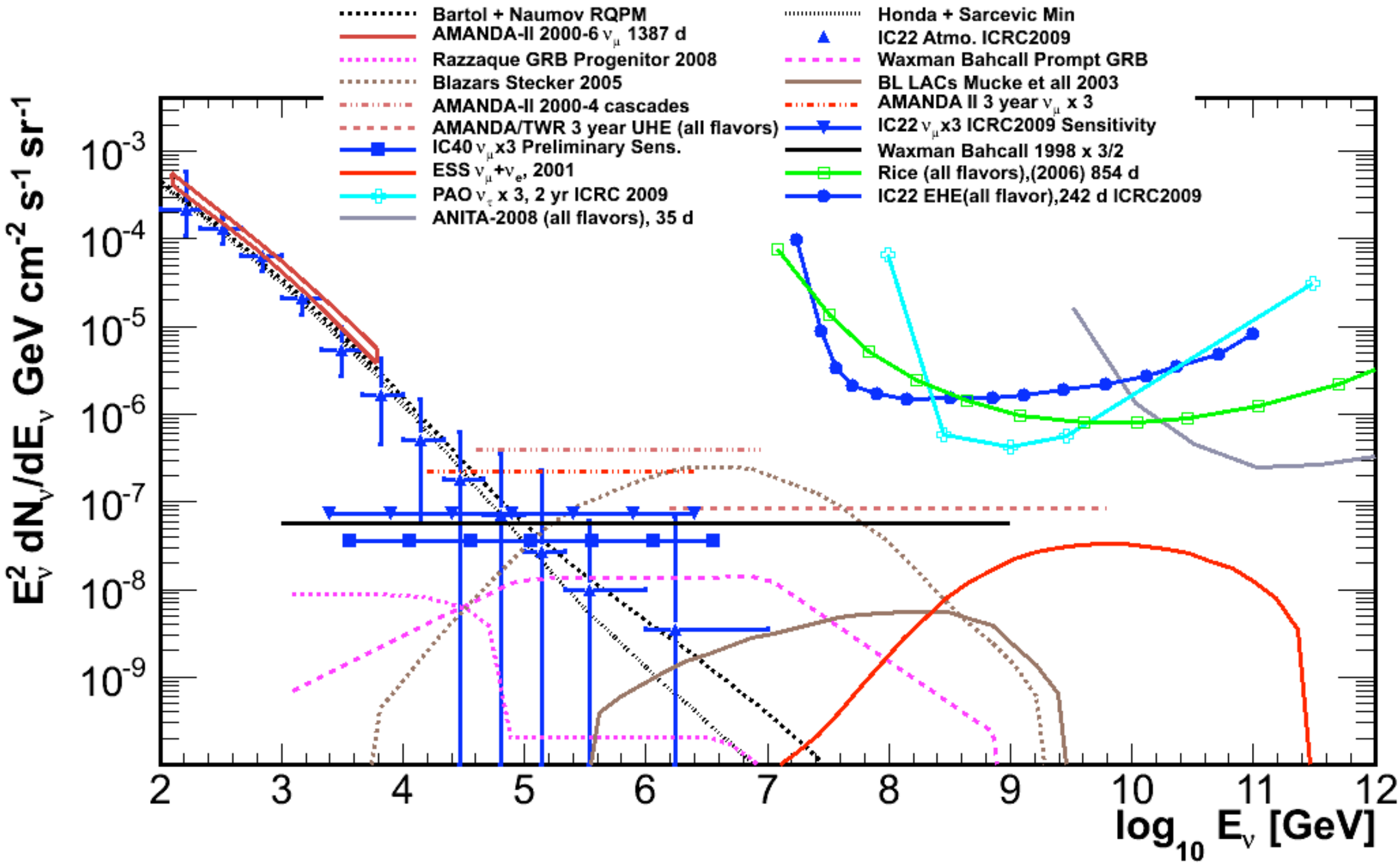


- hottest spot @ α = 114.95°
  δ = 15.35°
- pre-trial $-\log_{10}$(p-value) = 4.43
- best-fit # of source events = 7.1
- best-fit spectral index = 2.1
- all-sky p-value = 61%

- 175.5 days livetime
- northern hemisphere
  - 6,796 up-going atmospheric neutrino-induced muons
- southern hemisphere
  - 10,981 down-going high energy muons
  - 10^{-5} background rejection through energy cut ($\gtrsim$ 100 TeV)
  - $\mu_\downarrow / \mu_\uparrow \sim 10^6$



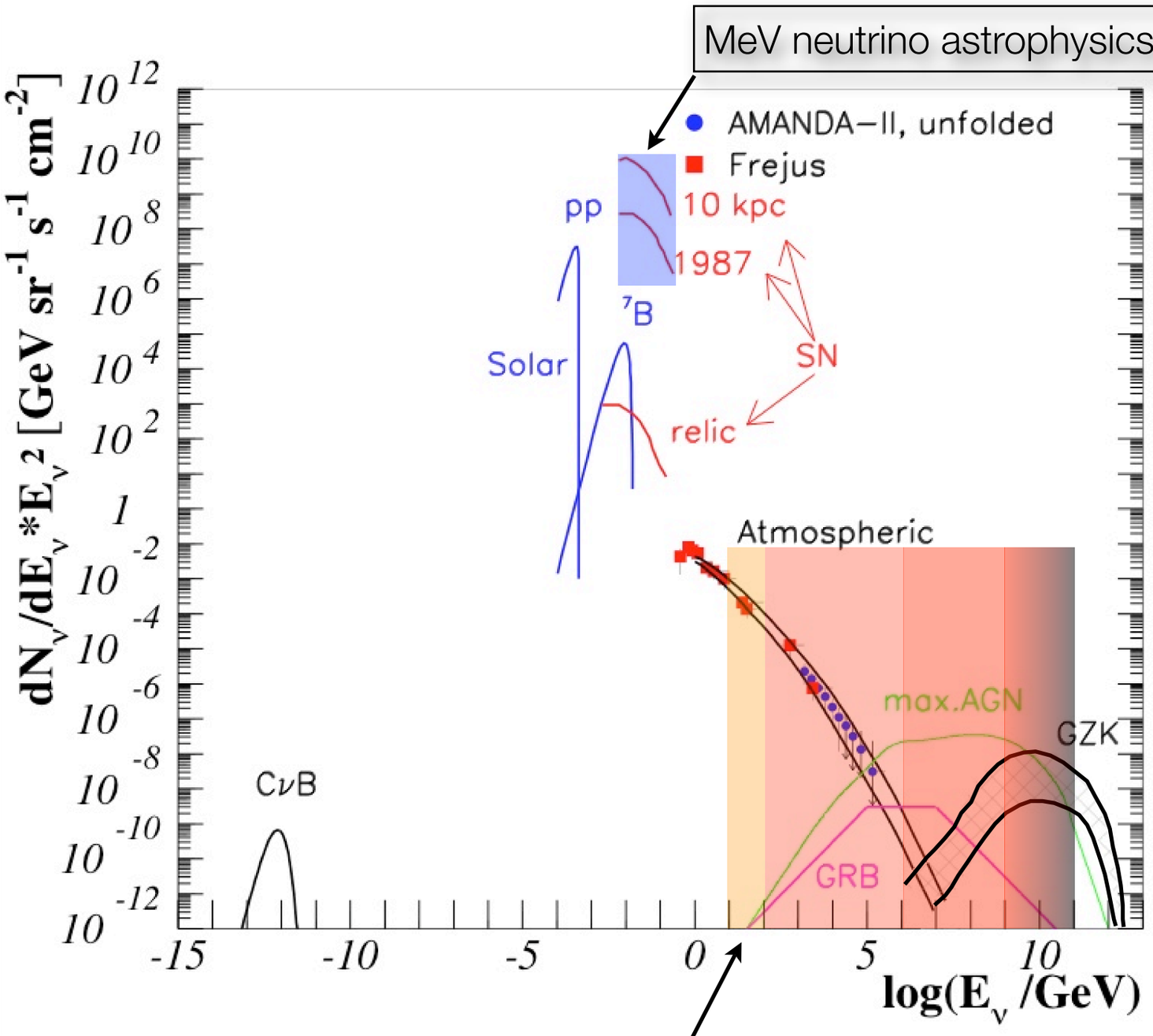
IceCube sensitivity for point source search

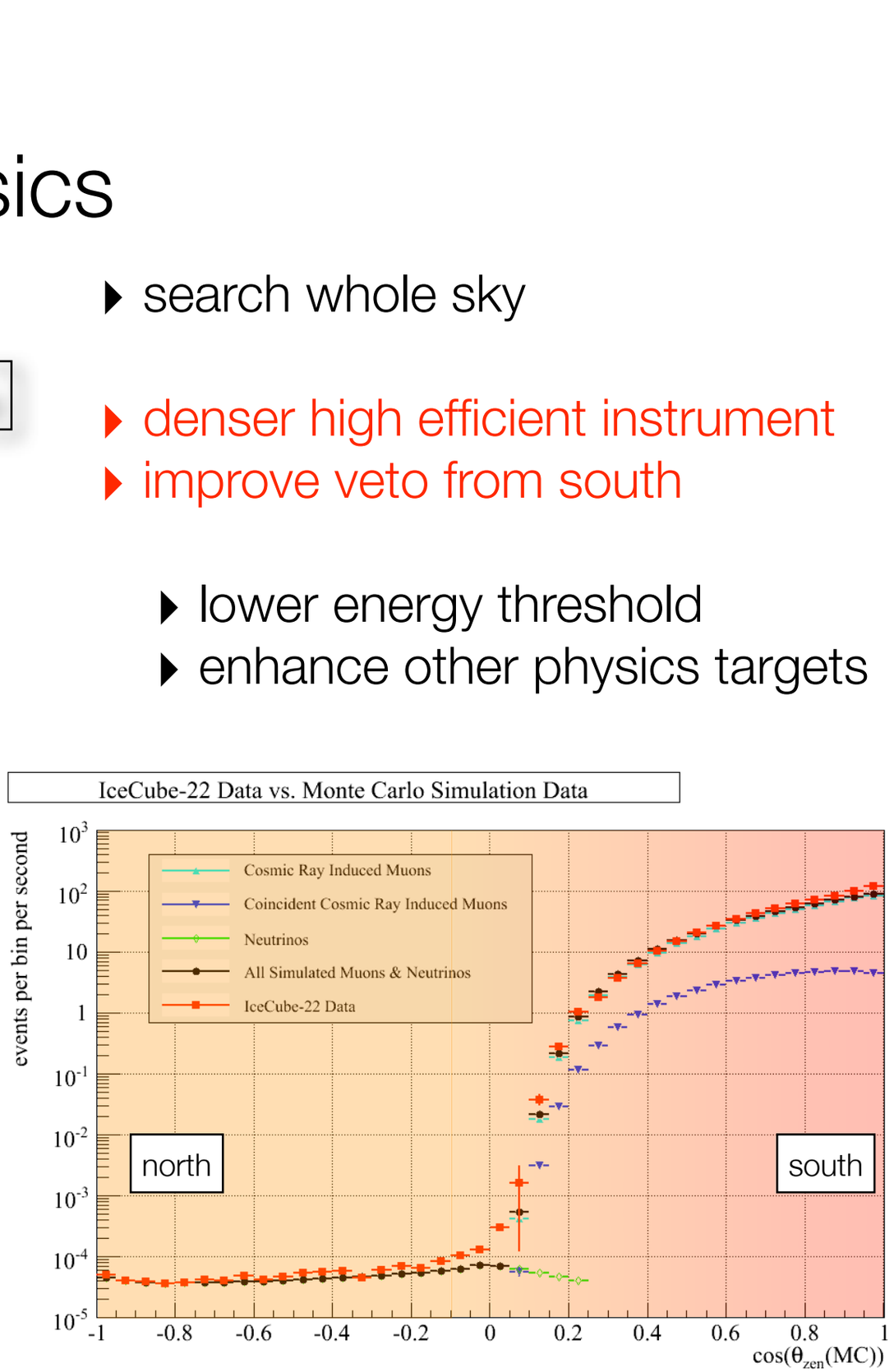


IceCube sensitivity for diffuse searches

low energy neutrino astrophysics

- search whole sky
- denser high efficient instrument
- improve veto from south
  - lower energy threshold
  - enhance other physics targets

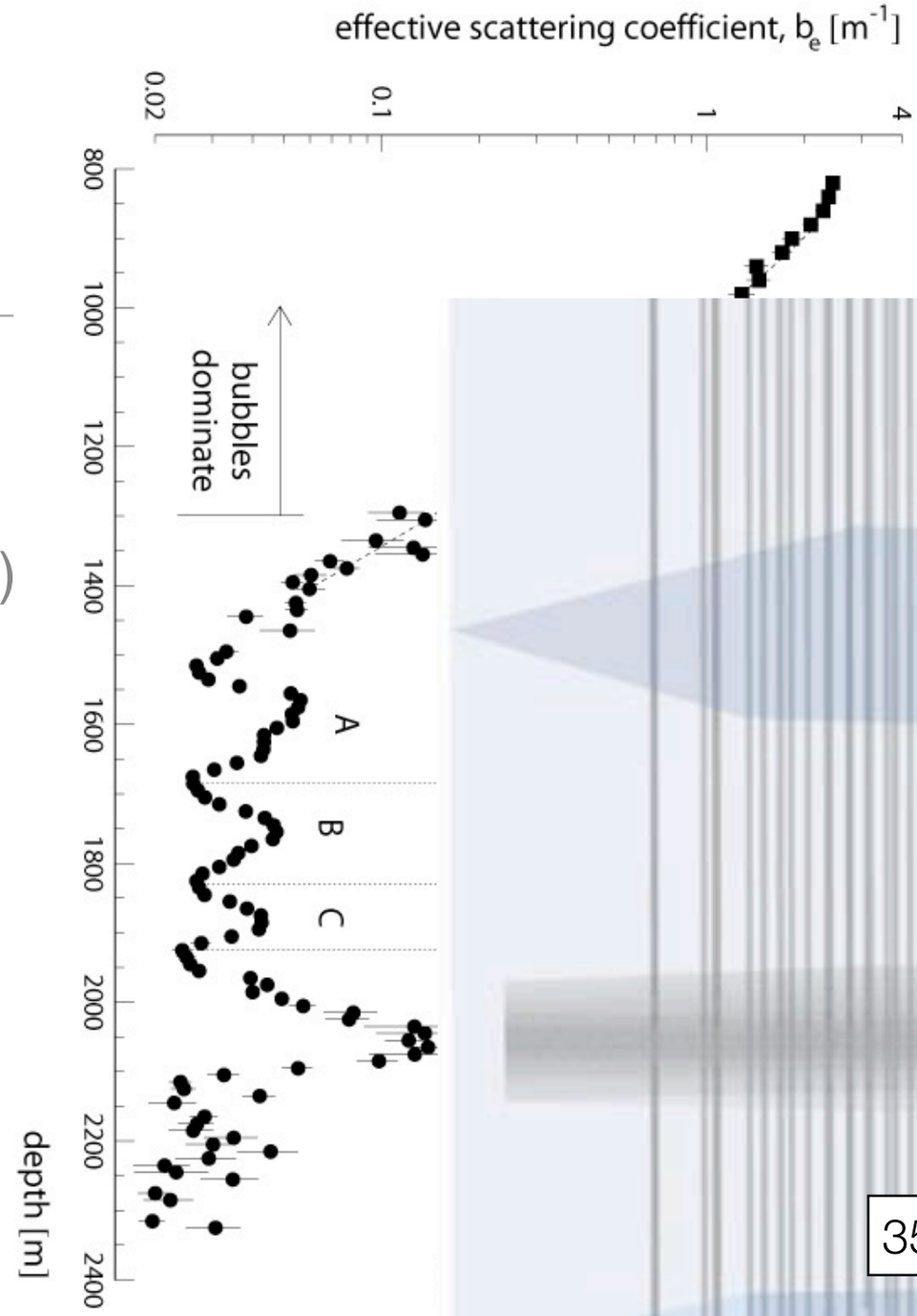




Patrick Berghaus, Kristin Rosenau

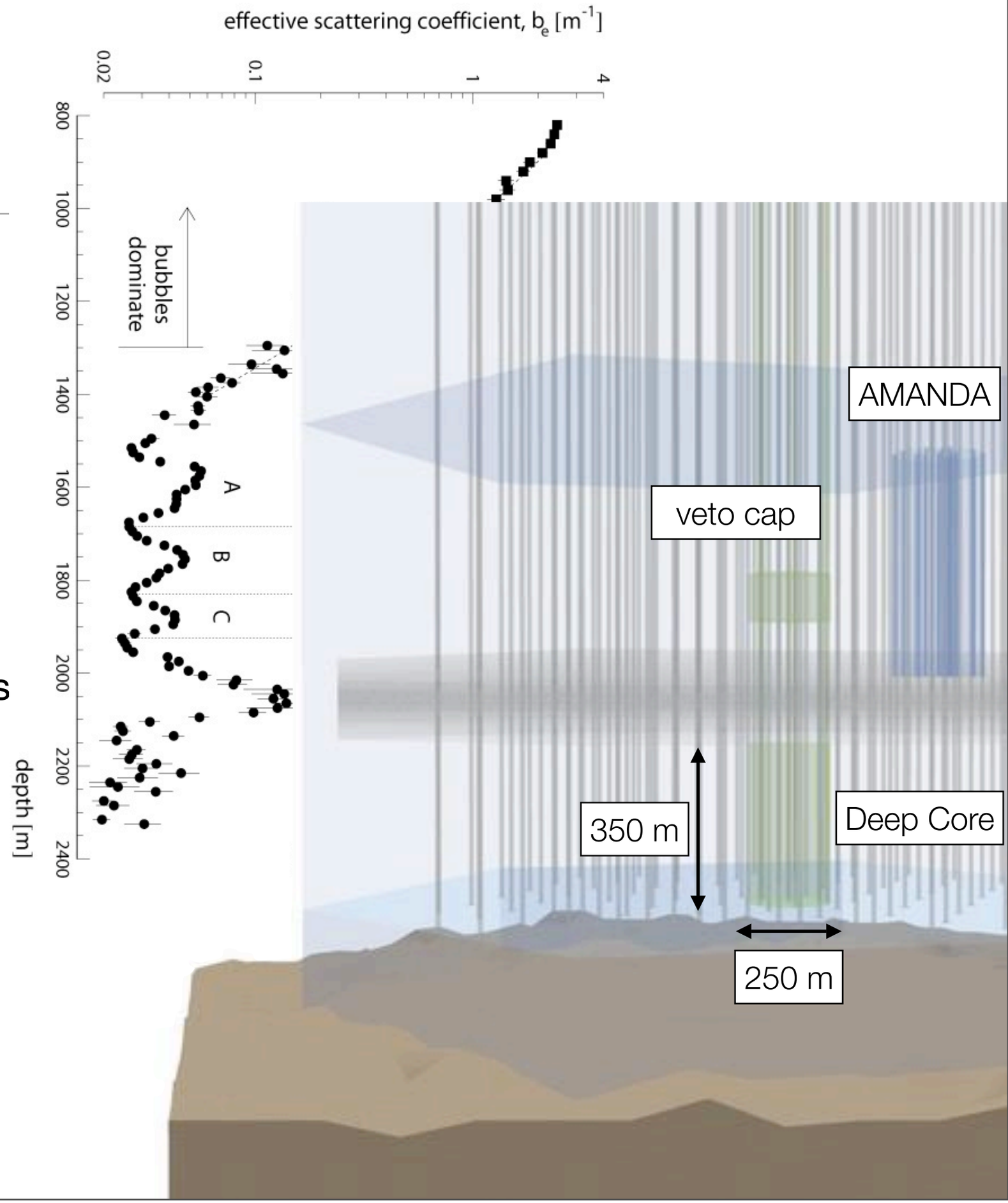
Deep Core

- 6 dedicated + 7 IceCube strings
  - 72m inter-string spacing (125m)
  - 7m DOM spacing (17m)
  - high QE PMT (38% higher)
    - ≳ 5x effective photocathode density
- IceCube as veto + veto cap
- in the clearest ice
  - λ_{atten} ~ 40-45m (cf. 20-25m in shallower ice)



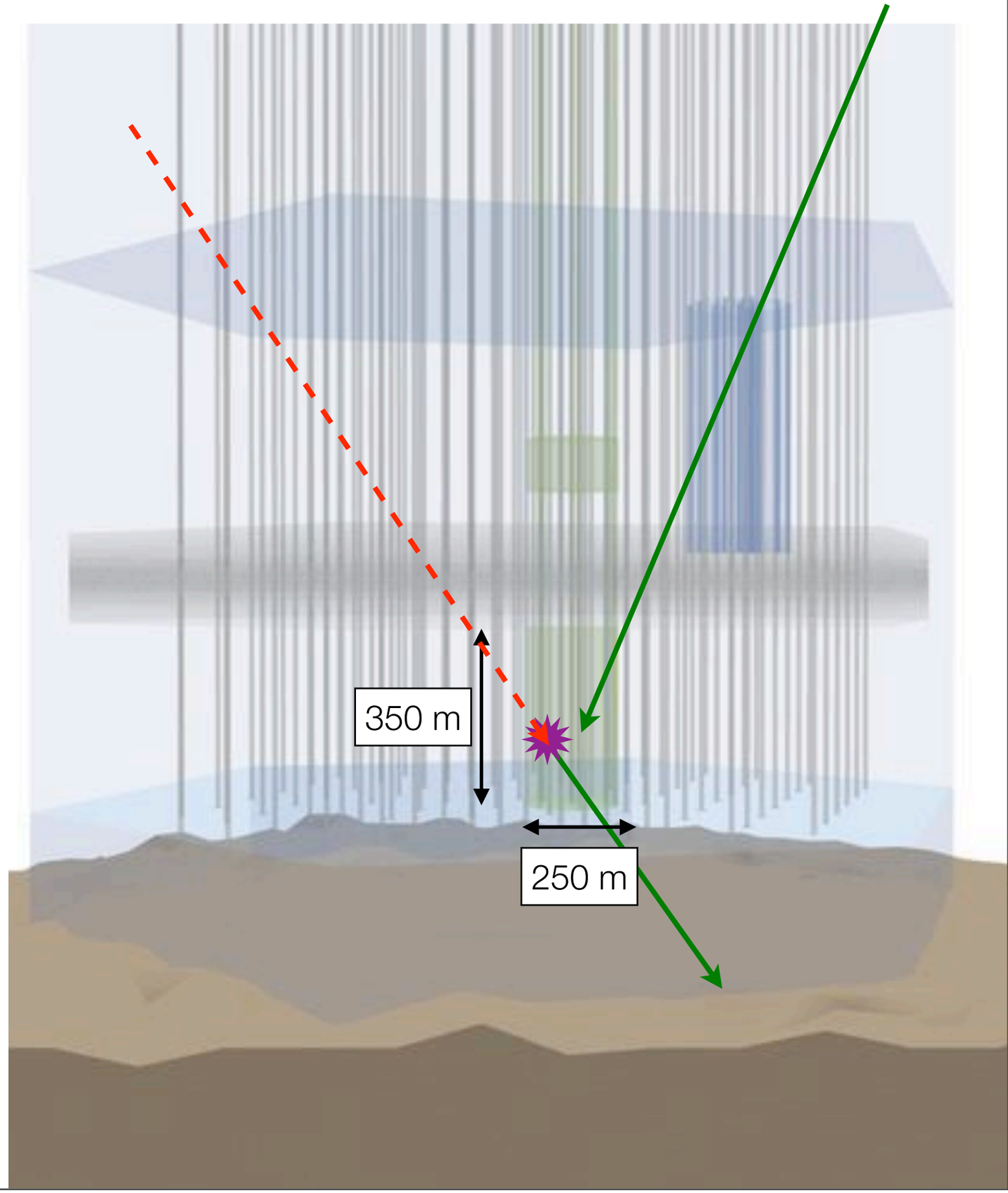
Deep Core

- augment IceCube response to LE
  - significant improvements for $E_{\nu\mu}$ ~ 10 - 300 GeV
  - extend to full sky searches
- funding: EU hardware, US logistics
- primary science goal is indirect search of dark matter
- capable of studying fundamental neutrino properties and searching for neutrino sources

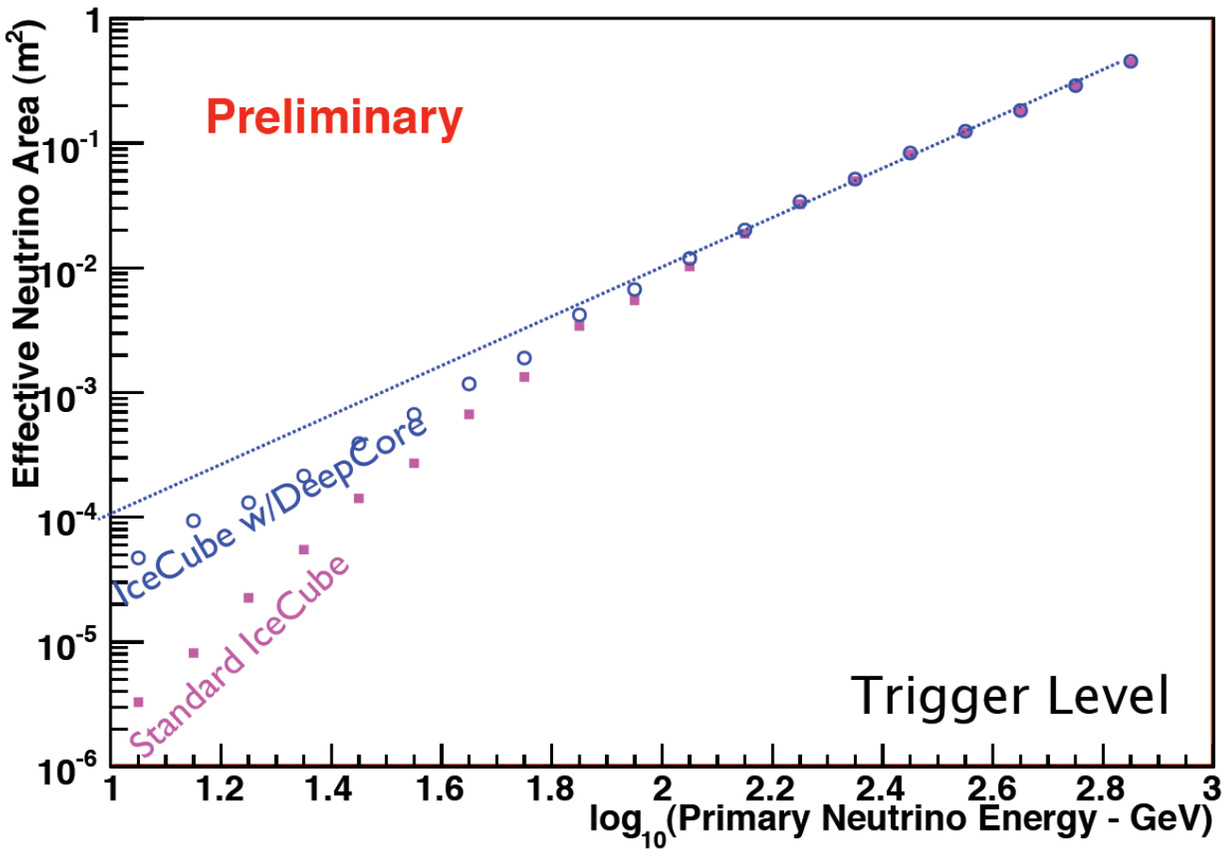


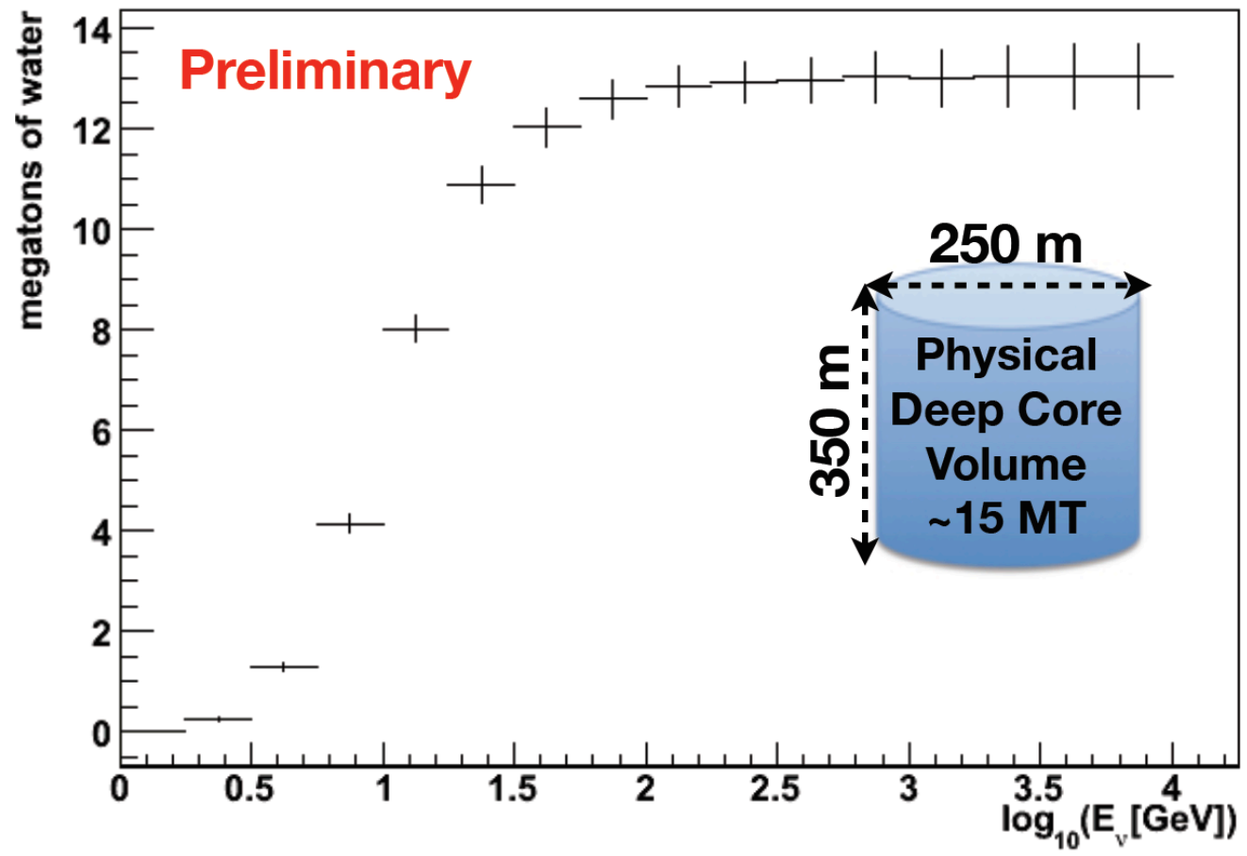
Deep Core atmospheric muon veto

- capability to detect *low energy* down-going neutrinos
  - visibility of southern hemisphere
- top/outer IceCube DOMs used to veto atmospheric muons
- identify atmospheric $\mu_{\downarrow}$ entering Deep Core
- enhance $\nu_{\downarrow}$ detection efficiency in Deep Core volume
- veto rejection $\lesssim 10^5$-10^6



Deep Core effective area & volume





- effective area for up-going ν_μ
- reconstruction efficiency not yet included
- relative improvement likely to increase

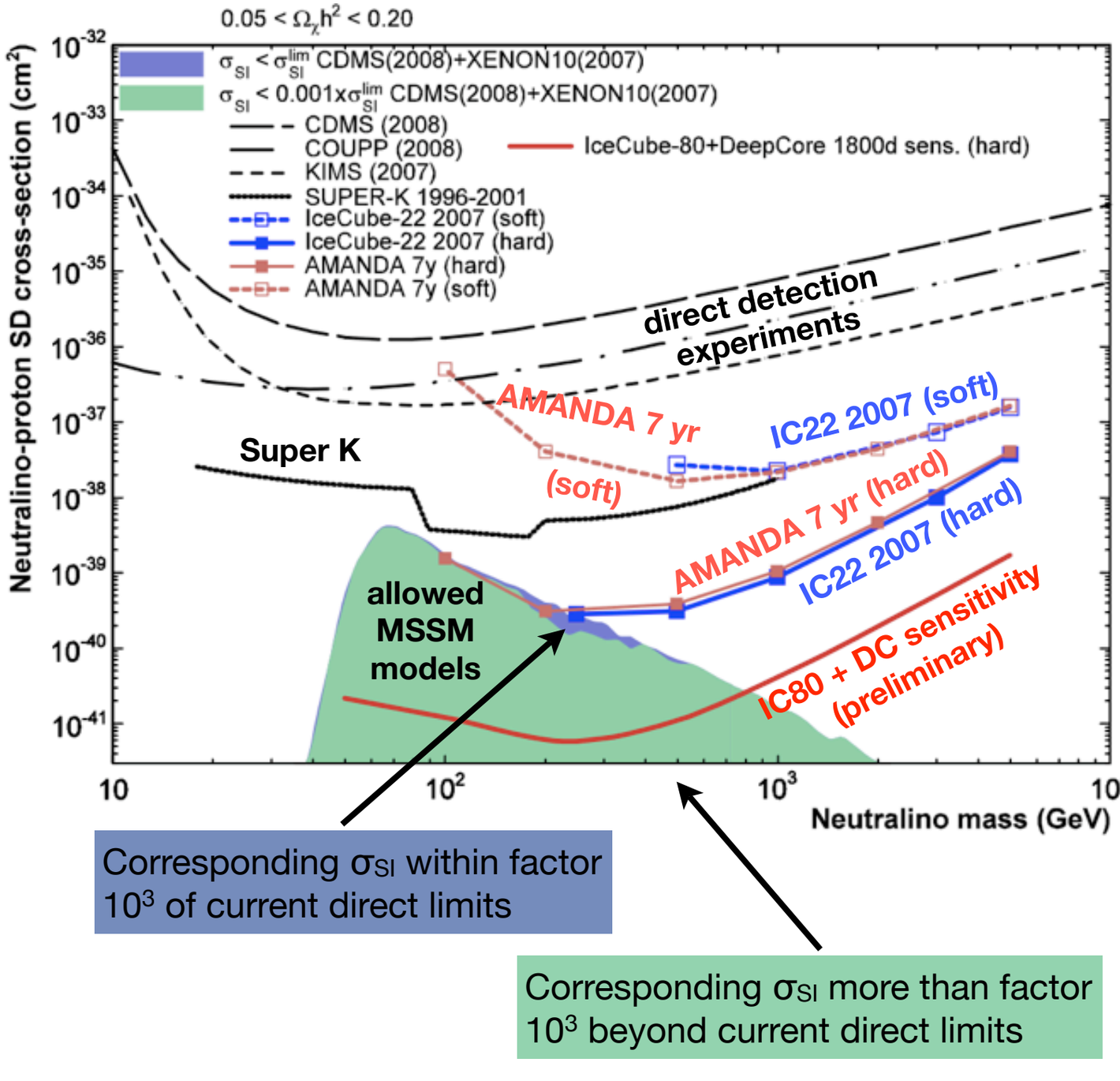
- effective volume for down-going ν_μ interacting in Deep Core
- reconstruction efficiency not yet included

indirect dark matter search : WIMP from Sun

- IceCube + Deep Core will extend sensitivity to lower energy and will probe large region of allowed phase space in the σ_{SD}

- σ_{SI} well constraint by direct detection experiments

- require models of solar DM distribution & annihilation modes : W^+W^- (hard), $b\bar{b}$ (soft)

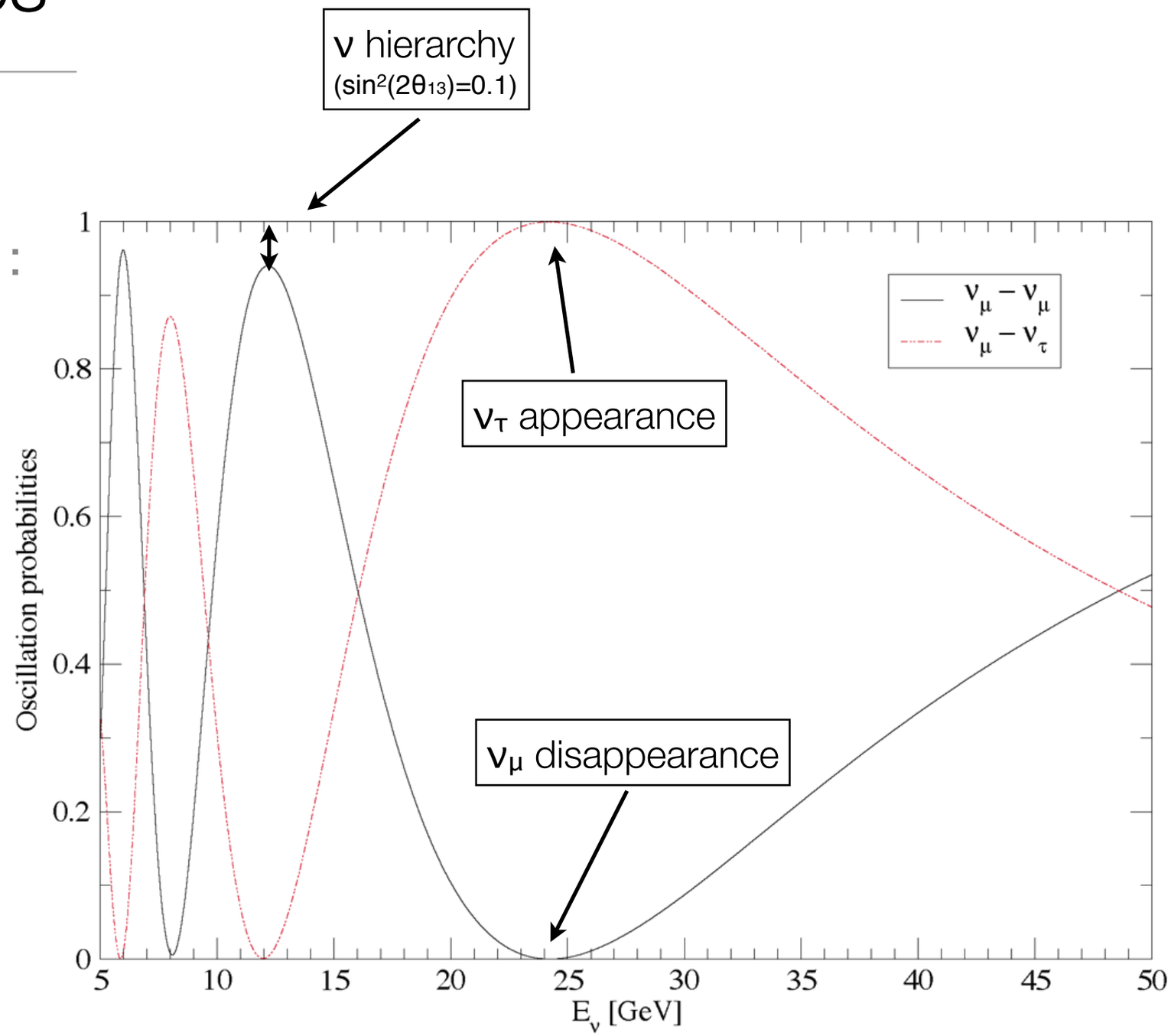


Corresponding σ_{SI} within factor 10^3 of current direct limits

Corresponding σ_{SI} more than factor 10^3 beyond current direct limits

Deep Core : fundamental physics

- muon neutrino disappearance : feasable
- tau neutrino appearance : reasonable
- neutrino mass hierarchy : difficult

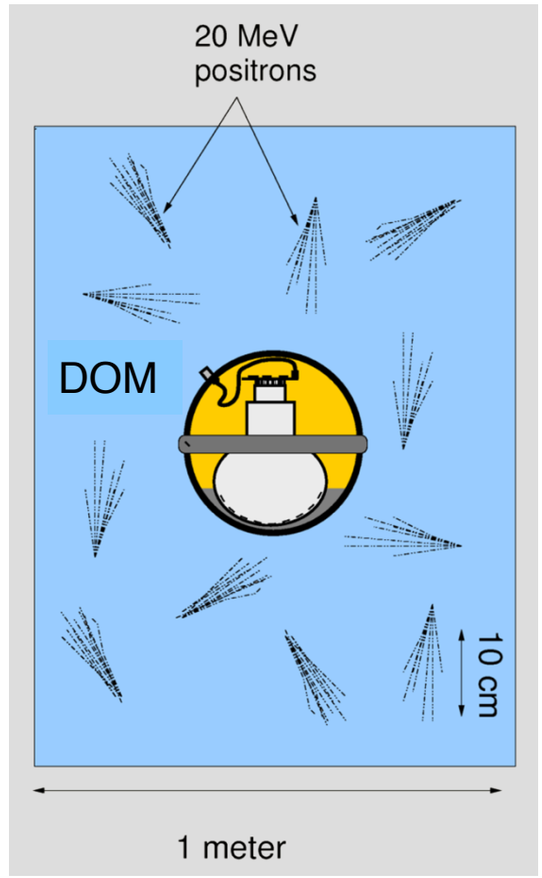


for vertically up-going neutrinos

baseline = Earth's diameter

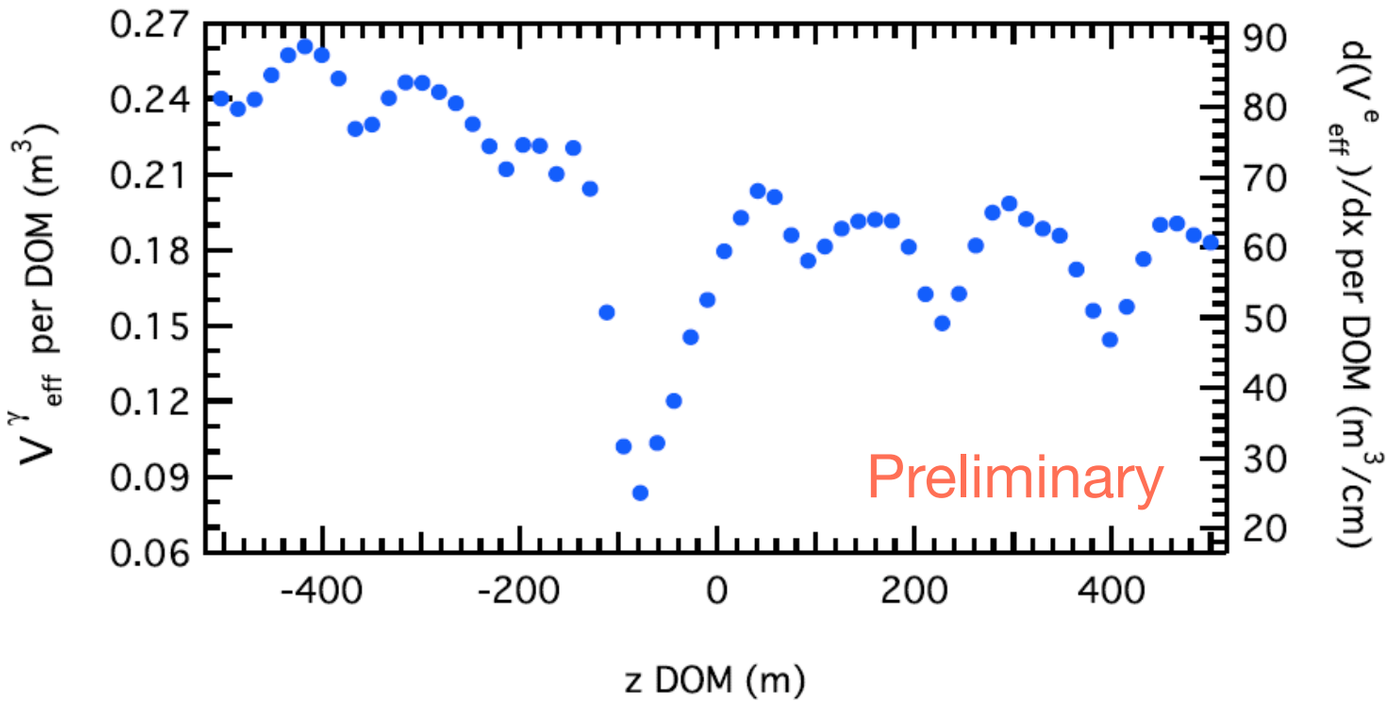
IceCube as supernova detector

- low energy ν_e illuminate the ice
  - 500,000+ hits/15sec for SN1987A-like event at 10 kpc
  - main detection : $\overline{\nu}_e p \rightarrow n e^+$



effective volume/DOM
depends on ice properties

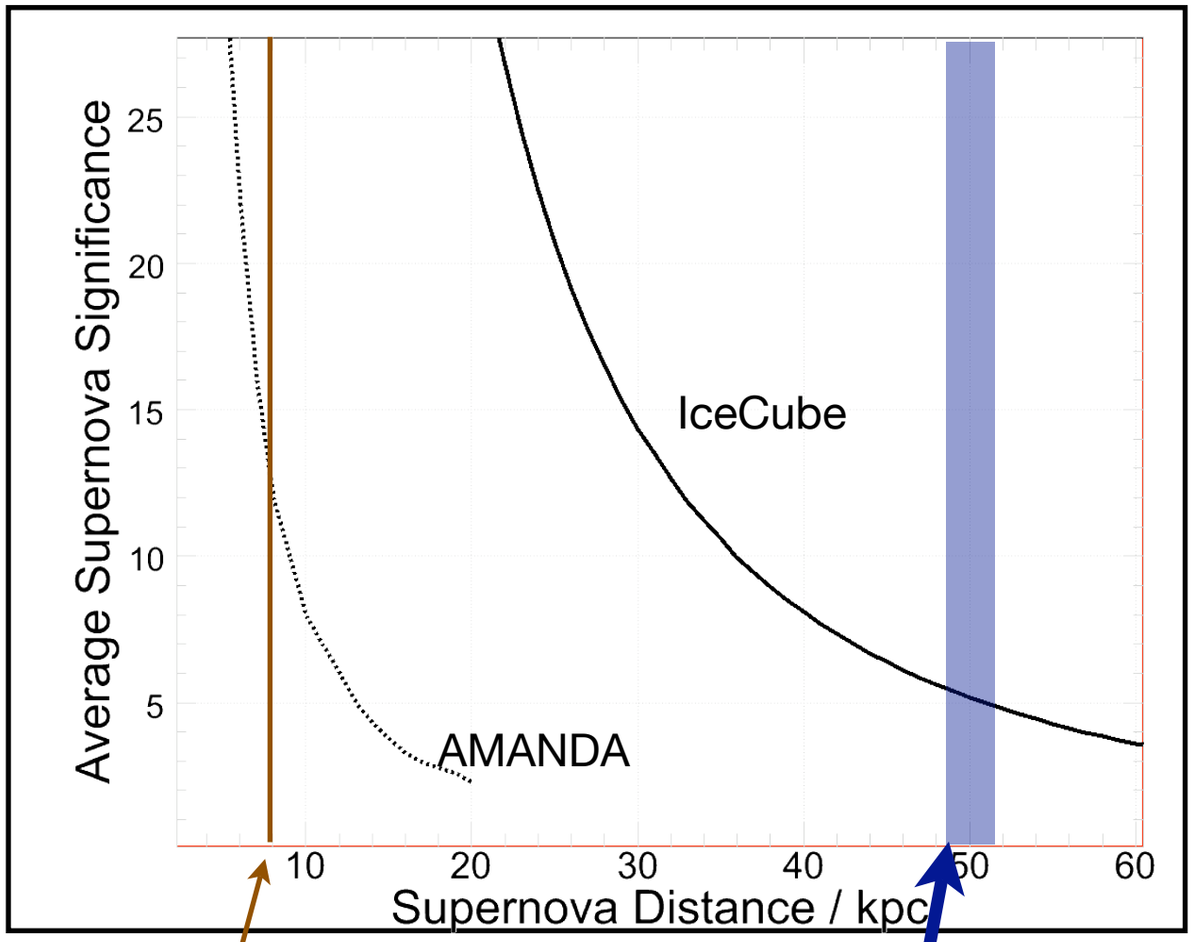
- high statistics (0.25%)
- low noise rate (280 Hz)
- no pointing
- no event-by-event detection

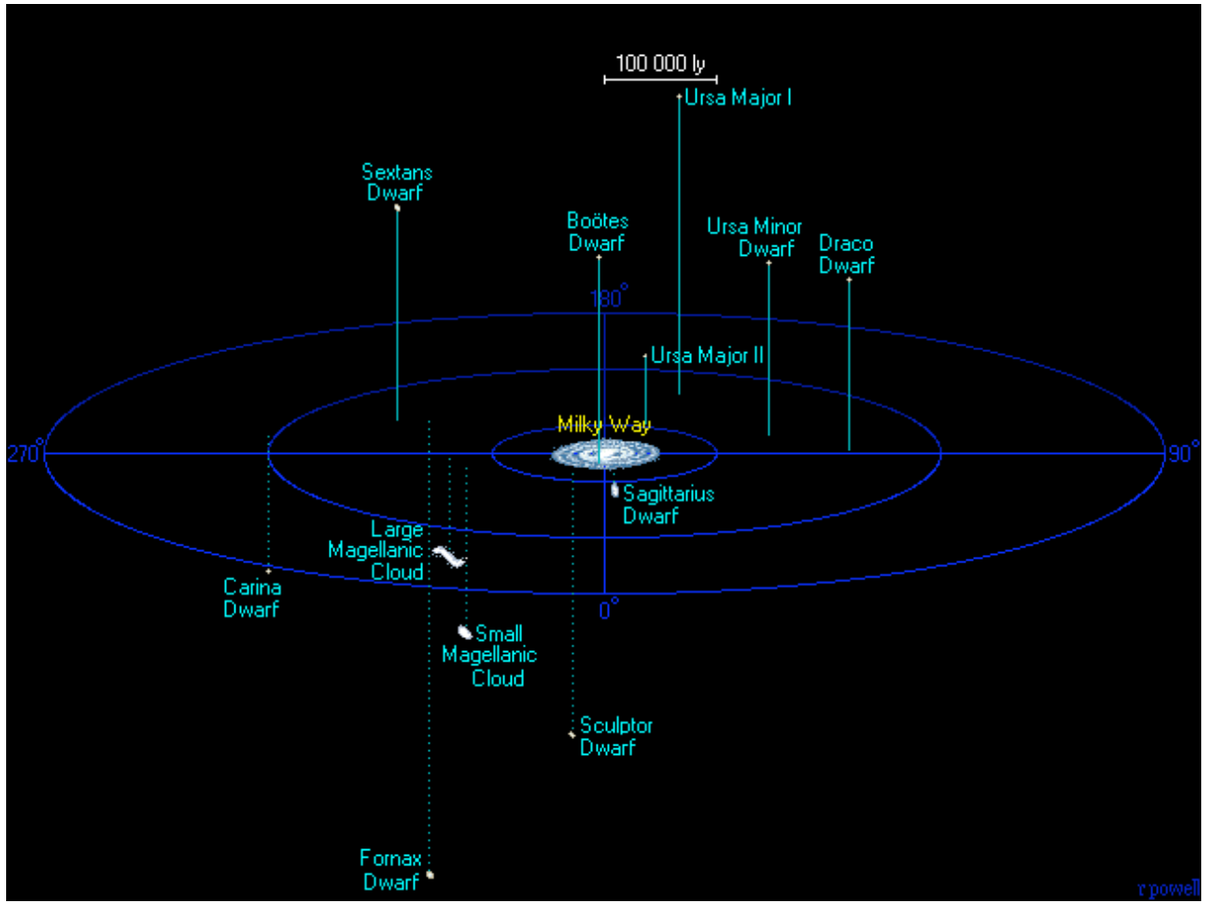


IceCube is a 2.5 Mton detector
for e^+ for 15 MeV $\overline{\nu}_e$

…first proposed by Halzen, Jacobsen & Zas, astro-ph/9512080

IceCube as supernova detector





center of Milky Way

5σ signal for SN1987A strength

sending alerts to SNEWS

summary

- construction of IceCube proceeds : 59 (2009), 77 (2010), 80 (2011) strings
  - collect & analyze data during construction : reliable and stable
- low energy extension Deep Core : 1 (2009), 6 (2010) strings
  - ~10 - 300 GeV
- IceCube to detect MeV neutrinos from stellar collapse : 2.5 Mton detector + significant incease from Deep Core high sensitivity PMTs
  - 5σ sens. @50 kPc
- IceCube to address topics of ν astrophysics and connection to the origin of cosmic rays, large scale anisotropy of GCR

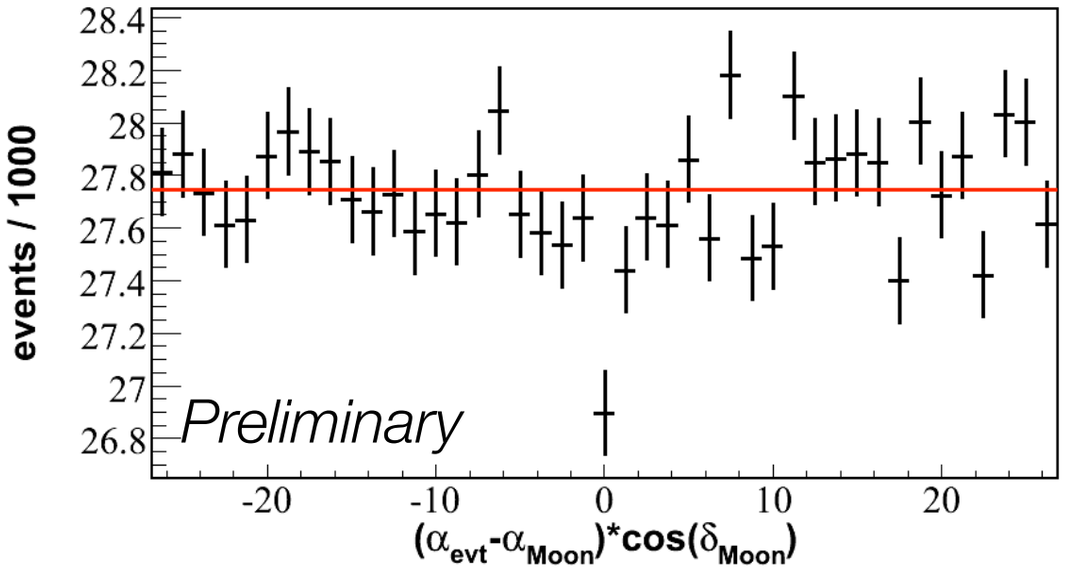
spare slides

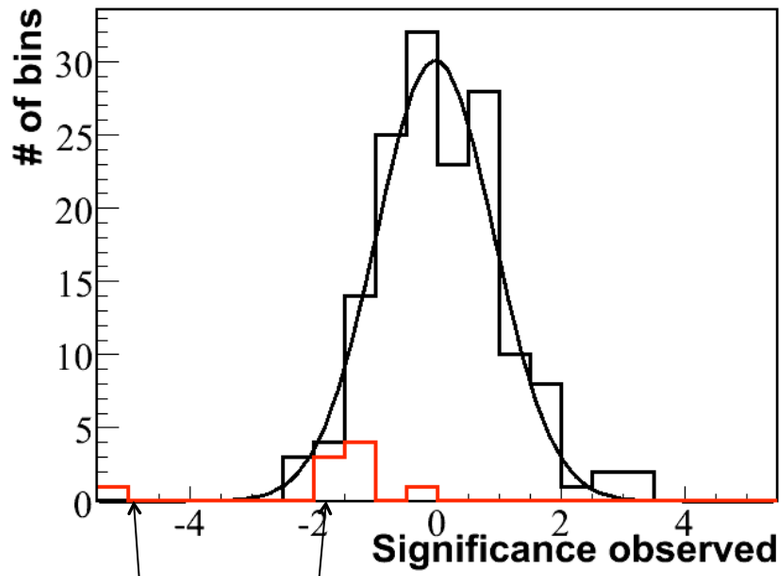
growing IceCube

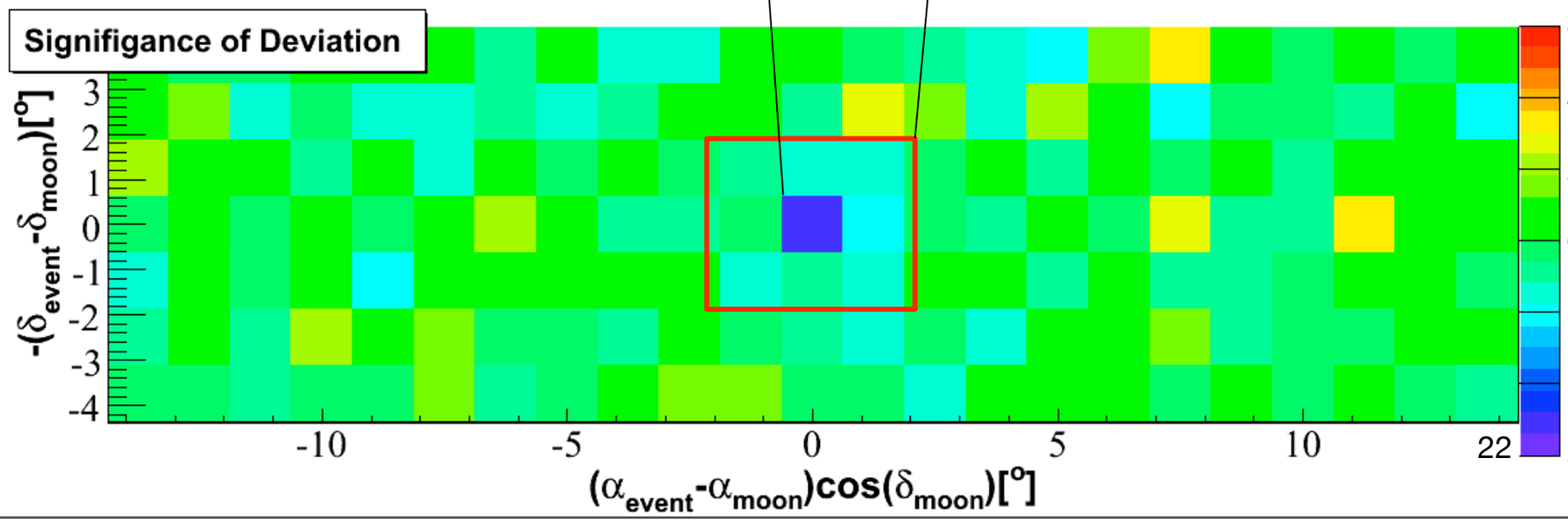
Strings	Year	Livetime	μ rate	ν rate
IC9	2006	137 days	80 Hz	1.7 / day
IC22	2007	275 days	550 Hz	28 / day
IC40	2008	~365 days	1000 Hz	110 / day
IC59	2009	~365 days	1500 Hz	160 / day
IC86*	2011	~365 days	1650 Hz	220 / day

Moon shadow

- 5 months of IC40
- Moon max. altitude at the South Pole (2008): 28°
- Median primary cosmic ray energy: 30TeV
- Deficit: 5 σ (~900 events of ~28000) - consistent with expectation.
- Verification of angular resolution and absolute pointing.
- More statistics will allow study of angular response function

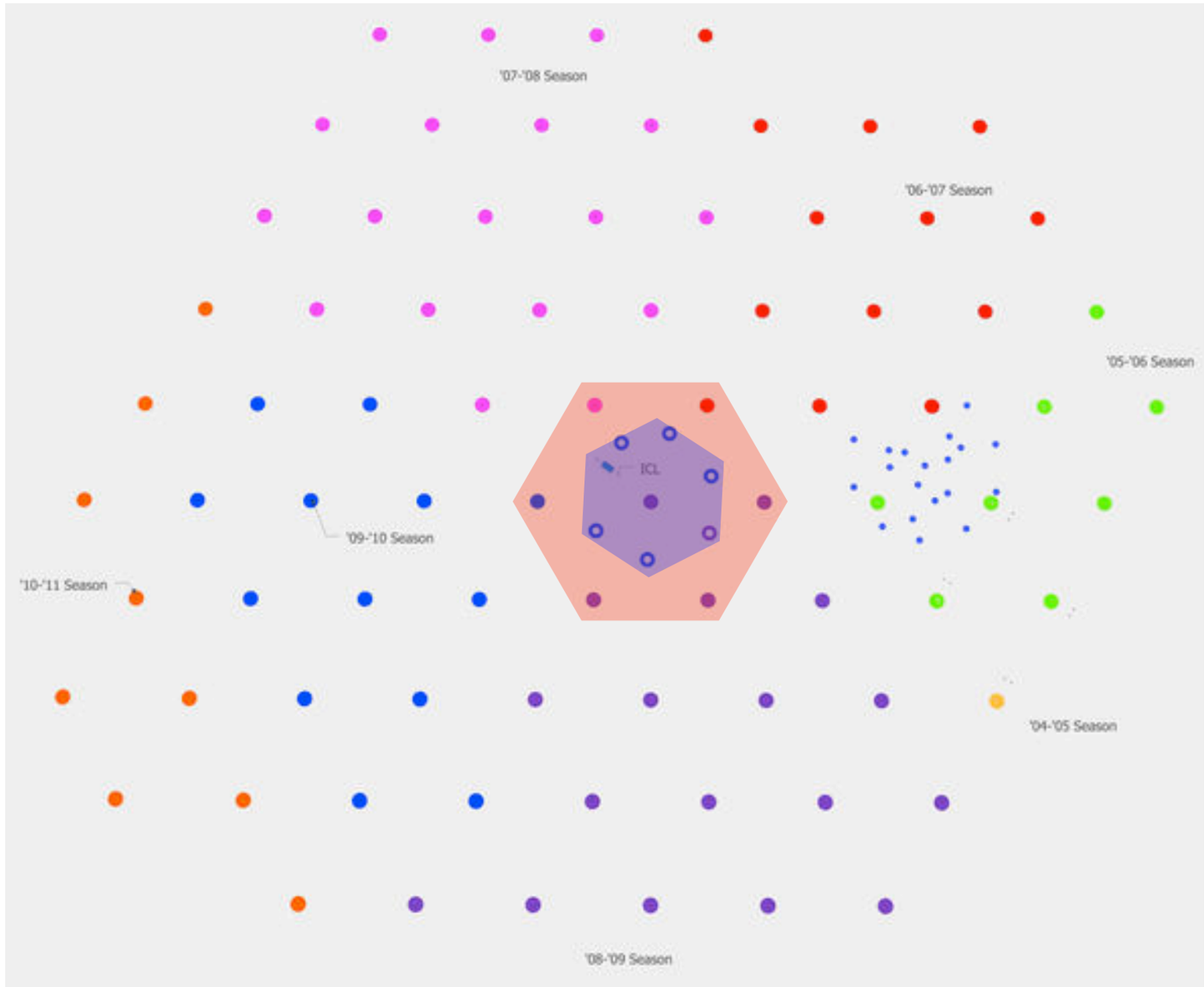




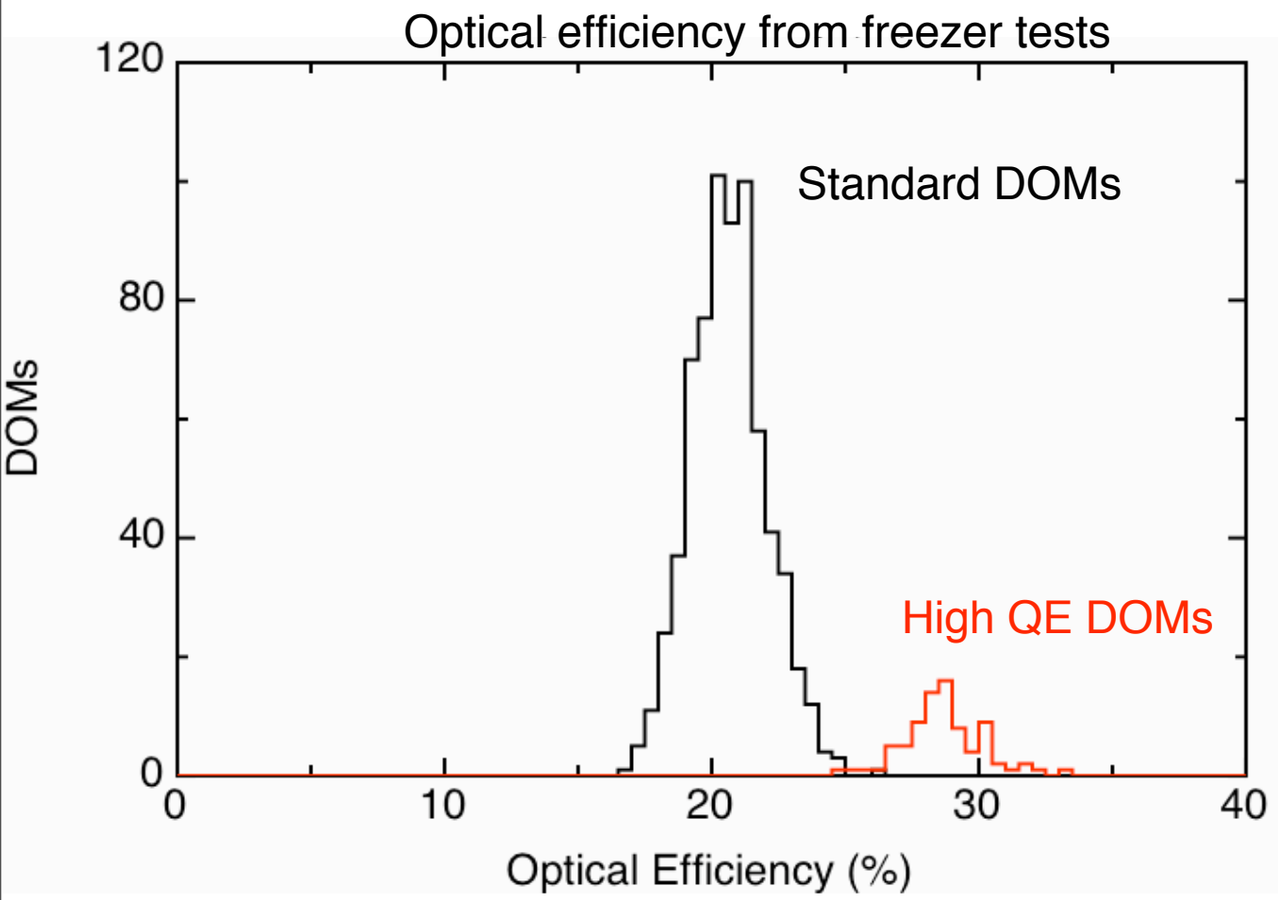


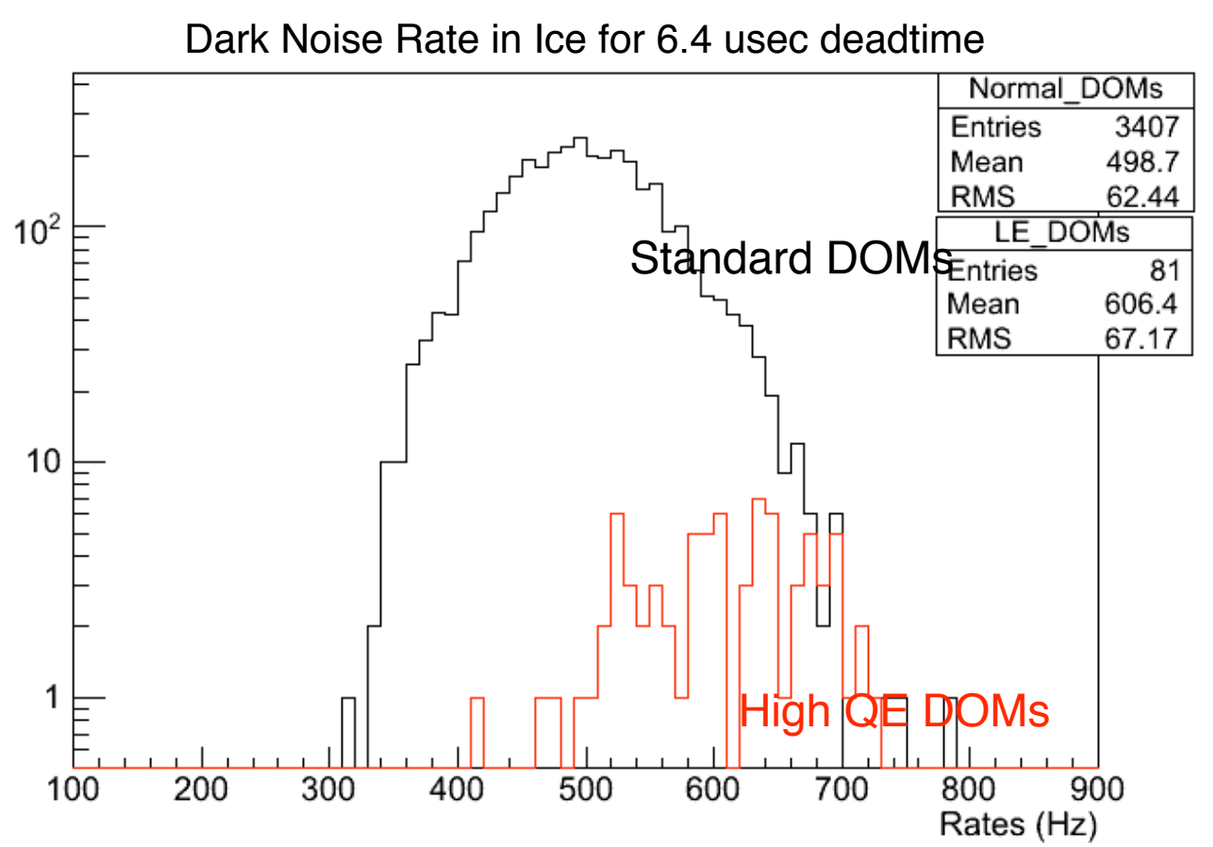
Deep Core from above

- 6 strings with hi QE PMT
  - 60 DOMs/string
- 7 surrounding IceCube strings
  - 22 DOMs in DC range



Deep Core PMT's

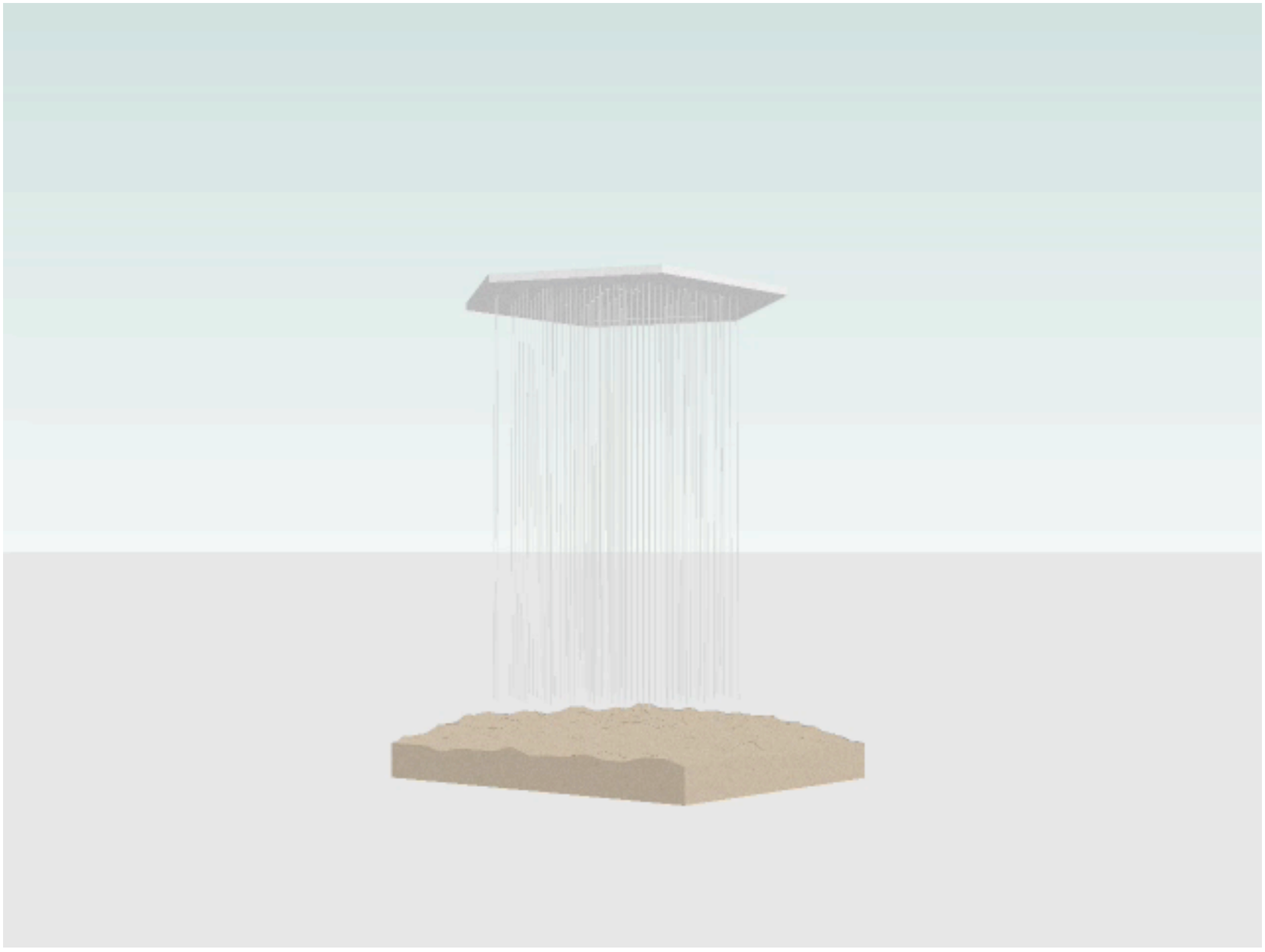




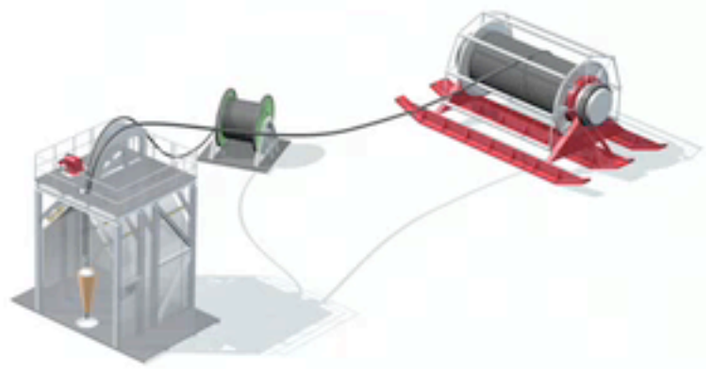
- quantum efficiency ~38% higher (405 nm, -40C), ~ 30% higher noise rate in ice.

- low temperature (-40°C) noise behavior scales with quantum efficiency as expected.

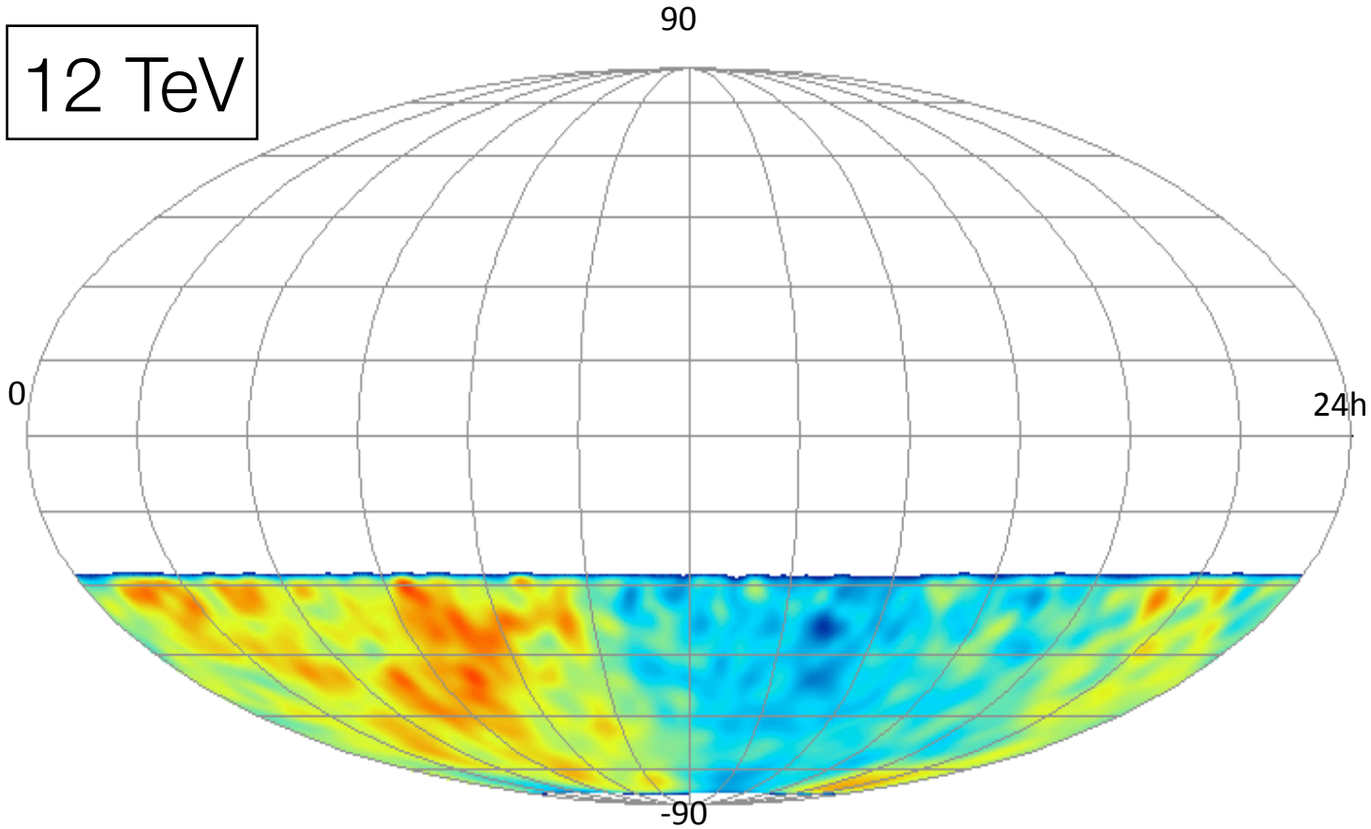
Deep Core (animation)

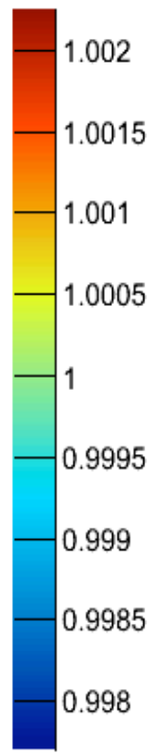


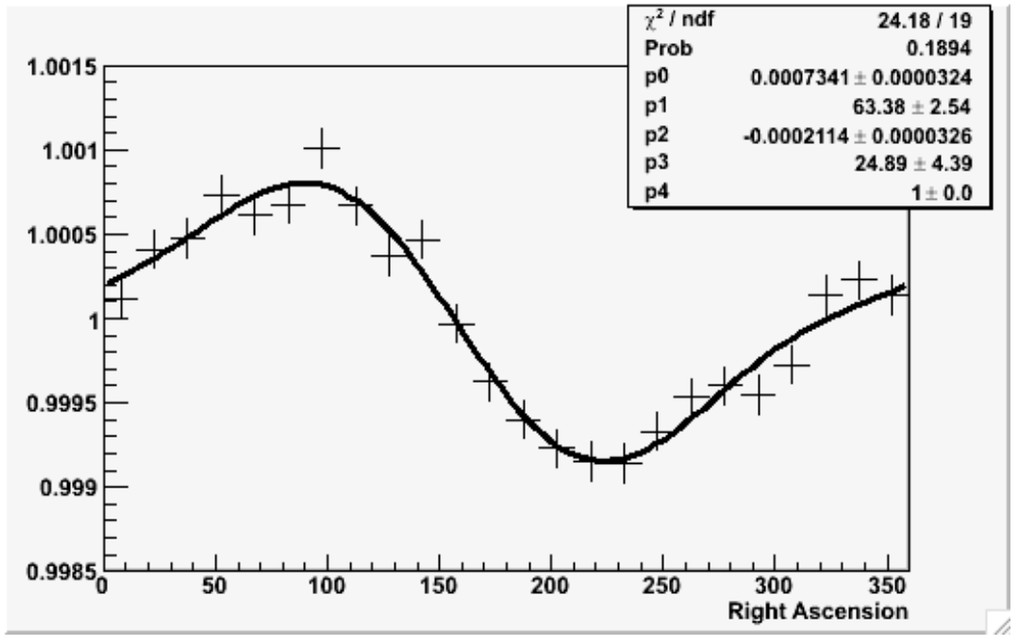
drill (animation)



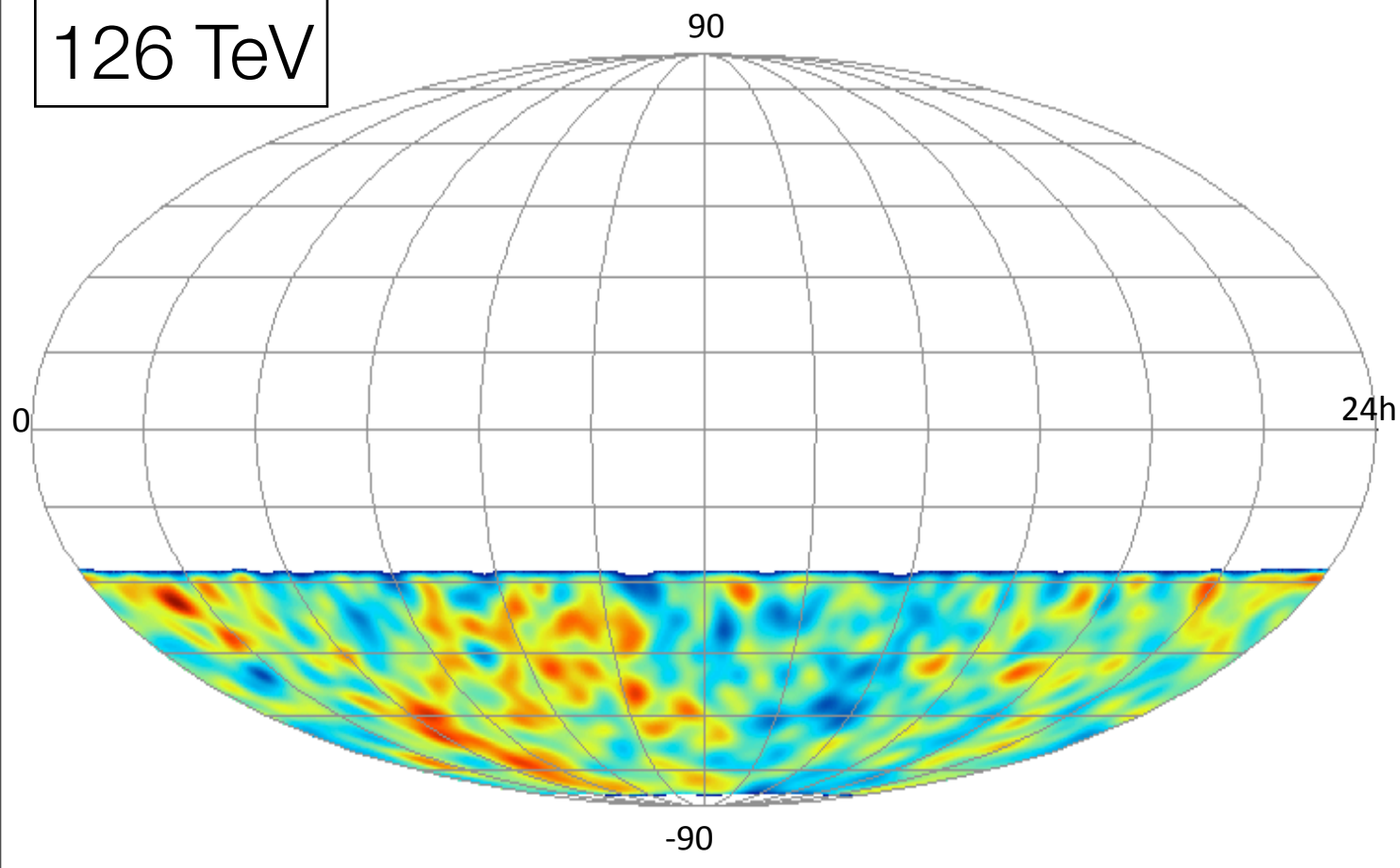
12 TeV

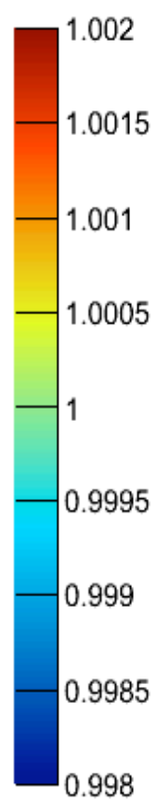


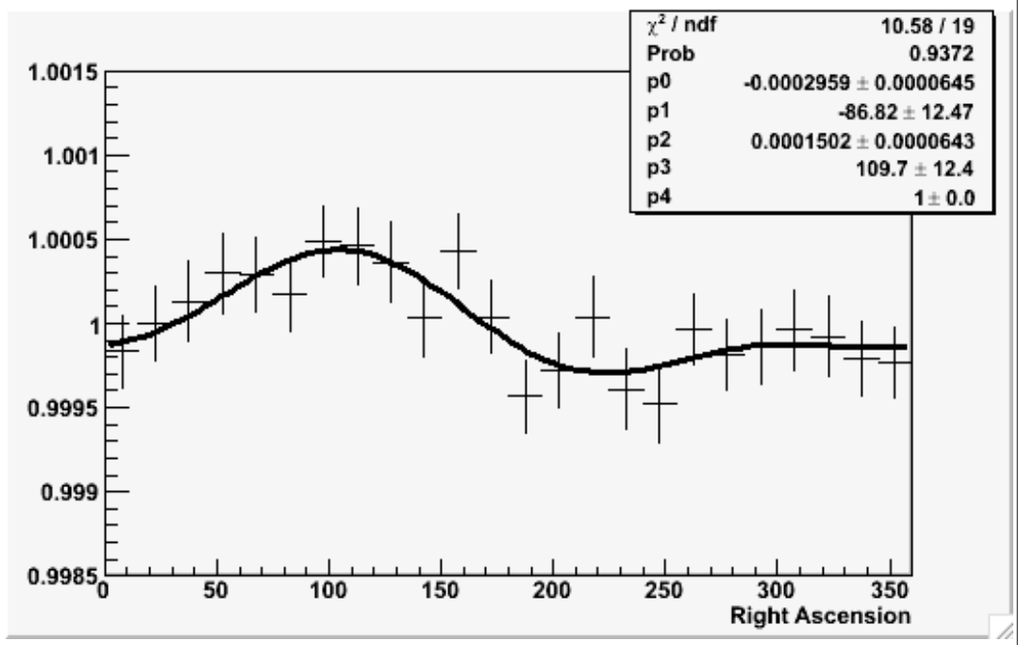




126 TeV







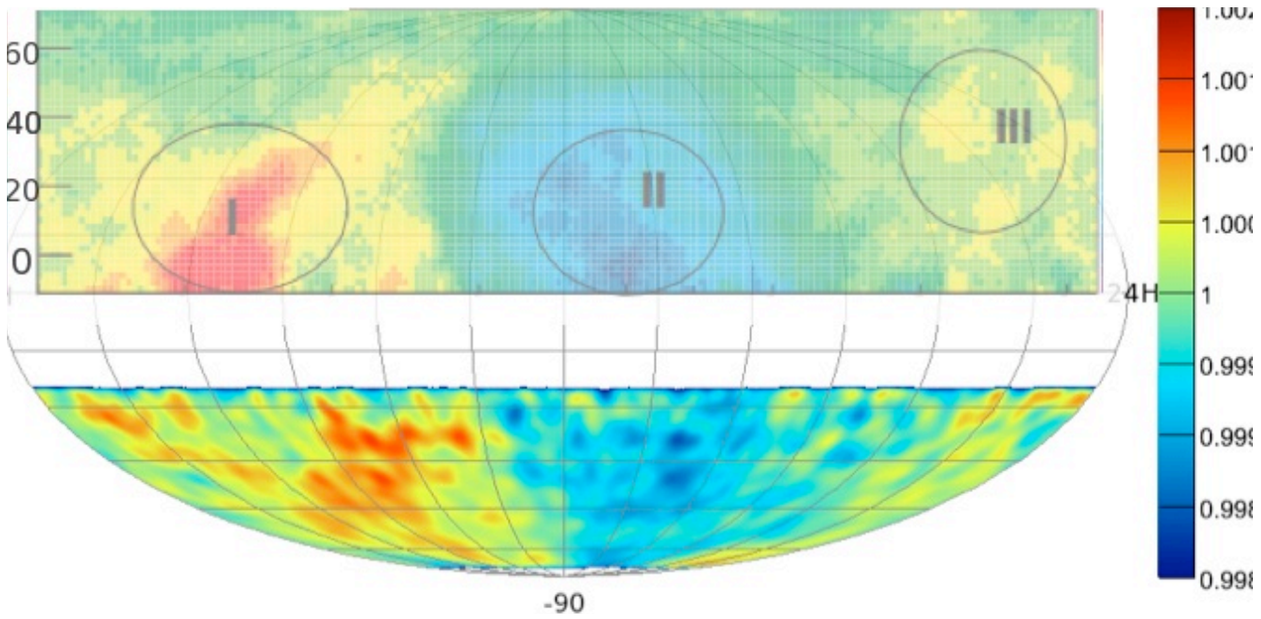
Large Scale Anisotropy of CR arrival direction with IC22

$4.3 \cdot 10^9$ events in 226 days

median angular resolution ~ 3^o

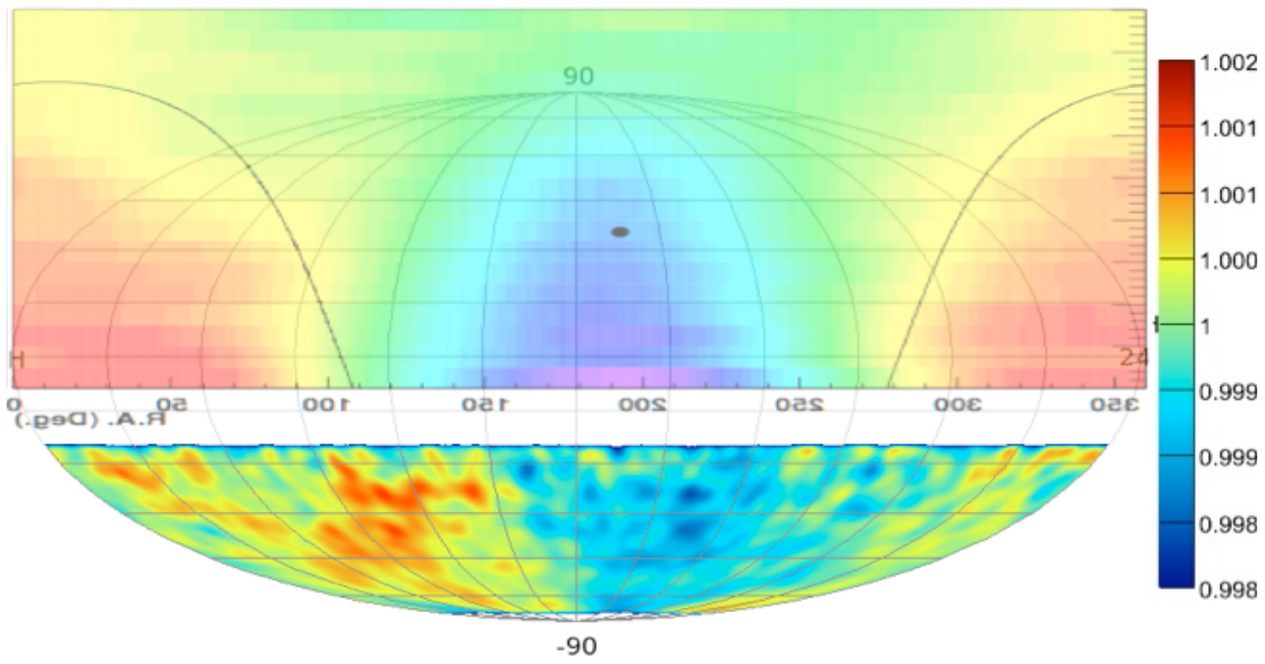
Rasha Abbasi, Juan Carlos Díaz Vélez, PD

IceCube & Tibet Array



M. Amenomori et. al Science, vol. 314, pp. 439–443, Oct. 2006

IceCube & Milagro



A. Abdoet. al. ArXiv:astro-ph/0806.2293, 2008.

first high statistics measurement @ southern hemisphere