IceCube, Neutrinos & Dark matter

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LAUNCH09, Heidelberg

IceCube

the IceCube Collaboration

34 institutions in 4 continents

Why build IceCube

Astrophysical questions:

Origin of the cosmic rays

Uncovering “invisible” phenomena with neutrinos

Cosmic ray physics

Particle physics:

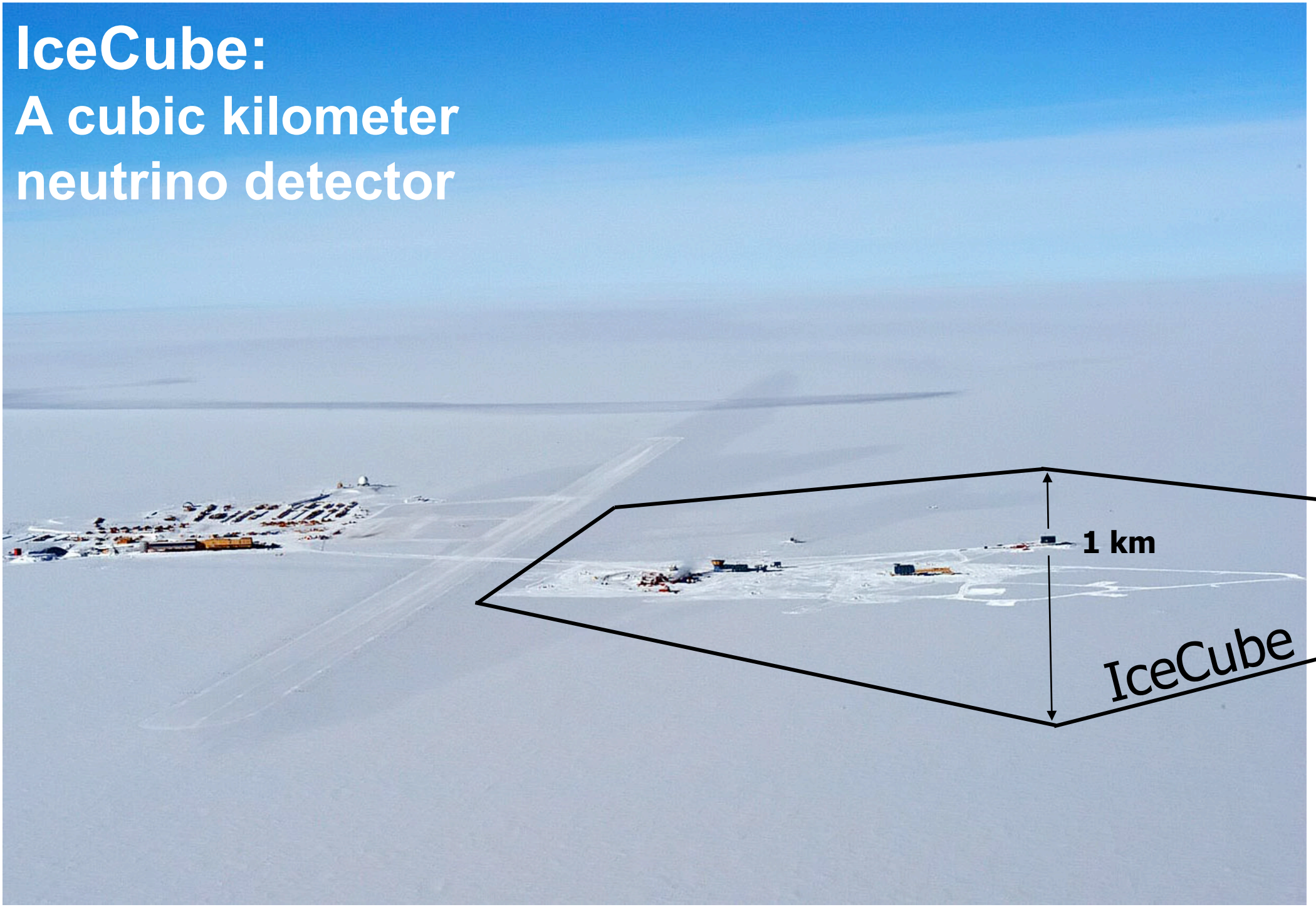
Search for dark matter

Neutrinos (oscillations,…)

Quantum gravity (and other BSM physics)

Magnetic Monopoles

IceCube:
A cubic kilometer neutrino detector



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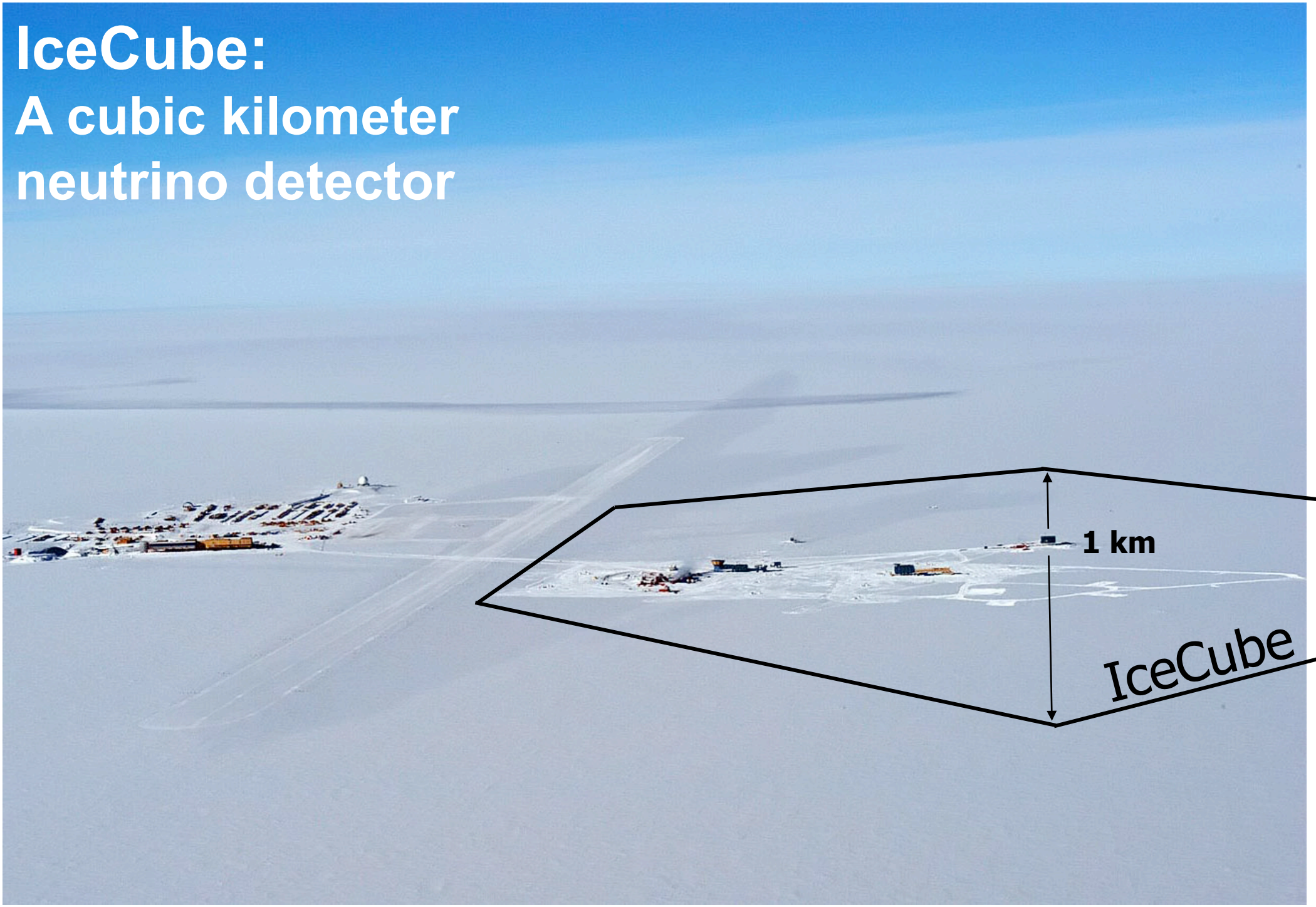

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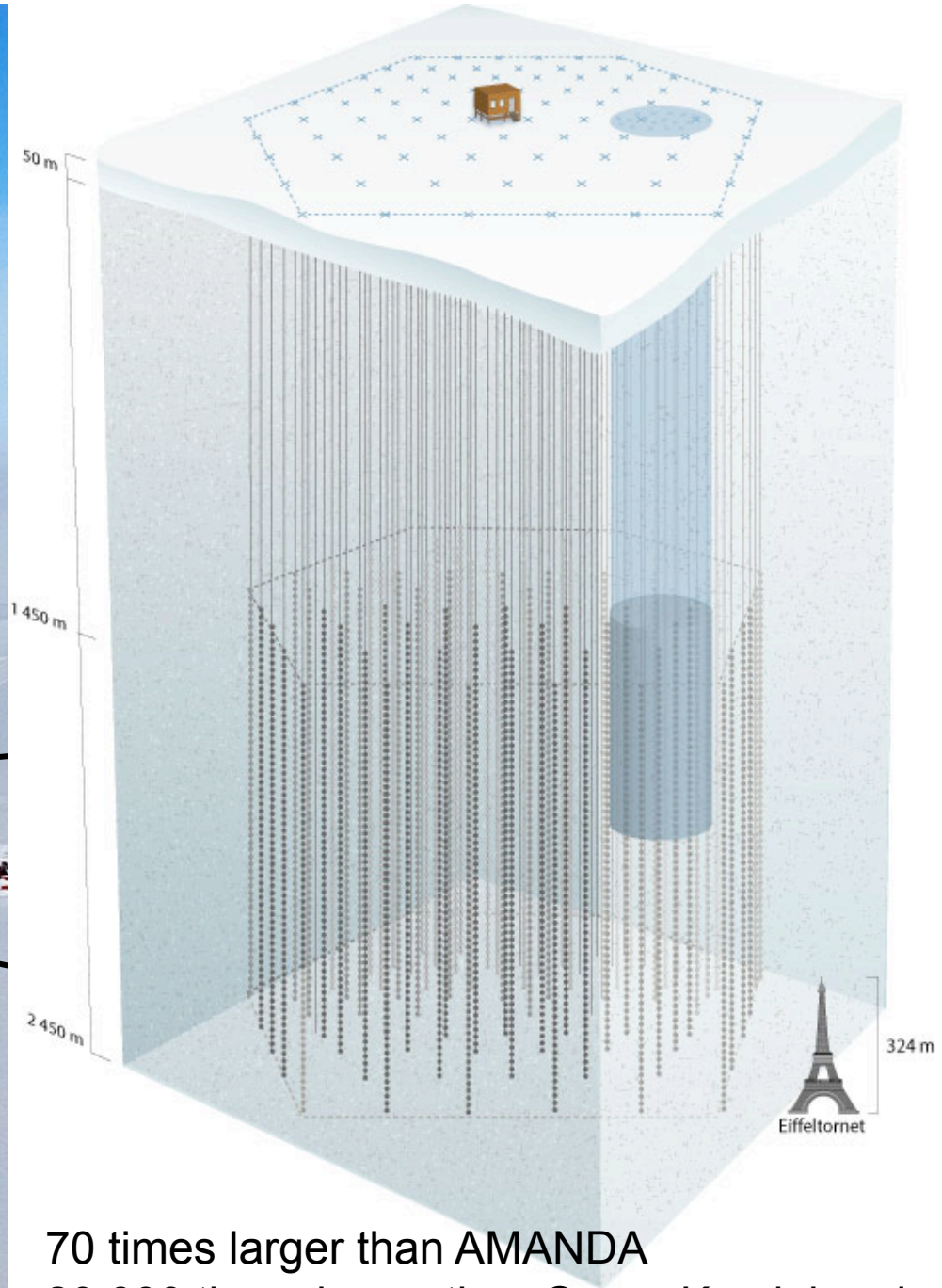
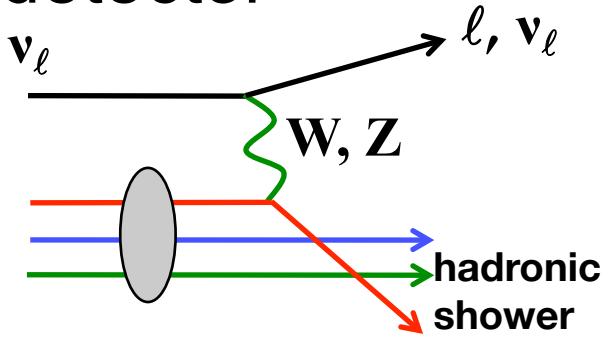


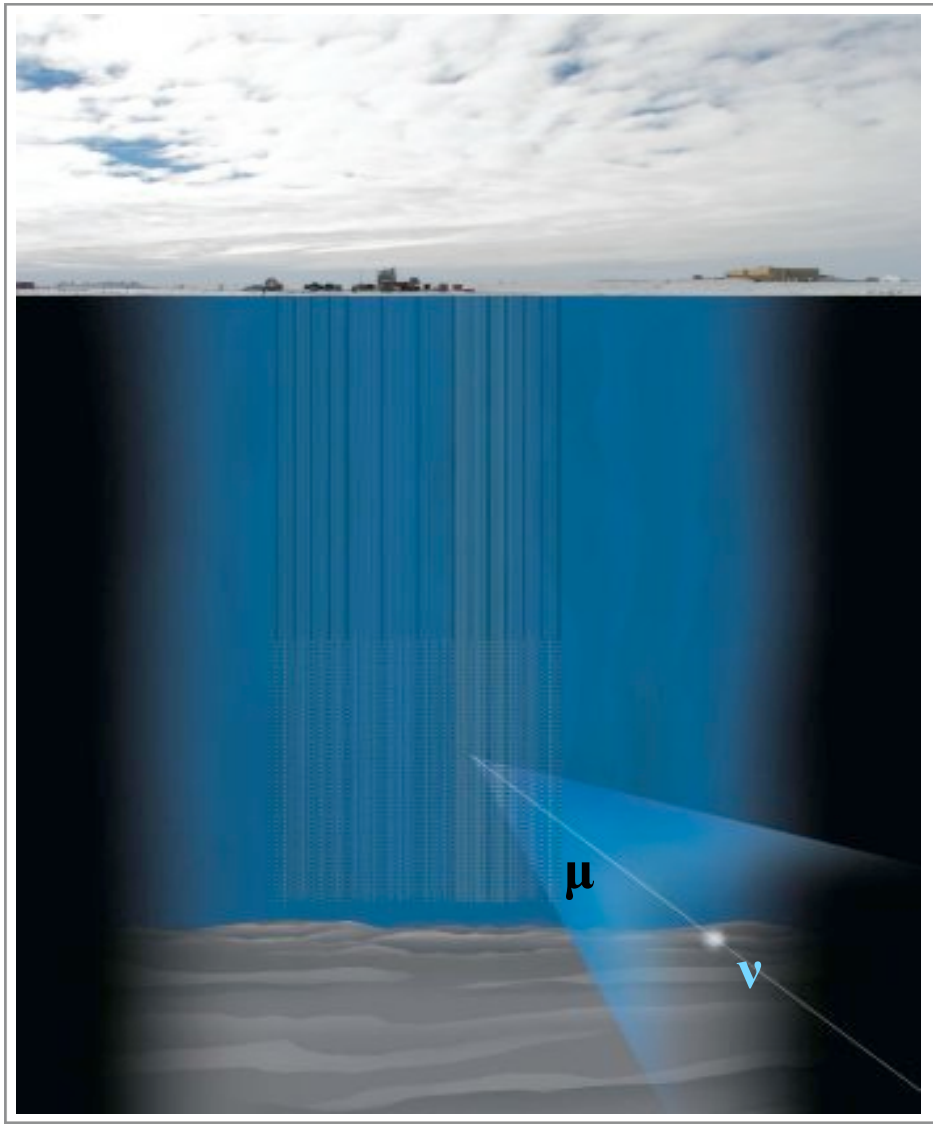
70 times larger than AMANDA
20.000 times larger than Super-Kamiokande

Detection principle

- Neutrinos interact in or near the detector



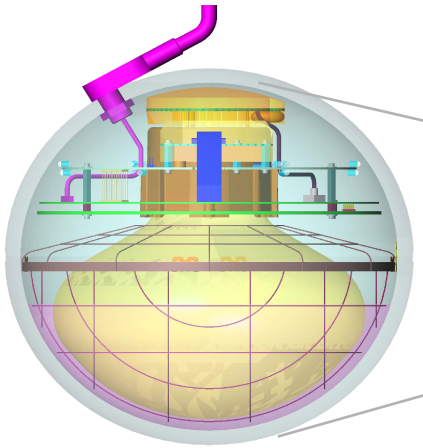
  - O(km) muon tracks from ν_μ CC
  - O(10 m) cascades from ν_e CC, low energy ν_τ CC, and ν_x NC
  - Cherenkov radiation detected by 3D array of optical sensors (OMs)



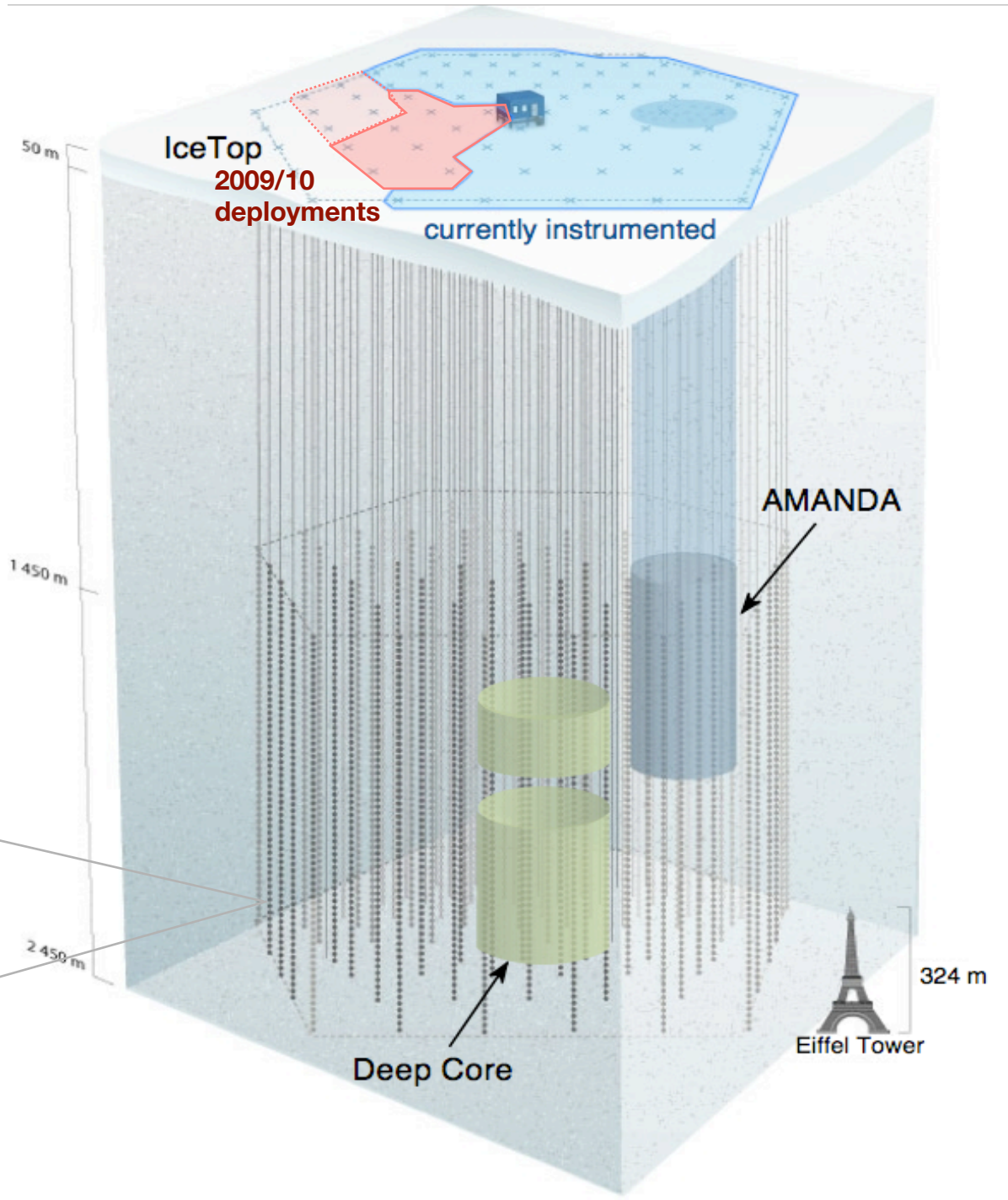
IceCube

- 5160 DOMs on 86 strings
- 1 km^3 instrumented volume
- 160 Ice-Cherenkov tank surface array (IceTop)
- 59 strings deployed to date in 5 construction seasons

Over 2/3 completed!

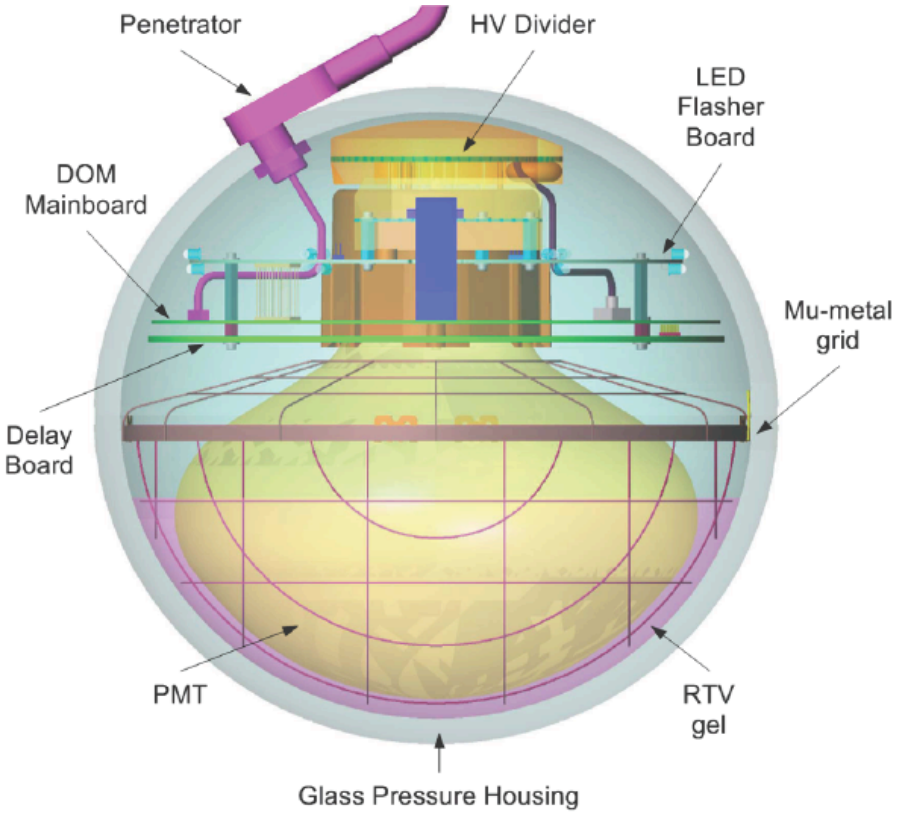


Digital Optical Module (DOM)



Digital Optical Module (DOM)

Each DOM is an autonomous data collection unit



- **PMT**: Hamamatsu, 10''

  Dark Noise rate ~ 400 Hz

  Local Coincidence rate ~ 15 Hz

- **Digitizers**:

  ATWD: 3 channels. Sampling 300MHz, capture 400 ns

  FADC: sampling 40 MHz, capture 6.4 ms

  Power consumption: 3W

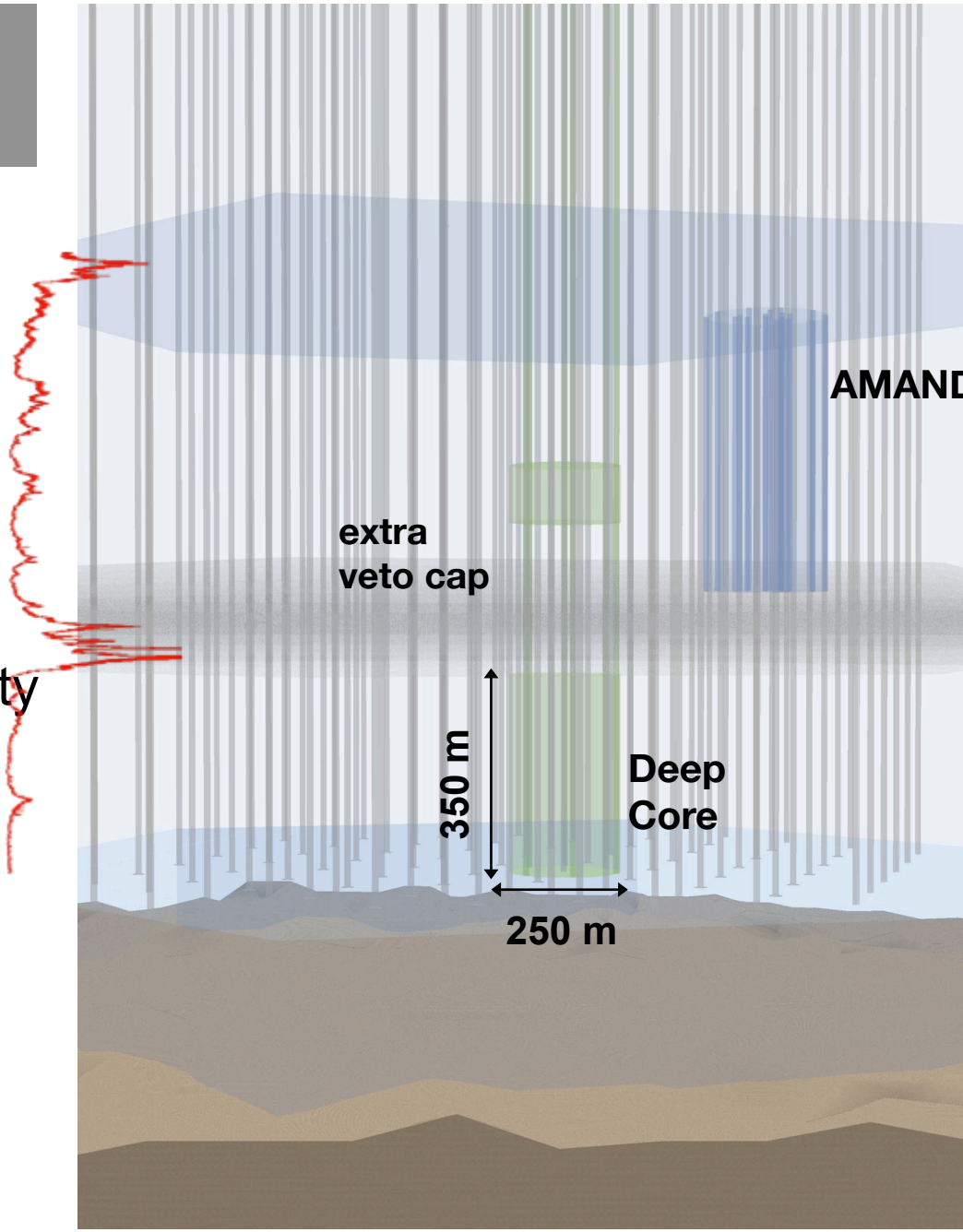
  Deadtime < 1%

- **Flasher board**:

  12 controllable LEDs at 0° or 45°

IceCube Deep Core

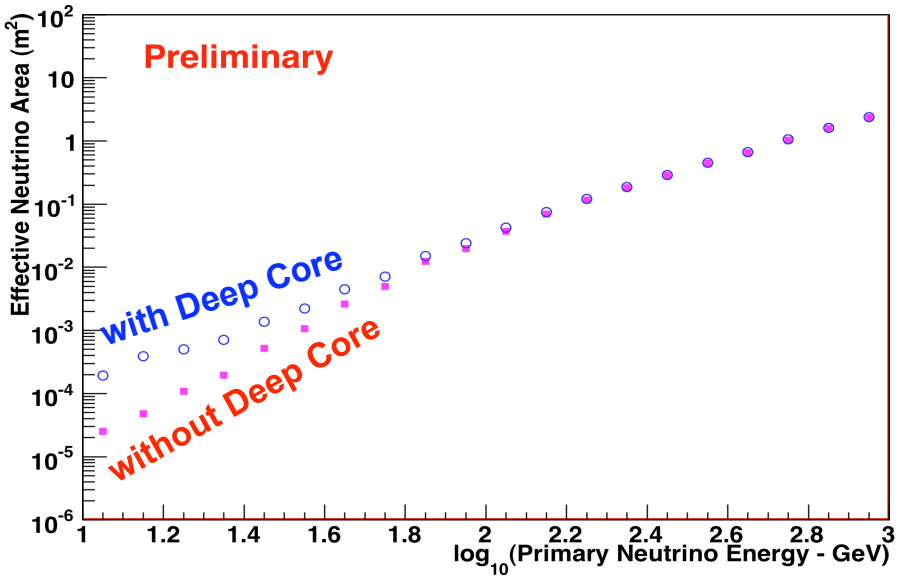
- Six special strings plus 7 nearest standard IceCube strings
  - 72 m interstring spacing
  - 7 m DOM spacing on string
  - High Q.E. PMTs
  - ~10x higher eff. photocathode density
- Clearest ice below 2100 m
  - $\lambda_{atten} \approx 40\text{-}45$ m
- Top and outer layers of IceCube used to veto atmospheric muons: Rejection power $\leq 10^5\text{-}10^6$

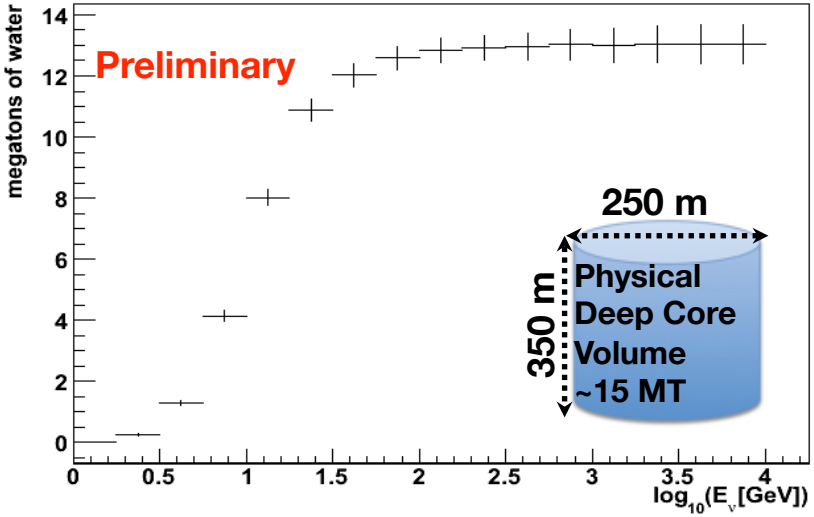


Deep Core Effective Area & Effective Volume

Effective area for upgoing ν_μ at trigger level

Reconstruction efficiencies not included yet – relative improvement likely to increase





Effective volume for downgoing ν_μ interacting in Deep Core

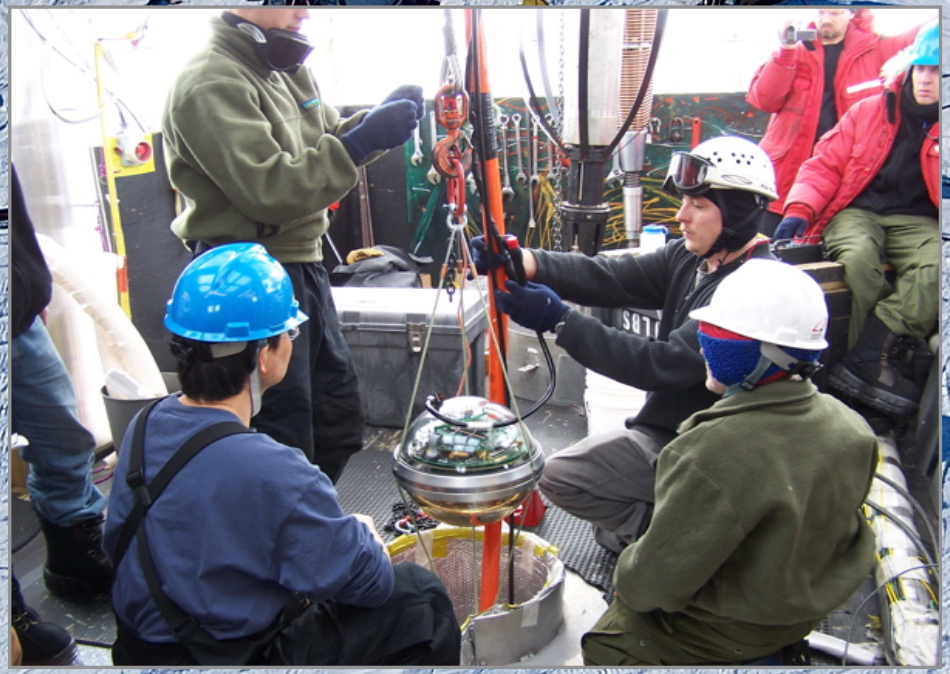
Trigger level, reconstruction efficiencies not included yet

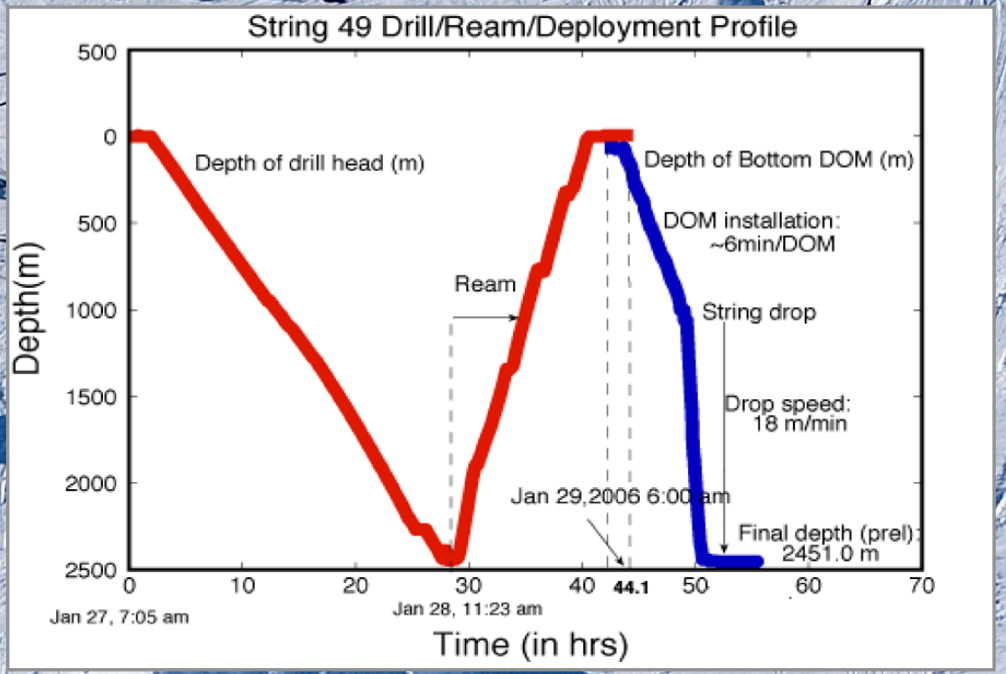
The IceCube Detector

Installation

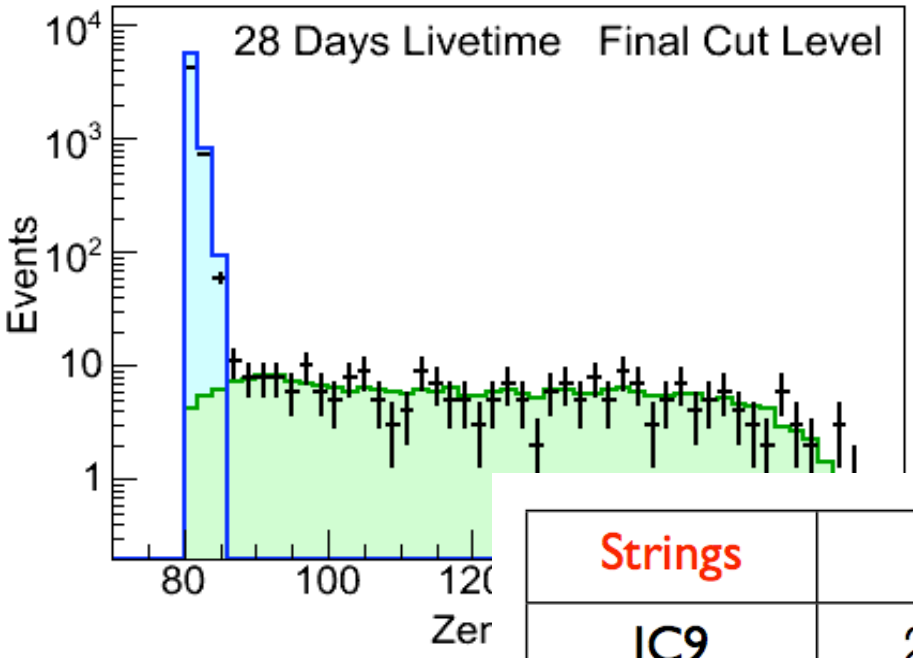
The IceCube Detector

Installation





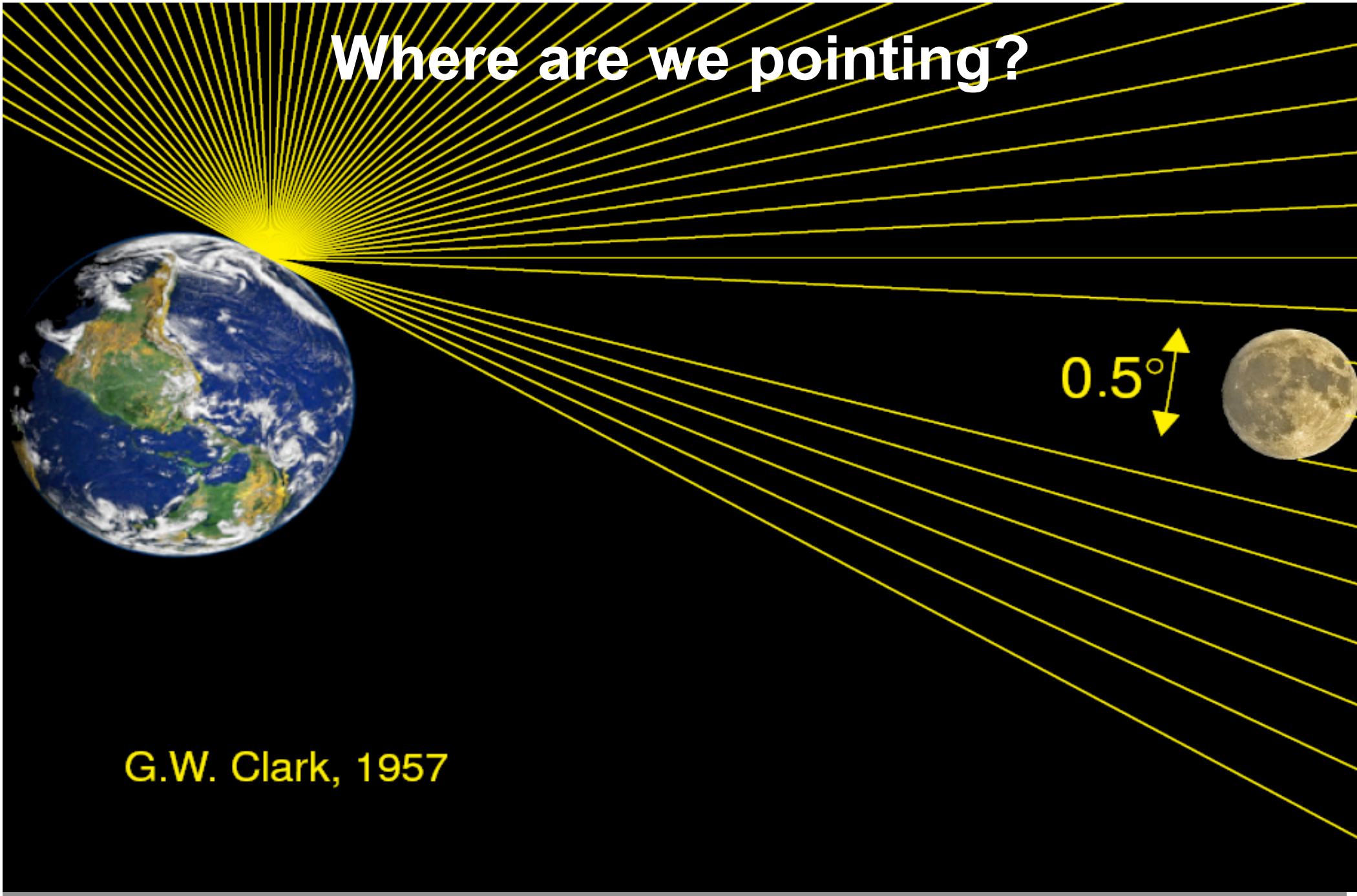
Atmospheric neutrinos



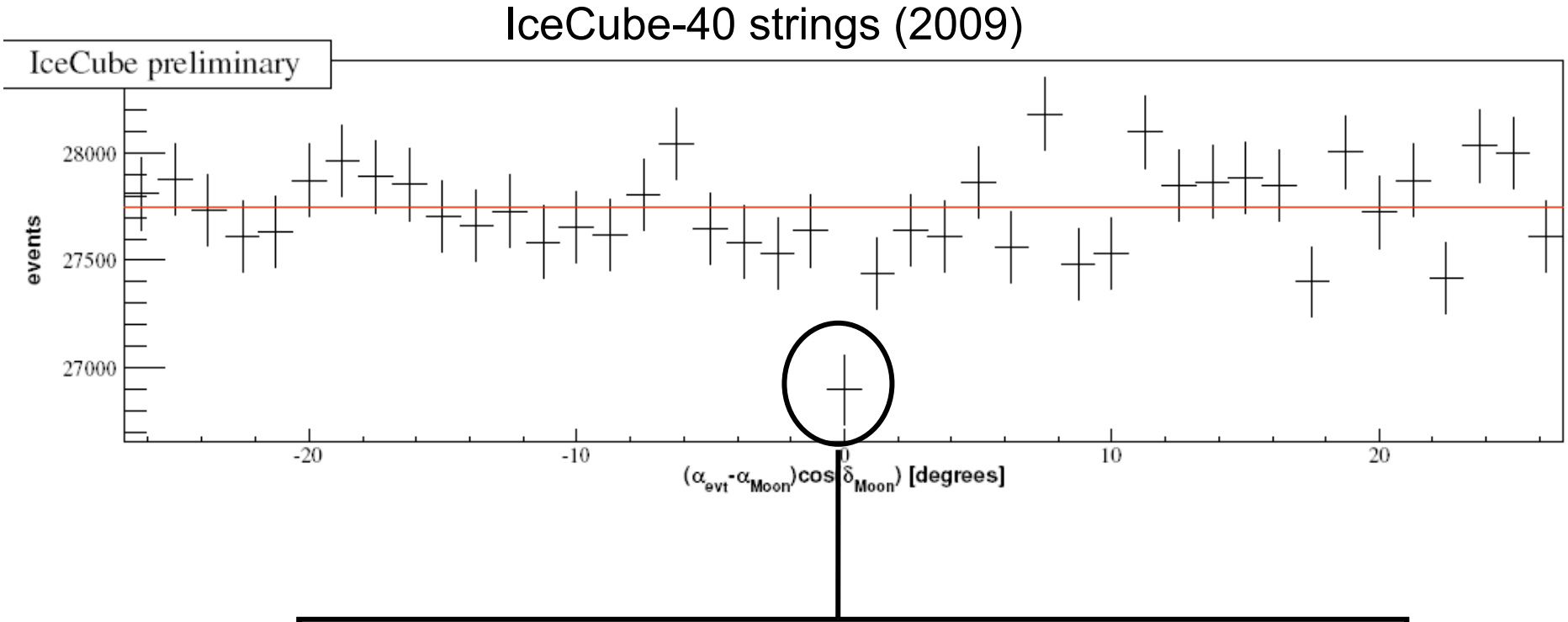
Quality cuts to select well reconstructed events & zenith angle cut (up-going)

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

Where are we pointing?



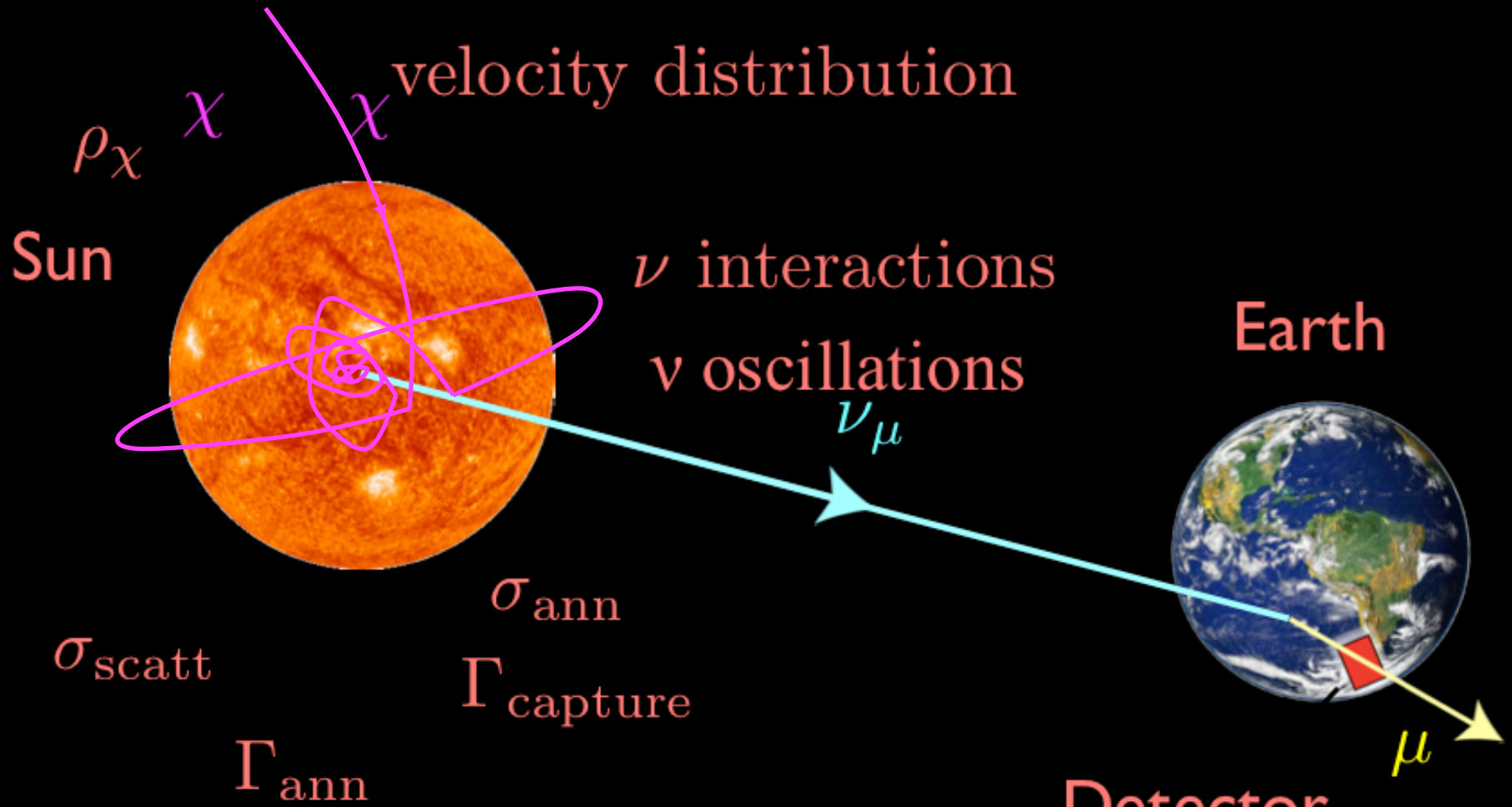
Pointing



Observation of moon shadow: 5.04 sigma
~ 1 degree angular resolution

Searching for Dark Matter with IceCube

Indirect detection principle: Neutrinos from the sun

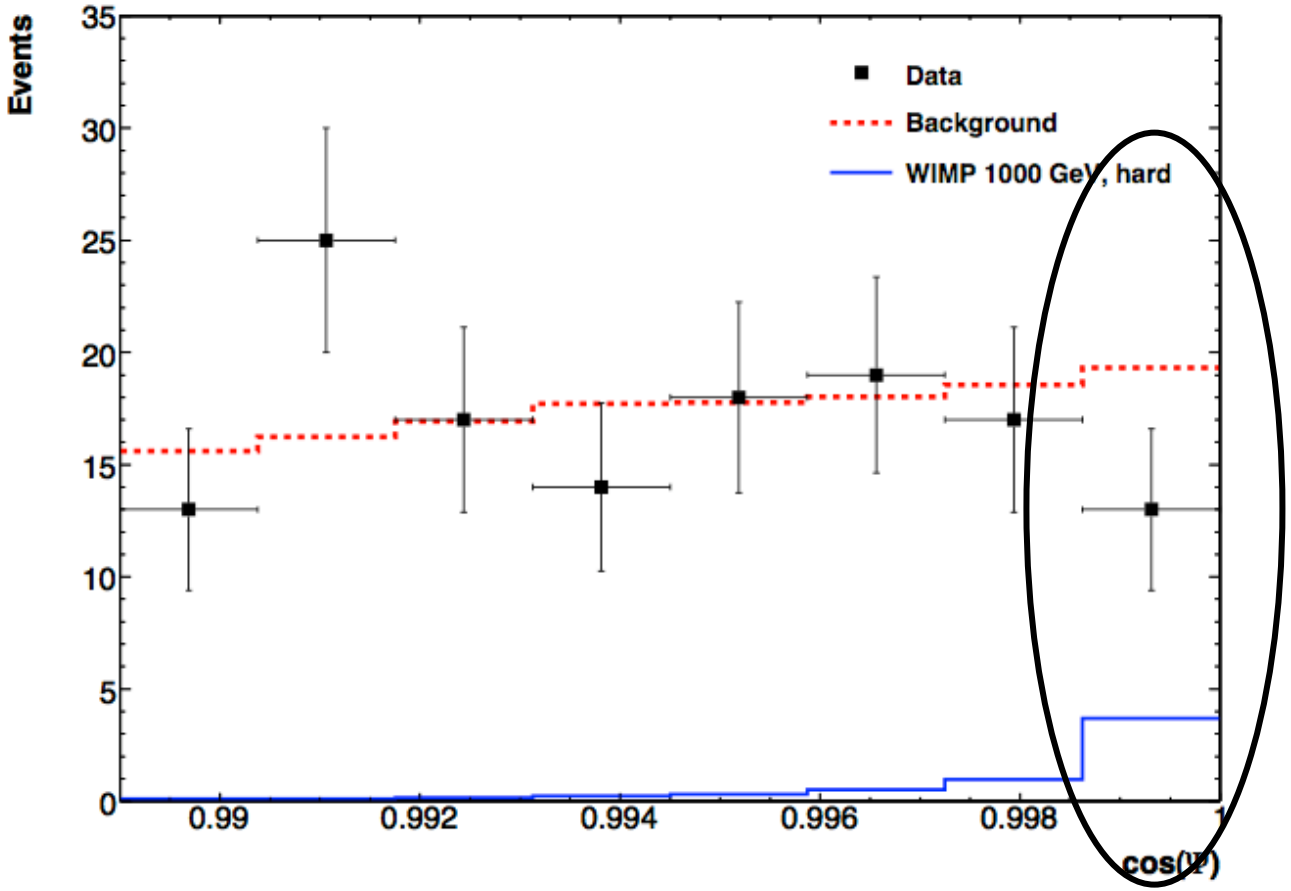


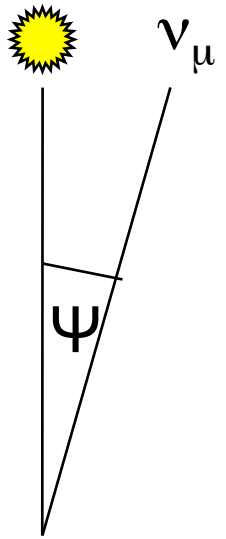
Silk, Olive and Srednicki '85
Gaisser, Steigman & Tilav '86

Freese '86
Krauss, Srednicki & Wilczek '86
Gaisser, Steigman & Tilav '86

Neutralino Searches

Muon flux from the sun



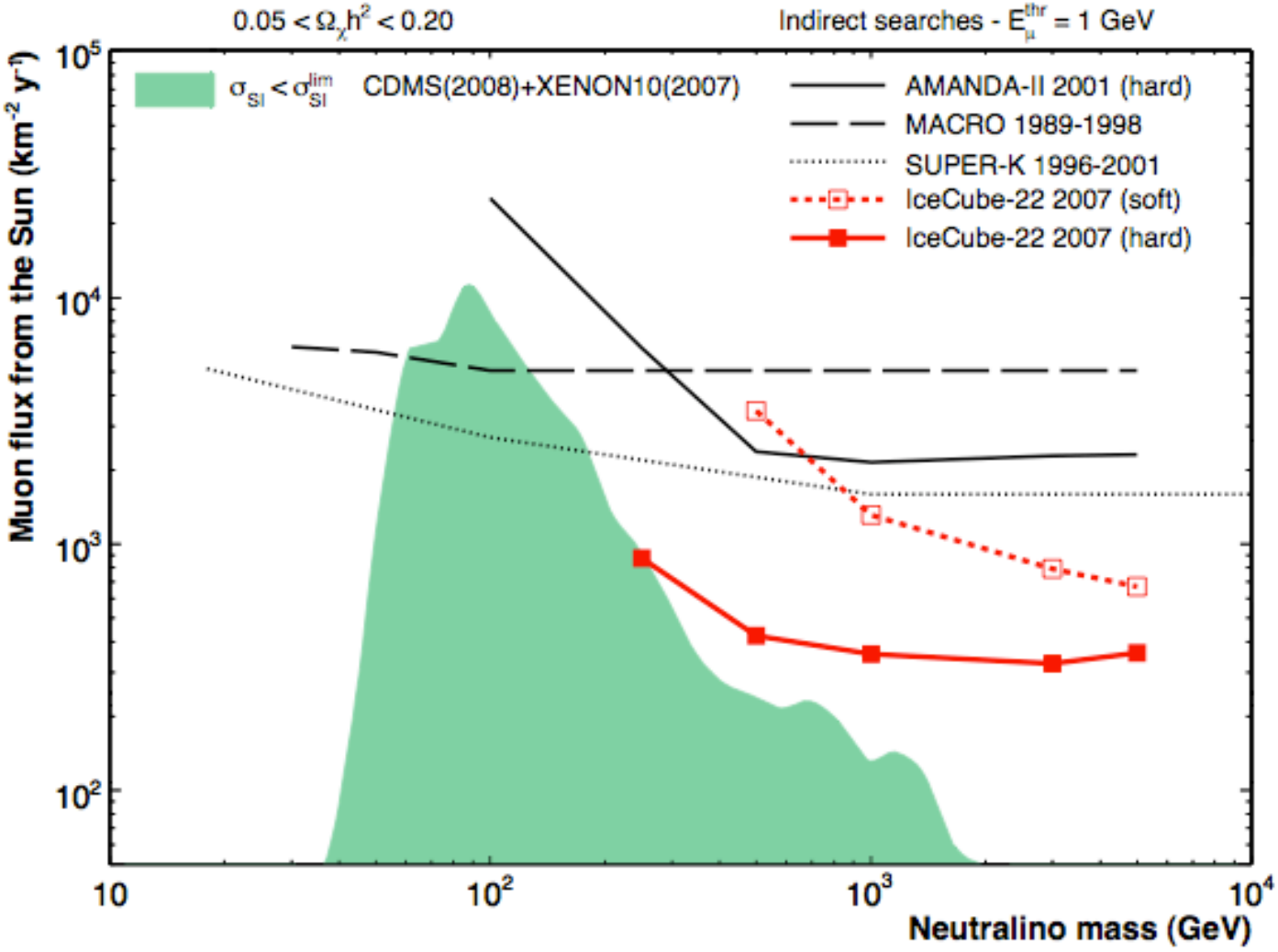


Observation consistent with expectation from atmospheric neutrinos⇒upper limit

Abbasi et al., PRL, 2009

Neutralino Searches

Muon flux from the sun



90% CL

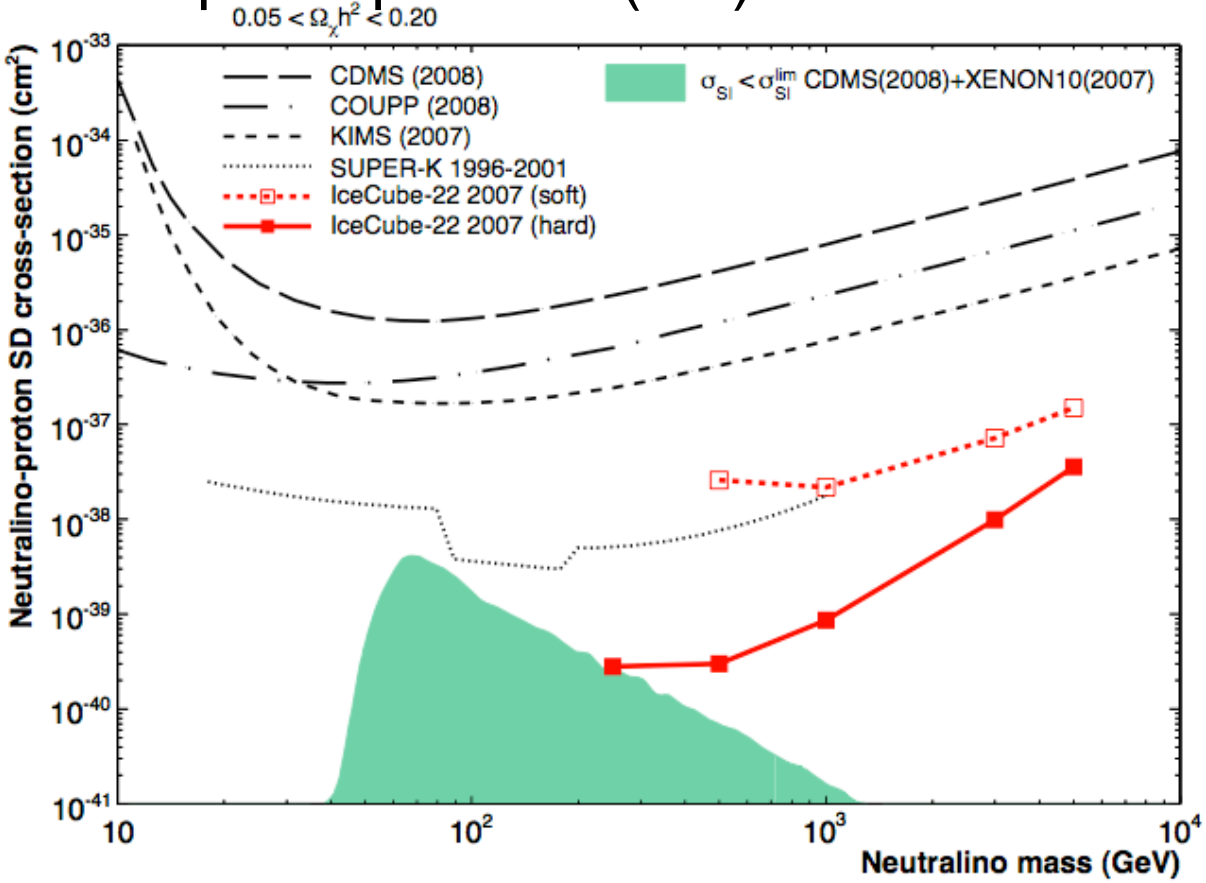
Abbasi et al., PRL, 2009

Spin dependent cross-section

From flux to cross-sections:
(assuming capture rate C_C in equilibrium)

$$\text{Flux} \propto C_C \propto \sigma_{\chi+n}$$

Spin dependent (SD) cross section

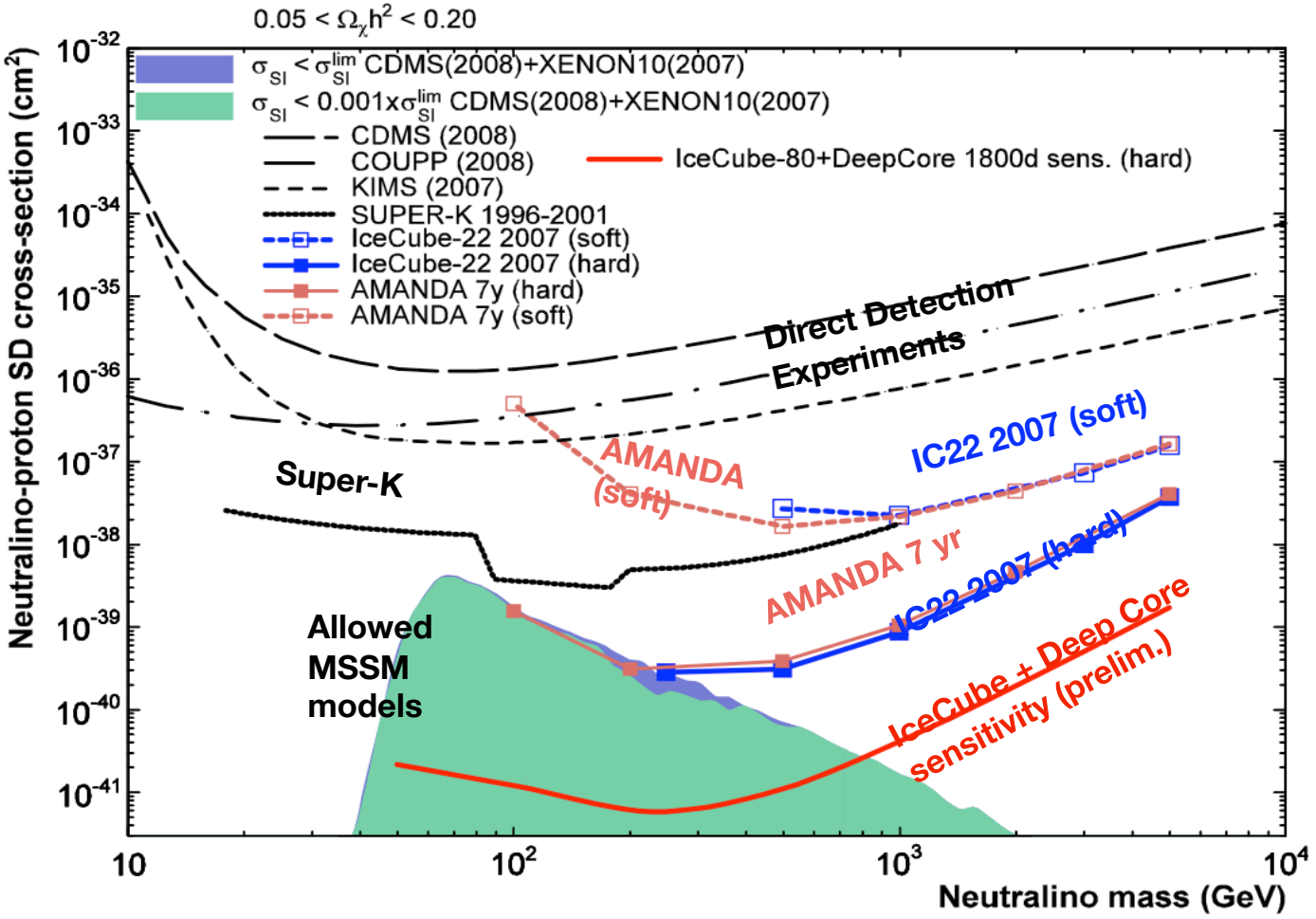


90% CL

Neutralino Searches

Spin dependent cross-section

- IceCube with Deep Core will probe large region of allowed phase space



Kaluza Klein Dark Matter

From Universal Extra Dimension theories

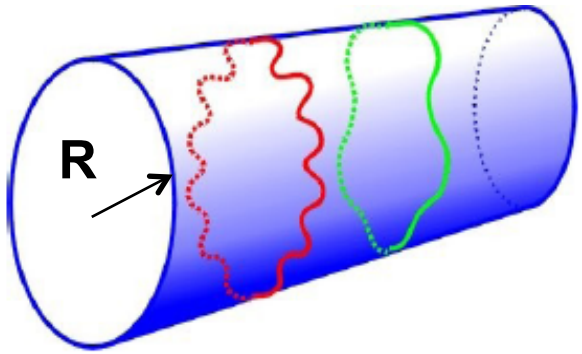
- 2 free parameters, R and cutoff scale L.

- finite space dimension → momentum is quantized

- p = *n*/R which can be interpreted as mass = *n*/R

→ tower of mass eigenstates.

The lightest is stable → candidate for dark matter



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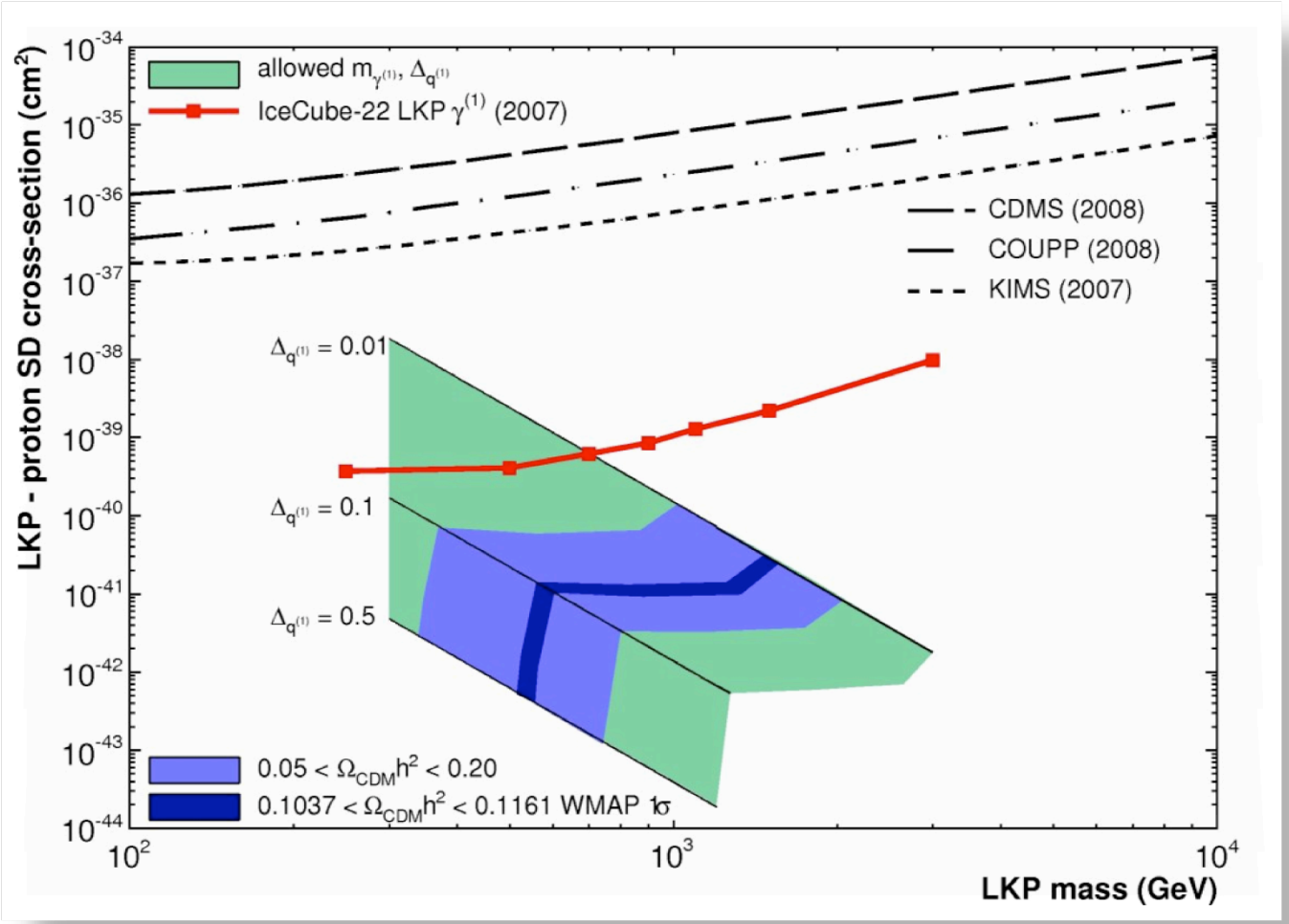
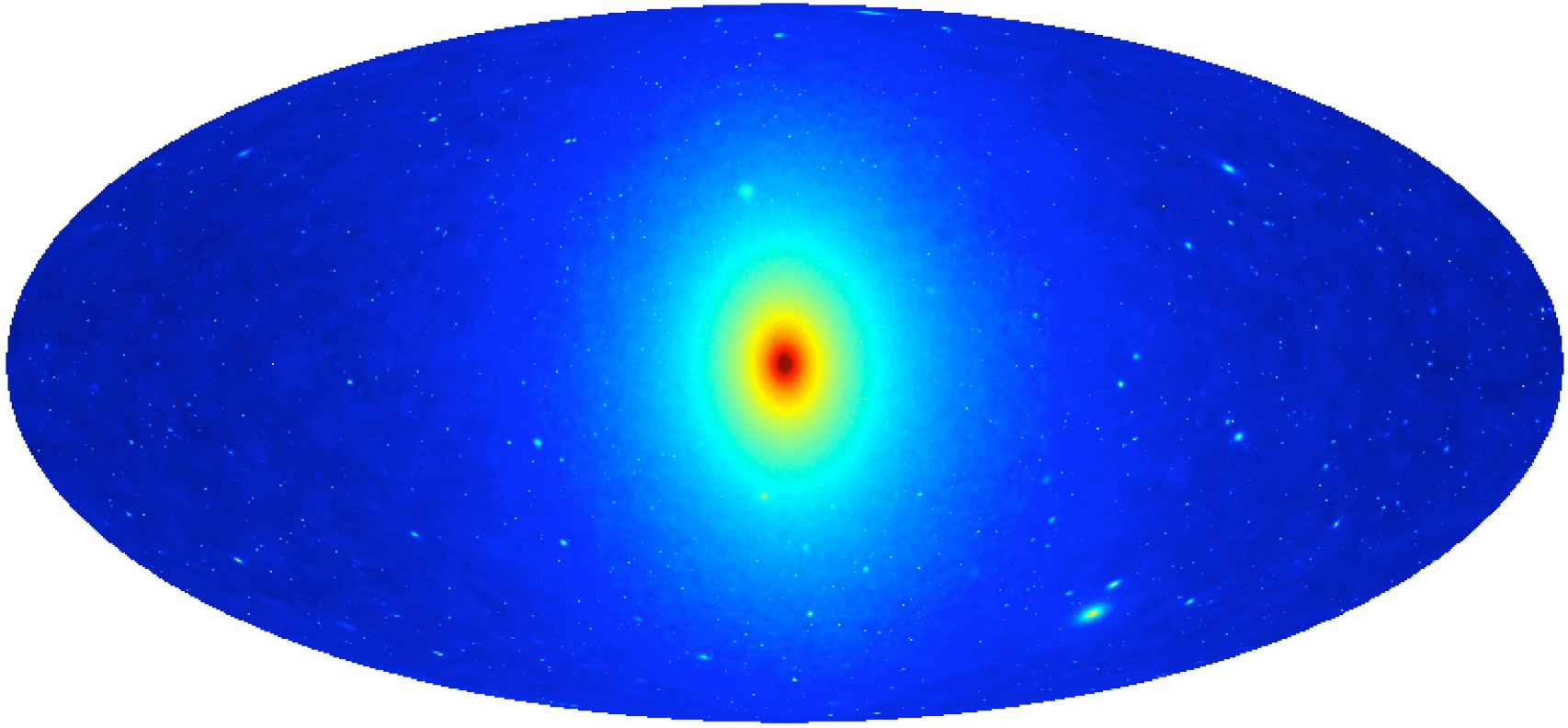


90% CL

Abbasi et al., submitted, 2009

Neutrino Halo Signatures



Picture: Springel et al, Nature 2008

~half the anniliation luminosity comes from the inner 20 degrees

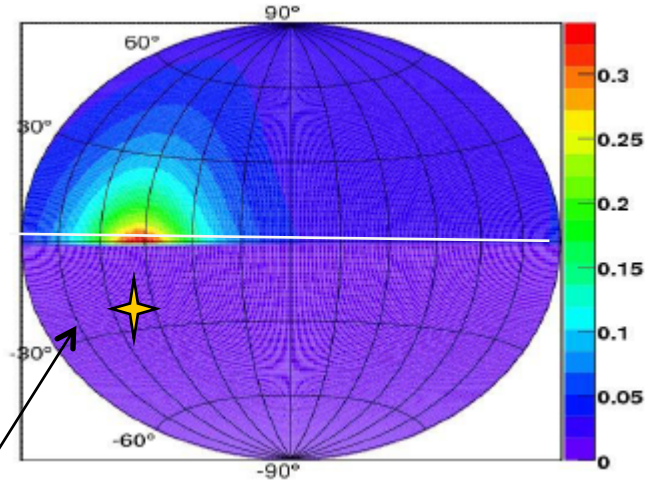
unlike for γ−radiation, the (atmospheric) background is well understood

Neutrino Halo Signatures

- Look for an excess of events in the on-source region w.r.t. the off-source

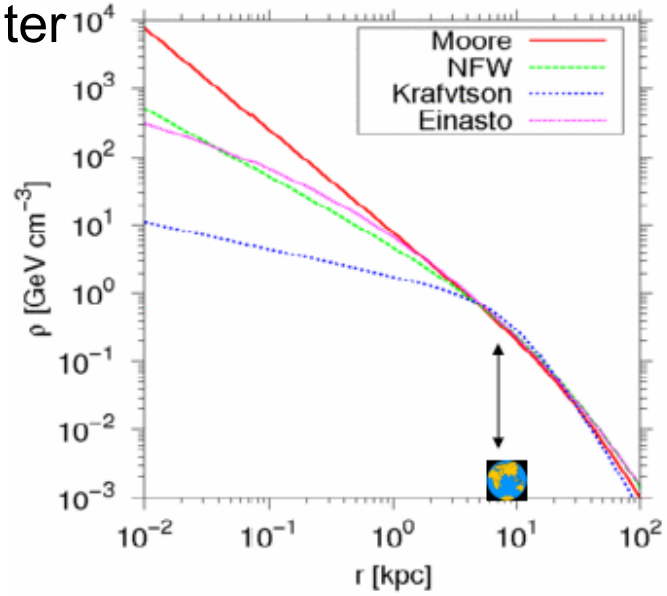
$$\frac{d\Phi}{dE} = \frac{<\sigma_A v>}{2} J(\psi) \frac{R_{sc}\rho_{sc}^2}{4\pi m_\chi^2} \frac{dN}{dE}$$

measure **halo** **SUSY**



Galactic center

- Assume a halo model and neutrino spectrum ⇒ limit on the **self annihilaton cross section**



Analyses on-going with IC 22-string and IC 40-string configurations.
IC+DeepCore will reach the galactic center.

Neutrino Halo Signatures

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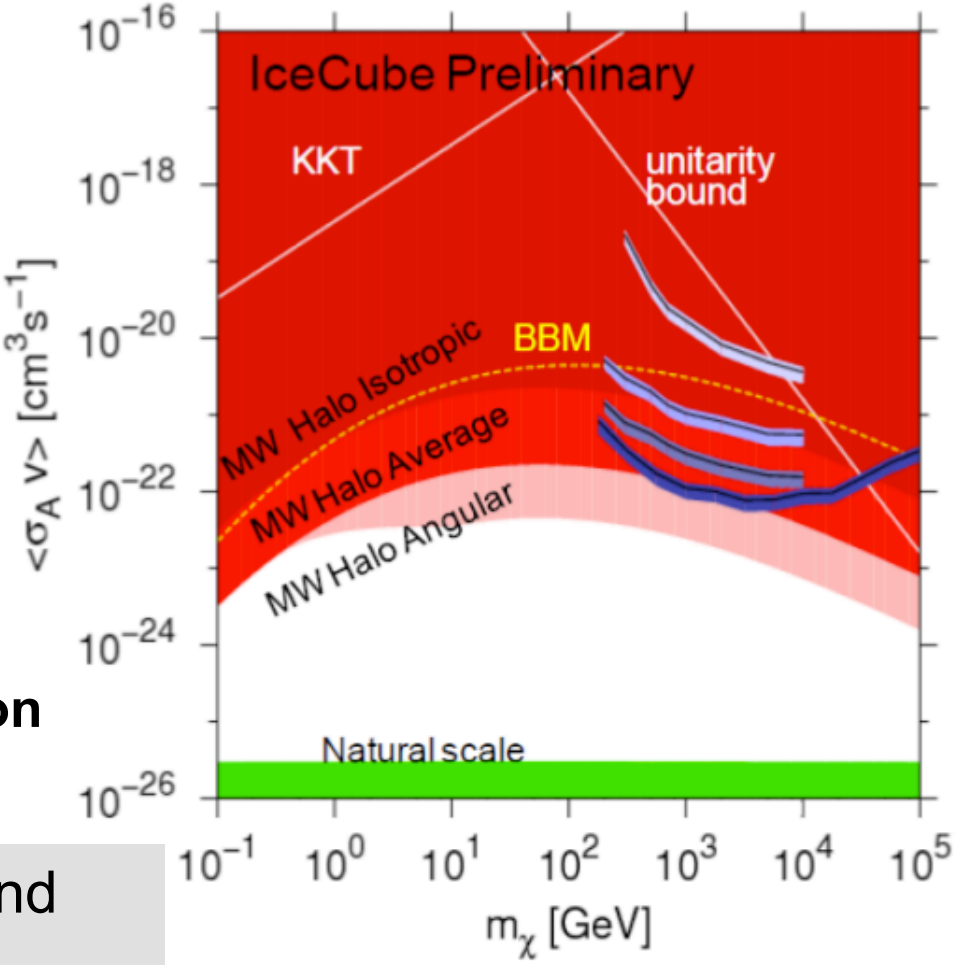

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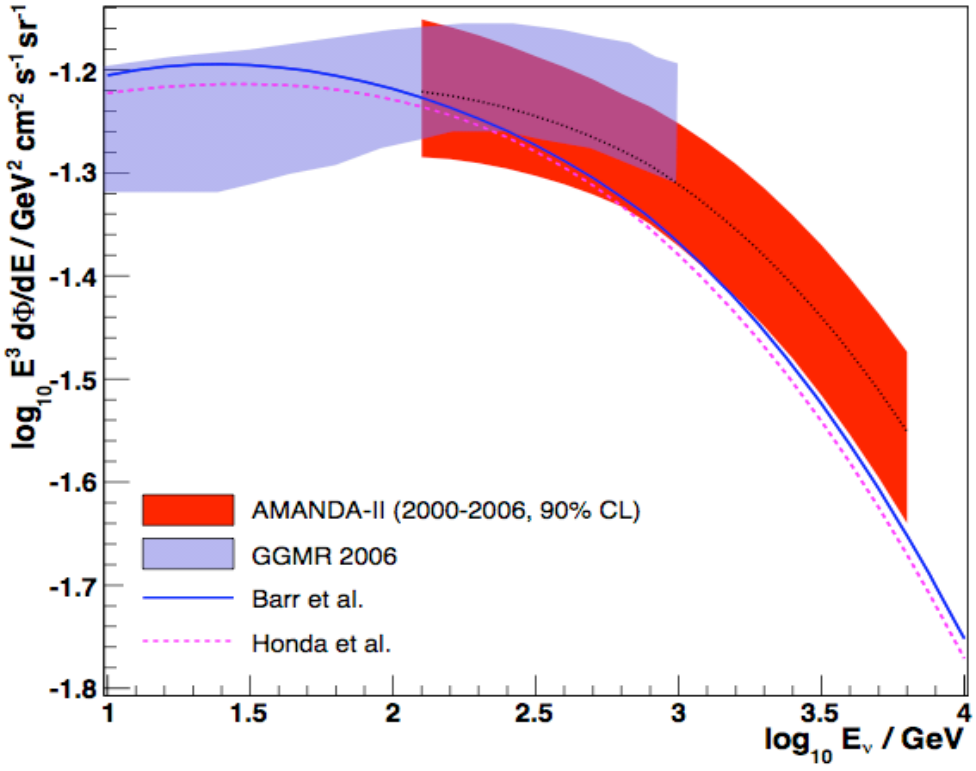
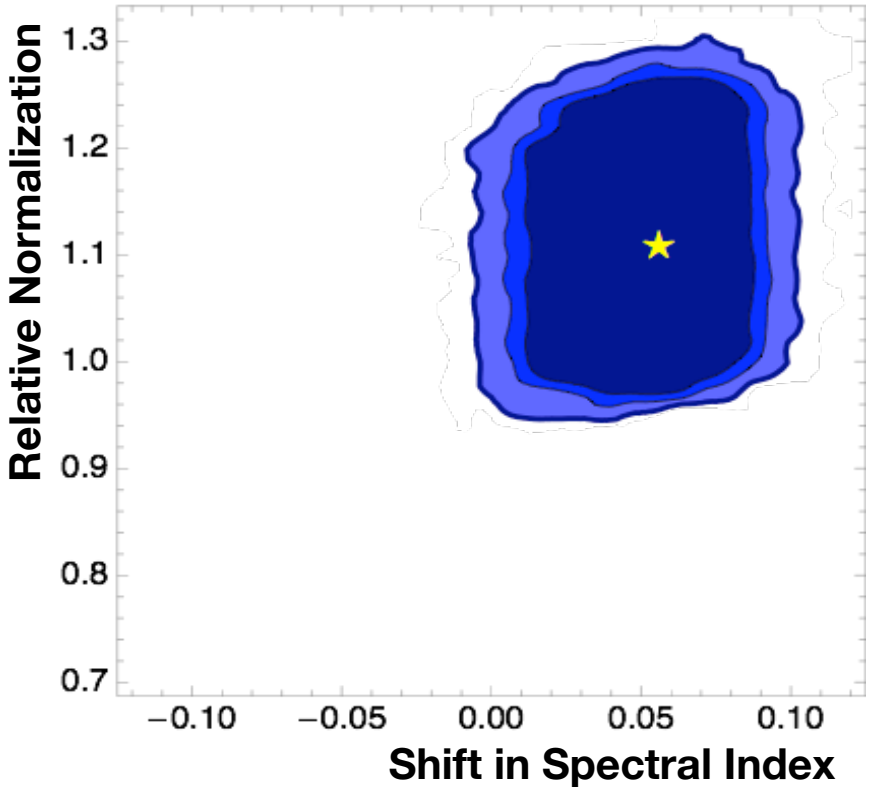
(Some) Neutrino Physics

Atmospheric Muon Neutrinos

- Based on complete 7-year AMANDA-II data set (3.8 years exposure)

Abbasi et al., Phys. Rev. D **79**, 102005 (2009

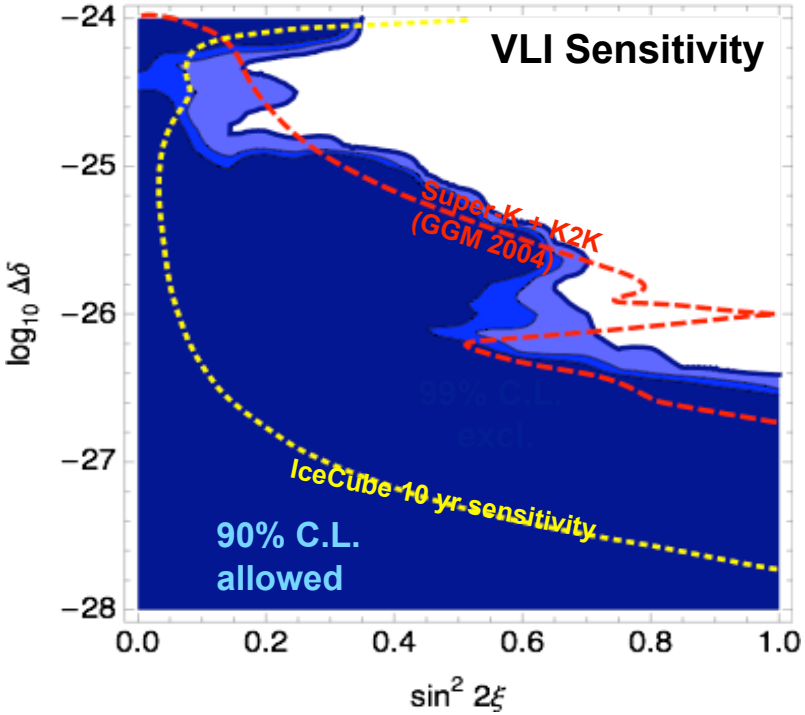


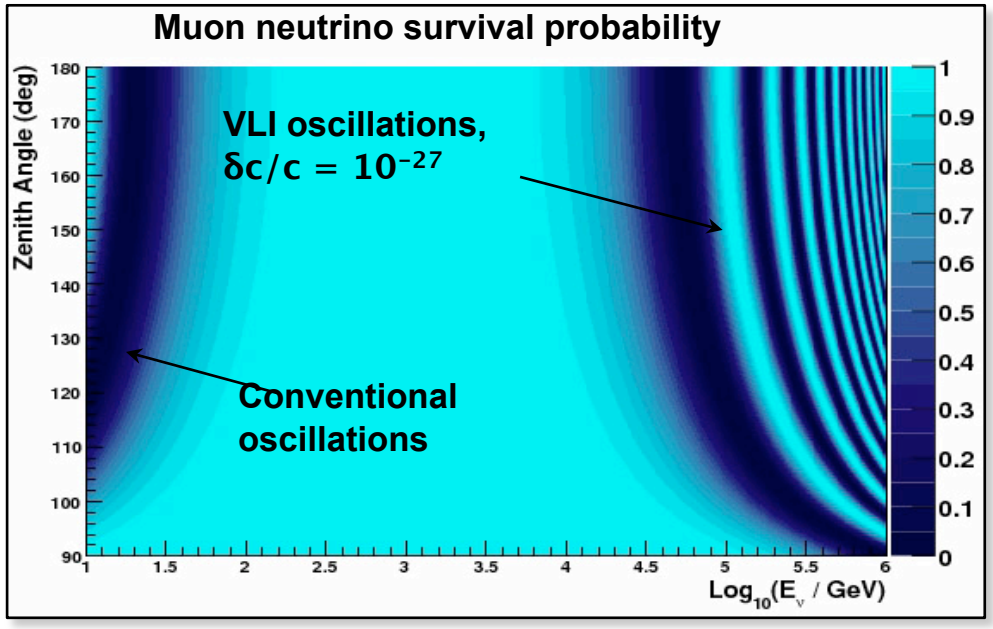


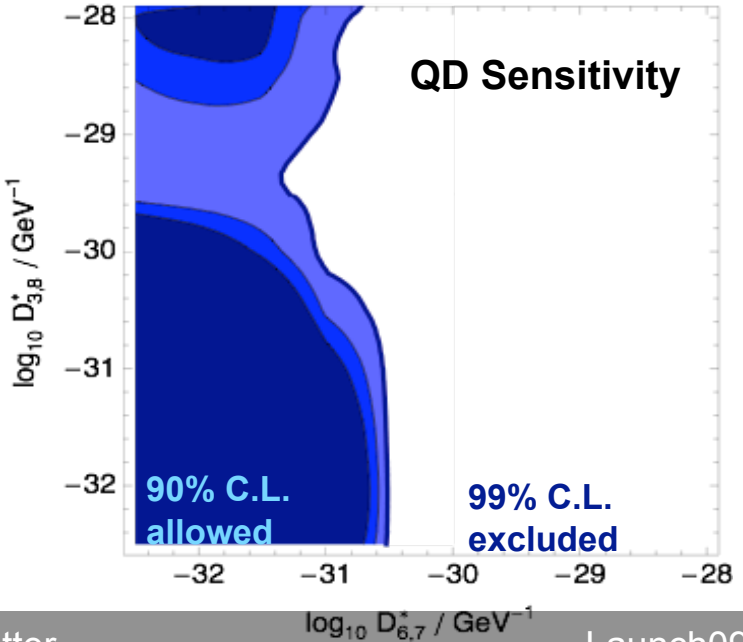
Search for BSM Physics

Look for non-standard ν_μ disappearance in AMANDA data

- Violation of Lorentz invariance (VLI)
- Quantum decoherence (QD)







Conclusion

- IceCube construction is on track: 2/3 strings deployed and first Deep Core string operating
- Final results from AMANDA, initial results from IceCube appearing
  - Leading limits on MSSM spin-dependent WIMP cross-sections
  - Atmospheric neutrinos and searches for new physics
- Deep Core underway: reduce threshold to ~10 GeV