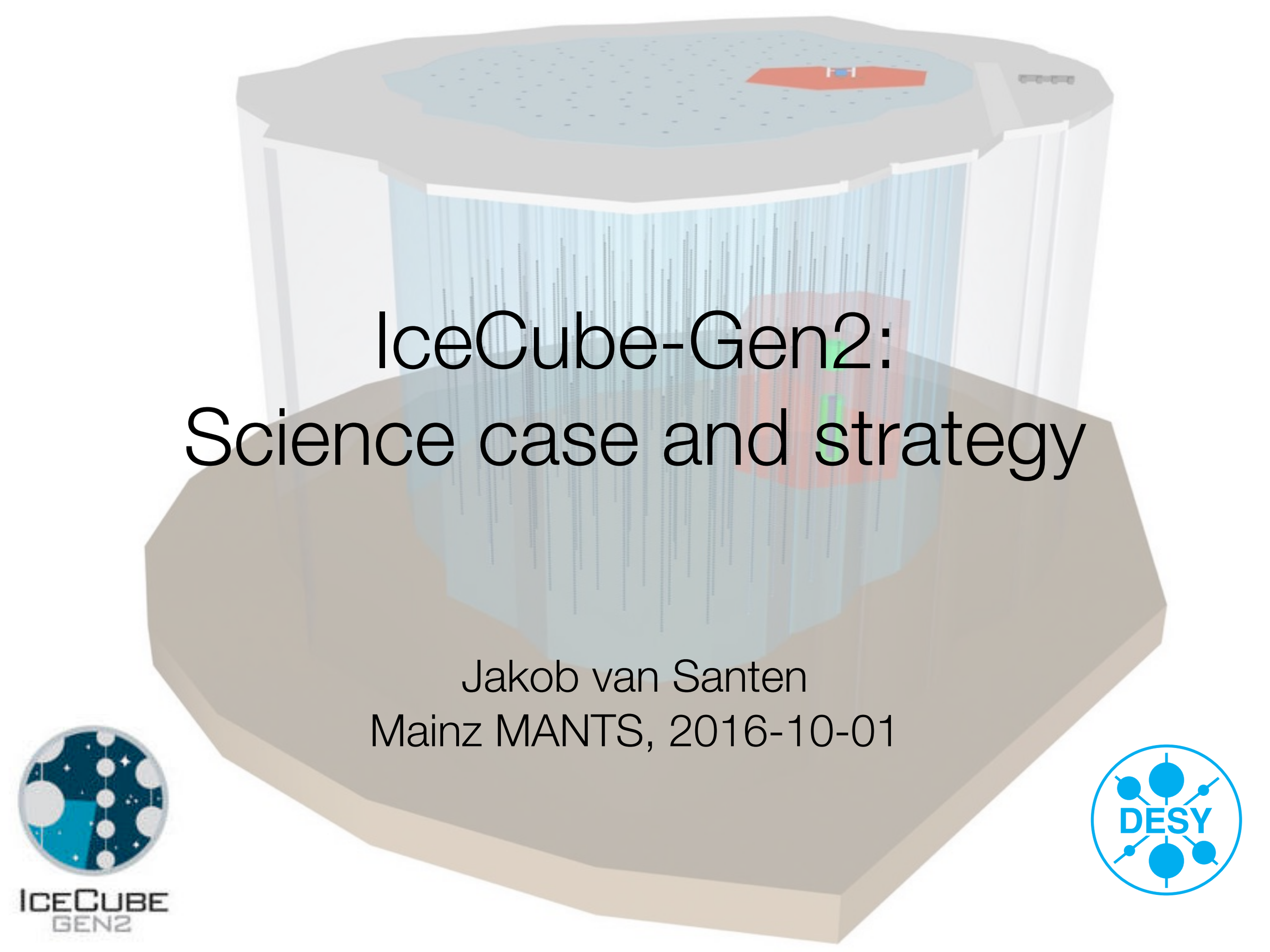


IceCube-Gen2: Science case and strategy

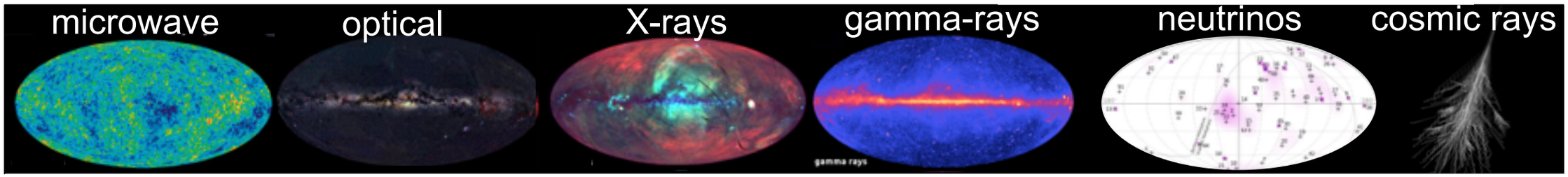
Jakob van Santen

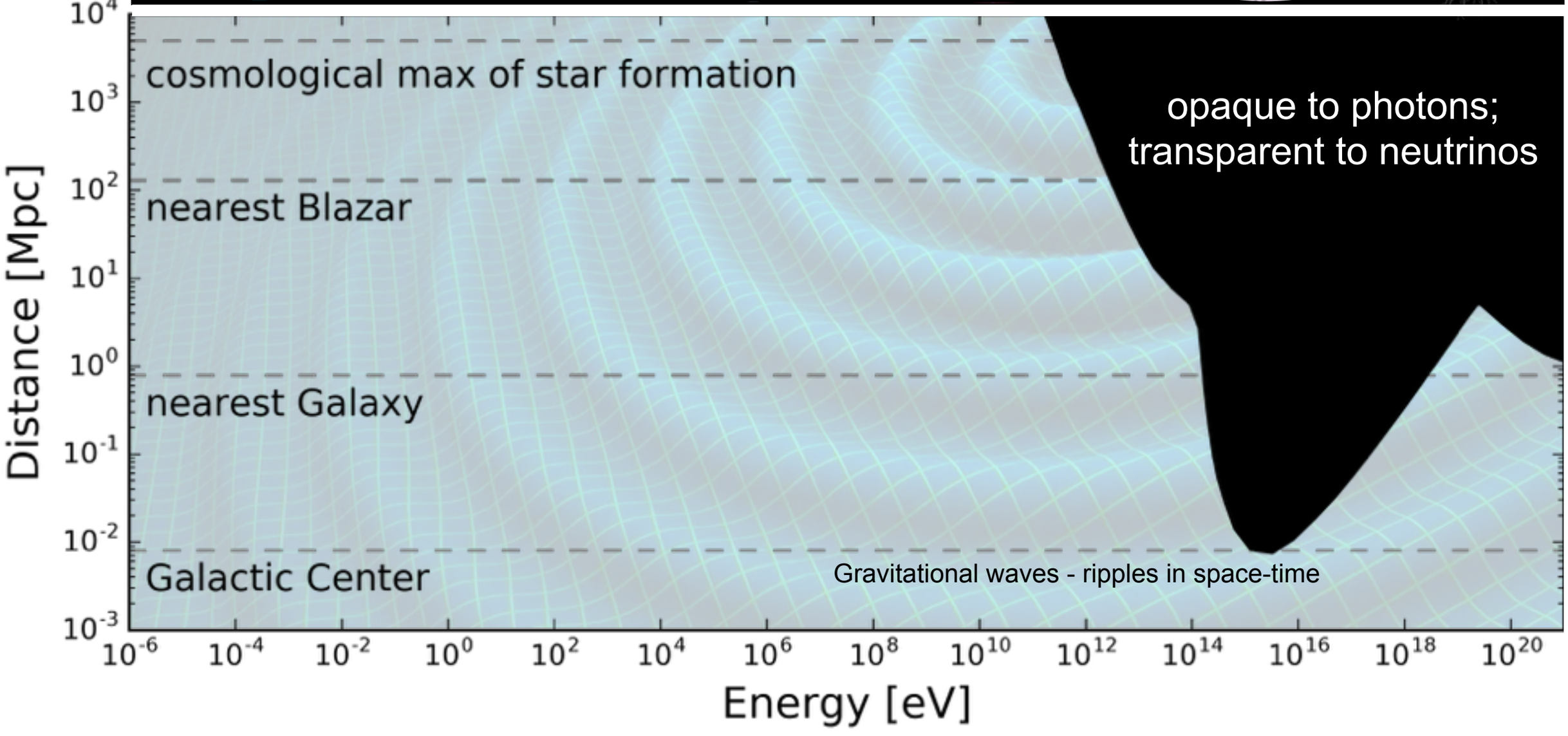
Mainz MANTS, 2016-10-01

ICECUBE GEN2

DESY

Multi-Messenger Astronomy





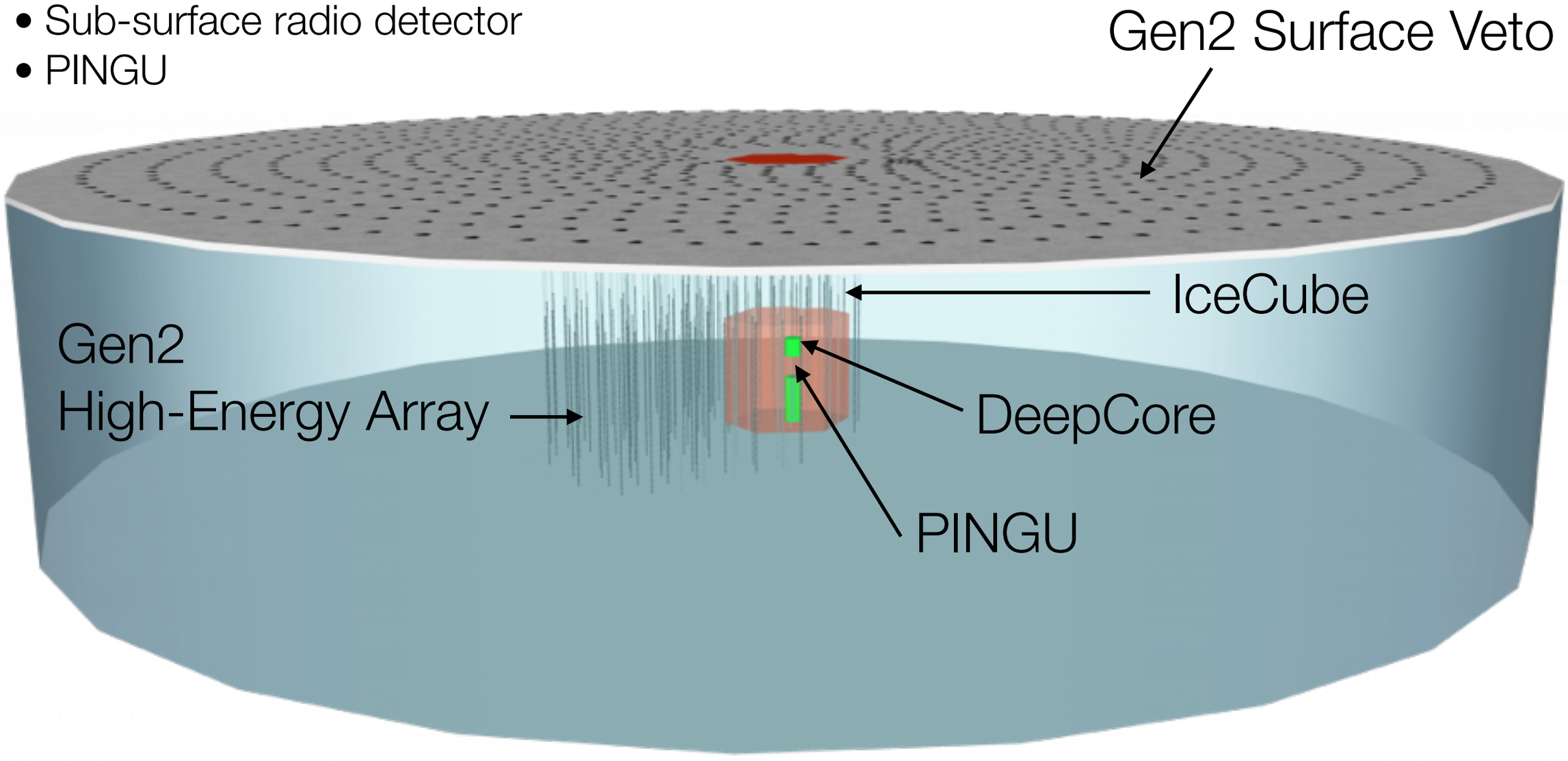
The Universe is opaque for 1/5 of the EM spectrum

IceCube-Gen2 Facility

A wide band neutrino observatory (MeV – EeV) using several detection technologies – optical, radio, and surface veto – to maximize the science

Multi-component observatory:

- Surface air shower detector
- Gen2 High-Energy Array
- Sub-surface radio detector
- PINGU

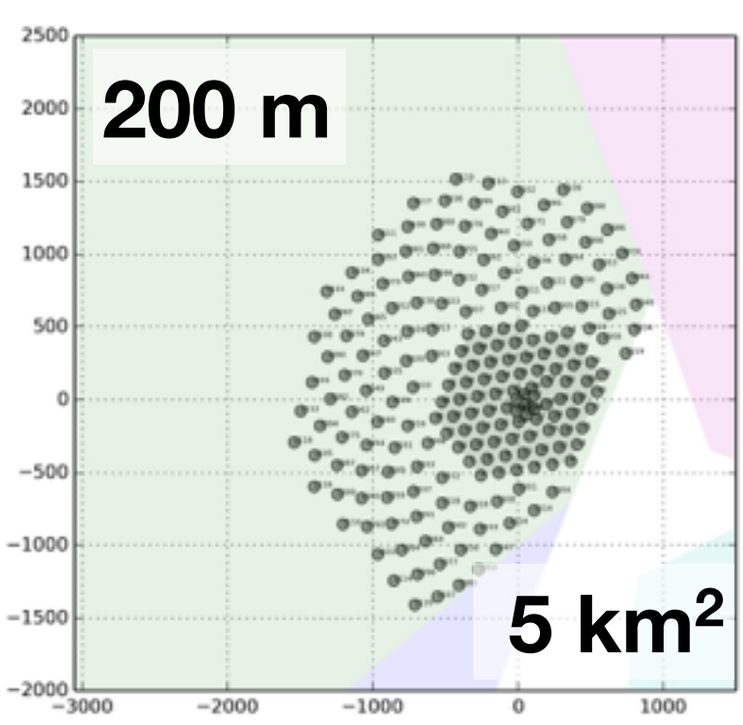


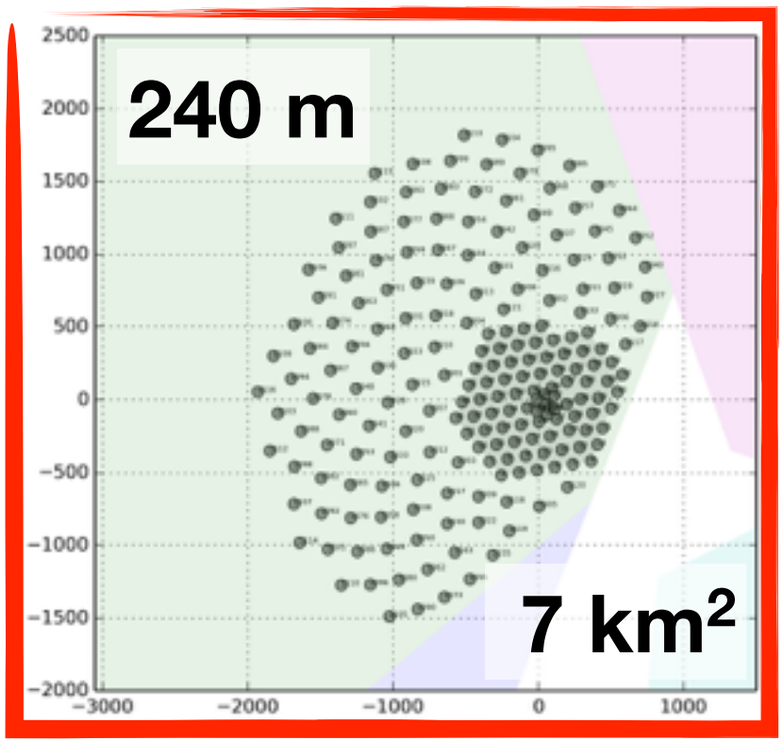
Open questions for neutrino astronomy / Gen2 HEA

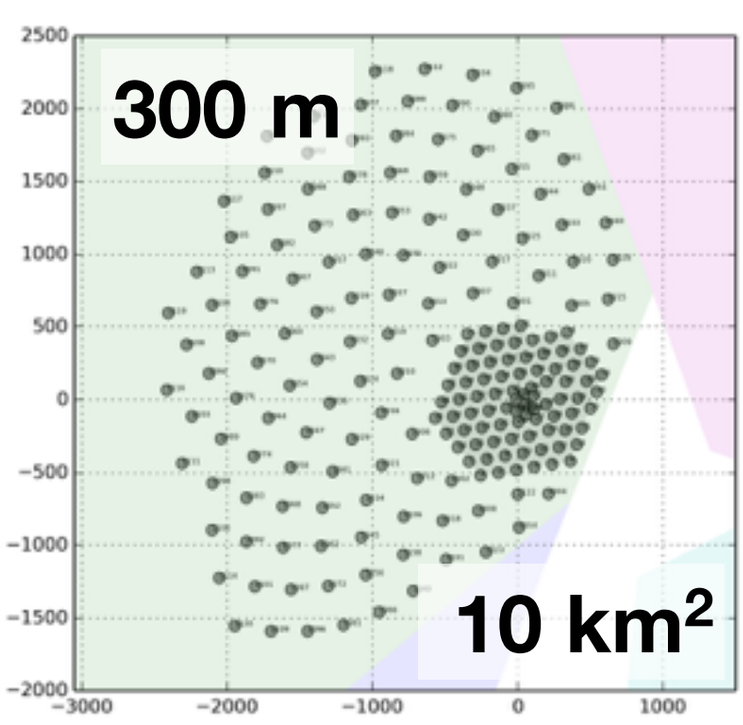
- Resolve the source populations that produce the high energy astrophysical neutrinos detected by IceCube
- Identify the sources of the highest energy cosmic rays
- Learn about the environments responsible for the highest energetic cosmic particles
- Study of galactic and extra-galactic propagation of CR with neutrinos as tracers
- Obtain a unique view into the explosion of stars
- Explore the very high-energy Universe when it was most active

Geometry optimization

- Several layouts under evaluation
- Example: “Sunflower” geometry with different string spacings

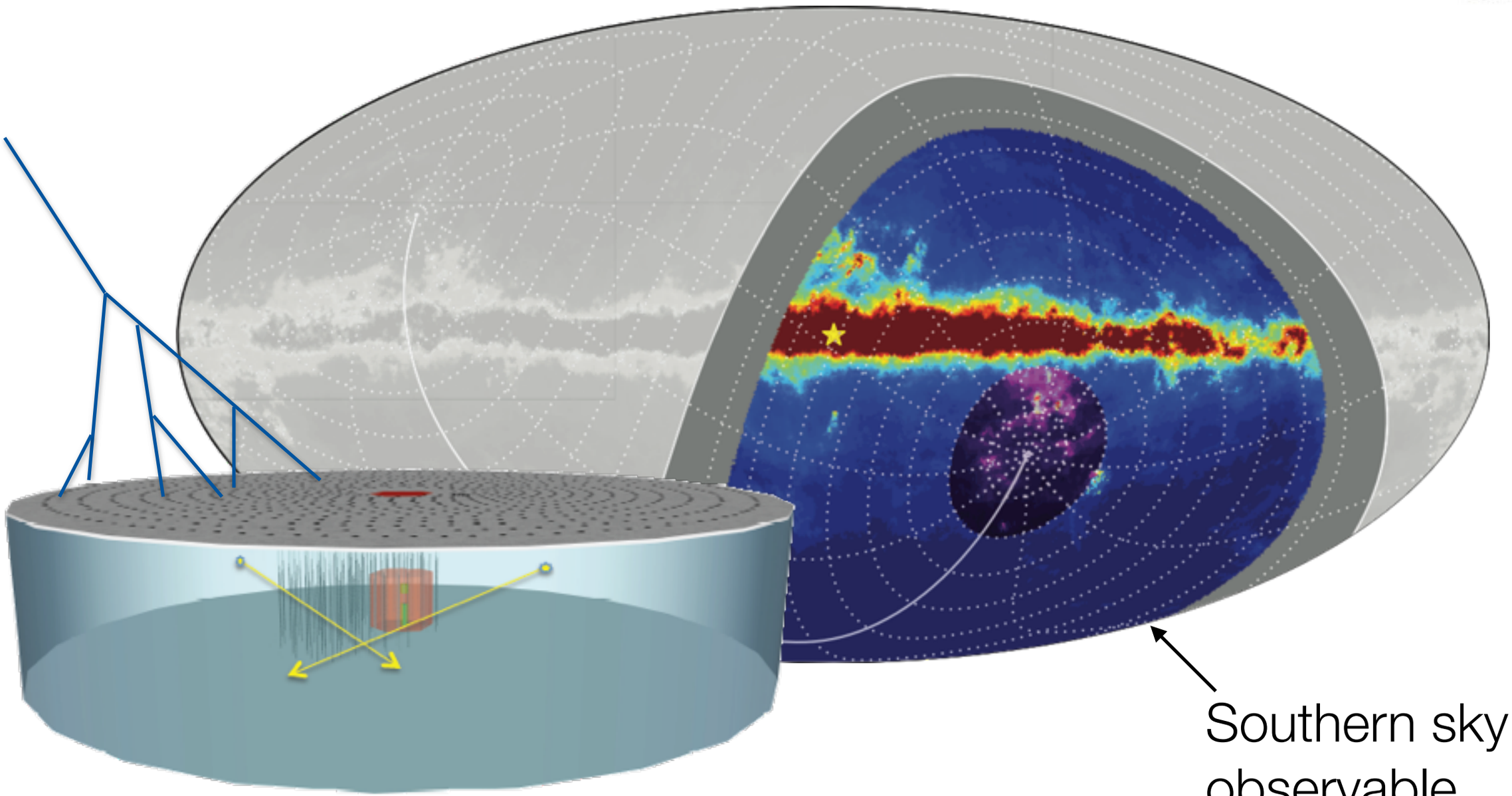






- ~120 new strings, 80 DOMs per string, instrumented over 1.25 km
- ~10 x IC volume for contained event analysis above 200 TeV

Extended surface veto



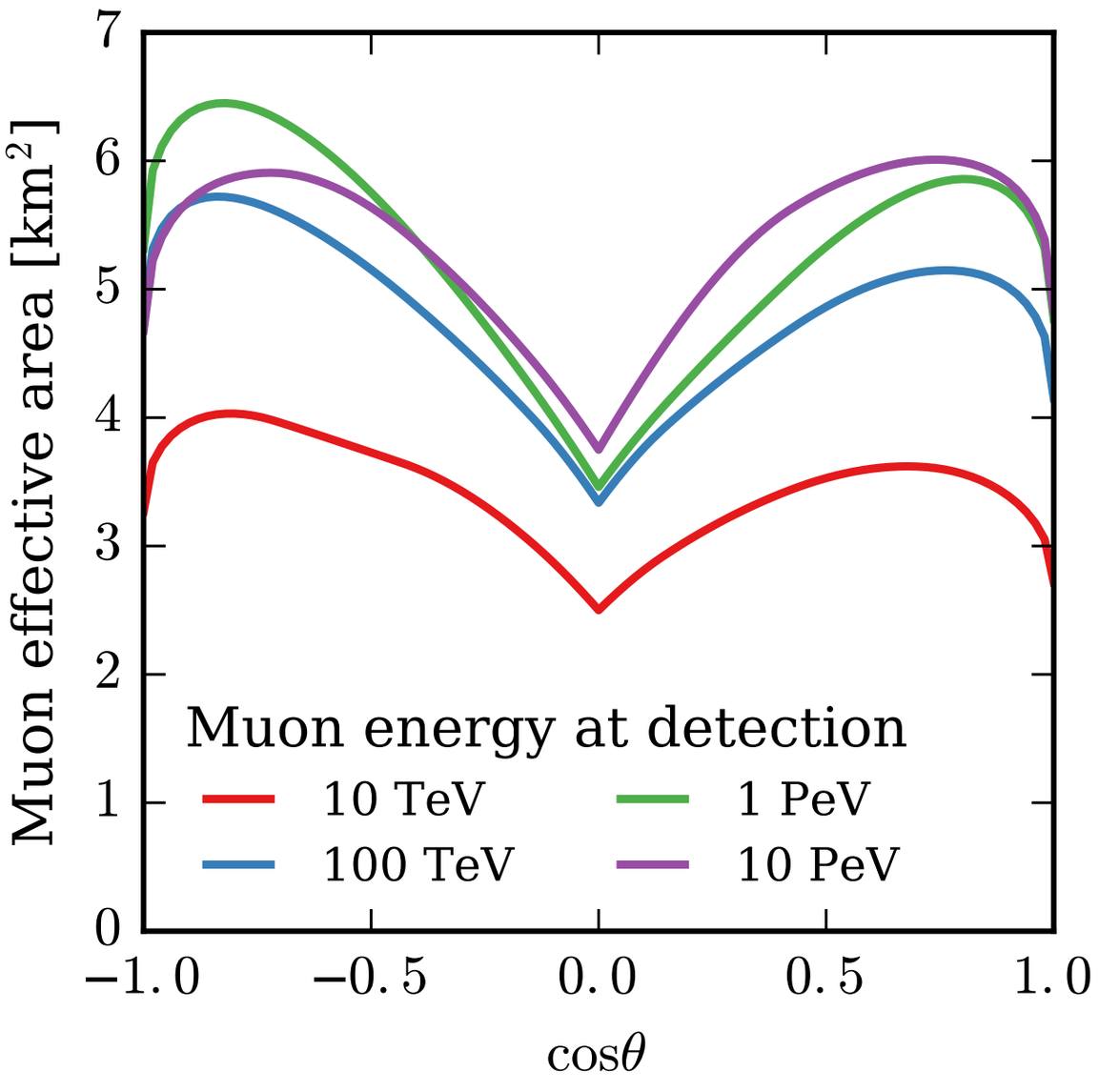
Southern sky observable via surface veto

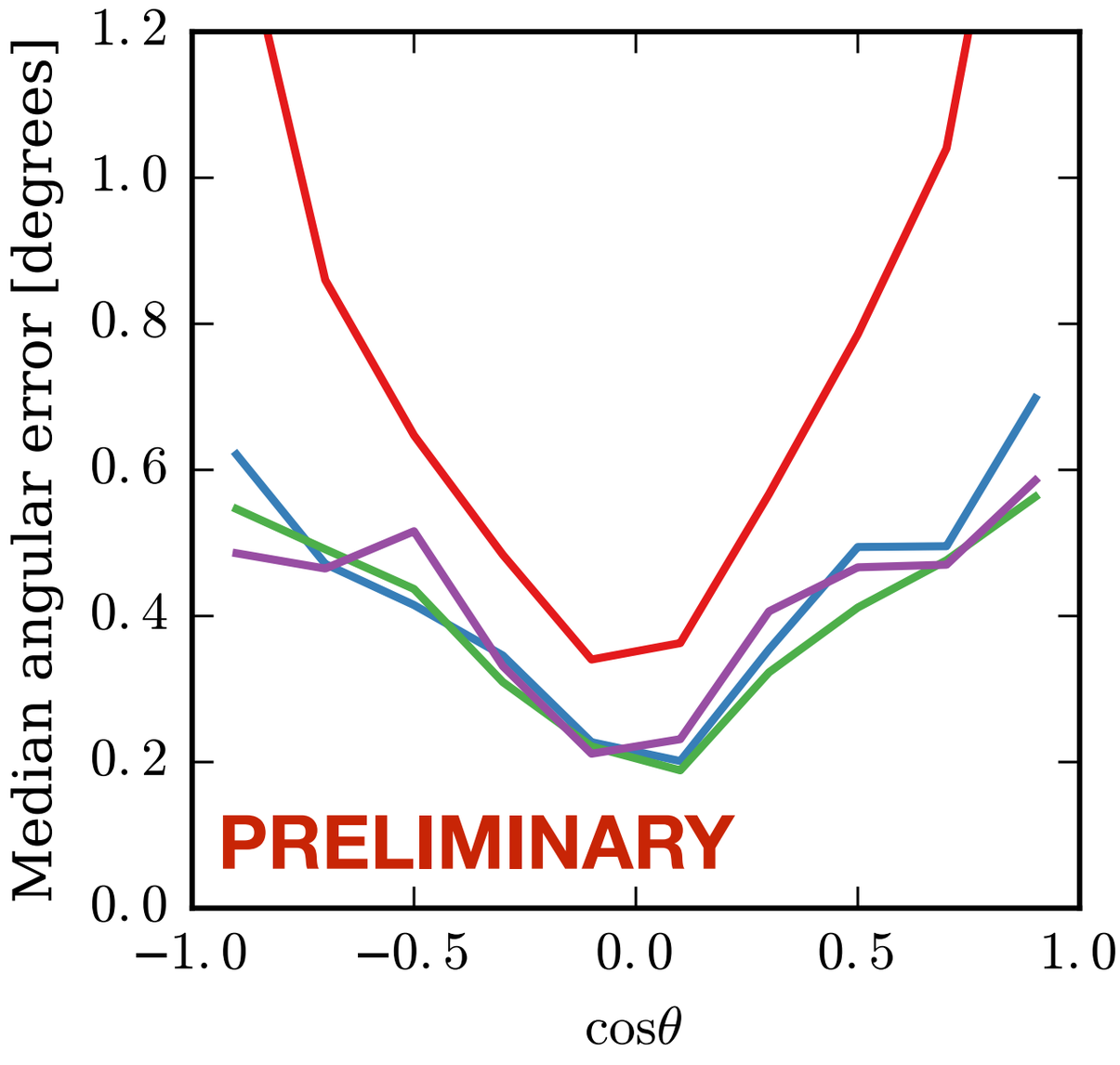
Potential gain for e.g. 75 km² veto:

~2x number of PeV tracks

~2x precision in spectral index

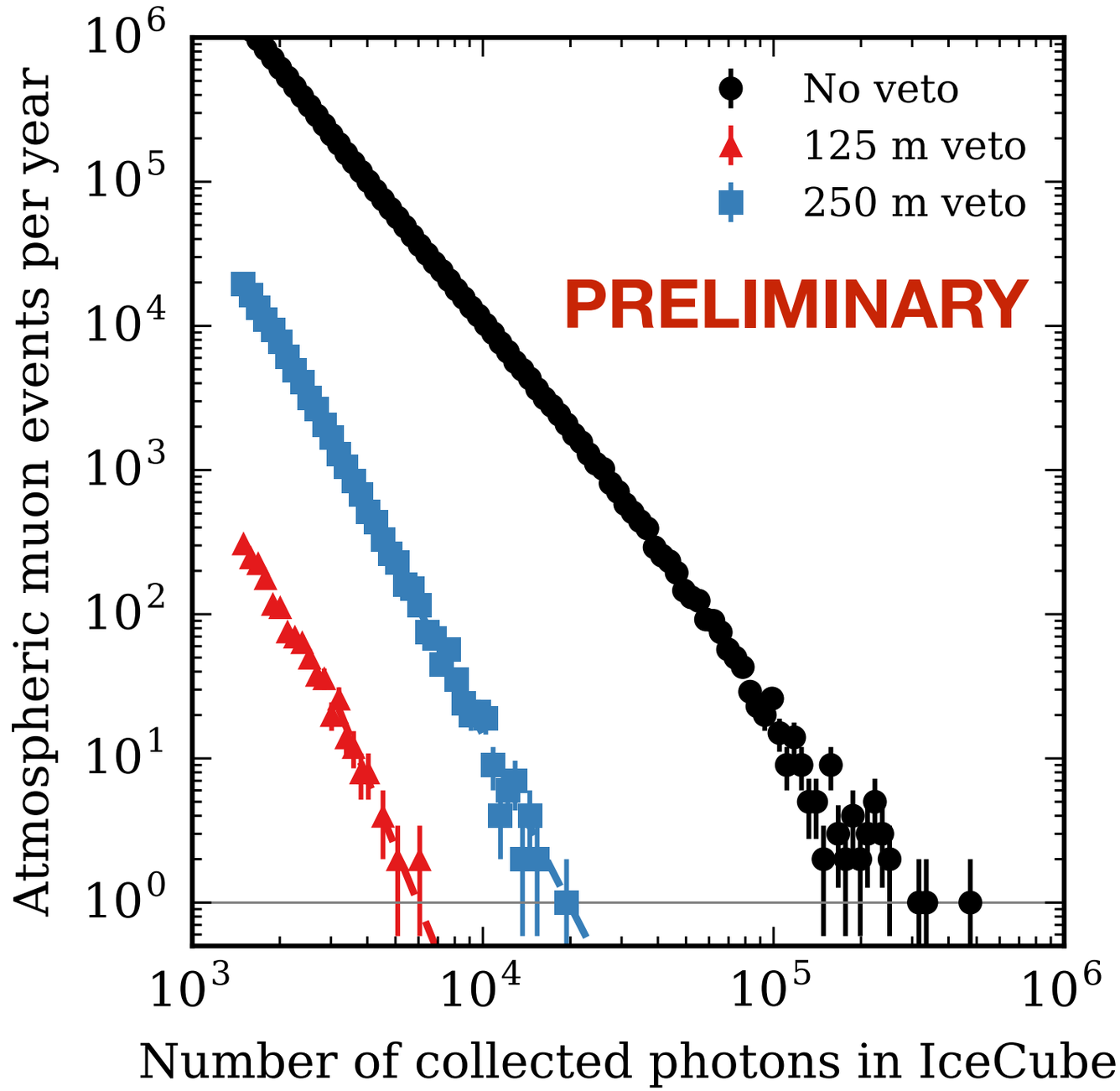
Performance: through-going muons





Penetrating muon background

- Estimate effectiveness of outer-layer veto from IceCube data
- 2x increase in string spacing leads to ~3x increase in effective energy threshold



Predicting event rates in Gen2

Physics

Neutrino flux

ν→μ conversion efficiency

Detector performance

Geometric area

Selection efficiency

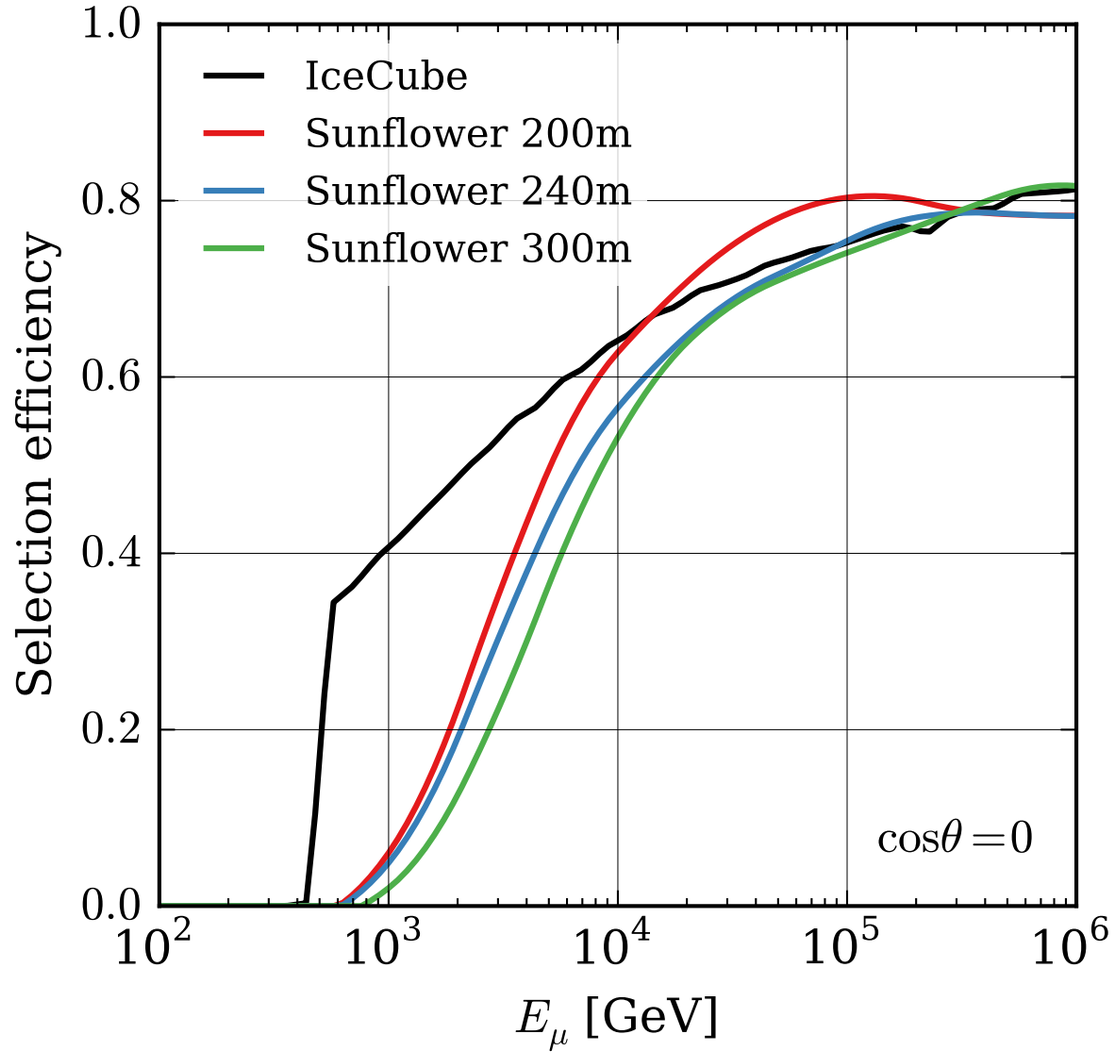
Angular resolution

Energy resolution

Observable distribution

Example:

Selection efficiency

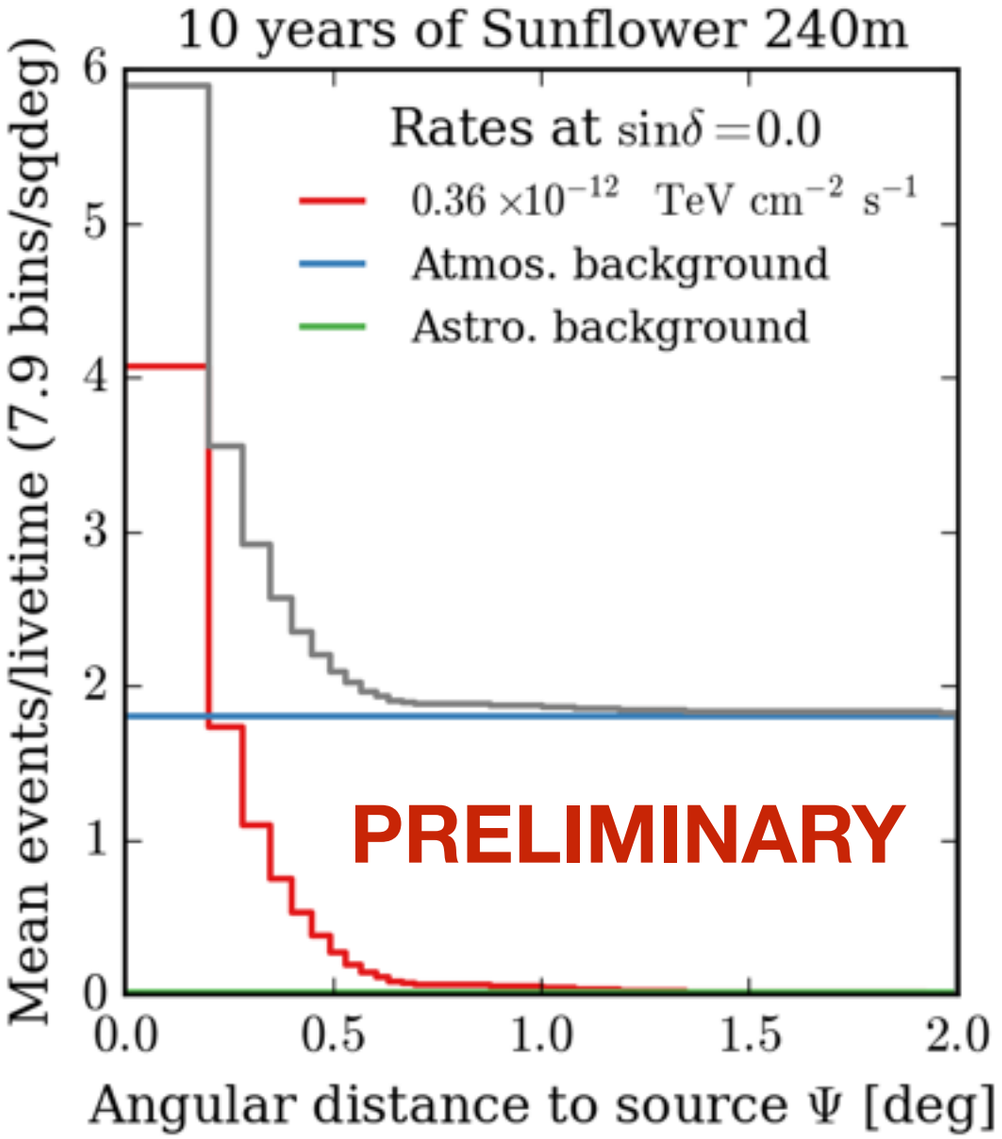


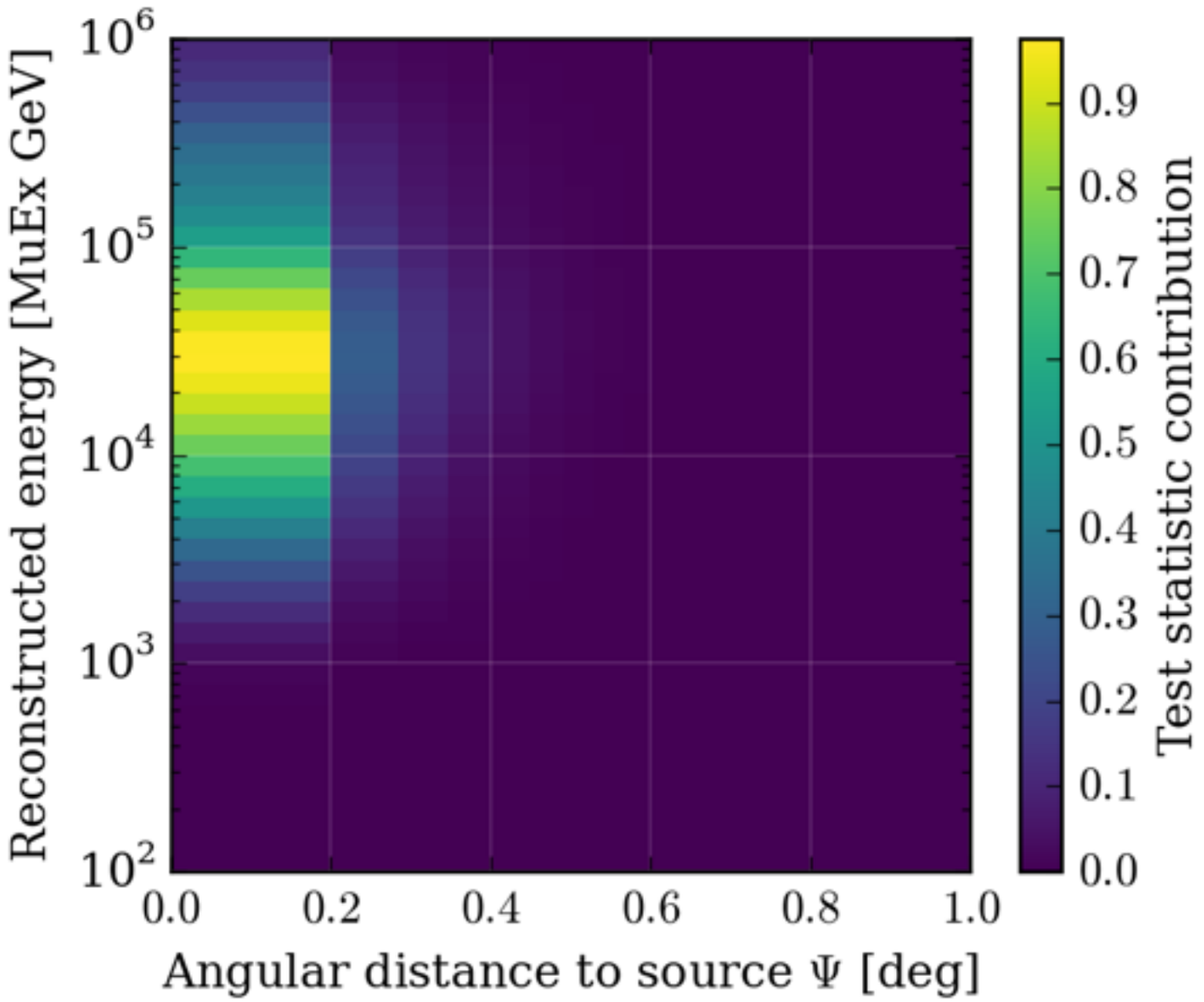
Event rates

Event type	10–100 TeV	100–1000 TeV	1–10 PeV	>10 PeV
Contained cascades	0 (2.6)	**20** (4.4)	**15** (1.6)	**2** (0.2)
Surface vetoed muons	0 (0)	**9.7** (0.06)	**4.8** (0.051)	**1.2** (0.014)
Upgoing muons	**100** (37)	**55** (16)	**11** (3.2)	**1.6** (0.47)

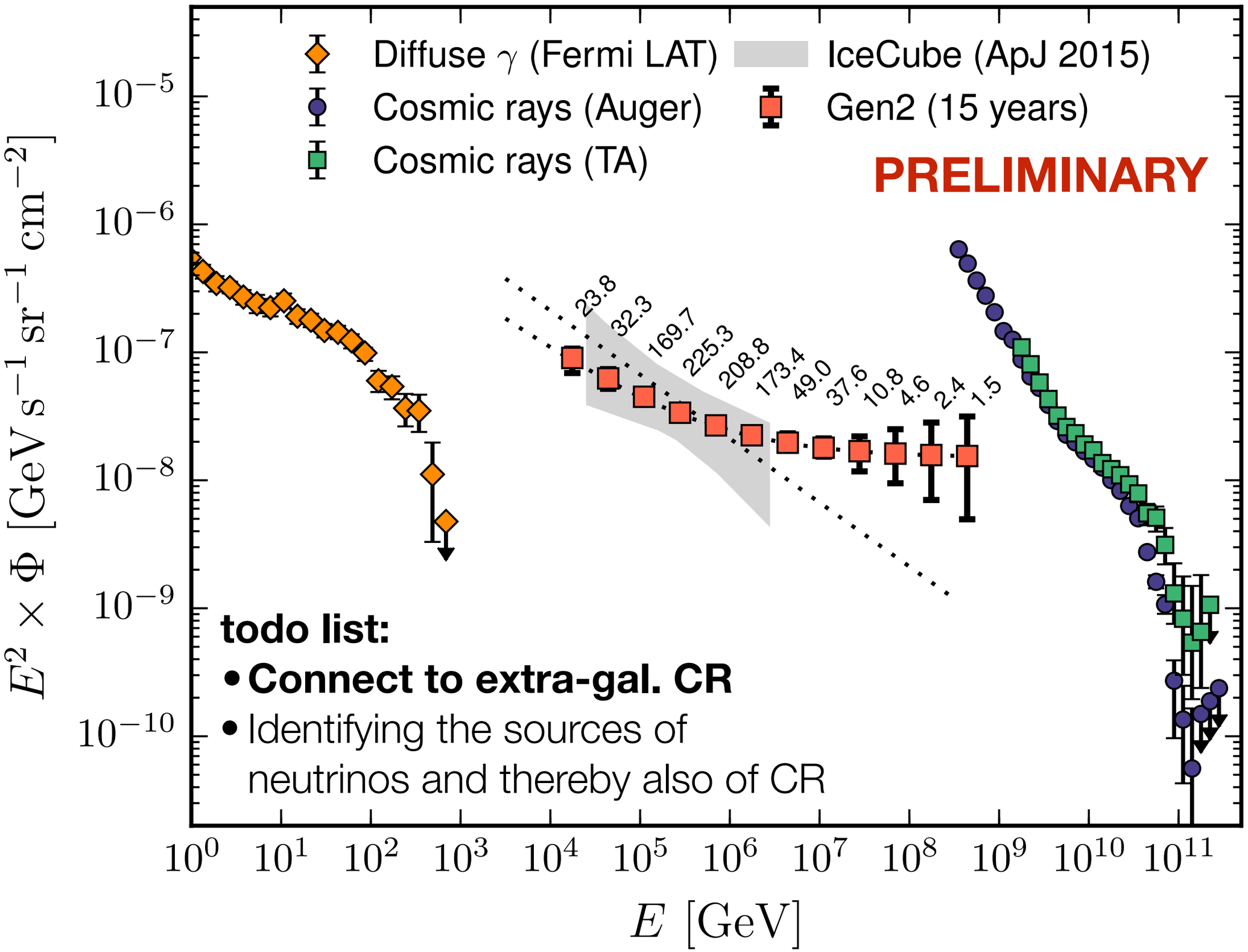
Number of neutrinos per year in **Gen2** (IceCube), assuming $E^2\Phi_\nu = 0.95\text{x}10^{-18}$ (Ev/100 TeV)$^{-0.13}$ GeV cm^{-2} sr^{-1} s^{-1} per flavor

Discovering a point source with Gen2

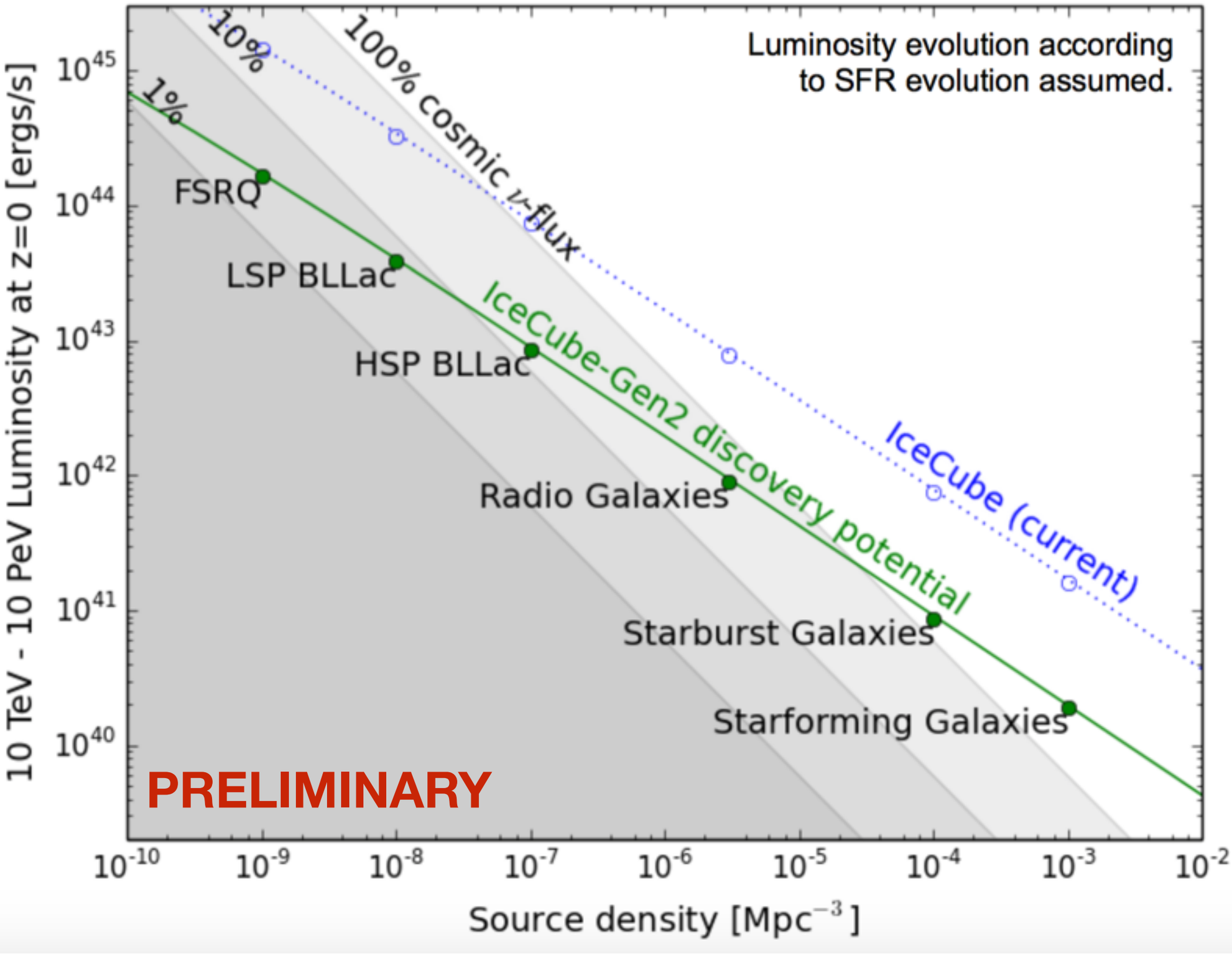




Resolving the mysteries of the UHE Universe

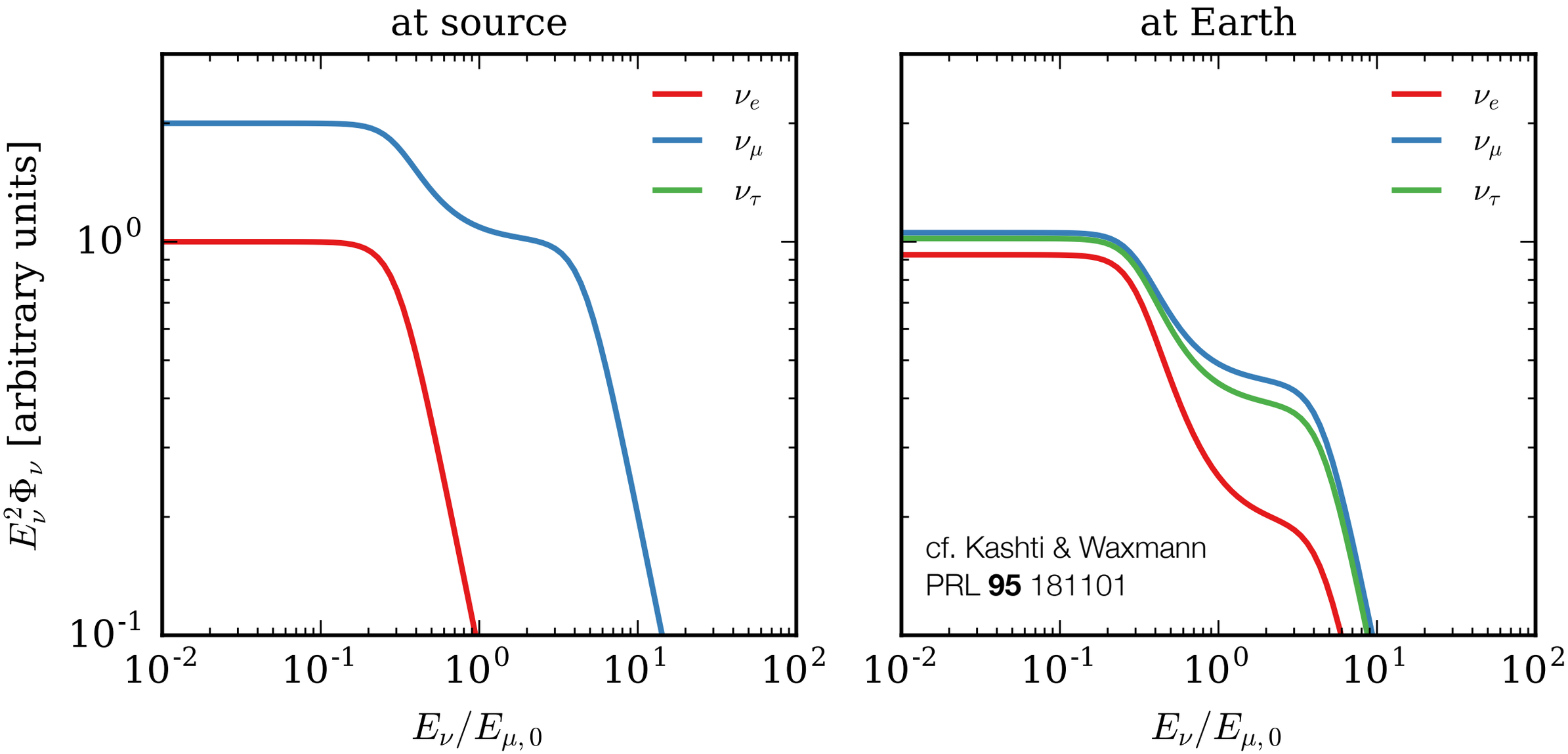


Finding the sources of HE neutrinos

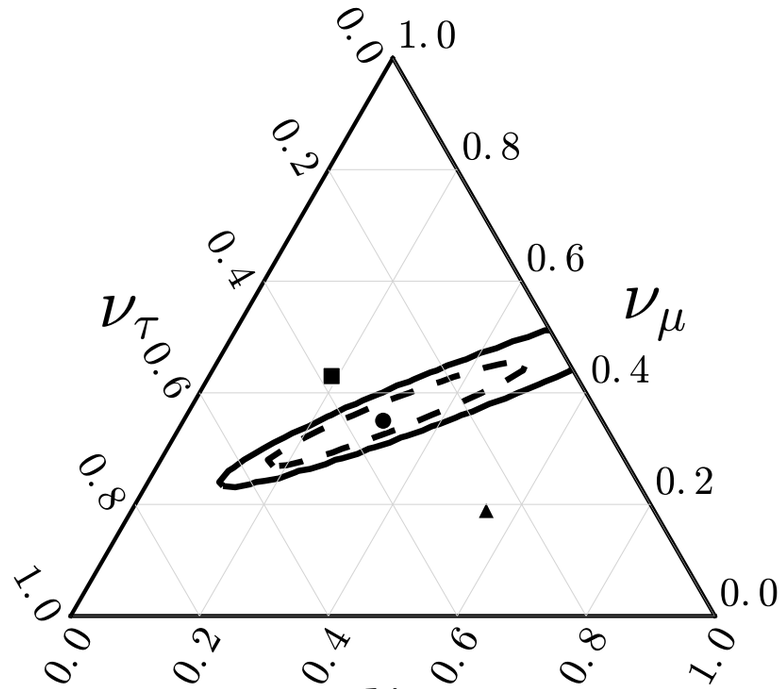


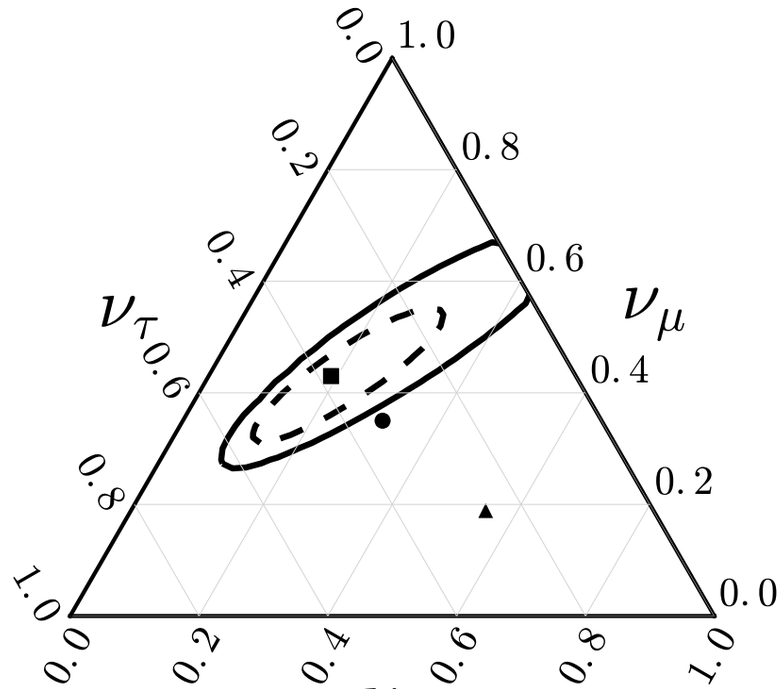
Probing acceleration environments

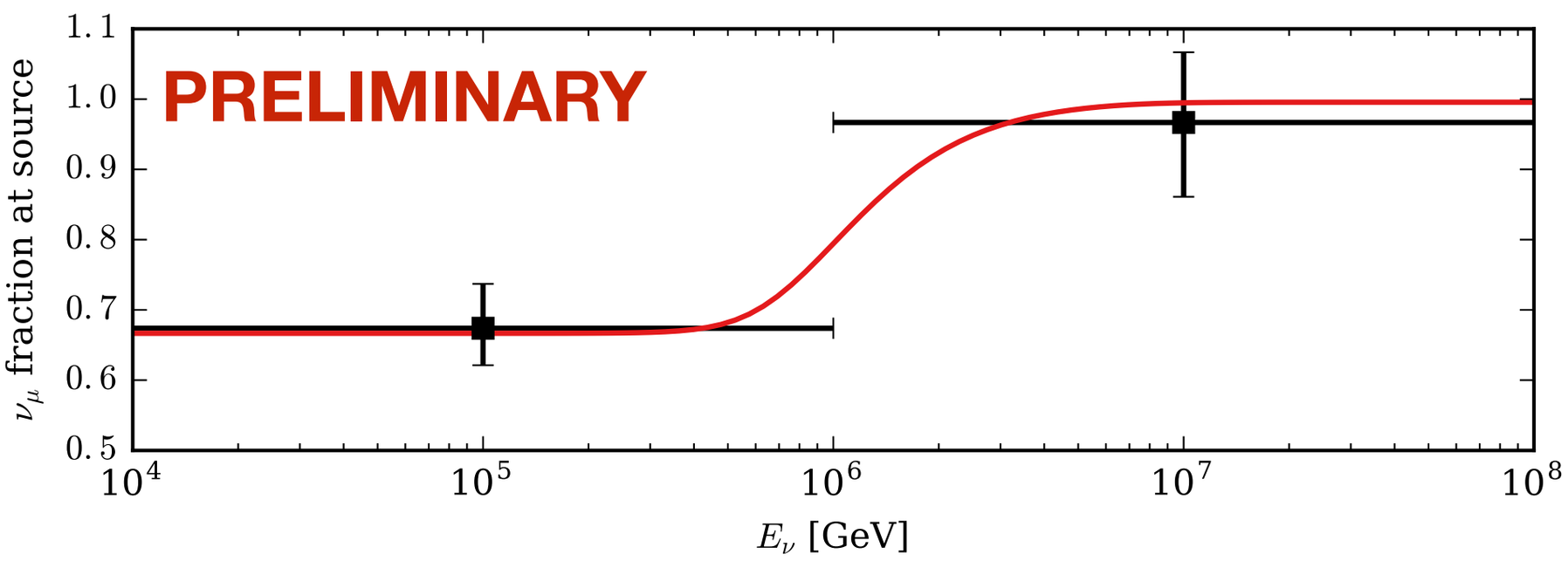
- Synchrotron cooling in the sources affects muons more
- Energy- and flavor-dependent cutoff, distinct from progenitor cutoff



Probing acceleration environments



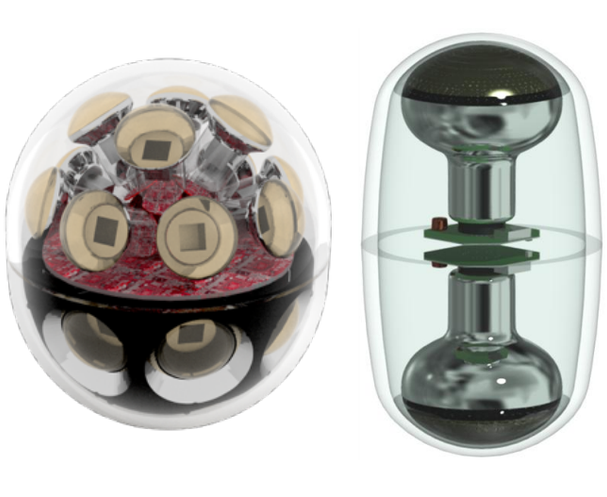




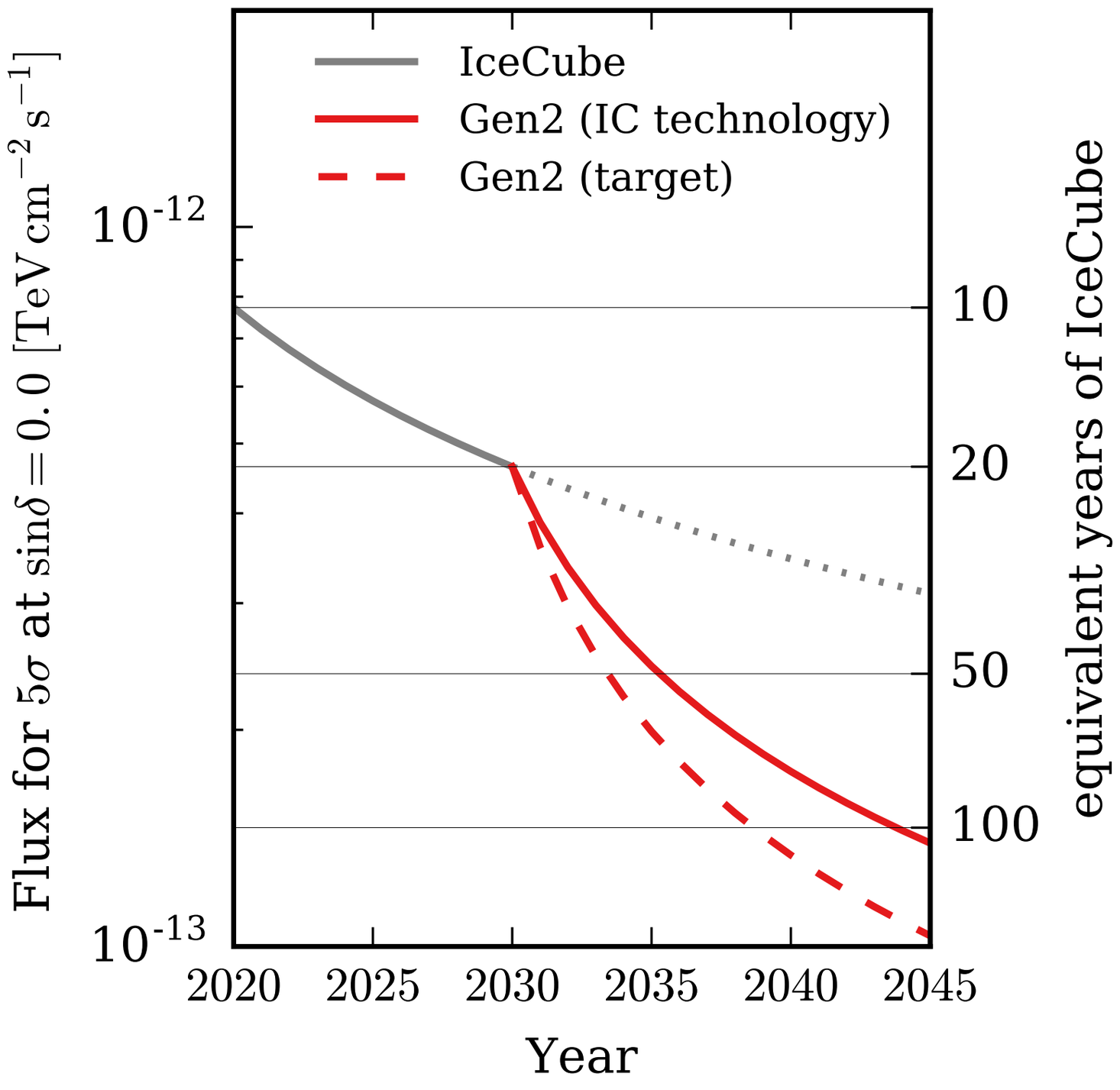
Gen2 can detect a flavor-dependent cutoff at PeV energies!

Point source sensitivity

- "Just a big IceCube" has ~four times the point source sensitivity
- Significant performance improvements expected from new sensors:



Sensitivity to steady point sources



New sensor designs for improved performance

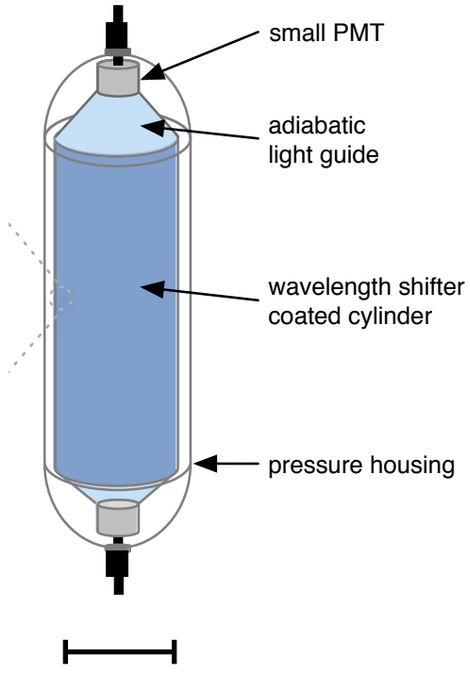
mDOM

- Directional information
- More sensitive area per module

D-Egg

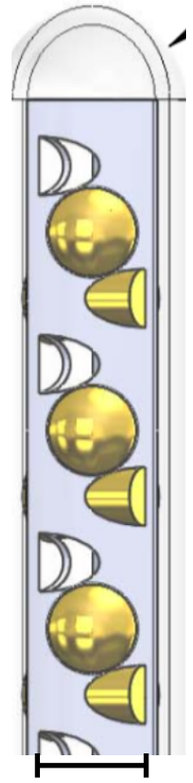
- Directional information
- More sensitive area per module
- Smaller geometry

WOM



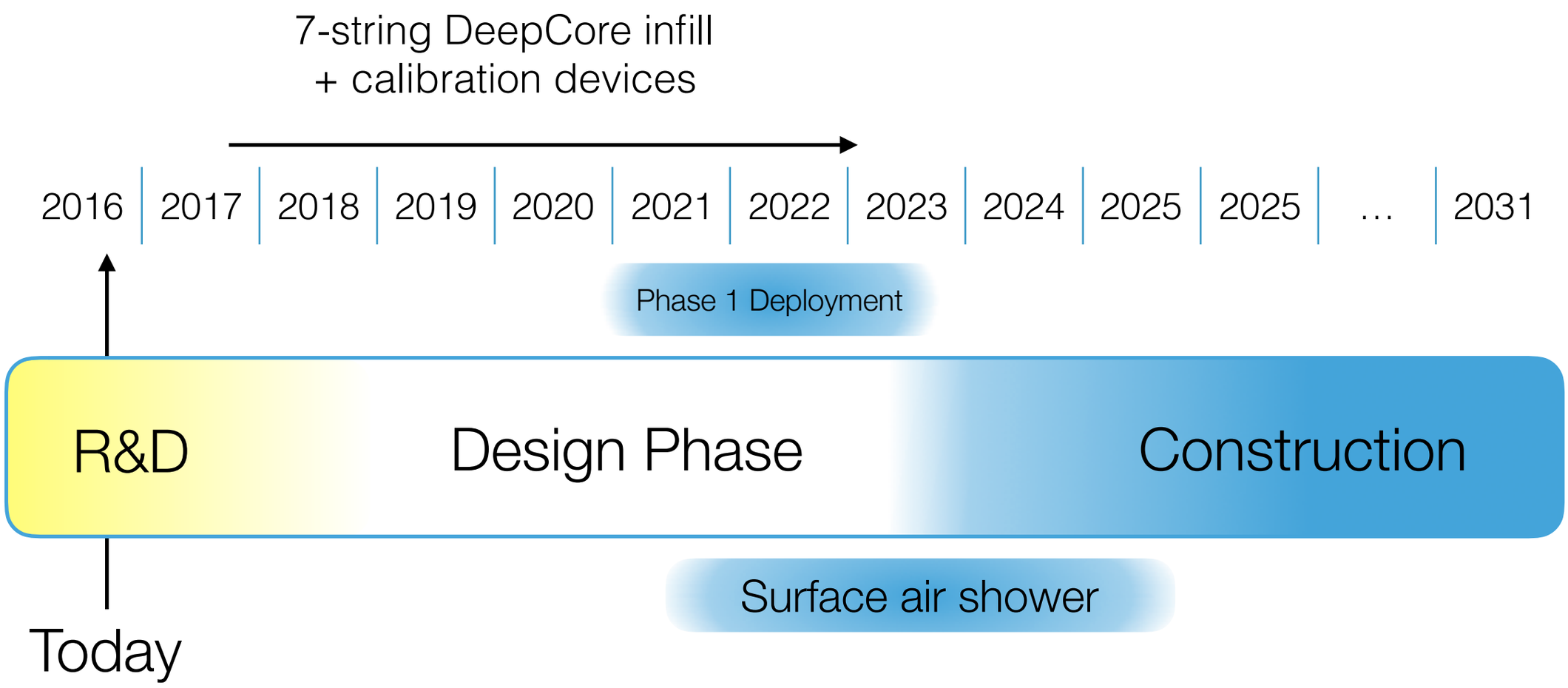
- more sensitive area per $
- Small diameter
- Lower noise rate

LOM



- Small diameter
- Directional info.
- More area per module

Preliminary timeline



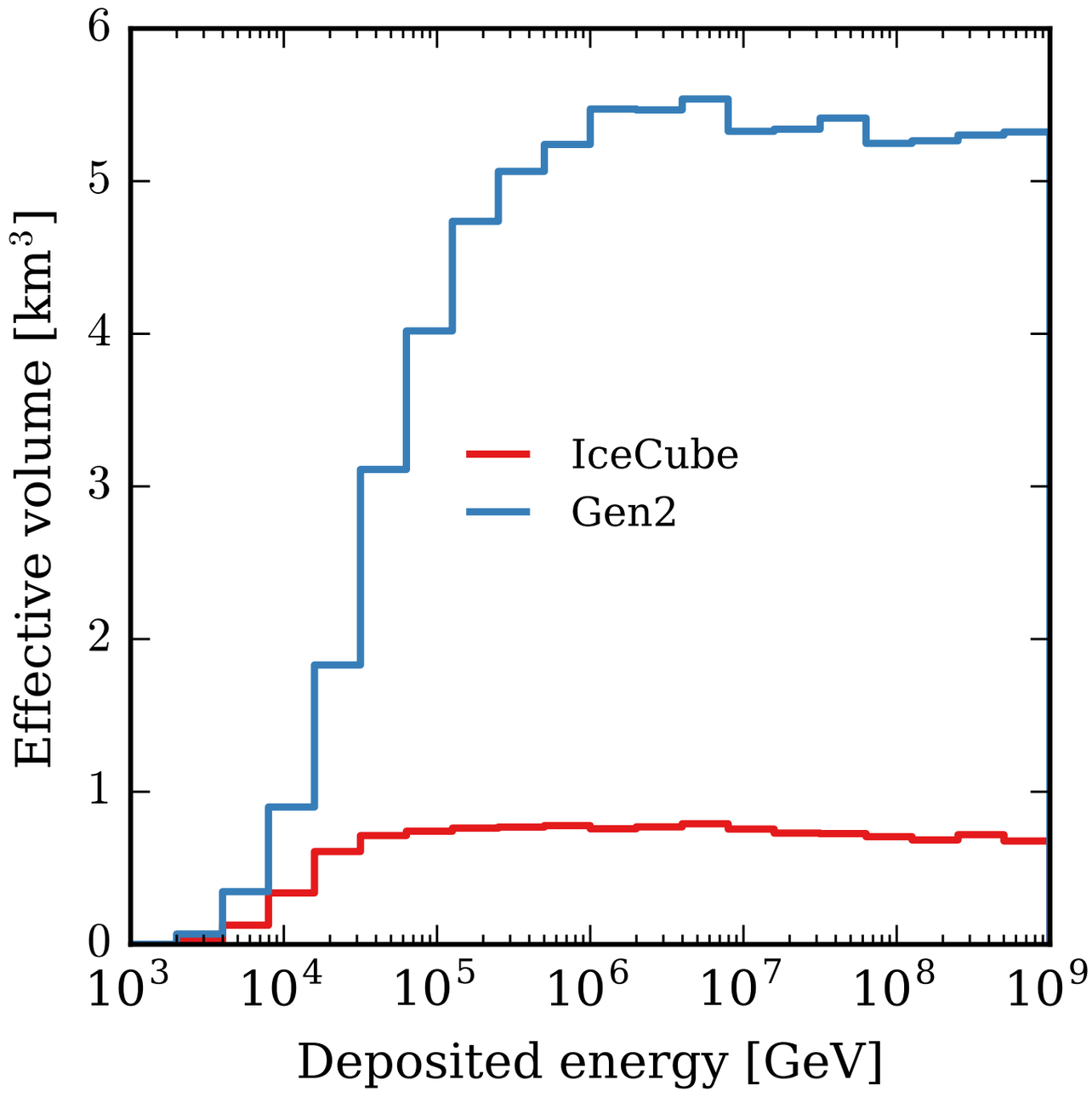
The way forward

- Science case maturing
- Reconstruction performance improving
- White paper in preparation
- Converging to a multi-phase proposal

Thank you!

Backup

Performance: starting events



The IceCube–PINGU Collaboration

International Funding Agencies

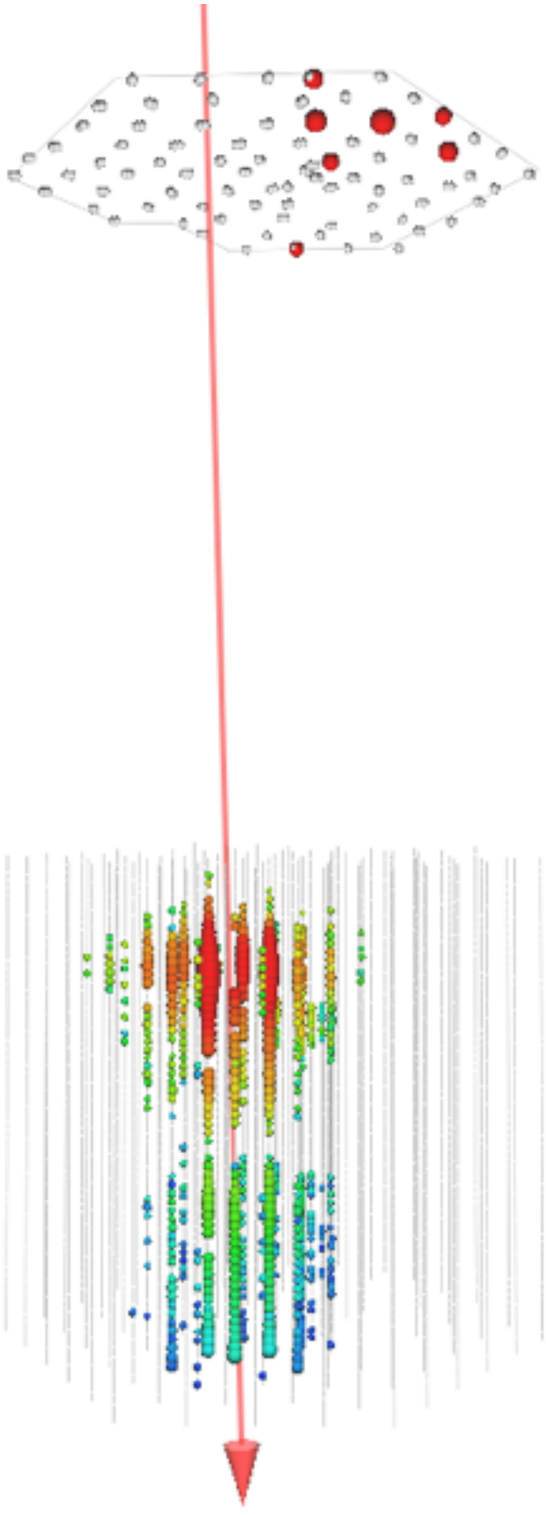
Fonds de la Recherche Scientifique (FRS–FNRS)
Fonds Wetenschappelijk Onderzoek–Vlaanderen (FWO–Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen–Synchrotron (DESY)
Inoue Foundation for Science, Japan
Knut and Alice Wallenberg Foundation
NSF–Office of Polar Programs
NSF–Physics Division
Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

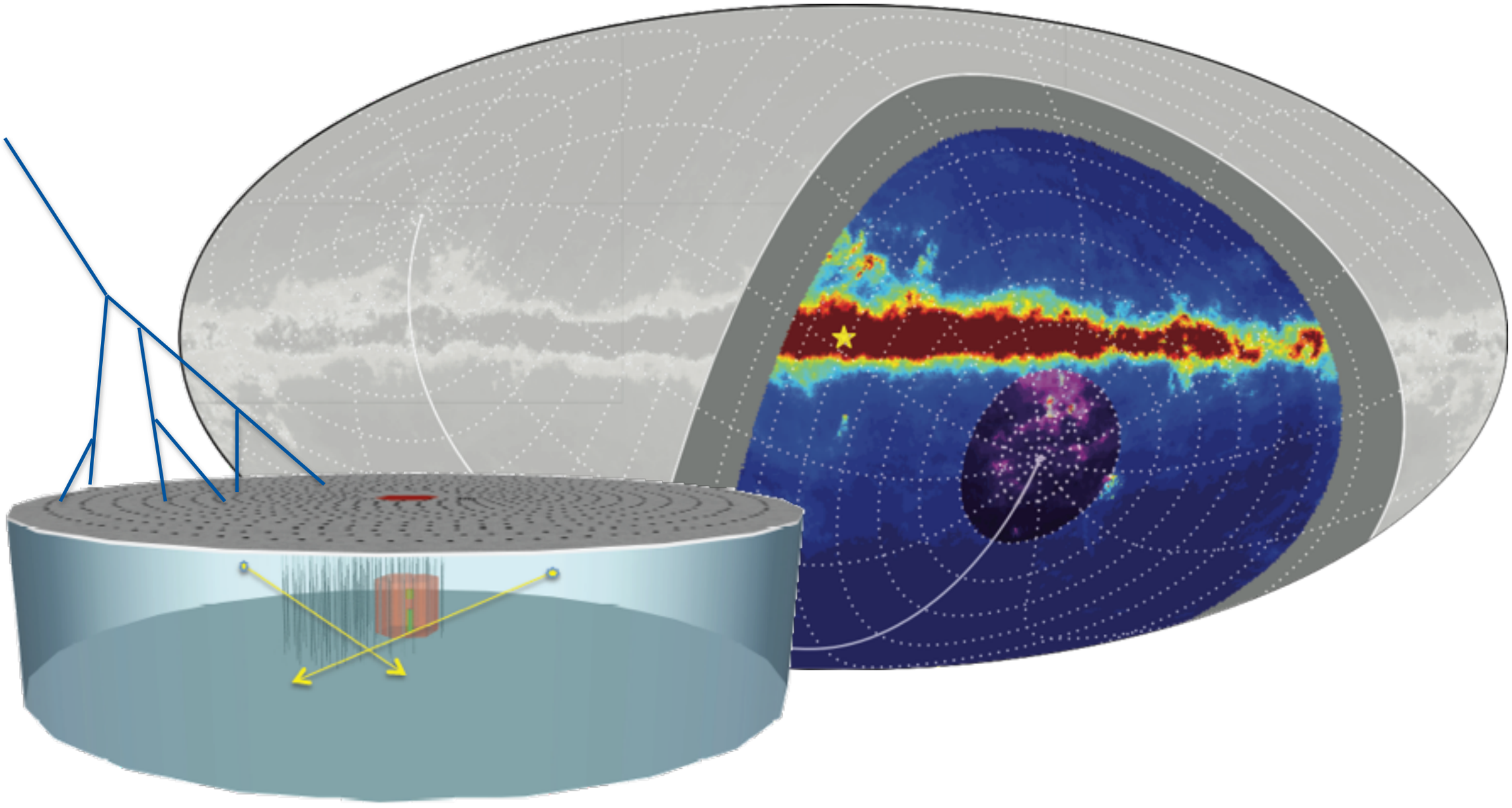
The IceCube–PINGU Collaboration

International Funding Agencies

Fonds de la Recherche Scientifique (FRS–FNRS)
Fonds Wetenschappelijk Onderzoek–Vlaanderen (FWO–Vlaanderen)
Federal Ministry of Education & Research (BMBF)
German Research Foundation (DFG)
Deutsches Elektronen–Synchrotron (DESY)
Inoue Foundation for Science, Japan
Knut and Alice Wallenberg Foundation
NSF–Office of Polar Programs
NSF–Physics Division
Swedish Polar Research Secretariat
The Swedish Research Council (VR)
University of Wisconsin Alumni Research Foundation (WARF)
US National Science Foundation (NSF)

Downgoing neutrinos





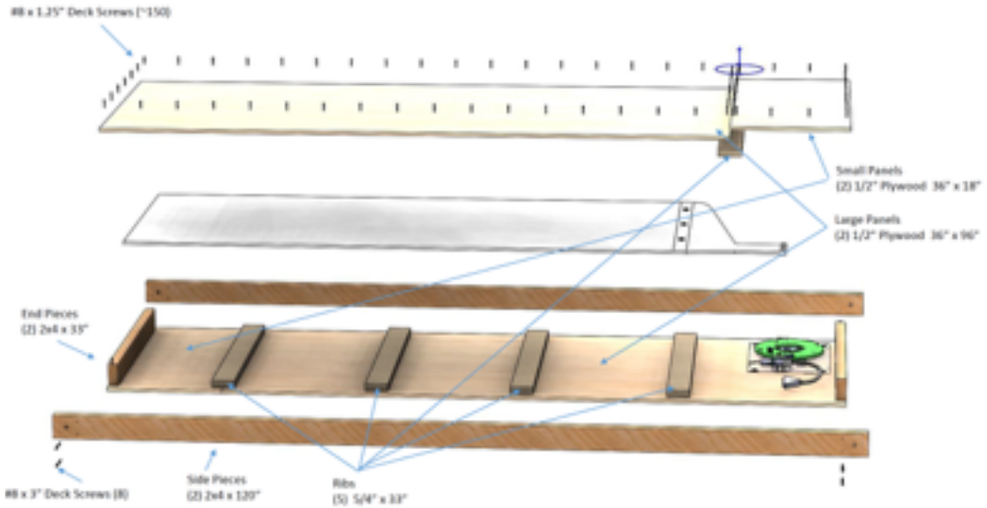
Surface veto technologies

IceTop tanks

1.8 m

- Deployment requires heavy equipment & power
- Segmented
- Operated at South Pole since 2007

Scintillator panels



3 m

- Easy deployment
- Low cost (cheap materials and small PMTs)
- Segmented
- Prototype in testing at South Pole

See T17.5 (this session)

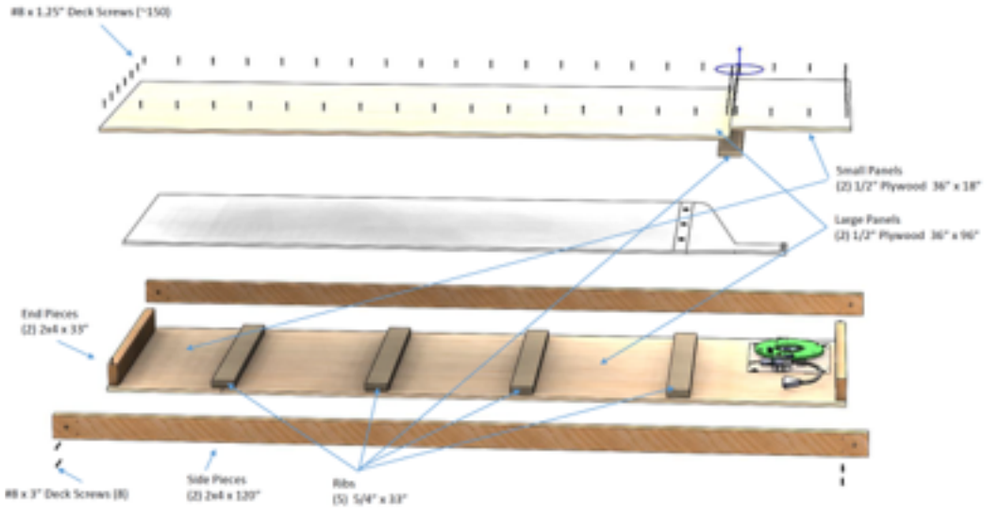
Surface veto technologies

IceTop tanks

1.8 m

- Deployment requires heavy equipment & power
- Segmented
- Operated at South Pole since 2007

Scintillator panels



3 m

- Easy deployment
- Low cost (cheap materials and small PMTs)
- Segmented
- Prototype in testing at South Pole

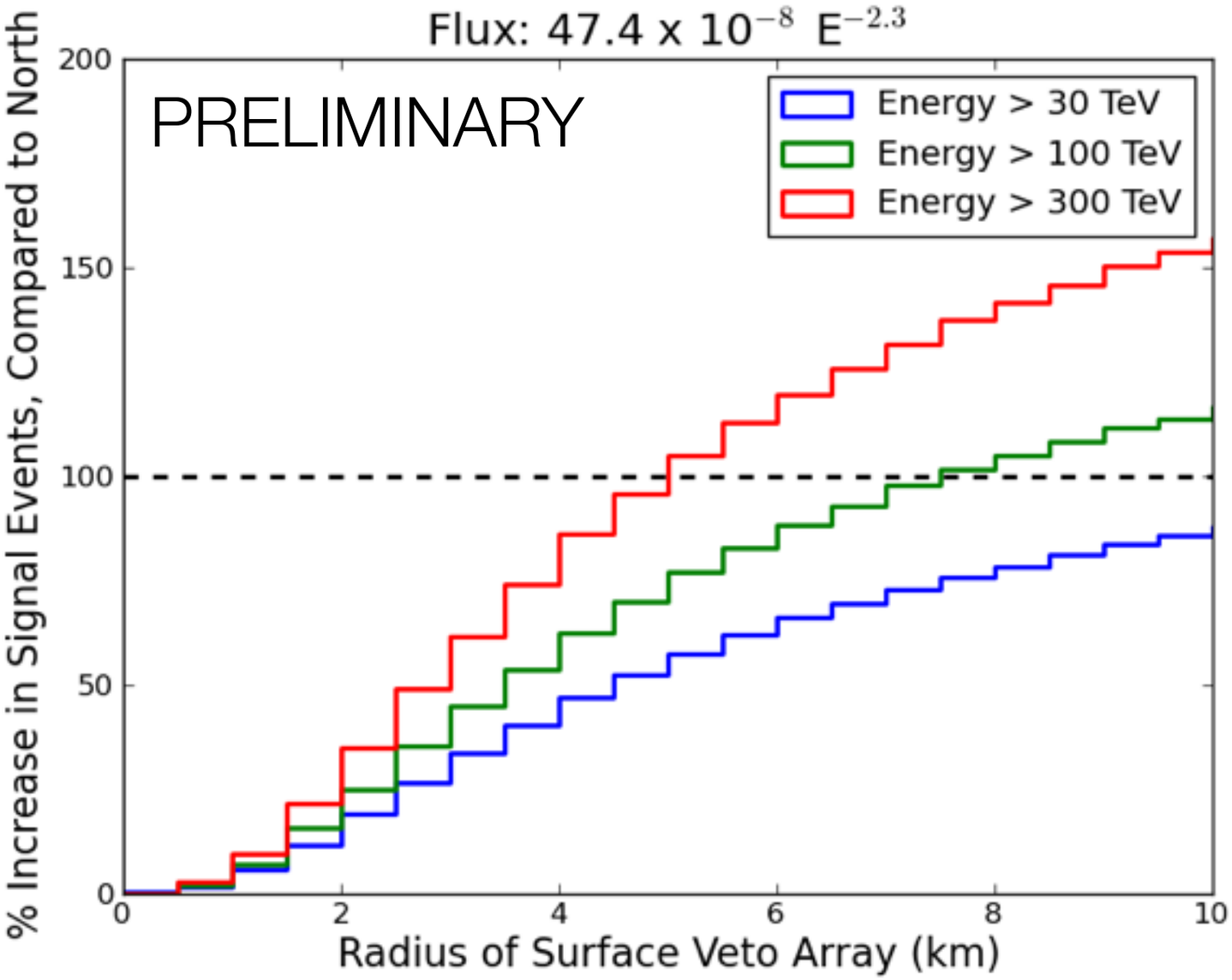
Air Cherenkov telescopes

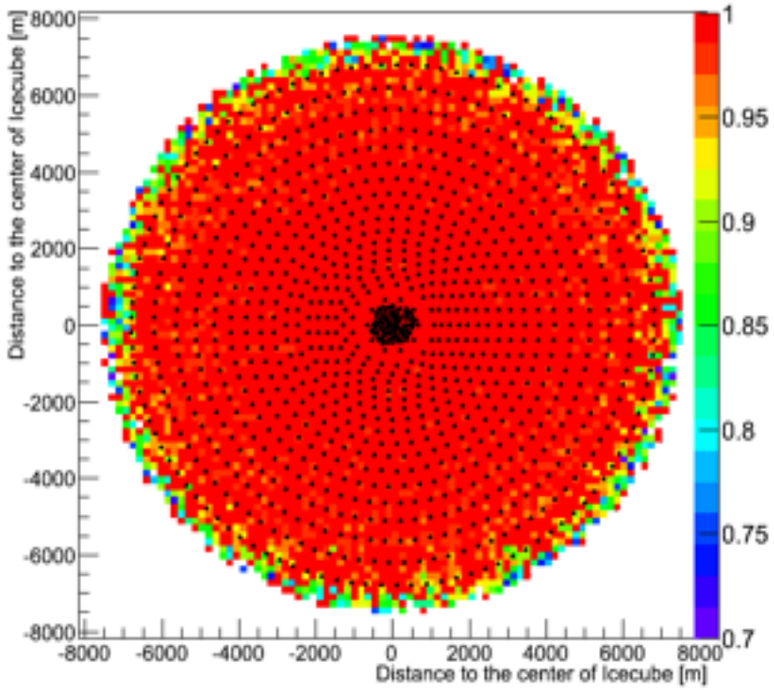
1 m

- Not segmented
- Low energy threshold
- Low duty cycle
- Prototype deployed at South Pole

See T17.5 (this session)

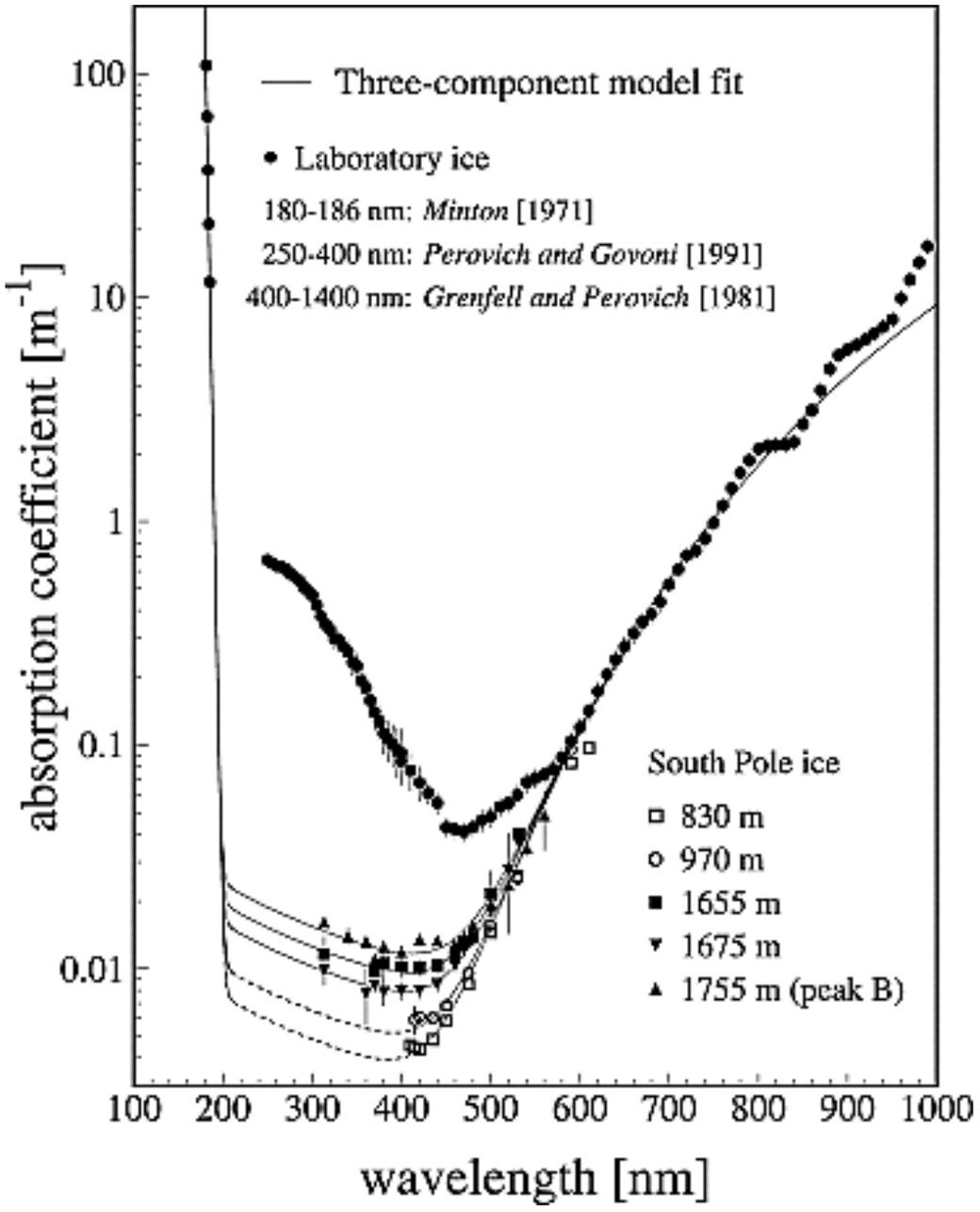
Vetoing cosmic rays at the surface



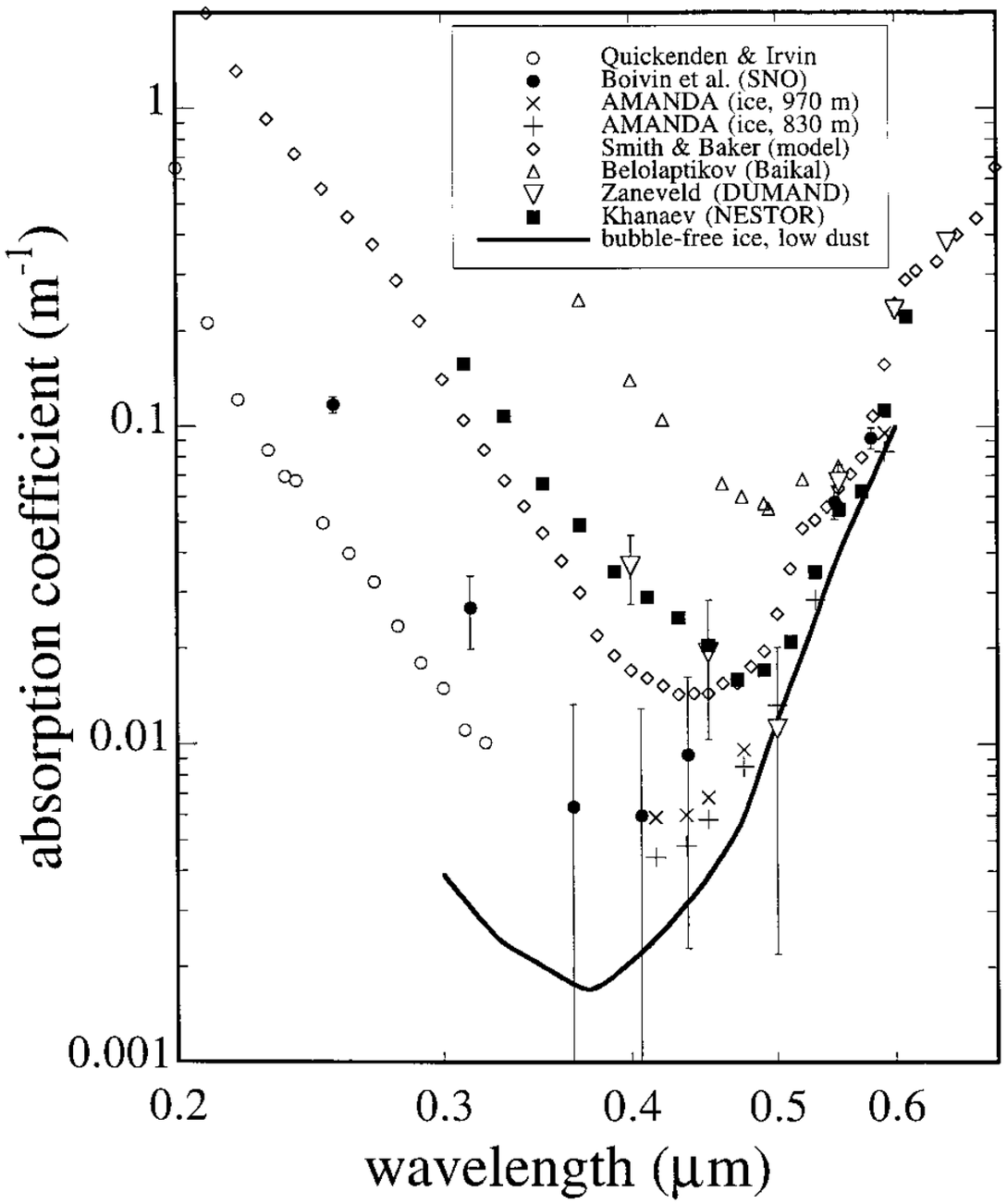


See T17.5 (this session)

UV transmission in ice



Ackermann, M., et al. (2006), Optical properties of deep glacial ice at the South Pole, J. Geophys. Res., 111, D13203, doi: 10.1029/2005JD006687.



Price (1997). Applied Optics, 36(9)