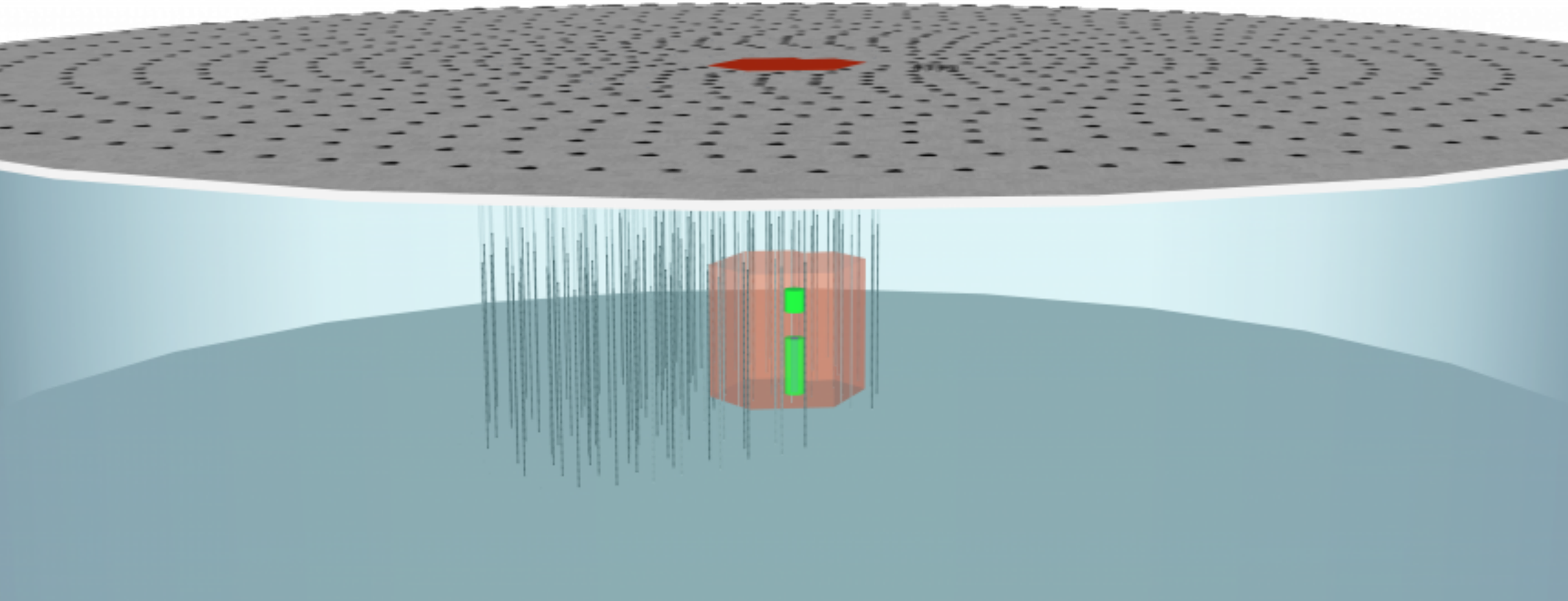
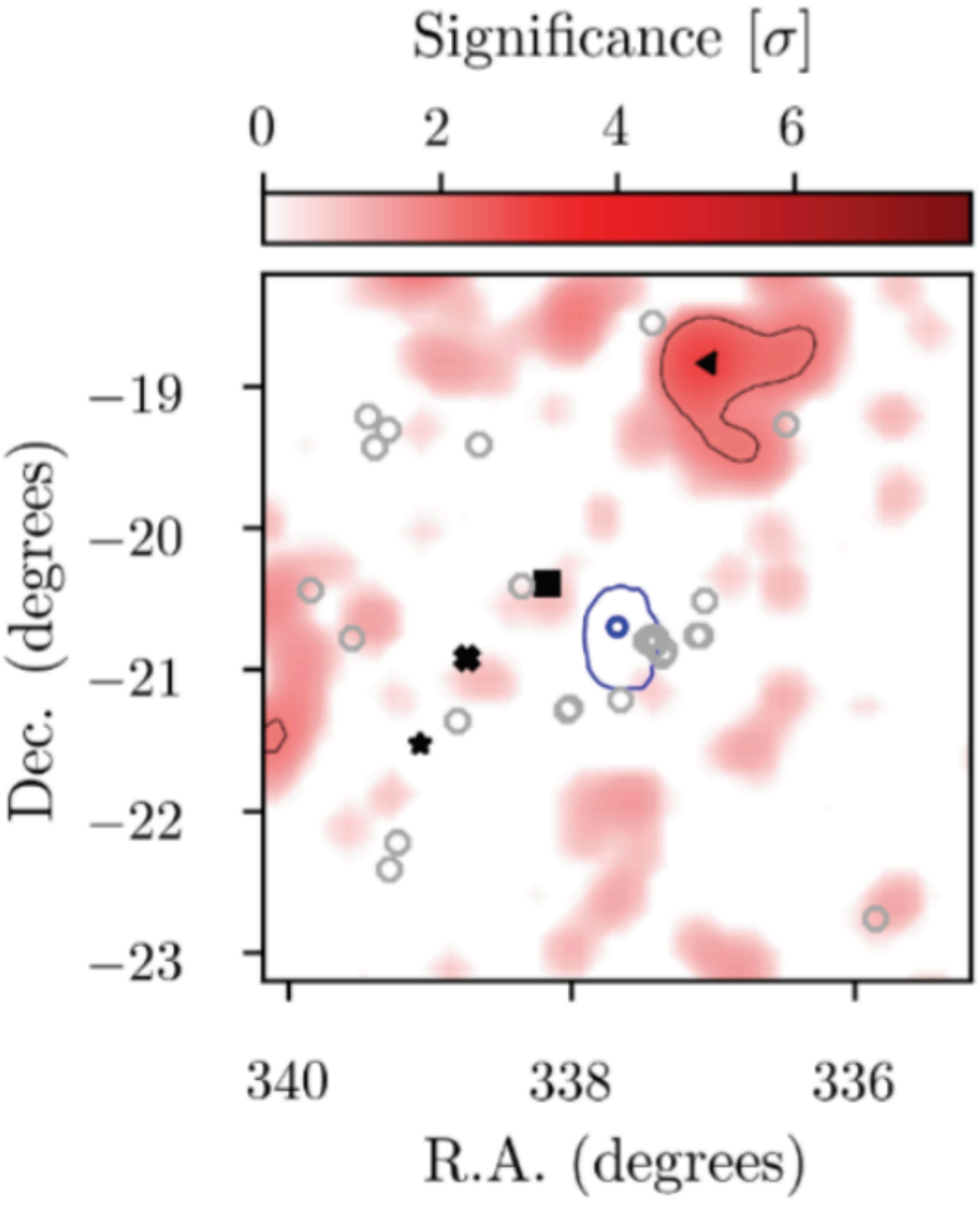
IceCube-Gen2

Marek Kowalski
Madison 04/28/2019



Science: sources of high-energy neutrinos

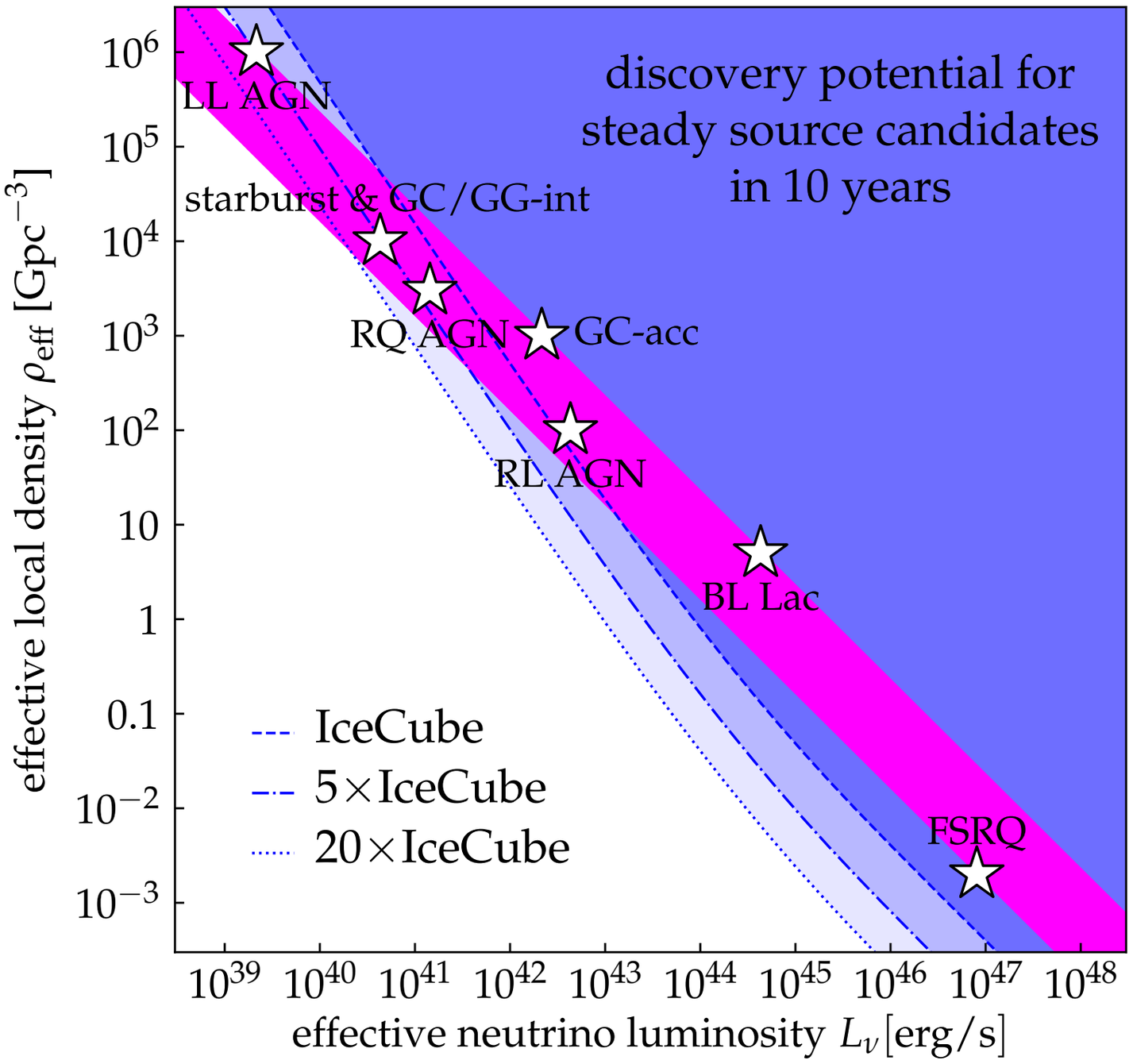


- So far only 1-2 EHE nu_mu counter parts identified
- ~90% of the IceCube flux still unidentified!

T. Gauch, GeV sky-map around IC190331A
https://gcn.gsfc.nasa.gov/gcn3/24028.gcn3

Science: sources of high-energy neutrinos

Requirements for Gen2



- So far only 1-2 EHE nu_mu counter parts identified
- ~90% of the IceCube flux still unidentified.
- **We need (at least) 5 x IC sensitivity** for all populations

decadal survey white paper
arXiv:1903.04334

Science: spectrum of high-energy neutrinos

Requirements for Gen2

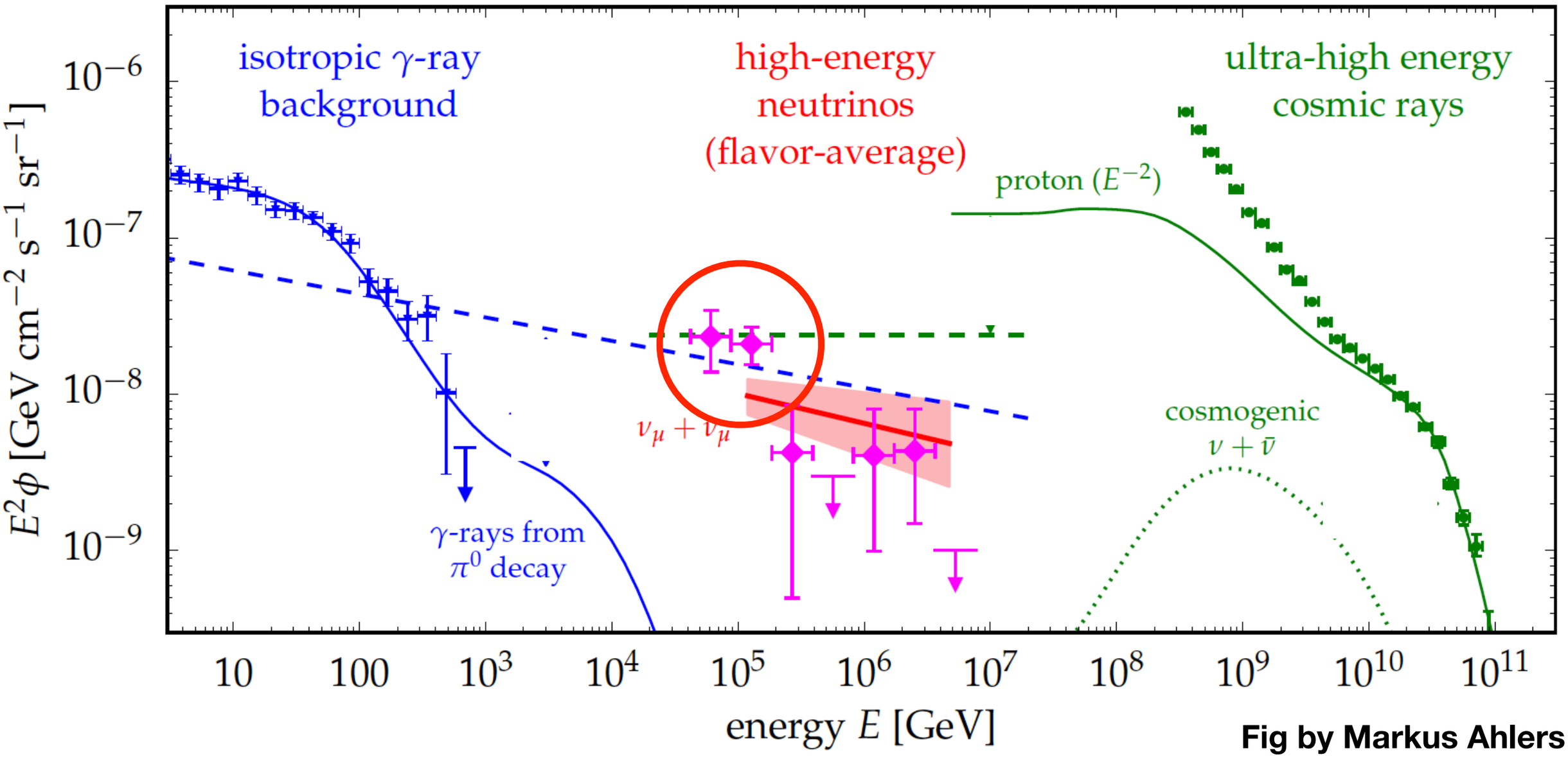


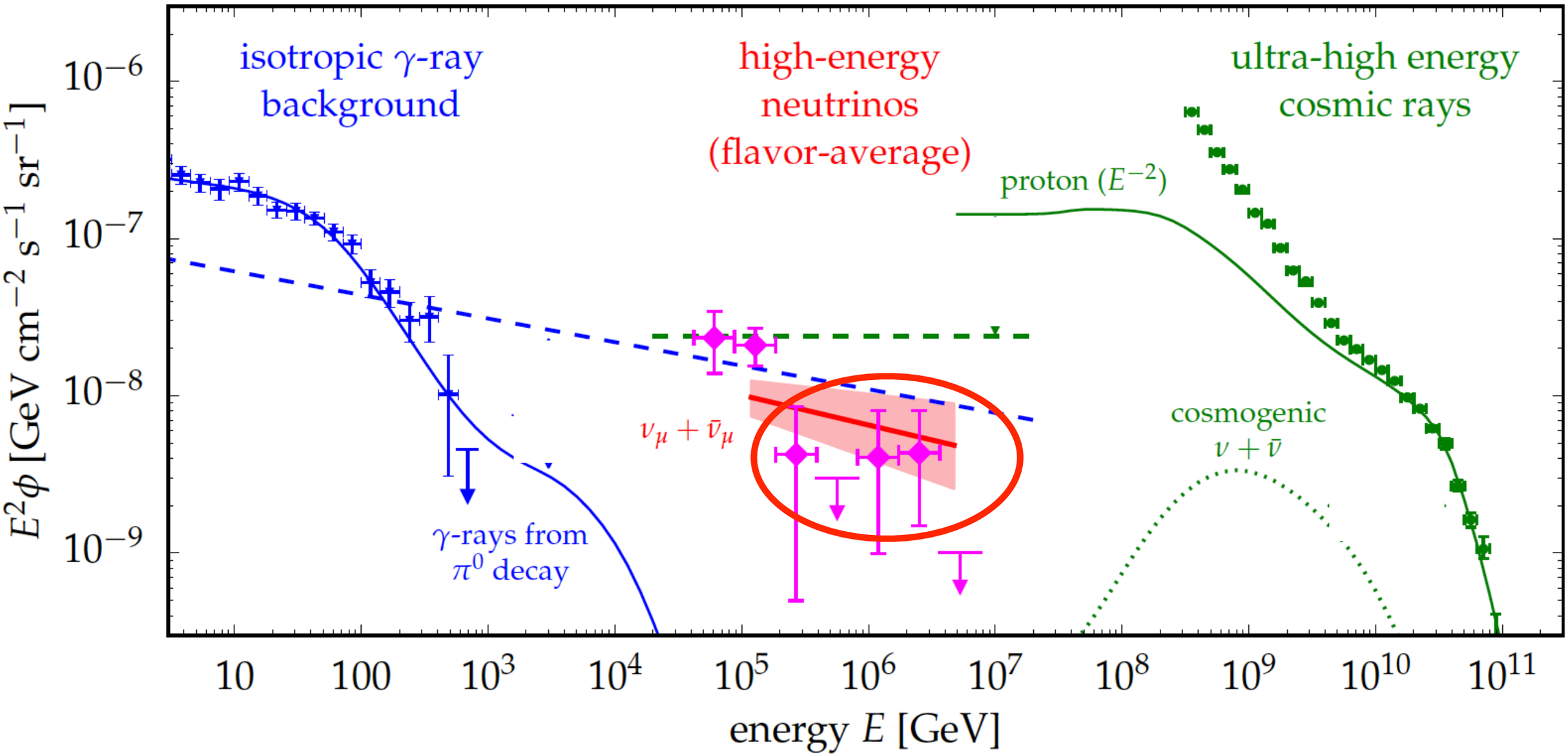
Fig by Markus Ahlers

Does the energy spectrum steepen at low energies?

What are the hidden sources? ⟹**Large sensitivity at 100 TeV**

Science: spectrum of high-energy neutrinos

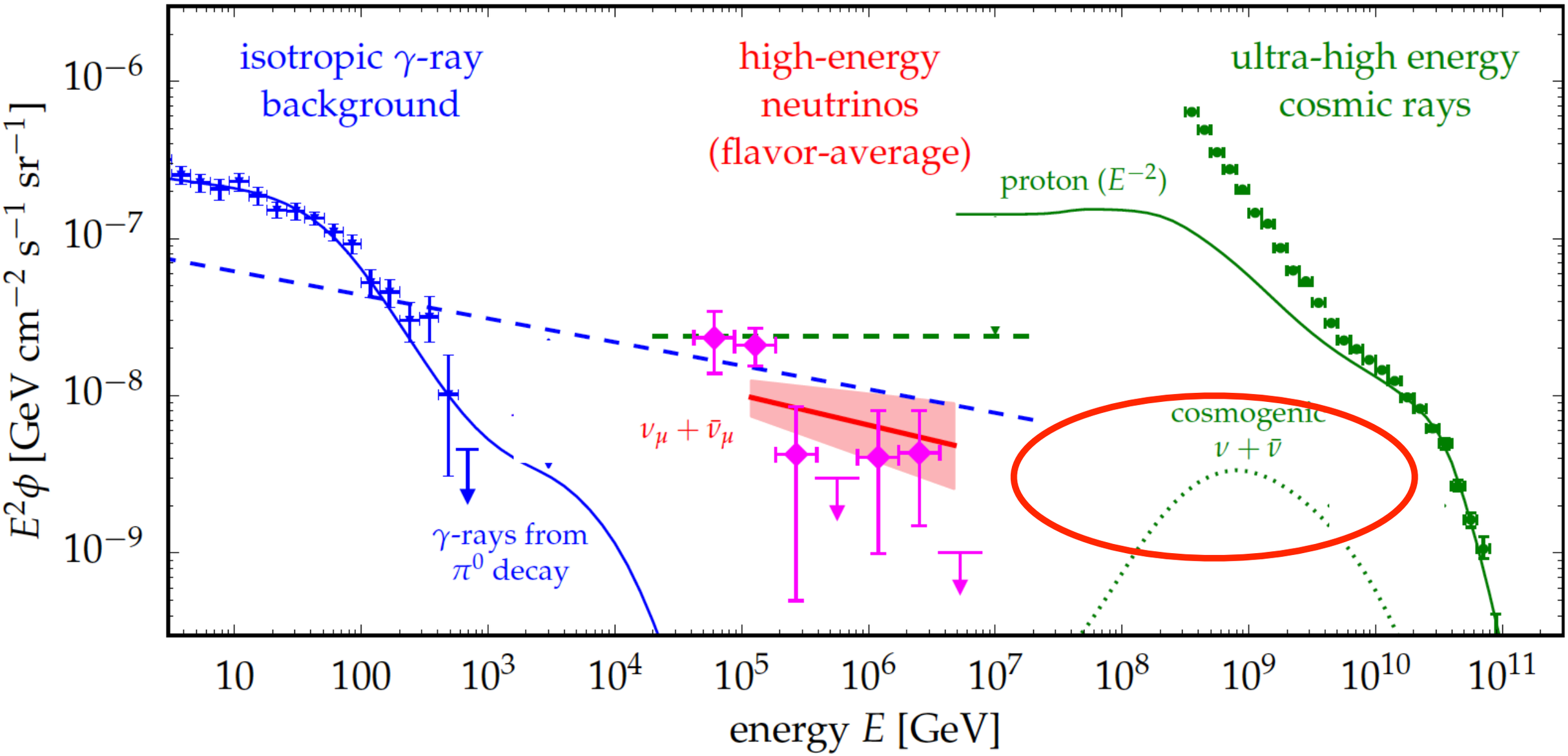
Requirements for Gen2



features in spectrum (e.g. cut-off, bumps), tau neutrinos &
Glashow resonance $\Longrightarrow$ **~10 x event rate @ PeV**

Science: spectrum of high-energy neutrinos

Requirements for Gen2

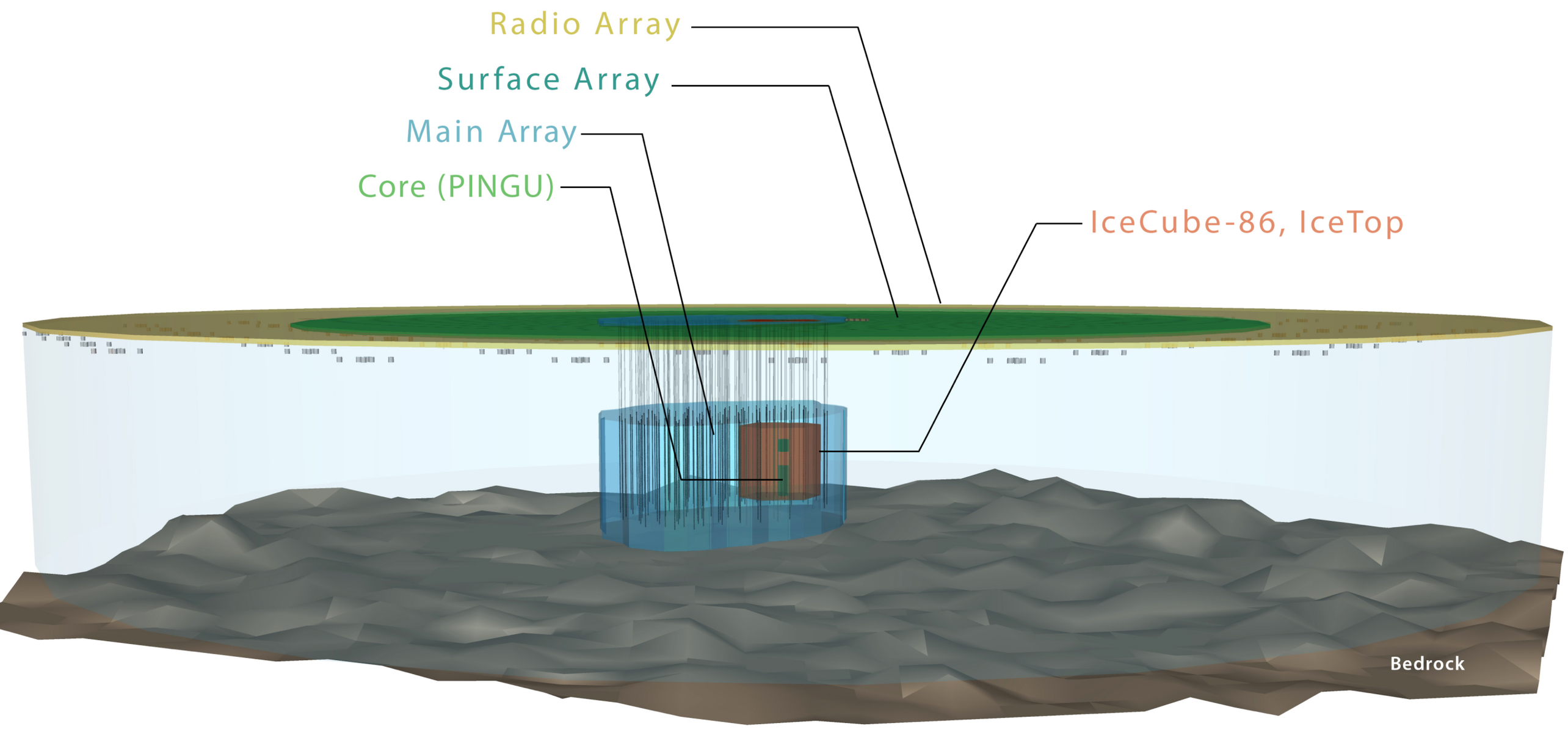


Extrapolate IC flux. sources of the highest energy CRs, GZK, ⟹

10^{-9} flux sensitivity @ ~EeV

IceCube-Gen2

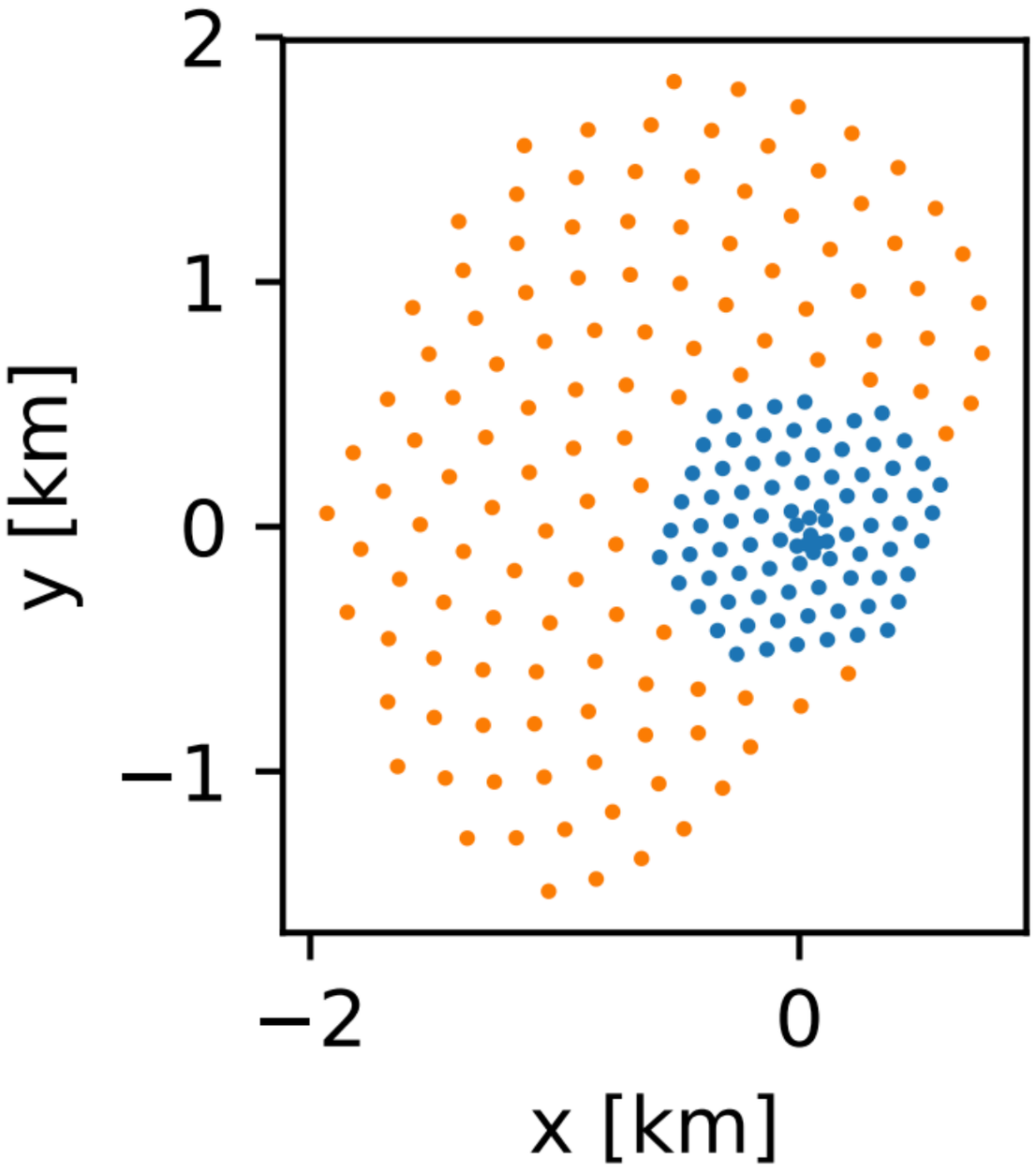
A multi-component facility



Gen2 optical array

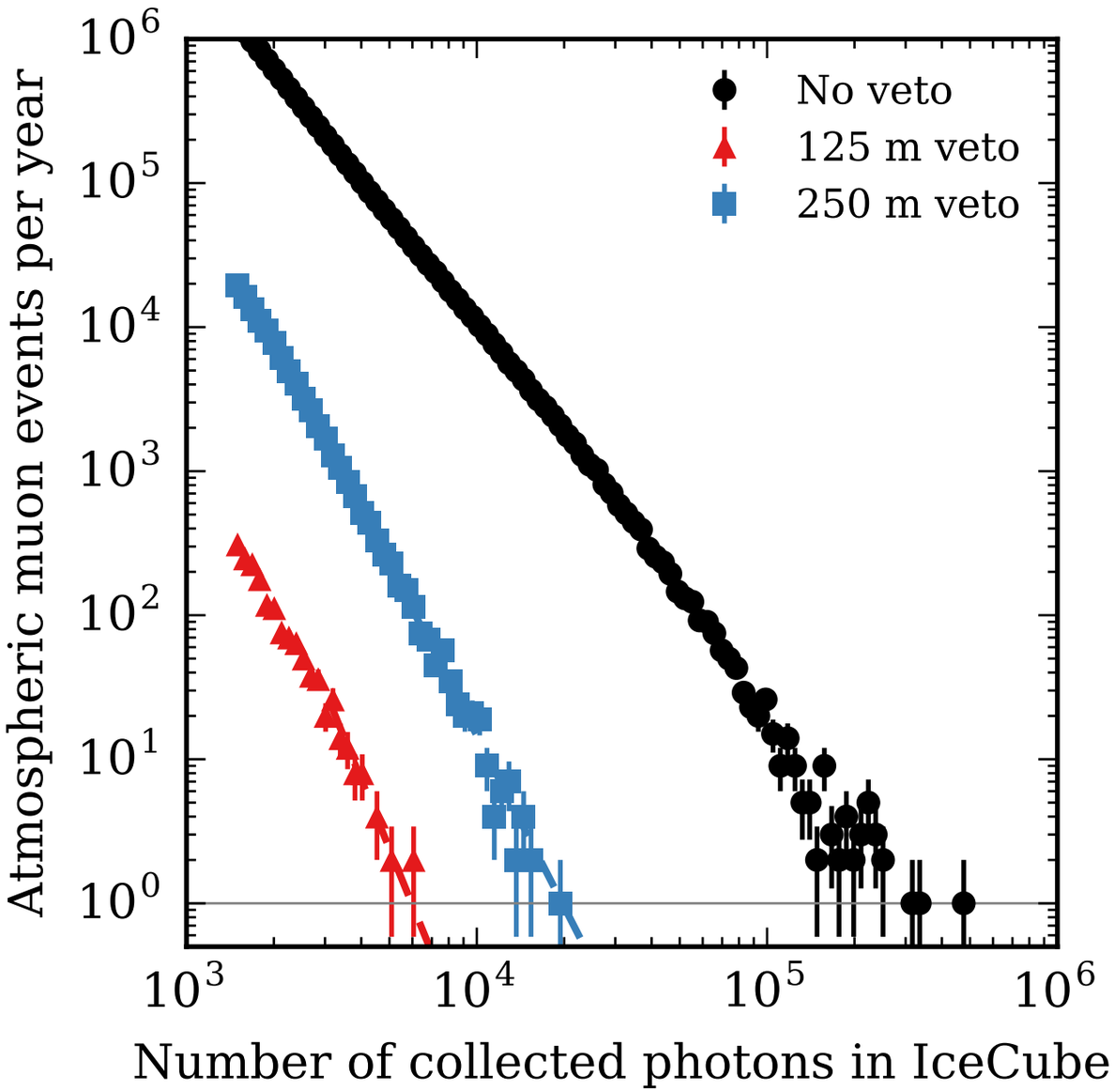
Reference detector:

- 120 strings, 100 sensors each
- vertical depth range: 1350-2600 m
- 240 m string spacing
- 1.25 (height) x 4 (spacing) x 1.5 (#strings) ⟹ 8 more volume
- With fiducial cuts (e.g. HESE) the gain is even larger



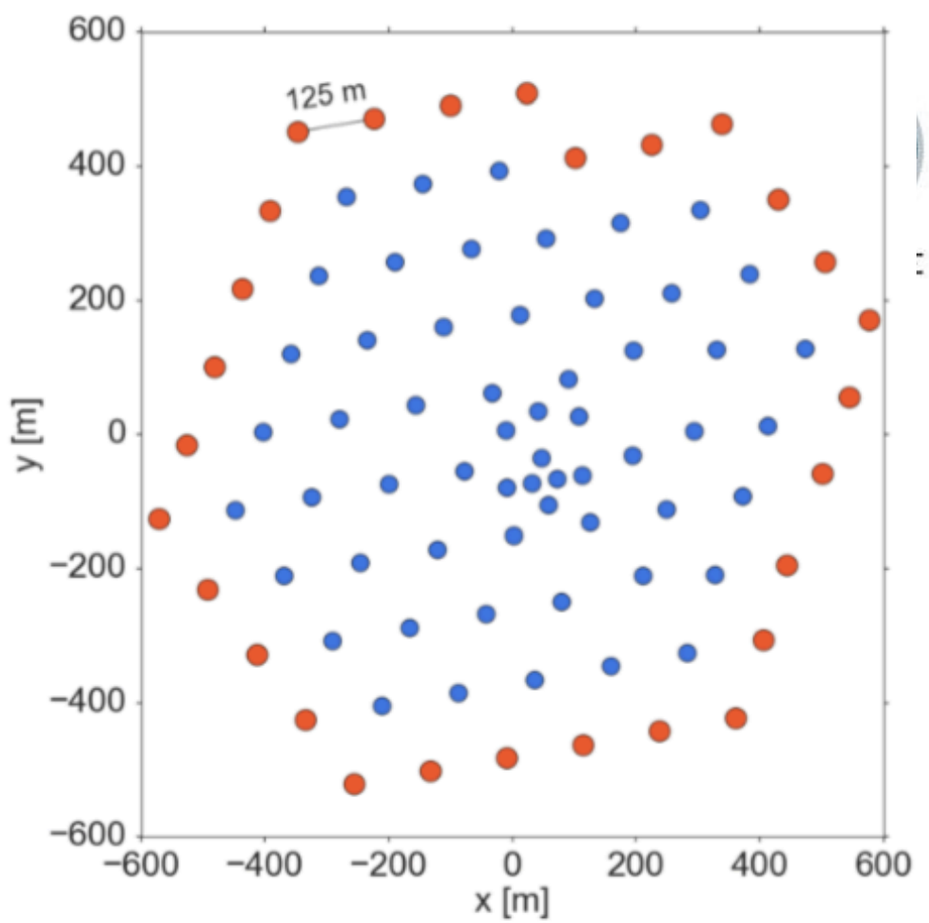
Gen2 optical array

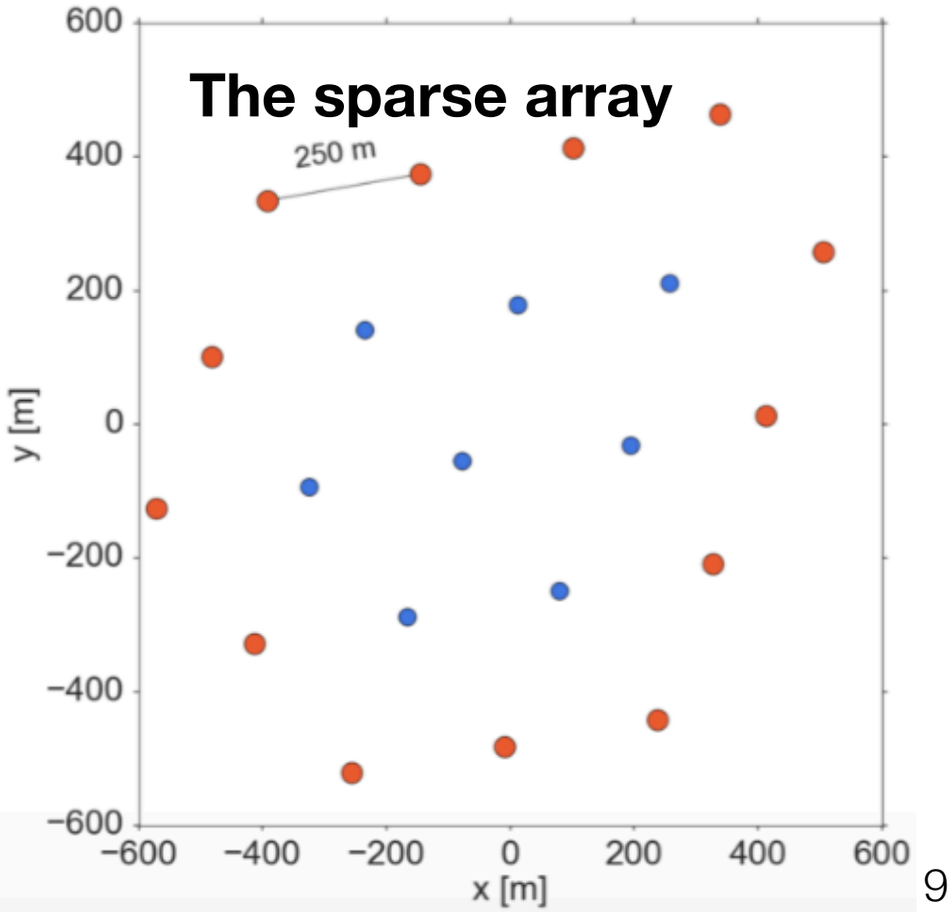
Testing it with IceCube



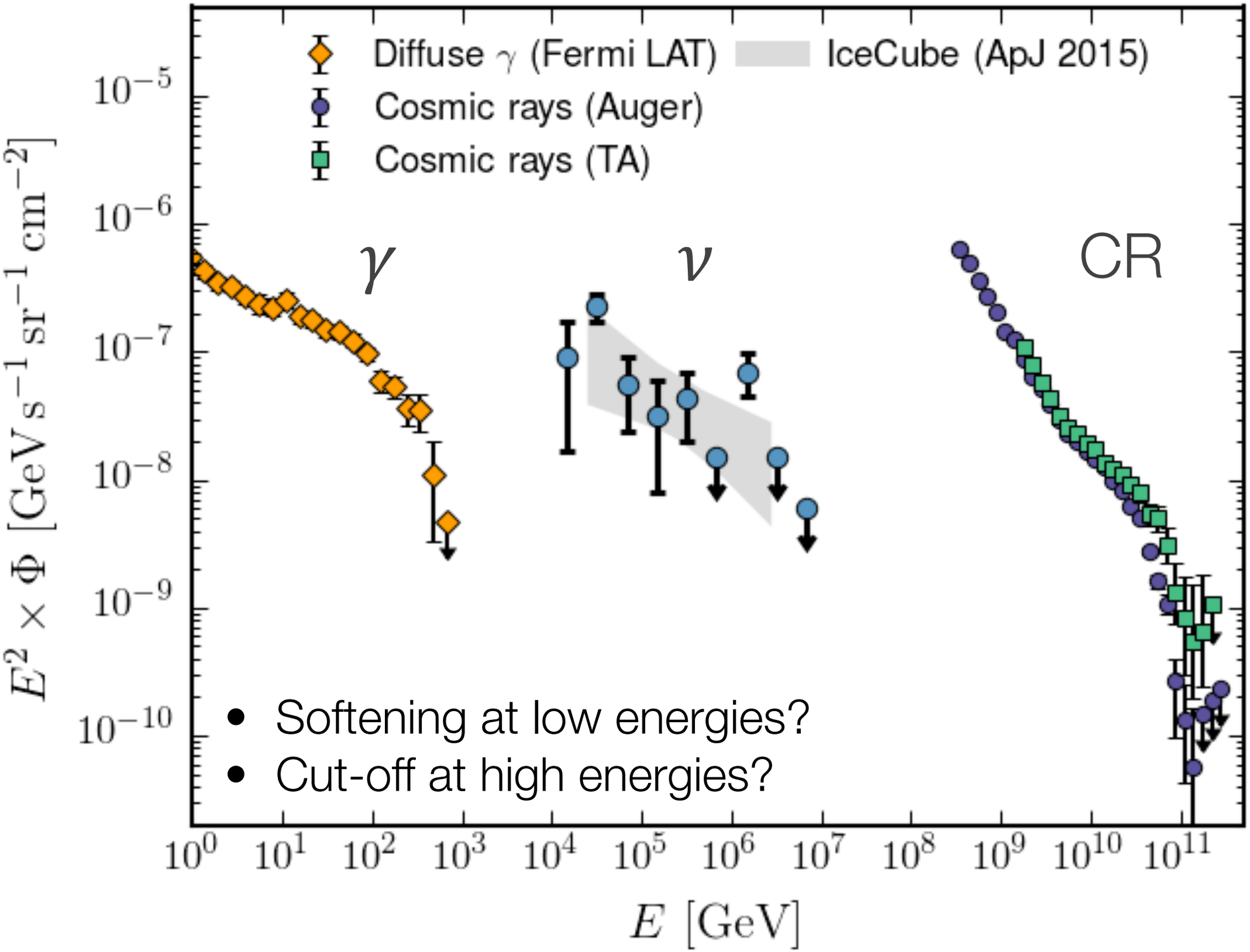
Vetoing atmospheric events works just like in IceCube!

but with 3 x higher energy threshold



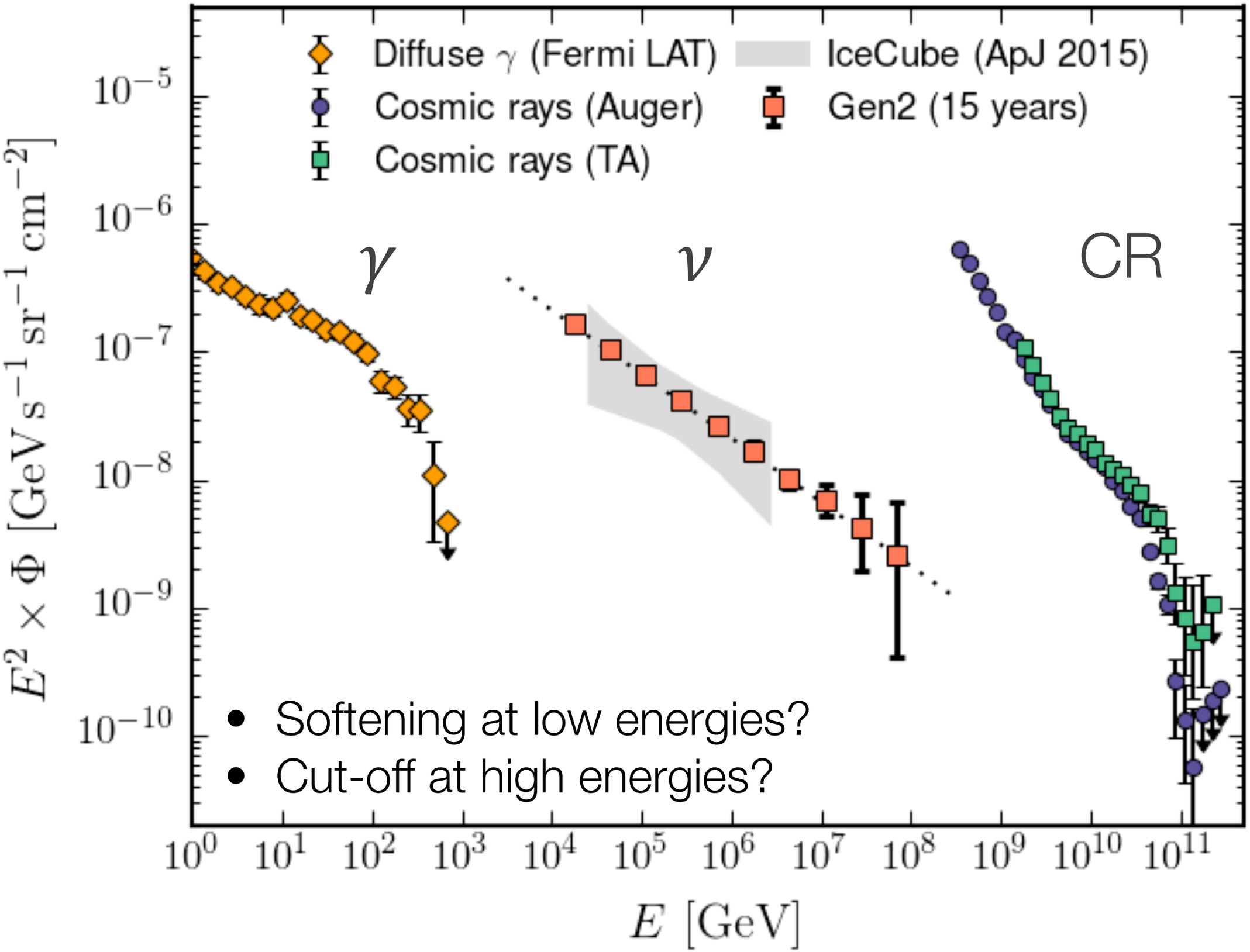


Spectra from the Optical Array



- Softening at low energies?
- Cut-off at high energies?

Spectra from the Optical Array



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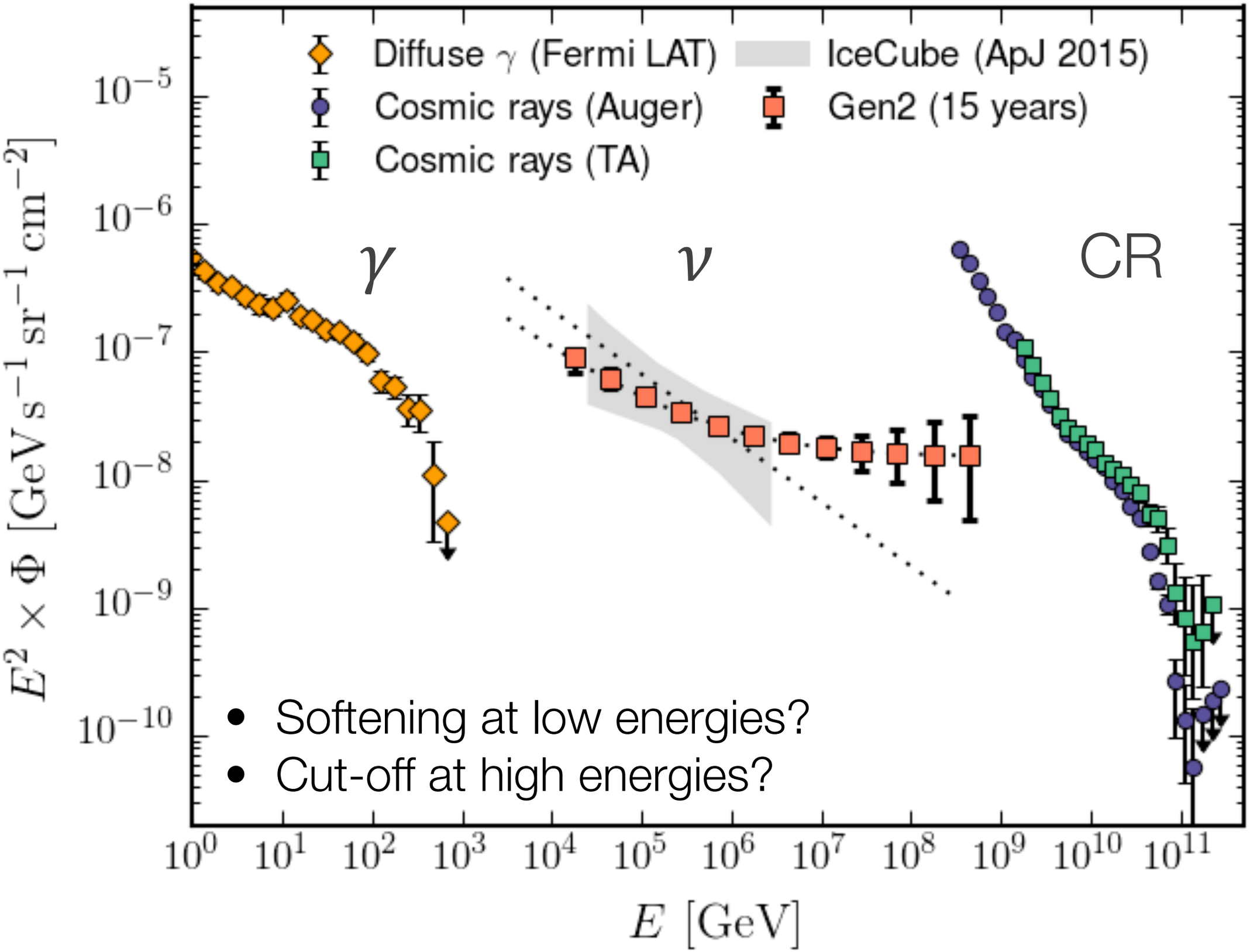
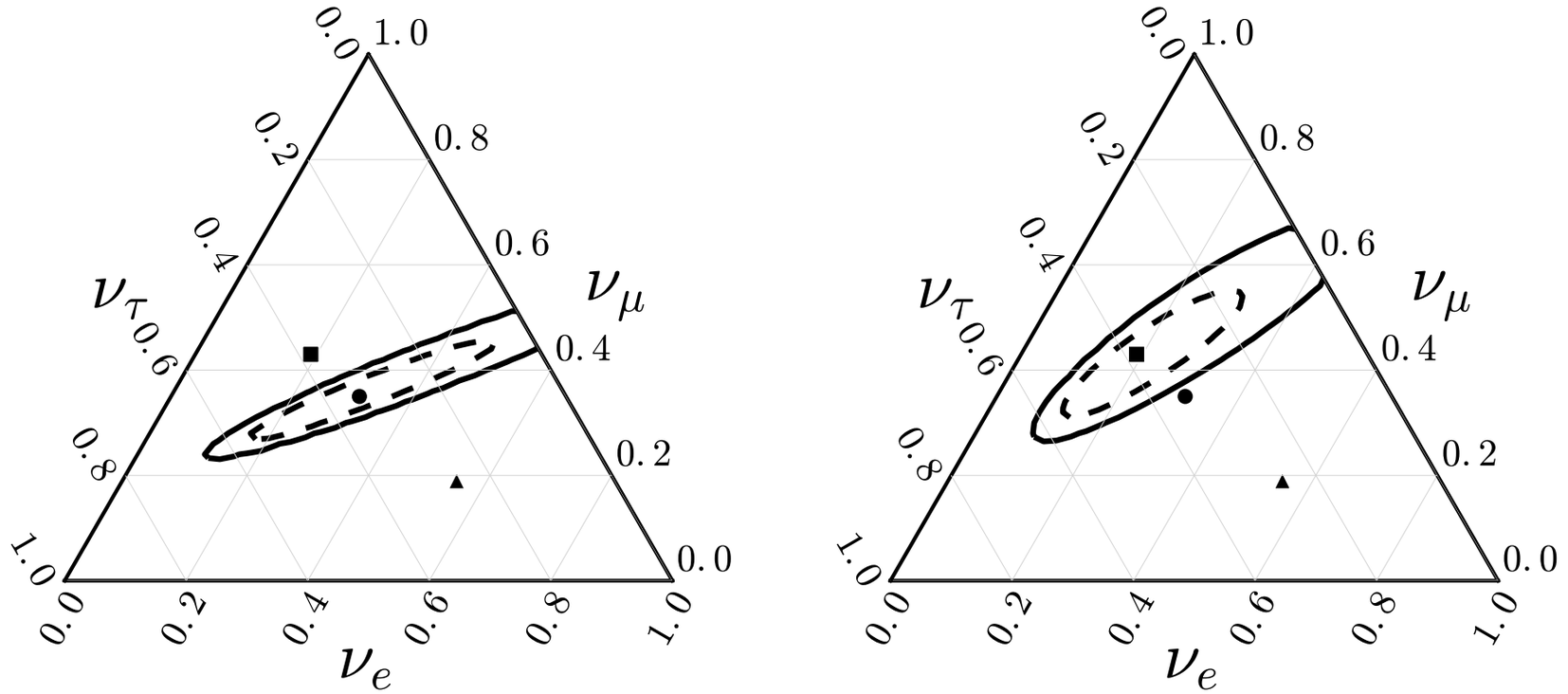
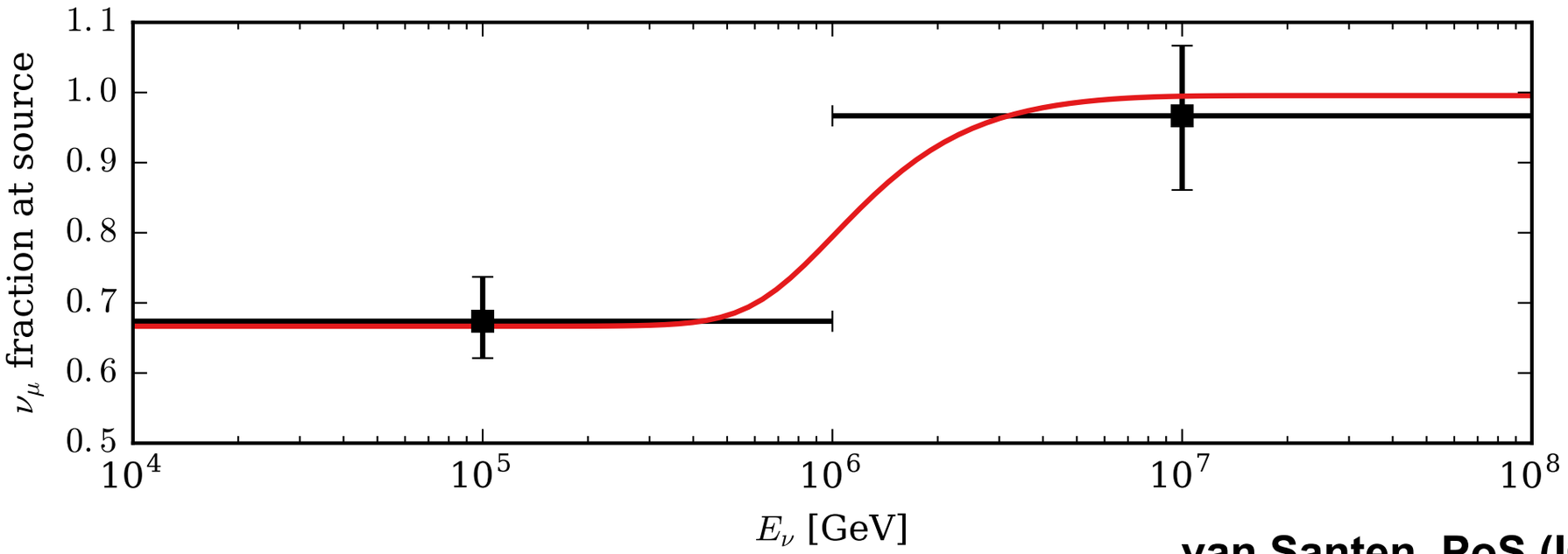


- Softening at low energies?
- Cut-off at high energies?

Flavor Physics - Energy Dependence





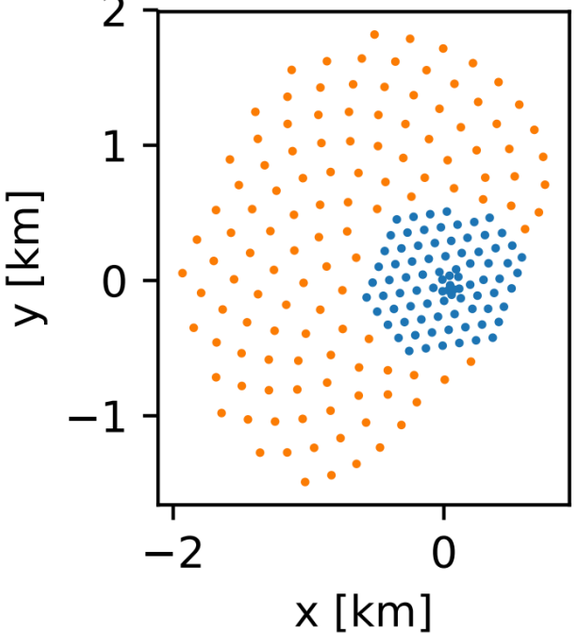
van Santen, PoS (ICRC2017) 991

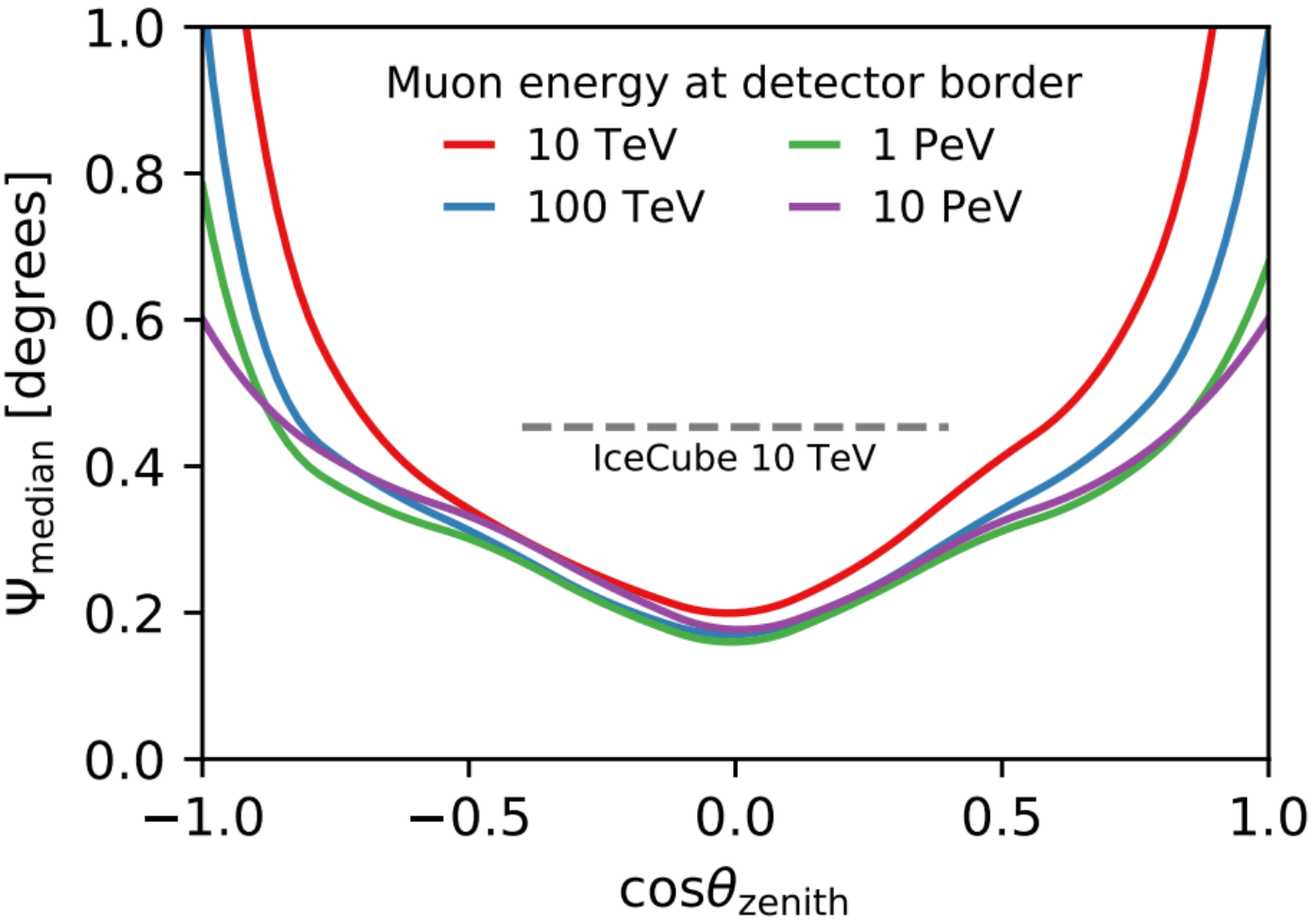
Sensitivity to source populations (e.g. Kasthi, Waxman 2005)

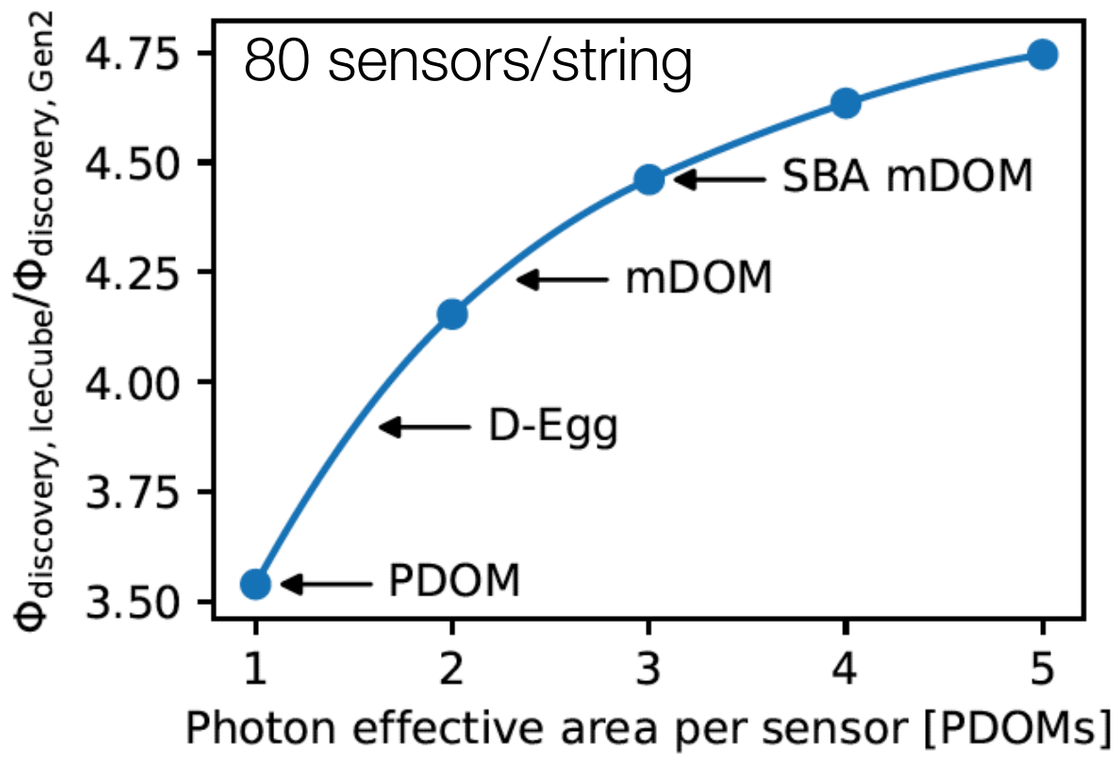
Sensitivity to point sources

Projected sensitivity

- Improved angular resolution
- Better point sensitivity, here shown for 15 y IC86 + 15 y IC-Gen2





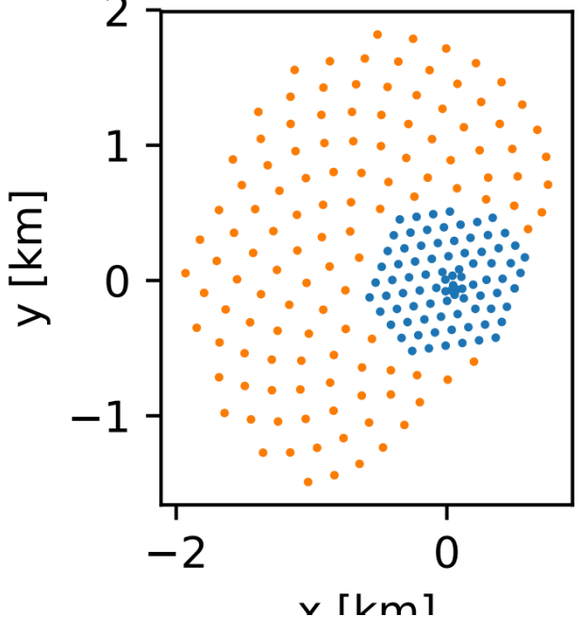


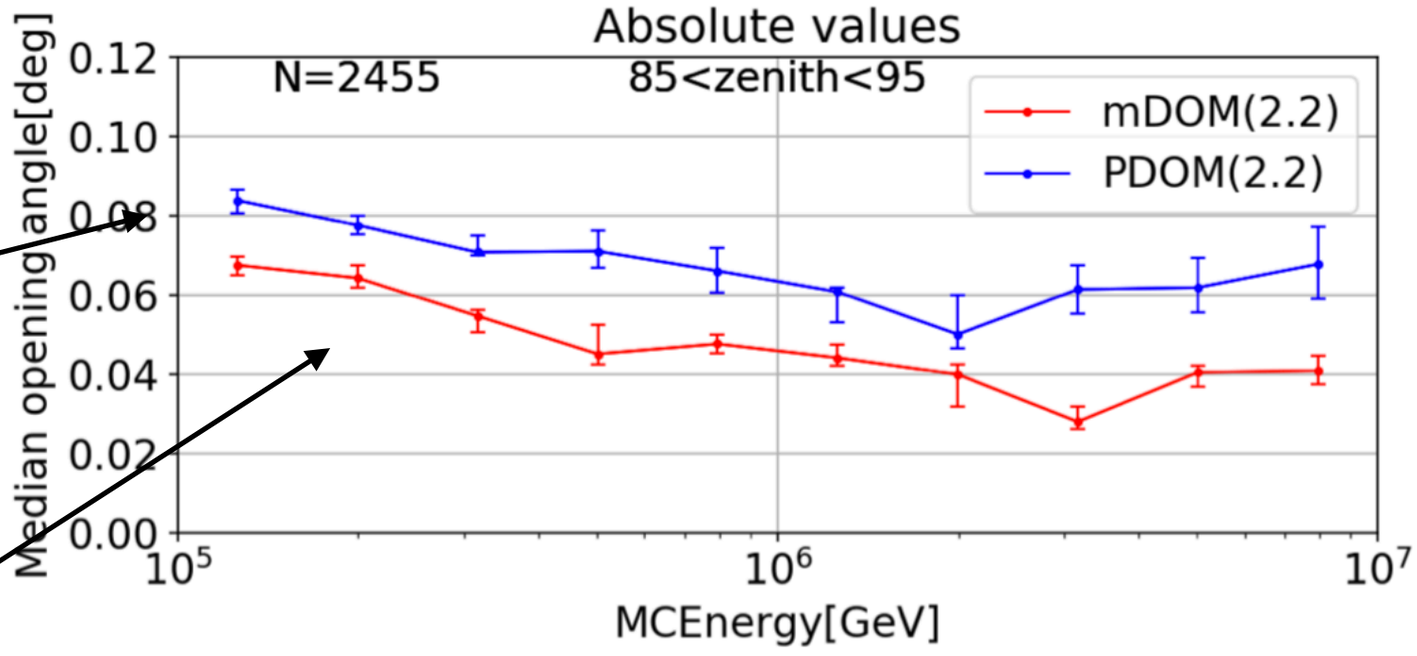
van Santen, PoS (ICRC2017) 991

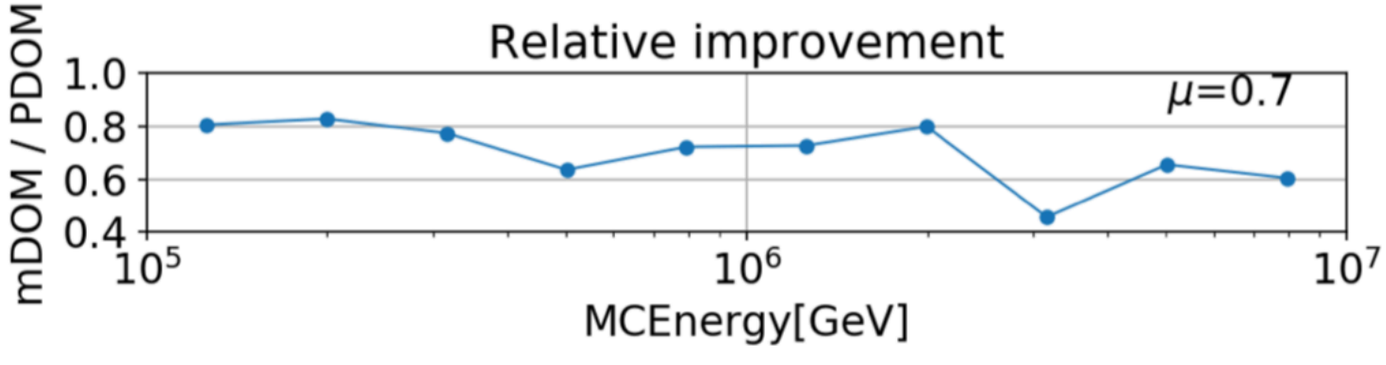
Sensitivity to point sources

Gains due to new technology

- multi-pixel Optical sensor
- ~30% better angular resolution for horizontal events for same cathode area







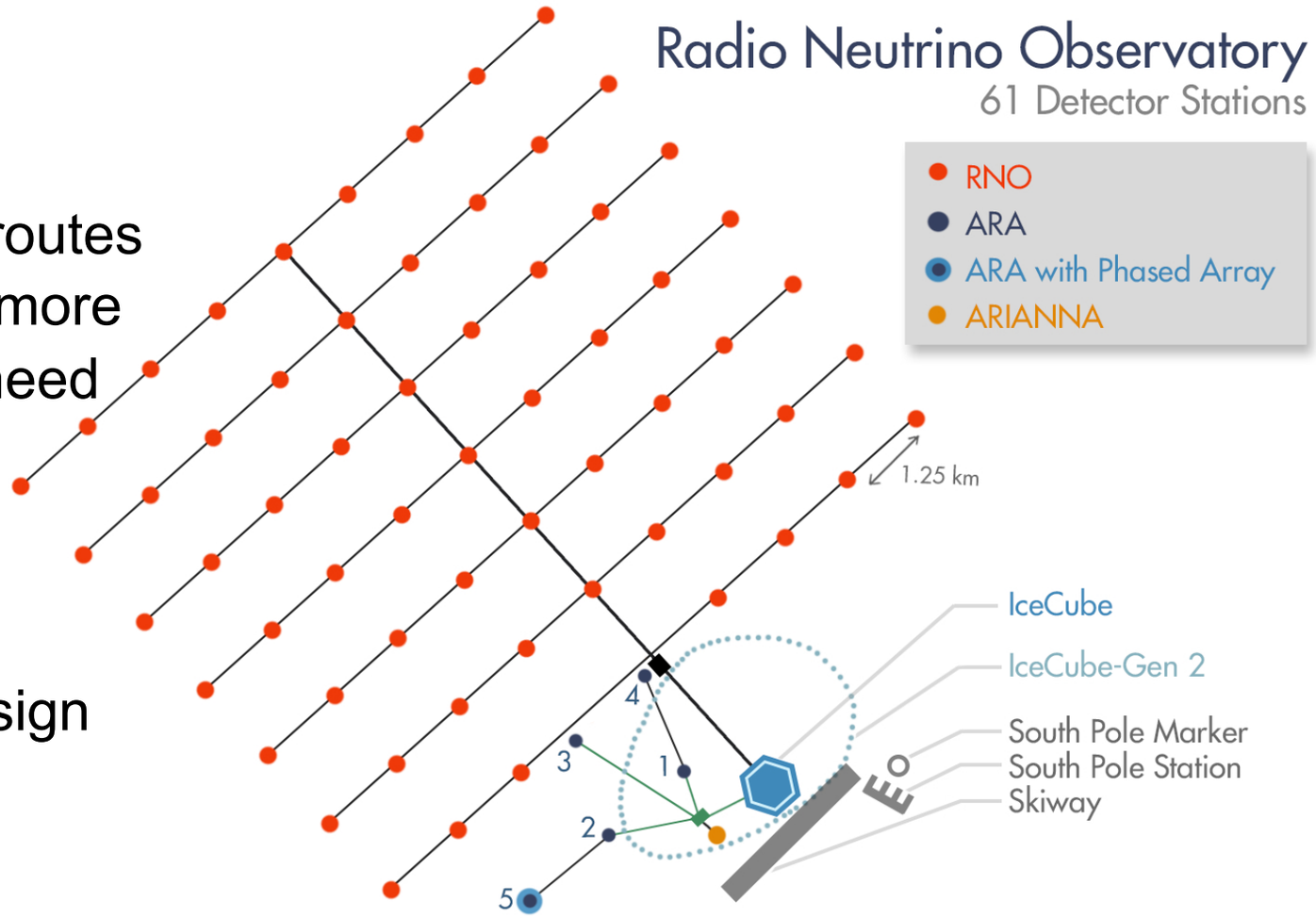
Thomas Kittler, Stockholm 2018

factor of 5 sensitivity increase for a detector with 100 mDOMs / string

Gen2 radio array

Using RNOx5 as proxy

- RNO currently best guess for station design for a first generation array
- Assumption for Gen2Radio: RNO sensitivity x5
- This may be achieved via different routes (deeper stations, more lightweight, more aggressive triggering, …), but we need additional experimental evidence to justify an adaptation of the detector design
- For now: simple scaling of RNO design as is



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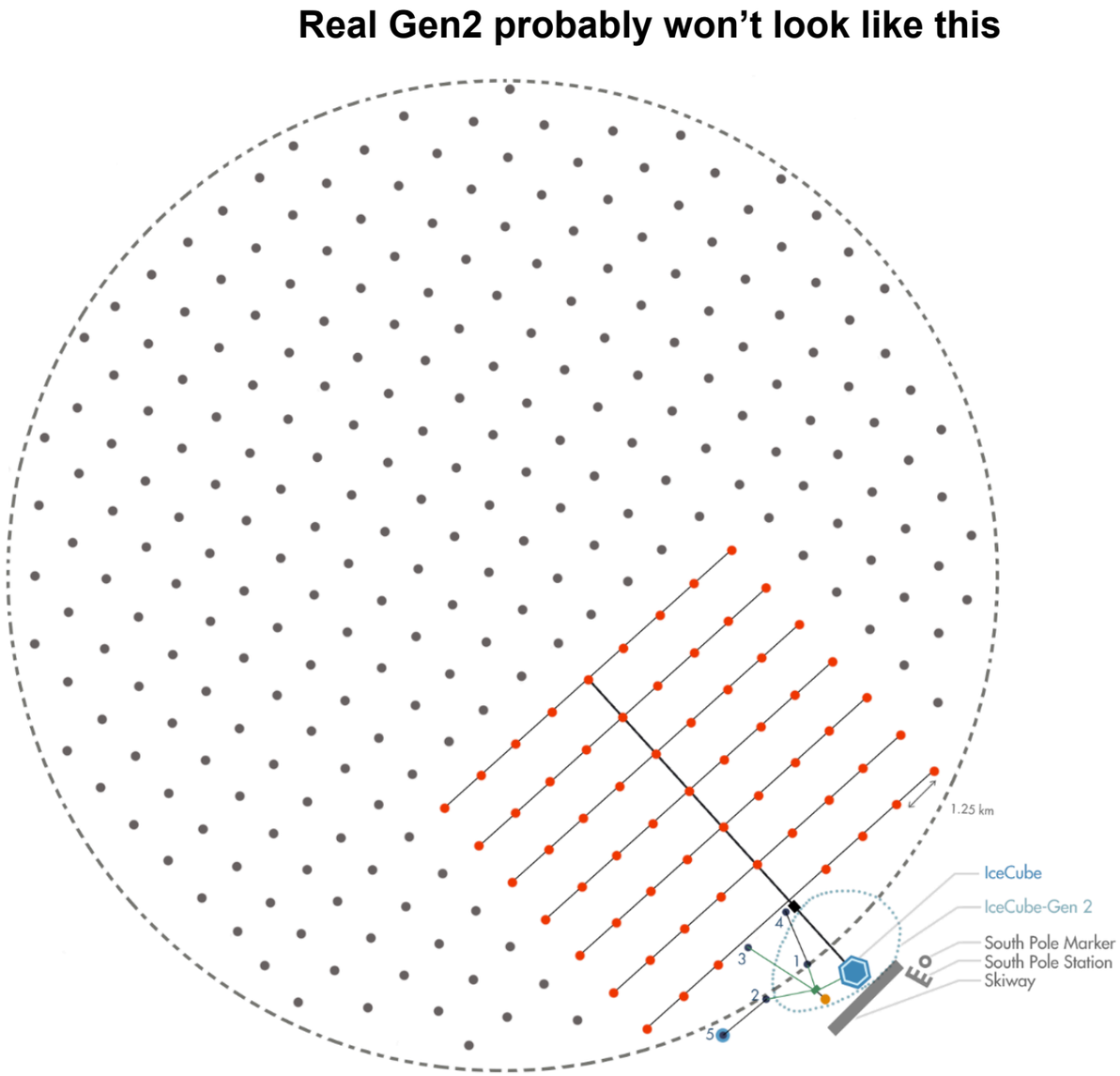
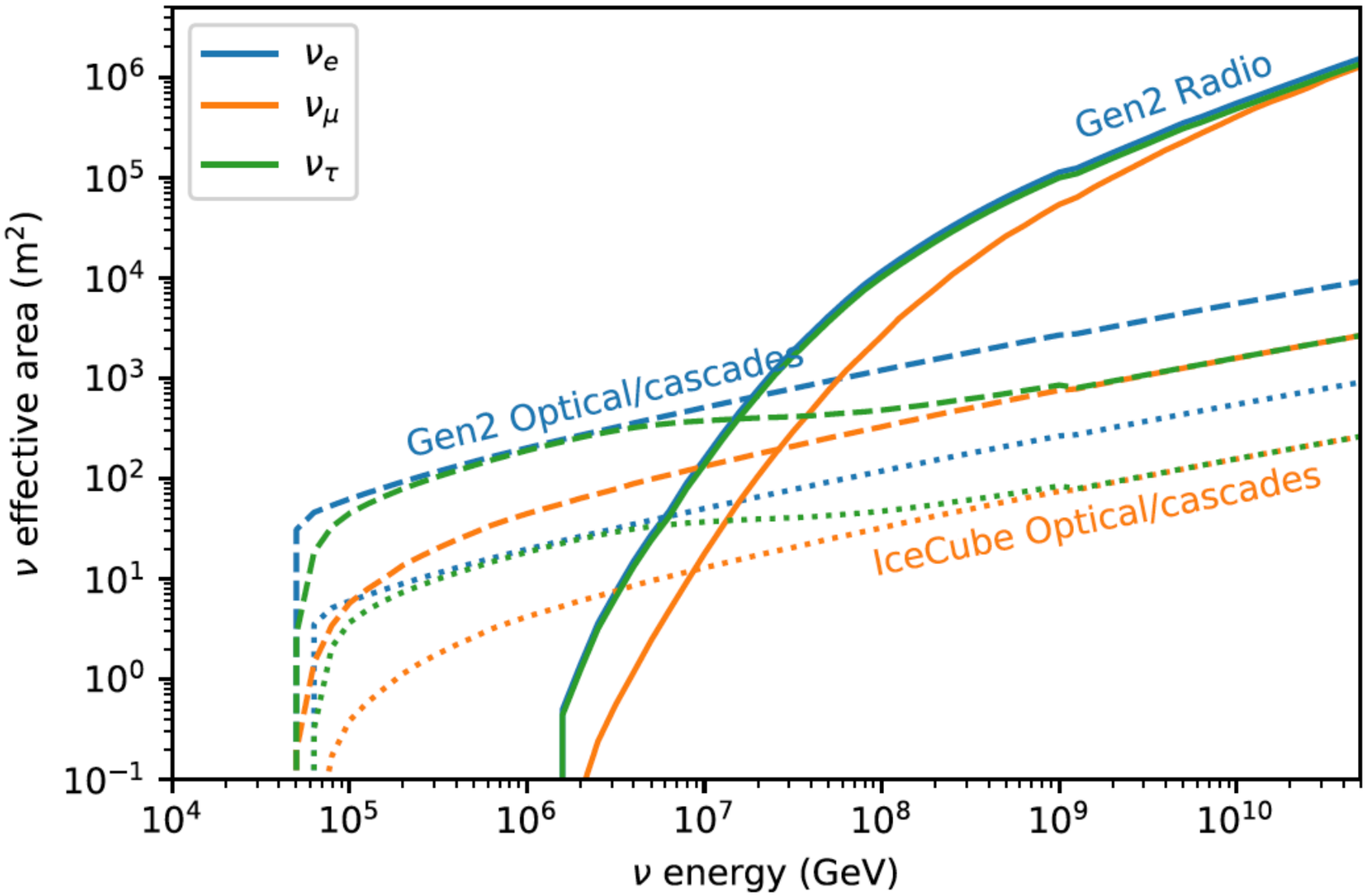


Effective Volumes

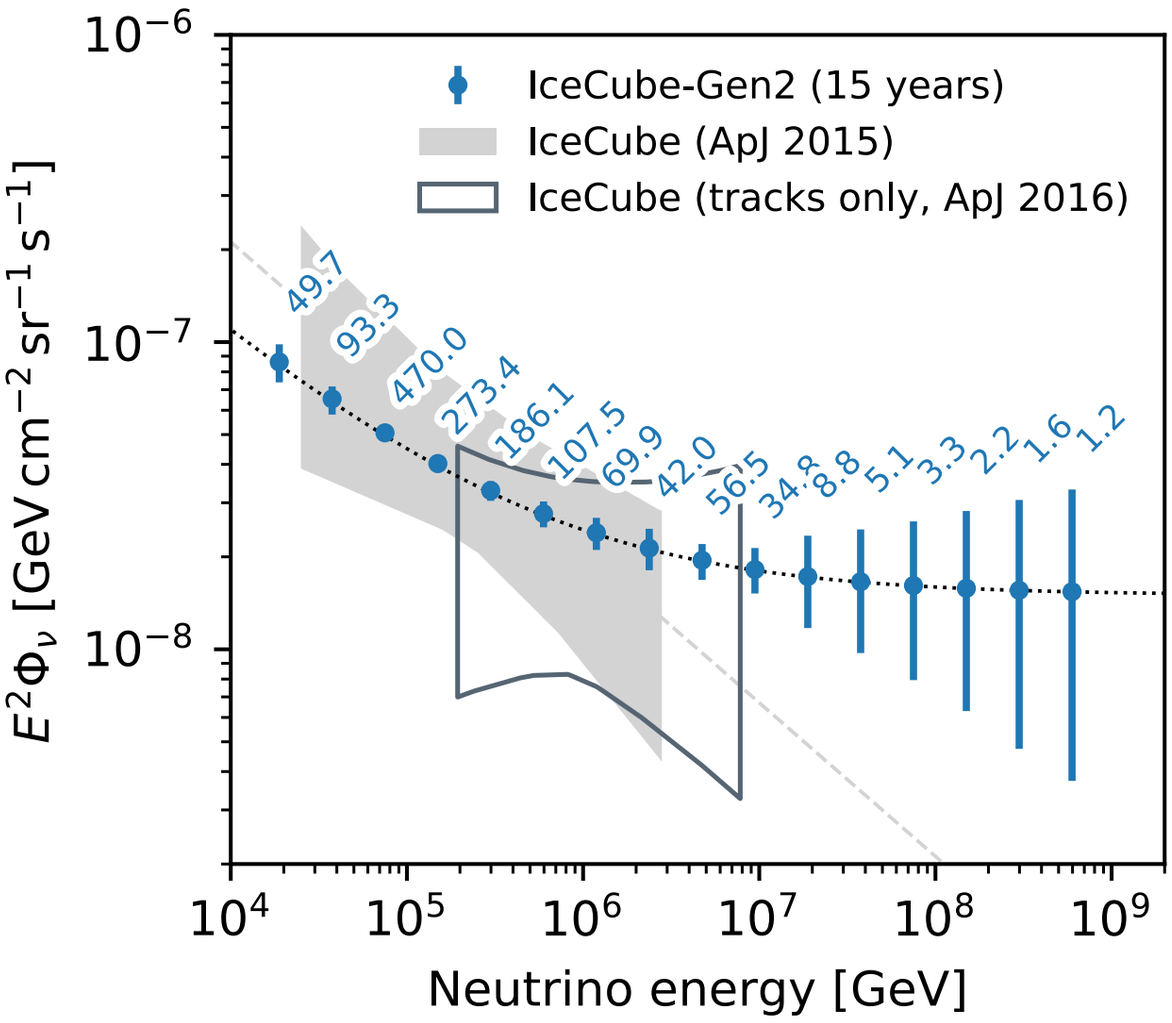


Caveats:

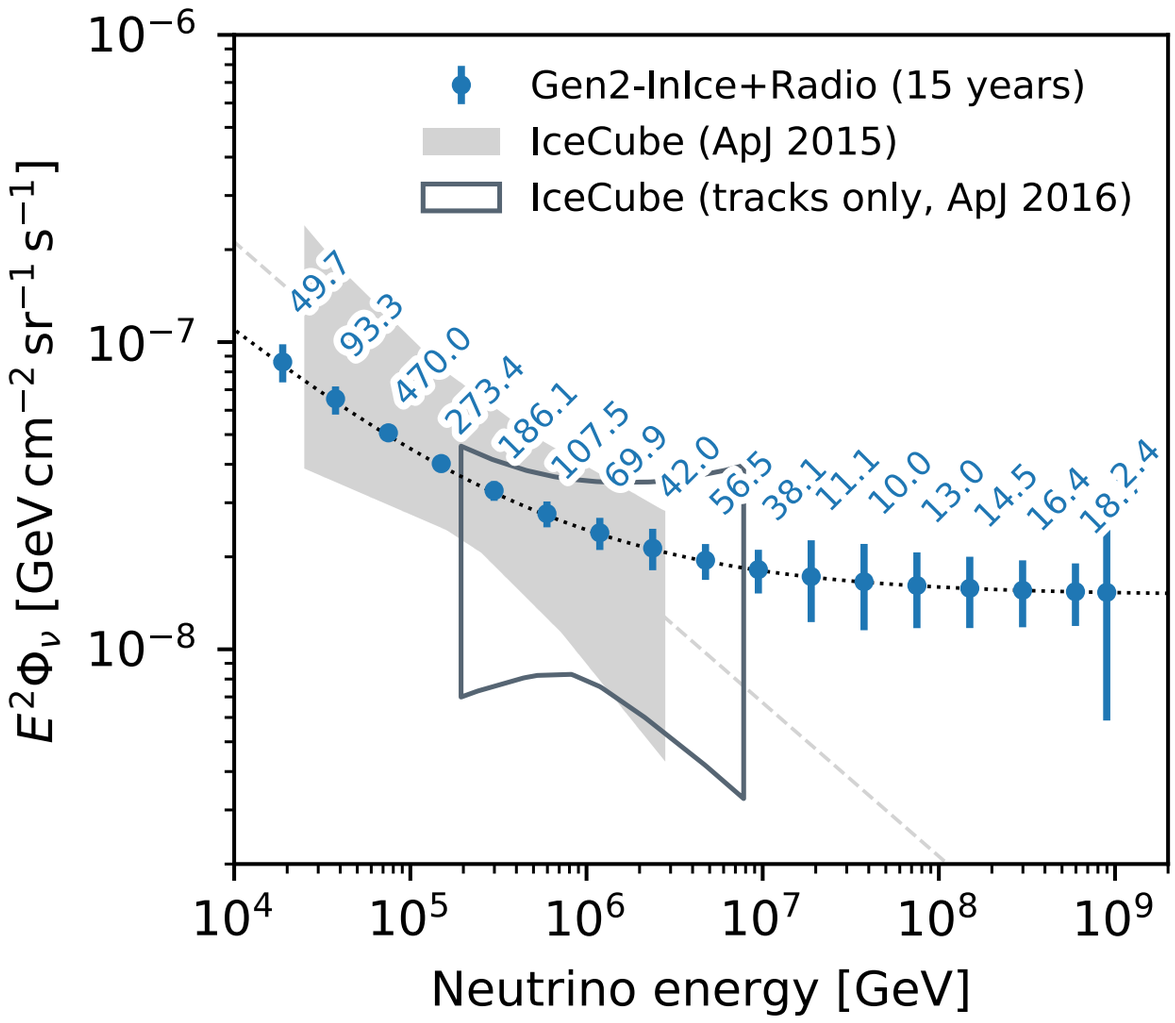
- ν_τ area approximated as proportional to the ν_e area (true at high energies)
- ν_μ area given by the framework multiplied by 3 (radio is sensitive to showers, not muons)
- Triggering is simplified

Daniel Garcia Fernandez (April Gen2 call)

Spectral measurement and event rates



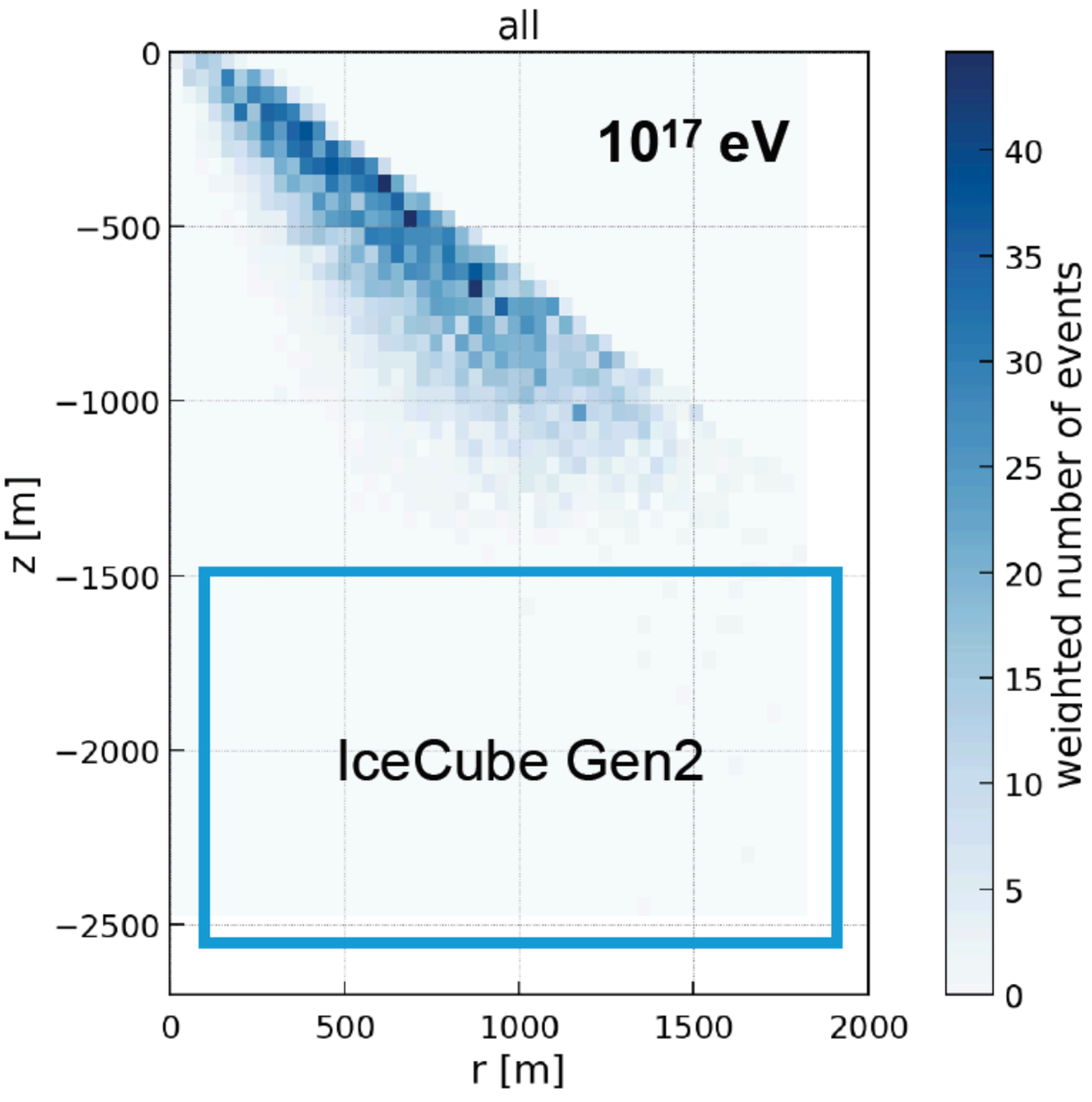
Optical only

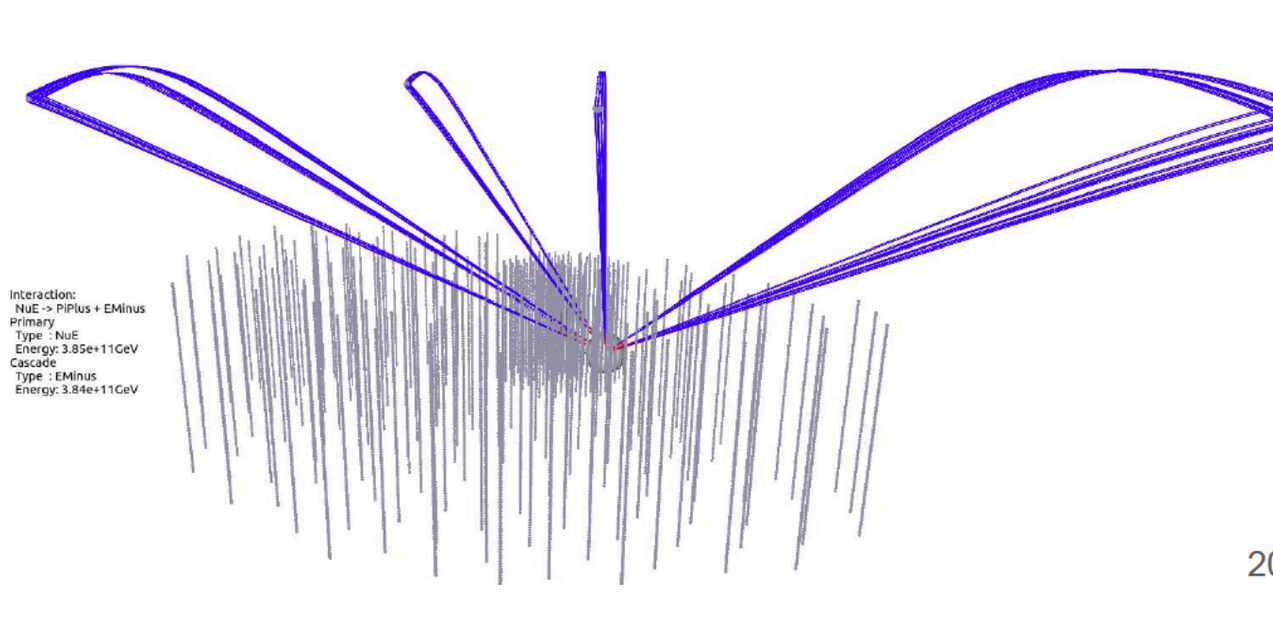


Optical and radio

Computed by Daniel Garcia Fernandez & Jakob van Santen

Hybrid events



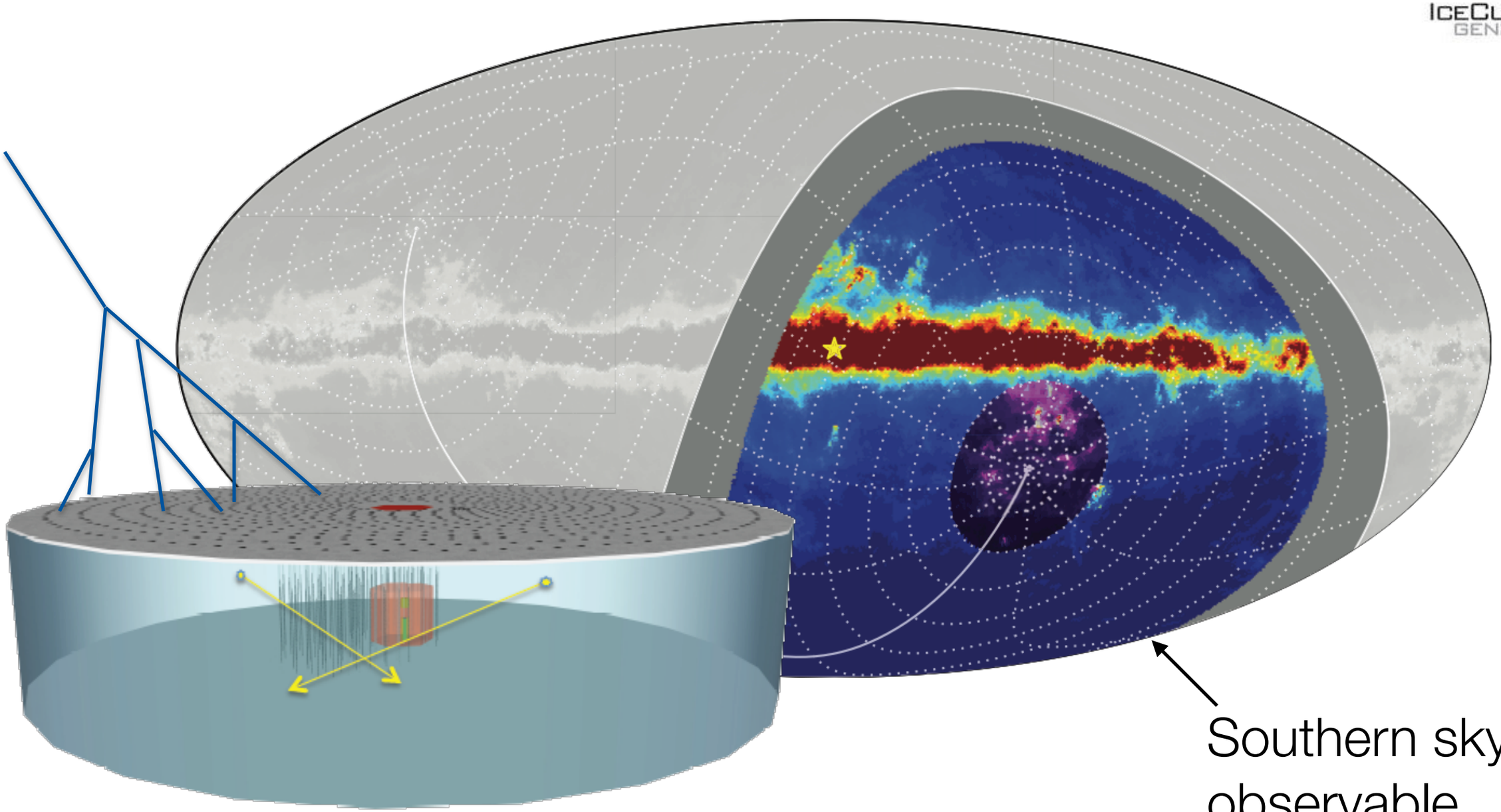


event display by Lu Lu

small numbers expected, but potentially very interesting; two studies on-going, see parallel session (Chiba, Brussels/DESY)

Daniel Garcia Fernandez (April Gen2 call)

Extended surface veto



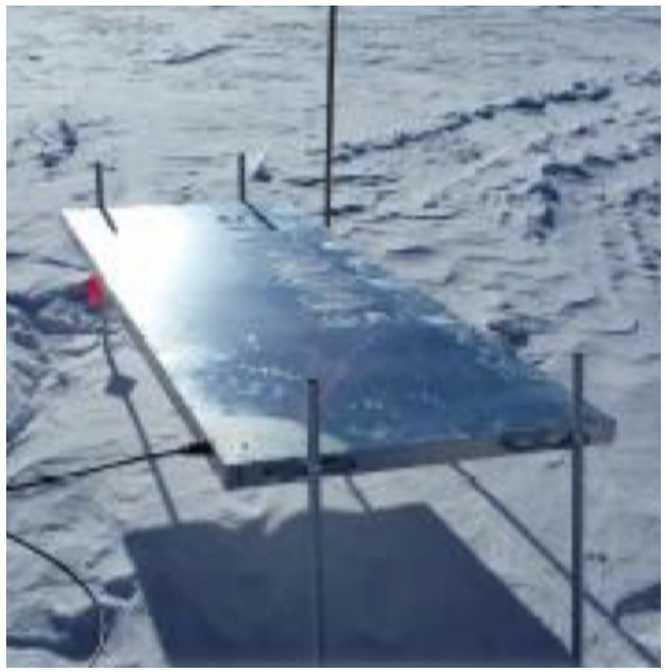
Potential gain for e.g. 75 km² veto:

~2x number of PeV tracks

Surface technology under consideration

Being tested at the South Pole as part of IceCube maintence program

Scintillator panels

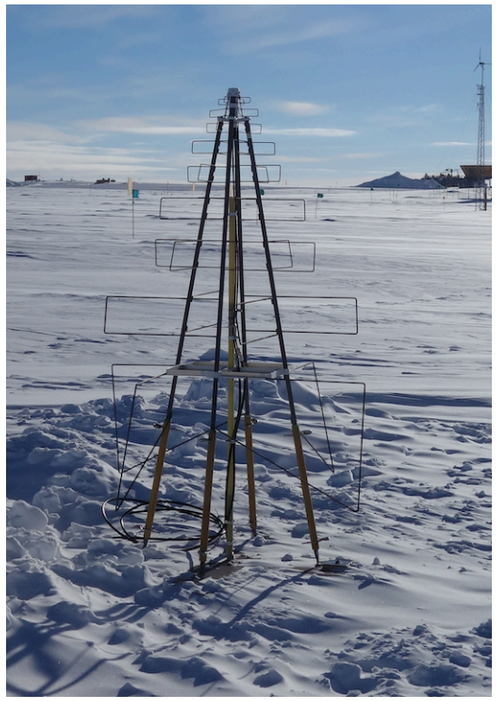


- Easy deployment
- Low cost (cheap materials and SiPMs)

Air Cherenkov Telescopes

- Reduced energy threshold
- Add resolution, particle ID,…

Surface radio antennas



- Cheap
- Complementary sensitivity to inclined showers,…

Extendended surface array

Baseline:
a surface scintillators detector on the footprint of Gen2 for CR physics (reaching ~10 higher energies), as well as other goals (veto, photon searchs, etc)

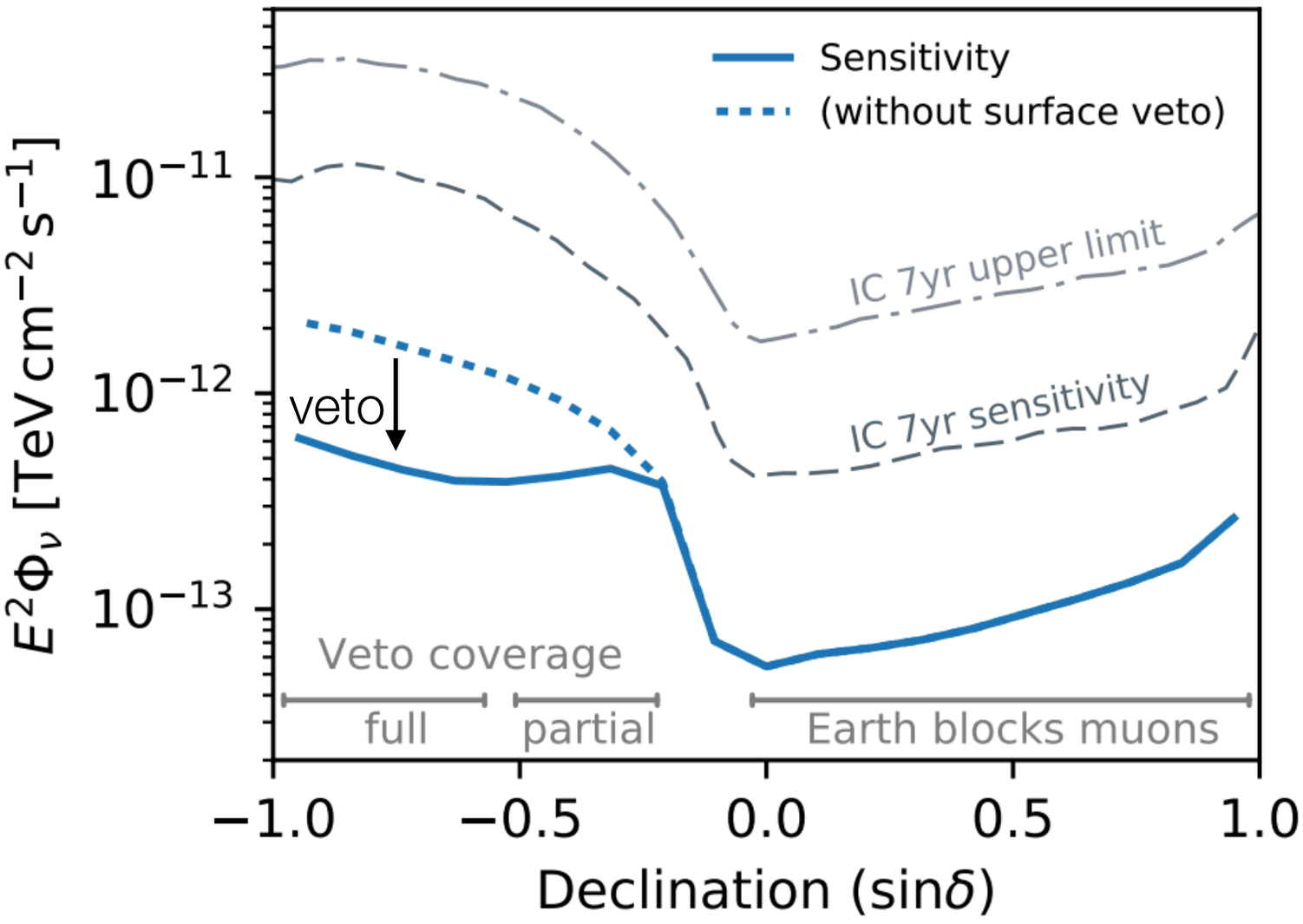
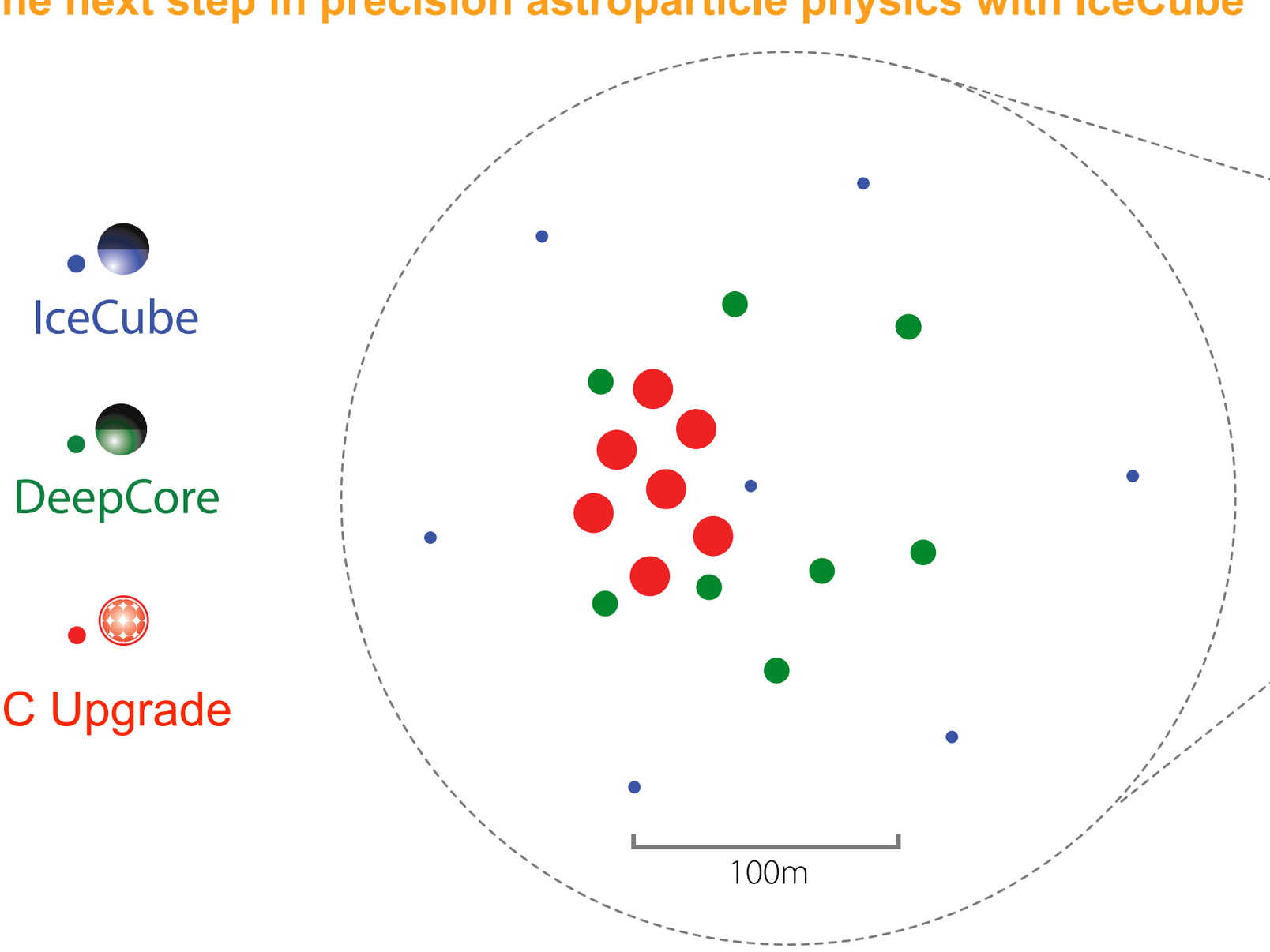
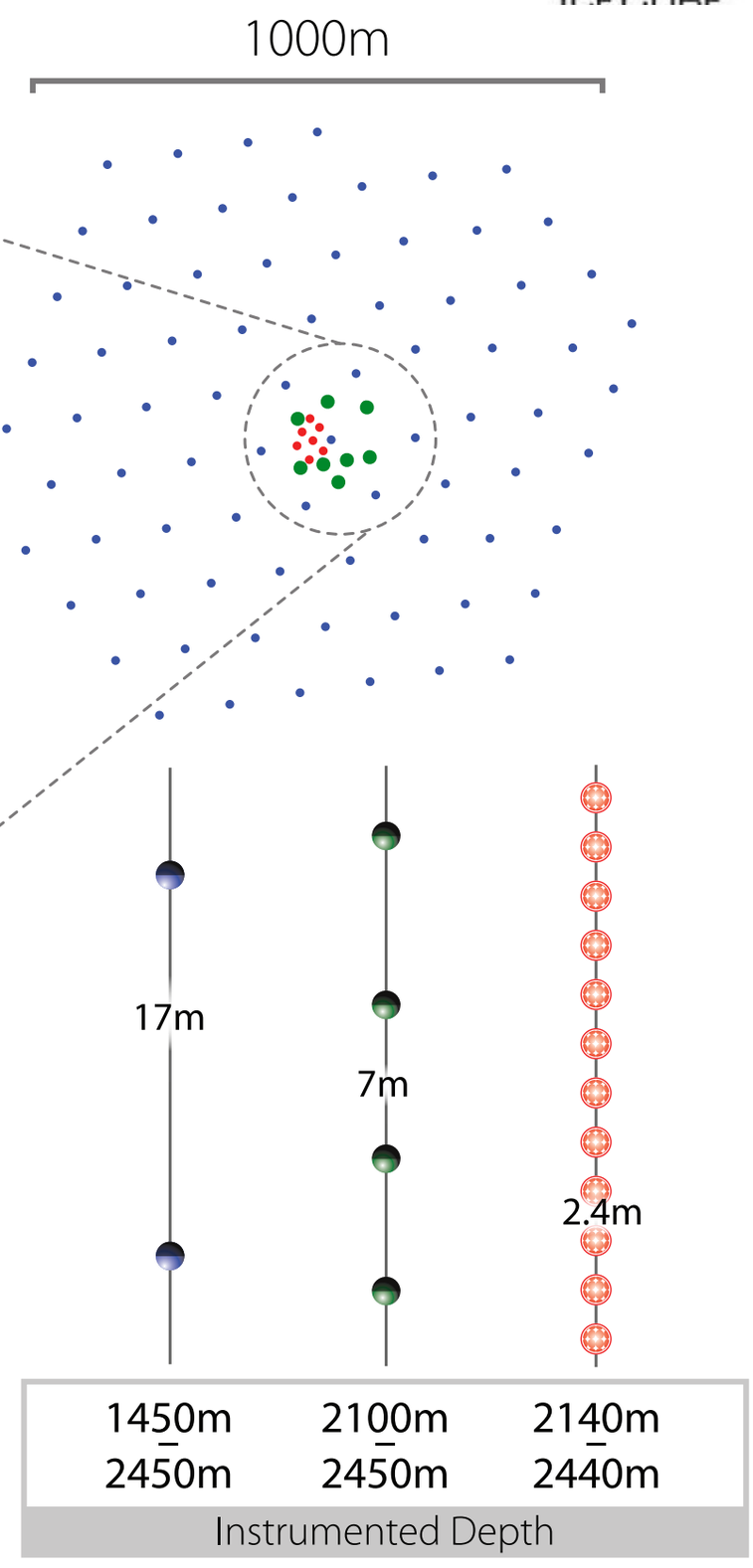


Fig assumes 75km2 instrumented area and assuming 100 TeV neutrino veto threshold. This would require very dense instrumentation and logistics support ($$$)

The IceCube Upgrade / Gen2 Phase I

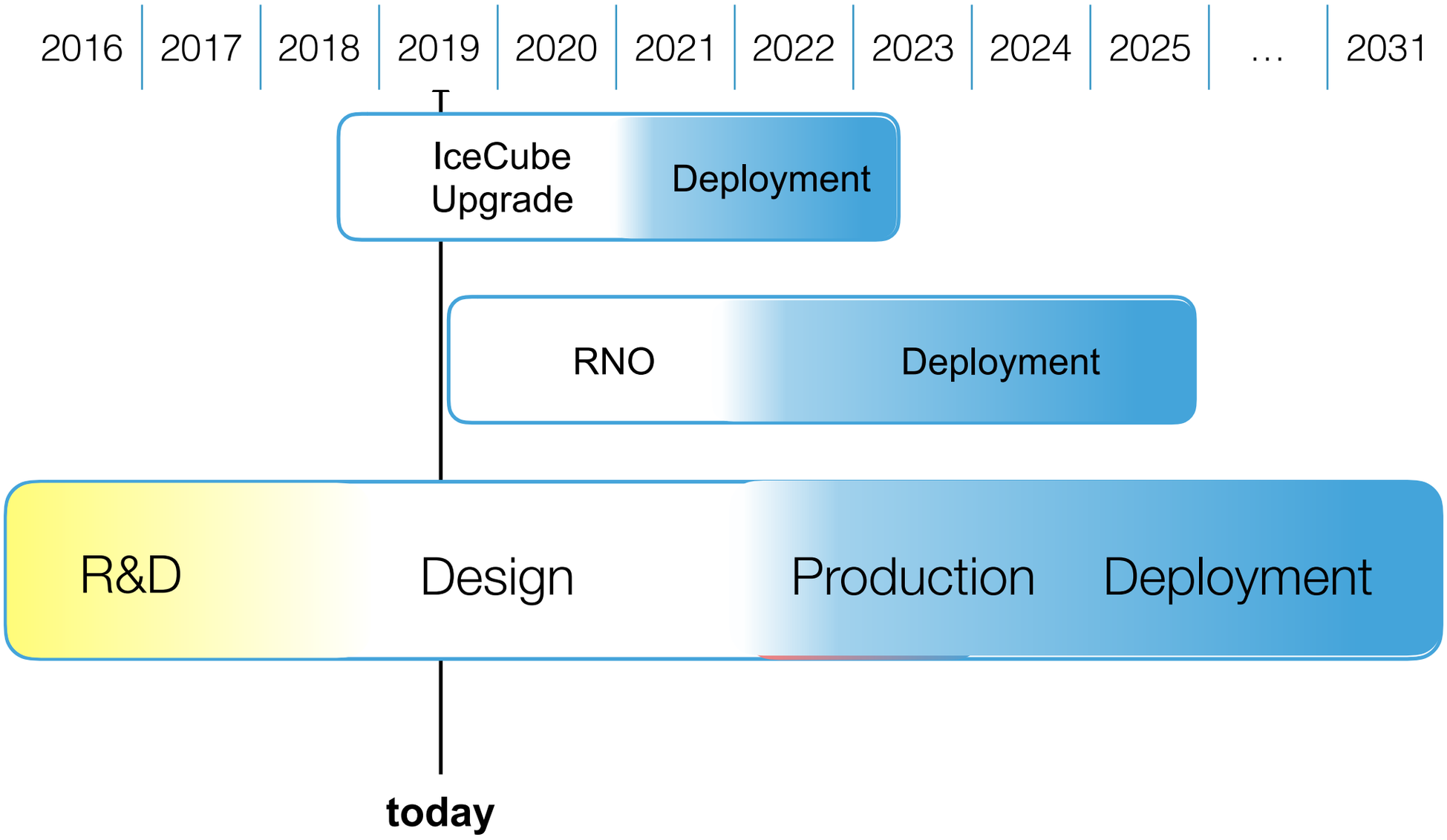
The next step in precision astroparticle physics with IceCube





- 7 strings with ~20 m spacing
- 2 m vertical spacing of 125 modules / string
- Located inside of IceCube-DeepCore

Project-driven IceCube-Gen2 Timeline



For this summer:

Gen2 white paper (extended), work towards CDR, upgrade organization

Backup

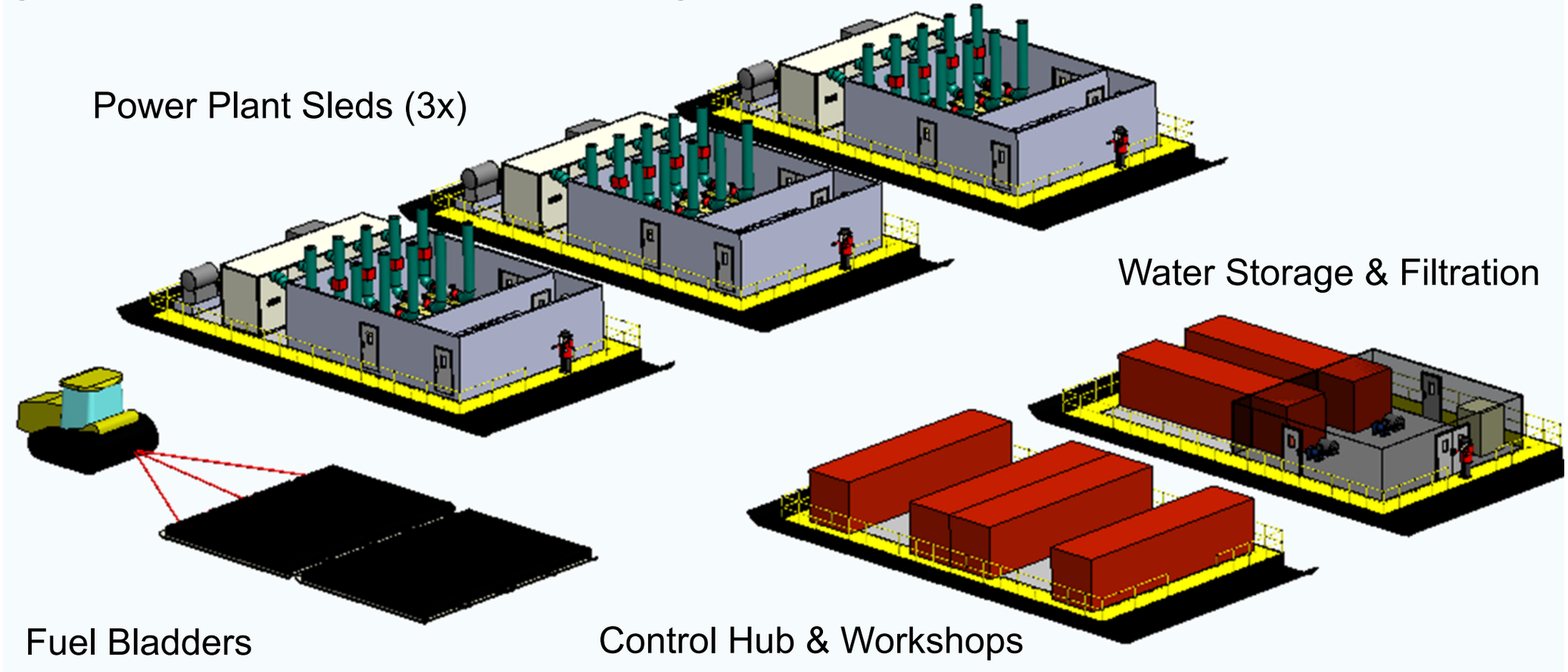
Simplified logistics & better performance

Simplified logistics:

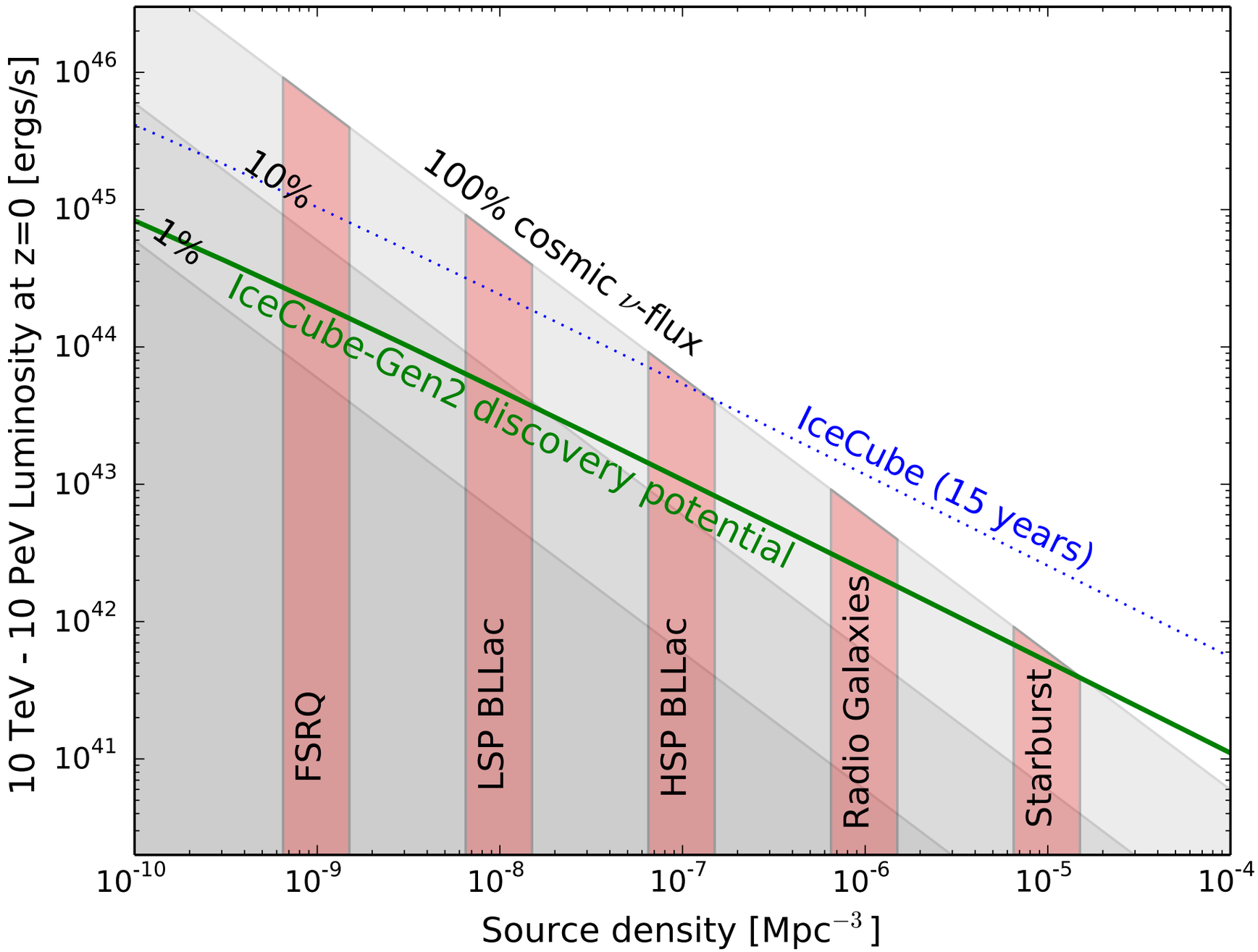
- Equipment and fuel delivered to Pole via single traverse instead of air
- Reduced logistical footprint at Pole; smaller crew

Improved performance:

- New sensors allow for narrower holes ⟹ large fuel savings
- Faster drilling
- Degassed holes, less scattering



Identifying the sources of IceCube's neutrinos

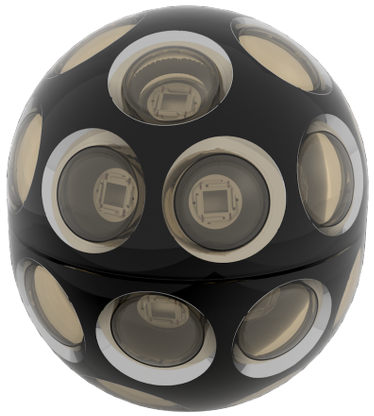


Five times IceCube's point source sensitivity required to detect any reasonable source scenario

*Sensitivity for source catalog search

New sensor designs for improved performance

mDOM



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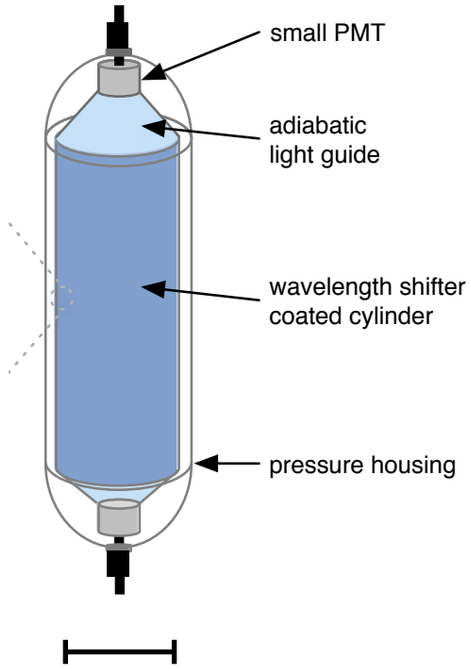
- Directional information
- More sensitive area per module

D-Egg

30

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

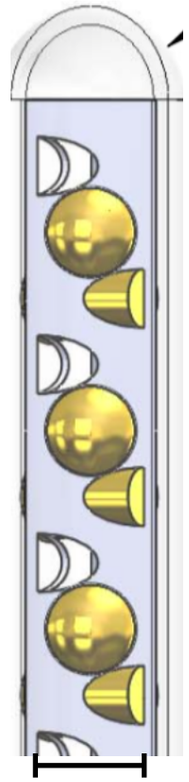
WOM



11

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

LOM

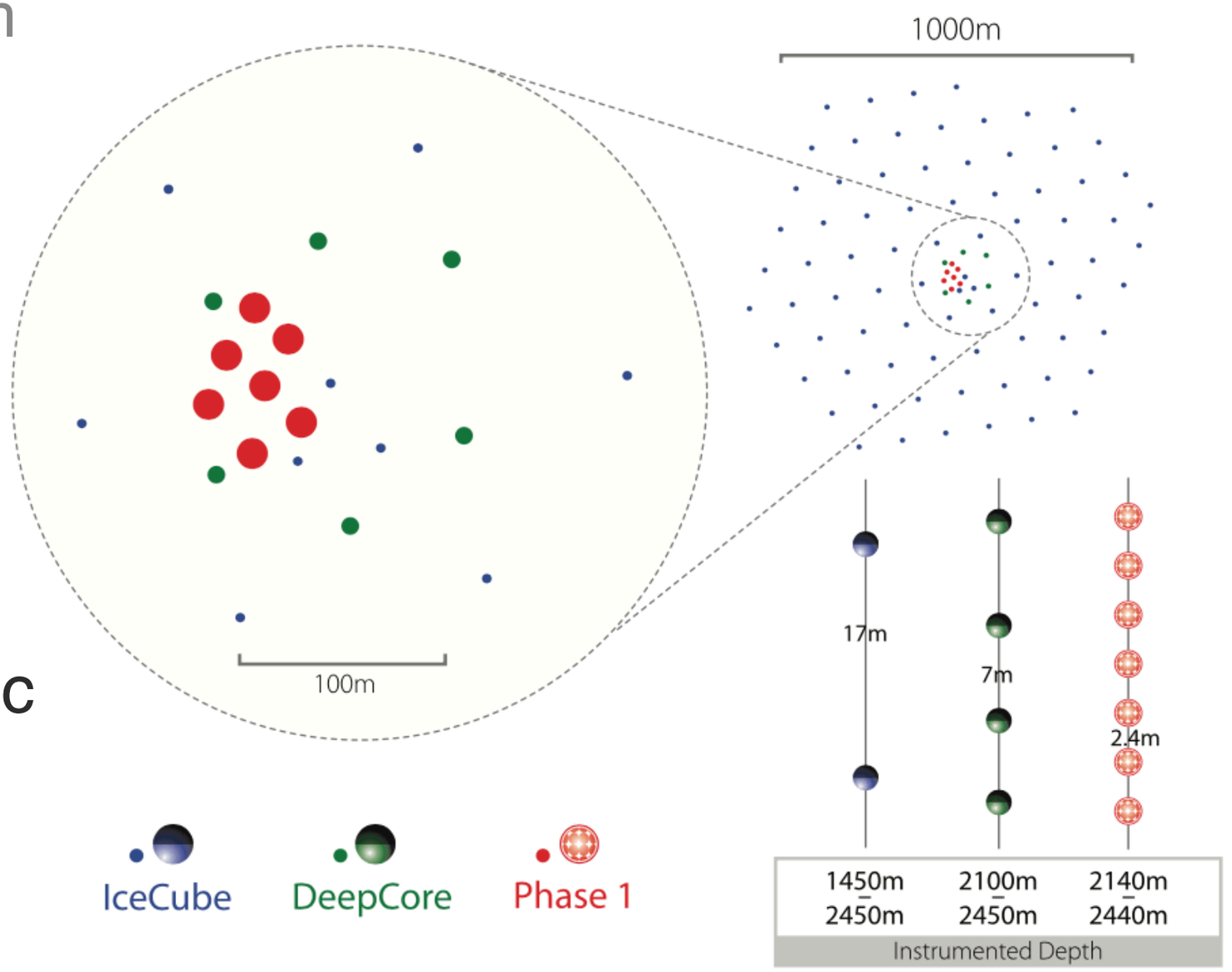


13

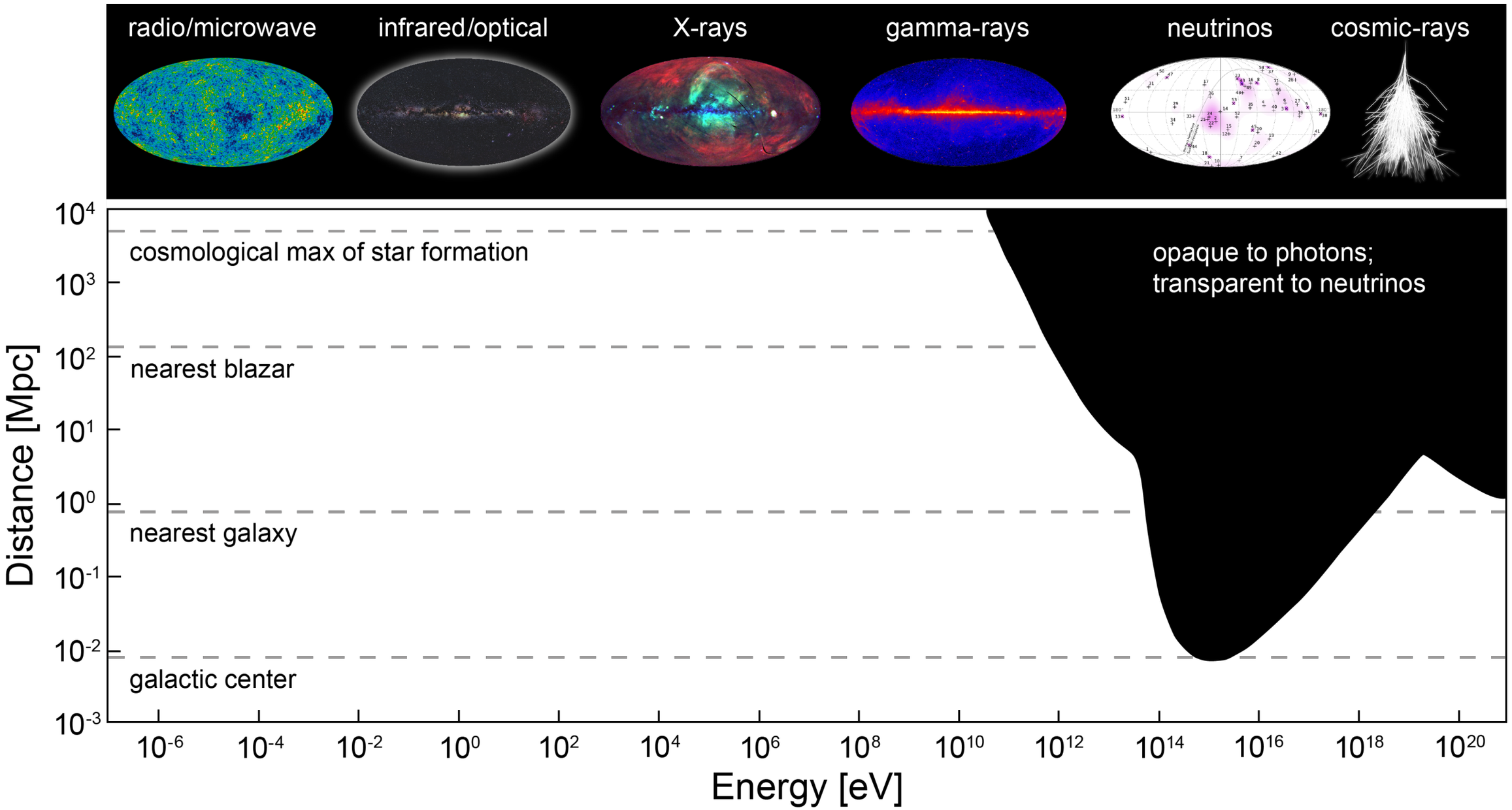
- Small diameter
- Directional info.
- More area per module

Gen2-Phase I

- Seven new strings of multi-PMT mDOMs in the DeepCore region
  - Inter-string spacing of ~22 m
- New calibration devices, incorporating lessons learned from a decade of IceCube calibration efforts
- Enhance IceCube's scientific of capabilities at both high and low energy



Science driver in a nutshell



The Universe is opaque to EM radiation for ¼ of the spectrum,
i.e. above 10-100 TeV where IceCube sees cosmic neutrinos.

⟹ **explore this mostly uncharted territory with IceCube-Gen2**