Recent Astrophysical results by IceCube

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Figure: J Yang


THE ICECUBE COLLABORATION
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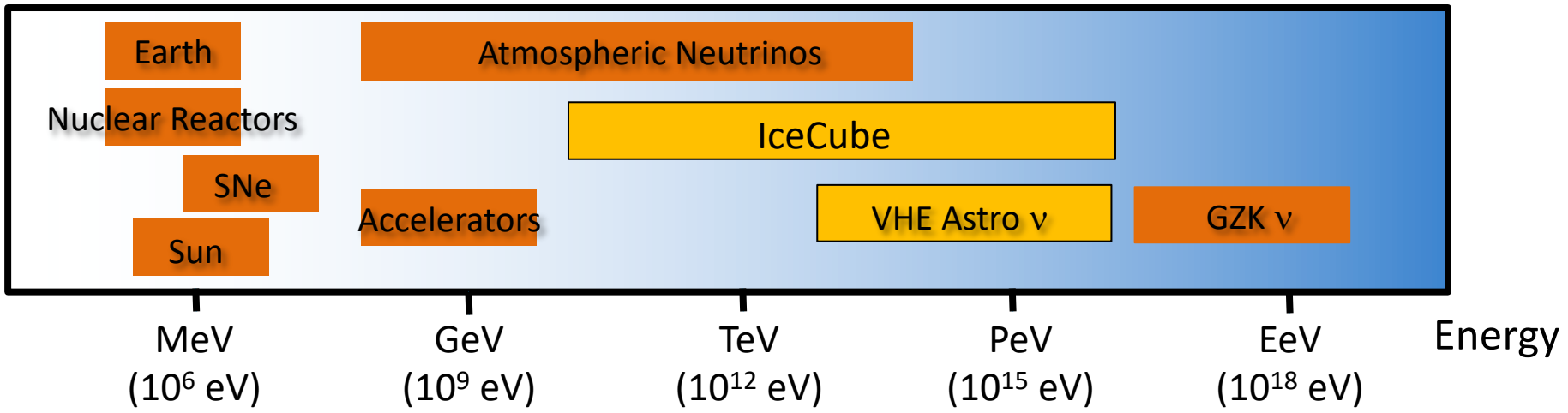
icecube.wisc.edu

Astrophysics of Neutrino Detectors



Galactic Core-Collapse SNe: 1-100 MeV

SNEWS: Super-K, Hyper-K, IceCube, Kamland, HALO, CEνNS, SNO+, nEXO, …
any ν detector worth its salt

Diffuse ν flux from cosmological core-collapse SNe: 10 – 100 MeV

Super-K, Gd-loaded Super-K, Hyper-K

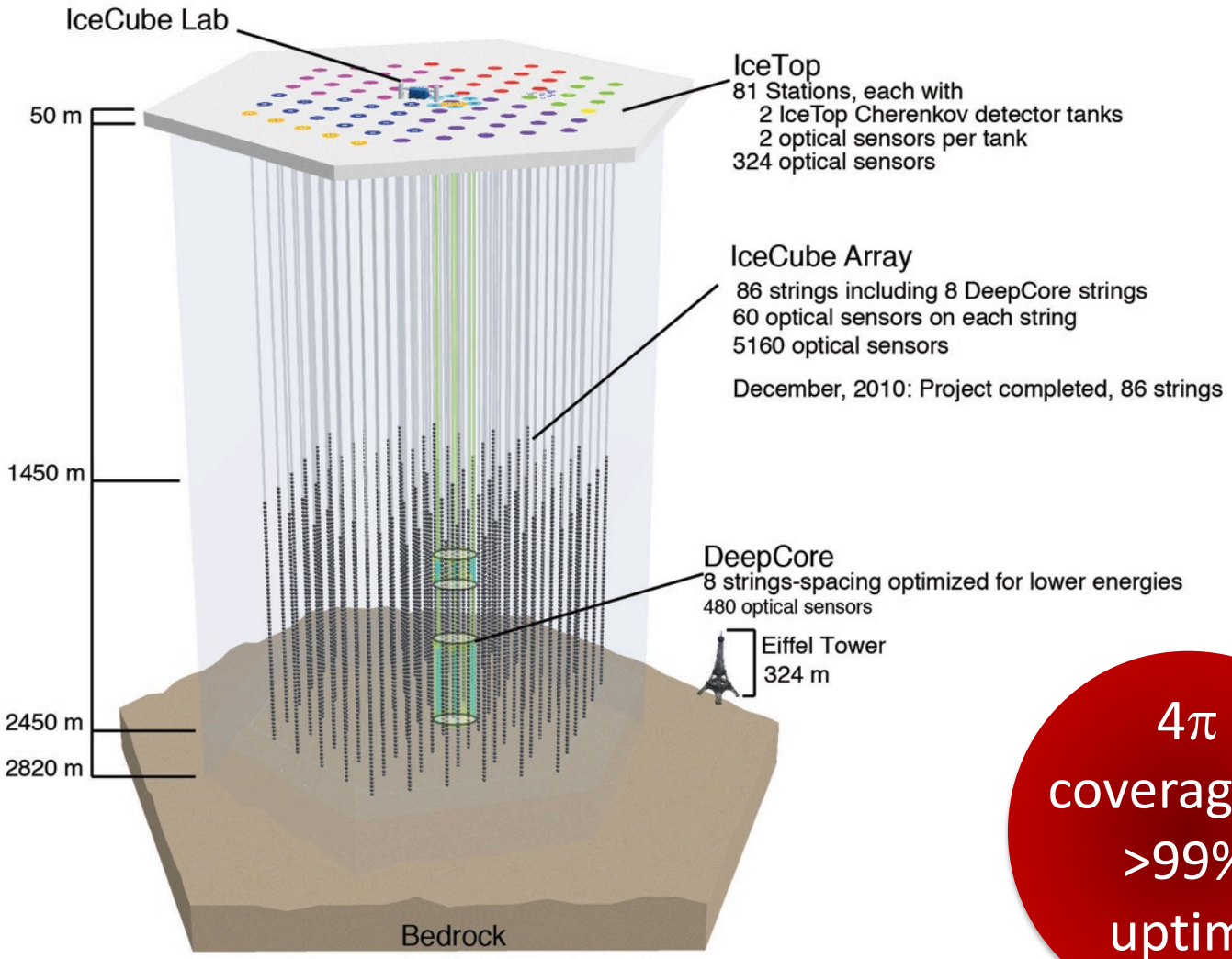
Very-High Energy Astrophysical ν: 10 TeV – 10 PeV

IceCube, KM3Net

Cosmogenic (GZK) neutrinos 10 PeV – 1 EeV

ARA, ARIANNA, RNO, TRINITY, GRAND, Gen2-Radio

IceCube: An Ice-Cherenkov ν Detector



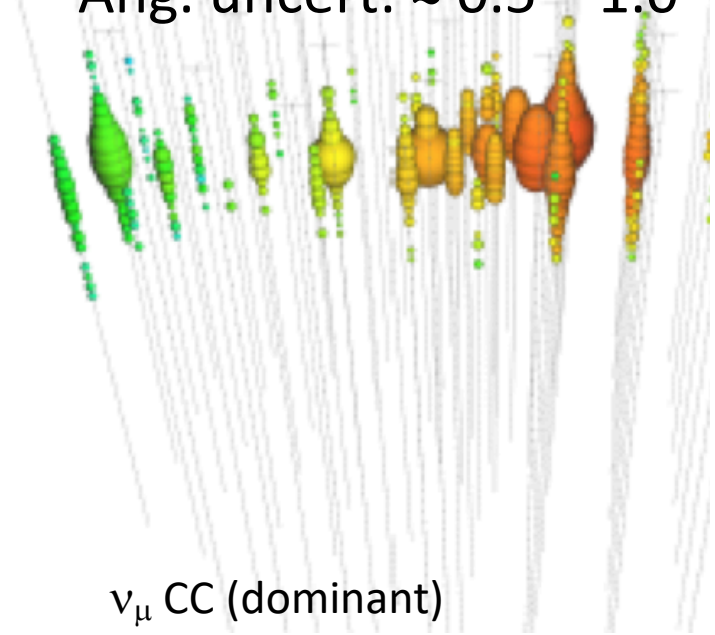
4π coverage (*) >99% uptime

Signals at IceCube

tracks

"Traditional ν astro channel"

Ang. uncert: ≈ 0.5 – 1.0°



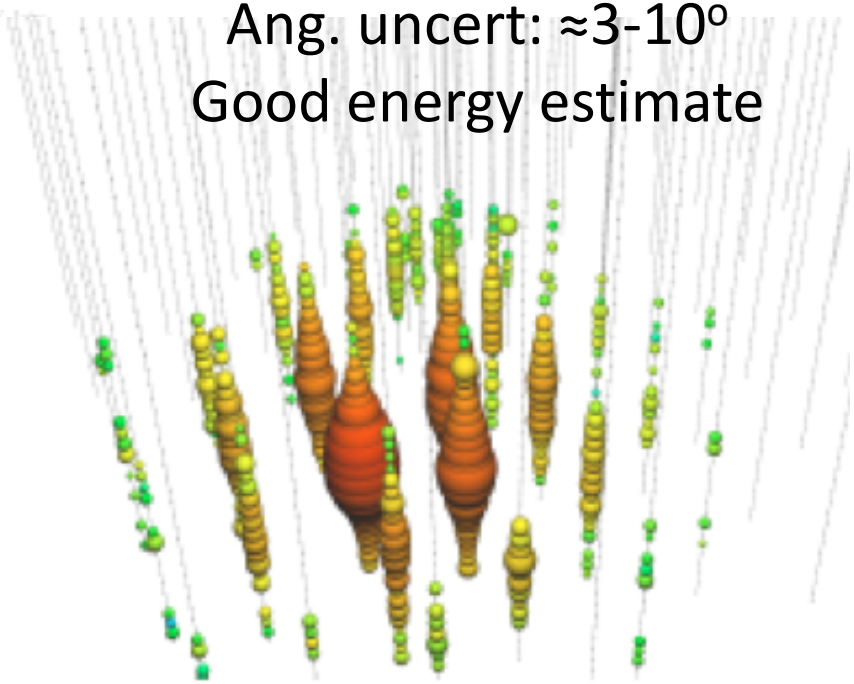
ν_μ CC (dominant)

ν_τ CC; τ decaying into μ (minor)

cascades / showers

Ang. uncert: ≈3-10°

Good energy estimate



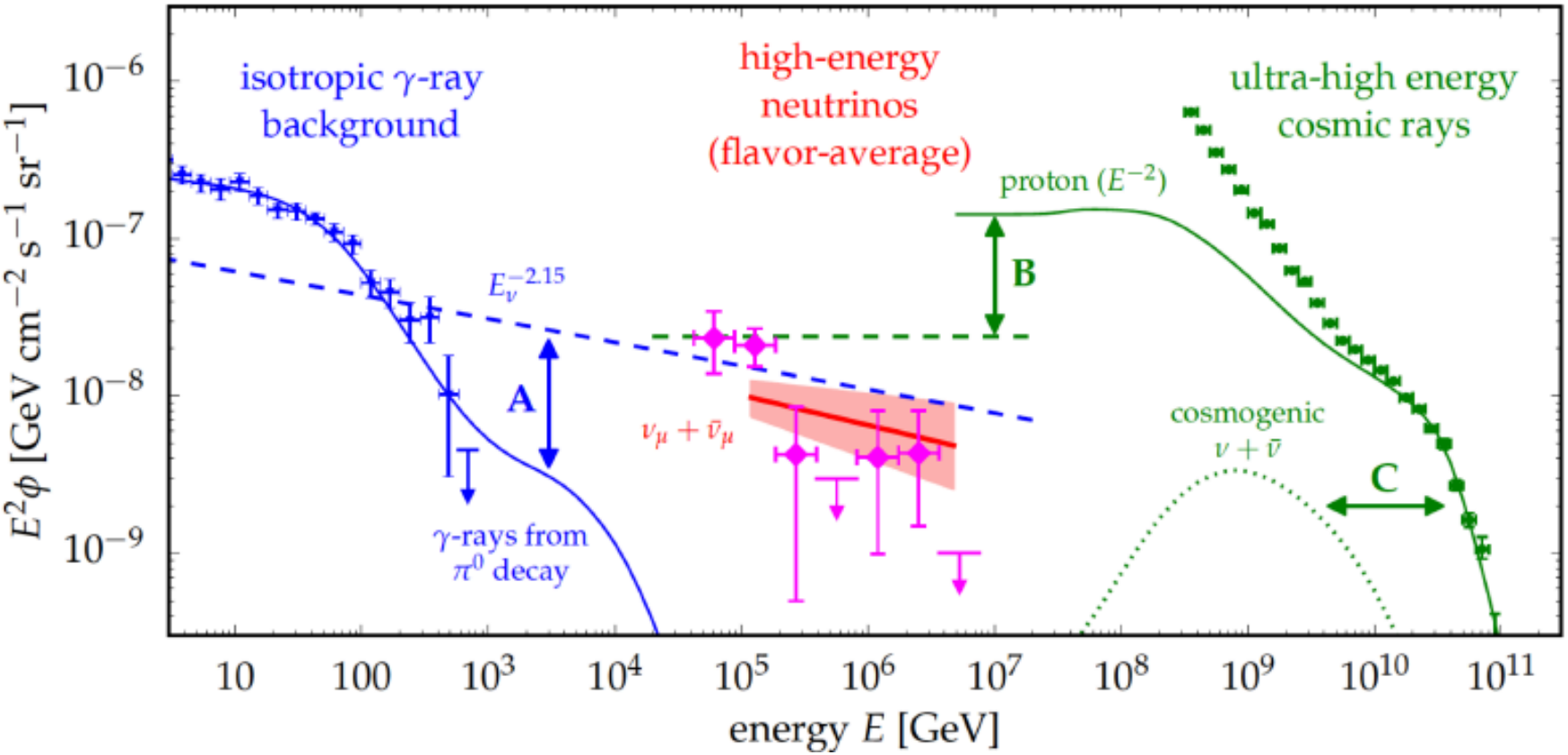
All other CC/NC/Glashow ν interaction (*)

Astro : Atm ν : Atm μ

$1 : 10^3 : 10^9$

(*) Actually, ν_τ interactions may have complicated topologies

The Diffuse Neutrino Background



Ahlers, Halzen. PPNP 102 (2018) 73

Neutrino sources are thin

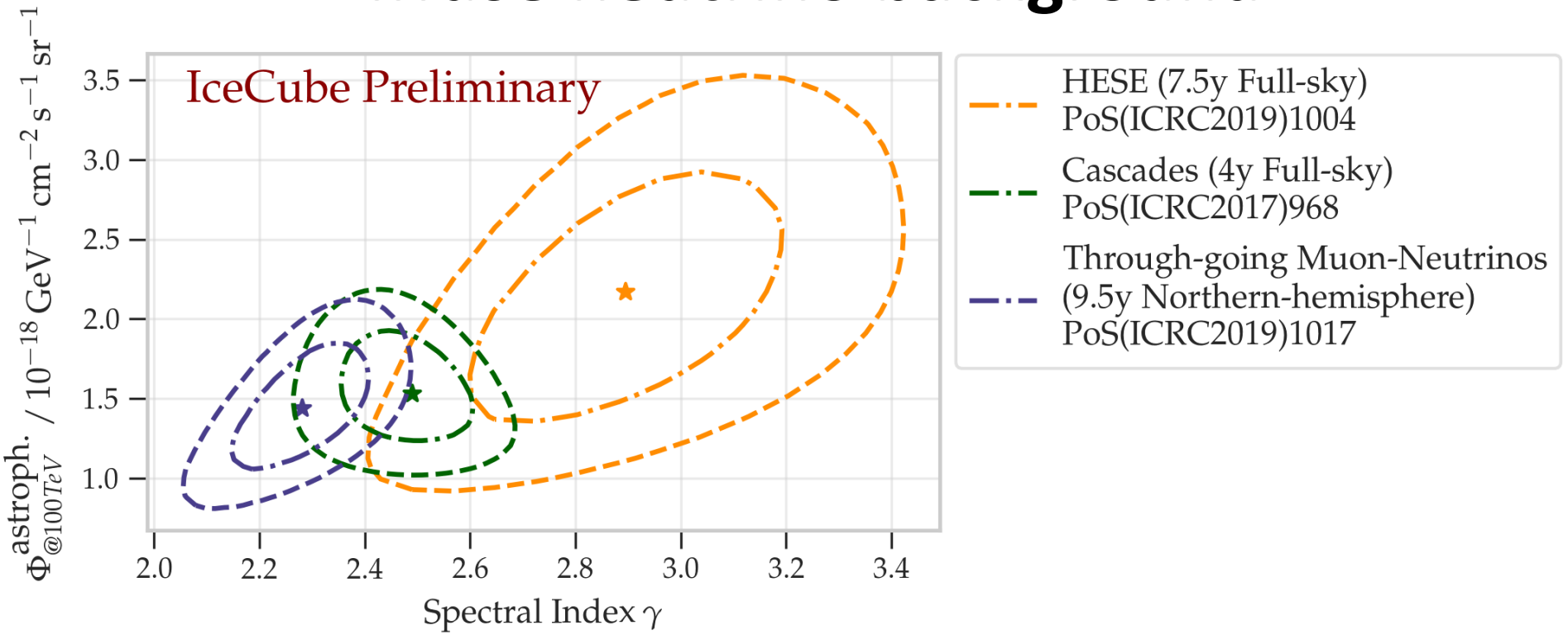
HE γ-rays / ν from π decay

Measuring the diffuse neutrino background

HESE	Cascades	Tracks
4π sr. All ν flavors (un-equal mix) E > 60 TeV	4π sr. All ν flavors (also un-equal mix) E > 20 TeV	~2π sr. (δ -5° to 90°) Mostly ν_μ E $\gtrsim$ 100 TeV
Deposited energy is well correlated with ν energy	Deposited energy is well correlated with ν energy	Angular resolution: 1.0° to 0.1°
7.5 years of data	4 years of data	9.5 years of data
PoS(ICRC2019)1004	PoS(ICRC2017)968	PoS(ICRC2019)1017

(*) We have more methods – the message will not change

Diffuse neutrino background



At face value tracks favor thin sources; cascades and HESE opaque sources. But > 100 TeV data is consistent among all channels.

A spectral breaks at 100 TeV (or other spectral options) is possible, but there's no clear evidence for this.

What are the sources?

Isotropic ν distribution is consistent with a diffuse flux

Event flavor consistent with oscillations over astrophysical scale

Point sources: No – but see ahead.

Follow up by multiple instruments: TXS 0506+056 – see ahead.

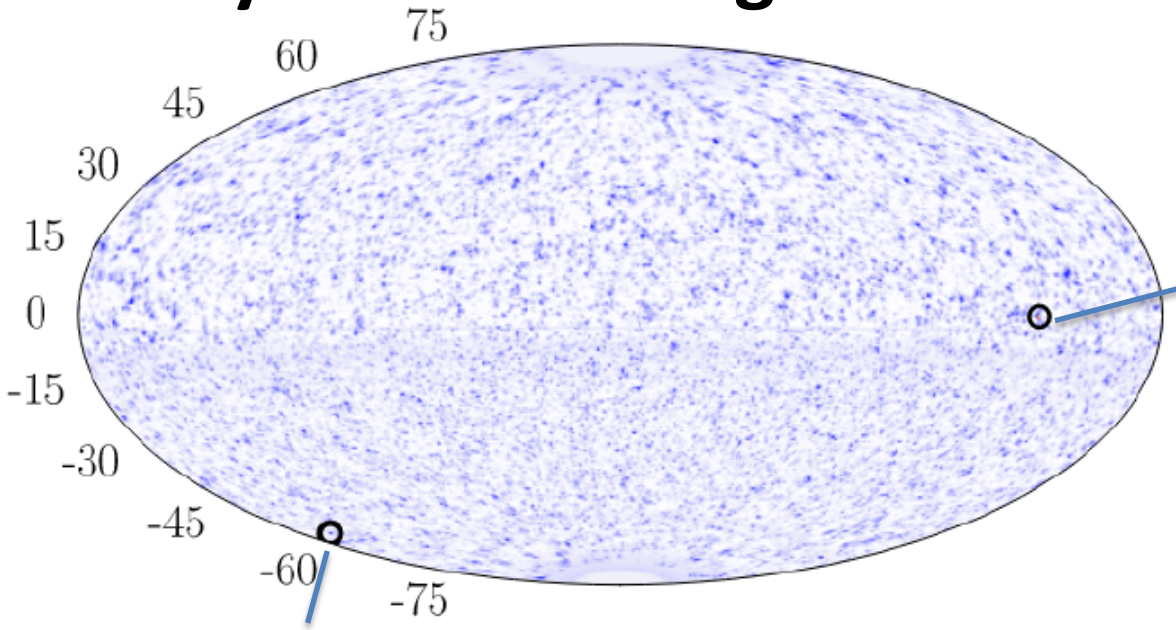
GRBs (prompt < 1-3%): No ApJL 824 (2016) 2

Any short (<100 s) transients: Probably not PRL 122 (2019) 051102

Galactic plane: No ApJ 849 (2017) 67

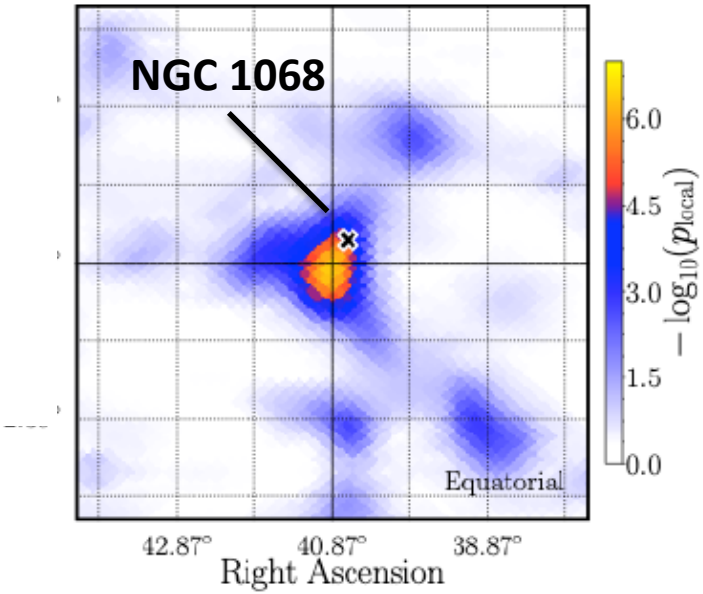
Many other usual suspects have been excluded …

10-year Time Integrated Point Source Searches



Northern sky hottest spot (δ>-5°)
p-value: 0.099
γ = -3.4 n_s = 61.5

Southern sky hottest spot
RA: 350.2°, δ=-56.5° (δ>-5°)
p-value: 0.75

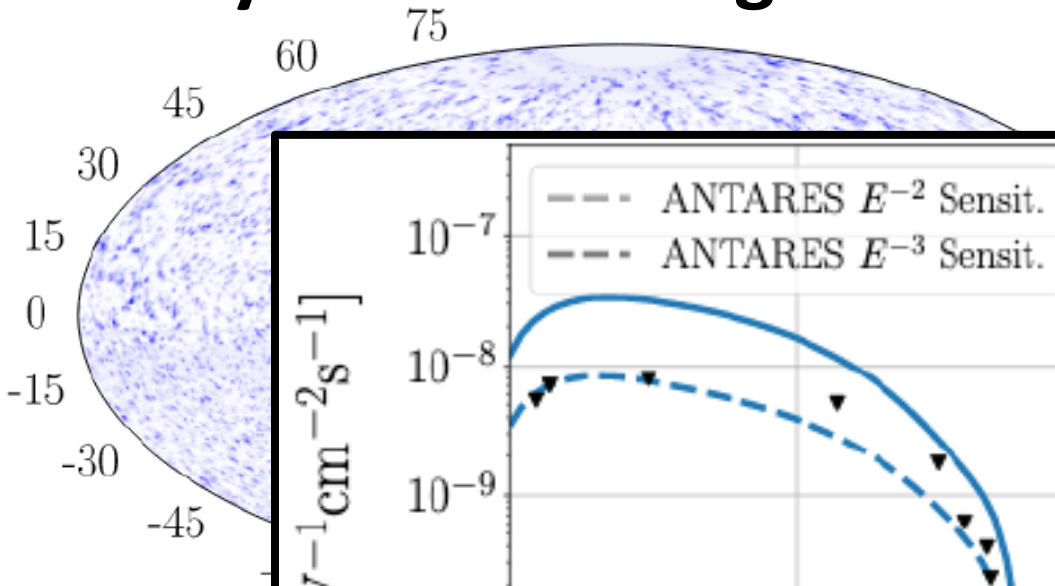


Source list: NGC 1068: 2.9 σ

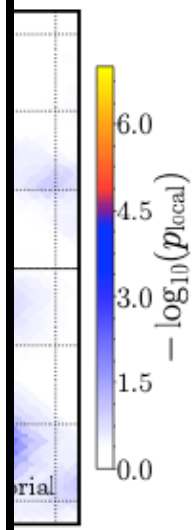
Binomial search. 4 sources (NGC 1068, TXS 0506+056, PKS 1424+240, GB6 J1542+6129): 3.3 σ

Phys. Rev. Lett. 124, 051103 (2020)

10-year Time Integrated Point Source Searches



Northern sky hottest



Southern

RA: 350.

p-value:

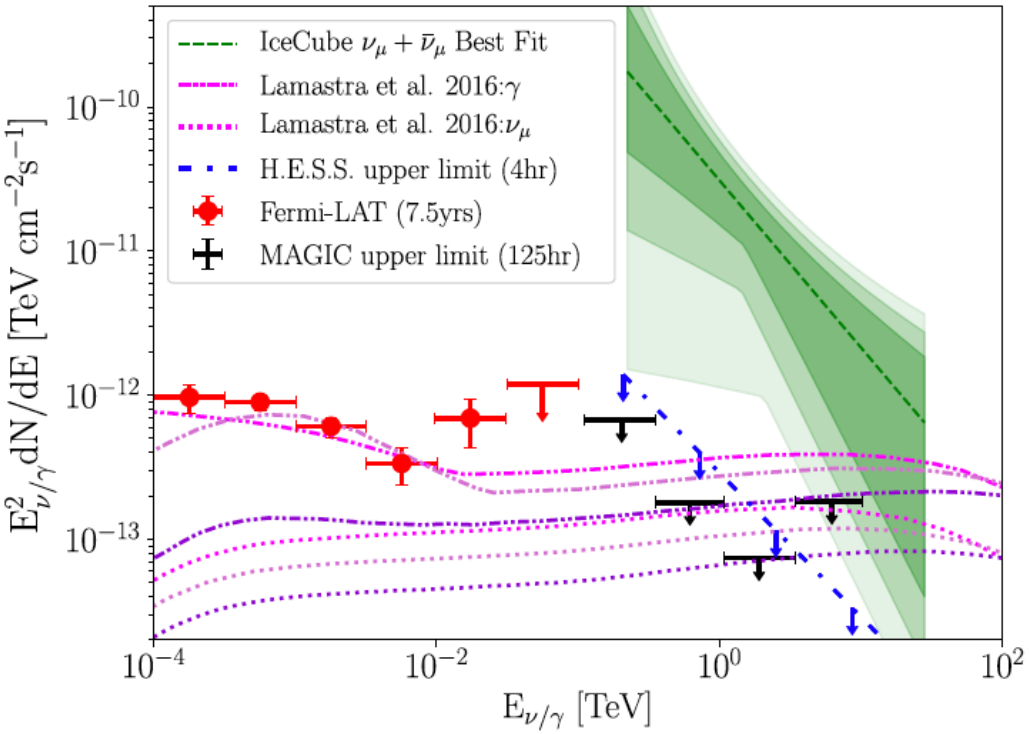
Source li

Binomial

PKS 1424+240, GB6 J1542+6129): 3.3 σ

NGC 1068

Star-burst galaxy and Seyfert II. 14 Mpc



See K. Murase on why MeV photons are expected.

IceCube's Multi-messenger program

Realtime alerts V1: April 2016 – June 2019
Realtime alerts V2: June 2019 – present

10 Gold (+20 Bronze) events / year

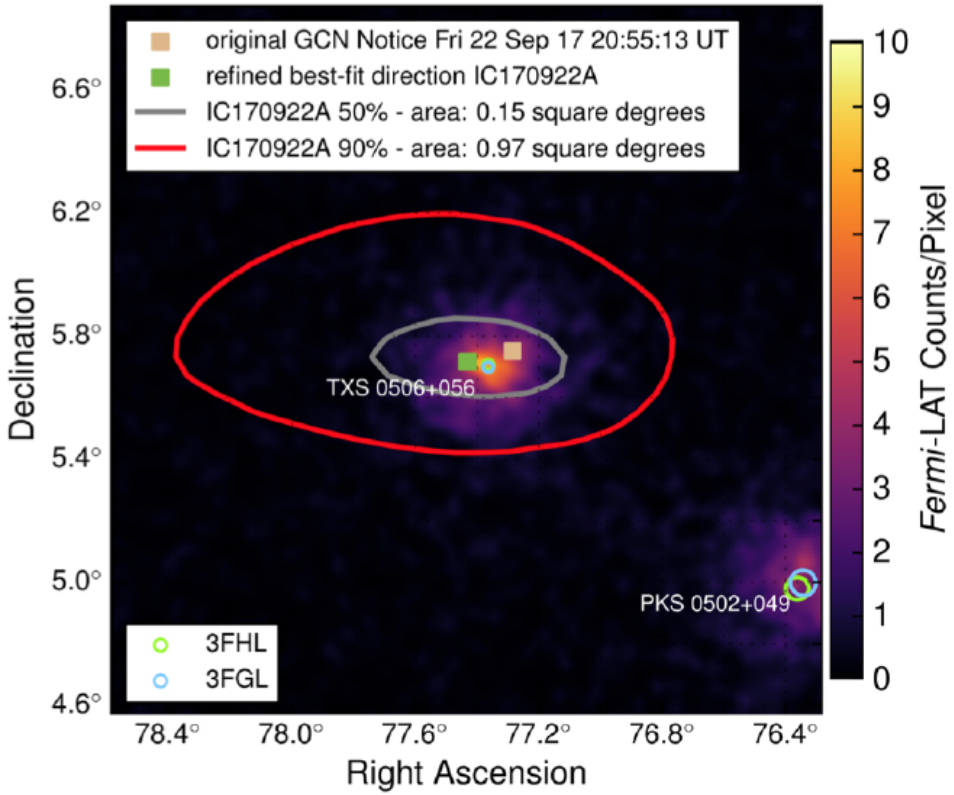
PoS(ICRC2019)1021

Fast Response Analysis

PoS(ICRC2019)1026

GW realtime follow-up

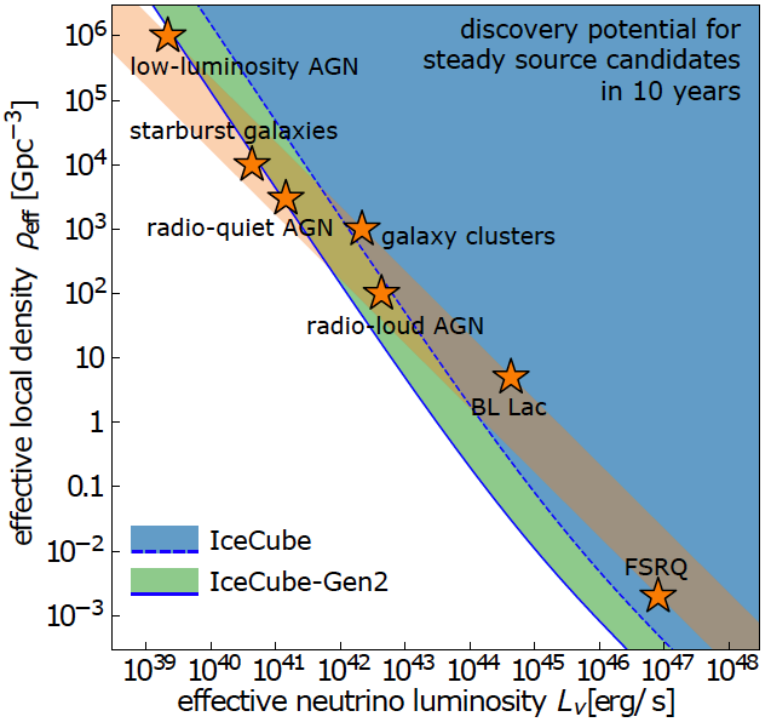
PoS(ICRC2019)918

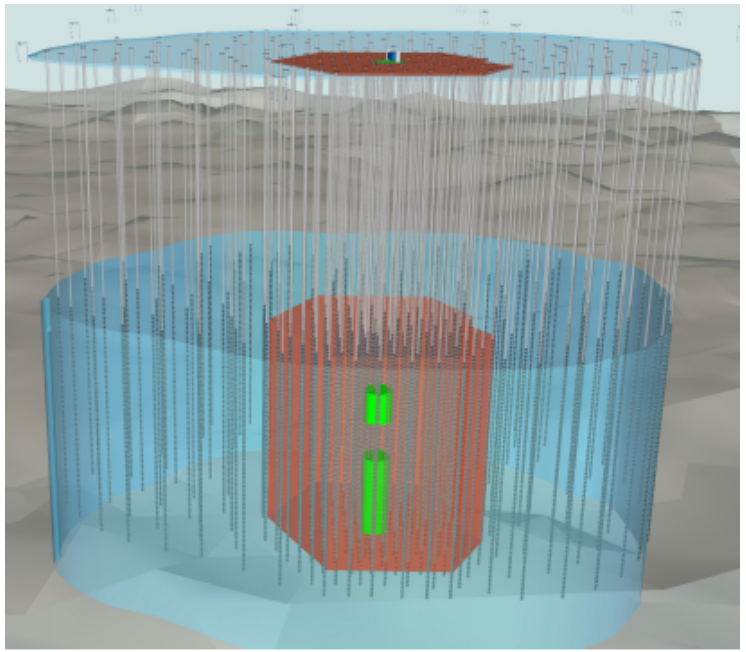


Science 361 (2018) eaat1378
Science 361 (2018) 147-151

IceCube Gen-2

8 times the instrumented (optical) volume + radio component.
5x better time-integrated point source sensitivity than IceCube (E^{-2})
Threshold is ~30 TeV ('Standard' IceCube's is ~1 TeV)
Better angular resolution, specially above ~100 TeV





Gen2 Whitepaper: arXiv:2008.04323

Conclusions

IceCube has observed a high energy astrophysical neutrino flux between 10 TeV and 10 PeV.

The sources of this flux have not been unequivocally identified.

A candidate source has been identified: the blazar TXS 0506+056.

Tantalizing hints of sources in the time integrated results.

Gen2 will reach a sensitivity that will enable it to uncover the sources of the diffuse flux.