IceCube

as a discovery observatory for physics beyond the standard model

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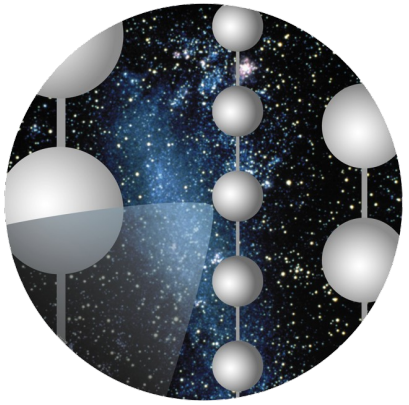
for the IceCube Collaboration

Rencontres de Moriond

Electroweak session

March 2011



IceCube Detector

5160 Digital Optical Modules (DOMs)
on 86 strings

1 km^3 instrumented volume = 1 G Ton
1.5 km - 2.5 km deep

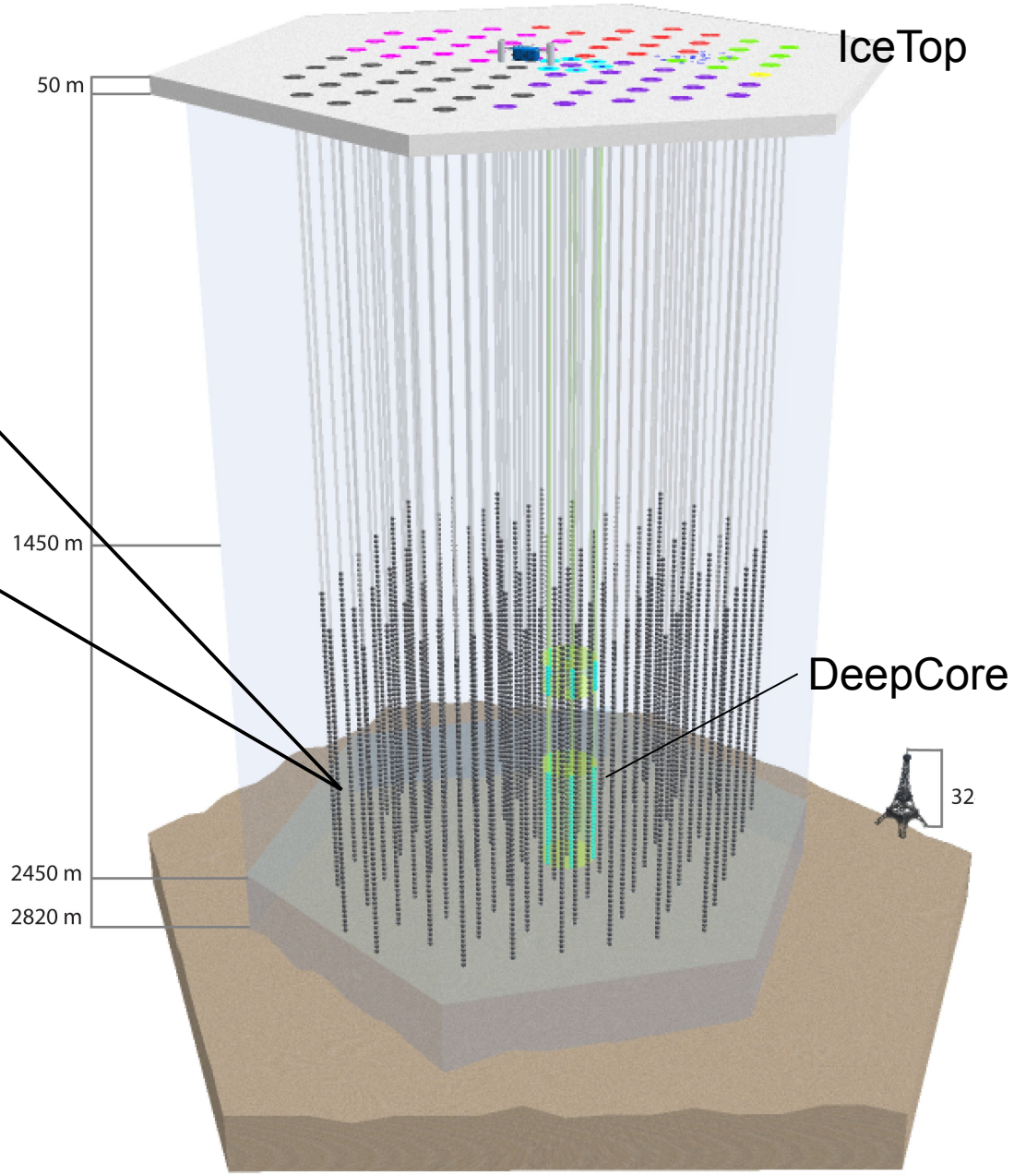
Energy threshold ~10 GeV

Dense inner array (DeepCore)

1 km^2 surface array
IceTop: 81 stations

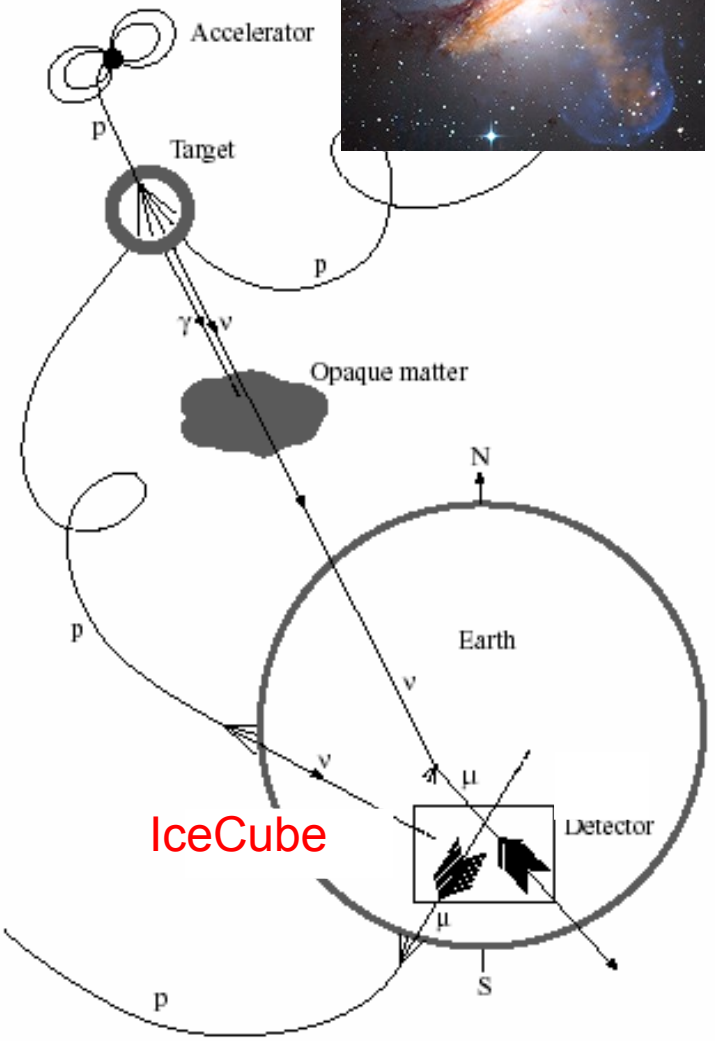
Detects ~10^8 muons &
~200 neutrinos **per day**

Detector now complete!

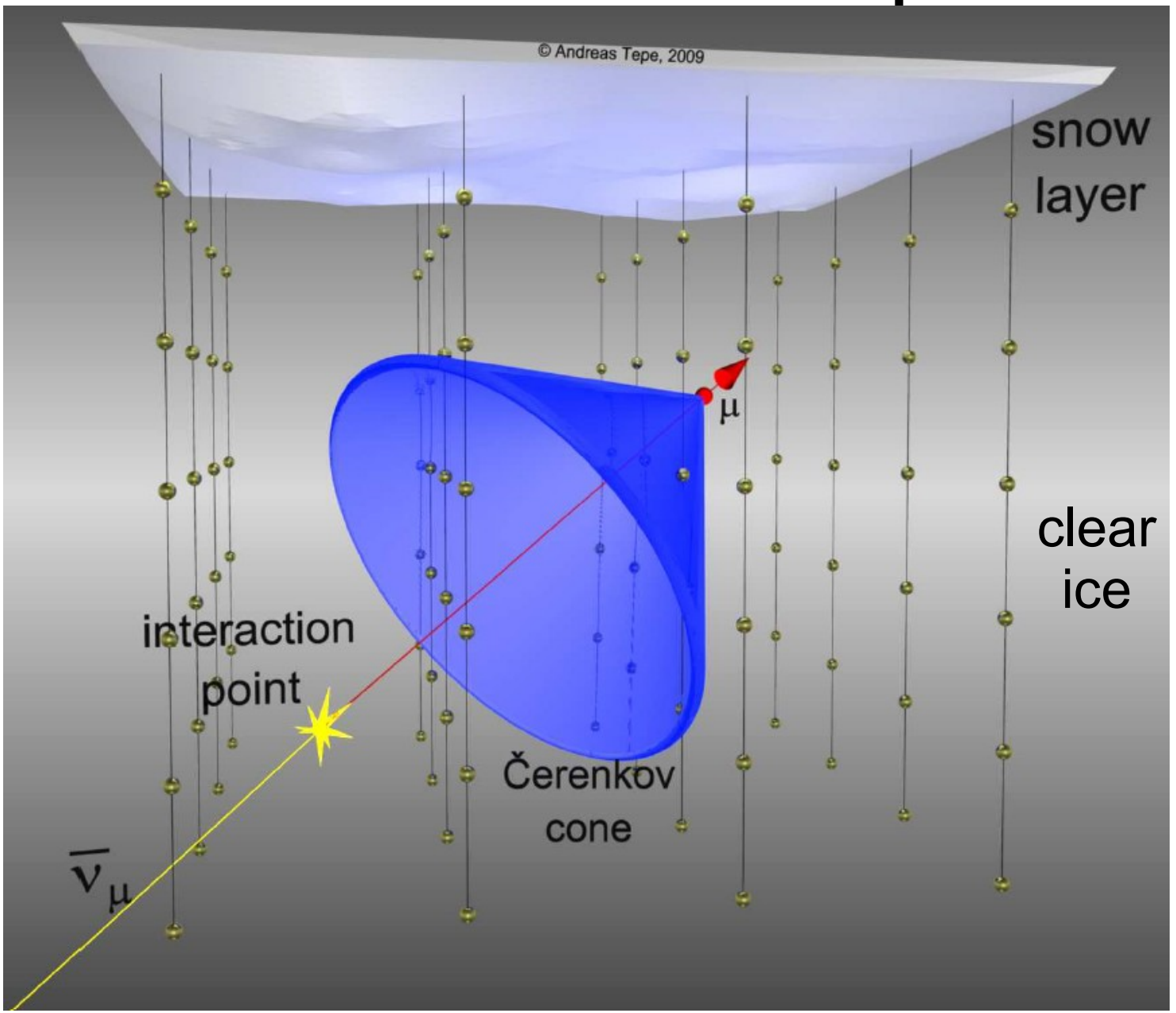


IceCube's main mission: astrophysics and cosmic rays

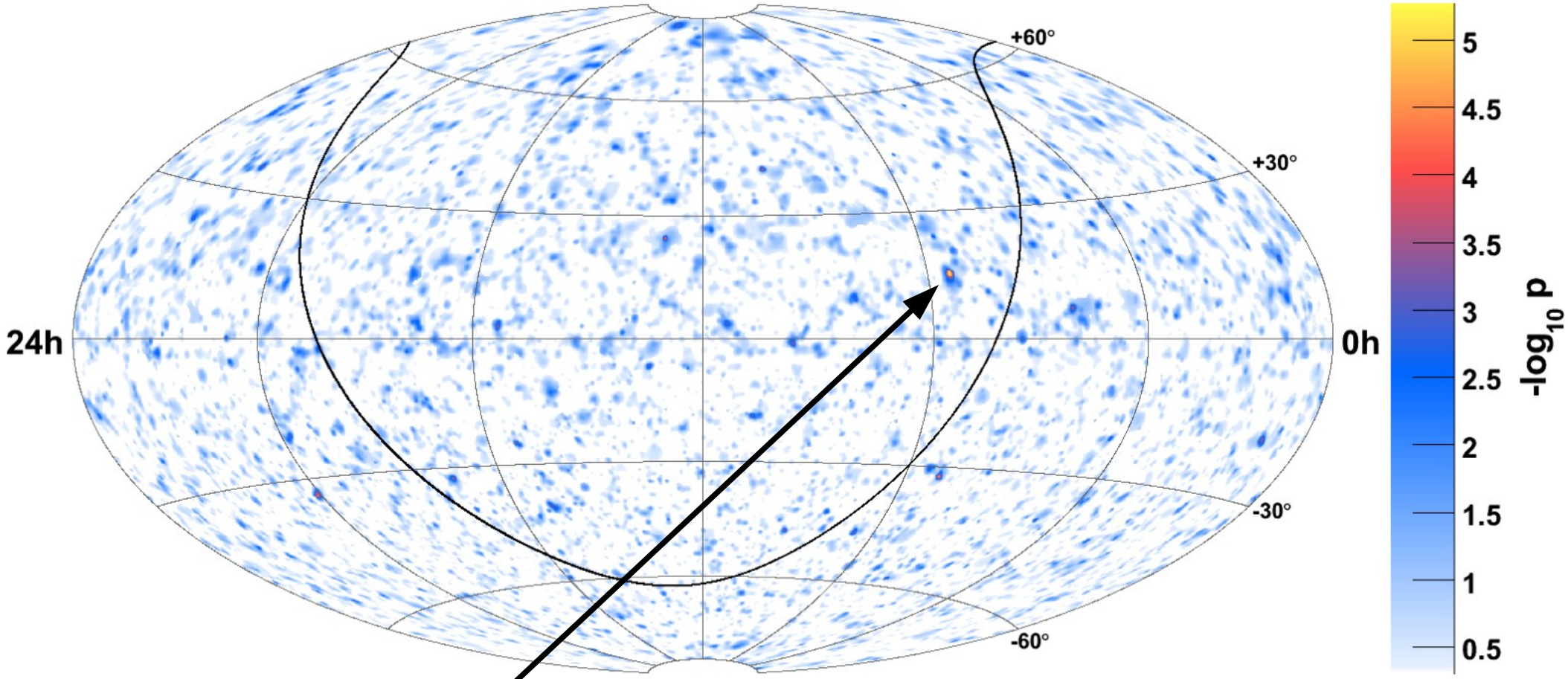
- search for extra-terrestrial neutrinos
  → natural accelerators producing HE cosmic rays
- Such as
  - Active Galactic Nuclei
  - Gamma Ray Bursts
  - SuperNovae
- Cosmic ray air showers with IceTop
  - Composition
  - Galactic ↔ Extra-Galactic



Work horse detection channel of neutrino telescopes



Astrophysics: Neutrino point sources

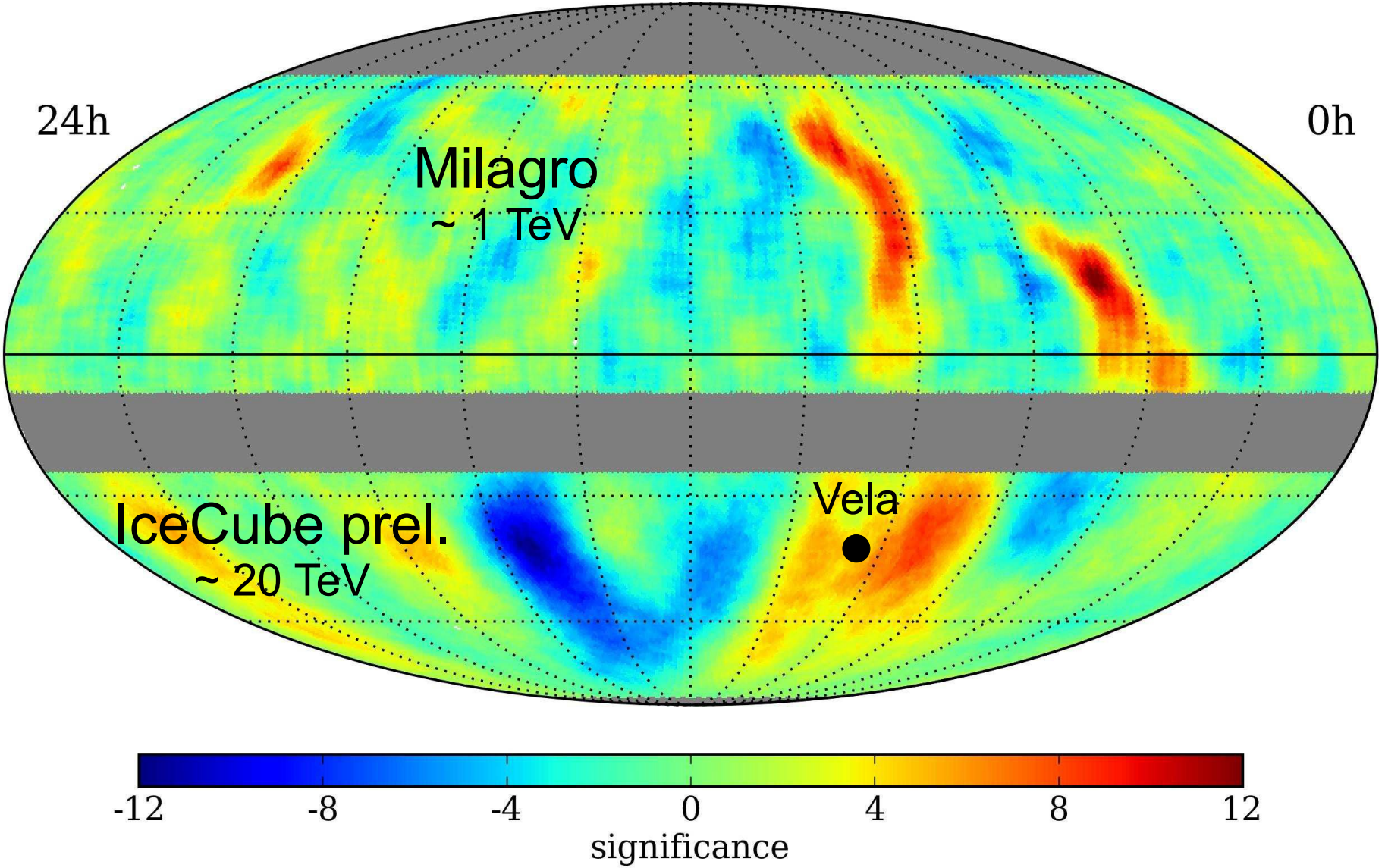


Hottest location in all-sky search
Ra=113.75, Dec=15.15

Pre-trial $-\log_{10}$(p-value) = 5.28

All sky p-value: 18%
No evidence yet

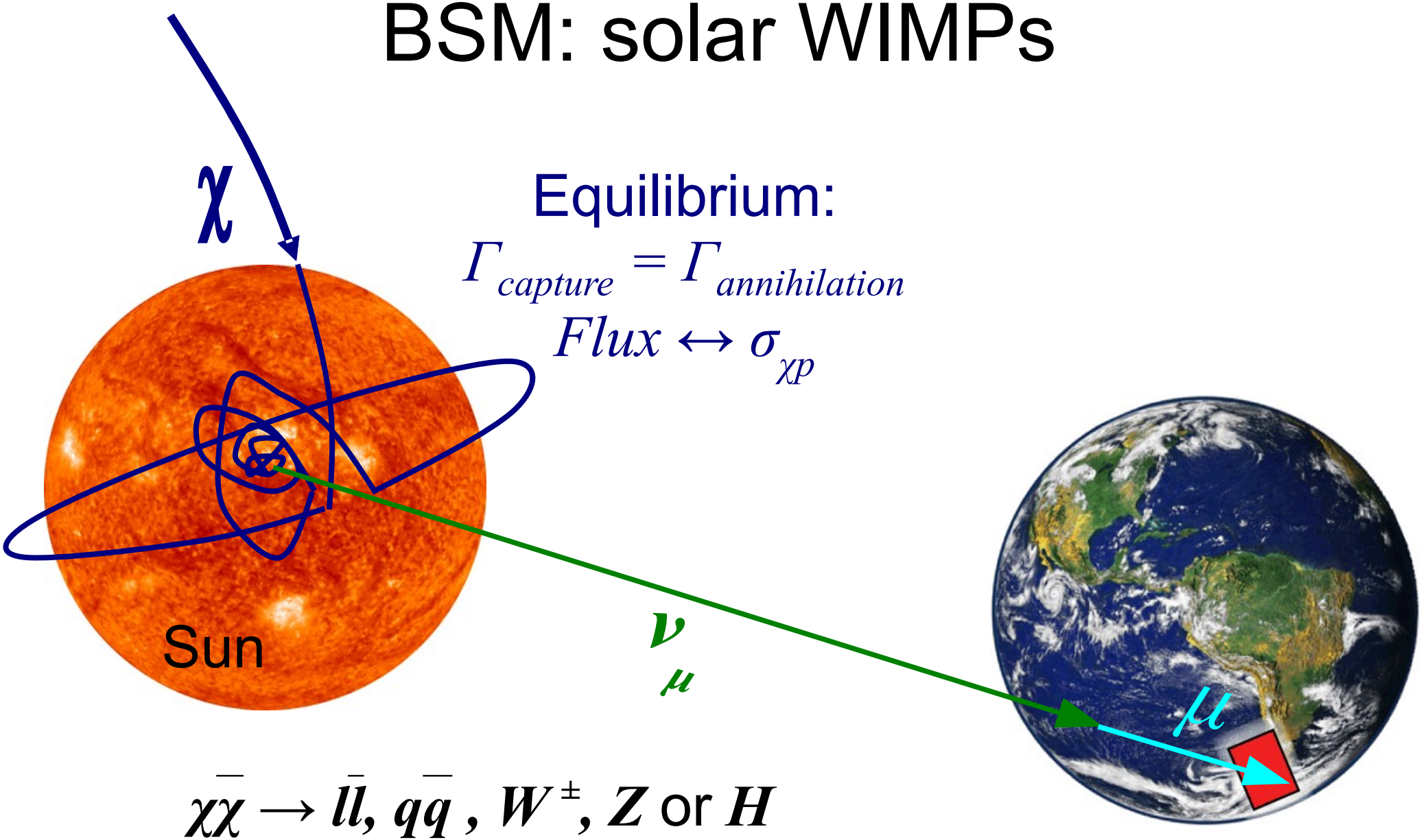
Cosmic rays: Anisotropies at TeV



General structure consistent with northern sky

Vela source not plausible due to gyro radius

BSM: solar WIMPs



Equilibrium:

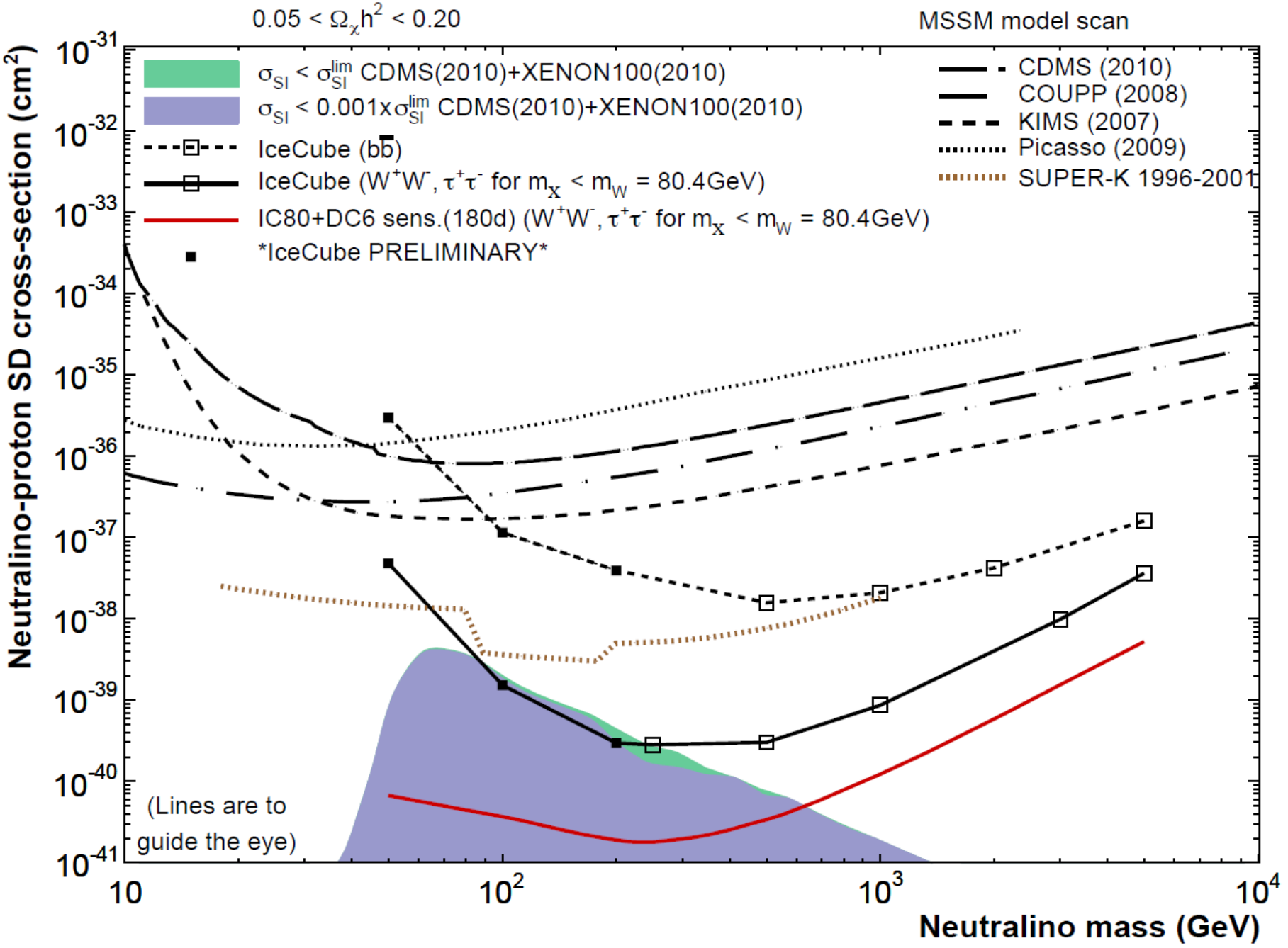
$$\Gamma_{capture} = \Gamma_{annihilation}$$

$$Flux \leftrightarrow \sigma_{\chi p}$$

$$\chi\bar{\chi} \rightarrow l\bar{l},\ q\bar{q},\ W^{\pm},\ Z \text{ or } H$$

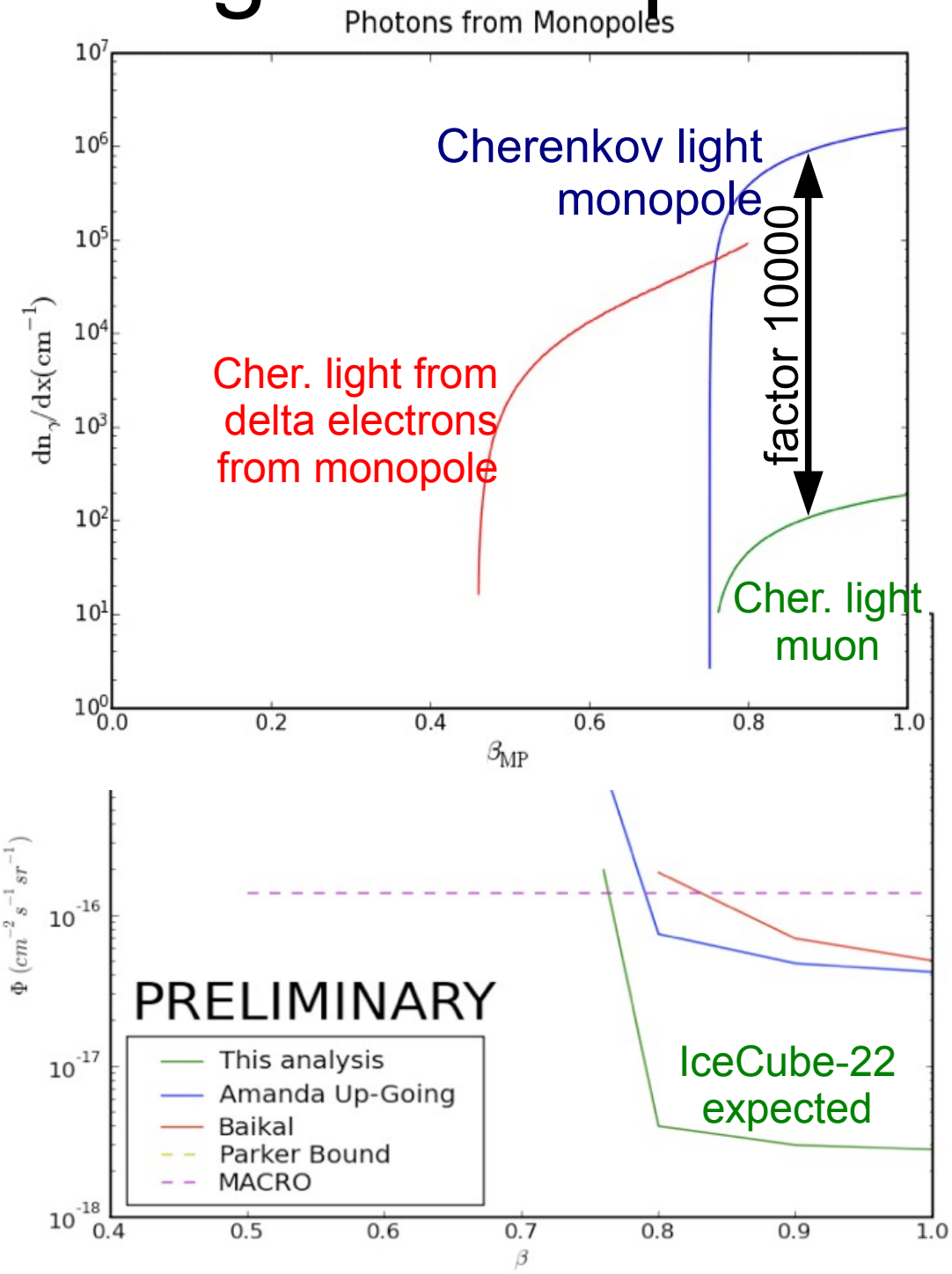
$$\rightarrow \cdots \rightarrow \nu_{\mu}$$

Spin dependent χ-p X-section



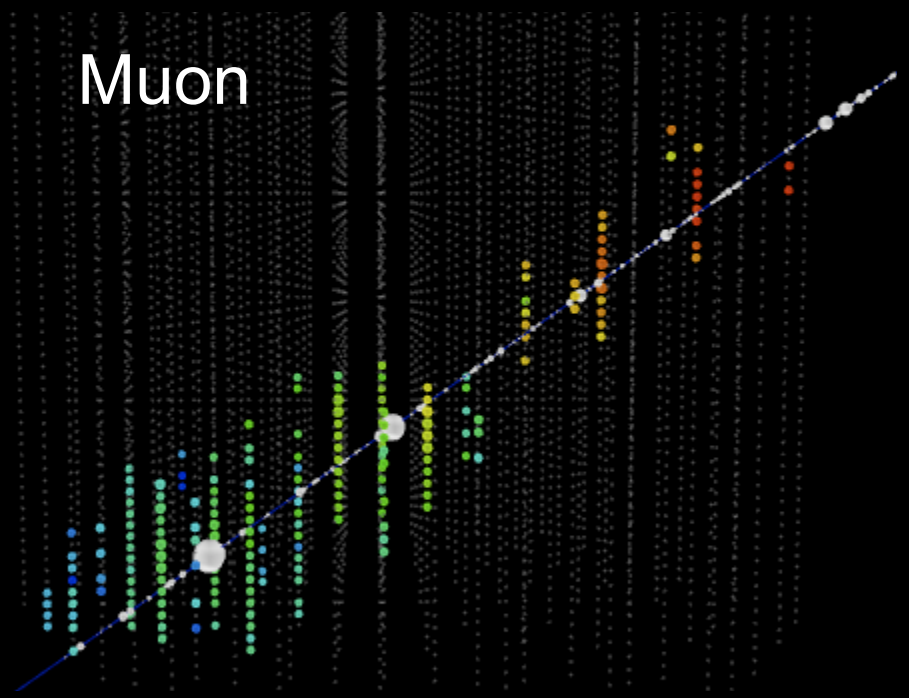
Searches for relic magn. monopoles

- Charge:
  $g \approx N \cdot 68.5\ e$
- Mass:
  $m = 10^4 - 10^{17}$ GeV
- Kinetic energy:
  $T = 10^9 - 10^{16}$ GeV
- **Cherenkov light:**
  $N_\gamma \propto (g \cdot n / e)^2$
  $\propto 8300\ N_\gamma(\mu)$

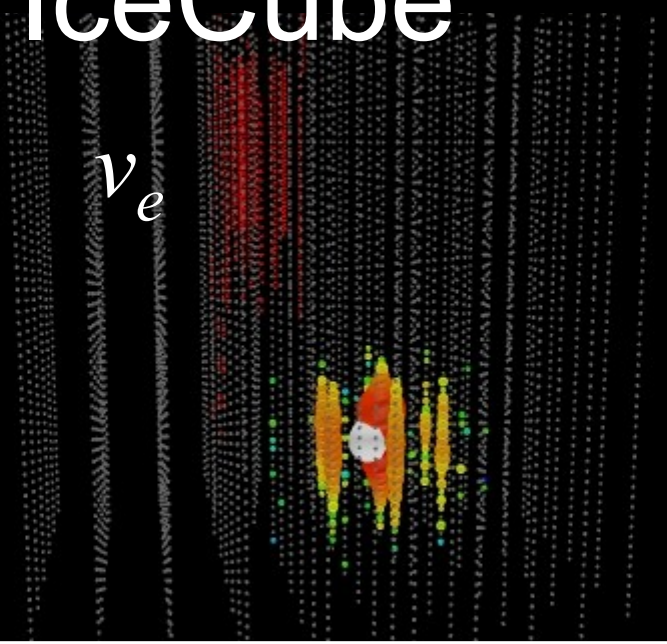


Event signatures in IceCube

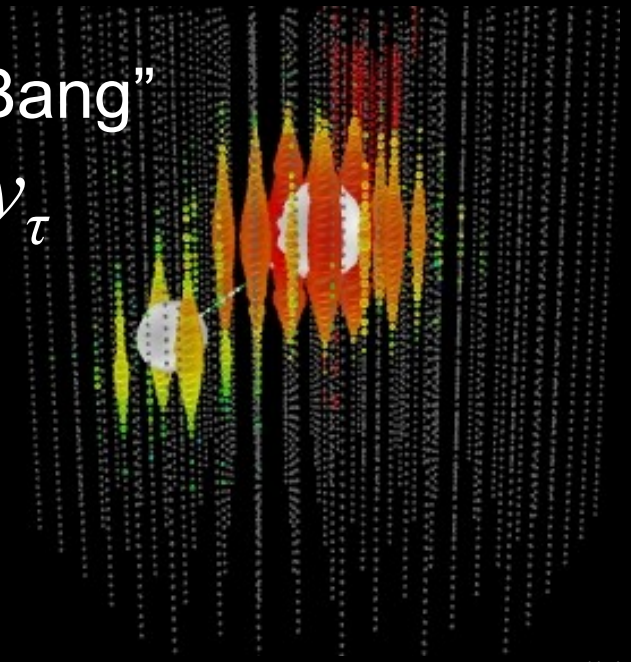
Muon



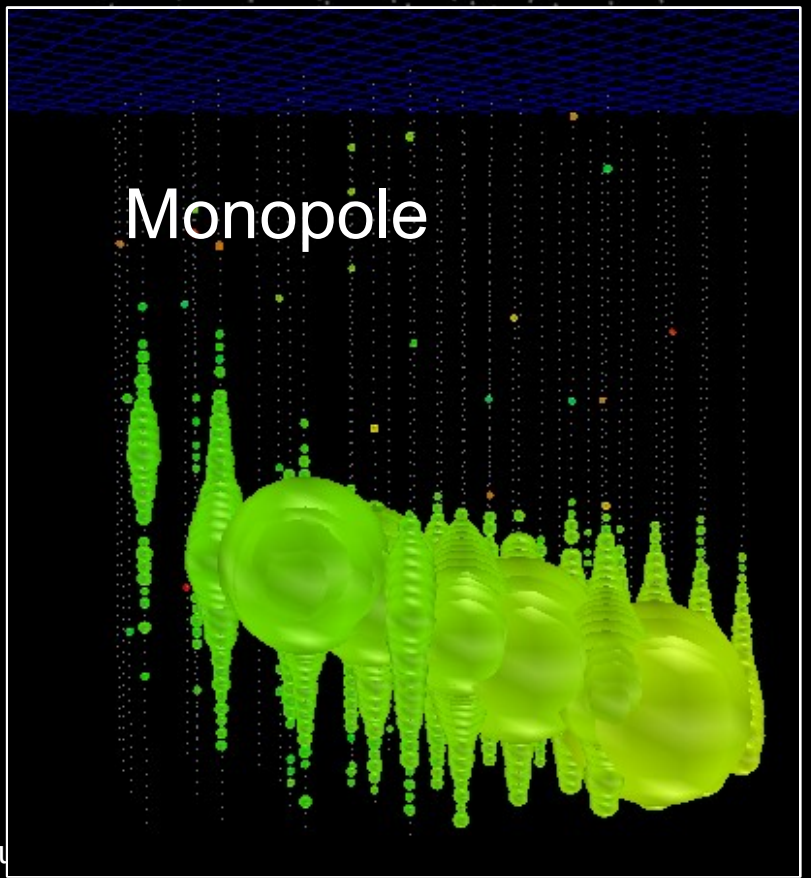
ν_e



"Double Bang"
from ν_τ

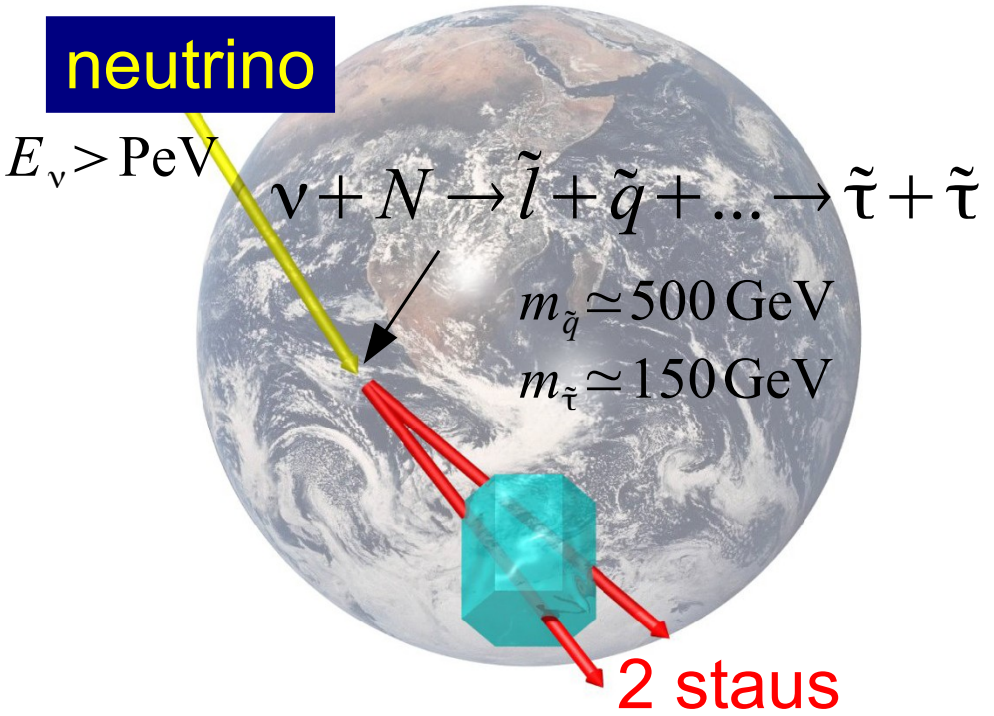


Monopole

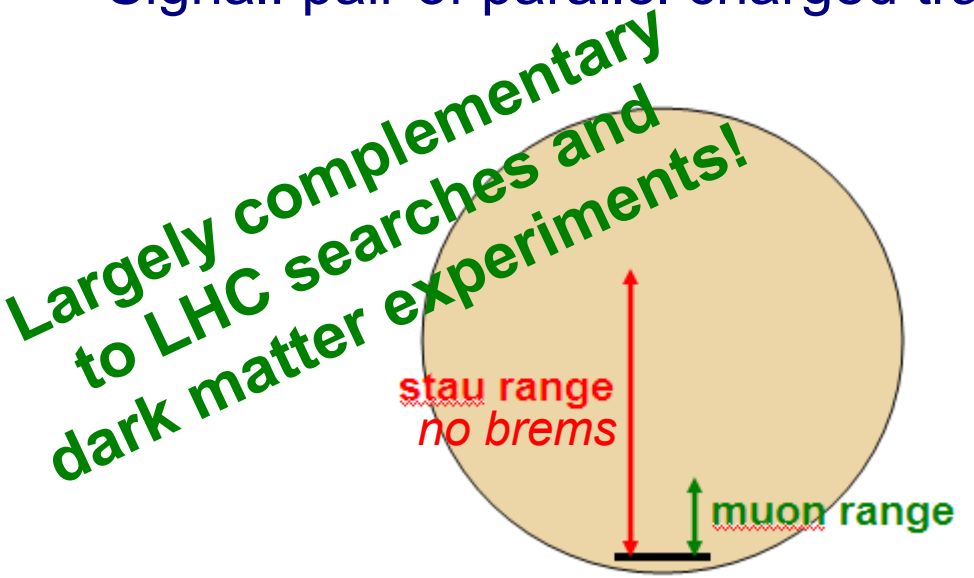


BSM: Direct (!) SUSY detection

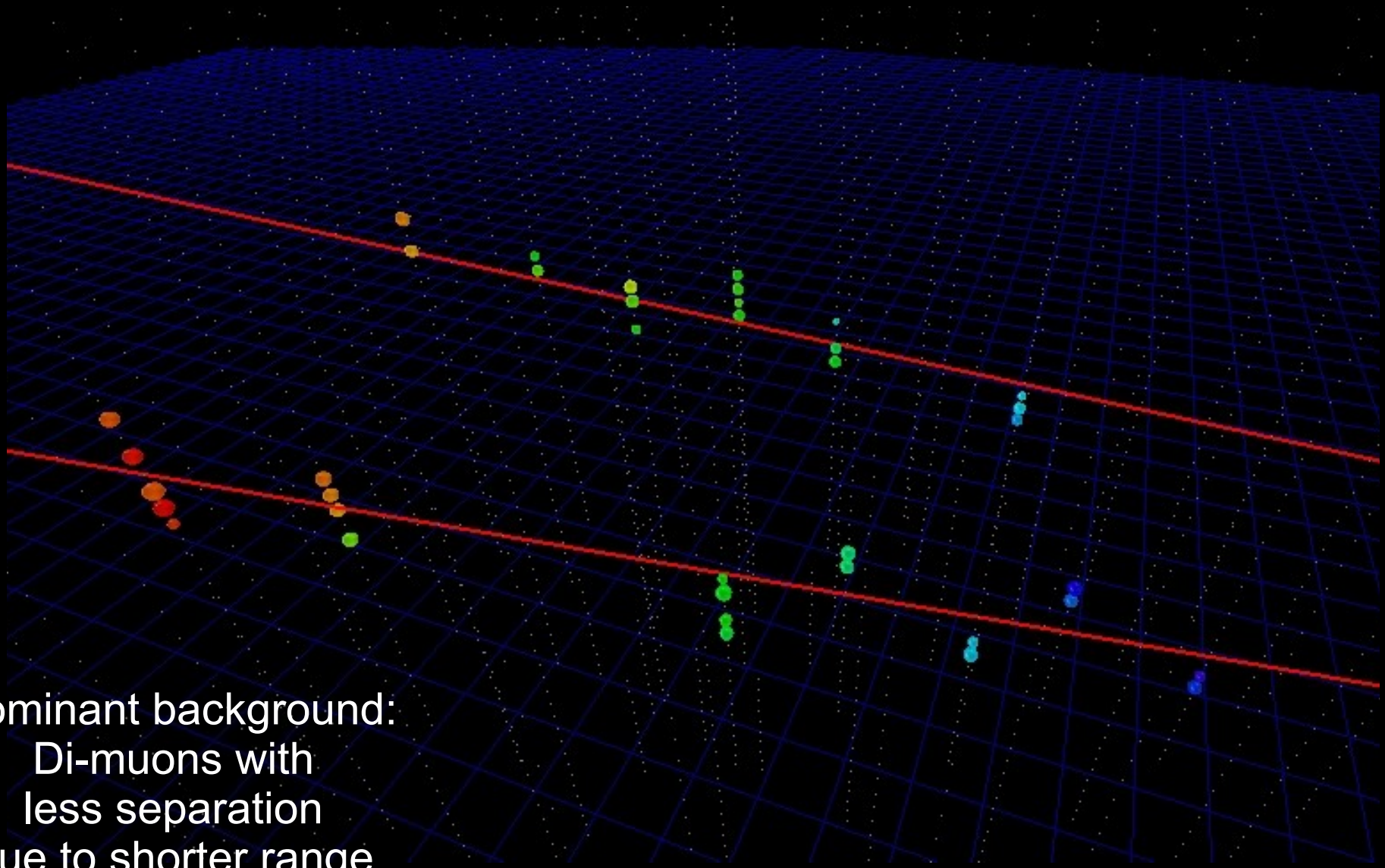
- X-section for heavies: $\sigma \sim 1/M^2$
- Large detector & range compensate
- Direct detection of charged, quasi-stable exotics
- Produced by UHE ν
- **LSP gravitino** (esp. gauge mediated) → NLSP: stau



Signal: pair of parallel charged tracks.

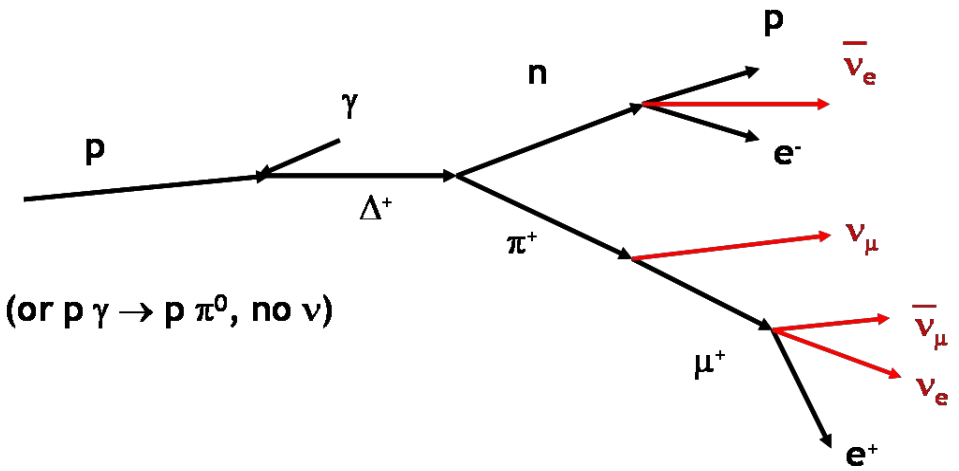


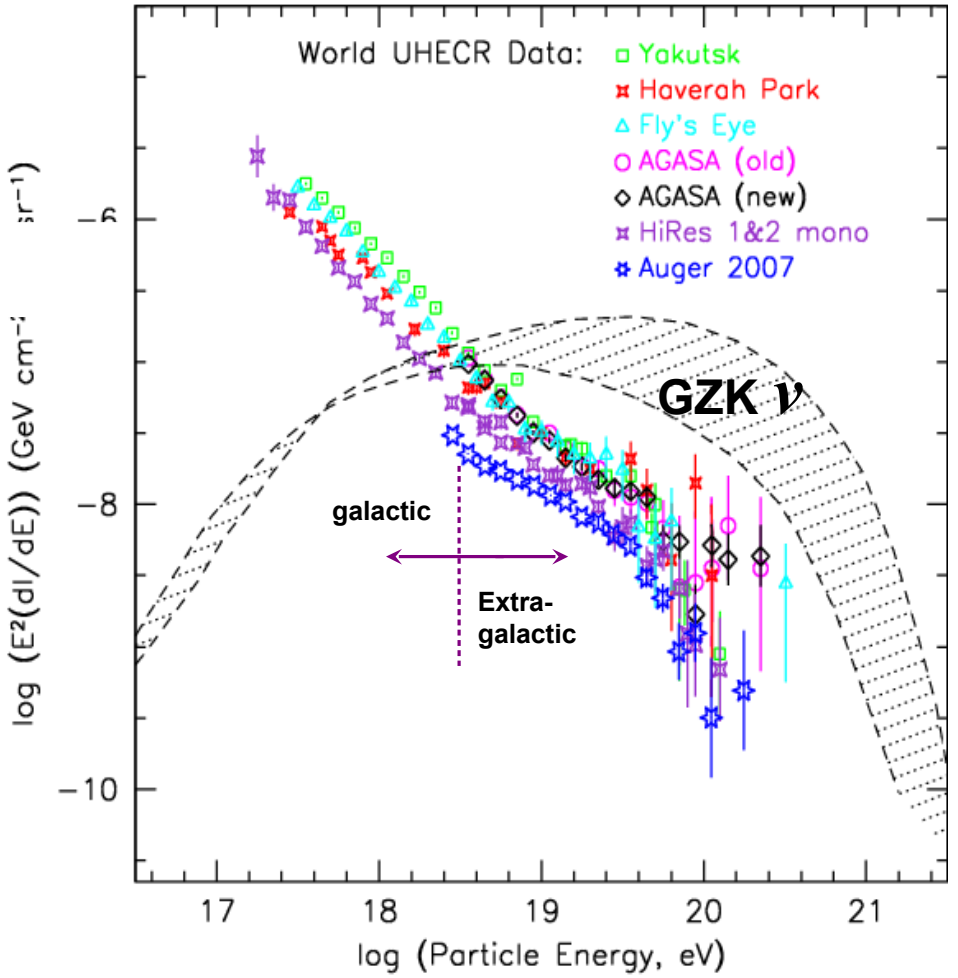
Track separation and reconstruction



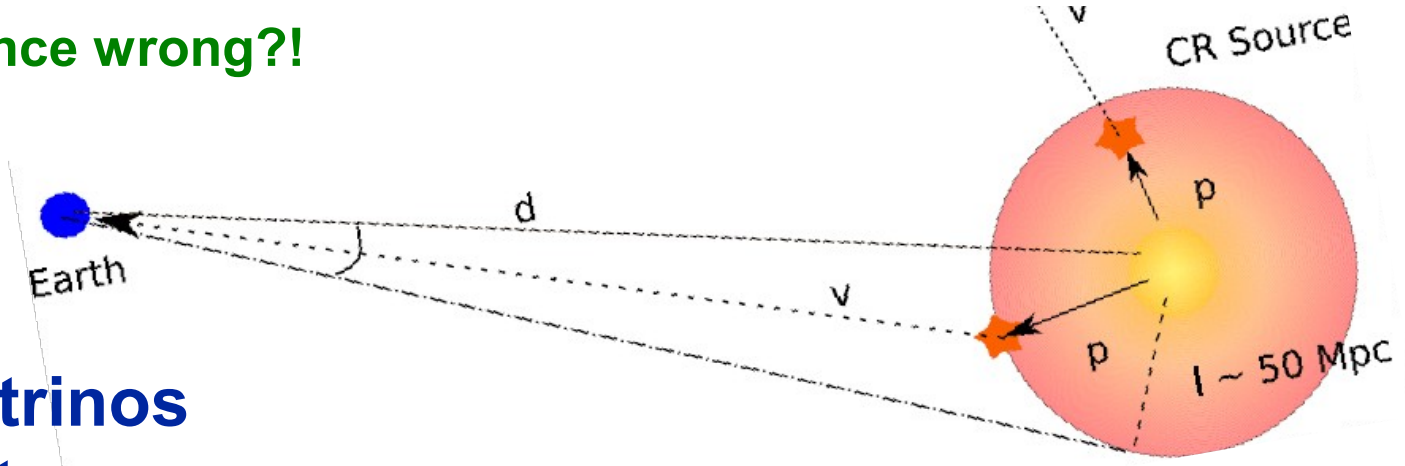
Dominant background:
Di-muons with
less separation
due to shorter range

GZK neutrino creation



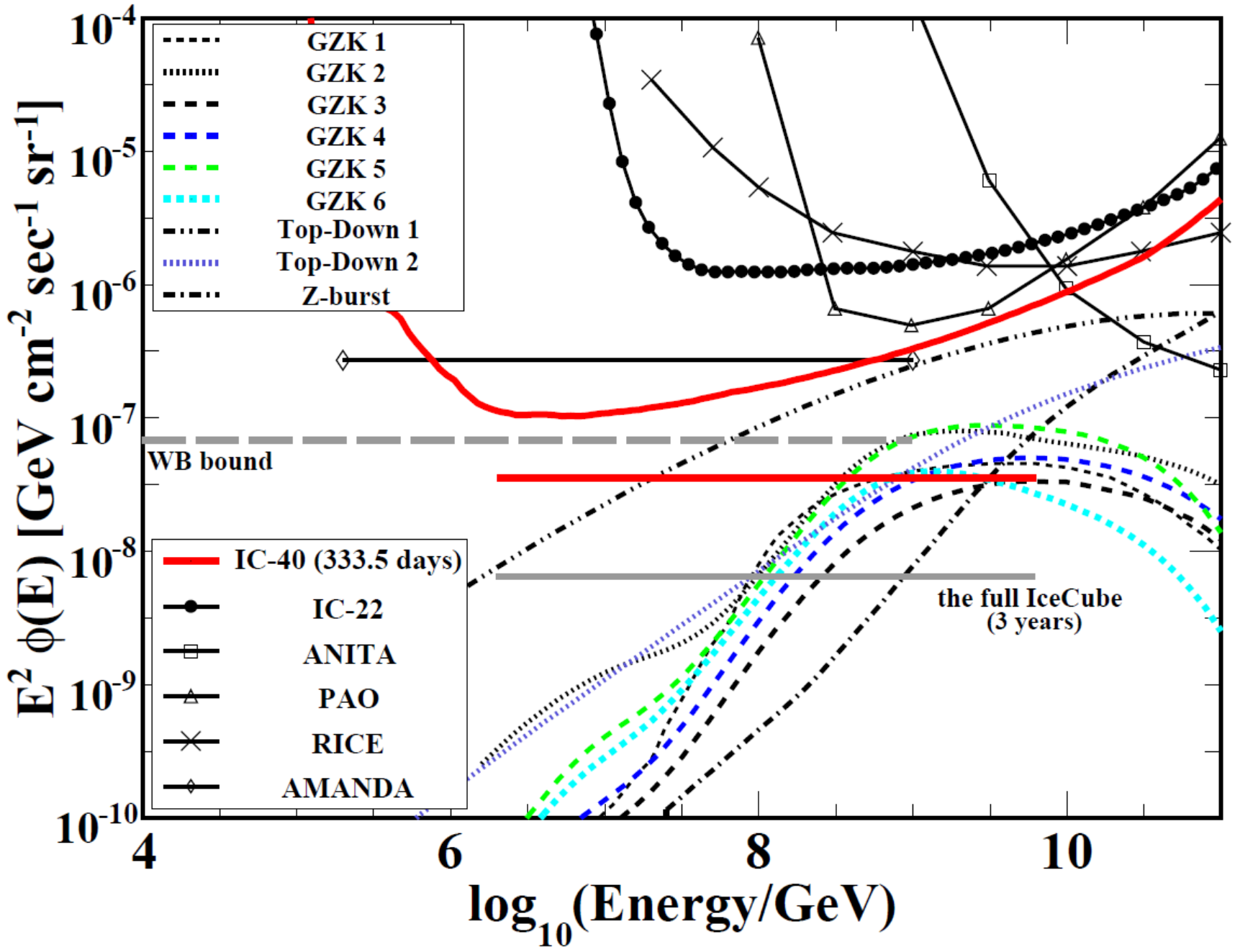


- Neutrinos at $10^{17\text{-}19}$ eV required by standard-model physics
  - Lack of neutrinos:
    - UHECRs all heavy nuclei?
    - "Just so" source spectra?
    - **Lorentz invariance wrong?!**
    - **New physics?**

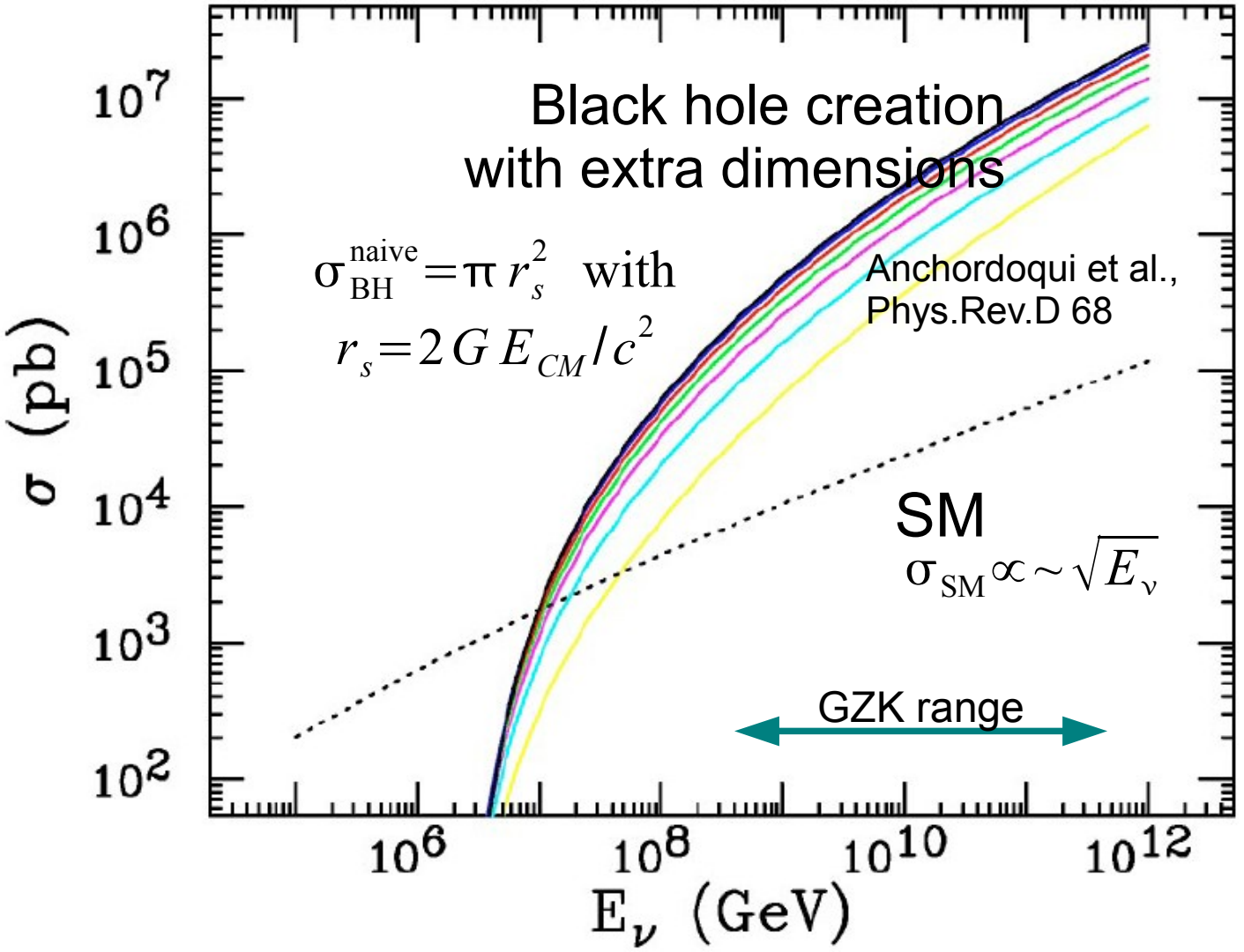


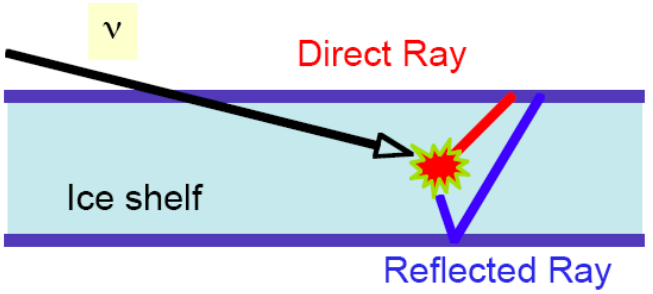
"GZK"-Neutrinos point back to source

EHE-neutrinos



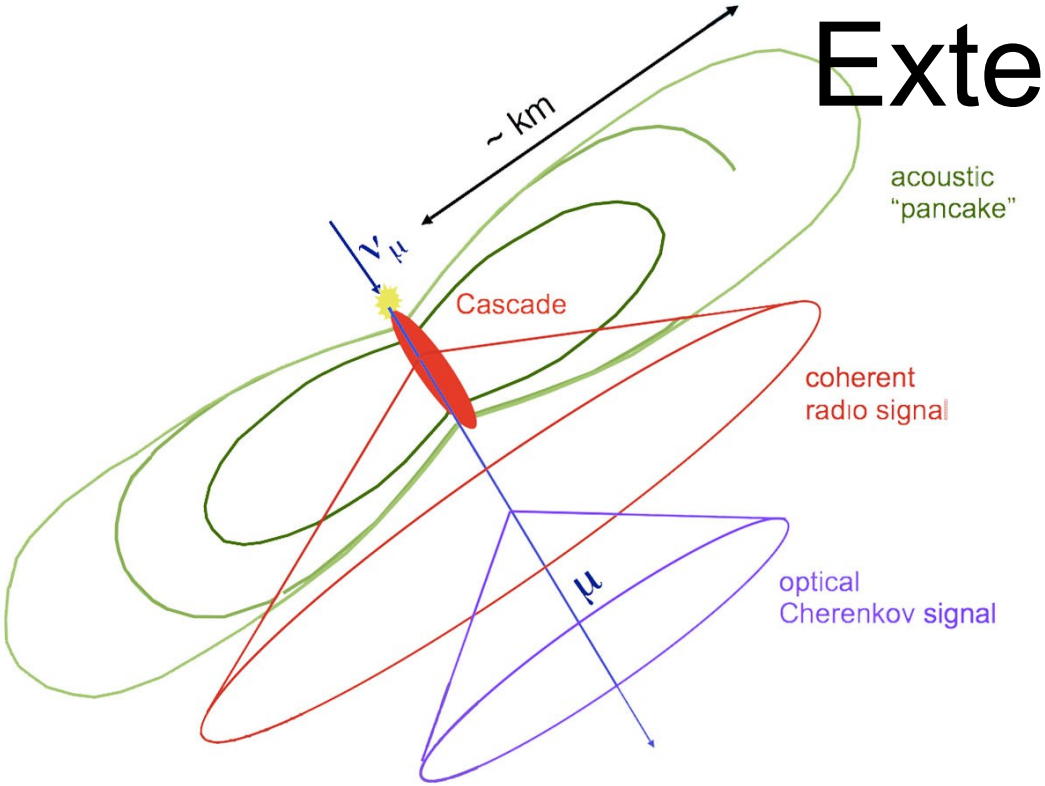
BSM: Neutrino cross section and black hole creation





Measurement:
depth distribution
& zenith angle

EHE detection methods in ice
Extensions of IceCube

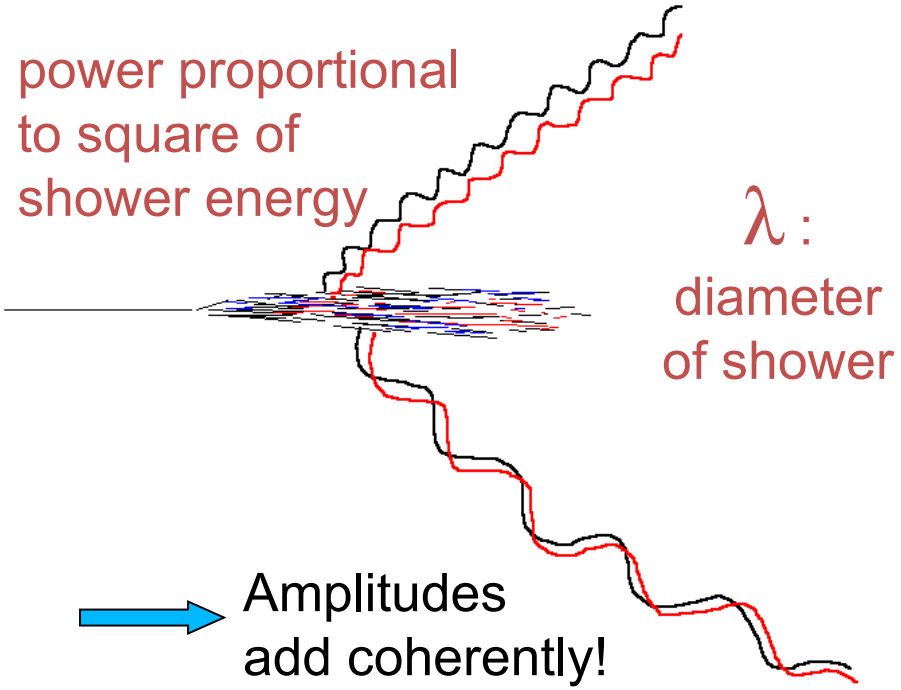


Ongoing R&D for future GZK energy neutrino detectors focus on radio and acoustic detection.

Promise: Cheap sensors & sparse spacing

Propagation of sound and RF are being studied using in situ measurements.

Optimal technologies and array configurations under investigation.



IceCube Collaboration

36 institutions ~ 220 scientists