IceCube

as a discovery observatory for physics beyond the standard model

Klaus Helbing

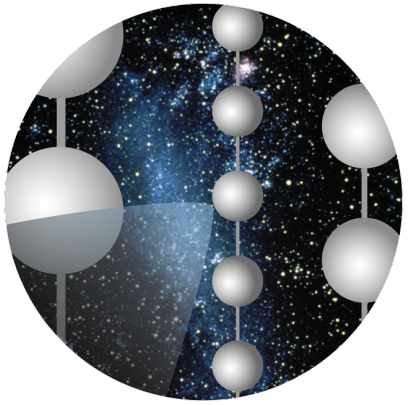
Bergische Universität Wuppertal

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

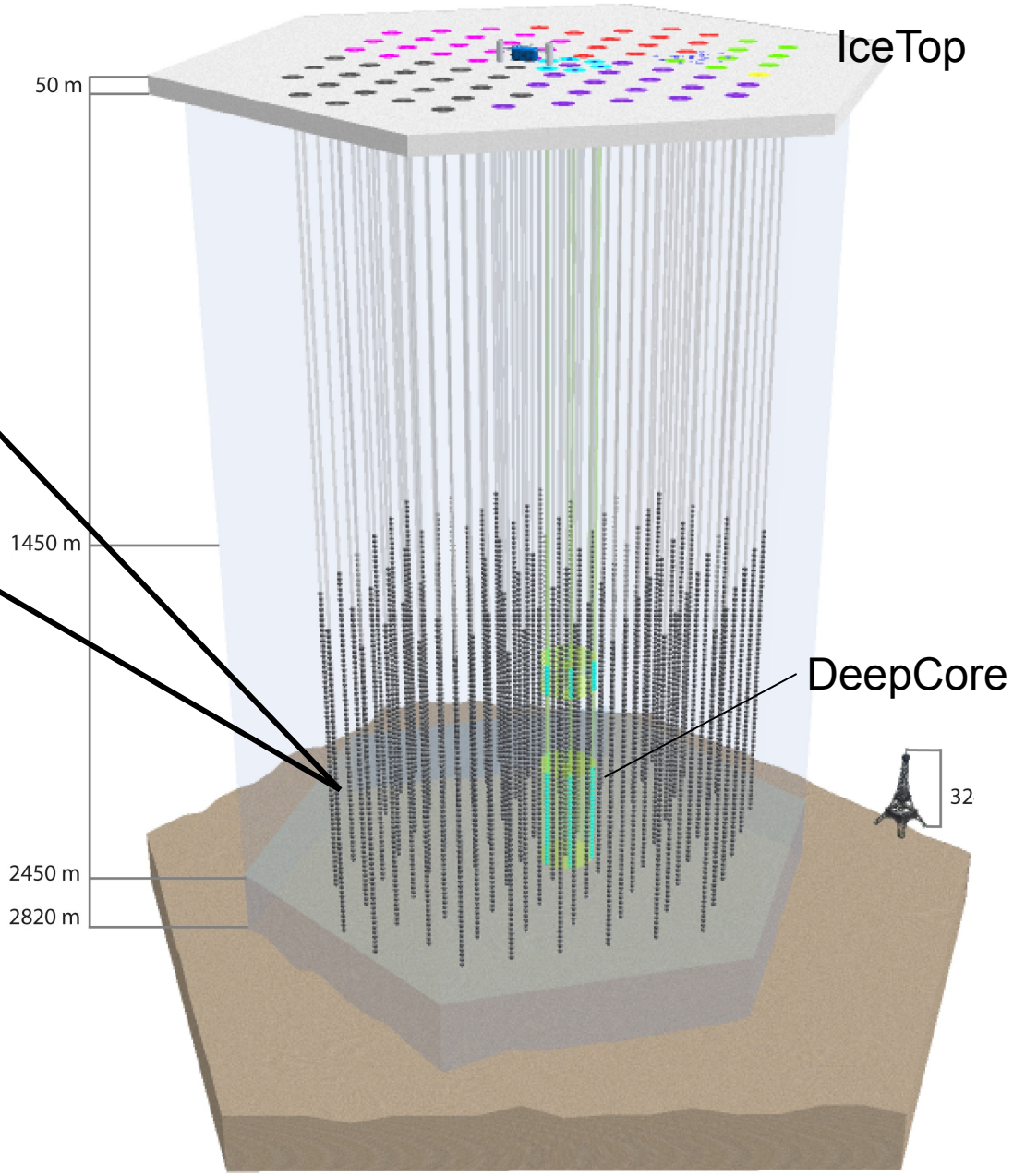
Energy threshold ~10 GeV

Dense inner array (DeepCore)

1 km^2 surface array
IceTop: 81 stations

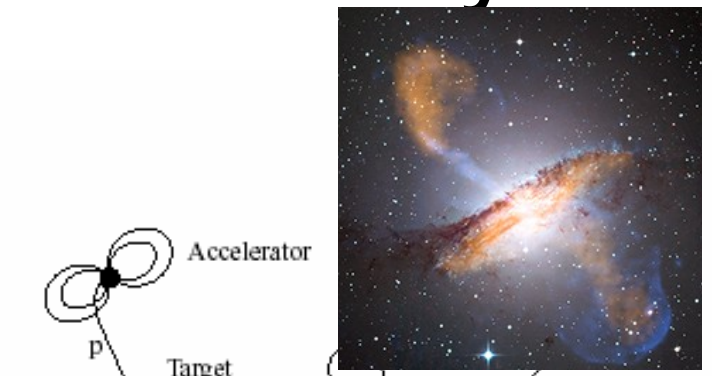
Detects ~10^8 muons &
~200 neutrinos **per day**

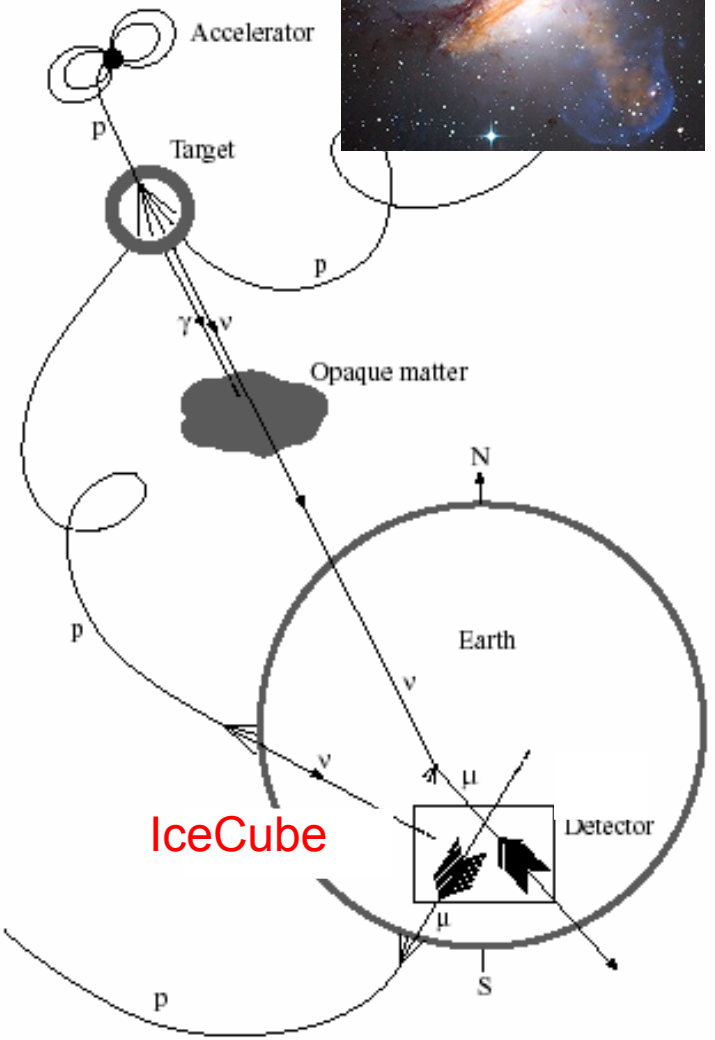
Detector now complete!



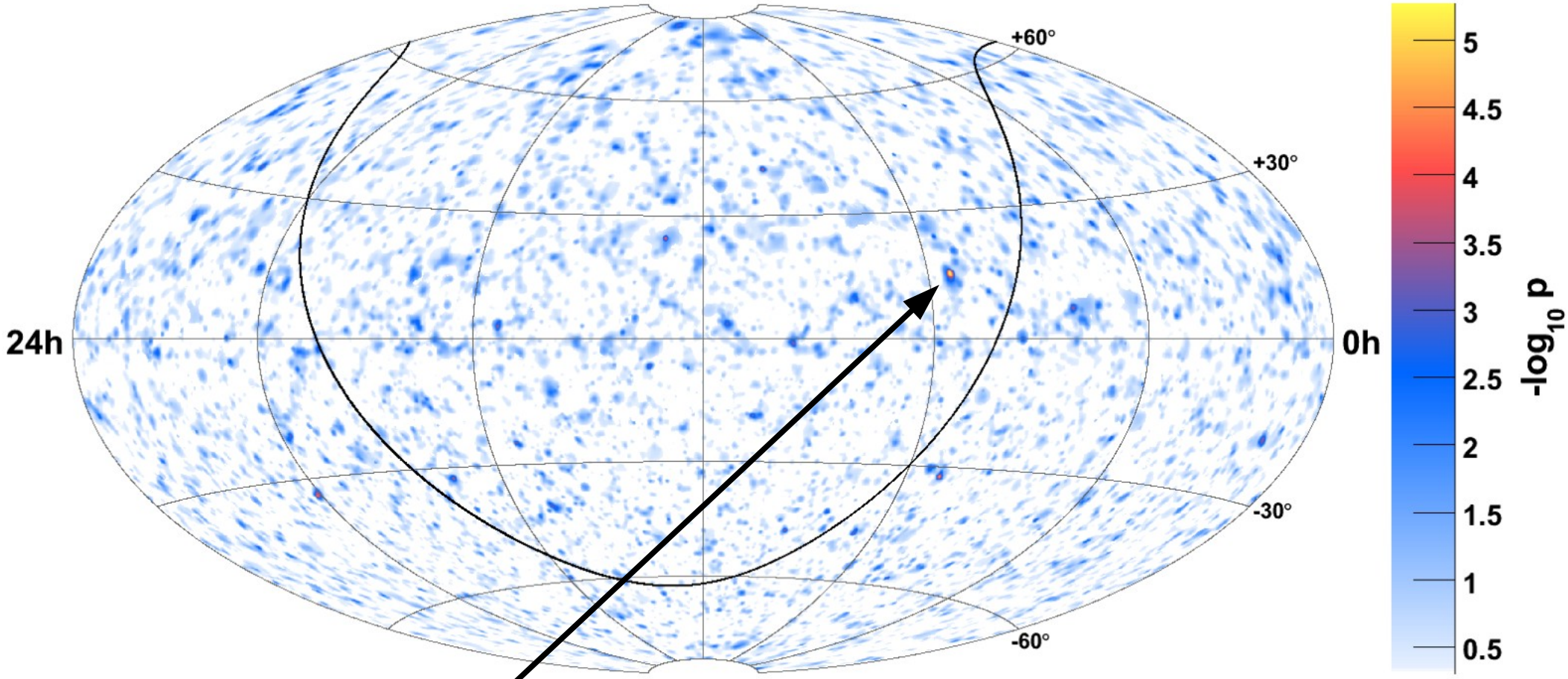
IceCube's main mission: astrophysics and cosmic rays

- 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





Astrophysics: Neutrino point sources

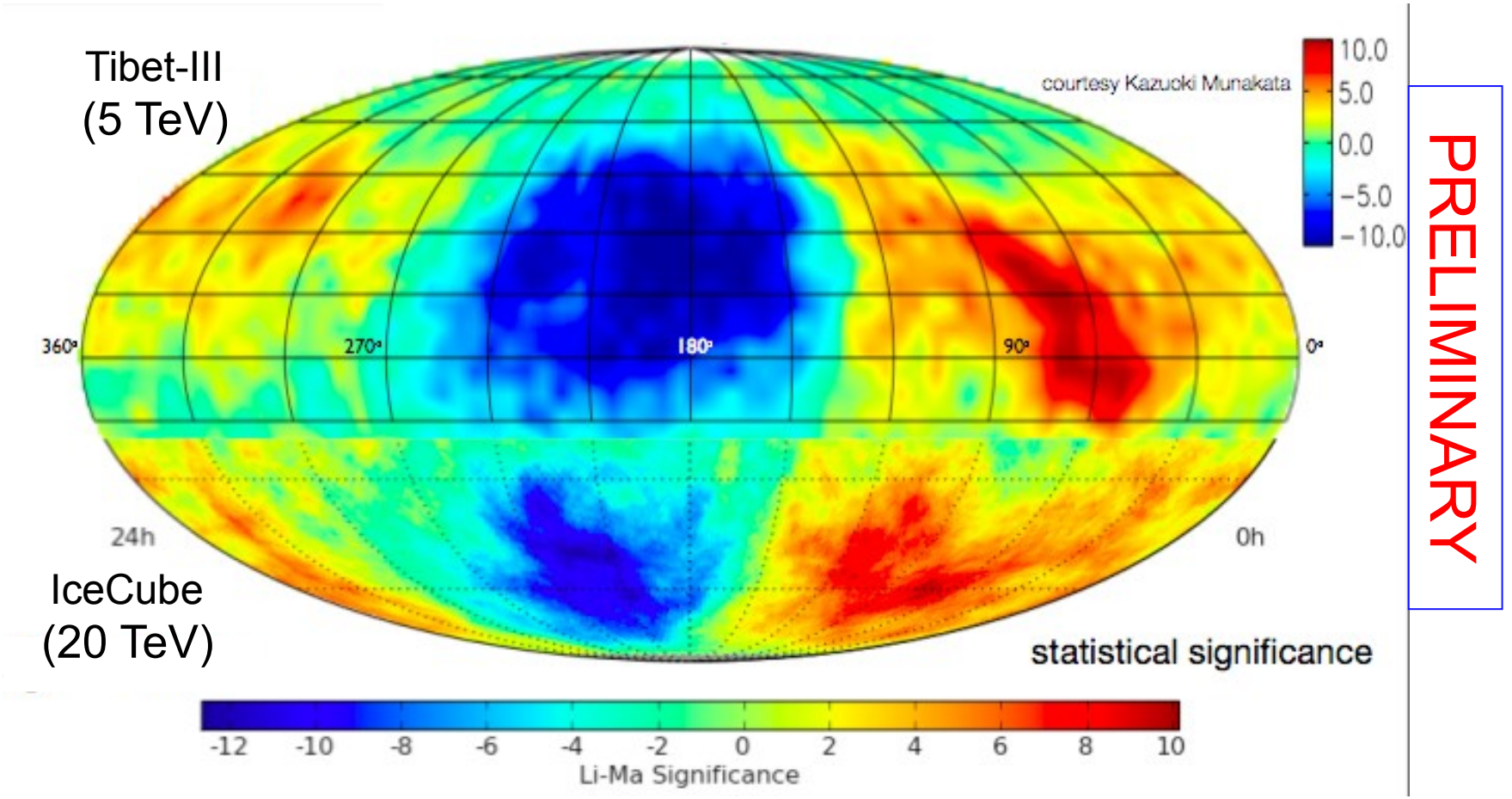


Hottest location in all-sky search
Ra=113.75, Dec=15.15

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

All sky p-value: 18%
No evidence yet

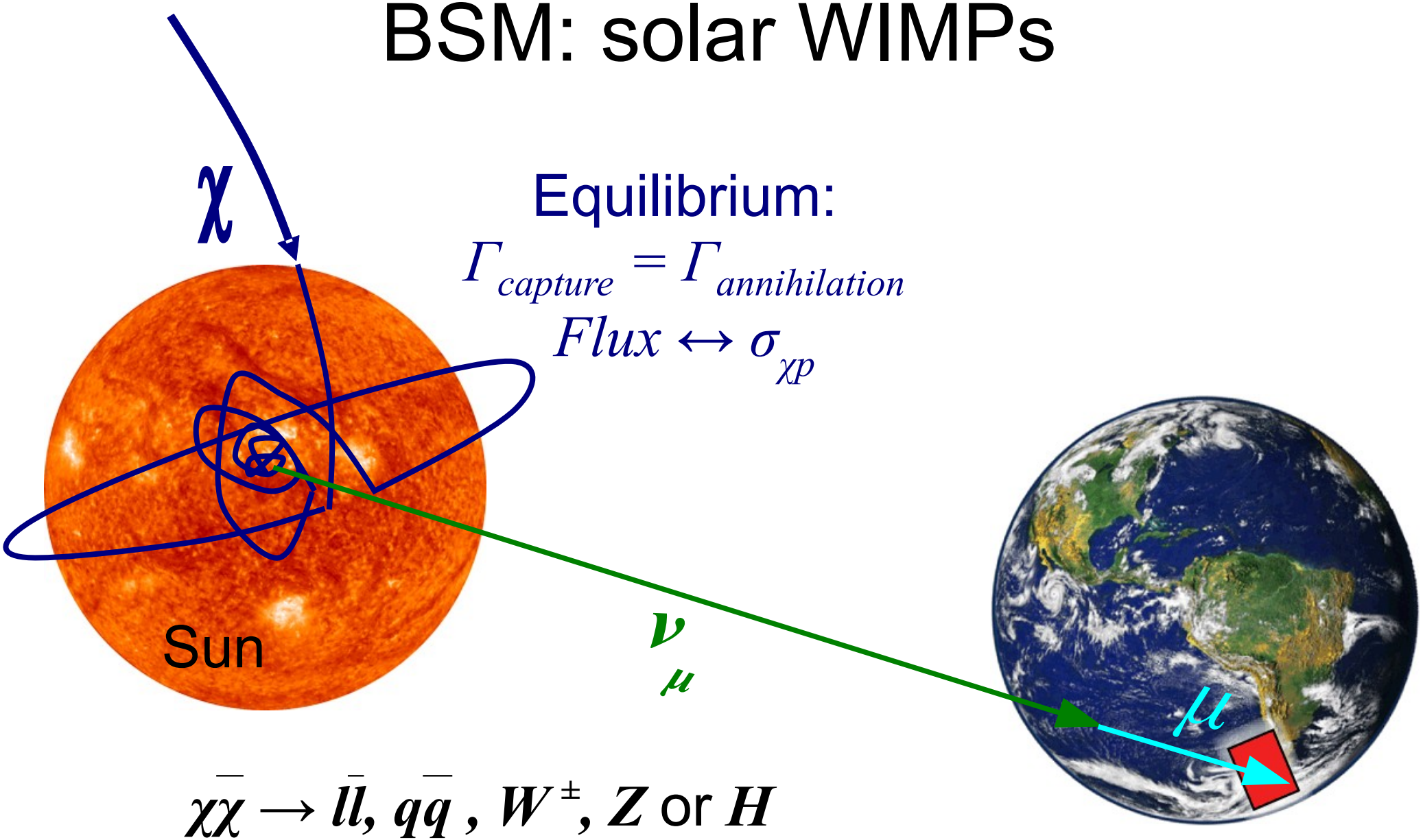
Cosmic rays: Anisotropies



Consistent with previous northern measurements

First measurement of CR anisotropy in the Southern hemisphere

BSM: solar WIMPs



Equilibrium:

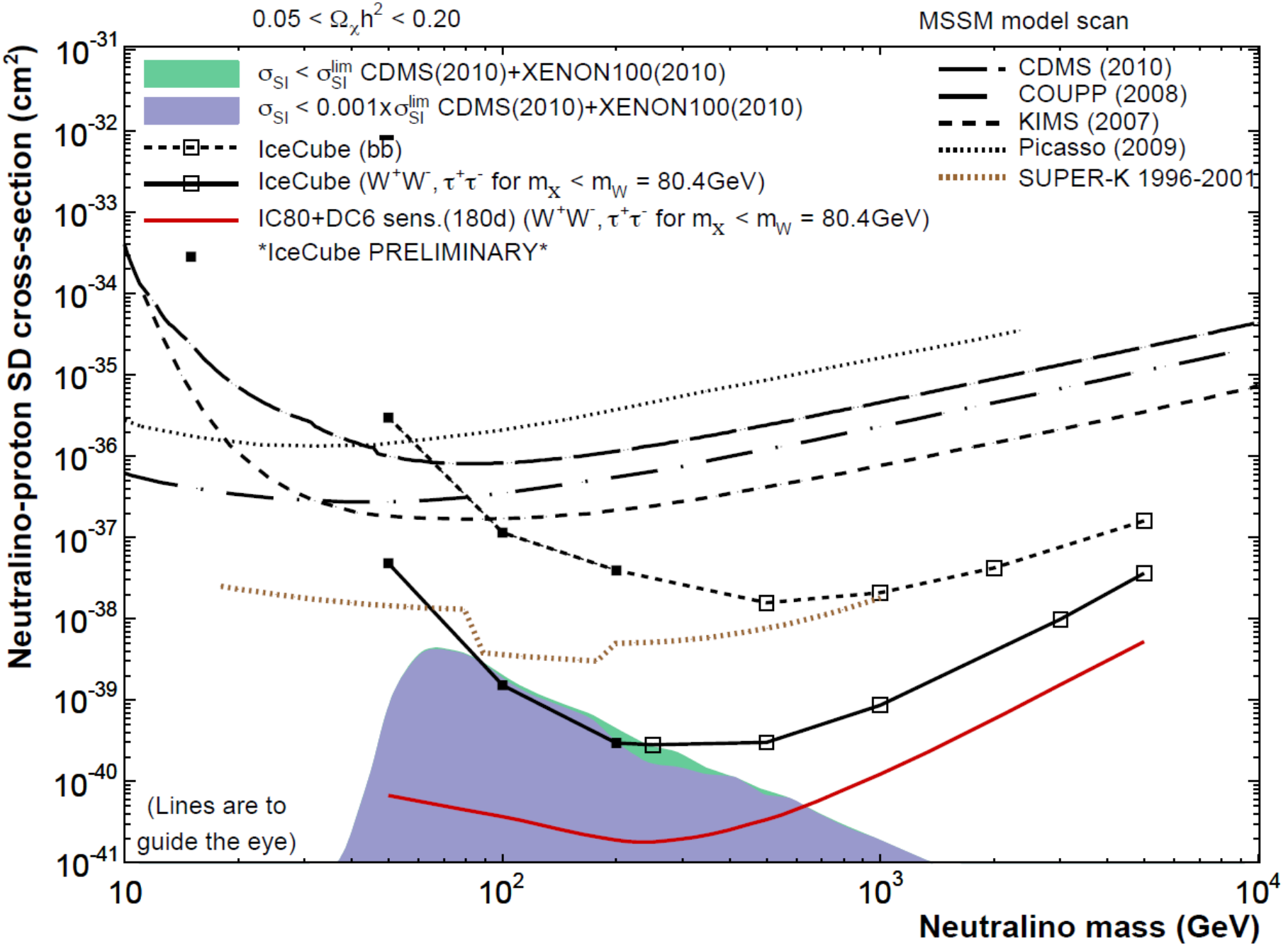
$$\Gamma_{capture} = \Gamma_{annihilation}$$

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

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

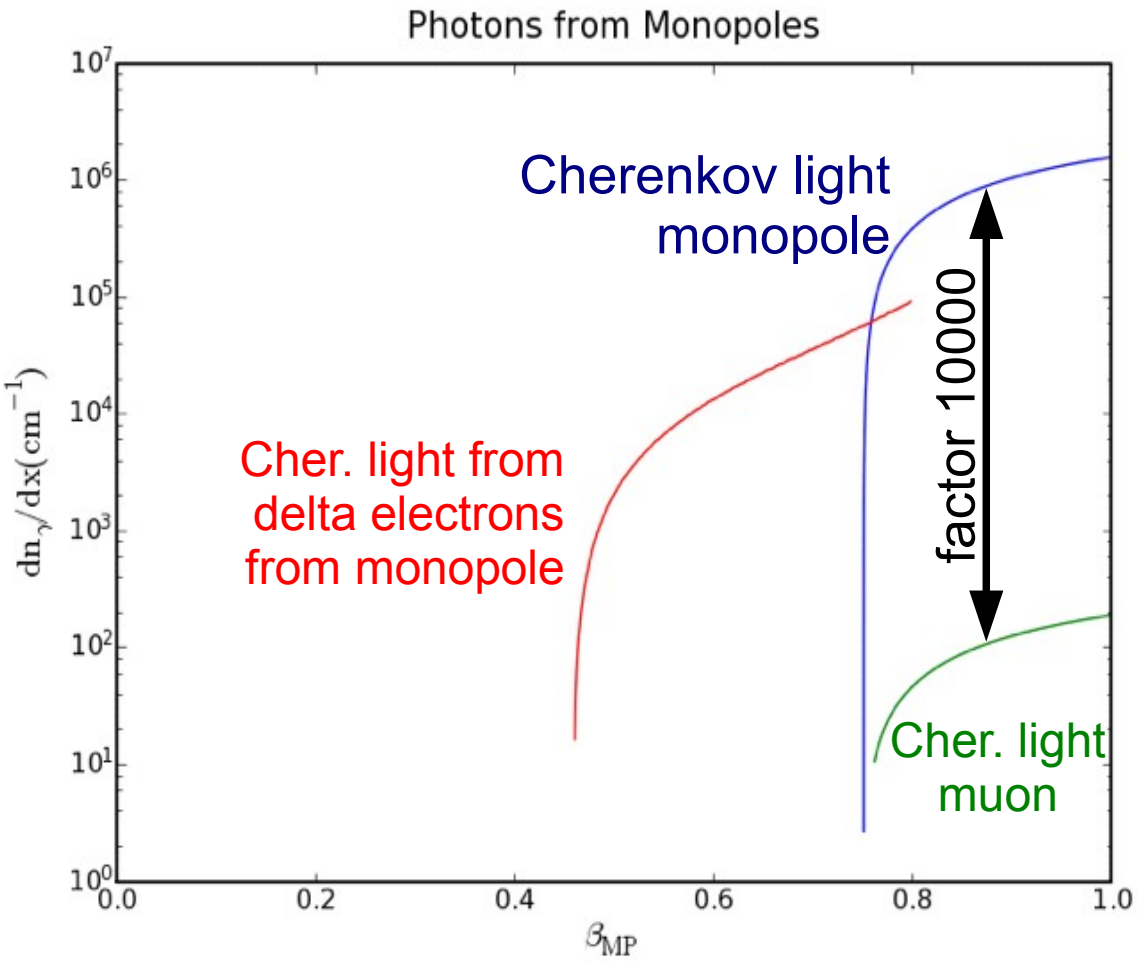
$$\rightarrow \cdots \rightarrow \nu_{\mu}$$

Spin dependent χ-p X-section



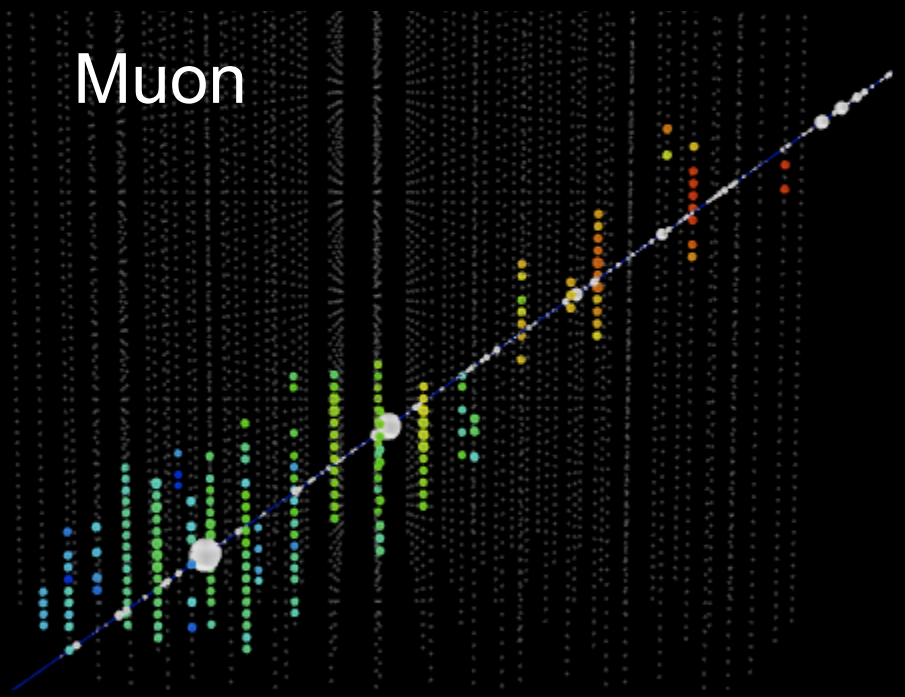
Searches for relic magn. monopoles

- 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:
  $N_\gamma \propto (g \cdot n / e)^2$
  $\propto 8300\ N_\gamma(\mu)$

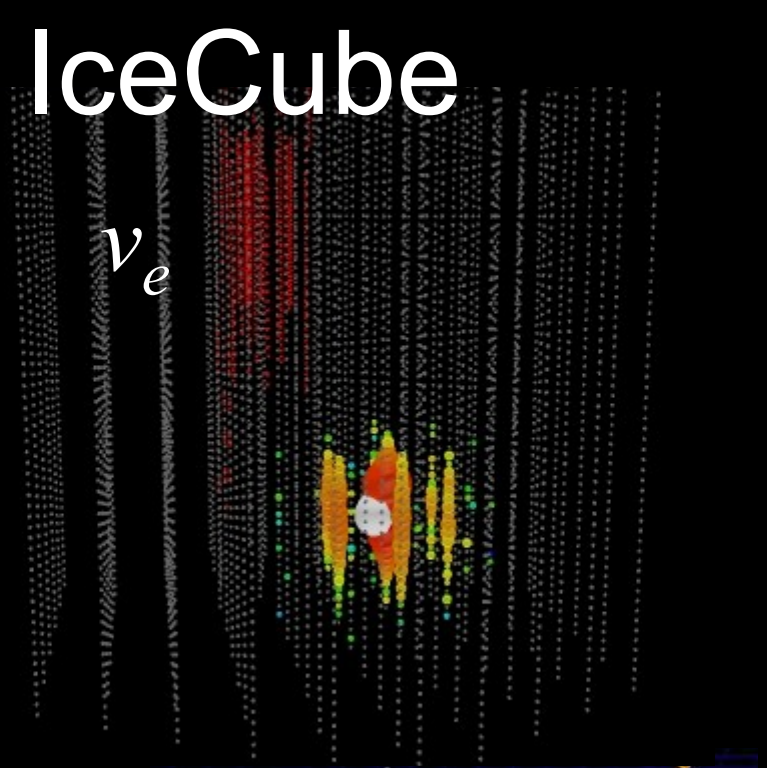


Event signatures in IceCube

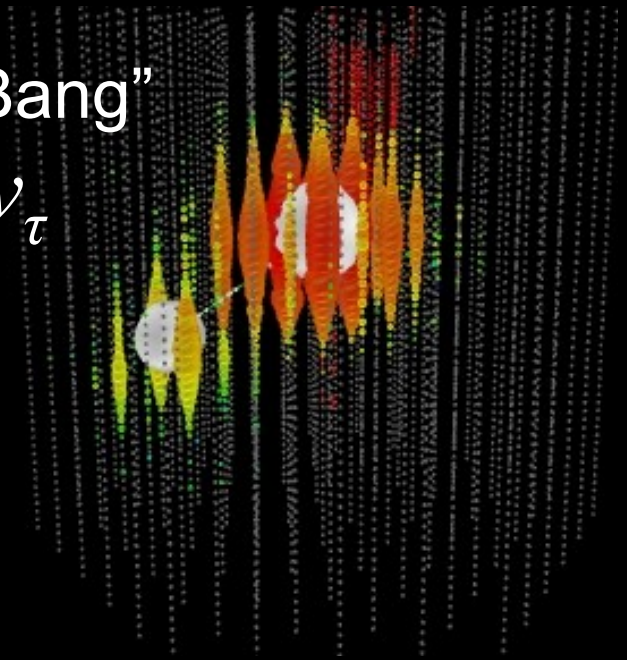
Muon



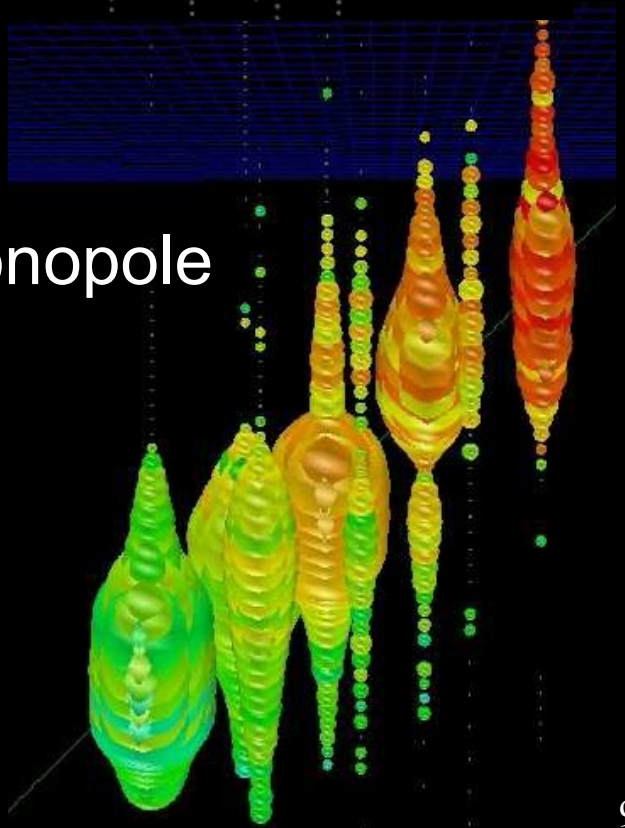
ν_e



"Double Bang" from ν_τ

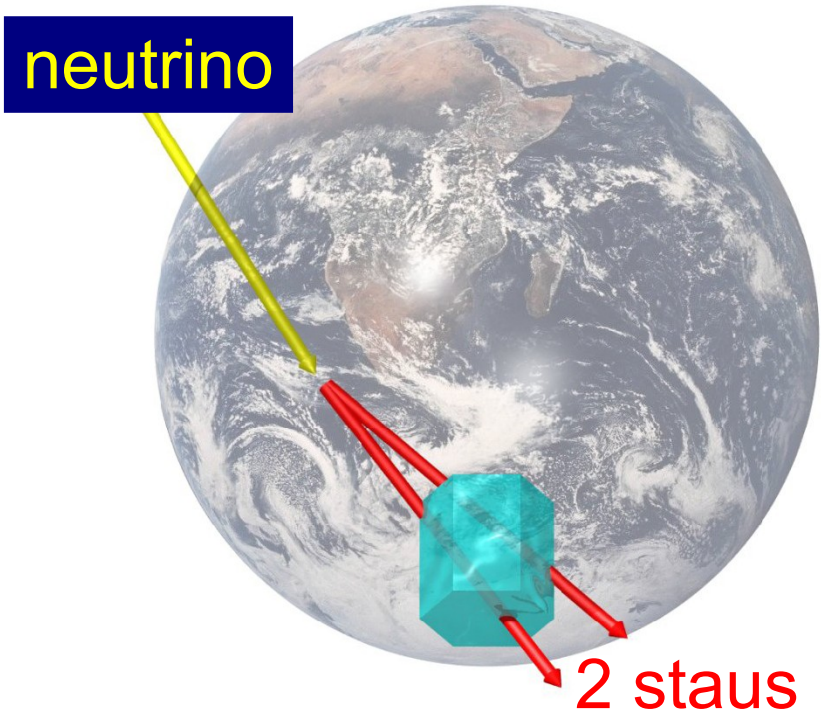


Monopole

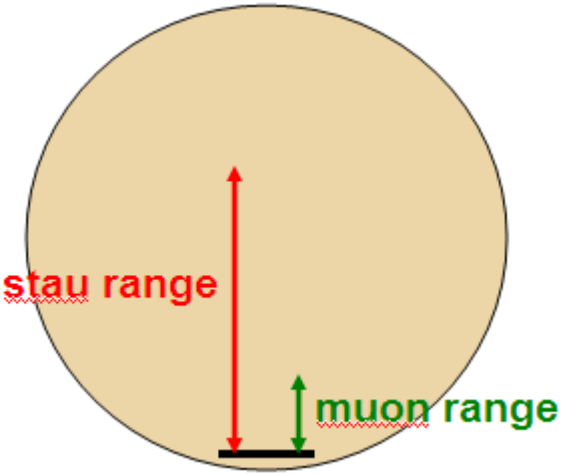


BSM: Direct (!) SUSY detection

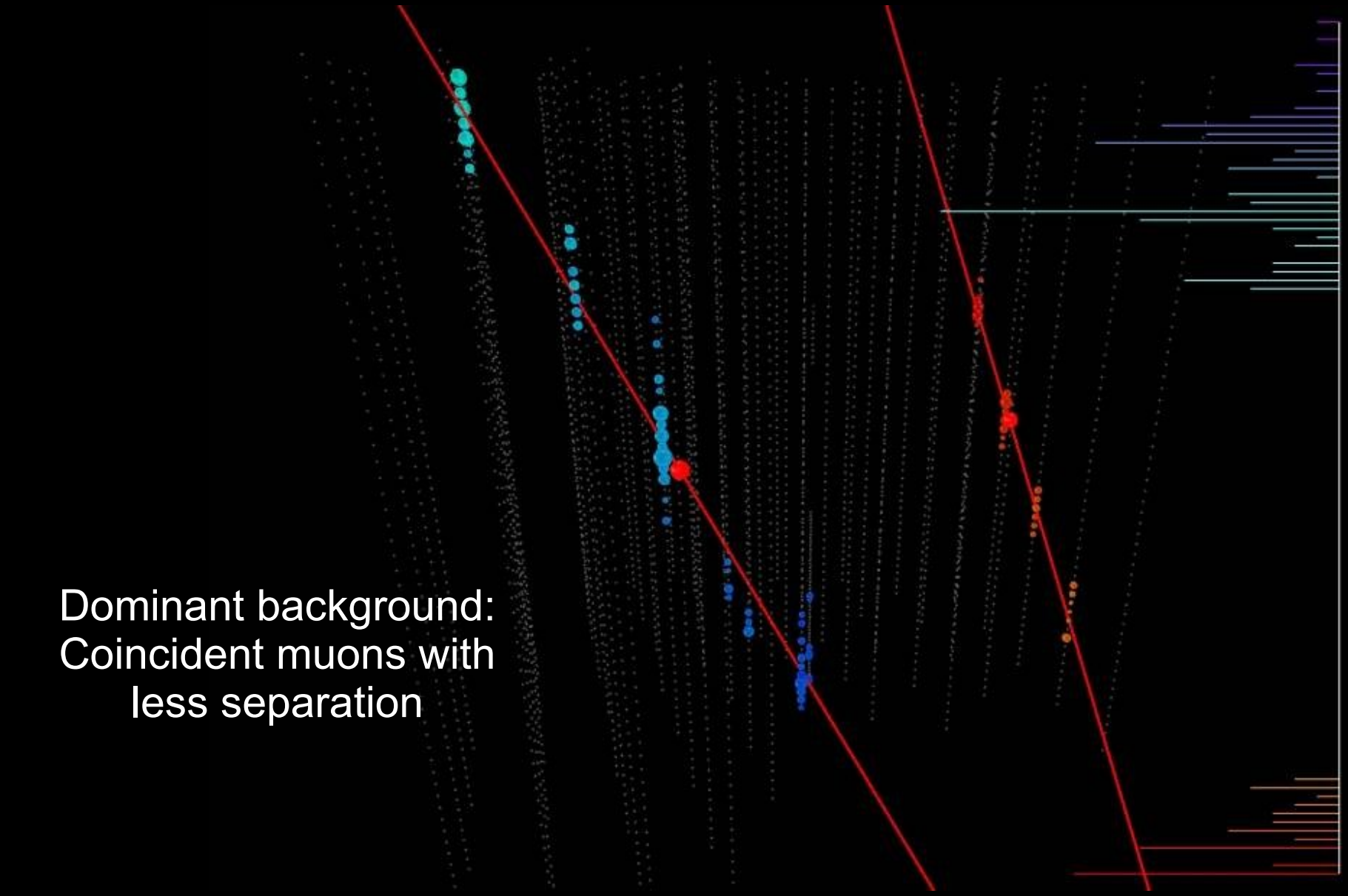
- X-section for heavies: $\sigma \sim 1/M^2$
- Large detector & range compensate
- Direct detection of charged, quasi-stable exotics
- Produced by UHE ν
- **LSP gravitino** (esp. gauge mediation) → NLSP: stau



Signal: pair of parallel charged tracks.

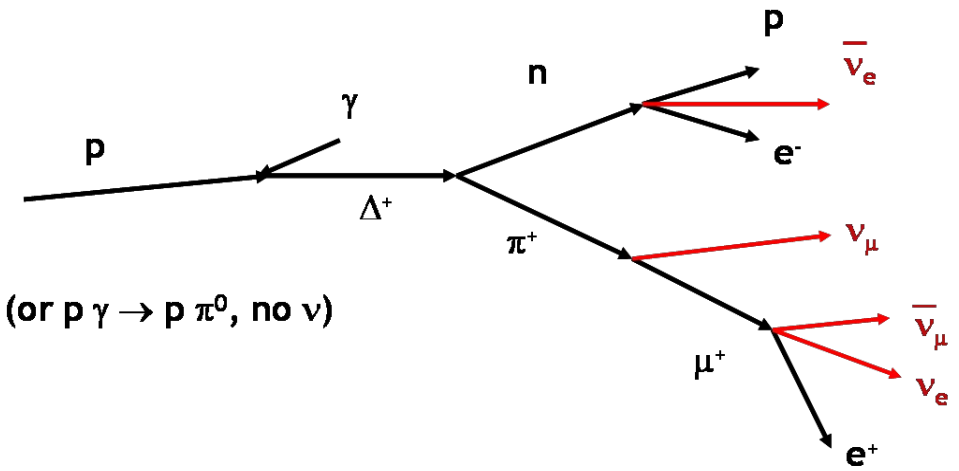


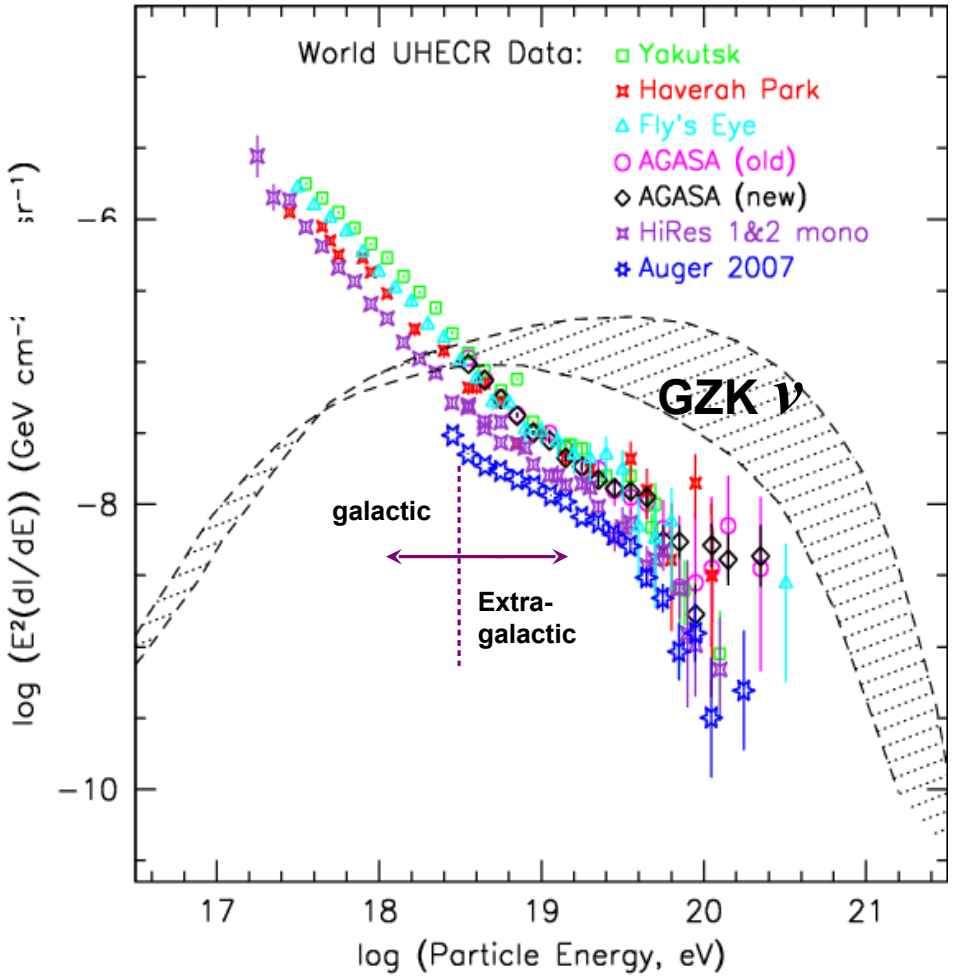
Track separation and reconstruction



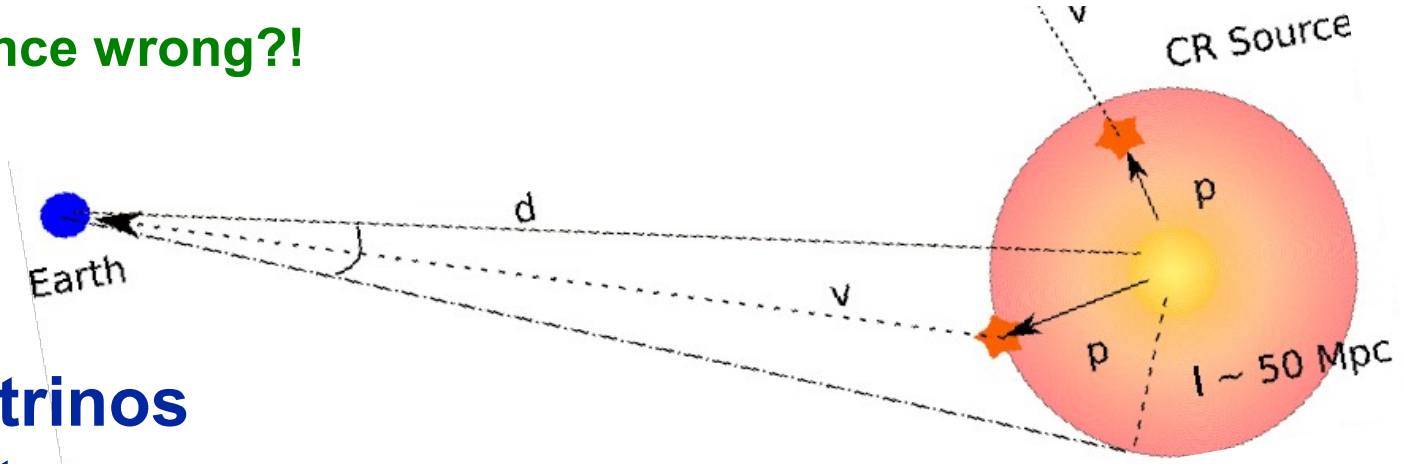
Dominant background:
Coincident muons with
less separation

GZK neutrino creation



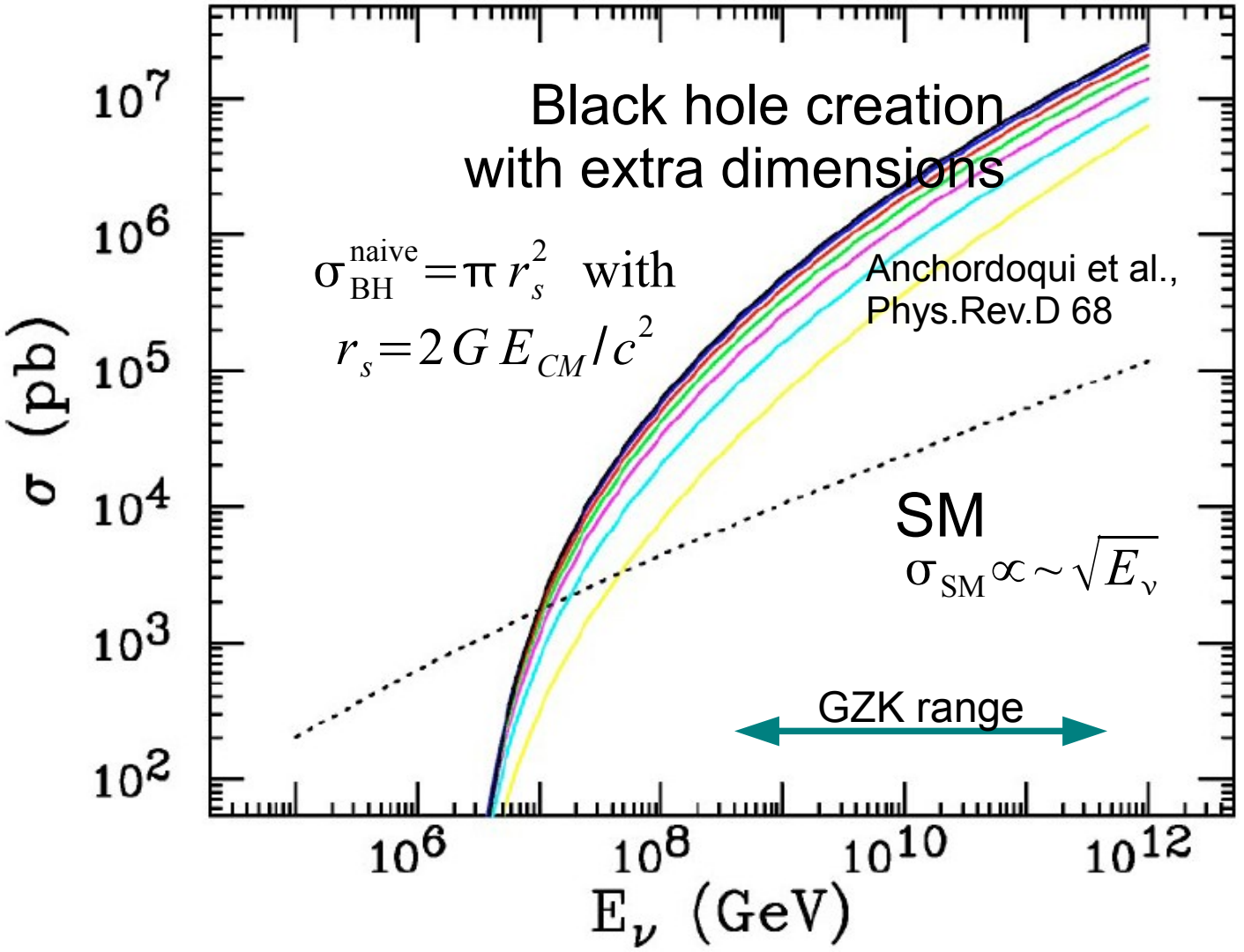


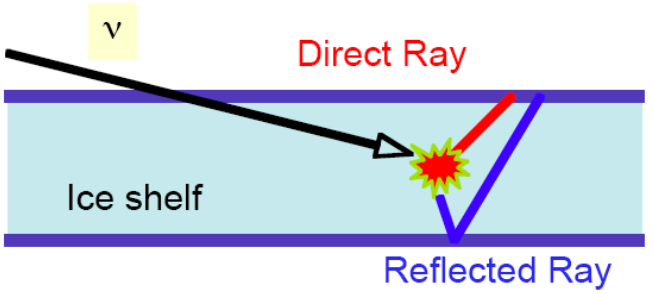
- Neutrinos at $10^{17\text{-}19}$ eV required by standard-model physics
  - Lack of neutrinos:
    - UHECRs all heavy nuclei?
    - "Just so" source spectra?
    - **Lorentz invariance wrong?!**
    - **New physics?**



"GZK"-Neutrinos point back to source

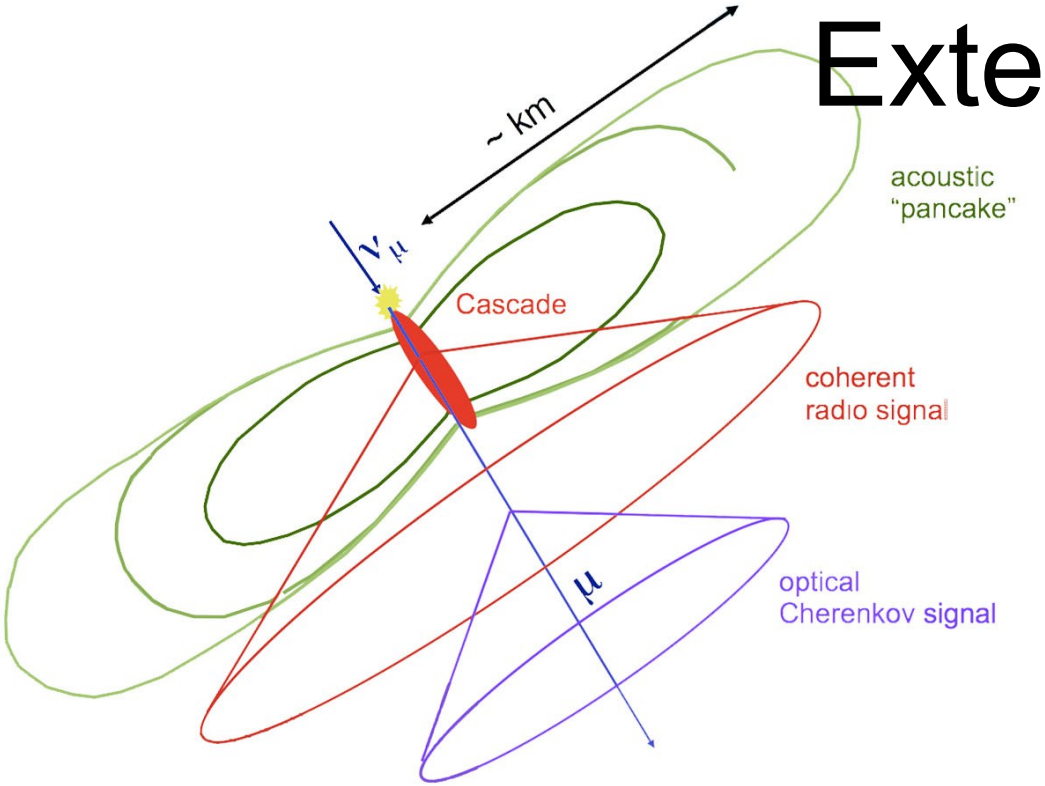
BSM: Neutrino cross section





Measurement:
depth distribution
& zenith angle

EHE detection methods in ice
Extensions of IceCube

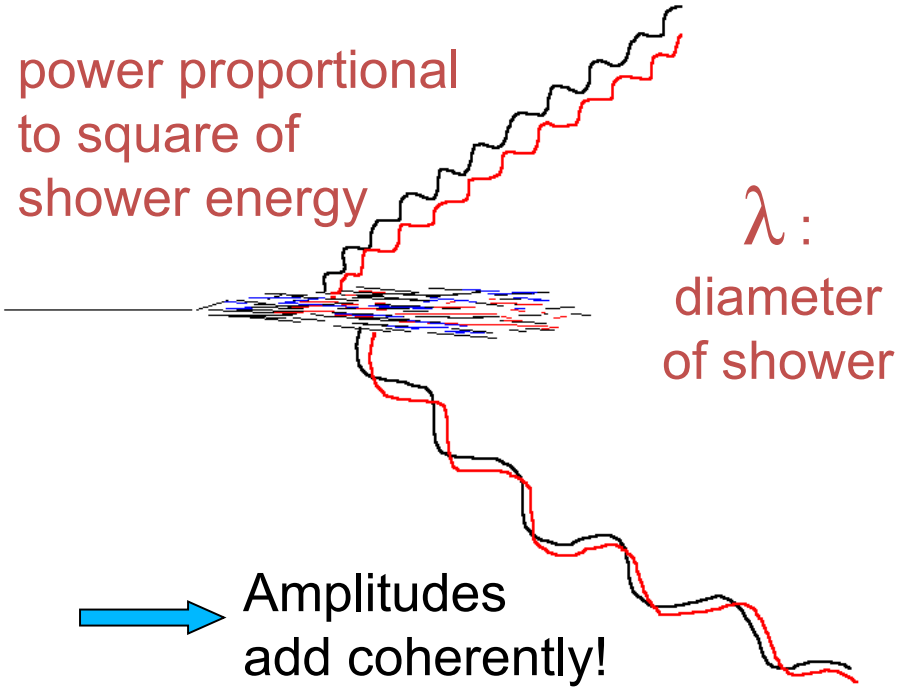


Ongoing R&D for future GZK energy neutrino detectors focus on radio and acoustic detection.

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; ~ 250 scientists