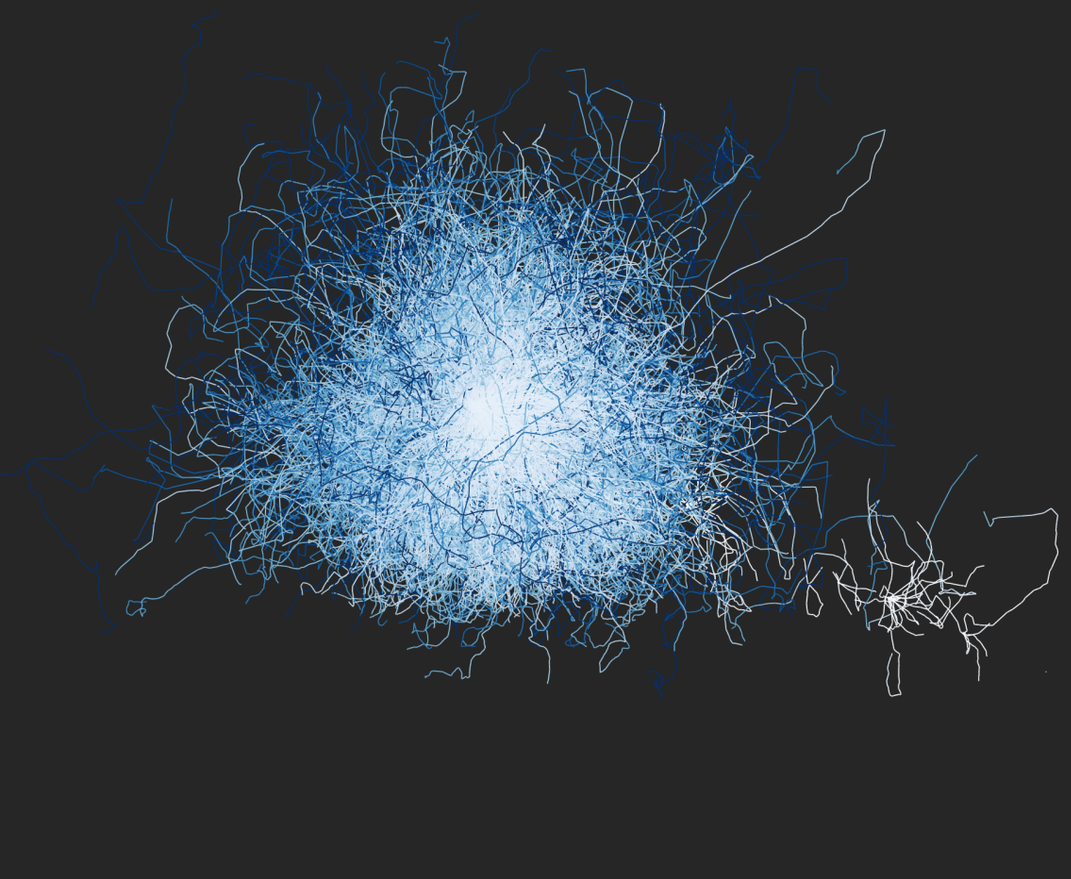
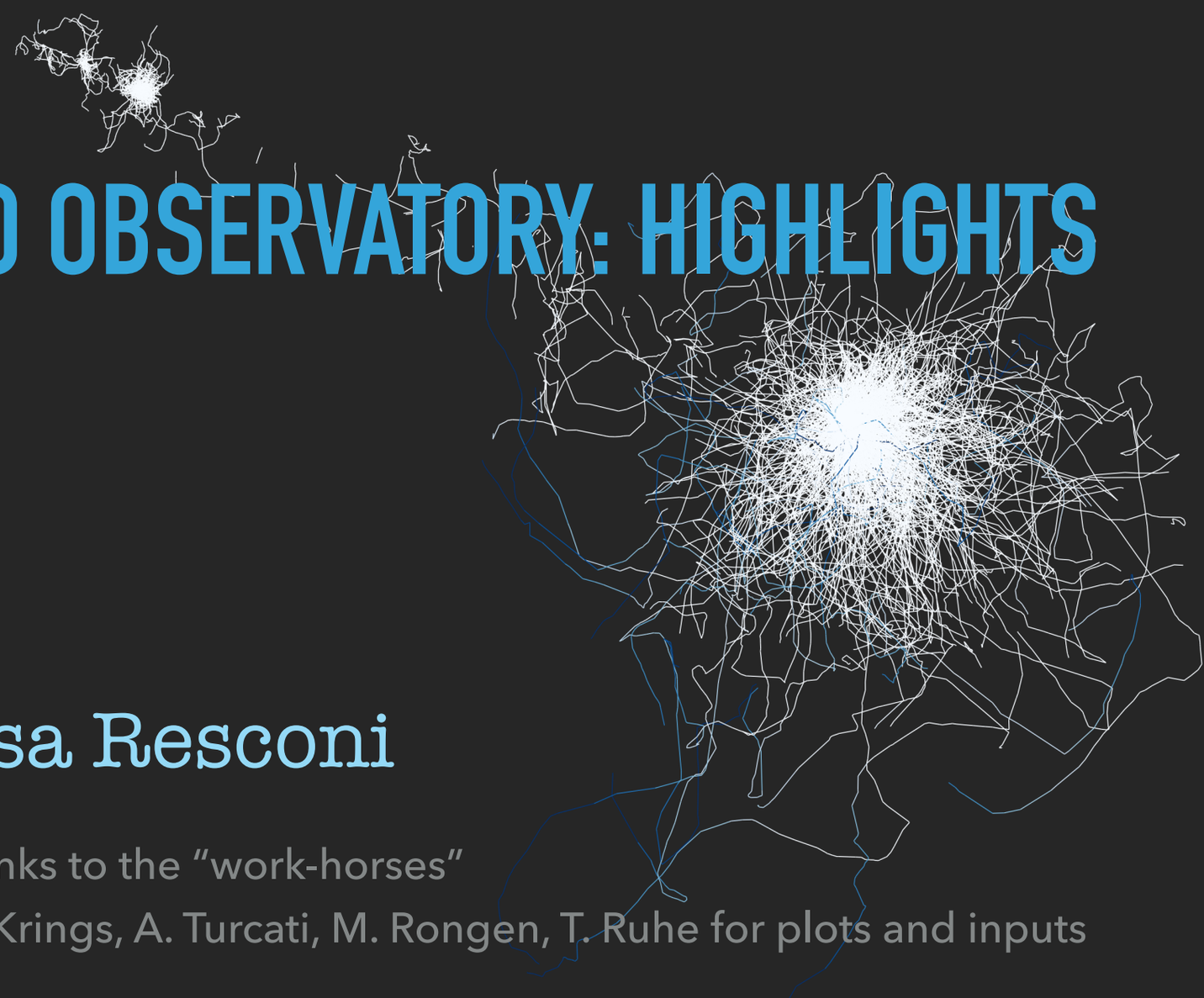




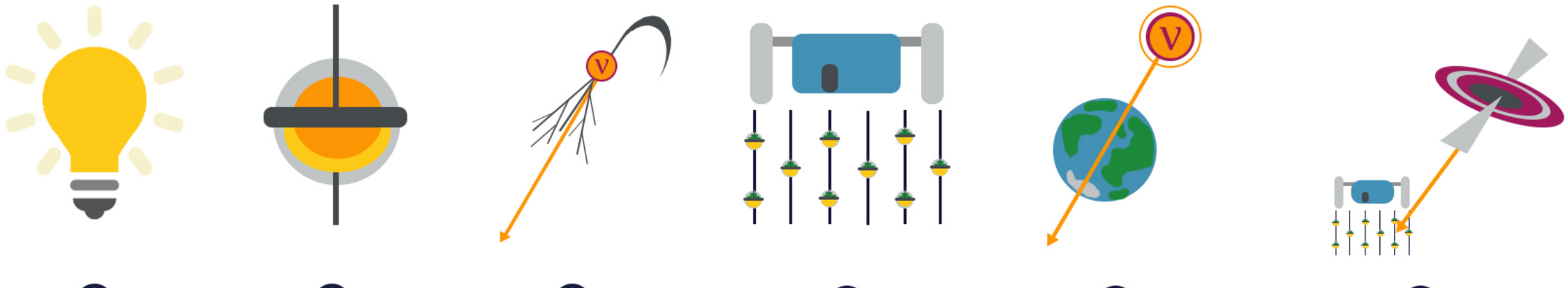
THE ICECUBE NEUTRINO OBSERVATORY: HIGHLIGHTS

Elisa Resconi

Many thanks to the “work-horses”

T.Glauch, T. Ehrhard, P. Eller, C. Haack,, K. Krings, A. Turcati, M. Rongen, T. Ruhe for plots and inputs

A History of Neutrino Astronomy in Antarctica



1960 Vision

1988 Telescope in the Ice Envisioned

2000 AMANDA Completed

2000-2001 Atmospheric Neutrinos Detected

2011 IceCube Completed

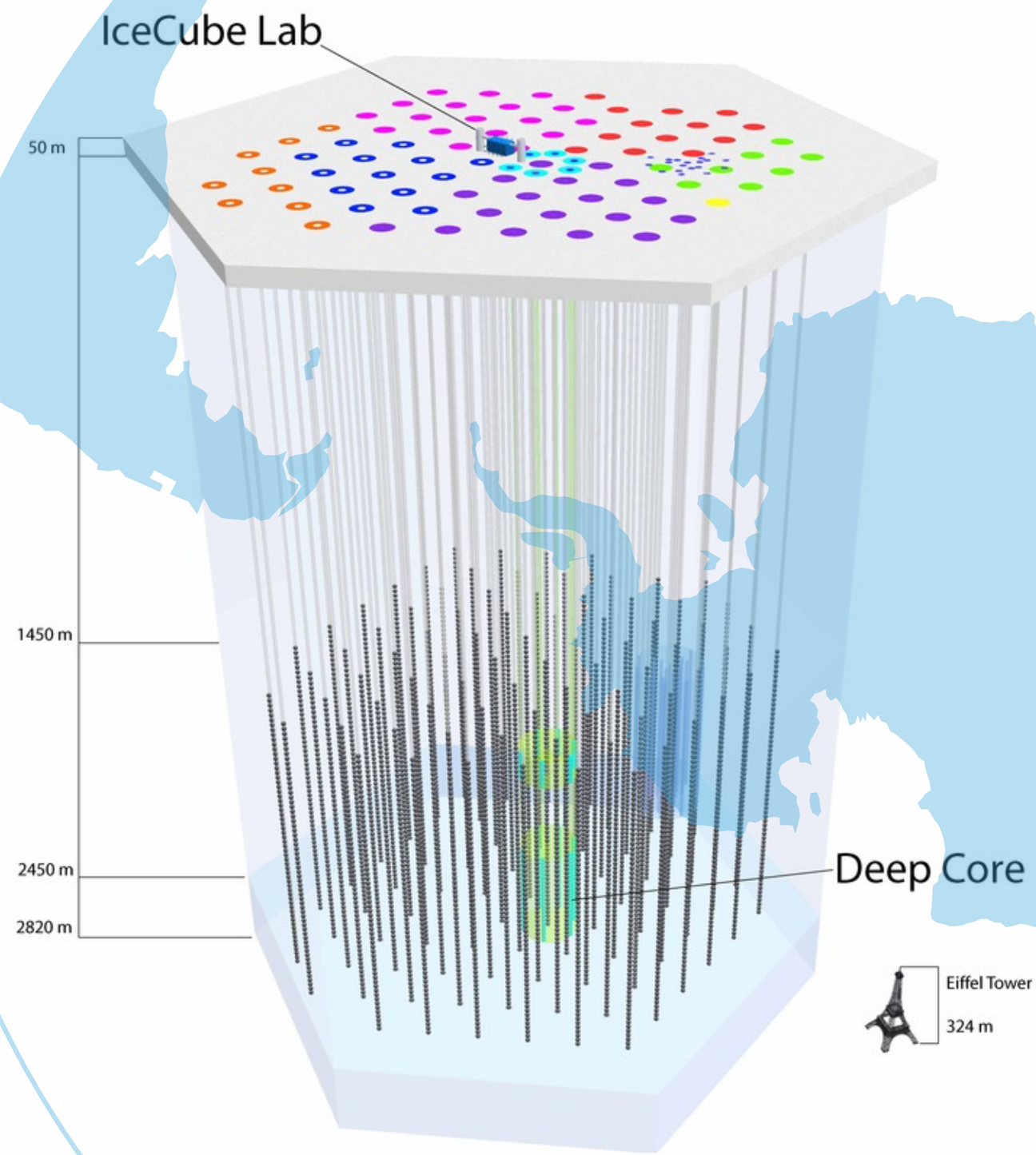
2013 Astrophysical Neutrinos Discovered

2018 First Source Identified

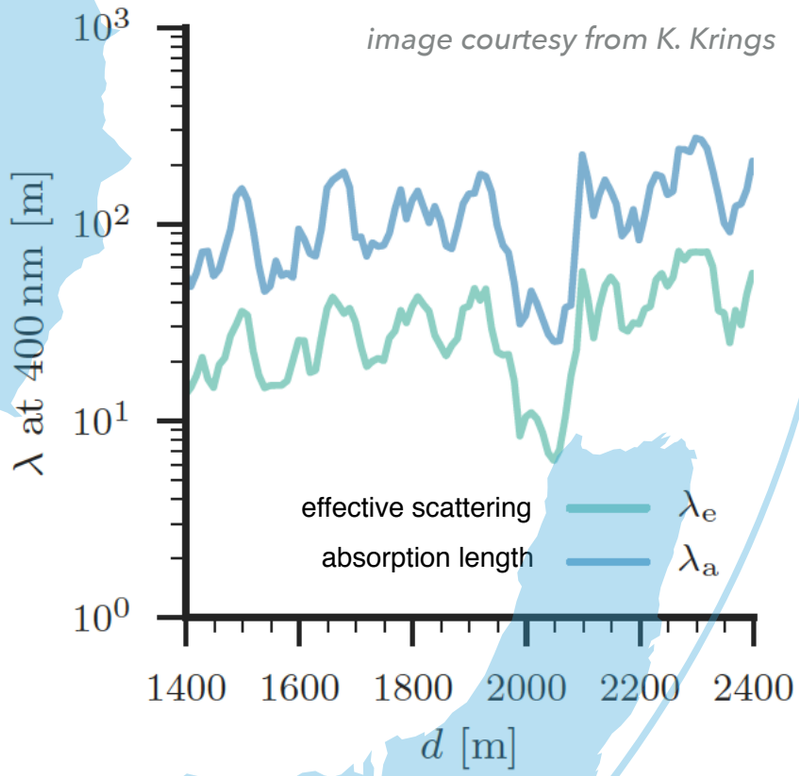
See AnnaF's talk

IceCube South Pole Neutrino Observatory

THE ICECUBE NEUTRINO OBSERVATORY

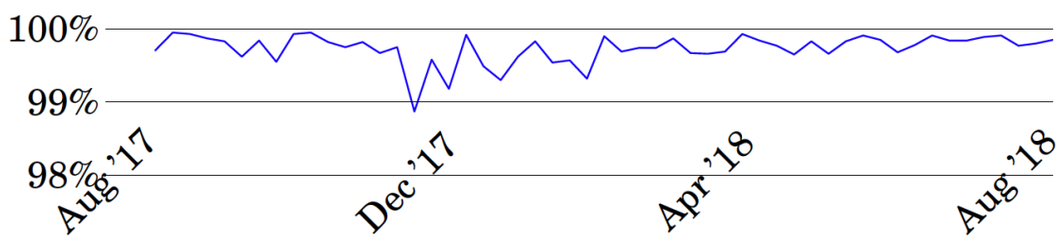


Digital Optical Modules



Martin Wolf, 20.09.17

Uptime



99.85%

ICECUBE SCIENCE: DISCOVERY VS PRECISION ERA

Neutrino Properties:

Atmospheric neutrino oscillations, sterile neutrinos, non-standard interactions

Neutrino Astronomy:

Supernovae neutrinos, GW - neutrino searches, high energy neutrino spectrum (diffuse), non-stellar neutrino sources, neutrino flavour composition …

Cosmic Rays:

Energy spectrum, chemical composition of high-energy cosmic rays, solar flares

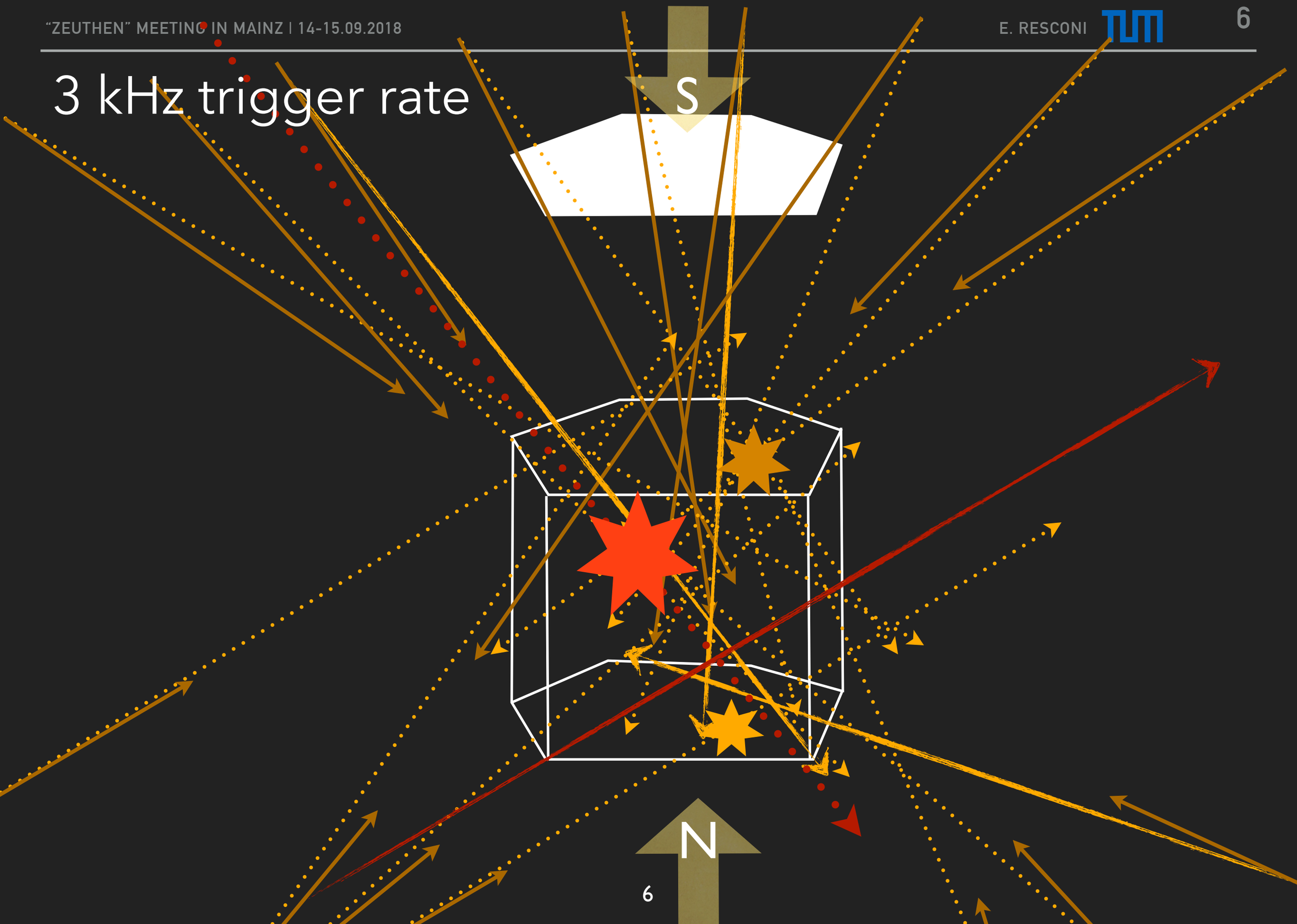
Beyond the Standard Model:

Indirect dark matter searches, monopoles, LIV

Environmental:

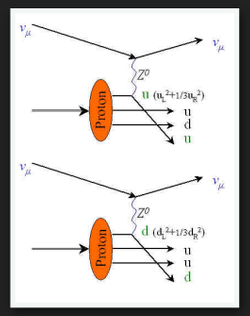
Neutrino earth tomography, glaciology

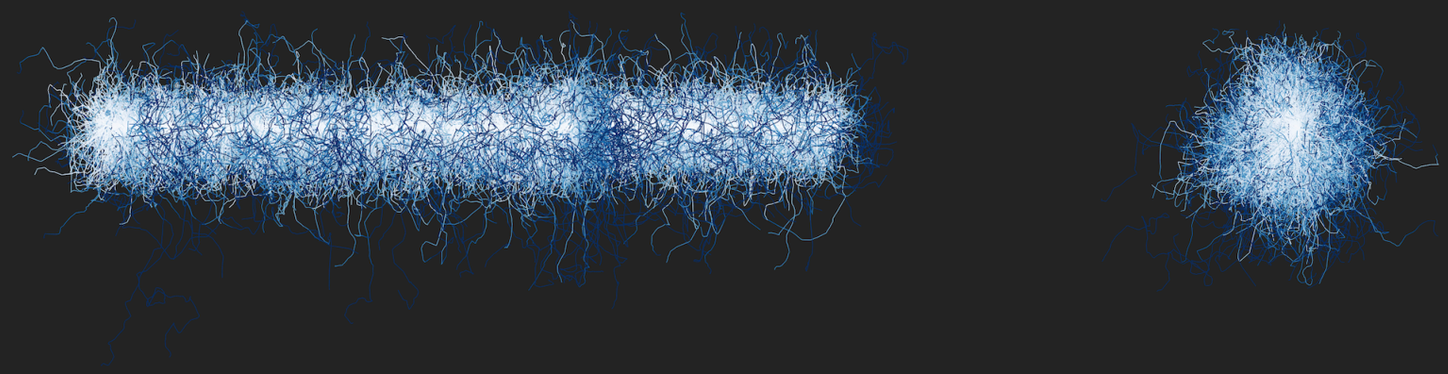
3 kHz trigger rate

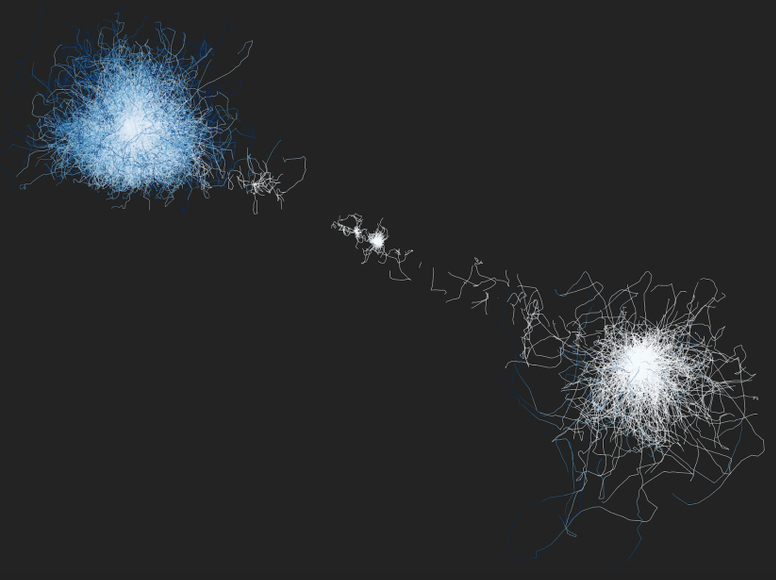


NEUTRINO INTERACTION CHANNELS

Photon path induced by a ν_μ ν_e ν_τ

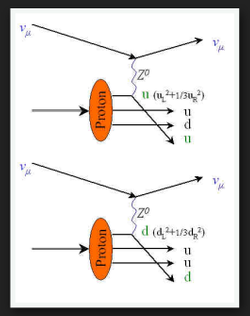


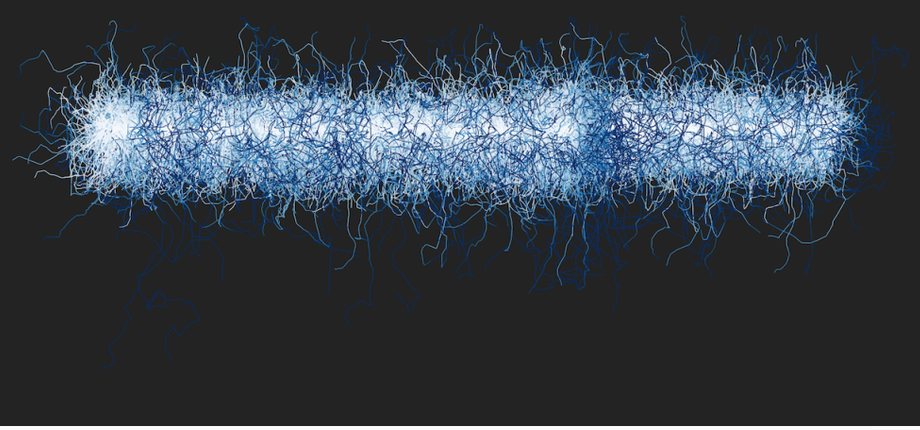


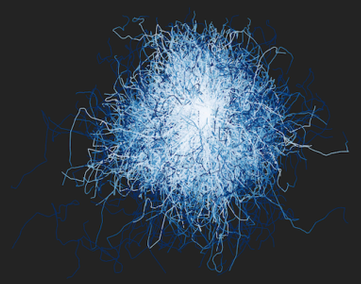


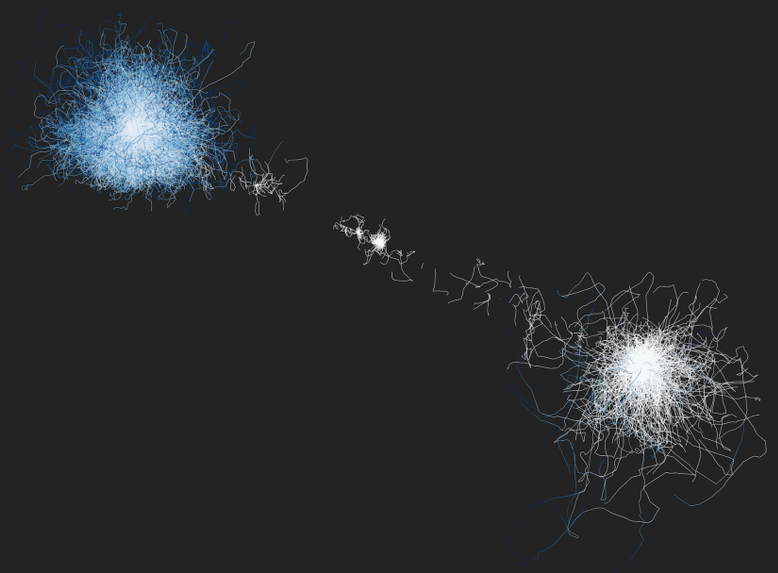
NEUTRINO INTERACTION CHANNELS

Photon path induced by a ν_μ ν_e ν_τ

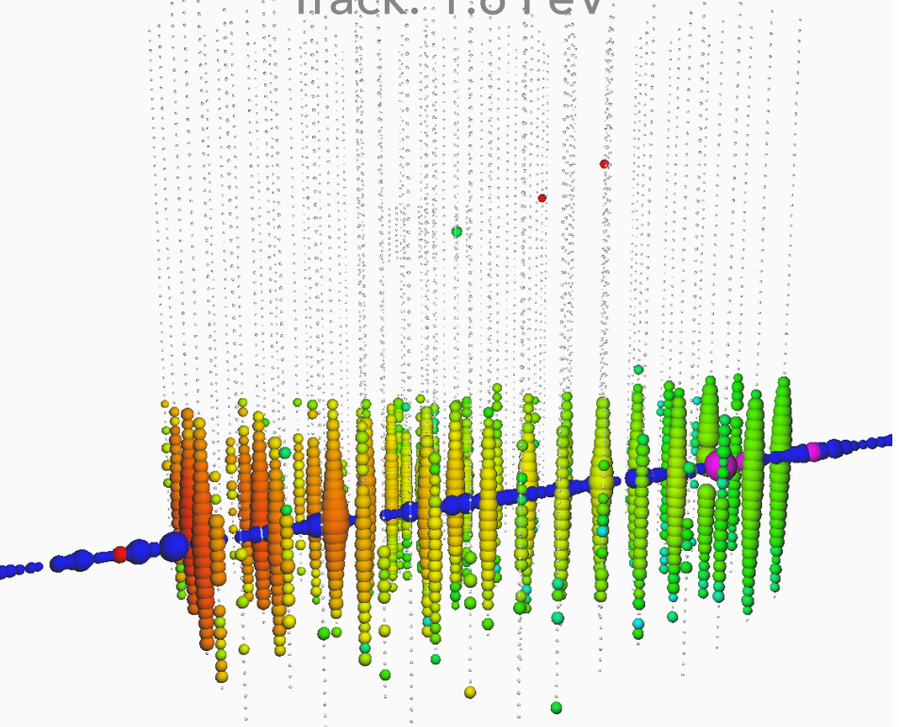




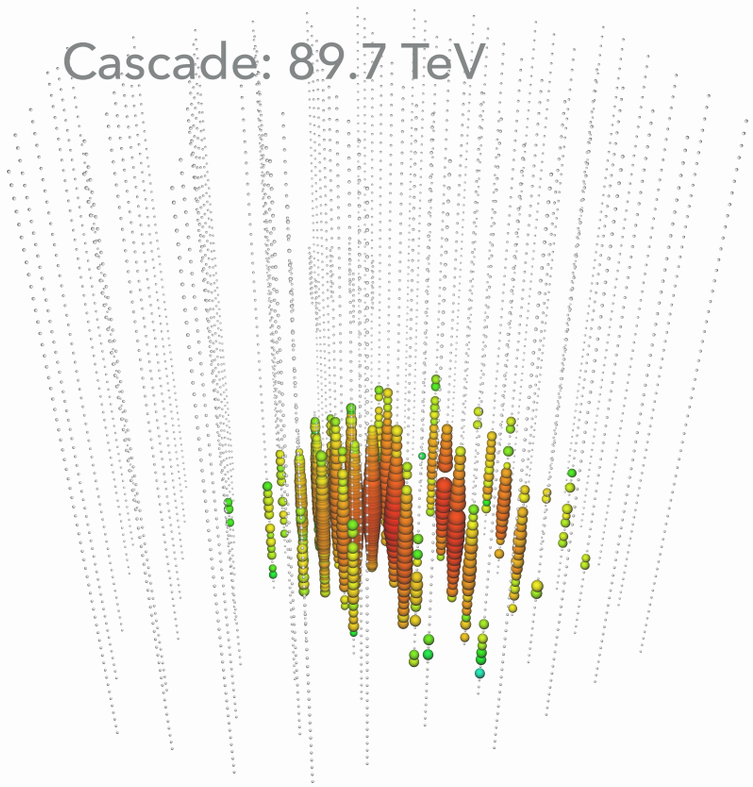




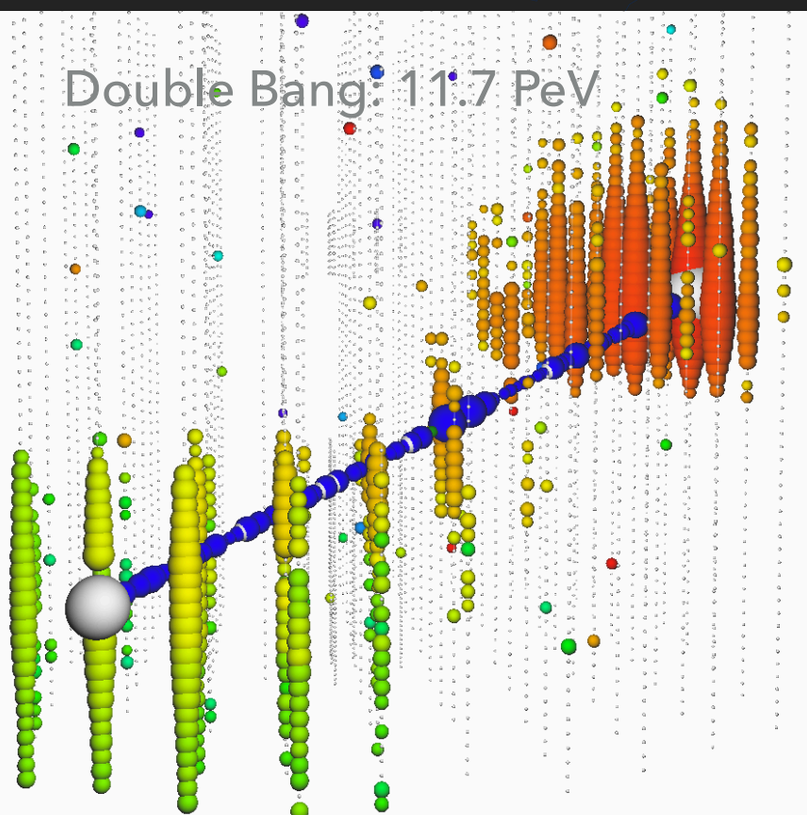
Track: 1.6 PeV



Cascade: 89.7 TeV



Double Bang: 11.7 PeV

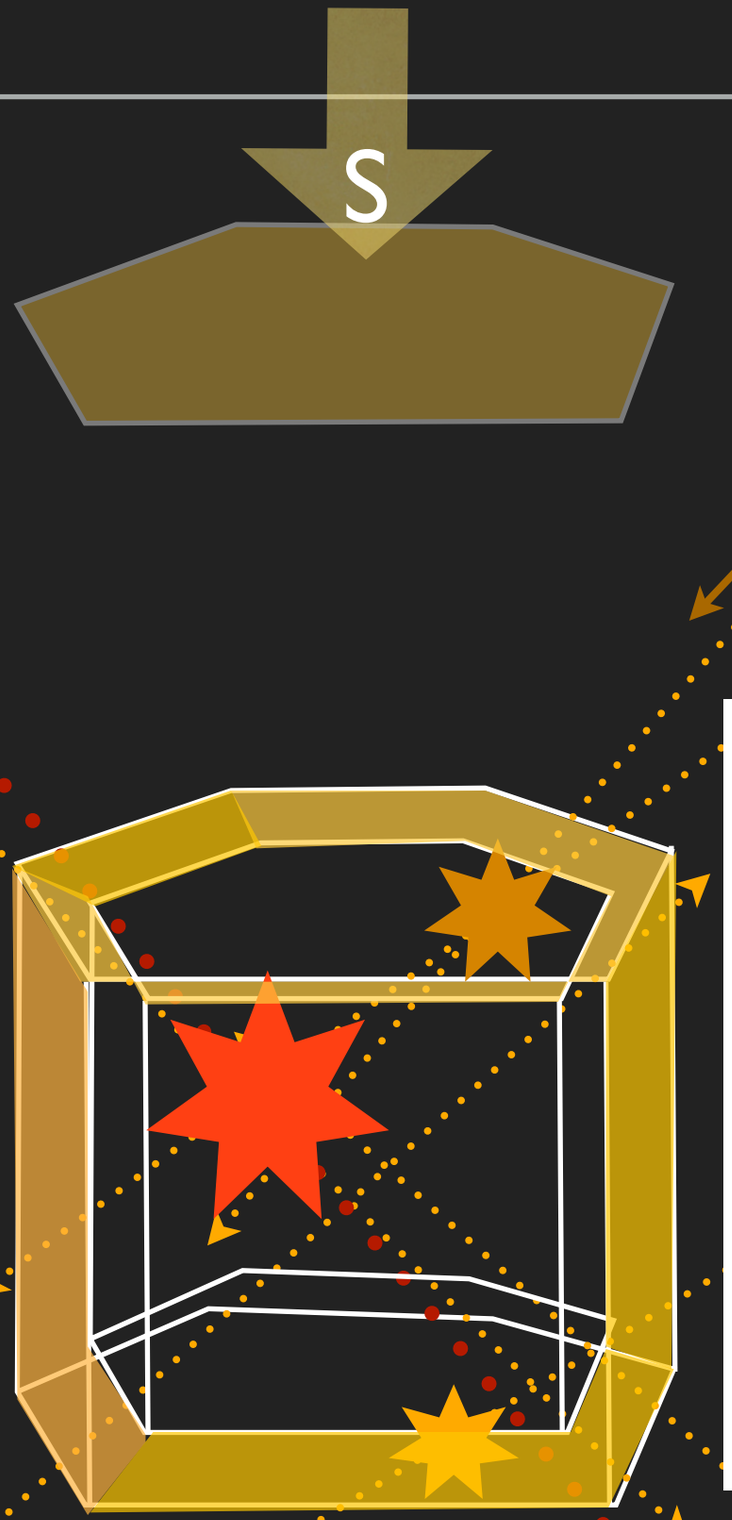


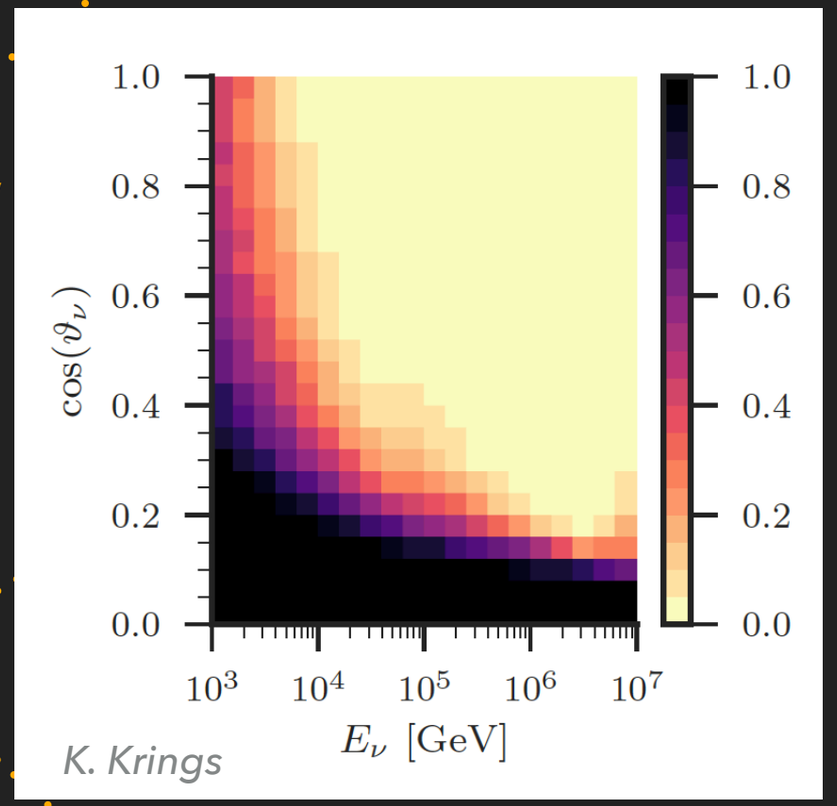
COSMIC NEUTRINOS (1)

HOW TO?

self-VETO

atmospheric neutrino-VETO





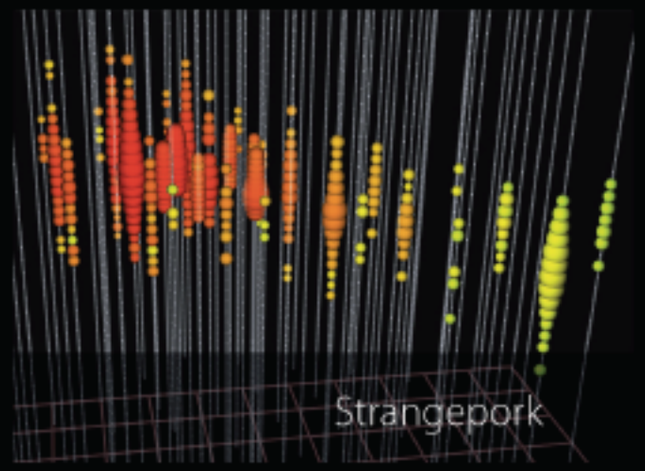
[S. Schönert, T. K. Gaisser, E.R., O. Schulz, PRD (2009),

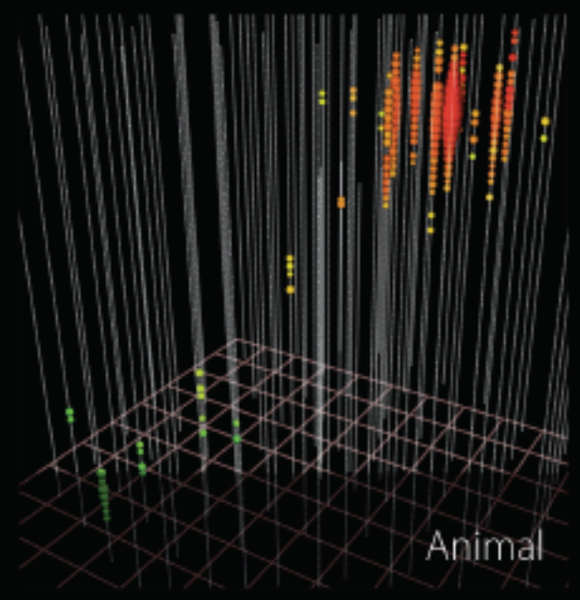
T. K. Gaisser, K. Jero, A. Karle, and J. van Santen, Phys. Rev. D (2014)]

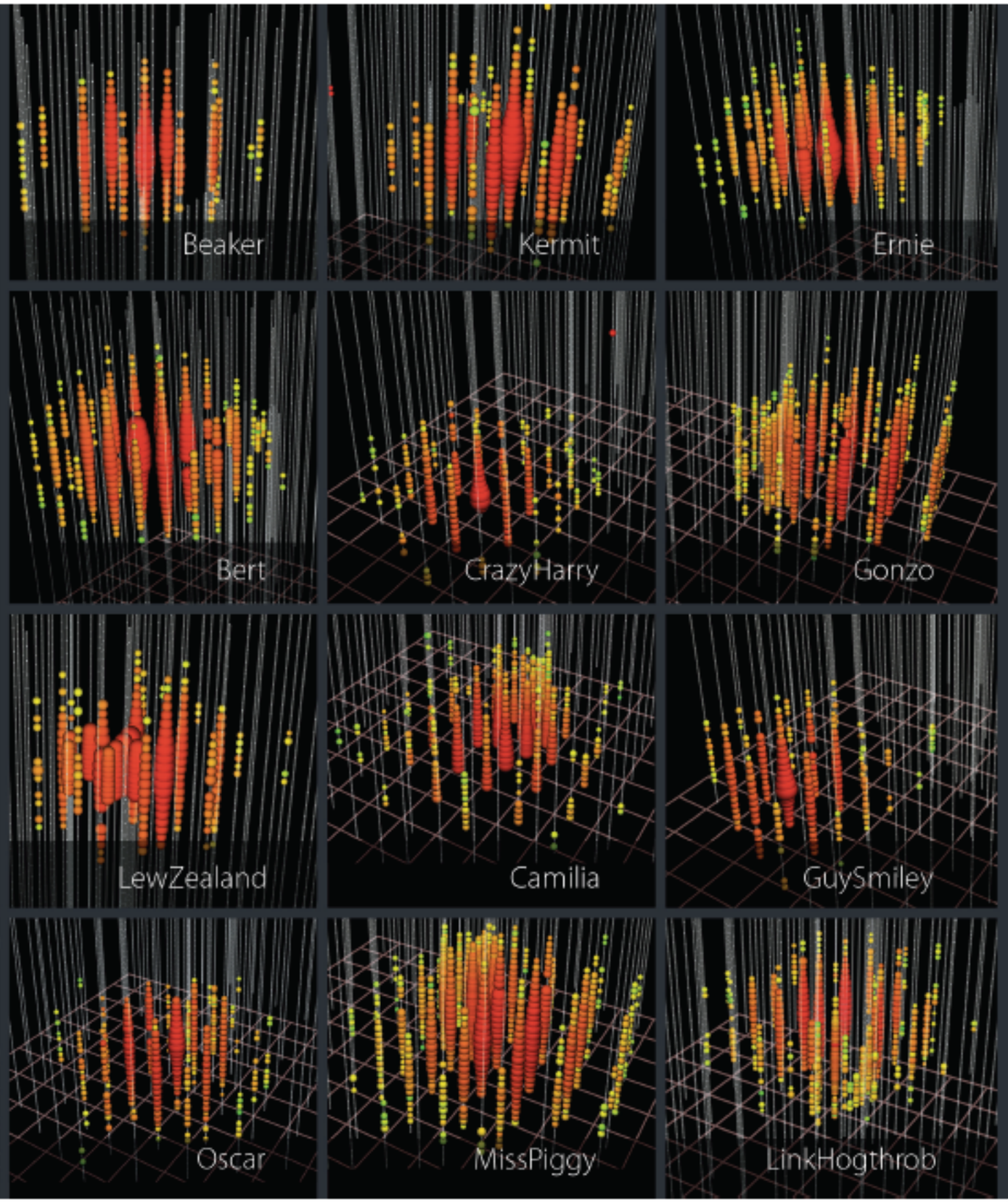
Examples of events:

charge threshold > 6000 p.e.
& < 3 p.e. in veto region

2078-day sample: 82 events



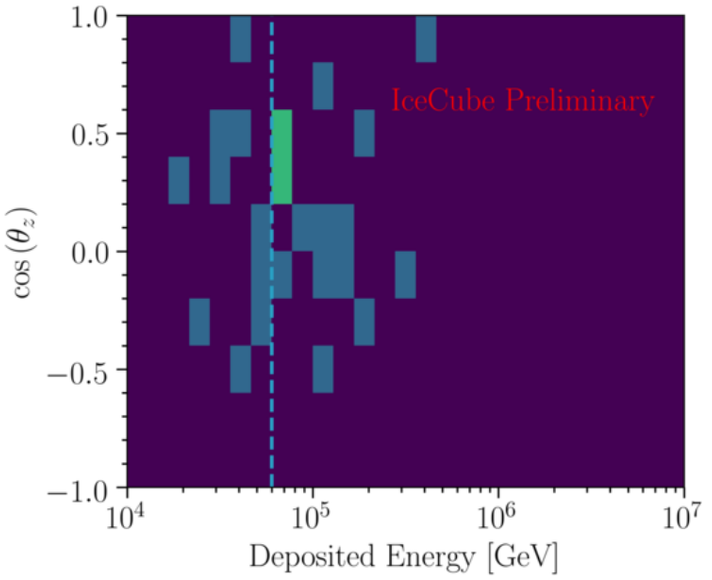




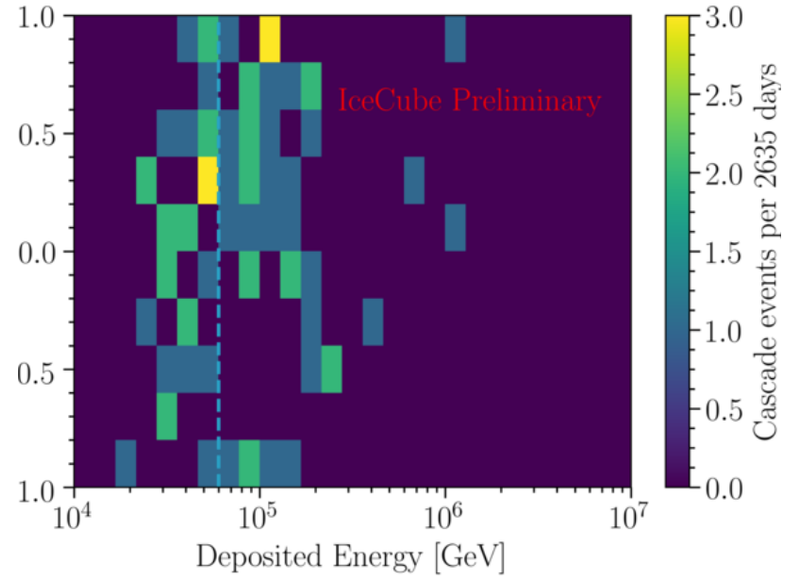
HIGH ENERGY, STARTING EVENTS, ALL FLAVOURS (2635 DAYS)

NEW

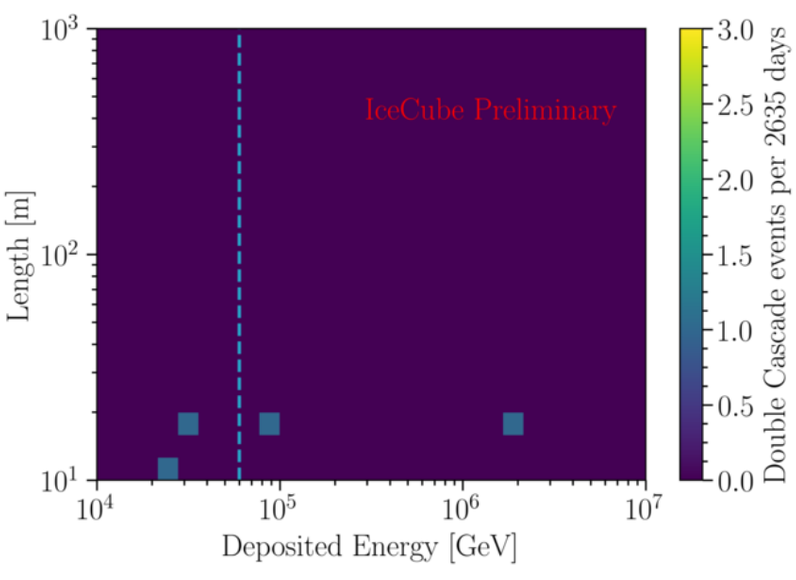
HE Starting Tracks
All energies: 26 events;
E > 60TeV: 16 events

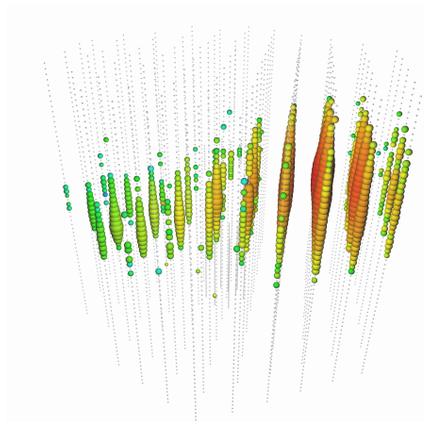


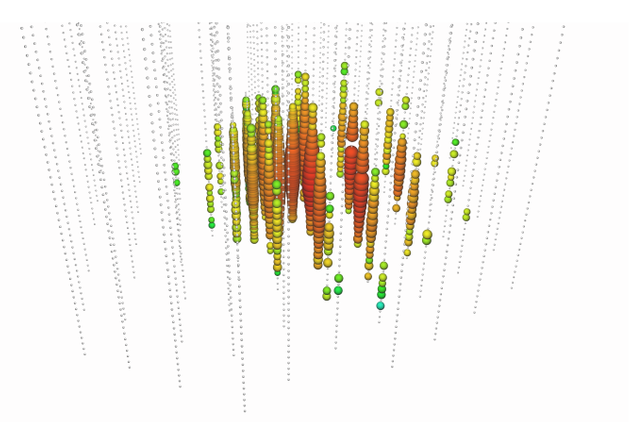
HE Starting Showers
All energies: 72 events;
E > 60TeV: 42 events

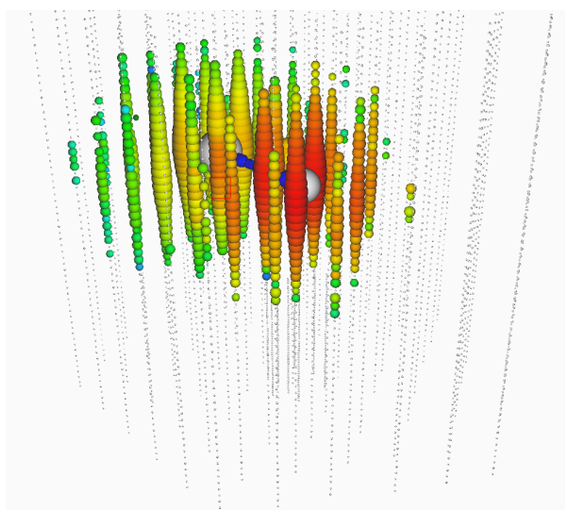


HE Starting Double Showers
All energies: 4 events;
E > 60TeV: 2 events









THE RECORD EVENT: HYDRANGEA -> GLASHOW RESONANCE EVENT CANDIDATE

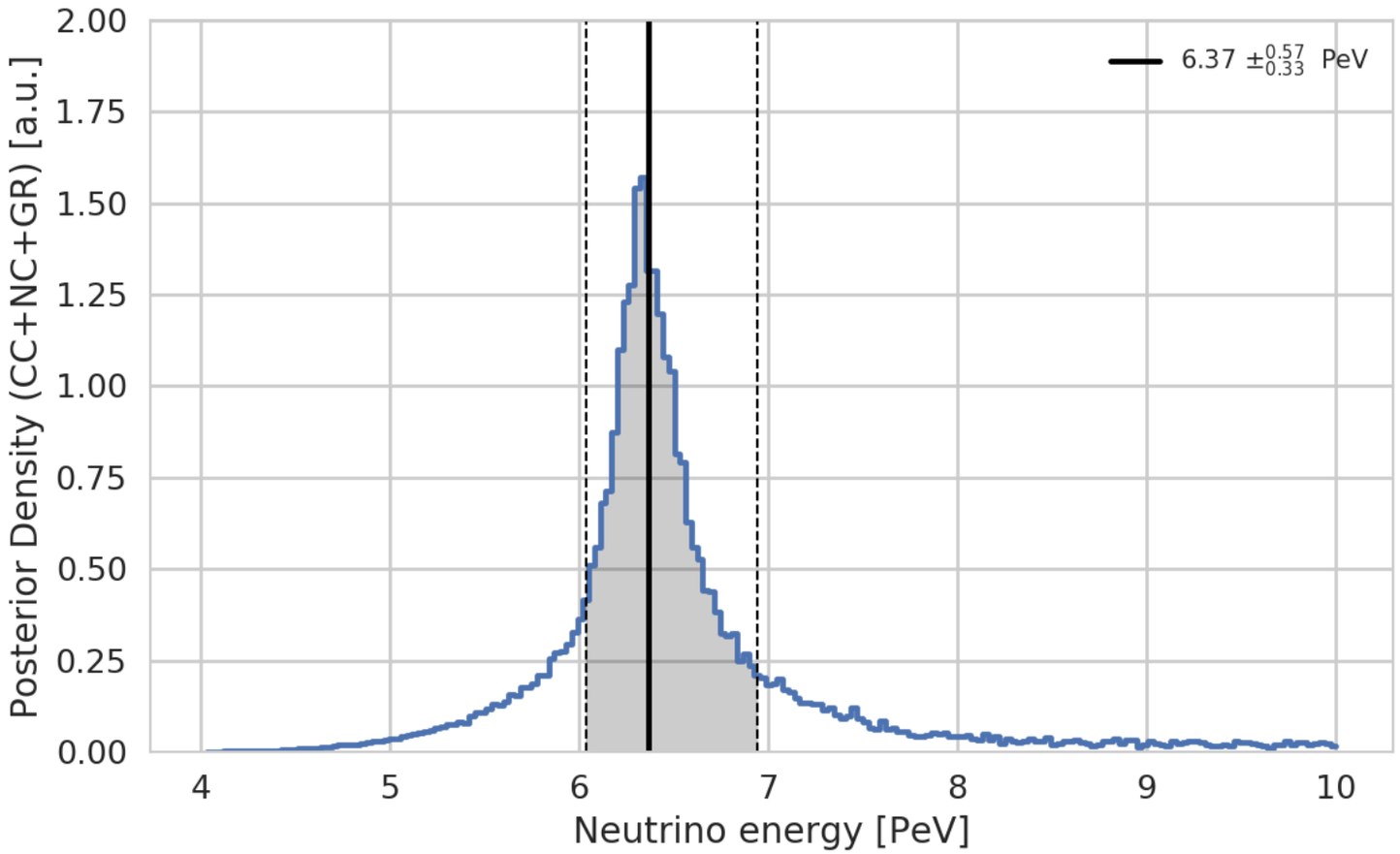
resonant scattering

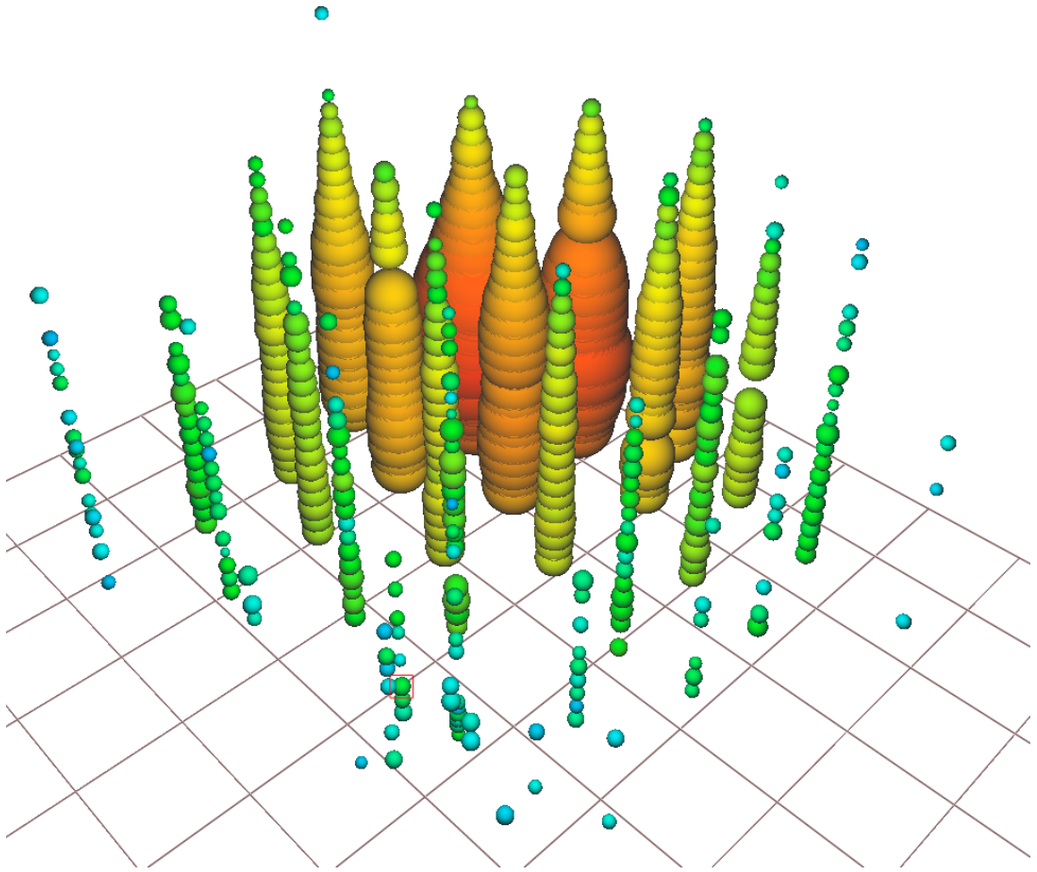
$$\bar{\nu}_e e^- \to W^- \to \text{anything} \qquad E_\nu \simeq 6.3 \text{ PeV}$$

ν_e candidate, CR origin excluded at the > 5 sigma level

IceCube, work in progress

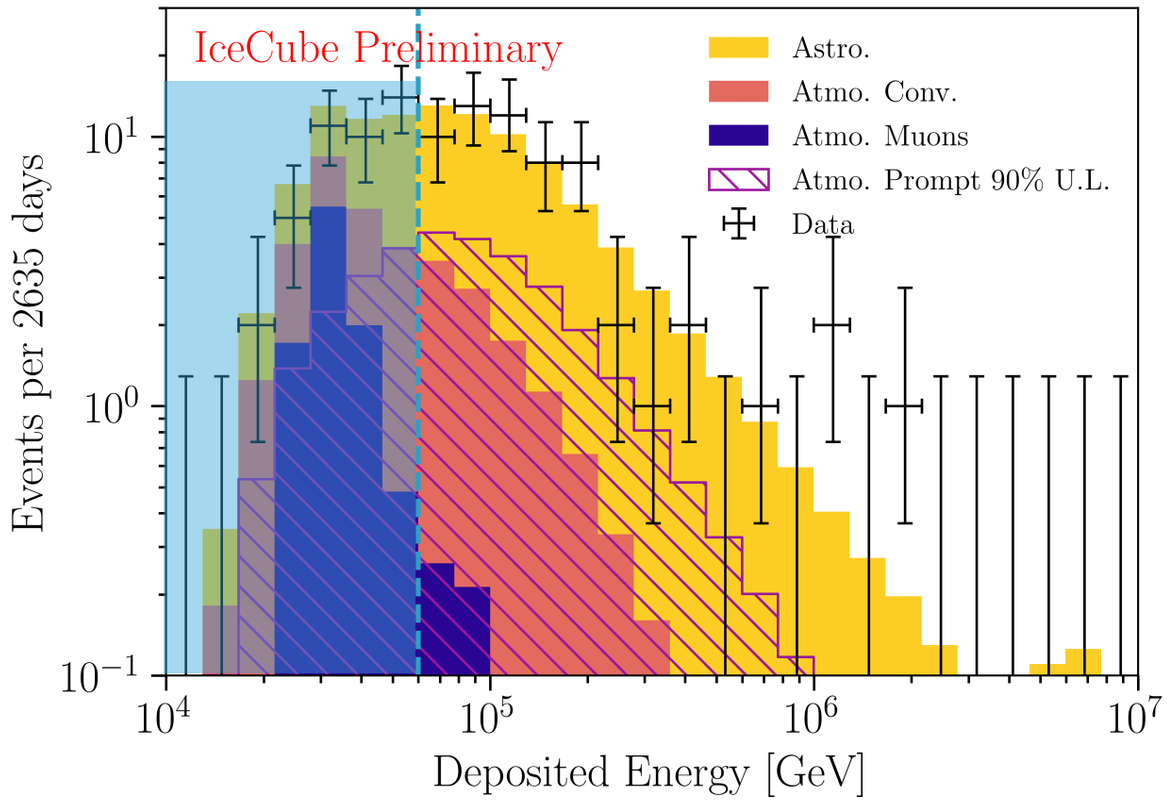
NEW

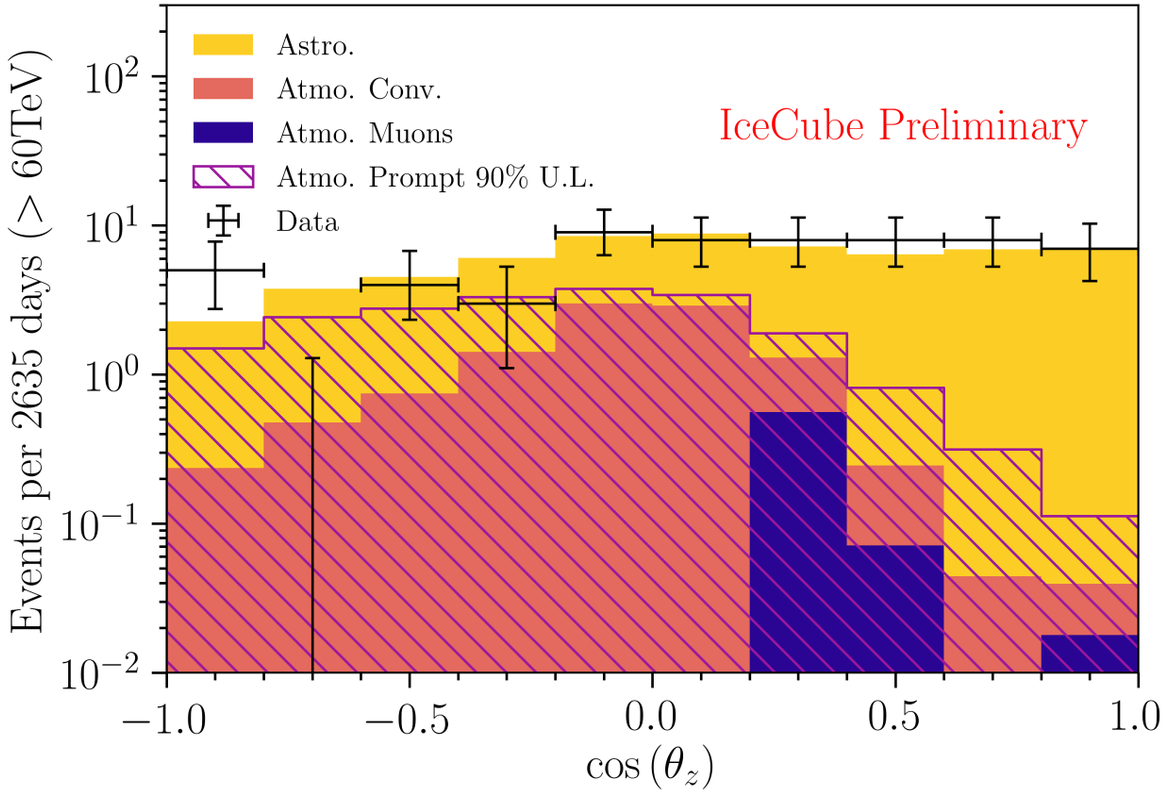




HIGH ENERGY, STARTING EVENTS, ALL FLAVOURS (2635 DAYS)

All energies: 102 events; E > 60TeV: 60 events



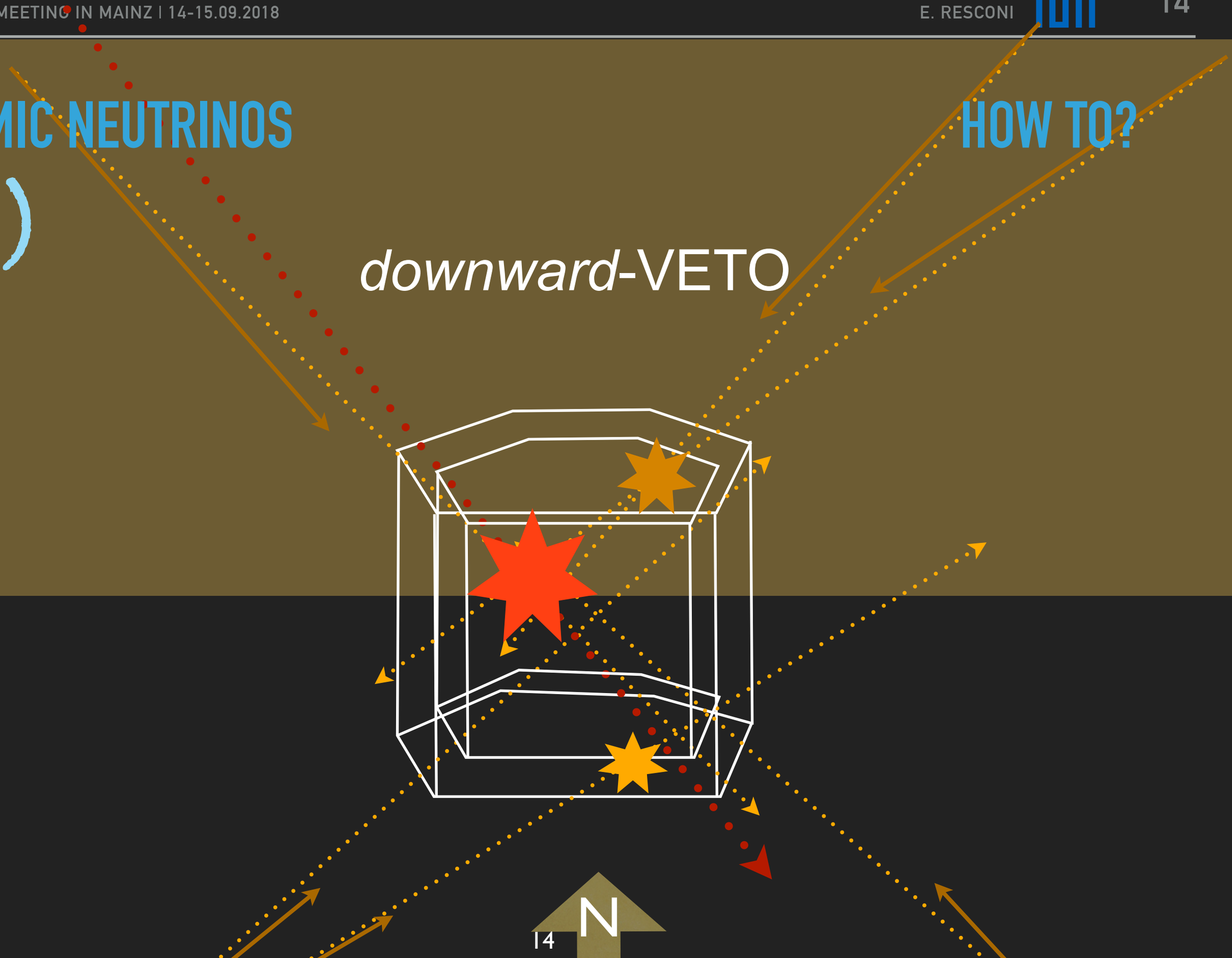


2.19(+1.10,-0.55)xE$^{-2.91(+0.33,-0.22)}$

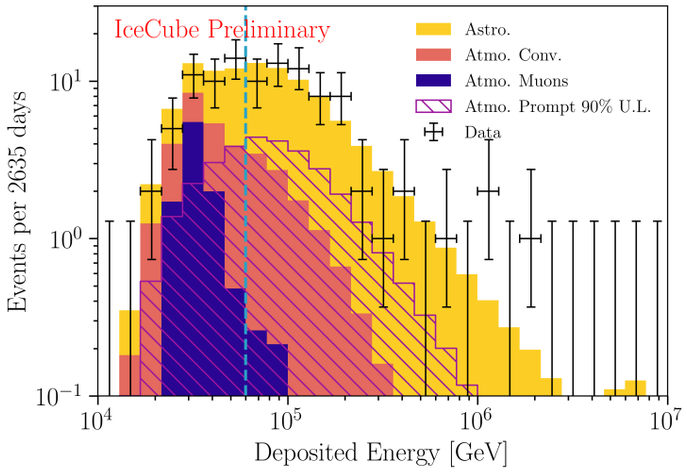
COSMIC NEUTRINOS (2)

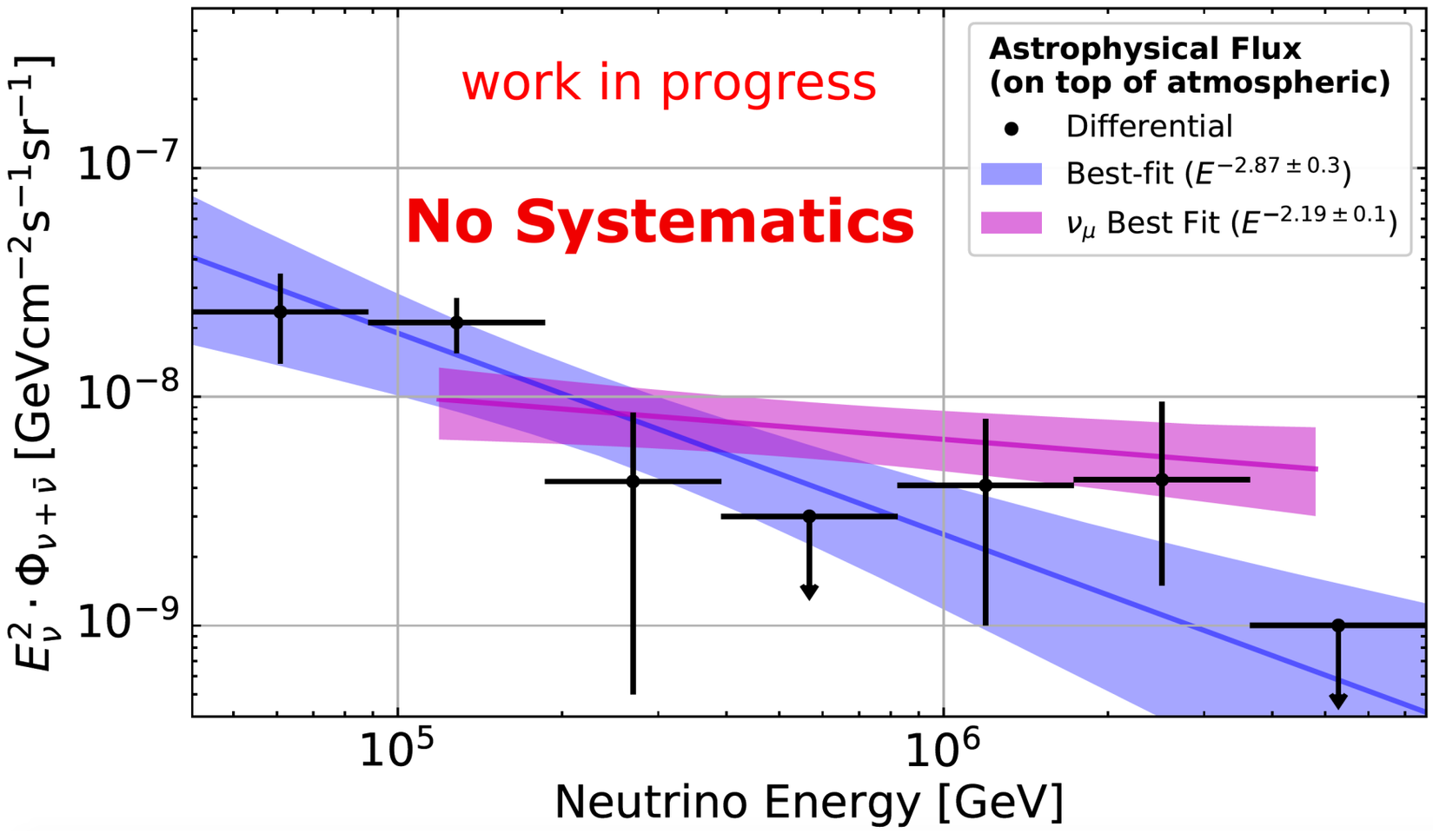
HOW TO?

downward-VETO



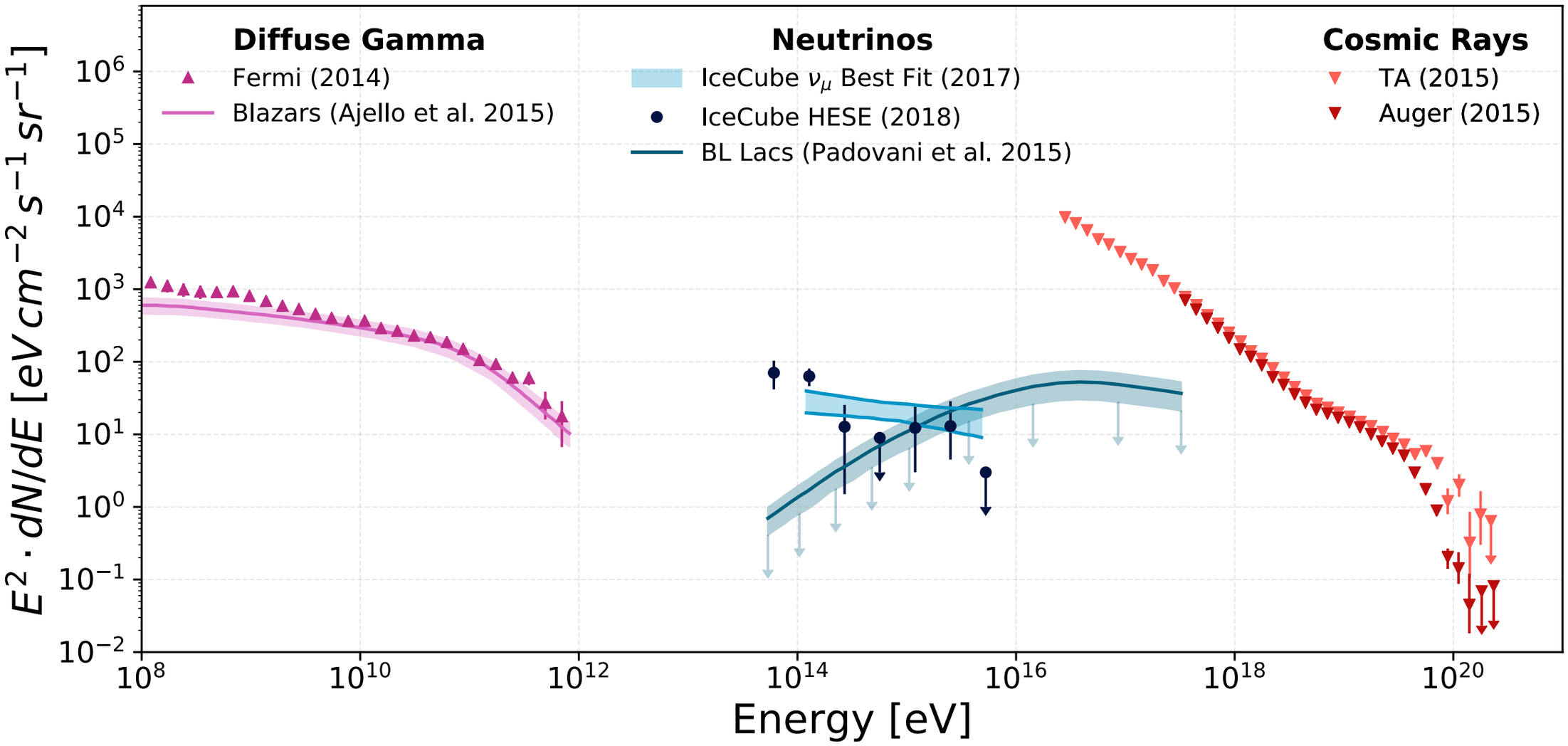
HIGH ENERGY SPECTRUM: ALL CHANNELS CONSISTENT





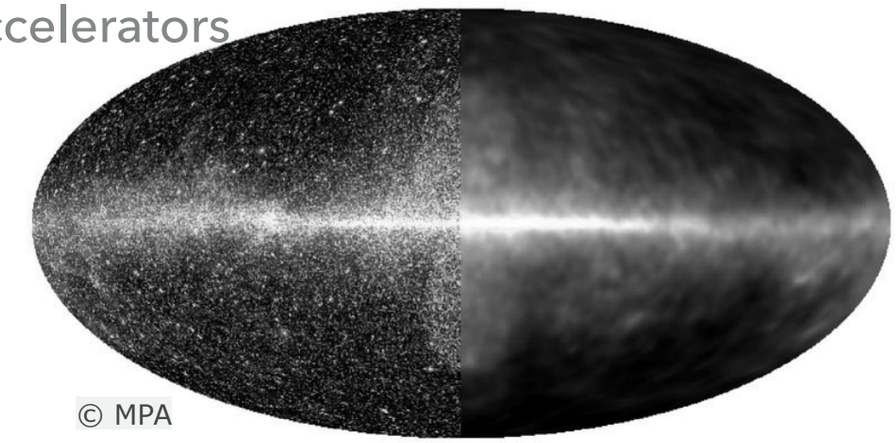
THE MULTI-MESSENGER OBSERVATIONS

SAME ENERGY FLUX FOR ALL THE THREE MESSENGERS: SUGGESTING A COMMON ORIGIN?



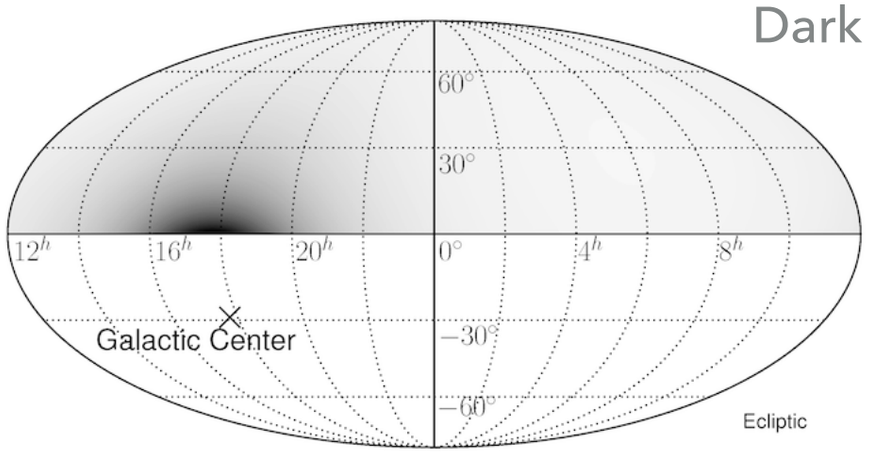
ORIGIN OF HIGH ENERGY COSMIC NEUTRINOS?

Galactic accelerators



© MPA

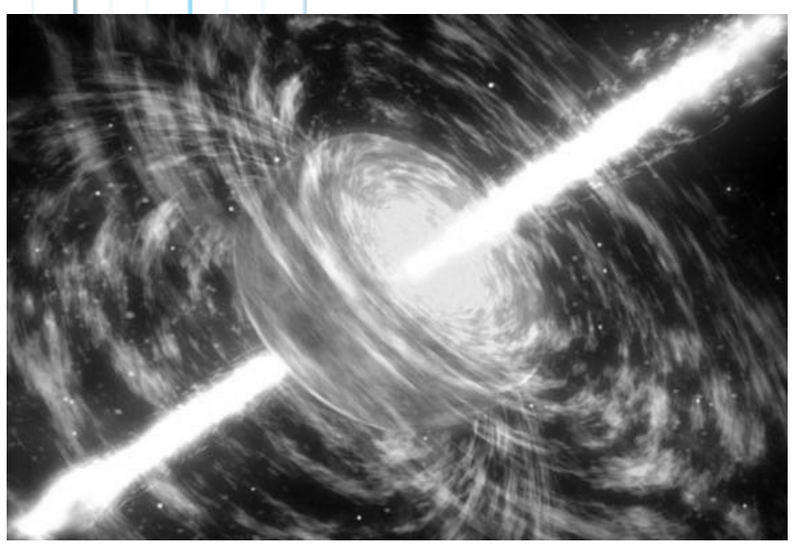
Dark Matter



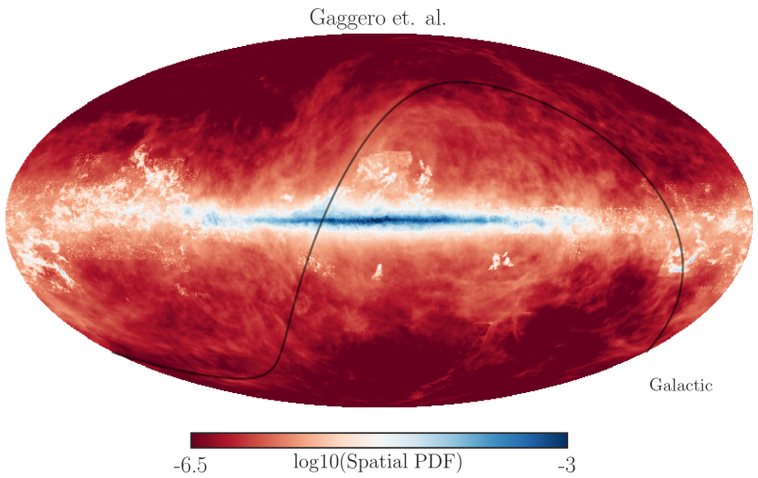
AGN, Blazars

See AnnaF's talk

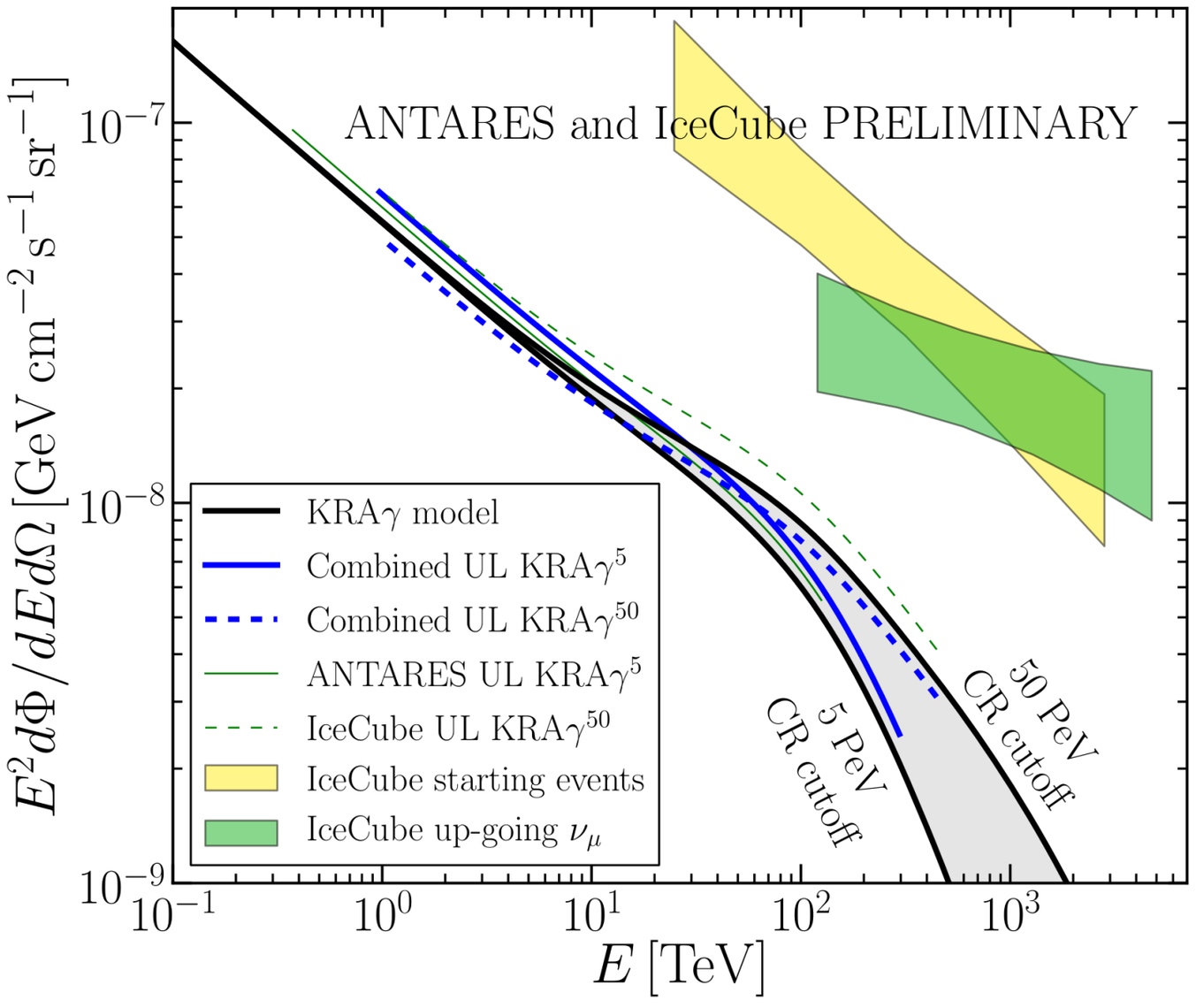
Gamma Ray Bursts



CONSTRAINTS ON THE FROM THE GALACTIC PLANE NEUTRINO COMPONENT



NEW

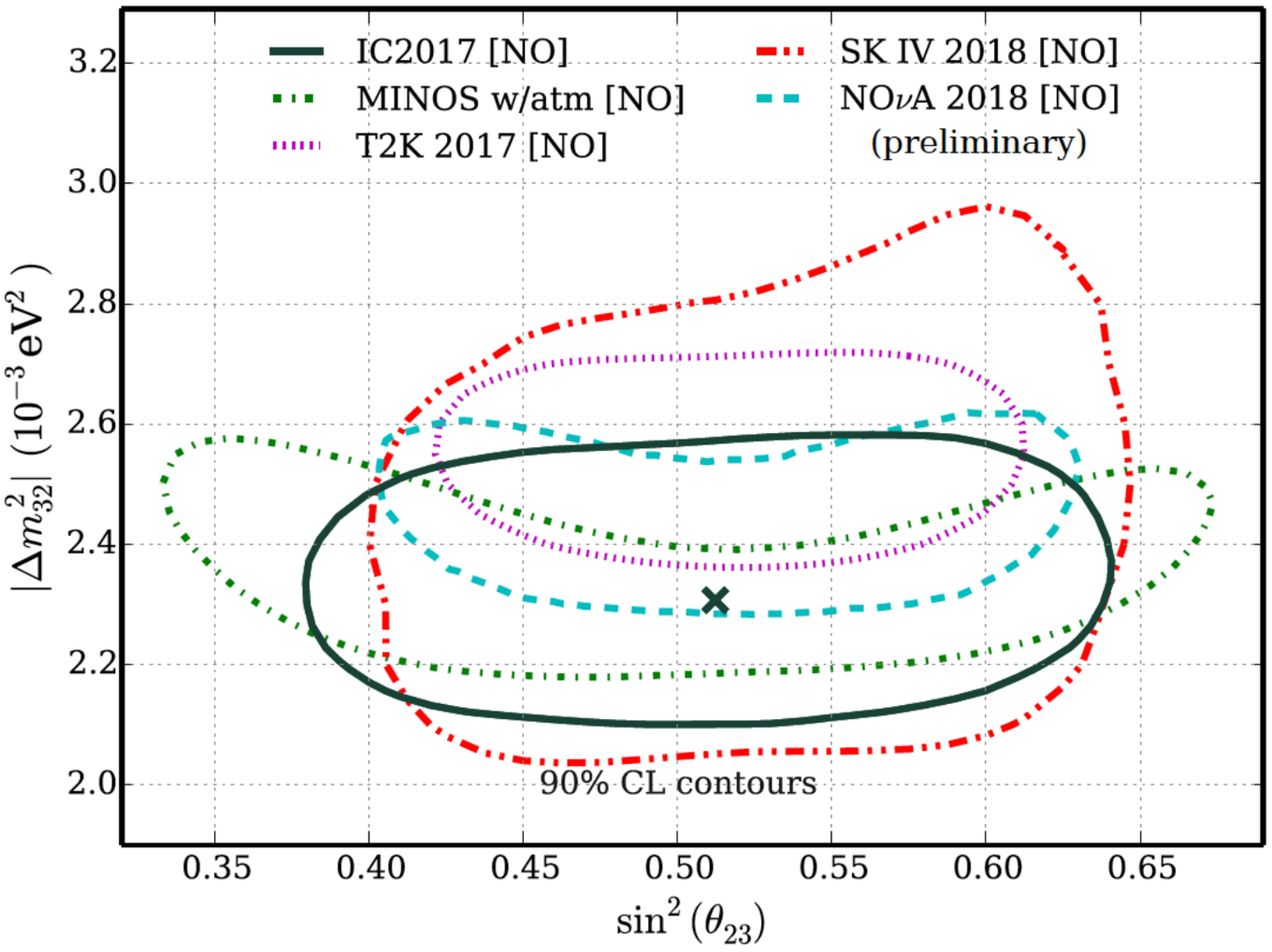


https://arxiv.org/abs/1808.03531
Submitted to APJL

TWO SLIDES ABOUT ICECUBE IN THE PRECISION ERA

ICECUBE DEEPCORE: OSCILLATION, MUON NEUTRINO DISAPPEARANCE

Most precise atmospheric measurement, highest energy range
(constraints primarily from 15-50 GeV neutrinos)



41,599 events (full-sky), all flavour low energy sample

[15,138 track, 26,461 cascade events]

Best fit values:

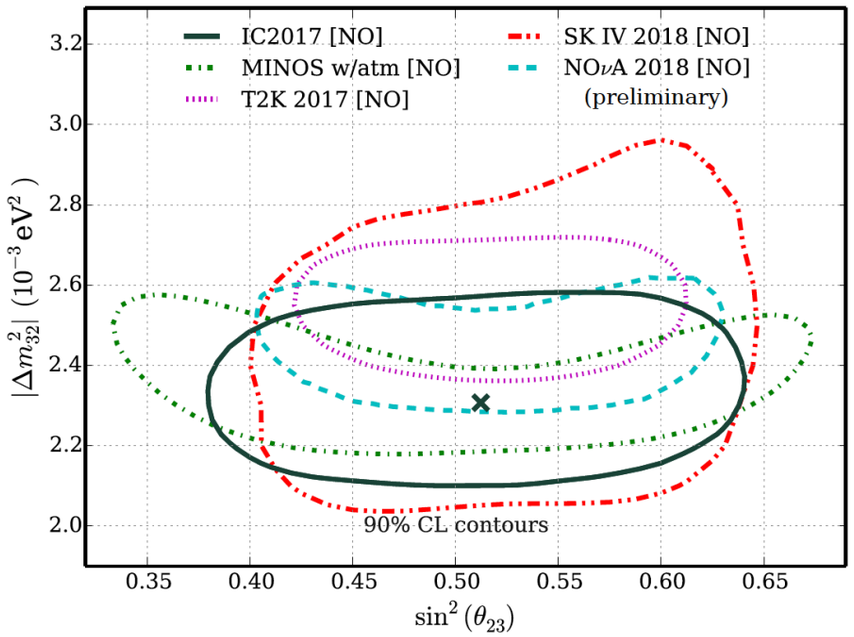
$\sin^2 \theta_{23} = 0.51(+0.07-0.09)$

$\Delta m^2_{32} = 2.31(+0.11-0.13) \times 10^{-3}$ eV^2

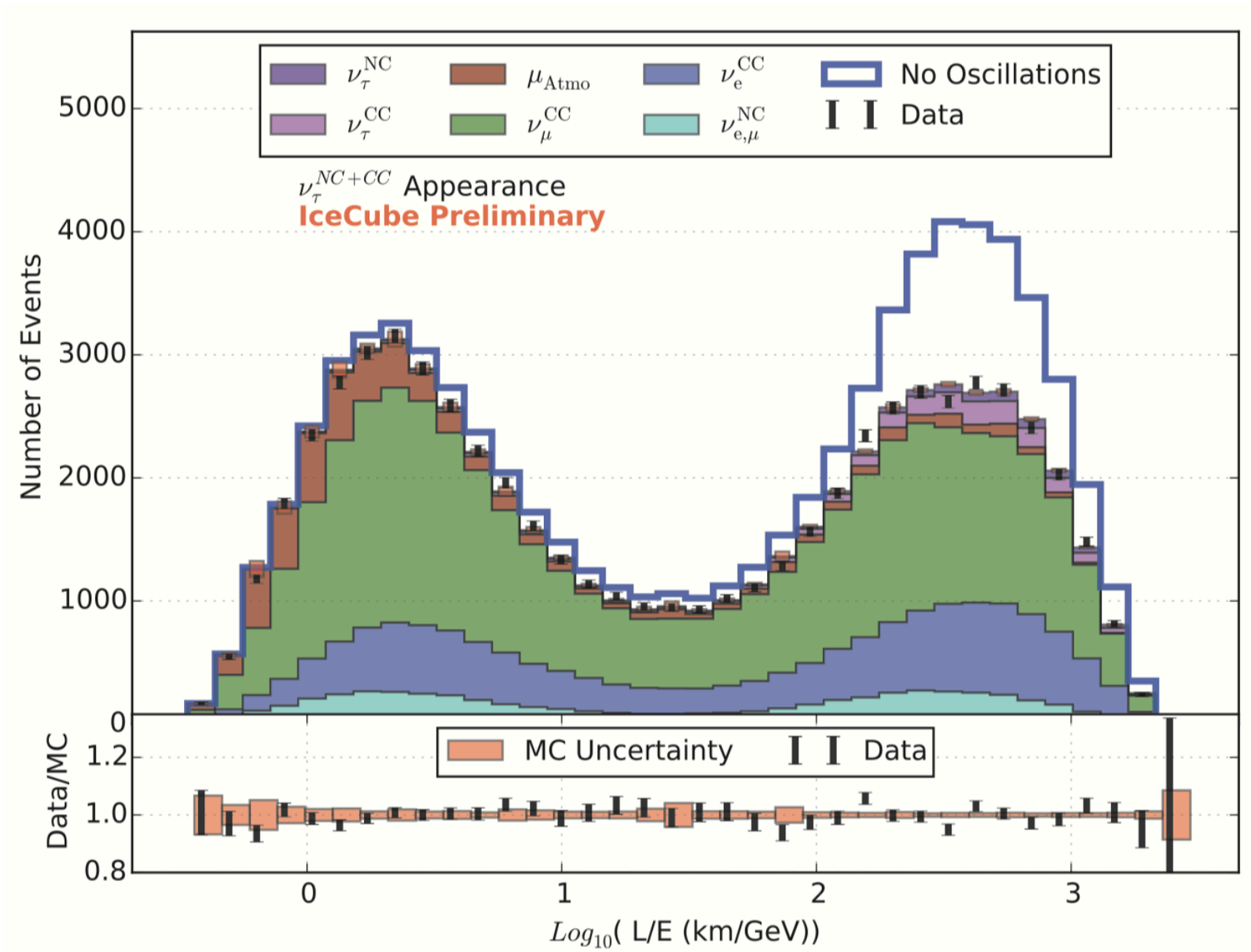
[M. Aartsen et al. (IceCube), Phys. Rev. Lett. 120, 071801 (2018)]

ICECUBE DEEPCORE: OSCILLATION, TAU NEUTRINO APPEARANCE

NEW



Similar precision on tau neutrino appearance as SK and Opera



IN SUMMARY

IceCube in the discovery era:

- Diffuse cosmic neutrinos - two independent channels
- First double shower events detected
- First Glashow resonance candidate event detected
- Compelling evidence for the first non-stellar neutrino source: a blazar

IceCube in the precision era:

- Atmospheric neutrino oscillation
  - competitive estimation of atmospheric mixing parameters
  - low energy nu_tau appearance at the precision level of other telescopes

and much more I could not cover.

NEUTRINOS AND THEIR DETECTORS CHALLENGE EVERYTHING WE THINK WE KNOW AND ARE

Jol Thoms

NEUTRINOS AND THEIR DETECTORS CHALLENGE EVERYTHING WE THINK WE KNOW AND ARE

We need more neutrinos!!!

Jol Thoms

see Marek and Jannik's talks and

stay open to new ideas