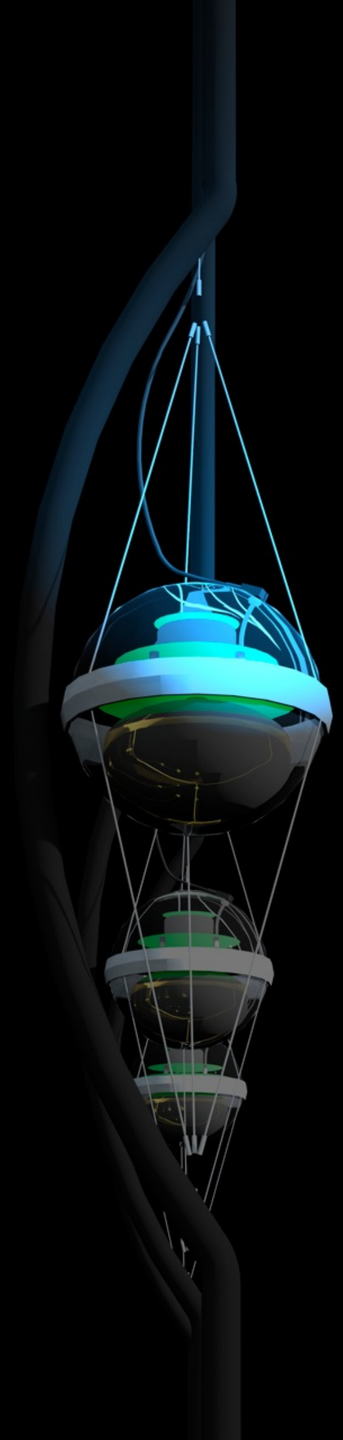


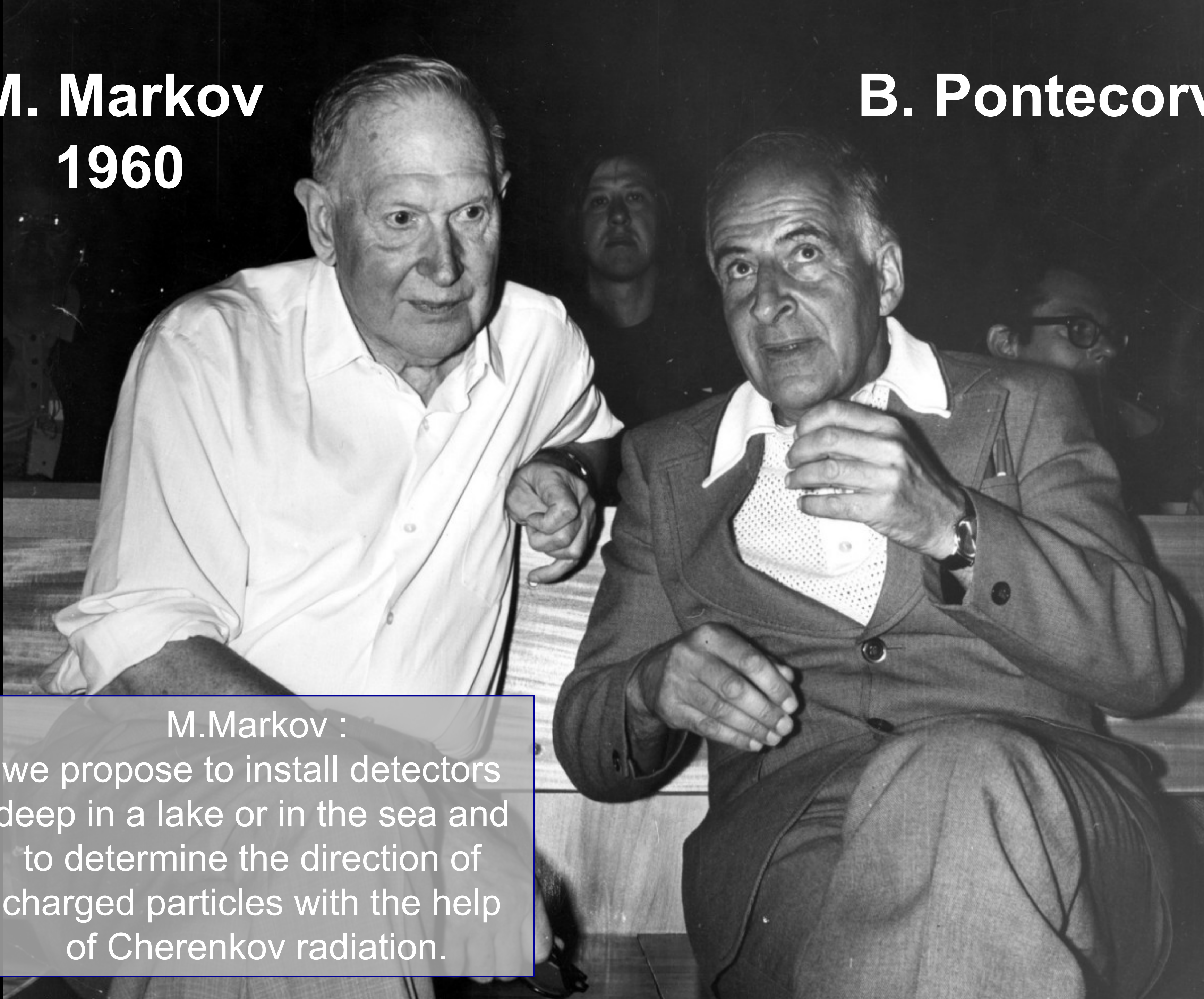
Bruno Pontecorvo Prize
francis halzen

- some history
- a kilometer cube detector
- the multiple ways of discovering cosmic neutrinos
- the first cosmic ray accelerator

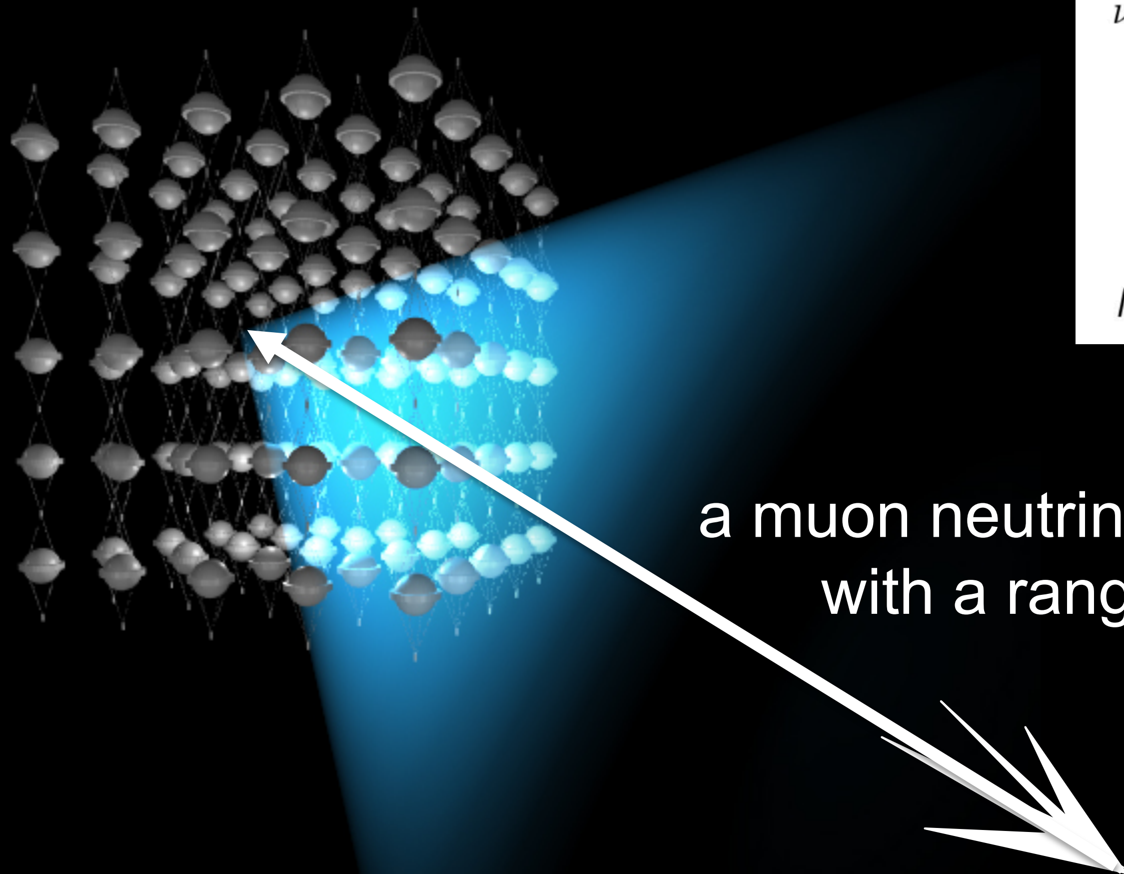
IceCube.wisc.edu

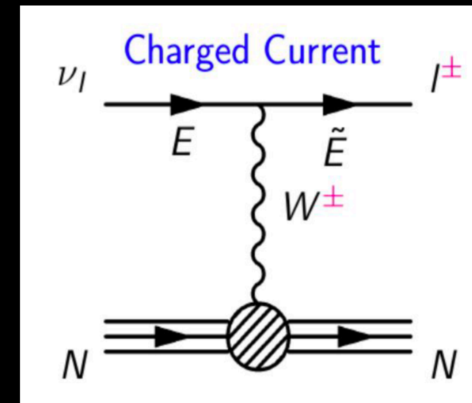
M. Markov
1960

B. Pontecorvo



M.Markov :
we propose to install detectors deep in a lake or in the sea and to determine the direction of charged particles with the help of Cherenkov radiation.





a muon neutrino produces a muon with a range of kilometers

- lattice of photomultipliers

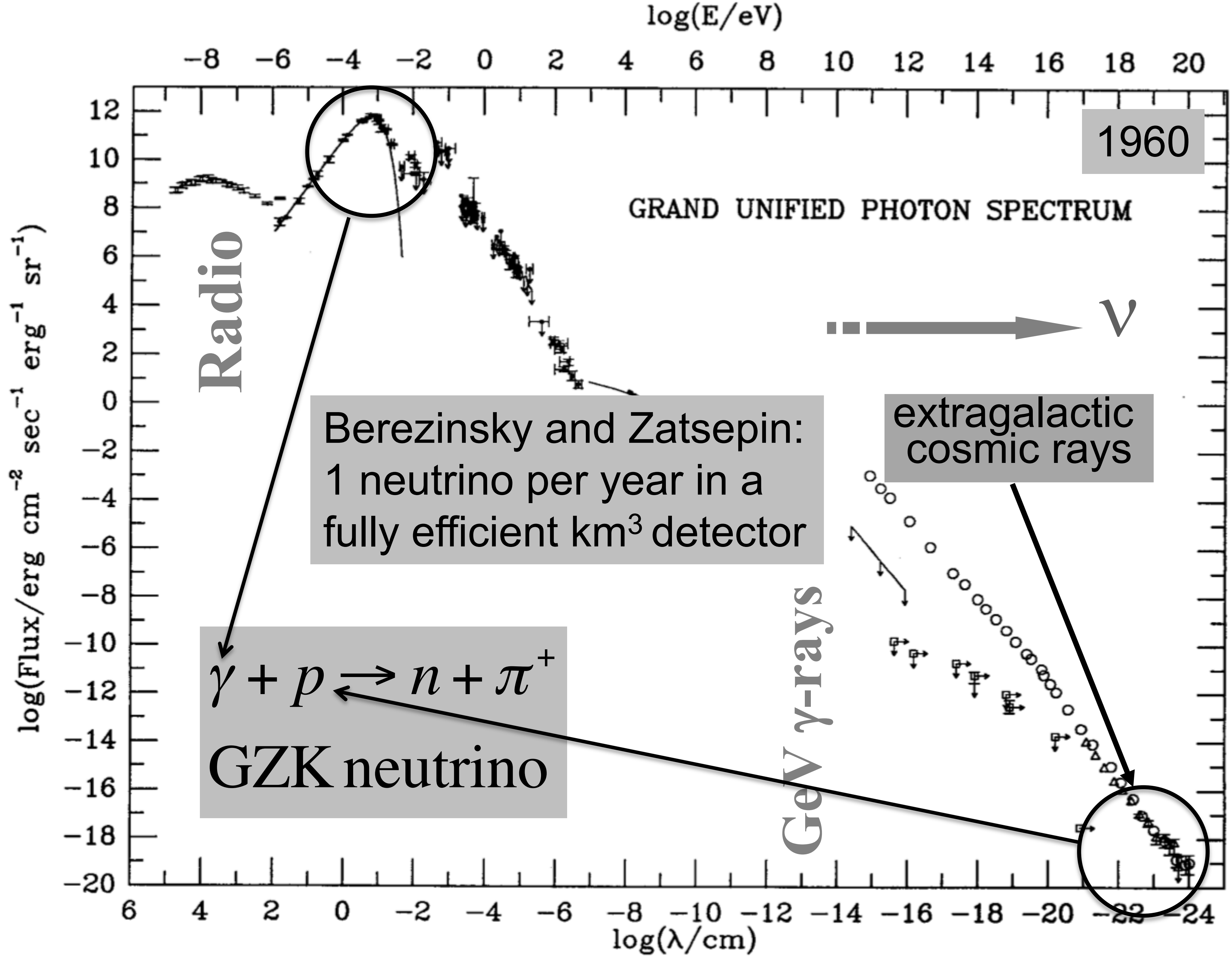
neutrino

standing on the shoulder of giants

1987: DUMAND test string

Lake Baikal experiment observes atmospheric neutrinos

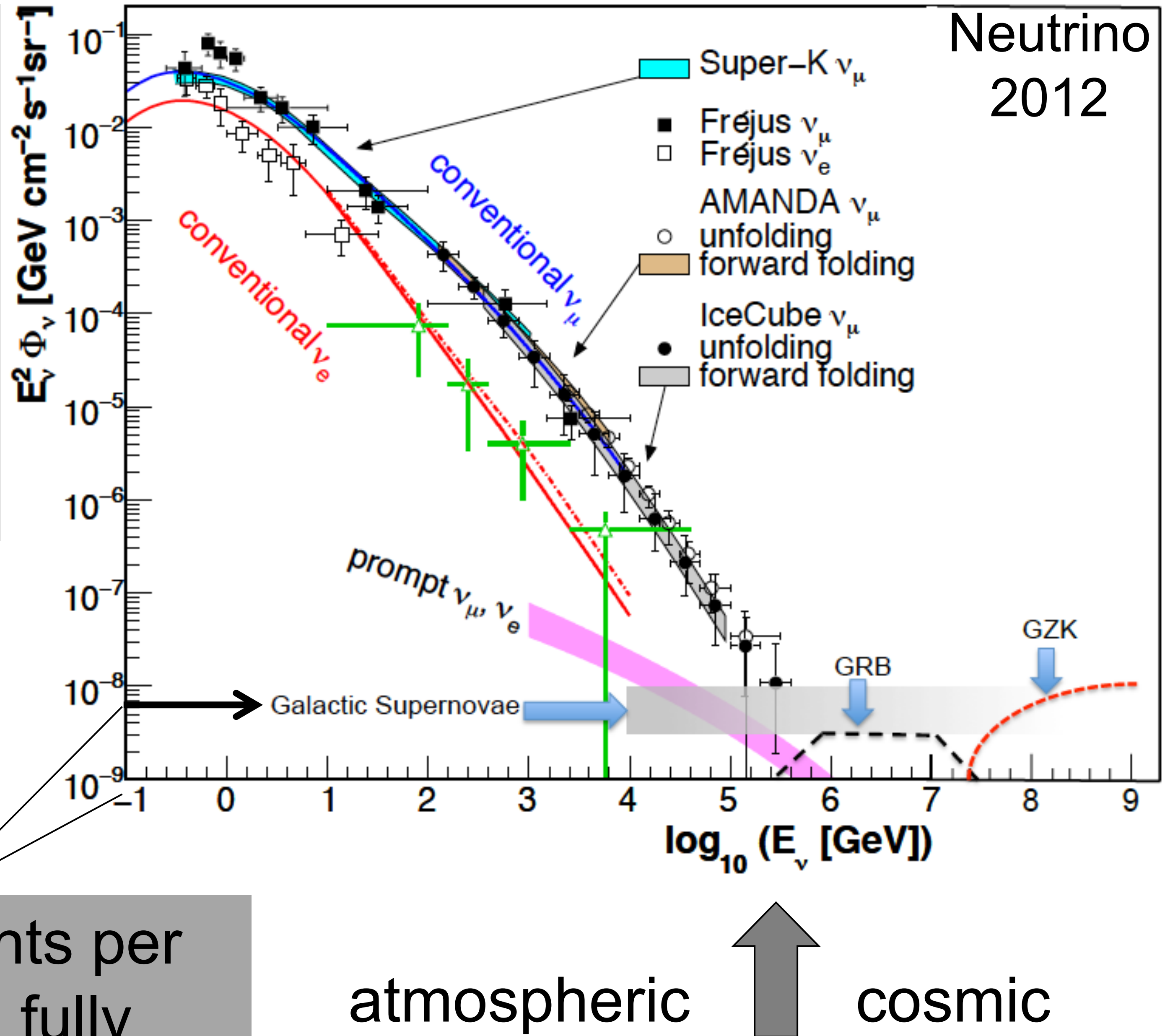

ANTARES
Running since 2007
885 10” PMTs
12 lines
25 storeys/line
3 PMTs / storey
2500 m deep
450 m
40 km to shore
Junction Box
70 m
Interlink cables
© François Montanet
France
Switzerland
Spain
Italy
Nantes
Zurich
Geneva
Lyon
Milan
Turin
Venice
Genoa
Bologna
Toulouse
Montpellier
Marseille
Monaco
Andorra
Barcelona
Zaragoza
Madrid
Valencia
Palma
Murcia
Malaga
Algiers
Tunis
Corse
Sardegna
ANTARES
Google



log(E/eV)
1960
GRAND UNIFIED PHOTON SPECTRUM
Radio
ν
Berezinsky and Zatsepin:
1 neutrino per year in a
fully efficient km^3 detector
extragalactic
cosmic rays
$\gamma + p \rightleftarrows n + \pi^+$
GZK neutrino
GeV γ-rays
log(Flux/erg cm^{-2} sec^{-1} erg^{-1} sr^{-1})
log(λ/cm)

above 100 TeV

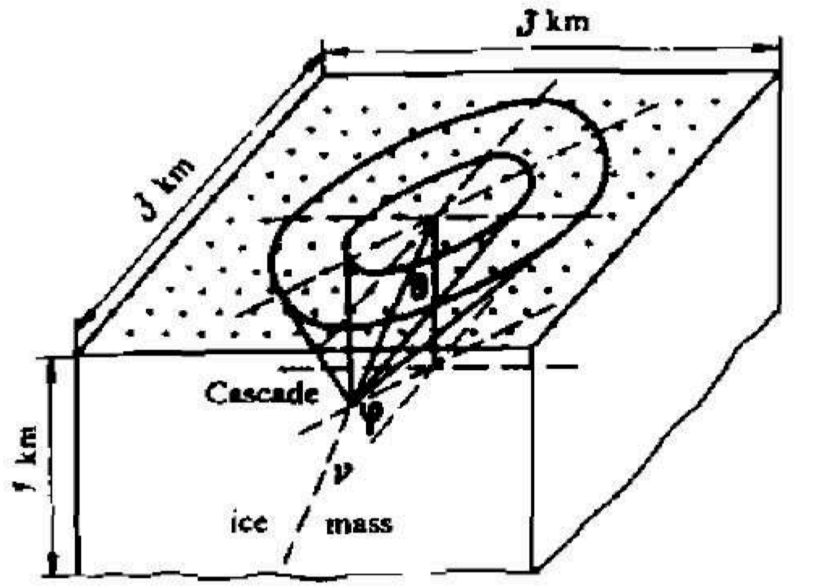
- cosmic neutrinos
- atmospheric background disappears



$$dN/dE \sim E^{-2}$$

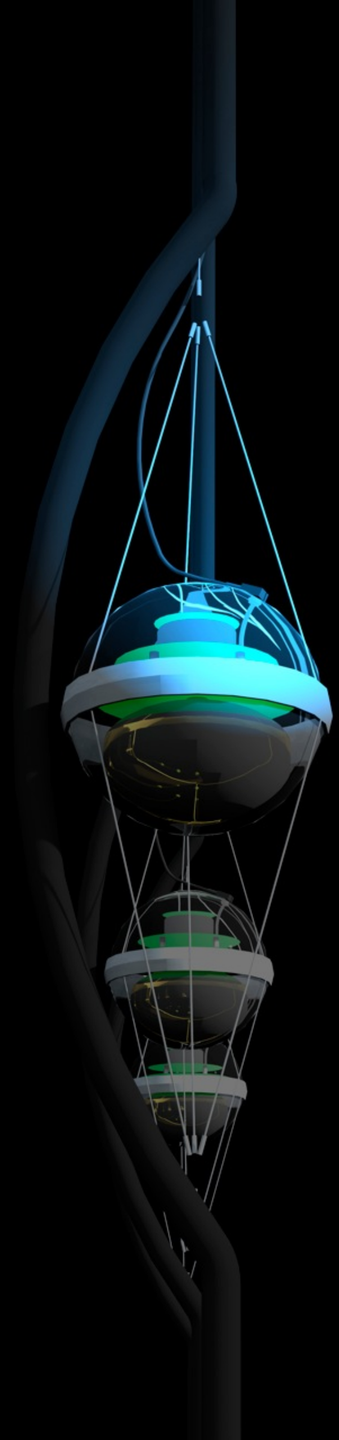
10-10² events per year for a fully efficient km³ detector

Askaryan G. A, "Coherent radio emission from cosmic showers in air and in dense media", SOV PHYS JETP-USSR 21 (3): 658 (1965)



G. A. Gusev, I. M. Zheleznykh, "On the possibility of detection of neutrinos and muons on the basis of radio radiation of cascades in natural dielectric media (antarctic ice sheet and so forth)," SOV PHYS USPEKHI, 1984, 27 (7), 550-552.

Electromagnetic pulses from high-energy showers: Implications for neutrino detection
E. Zas, F. Halzen (Wisconsin U., Madison), T. Stanev (Delaware U., Bartol Inst.). May 1991. 54 pp.
Published in **Phys.Rev. D45 (1992) 362-376**
MAD-PH-652



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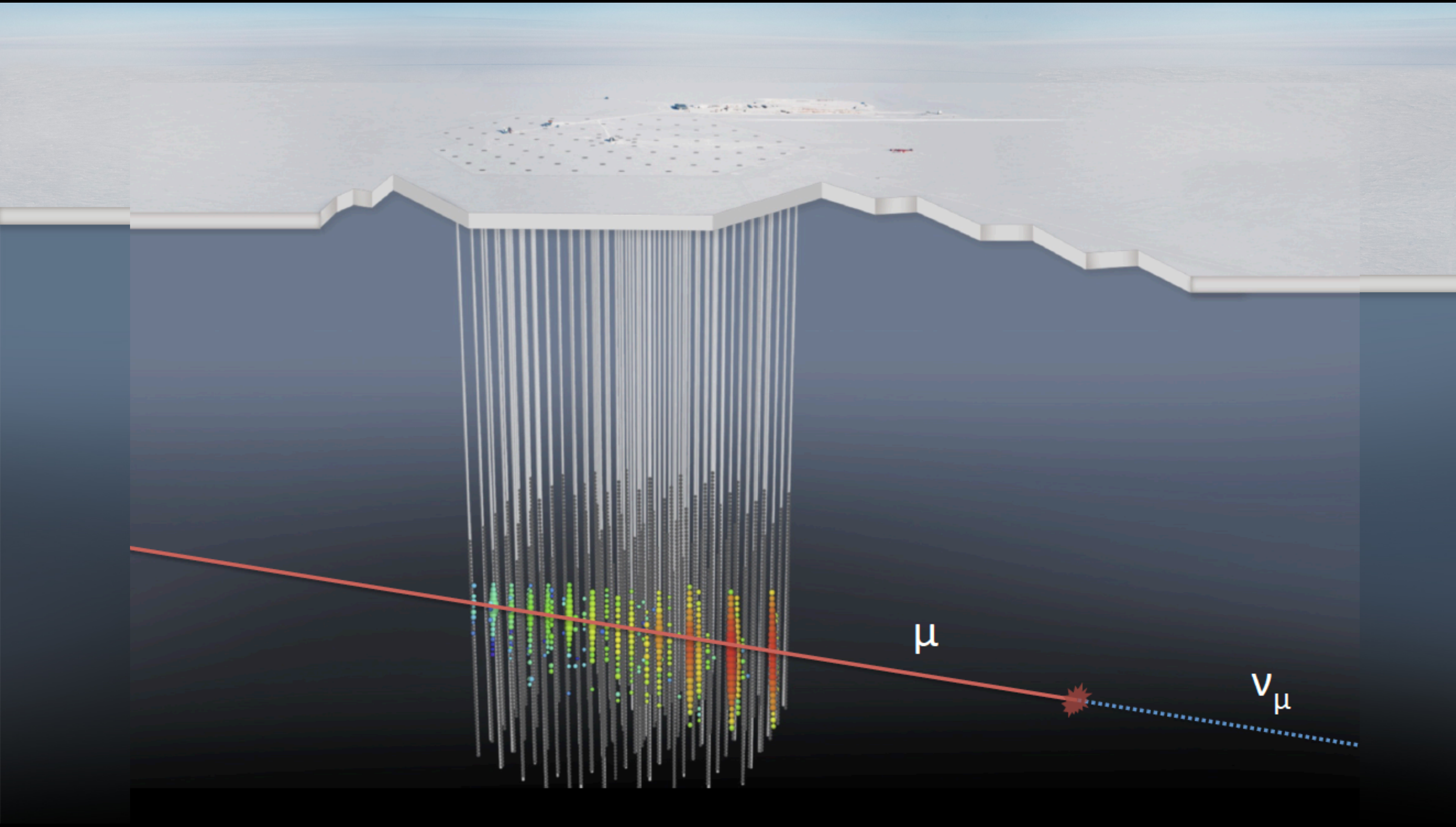
IceCube.wisc.edu


ultra-transparent ice below 1.35 km

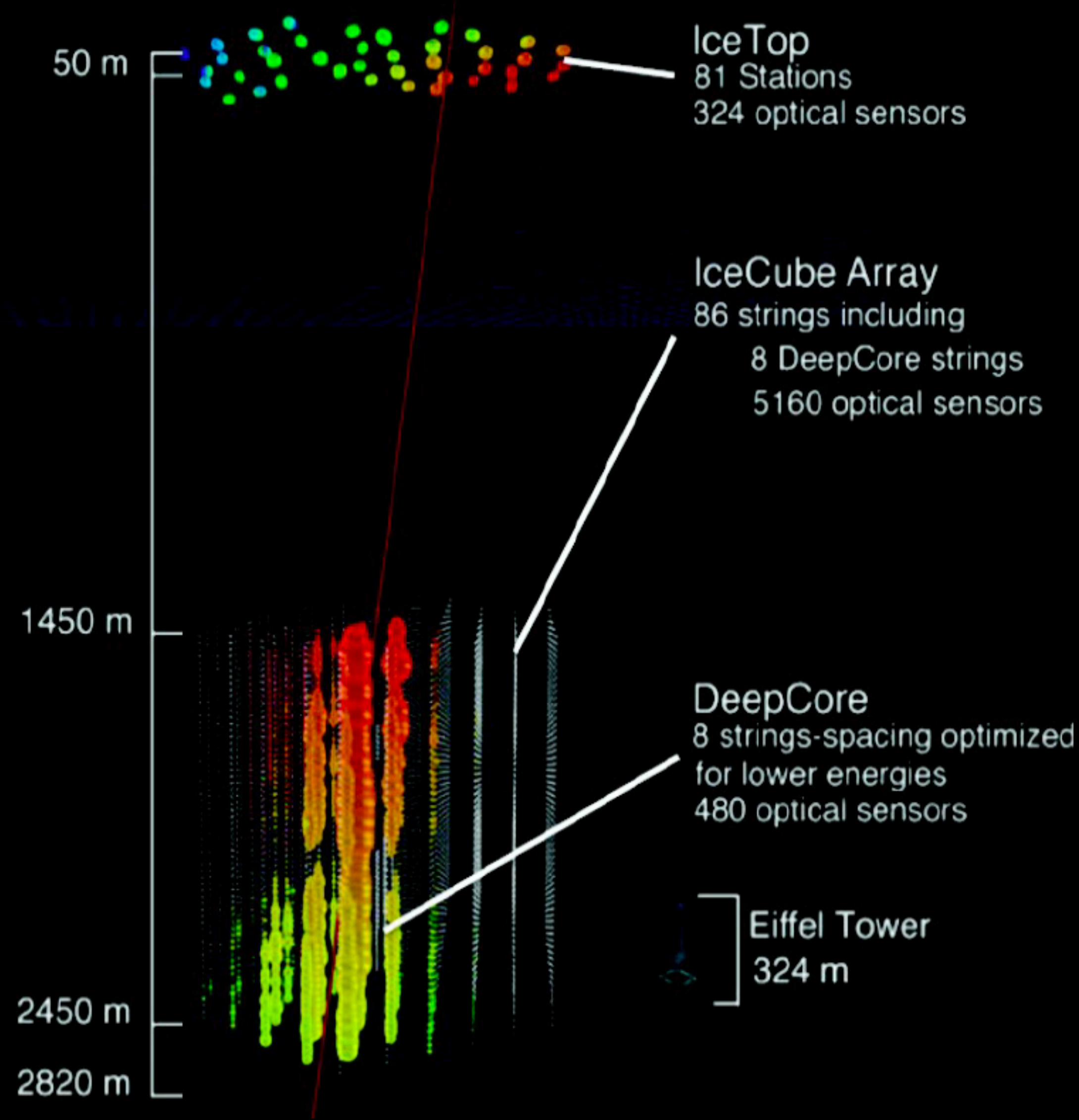
instrument 1 cubic kilometer of natural ice below 1.45 km



the IceCube Neutrino Observatory

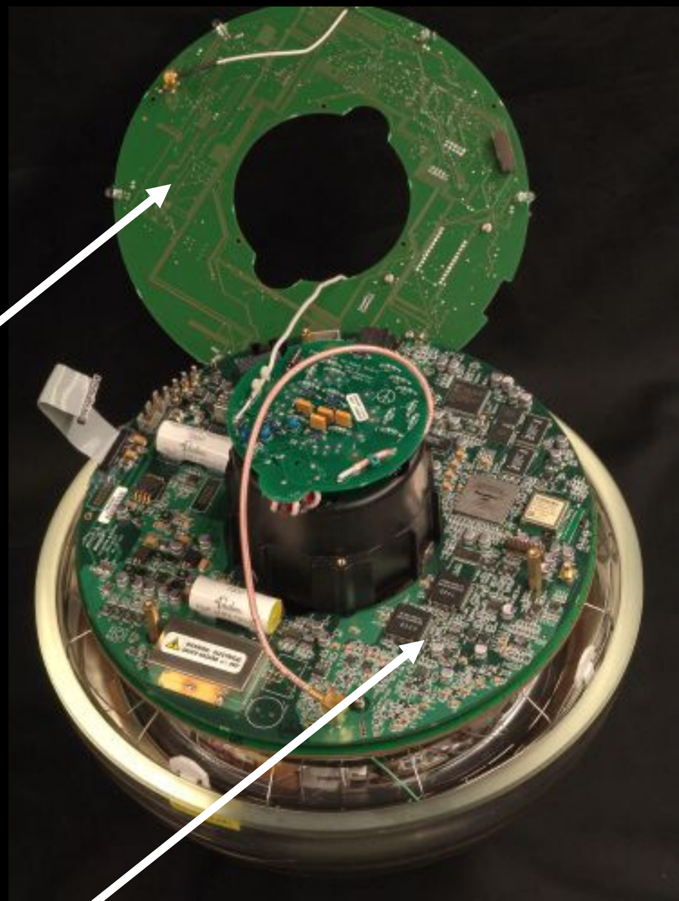
5160 DOMs
instrumenting 1 km^3
(1 GT) of clear ice

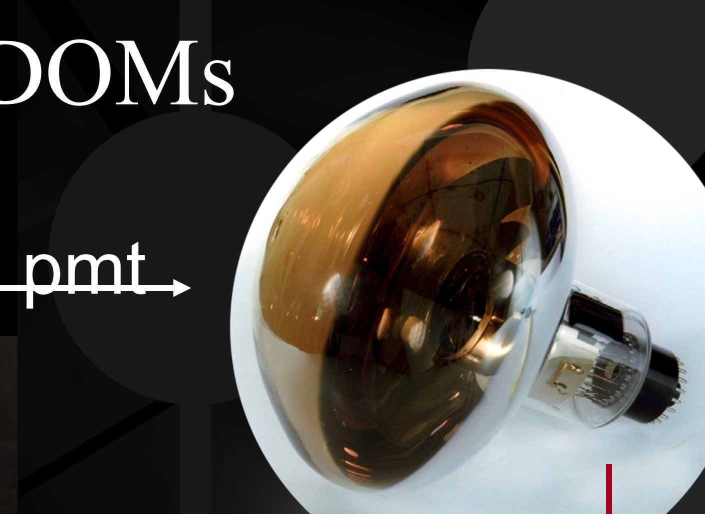
2 ns time resolution

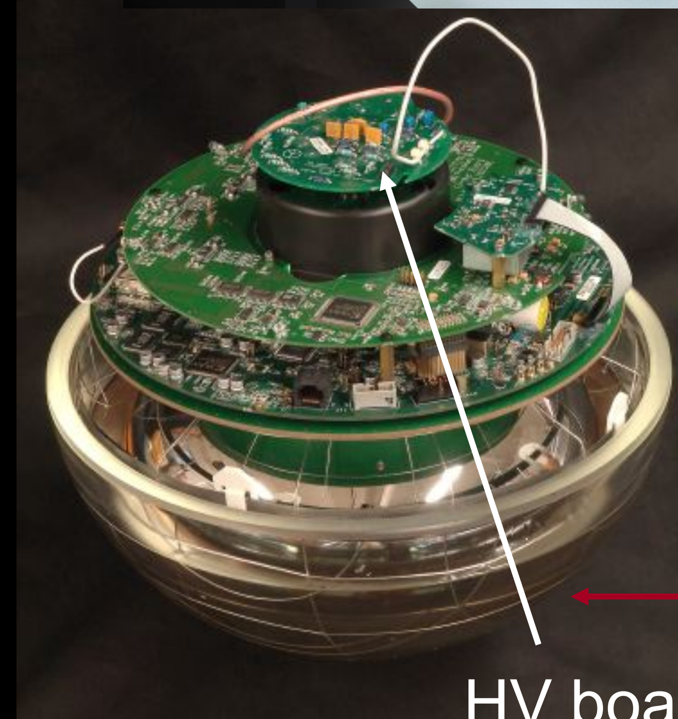


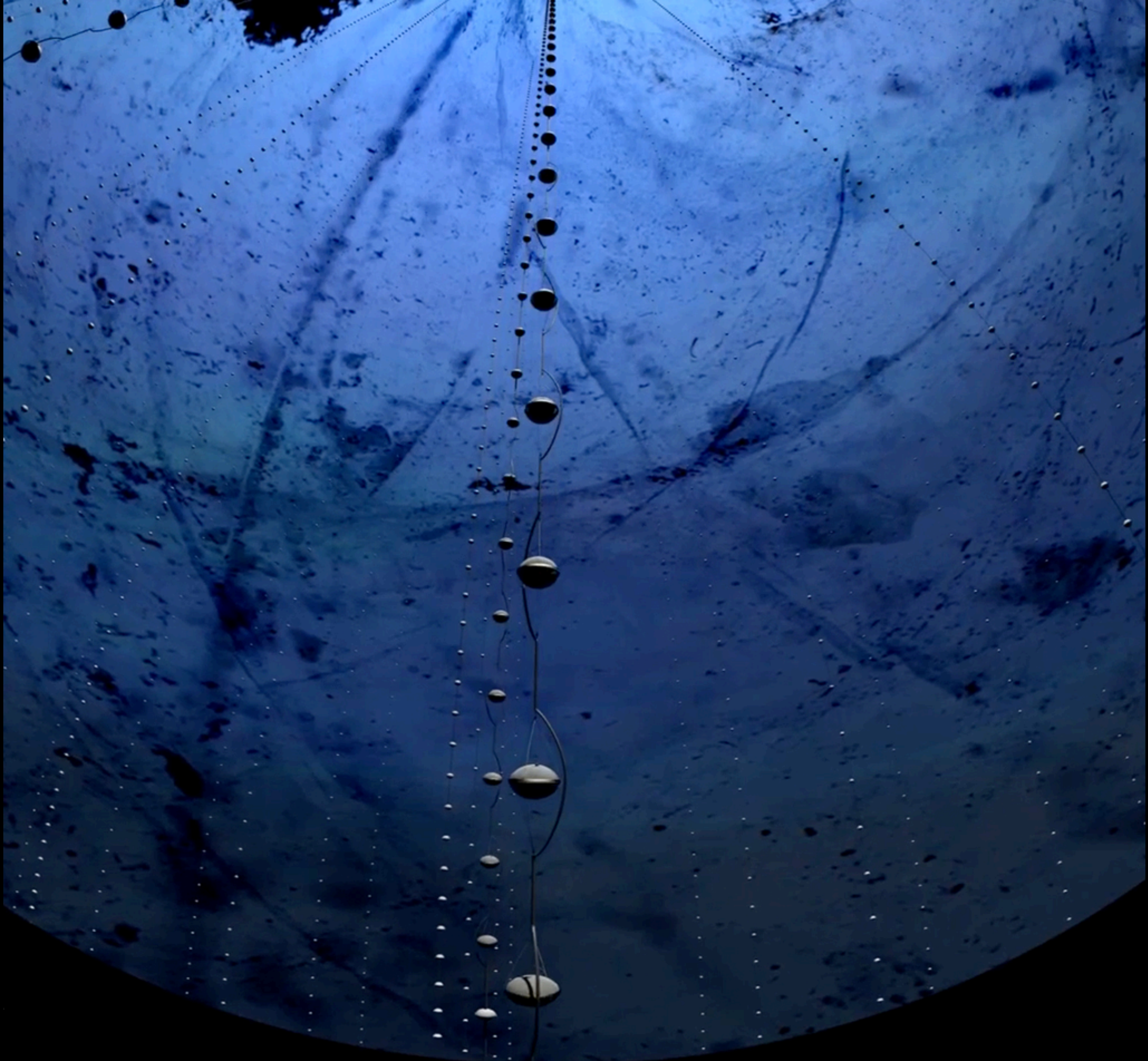
photomultiplier tube -10 inch

architecture of independent DOMs









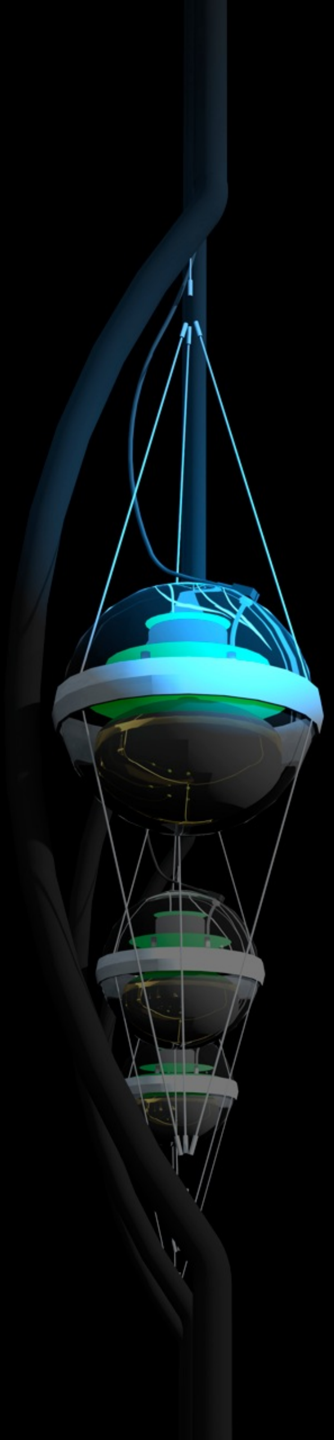
… you looked at 10msec of data !

muons detected per year:

• atmospheric*	μ	~ 10^{11}
• atmospheric**	$\nu \rightarrow \mu$	~ 10^{5}
• cosmic	$\nu \rightarrow \mu$	~ 120

* 3000 per second

** 1 every 6 minutes



Bruno Pontecorvo Prize
francis halzen

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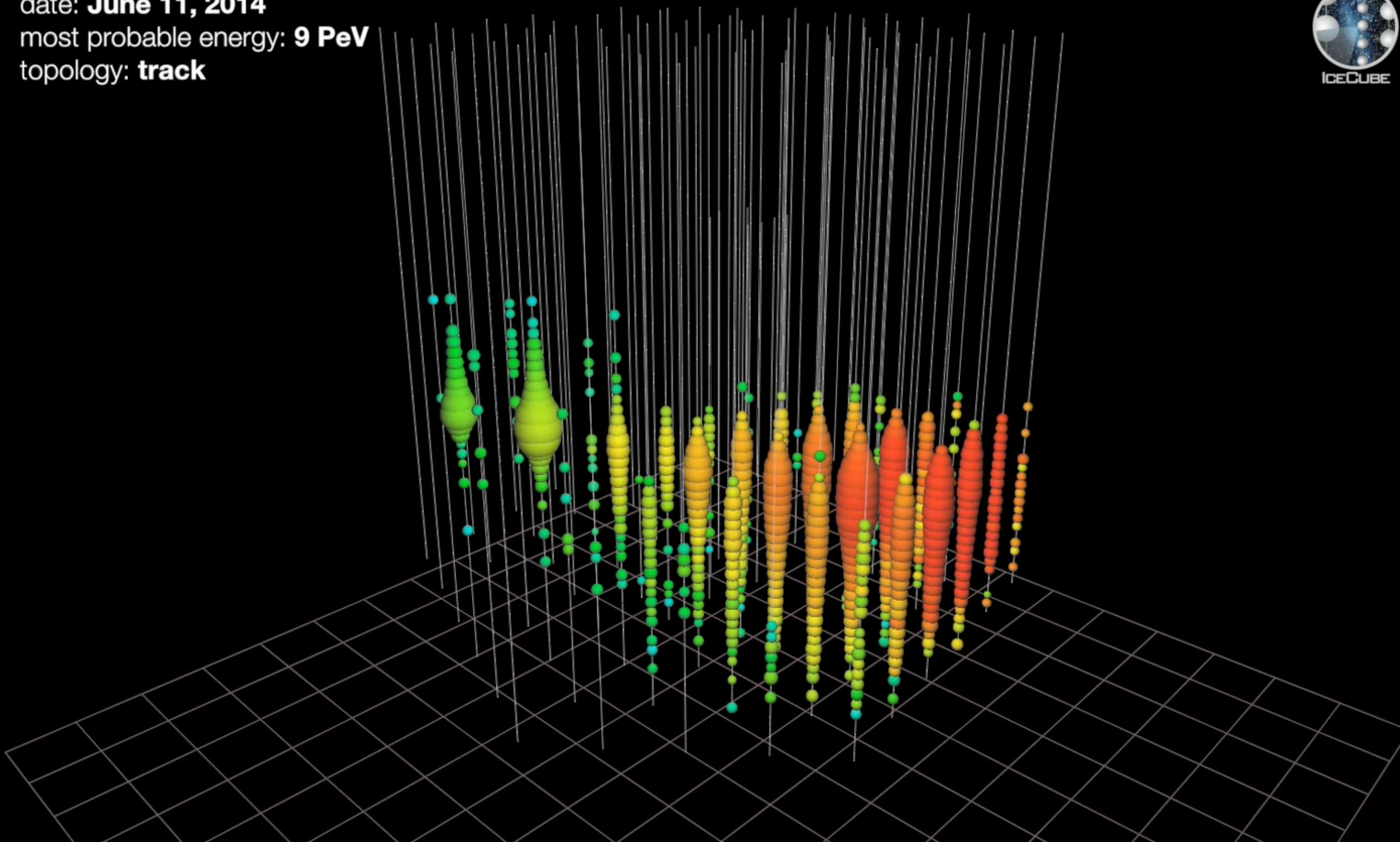
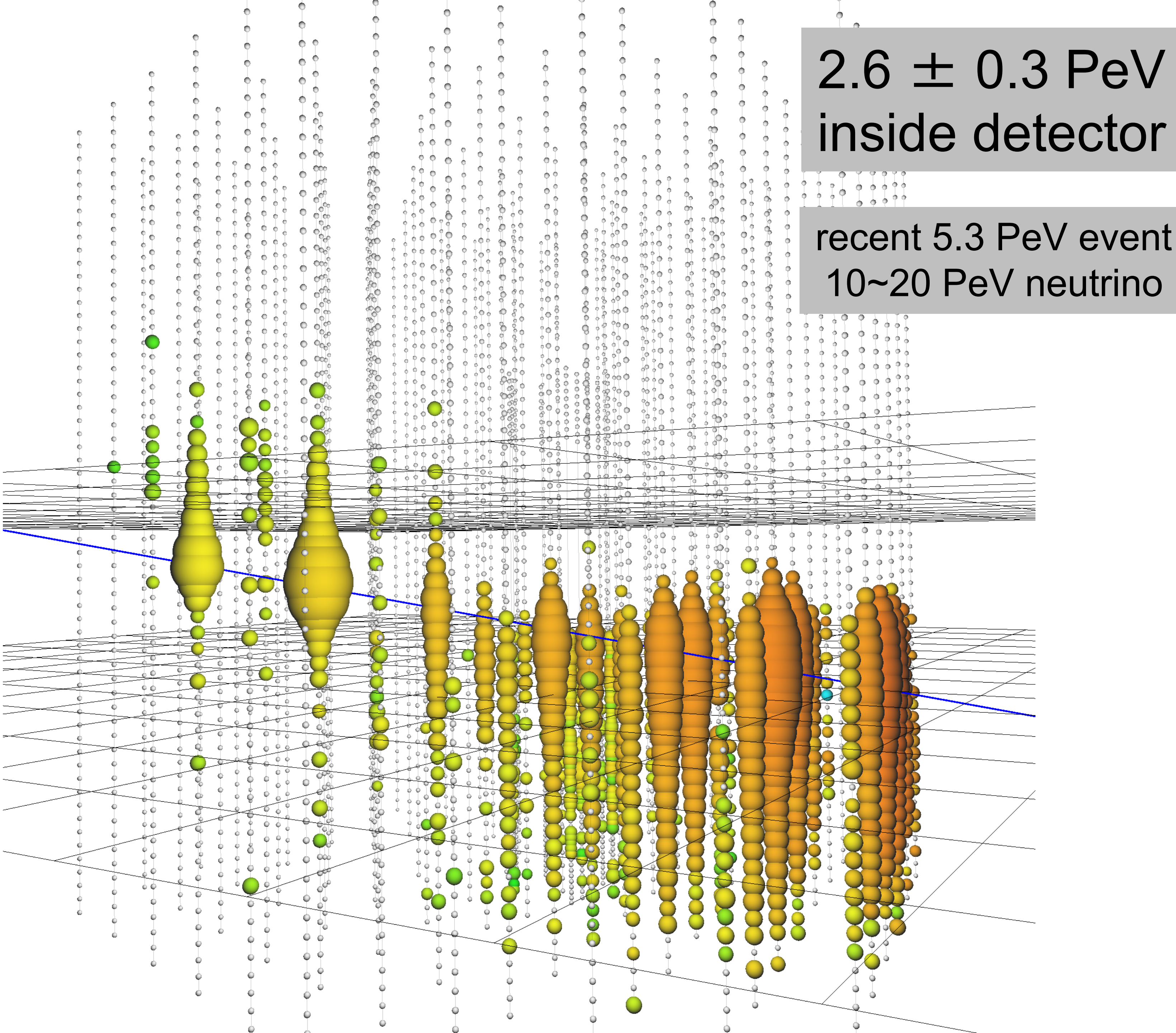
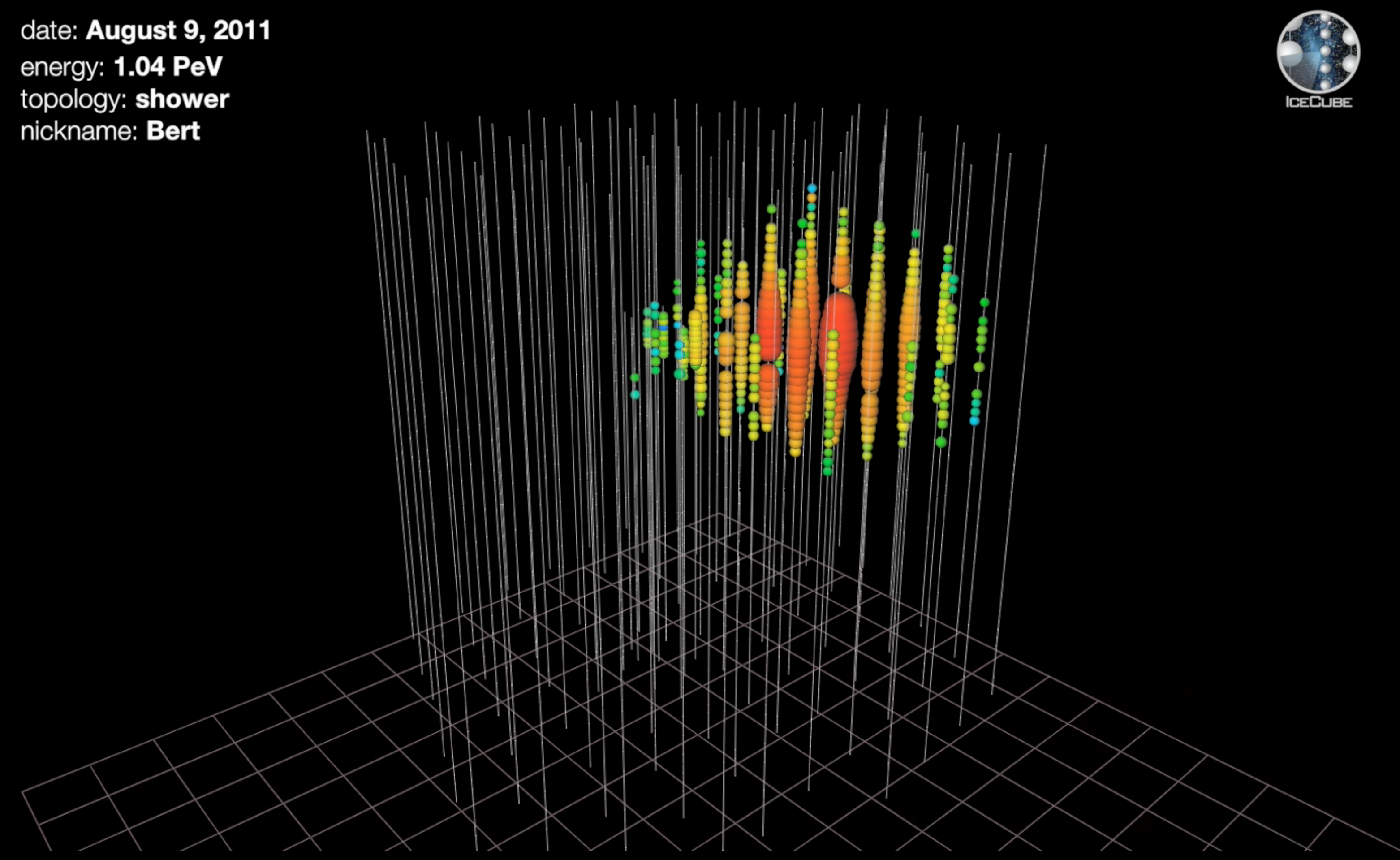
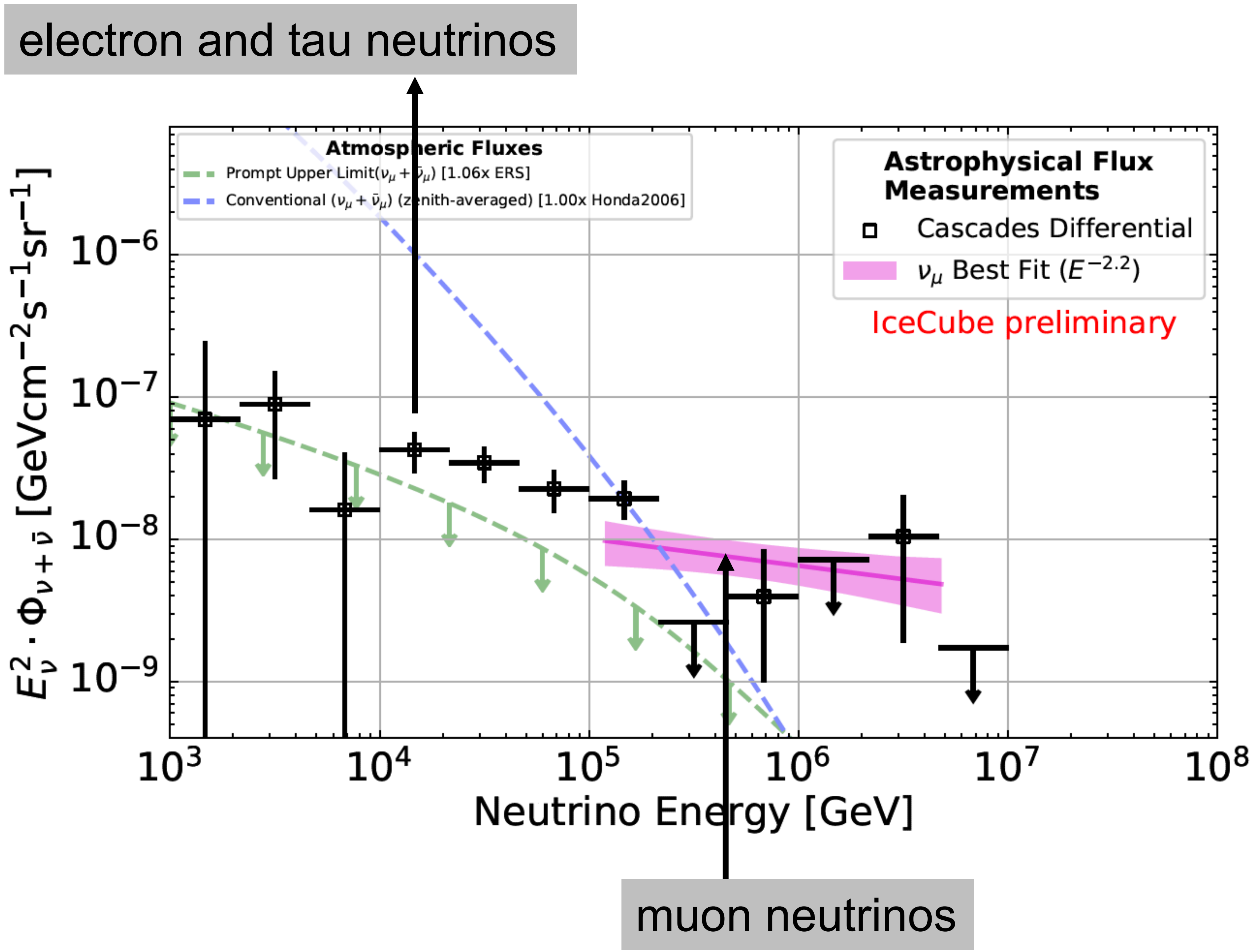
date: **June 11, 2014**
most probable energy: **9 PeV**
topology: **track**




2.6 ± 0.3 PeV
inside detector
recent 5.3 PeV event
10~20 PeV neutrino

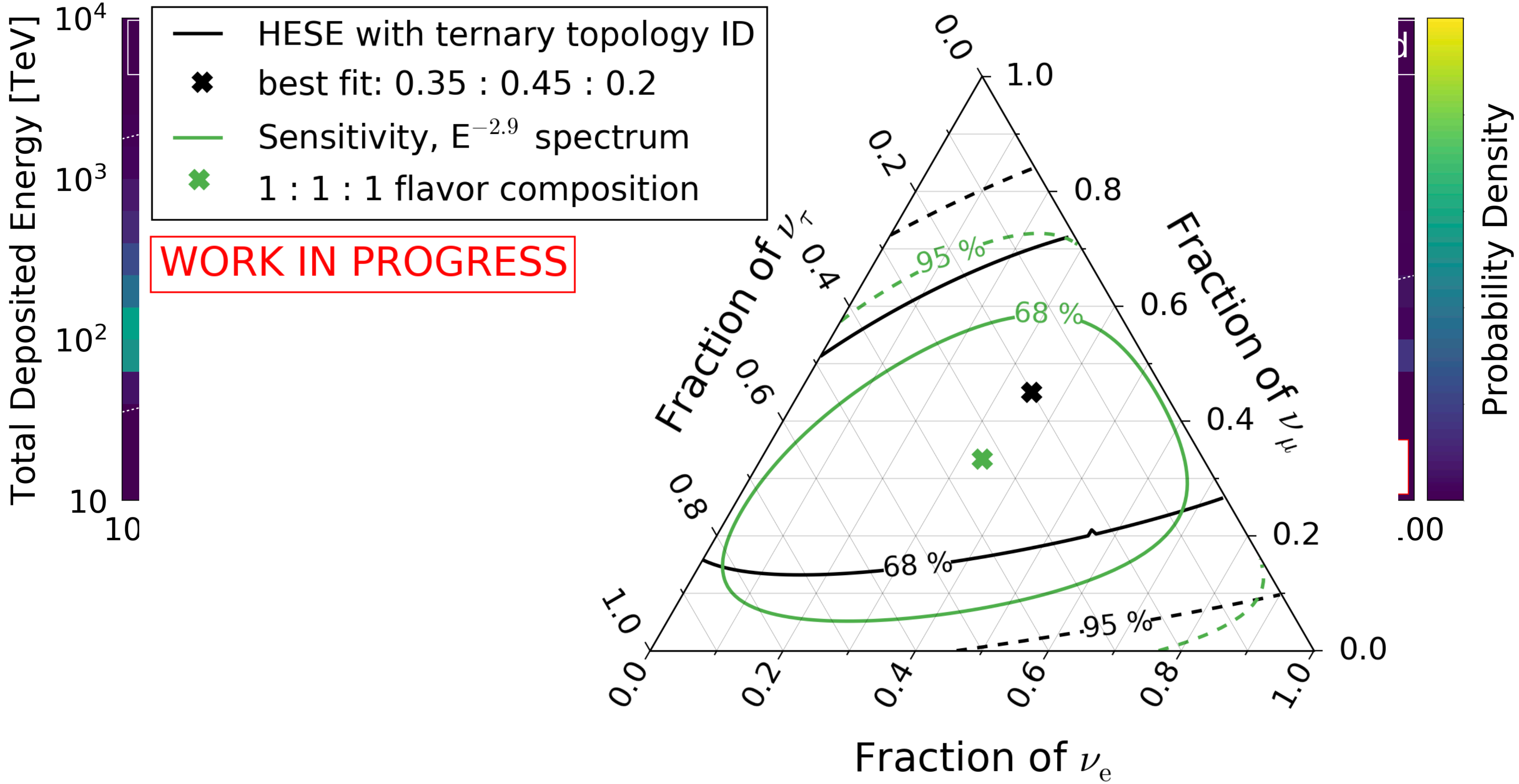
electromagnetic shower initiated by an electron or tau neutrino with energy > 1,000 TeV





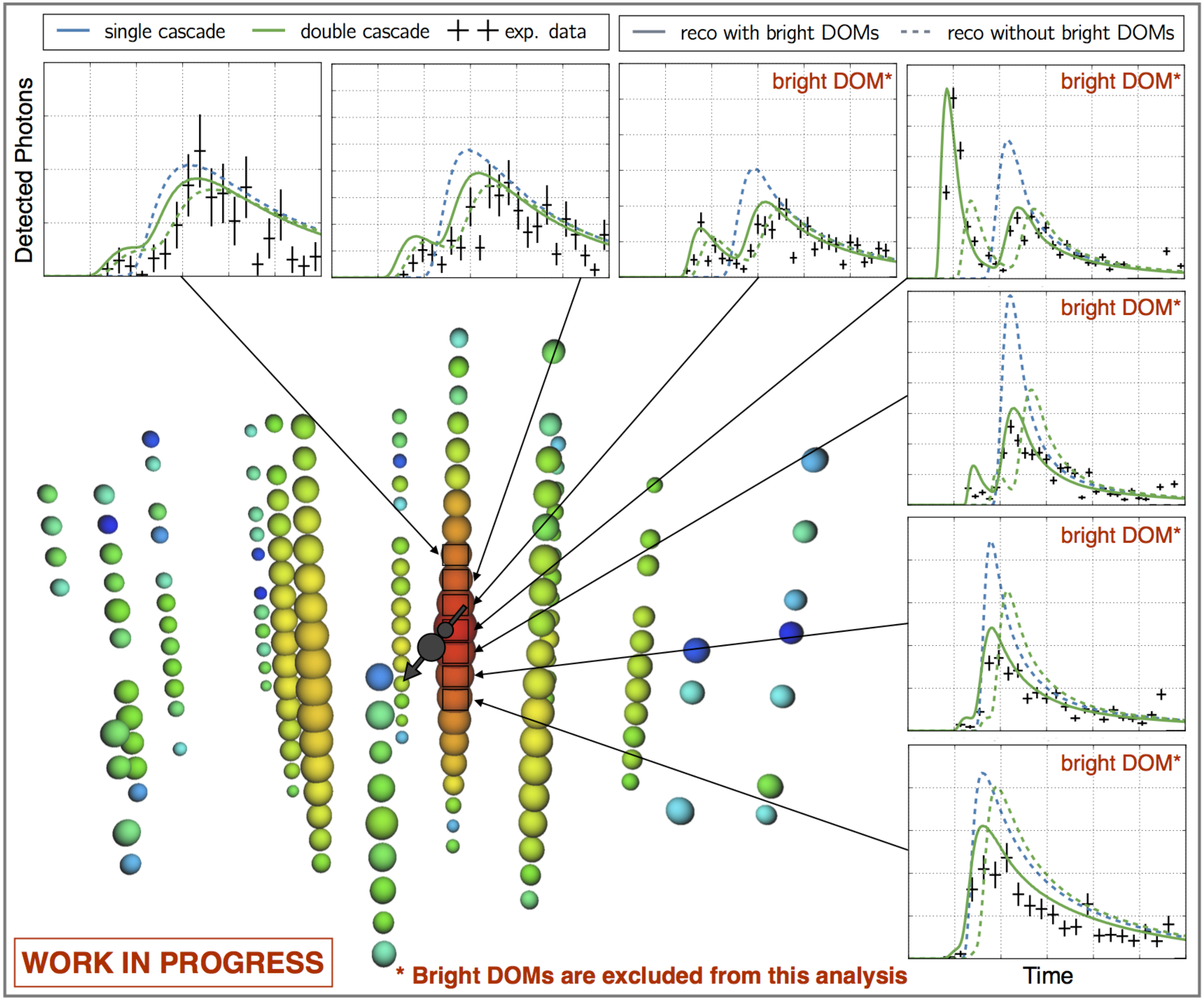
electron and tau neutrinos
Atmospheric Fluxes
Prompt Upper Limit($\nu_\mu + \bar{\nu}_\mu$) [1.06x ERS]
Conventional ($\nu_\mu + \bar{\nu}_\mu$) (zenith-averaged) [1.00x Honda2006]
Astrophysical Flux Measurements
Cascades Differential
ν_μ Best Fit ($E^{-2.2}$)
IceCube preliminary
10^{-6}
10^{-7}
10^{-8}
10^{-9}
$E_\nu^2 \cdot \Phi_{\nu+\bar{\nu}}$ [GeVcm^{-2}s^{-1}sr^{-1}]
10^3
10^4
10^5
10^6
10^7
10^8
Neutrino Energy [GeV]
muon neutrinos

high-energy starting events – 7.5 yr



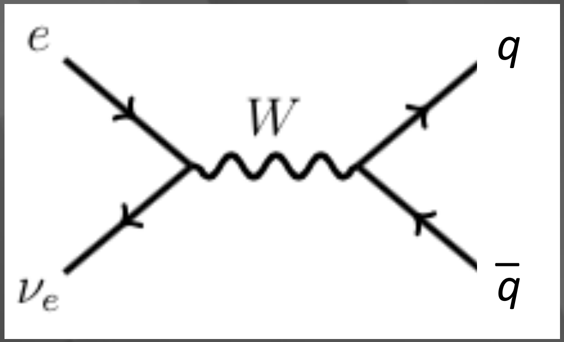
oscillations of PeV neutrinos over cosmic distances to 1:1:1

a cosmic tau neutrino: livetime 17m



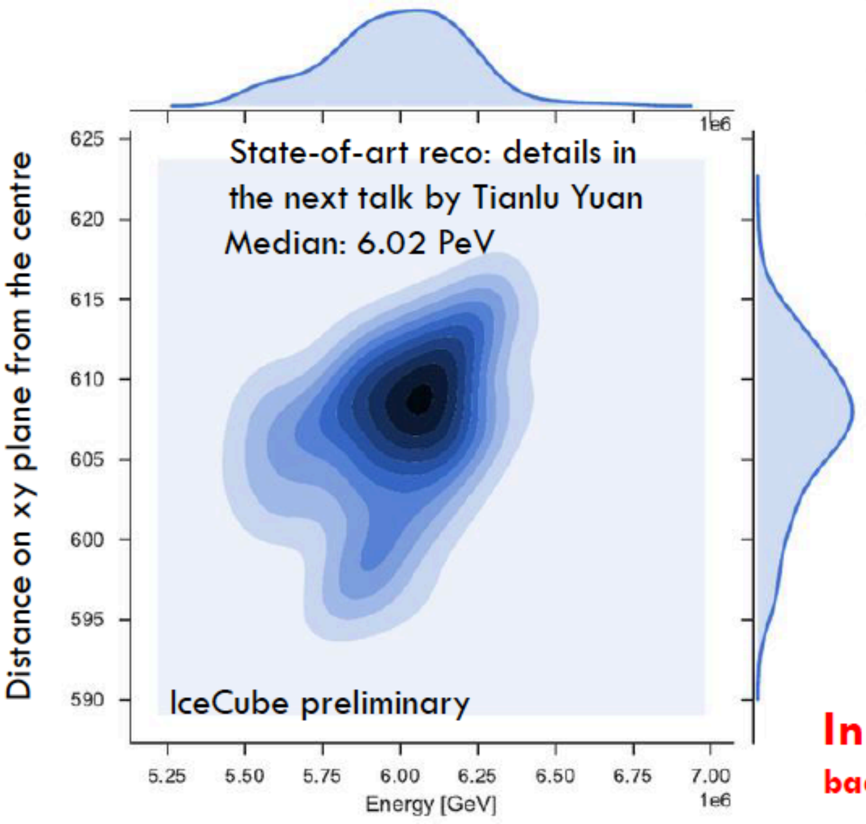
the first Glashow resonance event:

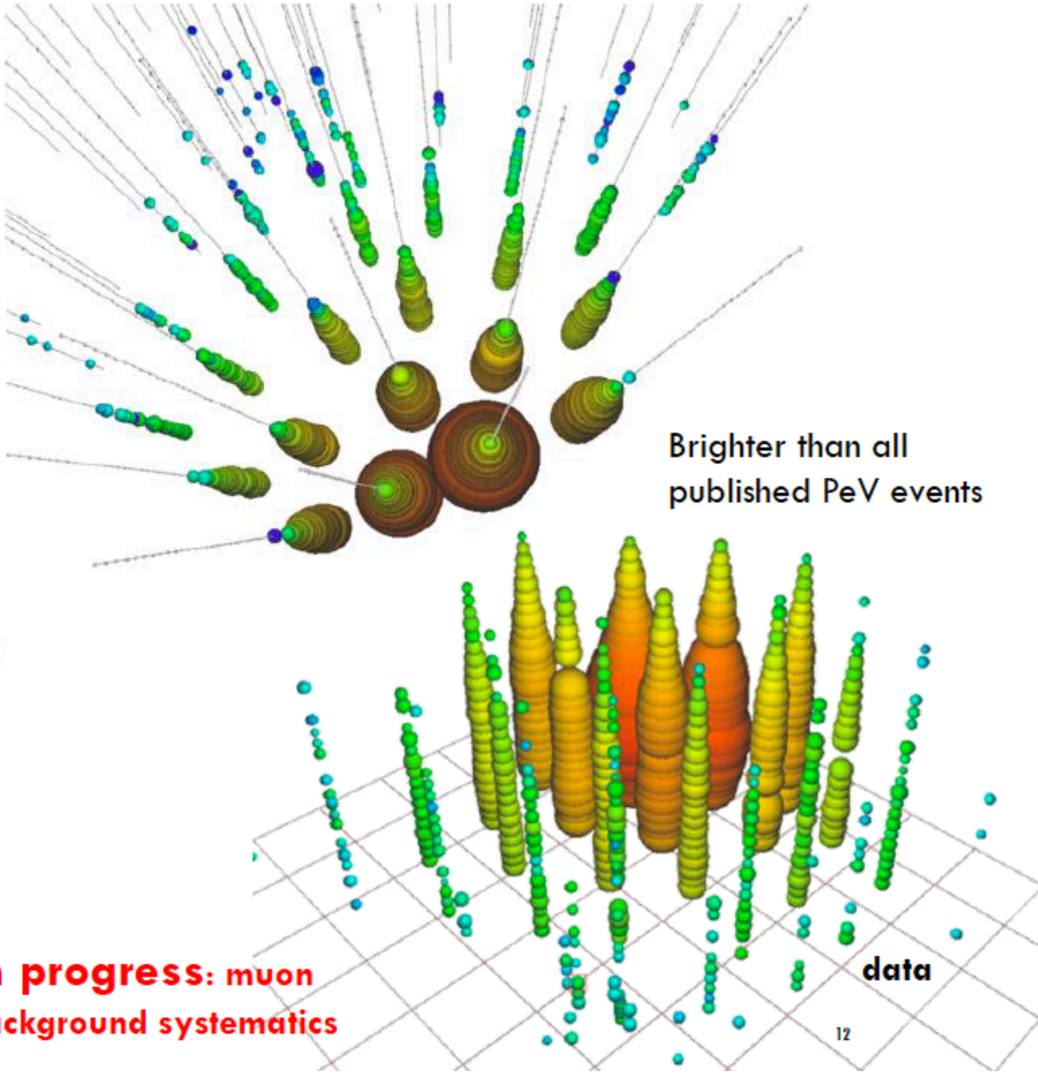
anti-ν_e + atomic electron → real W at 6.3 PeV



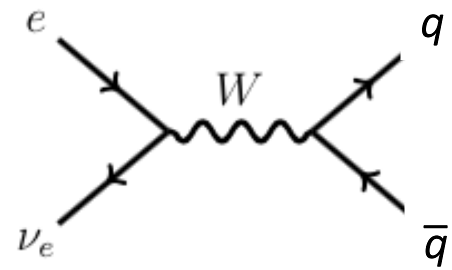
partially contained event with energy of 6.3 PeV

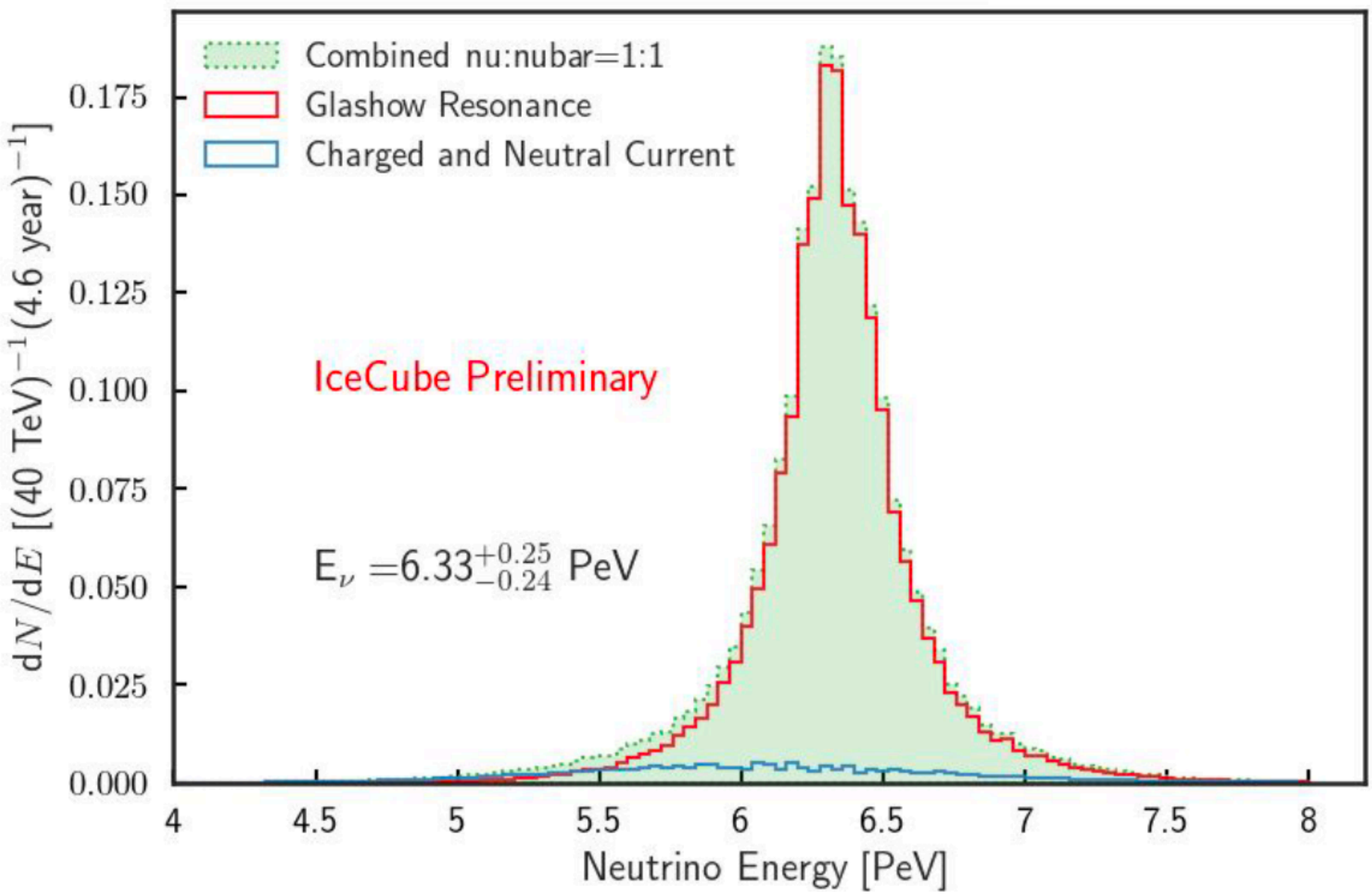
HIGHEST-ENERGY NEUTRINO CANDIDATE

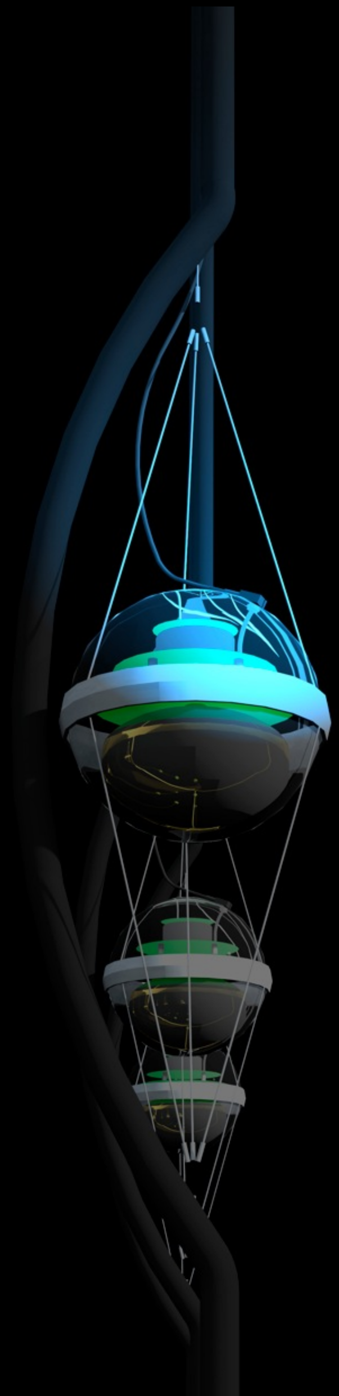




- energy measurement understood
- identification of anti-electron neutrinos







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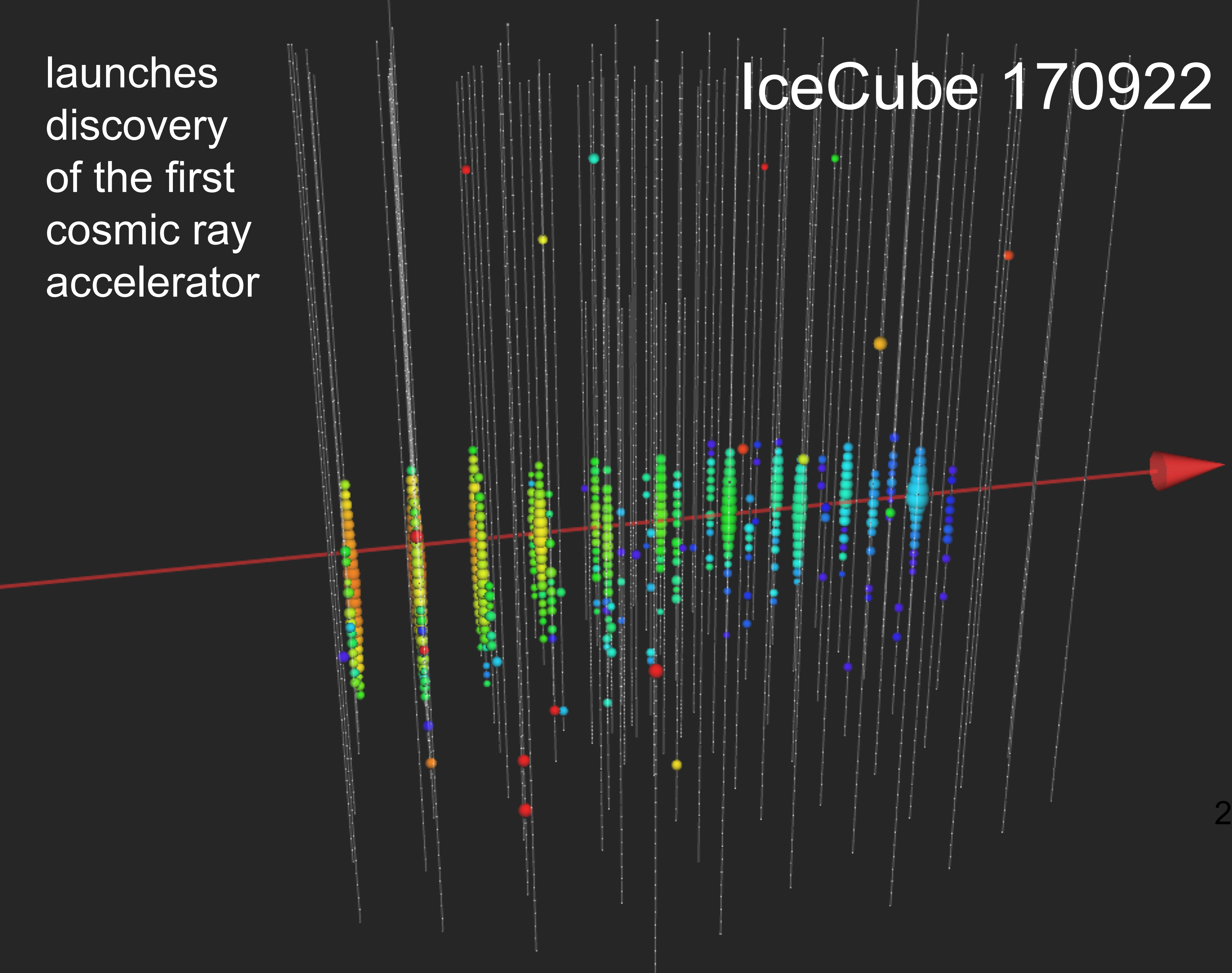
IceCube.wisc.edu

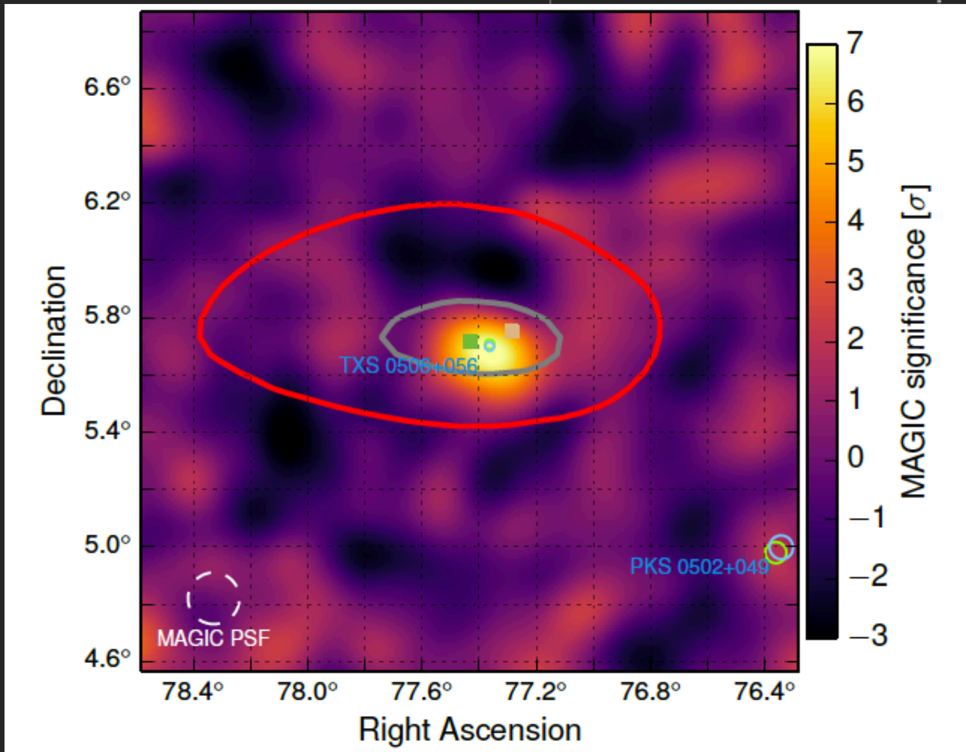
launches discovery of the first cosmic ray accelerator

IceCube 170922

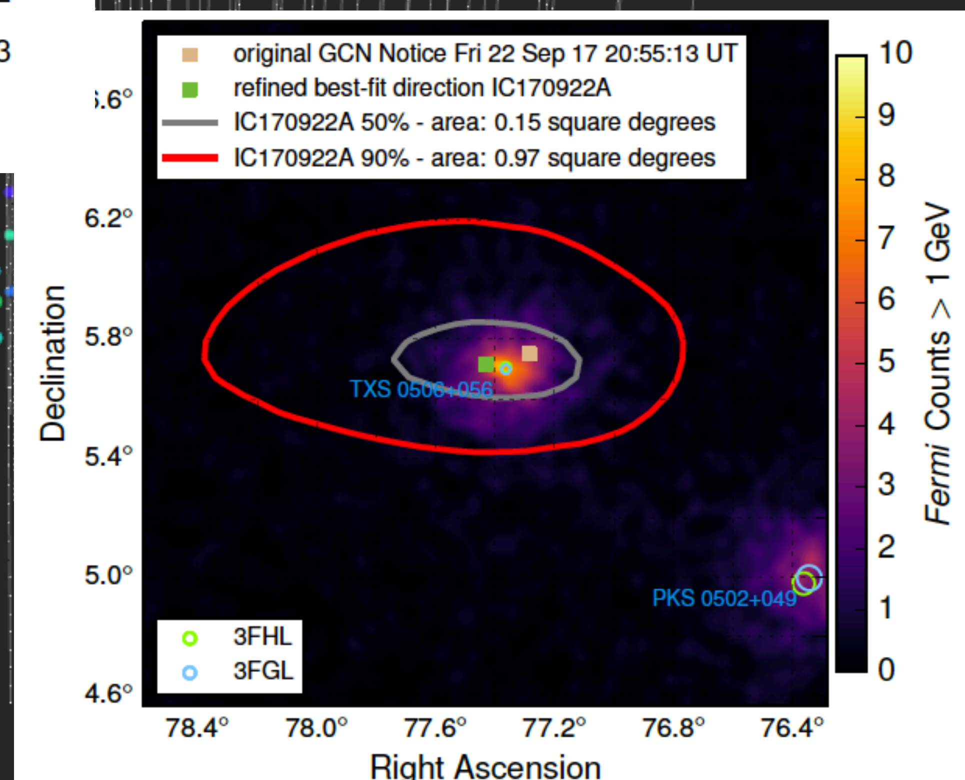


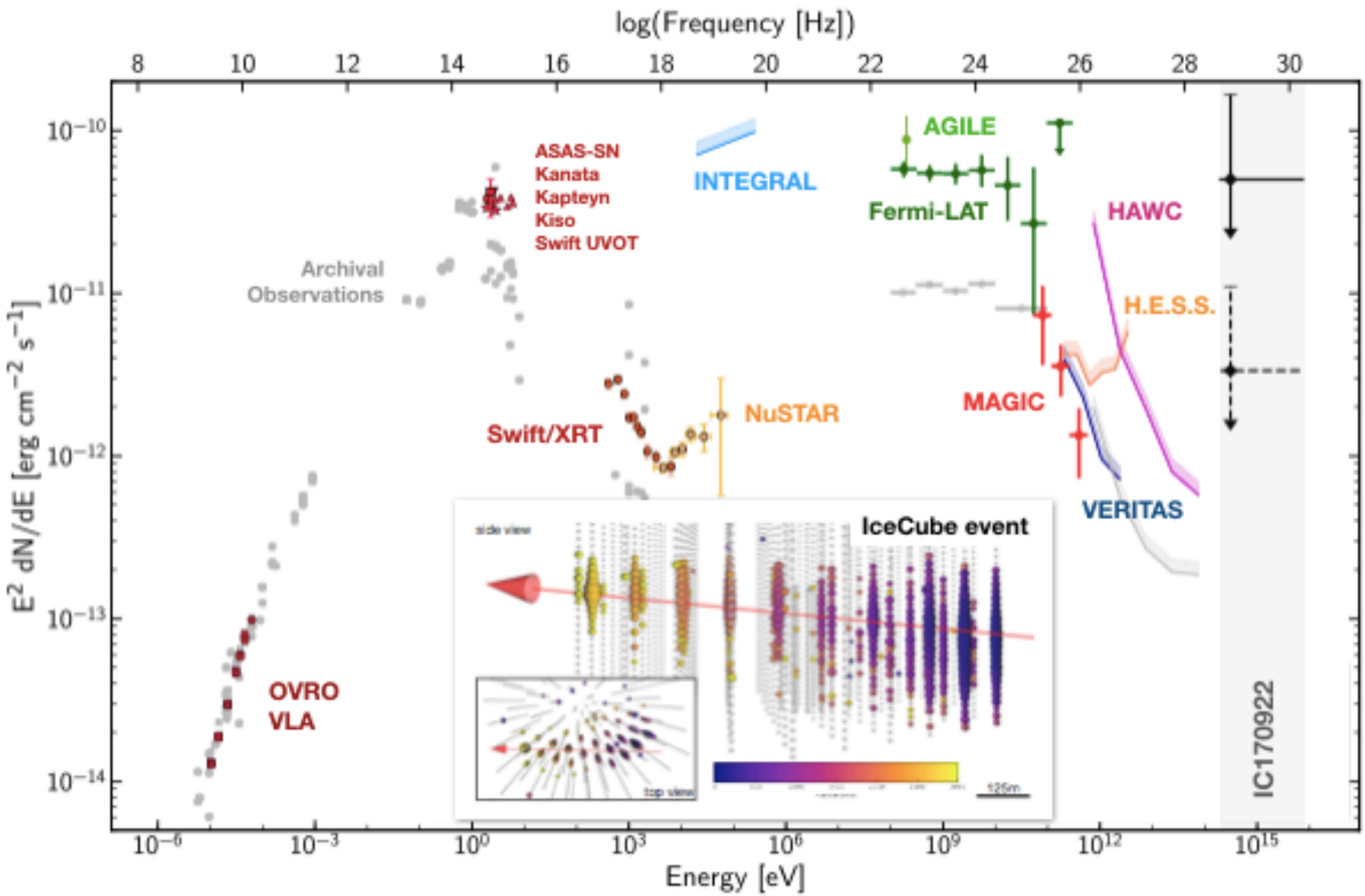
IceCube 170922

Fermi
detects a flaring blazar within 0.06°

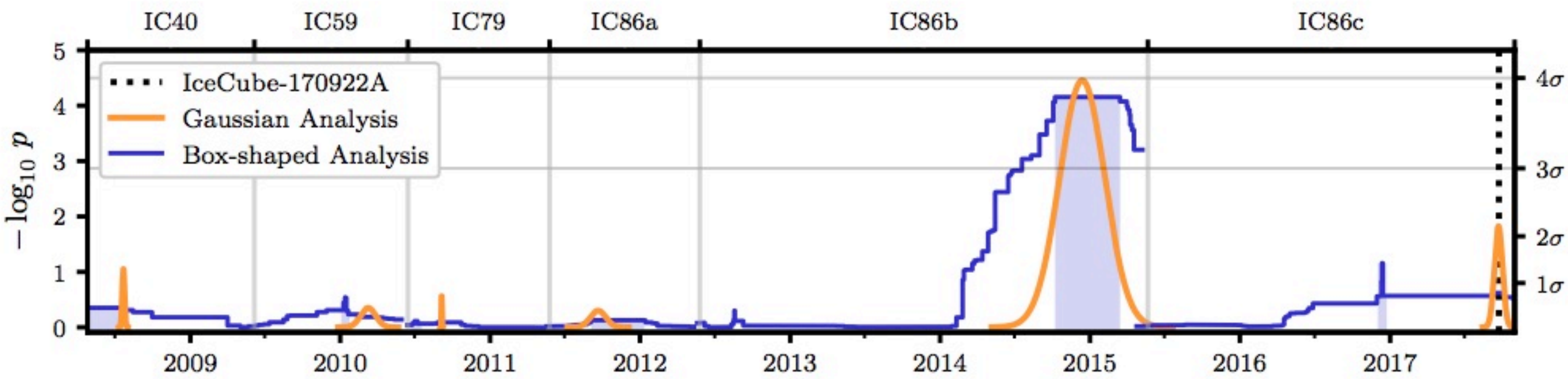


MAGIC
detects emission of > 100 GeV gammas



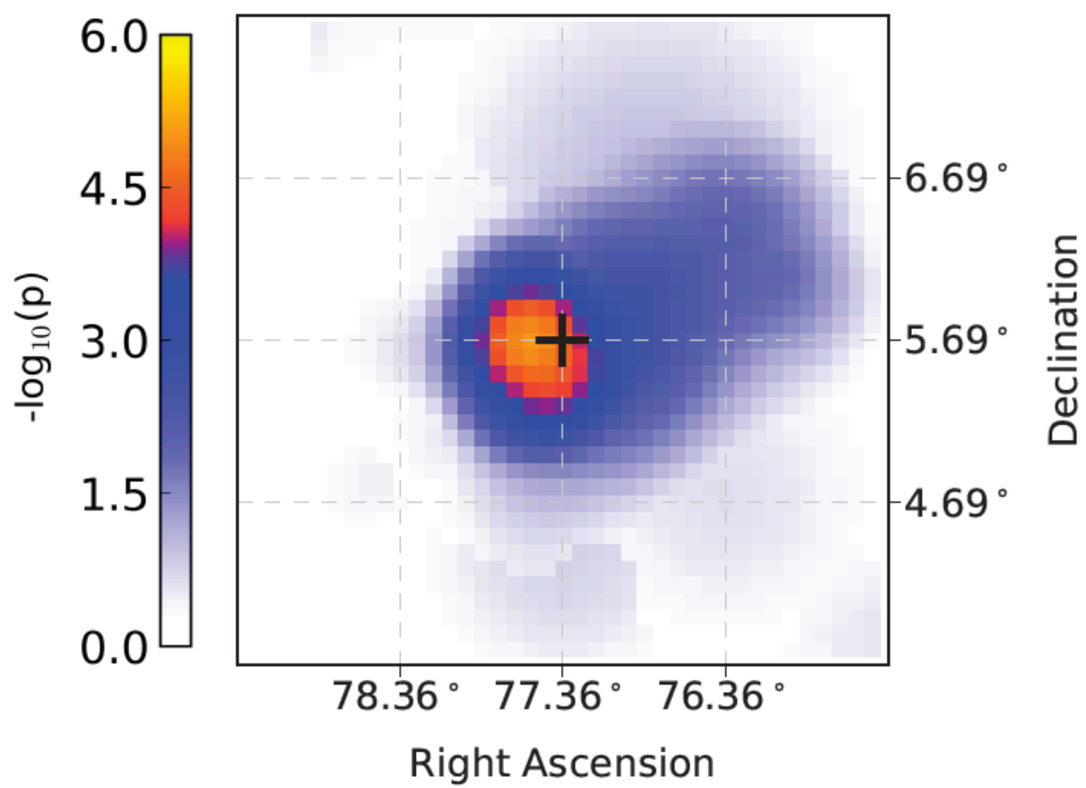


cosmic ray accelerator TXS 0506+056: blazar models fail



search in archival IceCube data:

- 150 day flare in December 2014 of 19 events (bkg <6)
- 2.10^{-5} bkg.probability
- spectrum $E^{-2.1}$



TXS 0506+056 is a galaxy merger

“We thus observe the interaction between jet features that cross each other’s paths.”

Astronomy & Astrophysics manuscript no. output
July 31, 2019

A Cosmic Collider: IceCube neutrino generated in a precessing jet-jet interaction in TXS 0506+056?

S. Britzen[1], C. Fendt[2], M. Böttcher[3], M. Zajaček[1,4,5], F. Jaron[1,6], I.N. Pashchenko[7], A. Araudo[8,9], V. Karas[8], and O. Kurtanidze[10]

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[9] ELI Beamlines, Institute of Physics, Czech Academy of Sciences, 25241 Dolní Břežany, Czech Republic
[10] Abastumani Observatory, Mt. Kanobili, 0301 Abastumani, Georgia

Received September 15, 1996; accepted March 16, 1997

ABSTRACT

Context. The neutrino event IceCube-170922A appears to originate from the BL Lac object TXS 0506+056. To understand the neutrino creation process and localize the emission site, we studied the radio images of the jet at 15 GHz.
Aims. Other BL,Lac objects show similar properties as TXS 0506+056, such as multi-wavelength variability or a curved jet. However, so far, only TXS 0506+056 has been identified as neutrino emitter. This paper aims to figure out, what makes the pc-scale jet of TXS 0506+056 specific in this respect.
Methods. We re-analyzed and re-modeled 16 VLBA 15 GHz observations between 2009 and 2018. We thoroughly examined the jet kinematics and flux-density evolution of individual jet components during the time of enhanced neutrino activity between Sept,2014 and March 2015, and in particular before and after the neutrino event.
Results. Our results suggest that the jet is very strongly curved and most likely observable under a special viewing angle of close to zero. We thus may observe the interaction between jet features which cross each others’ paths. We find subsequent flux-density flaring of six components passing the likely collision site. In addition, we find strong indication for precession of the inner jet and model a precession period of about 10 yrs by the Lense-Thirring effect. We discuss an alternative scenario that is the interpretation of observing the signature of *two* jets within TXS 0506+056, again hinting towards a collision of jetted material. We essentially suggest that the neutrino emission may result from the interaction of jetted material in combination with a special viewing angle and jet precession.
Conclusions. We propose that the enhanced neutrino activity during the neutrino flare in 2014 - 2015 and the single EHE neutrino IceCube-170922A could be generated by a cosmic collision within TXS 0506+056. Our findings seem capable of explaining the neutrino generation at the time of a low gamma-ray flux and also indicate that TXS 0506+056 might be an atypical blazar. It seems to be the first time that (i) a potential collision of two jets on pc-scales is reported and that (ii) the detection of a cosmic neutrino might be traced back to a cosmic jet-collision.

THE ICECUBE COLLABORATION

STRALIA 1

NGDOM 1

UNITED STATES 25