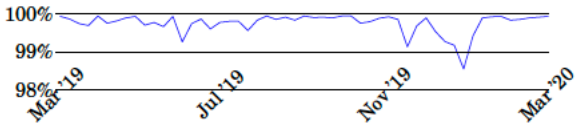
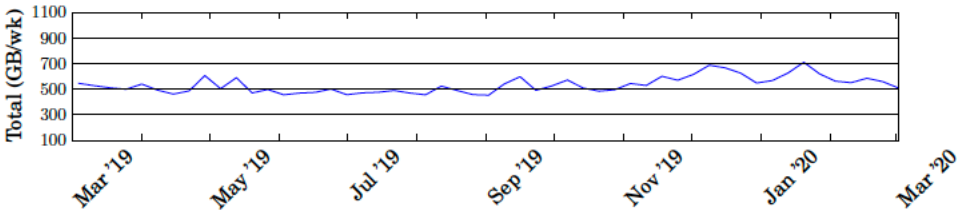
Feb24-Mar1, 2020

Uptime 

99.94%

TDRSS Satellite Transfer



The Daily Breakdown

Monday
February 24
- Skiway flag removal.

Tuesday
February 25
- Quiet.

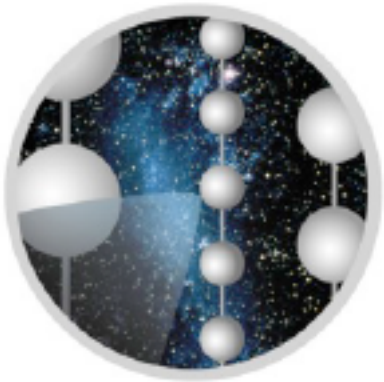
Wednesday
February 26
- Silent.

Thursday
February 27
- Pianissimo.

Friday
February 28
- Low noise.

Saturday
February 29
- Antenna cables disconnected.
- WR-LEN debugging started.

Sunday
March 1
- Snow wensor measurement.



IceCube:

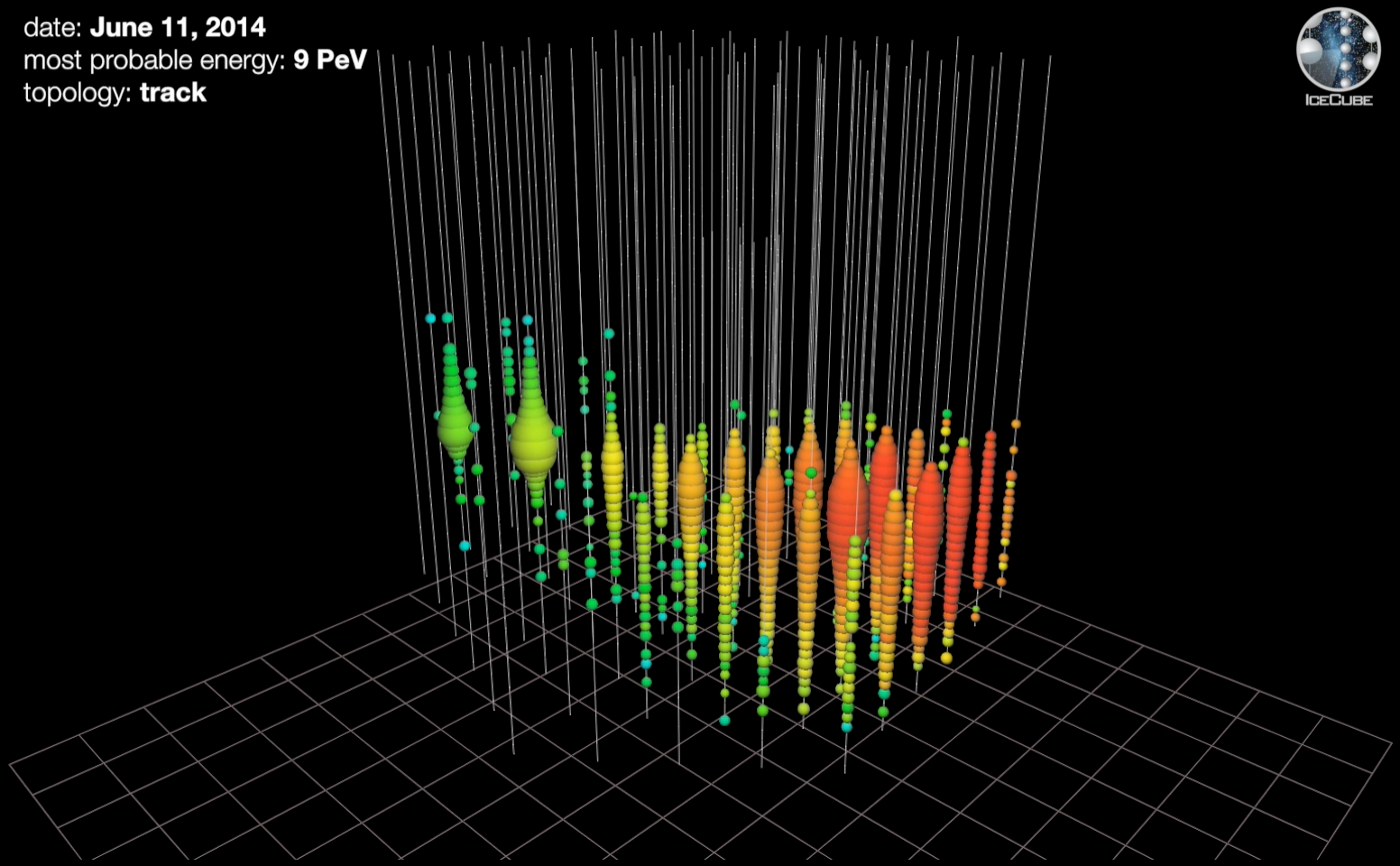
Closing in on Cosmic Ray Accelerators

francis halzen

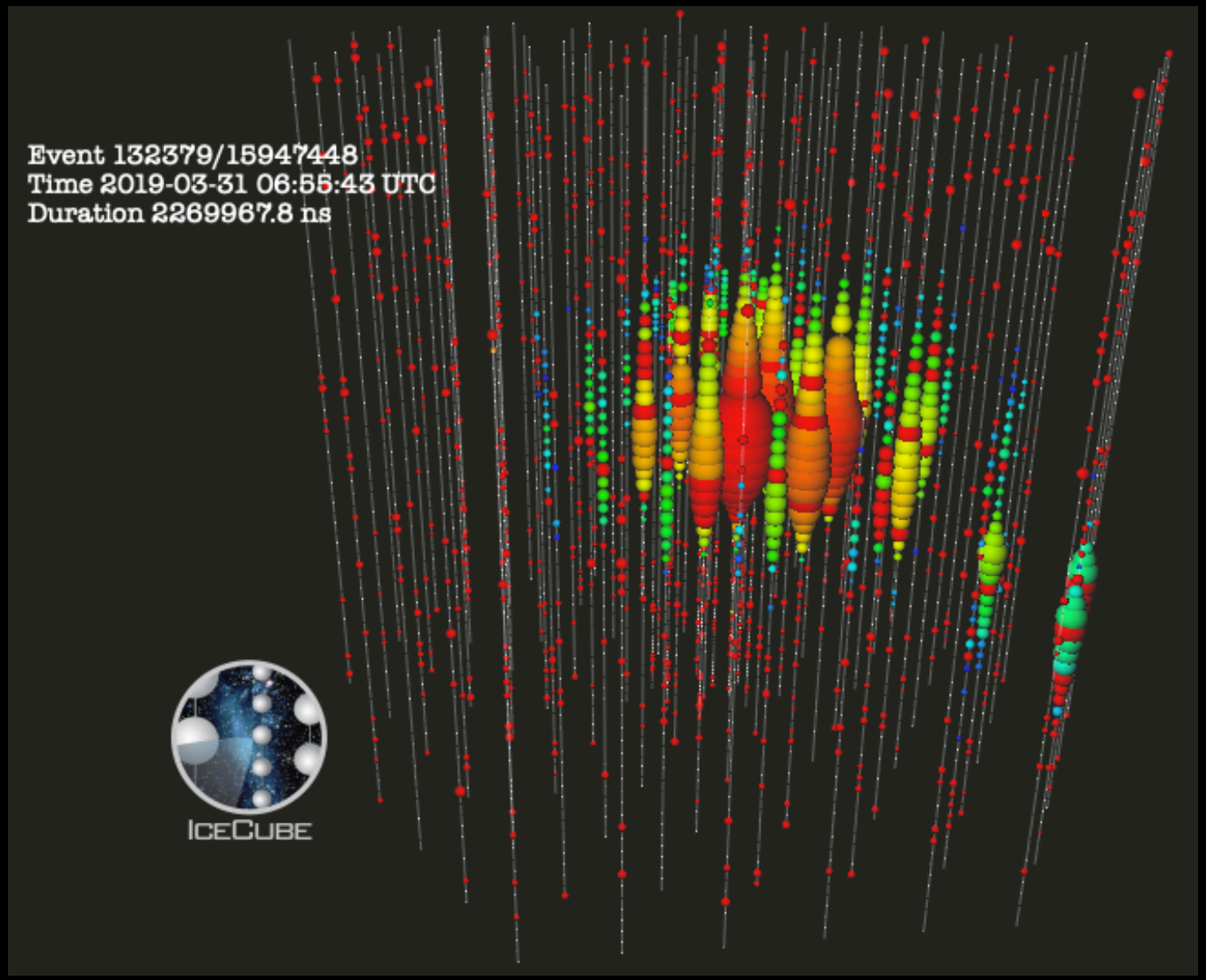
- cosmic neutrinos: four independent observations
  - → muon neutrinos through the Earth
  - → starting neutrinos: all flavors
  - → high energy tau neutrinos
  - → a Glashow event
- where do they come from?
- the first high-energy cosmic ray accelerator

icecube.wisc.edu

muon neutrinos observed through the Earth

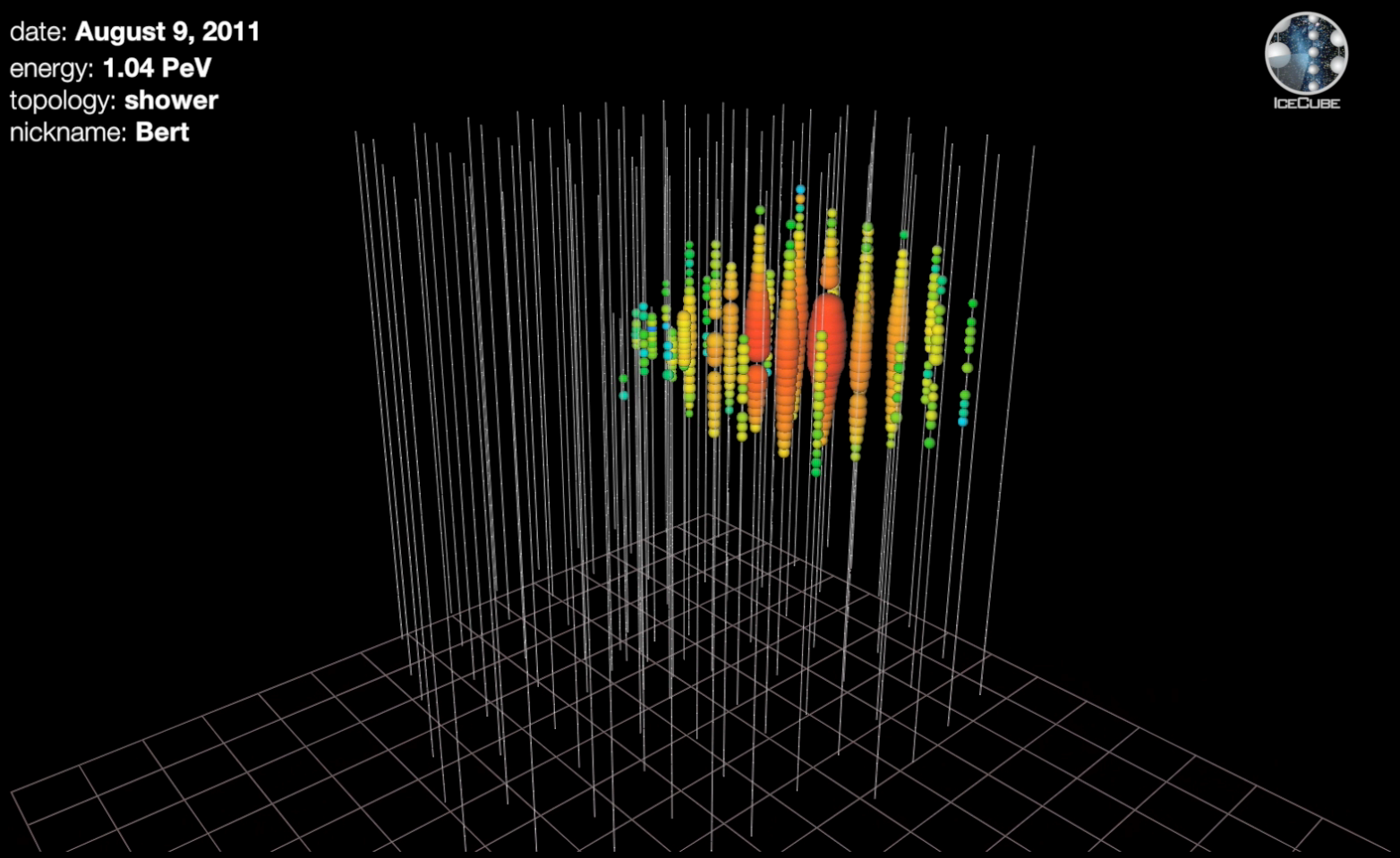


IC190331: 5300 TeV deposited inside the detector



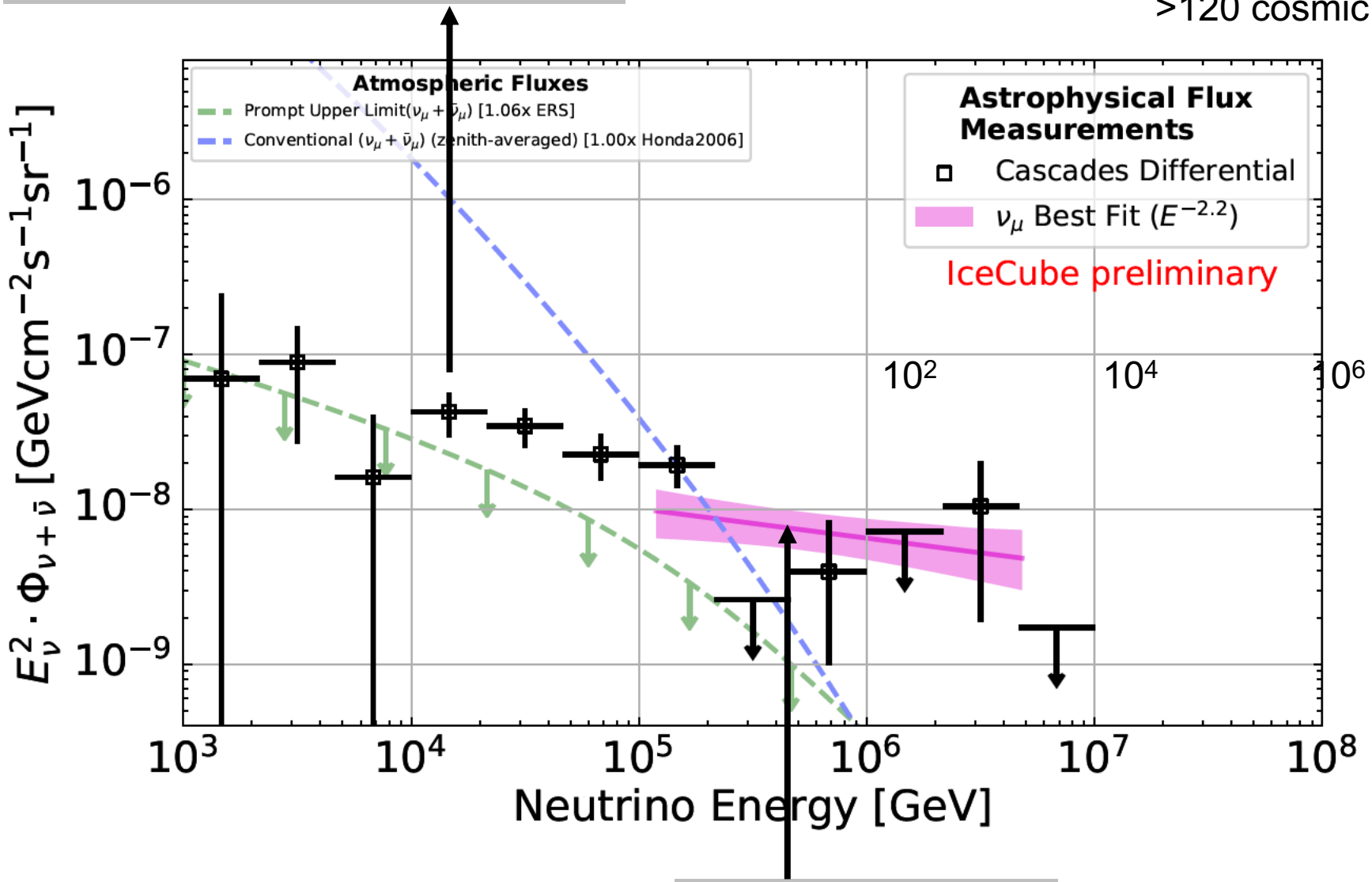
initial neutrino energy 10~20 PeV

electron and tau neutrinos: contained events



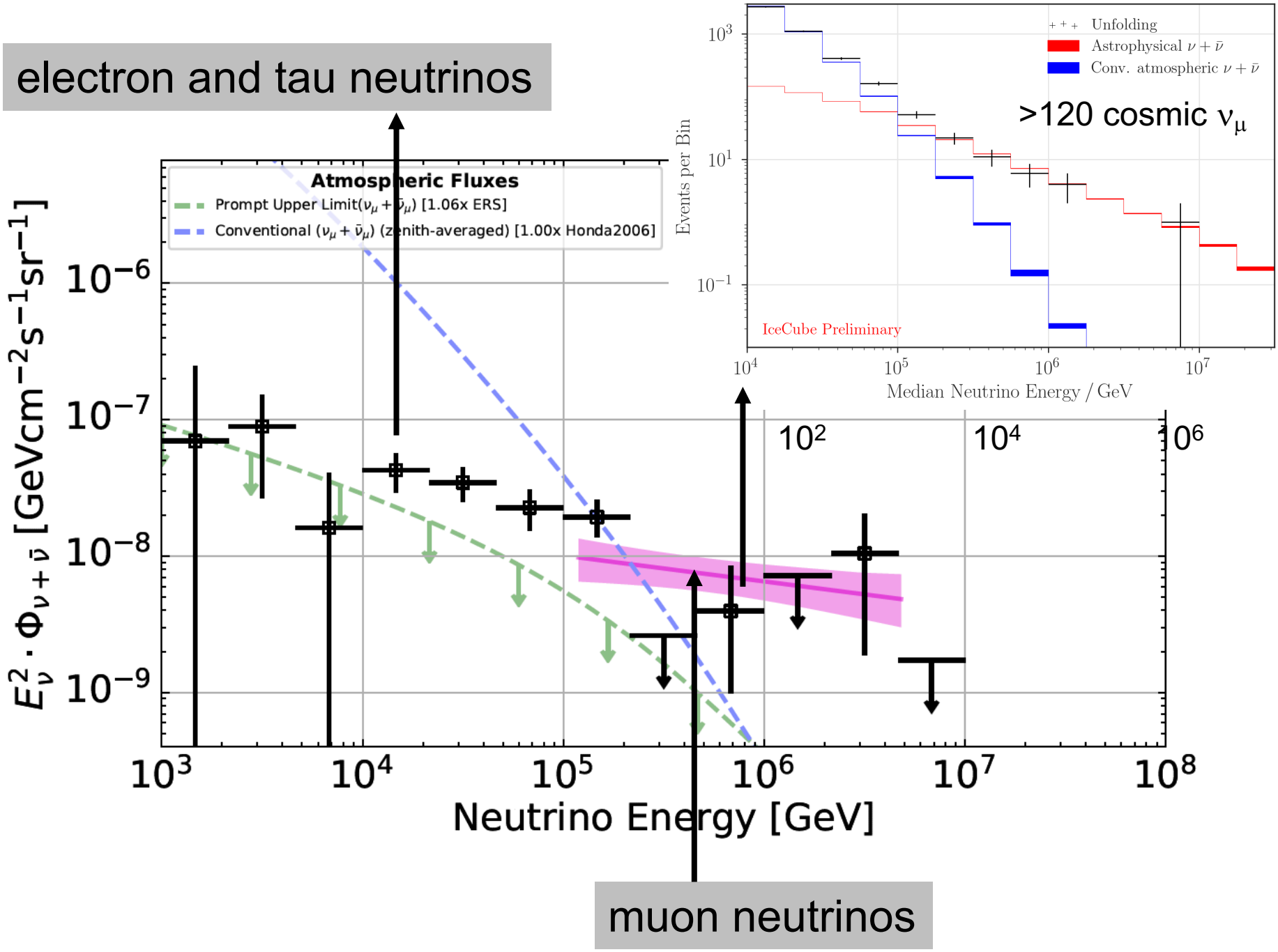
electron and tau neutrinos

>120 cosmic ν_μ



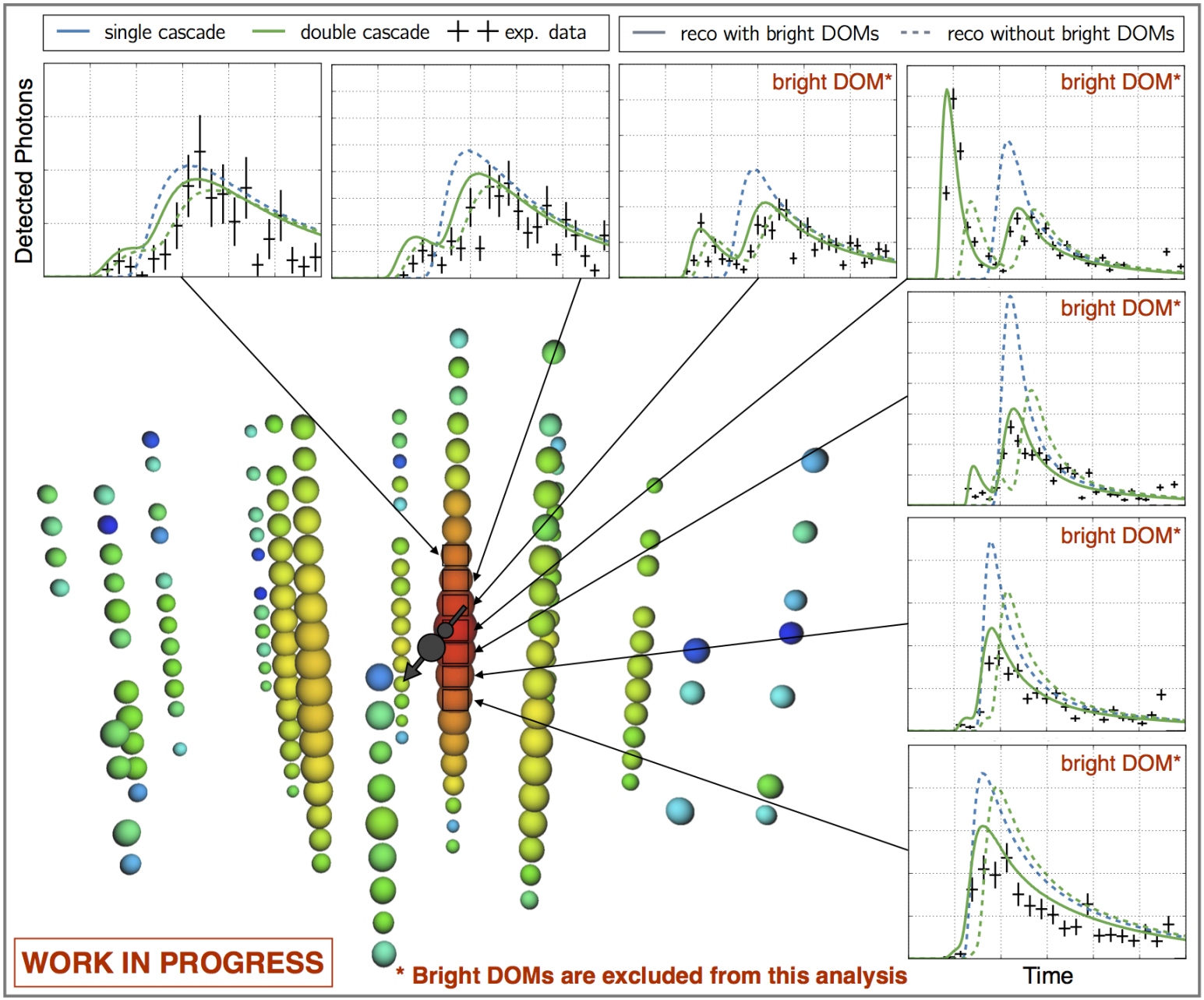
muon neutrinos

electron and tau neutrinos

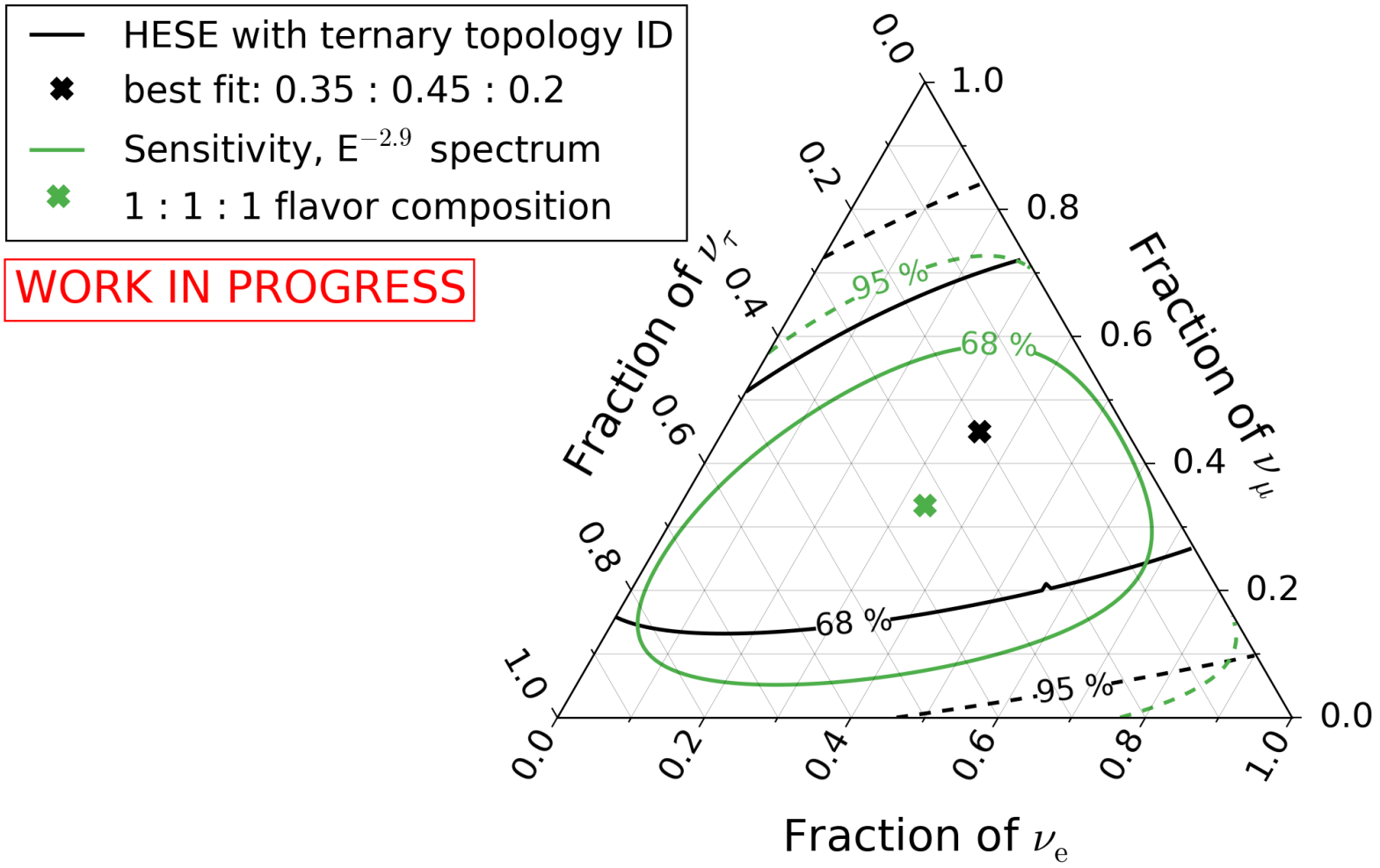


muon neutrinos

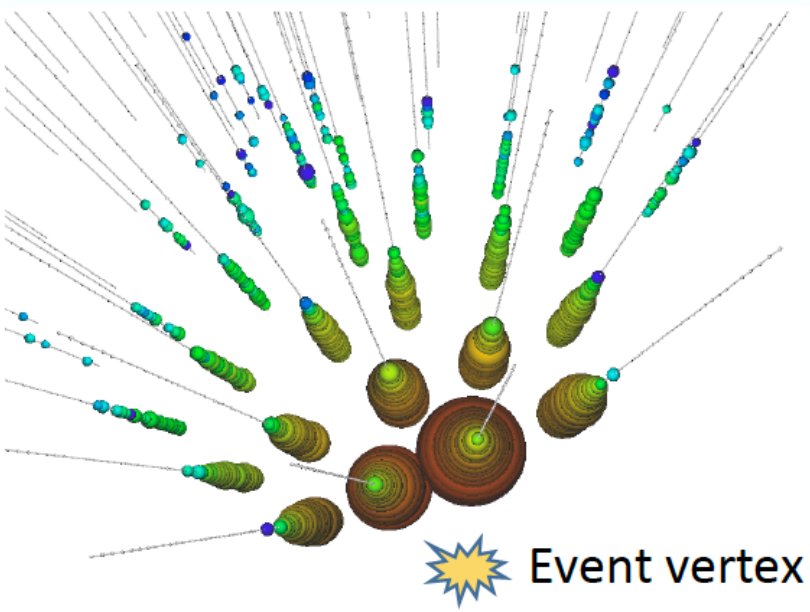
a cosmic tau neutrino: livetime 17m

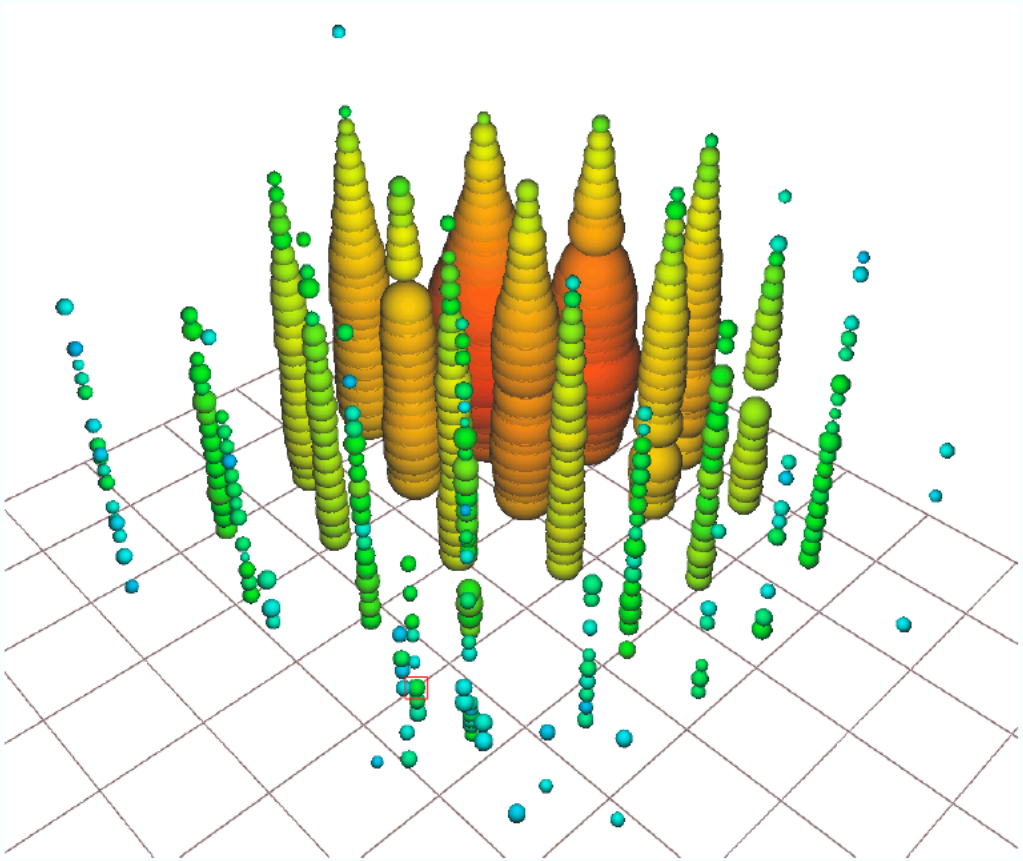


oscillations of PeV neutrinos over cosmic distances to ~ 1:1:1

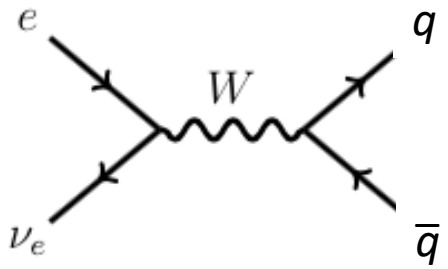


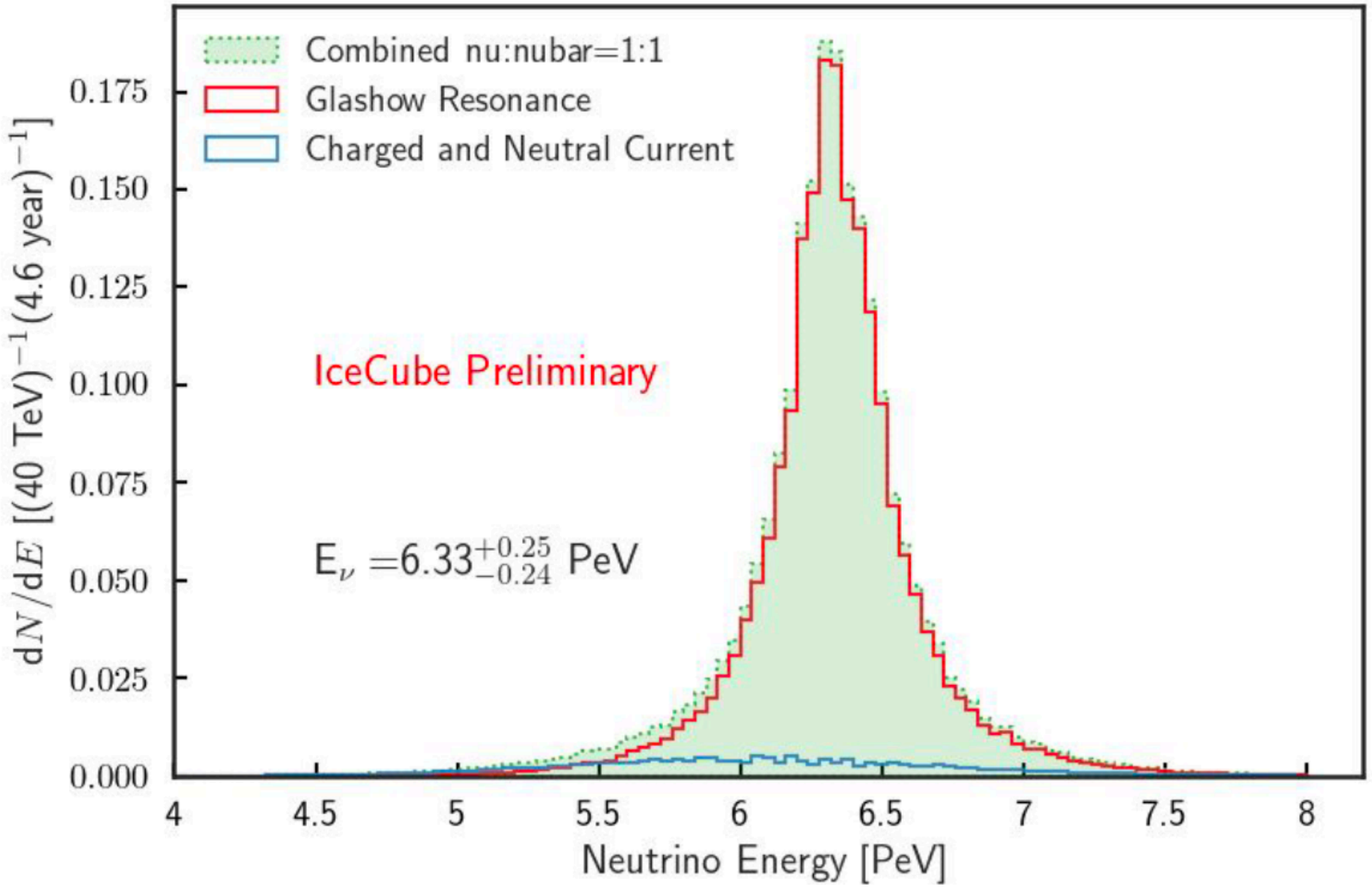
Partially contained event with energy 6.3 PeV

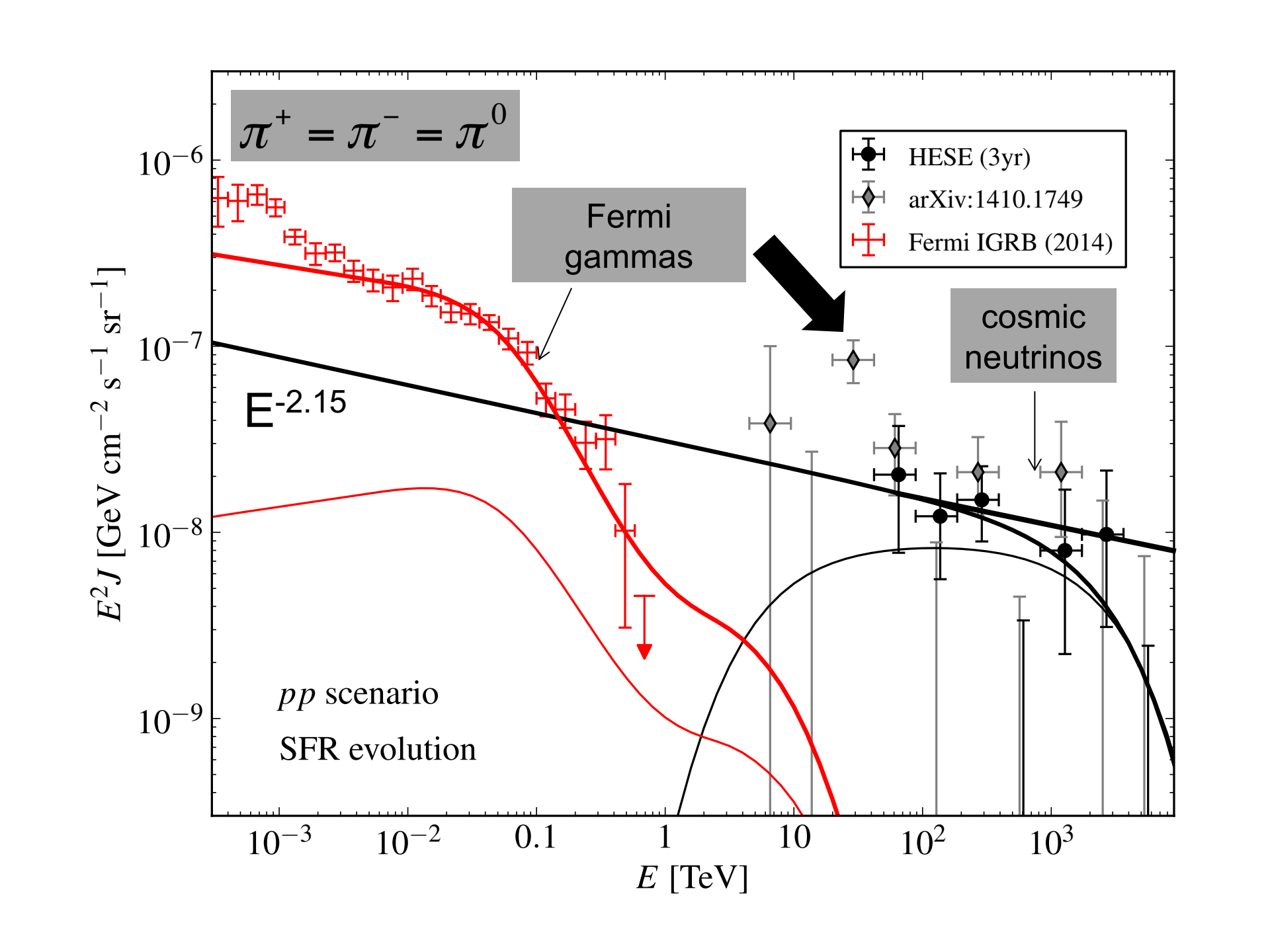


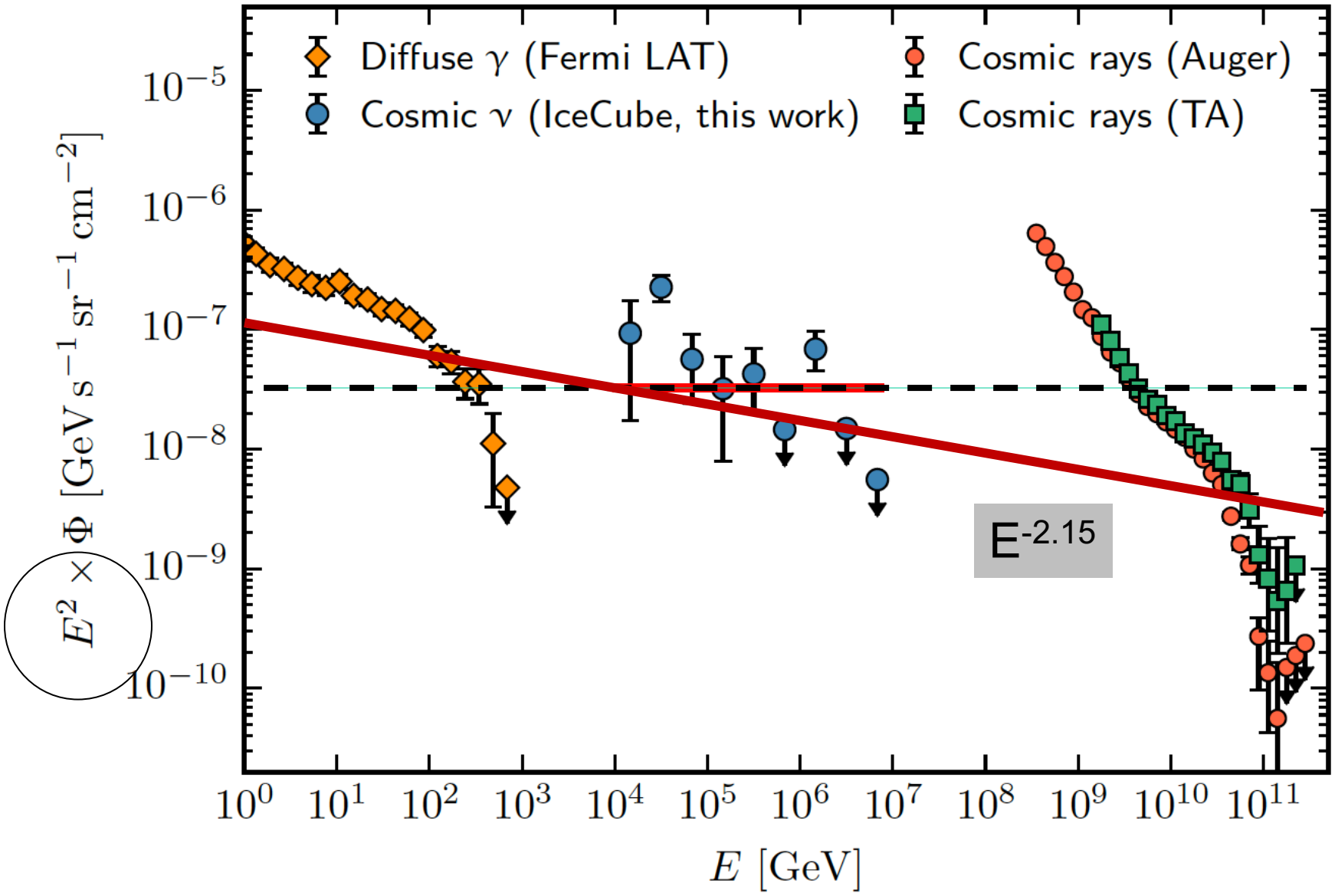


- energy measurement understood
- identification of anti-electron neutrinos





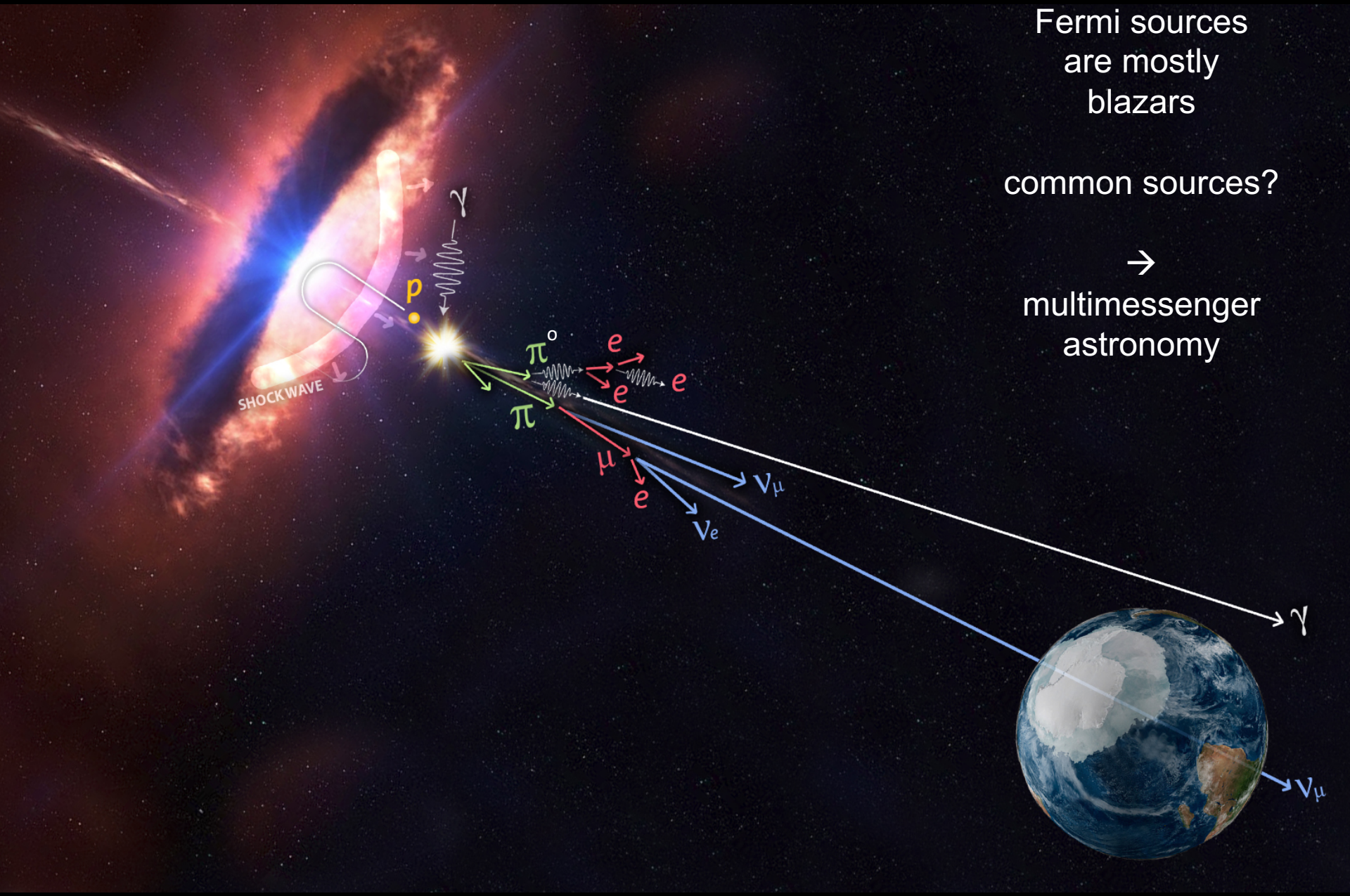

$\pi^+ = \pi^- = \pi^0$
HESE (3yr)
arXiv:1410.1749
Fermi IGRB (2014)
Fermi gammas
cosmic neutrinos
E^-2.15
pp scenario
SFR evolution
$E^2 J$ [GeV cm^{-2} s^{-1} sr^{-1}]
E [TeV]
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-3}
10^{-2}
0.1
1
10
10^2
10^3

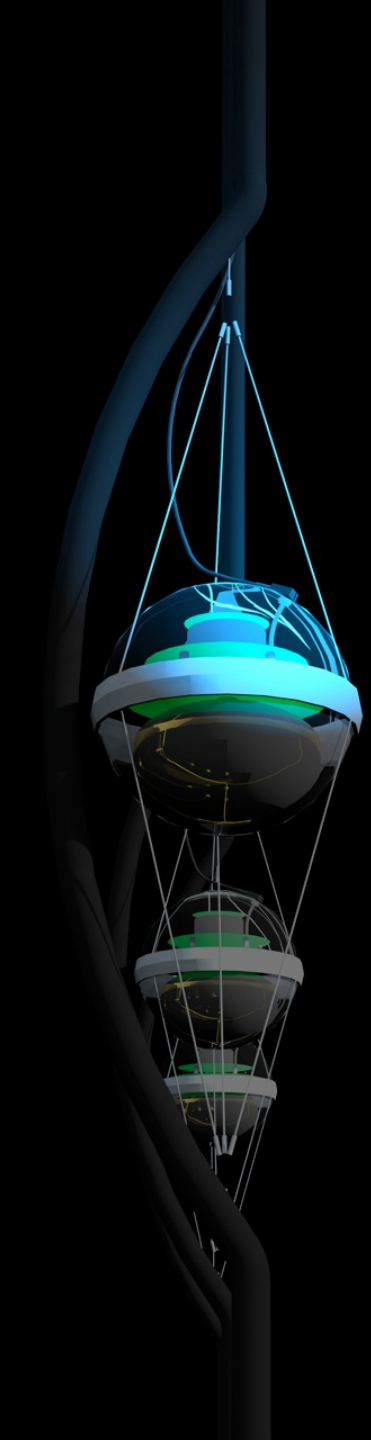


energy in the Universe in gamma rays, neutrinos and cosmic rays

energy density of neutrinos in the non-thermal Universe is the same as that in gamma-rays

→ multimessenger astronomy


Fermi sources
are mostly
blazars
common sources?
→
multimessenger
astronomy
SHOCK WAVE
p
γ
π°
e
e
e
π
μ
e
νμ
νe
γ
νμ



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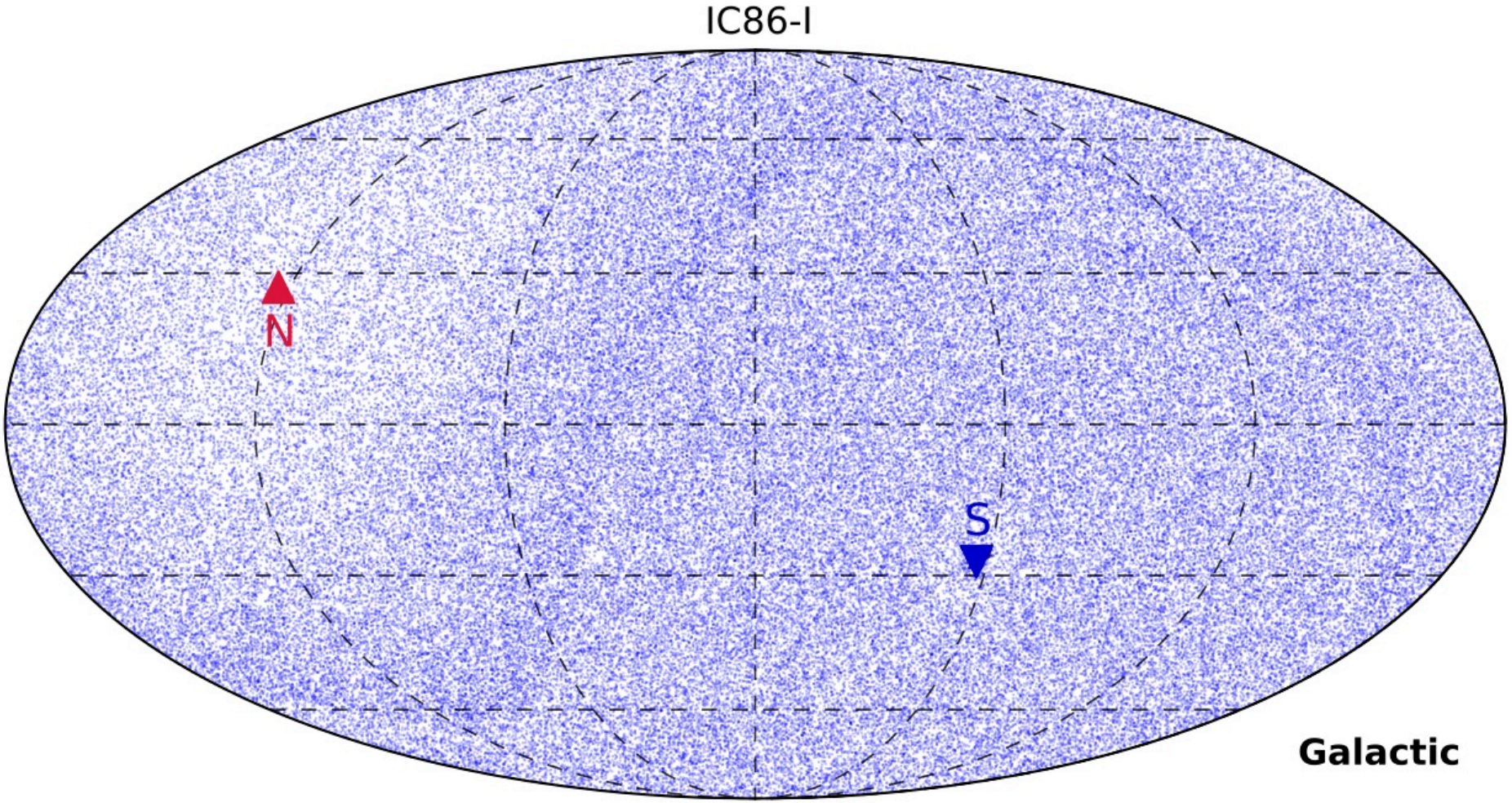
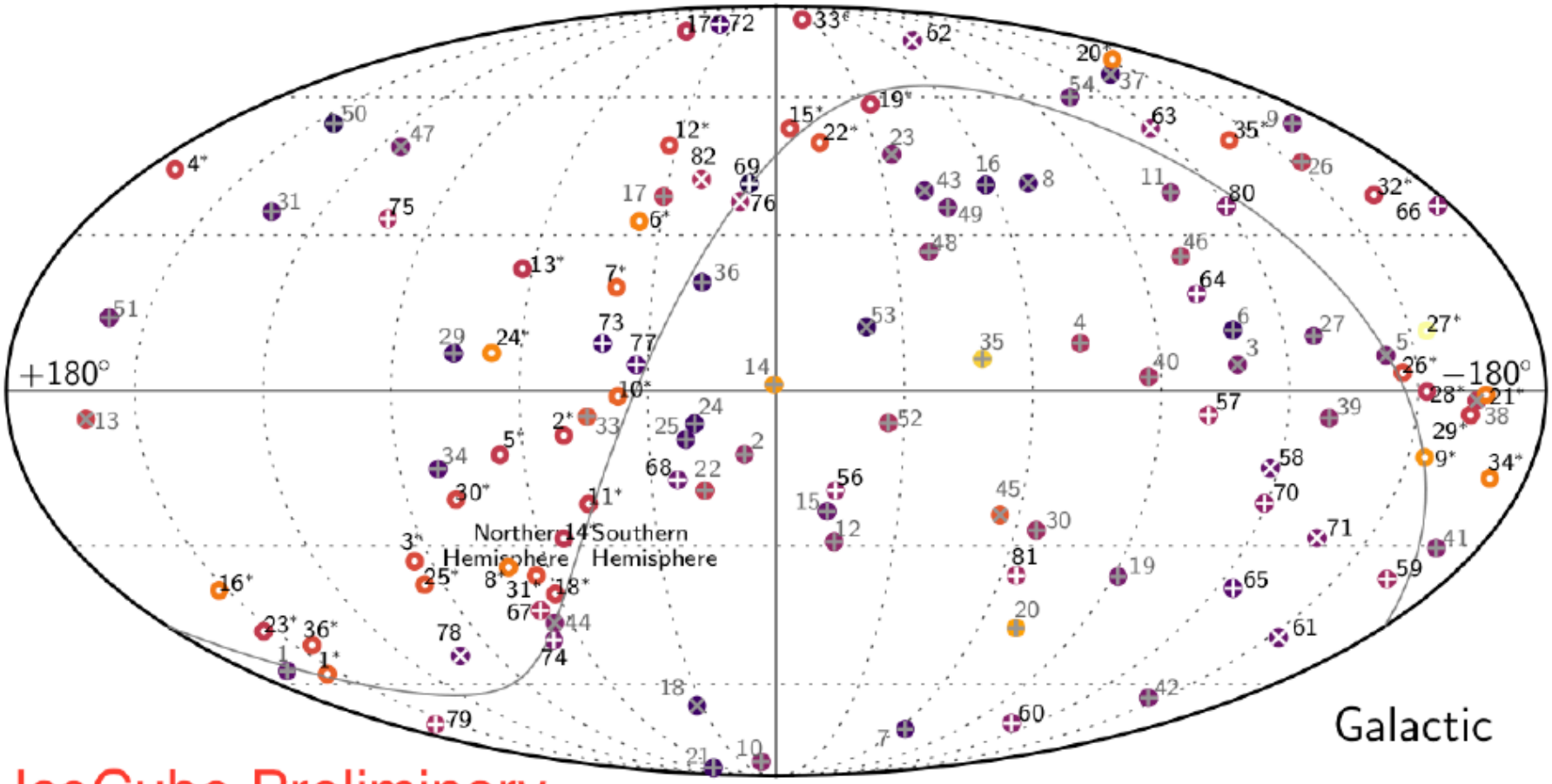


138322 neutrino candidates in one year

120 cosmic neutrinos

~12 separated from atmospheric background with E>60 TeV

structure in the map results from neutrino absorption by the Earth



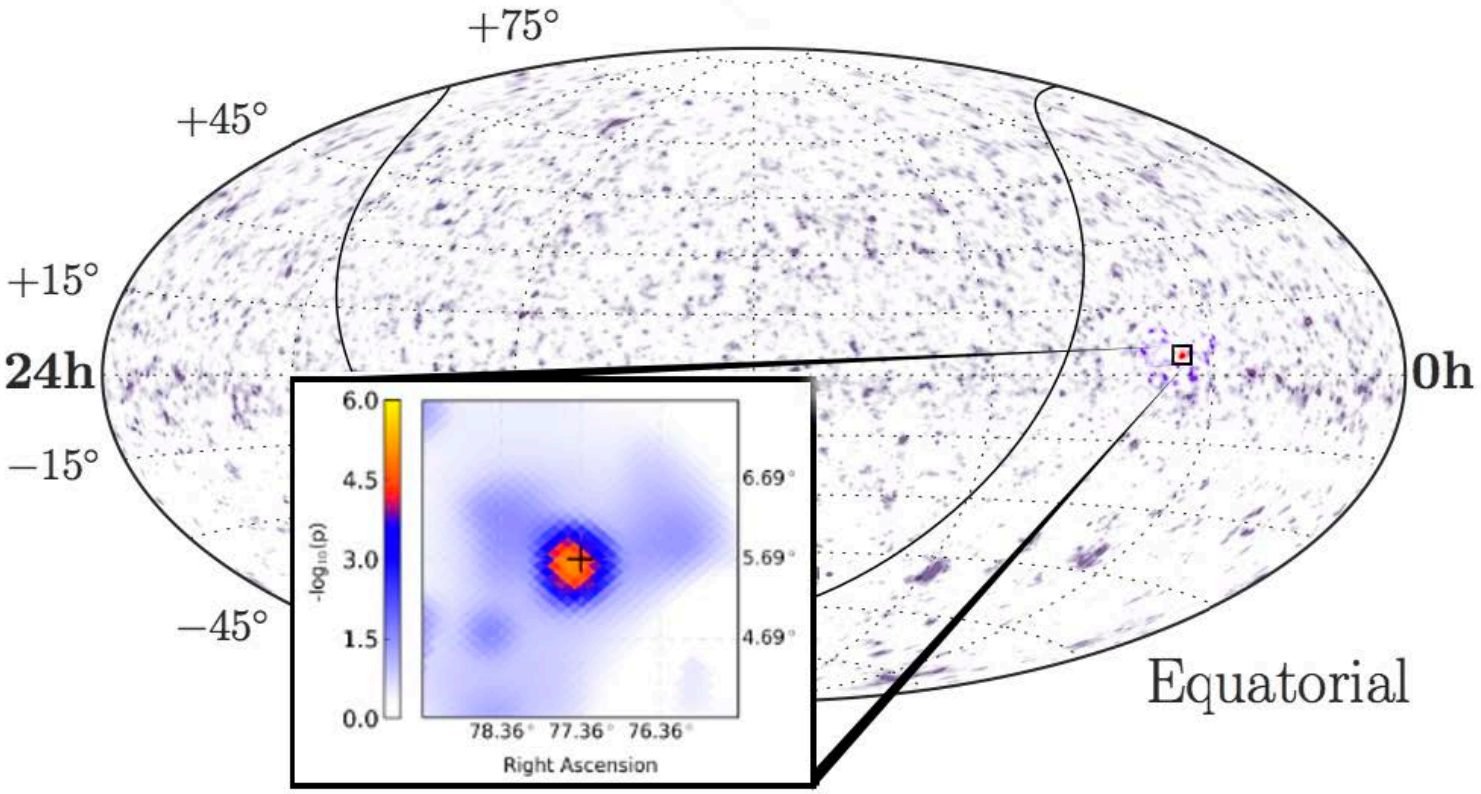
IceCube Preliminary

10^1 10^2 10^3

Deposited Energy or Muon Energy Proxy [TeV]

⊗ *N* New Starting Tracks
⊕ *N* New Starting Cascades
⊗ *N* Earlier Starting Tracks
⊕ *N* Earlier Starting Cascades
⊙ *N** Throughgoing Tracks

10 years of IceCube data: evidence for non-uniform skymap, mostly resulting from 4 source candidates



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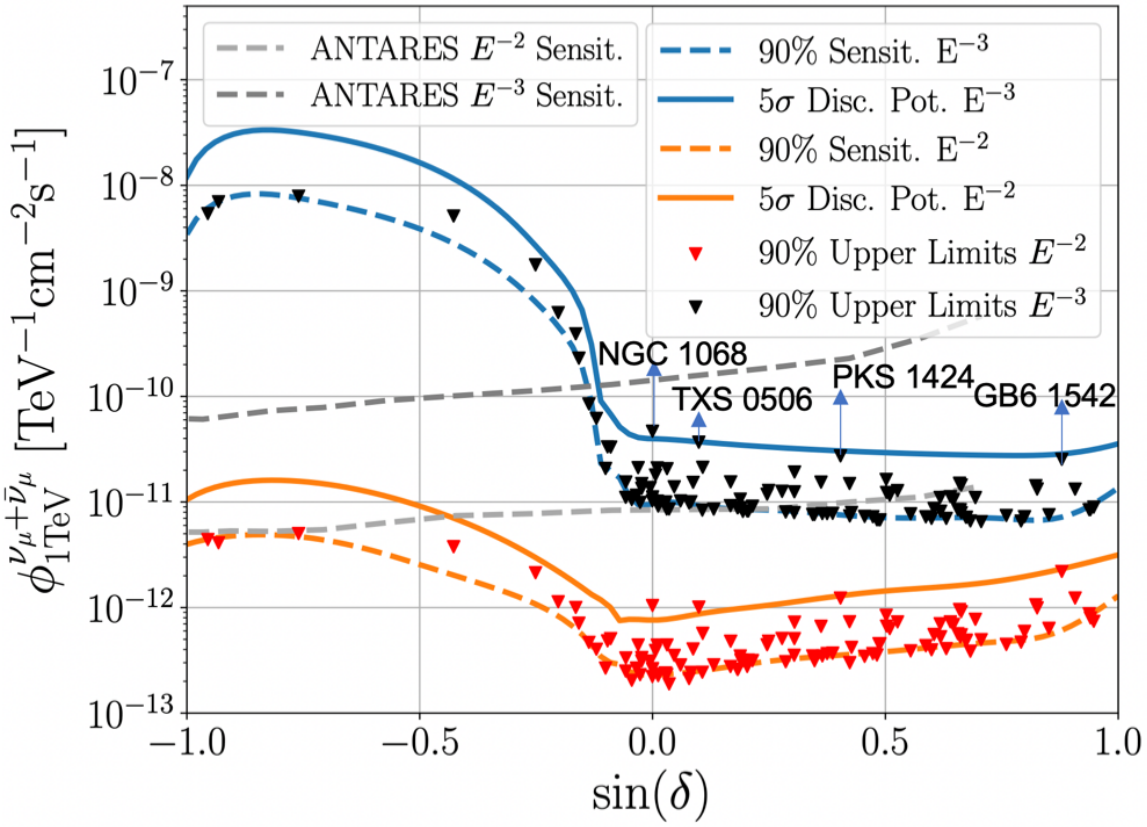
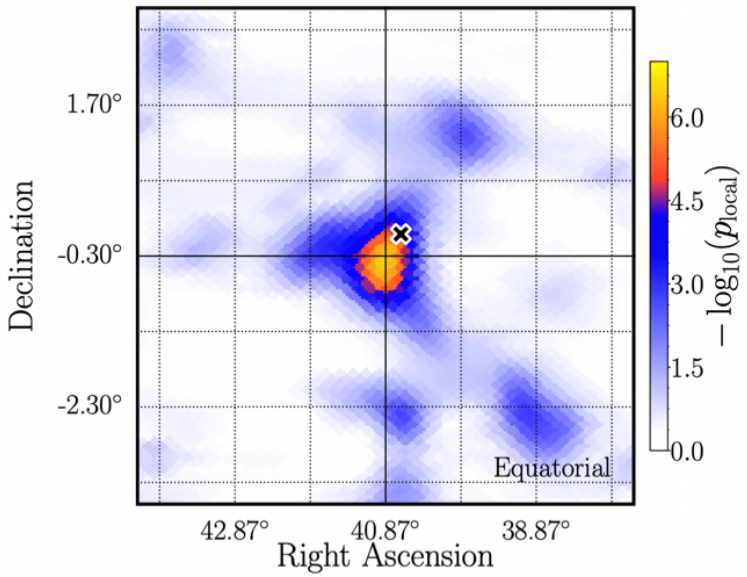
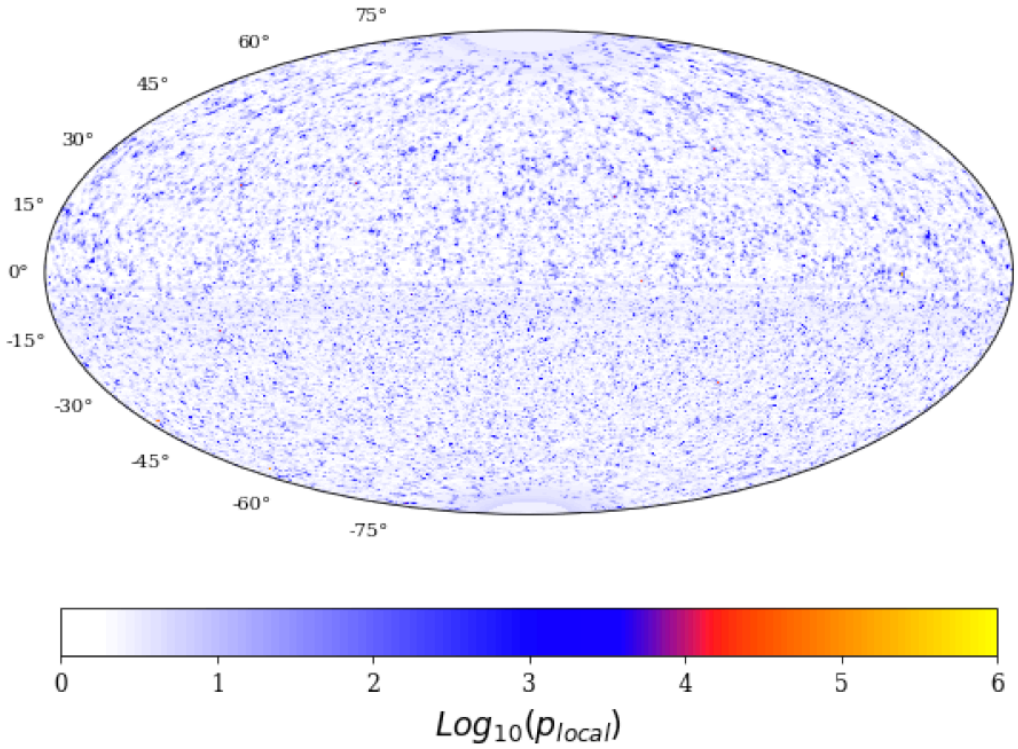
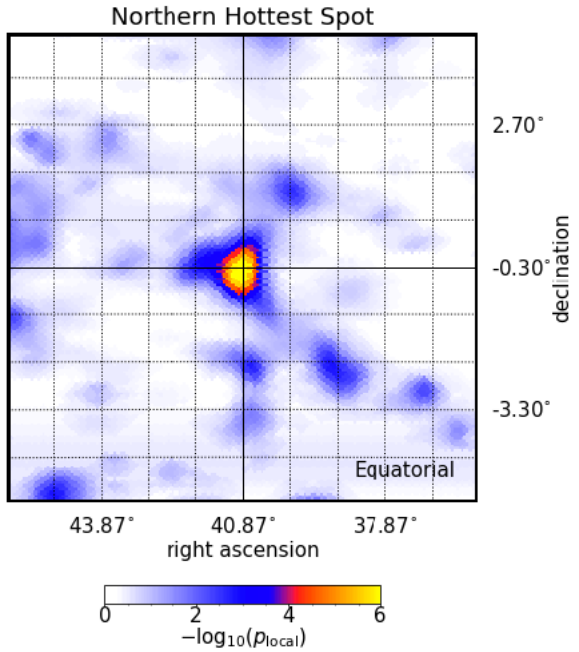


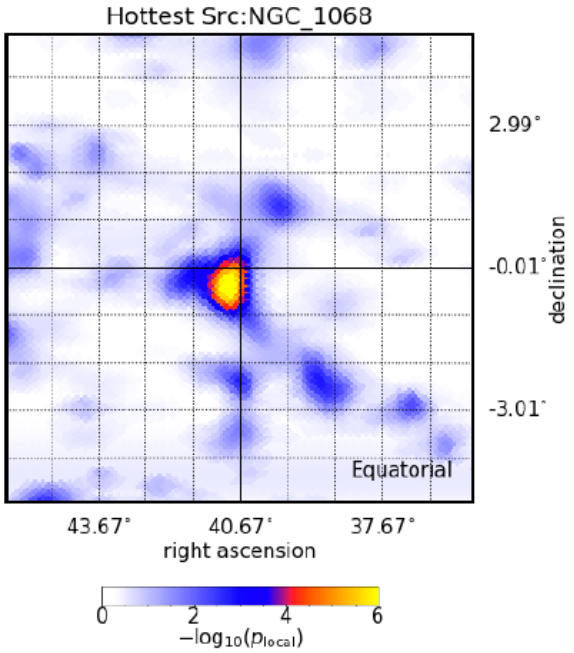


hottest spot: NGC 1068

hottest source in source list: NGC 1068

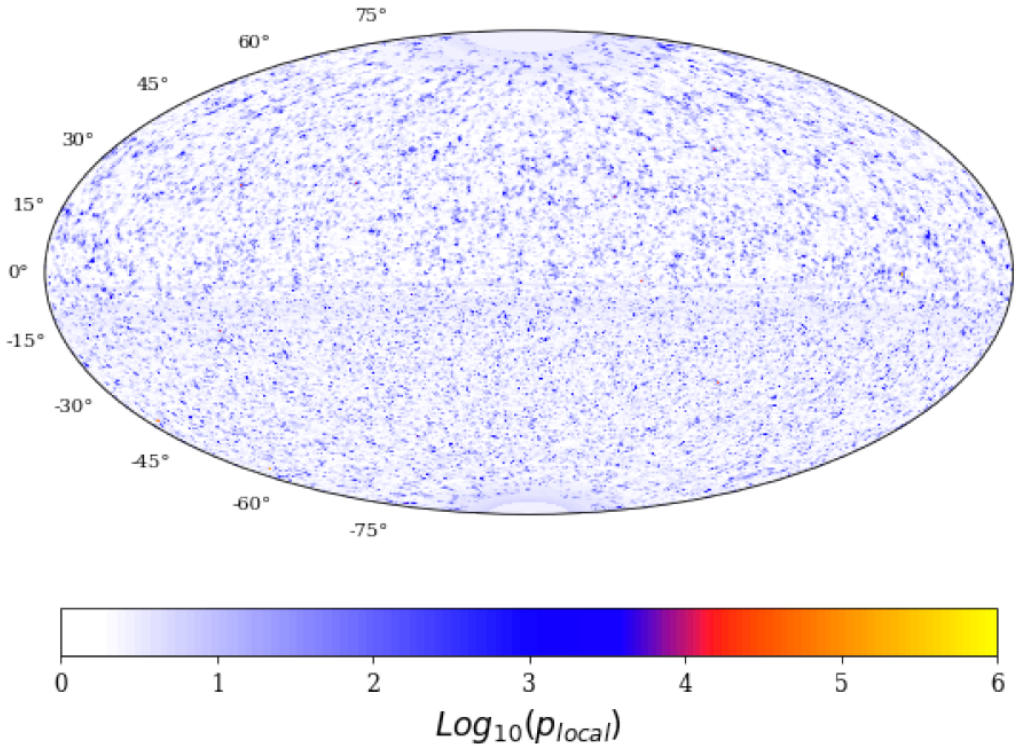


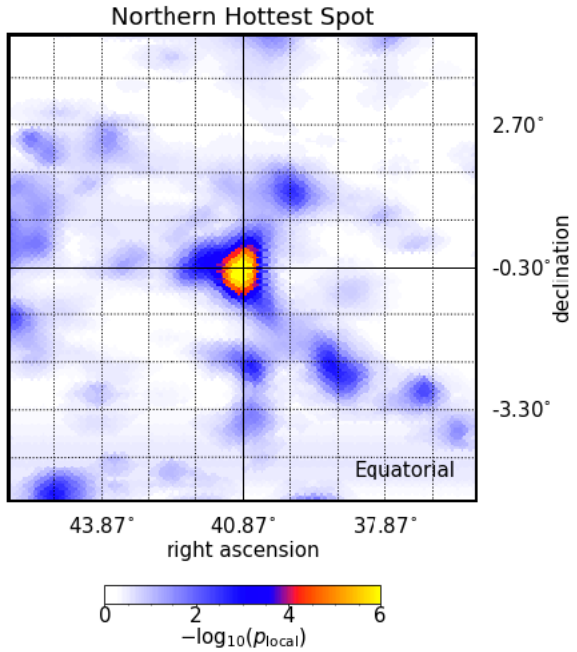


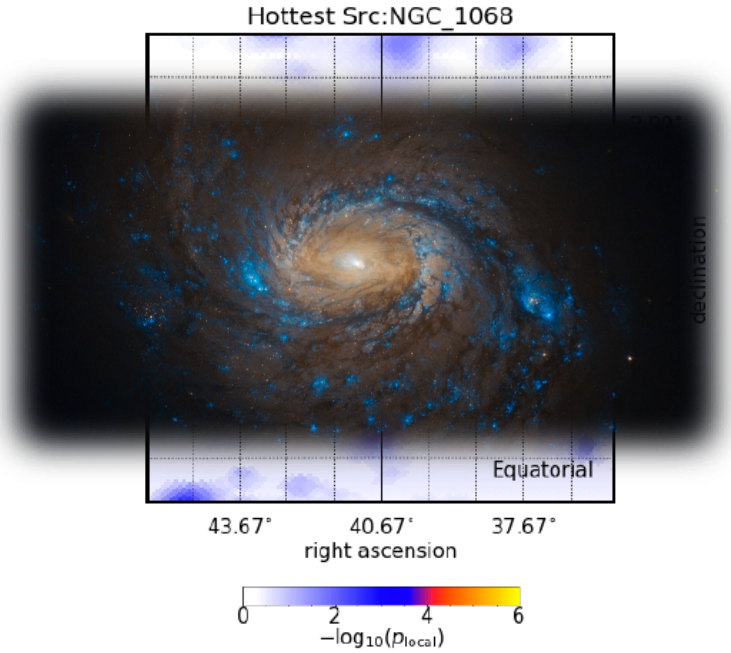


Analysis	Hemisphere	Best Pre-trial Pvalue	Post-trial Pvalue
All-Sky Scan	North	10**-6.45	0.09
	South	10**-5.37	0.476
Source List	North	10**-4.7 (4.1σ)	0.002 (2.875σ)
	South	0.0587	0.55
Src List Population	North	3.98σ	0.0005 (3.3σ)
	South	1.18σ	0.36
Stacking	SNR	0.475	0.475
	PWN	0.1	0.1
	UNID	0.496	0.496

hottest source in source list: NGC 1068







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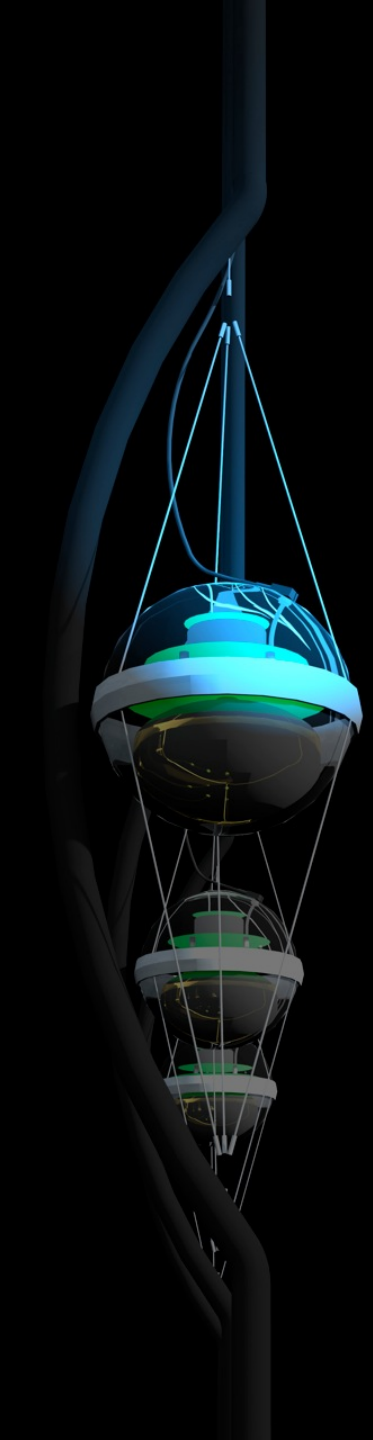
	UNID	0.496	0.496

- we observe a diffuse flux of neutrinos from extragalactic sources
- skymap reveals structure at the 3σ level associated with 4 sources
- a subdominant Galactic component is emerging but does not reach 3σ level
- where are the PeV gamma rays that accompany PeV neutrinos?



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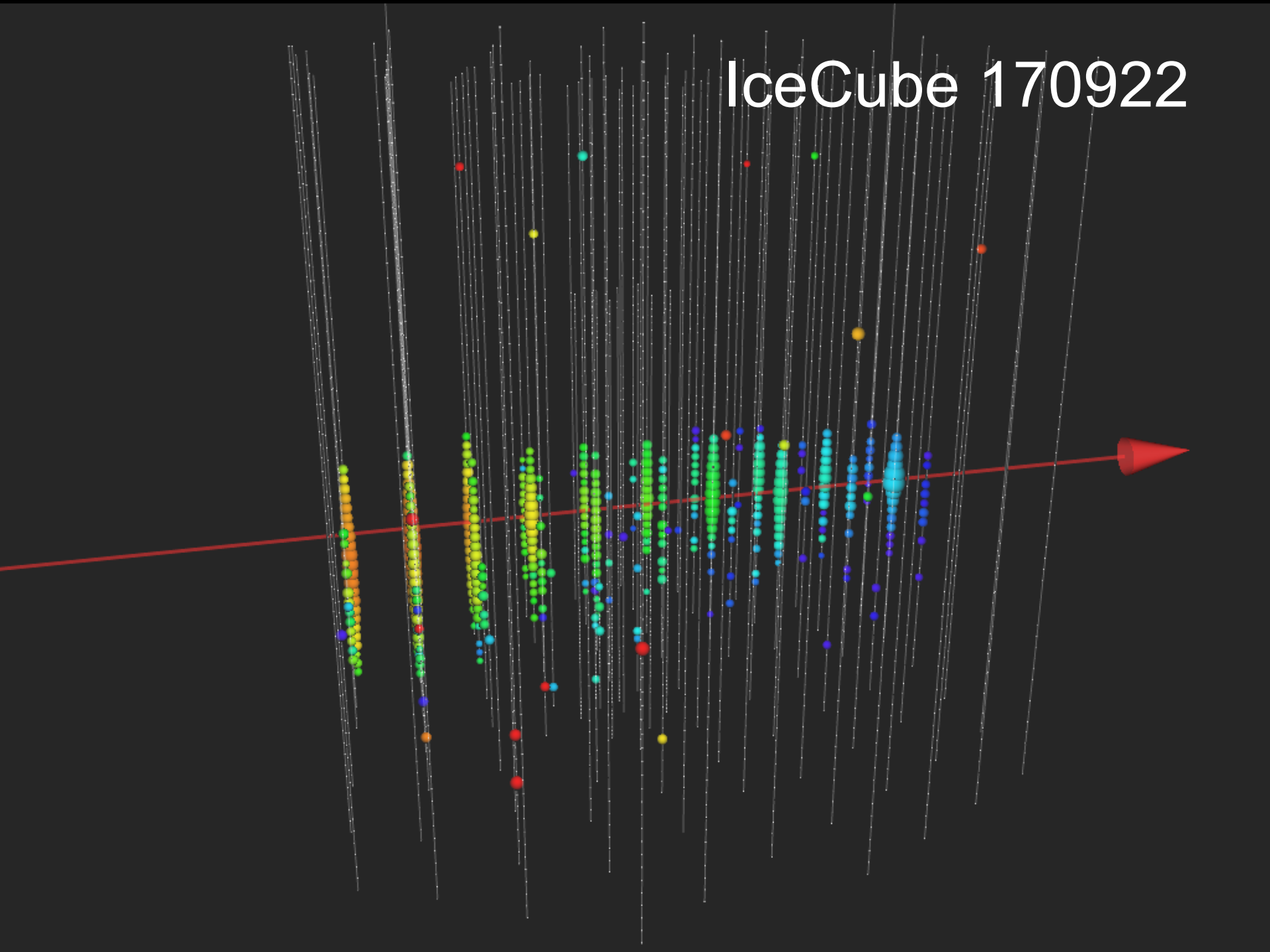
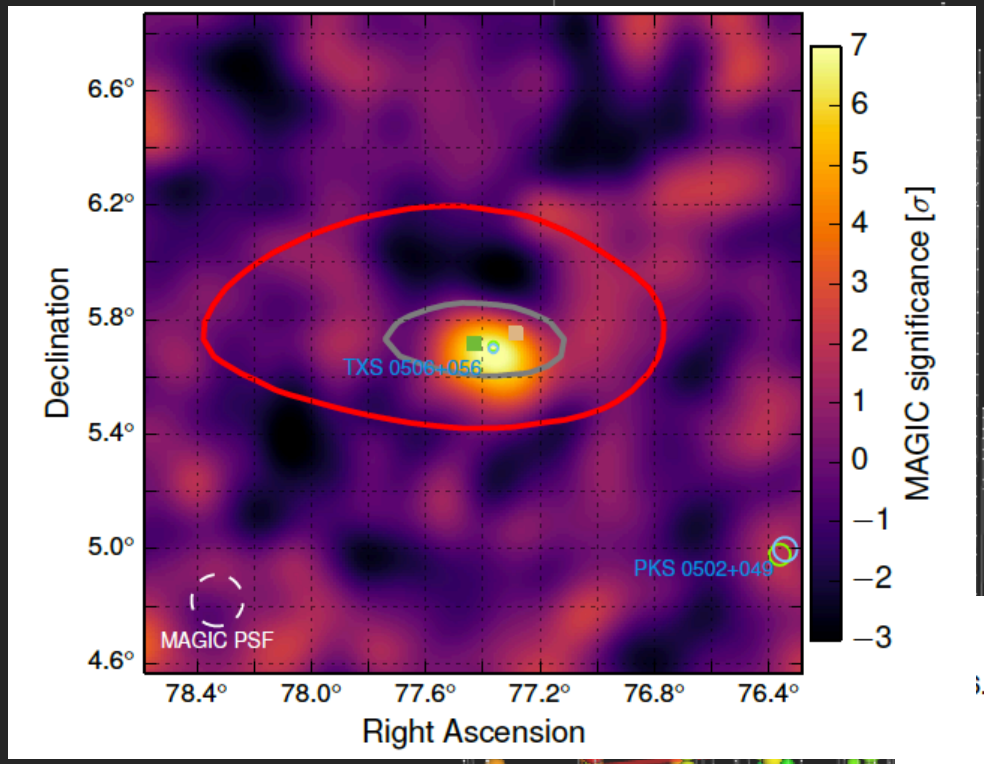
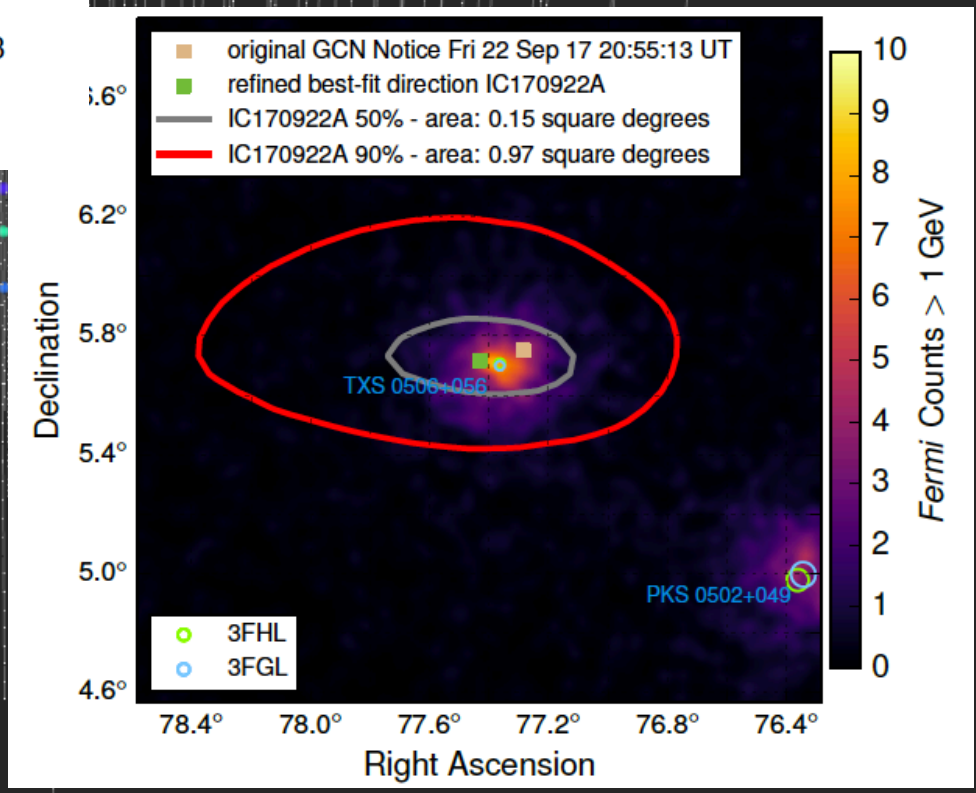

IceCube 170922

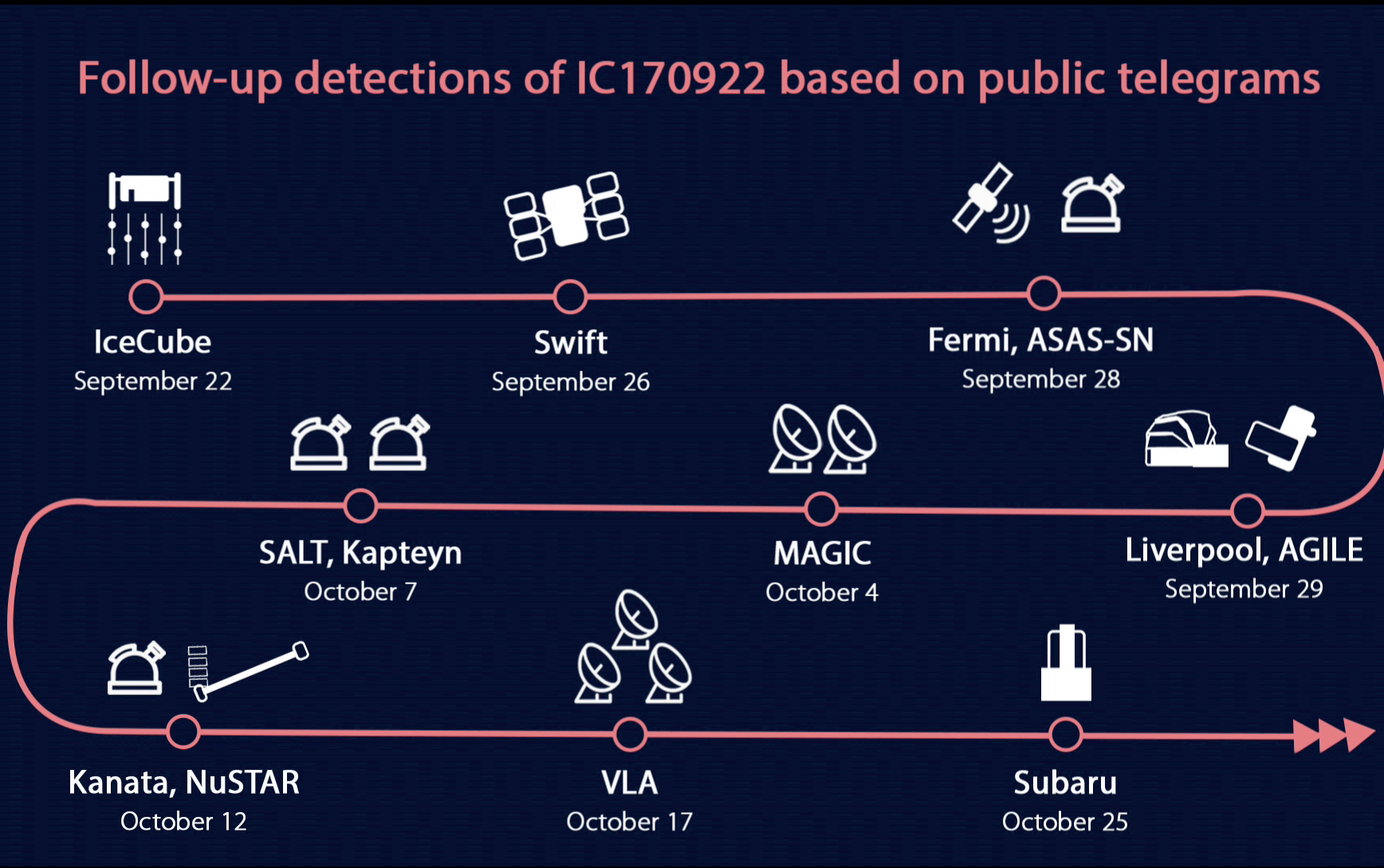


IceCube 170922

Fermi
detects a flaring
blazar within 0.06°

MAGIC
detects emission of
> 100 GeV gammas



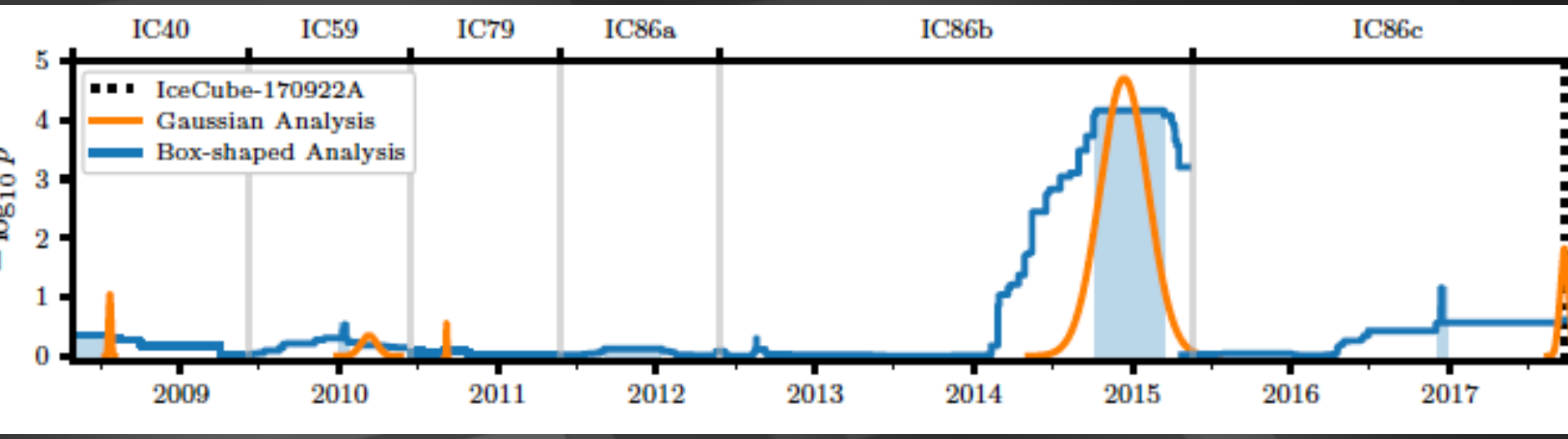

Follow-up detections of IC170922 based on public telegrams
IceCube
September 22
Swift
September 26
Fermi, ASAS-SN
September 28
Liverpool, AGILE
September 29
MAGIC
October 4
SALT, Kapteyn
October 7
Kanata, NuSTAR
October 12
VLA
October 17
Subaru
October 25

multiwavelength campaign launched by IC 170922

IceCube, *Fermi* –LAT, MAGIC, Agile, ASAS-SN, HAWC, H.E.S.S, INTEGRAL, Kapteyn, Kanata, KISO, Liverpool, Subaru, *Swift*, VLA, VERITAS

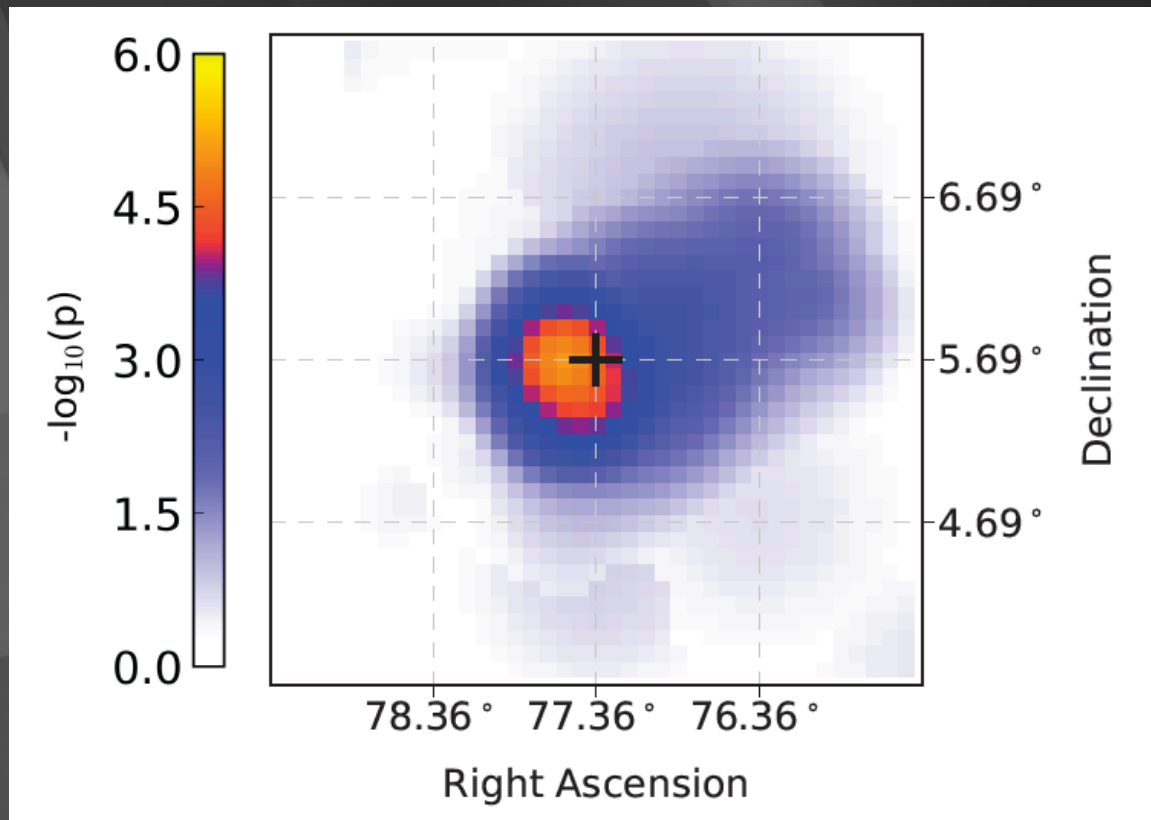
- neutrino: time 22.09.17, 20:54:31 UTC
  energy 290 TeV
  direction RA 77.43^{o} Dec 5.72^{o}
- Fermi-LAT: flaring blazar within 0.06^{o} (7x steady flux, daily variations)
- MAGIC: TeV source in follow-up observations
- follow-up by more telescopes

- → IceCube archival data (without look-elsewhere effect)
- → Fermi-LAT archival data

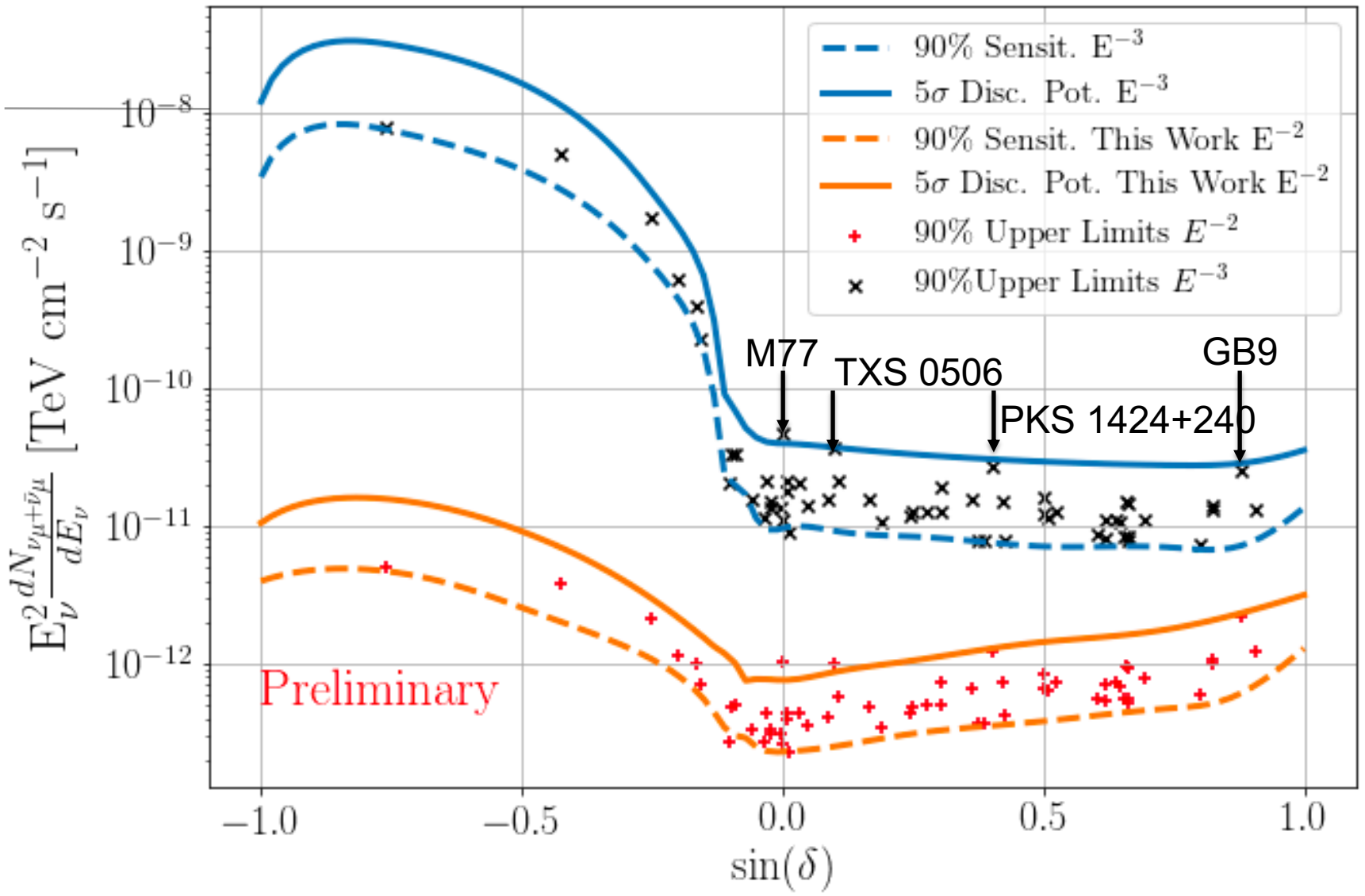


search in archival IceCube data:

- 150 day flare in December 2014 of 19 events (bkg <6)
- 10^{-5} bkg. probability
- spectrum $E^{-2.1}$



Why not seen before?



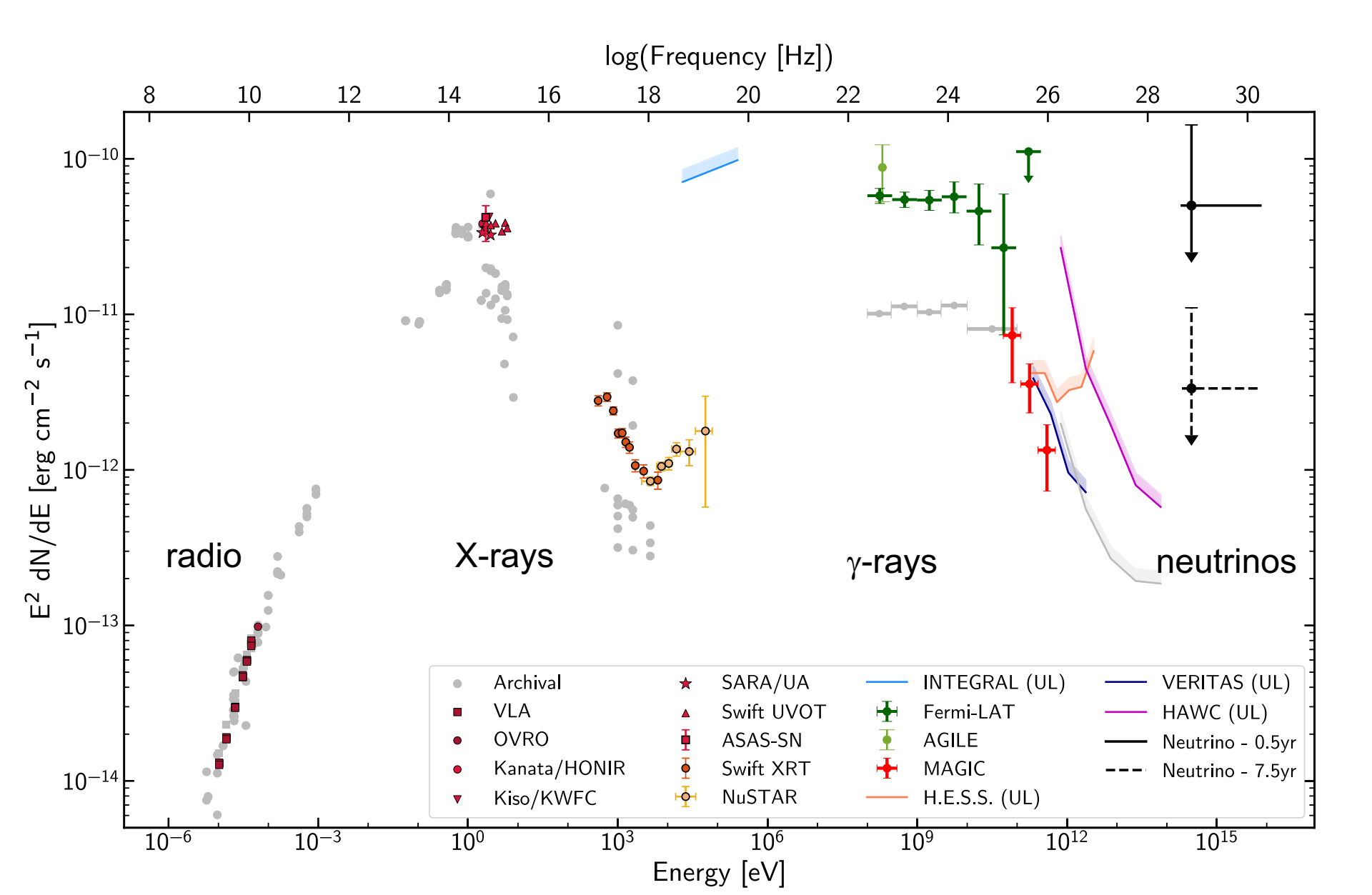
this is the case for larger detectors with better angular resolution!

we identified a source of high energy cosmic rays:

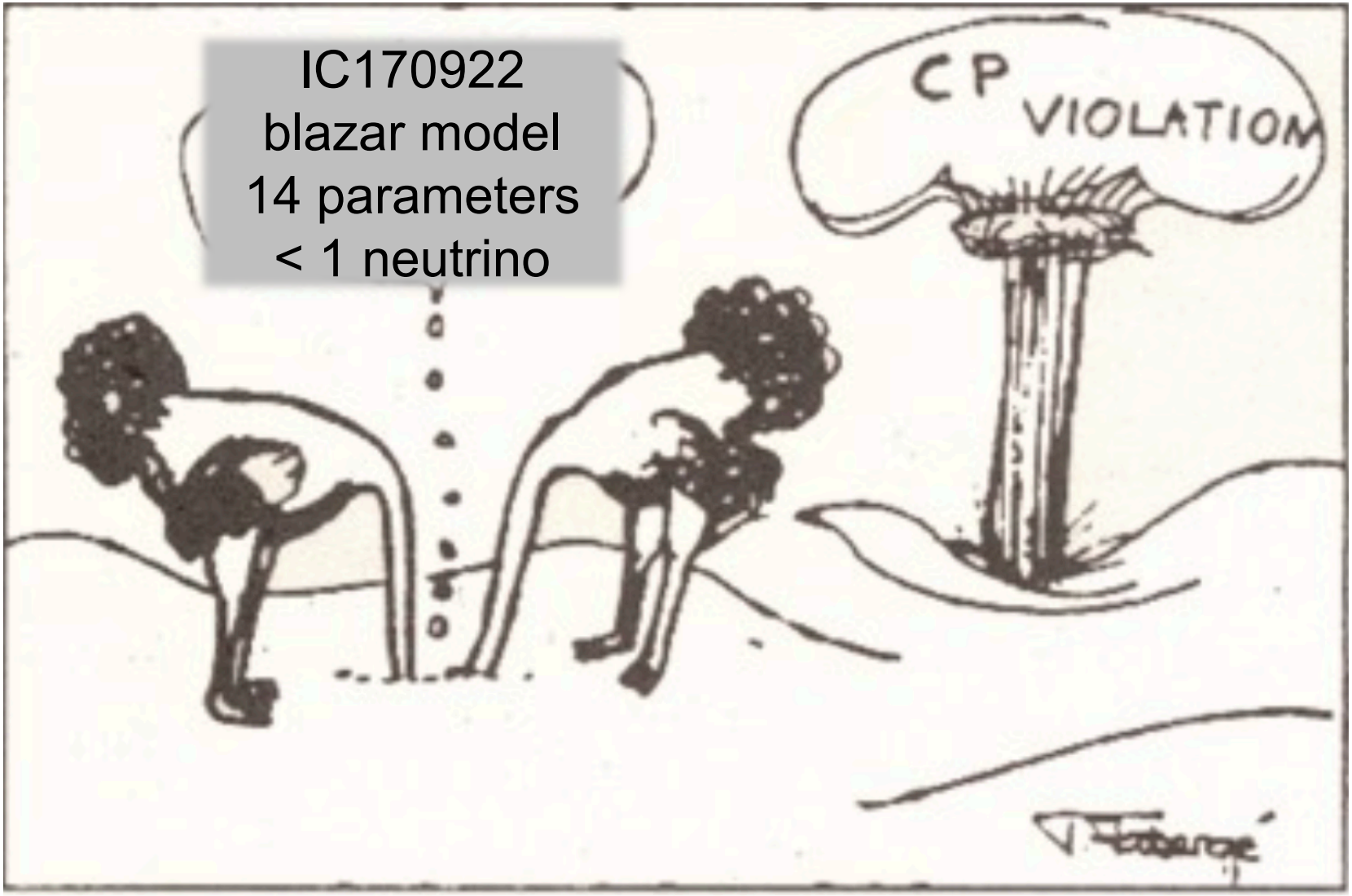
the active galaxy (blazar) TXS 0506+056 at a redshift of 0.33

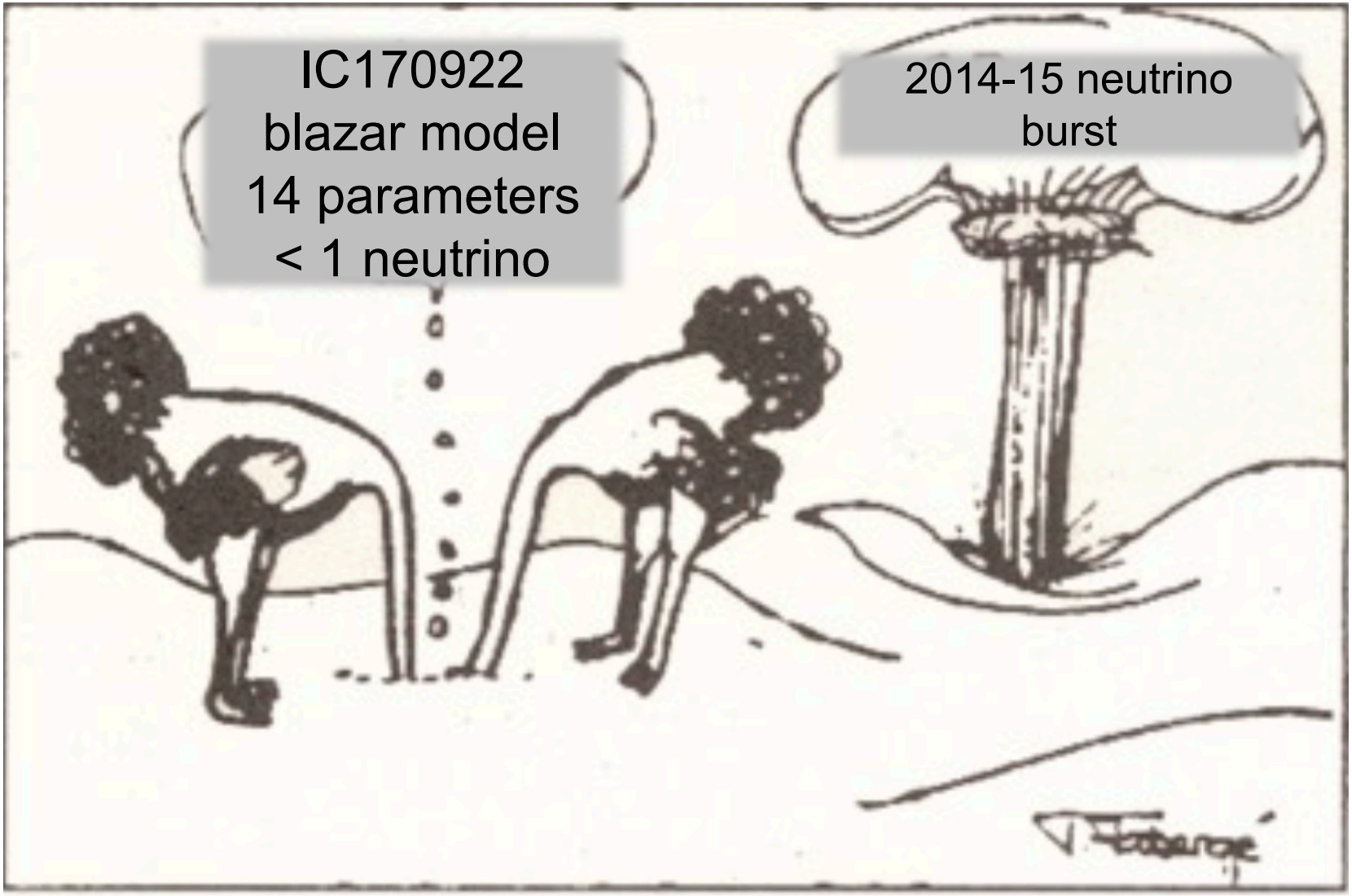
at ten times further distance, it outshines nearby active galaxies: is it special?

extensive multiwavelength campaign will allow us to study the first cosmic accelerator

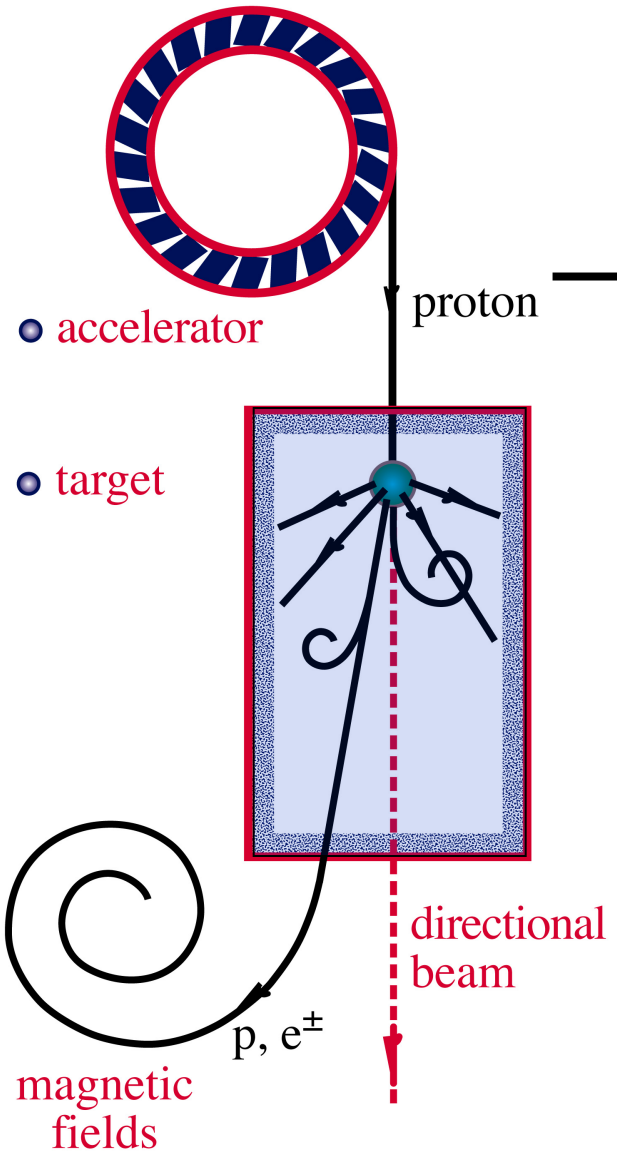


we know that this one is a cosmic ray source


IC170922
blazar model
14 parameters
< 1 neutrino
CP VIOLATION


IC170922
blazar model
14 parameters
< 1 neutrino
2014-15 neutrino
burst

ν and γ beams : heaven and earth



$p + \gamma \rightarrow n + \pi^+$

$\rightarrow$ cosmic ray + neutrino

black hole
neutron star

radiation
and dust

neutrino source
needs an accelerator
and
a target
source opacity?

relation between ν and γ-ray luminosities

- a jet that is transparent to high energy photons does not have the density to produce neutrinos– even if protons are accelerated along the electrons.
- the opacity of the jet to protons is only 1% of the opacity to photons!
- blazars cannot be sources of cosmic neutrinos.
- best guess: agn cores with supermassive black holes are the sources, but only if they merge with target material from a major merger onto the black hole.

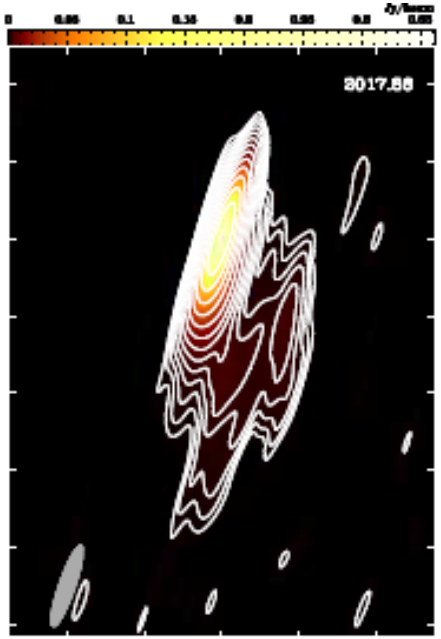
relation between p, ν and γ-ray luminosities

- efficiency for producing neutrinos $$L_\nu = \frac{3}{8} f_{p\gamma} L_p$$
- requires large opacity of the target to protons and large target density $$f_{p\gamma} \sim \tau_{p\gamma} \sim n_\gamma$$
- source is opaque to gamma rays $$\tau_{\gamma\gamma} \simeq 10^2 \ \tau_{p\gamma}$$

TXS 0506+056 a galaxy merger?

beyond 5 mas the core loses its tight collimation…

theory confirms observation?



Astronomy & Astrophysics manuscript no. 0506
December 5, 2019

LETTER TO THE EDITOR

Apparent superluminal core expansion and limb brightening in the candidate neutrino blazar TXS 0506+056

E. Ros[1], M. Kadler[2], M. Perucho[3,4], B. Boccardi[1], H.-M. Cao[5], M. Giroletti[5], F. Krauß[6], and R. Ojha[7,8,9]

[1] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
e-mail: ros@mpifr-bonn.mpg.de
[2] Lehrstuhl für Astronomie, Universität Würzburg, Emil-Fischer-Straße 31, D-97074 Würzburg, Germany
[3] Departament d'Astronomia i Astrofísica, Universitat de València, c/ Dr. Moliner 50, E-46100 Burjassot, València, Spain
[4] Observatori Astronòmic, Universitat de València, c/ Catedràtic José Beltrán Martínez 2, E-46980 Paterna, València, Spain
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[6] Department of Astronomy and Astrophysics, Pennsylvania State University, University Park, PA 16801, USA
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Submitted: November 28, 2019; Accepted: December 3, 2019

ABSTRACT

Context. IceCube has reported a very-high-energy neutrino (IceCube-170922A) in a region containing the blazar TXS 0506+056. Correlated gamma-ray activity has led to the first high-probability association of a high-energy neutrino with an extragalactic source. This blazar has been found to be in a radio outburst during the neutrino event.
Aims. Our goal is to probe the sub-milliarcsecond properties of the radio jet right after the neutrino detection and during the further evolution of the radio outburst.
Methods. We have performed target-of-opportunity very-long-baseline interferometry imaging observations at 43 GHz frequency, corresponding to 7 mm in wavelength, with the Very Long Baseline Array two and eight months, respectively, after the neutrino event.
Results. We produced two images of the radio jet of TXS 0506+056 at 43 GHz with angular resolutions of (0.2 × 1.1) mas and (0.2 × 0.5) mas, respectively. The source shows a compact, high brightness temperature core (albeit not approaching the equipartition limit, Readhead 1994) and a bright and originally very collimated inner jet. Beyond about 0.5 mas from the mm-VLBI core, the jet loses this tight collimation and expands rapidly. During the months after the neutrino event associated with this source, the overall flux density is rising. This flux density increase happens solely within the core. Notably, the core expands in size with apparent superluminal velocity during these six months so that the brightness temperature drops by a factor of three in spite of the strong flux density increase.
Conclusions. The radio jet of TXS 0506+056 shows strong signs of deceleration and/or a spine-sheath structure within the inner 1 mas (corresponding to about 70 pc to 140 pc in deprojected distance) from the mm-VLBI core. This structure is consistent with theoretical models that attribute the neutrino and gamma-ray production in TXS 0506+056 to interactions of electrons and protons in the highly-relativistic jet spine with external photons originating from a slower-moving jet region. Proton loading due to jet-star interactions in the inner host galaxy is suggested as the possible cause of deceleration.

Key words. Radiation mechanisms: non-thermal – Neutrinos – Techniques: interferometric – Radio continuum: galaxies – Galaxies: quasars: individual: TXS 0506+056

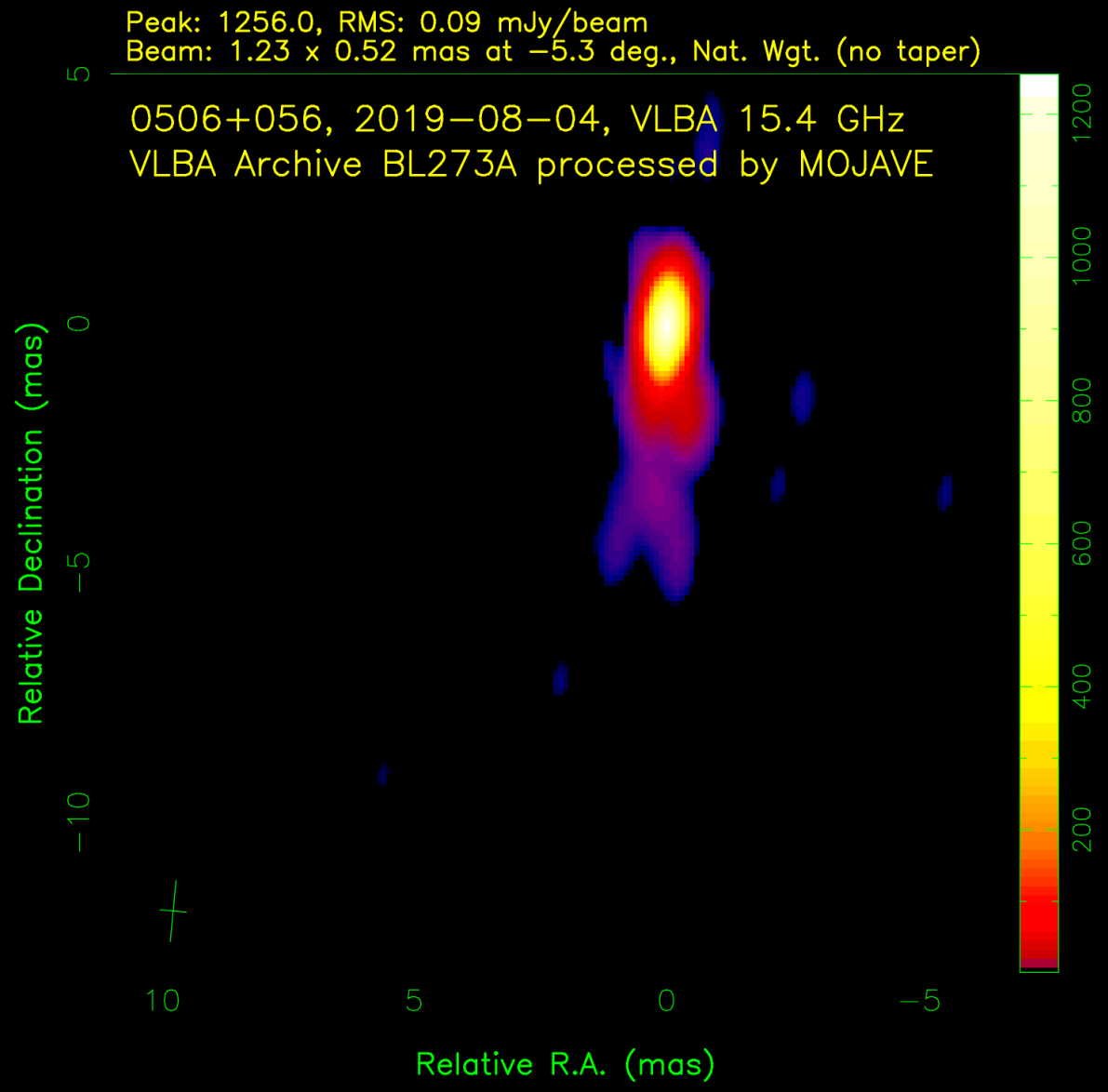
TXS 0506+056 a galaxy merger?

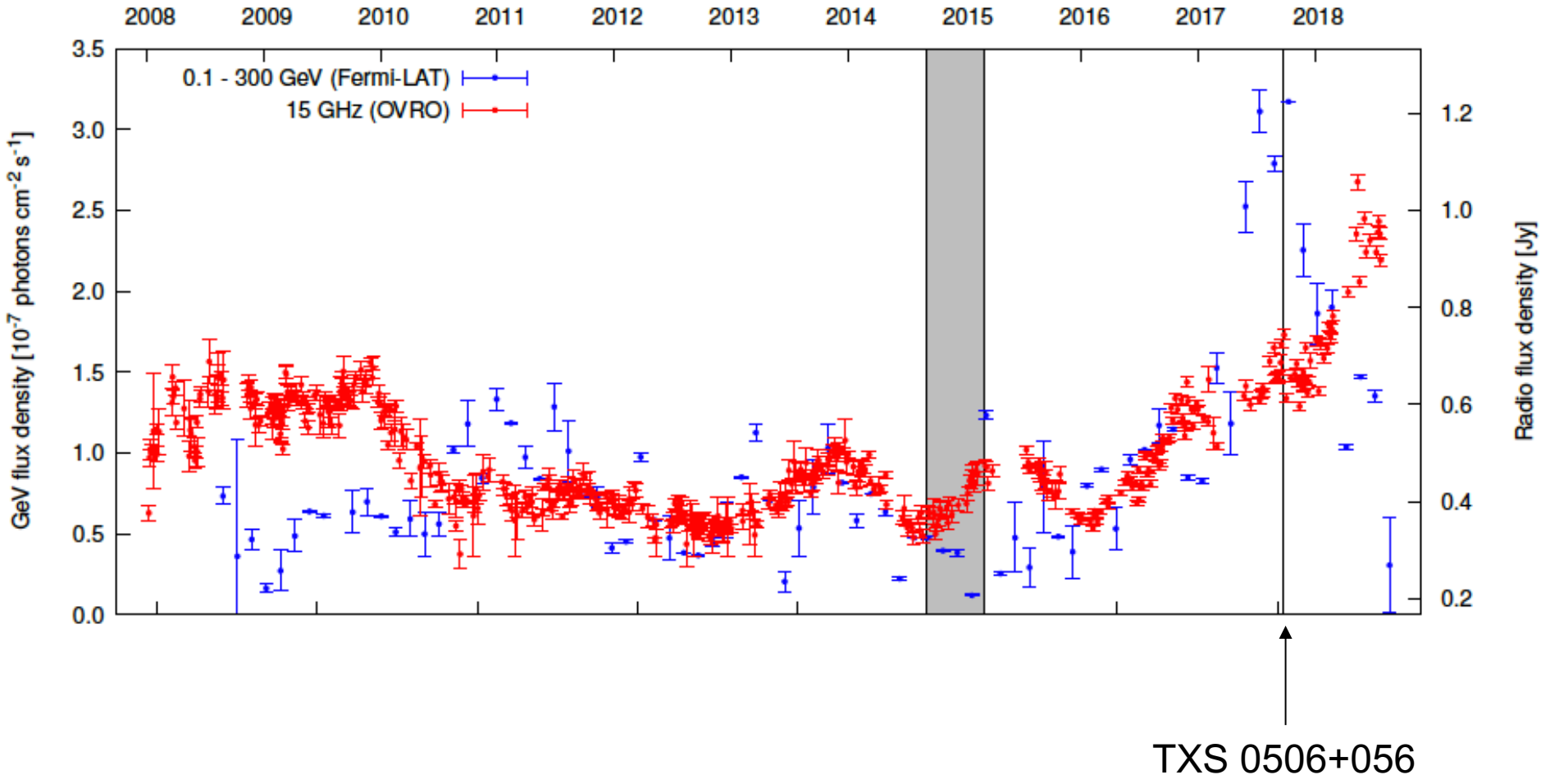
core brightening observed in a radio burst that started 5 years ago

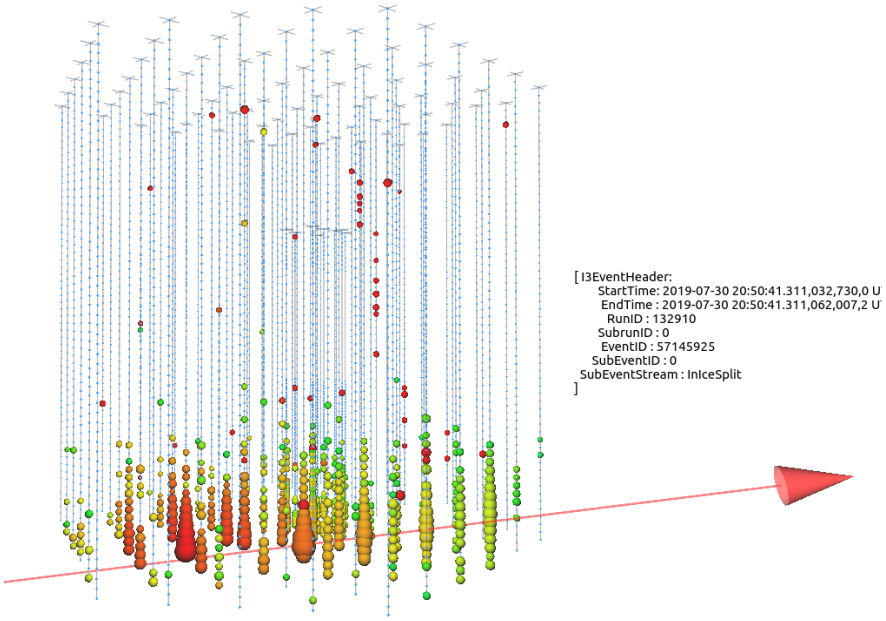
core expands with superluminal velocity

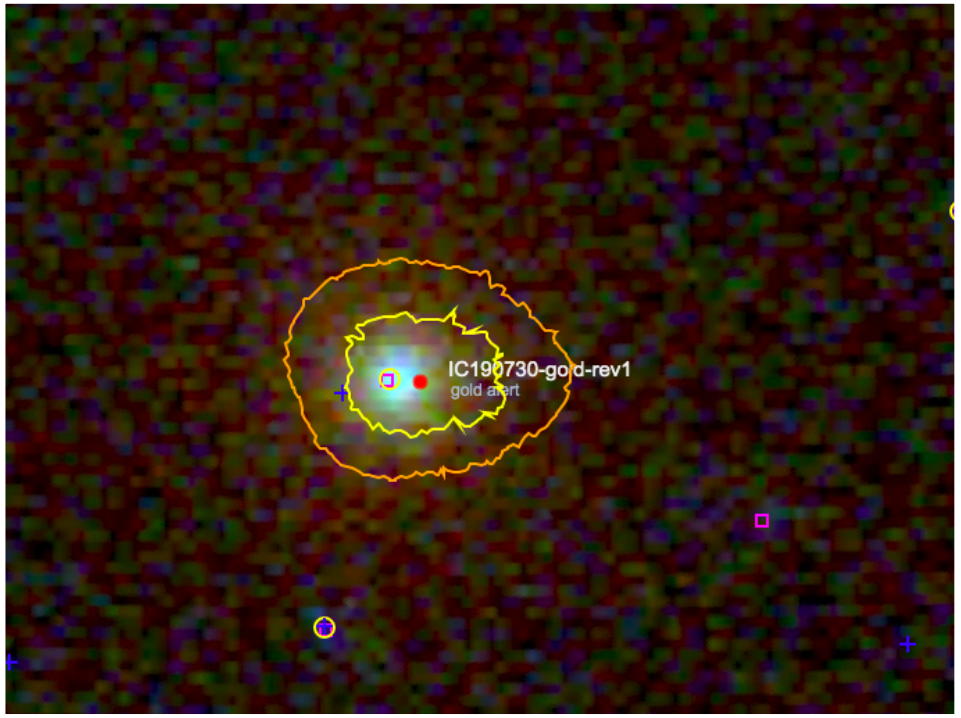
beyond 5 mas the core loses its tight collimation…

theory confirms observation?




2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
0.1 - 300 GeV (Fermi-LAT)
15 GHz (OVRO)
GeV flux density [10^-7 photons cm^-2 s^-1]
Radio flux density [Jy]
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0.2
0.4
0.6
0.8
1.0
1.2
TXS 0506+056





IC 190730: 300 TeV

- coincident with PKS 1502+106
- galaxy merger

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Neutrino candidate source FSRQ PKS 1502+106 at highest flux density at 15 GHz

ATel #12996; *S. Kiehlmann (IoA FORTH, OVRO), T. Hovatta (FINCA), M. Kadler (Univ. WÃ¼rzburg), W. Max-Moerbeck (Univ. de Chile), A. C.S. Readhead (OVRO)*
on 7 Aug 2019; 12:31 UT
Credential Certification: Sebastian Kiehlmann (skiehlmann@mail.de)

Subjects: Radio, Neutrinos, AGN, Blazar, Quasar

Tweet

On 2019/07/30.86853 UT IceCube detected a high-energy astrophysical neutrino candidate (Atel #12967). The FSRQ PKS 1502+106 is located within the 50% uncertainty region of the event. We report that the flux density at 15 GHz measured with the OVRO 40m Telescope shows a long-term outburst that started in 2014, which is currently reaching an all-time high of about 4 Jy, since the beginning of the OVRO measurements in 2008. A similar 15 GHz long-term outburst was seen in TXS 0506+056 during the neutrino event IceCube-170922A.

Related

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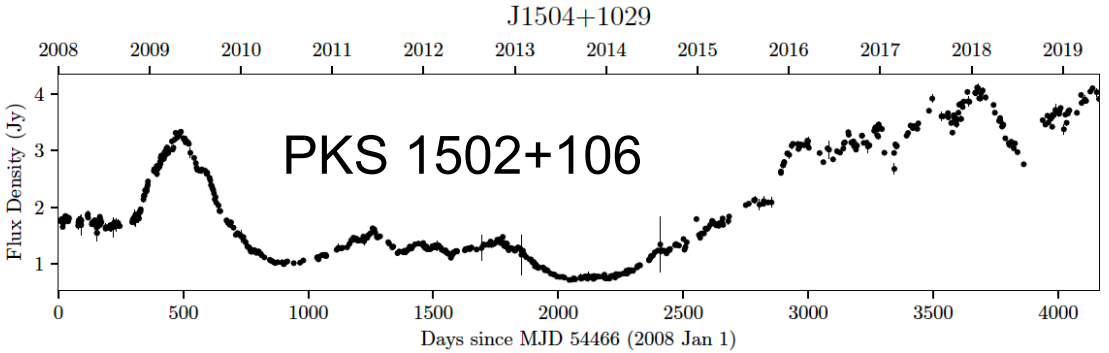
12926	VLA observations reveal increasing brightness of 1WHSP J104516.2+275133, a potential source of IC190704A

OVRO Radio Flare



OVRO Montitoring (http://www.astro.caltech.edu/ovroblazars/)

Neutrino candidate source FSRQ PKS 1502+106 at highest flux density at 15 GHz

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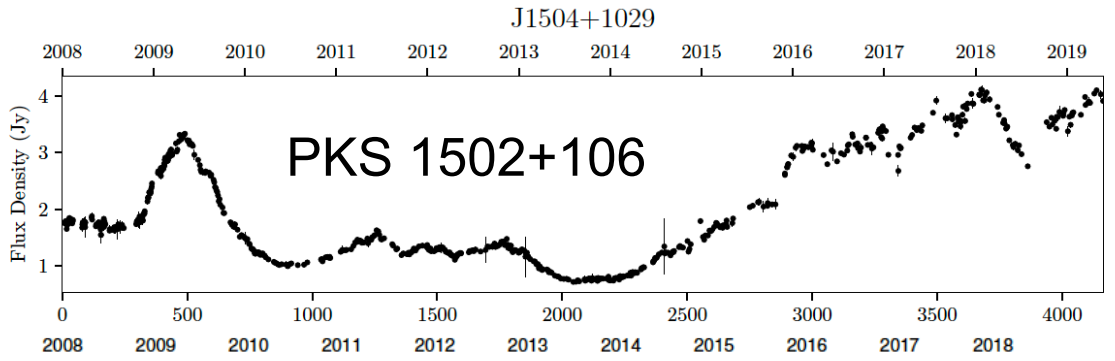
No evidence of short-term flaring activity in any wavelengths.

Long-term radio flare reported by OVRO, also reported for TXS 0506+056.

the two highest energy IceCube alerts are coincident with radio flares

OVRO Radio Flare



Neutrino candidate source FSRQ
highest flux density at 1

ATel #12996; *S. Kiehlmann (IoA FORTH, OVRO), T. Hova*
WÃ¼rzburg), W. Max-Moerbeck (Univ. de Chile), A.
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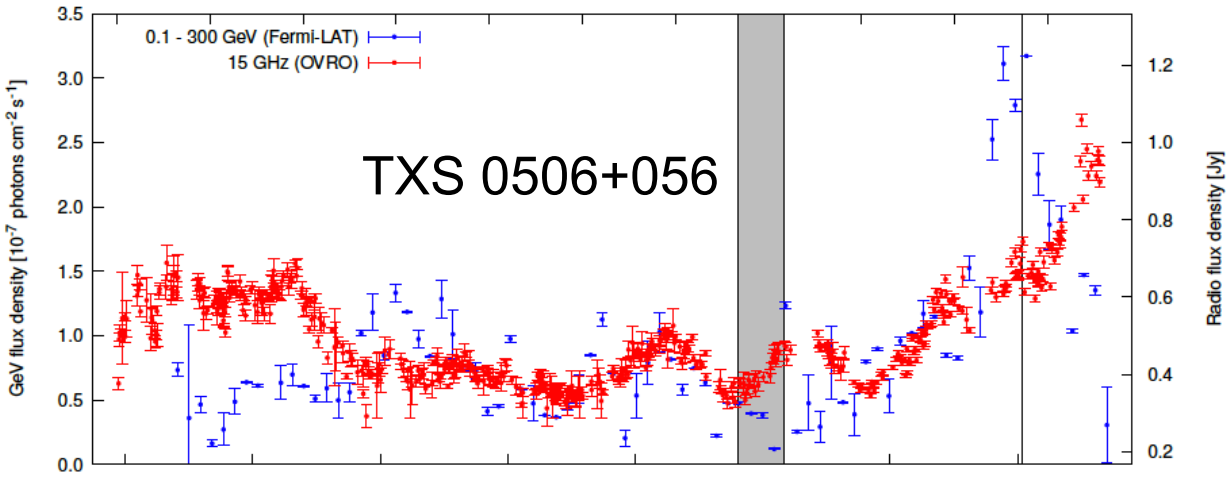


the two highest energy IceCube alerts are coincident with radio flares

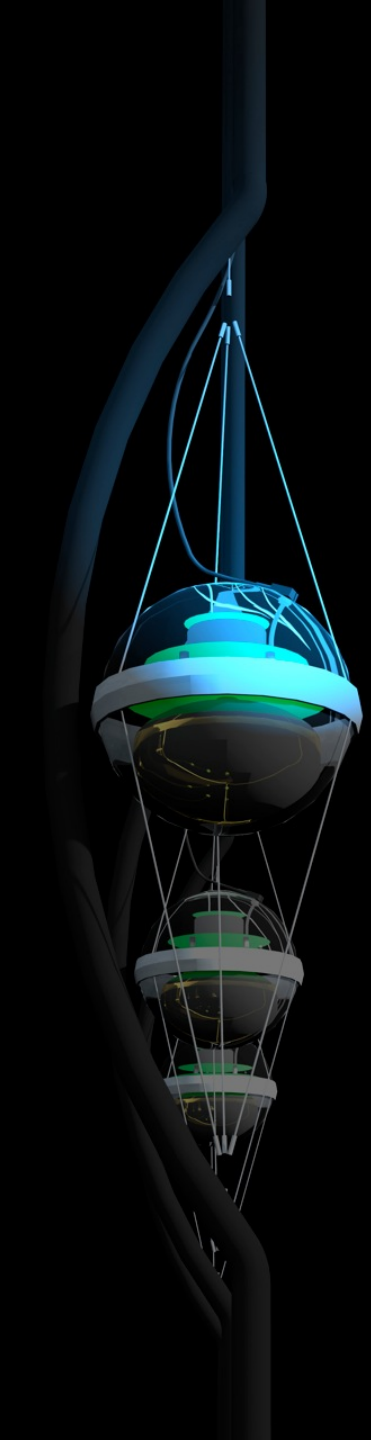
relation between ν and γ-ray luminosities

- a jet that is transparent to high energy photons does not have the density to produce neutrinos– even if protons are accelerated along the electrons.

- the opacity of the jet to protons is only 1% of the opacity to photons!

- blazars cannot be sources of cosmic neutrinos.

- best guess: agn cores with supermassive black holes are the sources, but only if they merge with target material from a major merger onto the black hole.



neutrino astronomy 2020

- it exists
- more neutrinos, better neutrinos
- closing in on cosmic ray sources

icecube.wisc.edu