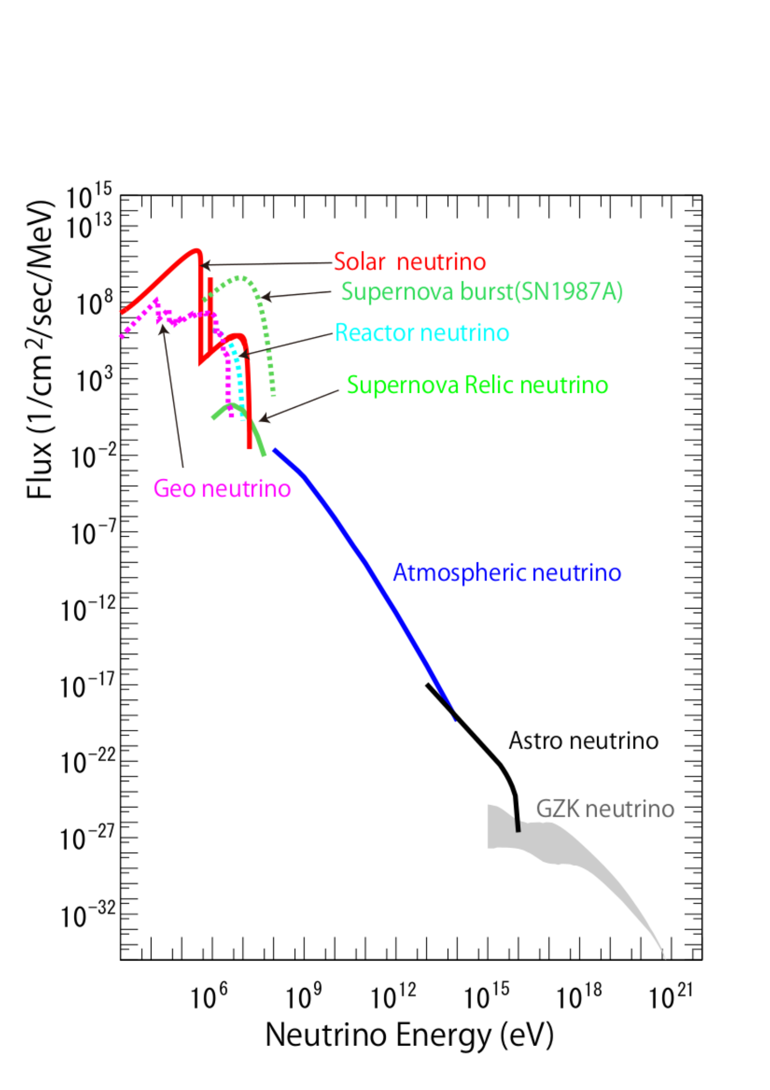
High Energy ν Astronomy

What the recent progress by IceCube tells about UHECRs

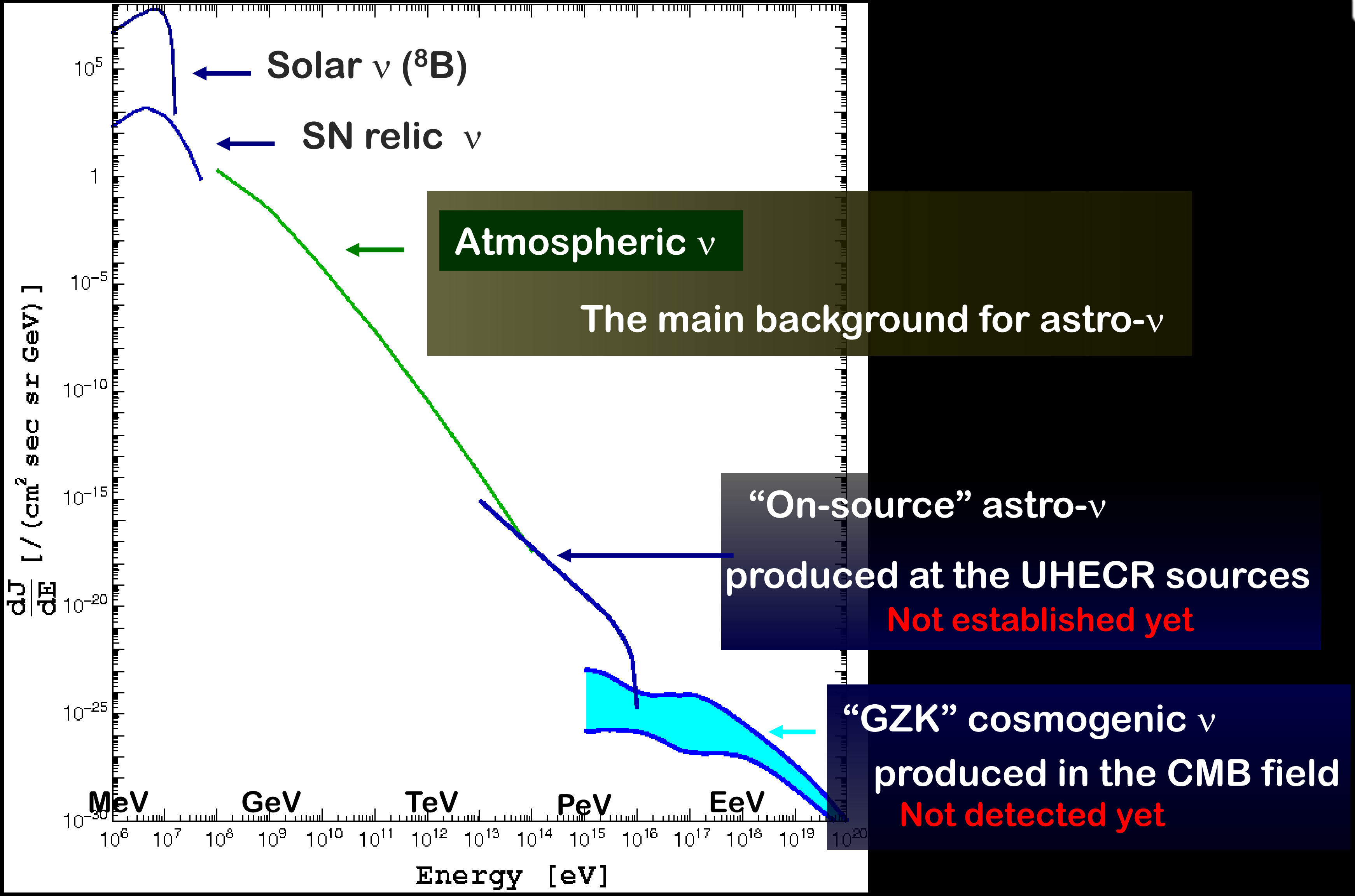
Shigeru Yoshida
ICEHAP
Chiba University

The Neutrino Flux from Geo Neutrino to GZK neutrino

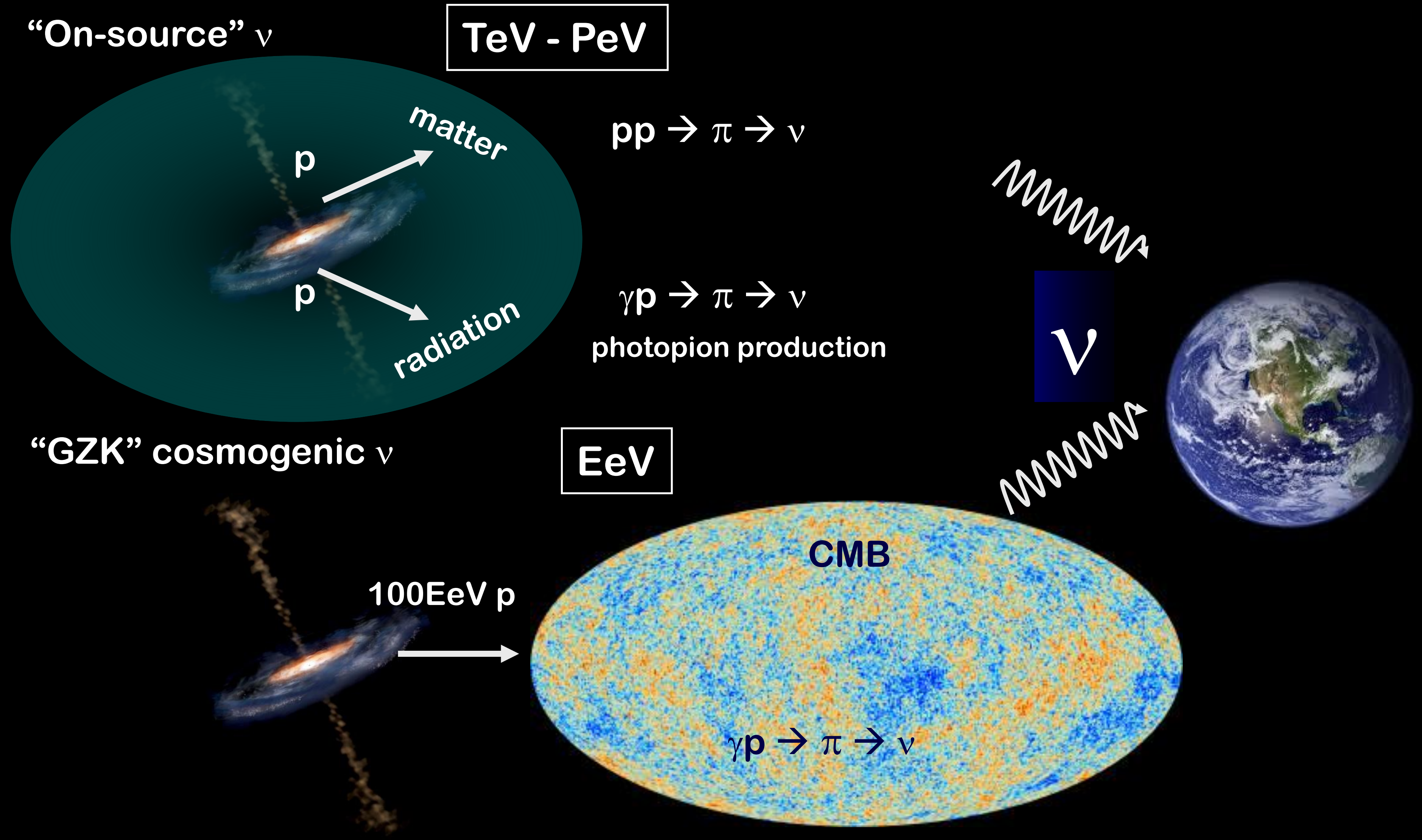


Extending to 18 orders of magnitude in Energy

The Neutrino Flux: overview



The Cosmic Neutrinos
Production Mechanisms



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ICECUBE SOUTH POLE NEUTRINO OBSERVATORY
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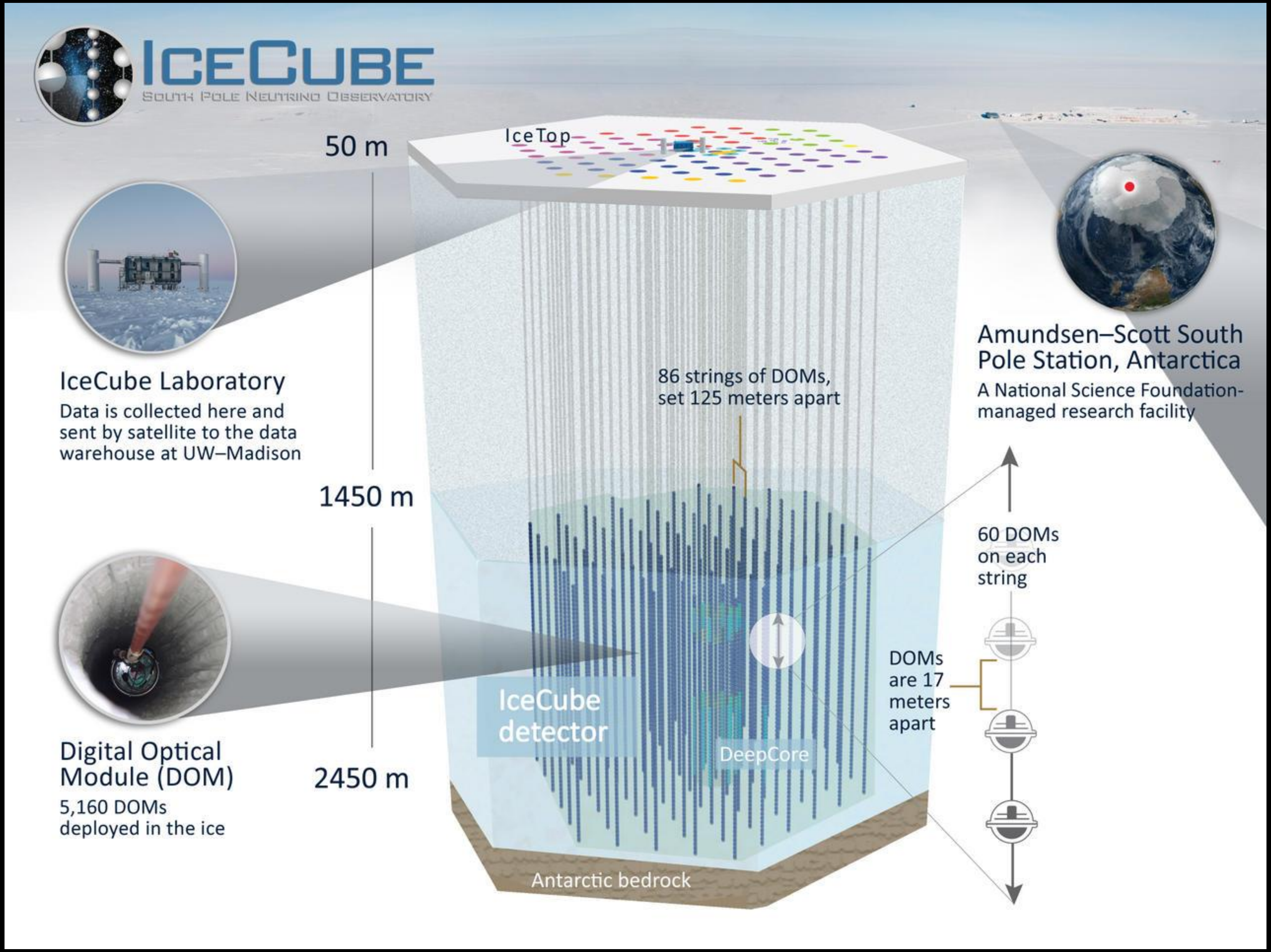
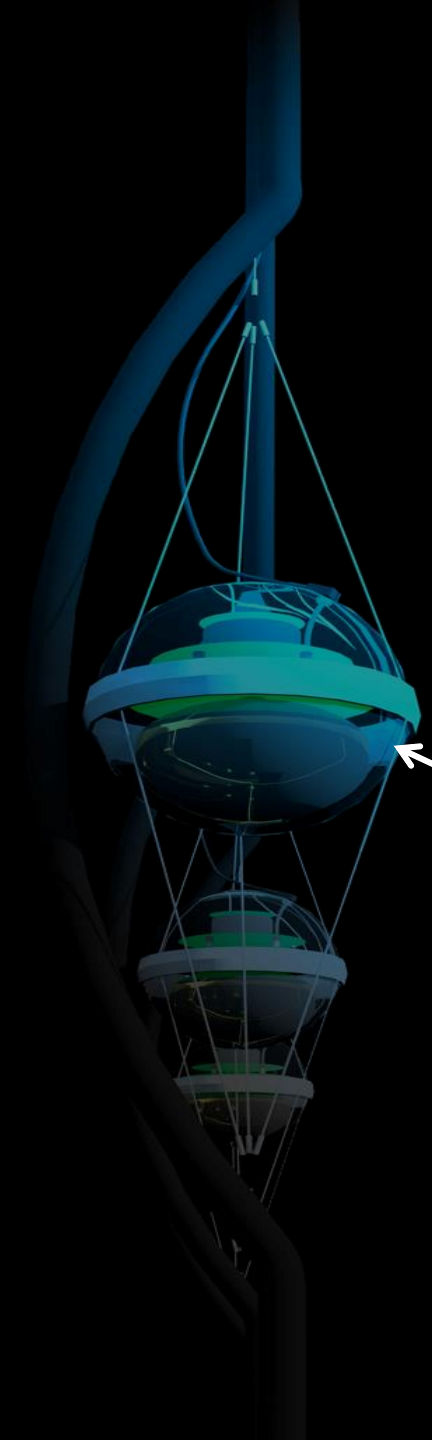
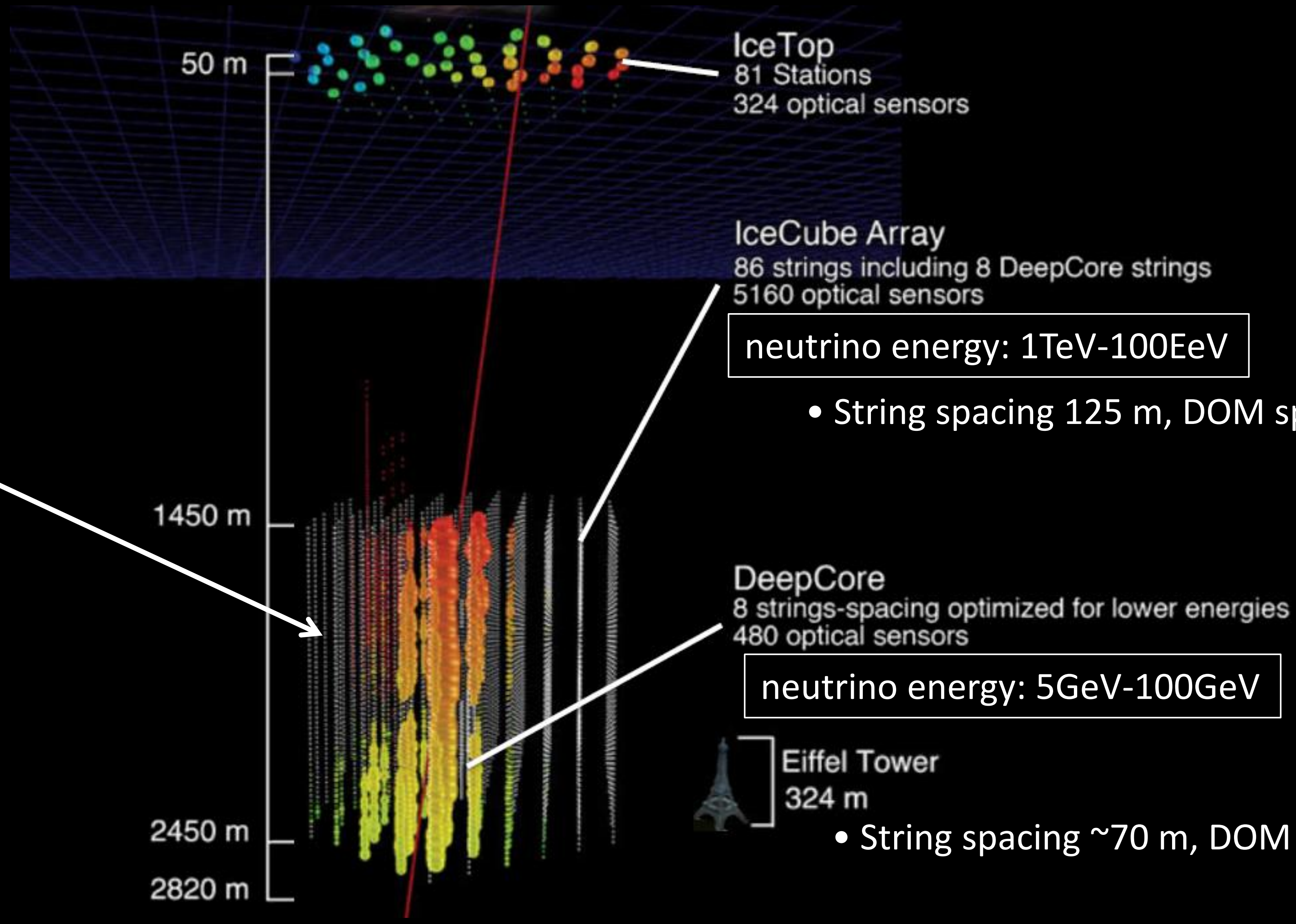
IceCube Neutrino Observatory



The IceCube Detector





neutrino energy: 1TeV-100EeV

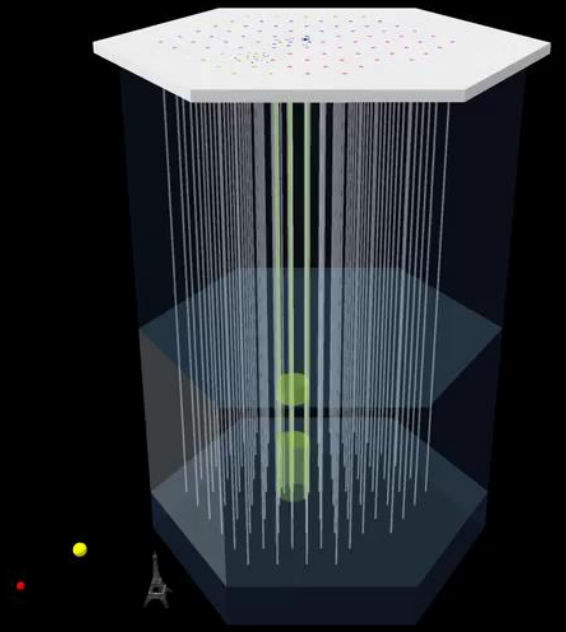
- String spacing 125 m, DOM spacing of 17 m

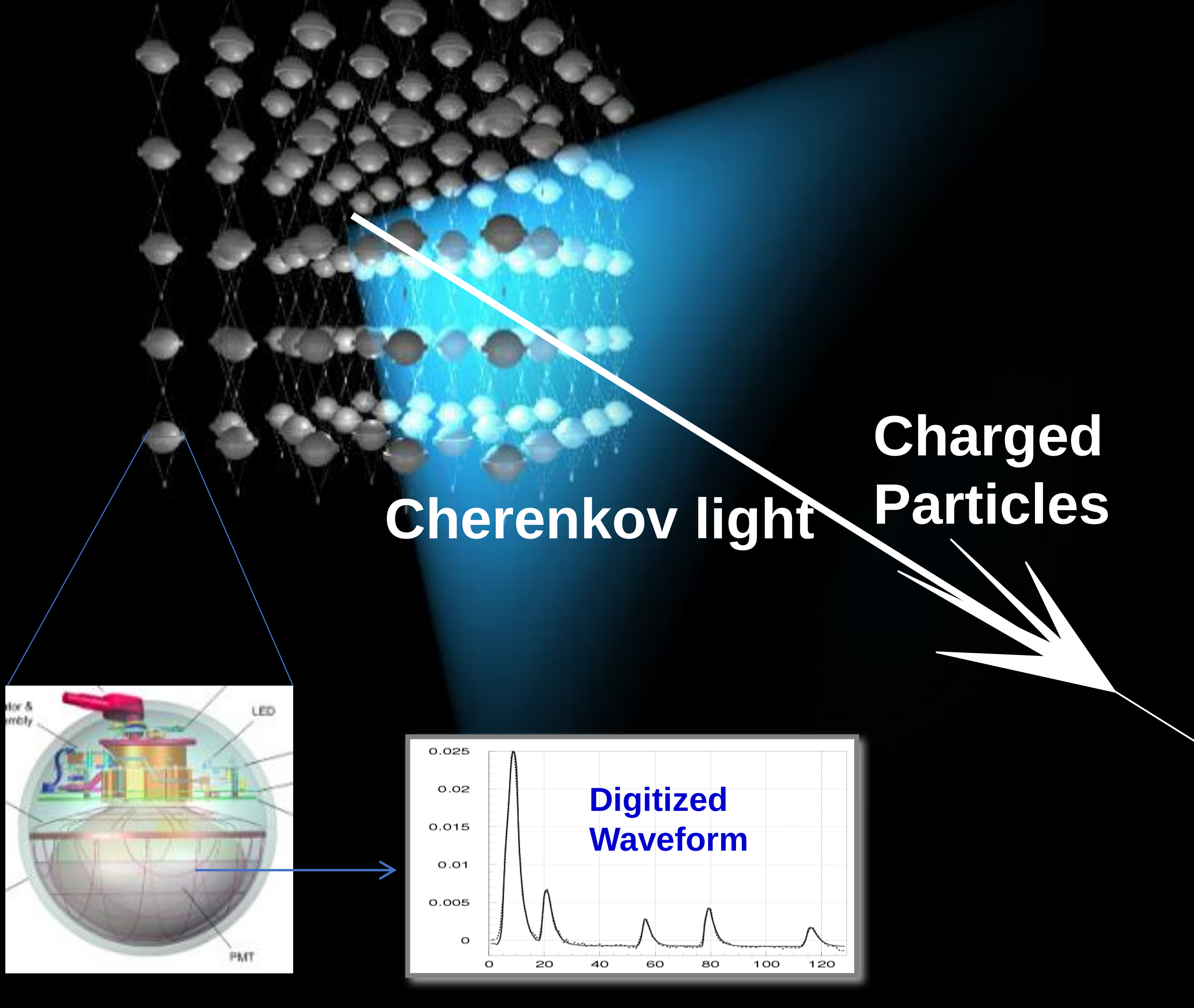
neutrino energy: 5GeV-100GeV

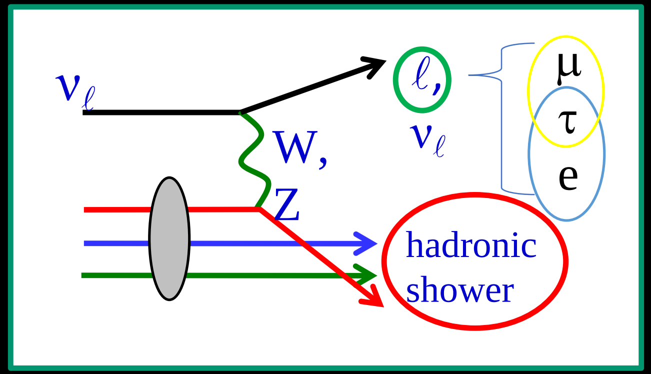
- String spacing ~70 m, DOM spacing of 7 m

Detection Principle

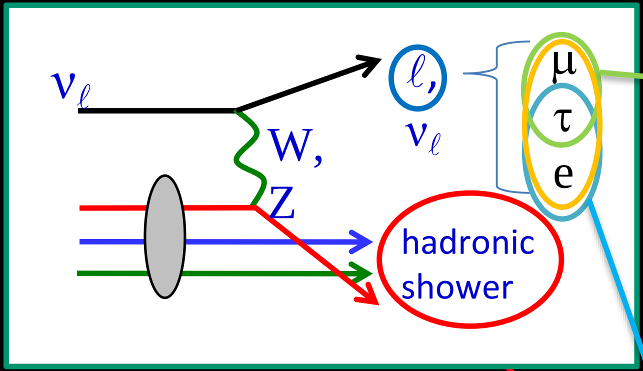
An array of photomultiplier tubes + Dark and transparent material



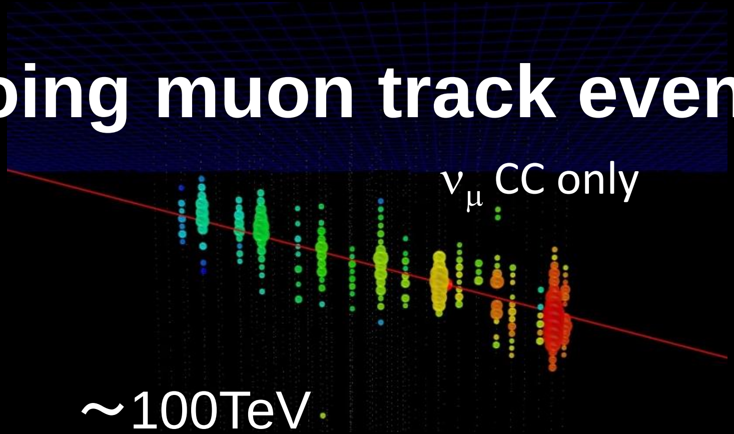




IceCube Flavor Identifications

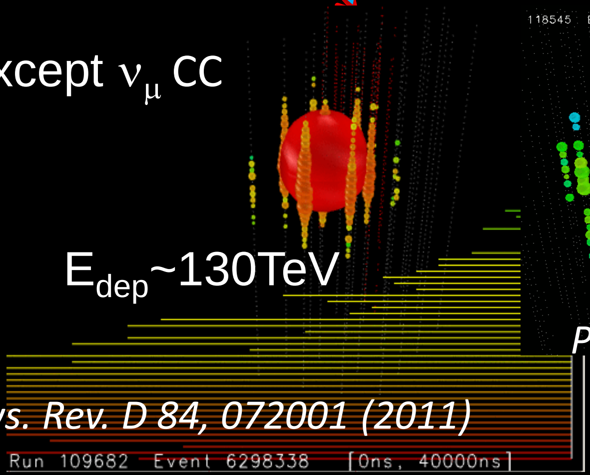


Up-going muon track event



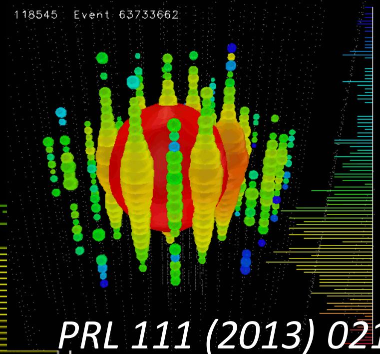
Cascade events

All except ν_μ CC

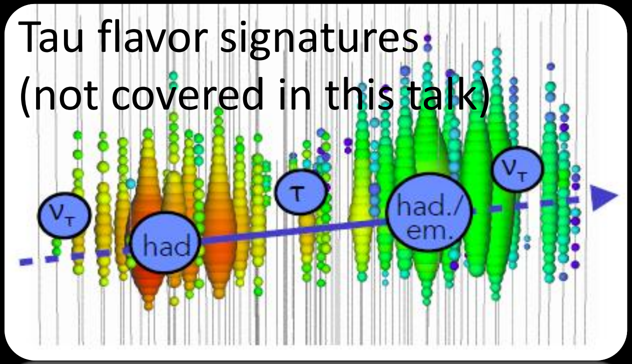


E_{dep}~130TeV

Phys. Rev. D 84, 072001 (2011)



PRL 111 (2013) 021103



IceCube Event Topology

Track

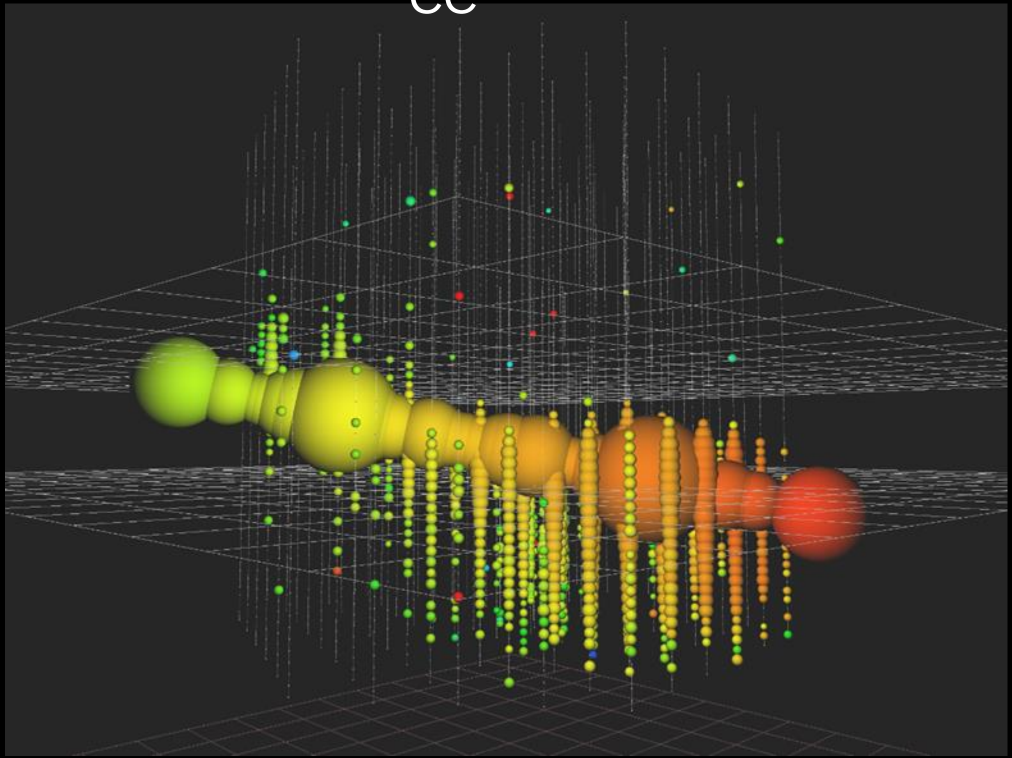
$\nu_\mu \xrightarrow[CC]{} \mu$

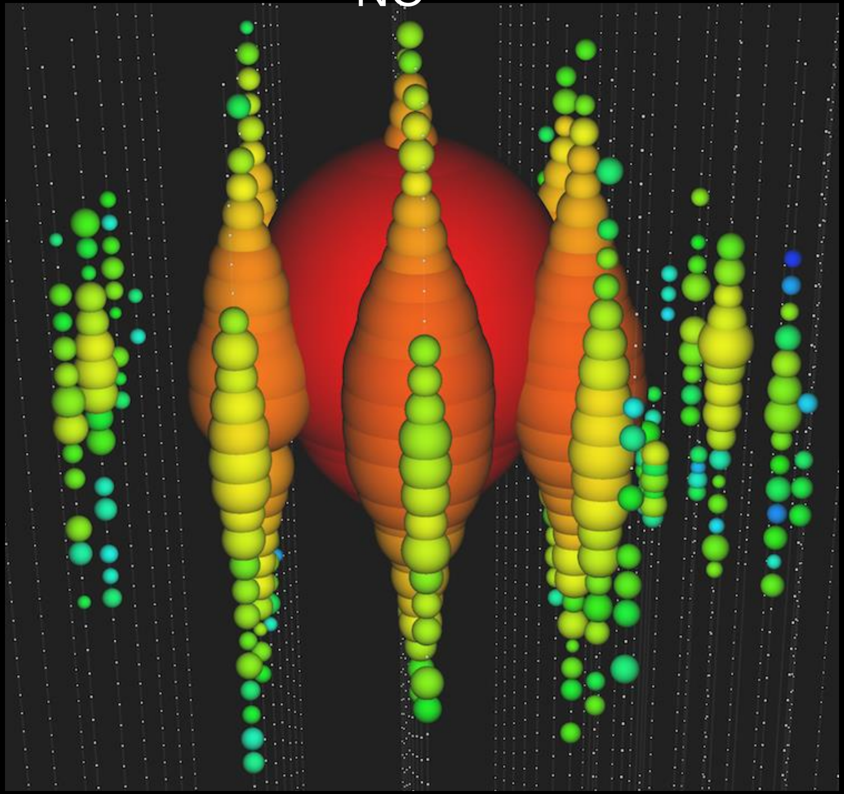
$\nu_\tau \xrightarrow[CC]{} \tau$ (only at ultra-high energies)

Cascade (shower)

$\nu_e \xrightarrow[CC]{} e + X$

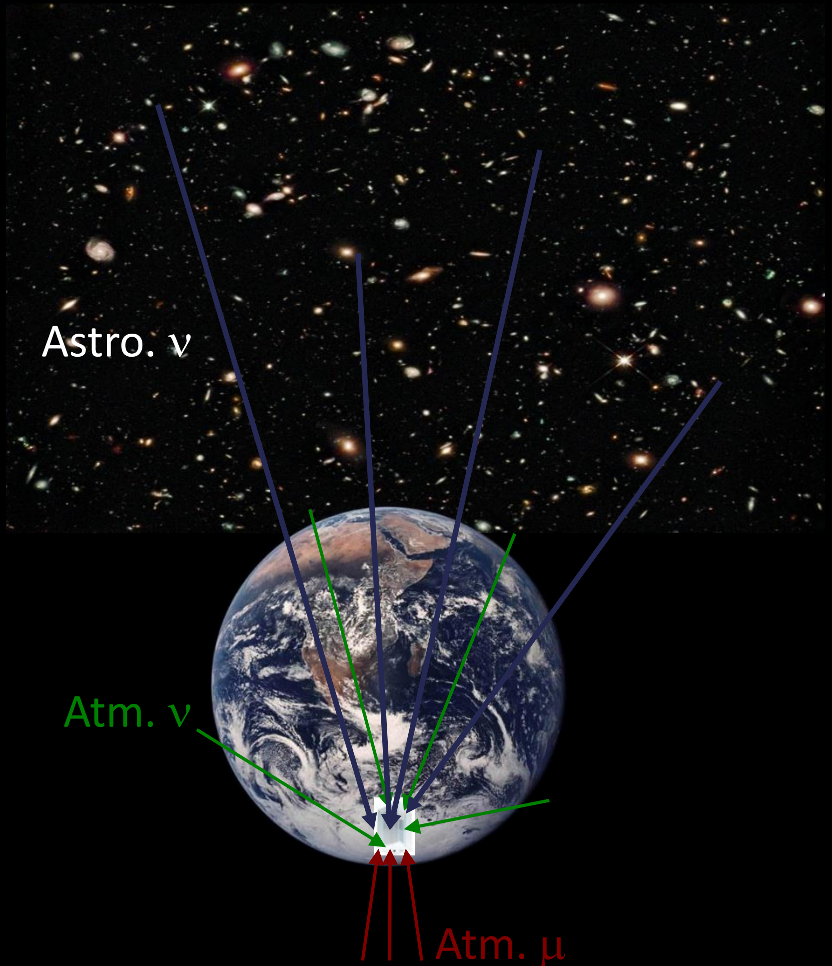
$\nu_x \xrightarrow[NC]{} x + X$ x=e, μ, τ



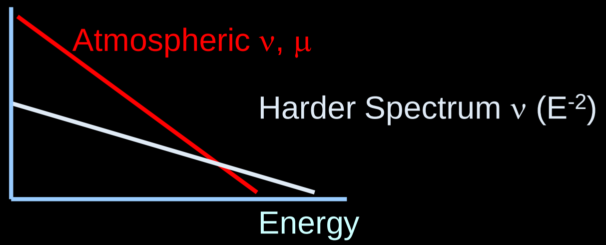


Searches for a Diffuse Neutrino Flux

Diffuse Flux = effective sum from all (unresolved) extraterrestrial sources (e.g., AGNs)
Possibility to observe diffuse signal even if flux from any individual source is too weak for detection as a point source



Search for excess of astrophysical neutrinos with a harder spectrum than background atmospheric neutrinos



Advantage over point source search:
- can detect weaker fluxes

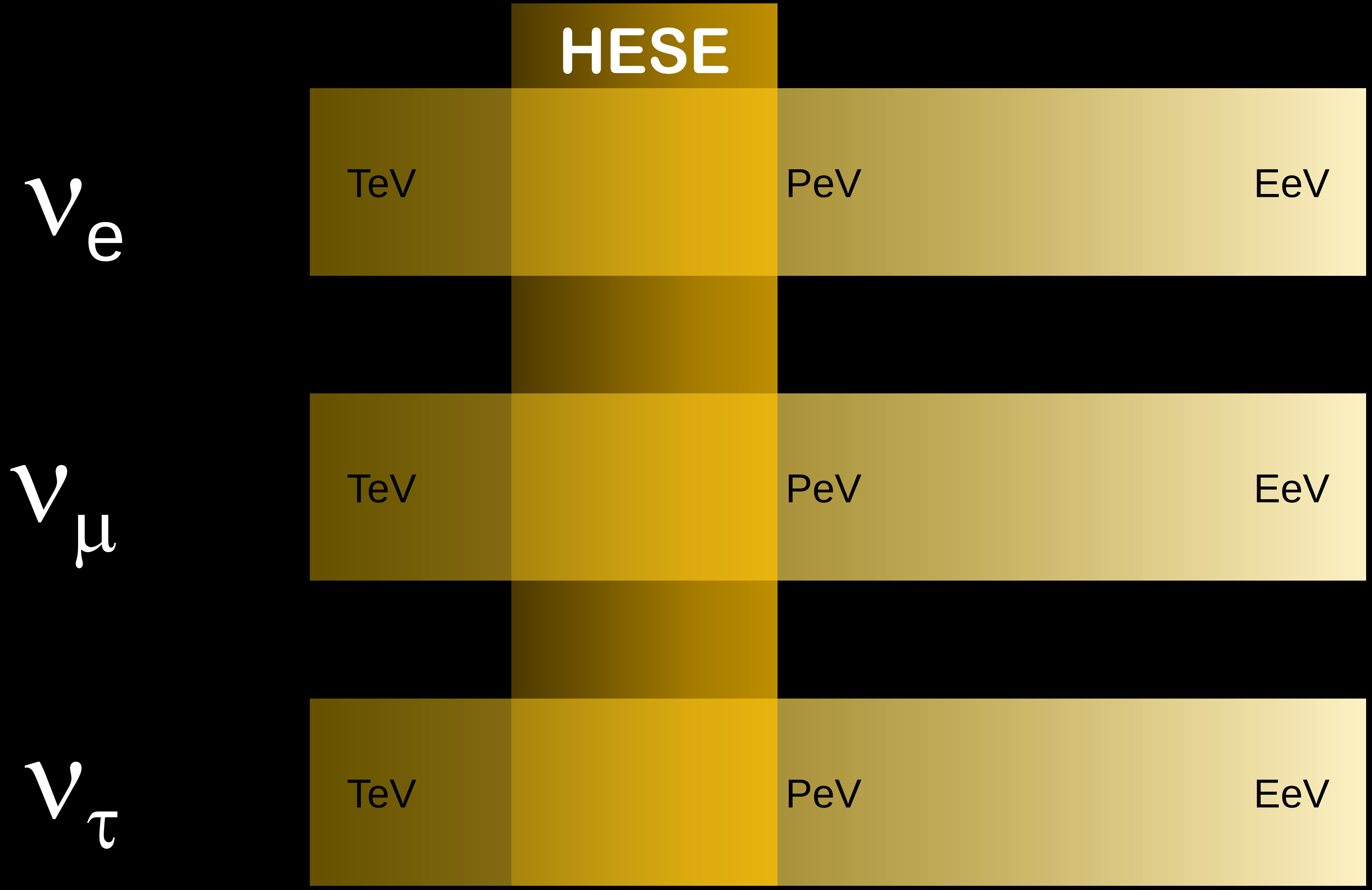
Disadvantages:
- high background
- must simulate background precisely

Sensitive to all three neutrino flavors in principle

IceCube ν search channels

ν_e	TeV	PeV	EeV
ν_μ	TeV	PeV	EeV
ν_τ	TeV	PeV	EeV

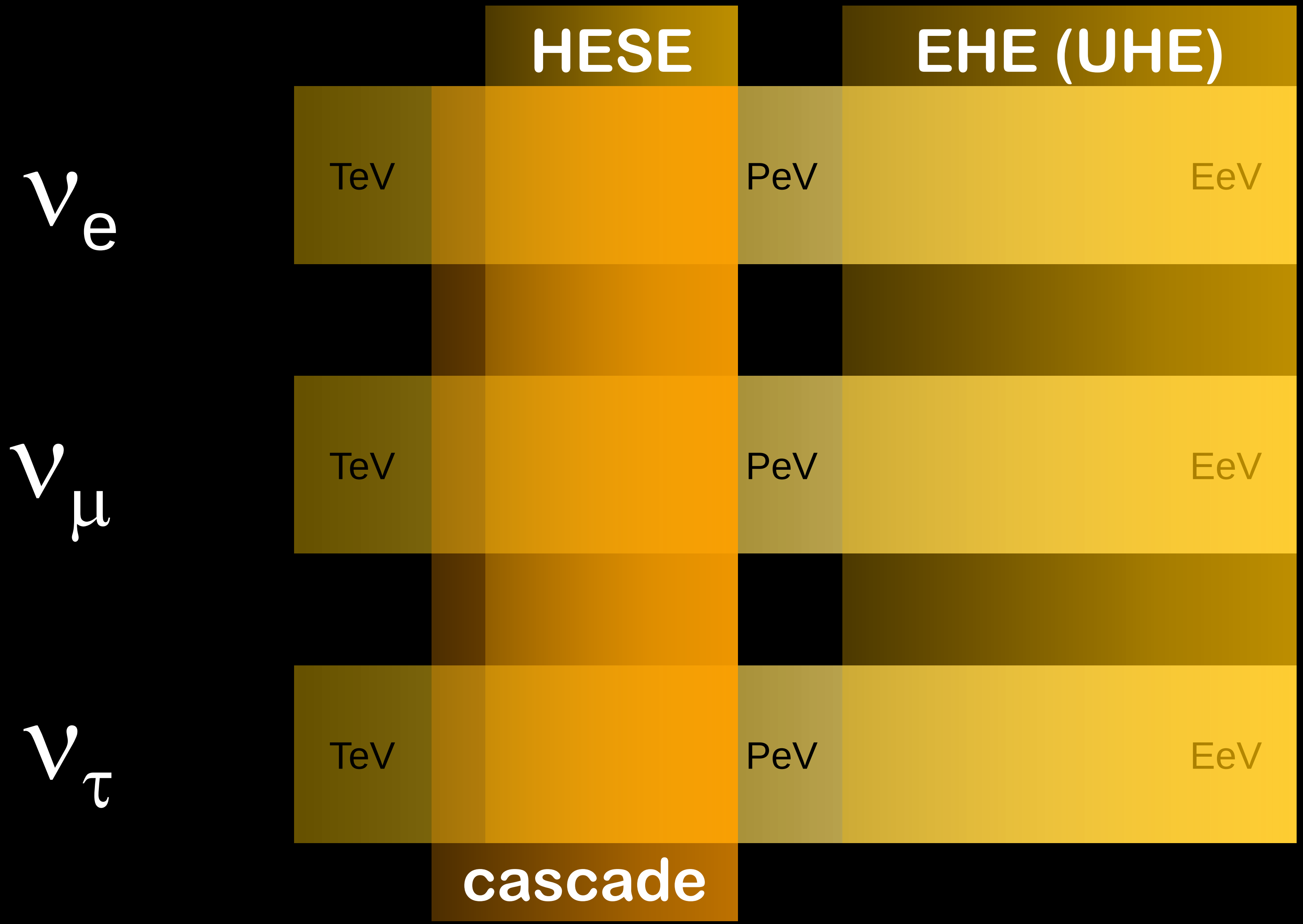
IceCube ν search channels



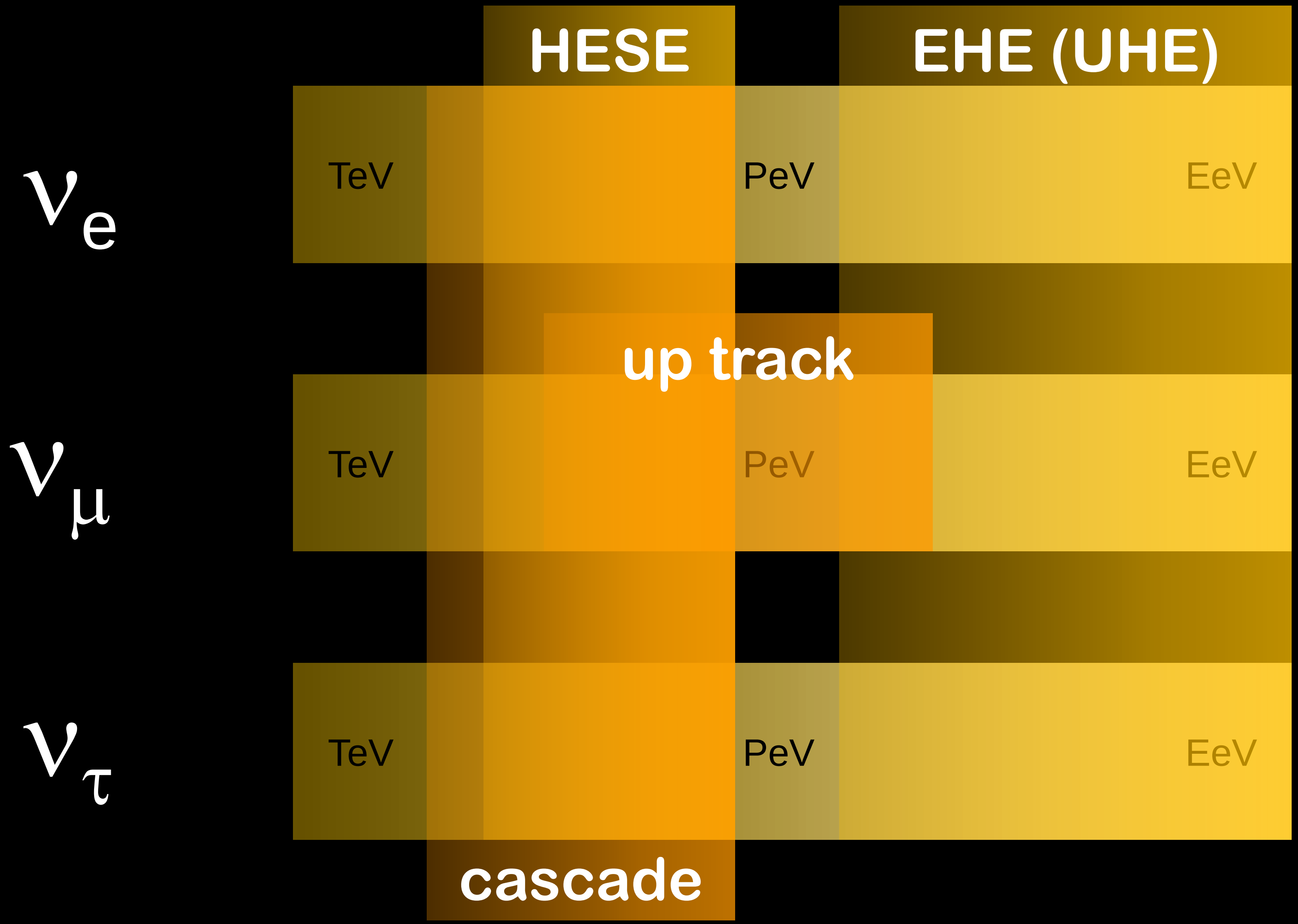
IceCube ν search channels

		HESE		EHE (UHE)
ν_e	TeV		PeV	EeV
ν_μ	TeV		PeV	EeV
ν_τ	TeV		PeV	EeV

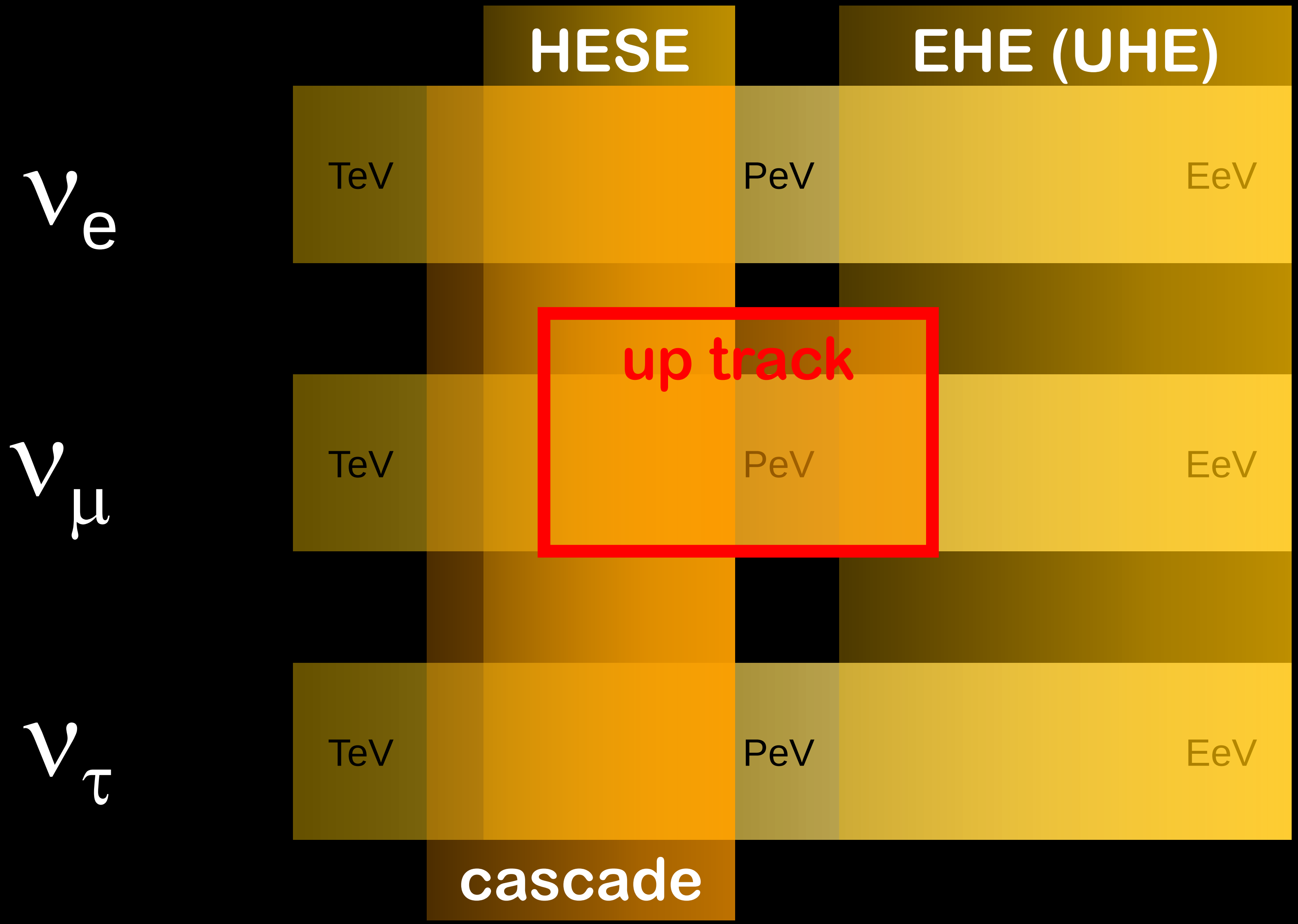
IceCube ν search channels



IceCube ν search channels



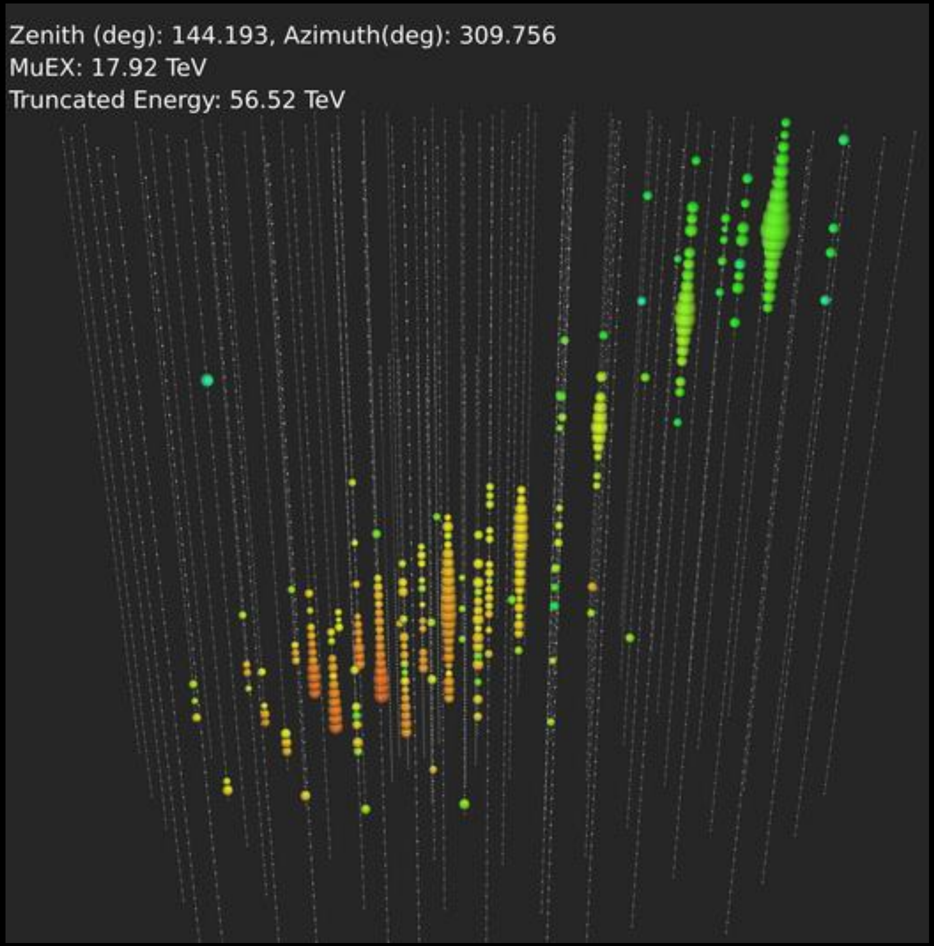
IceCube ν search channels



TeV PeV EeV

Upward track (~300 TeV-)

The “traditional” ν_μ search



BDT cuts on the following variables

Bayesian likelihood ratio

Center of gravity

Number of hit DOMs

Separation length spline-mpe

Number of directly hit DOMs

Direct track length

Reduced log-likelihood

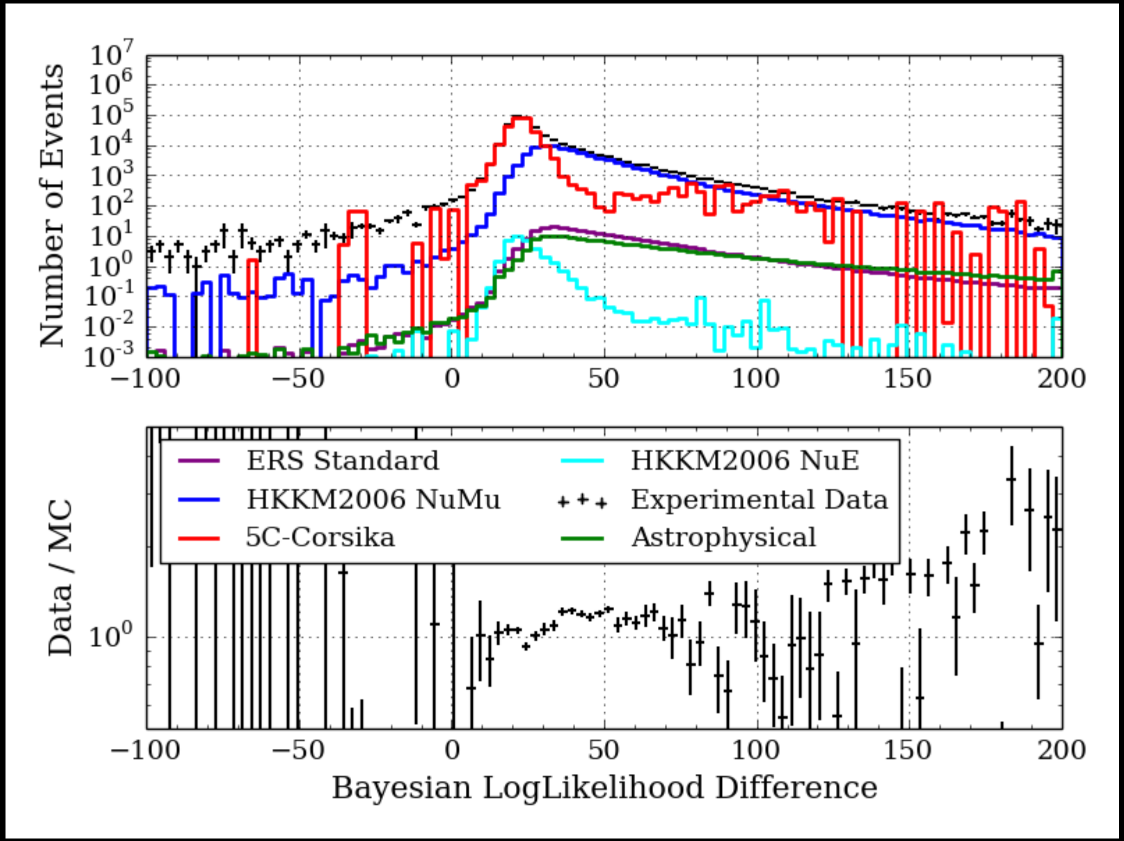
Direct smoothness

paraboloid

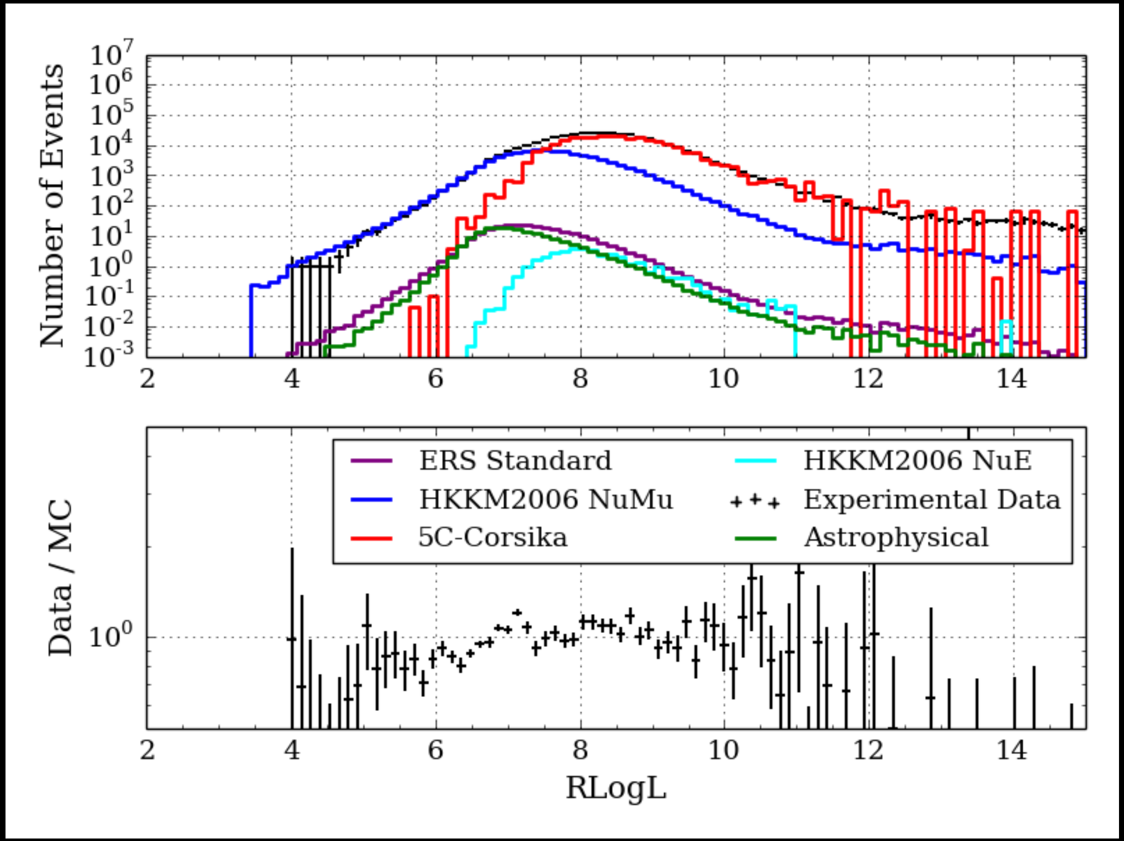
Upward track (~300 TeV-)

The “traditional” ν_μ search

Bayesian likelihood ratio



Reduced log-likelihood



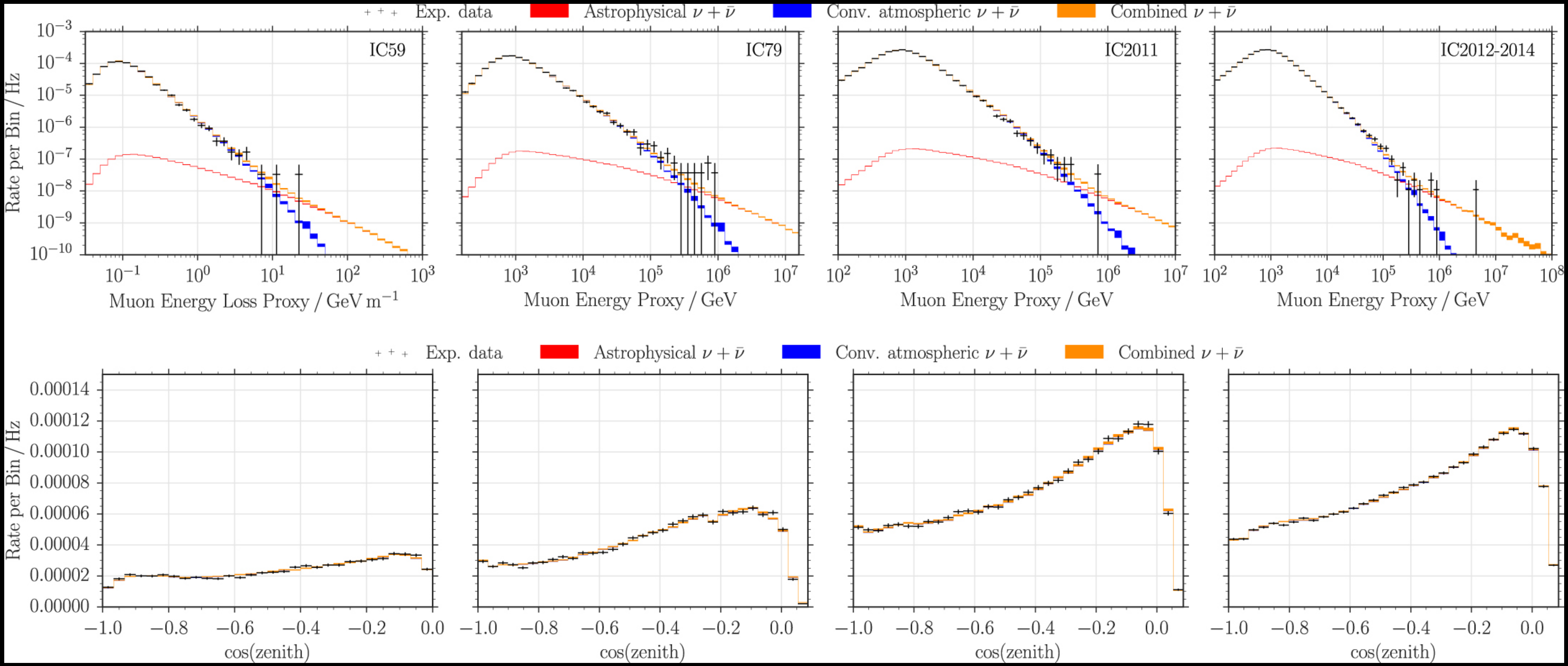
TeV PeV EeV

Upward track (~300 TeV-)

The “traditional” ν_μ search

IceCube collaboration Astrophys. J. **833** 3 (2016)

6 years of IceCube data (2009-2014)



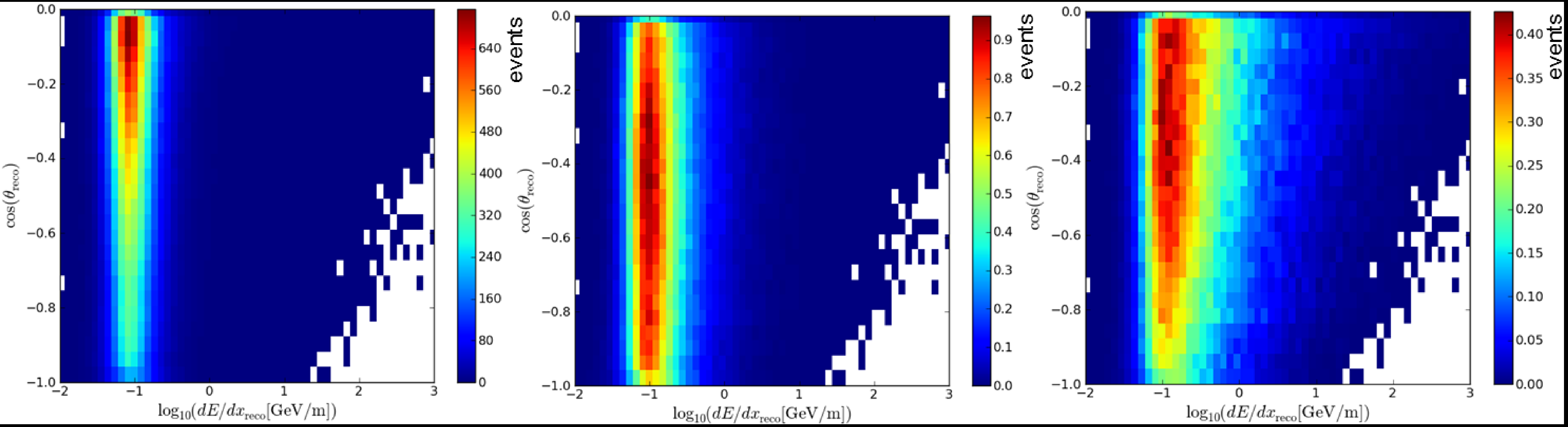
TeV PeV EeV

Upward track (~300 TeV-)

The “traditional” ν_μ search

IceCube collaboration Astrophys. J. **833** 3 (2016)

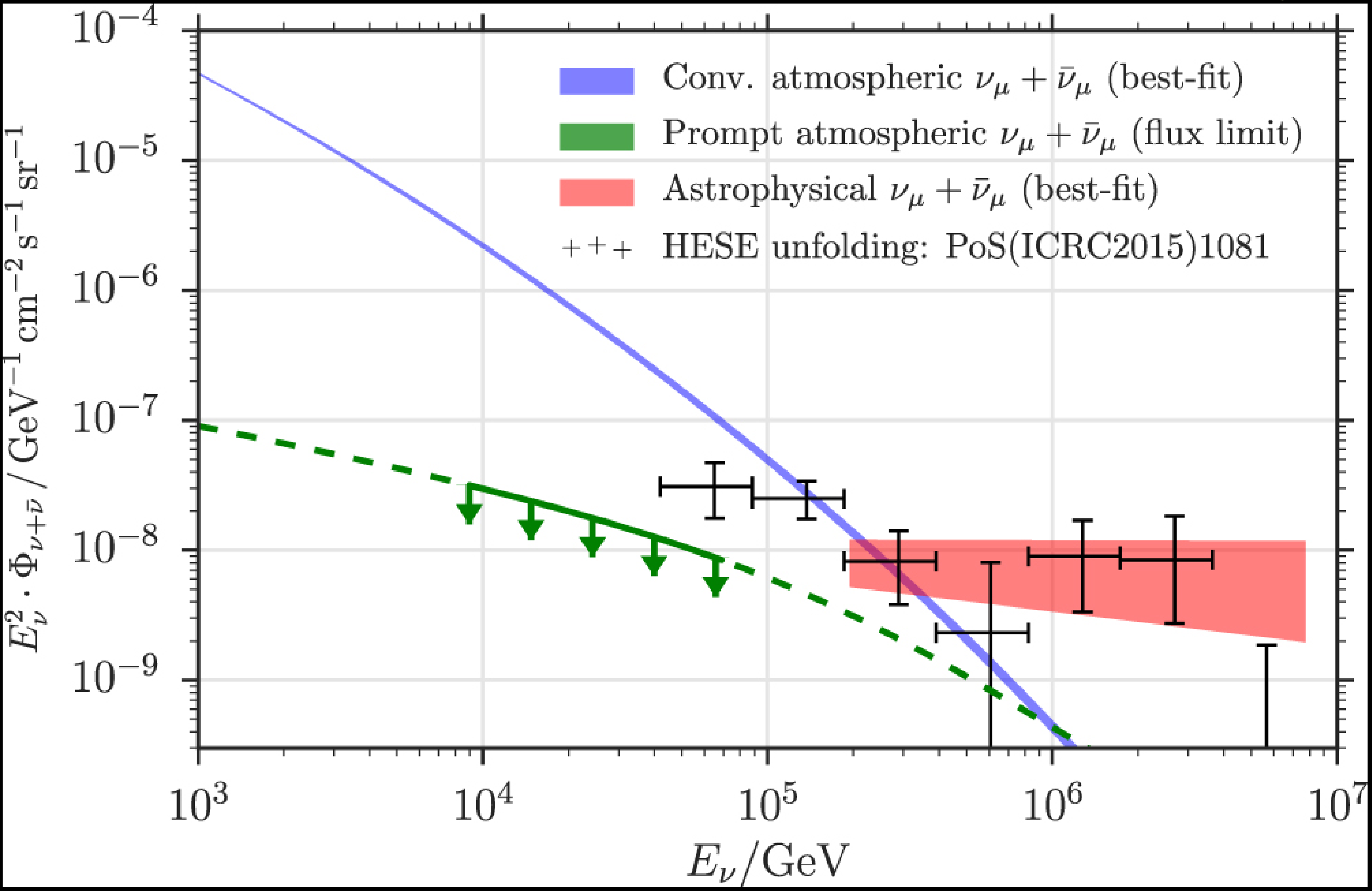
conventional atmospheric ν_μ prompt atmospheric ν_μ astrophysical atmospheric ν_μ

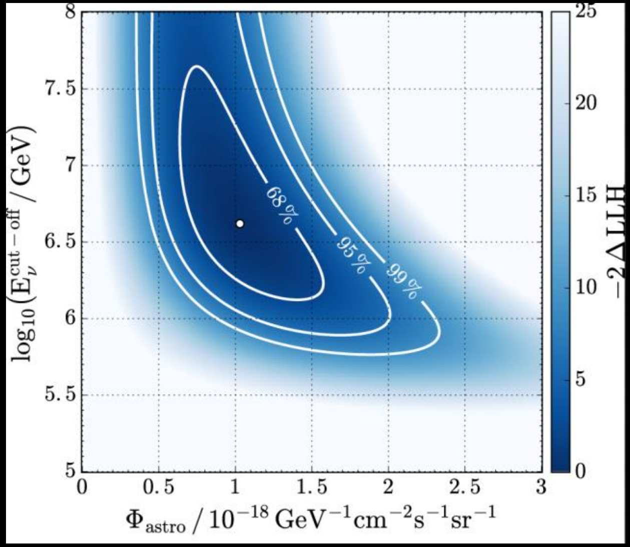


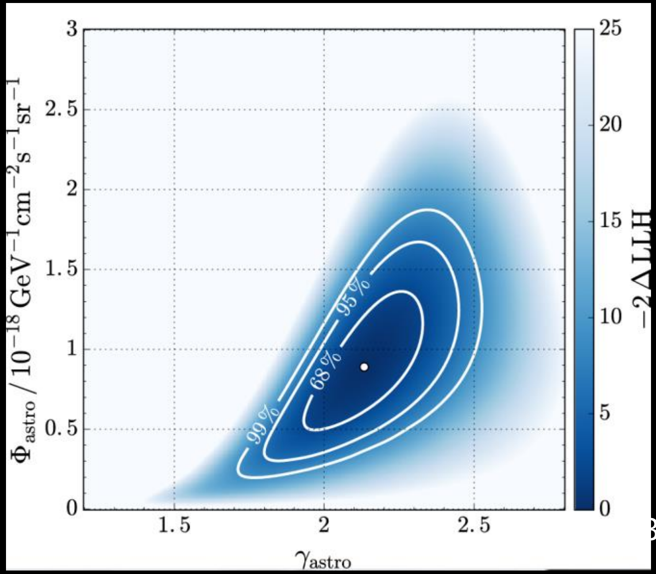
TeV PeV EeV

Upward track (~300 TeV-)

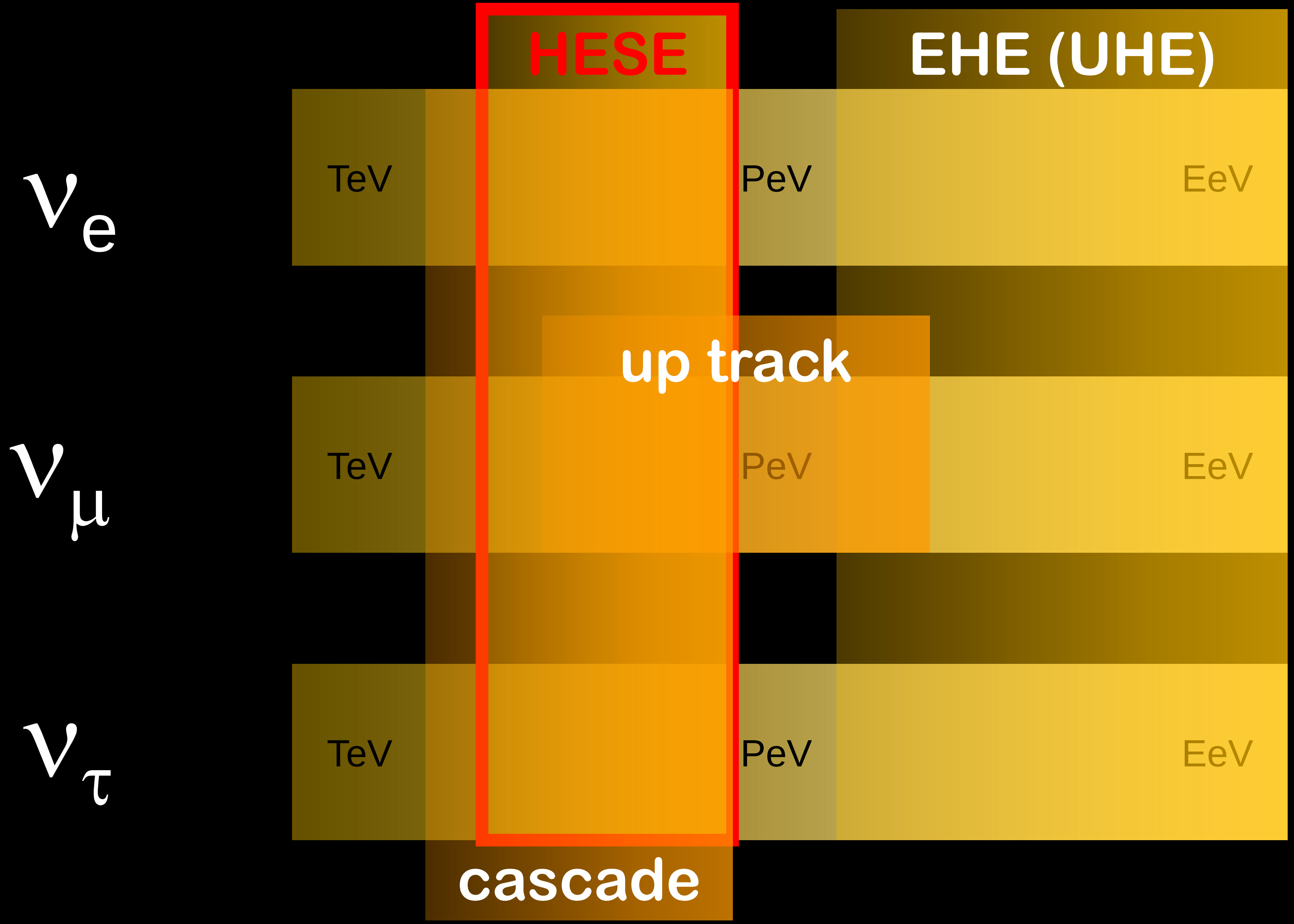
The “traditional” ν_μ search







IceCube ν search channels

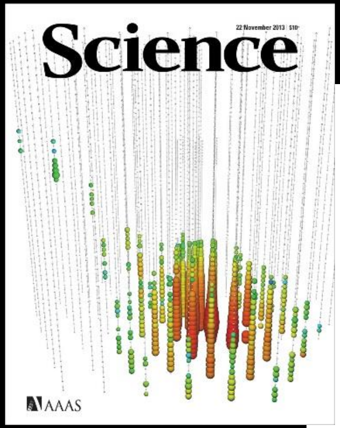


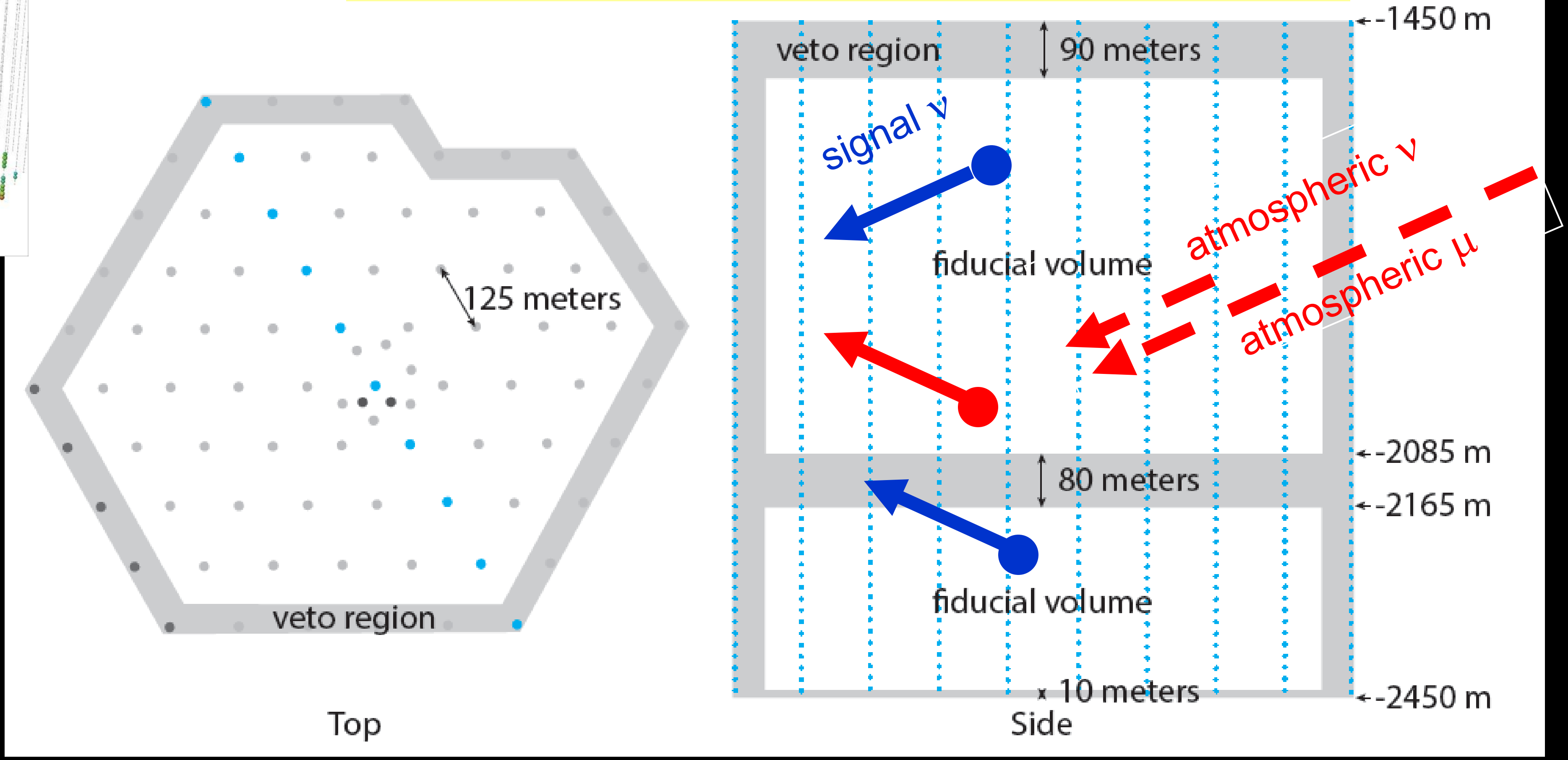
TeV PeV EeV

Mid Energy (60 TeV-)

HESE

look for only events with their interaction vertices within the fiducial volume



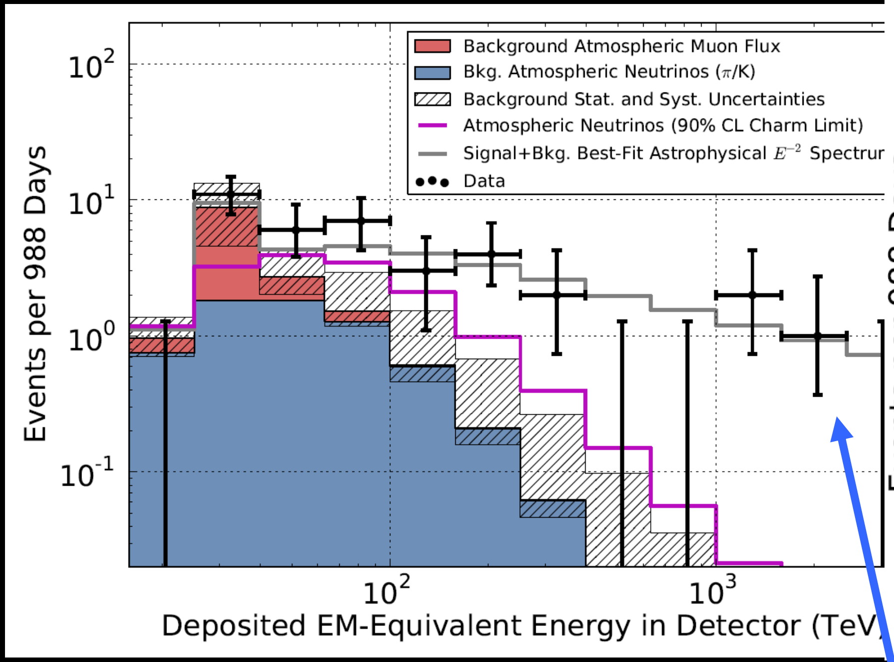


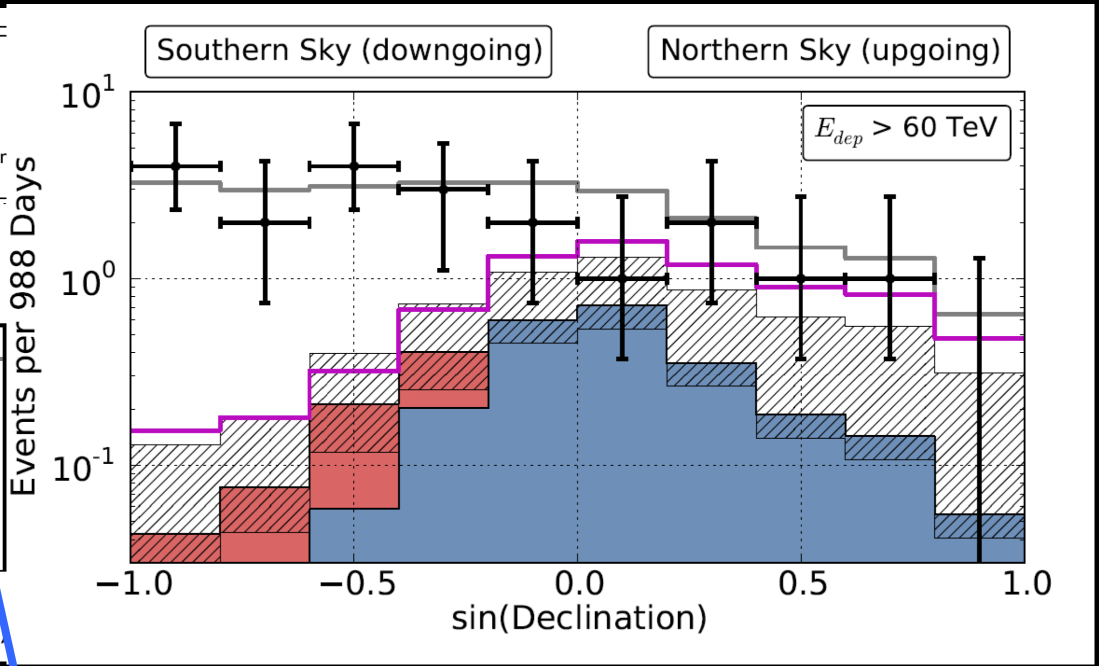
TeV PeV EeV

Mid Energy (60 TeV-)

IceCube collaboration
Phys. Rev. Lett. 113, 101101

IceCube 3 years data (2010-2013)

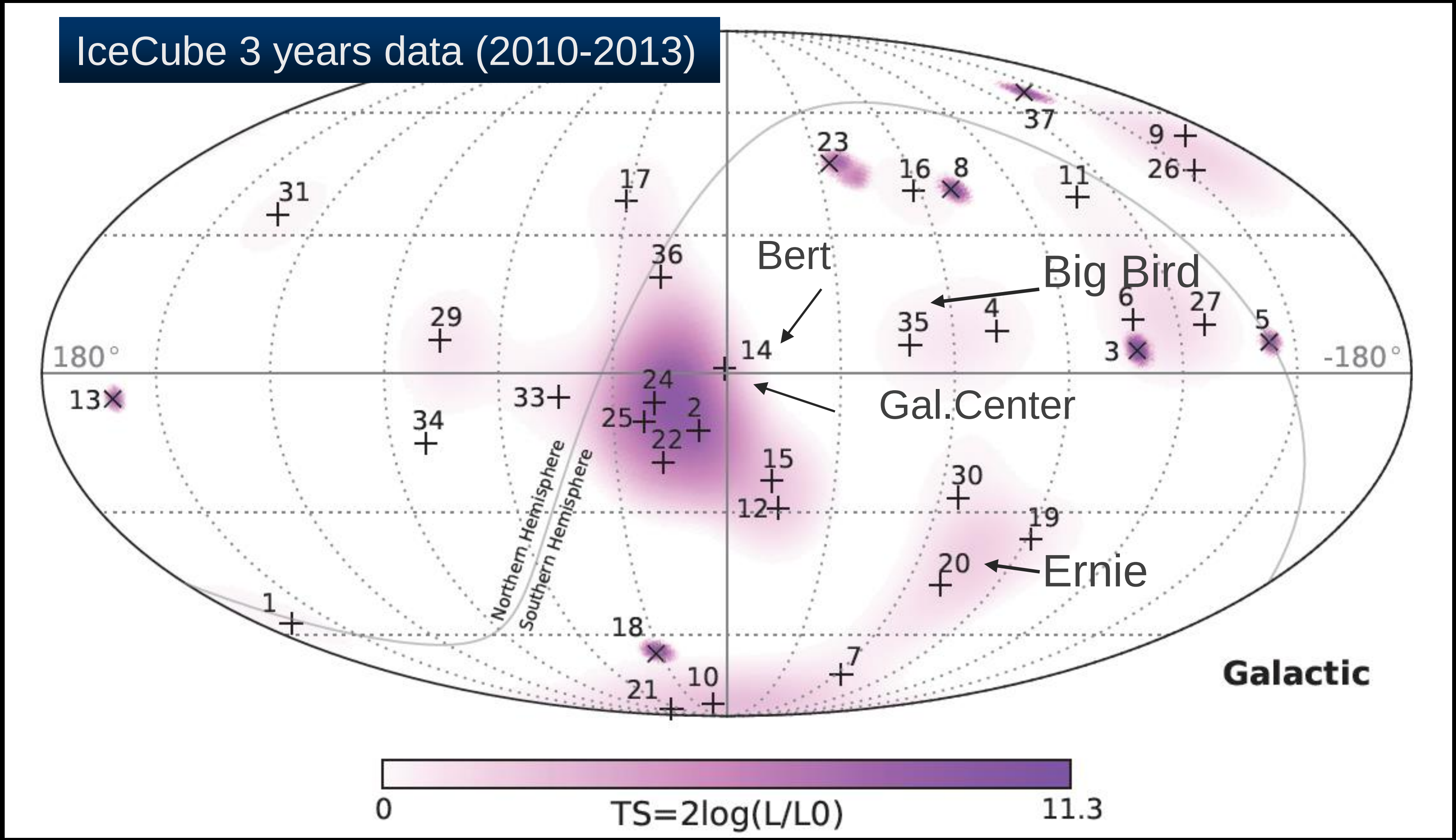




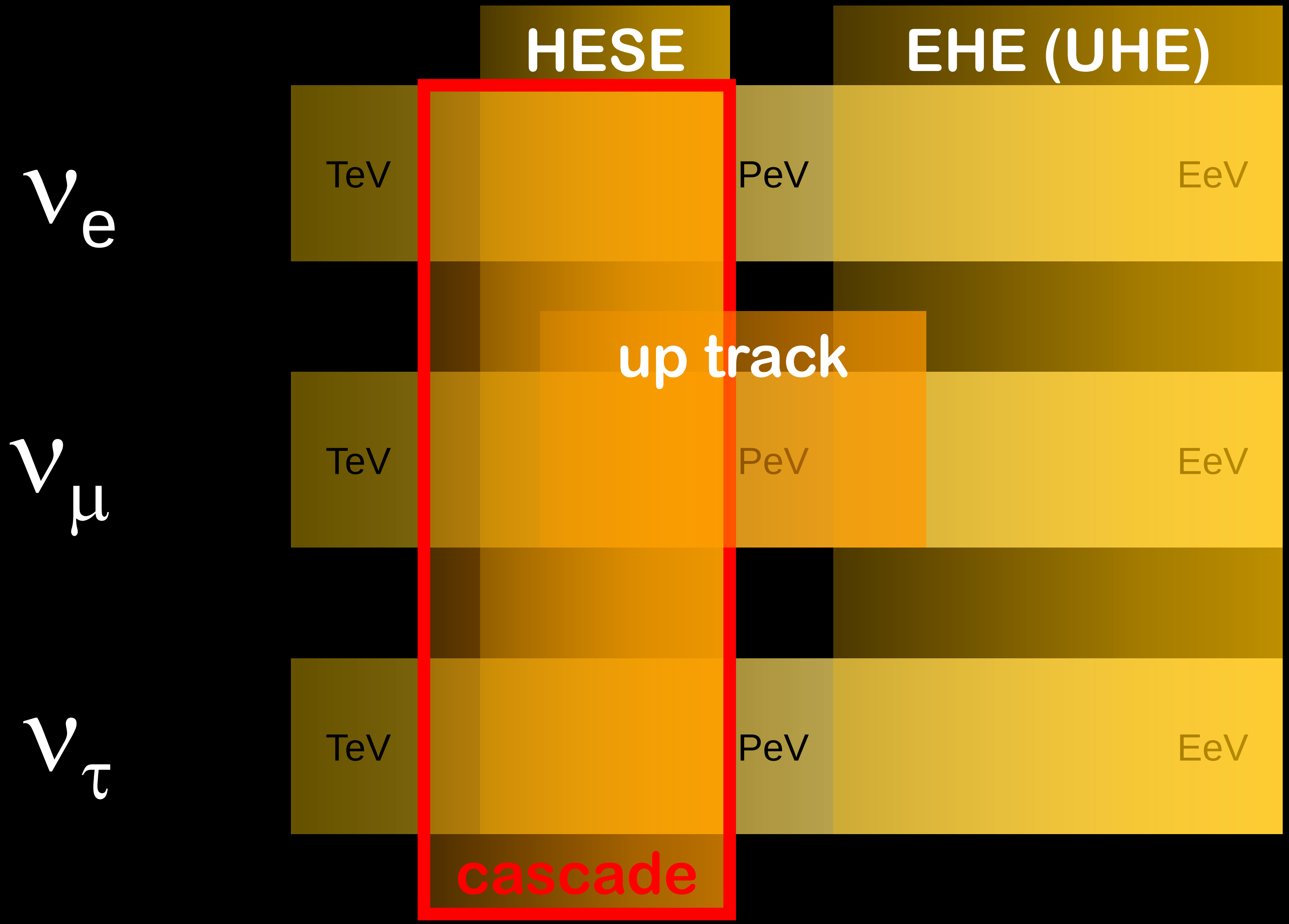
2PeV
“Big Bird”

Mid Energy (60 TeV-)

TeV PeV EeV



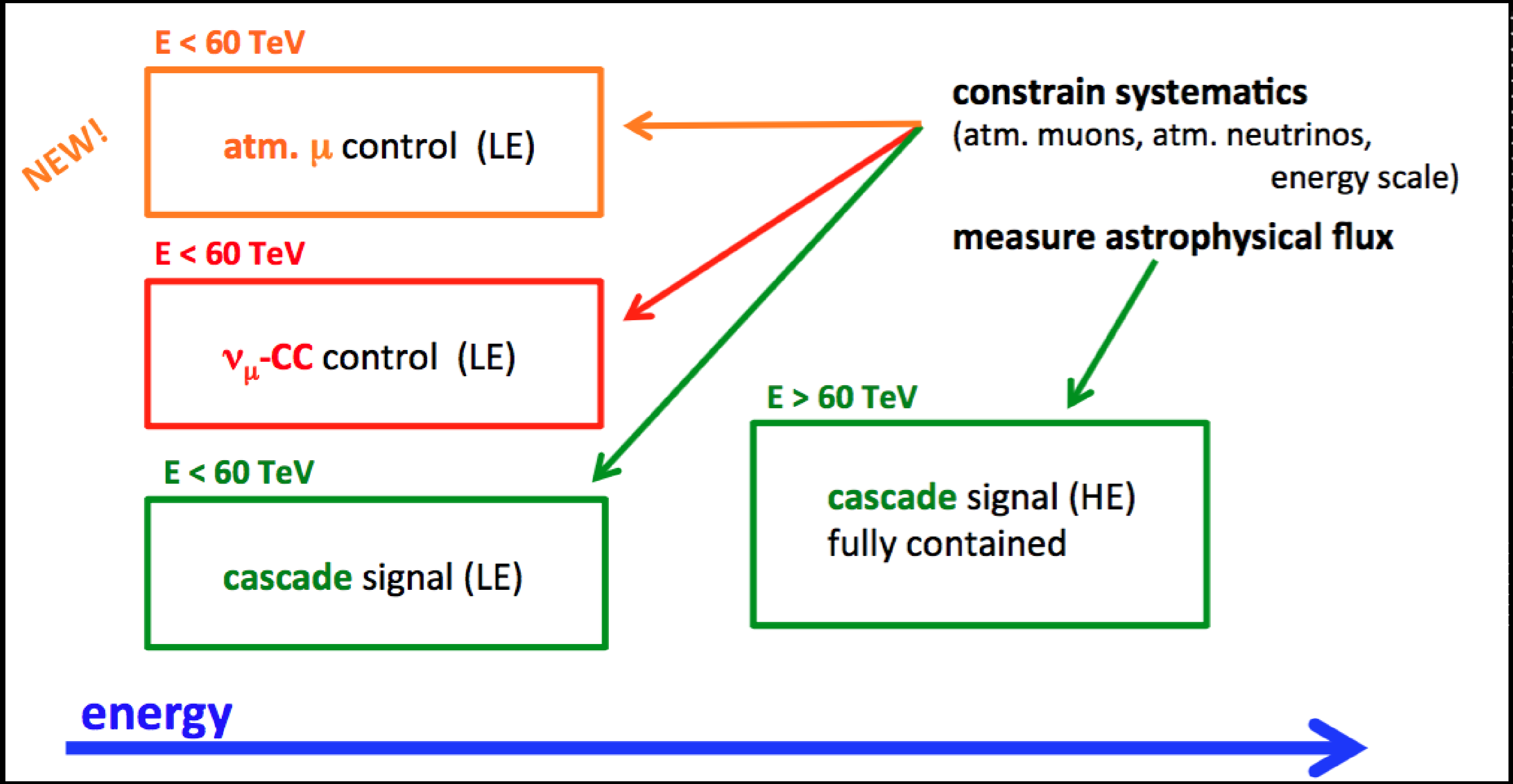
IceCube ν search channels

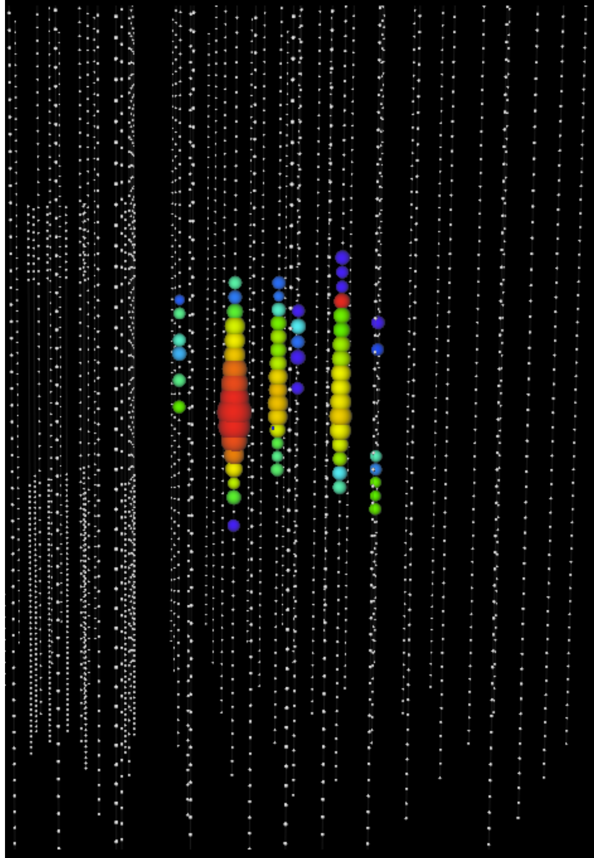


TeV PeV EeV

Search with Cascade Events

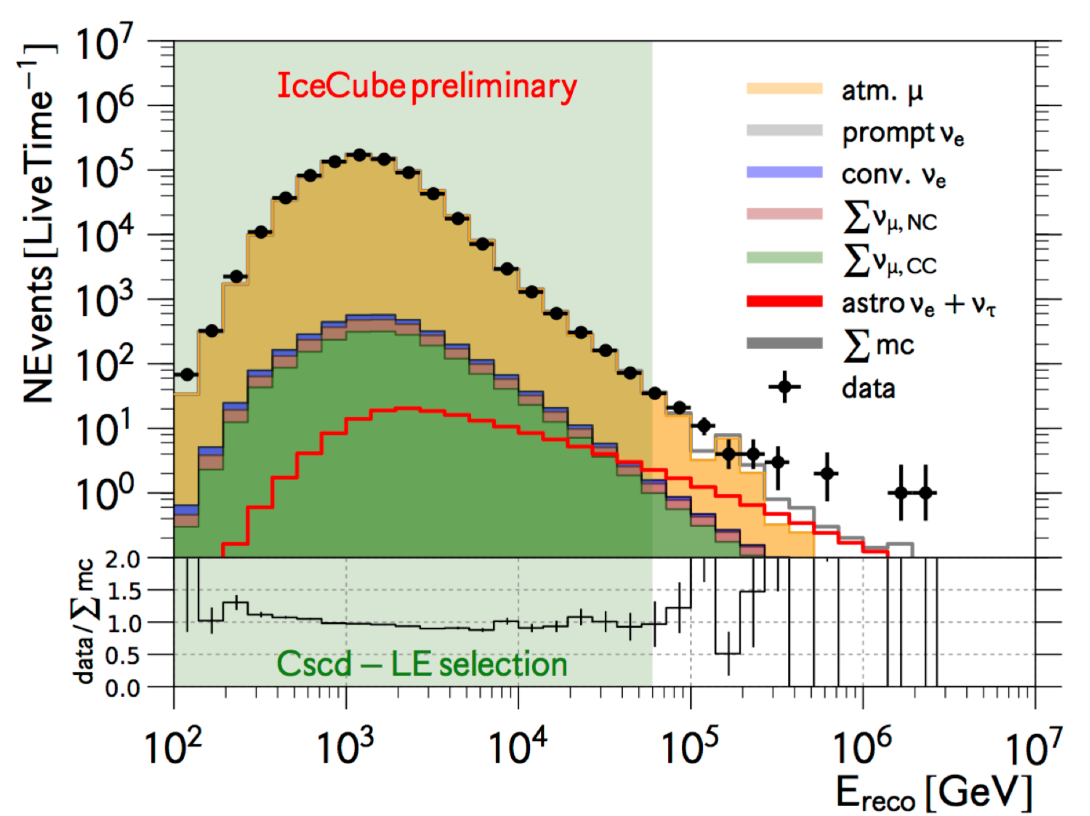
4 years of data (IC2012-IC2015)

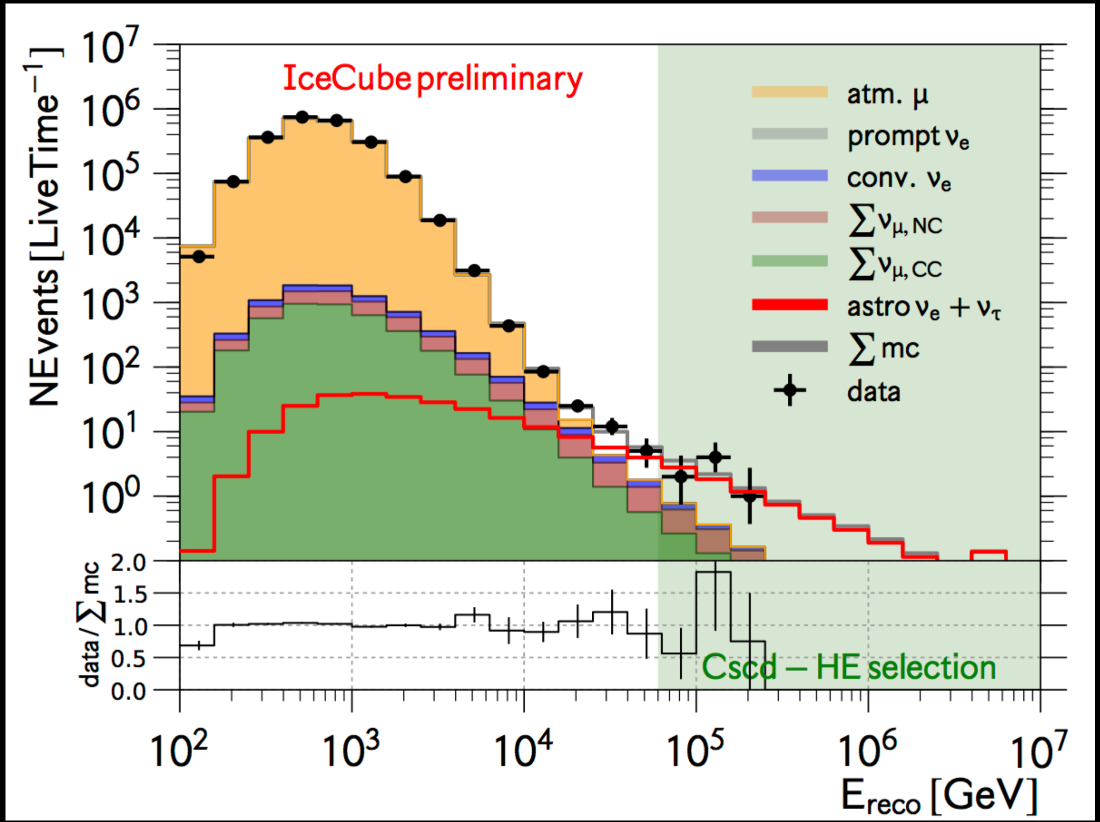




TeV PeV EeV

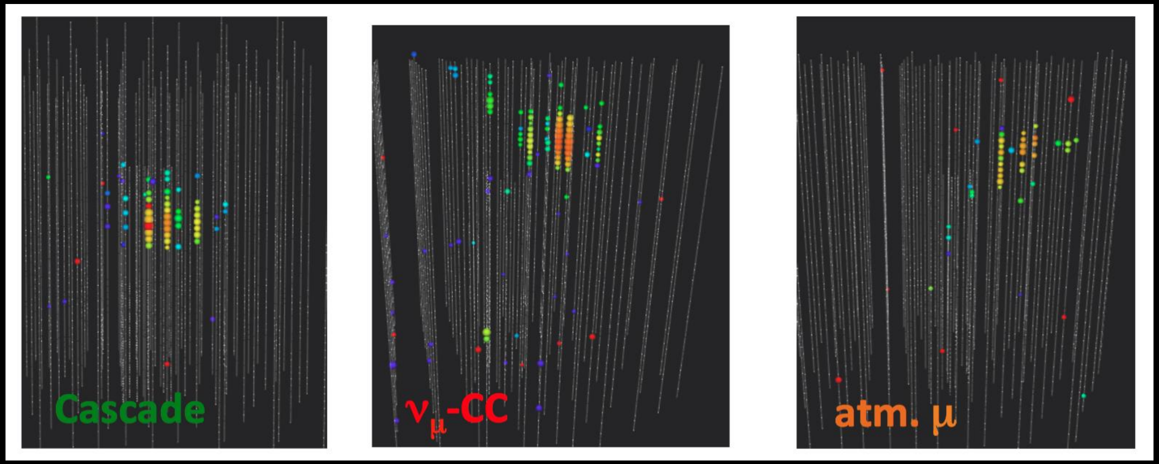
Search with Cascade Events

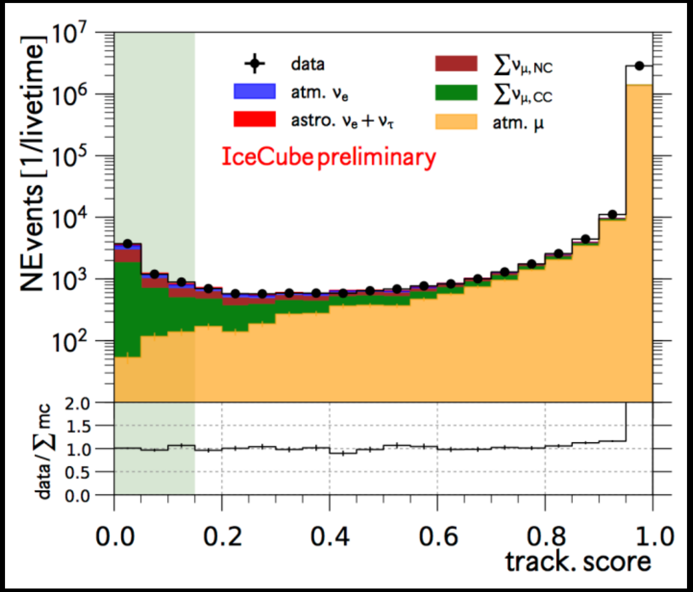


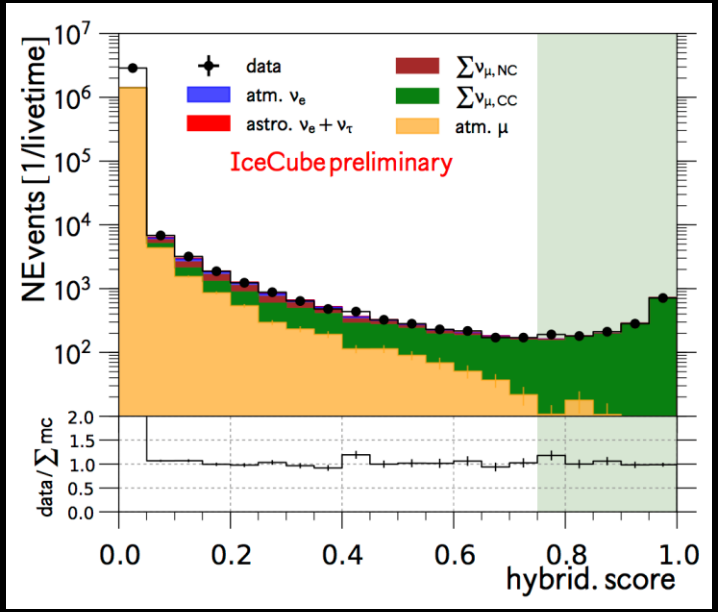


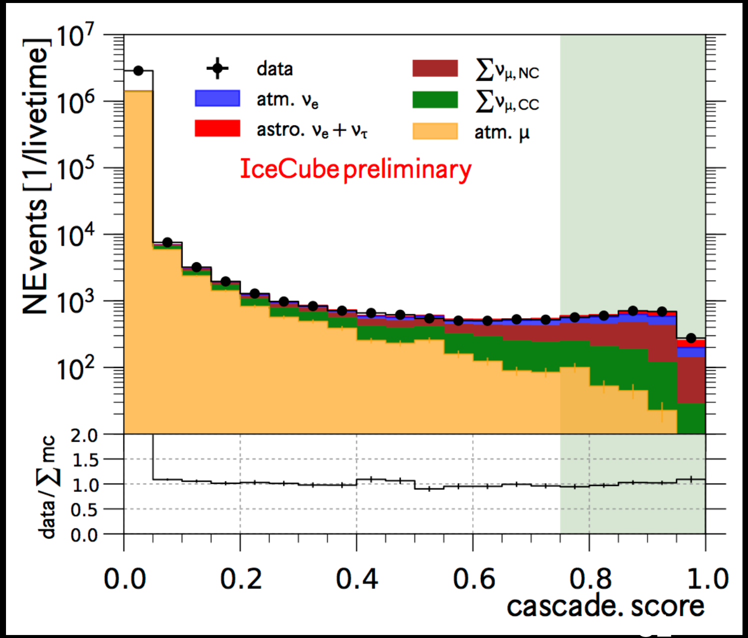
TeV PeV EeV

Search with Cascade Events







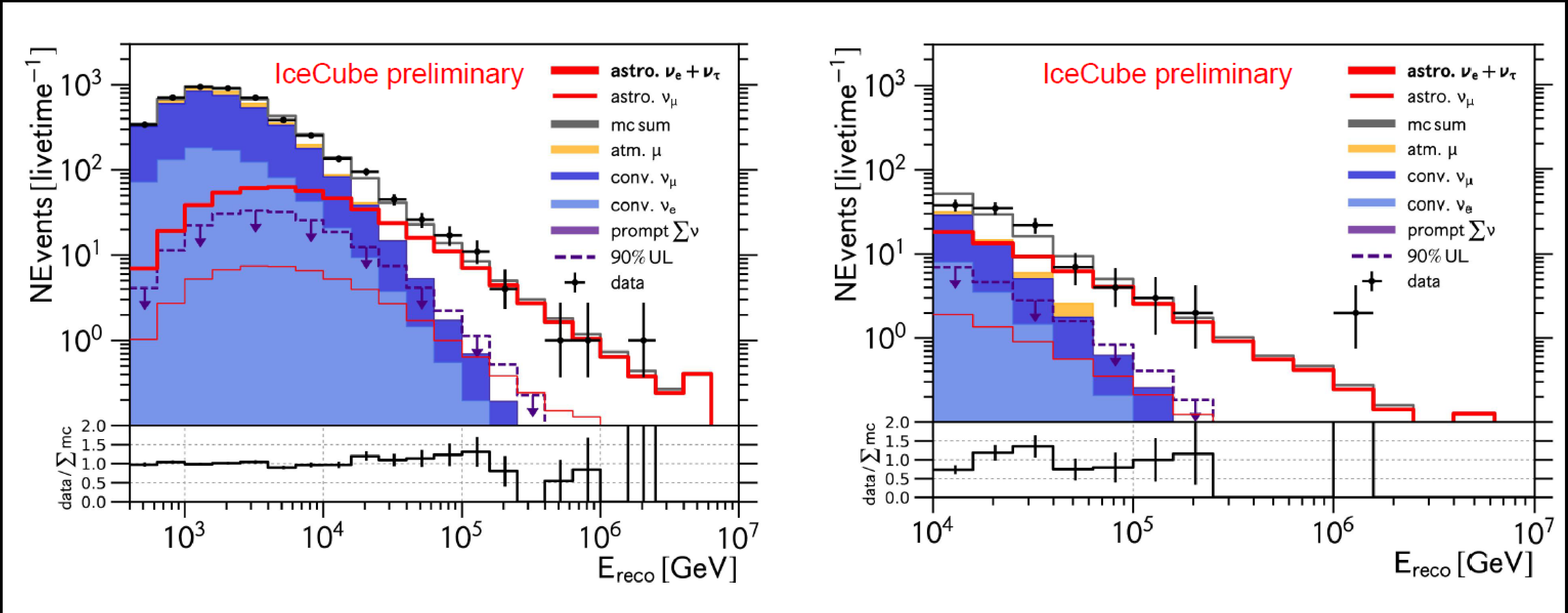


TeV PeV EeV

Search with Cascade Events

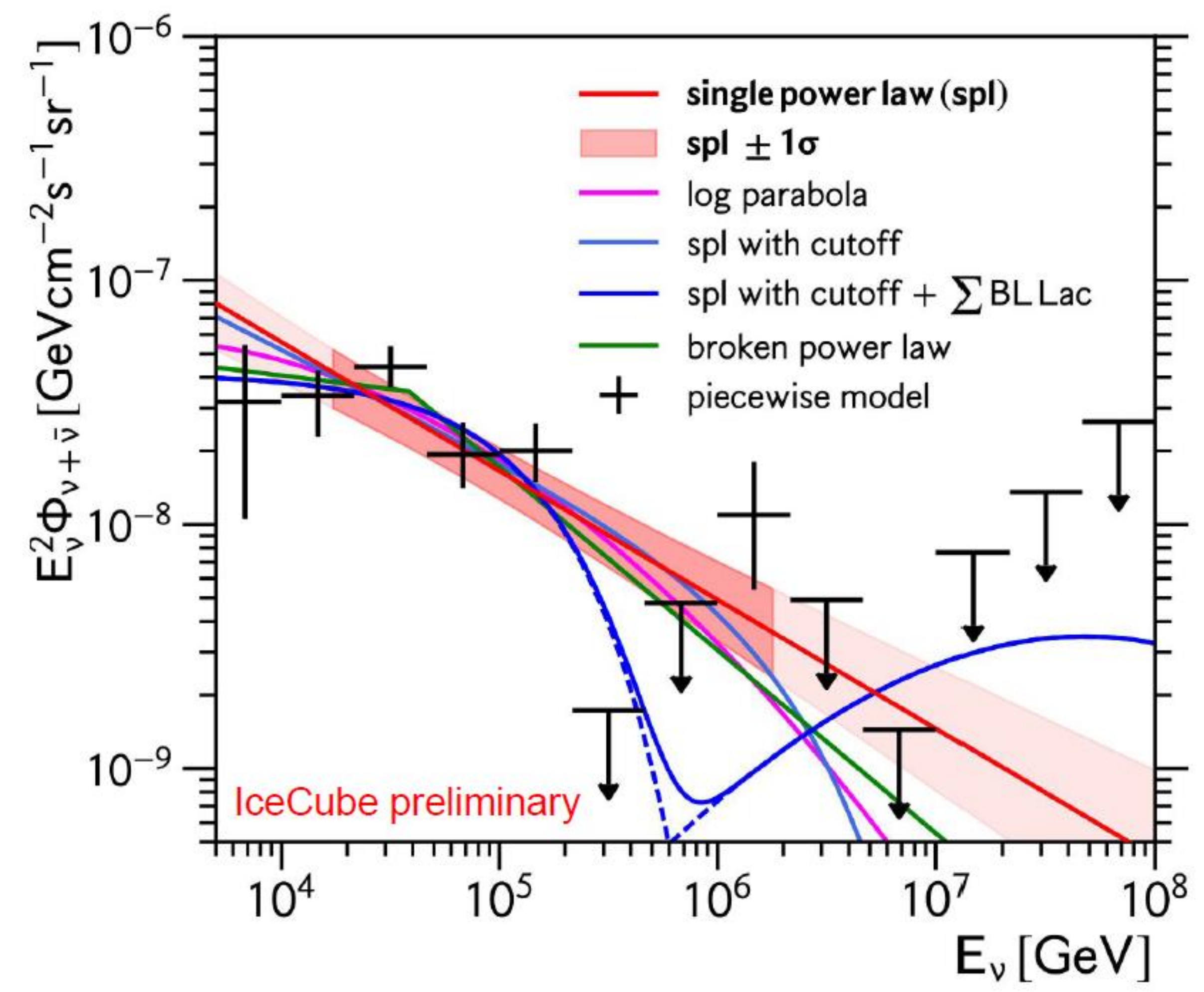
Downward events

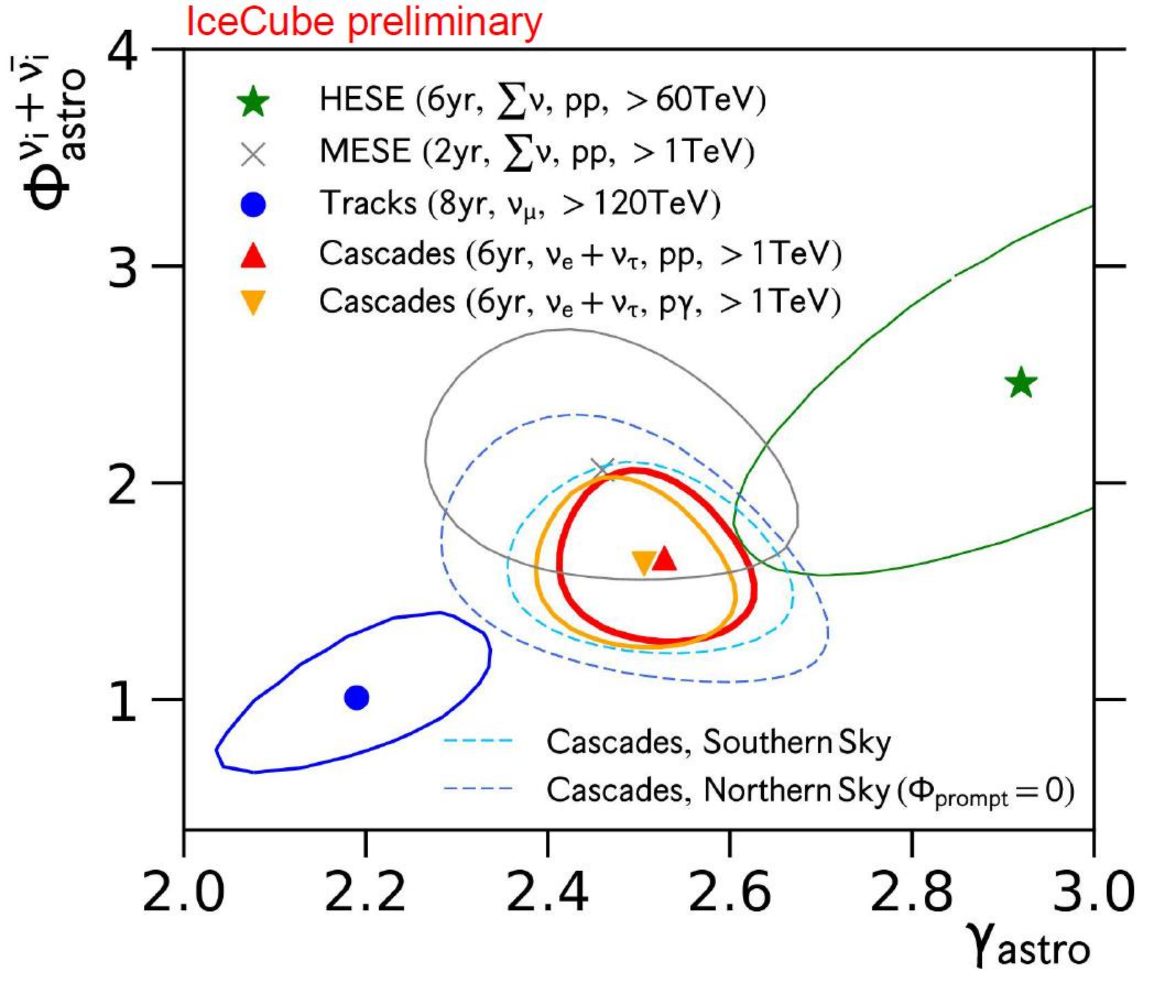
Upward events



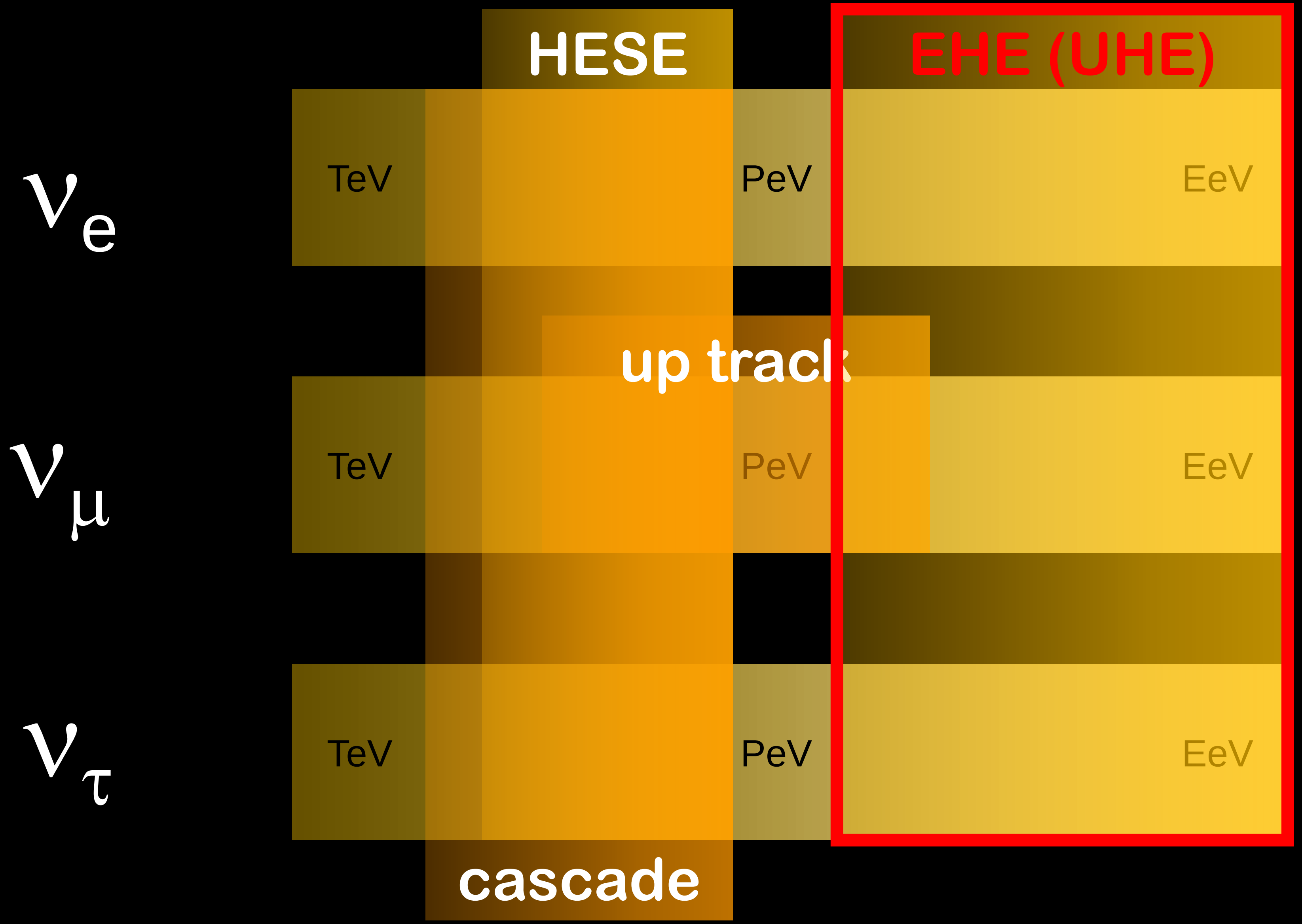
TeV PeV EeV

Search with Cascade Events



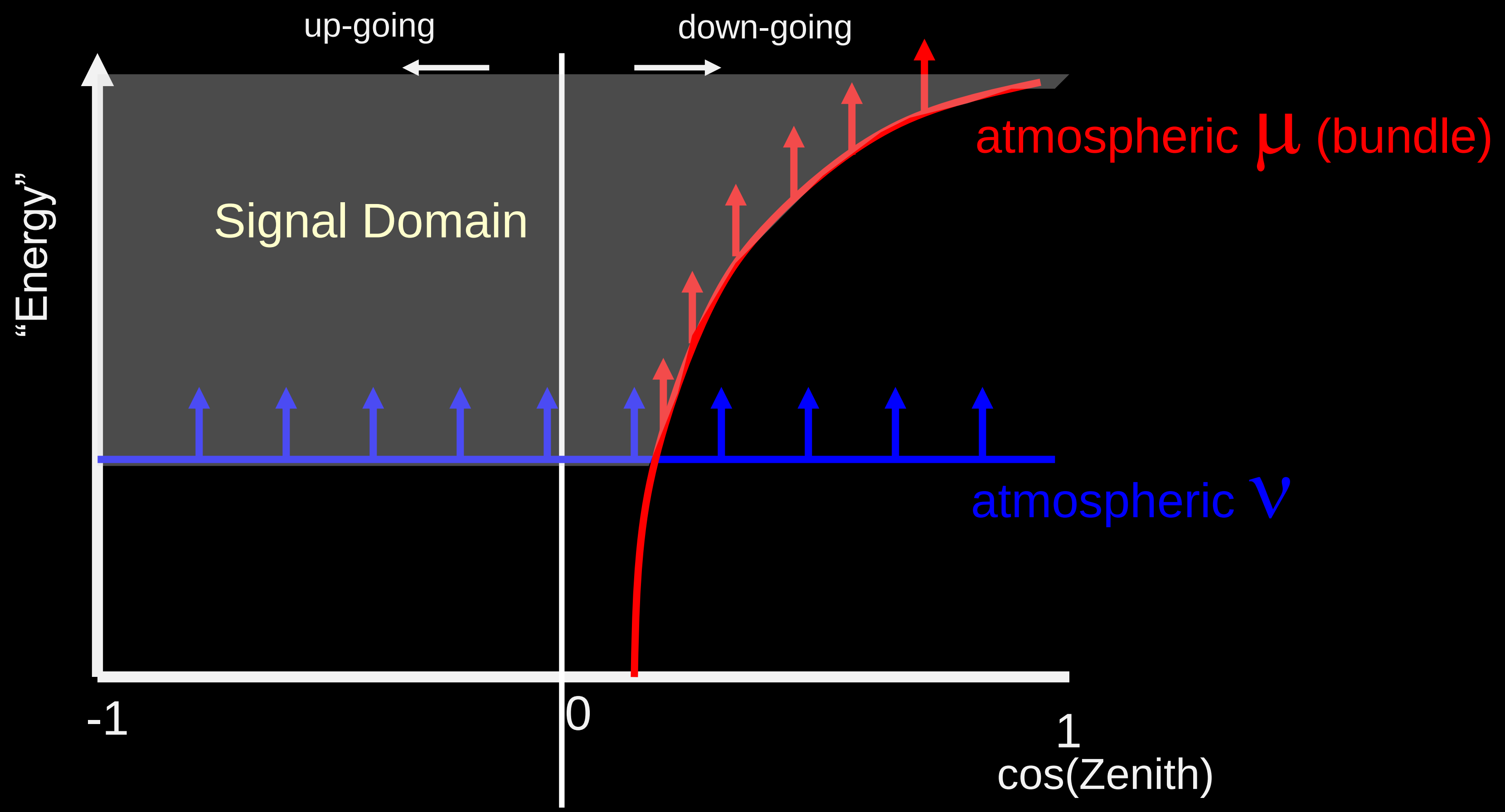


IceCube ν search channels



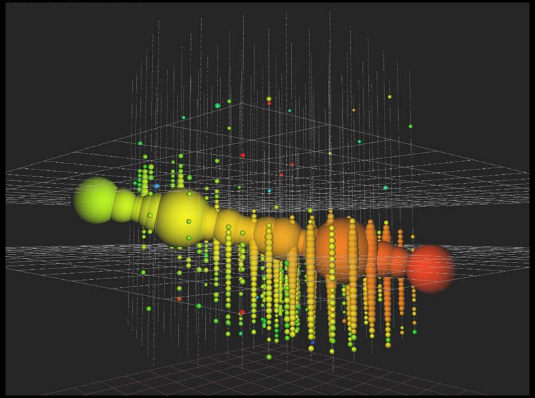
UHE (PeV-EeV)

Detection Principle – All flavor sensitive



Two PeV events found in the 9yr data sample

April 2008 – May 2017

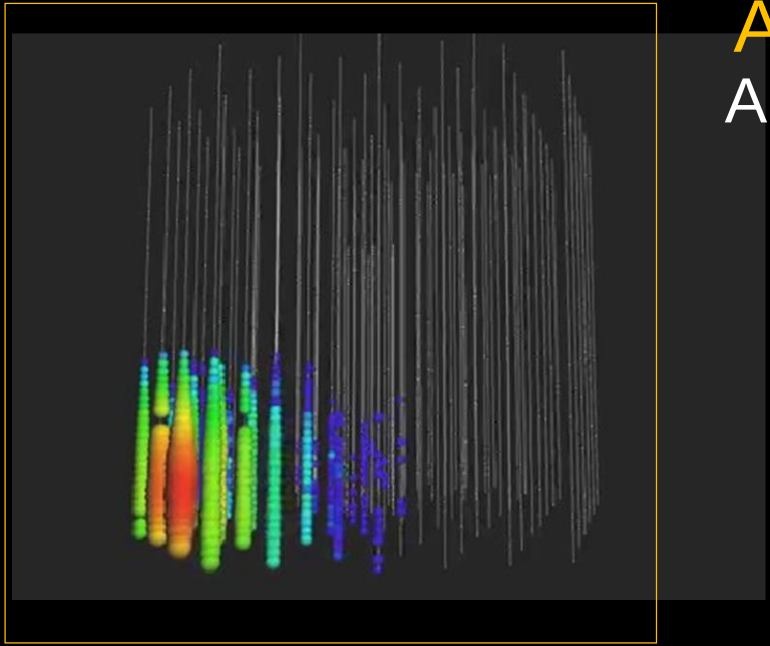


A track event in June 2014

Deposited energy 2.6 PeV

The event found in the previous EHE neutrino search

Of the two background events published in PRL 117 241101, one was discovered to be a detector artifact and has been removed



A new event in December 2016

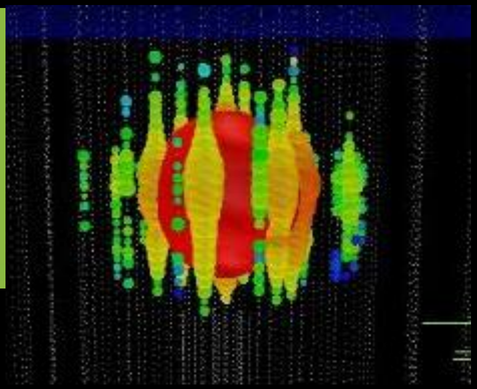
An uncontained shower event

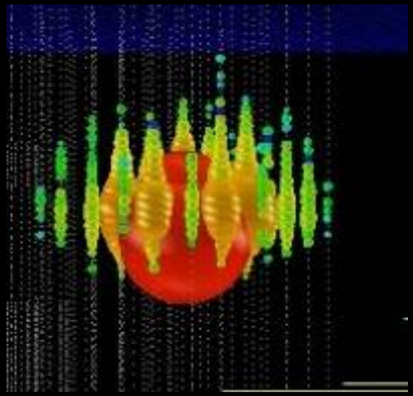
Preliminary deposited energy 6 PeV

Uncontained nature of this event indicates large uncertainty on energy estimate

- Investigations ongoing to see if a prompt atmospheric muon could be responsible for this event

Why the other (well-known) PeV ν events are missed?



The 1st two events were identified by the 2012's GZK ν search

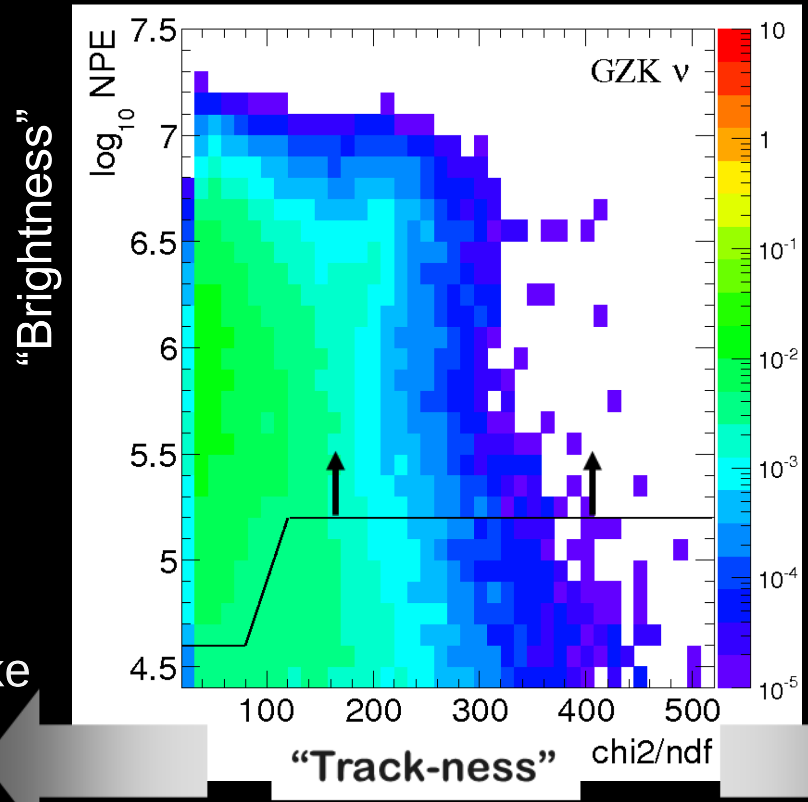
We tightened the cuts for shower-like events

For reduction of atmospheric background events

more than 2000 days of live time requires stronger BG reduction

"Brightness"

More track-like



More shower-like

(Tentative) Summary

TeV PeV EeV

$E^{-2.3\sim2.8}$

TeV PeV EeV

$E^{-2.1\sim2.3}$

Significance of the statistical tension

~ 2 σ

suggestive but not conclusive

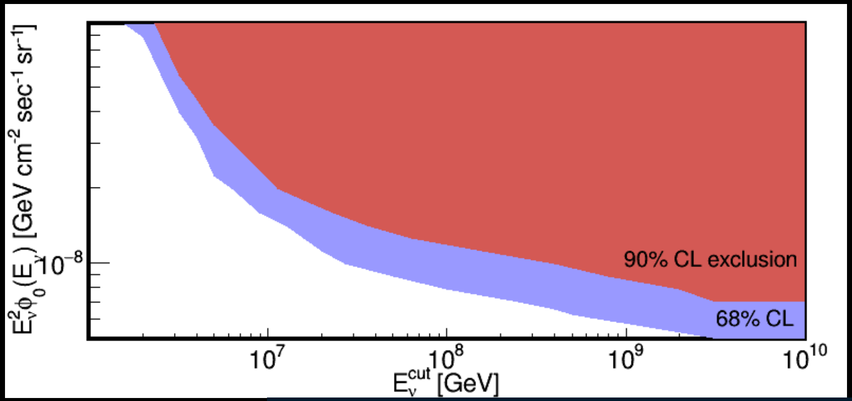
TeV PeV EeV

only 4 events

Less luminous

constraints on the power law flux (intensity Vs cutoff E)

all flavor ν intensity



Phys.Rev.Lett.**117** 241101(2016)

TeV PeV EeV

Upper limit only

Suggesting weakly evolved UHECR sources or mix composition

Other remark

No clearly identified ν_τ events yet with the current IceCube discrimination power

still consistent with 1:1:1 flavor ratio at ~90% CL

TeV PeV EeV

Implications to UHECR origin with the IceCube PeV-EeV data

Two PeV-ish events

No EeV-ish events

Test on the GZK ν models to constrain UHECR sources

Robust and solid constraints,
but UHECR composition limited

(Only sensitive to proton-dominated case)

Test on the on-source PeV-EeV-energy ν models (ex AGN jets)

model-dependent arguments
but mixed-composition case reachable

The Cosmic Neutrinos
Production Mechanisms

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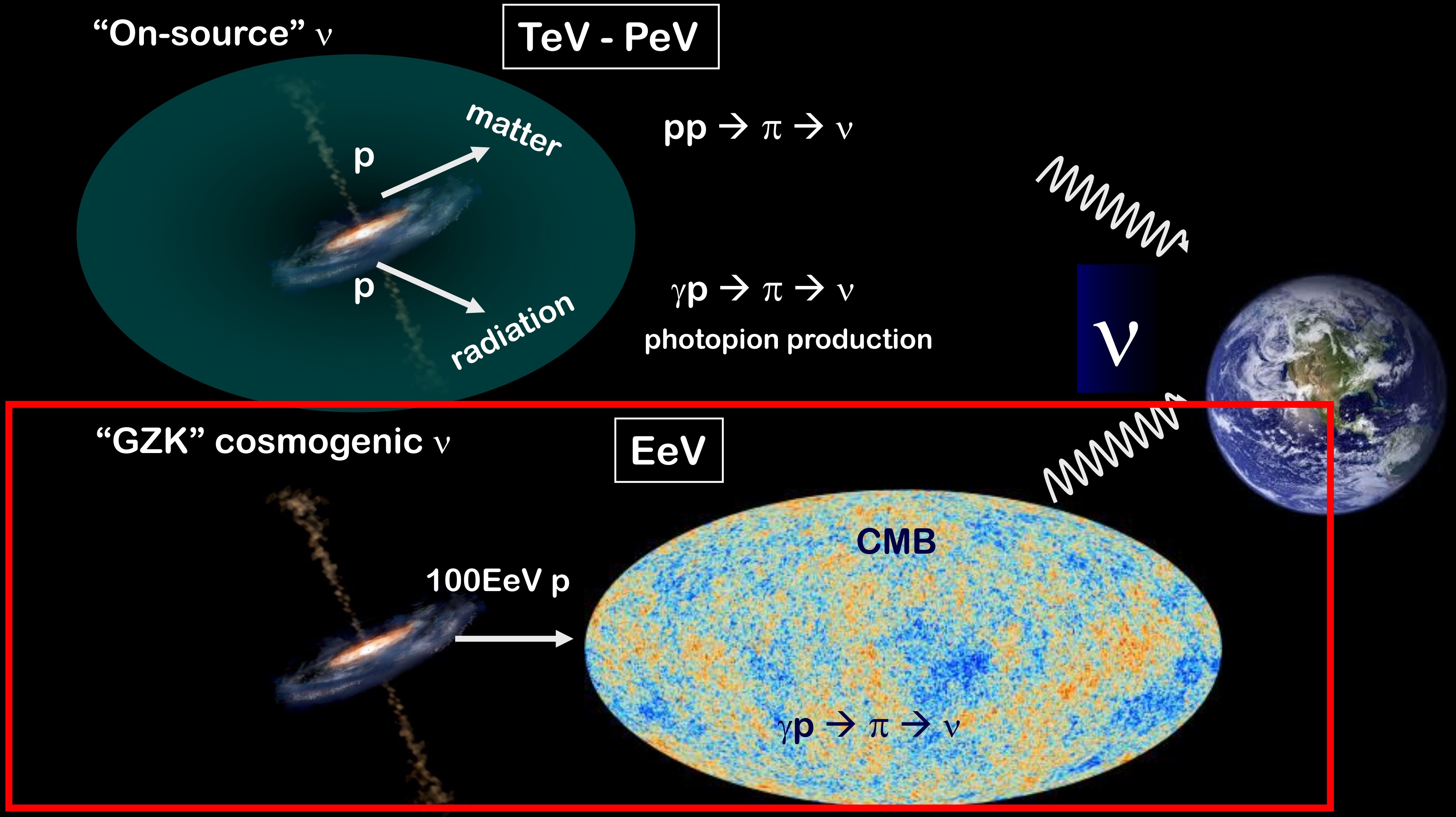
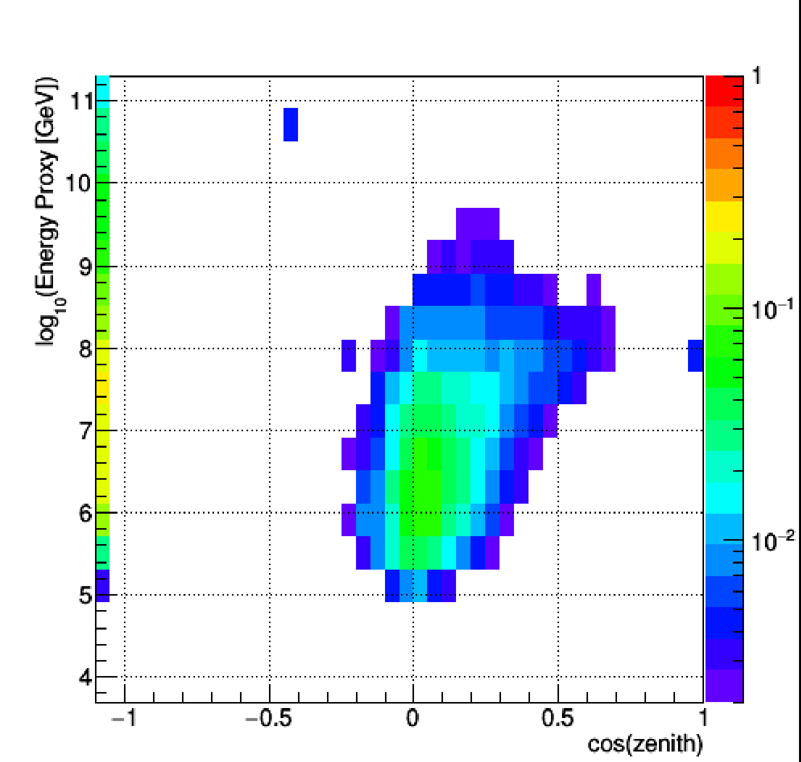


TeV PeV EeV

The detected 2 events are *not* GZK cosmogenic ν's

- p-value to support GZK ν hypothesis 2.47%
- compatible with a generic astrophysical E^{-2} power-law flux

Expected GZK ν event distribution



p-value 78.8%

TeV PeV EeV

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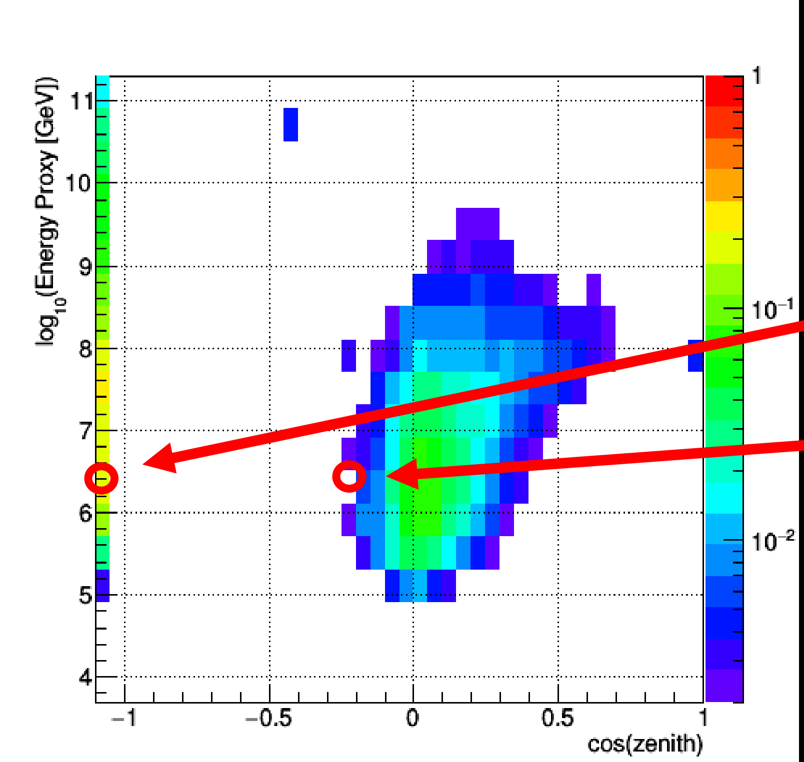


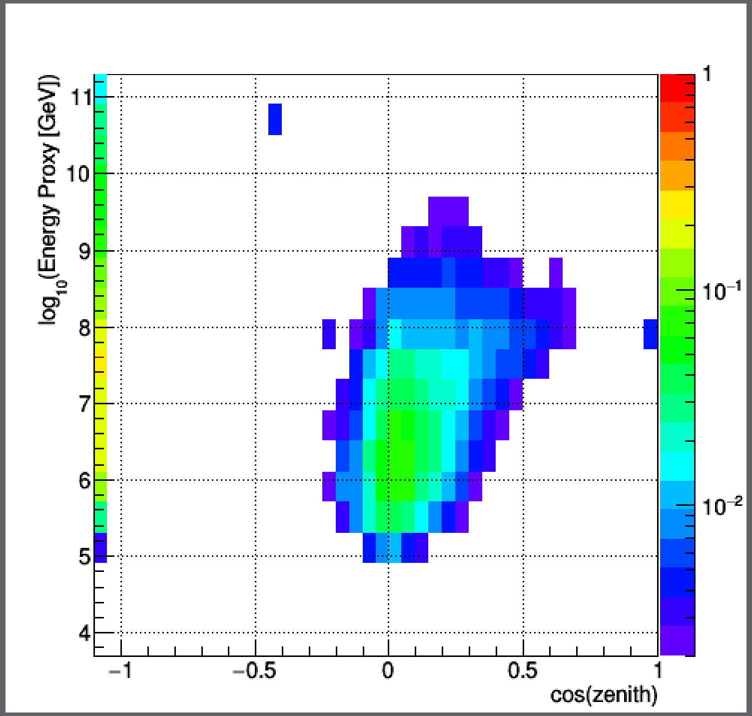
p-value 78.8%

The uncontained shower event

The track event

The method to test your UHE ν model

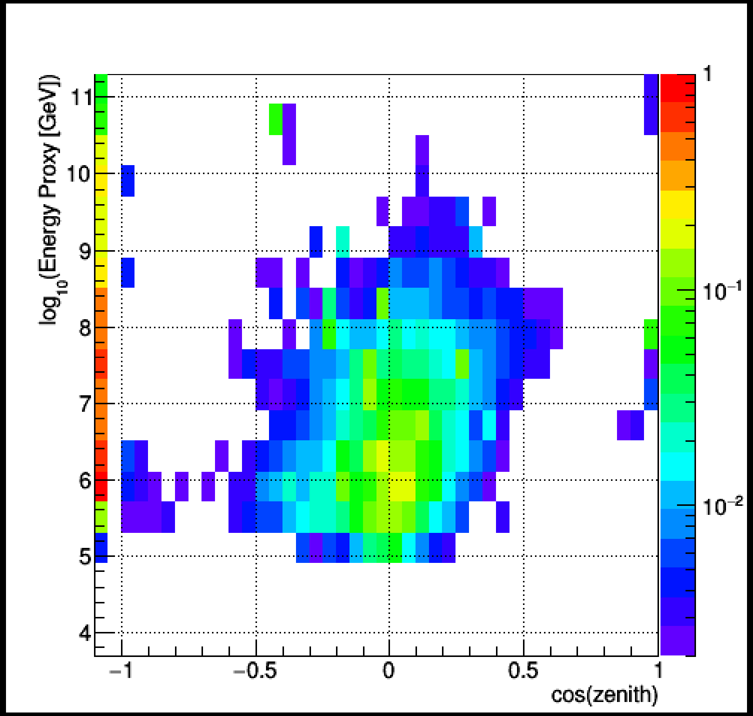
Binned Poisson Likelihood construction by
the expected event distribution on Energy-proxy and cos(zenith)



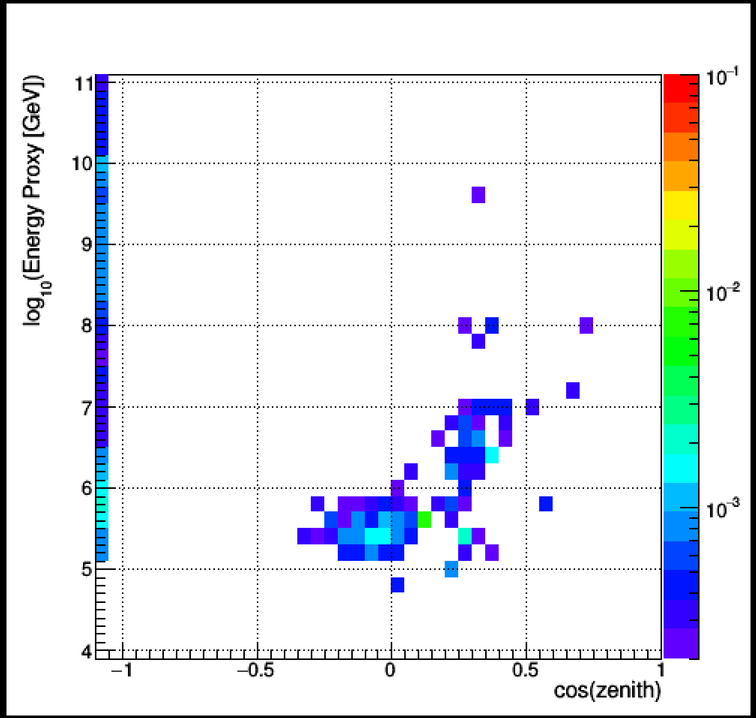
GZK cosmogenic (Ahlers + 2010)

The model to test

+



Astrophysical BG : E^{-2}



Atmospheric ν and μ BG

float the norm. to fit the data

TeV PeV EeV

UHE (PeV-EeV)

ν Model	GZK Y&T m=4,zmax=4	GZK Ahlers Best Fit 10EeV	GZK Ahlers Best Fit 1EeV	GZK Kotera SFR	GZK Aloisio SFR	AGN Murase γ=2.3 Load.fac 100	Young Pulsar Ke+ SFR
Expect. # of events	7.0	5.3	2.8	3.6	4.8	7.4	5.5
Model Rejection Factor	0.43	0.63	1.33	1.04	0.80	0.62	0.87
p-value	1.0×10^{-3}	1.1×10^{-2}	1.3×10^{-1}	6.0×10^{-2}	3.2×10^{-2}	3.0×10^{-3}	1.6×10^{-2}

Excluded

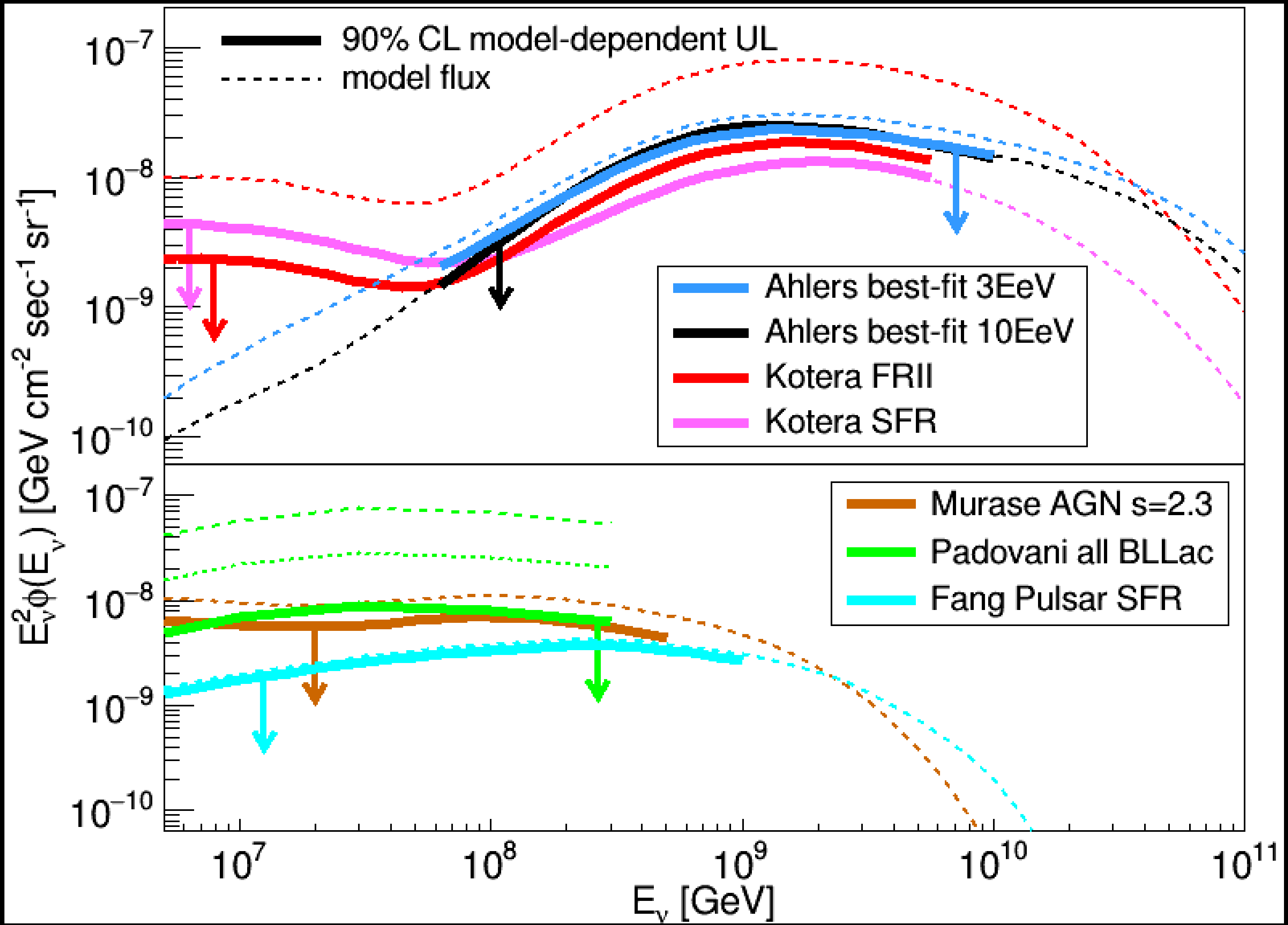
Mildly Excluded

IceCube collaboration
Phys.Rev.Lett.**117** 241101(2016)

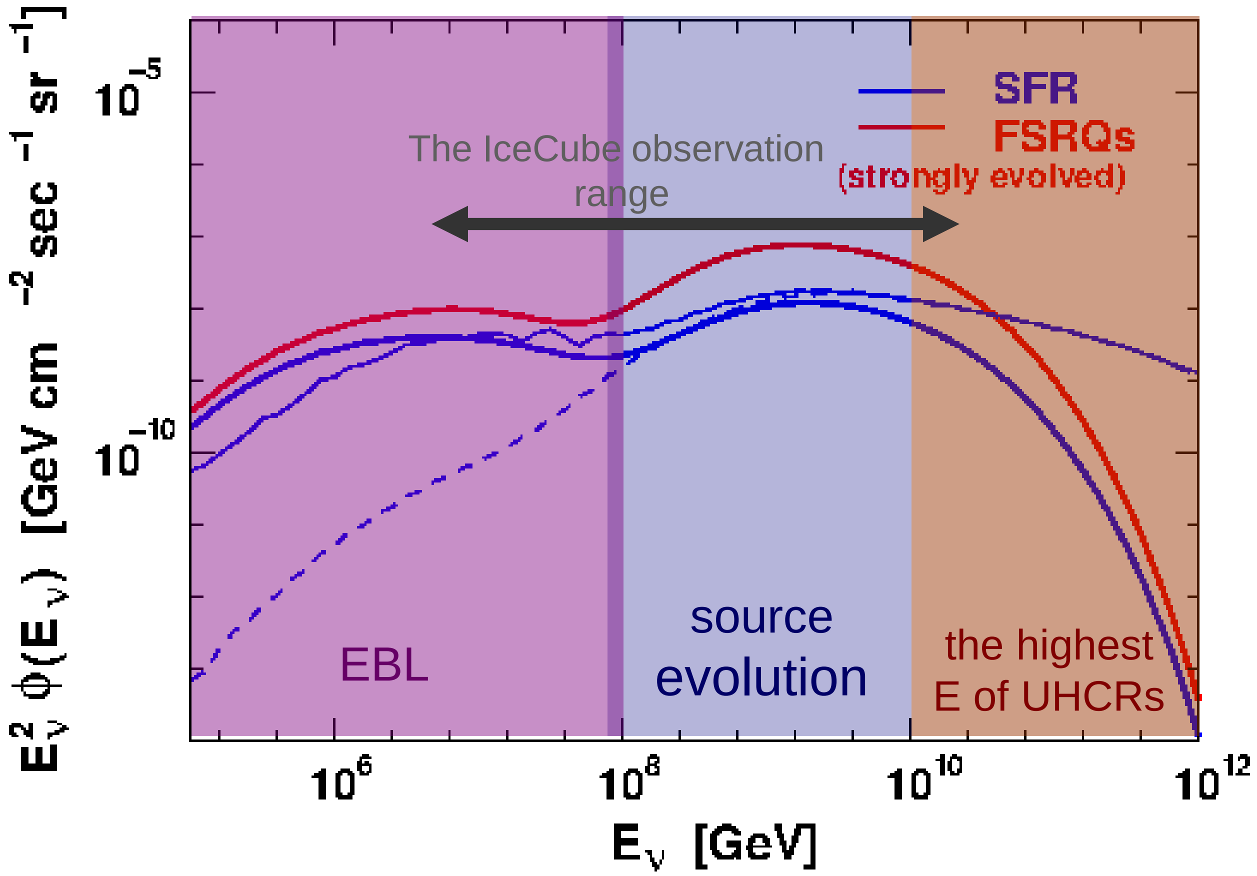
TeV PeV EeV

UHE (PeV-EeV)

all flavor sum

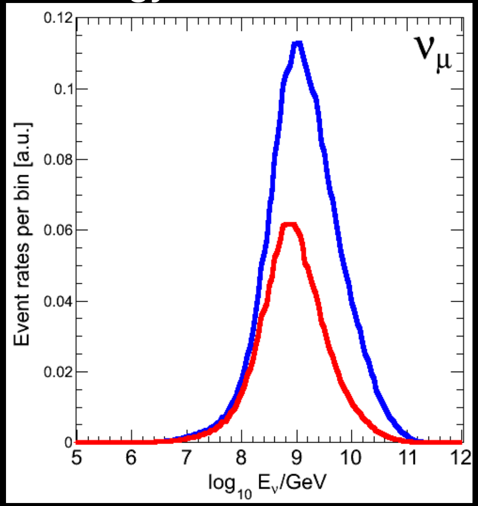


GZK cosmogenic ν models



- Kotera, Allerd, Olinto 2010
- Ahlers et al 2010
- Aloisio et al 2014

IceCube signal event energy distribution



Tracing *history* of the particle emissions with ν flux

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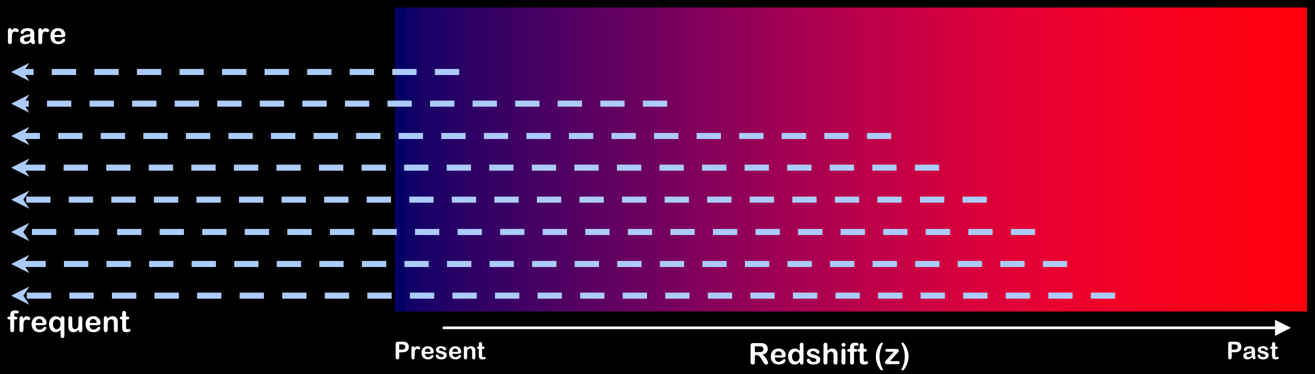
color : emission rate of ultra-high energy particles

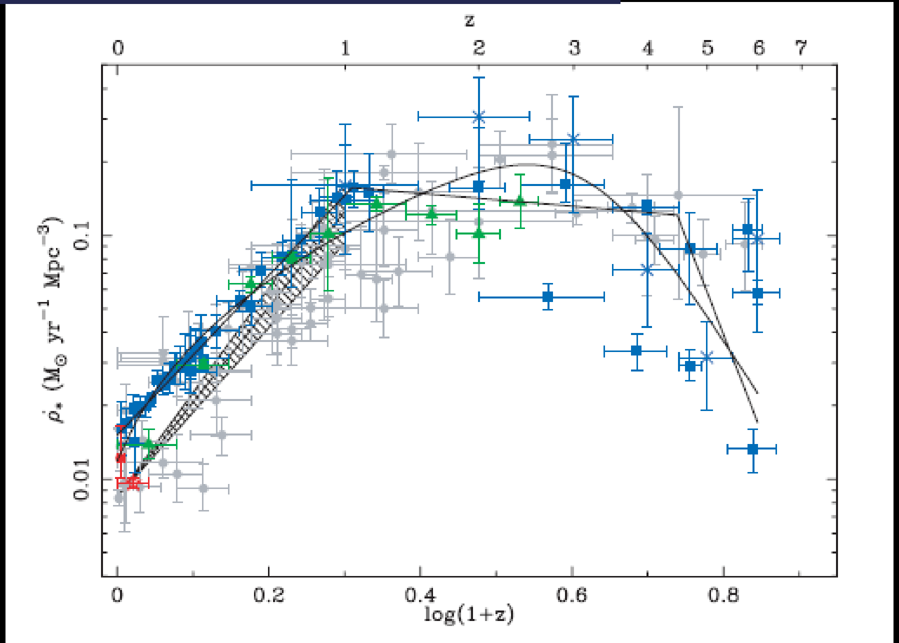
Intensity gets higher if the emission is more <u>active</u> in the past

because ν beams are penetrating over cosmological distances

ν



Hopkins and Beacom, Astrophys. J. **651** 142 (2006)



The cosmological evolution

> Many indications that the past was more active.

Star formation rate→

The spectral emission rate

$$\rho(z) \sim (1+z)^m$$

m= 0 : No evolution

Ultra-high energy ν intensity depends on the emission rate in far-universe

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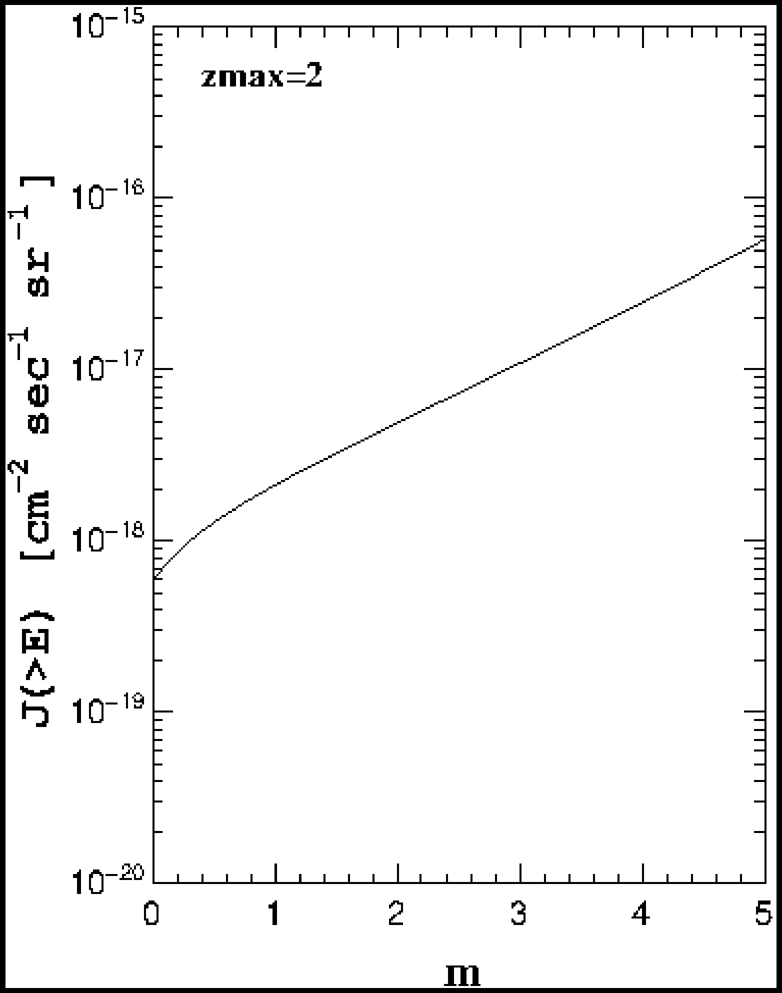
intensity above 1 EeV(=10^{18} eV)



more than an order of magnitude difference

Yoshida and Ishihara, PRD **85**, 063002 (2012)

$\rho(z) \sim (1+z)^m$

"quiet" "dynamic"

particle emissions in far-universe

GZK cosmogenic ν intensity @ 1EeV in the phase space of the emission history

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Yoshida and Ishihara, PRD **85**, 063002 (2012)

$\rho \sim (1+z)^m$

$0<z<z_{max}$

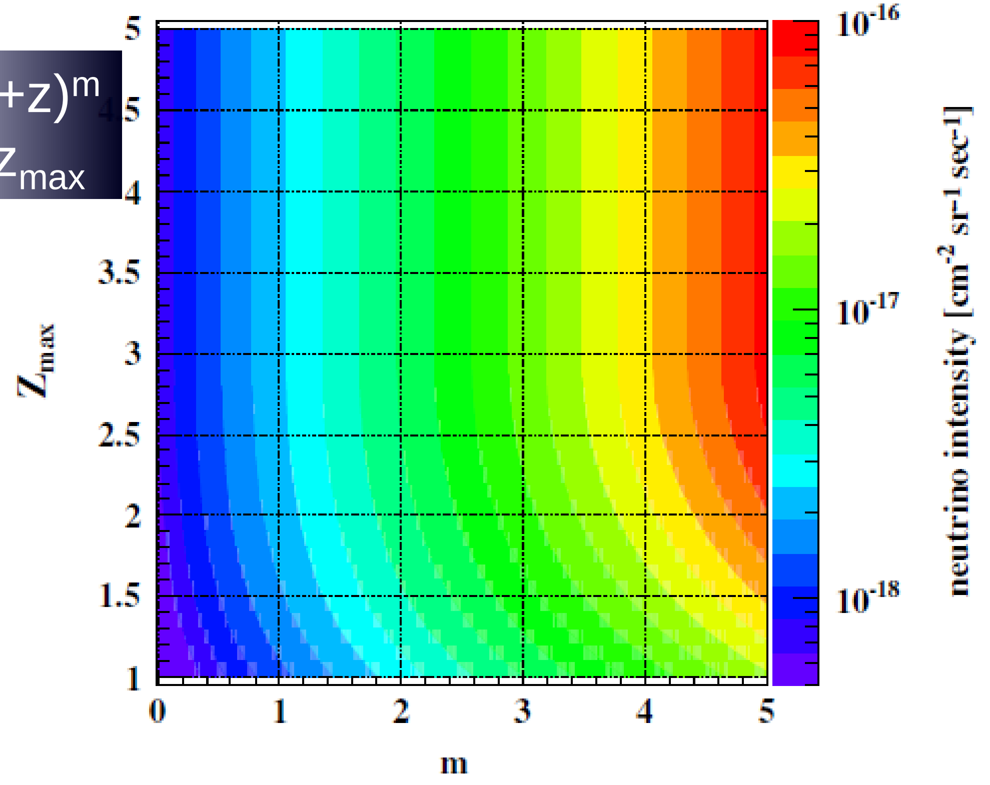


FIG. 2 (color online). Integral neutrino fluxes with energy above 1 EeV, J [cm^{-2} sec^{-1} sr^{-1}], on the plane of the source evolution parameters, m and z_{max}.

GZK ν flux $\phi = (m, z_{max})$

x IceCube Exposure

Event distribution
on plane of (E, cos(zenith)

The *observed* event distribution

TeV PeV EeV

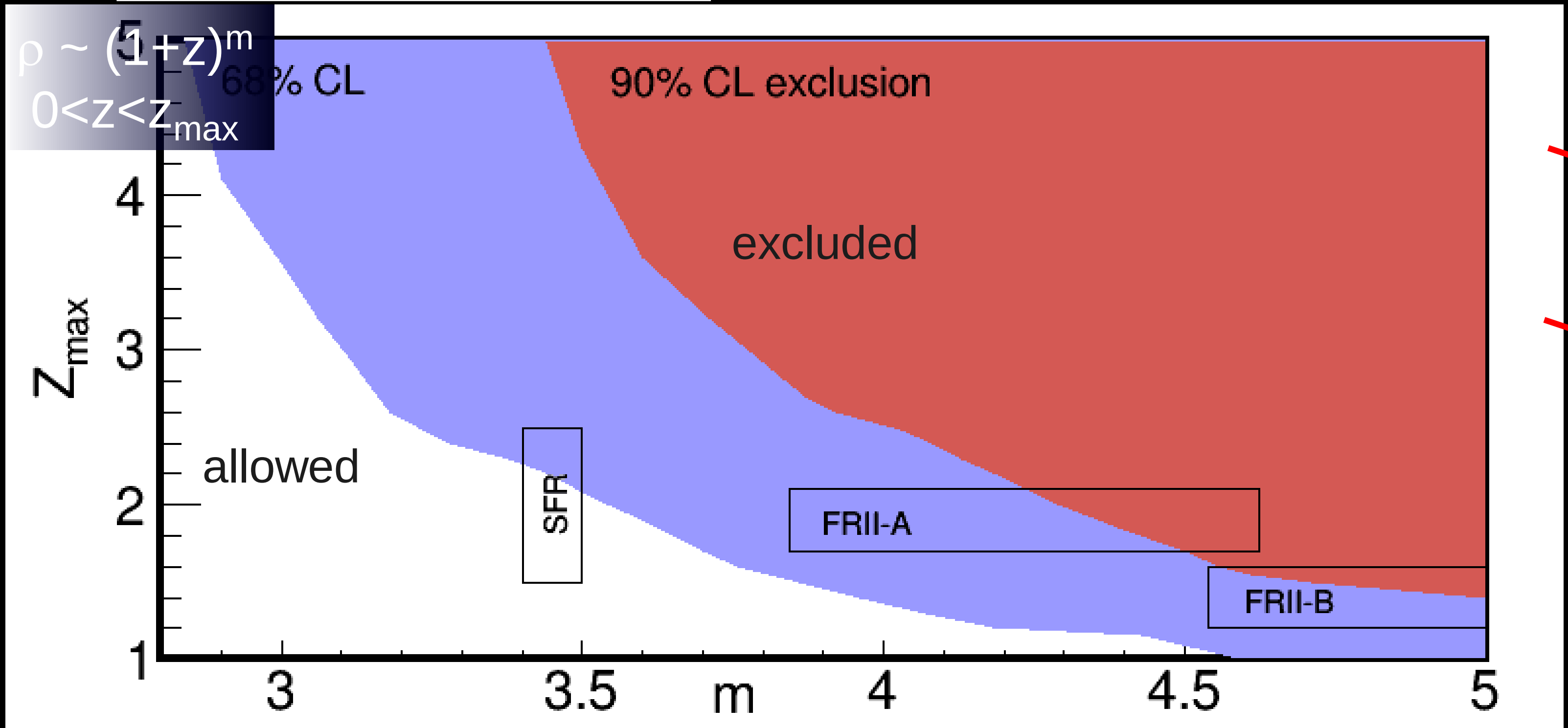
The Constraints on evolution (emission history) of UHE cosmic ray sources

IceCube collaboration
Phys.Rev.Lett.**117** 241101(2016)

UHECR source is cosmologically LESS evolved

Any sources with evolution compatible or stronger than star formation rate are disfavored

$\rho \sim (1+z)^m$
$0<z<z_{max}$



~~FRII (FSRQs)~~

~~GRBs~~

TeV PeV EeV

What IceCube tells
if UHECRs are <u>not</u> proton-dominated?

Move on to the on-source ν model-dependent constraints

Example: AGN(Blazar) inner jets taking into account the Blazar sequence
(Murase, Inoue, Dermer, PRD 2014)

FSRQs (QHB) → ν

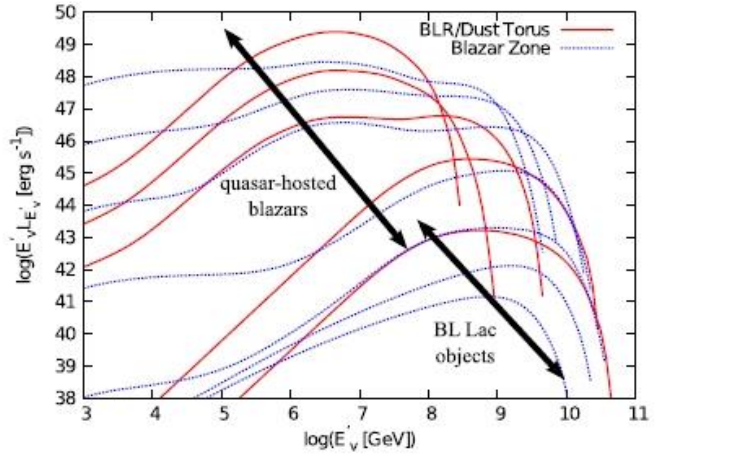
↕

middle class → γ

↕

BL Lac → UHECRs

ν luminosity from a Blazar



The highest energy CRs
are HEAVY nuclei

TeV PeV EeV

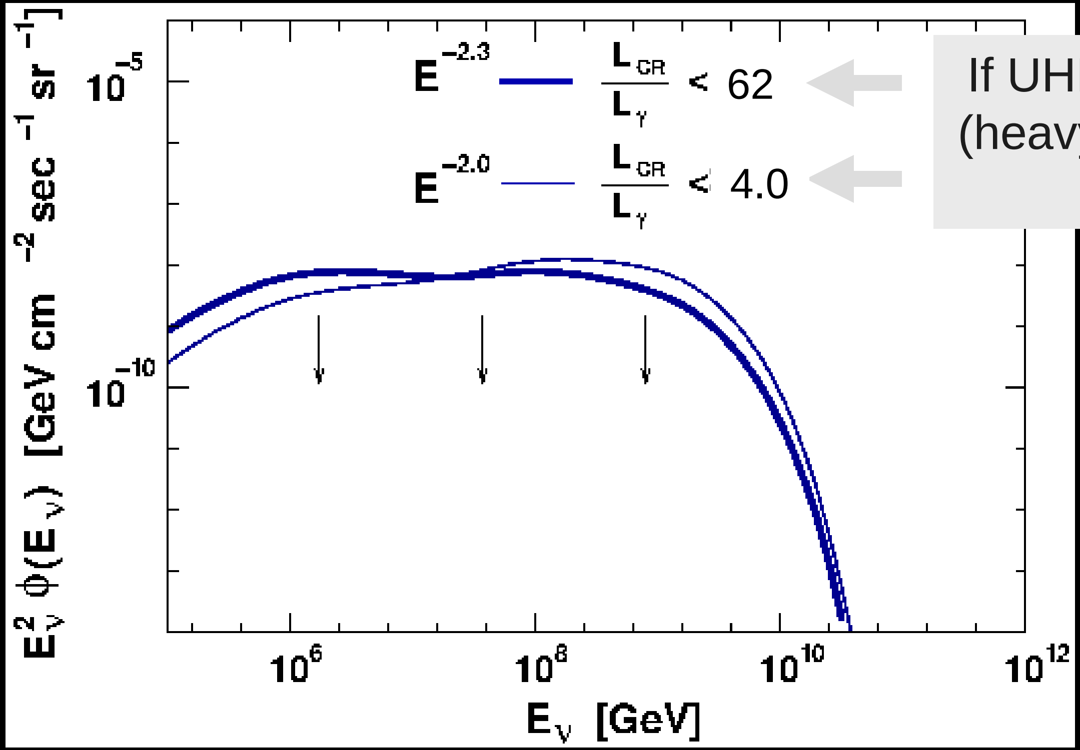
IceCube tests on *on-source* ν models

AGN (Blazar) Inner Jet

Murase, Inoue, Dermer, PRD 2014

$$\nu \text{ flux} \propto \frac{L_{CR}}{L_\gamma} \quad \begin{matrix} \leftarrow \text{Auger} \\ \leftarrow \text{Radio} \end{matrix} \approx \begin{cases} 100 & \text{if } E^{-2.3} \\ 4 & \text{if } E^{-2.0} \end{cases}$$

ν flux upper limit by IceCube



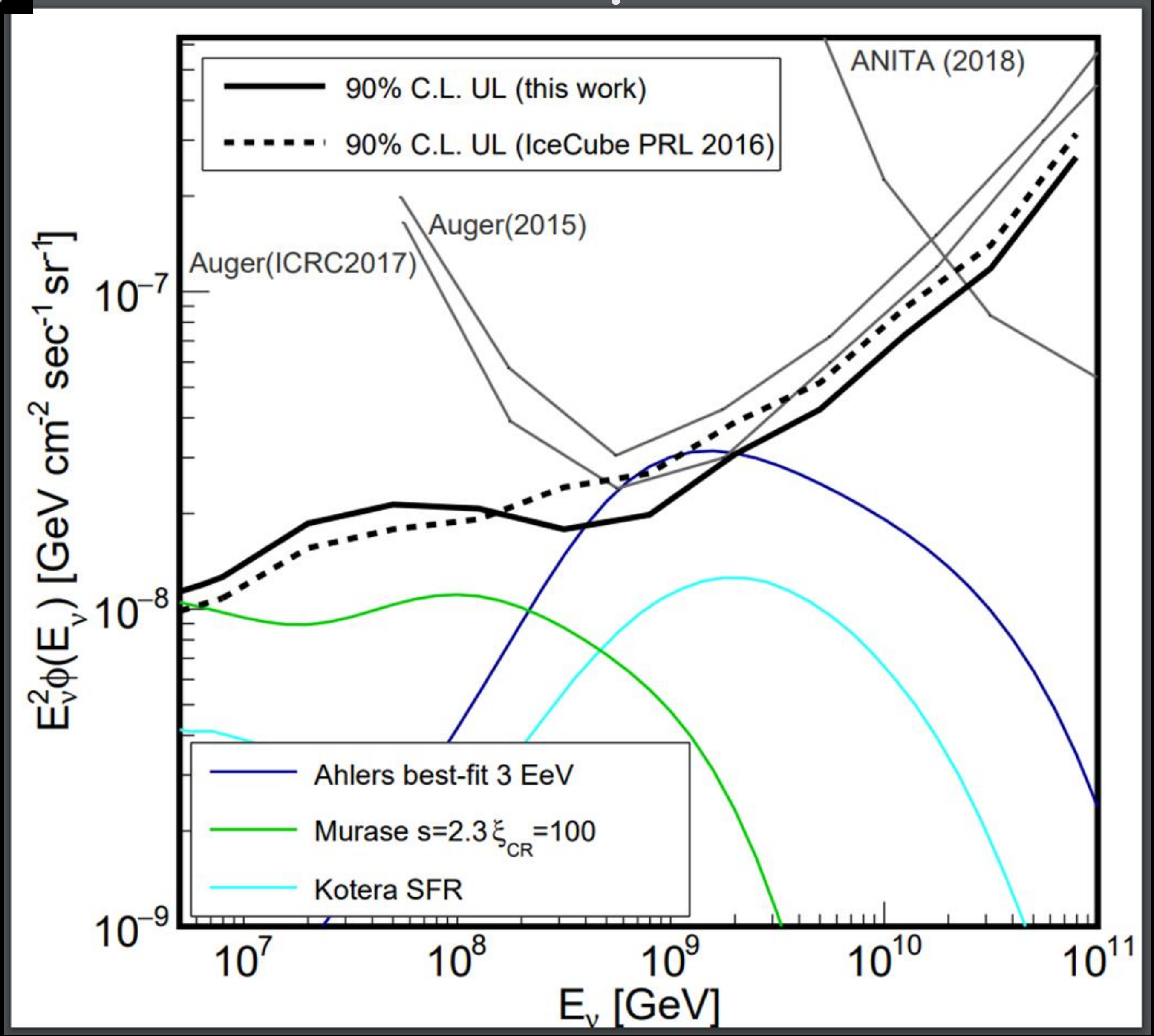
If UHECRs are 100% AGN-originated (heavy) nuclei, we would have already seen EeV neutrinos

AGN unlikely

though not completely ruled out

TeV PeV EeV

Model Independent Differential Limit



The obtained limit at 1 EeV

~ 2 x 10^{-8} GeV/cm^2 s sr

≈

Energy flux of UHECRs

IceCube collaboration
Phys.Rev.D **98** 062003 (2018)

ICECUBE

TeV PeV EeV

Summary in UHE ν

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Two PeV-ish events detected. No EeV events in the IceCube 9 year-long data

IF UHECRs are proton-dominated

(consistent with the TA's claim)

UHE sources are not populated at far universe

radio-loud ~~Blazar:FSRQs~~

~~GRB~~

The "standard" UHRCR models are dead

IF UHECRs are nuclei-dominated

(Auger is right !)

Exclusion of some on-source ν models started to constrain popular sites for UHECR production

Blazar jets may no longer be a plausible UHECR source candidate

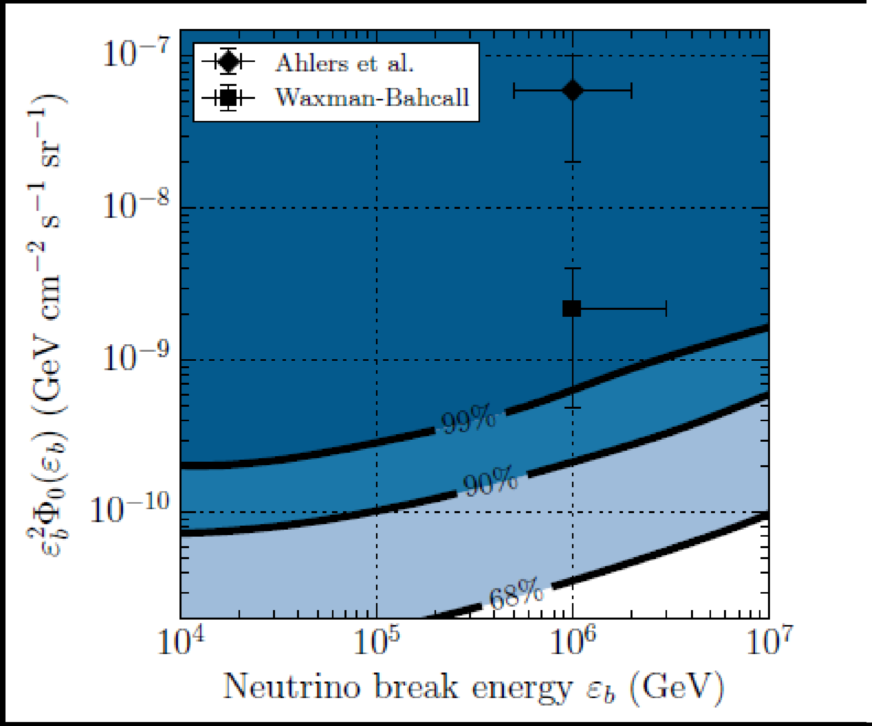
TeV PeV EeV

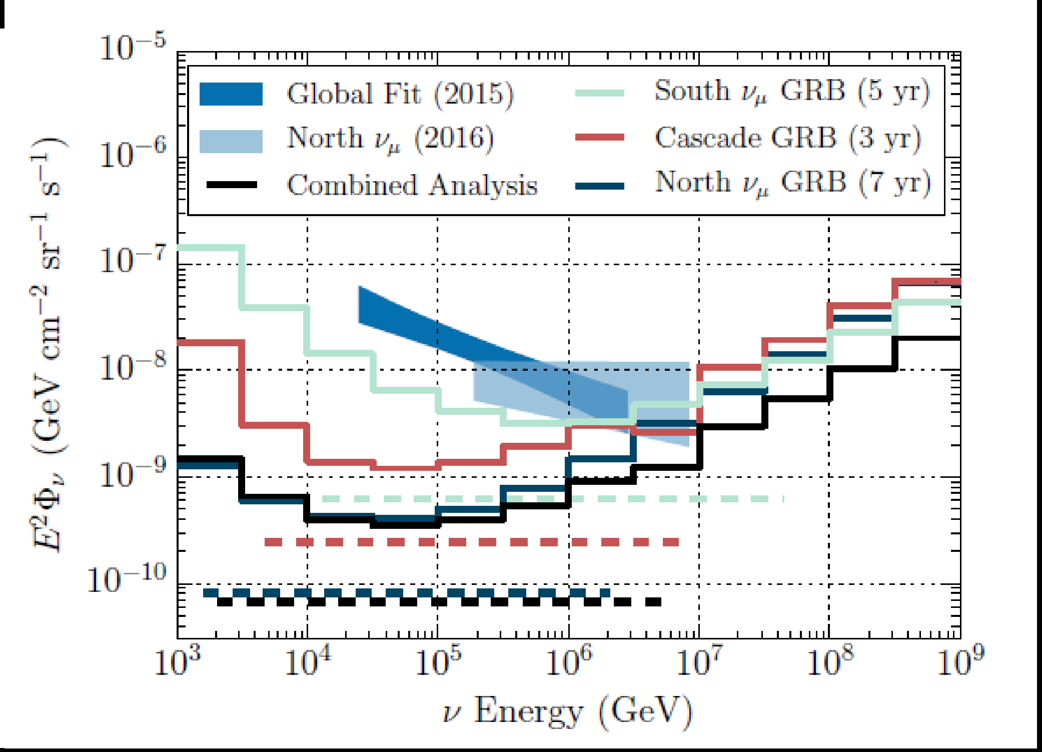
No GRBs as major sources

No neutrinos associated from GRBs

Based on 1172 GRBs

Arxiv:1702.06868





Significant constraints on single-zone fireball models of
GRB neutrino and UHECR production

TeV PeV EeV

No Blazars as major sources

Blazar stacking analysis

THE CONTRIBUTION OF *FERMI*-2LAC BLAZARS TO DIFFUSE TEV–PEV NEUTRINO FLUX

M. G. Aartsen[1], K. Abraham[2], M. Ackermann[3], J. Adams[4], J. A. Aguilar[5], M. Ahlers[6], M. Ahrens[7], D. Altmann[8], K. Andeen[9], T. Anderson[10]

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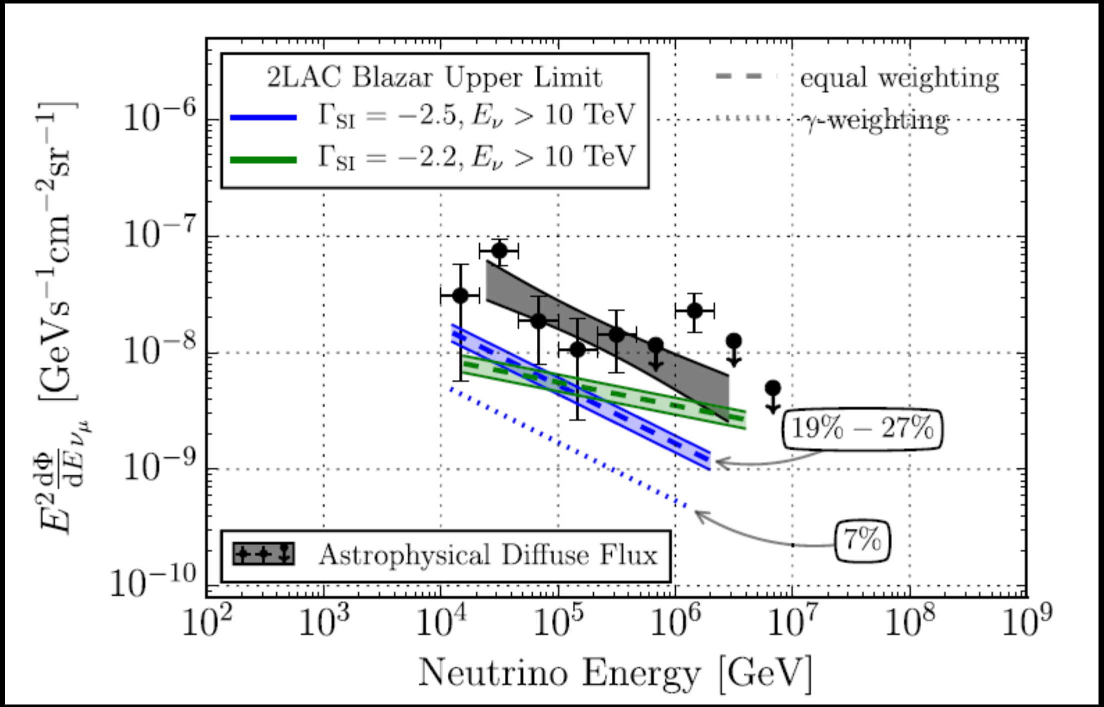
Published 2017 January 17 •

The Astrophysical Journal, Volume 835, Number 1

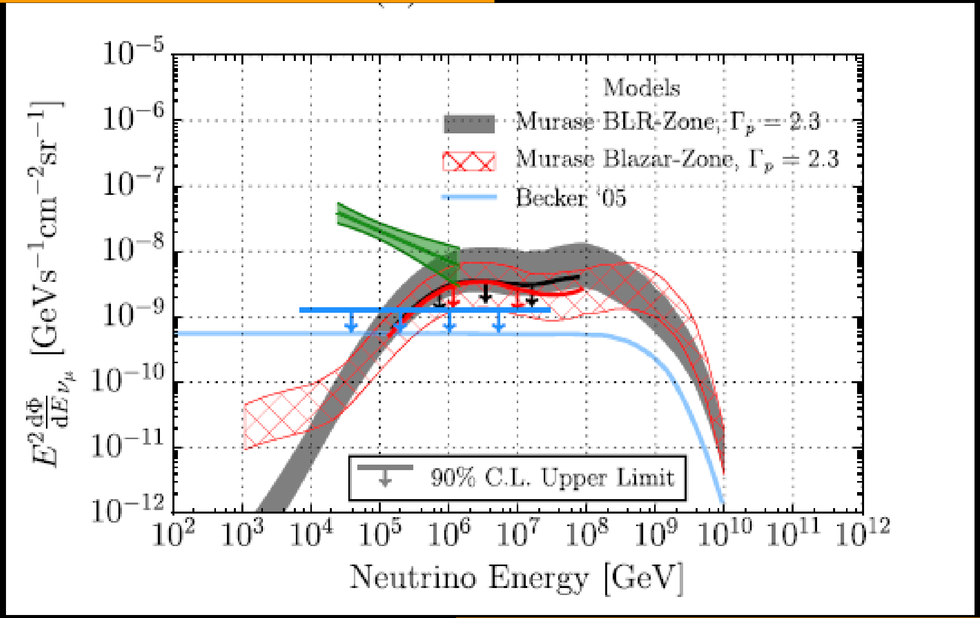


Search for a cumulative ν excess from 862 2LAC blazars

Model dependent constraints on Blazars

TeV PeV EeV

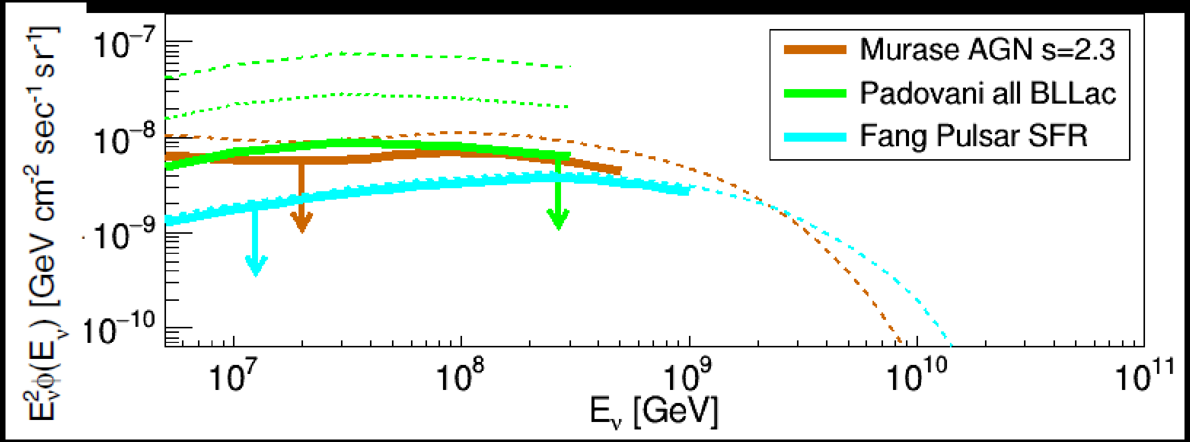
IceCube Collaboration
ApJ 835 no.1 45 (2017)



ν_μ only

TeV PeV EeV

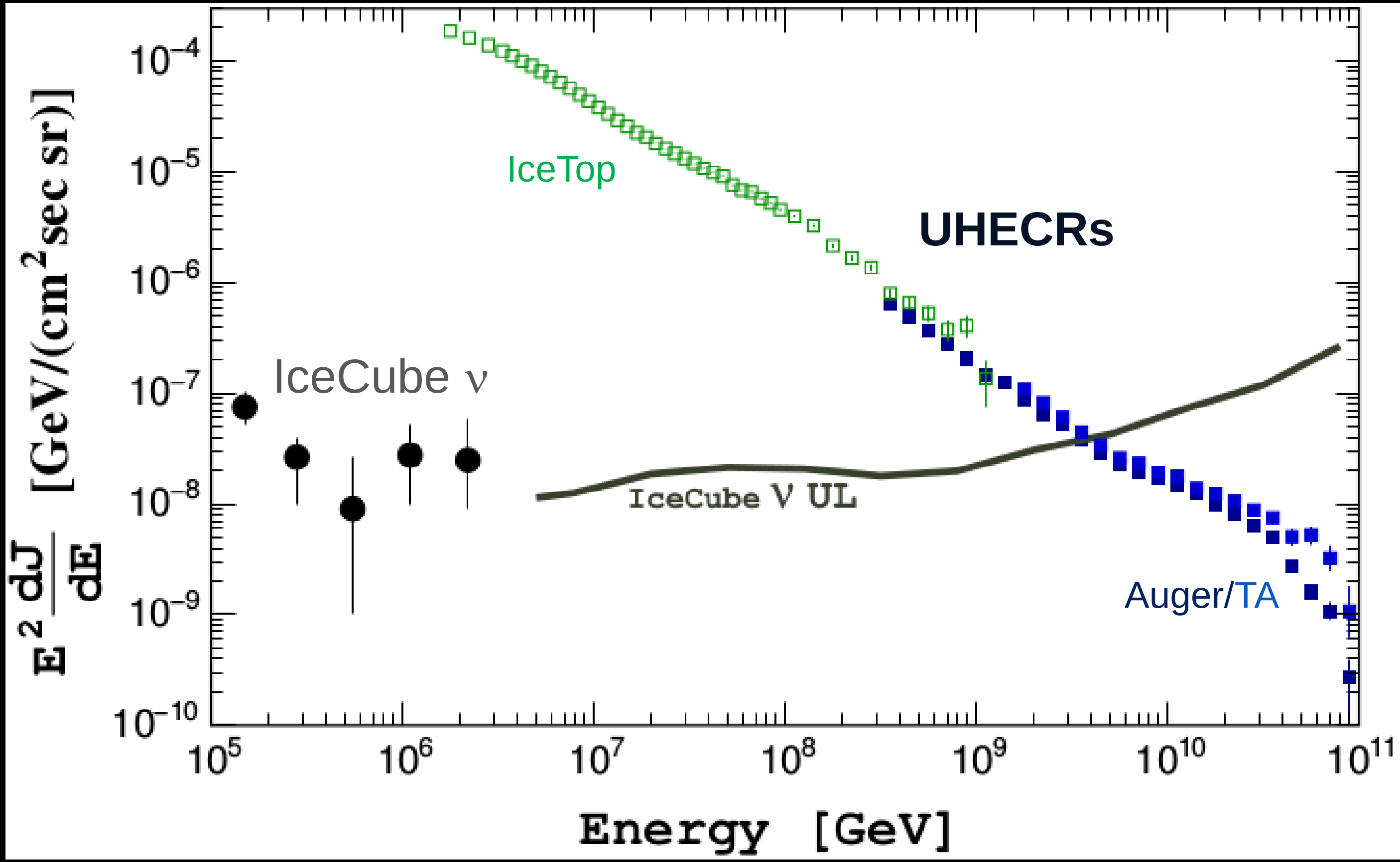
IceCube Collaboration
PRL 117 241101 (2016)



all flavor sum

Another big question

The (yet-unknown) UHECR sources are also the origin of IceCube TeV ν?



Energy flux

IceCube ν ~ UHECRs

Is this just a coincidence?

UHECR-IceCube ν Unified Model

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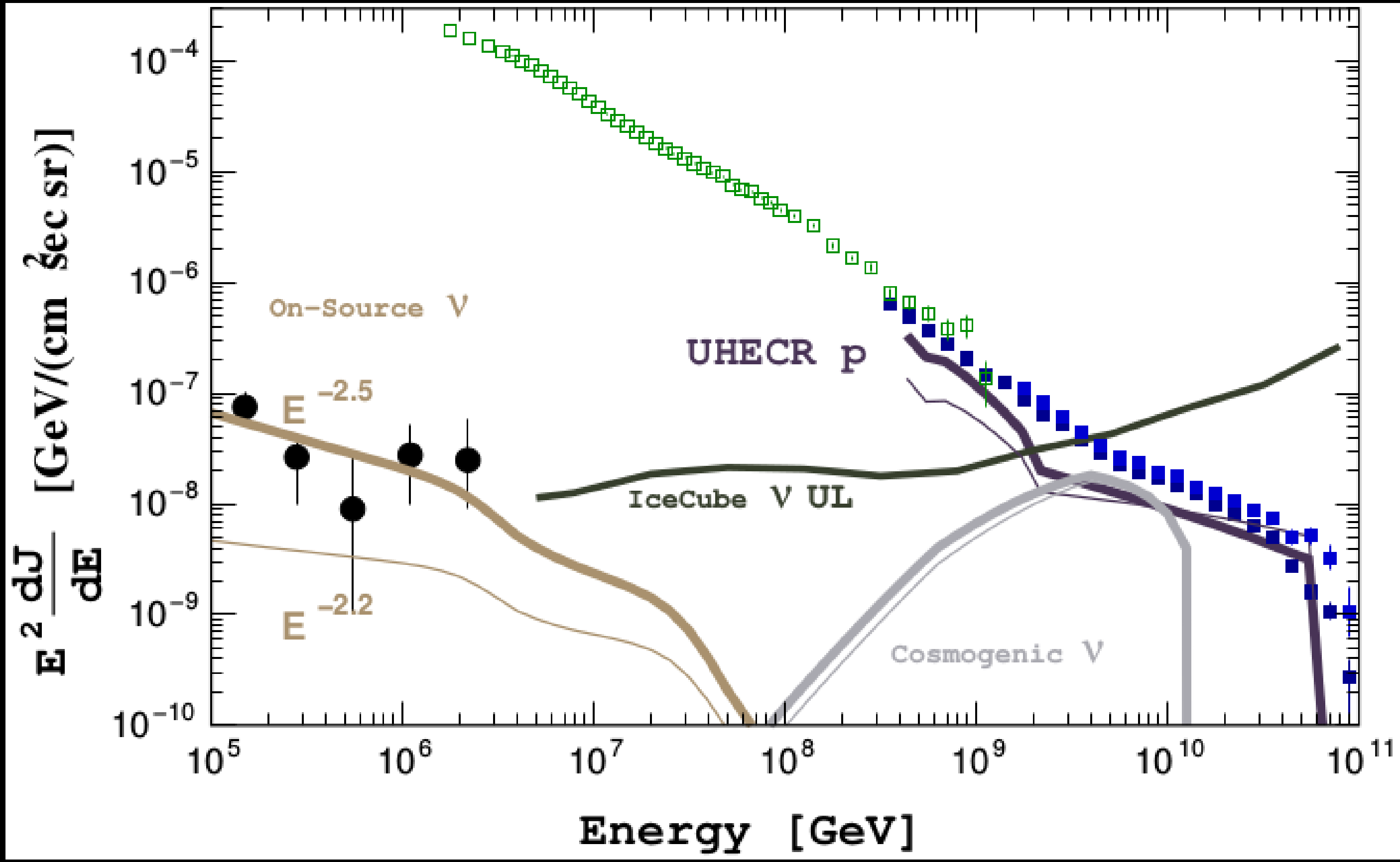
The (yet-unknown) UHECR sources are also the origin of IceCube TeV ν?



A genetic analytical model

- Optical Depth 0.1
- SFR-like evolution

Can be consistent with UHECR data and ν UL at higher energies

taking the formula from

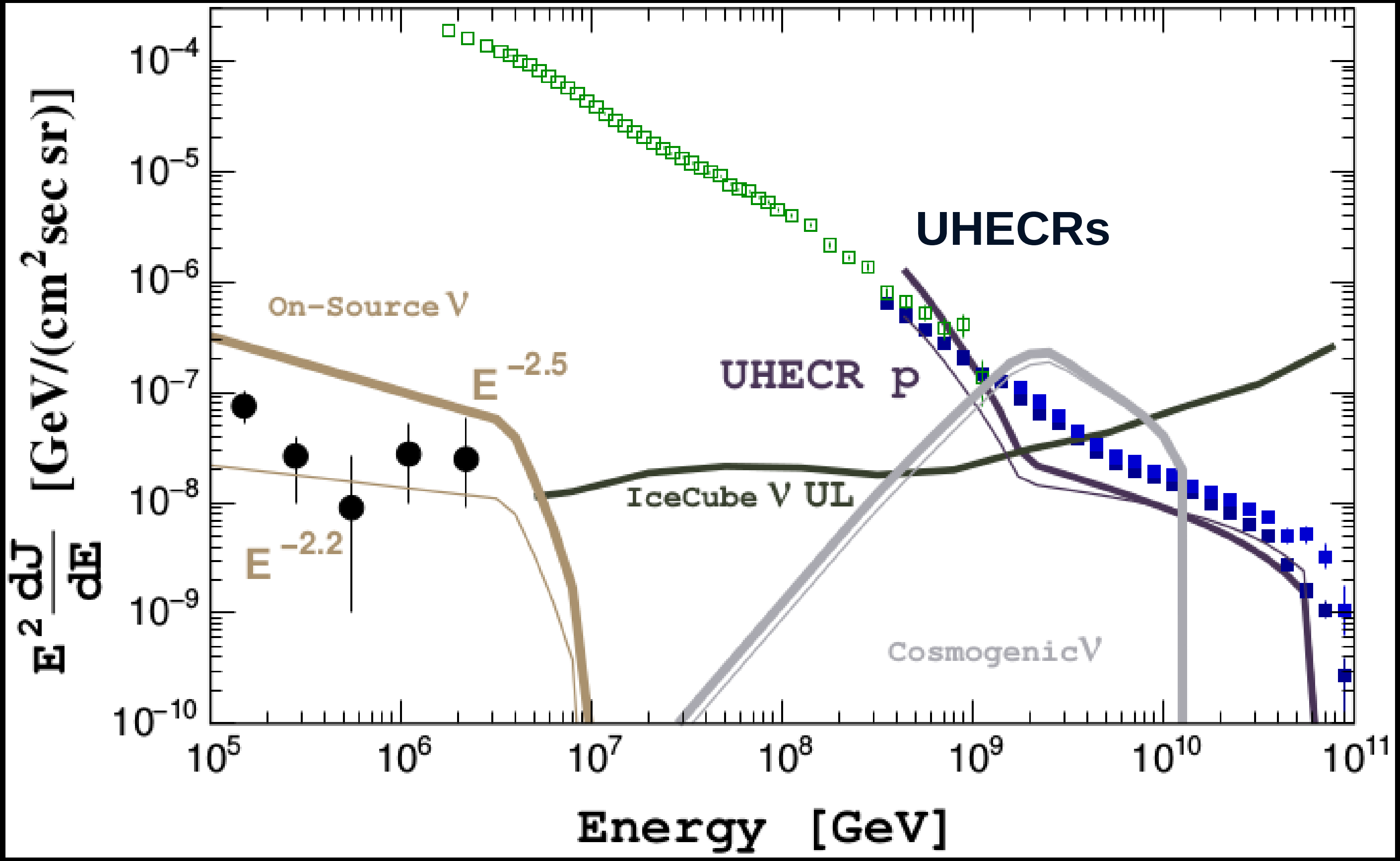
Yoshida & Takami PRD 2014

Yoshida & Ishihara PRD 2012

UHECR-IceCube ν Unified Model

CHIBA UNIVERSITY

The (yet-unknown) UHECR sources are also the origin of IceCube TeV ν?



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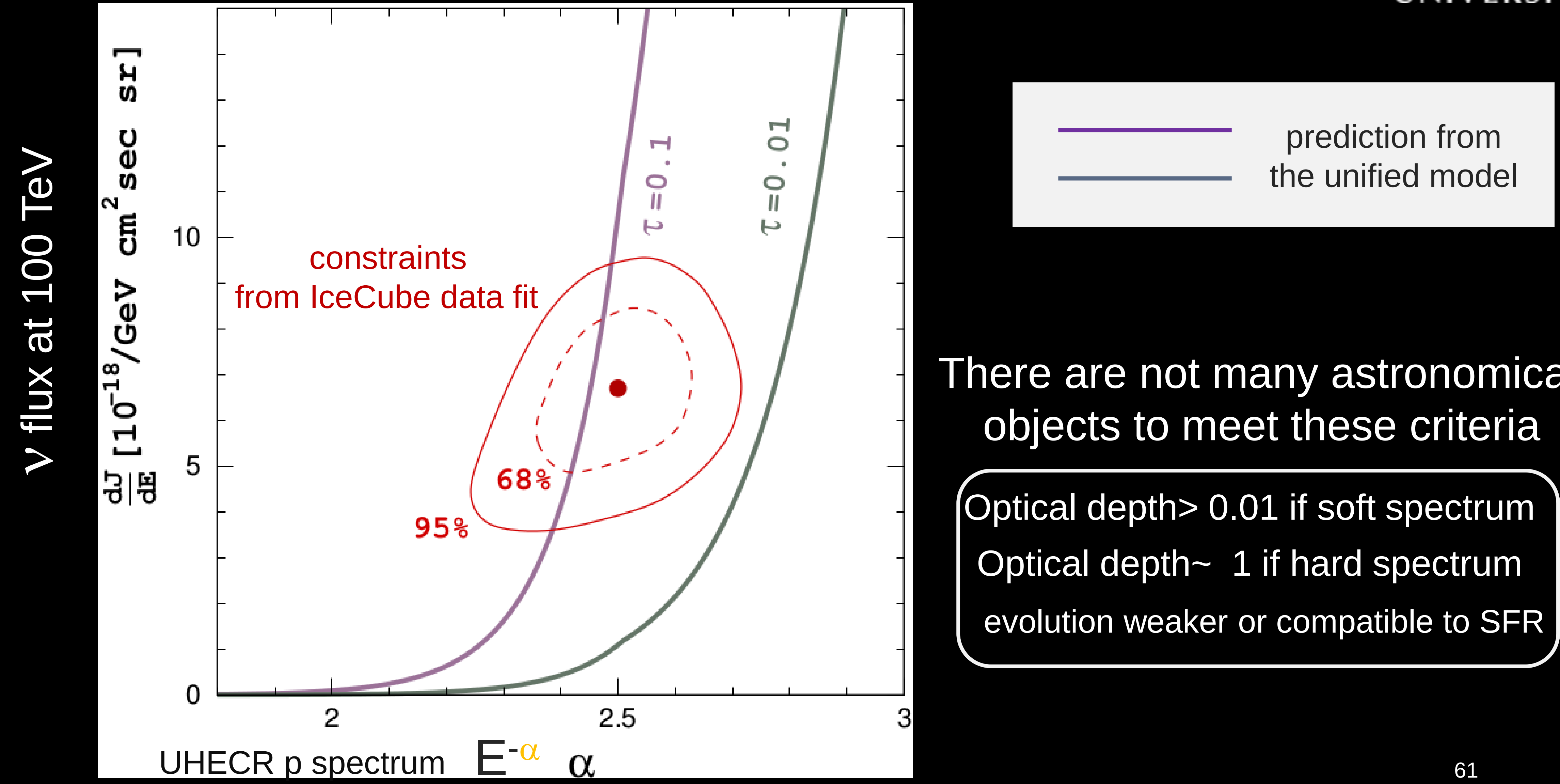
Yoshida & Ishihara PRD 2012

UHECR-IceCube ν Unified Model



There are not many astronomical objects to meet these criteria

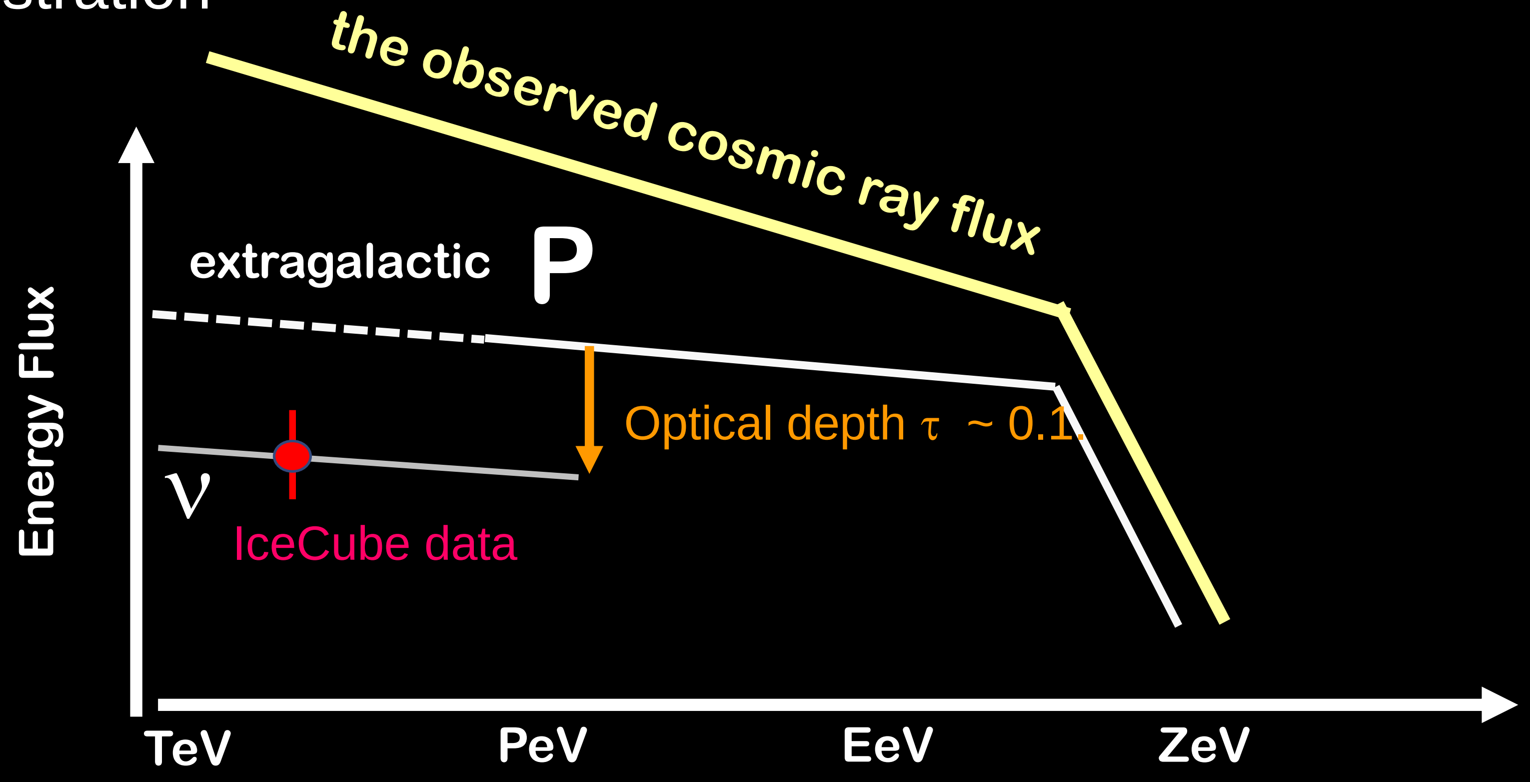
Optical depth> 0.01 if soft spectrum

Optical depth~ 1 if hard spectrum

evolution weaker or compatible to SFR

Connections between the observed TeV-PeV ν flux and UHECRs

Schematic Illustration



Connections between the observed TeV-PeV ν flux and UHECRs

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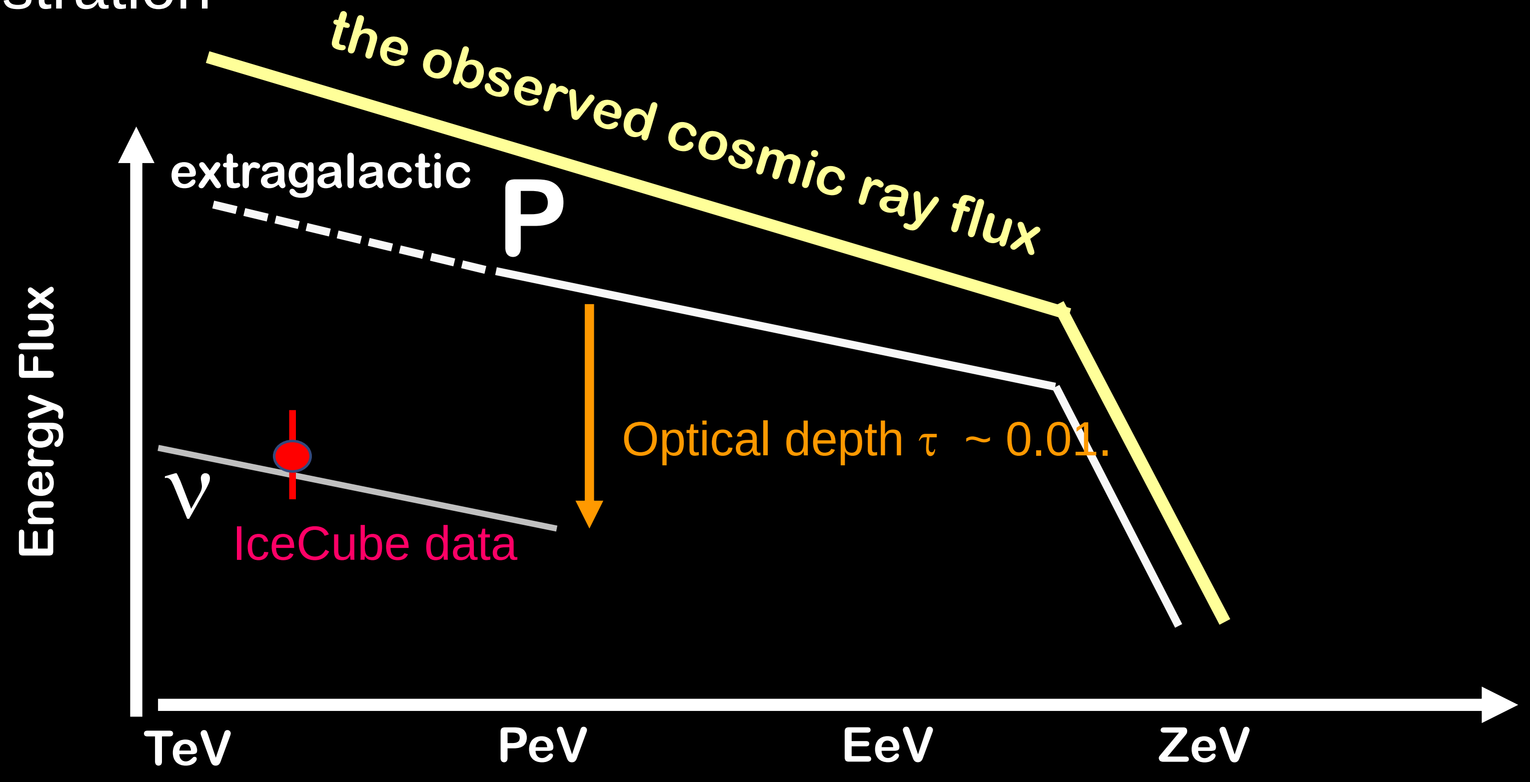
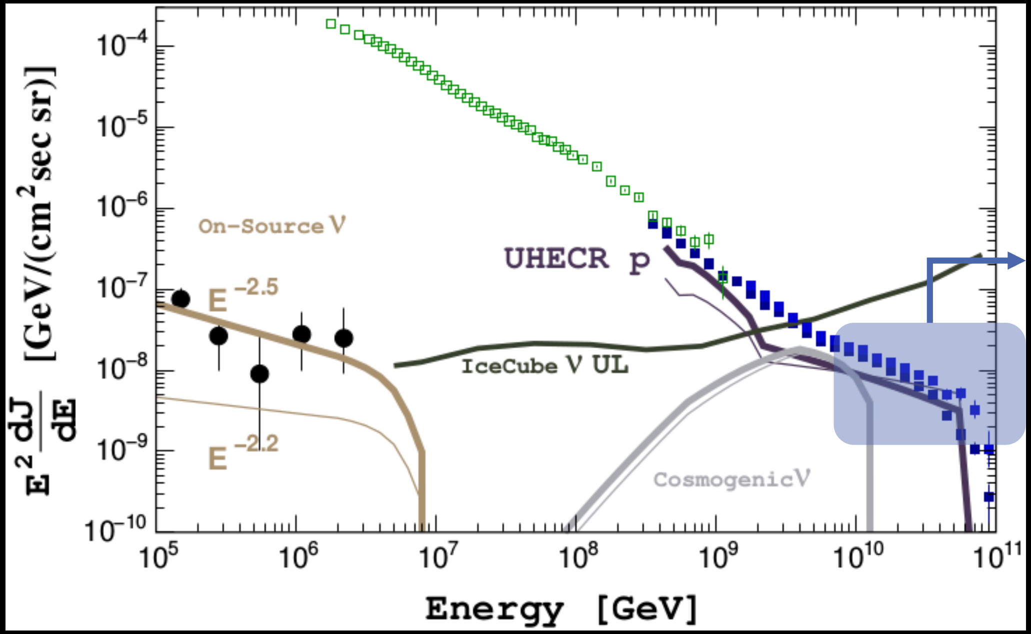
Schematic Illustration



UHECR-IceCube ν Unified Model

Energetics requirements



Source luminosity with SFR-like evolution

	$E^{-2.2}$	$E^{-2.5}$
E>10 EeV	~4×10^{44} erg/Mpc^3 yr	~2×10^{44} erg/Mpc^3 yr
extrapolate ↓ E>10 PeV	~2×10^{48} erg/Mpc^3 yr	~6×10^{48} erg/Mpc^3 yr

c.f. GRB L_γ ~ 10^{44} erg/Mpc^3 yr   FSRQ L_γ ~ 10^{46} erg/Mpc^3 yr

UHECR-IceCube ν Unified Model

genetic requirements to UHECR sources

cosmological evolution compatible or weaker than star formation rate

IceCube bounds on GZK ν

Fermi extra-galactic diffuse γ-ray bound

optical depth τ >~ 0.01 if $E^{-2.6}$, τ>0.1 if $E^{-2.3}$ or harder

IceCube TeV-PeV ν flux

c.f. GRB internal shock τ~0.1, afterglow $O(10^{-3})$, BL Lac $O(10^{-6})$

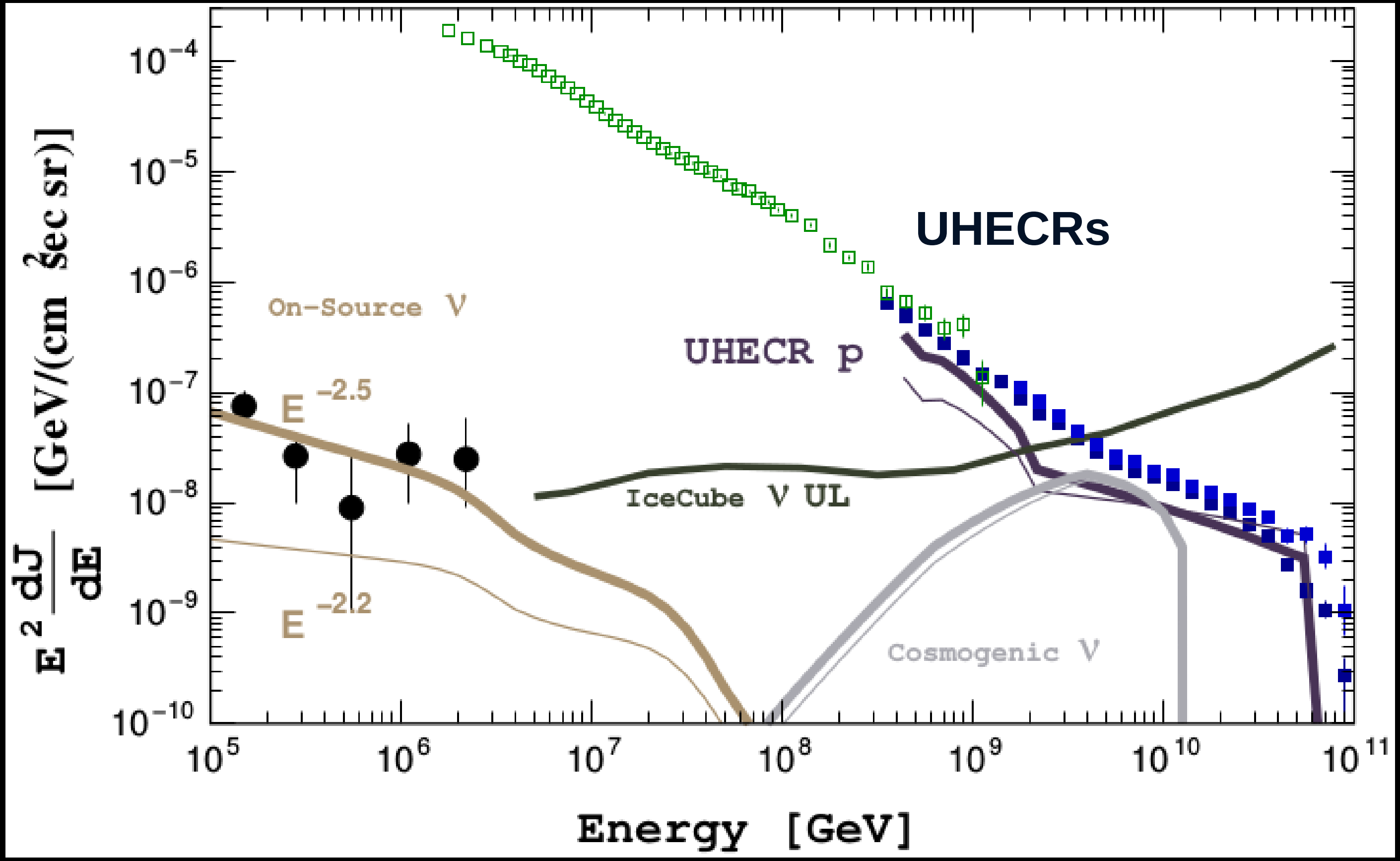
Energy luminosity $O(10^{48})$ erg/Mpc^3 yr @ E>10 PeV

extrapolated from UHECR luminosity

UHECR-IceCube ν Unified Model

An example of possible sources – black hole jets in the large scale structures

Fang & Murase 1704.00015



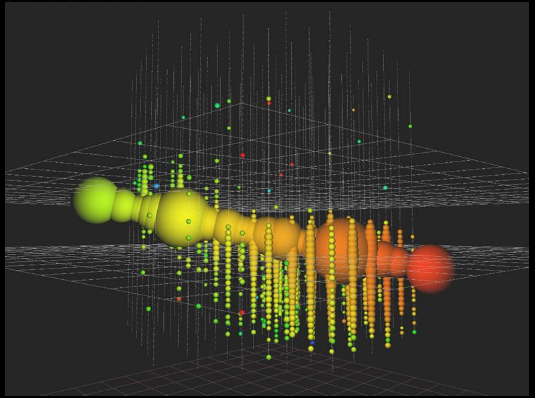
optical depth τ ~ 0.15
power law index α 2.3 (i.e. $E^{-2.3}$)
SFR-like evolution

meets the present generic criteria for being both UHECR and ν sources

Optical depth> 0.01 if soft spectrum
Optical depth~ 1 if hard spectrum
evolution weaker or compatible to SFR

Two PeV events found in the 9yr data sample

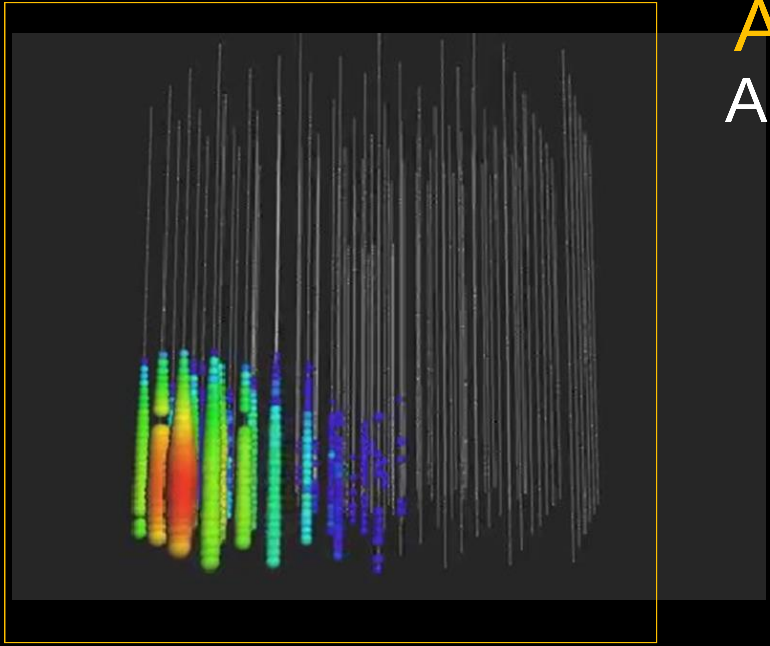
April 2008 – May 2017



A track event in June 2014 Deposited energy 2.6 PeV

The event found in the previous EHE neutrino search

Of the two background events published in PRL 117 241101,
one was discovered to be a detector artifact and has been removed



A new event in December 2016

An uncontained shower event

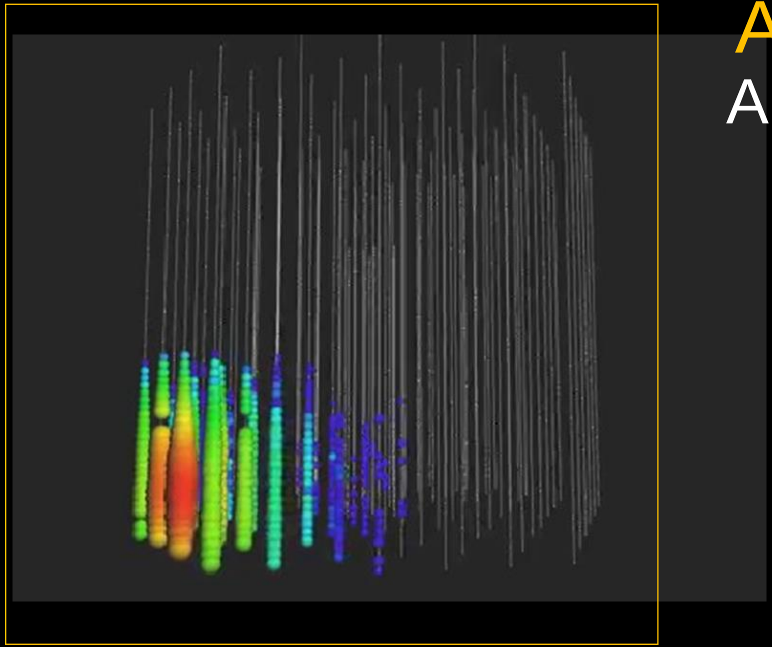
Preliminary deposited energy 6 PeV

Uncontained nature of this event indicates large uncertainty on energy estimate

- Investigations ongoing to see if a prompt atmospheric muon could be responsible for this event

TeV PeV EeV

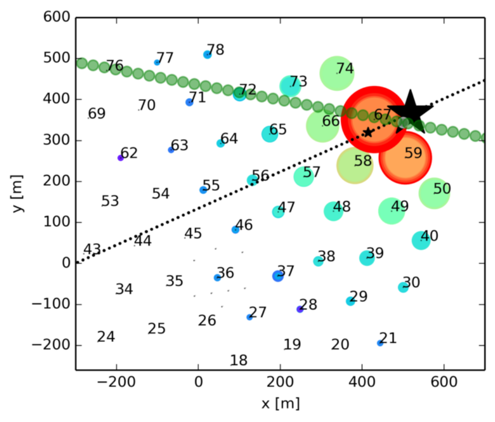
UHE (PeV-EeV)

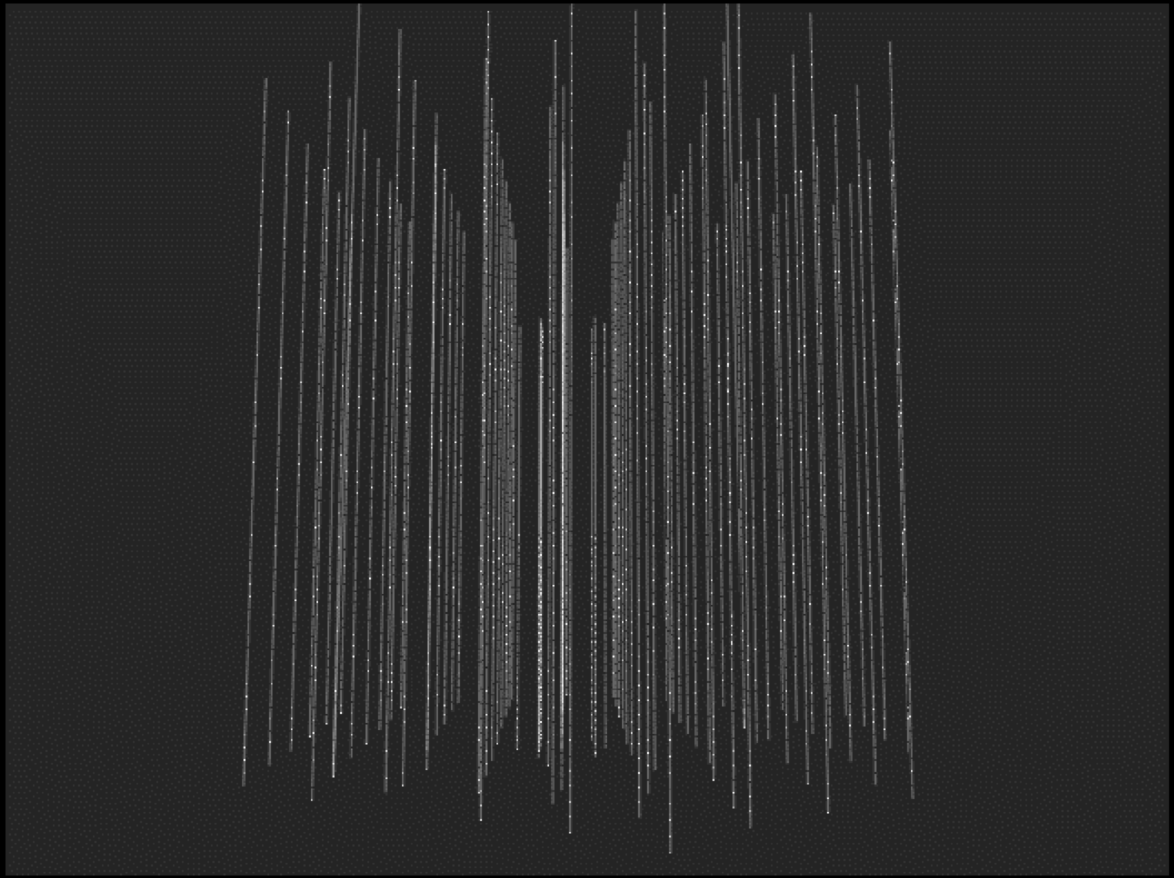


A new event in December 2016

An uncontained shower event

Preliminary deposited energy 6 PeV





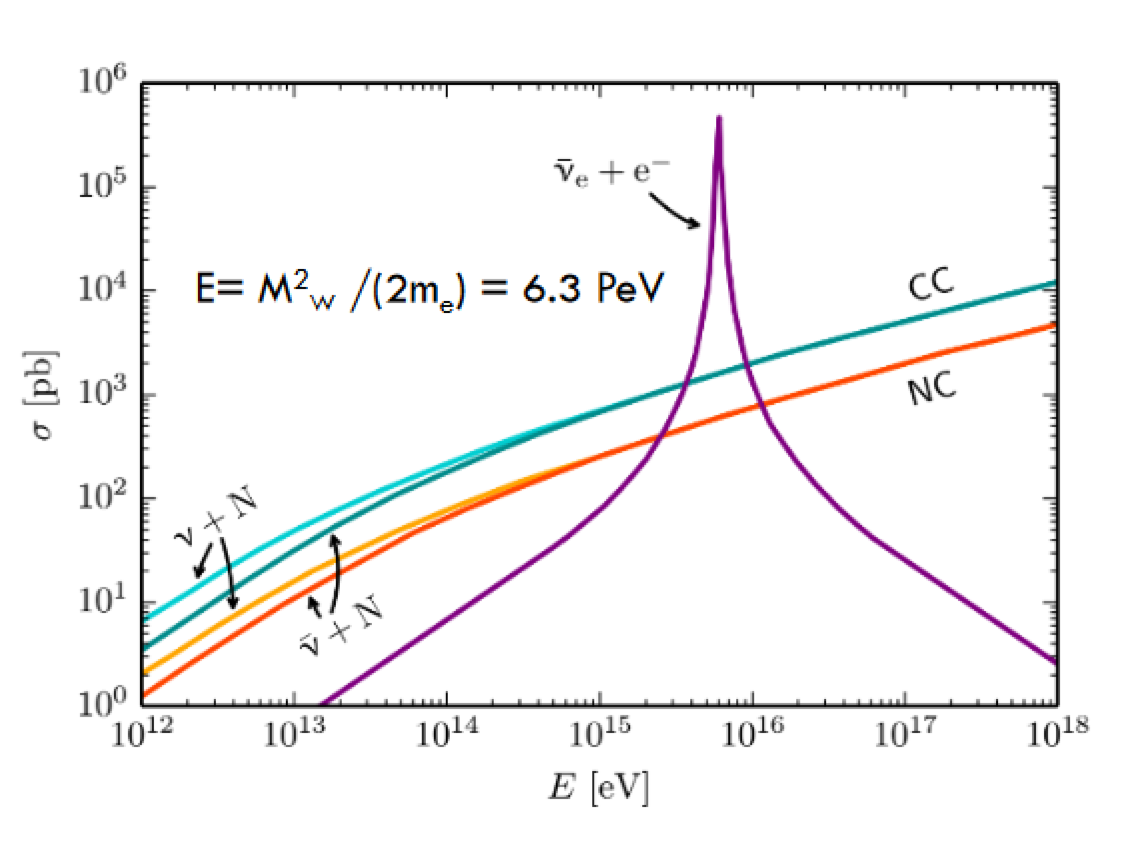
A new event in December 2016

An uncontained shower event

Preliminary deposited energy 6 PeV

Event “Hydrangea”

consistent with the Glashow Resonance



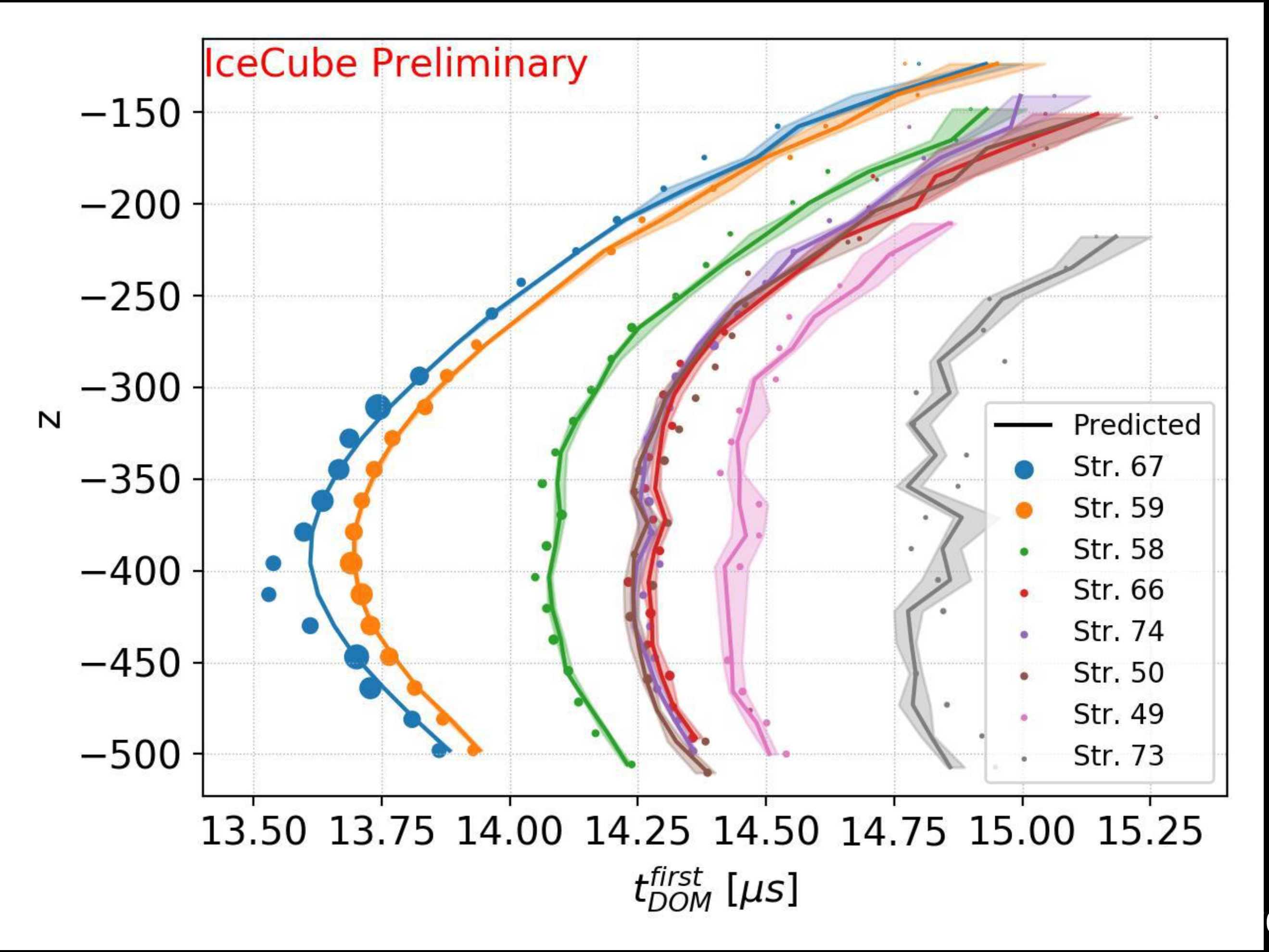
A new event in December 2016

An uncontained shower event

Preliminary deposited energy 6 PeV

Event “Hydrangea”

Cherenkov photon distribution

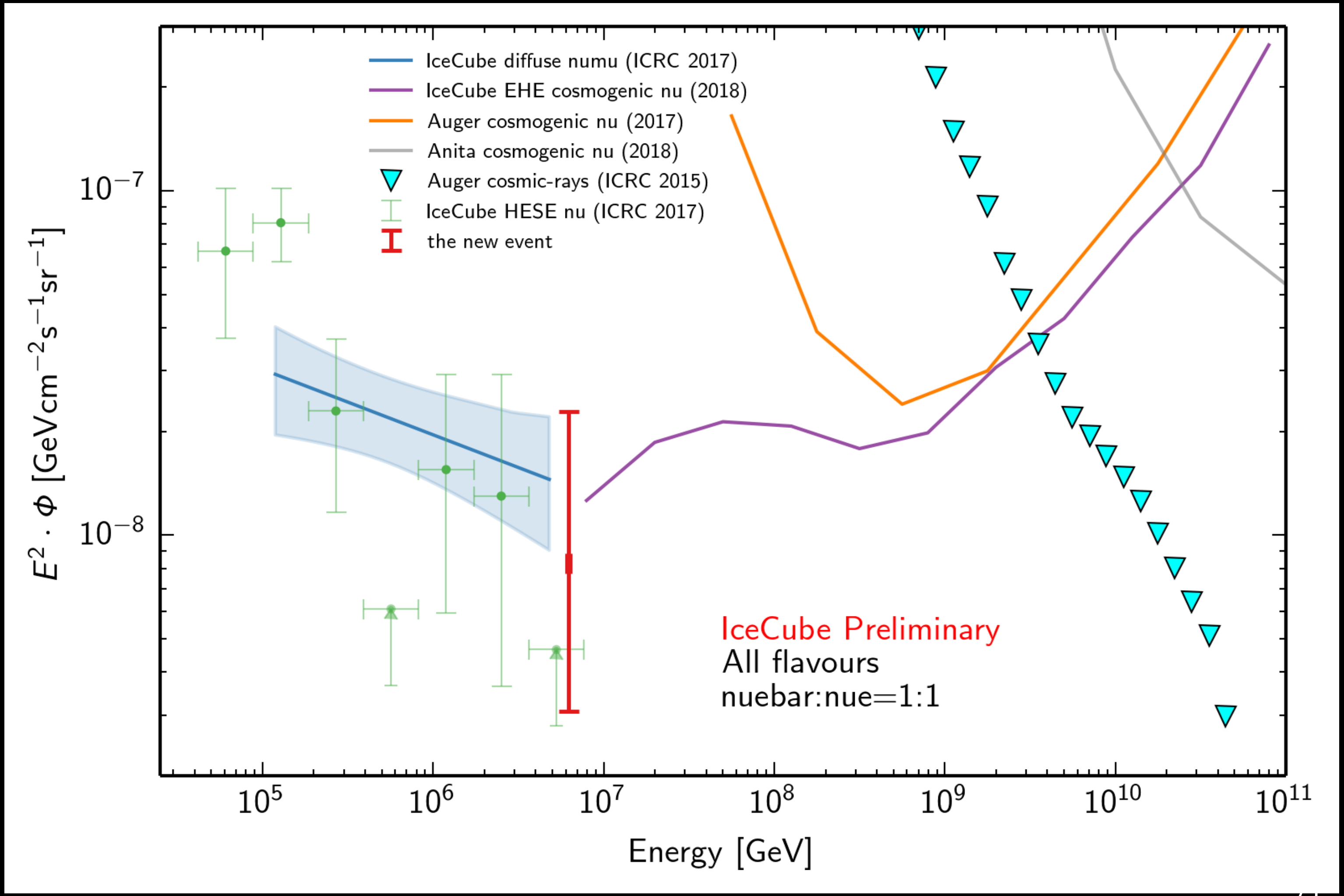


A new event in December 2016

An uncontained shower event

Preliminary deposited energy 6 PeV

Event "Hydrangea"



Realtime Multi-Messenger

South Pole

Northern Hemisphere

WIPAC
Wisconsin IceCube Particle Astrophysics Center

IceCube Realtime Analysis Chain

Deliver of public alerts via GCN

High cosmic ν purity samples.
Launched in 2016!

veto-based
HESE

TeV PeV EeV

all neutrino flavor sensitive
high chance of real cosmic neutrino signals
angular resolutions so-so

EHE (Ultra-High Energies)

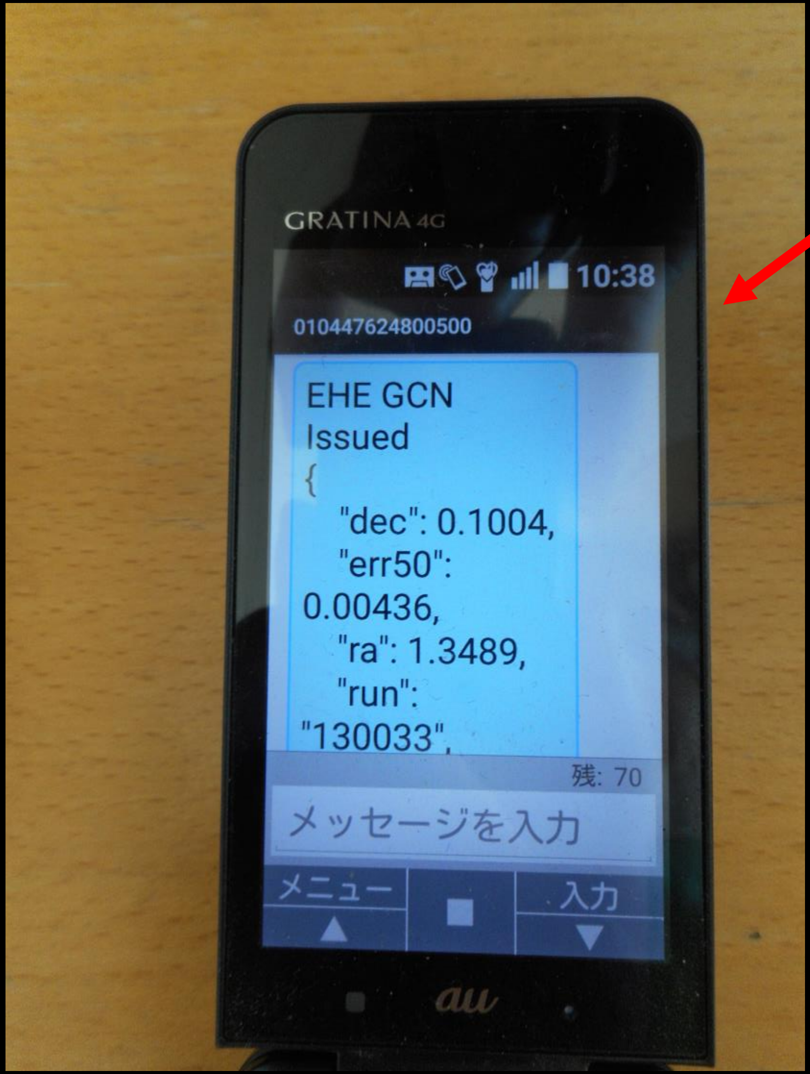
TeV PeV EeV

all neutrino flavor sensitive

high chance of real cosmic neutrino signals
good angular resolutions
signal flux highly uncertain

The breakthrough event
detected in this channel

And the story began here

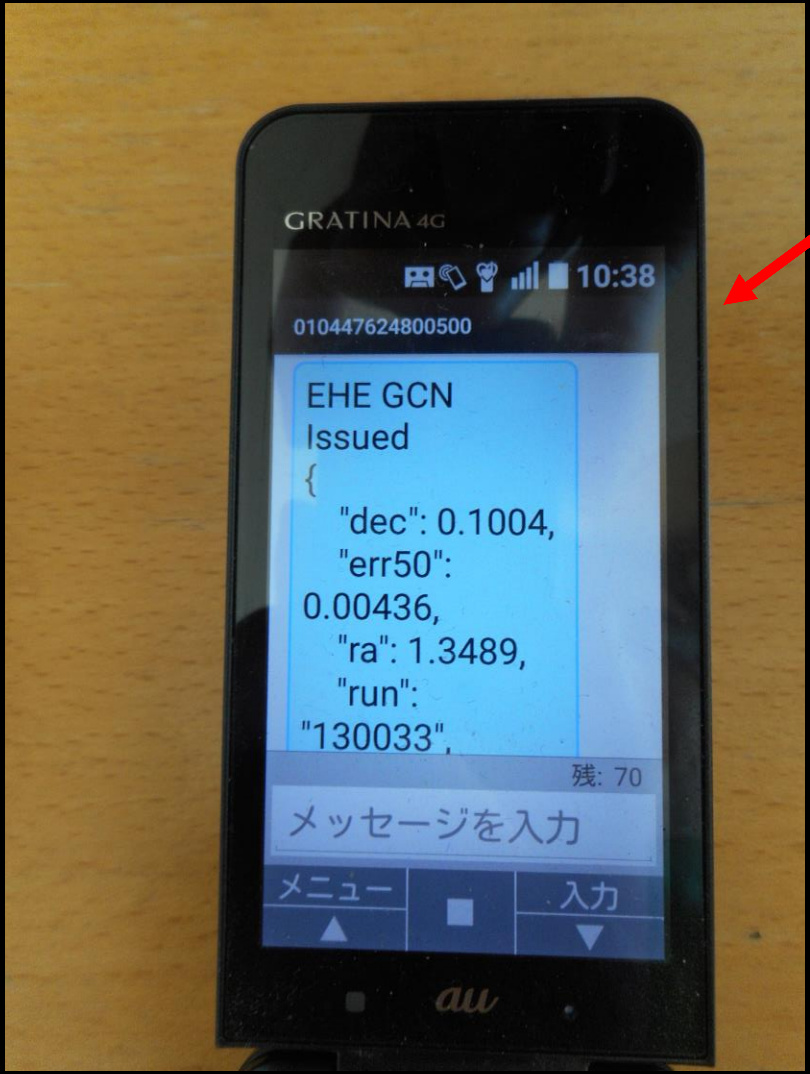


SMS notice
pinged my (non-smart) cellphone

5:55 am, Saturday, September 23, JST

the greatest wakeup call I’ve ever had in Saturday morning

And the story began here



SMS notice
pinged my (non-smart) cellphone

5:55 am, Saturday, September 23, JST

the greatest wakeup call I've ever had in Saturday morning

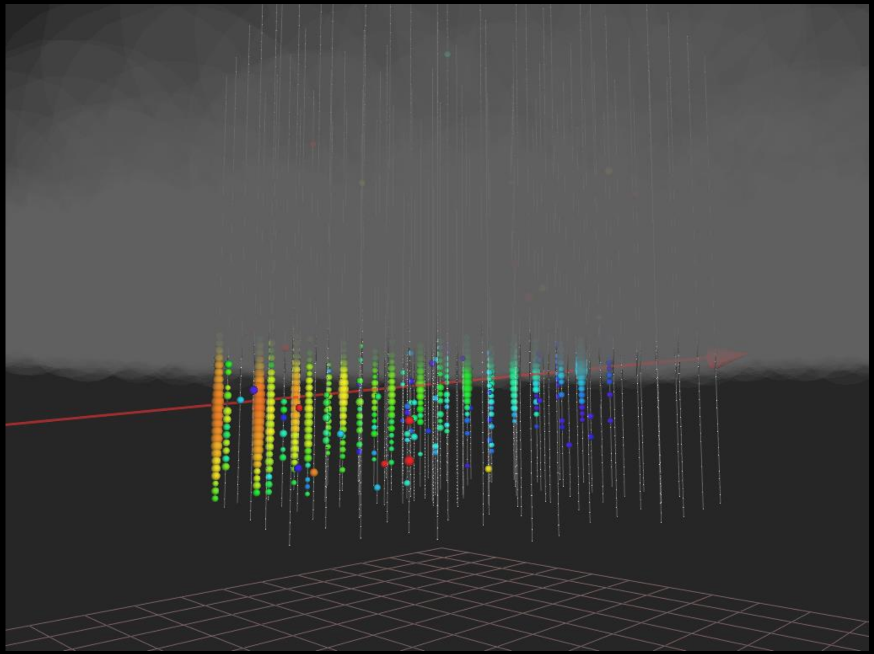
Numbers on IceCube 170922A

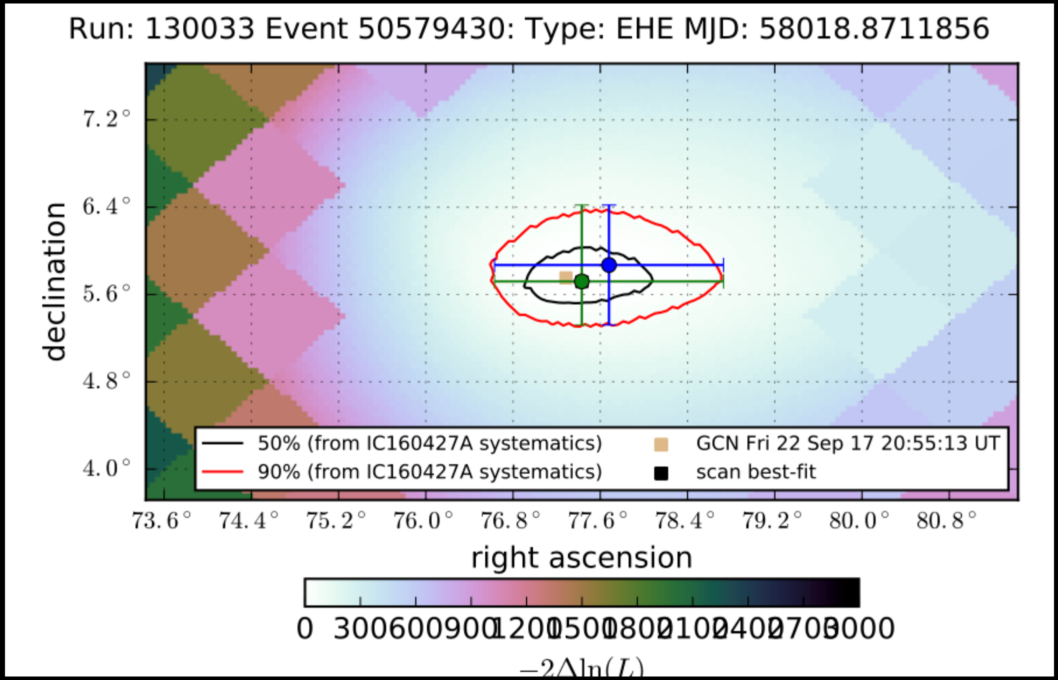
Identified by the EHE realtime stream

Date (UT):2017-09-22 20:54:30.436263 Run 130033 Evt 50579430

NPE:5785.94156

EHE linefit zenith 97.5 → Revised zenith 95.7 RA: 77.43 DEC: 5.72 (J2000)





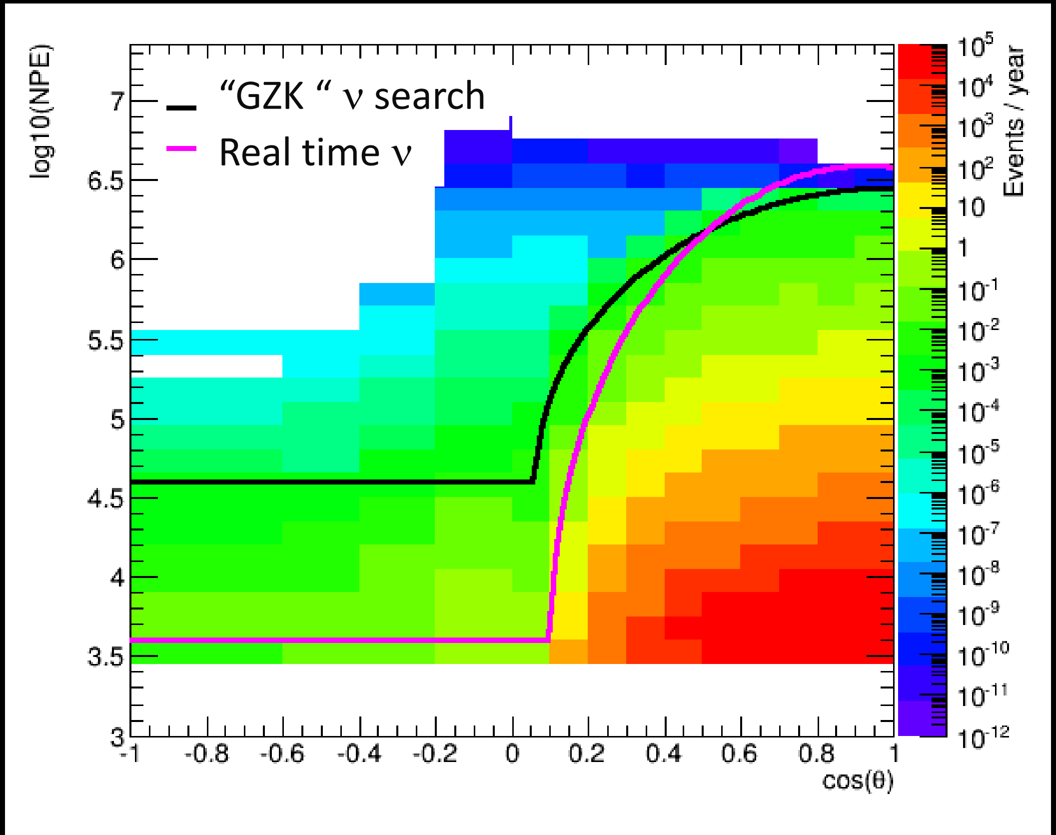
Provided by Claudio in the slack channel

Reminder : EHE real time stream

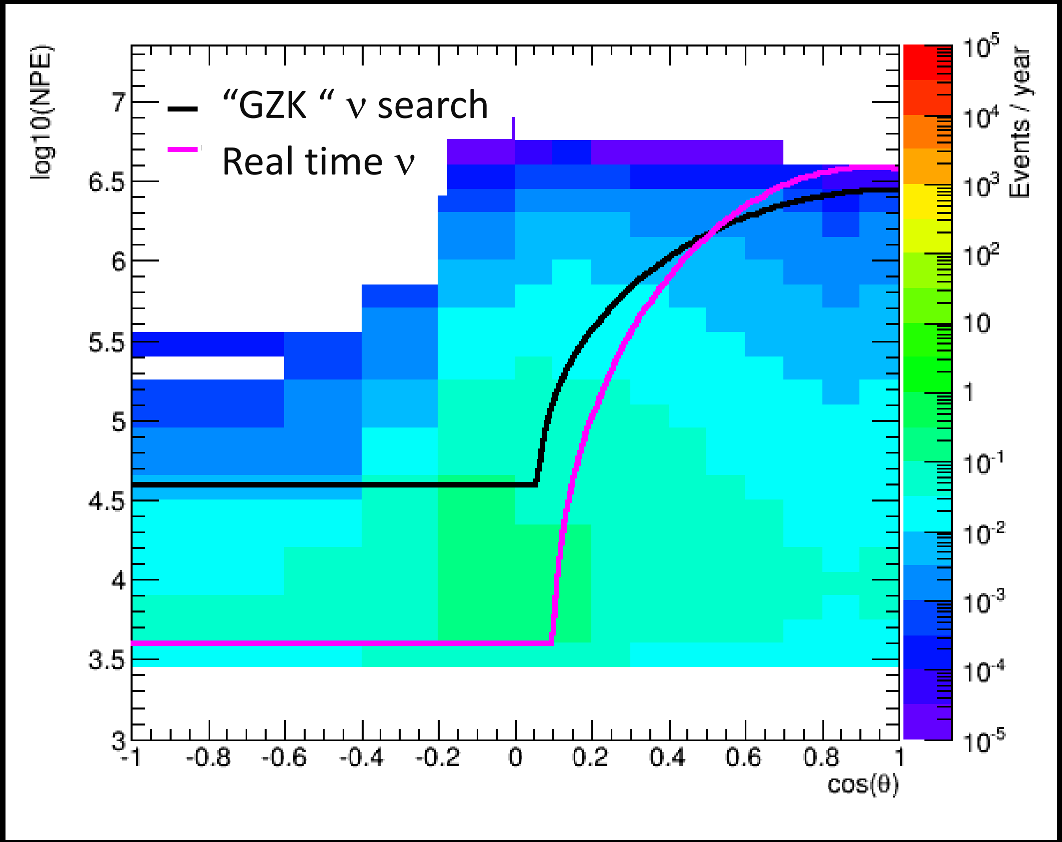
Relaxed cuts on NPE-cos(zenith) plane for track-like EHE L3

$\chi^2_{\text{EHE trackfit}} < 80$

Atmospheric BG



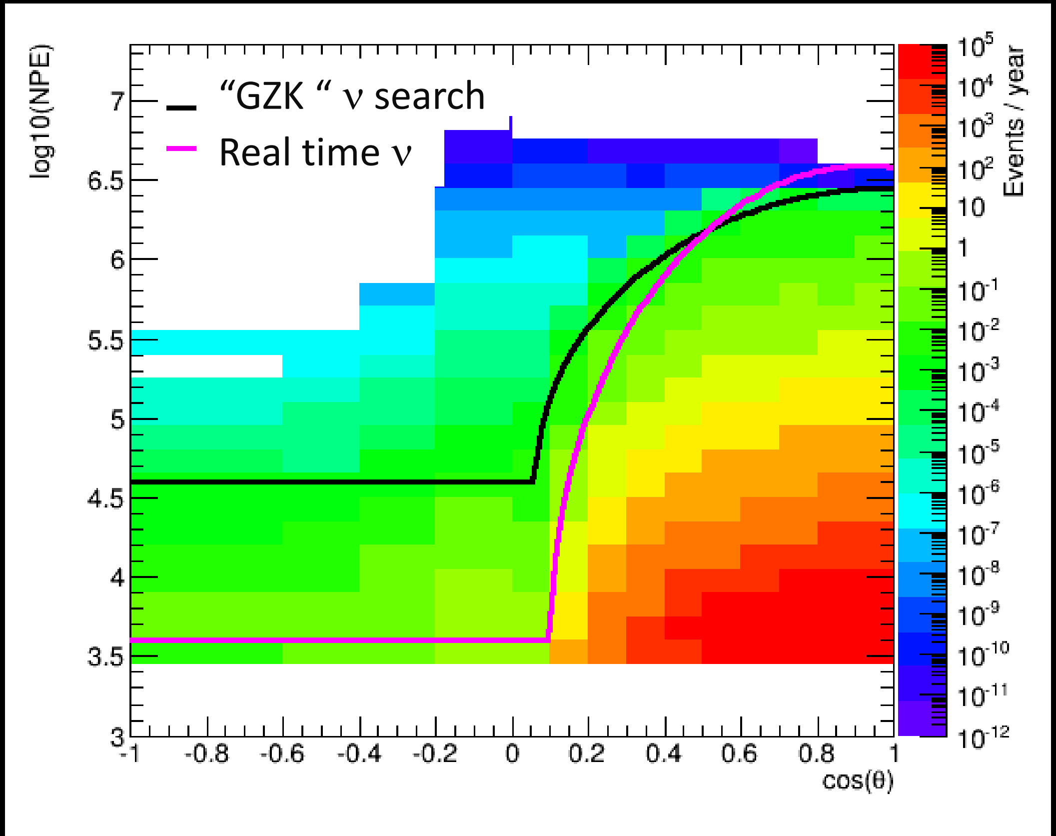
E^{-2} signal



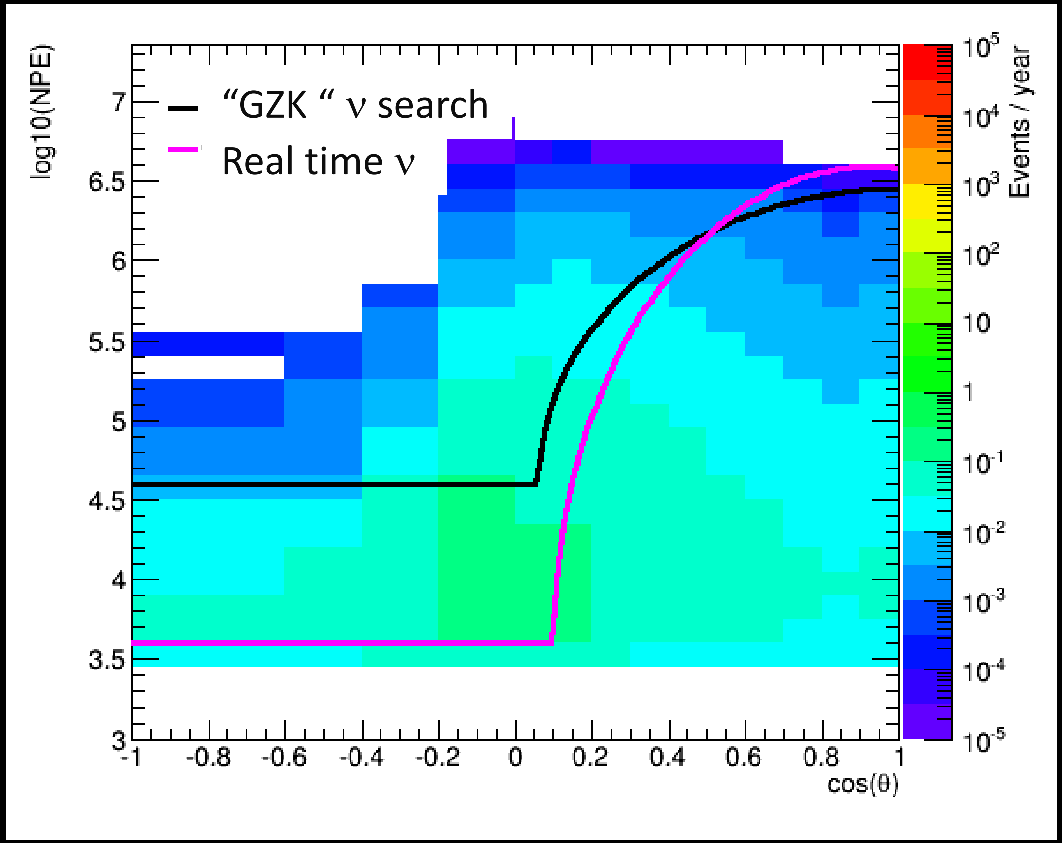
IceCube 170922A

NPE 5,786 cos(zenith) -0.13

Atmospheric BG



E^{-2} signal

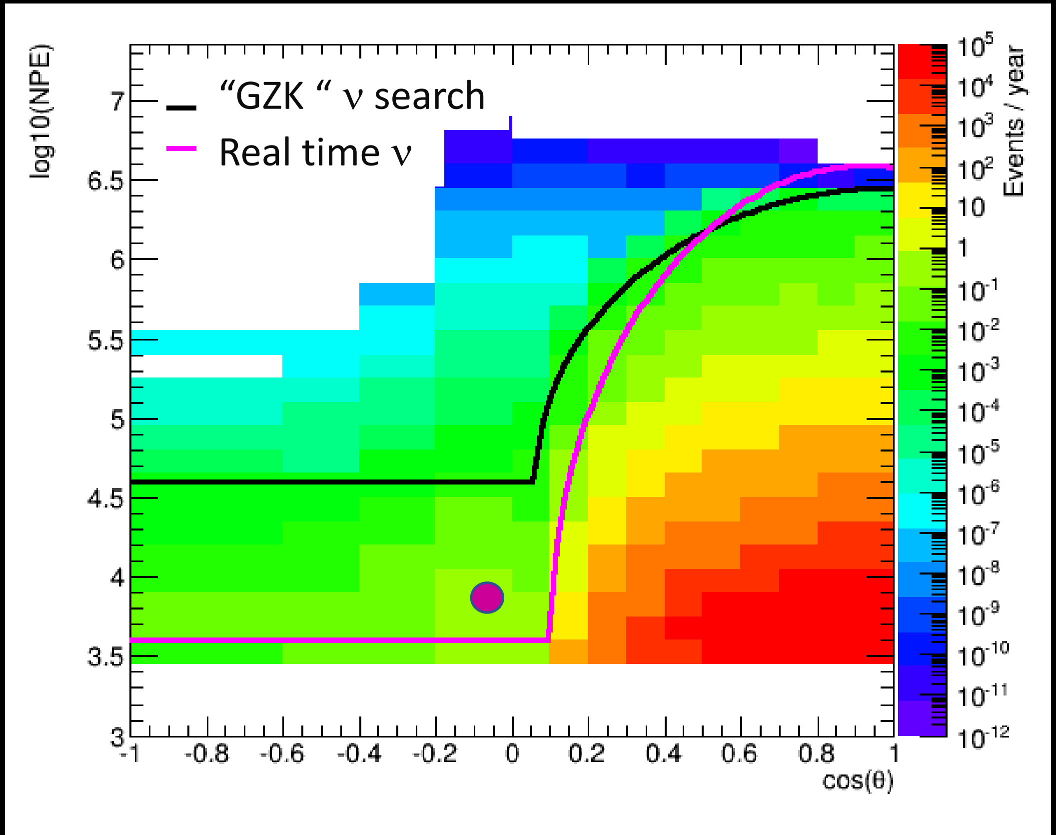


IceCube 170922A

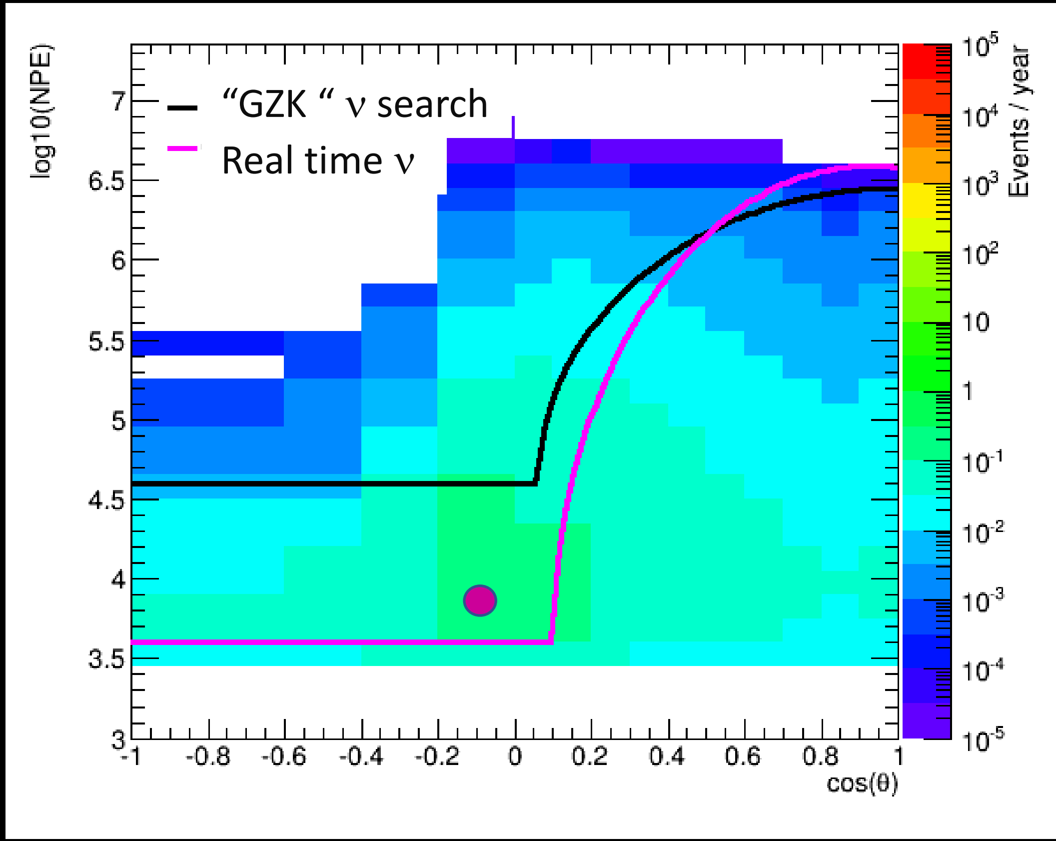
NPE 5,786 cos(zenith) -0.13

right on the "sweat spot" signalness : 56.5 %

Atmospheric BG



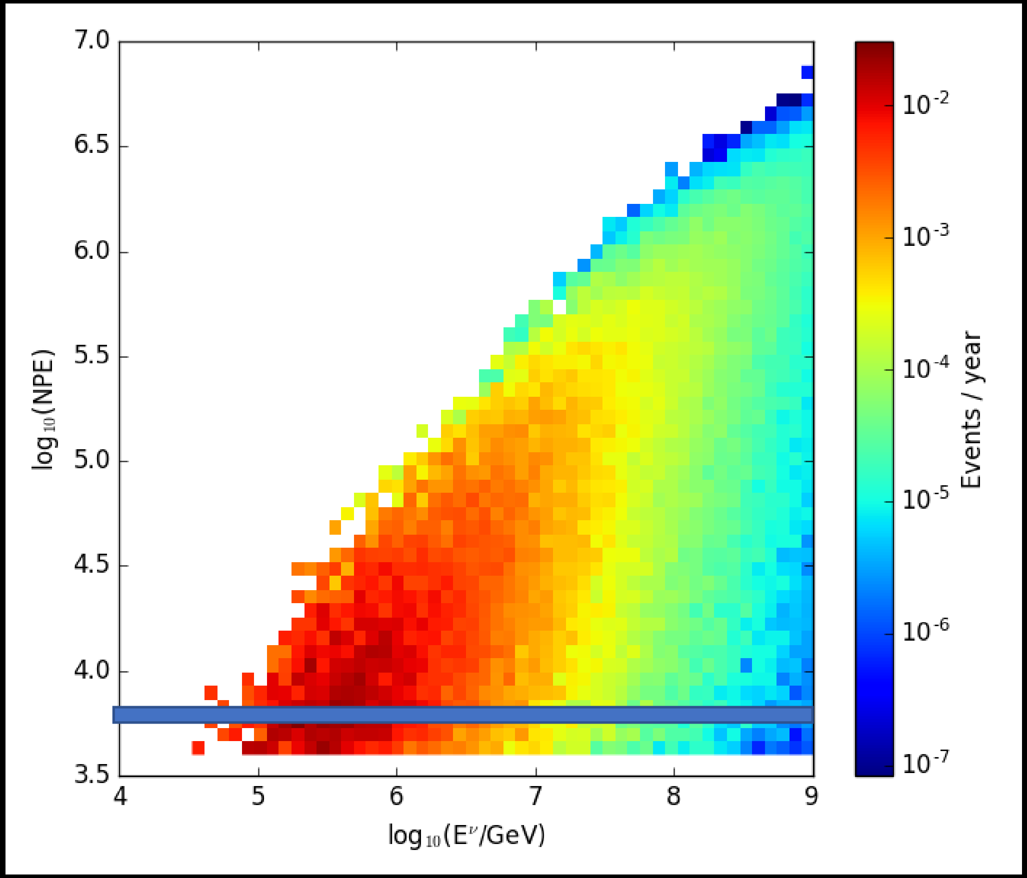
E^{-2} signal



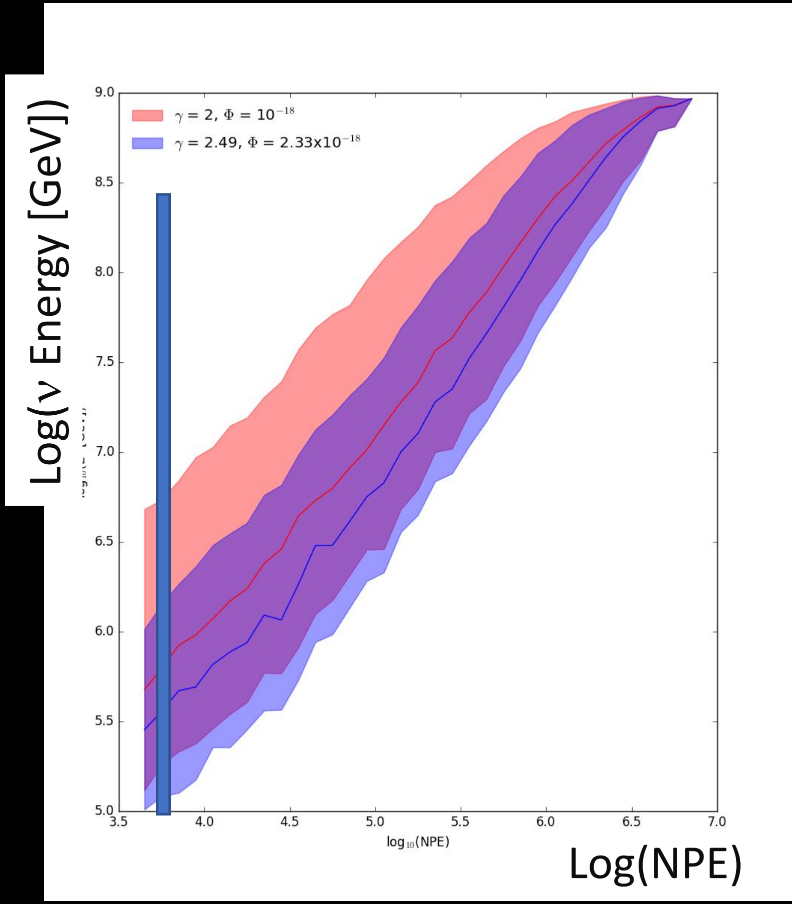
Neutrino Energy ?

Initial estimate reported in the GCN: 120 TeV

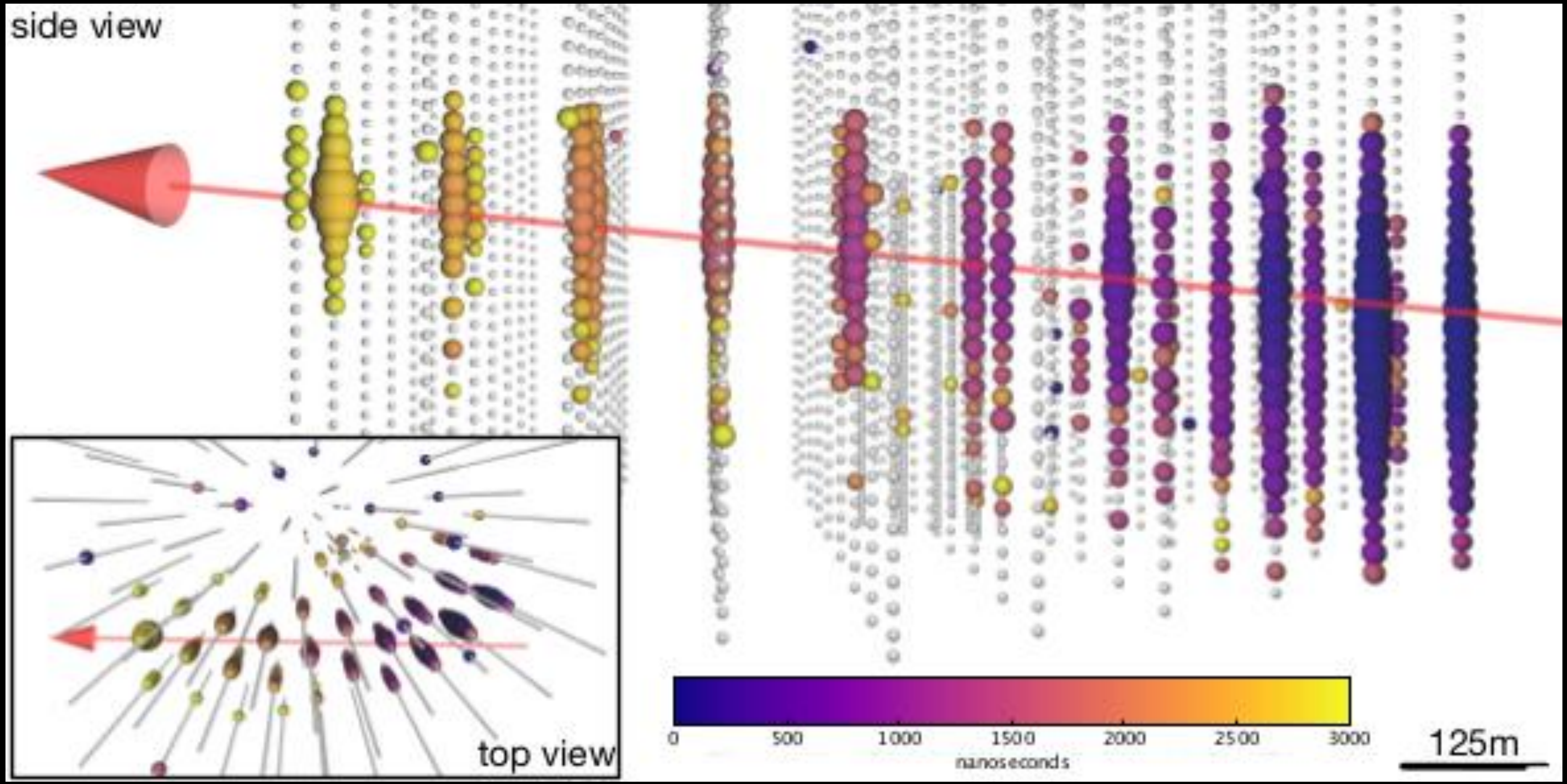
ν Energy Vs NPE ($E^{-2.5}$)



profile



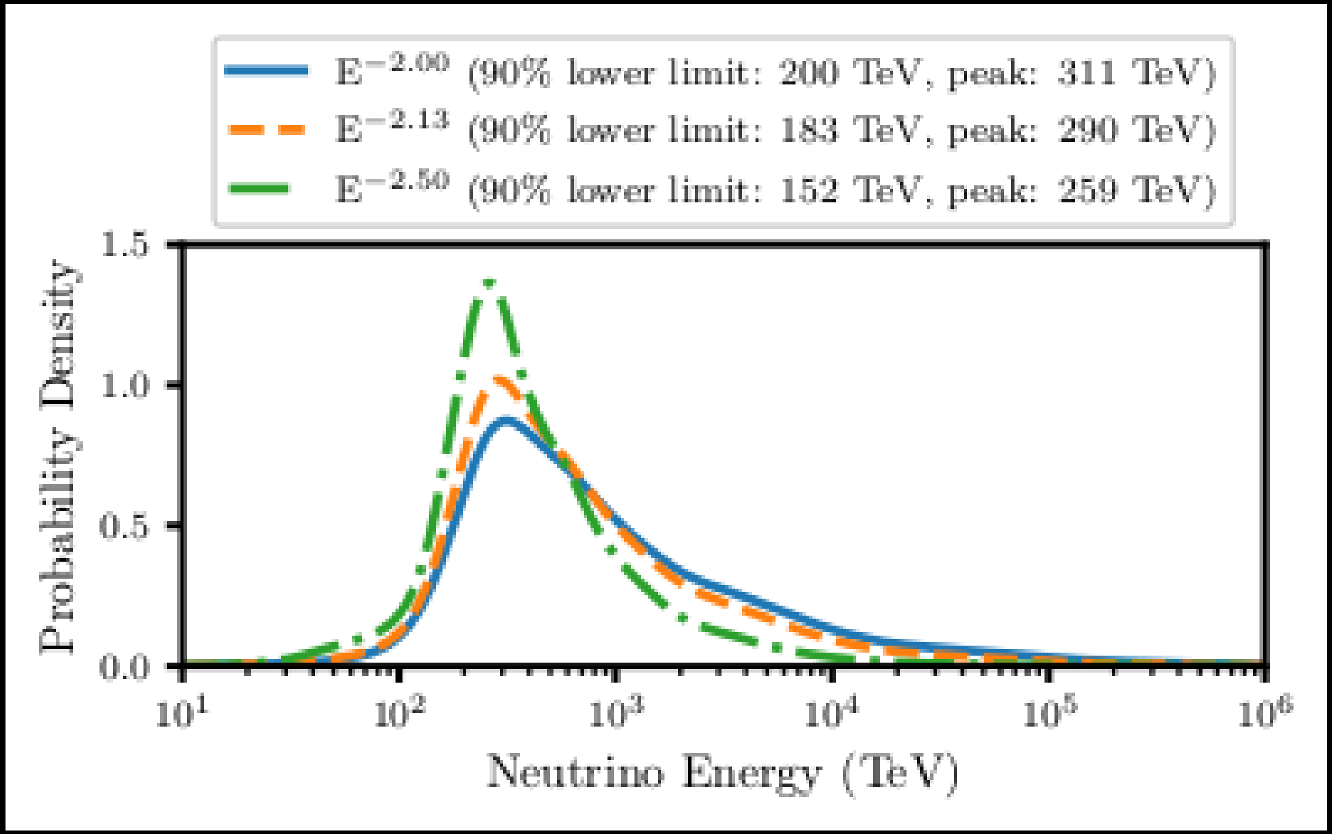
IceCube 170922A



Neutrino Energy ?

Energy deposit estimated : 21.6 TeV

→ ν_μ energy pdf at the earth surface



200TeV~ 7.5PeV

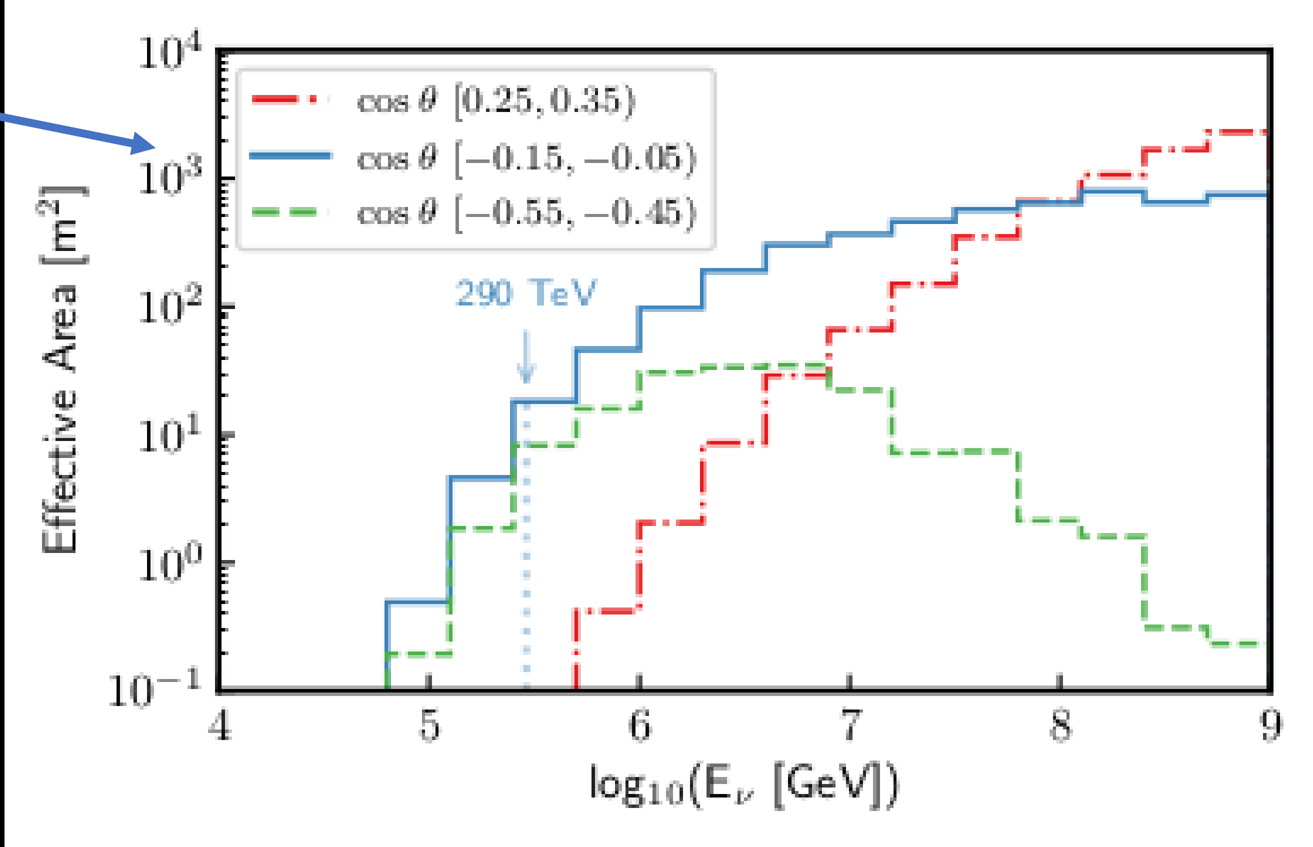
Log(NPE)

ν detection effective area

$$N = T \int d\Omega \int dE_\nu \phi_\nu(E_\nu)\, A_\nu(E_\nu)$$

\# of events time solid angle ν flux ν effective area

Zenith bin of this ν event



Neutrino Energy Flux

$$N = T \int d\Omega \int dE_\nu \phi_\nu(E_\nu)\, A_\nu(E_\nu)$$

$$\phi_\nu(E_\nu) \sim {E_\nu}^{-2}$$

$$L_\nu = \int_{200TeV}^{7.5PeV} dE_\nu \phi_\upsilon(E_\upsilon) E_\nu$$

$$= \frac{N}{T \int dE_\nu\, {E_\nu}^{-2} A_\nu(E_\nu)} \ln \frac{7.5PeV}{200TeV}$$

$$\boxed{\cong 1.8 \times\ 10^{-10} \left(\frac{T}{6month}\right)^{-1} erg\ cm^{-2}\ s^{-1}}$$

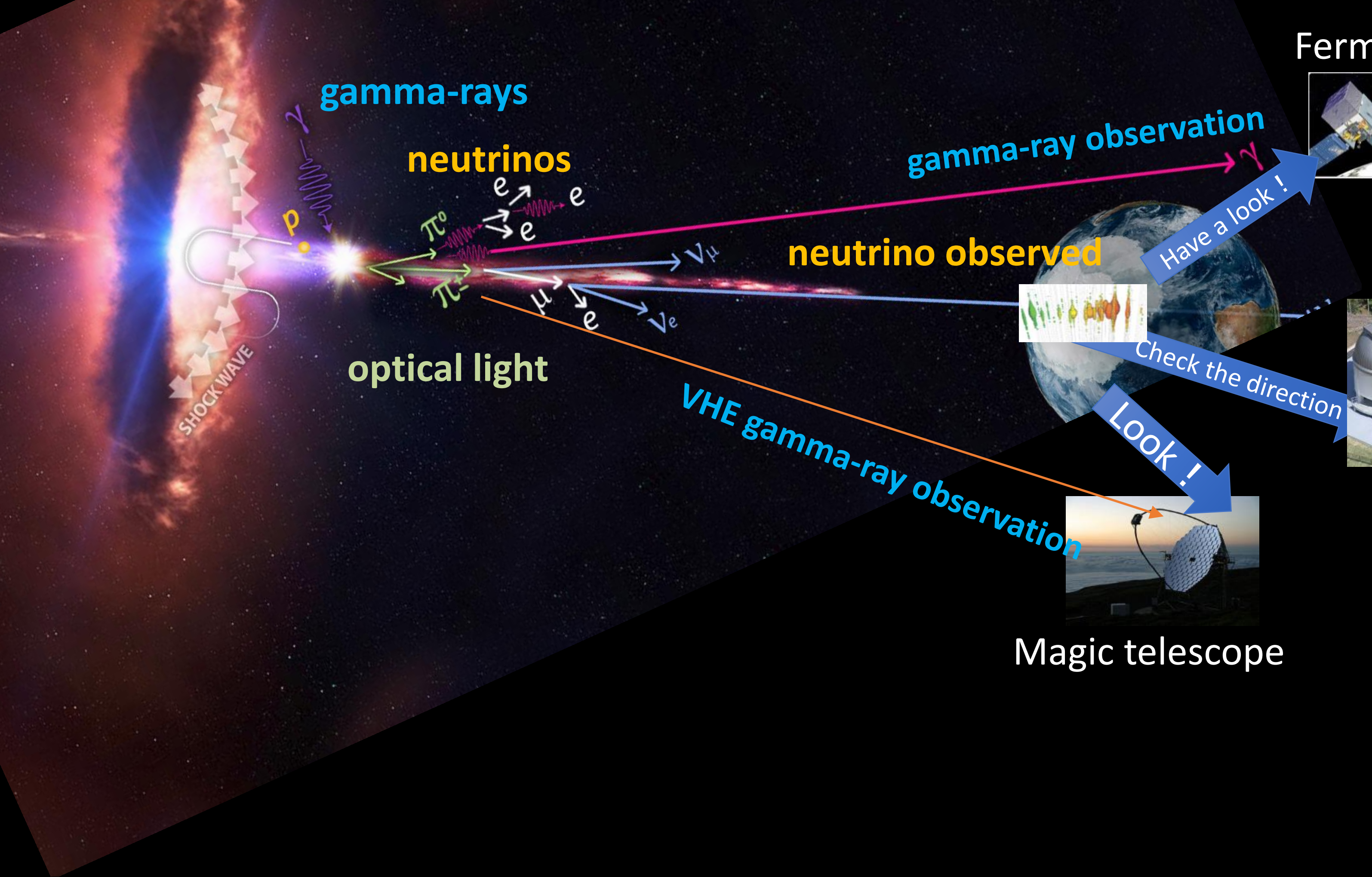
Summary of the follow-up observations

Observatory	Observation Time	Detection	Source	Comments
Fermi-LAT	Sept 15-27	✓	TXS 0506+056 / 3FGL J0509.4+0541 / 3FHL J0509.4+0542	Flaring >800 MeV
Swift-XRT	Sept 23 00:09-22:42 UT Sept 27 18:52 UT, 5 ks Sept 30 – Oct 7, 2 ks	✓	1SXPS J050925.9+054134	Spectral softening/evolution
Liverpool	Sept 28, 900 s	✓	TXS 0506+056 (PMN J0509+0541)	Typical BL Lac spectrum "Bluer when brighter"
ASAS-SN	-50 days	✓	TXS 0506+056	~0.5 mag in V-band
AGILE	Sept 18 12:00 UT + 3 days ±6 days	✓	< 1° from 3FGL J0509.4+0541	Excess > 100 MeV
H.E.S.S.	Sept 23 01:05 UT, 1 hr Sept 24 03:10 UT, 1 hr	×		Set 90% CL UL on ν fluence
HAWC	Sept 15 09:04 UT - Sept 19 14:41 UT Sept 21 08:41 UT to Sept 27 14:10 UT	×		At T0, this location was not in HAWC's fov
ANTARES	±1 hr and ±1 day of T0	×		Set 90% CL UL on ν fluence
INTEGRAL	±300 s of T0	×		Set 3σ UL
IC multi-day	Sept 15 00:00 UT – Sept 29 00:00 UT	×		
VERITRAS	Sept 23, 1 hr + Sept 28-39, 5.5 hrs	×		~200 GeV

And many more!

Science 361, eaat1378 (2018)

- 2017/9/22 20:54:30.43 UTC
- 5th and the most cosmic neutrino signal like EHE alert
- automated alert was distributed to observers just 43 seconds later



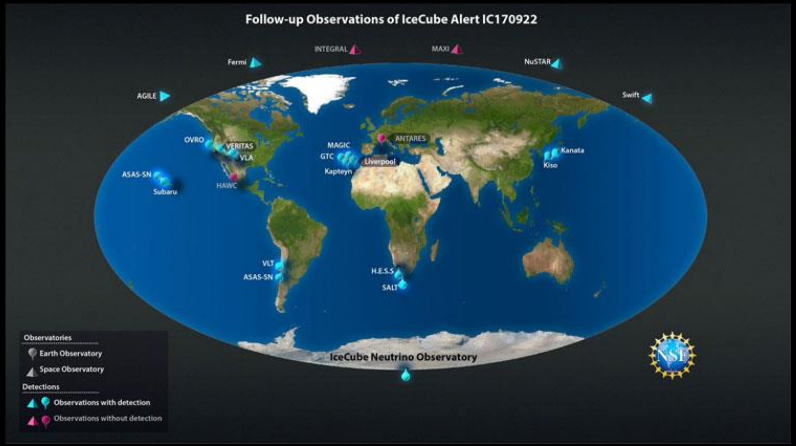
Fermi Telescope

Optical telescopes

Kanata telescope

Magic telescope

...and many more telescope



Fermi Blazar TXL 0506+56

Right on top of IceCube 170922A

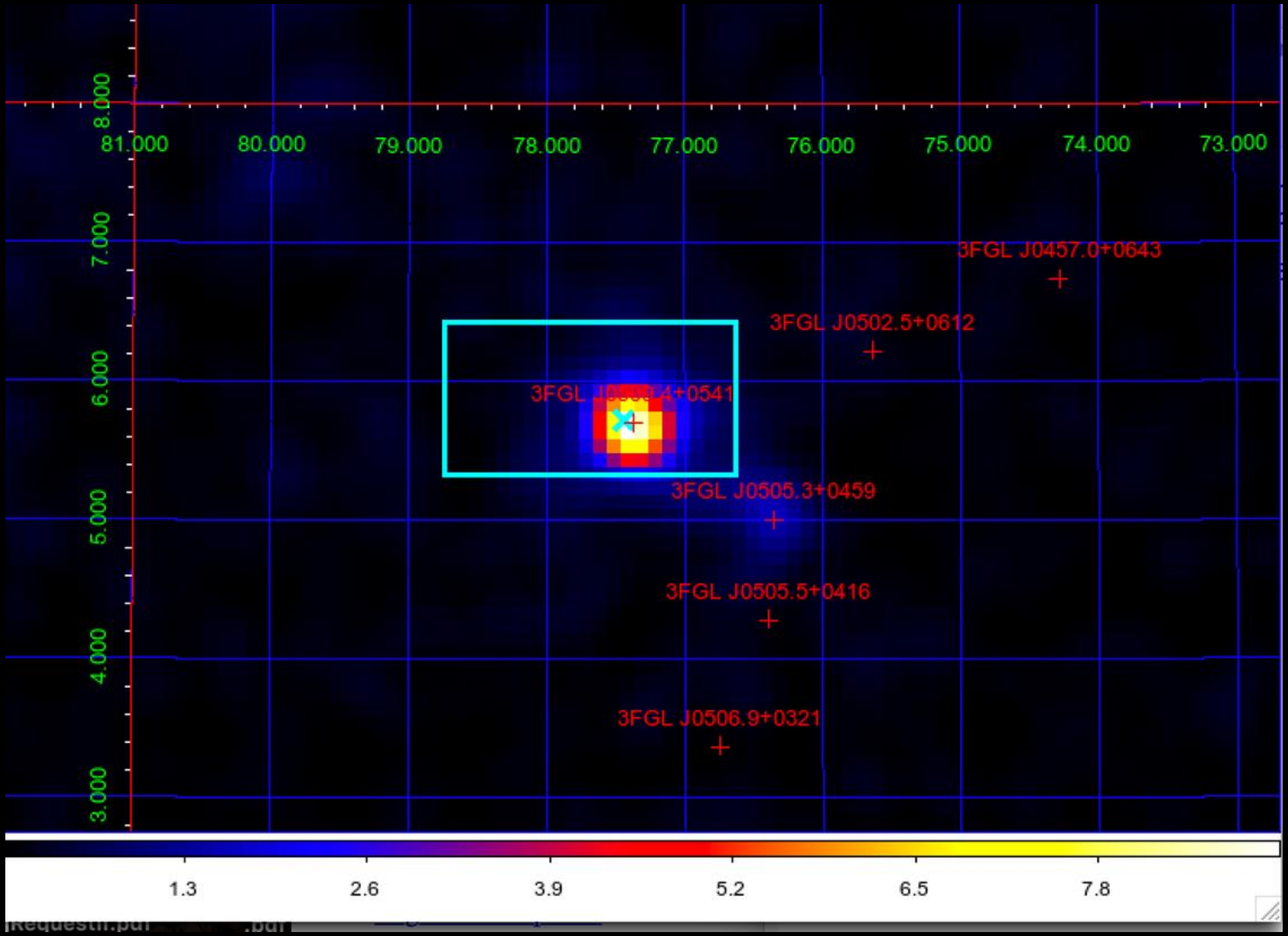
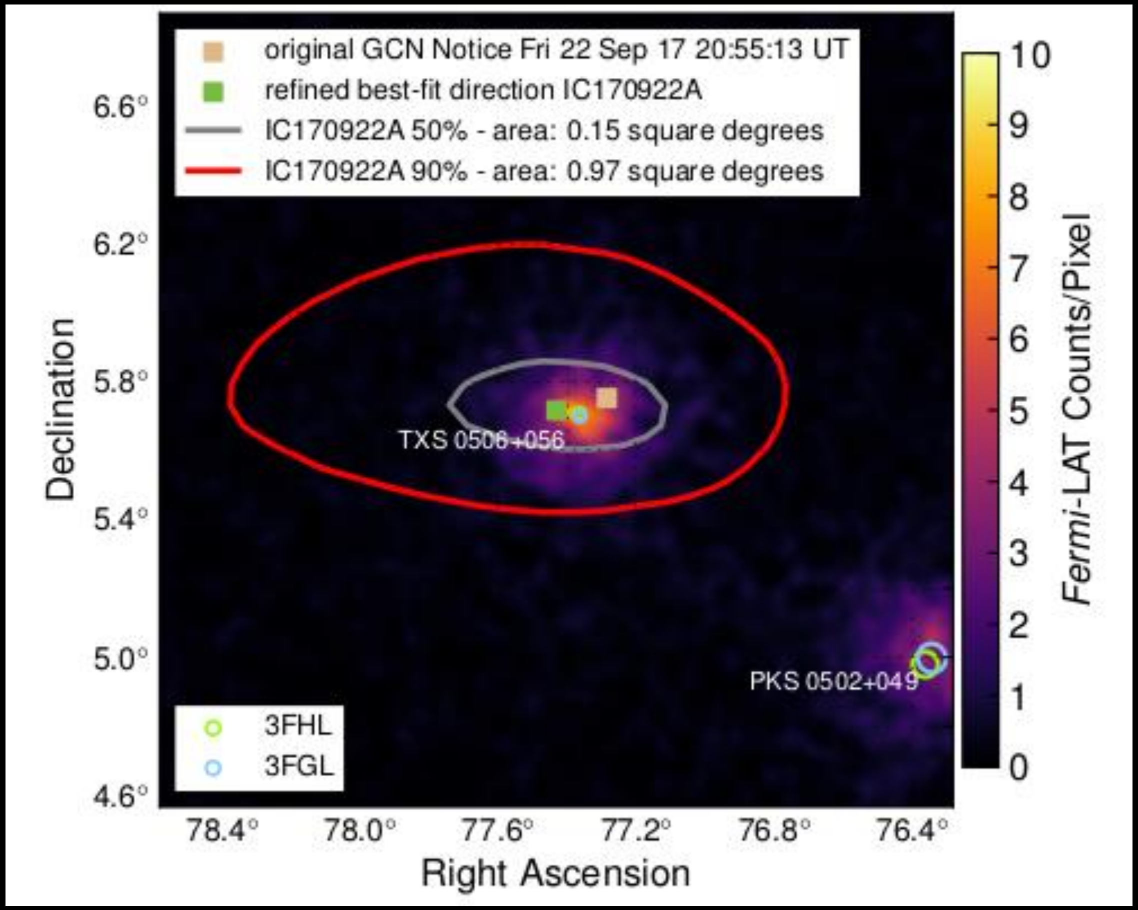


image made
by Masaaki Hayashida
(Fermi)

Fermi **Blazar** TXS 0506+56

Right on top of IceCube 170922A



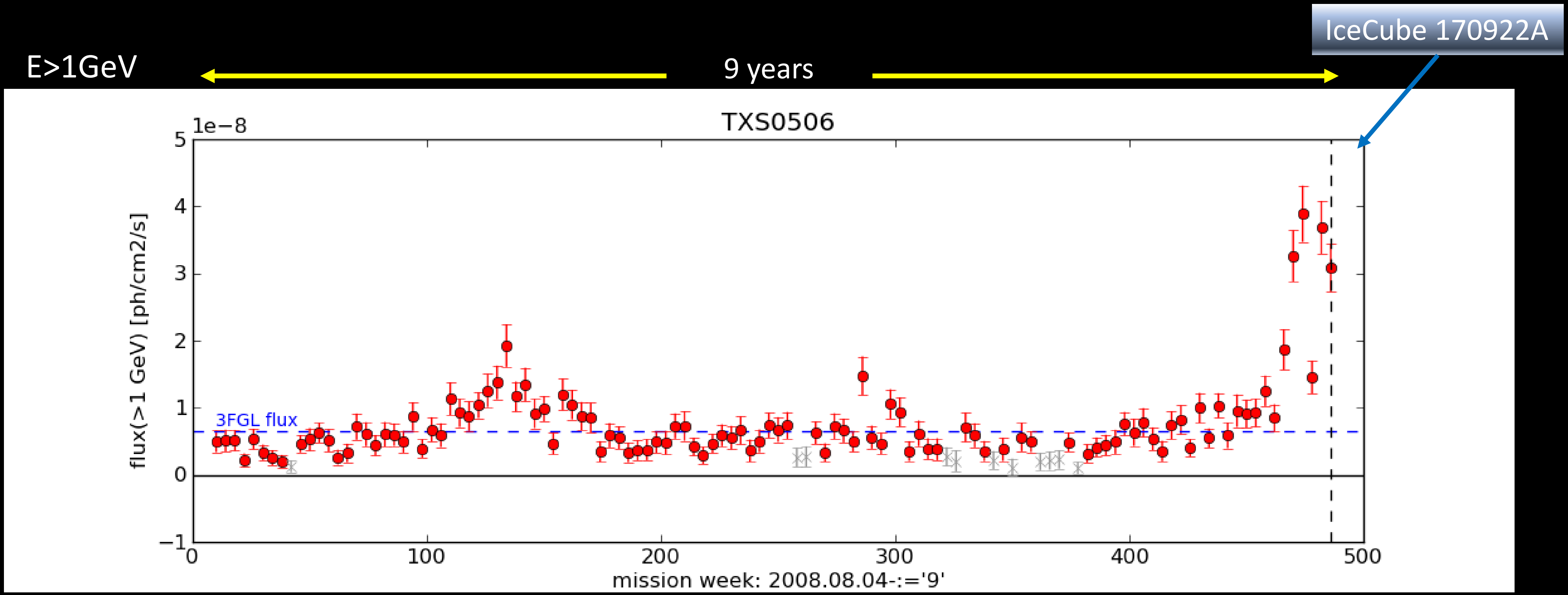
Fermi-LAT detection of increased gamma-ray activity of TXS 0506+056, located inside the IceCube-170922A error region.

ATel #10791; *Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration*
on 28 Sep 2017; 10:10 UT
Credential Certification: David J. Thompson (David.J.Thompson@nasa.gov)

Subjects: Gamma Ray, Neutrinos, AGN

Referred to by ATel #: 10792, 10794, 10799, 10801, 10817, 10830, 10831, 10833, 10838, 10840, 10844, 10845, 10861, 10890, 10942, 11419, 11430, 11489

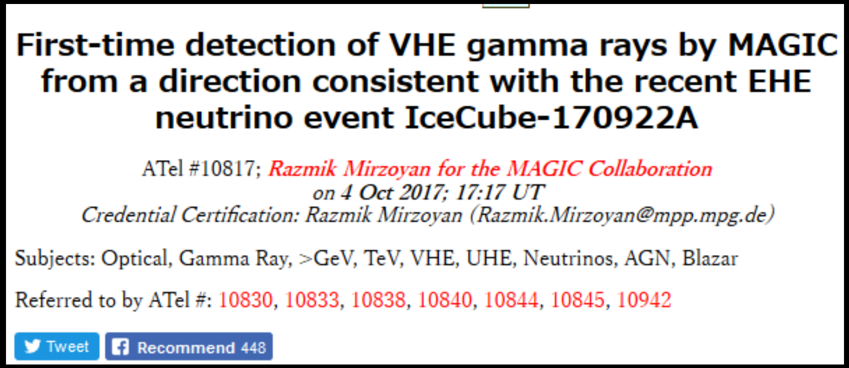
Fermi Blazar TXS 0506+56



Made By public tool FAVAl

VHE γ detection by MAGIC

E > 100 GeV



First-time detection of VHE gamma rays by MAGIC from a direction consistent with the recent EHE neutrino event IceCube-170922A

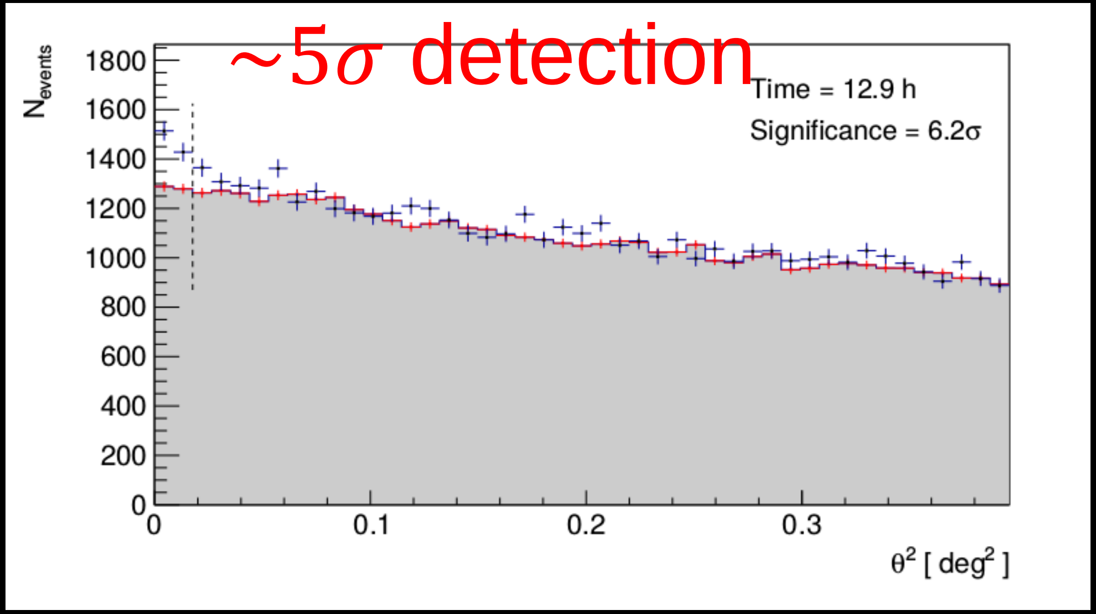
ATel #10817; *Razmik Mirzoyan for the MAGIC Collaboration*
on 4 Oct 2017; 17:17 UT
Credential Certification: Razmik Mirzoyan (Razmik.Mirzoyan@mpp.mpg.de)

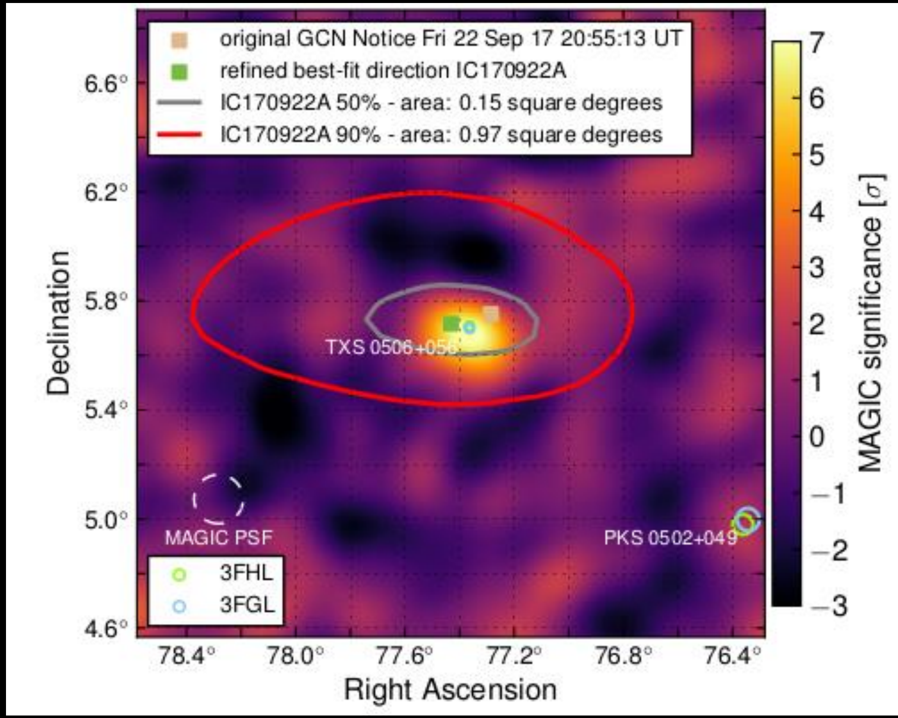
Subjects: Optical, Gamma Ray, >GeV, TeV, VHE, UHE, Neutrinos, AGN, Blazar

Referred to by ATel #: 10830, 10833, 10838, 10840, 10844, 10845, 10942

Tweet Recommend 448

~5σ detection



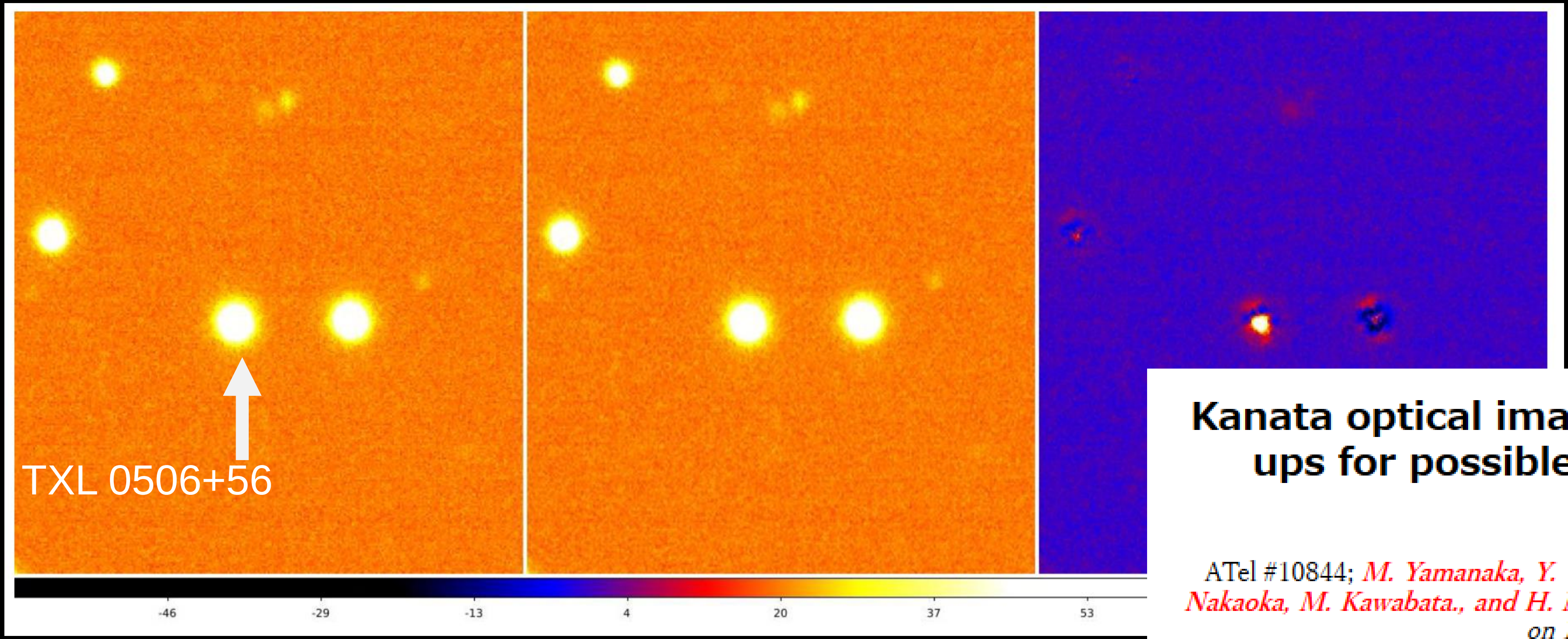


Optical follow-up

Kanata's follow-up

1.5 m dish at Hiroshima, Japan

September 23 September 24 Residual



Kanata optical imaging and polarimetric follow-ups for possible IceCube counterpart TXS 0506+056

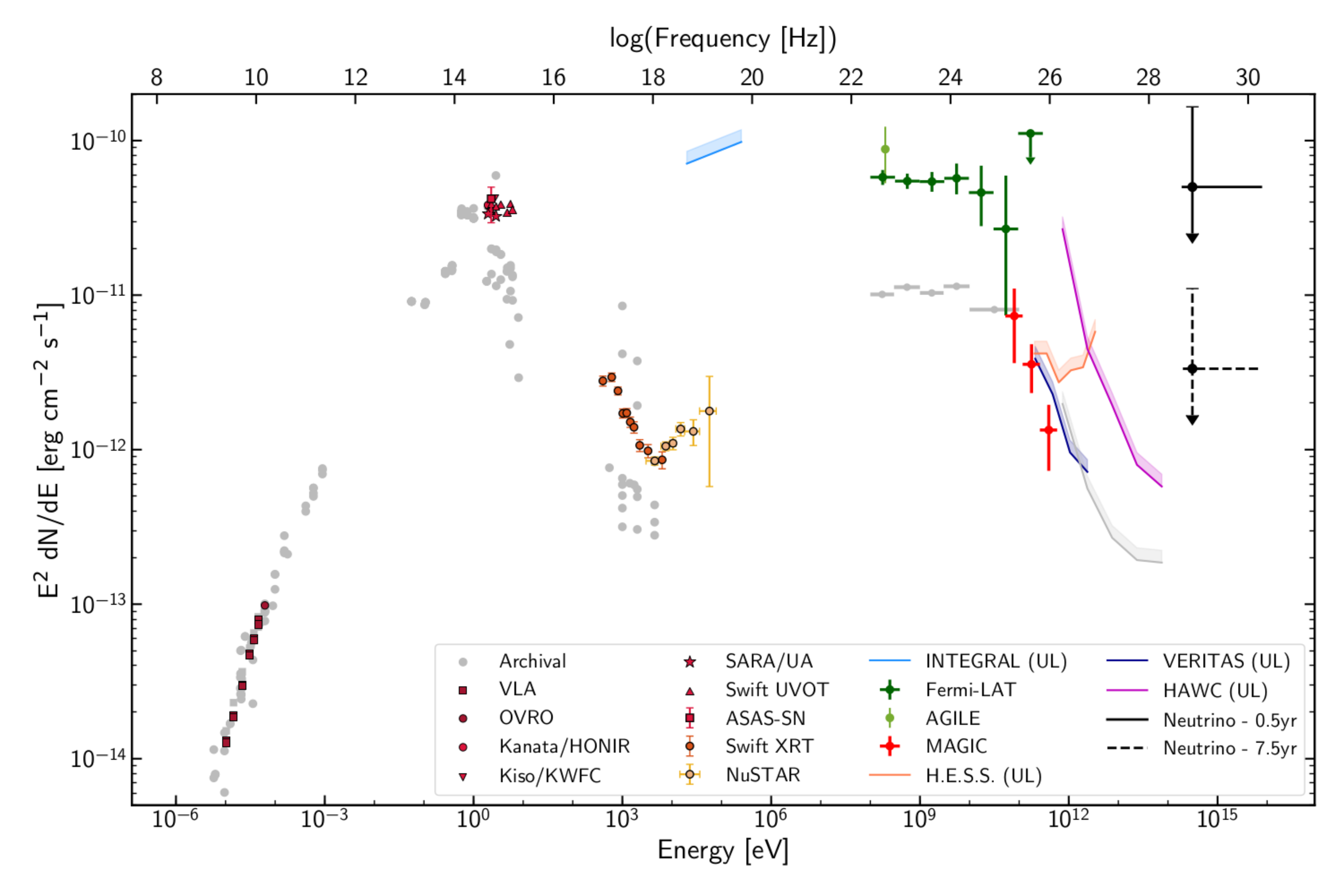
ATel #10844; *M. Yamanaka, Y. T. Tanaka, H. Mori, K. S. Kawabata, Y. Utsumi, T. Nakaoka, M. Kawabata., and H. Nagashima on behalf of Kanata and OISTER teams.*
on 12 Oct 2017; 15:50 UT
Distributed as an Instant Email Notice Transients
Credential Certification: Masayuki Yamanaka (masyamanaka@hiroshima-u.ac.jp)

Subjects: Infra-Red, Optical, Blazar, Transient

Referred to by ATel #: 10861, 11430, 11489

Spectral Energy Distribution

radio optical x-ray γ-ray ν



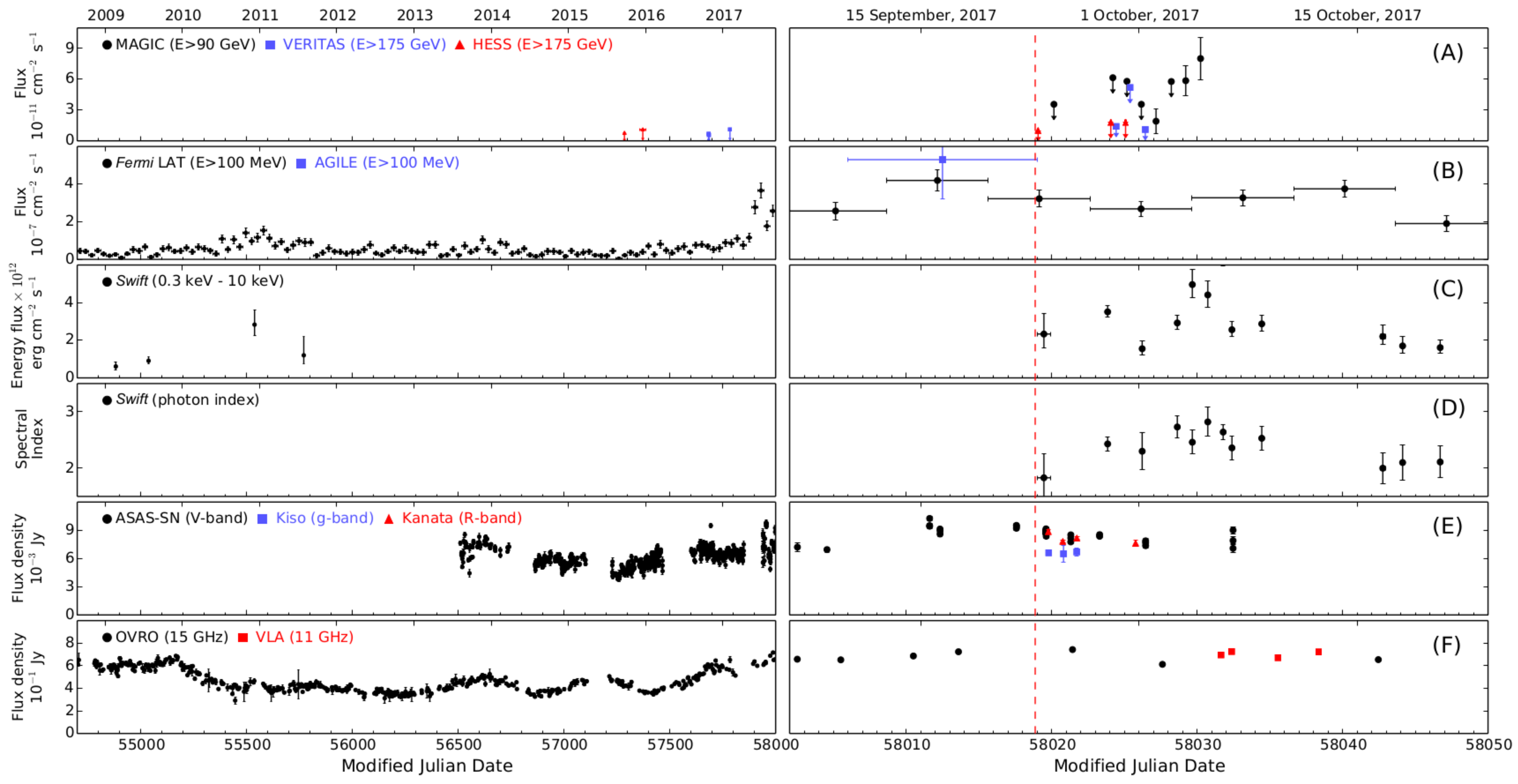
Light Curve

γ-ray

x-ray

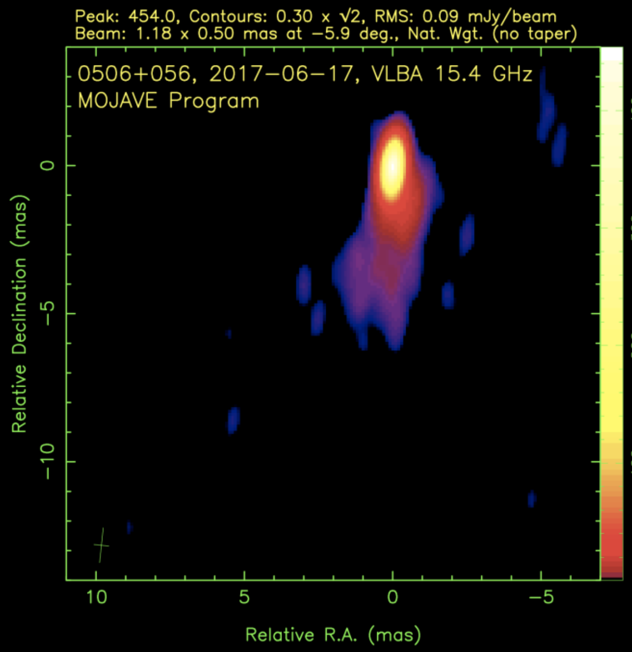
optical

radio

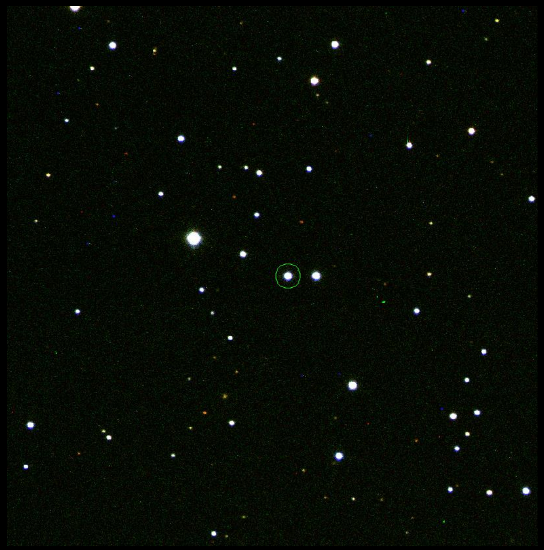


TXS 0506+56
The 1st High Energy ν Source

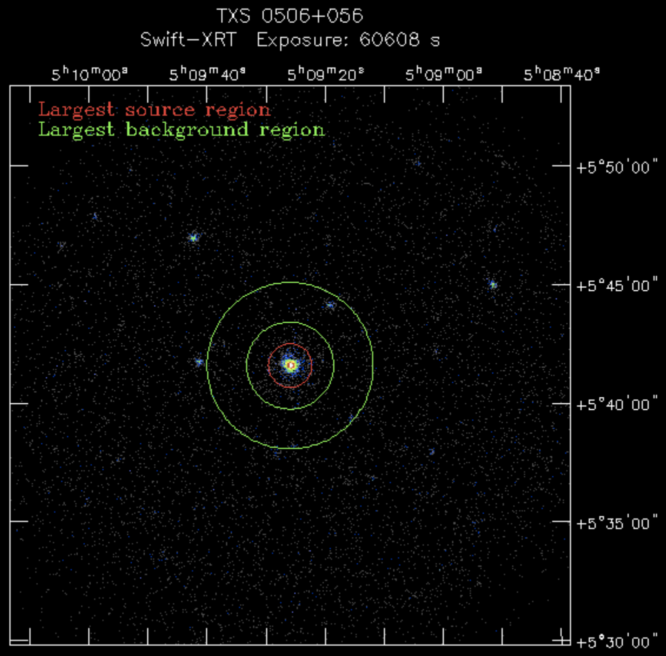
radio



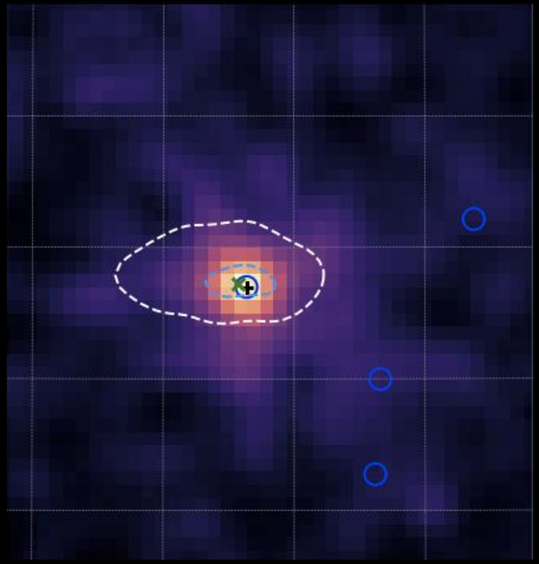
optical



x-ray



γ-ray



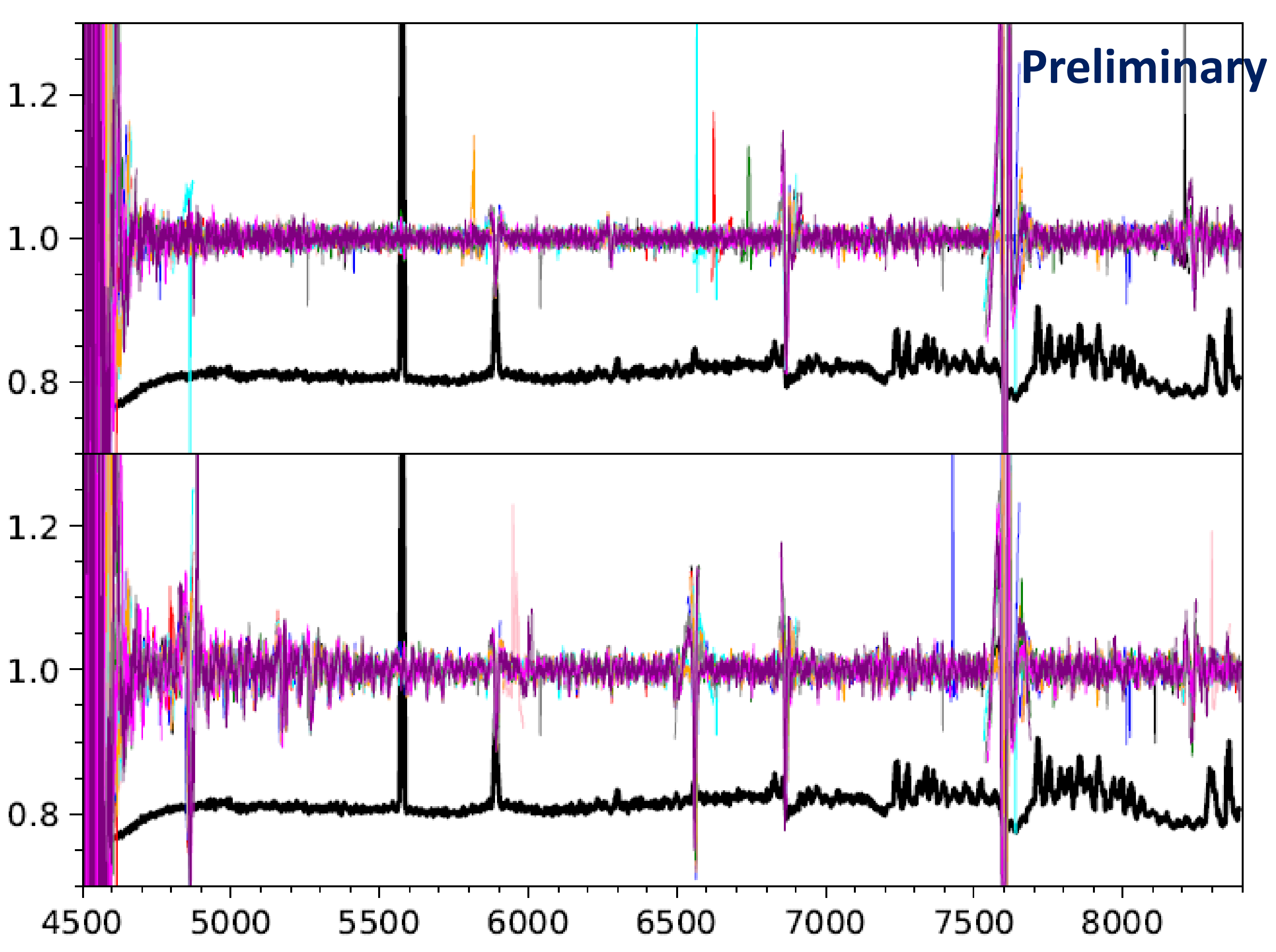
Quest of redshift determination

follow-up by the big dish Subaru

8.2 m dish at Mauna Kea, Hawaii

TXL 0506+56

A nearby star



Foreground sky emission

Featureless

we come back when dimmer

Courtesy of the Subaru Team
T. Morokuma (U. Tokyo),
Y.T. Tanaka (Hiroshima Univ),
K. Ohta (Kyoto Univ),
Y.Matsuoka (Ehime Univ),
M.Yoshida (NAOJ)

まとめ