ICRC Astrophysical Neutrino Discussion Session

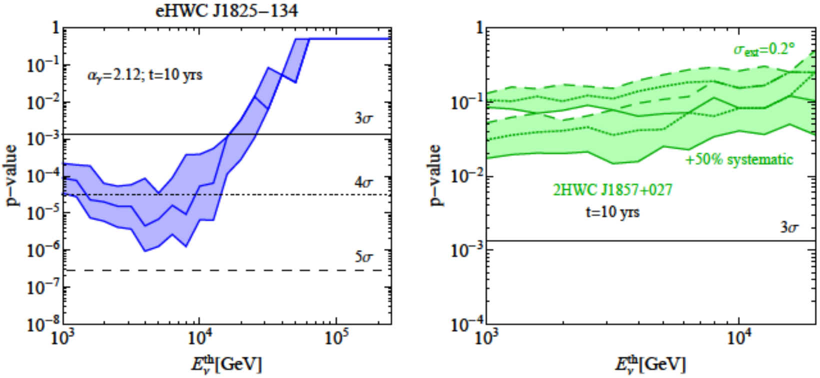
Introduction and review of the field – Markus Ahlers 10 minutes

Presenters' summaries of their contributions and questions – 50 minutes – 4 minutes including questions for each presenter

Open panel discussion – 30 minutes – panel members:

Markus Ahlers (NBI Copenhagen), Ke Fang (Wisconsin-Madison), Anna Franckowiak (U. Bochum), Uli Katz (Erlangen), Kohta Murase (Penn State), Paolo Padovani (ESO Munich), Walter Winter (DESY Zeuthen)

Galactic sources at neutrino telescopes



- PeVatrons: hadronic, hard spectrum that extends up to tens of TeV

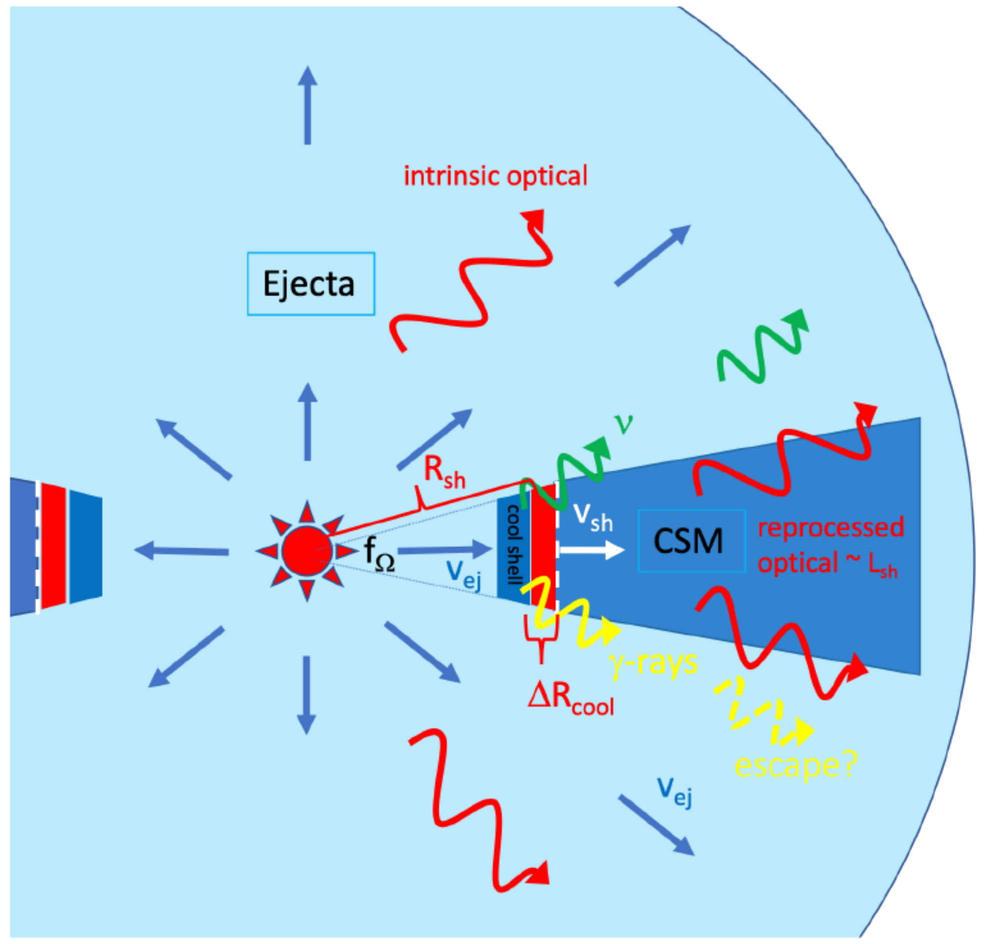
  ⇒ a gamma-ray experiment with sensitivity until about 100 TeV is needed

- Gamma-ray data are necessary to make correct estimations of neutrino fluxes

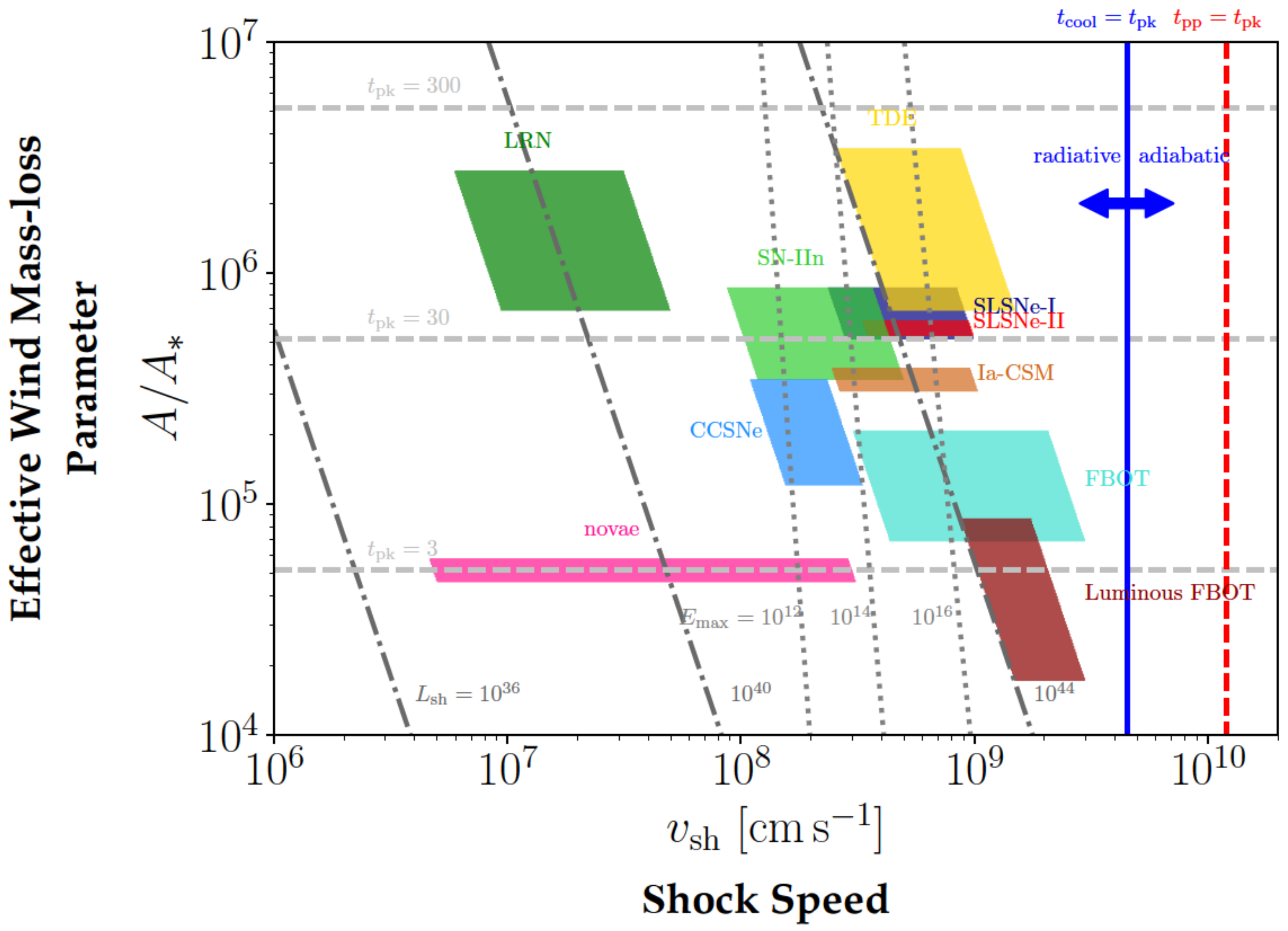
  ⇒ a multi-messenger search is mandatory

High-Energy Neutrinos from Non-Relativistic Shock-Powered Transients

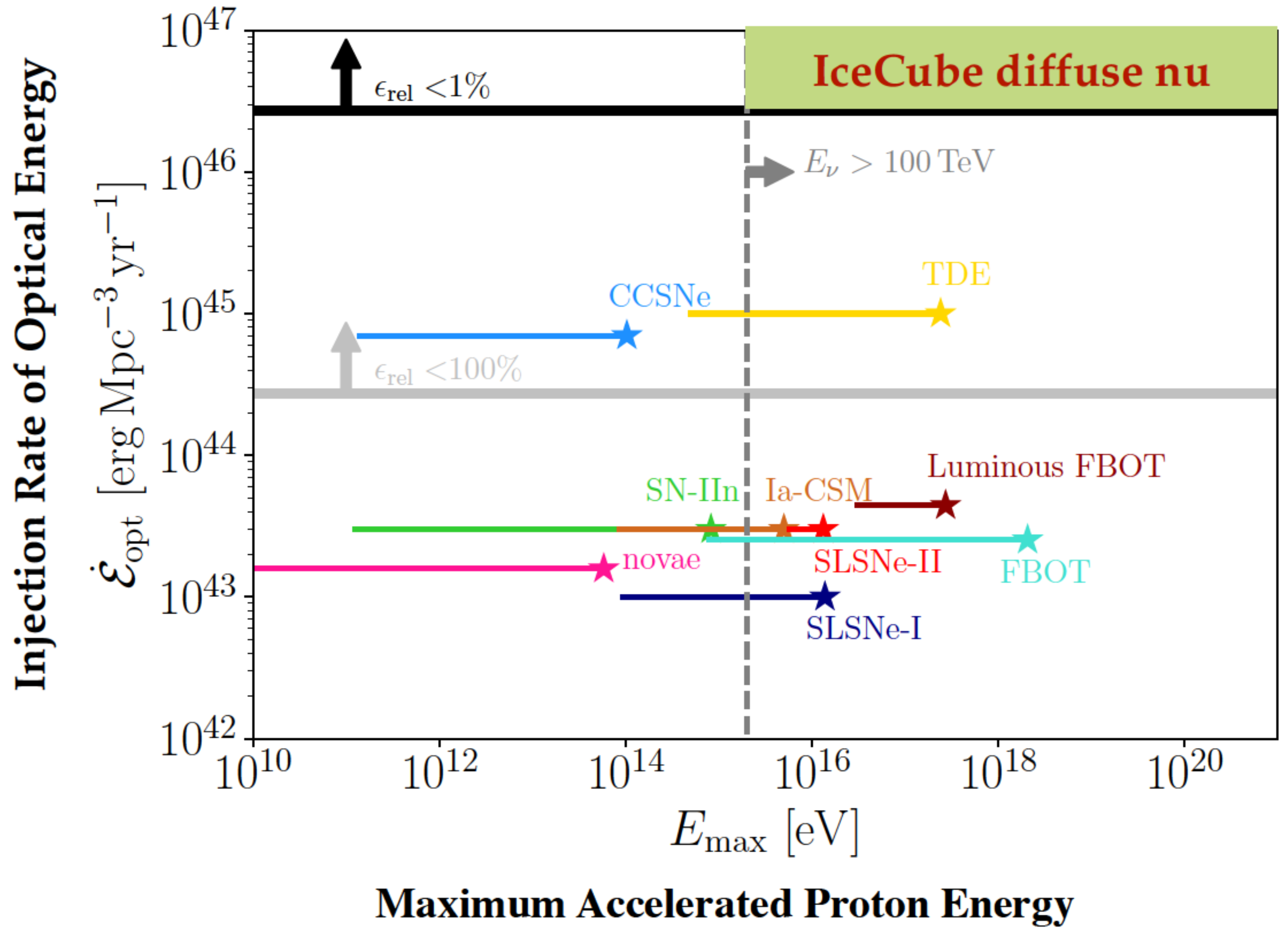
Ke Fang, Brian D. Metzger, Indrek Vurm, Elias Aydi, Laura Chomiuk



Cartoon of the Shocks and Radiation



Observed Properties of Extragalactic Transients ``Zoo"



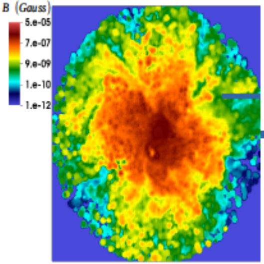
Derived Energy Injection Rate

- Shock-powered transients are plausible hadron accelerators. At the emission peak time, the shocks are radiative. The energy radiated in **neutrinos and gamma rays is directly proportional to the transient's shock-powered optical energy**.
- Optical transients **can barely produce the IceCube diffuse neutrino background**.
  Adiabatic shocks may have a cosmic-ray luminosity higher than the optical luminosity, though for most circumstellar medium profiles, the total shock-dissipated energy is dominated by early times when the shock is radiative.
- Nearby shock-powered transients are promising targets for **multi-messenger followups**.

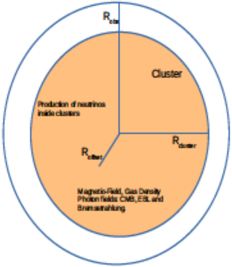
ApJ (2020) arXiv: 2007.15742

Neutrinos Flux from ICM (Saqib Hussain IAG-USP)

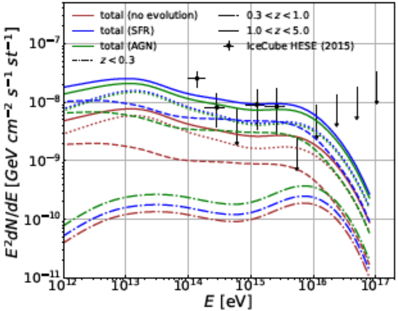
MHD Simulation of ICM



CR Simulation



Neutrino Flux



- **Total Neutrinos Flux from ICM is Comparable to IceCube Data**
- CRs of **E < 10^{17} eV** can trap in **massive clusters (> 10^{14} M_{sun})** and produce **Neutrino Flux** of **PeV energy**
- Most of the **Neutrino Flux** comes from nearby **Clusters at z < 0.3**
- Redshift evolution of CR sources like **AGN** and **SFR**, **enhance the flux of neutrinos**.

S. Hussain, R. Alves Batista, E. M. de Gouveia Dal Pino, and K. Dolag, MNRAS 2021 arXiv:2101.07702.

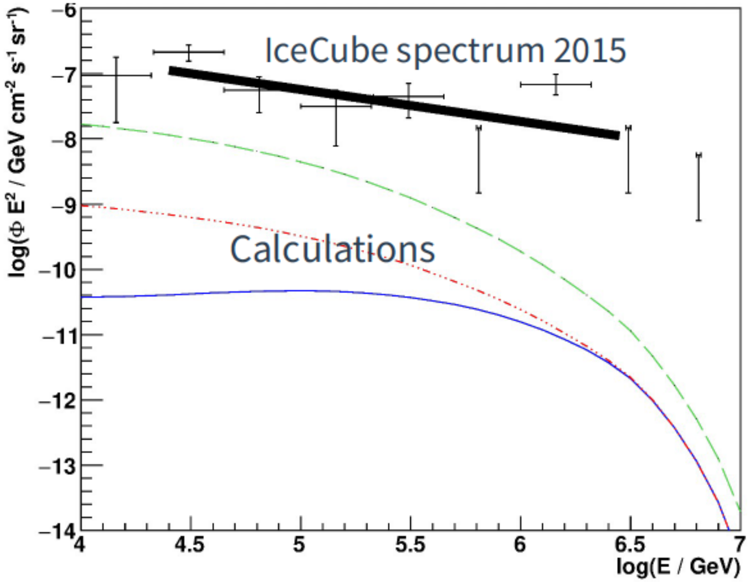
summary

Very high energy neutrinos from Gamma Ray Bursts in dense clusters

Włodzimierz Bednarek & Andrzej Śmiałkowski

Department of Astrophysics, University of Lodz, Poland

- **What is this contribution about?**
- We consider a scenario in which protons accelerated within the jet of GRB can escape to dense regions when they interact efficiently with the matter of the cluster and produce high energy neutrinos.
- **Why is it relevant?**
- We calculate the spectra of relativistic protons within the cluster and spectra of neutrinos from their interactions with the matter. Neutrino emission, produced in terms of this scenario, is expected to last for thousands of years after the initial GRB. Neutrinos produced by the whole population of the GRBs should contribute to the extragalactic neutrino background.
- **What is the result?**
- We compare the calculated extragalactic neutrino background from GRBs with the observations of the IceCube. Our model in the case of negligible adiabatic energy losses of relativistic hadrons is able to contribute significantly to the ENB at energies below ~100 TeV.



Extragalactic diffuse neutrino background (ENB) calculated for the three models with different assumptions on the importance of adiabatic energy losses of hadrons.

Neutrino predictions from choked GRBs and comparison with the observed cosmic neutrino flux

I. Di Palma, S. Celli, A. Capone, M. Fasano, D. Guetta & A. Zegarelli

- **What is this contribution about?**

Neutrino flux predictions from choked GRBs produced in type II SNe.

- **What we have done?**

A Monte Carlo simulation of photo-meson interaction between accelerated protons at internal shocks and thermal photons.

- **What is relevant/interesting?**

The population of choked GRBs might potentially produce a flux of high-energy neutrinos without violating the gamma-ray constraints of the isotropic gamma-ray background.

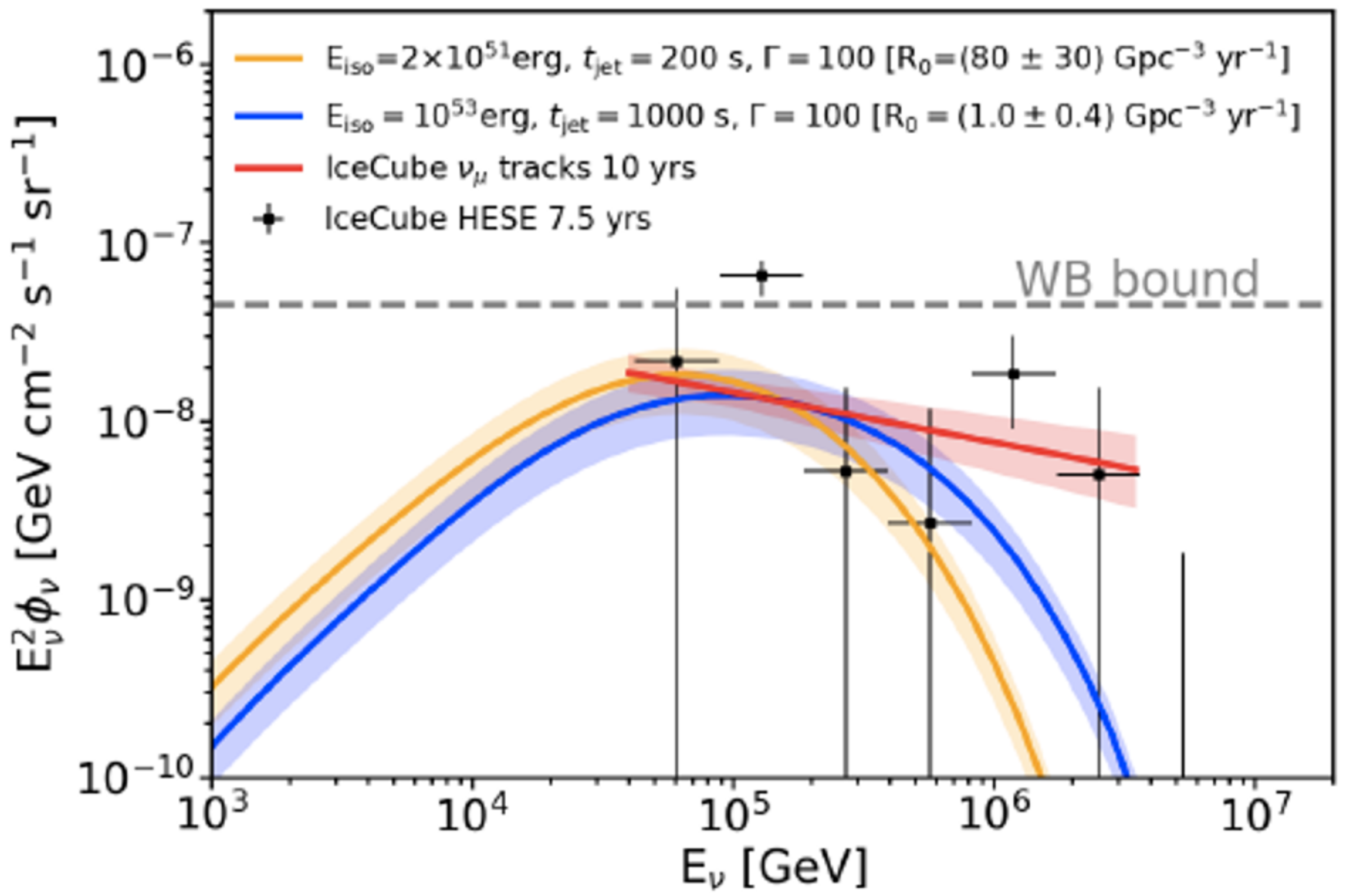
- **What are the results?**

While neutrino fluxes from individual choked GRBs can hardly be detected by current instruments, their cumulative contribution might possibly significantly contribute to the observed diffuse neutrino flux.

Expected event rates from ν_μ CC interaction of an individual choked GRB

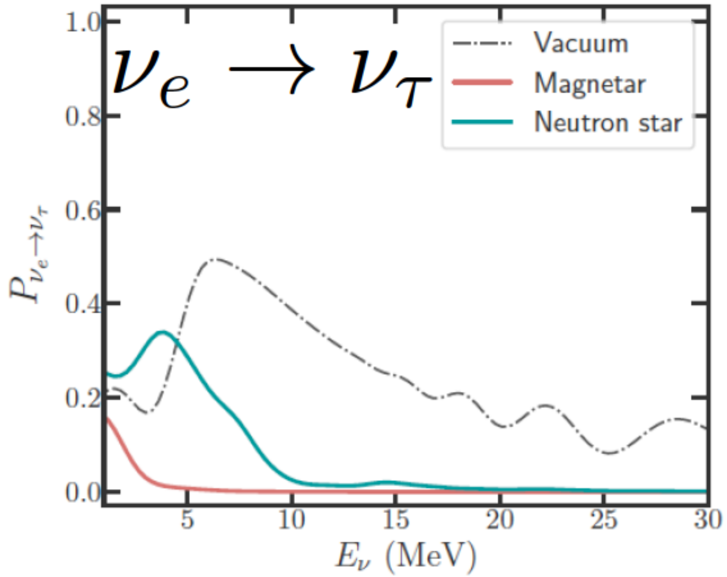
Detector	δ	N_{events}
ANTARES	$0° < \delta < 45°$	2×10^{-3}
	$-45° < \delta < 0°$	3×10^{-3}
	$-90° < \delta < -45°$	5×10^{-3}
KM3NeT-ARCA	Mean δ	2×10^{-1}
IceCube	$0° < \delta < 90°$	1×10^{-1}
	$0° < \delta < 30°$	2×10^{-1}

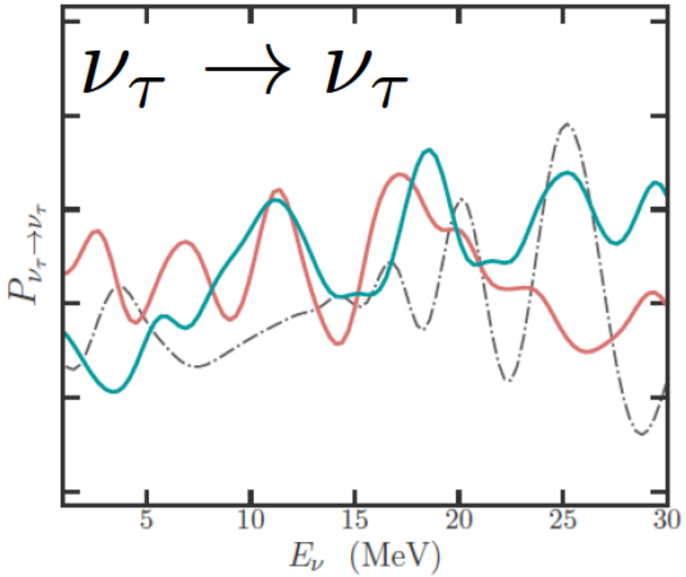
Expected muon neutrino flux from choked GRBs



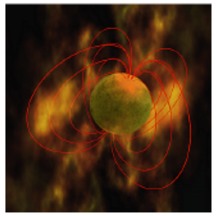
LGRBs PROGENITORS

PROBABILITIES



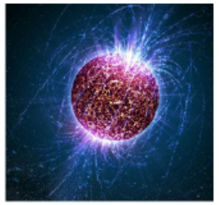


CASE 1: MAGNETAR



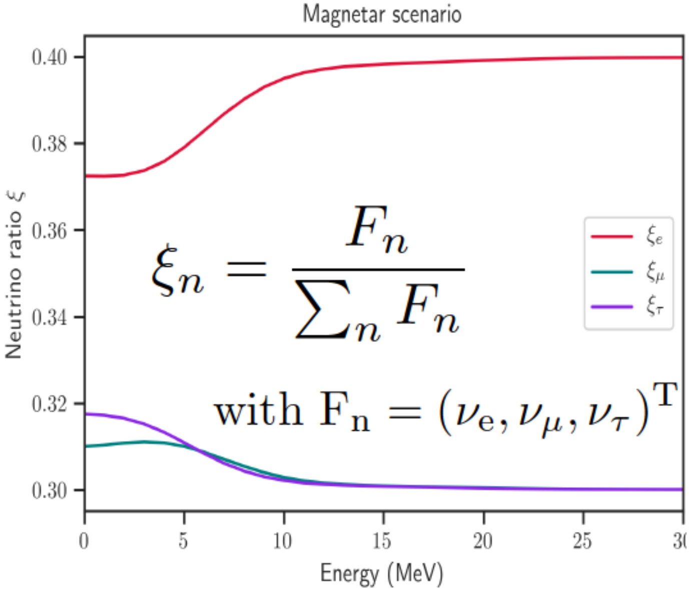
$$B = 10^{15}\ \mathrm{G}$$

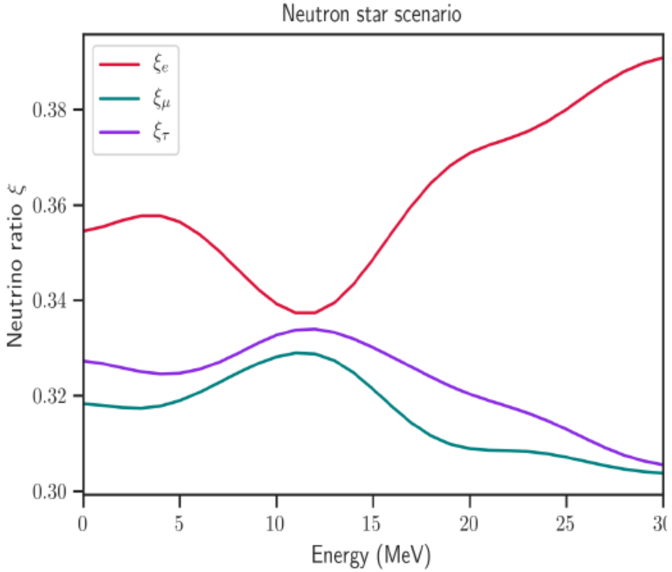
CASE 2: NEUTRON STAR



$$B = 10^{12}\ \mathrm{G}$$

FLAVOR RATIO





- **Different scenarios (B) produce different flavor rates.**
- **Variation of incident neutrino flavors allows characterization of the progenitor.**

(Morales, G. and Fraija, N., 2021, in prep.)

Searches for point-like sources of cosmic neutrinos with 13 years of ANTARES data

Giulia Illuminati on behalf of the **ANTARES** Collaboration **ICRC 2021**

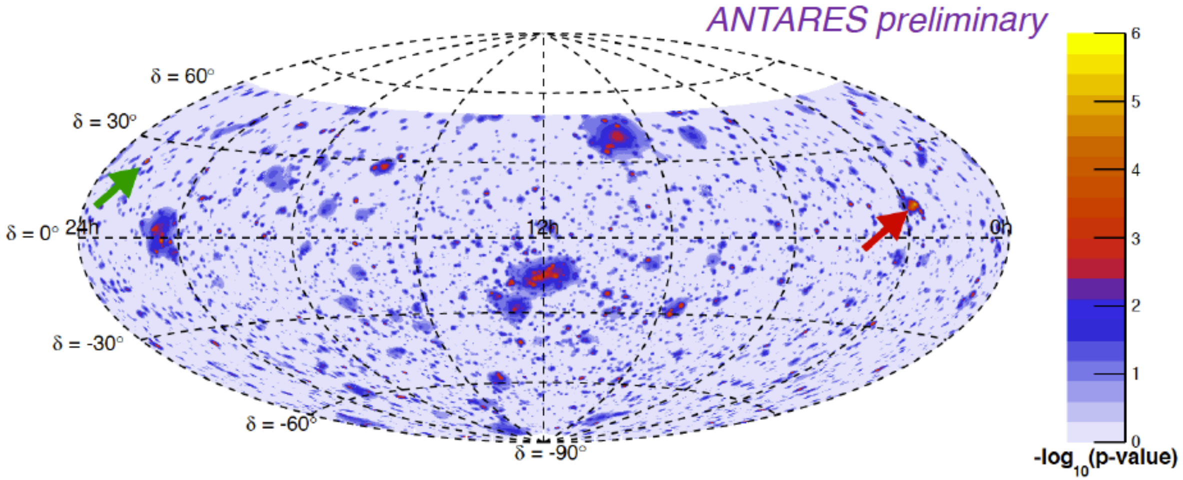
Data set:

Period: from Jan 2007 to Feb 2020

Livetime: 3845 days

Events: 10162 tracks and **225 showers**

Full-sky search



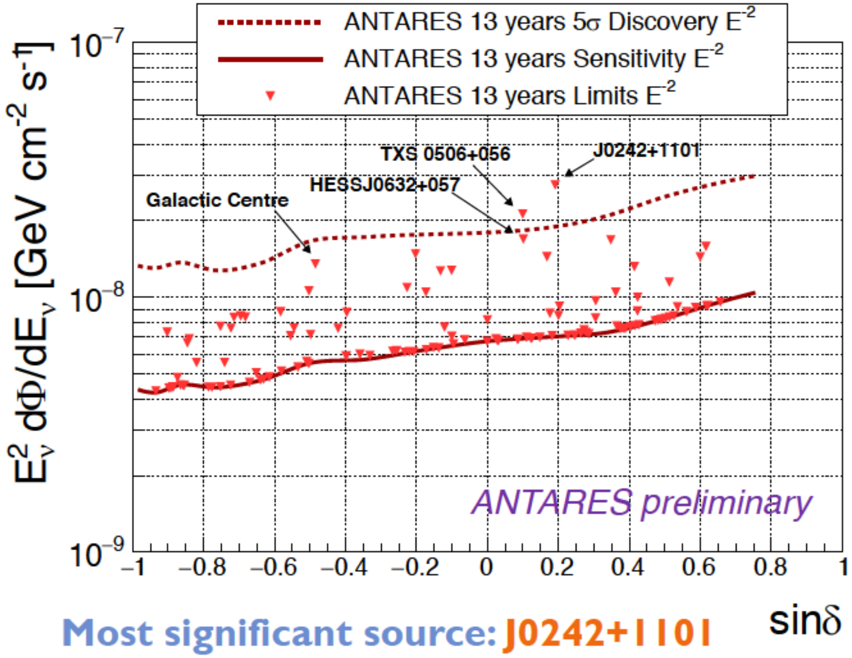
Full-sky hotspot

pre-trial p-value: of 6.8×10^{-6} (4.3σ)

post-trial p-value: of 48%

Candidate-list search:

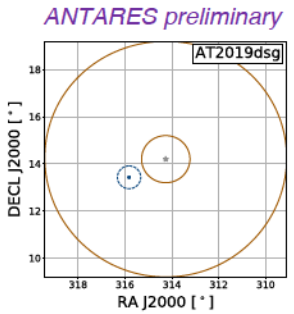
121 investigated sources

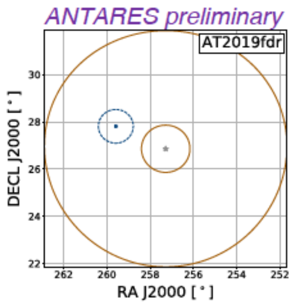


Most significant source: J0242+1101

pre-trial significance: 3.8σ

post-trial significance: 2.4σ





Search at the tidal disruption events AT2019dsg and AT2019fdr

Source		Results						
Name	γ	$\hat{\mu}_{sig}$	p-value	$\Phi_0^{90\%C.L.}$ sensitivity	$\Phi_0^{90\%C.L.}$ limit	$\mathcal{F}^{90\%C.L.}$ sensitivity	$\mathcal{F}^{90\%C.L.}$ limit	$\log(\frac{E_{min}}{GeV})$ - $\log(\frac{E_{max}}{GeV})$
AT2019dsg	2.0	< 0.1	12.4%	7.3×10^{-8}	1.0×10^{-7}	14	19	3.6 - 6.6
	2.5	0.2	10.2%	1.5×10^{-5}	2.2×10^{-5}	29	43	2.8 - 5.5
	3.0	0.7	8.9%	1.2×10^{-3}	2.0×10^{-3}	230	380	2.1 - 4.7
AT2019fdr	2.0	0.5	6.7%	8.5×10^{-8}	1.3×10^{-7}	15	23	3.6 - 6.6
	2.5	0.5	7.9%	2.1×10^{-5}	3.0×10^{-5}	39	55	2.8 - 5.5
	3.0	0.6	9.1%	2.0×10^{-3}	3.0×10^{-3}	360	540	2.1 - 4.7

Summary & Conclusion

- A search for an association between radio-selected blazars and ANTARES neutrinos detected in 13 years of operation has been performed.
- Indication of a collective excess of neutrino-blazar pairs with the ANTARES 13yr PS sample with the counting method, with a $2.3\,\sigma$ post-trial p-value.
- A complementary likelihood analysis gives p-values $\in [1.6 - 2.0]\,\sigma$ for the full blazar sample.
- Possible associations with a few high flux blazars, with neutrino arrival times during intense radio activity have been shown.
- Work in progress to better understand this potential signal, and provide an estimation of the p-value of the neutrino-radio association.

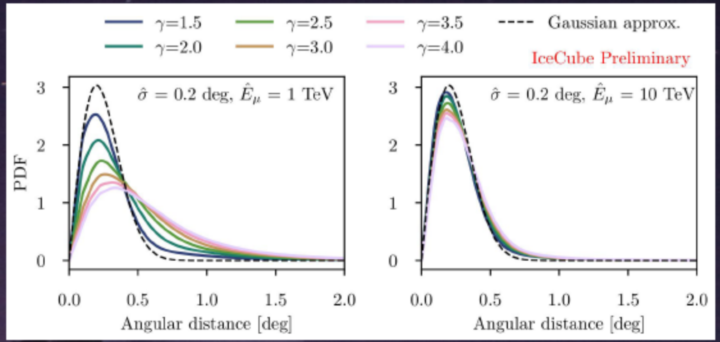
IceCube South Pole Neutrino Observatory

TUM | RWTH Aachen University | SFB 1258 Neutrinos Dark Matter Messengers | NSF | DFG Deutsche Forschungsgemeinschaft German Research Foundation

A New Search for Neutrino Point Sources with IceCube

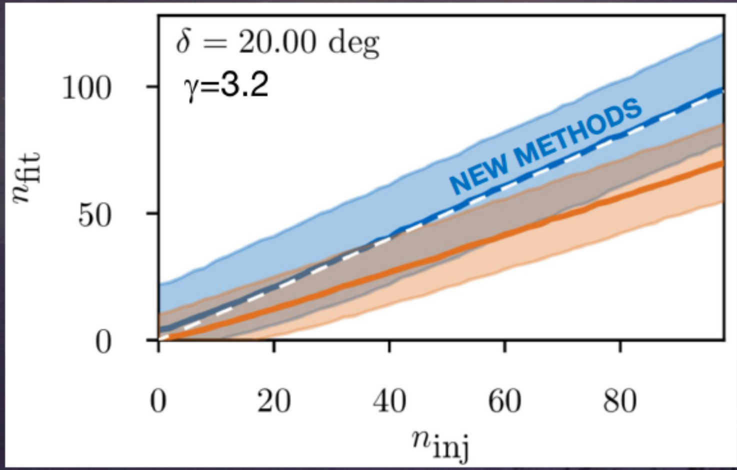
improved our standard point source searches in several ways, for example

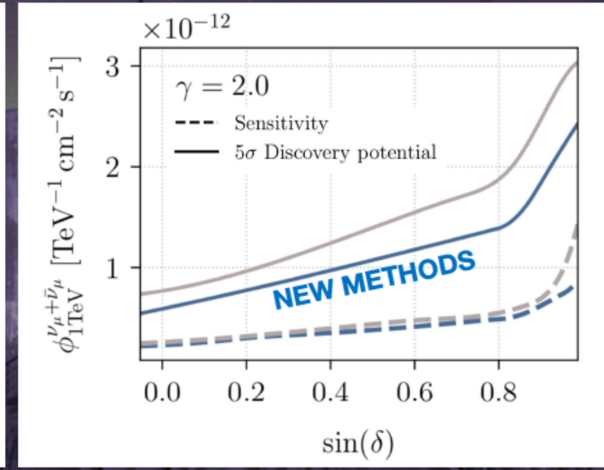
- new modelling of Point Spread Function for track events
- new track energy (DNN) and angular error (BDT) estimators



unbiased source characterization

improved discovery potential (up to 30% for γ=2.0)





\+ latest data calibration

\+ unified filtering / reprocessing

analyzed all
"Northern Sky Tracks" IC86 data
(full 86 string detector configuration)

results under internal review

✓ **to be released very soon**

stay tuned!

Theo Glauch [1], Chiara Bellenghi [1], Martin Wolf [1], Hans Niederhausen [1,3], Tomas Kontrimas [1], Matthias Huber [1], Christian Haack [1], Rene Reimann [2]

([1] Technical University of Munich, [2] University of Mainz, [3] Michigan State University)

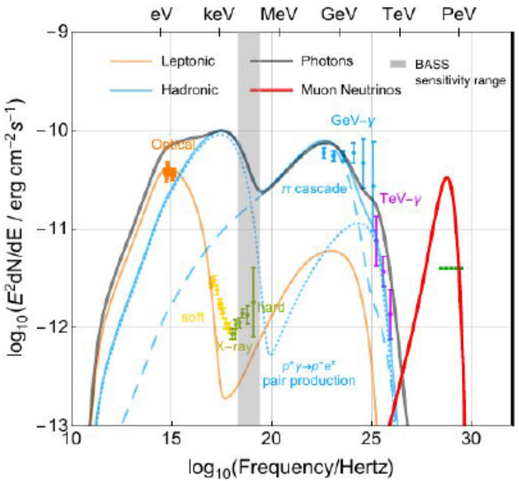
Search for high-energy neutrino emission from hard X-ray AGN with IceCube

Sreetama Goswami*, George C. Privon, Marcos Santander on behalf of the IceCube Collaboration

AGN: Potential candidate source of TeV-PeV neutrinos ?

Motivation:

Observational evidence of neutrinos from AGN.
Hadronic model predictions for AGN:
γ-rays produced alongside ν, can interact with ambient photons to cascade down to hard X-rays.



Analysis: All-sky hard X-ray (≳10 keV) catalog:

***Swift*-BAT AGN Spectroscopic Survey (BASS) DR-1.**

836 sources (105 blazars + 731 non-blazar AGN).
Time-integrated stacked search to find correlation with IceCube dataset.

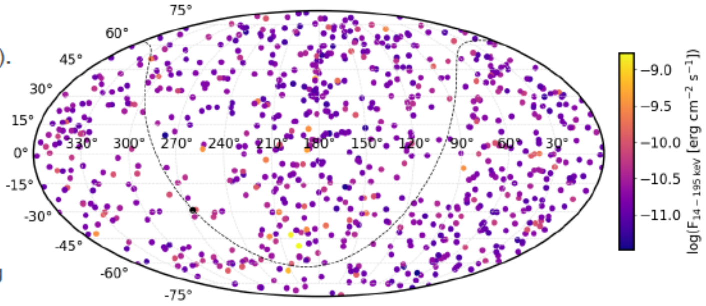


Fig.1 : Skymap showing BASS sources.

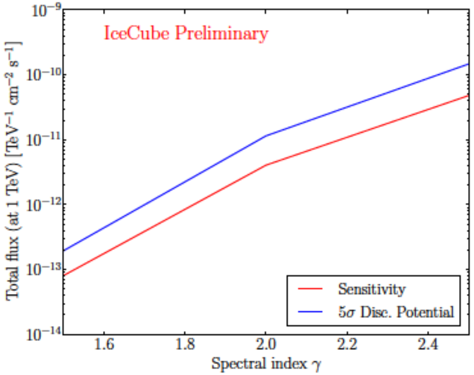


Fig. 2a

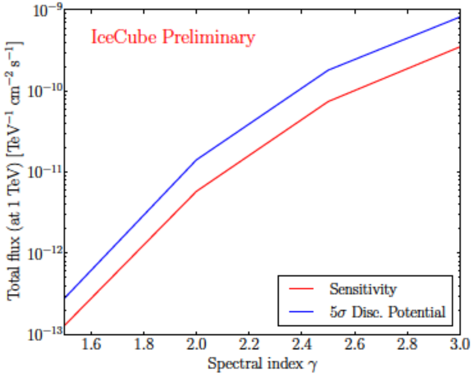


Fig. 2b

Summary: Preliminary estimates of sensitivities with all the sources using weighting schemes: **Flux** weights (Fig. 2a) and **Equal** weights (Fig. 2b).

Outlook: Test 2 hypotheses:

1. Analysis with blazars and non-blazar AGN.
2. Analysis on column density selected sub-categories of sources.

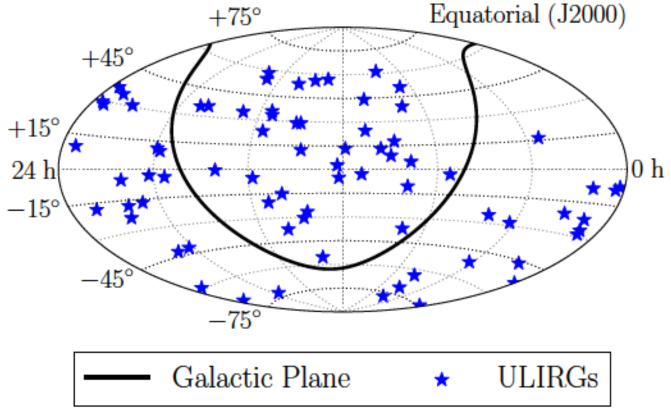
*Presenter email: sreetama.goswami@icecube.wisc.edu

ICECUBE SOUTH POLE NEUTRINO OBSERVATORY
THE UNIVERSITY OF ALABAMA®

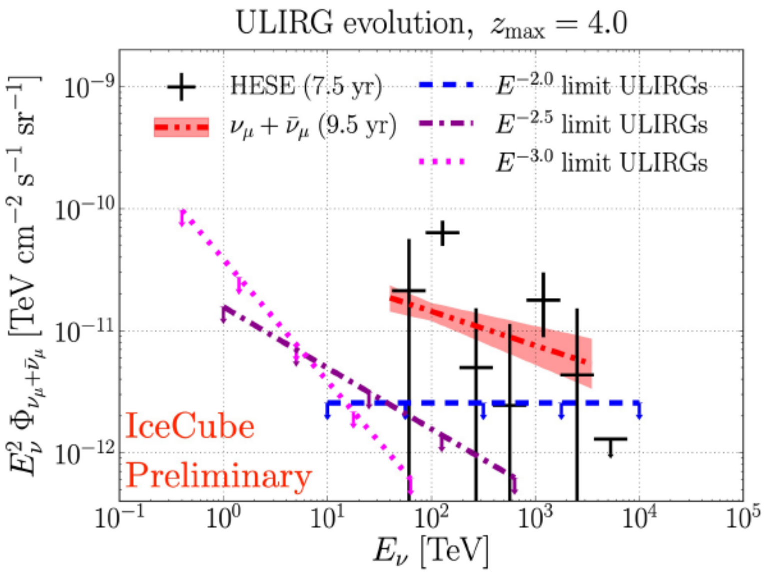
IceCube Search for High-Energy Neutrinos from Ultra-Luminous Infrared Galaxies

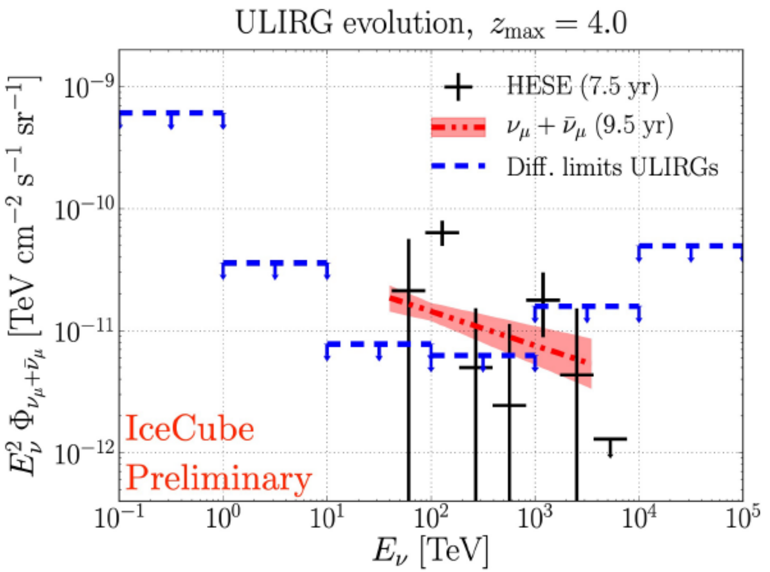
arXiv:2107.03149

- ULIRGs: $L_{IR} \geq 10^{12}\ L_{\odot}$ (8–1000 μm)
  - Powered by starburst/AGN
  - Relatively numerous
- Stacking analysis
  - 75 local ULIRGs ($z \leq 0.13$)
  - 7.5 years of data
  - Sources weighted by IR flux



- No neutrinos found
  - Set upper limits
  - Constrained diffuse contribution of ULIRGs
  - Constrained model predictions





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ONLINE ICRC 2021 The Astroparticle Physics Conference Berlin | Germany 37th International Cosmic Ray Conference 12–23 July 2021

Search for Astrophysical Neutrino Transients with IceCube DeepCore

Chujie Chen, Pranav Dave* and Ignacio Taboada for the IceCube Collaboration
Georgia Institute of Technology

ONLINE ICRC 2021 THE ASTROPARTICLE PHYSICS CONFERENCE Berlin | Germany
37th International Cosmic Ray Conference 12–23 July 2021

1.Astrophysical neutrino transients

- **Choked gamma-ray bursts** (duration < 1,000 s)
  - Insufficiently energetic jet or massive surrounding envelope of material
  - May occur at a higher rate than GRBs
  - Suppressed fluence of high-energy neutrinos due to energy losses of mesons and muons before decay
- Other unexpected transient sources from cataclysmic astrophysical events

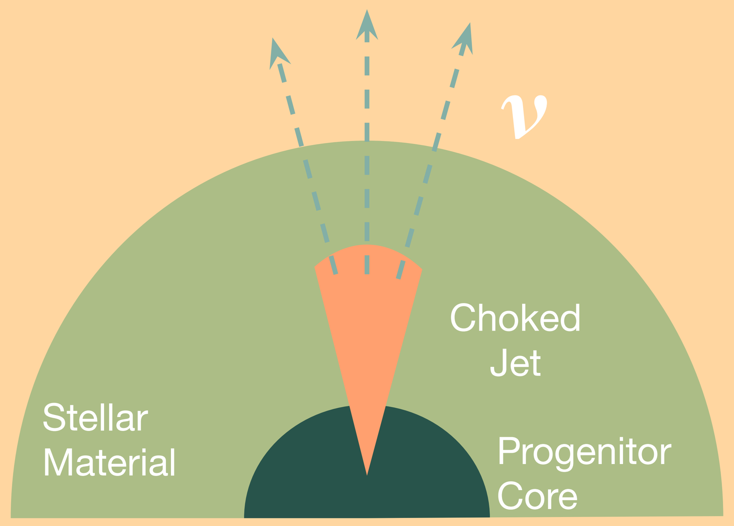

Fig 1. Simple diagram showing the choked jet

2. IceCube and DeepCore

- IceCube
  - km³-scale neutrino detector at geographical South Pole
  - 86 strings, 5,160 DOMs deployed in the ice
- DeepCore
  - Denser sub-detector
  - Low energy threshold ~ 10 GeV

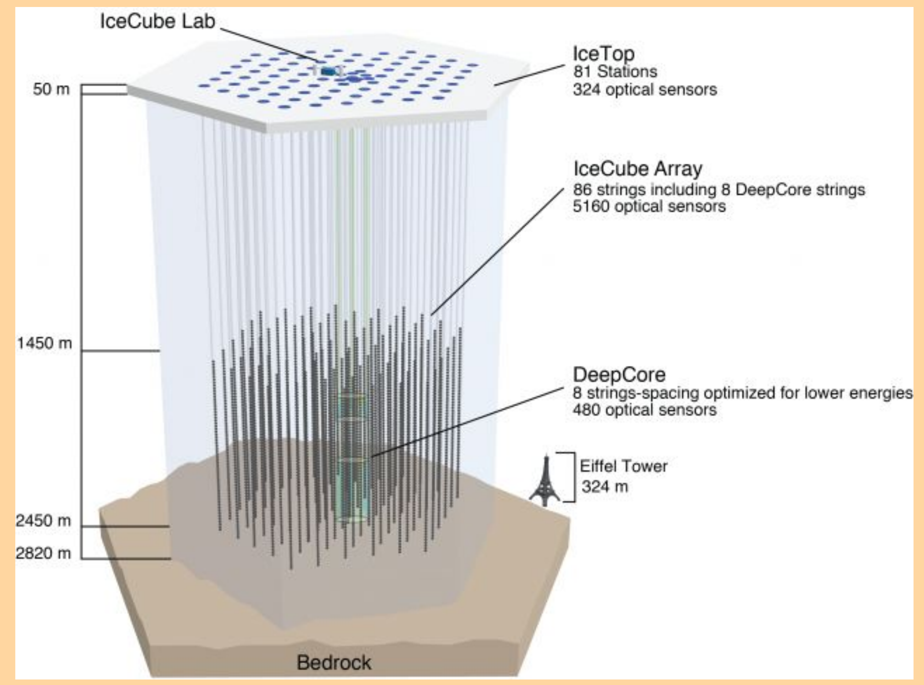

Fig 2. Diagram of the IceCube Neutrino Observatory

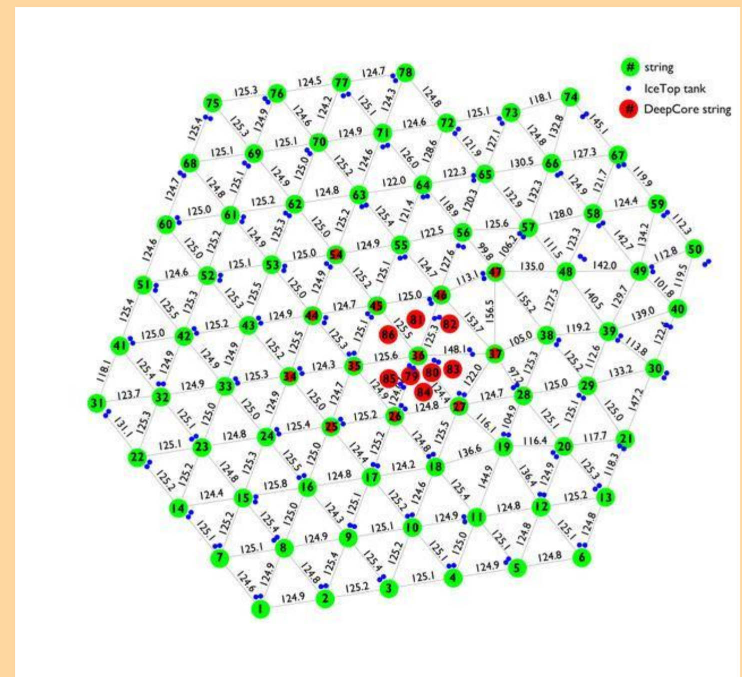

Fig 3. Top View of IceCube Arrays (red: DeepCore arrays)

3. Dataset: >10 GeV energy neutrinos

- High-statistics data sample also used for neutrino oscillations.
  - Both up-going and down-going, all sky
  - Tracks and cascades: all flavors
  - Final level event rate ~ 4 mHz

See talk by M. Larson

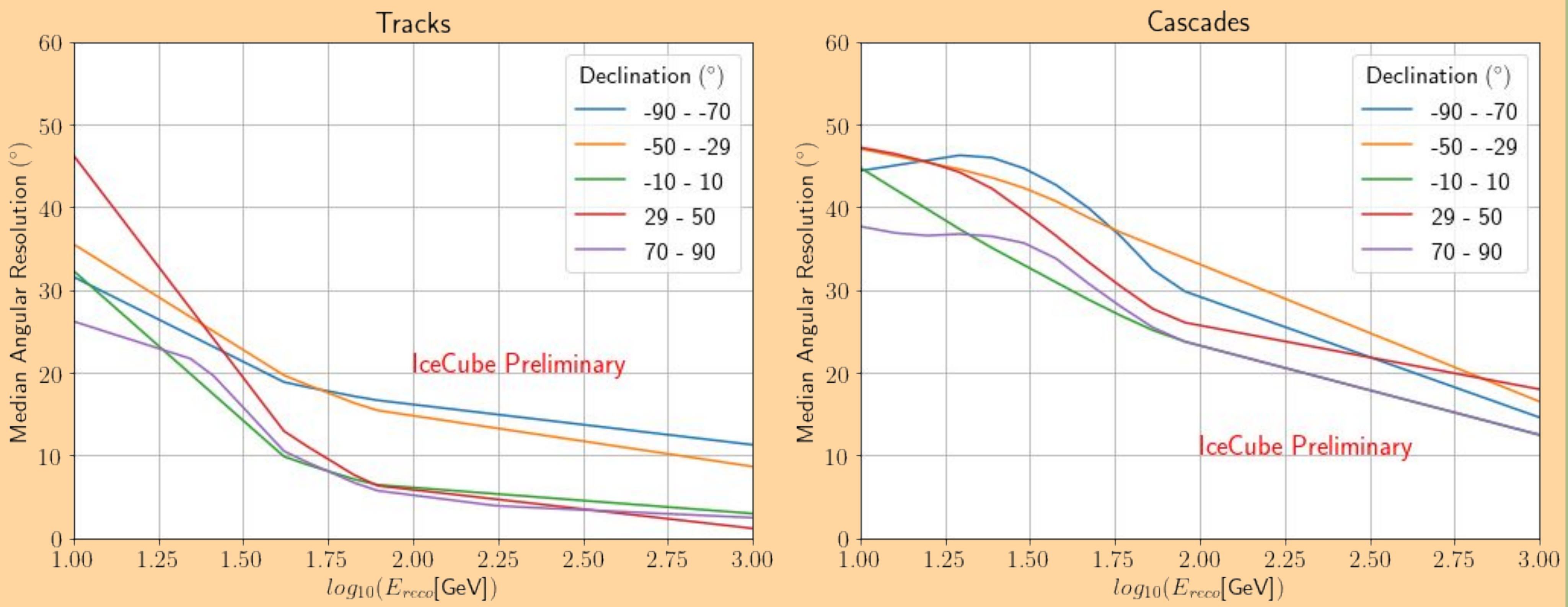

Fig 4. Per-event anular uncertainty vs. reconstructed neutrino energy at several declination

- **Event-wise angular uncertainty** (**left**: tracks; **right**: cascades)
  - Track versus cascade based on reconstructed track length
  - Per-event angular uncertainties derived from spline functions of declination and reconstructed energy

4. Sensitivity and discovery potential for >10 GeV transients

- Untriggered time-dependent search for flares
  - Flare in a ΔT-width box centered at a fitted time t_o
  - Best fit of number of signal events n_s, spectral index γ, time window center $t_{o,fit}$ and flare width ω

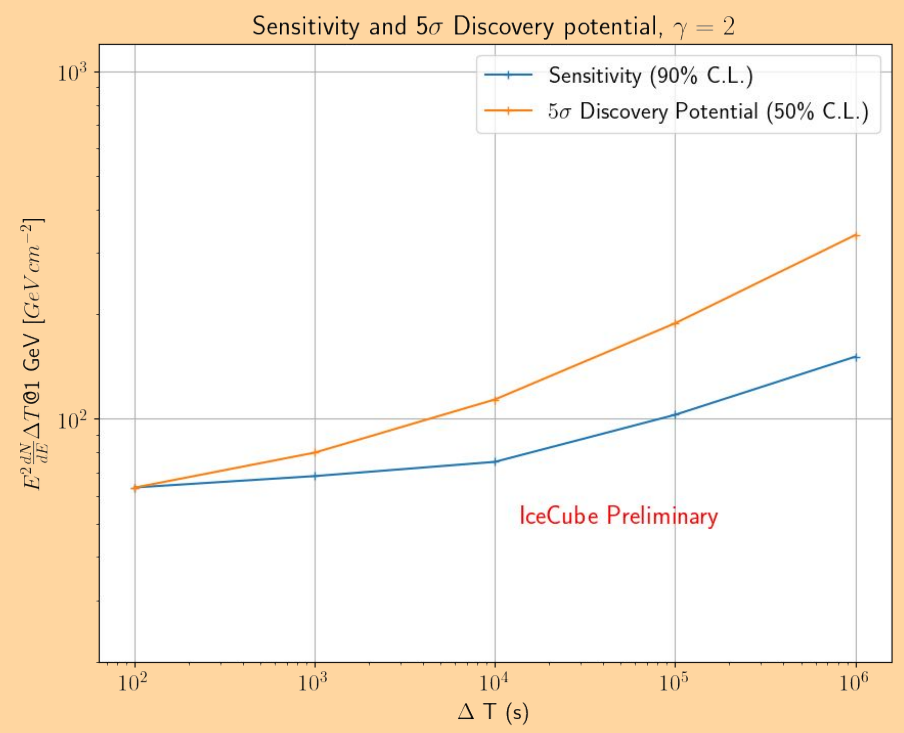

Fig 5. Results from different ΔTs

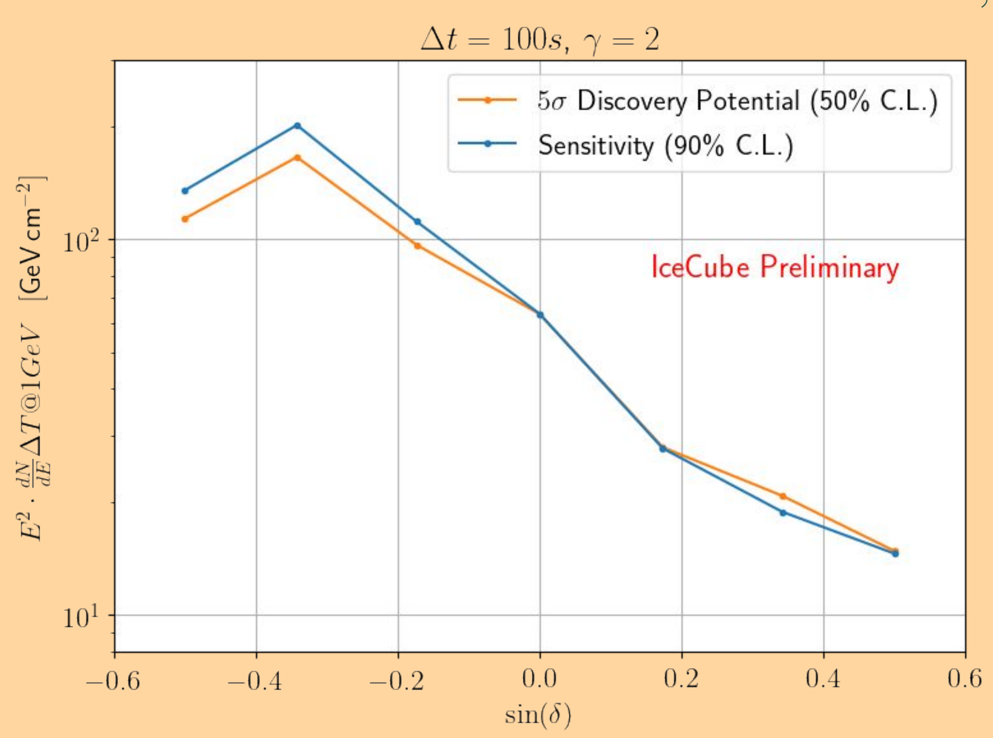

Fig 6. Results at different declinations

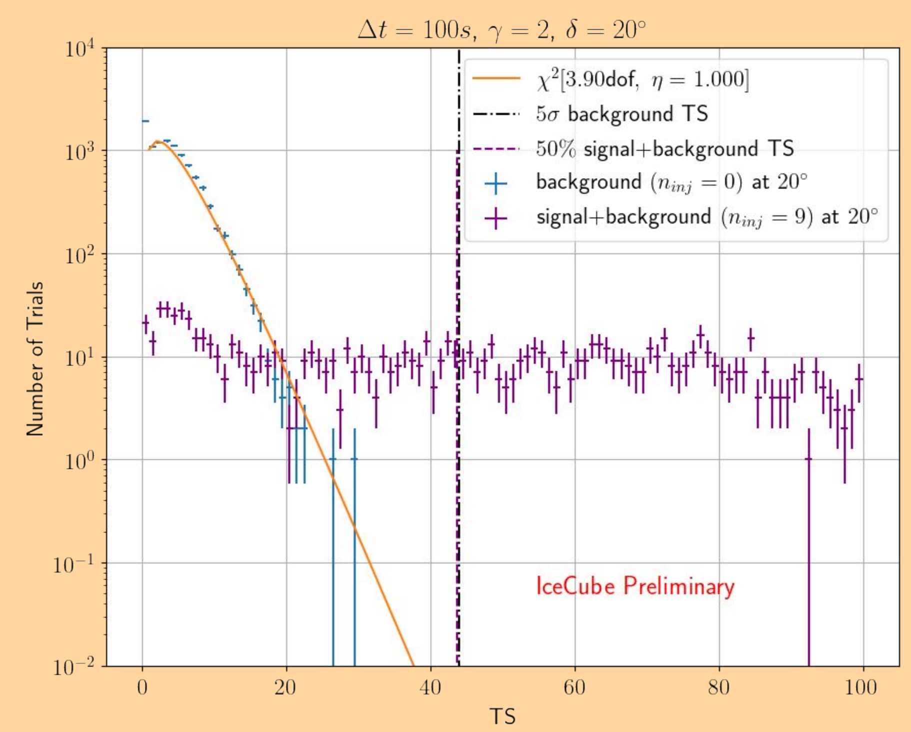

Fig 7. An example of TS distributions

- **Time-integrated flux** (the 5σ background TS is estimated using Wilk's theorem)
  - **Left:** fluence sensitivity and 5σ discovery potential as a function of injected time window width at declination = 0°
  - **Middle:** results at different declinations (half of the whole sky) when injected time window width is fixed as 100 seconds. For declinations near poles, results are not reliable due to large angular uncertainties
  - **Right:** an example graph of background test statistic (TS) distribution and signal + background TS distribution when injected time width is fixed to 100 seconds at declination = 20°

5. Discussion

- Less sensitive compared to triggered searches
- Better options for profiling the event angular resolution
- All-sky archival searches for GRBs
- Tend to improve previously published work

References

[1] Ando SI, Beacom JF. *Physical review letters.* 2005; 95(6):061103.
[2] Abbasi R *et al.* arXiv:2011.05096. 2020.
[3] Aartsen MG *et al. Physical review letters.* 2019;122(5):051102.
[4] Abbasi R *et al. Astroparticle physics.* 2012; 35(10):615-24.
[5] Aartsen MG *et al. The Astrophysical Journal*. 2016; 816(2):75.

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