

# UK High-Energy Astrophysical Neutrino (UK-HEAN)

## ANITA/PUEO

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- Ryan Nichol (UCL)

## IceCube-Gen2

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- Teppei Katori (King's College London)
- Stefan Söldner-Rembold (Manchester)

## P-ONE

- Matteo Agostini (UCL)

## Trinity

- Anthony Brown (Durham)

Teppei Katori

King's College London

🌐 OWAN💪 21, IoP building, London, UK, Nov. 10, 2021

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# UK High-Energy Astrophysical Neutrino (HEAN)

## PPAP roadmap update proforma

- HEAN for discovery particle physics
- Quantum gravity
- Dark matter and dark energy
- Neutrino decoherence
- Lorentz violation
- Conventional and anomalous neutrino mixing
- Other exotic physics



## PAAP roadmap update proforma

- Multi-messenger astronomy
- Mechanism of the highest energy engine in the universe
- Origin of ultra-high-energy cosmic rays
- Search of the Highest energy processes such as GZK cut off
- Study fundamental physics

## Reply to PPAP roadmap draft

- HEAN was not mentioned in the draft

# UK High-Energy Astrophysical Neutrino (HEAN)

## STFC PPGP

*“Here, we propose to coordinate the efforts of the UK high-energy neutrino astronomy community to maximize the scientific and societal impact”*

1. evaluate the suitability and synergies of optical vs radio detection for the next-generation facility
2. share UK developed analysis tools and techniques
3. prepare the groundwork for a Statement of Interest to PPRP during 2024

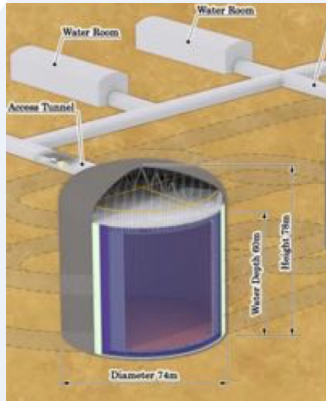
We asked some funding (£240k) to maintain current effort (travel, computation)

# UK HEAN, PPAP view

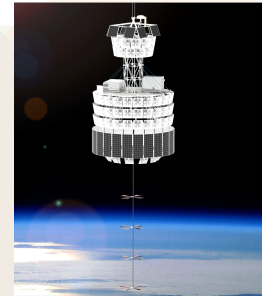
## Timeline

- 2021-2023: R&D period
- 2023-2025: down selection process

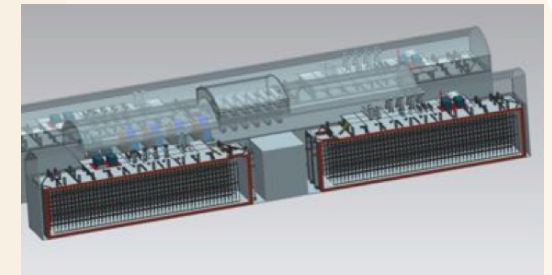
- Strong science
- Good future
- Synergy (particle physics and astroparticle physics community, industry, social challenge, countries)



Hyper-Kamiokande



ANITA/PUEO



DUNE

LHC?

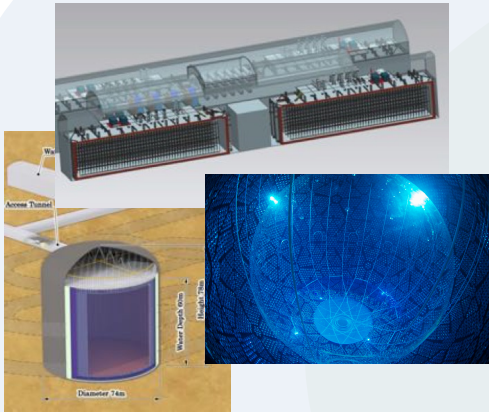


# UK HEAN, PAAP view

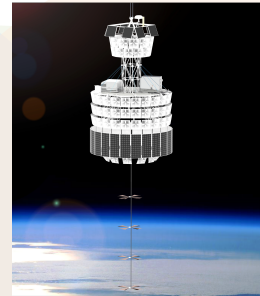
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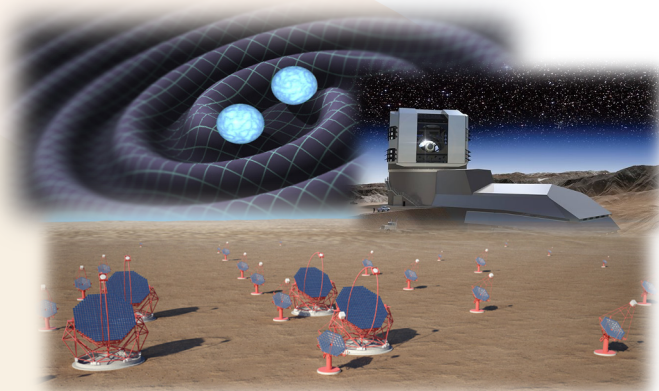
Neutrino astronomy



ANITA/PUEO



Dark matter (PPAP),  
underground lab (PPAP),  
Theory?



Multi-messenger

# UK HEAN, pass forward

## Timeline

- 2021-2023: R&D period
- 2023-2025: down selection process

## UK-HEAN activities

- Group meeting (local, national, global)
- Brain storming session
  - technology
  - synergy
  - status update

etc

# IceCube-Gen2

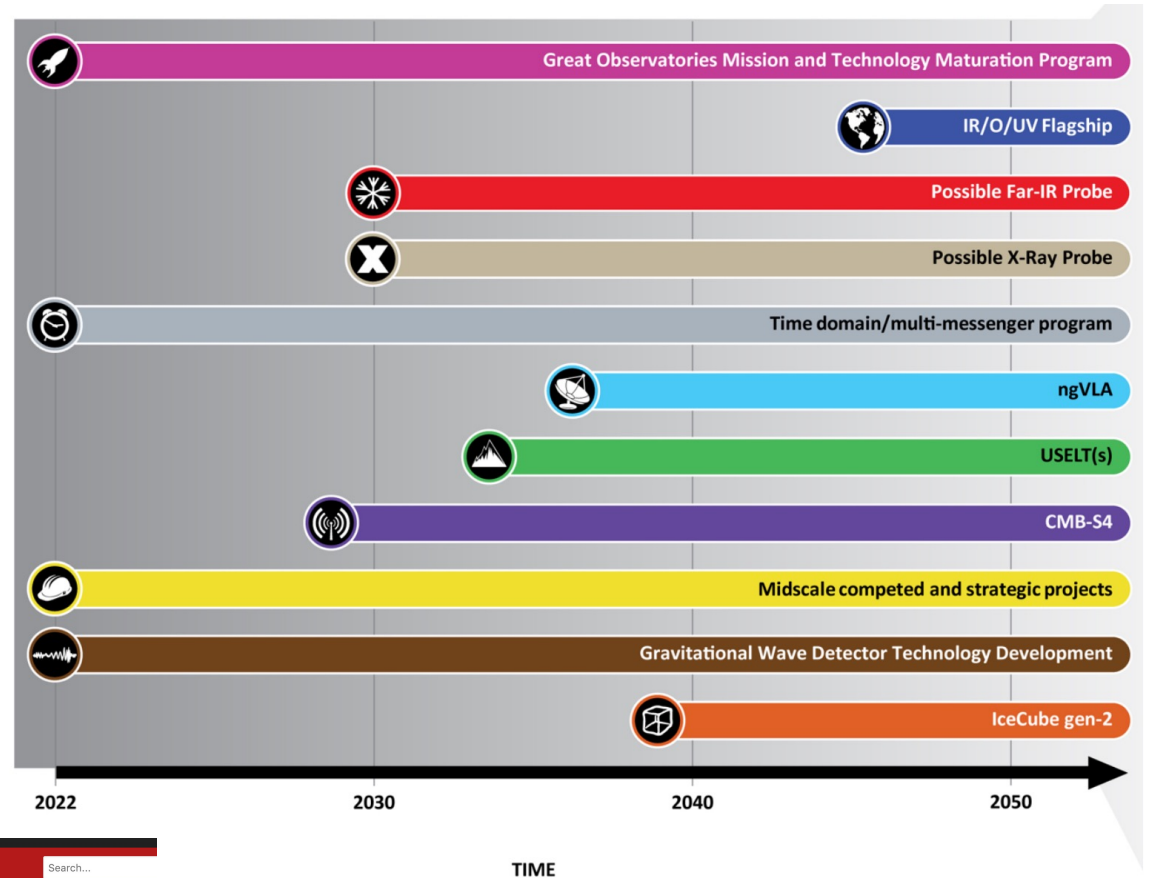


Astro2020

<https://www.nap.edu/resource/26141/interactive>

- IceCube-Gen2 received the strong recommendation form National Academies

Multi-messenger astronomy must be coordinated



New paper from IceCube@King's!  
<https://arxiv.org/abs/2111.04654>

arXiv.org > hep-ex > arXiv:2111.04654

Search...  
Help | Advanced Search

High Energy Physics - Experiment

[Submitted on 8 Nov 2021]

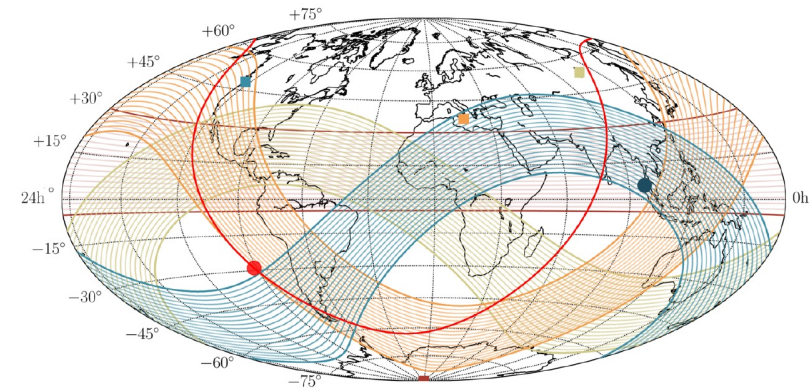
**Search for Quantum Gravity Using Astrophysical Neutrino Flavour with IceCube**

R. Abbasi, M. Ackermann, J. Adams, J. A. Aguilar, M. Ahlers, M. Ahrens, J.M. Alameddine, C. Alispach, A. A. Alves Jr., N. M. Amin, K. Andeen, T. Anderson, G. Anton, C. Argüelles, Y. Ashida, S. Axani, X. Bai, A. Balagopal V., A. Barbano, S. W. Barwick, B

# UK-based HEAN project?

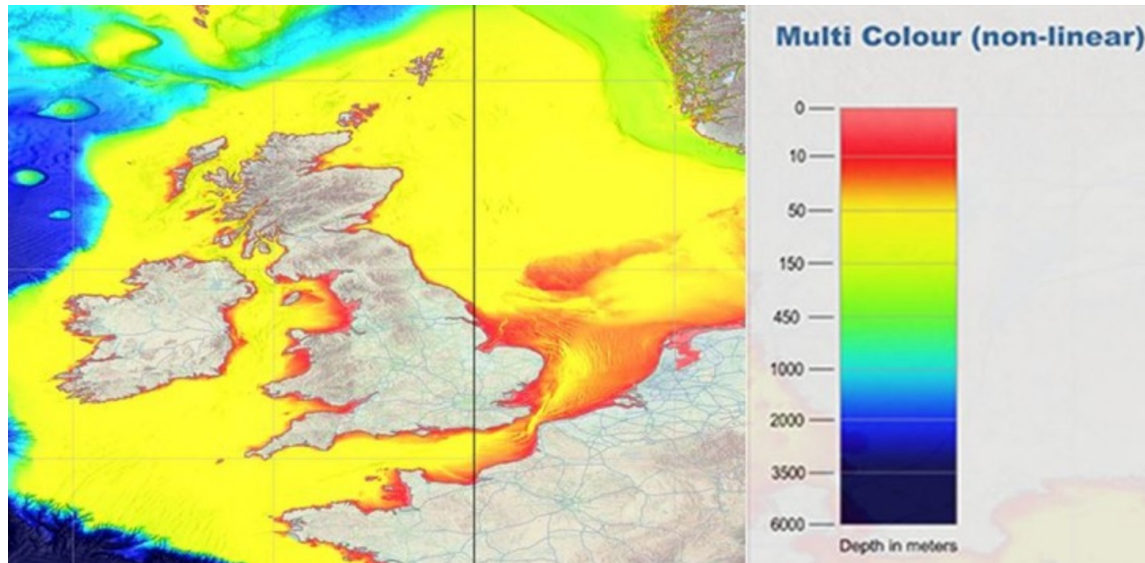
## Hai-Ling (海鈴?)

- East China sea-based neutrino telescope
- Hybrid PMT+SiPM design
- New coverage of sky



## Any good location around the UK?

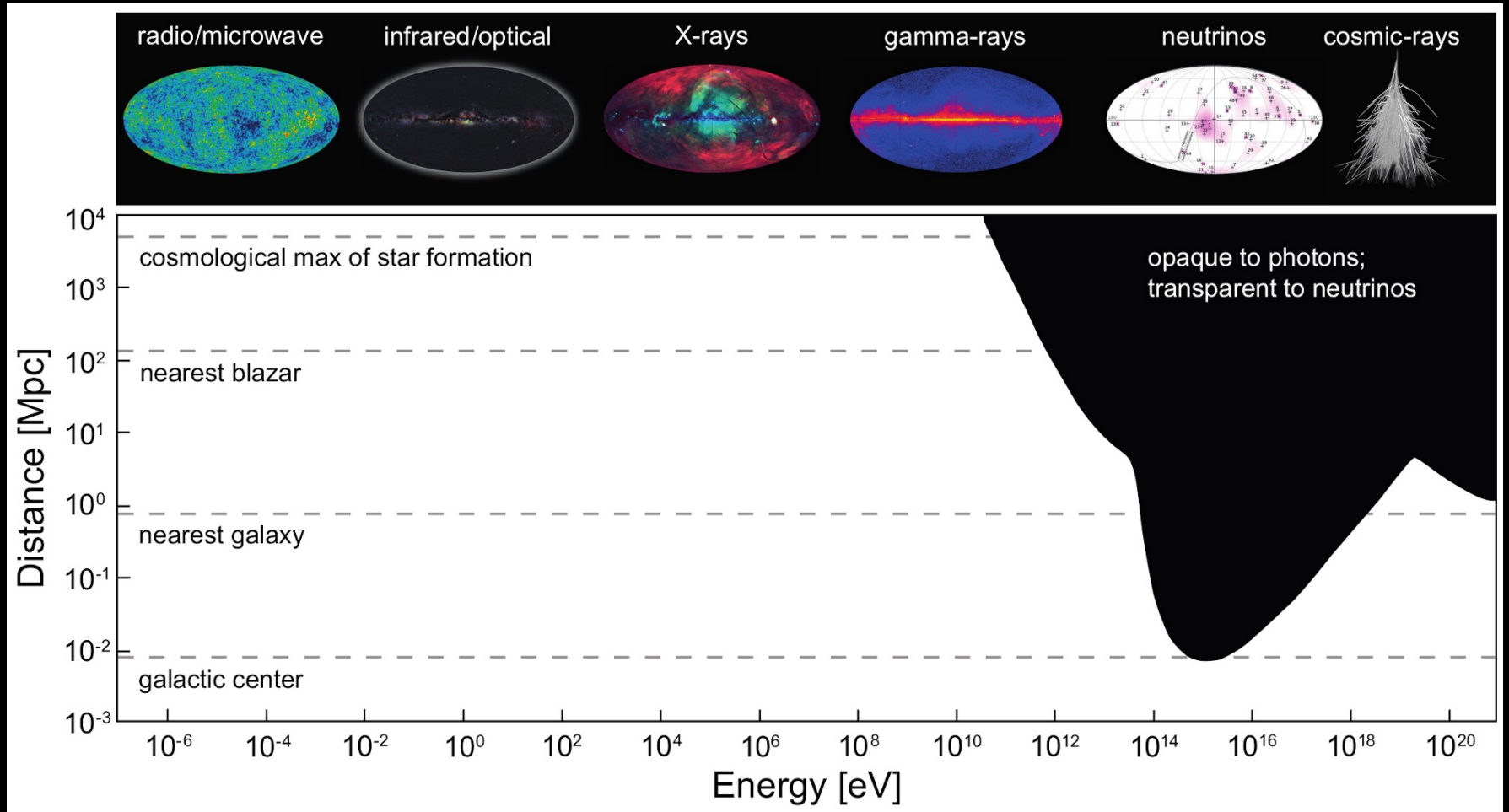
- Very shallow, except northwest?
- Windfarm map, infrastructure available?



# Backup

# High-Energy Neutrino Astronomy

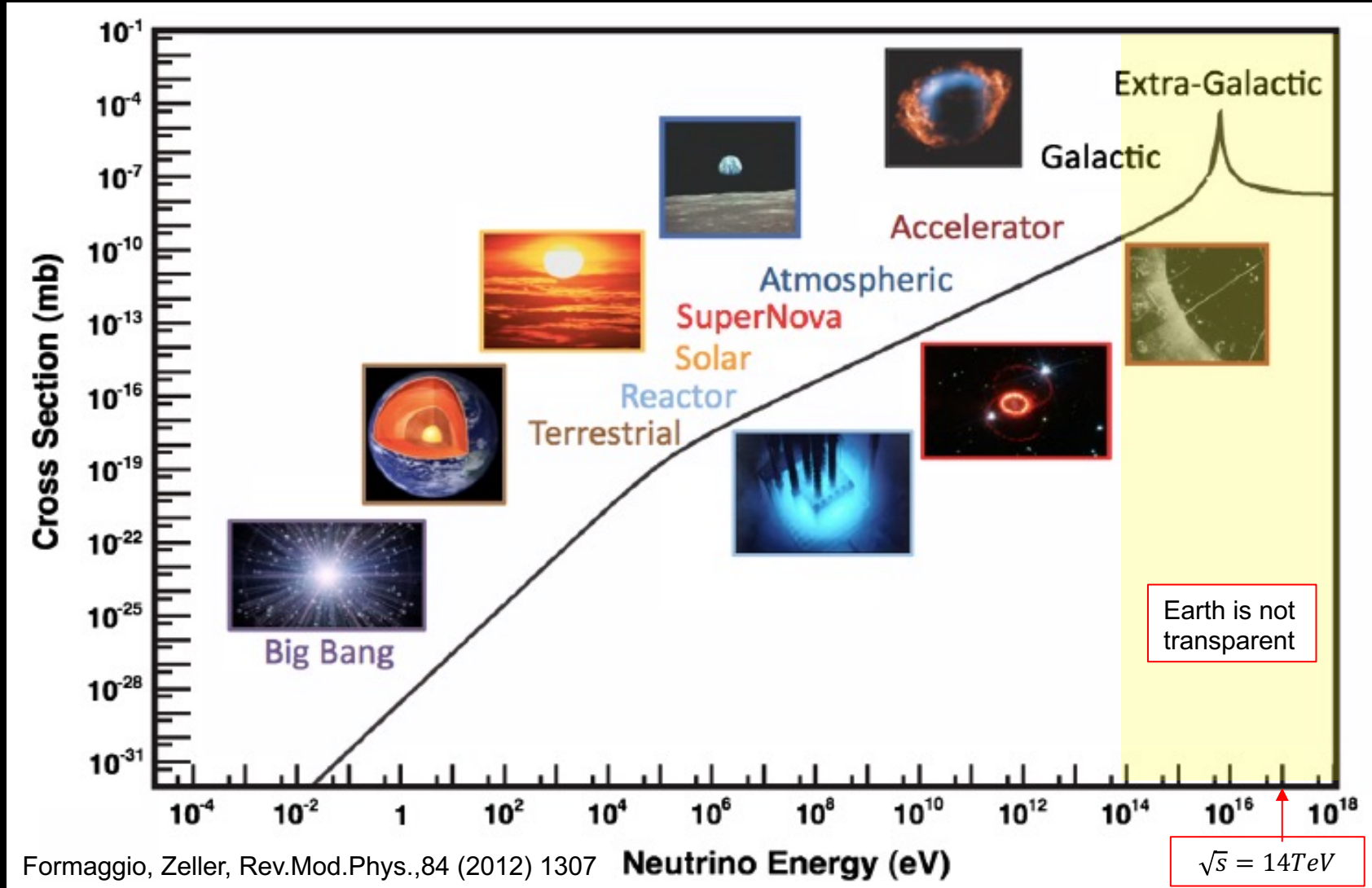
Above  $\sim 100$  TeV neutrinos are only direct messengers





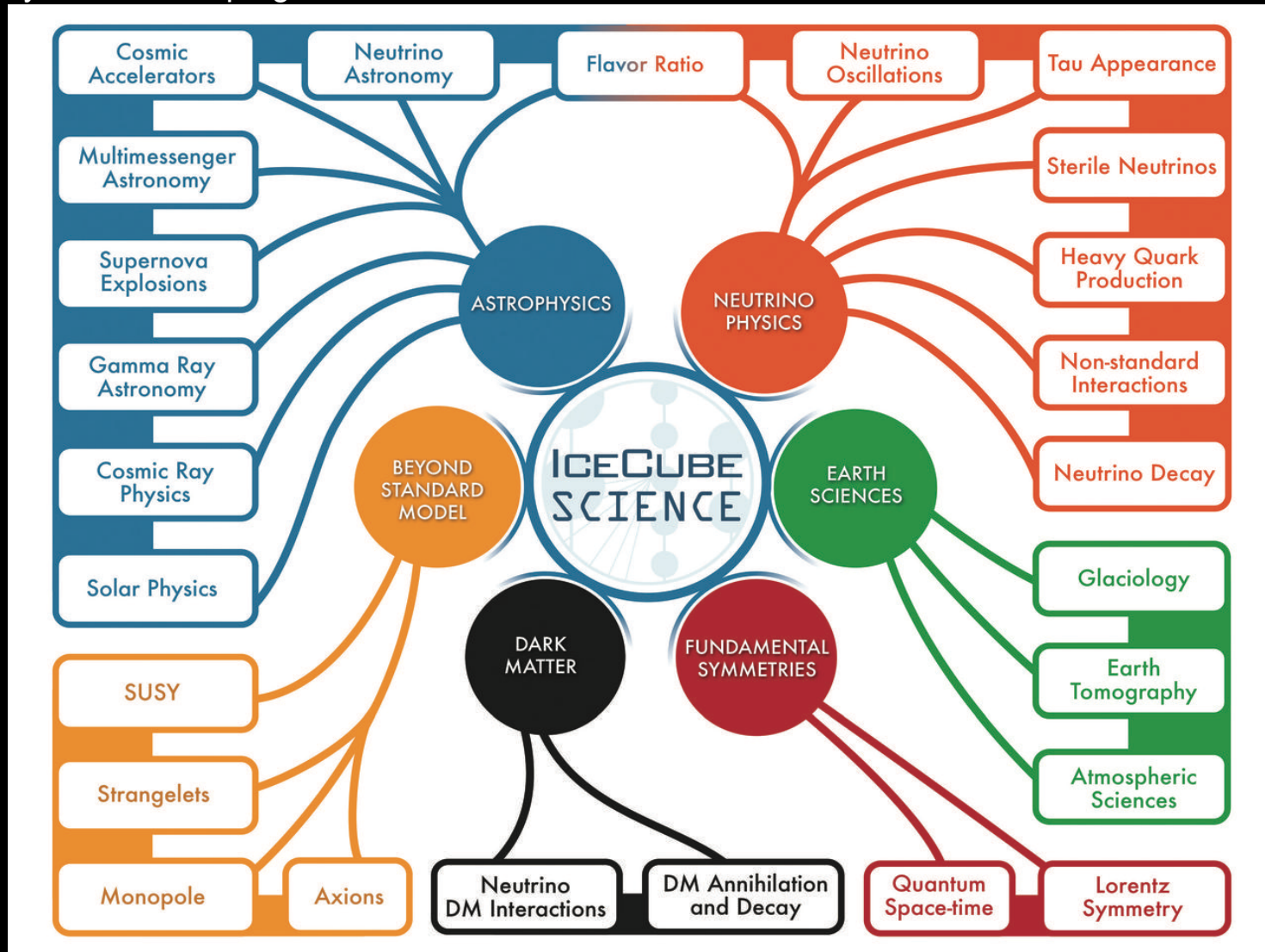
# High-Energy Neutrino Astronomy

Above  $\sim 100$  TeV neutrinos are only direct messengers



# High-Energy Neutrino Astronomy

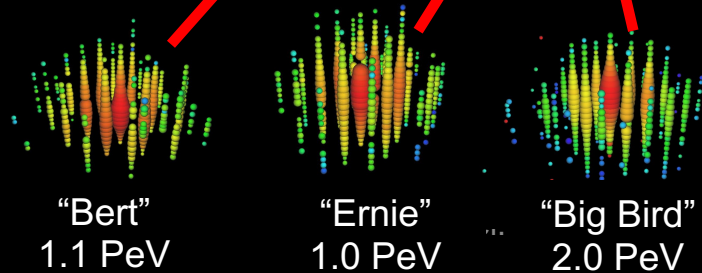
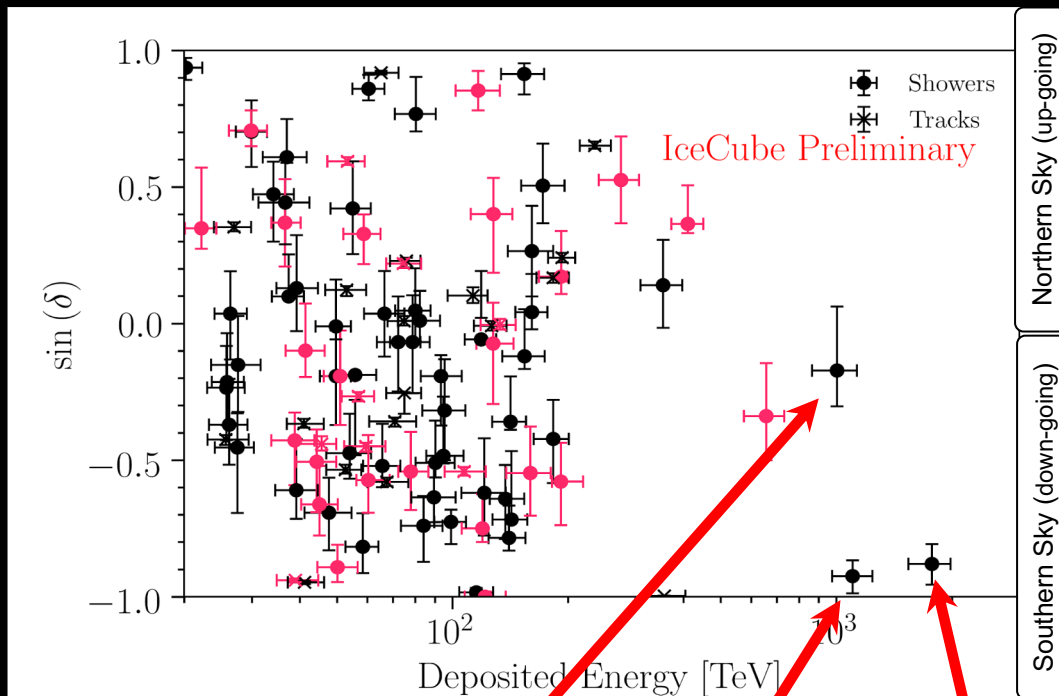
Above ~100 TeV neutrinos are only direct messengers  
Extremely rich science program



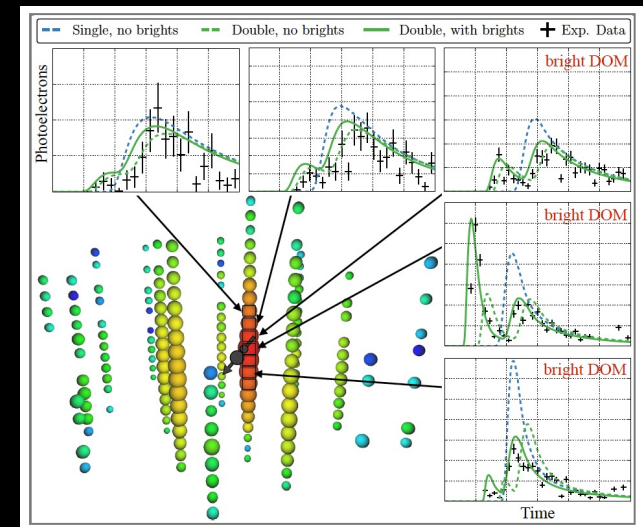
# IceCube

## Diffuse events

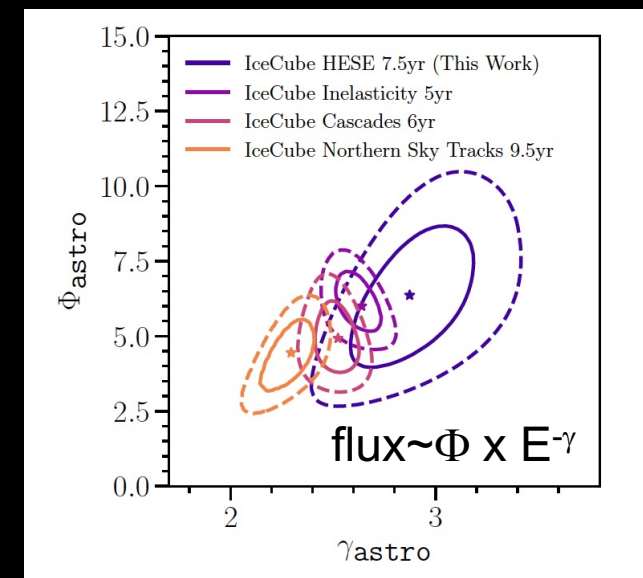
- Data set major update (2020)
- Improved reconstruction and systematics
- low energy events for oscillation physics



## “Double Double” tau-neutrino candidate



## Spectrum index



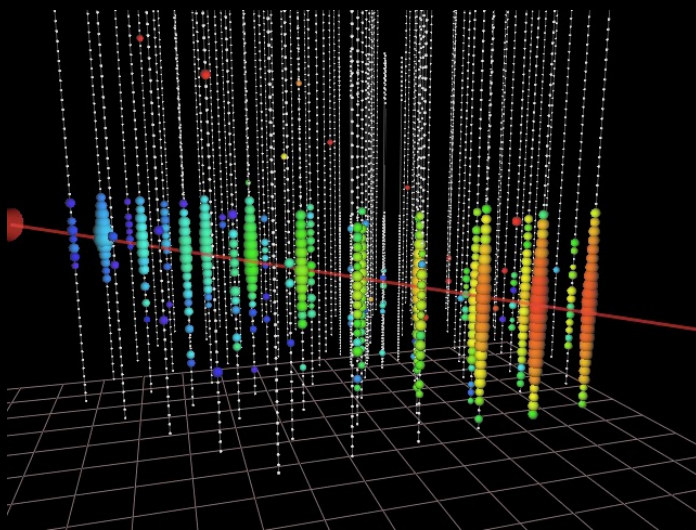
# IceCube

## Diffuse events

- Data set major update (2020)
- Improved reconstruction and systematics
- low energy events for oscillation physics

## Point source & transient events

- Multi-messenger astronomy (optics, GW)
- Realtime alert (2016)
- Blazar neutrino (2018)



IC170922A (290TeV)

tepp

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

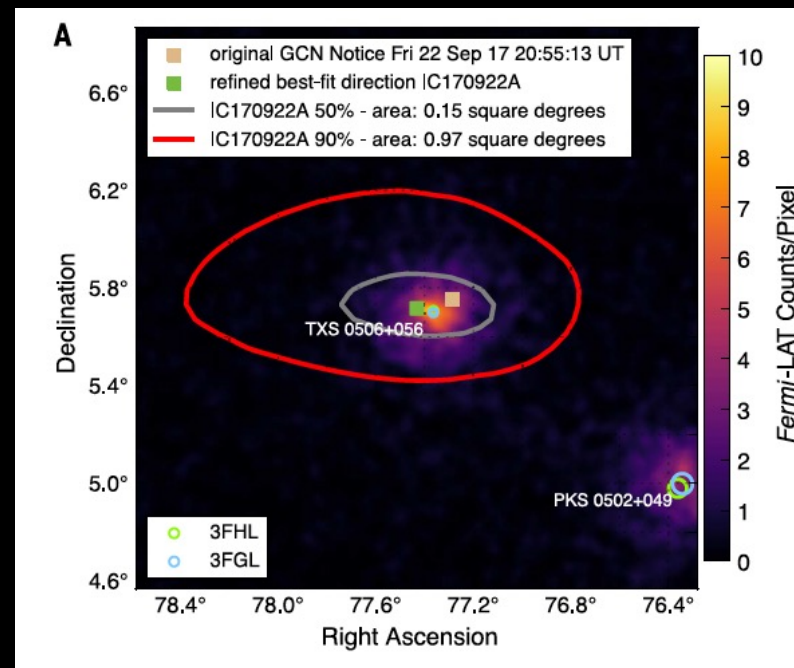
ATel #10791; *Yasuyuki T. Tanaka (Hiroshima University), Sara Buson (NASA/GSFC), Daniel Kocevski (NASA/MSFC) on behalf of the Fermi-LAT collaboration*  
on 28 Sep 2017; 10:10 UT

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-LAT



Full coverage, radio wavelength to gamma rays by everyone: Fermi-LAT, MAGIC, AGILE, ASAS-SN, HAWC, H.E.S.S, INTEGRAL, Kanata, Kiso, Kapteyn, Liverpool Telescope, Subaru, Swift/NuSTAR, VERITAS, VLA/17B-403



# IceCube-Gen2

IceCube-Gen2 include many projects

- Larger IceCube array ( $\sim 8$ )
- ARA (Askaryan Radio-telescope Array)
- PINGU (oscillation physics)
  - IceCube Upgrade (7 new PINGU strings, 2023)
- New sensors, calibration devices, surface array

IceCube-UK

- Funding: CG, Royal Society, university
- Analyses: Oscillation [EPJC80\(2020\)9](#)

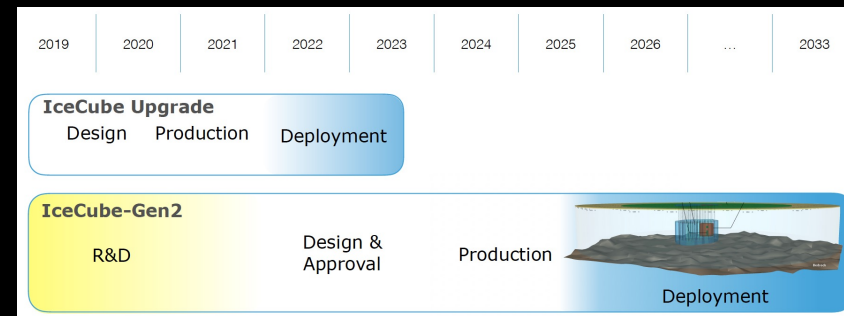
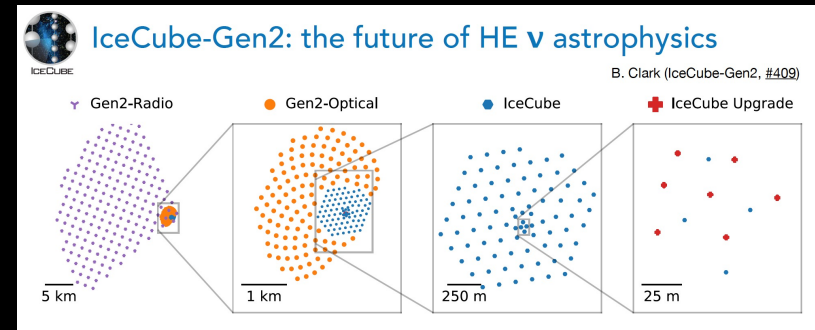
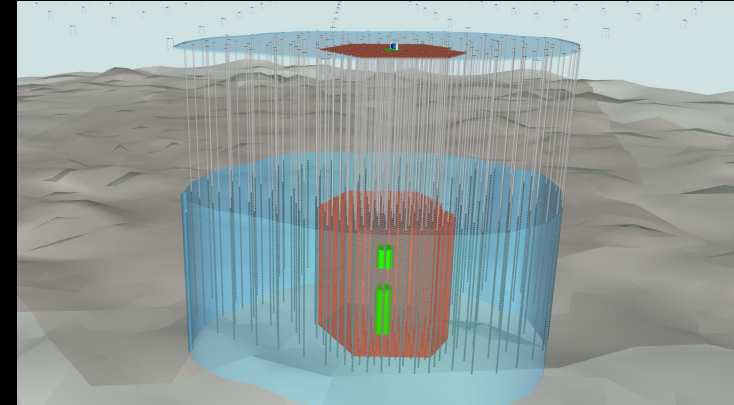
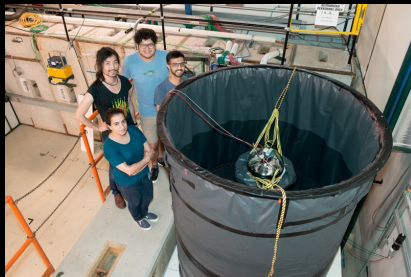
[PRD101\(2020\)032006](#), BSM physics [Nature Physics](#)

[14\(2018\)961](#), [ArXiv:2111.04654](#), flux/xs studies

[PRD95\(2017\)023012](#) [JPhysG42\(2015\)115004](#), etc

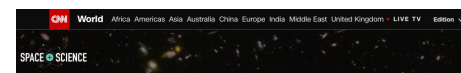
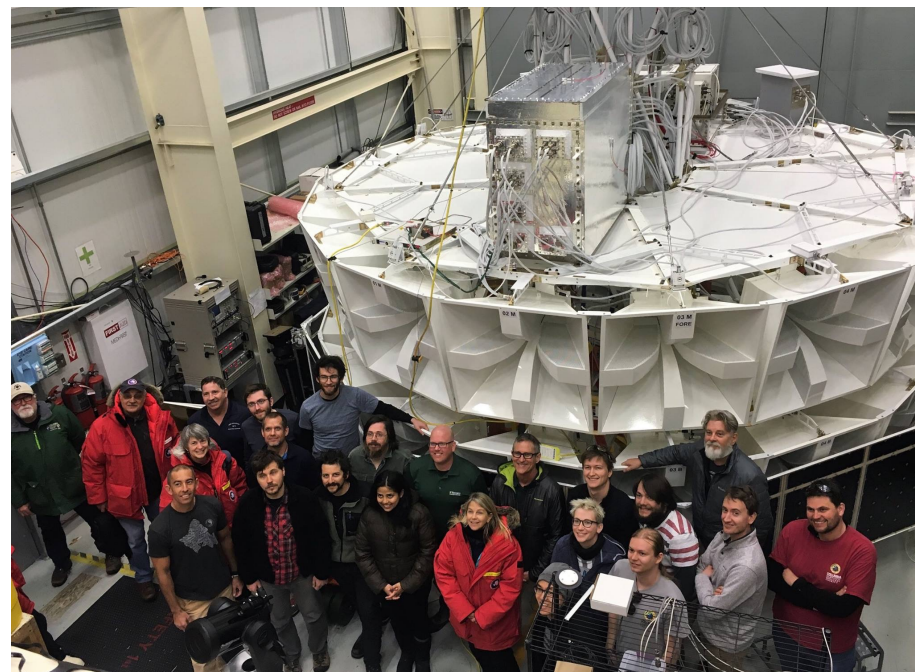
- Software: Oscillation fit code [NIMA977\(2020\)164332](#),  
Bayesian BSM fit [ArXiv:2011.03545](#), etc

- Hardware: Fermilab beam test [JINST15\(2020\)T05002](#),  
etc



# ANITA Past

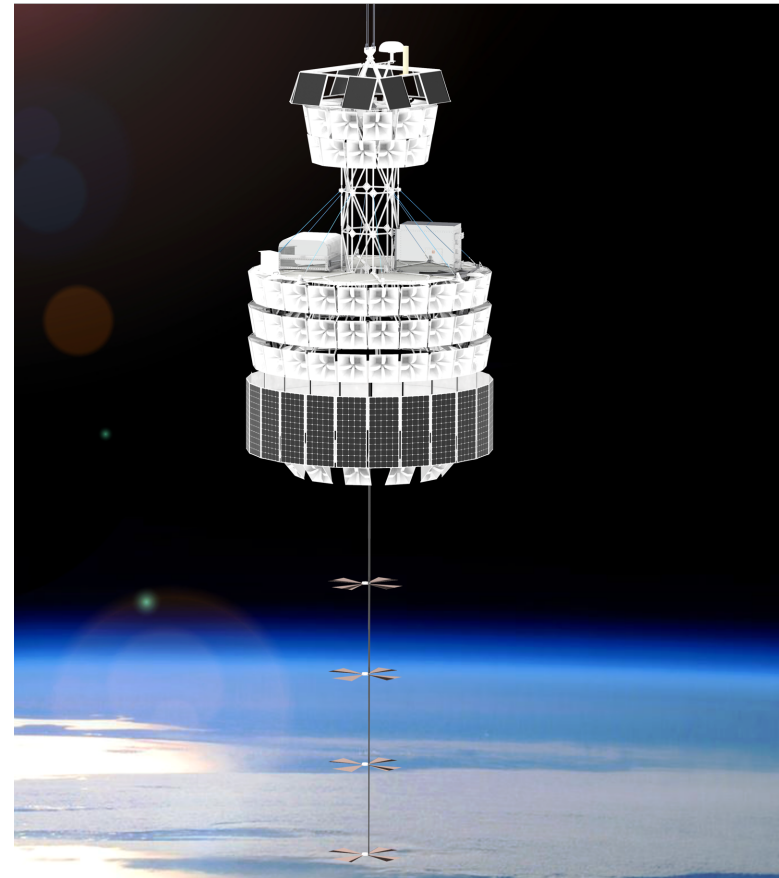
- Ultra-high energy neutrino search experiment using radio-Cherenkov technique
  - Searching for the neutrinos that come from the highest energy cosmic rays
- UK have been involved in all four ANITA flights (2006-2016/17)
  - Significant fraction of the collaboration (3/16th of on-ice effort)
  - Funded by STFC (PRD & CG), Royal Society and Leverhulme Trust
  - ‘Anomalous’ events which have resulted in ‘interesting’ theoretical interpretations... caused some fun headlines in 2019/2020.





# PUEO: Payload for Ultrahigh Energy Observations

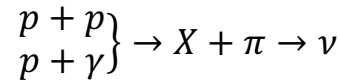
- A new name and a new paradigm
  - Embracing the technological advances to implement a trigger based on high-bandwidth digital filtering and beam forming
  - Prototype digitisation system based on XILINX RFSoc (FPGA) under development at UCL (and in the US)
- NASA Astrophysics Pioneers announcement expected this week with a launch date of December 2024
  - UCL and QMUL collaborators



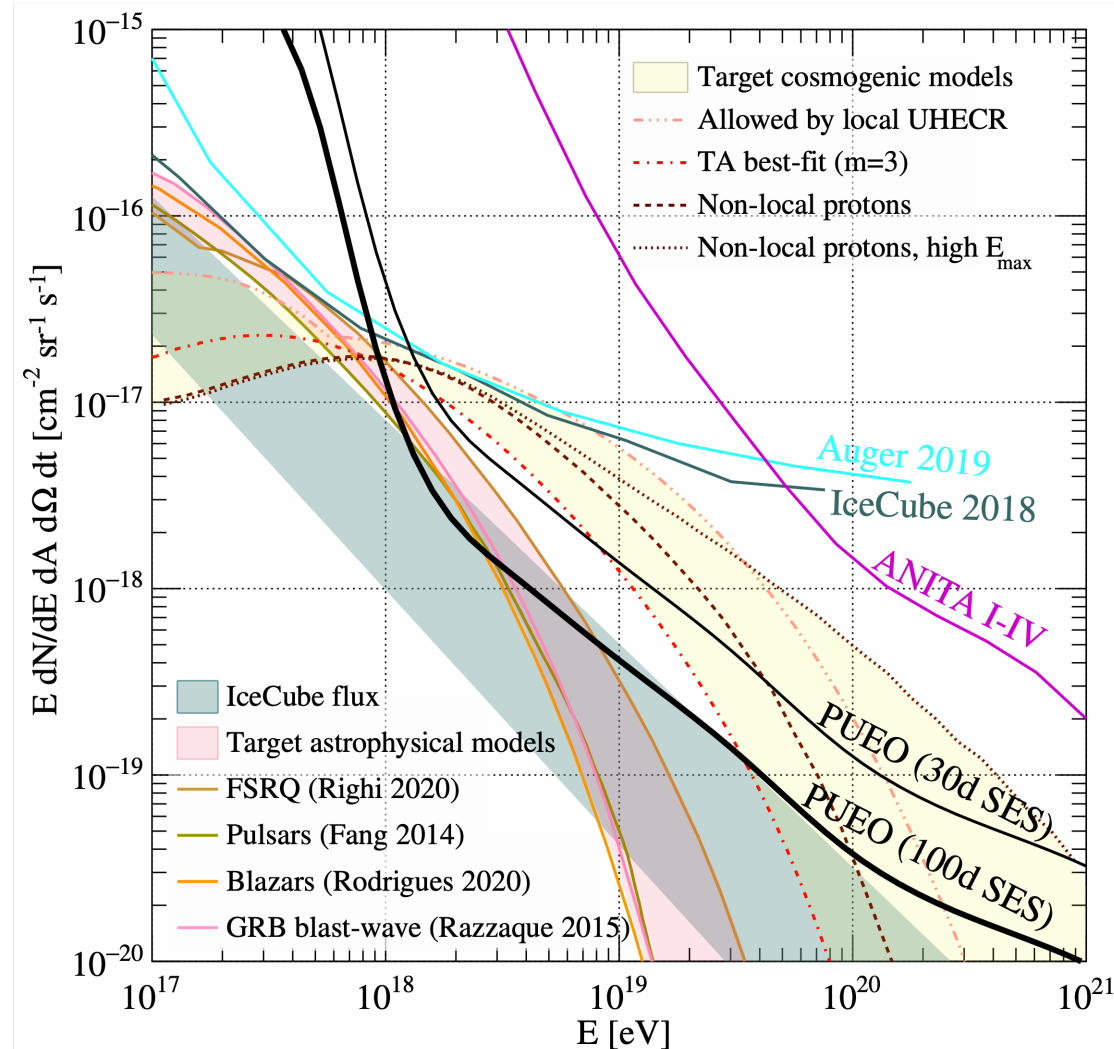
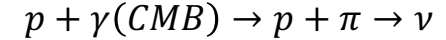
# PUEO Sensitivity

- World-leading cosmogenic neutrino sensitivity
- World-leading astrophysical neutrino sensitivity at EeV energies
- Dark matter sensitivity (e.g. decays of heavy DM particles)
- Unique energy regime for neutrino-nucleon cross-section measurements
- Other exotic searches (Lorentz violation, the anomalous ANITA events?)

Astrophysical neutrinos



Cosmogenic neutrinos



# Pacific Ocean Neutrino Experiment



## P-ONE:

- Optimized for horizontal tracks, effective ~ IceCube
- **Reliable** underwater infrastructure & detector installation provided by Ocean Network Canada (Vancouver)
- Up to factor 10 coverage increase, sensitive to galactic center

## Status:

- 2018: first string in situ, **verified** water properties (STRAW)
- 2023: installation of 10 strings, **funding** to be secured in 2021
- 2028: completion of detector

**UCL initial contributions:** STRAW data analysis, detector design and physics potential studies

