

IceCube research at UCLouvain

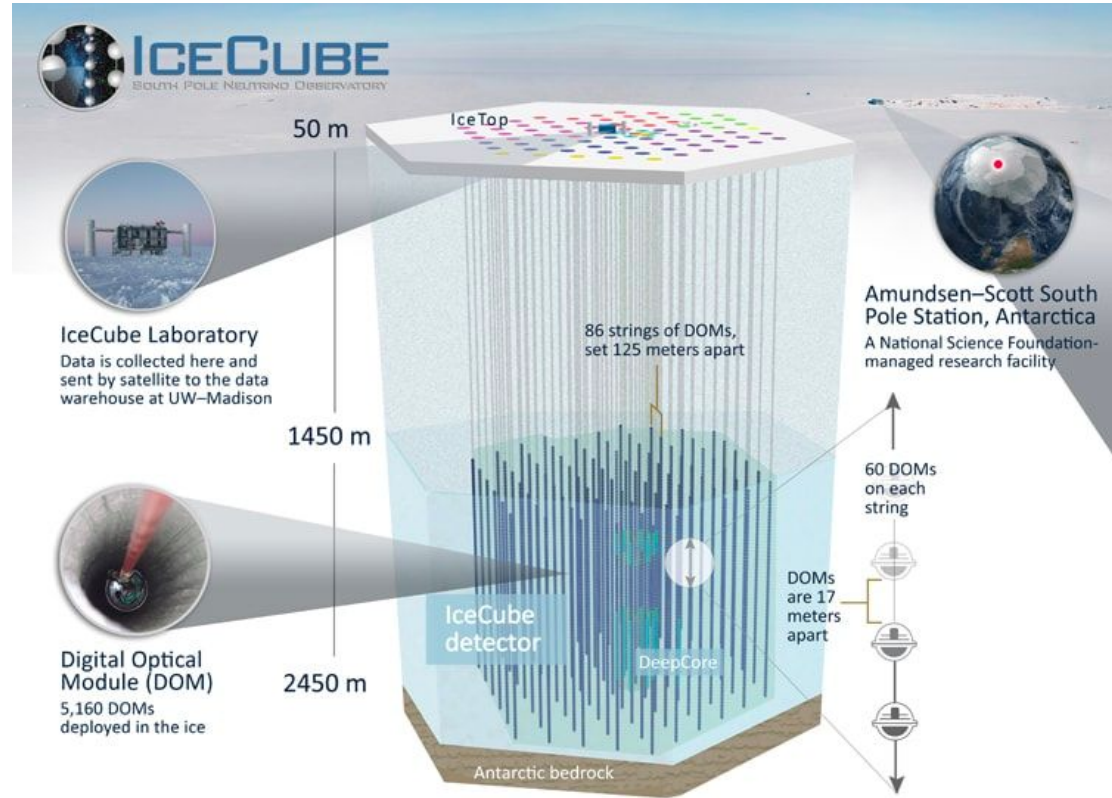
Belgian Neutrino meeting Monday 11 March 2024



IceCube

5160 DOMs with PMTs to observe Cherenkov radiation

DeepCore: 8 strings (6 have quantum efficiency about 35% higher) separated 40-70 m with vertical spacing of 7 m for the lowest 50 DOMs. (+7 surrounding strings)

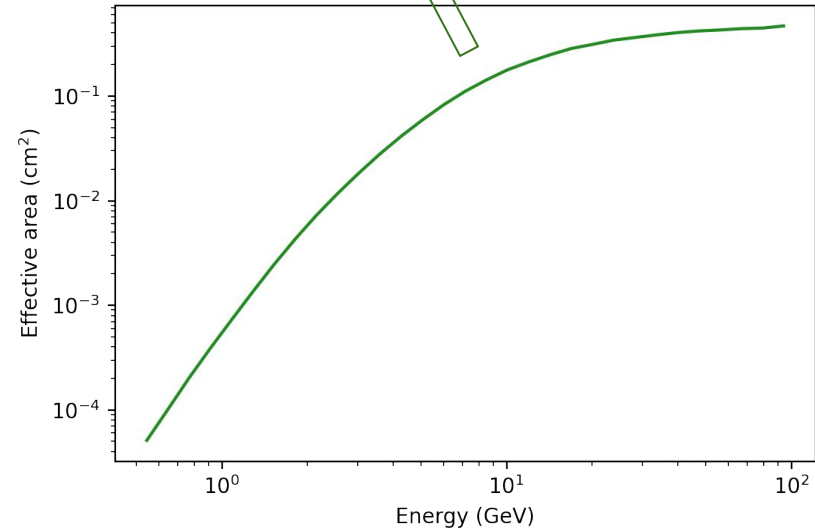
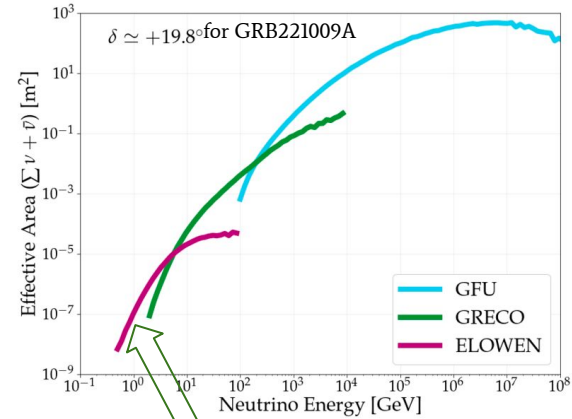


The ELWEN selection

Lowest energy for observing single neutrino events

Specialized for 0.5 - 5 GeV

Consists of several hard cuts on low-level variables to remove both noise and high-energy events (position, timing and charge of hits)

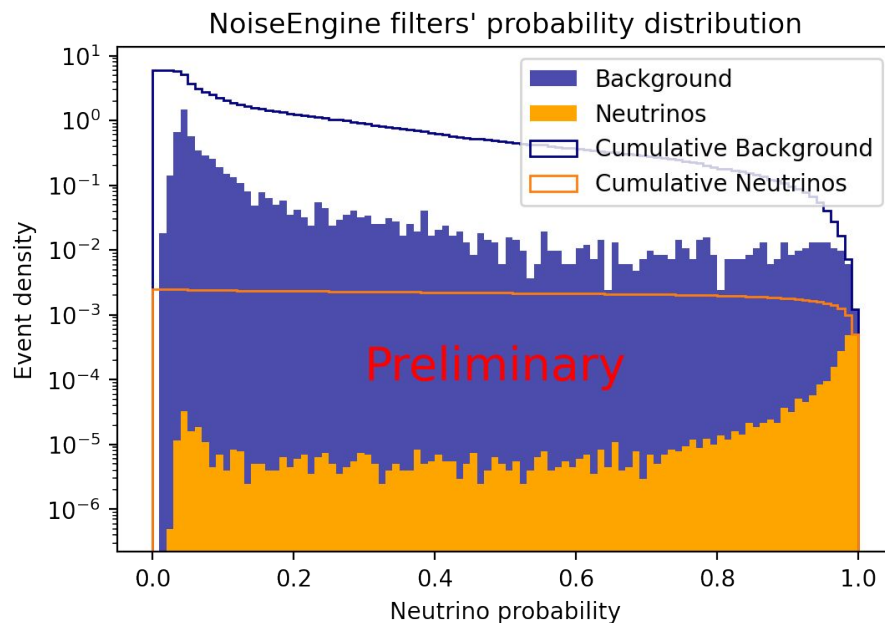


Improving ELOWEN noise reduction

NoiseEngine filters on:

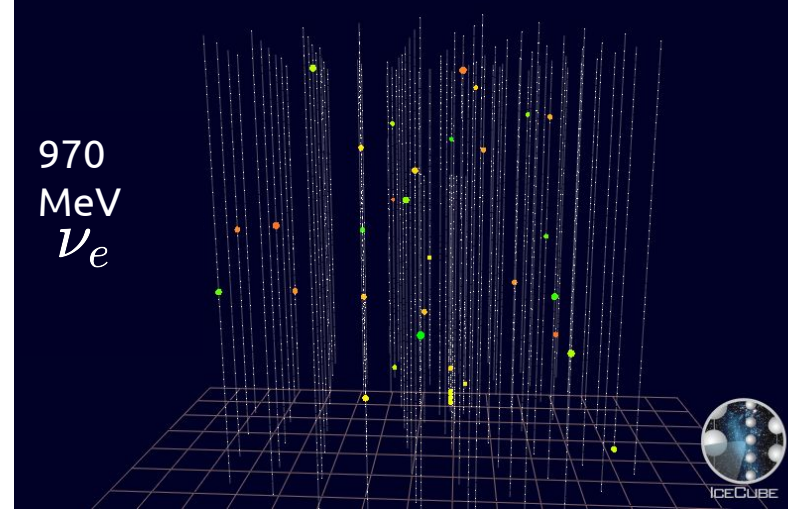
- Number of hit-pairs necessary
- Velocity window
- Time window

Combine many settings to train a BDT
can reach nearly 10^4 reduction in noise

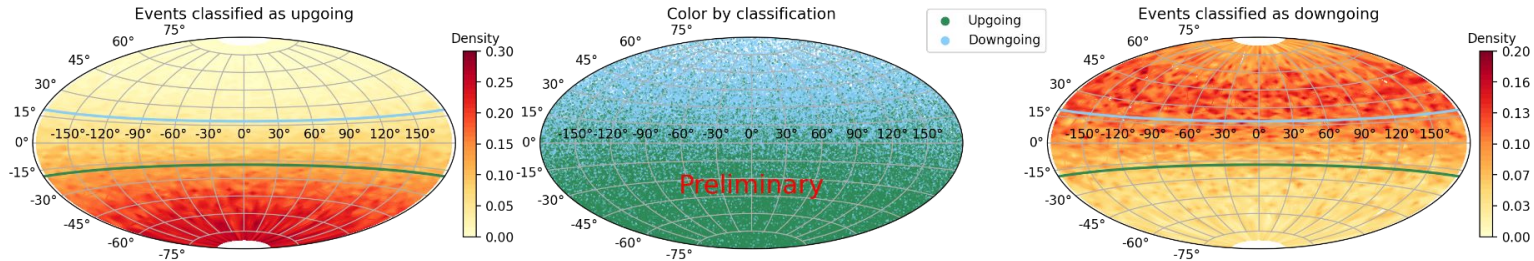


Direction reconstruction

- Single string reconstruction
 - Zenith direction
- Using 2 boosted decision trees
 - 77% accuracy



Direction classification of 0.5-5 GeV neutrinos



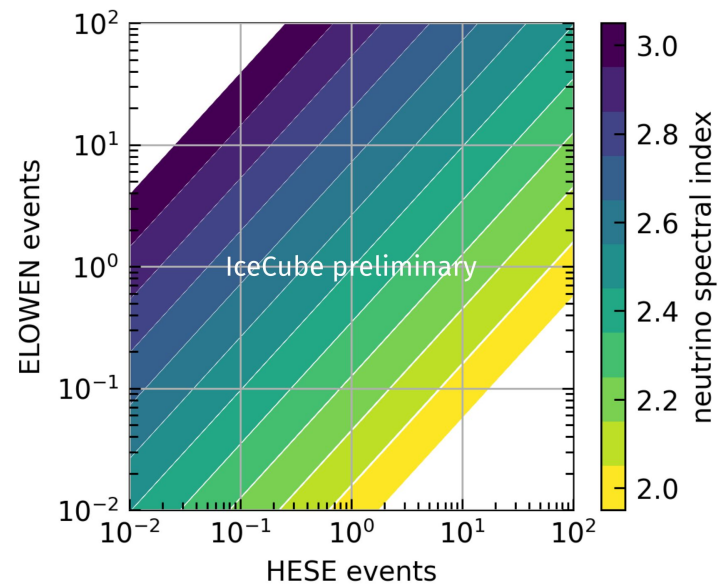
ELOWEN HESE follow-up

Motivation

- Astropysical flux observed at TeV-PeV
- Short transient origin possible
 - Can also produce GeV neutrinos

Analysis plan

- Check possible impact of HESE on ELOWEN precursors
- Counting analysis in window around HESE event
 - Check stable background etc
- Time series analysis
- HESE subgroup clustering



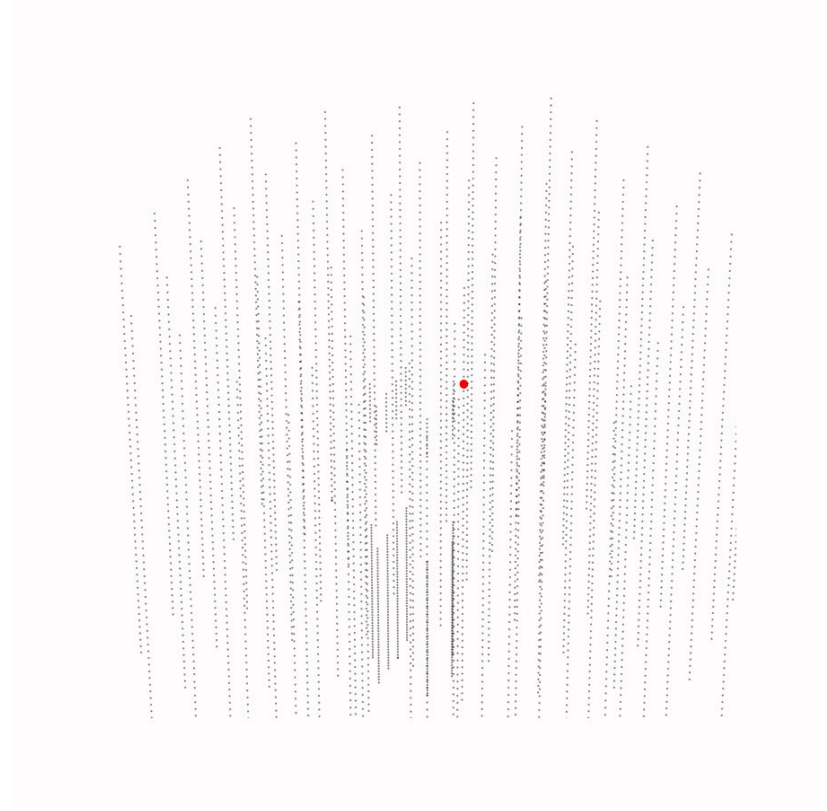
Sub-GeV emission

Bridge energy gap between ELOWEN and SNDAQ

Differentiate between

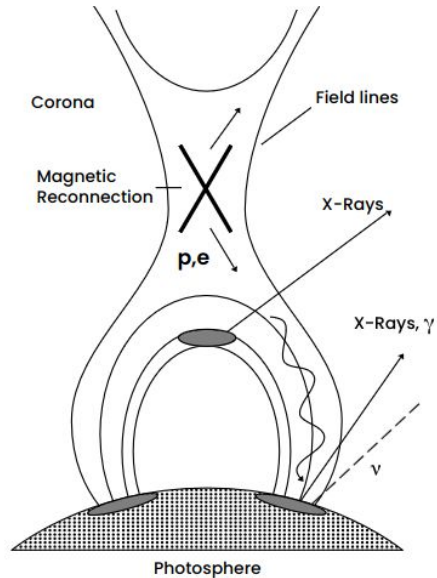
- Noise
- Atmospheric muons
- Neutrinos

More on that from Jonathan :)

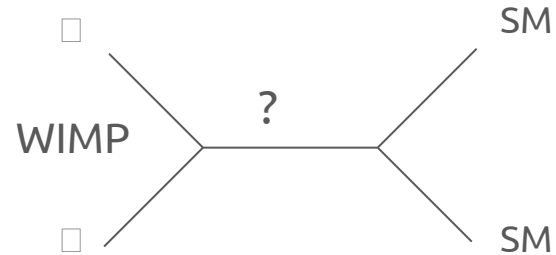


Solar neutrinos

Solar flare: MeV-GeV, from atmosphere, transient



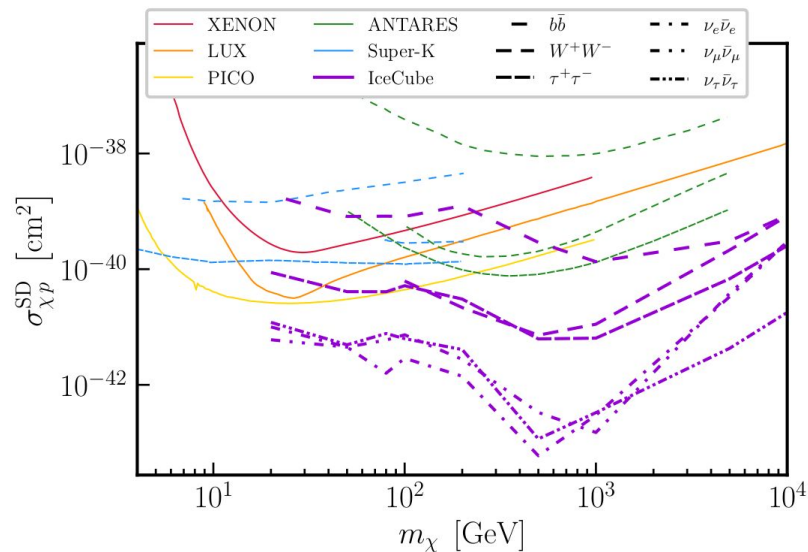
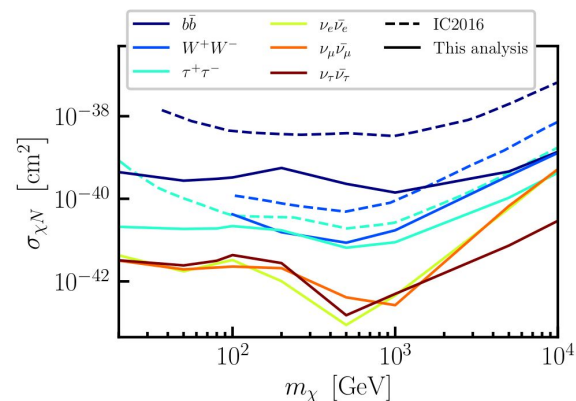
Dark matter: GeV-TeV, from core, continuous



All-energy Solar WIMP Search

Probed 3 orders of magnitude of WIMP masses

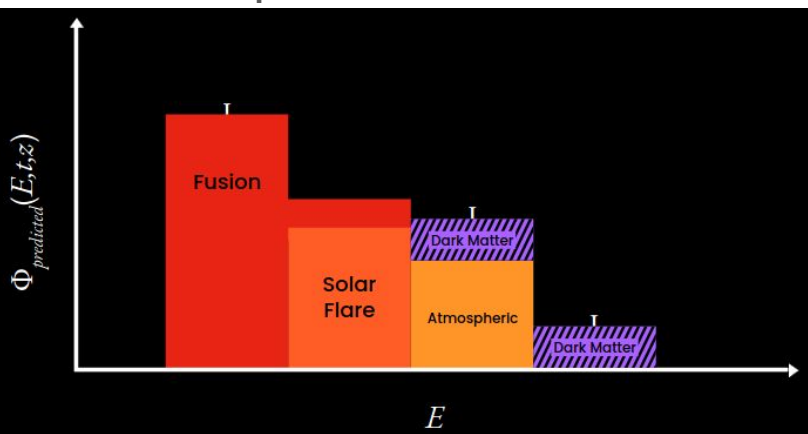
World leading limits on spin-dependent WIMP-nucleon cross section for most annihilation channels >100 GeV



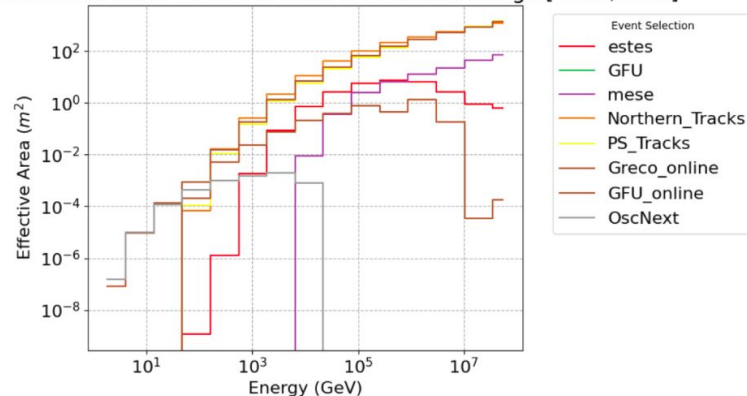
Solar neutrinos: Next

Go to 10 orders of magnitude!

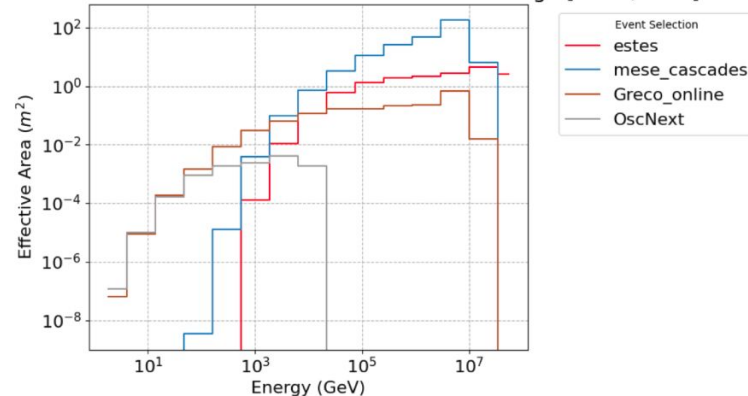
- Probe different neutrino production modes
- Help answer solar anomalies



Effective Area for Track Events in Solar Declination Range $[-23.5, 23.5]^\circ$



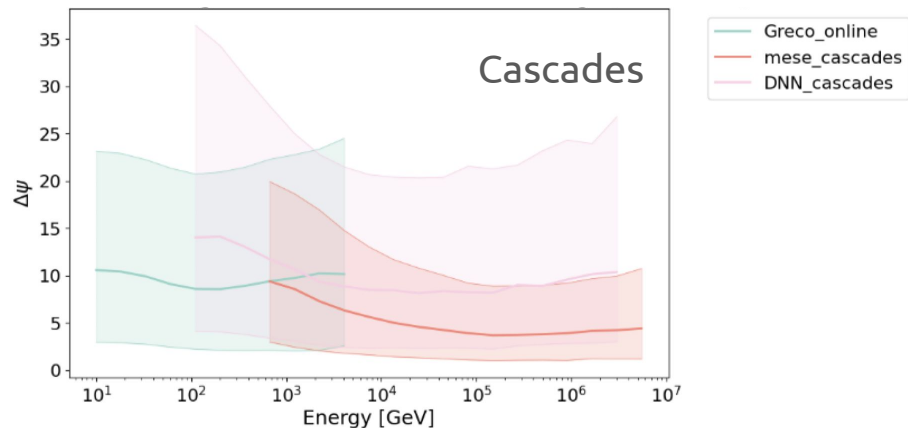
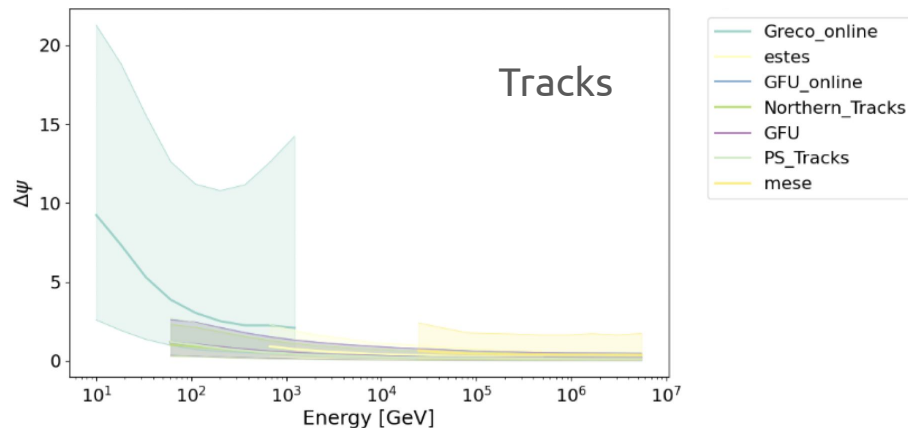
Effective Area for Cascade Events in Solar Declination Range $[-23.5, 23.5]^\circ$



Solar neutrinos: Next

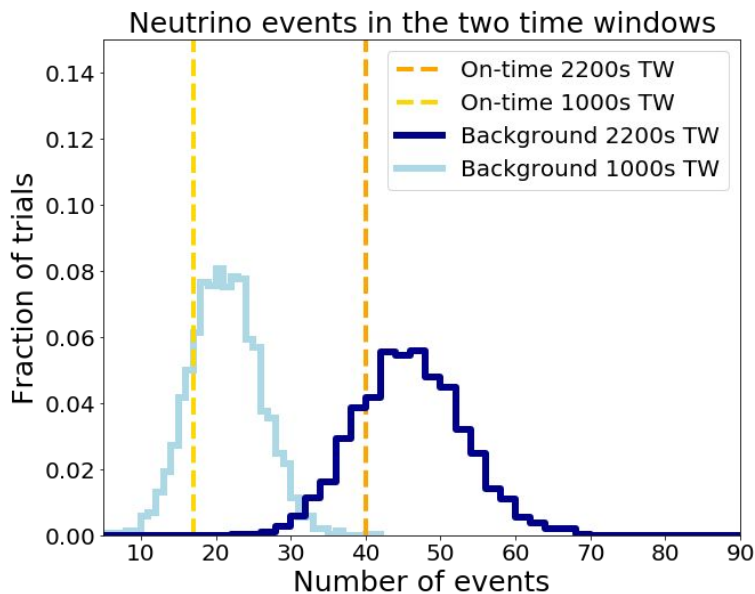
Single out solar neutrinos

→ Direction reconstruction



GRB221009A

Combined search, tested models



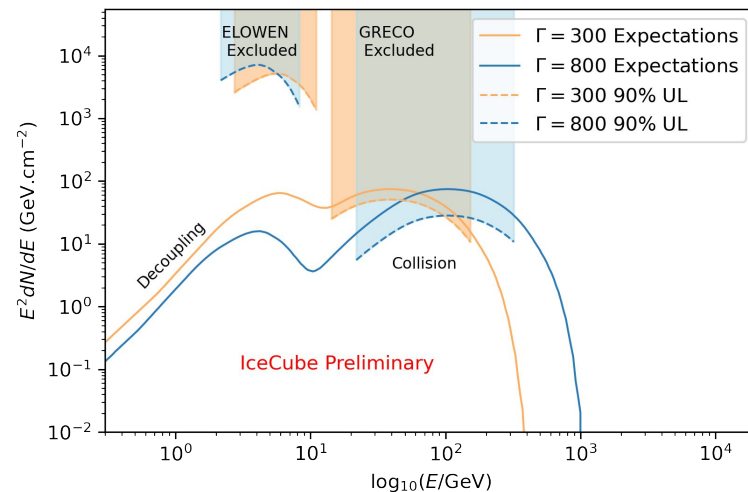
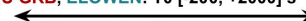
Time windows for different analyses for GRB221009A



ELOWEN: T0 ±500s



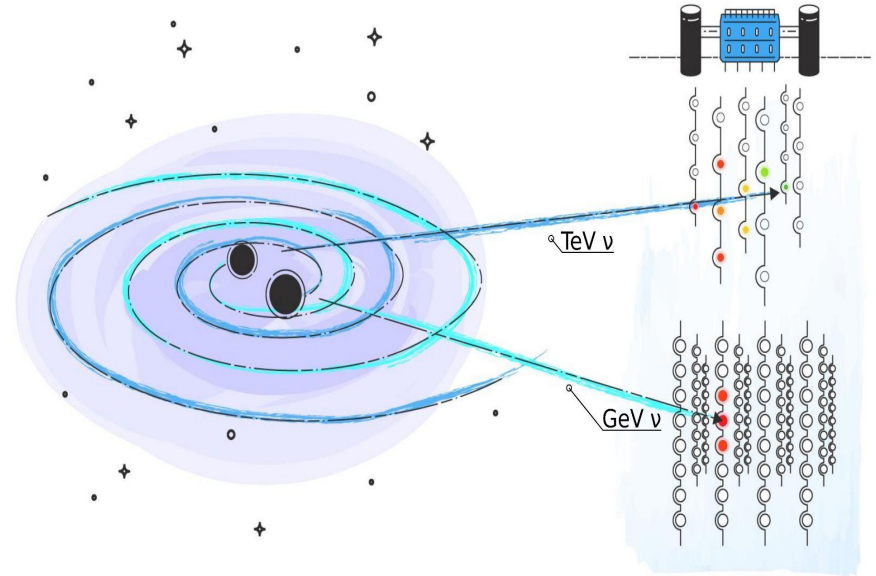
Coordinated: GRECO, GFU GRB, ELOWEN: T0 [-200, +2000] s



Gravitational wave follow up

Neutrinos from Gamma-Ray burst
following merger

Low-energy neutrinos emitted from
pp/pn interactions inside photosphere



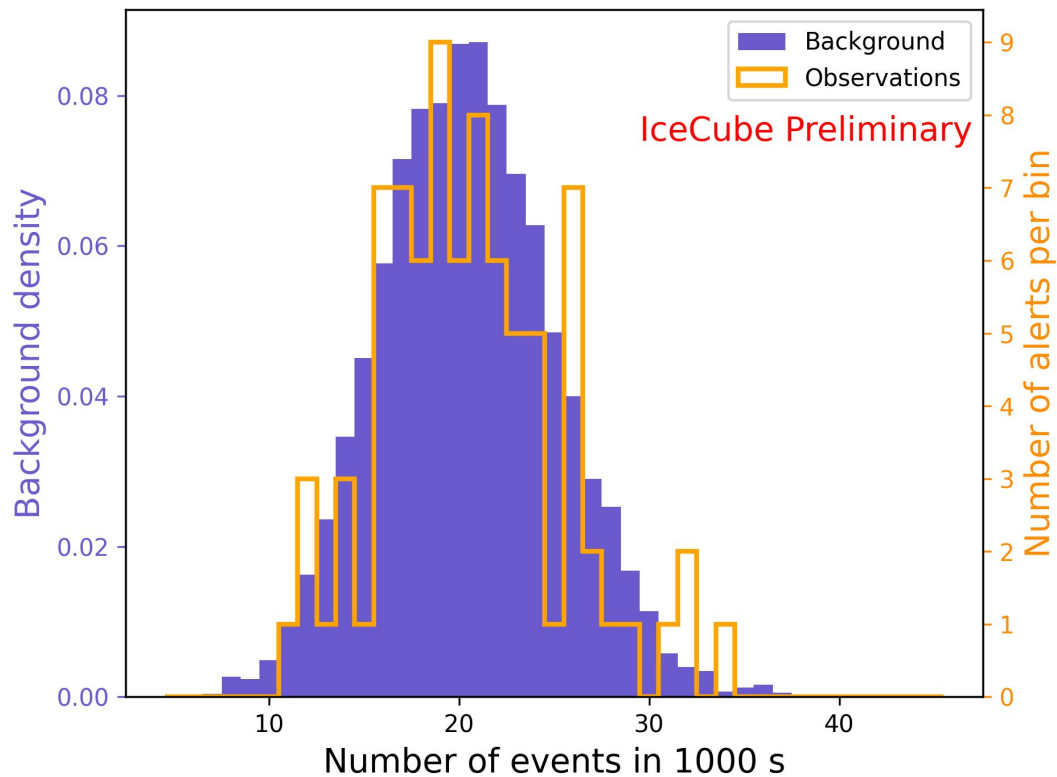
O4 follow up

Currently ongoing

2 Time Windows:

- ± 500 s around merger time
- 3 s starting at merger time
 - Only for BNS and NSBH

So far no significant deviation from background



Searching for AGN neutrinos and gravitational waves

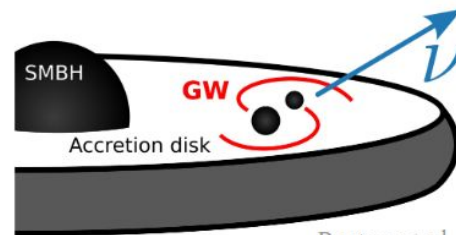
Multi messenger search for common source of GW and neutrinos

Non-GW emission from BBH mergers:

No clear singular model prediction

Localization alone can already probe this by counting AGN

Binaries in AGN accretion disks



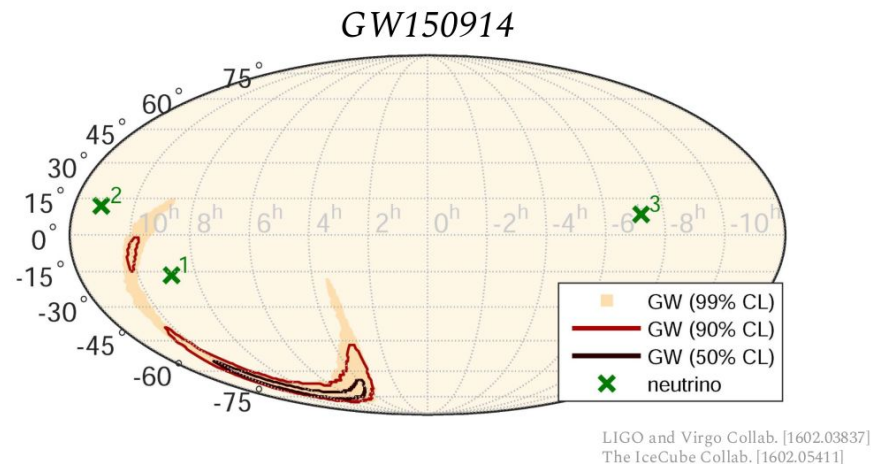
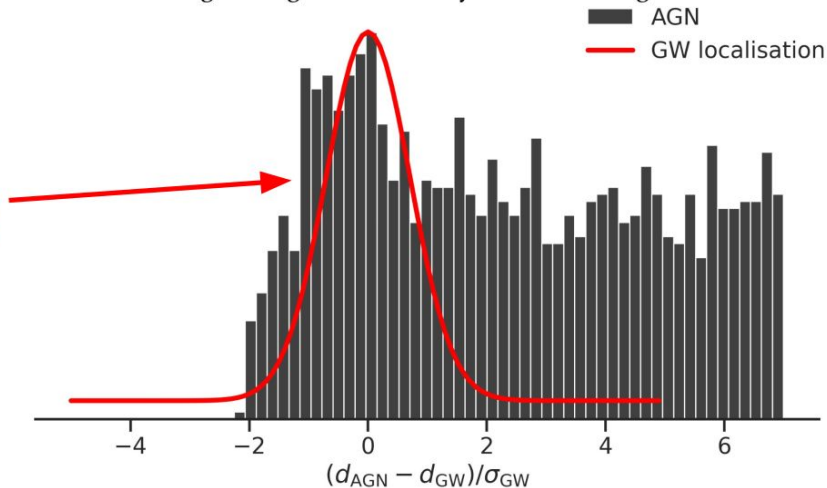
Bartos et al. [1602.03831]
McKernan et al. [1907.03746]
Kimura et al. [2103.02461]
Tagawa et al. [2303.02172]
...

- ✓ Many (heavy) black holes
- ✓ Frequent mergers
- ✓ Gas-rich environment

Joint ν -GW search for BBH in AGN disks

Spatial distribution of GWs and AGNs

E.g. using Véron-Cetty AGN catalogue



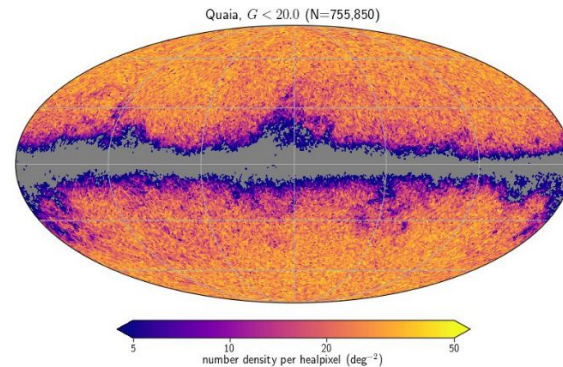
Joint ν -GW search for BBH in AGN disks

Neutrino Follow Up

Time window: standard 1000s

First High-energy sample ($>100\text{GeV}$)

add lower-energy samples in future
(GRECO, ELOWEN)



Storey-Fisher et al. [2306.17749]

AGNs

Need uniform and complete catalog:

enough events, but not too many to lose sensitivity:

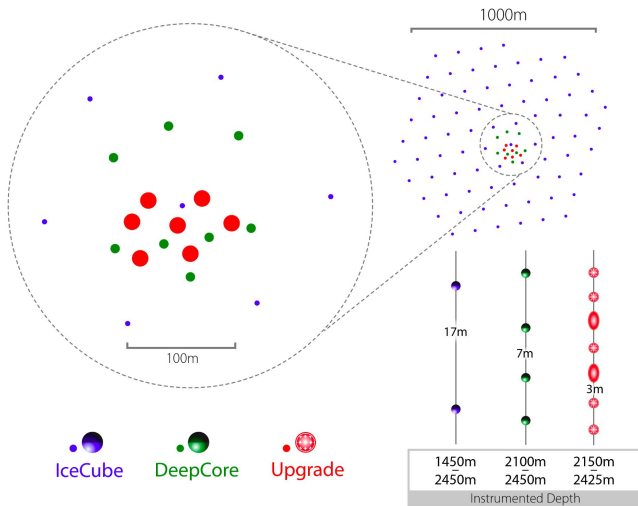
TOOK EXTENSIVE LITERATURE SEARCH

Settled on Quiaia, best coverage

IceCube Upgrade

Lower energies, different DOMs

Planned to deploy 2025-2026

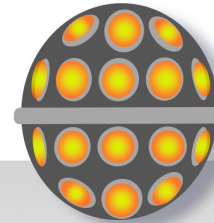


ICECUBE UPGRADE OPTICAL SENSORS



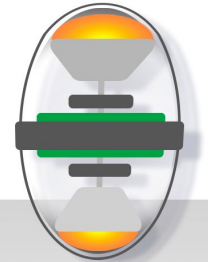
PDOM

1 x 10" PMT
120 sensors
UW-Madison



MDOM

24 x 3" PMT
300 sensors
DESY, MSU



D-EGG

2 x 8" PMT
300 sensors
CHIBA

IceCube Upgrade

BSM:

- Probe lower energies of Dark Matter
- Calculate improvements in sensitivity
- Expand DM limits to $m_{\chi} < 20$ GeV

ELOWEN:

- Creating new simulations using two different photon propagators and comparing results for low energies
- Calculate improvements in sensitivity
- Plan transient searches for after deployment

Summary and Outlook

Working on many different activities

- Event selection and reco
 - ELOWEN
 - Sub-GeV
 - TeV
 - Upgrade
- Study different sources
 - Sun
 - Gravitational Waves
 - GRBs

Much planned for the future

- Also DOM building (together with ULB)