ELOWEN-HESE CORRELATION ANALYSIS

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ON BEHALF OF THE ICECUBE COLLABORATION

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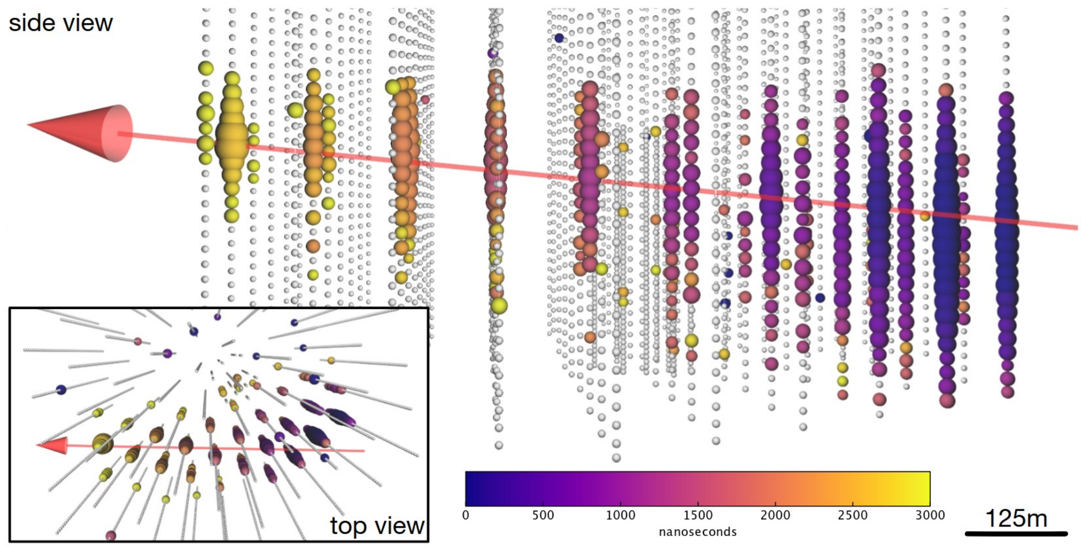
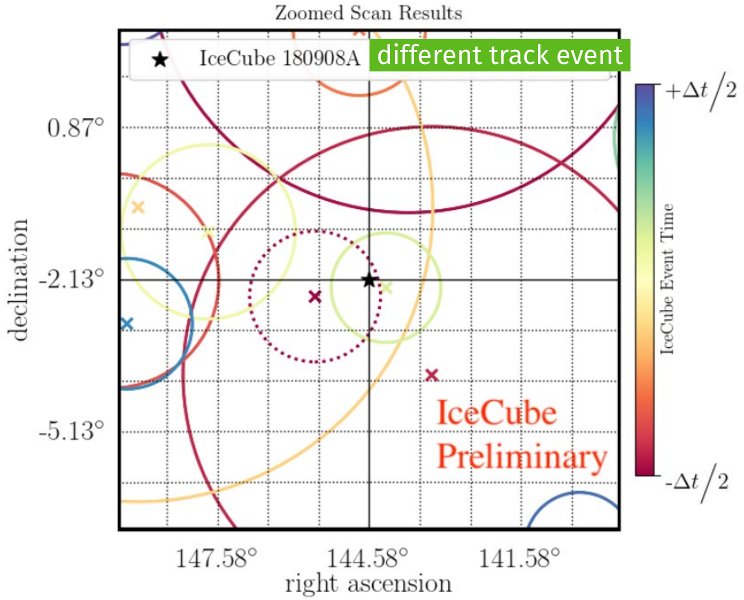
Multi-energy follow-ups: current

- IceCube sends singlet alerts that have a high signalness (→ energy)
- If astrophysical, these trace neutrino production sites
- They are followed up by searching for a coincident cluster of TeV-scale neutrinos [1]
- Reflects assumption that such a source could be transient





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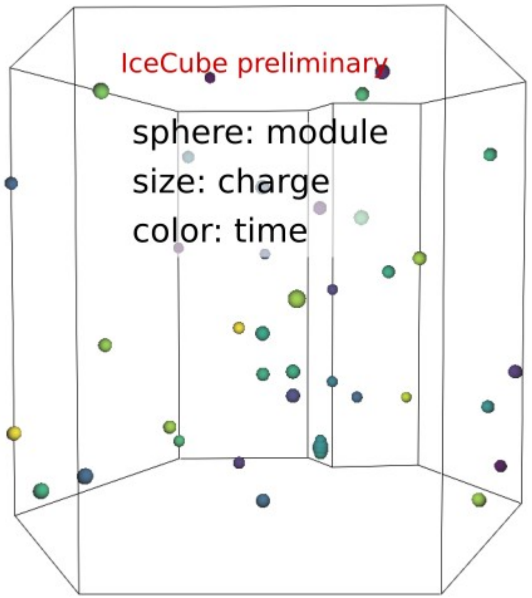
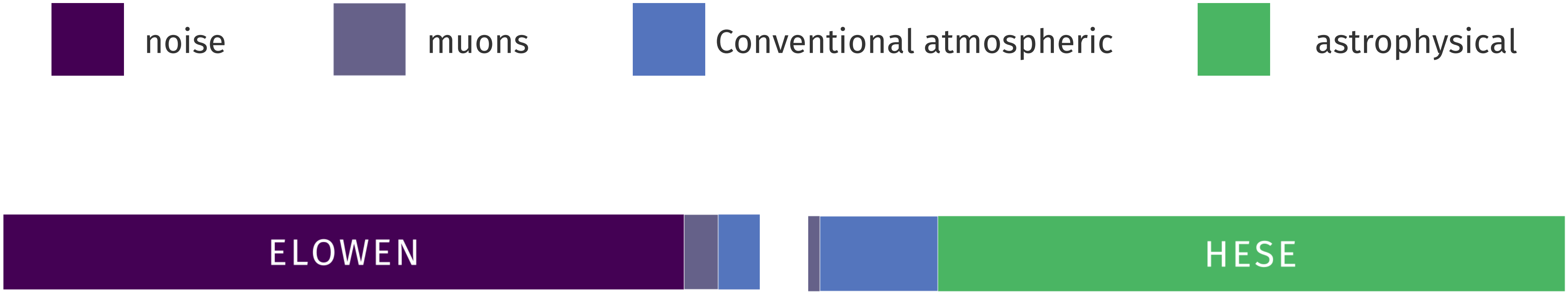
Multi-energy follow-ups: proposed

- Take this approach to the extreme:
- Lowest energy events triggering IceCube/DeepCore
  → sensitive to GeV component **if** transient short enough
- Physical candidates exist (more on that later)
- Event samples exist already in IceCube



simulated ν_τ, 4.9 GeV, zenith = 116°

Event samples



- 2.6 to 64 GeV (90% for E^{-2}), down to 0.5 GeV
- 20 mHz, dominated by noise
- all-flavour, all-sky coverage

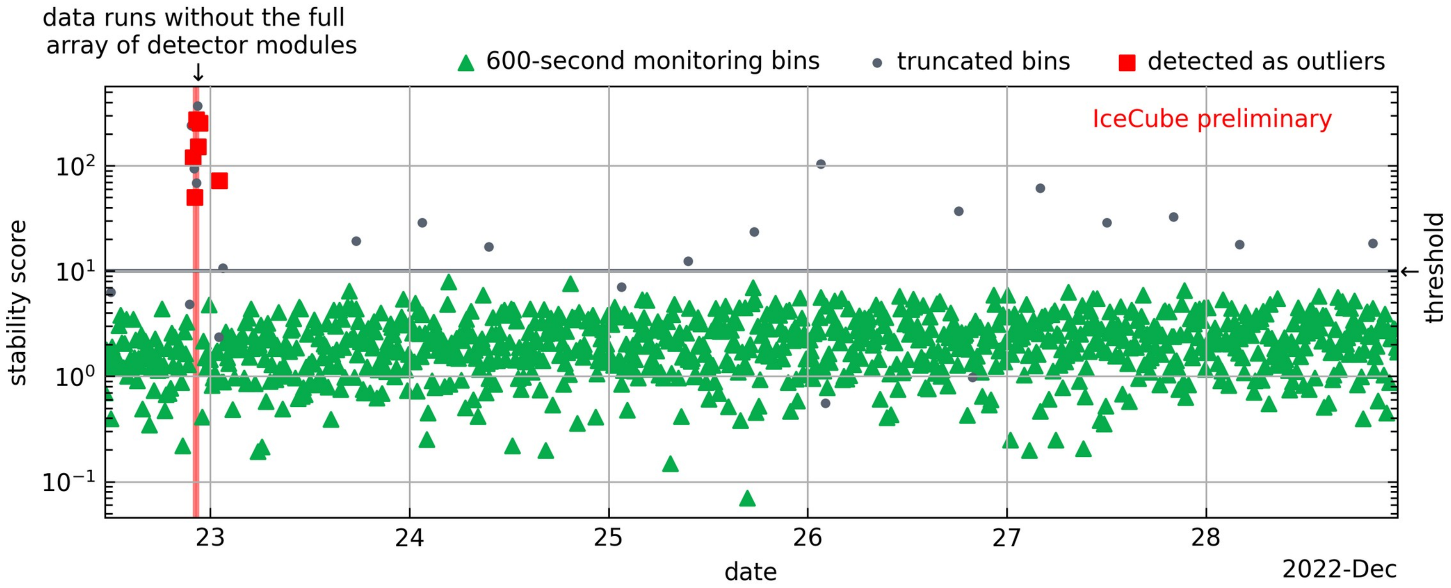
  → search for GeV transients [5,6]

- 65 to 969 TeV (90% for $E^{-2.9}$), up to O(PeV)
- 97 events in 12 seasons, mostly astrophysical
- all-flavour, all-sky coverage

  → diffuse [7], trigger MM follow-ups [8]

Selection stability score

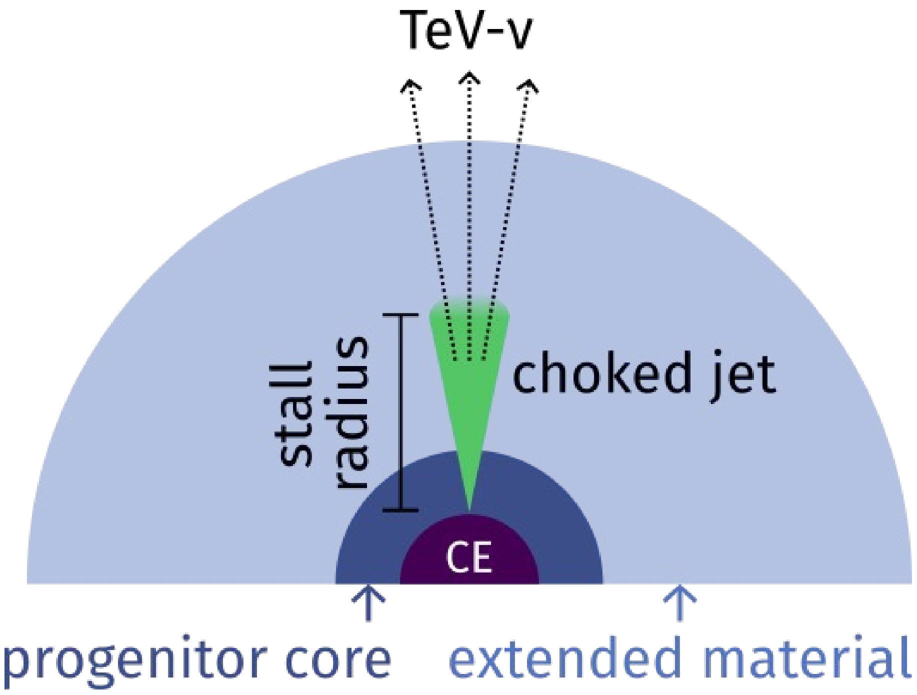
- Control transient detector effects in background dominated sample
- In addition to IceCube's run monitoring, we propose analysis-specfic stability pre-check
- Similar method as ref. [9] using intermediate stages of the ELOWEN selection chain



Physical example and time scales

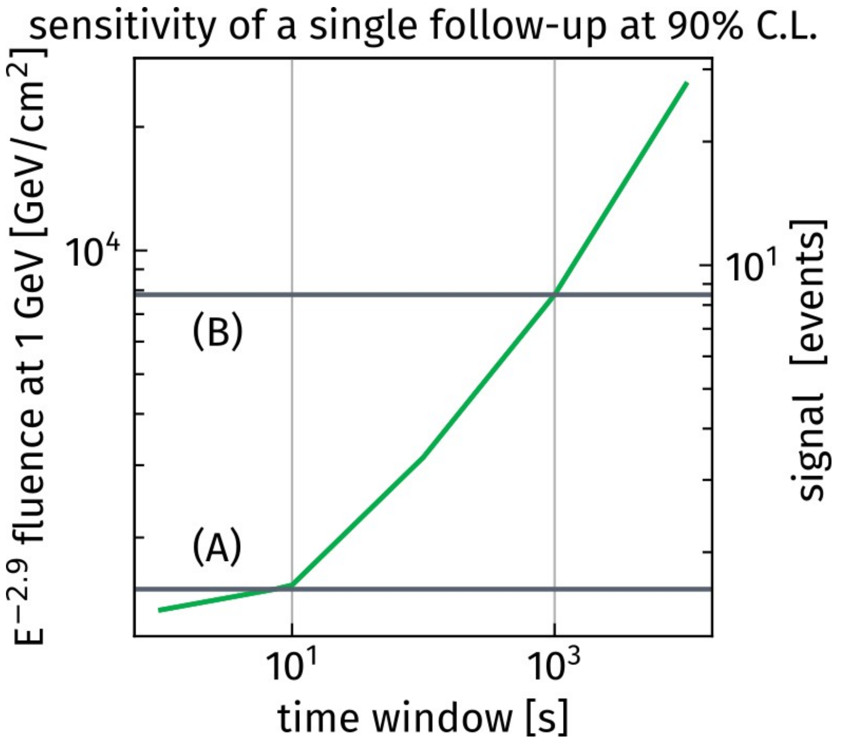
- Choked-jet GRBs [2,3]
- GRB jet choked in extended material 10^{13-14} cm
- TeV neutrinos from p-p and p-γ interactions
- GeV neutrinos from p-n collisions [4]
- Many parameters affect the time scale
  - Livetime of engine
  - Lorentz factor ($r = 2\,\Gamma\,\Delta t^2$)
  - p-n in the jet or with external medium

→ 1 – 1000 sec between GeV and TeV neutrinos



Counting analysis

- Time only observable in ELOWEN
- 1000 s and 3 s time window
- Method: same as O4 followup [10]
- Further:
    - binomial test for signal below threshold
    - subgroups, use signalness



Time series analysis

- To exploit faster variability
- Generic hypothesis to test:
  - GeV emission lasting Δt after unknown transient
  - 1 HESE event on its own time scale Δt_{HESE} (defines analysis window)

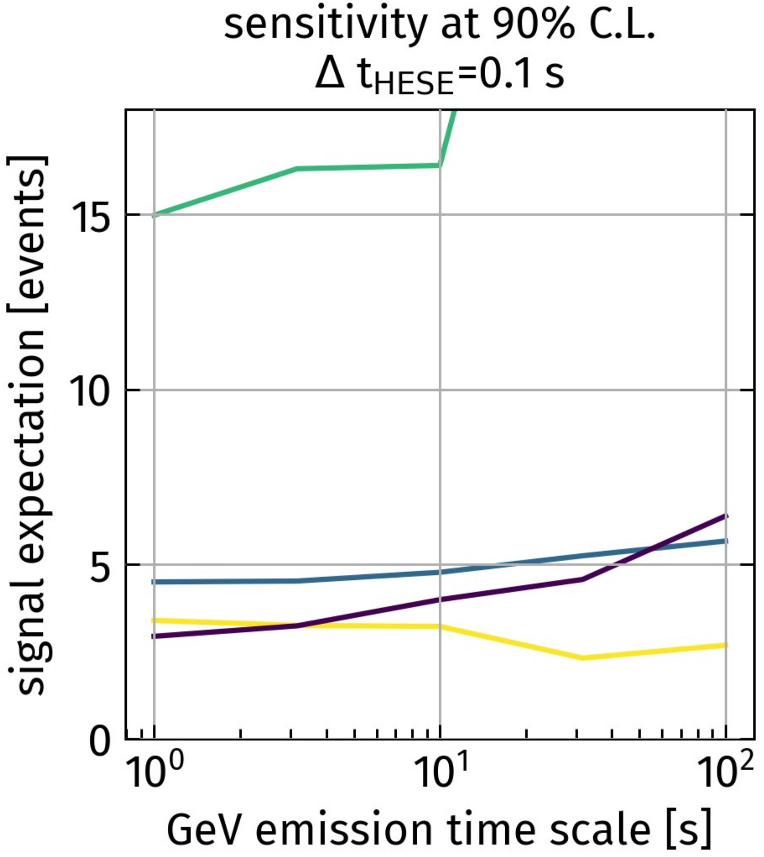
    → combined: random relative signal times $(t - t_{HESE})$

    + 20 mHz background
- Methods developed by my colleagues:
  - de Wasseige (2021) doi:10.1088/1748-0221/16/12/C12012
  - Lamoureux & De Wasseige (2023) doi:10.22323/1.444.1507
    (which also a contains a comparison)

Performance comparison

- Likelihood: most consistent
- PeANuTS: better until 100 seconds
- PCA: depends on hypothesis, less flexible to offset

— extended unbinned ML with gaussian p.d.f.
— PCA classifier, trained on 100-second emission
— PCA classifer, trained on 10-second bursts
— PeANuTS



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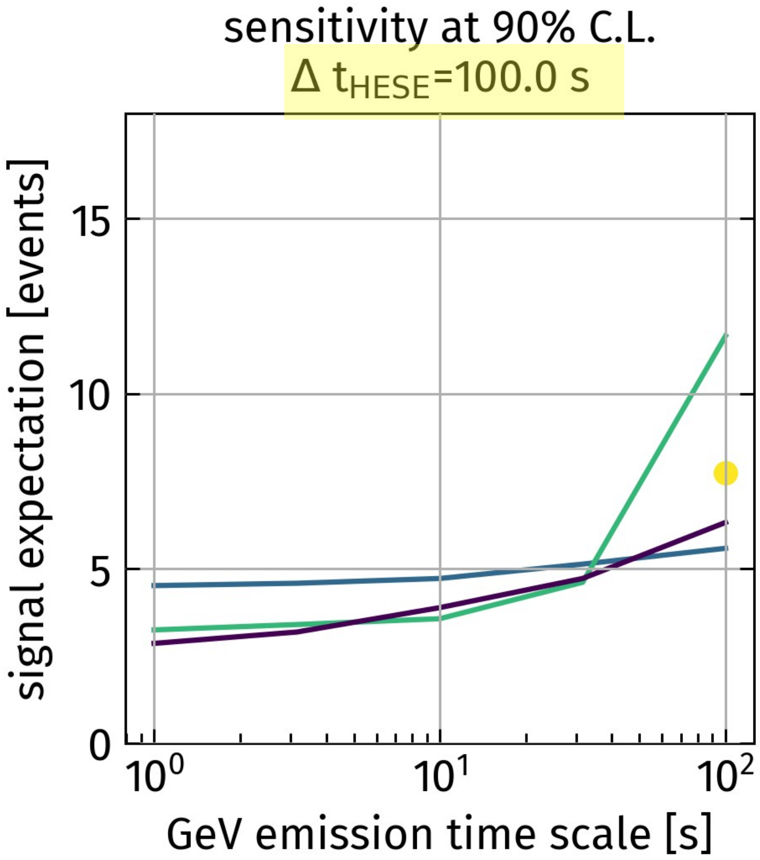

BACKUP

References

[1] Vandenbroucke et al. (2021) doi:10.22323/1.358.1026

[2] Nakar (2015) doi:10.1088/0004-637X/807/2/172

[3] Senno et al. (2016) doi:10.1103/PhysRevD.93.083003

[4] Carpio et al. (2023) doi:10.48550/arXiv.2310.16823

[5] IceCube Collaboration (2021) doi:10.1103/PhysRevD.103.102001

[6] IceCube (2023) doi:10.3847/2041-8213/acc077

[7] IceCube Collaboration (2021) doi:10.1103/PhysRevD.104.022002

[8] Abbasi et al. (2023) doi:10.3847/2041-8213/acc077

[9] Method: IceCube/MAGIC/Veritas (2016) doi:10.1088/1748-0221/11/11/P11009

[10] Method: Kruiswijk et al. (2023) doi:10.48550/arXiv.2307.15902

[11] Method: de Wasseige (2021) doi:10.1088/1748-0221/16/12/C12012

[12] Method/code: Lamoureux & De Wasseige (2023) doi:10.22323/1.444.1507

[13] Pizzuto et al. (2022) doi:10.22323/1.395.0952

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