Lowering Energy Threshold for GRAND/BEACON

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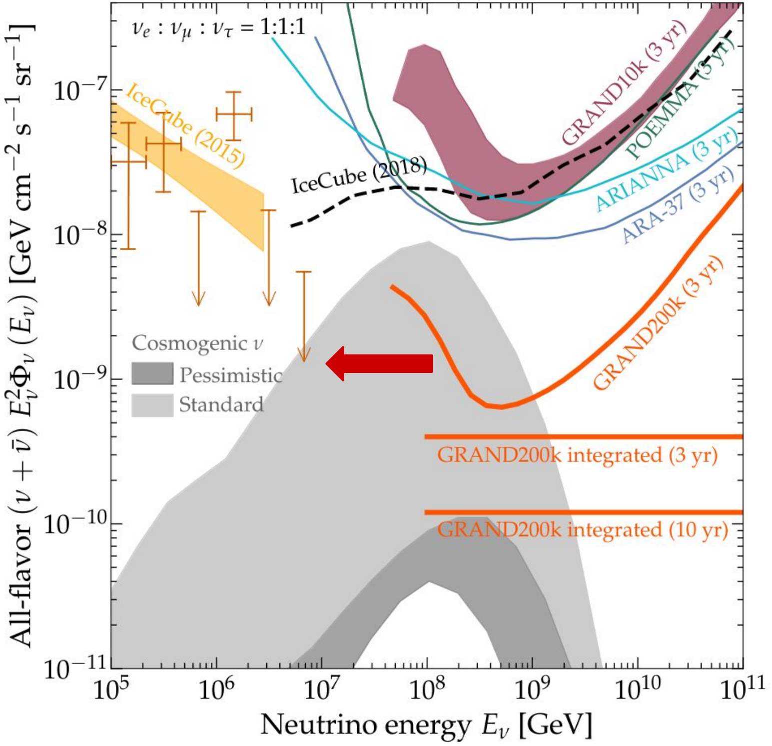
Motivation For Decreasing Energy Threshold

- More events!
- Bridge the gap towards IceCube Optical Measurements
  - GRAND threshold ~100PeV compared to IceCube upper bound ~10PeV
- Large uncertainties for Eν > 100PeV
  - Tau energy: ~10 from neutrino propagation
  - Shower energy: ~2 from decay distribution

- We should do this without completely sacrificing UHECR statistics above 10EeV



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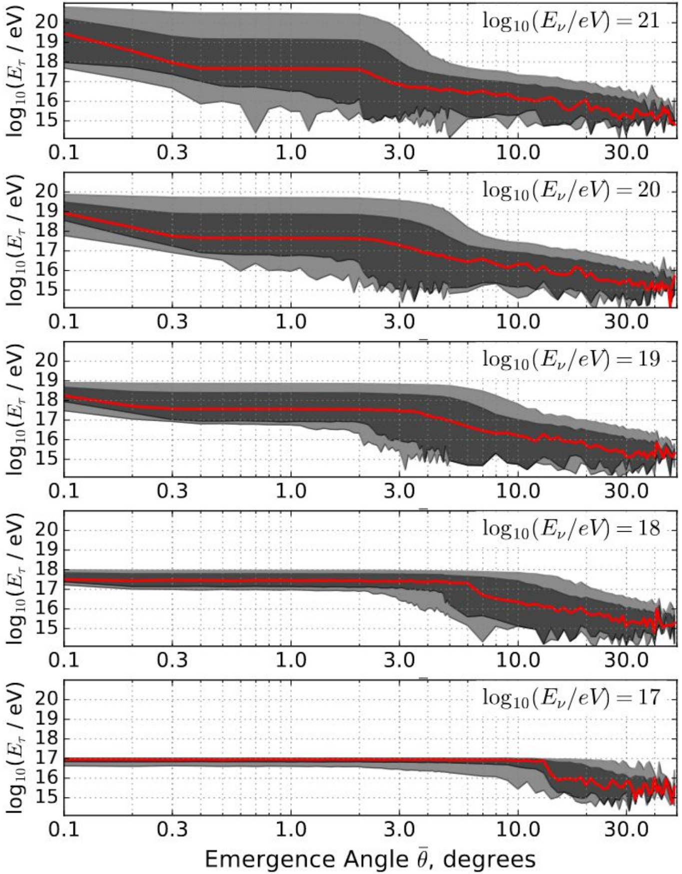

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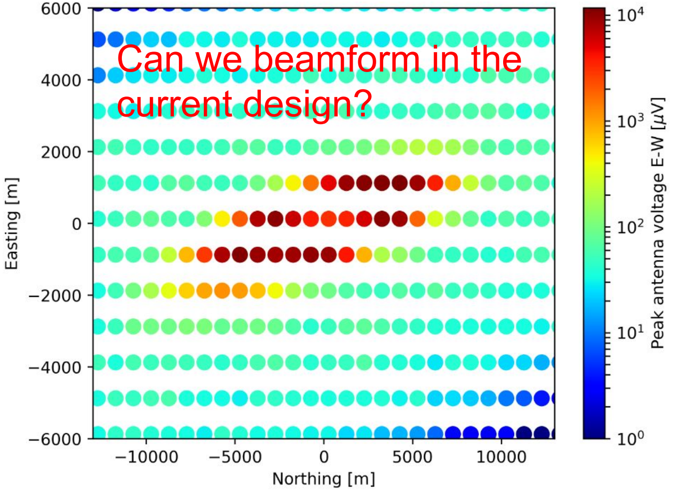
Antenna Phasing/Beamforming



E = 10EeV, θ = 80°

- Pros of phasing:
  - SNR increased by √N, the number of phased antennas
  - Improved directional reconstruction
  - Exclusion of noisy regions
- Cons of phasing:
  - With a set number of antennas, smaller overall footprint
  - Missing Cherenkov pattern
- Minimum number of antennas for phasing?
  - Antennas spaced by ~1km, view same portion of the shower only for very horizontal events
  - 3 antennas lowers threshold by factor 1.7, and allows for directional reconstruction
    - Improves reconstructions for UHECR with zenith angles < 70°
  - Diminishing returns for N > 10
  - Include phasing infills sporadically throughout the array, instead of everywhere?
- Optimal positioning of phased antennas?

Array Layout Suggestion

- Designate fraction of total antennas to be phased in infill arrays (15%?)
  - Minimally changes UHECR sensitivity
- Optimal locations for phased arrays targeting E_ν < 100PeV:
  - Upgoing ν:
    - Altitudes around 2km provide increased exposure
  - Downgoing ν (for certain topographies):
    - Tau decay length < 5km: nearby mountains maximize intensity
    - Near ground?
  - Radio quiet (duh)
- Antarctic Mountain?
  - Askaryan emission possible? Removes Earth emergence probability factor, and opens all 3 flavors

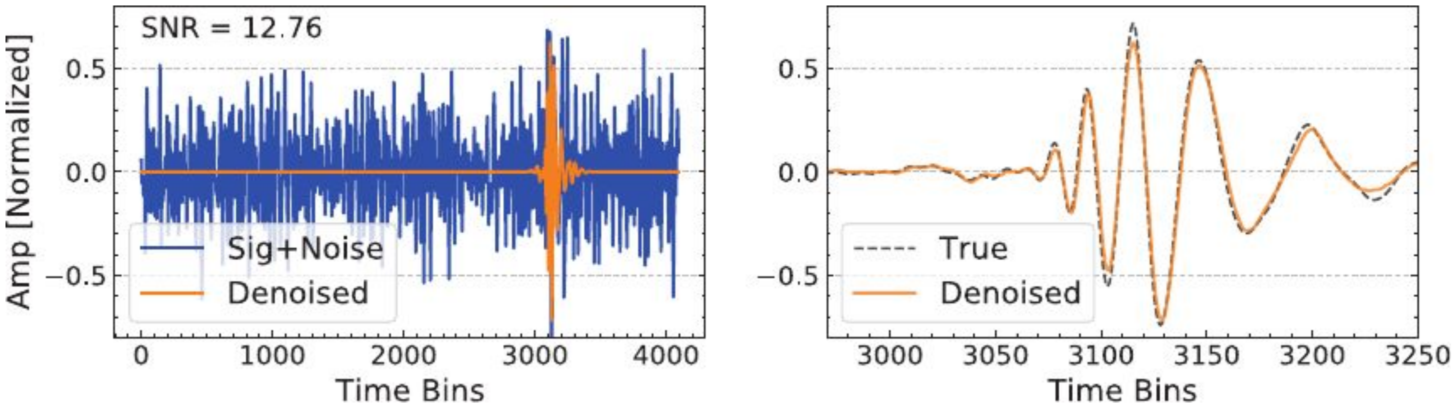
Trigger conditions

At fixed shower energy

- SNR criteria → depends on local conditions but ultimately bound to galactic or thermal noise → noise mitigations
- Other criteria → impulsivity, polarisation, etc.
- Sub-threshold analysis → template fitting / ML (online or not ?)

Denoising/ML?

- Trained with simulations (COREAS/ZHAireS), real background, and external triggers
  - Early training can guide minimal energy
  - Scintillator station for verification?
- In a prototype station with 3 antennas co-located with IceTop, 3X more events
  - Beamforming less necessary?



Example of denoising of a radio pulse with neural networks. An air-shower radio pulse simulated by CoREAS with noise is identified and reconstructed using a CNN
A. Rehman, A. Coleman, F. G. Schr ̈oder, and D. Kostunin, "Classification and Denoising of Cosmic-Ray Radio Signals using Deep Learning," PoS, vol. ICRC2021, p. 417, 2021.