The Askaryan Radio Array:
Overview and Recent Results

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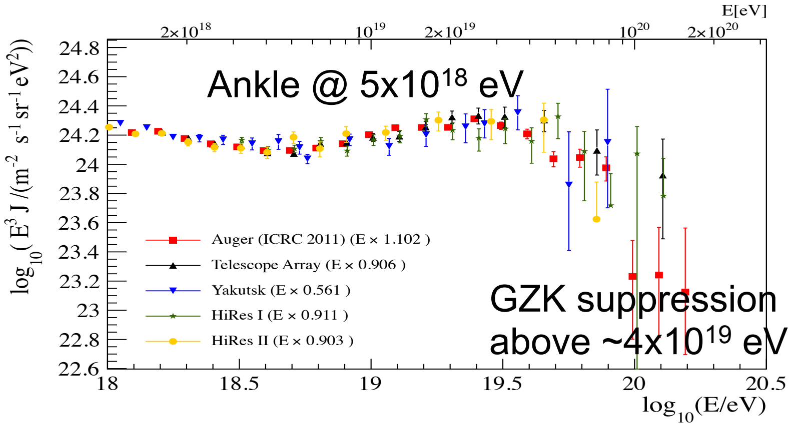
UHE Neutrinos

- Ultrahigh energy (UHE) neutrinos
  - $E > 10^{18}$ eV
  - Only UHE particle probes at cosmological distances – no horizon!
- Greisen-Zatsepin-Kuzmin (GZK): Cosmic rays with $E > 10^{19.5}$ eV + CMB → BZ neutrinos, some at UHE
- Also expect UHE neutrinos produced at sources
- Low flux at Earth
- Large volume needed!



Proceedings of UHECR 2012

$$\mathbf{p} + \gamma_{\mathrm{CMB}} \rightarrow \mathbf{\Delta}^* \rightarrow \mathbf{n} + \pi^+$$

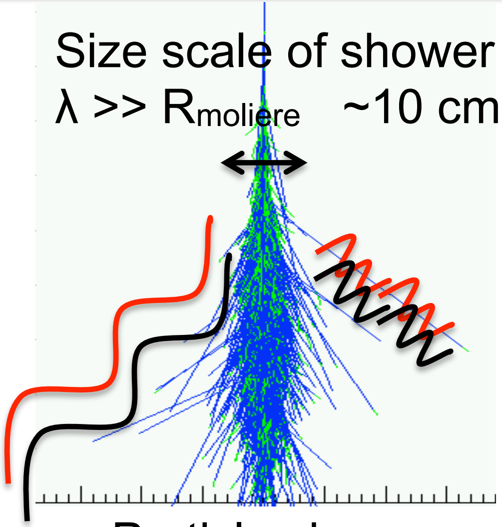
$$\mathbf{n} \rightarrow \mathbf{p} + \mathbf{e}^- + \bar{\nu}_{\mathbf{e}}$$

$$\pi^+ \rightarrow \mu^+ \nu_\mu$$

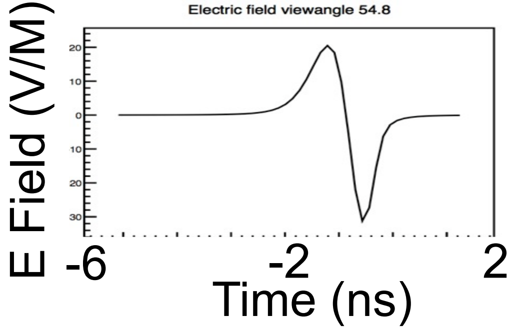
$$\mu^+ \rightarrow \mathbf{e}^+ \bar{\nu}_\mu \nu_{\mathbf{e}}$$

Radio Detection

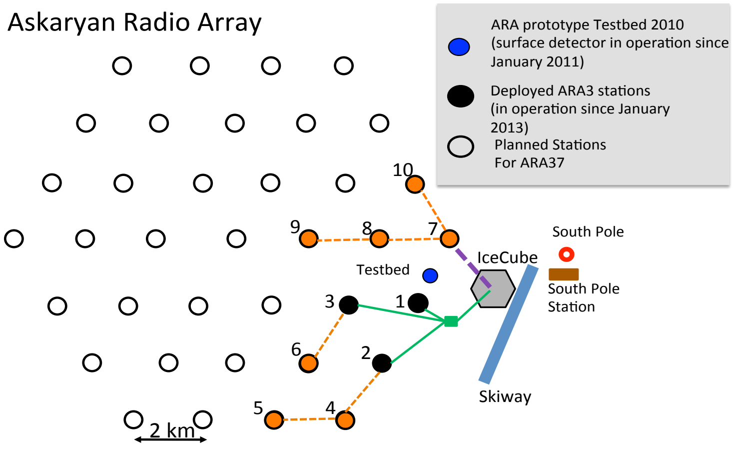
- Detection of rare signals -
  1. Make 100X IceCube (or…)
  2. Radio Cherenkov technique
- Coherent signal from net ~20% charge asymmetry in shower
  - Gurgen Askaryan, 1962
  - Observed in ice, salt, sand, air
  - Impulsive bipolar signal
- South Pole ice: ~2.8 km thick, cold
- ~1 km radio attenuation lengths → large observable volume

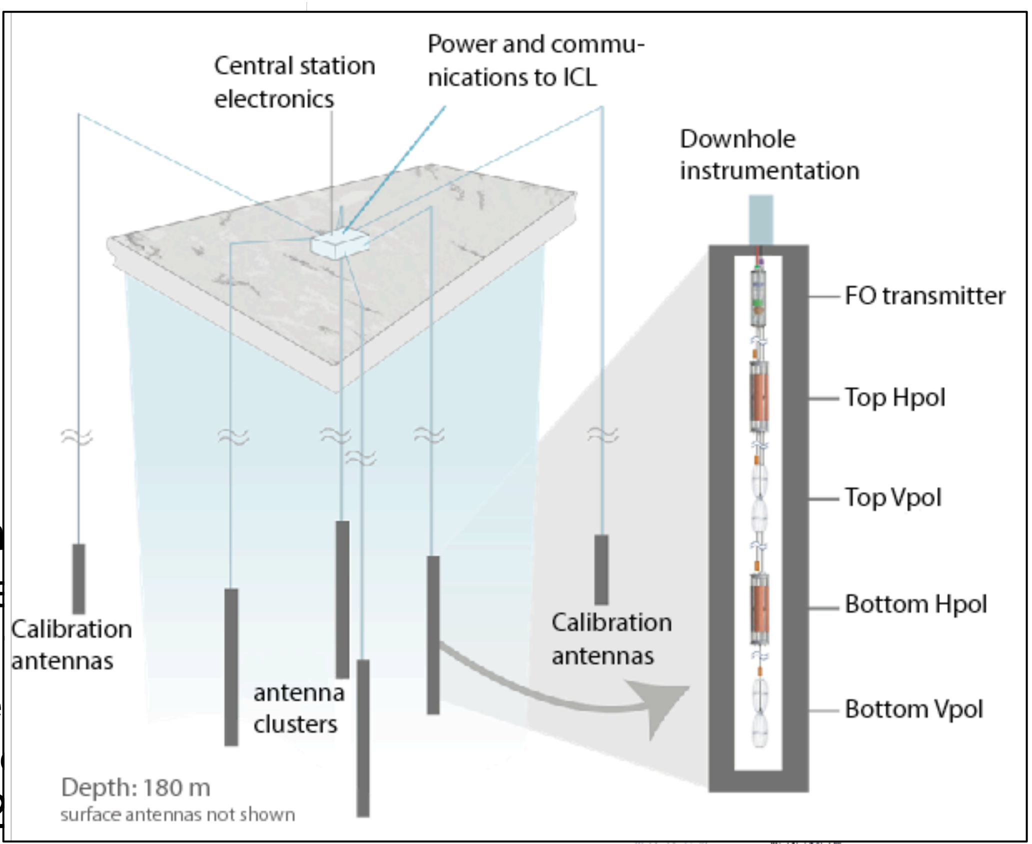


Particle shower



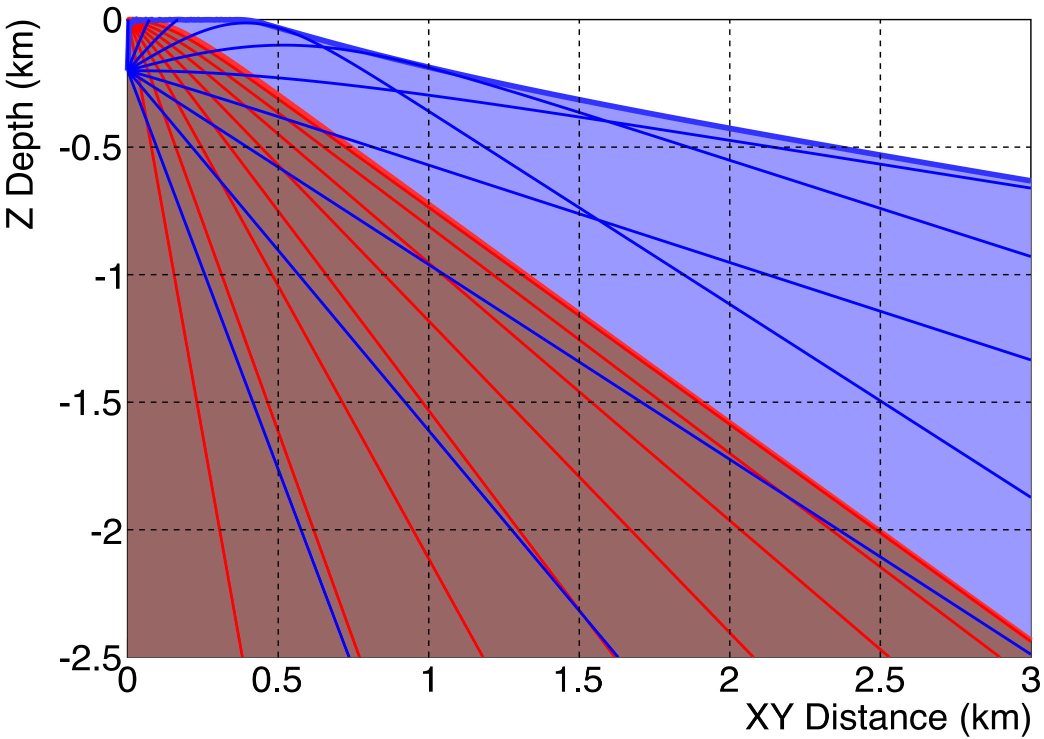
Askaryan Radio Array (ARA)





- Deploy RF stations in ~100 km^2 a
- Currently: 3 stations + 1 prototype
- Full plans: 37 stations viewing O(
- Can reach the low flux of UHE ne
  - $E^2 dN/dE < 10^{-8}$ GeV/cm^2/s/sr abov
- International collaboration with 12

Deep Deployment



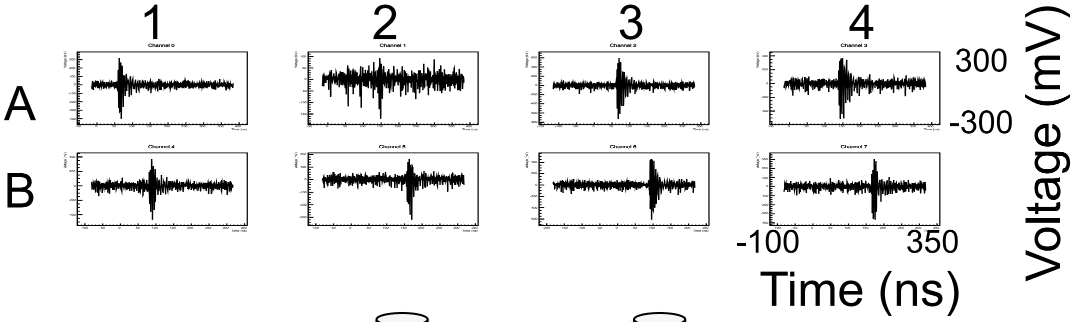
- Important to put stations deep in the ice
- "Firn" – changing n(z)
  - top ~150 m of ice
- Causes curvature in paths of rays in ice
- Greater depth → increased viewable volume and observable neutrino incident angles

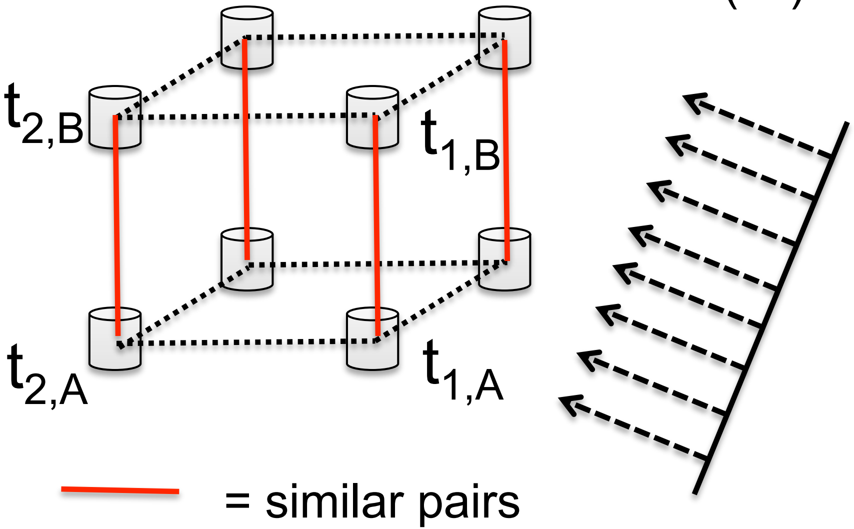
Viewable volume:
Red – station @ 30 m
Blue – station @ 200 m

Effective volume increases by factor of 3.2

Data Filtering

- Radio - thermal background, anthropogenic signals, neutrino signals
- Important to construct efficient, simple filters
- Interferometry = computationally complex
- Deep stations have regular geometry
- Assume plane-wave geometry
- Filter >99% of noise before reconstruction



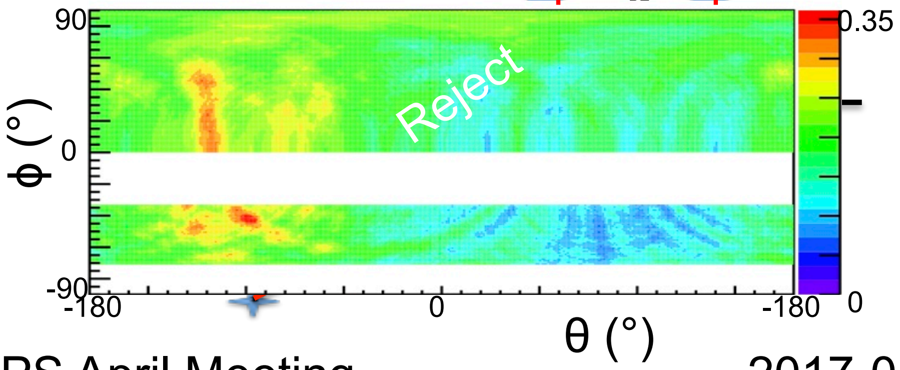


Reconstruction

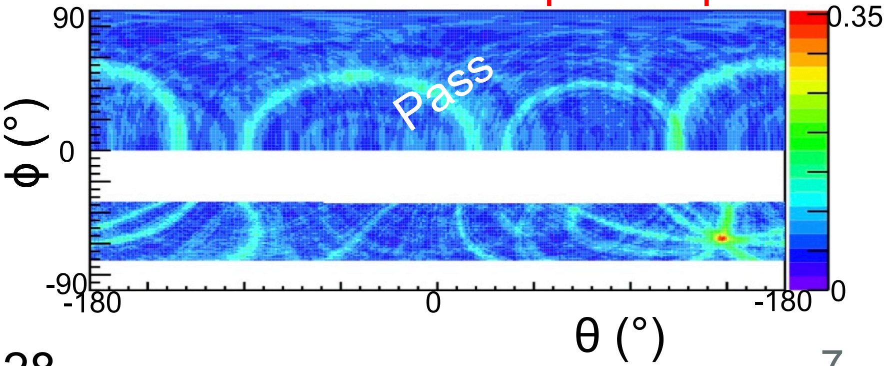
- Event position = important – provides energy, neutrino direction
- Use interferometry: signal arrives at antennas at different times
- Time delays between pairs of antennas → direction
- Strength/qualities the peak on the map → event type (noise vs signal)
- Anthropogenic noise rejected by position – neutrinos don't repeat

$$\Delta t \approx \frac{(d_2 - d_1)n}{c}$$

Known background event reconstruction map example

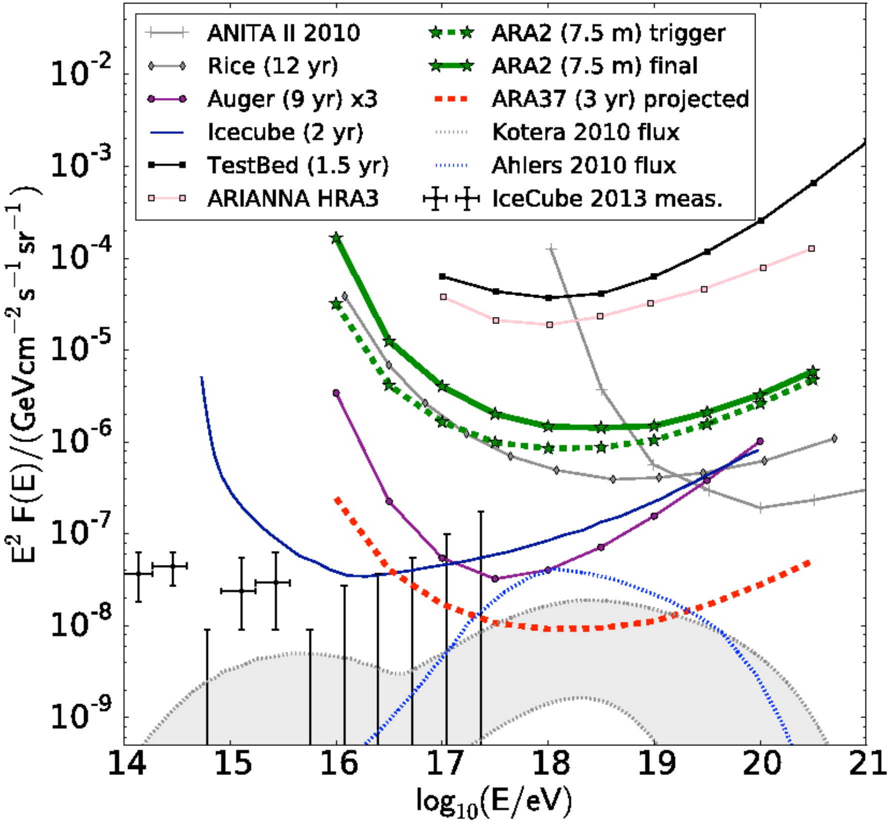


Simulated ν event reconstruction map example



Diffuse Searches

- Performed 2 searches for diffuse flux of neutrinos
  - Prototype station, 2 years
  - 2 deep stations, 1 year
- No candidates
- Deep station search improved limit over prototype result
  - Efficiency
  - Effective volume
- Projections: full ARA-37 array will be sensitive to GZK flux models



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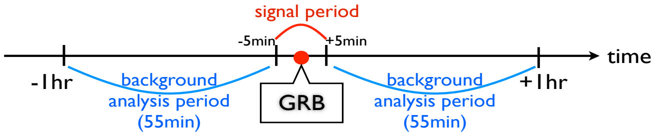
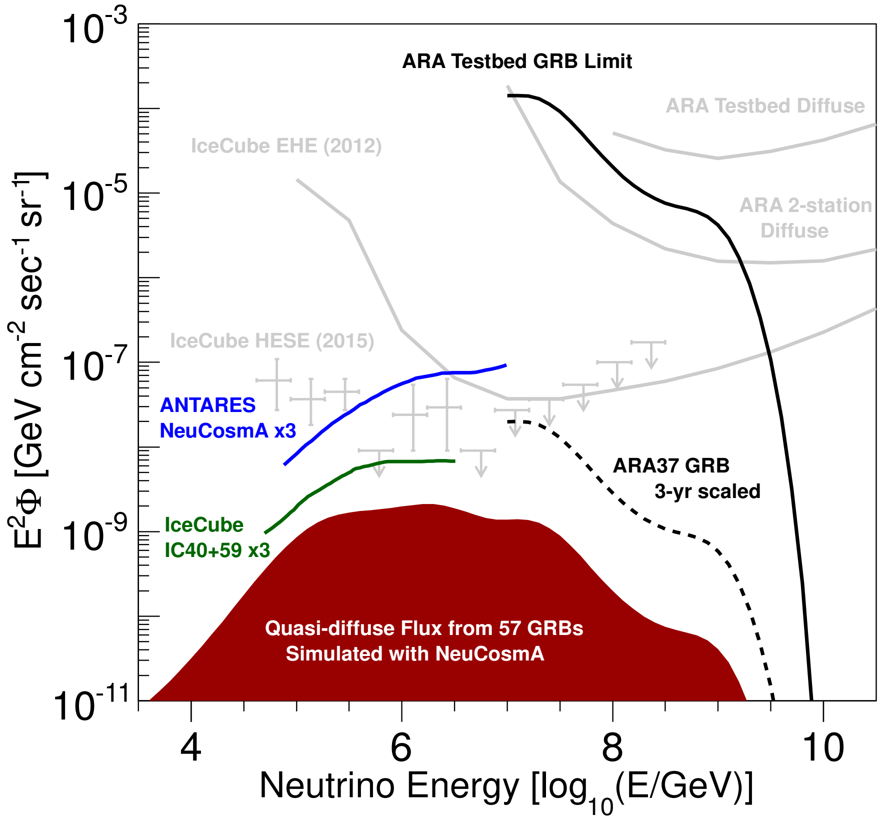
GRB Search

- Search for neutrinos coincident with Gamma-Ray Bursts (GRBs)
- 2 years of prototype station data
- First targeted search with ARA
- Tightened constraints on timing → relaxation of threshold



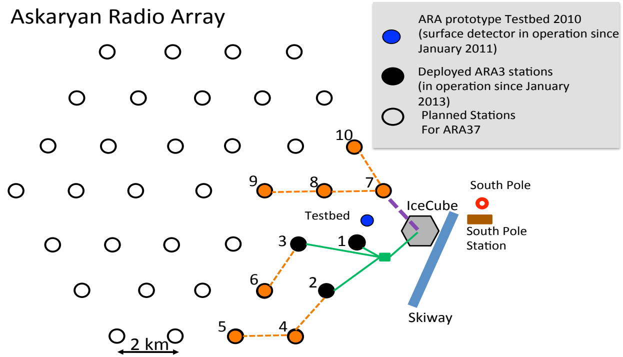
  - 2.4X improvement in sensitivity
- First quasi-diffuse flux limit above 10^{16} eV
- Additional improvements expected:
  - Trigger, analysis techniques

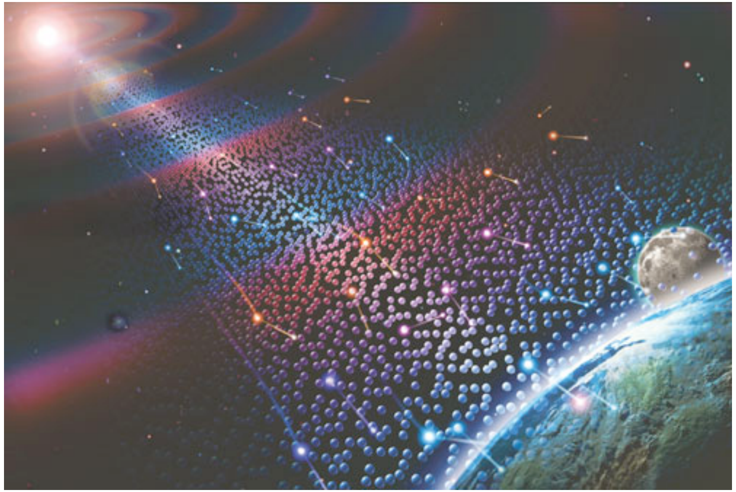


Astropart. Phys. 88 (2017) 7-16

Conclusions

- ARA is a radio-based UHE neutrino detector being built at the South Pole
- Deployment of 3 stations approved for next austral summer (2017-2018)
- 3 neutrino searches completed
  - 2 diffuse (prototype, 2-station)
  - 1 GRB (prototype)
- Further analyses in progress
- Expect the first detection of UHE neutrinos in the coming years!





Source: Jovian Archive

Questions?

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