Towards Improving the Analysis Efficiency of the Askaryan Radio Array (ARA)

Kaeli Hughes, on behalf of the ARA Collaboration

By taking advantage of improved pointing resolution and a phased array trigger, we are designing an analysis with improved signal efficiency at low SNR.

ARA STATION LAYOUT

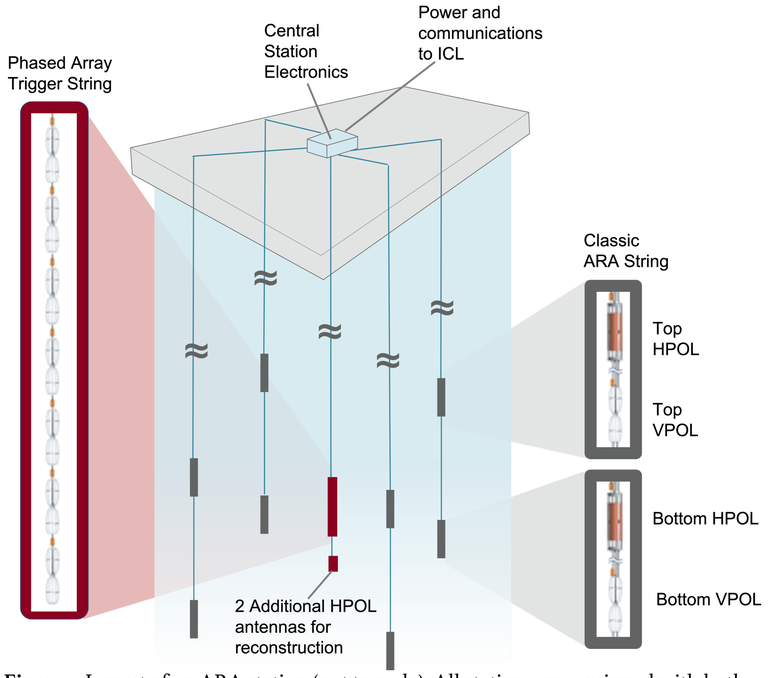

Figure 1: Layout of an ARA station (not to scale). All stations are equipped with both vertically and horizontally polarized antennas. The ARA5 station is additionally equipped with a phased array trigger string, highlighted in red above.

COMPARING TRIGGER AND ANALYSIS EFFICIENCIES

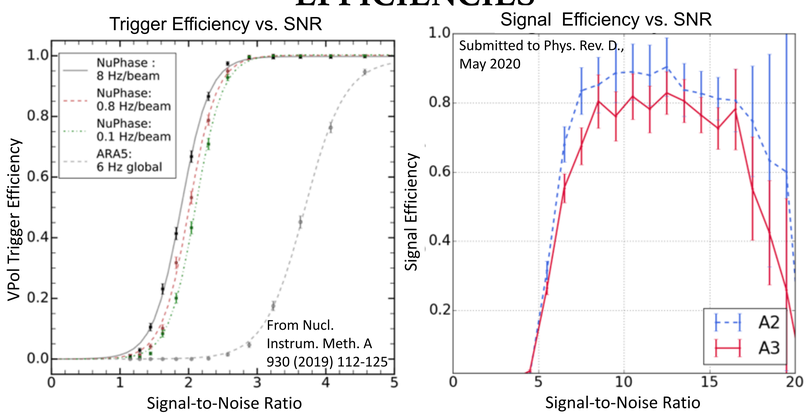

Figure 2: Left: *in situ* measurement of trigger efficiency vs. SNR for the ARA5 station using calibration pulses. Right: most recent analysis efficiency for the ARA2 and ARA3 stations. Our current challenge is to improve the analysis efficiency at low SNR and take advantage of the low SNR triggers.

ABOUT ARA

- Designed to detect radio emission from ultra-high-energy cosmic neutrino interactions in Antarctic ice
- Sensitive in 200-850 MHz range
- Consists of 5 independent stations (see Fig. 1); the newest station (ARA5) includes a phased array trigger design

PHASED ARRAY TRIGGER

- A string of compact antennas, deployed in the center of the ARA5 strings, that phase signals together in beams prior to triggering
- Antennas have nearly identical impedances and impulse responses
- More sensitive to events with a lower signal-to-noise ratio (SNR) (see Fig. 2)
- Big question: can this improved trigger efficiency be matched in analysis?

CURRENT STATUS

- Phased array trigger has updated ADC digitizer boards that are stable and automatically calibrated
- Careful calibration has improved pointing resolution by factor of 10 compared to previous ARA calibrations (see Figs. 3 and 4)

FUTURE PLANS

- Designing cuts utilizing best features of phased array
- Low SNR local calibration pulser study shows optimistic results

POINTING RESOLUTION IMPROVEMENTS

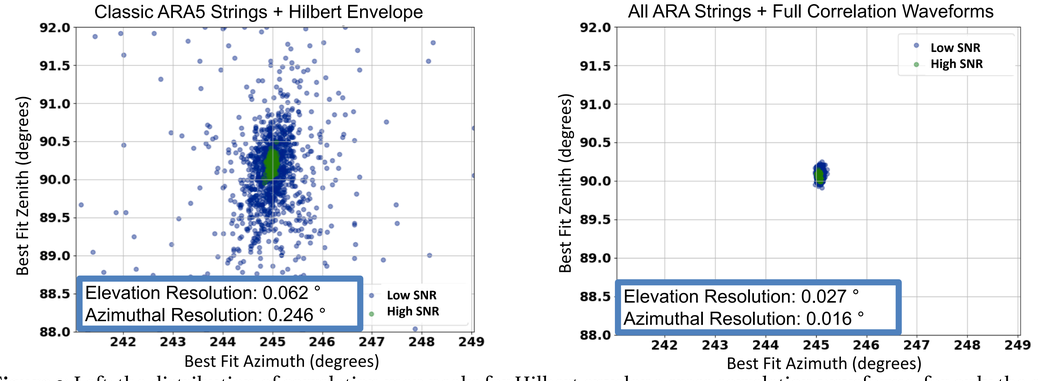

Figure 3: Left: the distribution of correlation map peaks for Hilbert envelope cross correlation waveforms, for only the classic ARA string antennas. Right: the distribution of peaks using full correlation waveforms and waveforms from all antennas. Here, "Low SNR" refers to an SNR of ~3, while "High SNR" refers to an SNR above 7. Previous ARA resolution was 0.5 °.

A CLOSER LOOK AT LOW SNR PULSES

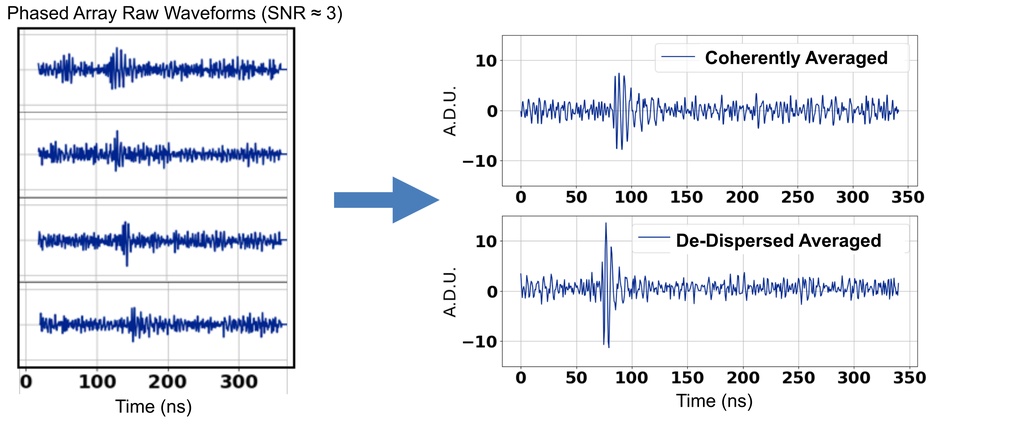

Figure 4: An example low SNR local calibration pulser as seen by the phased array trigger antennas. That signal can then be coherently summed as-is, or the filter response can first be removed, creating a de-dispersed waveform.

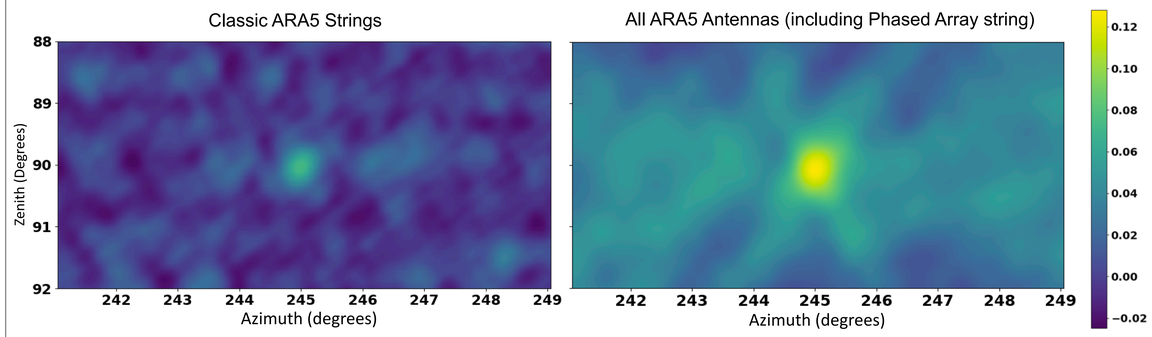

Figure 5: The same low SNR calibration pulser event, as it reconstructs for only the antennas on the classic ARA strings (left) and for all antennas including the phased array trigger antennas (right).

The Department of Physics, Enrico Fermi Institute, Kavli Institute for Cosmological Physics, University of Chicago

kahughes@uchicago.edu