COLLEGE OF ARTS AND SCIENCES - DEPARTMENT OF PHYSICS

THE OHIO STATE UNIVERSITY

The Askaryan Radio Array: Hardware and Modelling

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Acknowledgements

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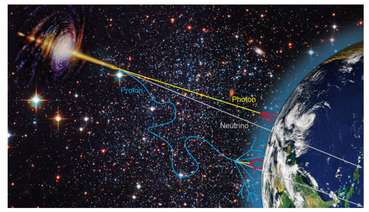
Detecting Ultra-High-Energy (UHE) Neutrinos

Why Neutrinos?

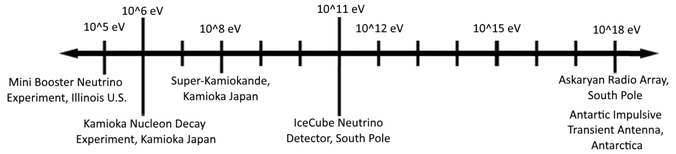
- Probe energies greater than 100 times the Large Hadron Collider
- Travel cosmic distances above 100 Mpc
- Light-like travel due to no charge and a low interaction rate



http://sites.psu.edu/amon/wp-content/uploads/sites/22842/2016/01/astro-web-titel.jpg

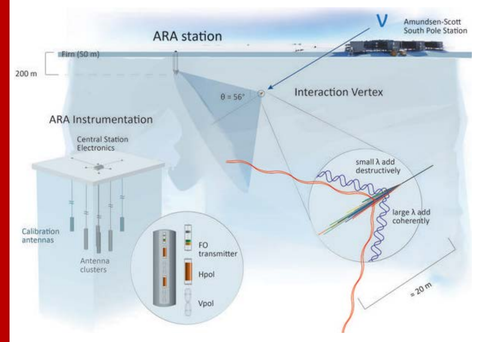
Neutrino Detection Experiments

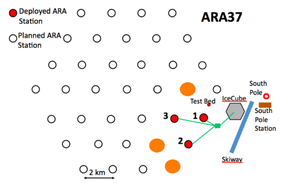
In the past decade, many neutrino detectors have been built with varying energy bandwidths:



Askaryan Radio Array (ARA)

- Neutrino-ice collision creates a shower of particles that emit broadband Cherenkov radiation through the Askaryan effect
- Deploys 16 antennas 200m deep in the ice (Hpol and Vpol)
- 6 stations by 2018, a planned total of ~37 stations





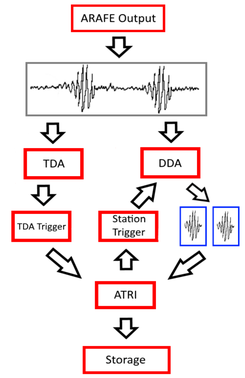
Full ARA37 covers ~100km^2
Most cost-effective for determining cosmic neutrino flux > 10^{17}eV

New stations 2017-18

https://ara.wipac.wisc.edu/home

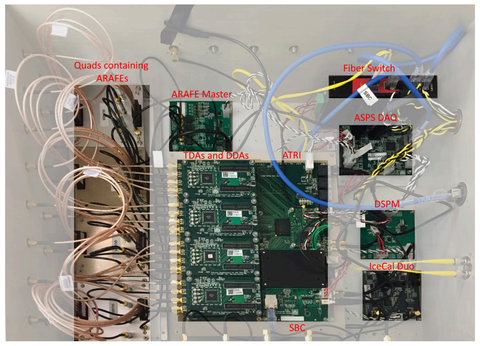
ARA Data Acquisition Box (DAQ Box)

1. Continuous analog signal from antennas enter the ARA Front End (ARAFE)
2. ARAFE filters and amplifies the signal
3. Sends signal to the Digitizing Daughter board (DDA)
4. Also sends signal through the tunnel diodes and into the Triggering Daughter board (TDA)
5. TDA issues the TDA trigger to the ATRI board when signal power passes a threshold
6. If three antennas of the same polarization send TDA trigger in 120 ns, ATRI board tells DDAs to digitize the signal
7. DDAs send signal data back to the ATRI board and into storage.



Contents

- 16 Tunnel Diodes
- 4 Triggering Daughter Boards (TDA)
- 4 Digitizing Daughter Boards (DDA)
- 4 Quads containing ARA Front Ends (ARAFE)
- ARA Triggering and Readout Board (ATRI)
- Single Board Computer (SBC)
- GPS
- Fiber Switch
- DAQ Stack Power Module (DSPM)
- ARA Smart Power System (ASPS)



Building and Testing

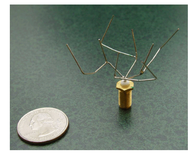
- Boards arrive as blank PCBs
- All components are soldered by hand
- Cables are made and modified as necessary
- Mounting plates are made and modified in the machine shop
- Boards are tested individually
- DAQ box is cabled up and tested along with the power box
- Box is sealed and tested in thermal chamber at -40° C

✓Soldering Components
✓Cable-making
✓Machine Shop Work
✓Hardware Assembly
✓and LOTS of Troubleshooting!

During my time, I made major contributions to building, testing, and fixing stations that will be deployed in the ice this coming season.

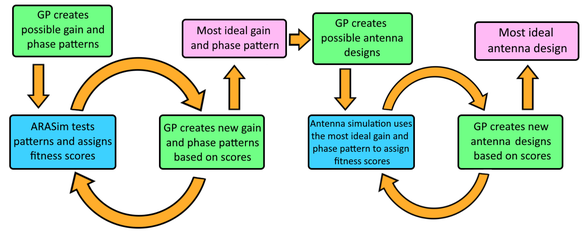
Antenna Creation using Genetic Programming (GP)

- NASA designed this antenna in 2006 for the Space Technology 5 Mission [1].
- Antenna shape determined by genetic algorithm



The Goal

- By Improving antenna sensitivity, we can increase neutrino detection efficiency
- Genetic programming may help us create such an antenna.

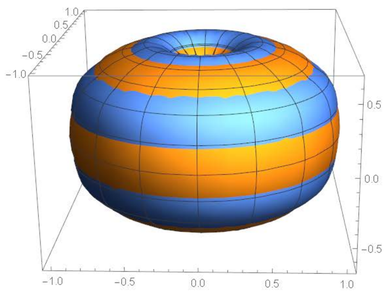


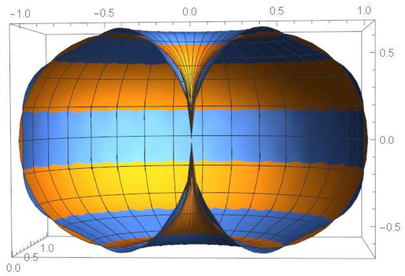
Antenna Simulation using Spherical Harmonics

- Convenient to package information in coefficients that GP software can adjust
- Spherical harmonics are ideal: the full set in linear combinations span all 2d surfaces
- My goal was to fit the gain and phase pattern of our current antenna

1. Took excel data that had a gain and phase for 2664 directions, in phi and theta.
2. Created C++ script to format data into a Mathematica-friendly format
3. Interpolated data into a function to allow for plotting
4. Confirmed that spherical harmonics with non-zero m values did not sufficiently affect model (so rotational symmetry)
5. Mathematica "FindFit" function chose coefficients for the spherical harmonics
6. Computed the Chi^2 to quantify the agreement between model and data

https://inspirehep.net/record/900207/files/Antennas.png





Freq: 83.33 MHz Orange = Gain Data Blue = L 0-8 Model Chi^2: 35.42

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Achieving in Science through Physics Instrumentation, Research and Exploration

- Workshop to introduce high school women to STEM fields, including physics
- Supported by NSF, coordinated by Prof. Connolly's group
- 5 days from 9 am to 5 pm, approximately twice a year
- Draws young minds to physics, provides an idea of what our group does, provides a tour of OSU, and supplies students with future projects

This year was my first time volunteering. I ran the Antenna Pulser experiment along with Dr. Allison and two other undergraduates.

Future Goals

- The ARA 6 DAQ box will have its parts finished, mounted, cabled, and tested before being sent to the University of Wisconsin (one of our collaborators) for further testing
- Completed and tested stations will be deployed this winter (2017-2018)
- The rest of the antenna frequencies will have their gain and phase fitted to test Spherical Harmonic fitting effectiveness
- The optimal gain and phase pattern will be found using spherical harmonic fitting before evolving the optimal antenna shape
- Detect UHE astrophysical neutrinos!

Sources

1. Lohn, J. D., Hornby, G. S., & Linden, D. S. (2005). In *Genetic Programming Theory and Practice II* (pp. 301-315). Pg. 11. Springer US.