

Neutrino Vertex Reconstruction in ARA02

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March 24, 2023



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The Askaryan Radio Array (ARA)

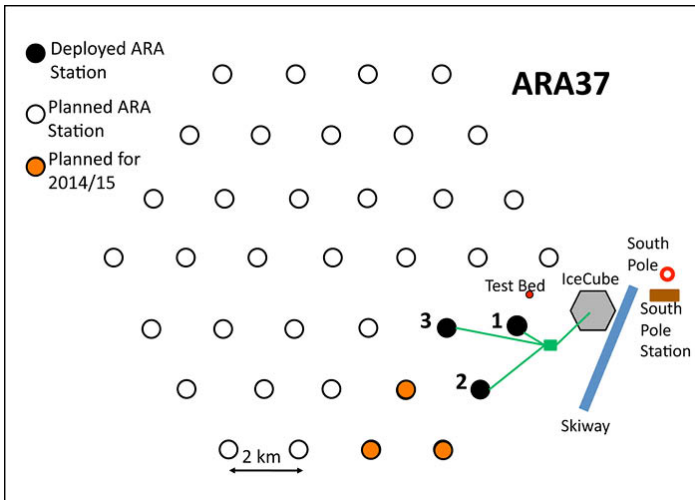


Figure: source:<https://ara.wipac.wisc.edu/home>

A Station of ARA

- 1 Energy:
 $> 10^{16.5} eV$
- 2 Location:
South pole
- 3 status:
5-st installed
38-planned
- 4 deployment:
started 2011

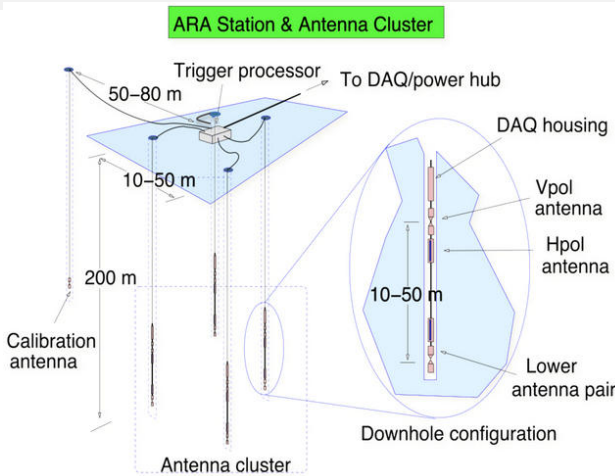
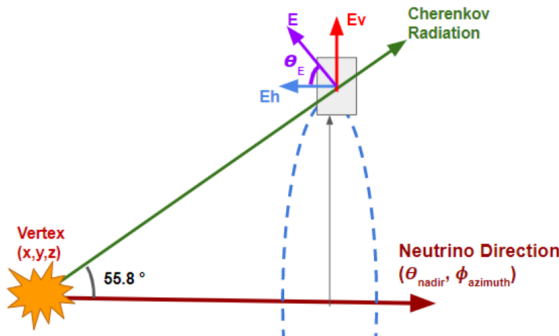


Figure: source:<https://ara.wipac.wisc.edu/home>

Neutrino Interaction

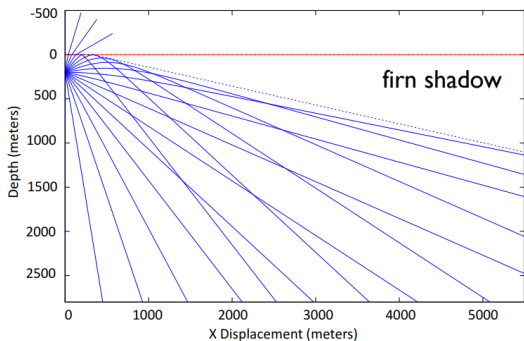
- 1 Neutrino interaction with ice gives particle shower
- 2 particle shower in ice develops charge asymmetry
- 3 Time-varying charge produces coherent radio waves(Askaryan radiation)



Optics in South pole Ice

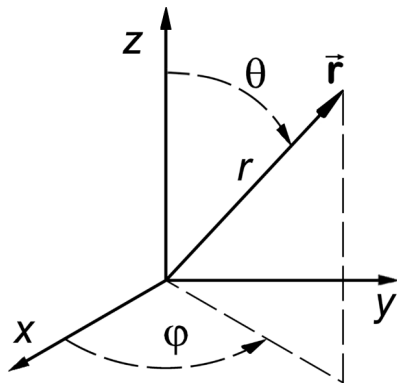
- 1) Multiple trajectories are followed: 1) D and R rays
2) horizontal and surface propagation
- 2) Different Snow models: index of ref is a function of depth

I am using
Arasim Ice
Model



ARA Coordinates

- 1 Center of the coordinates = center of the station (in ice)
- 2 Zenith Angle = measured from the vertical axis(parallel to the hole)
- 3 Azimuth Angle: measured with respect to x-axis (parallel to iceflow)
- 4 using spherical coord



Reconstruction via Interferometry

- 1 This method is using the D and R pulses and the relative hit times of channels to find the position of the source within the ice
- 2 Used ray tracing to find simulated hit times
- 3 Hit times from the data are calculated using the waveform of the channels
- 4 The two types of hit times are then used to calculate the Chi-squared values
- 5 The minimization of Chi-squared values is then used to obtain minima. It pinpoints the source
- 6 This method has been developed by Uziar

Reconstruction via AraVetex

- 1 This is using the time delays. It can work for a single ray too.
- 2 The time delays are calculated using the cross-correlation of the waveforms of the channels
- 3 It is comparing the delay times to locate the source
- 4 It is good for fast computation
- 5 It has been developed by Dave Besson and Brian Clack

Recons Results of Calpulsar Events

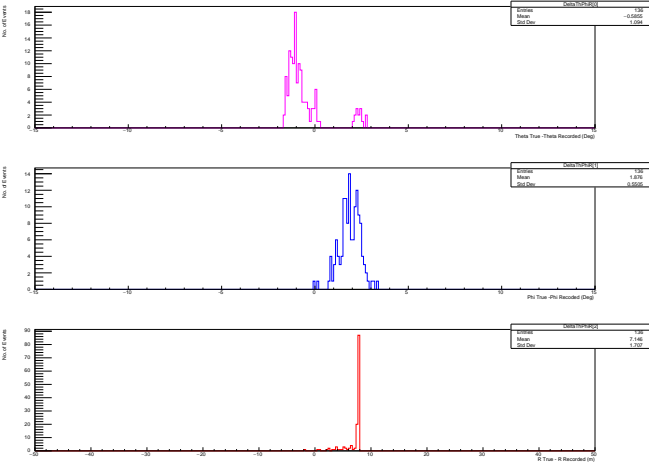


Figure: data from 2014: run1880

Conti...

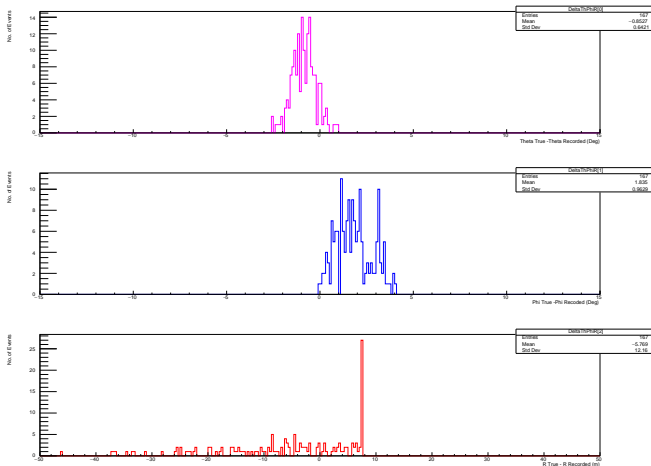
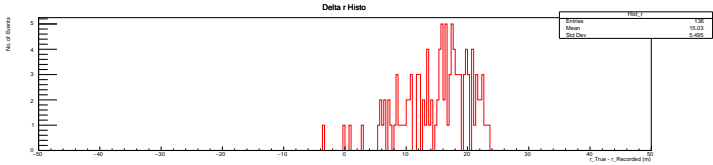
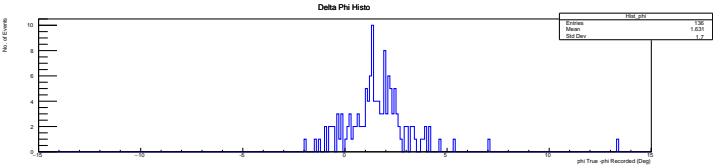
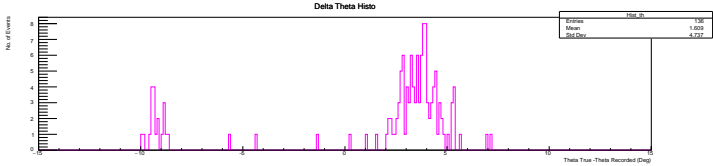
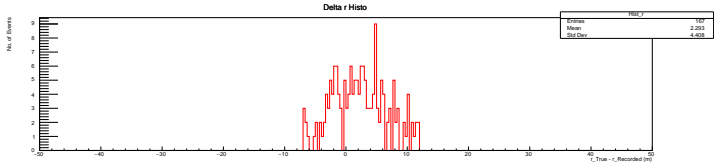
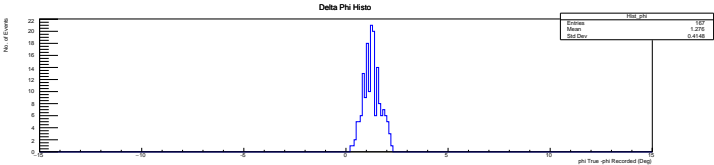
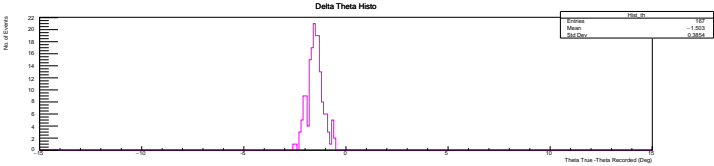


Figure: run1653

Recons Results Via AraVertex



Conti...



A tabular Comparison

Recons of Calpulser event: run1942 event40			
Coord	True Coord	via Interfero	via AraVx
Theta (Deg)	84.1472	85.73581714	86.0527
Phi (Deg)	65.1880	64.94077204	63.7810
r (m)	47.5119	61.1849	37.0097

- True coordinates of calpulser event have been obtained through AraRoot.

What is Next..?

- 1 I have been reconstructing the events in ARA01 (deployed in 2011, this is the shallowest station)
- 2 Applying the same methods for reconstruction
- 3 Have looked into the data of local cal pulsing antennas, but did not get success!
- 4 Currently, trying to get the results for SPICE events (600m-1100m depth) and the Rooftop pulsar (Installed on the top of the ICL). The results show a shift from the true directions suggesting a global rotation of around 20° .
- 5 Currently investigating this aspect to end up with a conclusion.

Summary

- 1 Both AraVertex and Interferometry are giving the direction reconstruction within a precision of a degree for ARA02.
- 2 The results also show a satisfactory calibration of ARA02
- 3 We have not yet reached a conclusion for ARA01.
- 4 Studying to figure out a possible global rotation of the station

References

- 1 <https://inspirehep.net/files/1bd3e45e56168c872ceae8d1e5f1cd7d>
- 2 <https://arxiv.org/pdf/1908.10689.pdf>
- 3 <https://arxiv.org/pdf/2202.07080.pdf>

Acknowledgement

- 1 Thanks to Dave for his support, encouragement, and his knowledge.
- 2 I am also thankful to Uzair, Alisa, Mohammad, and Kenny for their valuable discussions.
- 3 Thanks PALOOZA for providing us with a platform to share our understanding/knowledge.