Identifying Weak Cosmic Ray Signatures in Cascade-Like Events in IceCube.

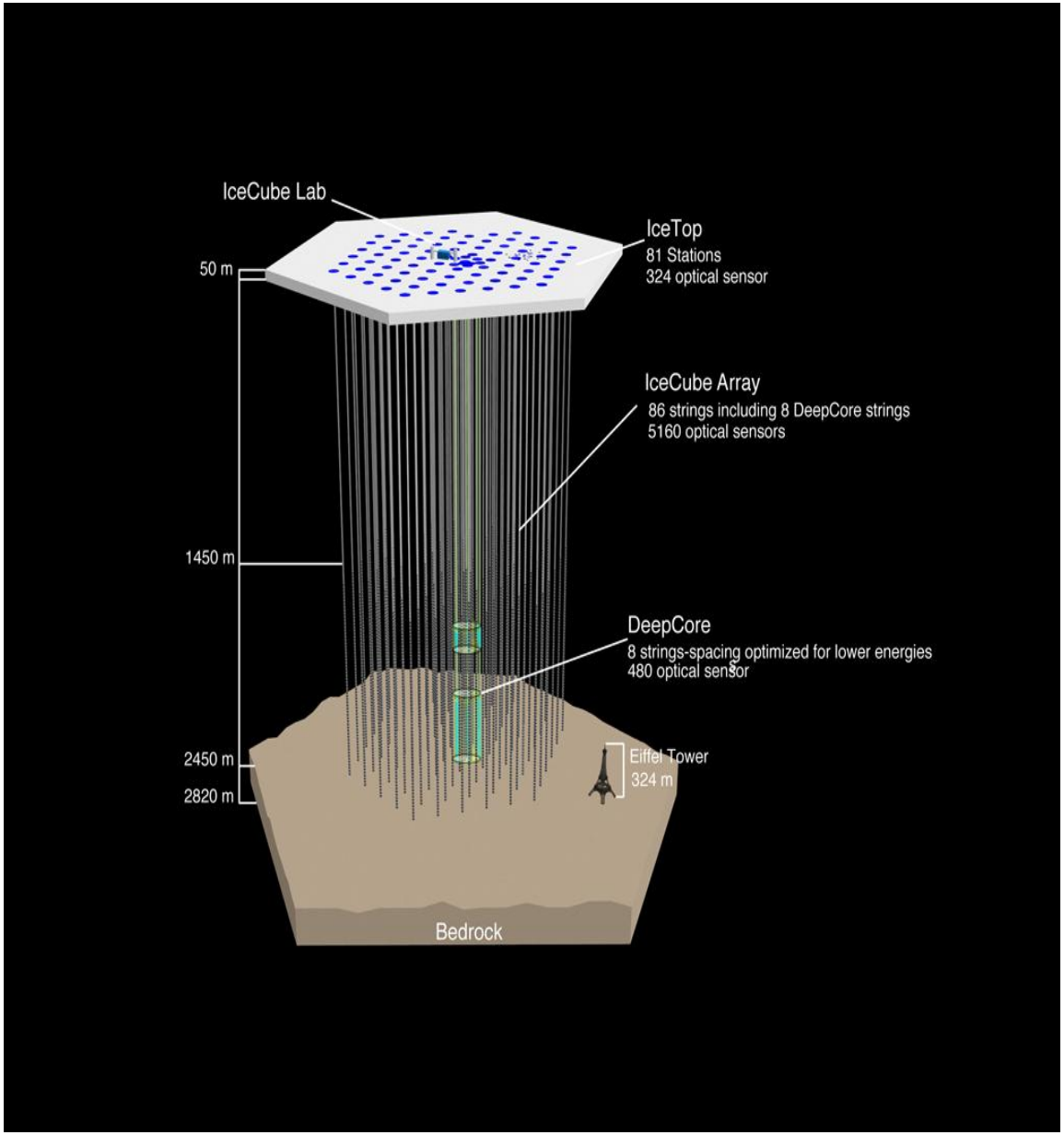
By Laura Wanjiru Mari.

University of Nairobi, Kenya.

Supervisor: Markus Ackermann.

THE ICECUBE DETECTOR

- Neutrino telescope , 1450 to 2450m in the Antarctic Ice
- 86 strings, each with 60 DOMs. 125m horizontal spacing, and 17m vertical
- High energy astrophysical neutrinos >100Gev.
- Low cross section of neutrino interactions; large volume.
- Deep Core section
- DOMs detect Cherenkov radiation

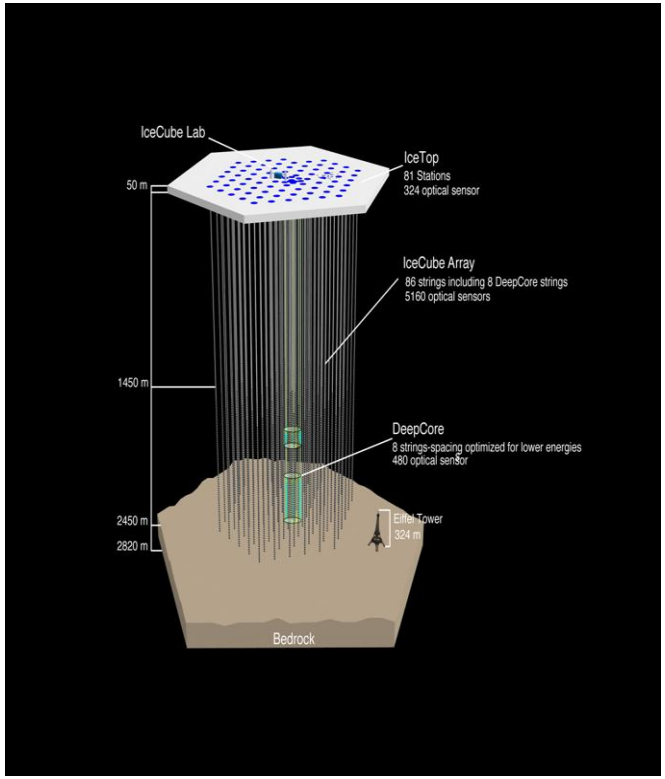


THE ICECUBE DETECTOR

- Neutrino telescope ,buried between 1450 to 2450 meters deep in the Antarctic Ice
- 86 strings, each with 60 DOMs. 125m horizontal spacing, and 17m vertical
- Sensitive to high energy astrophysical neutrinos >100Gev.
- Low cross-section of neutrino interaction hence large detector volume
- DOMs detect Cherenkov radiation emitted by secondary charged particles produced by neutrino interaction with the ice
- Deep Core section , sensitive to low energy neutrinos, where the DOMs are more closely spaced.

•Each DOM has a photomultiplier tube.

•The voltage drop over the resistor is the recorded signal.



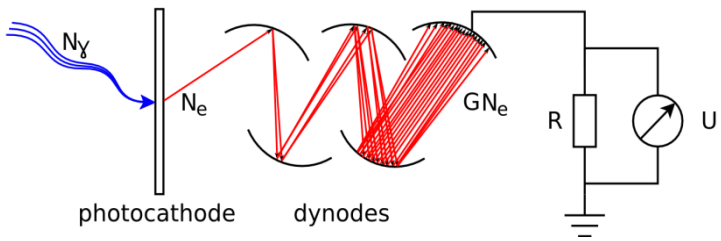
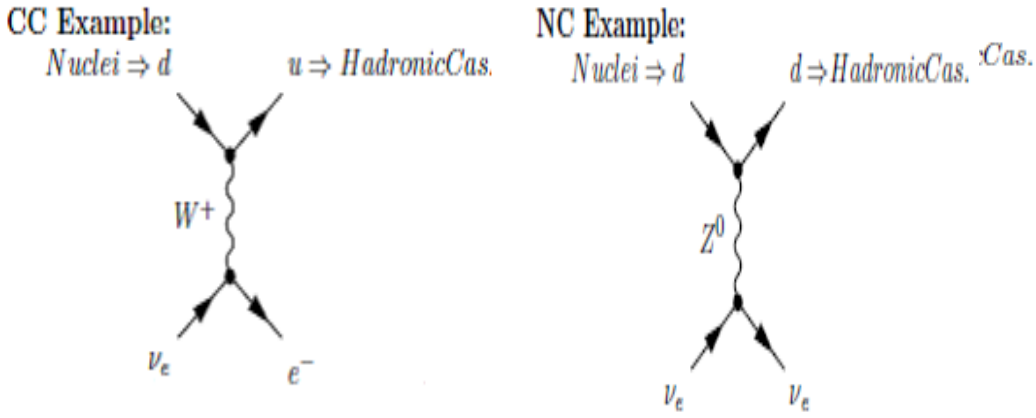


Photo-multiplier

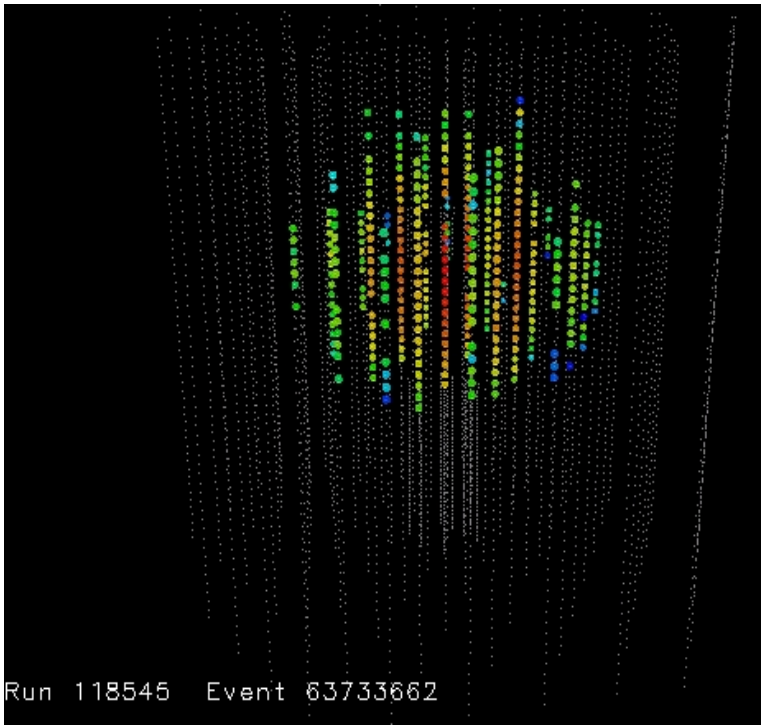
EVENT SIGNATURES

CASCADE-LIKE EVENTS



- Electron neutrino charged current; electromagnetic cascade
- Neutral Current produces hadronic cascade. Sensitive to all 3 neutrino flavors.
- Good energy resolution.

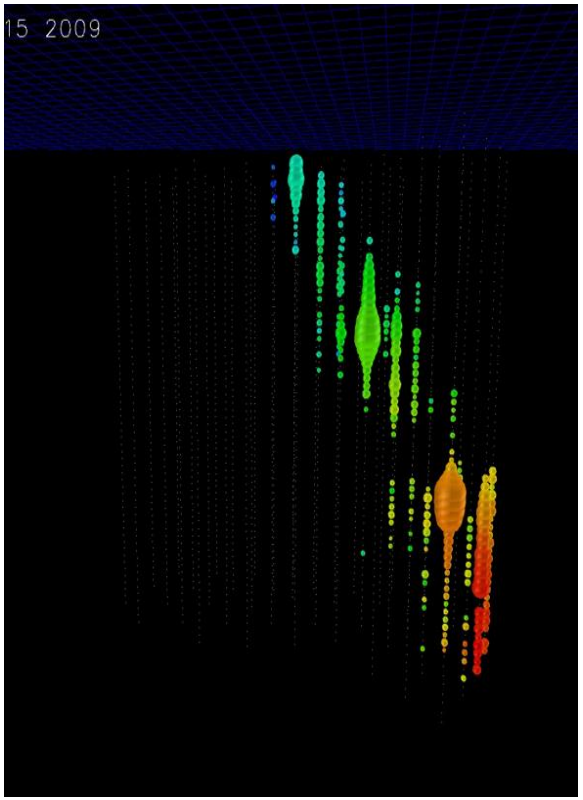
- Launch time is color-coded from red to blue.



EVENT SIGNATURES

TRACK LIKE EVENTS

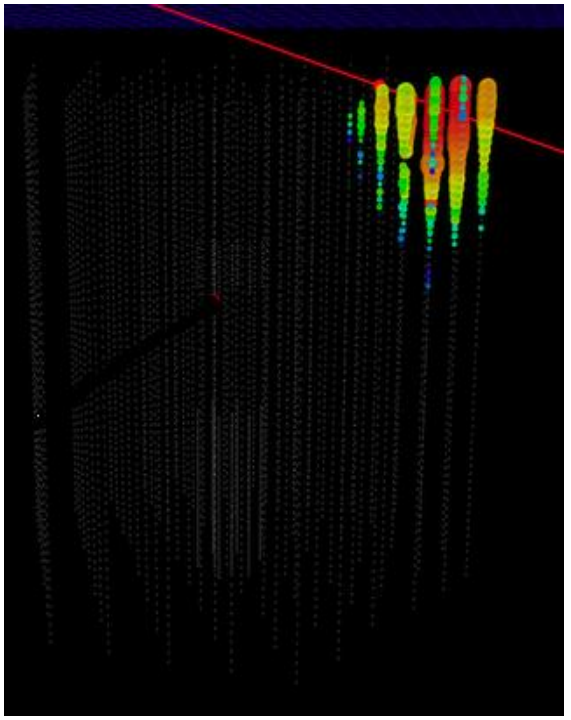
- charged current ν_μ interaction and cosmic ray μ
- Muon emits mainly Cherenkov without significant energy loss.
- good direction resolution; point back to sources.
- Primary cosmic rays produce muons which are the dominant background in the cascade channel.



Size denotes collected charge

WEAK COSMIC RAY SIGNATURES

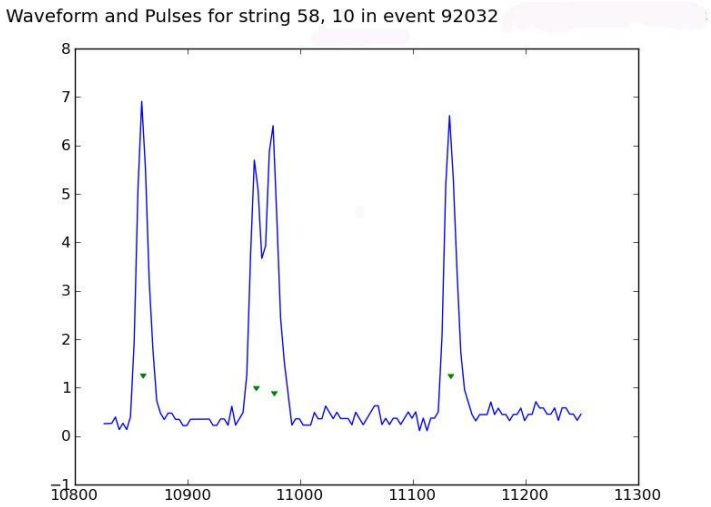
- cosmic μ may create a signature almost identical to a cascade event
  - ❖ Catastrophic energy loss along μ track
  - ❖ Corner clipper
- AIM: Evaluate different cut strategies to remove this class of background events.
- By studying differences in waveforms, charge and arrival times.



Example of a Corner Clipper.

ANALYSIS
Studying early waveforms and pulses

- **Waveform**: Time resolved recording of the voltage drop over the resistor.
- **pulses:** response of Photomultiplier Tube to a single photo electron. Reconstructed from the waveform.
- For cascade event, first peak is expected to be highest



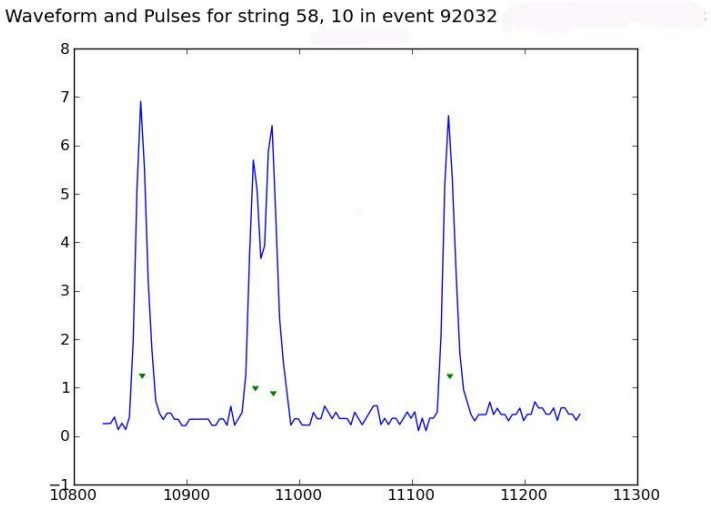
ANALYSIS

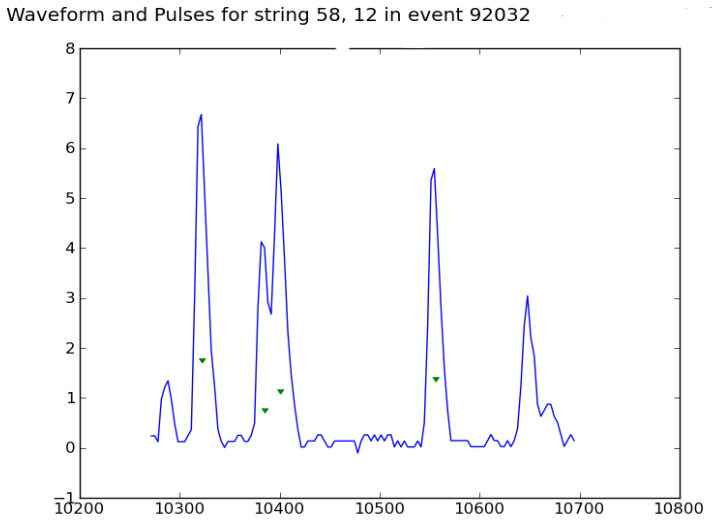
Studying early waveforms and pulses

- **Waveform**: The time resolved recording of the voltage drop over the resistor.
- **pulses:** response of the Photomultiplier Tube to a single photo electron. This is reconstructed from the waveform.
- For cascade event, the first peak is expected to be the highest

❑ Some waveforms did not have pulses in the small features!

❑ This needs to be investigated further.



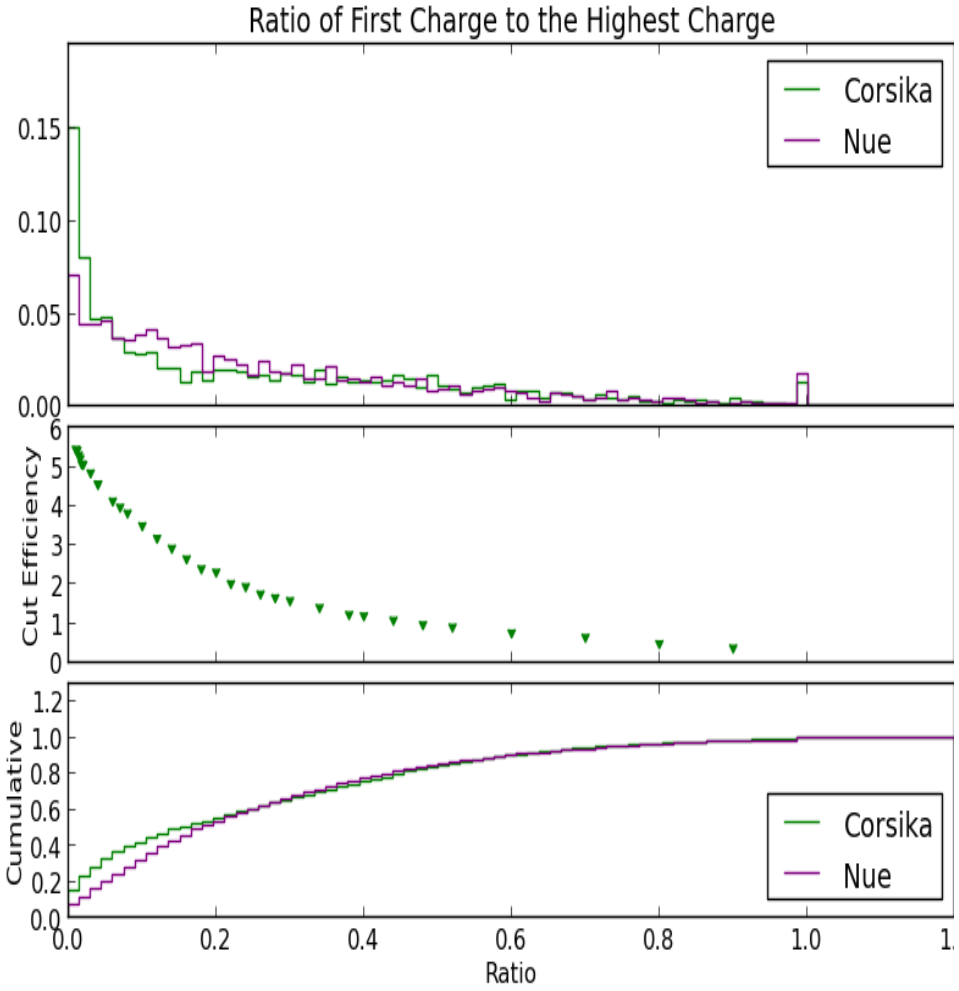


- Data sets used:
  - Pre-filtered Simulated cosmic ray muons (μ that mimic cascade events)
  - Simulated electron neutrinos
- An efficient variable makes a clear distinction between background and signal
- Goal is to keep as much signal while removing as much background as possible.

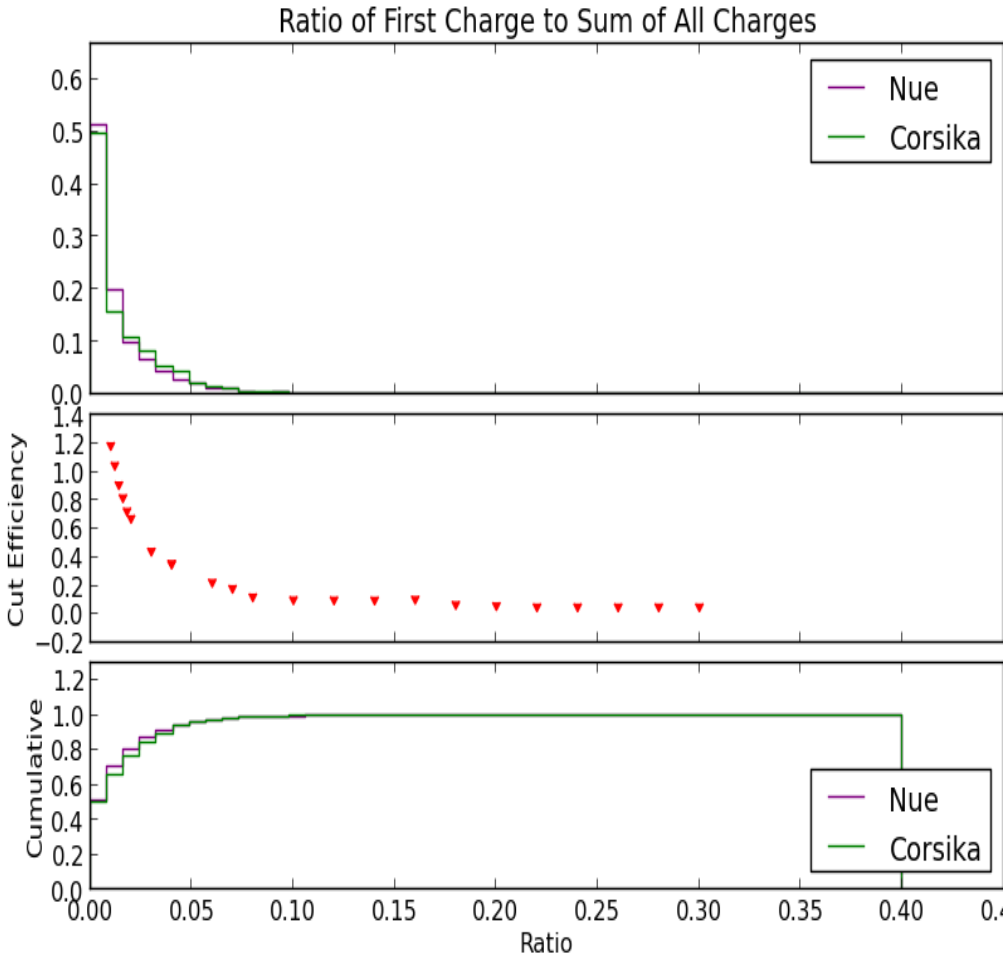
$$Cut\ Efficiency = \frac{Number\ of\ remaining\ singal\ events}{\sqrt{Number\ of\ remaining\ background\ events}}$$

- Cumulative distribution shows signal efficiency

A) Ratio of the First Charge to the Highest Charge.



B)Ratio of the First Charge to the Sum of all Charges

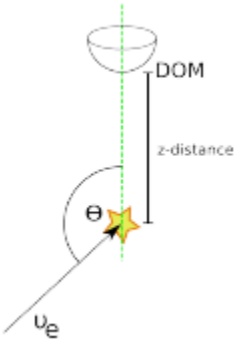


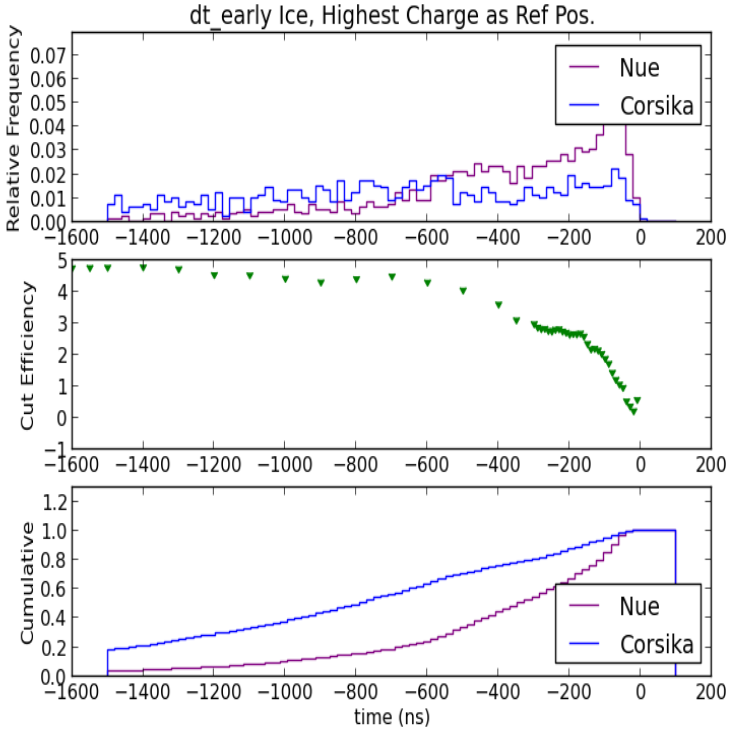
- Low signal efficiency

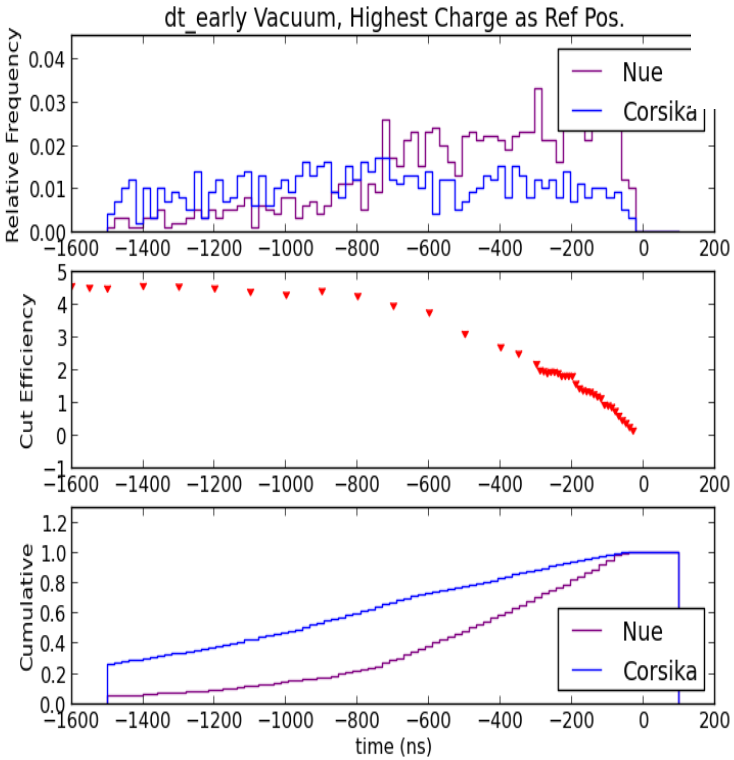
C)Delay time window, dt_nearly

dt_nearly = Expected arrival time - Actual arrival time, with respect to a reference position.

i) DOM with the highest charge as reference position

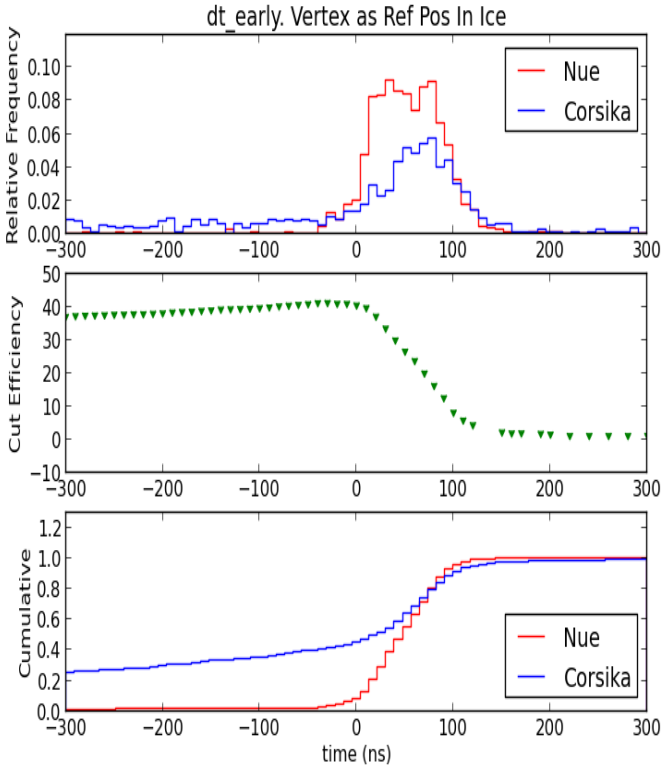


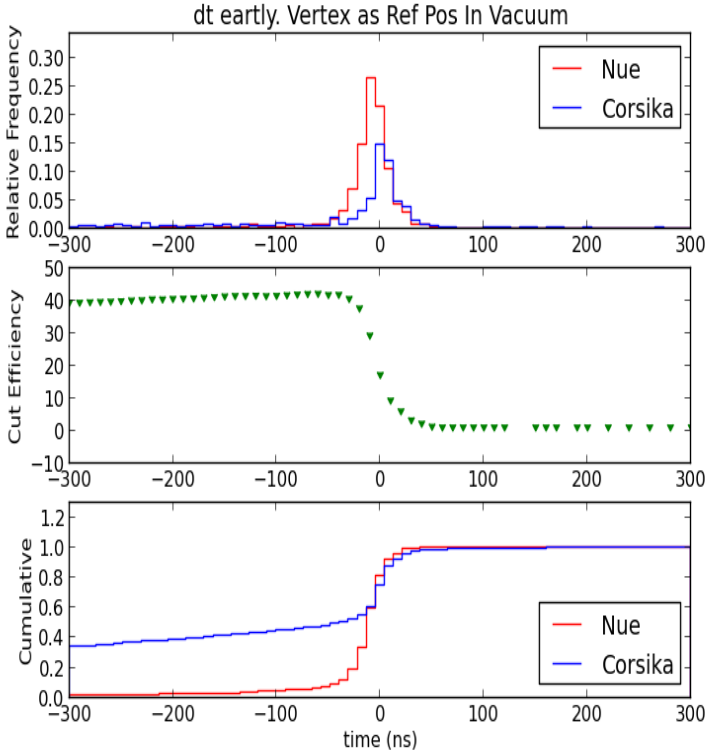




)Delay time window, dt_nearly

ii) Vertex position as reference position.





SUMMARY

- The problem of the reconstruction of pulses of small features in the waveforms needs further investigation
- dt_nearly significantly better in ice with vertex position as reference postion
- The assumption that the earliest pulse is the highest may not be ideal.

Thank you!

This has been an invaluable learning experience.