Finding Muons

Patrick Younk
HAWC Collaboration Meeting
February 2013, CSU

Need two tools

- TOOL #1: Fast Muon Simulator
  - Cherenkov spectrum & geometry known
  - Average QE curves known (Gus multiplied the Cher spec with QE curve for me)
  - Input: Muon geometry, Output: PMT charge & timing.
- TOOL #2: Tank Event Builder
  - Builds hits in a tank within a 50 ns window into a Tank Event.
  - Slewing and Charge & Calibration is applied (using CSU average).
  - A custom module writes info to a root file.

First go at a Muon Selector

- Look at Run 169 (untriggered run from Nov).
- Select 4 PMT events. (From my simulator I know Muons make 4 PMT events).
- To insure decent time and charge calibration, I select PMTs with Charge > 2pe.
- Typical Selected Event:

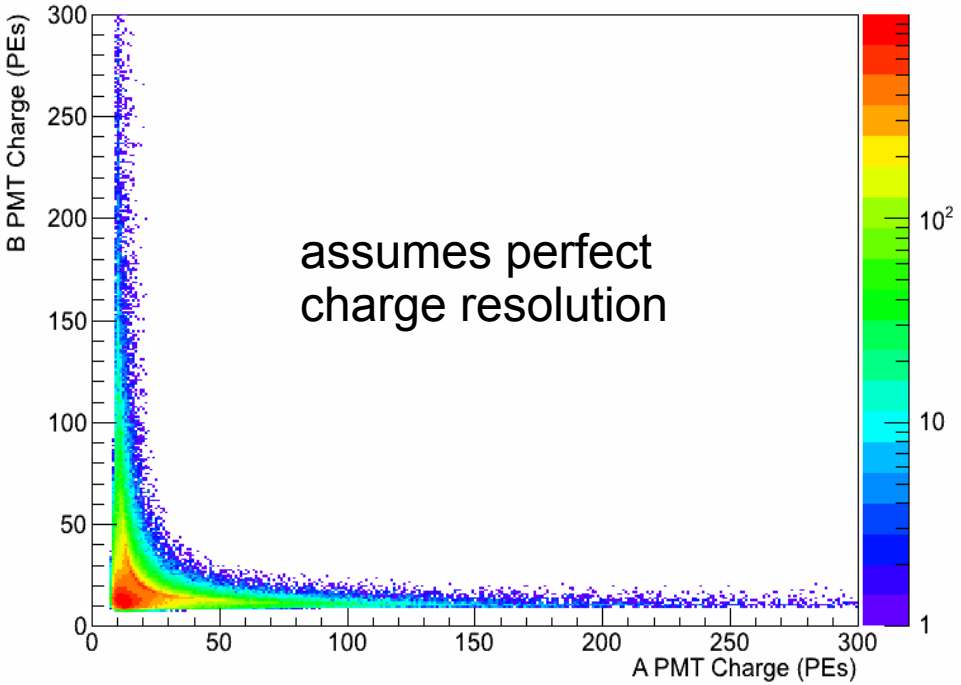
I measure time relative to C →

Time A: -1.0 ns	Sa: 24 pe
Time B: 6.6 ns	Sb: 9.2 pe
Time C: 0 ns	Sc: 60 pe
Time D: 6.7 ns	Sd: 6.8 pe

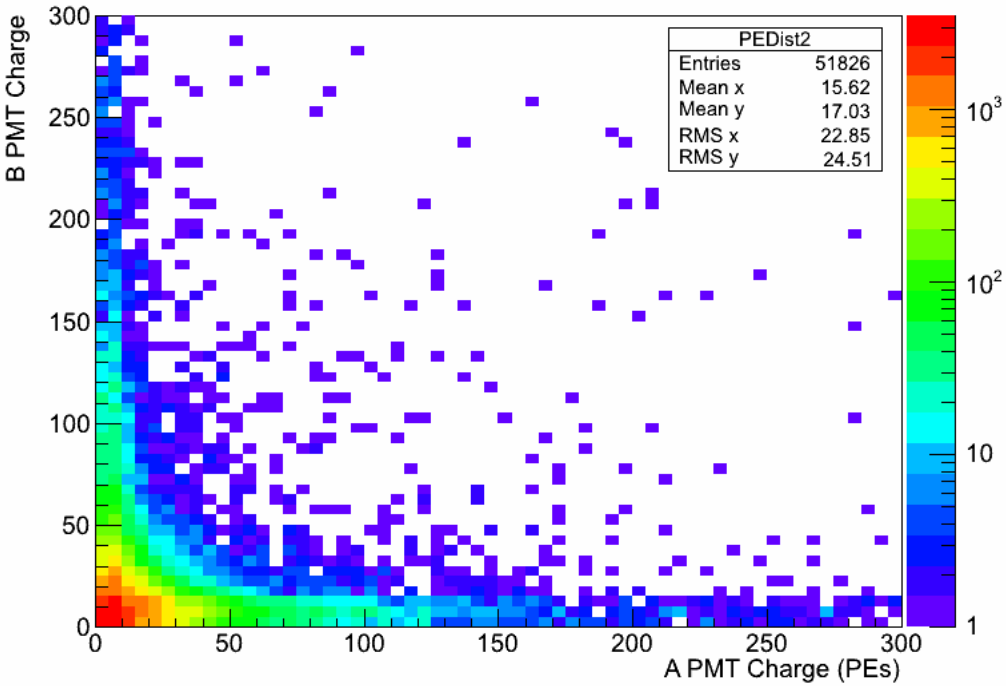
Muon Signature #1

- If one PMT is hit hard, the others will be hit less.

Simulation of Muons

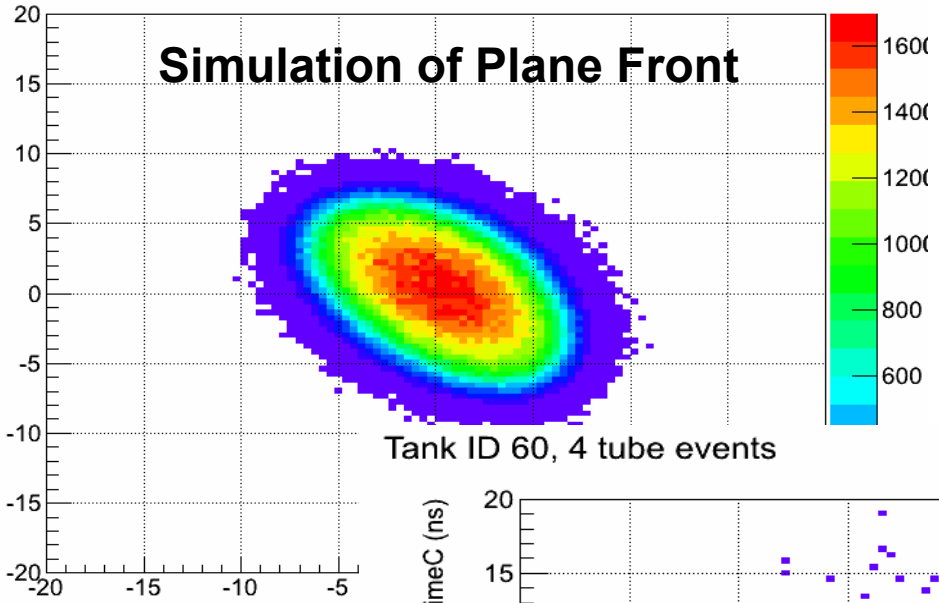


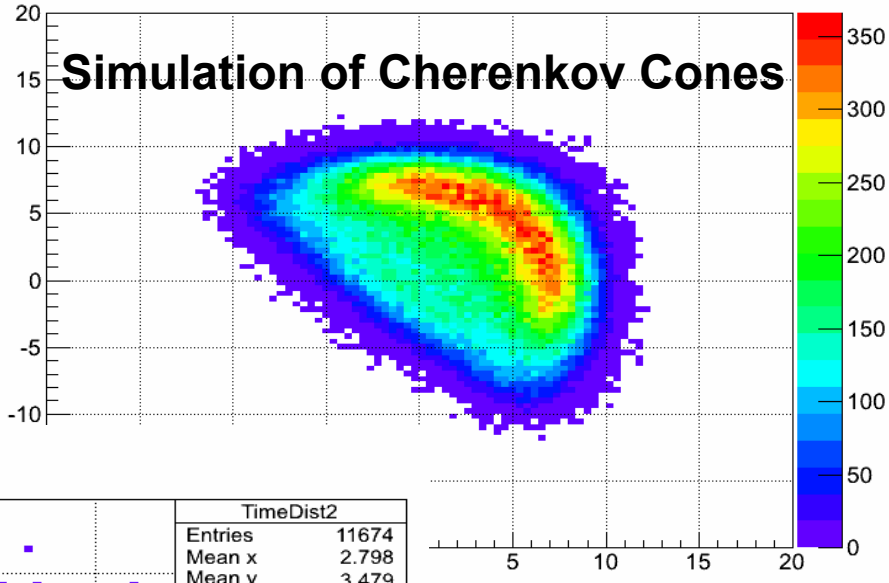
Data

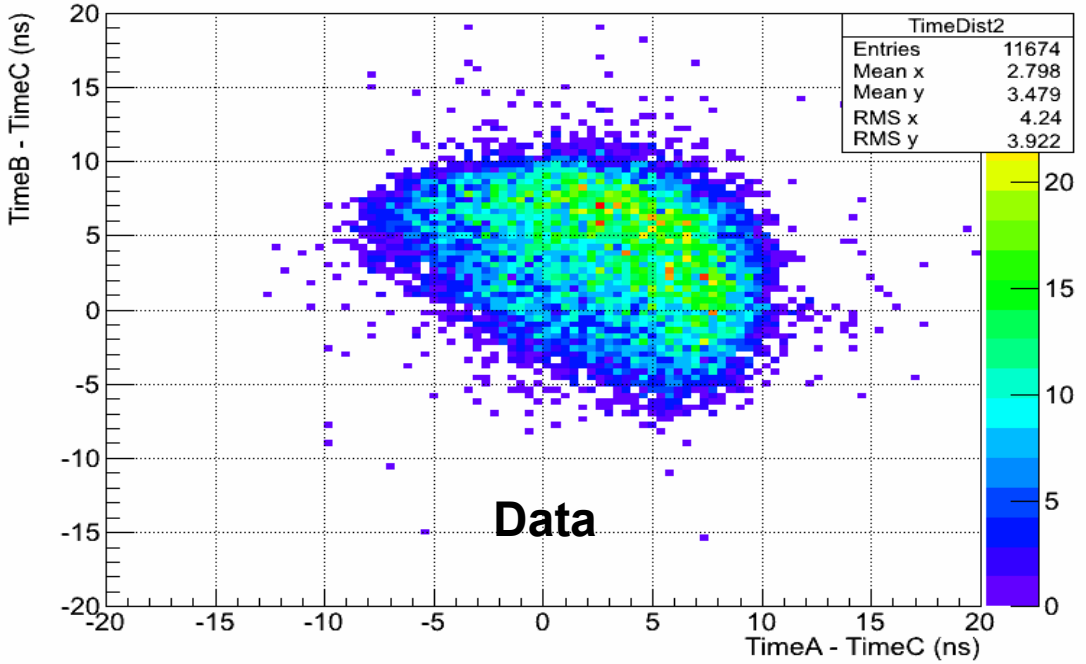


Muon Signature #2

- Characteristic timing between the PMTs.



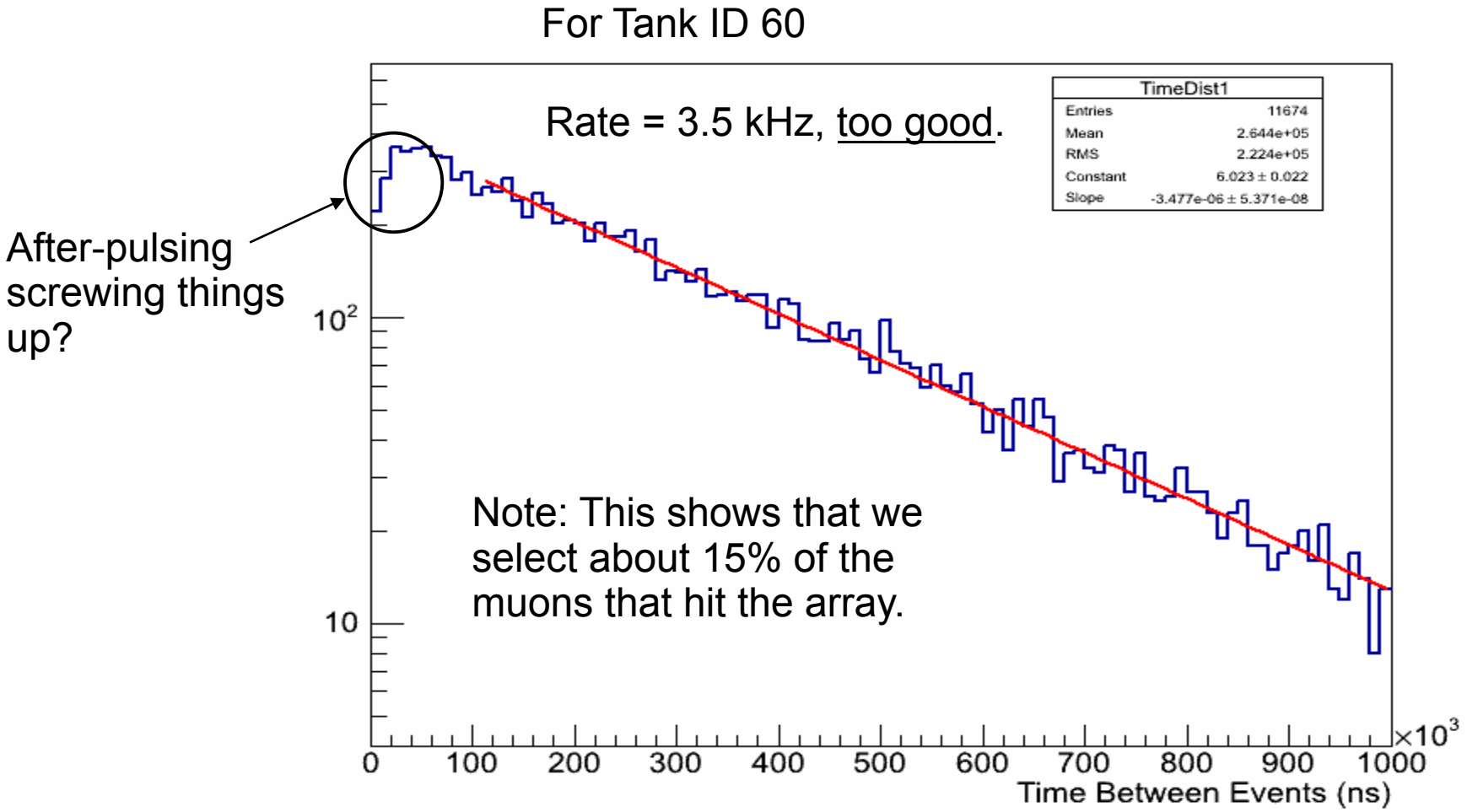




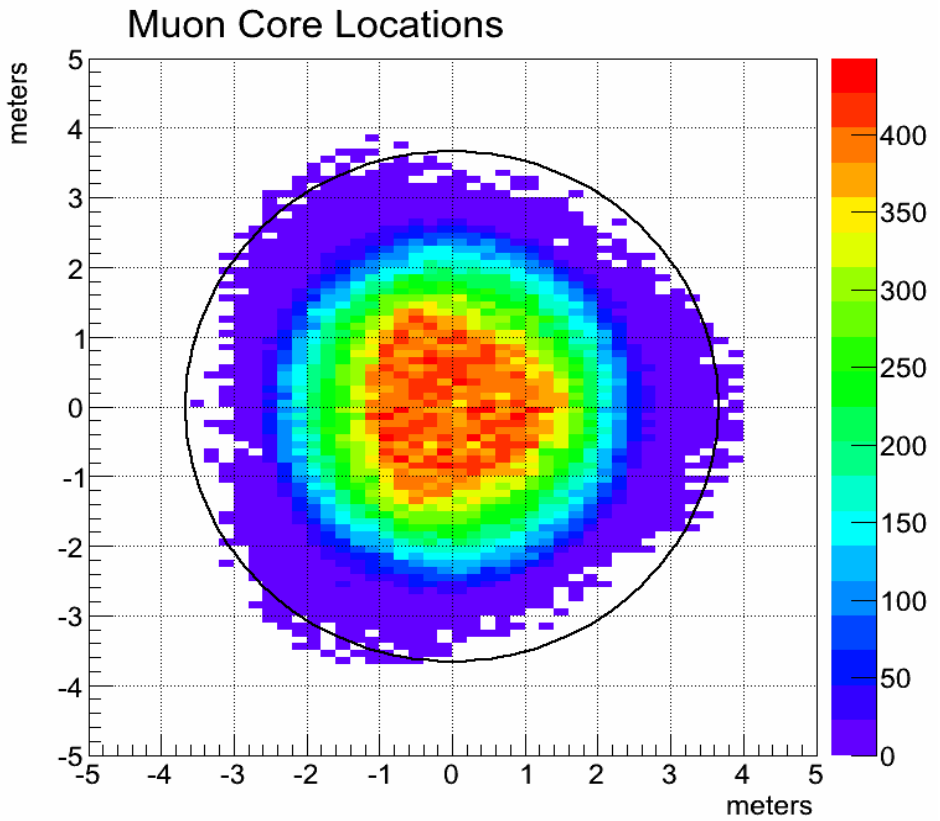
simulations assume
1 ns resolution

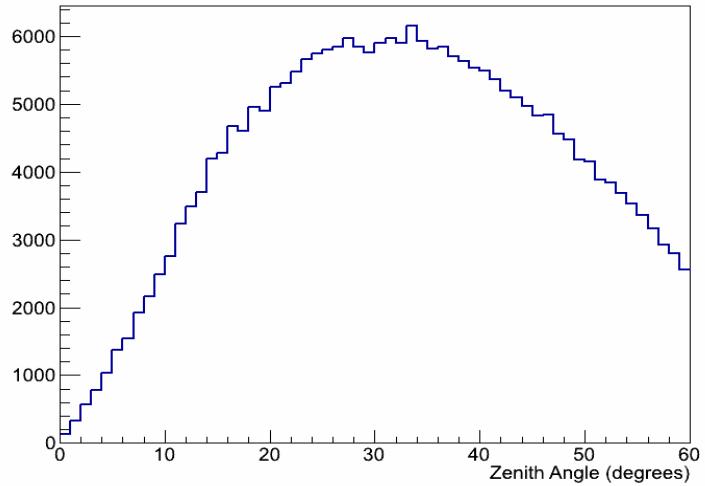
Muon selector looks like it is working!

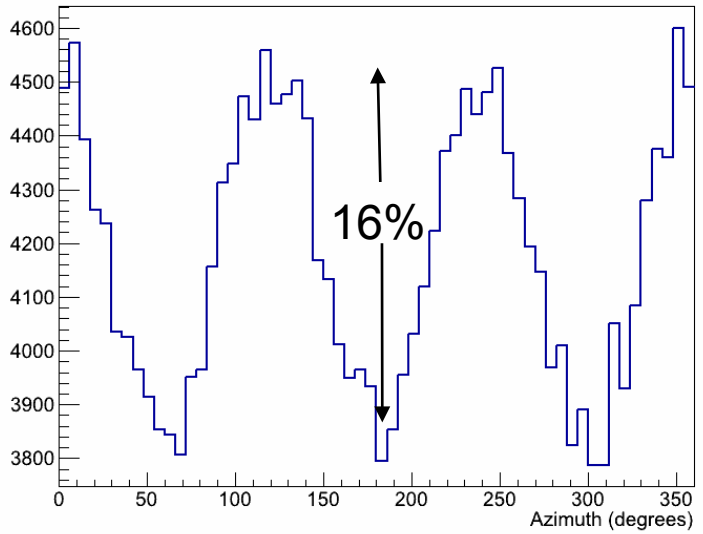
- The expected muon rate through the bottom of the tank is ~14 kHz (PDG). 3.5 kHz exp to pass selection.



What muons trajectories do I accept?



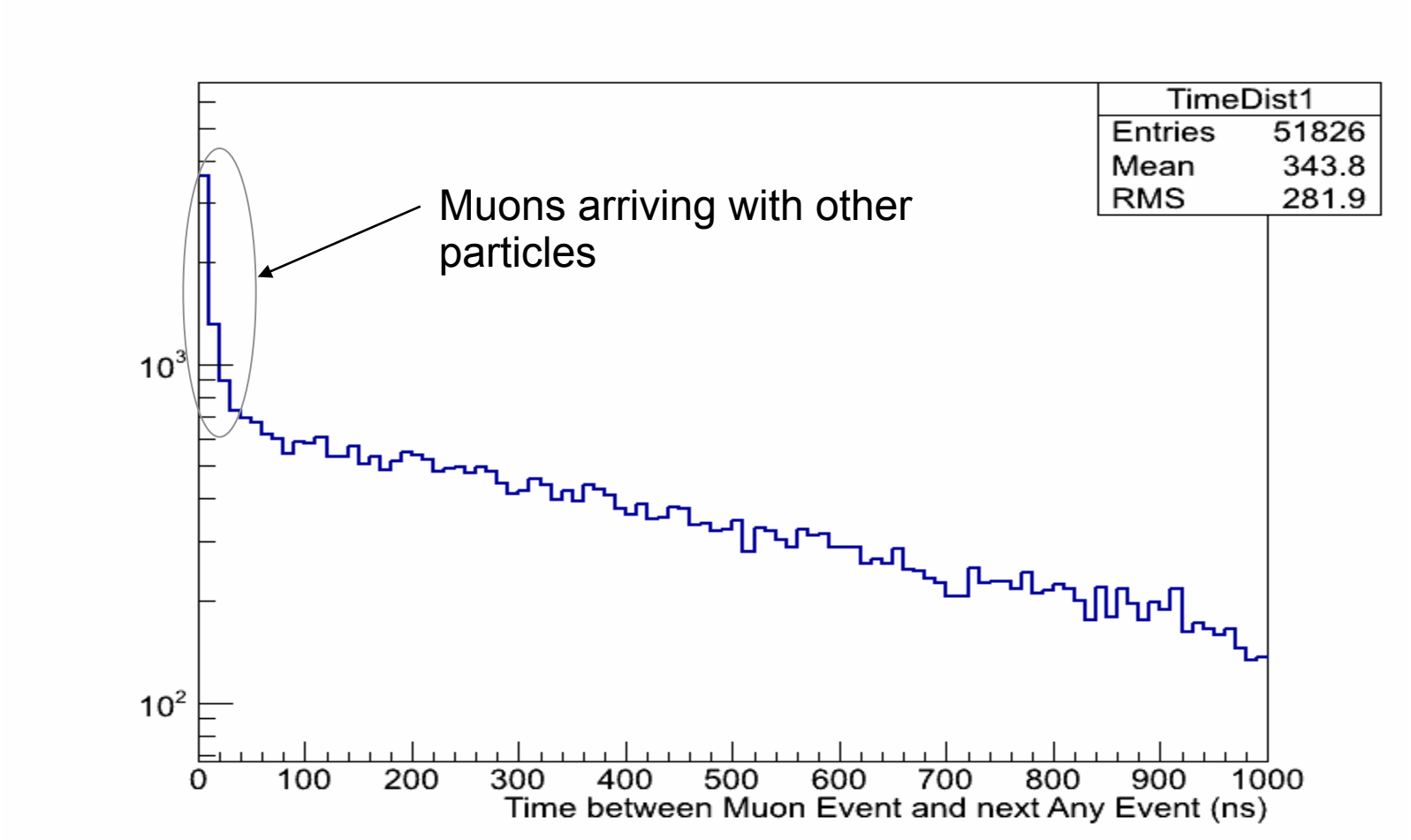




Have to work on a 3-PMT Muon Selection..... Simulate says I will double the rate.

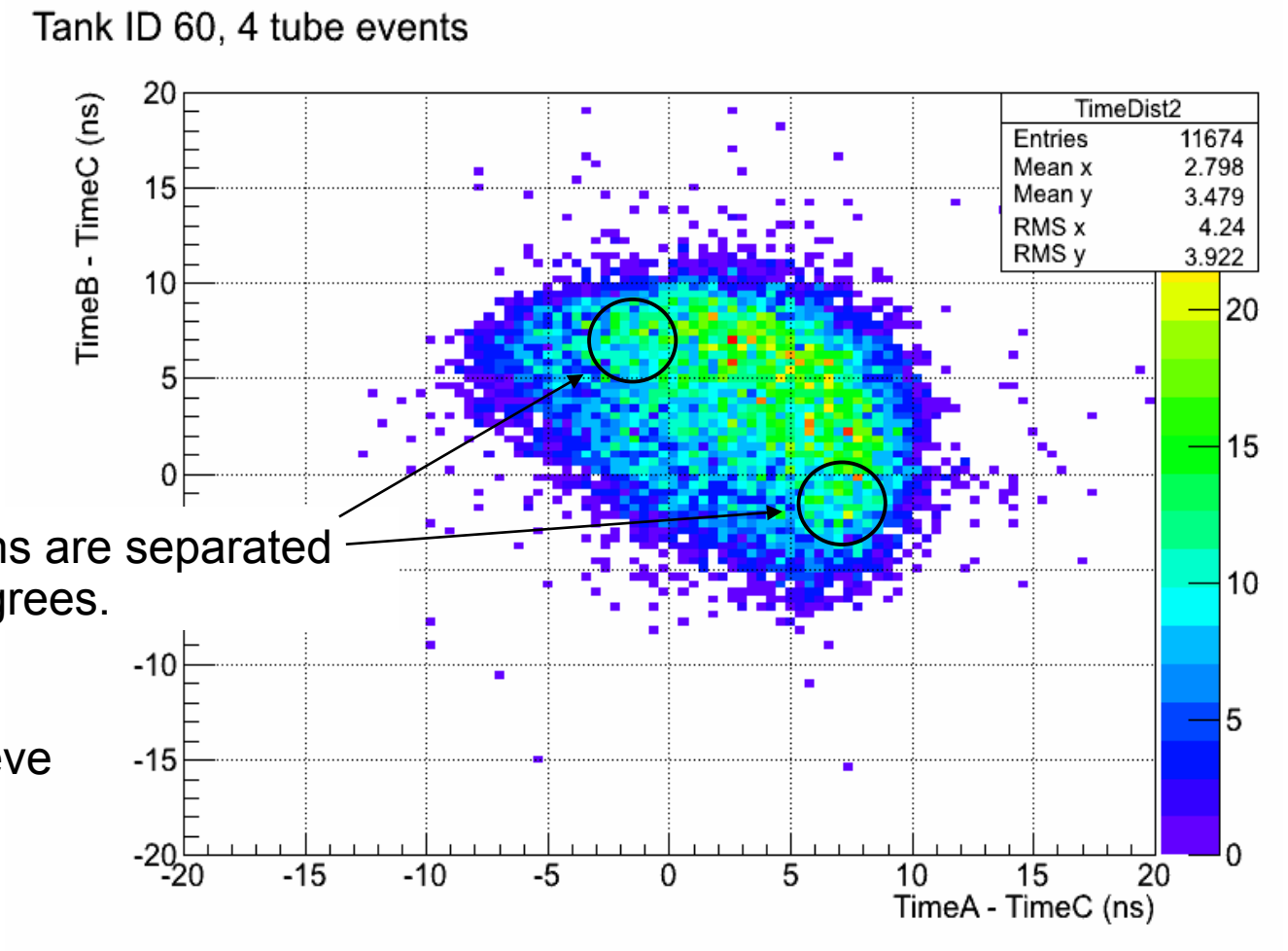
Do I see muons in showers?

- Yes! But most are single, uncorrelated muons.



Can I tell the muon direction?

- Yes! I need some more time...can test with CSU Tank.

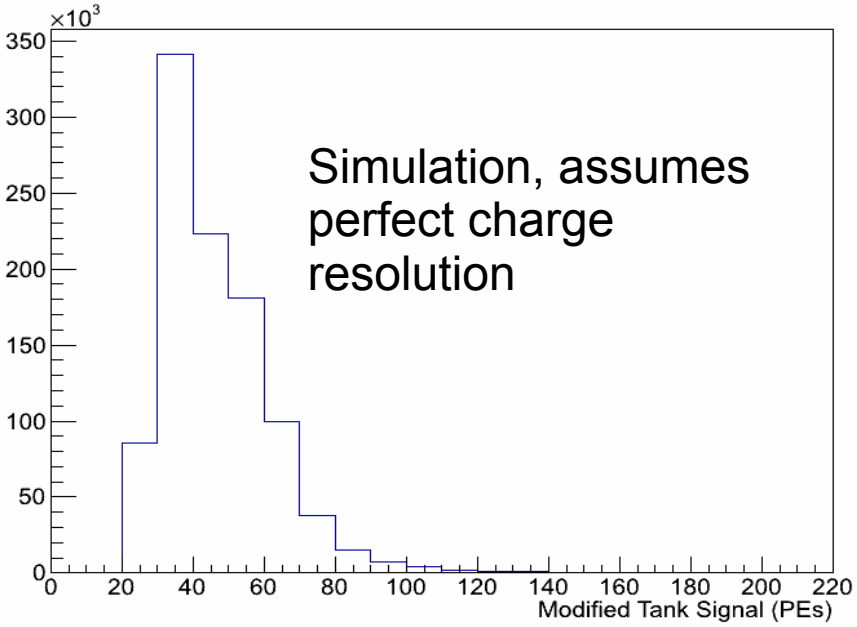


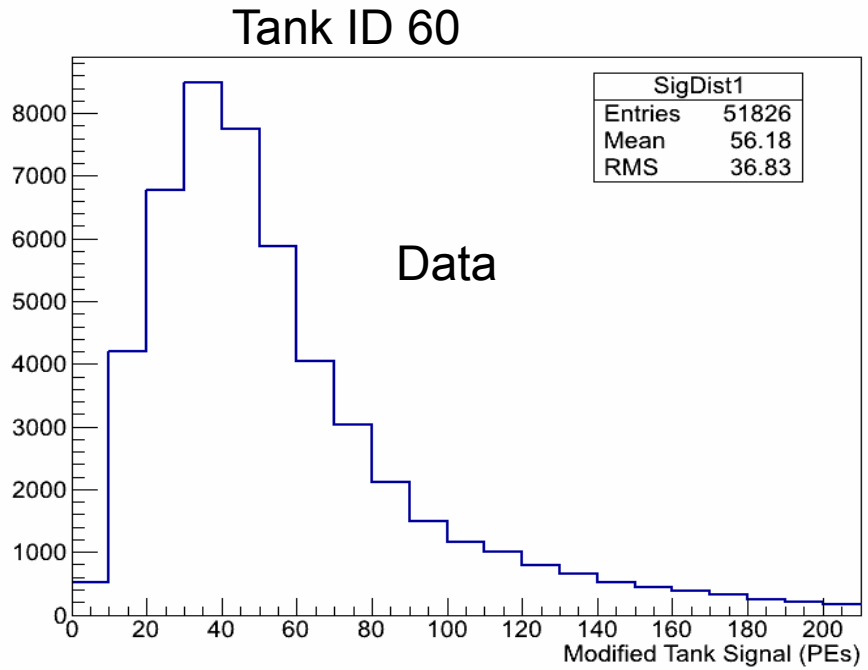
These Muons are separated by ~120 degrees.

Can we achieve 30 degree resolution?

Uses for Muons:
Light-to-Signal Calibration (includes QE)

- Histogram total charge in tank minus hardest hit PMT.





Apparently Tank 60 has decent calibration.

There's a lot more work work to be done .... but promising, no?

Uses for Muons: Significantly reduce our low energy CR BG

- Selecting Muons in showers is a new handle on Gamma Hadron Separation.
- A 1 TeV proton produces ~15 muons at our elevation. Say there is one “nice” muon event on the array. (“nice” means I select it 95% of the time).
- How often am I fooled? Difficult BotE calculation. By the looks of my charge and time distributions (slide 4&5), this could be quite rare for a 1 TeV gamma.
- Then muon selection is about the same as CxPE.
- Lower E: Anti-Muon cut pre-trigger???

Uses for Muons:

- Solar & Terrestrial Physics....
- UHECRs....

Summary

- Isolated muons are evident in the untriggered data, both in signal distribution and relative timing.
- The measured rate is consistent with the known rate.
- We will be able to determine a rough muon direction.
- Single muons events can give us a useful calibration signal.
- Working on finding muons in showers. Early calculations show promise.
- Muons events in showers will give us a different handle on hadron rejection.
- There are other interesting lines of investigation.
- I plan on adding rigor to this study for an ICRC Poster…..

Abstract

The High Altitude Water Cherenkov (HAWC) gamma-ray observatory is being built at an altitude of 4100 meters at Sierra Negra, Mexico. The detector consists of 300 water tanks, each instrumented with four photomultiplier tubes. The detector area is 22,000 m^2 and the detector mass is 60 kilotons. The HAWC detector is capable of identifying single atmospheric muon events. The approximate arrival direction of the muon can be reconstructed. We demonstrate this using data from the portion of the detector that is currently operational. Muons generate a well known Cherenkov spectrum in water and thus can be used as a calibration source. We discuss the details of how this can be accomplished for the HAWC observatory. We also discuss the ancillary science capabilities of HAWC with regard to it being a large area muon detector. For example, we discuss the possible measurement of very high energy distant air showers.

Large Area Surface Muon Detectors

- Tracking Muon Detectors:
  - GRAPES-3: 560 m^2
  - KASCADE: 150 m^2
  - HAWC: 3,000 m^2 *
- Non-tracking:
  - MIA: 2,500 m^2
  - AUGER: ~4,000 m^2 *
  - LHAASO: 42,000 m^2

*Edge effects accounted for.