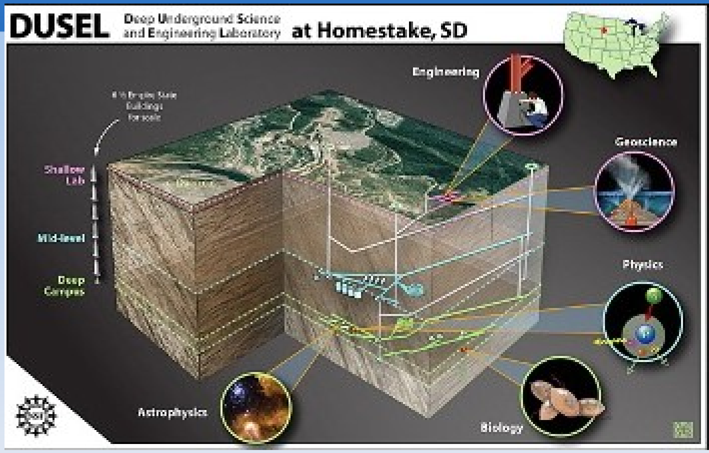

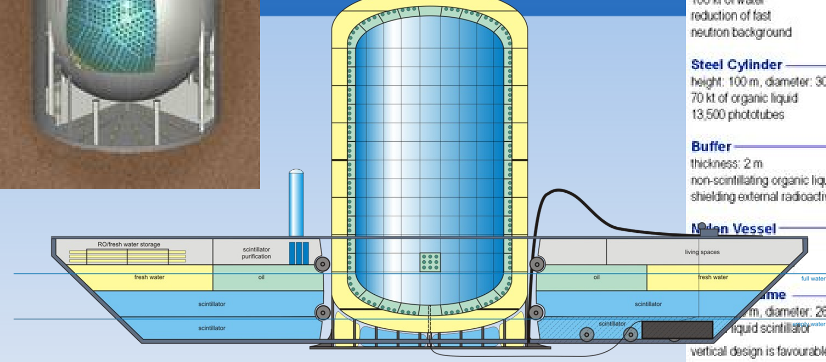

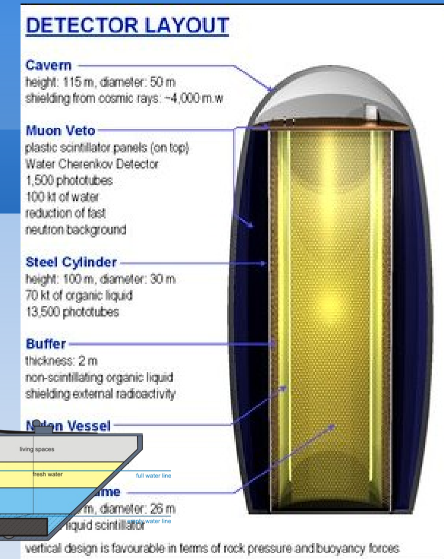

Liquid Scintillation Detectors for High Energy Neutrinos

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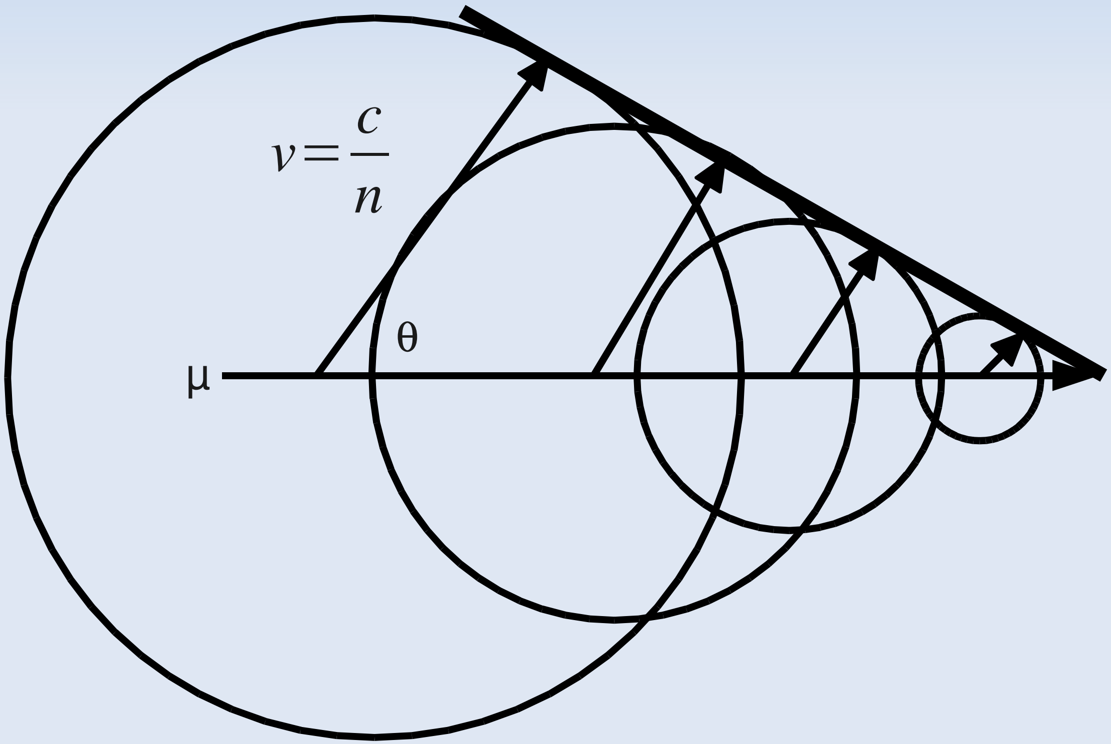
Department of Physics and Astronomy, University of Hawaii

See: arXiv:0902.4009 "High Energy Neutrino Physics with Liquid Scintillation Detectors" John G. Learned

Fermat's Principle

"The path taken between two points by a ray of light is the path that can be traversed in the least time."



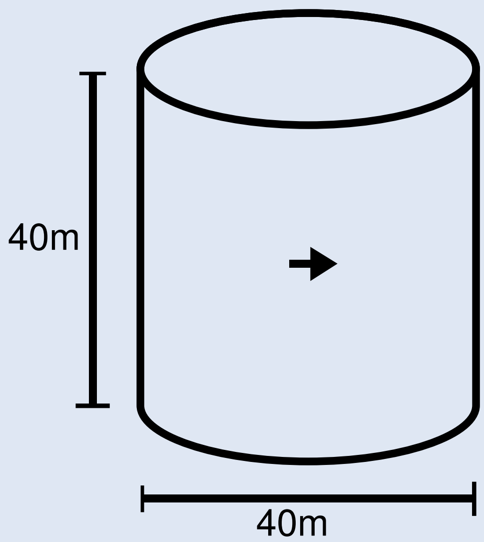
- As muon travels through liquid scintillator, photons are emitted isotropically.
- A "Fermat Surface" (Cerenkov and spheres) is defined by the wavefronts of first hit times
- Huge statistics determining this surface

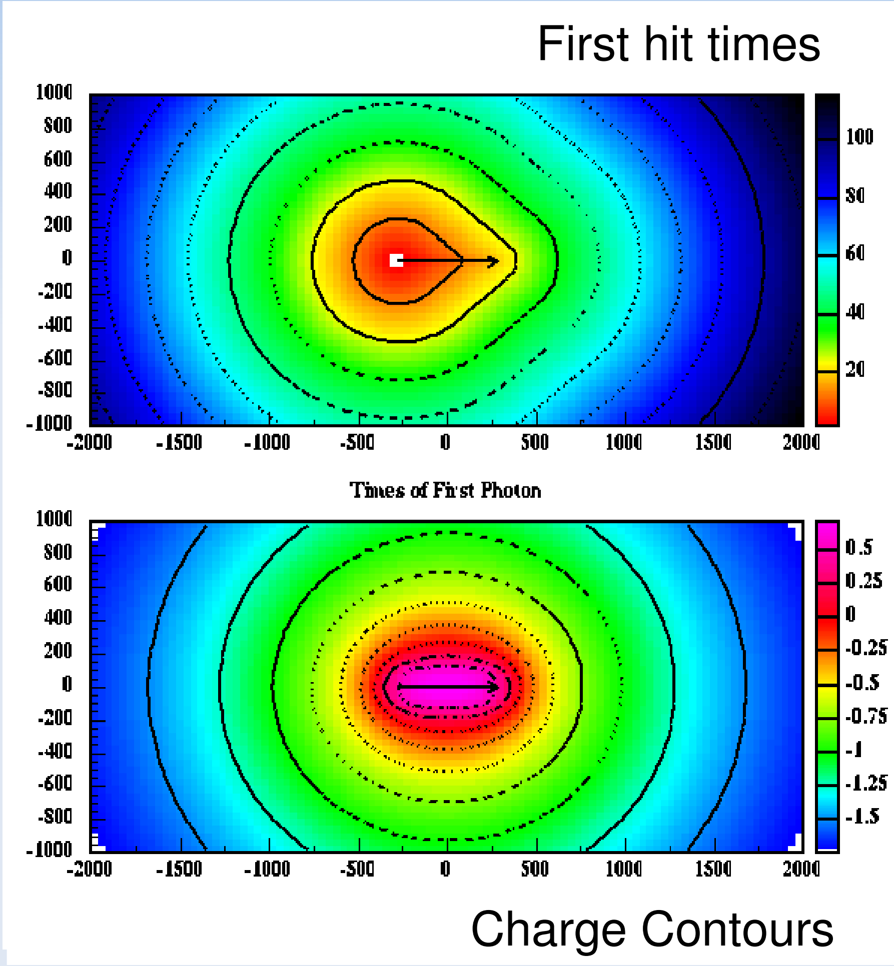
The Fermat Surface

- Electron and muon events are distinguishable by differences between equi-charge and equi-time surfaces
- There is much more information… how complex a topology can we extract?
- Opens up the study of high energy (~1GeV) neutrino interactions with LS detectors
- Potential for long baseline experiments
- Does not interfere with lower energy (MeV) physics (e.g. reactors, geonus, supernovae, etc.)

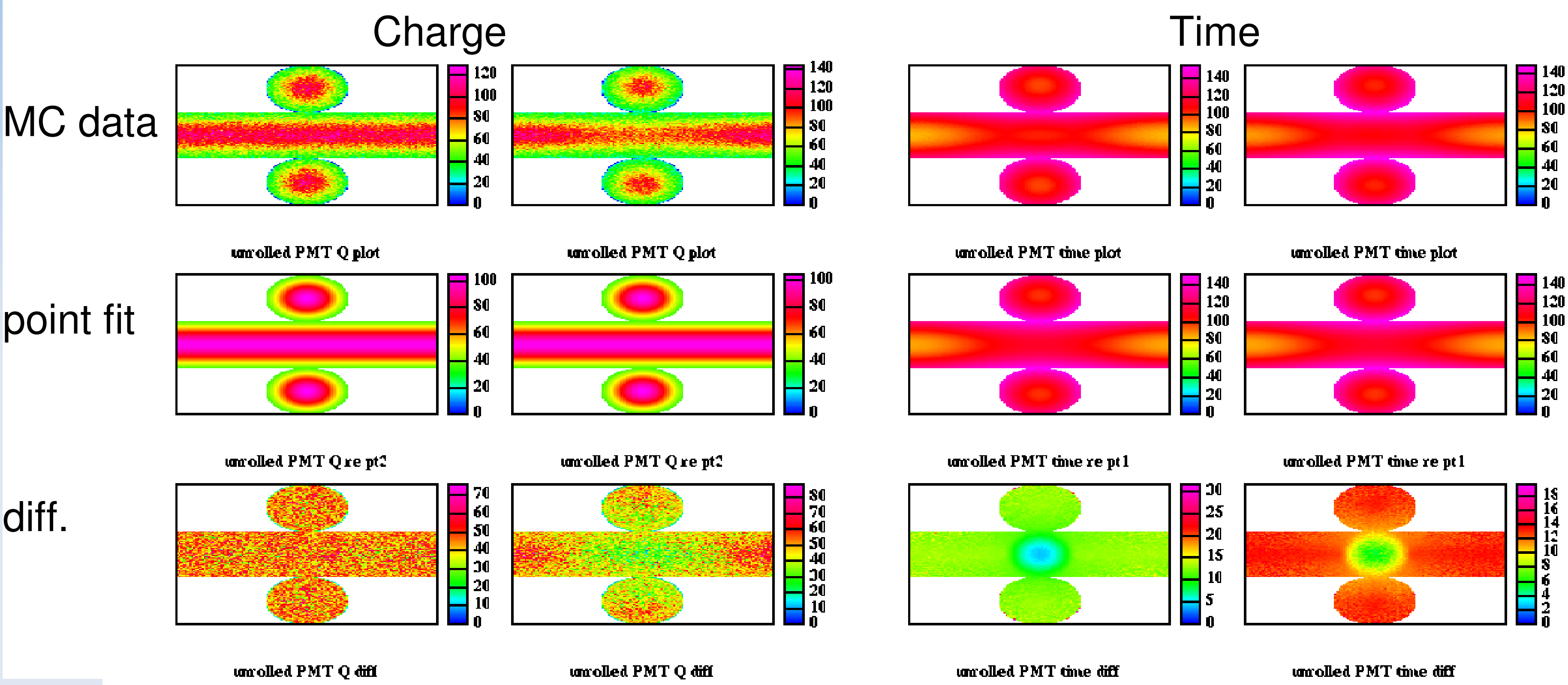
Fermat and Equi-Charge Surfaces

- Approx. 5m long muon track centered in a 40m x 40m right cylinder detector





Time and Charge Fits



muon electron muon electron

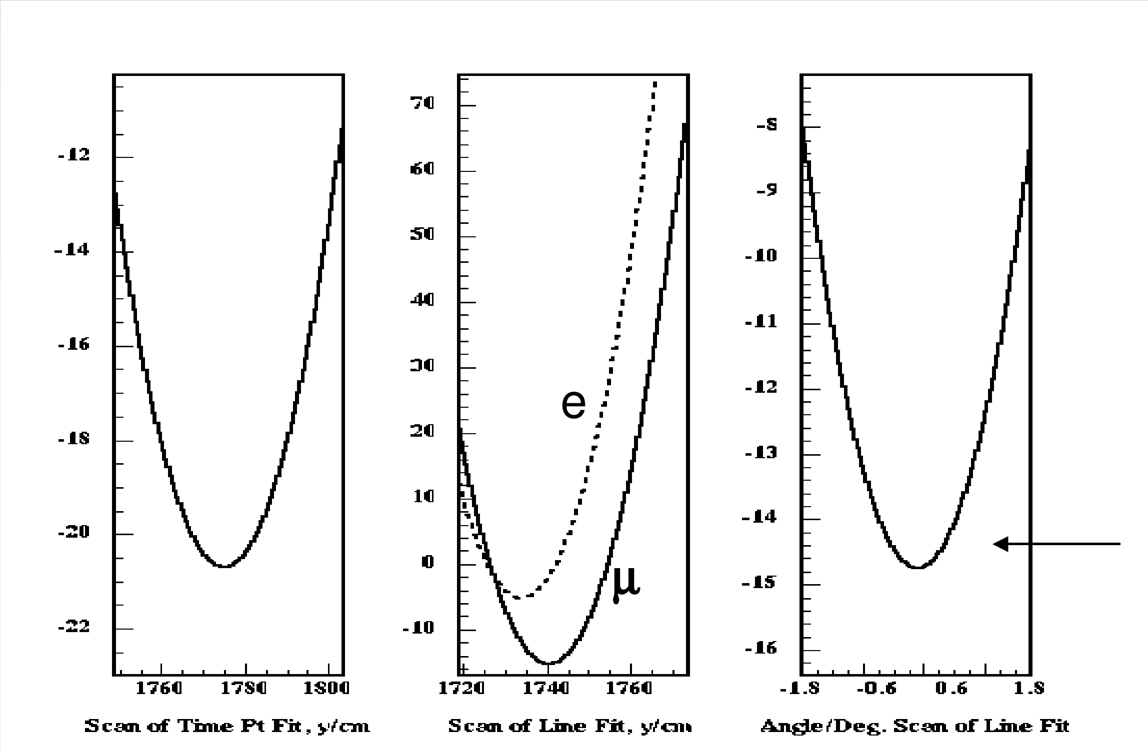
Conclusions: - Charge point fit to middle of track works well

- Time point fit to near start of muon track works well

Simple Point Fits (Q and T) Give Center of Track and point Near Origin

Chisquare/ DOF

Equivalent



Muon angular resolution to <1 Degree

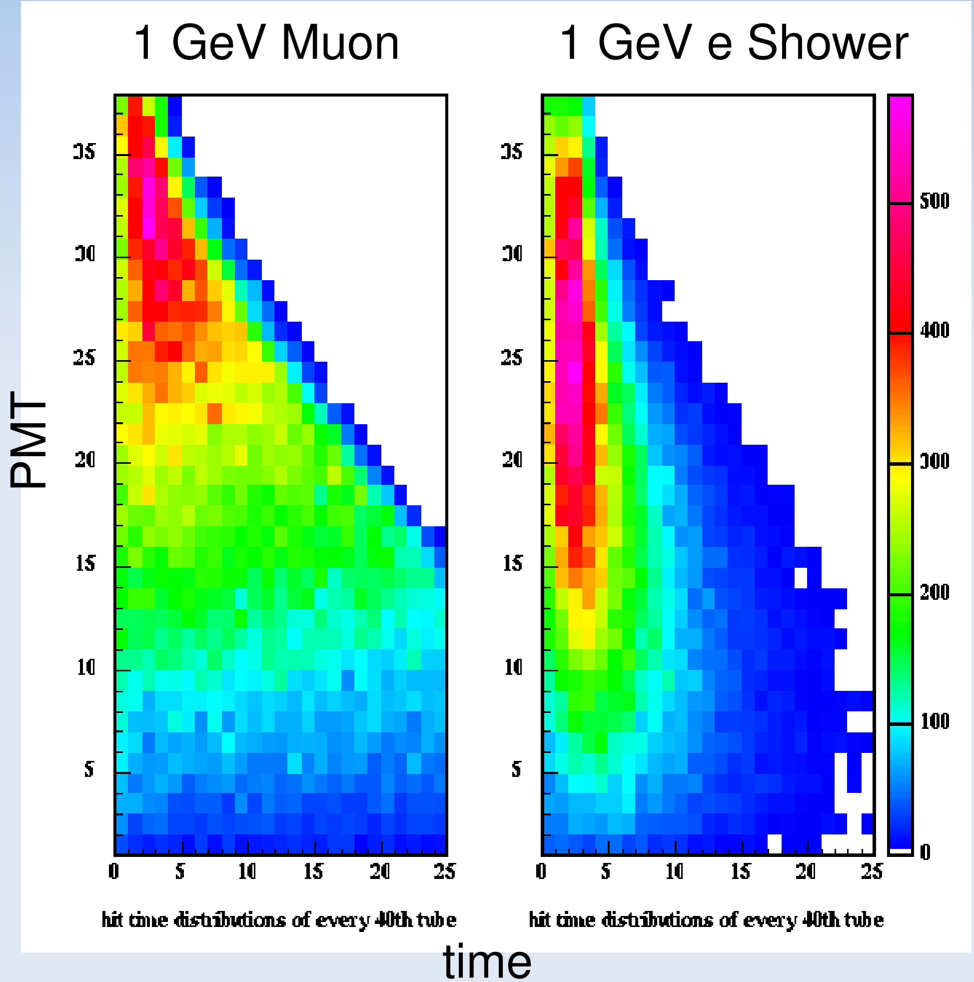
Vertex location to few cm with first point fit.

10 sigma better fit to line than shower profiles

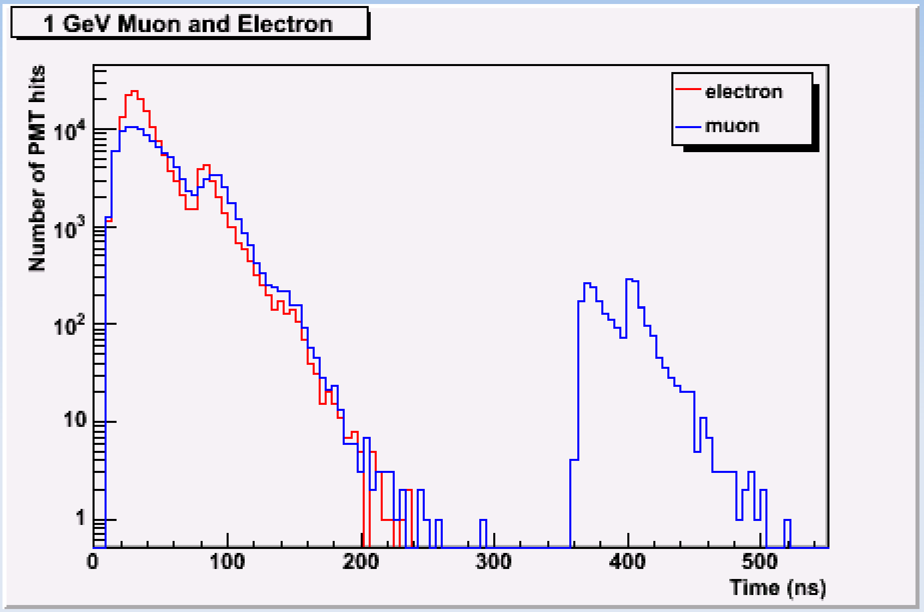
Further: Much Information in Time Distribution of Hits (PMT Waveform)

Sample PMT hit time distributions from top of detector:

- Muon event is focused in space and spread out in time
- Electron shower is quicker and more spread out in space

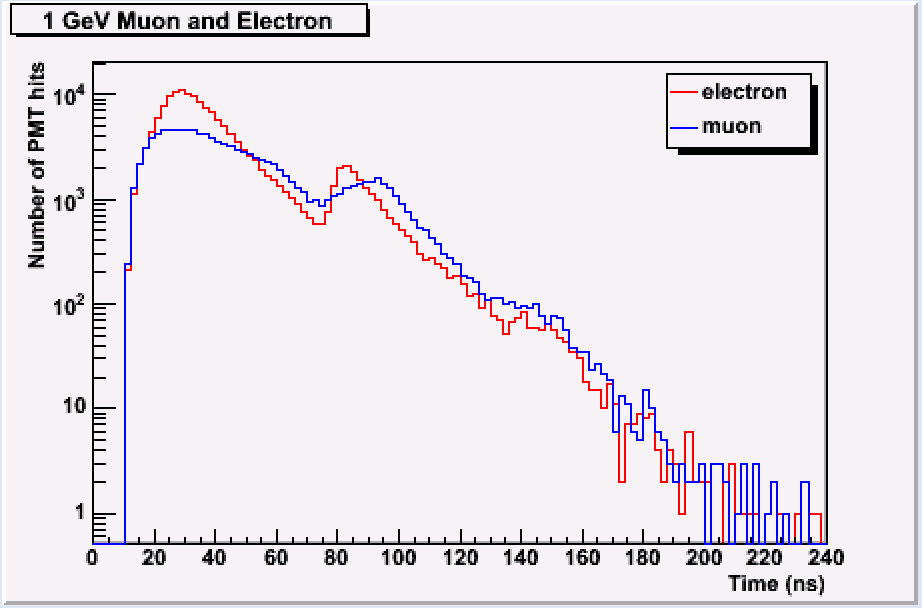


GEANT4 Simulation

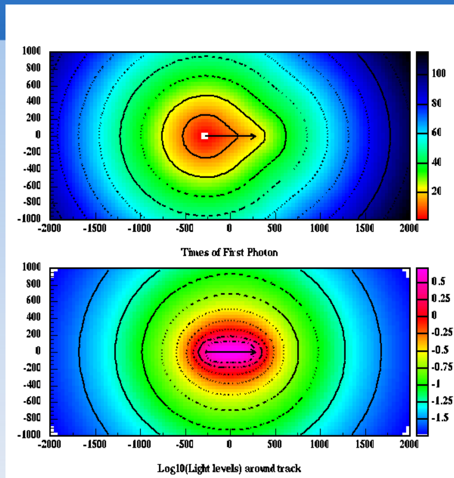


Muon decay clearly distinguishes 1Gev muon and electron events.

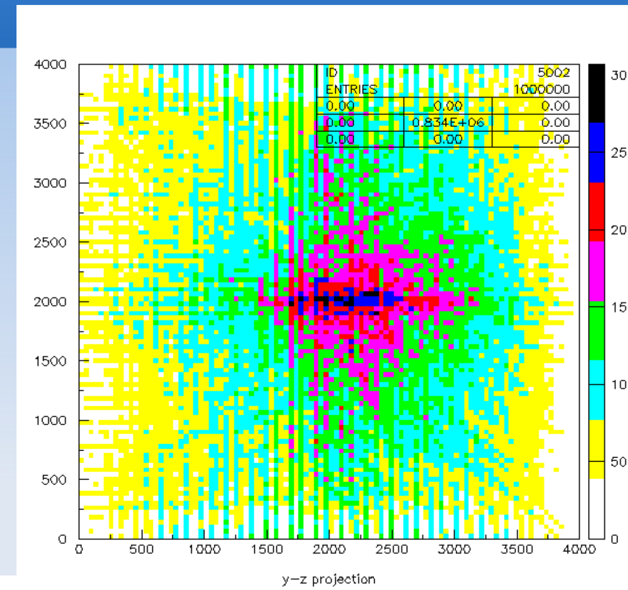
Even without the decay, there are distinguishing features.

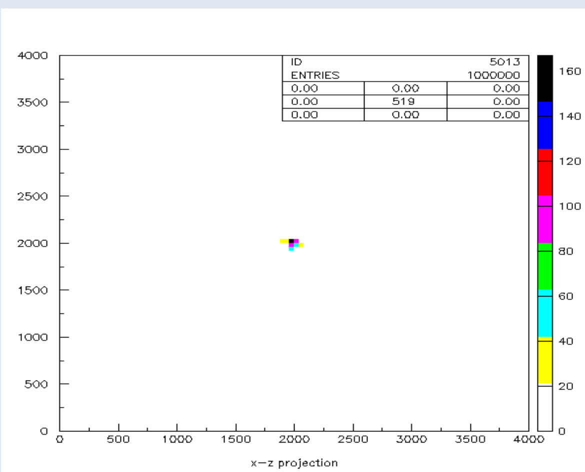


First Results on Tomographic Reconstruction

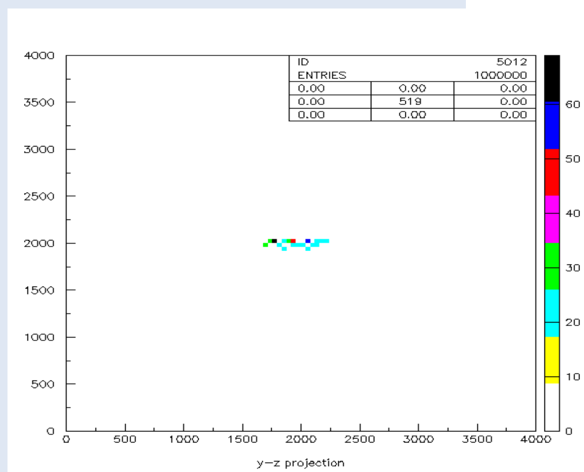


before contrast cuts

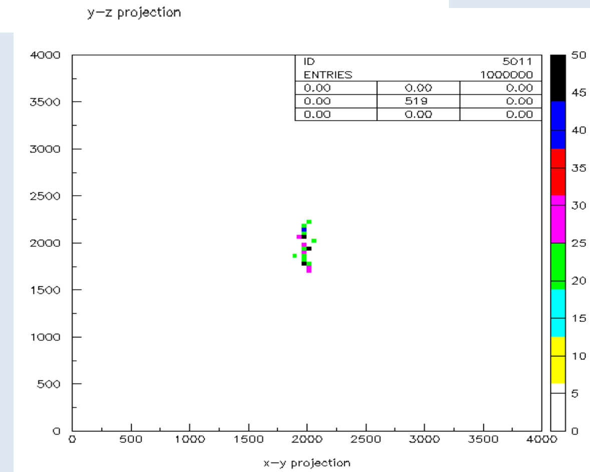




x-z projection

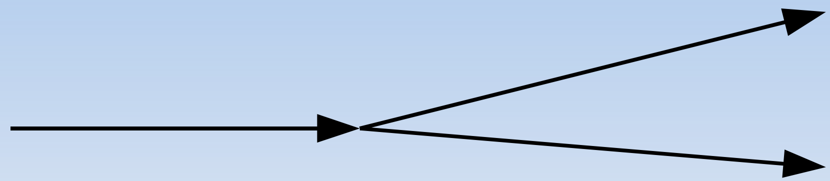


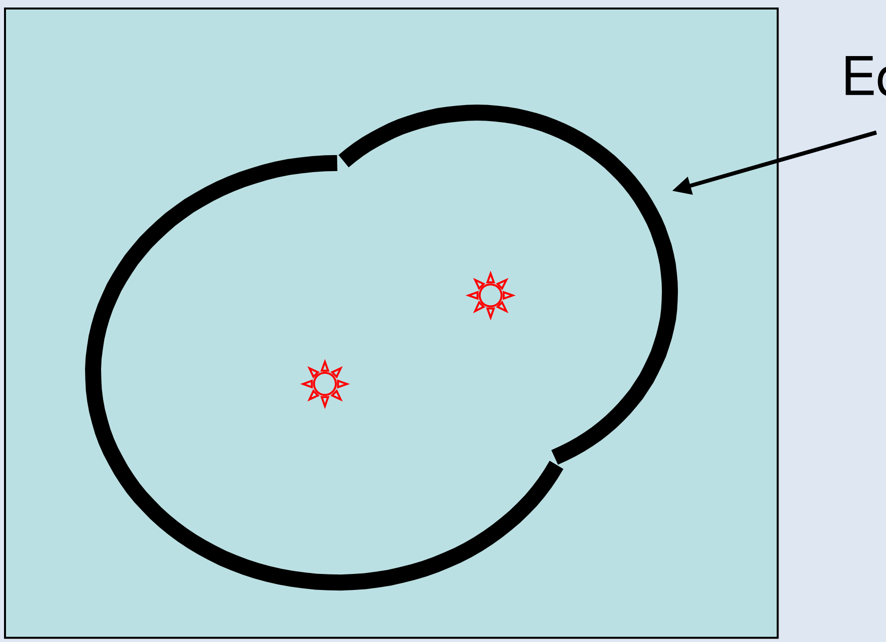
y-z projection



x-y projection

Fermat Surface Cross-section for Two Tracks





Equi-time contours

- How well can we resolve multi-track events via Fermat Surface fitting?

Applications

- Long Baseline with accelerators ~ 1 GeV
  - Hanohano with Tokai Beam?
  - LENA with CERN beam?
  - New DUSEL Experiment with Fermilab Beam?
- Nucleon Decay (high free proton content)
  - See details of decays such as Kaon modes
- Particle Astrophysics (low mass WIMPS,…)
- All the Low Energy Physics (geonus, reactor studies, monitoring, solar neutrinos…..) unimpeded!

Outlook

- Large LS detectors are capable of detailed neutrino physics.
- Further detailed simulations and laboratory studies needed.
- This technique opens new avenues for neutrino physics with LS detectors.