Hawai'i Anti-Neutrino Observatory (HANOHANO)

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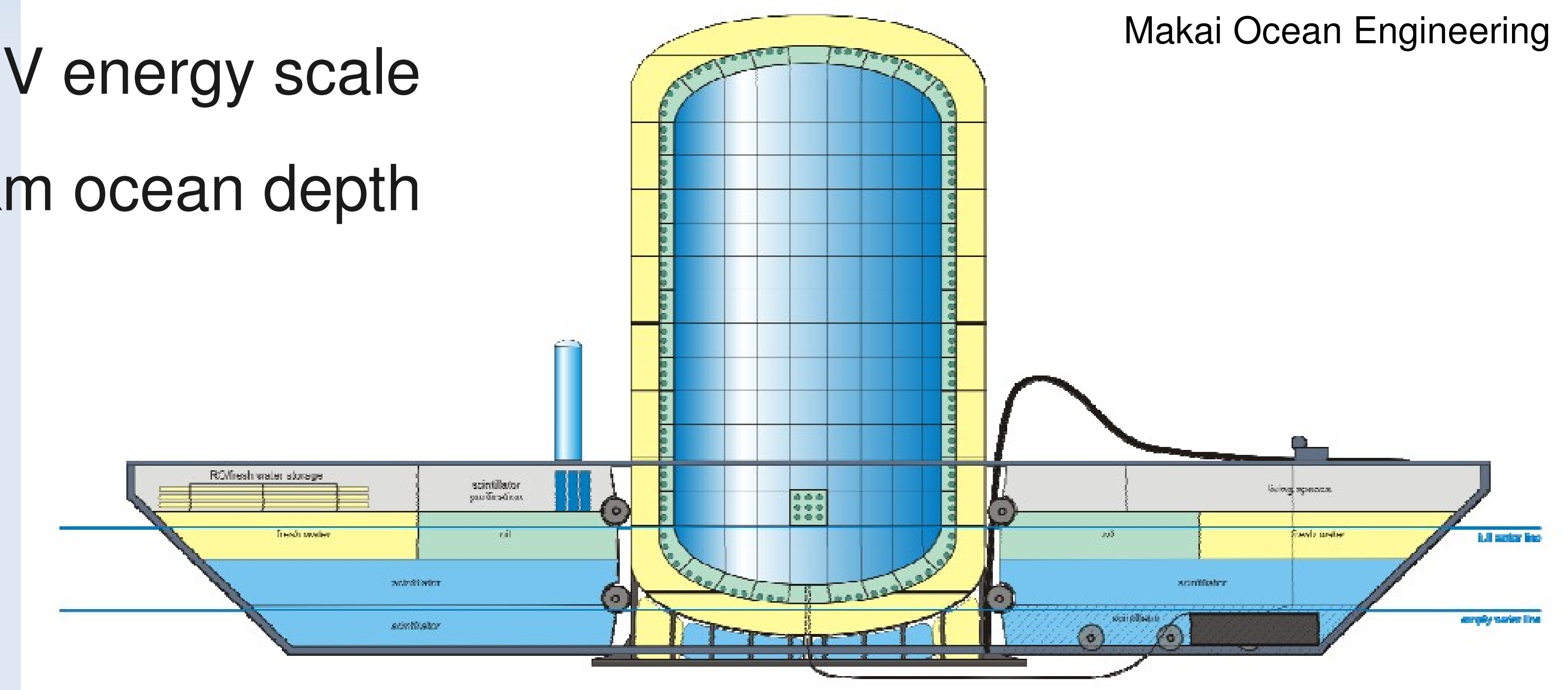
HANOHANO

- Hawaii Anti-Neutrino Observatory
- “distinctive”, “glorious”
- 10 kton, liquid scintillator
- 1 MeV energy scale
- 3-5 km ocean depth



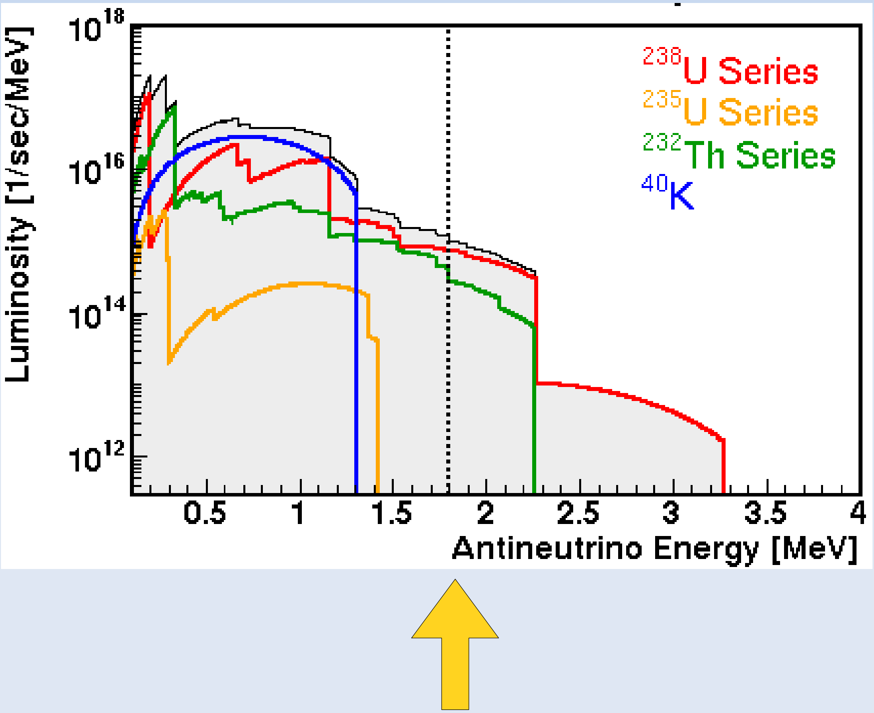
Geo-Neutrinos

- Radioactive decay ν's, 3.3 MeV or less
- Radiogenic heating contributes to plate tectonics and geomagnetic field
- Won't speak to ^{40}K content

$$^{238}\mathrm{U} \rightarrow \ ^{206}\mathrm{Pb} + 8\ ^{4}\mathrm{He} + 6\,e^{-} + 6\,\bar{\nu}_e$$

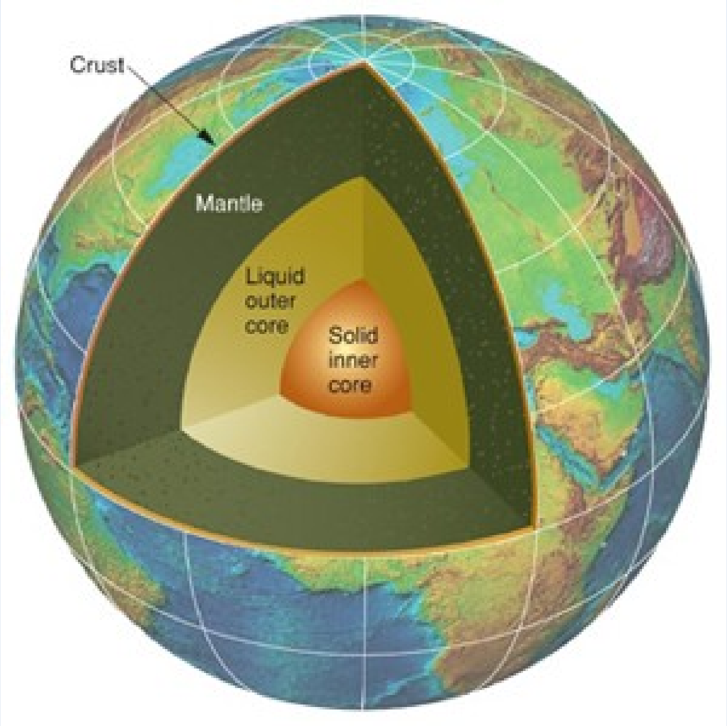
$$^{232}\mathrm{Th} \rightarrow \ ^{208}\mathrm{Pb} + 6\ ^{4}\mathrm{He} + 4\,e^{-} + 4\,\bar{\nu}_e$$

$$^{40}\mathrm{K} \rightarrow \ ^{40}\mathrm{Ca} + e^{-} + \bar{\nu}_e$$

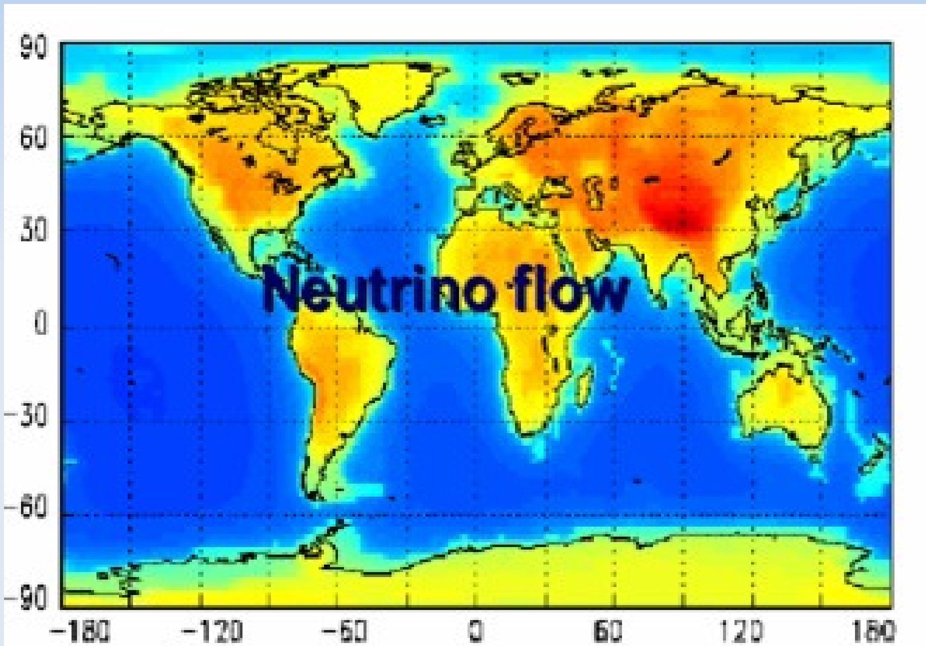


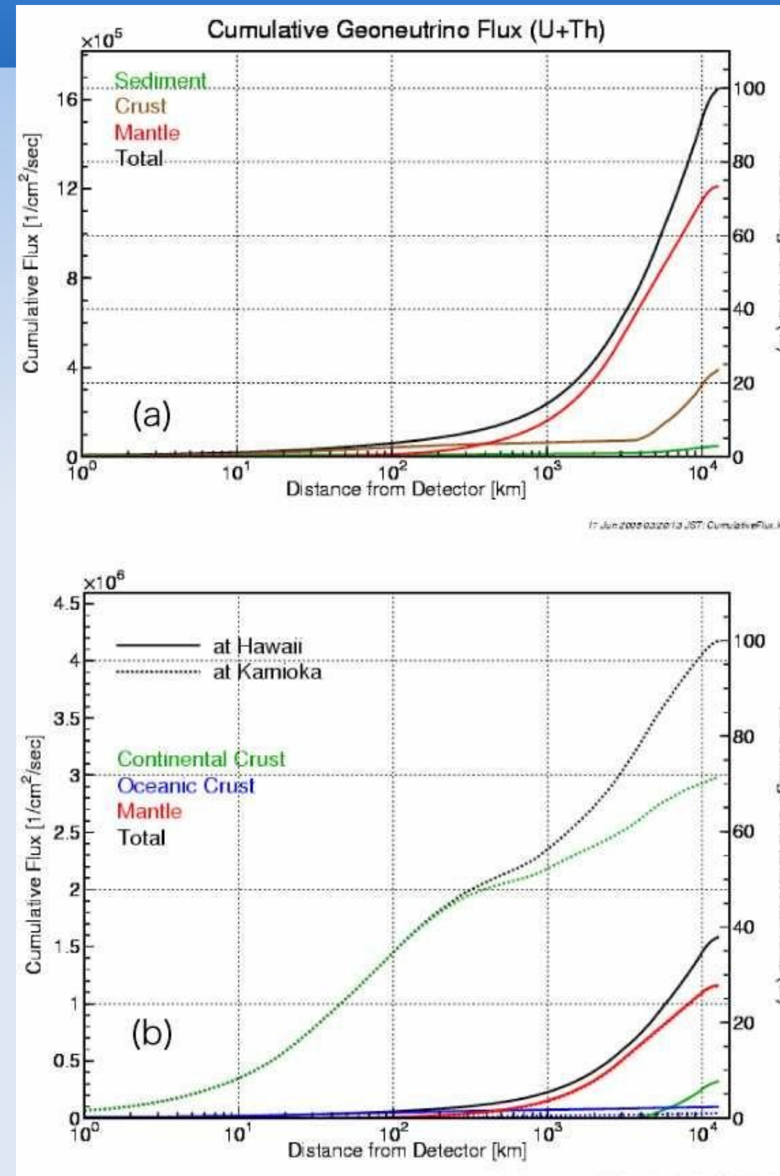
What's going on inside our planet?

- Seismic data gives density: inner/ outer mantle, inner/outer core
- Fractional U/Th in the crust is thought to be 100x that in the mantle, while the mass of the mantle is 100x the mass of the crust.
- Geo-reactor?
- Continental vs Oceanic



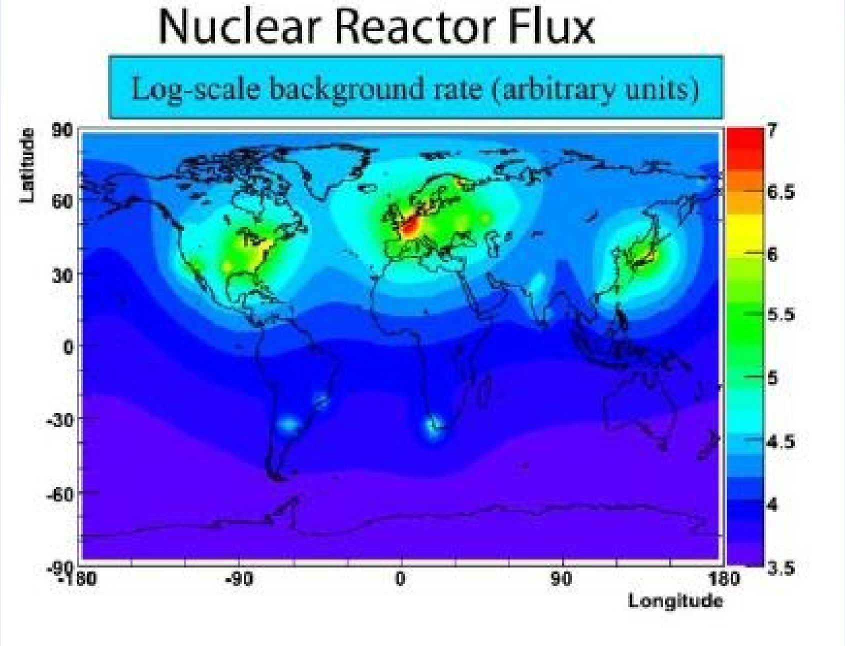
Where?


Neutrino flow
90
60
30
0
-30
-60
-90
-180
-120
-60
0
60
120
180


Cumulative Geoneutrino Flux (U+Th)
×10^5
Sediment
Crust
Mantle
Total
(a)
Cumulative Flux [1/cm^2/sec]
Distance from Detector [km]
Percentage of total (%)
×10^6
at Hawaii
at Kamioka
Continental Crust
Oceanic Crust
Mantle
Total
(b)
Cumulative Flux [1/cm^2/sec]
Distance from Detector [km]
Percentage of total at Kamioka (%)

Reactor Neutrino Background

- When trying to see geoneutrinos from the mantle (and/or core) reactors become background

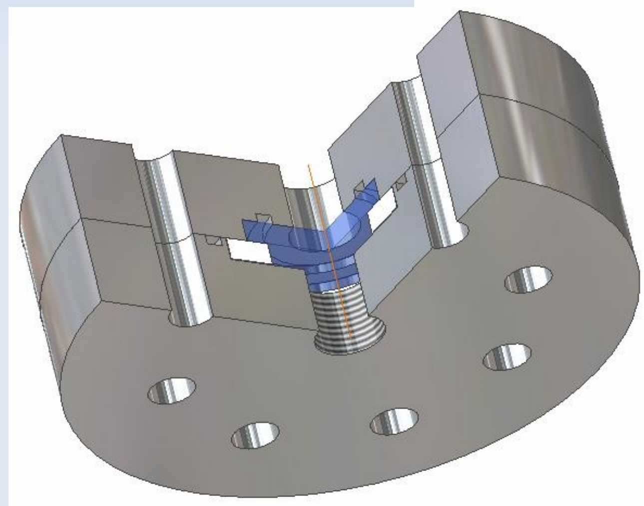


HANOHANO Applications

- Geoneutrinos – mapping the Uranium and Thorium content of the mantle (and core?)
- Reactor monitoring
- Measurements of mixing parameters:
    - Mass Hierarchy
    - Mixing angles
- Long baseline experiments

Liquid Scintillator Studies

- How will the scintillator perform at the ocean floor?
- LAB, PPO & BisMSB
- Bicron (proprietary)
- Depth of 4km:
  - 4 °C
  - 6000 PSI



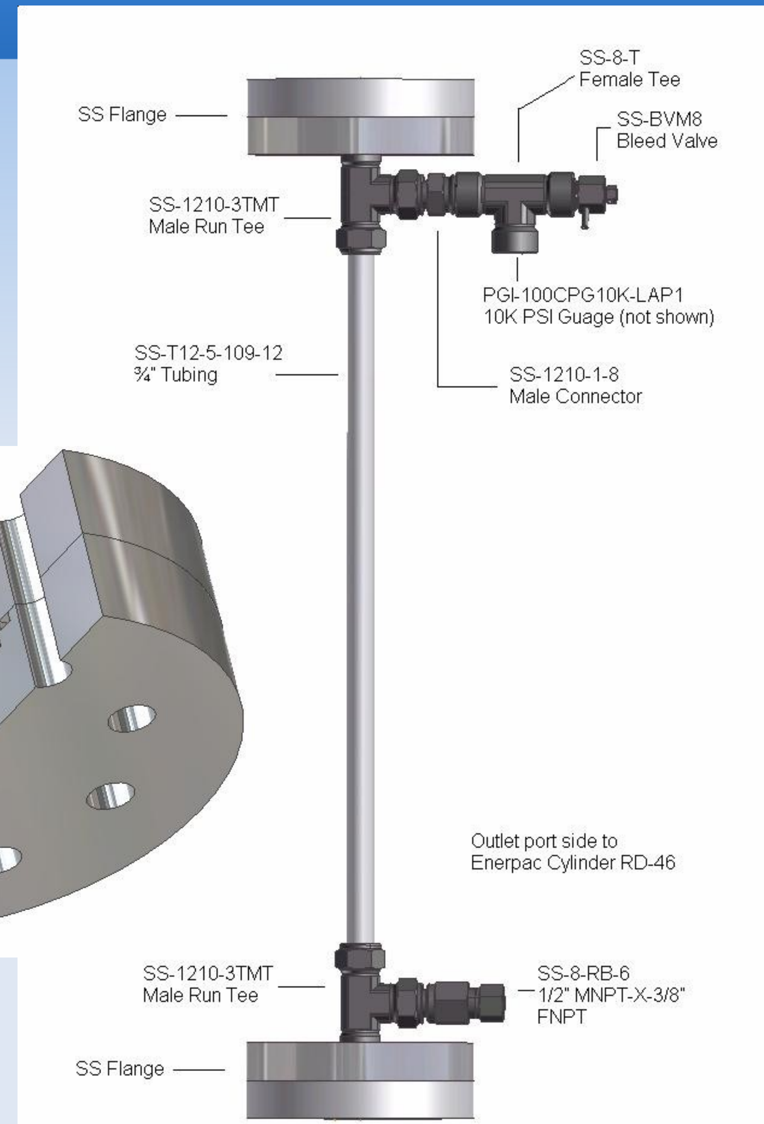
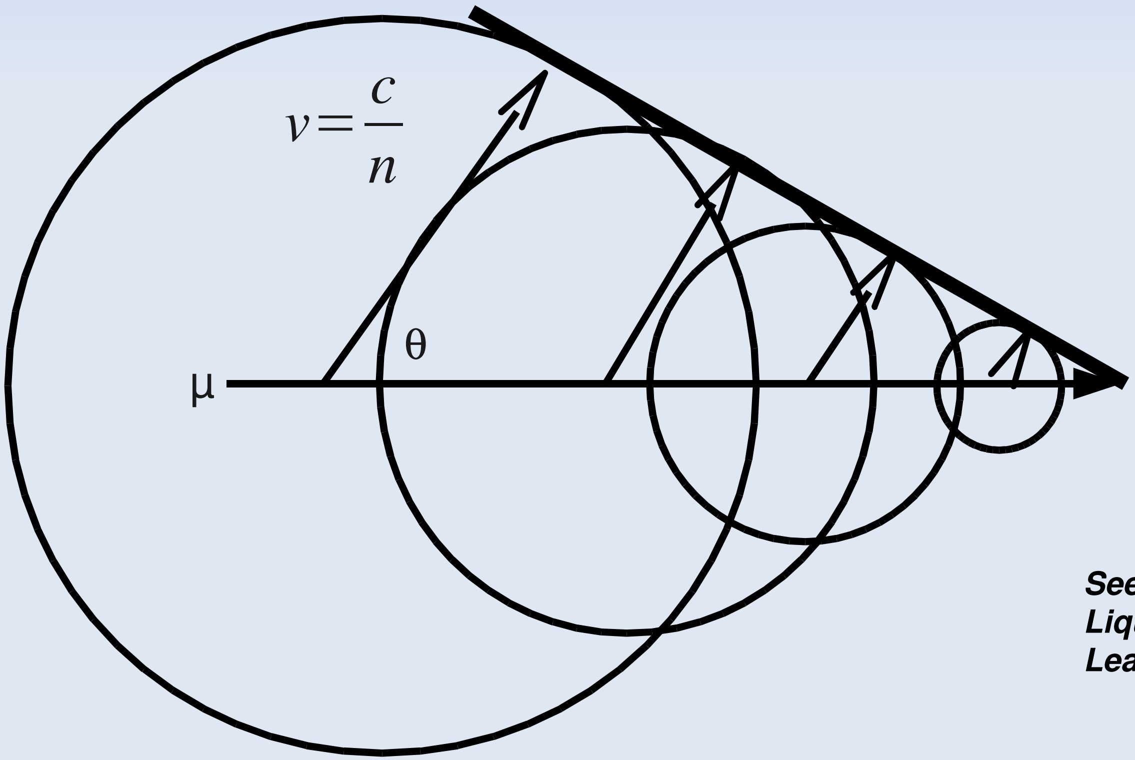


Figure 4.1: Stainless Steel Test Assembly

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."

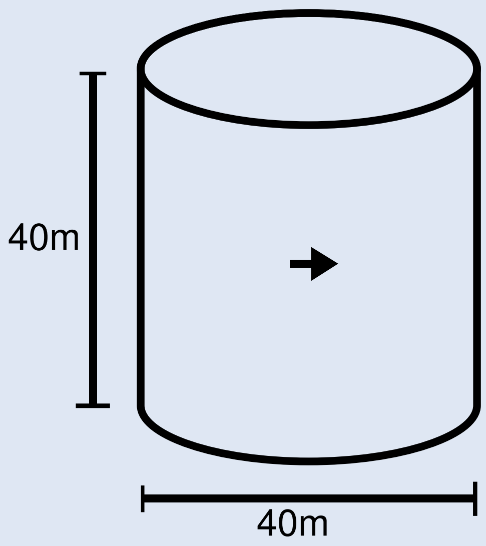


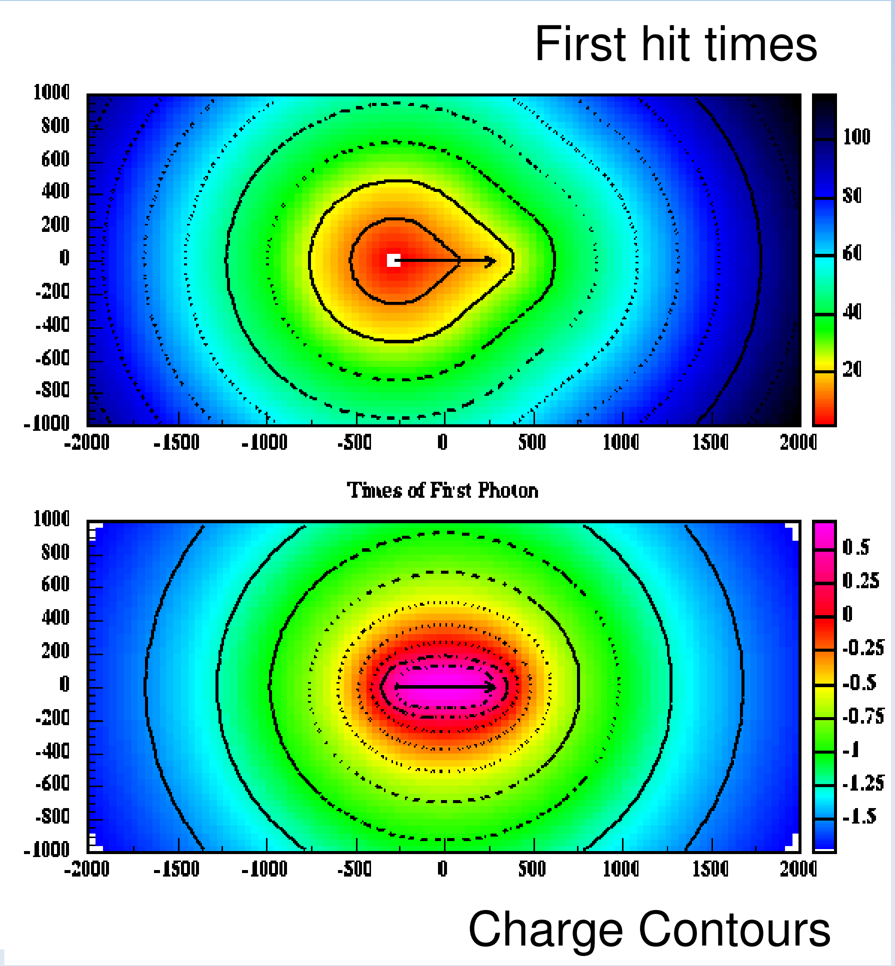
- As muon travels through liquid scintillator, photons are emitted isotropically.
- A "Fermat Surface" (Cerenkov and spheres) is defined by the wavefronts of first hit times
- Huge statistics determining this surface

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

Fermat and Equi-Charge Surfaces

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





The Fermat Surface

- Electron and muon events are distinguishable by differences between equi-charge and equi-time surfaces
- 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.)

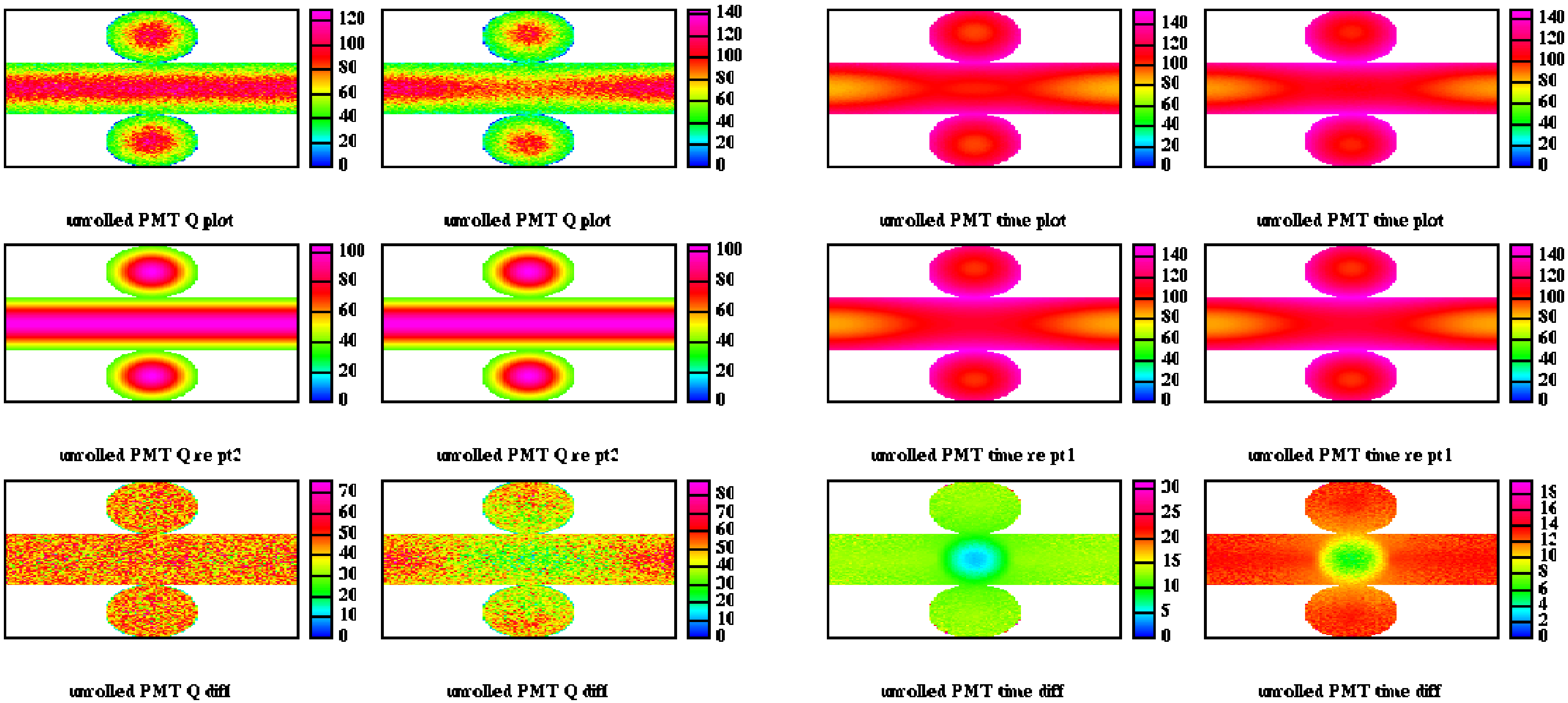
Time and Charge Fits

Charge | Time

MC data

point fit

diff.



muon | electron | muon | electron

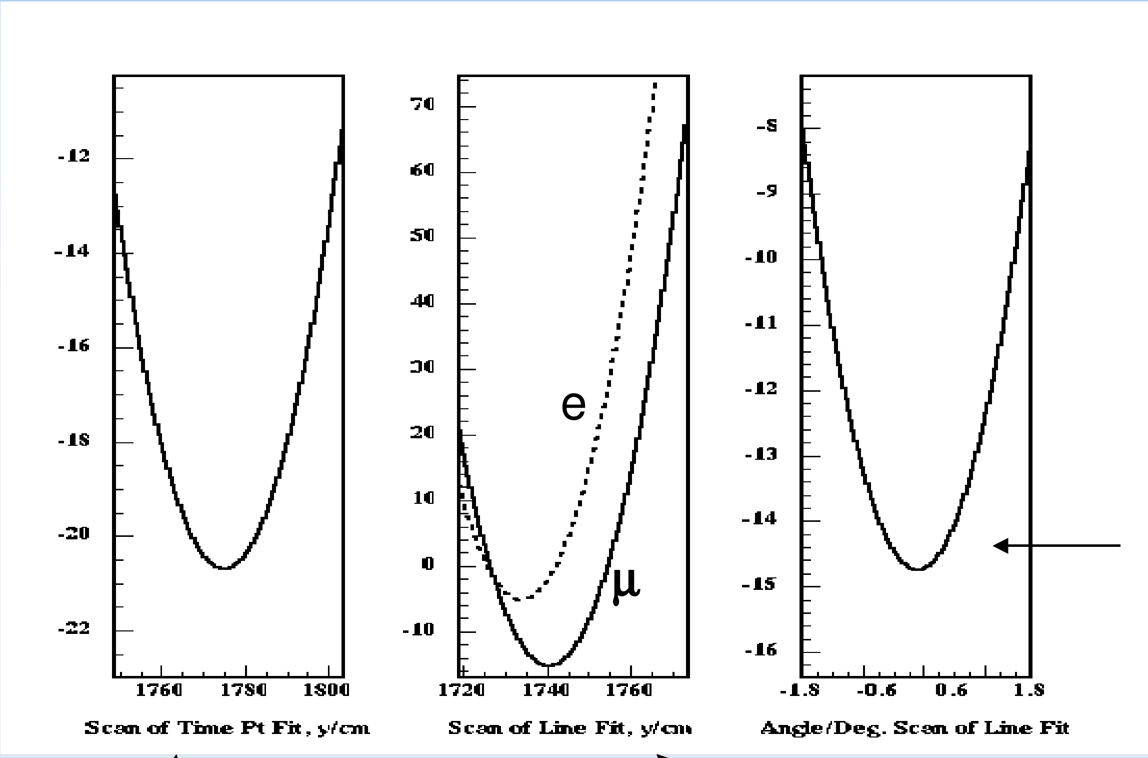
Conclusions: - Charge point fit to middle of track works well

- 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

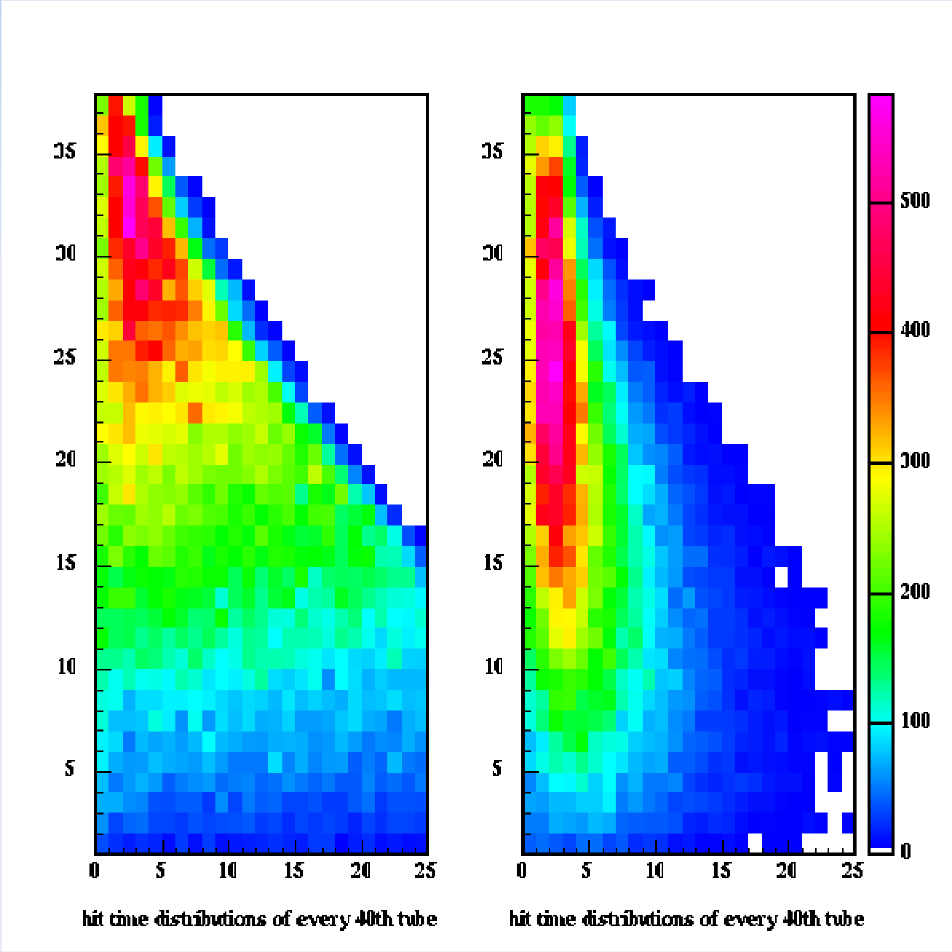
Vertex location to few cm with first point fit.

10 sigma better fit to line than shower profiles

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

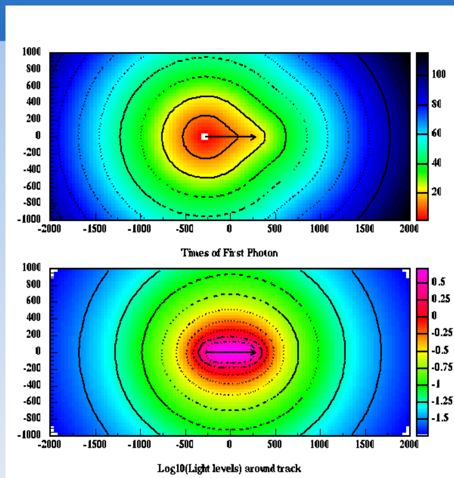
Sample PMT hit time distributions from top of detector

1 GeV Muon

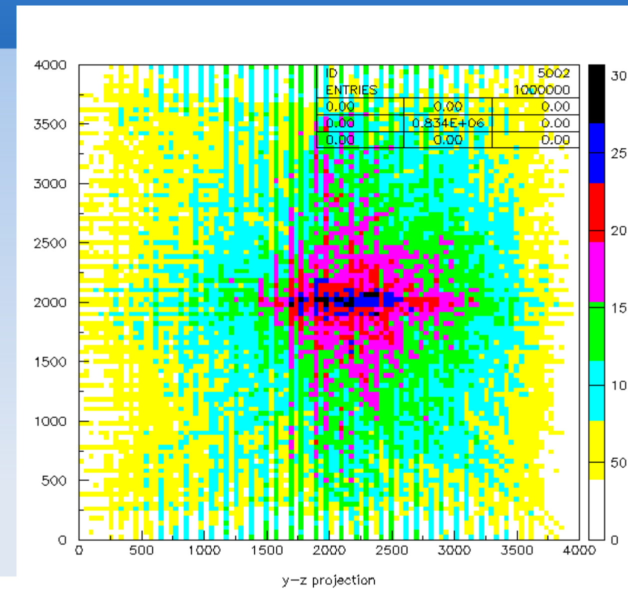


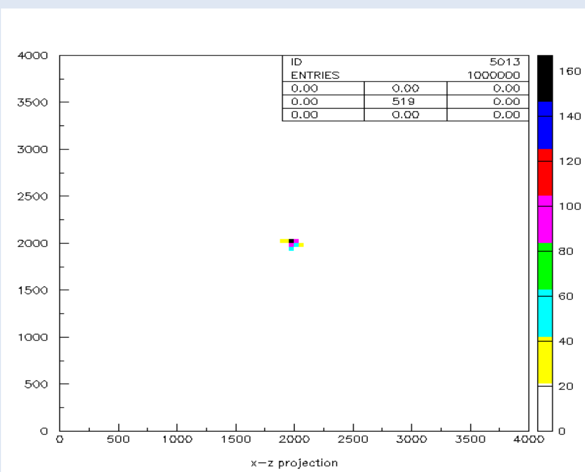
1 GeV e Shower

First Results on Tomographic Reconstruction

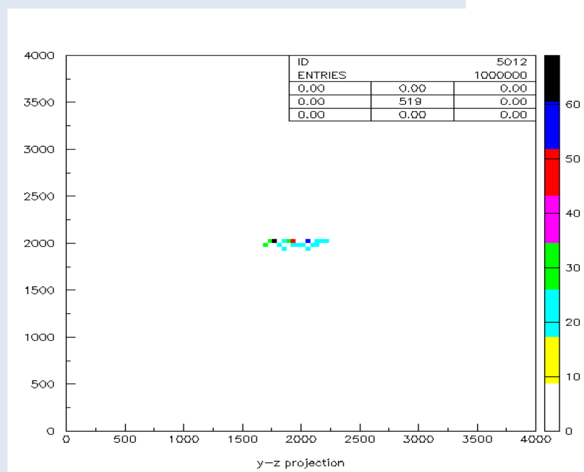


before contrast cuts

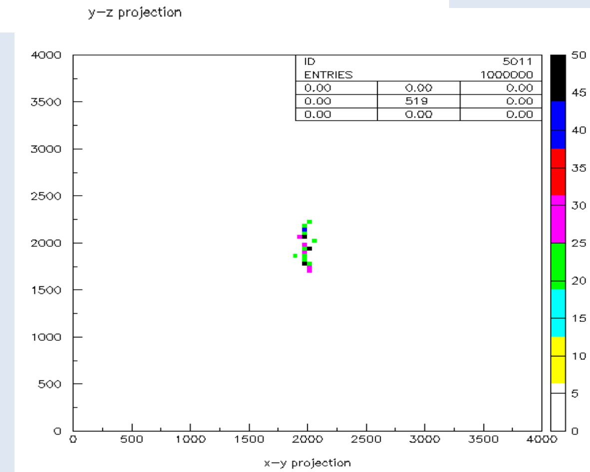




x-z projection



y-z projection



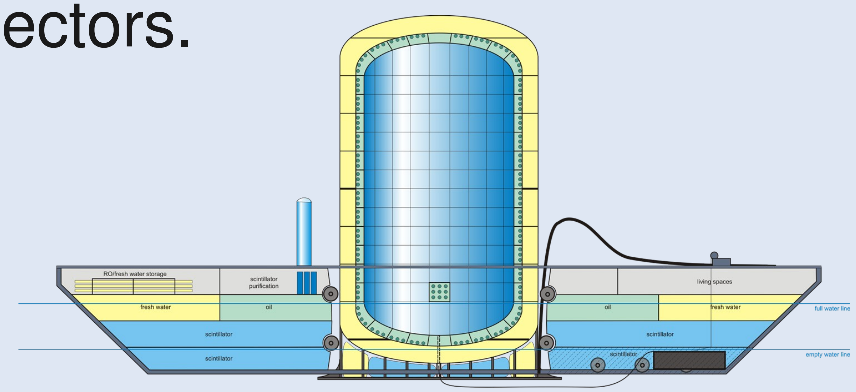
x-y projection

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

- Hanohano will give unique insights in geology and neutrino physics
- Development of Hanohano technologies is key to geoneutrino and reactor studies
- Large LS detectors are capable of detailed neutrino physics.
- “Fermat Surface” technique opens new avenues for neutrino physics with LS detectors.




Mahalo!