Muon Track Reconstruction: Likelihood Analysis

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Pacific Ocean Neutrino Explorer

• Neutrino Telescope
• Supported by ONC

• Will be part of Global Neutrino Network (GNN)

https://www.oceanetworks.ca/
STRAW: Pathfinder

Strings for Absorption length in Water

arXiv:1810.13265
https://www.pacific-neutrino.org/
Cherenkov Muon Tracks

\[ \nu \ell \rightarrow \ell \]

Courtesy of Wikipedia

Advanced Test Reactor core, Idaho National Laboratory

Illustration: APS/Joan Tycko; Neutrino event: IceCube
Simulation

- IceCube Software on Illume
- NuGen
- Clsim

- Pentagon Geometry:
  - 100 meters between strings
  - 40 meters between DOMs
  - 19 DOMs per string
  - 10 strings

- 400,000 events ranging from 100 GeV – 10,000 GeV
Reconstruction

LineFit

– Simple Chi-squared fit of a line to position-time of hits.

3D Track in Time
Reconstruction

Likelihood Fit
  – Statistical fit on hits of DOMs.

\[ L(\vec{\theta}; \vec{x}) \]

3D Track in Time
Likelihood Reconstruction

\[ p(\vec{x} | \vec{\theta}) \]

\[ t_{\text{res}} = t_{\text{hit}} - t_{\text{geo}} \]

\[ \mathcal{L}(\vec{\theta}) = \prod_{i} p(\vec{x}_{i} | \vec{\theta}) \quad \ell(\vec{\theta}) = - \log(\mathcal{L}(\vec{\theta})) \]
Muon Track

- Simple geometric derivations
- Rests on finding distance of closest approach

\[ d_i = \frac{d_{i,c}}{\sin \theta_c} \]

\[ t_{i,geo} = \frac{d_{i,c}}{\sin \theta_x \cdot c_n} + \frac{|q_i - q_0|}{c} \]
Muon Track

• Simple geometric derivations

• Rests on finding distance of closest approach

\[ d_{i,c} = |(\vec{r} - \vec{x}) - ((\vec{r} - \vec{x}) \cdot \hat{\vec{u}})\hat{\vec{u}}| \]
Likelihood Distribution

![Likelihood Distribution Diagram](image_url)
Likelihood Distribution
Testing Likelihood

- ~60 hit DOMs
- Fixed at True Vertex
- True direction \((\phi, \theta) = (1.10, 0.81)\)
Take Away

• P-ONE is an exciting new avenue of Neutrino Research!
• Analysis Software is being developed.
  – Track Reconstruction
  – Tau analysis
  – K decay