High Energy Imaging

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Motivation

- Utilize many photons at high energies to reconstruct event track shape.
- Reconstructing lepton direction gives handle on neutrino direction.
- lepton track shape gives handle on neutrino flavor.
- Use Fully contained events.

Where are They?

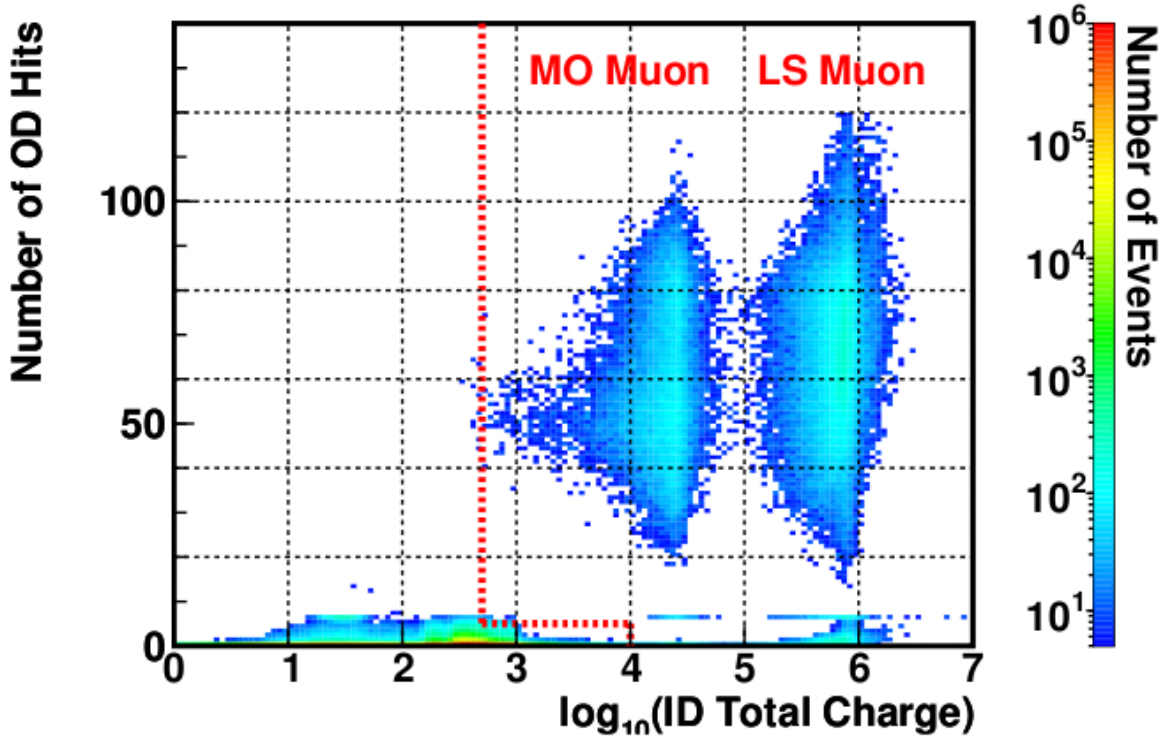
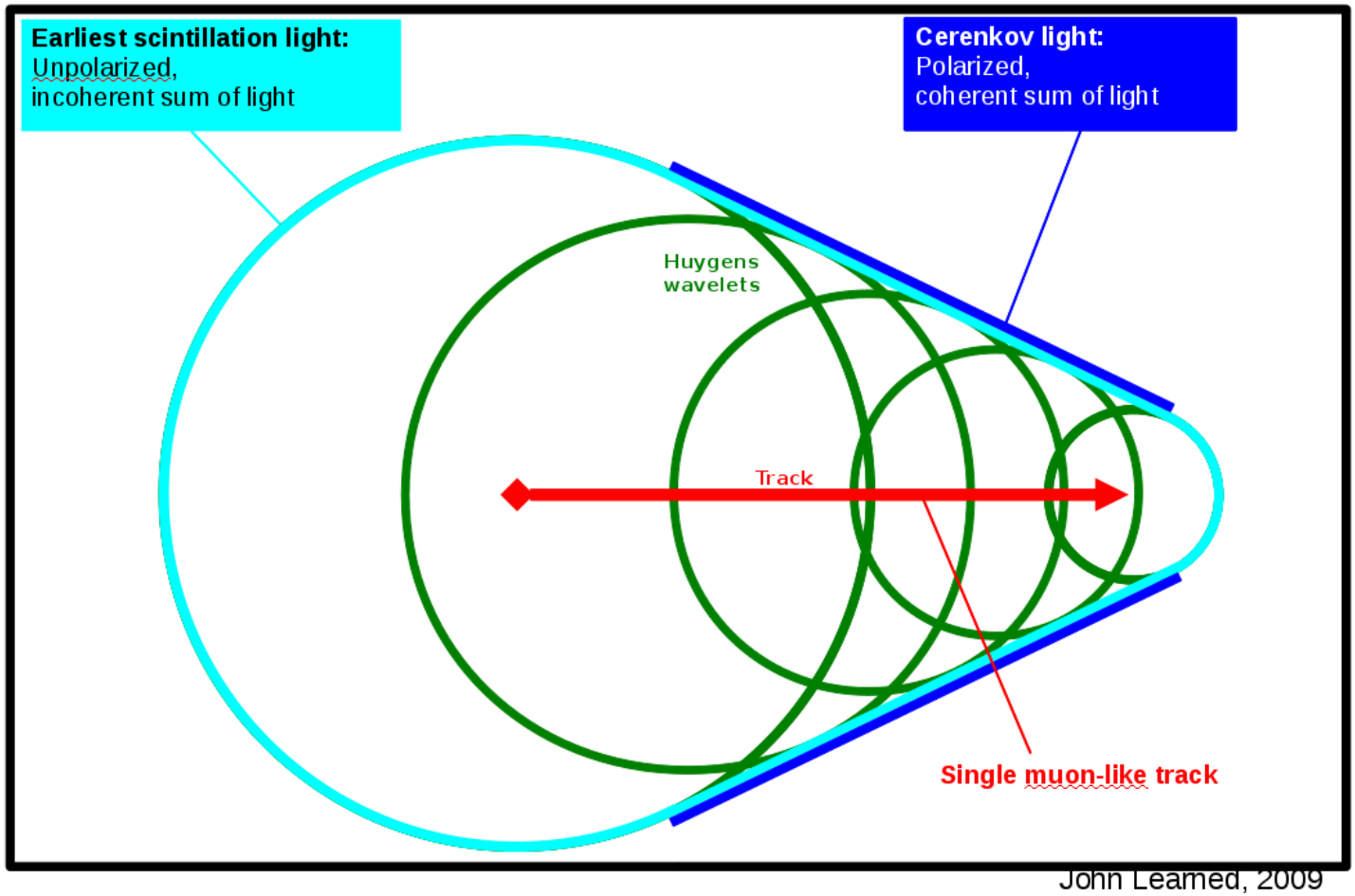


Figure 4.4: ID Charge and OD Hit Distribution

Figure: High ID PMT charge. Low OD hits.

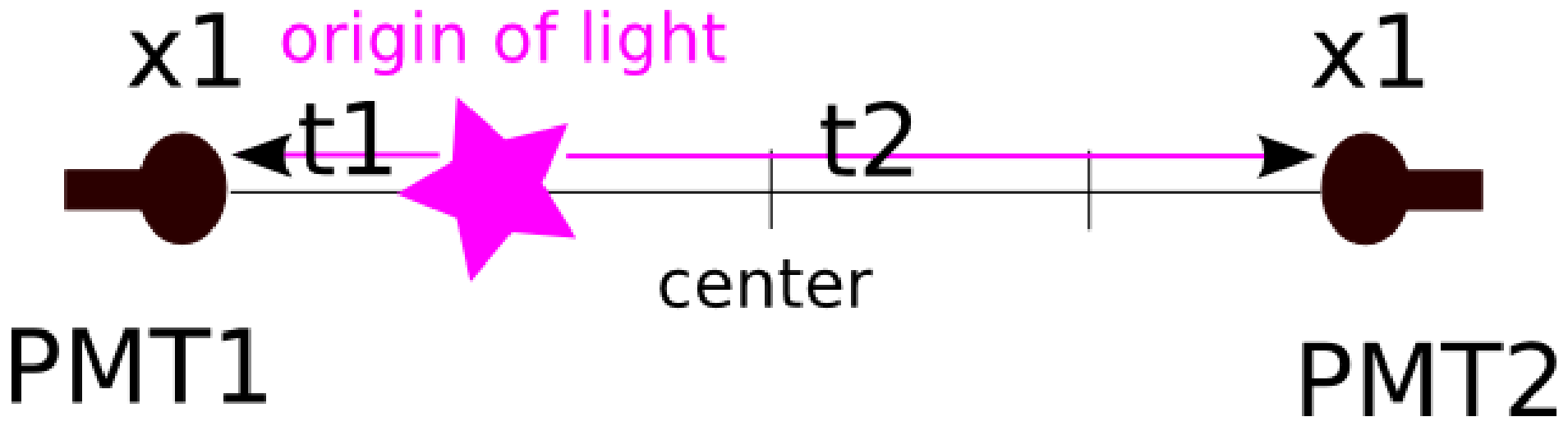
Diagram of Fermat Surface



Algorithm

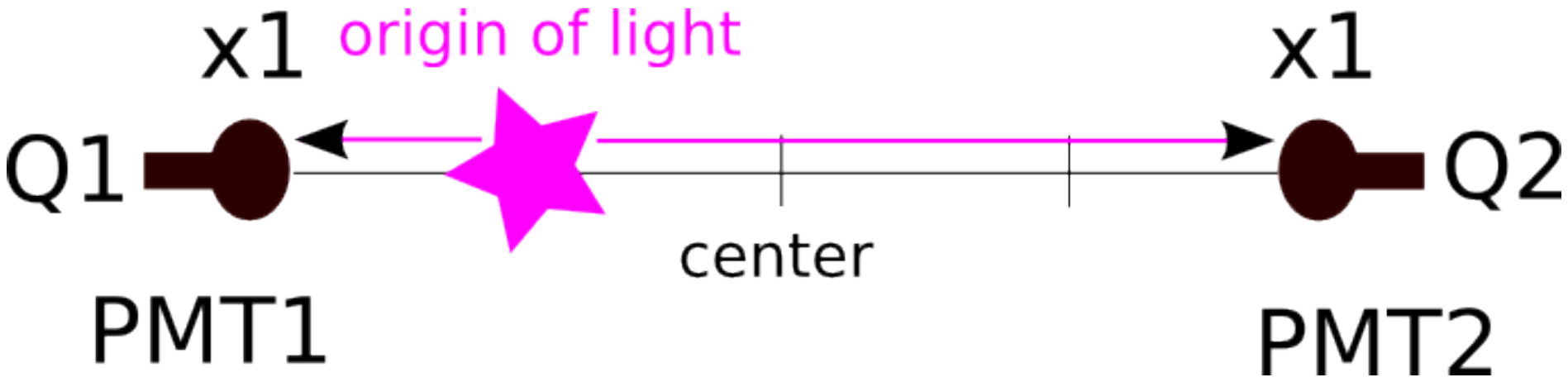
- Start with an initial guess of track direction.
- Center of $\frac{1}{time}$ to fit initial guess of beginning of track.
- Center of $\sqrt{charge}$ to fit initial guess of middle of track.
- Start with simple isotropic point source of light to test guess.

Algorithm



- Center of $\frac{1}{time}$ to fit initial guess of beginning of track.
- Center of $\frac{1}{time} = \frac{\frac{1}{t_1}x_1 + \frac{1}{t_2}x_2}{\frac{1}{t_1} + \frac{1}{t_2}} = \frac{1}{2}x_1$ gives correct vertex.

Algorithm



- Center of $\sqrt{charge}$ to fit initial guess of middle of track.
- Center of $\sqrt{charge} = \dfrac{\sqrt{q_1}x_1 + \sqrt{q_2}x_2}{\sqrt{q_1} + \sqrt{q_2}} = \dfrac{1}{2}x_1$ gives correct vertex.

Algorithm

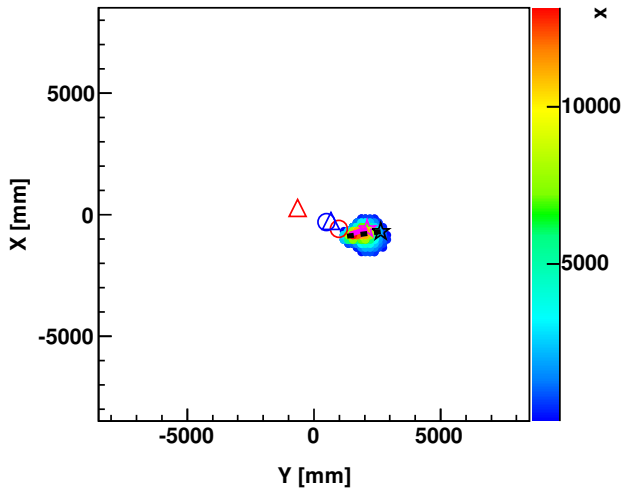
- Original algorithm by work left by D. Hellgartner.
- For given point x in detector:
  $h(x,t) = \sum_{\#PMT} \theta(q_i - q_{threshold}) f(\Delta t, t)$ where

  $f(\Delta t, t) = (\Delta t - t) exp(-\frac{(\Delta t - t)^2}{2\sigma^2})$, and $\Delta t = t_{hit} - t_{TOF}$
- Figure of Merit for Point x: $\int_{-\infty}^{\infty} |h(x,t)|^2 dt$
- Fit 3d regression line to resulting 4d FOM plot above some threshold.

Simulation Test

- Reconstruction algorithm was tested using KLG4sim.
- Energy = 1GeV
- Lepton flavor = e^+ and μ^-
- Events uniformly distributed inside outer buffer oil.
- Fully contained events (All ID PMTs hit and OD hit ¡ 5)

1GeV e^+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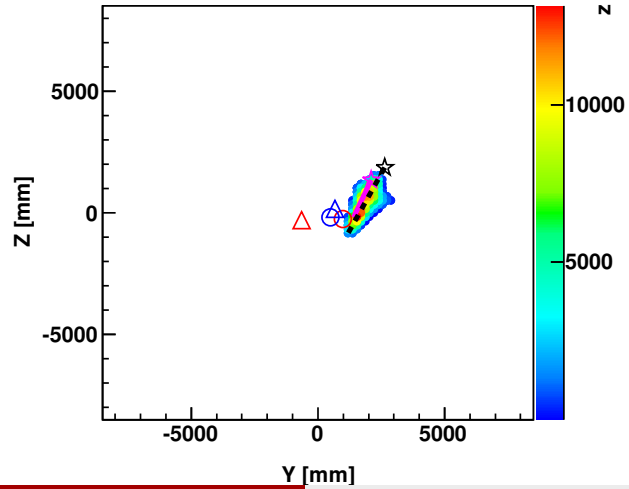
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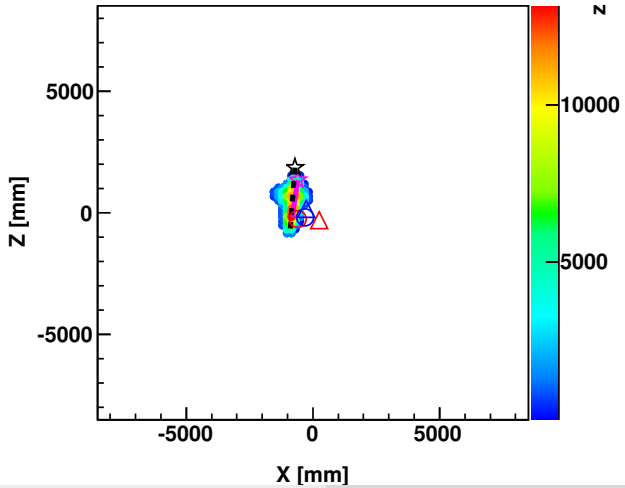
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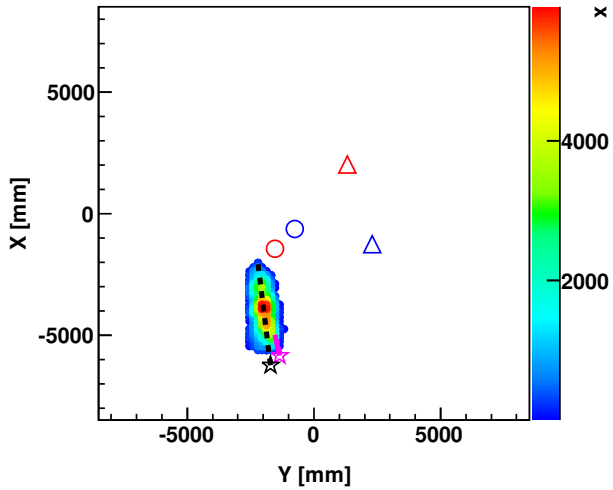
1GeV e^+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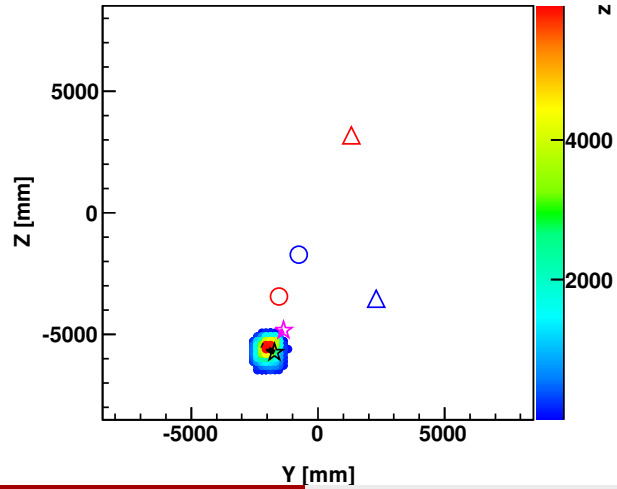
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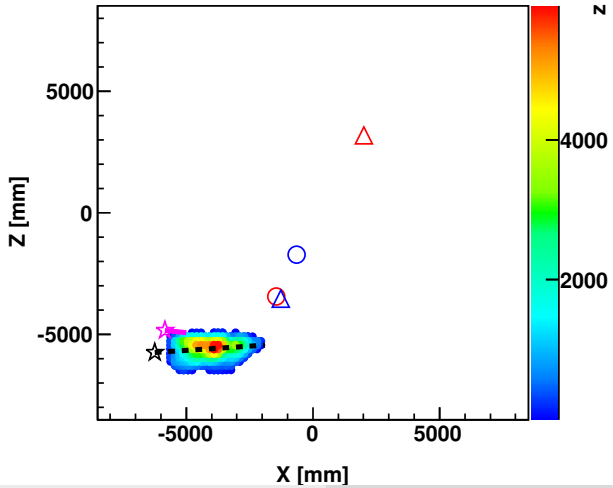
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X [mm]
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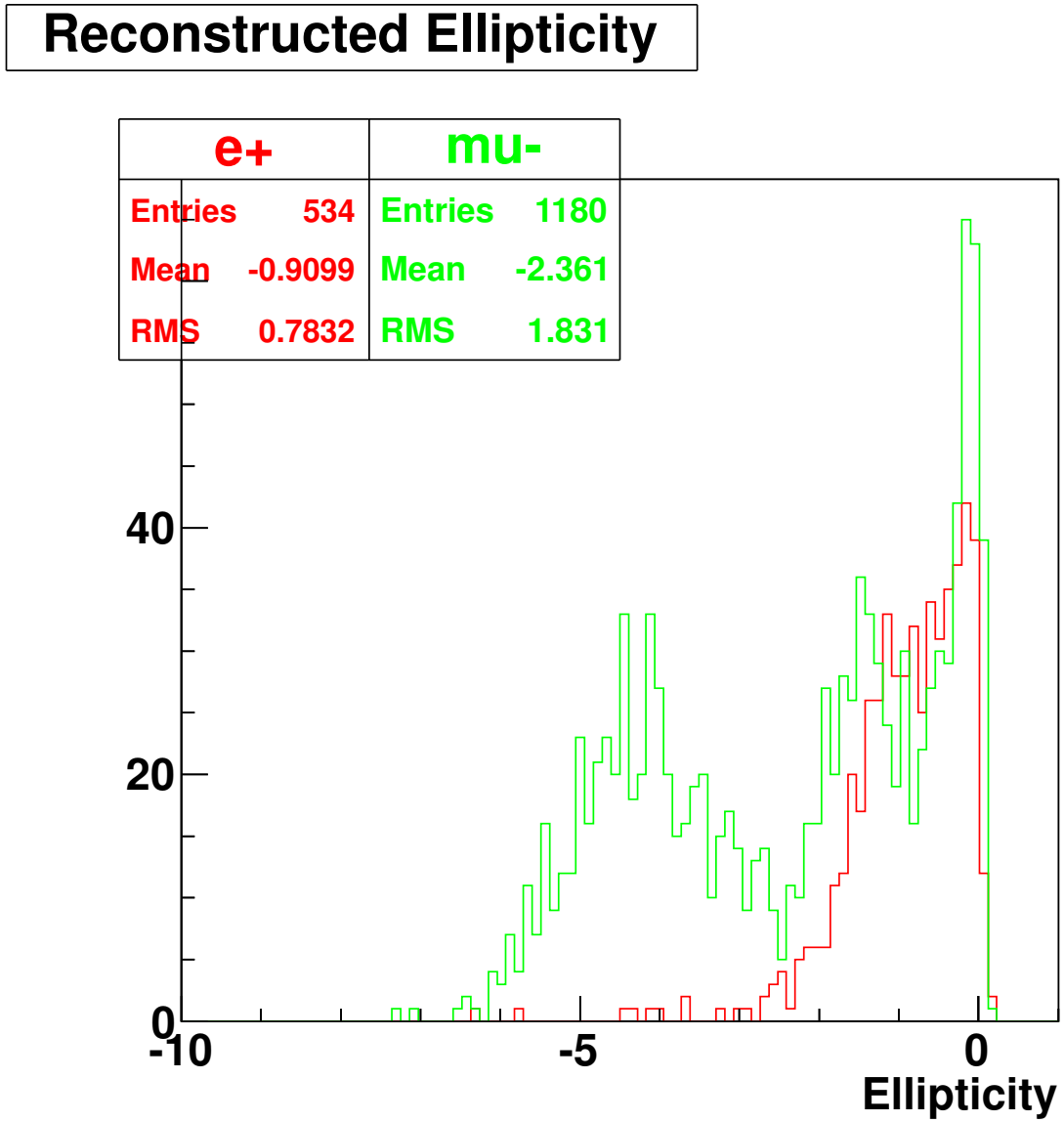
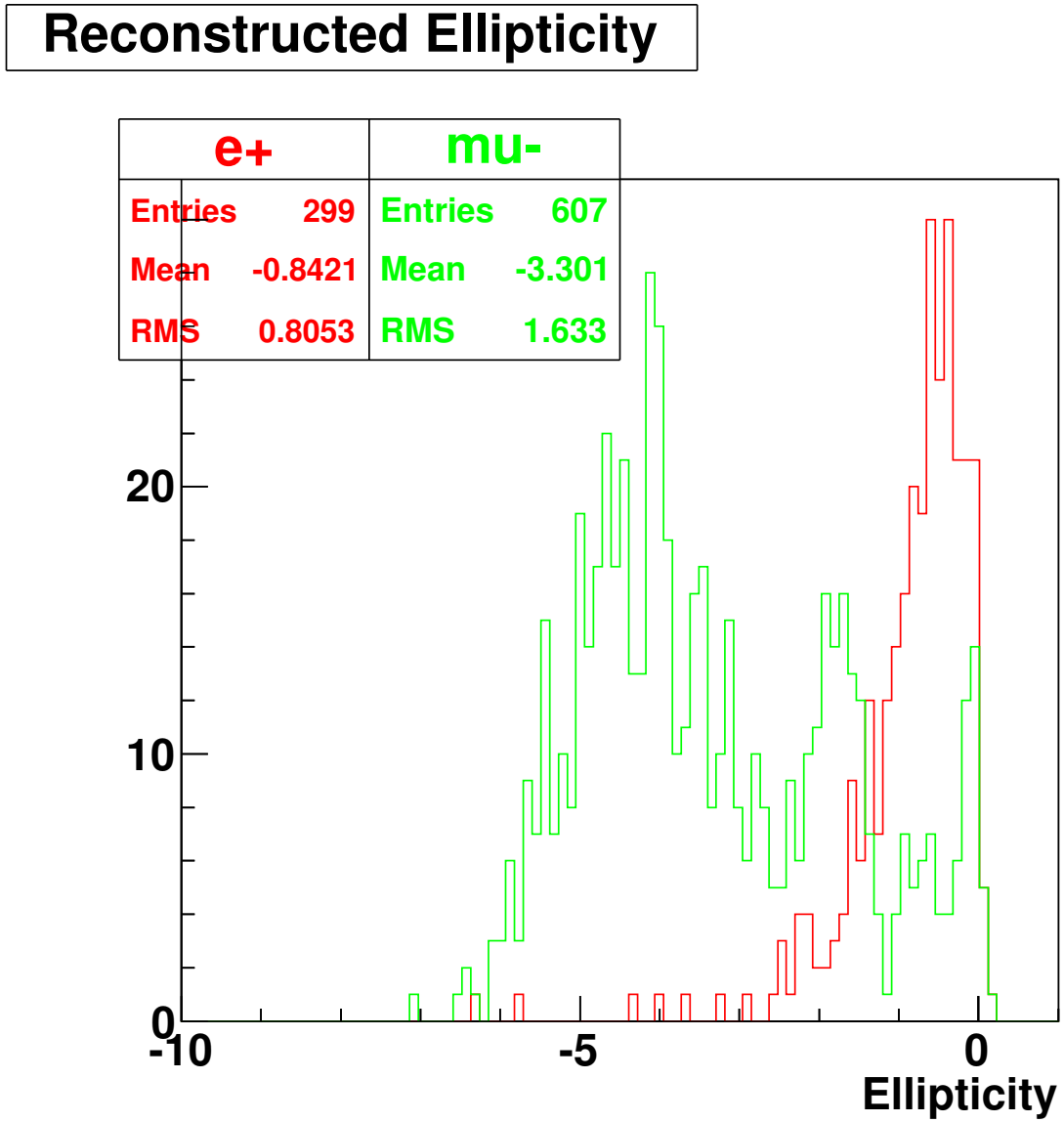
-5000
0
5000
4000
2000
z

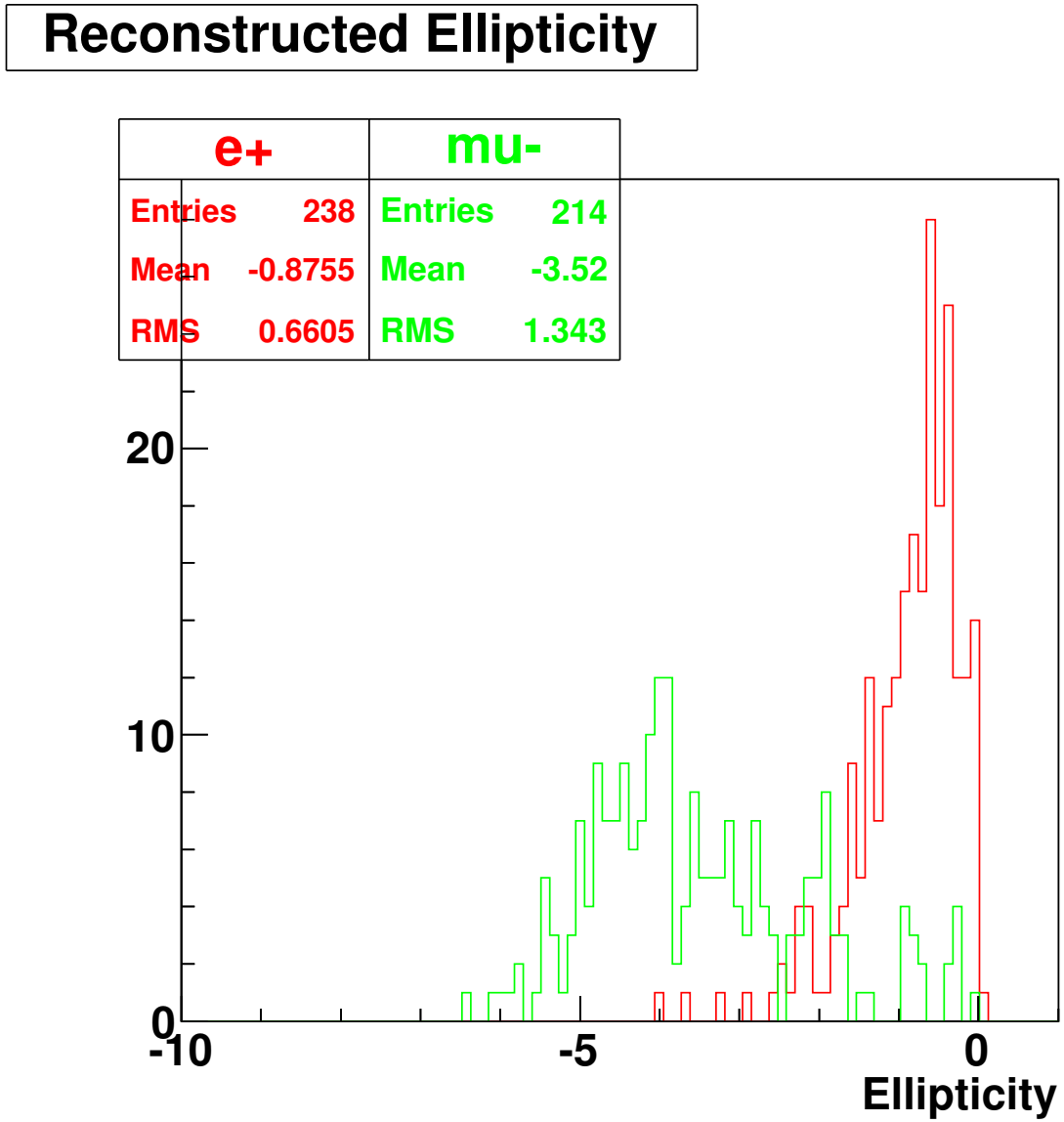
Lepton Flavor Discrimination (No Cut)



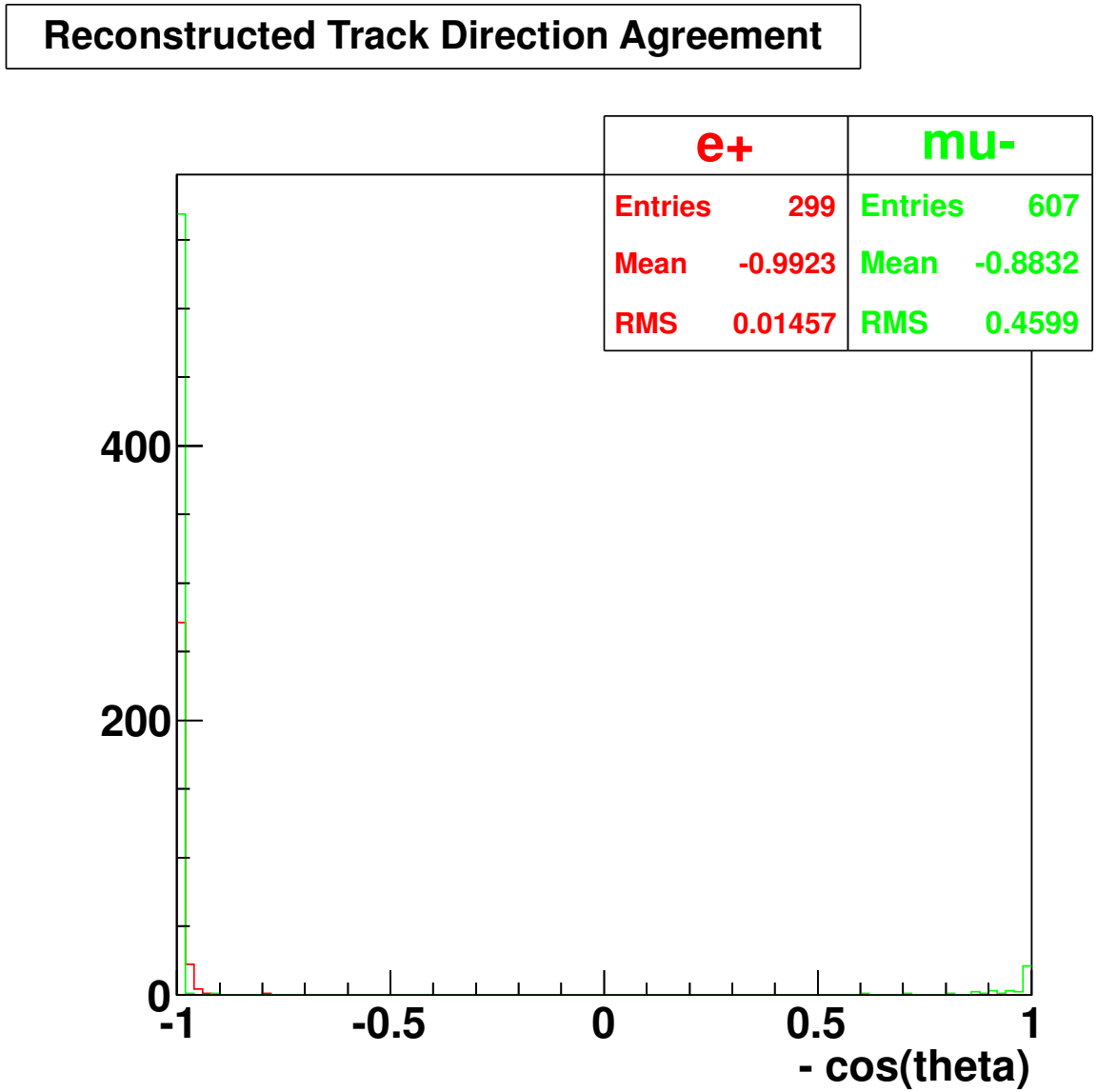
Lepton Flavor Discrimination (Track End 4m Cut)



Lepton Flavor Discrimination (Track End 3m Cut)



Reconstructed Angle



Lepton Flavor Discrimination

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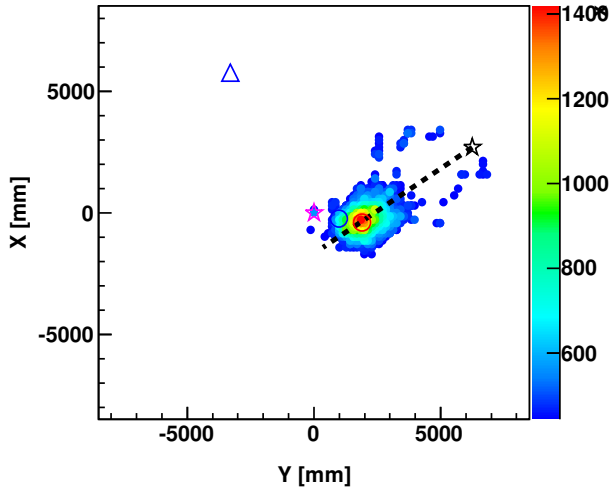
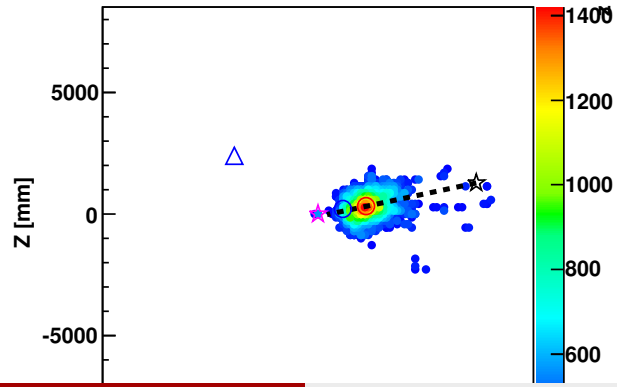
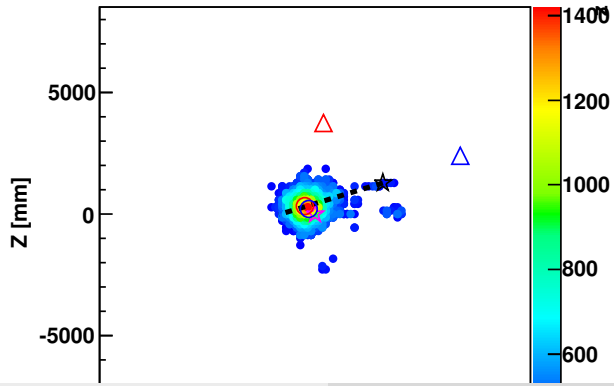
Fully Contained T2K Event A

- 76MeV

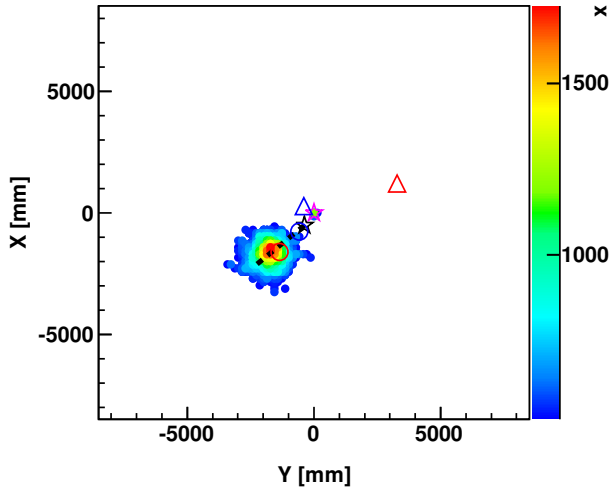


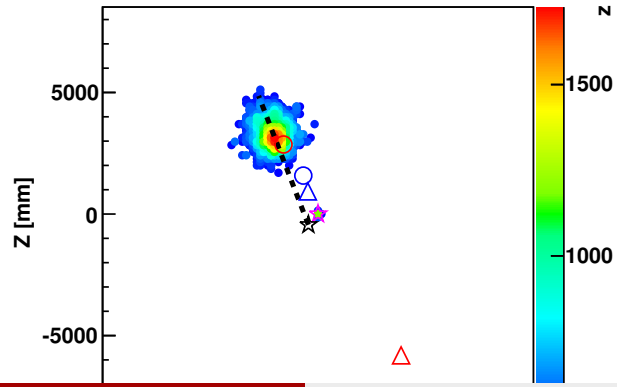


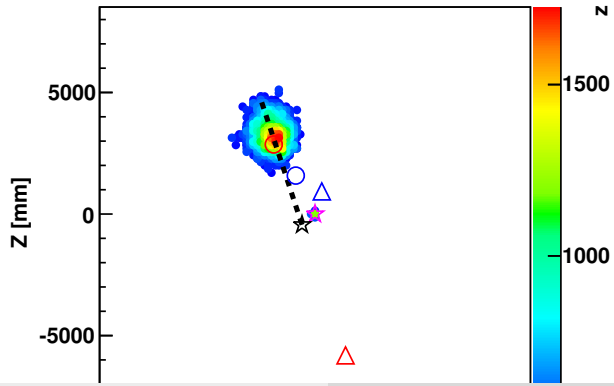


Fully Contained T2K Event B

- 131MeV

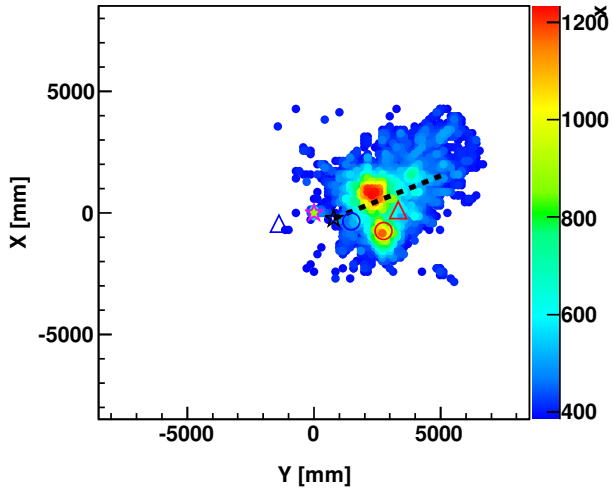


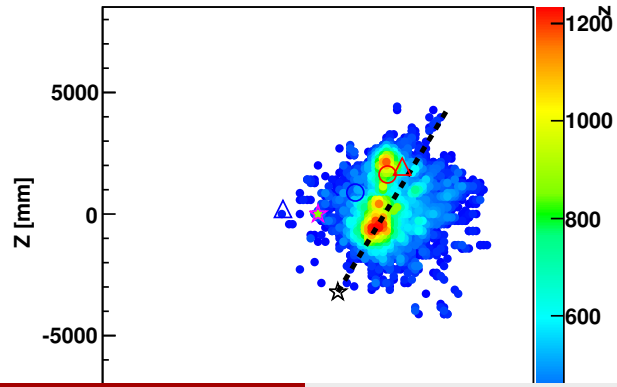


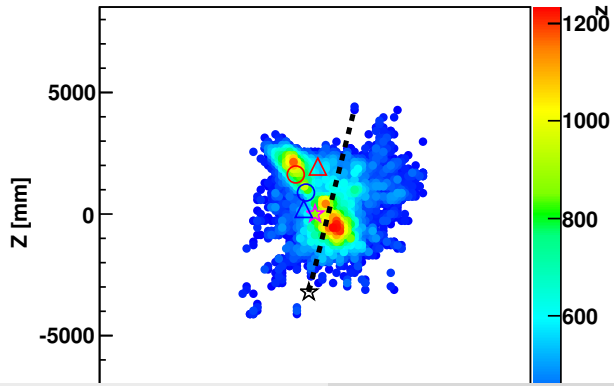


Fully Contained T2K Event C

- 363MeV







T2K Event Direction

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T2K Event e/μ-like discrimination

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