Muon reconstruction in AD

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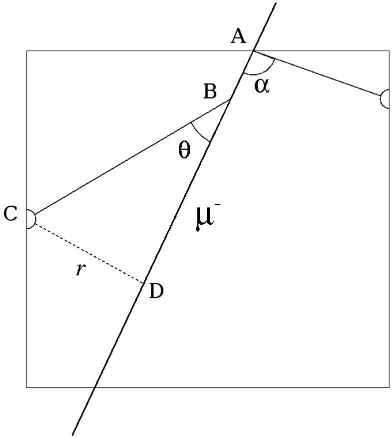
Dayabay Collaboration

First light

$$t = \frac{|BC|}{c/n} + \frac{|AD| - |BD|}{c} = \frac{n|CD|}{c\sin(\theta)} + \frac{|AD| - |CD|\mathrm{ctg}(\theta)}{c} \qquad (1)$$

- Assume muon travels at the speed of c. Mineral oil and liquid scintillator have similar reflective index, $n \sim 1.5$. $(|CD|, |AD|)$ are constants once the track's direction and position are known. $dt/d\theta = 0$ $\rightarrow \cos(\theta) = 1/n$. The angle happens to be same as Cherenkov angle.
- If $\alpha > \theta_{ch}$ at entry point, direct light is the first light arriving PMT.
- If $\alpha < \theta_{ch}$ at exit point, direct light is the first light arriving PMT.

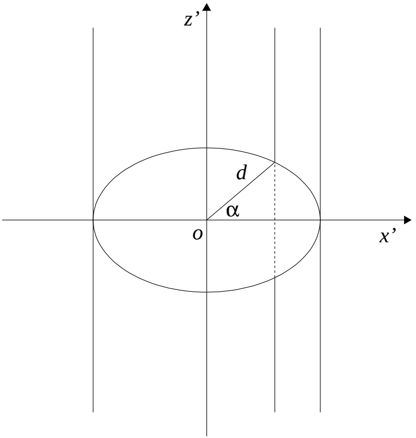


Some input parameters

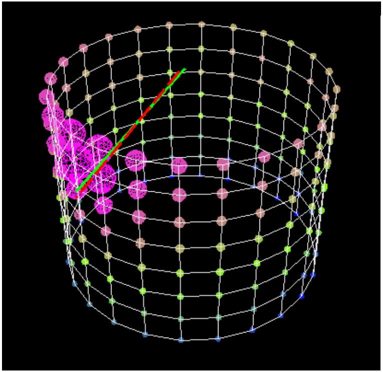
- Liangjian's Doc 2328, 3783.
- From Doc 2328, $\sigma(t)$ ~1.2 ns
- About 90000 photons for 5 GeV μ^-
- $\sigma(t_{firsthit})$ ~0.5 ns for 100 hits per PMT
- $\sigma(t_{firsthit})$ depends on number of hits, currently all use $\sigma(t_{firsthit})$ =1 ns.
- Construct $\chi^2 = \sum(\frac{t_{firsthit} - t_{expect}}{\sigma(t_{firsthit})})^2$.

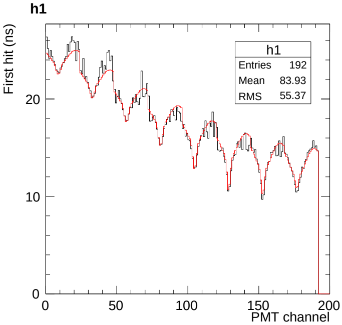
A trick from Dan

- If fit the track with direction (θ, ϕ) and a point (x_0, y_0, z_0), the fit will not be stable since the point can move along the track.
- Dan's suggestion: select the nearest point which is unique.
- Only need two parameters for this point, instead of three.
- Rotate the original coordinates (x-y-z) to a new coordinates $(x' - y' - z')$ with $x' - y'$ plane perpendicular to the μ track. The nearest distance d and angle α give the point position in the new coordinates, then roates back to original coordinates to get the original position.



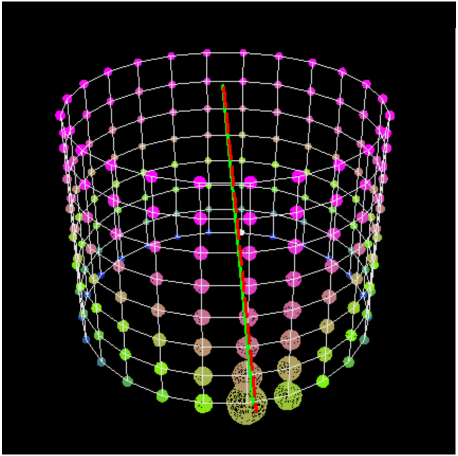
Event 0

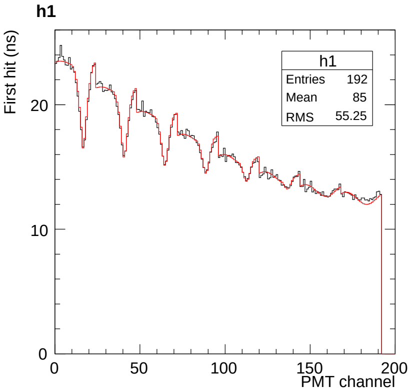


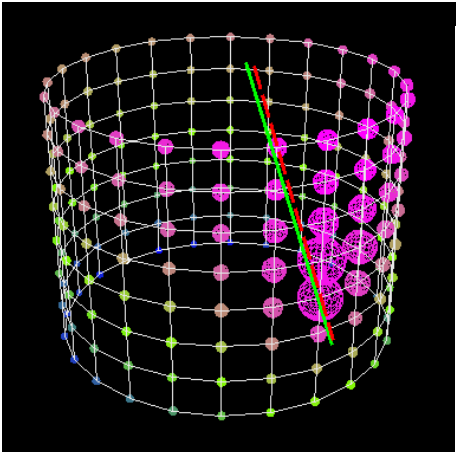


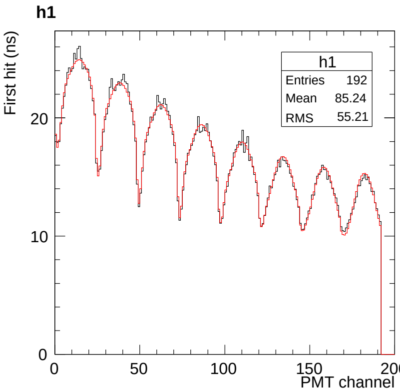
- Left: PMT size shows the charge, color shows the first hit time.
- Green line is the true μ track
- Dashed red line is the reconstructed track
- Right: First hit distribution for the 192 PMTs, red is the fit result.

Event 1

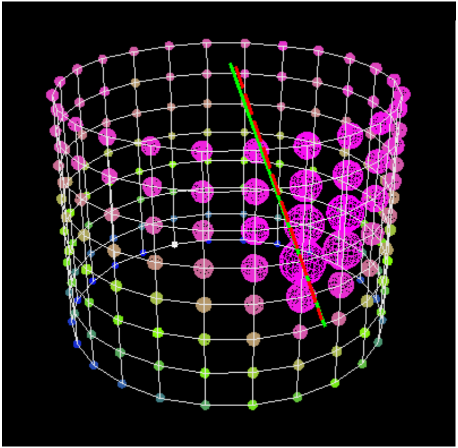


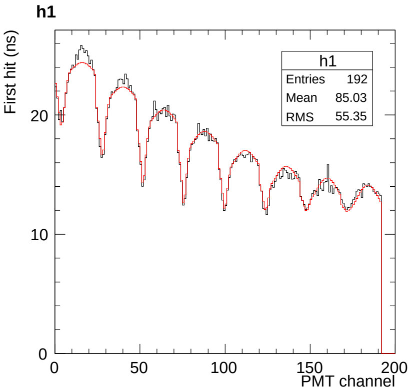

h1
First hit (ns)
PMT channel
0
10
20
0
50
100
150
200
h1
Entries 192
Mean 85
RMS 55.25

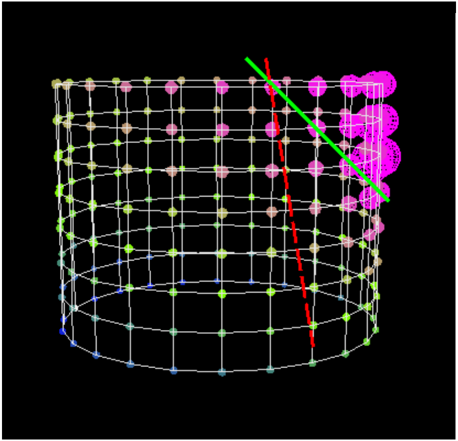


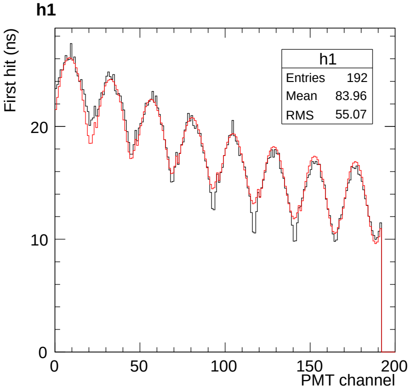

h1
First hit (ns)
PMT channel
0
10
20
0
50
100
150
200
h1
Entries 192
Mean 85.24
RMS 55.21

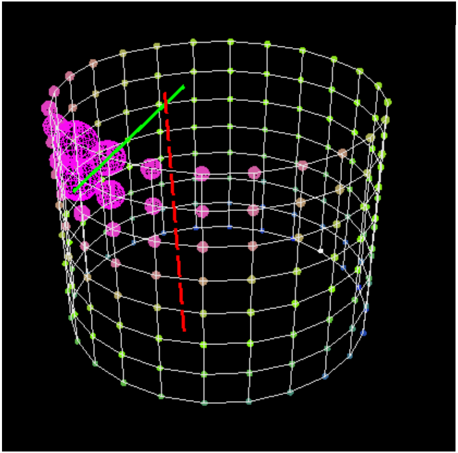
Event 4

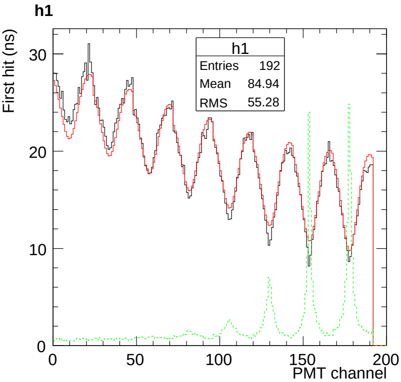



h1
First hit (ns)
h1
Entries 192
Mean 85.03
RMS 55.35
0
10
20
0
50
100
150
200
PMT channel



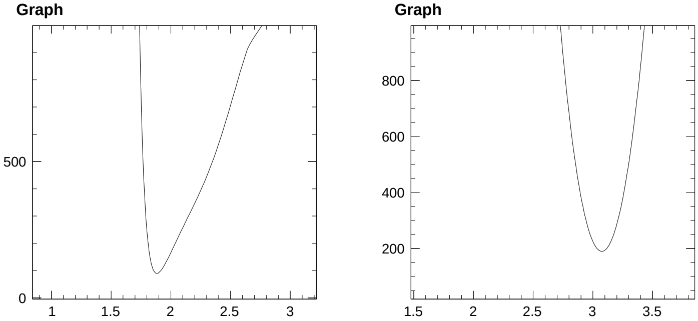

h1
First hit (ns)
h1
Entries 192
Mean 83.96
RMS 55.07
0
10
20
0
50
100
150
200
PMT channel





- Green dashed histogram shows number of hits

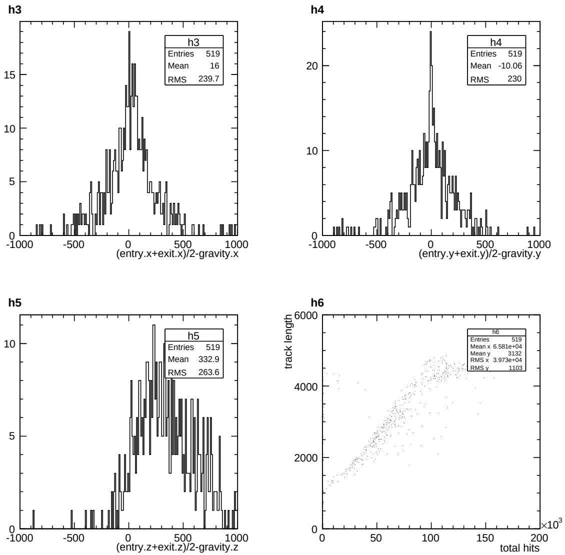
Event 15: χ^2 vs. θ



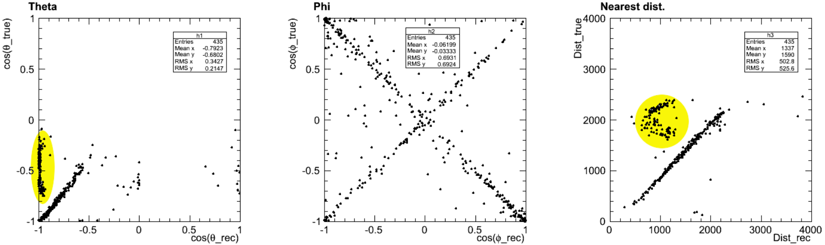
- left: χ^2 around truth value (minimum $\sim$ 90)
- right: χ^2 around fitted value (minimum $\sim$ 190)
- fitted value is a local minimum

Incorporating charge information

- We can incorporate some charge information in the fit
  - Gravity center (Zhe's Doc 4054)
  - Track length
- In the last plot, the track length does not start from 0, probably is due to the track length is calculated in Mineral oil, not in liquid scintillator.



Fitting with gravity center included



- Only gravity center is considered in this fit.
- If θ changes from $< \pi$ to $> \pi$, ϕ changes by π.
- Results improved, but still have 36% fits not good.
- Hope including track length and fine tuning fit parameters will improve more.

Future work

- Current work is based on SimHeader, better to use readout later.
- Fine tuning some input paramters.
- Incorporate charge information more carefully.
- Think about incorporating all muon systems to make a single fit.
  - RPC can give good constrain on entry point.
  - Inner water shield and outer water shield reconstruction also use first light information.