Water Pool Muon Reconstruction

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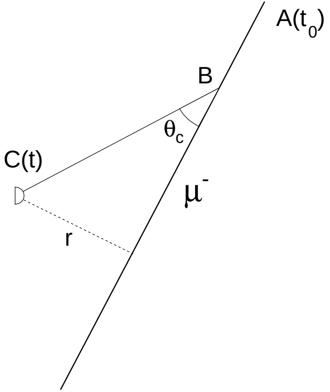
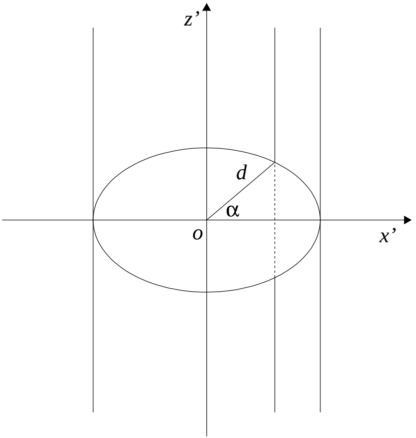
Dayabay Collaboration

- Assume μ travel with speed of light c.
- n = refractive index of water
- $t_{expect} = t_0 + |AB|/c + |BC|/(c/n)$
- $\chi^2 = \sum(\frac{t_{expect} - t_{observe}}{\sigma})^2$
- Choose the cloest point to OWS center as $A(t_0)$, 5 parameters (θ, ϕ, *dist*, α, t_0) in the fit. (*dist*, α definition explained in next page.)

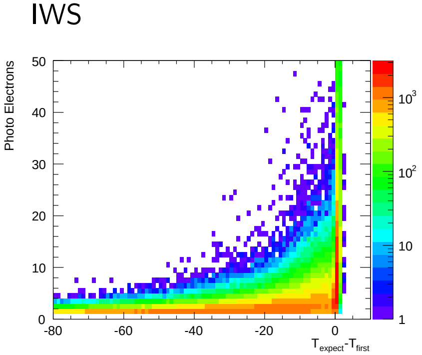


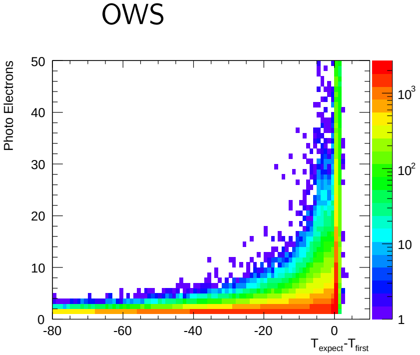
A trick from Dan

- 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.



$T_{expect} - T_{first}$ distribution

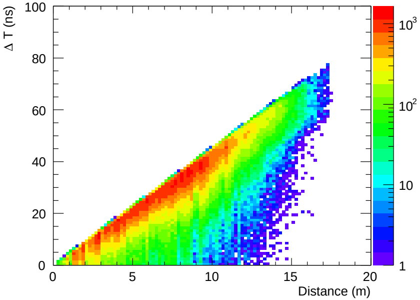




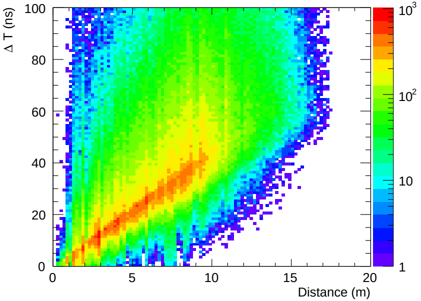
- Lots of reflect light

Distance vs. Δt

Expect



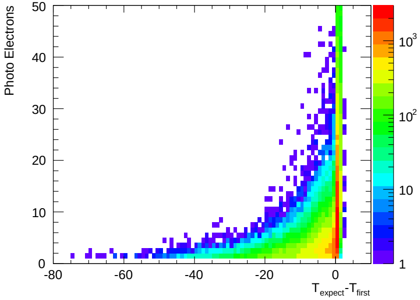
Observe



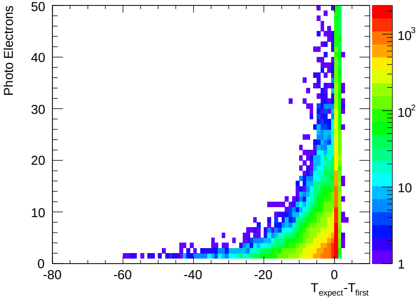
- Distances from the first hitted PMT to other PMTs
- dist/$\Delta t \geq$ c/n if there is no reflect light
- It is a great tool to remove reflect light.

Remove reflect light

IWS



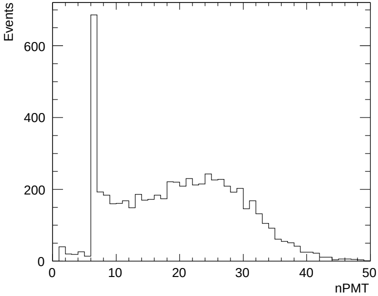
OWS

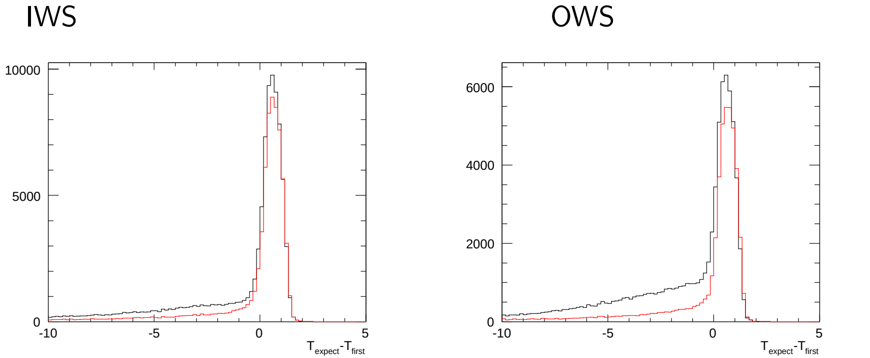


- Apply the cut: dist$/\Delta t \geq$ c$/$n

Remove reflect light

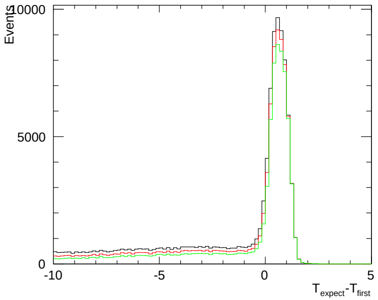
- The above cut uses distances and Δt information with respect to the first hit PMT
- We may benefit more from similar cuts with respect to other PMTs as long as those PMTs' first hits are not from reflected light.
- PMTs with large hits usually has first hit from direct light.
- Loop the PMTs with large hits and apply the $dist/\Delta t$ cut (if $n_{PMT} \leq 6$, stop the process).



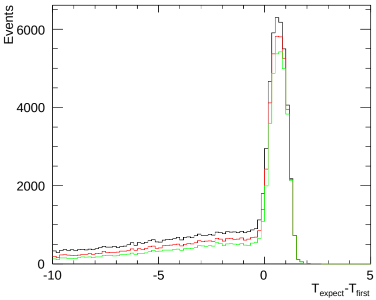


- Black hitogram: Only apply the cut with respect to first hit PMT
- Red histogram: Also apply cuts with respect to large hits PMTs ($n_{PE} \geq 8$)
- Possible reason for offset: PMT position is different from photon collection point, refractive index depends on wave length, μ speed not equal speed of light.

IWS

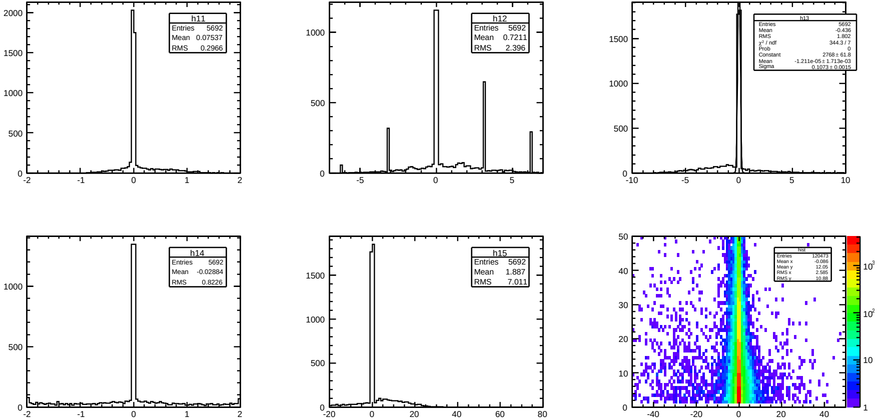


OWS



- Black hitogram: $n_{PE} \geq 3$
- Red hitogram: $n_{PE} \geq 4$
- Green hitogram: $n_{PE} \geq 5$

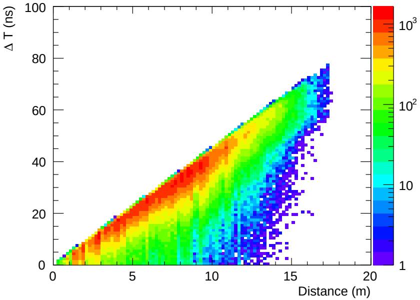
Initial value dependent fit



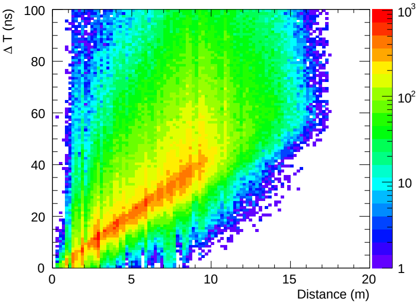
- Set the data with true value, then fit it.
- Initial values: $\theta = 2.7$, $\phi = 1$, $d = 2\,\text{m}$, $\alpha = 2$, $t_0 = 5\,\text{ns}$
- 6041 events passed μ trigger, 5692 fits converged (94.2%). About 1/3 events not converged to true values.

What else can we learn from these plots?

Expect

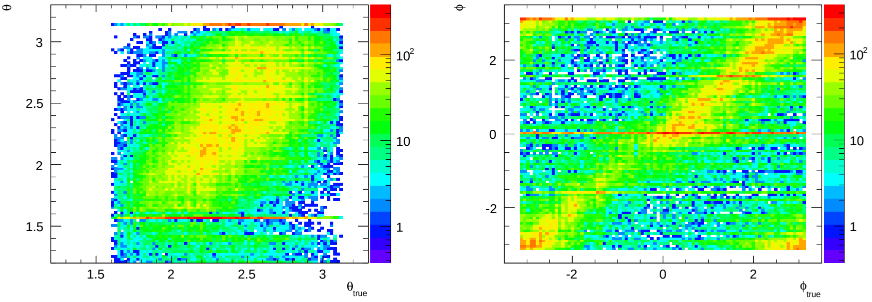


Observe



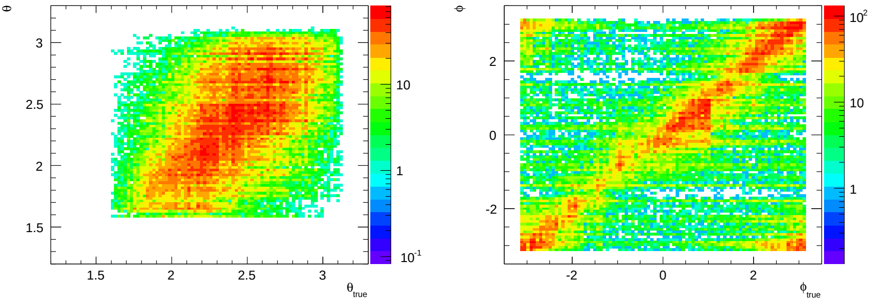
- We can guess θ, ϕ initial values from vectors $\vec{d} = \vec{p}_{hit} - \vec{p}_{firsthit}$

θ, ϕ initial values



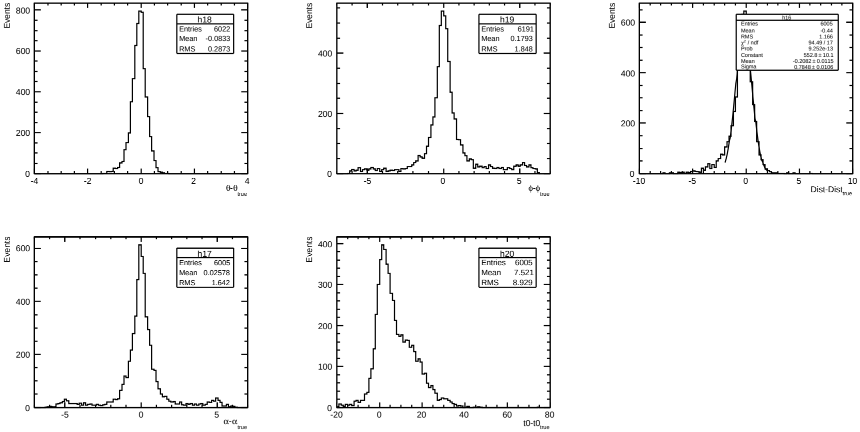
- Lots of $\theta, \phi = \pi, \pi/2$ due to PMT arrangements.

θ, ϕ initial values

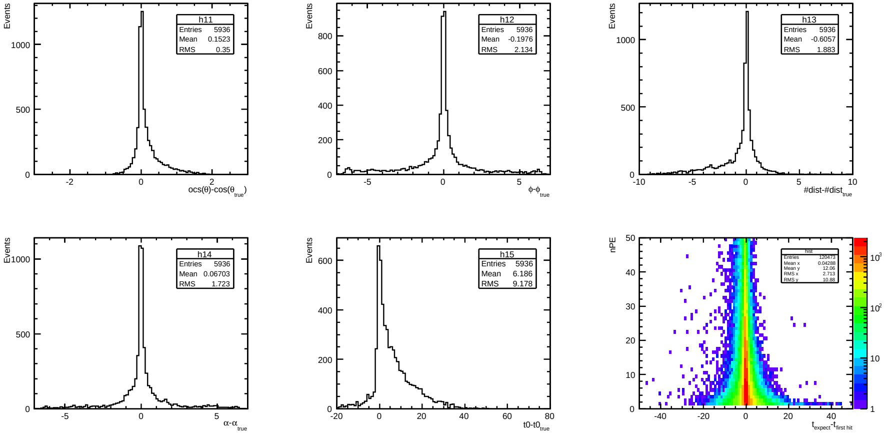


- Remove $\theta, \phi = \pi, \pi/2$ bands and other unphysical values.
- Average θ, ϕ to get the initial values.
- Use the first hit PMT as entry point, so that we have a point and direction for μ track.

Initial values



- θ, ϕ, *dist*, α, t_0 distributions



- 6041 events passed μ trigger, 5936 events converged (98.3%)

Things need to do

- Fine tuning initial values
- Fine tuning fitter:
  - remove outliers
  - try different sets of initial values, choose the lowest χ^2 results
- Consider electronic effects to first hit distribution