

Water Pool Muon Reconstruction

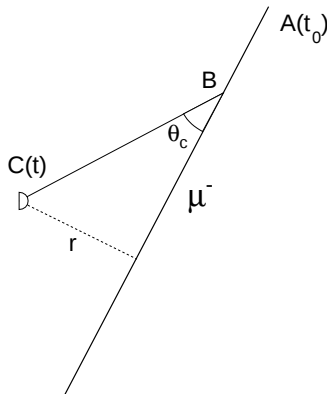
Qing He

Princeton University

Dayabay Collaboration

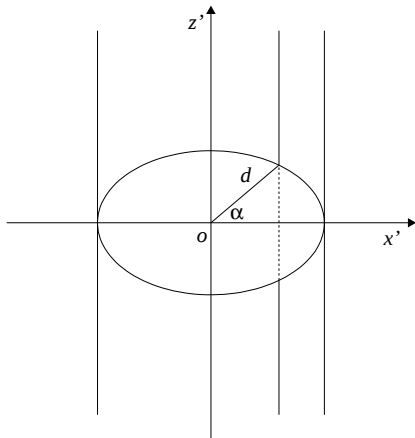
Water Pool Muon Reconstruction

- 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 closest 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.)



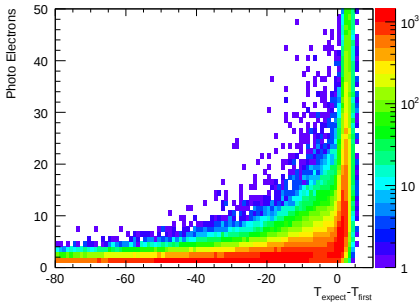
A trick from Dan

- 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 rotate back to original coordinates to get the original position.

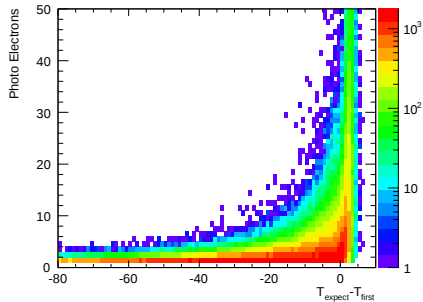


$T_{\text{expect}} - T_{\text{first}}$ distribution

IWS



OWS

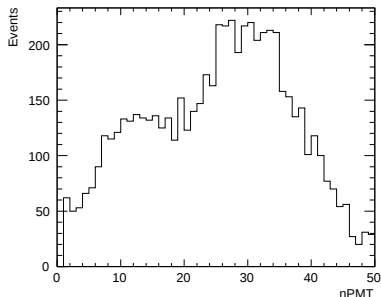


- All SimHits are smeared by the time resolution (1.2 ns).

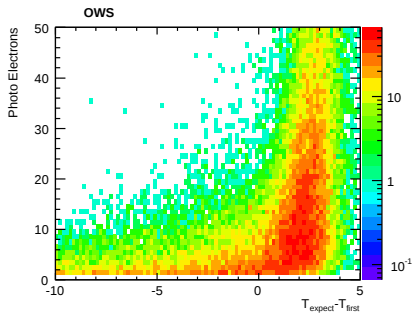
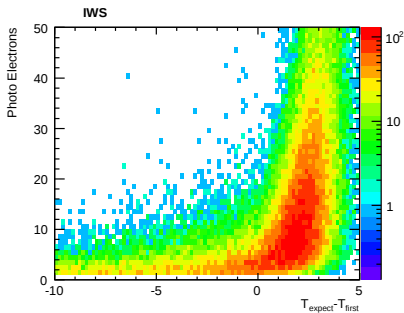
Remove reflect light

- Use $dist/\Delta t > 200$ mm/ns to remove reflect light, where $dist$ is the distance between PMT in question and the reference PMT, Δt is the time difference of the first hit between these two PMTs.
- The first reference PMT is the first hit PMT.
- Then select PMTs with large hits (≥ 8 PEs) as reference PMTs.
- Loop the PMTs with large hits and apply the $dist/\Delta t$ cut.

Number of PMTs after cuts applied

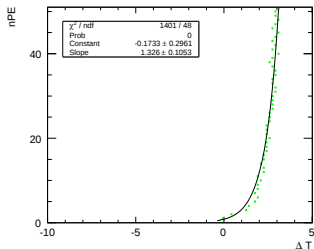


Time skew

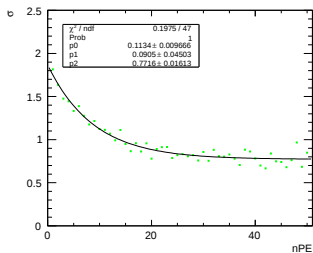
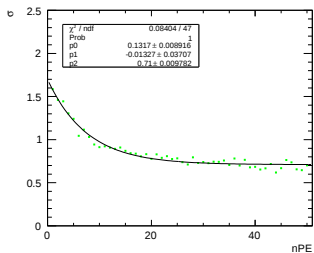
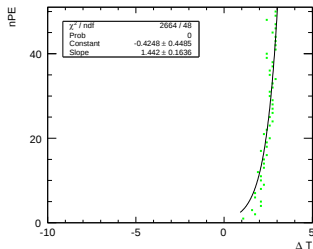


- PMTs with large hits tend to have shift in time due to time resolution smearing.

IWS

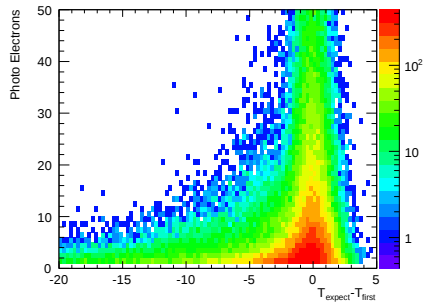
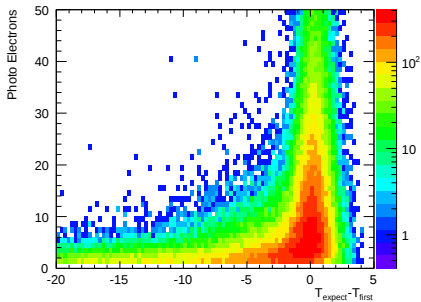


OWS



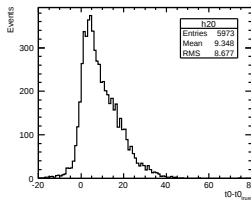
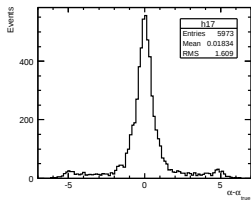
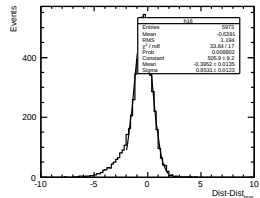
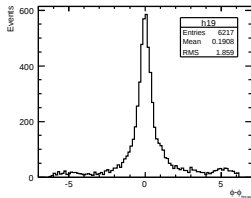
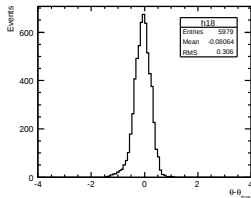
- Peak and sigma fit.

Time skew correction



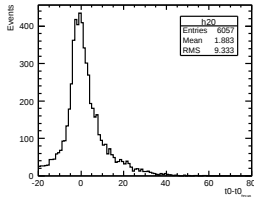
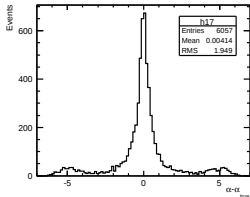
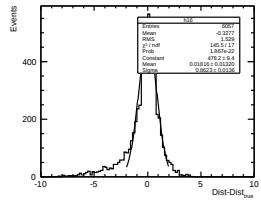
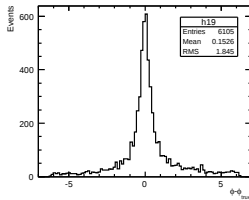
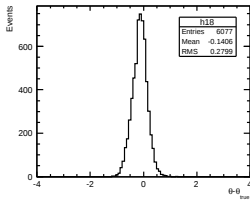
- After time skew correction

Initial value I



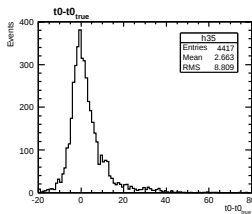
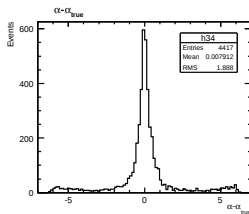
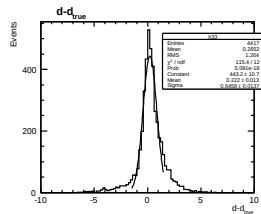
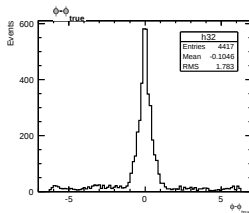
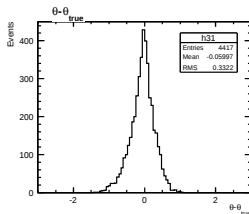
- Initial value calculation with respect to first hit PMT.

Initial value II

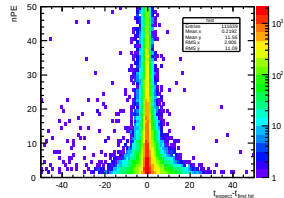
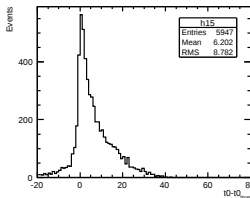
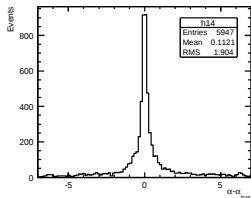
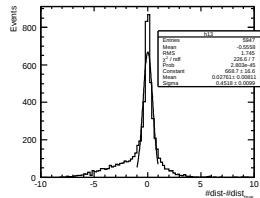
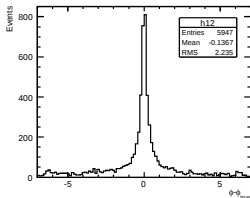
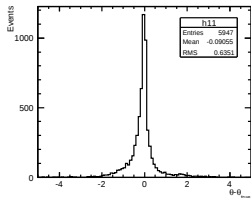


- Initial value calculation with respect to the PMT which has the largest hit.

Initial value III

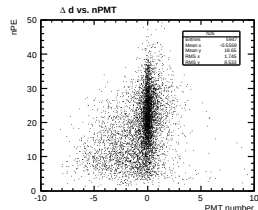
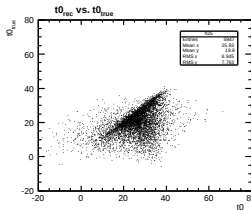
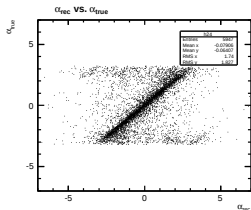
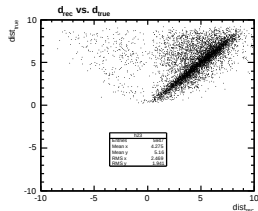
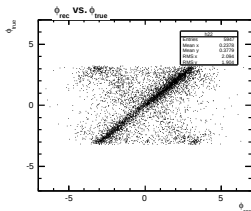
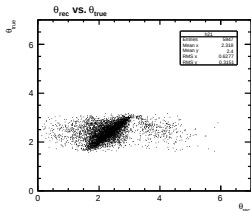


- Initial value from two PMTs (largest hit in IWS and OWS).



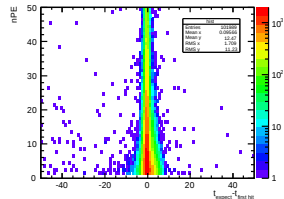
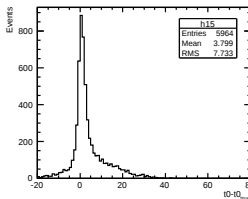
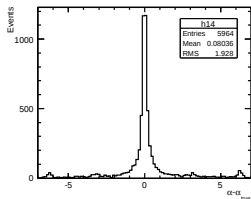
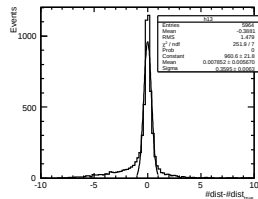
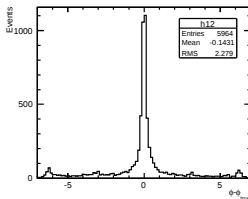
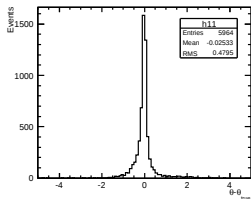
- Used initial values I & II, choose the smaller χ^2 .
- 4569 go through IWS, 6112 go through OWS, 6041 pass muon trigger, 5947 converged (98.4%)

Fit 2d plot



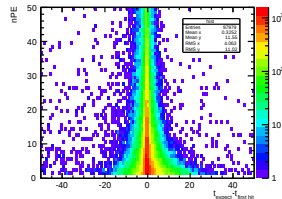
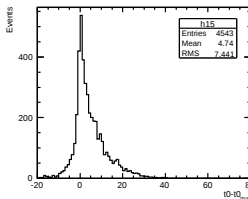
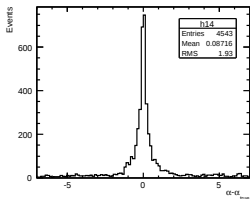
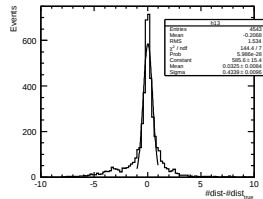
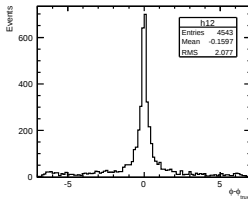
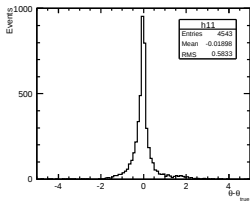
- If $(\theta, \phi) \rightarrow (2\pi - \theta, \phi + \pi)$, or $(d, \alpha) \rightarrow (-d, \alpha + \pi)$, results will not change.

Effect of reflect light



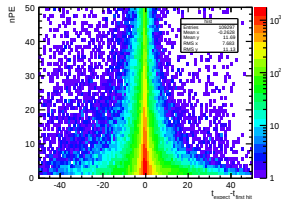
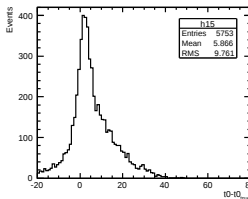
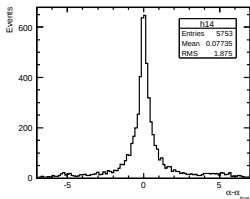
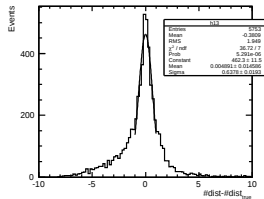
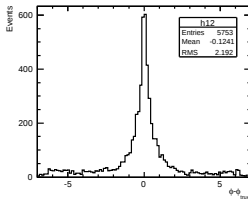
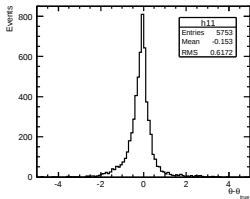
- Remove $fabs(T_{expect} - T_{firsthit}) > 10$ ns PMTs.
- Reflect light cause T_0 distribtuion not symmetric, and the bump of large Δd .

Fit only IWS



- 4569 go through IWS, 6112 go through OWS, 6041 pass muon trigger, 4543 converged (99.4%)

Fit only OWS



- 4569 go through IWS, 6112 go through OWS, 6041 pass muon trigger, 5753 converged (95.2%)

- A spatial resolution of ~ 45 cm can be achieved.
- IWS provides most of the information in the fit.
- Reflect light tend to bias fit result.
- Can use initial values if fit not converge or too few PMTs in the fit.