

Muon reconstruction in AD

Qing He

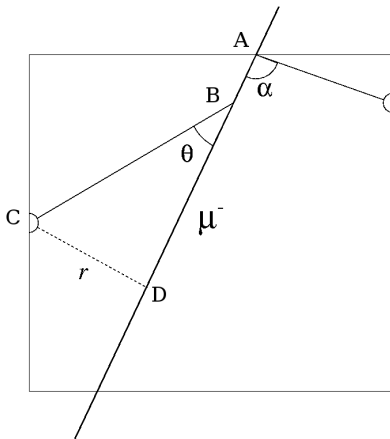
Princeton University

Dayabay Collaboration

First light

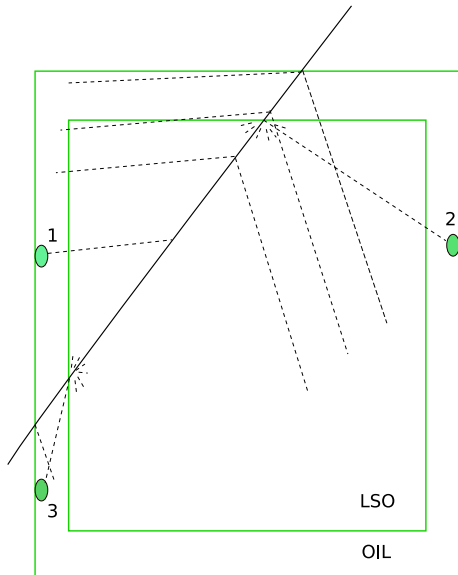
$$t = \frac{|BC|}{c/n} + \frac{|AD| - |BD|}{c} = \frac{n|CD|}{c\sin(\theta)} + \frac{|AD| - |CD|\operatorname{ctg}(\theta)}{c} \quad (1)$$

- 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.



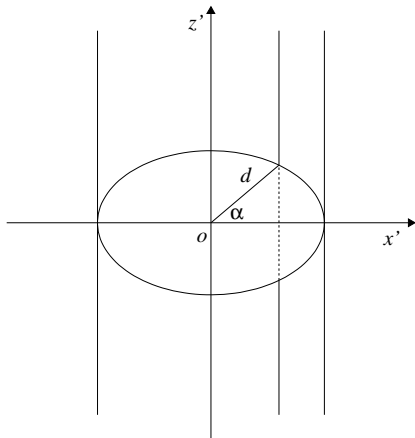
The real case

- Currently, mineral oil has no scintillation in MC.
- Three cases
 - Case 1: first light comes from Cherenkov light or scintillation light with Cherenkov angle.
 - Case 2: first light comes from scintillation light at the entry point in LSO.
 - Case 3: first light comes from scintillation light at the exit point in LSO.



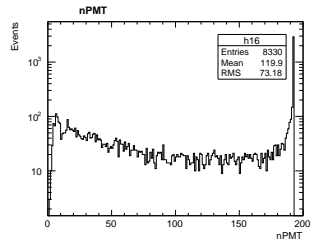
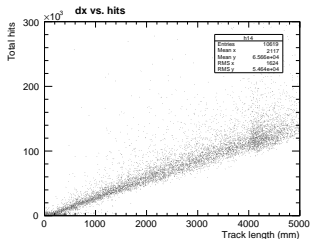
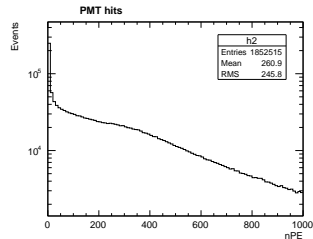
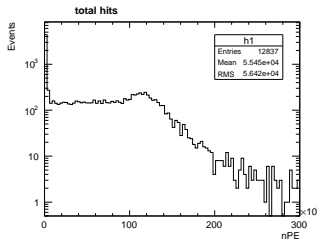
Five parameters ($\theta, \phi, d, \alpha, t_0$)

- 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.



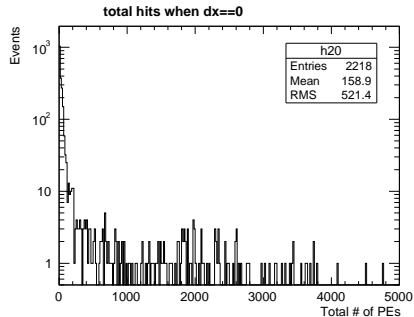
Some basic plots

- Track length = Track length in the oil tank, including the length in subregions.
- Require total hits > 4000 photo electrons.
This removes about 1/3 events which has short track length in the oil tank.
- Require each PMT has hits > 200 photo electrons.
Fit is not sensitive to this requirement, can lower it.
- Need to optimize the requirements later.

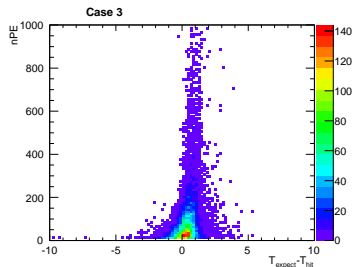
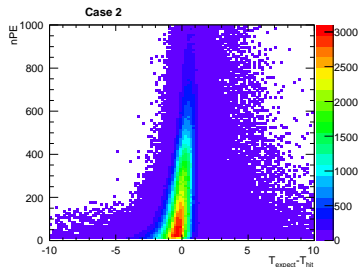
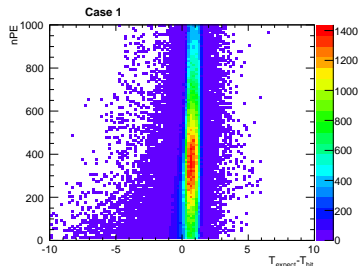
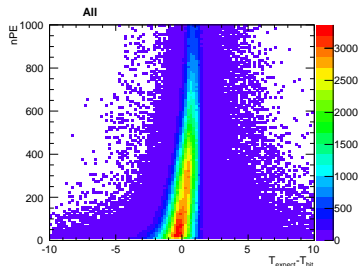


Some not understood events

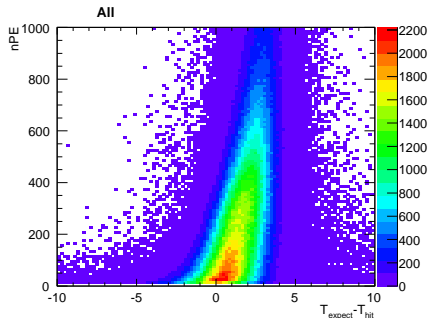
- More than 2000 events has hits in AD but with track length equal 0 in the oil tank.



$T_{expect} - T_{hit}$ distribution for SimHits



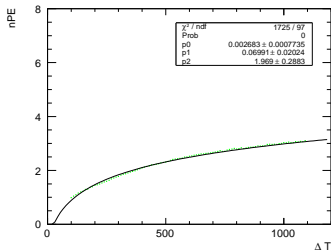
Time resolution smearing



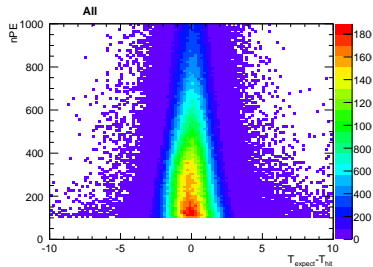
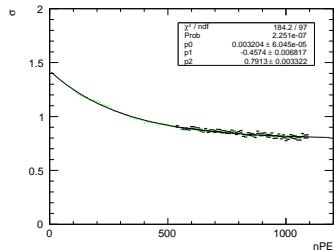
- In order to simulate PMT response, electronics effect etc., smear all hits with 1.2 ns resolution.

Time skew correction

peak



sigma



- Use Zhe's method (Doc 4054) to get initial values
 - Entry point + Gravity center
- Zhe used weighted position center as entry point when muon enters top or bottom panels (first hit PMT is in the top or bottom ring).

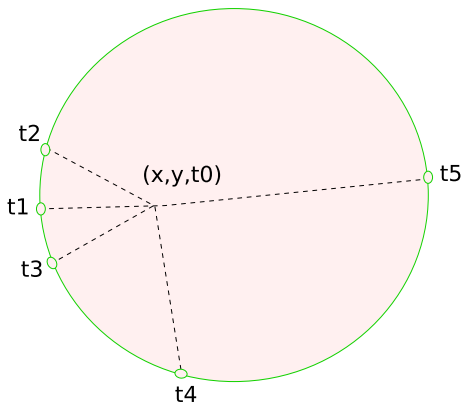
$$weight = \exp\left(-\frac{t_{PMTi} - t_{min}}{t_{maxInRing} - t_{min} + 20}\right) \quad (2)$$

$$\vec{P} = \frac{\sum \vec{P}_{PMTi} \times Charge_i}{\sum Charge_i} \times 7.5 \quad (3)$$

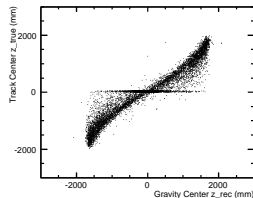
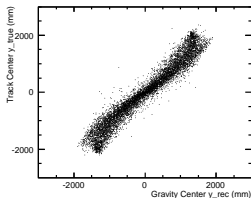
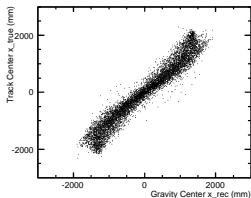
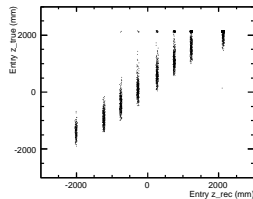
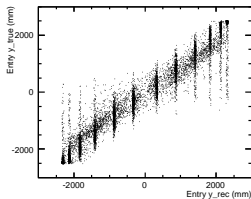
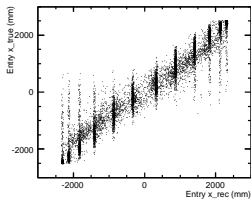
- I use another method to calculate the entry point for this case.

Entry point

- If muons entry from top or bottom panels, the PMTs in the top ring or bottom ring usually receive first light from scintillation light (i.e. case 2).
- For the 24 PMTs' time information, it should be easy to fit (x,y,t_0) . However, only two PMTs' information will give good guess for (x,y,t_0) : the first hit PMT and last hit PMT in that ring (t_1 and t_5 in the diagram).
- Use t_1-t_0 and t_5-t_0 as weights to calculate (x,y) . (Under the assumption $t_5-t_1 \approx 2R/(\text{light speed in oil})$, where R is the radius of PMT ring.)

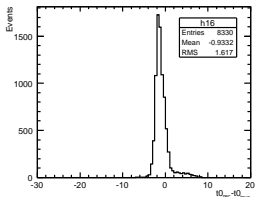
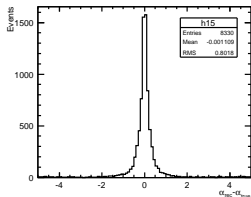
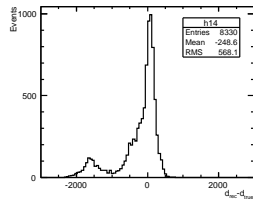
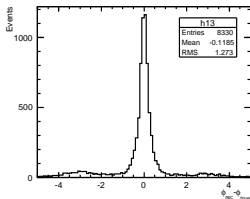
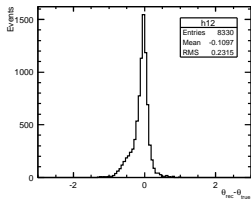


Entry point & Gravity center



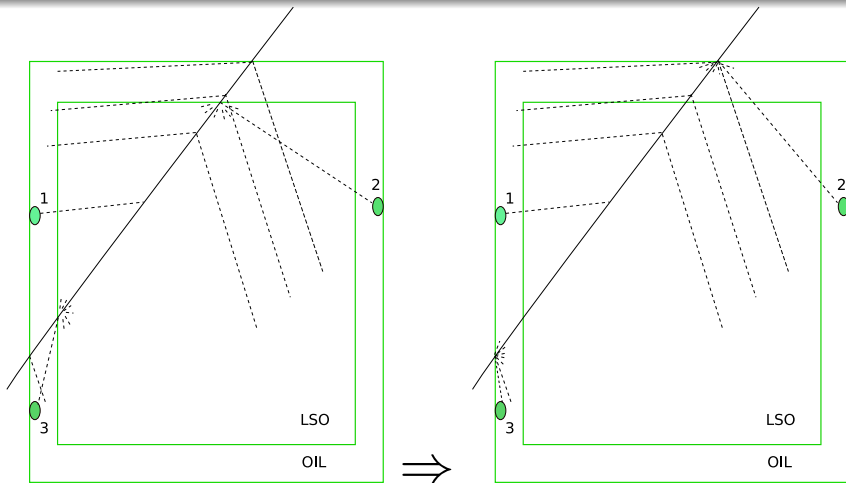
- The bands in Entry point values are due to choosing the first hit PMT position as entry point.
- Gravity Z_{rec} has been applied a factor of 1.5 to make it more closer to Z_{true} .

Initial values for fit



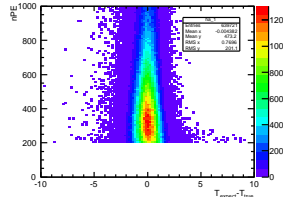
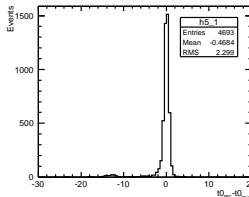
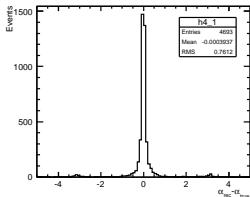
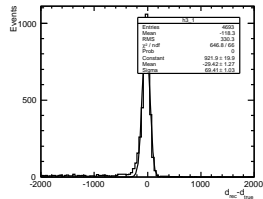
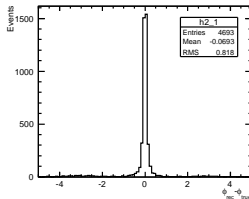
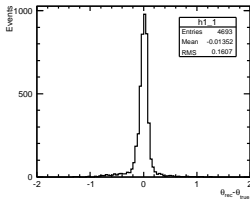
- Transform Entry point & Gravity center to $(\theta, \phi, d, \alpha, t0)$.

One problem in the fit



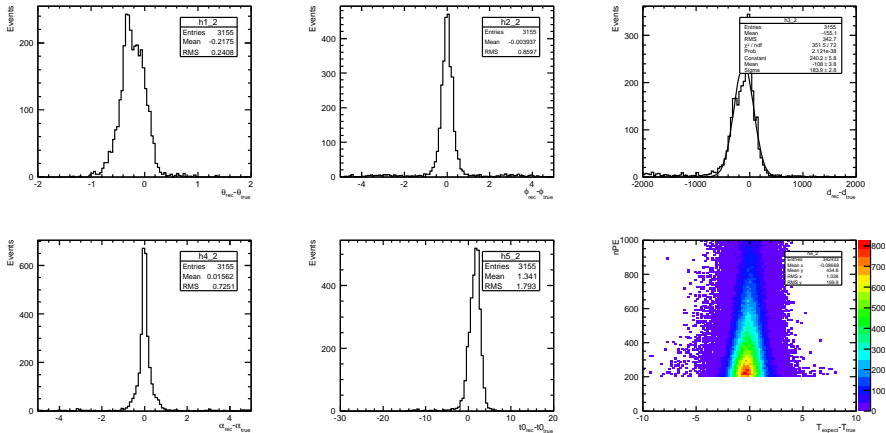
- Some events not converge in the fit.
- If the fit in scenario 1 not converge, switch to scenario 2.

Fit results for scenario 1



- 8330 muon events, 4693 (56.3%) events converged in scenario 1, 3155 (37.9%) events converged in scenario 2.

Fit results for scenario 2



- 8330 muon events, 4693 (56.3%) events converged in scenario 1, 3155 (37.9%) events converged in scenario 2.

- It is promising to reconstruct muon in AD.
- Details still need to be investigated.
- AD gives best muon spatial resolution.
- Future: compare & combine water pool, AD, RPC muon reconstruction.