Track segment reconstruction in ST planes

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Overview

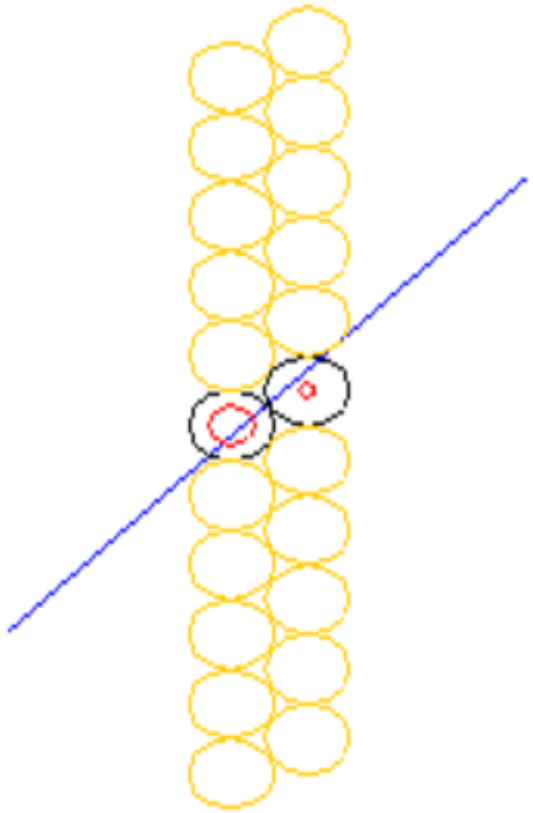
- **Goal**: reconstruct track segment in ST YY plane:
  - Position and direction (+ $t0$)
- **Input**:
  - STT digits: tube position and tdc
  - drift velocity, electric signal velocity along the wire and a 4 ns smearing are considered in straw tube signal digitization
- **Assumption**:
  - The time (t_{bucket}) of the beam bucket of the interacting neutrino is known
- Or *almost* **equivalently**:
  - The time (t_{vtx} and z_{vtx}) and position of the neutrino interaction:

$$t_{bucket} = t_{vtx} - \frac{z_{vtx} - z_{target}}{c}$$

Clusters

- In each YY ST plane (whose z coordinate is z_{plane}), adjacent **hit straw tubes are grouped into clusters**
- **Additional not-hit tubes** on both side are added to the cluster.
- A **guess $t0_{guess}$** is assigned to the ST plane according to the formula:

$$t0_{guess} = t_{bucket} + \frac{z_{plane} - z_{target}}{c}$$

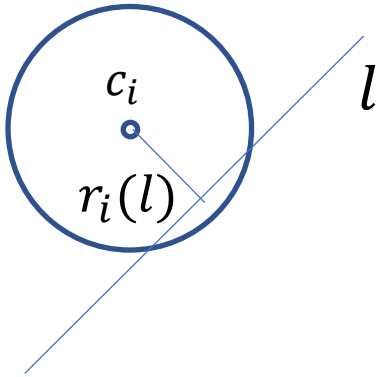


Model

- A track segment is parameterized as a **straight line $\boldsymbol{l}$**:
  - Slope: m
  - Intercept: q
- Given a line l and a tube with center $c_i = (z_i, y_i)$, the minimal distance is evaluated: $r_i(l)$
- Given a $t0$, the **expected $\boldsymbol{tdc}$** of a tube is evaluated:

$$tdc_{\text{exp}} = t0 + \frac{r_i(l)}{v_{drift}}$$

- N.B. here electric signal velocity is not taken into account



Log-Likelihood

$$\sigma_t = 4\ ns$$
$$r_{tube} = 25\ mm$$
$$v_{drift} = 0.05\ mm/s$$

- For **hit tubes**:

$$\left(tdc_{exp} - tdc_{meas}\right)^2 / \sigma_t^2$$

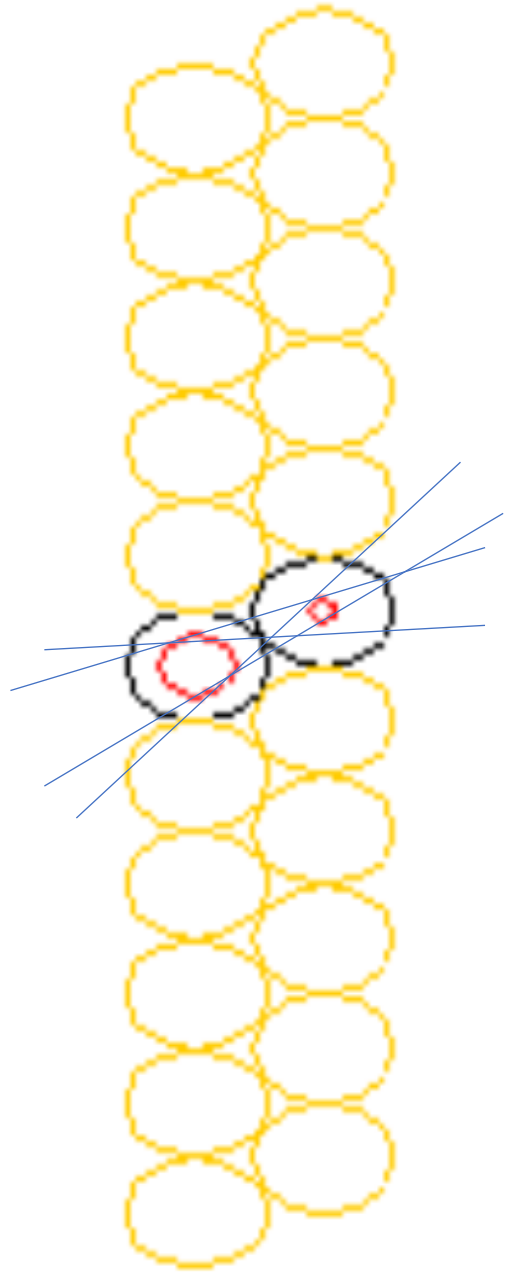
- For **not hit tubes**, if $r_i(l) < r_{tube}$:

$$\left(\frac{r_i(l)}{v_{drift}} - \frac{r_{tube}}{v_{drift}}\right)^2 / \sigma_t^2$$

- **Log-Likelihood**:
  sum over all tubes in the clusters (not hit tubes included)
- **POI**: m, q, $t0$
- Minimize log-likelihood with **TMinuit**

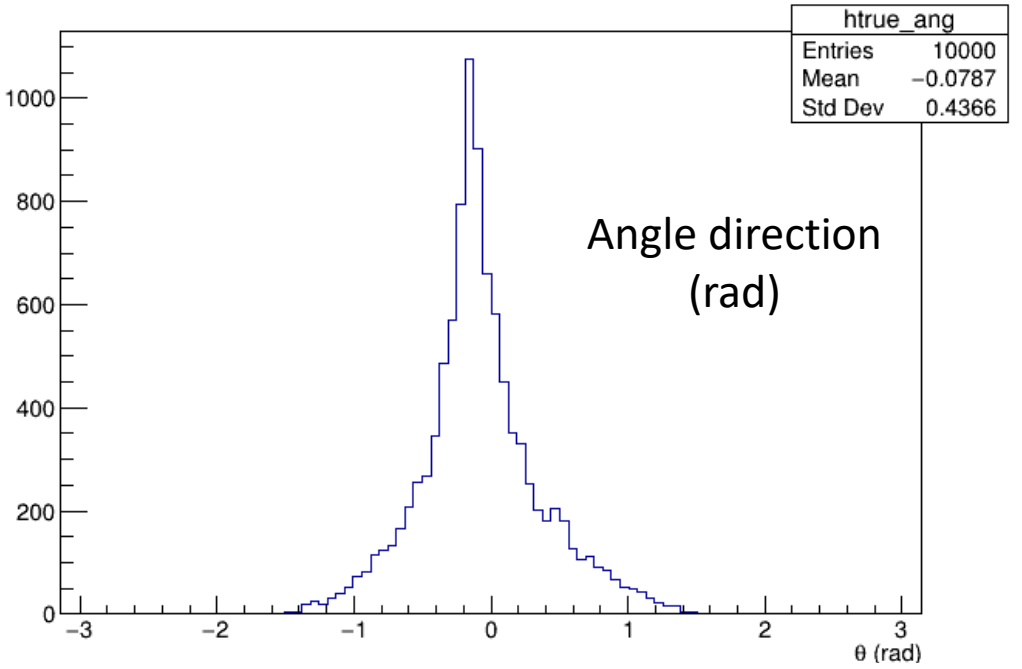
Minimizer I/O

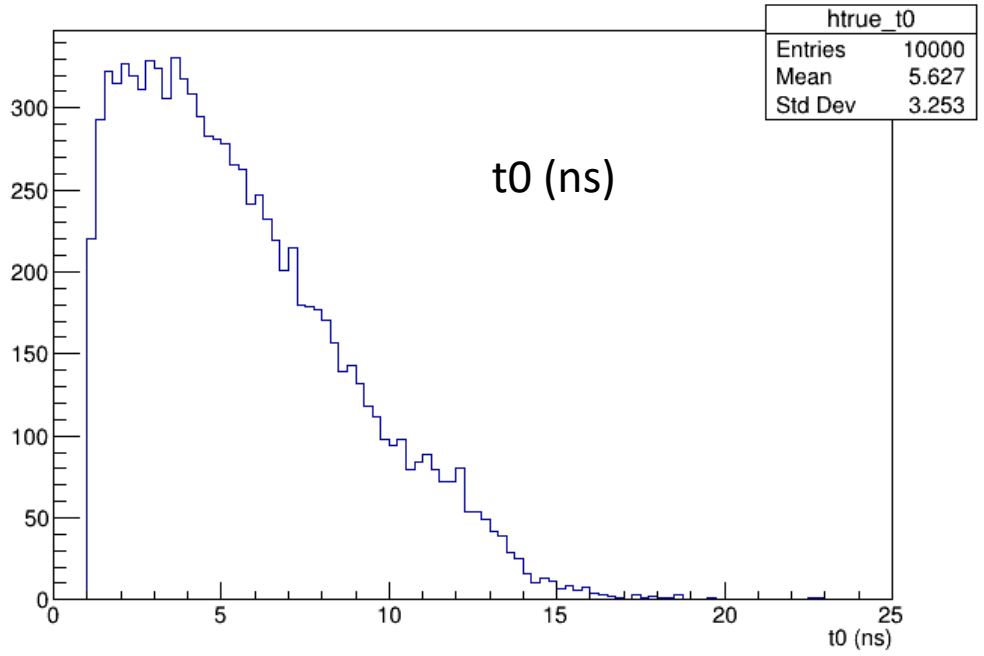
- $\boldsymbol{t0}$: $t0_{guess}$ from ST plane
- Determination of **line ($\boldsymbol{m}$, $\boldsymbol{q}$)** guess parameters:
  - identify the most distant hit tubes in the cluster
  - Use tdc of these tubes and ST plane $t0_{guess}$ to reconstruct their circles
  - Slope and intercepts of the tangents of both circles are the guess parameters
- Log-likelihood are minimized for all the **four guess** line parameters
- Reco parameters: the one with the **minimal log-likelihood**

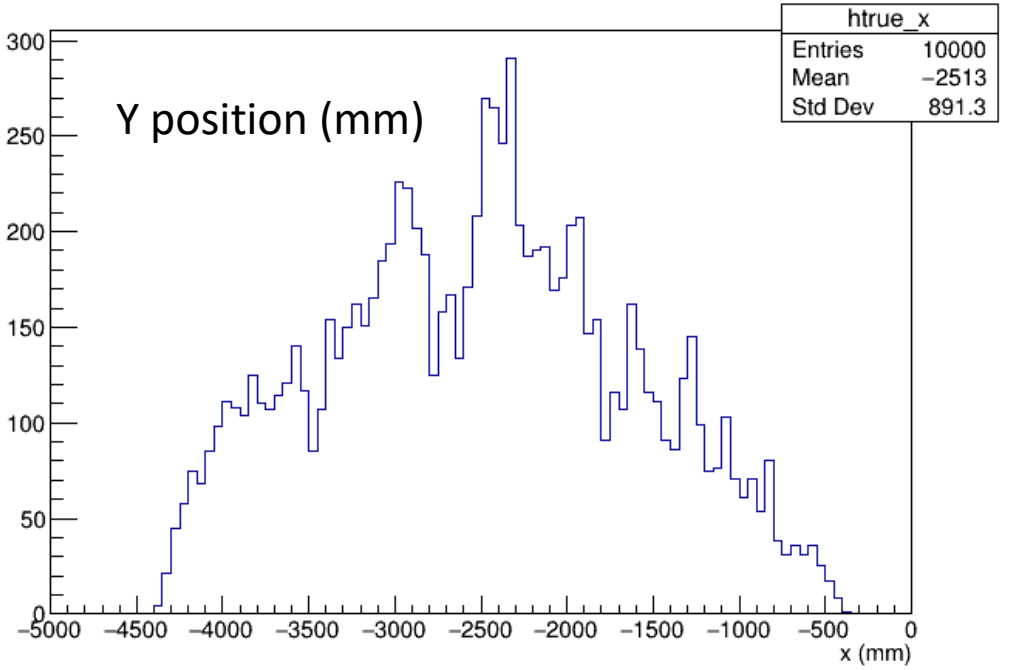


Golden clusters: ~78%

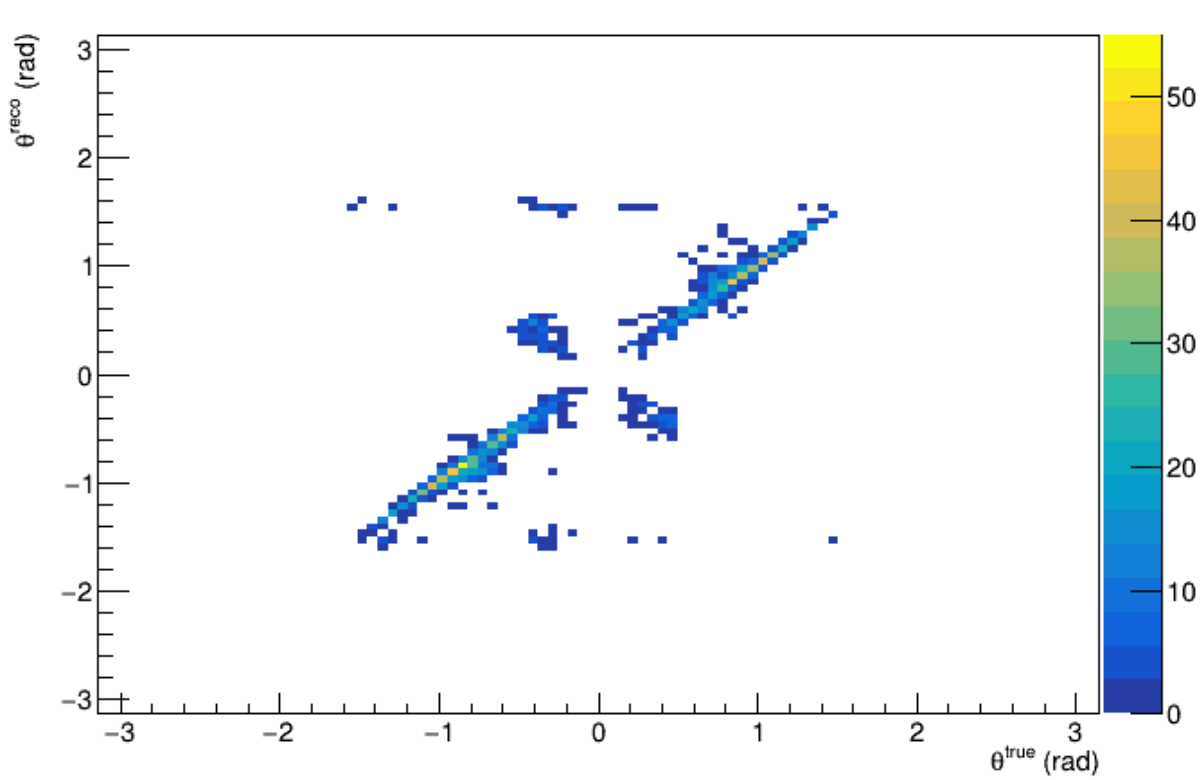
- clusters due to single particle with RMS(angle direction) < 0.1 rad within the ST plane

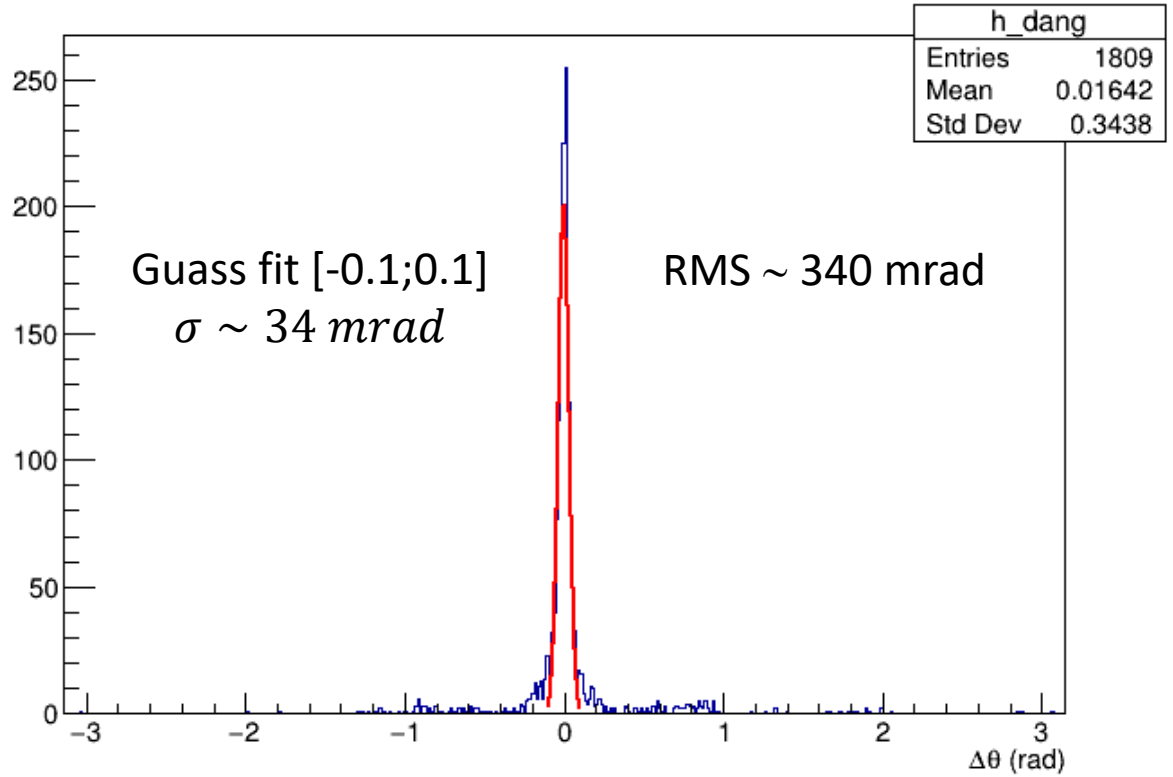




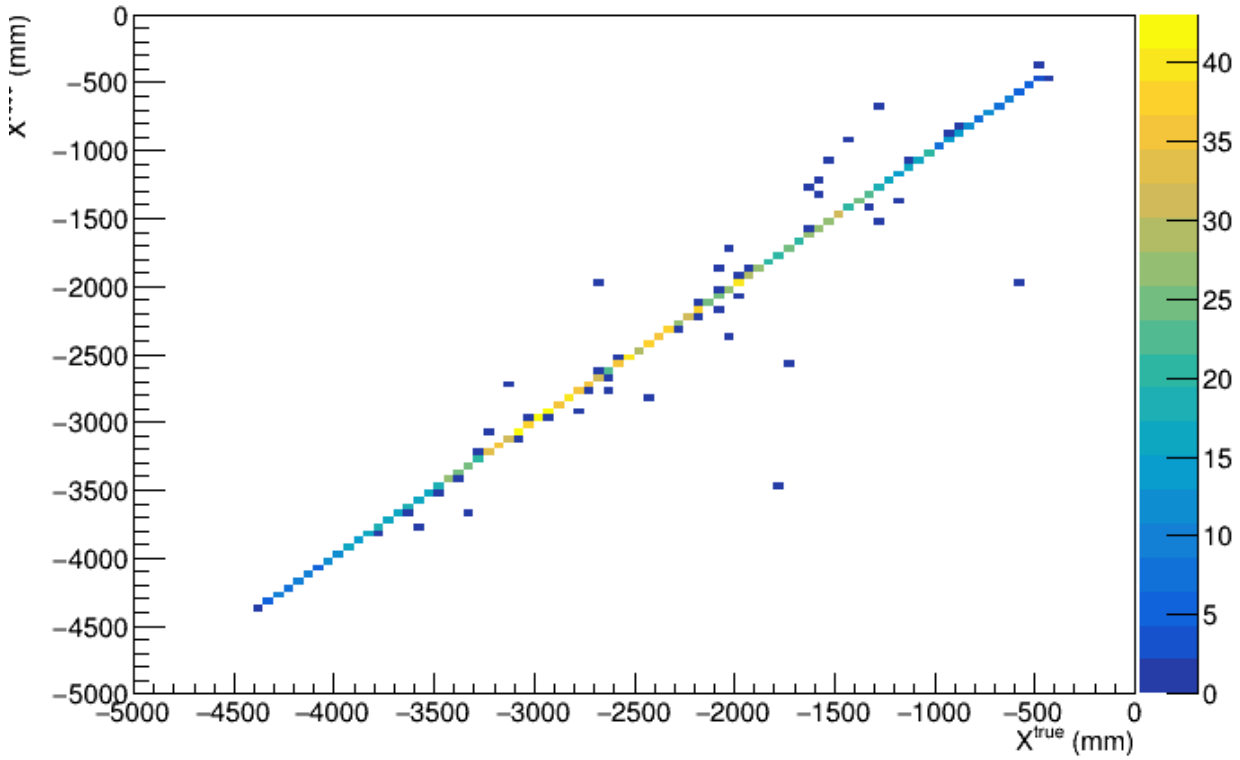


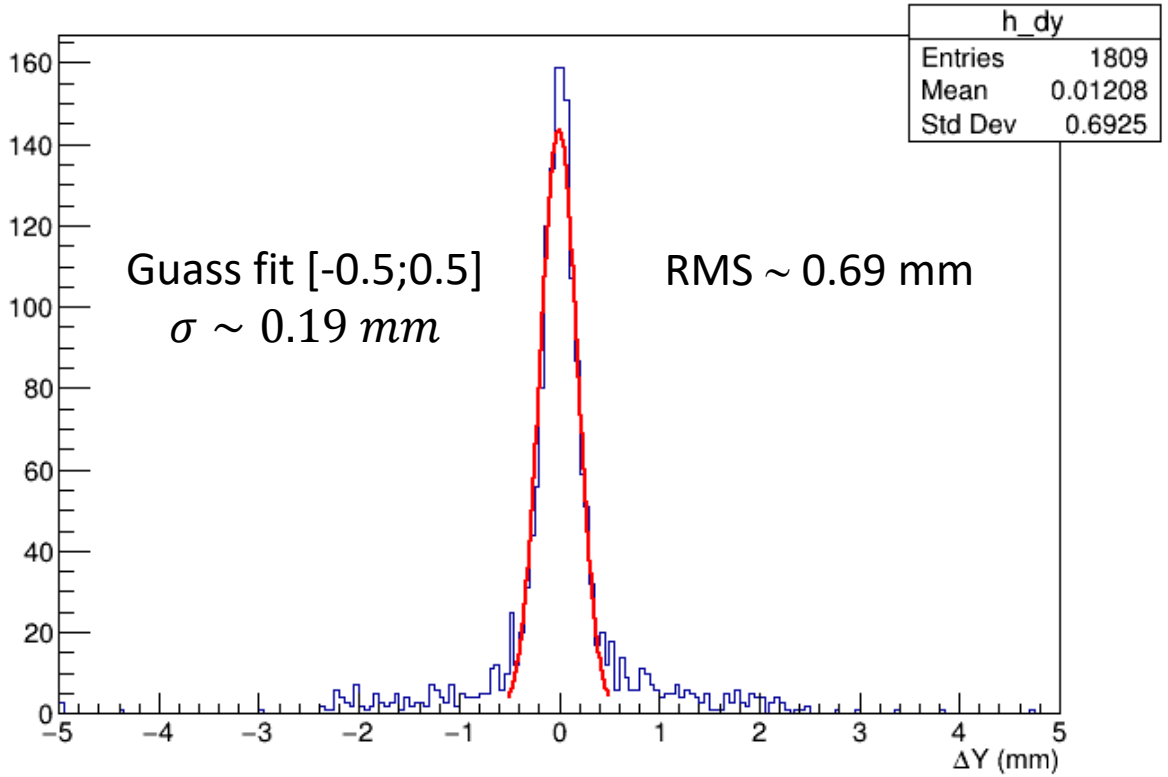
Angle direction: $cluster(n_{tube} > 2)$ [18%]



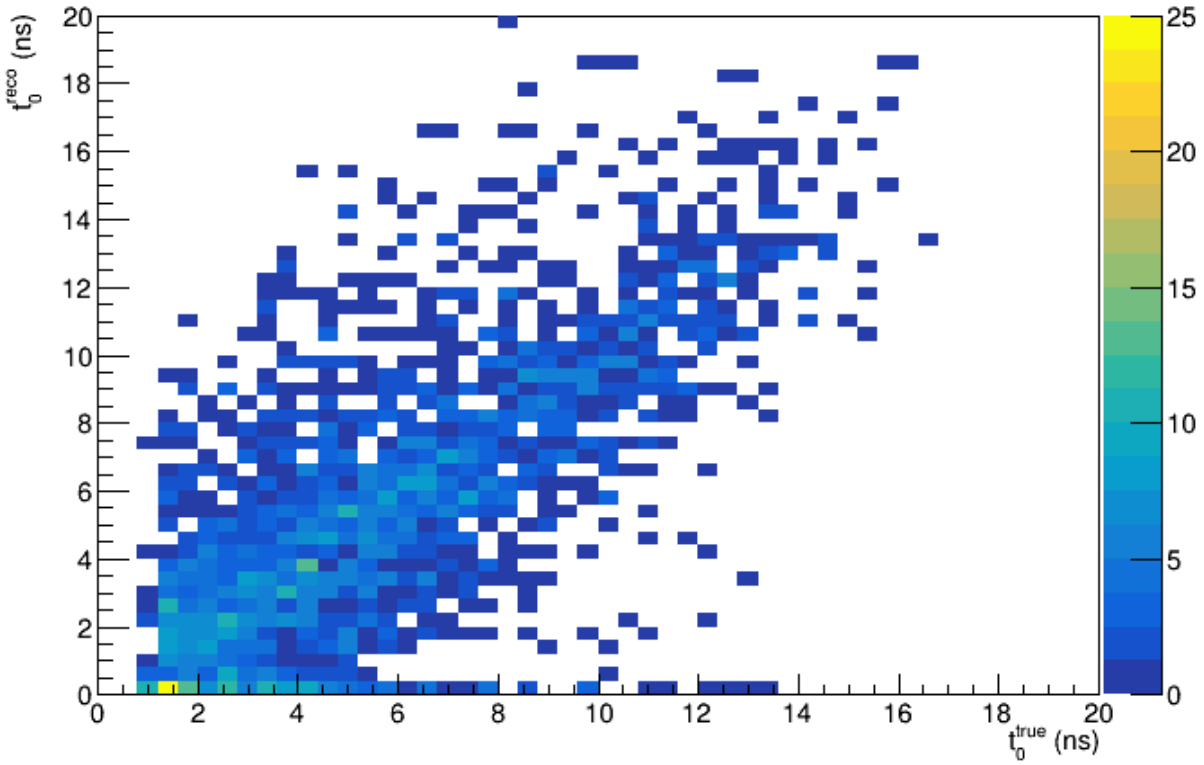


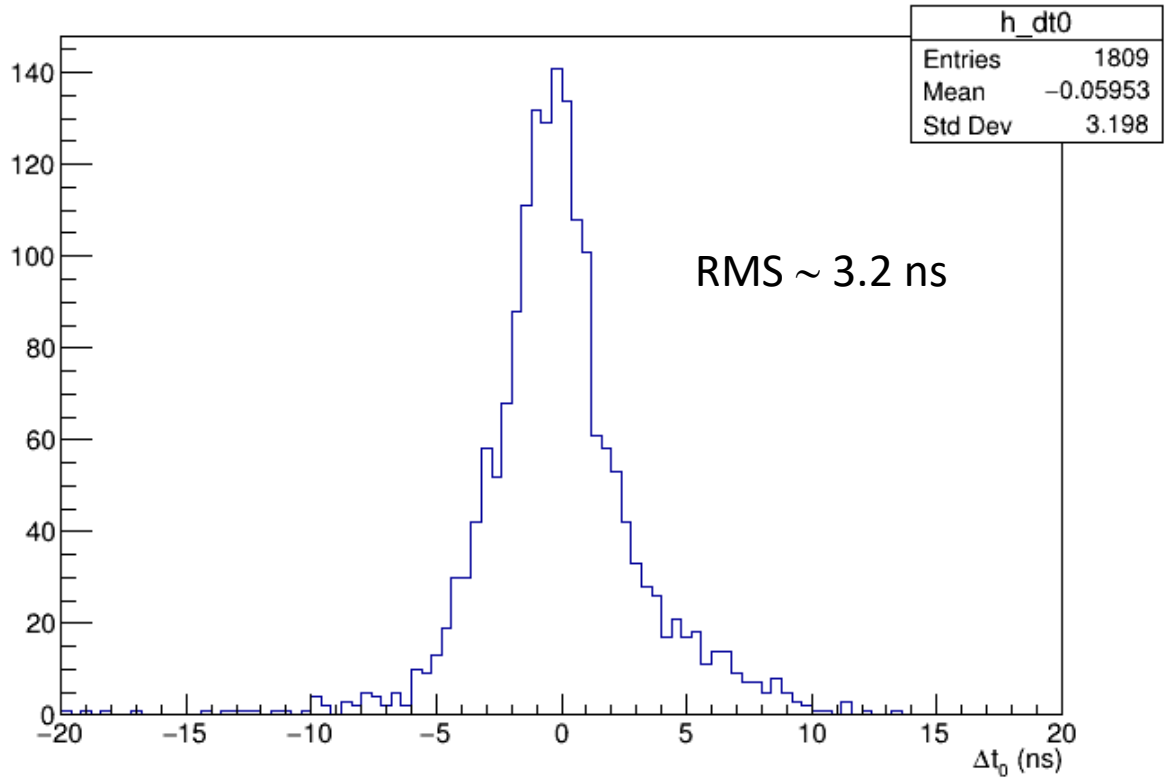
Y coordinate: $cluster(n_{tube} > 2)$ [18%]



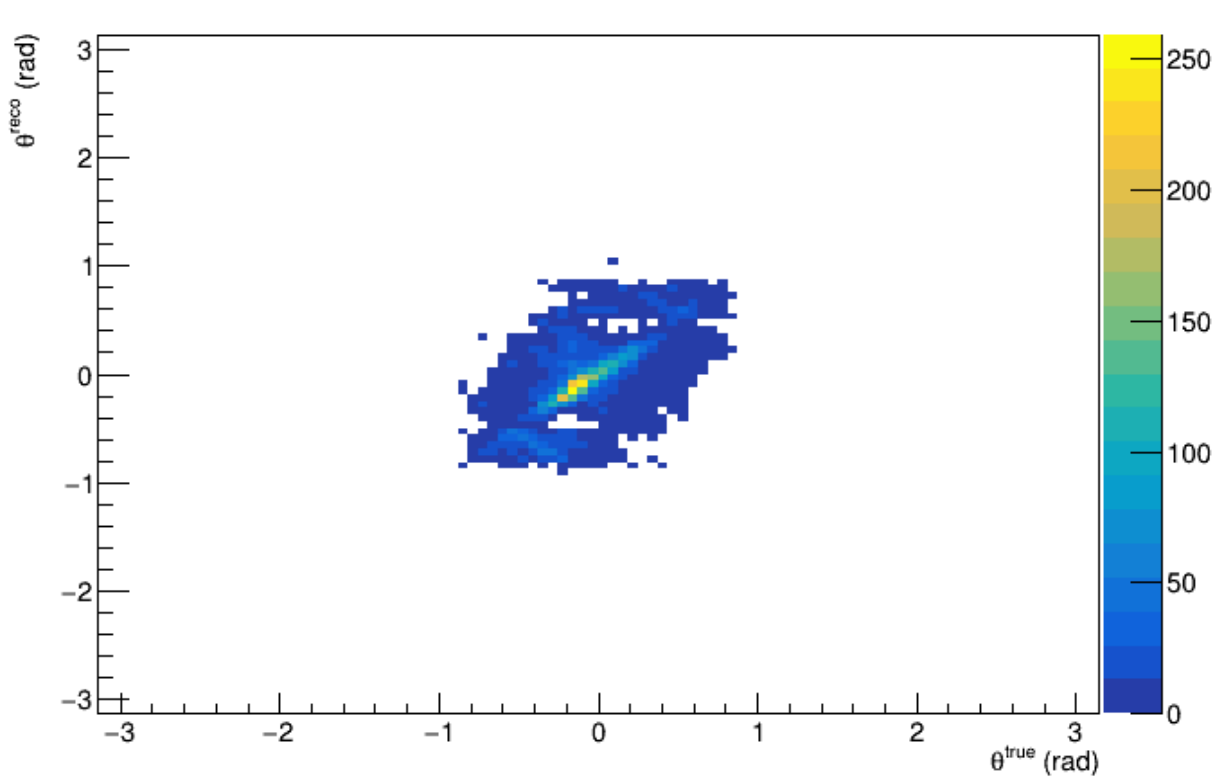


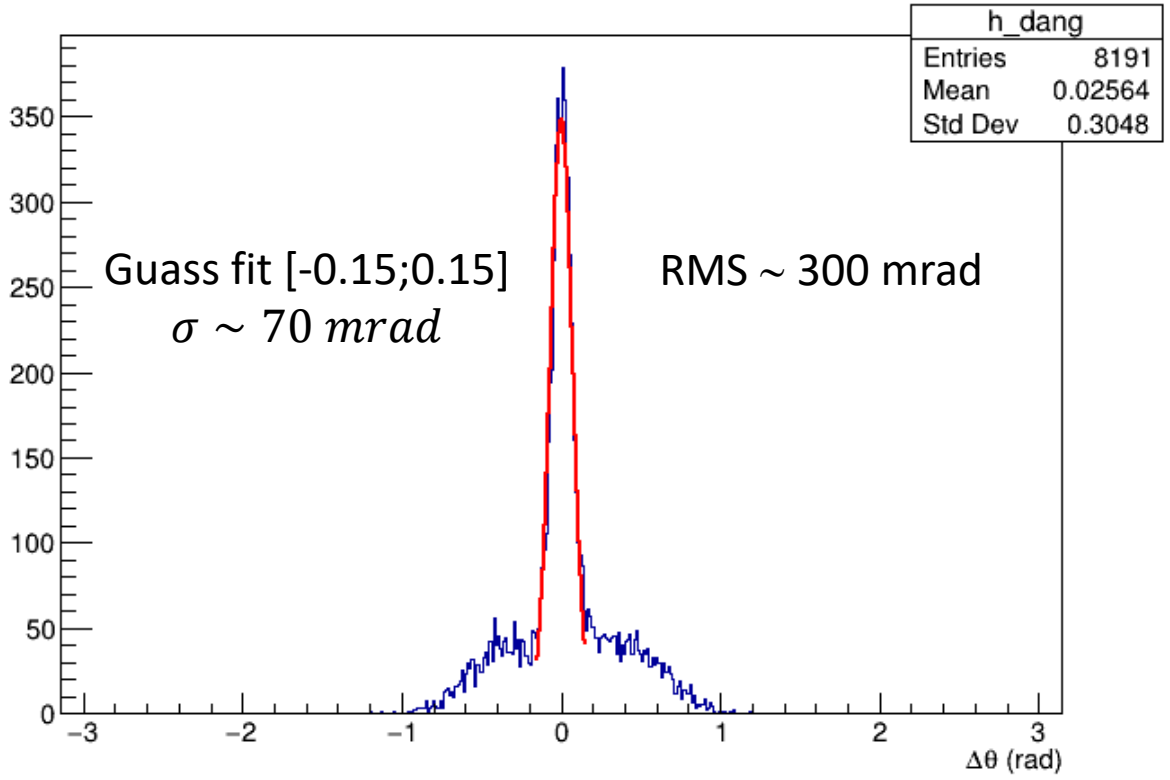
$t0$: $cluster(n_{tube} > 2)$ [18%]





Angle direction: $cluster(n_{tube} == 2)$[82%]





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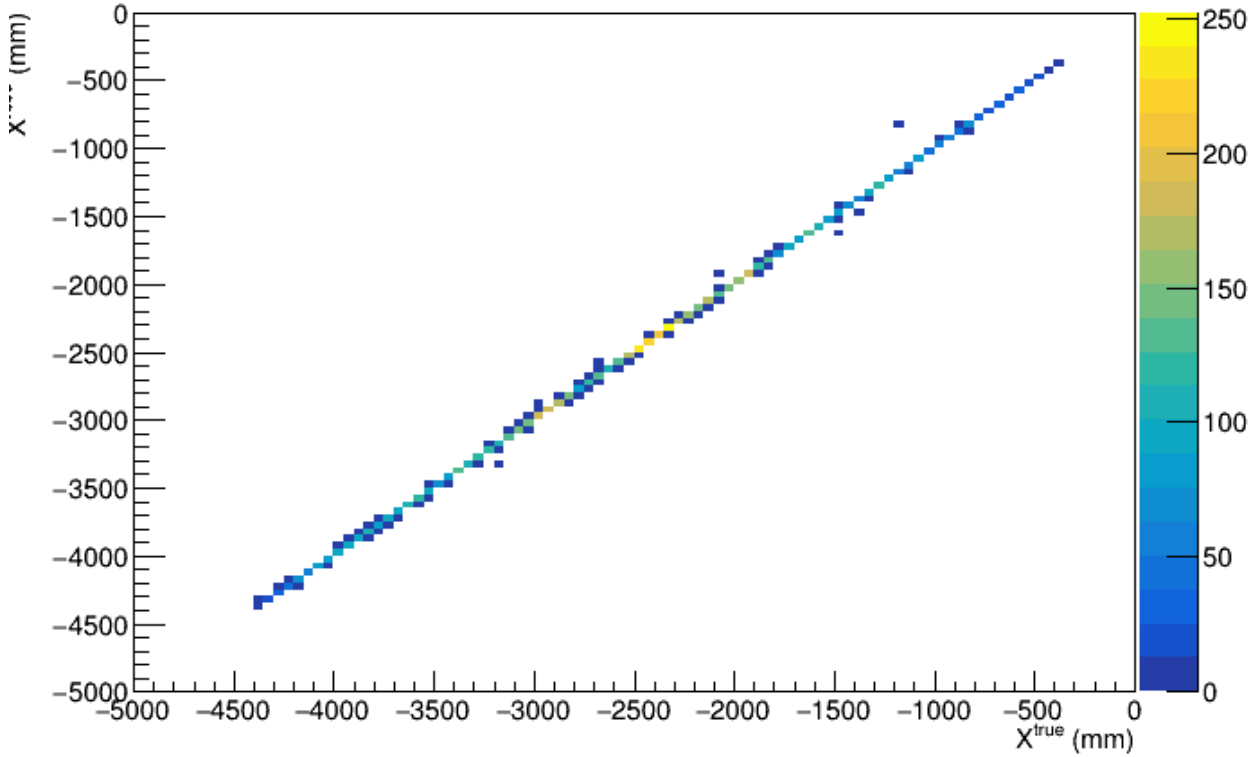

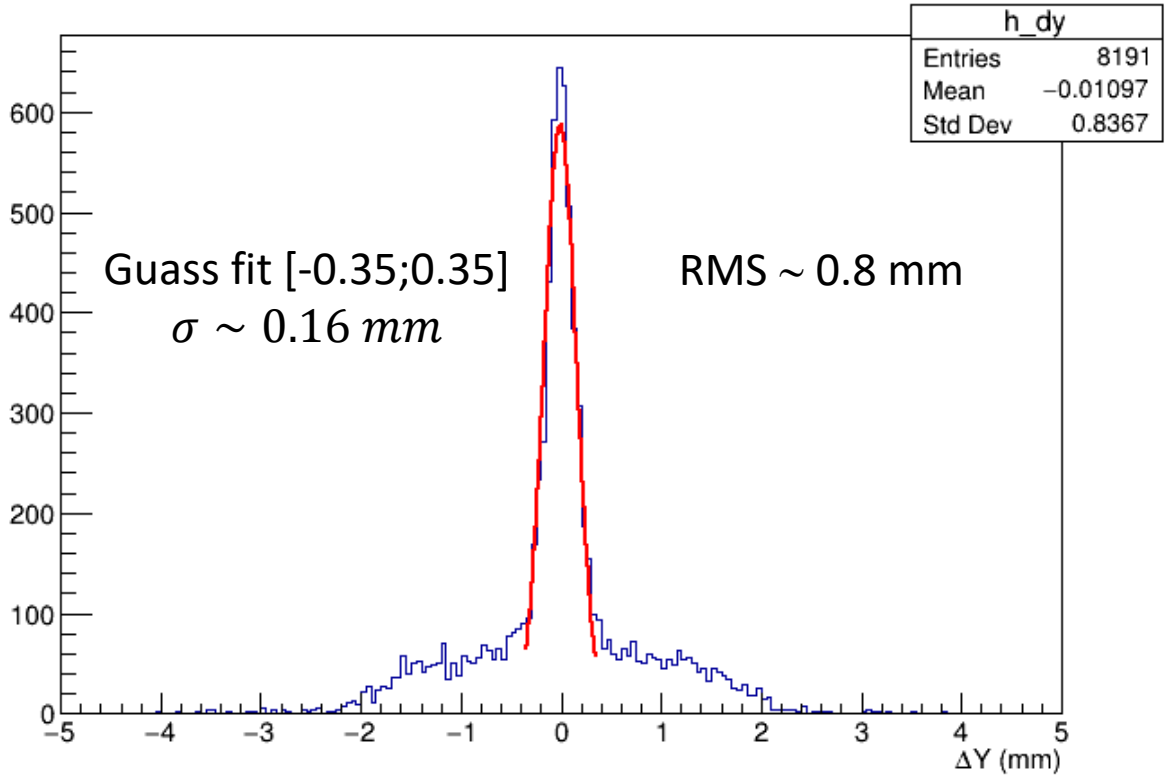

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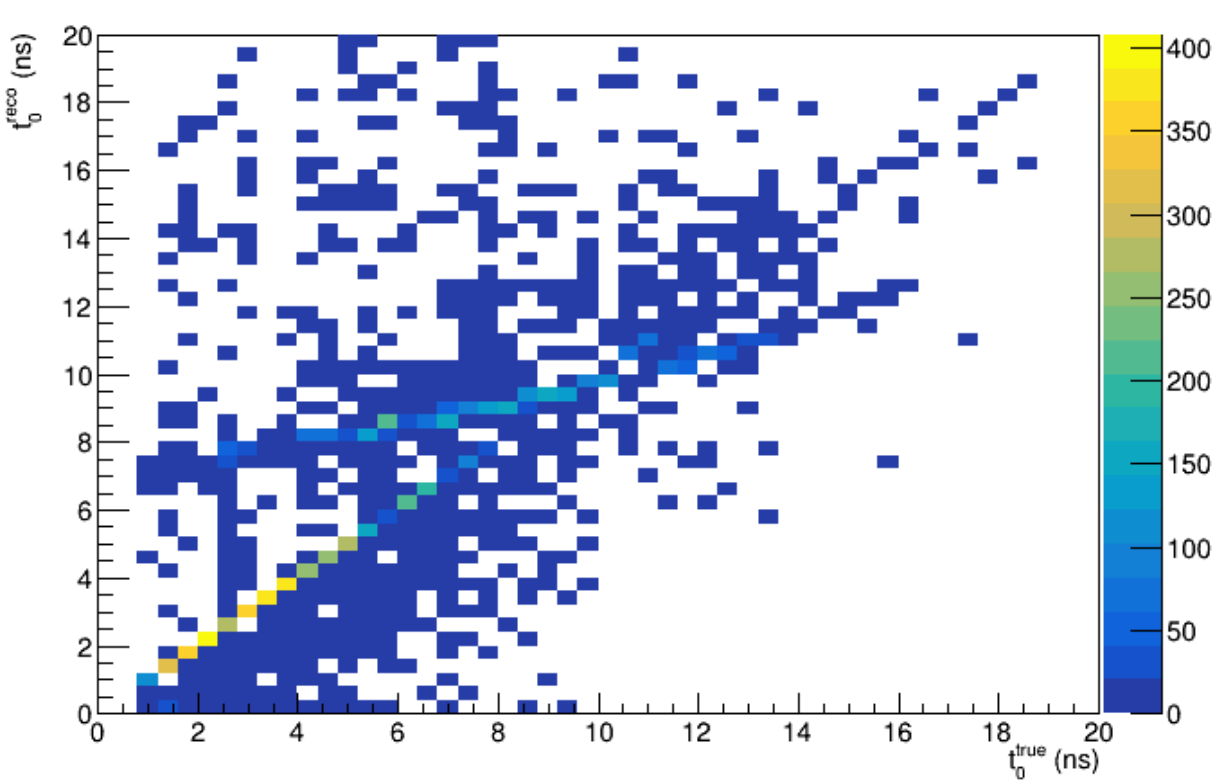

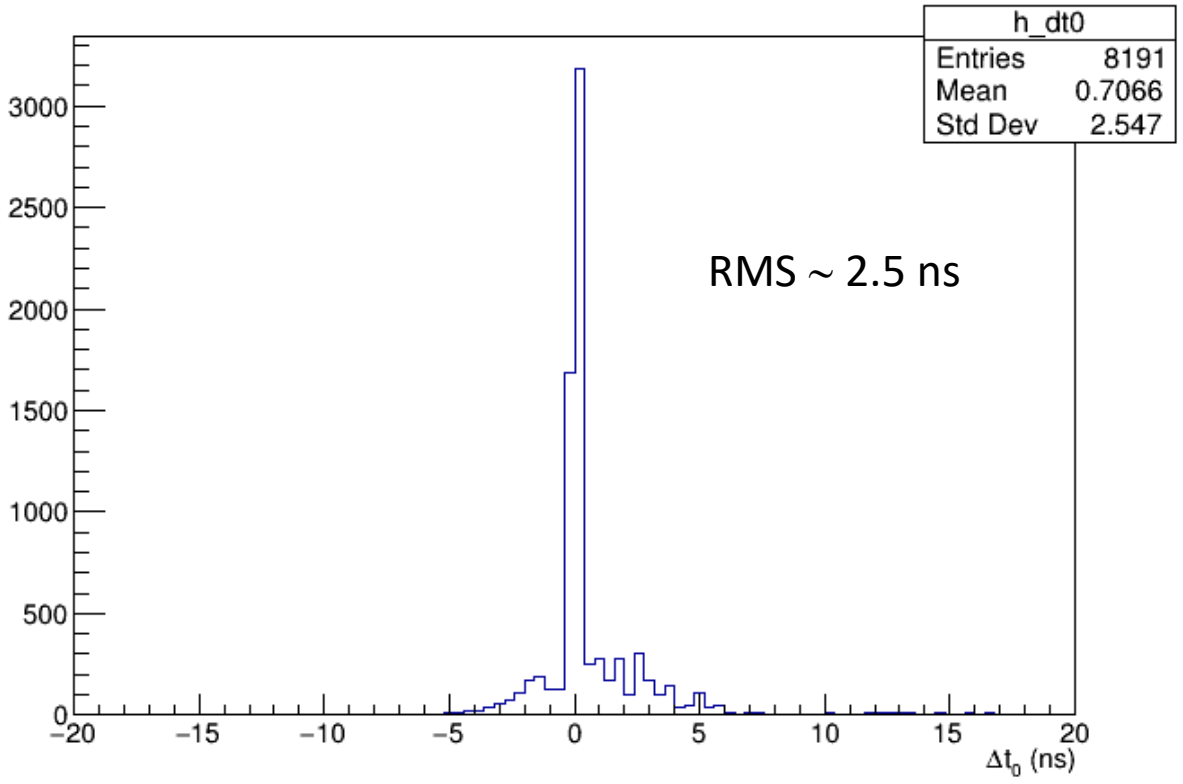

Conclusions

- Algorithm for track segment reconstruction in ST plane
- Minimal assumption and no true MC info
- Based on the minimization of log-likelihood function
- I/O: ST $tdc_{meas} \Rightarrow$ line (l,m) + $t0$
- Performances with Golden Clusters (78%)

82%	$Cluster(\boldsymbol{n_{tubes}} == 2)$	
Angle direction (mrad)	RMS	300
	σ	70
Y coordinate (mm)	RMS	0.8
	σ	0.16
$t0$ (ns)	RMS	2.5

18%	$Cluster(\boldsymbol{n_{tubes}} > 2)$	
Angle direction (mrad)	RMS	340
	σ	34
Y coordinate (mm)	RMS	0.69
	σ	0.19
$t0$ (ns)	RMS	3.2