

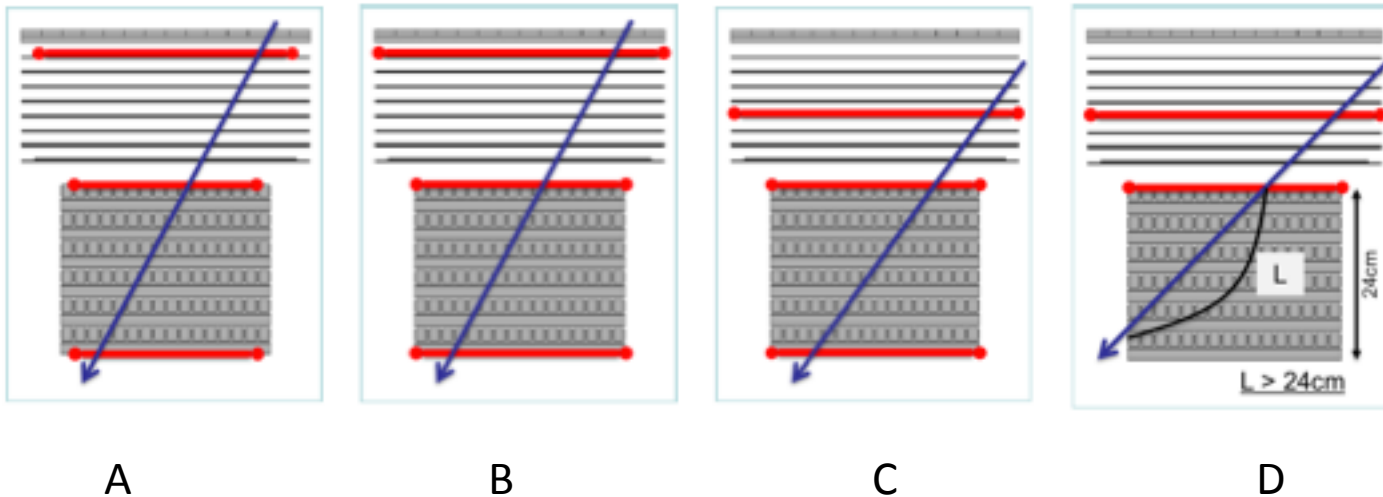
Particle Tracking using a Kalman Filter Technique

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Simulation data

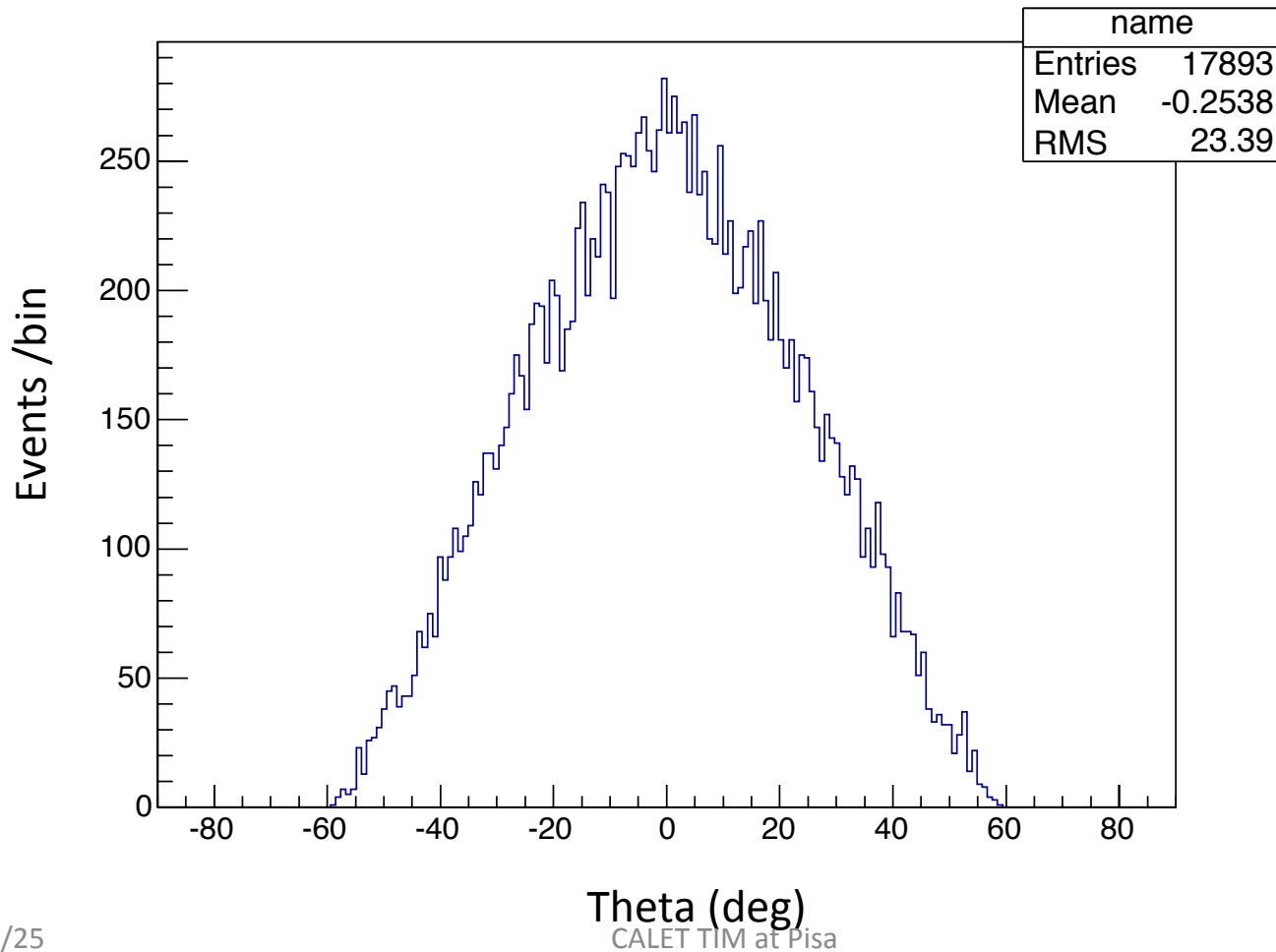
- CALET CAD rev.15 simulation data
- Electron 1TeV
- Down (-90deg ~ +90deg)
- HE Triggered events
- The number of events
 - 88537 events

Geometric Conditions



	A	B	C	D	Others	Total
The number of true simulation events	6525	3965	2893	4510	70644	88537

Angular distribution of simulated events in A-D Conditions (true)



Kalman Filter

- Estimation of states from measurements
 - State: Position and Angle of Shower axis
 - Measurement: IMC output
- Modeling of State equation and Measurement equation
 - State equation: $a_{k+1} = Fa_k + w_k$
 - Measurement equation: $m_k = Ha_k + \varepsilon_k$

Modeling

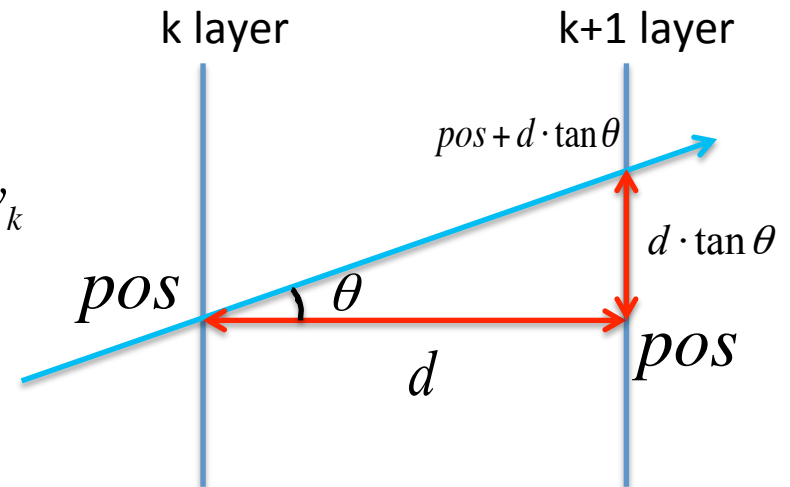
- Linear Discrete Kalman Filter using IMC 1~8 layers Output

(State equation)

$$a_{k+1} = F a_k + w_k$$

$$\begin{pmatrix} position \\ \tan \theta \end{pmatrix}_{k+1} = \begin{pmatrix} 1 & d \\ 0 & 1 \end{pmatrix} \begin{pmatrix} position \\ \tan \theta \end{pmatrix}_k + w_k$$

$$\left\{ \begin{array}{l} position_{k+1} = position_k \cdot d \tan \theta_k + w_k \\ \tan \theta_{k+1} = \tan \theta_k + w_k \end{array} \right\}$$



w_k : System Noise = Multiple Coulomb Scattering in W of IMC

(Measurement Equation)

$$m_k = H a_k + \varepsilon_k$$

$$\begin{pmatrix} \textit{position} \\ 0 \end{pmatrix}_k = \begin{pmatrix} 1 & 0 \\ 0 & 0 \end{pmatrix} \begin{pmatrix} \textit{position} \\ \tan \theta \end{pmatrix}_k + \varepsilon_k$$

m_k : Measurement Vector = Position Information of SciFi

a_k : State Vector = Position and Angle of Shower Axis

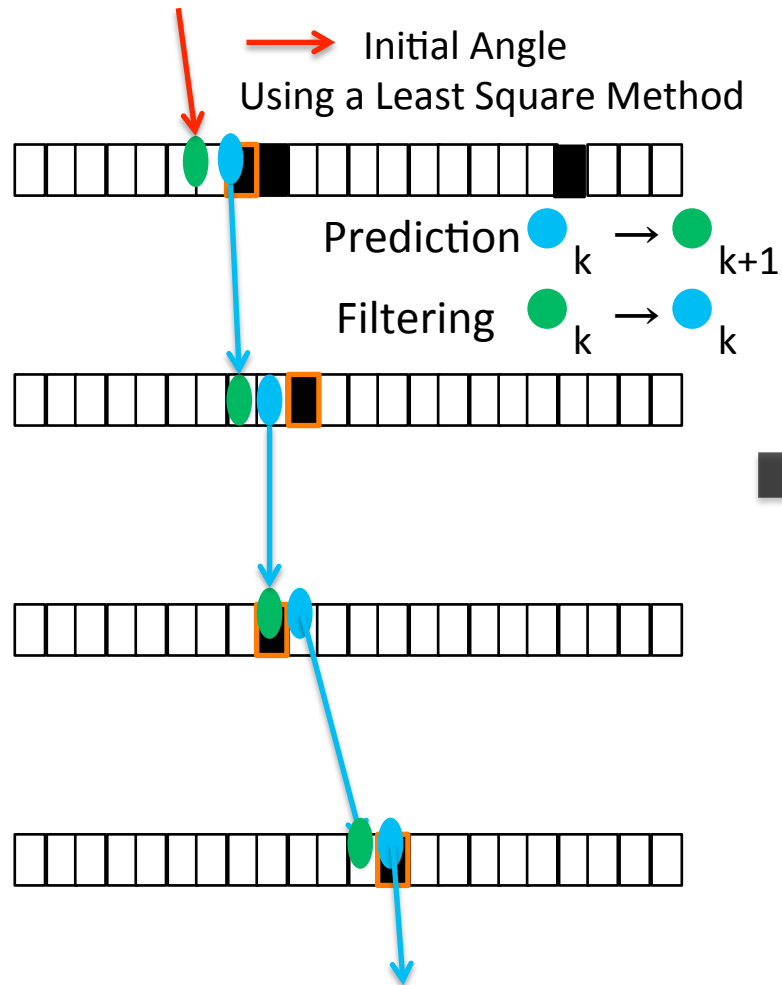
ε_k : Measurement Noise = SciFi Position Resolution of 1mm

=> Estimation of the state vector from the measurement vector

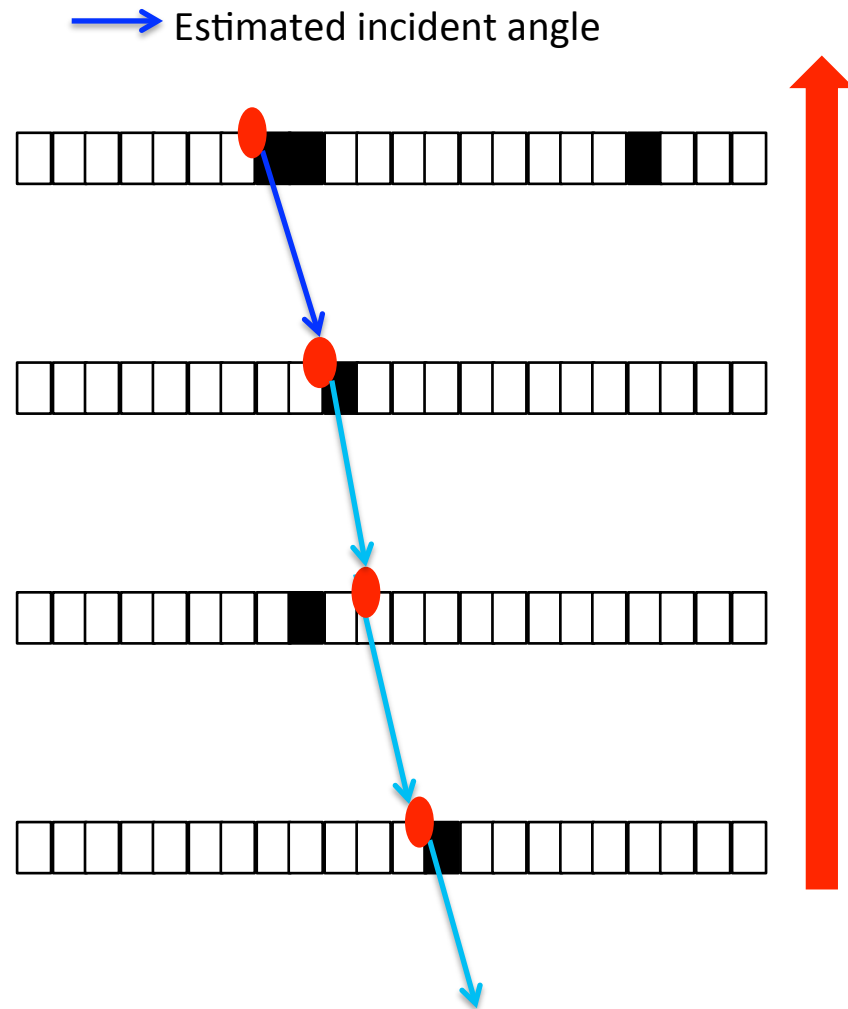
Kalman filter processes

- **Prediction**
 - Prediction of next layer position from (position, angle) of the state vector a_k
- **Filtering**
 - Correction of the predicted position from the measurement vector m_k
- **Smoothing**
 - Smoothing the state vector using the new information of the measurement in backward direction

Prediction & Filtering



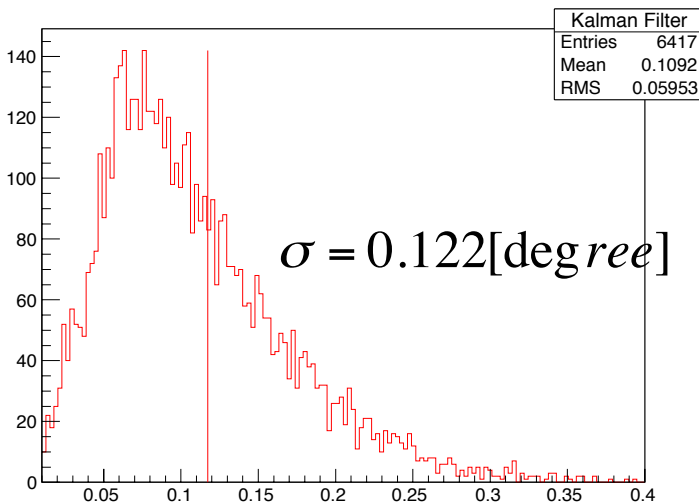
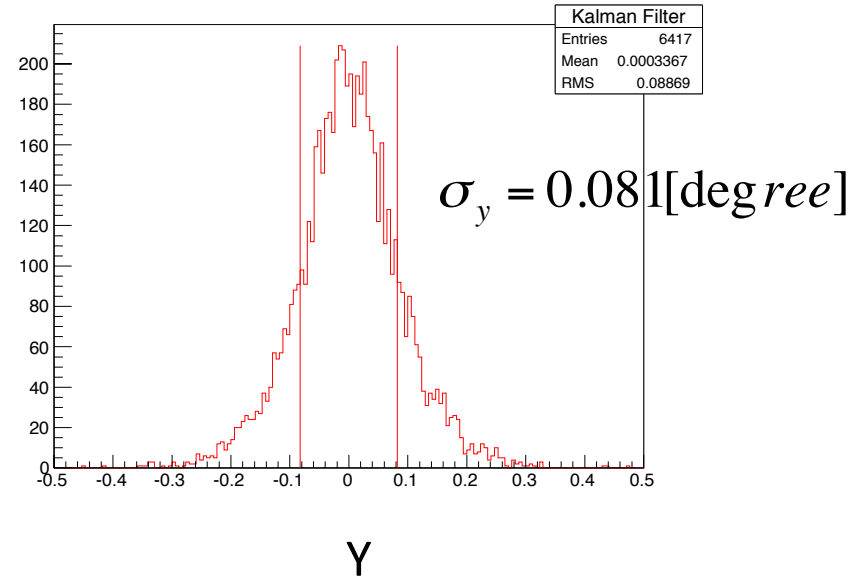
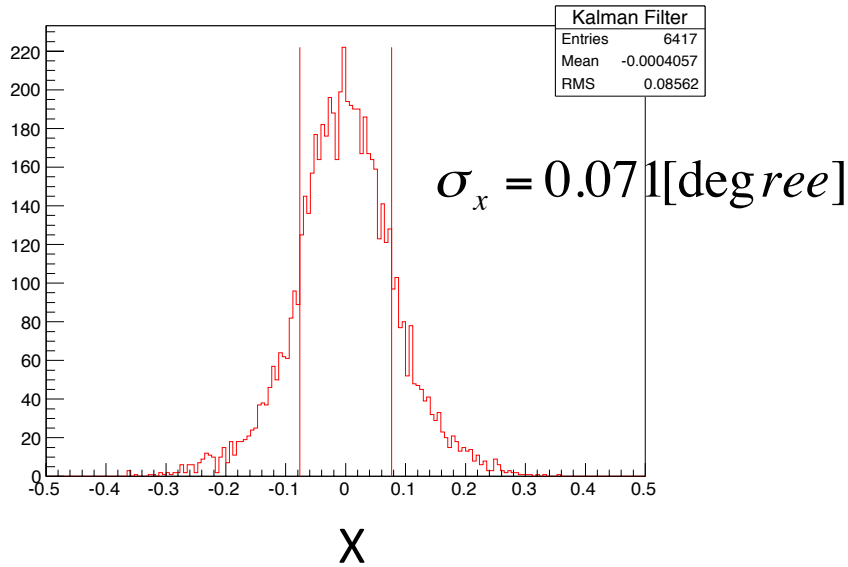
Smoothing



Measurement vector: m_k

= Weighted mean position within +/-5mm SciFi of Predicted SciFi position

Angular Resolution: Geometric Condition A



The number of true events of A

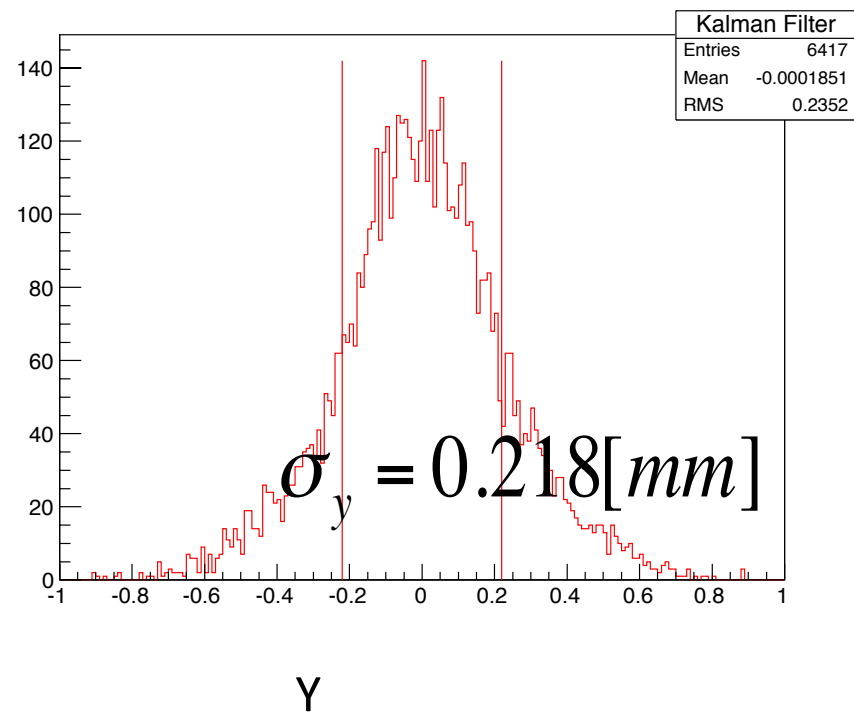
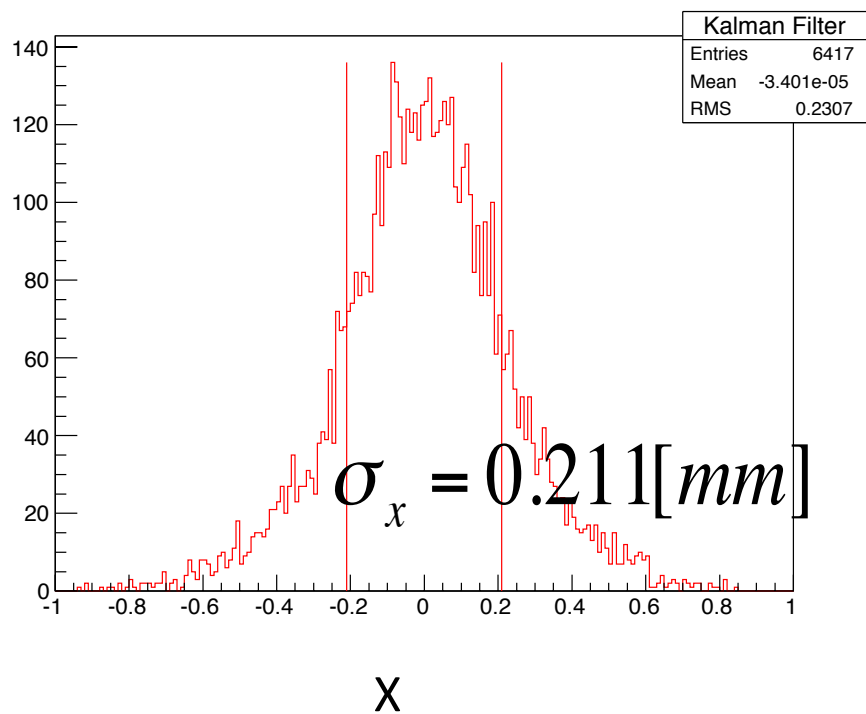
$$A_{\text{true}} = 6525$$

The number of reconstructed events as A

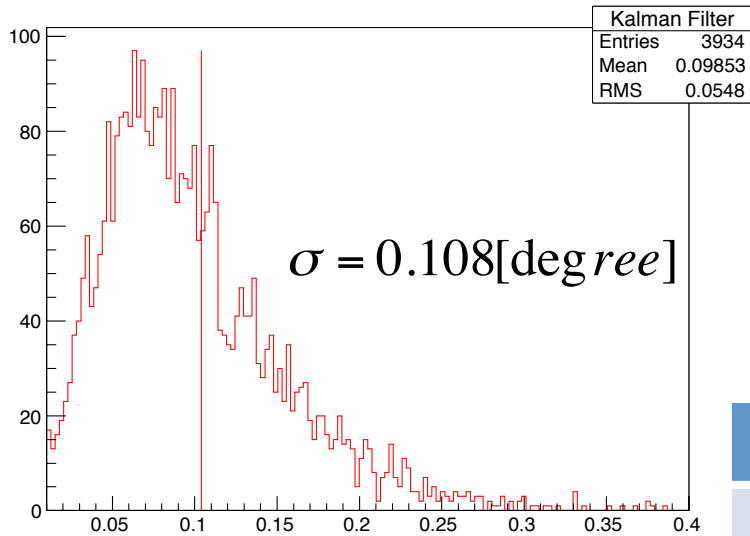
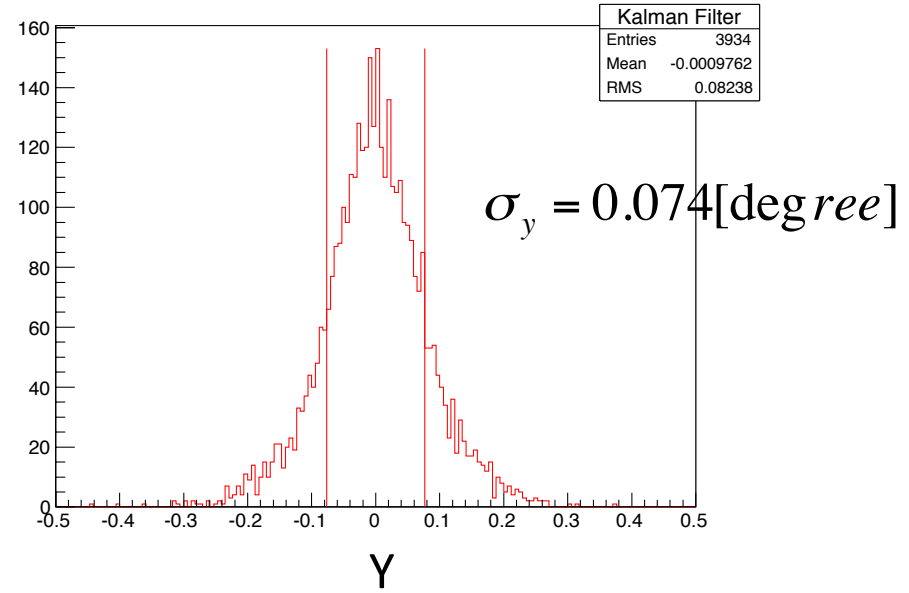
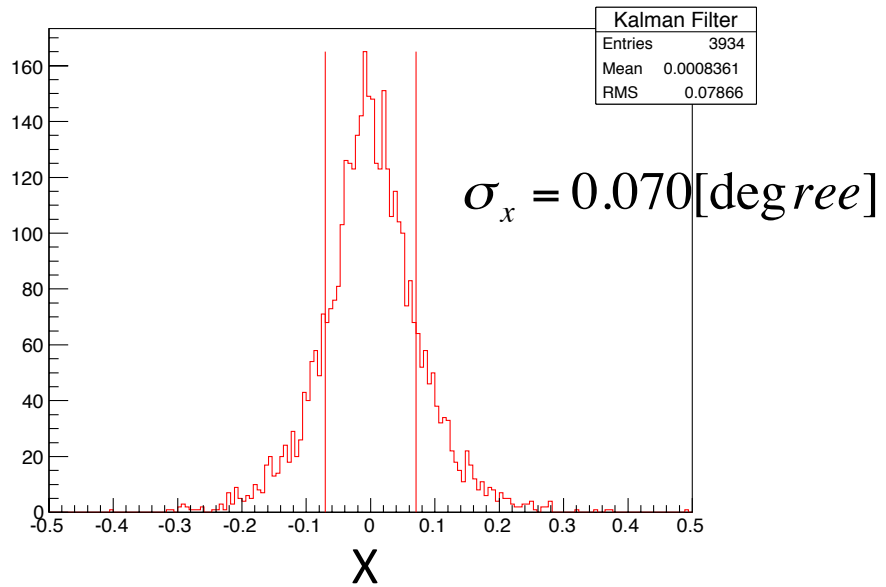
$$A_{\text{esti}} = 6417$$

Breakdown	A_{true}	B_{true}	C_{true}	D_{true}	$\text{Else}_{\text{true}}$
True events	6330	45	0	0	42

Position Resolution on CHD-X: Geometric Condition A



Angular Resolution: Geometric Condition B



The number of true events of B

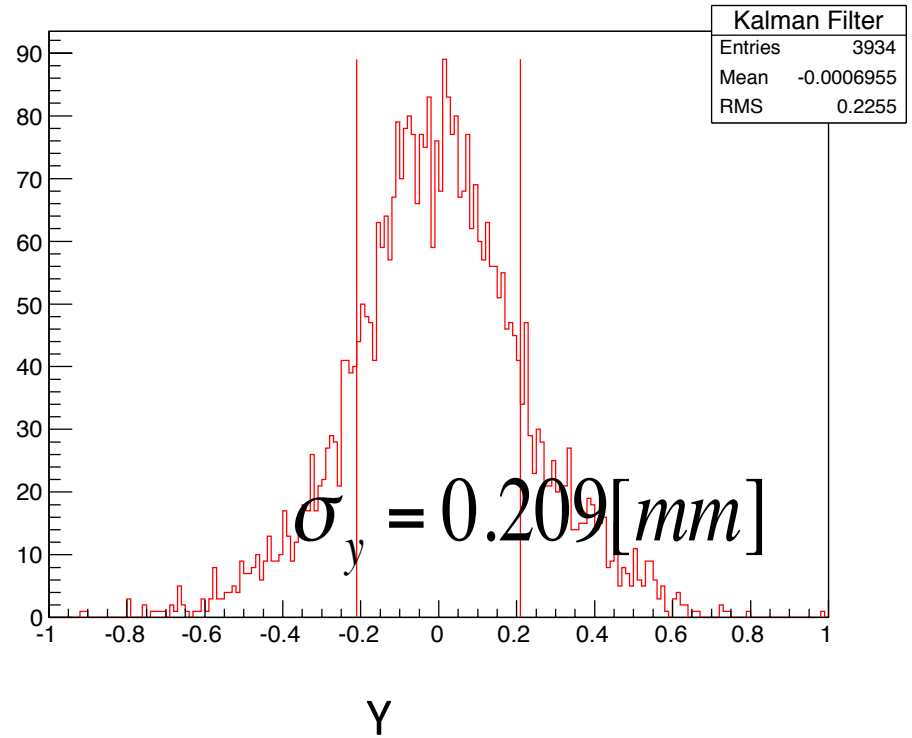
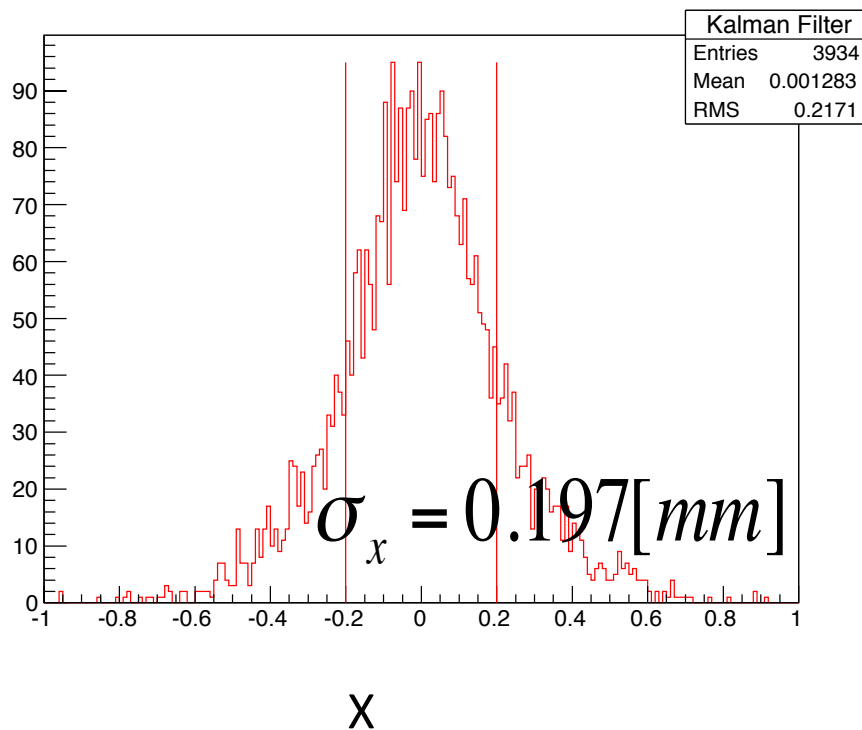
$$B_{\text{true}} = 3965$$

The number of reconstructed events as B

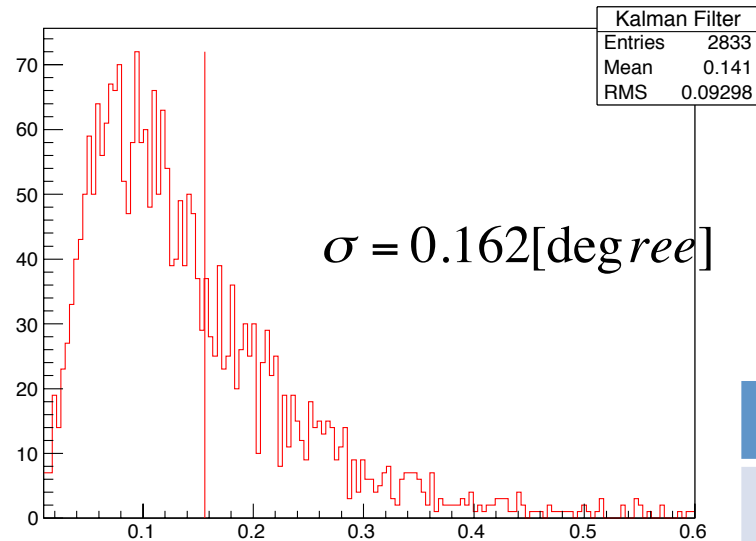
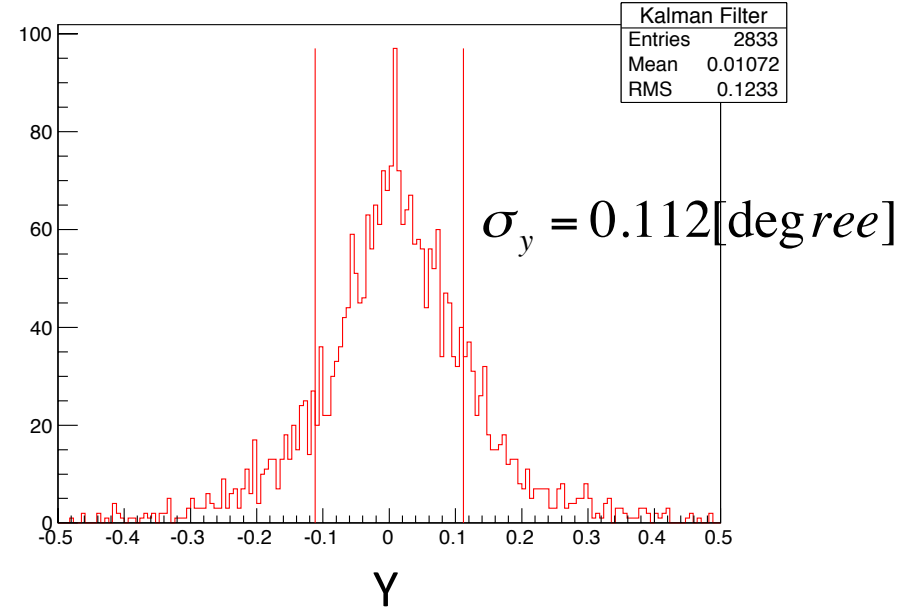
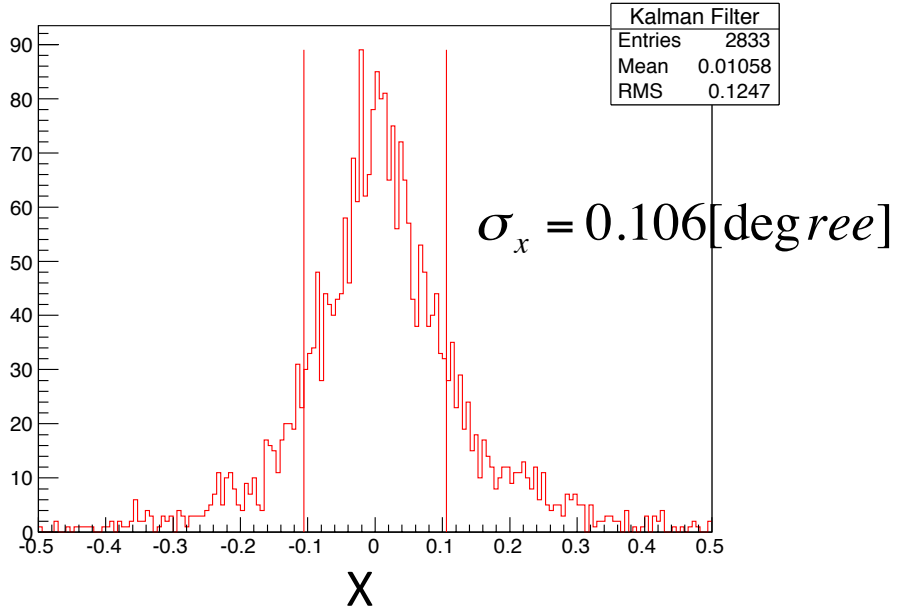
$$B_{\text{esti}} = 3934$$

Breakdown	A_{true}	B_{true}	C_{true}	D_{true}	$\text{Else}_{\text{true}}$
True events	57	3798	16	33	30
CALET TIM at Pisa					13

Position Resolution on CHD-X: Geometric Condition B



Angular Resolution: Geometric Condition C



The number of true events of C

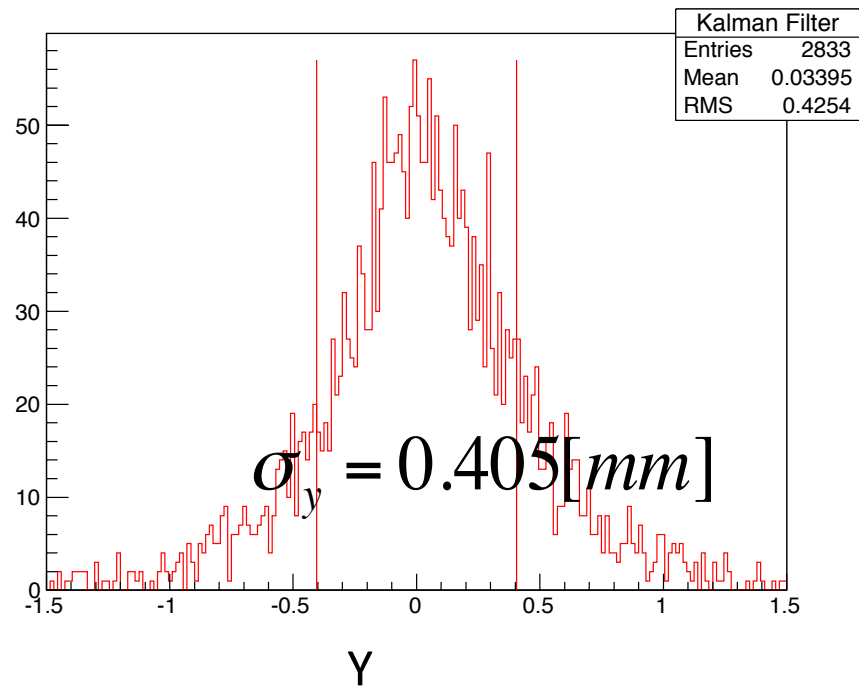
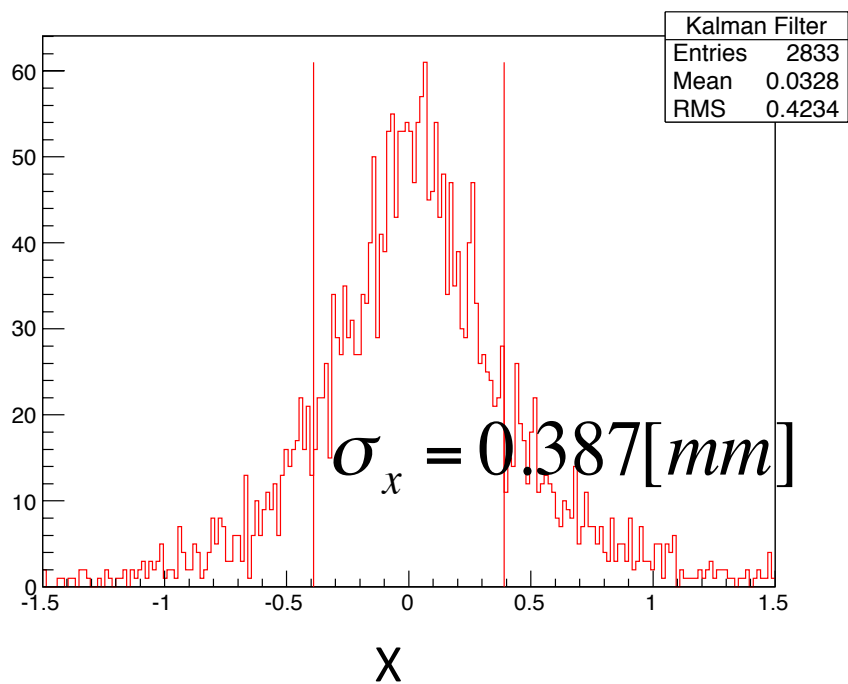
$$C_{\text{true}} = 2893$$

The number of reconstructed events as C

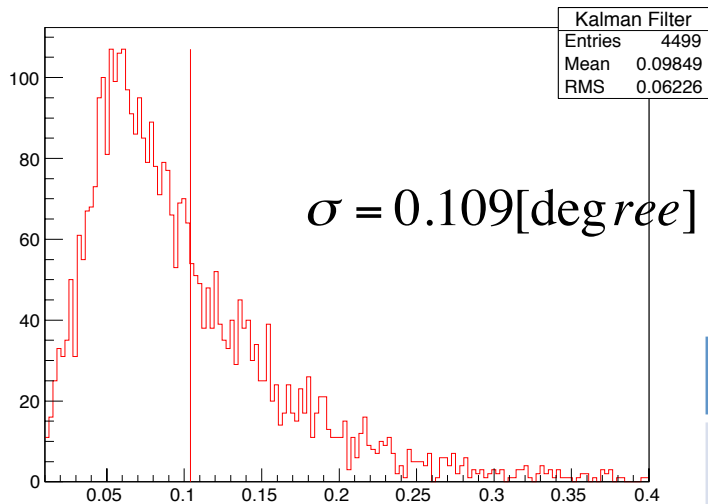
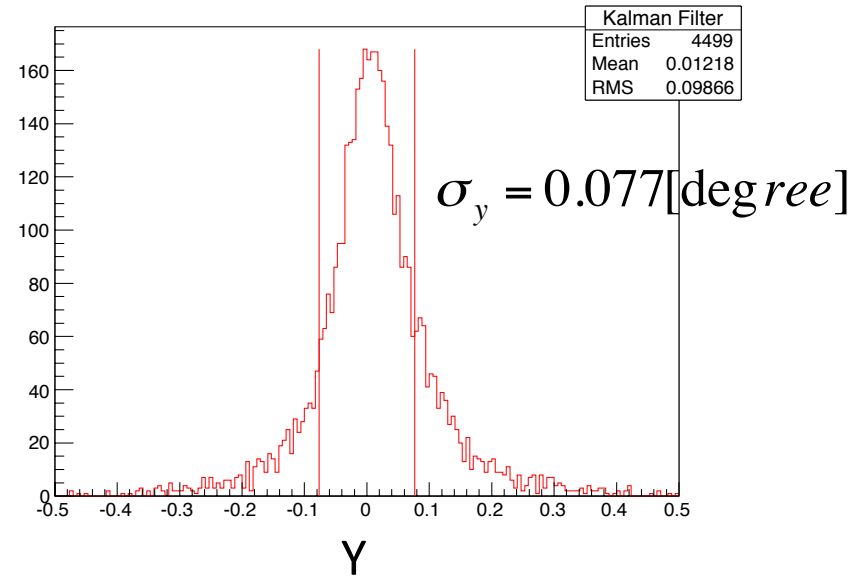
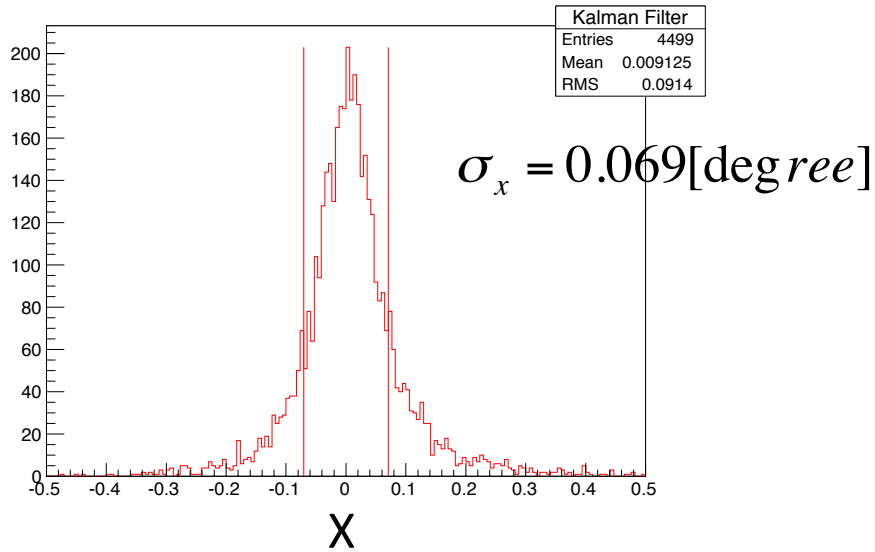
$$C_{\text{esti}} = 2838$$

Breakdown	A _{true}	B _{true}	C _{true}	D _{true}	Else _{true}
True events	0	9	2753	25	46

Position Resolution on CHD-X: Geometric Condition C



Angular Resolution: Geometric Condition D



The number of true events of D

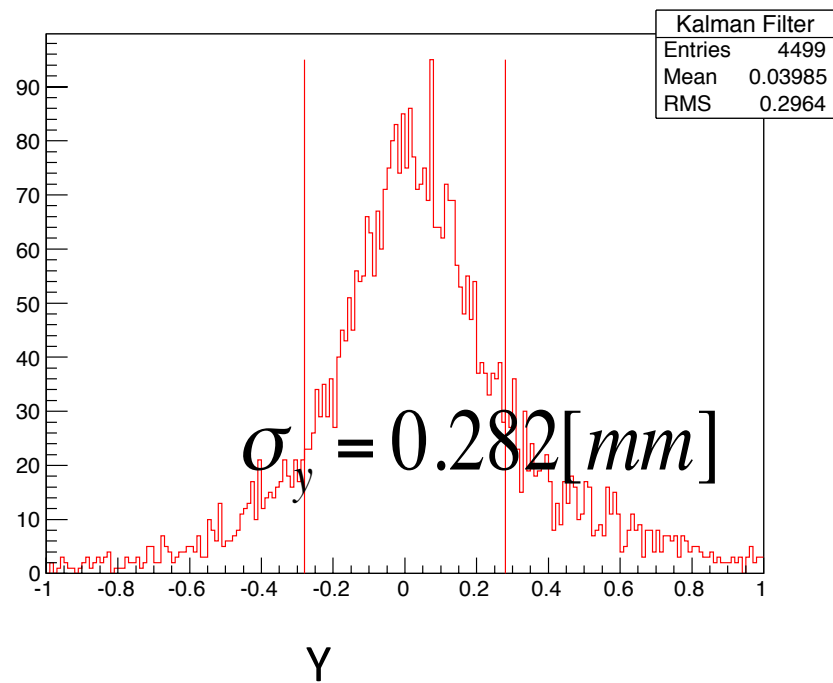
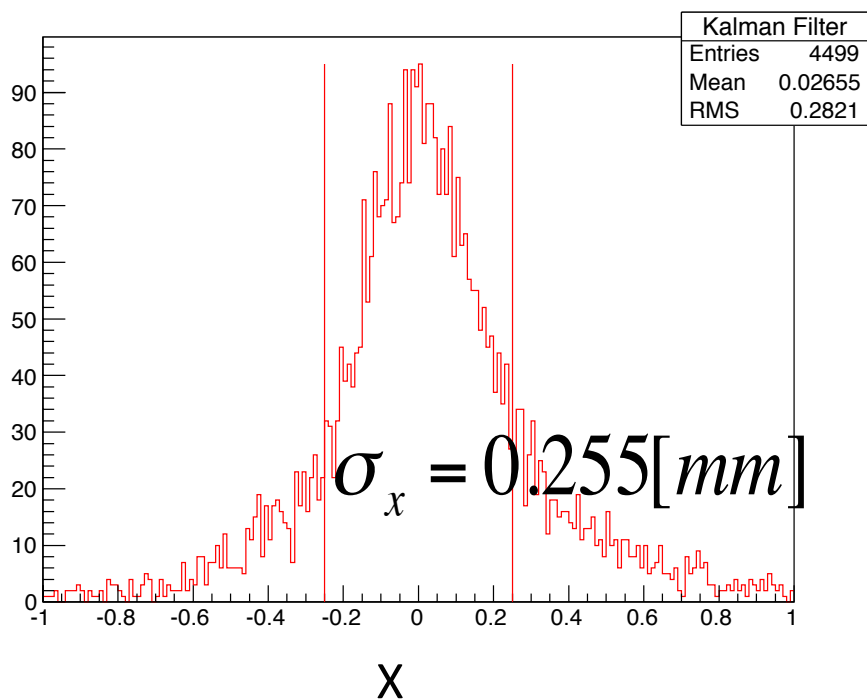
$$D_{\text{true}} = 4510$$

The number of reconstructed events as D

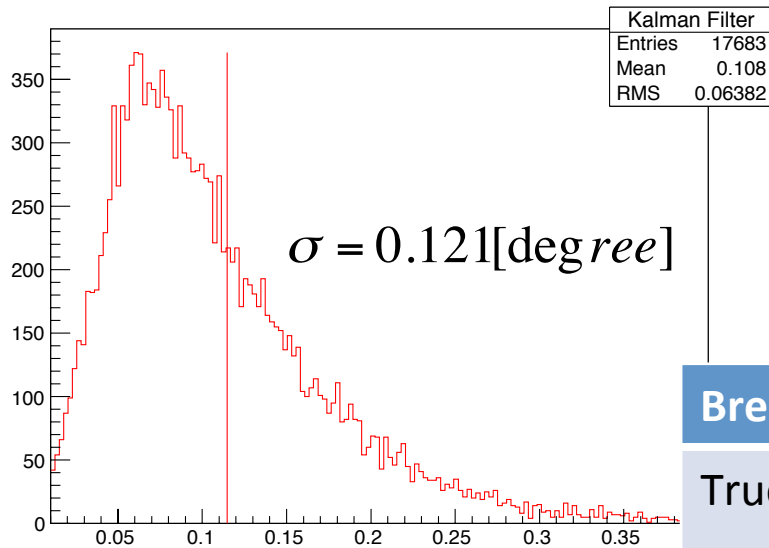
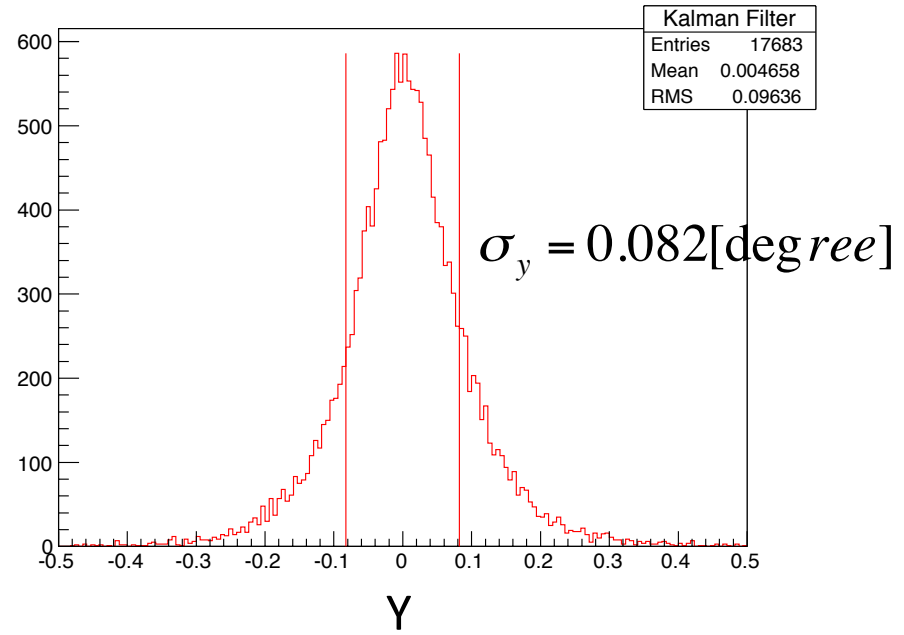
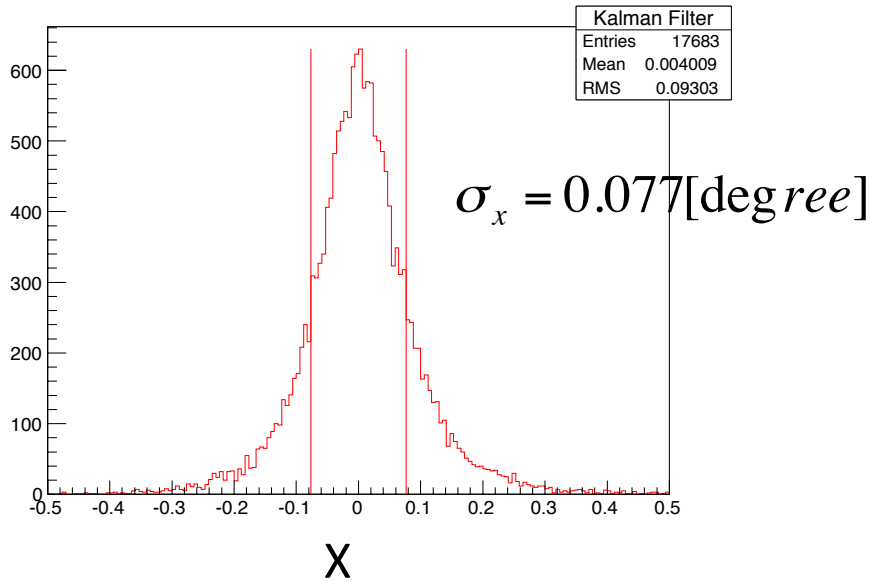
$$D_{\text{esti}} = 4499$$

Breakdown	A_{true}	B_{true}	C_{true}	D_{true}	$\text{Else}_{\text{true}}$
True events	0	42	39	4305	113

Position Resolution on CHD-X: Geometric Condition D



Angular Resolution: Geometric Condition A-D



The number of true events of A-D

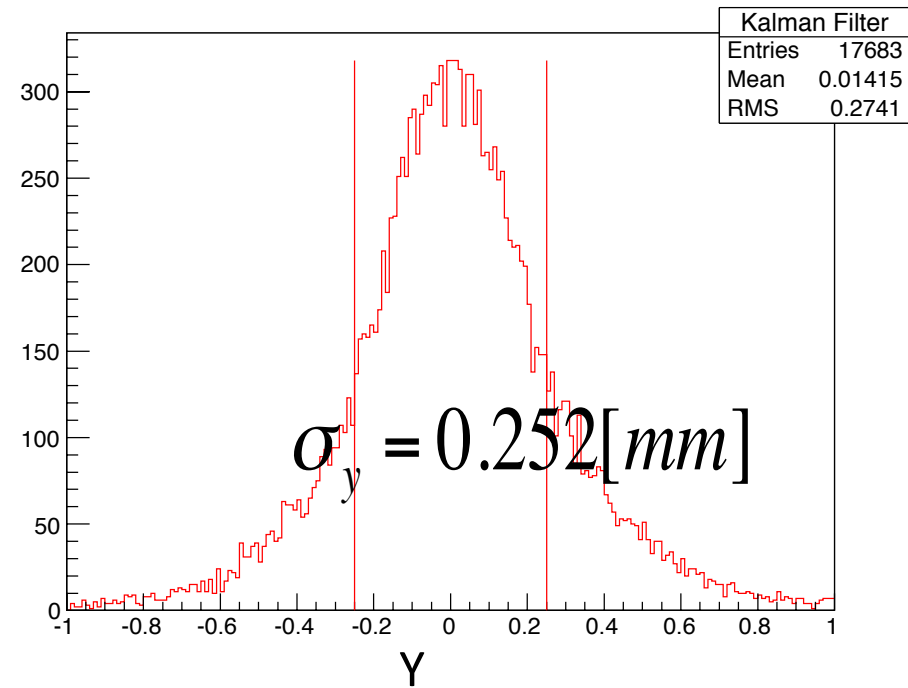
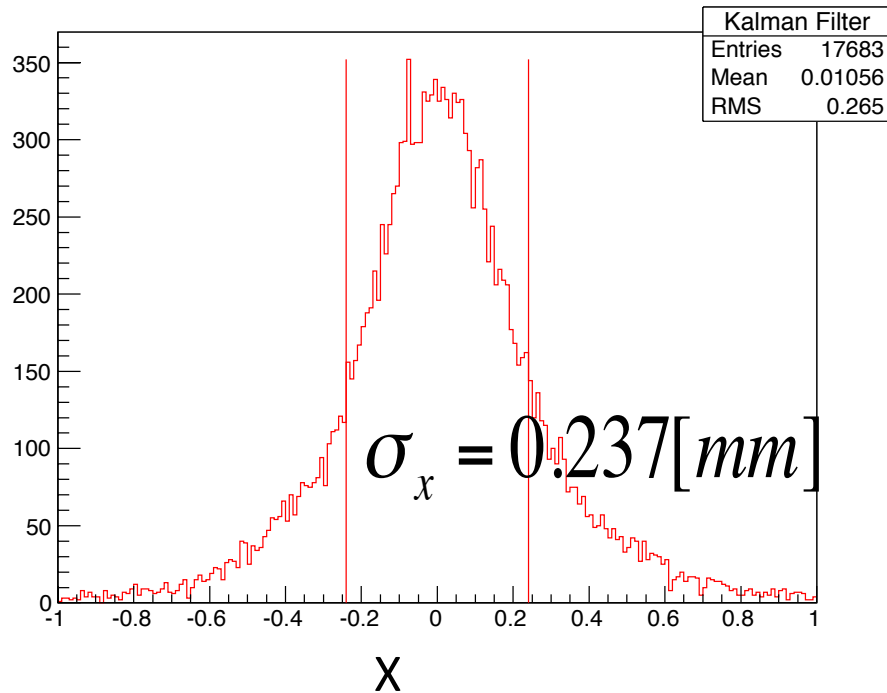
$$A \sim D_{\text{true}} = 17893$$

The number of reconstructed events as A-D

$$A \sim D_{\text{esti}} = 17683$$

Breakdown	A_{true}	B_{true}	C_{true}	D_{true}	$\text{Else}_{\text{true}}$
True events	6387	3894	2808	4363	231

Position Resolution on CHD-X: Geometric Condition A-D



Summary

- Reconstruction of Electron 1TeV for condition A-D
 - Reconstruction rate for true A-D events: 98% (17452 / 17893)
 - Contamination rate outside A-D: 1.3% (231 / 17683)
 - The number of Kalman Filter iteration: 200

		A	B	C	D	A~D
Angular Resolution [degree]	X	0.076	0.070	0.106	0.069	0.077
	Y	0.081	0.074	0.112	0.077	0.082
	3D	0.122	0.108	0.162	0.109	0.121
Space Resolution [mm]	X	0.211	0.197	0.387	0.255	0.237
	Y	0.218	0.209	0.405	0.282	0.252