Drift Chamber Tracking for CLAS12

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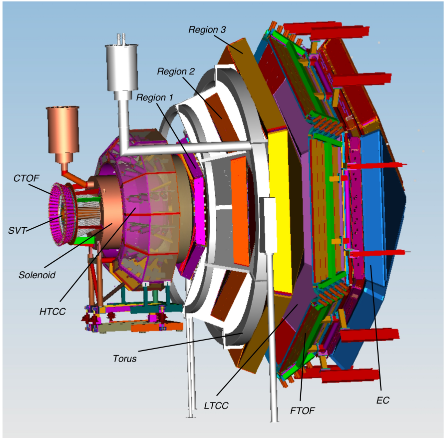
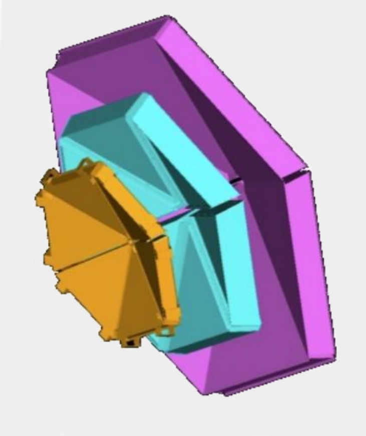
CEBAF Large Acceptance Spectrometer

Outline

Drift Chamber for CLAS12

- The CLAS12 DC will measure trajectories (path length) and hence the momentum of the charged particle emerging from the target.





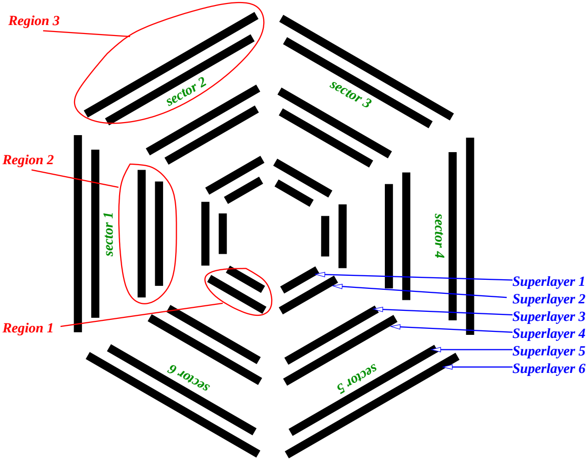
Specifications and Geometry

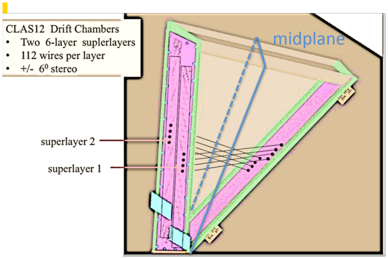
- Includes 18 wire chambers, each with 2 superlayers of 6 layers and 112 wires $\rightarrow$ a total of 24,192 sense wires.
- Each cell will give a spacial resolution of $\sim$ 250 - 350 μm.
- Small cells and fast drift velocity to meet the luminosity requirement of 10^{35} cm^{-2}s^{-1}.

DC – Tracking Specifications	
PARAMETER	**SPECIFICATION**
Angular coverage	$5^o – 40^o$ (50% ϕ-coverage at 5^o)
Momentum resolution	dp/p < 1%
θ Resolution	1 mrad
ϕ Resolution	1 mrad/sinθ
Luminosity	10^{35} cm^{-2} s^{-1}

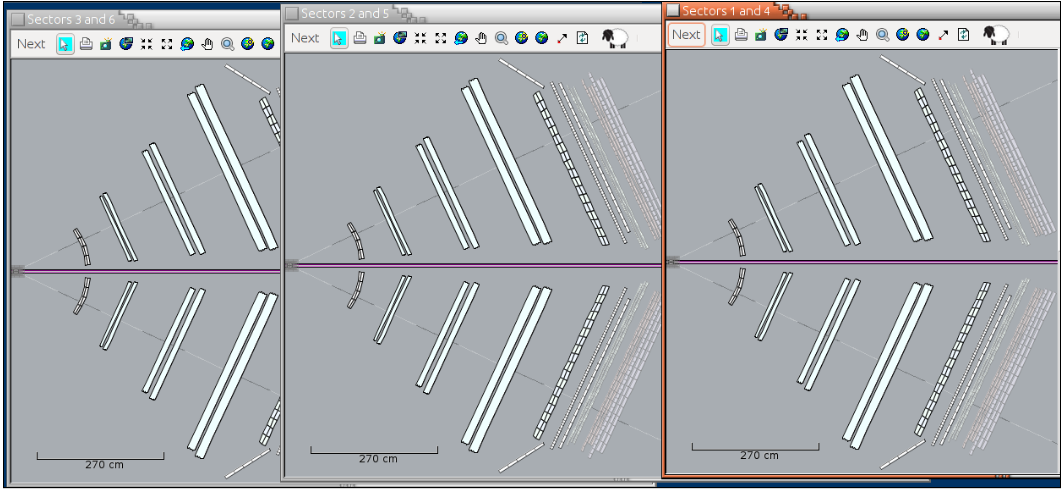
DC – Design Summary	
Cell type	Hexagonal cell
Wire layout	6 sectors, 3 regions, 2 sl's / region
Stereo	+/- 6^0 stereo
Position	Regions at ~2, 3, 4m. From target
Granularity	112 wires/ layer (24192 total)
Gas Choice	90/10 Argon / CO_2

Specifications and Geometry

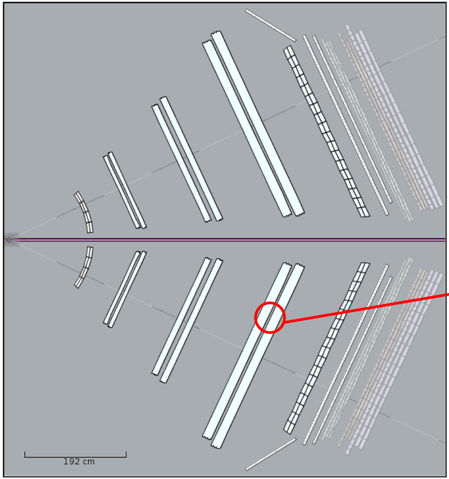


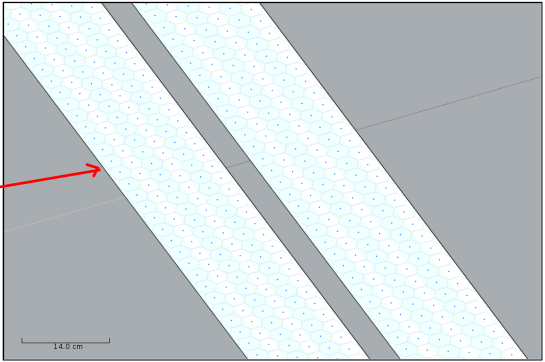


CED Cross-sectional view

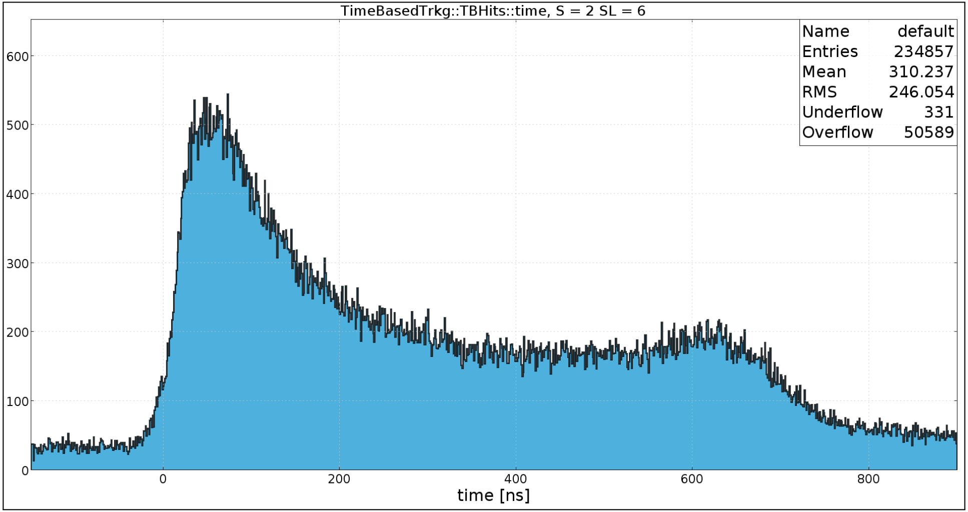


CED Cross-sectional view





Signal From Drift Chamber

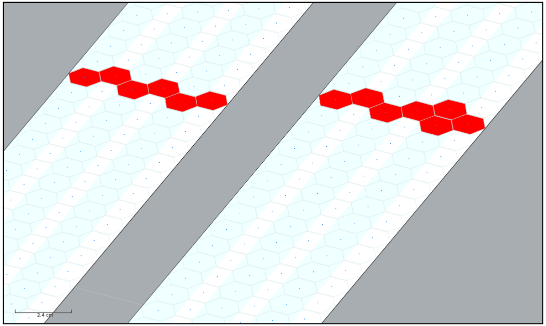


DC Tracking

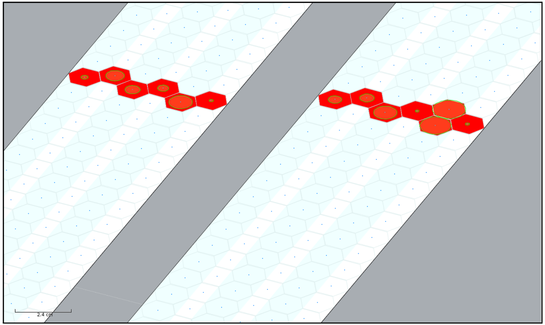
- With the time information and wire index, two separate tracking are implemented:
  - Hit-Based tracking: Uses hit position information
  - Time-Based tracking: Uses timing information

Several hits $\rightarrow$ Each cluster, Cluster $\rightarrow$ Segment, Two segments (from both SL) $\rightarrow$ Cross, Three Crosses $\rightarrow$ Track

DC Tracking: Hits



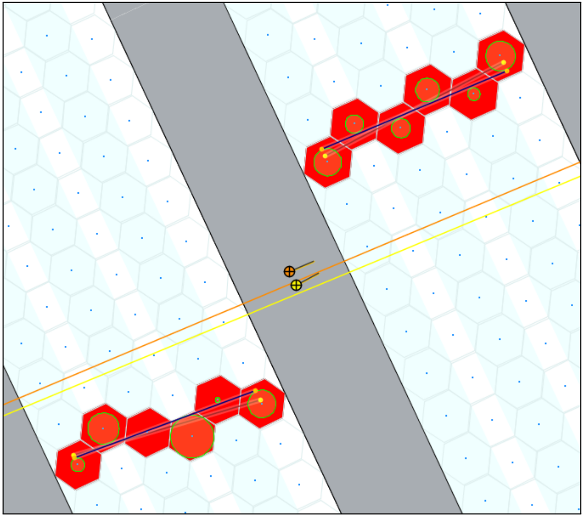
(Hit Based)



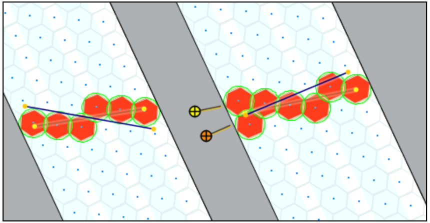
(Time Based)

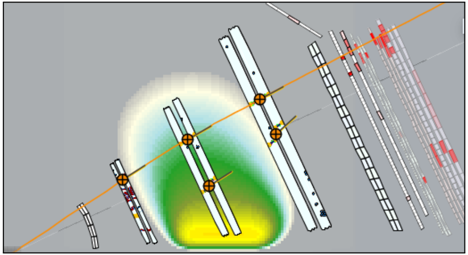
DC Tracking: Segments and Crosses

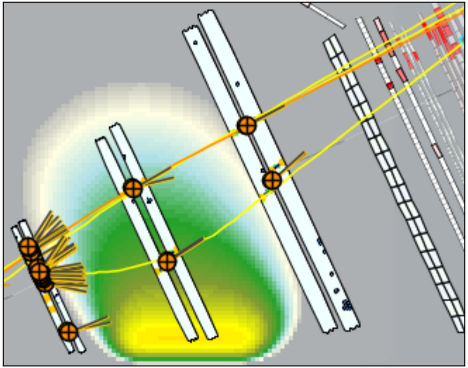
- Hits within each cluster is fitted to form segment.
- Segments from adjacent superlayers are used to construct cross.
- This is done both for hit-based and time-based tracking.



DC Tracking: Out-of-time-hits Rejection



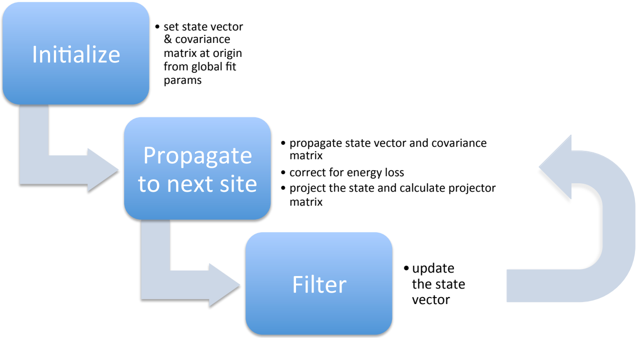




$$\sum_{\text{i:hit in segment}} Doca \sim \sum_i cell - size$$

(Slide courtesy of V. Ziegler)

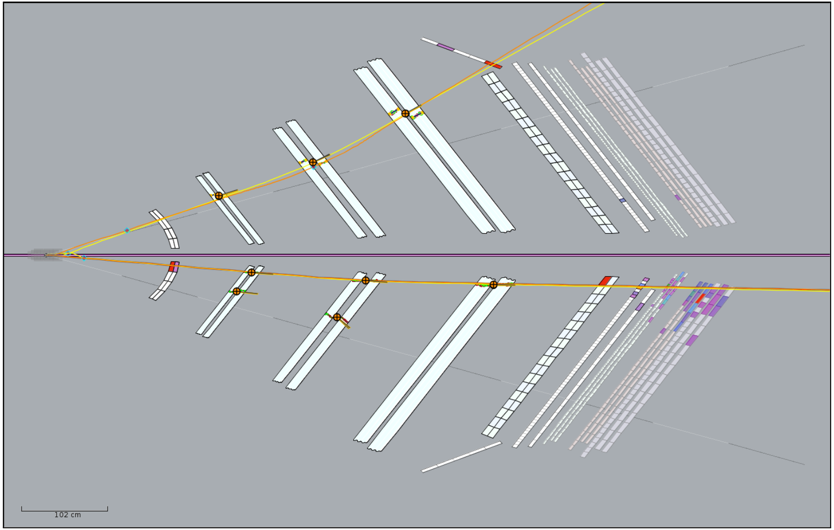
DC Tracking: Kalman Filter



- Start process by propagating the state vector from the first measurement plane using the pattern recognition estimates (swim back from point at first cross to first plane).

(Slide courtesy of V. Ziegler)

DC Tracking: Tracks



DC Calibration

Motivation:

- We want to improve the resolution of DC Tracking by utilizing the timing information.
- This requires extraction of distance (Distance Of Closest Approach - Doca) from the timing information.
- However the challenge is the exact relation between time and distance is not known.
- The time-to-distance relation might evolve over different run periods.

DC Calibration

Solution:

- Constrain the time to distance relation by invoking –
  – Symmetry
  – Physics constraints
  – Other studies like Garfield simulations
- Express time-to-distance relation in terms of adjustable calibration constants.
- Calibrate the adjustable constants through iterative procedure.
- Achieve convergence on time-residual, where

Time residual = Distance from T2D function (calcDoca) - Distance from the fitted track (trkDoca)

Time to Distance Relation: Functional Form

The total drift time t has three contributions,

- i) The main drift time
- ii) Beta-dependent timewalk correction
- iii) The B field dependent contribution

Thus

$$t(x) = t_d + \Delta t_\beta + \Delta t_B \tag{1}$$

i)The main drift time contribution:

$$\boxed{t_d(x) = \frac{x}{v_0} + a\hat{x}_\alpha^n + b_\alpha \hat{x}_\alpha^m} \tag{2}$$

where

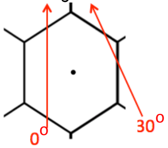
$$\hat{x}_\alpha = \frac{x}{x_{max}^\alpha} = \frac{x}{x_{max}\cos(30-\alpha)} \tag{3}$$

ii) Beta-dependent time-walk correction:

$$\boxed{\Delta t_\beta = \frac{\sqrt{x^2 + (x_\beta \beta^2)^2} - x}{v_0}} \tag{4}$$

Time to Distance Relation: Functional Form

Local angle definition



iii) The B field dependent contribution:

The B-field dependent contribution (applicable only for region 2 i.e. super layers 3, 4)

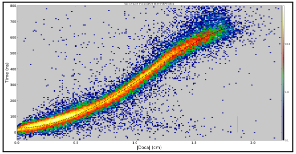
$$\boxed{\Delta t_B = \delta_B B^2 t_{max}(b_1 \hat{x}_\alpha + b_2 \hat{x}_\alpha^2 + b_3 \hat{x}_\alpha^3 + b_4 \hat{x}_\alpha^4)} \tag{5}$$

The physics constraints:

$$t(x = x_0) = t_0, \tag{6}$$

$$\frac{dt}{dx}(x = x_0) = \frac{1}{v_0}, \tag{7}$$

$$\frac{d^2 t}{dx^2}(x = 0.615 x_0) = 0. \tag{8}$$

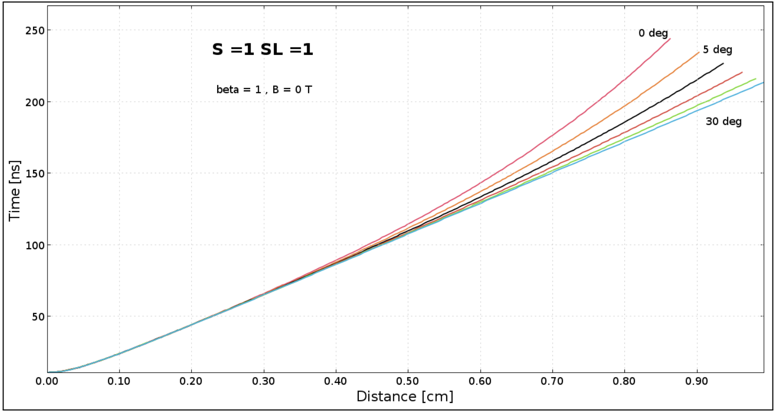


Calibration Constants

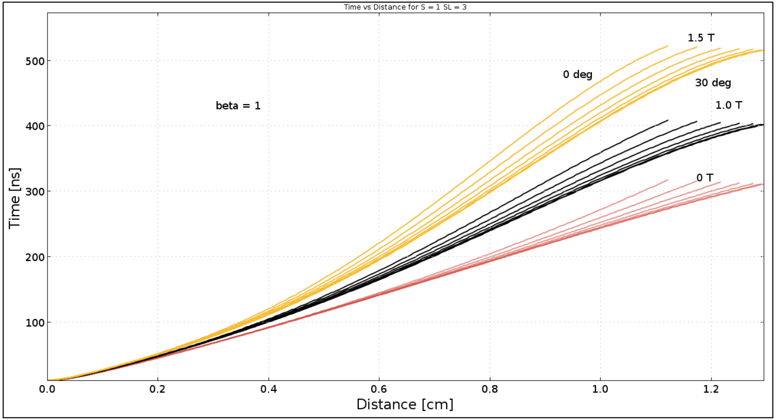
After removing correlation using physics constraints:

$$
\begin{aligned}
p_0 &= v_0 \\
p_1 &= \delta_{mn} \\
p_2 &= t_{max} \\
p_3 &= x_\beta \\
p_4 &= \delta_B \\
p_5 &= b_1 \\
p_6 &= b_2 \\
p_7 &= b_3 \\
p_8 &= b_4
\end{aligned}
\tag{9}
$$

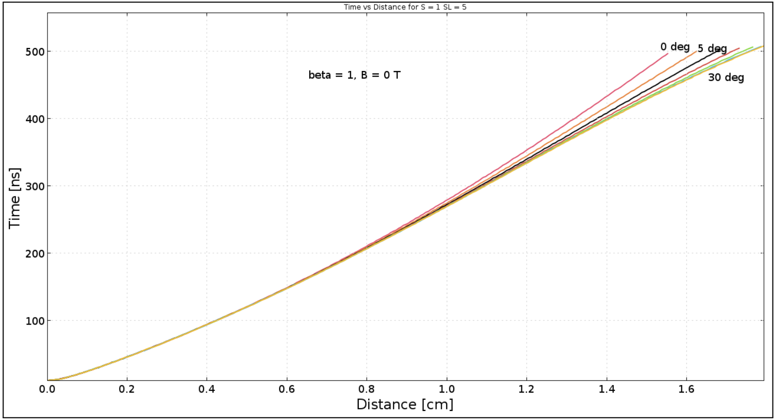
Function form of T2D function: Region 1



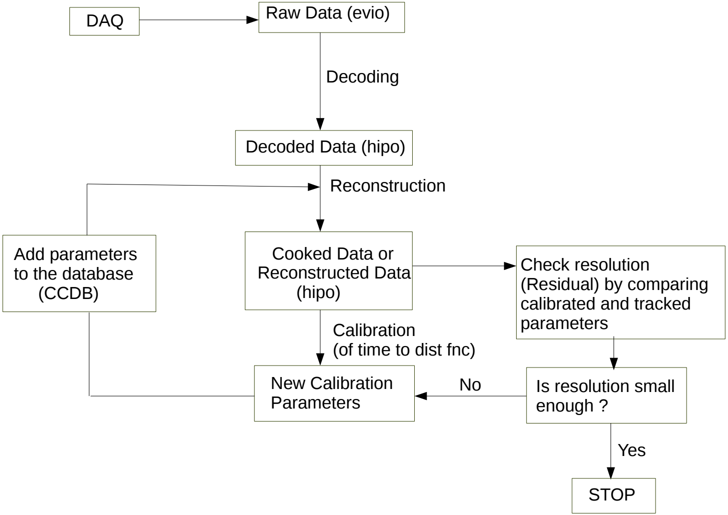
Function form of T2D function: Region 2



Function form of T2D function: Region 3

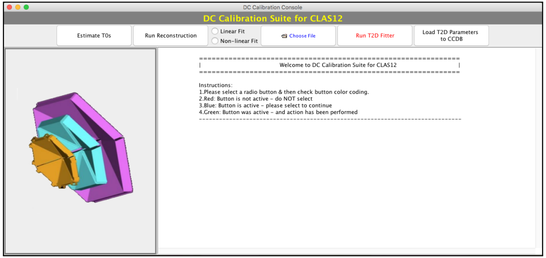


DC Calibration Flow Chart

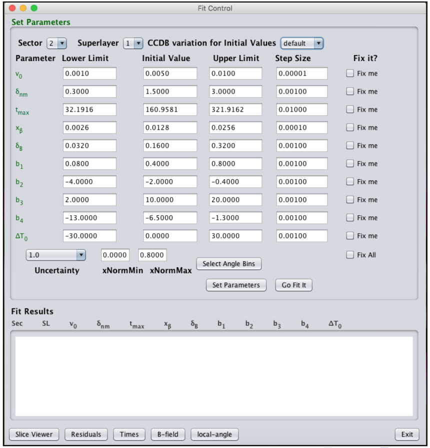


DC Calibration Suite

- GUI driven complete calibration suite for DC
- Tested with KPP data for convergence, stability and improved resolution

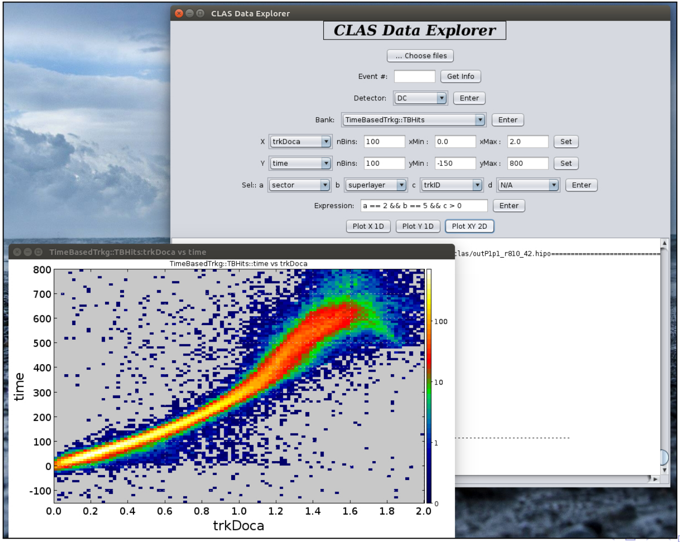


(DC calibration main GUI)

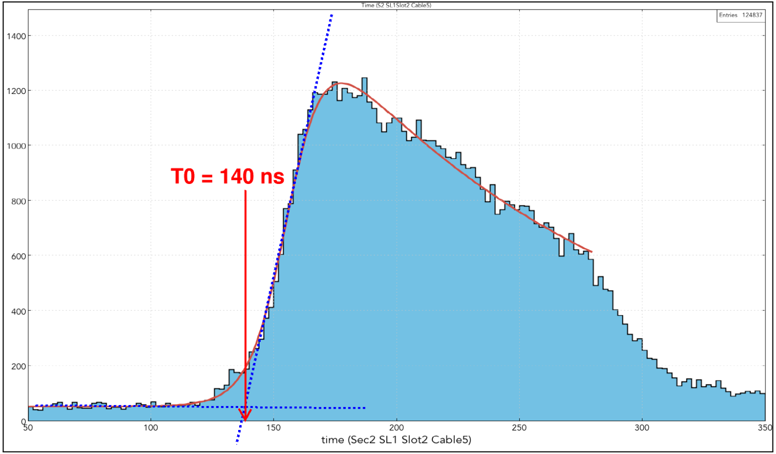


(DC calibration fit control panel)

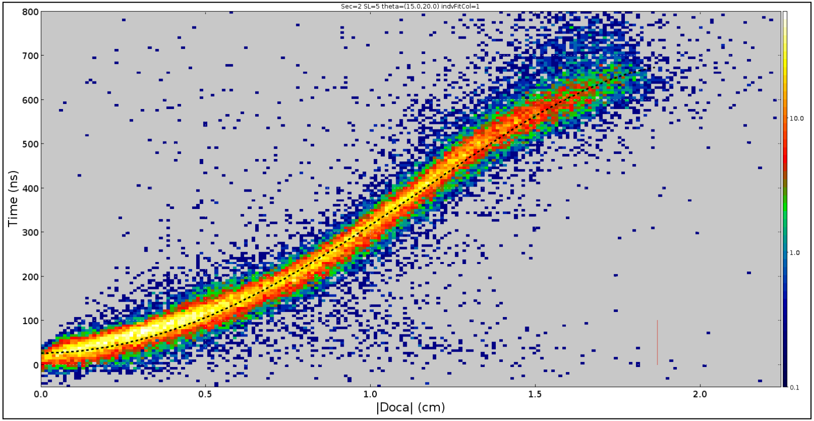
DC Calibration Suite



T0 Correction



Time to Distance Fit

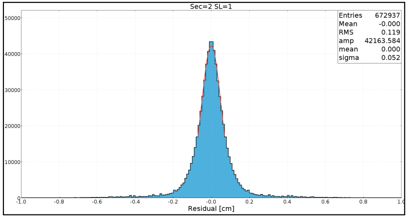


(A typical fit for time to distance function from SL = 5)

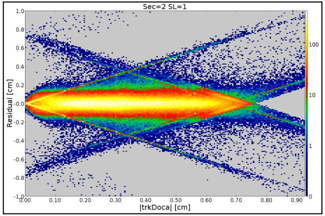
KPP Data Calibration for Sector = 2 Superlayer = 1

Before

$\sigma = 0.052$ cm



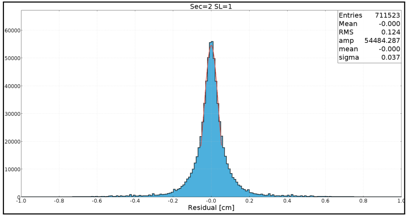
(a) Residual distribution



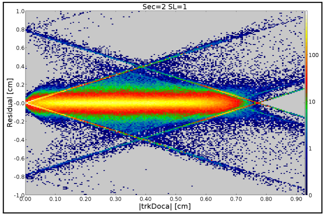
(b) Residual vs trkDoca

After

$\sigma = 0.037$ cm



(a) Residual distribution

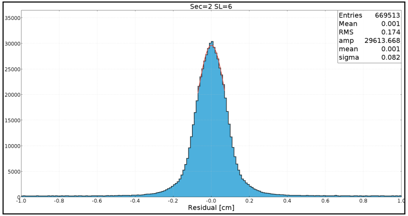


(b) Residual vs trkDoca

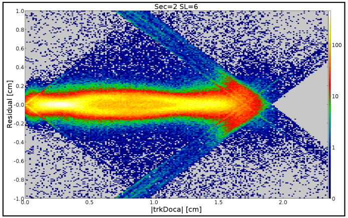
KPP Data Calibration for Sector = 2 Superlayer = 6

Before

$\sigma = 0.082$ cm



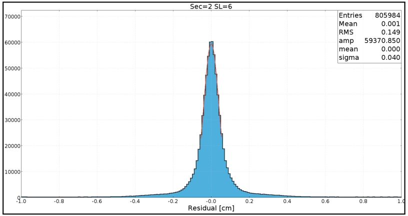
(a) Residual distribution



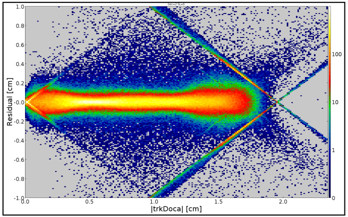
(b) Residual vs trkDoca

After

$\sigma = 0.040$ cm



(a) Residual distribution



(b) Residual vs trkDoca

Summary

- Drift chamber is one of the core tracking detectors for CLAS12
- DC tracking utilizes both hit-based and time-based tracking to achieve best possible resolution
- DC calibration is an essential part in achieving the desired resolution
- The calibration suite and algorithm are well advanced
- Further fine tuning is in progress