TARGET EFFECT, BEAM CORRECTION, T0 ADJUSTMENT AND KINEMATICS

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1,Target Effect

- Due to Bremsstrahlung, Ionization, Multi-Scattering and so on:

$$E_{beam} = E_0 - \Delta E_0^t, P_k = P_k + \Delta P_k^t, P_{e'} = P_{e'} + \Delta P_{e'}^t$$

Different target materials, densities, thicknesses, and kinematics settings, cause different values of energy loss.

- **SIMC:** Hall-C Standard Monte Carlo Simulation Package.

  It simulates three major processes, including beam, target, e-arm (HMS), p-arm(SOS).

  Our Spectrometers (HKS&HES) are not defined in SIMC, but we only care about the target effect with specific kinematics setting.

- **Kinematics Setting in SIMC**

---- Similar to the setting in Geant4

Beam: 2344.0 MeV(0.005%), Pe:844.0 MeV/c, Pk: 1200.0 MeV/c

E-Arm: (HES)

Momentum (%): -17.77 ~ 36.26

Angle: X'(mrad): -110.00 ~ -30.00

Y'(mrad): -250.00 ~ 250.00

K-Arm: (HKS)

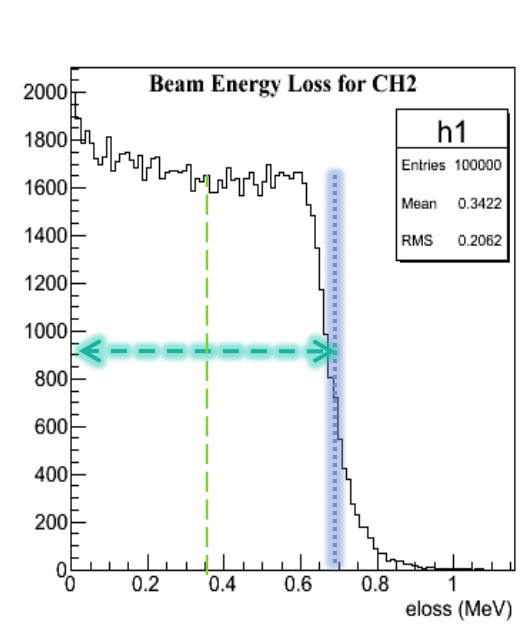
Momentum (%): -12.5 ~ 12.5

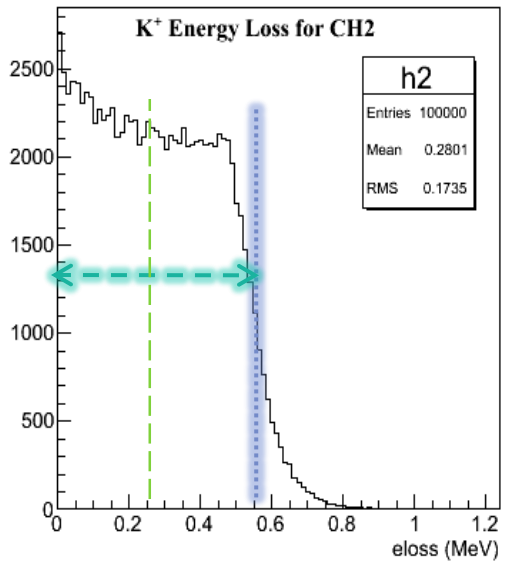
Angle: X'(mrad): -150.00 ~ -150.00

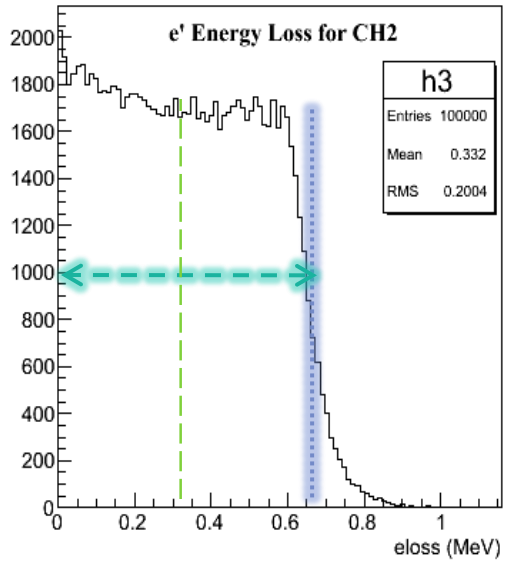
Y'(mrad): -30.00 ~ 270.00

- CH2 Target:

density: 0.93 g/cm3, thickness: 465.0 mg/cm2







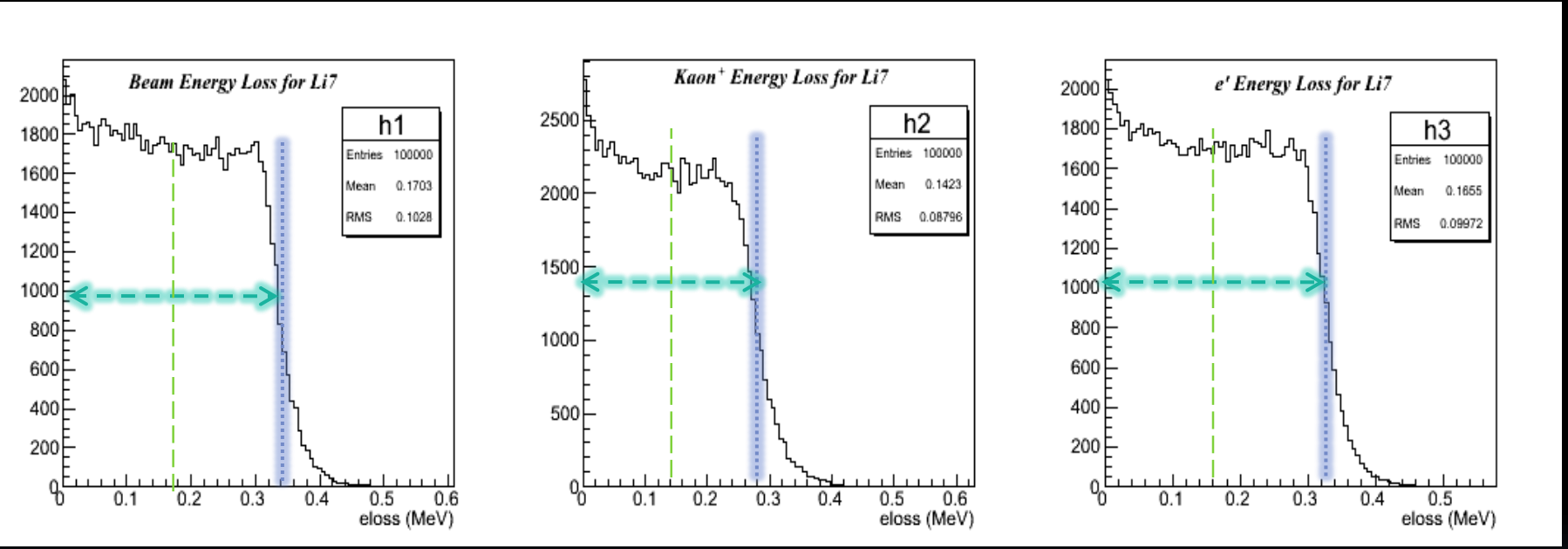
$$\Delta\overline{E}_0^t \approx 0.35MeV$$

$$\Delta\overline{P}_k^t \approx 0.25MeV/c$$

$$\Delta\overline{P}_e^t \approx 0.33MeV/c$$

- Li7 Target:

density: 0.54 g/cm3, thickness: 207.0 mg/cm2



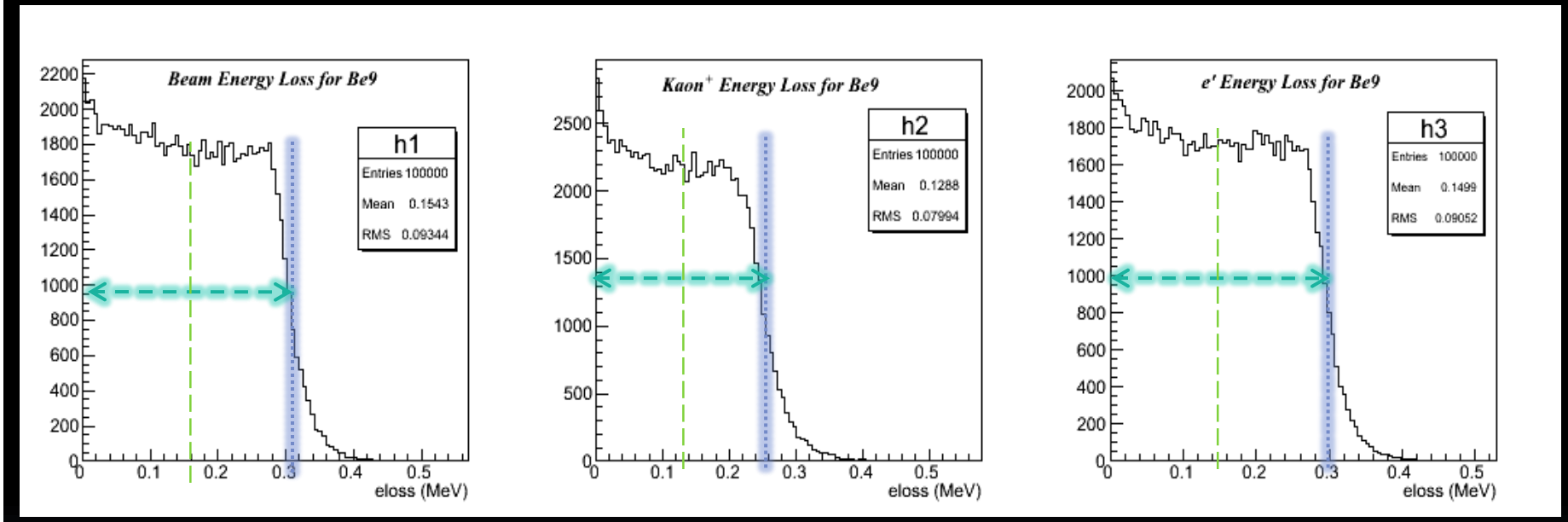
$$\Delta\overline{E}_0^t \approx 0.18MeV$$

$$\Delta\overline{P}_k^t \approx 0.14MeV/c$$

$$\Delta\overline{P}_e^t \approx 0.16MeV/c$$

- Be9 Target:

density: 1.848 g/cm3, thickness: 188.12 mg/cm2



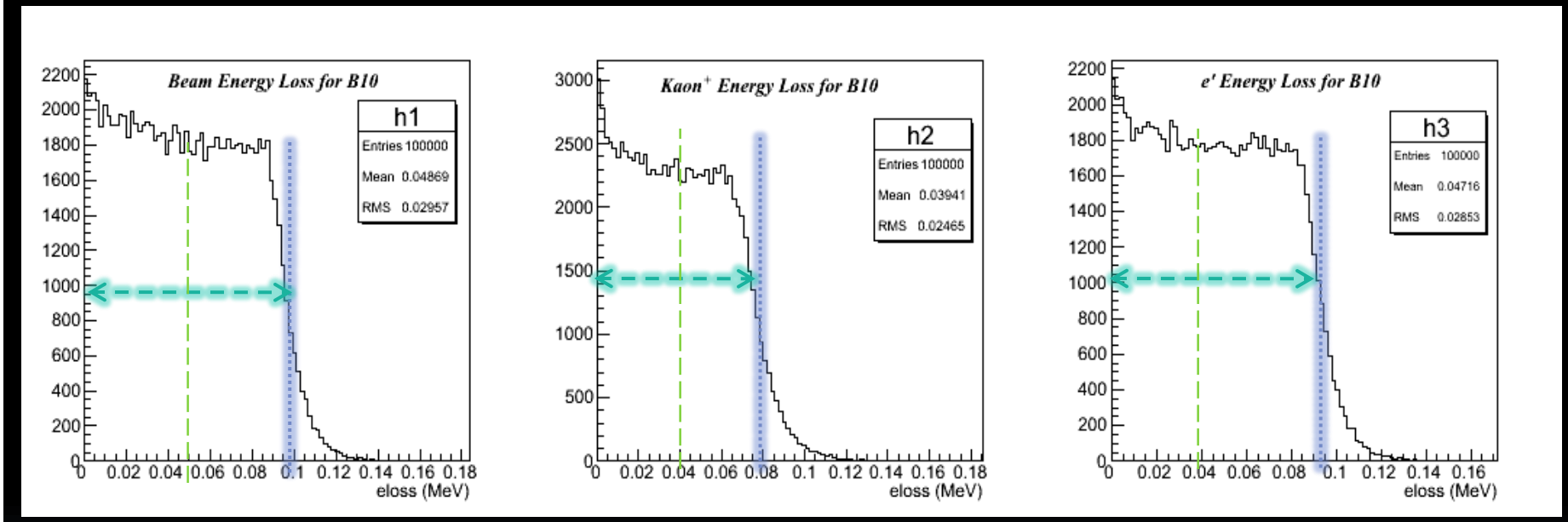
$$\Delta\overline{E}_0^t \approx 0.15MeV$$

$$\Delta\overline{P}_k^t \approx 0.13MeV/c$$

$$\Delta\overline{P}_e^t \approx 0.15MeV/c$$

- B10 Target:

density: 2.16 g/cm3, thickness: 56.1 mg/cm2



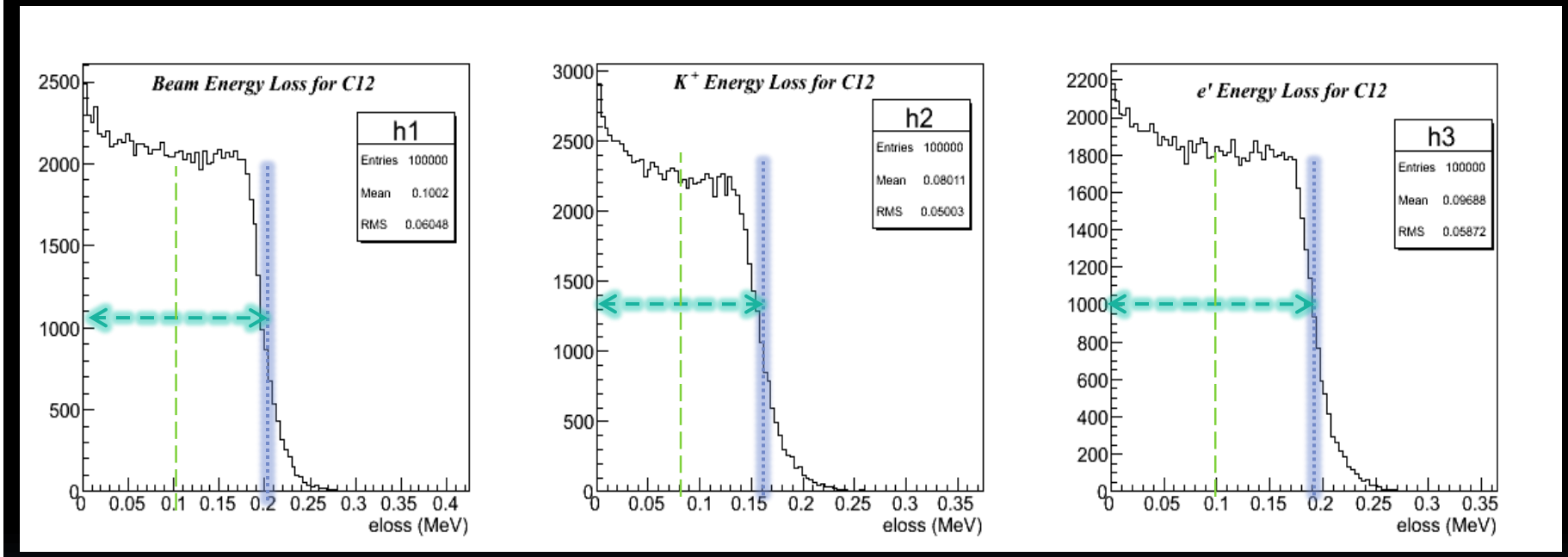
$$\Delta\overline{E}_0^t \approx 0.05MeV$$

$$\Delta\overline{P}_k^t \approx 0.04MeV/c$$

$$\Delta\overline{P}_e^t \approx 0.04MeV/c$$

- C12 Target:

density: 2.25 g/cm3, thickness: 112.5 mg/cm2



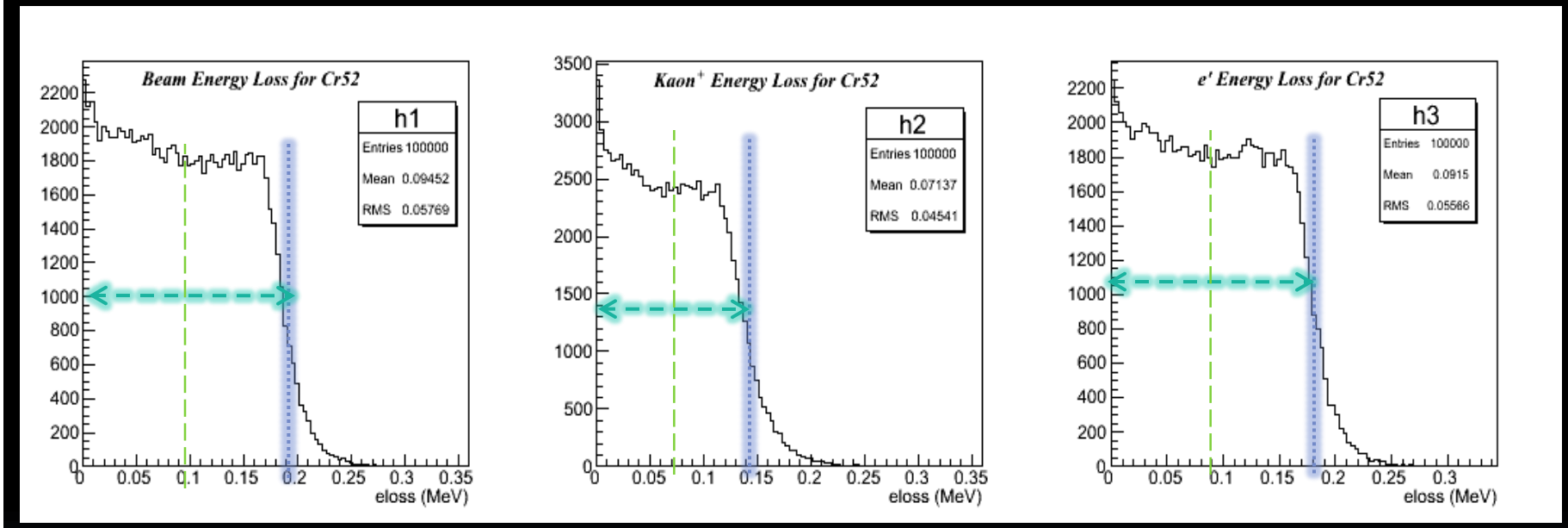
$$\Delta\overline{E}_0^t \approx 0.10 MeV$$

$$\Delta\overline{P}_k^t \approx 0.08 MeV/c$$

$$\Delta\overline{P}_e^t \approx 0.09 MeV/c$$

- Cr52 Target:

density: 7.15 g/cm3, thickness: 125.0 mg/cm2



$$\Delta\overline{E}_0^t \approx 0.09 MeV$$

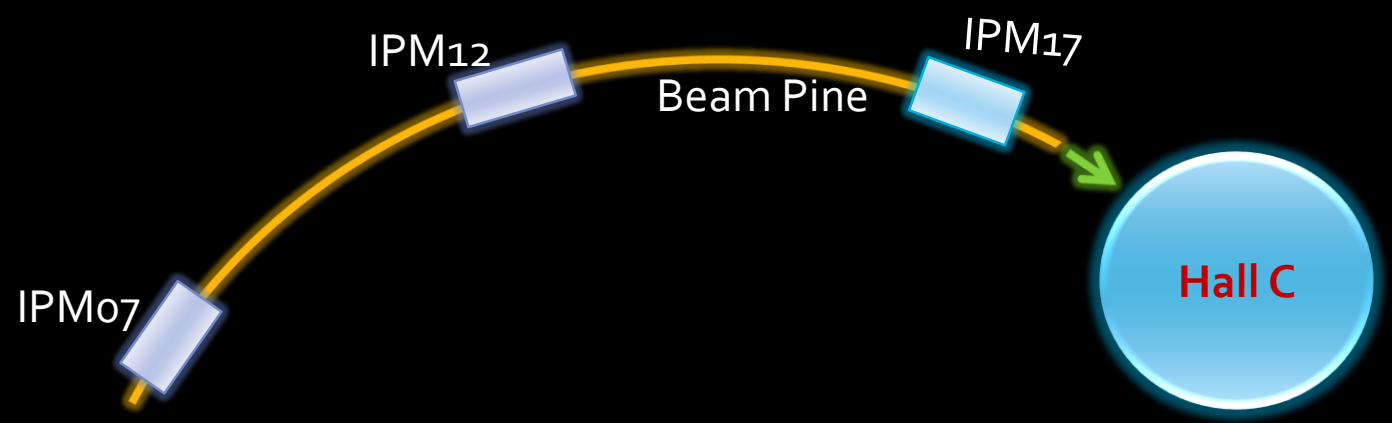
$$\Delta\overline{P}_k^t \approx 0.07 MeV/c$$

$$\Delta\overline{P}_e^t \approx 0.08 MeV/c$$

Summarize:

Target	Density (g/cm3)	Thickness (mg/cm2)	ΔE (KeV)	ΔPk (KeV/c)	ΔPe (KeV/c)	Error (KeV)
CH2	0.93	465.0	350.0	250.0	330.0	??
Li7	0.54	207.0	180.0	140.0	160.0	??
Be9	1.85	188.2	150.0	130.0	150.0	??
B10	2.16	56.1	50.0	40.0	40.0	??
C12	2.25	112.5	100.0	80.0	90.0	??
Cr52	7.15	125.0	90.0	70.0	80.0	??
H20+Cell						

2,Beam Correction



Two energy scan run: E = E_{beam} $\pm$ *1.0 MeV, so* we want to have the correction function:

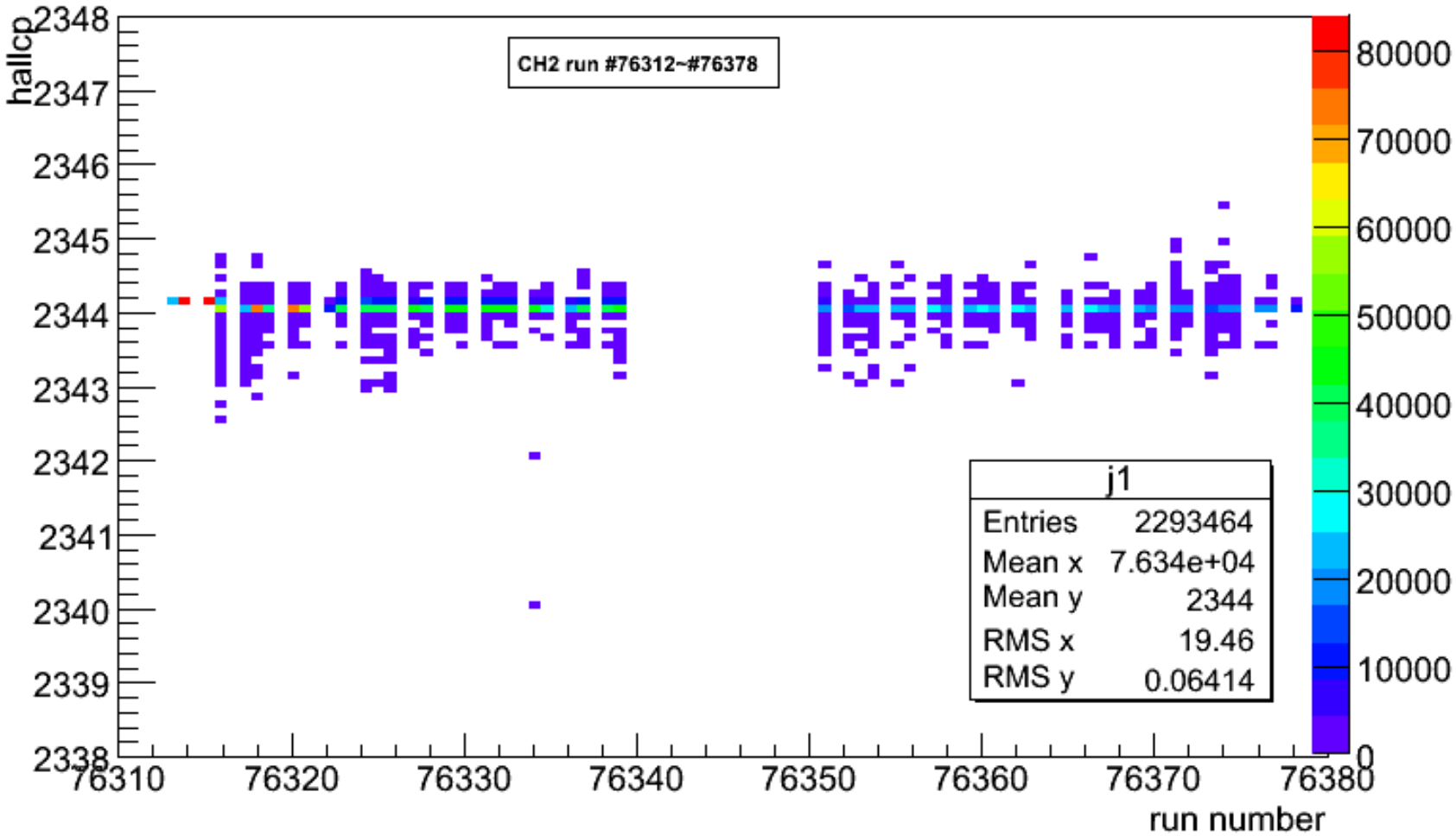
$$\Delta E_{offset} = f(bpm06x, bpm06y, bpm12x, bpm12y, bpm17x, bpm17y)$$

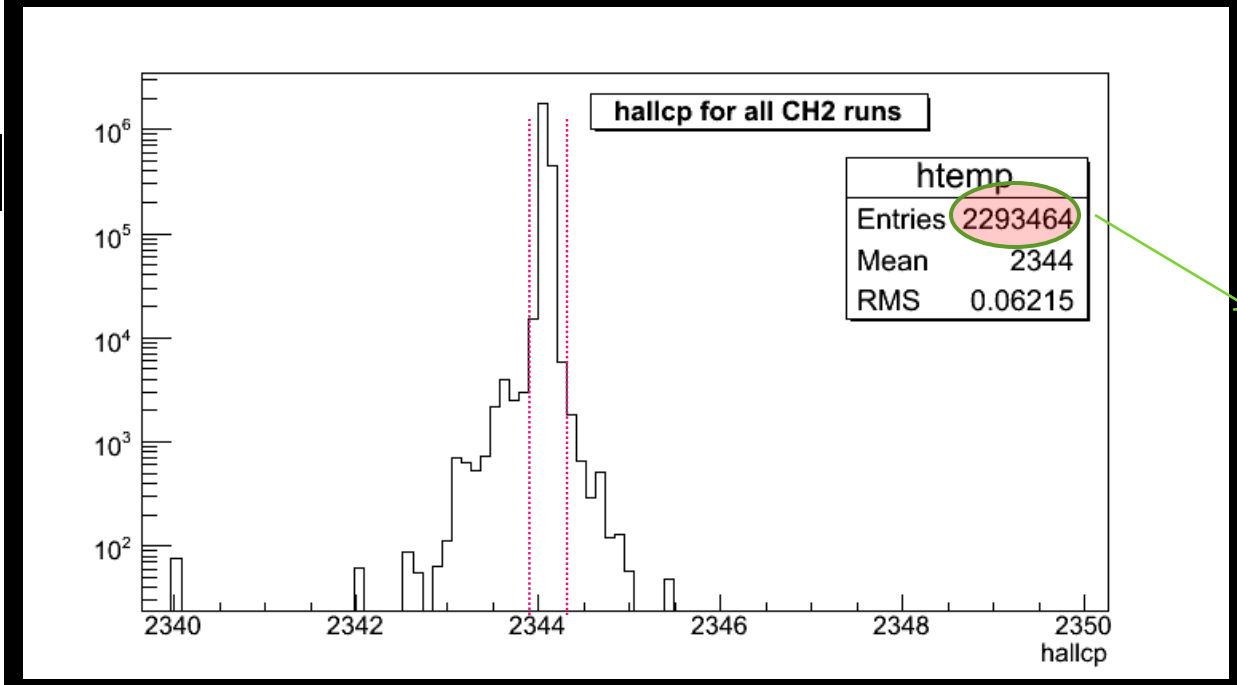
However,

- Two data sets can not fit six variables.
- Beam energy lock was on during the two data sets taking, so we miss the info between energy shifts and the change of BPM info.

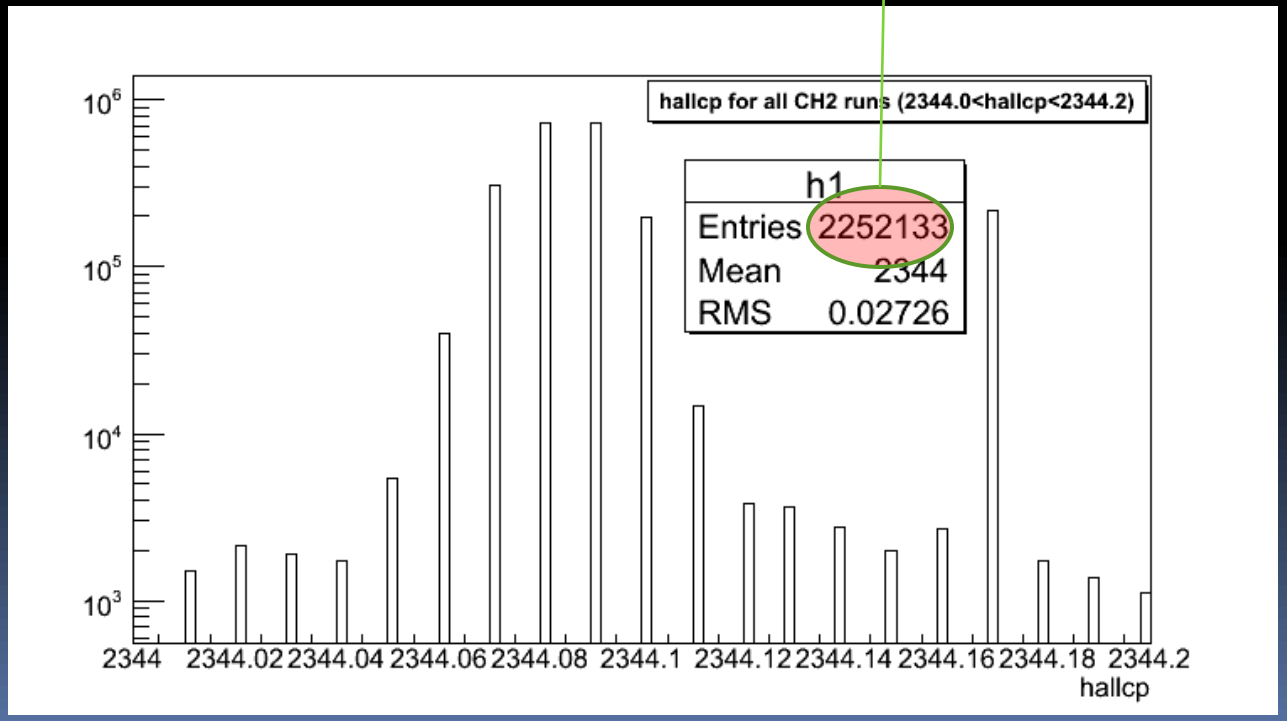
From Tomo: Using other BPM info inside Hall C

Look at the 'hallcp' in whole period of CH2 runs:

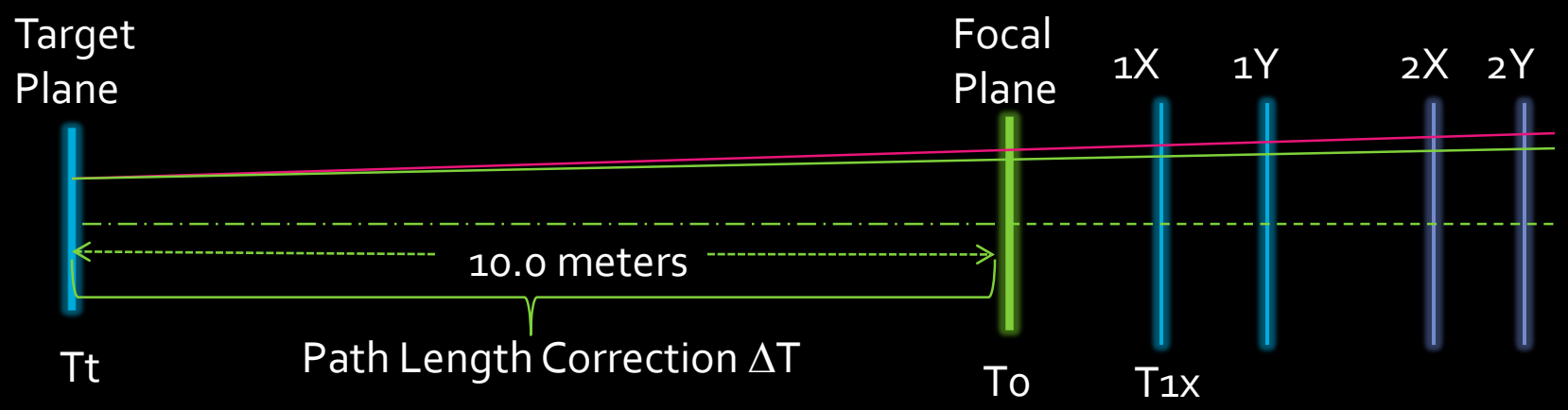




$$R = \frac{2252133}{2293464} \approx 98.20\%$$



3,T0 Adjustment



$Tt = T0 + \Delta T$, where T0 is determined by T1x (Or T1y if 1X has not hit)

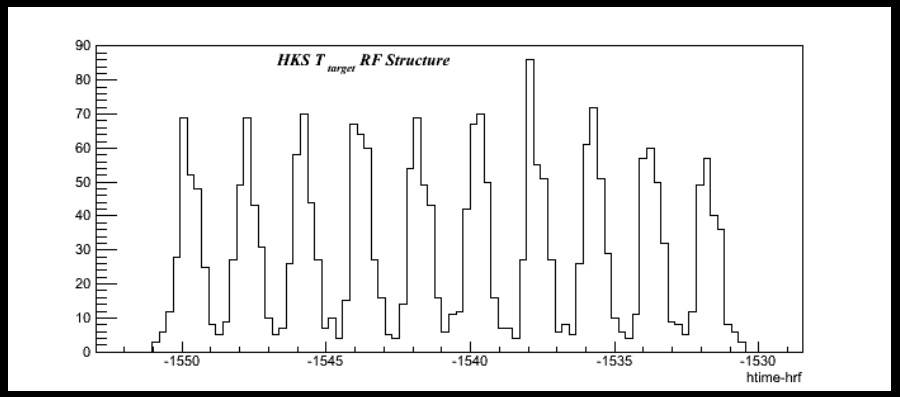
Since the distance between Focal Plane and Target Plane is about 10 meters, the path length correction ΔT is accurate enough, no matter how precise the tracking is.

So if we can improve the Target time Tt, the T0 can be adjusted more precisely.

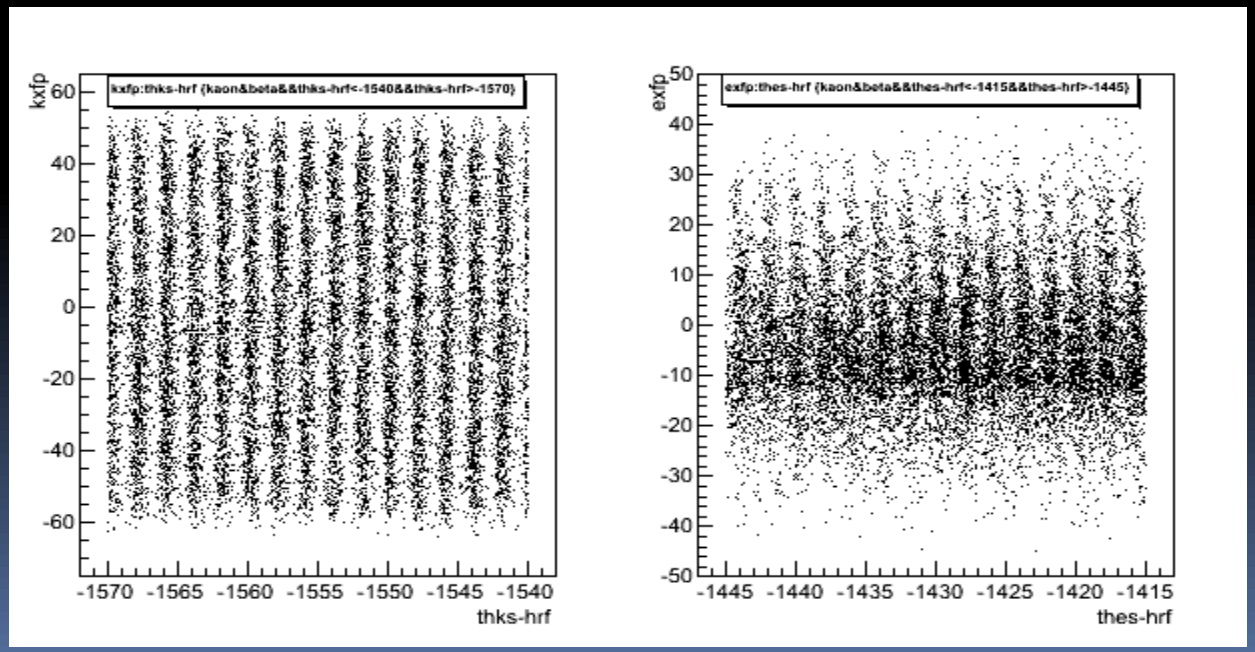
$$T0 = Tt - \Delta T$$

- RF Structure:

The correlation between Tt and RF time will give us the RF structure:

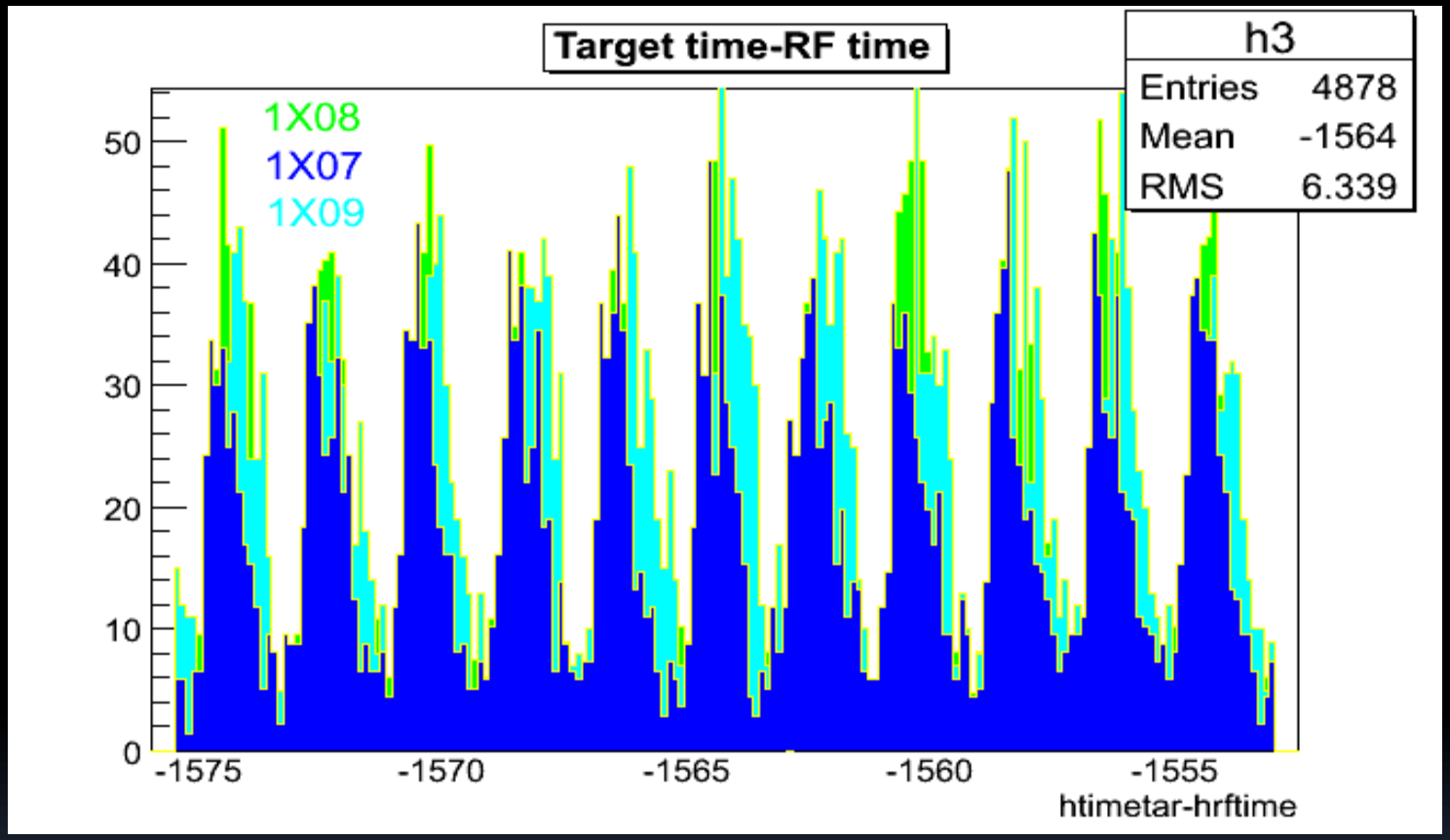


$$T_t - T_{RF} - T_{pathc}$$



Further Path Correction using Focal Plane info.

- Separate events by 1X counters:



The shifts of RF peaks for events detected by different counters on 1X, are caused by the target time differences and hence the T0 differences, which means that the T0 needs to be adjusted.

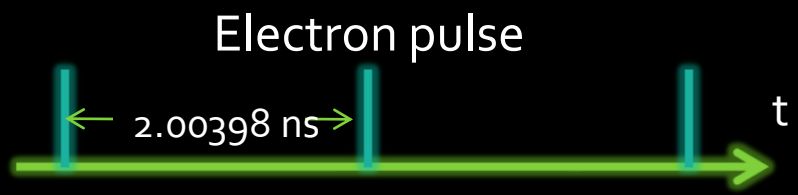
- Fine Adjustment:

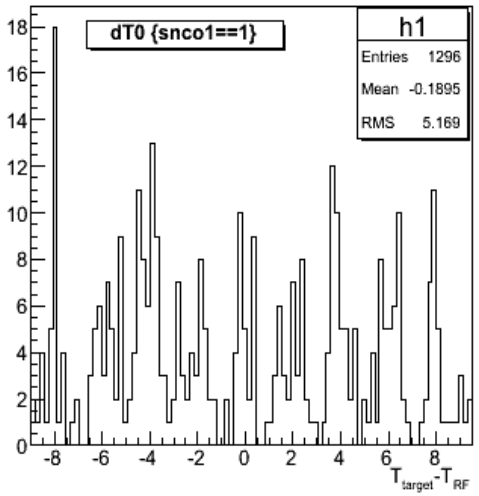
1X07 as reference counter, differences of RF peaks determined by other counters from 1X and RF peak of 1X07, give the offers of T0:

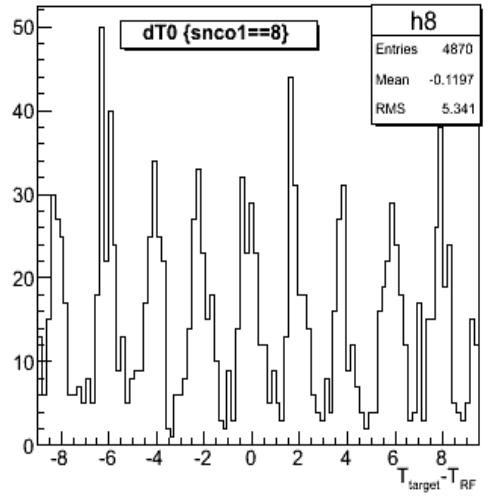
$$
\begin{aligned}
\Delta T^{1X08-1X07} &= T_0^{1X08} - T_0^{1X07} \\
&= (T_t^{1X08} - \Delta T_{path}^{1X08}) - (T_t^{1X07} - \Delta T_{path}^{1X07}) \\
&= (T_t^{1X08} - T_t^{1X07}) - (\Delta T_{path}^{1X08} - \Delta T_{path}^{1X07}) \\
&\approx (T_t^{1X08} - T_t^{1X07})
\end{aligned}
$$

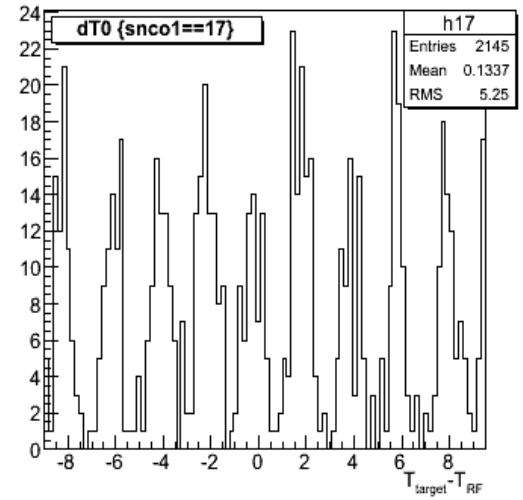
So base on the time correction of hodoscopes, fine adjustment of RF structure will give us a tool to adjust T0 on focal plane.

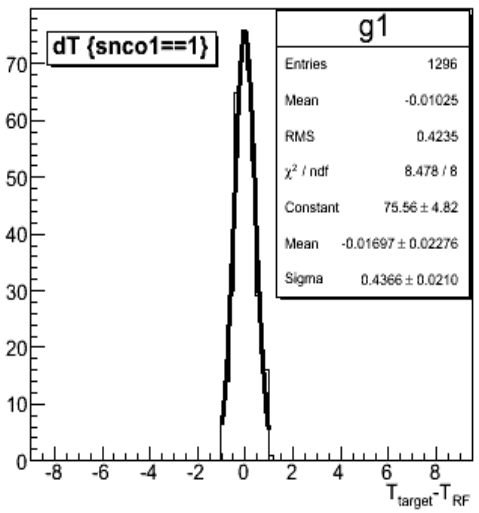
- Gather RF peaks into one:

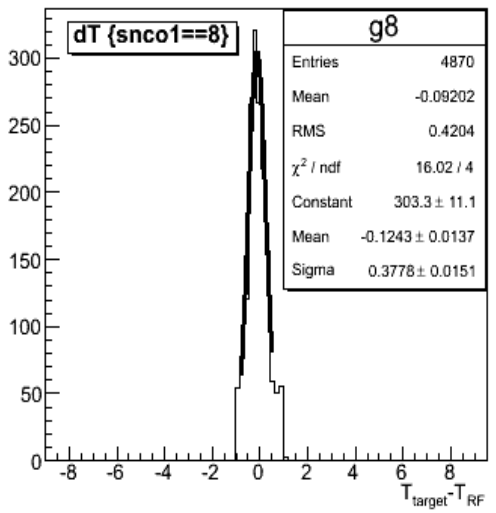


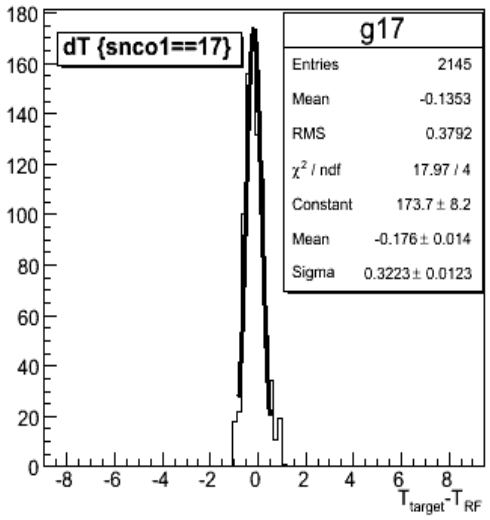












- Conclusion for T0 adjustment:

  - New Parameters of T0 fine offsets for CH2 data are ready, but need to wait for Chunhua's work on tracking to conform the improvement.

  - For different targets and different hodoscopes parameters, this adjustment has to be redone.

4, New method of Kinematics Scan

$$\Delta mm = f(E_{beam}, p_K, x'_K, y'_K, p_{e'}, x'_{e'}, y'_{e'})$$
$$= \left[m_{hyper} + \sqrt{m_e^2 + p_e^2} - \sqrt{m_K^2 + p_K^2} - \sqrt{m_{e'}^2 + p_{e'}^2}\right]^2$$
$$- \left[p_e^2 + p_K^2 + p_{e'}^2 - \frac{2 p_e p_K}{\sqrt{x_K'^2 + y_K'^2 + 1}} - \frac{2 p_e p_{e'}}{\sqrt{x_{e'}'^2 + y_{e'}'^2 + 1}} + \frac{2 p_{e'} p_K}{\sqrt{x_K'^2 + y_K'^2 + 1}\sqrt{x_{e'}'^2 + y_{e'}'^2 + 1}}\right]$$

Energy loss: -- Given by SIMC

$$E_{beam} = E_0 - \Delta E_0^t, p_k = p_k + \Delta P_k^t, p_{e'} = p_{e'} + \Delta P_{e'}^t$$

Targets Related!

Magnet field setting, Installation, and Coordinate definition…

- Central Momentum: $p_k = p_k + \Delta P_k, p_e = p_e + \Delta P_e$
- Central Angle: $x'_k = x'_k + \Delta X'_k, y'_k = y'_k + \Delta Y'_k$
  $x'_{e'} = x'_e + \Delta X'_{e'}, y'_{e'} = y'_{e'} + \Delta Y'_{e'}$

Spectrometers Related!

Using the well-known Λ&Σ missing mass, define minimization Chi-Square:

$$\chi^2 = \omega_\Lambda (\Delta m_\Lambda)^2 + \omega_\Sigma (\Delta m_\Sigma)^2$$

And set $\Delta X'_{k'}$ $\Delta Y'_{k'}$ $\Delta P_{k'}$ $\Delta X'_{e'}$ $\Delta Y'_{e'}$ $\Delta P_{e'}$ as parameters, we can fit

Λ&Σ data to minimize the Chi-Square, and obtain offset values:

$$\chi^2 \to 0 \Rightarrow \Delta P_k = ?, \Delta X'_k = ?, \ldots$$

- Tminuit2: Minimization package to minimize Chi-Square.
- Data: Geant4 simulated Lambda & Sigma missing mass
- Problem: Two sets of data, but six parameters.
- Solutions?

1, More missing mass states, or,

2, Reduce fitting parameters.

Can we fit momentum offsets and angle offsets separately?

If only fit momentum parts, and all angle offers < 1.0 MeV, my minimization package can get the very good results:

Unit= MeV/c	Set Value	Fit Value	Set Value	Fit Value	Set Value	Fit Value	Set Value	Fit Value	Set Value	Fit Value
Pk	1.0	FIX	1.0	3.202	1.0	1.67	-1.0	FIX	-1.0	0.877
Pe	2.0	2.87	2.0	FIX	2.0	1.42	2.0	1.140	2.0	FIX

Unit= MeV/c	Set Value	Fit Value	Set Value	Fit Value	Set Value	Fit Value	Set Value	Fit Value	Set Value	Fit Value
Pk	2.0	2.001	2.0	FIX	2.0	2.84	-1.0	-1.81	2.0	2.77
Pe	0.0	FIX	0.0	1.73	0.0	-0.82	2.0	1.29	-2.0	-2.76

The fitting results show that the Pe and Pk are not independent:

$$\frac{w_0}{2}(\Delta P_k^{set} + \Delta P_{e'}^{set}) = \frac{\Delta P_k^{fit}}{w_1} + \frac{\Delta P_{e'}^{fit}}{w_2}$$

$$w_1 \approx 1.07, w_2 \approx 0.96,$$

$$w_0 = 1, \text{ When fit Pe/Pk}$$

$$w_0 = 2, \text{ When fit Pe\&Pk}$$

- Doing and To do for myself:

➢ Study Optics property using Geant4 and obtain more realistic initial matrices for HKS and HES.

By modifying the locations, rotation, and field values of spectrometers, I can check the patterns of focal planes, reconstructed Sieve Slit planes, and compare with real data, to figure out the real installation of spectrometers.

➢ Kinematics offsets scan.

Momentum part might need to redefine a single parameters. Have to check the angle parts.