Optics for mistuned spectrometers

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Challenge: Determine optics for mistuned spectrometer if qualiity optics were taken with a *nominal* tune

→ Nominlal tune consistist of a particular set of B*dl ratios

eg. B*dl (Q1) / B*dl (D) = 0.25

→ Mistuned setting consists of one or more magnets set to wrong ratio

eg. B*dl (Q1) / B*dl (D) = 0.23

Solution: Utilize optics model (eg. COSY) to determe corrections *relative* to *nominal* tune, eg.

$$X'^{sat}_{tar}(x_{fp}, x'_{fp}, y_{fp}, y'_{fp}) = X'^{Nominal}_{tar}(x_{fp}, x'_{fp}, y_{fp}, y'_{fp}) + \Delta X'_{tar}(x_{fp}, x'_{fp}, y_{fp}, y'_{fp})$$

Even if forward transport model is not perfect we expect that small variations about *nominal* tune can me modeled accurately.

Formalism

The forward transport matrix takes vector at target and maps to vector at focal plane

Target x_f → **Forward matrix** → **Focal** x_t

$$x_f = M_{if} x_i$$

The reconstruction matrix takes vector at focal plane and maps to target

Target x_f ← **Recon matix** ← **Focal** x_t

Recon: $$x_t(y, x', y', \delta) = M_{fi} x_f(x, y, x', y')$$

Optics correction for saturated Q1

Goal: To generate the Q1 saturated optics corrections for the data using MC

For example: $X'^{sat}_{tar}(x_{fp}, x'_{fp}, y_{fp}, y'_{fp}) = X'^{Nominal}_{tar}(x_{fp}, x'_{fp}, y_{fp}, y'_{fp}) + \Delta X'_{tar}(x_{fp}, x'_{fp}, y_{fp}, y'_{fp})$

From MC

What was done?: → Simulated events uniformly generated for target Y and angles calibration

→ Simulated elastic events in SIMC for momentum calibration

- Generated MC sieve slit events using the model of the spring 2016 sieve slit for both **nominal** as well as **saturated** MC events
- Fit both MC in the same way as data because it gives same matrix format as data

Although MC does not accurately predict the nominal optics we expect MC can accurately describe small variation in optics due to small change in fields of the individual magnets

- Correction factors determined as a differences of mistuned and nominal reconstruction matrix elemens from optics model:

For example for X'_{tar} matrix:

$$X'^{Nominal}_{tar} = A_{0000} + A_{1000} x_{fp} + A_{0100} x'^{2}_{fp} + A_{1100} x_{fp} x'_{fp} \ldots\ldots$$

$$\Delta X'_{tar}(x_{fp}, x'_{fp}, y_{fp}, y'_{fp}) = B_{0000} - A_{0000} + (B_{1000} - A_{1000}) x_{fp} + (B_{1100} - A_{1100}) x_{fp} x'_{fp} + \ldots\ldots.$$

→ Correction factors determined order by order in target variable expansion

→ Must use same order expansion as in data for consistent expansion.

→ If using COSY in both data and MC then determination is farily trivial.

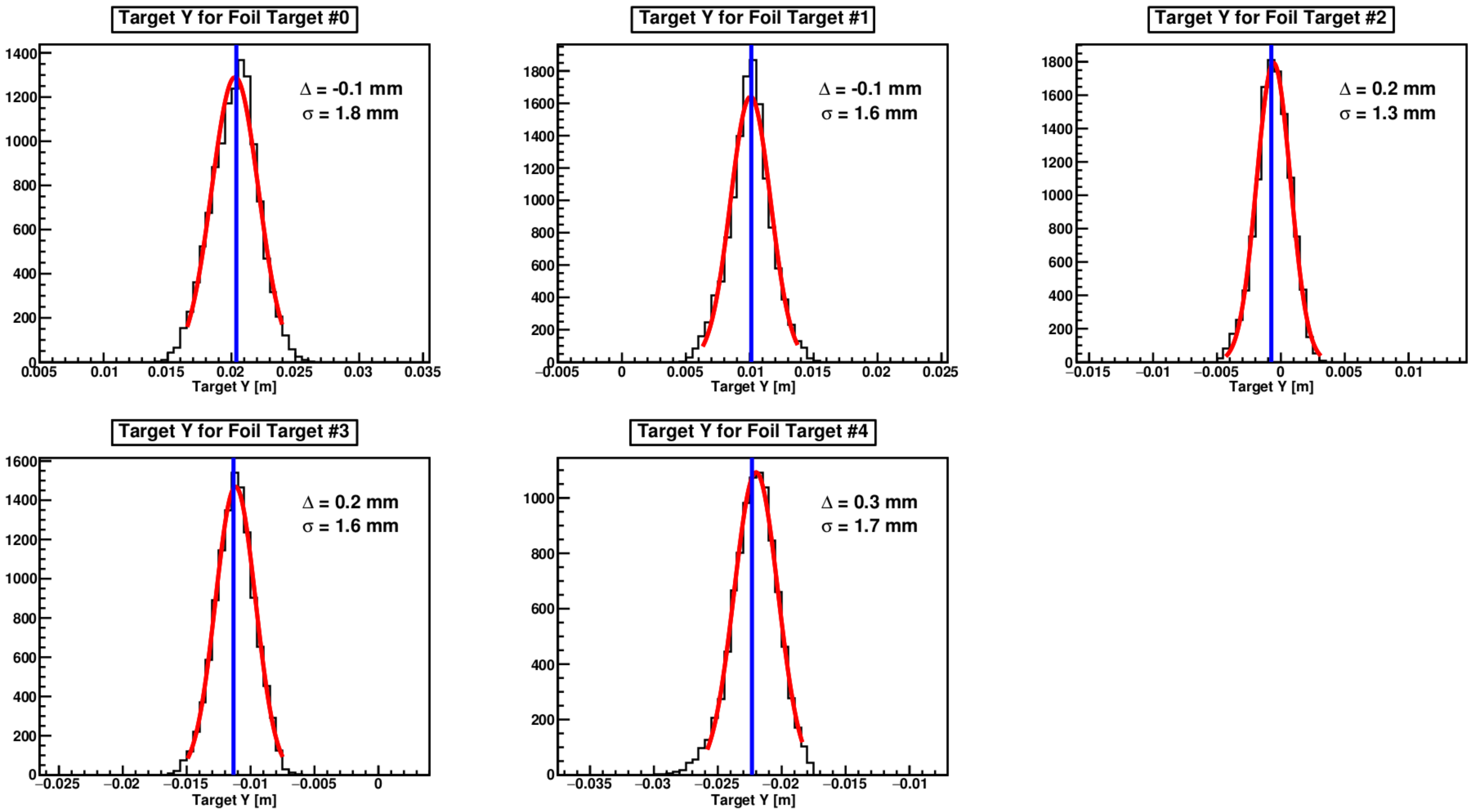
But Hall A Analyzer uses different format from COSY and rotated coordinates at detectors.

How To deal with this?

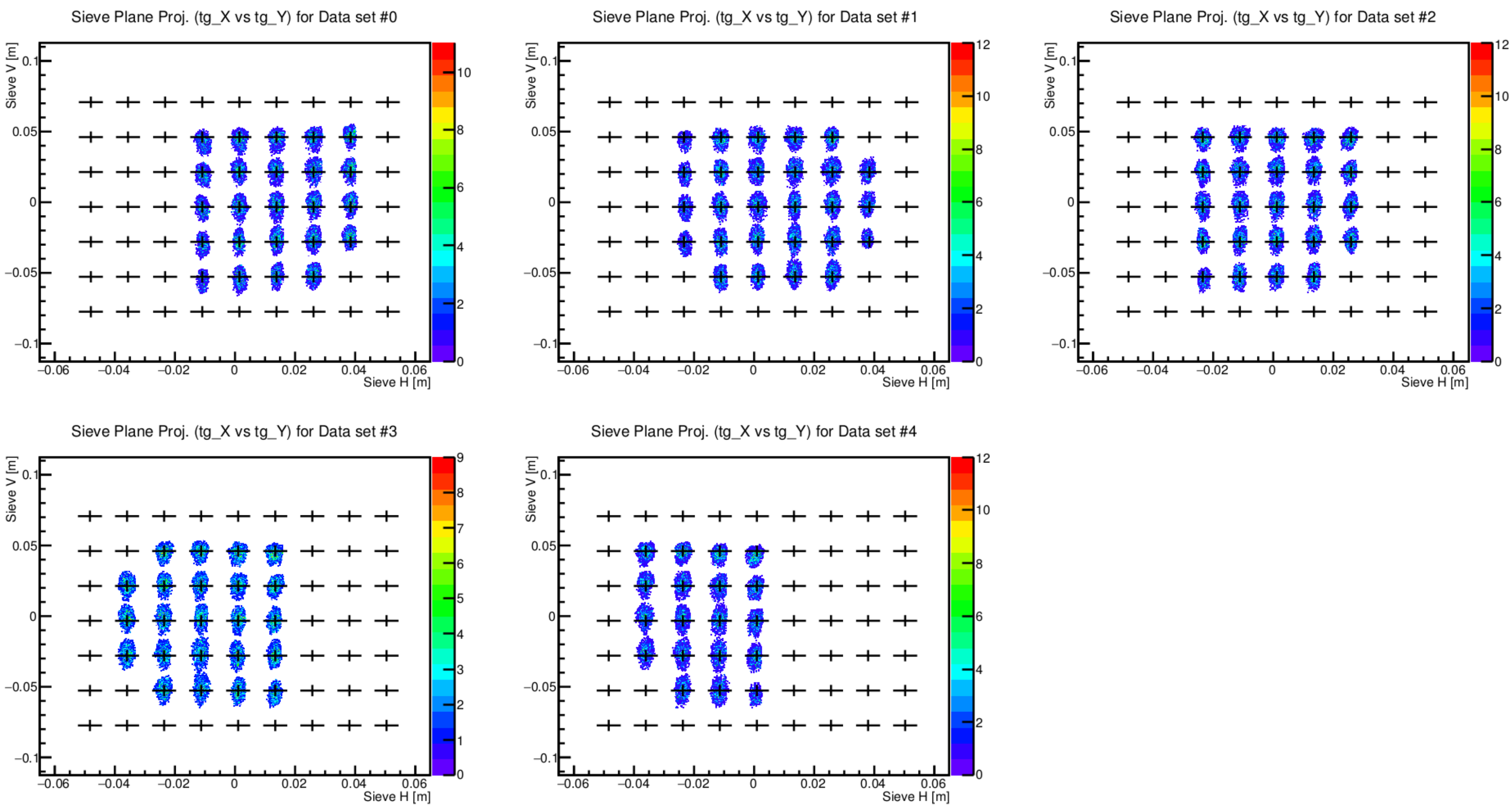
For GMp we decided it was easier to simply use the COSY Based Monte Carlo to generate optics pseudo data for Sieve slit and e-p elastic δ-scans

=> Then we could simply use the existing data optimization code to determine the reconstruction matrices in the same format as the Analyzer

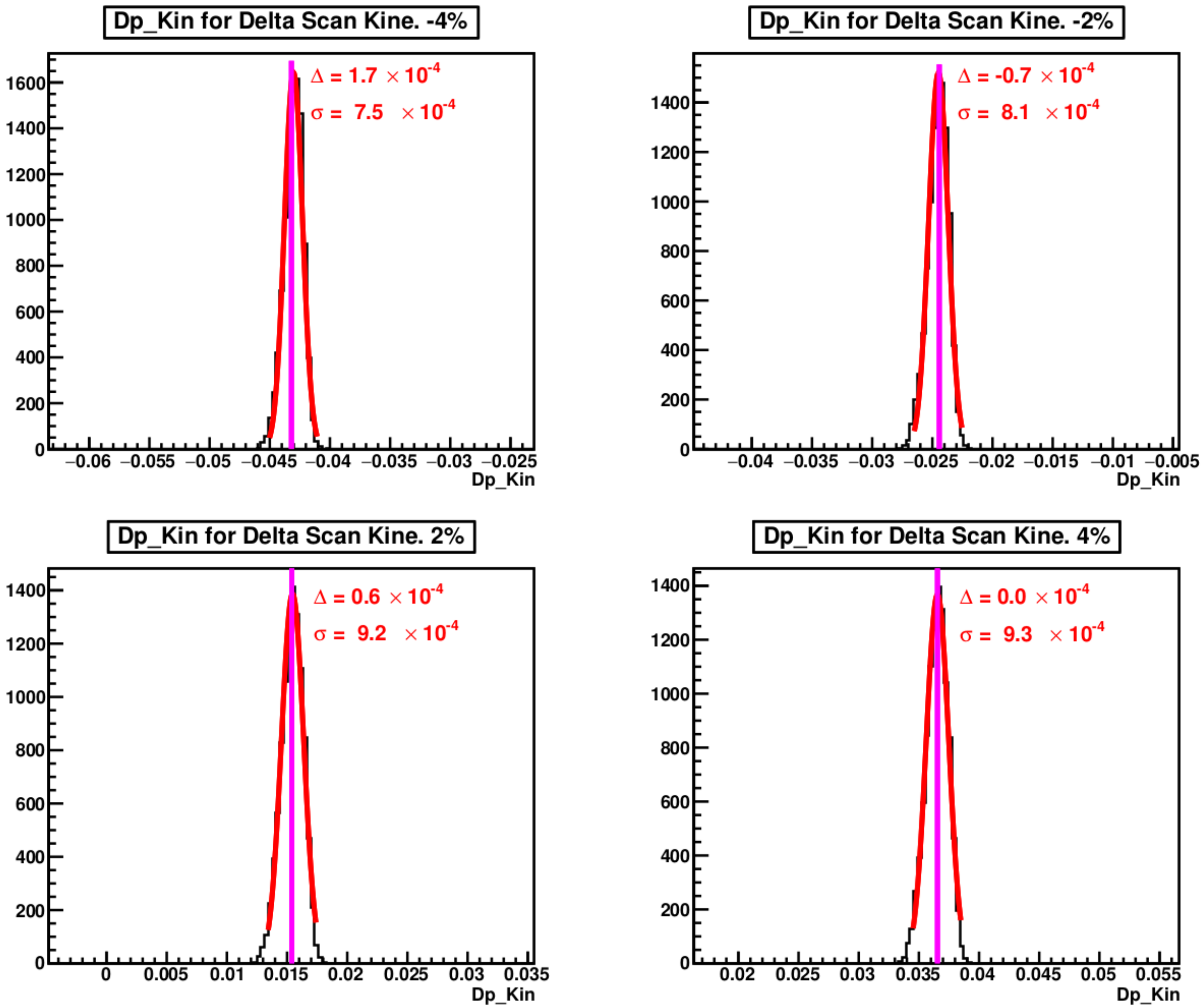
Target y calibration for nominal MC



Optimization results of MC x'_{tar} and y'_{tar}



Results of Momentum calibration for Nominal MC

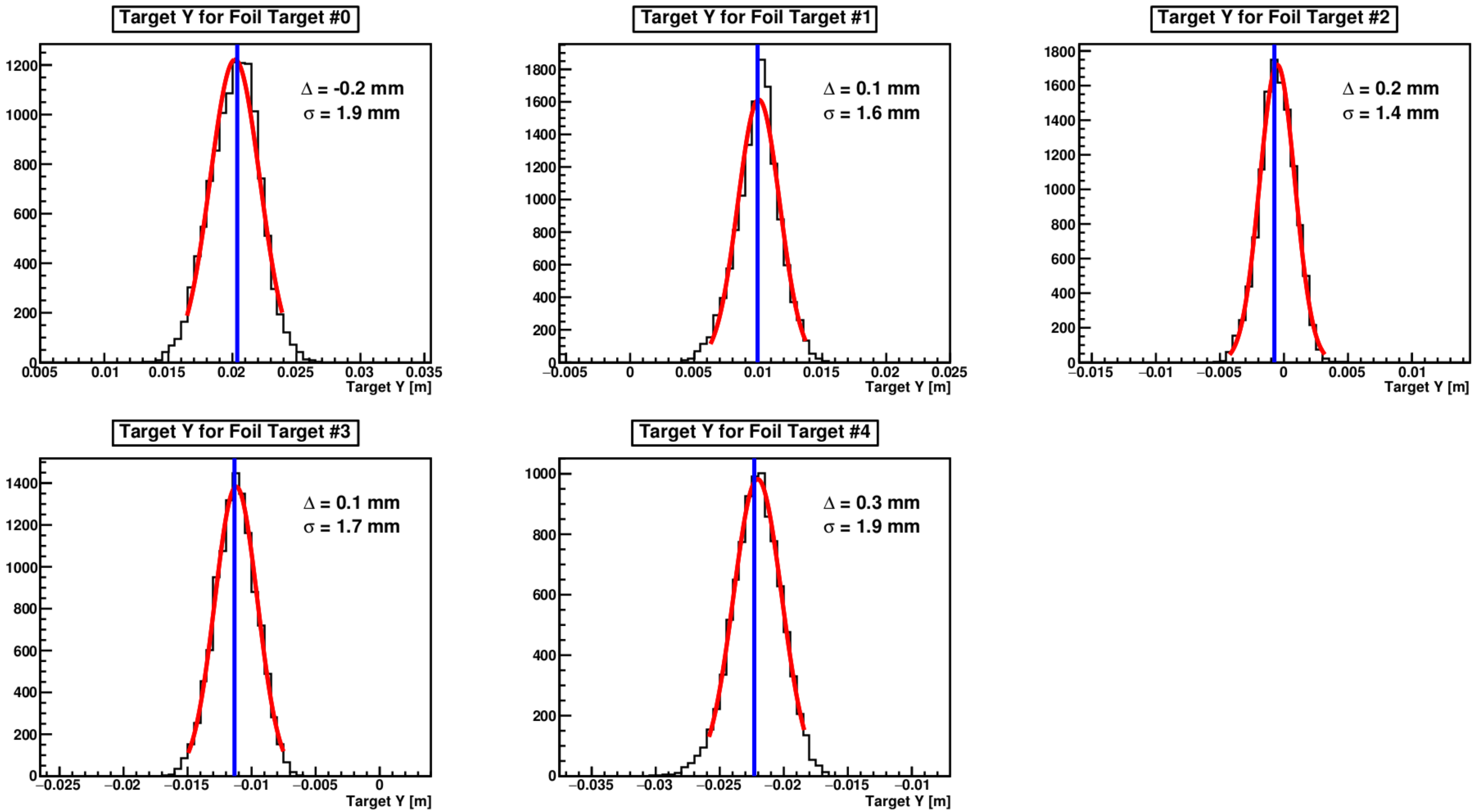


$$DpKin_{Real} = \frac{P_{\theta_{HRS}} - P_{Central}}{P_{Central}}$$

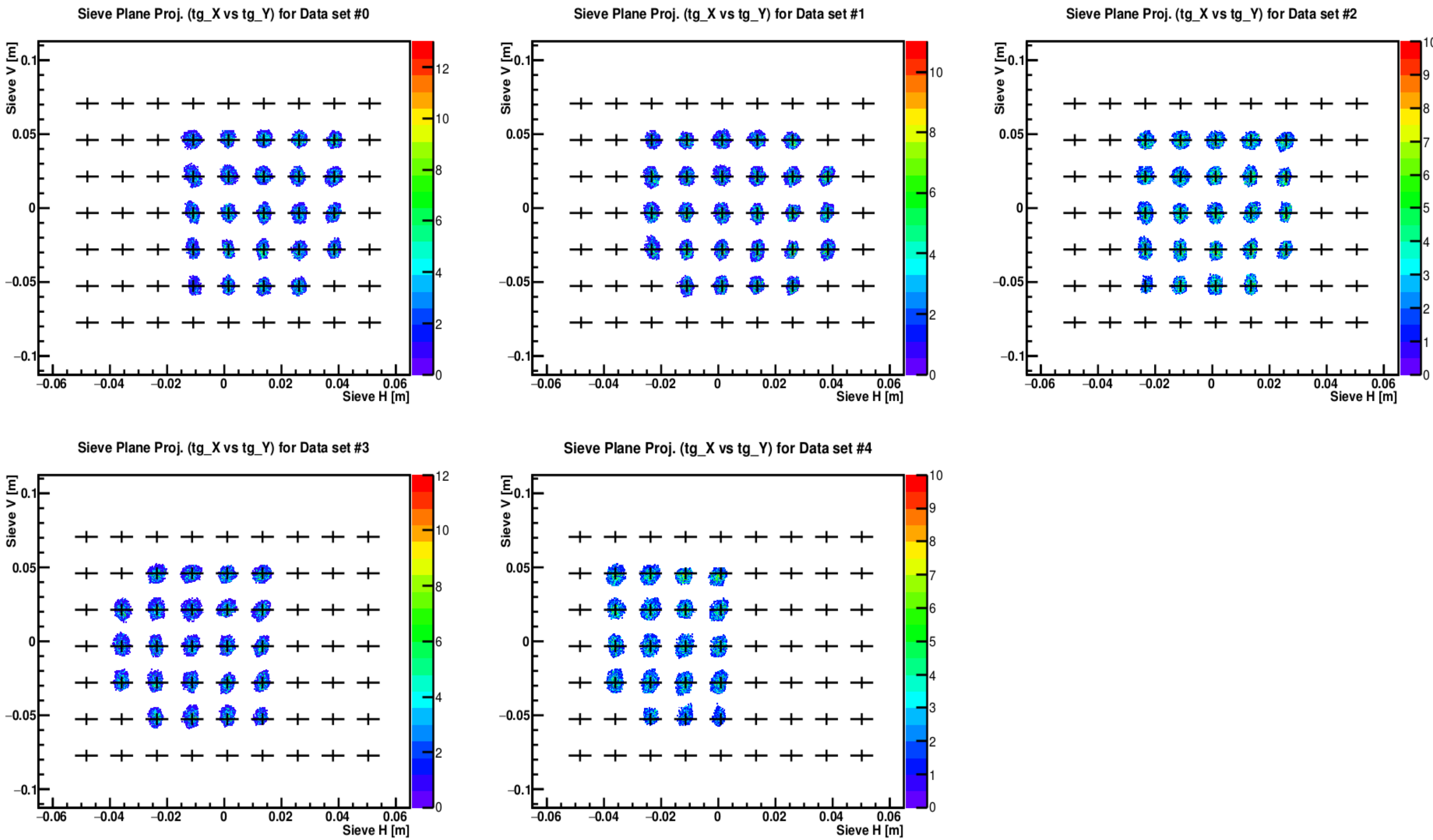
$$DpKin = dp - \frac{(P_{\theta} - P_{Loss}) - P_{\theta_{HRS}}}{P_{Central}}$$

$$DpKin - DpKin_{Real} = dp - \frac{(P_{\theta} - P_{Loss}) - P_{Central}}{P_{Central}}$$

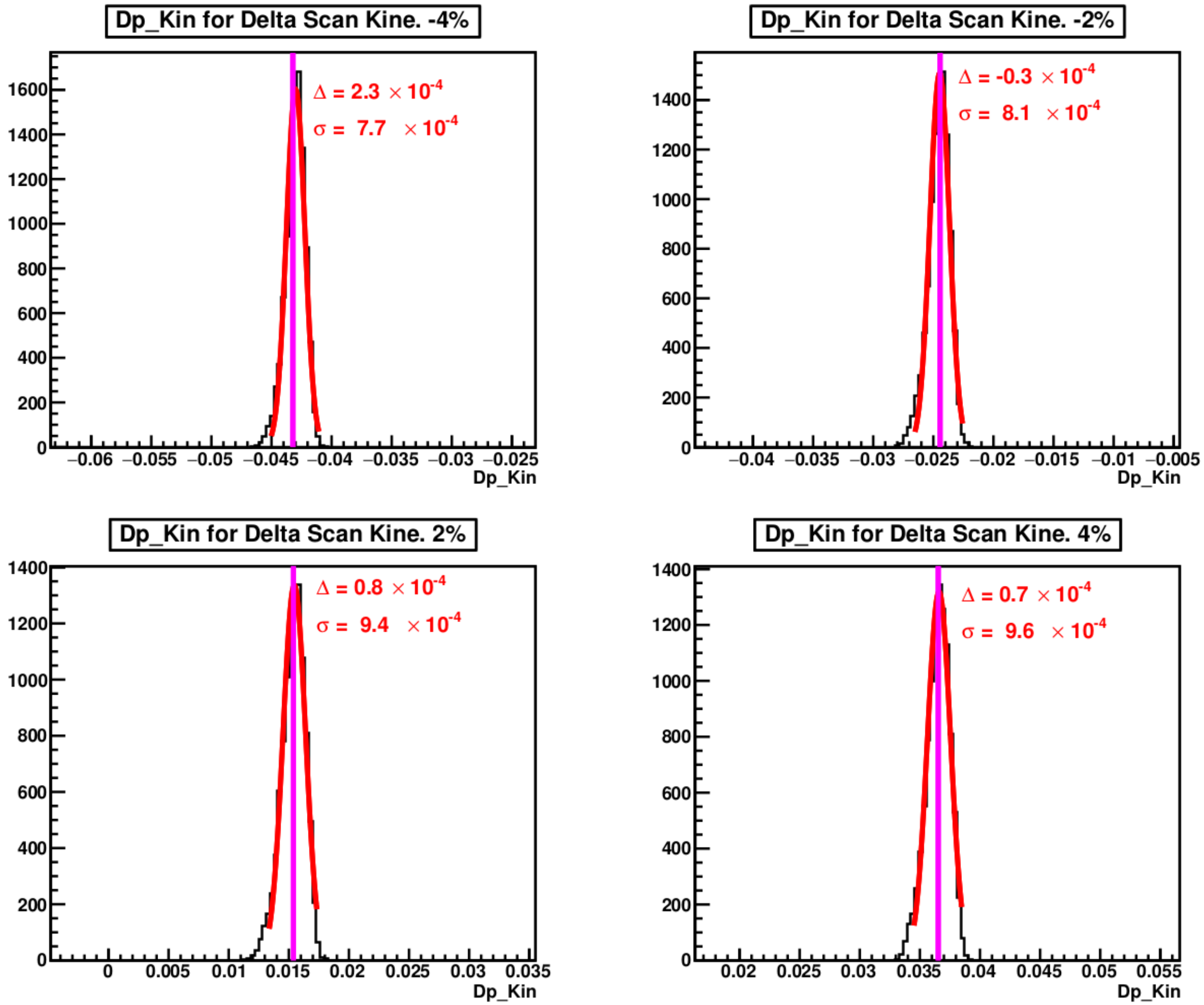
Target y calibration for mistuned MC



Results of optimization of x'_{tar} and y'_{tar} mistuned matrix



Results of Momentum calibration for mistuned MC



$$DpKin_{Real} = \frac{P_{\theta_{HRS}} - P_{Central}}{P_{Central}}$$

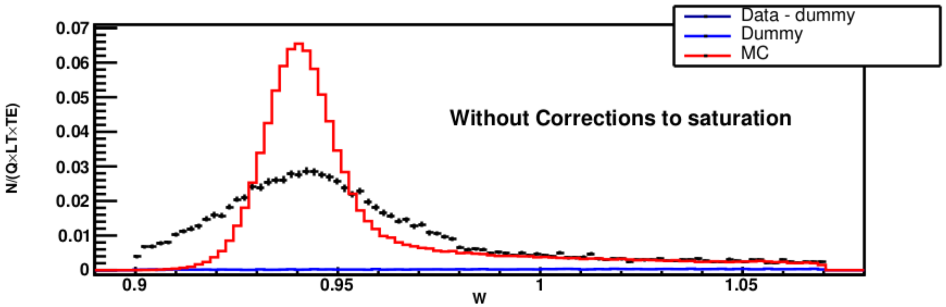
$$DpKin = dp - \frac{(P_{\theta} - P_{Loss}) - P_{\theta_{HRS}}}{P_{Central}}$$

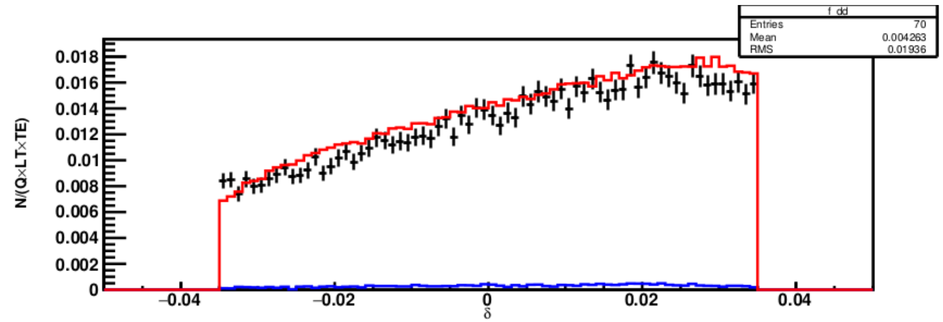
$$DpKin - DpKin_{Real} = dp - \frac{(P_{\theta} - P_{Loss}) - P_{Central}}{P_{Central}}$$

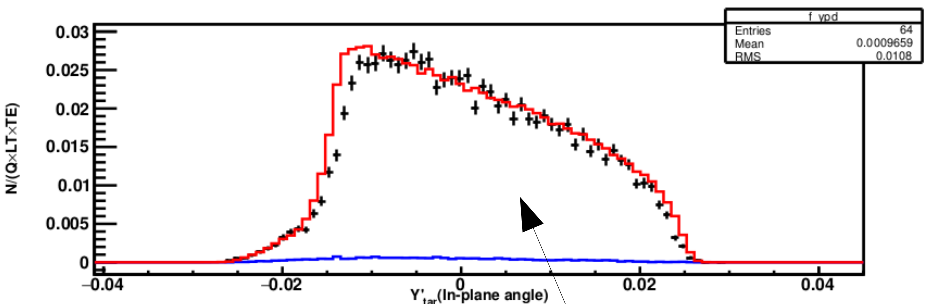
Apply procedure to mistuned case due to uncorrected Q1 saturation

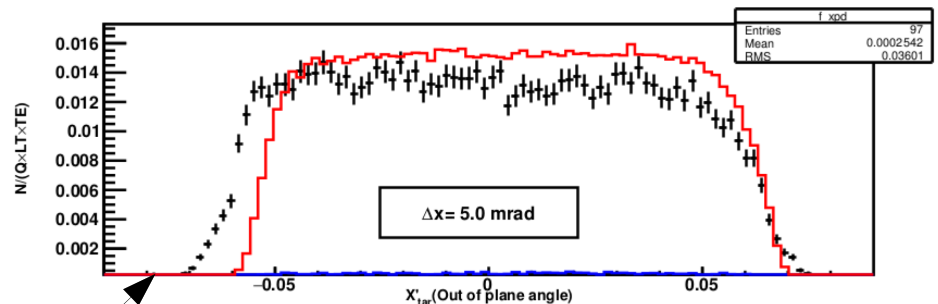
Data vs SIMC for Q1 saturated kinematics (uncorrected)

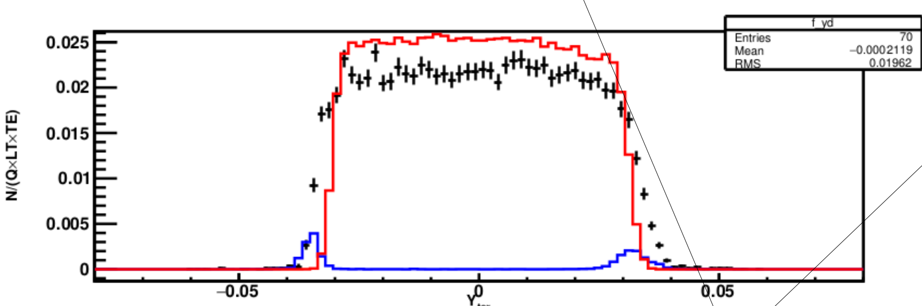
Q1 8% reduced B*dl from nominal tune









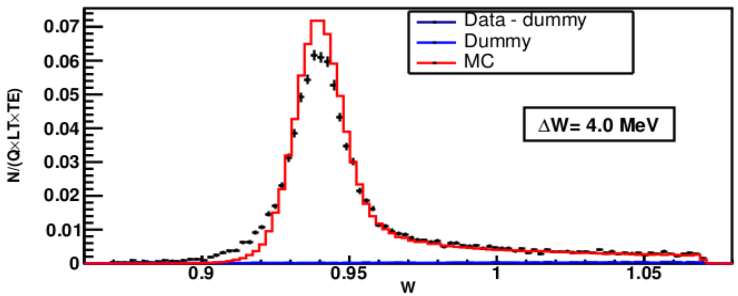


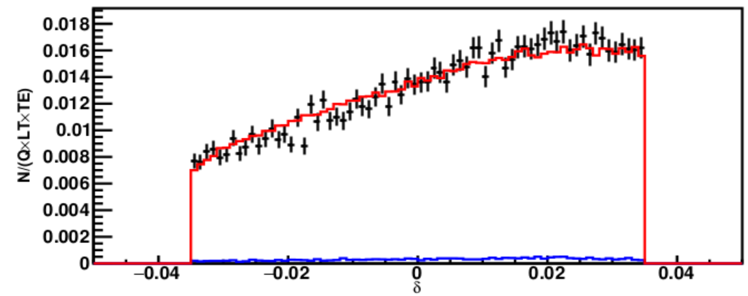
Kinematics: K34
E = 6.427 GeV, θ = 24.2 °, p_0 = 3.962GeV , Q2 = 4.543 GeV^2
Y^{data}/Y^{MC} = 0.944130 ± 0.006654
Cross section = 7.277897e-05 ± 5.129591e-07 μbarn/sr

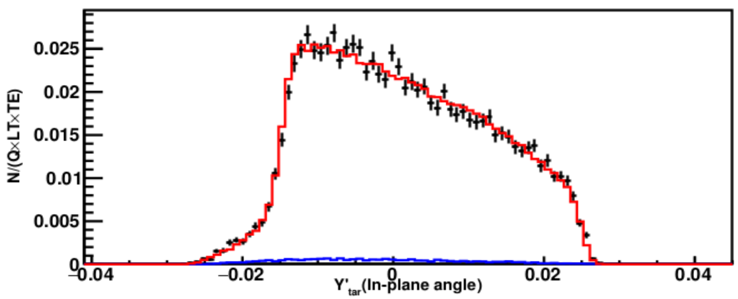
Cuts:
PID, One cluster cut
$-0.035<\delta<0.035$
$-0.04<y'_{tar}$(rad)<0.040, 0.90<W(GeV)<1.07
$-0.080<x'_{tar}$(rad)<0.080, $|y_{tar}$(cm)$|<6$

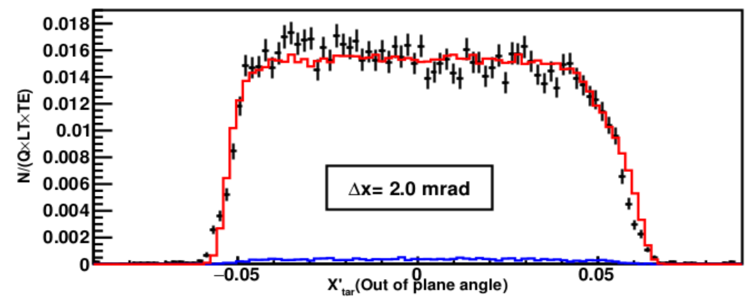
Quads focus in one direction and defocus in other
=> expect that utilizing nominal Reco MEs for mistuned Q1 will result in smaller distribution in in-plane angle and larger distribution in out-of-plane angle.

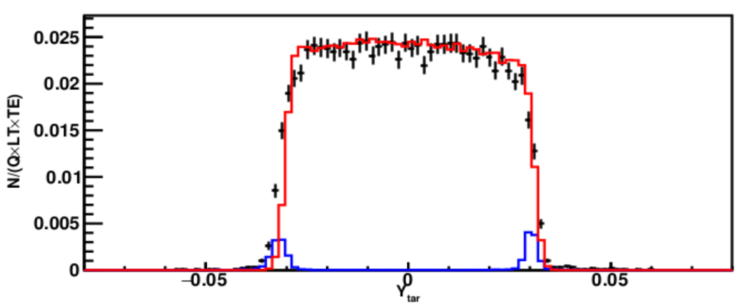
Corrected GMp K34 kinematics







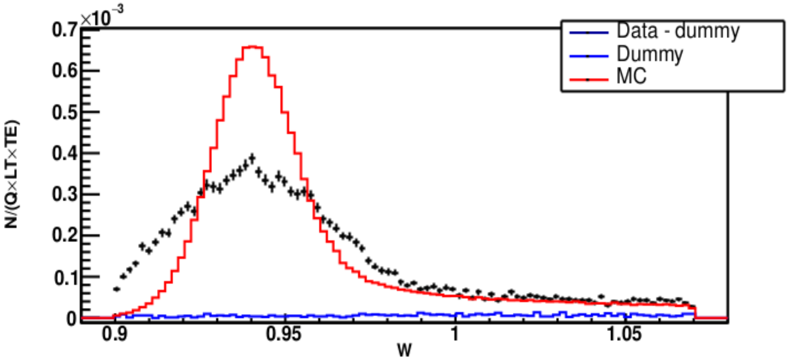


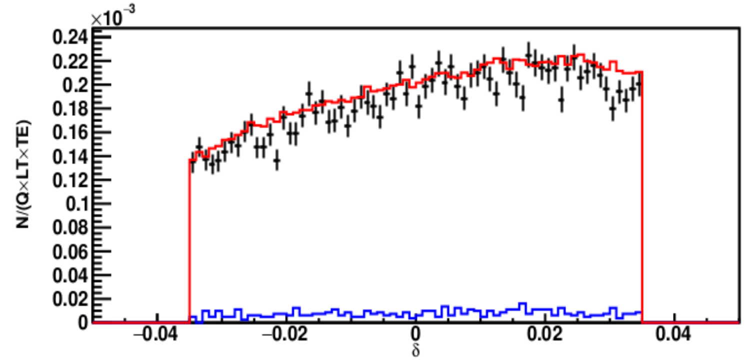


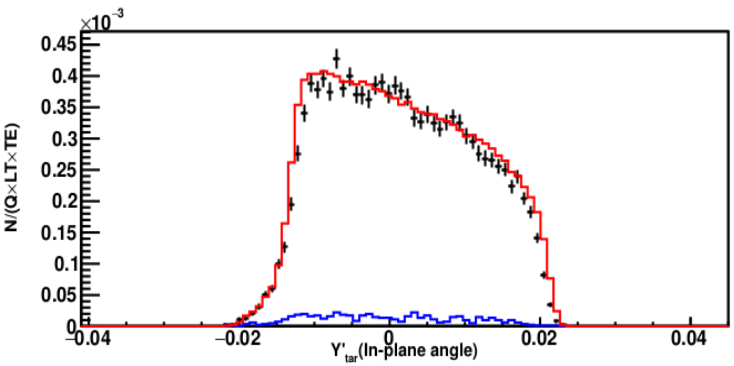
Kinematics: K34
E = 6.427 GeV, θ = 24.2 °, p_0 = 3.962GeV , Q2 = 4.543 GeV^2
Y^{data}/Y^{MC} = 1.002462 ± 0.007027
Cross section = 7.727558e-05 ± 5.416744e-07 μbarn/sr

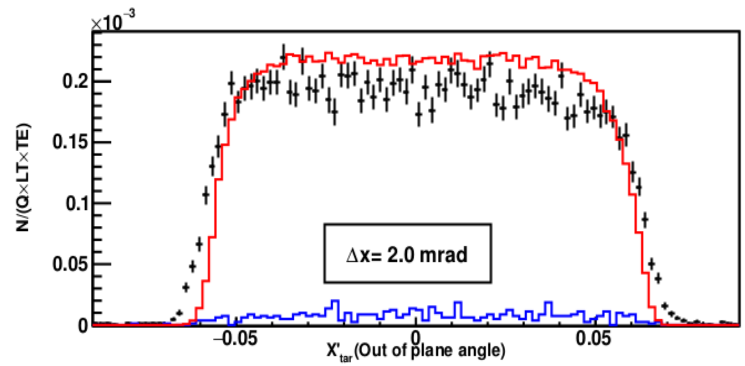
Cuts:
PID, One cluster cut
$-0.035<\delta<0.035$
$-0.04<y'_{tar}$(rad)<0.040, 0.87<W(GeV)<1.07
$-0.080<x'_{tar}$(rad)<0.080, $|y_{tar}$(cm)$|<6$

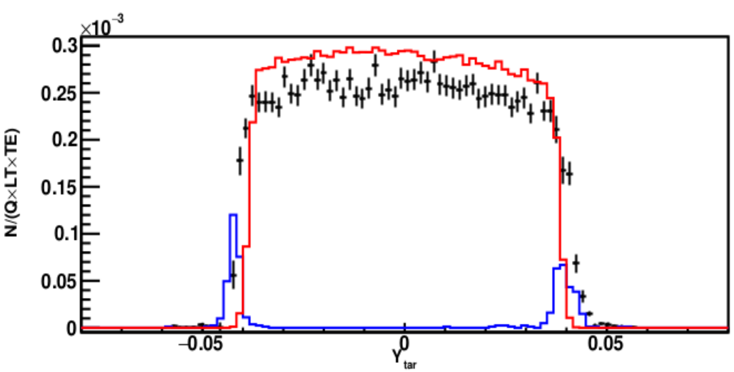
Data vs SIMC for no corrections to saturation











Kinematics: K49

E = 8.518 GeV, θ = 30.9 °, p_0 = 3.685GeV , Q2 = 9.002 GeV^2

Y^{data}/Y^{MC} = 0.953322 ± 0.006410

Cross section = 1.207156e-06 ± 8.116522e-09 μbarn/sr

Cuts:

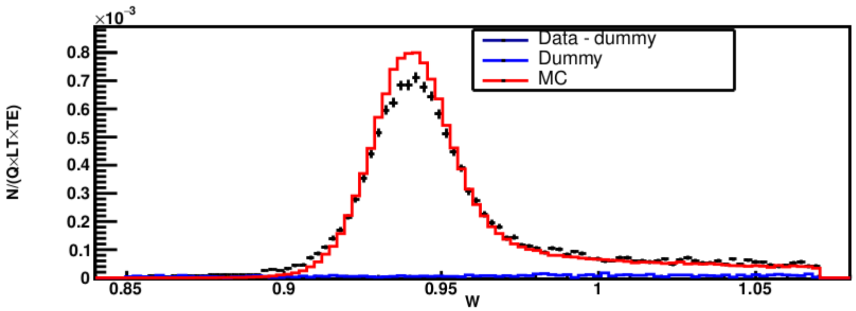
PID, One cluster cut

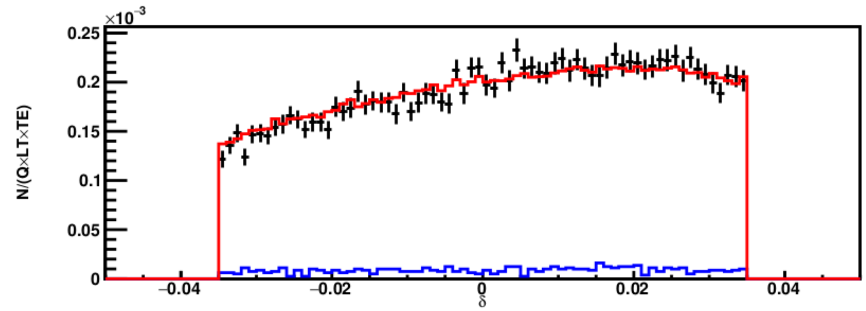
-0.035<δ<0.035

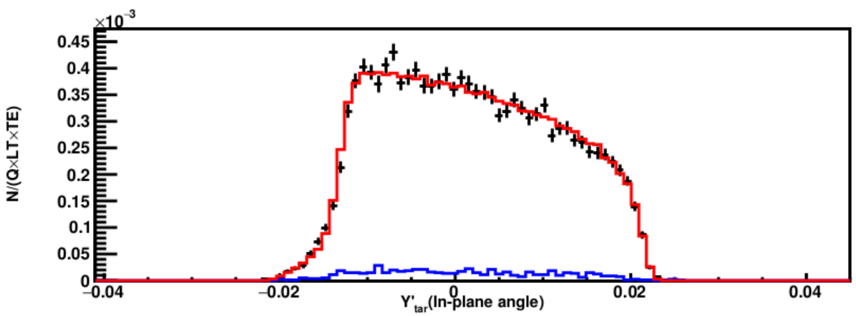
-0.04<y'_{tar}(rad)<0.040, 0.90<W(GeV)<1.07

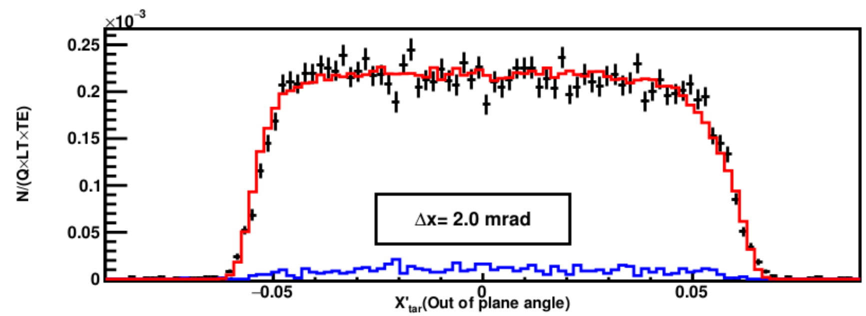
-0.080<x'_{tar}(rad)<0.080, |y_{tar}(cm)|<6

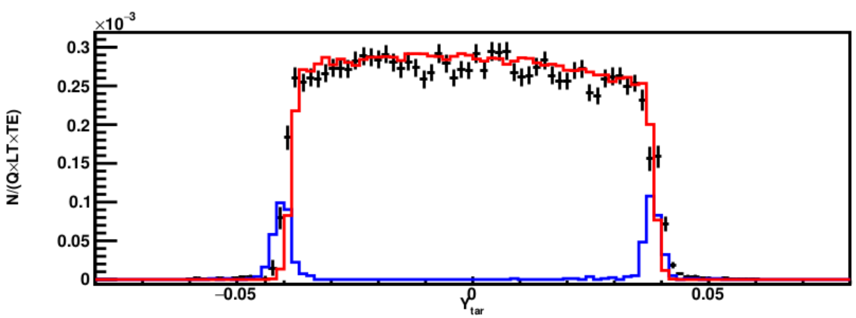
Data vs SIMC with corrections to saturation











Kinematics: K49

$E = 8.518$ GeV, $\theta = 30.9$ °, $p_0 = 3.685$GeV , $Q2 = 9.002$ GeV^2

$Y^{data}/Y^{MC} = 0.997638 \pm 0.006656$

Cross section = 1.263270e-06 ± 8.428235e-09 μbarn/sr

Cuts:

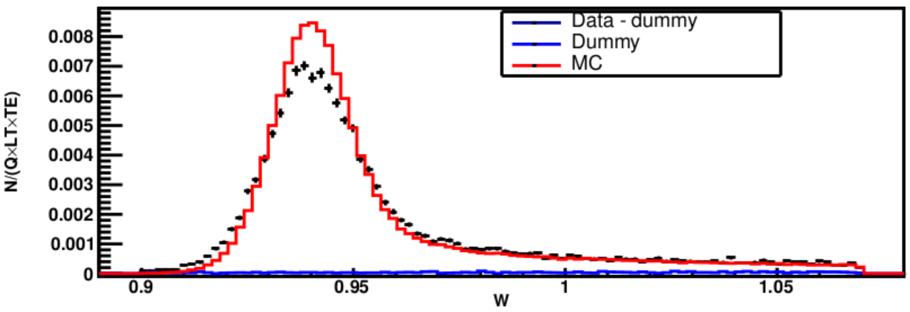
PID, One cluster cut

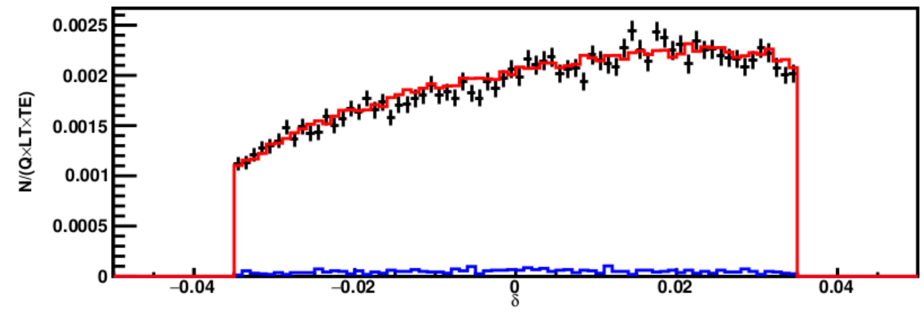
$-0.035<\delta<0.035$

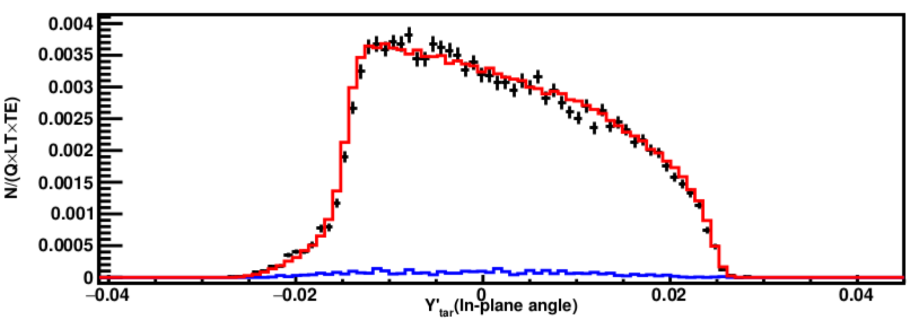
$-0.04<y'_{tar}$(rad)<0.040, 0.85<W(GeV)<1.07

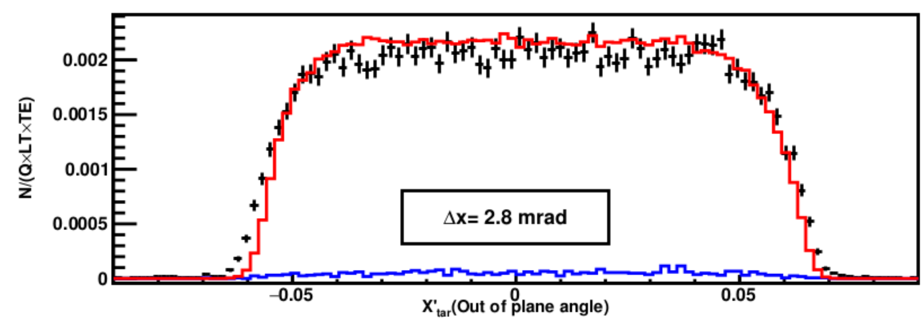
$-0.080<x'_{tar}$(rad)<0.080, $|y_{tar}$(cm)$|<6$

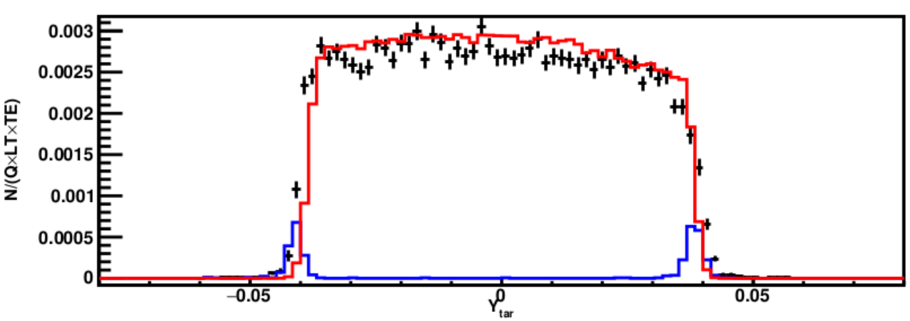
Data vs SIMC for no corrections to saturation











Kinematics: K36

E = 6.427 GeV, θ = 30.9 °, p_0 = 3.224GeV , Q2 = 5.947 GeV^2

Y^{data}/Y^{MC} = 0.986280 $\pm$ 0.005638

Cross section = 1.076317e-05 $\pm$ 6.152675e-08 μbarn/sr

Cuts:

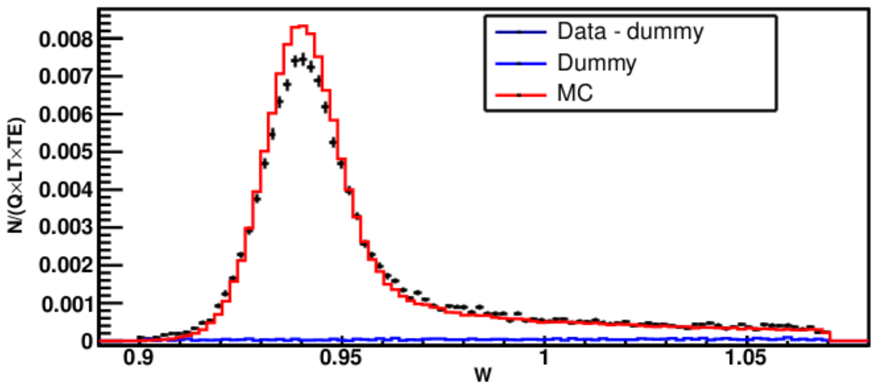
PID, One cluster cut

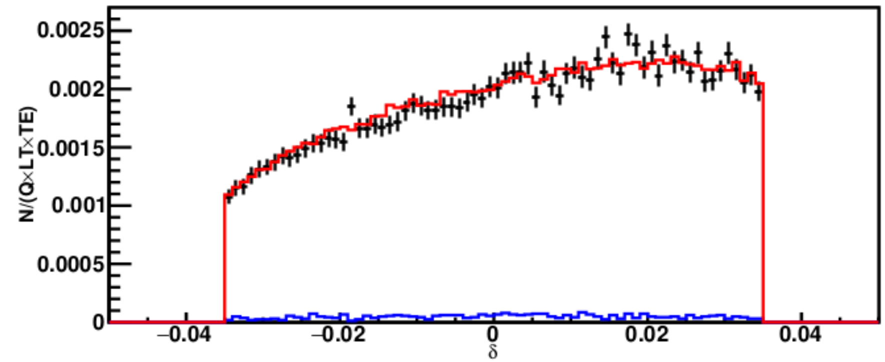
$-0.035<\delta<0.035$

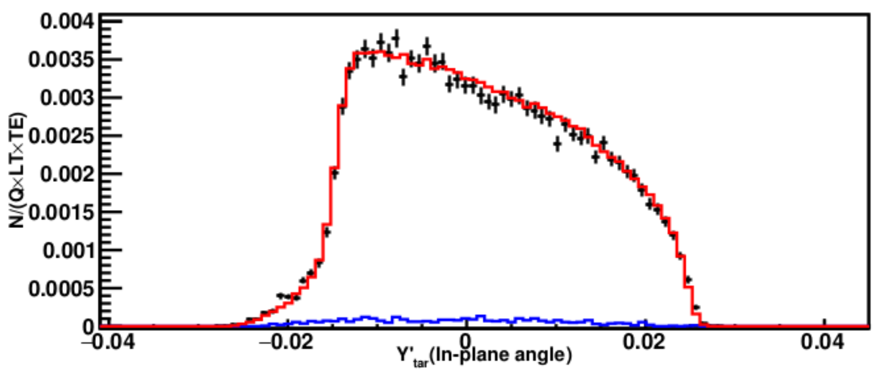
$-0.04<y'_{tar}$(rad)<0.040, 0.90<W(GeV)<1.07

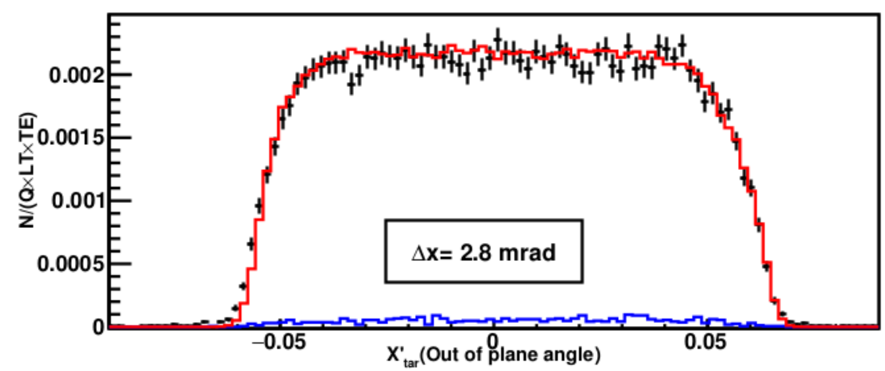
$-0.080<x'_{tar}$(rad)<0.080, $|y_{tar}$(cm)$|<6$

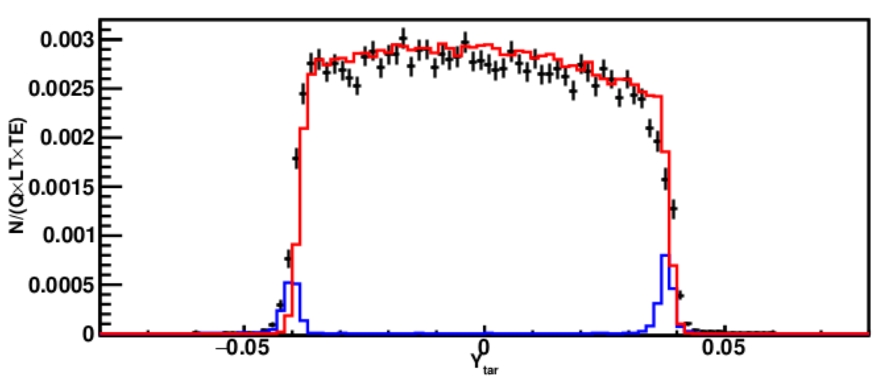
Data vs SIMC with corrections to saturation











Kinematics: K36

$E = 6.427$ GeV, $\theta = 30.9$ °, $p_0 = 3.224$GeV , Q2 = 5.947 GeV^2

$Y^{data}/Y^{MC} = 0.989422 \pm 0.005664$

Cross section = 1.079746e-05 ± 6.180768e-08 μbarn/sr

Cuts:

PID, One cluster cut

$-0.035<\delta<0.035$

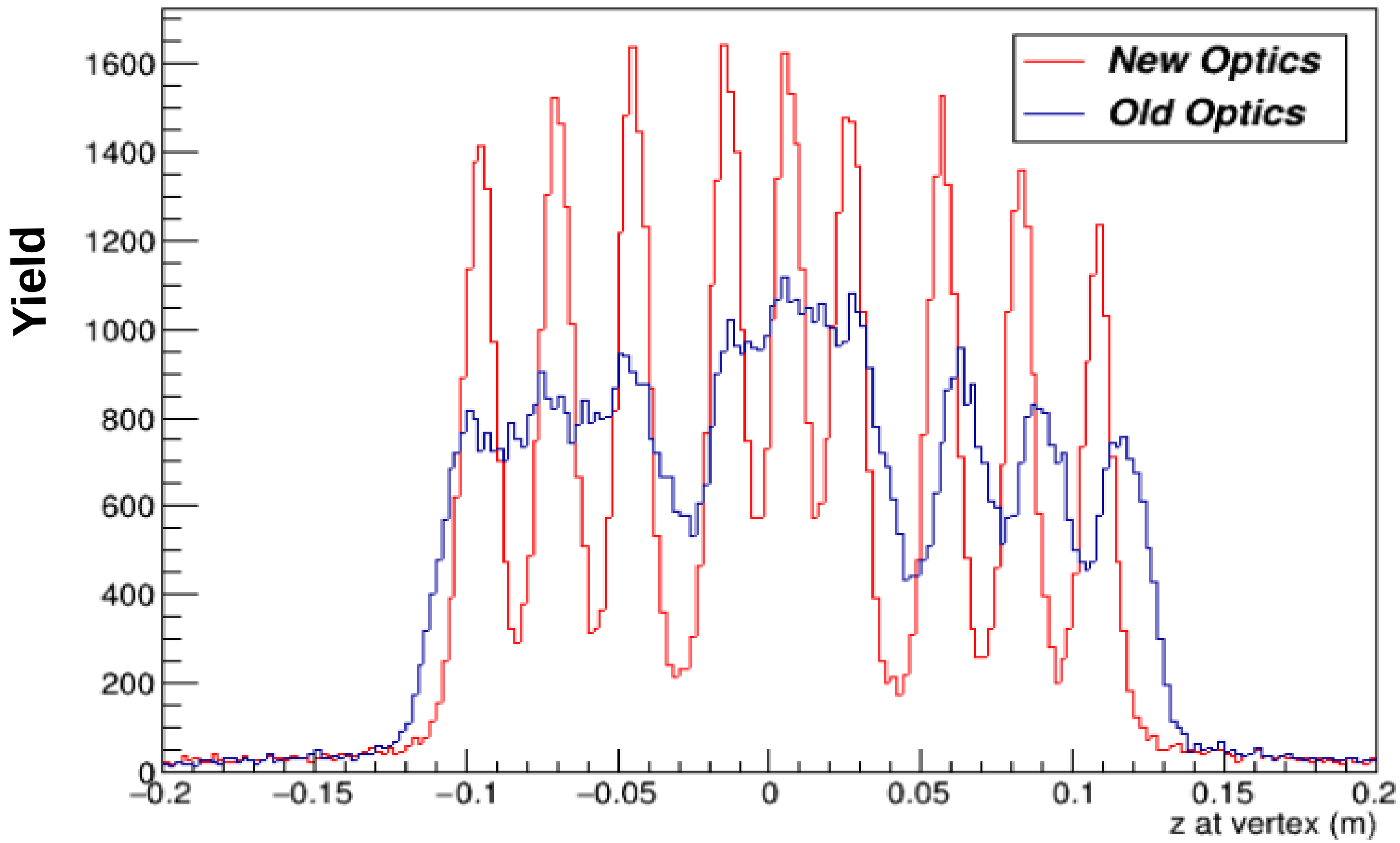
$-0.04<y'_{tar}$(rad)<0.040, $0.90<W$(GeV)<1.07

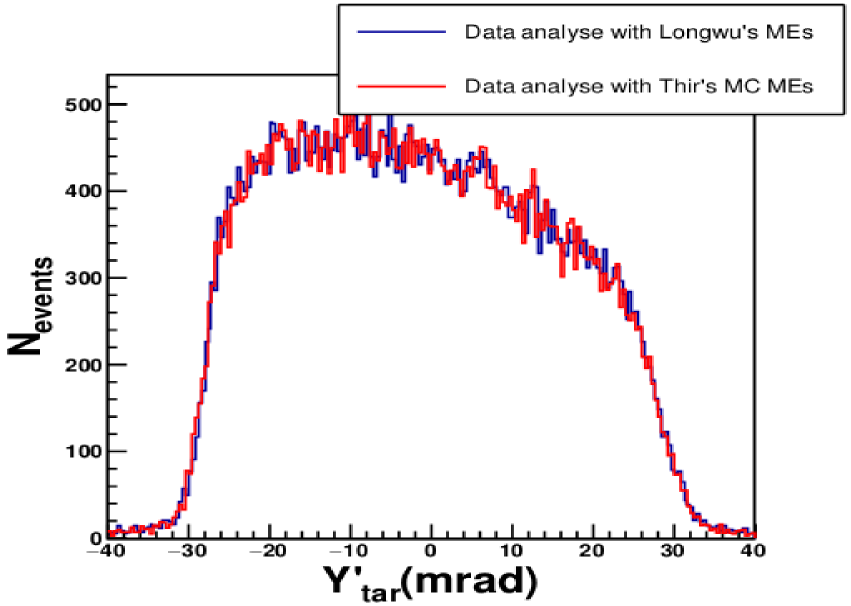
$-0.080<x'_{tar}$(rad)<0.080, $|y_{tar}$(cm)$|<6$

Example correction applied to DVCS saturated kinematics for Z target

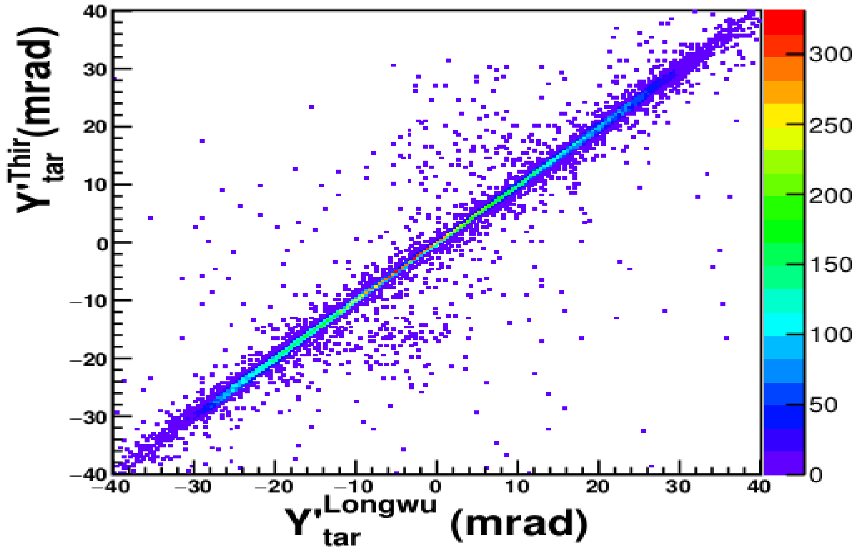
From Bishnu Karki (DVCS)

Multifoil carbon run for with Q1 saturation

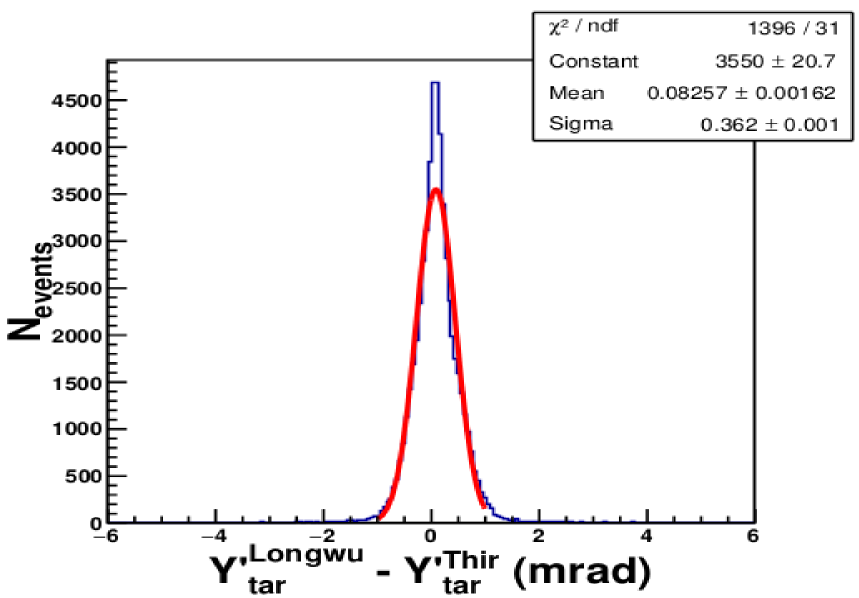




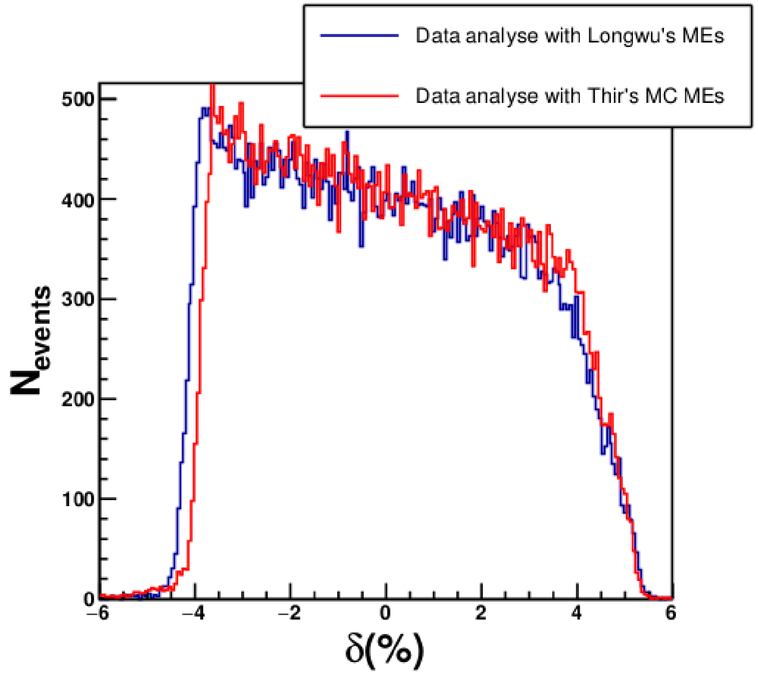
Data analyse with Longwu's MEs
Data analyse with Thir's MC MEs
N_{events}
Y'_{tar}(mrad)

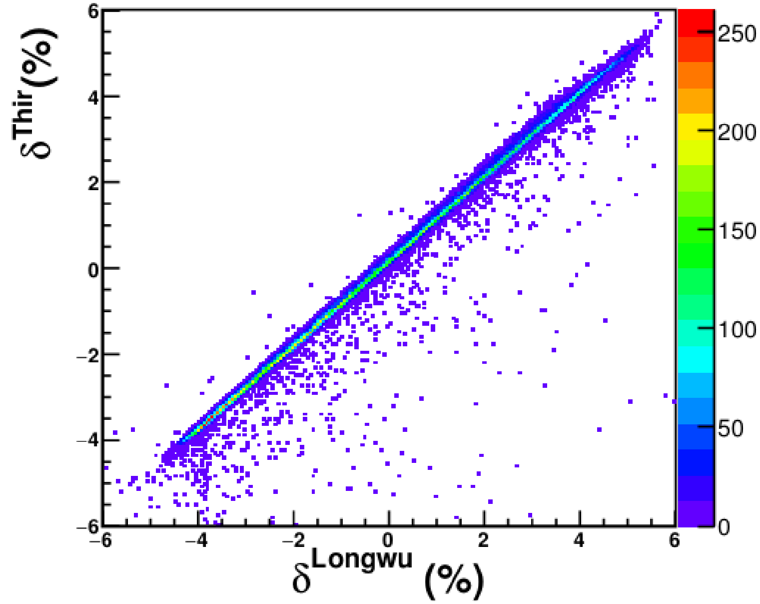


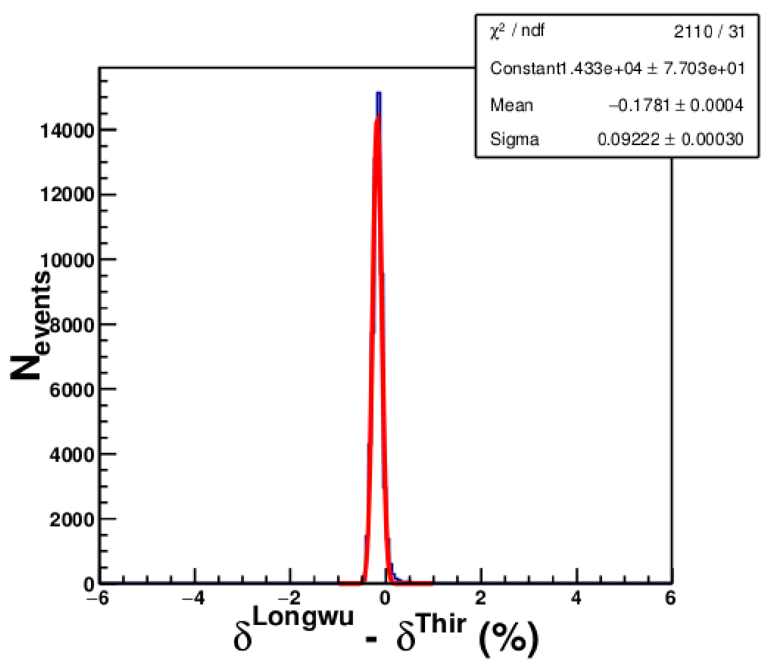
Y'^{Thir}_{tar}(mrad)
Y'^{Longwu}_{tar} (mrad)



χ^2 / ndf 1396 / 31
Constant 3550 ± 20.7
Mean 0.08257 ± 0.00162
Sigma 0.362 ± 0.001
N_{events}
Y'^{Longwu}_{tar} - Y'^{Thir}_{tar} (mrad)


Data analyse with Longwu's MEs
Data analyse with Thir's MC MEs
N events
δ(%)


δ Thir (%)
δ Longwu (%)


χ² / ndf 2110 / 31
Constant 1.433e+04 ± 7.703e+01
Mean −0.1781 ± 0.0004
Sigma 0.09222 ± 0.00030
N events
δ Longwu - δ Thir (%)