HMS Optics Optimization at High Momentum

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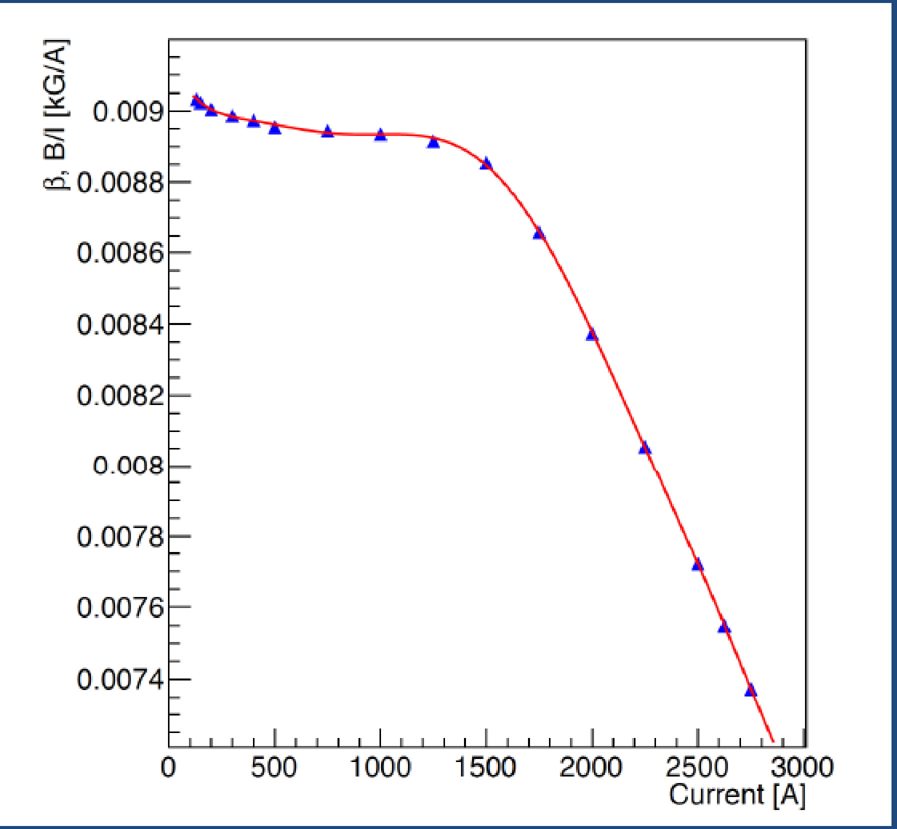
Ohio University (NSF Award #1913170)

Work Done in Collaboration with Holly Szumila-Vance and Mark Jones

Saturation at High Momentum

Commissioning the HMS optics in the 2017-18 run period
Holly Szumila-Vance
12/04/2018

- Figure shows central field B/I as a function of set current
- When set to high central momentum settings, HMS dipole and quadrupole saturation effects occur
- This study was done using Kaon-LT Data at 6.59 GeV/c Central Momentum



1.6 3.3 4.8 6.1 6.9 7.5
Approximate Central Momentum [GeV/c]

Calibration Runs

Beam Energy = 10.5965 GeV
HMS Central Momentum = 6.59 GeV/c

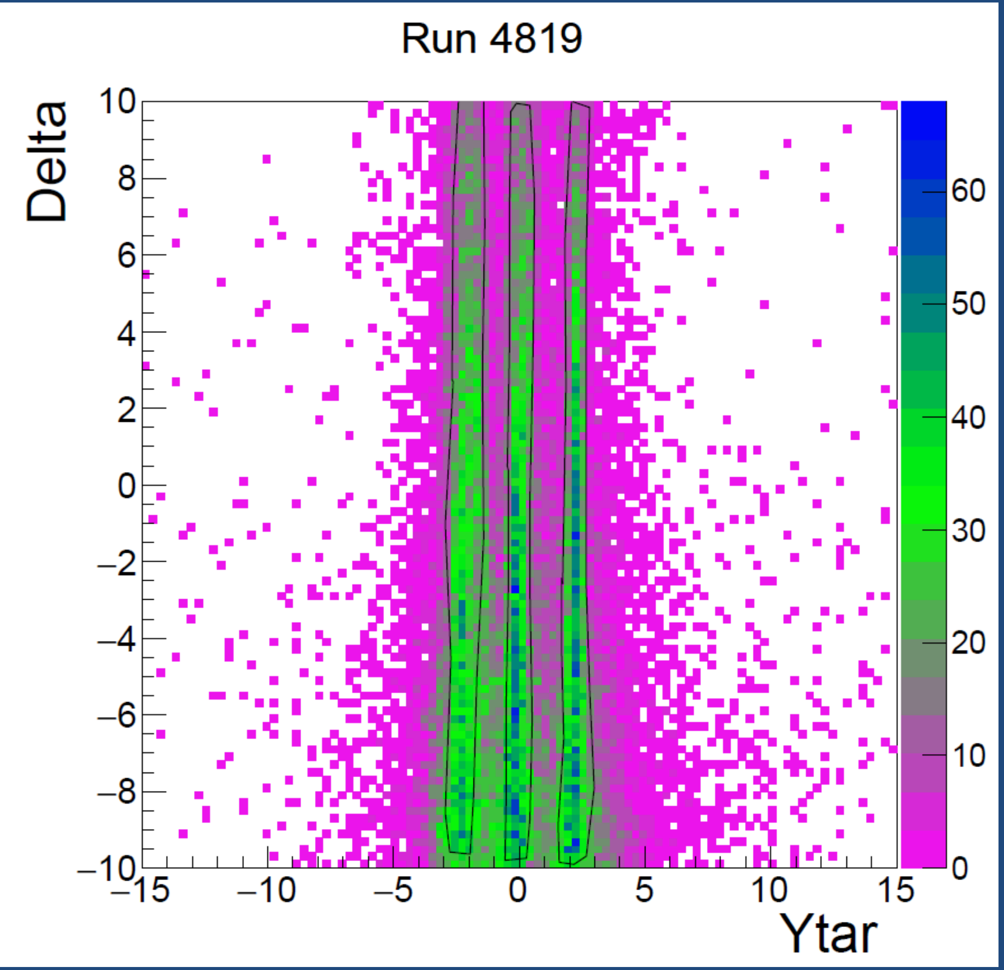
Run	HMS Angle (deg)	Target	Run Purpose
4819	-13.005	Carbon Foil	Sieve Slit Data
4805	-18.8	LH2	Elastic Delta Scan
4806			
4808			
4811			
4816	-17.2		
4817			
4821	-19.755		
4824			
4825			

Carbon-Sieve Data

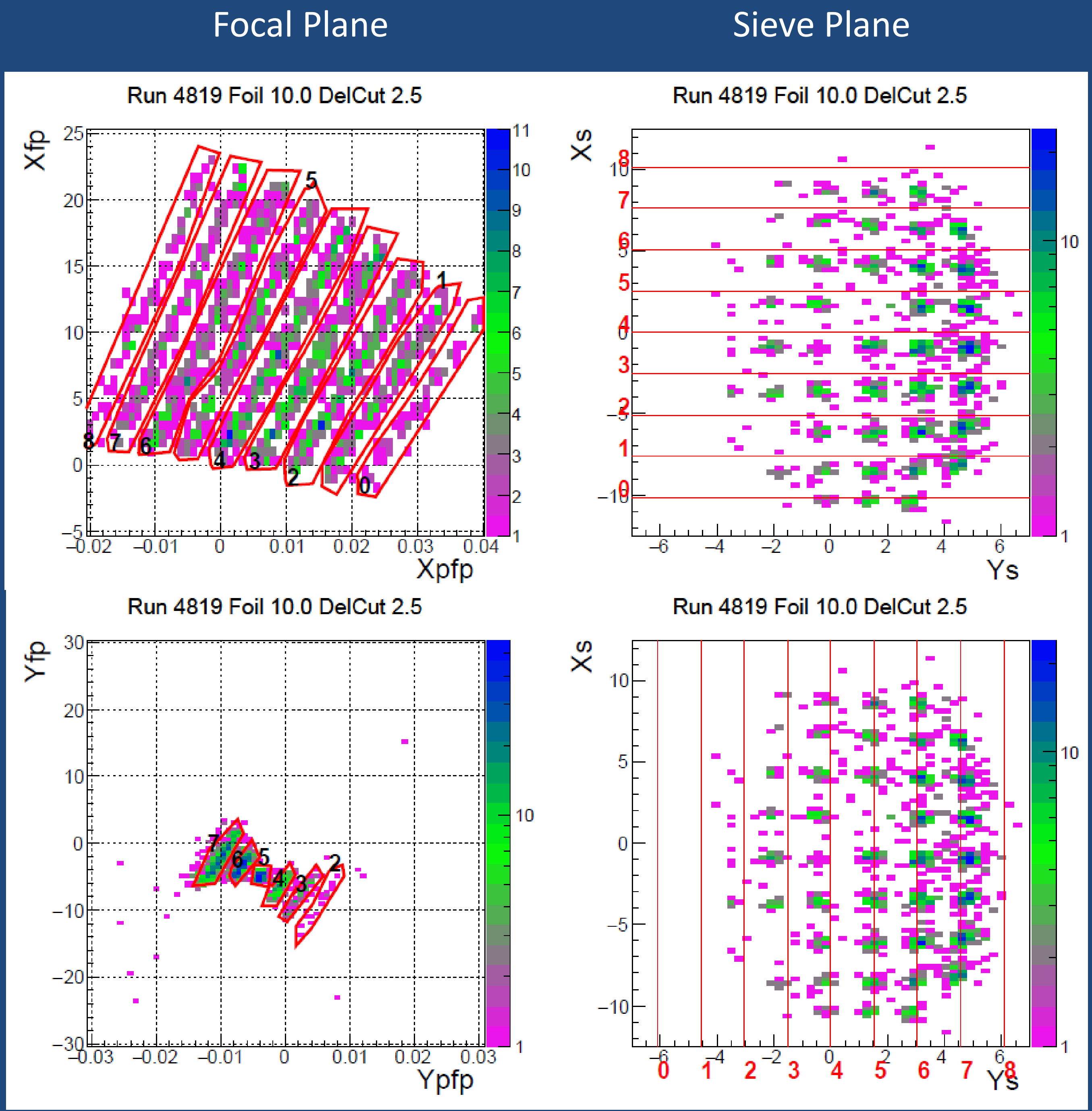
Angles (XpTar and YpTar) and Target Position (YTar) Optimizations

Carbon Foil Target Position (YTar) versus Momentum (Delta) Cuts

- YTar-Delta cuts along 3 carbon foils
- Examine Delta regions between 10 % and -10 %



Sieve Hole Focal Plane Cuts



- Goal is to determine sieve hole entrance for events
- Cuts completed for each foil and delta cut

XpTar, YTar, and YpTar Coefficients Optical Matrix Corrections

$$XpTar = \sum_{i,j,k,m=0}^{6} C_{ijkm}(xfp)^i(xpfp)^j(yfp)^k(ypfp)^m$$

New coefficients are found for to minimize difference between reconstructed values and true values found from foil and sieve-hole cuts

1st Order Coefficients - Original

	XpTar	Ytar	YpTar
xfp	3.486382286e-01	1.936267908e-02	-7.917605230e-03
xpfp	-3.111416894e+00	-1.376142539e-01	4.131009628e-02
yfp	-1.325529815e-02	-4.299047409e-01	2.767196744e-01
ypfp	2.475625673e-01	-1.876497295e-01	-2.546308775e+00

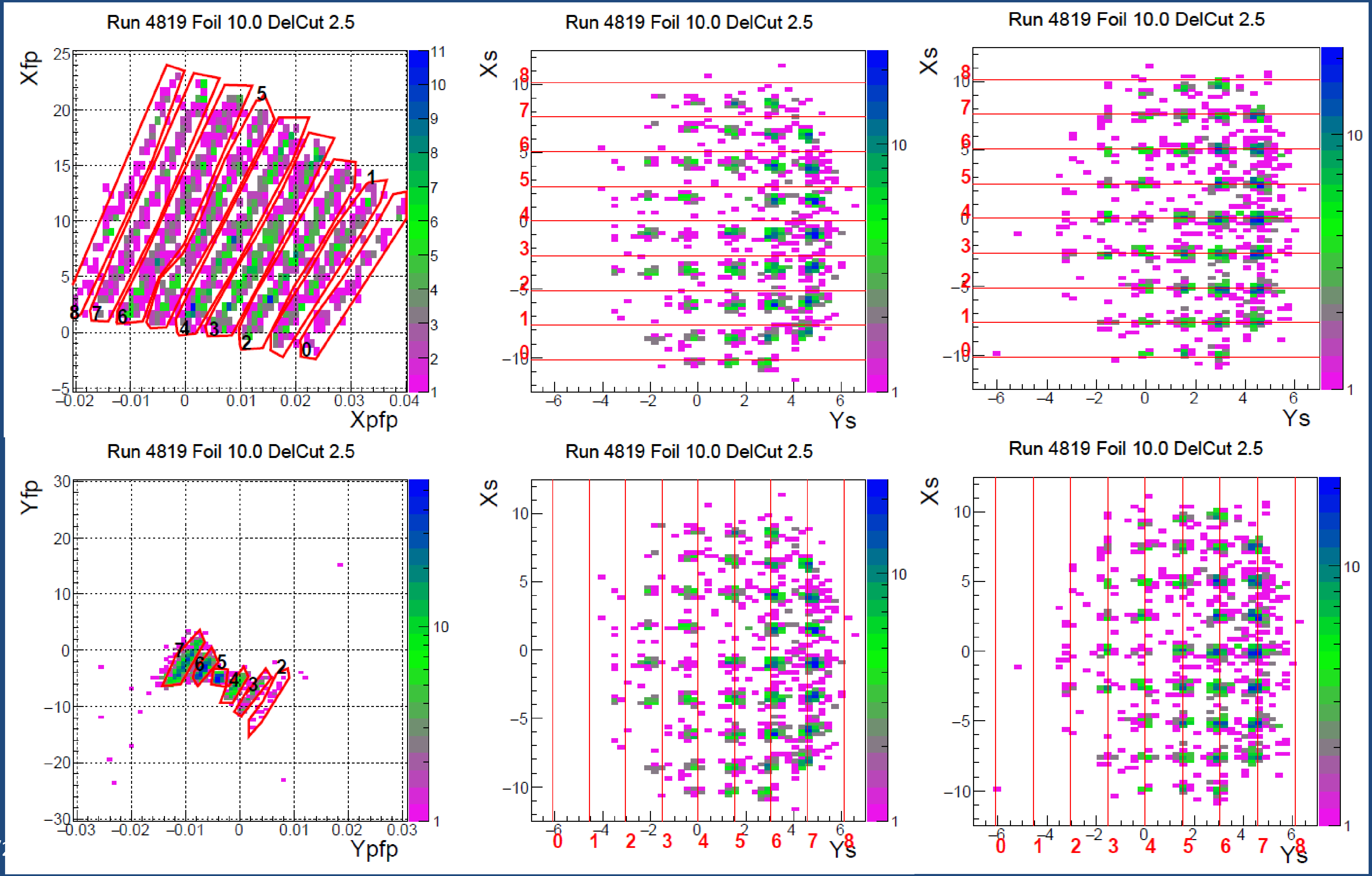
1st Order Coefficients - Corrected

	XpTar	Ytar	YpTar
xfp	3.388097601e-01	1.682202834e-02	-6.160588545e-03
xpfp	-2.997029838e+00	-1.310395456e-01	3.216214407e-02
yfp	-3.077736828e-02	-4.473139347e-01	2.726089109e-01
ypfp	3.553928161e-01	9.489608147e-02	-2.369974591e+00

1st Order Coefficients - Difference

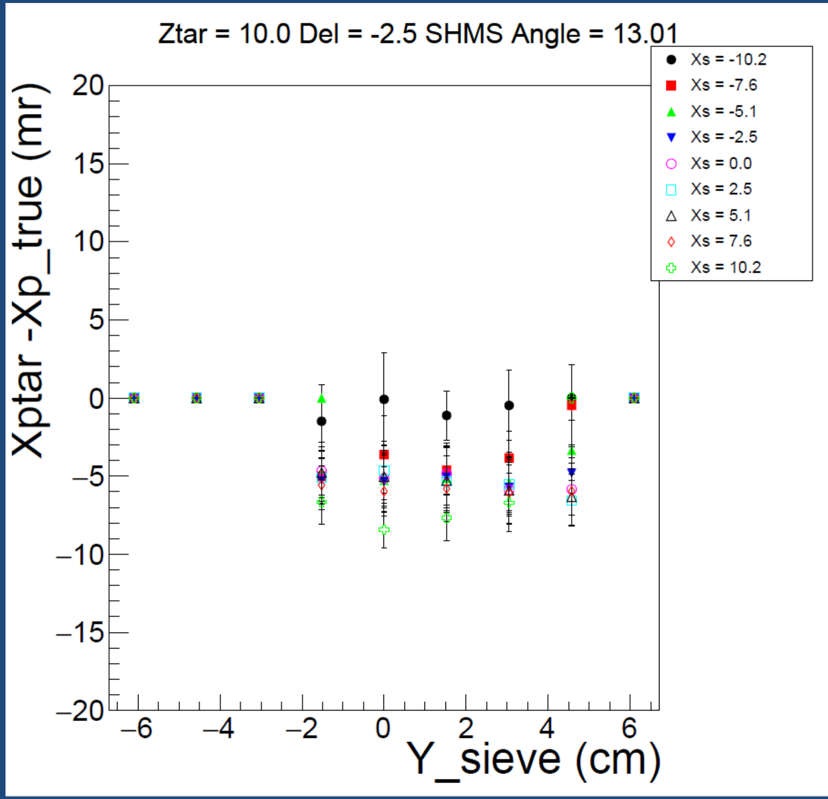
	XpTar	Ytar	YpTar
xfp	-9.828468500e-03	-2.540650740e-03	1.757016685e-03
xpfp	1.143870560e-01	6.574708300e-03	-9.147952210e-03
yfp	-1.752207013e-02	-1.740919380e-02	-4.110763500e-03
ypfp	1.078302488e-01	2.825458110e-01	1.763341840e-01

Focal Plane | Sieve Plane Original | Sieve Plane Corrected

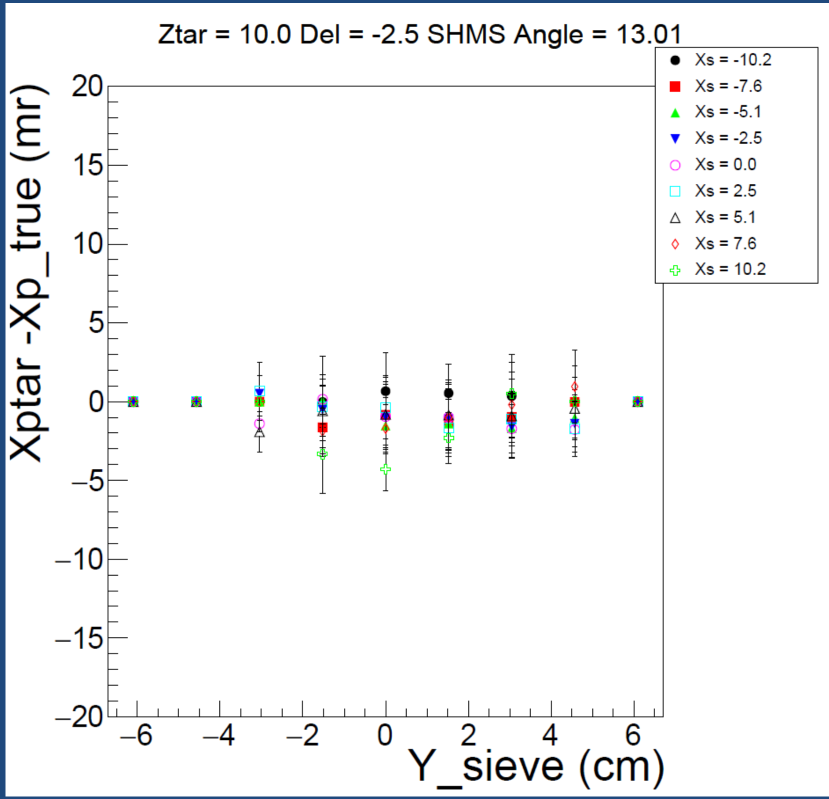


Quality of XpTar Reconstruction

Original

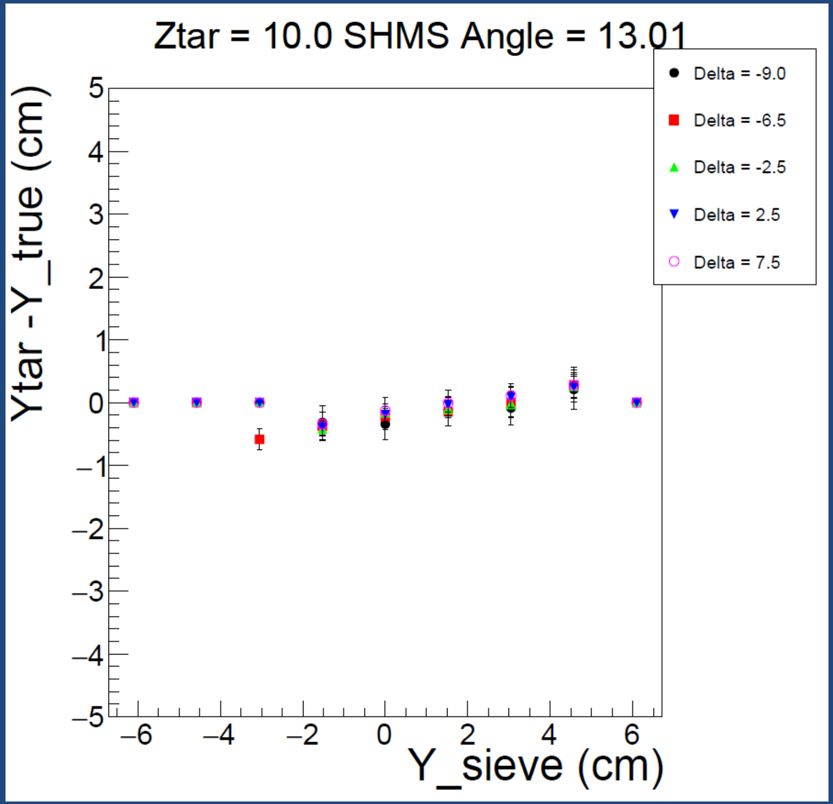


Corrected

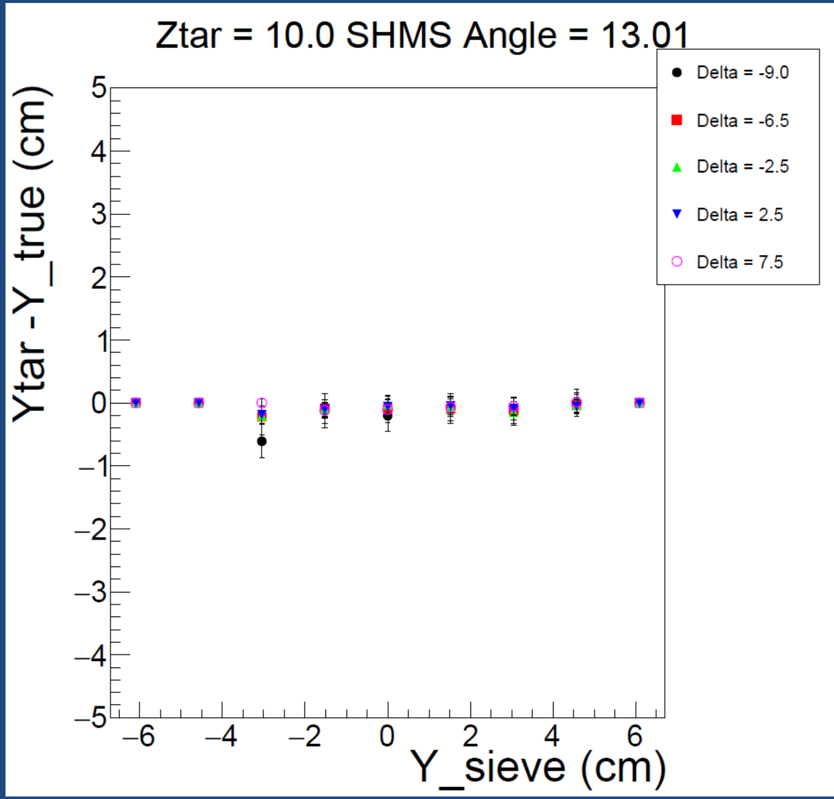


Quality of Ytar Reconstruction

Original

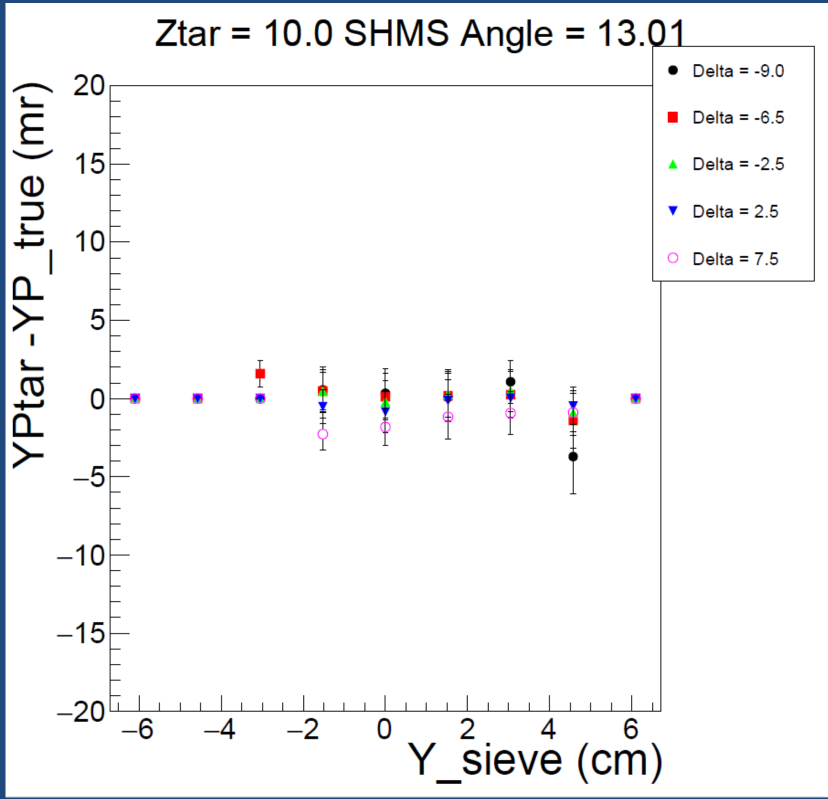


Corrected

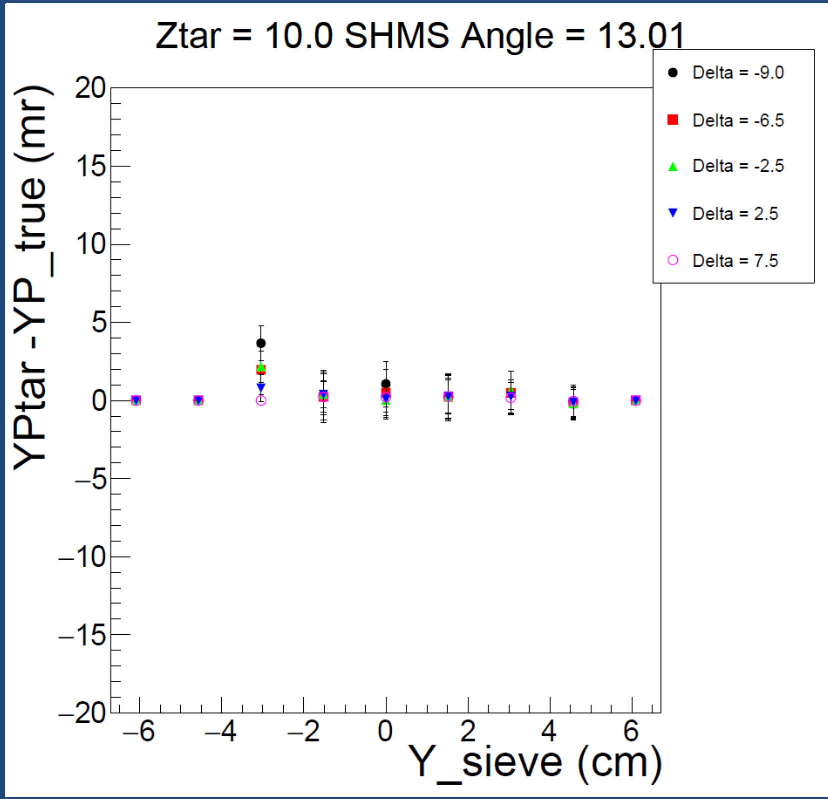


Quality of YpTar Reconstruction

Original



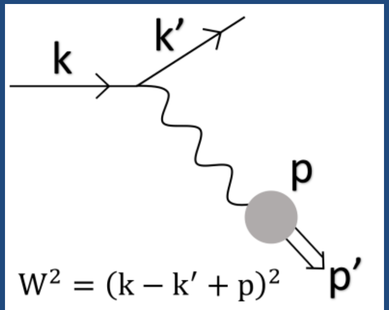
Corrected

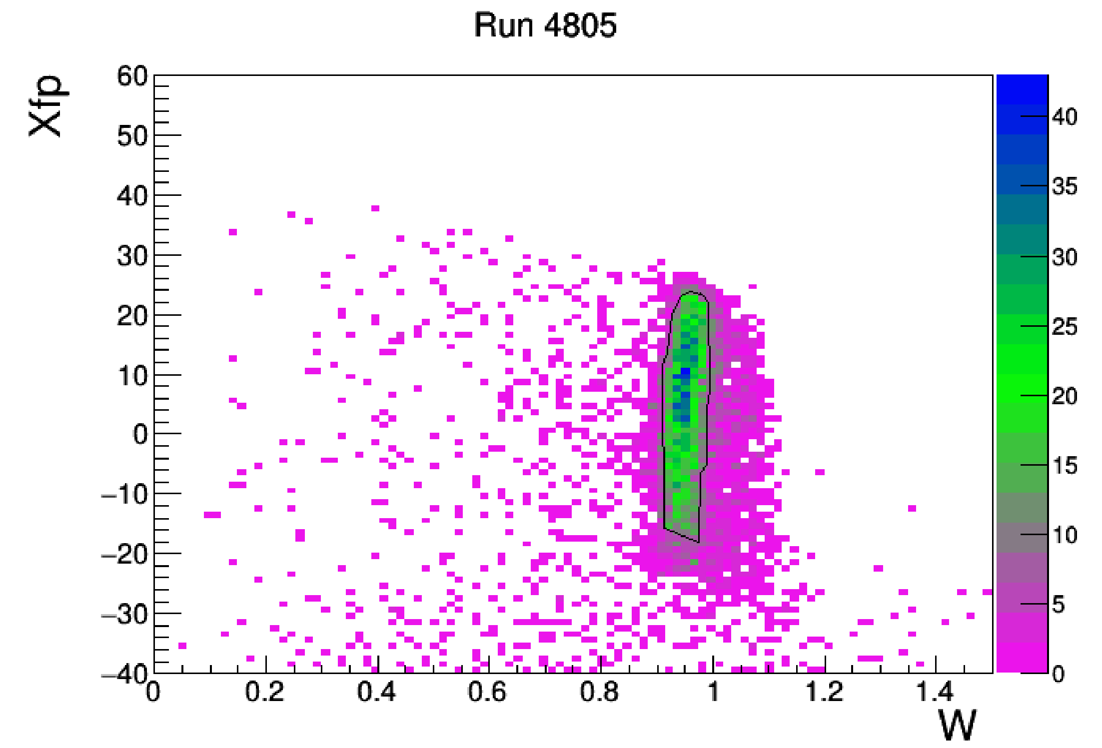


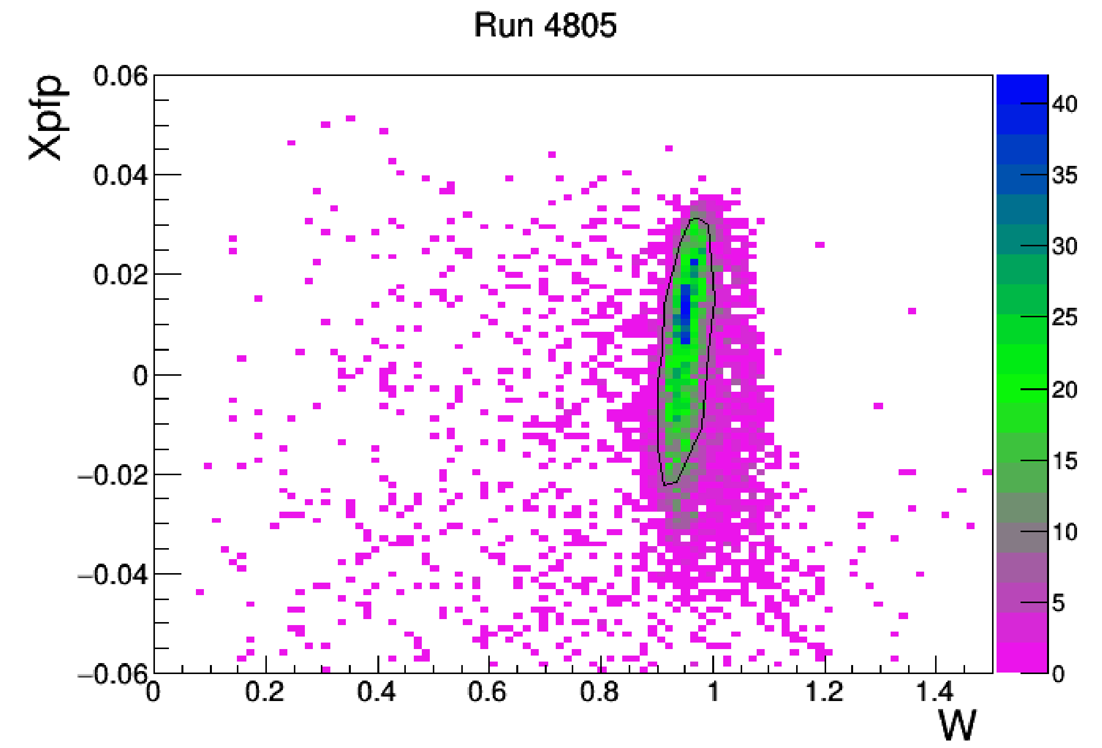
Elastic Delta Scan: Delta Optimization

Using LH2 Data

Elastic W Cuts







$X_{Bjorken}$ and electron identification (E to track norm) cuts were also made prior to these histograms

Delta Coefficients Optical Matrix Corrections

$$Delta = \sum_{i,j,k,m=0}^{6} C_{ijkm}(xfp)^i(xpfp)^j(yfp)^k(ypfp)^m$$

- W = Mp (elastic) => Delta true
- Minimizing difference between reconstructed values and true values resulted in new Delta coefficients

1st Order Coefficients - Original

xfp	2.560211410e-01
xpfp	1.301929760e-01
yfp	2.785652650e-03
ypfp	4.078742980e-02

1st Order Coefficients - Corrected

xfp	2.452771813e-01
xpfp	1.792372539e-01
yfp	1.576222190e-02
ypfp	-2.774811364e-02

1st Order Coefficients - Difference

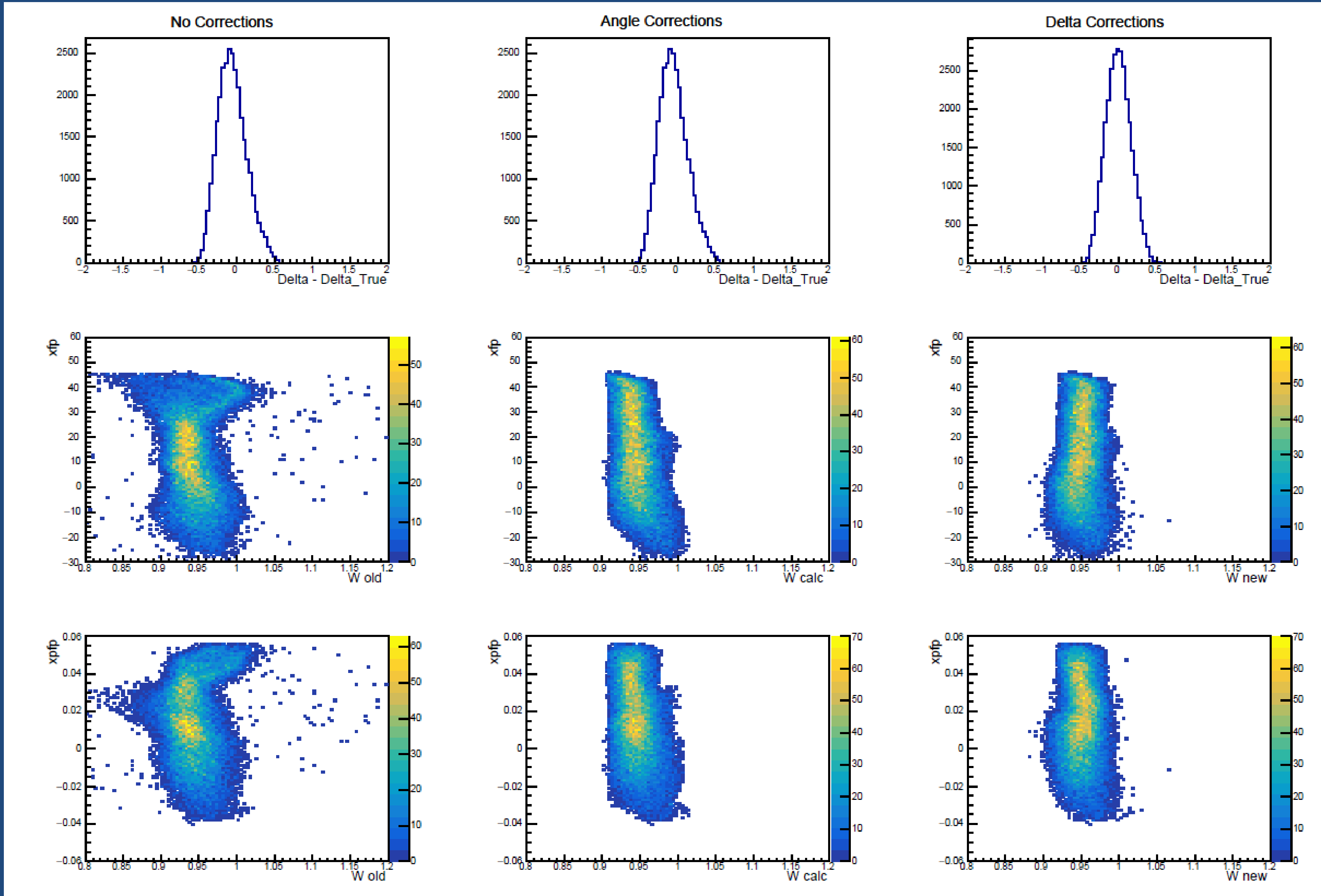
xfp	-1.074395970e-02
xpfp	4.904427790e-02
yfp	1.297656920e-02
ypfp	-6.853554340e-02

NMR Readback Drop and Central Momentum Offset

Run	HMS Angle (deg)	NMR Readback (T)	HMS Adjusted Central Momentum (GeV/c)	Central Momentum Offset (GeV/c)
4805	-18.8	1.84204	6.613	+0.023
4806	-18.8	1.84204	6.613	+0.023
4808	-18.8	1.83462	6.587	-0.003
4811	-18.8	1.83462	6.587	-0.003
4816	-17.2	1.83467	6.587	-0.003
4817	-17.2	1.83467	6.587	-0.003
4821	-19.755	1.831	6.574	-0.016
4824	-19.755		6.574	-0.016
4825	-19.755	1.831	6.574	-0.016

Note – runs listed above are for a Delta scan with LH2 target

New Optics Calibration Results



Conclusions

- New coefficients extracted from carbon-sieve data resulted in:
  - Significant improvement to reconstructed XpTar angle
  - Some improvement in reconstructed YpTar angle and Ytar position
- Optimization from LH2 Delta scan produced slight improvement in reconstructed Delta value
  - Unlocked NMR readback limited Delta improvements
- Elastic W shows:
  - Significant improvement from angular corrections (carbon-sieve data)
  - Slight improvement from momentum corrections (Delta scan)
- New matrix elements and the relevant documentation on corrections will be uploaded to the Hall C doc DB soon
- Future work - use corrected optical matrix on Kaon-LT data at 6.59 GeV HMS central momentum
  - Examine target length, missing-mass, and acceptance of spectrometer in collimator plane

Questions?

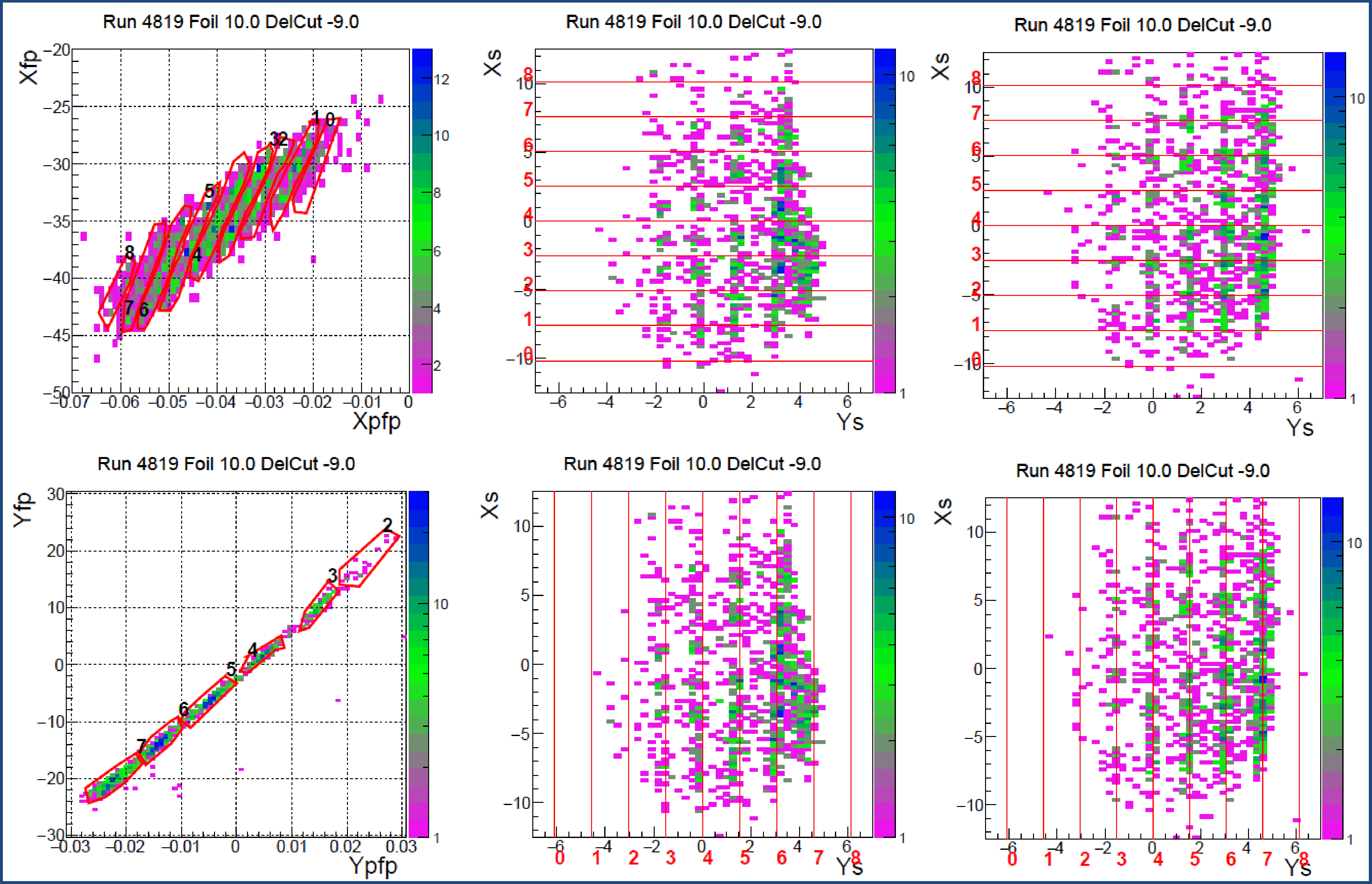
Backup Slides

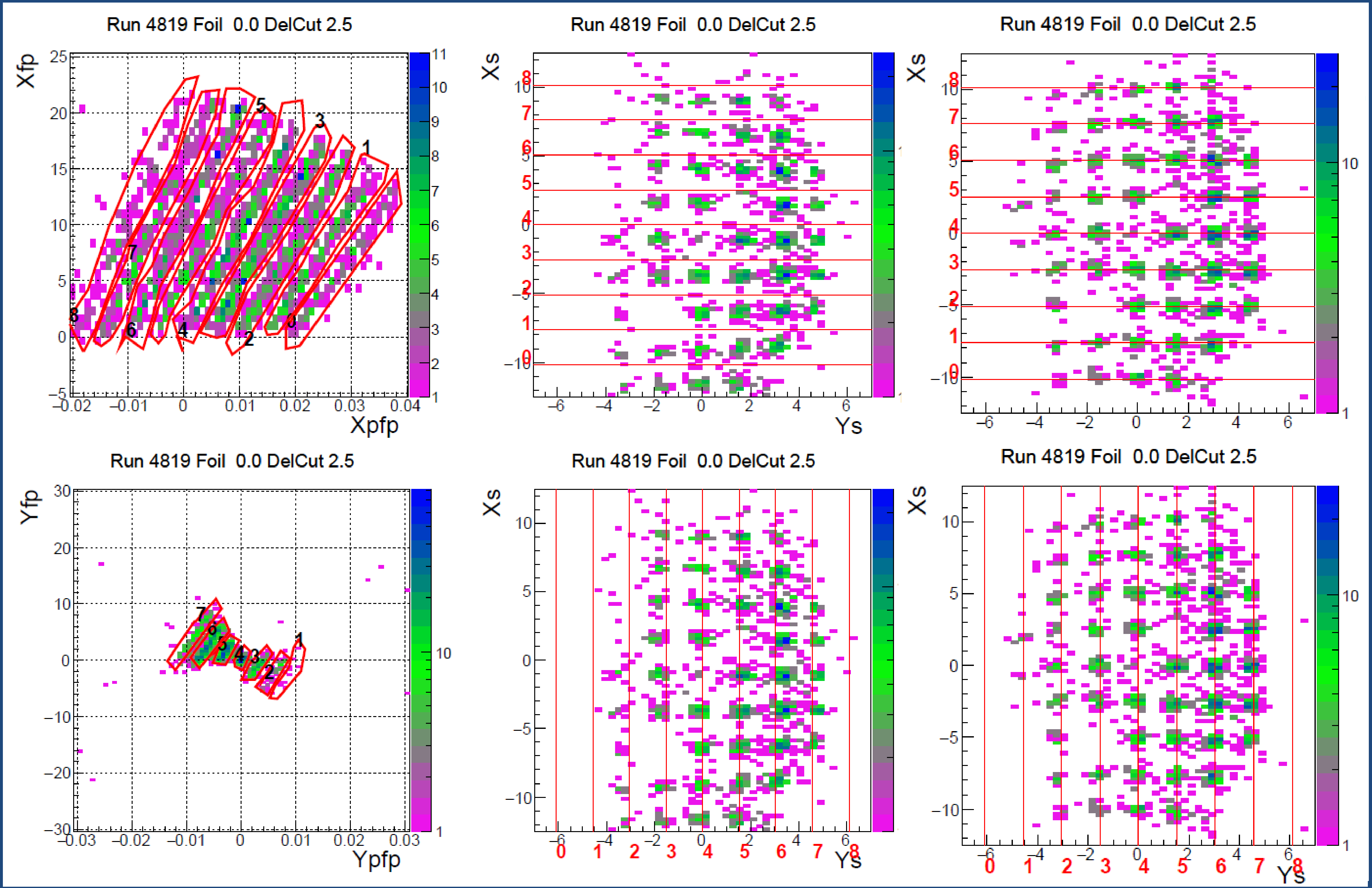
Sieve Hole Focal Plane Cuts

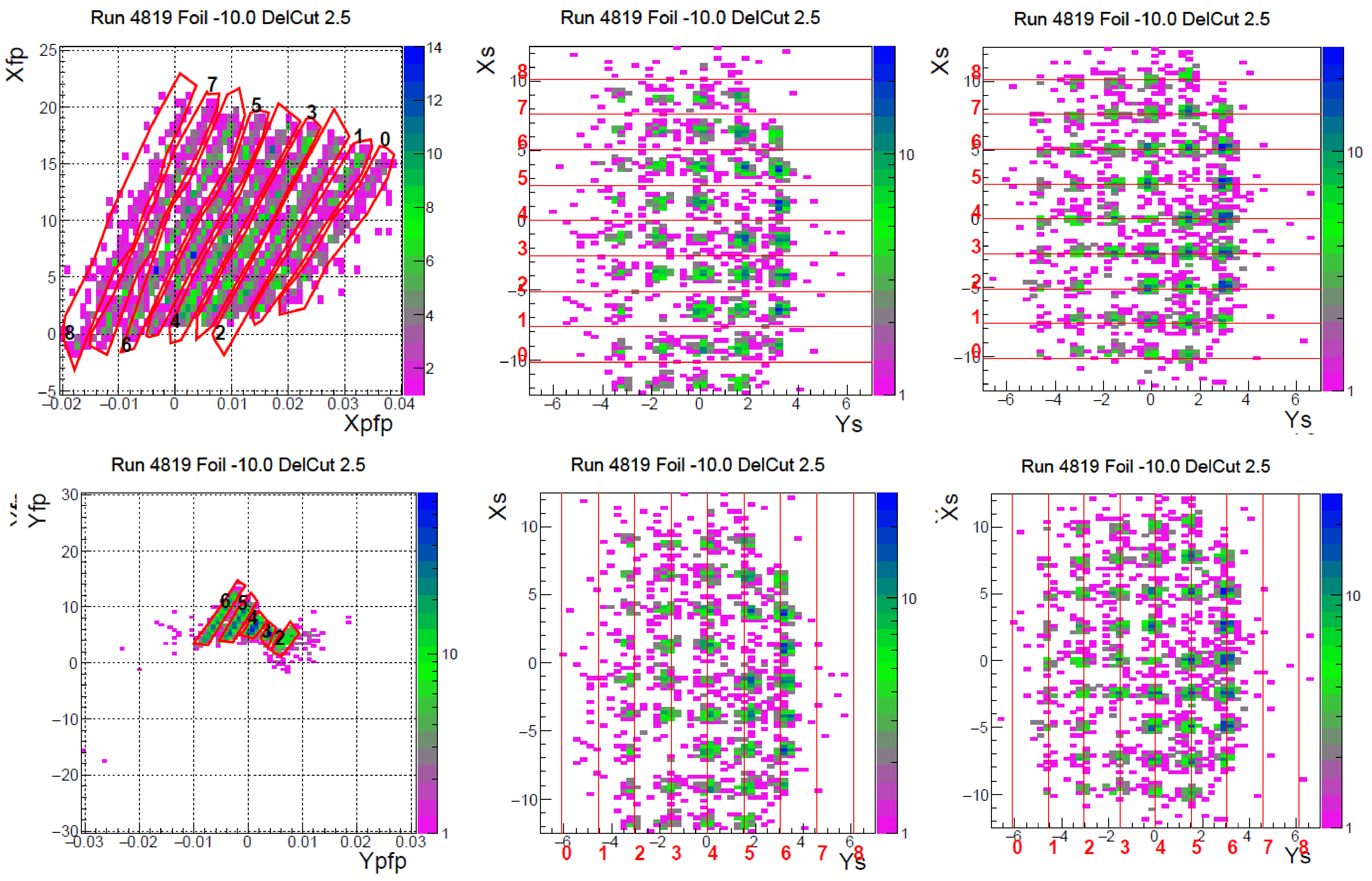
Foils 10, 0, -10

Deltas -9, -6.5, -2.5, 2.5, 7.5

Selection Shown Here


Run 4819 Foil 10.0 DelCut -9.0
Xfp
Xpfp
Run 4819 Foil 10.0 DelCut -9.0
Xs
Ys
Run 4819 Foil 10.0 DelCut -9.0
Xs
Ys
Run 4819 Foil 10.0 DelCut -9.0
Yfp
Ypfp
Run 4819 Foil 10.0 DelCut -9.0
Xs
Ys
Run 4819 Foil 10.0 DelCut -9.0
Xs
Ys


Run 4819 Foil 0.0 DelCut 2.5
Xfp
Xpfp
Xs
Ys
Yfp
Ypfp

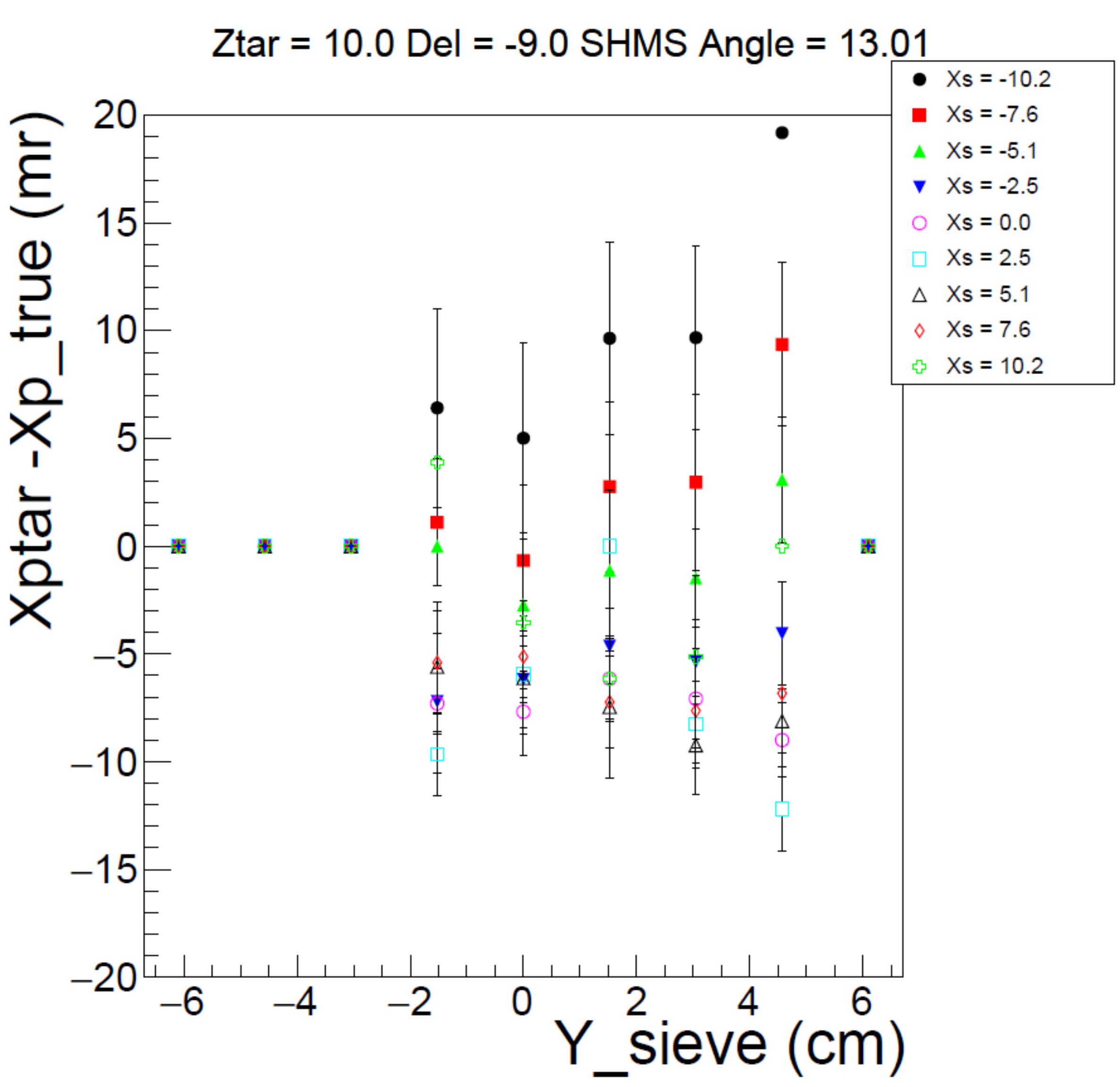

Run 4819 Foil -10.0 DelCut 2.5
Xfp
Xpfp
Xs
Ys
Yfp
Ypfp

Quality of XpTar Reconstruction

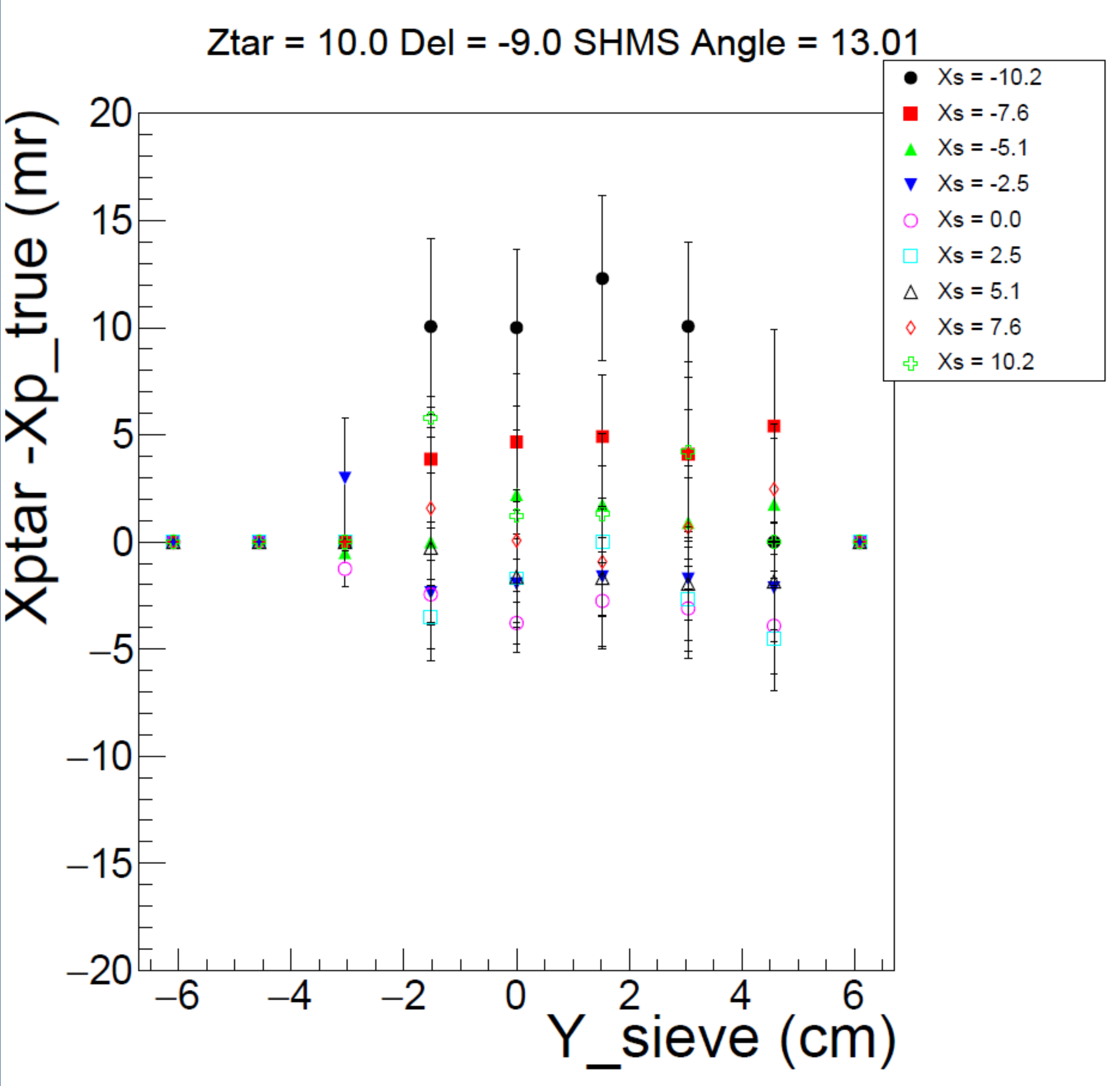
Foils 10, 0, -10

Deltas -9, -6.5, -2.5, 2.5, 7.5

Selection Shown Here



Ztar = 10.0 Del = -9.0 SHMS Angle = 13.01
Xs = -10.2
Xs = -7.6
Xs = -5.1
Xs = -2.5
Xs = 0.0
Xs = 2.5
Xs = 5.1
Xs = 7.6
Xs = 10.2
Xptar -Xp_true (mr)
Y_sieve (cm)



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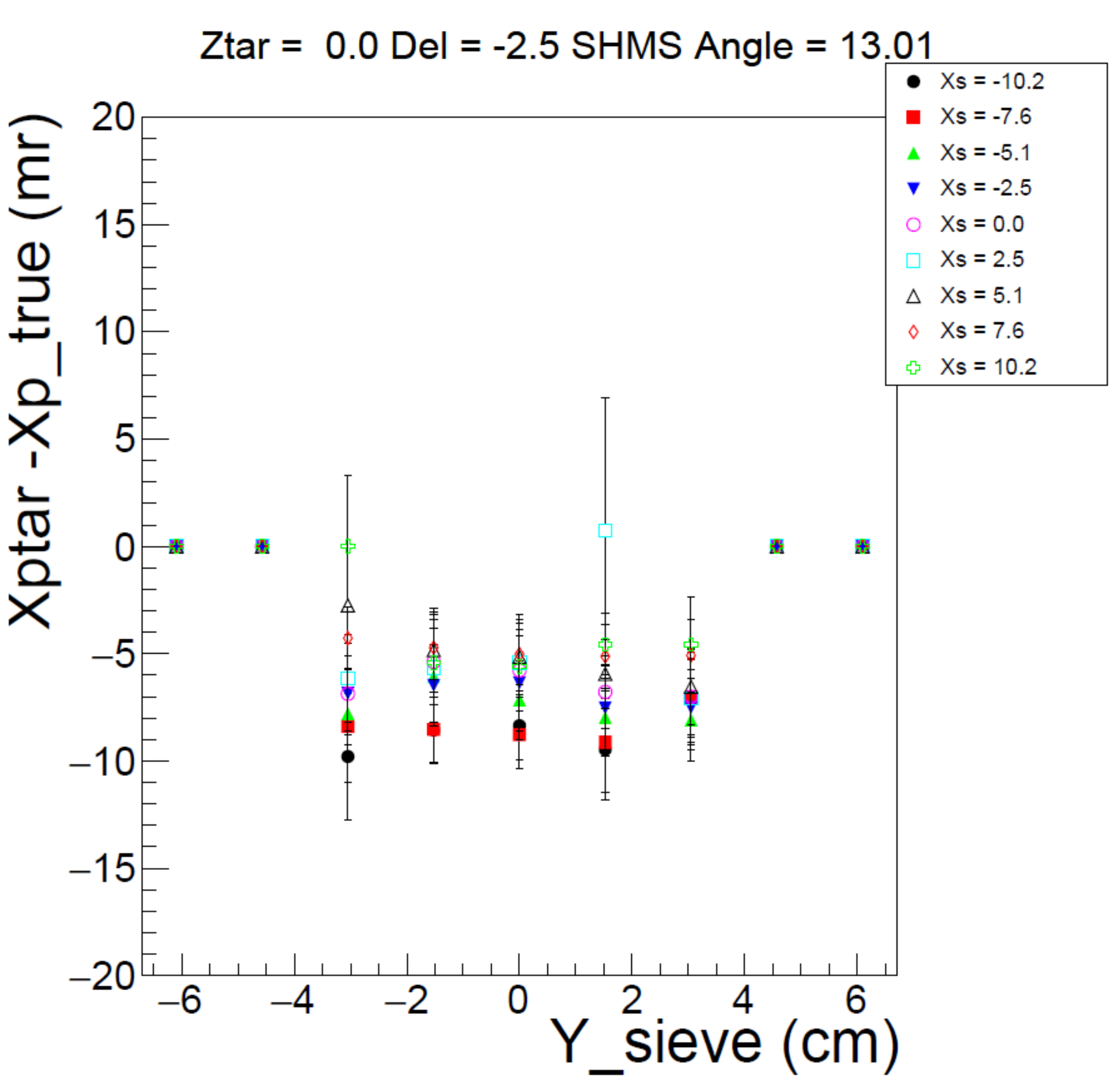
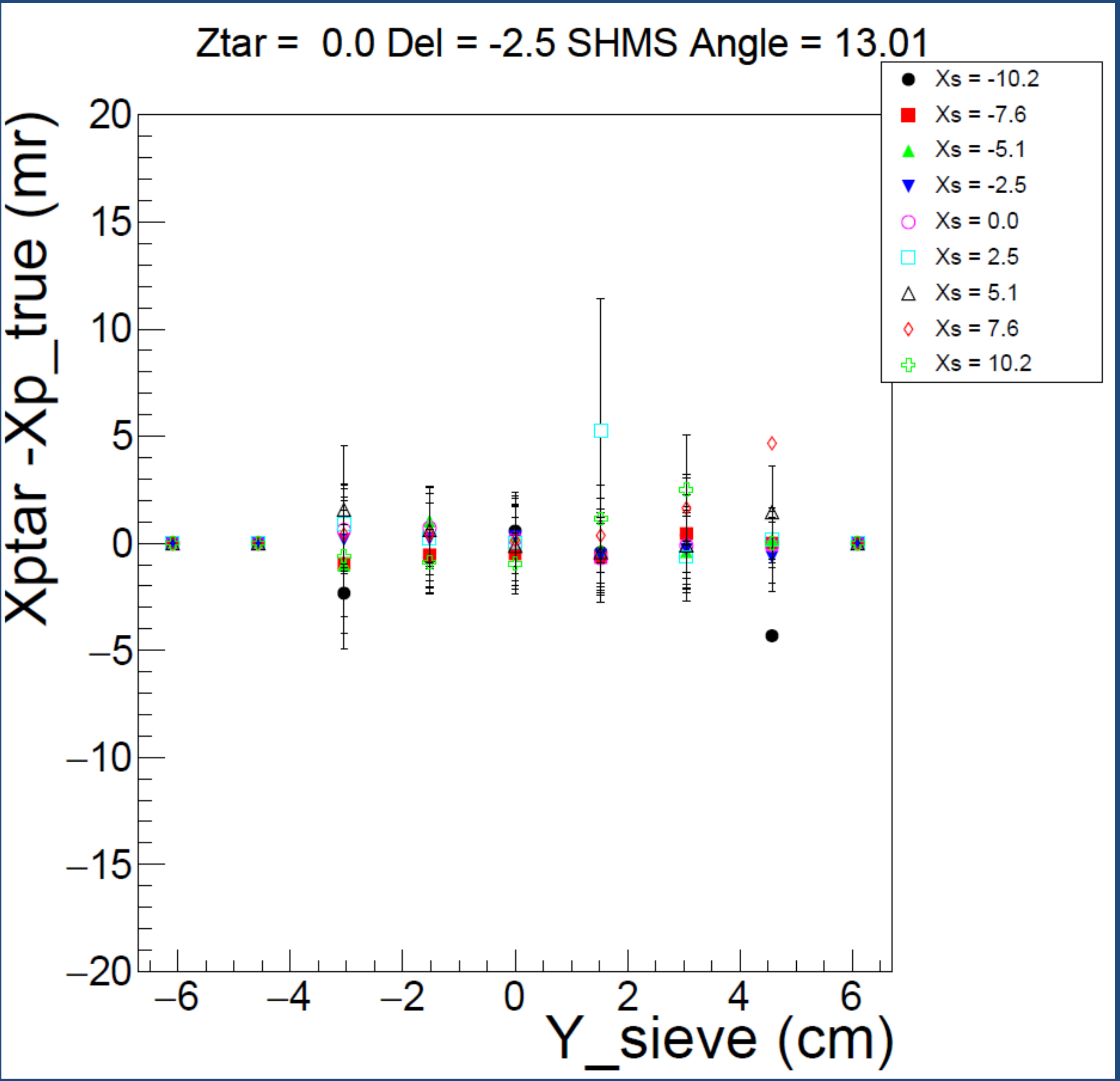


Ztar = 0.0 Del = -2.5 SHMS Angle = 13.01
Xs = -10.2
Xs = -7.6
Xs = -5.1
Xs = -2.5
Xs = 0.0
Xs = 2.5
Xs = 5.1
Xs = 7.6
Xs = 10.2
Xptar -Xp_true (mr)
Y_sieve (cm)



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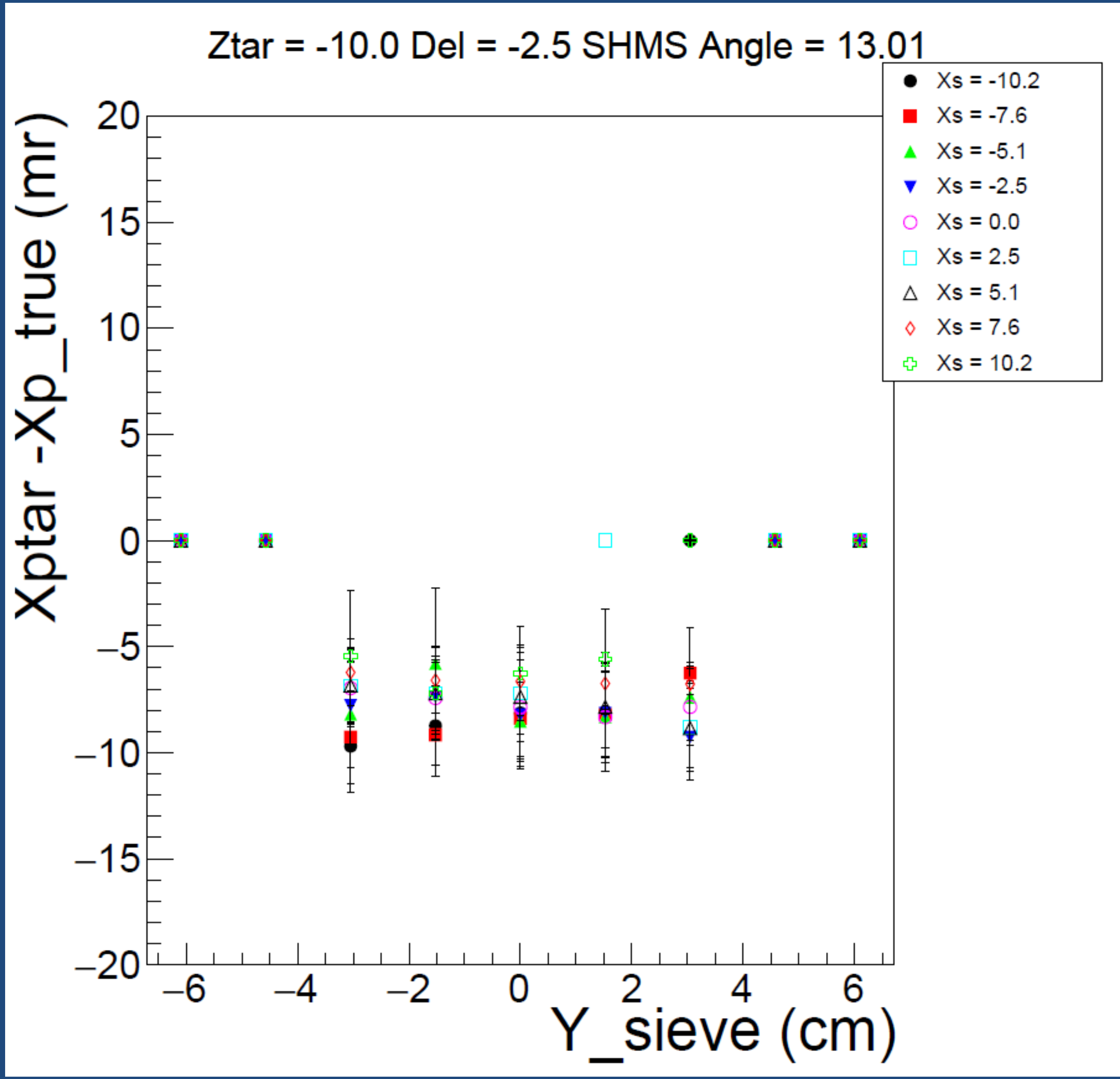
Xs = 10.2
Xptar -Xp_true (mr)
Y_sieve (cm)



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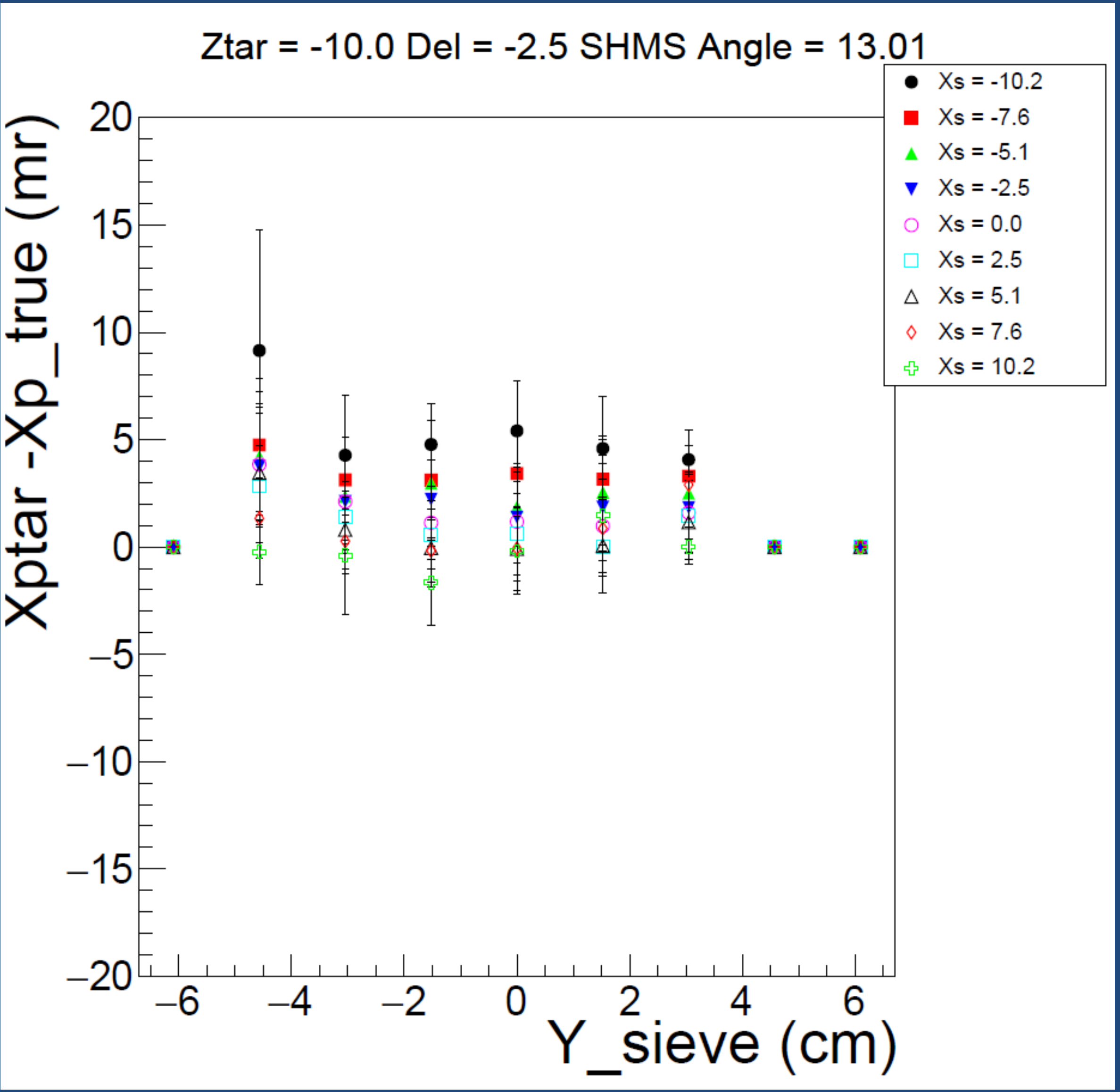
Xs = 10.2
Xptar -Xp_true (mr)
Y_sieve (cm)



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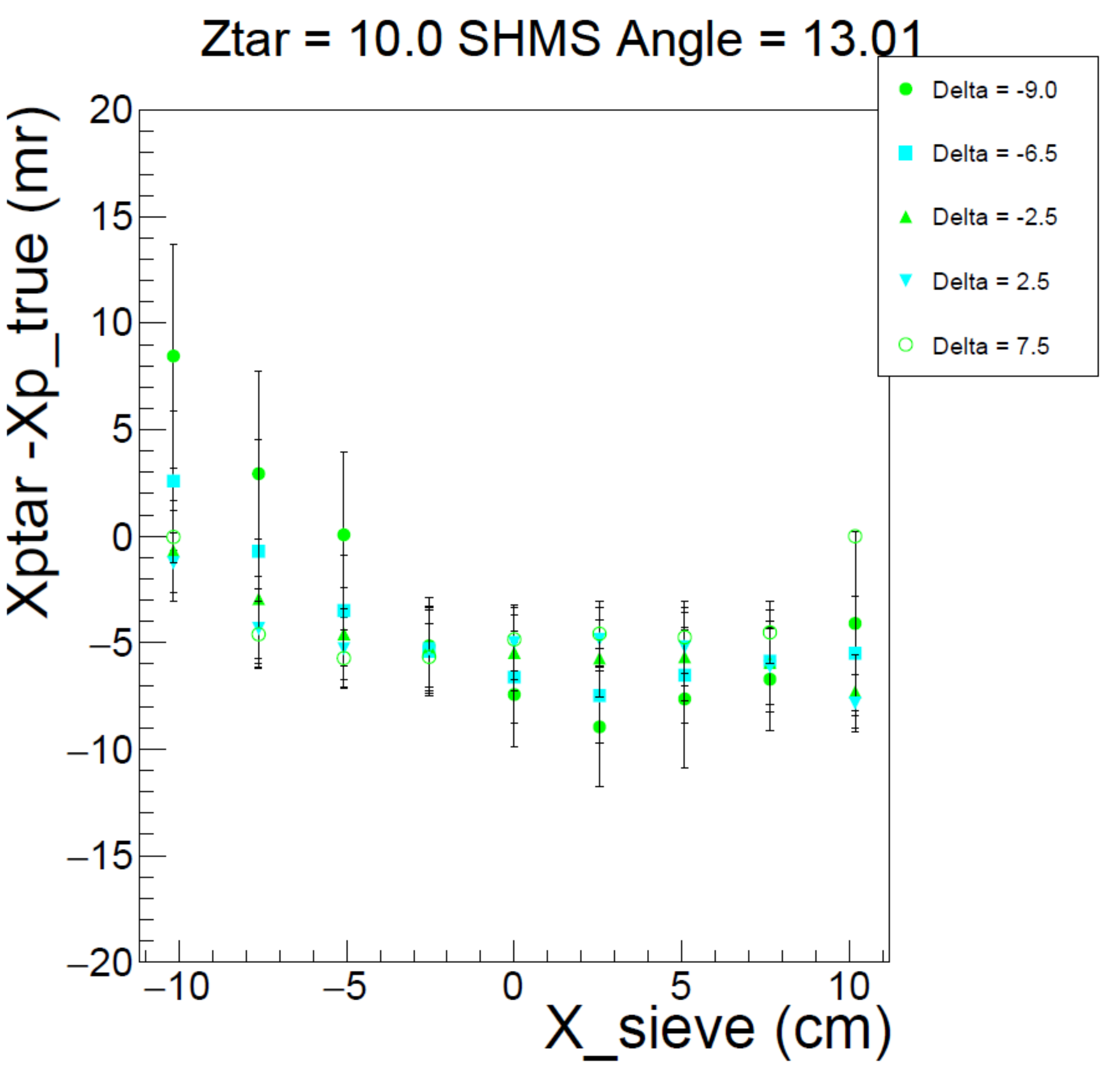
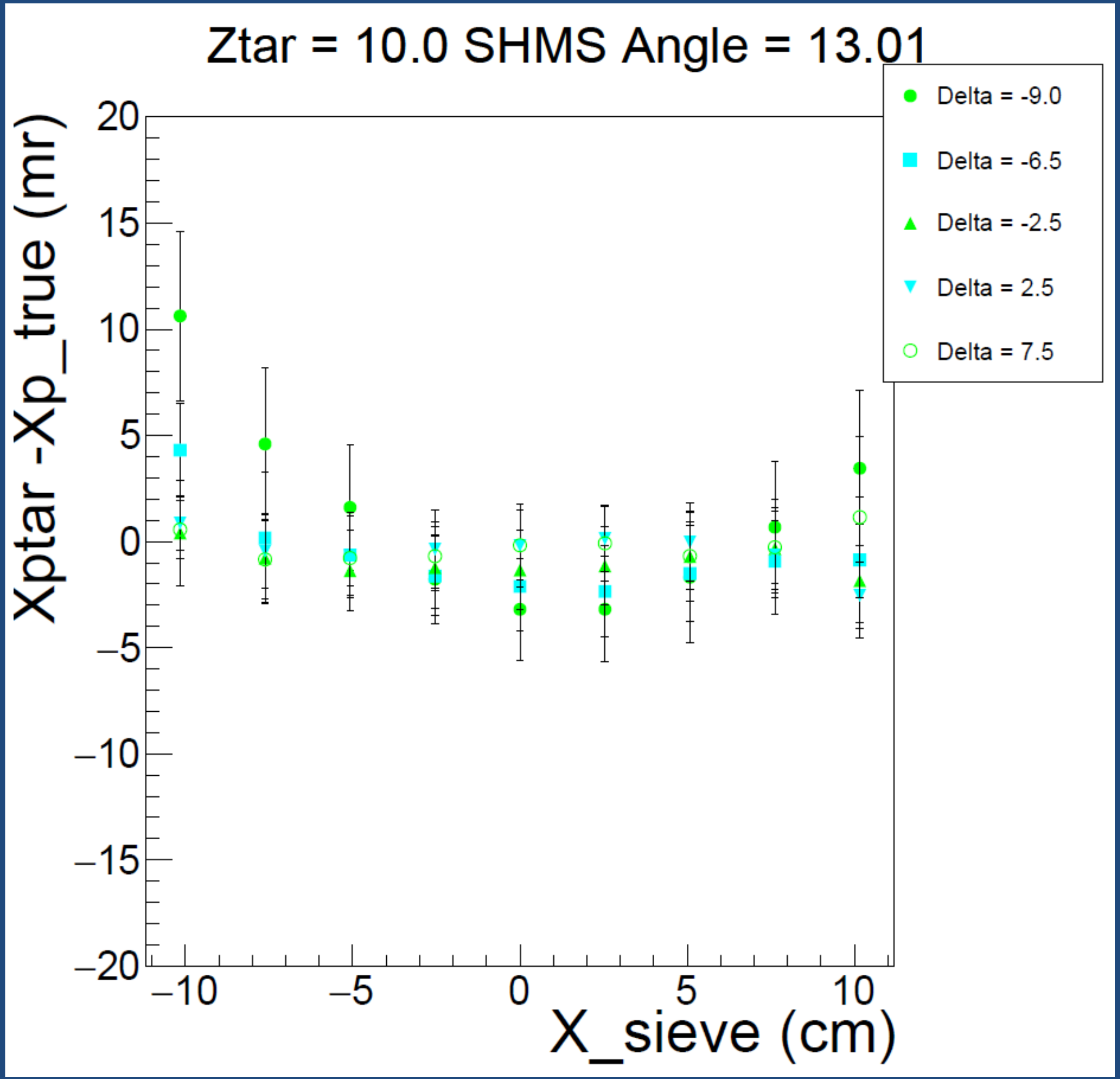
Xs = 2.5
Xs = 5.1
Xs = 7.6
Xs = 10.2
Xptar -Xp_true (mr)
Y_sieve (cm)

XpTar Reconstructed versus Xs

Foils 10, 0, -10


Ztar = 10.0 SHMS Angle = 13.01
Delta = -9.0
Delta = -6.5
Delta = -2.5
Delta = 2.5
Delta = 7.5
Xptar -Xp_true (mr)
X_sieve (cm)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Delta = -2.5
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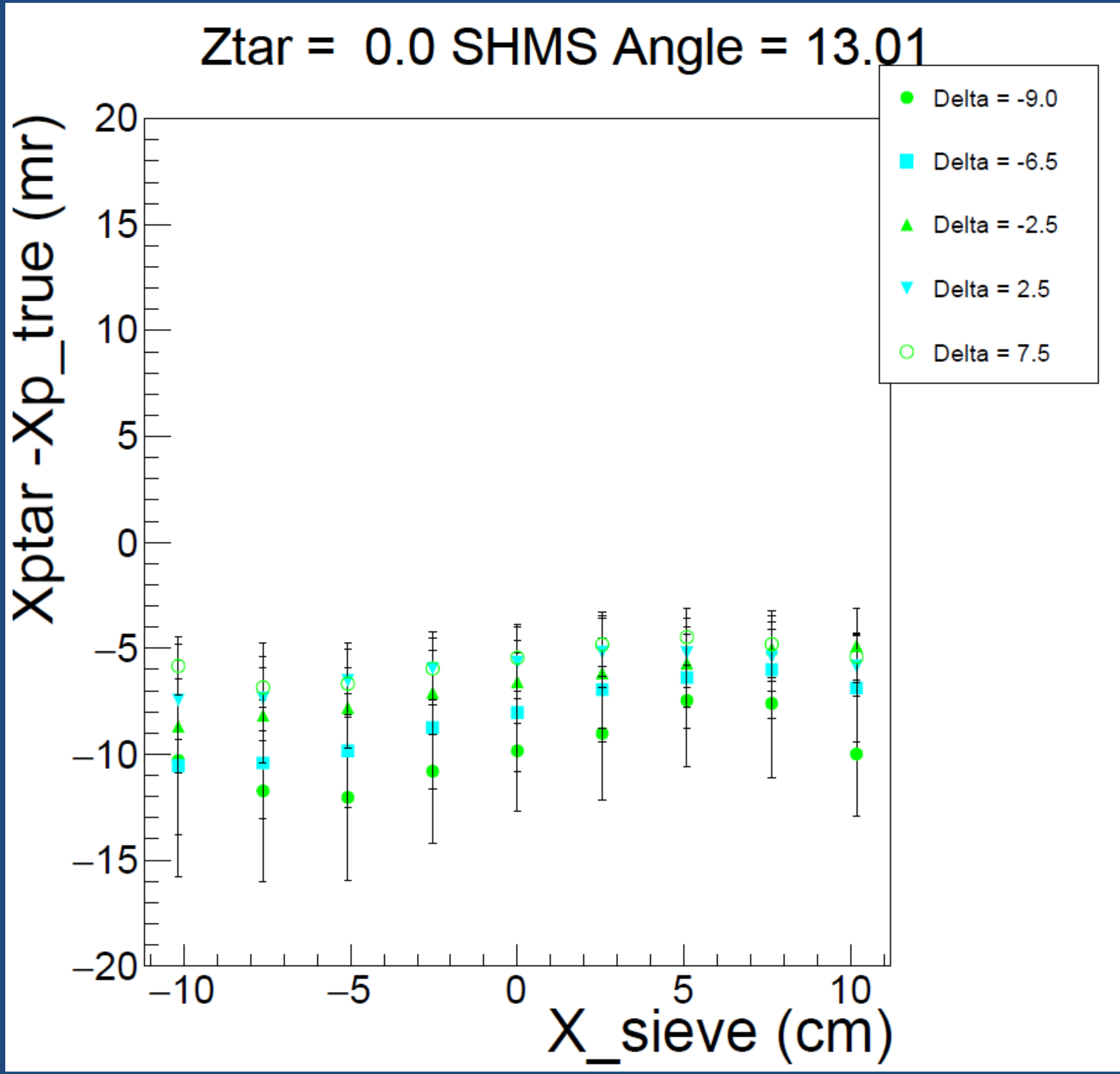
Xptar -Xp_true (mr)
X_sieve (cm)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Delta = -9.0
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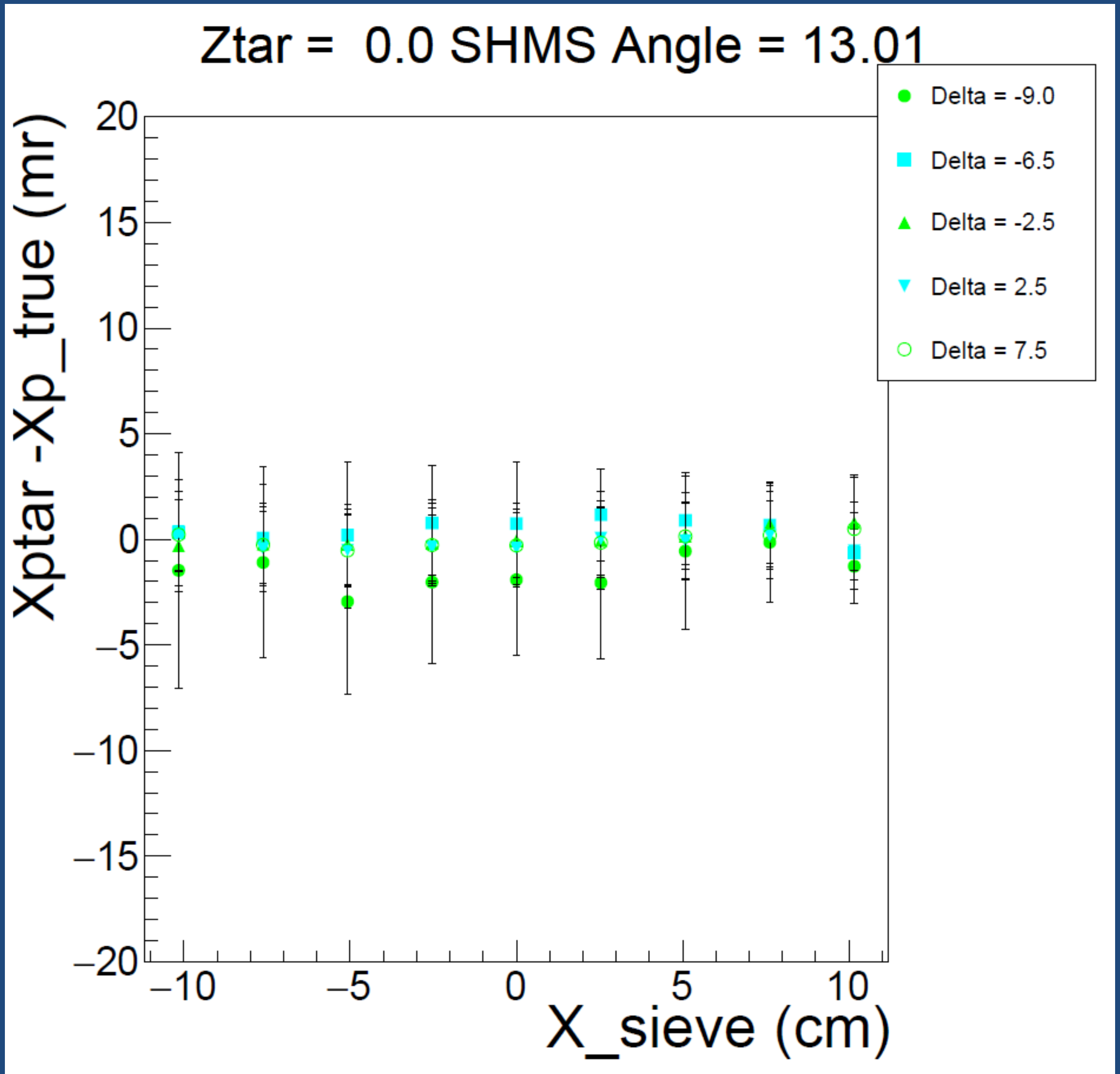
Delta = -2.5
Delta = 2.5
Delta = 7.5
Xptar -Xp_true (mr)
X_sieve (cm)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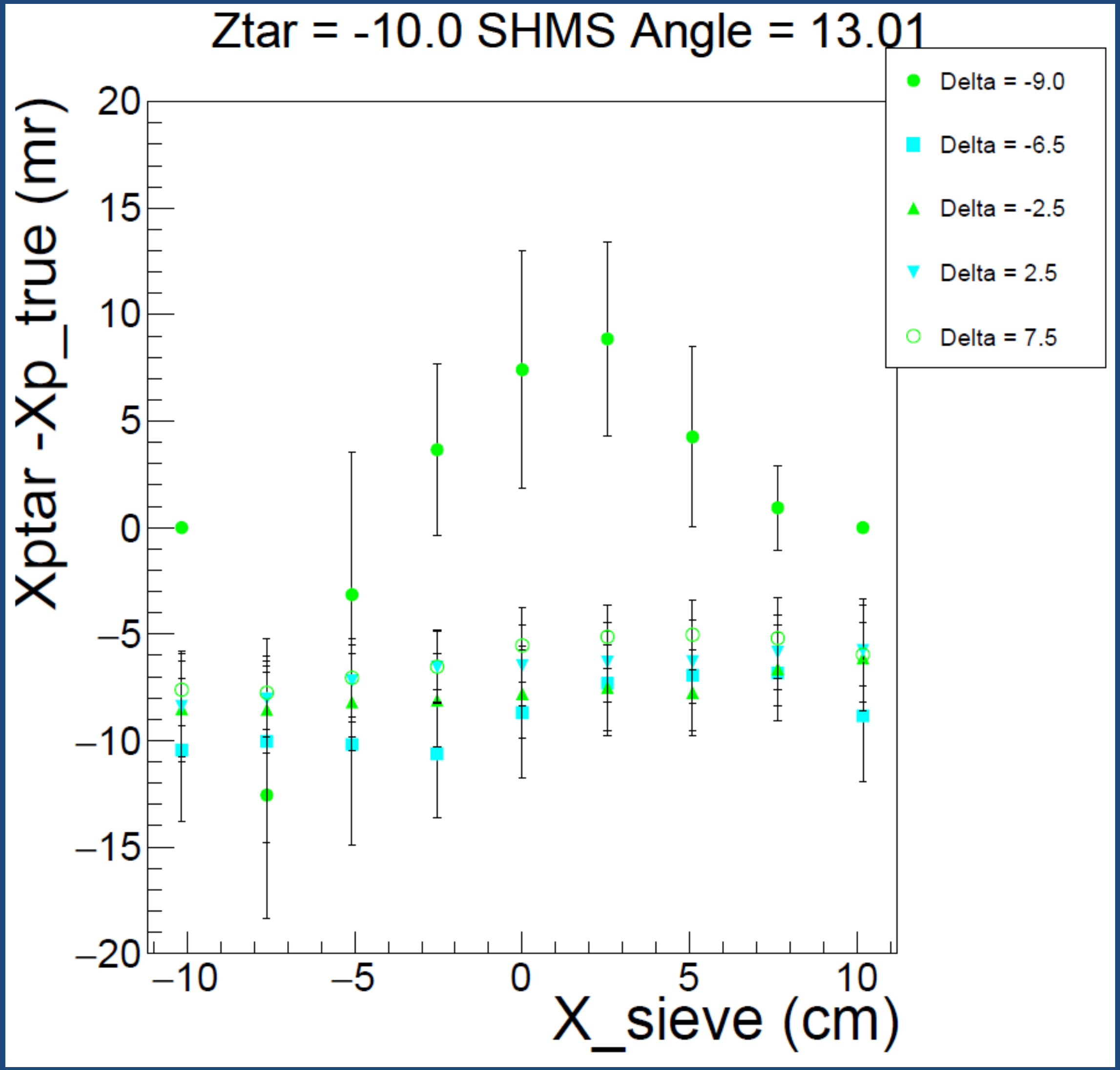
Xptar -Xp_true (mr)
X_sieve (cm)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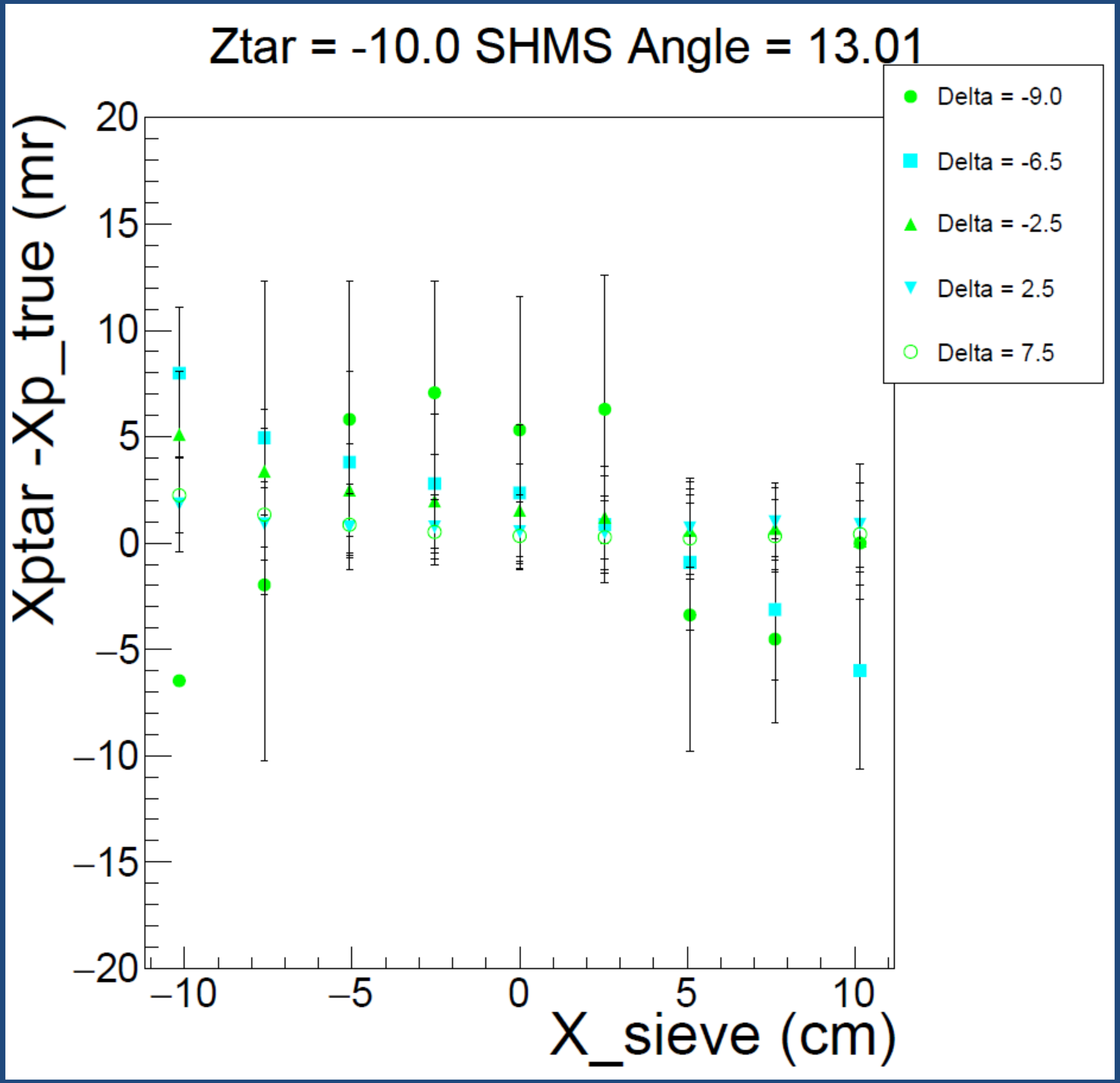
X_sieve (cm)


Ztar = -10.0 SHMS Angle = 13.01
Delta = -9.0
Delta = -6.5
Delta = -2.5
Delta = 2.5
Delta = 7.5
Xptar -Xp_true (mr)
X_sieve (cm)

Derivation of Delta-True

$$W^2 = M_P^2 + Q^2(\frac{1}{x_{Bj}} - 1)$$

$$Q^2 = 4E_0E' \sin^2(\theta/2)$$

$$x_Bj = \frac{Q^2}{2M_P(E_0 - E')}$$

We want $W^2 = M_P^2$, therefore

$$Q^2(\frac{1}{x_{Bj}} - 1) = 0$$

$$Q^2(\frac{2M_P(E_0 - E')}{Q^2} - 1) = 0$$

$$2M_P(E_0 - E') - Q^2 = 0$$

$$2M_P(E_0 - E') - 4E_0E' \sin^2(\theta/2) = 0$$

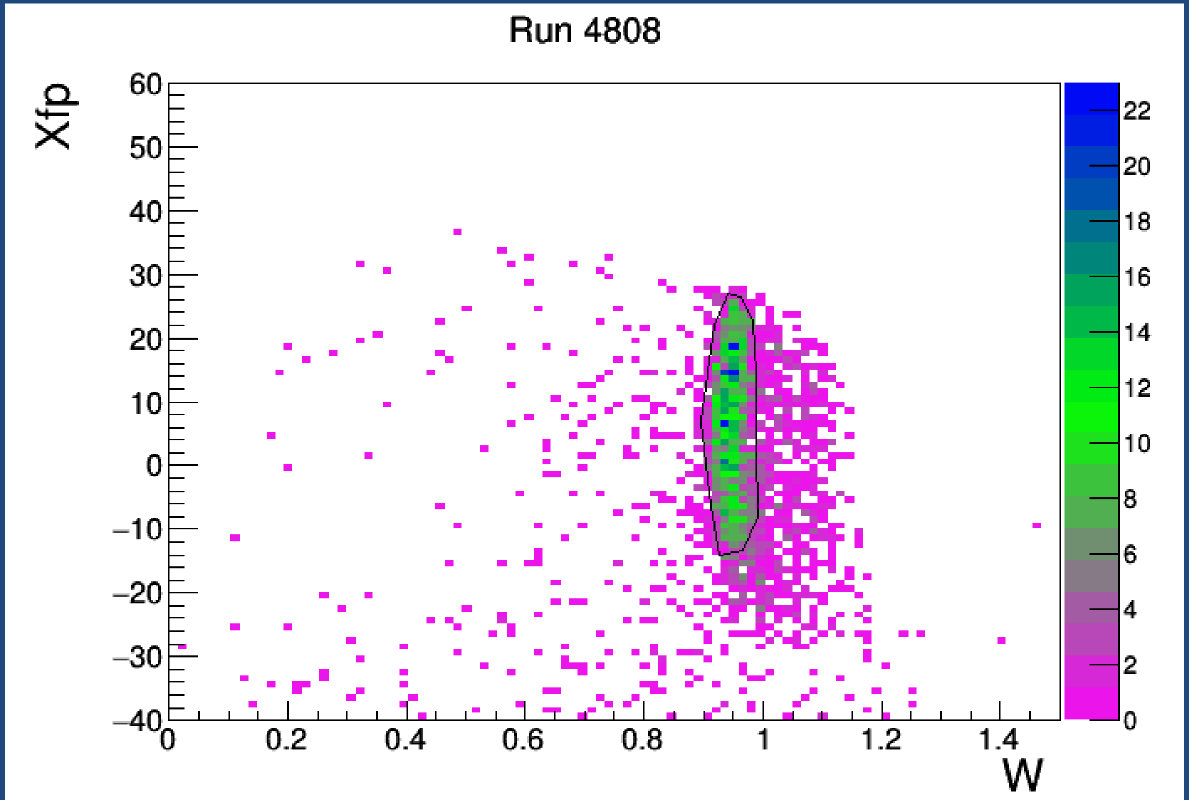
$$2M_PE_0 = 2E'(M_P + 2E_0 \sin^2(\theta/2)) = 0$$

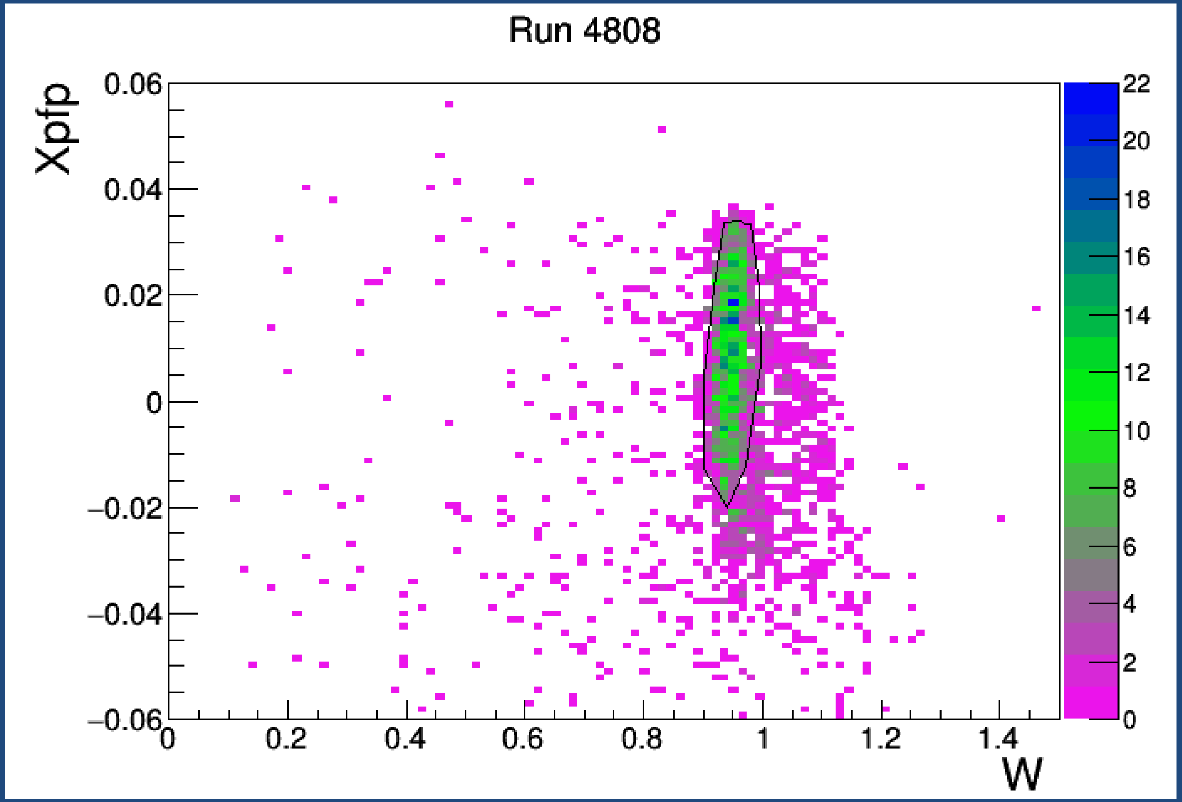
$$E' = \frac{M_PE_0}{(M_P + 2E_0 \sin^2(\theta/2)}$$

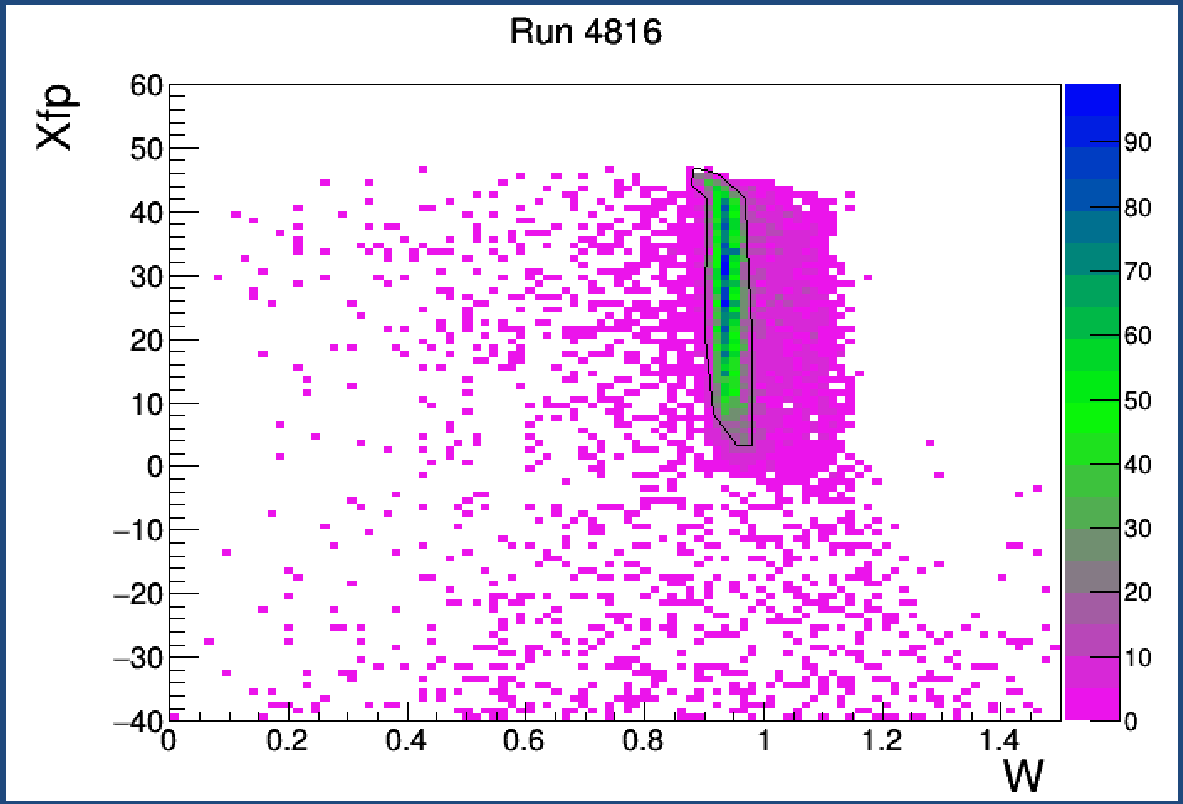
$$P_T = \sqrt{E'^2 - M_e^2}$$

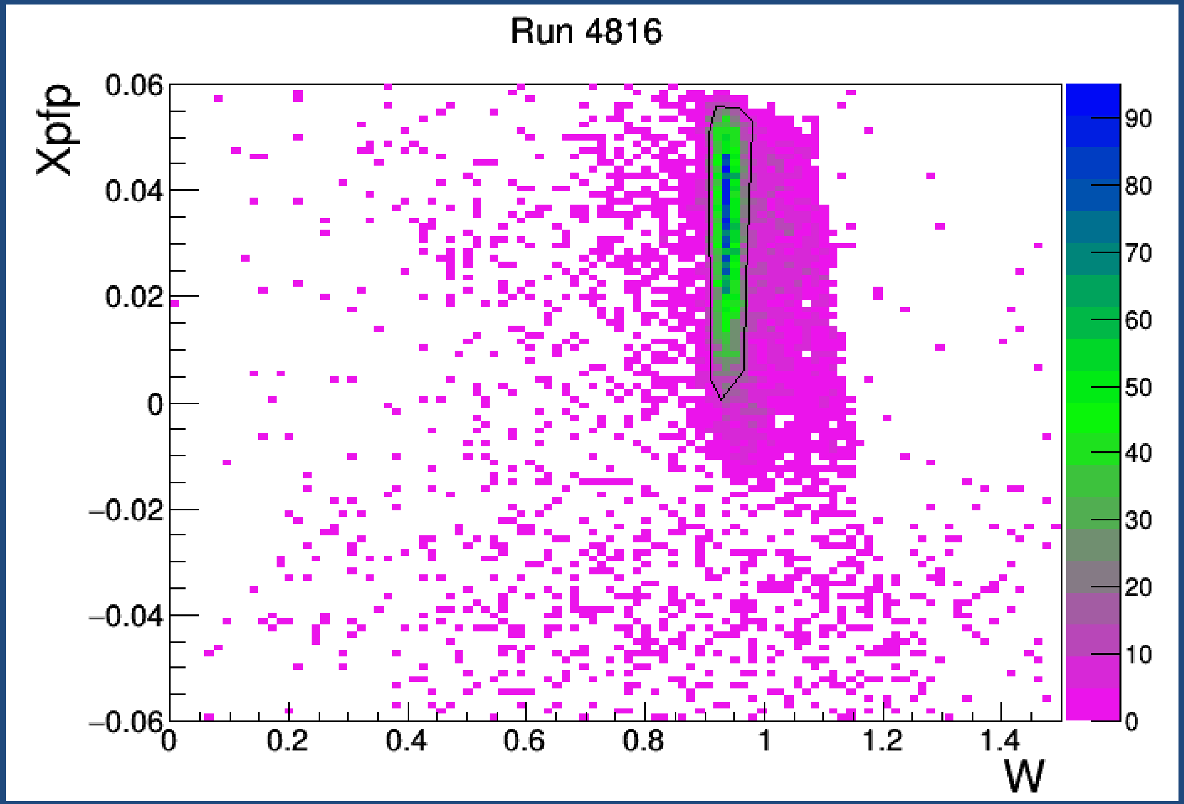
$$\delta_T = \frac{P_T - P_0}{P_0}$$

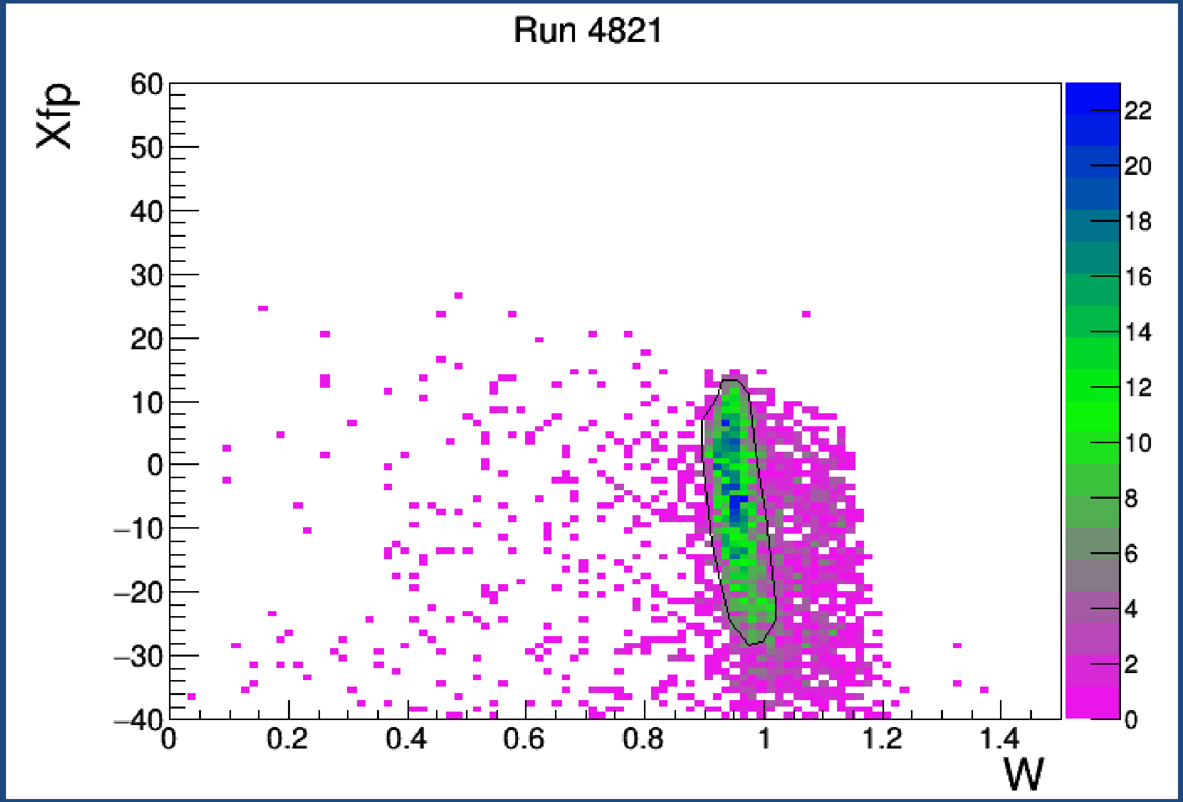
Elastic W Cuts

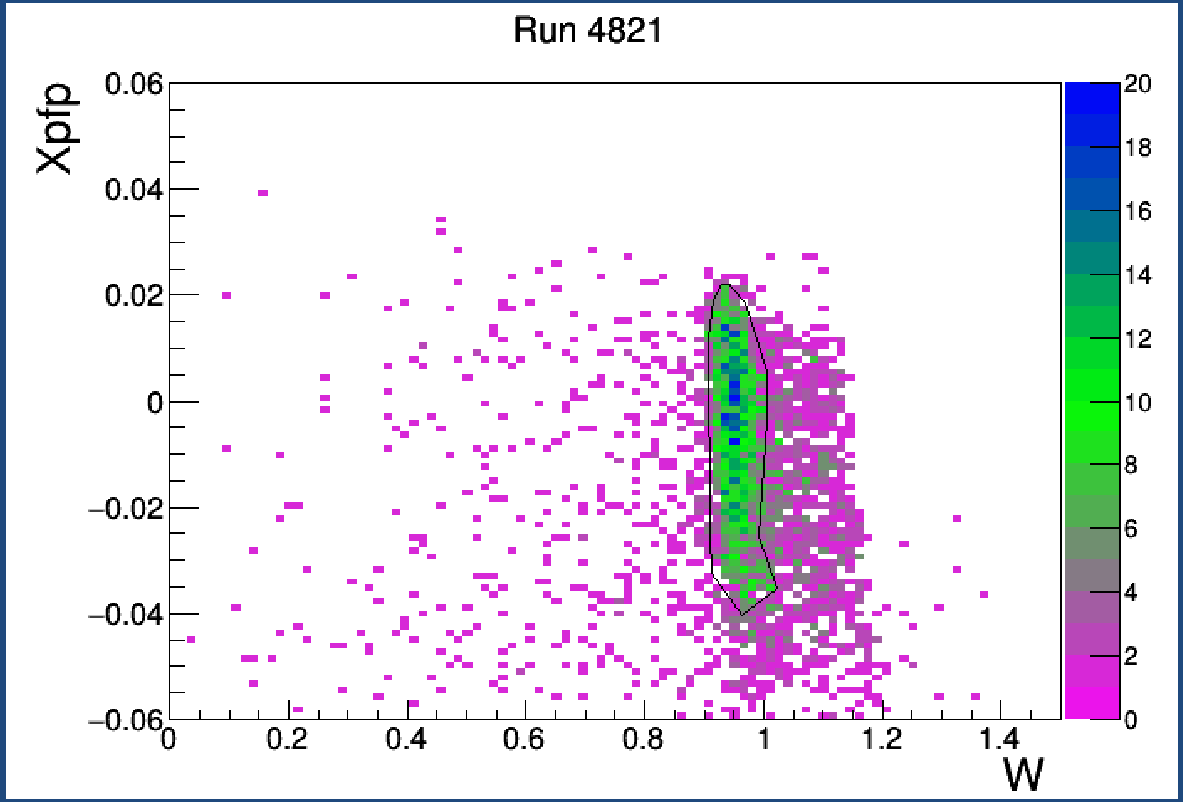

Run 4808
Xfp
W
60
50
40
30
20
10
0
−10
−20
−30
−40
0
0.2
0.4
0.6
0.8
1
1.2
1.4
22
20
18
16
14
12
10
8
6
4
2
0


Run 4808
Xpfp
W
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
22
20
18
16
14
12
10
8
6
4
2
0


Run 4816
Xfp
W
60
50
40
30
20
10
0
−10
−20
−30
−40
0
0.2
0.4
0.6
0.8
1
1.2
1.4
90
80
70
60
50
40
30
20
10
0

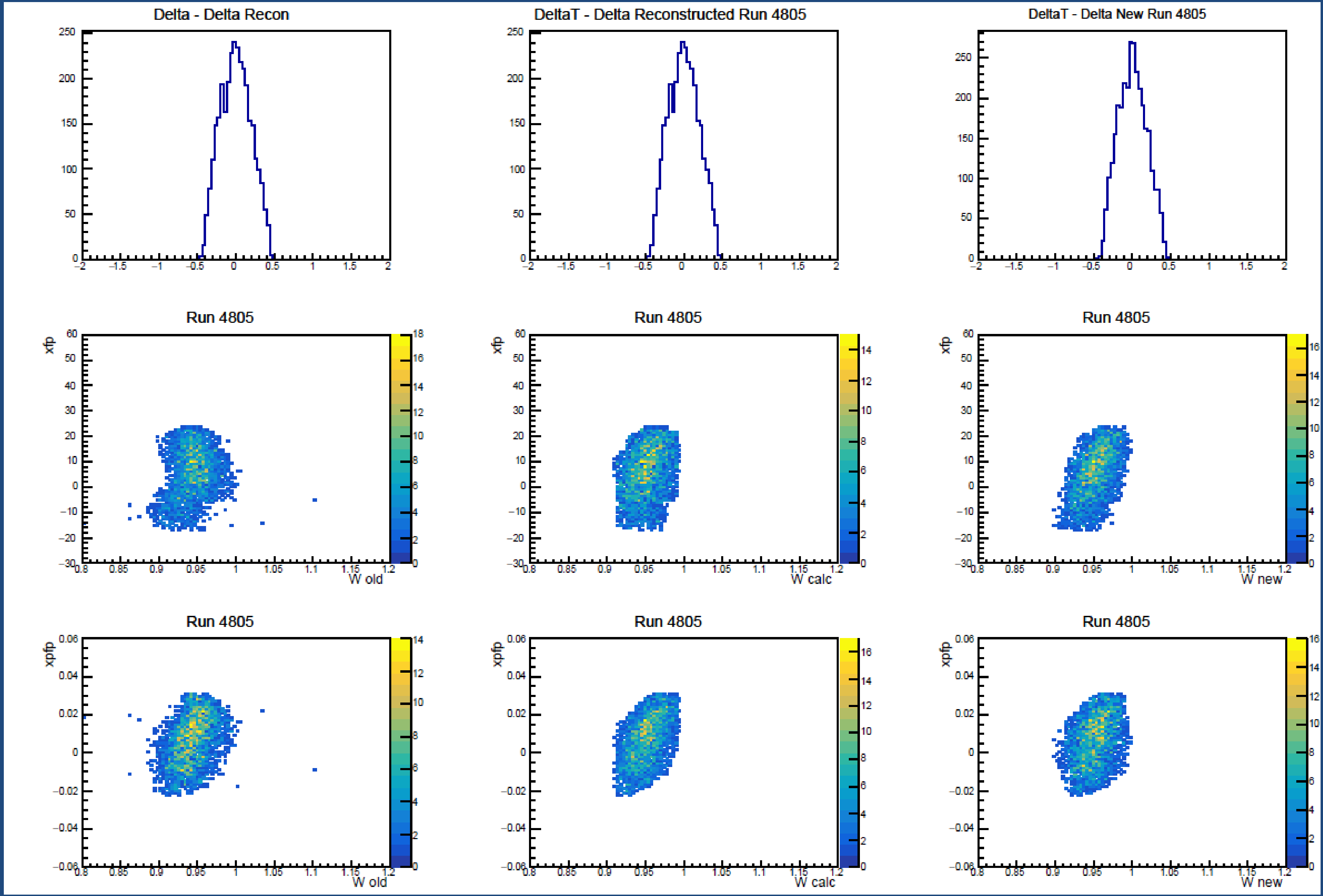

Run 4816
Xpfp
W
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
0
0.2
0.4
0.6
0.8
1
1.2
1.4
90
80
70
60
50
40
30
20
10
0


Run 4821
Xfp
W

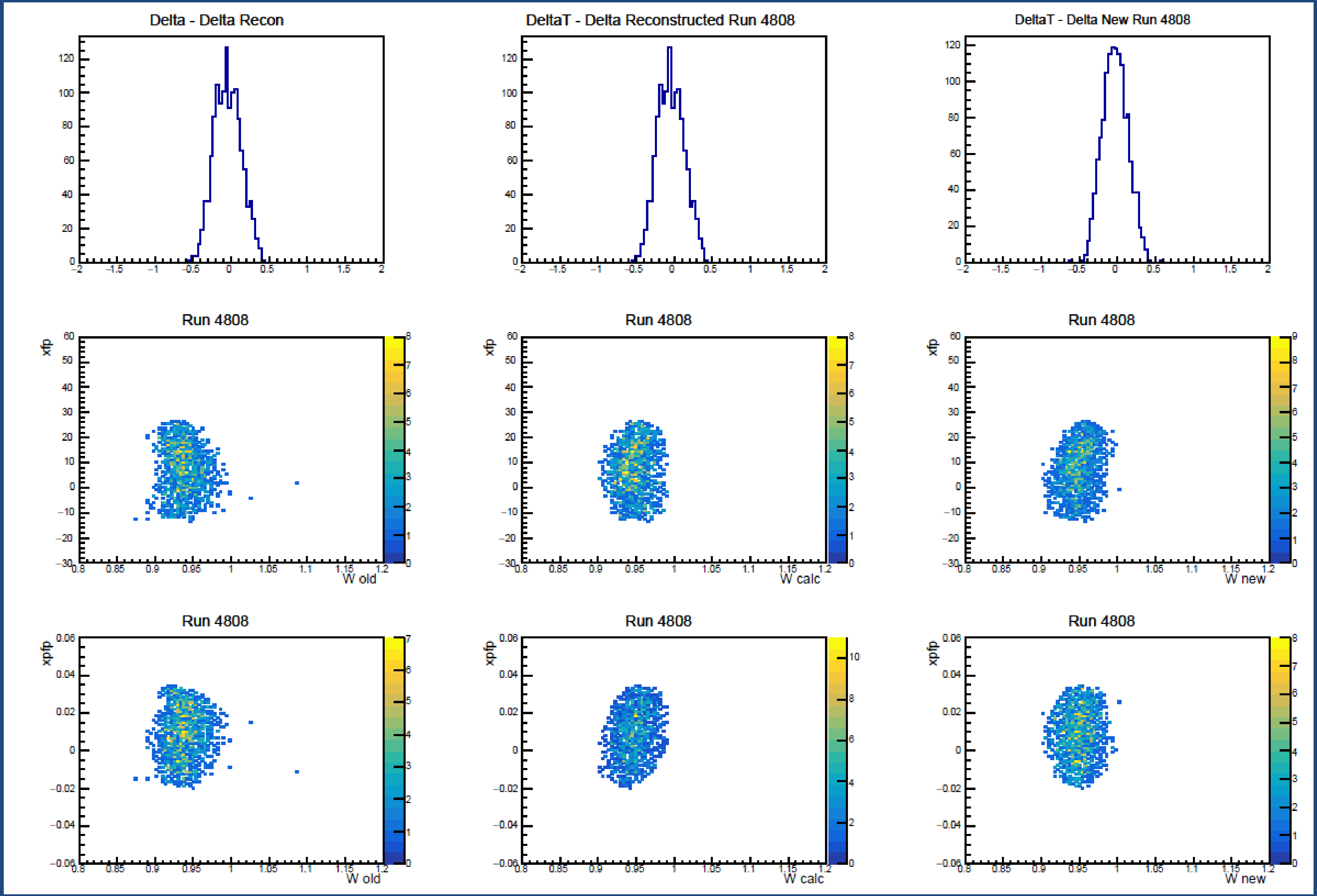

Run 4821
Xpfp
W

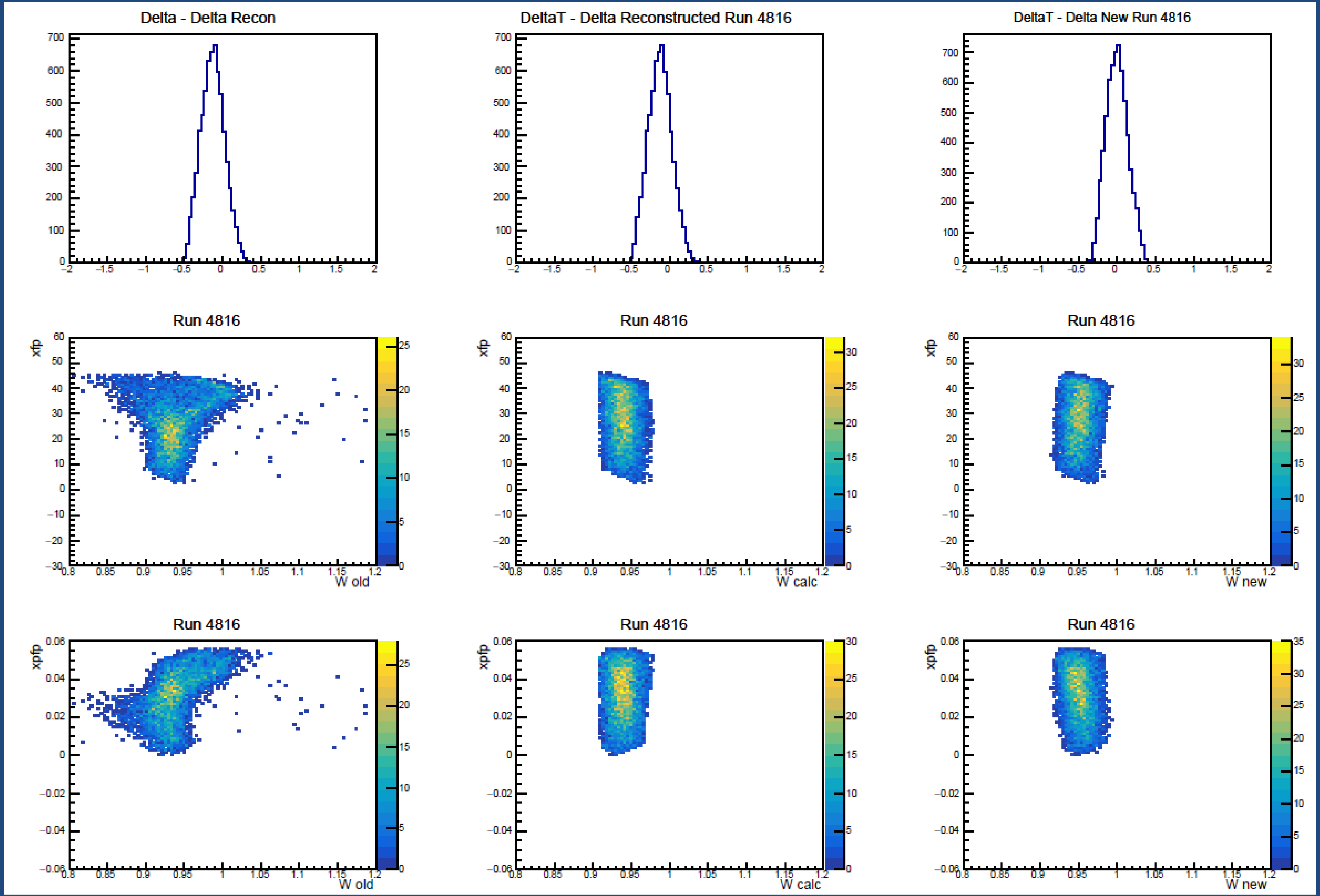
New Optics Calibration Results

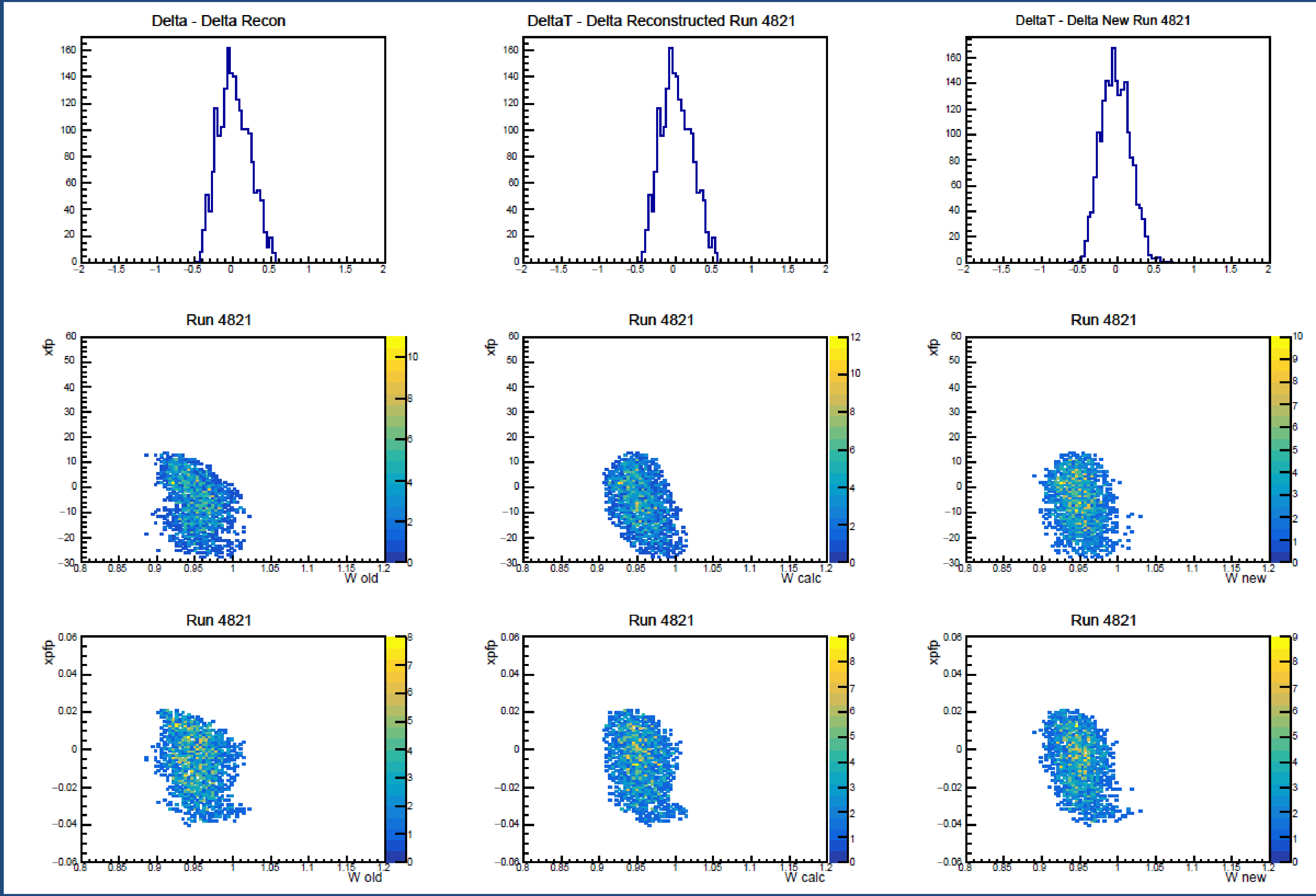
Run-by-Run



Delta - Delta Recon
DeltaT - Delta Reconstructed Run 4805
DeltaT - Delta New Run 4805
Run 4805
Run 4805
Run 4805
xfp
W old
W calc
W new
Run 4805
Run 4805
Run 4805
xpfp
W old
W calc
W new


Delta - Delta Recon
DeltaT - Delta Reconstructed Run 4808
DeltaT - Delta New Run 4808
Run 4808
Run 4808
Run 4808
xfp
W old
W calc
W new
Run 4808
Run 4808
Run 4808
xpfp
W old
W calc
W new


Delta - Delta Recon
DeltaT - Delta Reconstructed Run 4816
DeltaT - Delta New Run 4816
Run 4816
xfp
W old
W calc
W new
xpfp


Delta - Delta Recon
DeltaT - Delta Reconstructed Run 4821
DeltaT - Delta New Run 4821
Run 4821
xfp
W old
W calc
W new
xpfp