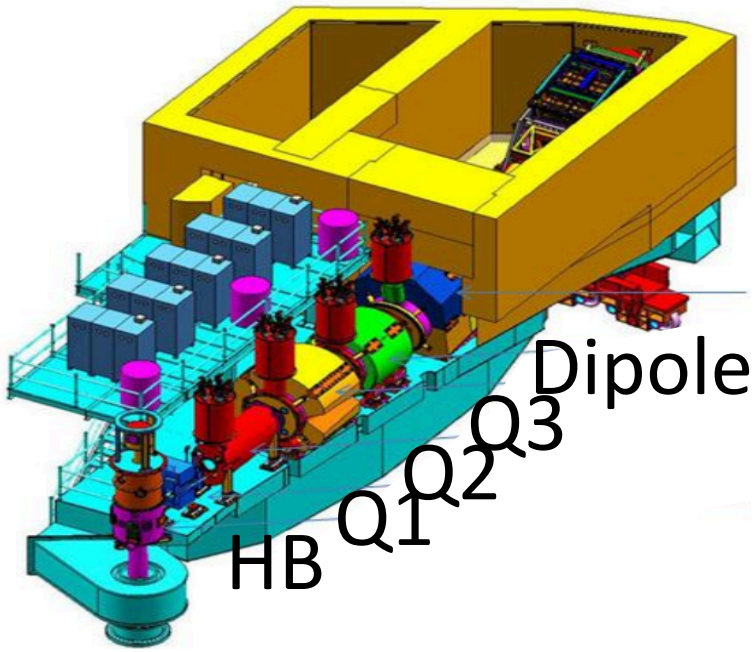
SHMS Optics commissioning



Hall C Collaboration Meeting
Holly Szumila-Vance

Guided by Mark Jones and Dave Mack, and studies from Burcu Duran
And lots of help and thanks to Steve Lassiter, Eric Sun, and Paul Brindza

22 January 2017

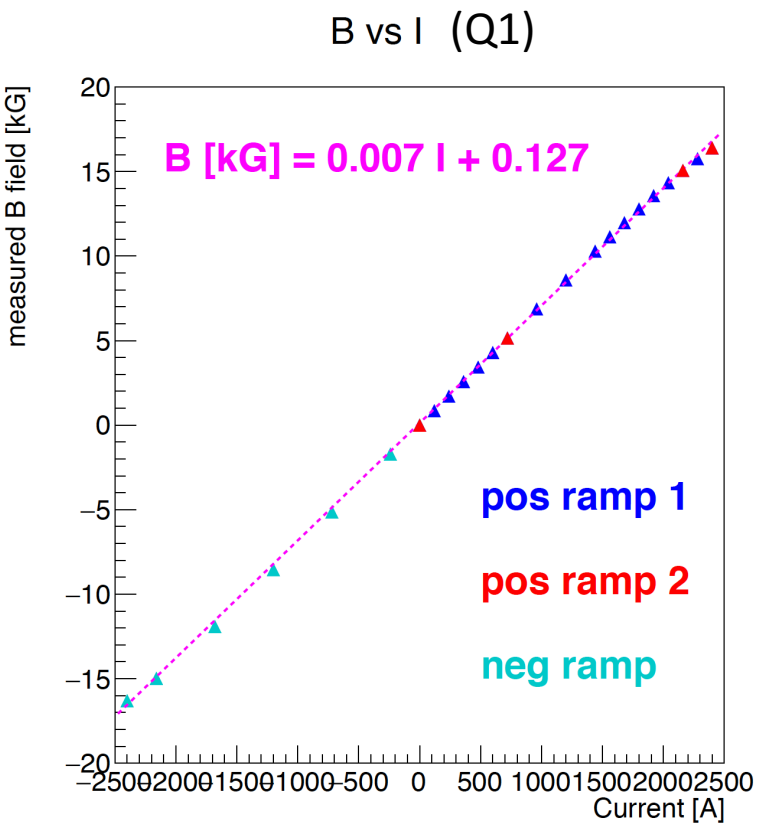
Overview:

- Magnet testing
- Finding the golden tune in December 2017
- Dipole setting (preliminary)
- SHMS matrix optimization (preliminary)
- Outlook

Magnet Testing (prior to beam):

- Characterize saturation (non-linearities)
- Hysteresis for cycling procedure

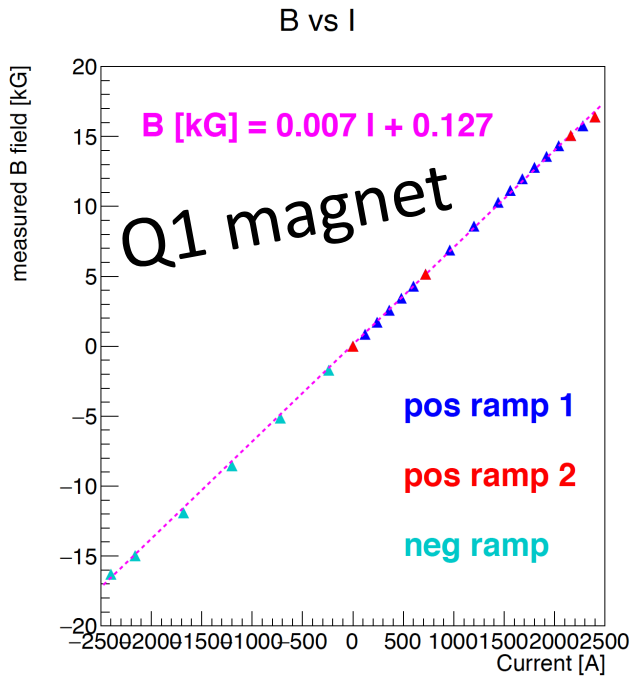
SHMS magnets	Targeted precision*
HB	Mean of ypTar and yTar
Q1	<0.2%
Q2	<0.2%
Q3	<0.1%

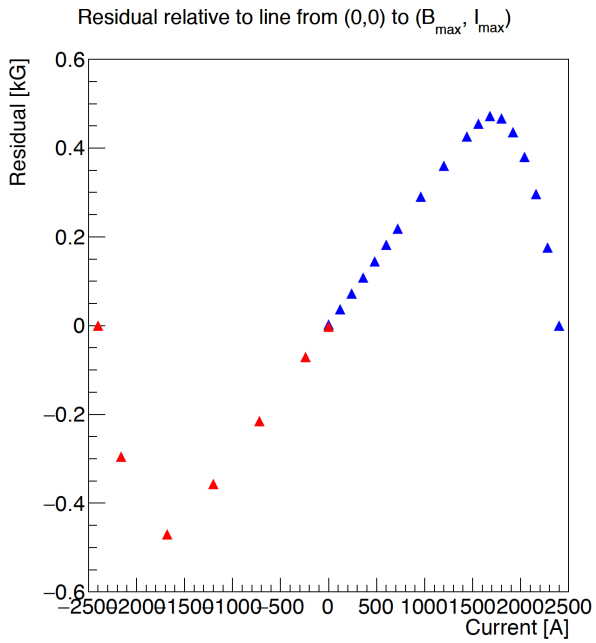


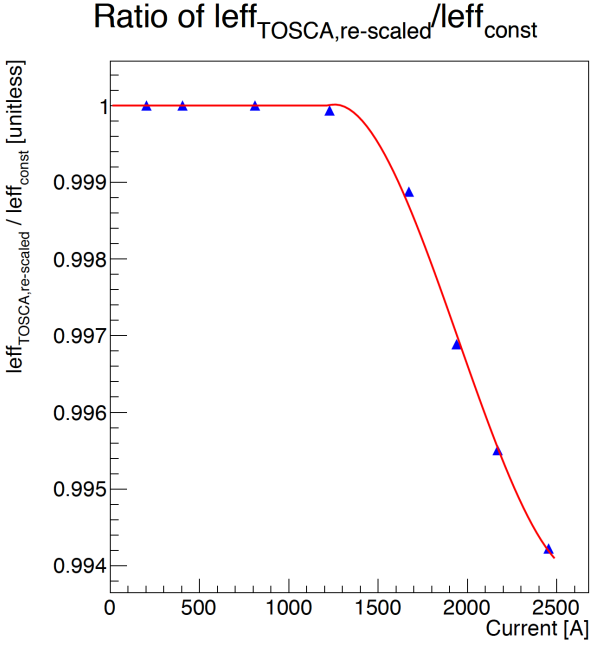
Procedure:

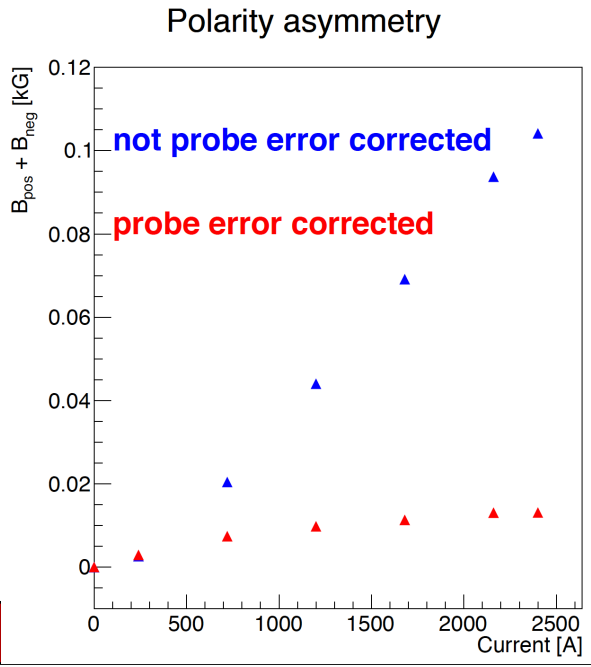
- Measurements ramping up and down
- Uncertainty from asymmetry in +/- measurements
- Compare with TOSCA central B, eff length if available

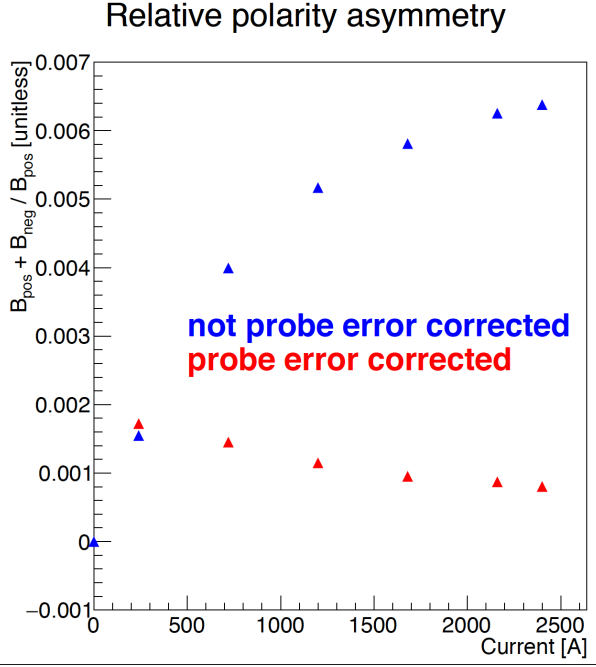
*Details from Mark Jones simulation studies: https://hallcweb.jlab.org/doc-public/ShowDocument?docid=886

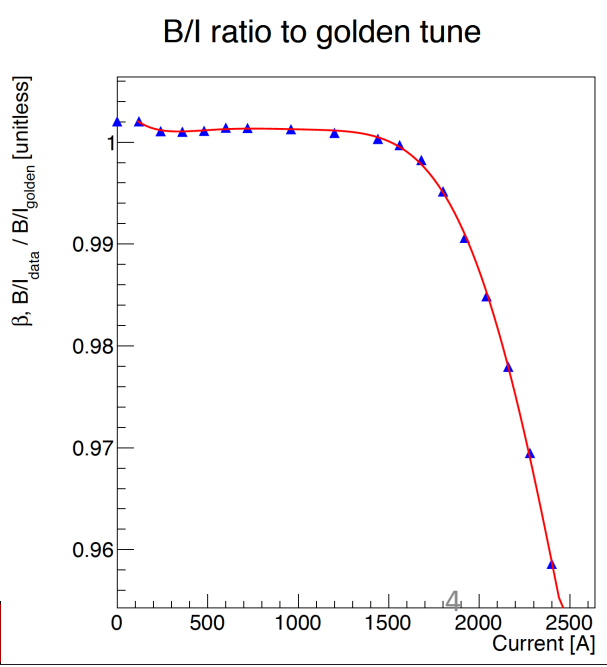

B vs I
measured B field [kG]
B [kG] = 0.007 I + 0.127
Q1 magnet
pos ramp 1
pos ramp 2
neg ramp
Current [A]

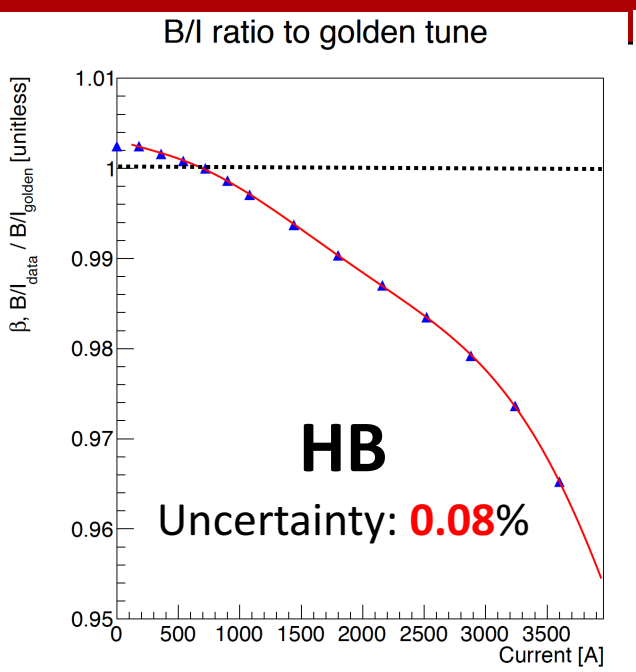

Residual relative to line from (0,0) to (B_max, I_max)
Residual [kG]
Current [A]

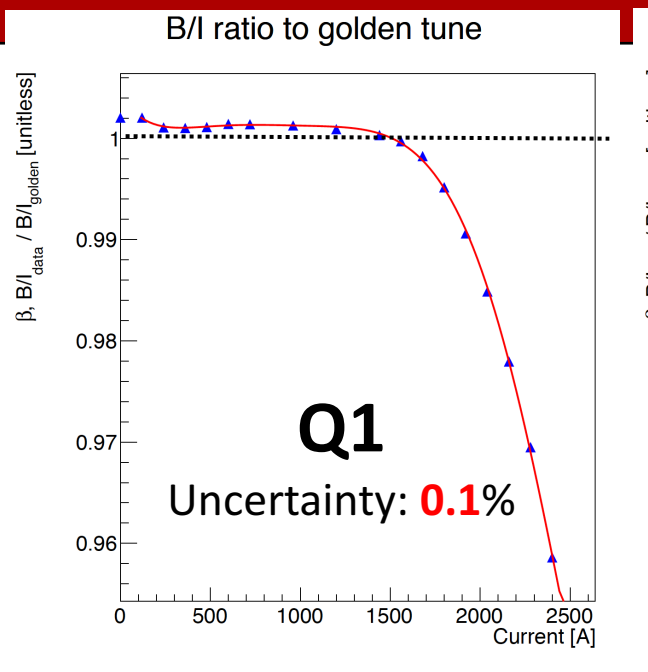

Ratio of leff_TOSCA,re-scaled/leff_const
leff_TOSCA,re-scaled / leff_const [unitless]
Current [A]

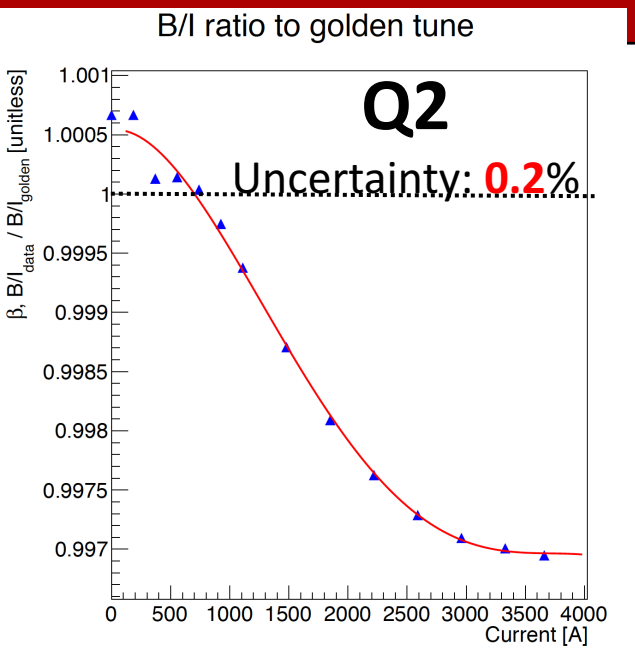

Polarity asymmetry
B_pos + B_neg [kG]
not probe error corrected
probe error corrected
Current [A]

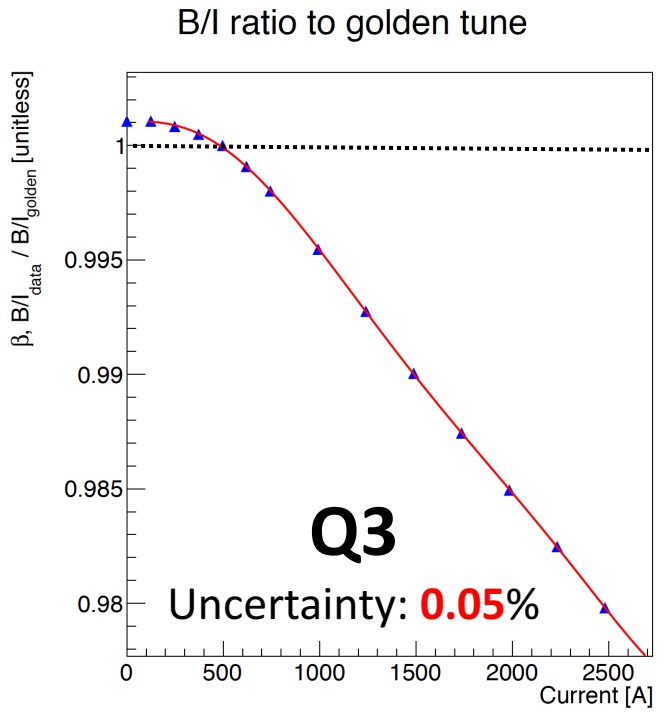

Relative polarity asymmetry
B_pos + B_neg / B_pos [unitless]
not probe error corrected
probe error corrected
Current [A]

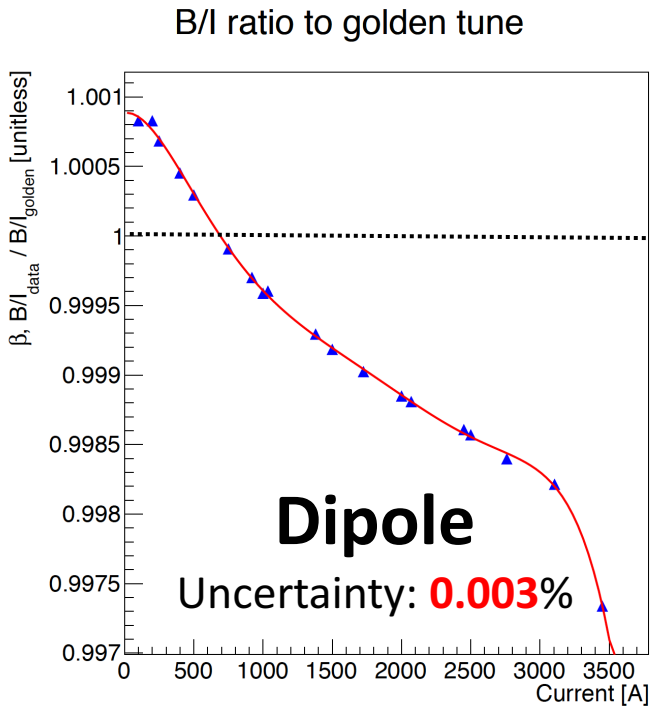

B/I ratio to golden tune
β, B/I_data / B/I_golden [unitless]
Current [A]


B/I ratio to golden tune
β, B/I_data / B/I_golden [unitless]
Current [A]
HB
Uncertainty: 0.08%


B/I ratio to golden tune
β, B/I_data / B/I_golden [unitless]
Current [A]
Q1
Uncertainty: 0.1%


B/I ratio to golden tune
β, B/I_data / B/I_golden [unitless]
Current [A]
Q2
Uncertainty: 0.2%


B/I ratio to golden tune
β, B/I_data / B/I_golden [unitless]
Current [A]
Q3
Uncertainty: 0.05%


B/I ratio to golden tune
β, B/I_data / B/I_golden [unitless]
Current [A]
Dipole
Uncertainty: 0.003%

- Results in field17 program: https://github.com/hszumila/field17

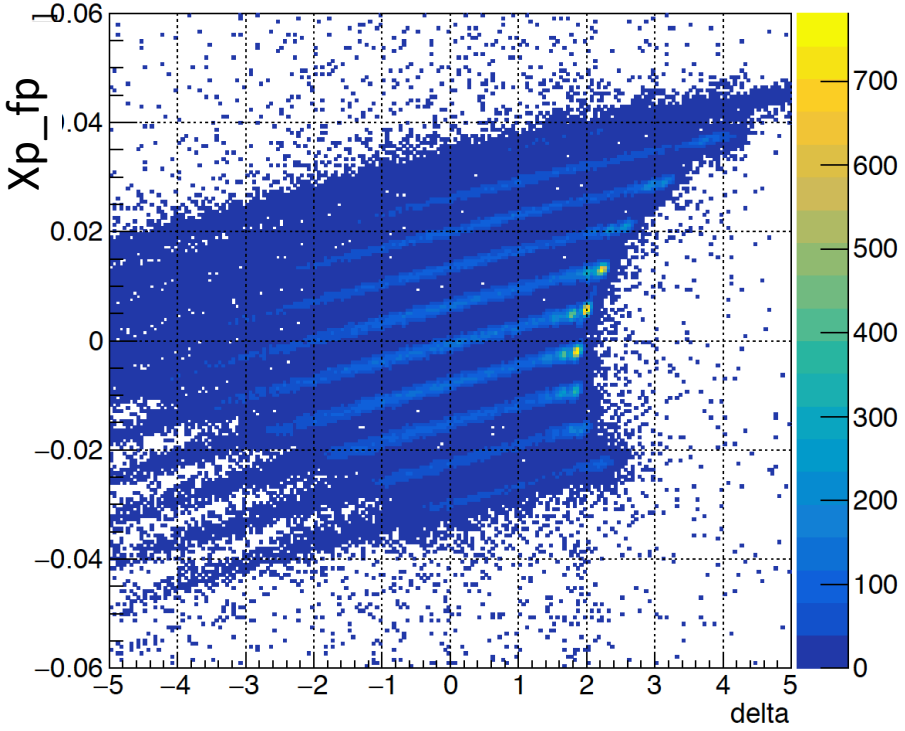
- Did not include Q2 non-linearities because they were small (<0.3%) and the probe error corrections didn't make sense

- Early January, studied hysteresis measurements (differences in measurements ramping up and down)
  - No hysteresis for dipole, Q2, Q3 (as expected)
  - Q1 has small hysteresis below 1440 A (1%)
  - HB hysteresis less than <0.1% below 500A

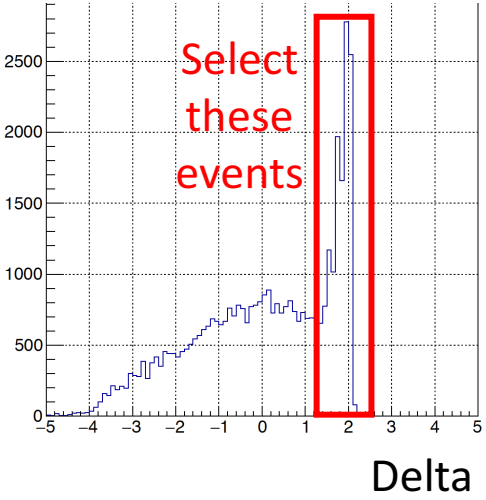
Searching for the Golden Tune

- Two solid night shifts of data during first pass running (see OWL 11 & 19 Dec)
- Central P at -2.2 GeV, 13.5 deg and 7.5 deg
- 4.4 MeV carbon excited state

Run 1647, 7.5 deg data, no cut



Selected events from hole



Procedure:

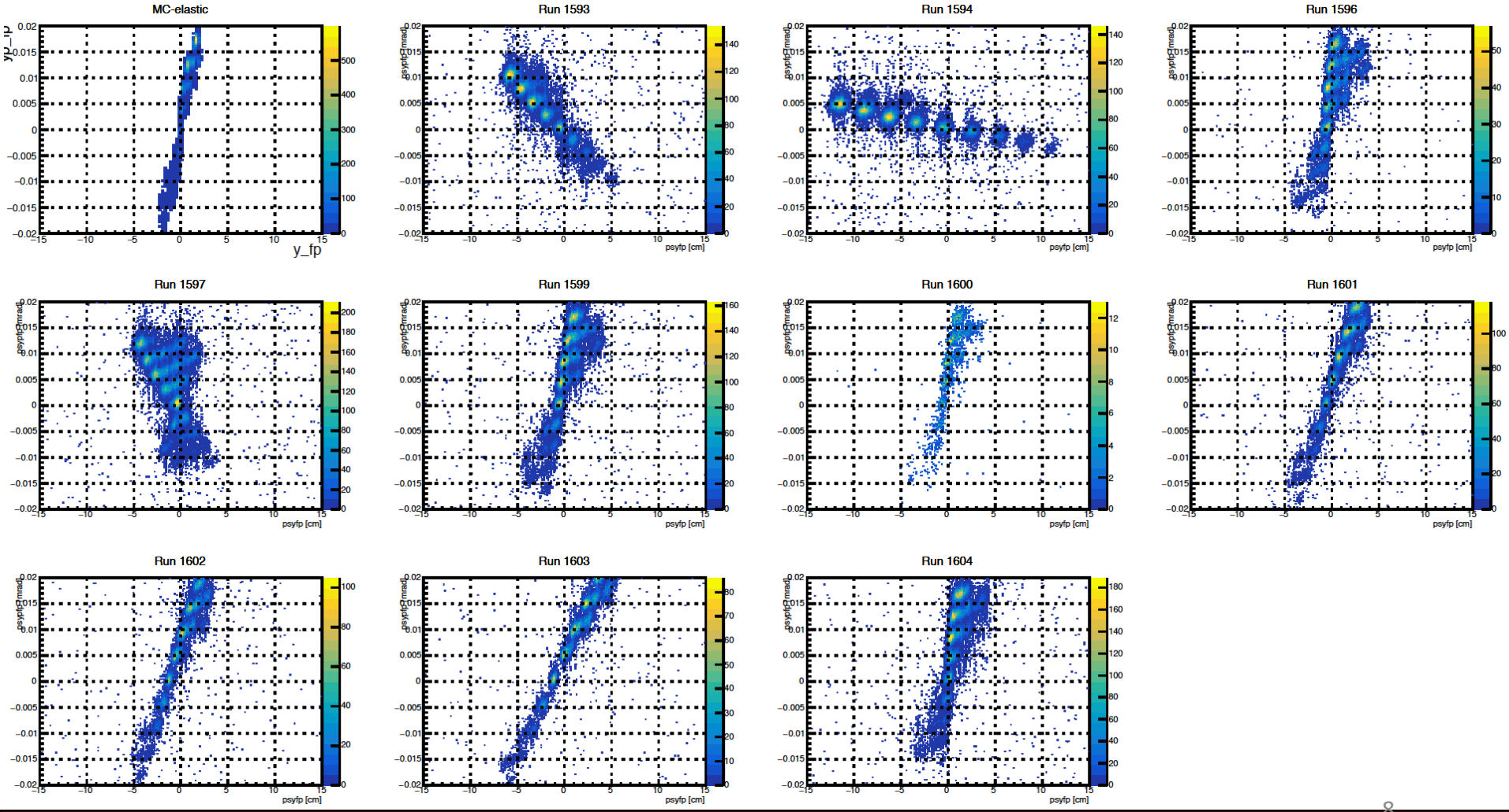
- Cleanly select events in 4.4 MeV excited state
- Interpret focal plane distributions

Interpret focal plane quantities from simulation:

- x’ vs y’
- y vs y’
- y vs x’
- y vs y
- y’ vs x
- y’ vs y

https://logbooks.jlab.org/entry/3506808

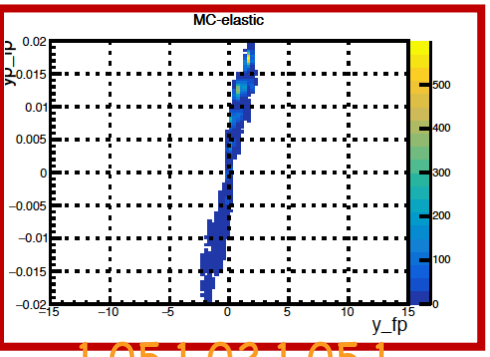
Shown below is just y’ vs y for runs at 13.5 deg:



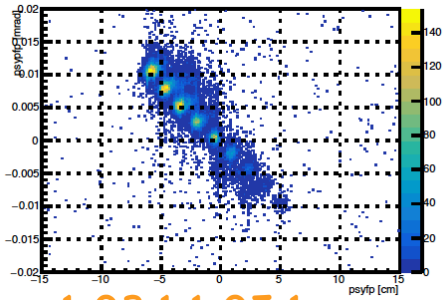
Interpret focal plane quantities from simulation:

- x’ vs y’
- y vs y’
- y vs x’
- y vs y
- y’ vs x
- y’ vs y

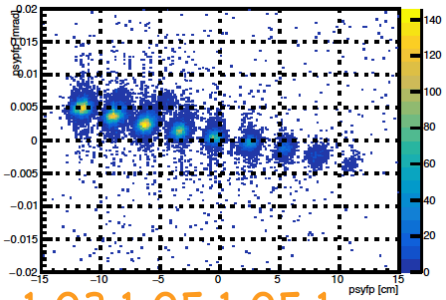
Shown below is just y’ vs y for runs at 13.5 deg:



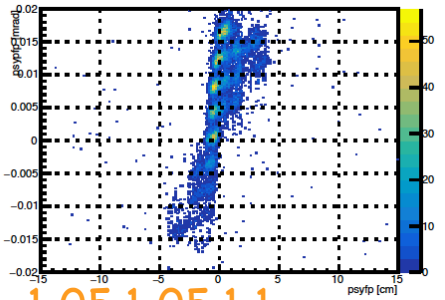
1,1,1,1



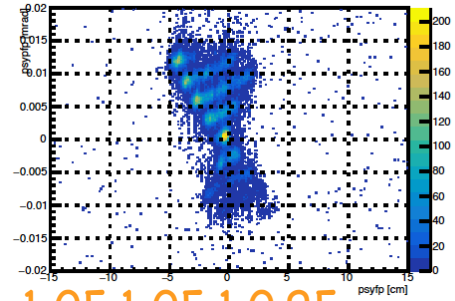
0.95,0.95,0.95,1



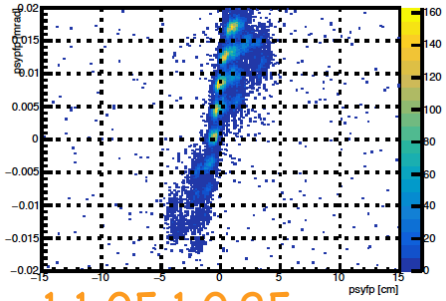
1.05,1.05,1.05,1



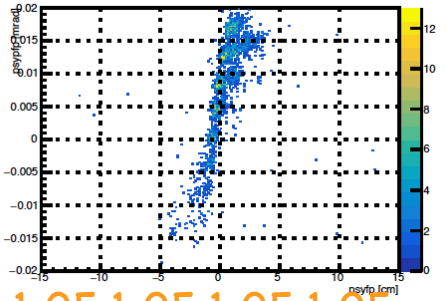
1.05,1.02,1.05,1



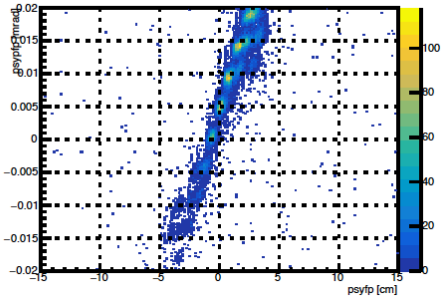
1.03,1,1.05,1



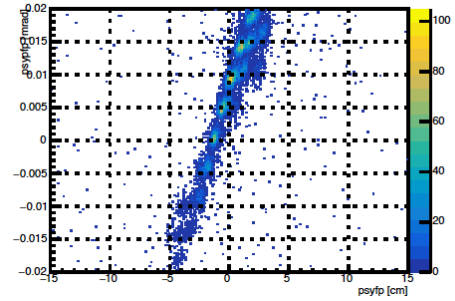
1.03,1.05,1.05,1



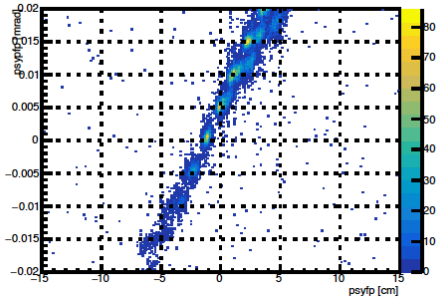
1.05,1.05,1,1



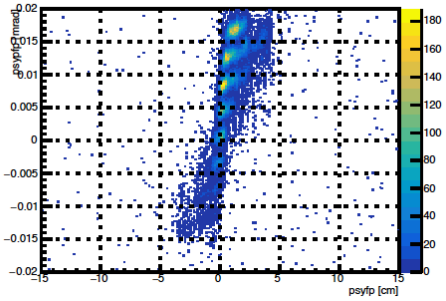
1.05,1.05,1,0.95



1,1.05,1,0.95



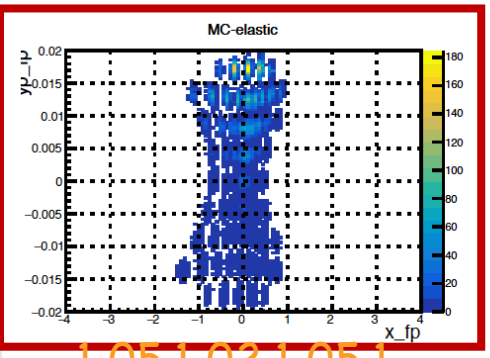
1.05,1.05,1.05,1.05



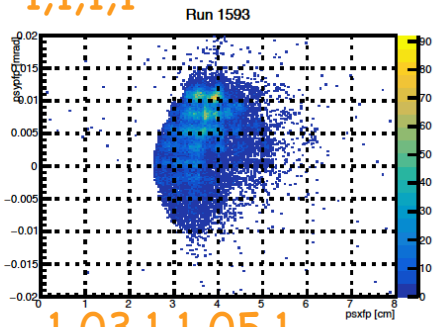
Scaling key:
Q1,Q2,Q3,HB

Just to give you a sense of the parameters used to interpret…I'll toggle through some tweaks.

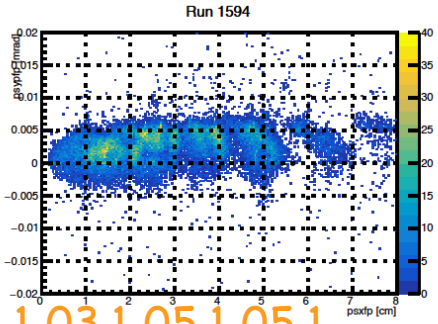
Shown below is just y' vs x for runs at 13.5 deg:



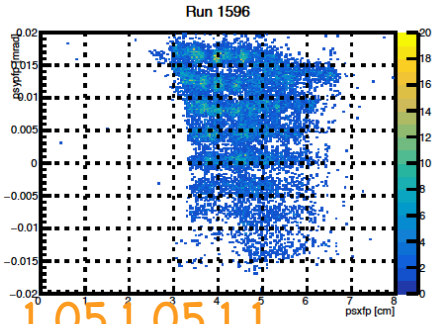
1,1,1,1



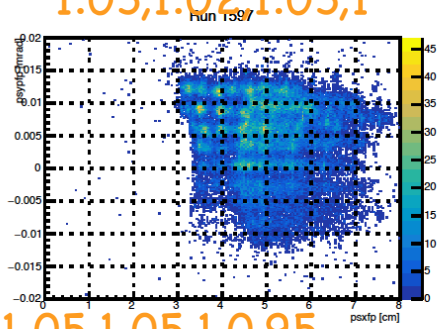
0.95,0.95,0.95,1



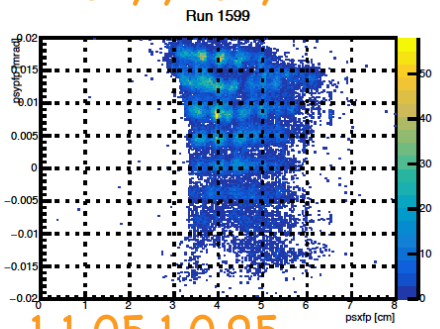
1.05,1.05,1.05,1



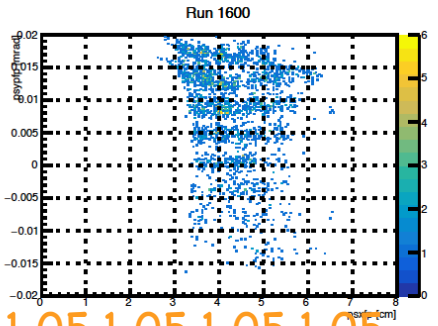
1.05,1.02,1.05,1



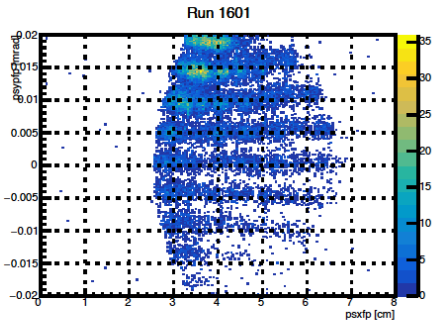
1.03,1,1.05,1



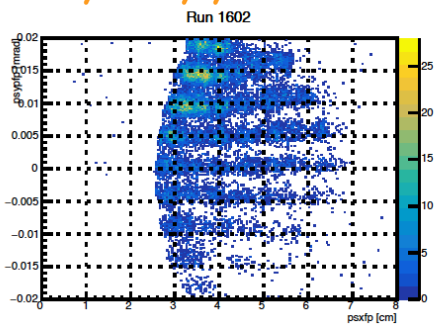
1.03,1.05,1.05,1



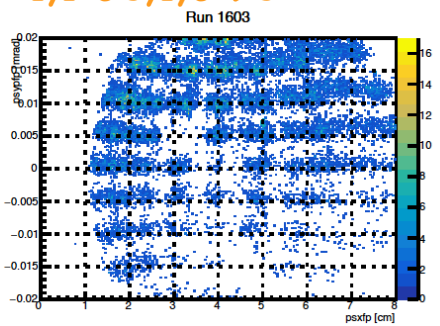
1.05,1.05,1,1



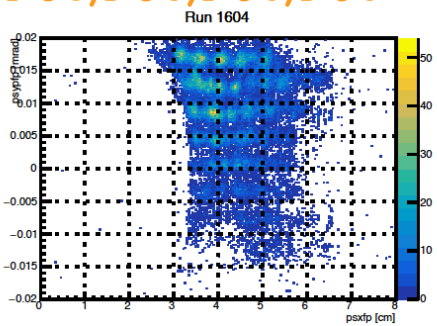
1.05,1.05,1,0.95



1,1.05,1,0.95

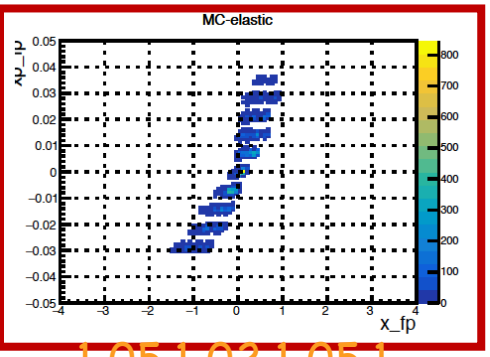


1.05,1.05,1.05,1.05

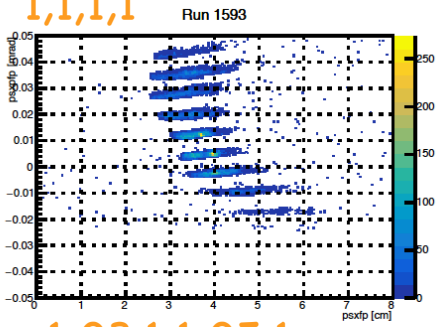


Scaling key:
Q1,Q2,Q3,HB

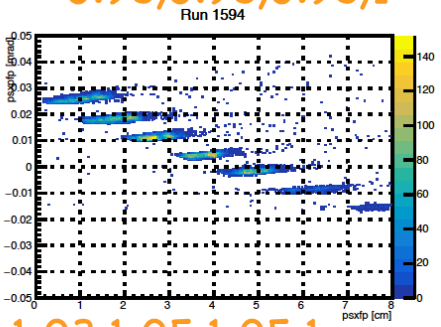
Shown below is just x’ vs x for runs at 13.5 deg:



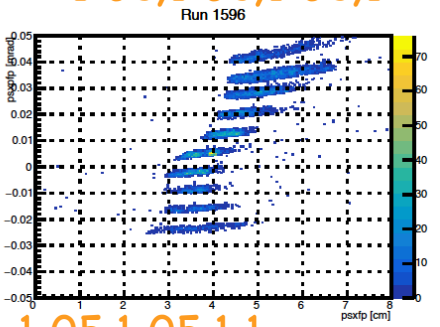
1,1,1,1



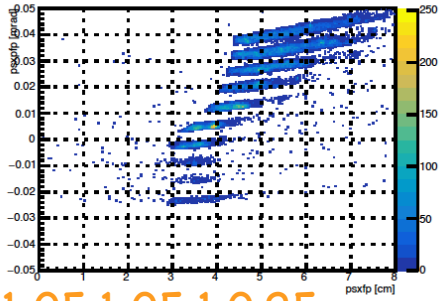
0.95,0.95,0.95,1



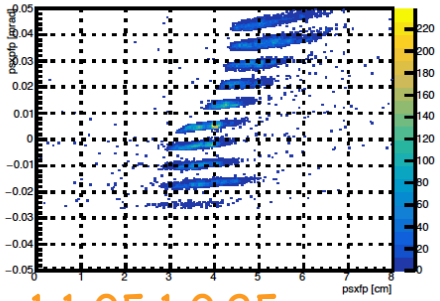
1.05,1.05,1.05,1



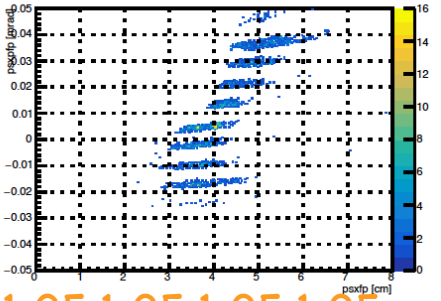
1.05,1.02,1.05,1



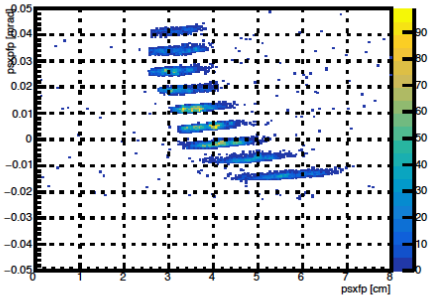
1.03,1,1.05,1



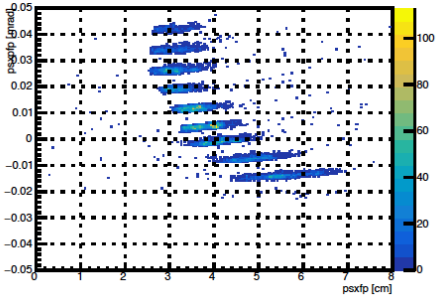
1.03,1.05,1.05,1



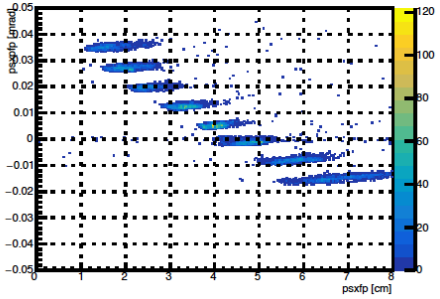
1.05,1.05,1,1



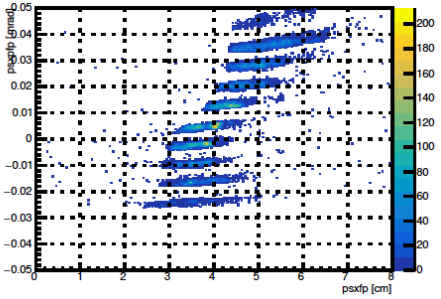
1.05,1.05,1,0.95



1,1.05,1,0.95

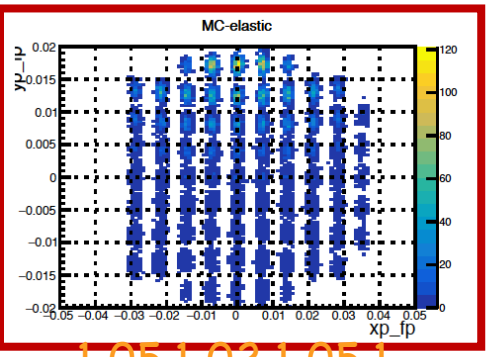


1.05,1.05,1.05,1.05

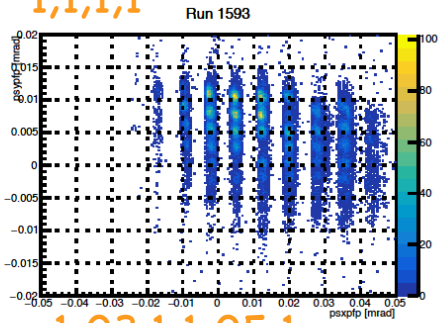


Scaling key:
Q1,Q2,Q3,HB

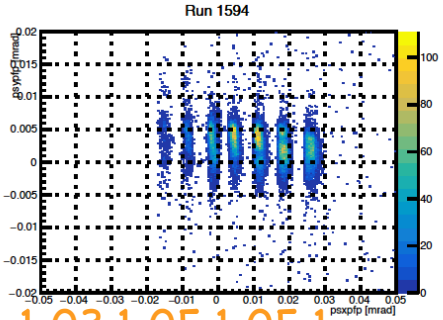
Shown below is just y' vs x' for runs at 13.5 deg:



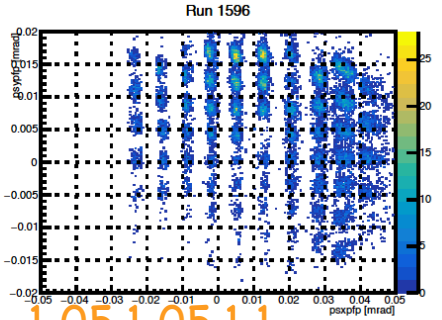
1,1,1,1



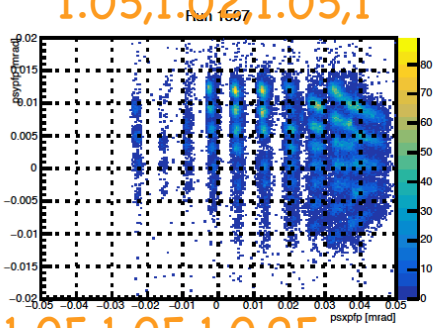
0.95,0.95,0.95,1



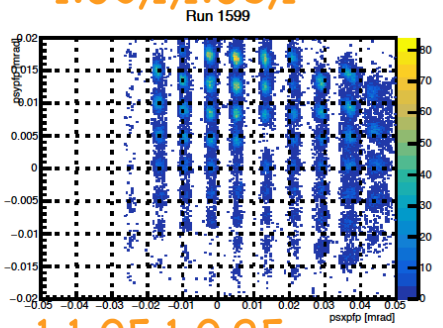
1.05,1.05,1.05,1



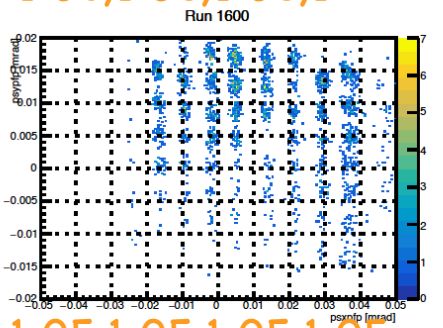
1.05,1.02,1.05,1



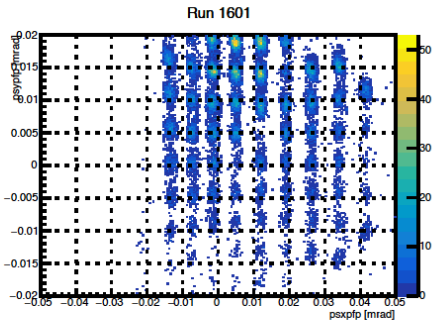
1.03,1,1.05,1



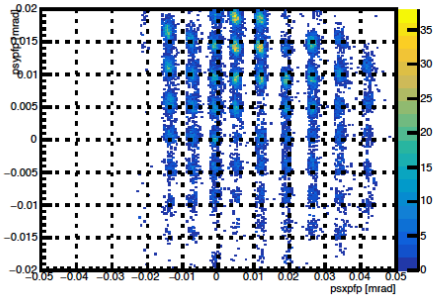
1.03,1.05,1.05,1



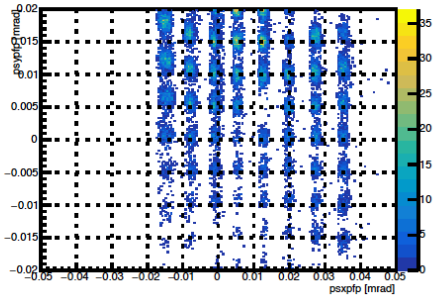
1.05,1.05,1,1



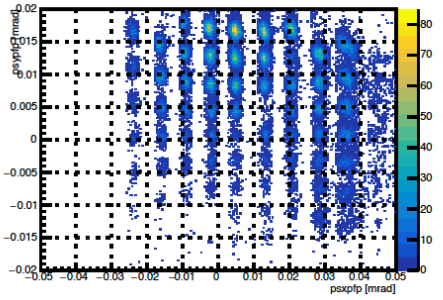
1.05,1.05,1,0.95



1,1.05,1,0.95

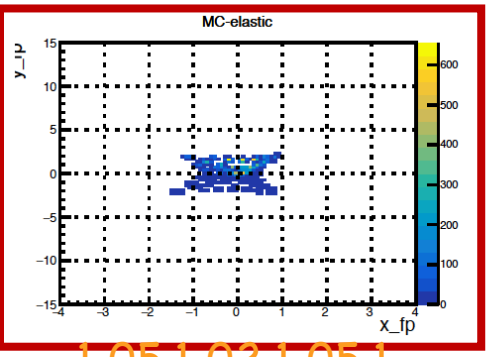


1.05,1.05,1.05,1.05

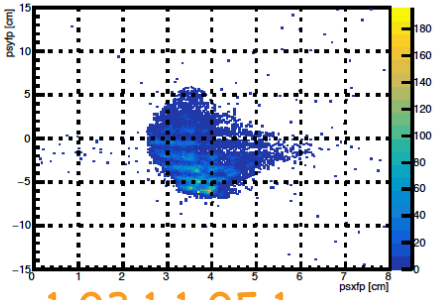


Scaling key:
Q1,Q2,Q3,HB

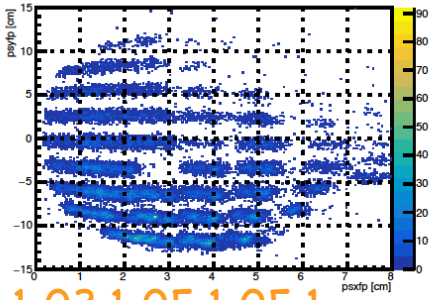
Shown below is just y vs x for runs at 13.5 deg:



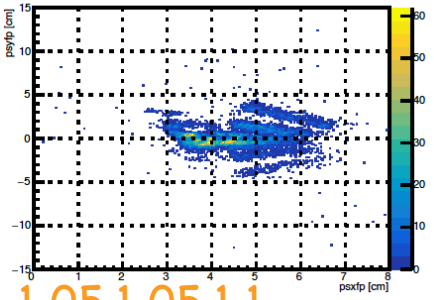
1,1,1,1



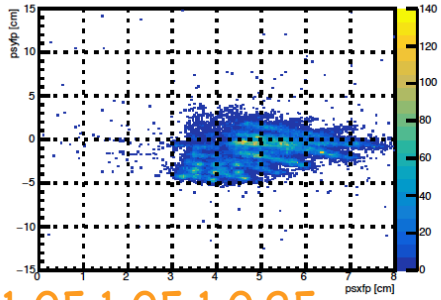
0.95,0.95,0.95,1



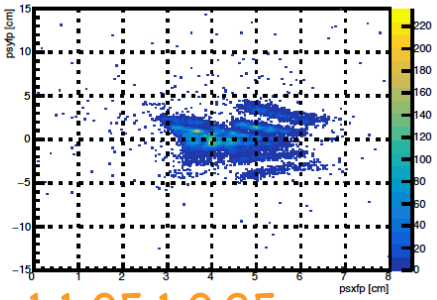
1.05,1.05,1.05,1



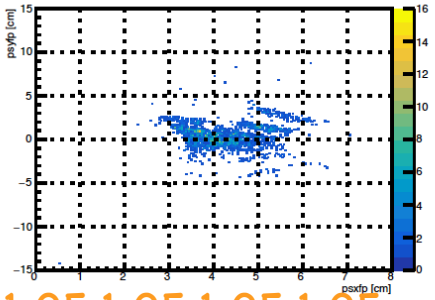
1.05,1.02,1.05,1



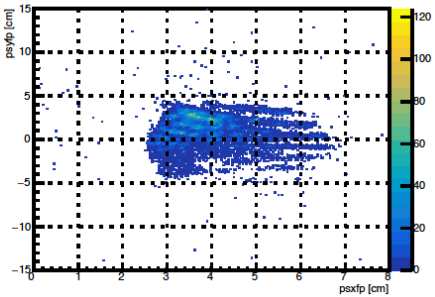
1.03,1,1.05,1



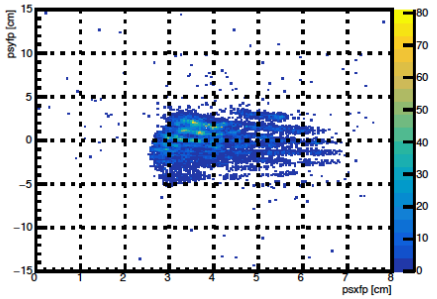
1.03,1.05,1.05,1



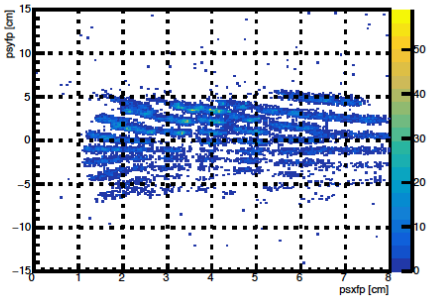
1.05,1.05,1,1



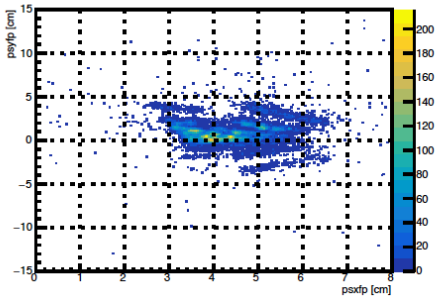
1.05,1.05,1,0.95



1,1.05,1,0.95

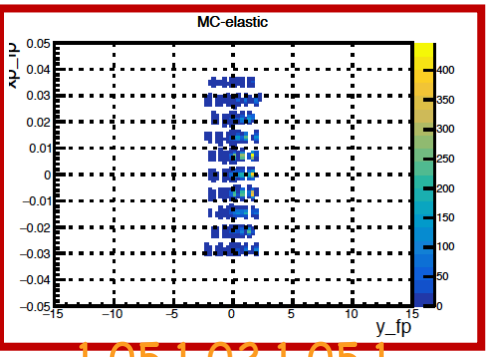


1.05,1.05,1.05,1.05

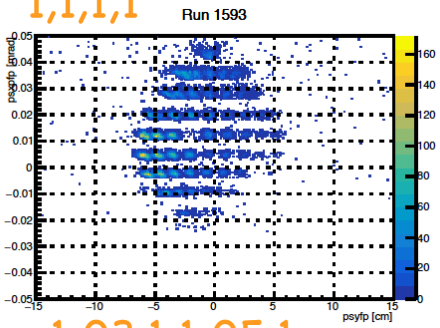


Scaling key:
Q1,Q2,Q3,HB

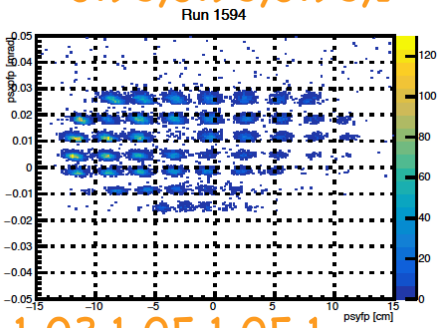
Shown below is just x’ vs y for runs at 13.5 deg:



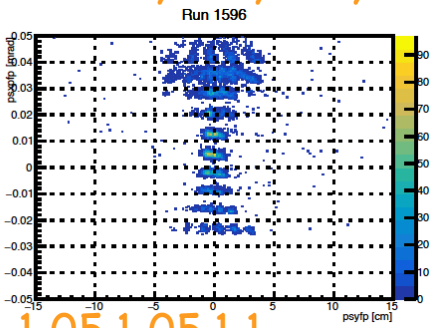
1,1,1,1



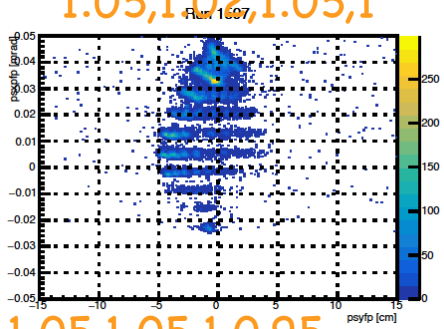
0.95,0.95,0.95,1



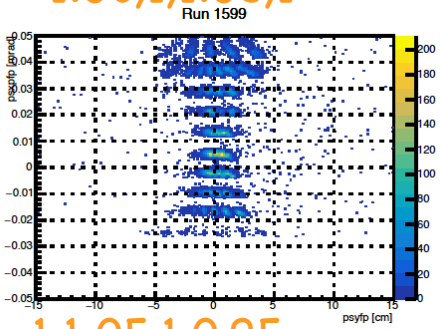
1.05,1.05,1.05,1



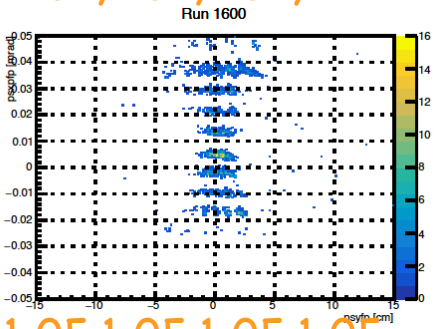
1.05,1.02,1.05,1



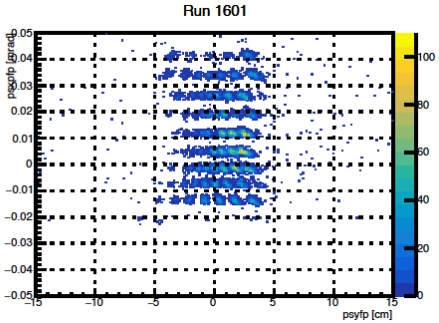
1.03,1,1.05,1



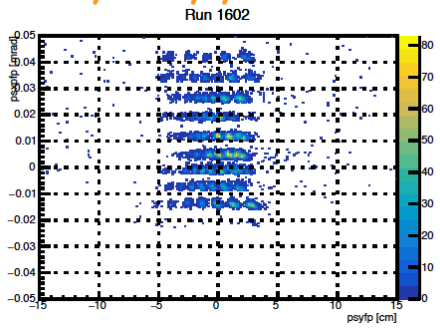
1.03,1.05,1.05,1



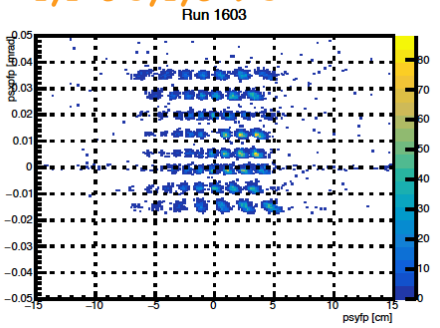
1.05,1.05,1,1



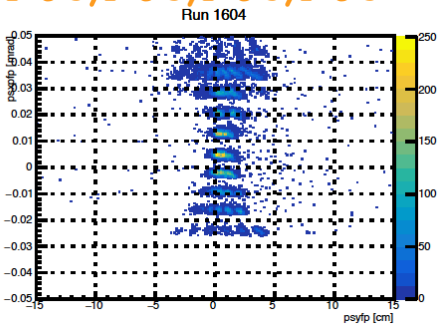
1.05,1.05,1,0.95



1,1.05,1,0.95



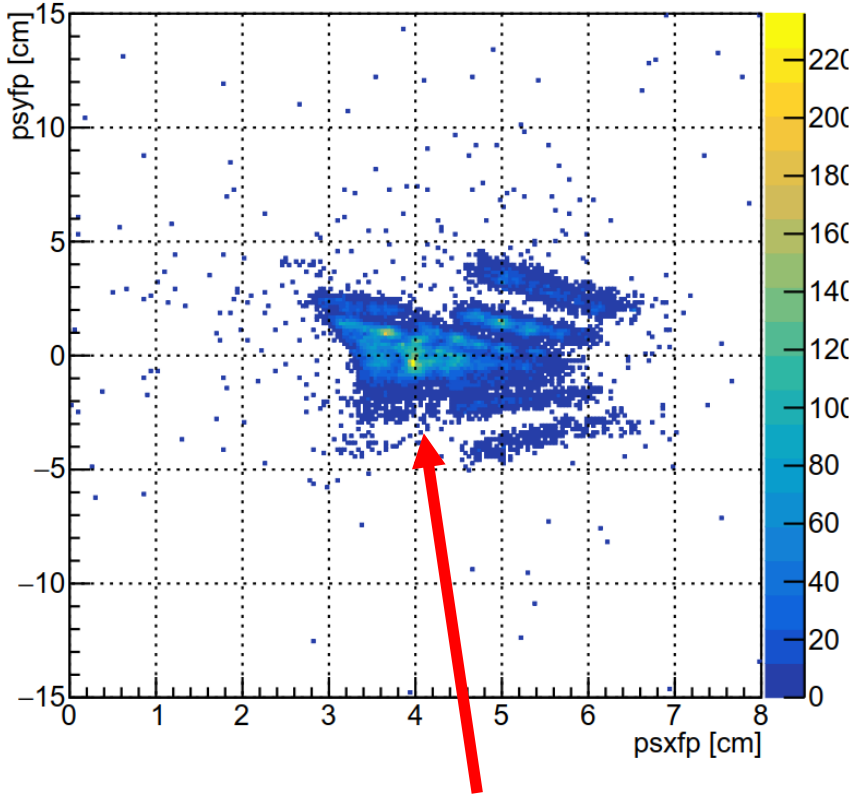
1.05,1.05,1.05,1.05



Scaling key:
Q1,Q2,Q3,HB

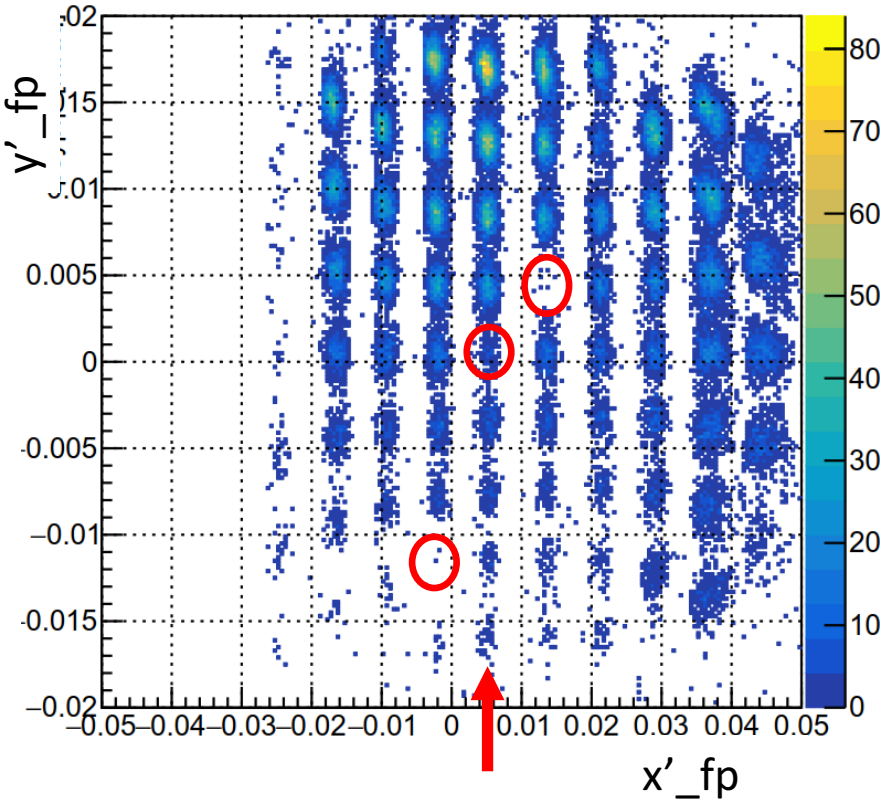
- Settled on a tune that scaled Q1, Q2, Q3 by 1.03, 1.04, 1.03 (SHMS run 1647)
- After changing quads, still had apparent offsets in x_fp and x'_fp

4 cm shift in x_fp



Not dependent on quad tune

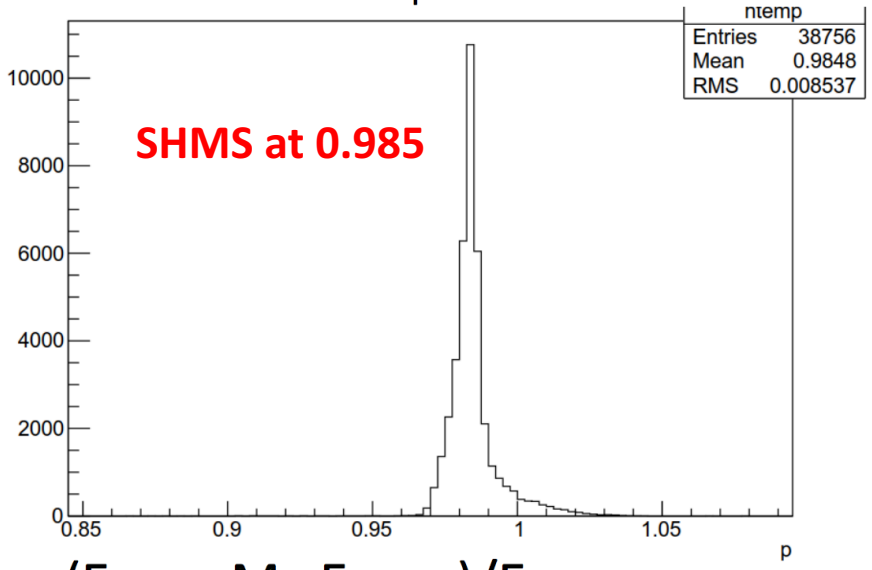
5 mrad shift in x'_fp



Mark looked at p(eep) coincidence run:

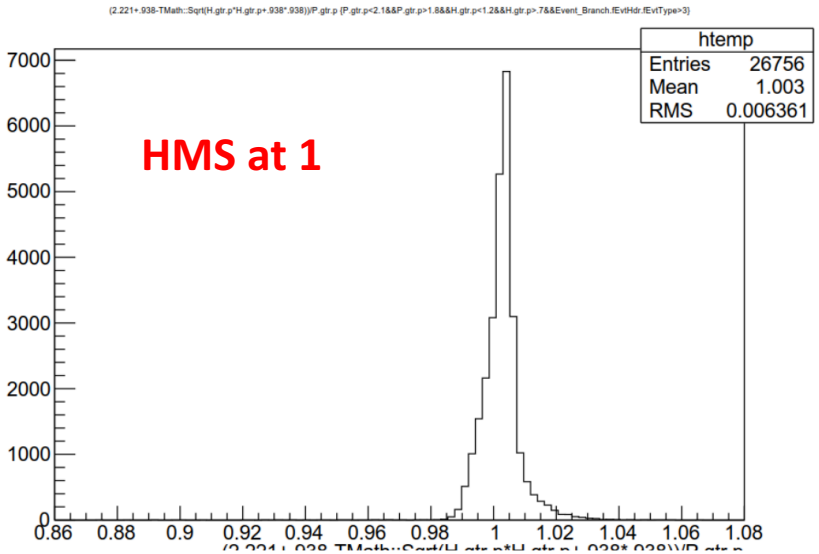
- SHMS electrons at p=-1.816 and 25 deg
- HMS protons at p=0.957 and 53.33 deg

E_{beam}= 2.221 P_{proton}= 0.957*(1-δ_{HMS})



$(E_{beam}+M_p-E_{proton})/E_{elec}$

E_{elec}= 1.816*(1-δ_{SHMS})



$(E_{beam}+M_p-E_{proton})/E_{elec}$

E_{elec}= 1.816*0.98*(1-δ_{SHMS})

Preliminary results show SHMS dipole is set about 2% low

https://hallcweb.jlab.org/wiki/images/1/10/First-look-shms-carbon-elastic.pdf

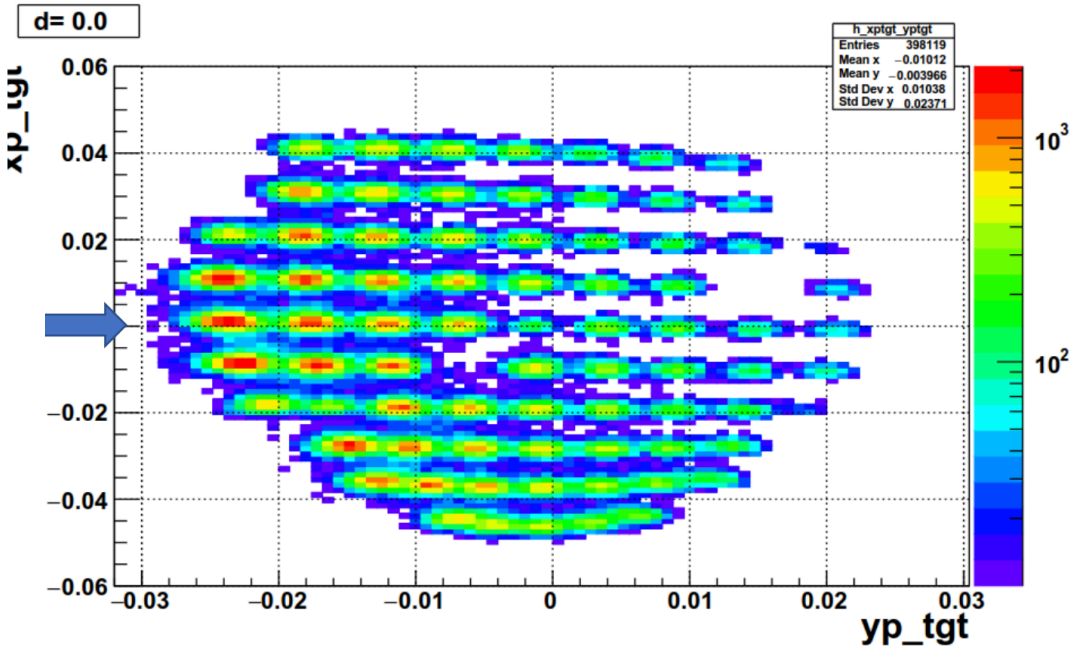
SHMS dipole 2% low could explain x_fp and x'_fp offsets!
We need matrix optimization of HMS and SHMS….

SHMS First order optics: Compare to Xp and Yp at focal plane

Look at Delta=0% carbon elastic

Use the COSY recon matrix elements

Beam energy nominal =2.218 GeV
Hall C measured =2.221 GeV
SHMS Pcentral = 2.214GeV
SHMS angle = 7.45 deg
Xtar = -1mm



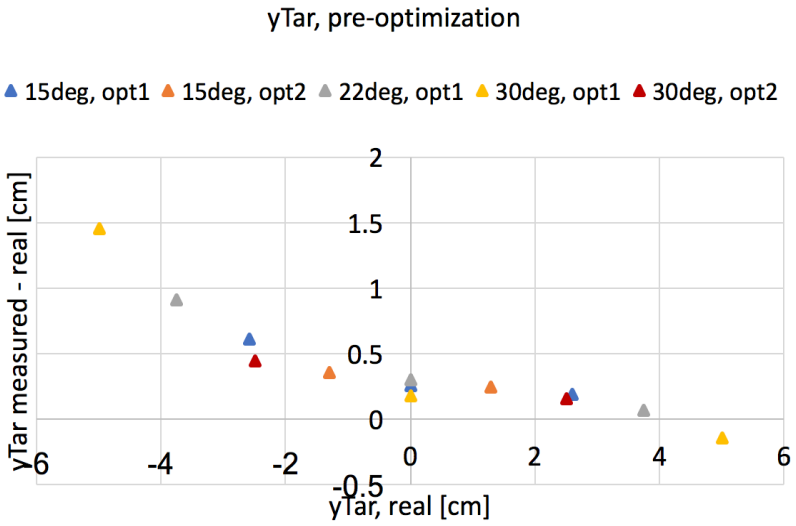
Beam energy	δ (%)	Xfp (cm)	Xpfp (mr)
2.218	0.0	0.02	0.042
2.221	0.14	0.24	0.47
2.221	0.24+2.0	3.6	7.0

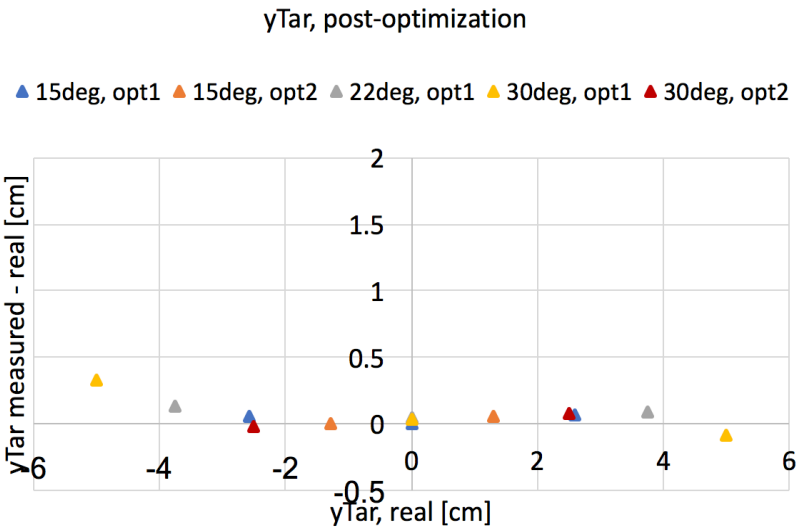
SHMS first order forward optics:

$$xfp(mm) = -1.38 * xtar(mm) - 0.004 * xptar(mr) + 16.5 * delta \quad (1)$$
$$xpfp(mr) = -.0602 * xtar(mm) - .72 * xptar(mr) + 3.2 * delta \quad (2)$$
$$yfp(mm) = -1.6 * ytar(mm) - 0.03 * yptar(mr) - 1.5 * delta \quad (3)$$
$$ypfp(mr) = -.268 * ytar(mm) - 0.61 * yptar(mr) + 0.074 * delta \quad (4)$$

https://hallcweb.jlab.org/wiki/images/1/10/First-look-shms-carbon-elastic.pdf

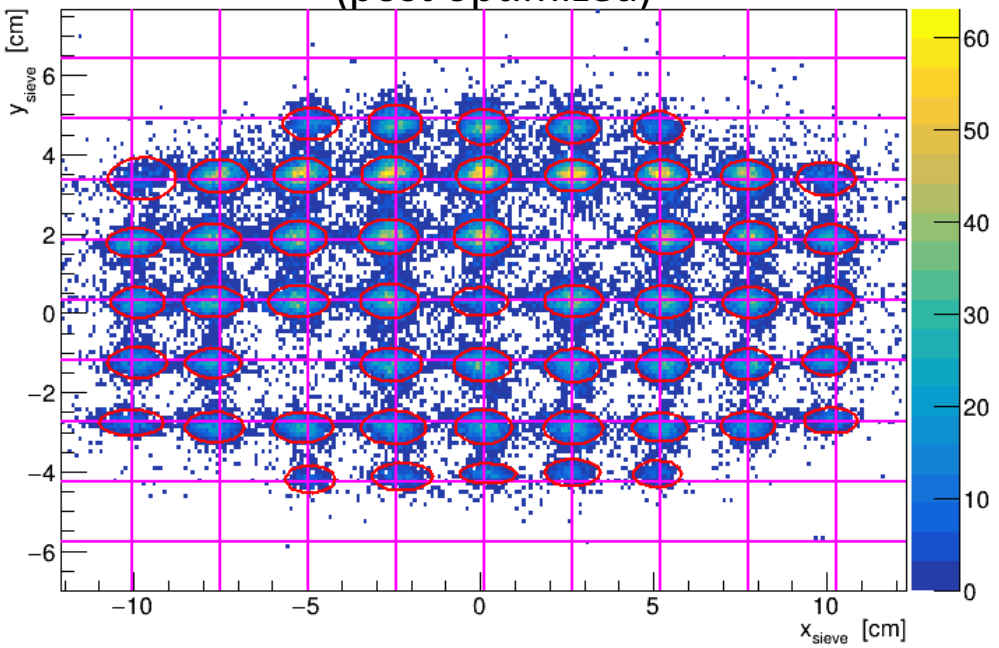
HMS Matrix Optimization





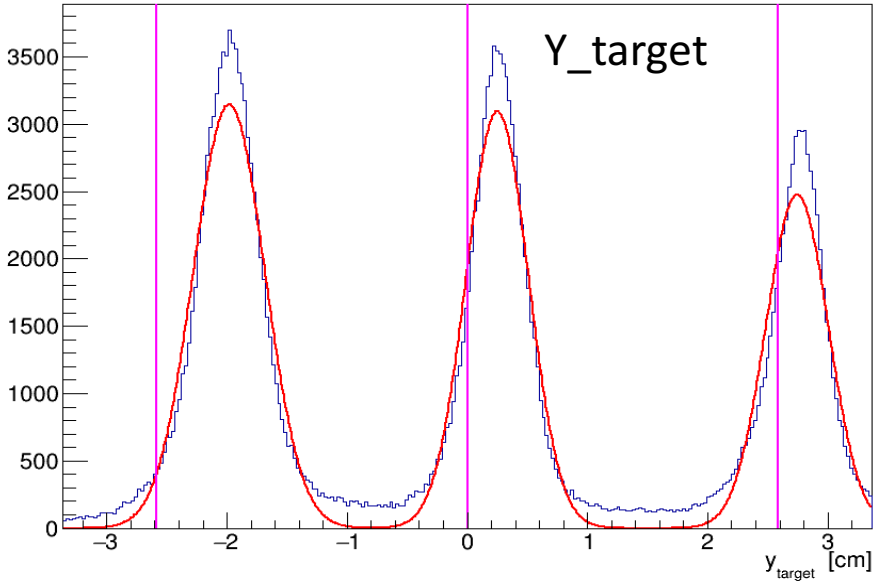
- Took data over a wide range of yTar values, angles from 15-30 degrees and targets at +/- 5cm and +/-10cm and 0cm
- Focal plane distribution relatively unchanged
- Improved yTar and zVertex

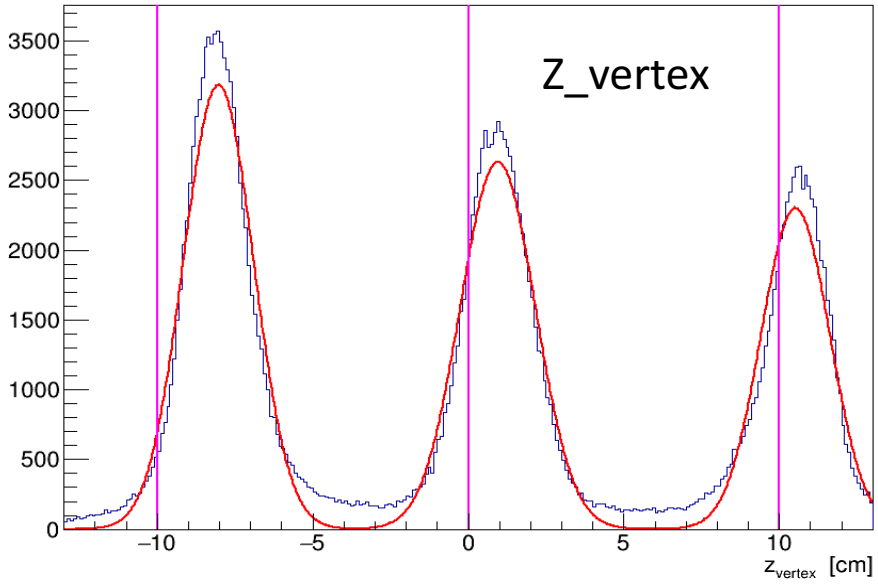
HMS at 15degrees, Foil at 0 cm (post optimized)



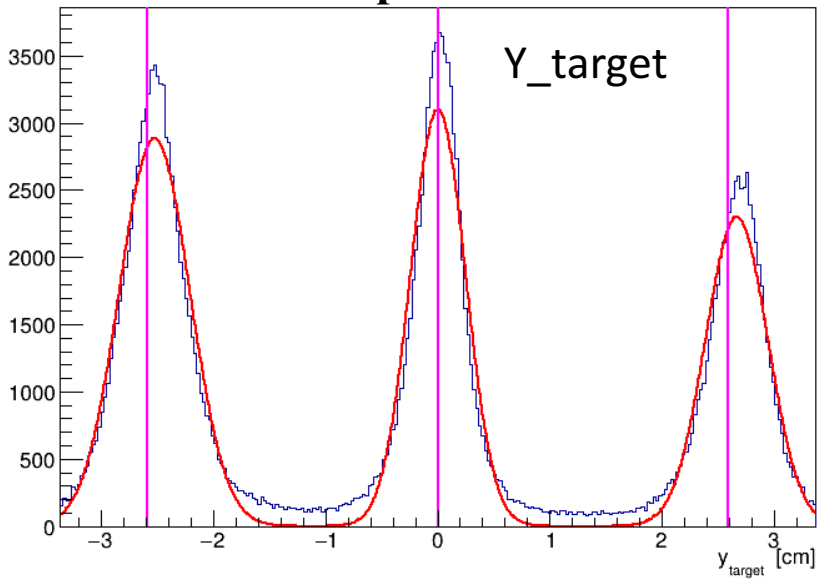
Target at +/-10cm,0cm, HMS at15deg

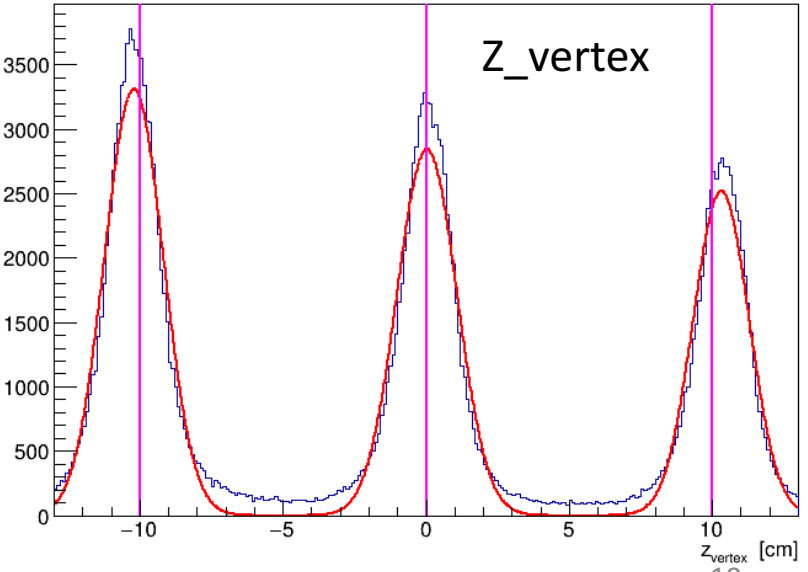
Pre-optimization





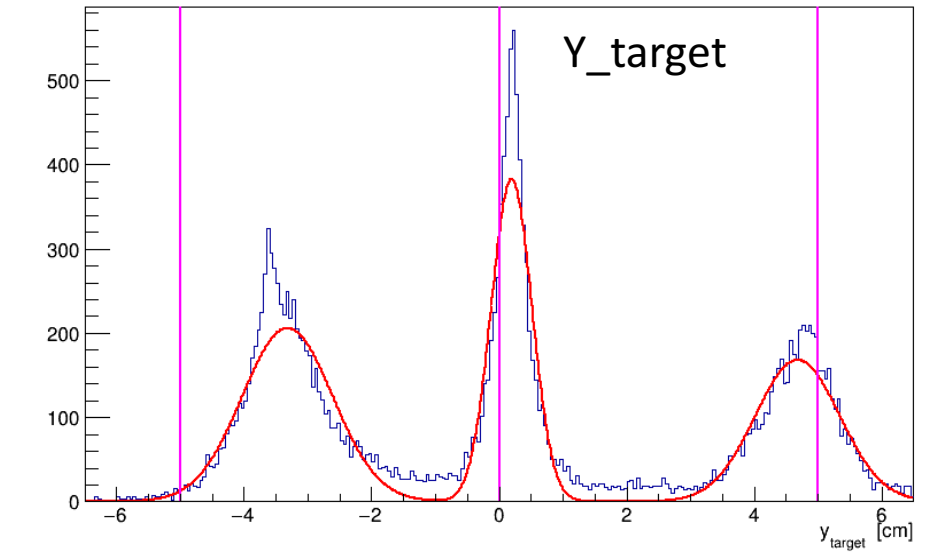
Post-optimization

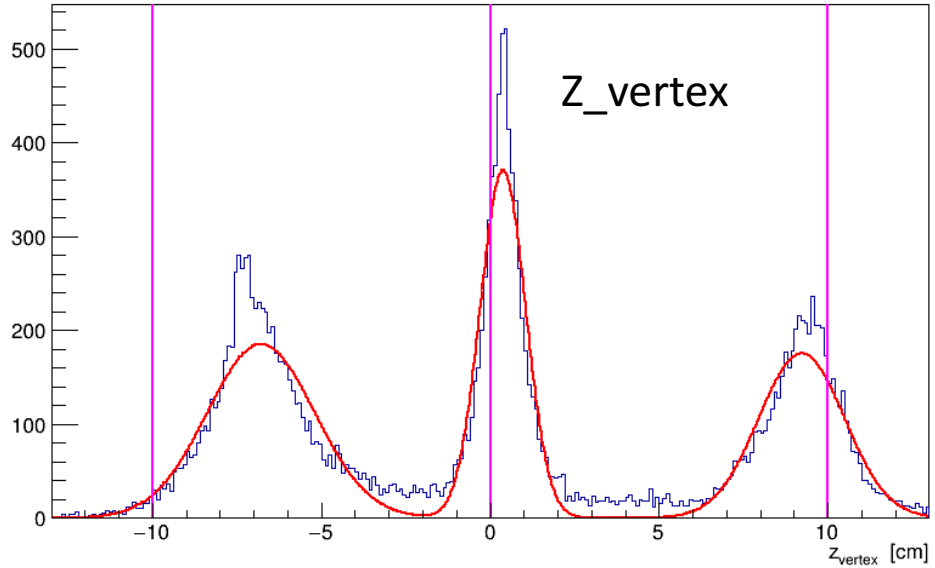




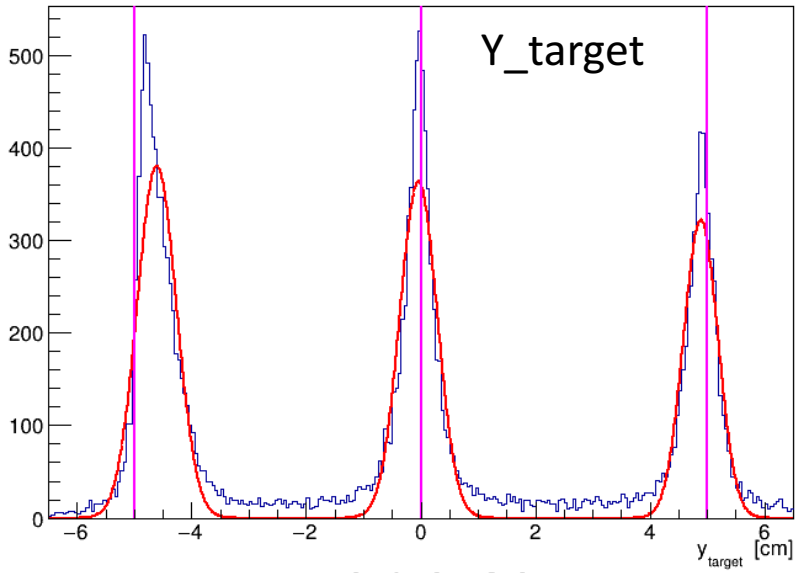
Target at +/-10cm,0cm, HMS at 30deg

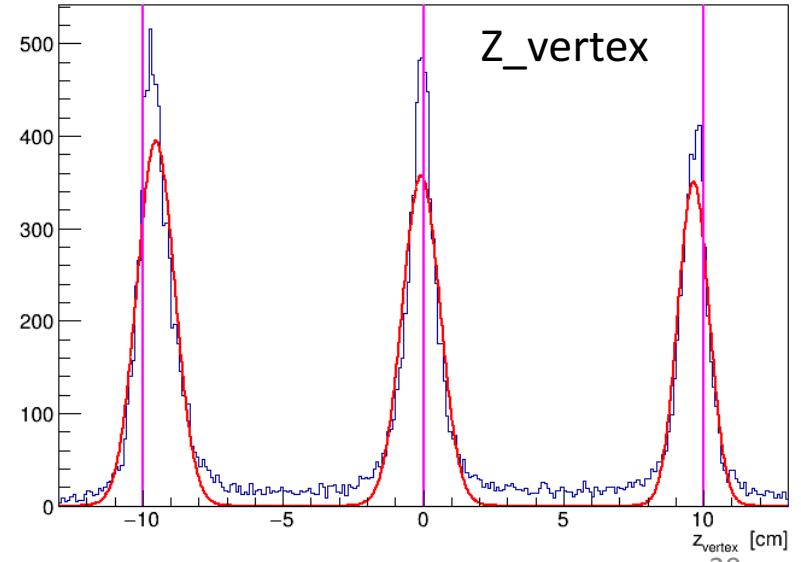
Pre-optimization





Post-optimization

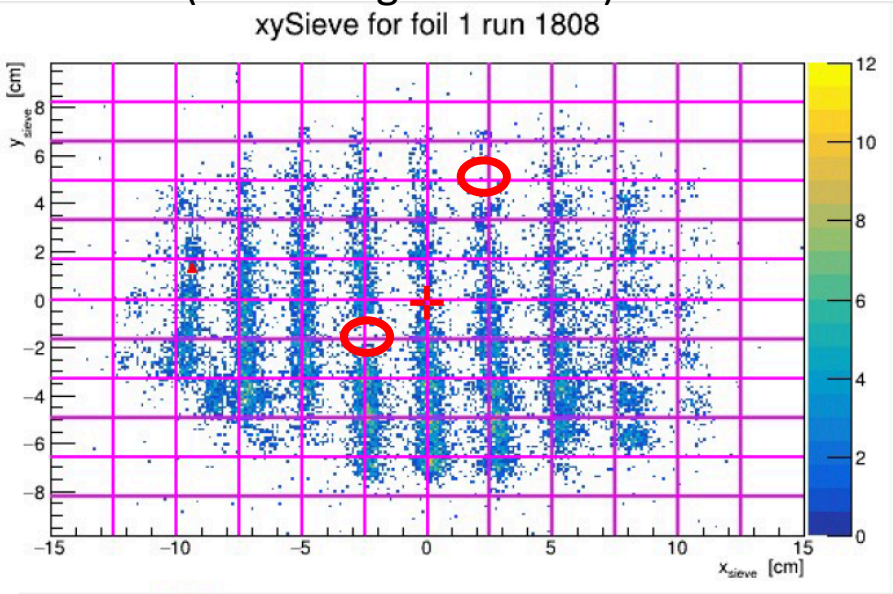


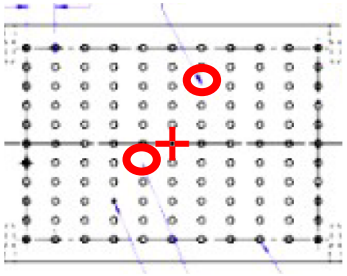


SHMS Matrix Optimization

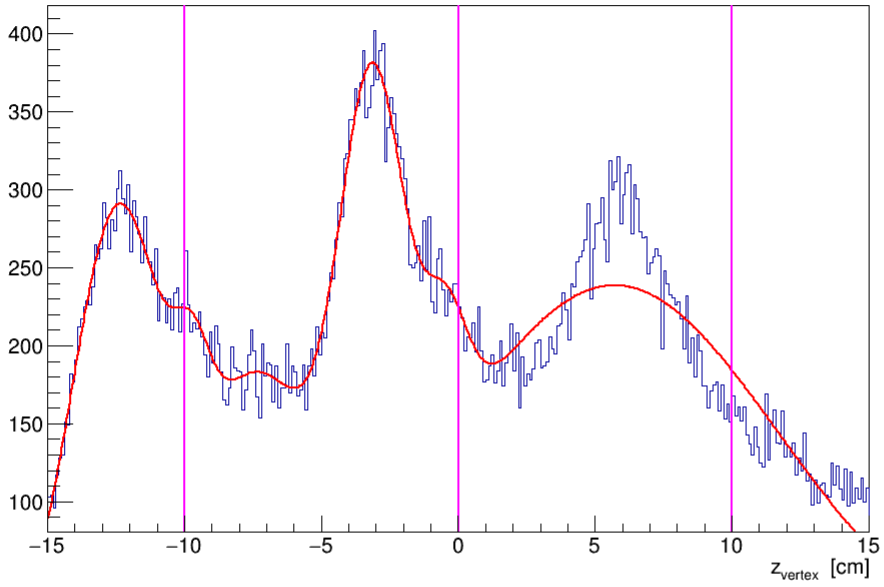
- Still needs some work
- Low statistics and high backgrounds tough
- Delta correlation with y_sieve

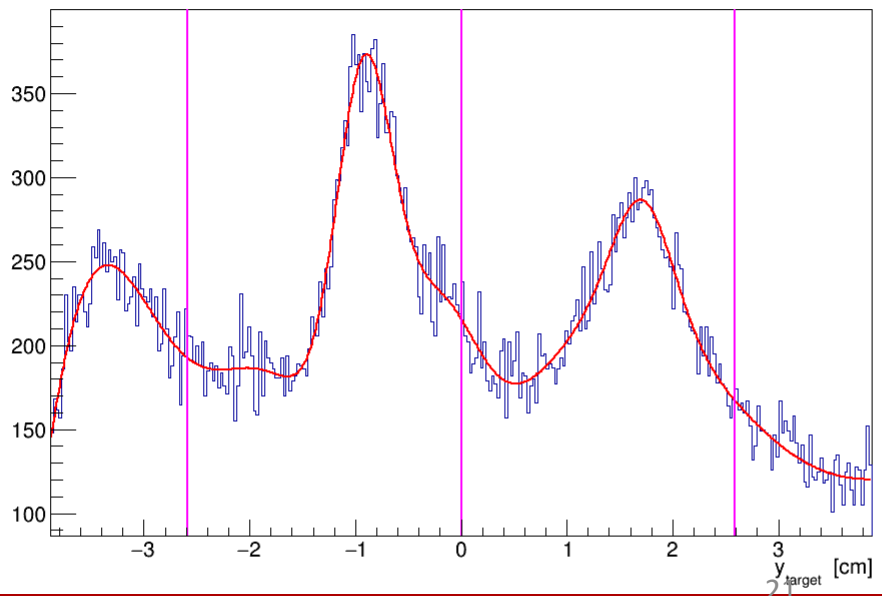
(Wide range of deltas)



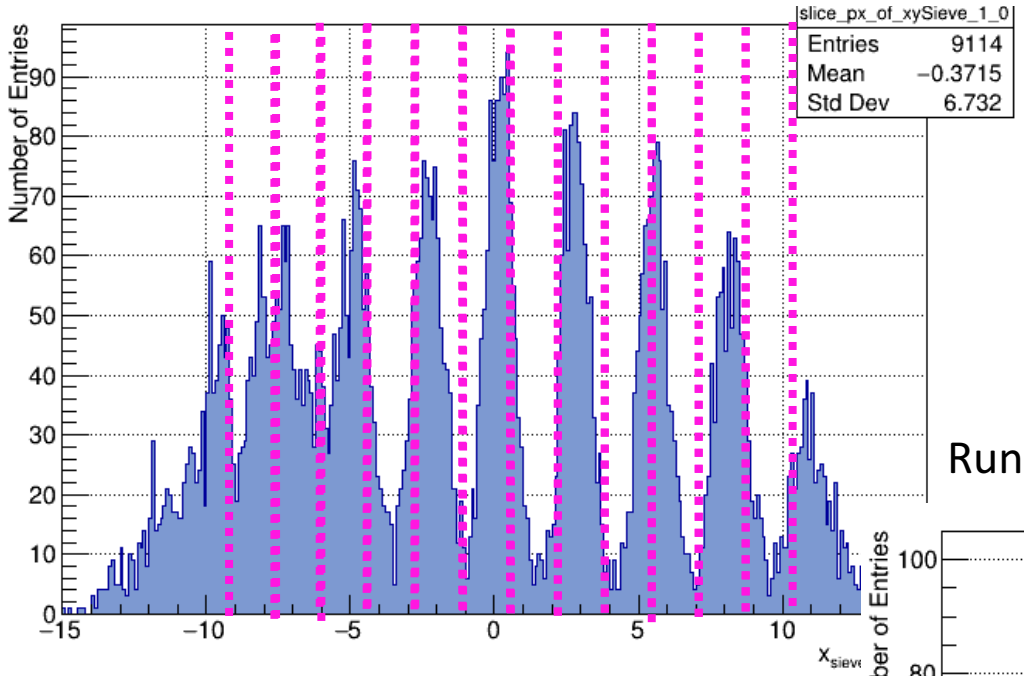


SHMS at 15deg



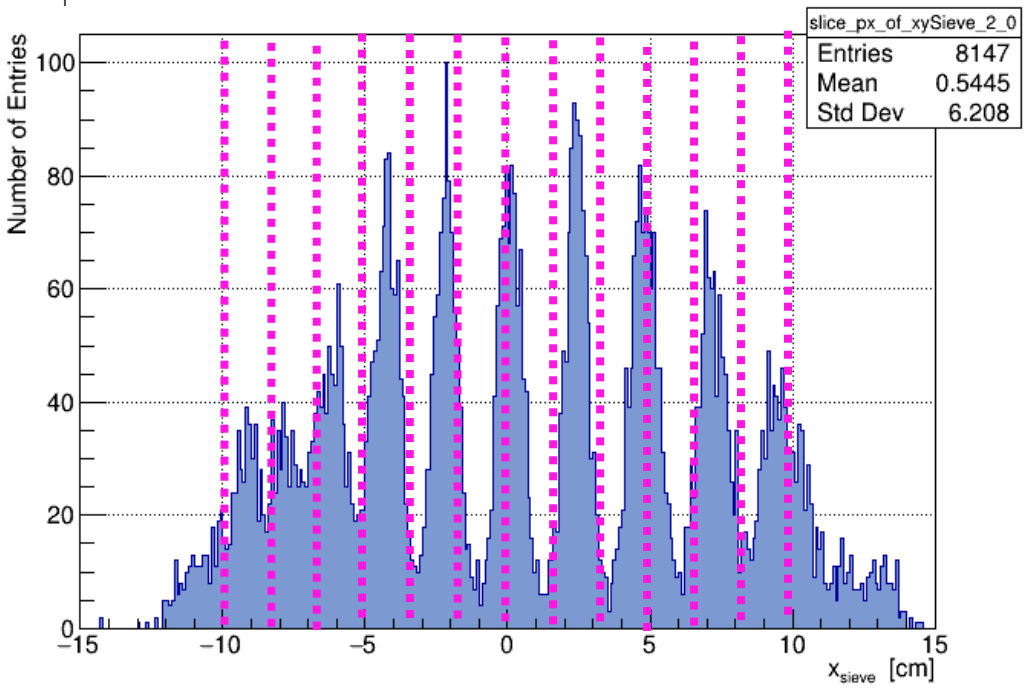


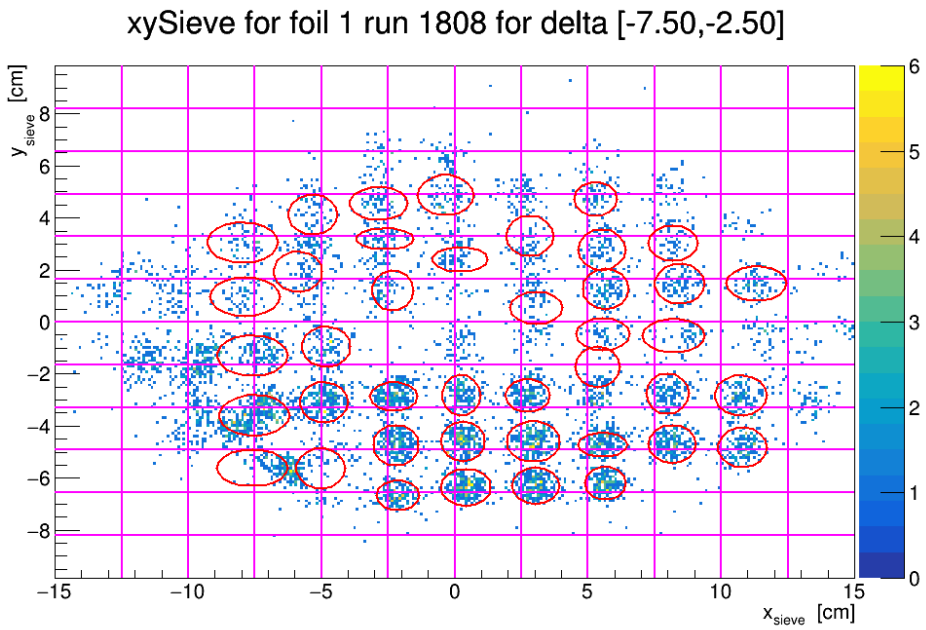
SHMS at 15deg
Run 1809, delta [-7.5,-2.5], shifted sieve

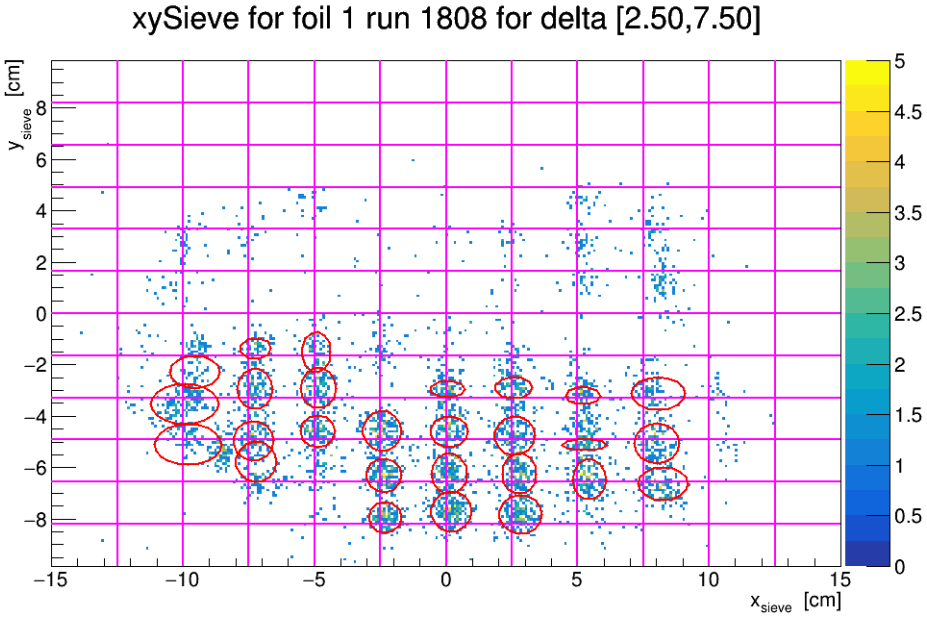


- Still have to improve the matrix optimization
- Seems like we see the shifted vs centered sieve

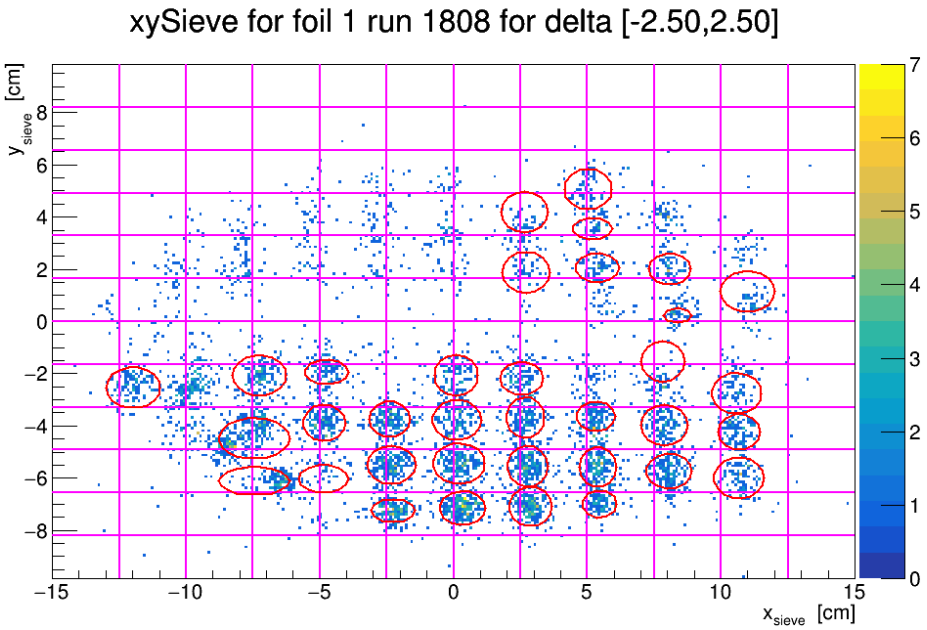
SHMS at 15deg
Run 1808, delta [-7.5,-2.5], centered sieve







Target foil at 0 cm, SHMS at 15 deg for various delta

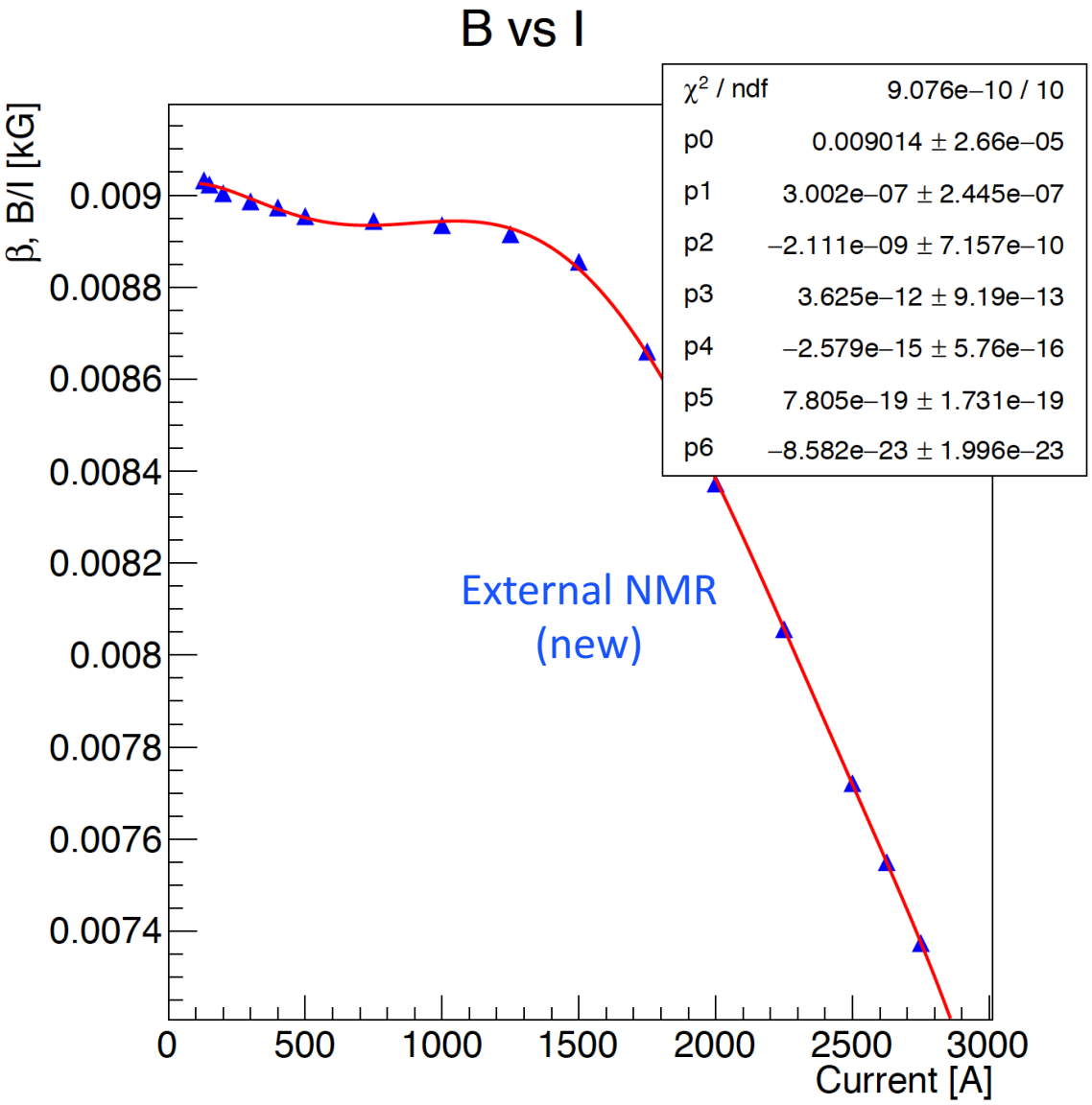


Summary:

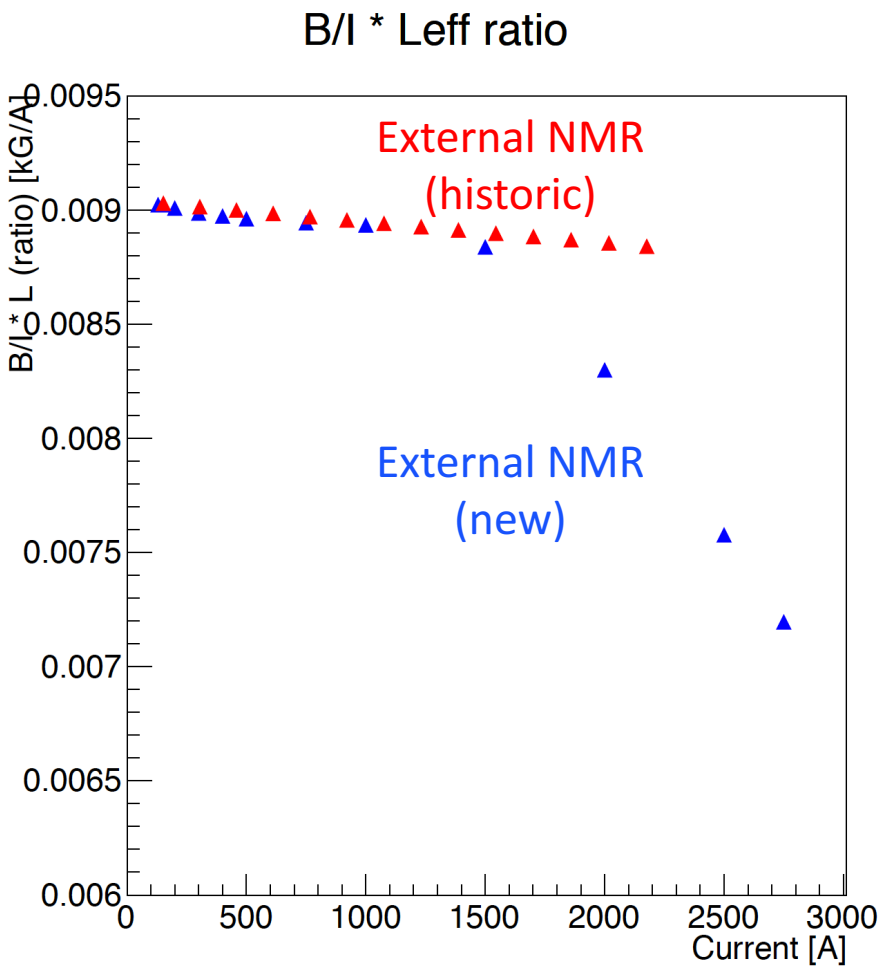
- New HMS optimized matrix
- Fine tune procedure and optimization of SHMS matrix elements
  - Lots of backgrounds
  - Low statistics
  - Delta effects on y_sieve due to HB

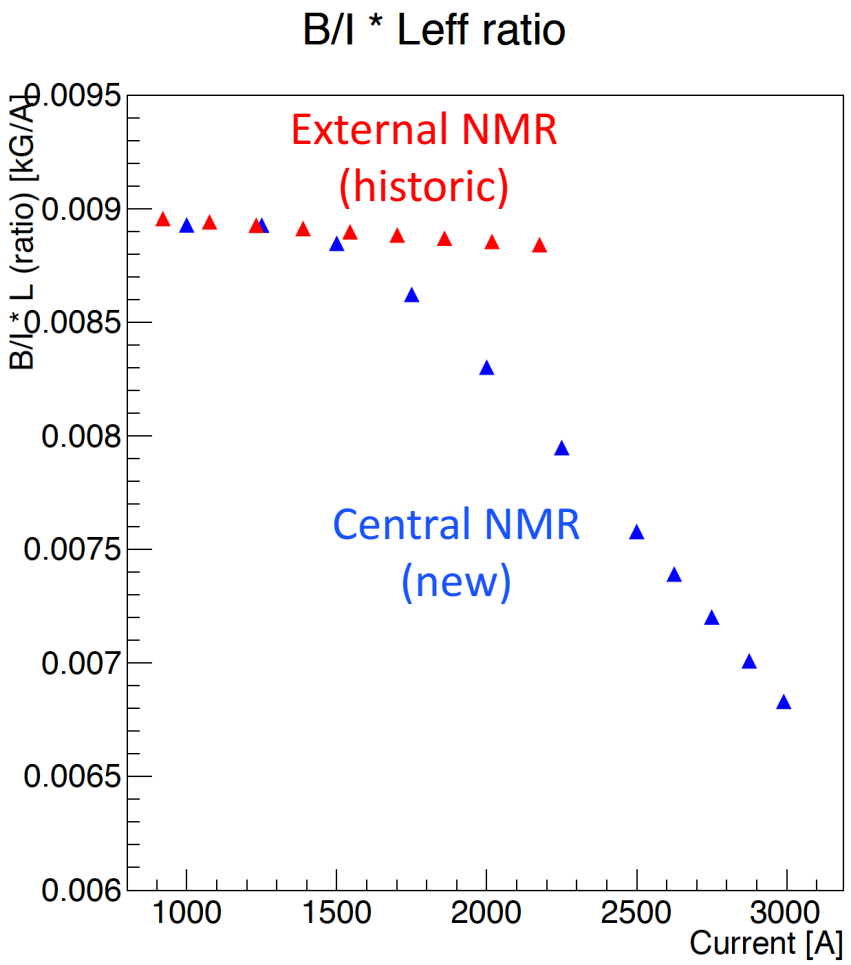
- Scale the SHMS central momentum (1.5-2%)
  - Reduces the original quad scaling by some factor (could be 1.01,1.02,1.01 for Q1,Q2,Q3)
  - Need to look at No Quad running to see how HB is correlated with the Dipole

HMS Dipole


B vs I
χ² / ndf 9.076e−10 / 10
p0 0.009014 ± 2.66e−05
p1 3.002e−07 ± 2.445e−07
p2 −2.111e−09 ± 7.157e−10
p3 3.625e−12 ± 9.19e−13
p4 −2.579e−15 ± 5.76e−16
p5 7.805e−19 ± 1.731e−19
p6 −8.582e−23 ± 1.996e−23
External NMR
(new)
β, B/I [kG]
0.009
0.0088
0.0086
0.0084
0.0082
0.008
0.0078
0.0076
0.0074
0
500
1000
1500
2000
2500
3000
Current [A]

HMS Dipole


B/I * Leff ratio
B/I * L (ratio) [kG/A]
0.0095
0.009
0.0085
0.008
0.0075
0.007
0.0065
0.006
0
500
1000
1500
2000
2500
3000
Current [A]
External NMR
(historic)
External NMR
(new)


B/I * Leff ratio
B/I * L (ratio) [kG/A]
0.0095
0.009
0.0085
0.008
0.0075
0.007
0.0065
0.006
1000
1500
2000
2500
3000
Current [A]
External NMR
(historic)
Central NMR
(new)