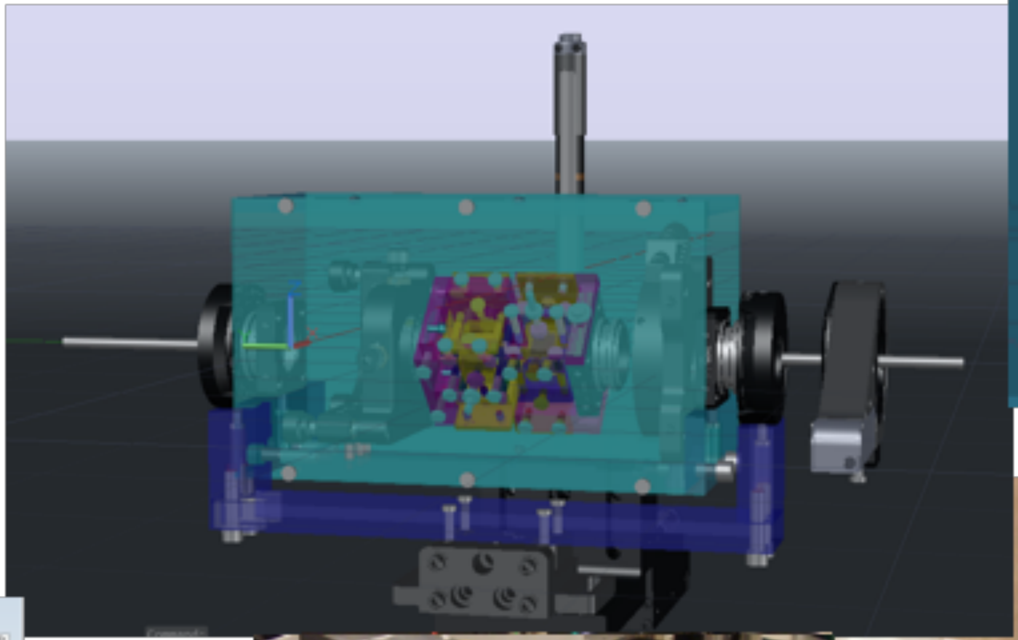
PQB Meeting

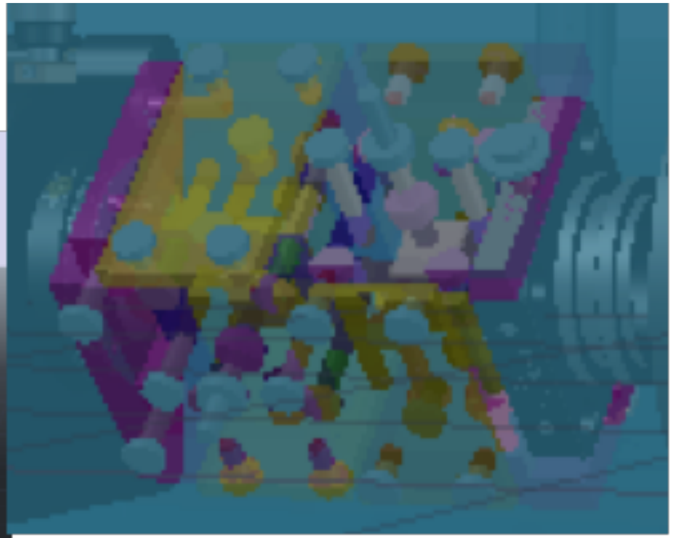
RTP e-beam studies

9/22/2017

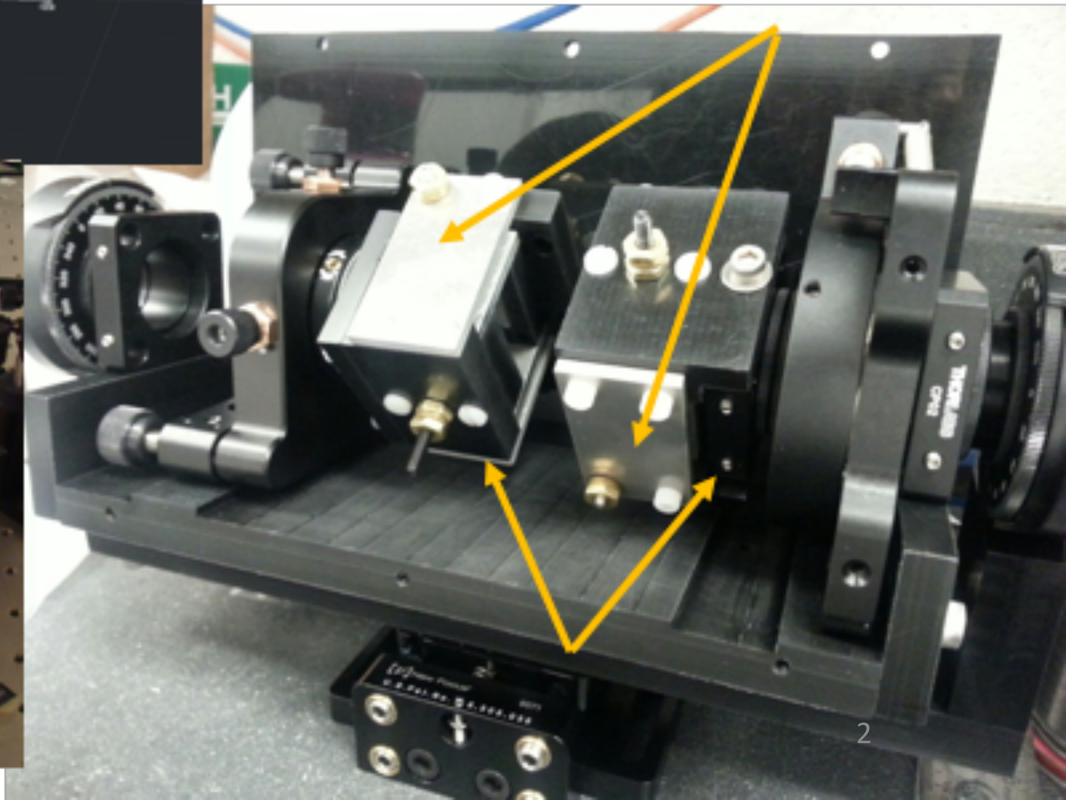
RTP mount design

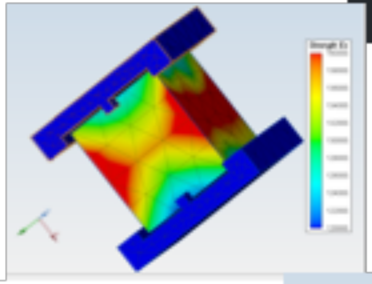
- **2 crystals, 4 plates, 8HV**
- **one HV per plate for each helicity**
- **GND side panels**
- **10x10mm aperture**

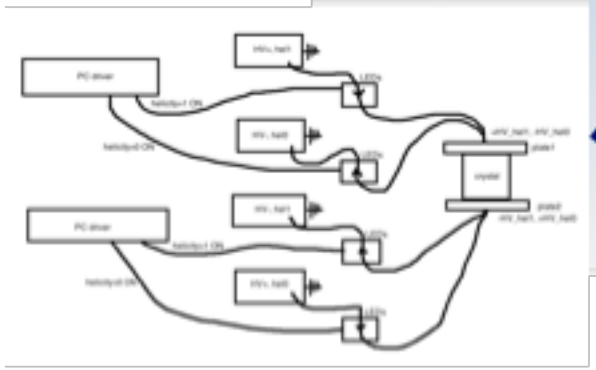


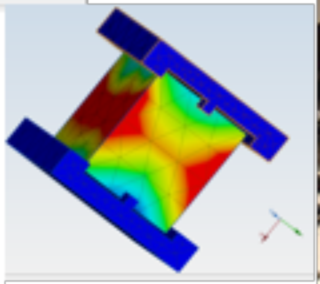


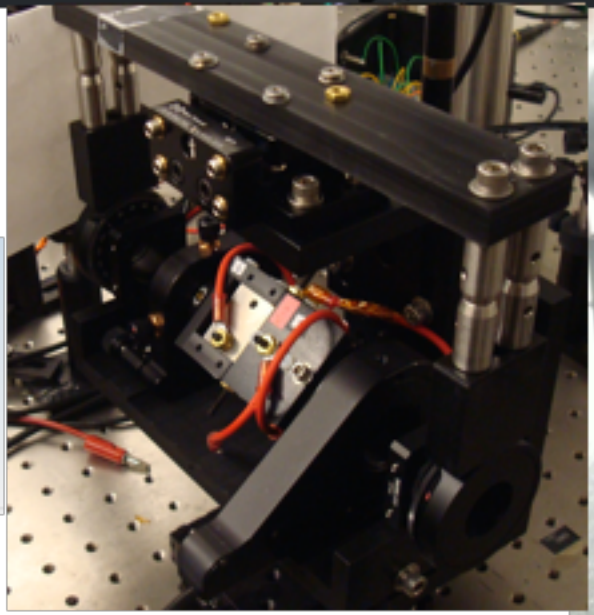
GND side-panels



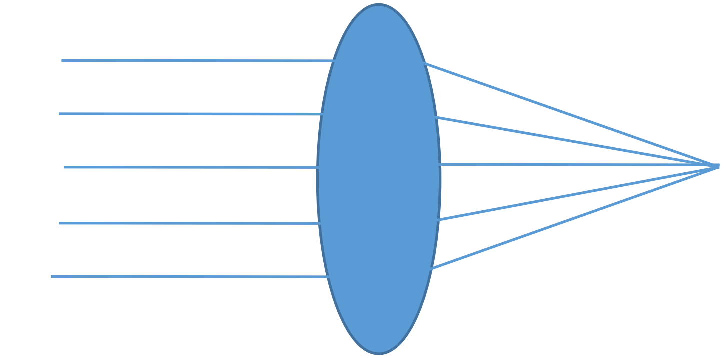


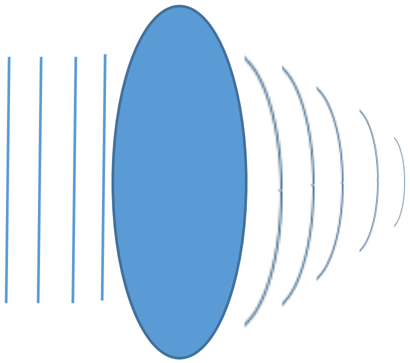






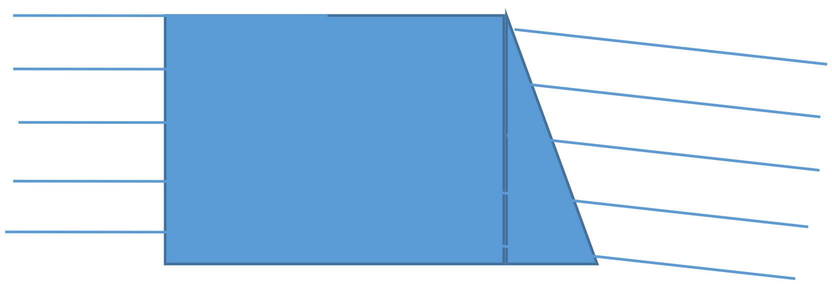
Steering in RTP : Field Gradients

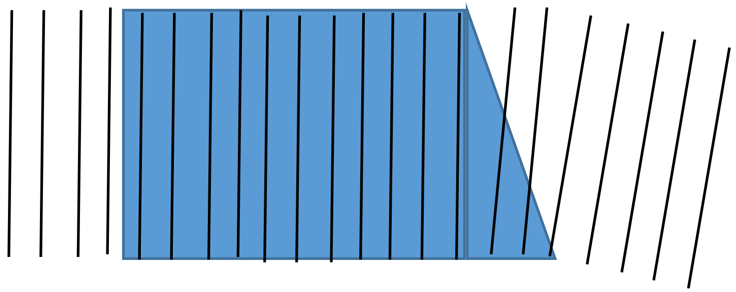


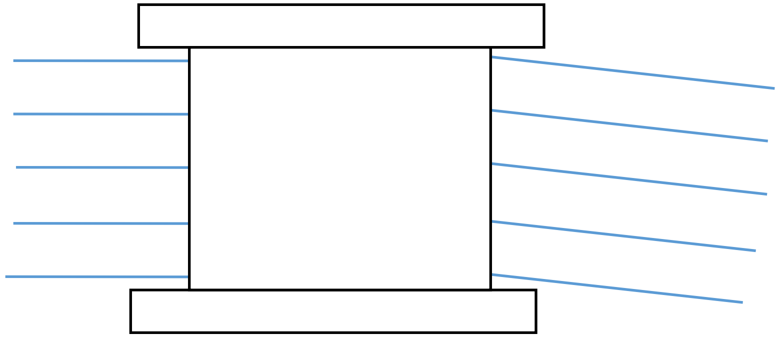


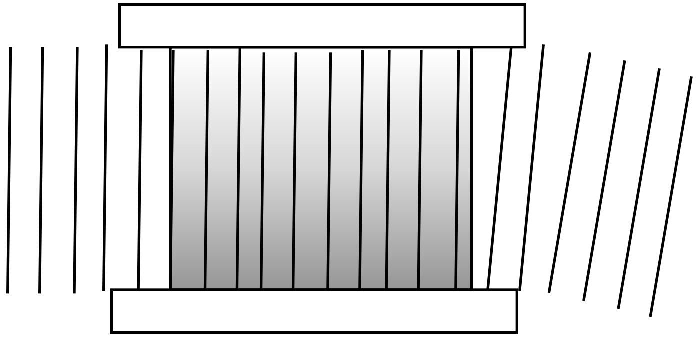
$$\varphi = 2\pi nL/\lambda$$

$$\theta \sim \frac{\partial \varphi}{\partial Z}$$





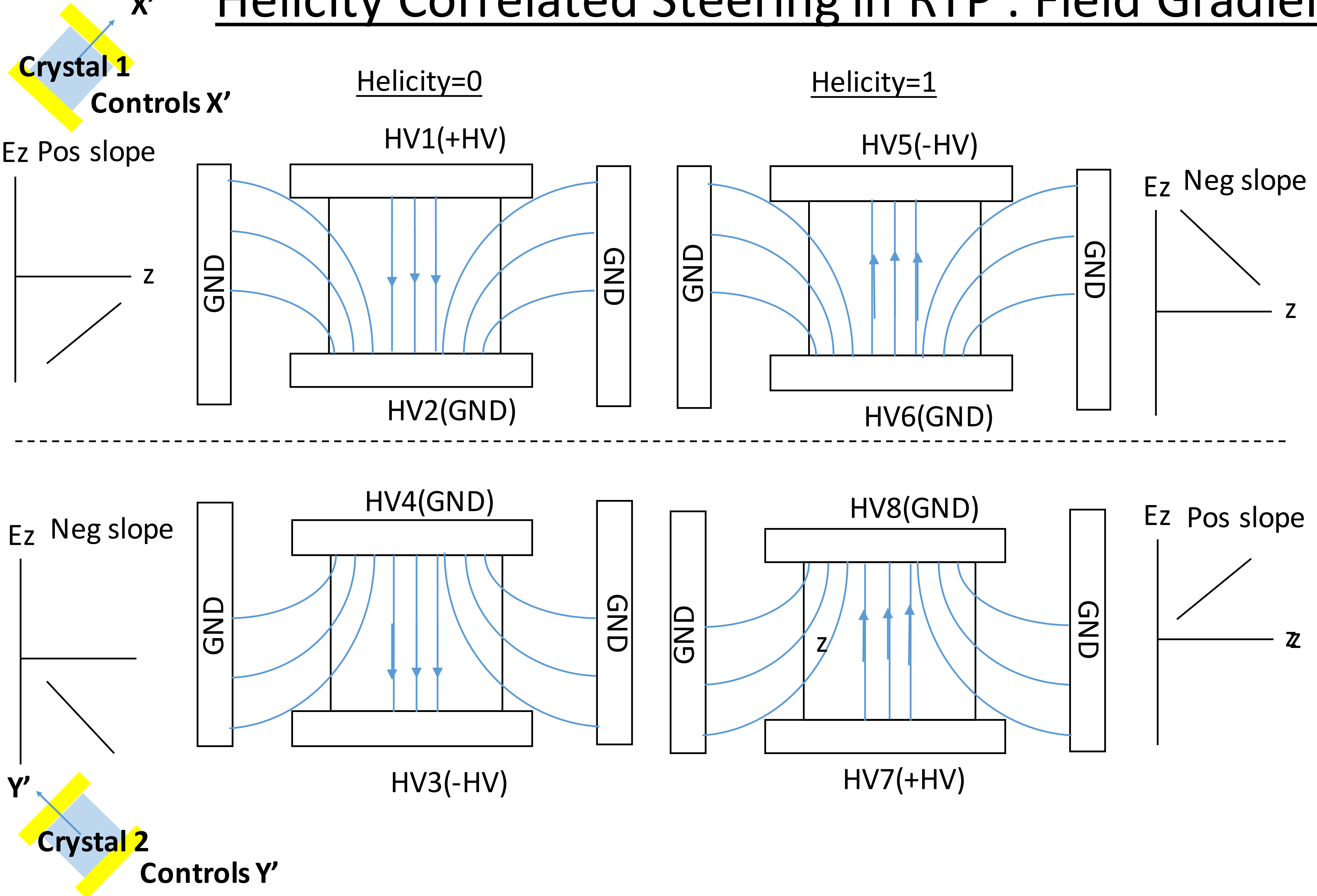




$$n_z = n_{z0} - 1/2 n_{z0}^3 r_{33} E_z$$

$$n_y = n_{y0} - 1/2 n_{y0}^3 r_{23} E_z$$

Helicity Correlated Steering in RTP : Field Gradient



$$\Delta\theta \sim \frac{\partial E0}{\partial Z} - \frac{\partial E1}{\partial Z}$$

$$\Delta\theta \sim pos - neg \sim 2pos$$
$$\Delta\theta > 0 \sim 1urad$$

$$\Delta\theta \sim neg - pos \sim -2pos$$
$$\Delta\theta > 0 \sim 1urad$$

Run Plan

- **RTP test HV control of Position Differences , Linear Array Studies,**
- **RTP Alignment in Injector Beamline- fundamental qualification of RTP working for MOLLER**
- **KD*P electron beam/show actual Parity Quality Beam (not yet achieved)**

- M Aug21 morning- John spot size reduction on HallA laser, M2/mode check, if poor mode reduce HallC laser spot
- M Aug21 afternoon (e-beam 1pm-6pm or later) -benchmark KD*P with 1mm spot (e-beam, HallA or C lasers) RHWP scans
- T Aug22 morning (e-beam 9am-1pm) - continue benchmark KD*P with 1mm spot (e-beam, HallA or C lasers) RHWP scans
- T Aug22 afternoon- setup electronics for RTP (John, HallA or C lasers)
- W Aug23-25 Align RTP mount with qpd, S1,S2, no anal
- F Aug25- laser RHWP scans
- S Aug26-Linear array setup
- Su Aug27-RTP spot-size asymmetry studies *begin* –dependence angle, translation, HV analyzer S1&S2&out, along x&y&45deg
- M Aug28(e-beam 9am-6pm)-e-beam RHWP scans (e-beam, HallA or C lasers)
- M Aug28(e-beam 9am-6pm)-PITA-position scan X & Y (e-beam, HallA or C lasers) – demonstrate HV control of Pos Diff
- T Aug29-RTP spot-size asymmetry studies *finish*–dependence angle, translation, HV analyzer S1&S2&out, along x&y&45deg
- T Aug29-Align RTP mount with linear array + RHWP scans
- W Aug30-KD*P reinsert
- Th Aug31-KD*P realign with qpd for smaller spot
- Th Aug31-KD*P RHWP scans
- F Sept1(e-beam 9am-6pm)-KD*P e-beam RHWP scans (e-beam, HallA&Clasers)

Results

- Laser setup well & well-defined
- RTP fully characterized with laser
- RTP can achieve <100nm position differences in 1st 8 bpms (1I02-0I05) at 25uA
- Spot size asymmetry for RTP off of cathode <~2e-4
- PITA position voltages control steering position differences as predicted
- PITA position corrections ultimately used are small <100V
- Bpm RMS noise for the RTP is similar to the KD*P – relevant for statistics
- Learned RTP can drift Aq –beam by ~100ppm in ~30min –likely T dependence
- KD*P achieved <200nm position differences in 1I02-0I05 region

Moving Forwards

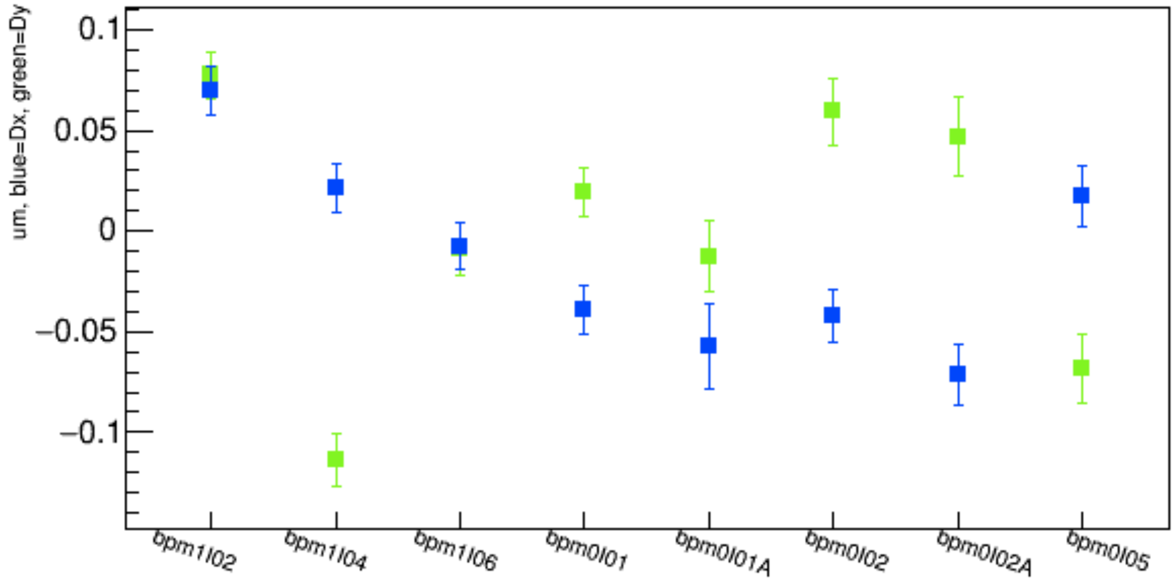
- RTP achieves parity quality beam (<100nm,1st 8 bpms, 25uA)… for 10min
  - Aq e-beam drifts ~100ppm in ~30min
  - If we can make Aq drifts stable we can use it for PREX
- Ease of alignment
  - Throw in crystal, center with tissue, align back reflection, spinning LP, go…fix e-beam with voltage
  - Huge range of PITApos control compared with corrections to make after cathode
  - 10um Dx 4theta term on qpd is ~500nm correction on cathode which is~100V
- 960Hz – freeclock beating
  - There is reason to believe there's a beating with a multiple of 60Hz and compromises RMS
  - Linesynch and 'trigint-tet' (30), otherwise 960Hz doesn't give large statistical improvement
- Beamline – which bpm to choose for pos. diff. minimization
  - Momentum– could 50nm pos diffs improve later in the beamline? What happens in 5MeV region?
  - Apertures/chopper – could they affect our ability to zero out position differences everywhere?
- Stability (we have reason to believe) would improve with crystal Tcontrol
  - Tcontrol in the works, ordering parts
  - Feedback on PITAV in the works, would also fix stability in Aq
  - Feeback on Pos Diffs would make iterative process of setting PITApos voltages automated

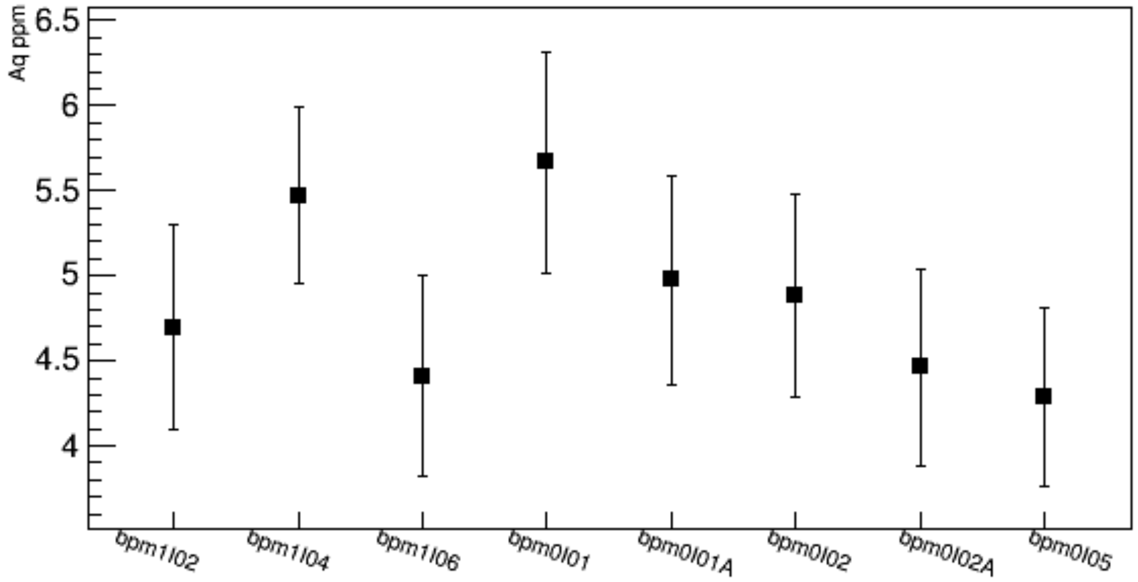
Parity Quality Beam

Using 8 Voltages on RTP cell…

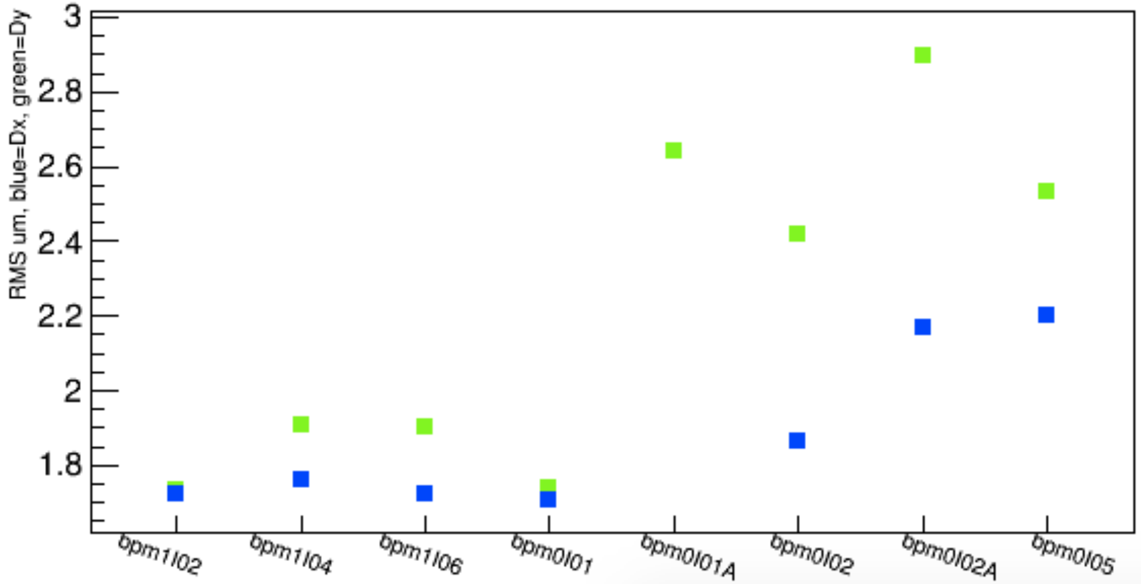
			JLab coupling matrix	IHWP out			coupling matrix IHWP out				Offsets	
				PITAV	PITAposU	PITAposV		PITAV indv	PITAposU	PITAposV	IHWP out	um
base HV	788.78		Aq S1 ppm/V	1698	-	-	Aq ppm/V	1698	-	-	Du 104cm	0.57
PITAV indv	56.6		Du 104cm nm/V	-	-	-	Du nrad/V	#VALUE!	#VALUE!	#VALUE!	Dv 104cm	0.003
RTP Weight V	0		Dv 104cm nm/V	-	-	-	Dv nrad/V	#VALUE!	#VALUE!	#VALUE!	Du S1	-1.042
PITA U V	12.69	-X+Y/SQRT(2)	Du S1 nm/V	-	-	-	Du nm/V S1	#VALUE!	#VALUE!	#VALUE!	Dv S1	0.877
PITA 'V' V	69	X+Y/SQRT(2)	Dv S1 nm/V	-	-	-	Dv nm/V S1	#VALUE!	#VALUE!	#VALUE!	Du S2	-
PITA X V	0		Aq "S2" ppm/V	-	-	-	Du nm/V S2	#VALUE!	#VALUE!	#VALUE!	Dv S2	-
PITA Y V	0		Du S2 nm/V	-	-	-	Dv nm/V S2	#VALUE!	#VALUE!	#VALUE!		
Aq	0		Dv S2 nm/V	-	-	-		*most Du/Dv in S1 due to PITA is qpd pedestal error				
Du	0			Run3146	Run3144	Run3145						
Dv	0											
Dx	0											
Dy	0					0	0			Vlim		
		56.6	0	12.69	69	0	0		16.384	2001		
	base	PITA shift	RTP weight V	PITA U V	PITA V V	PITA X V	PITA Y V	TOT	units	ok?	V shift	
HV1+, +z1, +U, hel0	788.78	56.6	0	12.69	0	0	0	858.07	**14059**	1	69.29	DAC03, HALLA IA
HV2-, -z1, -U, hel0	-788.78	-56.6	0	12.69	0	0	0	-832.69	**-13643**	1	-43.91	DAC04, HALLA IA
HV3+, -z2, -"V", hel0	788.78	56.6	0	0	69	0	0	914.38	**14981**	1	125.6	DAC05, HALLA IA
HV4-, +z2, +"V", hel0	-788.78	-56.6	0	0	69	0	0	-776.38	**-12720**	1	12.4	DAC06, HALLA IA
HV5-, +z1, +U, hel1	-788.78	56.6	0	-12.69	0	0	0	-744.87	**-12204**	1	43.91	DAC07, HALLB IA
HV6+, -z1, -U, hel1	788.78	-56.6	0	-12.69	0	0	0	719.49	**11788**	1	-69.29	DAC08, HALLB IA
HV7-, -z2, -"V", hel1	-788.78	56.6	0	0	-69	0	0	-801.18	**-13127**	1	-12.4	DAC09, HALLB IA
HV8+, +z2, +"V", hel1	788.78	-56.6	0	0	-69	0	0	663.18	**10866**	1	-125.6	DAC10, HALLB IA
PITA effective sys	226.4					hel0	hel1	hel0-hel1	avg DC V			
RTP1 Weighting	0.5	RTP2 Weighting	0.5		V effective RTP1	1690.76	-1464.36	3155.12	113.2			
U Weighting	0.008044	X Weighting	0.025239726		V effective RTP2	-1690.76	1464.36	-3155.12	-113.2			
"V" Weighting	0.043738	Y Weighting	0.036615757		V effective system	3381.52	-2928.72	6310.24				
Aq	96106.8				PITA effective sys	226.4						
Du	#VALUE!				HWV effective sys	3155.12						
Dv	#VALUE!				PITA eff per crystal	113.2						
					HWV eff per crystal	1577.56						

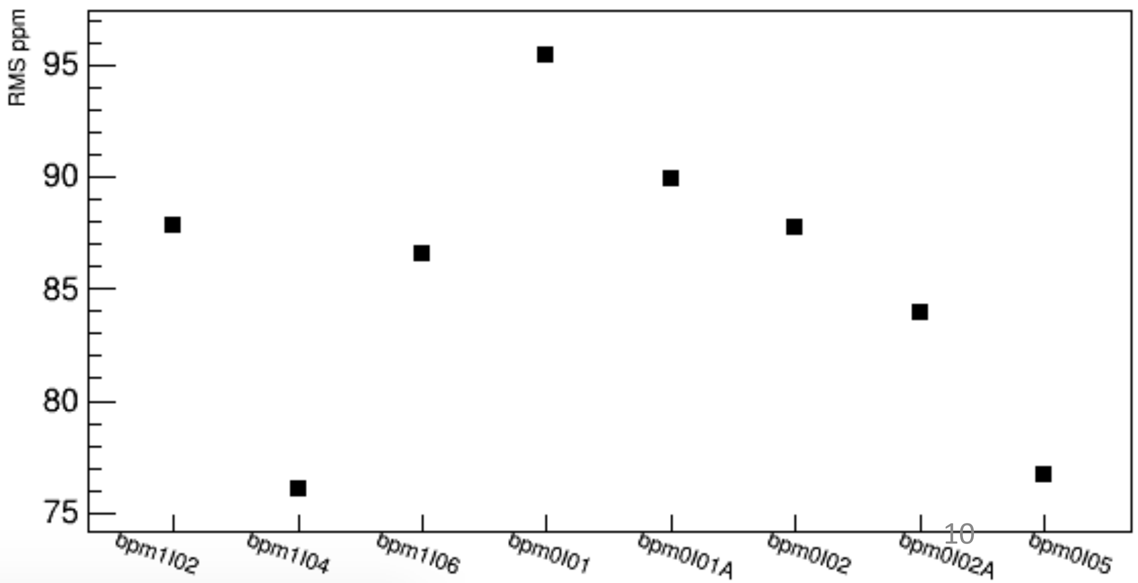
RTPcell_Run3331_ebeamWalking_IHWPout_S1RHWP24_PITA54p5PITAposU12p69PITAposV70p98





BUT Aq drifts ~100ppm over 30min or so (likely due to temperature)





For comparison…Qweak

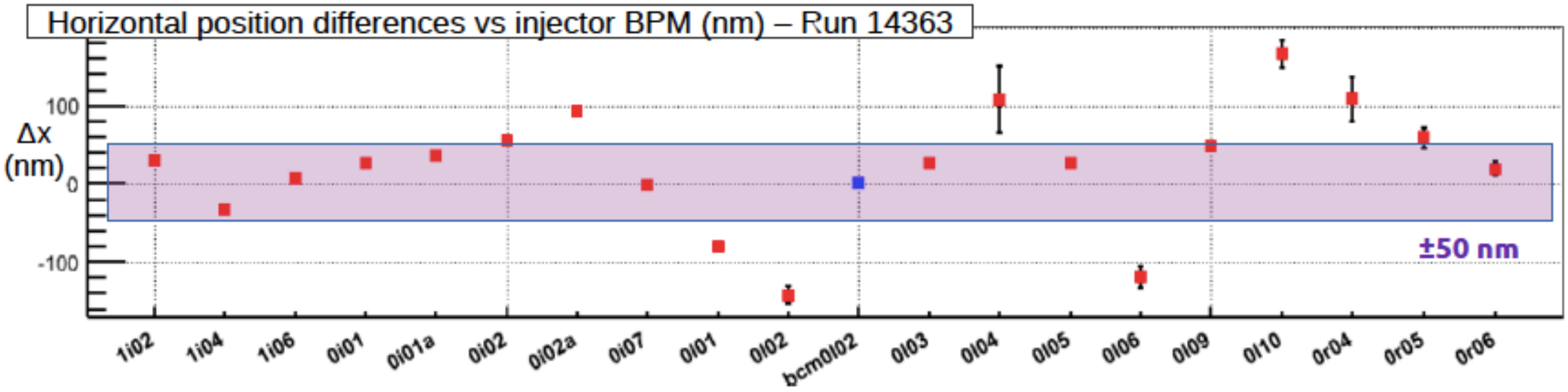


Figure 4.19: Horizontal position differences on successive injector BPMs. The purple band corresponds to ±50 nm of position differences.

Kargiantoulakis_thesis_qweakinjbpms

Laser Setup

Laser

- PPLN lenses: 1st lens f=40mm (John's), 2nd lens f=35mm (UVa's Thorlabs)
- Extra lens: ~1m upstream of the PC, a f=50cm lens (UVa's Thorlabs) was inserted
- Measured spot sizes, 2sigma: w=0.825mm Horizontal, w=0.94mm Vertical at PC center
- Measured divergences: dw/dz 0.51mrad horizontal, 0.66mrad vertical at PC center
- Measured M2: ~1.0, no observed tails like before
- steering lens is 2m, cathode 4sigma 2.9mm Horiz, 3.1mm Vert, distance to cathode ~3.1m 1/19/17, distance to steering lens ~1.067m, effective throw from PC to cathode ~2.015m
- cathode analyzing power was measured to be ~6%

Characterizing RTP

Covered parameter space

Laser

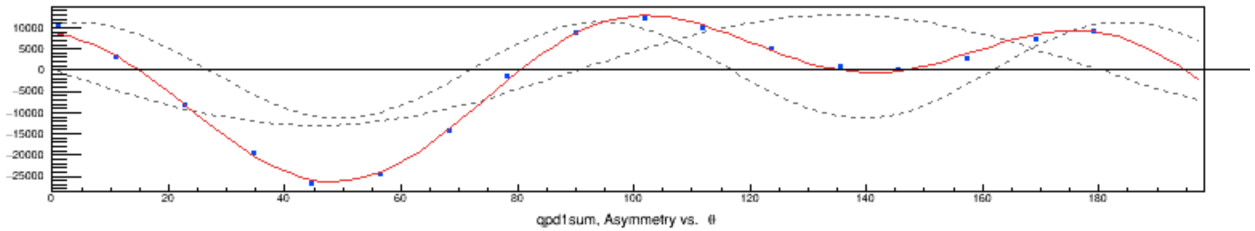
- Pitch, Yaw, PITA, PITAposU, PITAposV, X translation, Y translation dependence
- S1, S2, no analyzer
- RHWP scans

e-beam

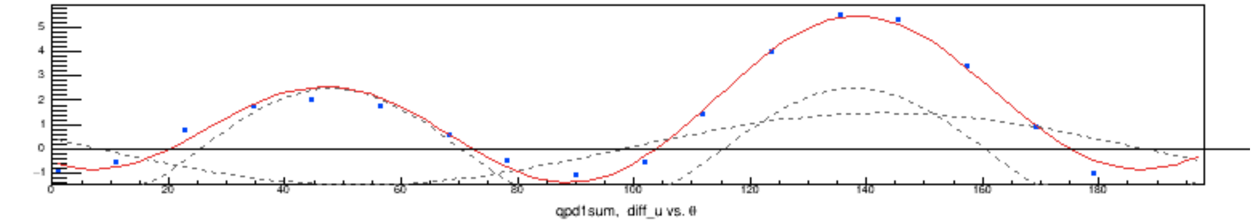
- RHWP scans for IHWPin, IHWPout, PITA shift, PITA pos shift
- PITApos scans for RHWP S1, RHWP S2 for IHWPin/IHWPout

Laser RHWP scans
shift in PITAposV results in shift in Dv offset

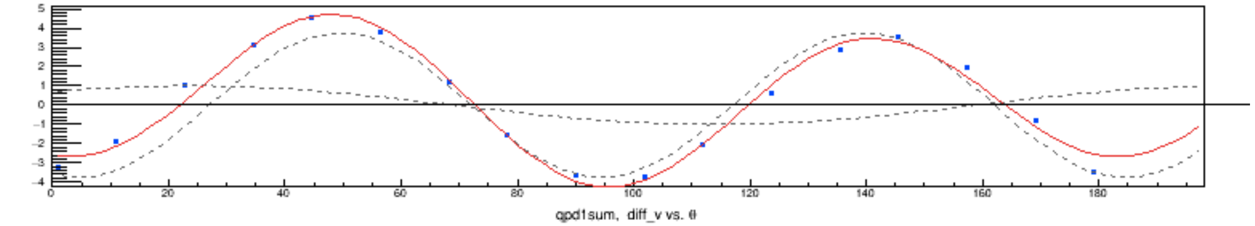
RHWP scan, Run 3250, IHWP OUT, PITA=74, PITAposU=227, PITAposV=-197, qpd1sum



Aq = -2061.66 + 12992.39 sin (2θ + 179.43) + 11316.56 sin (4θ + 72.86) (ppm)

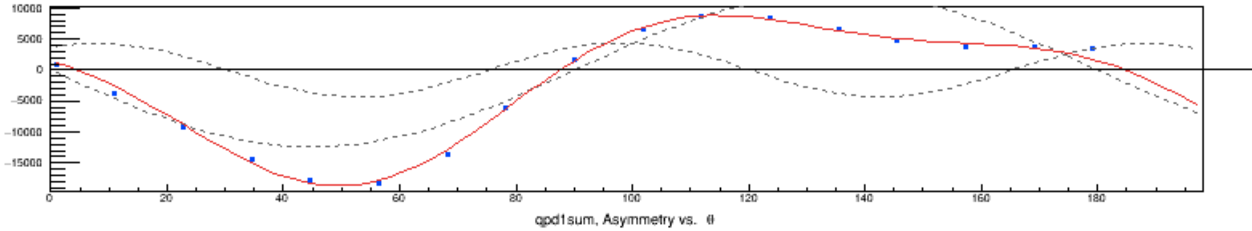


Du = 1.51 + 1.48 sin (2θ + 163.83) + -2.49 sin (4θ + 78.57) (um)

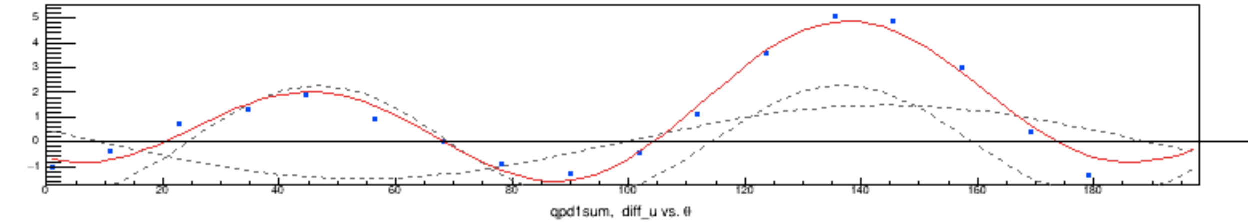


Dv = 0.31 + 1.01 sin (2θ + 42.20) + -3.75 sin (4θ + 71.84) (um)

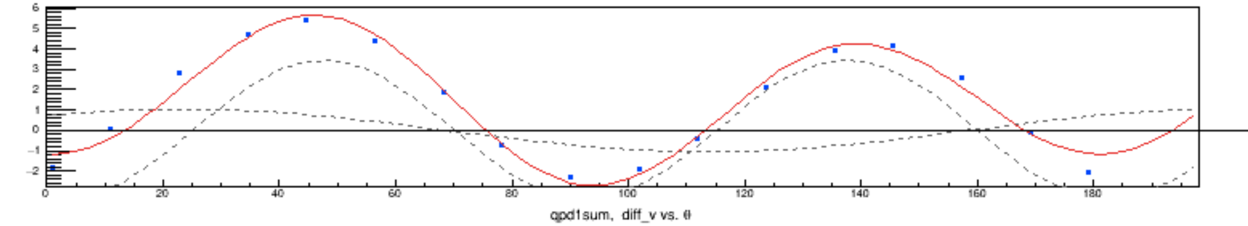
RHWP scan, Run 3248, IHWP OUT, PITA=74, PITAposU=227, PITAposV=213, qpd1sum



Aq = -2206.04 + 12361.50 sin (2θ + 179.86) + 4326.15 sin (4θ + 58.76) (ppm)



Du = 1.18 + 1.48 sin (2θ + 161.58) + -2.27 sin (4θ + 83.15) (um)



Dv = 1.51 + 1.05 sin (2θ + 42.71) + -3.42 sin (4θ + 79.62) (um)

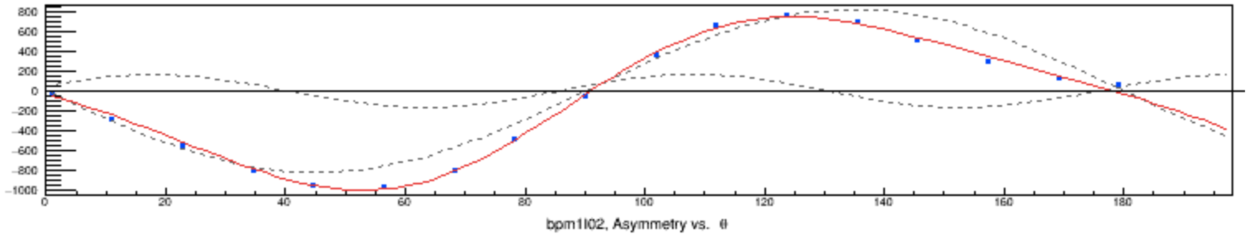
RTP Position Difference Control

e-beam RHWP scans

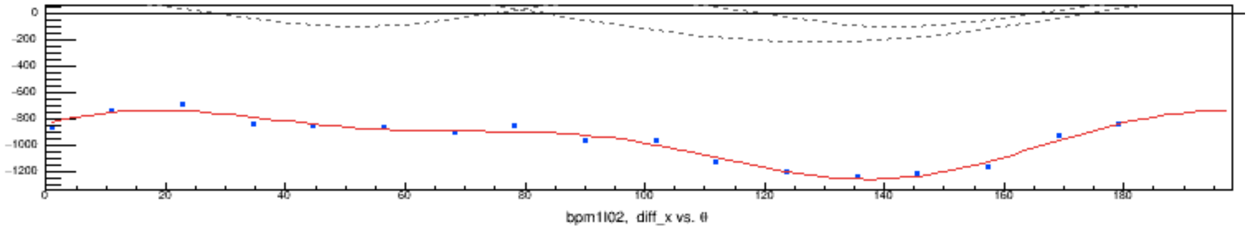
shift in PITApos results in shift in PosDiff offset

PITAposU=227 PITAposV=213

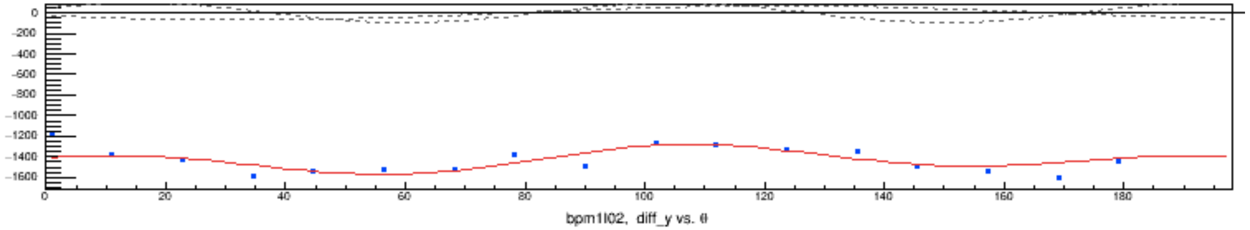
RHWP scan, Run 3303, IHWP OUT, PITA=57, bpm1I02



$Aq = -84.98 + 819.10 \sin(2\theta + 179.72) + 164.49 \sin(4\theta + 17.63)$ (ppm)



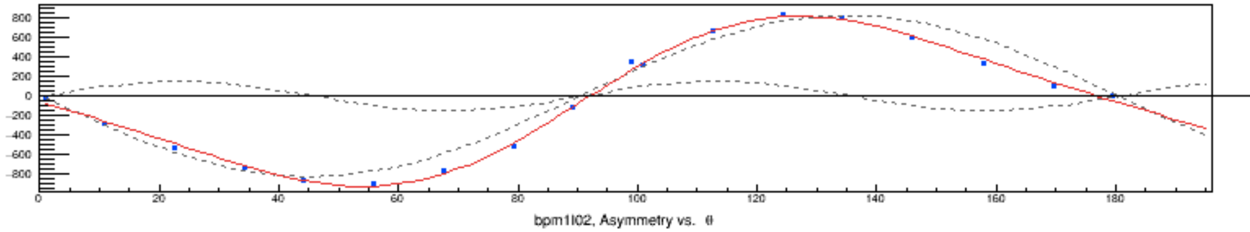
$Dx = -963.07 + 213.28 \sin(2\theta + 12.69) + 97.06 \sin(4\theta + 62.47)$ (nm)



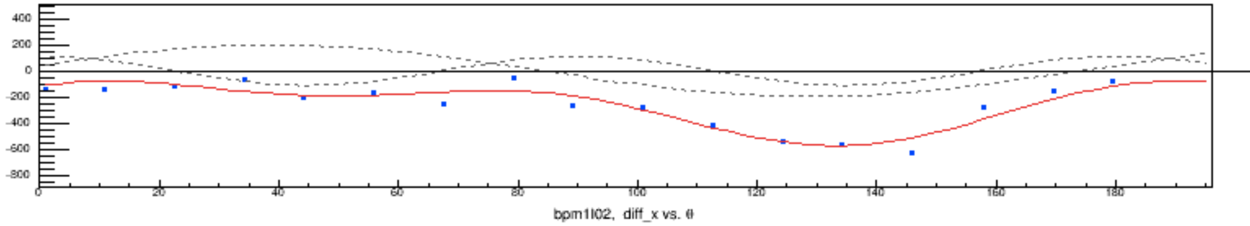
$Dy = -1431.65 + -67.85 \sin(2\theta + 23.97) + 95.74 \sin(4\theta + 30.38)$ (nm)

PITAposU=-24 PITAposV=-125

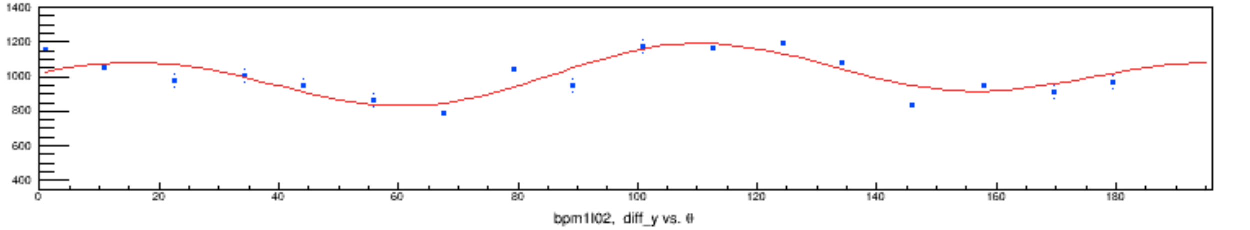
RHWP scan, Run 3315, IHWP OUT, PITA=57, bpm1I02



$Aq = -58.80 + 823.66 \sin(2\theta + 179.26) + -148.79 \sin(4\theta + 176.63)$ (ppm)



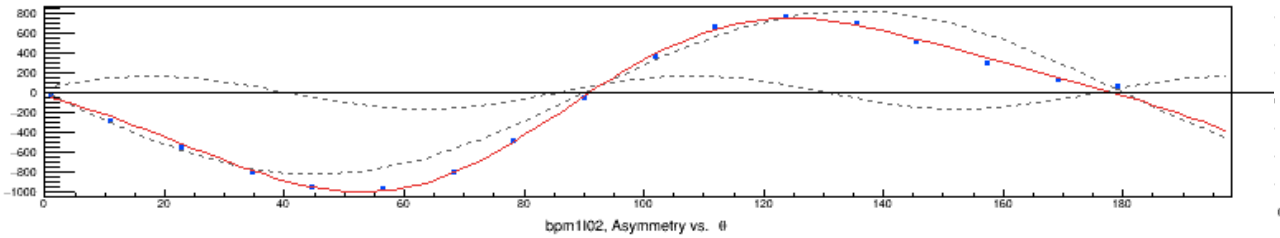
$Dx = -270.24 + 197.45 \sin(2\theta + 12.08) + 111.86 \sin(4\theta + 90.15)$ (nm)



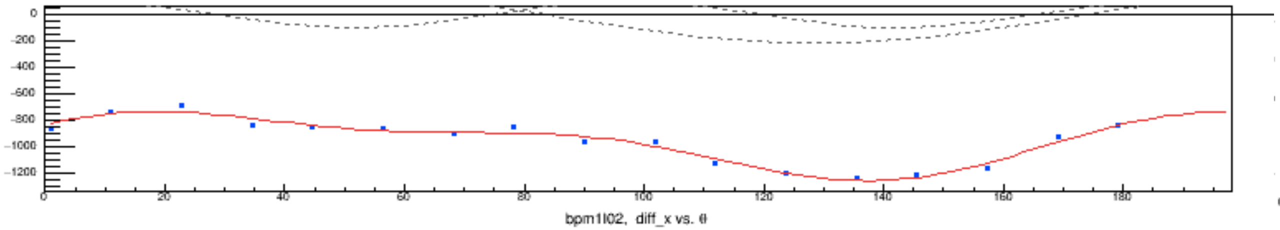
$Dy = 1005.71 + -68.88 \sin(2\theta + 15.59) + 129.44 \sin(4\theta + 16.01)$ (nm)

e-beam RHWP scans
shift in PITAV results in 4theta terms

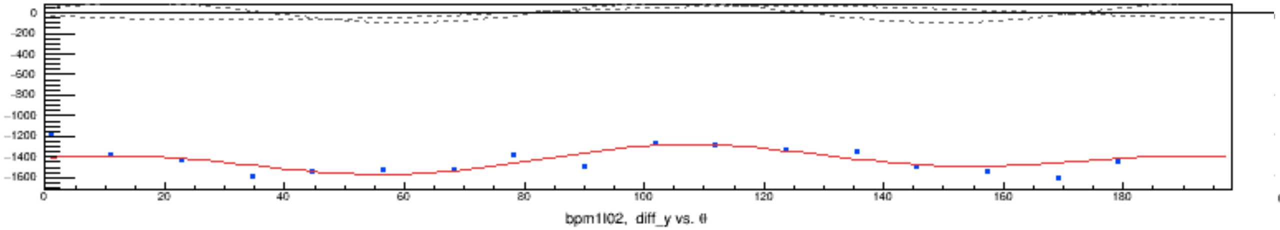
RHWP scan, Run 3303, IHWP OUT, PITA=57, bpm1I02



Aq = -84.98 + 819.10 sin (2θ + 179.72) + 164.49 sin (4θ + 17.63) (ppm)

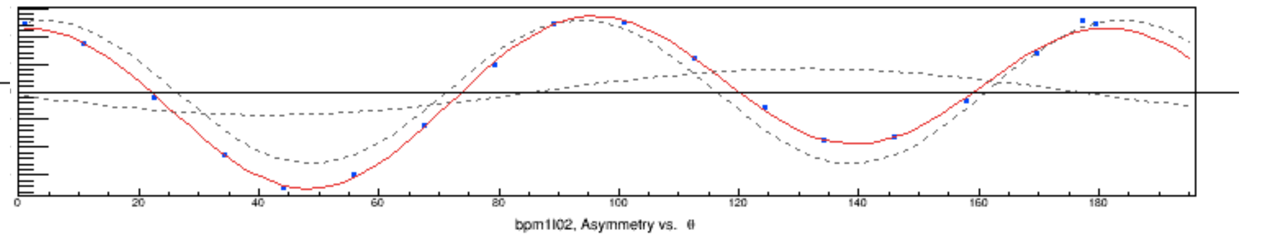


Dx = -963.07 + 213.28 sin (2θ + 12.69) + 97.06 sin (4θ + 62.47) (nm)

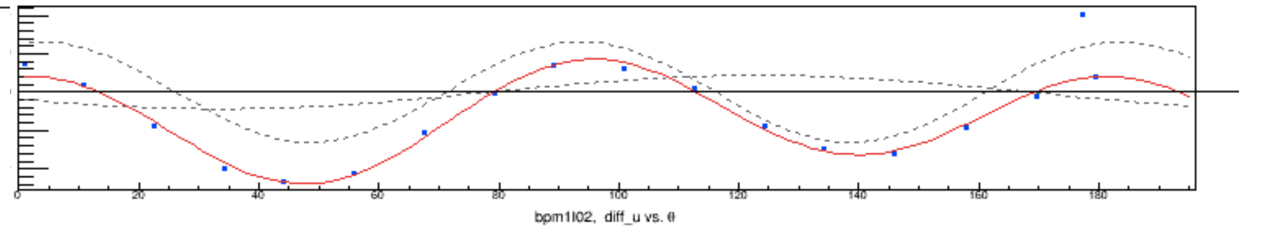


Dy = -1431.65 + -67.85 sin (2θ + 23.97) + 95.74 sin (4θ + 30.38) (nm)

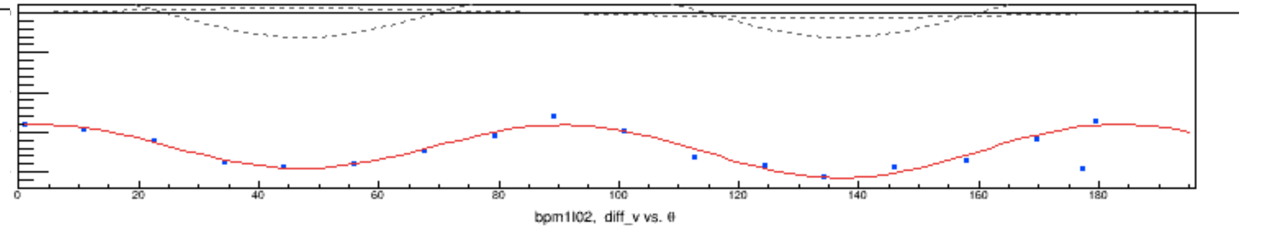
RHWP scan, Run 3304, IHWP OUT, PITA=77, bpm1I02



Aq = -105.18 + -830.96 sin (2θ + 7.45) + 2579.11 sin (4θ + 74.87) (ppm)



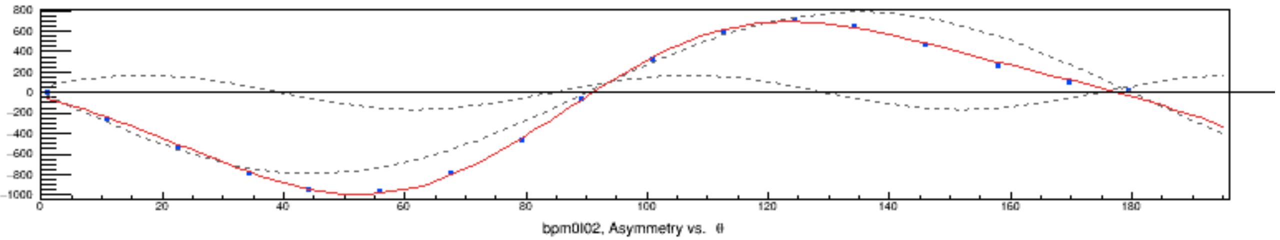
Du = -345.72 + -218.26 sin (2θ + 23.15) + 657.14 sin (4θ + 75.28) (nm)



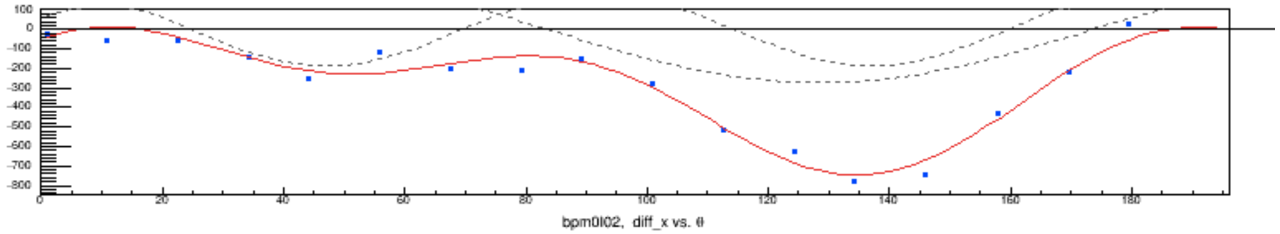
Dv = -1712.11 + -58.52 sin (2θ + 179.54) + 303.92 sin (4θ + 81.85) (nm)

e-beam RHWP scans
Chose RHWP=24counts, then iterated PITA,PITApos

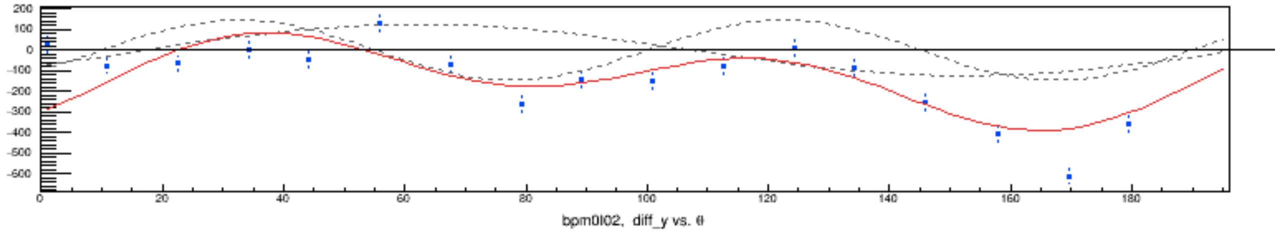
RHWP scan, Run 3335, IHWP OUT, PITA= 53.68, PITAposU= 12.69, PITAposV= 69.00, bpm0I02



Aq = -98.97 + 787.01 sin (2θ + 179.98) + 165.29 sin (4θ + 22.23) (ppm)

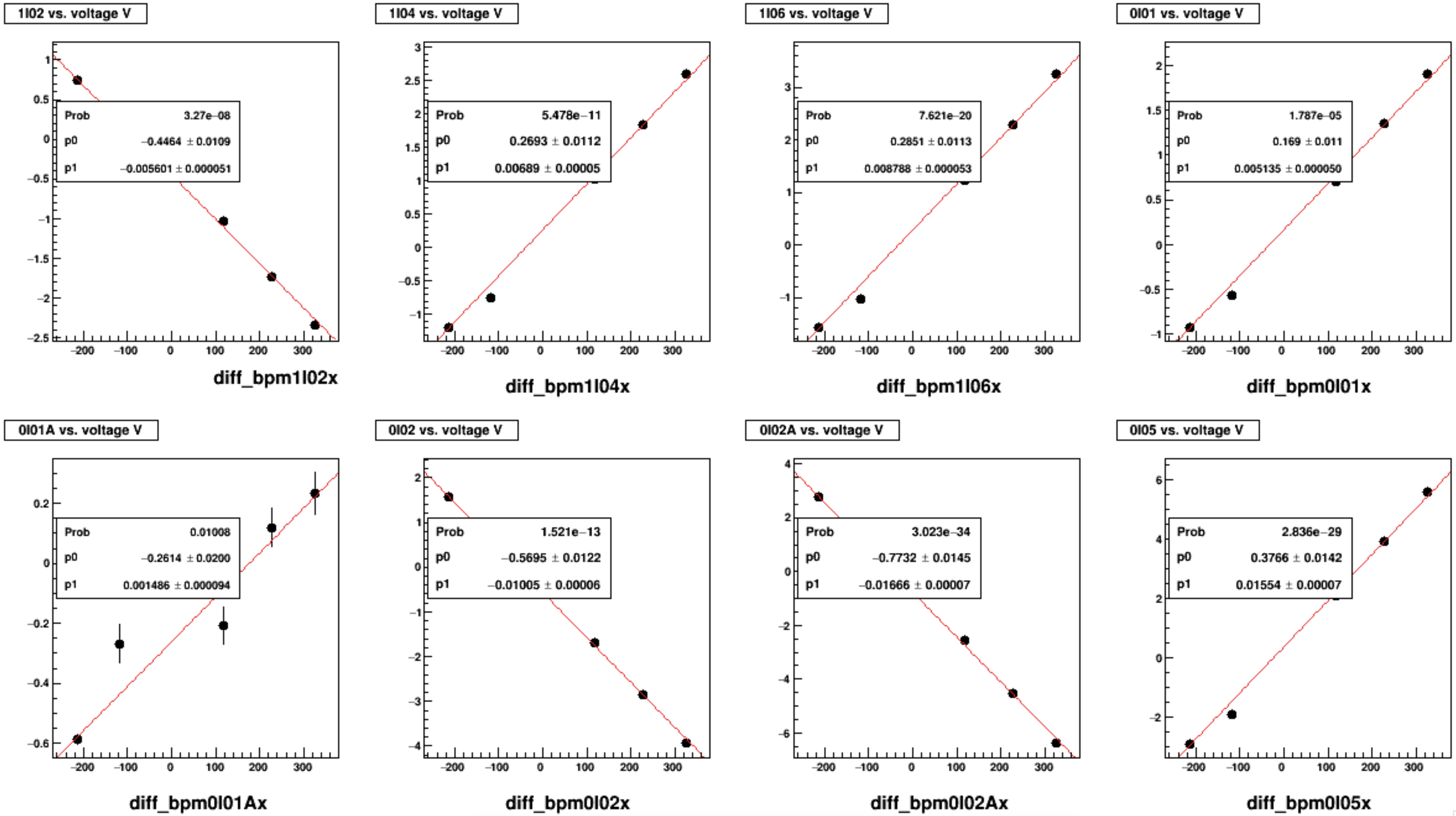


Dx = -295.26 + 273.05 sin (2θ + 12.84) + 187.68 sin (4θ + 82.13) (nm)



Dy = -134.44 + -124.36 sin (2θ + 145.29) + -146.07 sin (4θ + 139.82) (nm)

PITA position voltage scans



Couplings

RTP S1 – RHWP(24steps)

Run3338,3339		PITA		PITAposU			PITAposV		
monitor	units	<slope>	error	<slope> U	std. dev.	error	<slope> V	std. dev.	error
diff_bpm1I02x	nm/V	-17.305	2.158	-5.823	4.31%	3.15%	2.434	8.95%	7.51%
diff_bpm1I04x	nm/V	26.500	2.136	7.238	4.97%	2.56%	-0.542	19.45%	33.61%
diff_bpm1I06x	nm/V	-0.107	2.124	9.001	2.23%	2.05%	-0.143	74.52%	127.39%
diff_bpm0I01x	nm/V	-1.612	2.076	5.354	5.18%	3.34%	0.154	108.75%	115.85%
diff_bpm0I01Ax	nm/V	33.632	3.870	1.486	15.43%	22.16%	0.321	112.23%	102.53%
diff_bpm0I02x	nm/V	-10.873	2.265	-10.581	0.98%	1.88%	1.032	19.53%	19.06%
diff_bpm0I02Ax	nm/V	-35.798	2.674	-17.335	2.16%	1.35%	2.296	19.48%	10.10%
diff_bpm0I05x	nm/V	24.757	2.707	16.444	2.70%	1.41%	0.097	153.34%	239.97%
diff_bpm1I02y	nm/V	29.495	2.139	-3.364	6.84%	5.46%	-4.704	3.82%	3.88%
diff_bpm1I04y	nm/V	11.256	2.365	0.738	32.20%	27.00%	7.708	1.03%	2.54%
diff_bpm1I06y	nm/V	50.118	2.402	1.412	13.86%	14.35%	6.896	2.38%	2.93%
diff_bpm0I01y	nm/V	3.037	2.184	0.810	8.96%	23.92%	1.665	6.28%	11.14%
diff_bpm0I01Ay	nm/V	-2.484	3.265	0.448	17.00%	60.86%	-1.777	7.98%	15.22%
diff_bpm0I02y	nm/V	11.773	3.009	-0.840	58.42%	30.44%	-12.659	3.84%	1.98%
diff_bpm0I02Ay	nm/V	-38.682	3.607	-1.075	42.96%	28.74%	-17.615	2.29%	1.75%
diff_bpm0I05y	nm/V	3.120	3.125	2.083	9.21%	12.93%	13.885	2.12%	1.94%
asym_bpm1I02ws	ppm/V	124.202	0.208	0.123	23.35%	11.00%	-0.008	287.46%	161.52%
asym_bpm1I04ws	ppm/V	122.884	0.193	0.116	19.14%	10.82%	-0.007	271.14%	166.21%
asym_bpm1I06ws	ppm/V	122.836	0.204	0.150	14.99%	8.90%	0.008	235.29%	155.94%
asym_bpm0I01ws	ppm/V	123.443	0.206	0.144	19.71%	9.73%	0.007	278.14%	196.83%
asym_bpm0I01Aws	ppm/V	123.571	0.207	0.161	14.79%	8.55%	0.022	98.82%	61.90%
asym_bpm0I02ws	ppm/V	120.320	0.196	0.147	19.29%	9.10%	0.014	182.24%	93.28%
asym_bpm0I02Aws	ppm/V	122.364	0.194	0.130	21.96%	10.07%	-0.002	1174.30%	575.04%
asym_bpm0I05ws	ppm/V	121.954	0.189	0.147	12.74%	8.63%	0.018	97.29%	68.37%

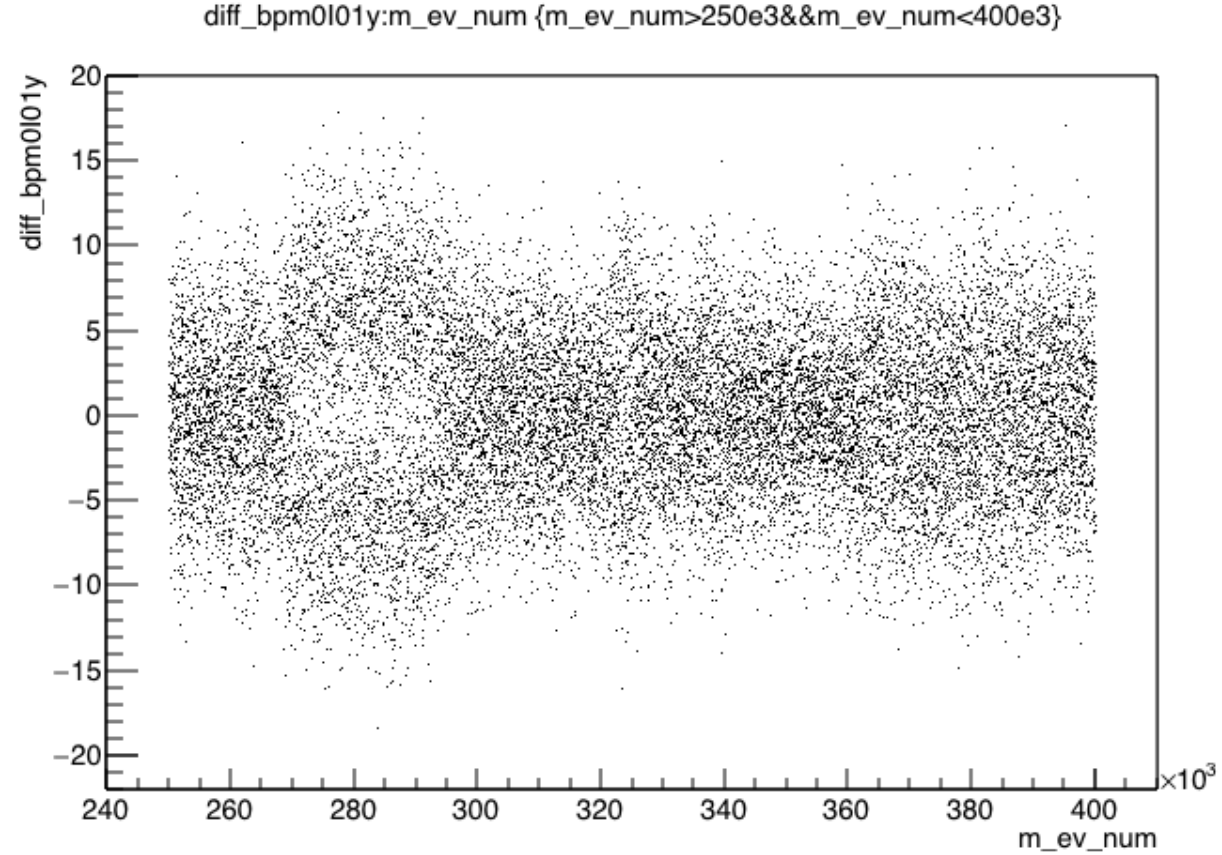
Bpm RMS noise for the RTP

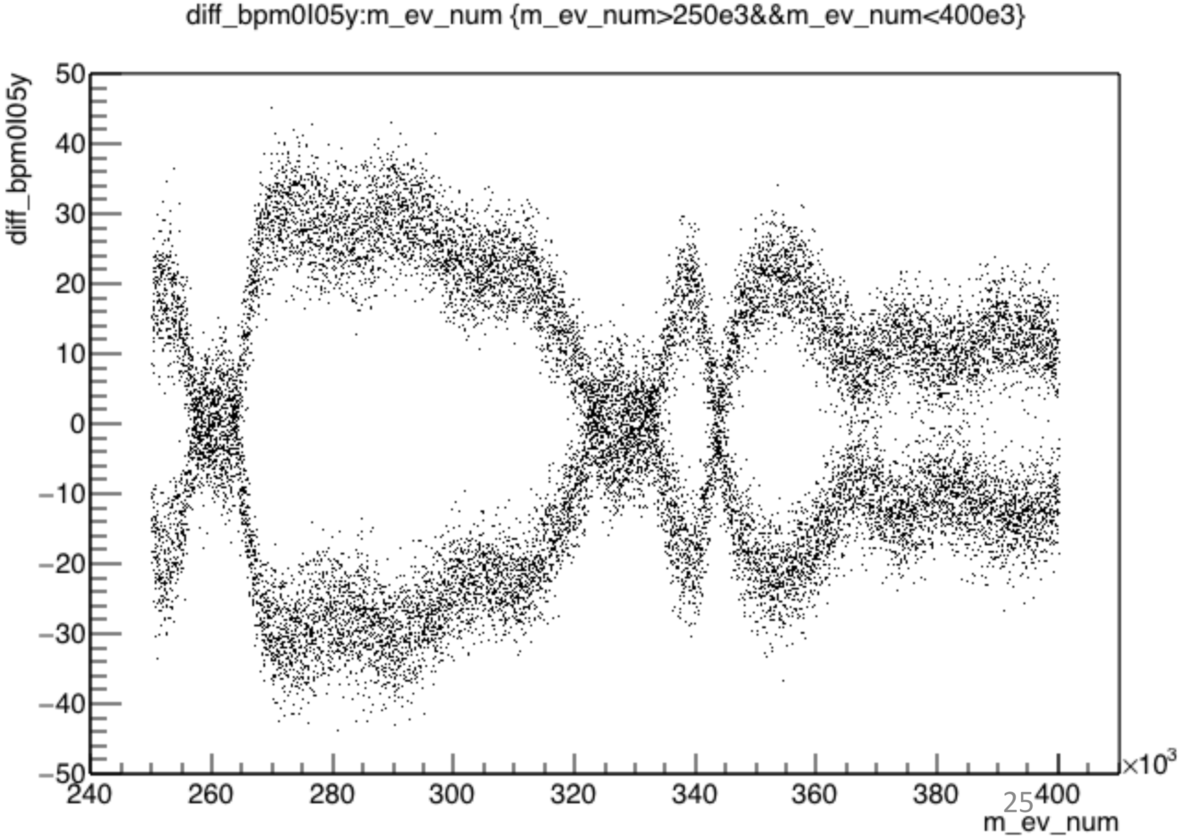
Noise Table

S1 RHWP 2.25deg	Aq RMS (ppm) Mtree	Dx ,yRMS (um) Mtree	# samples per block , pattern	N	Aq RMS sqrt(N) (ppm) [RMS/sample]	Dx,y RMS sqrt(N) (um) [RMS/sample]	Time to get 10nm precision (min)
KD*P 30Hz RHWP 56.2	100-(170)	1.5-(8)	4141, quad	66256	25740-(43758)	386-(2059)	50-(1422)
KD*P 240Hz RHWP 59.4	185-(195)	2.2-(3.5)	495, octet	15840	23284-(24542)	277-(441)	27-(68)
RTP 240Hz RHWP 1	75-(95)	1.7-(2.9)	512, octet	16384	9600-(12160)	218-(371)	16-(47)
KD*P 960Hz RHWP 59.4	230-(285)	5-(17)	107, octet	3424	13458-(16677)	293-(995)	34-(401)
RTP 960HZ RHWP 1	140-(200)	4-(19)	120, octet	3840	8675-(12394)	248-(1177)	22-(501)

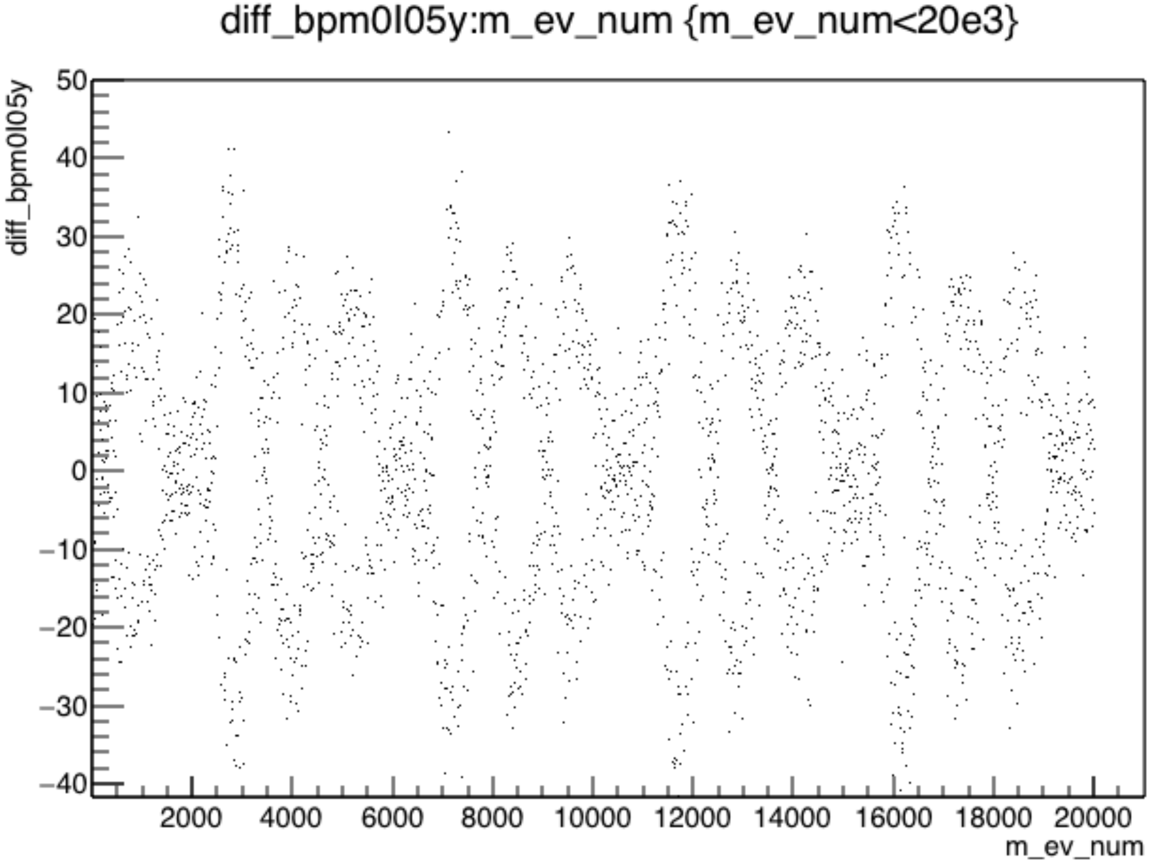
Some of the RMS may not be normal noise

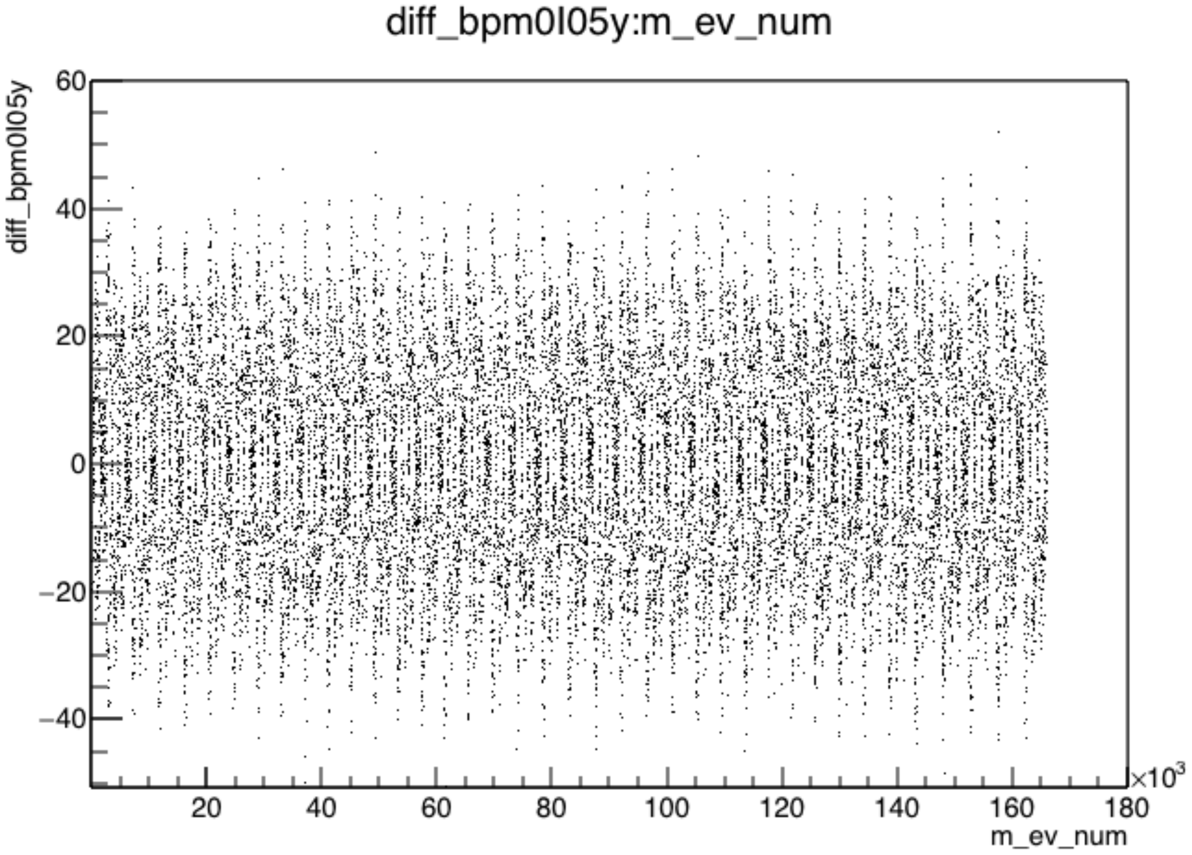
- Run3330 , 960Hz Mtree, Free clock, 40us Tsettle, 1001.65usec Tstable, Octet, No Delay, 960.02Hz → periodicity >150e3 events, T >156s, <0.0064Hz beat and (960-960.02Hz)/8=0.0025Hz
- vqwk SamplesPerBlock=120, GateDelay=10, NumberofBlocks=4 (2us/sample)





- 960Hz, KD*P, Run3449, Mtree, -Free clock, T-settle-140us, T-stable-900usec, octet, no delay--> 961.54Hz-> periodicity ~4000 events, T 4.17s, 0.234Hz beat and (960-961.54Hz)/8=0.19Hz
- vqwk SamplesPerBlock=107, GateDelay=10, NumberofBlocks=4 (2us/sample)





Zeroing Position Differences

Which bpms work best for minimizing the rest?

- Took ‘best’ case measurement with <100nm pos diffs in 1st 8 bpms
- Found for each bpm a PITA,PITAposU,PITAposV which would zero it out
- Extrapolated from measured position differences using PITApos couplings
- Found bpm0I05 worked the ‘best’

Example bpm1I02…this is what a Aq,Dx,Dy feedback script might do

For a 3×3 matrix

$$A \equiv \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix},$$

the matrix inverse is

$$A^{-1} = \frac{1}{|A|} \begin{bmatrix} \begin{vmatrix} a_{22} & a_{23} \\ a_{32} & a_{33} \end{vmatrix} & \begin{vmatrix} a_{13} & a_{12} \\ a_{33} & a_{32} \end{vmatrix} & \begin{vmatrix} a_{12} & a_{13} \\ a_{22} & a_{23} \end{vmatrix} \\ \begin{vmatrix} a_{23} & a_{21} \\ a_{33} & a_{31} \end{vmatrix} & \begin{vmatrix} a_{11} & a_{13} \\ a_{31} & a_{33} \end{vmatrix} & \begin{vmatrix} a_{13} & a_{11} \\ a_{23} & a_{21} \end{vmatrix} \\ \begin{vmatrix} a_{21} & a_{22} \\ a_{31} & a_{32} \end{vmatrix} & \begin{vmatrix} a_{12} & a_{11} \\ a_{32} & a_{31} \end{vmatrix} & \begin{vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{vmatrix} \end{bmatrix}.$$

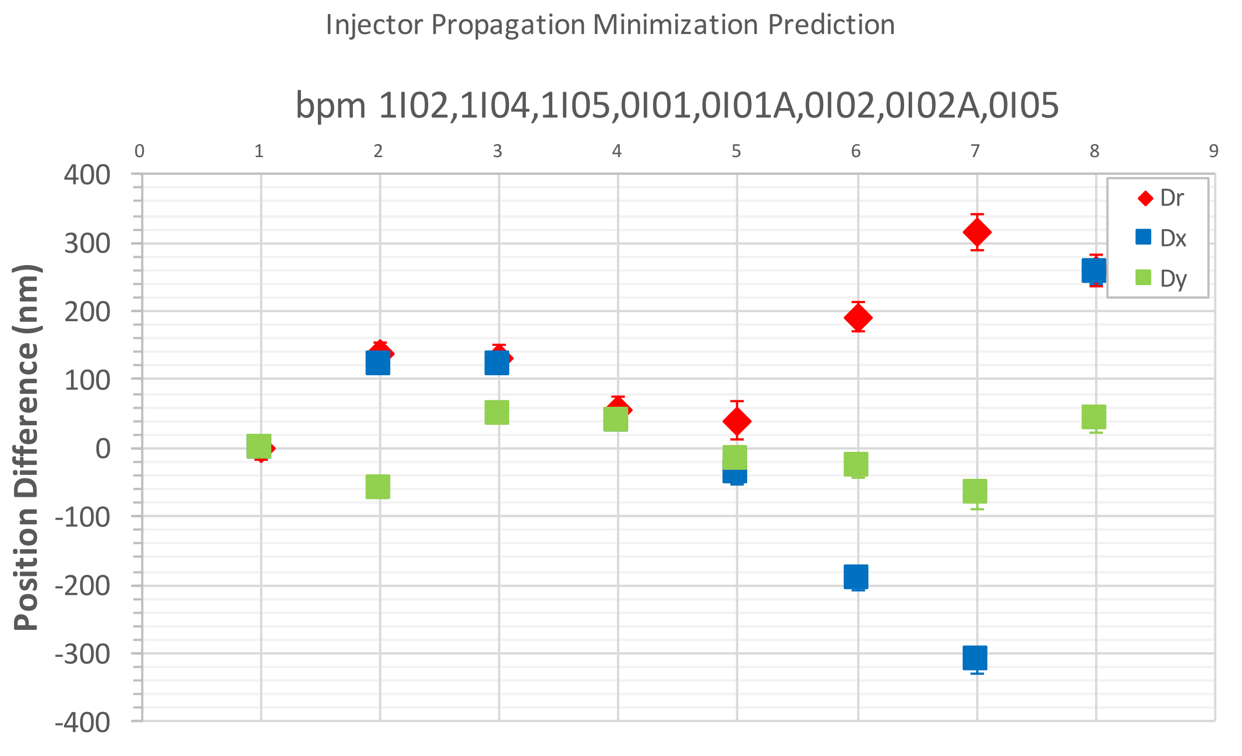
M(v-v0)+p0=p=0
v=-Minv*p0 + v0

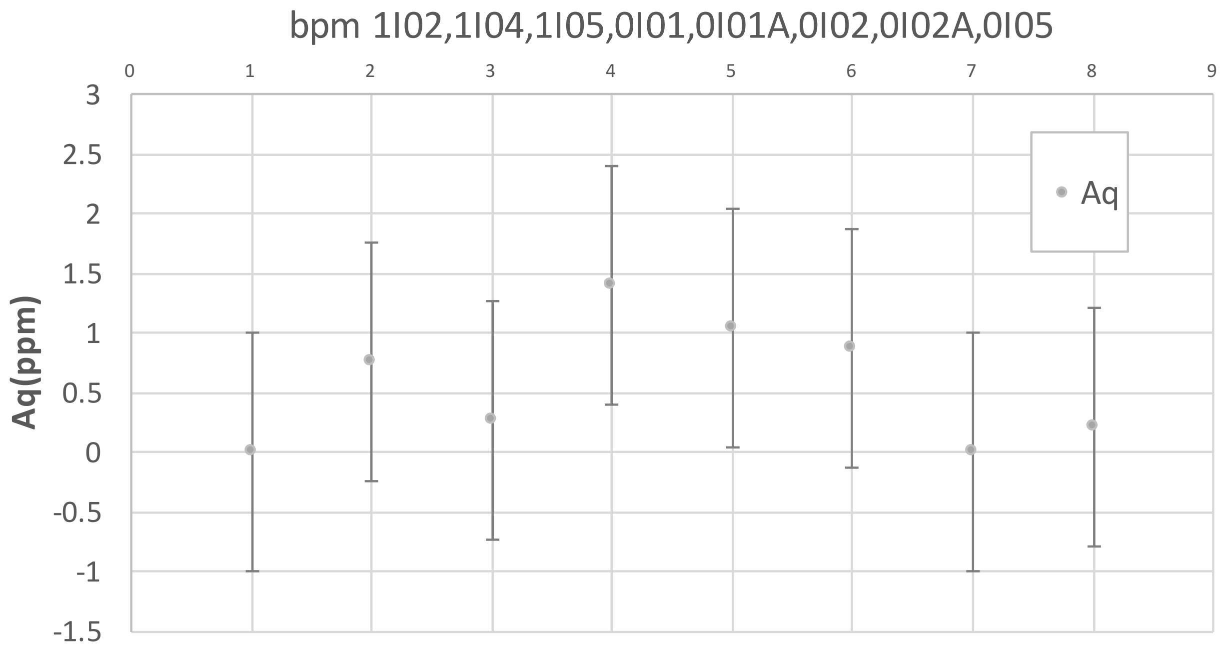
$$\begin{vmatrix} a_1 & a_2 & a_3 \\ b_1 & b_2 & b_3 \\ c_1 & c_2 & c_3 \end{vmatrix} = a_1\, b_2\, c_3 - a_1\, b_3\, c_2 - a_2\, b_1\, c_3 + a_2\, b_3\, c_1 + a_3\, b_1\, c_2 - a_3\, b_2\, c_1\,.$$

			M				p0	ep0		v0
pita	*I,x,y*	bpm1I02	124.202	-17.305	29.4954	*i*	4.69787	0.601403	*pita*	54.5
u			0.1225571	-5.82291	-3.36447	*x*	69.8413	11.7968	*pitaposu*	12.69
v			-0.008347317	2.433733333	-4.703653333	*y*	77.3772	11.8645	*pitaposv*	70.98

Minimize bpm1I02 <Dr>=141nm

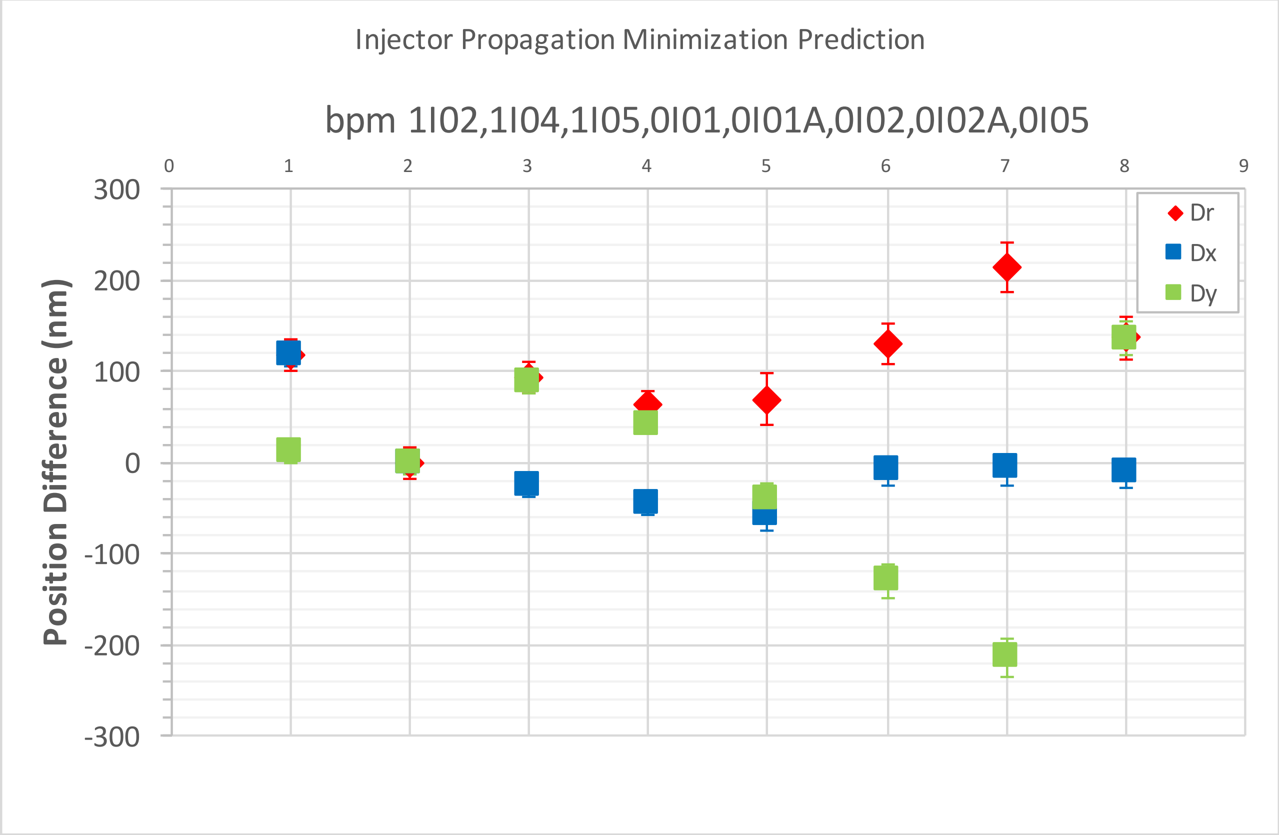
new v	
54.448212	*pita*
27.2308564	*pitaposu*
76.704788	*pitaposv*

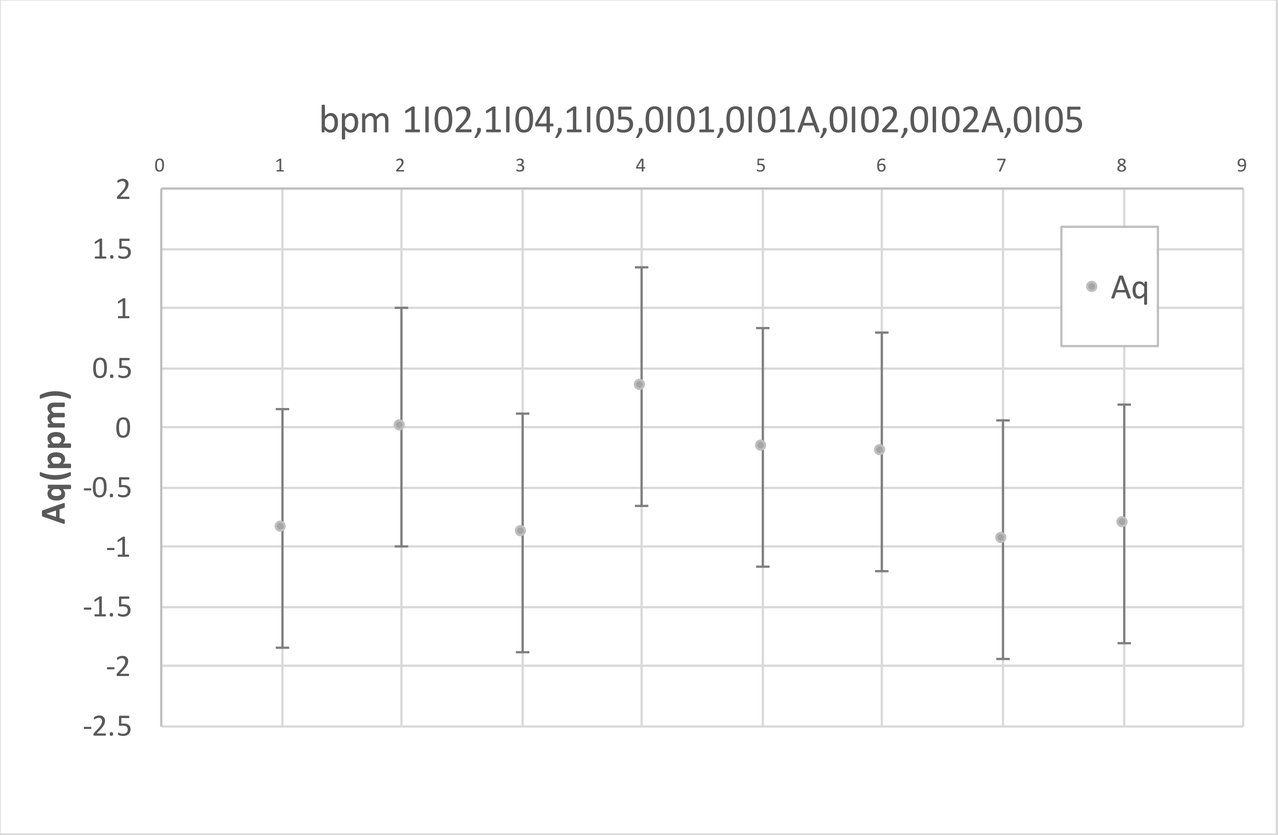




Minimize bpm 1I04 <Dr>=103nm

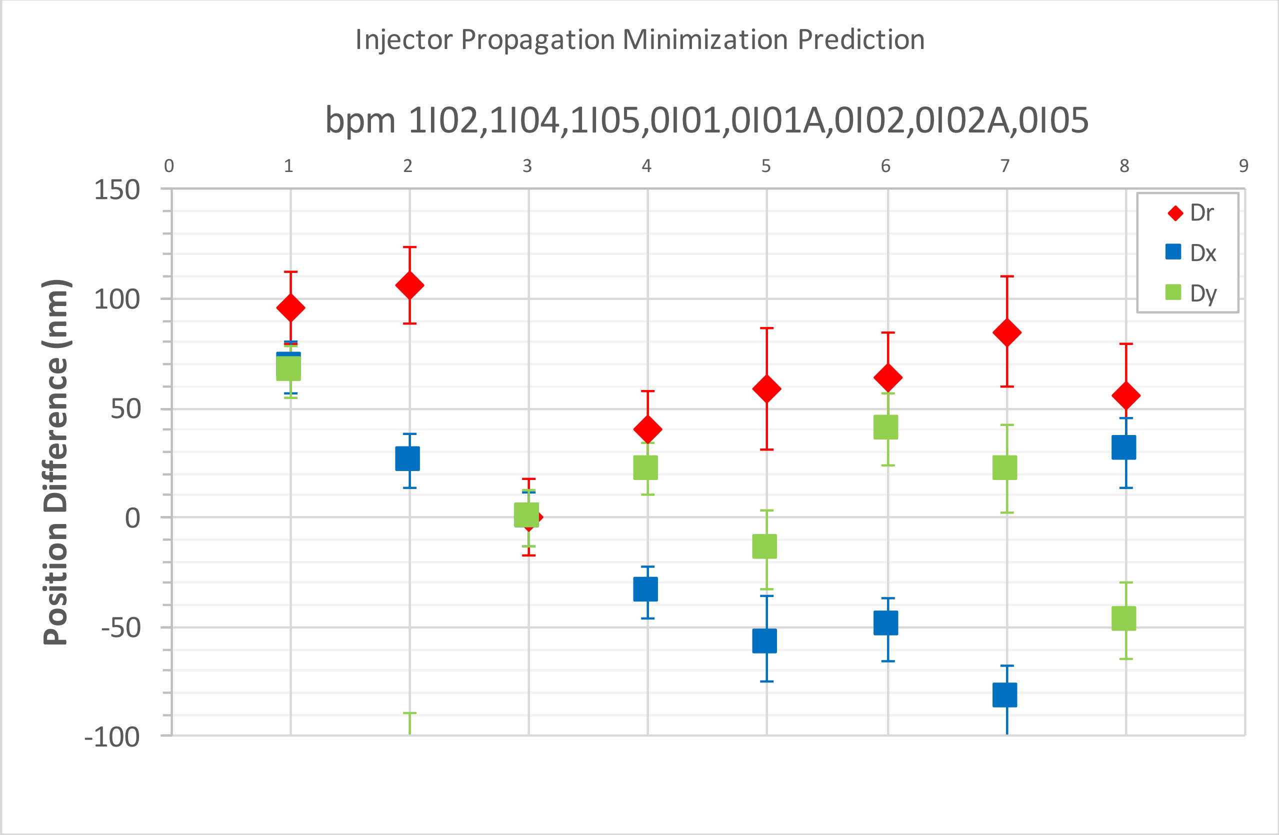
new v	
54.4579816	*pita*
10.983974	*pitaposu*
85.9710733	*pitaposv*

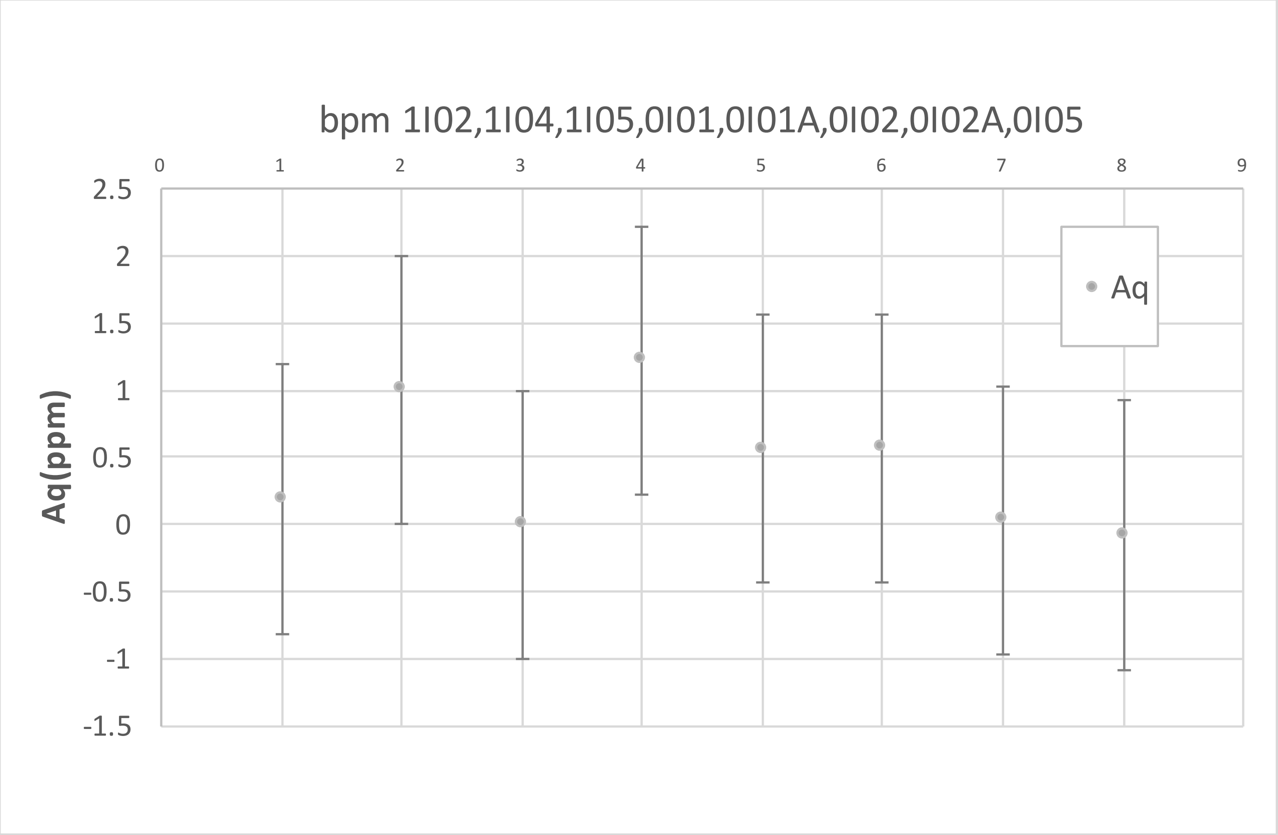




Minimize bpm1I06 <Dr>=63nm

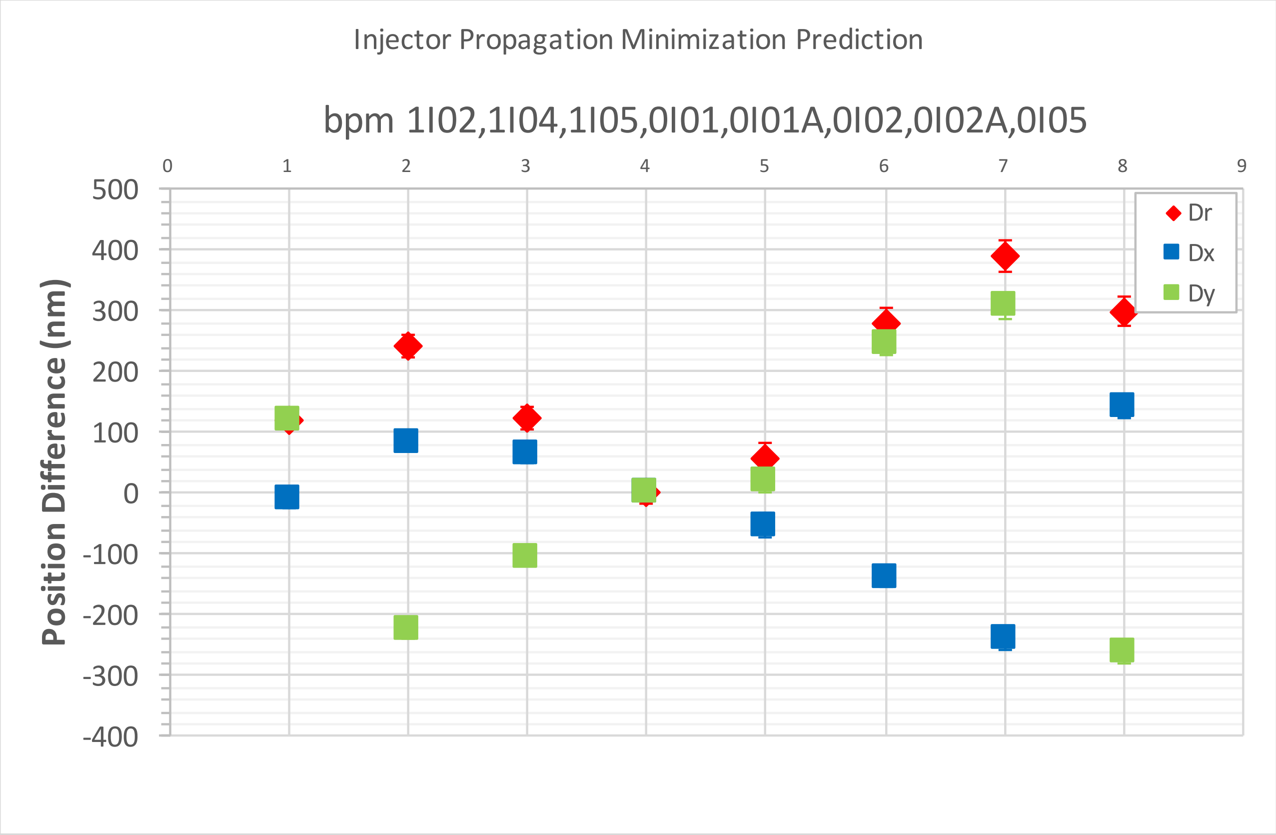
new v	
54.4629348	*pita*
13.5544118	*pitaposu*
72.4070407	*pitaposv*

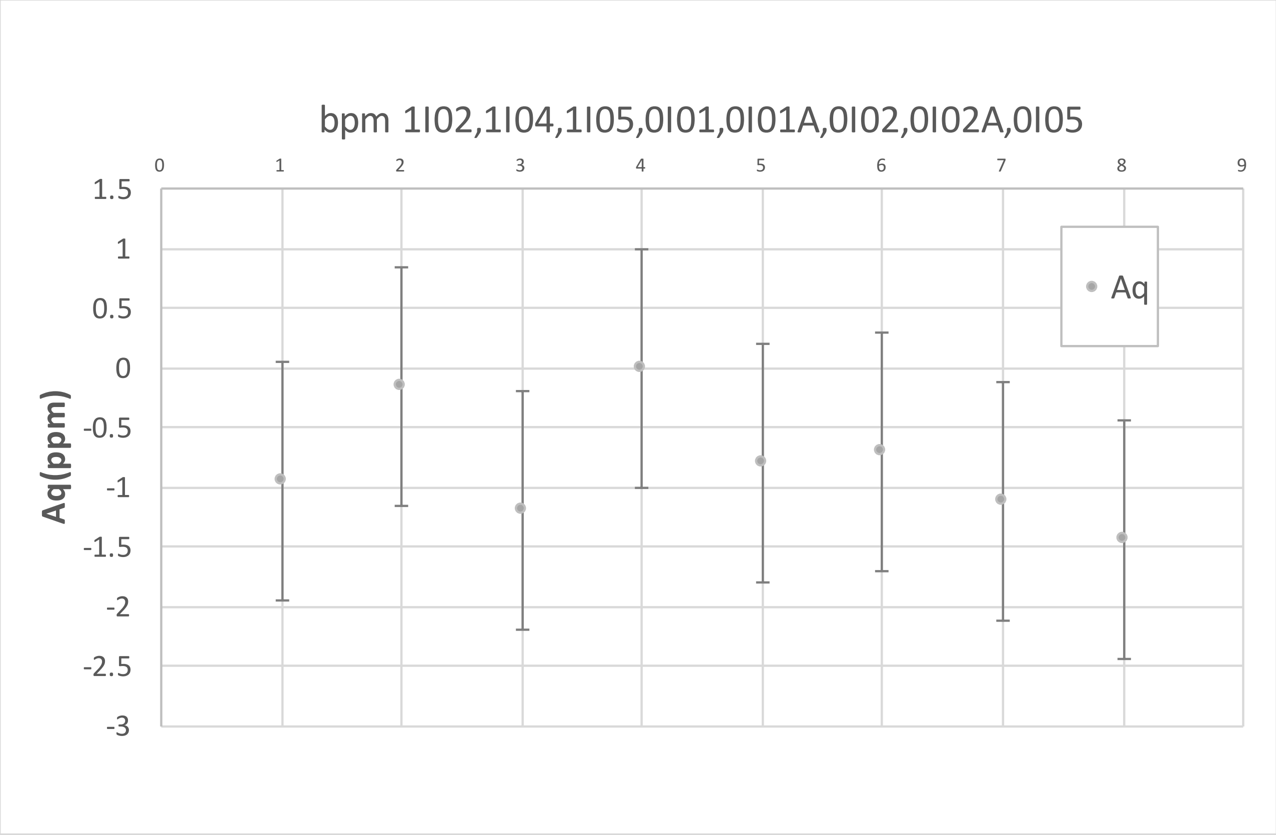




Minimize bpm0I01 <Dr>=189nm

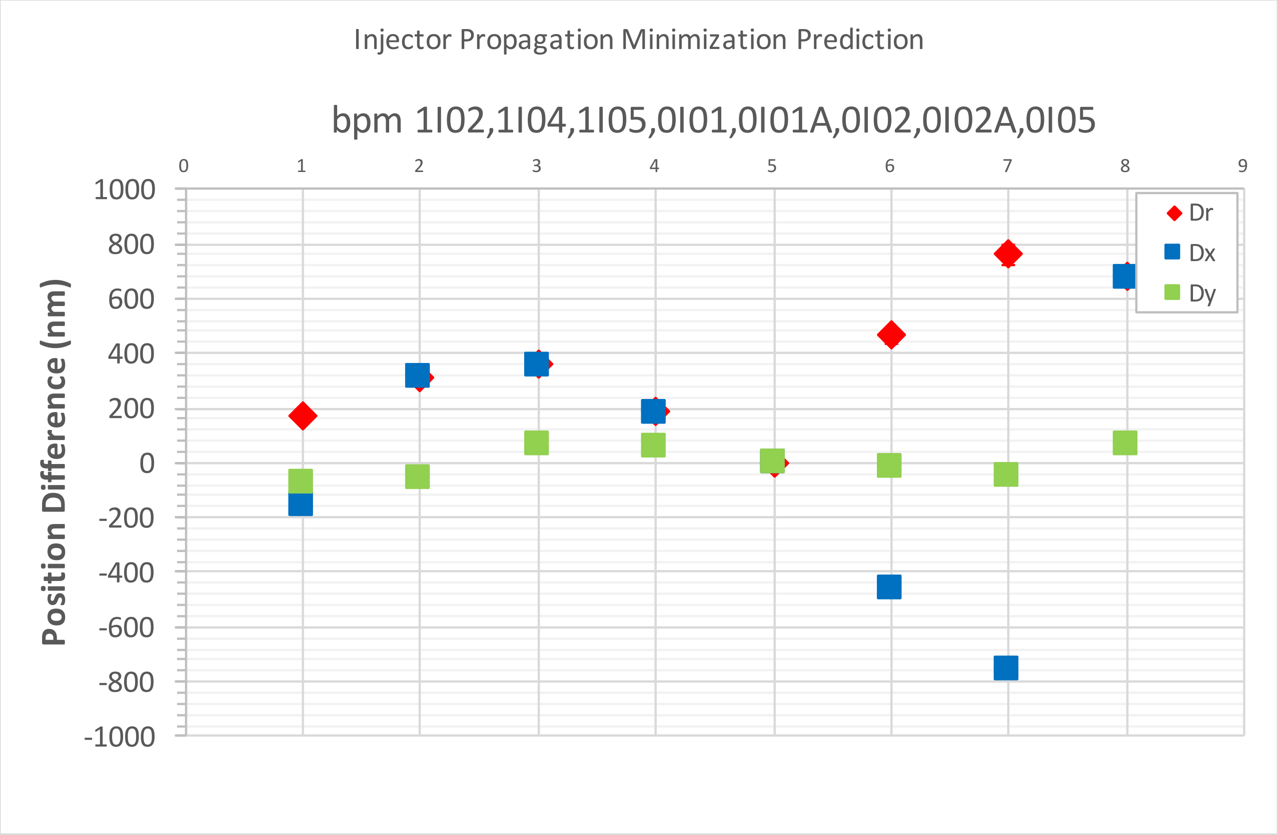
new v	
54.4459592	*pita*
20.414738	*pitaposu*
55.8316595	*pitaposv*

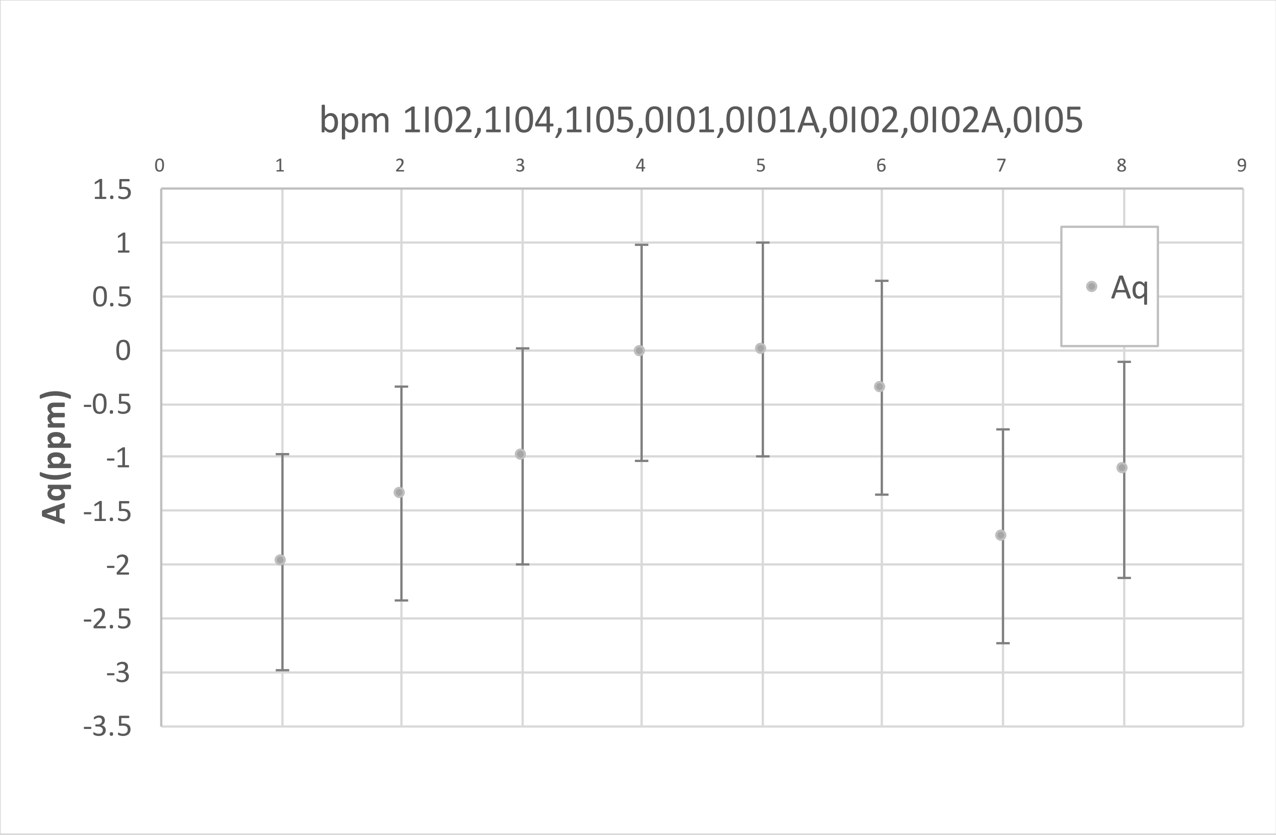




Minimize bpm0I01A <Dr>=367nm

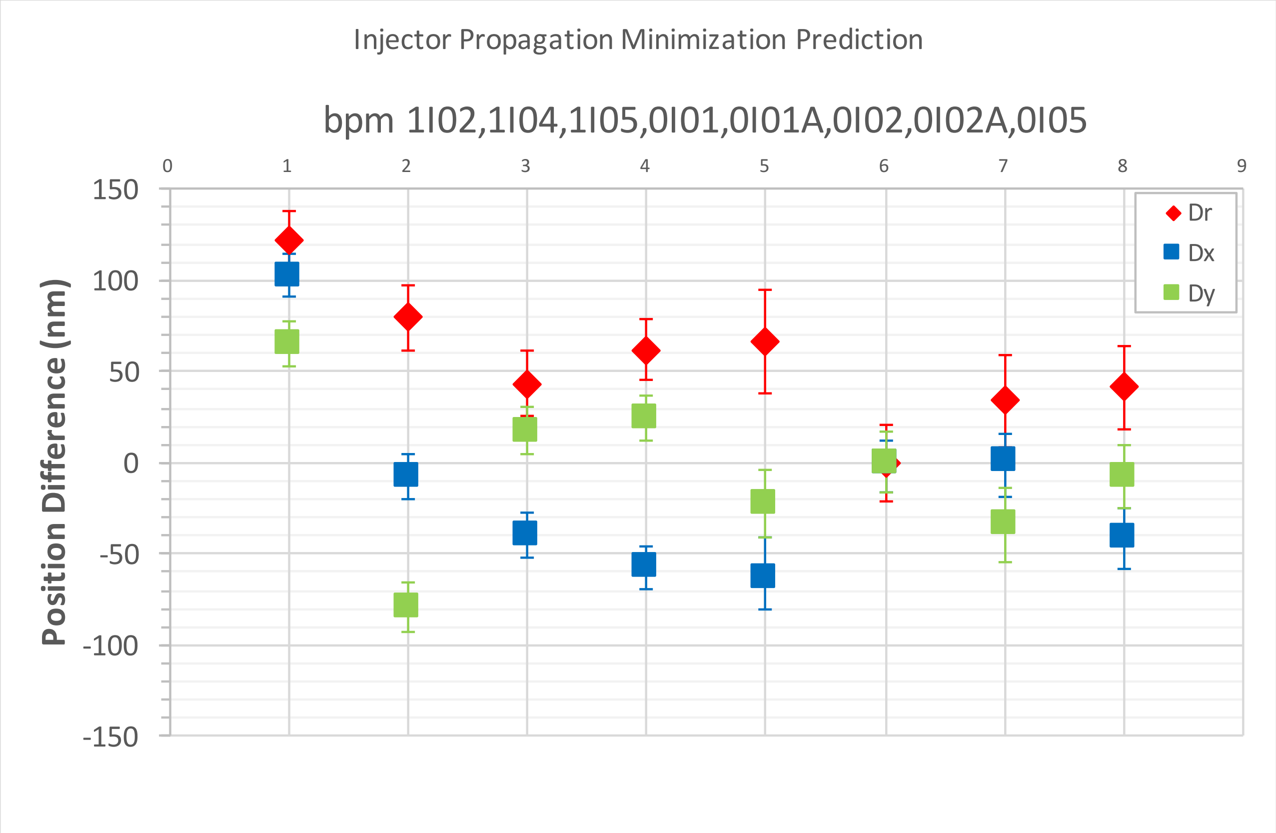
new v	
54.406771	*pita*
52.9186379	*pitaposu*
74.2563103	*pitaposv*

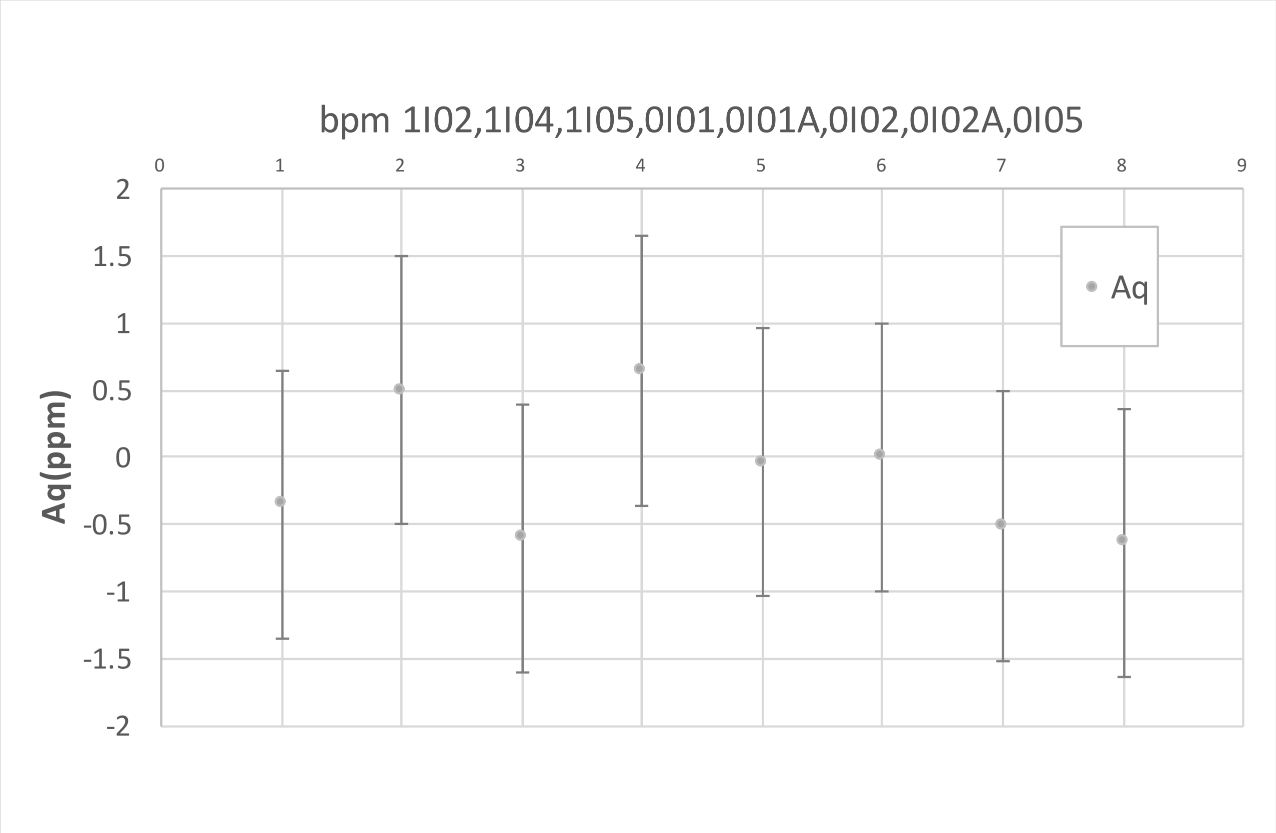




new v	
54.463109	*pita*
9.21076247	*pitaposu*
75.8551381	*pitaposv*

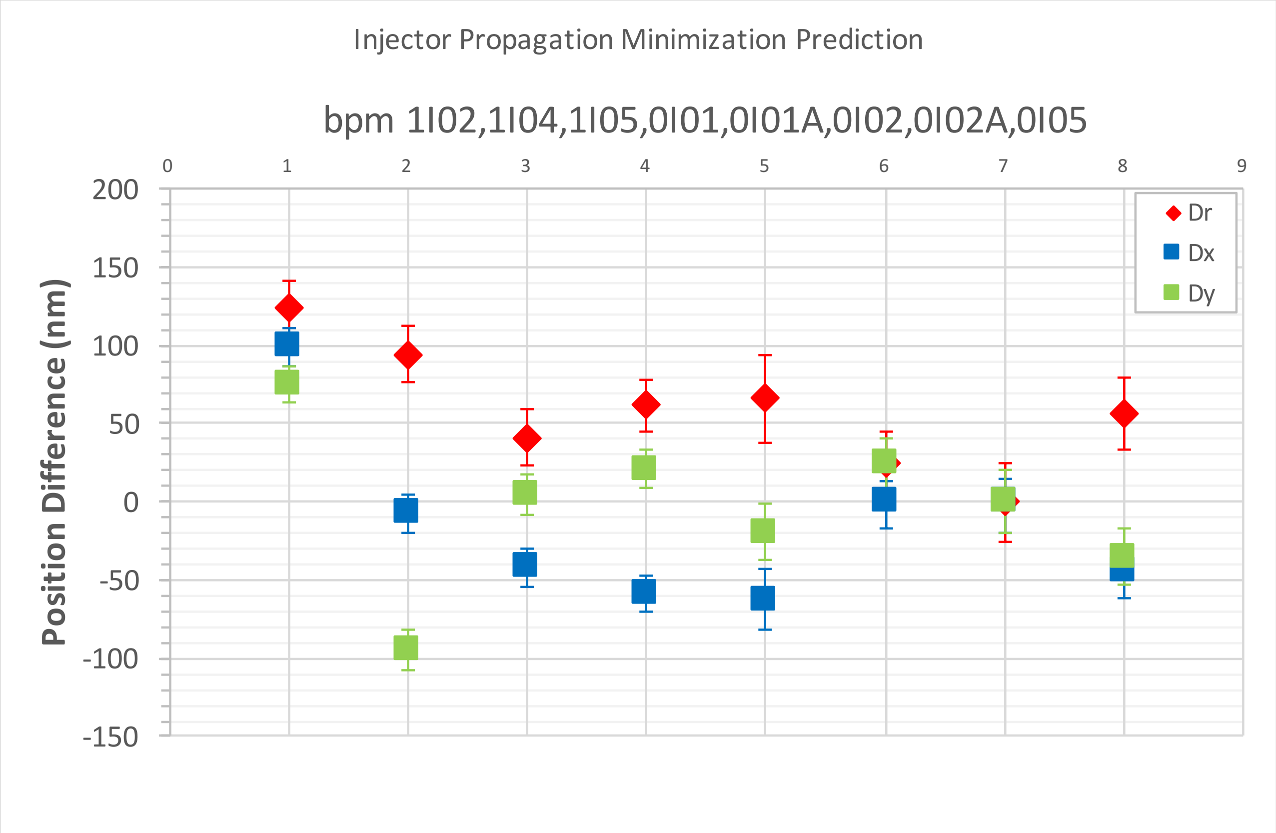
Minimize bpm0I02 <Dr>=56nm

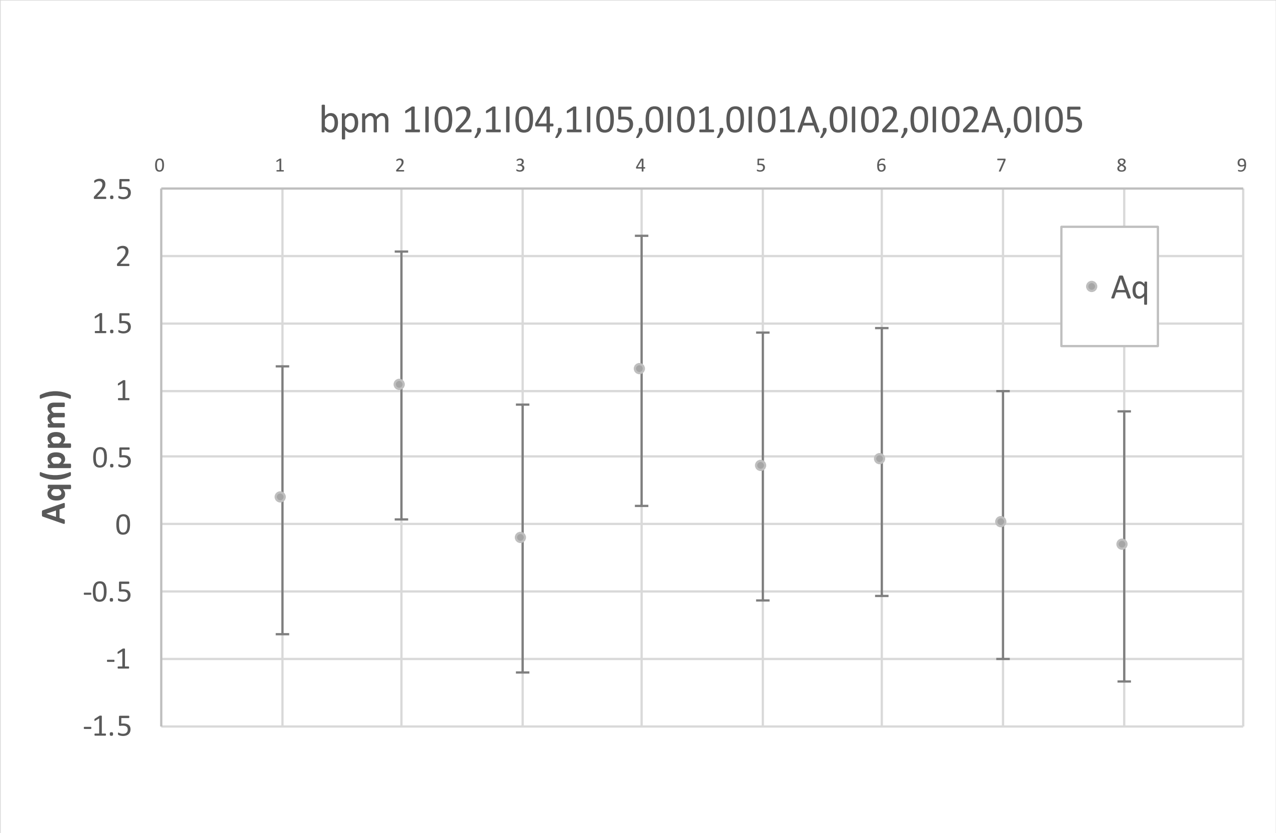




Minimize bpm0I02A <Dr>=59nm

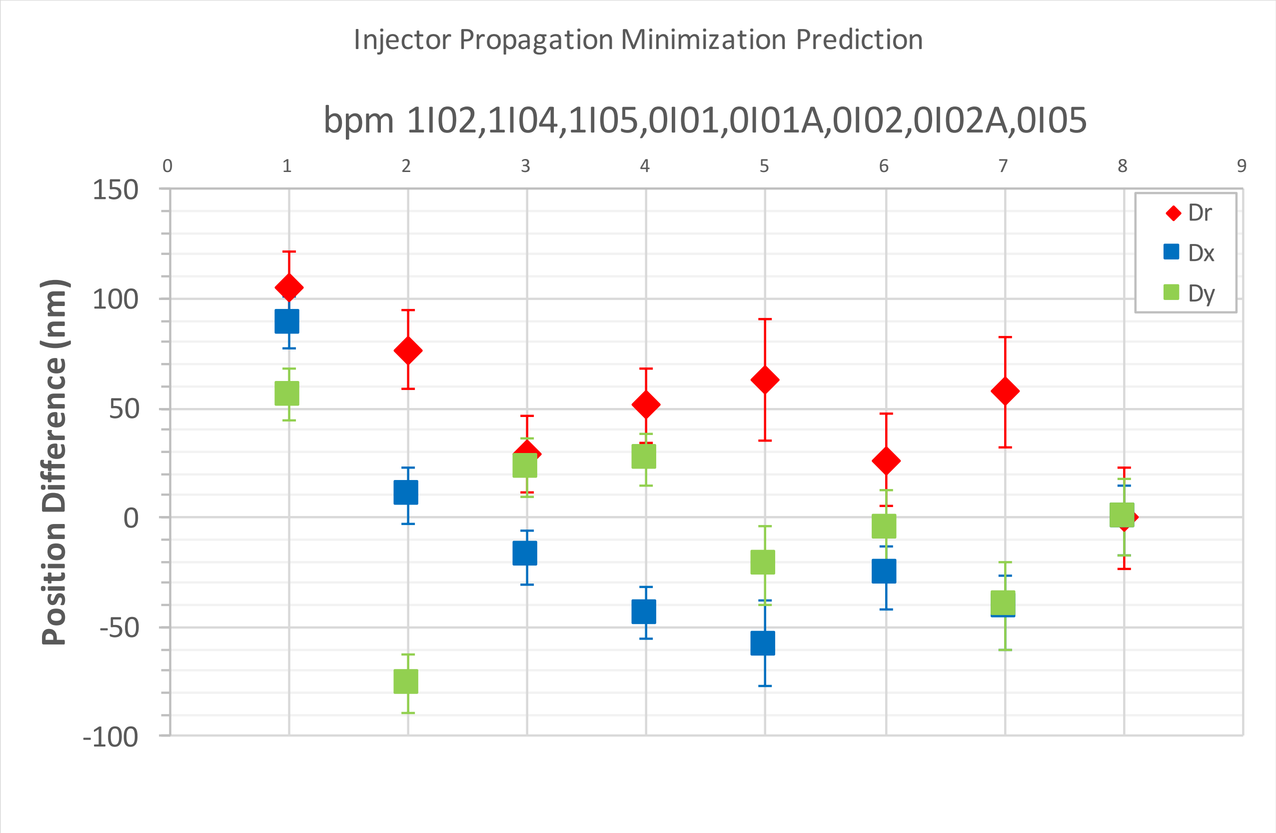
new v	
54.4674877	*pita*
9.01563217	*pitaposu*
73.9364543	*pitaposv*

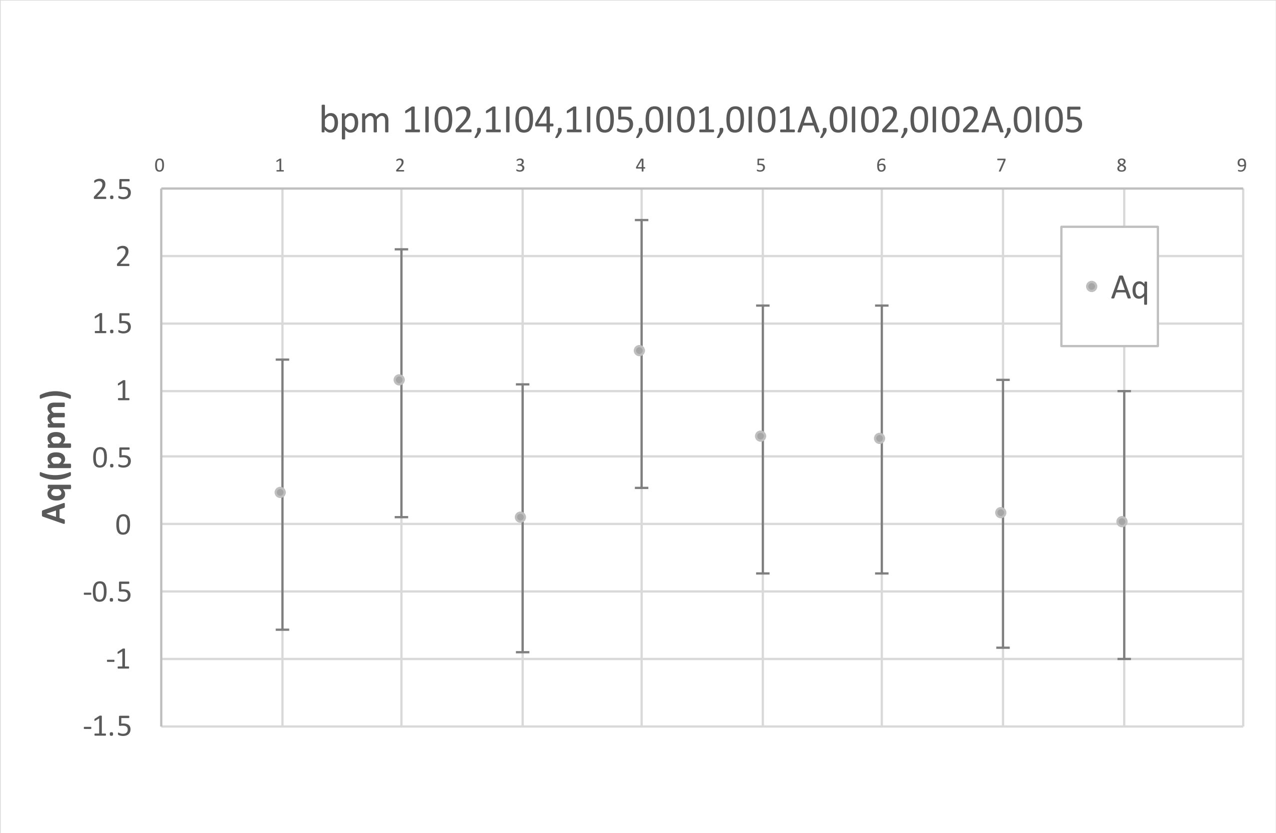




Minimize bpm0I05 <Dr>=51nm

new v	
54.4653136	*pita*
11.6694716	*pitaposu*
76.0573307	*pitaposv*





Which bpms work best for minimizing the rest?

ANSWER: The ones with the larger PITApos slopes

Couplings before solenoid flip

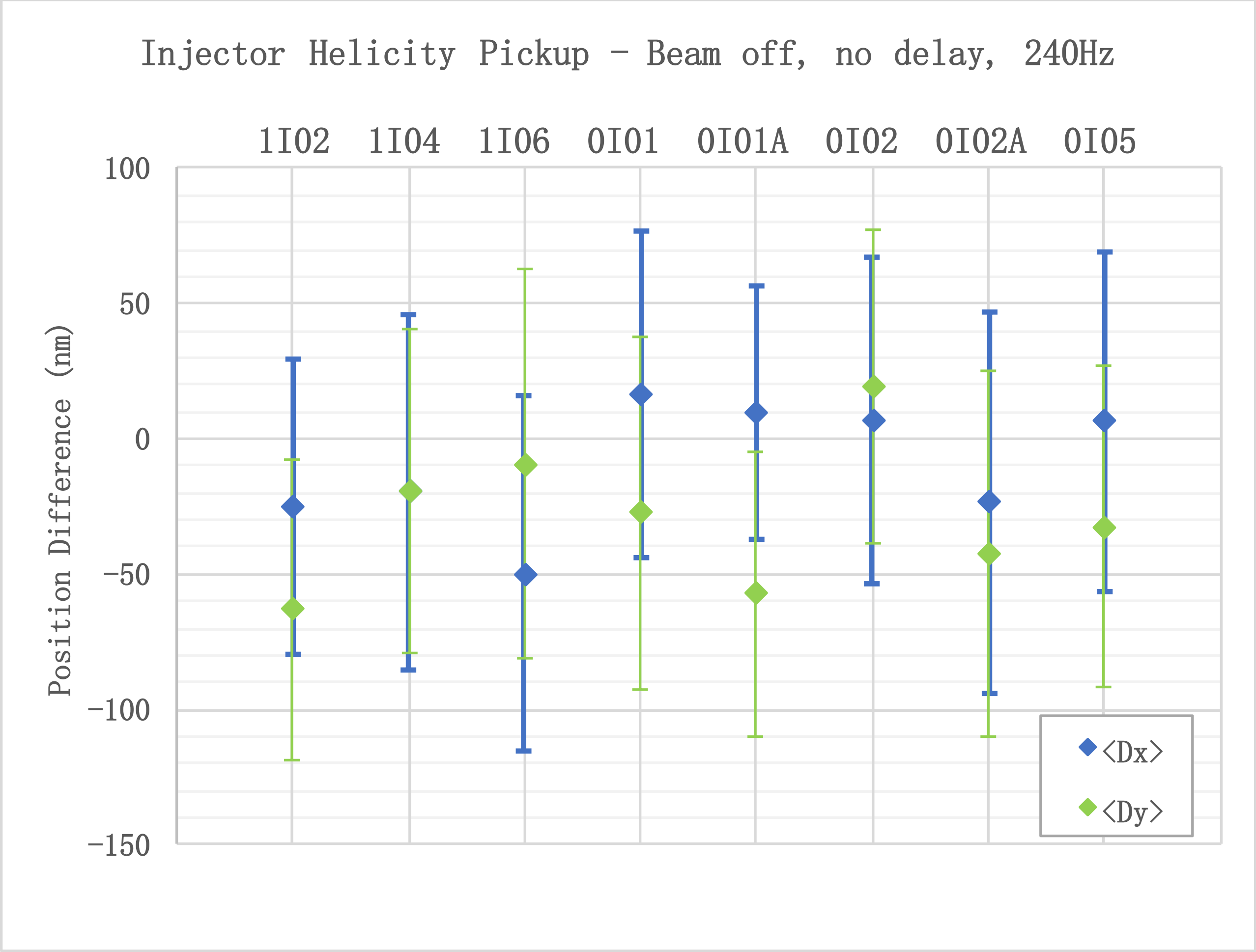
IHWP out, S1, Run3339

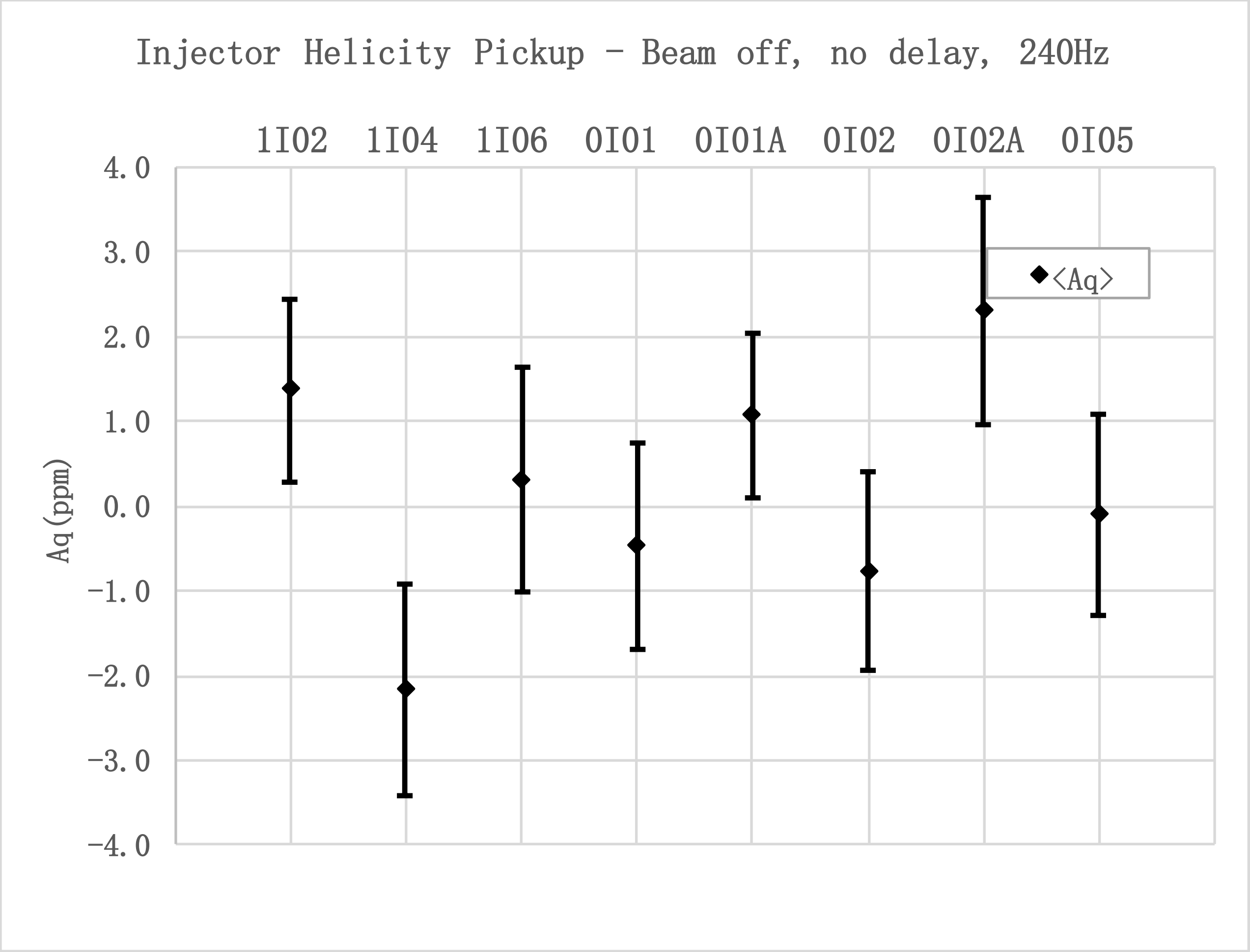
nm/V	PITAposU	PITAposV		PITAposU	PITAposV		<Dr> when minimized
Dx ~ laser	-4.75	4.80	Dr ~ laser	**7.1**	**5.7**	nm/V	
Dy ~ laser	5.26	3.11	theta laser	**-48.0**	**33.0**	deg	
Dx 1I02	-5.47	2.736	Dr 1I02	**6.3**	**5.2**	nm/V	141.24nm
Dy 1I02	-3.057	-4.475	theta 1I02	**29.2**	**-58.6**	deg	
Dx 1I04	7.74	-0.5879	Dr 1I04	**7.8**	**7.8**	nm/V	102.89nm
Dy 1I04	1.068	7.768	theta 1I04	**7.9**	**-85.7**	deg	
Dx 1I06	9.29	0.005337	Dr 1I06	**9.4**	**6.9**	nm/V	63.25nm
Dy 1I06	1.563	6.89	theta 1I06	**9.6**	**90.0**	deg	
Dx 0I01	4.956	0.3933	Dr 0I01	**5.0**	**1.8**	nm/V	366.97nm
Dy 0I01	0.7354	1.794	theta 0I01	**8.4**	**77.6**	deg	
Dx 0I01A	1.502	0.7162	Dr 0I01A	**1.5**	**2.1**	nm/V	55.99nm
Dy 0I01A	0.3452	-1.976	theta 0I01A	**12.9**	**-70.1**	deg	
Dx 0I02	-10.64	1.291	Dr 0I02	**10.6**	**12.1**	nm/V	55.99nm
Dy 0I02	-0.1681	-12.01	theta 0I02	**0.9**	**-83.9**	deg	
Dx 0I02A	-17.62	2.765	Dr 0I02A	**17.6**	**17.3**	nm/V	58.56nm
Dy 0I02A	-0.4113	-17.04	theta 0I02A	**1.3**	**-80.8**	deg	
Dx 0I05	17.04	0.1174	Dr 0I05	**17.2**	**13.6**	nm/V	50.94nm
Dy 0I05	1.996	13.55	theta 0I05	**6.7**	**89.5**	deg	

But why are there different offsets in Dx,Dy along injector beamline?

- Offset == a non-zero position difference in a bpm when another bpm is zeroed out
- Helicity Pickup in DAQ – 20hours of beam off data, no-delay, haven't yet ruled out +-60nm of pickup…
- Helicity pickup in beamline – could assess this with a PC off run: turn of KD*P, run beam, examine Aq,Dx,Dy
- Apertures – Aq varies along the beamline, there are apertures and the chopper, these things might also affect pos diffs
- The ability to have zero position difference on the cathode, but non-zero angle difference off the cathode
- The cathode 'knowing' the difference between analyzing-like position differences and position like position differences

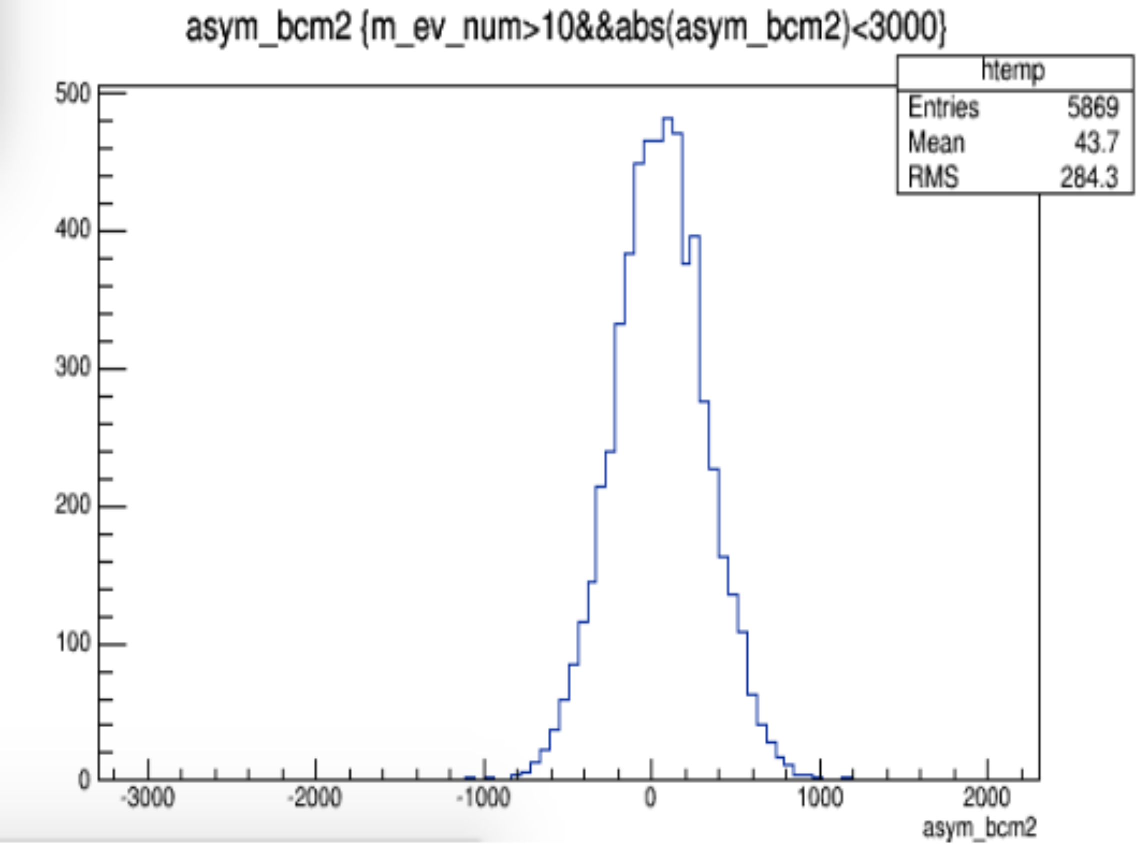
Helicity pickup in DAQ?



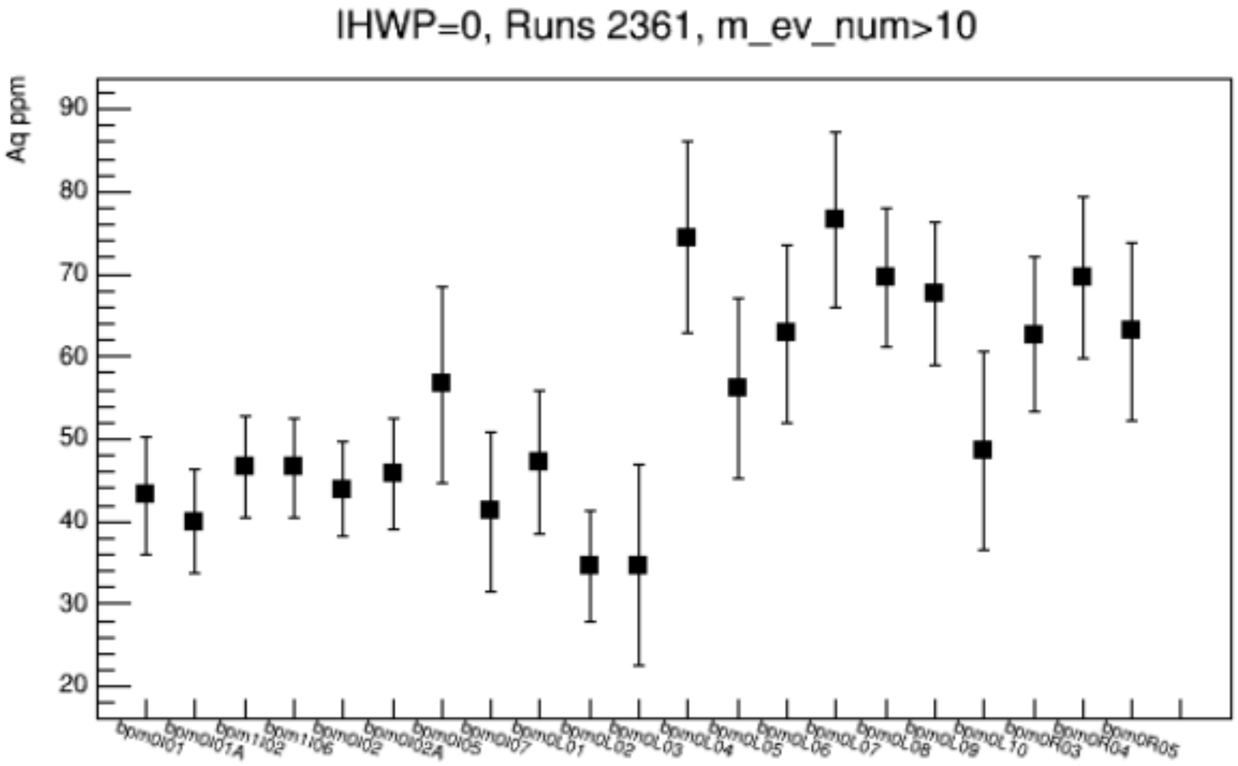


PC off -Injector

- Charge asymmetry according to BCM 0L02 is 44ppm even with PC off

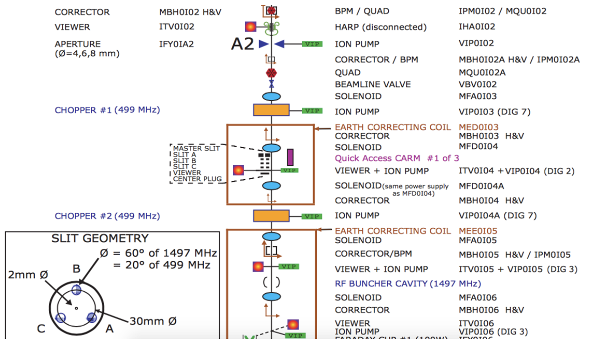


Run2361_PCoff_HallClaser_IHWPout_RHWP0deg_Oct202016_asymbcm2_0l02_44ppm



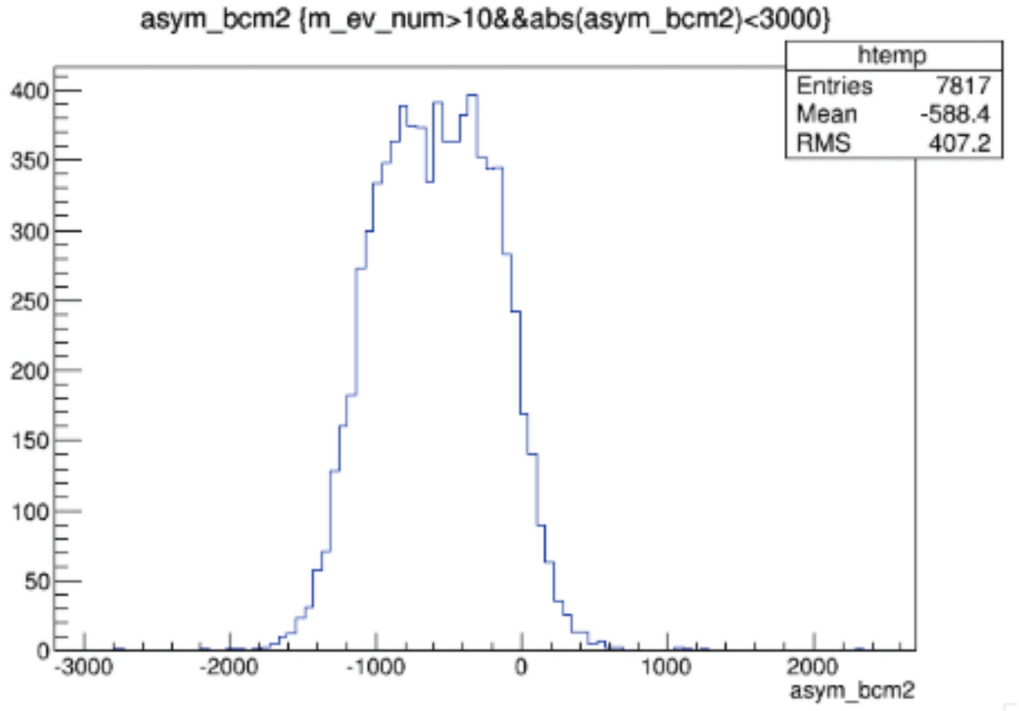
Run2361_PCoff_HallClaser_IHWPout_RHWP0deg_Oct202016_InjBPMSAqpropagationp

Apertures and Chopper?

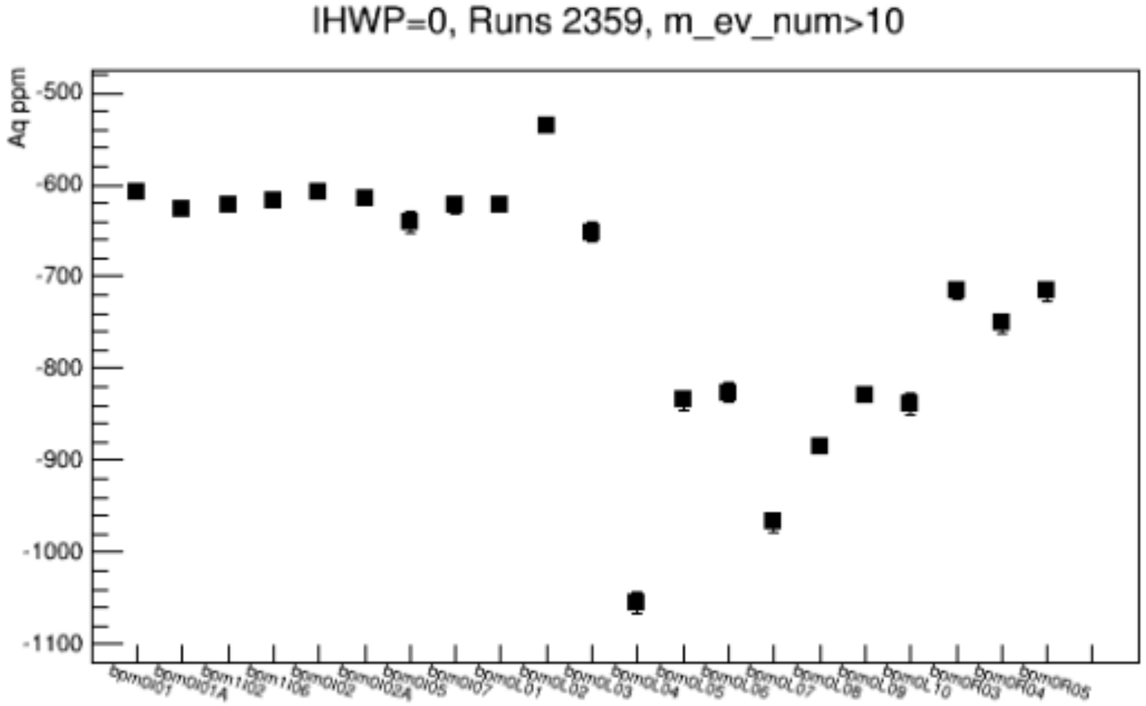


PC on - Injector

- Charge asymmetry according to BCM 0L02 is -588.4pppm



Run2359_HallClaser_IHWPout_RHWP0deg_Oct20 2016_asymbcm2_0l02_m588ppm



Run2359_HallClaser_IHWPout_RHWP0deg_ Oct202016_InjBPMSAqpropagation

Spot size asymmetry for RTP

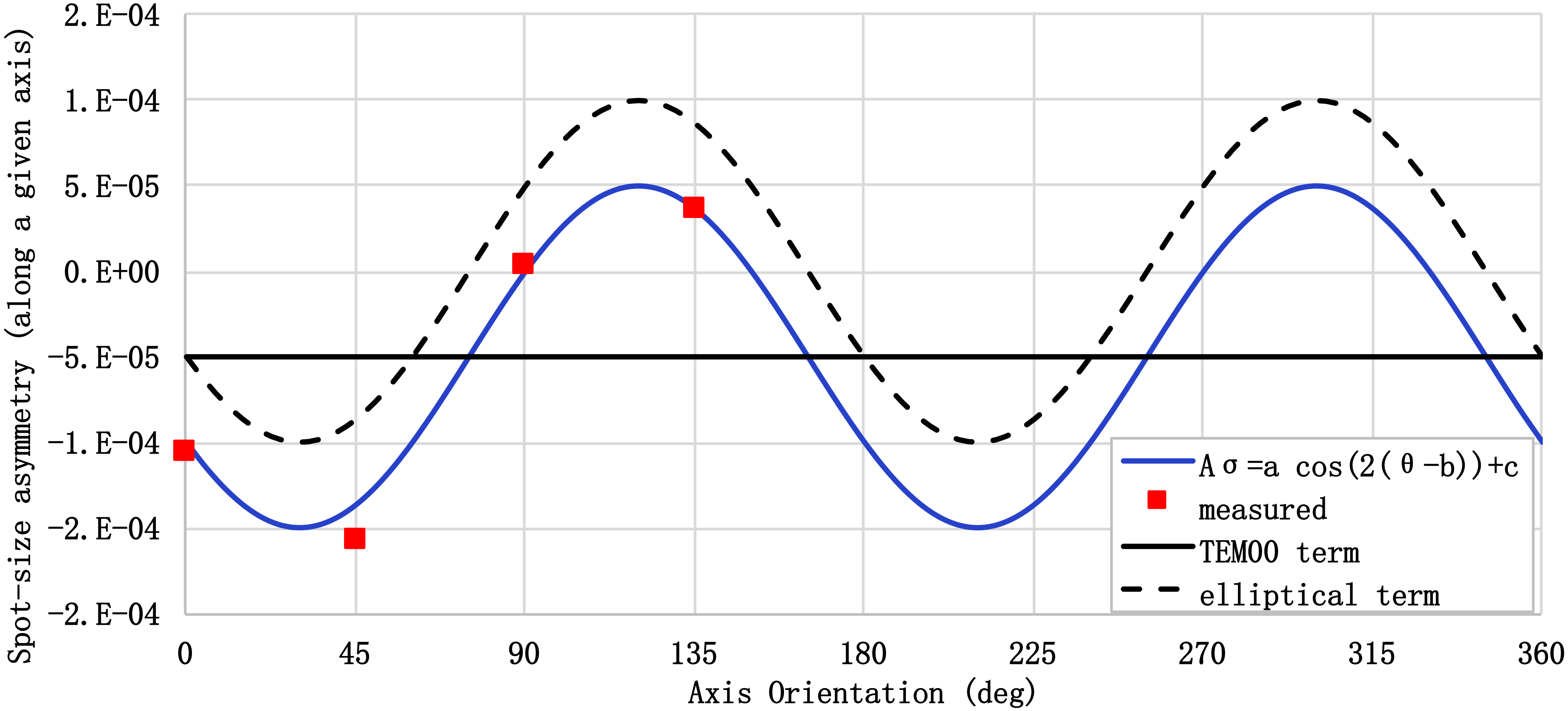
Spot-Size Asymmetry

No number on here is >1e-4

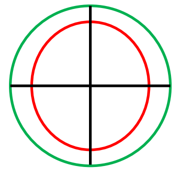
	Extracted Aσ at qpd 1m throw 100% analyzer		Extracted Aσ at cathode 2.015m throw 6% analyzer	
	Arms	Armsg	Arms	Armsg
X angle-like	-5.32E-05	-5.99335E-05	-1.07E-04	-1.21E-04
X S2	-6.09E-06	1.57E-05	-3.65E-07	9.39E-07
X S1	1.58E-04	1.12E-04	9.48E-06	6.71E-06
Y angle-like	-2.03E-06	4.68616E-06	-4.08E-06	9.44E-06
Y S2	-2.15E-05	-3.74E-05	-1.29E-06	-2.25E-06
Y S1	2.43E-05	2.83E-05	1.46E-06	1.70E-06
45 angle-like	-8.49E-05	-1.09E-4	-1.71E-04	-2.20E-04
45 S2	-2.66E-05	1.02E-05	-1.60E-06	6.12E-07
45 S1	5.83E-04	7.19E-04	3.50E-05	4.31E-05
-45 angle-like	4.91E-06	2.78309E-05	9.89E-06	5.61E-05
-45 S2	-2.02E-04	-3.28E-04	-1.21E-05	-1.97E-05
-45 S1	1.79E-05	1.29E-04	1.07E-06	7.72E-06

- Collected with linear array oriented along X,Y,+45,-45
- for no analyzer, analyzer 90deg, analyzer 0deg
- Took no analyzer data to be angle-like Arms, subtracted from S1,S2 measurements to obtain analyzer-like Arms
- Extrapolated Arms off of cathode given:
  - angle-like Arms ~ throw distance
  - analyzing-like Arms ~ analyzing power

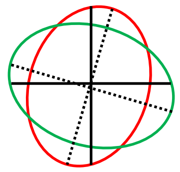
Spot-size Asymmetry off cathode, 6% analyzing along S1 (Ydirection)



Breathing mode



Elliptical term



Aσ = a cos(2(θ-b)) + c

MODEL by-eye

a	-1.00E-04
c	-5.00E-05
b	30

Values used for Spot-Size asymmetry Plot

MODEL by-eye

$A\sigma = a \cos(2(\theta - b)) + c$

a	-1.00E-04
c	-5.00E-05
b	30

TOTAL along a given RHWP angle

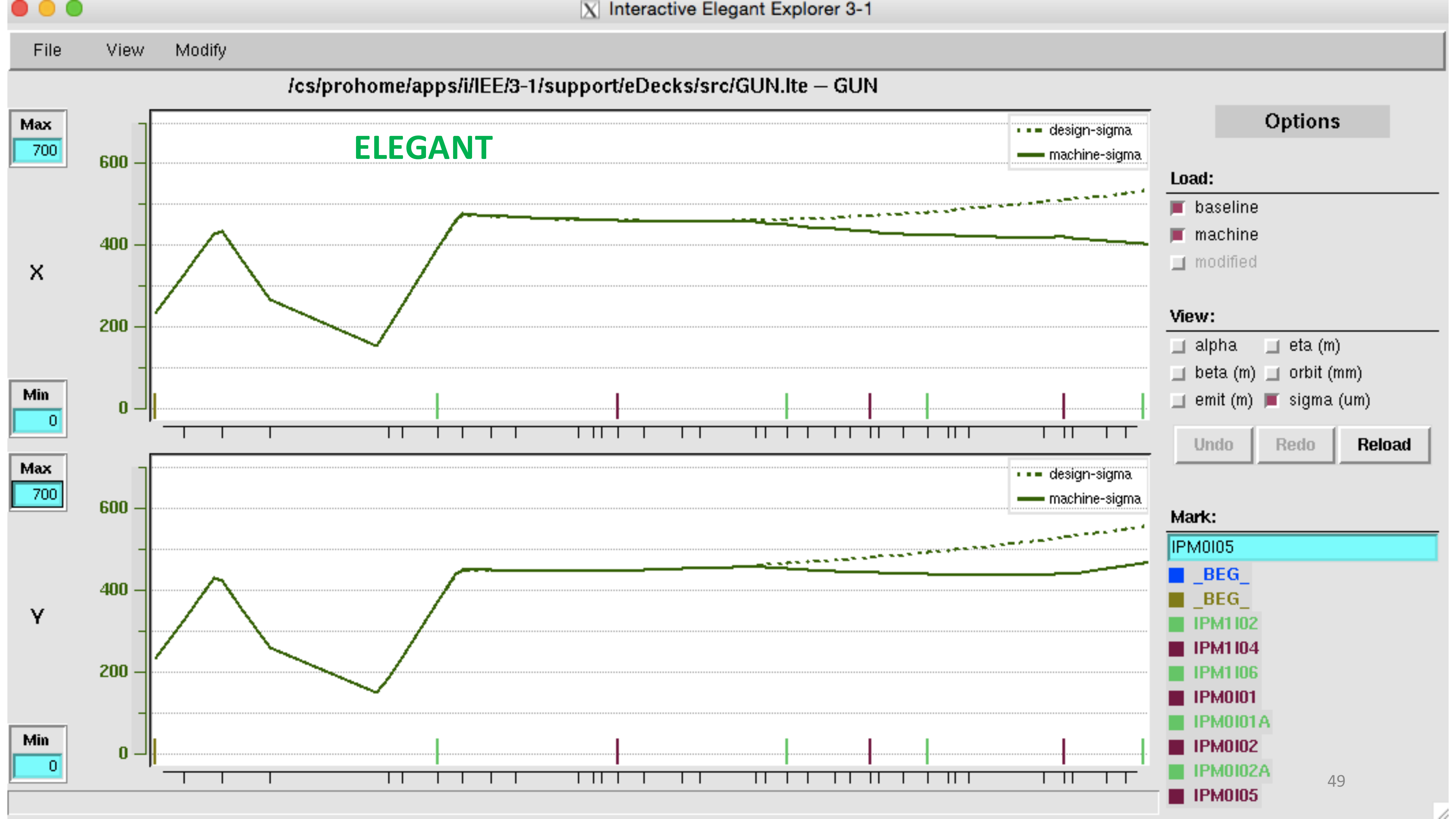
analyzer direction, projection direction	Arms	Armsg	<Aσ>meas	Aσ model
no anal X	-1.07E-04	-1.21E-04	-1.14E-04	-1.30E-04
no anal Y	-4.08E-06	9.44E-06	2.68E-06	0.00E+00
no anal 45	-1.71E-04	-2.20E-04	-1.95E-04	-1.78E-04
no anal -45	9.89E-06	5.61E-05	3.30E-05	4.76E-05
S1(90deg) X	-9.77E-05	-1.14E-04	-1.06E-04	-1.00E-04
S1(90deg) Y	-2.62E-06	1.11E-05	4.26E-06	0.00E+00
S1(90deg) 45	-1.36E-04	-1.77E-04	-1.56E-04	-1.37E-04
S1(90deg) -45	1.10E-05	6.38E-05	3.74E-05	3.66E-05
S2(45deg) X	-1.08E-04	-1.20E-04	-1.14E-04	-1.35E-04
S2(45deg) Y	-5.37E-06	7.20E-06	9.12E-07	5.00E-06
S2(45deg) 45	-1.73E-04	-2.19E-04	-1.96E-04	-1.86E-04
S2(45deg) -45	-2.20E-06	3.64E-05	1.71E-05	5.62E-05

Elegant

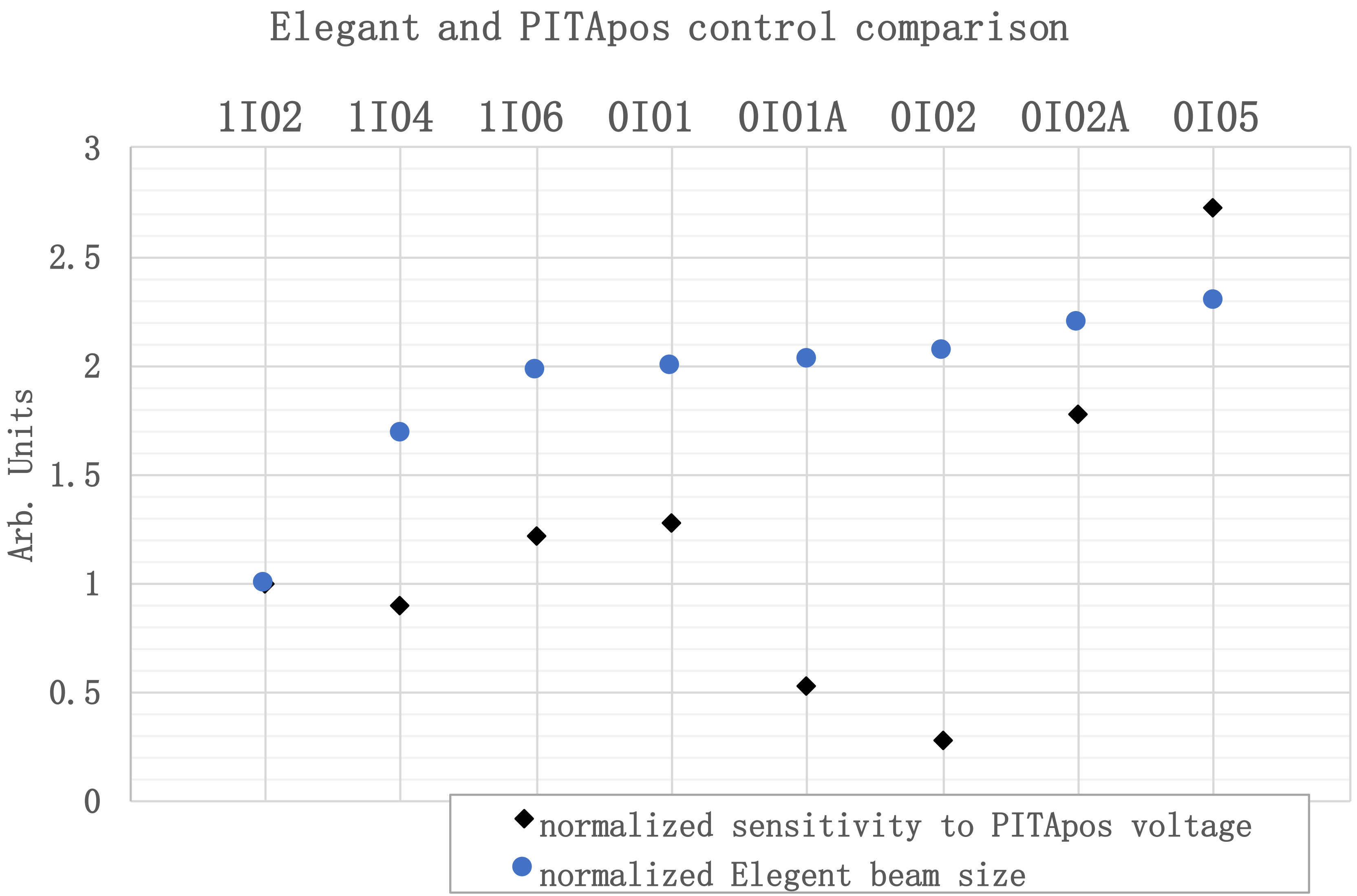
SOLENOID REVERSAL

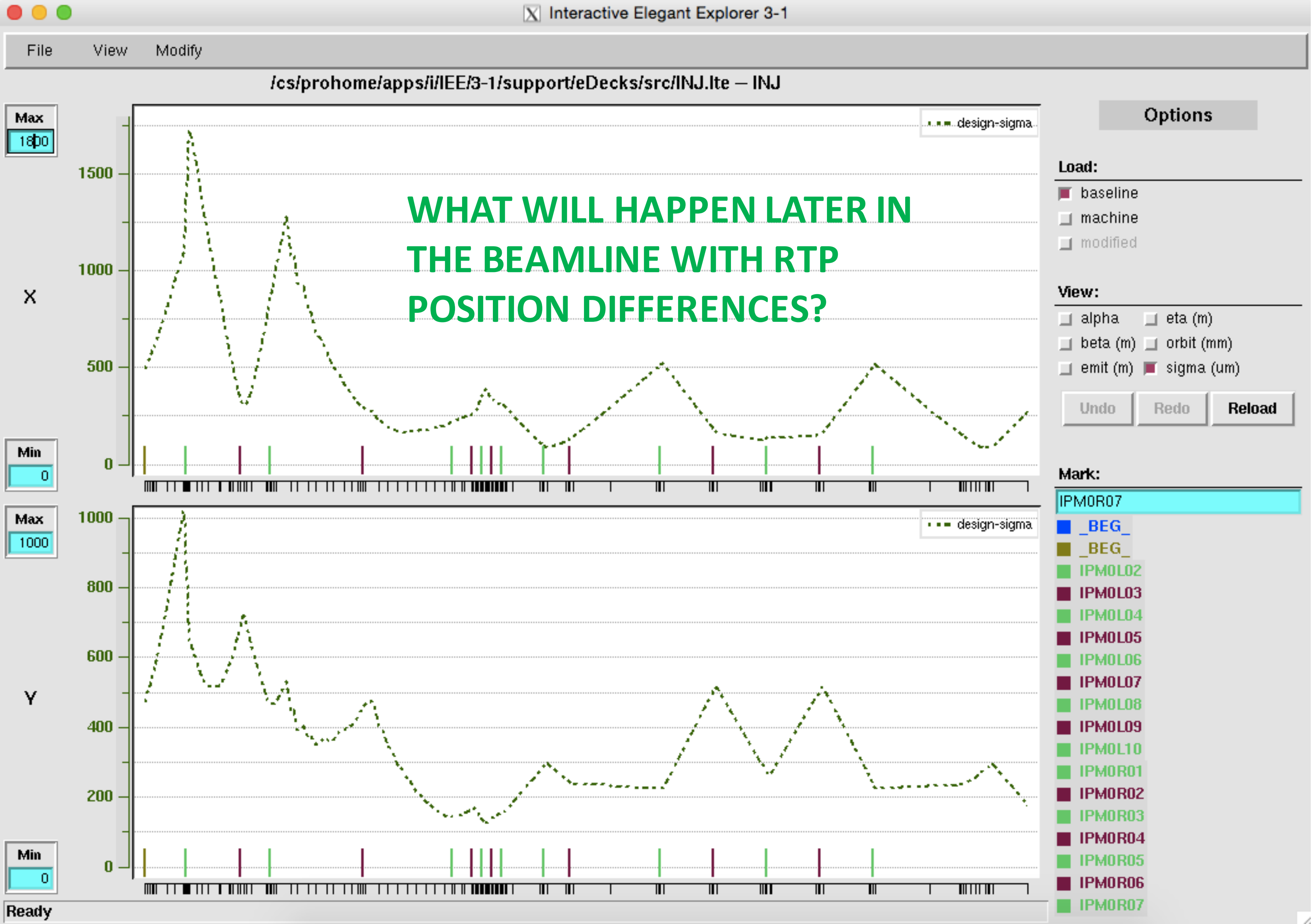
MFB1I02 current switched(which was between 1I02 and 1I04)

		Couplings before solenoid flip IHWP out, S1, Run3339		Couplings after solenoid flip IHWP out, S1, Run3352		"ROTATION"	
		PITAposU	PITAposV	PITAposU	PITAposV	PITAposU	PITAposV
Dr ~ laser	nm/V	7.09	5.72	7.09	5.72		
theta laser	deg	-47.96	32.97	-47.96	32.97		
Dr 1I02	nm/V	6.27	5.25	6.41	5.07		
theta 1I02	deg	29.20	-58.56	26.27	-66.60	-2.93	-8.04
Dr 1I04	nm/V	7.81	7.79	8.20	7.67		
theta 1I04	deg	7.86	-85.67	49.91	-40.14	42.05	45.53
Dr 1I06	nm/V	9.42	6.89	9.13	6.79		
theta 1I06	deg	9.55	89.96	47.45	-33.55	37.90	-123.50
Dr 0I01	nm/V	5.01	1.84	4.00	2.49		
theta 0I01	deg	8.44	77.63	36.14	-22.80	27.70	-100.44
Dr 0I01A	nm/V	1.54	2.10	1.40	1.22		
theta 0I01A	deg	12.94	-70.08	6.59	-64.88	-6.36	5.20
Dr 0I02	nm/V	10.64	12.08	11.19	11.54		
theta 0I02	deg	0.91	-83.86	51.87	-46.01	50.97	37.86
Dr 0I02A	nm/V	17.62	17.26	16.66	17.26		
theta 0I02A	deg	1.34	-80.78	48.36	-41.08	47.02	39.71
Dr 0I05	nm/V	17.16	13.55	17.18	12.78		
theta 0I05	deg	6.68	89.50	41.74	-33.96	35.06	-123.46


Interactive Elegant Explorer 3-1
File
View
Modify
/cs/prohome/apps/i/IEE/3-1/support/eDecks/src/GUN.lte — GUN
ELEGANT
Max
700
Min
0
X
Y
600
400
200
0
design-sigma
machine-sigma
Options
Load:
baseline
machine
modified
View:
alpha
eta (m)
beta (m)
orbit (mm)
emit (m)
sigma (um)
Undo
Redo
Reload
Mark:
IPM0I05
BEG
BEG
IPM1I02
IPM1I04
IPM1I06
IPM0I01
IPM0I01A
IPM0I02
IPM0I02A
IPM0I05

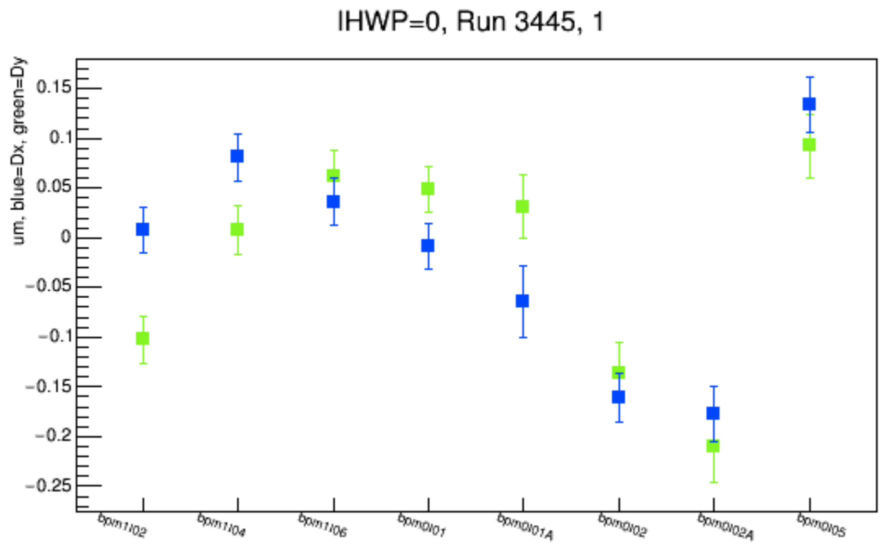
PERHAPS WE CAN USE ELEGENT TO PREDICT POSITION DIFFERENCE CONTROL



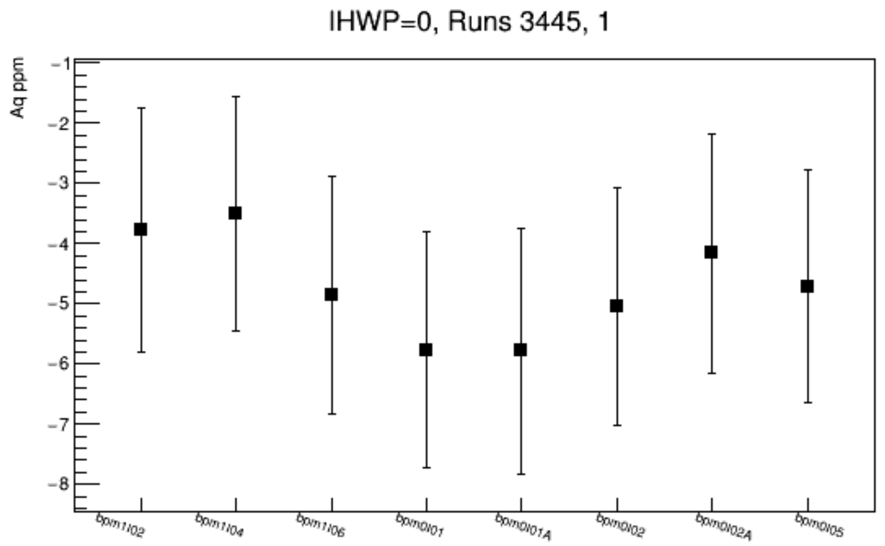

Interactive Elegant Explorer 3-1
File
View
Modify
/cs/prohome/apps/i/IEE/3-1/support/eDecks/src/INJ.lte — INJ
WHAT WILL HAPPEN LATER IN THE BEAMLINE WITH RTP POSITION DIFFERENCES?
Max
1800
Min
0
X
1500
1000
500
0
design-sigma
Max
1000
Min
0
Y
1000
800
600
400
200
0
design-sigma
Options
Load:
baseline
machine
modified
View:
alpha
eta (m)
beta (m)
orbit (mm)
emit (m)
sigma (um)
Undo
Redo
Reload
Mark:
IPM0R07
BEG
BEG
IPM0L02
IPM0L03
IPM0L04
IPM0L05
IPM0L06
IPM0L07
IPM0L08
IPM0L09
IPM0L10
IPM0R01
IPM0R02
IPM0R03
IPM0R04
IPM0R05
IPM0R06
IPM0R07
Ready

KD*P as of August

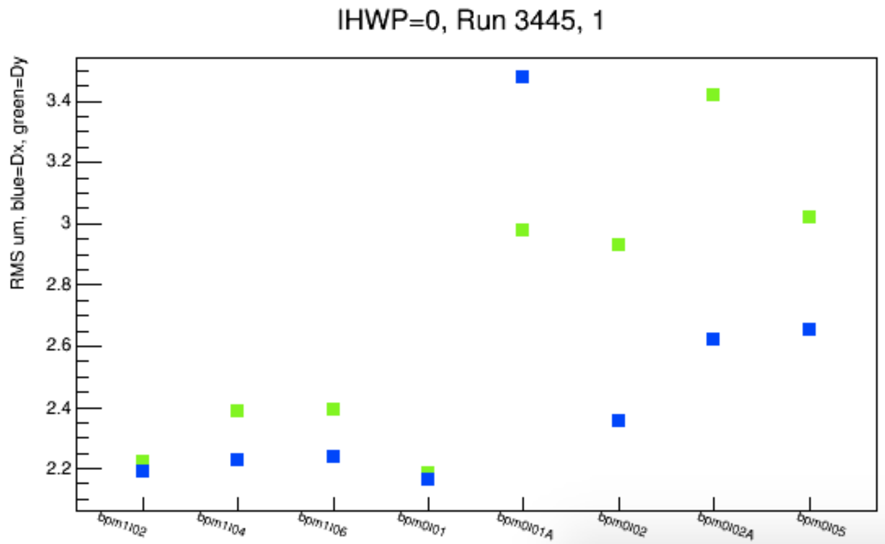
KD*P 9/1/2017



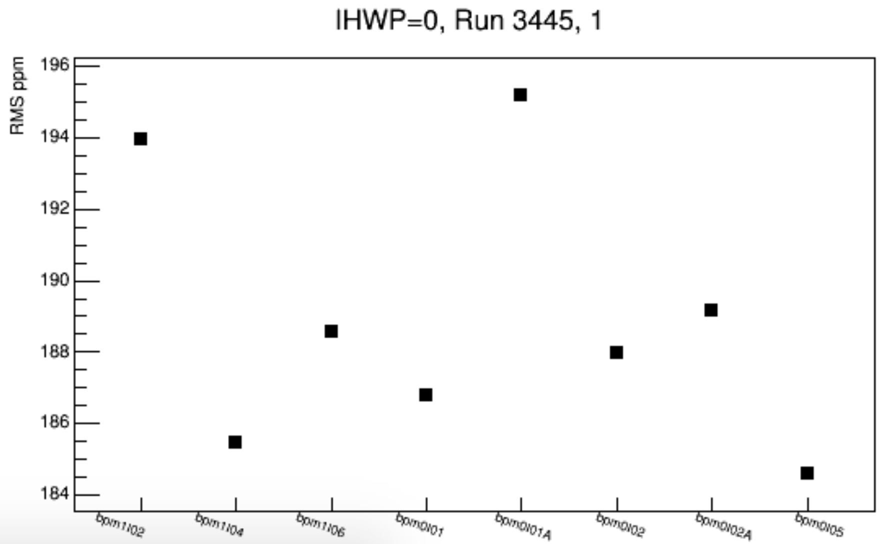
IHWP=0, Run 3445, 1
um, blue=Dx, green=Dy
bpm1I02
bpm1I04
bpm1I06
bpm0I01
bpm0I01A
bpm0I02
bpm0I02A
bpm0I05



IHWP=0, Runs 3445, 1
Aq ppm
bpm1I02
bpm1I04
bpm1I06
bpm0I01
bpm0I01A
bpm0I02
bpm0I02A
bpm0I05



IHWP=0, Run 3445, 1
RMS um, blue=Dx, green=Dy
bpm1I02
bpm1I04
bpm1I06
bpm0I01
bpm0I01A
bpm0I02
bpm0I02A
bpm0I05



IHWP=0, Run 3445, 1
RMS ppm
bpm1I02
bpm1I04
bpm1I06
bpm0I01
bpm0I01A
bpm0I02
bpm0I02A
bpm0I05

Results reiterated

- RTP fully characterized with laser
- RTP can achieve <100nm position differences in 1st 8 bpms (1I02-0I05) at 25uA
- Spot size asymmetry for RTP off of cathode <~2e-4
- PITA position voltages control steering position differences as predicted
- PITA position corrections ultimately used are small <100V
- Bpm RMS noise for the RTP is similar to the KD*P – relevant for statistics
- Learned RTP can drift Aq –beam by ~100ppm in ~30min –likely T dependence
- KD*P achieved <200nm position differences in 1I02-0I05 region

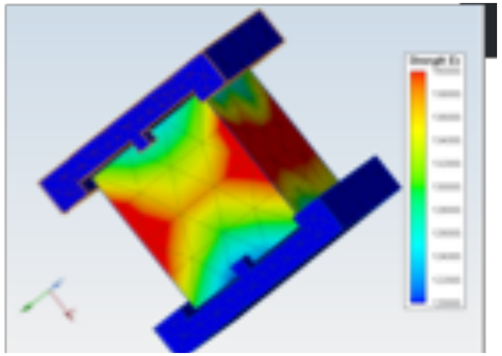
SO WHAT NEXT?

- Next time, just pop-in RTP, (center with tissue, align back reflection, spinning LP, go…fix e-beam with voltage)
- RTP Run with:
  - Charge feedback – *at least* – show can get stable Aq
  - T control on crystals – in the works…t controller, metal ceramic heater, thermocouple on *each* crystal
  - Delayed helicity – to be *sure* of any artificial offsets
  - 5MeV region- answer the Qu: which bpm is the best to minimize
- KD*P - Run with PC off, no-delay, to examine potential helicity pickup

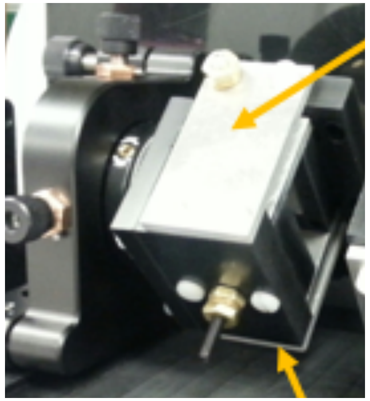
SOLO single-loop temperature controller

Metal Ceramic Heater

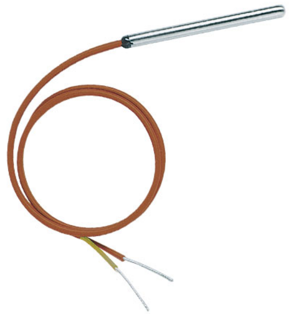
Thermal contact with one Aluminum plate



Inside Delrin mount



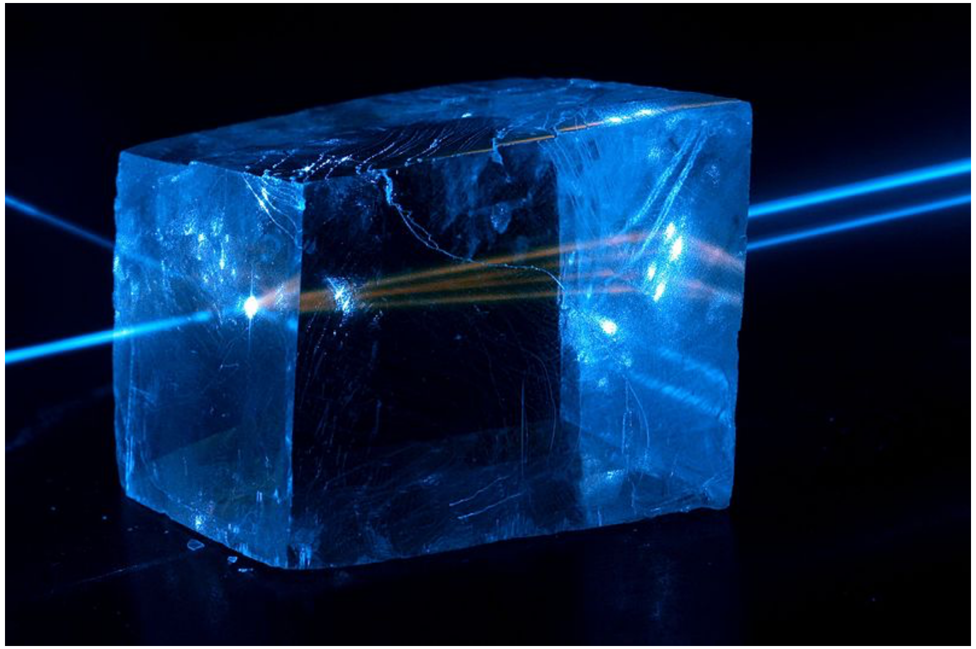
Thermocouple



How is this possible? Things to consider…

- A) zeroing out the position difference on the cathode does not zero out the position difference in the injector bpms
- B) zeroing out the position difference on the cathode DOES zero out the position differences in the injector bpms BUT the converse is not true and an injector bpm may also be zeroed out without zeroing out the cathode position difference.
- C) the data are wrong / misinterpreted
  - Analyzing power of the cathode
  - Analyzing-like position differences not being able to be cancelled by steering-like position differences due to some kind of psuedo-analyzing power in different bpm areas
  - Apertures in beamline – we know this turns pos diffs into charge asymmetries, know Aq varies
  - Spot-size asymmetries – can these turn into position differences somehow?
  - We have 4 spots, not 2, birefringent material…so a pair of e-beams propagate down the inj together for each helicity state, separation between a pair, their average position….
  - Temporal chopper-like phenomenon
  - Tails
  - Unpolarized light
  - Error bars on data treated RMS like statistical noise, we know there was drift in Aq which could mean drift in Dx,Dy which could mean central values of data points are off via drift.
  - Slopes aren't right – try by hand regression slopes…
  - Helicity pickup in DAQ or in elements along beam line – examine PC off data, and beam off data

Birefringent material = 2 simultaneous beams



2 beams * 2 helicity states = 4 beams, 2 *beam pairs*

Hel0 beam pair: hel0, polarization +45deg & hel0, polarization -45deg ->where they overlap is R circ.

Hel1 beam pair: hel1, polarization +45deg & hel1, polarization -45deg ->where they overlap is L circ.

Position Difference = <pair0 position>-<pair1 position>

= ½((hel0,pol+45)pos + (hel0,pol-45)pos -hel0,pol+45)pos -(hel0,pol-45)pos