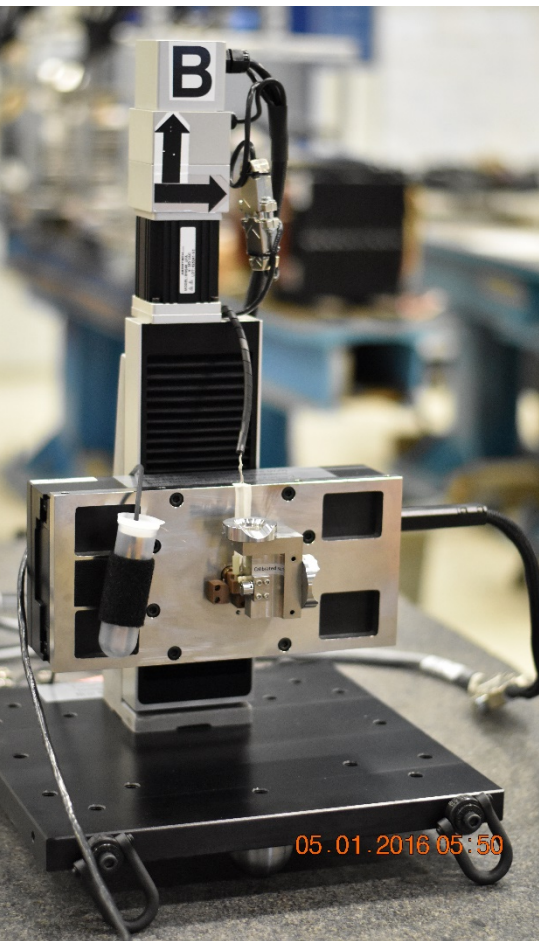
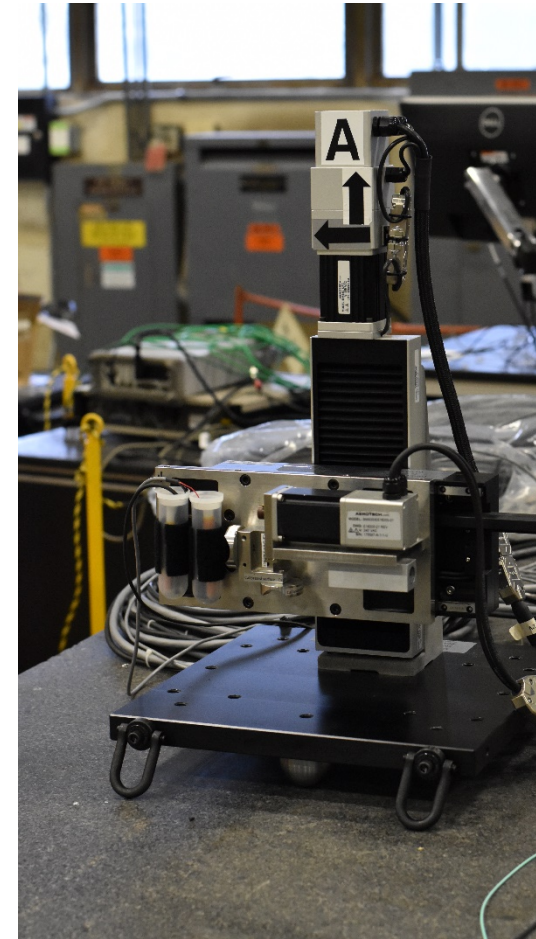


Measurement of the magnet center with Single Stretched Wire system

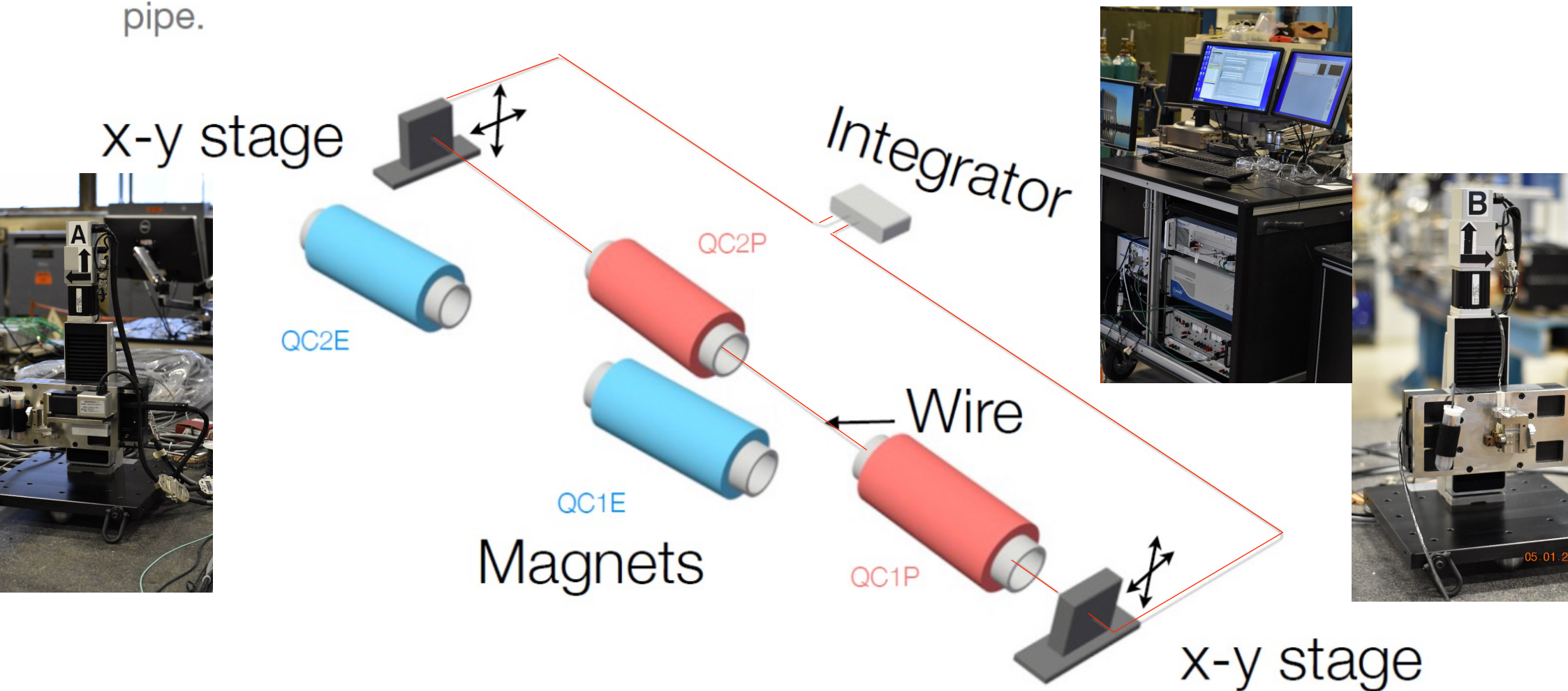


Y. Arimoto, N. Ohuchi,
M. Masuwawa, R. Ueki, Y. Ohsawa, T. Kawamoto
and H. Iinuma

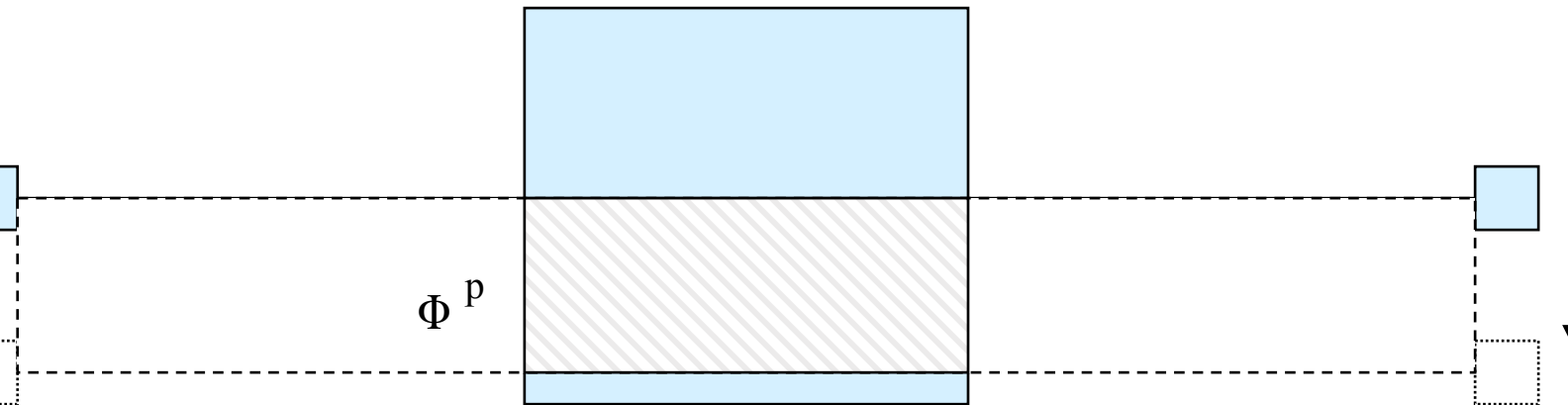


Single Stretched Wire

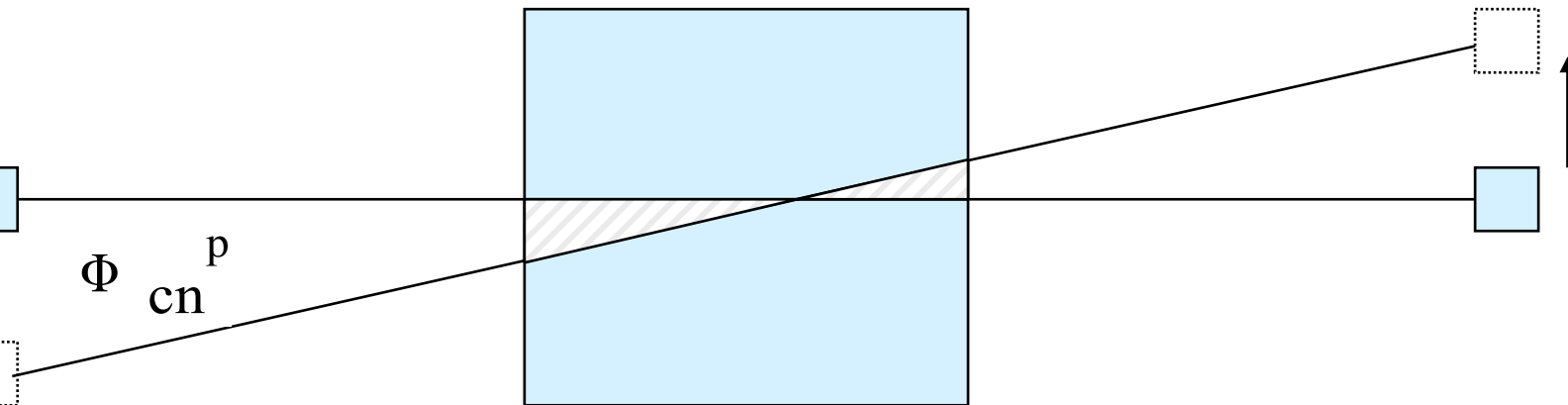
- Search real magnet center (not mechanical center) in stage coordinate system
- At test experimental hall, wire is stretched through one cryostat beam pipe.



Co-directional motion (finds nodal point (average axis))



Counter-directional motion (to find true axis)



- Output wire ends points in stage coordinates (x, y)
 - Input z positions from design
 - Sag corrections
- Measure roll angles, too.

Stage motion causes the wire to move in the B-field to generate change in flux, Φ , measured by the SS data acquisition system.

$$\delta_{CO} = -\frac{D}{2} \frac{\Phi_+^{CO} - \Phi_-^{CO}}{\Phi_+^{CO} + \Phi_-^{CO}}$$

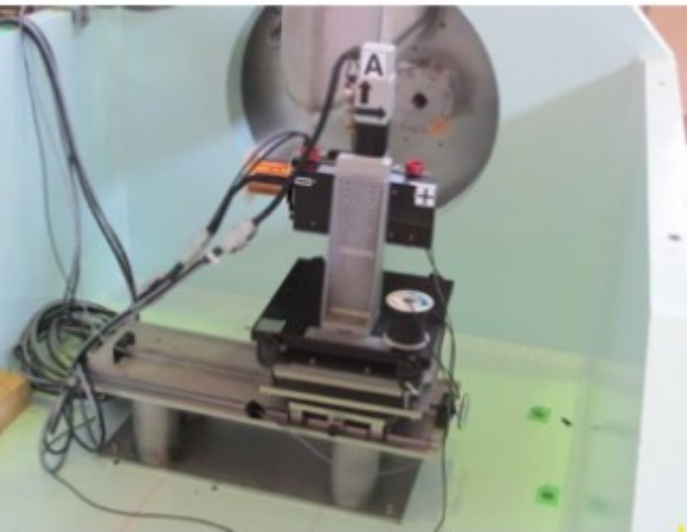
$$\delta_{CN} = -\frac{D}{2} \frac{\Phi_+^{CN} - \Phi_-^{CN}}{\Phi_+^{CN} + \Phi_-^{CN}}$$

Move wire ends till $\delta_{CO} \rightarrow 0$
and $\delta_{CN} \rightarrow 0$

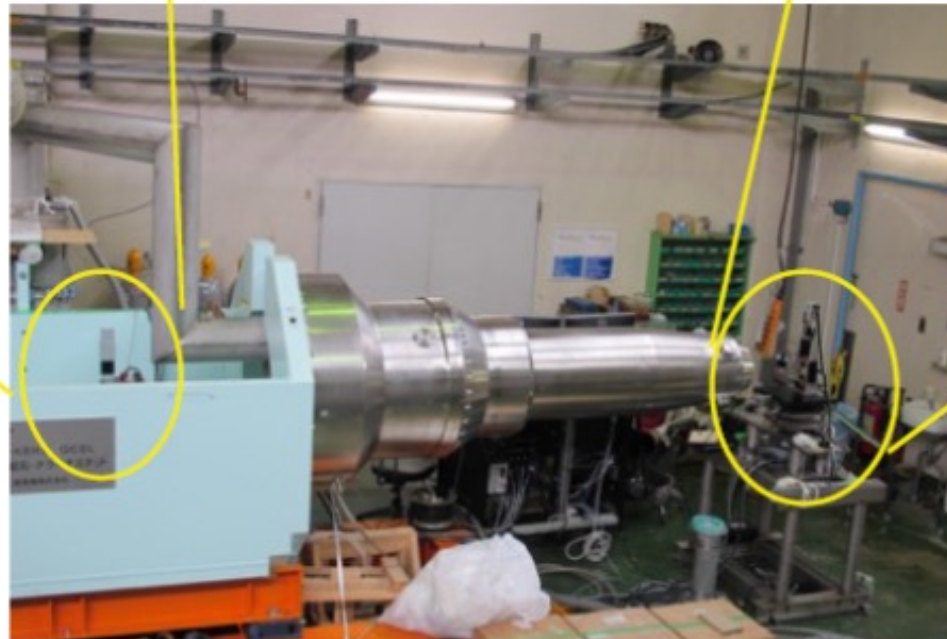
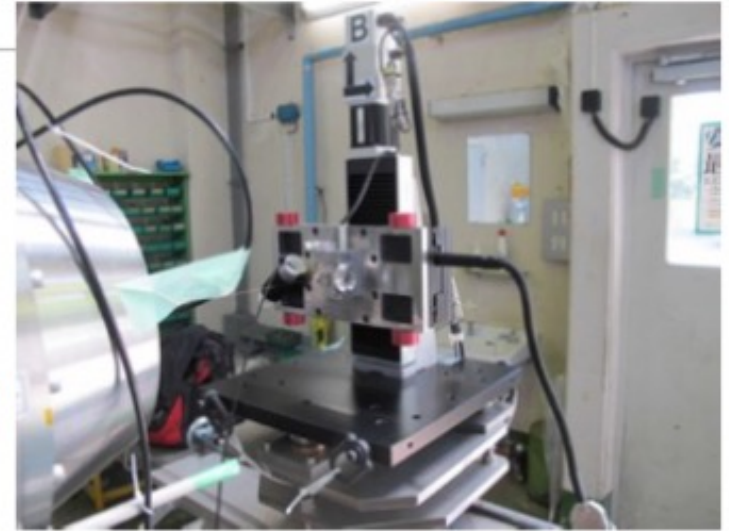
Find magnets center positions (x, y)

SSW @ 低真棟

Test bench, just across the street



SSW system
delivered on
May 12



- We care the stage level
~ 0.17mrad
- After earthquake, we
need to arraigh them
again

Repeatability check

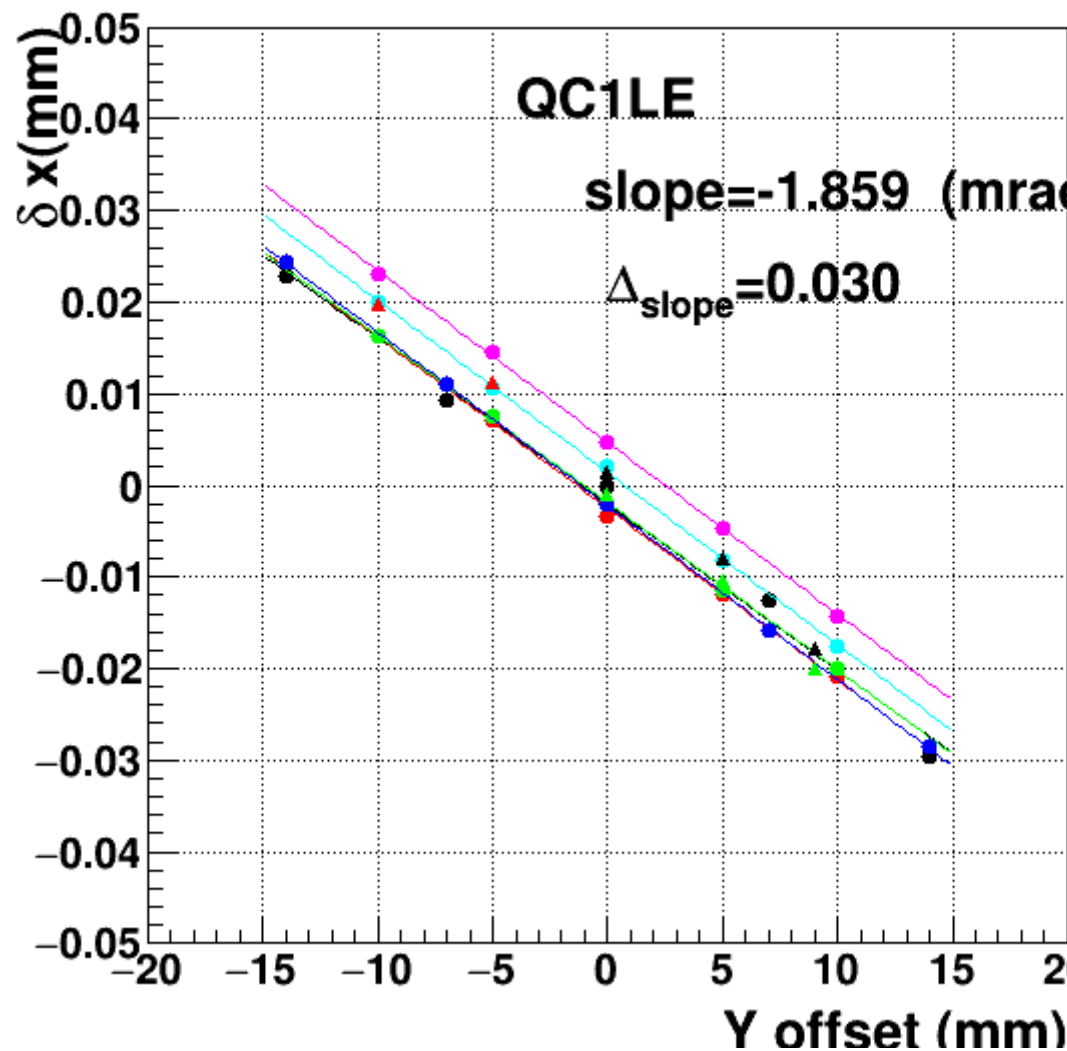
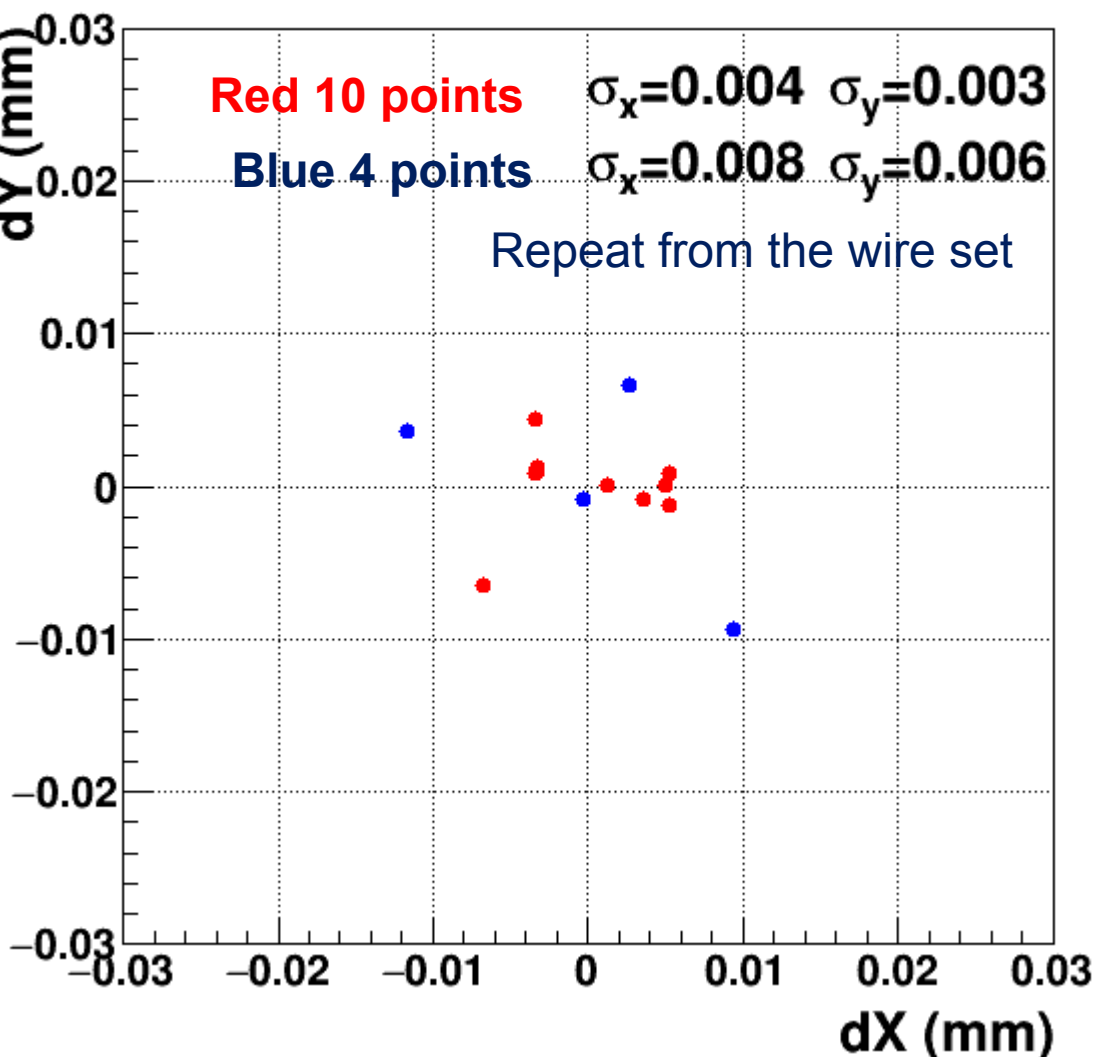
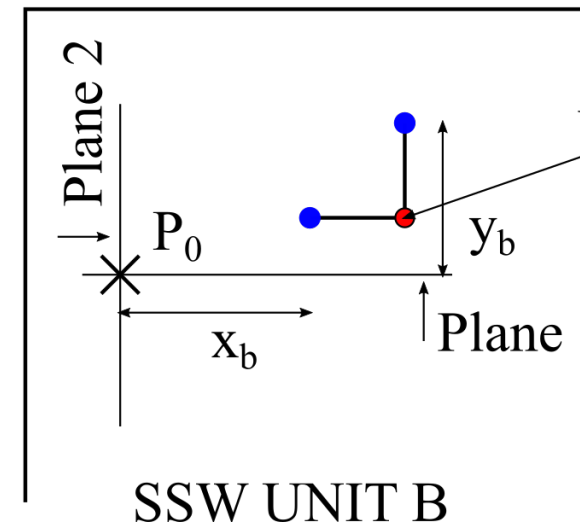
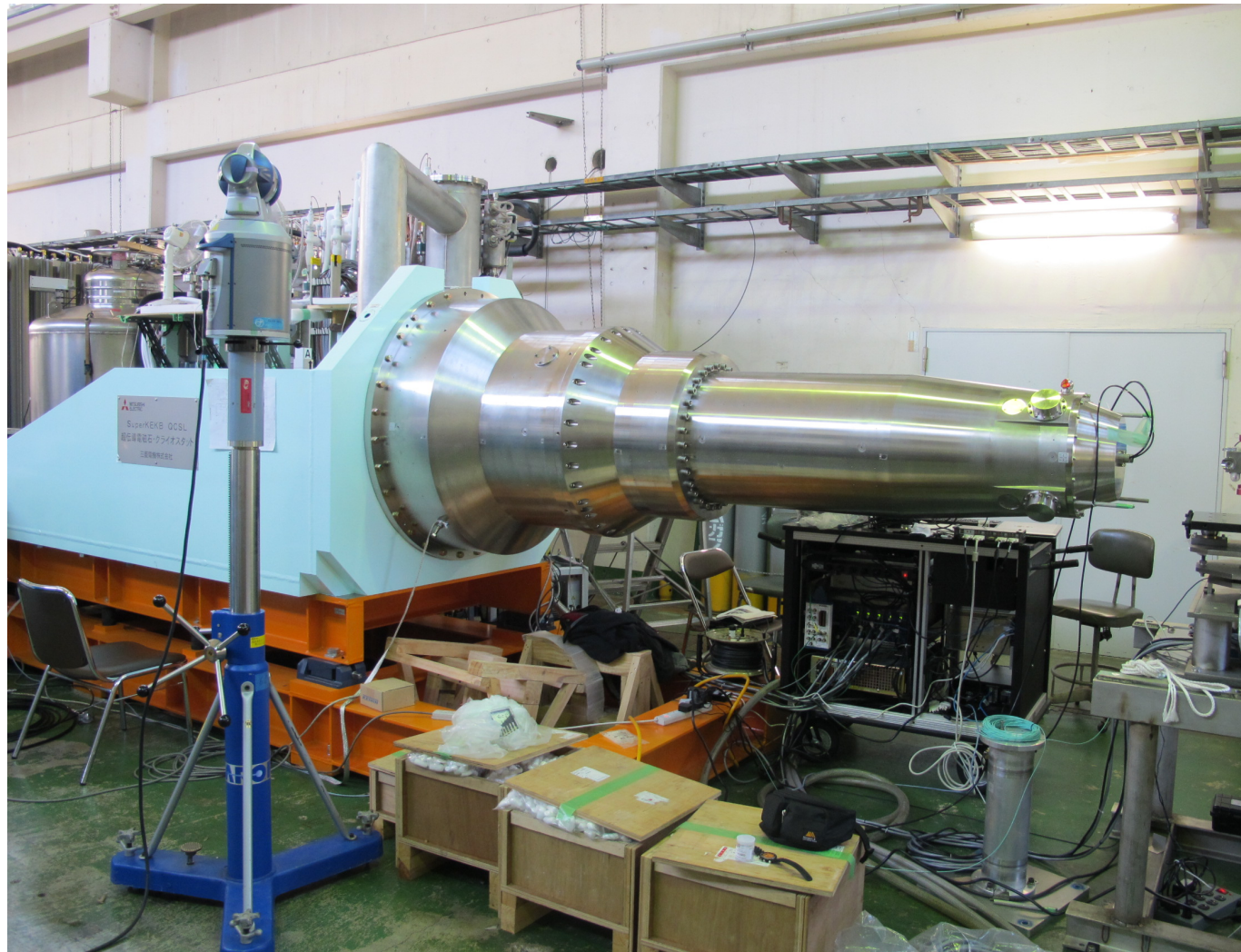
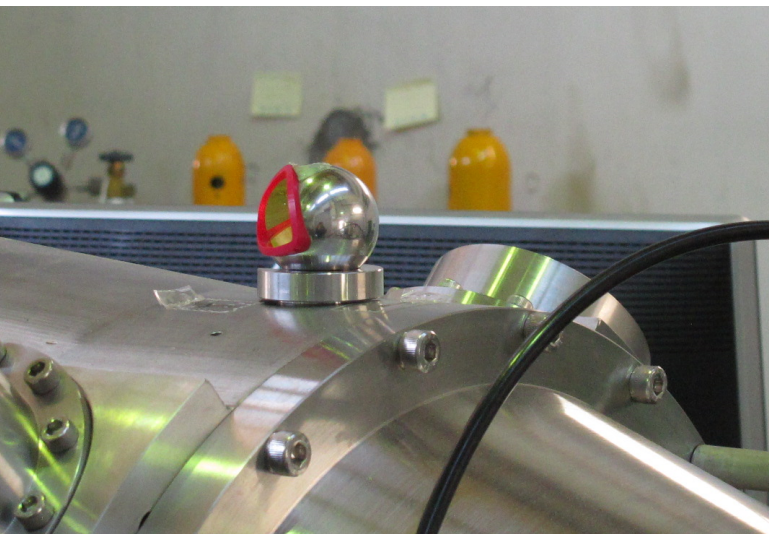


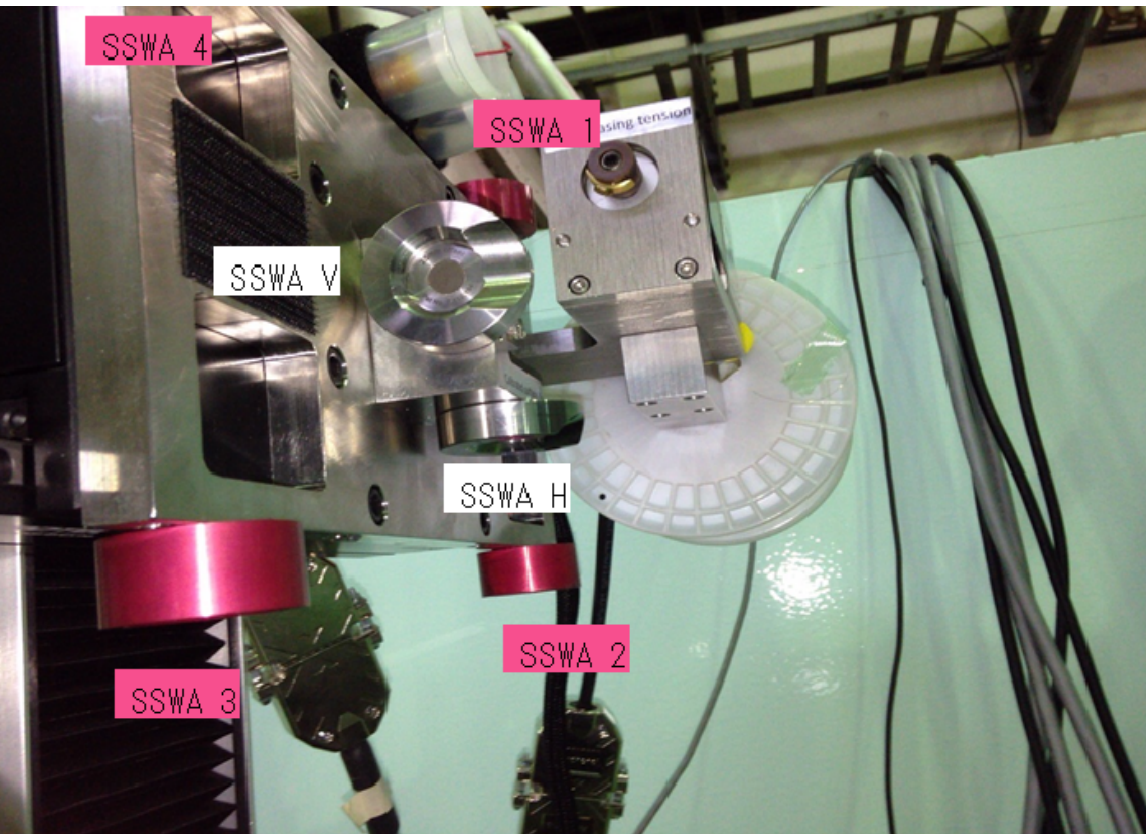
Diagram illustrating the SSW Unit A. The unit is positioned between Plane 1 and Plane 2. A wire is connected to a point on Plane 1, extending vertically upwards. The horizontal distance from the base of the wire to Plane 2 is labeled X_a . The vertical distance from Plane 1 to the top of the wire is also indicated. A point P_0 is marked on Plane 2.



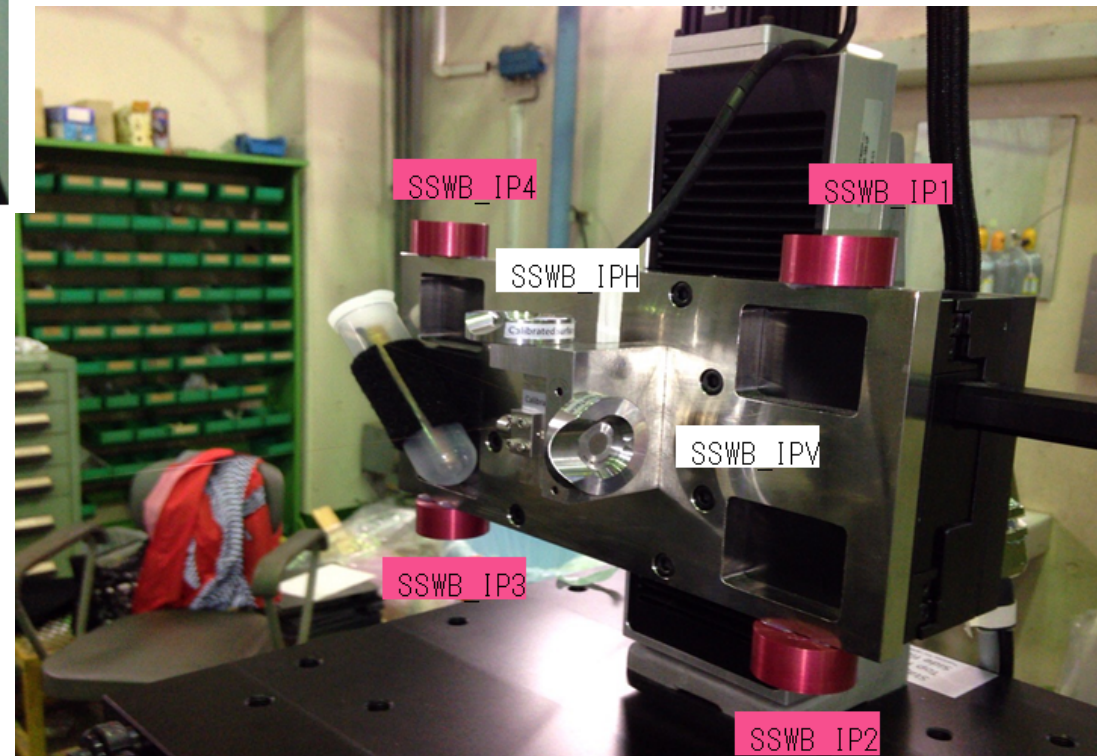
Survey data is consistent with design values and stable within few tens of microns

Survey by Laser tracker



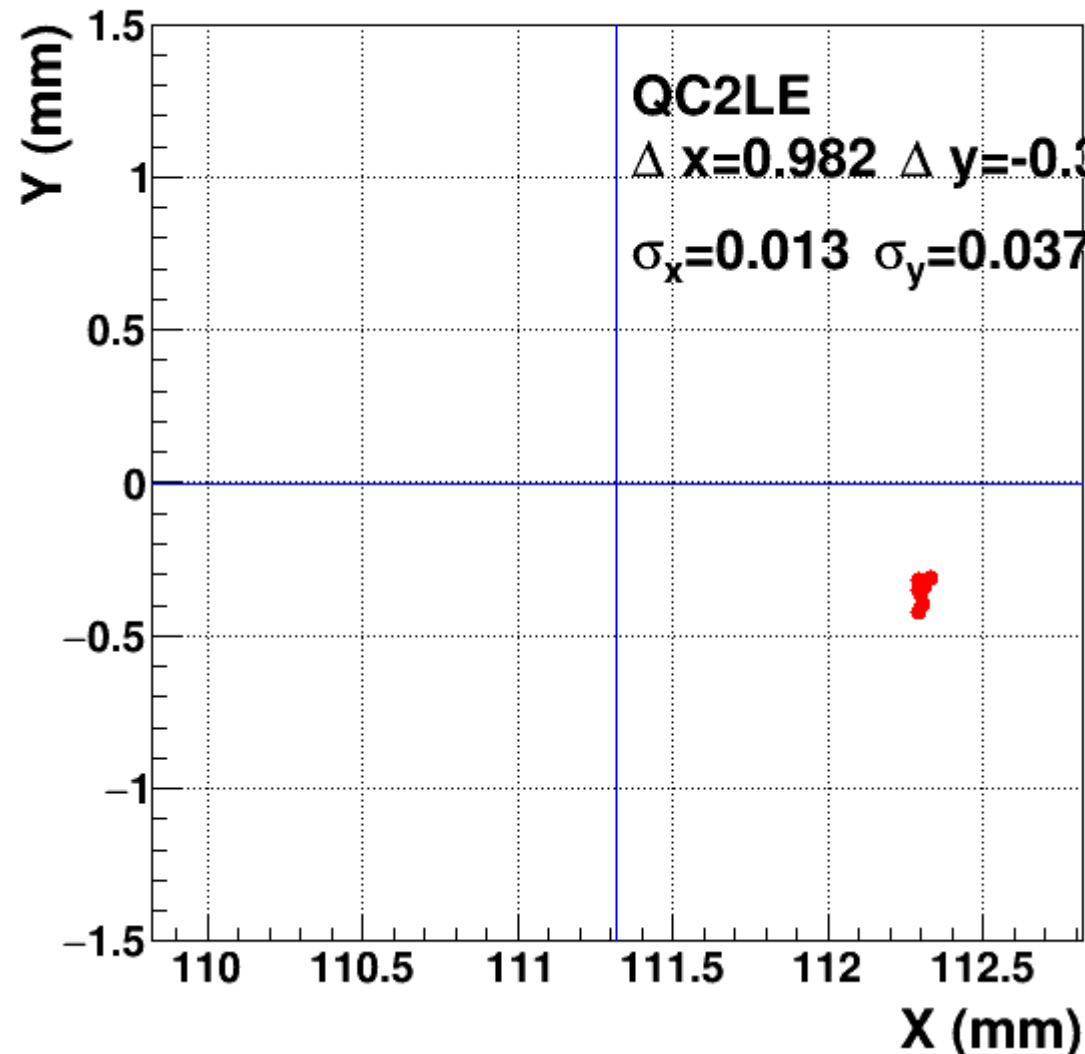
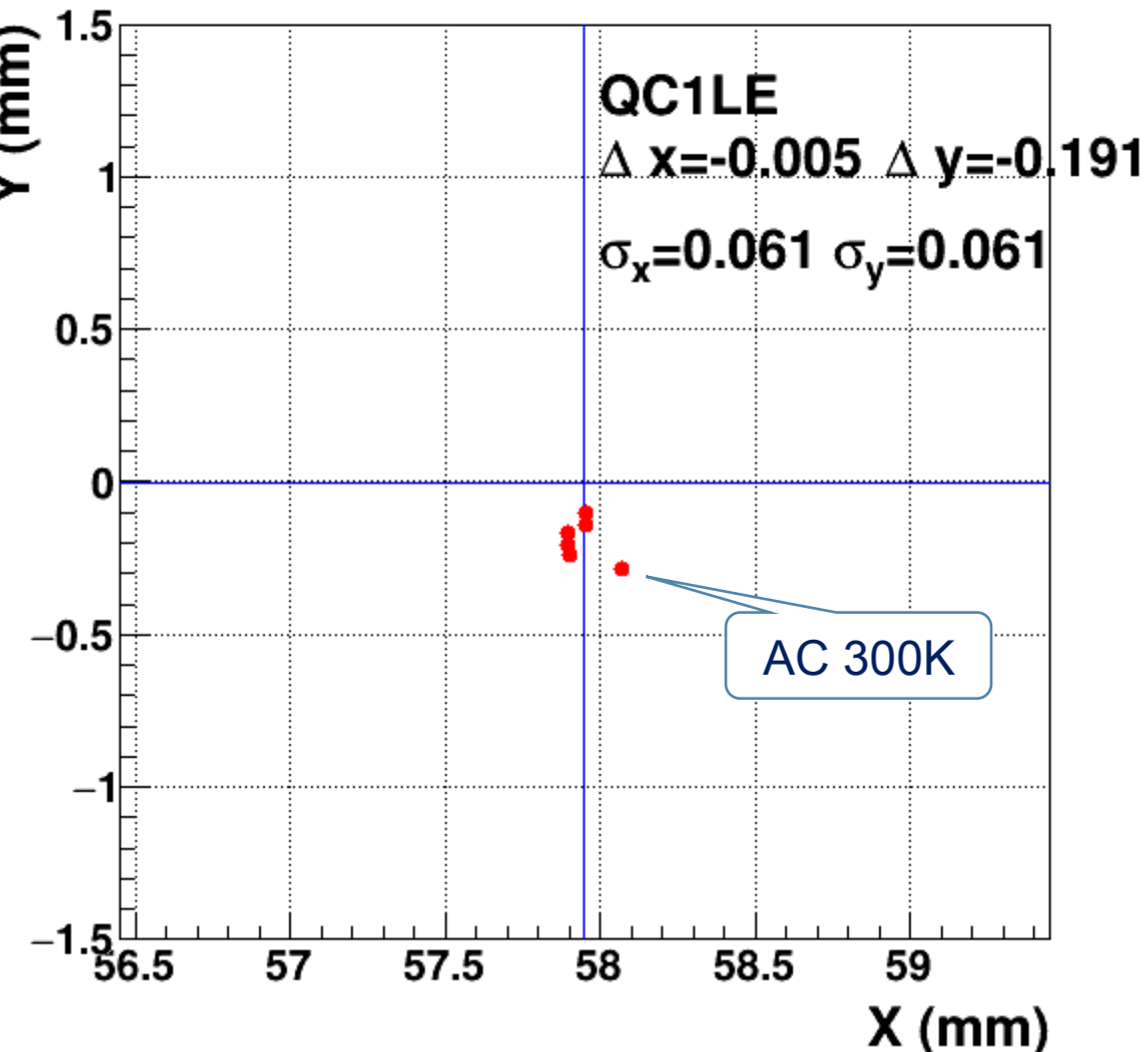


We added 4 points for each stage to increase accuracy

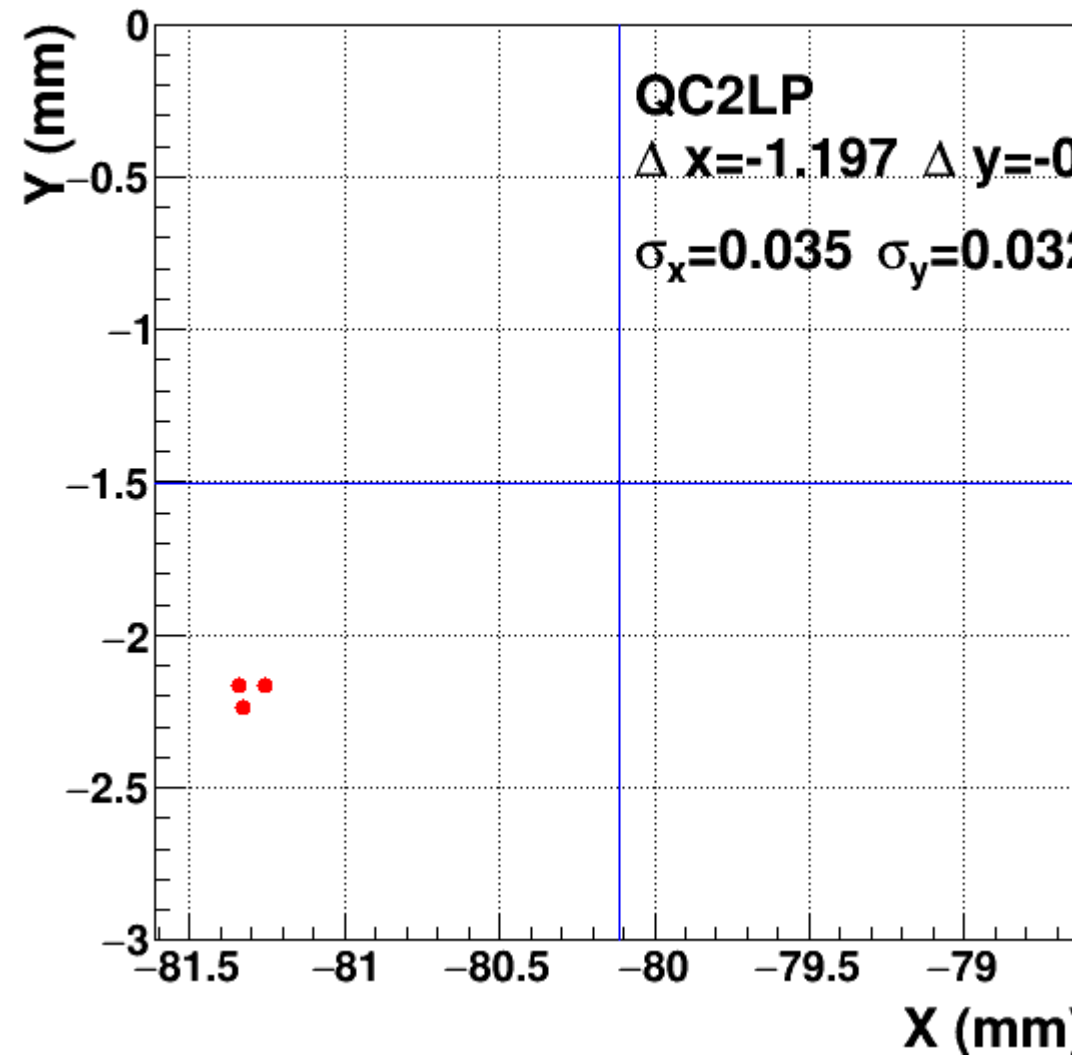
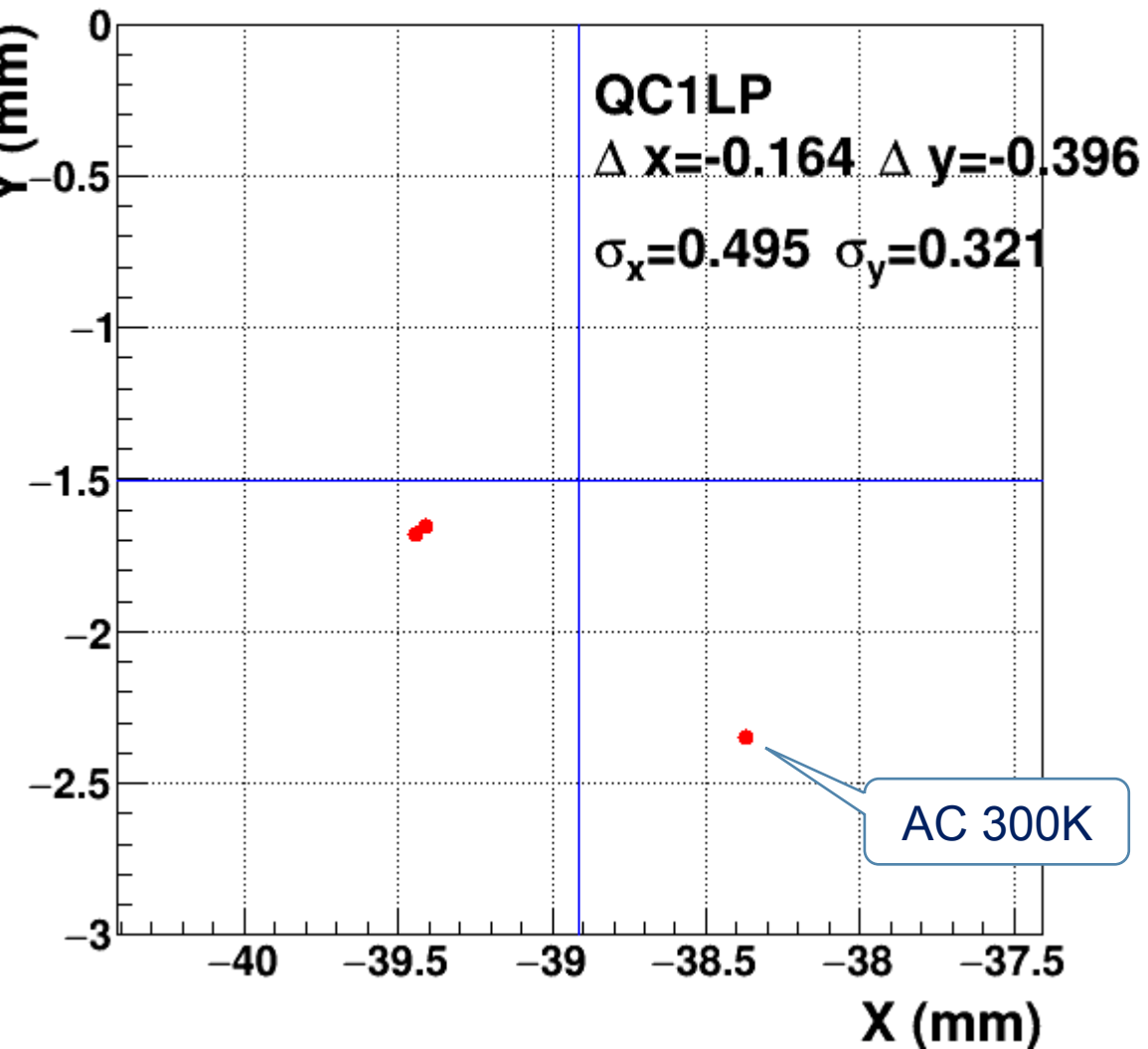


Measured magnet centers vs. designs: HER

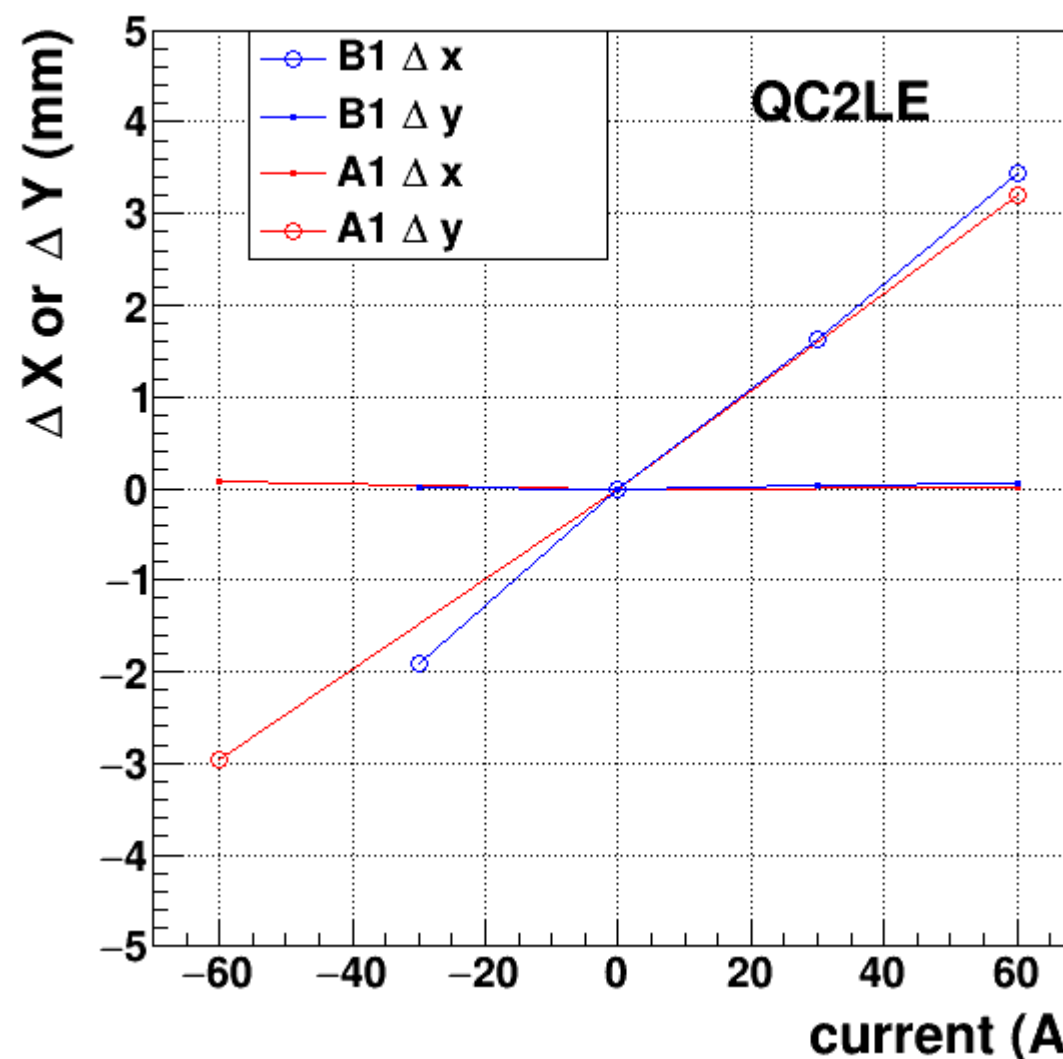
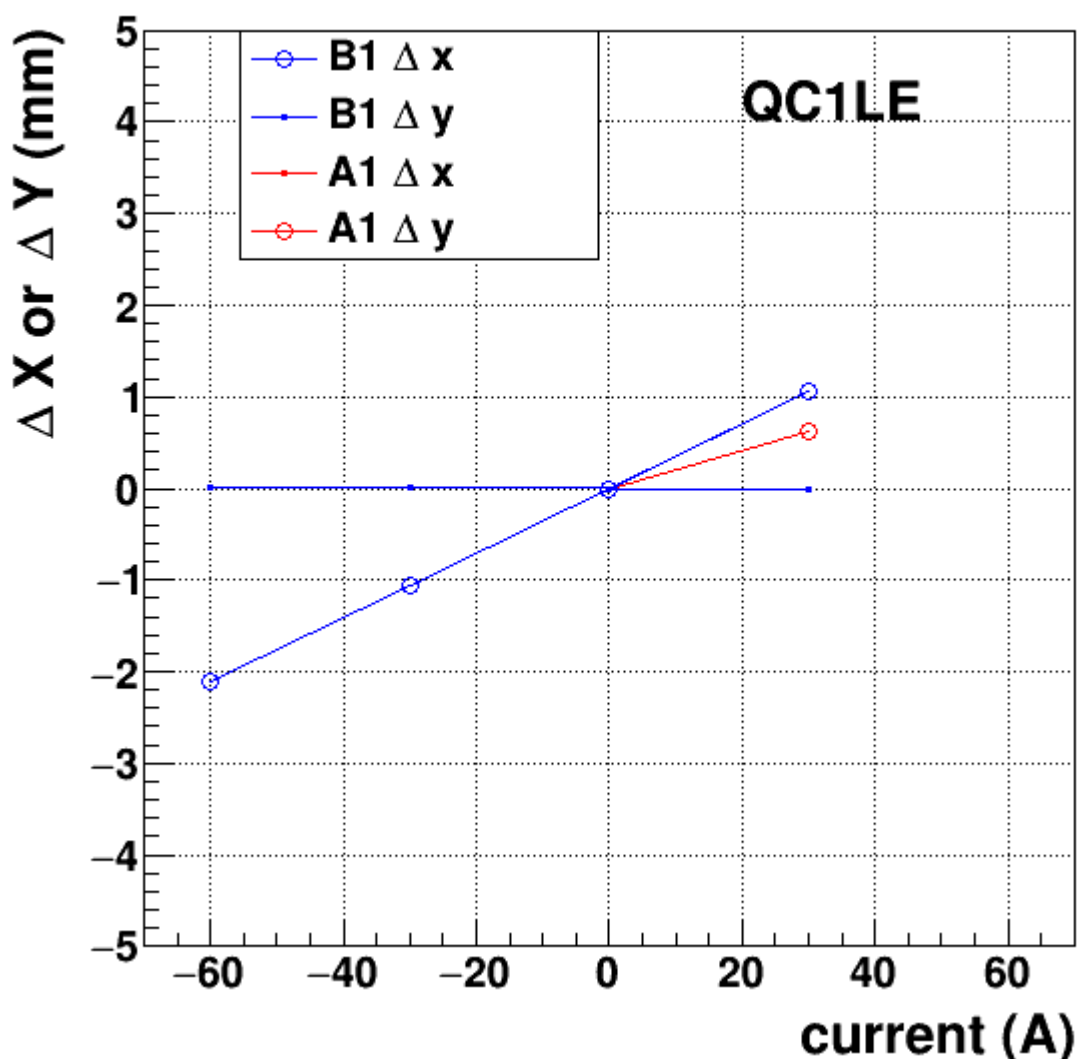
- Magnet center positions with several conditions (AC: 300K, ~50K, 4K and DC) are stable within 50~80 μ m for x and y directions



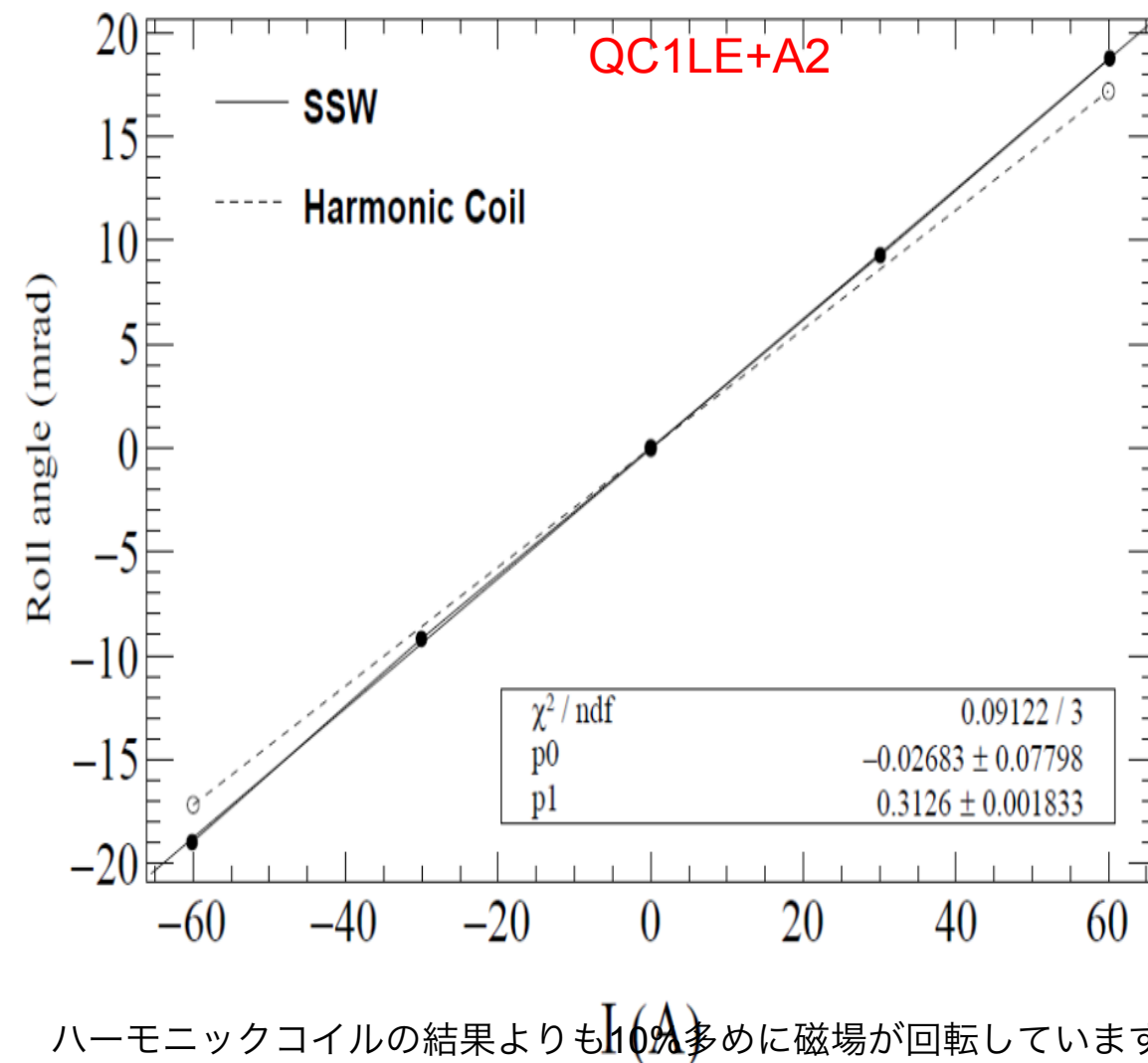
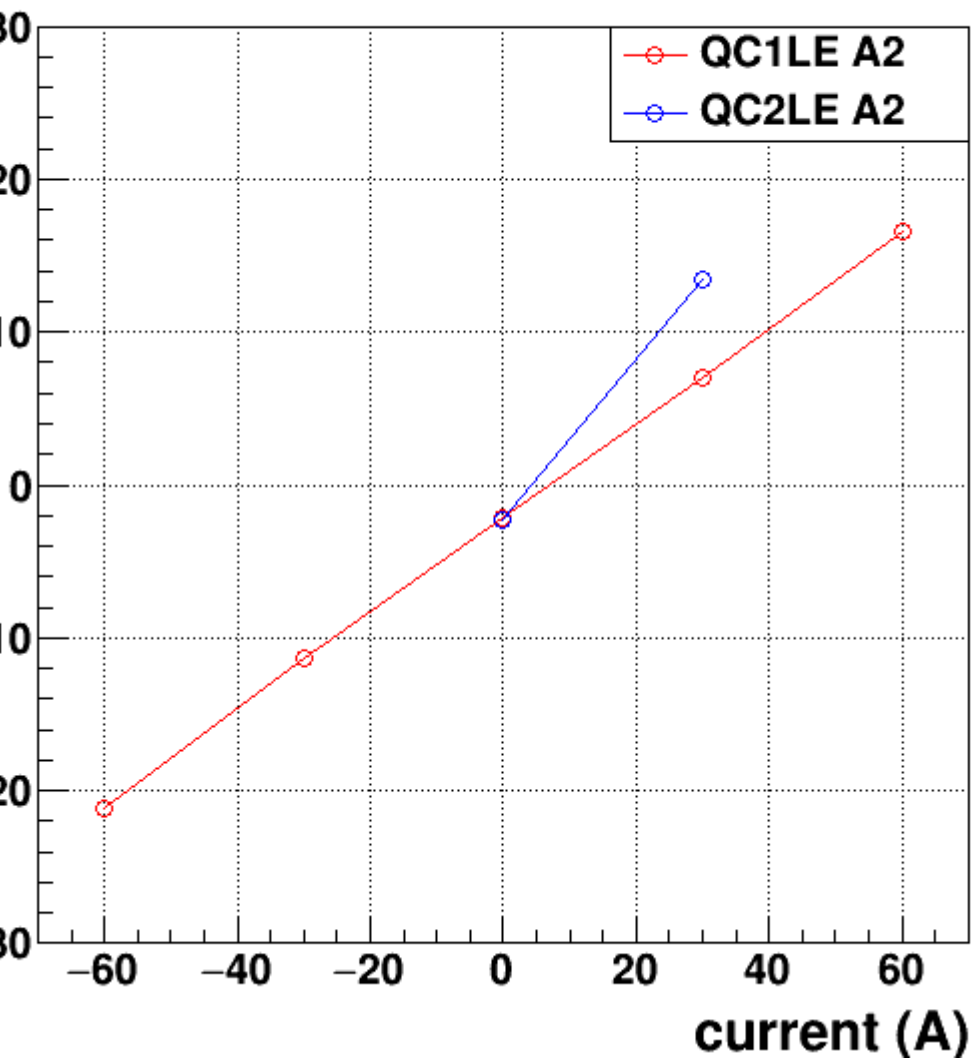
Measured magnet centers vs. designs :LE



Corrector coil measurement



Corrector coil measurements



ハーモニクコイルの結果よりも10%多めに磁場が回転しています

Roll Angle Summary

	time	step	points	AC/DC	temp [K]	Corrected.Angle.avg	Corrected.Angle.sdev	Y.Intercept		
60512_221003_AC_RA	2016/05/13 12:10:07.303 PM	7.99997	3	AC	284.8	-2.160051362	7.440711411	-0.026341185		
60512_222013_AC_RA	22:20:17 17 May 2016	8.00008	3	AC	4.5	-2.138861935	0.449960727	-0.003875694		
60518_230533_AC_RA	2016/05/19 01:05:37.523 PM	7.99998	5	AC	53.5	-2.30230864	0.293487898	0.000230944		-2 m
60519_025127_AC_RA	2016/05/19 04:51:31.488 PM	3.99998	5	AC	4.6	-2.400773409	0.550683523	0.000553904		
60518_003159_DC_RA	2016/05/18 02:32:03.767 PM	7.99998	3	DC	4.6	-2.46632869	0.047816677	0.000587368		
	time	step	points	AC/DC	temp [K]	Corrected.Angle.avg	Corrected.Angle.sdev	Y.Intercept		
60513_011539_AC_RA	2016/05/13 03:15:43.375 PM	8.00005	3	AC	296.2	-1.16660143	0.151872413	-0.004966655		
60518_035515_AC_RA	2016/05/18 05:55:19.251 PM	8.00004	3	AC	4.5	-2.12638445	0.267955035	-0.009699683		
60518_192234_AC_RA	2016/05/19 09:22:38.091 AM	7.99993	5	AC	56.3	-2.094823437	0.197282815	0.020384004		-2 m
60518_025530_DC_RA	2016/05/18 04:55:34.838 PM	8.00001	3	DC	4.5	-2.296204478	0.070374621	-0.004670836		
60519_040838_DC_RA	2016/05/19 06:08:42.984 PM	7.99999	5	DC	4.6	-2.004813375	0.063341007	-0.011126347		
60519_044144_DC_RA	2016/05/19 06:41:49.012 PM	8.00004	5	DC	4.6	-2.050238036	0.081168485	0.004654312		
60519_045040_DC_RA	2016/05/19 06:50:44.220 PM	5.00002	5	DC	4.6	-1.997091085	0.120715685	0.007784411		
	time	step	points	AC/DC	temp [K]	Corrected.Angle.avg	Corrected.Angle.sdev	Y.Intercept		
60513_035500_AC_RA	2016/05/13 05:55:04.996 PM	8.00006	3	AC	288.1	-14.43288577	0.04489989	-0.118536256		
60516_052715_AC_RA	2016/05/16 07:27:19.583 PM	8.00002	3	AC	4.6	-14.57047401	0.518588106	-0.002086444		-15 m
60516_223413_DC_RA	2016/05/17 12:34:17.004 PM	8.00006	3	DC 1628.4	4.5	-14.93872642	0.050338415	0.004134953		
60517_003309_DC_RA	2016/05/17 02:33:13.596 PM	7.99999	3	DC 98.554	4.5	-15.65305035	0.761524057	0.095606907		
	time	step	points	AC/DC	temp [K]	Corrected.Angle.avg	Corrected.Angle.sdev	Y.Intercept		
60513_052206_AC_RA	2016/05/13 07:22:10.011 PM	7.99994	3	AC	286.6	-6.595074408	3.389687284	0.001527953		
60516_025008_AC_RA	2016/05/16 04:50:12.853 PM	7.99999	3	AC	4.6	-6.804040194	0.202965363	0.003512968	before survey	
60516_035921_AC_RA	2016/05/16 05:59:25.910 PM	8.00003	3	AC	4.6	-6.825448012	0.212391325	-0.029504372	after survey	
60517_041039_AC_RA	2016/05/17 06:10:43.035 PM	7.99998	3	AC	6.7	-7.054579133	1.886782532	-0.009793589		
60517_190122_AC_RA	2016/05/18 09:01:26.228 AM	7.99997	3	AC	51	-7.167213307	1.935567394	0.051505677		
60517_032610_DC_RA	2016/05/17 05:26:14.117 PM	8.00006	3	DC	4.6	-7.418722365	0.110512295	0.005082247		

Summary

from measurements so far :

Magnet center positions with several conditions (AC: 300K, ~50K, 4K and DC) are stable within 50~80 μm in x and y directions

Horizontal magnet centers of QC2LP and QC2LE differ ~1mm from the design.

- True?
- B1 corrector coil can correct
- How about QC1LP and QC2LP ? $\rightarrow$ we will measure soon.

Vertical positions differ 100~600 μm compared to the design values

- True?
- Hard to correct especially for QC1LP

Roll angles also differ ~2mrad.

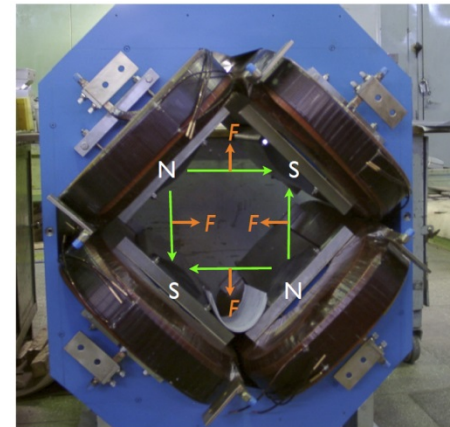
- A2 corrector coils are available
- Careful comparison with Harmonic coils' data と

Next:

We will resume SSW measurement in the next week.

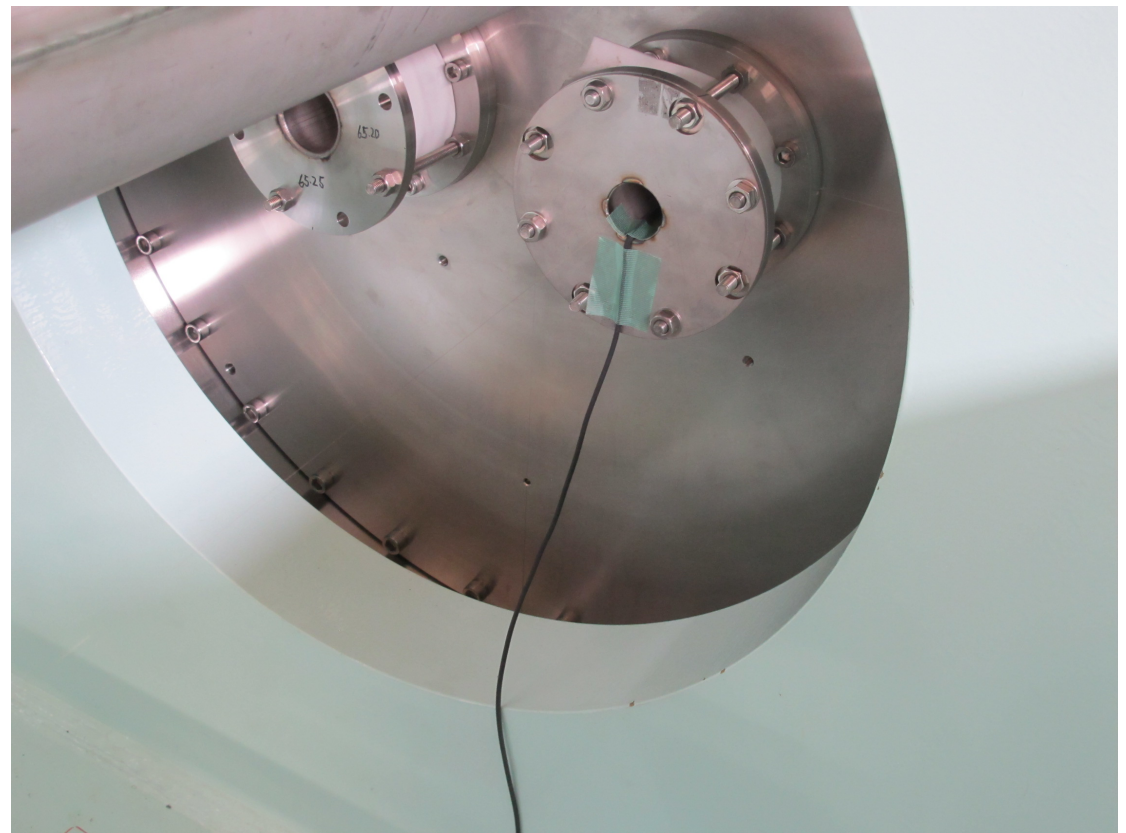
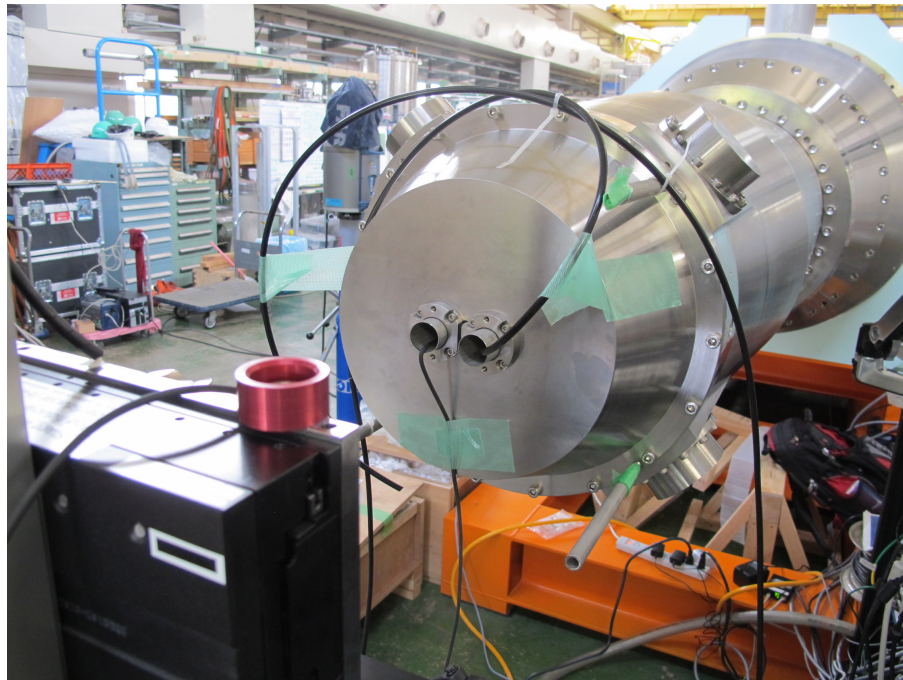
Understanding (hidden) systematic uncertainties ... use normal magnets

Measurements of QCSR in November...



seeing is believing

Return is also in the pipe



Repeatability

Qualitative								
Repeatability (7 or 10mm step)								
(microns)	ave_X	ave_Y_noSagCor	ave_Y_TsagCor	ave_Y_FsagCor	magEnds_X	magEnds_Y_noSagCor	magEnds_Y_TsagCor	magEnds_Y_FsagCor
warm 10A AC	2	2	20	NA	50	50	80	NA
cold 10A AC	2	2	20	NA	50	50	80	NA
cold full cur DC	5	5	20	10	100	100	200	200
	(RA runs)	(sagCal runs)	(intcpUncert)	(intcpUncert)	(PYmeas)	(PYmeas)	(PYmeas)	(PYmeas)

length measurements at full field

net	step	Cur	SSW_IntStrTF(T/kA)	s.d. (x/y)	Lm	Grad	ref_strTF(T/kA)	%diff
2LE	7mm	979.2A	0.01526	0.00004	0.537	0.02911	0.01563	-2.4
	5mm	979.2A		0.00009	0.537	0.02911		-2.6
1LE	10mm	1580.384		0.00012	0.373	0.04580		1.6
	7mm	1580.384		0.00005	0.373	0.04580		0.7
2LP	10mm	879.083		0.00002	0.4099	0.03197		-0.3
LLP	7mm	1628.464		0.00002	0.3336	0.04242		1.7

d to understand variations – e.g. slight wire susceptibility may influence large step
 surements in strong magnet (perhaps sag calibration measurements can be used to
 apolate this to “infinite tension”)

全体組立

【器】メーカー API社 製品名 レーザトラッカ 型名(T3)
【申請図面】 A12K012

図面指示値	ピン穴直径
6H7	$\begin{matrix} +0.012 \\ 0 \end{matrix}$

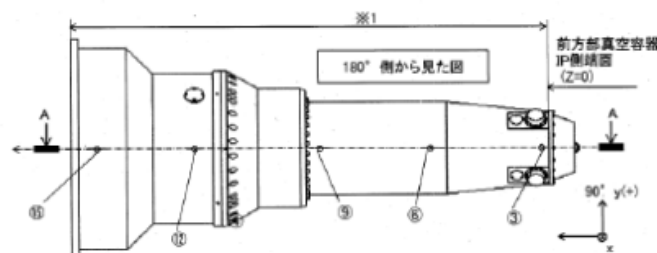
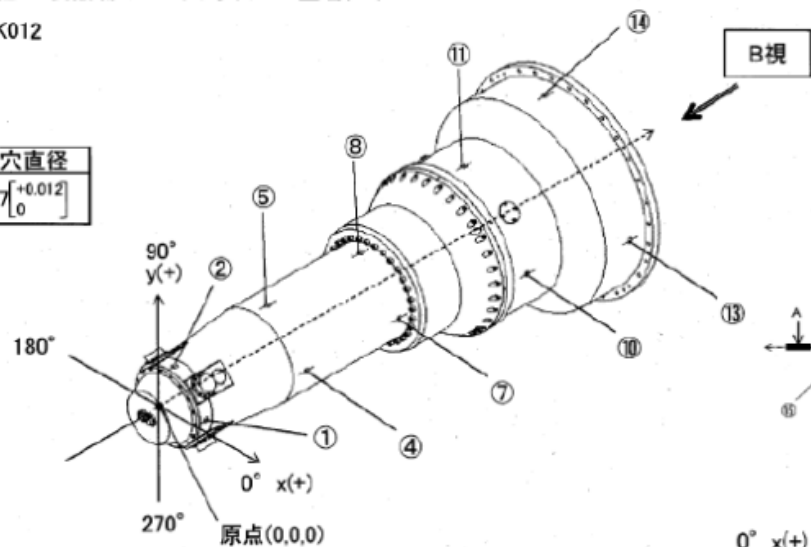


図1 クライオスタット全体

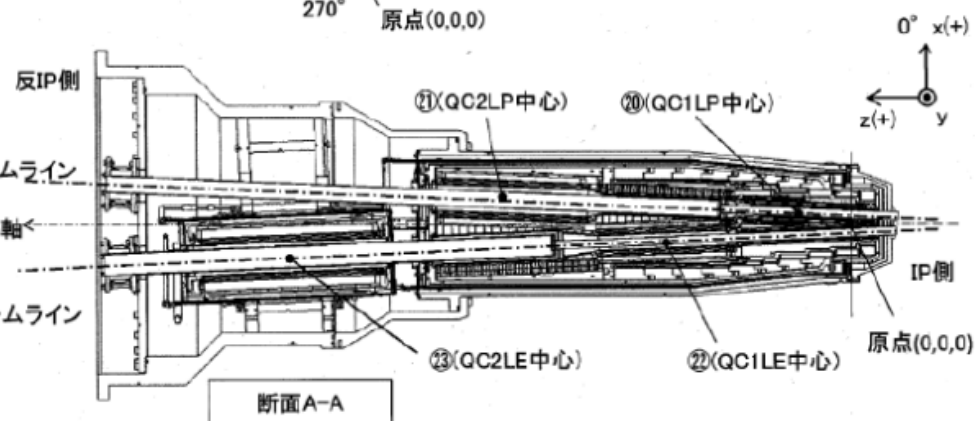
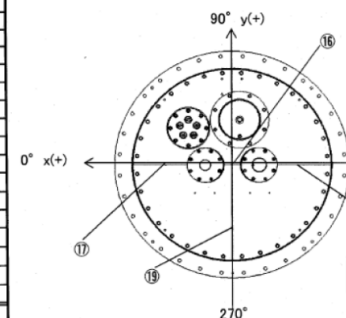
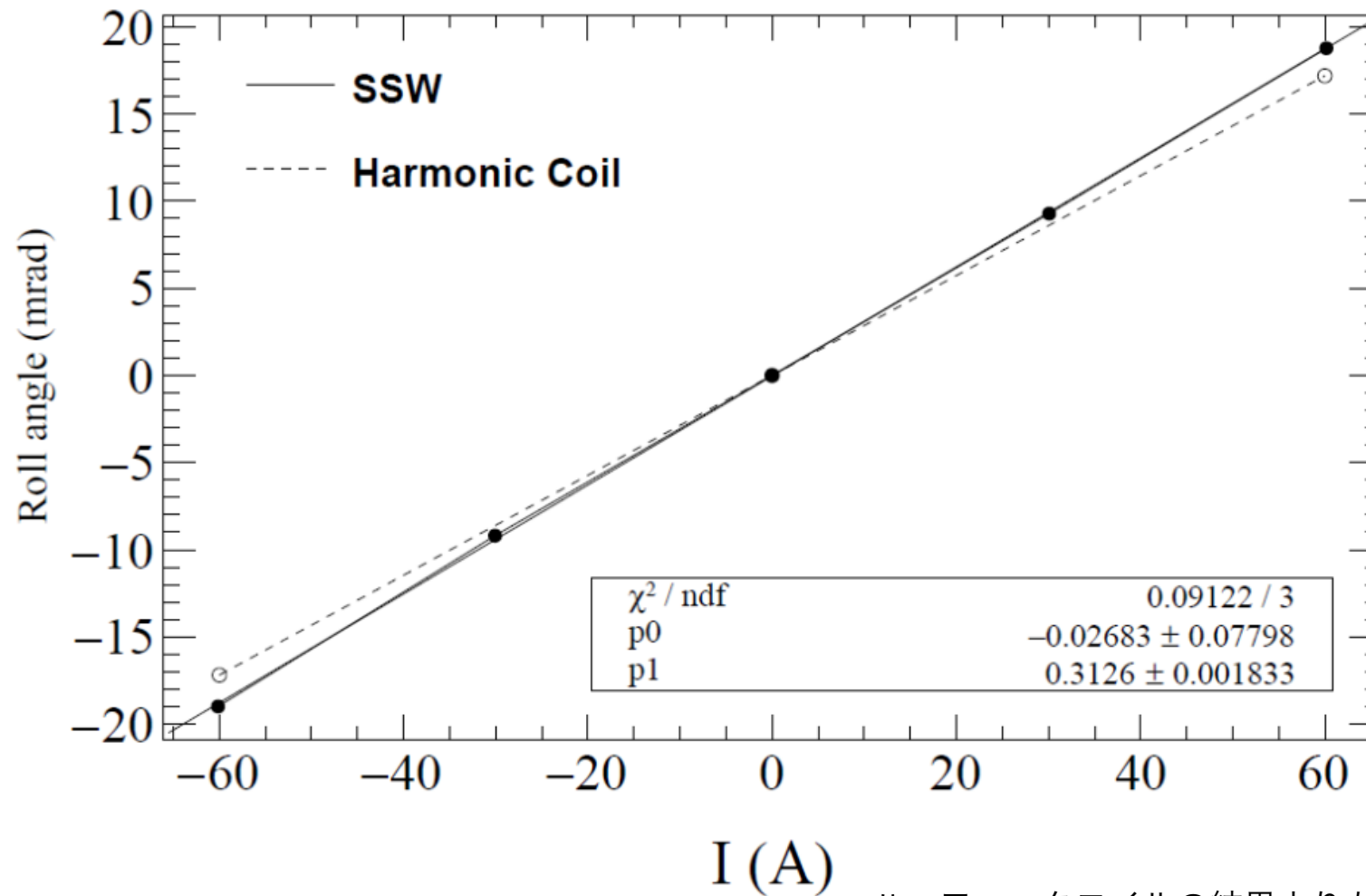


表3 各部座標 [mm]

測定位置		目標値			単品測定値の合成			目標値と測定値の差			
		x	y	z	x	y	z	x	y	z	
		0	0	0	0	0	0	0	0	0	
真空容器ピン穴	前方	①	201.5	0	40	201.60	-0.03	40.06	0.10	-0.03	0.06
		②	0	201.5	40	0.03	201.54	40.05	0.03	0.04	0.05
		③	-201.5	0	40	-201.77	0.15	40.08	-0.27	0.15	0.08
		④	249	0	644.5	249.12	0.04	644.51	0.12	0.04	0.01
		⑤	0	249	644.5	0.08	249.25	644.56	0.08	0.25	0.06
		⑥	-249	0	644.5	-249.17	0.22	644.51	-0.17	0.22	0.01
		⑦	249	0	1244.5	249.05	0.07	1244.63	0.05	0.07	0.13
		⑧	0	249	1244.5	0.17	249.27	1244.56	0.17	0.27	0.06
		⑨	-249	0	1244.5	-249.04	0.31	1244.56	-0.04	0.31	0.06
	後方	⑩	409	0	1919.5	409.01	0.39	1919.56	0.01	0.39	0.06
		⑪	0	409	1919.5	0.12	409.26	1919.55	0.12	0.26	0.05
		⑫	-409	0	1919.5	-408.91	0.56	1919.50	0.09	0.56	0.00
		⑬	549	0	2448	549.10	0.41	2448.04	0.10	0.41	0.04
		⑭	0	549	2448	0.11	549.28	2448.01	0.11	0.28	0.01
		⑮	-549	0	2448	-548.87	0.57	2448.06	0.13	0.57	0.06
	後方端板	⑯	0	0	2448	-0.19	0.42	2447.80	-0.19	0.42	-0.20
		⑰	340	0	2448	339.77	0.06	2447.95	-0.23	0.06	-0.05
		⑱	-340	0	2448	-340.16	0.59	2448.08	-0.16	0.59	0.08
		⑲	0	-340	2448	-0.44	-339.60	2448.00	-0.44	0.40	0.00
磁石中心	QC1LP	⑳	38.91	-1.50	169.36	38.91	-1.44	169.45	0.00	0.06	0.09
	QC2LP	㉑	80.11	-1.50	1161.56	80.16	-1.47	1161.70	0.05	0.03	0.14
	QC1LE	㉒	-57.95	0.00	645.15	-57.91	0.01	645.20	0.04	0.01	0.05
	QC2LE	㉓	-111.32	0.00	1934.71	-111.64	0.08	1934.56	-0.32	0.08	-0.15
測定日		①～⑱: 2015/12/9 ㉑～㉒: 2015/10/27 ㉓: 2015/7/24									
測定者		中村									



QC1LE+A2



ハーモニックコイルの結果よりも10%多めに磁場が回転しています

QC1LE

			trackStageA	trackStageB	trackMagA	trackMagB	center	TrackSagMagA	TrackSagMagB	center	sag_correction	
											magA	magB
176	AC 4.5K	x	167.617	12.08	65.70022453	50.10140086	57.9008127	65.71455733	50.08015574	57.89735654	0.014333	-0.0212
Y0		y	0.512	-0.509	-0.15701784	-0.259414048	-0.208215944	-0.091425432	-0.323755047	-0.20759024	0.065592	-0.064
182	DC	x	167.637	12.06	65.69401424	50.09117896	57.8925966	65.71852526	50.07478121	57.89665323	0.024511	-0.0163
Y0		y	-3.808	1.321	-0.447184623	0.067203379	-0.189990622	-0.475856962	0.142960117	-0.166448423	-0.02867	0.07575
181	AC53K	x	167.587	12.09	65.69643483	50.10162276	57.8990288	65.69814867	50.10102994	57.89958931	0.001714	-0.0005
Y2_10mmste		y	-0.178	-0.269	-0.237628426	-0.246754827	-0.242191627	-0.266604528	-0.213391969	-0.239998249	-0.02898	0.03336
249	AC 4.7K	x	167.487	12.21	65.74059147	50.16784322	57.95421734	65.74757512	50.15436334	57.95096923	0.006984	-0.0134
Y3		y	1.362	-0.729	-0.008143294	-0.217849925	-0.112996609	-0.007694291	-0.20179481	-0.10474455	0.000449	0.01605
246	DC	x	166.667	12.55	65.68069009	50.22427838	57.95248423	65.63983751	50.26843836	57.95413793	-0.04085	0.04415
Y3		y	0.012	-0.209	-0.132811893	-0.154976008	-0.143893951	-0.166476934	-0.117781314	-0.142129124	-0.03367	0.03719
125	AC room	x	167.527	12.36	65.85266978	50.29095345	58.07181162	65.86419547	50.27400258	58.06909902	0.011526	-0.0169
Warm1		y	-1.978	0.431	-0.399484842	-0.157885954	-0.278685398	-0.381126052	-0.192837735	-0.286981893	0.018359	-0.0349
								ave_x		-57.94	design_x	-57
								ave_y		-0.19	design_y	

QC2LE

			trackStageA	trackStageB	trackMagA	trackMagB	center	TrackSagMa gA	TrackSagMa gB	center	magA	magB	
20160518_024910	DC	x	169.827	9.34	123.884311	100.712315	112.2983	123.82473	100.76752	112.2961	-0.05958	0.055203	
SURVEY1		y	-0.898	0.591	-0.4717433	-0.2567533	-0.36425	-0.4641617	-0.259269	-0.36172	0.007582	-0.00252	
20160518_035039	AC 4.5K	x	169.307	10.28	123.782266	100.821073	112.3017	123.77206	100.81551	112.2938	-0.0102	-0.00557	
SURVEY1		y	-0.748	0.351	-0.4333888	-0.2747091	-0.35405	-0.4425508	-0.256245	-0.3494	-0.00916	0.018464	
20160518_195218	AC	x	169.287	10.37	123.793755	100.848445	112.3211	123.80034	100.81964	112.31	0.006588	-0.02881	
SURVEY2		y	-0.638	0.181	-0.4035445	-0.2852928	-0.34442	-0.3881773	-0.291196	-0.33969	0.015367	-0.0059	
20160519_043749	DC	x	169.957	9.1	123.908391	100.682972	112.2957	123.90066	100.70762	112.3041	-0.00773	0.024644	
5mmstep+SURVEY2		y	-1.008	0.881	-0.4672351	-0.1944909	-0.33086	-0.5701009	-0.22443	-0.39727	-0.10287	-0.02994	
20160525_102933	AC	x	169.307	10.24	123.770815	100.803846	112.2873	123.77013	100.80837	112.2892	-0.00069	0.004522	1/f2
SURVEY4		y	-0.868	0.671	-0.4274297	-0.2052205	-0.31633	-0.4146487	-0.222609	-0.31863	0.012781	-0.01739	1/f2
20160525_140642	DC	x	169.687	9.58	123.853094	100.735964	112.2945	123.85557	100.73068	112.2931	0.002481	-0.00528	1/T
SURVEY4		y	0.542	-2.139	-0.2254911	-0.6125887	-0.41904	-0.1791846	-0.66073	-0.41996	0.046307	-0.04814	1/T
20160513_001236	AC_room	x	169.217	10.52	123.786735	100.873189	112.33	123.81087	100.84881	112.3298	0.024137	-0.02438	
surveyWarm2		y	-0.208	-0.449	-0.2769912	-0.3117881	-0.29439	-0.3146003	-0.305977	-0.31029	-0.03761	0.005811	
									ave_x	-112.30	design_x	-111.32	
									ave_y	-0.36	design_y	0	

QC1LP & QC2LP

			trackStageA	trackStageB	trackMagA	trackMagB	center	TrackSagMagA	TrackSagMagB	center	magA	magB	
0516 5401	AC	x	-166.783	-13.79	-46.312957	-32.572255	-39.4426	-46.3466782	-32.53125995	-39.438969	-0.033721	0.040995055	
eyA		y	-2.188	-1.579	-1.70846	-1.65376416	-1.68111	-1.70778584	-1.654880837	-1.6813333	0.0006742	-0.001116676	
0516 636	DC	x	-171.243	-12.84	-46.513005	-32.2864161	-39.3997	-46.554758	-32.26478877	-39.409773	-0.041753	0.021627337	
eyB		y	-4.138	-1.159	-1.7922701	-1.52471829	-1.65849	-1.80819186	-1.505194702	-1.6566933	-0.015922	0.019523584	
0513 5418	AC_room	x	-168.833	-13.32	-46.378654	-30.361624	-38.3701	-46.3225859	-30.42501199	-38.373799	0.0560682	-0.063388043	
eyWarm3		y	-9.578	-0.889	-2.7360909	-1.95570902	-2.3459	-2.61632632	-2.08254121	-2.3494338	0.1197646	-0.126832186	sagBig?
									ave_x	39.07	design_x	38.91	
									ave_y	-1.90	design_y	-1.5	

			trackStageA	trackStageB	trackMagA	trackMagB	center	TrackSagMagA	TrackSagMagB	center	magA	m
0516_024430	AC(~4K)	x	-167.813	-14.61	-89.7101568	-72.80354746	-81.25685213	-89.69582928	-72.8192085	-81.25751889	0.014328	-
eyD		y	-2.288	-2.079	-2.181451863	-2.158387815	-2.169919839	-2.179956122	-2.155532459	-2.16774429	0.0014960	-
0517_022234	DC	x	-172.913	-10.79	-90.26274348	-72.37177383	-81.31725866	-90.21191545	-72.43588234	-81.32389889	0.050828	-
ryC		y	-6.538	1.201	-2.592660134	-1.738628231	-2.165644182	-2.519728924	-1.950059456	-2.23489419	0.072931	-
0513_043512	AC_room	x	-168.323	-14.36	-89.83270902	-72.84223043	-81.33746973	-89.78941716	-72.88746965	-81.3384434	0.043292	-
eyWarm4		y	-2.308	-2.029	-2.165765884	-2.134977035	-2.15037146	-2.170340417	-2.159442026	-2.164891222	-0.00457	-
									ave_x	81.31	design_x	
									ave_y	-2.19	design_y	

QC2LE+A1, B1 and A2

Harmonic coilの結果との比較も準備しま

QC2LE_correction coils			dx	dy
SSW_R_20160525_200006_DC_SO	2016/05/25 08:00:10.618 PM	QC2LE_main	0	0
SSW_R_20160525_200348_DC_SO	2016/05/25 08:03:51.900 PM	QC2LE+A1_+60A	0.0140205	3.1974287
SSW_R_20160525_200555_DC_SO	05:58.8	QC2LE+A1_+60A	0.0162405	3.1938276
SSW_R_20160525_201033_DC_SO	2016/05/25 08:10:37.272 PM	QC2LE+A1_-60A	0.0811598	-2.960667
SSW_R_20160525_201222_DC_SO	2016/05/25 08:12:26.095 PM	QC2LE+A1_-60A	0.0795518	-2.960187
SSW_R_20160525_201514_DC_SO	2016/05/25 08:15:18.648 PM	QC2LE+A1_-60A	0.0788113	-2.957992
SSW_R_20160525_204744_DC_SO	2016/05/25 08:47:48.893 PM	QC2LE+B1_+60A	3.4432189	0.0451268
SSW_R_20160525_205039_DC_SO	2016/05/25 08:50:43.432 PM	QC2LE+B1_+60A	3.450505	0.0439505
SSW_R_20160525_205524_DC_SO	2016/05/25 08:55:28.708 PM	QC2LE+B1_+60A	3.4449356	0.0481159
SSW_R_20160525_212356_DC_SO	2016/05/25 09:24:00.510 PM	QC2LE+B1_+30A	1.6387746	0.0264326
SSW_R_20160525_212816_DC_SO	2016/05/25 09:28:20.002 PM	QC2LE+B1_-30A	-1.903114	0.0035128
			Angle.avg	Angle.sdev
SSW_R_20160525_214658_DC_RA	2016/05/25 09:47:02.568 PM	QC2LE	-2.284629	0.1364434
SSW_R_20160525_215436_DC_RA	2016/05/25 09:54:40.081 PM	QC2LE+A2_+30A	13.45524	0.119109

ヒステリシス5%くらい

Harmonic coilの結果との比較も準備しま

QC1LE+A1, B1 and A2

QC1LE_correction coils			dx	dy
SSW_R_20160526_144713_DC_PY	2016/05/26 02:47:17.466 PM	QC1LE	0	0
SSW_R_20160526_150302_DC_SO	2016/05/26 03:03:05.936 PM	QC1LE+B1_+30A	1.056283	-0.01793
SSW_R_20160526_151312_DC_SO	2016/05/26 03:13:16.228 PM	QC1LE+B1_-30A	-1.05438	0.006157
SSW_R_20160526_151629_DC_SO	2016/05/26 03:16:33.615 PM	QC1LE+B1_-60A	-2.1083	0.013085
SSW_R_20160526_152959_DC_SO	2016/05/26 03:30:03.461 PM	QC1LE+A1_+30A	-0.01298	0.622072
SSW_R_20160526_153649_DC_SO	2016/05/26 03:36:53.593 PM	QC1LE+A1_-30A	-0.01758	-0.62879
roll			Corrected. Angle.avg	Corrected. Angle.sdev
SSW_R_20160526_160723_DC_RA	2016/05/26 04:07:27.939 PM	QC1LE	-2.20886	0.078277
SSW_R_20160526_163254_DC_RA	2016/05/26 04:32:58.000 PM	QC1LE+A2_30A	7.076841	0.060697
SSW_R_20160526_164510_DC_RA	2016/05/26 04:45:14.000 PM	QC1LE+A2_-30A	-11.4009	0.061995
SSW_R_20160526_165800_DC_RA	2016/05/26 04:58:03.922 PM	QC1LE+A2_-60A	-21.2021	0.072452
SSW_R_20160526_171628_DC_RA	2016/05/26 05:16:32.788 PM	QC1LE	-2.93344	0.078084
SSW_R_20160526_172655_DC_RA	2016/05/26 05:26:58.874 PM	QC1LE+A2_+60A	16.56536	0.082787

測定量 (続き)

Co-directional measurement

$$\delta_{\text{co}} = \frac{x_a + x_b}{2}$$

Counter-directional measurement

$$\delta_{\text{cn}} = x_a \frac{\alpha_1 + \alpha_2}{\alpha_3} - x_b \frac{a_2}{a_3}$$

$$\alpha_1 = 1 - \frac{b+a}{L_w}$$

$$\alpha_2 = \frac{2a + 4b - 3L_w}{6L_w}$$

$$\alpha_3 = 1 - \frac{2(b+a)}{L_w} + \frac{4}{3} \frac{a^2 + b^2 + ab}{L_w^2}$$

Geometricalに決まる

