



MQXFAP2 magnetic measurements during magnet assembly

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MQXFAP2 Features and Warm Measurements

From MQXFAP1 to MQXFAP2:

- Final magnetic length (4.2 m) and strand specification
- Improved coil sizes: no mid-plane shims or asymmetric radial shims

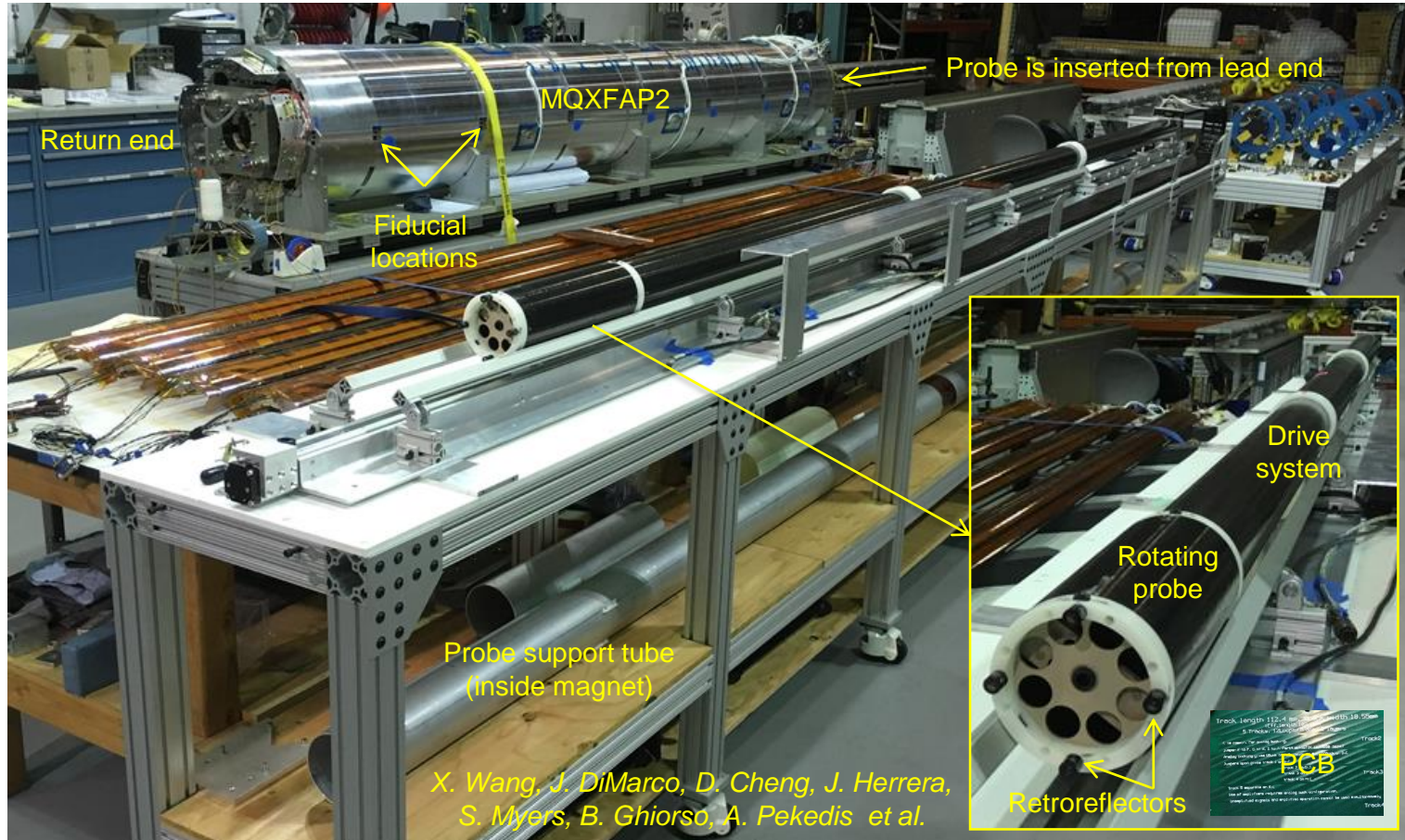
Magnetic measurement goals during magnet assembly

- Field harmonics as a function of longitudinal position
- Magnetic axis vs. longitudinal position relative to external fiducials
- Relative change in the field orientation vs. longitudinal position

Longitudinal scans performed so far:

- 6/1, azimuthal loading only: 110 mm step, without probe position survey
- 6/4, azimuthal loading only: 110 mm step, including probe position survey
- 6/14, after axial loading: both 110 mm and 123 mm step, with survey
 - 123 mm step allows to overlap the positions of the two PCBs mounted on the probe

Magnetic Measurement System



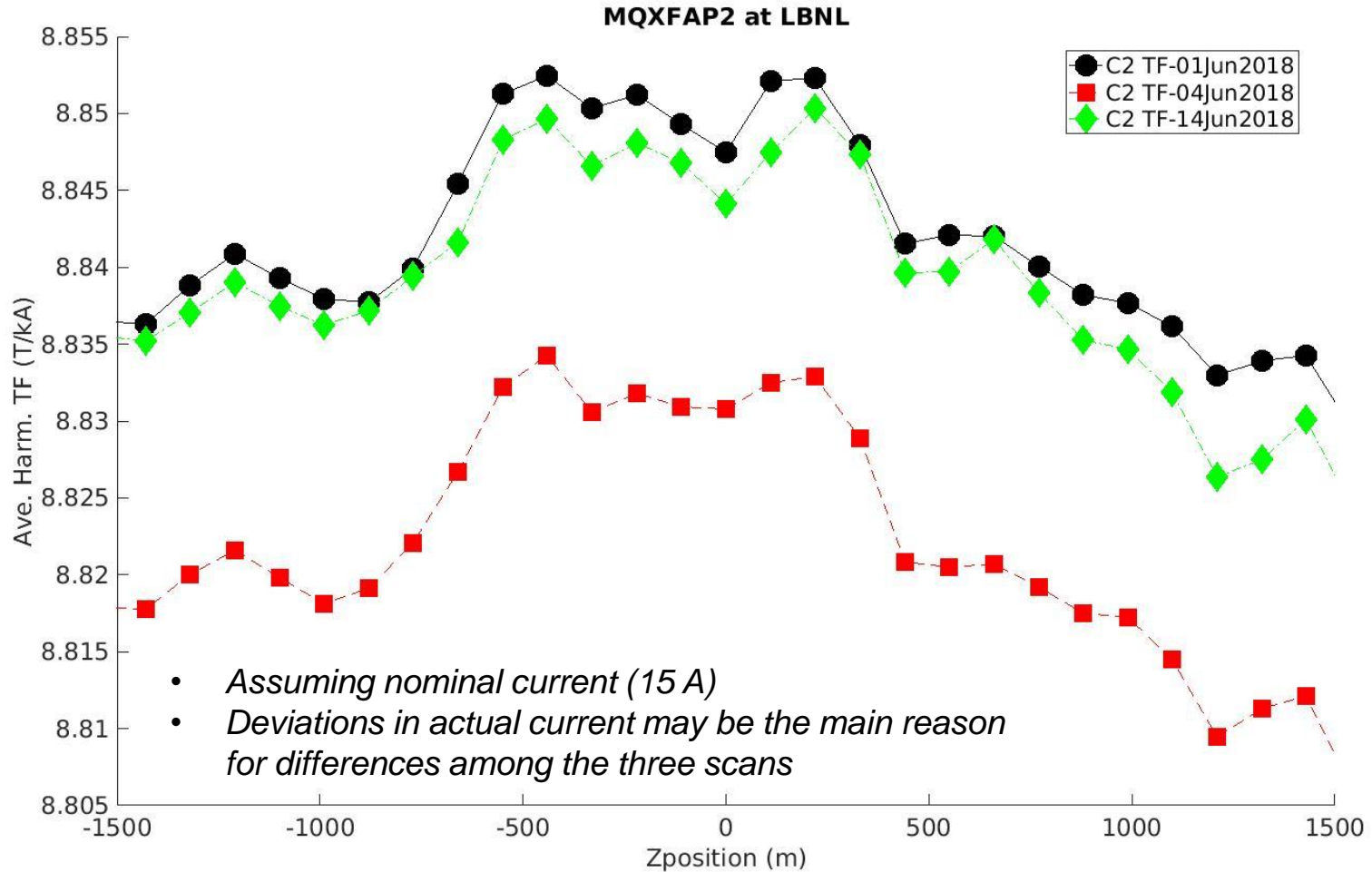
X. Wang, J. DiMarco, D. Cheng, J. Herrera,
S. Myers, B. Ghiorso, A. Pekedis et al.

Rotating probe includes two identical PCBs from FNAL with 108.74 mm effective length and 59.5 mm radius

Magnetic Field Harmonics

- Measurement conditions:
 - Magnet current: ± 15 A (within 0.2%)
 - Accurate current measurement will be implemented for future runs
 - Results are the average over 30 probe rotations
 - Data reduction by Joe DiMarco
- Splice connection not yet performed →
 - Affects lead end harmonics and field decay (magnetic length)
- Probe support tube inside magnet needs improvement
 - Split in two parts: discontinuity near magnet center, in particular for the 6/1 run
 - Improved central connection in 6/4 and 6/14 runs
 - Length of tube did not allow to cover the entire magnetic length
 - A longer tube is being procured
- Plots are shown for the central section of the magnet (± 1.5 m)
- Some open issues with the data validation and processing →
 - Results shown are still PRELIMINARY

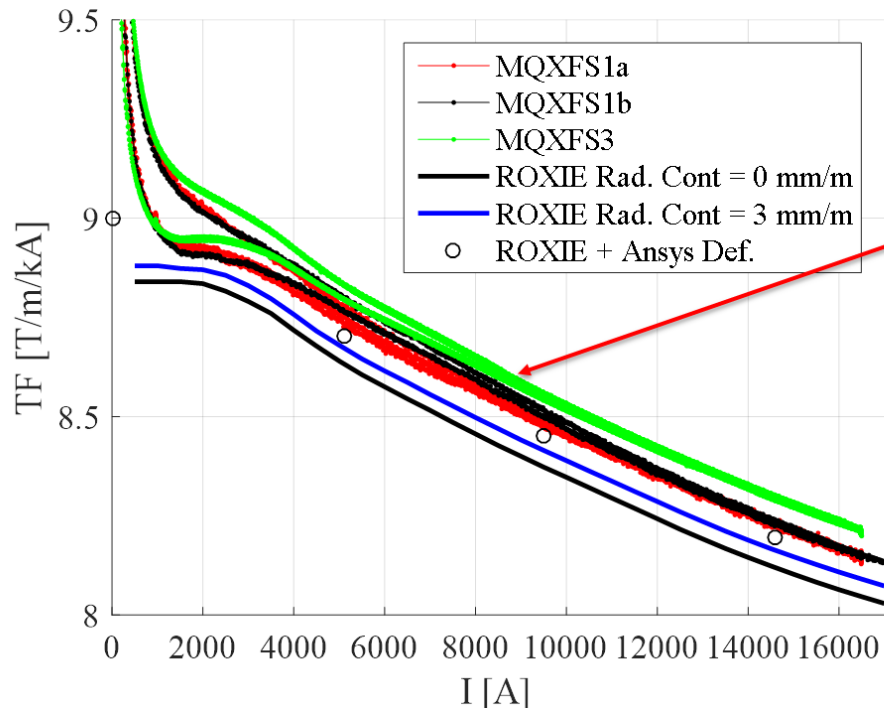
Transfer Function



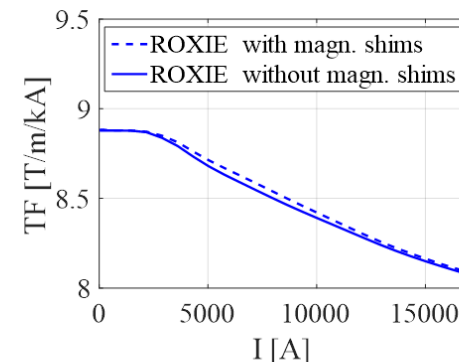
T.F. Reference: Design and Short Models

Susana Izquierdo Bermudez, Joint LARP CM28/HiLumi Meeting, April 2017, Napa

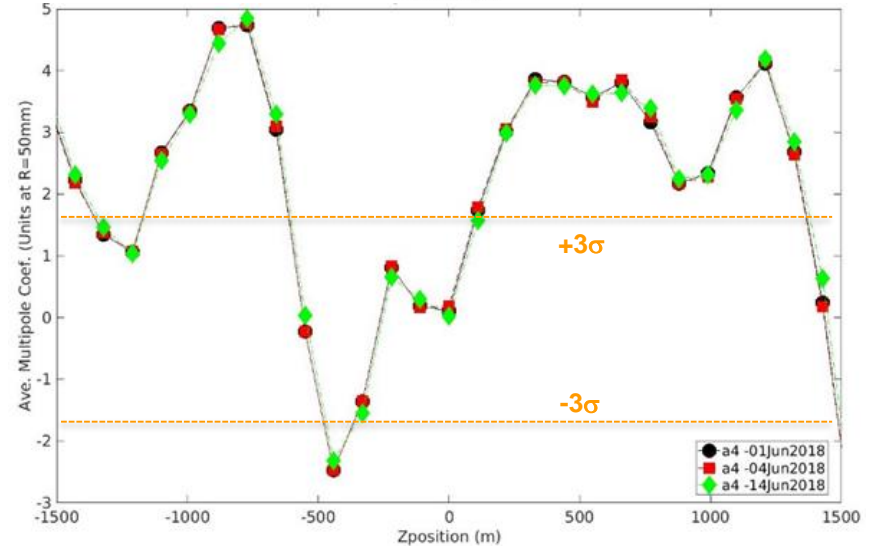
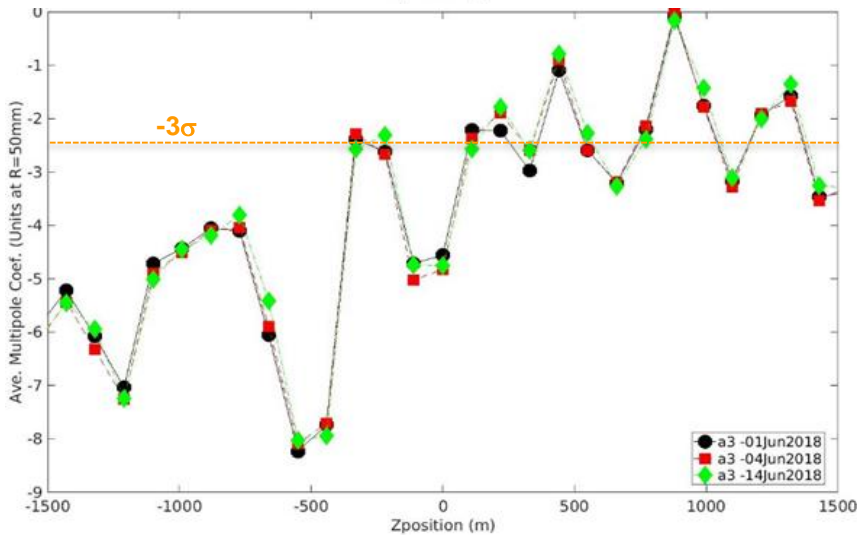
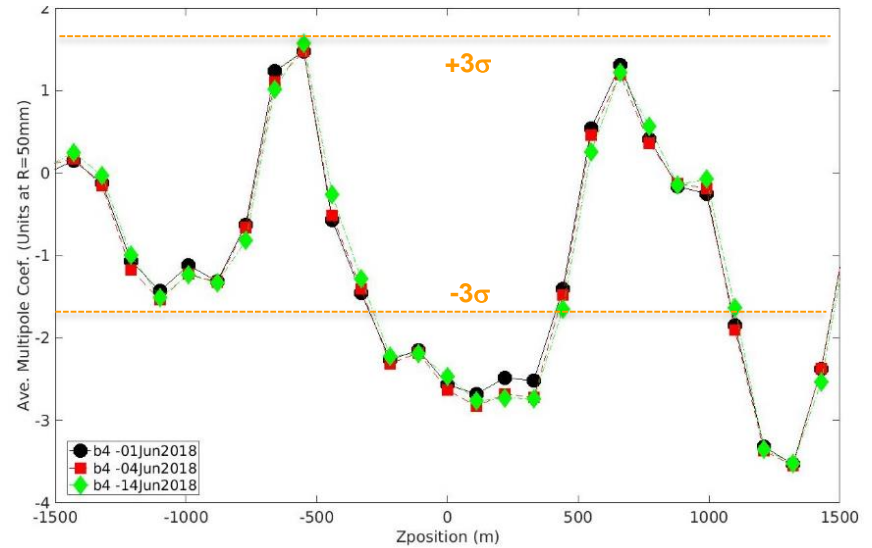
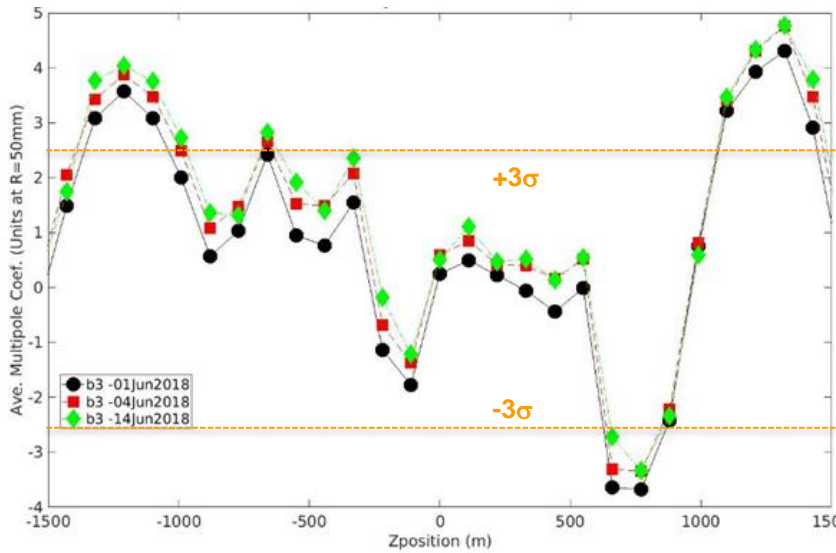
- Saturation well captured by ROXIE model
- Good agreement calculation/measurements on geometric transfer function for MQXFS1:
 - Measured field is 30 units stronger assuming a coil radial contraction during cool down of 3 mm/m
 - Measured field is 10 units stronger introducing the coil deformation as computed in ANSYS.
- Measured transfer function in MQXFS3a is 20 units stronger than in MQXFS1.



- Remark: the small differences in saturation in the intermediate current level for MQXFS1a and MQXFS1b are expected due to the insertion of magnetic shims.



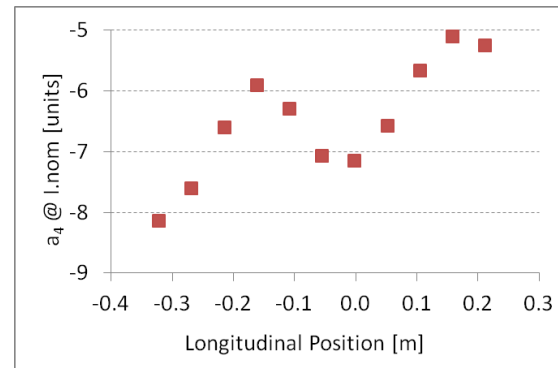
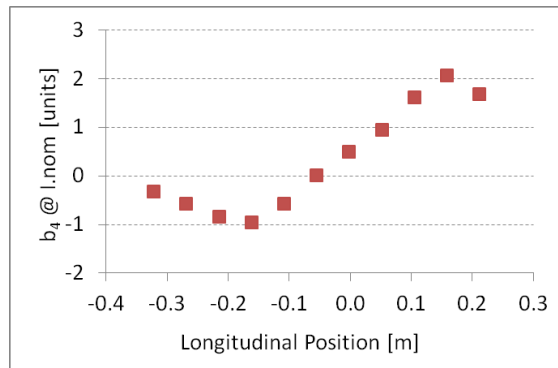
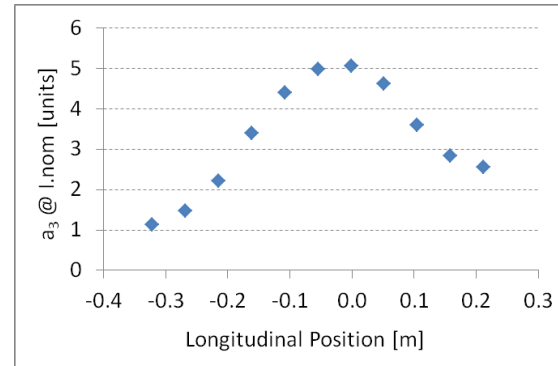
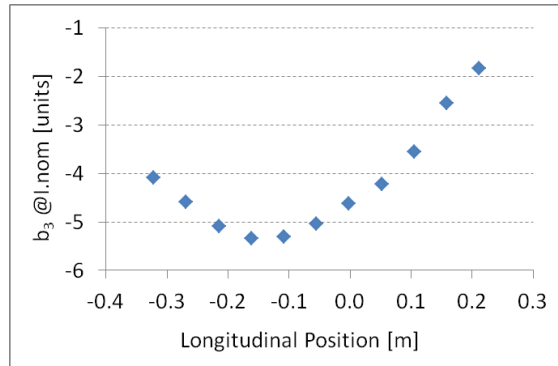
Low order harmonics (n=3, 4)



Reference: MQXFS1 low-order harmonics

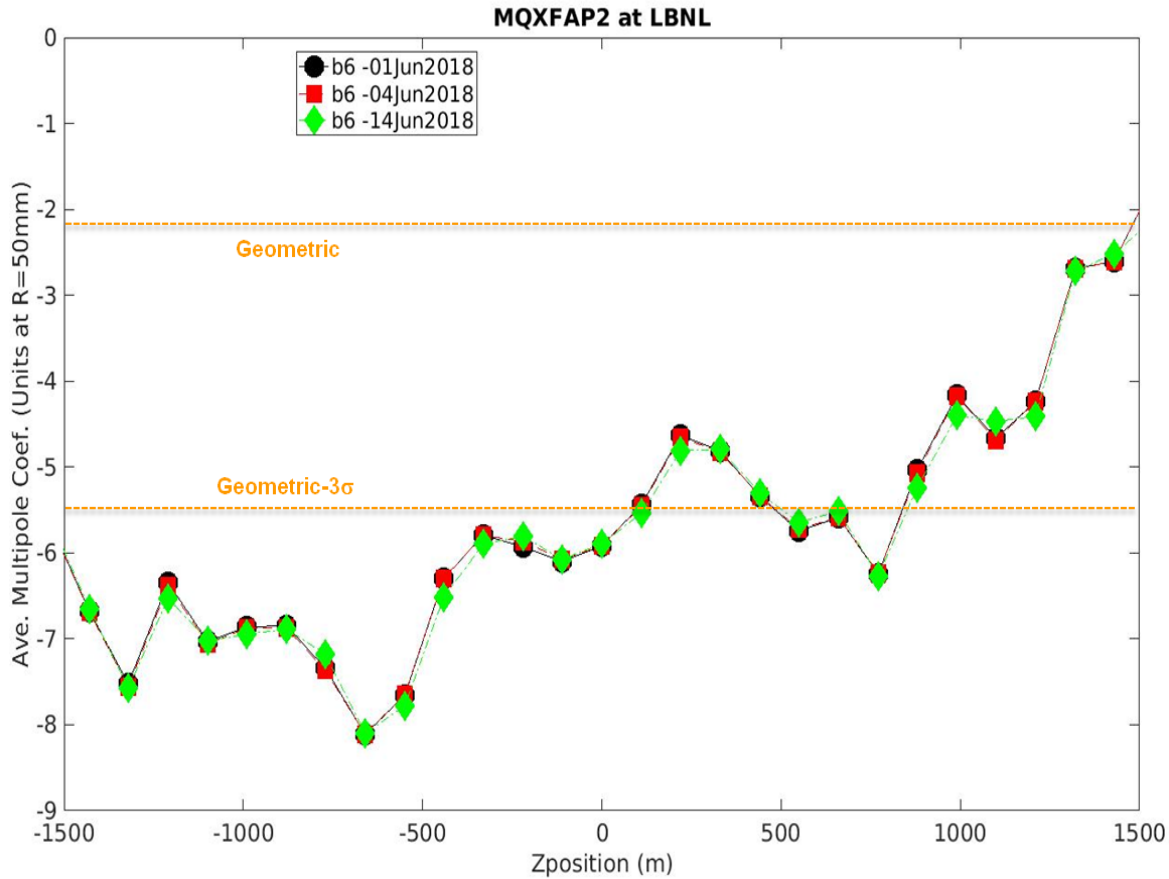


Straight section b_3 , a_3 , b_4 , a_4

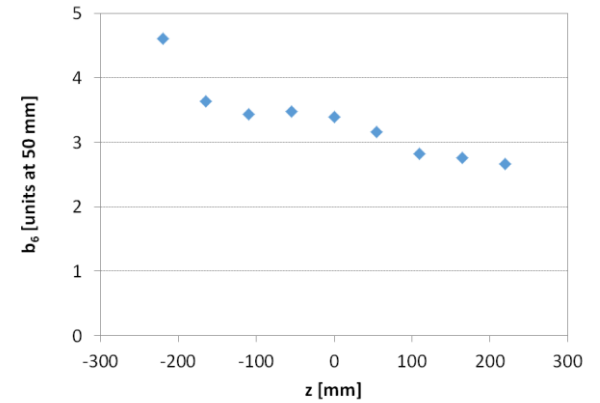


Axial variations (measured with short probe) need to be considered when analyzing/evaluating results

Allowed harmonics: b_6



MQXFS1a warm measurements after loading: b_6

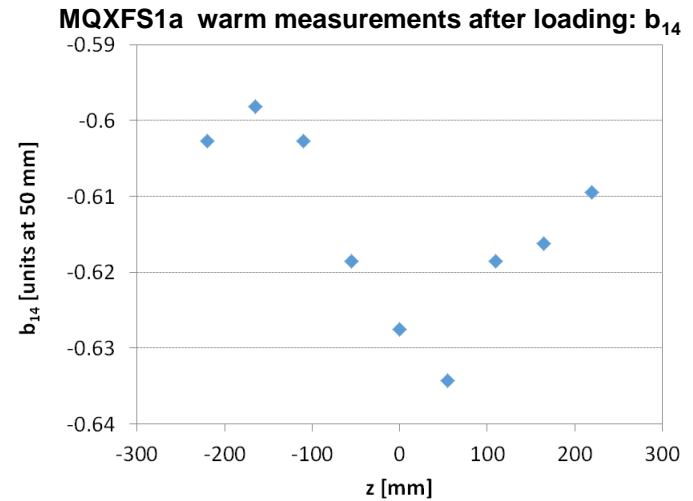
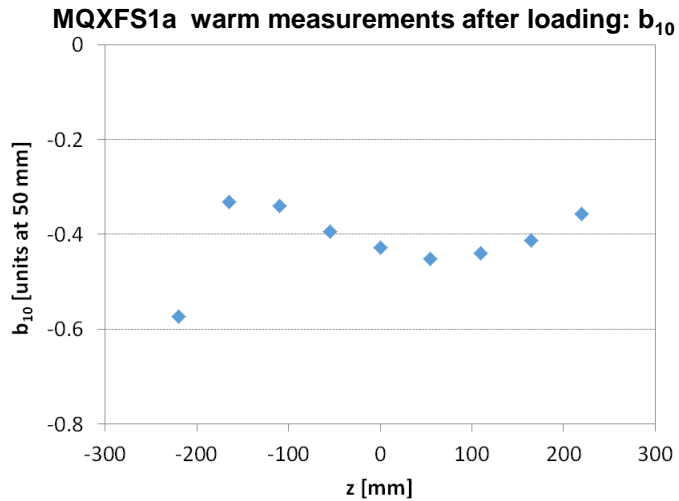
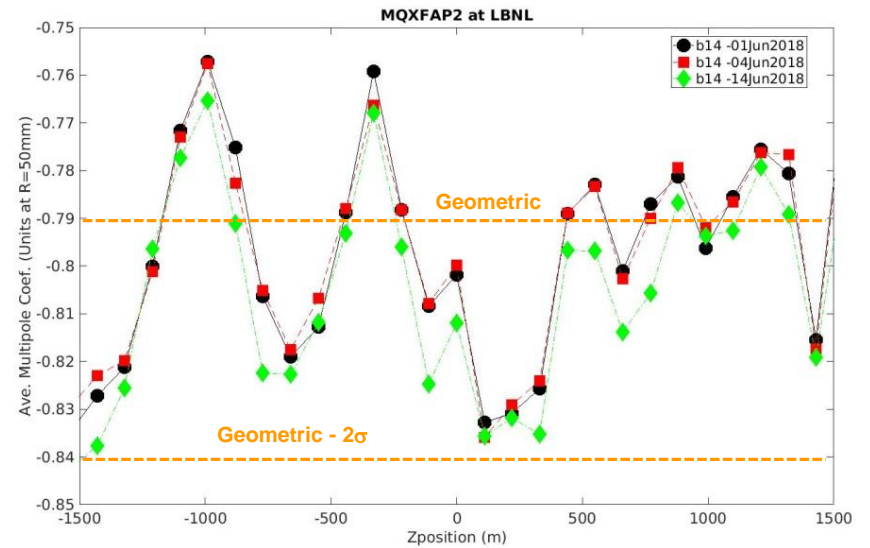
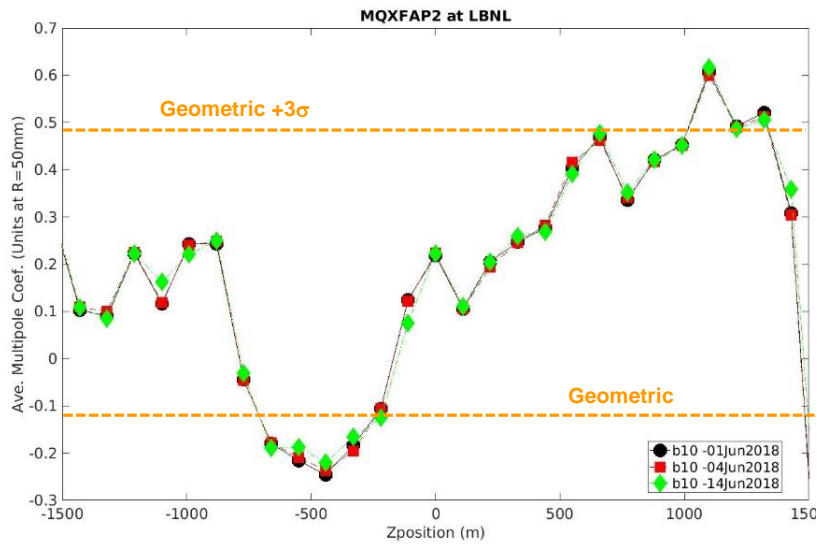


AVERAGE FIELD HARMONICS IN THE STRAIGHT SECTION AFTER MAGNET LOADING AT ROOM TEMPERATURE

n	MQXFS1a		MQXFS3a		MQXFS5a	
	b_n	a_n	b_n	a_n	b_n	a_n
3	-3.24	3.46	-1.69	-1.30	-1.30	-0.27
4	0.30	-4.18	2.13	2.75	0.55	-1.96
5	2.47	-0.55	-2.37	-1.55	0.35	-0.22
6	3.57	0.65	-1.90	0.60	-4.84	-0.08
7	0.15	0.27	0.22	-0.28	-0.61	-0.23
8	0.23	-0.25	-0.09	0.27	0.03	-0.04
9	0.15	0.31	-0.07	-0.06	0.09	-0.01
10	-0.49	0.12	0.23	-0.04	0.29	-0.08
14	-0.61	-0.03	-0.73	0.05	-0.77	-0.03

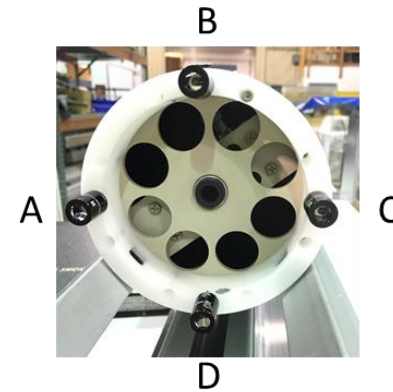
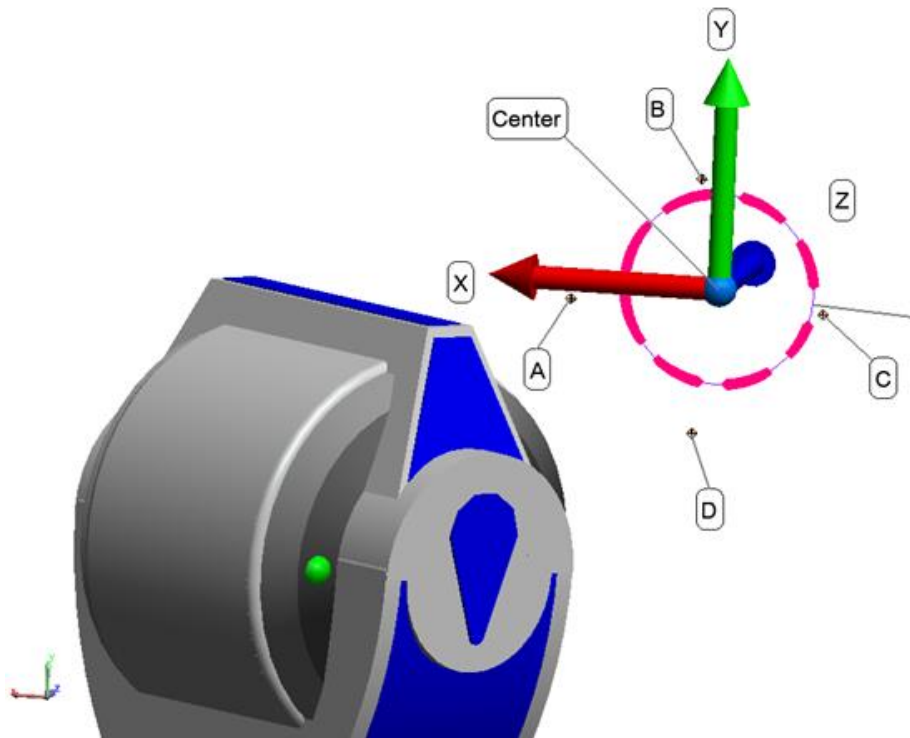
Bermudez et al., TASC 28/3, April 2018

Allowed harmonics: b10 and b14



Probe rotation axis survey

- A target was placed on the PCB and tracked during a test rotation
 - Fit the locus of the target with a circle to determine the probe rotation axis relative to the four retroreflectors
 - Stability of the rotation center relative to the retroreflectors is within $\pm 15 \mu\text{m}$

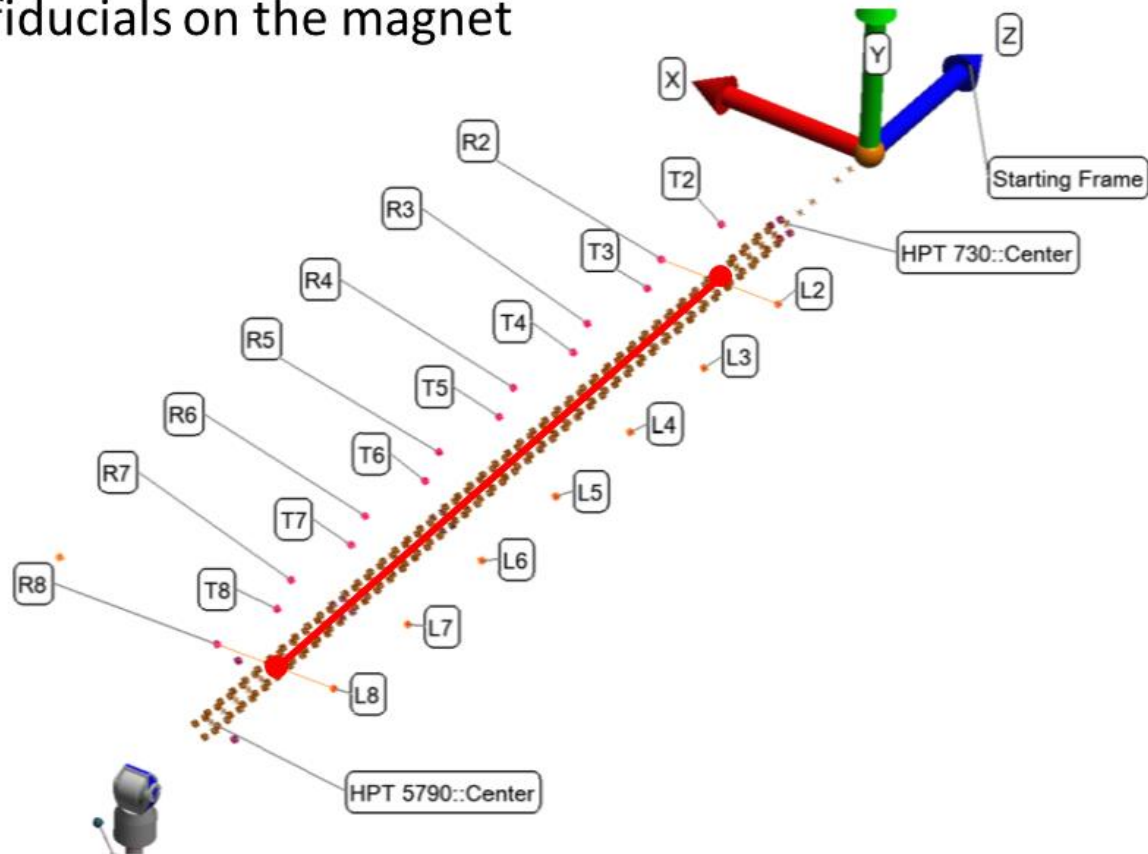


PROBE FIDUCIALS			
Point Name	X	Y	Z
A	54.562	-0.164	-53.112
B	-0.02	54.991	-53.275
C	-54.697	0.049	-53.143
D	-0.02	-54.698	-53.136
Center	0	0	0

Survey performed by Chris Hernikl (ALS)

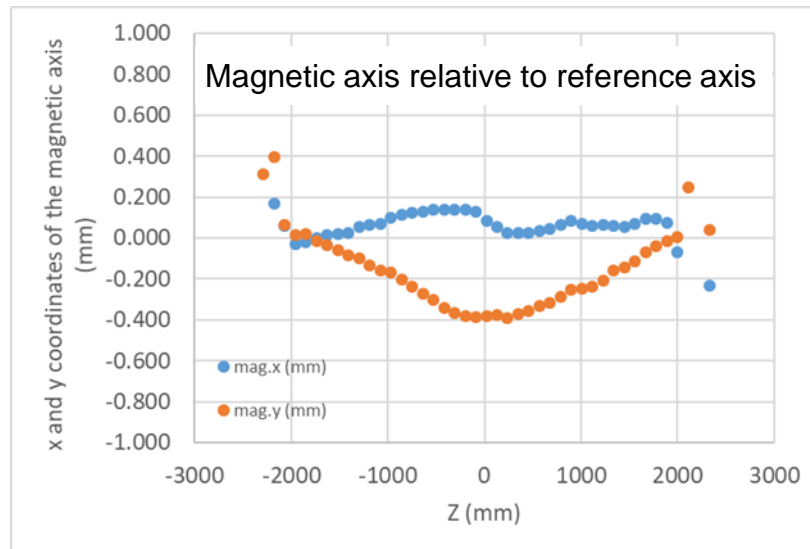
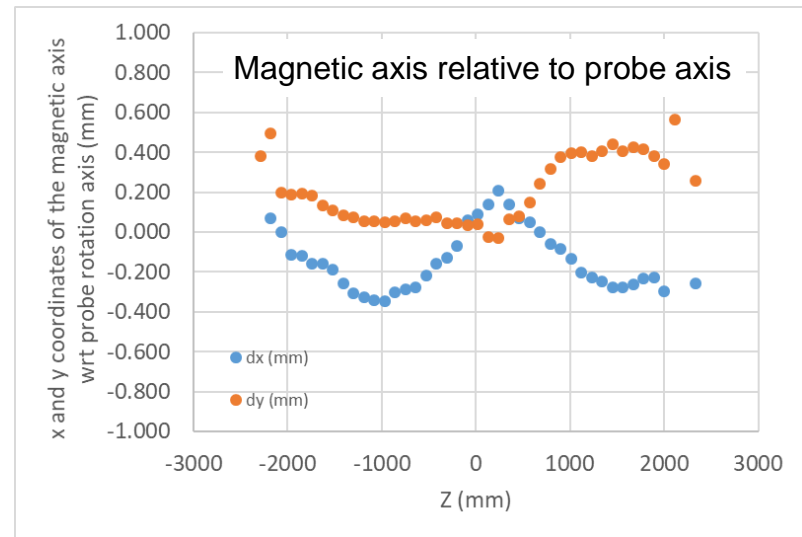
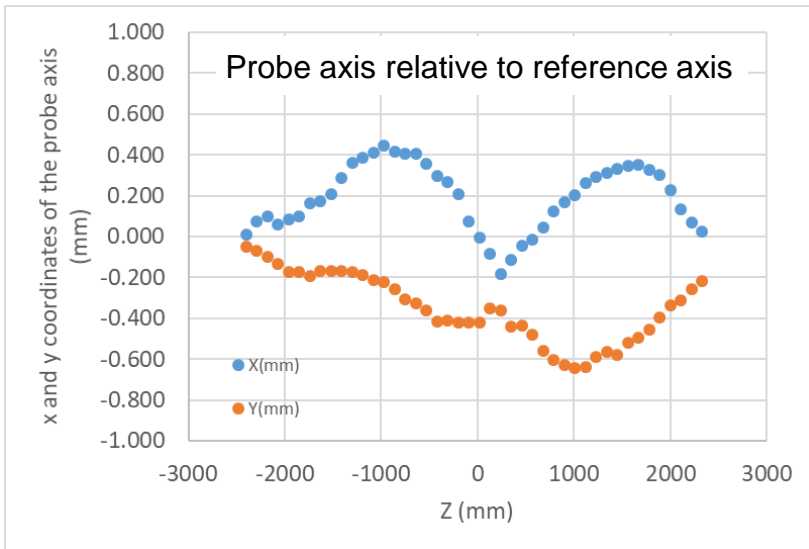
Reference axis for probe position survey

L, T, R are fiducials on the magnet



Survey performed by Chris Hernikl (ALS)

Measurement of the Magnetic Axis



Summary

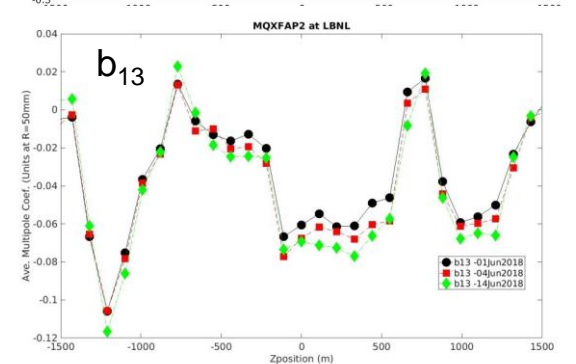
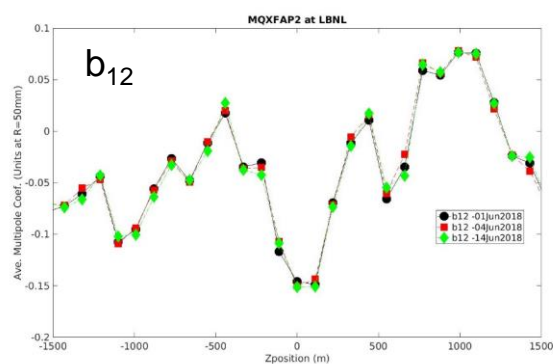
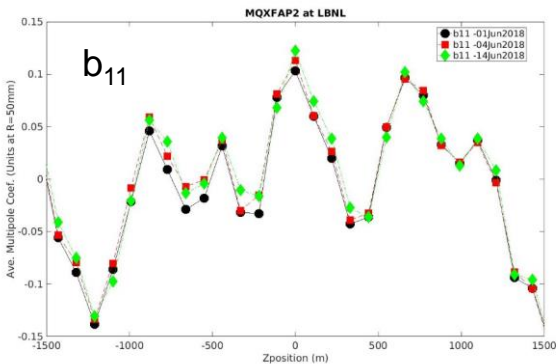
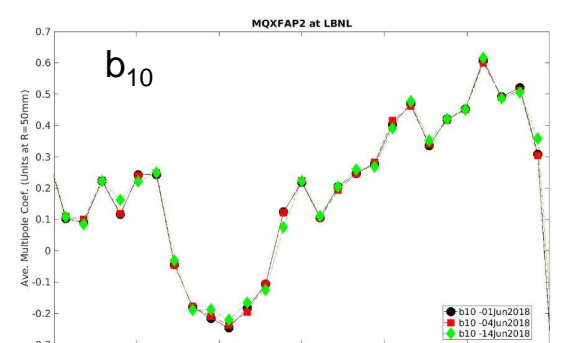
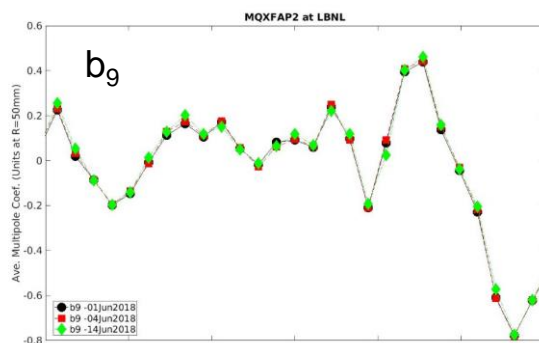
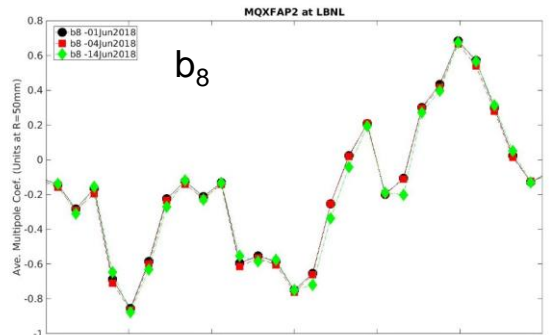
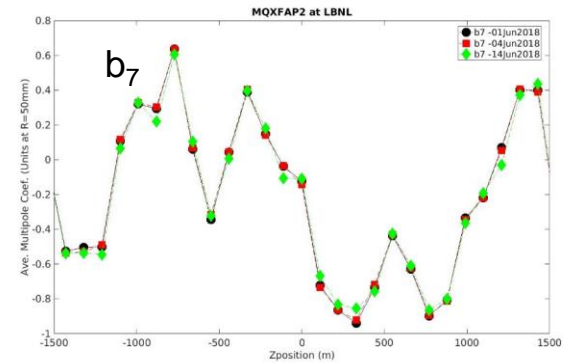
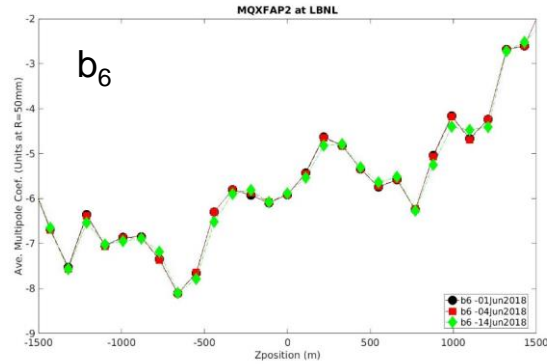
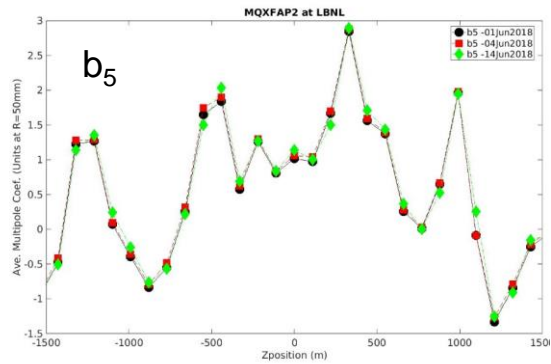
- The new magnetic measurement system was successfully commissioned
 - PCB (from FNAL), probe, drive system and survey
- First scans performed during MQXFAP2 assembly
- Some open issues still to be resolved: results are preliminary
- Accurate current measurement will be implemented to improve transfer function measurement
- Harmonics are generally consistent with results from short models
- Good results from magnetic axis measurement
- Analysis of the field orientation as a function of z is underway

Backup slides

Field Quality Reference Table

Triplet field quality version 4 - May 20 2015 - $R_{ref}=50$ mm																
Straight part											Ends		Integral			
Normal	Systematic				Injection		Uncertainty		Random		CS	NCS	Q1/Q3		Q2a/b	
	Geometric	Ass. & cool	Saturation	Persistent	High Field	High Field	Injection	High Field	Injection	High Field			Injection	High Field	Injection	High Field
2									10	10						
3	0.000	0.000	0.000	0.000	0.000	0.000	0.820	0.820	0.820	0.820			0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.570	0.570	0.570	0.570			0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.420	0.420	0.420	0.420			0.000	0.000	0.000	0.000
6	-2.200	0.900	0.660	-20.000	-21.300	-0.640	1.100	1.100	1.100	1.100	8.943	-0.025	-16.692	0.323	-18.593	-0.075
7	0.000	0.000	0.000	0.000	0.000	0.000	0.190	0.190	0.190	0.190			0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.130	0.130	0.130	0.130			0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.070	0.070	0.070	0.070			0.000	0.000	0.000	0.000
10	-0.110	0.000	0.000	4.000	3.890	-0.110	0.200	0.200	0.200	0.200	-0.189	-0.821	3.119	-0.175	3.437	-0.148
11	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.026	0.026	0.026			0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.018	0.018	0.018	0.018			0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.009	0.009	0.009			0.000	0.000	0.000	0.000
14	-0.790	0.000	-0.080	1.000	0.210	-0.870	0.023	0.023	0.023	0.023	-0.545	-1.083	0.033	-0.856	0.106	-0.862
Skew																
2									10.000	10.000	-31.342		-2.985	-2.985	-1.753	-1.753
3	0.000	0.000	0.000	0.000	0.000	0.000	0.650	0.650	0.650	0.650			0.000	0.000	0.000	0.000
4	0.000	0.000	0.000	0.000	0.000	0.000	0.650	0.650	0.650	0.650			0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000	0.000	0.000	0.430	0.430	0.430	0.430			0.000	0.000	0.000	0.000
6	0.000	0.000	0.000	0.000	0.000	0.000	0.310	0.310	0.310	0.310	2.209		0.210	0.210	0.124	0.124
7	0.000	0.000	0.000	0.000	0.000	0.000	0.190	0.190	0.190	0.190			0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.110	0.110	0.110	0.110			0.000	0.000	0.000	0.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.080	0.080	0.080			0.000	0.000	0.000	0.000
10	0.000	0.000	0.000	0.000	0.000	0.000	0.040	0.040	0.040	0.040	0.065		0.006	0.006	0.004	0.004
11	0.000	0.000	0.000	0.000	0.000	0.000	0.026	0.026	0.026	0.026			0.000	0.000	0.000	0.000
12	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.014	0.014	0.014			0.000	0.000	0.000	0.000
13	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.010	0.010	0.010			0.000	0.000	0.000	0.000
14	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.005	0.005	0.005	-0.222		-0.021	-0.021	-0.012	-0.012
Magnetic length straight part					Q1/Q3	3.459	Q2a/b	6.409	Mag. Len. Ends		0.400	0.341				

Normal components: n=5 to n=13



Skew components: n=5 to n=13

