Magnetic Measurement activities at Magnet Division, Brookhaven National Laboratory

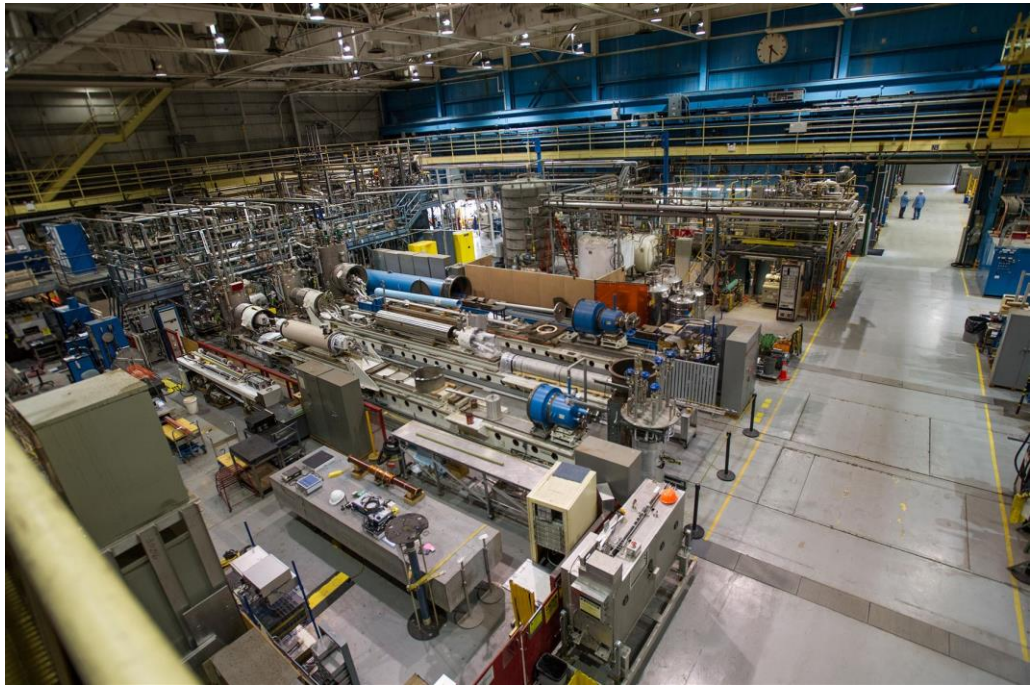
Vikas Teotia

Superconducting Magnet Division

Brookhaven National Laboratory

Contributions:

Piyush Joshi, Andy Marone, Michael Anerella



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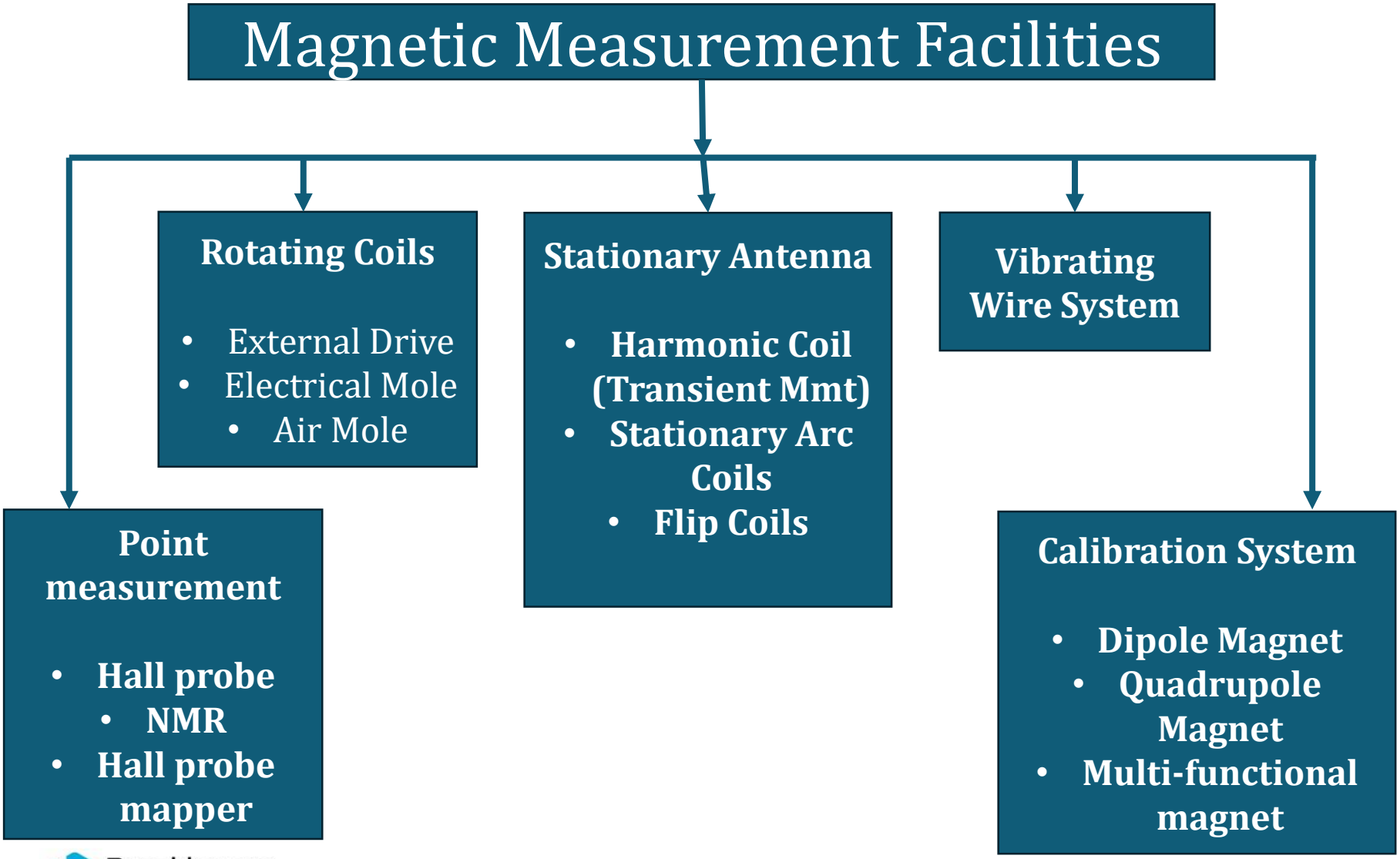
Magnetic measurement facilities at Magnet Division, Brookhaven National Laboratory



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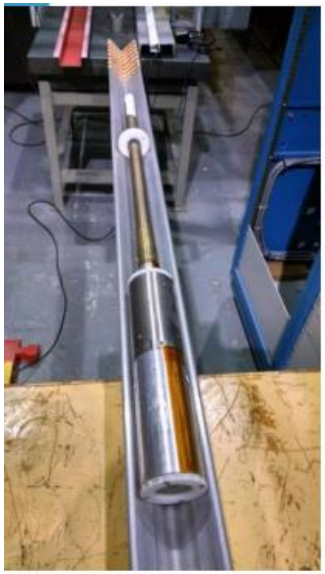
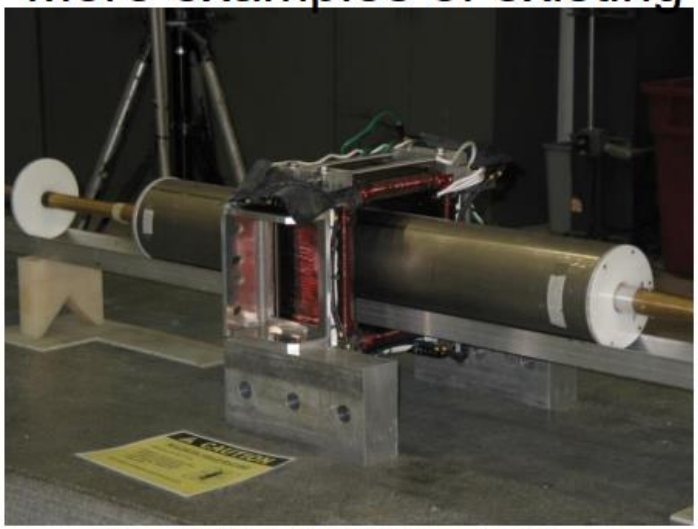
Some snaps



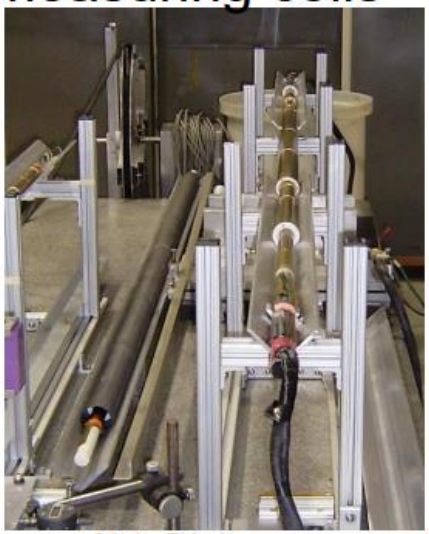
Mole RA-7

External Drive Coil 76 8 cm

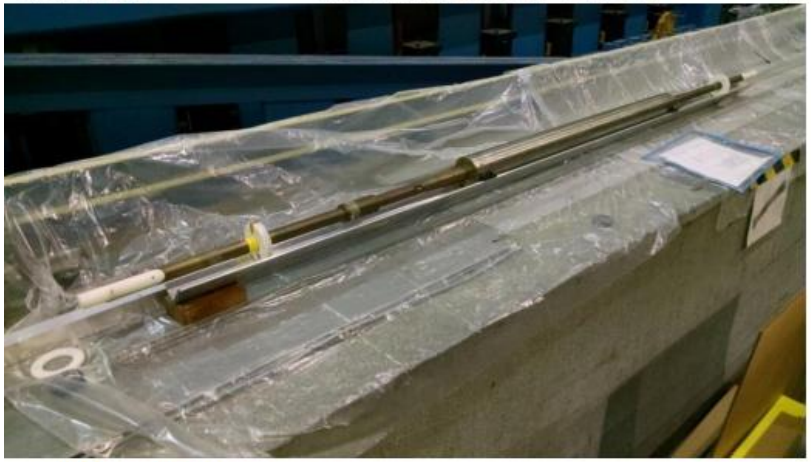
More examples of existing measuring coils



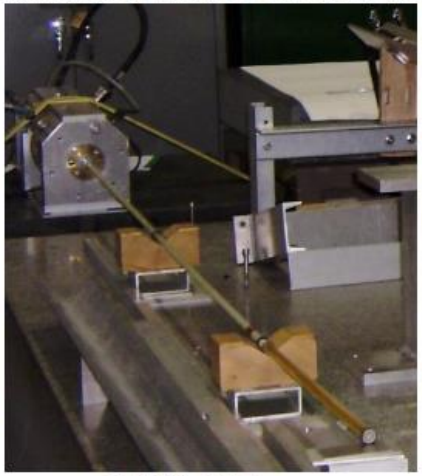
Warm DX Mole in AGS Corrector Magnet



Mole RA-3



D0 Warm Mole 13 cm



Coil 96 2.54 cm

Coil 203 9-Windings 30 cm

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Recent Magnetic Measurement Activities

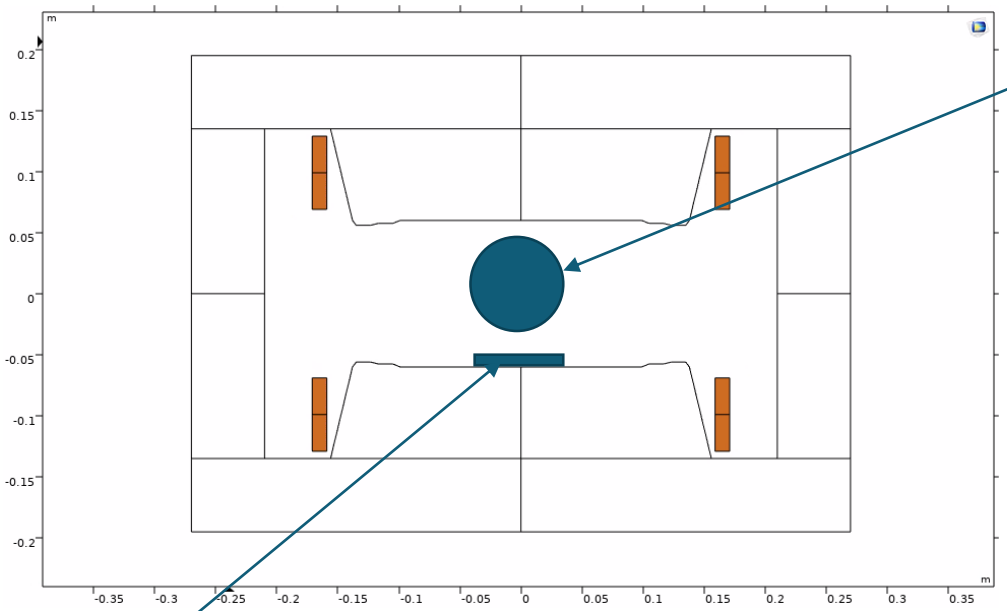
1. Low Field RCS test magnet for EIC
2. DX magnet (Dipole Magnet of RHIC)
3. APS Sextupole Magnet (refurbished for EIC)
4. Q1ABpF (Double helical Quadrupole on Direct Wind Technology) for EIC
5. MX Quadrupole for Hi-Lumi
6. Rotating Coil Calibration

RCS Test Magnet

- Energy range: 0.4-18GeV
  - Factor 45
- Dipoles:
  - 18 GeV: 0.25T
  - 0.4 GeV: 0.4/18*0.25T = **5mT**
- Quads are similar (pole tip field)
  - ~8mT
  - Sextupoles?
- **This is a very low field**
- Field quality: ’10 units is ok’
- Issues:
  - BH curve
  - Hysteresis
  - Stray fields

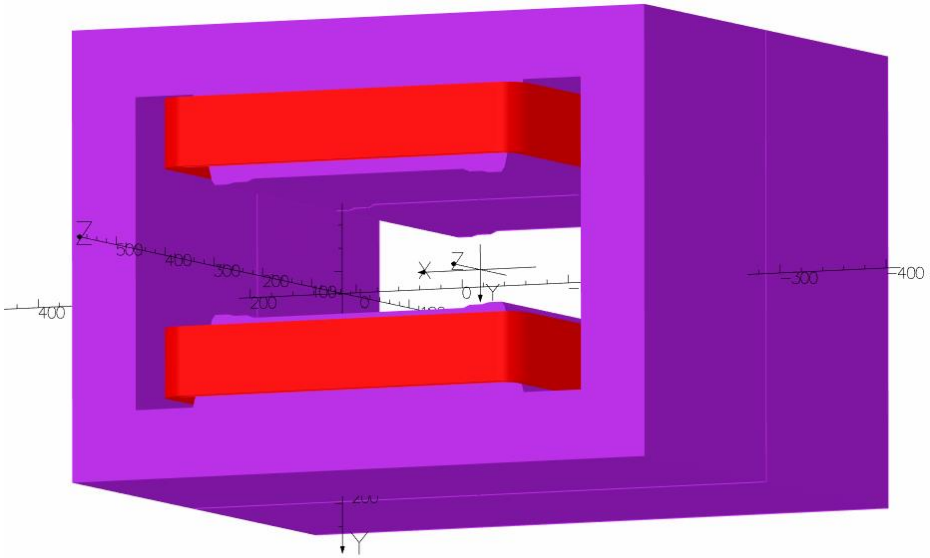
Magnet designed and developed by EIC (Holger et. al.)

Rotating Coil and Hall probe arrangement



Rotating Coil (R_ref=50mm)

Hall probe (Group-3) at pole flat



Model courtesy : Holger

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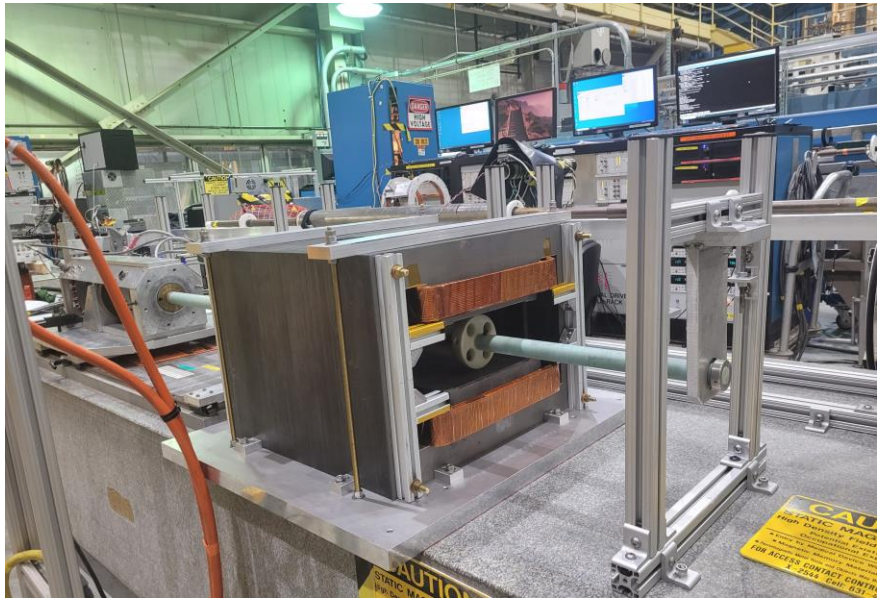
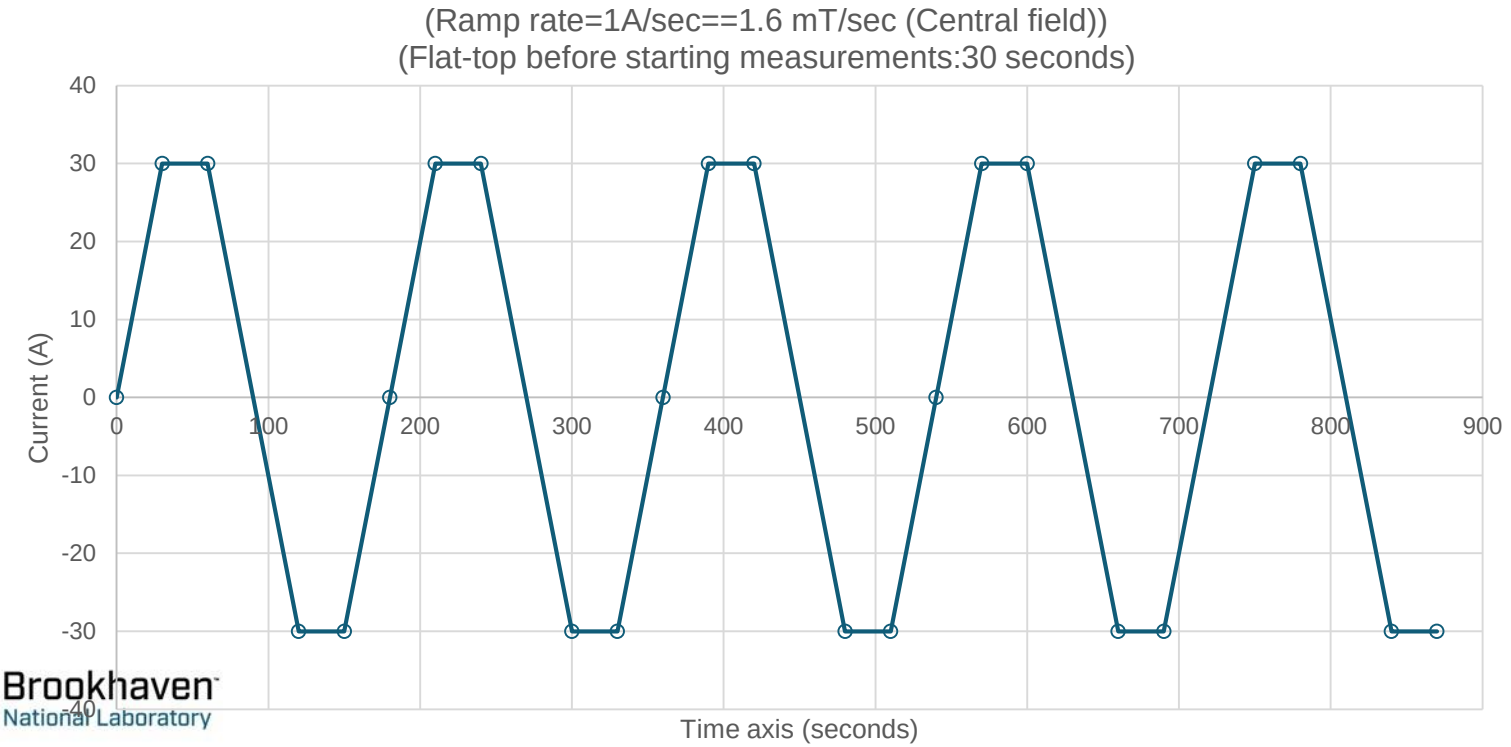
Measurement plan

Magnetic Measurements with internal drive R_{ref}=50 mm; Coil Length=110 mm





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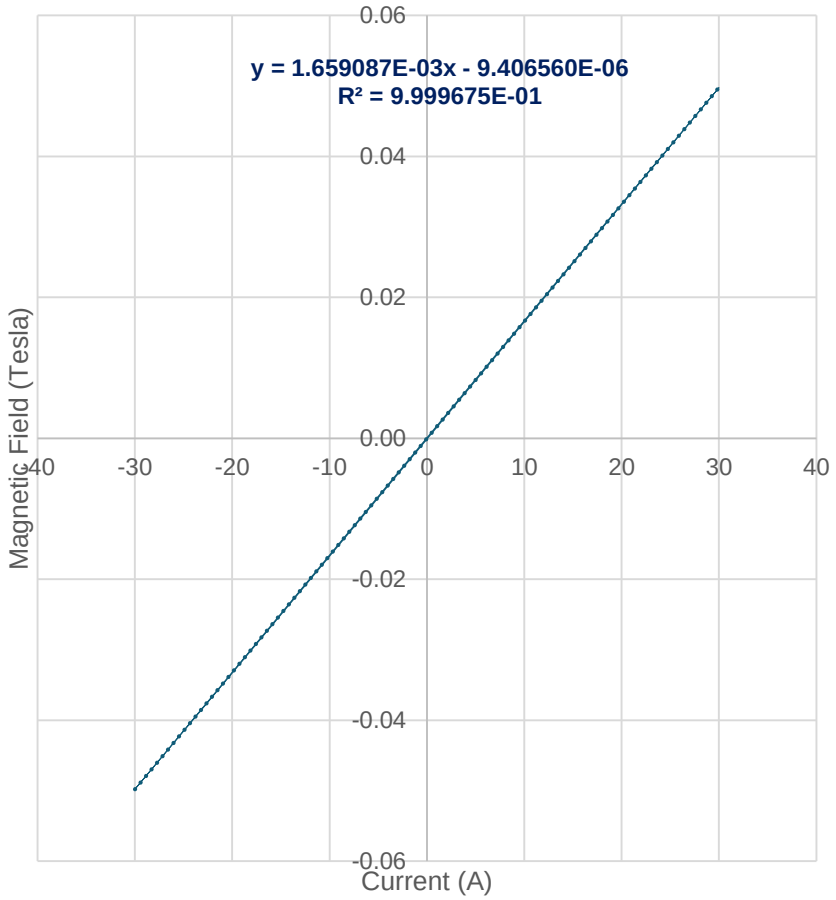
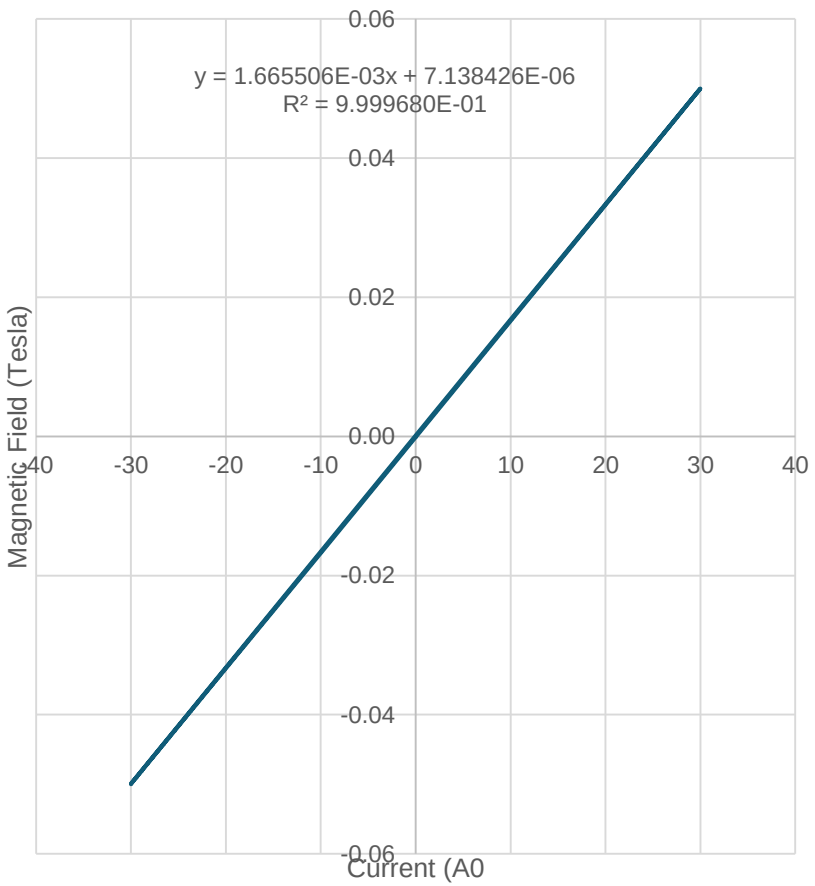
After Cycling: Transfer Function

Hall Probe : after full Cycling of the magnet



Rotating Coil: after full Cycling of the magnet



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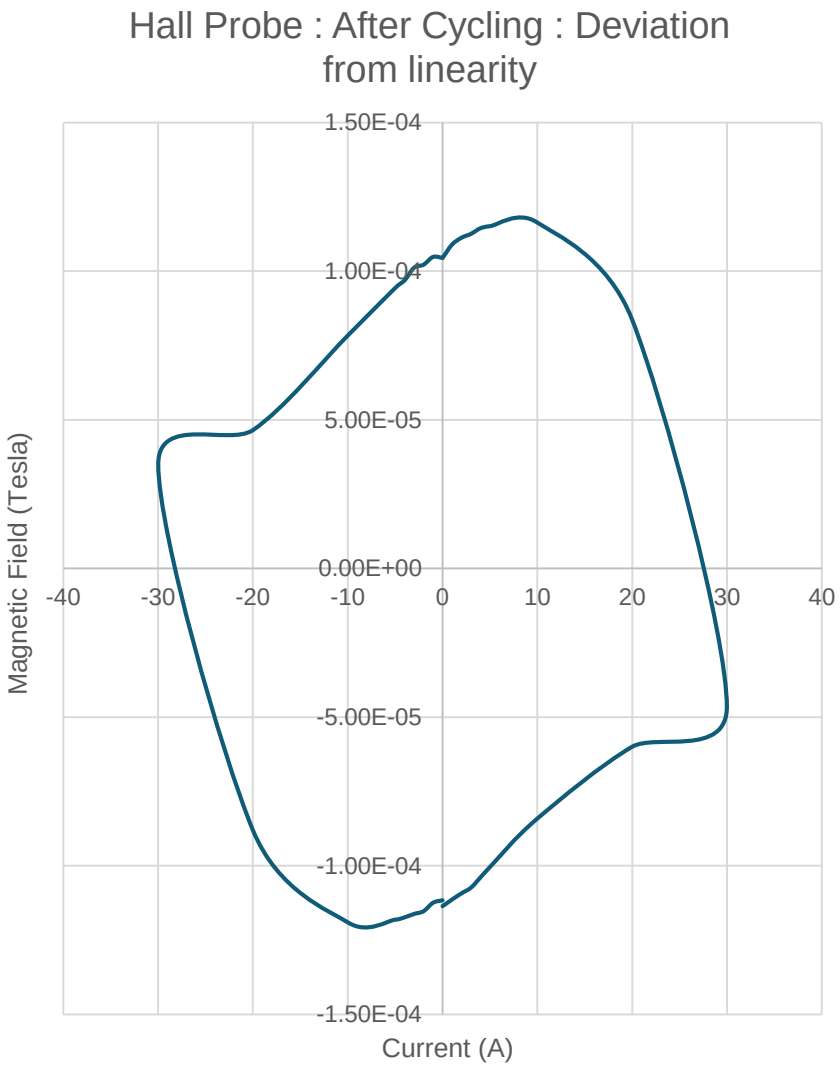
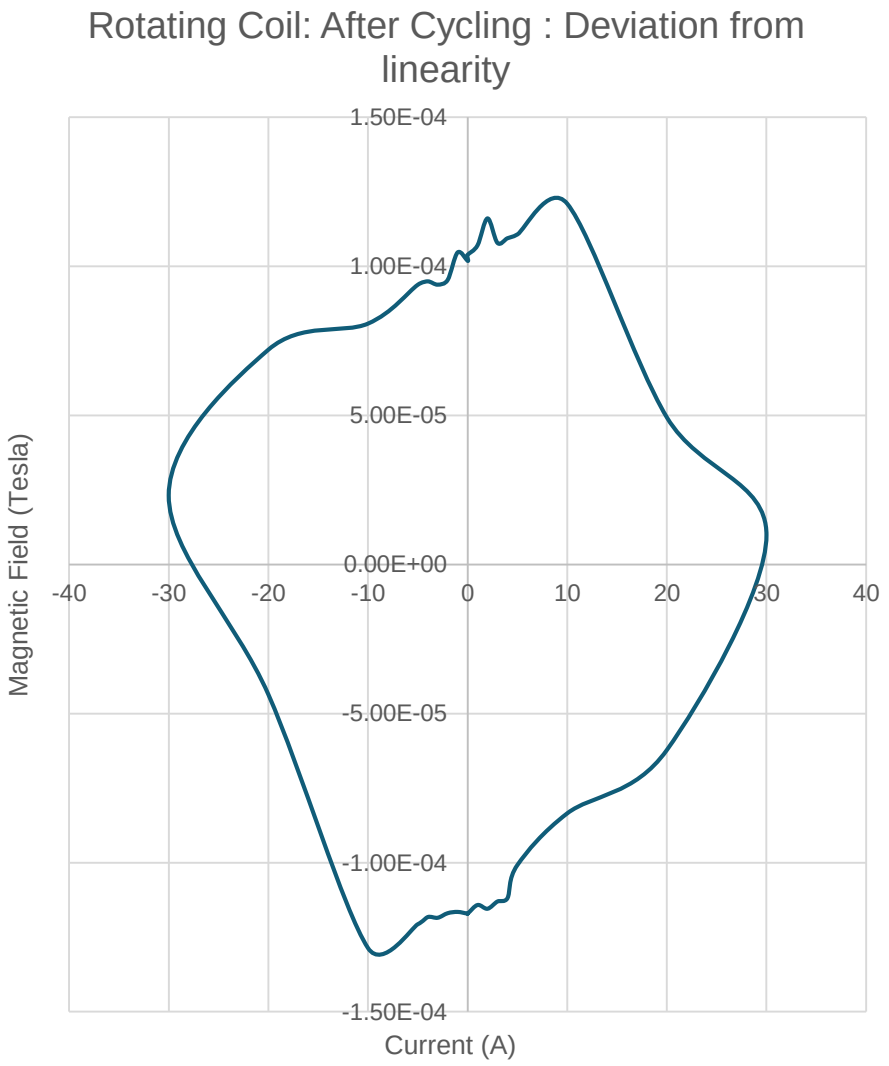
Deviation from Linearity





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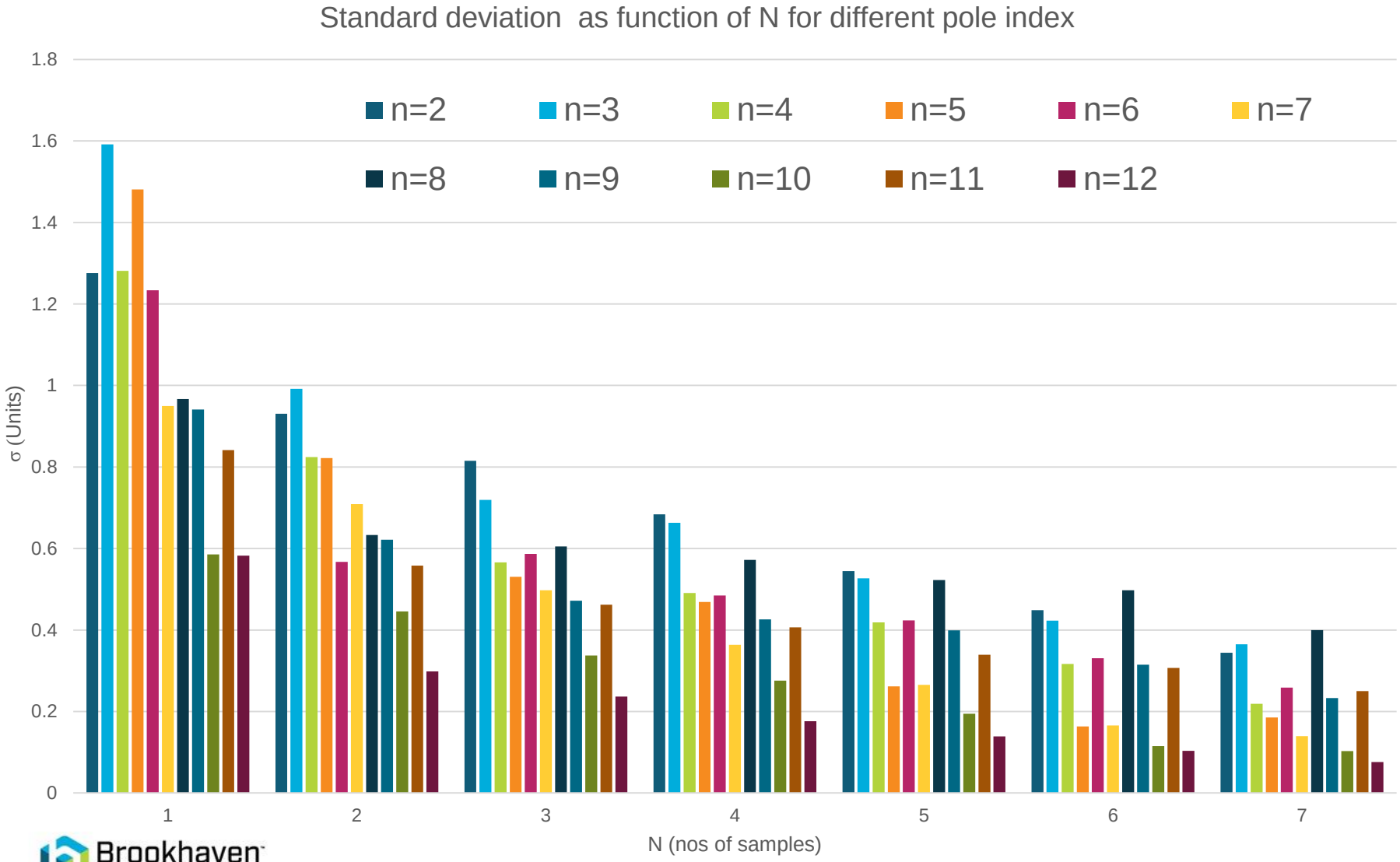
Repeatability measurements with Rotating Coil : Harmonics (@ 1A, 1.65 mT)



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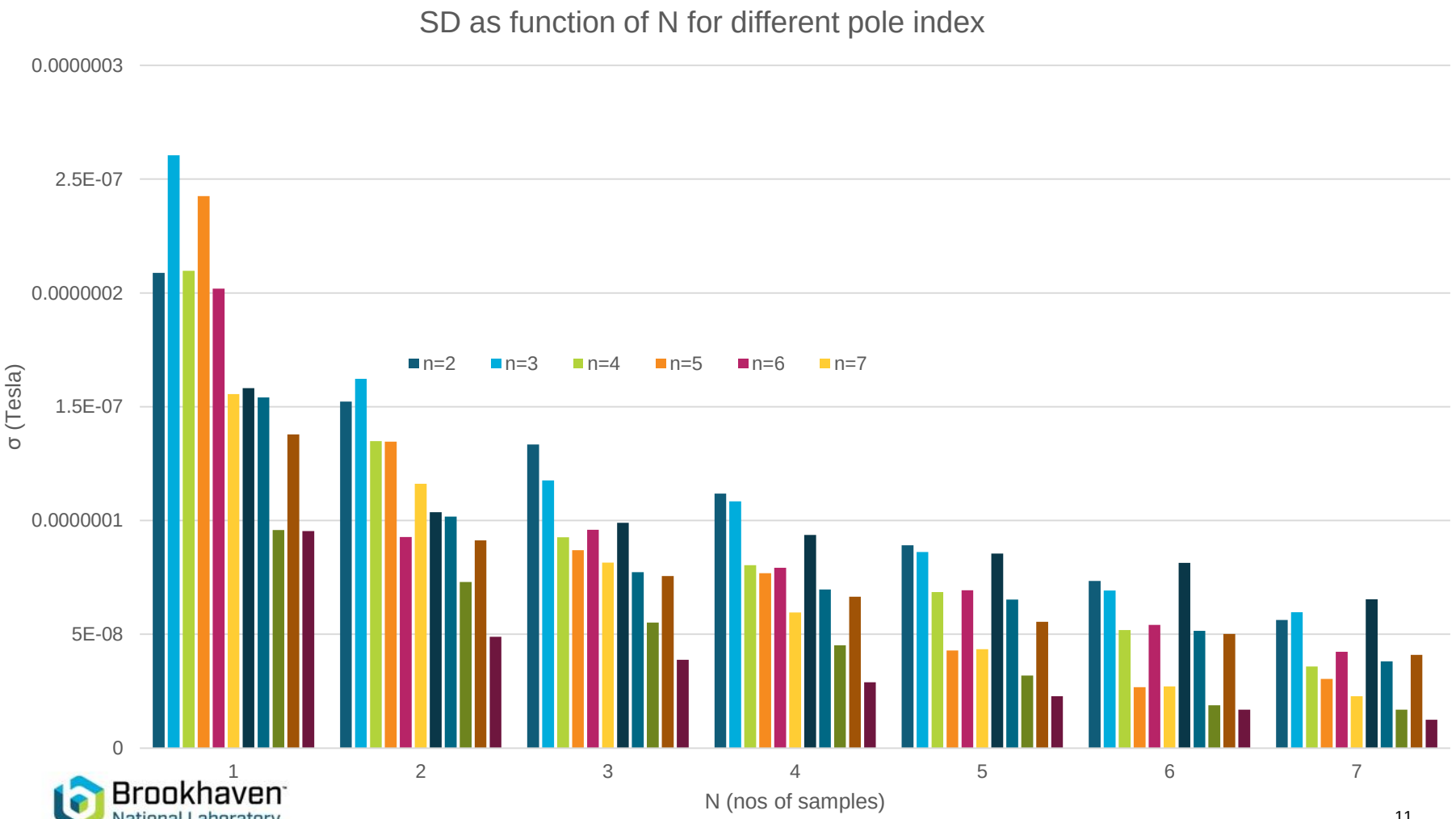
Repeatability measurements with Rotating Coil : Absolute magnetic field



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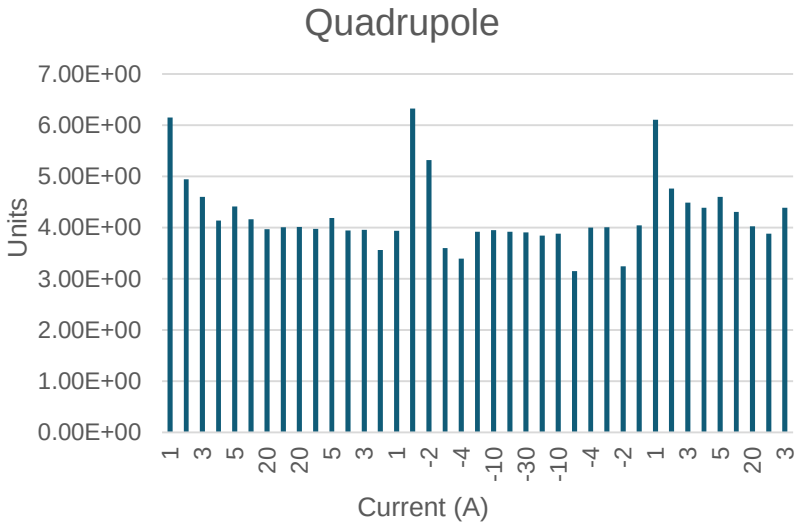
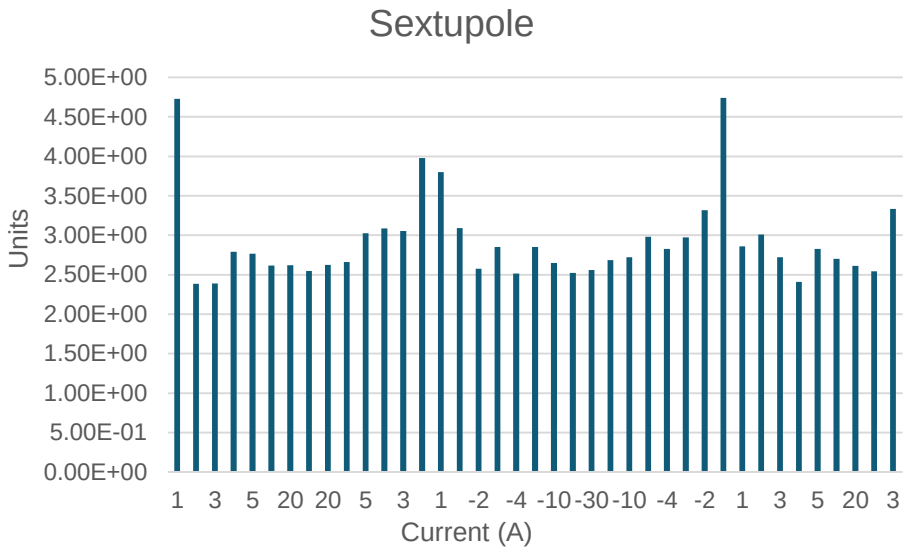
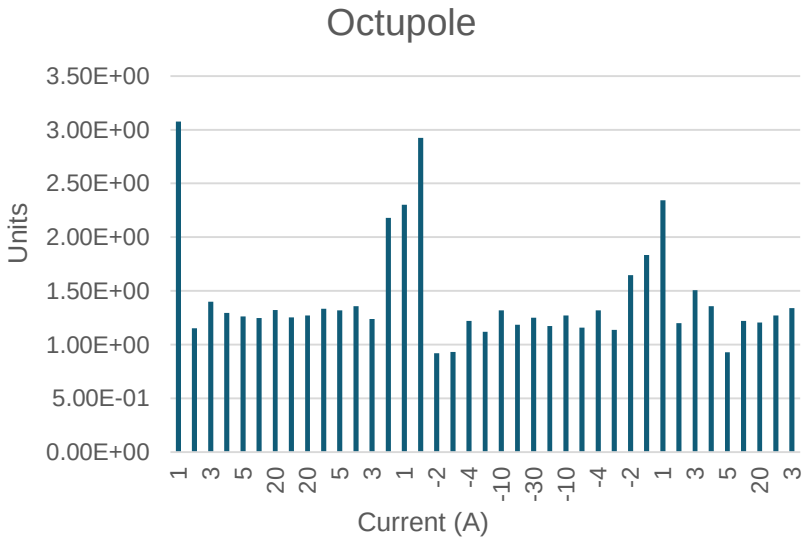
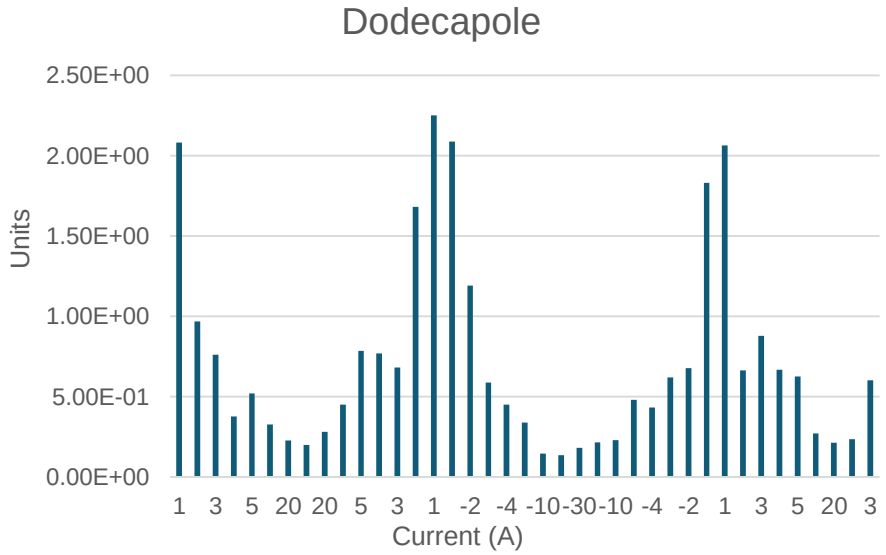
Harmonics









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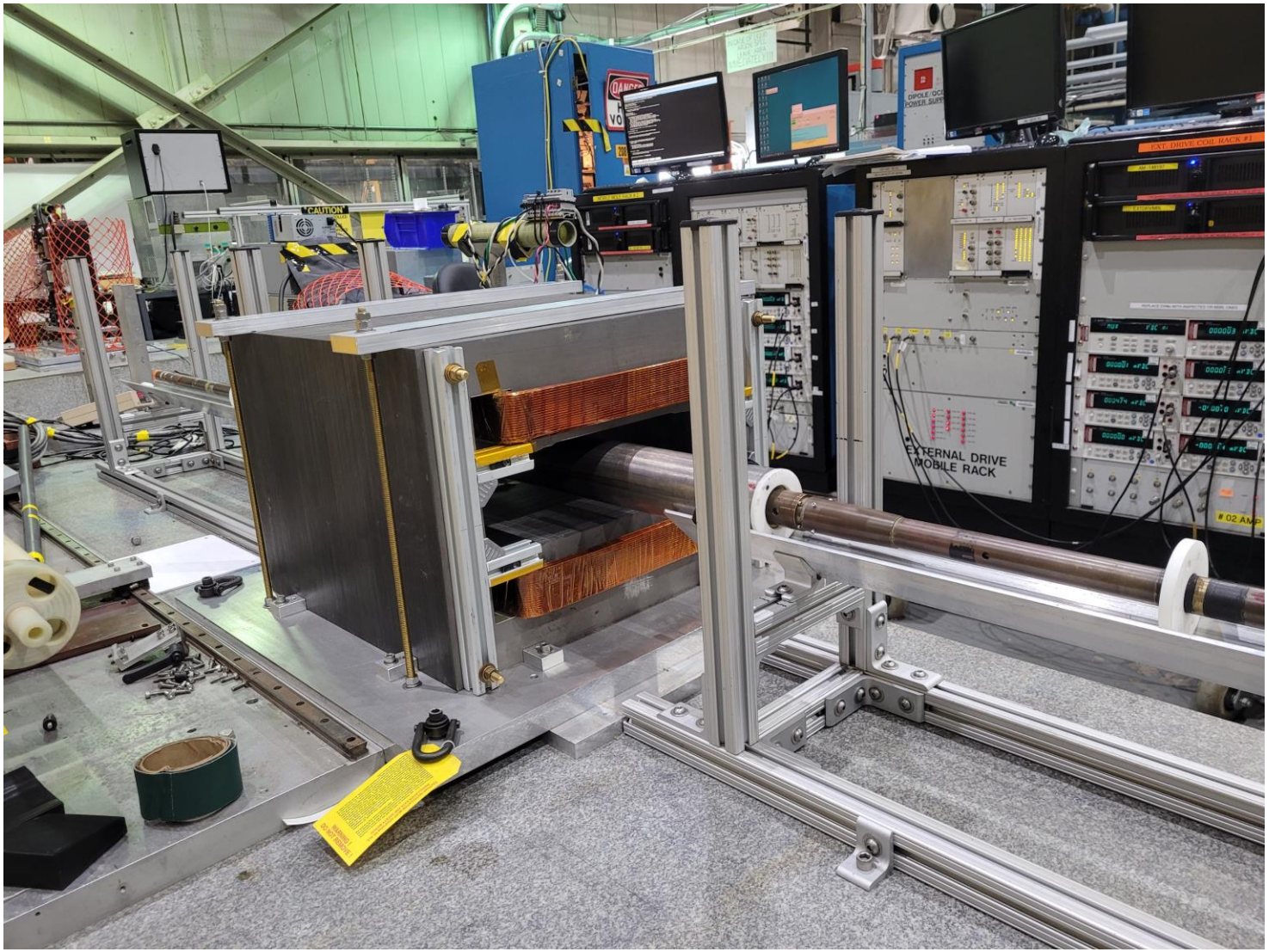
Magnetic Measurements with internal drive R_{ref}=31 mm; Coil Length=914 mm



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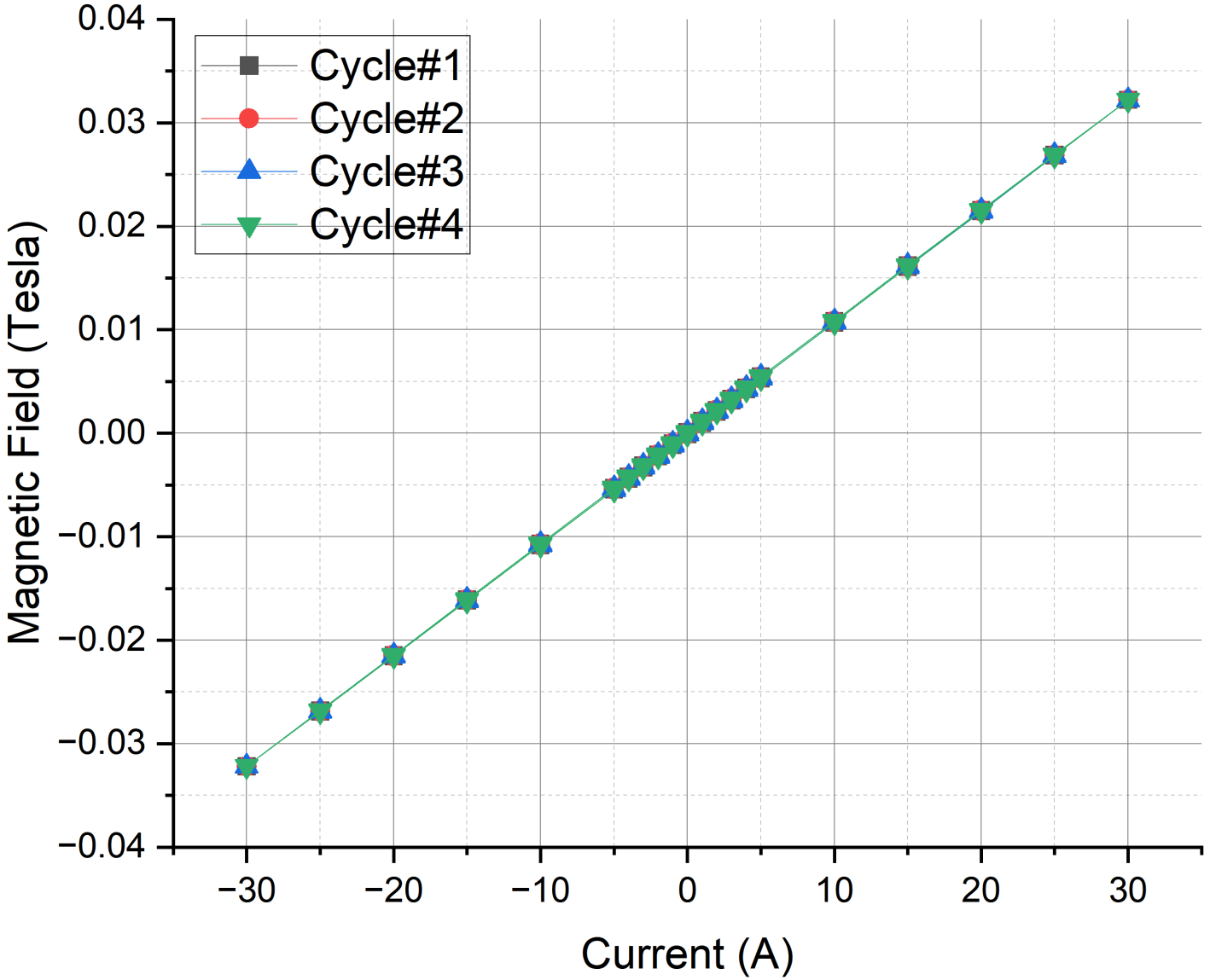
Transfer Function (Up-ramp and down ramp)



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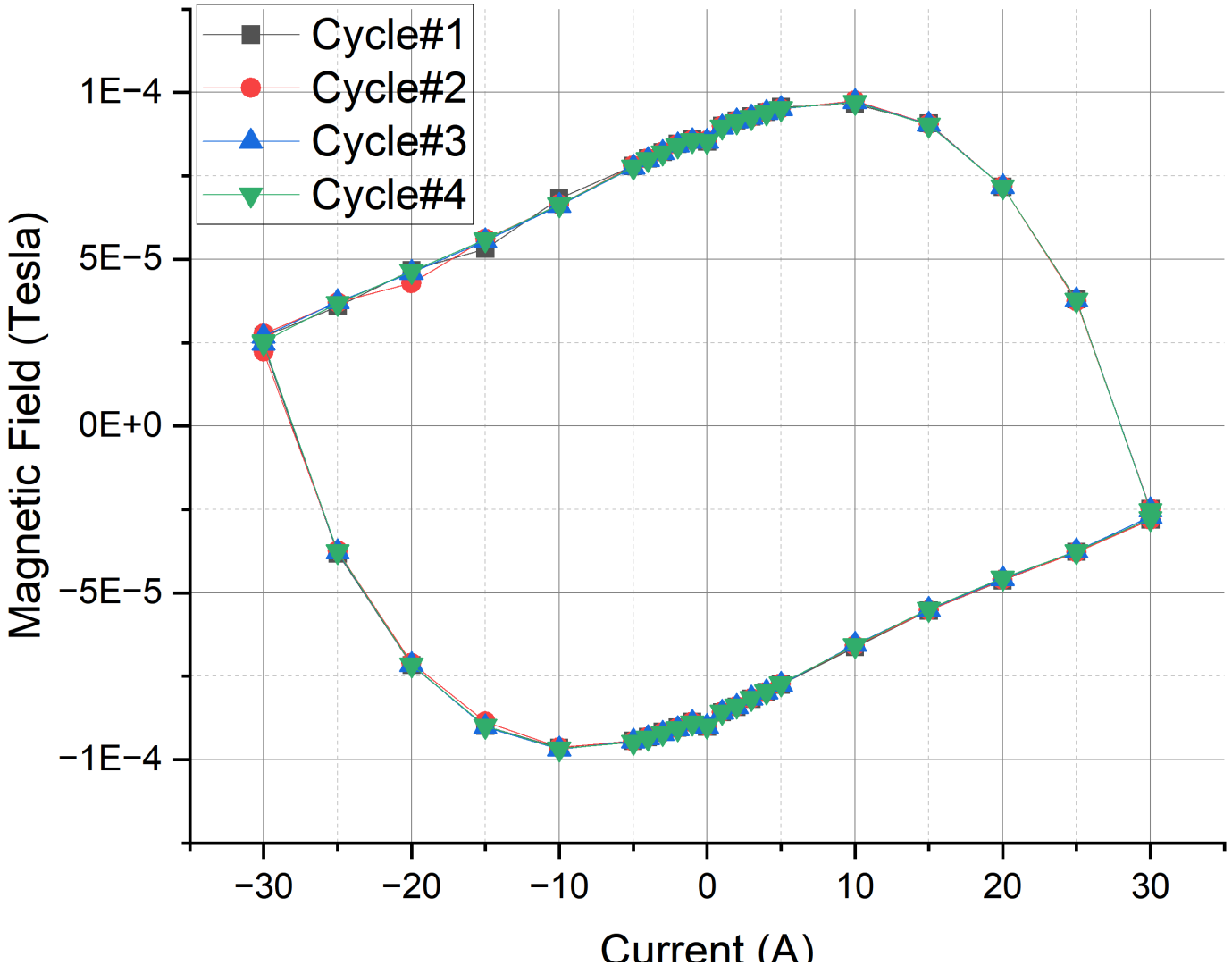
Deviation from Linearity



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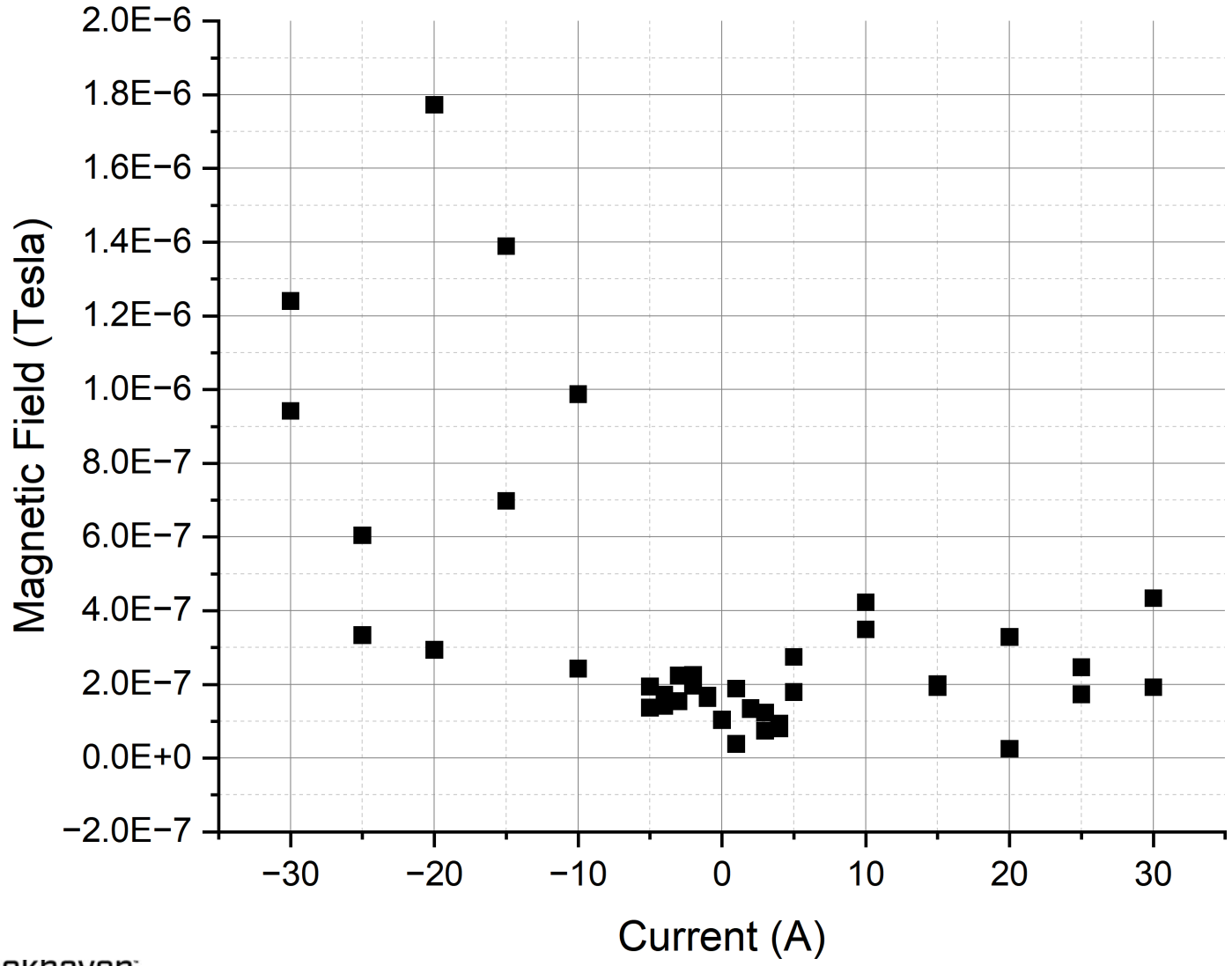
Standard deviation of deviation of linearity



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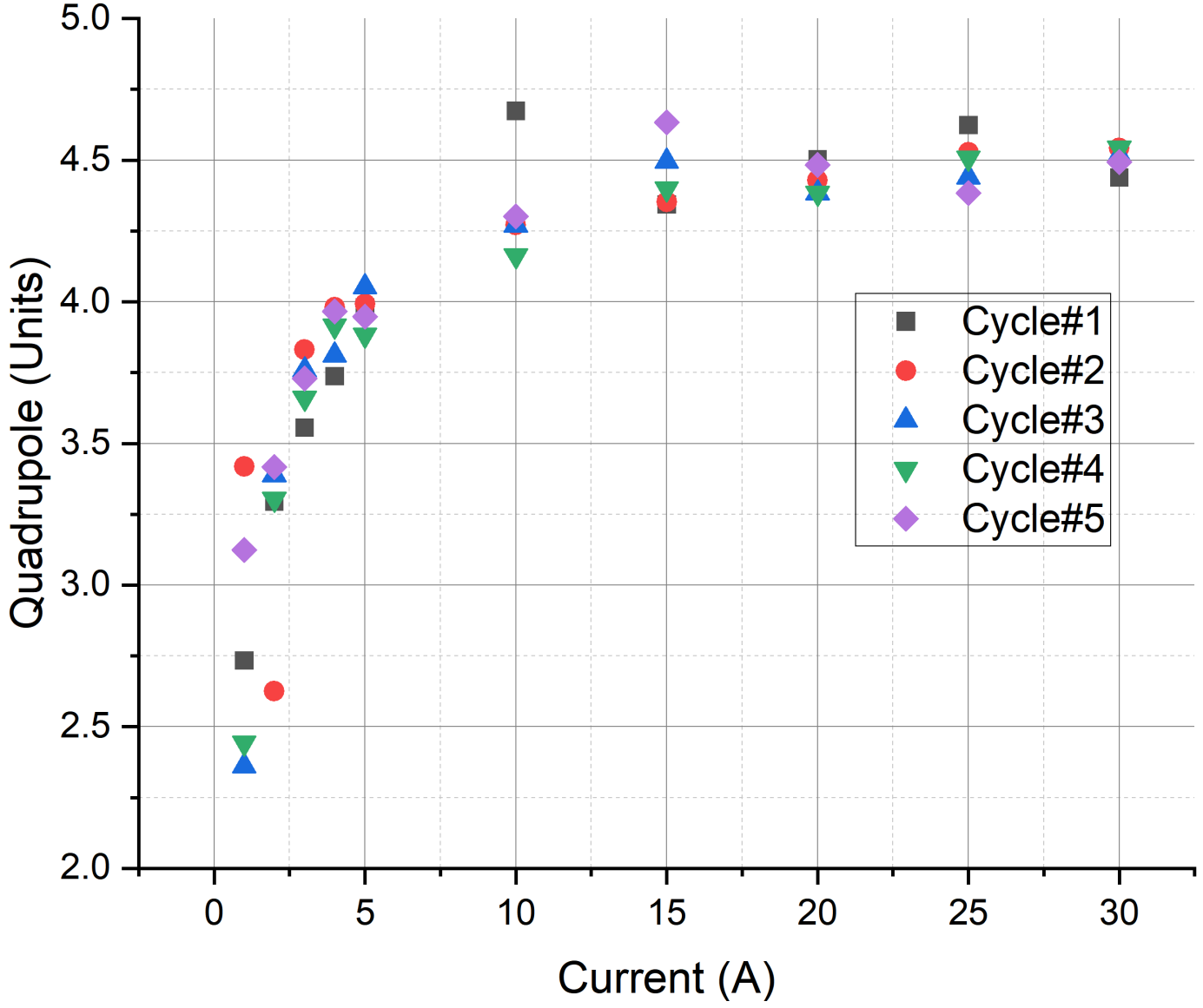
Quadrupole repeatability measurements



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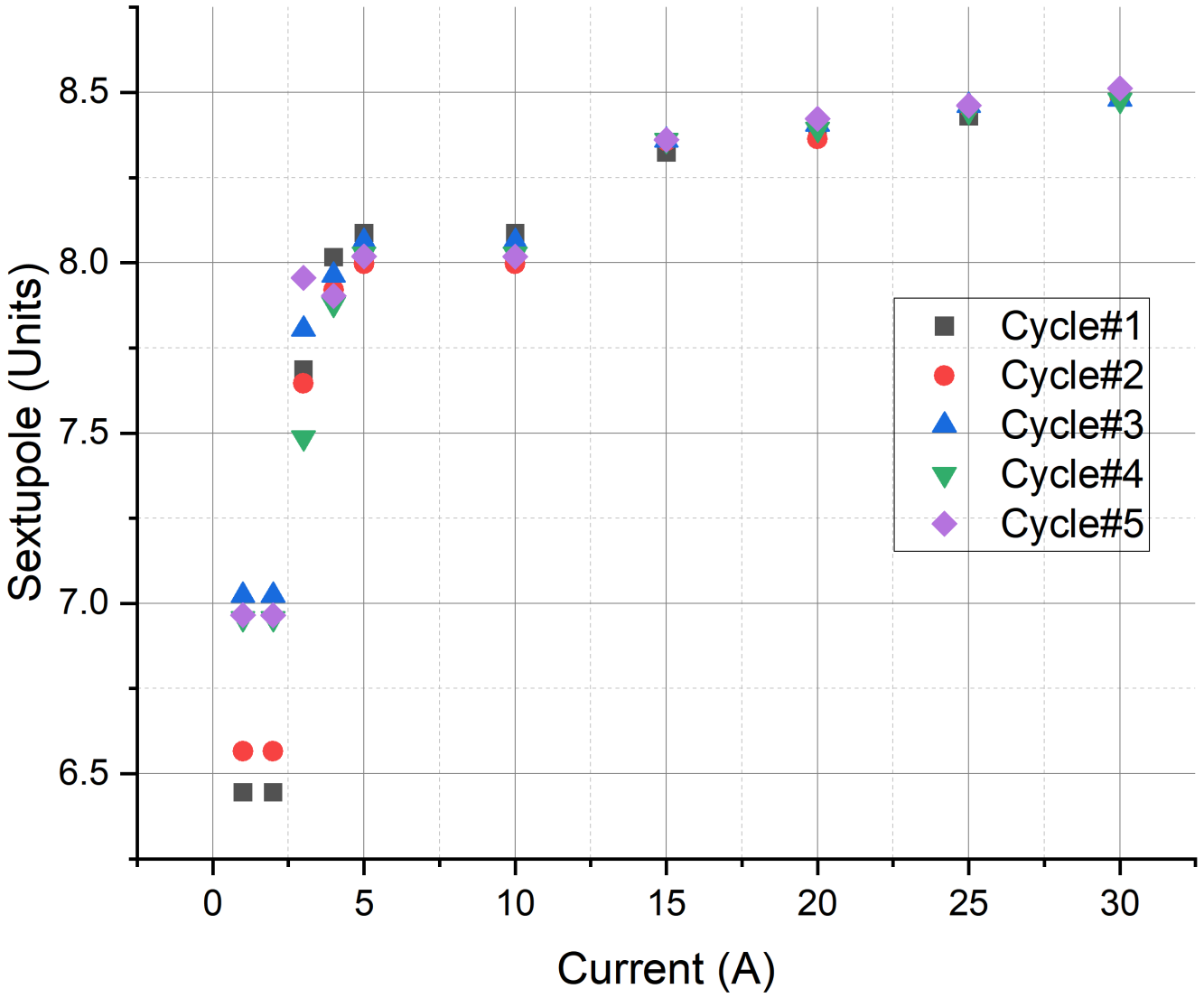
Sextupole repeatability measurements



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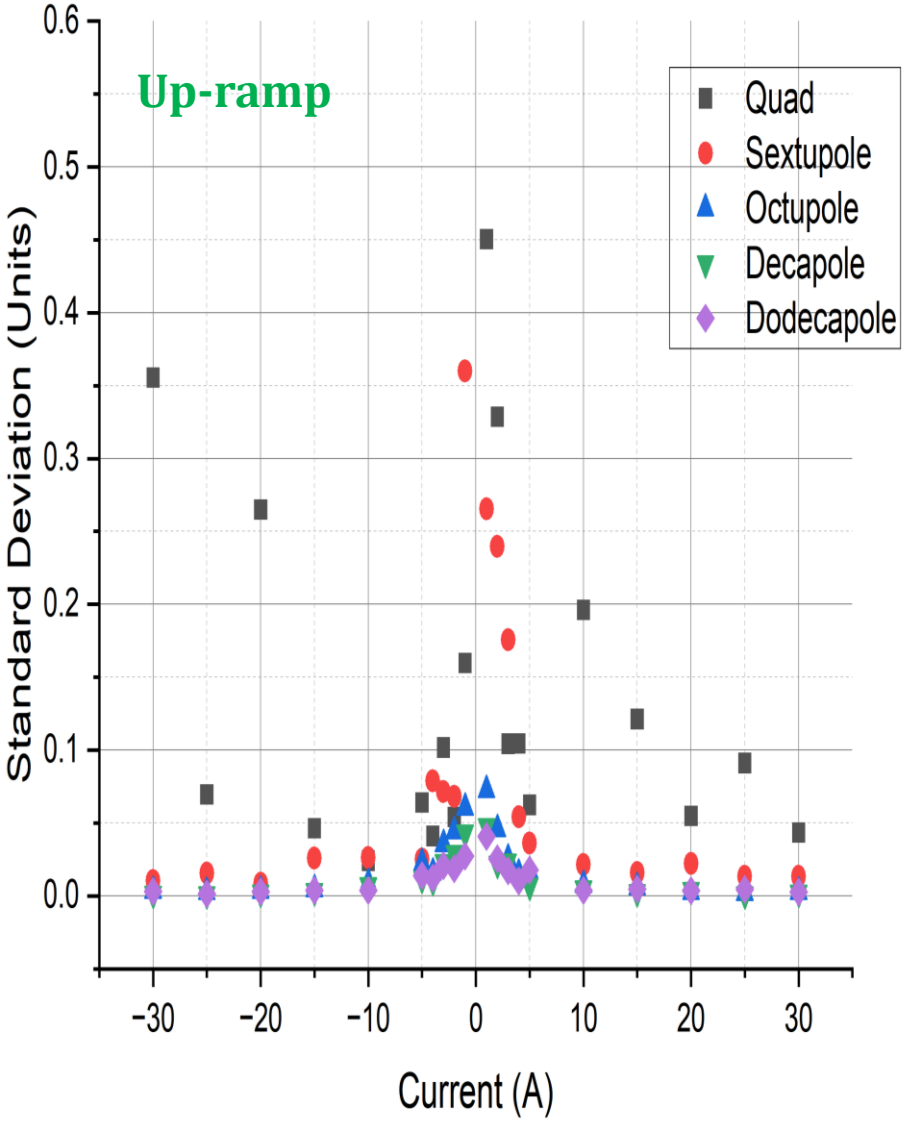
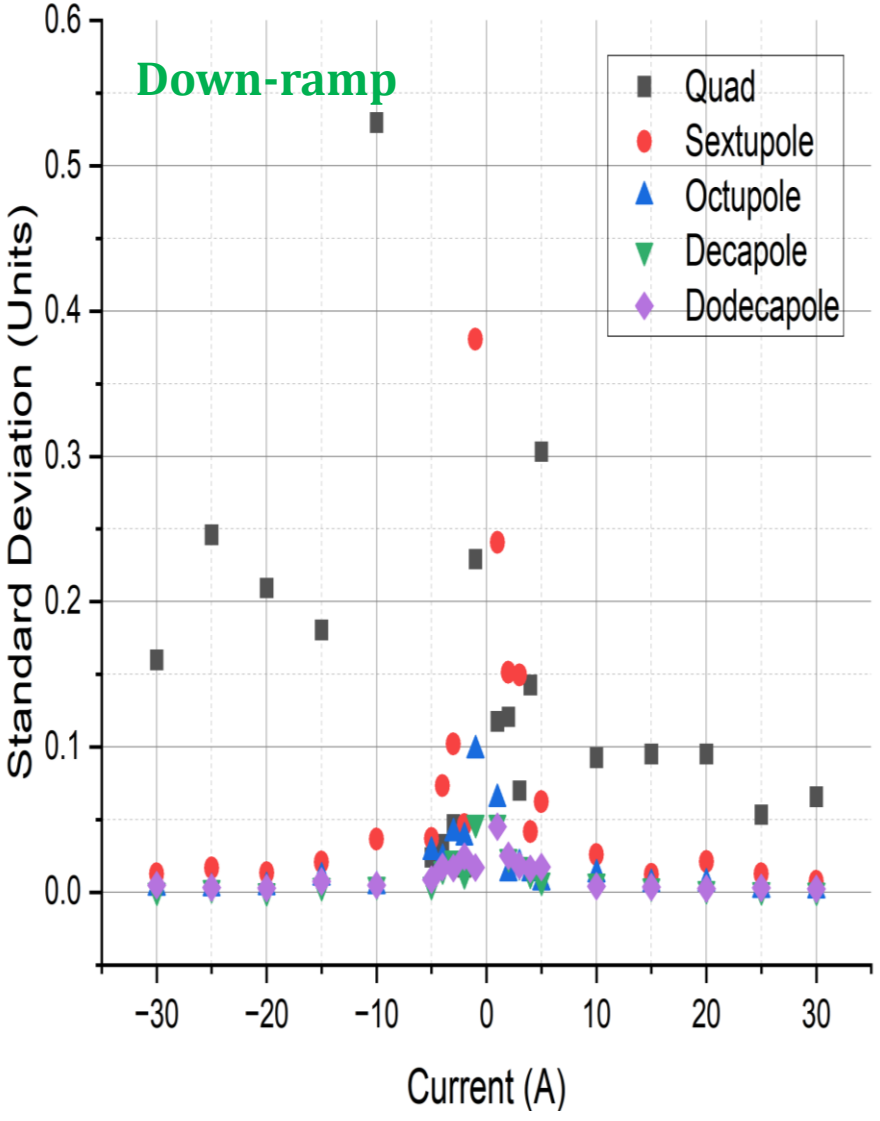
Standard deviation harmonics





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Refurbished APS Sextupole Magnets for EIC

1. These magnets are more than 20 years old
2. Magnetic Measurements with internal drive R_{ref}=31 mm; Coil Length=914 mm
3. 2 Magnets are measured to check efficacy of these magnets for using in EIC
4. Results closely matched to previous measurements

Magnet provided by
Christoph Montag, and Mahler George J

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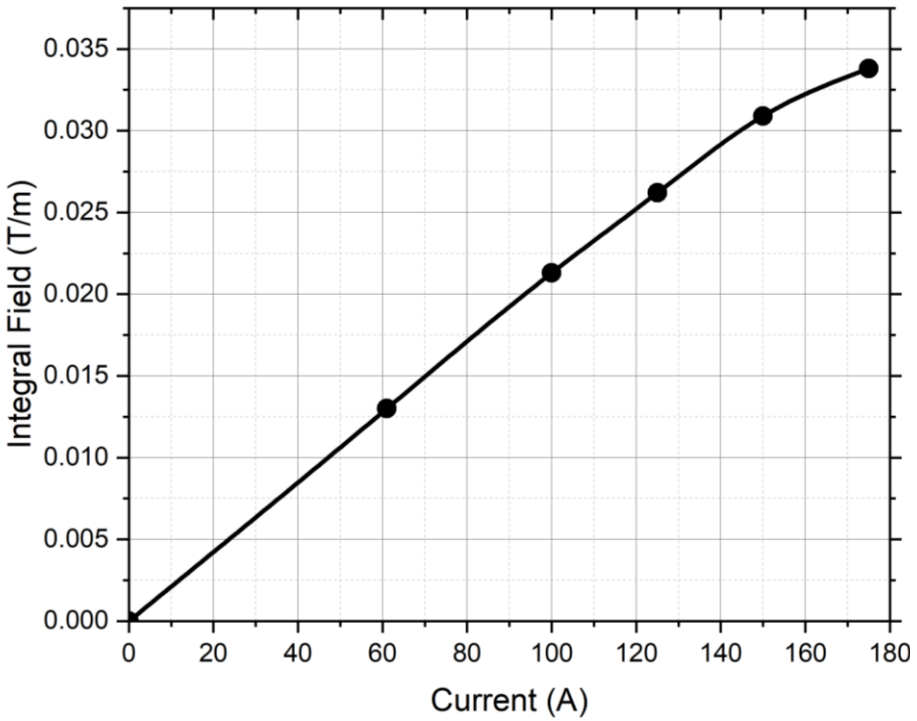
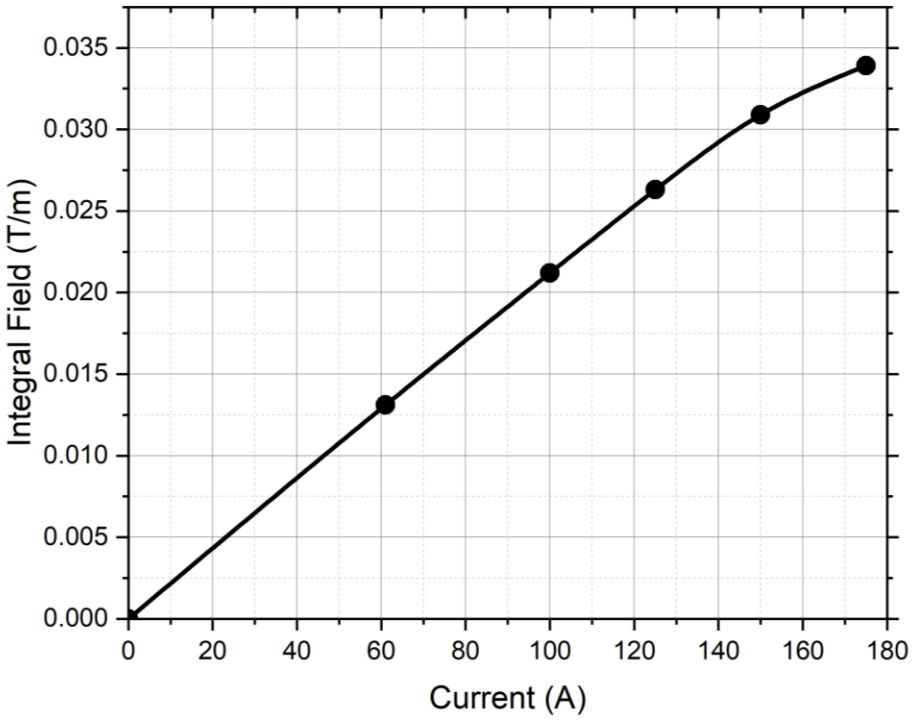
Transfer Function of Measured Sextupole

Sextupole #1



Sextupole #2



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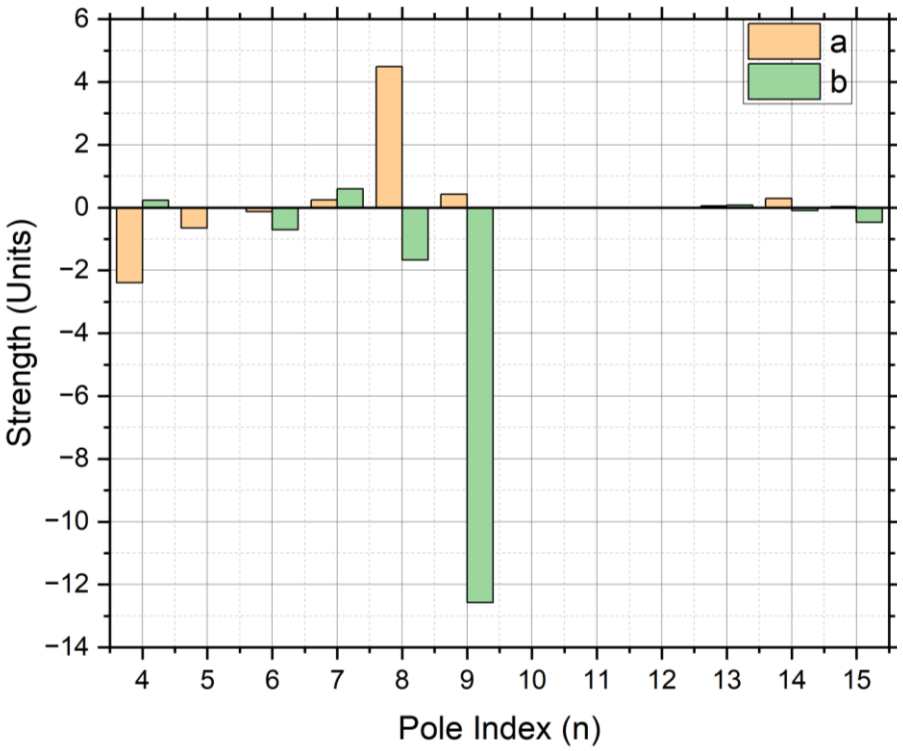
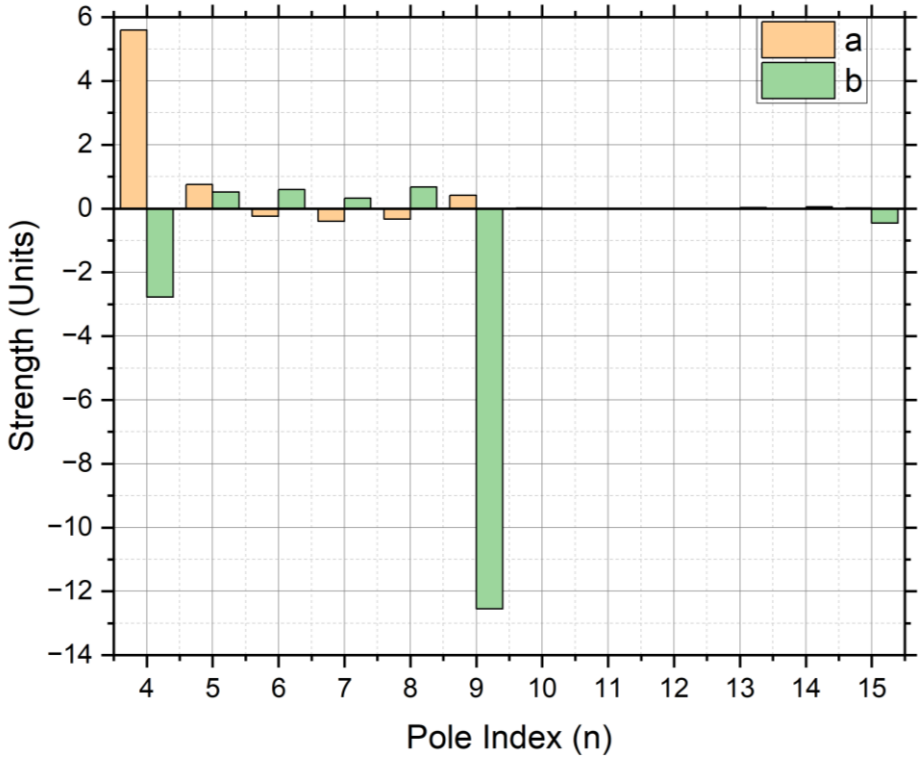
Harmonics of the measured Sextupole

Sextupole #1



Sextupole #2



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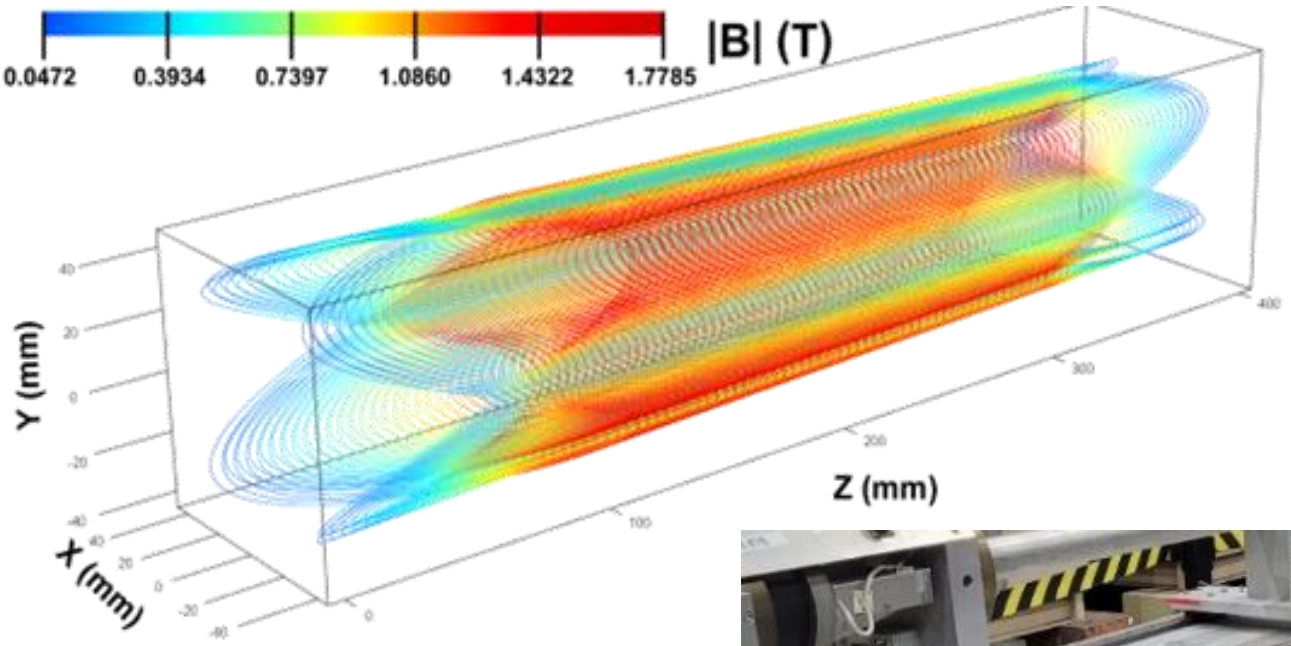
Q1ABpF Direct Wind Quadrupole Magnet



Double Helical (CCT)

EM Design by Holger, EIC

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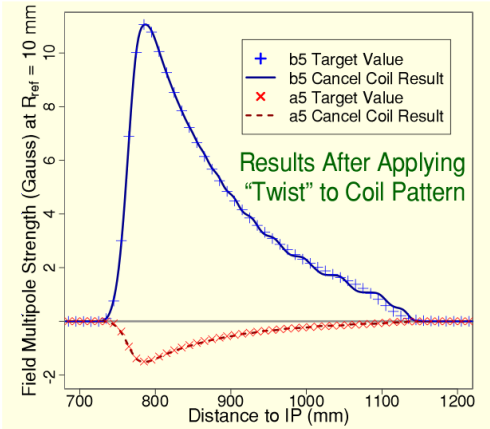
Introduction to BNL Direct Wind Magnet Technology

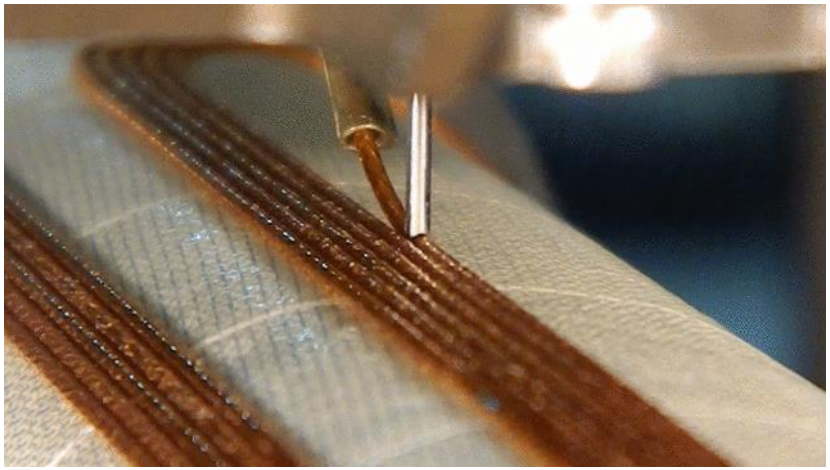
We place superconductor (round wire or cable) on a support tube under computer control.

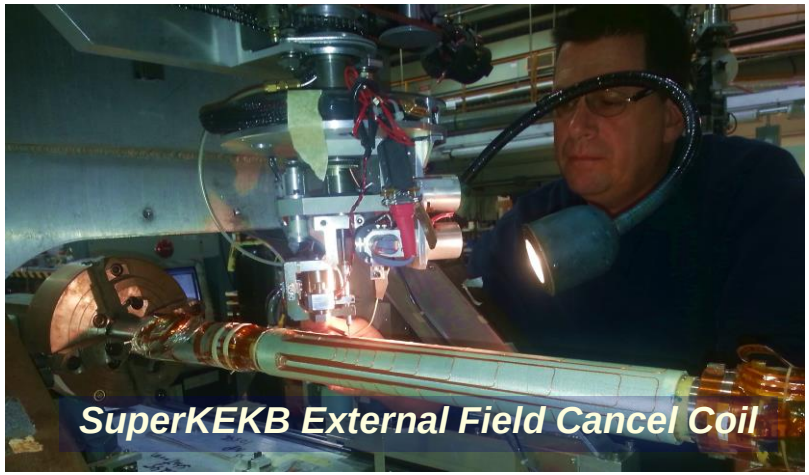
- General purpose, e.g. no need for costly tooling.
- Very good field quality (correct during production).
- Compact coils (force management without collars).
- Easily nest coils (e.g. b_1, a_1, b_2, a_2, b_3, a_3, b_4…).
- Vary aperture along length (wind on tapered tubes).
- Vary field along length (SuperKEKB, EIC, FCC-ee).
- Technology appropriate for doing “one off magnets.”
- Experience so far: Direct Wind magnets do not train.
- Used for decades in accelerators around the world.



Calculated b5 Normal/Skew Fields Compared to Targets.

BNL’s unique, world class magnet technology.





Magnetic Measurement Set-up

2 meter long, 31 mm Ref Radius

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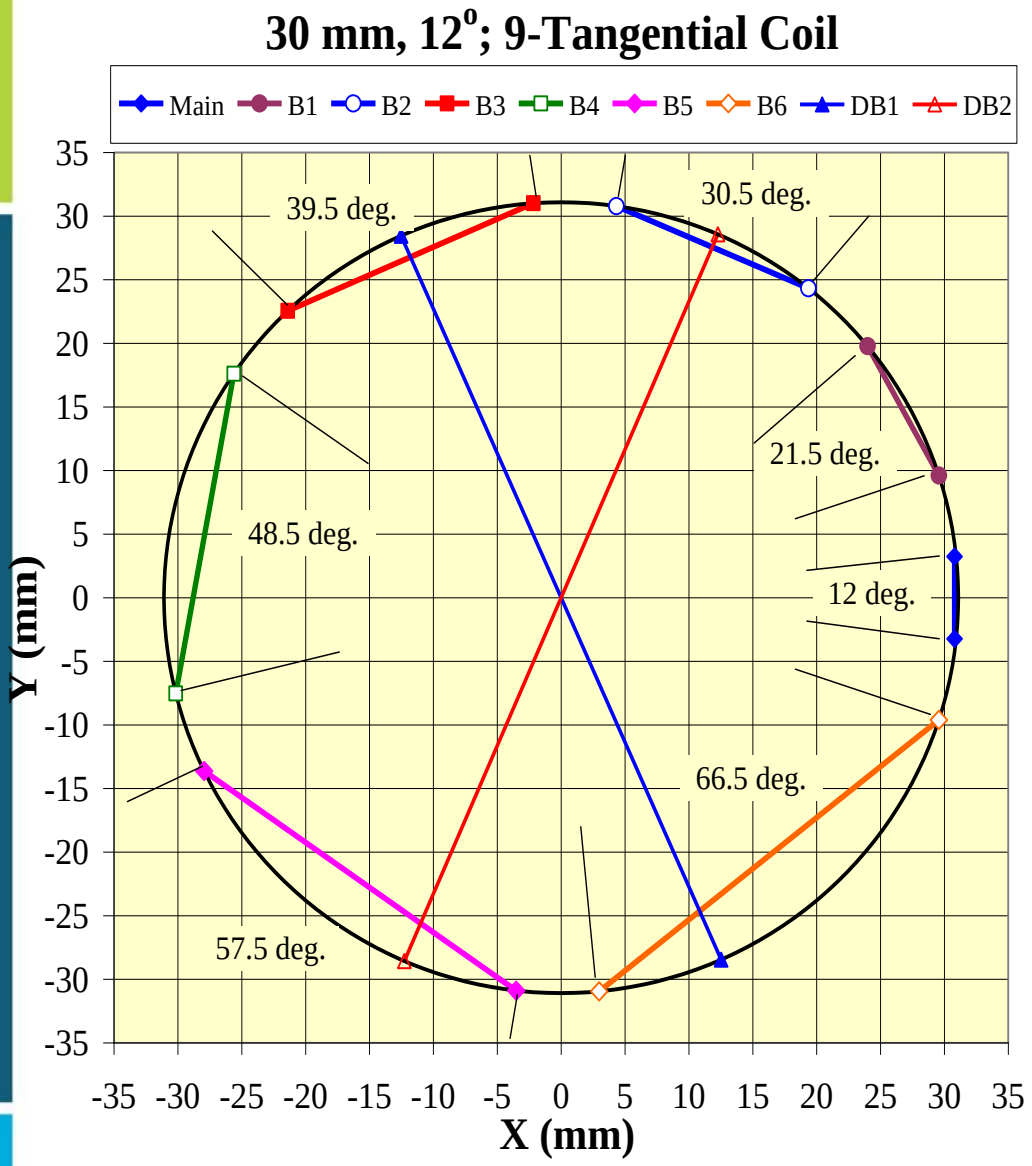
BNL "9-Tangential" Coil Design



- 12 deg., 36 Turns "Main" coil.
- 16 turns in each of the six bucking windings.
- 18 grooves needed.
- Minimum groove separation is 12 deg. (quite comfortable).
- Coil parameters are manually optimized to ensure applicability to all magnet types. (12 free parameters)
- Very simple end design (No overlapping turns, except DB).
- Only 7 windings are essential.
- Dipole windings were added to help with calibration but are also useful in providing more flexibility in measurements.

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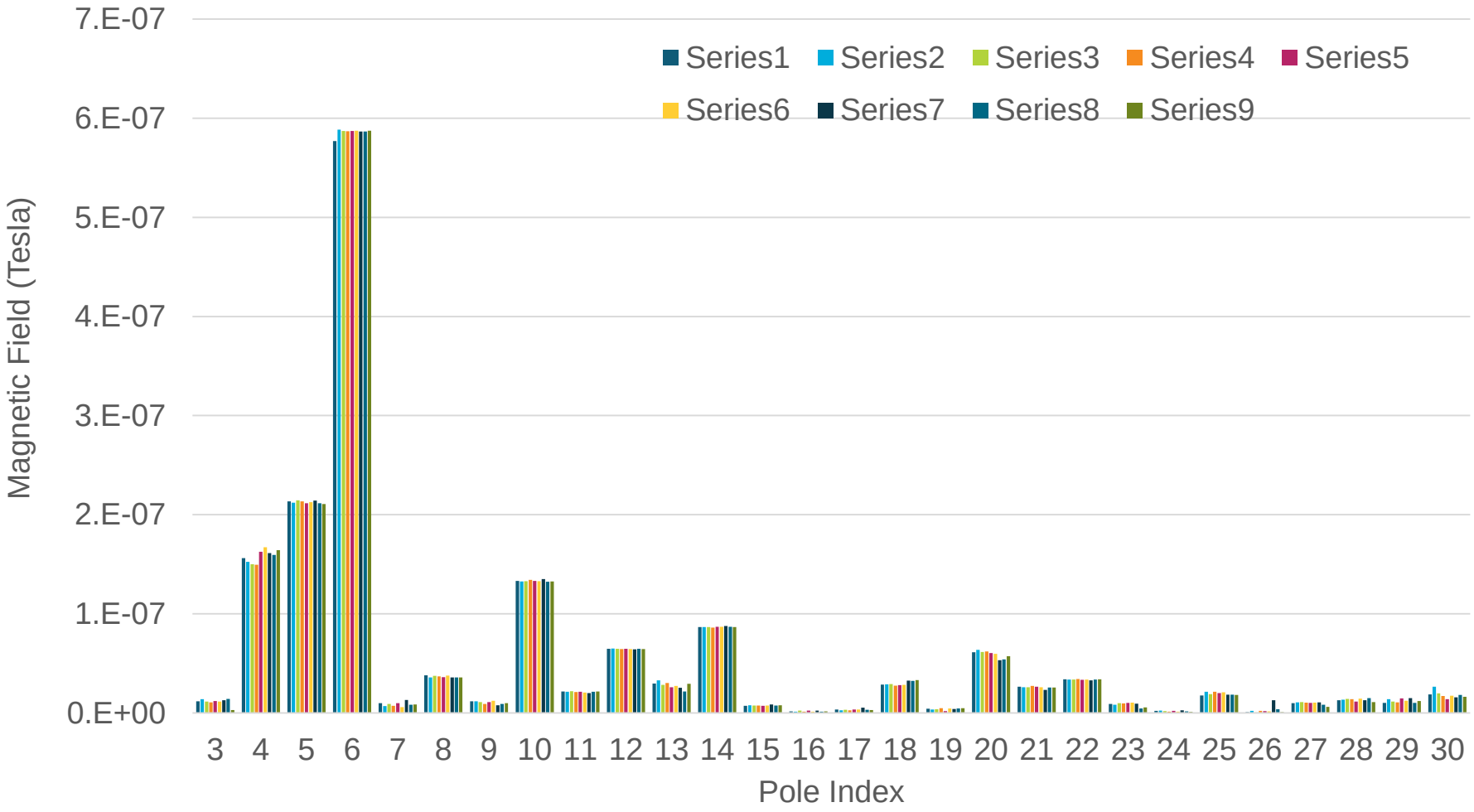
Animesh Jain

HoM using different tangential windings



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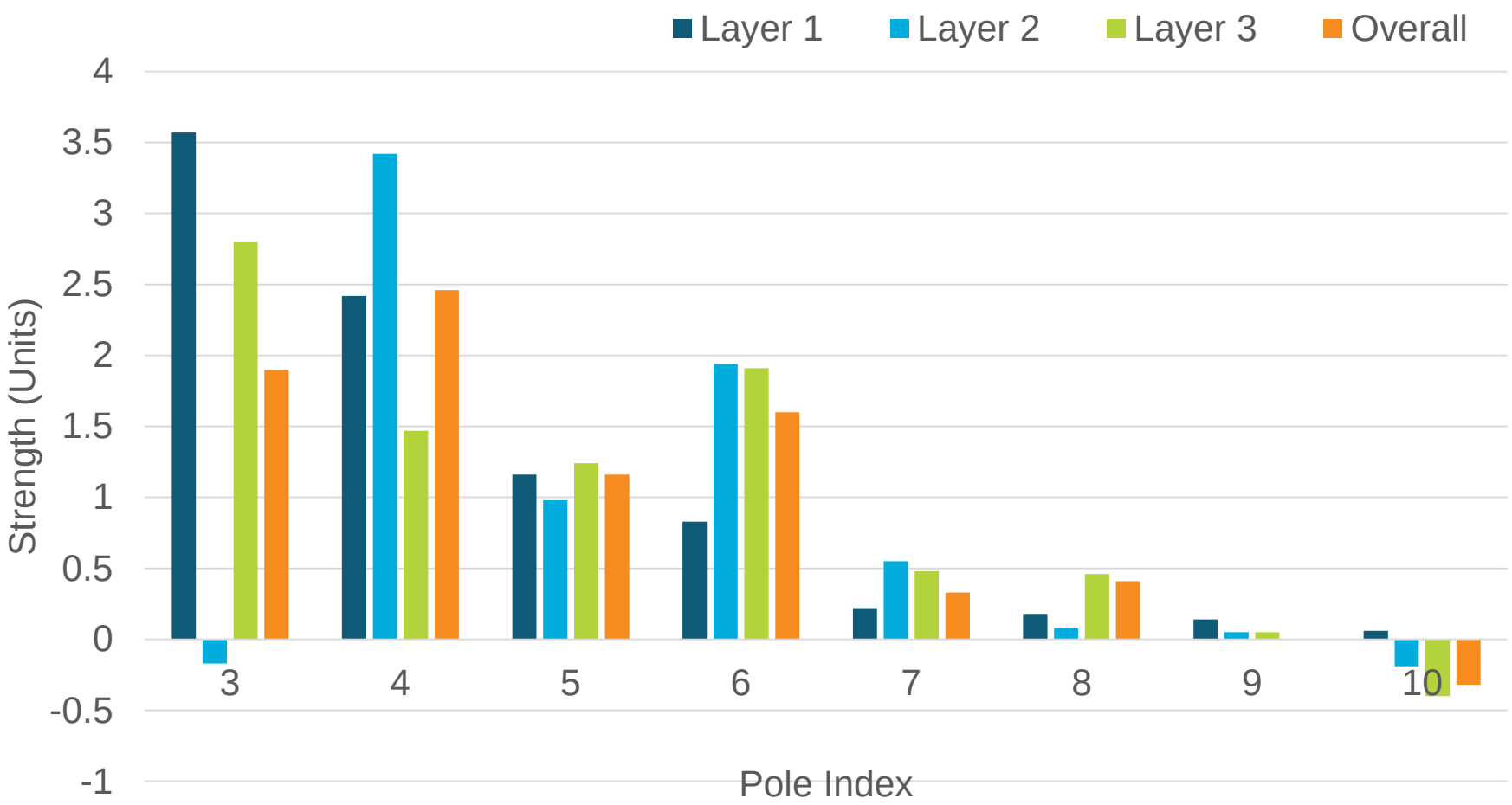
Measured Harmonics of individual Coil-set and overall



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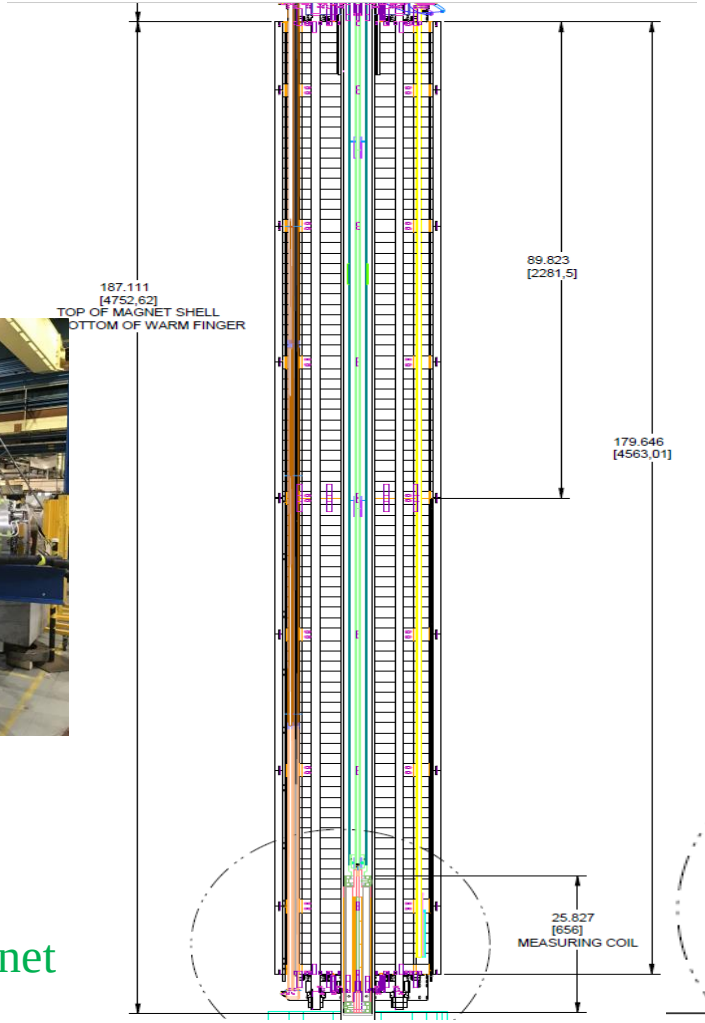
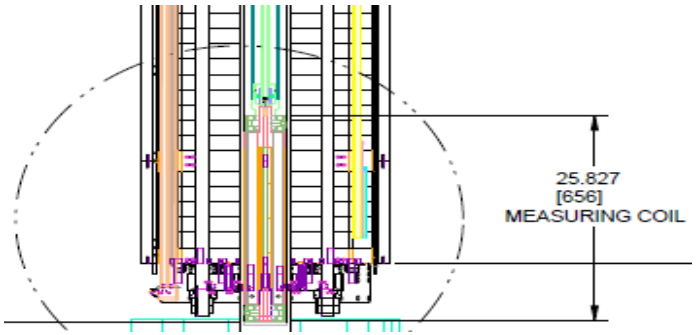
MQX Quadrupoles for Hi-Lumi: Field measurement system





Contribution to the Magnet
BNL, LBNL, Fermilab

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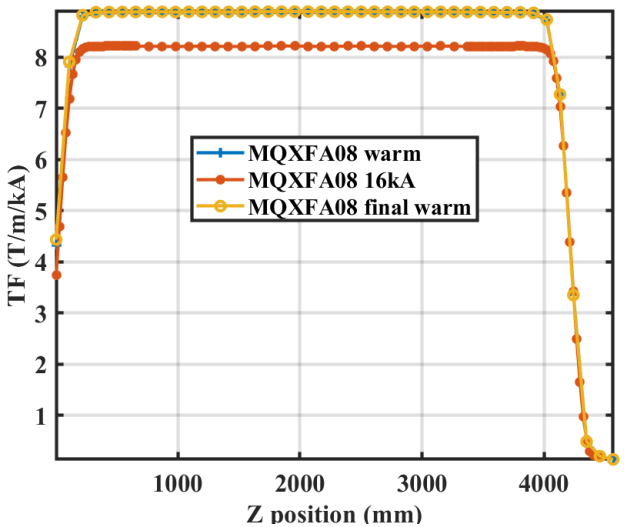
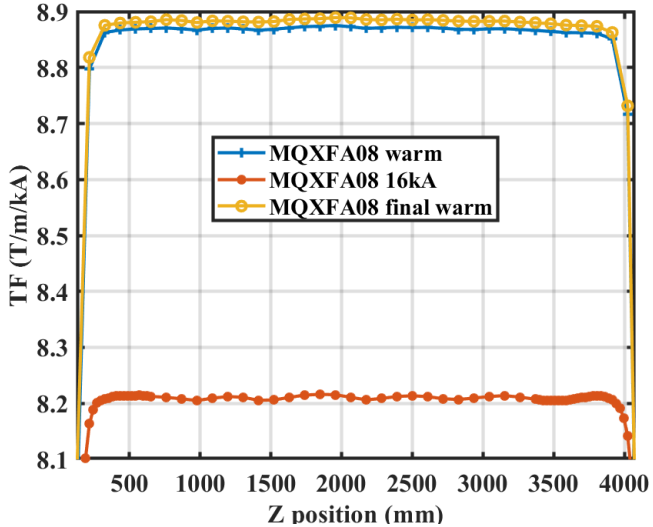
MQX Quadrupoles for Hi-Lumi: Transfer Function





	MQXFA03	MQXFA04	MQXFA05	MQXFA06*	MQXFA07	MQXFA08
B2	SS avg (T/m/kA)	SS avg (T/m/kA)	SS avg (T/m/kA)	SS avg (T/m/kA)	SS avg (T/m/kA)	SS avg (T/m/kA)
Warm pre-test	8.837	8.831	8.862	8.839	8.867	8.868
Cold at Inom	8.166	8.175	8.205	8.189	8.230	8.210
Warm after test	8.846	8.853	8.873	8.873	8.882	8.883
change warm before and after (units)	11	25	13	39	17	16
	*rot coil changed during the test. The new coil reads ~0.2% higher. MQXFA06, change would be ~19 units when the coil change is considered.					

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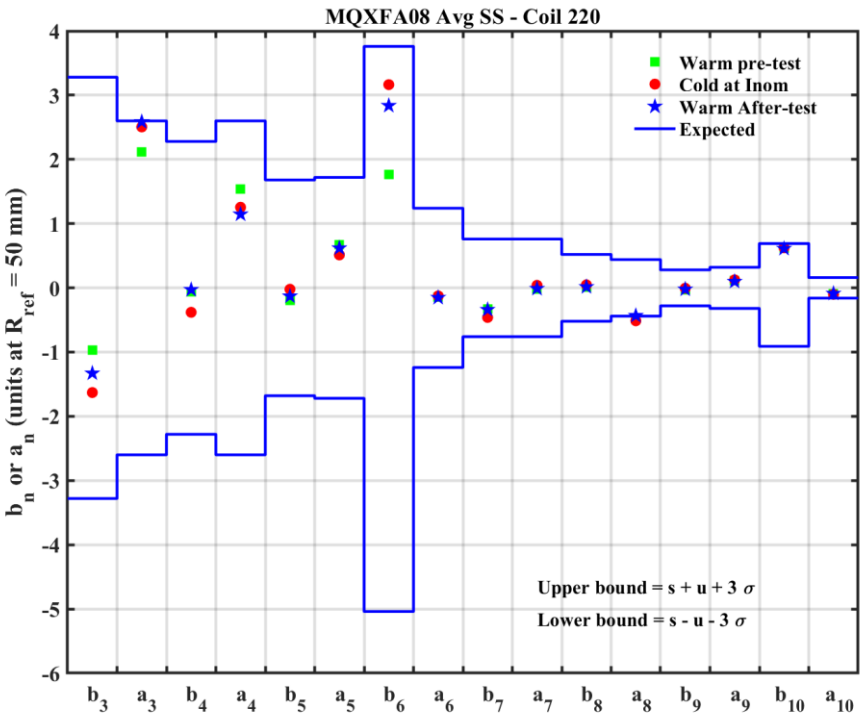
Anis Ben Yahia/
Febin Kurian

Field Quality in the straight section



	Warm Pre-test	Cold 16 kA	Warm After test
	SS avg (unit)	SS avg (unit)	SS avg (unit)
b3	-0.96	-1.63	-1.33
b4	-0.06	-0.38	-0.03
b5	-0.19	-0.02	-0.13
b6	1.77	3.16	2.84
b7	-0.33	-0.46	-0.34
b8	0.01	0.05	0.02
b9	-0.03	-0.01	-0.02
b10	0.62	0.62	0.61

	Warm Pre-test	Cold 16 kA	Warm After test
	SS avg (unit)	SS avg (unit)	SS avg (unit)
a3	2.12	2.51	2.58
a4	1.54	1.25	1.15
a5	0.67	0.51	0.62
a6	-0.15	-0.13	-0.15
a7	-0.01	0.04	-0.01
a8	-0.47	-0.51	-0.43
a9	0.12	0.12	0.10
a10	-0.09	-0.10	-0.09

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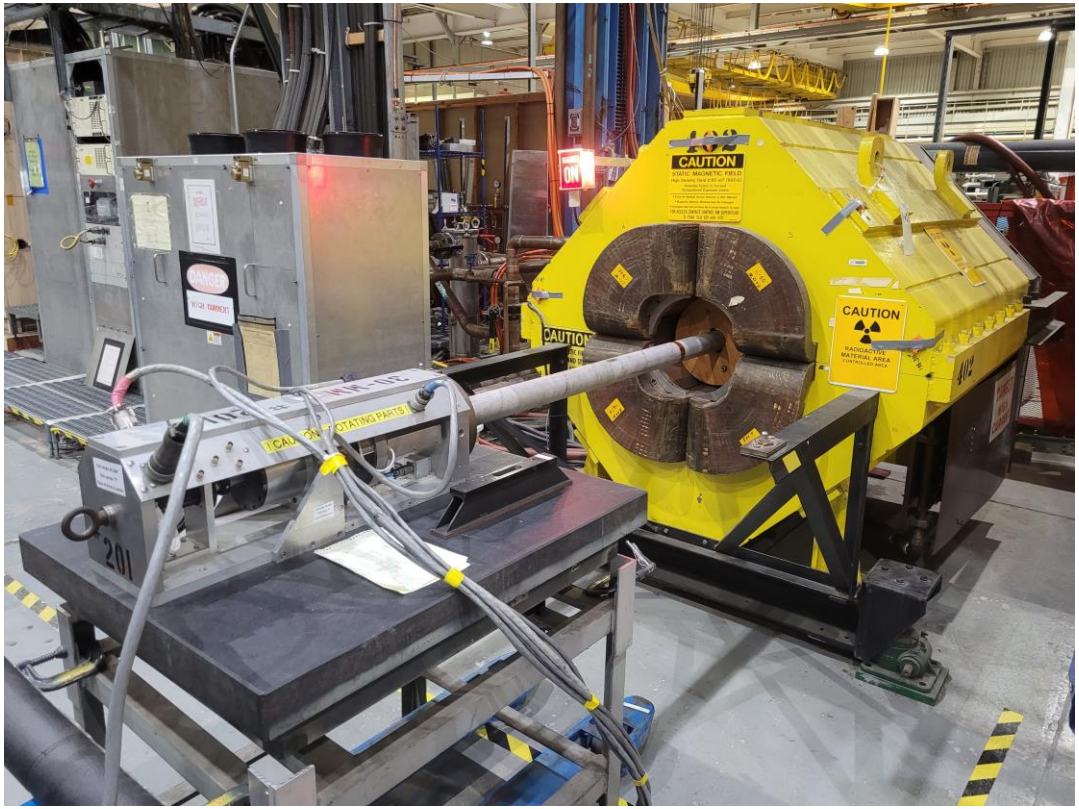
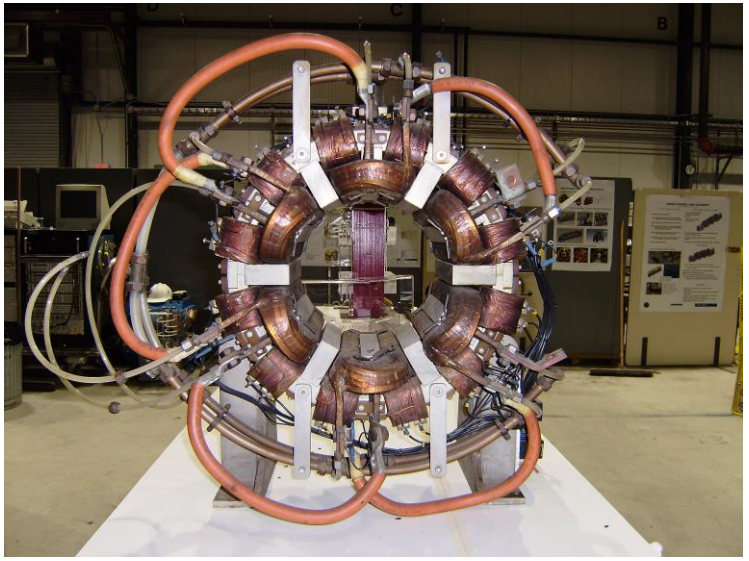
Anis Ben Yahia/
Febin Kurian

Rotating Coil Calibration Facility



Quadrupole Magnet



Multi-functional Magnet

Brookhaven National Laboratory

Summary

1. Magnetic Measurement systems built over years are serving the purpose of accelerator magnet measurements
2. Rotating coils with different coil length and ref. radius are available
3. The rotary mechanism and software are planned to be upgraded
4. Electrical motors in Moles being replaced with Piezo Motors for making them compatible for high fields
5. Z-harmonic scanner is under development
6. PCB based rotating coils are being designed to meet requirements of EIC.

Thanks for your kind attention

(Thanks to Bill, Chris, Leo and Pat at Magnet Division)