FFA@CEBAF Working Group | MINUTES

Meeting date | time *09/05/2025 | 11 AM EST* | Meeting location https://jlab-org.zoomgov.com/j/1614898082?pwd=TnUzMS81M2sxbDZIbERJU01tYkJCQT09

Meeting called by Alex B

Type of meeting Weekly Meeting

Facilitator Salim

Note taker Donish

Timekeeper Salim

Attendees

Salim, Donish, Ryan, Stephen, Scott, Dejan, Kirsten, Vasiliy, Patrick,

INTRO DISCUSSION

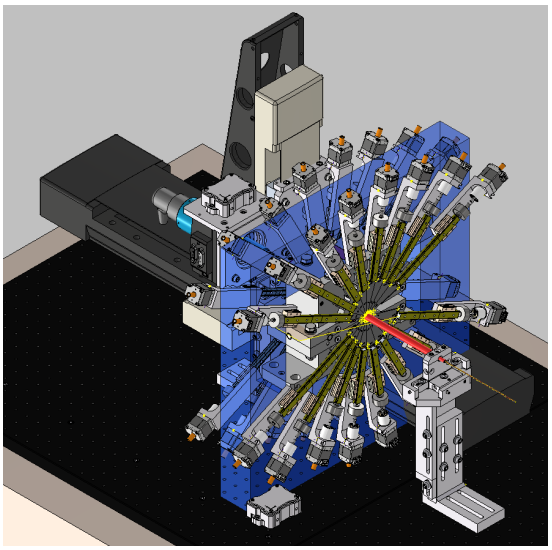
Patrick N'Gotta is a magnet physicist in the Mechanical Group at BNL-NSLS-II. He specializes in accelerator magnet design and develops permanent magnet-based magnets for the future NSLS-II upgrade. His research focuses on permanent magnet multipoles for accelerators and insertion devices. He earned his PhD in applied physics from Université Grenoble Alpes / ESRF, France, in 2015.

Patrick's slides have been uploaded here:
Magnet_design_meeting_JLAB.pptx

Time allotted | *55 mins* | Agenda topic Developments in PMQ Magnets | Presenter *Patrick Gotta*

Halbach Magnet Field Correction

Radial adjustment System In-situ of the Rotating Coil Measurement Bench



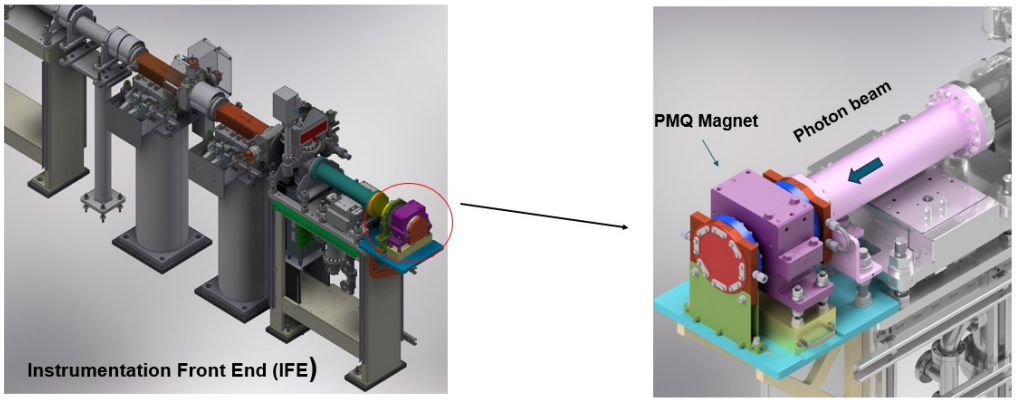
- 150 Units correction capability
- ±500 µm PM wedge radial displacement
- 5 µm resolution displacement
- Large scale PMQ correction (2700 PMQs)
- Expected ~ 1 hour for PMQ tuning

- Ryan: Question about the “magic fingers”; SmCo is very brittle, how do you deal with the physical damage to the magnets?
- Patrick: This is something we are testing at the moment by moving wedges and calculating forces on the fingers. This is done with simulation as well; tests say the magic fingers can withstand the intended movement.

Halbach Magnet Development- PM Radiation damage study

- Sm2Co17 PM choice for radiation hardness
- Magnet long term radiation exposure test
- Magnet field change will be measured

Radiation Resistance Test of the PM Material



Scattering of X-ray beam from an undulator with the PMQs PM wedges material (Sm2Co17) for long term experiment ~6 months, to test resistance of PM material and field stability of the PMQ magnet.

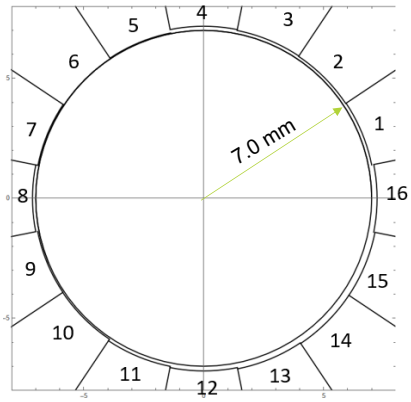
- Ryan: Question about the radiation damage impact; the PMQ film may be sensitive to gamma and not be able to detect secondaries. Is there a known way to get secondaries/neutron data as well?
- Patrick: Did not seem to be “aware” or a problem for our study.

Halbach Magnet Field Correction (Test 1)

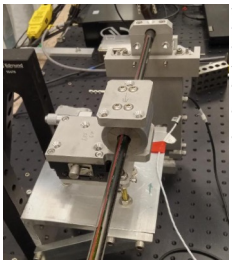
Inner Bore profiling with wire EDM

Wedges Machining calculated with magnet model and measurement

Wedge	[um]
1	137
2	116
3	134
4	172
5	29
6	1
7	43
8	135
9	57
10	65
11	142
12	195
13	248
14	277
15	277
16	225



Test magnet



Rotating coil bench

Measurement before and after magnet correction

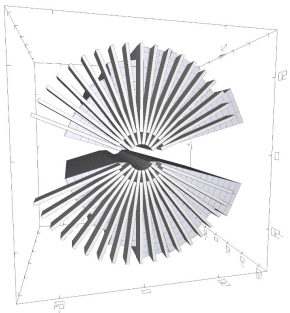
			Rref= 5mm		Rref= 3mm	
	4-Initial		5th correction		5th correction	
	normal	skew	normal	skew	normal	skew
1	0	0	0	0	0	0
2	10000	0	10000	0	10000	0
3	110.048	-71.3283	-3.5266	15.8983	-2.11596	9.53898
4	5.395	23.291	-1.584	-9.7693	-0.57024	-3.51695
5	-24.384	-20.5751	-1.927	-1.8615	-0.41623	-0.402084
6	-25.65	11.2632	-5.1886	-1.369	-0.672443	-0.17742
7	-4.11	5.2348	-0.7688	0.904	-0.05978	0.070295
8	-1.082	-0.1778	-0.1101	0.2293	-0.005137	0.010698
9	-2.171	-3.8952	-0.025	-1.1323	-0.0007	-0.031697
10	-2.218	0.9168	0.8741	-0.001	0.0146815	-1.7E-05
11	1.297	-2.666	1.6097	-3.1816	0.016222	-0.032063
12	0.256	0.3476	0.4746	0.0425	0.0028697	0.000257
13	0.099	0.0115	0.7017	0.5248	0.002546	0.001904
14	0.912	-0.0207	1.361	0.0592	0.0029626	0.000129
15	-0.031	-0.1465	0.0799	-0.2427	0.000104	-0.000317
	317 Units		53 Units		Sum: 17 Units	
					RSS: 10 Units	

- Large quantity of harmonics corrected (300 Units)
- Low harmonic content remain after correction (10 units @ 3mm GFR radius)
- Efficient method
- Test on the real magnet prototype
- Implementation of radial wedge moving correction for the next prototype

- Scott: Comment; SmCo is brittle even with coating?
- Ryan: Yes, someone got a splinter. Even Patrick has slide (see above) where some chipping is displayed.

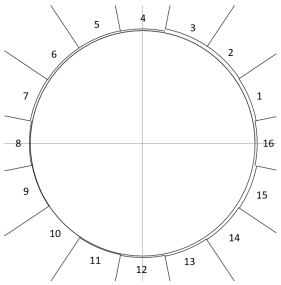
Halbach Magnet Development- Magnetic correction

"Magic" Fingers
(15 mm longitudinal length)

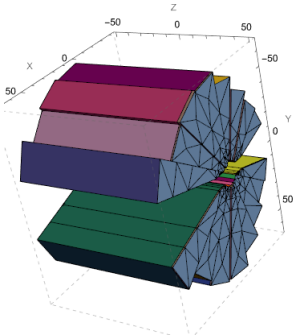


Courtesy, O.Chubar

Inner Bore profiling (Radial adjustment)



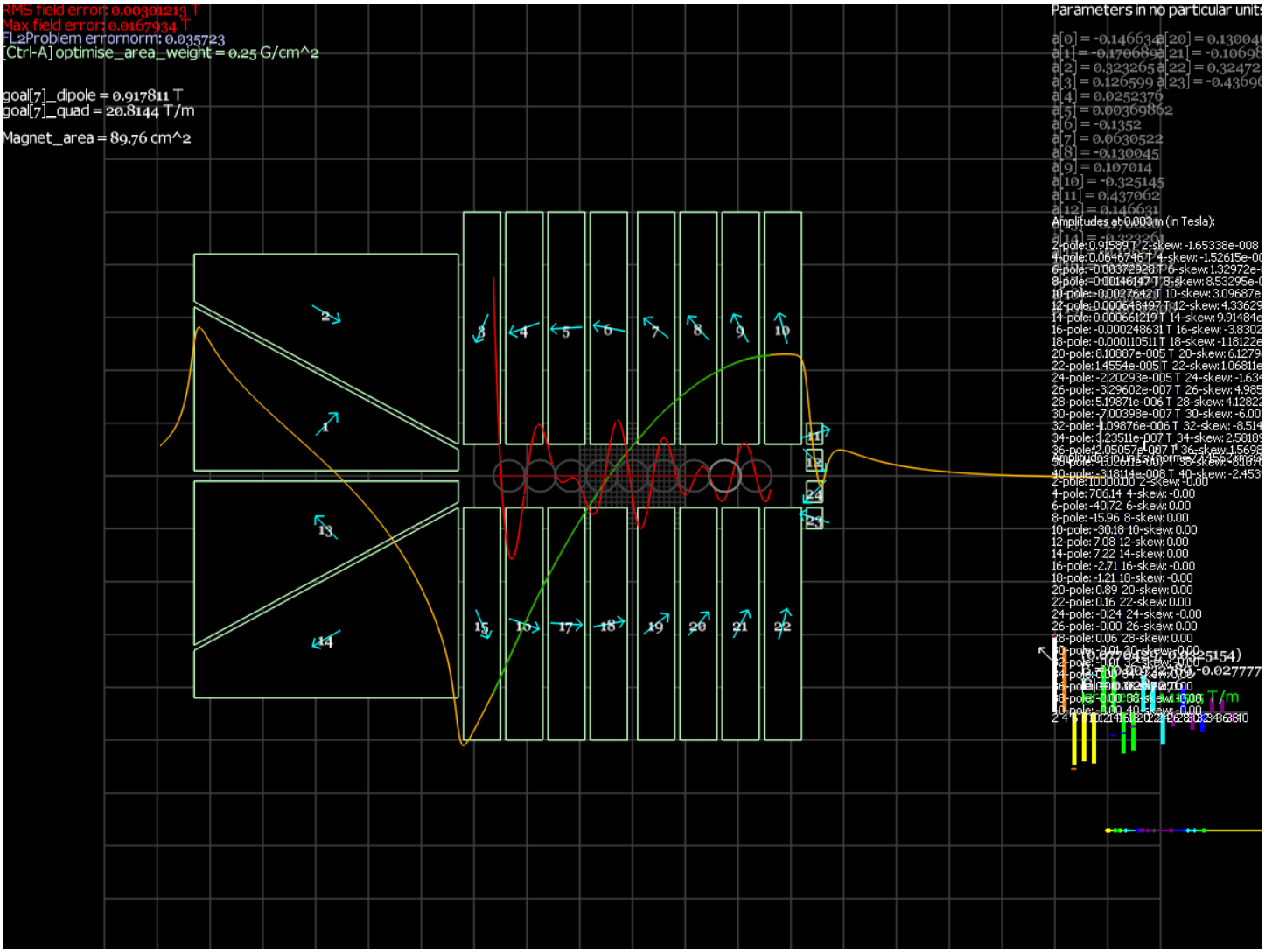
Iron Shim



Machined Iron Shim

- Two methods are being investigated for correcting the field harmonics: (1) "magic fingers, (2) machining (by EDM) the inner radii of the wedges
- An alternative to the second method is to move the wedges mechanically in the radial direction
- Machined iron shim method is efficient, however not planned due to implementation complexity (magnetic forces, clamping, inner bore space limited)

- Scott: Second comment; Regarding iron shim, I'm assuming its similar to what Stephen did for the CBETA magnets, where it was very successful in implementing using wires but aperture difference is large between cases.
- Stephen: Yes, aperture difference is the key problem; large gradients ~130 T/m and small aperture 8mm.
- Patrick: Yes, wire method is efficient and effective but not in our case where space is limited.
- Scott: For the given accelerator application (large magnet gradients hence large chromaticities), the RSS of 10 units seems too relaxed.
- Patrick: Initially it was 5 units and a study was done to get it to its current value.
- Dejan: Is there a way to do the shim outside instead of inside?
- Stephen: Putting shims outside is not effective in correcting higher order harmonics.
- Ryan: Another question; The degradation is uneven so the good field range should change as well. Does the hybrid set up address this issue?
- Patrick: One aspect of using this technology that we must accept is that the magnet/magnetic properties will change over time. One way we are addressing this is in the design of a corrector that can be used to commissioning, tuning and correction of the beam orbit over time as the magnet changes. For the hybrid case, it is currently running in the ring and have not observed any significant demagnetization.
- Scott: Doesn't machining mess up the magnetization?
- Patrick: This was a concern from several people at a workshop in Italy, short answer is "yes". My experiments were done as a trial.
- Dejan: We just had a very interesting experiment with building these magnets with a company in MA; though, the apertures were very small.
- Stephen: That company requested rectangular magnetic pieces instead of wedges. Wedges were done to prevent pieces from falling into the aperture but the gluing nullifies this concern.
- Patrick: I've been testing out several designs for magnets built with rectangular pieces with good preliminary success (but low field).



- Stephen: Let me share my screen (above), a design that this company in MA (SABR) based on Dejan's non linear FFA magnet except with rectangles and small gaps between the pieces. Overall its hopeful and matches field profile quite well; could be a potential magnet design for CEBAF. After running it through my optimizer I can get the matching error down to a fraction of a percent.
- Salim: How do you move the wedges?
- Patrick: With a motor, two wedges will have two motors.
- Salim: I asked because my experience with hadron machines that used PMQs, we could move the magnets to be used as a beam-based alignment method.

Special notes

Pathway to Repository: https://jeffersonlab-my.sharepoint.com/:f:/g/personal/tristan_jlab_org/EqZ5MeS-nipCgPfZB5p0oS4B9Is67d3nQb9sLJI3Zyev9g