Relevance, Analysis and Context of the Test Results of the Optimum Integral Dipole B0ApF Built Under PBL/BNL STTR

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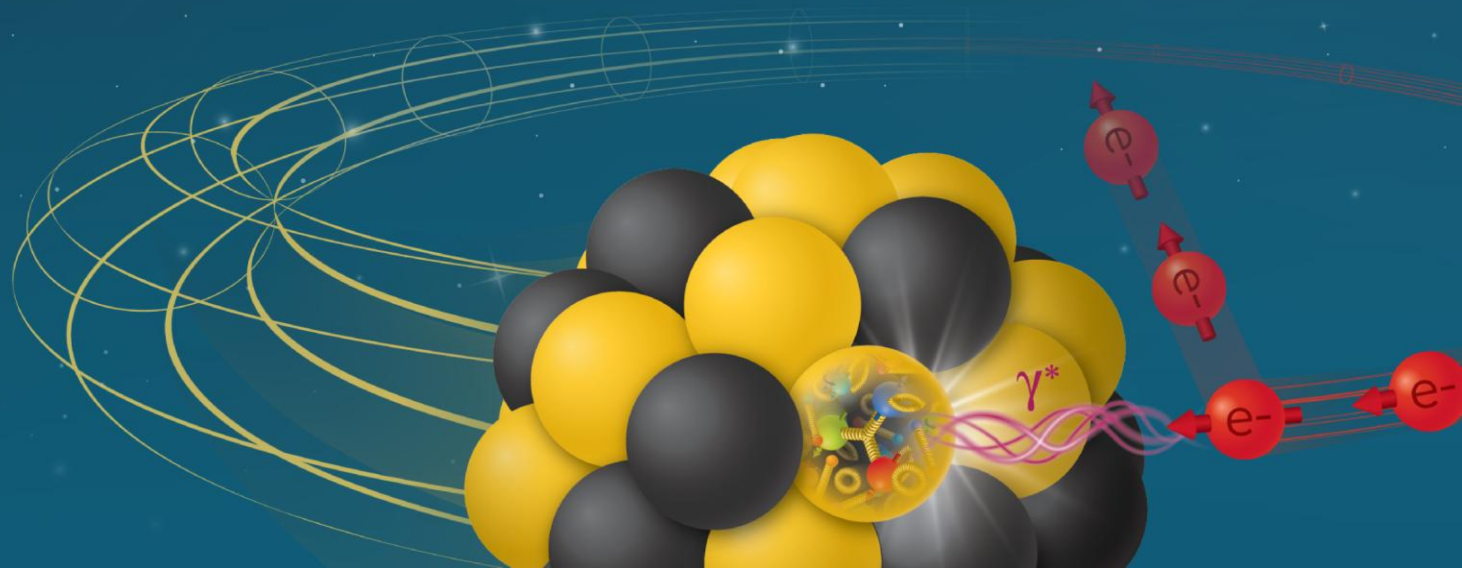
Electron-Ion Collider



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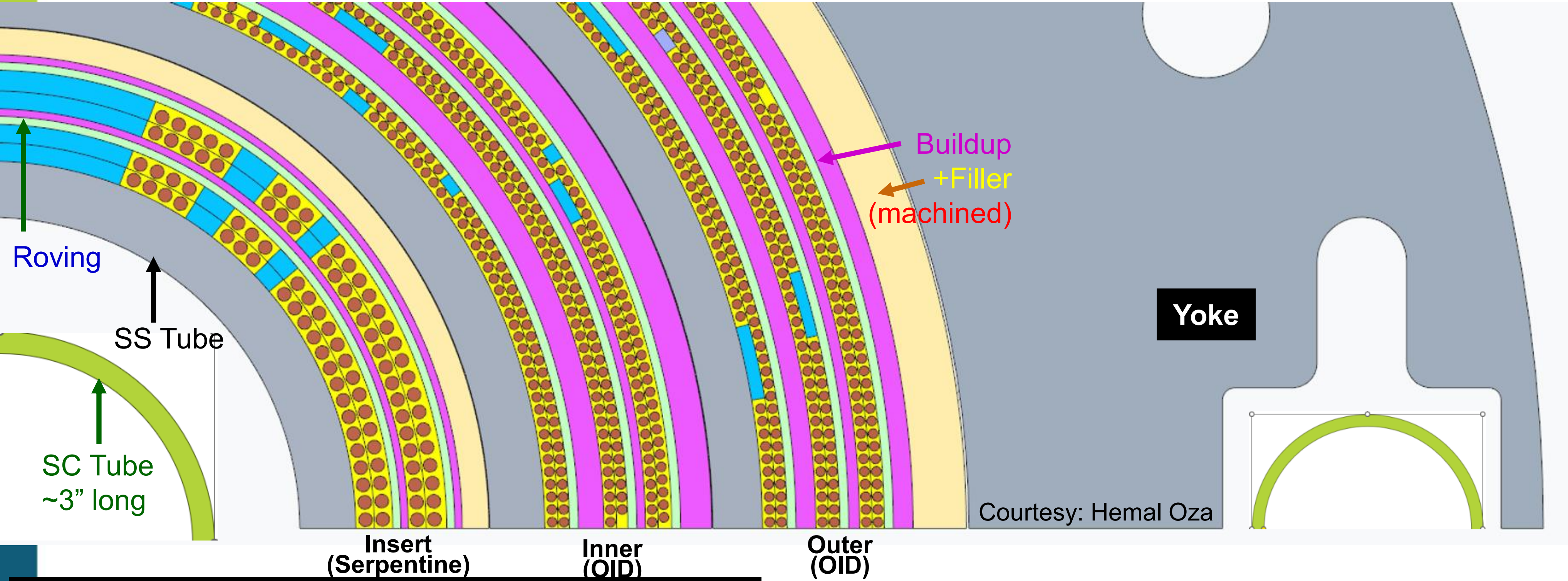
Background and Relevance

- Recent test results confirm that the previous signal that limited the testing to ~150 A (after 400+ A test) were not due to quenching in the magnet
- The magnet reached 89% of the short sample (Bo ~3.6 T, Bpeak ~4 T, coil i.d. 114 mm). This test, along with the previous Q1ABpF test, demonstrates the basic potential of the direct wind technology and benefit to EIC.
- The magnet was built to demonstrate the basic principle of the optimum integral design under very limited funding of SBIR/STTR. Many decisions were based on the budget limit (~1.2 M$ shared between PBL/BNL). Just building the magnet is not enough; it must be tested.
- The focus was on demonstrating the optimum integral design for EIC. Without such a demonstration a new design can't be used in an accelerator.

Basic Design and Construction



Key Parameters of OID:
- **Coil id, od: 114, 183 mm**
- **Coil length: 600 mm**
- **OID B_o,B_{pk}:4.0T, 4.4T@480A**

- **Support structure was segmented with intermediate tubes to avoid stress build-up (stress management)**
- **Outer SS tube was part of the original design, but not installed due to budget limitation of the STTR**
- **Yoke was not straight (no line-to-line fit structurally)**

A Series of Tests During the OID Program

Test #1: Two-layer OID

Test #2: Six-layer OID

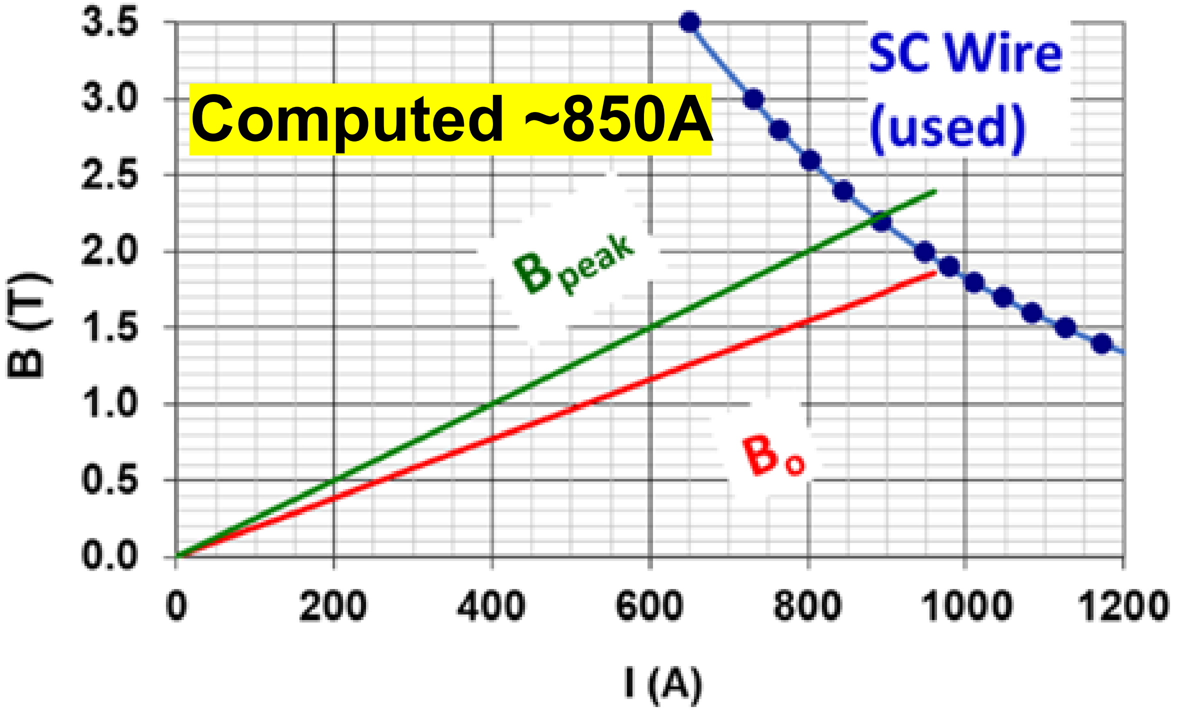
Test #3: Twelve-layer OID (six layers each on two tubes)

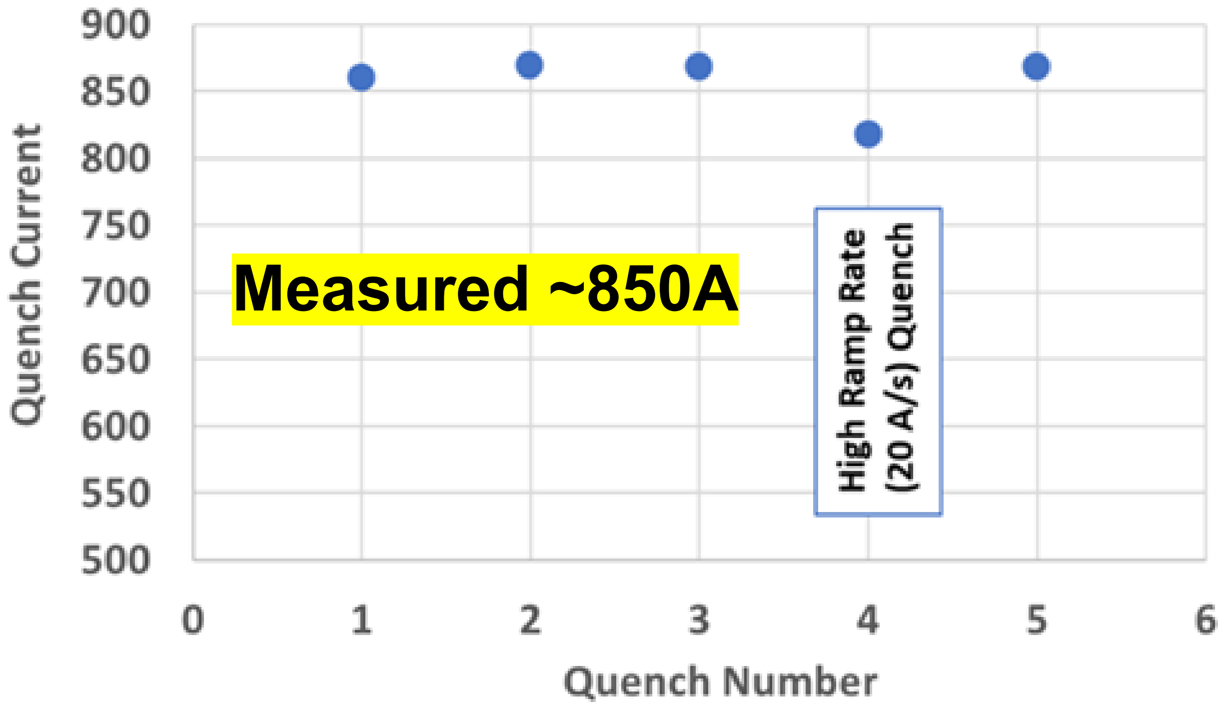
Test #4: Four-layer Serpentine Insert plus Twelve-layer OID

Test #5: Re-test of Twelve-layer OID after removing insert

- **Only test #1 and test #5 produced quenches in the magnet.**
- **Other tests were limited by conditions external to the magnet.**

First Test: 2-layer Optimum Integral Dipole



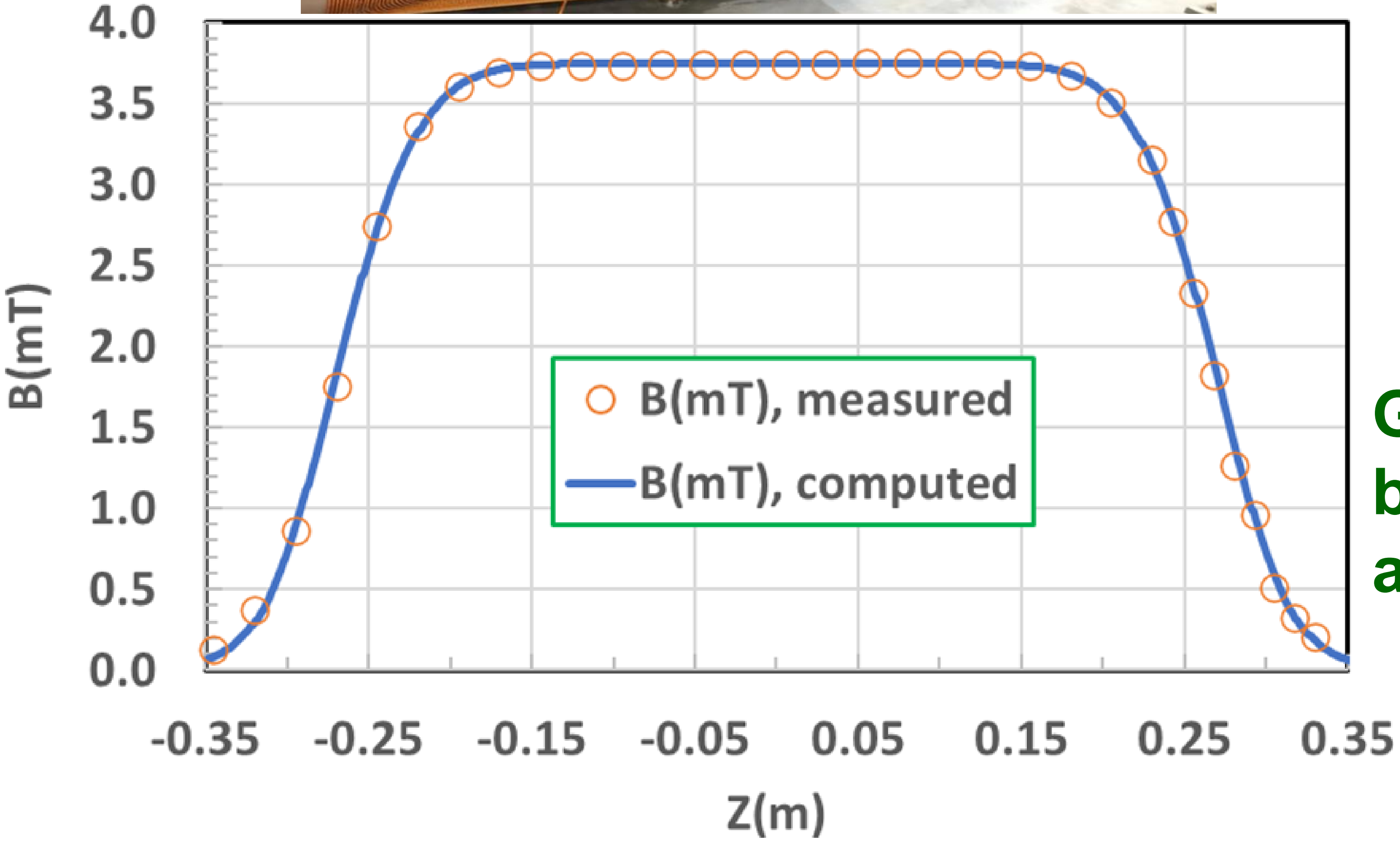


Excellent Quench performance

(reached computed short sample without any training)

B_o = ~1.7 T, B_{pk} = ~2.2 T, Coil i.d. = 114 mm

Demonstration of the optimum integral design to extend the magnetic length



Major motivation of the optimum integral design demonstrated

Good agreement between the calculations and the measurements

Field Quality Demonstration of the Design and of the Code

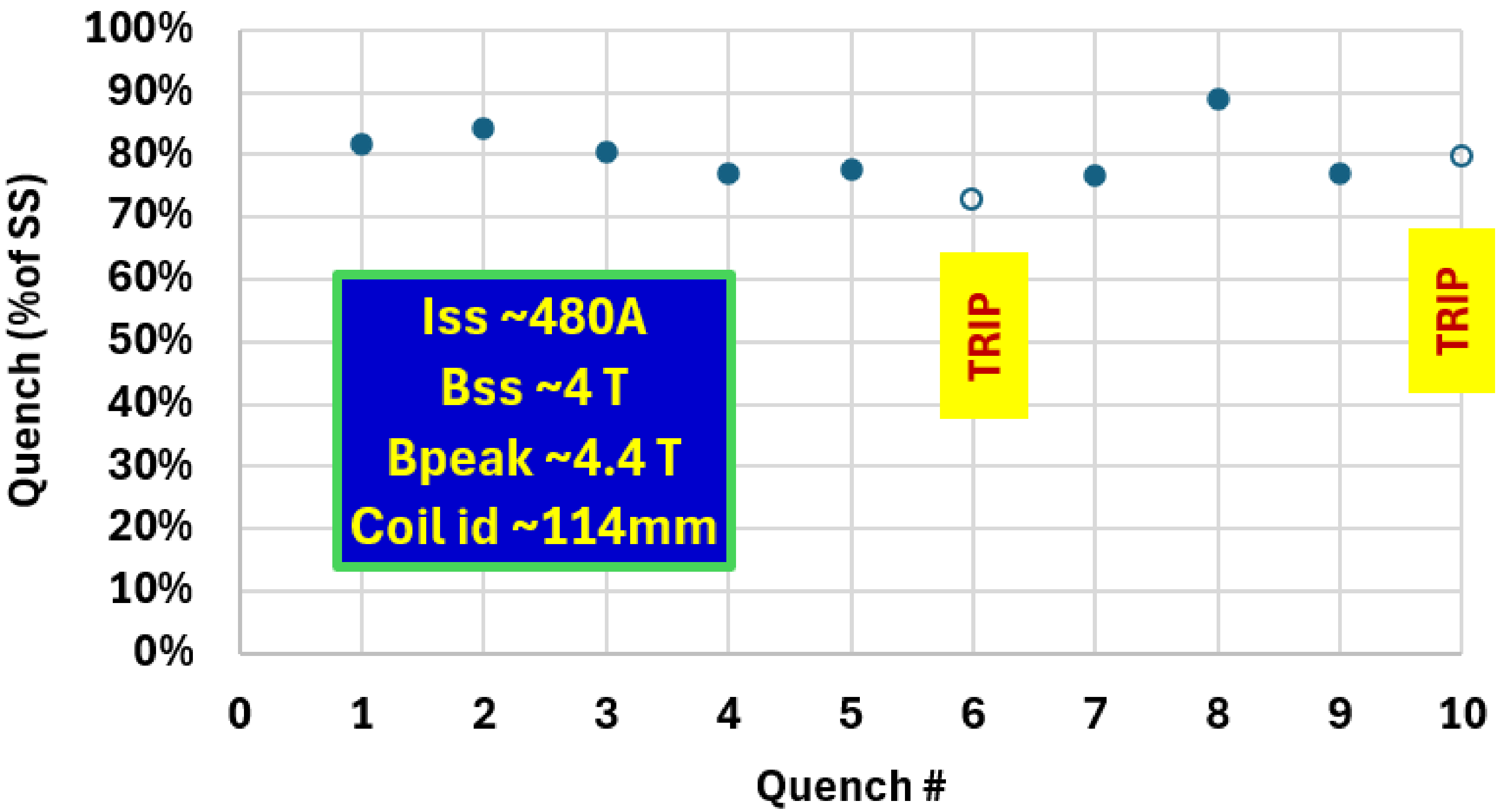
Warm testing of 6-layer design

Optimum Integral Dipole 6-layer Design		
ITF (NO Fe)	1.860	mT.meter/A
Measured Integral Harmonics@31mm		
No.	bn	an
2	0.77	3.51
3	6.12	4.32
4	0.43	-0.98
5	0.93	0.50
6	0.20	-0.61
7	1.85	0.58
8	-0.02	0.22
9	-0.66	-0.19
10	0.02	-0.08
11	0.18	0.05
12	0.00	0.02

Small harmonics from the testing leads (yellow)

- A good field quality despite several changes on the fly (as in any R&D project)
- Next layers can be used to compensate the small harmonics.

Recent Test: 12-layer Optimum Integral Dipole



Quench #	Quench Cur(A)	Location	Bo(T)	Bpk(T)	%of SS
1	392	CS4	3.3	3.6	82%
2	404.5	CS2	3.4	3.7	84%
3	386	CS2	3.2	3.5	80%
4	370	CS2	3.1	3.4	77%
5	372.45	CS2	3.1	3.4	78%
6	349.5	TRIP	2.9	3.2	73%
7	367.9	CS2	3.1	3.4	77%
8	426.3	CS2	3.6	3.9	89%
9	369	CS2	3.1	3.4	77%
10	382.5	TRIP	3.2	3.5	80%

For Reference: RHIC Dipole

B_o = ~3.45 T

Coil i.d. = 80 mm

(with many years of R&D)

Bo ~3.6 T, Bpeak ~4 T @426 A; 89% of Short Sample.

All quenches above 77%, which is impressive for such a magnet, and perhaps can be eliminated

Summary and Conclusions

- A new design must be demonstrated before it can be used in a machine. Recent test showed a basic demonstration of the optimum integral design.
- Superconducting magnet technology usually takes several years of R&D. If a certain test doesn't achieve the desired performance, we analyze what limited the performance, fix the source and move ahead. That's what we did in this case. All issues were found to be outside the magnet structure.
- We achieved the short sample in the first quench in the 2-layer, Bo = ~1.7 T, Bpk = ~2.2 T, Coil i.d. = 114 mm optimum integral dipole.
- Recent 12-layer (coil i.d. 114 mm), reached Bo ~3.6 T, Bpeak ~4 T, which is 89% of the short sample. No quench was below 77% (it is possible that these quenches were due to other than the basic design and construction).
- In any case, this is a significant demonstration in a budget limited program which couldn't do certain engineering, etc.. This should be a sufficient demonstration for EIC to keep moving with the design and technology.