Brookhaven National Laboratory | Jefferson Lab | U.S. DEPARTMENT OF ENERGY

EIC IR Magnets Magnetic Analysis Bi-weekly Meeting

Introduction and Standardizing Conductor Parameters

Ramesh Gupta

January 9, 2026

Electron-Ion Collider

Introduction and Purpose of these Meetings

- **The focus of these meetings will be on technical discussion on a specific topic or EM design of a magnet, rather than providing the status report.**
- **Expect to have a technically objective and lively (respectful) discussion.**
- **Today's meeting is for producing a common set of conductor parameters. Test results and facilities will also be presented.**
- **Future topics:**
  - **2-d and 3-d designs (approach and modelling)**
  - **Cross-talk**
  - **Assuring good field quality**
- **Above will follow by in-depth discussion on EM design of individual magnets**
- **Feedback to above and suggestions on more topics are welcome.**
- **A SharePoint site has been created (thanks Angelika) to store presentations.**

Agenda (January 9, 2026)

- Introduction to the meeting & standardizing conductor parameters
  - Ramesh Gupta
- Test facilities at FSU for testing EIC wires and cables
  - Jun Lu
- Measurements and parameterization of EIC wires
  - Ye Bei
- Test facilities at OSU for testing EIC wires and cables
  - Mike Sumption
- Parameterization for quench calculations and 6-around-1 cable
  - Emmanuele Ravaioli
- General discussion
  - All

Standardized Ic(B,T) Curves for Magnet Designers

- All EIC IR magnet designers should use the same I_c(B,T) curve for various analysis.
- The I_c(B,T) curves are standardized with a set of fitting parameters. The type of fitting (e.g., Bottura curve) should be the same even if the exact values of the fitting parameters is different for different wires and/or cables, if and as necessary.
- The fittings should ideally be based on the measurements. However, in the absence of the measurements (e.g., they are currently not available at 1.92 K for margin calculations, and they may never become available at higher temperature for quench analysis), they should be based upon agreed set of fitting parameters.
- The basis of arriving to a set of parameters maybe debated and periodically updated (with version numbers) as the measurements become available.
- Measurements at 4.2 K and possibility of performing them at 1.9 K and also the proposed fitting parameters will be presented in the following talks.

Experience on 4.2K/1.9K Ratio

IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 17, NO. 2, JUNE

Critical Current Measurements of the Main LHC Superconducting Cables

A. P. Verweij and A. K. Ghosh

Guidance from Arup Ghosh and Amalia Ballarino:
(a) 4.2K/1.9K ratio doesn't vary too much, at least when the process remains the same,
(b) Can use a shift of 3T +/- 0.1T in I_c

TABLE I
MAIN CABLE AND STRAND CHARACTERISTICS

	Cable 01	Cable 02	Cable 03
Delivered no of UL	5369	5407	894
Length of a UL	450 m	740 m	660 m
Cable			
Width	15.08-15.10 mm	15.08-15.10 mm	
Thin edge	1.736±0.006 mm	1.462±0.006 mm	
Thick edge	2.064±0.006 mm	1.598±0.006 mm	
Mid thickness	1.900±0.006 mm	1.480±0.006 mm	
Number of strands	28	36	
Transposition pitch	110±5 mm	100±5 mm	
Cable Ic @ 4.222K, 7 T	>14140 A		
Cable Ic @ 4.222 K, 6 T		>13236 A	
Cable Ic @ 1.900 K, 10 T	>13750 A		
Cable Ic @ 1.900 K, 9 T		>12960 A	
Strand			
Diameter	1.0650±0.0025 mm	0.8250±0.0025 mm	
Cu/SC ratio	1.6-1.7	1.9-2.0	
Strand Ic @ 1.900 K, 10 T	>515 A		
Strand Ic @ 1.900 K, 9 T		>380 A	

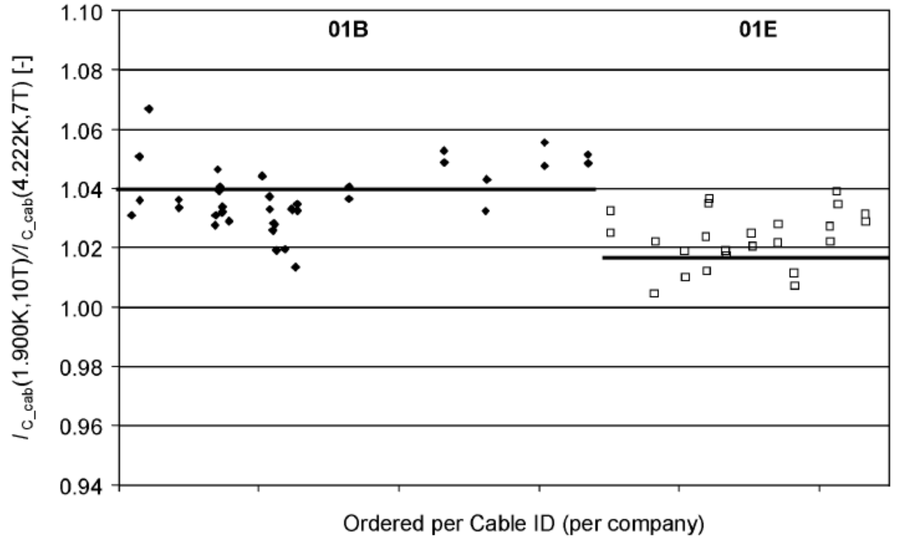
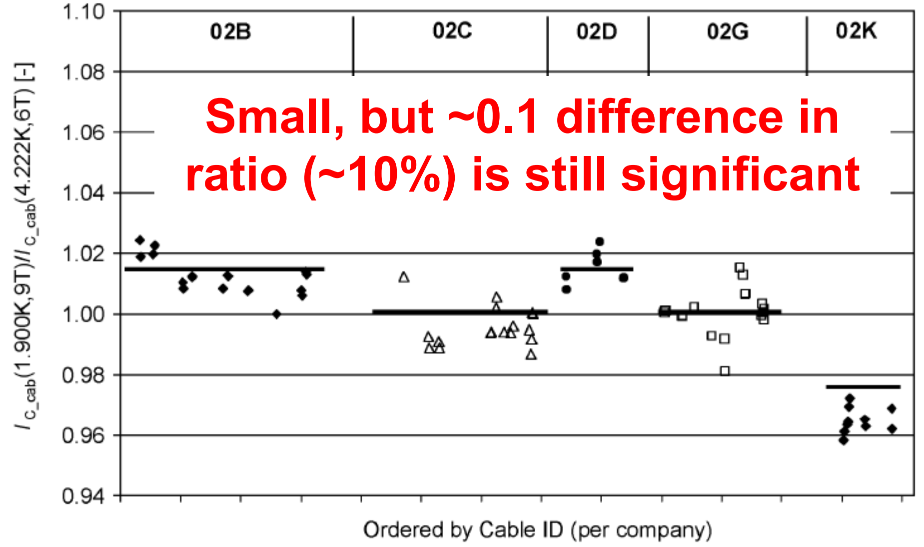


Fig. 11. Ratio between cable I_C at 1.9 K (10 T) and at 4.222 K (7 T) for the cables of type 01.

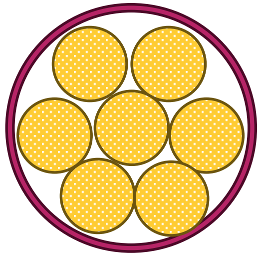


Small, but ~0.1 difference in ratio (~10%) is still significant

Fig. 12. Ratio between cable I_C at 1.9 K (9 T) and at 4.222 K (6 T) for the cables of type 02. The 02B production cables at FEC is not included.

➢ Message: Need a few (not too many) measurements at 1.9K

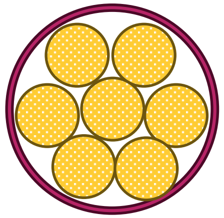
Role of the Cetral Wire in 6-around-1 Cable On Quench Protection



- Direct wind magnets operate at low current (<2 kA, most < 1 kA). This is a positive feature for current leads and for power supplies. However, the quench protection becomes challenging due to high inductance in many large aperture, high field direct wind magnets in EIC IR.
- These high field magnets are built with 6-around-1 cable, with the central wire not transposed. As a result, the transport current may not be shared equally between the central wire and the 6 wires around it, particularly at high ramp rates.
- We have seen a negative impact of it in the quench current experimentally at a ramp rate higher than 20 A/s. Models are being developed to explain this drop. However, this is not a practical concern in EIC IR magnets operate at a lower ramp rate.
- Fortunately, this could have a large positive impact on the quench protection and in quench analysis as the current falls rapidly (high ramp rate) after the power supply is shut off. The cable may go normal much sooner than assumed in the models.
- We need to know that soon, as that is driving the magnet and quench protection system design. By not including this, we may be unnecessarily increasing the cost.

Measurements to Help Build More Complete Quench Models

- We must experimentally measure if the central wire has a significant impact in driving the cable normal sooner, as it will reduce the hot-spot temperature and will change the quench protection system design.



- Relatively simple measurements, as proposed below, will not only determine that but should also give necessary input for accounting them in quench analysis.
- Keep the background field at a constat value. The value will change in different runs.
- First ramp up the 6-around-1 cable at different ramp rates from 10 A/s to 1000 A/s and measure the impact on critical current. Perform this experiment at different fields.
- Second ramp up the cable to a set of currents (say 500 A to 1500 A, depending on the field), and then ramp down at different ramp rates (say 10 A/s to 1000 A/s). Perform this experiment at different background fields.
- Above experiments (particularly the second), will give an idea of how important the role of non-transposed central wire is. It will also provide input to quench models.
- These measurements should not be too expensive but would have major impact.

Other Measurements

- Magnetization measurements have a significant impact on the models to compute errors due to persistent currents.
- They are already being performed in certain ways and more possible and will be discussed in next presentations.
- Measurements of cable performance (I_c Vs. B) are expensive. They should be carried out at certain stage. As such, relatively speaking, we don’t expect much degradation to have significant impact on designs, particular since the keystone angles are small and operating margins are large (65%-70% on the loadline).
- Given above, I suggest not to include cable degradation in the magnetic design calculations.
- Any feedback?