Design and Prototyping of Superconducting EIC – Interaction Region Magnets

Nuclear Physics Accelerator R&D PI Meeting
Peter Wanderer, BNL
November 13-14, 2018

Electron Ion Collider – eRHIC
Acknowledgements

• Brett Parker
• Mike Anerella
• Jesse Schmalzle
• DOE OHEP LARP R&D, ILC R&D
Design and Prototyping of Superconducting EIC – Interaction Region Magnets

The panel identified the validation of magnet designs associated with high-acceptance interaction points by prototyping as a key area that is common for all EIC concepts (p. 41).

<table>
<thead>
<tr>
<th>Funding Source</th>
<th>PI</th>
<th>R&amp;D Report Priority #</th>
<th>R&amp;D Panel Priority Rating</th>
<th>Total $</th>
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<tr>
<td>FY17</td>
<td>P. Wanderer, M. Anerella</td>
<td>28</td>
<td>Hi-C</td>
<td>$210,000</td>
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Outline

• Superconducting Quadrupole for EIC Insertion Region (IR)
• FY17 Task and Status
• Conclusions and Outlook
Superconducting Quad for EIC IR (1)

• EIC (Generic) Requirements for IR Magnets:
  • Hadron beam → superconducting (high energy)
  • Electron beam → low field (avoid synchrotron rad.)
  • Beams near the collision point are very close to one another → novel magnets

• Approach:
  • Proof of principal magnets useful to both labs. Most difficult magnet is Q1PF (first quad on proton forward side of IR), which needs Nb$_3$Sn coils. (NbTi inadequate)
Superconducting Quad for EIC IR (2)

• Value Engineering:
  • Use existing hardware, specifically Nb$_3$Sn coils from the OHEP LARP program
  • Use novel concept: “Active Shielding,” from OHEP ILC R&D program. Shield quad has opposite gradient and larger radius than main quad.

• Engineering Challenge:
  • much less radial space available for the structure that supports the quad coils against Lorentz forces.
**eRHIC and JLEIC: Fast Track R&D**

- Use existing \(\text{Nb}_3\text{Sn}\) coils (from LARP work) with a new active shield to prove out Q1PF concept.
- Main challenge is limited space for mechanical structure.

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**LARP mechanical structure comparison**

**NbTi active shield coil around an \(\text{Nb}_3\text{Sn}\) inner coil**

See B. Parker, *et al.*, IPAC18 paper, WEPMF014, “Fast Track Actively Shielded \(\text{Nb}_3\text{Sn}\) IR Quadrupole R&D,” at URL: https://doi.org/10.18429/JACoW-IPAC2018-WEPMF014
Fast Track R&D Magnet: Design Summary

- Longitudinal pre-stress is applied from endplates.
- Linear transfer function (i.e. no yoke to saturate).
- Coordinated operation using two power supplies.

Operating Gradient:

\[ G_{\text{main}} = 143 \text{ T/m} \]
\[ G_{\text{shield}} = -10 \text{ T/m} \]
\[ G_{\text{net}} = 133 \text{ T/m} \]

Operating: \( I_{\text{main}} = 13.6 \text{ kA} \)
\( I_{\text{shield}} = 705 \text{ A} \)

Stored Energy = 466 kJ

(Total Combined Energy)

Inductance: \( L_{\text{main}} = 5.6 \text{ mH} \)
\( L_{\text{shield}} = 192 \text{ mH} \)

Mutual Inductance:
\( L_{12} = 5.2 \text{ mH} \)

Inductance Coupling

Coefficient: \( K = 16\% \)

\[ (K = L_{12} / \sqrt{L_1 \times L_2}) \]
Task Using FY17 Funding

• Response to Engineering Challenge:
  • Assemble 15 cm-long LARP coil sections, available from a previous engineering test.
  • Instrument with strain gauges.
  • Assemble at high preload by pressurizing “bladders” made from stainless steel.
  • Cool to 77K (liquid nitrogen).
  • Measure preload.
Status: Nearly Complete
## Costs and Schedule

<table>
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<tr>
<th>Activity</th>
<th>Start Date</th>
<th>End Date</th>
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<tr>
<td>Design and purchase of an initial set of components</td>
<td>September 2017 ✔</td>
<td></td>
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<tr>
<td>Complete Assembly and Test</td>
<td></td>
<td>September 2018</td>
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- Assembly and test – anticipate completion November 2018
Conclusion and Outlook

• Test will be completed by 11/30/18.
• Test will yield engineering data needed for final design of High Gradient Actively Shielded Quadrupole project (funded via FY18 FOA)
  • Schedule: fabrication complete 8/19; test complete 12/19.