

Electron-Ion Collider

Final Design Review of the EIC 90% Solenoid Magnet Subsystem

Performed In-Person and Remotely at Jefferson Lab

Newport News, Virginia

October 5-6, 2023

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1. Executive Summary

A review of the EIC detector solenoid was held at JLab on October 5-6, 2023. The scope included the 90% design of the magnet and planning to support a “vendor design-build” magnet procurement leading up to the CD-3A review.

Significant progress has been made since the 60% design review and the magnet reference design is now complete.

The design needs to be documented in a reference drawing package and change control processes should be applied from that point

Remaining interfaces that are directly relevant to the CD3A scope (conductor and magnet) need to be documented and formally approved prior to contract awards.

The collaboration between CEA-Saclay, JLab and BNL has continued to make excellent progress and the review committee strongly supports extending this collaboration into the procurement, fabrication and commissioning phases.

2. Responses to Charge Questions

Charge Question 1:

Does the design meet the technical performance requirements for the EIC detector magnet?

YES. Detailed analysis was presented for all areas of the reference design showing that targets are met with sufficient margins.

Charge Question 2:

Does the design support the anticipated SC magnet procurement award date?

PARTLY. Although the magnet reference design is complete, the design report and reference drawing package are still in progress and the timeline to perform the required procurement steps by the target award dates seems very challenging. See comments and recommendations.

Charge Question 3:

Are the recommendations from the previous reviews appropriately addressed?

PARTLY. Two recommendations are still Open - the interface documentation is still in progress and prototyping/characterization of sample conductor is still ongoing. See also answer to charge question #5.

Charge Question 4:

Is the procurement strategy and the planning for vendor interactions sound and sufficiently well-developed to initiate a long-lead procurement?

YES. Fabrication and testing of conductor samples is in progress, and the vendor has successfully delivered the ISEULT conductor with similar characteristics. The magnet procurement strategy is based on previous experience e.g. Hall B 12 GeV upgrade. An RFI was issued with positive responses received from several magnet vendors.

Charge Question 5:

Have interfaces with other systems been appropriately defined and appraised?

PARTLY. A formal systems engineering approach is in place that provides control of interfaces and integration of different subsystems. The project is on track to complete the interface control documentation by CD2. However, the remaining interfaces relevant to the detector solenoid procurement in CD3A should be finalized and approved before the vendor solicitation process begins.

Charge Question 6:

Have ESH&Q considerations been adequately incorporated into the design?

YES. Design criteria and analysis were presented for all sub-systems showing that the detector design satisfies established safety standards.

3. Findings

- The team intends to provide a reference design and CAD models to magnet vendors who will then design and build the magnet.
- The team has already sent out RFIs to various magnet vendors and have received several positive responses from some vendors.
- It does not appear that prototyping of individual components has been included in magnet fabrication costs and plan.
- The team is due to visit and discuss the conductor development plan with the conductor vendor soon.
- Examination of the full P6 plan reveals that the award for sample conductor testing has slipped by about 2 months
- There are no specific KPPs defined for the magnet
- The team is using a controlled version of the overall system CAD model to communicate interfaces within the project. There are plans to produce interface documentation. An Excel sheet describing some interfaces with the magnet was shared but it is not sufficiently detailed yet.
- Production of the ISEULT conductor with similar characteristics provides a solid basis for the EIC detector cable.
- The team has produced Advanced Procurement Plans for the conductor development and solenoid.
- The magnet vendor will be given the option of also designing and fabricating the cryogenic supply system (phase separator vessel etc.)
- Under either quench or loss of vacuum conditions, all helium from the magnet will be exhausted into the hall.
- Pneumatic valves are used on the phase separator vessel.
- The cryogenic system has been designed to EN21013-3 and conforms to ASME standards.
- The team intends to provide any best-practice process instructions to the magnet vendor – e.g. application of voltage taps, superconducting joint soldering.

4. Comments

- Although the solenoid magnet is not in the project critical path, it is critical that it is delivered and installed as early as possible to allow for the detector installation
- The team should incorporate all detailed vendor plans in their P6 plan (perhaps rolled up to show only the major activities)
- The team should continue to work closely with the JLab Procurement Department to refine procurement timelines also taking into consideration any additional timelines dictated by approvals required from the DOE.
- The team should consider prototyping critical items (e.g. tie-rods) either in-house or at the various vendors and include this in their cost and planning.
- Configuration control of all documentation, drawings and CAD models should be implemented by CD3A.
- Interface definitions should be completed with all documentation being configuration controlled.
- The team has carried out sensitivity analyses on all critical dimensions and performance parameters. The output of these analyses should be used to define tolerance ranges and acceptability criteria for designs produced by the various vendors.
- The team should consider reaching out to vendors early for other critical components (e.g. magnet power supplies, high current leads, etc) to ensure that there are sufficient capable vendors available and that these vendors are interested in participating in this project.
- The team should re-evaluate what they consider long lead and/or critical components and use the possible opportunity of a CD-3B later in FY24 to include additional items in the project long lead procurements.
- The team should re-evaluate whether the Belleville washers (disc-spring washers) can be moved to the warm end of the tie-rod – relocating the washers might put them in a lower magnetic field and also alleviate any potential issues with shrinkage and binding at cryogenic temperatures.
- Considering the fringe field at the IR magnet location is higher than the current target of 10 G, the team should study possible local shielding configurations capable of decreasing the fringe field at these locations in consultation with the IR magnet team.
- The team should ensure that the conductor procurement schedule is compatible with fabrication of the solenoid coils.
- Detailed QA plans for the cable production units and for the solenoid magnet fabrication should be defined including measurements to be performed by the vendor and additional/verification testing by external Labs.
- Additional testing of the detector solenoid may be beneficial, including cooldown and low current testing after receipt of the magnet from the vendor, in addition to the already planned full power test.

- The team should be cautious about leaving too many design decisions up to the vendor – e.g. selection of instrumentation, application of certain specialized processes (VT application, SC joints).
- The team should complete a full FMEA for the cryogenic and I&C systems.
- The team should continue to review, with input from the procurement department, any emerging risks involving vendors – e.g. lack of vendor capability, supply chain delays, etc.
- The collaboration between CEA-Saclay, JLab and BNL has continued to make excellent progress and the review committee strongly supports extending this collaboration into the procurement, fabrication and commissioning phases.

5. Recommendations

- The review committee recommends proceeding to initiating long lead procurements as planned.
- Complete and approve magnet design report, reference drawing package and SOW for the magnet procurement before the vendor solicitation process begins.
- Apply a formal documentation and approval process for any requested design changes to the reference design before the vendor solicitation process begins.
- Formalize the contracts for characterization of the cable samples and complete the test program by March 2024.
- Consider possible additions to the long lead procurements that support the timely commissioning of the detector magnet to be included in a potential CD-3B

Status of recommendation from 60% design review

1. By end Dec 2022, reassess the use of the BABAR magnet as an opportunity, now that the team has a better understanding of the requirements and any shortcomings of the BABAR magnet in achieving those requirements. Given the field requirement of 1.7 T to 2.0 T, we recommend dropping the BABAR magnet option. -> **CLOSED**
2. By end Feb 2023, approve the magnet requirements document formally, and utilize a change control process for any further changes to requirements. -> **CLOSED**
3. By Mar 2023, fast-track the design aspects of the magnet that presently appear to be at a lower maturity level than the 60% design point. -> **CLOSED**
4. By Sep 2023, complete and approve the interface document. Utilize a change control process for any further changes to interfaces. -> **OPEN**
5. By Sep 2023, include ESH&Q considerations in the magnet and system design. -> **CLOSED**
6. By the CD2/3A review date, demonstrate significant progress in prototyping and characterization of sample conductor and plans for full conductor production. -> **OPEN**

Status of recommendations from 30% review

1. 5 Gauss stray field requirements – Review the requirements and continue to evaluate the possibility and trade-offs of using local shielding around affected IR magnets and sub-systems. **CLOSED (90% review)**
2. Calculated peak Von Mises stress at energization is 63 MPa in coils vs. 70 MPa design limit. We recommend to increase margin, which appears to be feasible without

significant design complications or cost increase. **CLOSED (60% review)**

3. Conductor development – It should be a high priority to start the development work as soon as possible. Produce a plan which clearly lays out all the key tasks together with milestones. **CLOSED (90% review)**
4. Fault Conditions – Carry out a FMEA to investigate and mitigate potential fault conditions for all the magnet sub-systems for the 60% design review. **CLOSED (60% review)**
5. Integration – Address interface and integration requirements between solenoid magnet and all other detector components as part of the 60% design review. **OPEN**
6. sPHENIX (BABAR) 1.5 T magnet – Re-evaluate the remaining risk of re-using this magnet under the assumption that only minimal (non-invasive) refurbishment is carried out. **CLOSED (90% review)**
7. New 1.5 T magnet design – Produce a resource-loaded plan for the design of this magnet. **CLOSED (60% review)**

6. Appendices

6.1 Appendix A: Charge to the Review Committee



MEMO

Date: September 26, 2023

To: Gianluca Sabbi (LBL), Ruben Fair (JLab), Vladimir Kashikhin (FNAL),
William Schneider (JLab-retired)

From: Renuka Rajput-Ghoshal and Rolf Ent

Subject: EIC 90% Detector Magnet Final Design Review, October 5-6, 2023

This review is a continuation of our previous reviews (30%-design in February 2022 and 60%-design in October 2022) for the detector solenoid magnet. The present review is for the 90% magnet design point, which is equivalent to a final design review for the "Vendor Design-Build" procurement of the magnet. In this procurement process, we will provide a 'Performance Specification', a working design and a Statement of Work (SOW) to the vendor, who then completes the design, produces their own manufacturing drawings and builds the magnet in close consolidation with the EIC Magnet project team. This gives the vendor an option to validate and modify the design. The detector magnet qualifies for a "Long Lead Procurement" and will be part of the EIC project CD-3A scope. The conductor used in this magnet will be NbTi strands formed to make a Rutherford cable and this cable is soldered to the copper channel. Due to the long lead time required to procure the conductor, the conductor is also a long lead procurement item and will be provided to the magnet vendor as "Government Furnished Item." The power supply, instrumentation and controls, cryocan and cryoflex lines are not part of the long lead procurement. The main purpose of this review is to assess the long-lead procurement readiness for the magnet and the conductor.

The scope of this review includes the 90% design of the EIC detector solenoid magnet and the planning to support a "vendor design-build" procurement.

For the Final Design and Safety Review, you are asked to address the following questions:

1. Does the design meet the technical performance requirements for the EIC detector magnet?
2. Does the design support the anticipated SC magnet procurement award date?
3. Are the recommendations from the previous reviews appropriately addressed?
4. Is the procurement strategy and the planning for vendor interactions sound and sufficiently well-developed to initiate a long-lead procurement?
5. Have interfaces with other systems been appropriately defined and appraised?
6. Have ESH&Q considerations been adequately incorporated into the design?

Please address the above questions.

cc: J. Fast

6.2 Appendix B: Review Committee

Gianluca Sabbi (Chair)	gl sabbi@lbl.gov	LBNL
Bill Schneider	schneide4@gmail.com	JLab (Retired)
Ruben Fair	fair@jlab.org	JLab
Vladimir Kashikhin	kash@fnal.gov	FNAL

6.3 Appendix C: Agenda

Electron-Ion Collider
90% Design Review of the EIC Detector Magnet
Thursday, October 5, 2023 – Friday, October 6, 2023
Hybrid Meeting (CC 326-327, CEBAF Building, 3rd
Floor and Zoom)

Thursday, October 5, 2023 (Day 1)

[Click here for Plenary \(OPEN\) Zoom](#)

CET	PST	CST	EST	Topic	Presenter	Duration (Min)
3:00 PM	6:00 AM	8:00 AM	9:00 AM	Executive Session (Closed)	Review Committee	15
3:15 PM	6:15 AM	8:15 AM	9:15 AM	Welcome and Project Status	R. Ent (JLab) / E. Aschenauer (BNL)	20+10
3:45 PM	6:45 AM	8:45 AM	9:45 AM	Magnet overview and Recommendations from Previous Reviews	R. Rajput-Ghoshal (JLab)	20+10
4:15 PM	7:15 AM	9:15 AM	10:15 AM	Magnet Model Details	D. Young (JLab)	15+5
4:35 PM	7:35 AM	9:35 AM	10:35 AM	Tea Break	All	30
5:05 PM	8:05 AM	10:05 AM	11:05 AM	Electromagnetic Design and Analysis	V. Calvelli (CEA)	20+10
5:35 PM	8:35 AM	10:35 AM	11:35 AM	Conductor and Conductor Validation Status	F. Stacchi (CEA)	20+10
6:05 PM	9:05 AM	11:05 AM	12:05 PM	Quench Protection Design and Analysis	V. Calvelli (CEA)	20+10
6:35 PM	9:35 AM	11:35 AM	12:35 PM	Executive Session & Lunch	Review Committee	60
7:35 PM	10:35 AM	12:35 PM	1:35 PM	Mechanical Design and Analysis	H. Reymond (CEA)	30+15
8:20 PM	11:20 AM	1:20 PM	2:20 PM	Thermal Analysis	S. Gopinath (JLab)	20+10
8:50 PM	11:50 AM	1:50 PM	2:50 PM	Tea Break	All	30
9:20 PM	12:20 PM	2:20 PM	3:20 PM	System Electrical Safety	P. Ghoshal (JLab)	20+10
9:50 PM	12:50 PM	2:50 PM	3:50 PM	Magnet Infrastructure	R. Wimmer (BNL)	10+5
10:05 PM	1:05 PM	3:05 PM	4:05 PM	Discussion & Questions	All	30
10:35 PM	7:35 PM	5:35 PM	4:35 PM	Executive Session	Review Committee	60
				Dinner (TBD)		
				Homework (if any)		

Friday, October 6, 2022 (Day 2)

[Click here for Plenary \(OPEN\) Zoom](#)

CET	PST	CST	EST	Topic	Presenter	Duration (Min)
3:00 PM	6:00 AM	8:00 AM	9:00 AM	Homework & Discussion	All	60
4:00 PM	7:00 AM	9:00 AM	10:00 AM	Cryogenic Analysis	J. Lottin (CEA)	20+10
4:30 PM	7:30 AM	9:30 AM	10:30 AM	Tea Break	All	30
5:00 PM	8:00 AM	10:00 AM	11:00 AM	Pressure Vessel Safety	E. Sun (JLab)	15+5
5:20 PM	8:20 AM	10:20 AM	11:20 AM	System Instrumentation	D. Simon (CEA)	15+5
5:40 PM	8:40 AM	10:40 AM	11:40 PM	Design FMEA	P. Ghoshal (JLab)	20+10
6:10 PM	9:10 AM	11:10 AM	12:10 PM	Plan and Status of the Procurement	R. Rajput-Ghoshal (JLab)	20+10
6:40 PM	9:40 AM	11:40 PM	12:40 PM	Executive Session (Closed) and Lunch	Review Committee	200
10:00 PM	1:00 PM	3:00 PM	4:00 PM	Closeout	All	30