SBIR Phase I Proposal on Superconducting Shield on eRHIC IR Magnets

Ramesh Gupta

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U.S. DEPARTMENT OF ENERGY

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Motivation

- SBIR brings extra funding to explore alternatives
- Superconducting shielding, either made with LTS or HTS provides an alternate method to active shielding to create field-free region for electron passage in eRHIC IR region
- Letter of Interest (next slide) explains more on motivation
- HTS shielding can be investigated in Phase I itself with Liquid Nitrogen (LN2)
- We have investigated and tested HTS shields earlier. It was also investigated in “Cloak” experiment by Abhay Deshpande’s group where SMD was a collaborator and provided guidance
- Next few slides examine it the design of Q1pf magnet which was presented recently at the EIC collaboration Meeting

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Letter of Intent (LOI) for Phase I SBIR/STTR submitted by the Particle Beam Laser, Inc. (PBL) with BNL as the collaborator (subcontractor)

Subcontractors and Consultants:
Dr. Ramesh Gupta – Brookhaven National Laboratory.

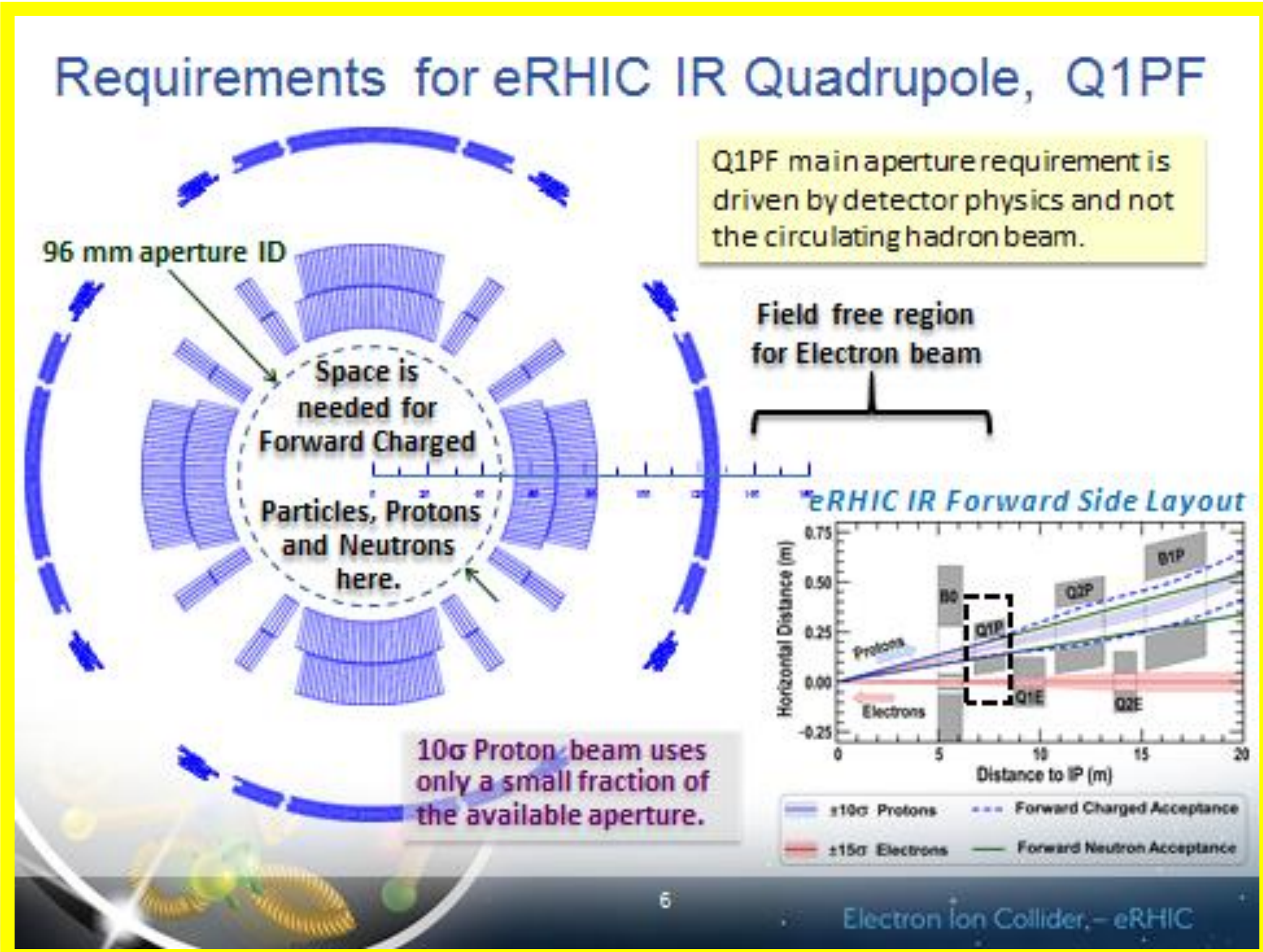
Application type:
Phase I SBIR/STTR

Technical Abstract:

In the proposed Electron-Ion Collider, the electron beam must travel very close to the proton or ion-beam in the interaction regions (IR). Whereas the ion or proton beams need high field magnets, the beams of lighter electrons must be magnetically shielded from the fringe fields of the ion beamline magnets. Active shielding with superconducting coils, together with or without a high permeability magnetic material such as iron, has been considered to reduce fringe fields to acceptably low values. However, the limited space between the electron beam and the ion beam poses a significant challenge on the design. This proposal is for a device using passive superconducting shielding, which due to the "Meissner Effect" will exclude the flux lines, and provide natural shielding. Shielding made of Low Temperature Superconductor (LTS) sheets and High Temperature Superconductor (HTS) tapes will be considered. In addition, a thin sheet of high permeability magnetic material such as mu-metal or Cryoperm will also be used. If successfully developed, demonstrated and incorporated with the magnet designs, then not only will this technique provide a technically good solution, it will also simplify the design of challenging magnets in the interaction regions, remove certain constraints, and allow higher field options for increasing the luminosity of the proposed Electron-Ion Collider.

In Phase I, design studies will be performed for providing and integrating this shielding with the magnets. In addition, proof-of-principle shielding made with HTS tape will be demonstrated at 77 K in liquid nitrogen. In Phase II, we plan to (1) test both LTS and HTS shielding using one of the existing superconducting magnets, and (2) fully develop the engineering design of the shielding with the various EIC IR magnet designs available at the time.

Brett Parker's Slide at EIC Meeting for Active Shielding



We will use the recent Q1PF quadrupole coil cross-section for investigation. We will study the super-conducting shielding with and inside the iron yoke as an alternate to the active field cancelling external coils.

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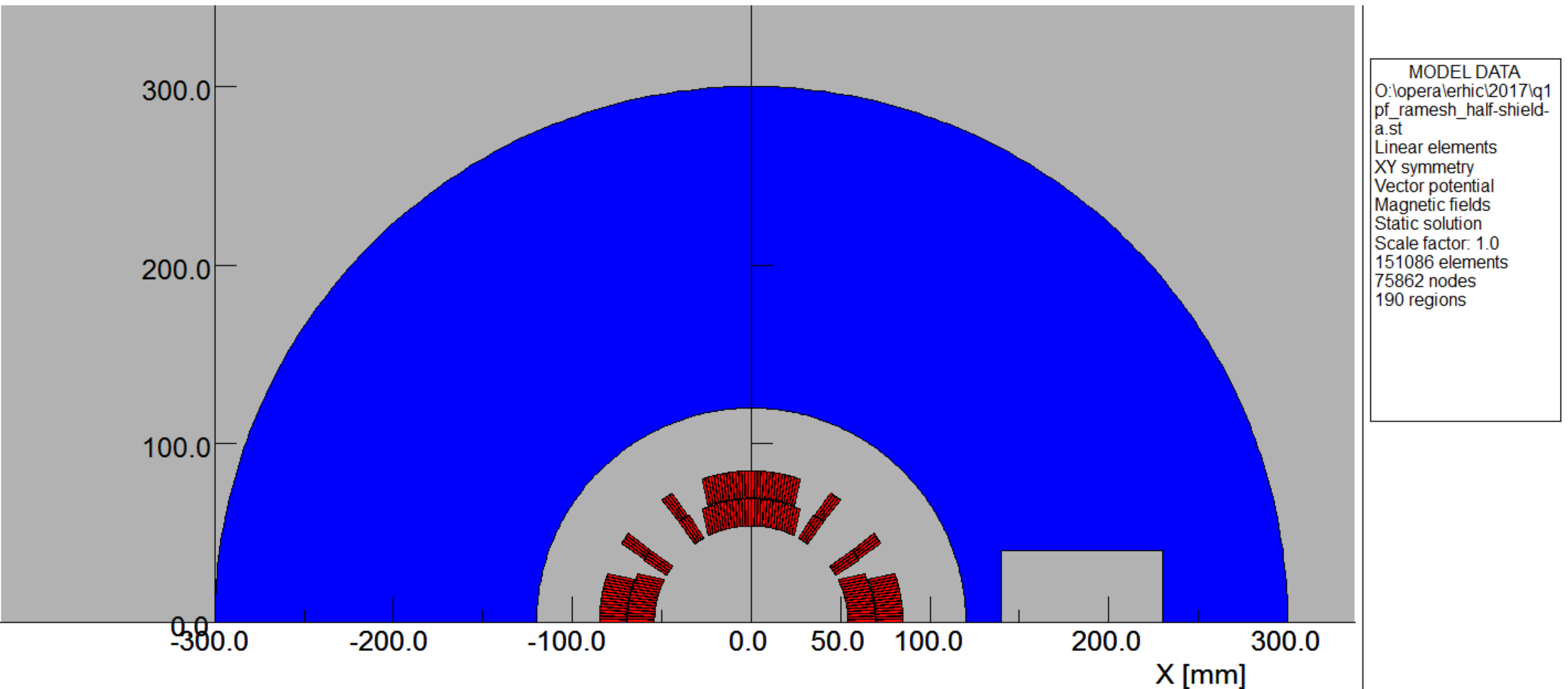
Basic Approach for Superconducting Shield in eRHIC

- **First place Iron Yoke around the Q1pf coil with a cutout to reduce the field in the region of electron beam path**
- **With field reduced to a lower level, place superconducting shielding around the beam pipe of electron beam**
- **Even though the investigation is made on eRHIC Q1pf magnet. The method/approach is useful in all eRHIC (or in more general EIC) IR magnets (quadrupoles and dipole), where needed.**

½ Model of the magnet with cutout left for electron Beam (same coil cross-section as used in the recent EIC meeting)



07/Nov/2017 13:29:16 Page 132

Opera

Model to make initial evaluation of the concept
(shielding will go in the region of cutout)
(not intended to represent actual geometry or other details)

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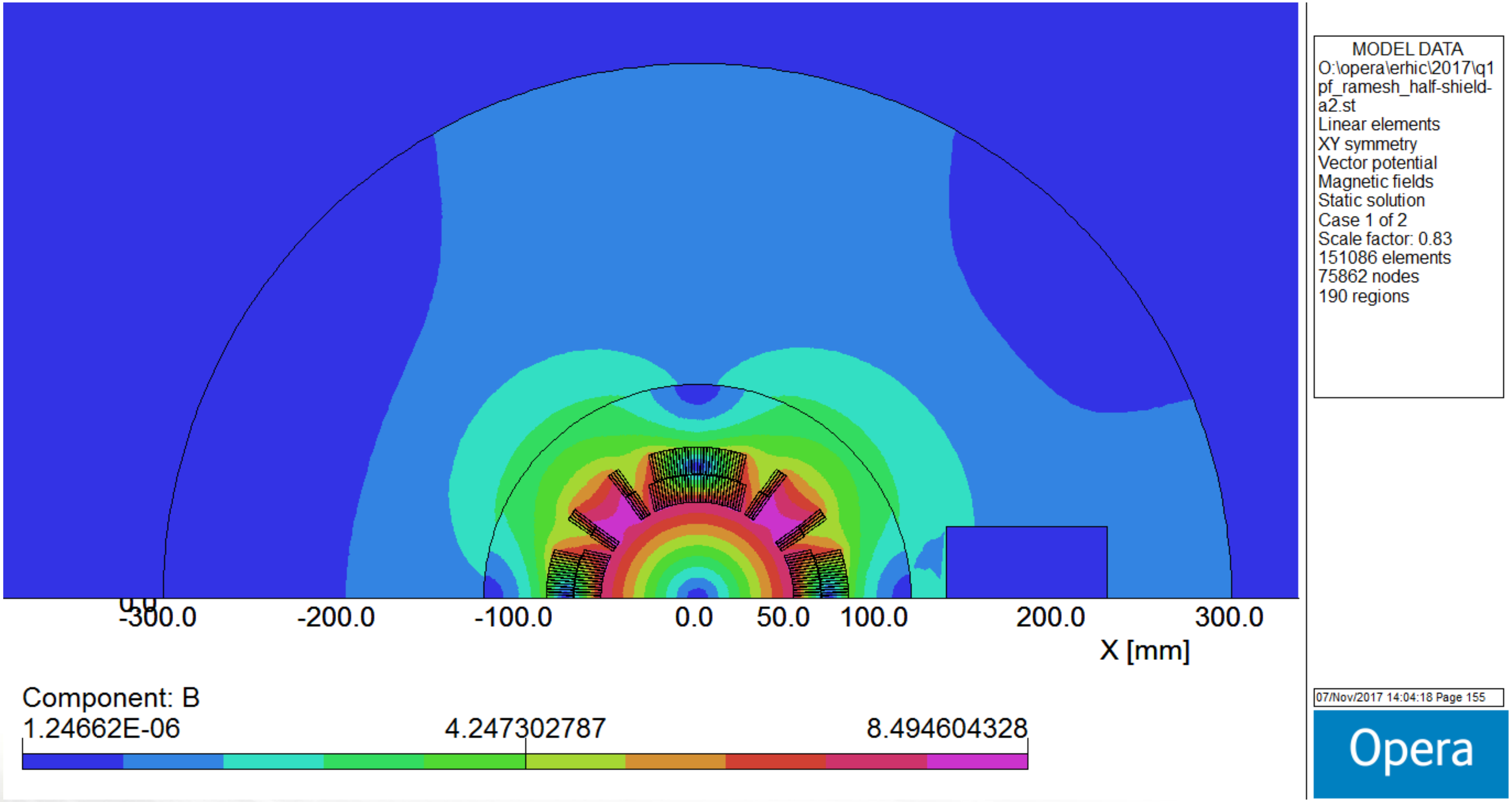
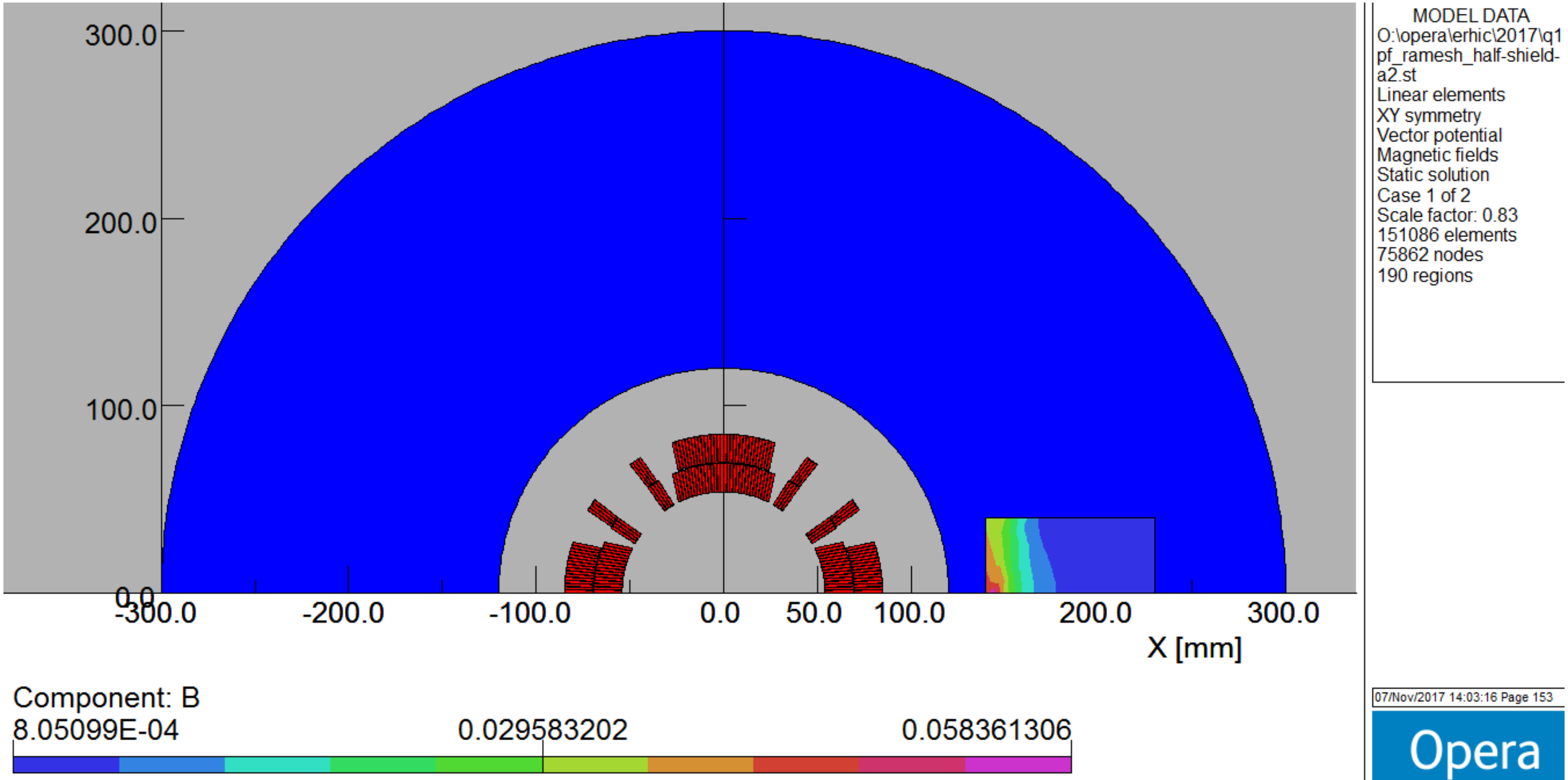
Field contour (T) at the gradient of 140 T/m

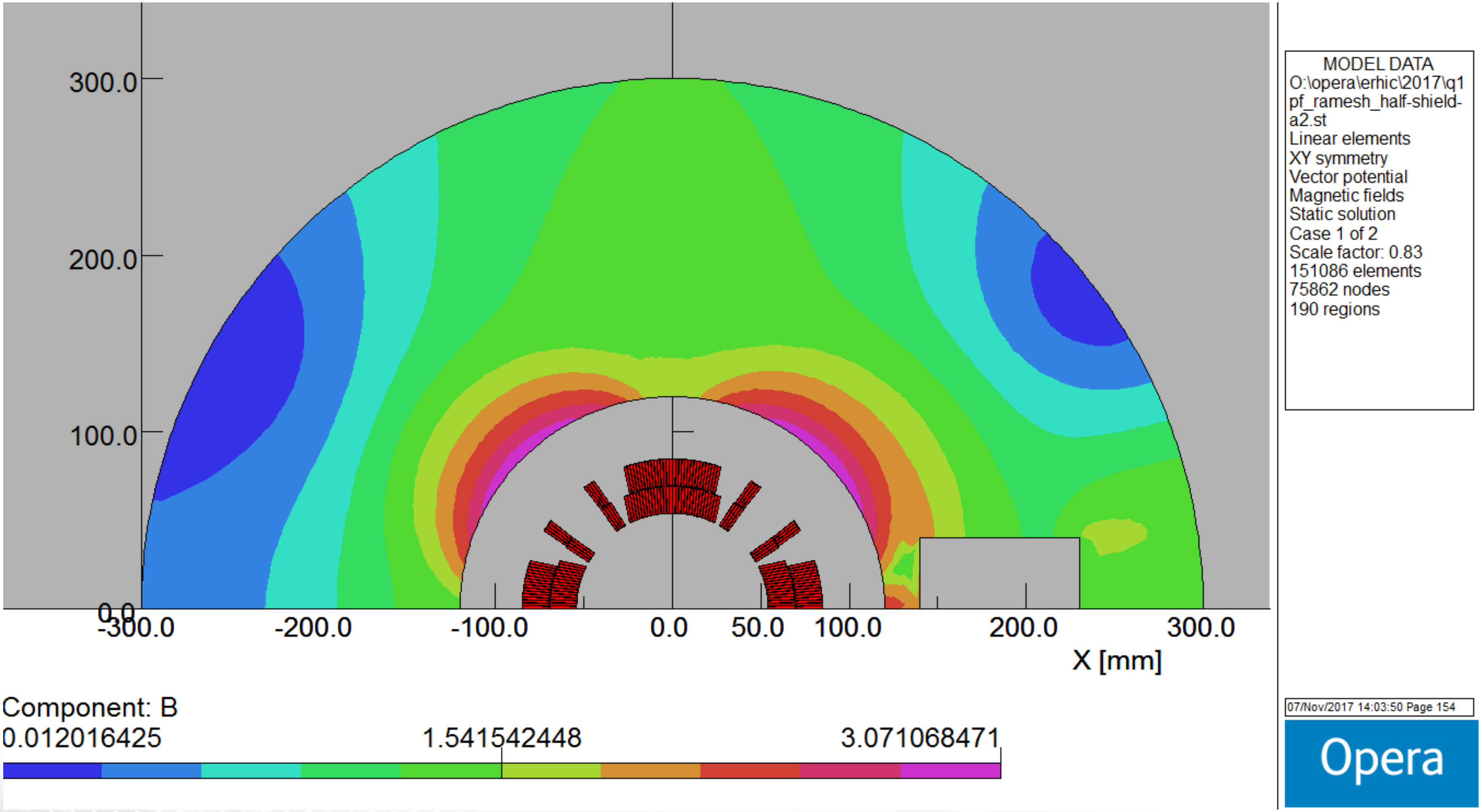


Field inside the cutout for electron passage @140 T/m

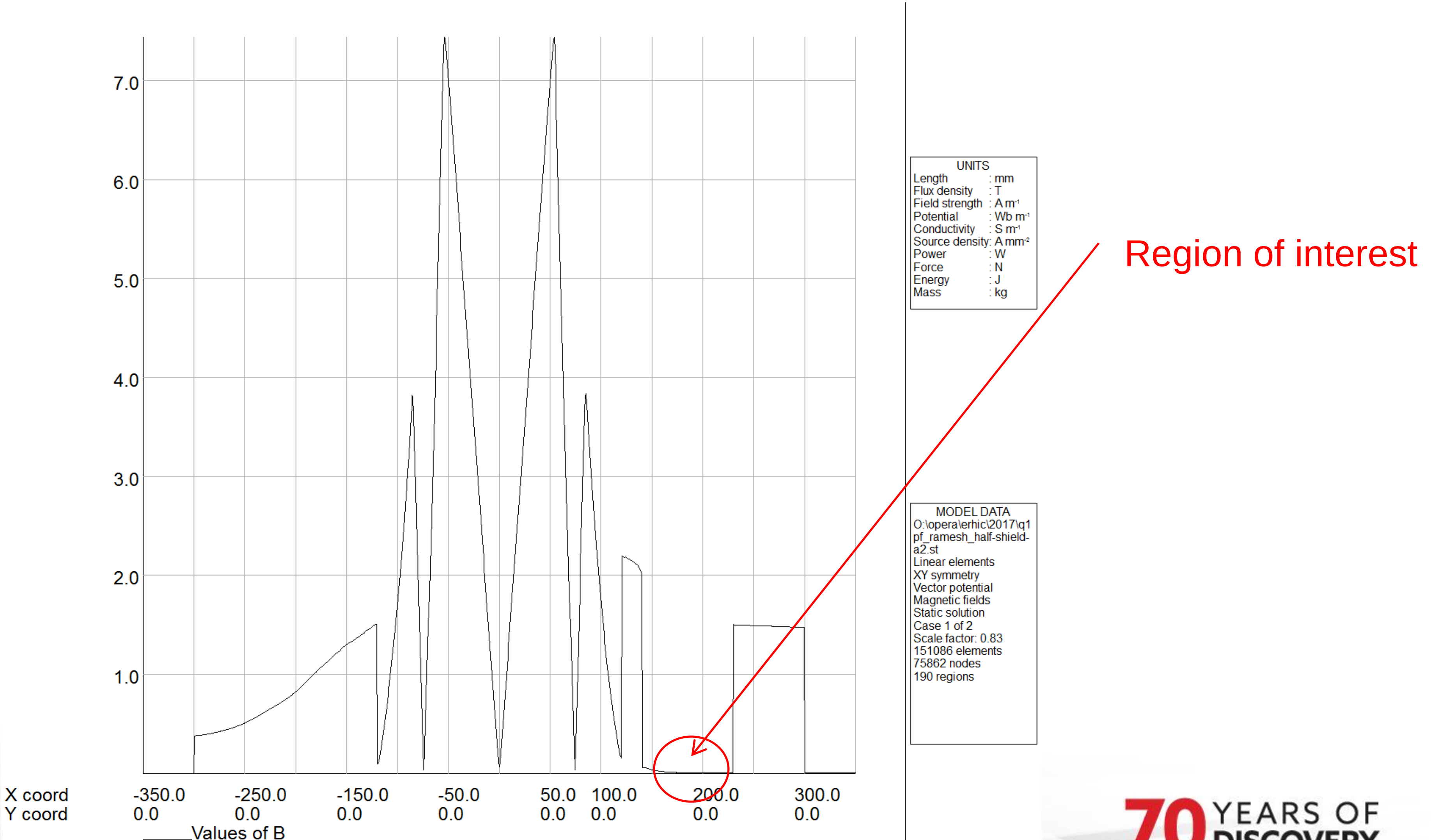


Small field (<0.06 T or 600 G) inside the cutout meant for electron beam. This can be easily handled by a superconducting shield

Field inside the iron yoke for electron passage @140 T/m



Magnitude of the Field (T) on the Horizontal Axis @140 T/m



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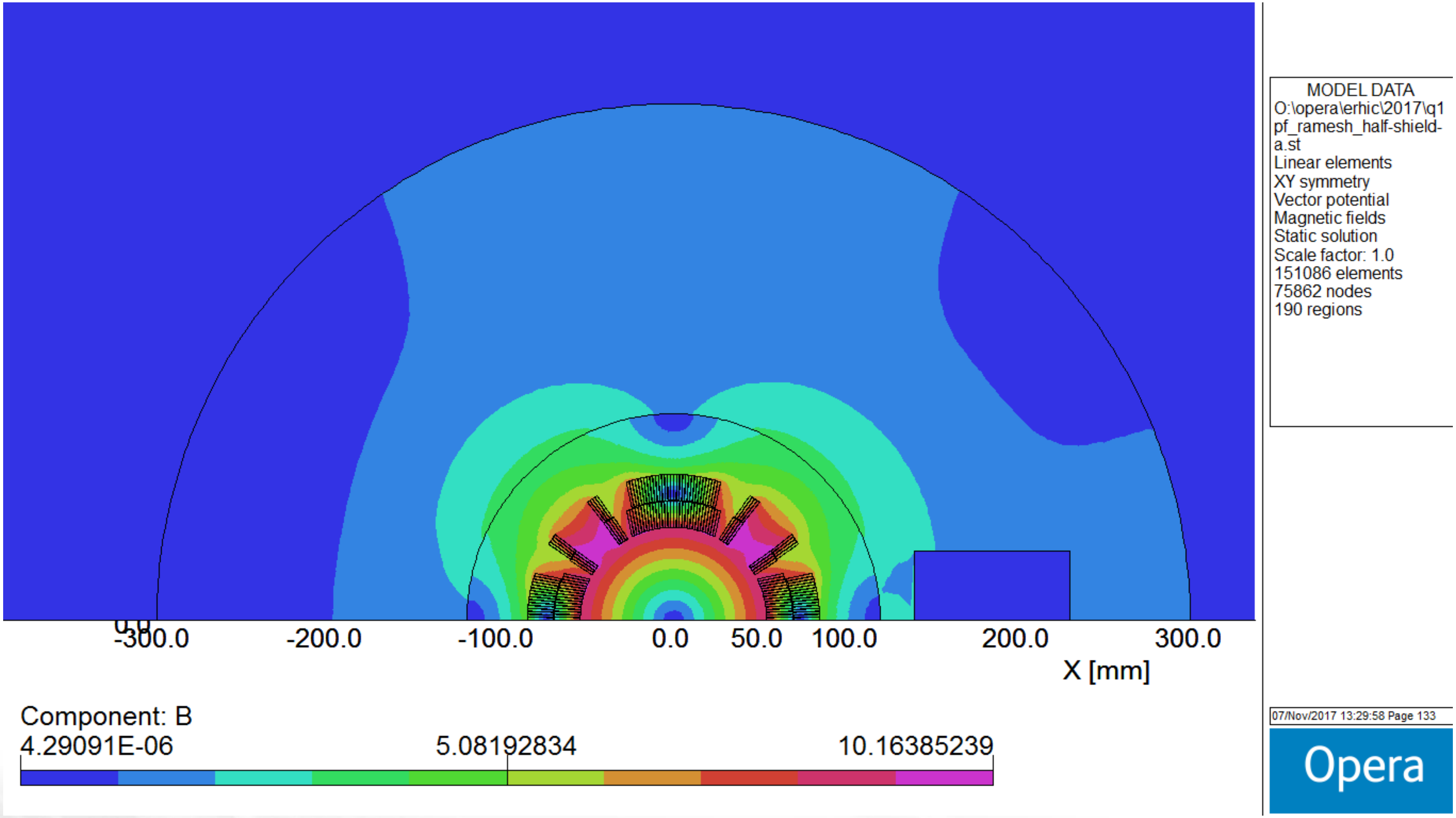
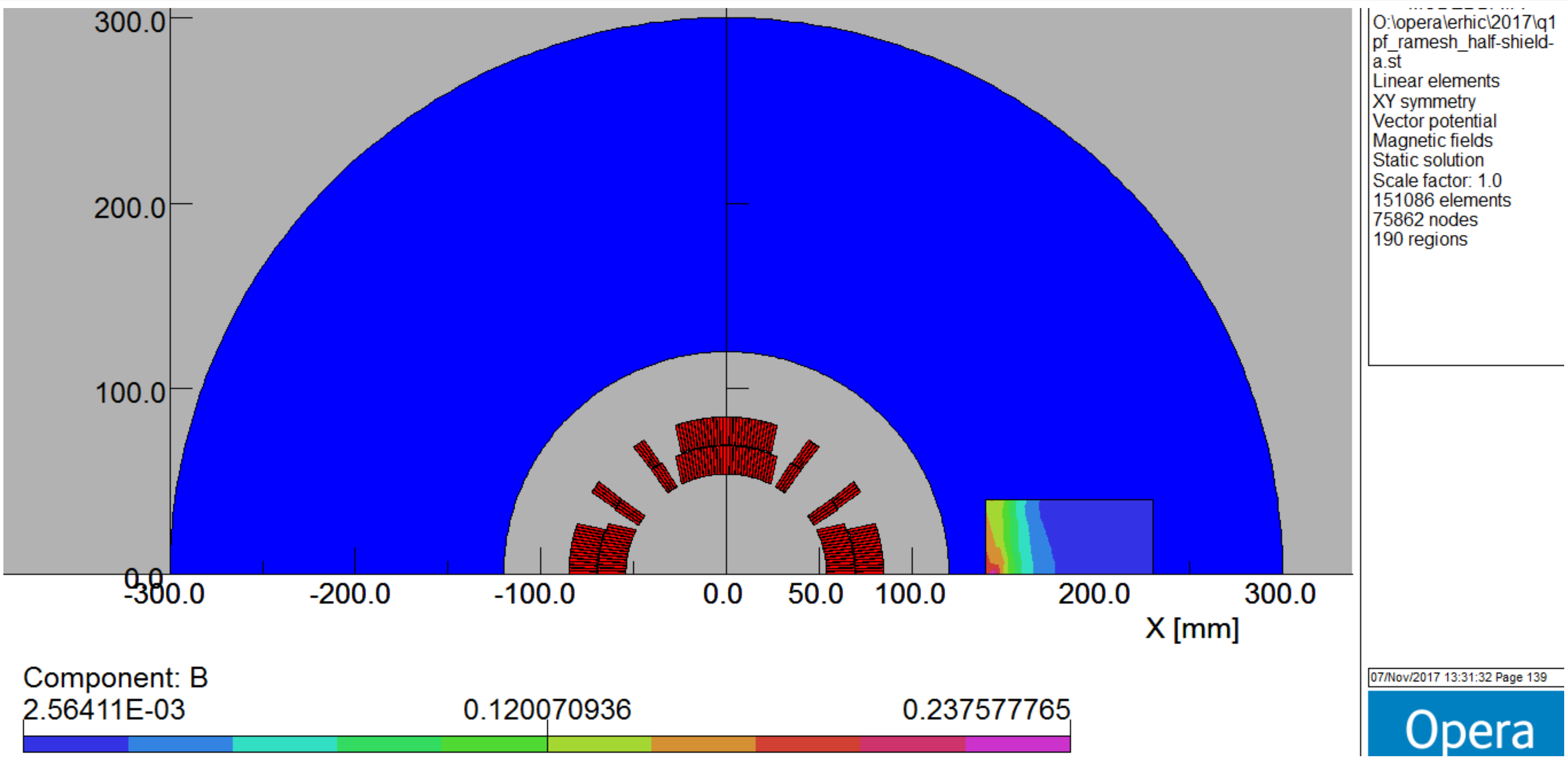
Field contour (T) at the gradient of 168 T/m (~20% over the design gradient)

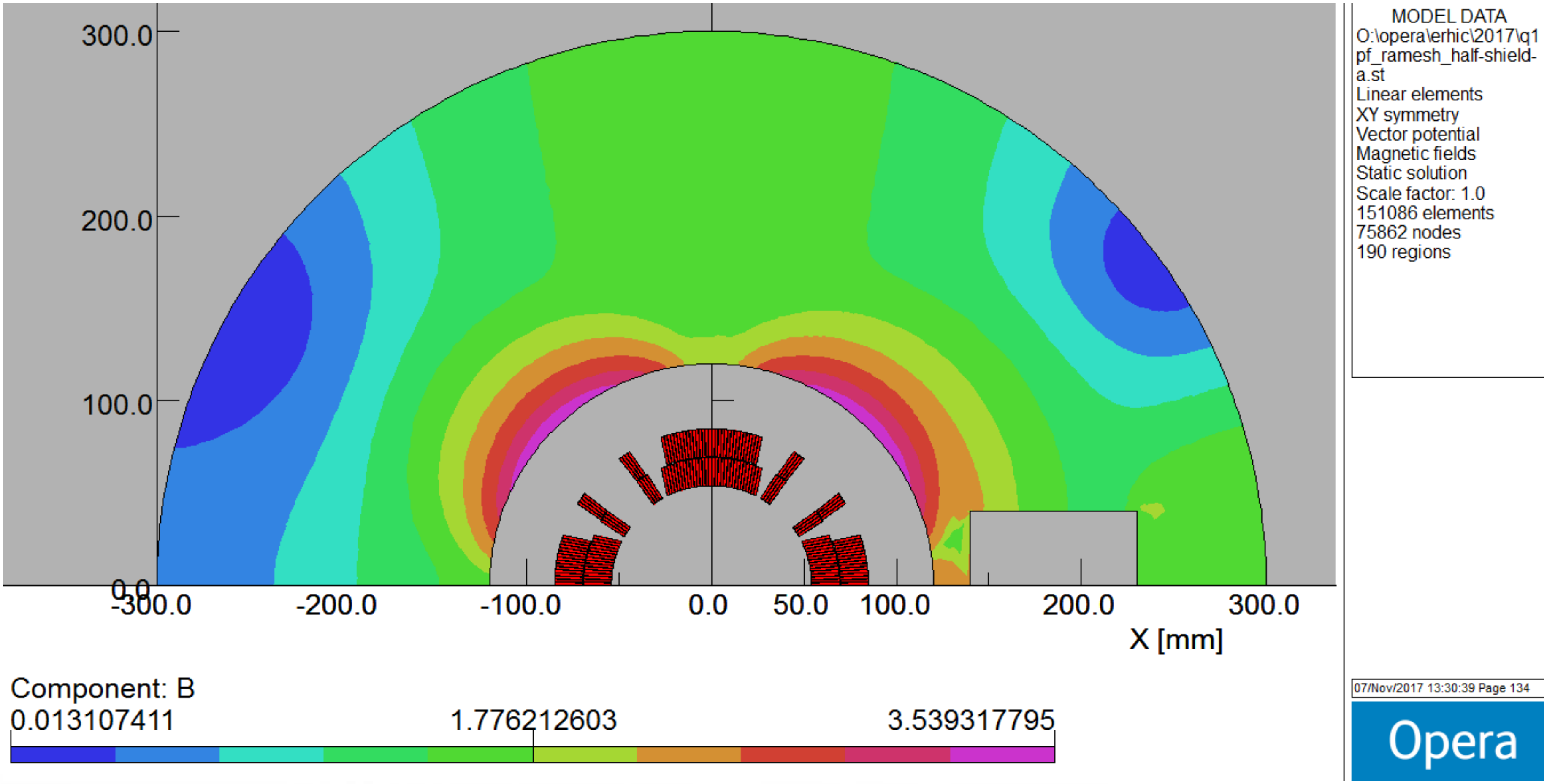


Field inside the cutout for electron passage @168 T/m (~20% over the design gradient)

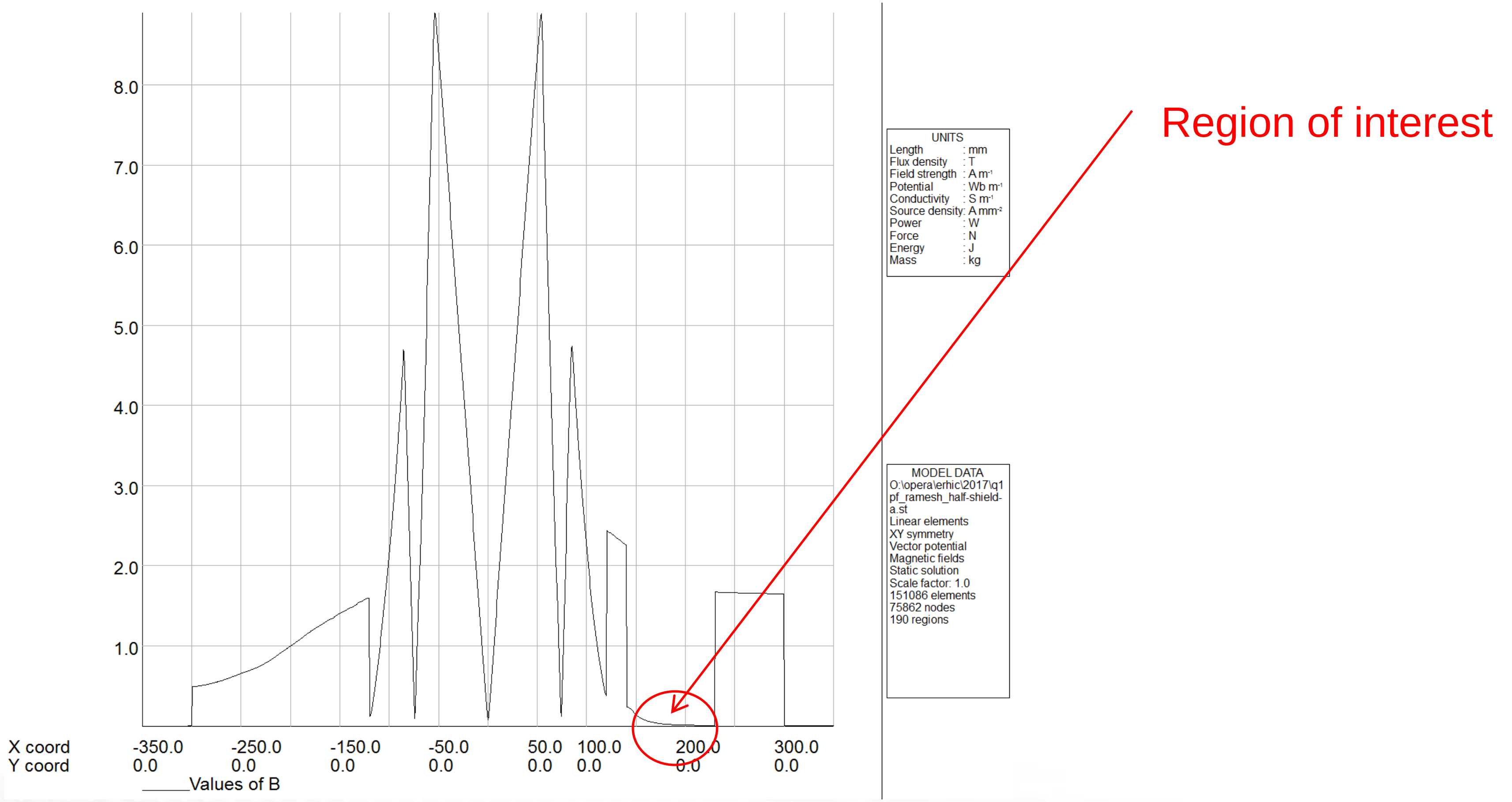


Field inside the cutout meant for electron beam: <0.24 T or 2.4 kG
This can be handled by a superconducting shield

Field inside the iron yoke for electron passage @168 T/m (~20% over the design gradient)



Magnitude of the Field (T) on the Horizontal Axis @140 T/m



Conclusion

- **Initial evaluation shows that the field in the cutout region (a region indicating the path of the electron beam) is comfortably within the reach of a small superconducting passive shielding.**

- **This concept can be evaluated through an SBIR, if funded.**