Permanent Magnets for MHD Testing

M. Ulrickson

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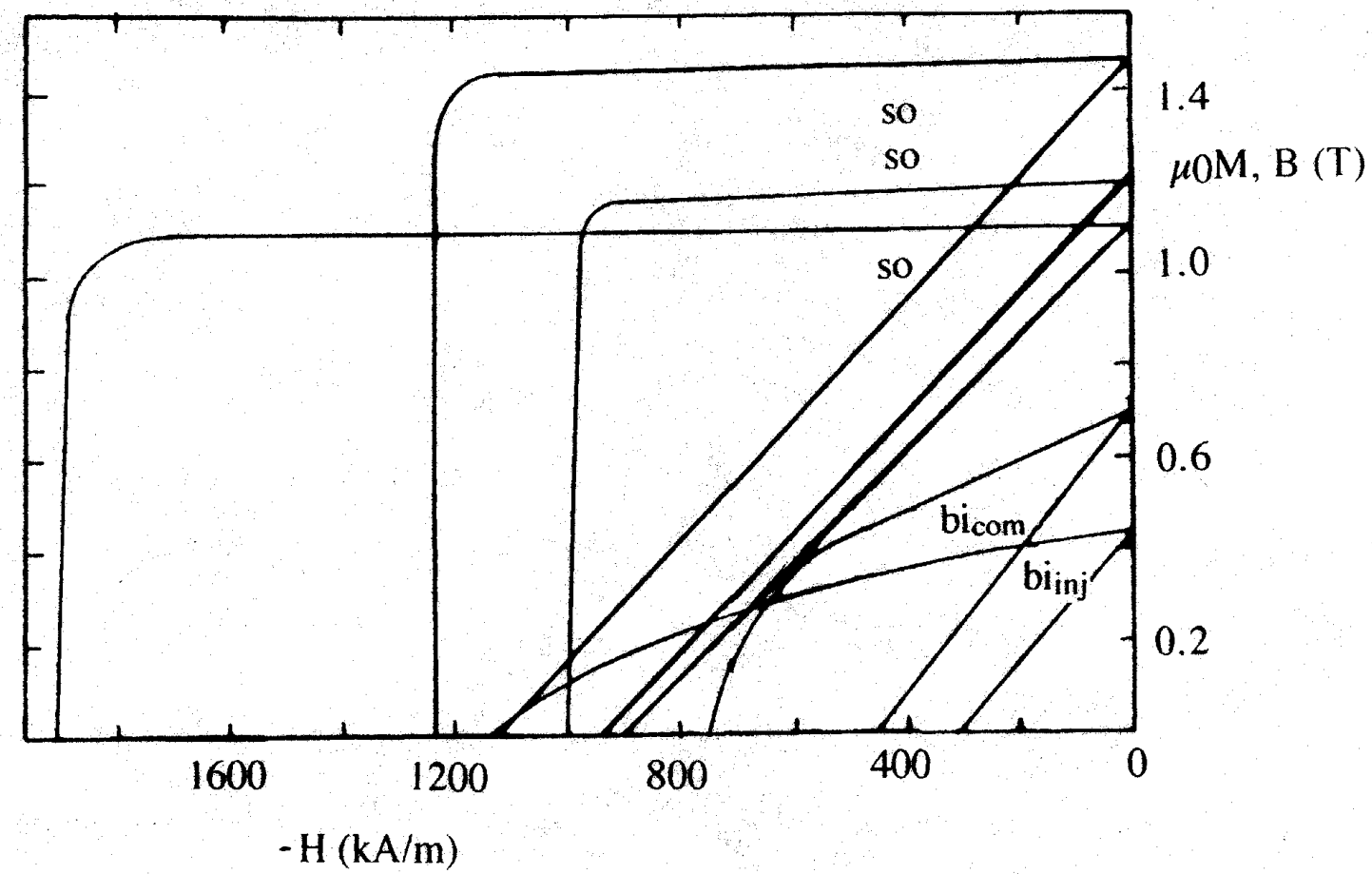
Outline

- Permanent magnet characteristics
- Design guidelines and capabilities
- Conceptual design of a system to simulate tokamak fields
- Conclusions

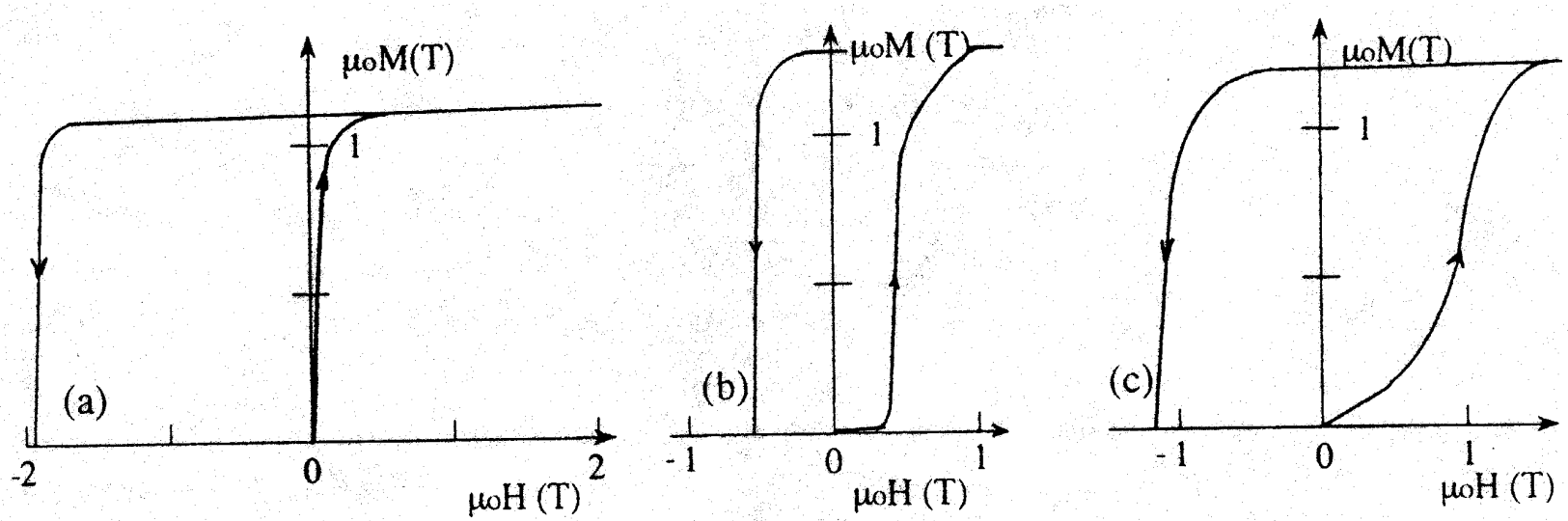
Properties of Permanent Magnets

	Br (T)	Hc (kA/m)	BH (kJ/m^3)
$Nd_2Fe_{14}B$ Standard	1.2	1000	260
NdFeB High Br	1.46	1250	400
NdFeB High Hc	1.15	2000	250
$SmCo_5$	0.92	1500	160
Sm_2Co_{17}	1.20	1100	260

NdFeB Magnetization Curve



SmCo Magnetization Curve



Permanent Magnet System Design

- The permanent magnet provides the source of magnetic energy to power the circuit.
- If there is no loss of flux, the equations for the flux in the gap are easily derived.
- The permeance of the elements of the magnetic circuit is determined by the size, shape and material in the element

$$P = \mu \frac{A}{L}$$

Permanent Magnet Design

Field in the gap

$$B_m A_m = -B_g A_g$$

Permanent magnet operating point

$$-\frac{B_m}{H_m} = \mu_0 \frac{A_g L_m}{A_m L_g}$$

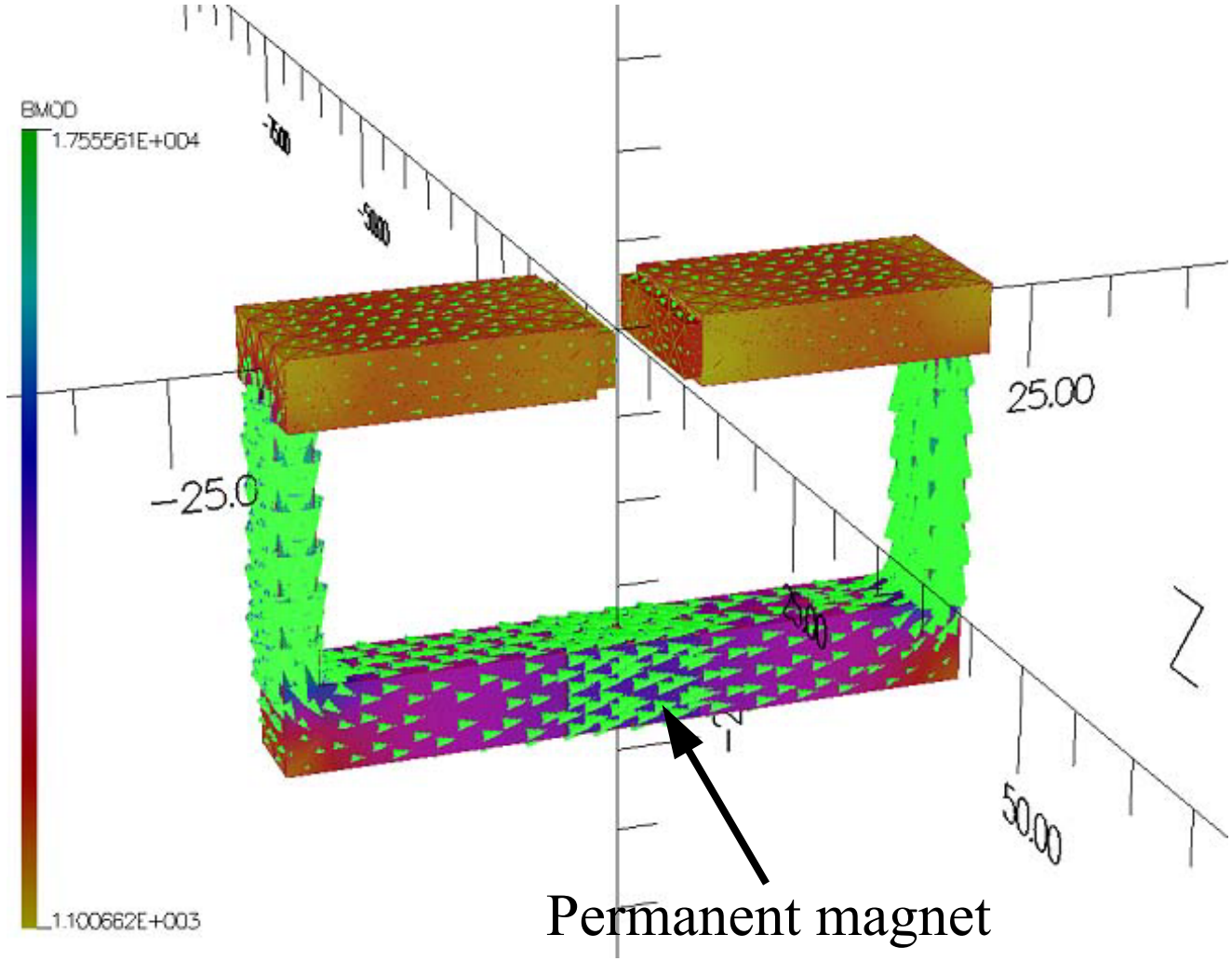
Magnetic energy

$$B_m H_m V_m = \frac{-B_g{}^2 V_g}{\mu_0}$$

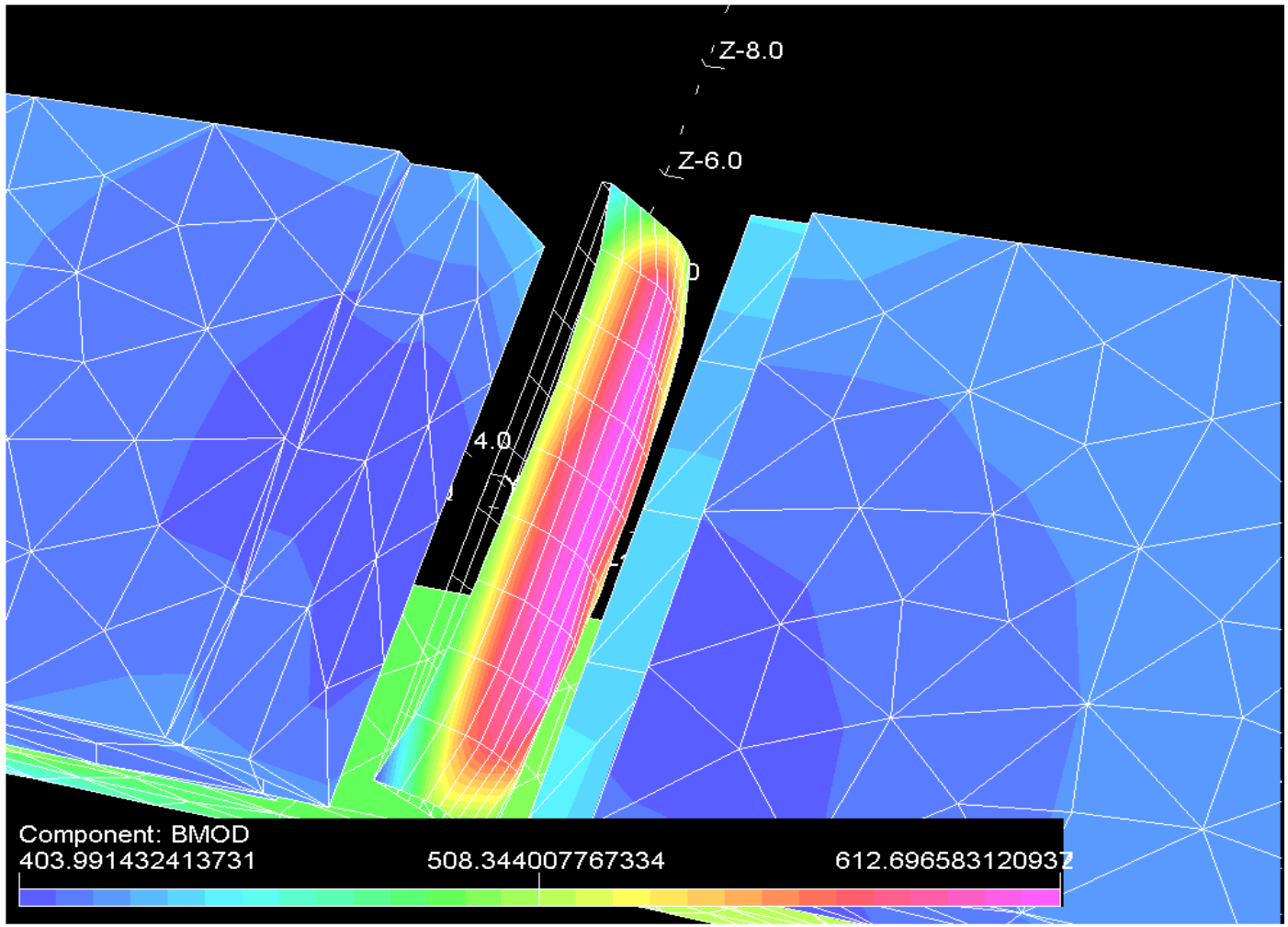
PC Opera Code

- A product of Vector Fields
- Complete static and dynamic field calculations in 2 and 3 D including hysteresis
- We have used the code to design a bending magnet for electron beams and to calculate eddy currents in FIRE divertor plates and vacuum vessel due to a vertical disruption event.
- Has a database of materials properties including Fe, NdFeB, SmCo, etc.
- Analysis by Dennis Youchison

Design Option 1



Field in Gap Option 1



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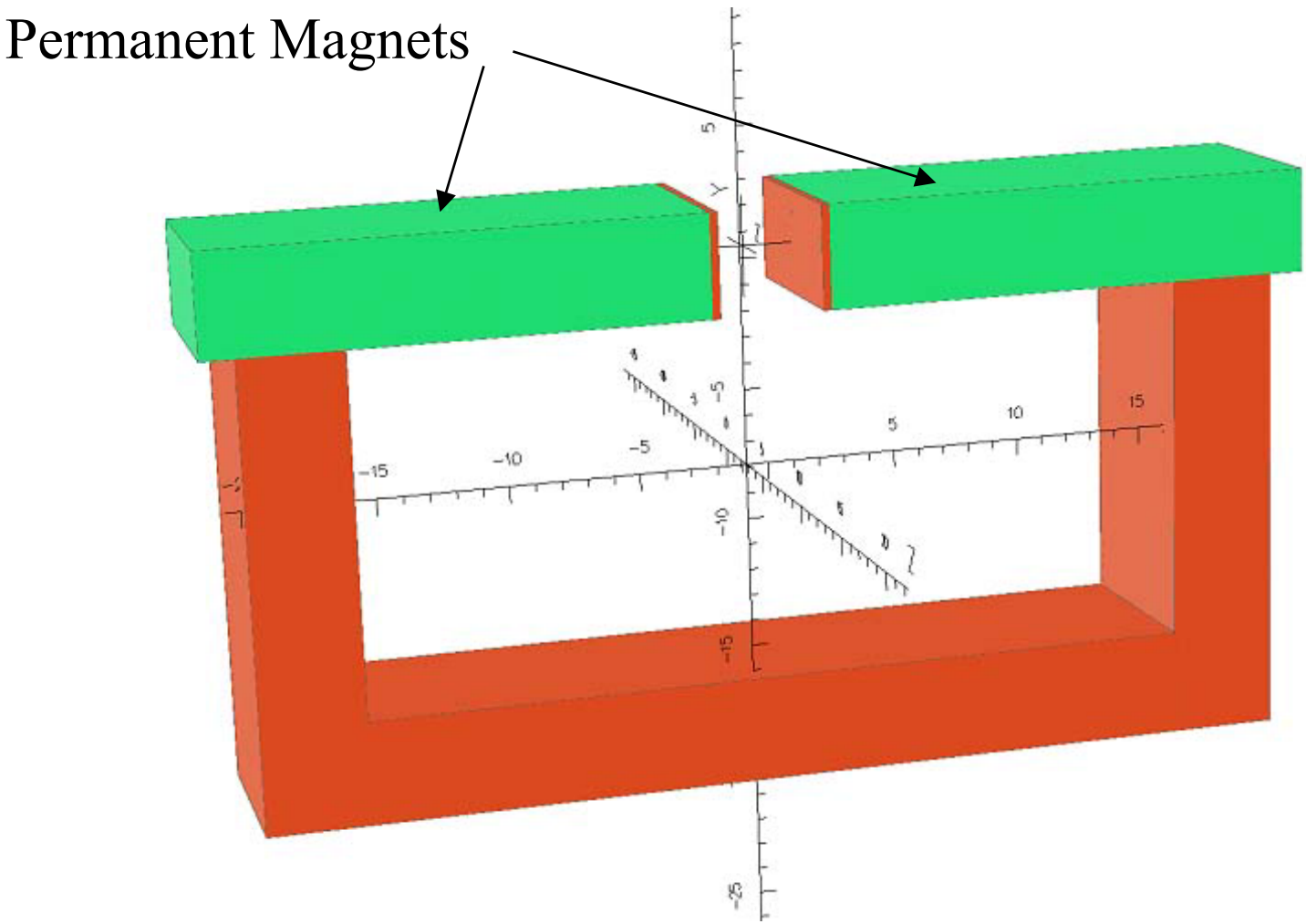
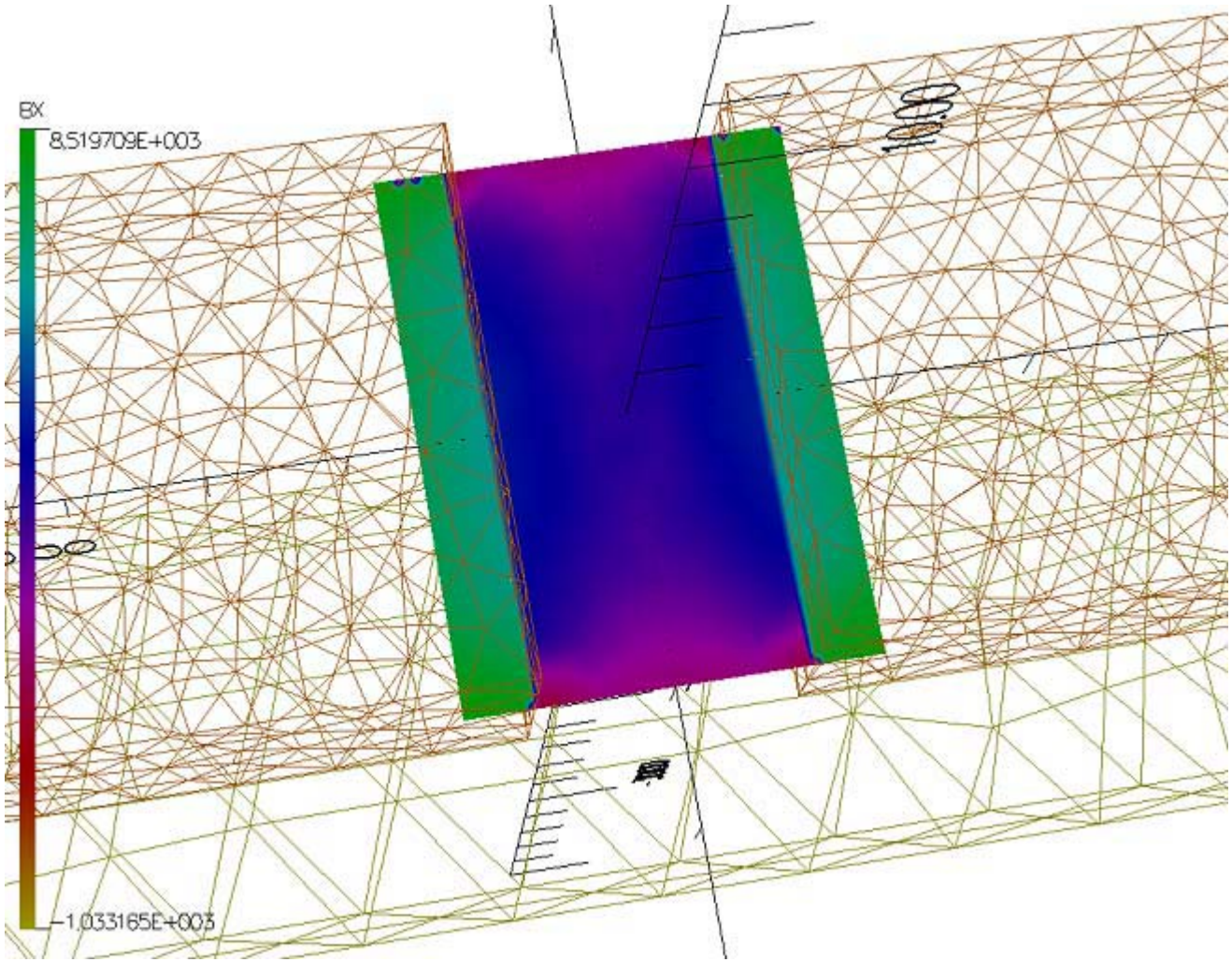
Design Option 2



Field in Gap 10 mm Fe



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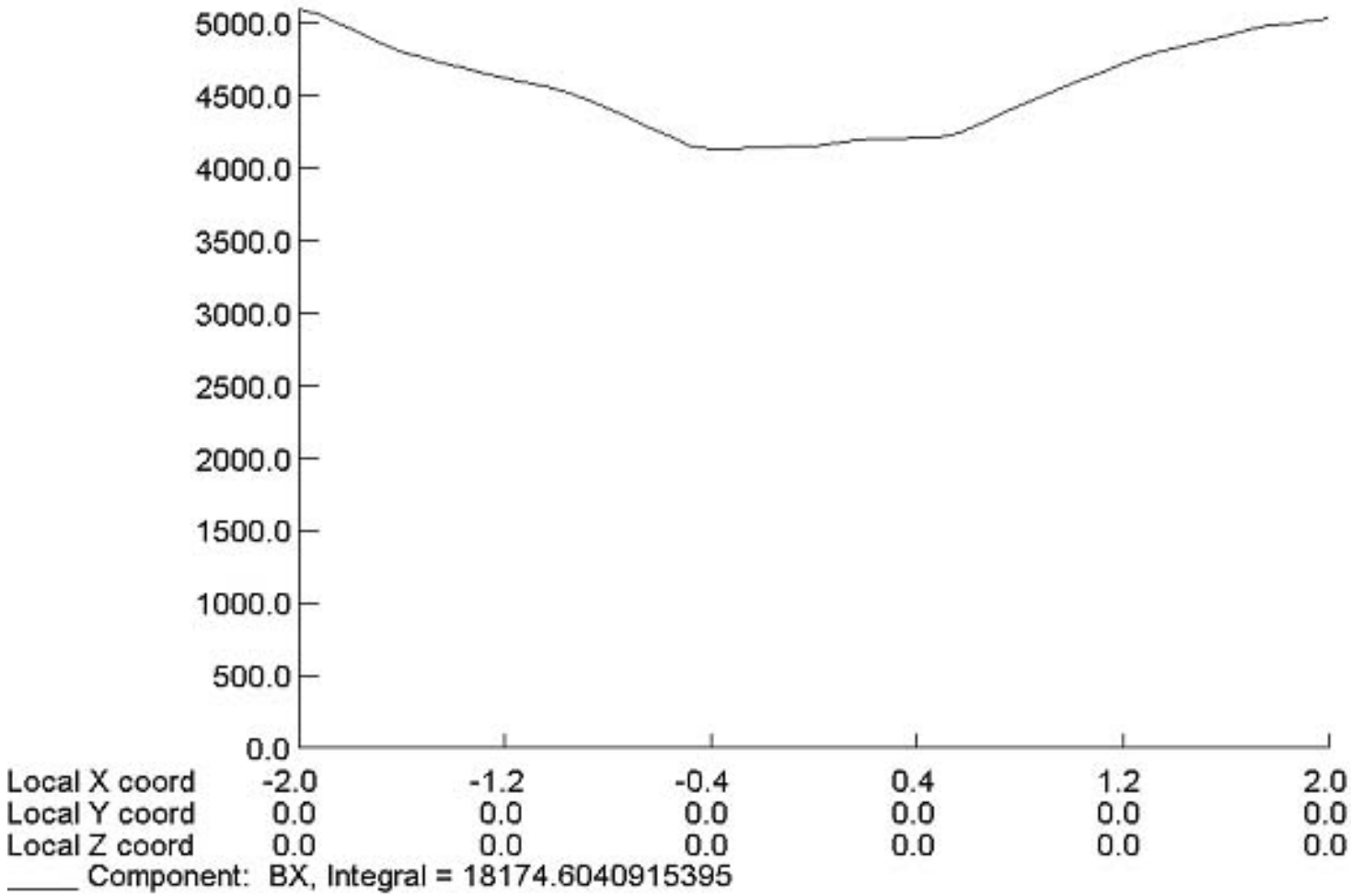
Field in Gap 10 mm Fe



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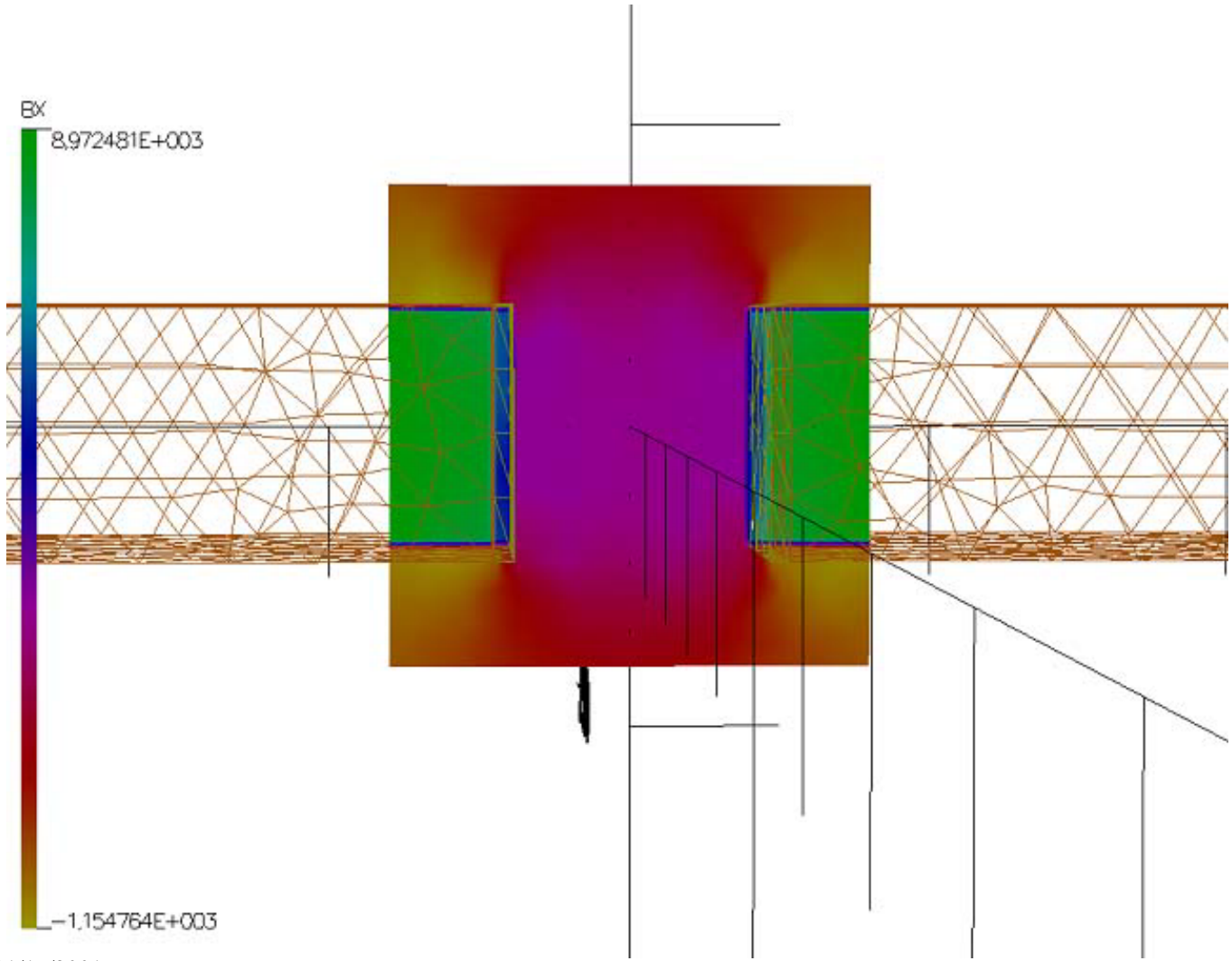
Field in Gap 3 mm Fe



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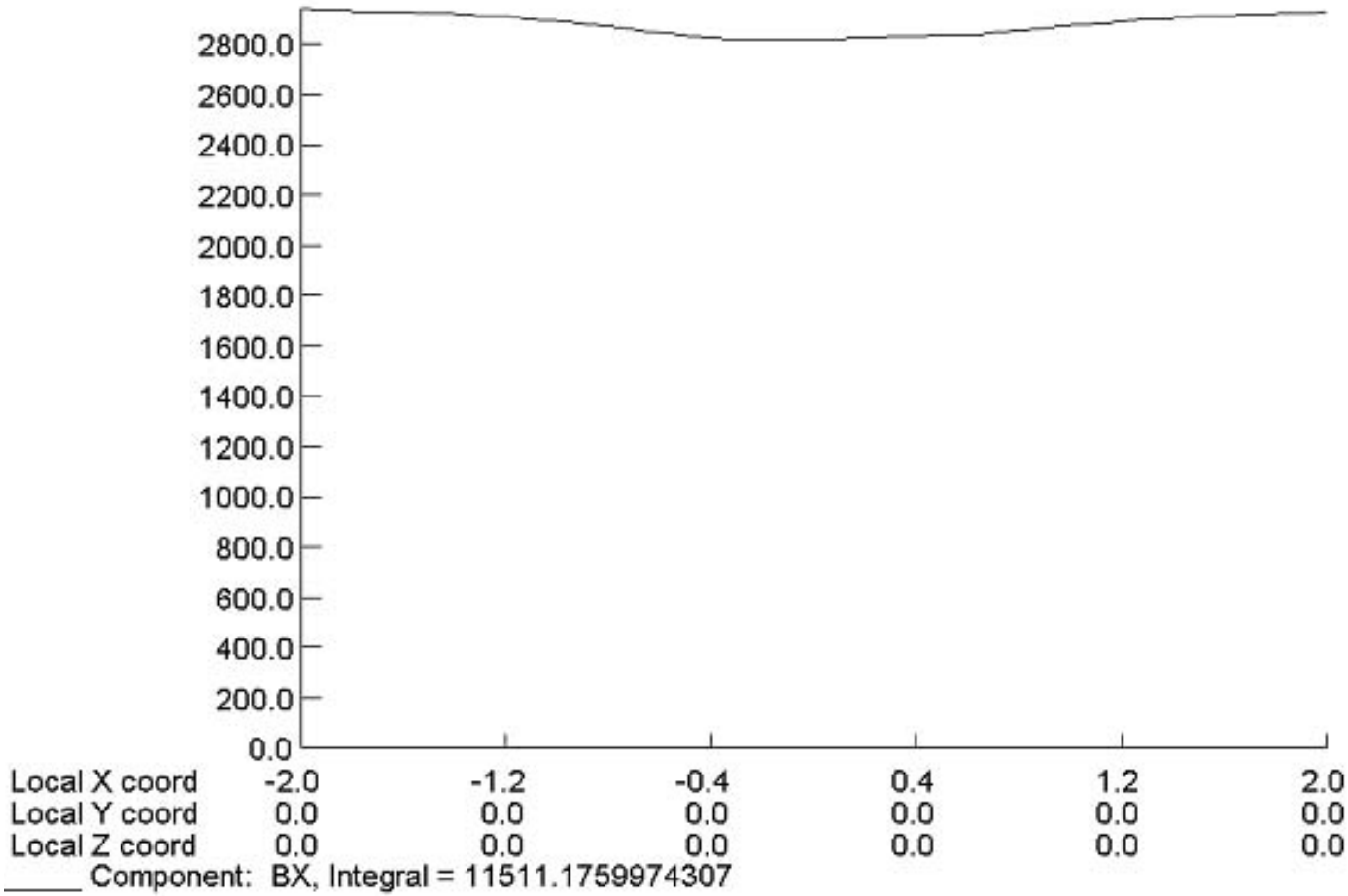
Field in Gap 3 mm Fe



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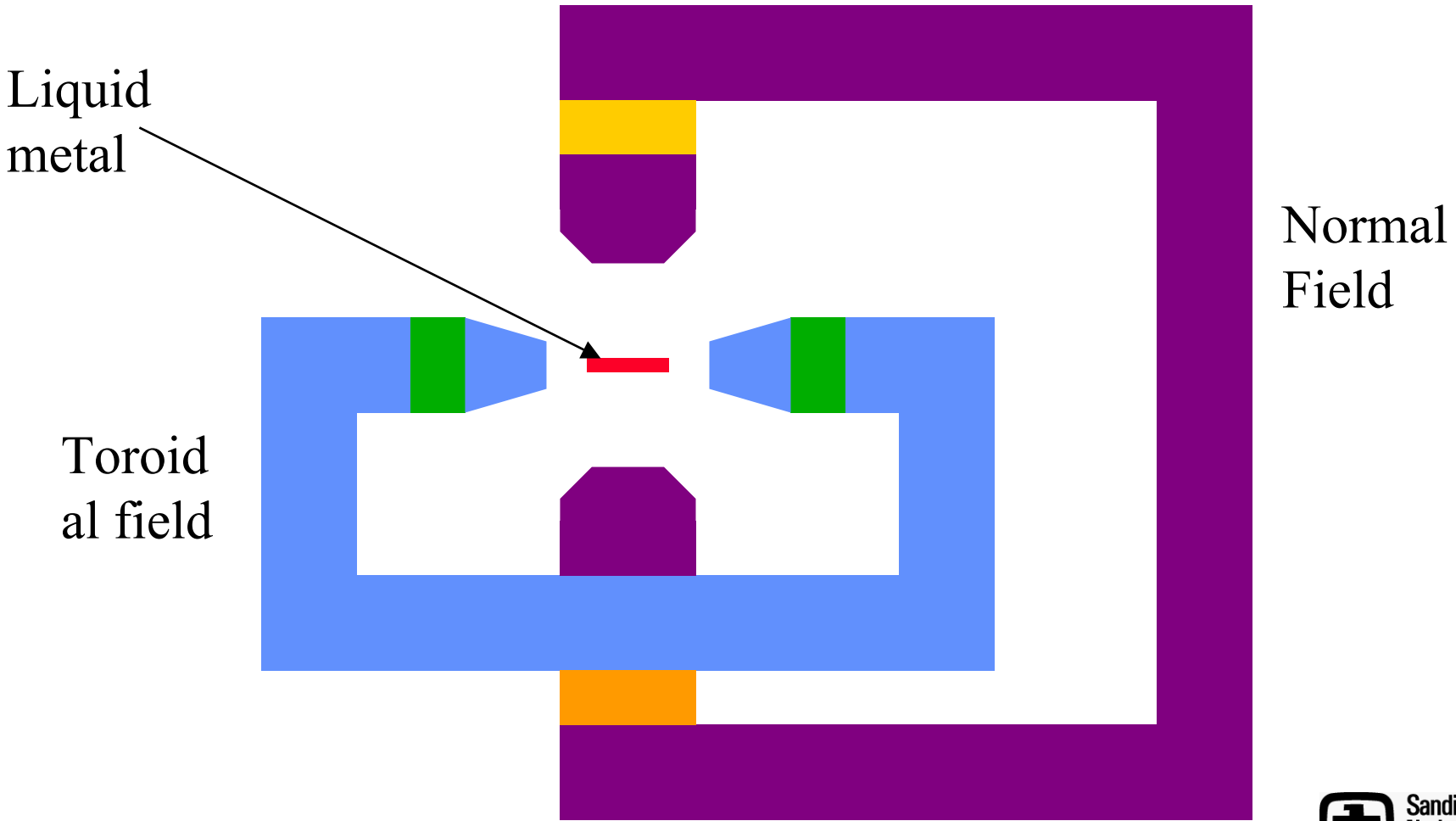
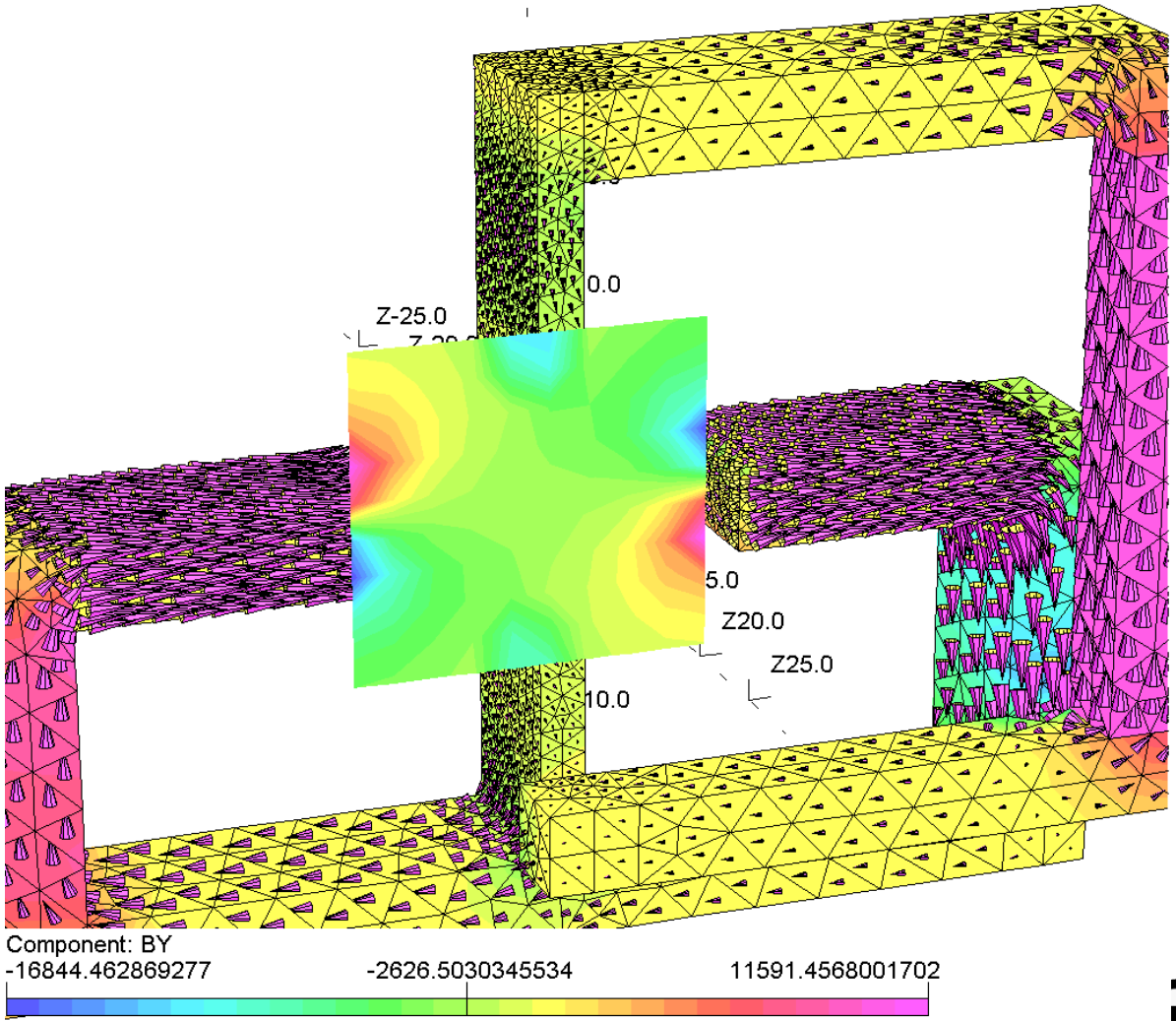
Schematic of Permanent Magnetic System



Cross Field Concept



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Advantages of a Permanent Magnet System

- Iron pole faces can be easily modified to create different field configurations and gradients (by changing the shape and gap between the poles).
- The system can be tilted for flow on an incline.
- Only small amounts of magnetic energy are needed because of the small volumes.
- Dynamic field changes can be added by wrapping coils around the iron (as in speakers).
- Diagnostics will not be affected by stray fields.

Disadvantages of Permanent Magnets

- Field is limited to about 2 Tesla (iron saturates)
- The magnets are thermally limited to <~150C for NdFeB and <~500C for SmCo
- Large systems cannot be tested because of the limited volume available.

Conclusions

- We have the tools to design a permanent magnet system to perform liquid metal MHD experiments in a field configuration that closely represents the field in tokamaks.
- Permanent magnets are a fast and cost effective way to do experiments that are essential for ALIST.
- The data produced will provide the input needed to complete the calibration of the MHD models.