## HTS Solenoid Design Review

# Coil Design

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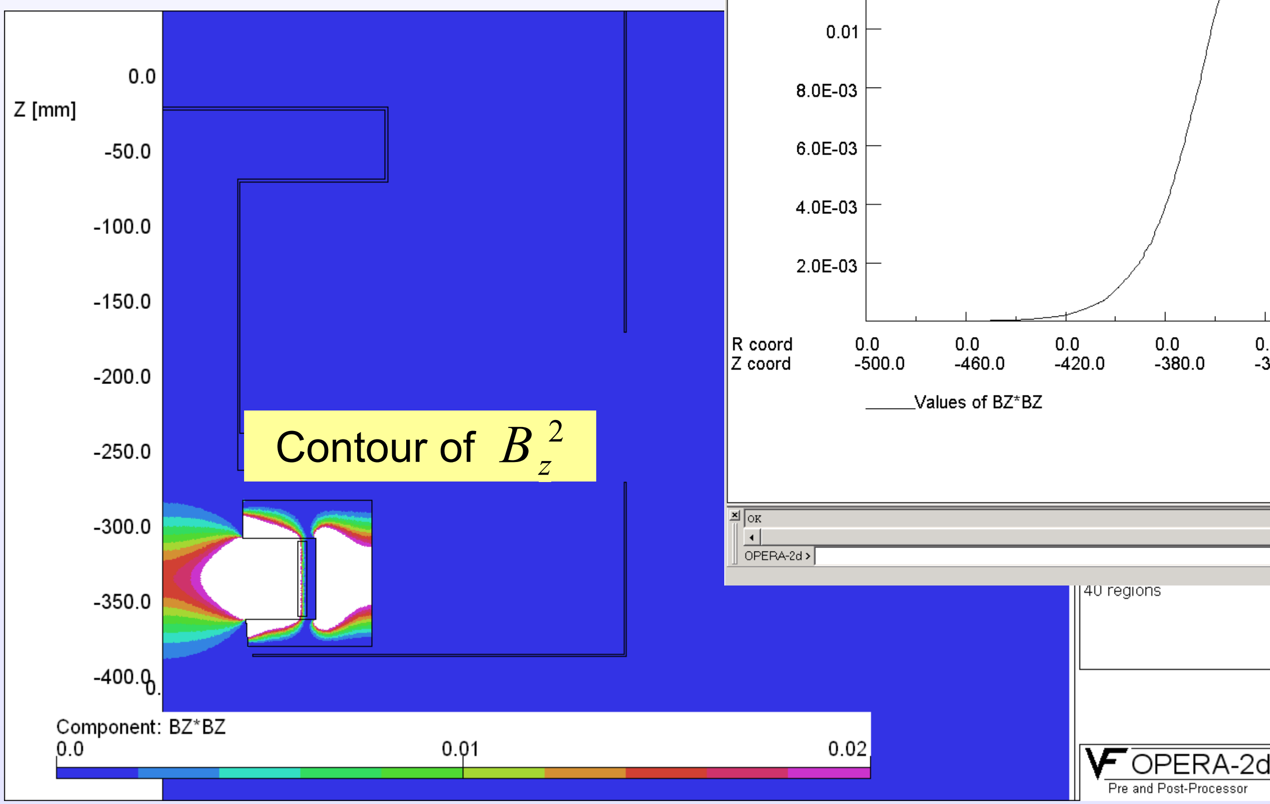
# Overview of the Presentation

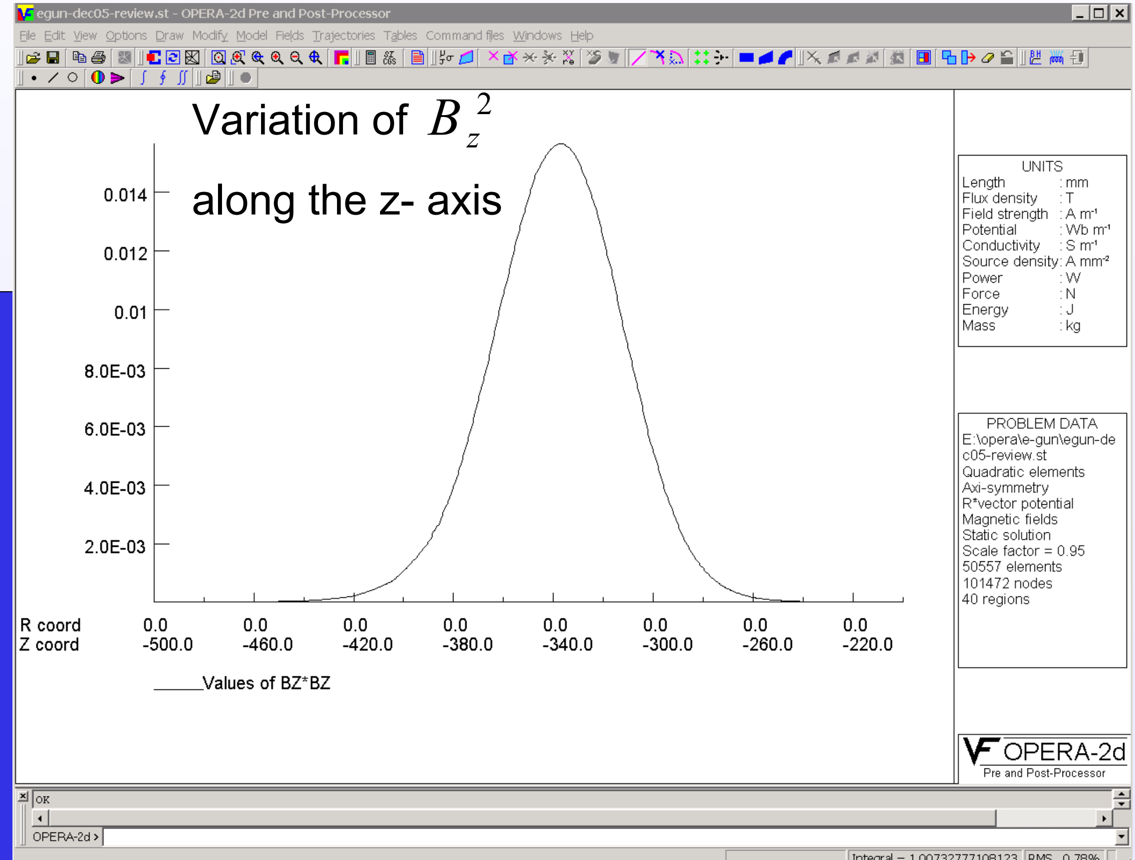
- Brief and a limited review of the general requirements
- Magnetic analysis conforms to the latest engineering design
- $LN_2$ (77K) testing

# Desired Focussing from Solenoid

## Basic Requirement :

$$\int B_z^2 dz \approx 1\ T^2 \ .\ mm$$

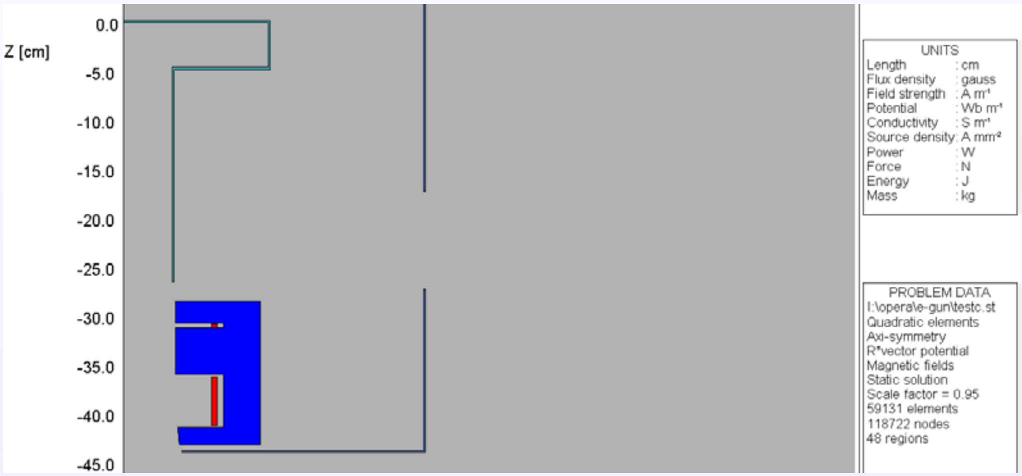


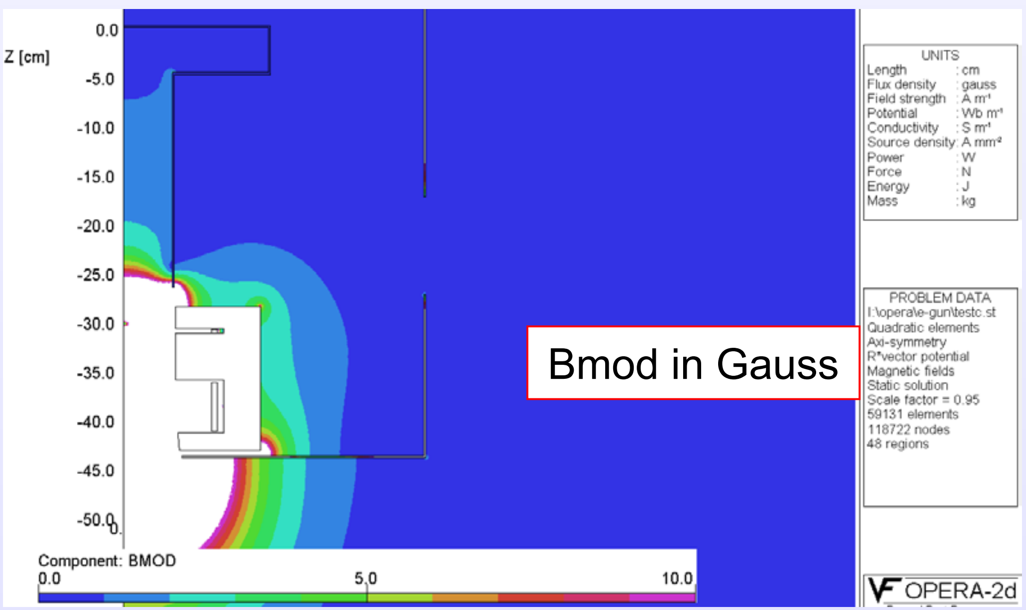



# Fringe Field

1. Should be less than 1.5 kG (0.15 T) on the superconductor when the solenoid is ON.
2. Should be less than a few mG on the cavity when the cavity is turning to superconducting state (solenoid is OFF at this time).
3. Trap field is a concern.
4. Field calculations (for beam focussing, etc.) must include the influence of shielding from superconductor and mu-metal

# Earlier Design (Jan/April '06)



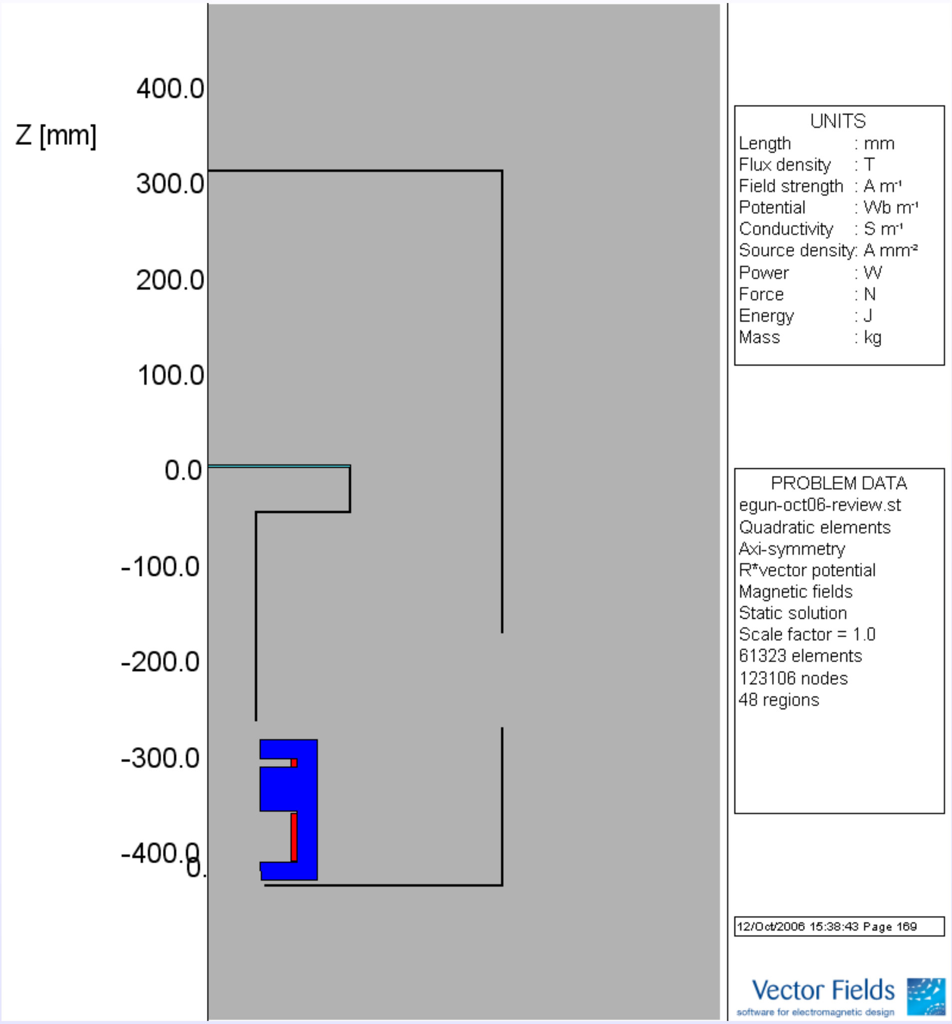




- There are two solenoid coils in the design.
- Smaller coil was added later on to reduce (buck) the exterior field in superconducting cavity region.
- Iron yoke plays a major role in creating field and in providing shielding.
- The two coils are connected in series.
- Small coil will also have a shunt power supply for tuning. However, model was optimized for cancellation at zero shunt.
- The analysis of this model was sent to Dmitry Kayran in April 06.

**• The focus of this review is on the coil design.**

**• This model had 14 layers in both bigger and smaller coils.**

# Current Coil Design




- **Magnetic model on this slide conforms to the latest design (Tuesday, October 10, 2006).**
- **It has 15 layers instead of 14 layers in both coils. Larger coil has 12 turns. Smaller coil is a double pancake coil (2 turns).**

**Calculations are done in two cases:**

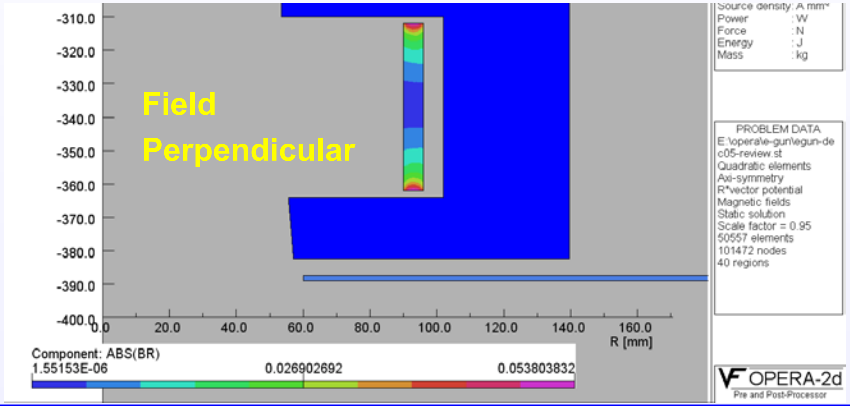
**Case 1 : Bucking coil in series (as per the current engineering design).**

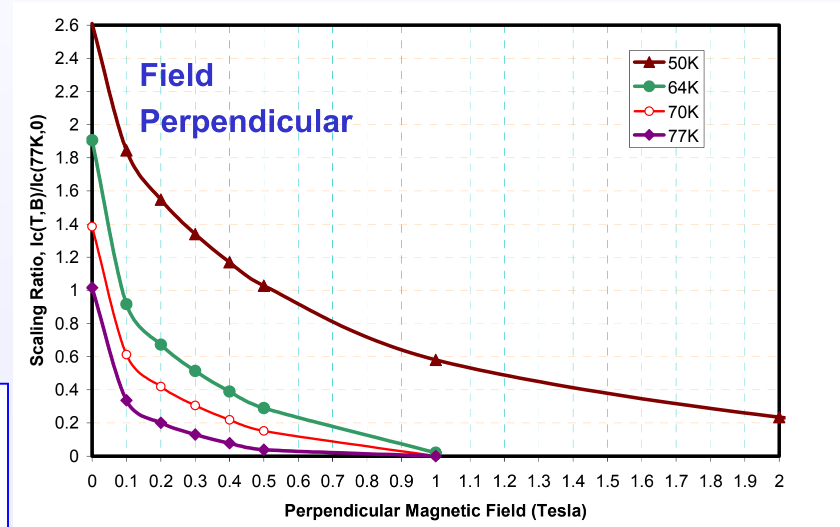
**Case 2: Bucking coil turned off.**

**Case 2 (without bucking coil) will be presented first.**

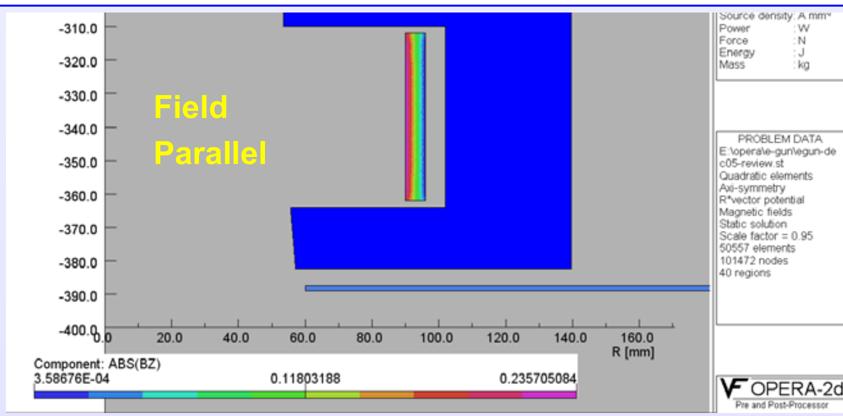
# Testing In Liquid Nitrogen (77 K) Will Validate the Required Design Performance

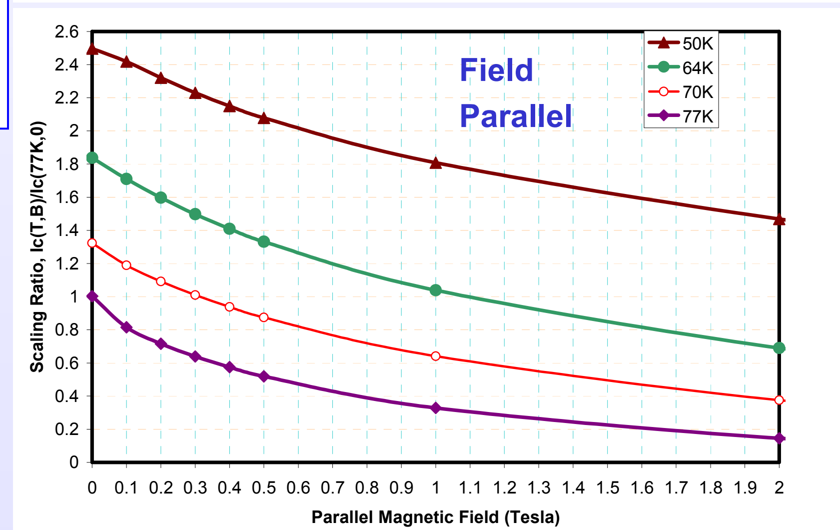
Magnetic model has also been optimized to reduce the perpendicular field in the superconductor




We will be able to test solenoid at a current greater than the design value @77 K itself with liquid nitrogen only. No need for the liquid helium or even sub-cool nitrogen testing (significant cost saving). Lower temperature operation gives extra margin.



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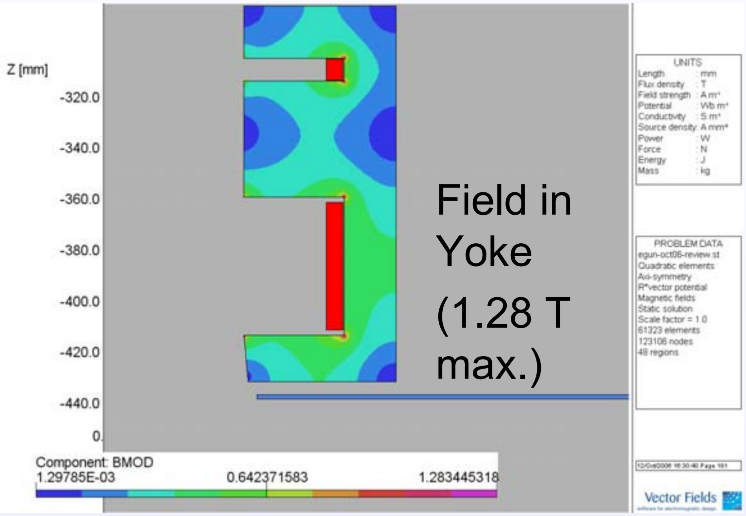
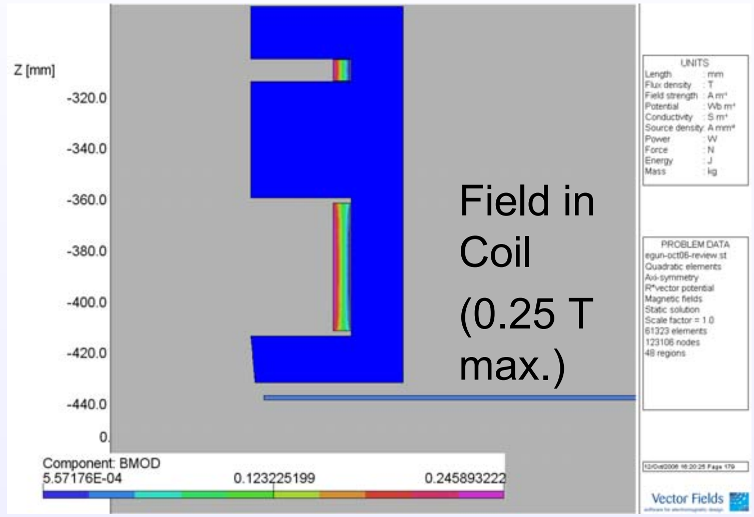
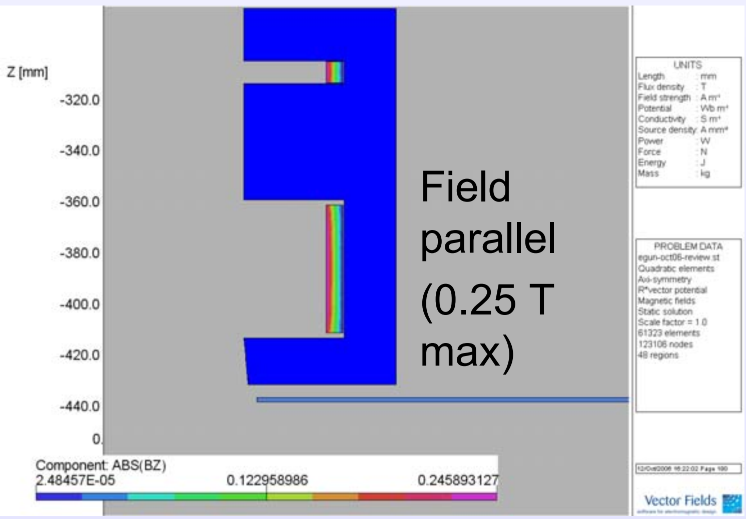
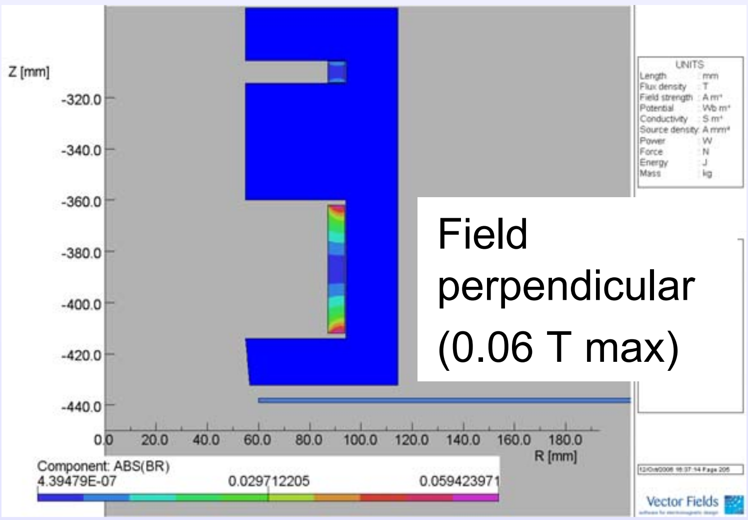
# Field Components at Design Field (Important for 77 K testing at $LN_2$)




Nominal self-field performance of conductor: 145 A (verified by measurement).



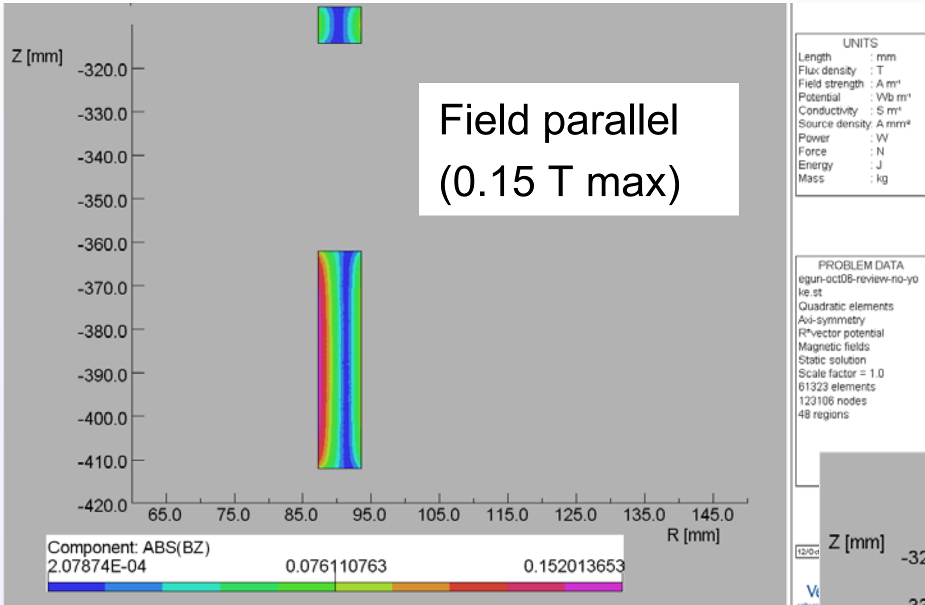

Scale factor at these field is : ~0.6 at 77 K.

Expected performance: 145*0.6= ~87 A.

Design requires <34 A at ~5K

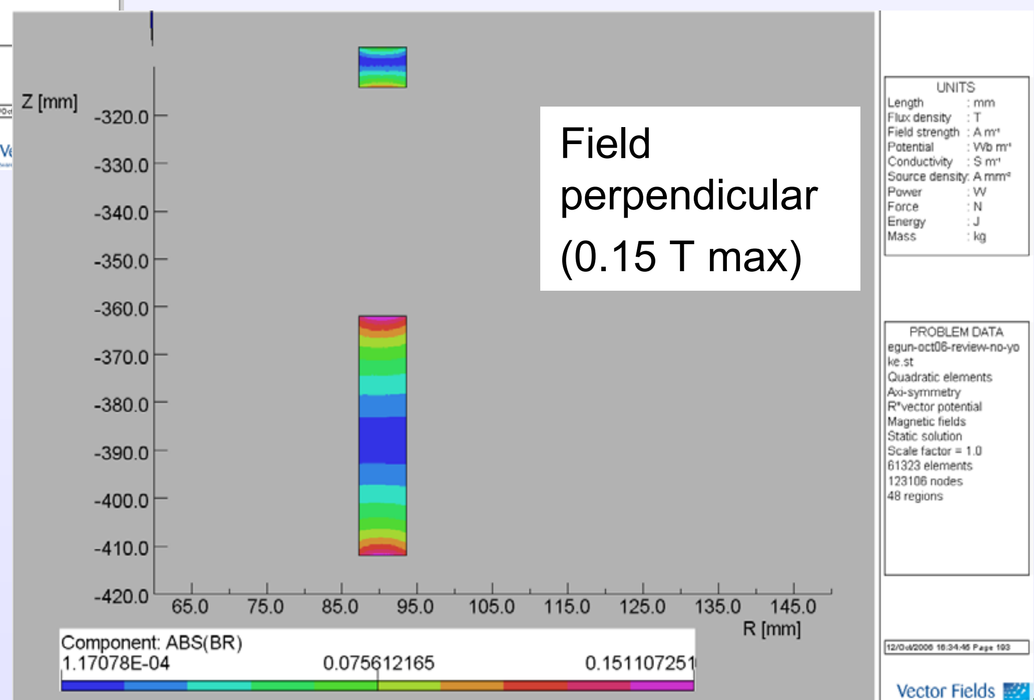
(huge margin even for 77 K test).

# Field Component in Yoke Free Case at design current ($LN_2$ test)




- The maximum value of both field parallel and field perpendicular is ~0.15 T.
- This is significantly different than 0.25 T and 0.06 T respectively in the case when these coils are in yoke.

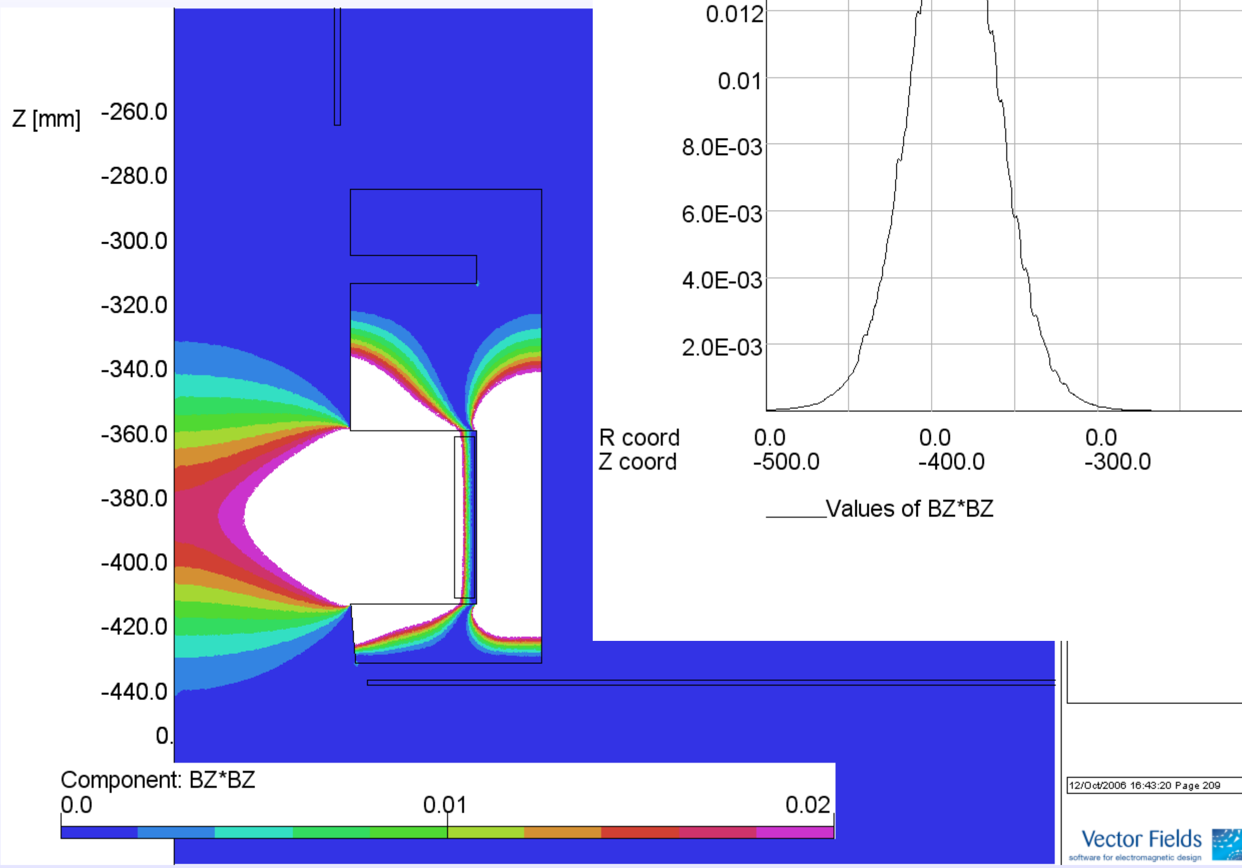
- Scale factor at 0.15 T is ~0.22.
- Expected current: 145*.22 =32A
- This is close to the design current of 33.6 A and thus the solenoid can be tested close to the operating current.
- However, Lorentz forces will be significantly lower and different.

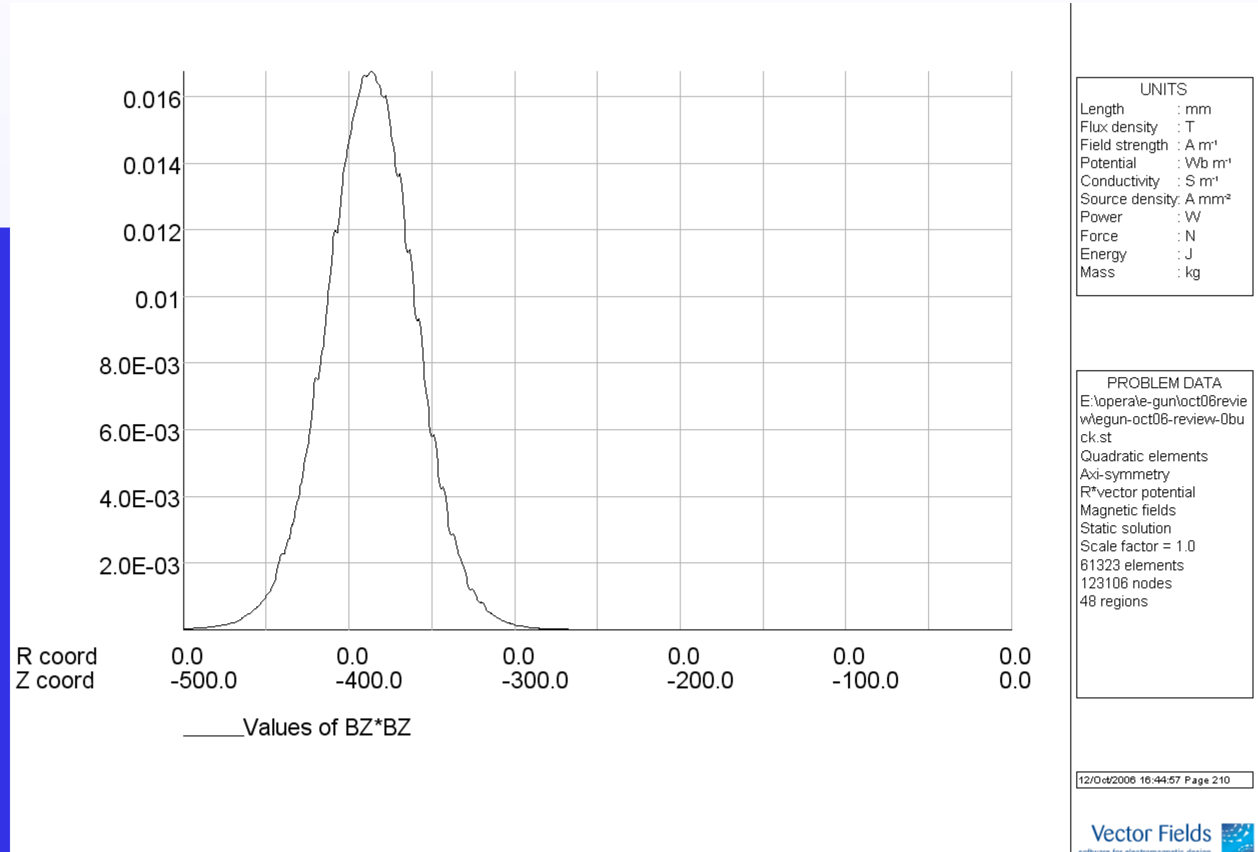


# Focusing in One Solenoid Case (Bucking coil turned off)

## Basic Requirement :

$$\int B_z^2 dz \approx 1\ T^2 \ .\ mm$$



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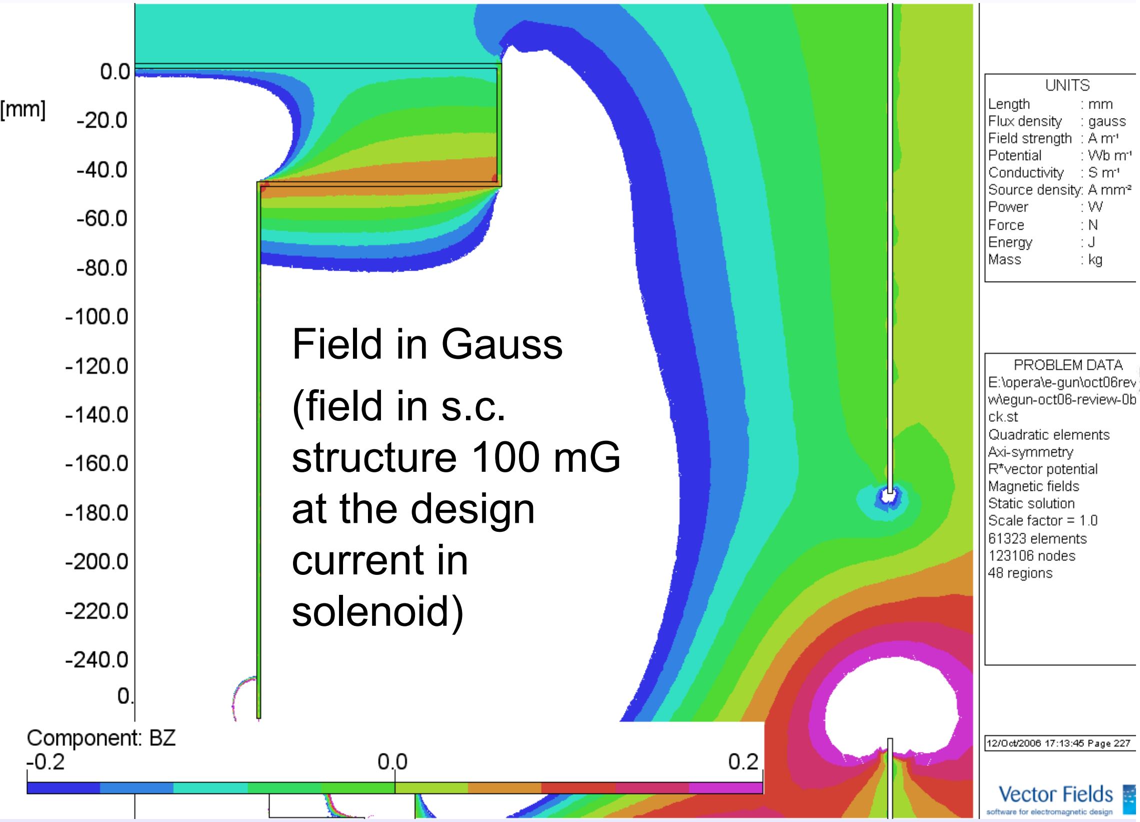
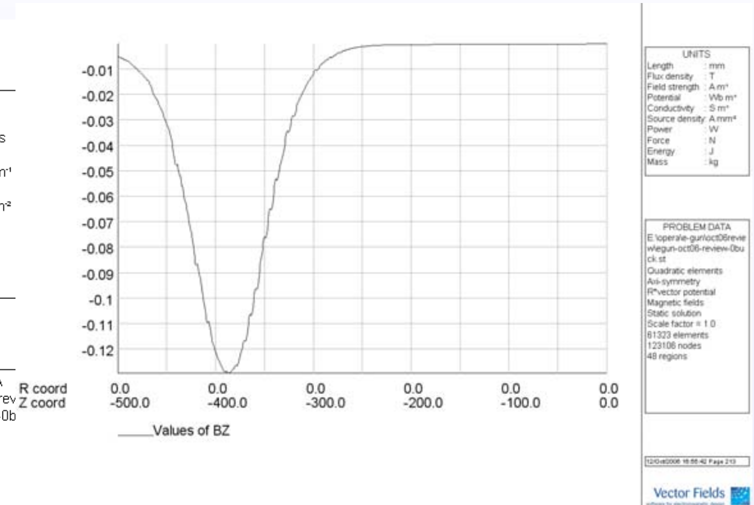
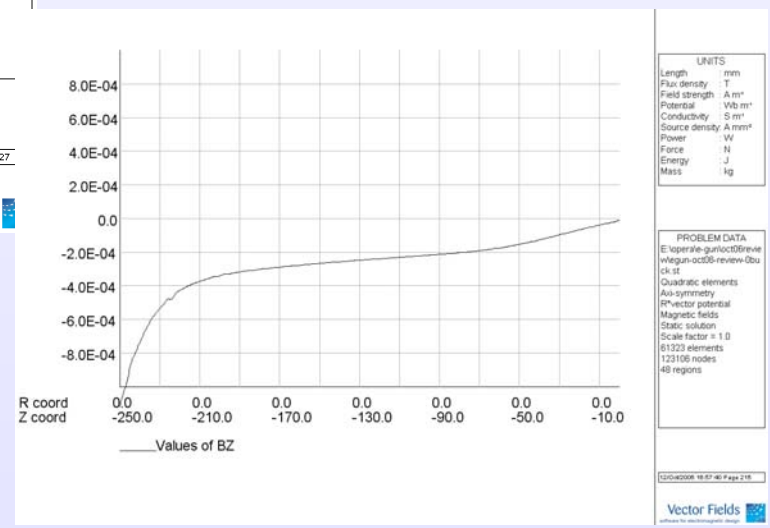
# Field in Cavity Region (Bucking coil turned off)




Field on axis in Tesla

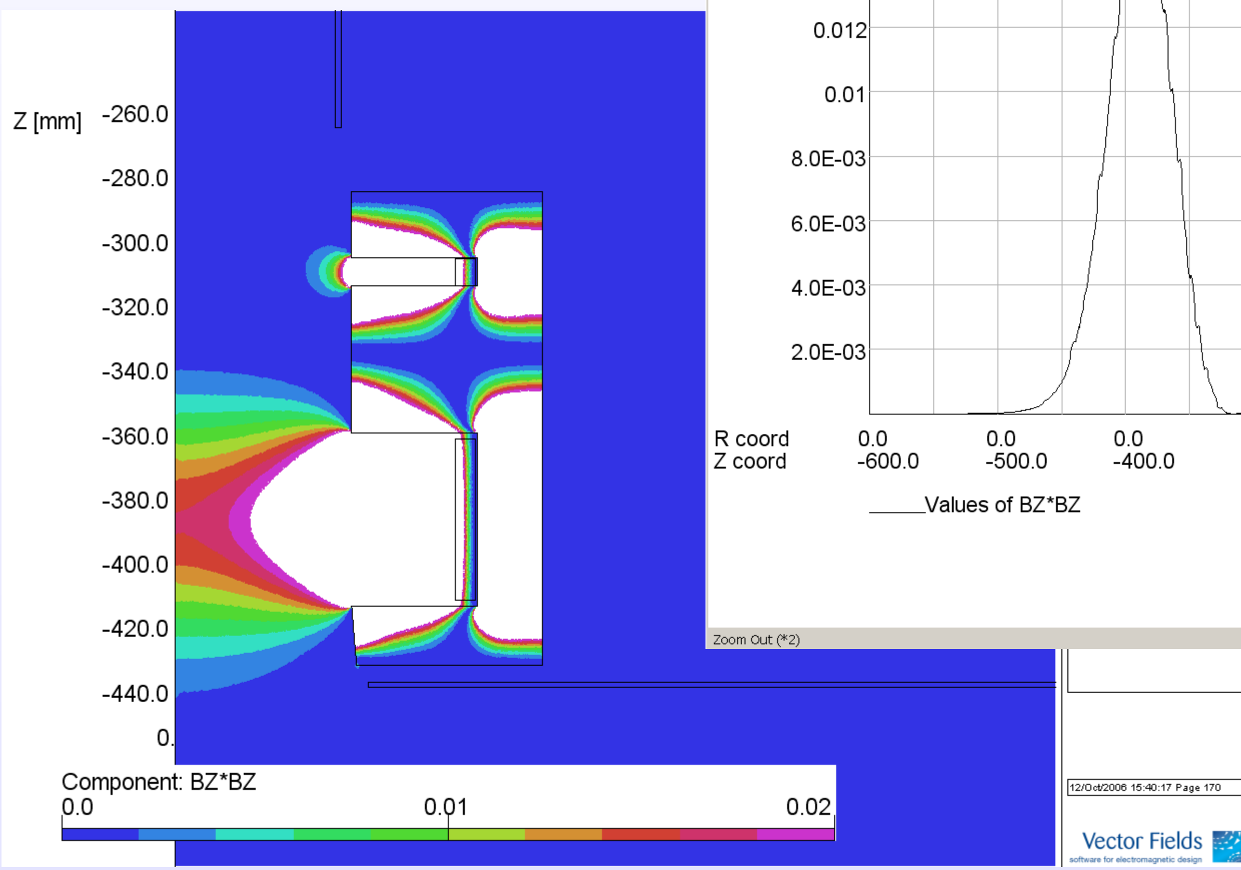


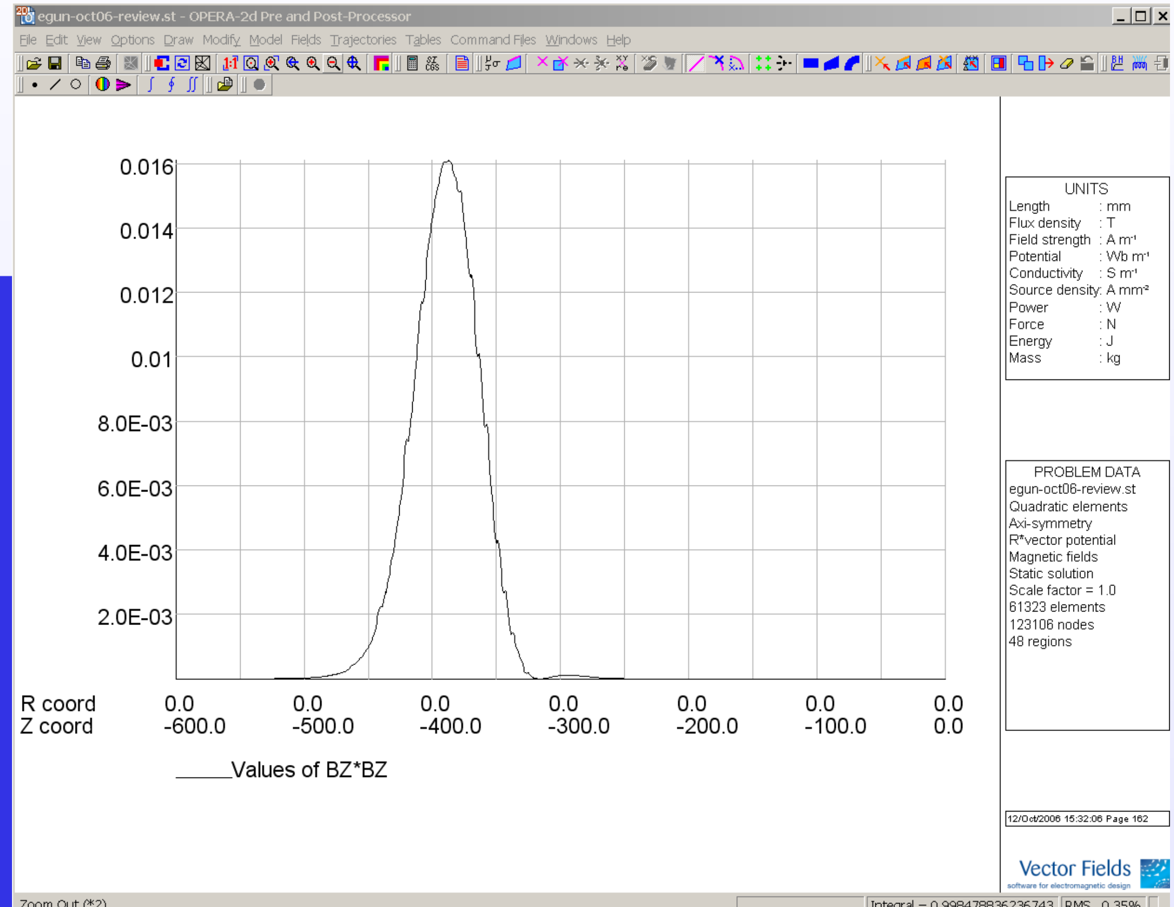

- The influence of the remnant field of the yoke will be reduced by demagnetization cycle.
- To further reduce the field on superconducting structure, a bucking solenoid is added (see next slide).

# Focusing in Two Solenoid Case (Bucking coil turned on, in series)

## Basic Requirement :

$$\int B_z^2 dz \approx 1\ T^2 \ .\ mm$$




Larger coil : 15 X 12 turns
Smaller coil : 15 X 2 turns
Nominal current : 33.6 Amp

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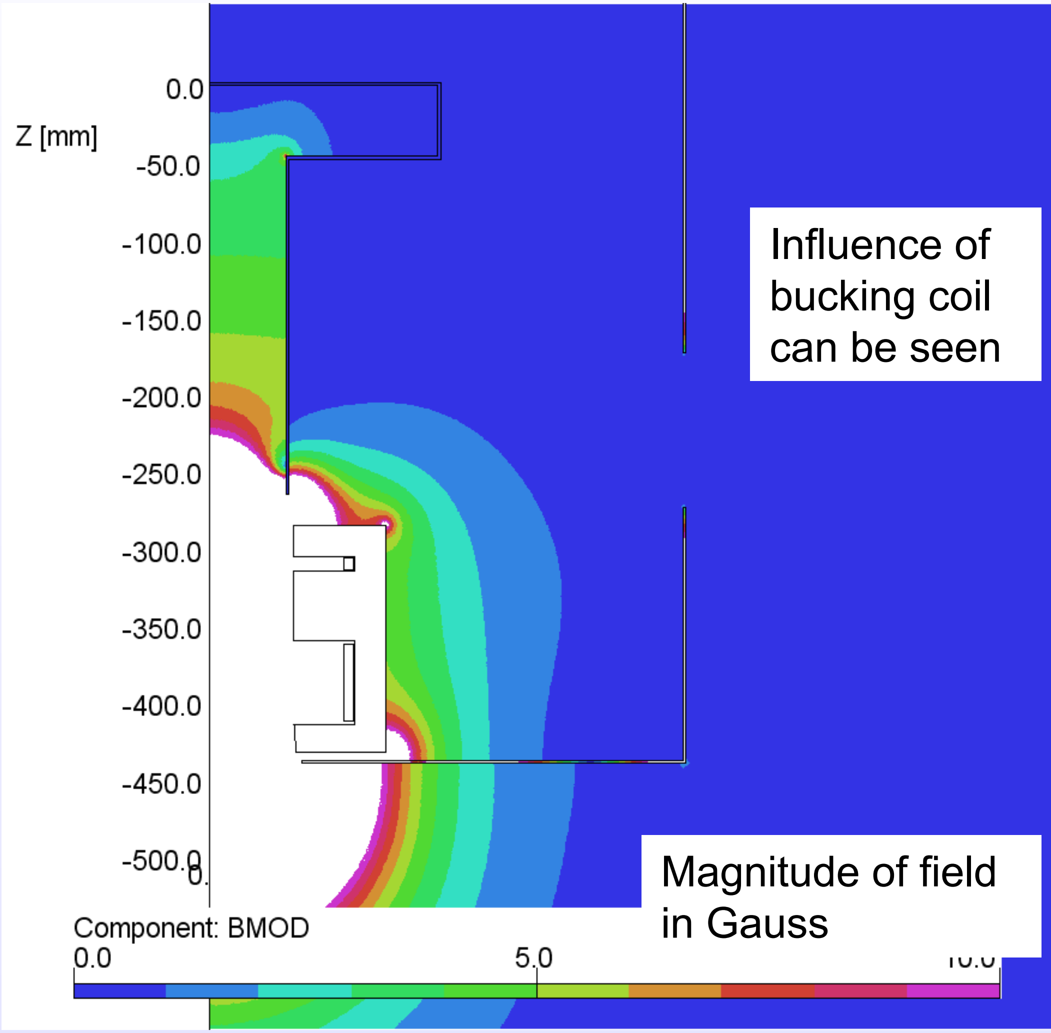
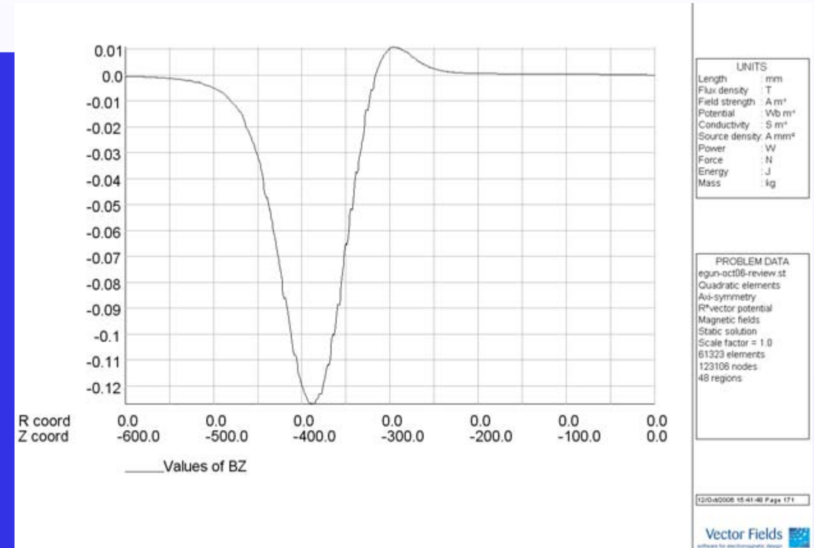
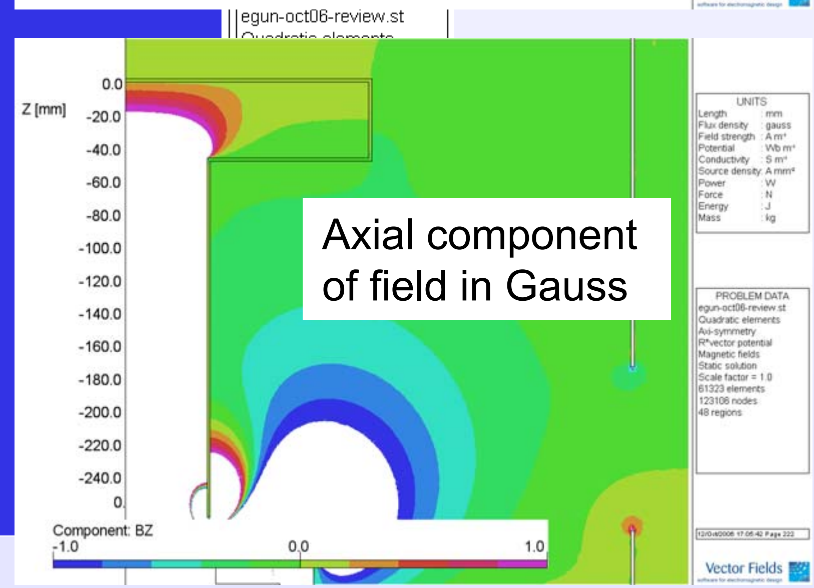
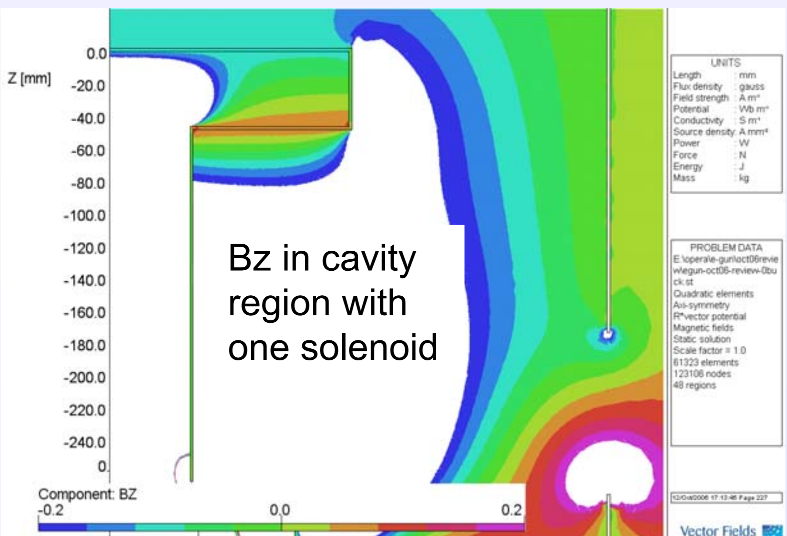
# Fringe Field in the Design Presented Today (Bucking coil turned on, in series)



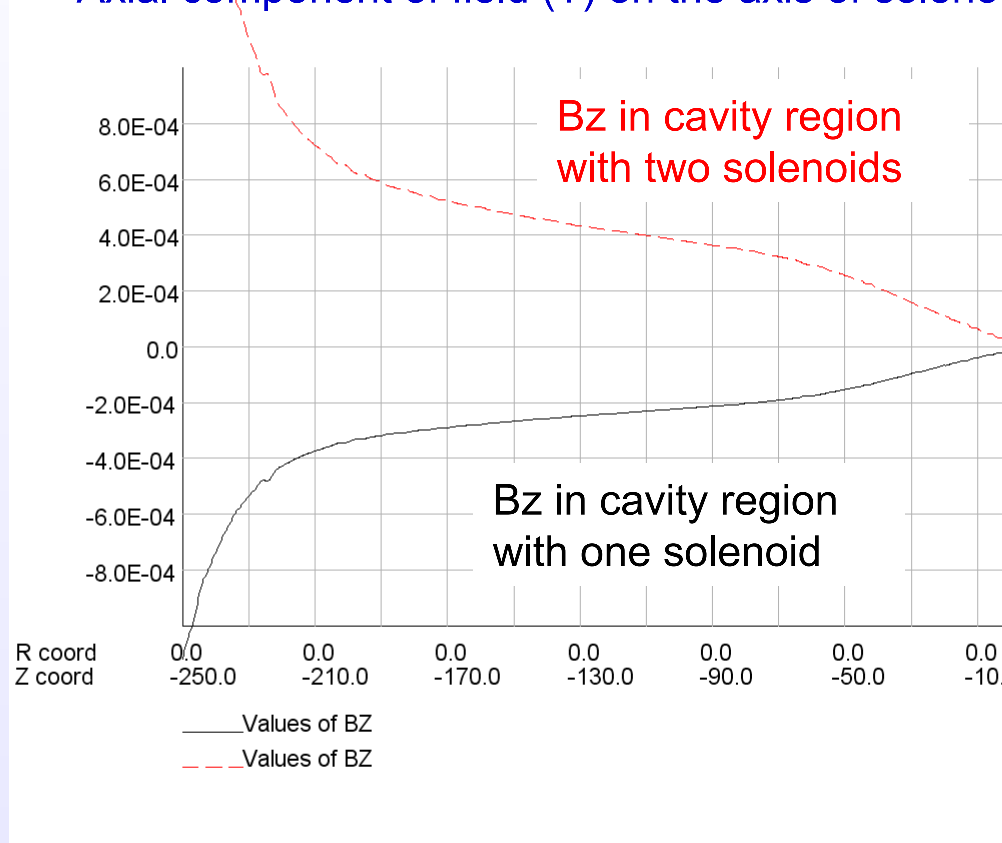



# Comparison of Designs
## (without bucking coil and the present design)


Axial component of field (T) on the axis of solenoid




Whereas an earlier design (January/April 06 version) that was sent to beam physicist gave correct compensation, the engineering design in the current form clearly over compensates the field.

# Summary and Thoughts on the Present Design

Since the compensation is too much (not too little), the error, in principle, should be fixable with a redesign of the yoke (not yet built) and by taking out turns from the bucking coil. It is possible that the compensation may require non-zero shunt current even in nominal design.

**Added after the review:**

**Two separate power supplies (as suggested by George Ganetis) gives an added benefit that it should allow the use of present bucking coil running at a different current.**