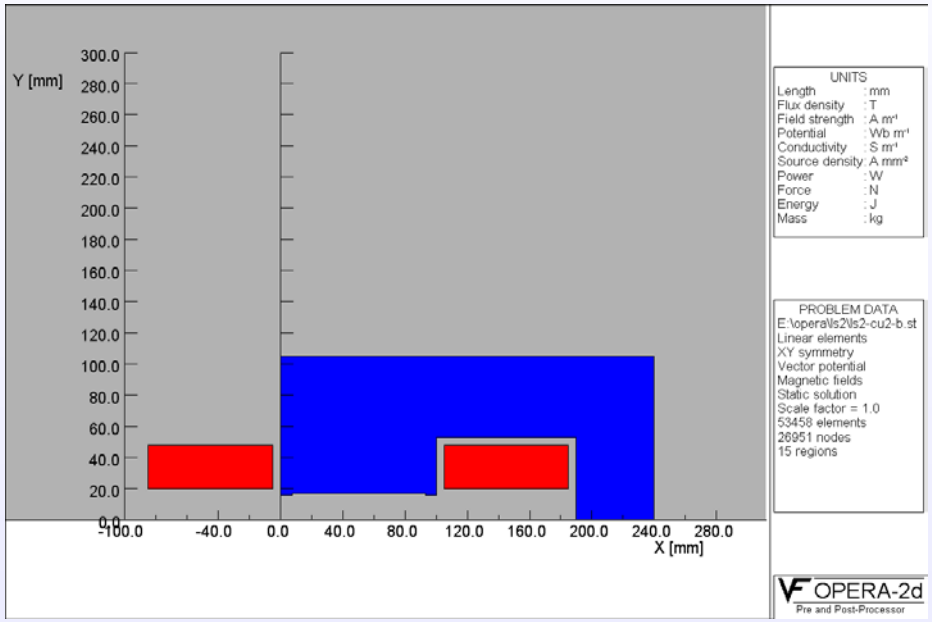
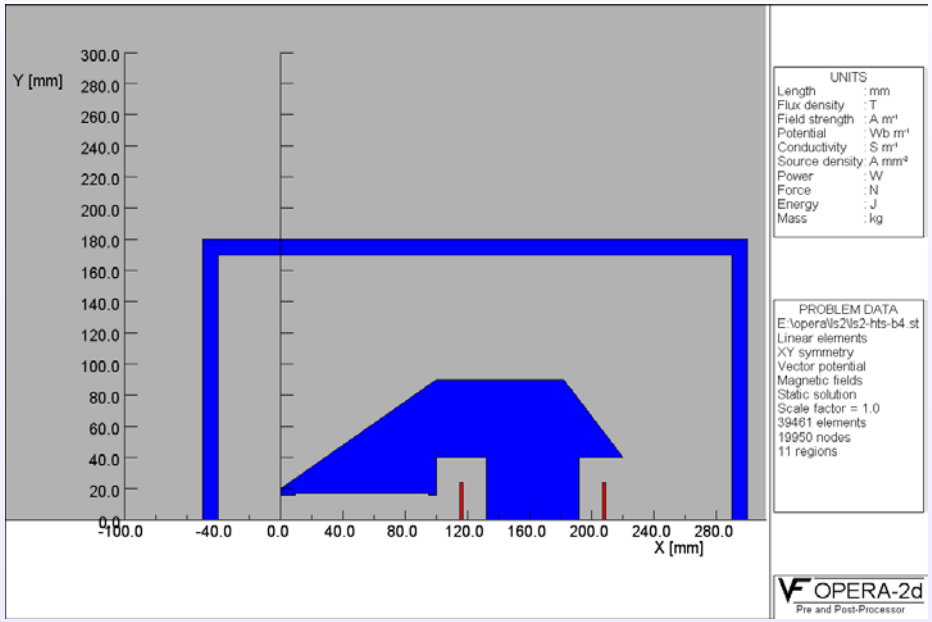
BROOKHAVEN NATIONAL LABORATORY

Superconducting Magnet Division

Magnetic Models of 3 kG Magnet Designs for Light Source 2 (LS2)





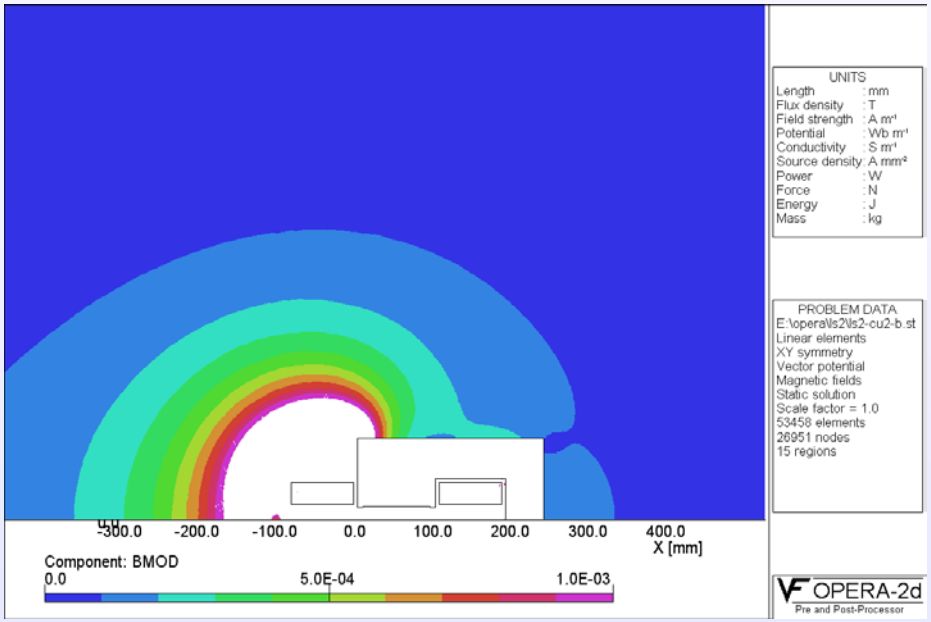
Water-cooled copper magnet
(Pole powered)
Current Density = 2 A/mm^2

HTS magnet with shield
(Back-leg powered)
Current Density = 50-100 A/mm^2

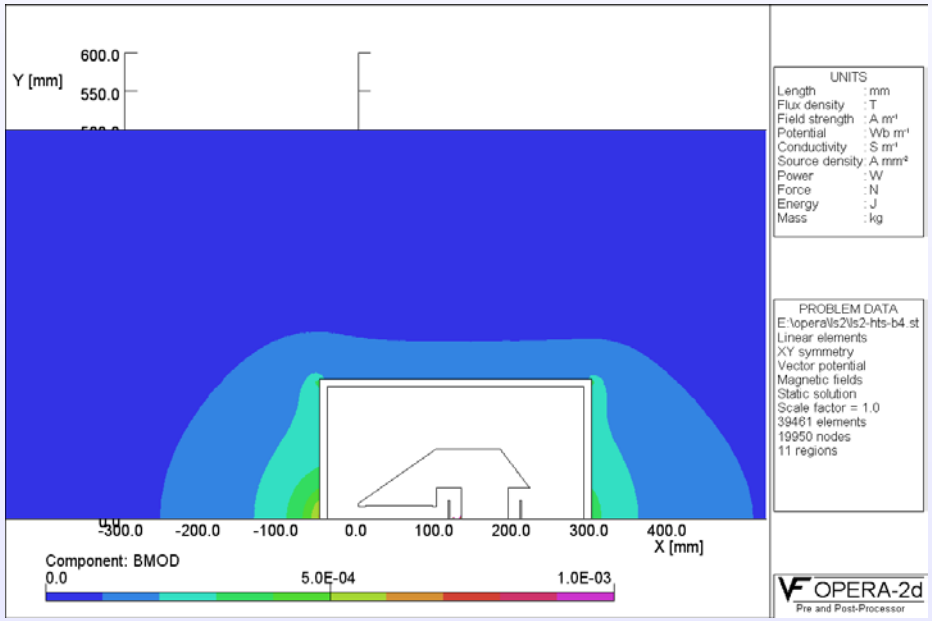
Fringe Fields in Magnet Cross-section

Note: Fringe field is significantly lower at a similar distance (as compared to conventional pole-powered water-cooled magnet) from magnet center in back leg powered HTS magnet with appropriate shield (maximum width 10mm).

There are a variety of simple and practical ways to incorporate this shield.



Water-cooled copper magnet
(Pole-powered)

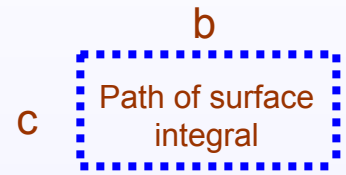


HTS magnet with shield
(Back leg-powered)

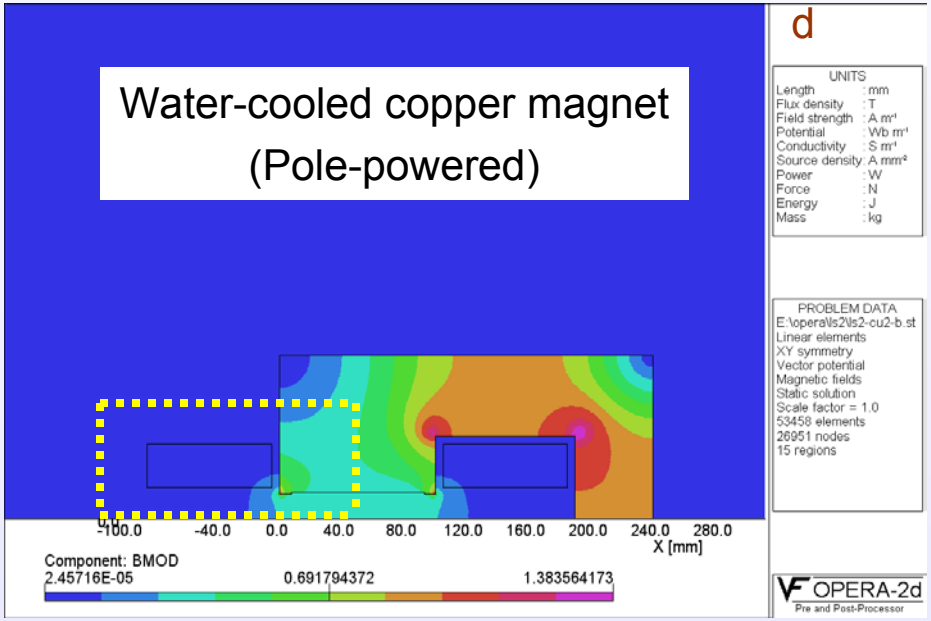
Maximum scale 10^{-3} T (10 G); Pacemaker limit: 5 G
Field is much lower a certain distance away from the shield.

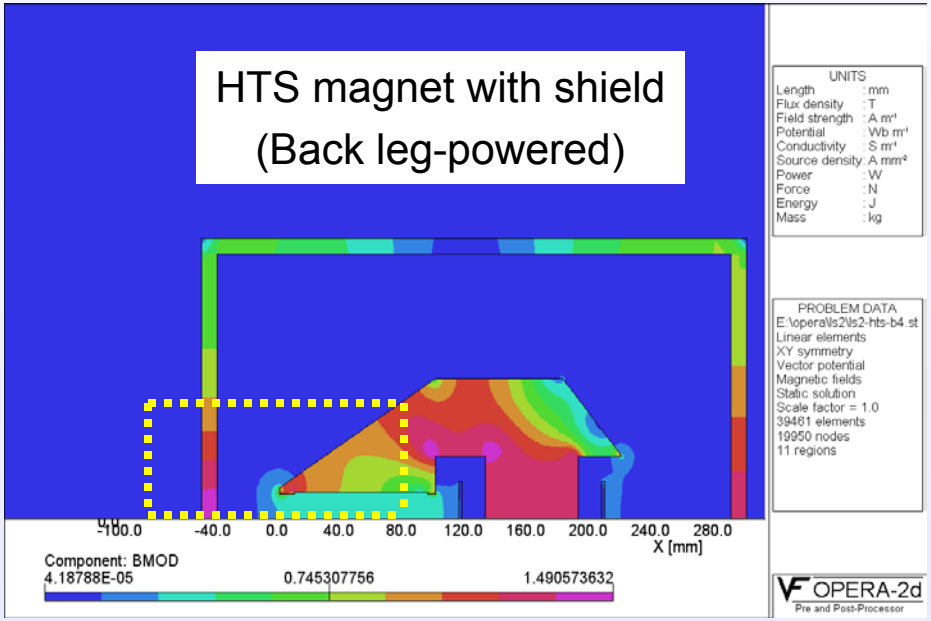
How Ampere's Law Is Satisfied and Fringe Field is Kept Low

$$\oint H \cdot dL = N \cdot I$$



With a properly designed shielding, Ampere's law does not come in the way of low fringe field outside the shield





Only significant contribution comes from H (B_y/μ_o) in gap (*g*) region. One can obtain:

$$B_y \cdot g / \mu_o = N \cdot I$$

- Fringe field ***"c"*** can be small !

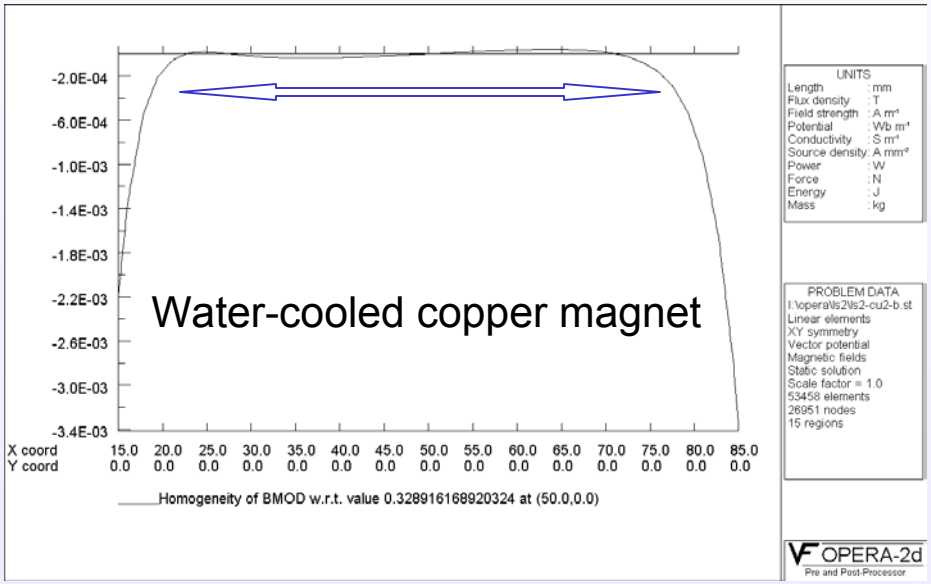
Significant contributions come from H_y in gap (g) and H_x separation (*s*) between shield and iron region. Fringe field can be small if:

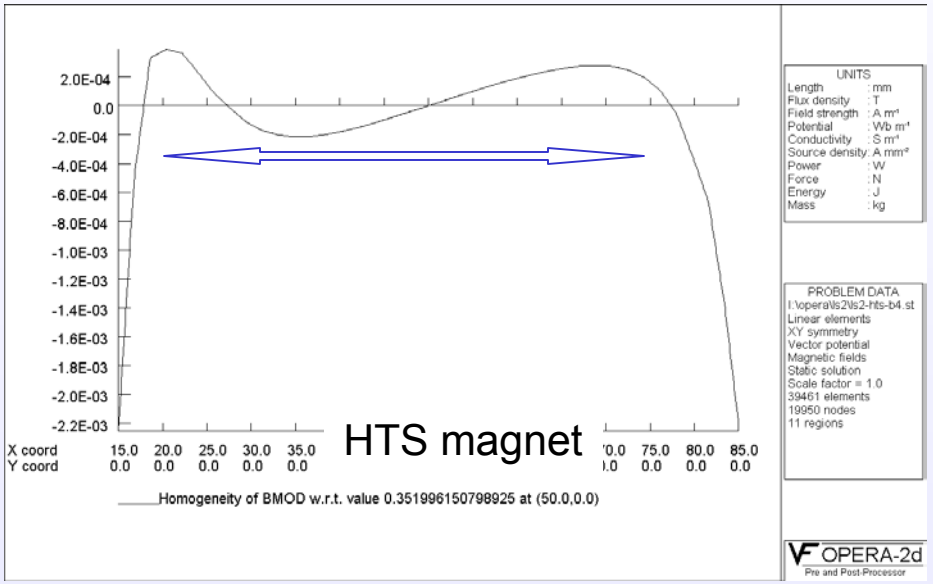
$$H_y \cdot g \sim -H_x \cdot s$$

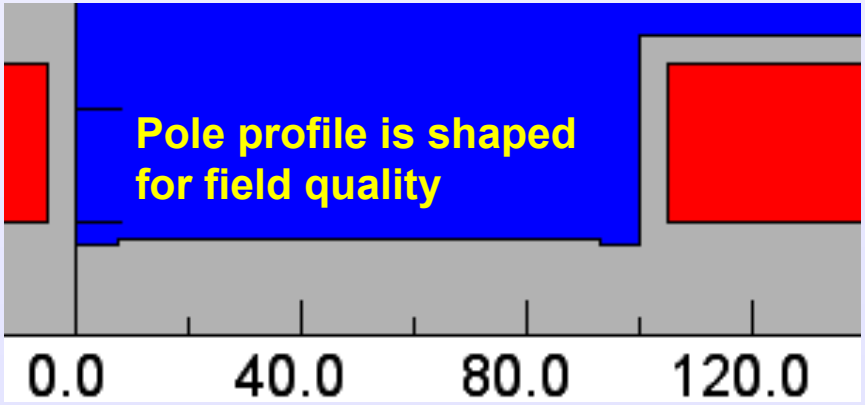
- Fringe field ***"c"*** can be small !

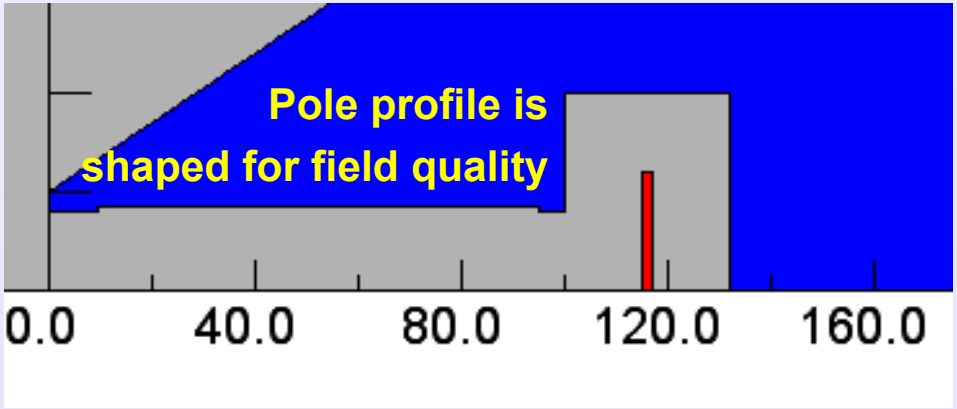
Field Quality in Preliminary Design

These are preliminary conceptual designs. Nevertheless field quality requirement of a few parts in 10^{-4} in 6 cm horizontal aperture (+/- 3 cm) has been obtained by shaping the pole.

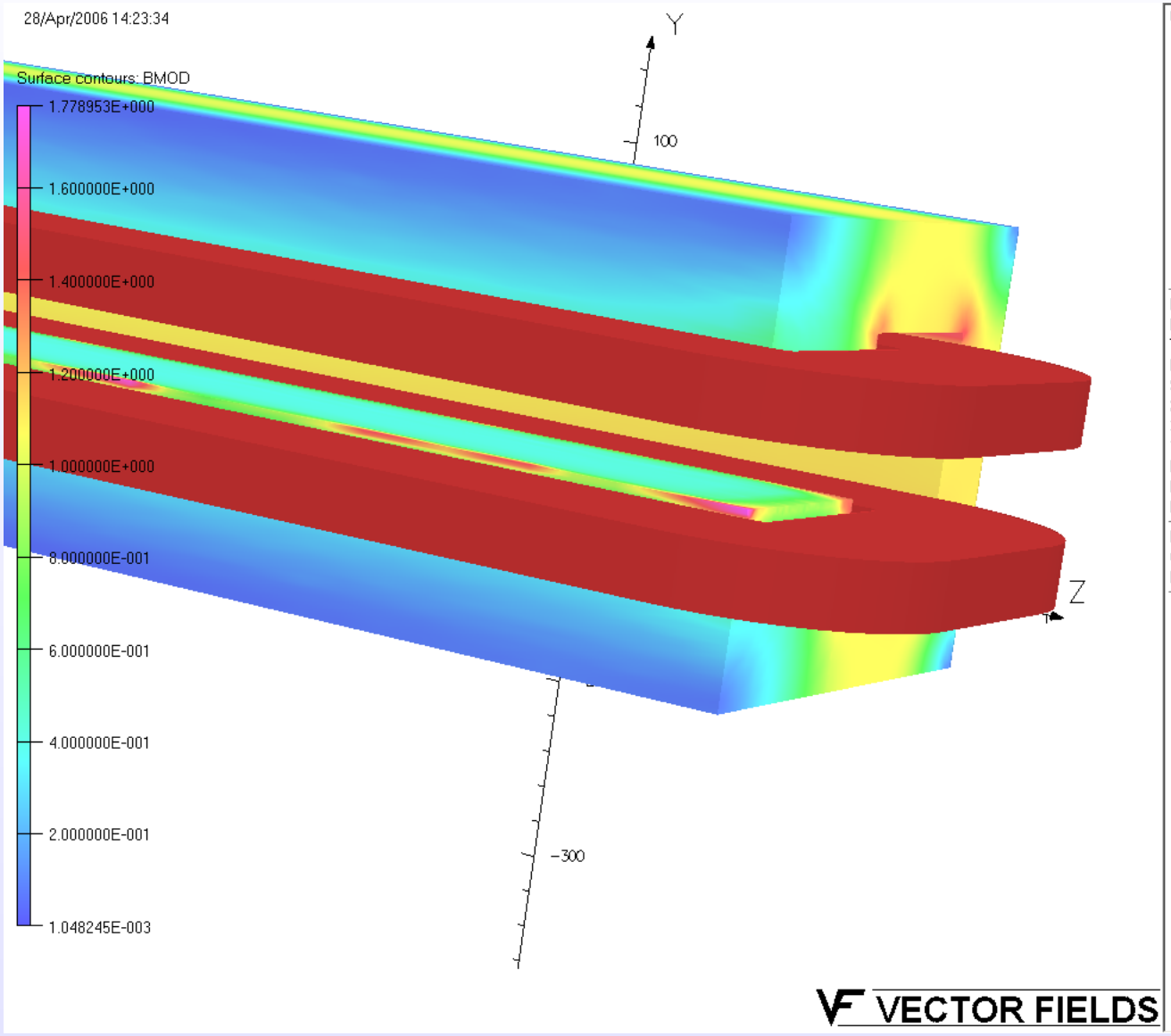








Water-cooled Cu Coil Magnet Design



UNITS

Length	mm
Magn Flux Density	T
Magn Field	A m^{-1}
Magn Scalar Pot	A
Magn Vector Pot	Wb m^{-1}
Elec Flux Density	C m^{-2}
Elec Field	V m^{-1}
Conductivity	S mm^{-1}
Current Density	A mm^{-2}
Power	W
Force	N
Energy	J

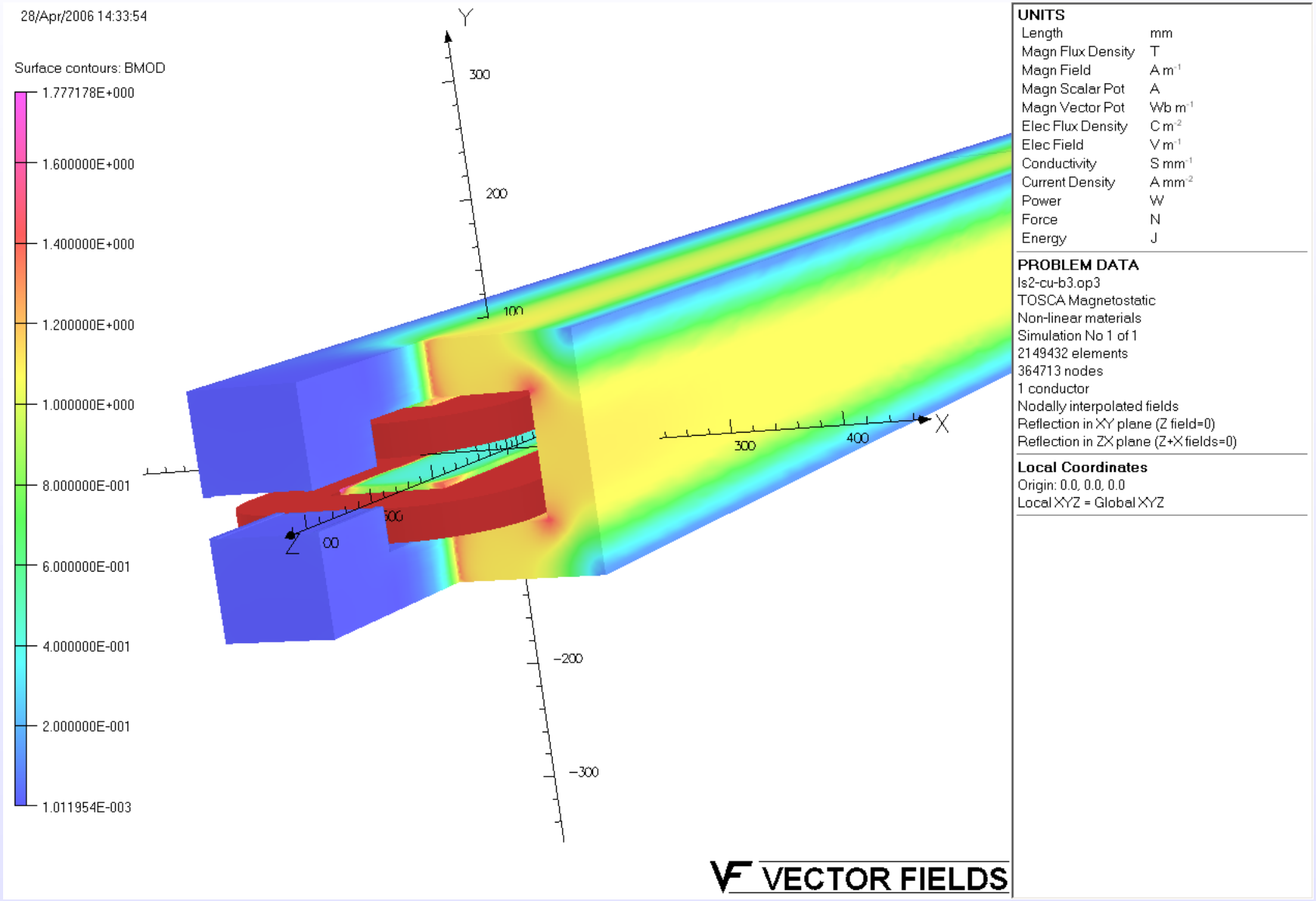
PROBLEM DATA

ls2-cu-b2.op3
TOSCA Magnetostatic
Non-linear materials
Simulation No 1 of 1
2149432 elements
364713 nodes
1 conductor
Nodally interpolated fields
Reflection in XY plane (Z field=0)
Reflection in ZX plane (Z+X fields=0)

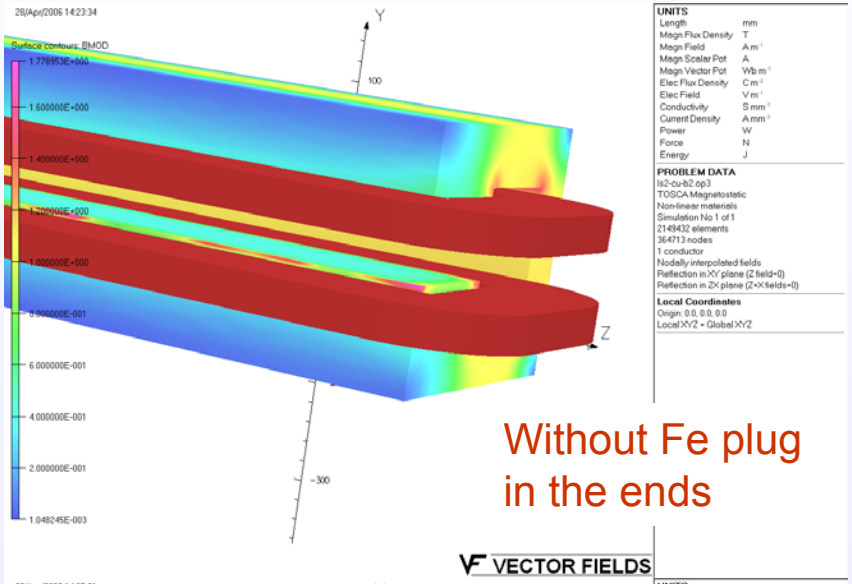
Local Coordinates

Origin: 0.0, 0.0, 0.0
Local XYZ = Global XYZ

Iron Plug In The Ends
An Attempt To Trim Fringe Fields

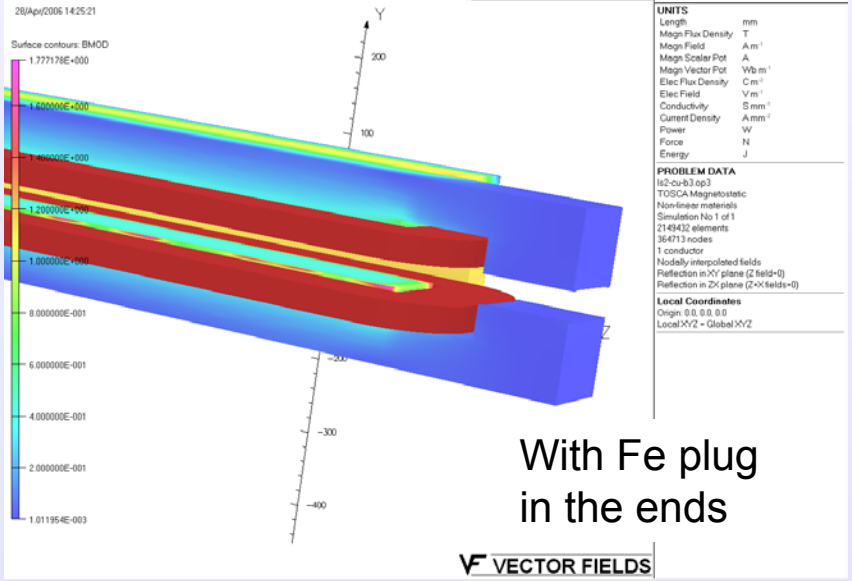


End Fields With and Without Iron Plug



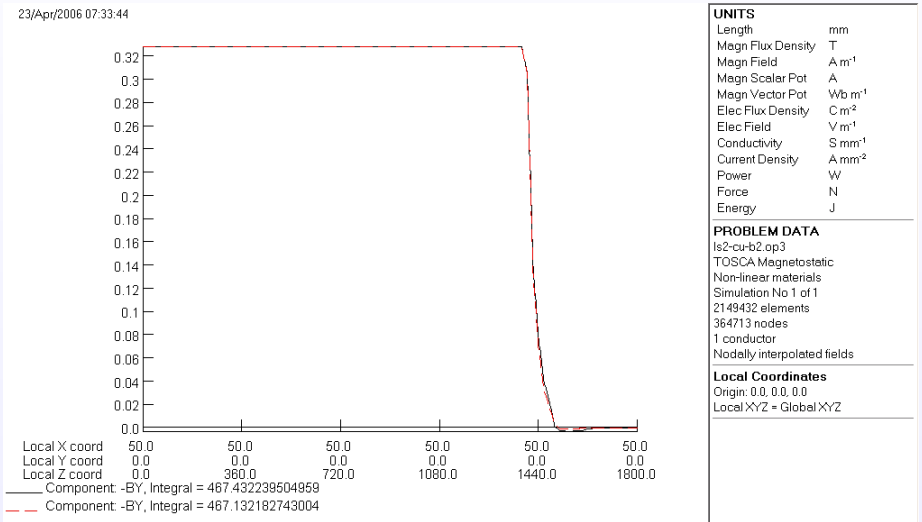
Without Fe plug in the ends

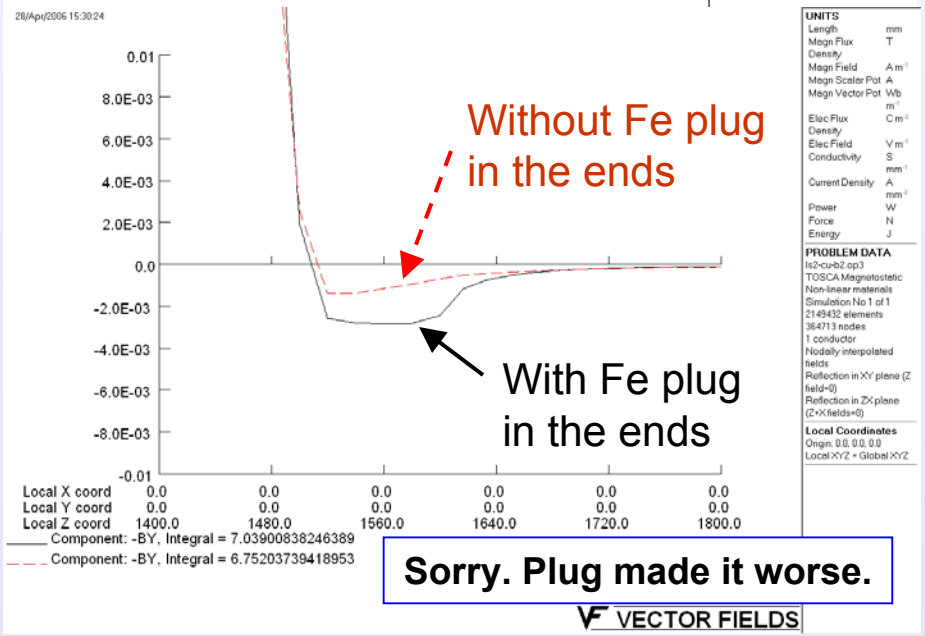
VECTOR FIELDS



With Fe plug in the ends

VECTOR FIELDS





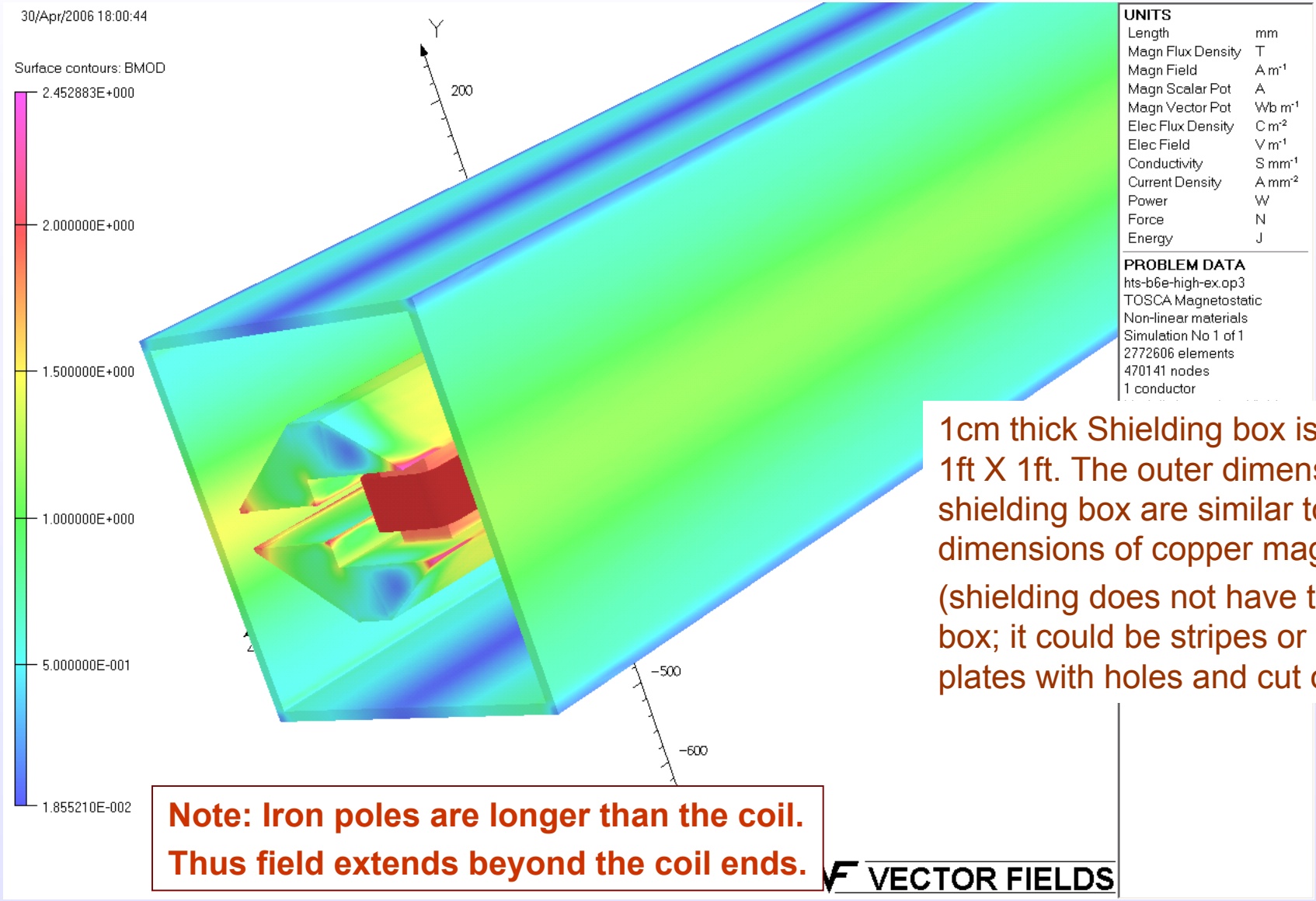
Without Fe plug in the ends

With Fe plug in the ends

Sorry. Plug made it worse.

VECTOR FIELDS

HTS Back-leg Powered Magnet (Without End Shields)

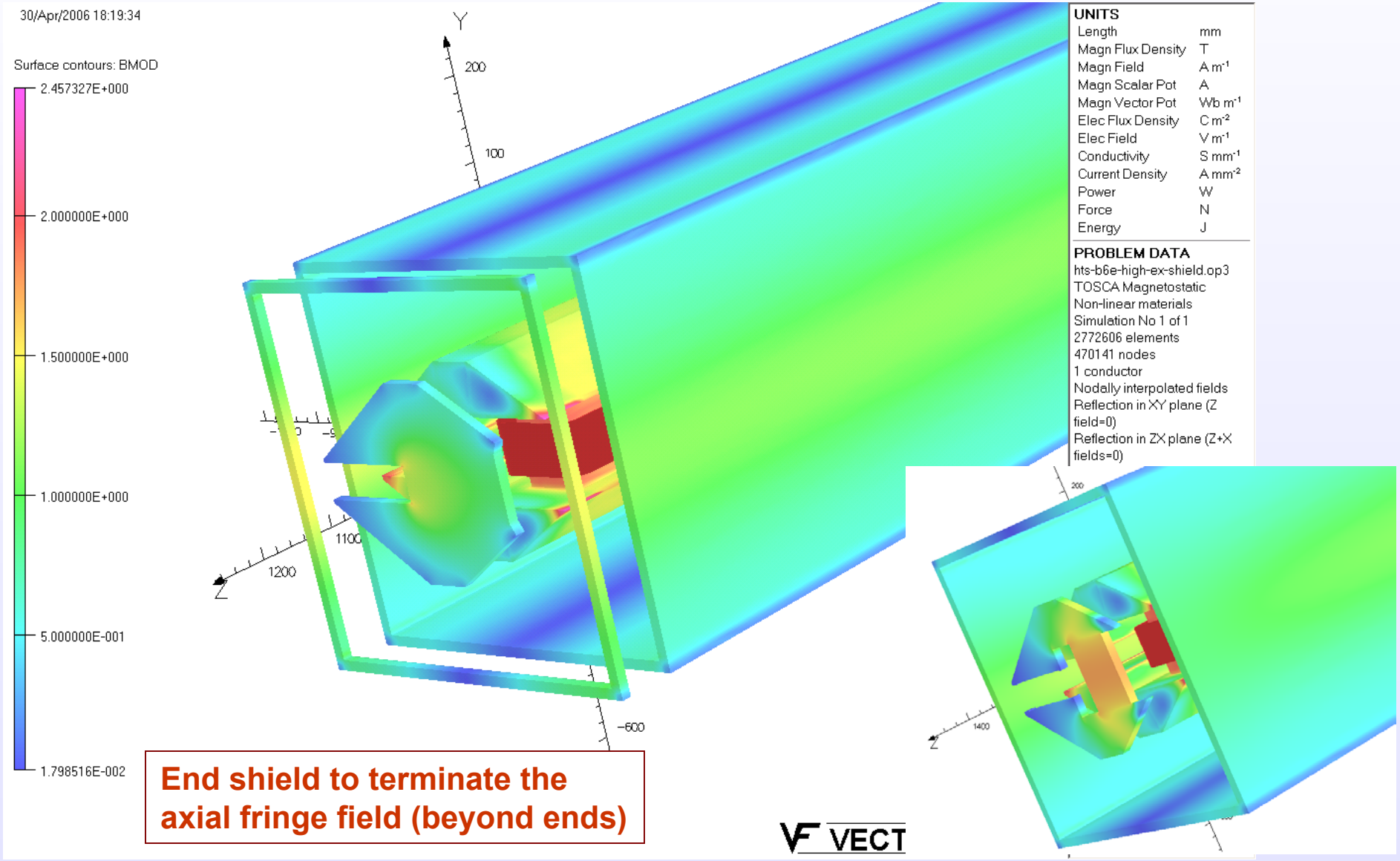


1cm thick Shielding box is about 1ft X 1ft. The outer dimension of shielding box are similar to overall dimensions of copper magnet.

(shielding does not have to be a box; it could be stripes or simple plates with holes and cut out, etc.)

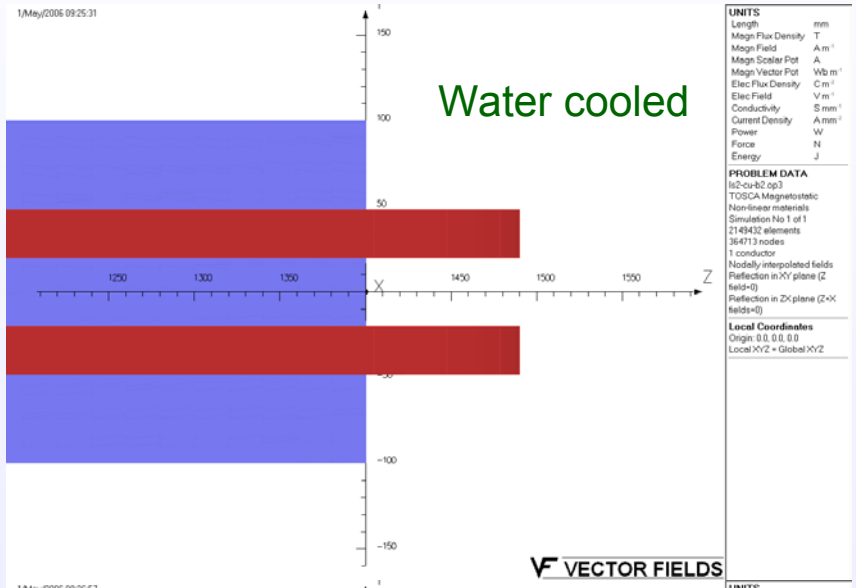
Note: Iron poles are longer than the coil. Thus field extends beyond the coil ends.

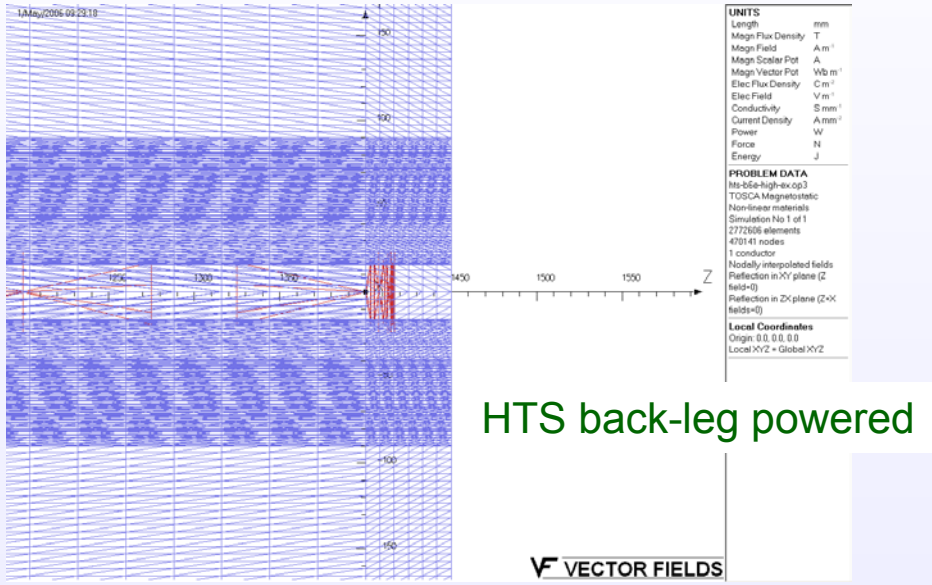
HTS Back-leg Powered Magnet (With End Shields)

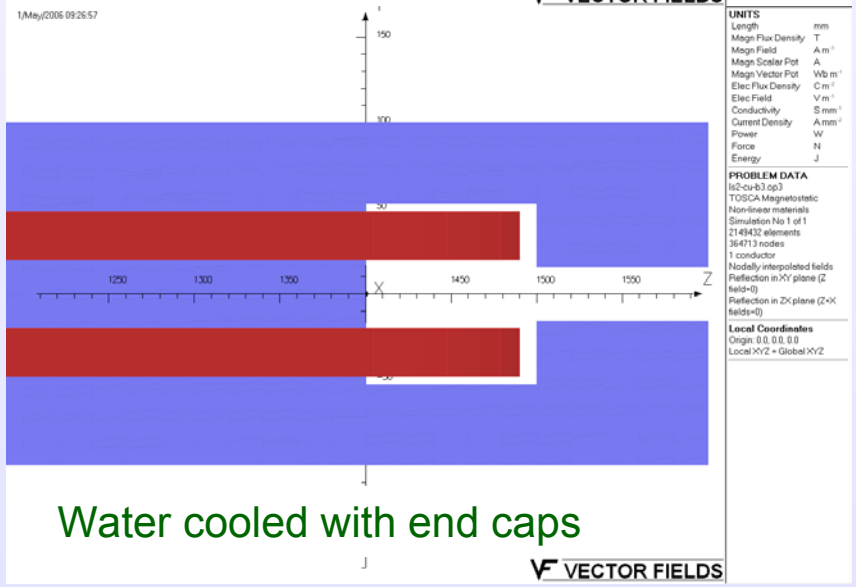


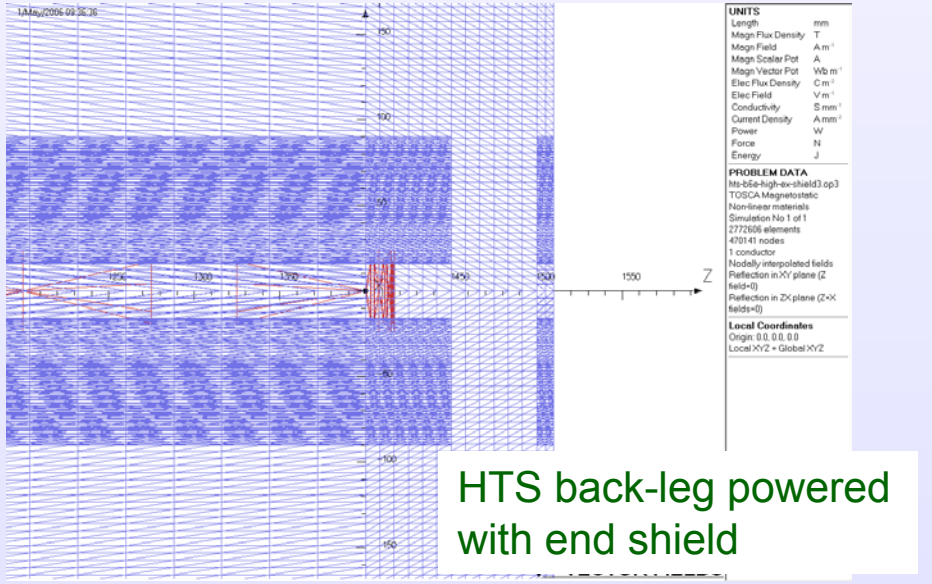
End shield to terminate the axial fringe field (beyond ends)

Fringe Field Beyond the Magnet Ends
(All designs have same inner coil length)

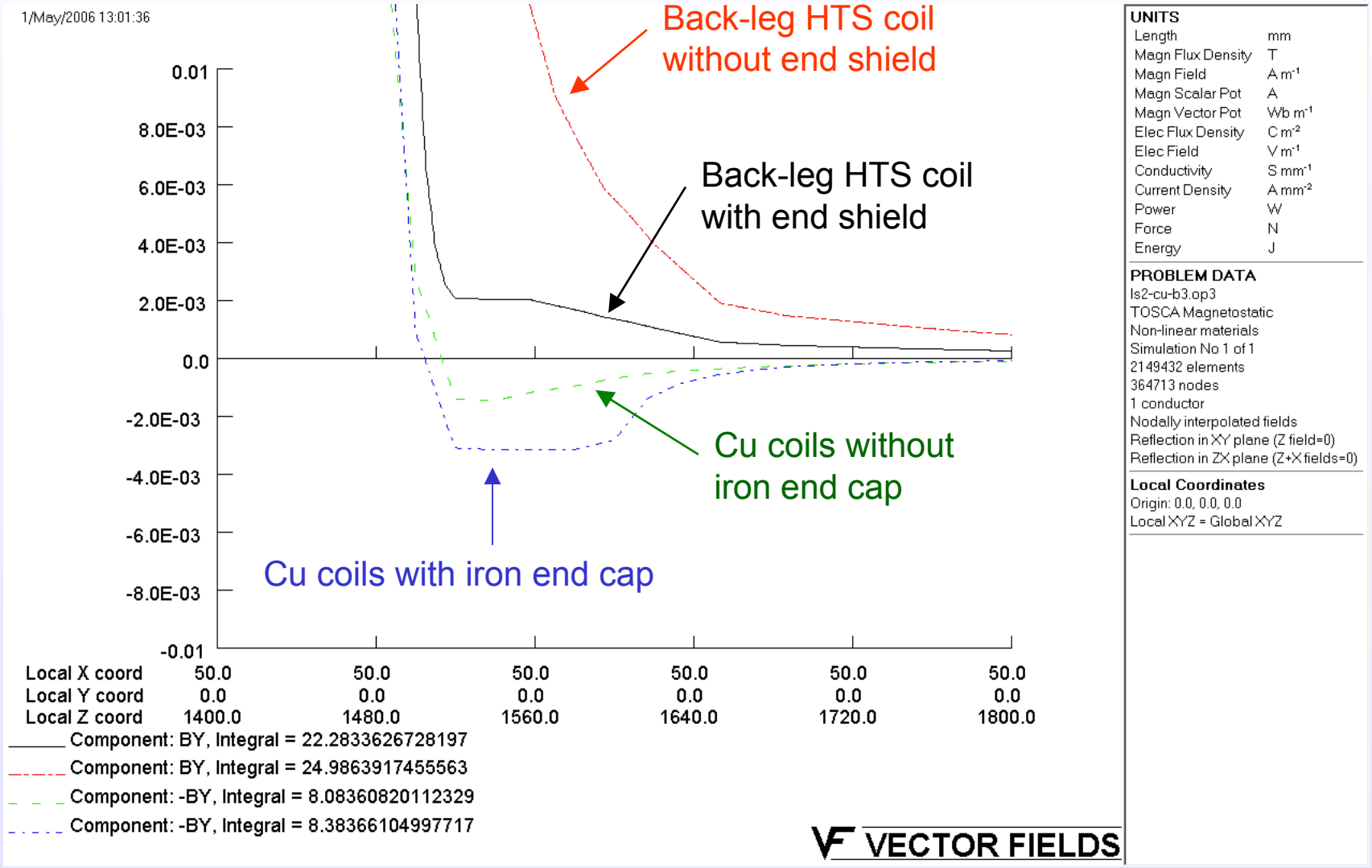






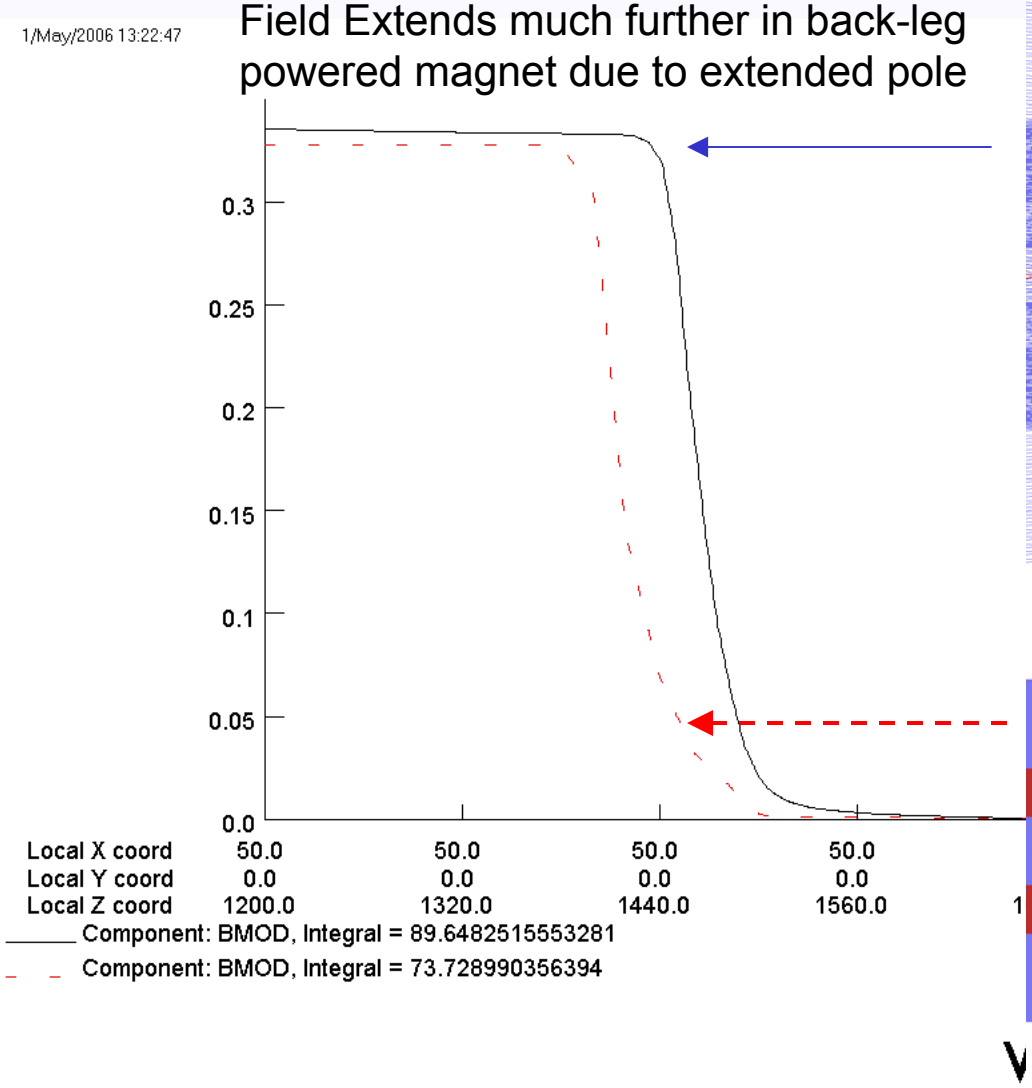


Field Beyond Ends in Copper and HTS Coil Magnets

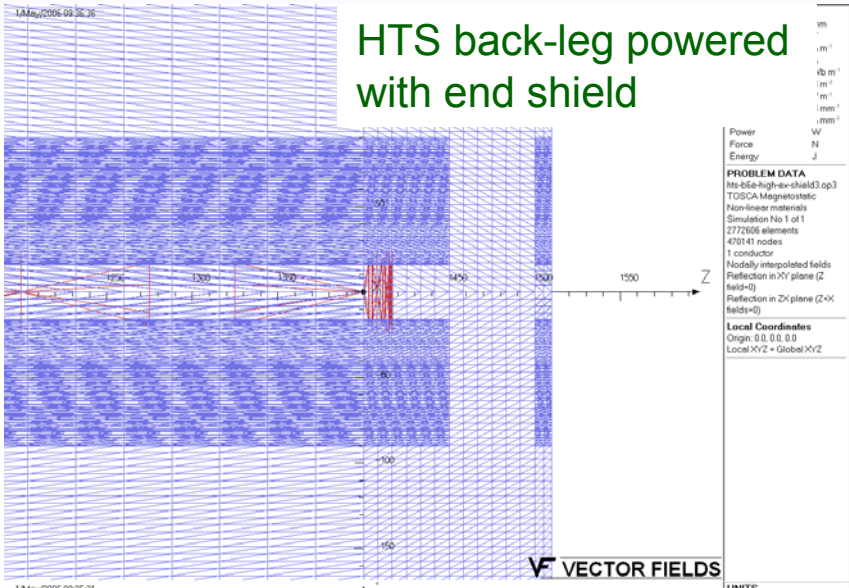


Extent of Field in Cu Coil Design And Back-leg Powered HTS Design

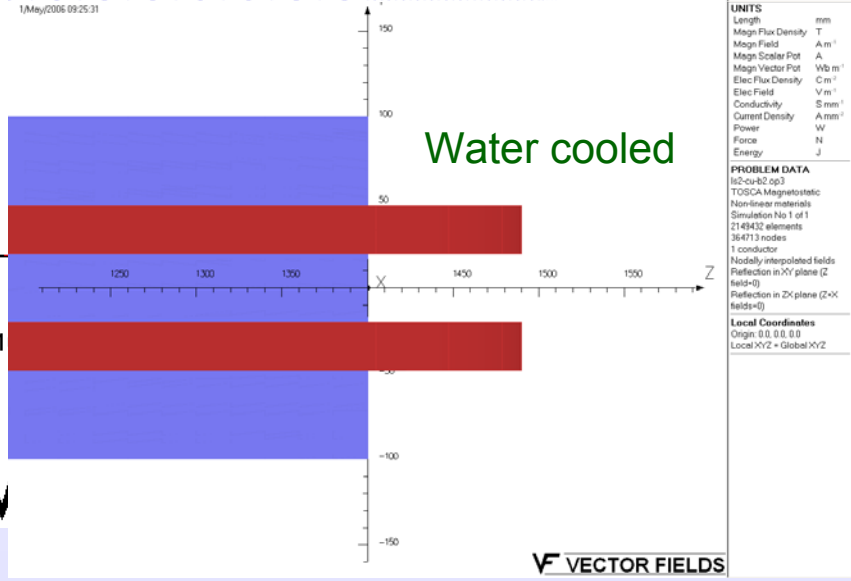
Field Extends much further in back-leg powered magnet due to extended pole



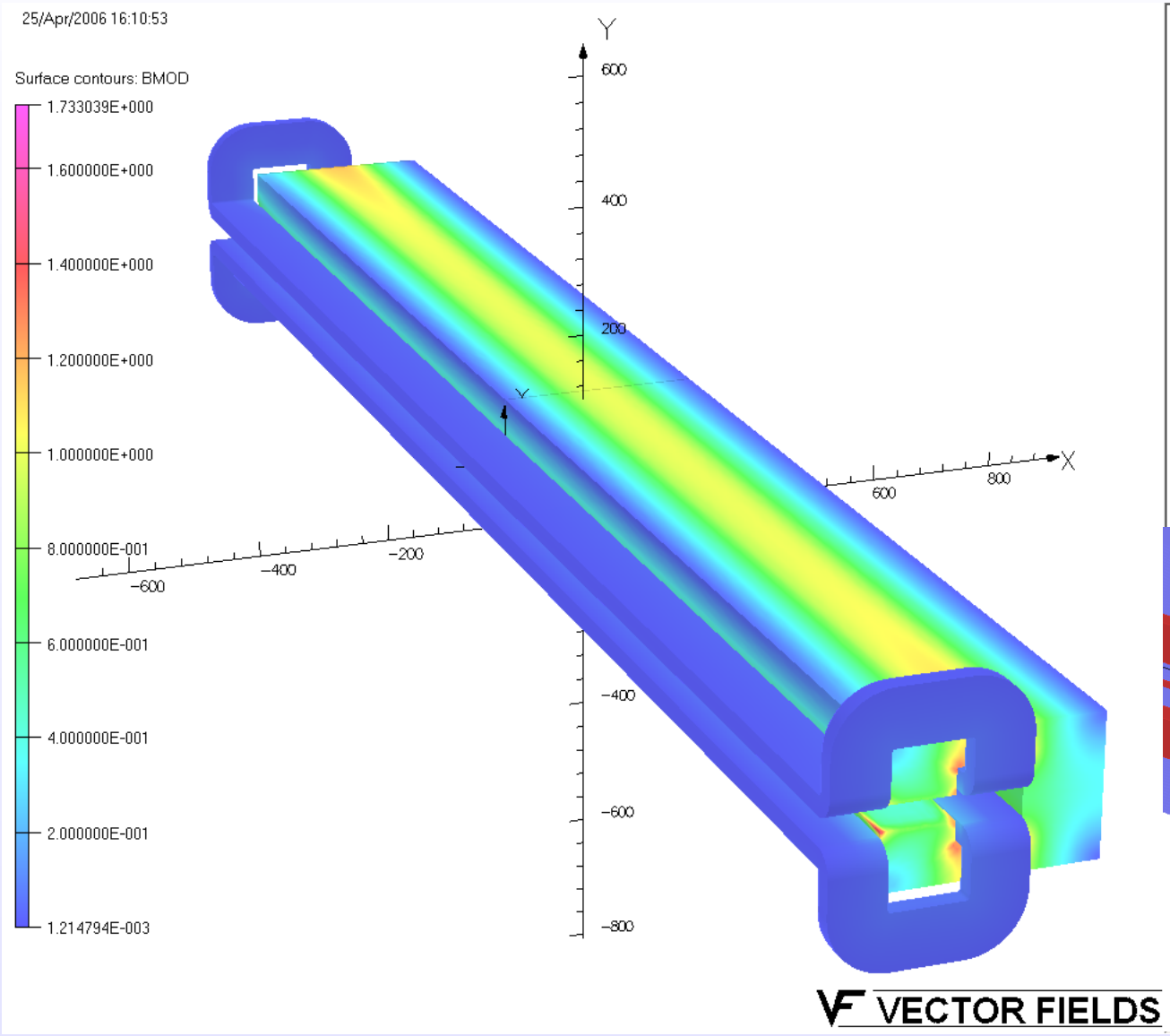
HTS back-leg powered with end shield



Water cooled



Bedstead Coils To Reduce Dead Region In The Ends



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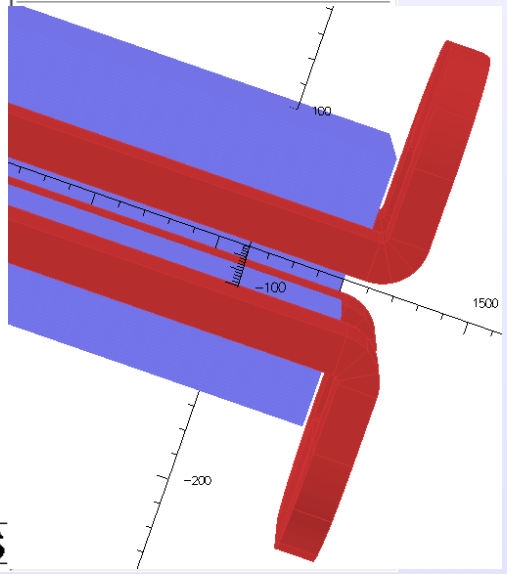
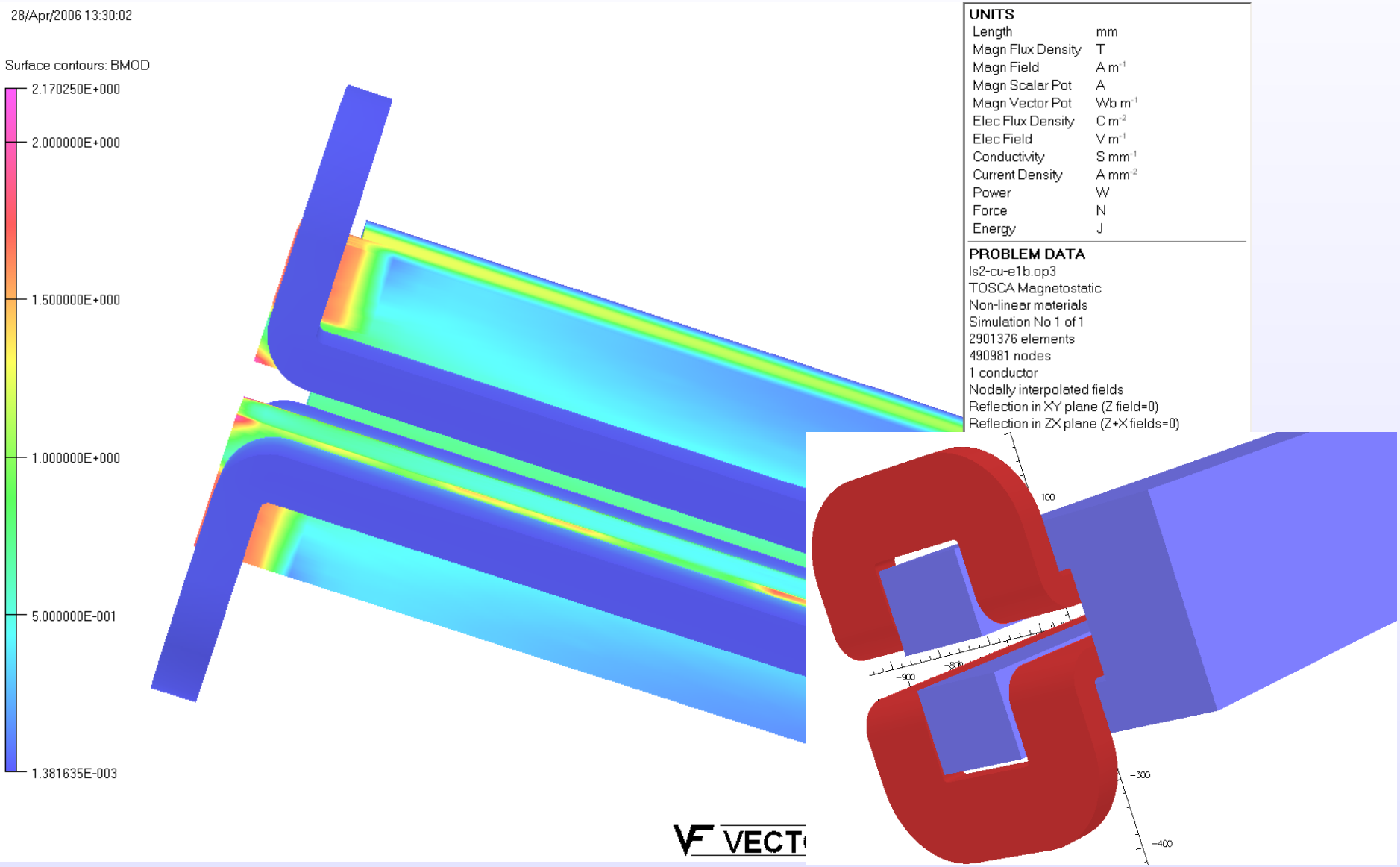
Length	mm
Magn Flux Density	T
Magn Field	A m^{-1}
Magn Scalar Pot	A
Magn Vector Pot	Wb m^{-1}
Elec Flux Density	C m^{-2}
Elec Field	V m^{-1}
Conductivity	S mm^{-1}
Current Density	A mm^{-2}
Power	W
Force	N
Energy	J

PROBLEM DATA

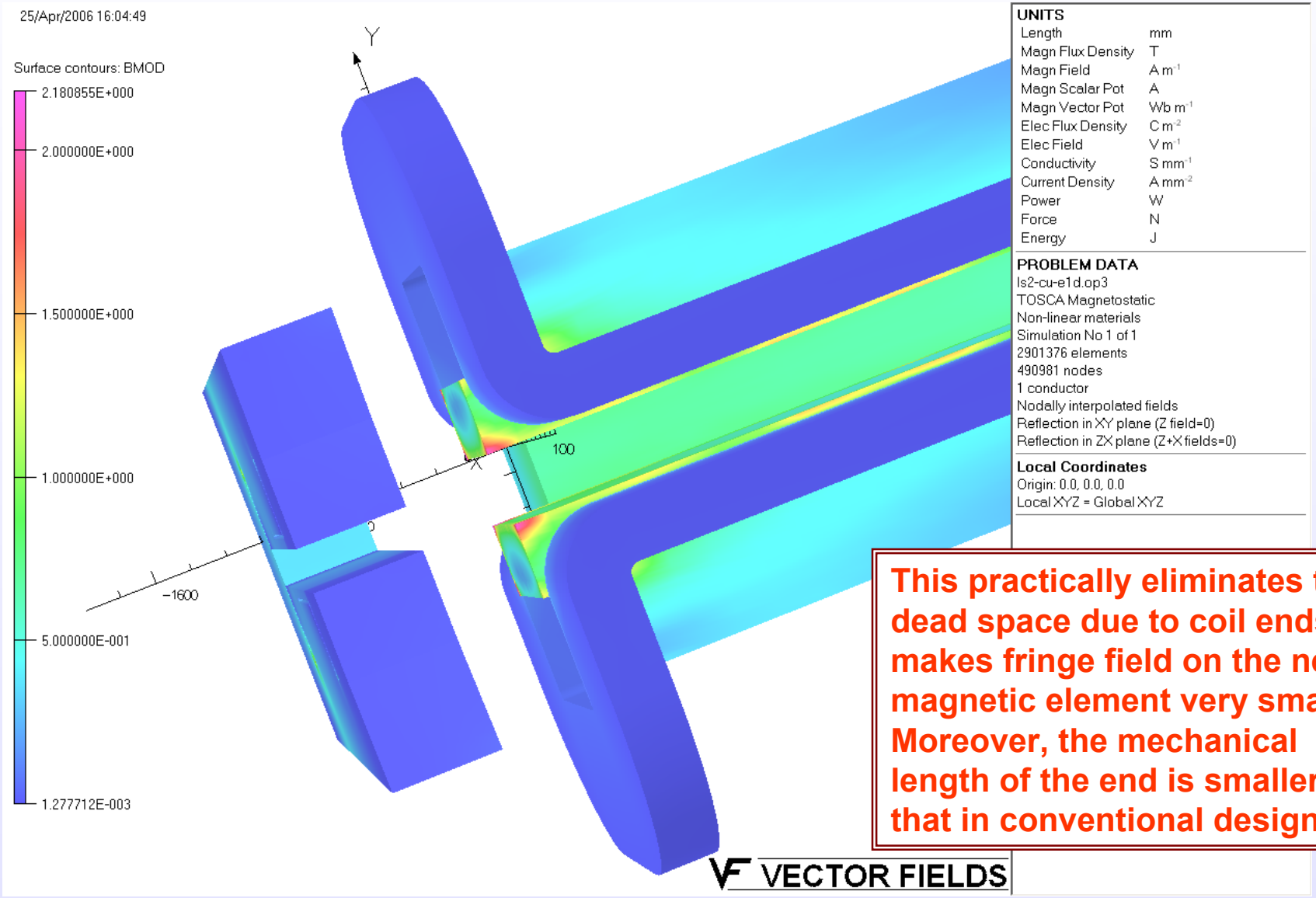
ls2-cu-e1c1.op3
TOSCA Magnetostatic
Non-linear materials
Simulation No 1 of 1
2901376 elements
490981 nodes
1 conductor
Nodally interpolated fields
Reflection in XY plane (Z field=0)
Reflection in ZX plane (Z+X fields=0)



Extended Pole Piece to Completely Eliminate Loss in Magnetic Length Due to Ends

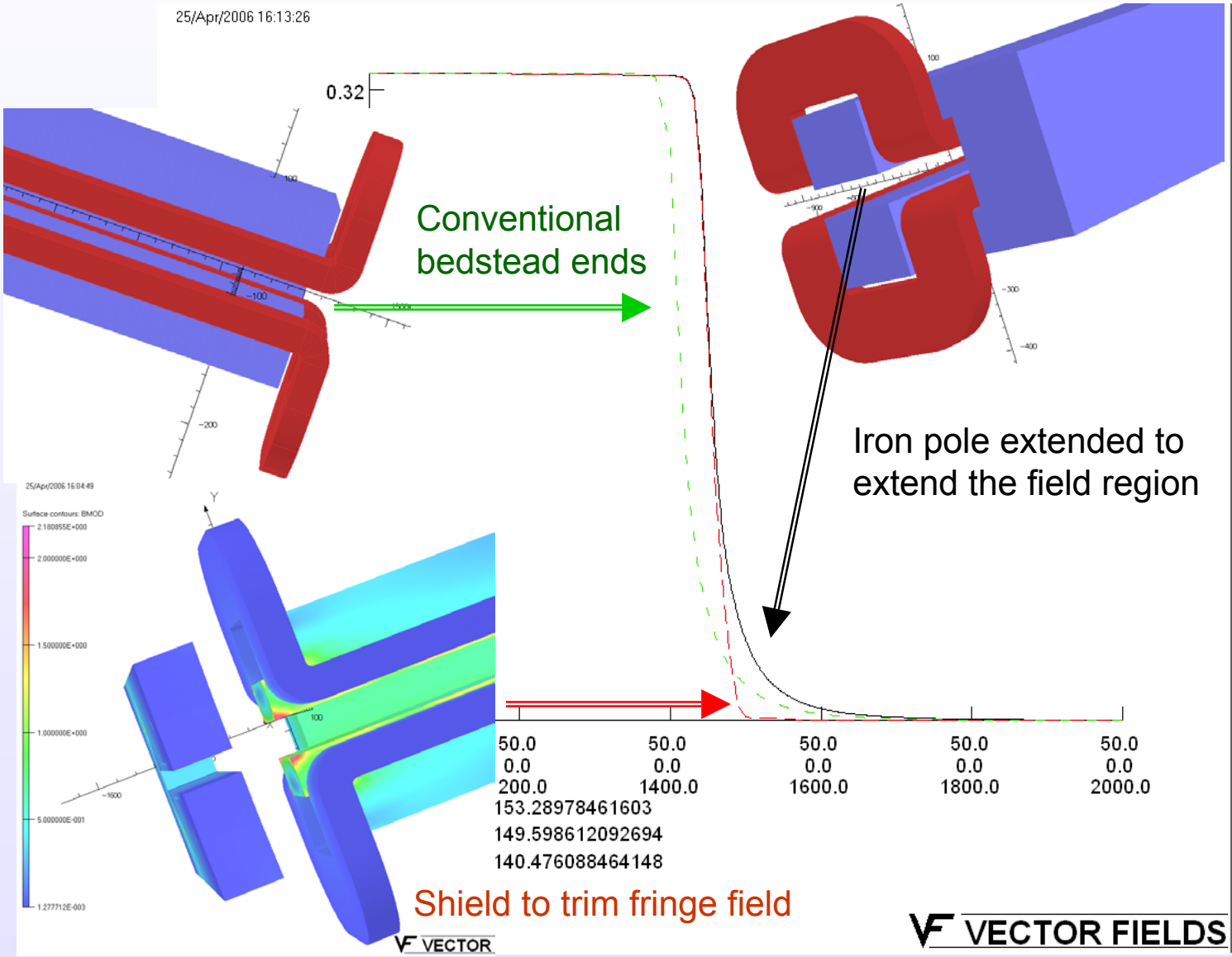


Extended Pole Piece And Axial Shielding



This practically eliminates the dead space due to coil ends and makes fringe field on the next magnetic element very small. Moreover, the mechanical length of the end is smaller than that in conventional designs.

Magnet Ends Optimized For Machine



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Conductivity	S mm^{-1}
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