Thermal Performance of HT-7U TF Coil under Plasma Disruption

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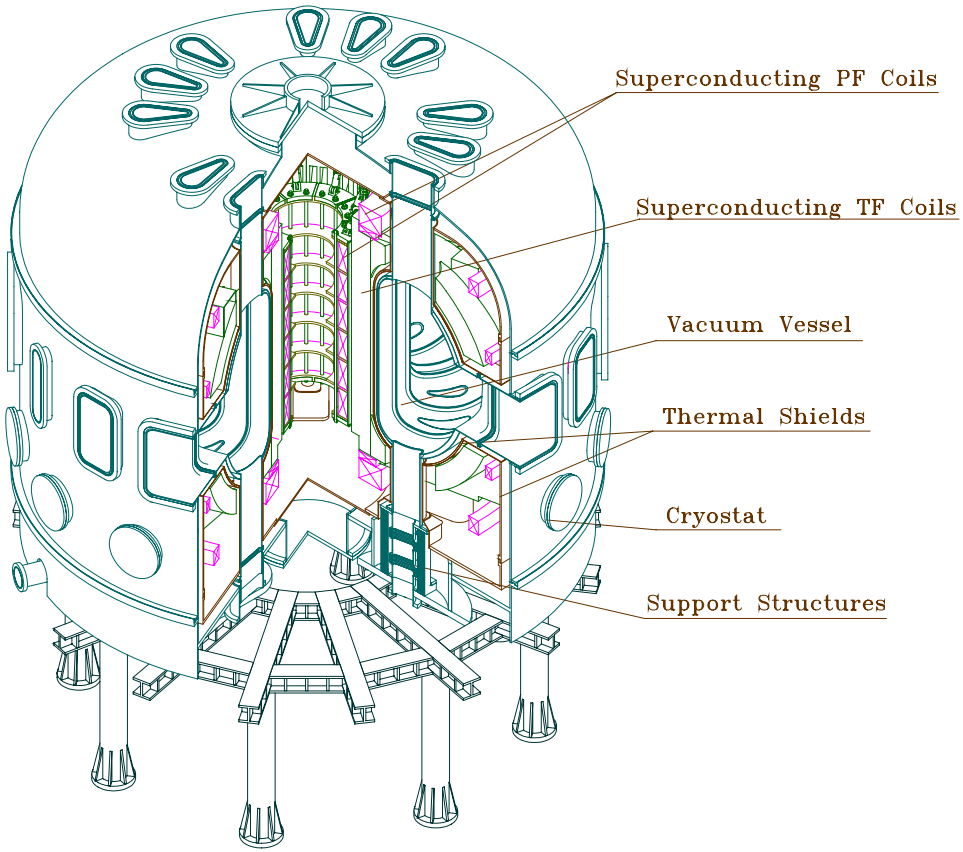
Outline

- Introduction
- Electromagnetic and thermal models of HT-7U TF coil system
- Solution results and Stability of CICC
- Summary

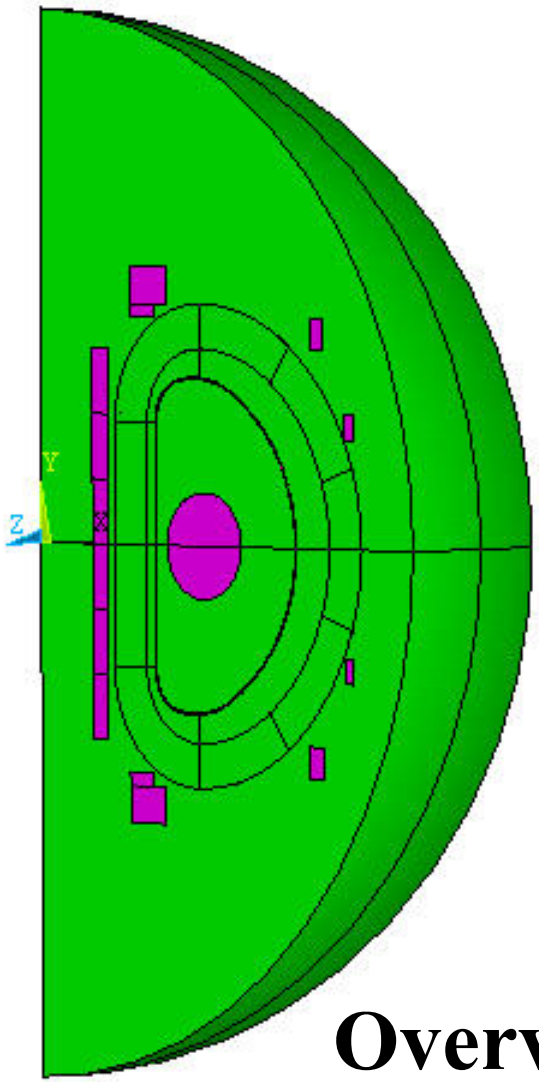
Introduction

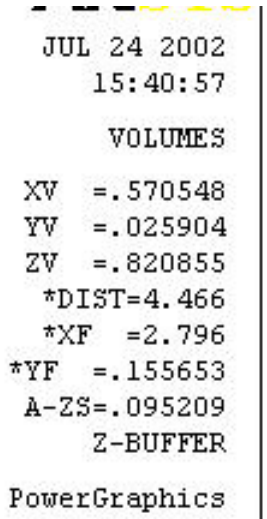


- HT-7U
  - R=1.7 m, a=0.4m, Ip=1.5 MA
  - All magnets Superconducting
  - Long pulse->steady state
- HT-7U TF coils
  - 16
  - NbTi/Cu, LHe(4bar, 4 K)
- Large heating rate to TF cases due to plasma disruption

Model

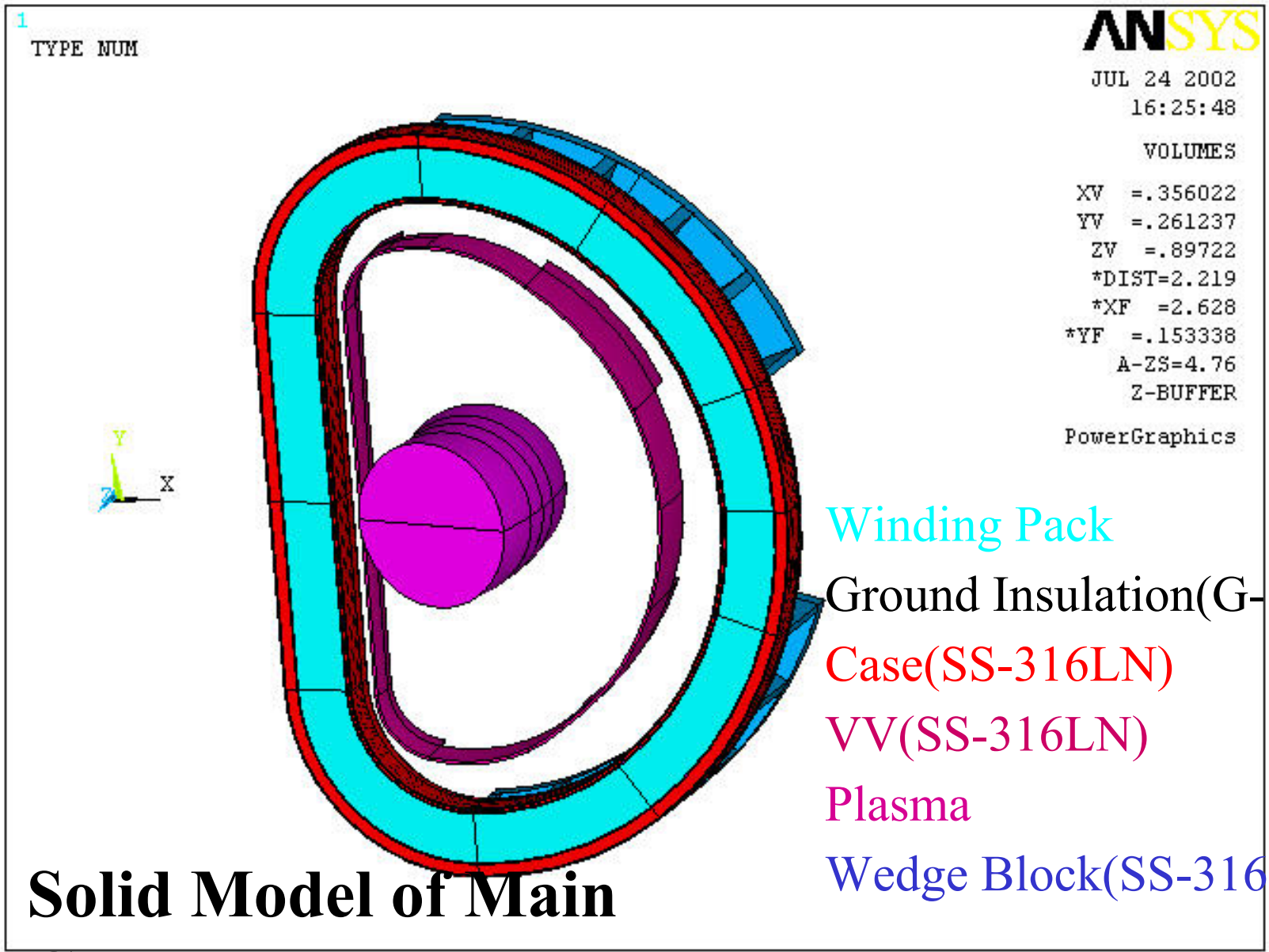
- 14 PF coils
- Plasma Column
- VV
- Winding pack
- Ground Insulation
- Wedges
- Air



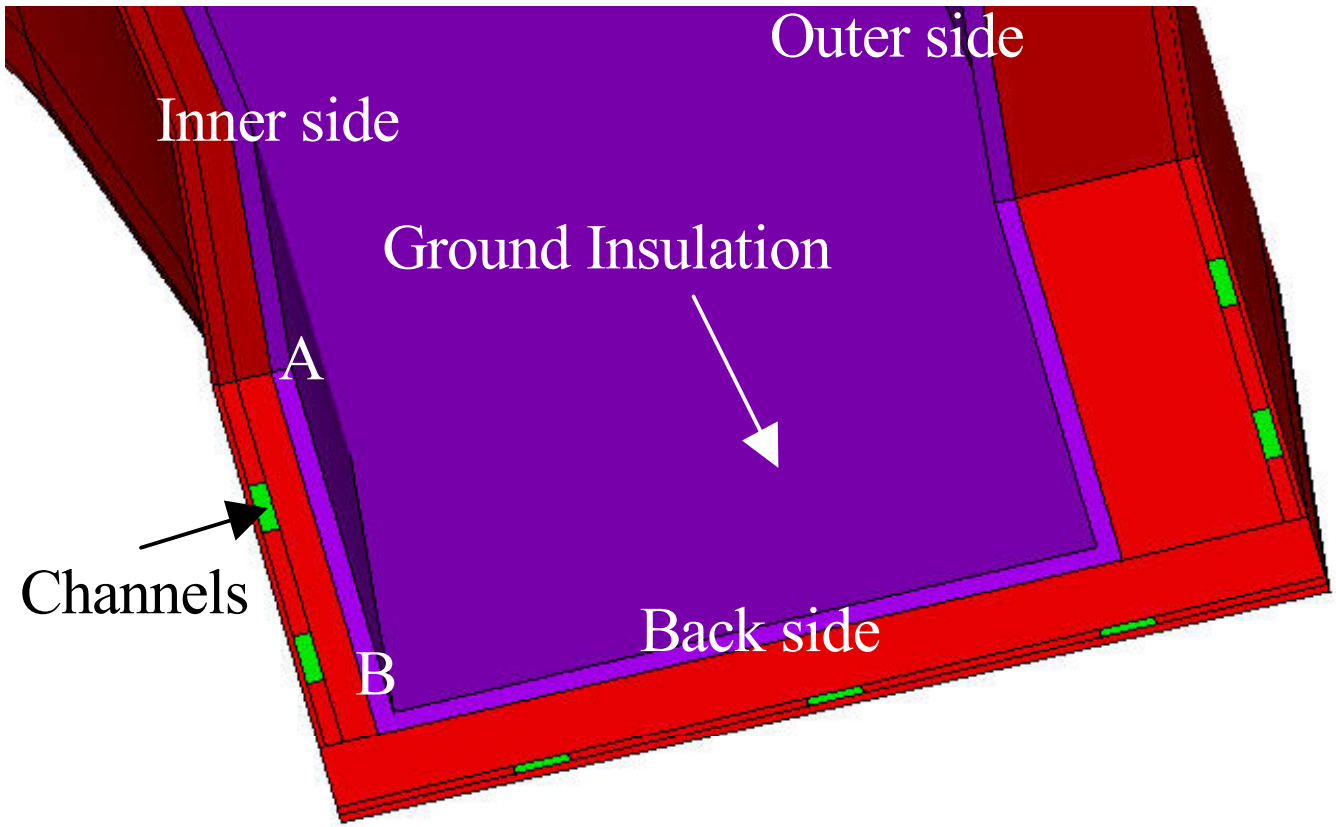


- **Available to extend for structural (stress) analysis**
- **Parameterized for extension/modification**

Overview of Solid Model



Solid Model of Main Components



Section View of TF Case

FE Model and BC for EM Calculation

- FE Model
  - Solid97 elements
    - MVP method
    - With DOF of Volt in E conducting regions(VV, case and wedge block)
- Boundary Conditions
  - 1/16 cyclic symmetry
  - Far field (infin111)
- B parallel on center axis
- Load
  - Plasma current decay characterized by(center disruption):

    $Ip=Ip0*\exp(-t/tconst)$

    $Ip0=1.5$ MA, $tconst=3$ ms

Usage of ANSYS PHYSICS

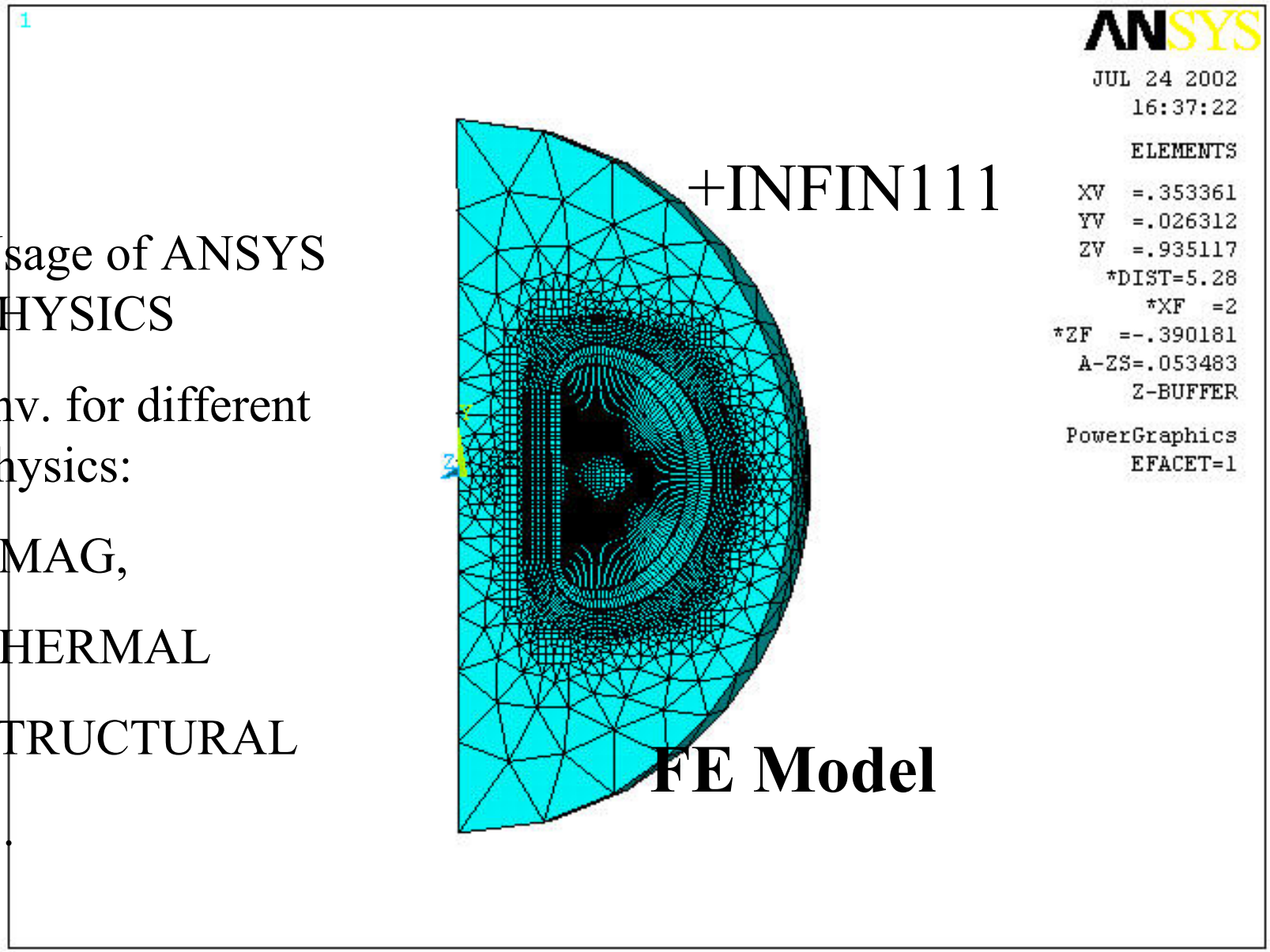
env. for different physics:

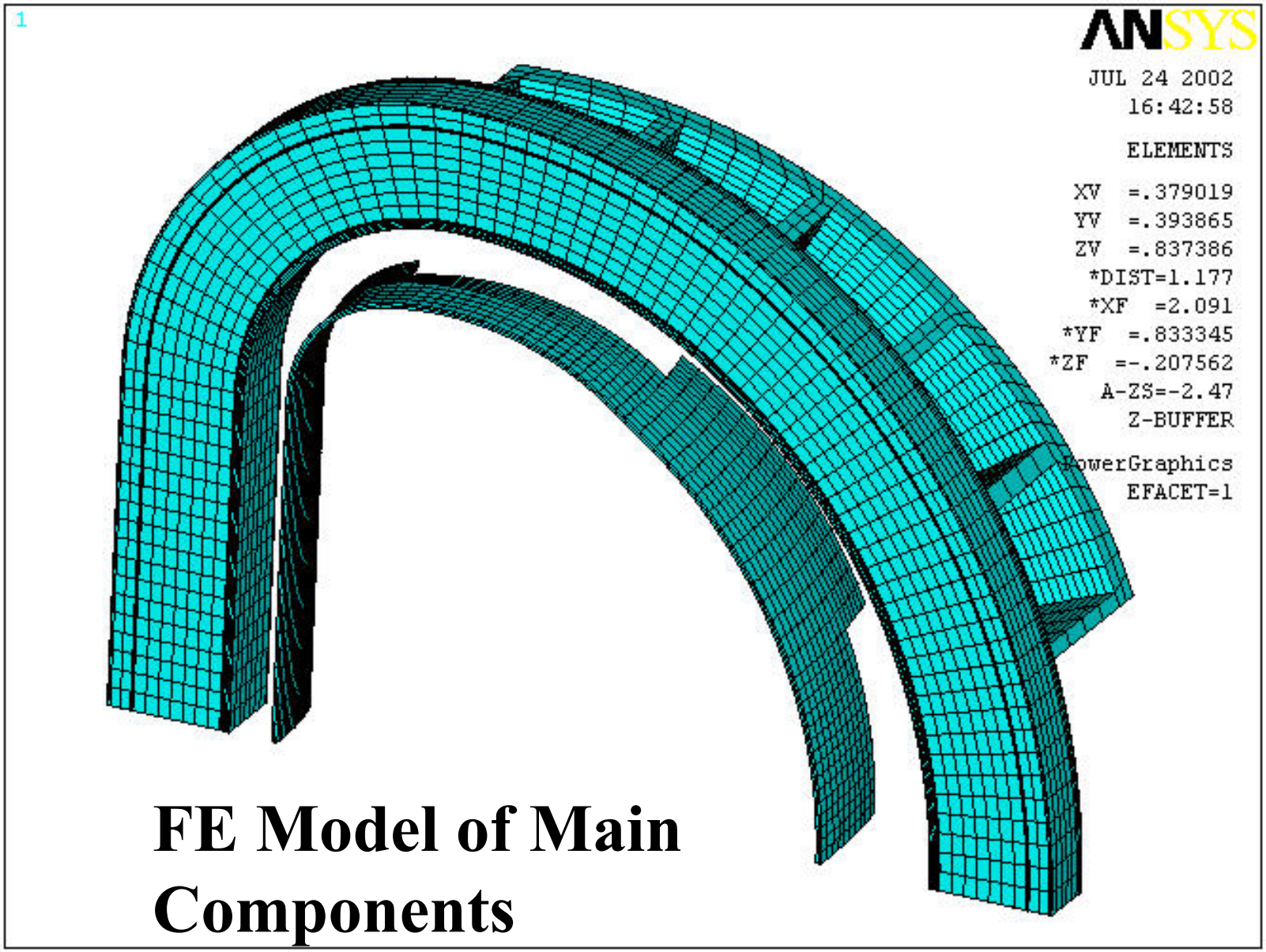
EMAG,

THERMAL

STRUCTURAL

…

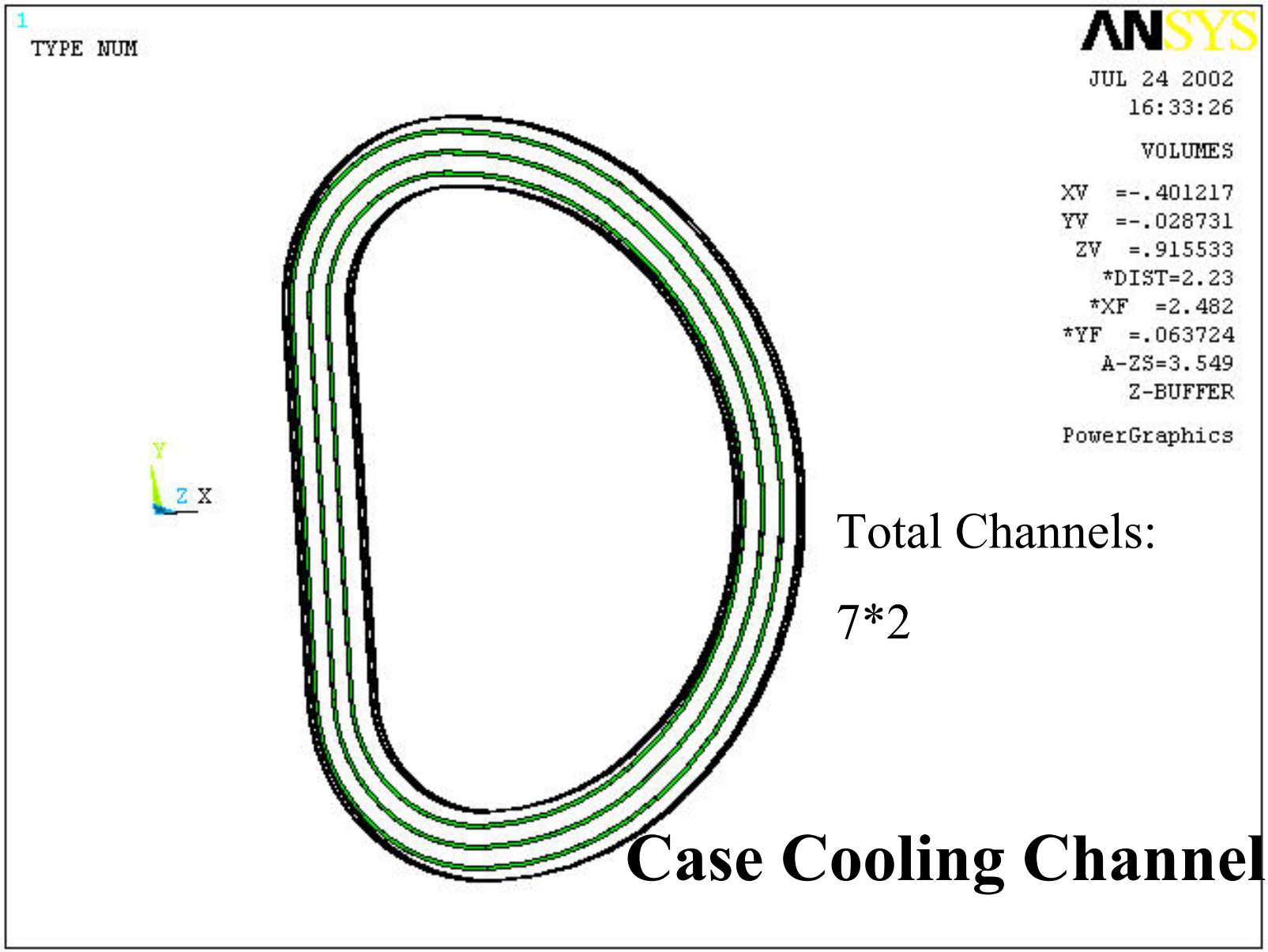




FE Model of Main Components

FE model and boundary conditions for thermal calculation

- One half of the whole FE model because of symmetry
- Element types:
  - Solid70(hexahedral, 8 nodes) for all solid structures
  - SURF152/fluid116 for the heat convection between case and the coolant
- Loads & boundary conditions
  - T_{ini}=4 K
  - Mass flow rate: 260/16/2 g/s for a half case
    2.5 g/s for CICC
  - Heating: from EMAG calculation
  - Coolant inlet temperature: 4 K
- Channel size, (22-2*1.5)mm*(8-2*1.5) mm

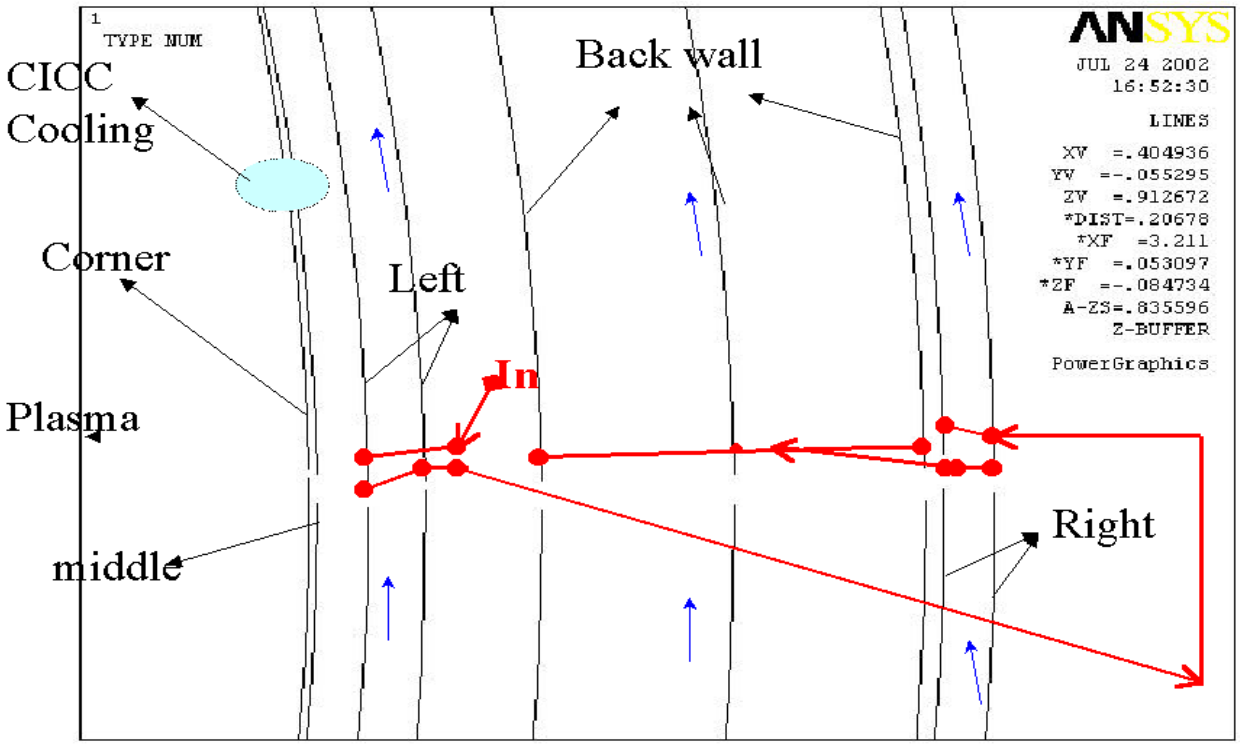


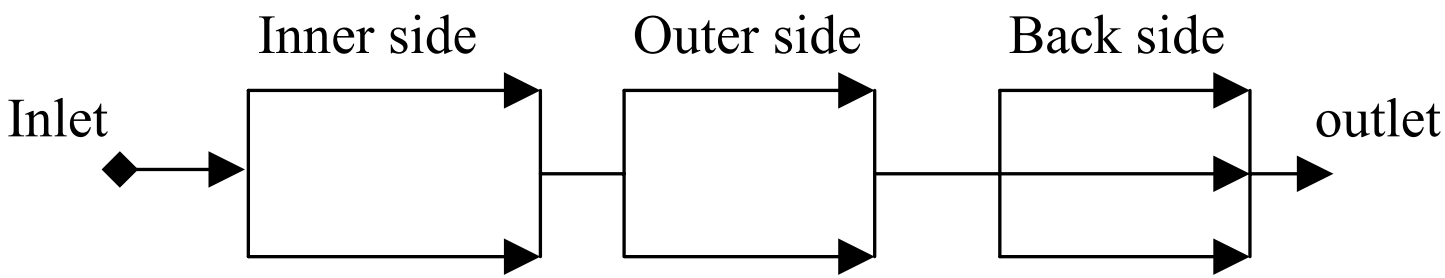
Total Channels:

7*2

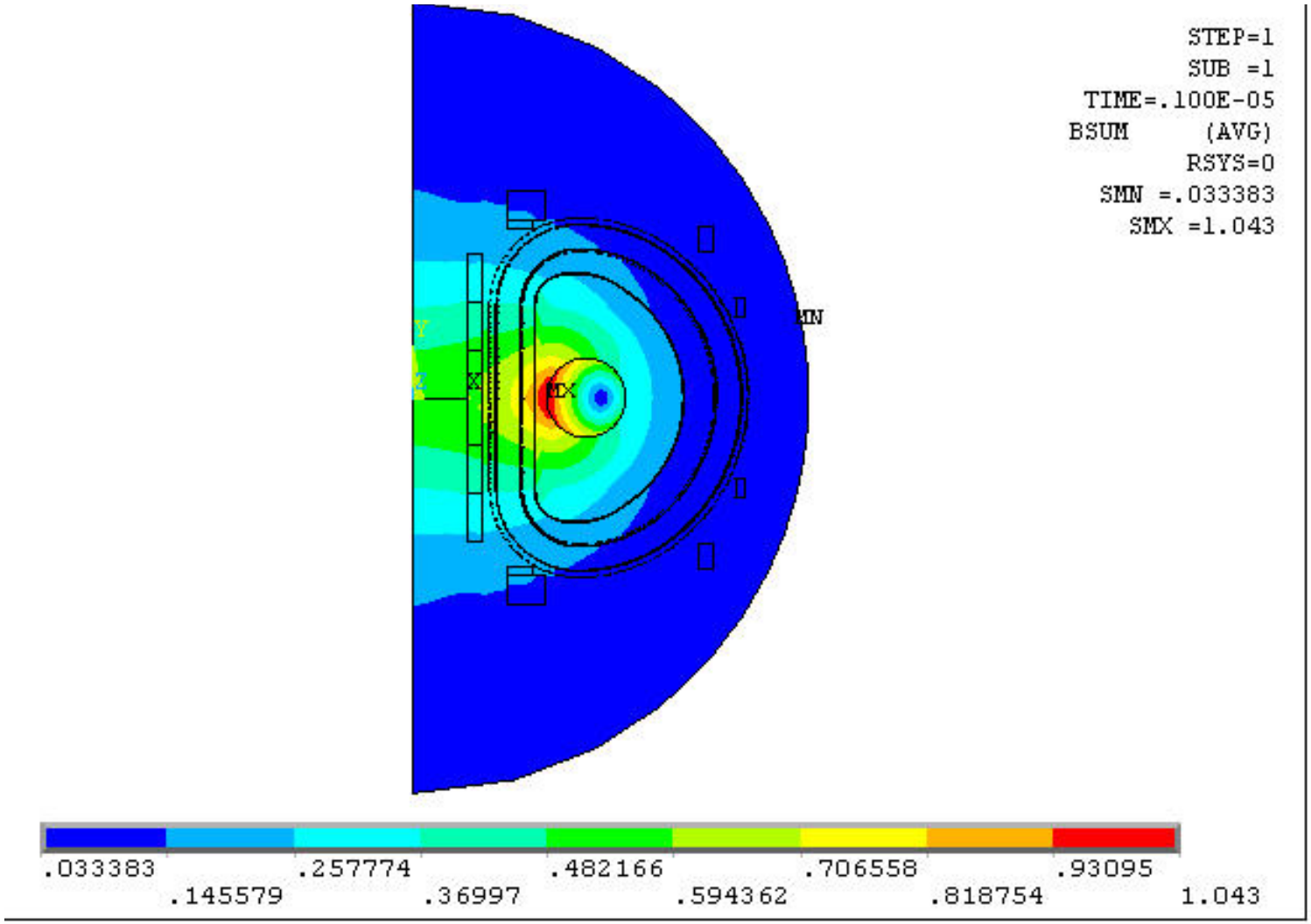
Case Cooling Channels

Coolant flow diagram

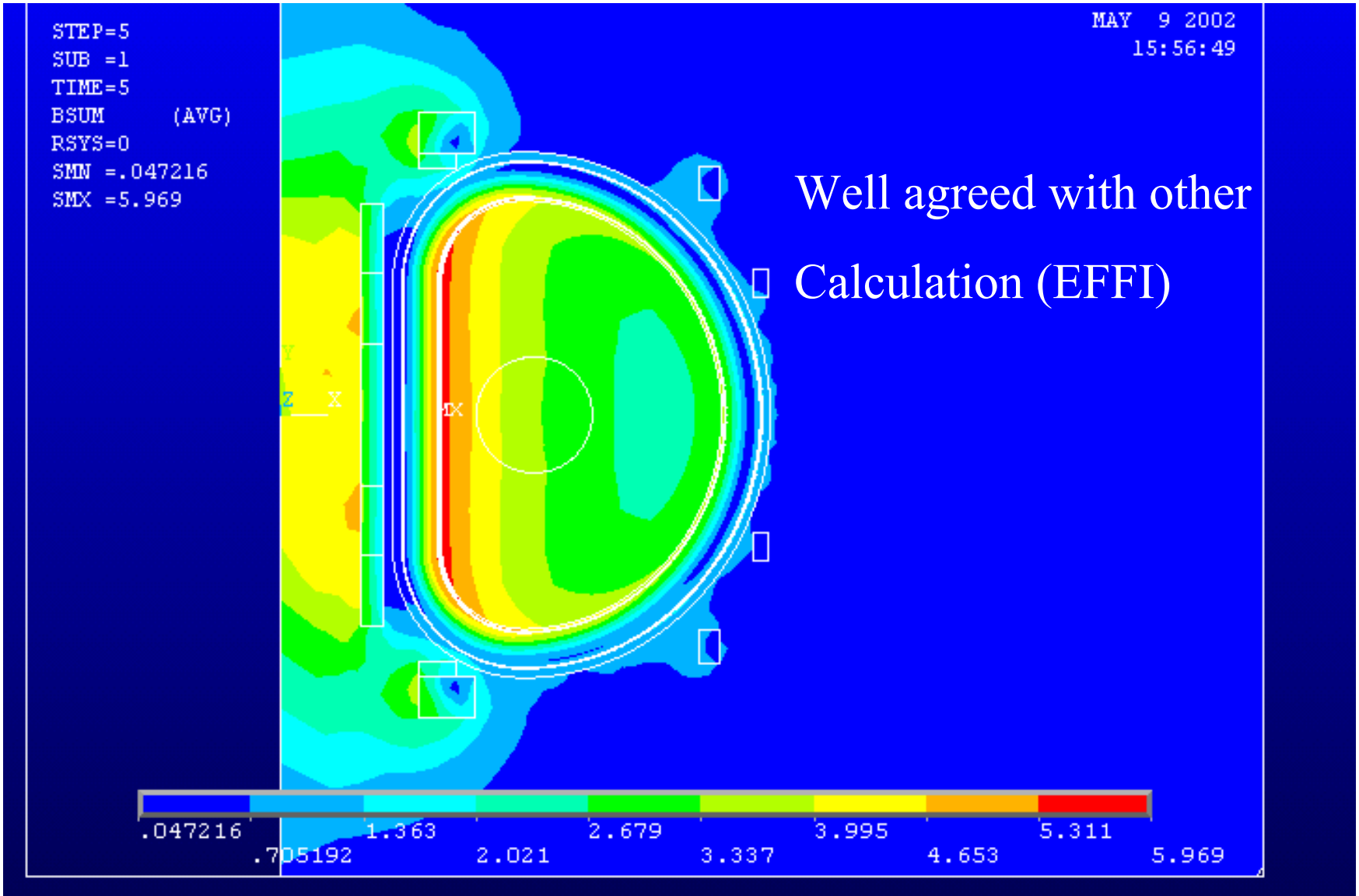




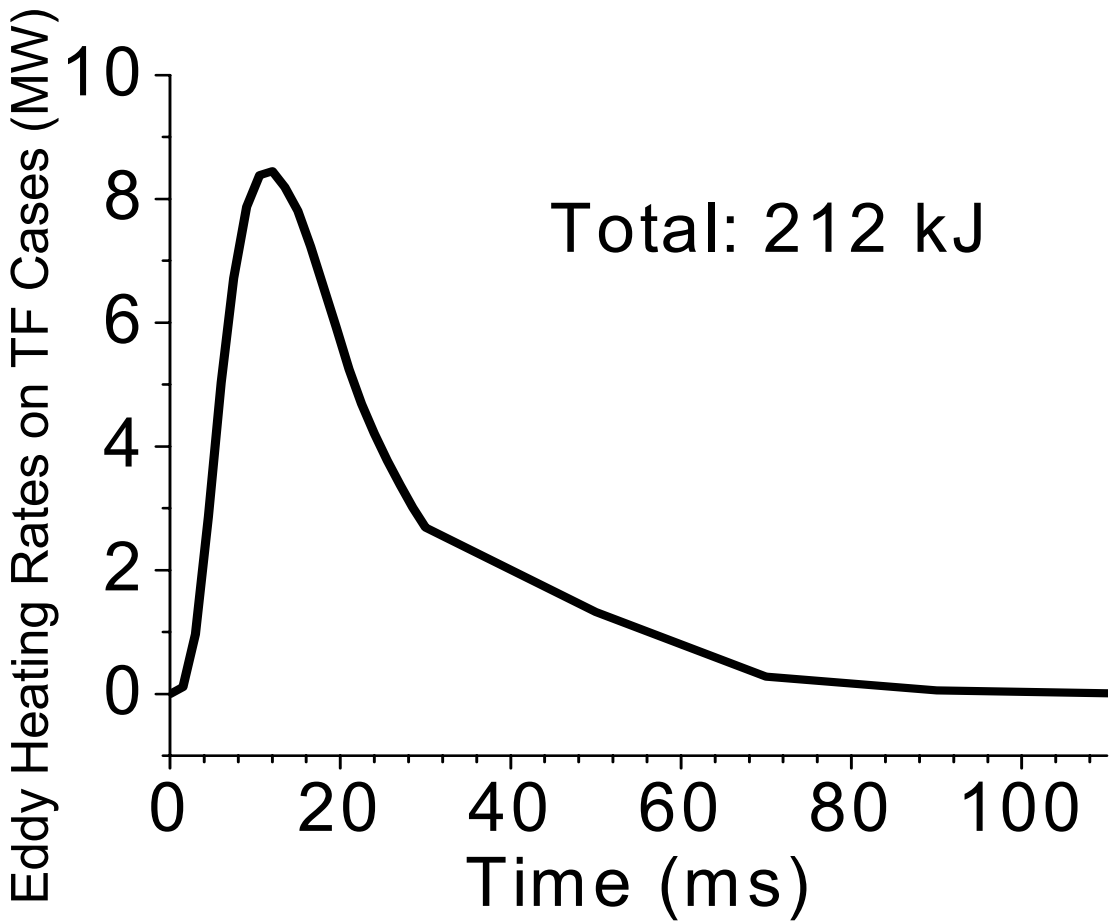
Results: Magnetic field by Ip



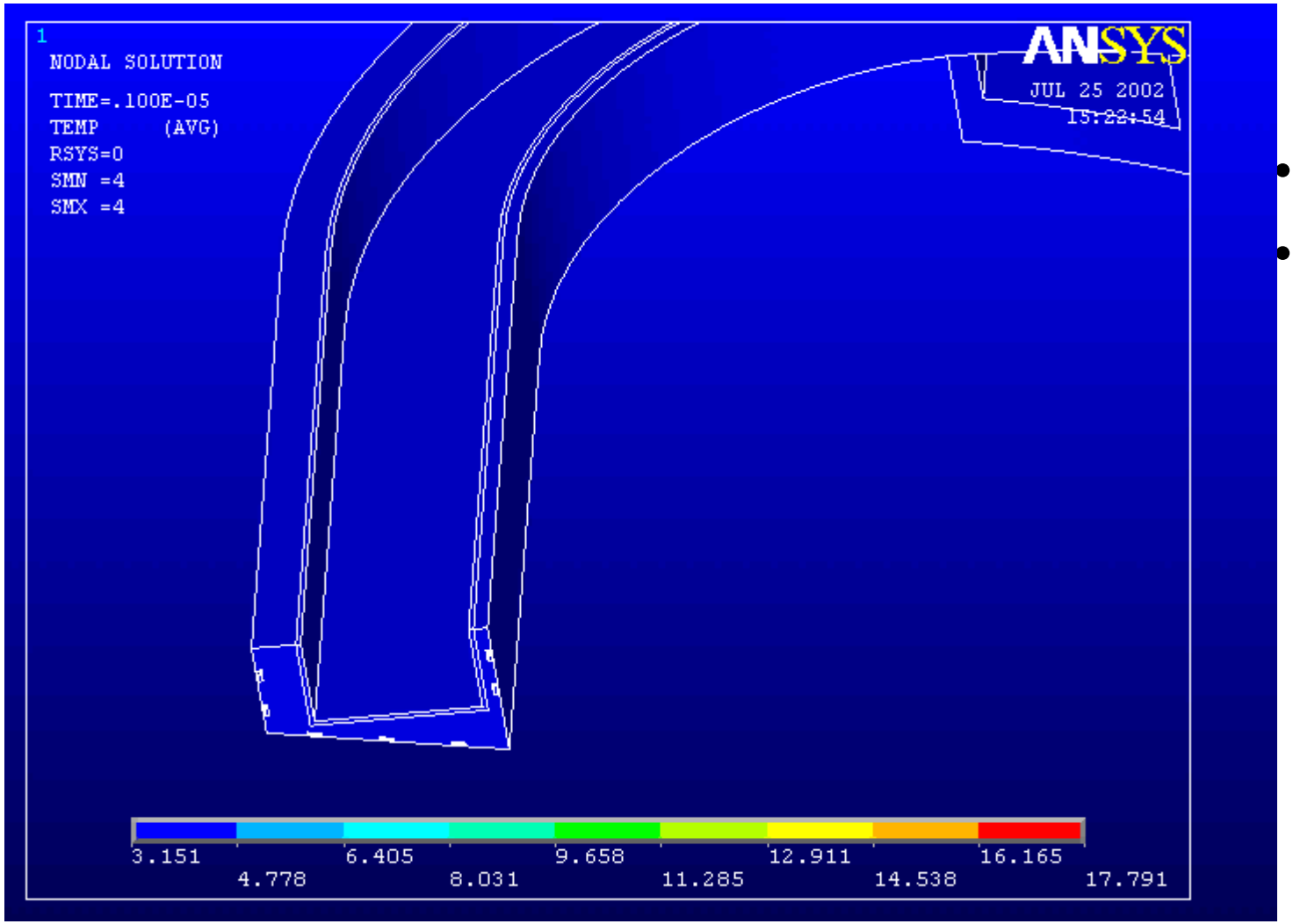
Example: whole magnetic field calculation



Results: Eddy Current Heat dissipation on Cases



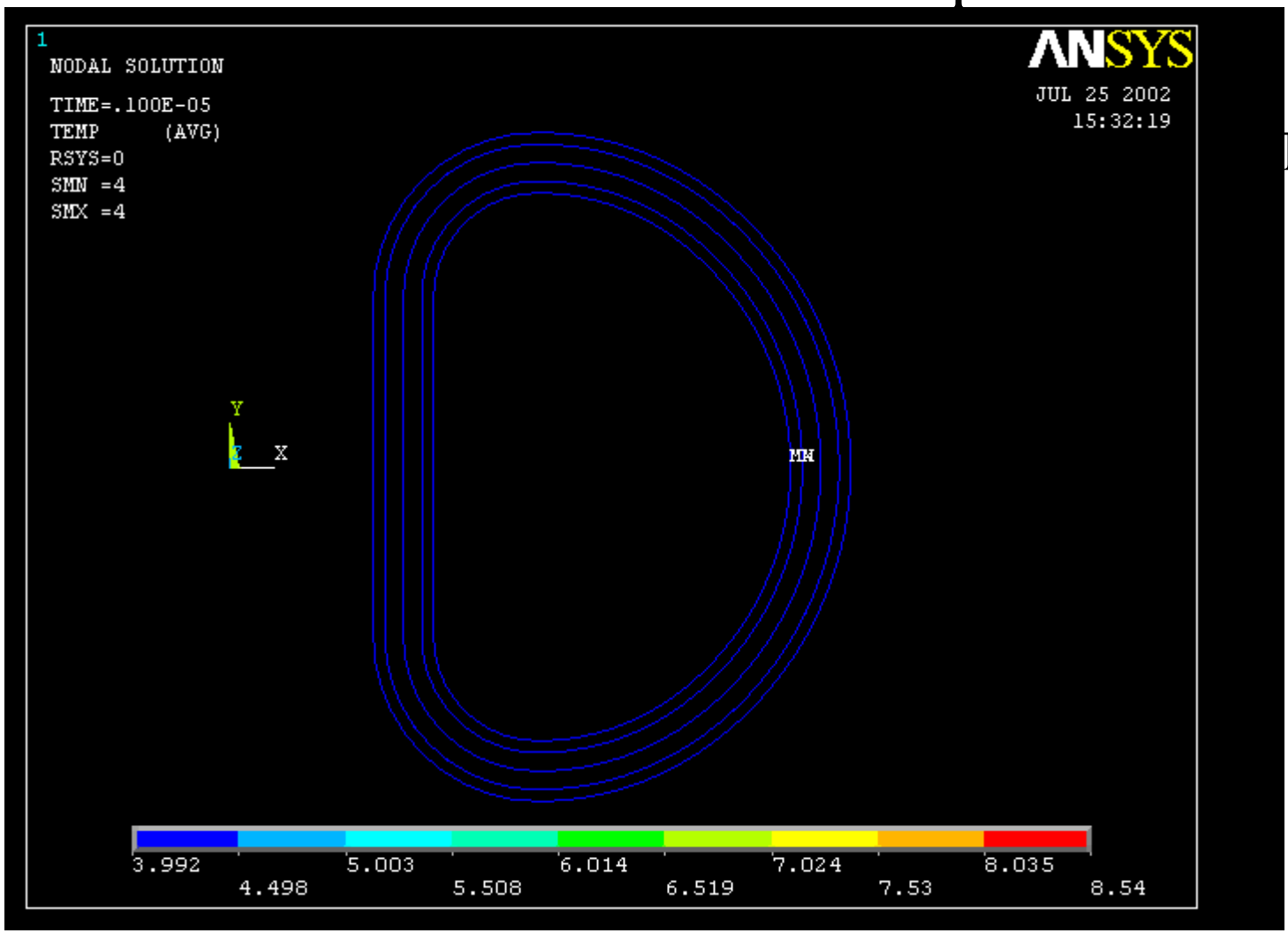
Results: Case Temperature Evolution



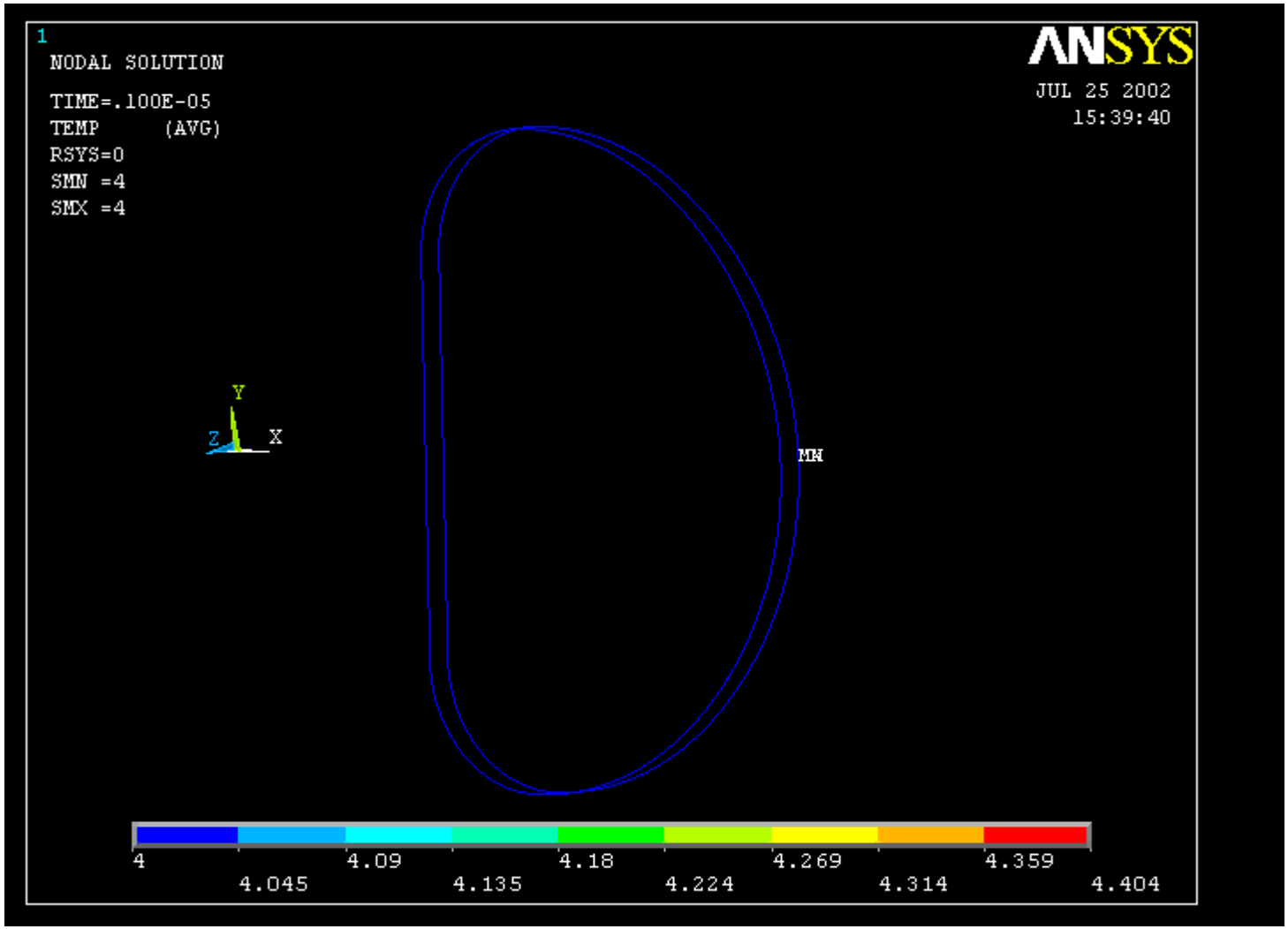
- Tmax: 19 K
- Recover Time:

  3 min.

Results: Case Coolant Temperature Evolution



Tmax: 8.9K


1
NODAL SOLUTION
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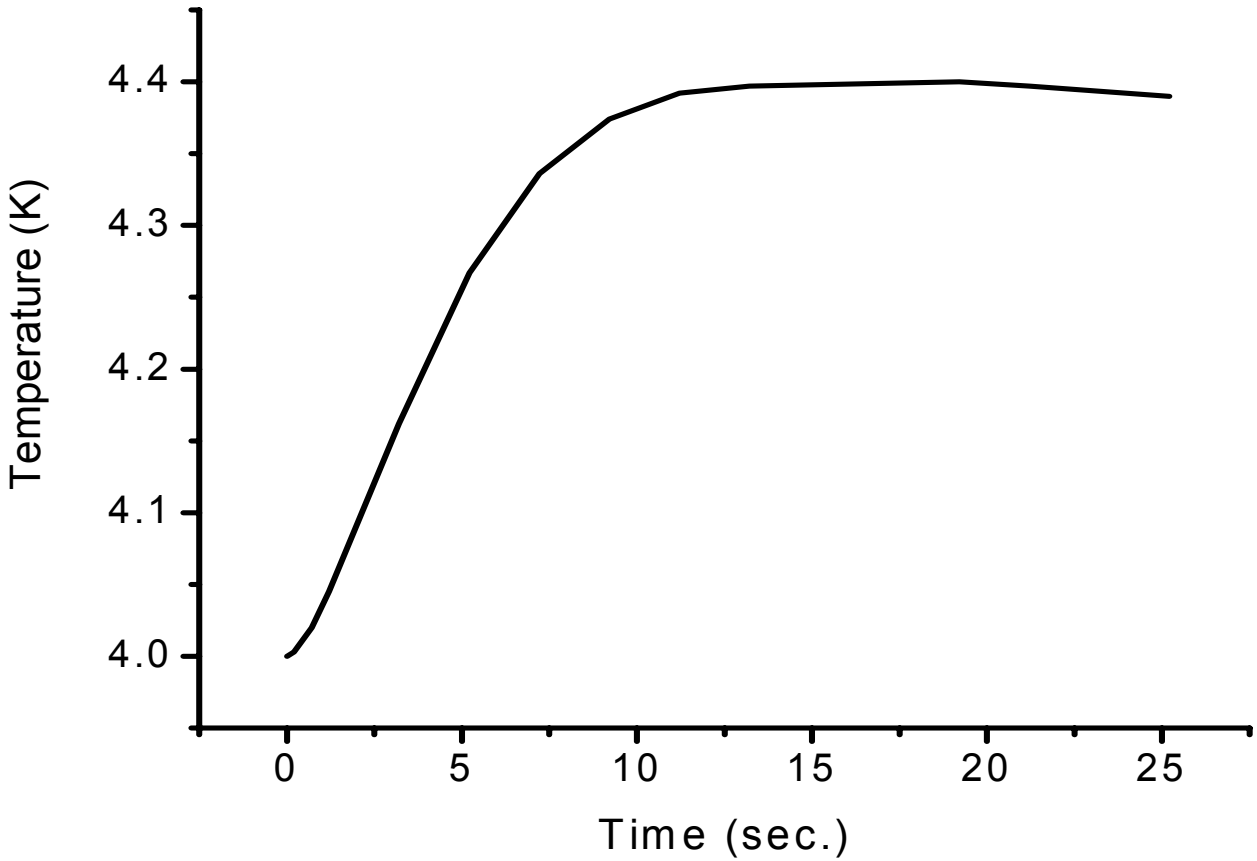
TEMP (AVG)
RSYS=0
SMN =4
SMX =4
ANSYS
JUL 25 2002
15:39:40
Y
Z
X
MN
4
4.045
4.09
4.135
4.18
4.224
4.269
4.314
4.359
4.404

- T_{max}: 4.4 K



The temperature rise of the coolant in CICC
of the inner corner turn due to case heating under plasma disruption.

Peak temperatures of TF case and coolants

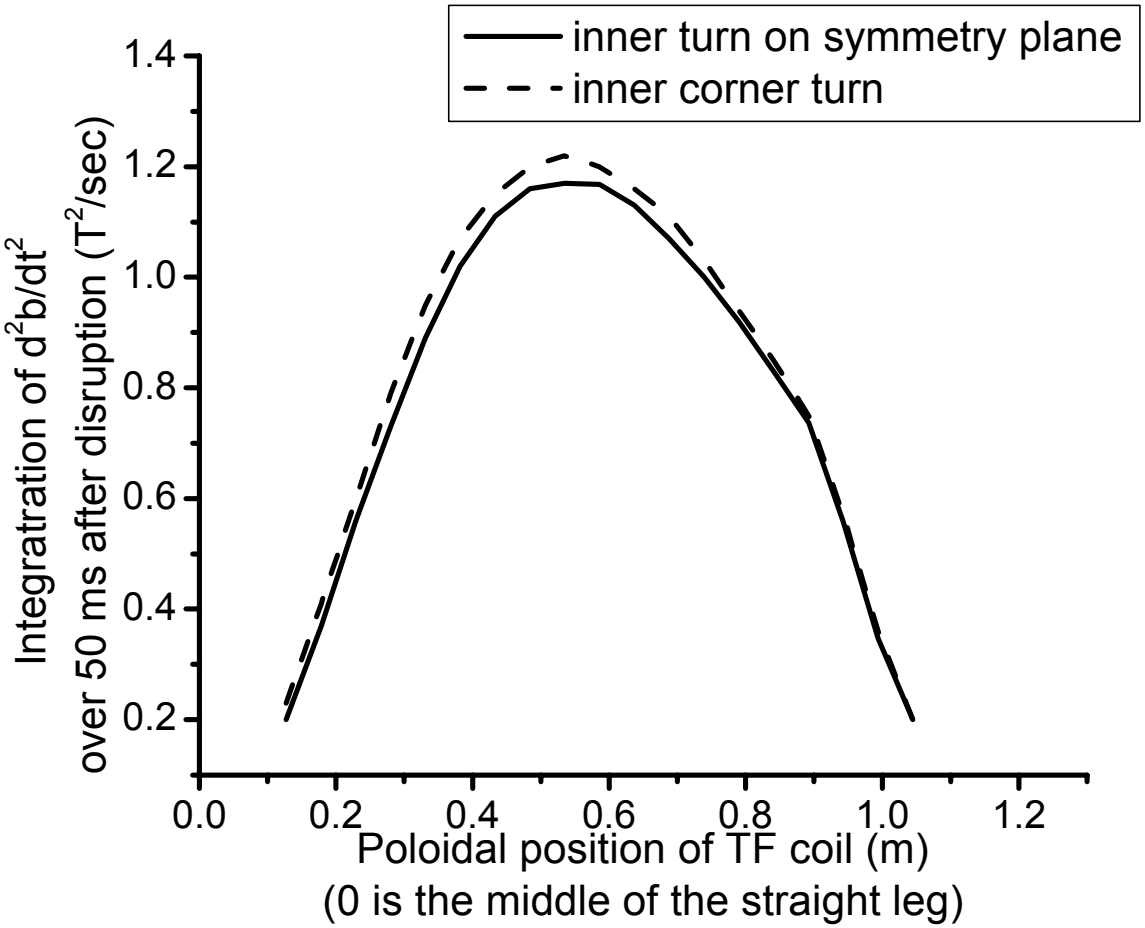
	case	Case coolant	He in CICC
Tmax	19.4	8.8	4.4
Occur time(s)	0.07	2	10-15
position	Middle of inner straight leg	~Middle of inner straight leg	~Middle of inner straight leg
Recover time	3 min		

Stability of Conductors under Plasma Disruption

- Modeling: GANDALF-1.5 code
  - Parameters
  - Coupling heat loss in CICC
- Influence to Temperature Margin

Main Parameters of CICC for HT-7U TF Coils

Dimension	20.7 mm * 20.7 mm	/(2SC+2Cu)*3*4 *5	without cooling hole
SC strands	NbTi/copper	Cu/NbTi ratio in SC strands	1.38
Diameter of SC	0.87 mm	Number of SC strands	120
Diameter of Cu	1.06 mm	Number of Cu strands	120
RRR of Cu	100		
Jacket	SS-316LN	Thickness of jacket	1.5 mm
Porosity	0.37		
Coolant	Helium/3.8K/4bar	Maximum B	5.8 T



Integration of d^2B_n/dt^2 over 50 ms after plasma disruption, half of straight leg lasts 0.917 m.

GANDALF Modeling

- SC properties:
  - Tcs: 5.83 K, Jc: 71% of theoretical value
- Coupling loss

$$\dot{q}''' = \frac{2\theta}{\mu_0}\frac{d^2 B_n}{dt^2}$$

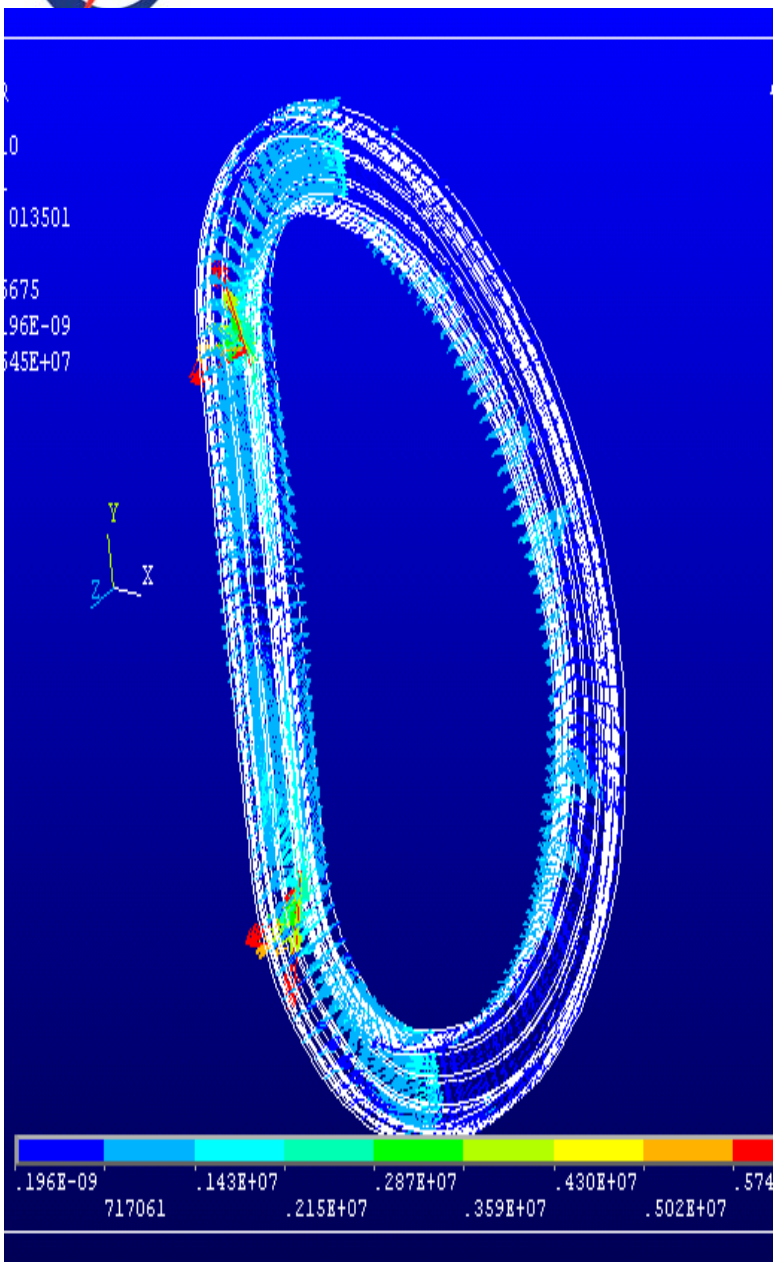
  - coupling time constant θ : 37 ms
- Cables modeled: inner corner turn, ~ 10 m

- Results: Temperature margin reduced: 0.63 K

Summary

- Most of the eddy heating on cases occurred on the inner straight leg,

  causing case temperature rise to 19 K
- Eddy heating on cases can heat up LHe in winding pack to 4.4 K at 15 s, reducing temperature margin by 0.4 K, but before 2s, the rise is less than 0.1 K
- Coupling loss reduces temp. margin by 0.63 K
  - Temperature margin still have: 1.3 K (Top=3.8 K)
- After a major centered disruption, the case can be recovered within ~3 minutes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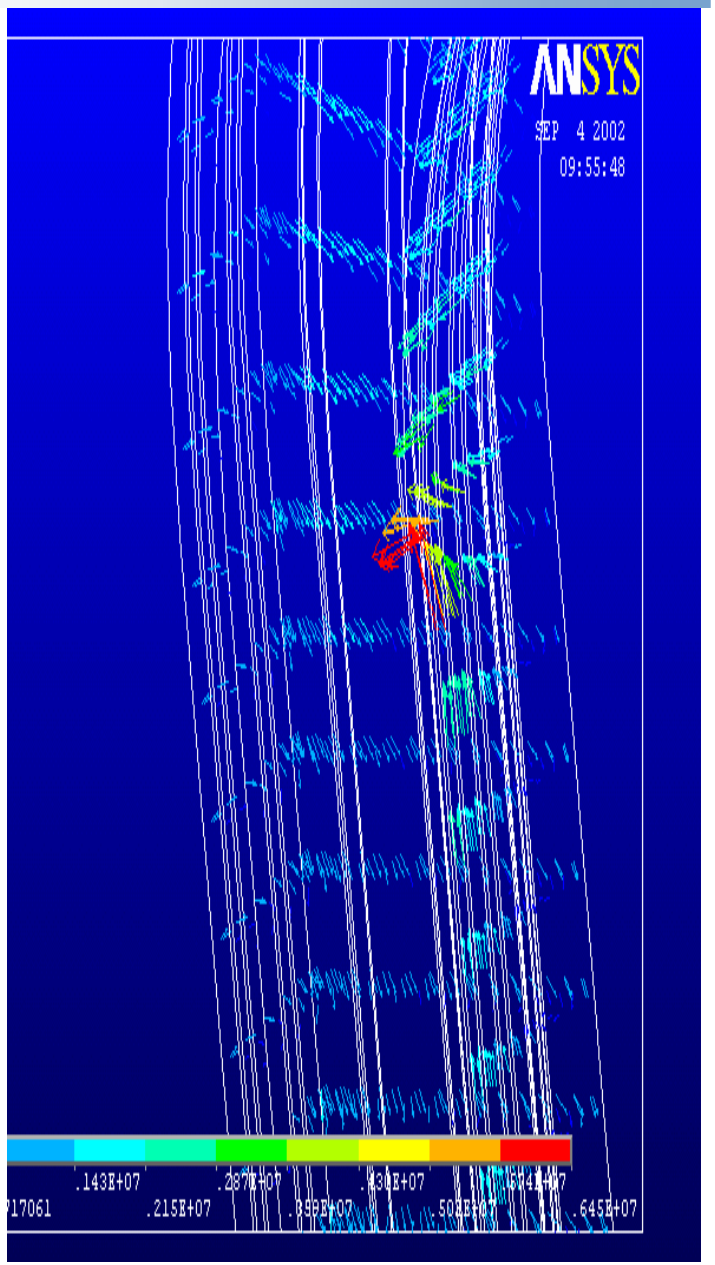
Y
X
Z


ANSYS
SEP 4 2002
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