ITER First Wall and Shield Design

Unique Lessons

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M. Ulrickson
Presented to VLT Call

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Outline

- Design Status
- Net Electromagnetic Forces
- Plasma Wetting of the First Wall
- Error Fields due to Ferritic Steel
- Summary

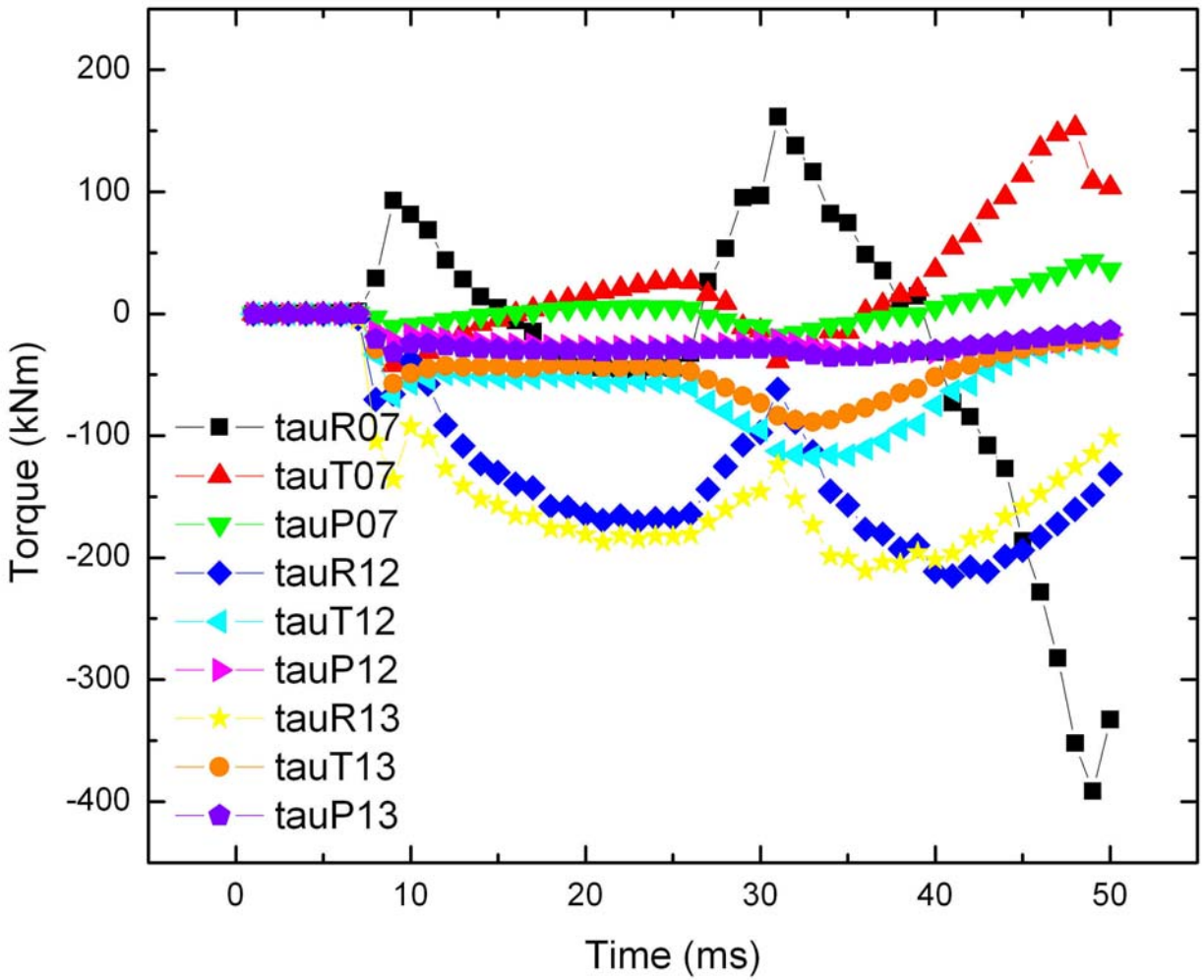
Design Status

- A Conceptual Design Review for the US contribution to the First Wall and Shield (7, 12, 13) was held in February 2007.
- The review was successful and the review panel noted several issues that should be addressed during Preliminary Design.
- Nearly simultaneously the IO announced Design Change Requests that would initiate a complete redesign of the FW and SM and might eliminate the Port Limiter.

Net Electromagnetic Forces

- Disruption analysis conducted by the IO during the EDA never reported any net force on Shield modules. They only reported moments (torque) in various directions.
- The moments we calculate generally agree with the IO values. The differences are in specific modules and some of peak times differ. The IO specifications of the disruption have changed since the EDA analysis.
- We calculate net force on each Shield module

Disruption Induced Moments



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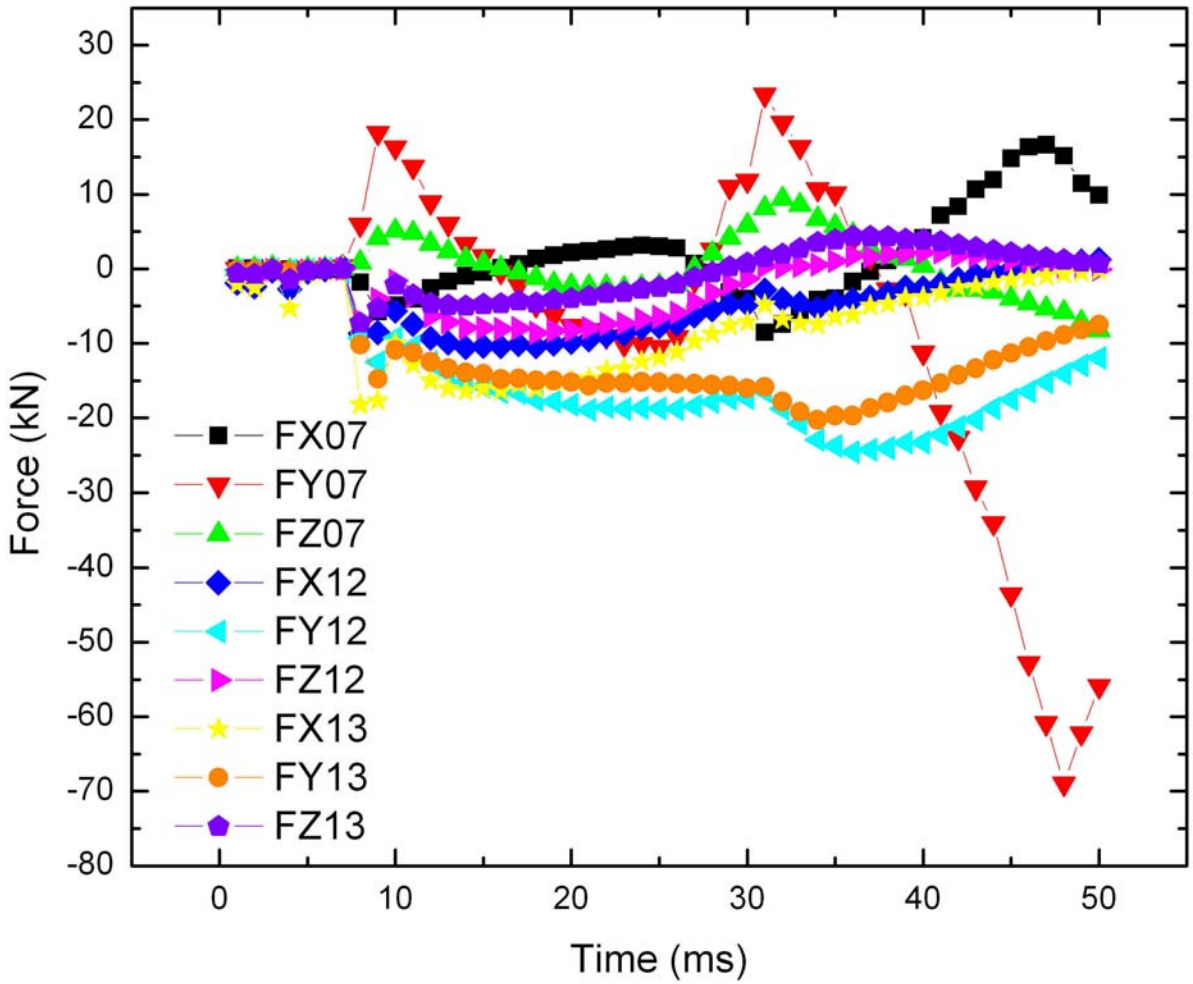
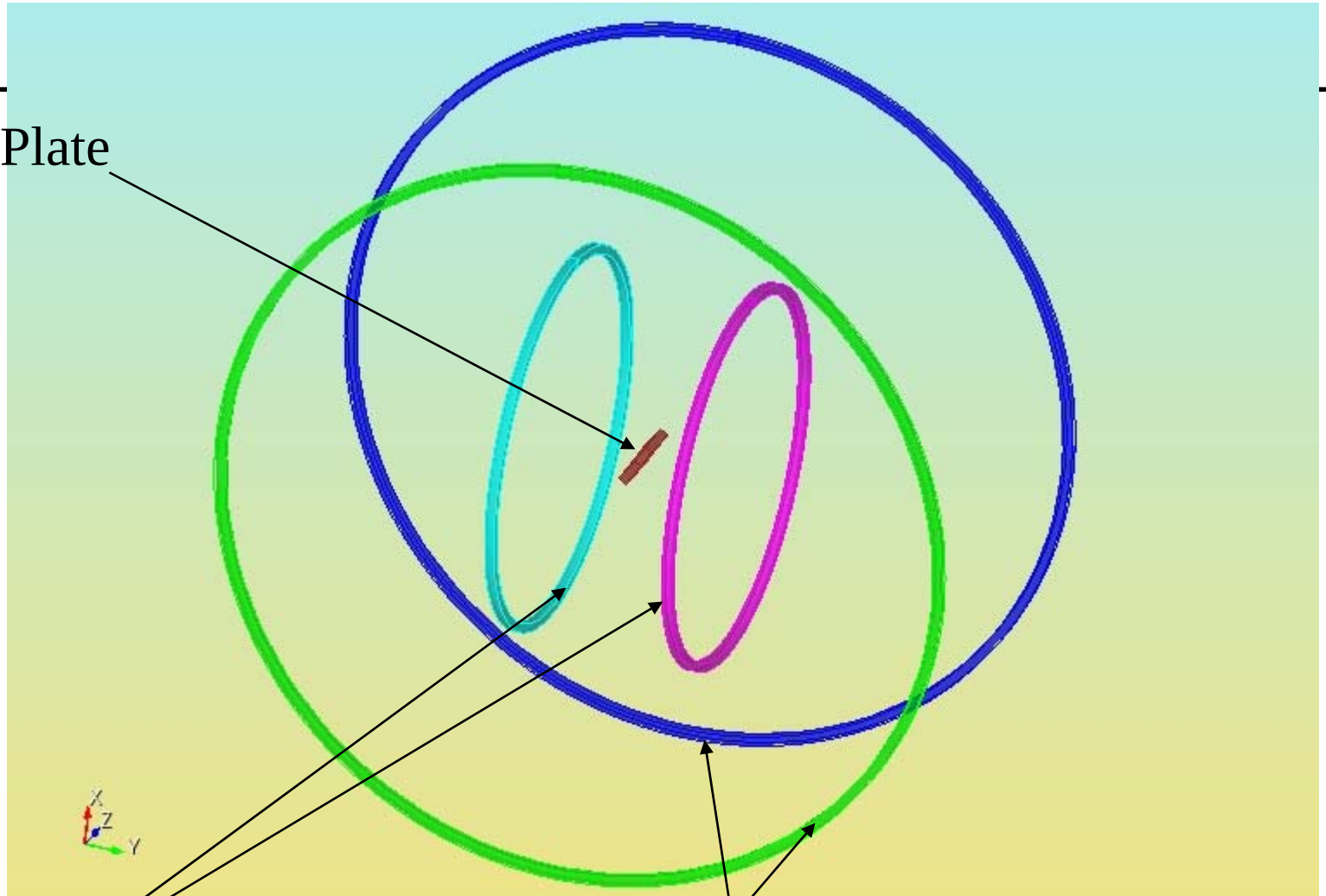
Disruption Induced Net Force



How can there be net force?

- The shield modules are large (~1X1x0.5 m) and the background magnetic fields are not constant over a module.
- The field gradients cause the integral of JXB over a module to be non-zero
- Illustrated in the following example

Two Pairs of Coils for no Gradient



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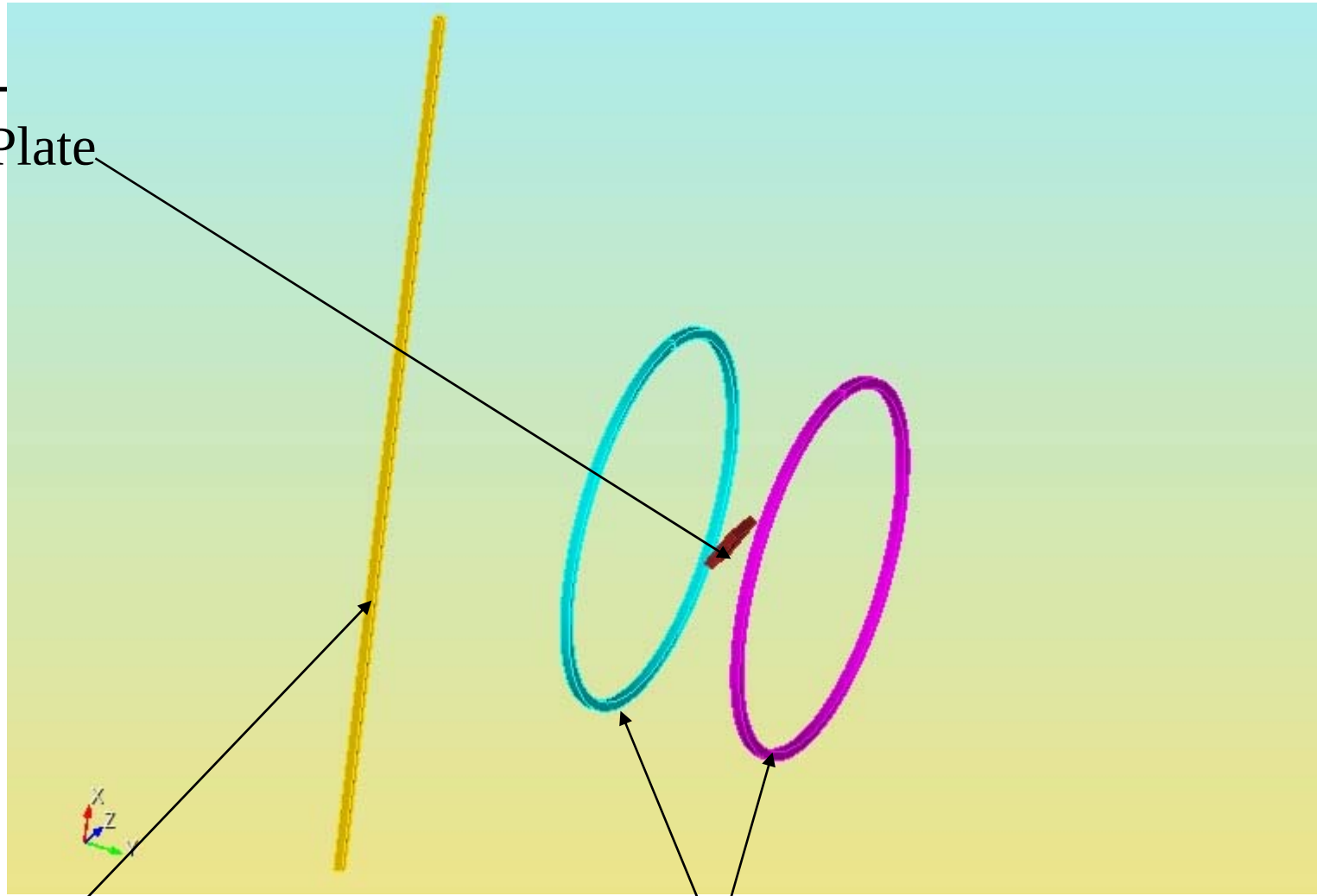
Field Gradient Case



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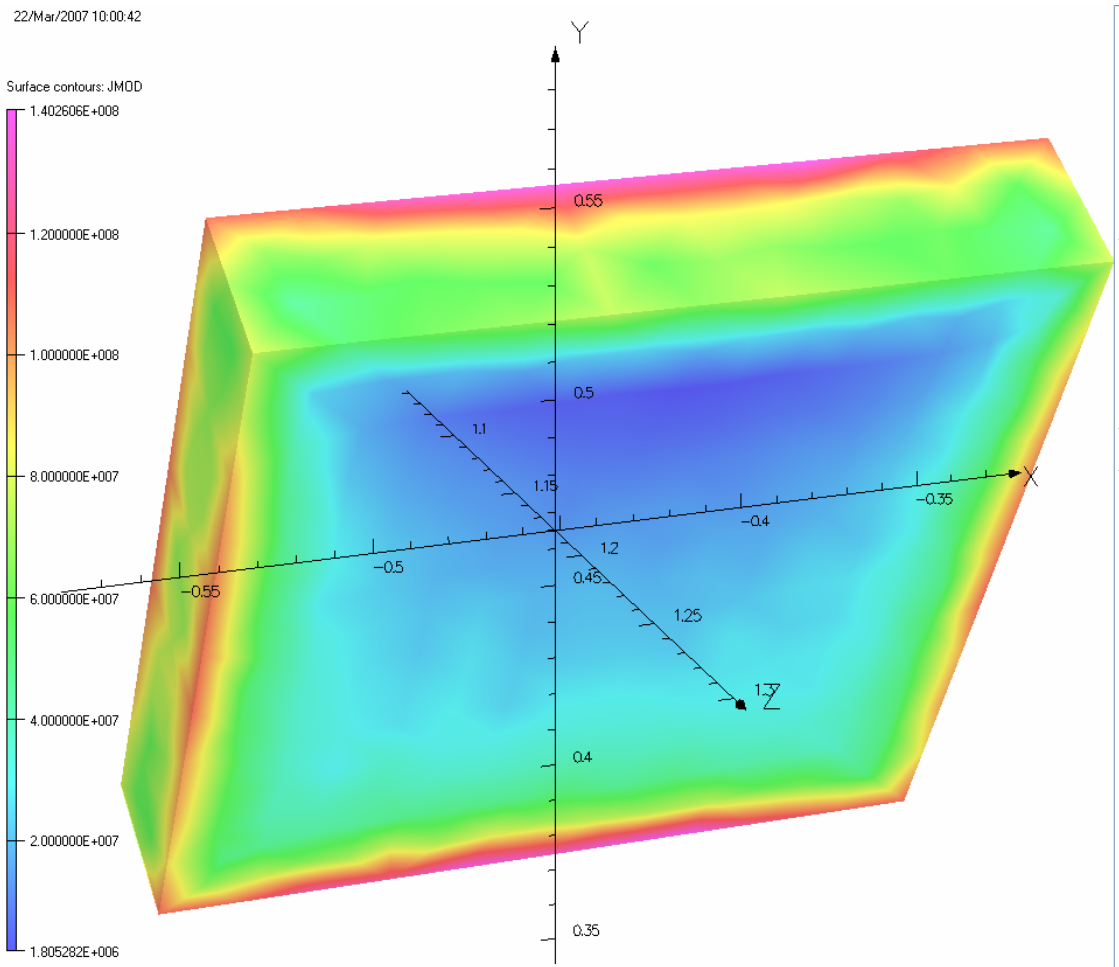
Current Density in Test Plate



UNITS

Length	m
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	$S\,m^{-1}$
Current Density	$A\,m^{-2}$
Power	W
Force	N
Energy	J

PROBLEM DATA

hc_grad_tilt_ramp.op3
ELEKTRA Transient
Time = 0.025
Linear materials
Simulation No 6 of 12
687174 elements
809566 edges
3 conductors
Nodally interpolated fields
Activated in global coordinates

Field Point Local Coordinates

Local = Global

Vector Fields
software for electromagnetic design

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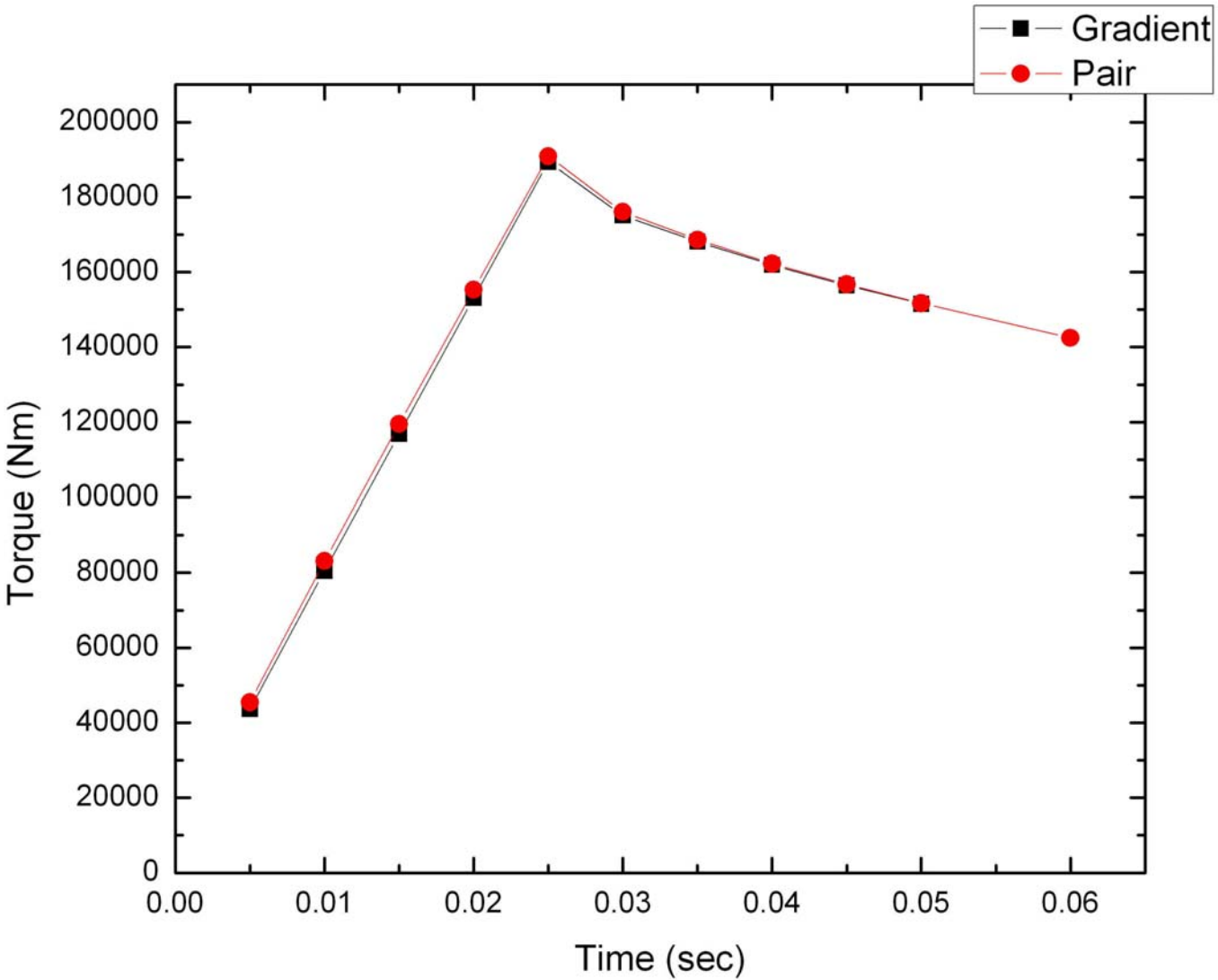
Comparison of Torque



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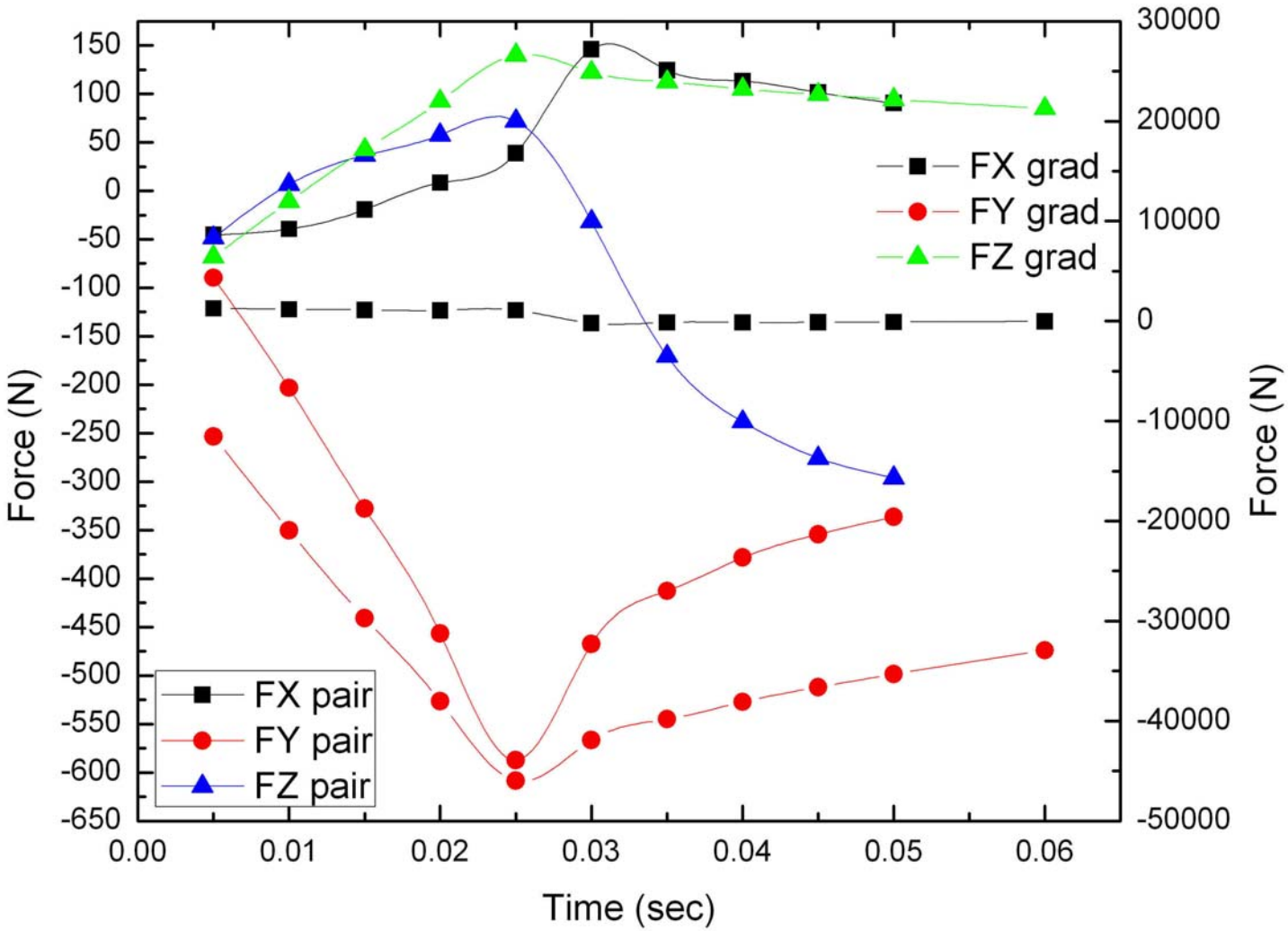
Comparison of Net Force



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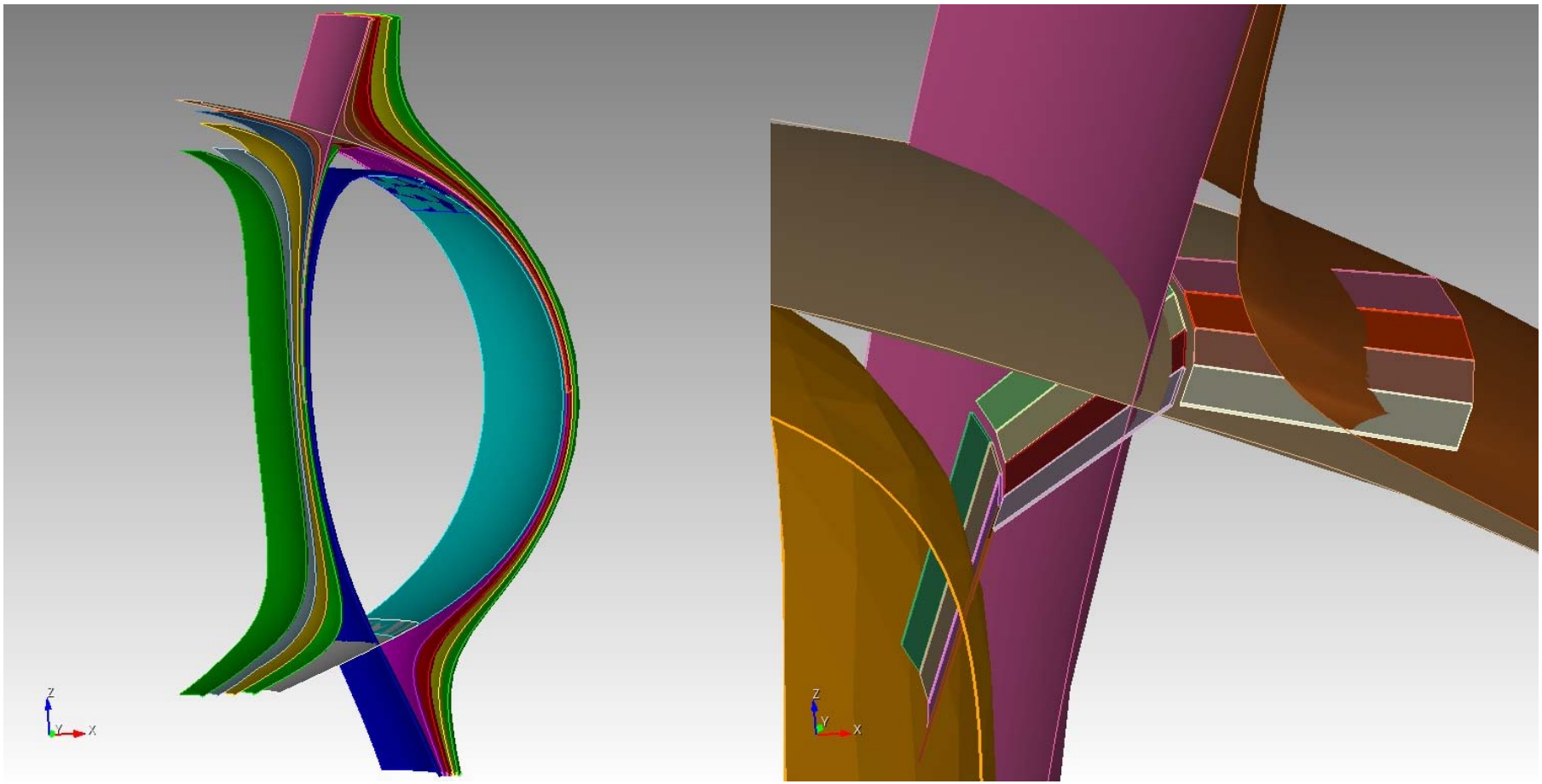
Plasma Wetting of the First Wall

- Compute Plasma flux surfaces from magnetic vector potential
- Intersect flux surfaces with first wall panels that are faceted.
- The plasma heat flux is $\Gamma_0 * b \bullet n$ where Γ_0 is the plasma heat flux parallel to B and b is a unit vector along B and n is the unit surface normal to the first wall.

Plasma Flux Surfaces



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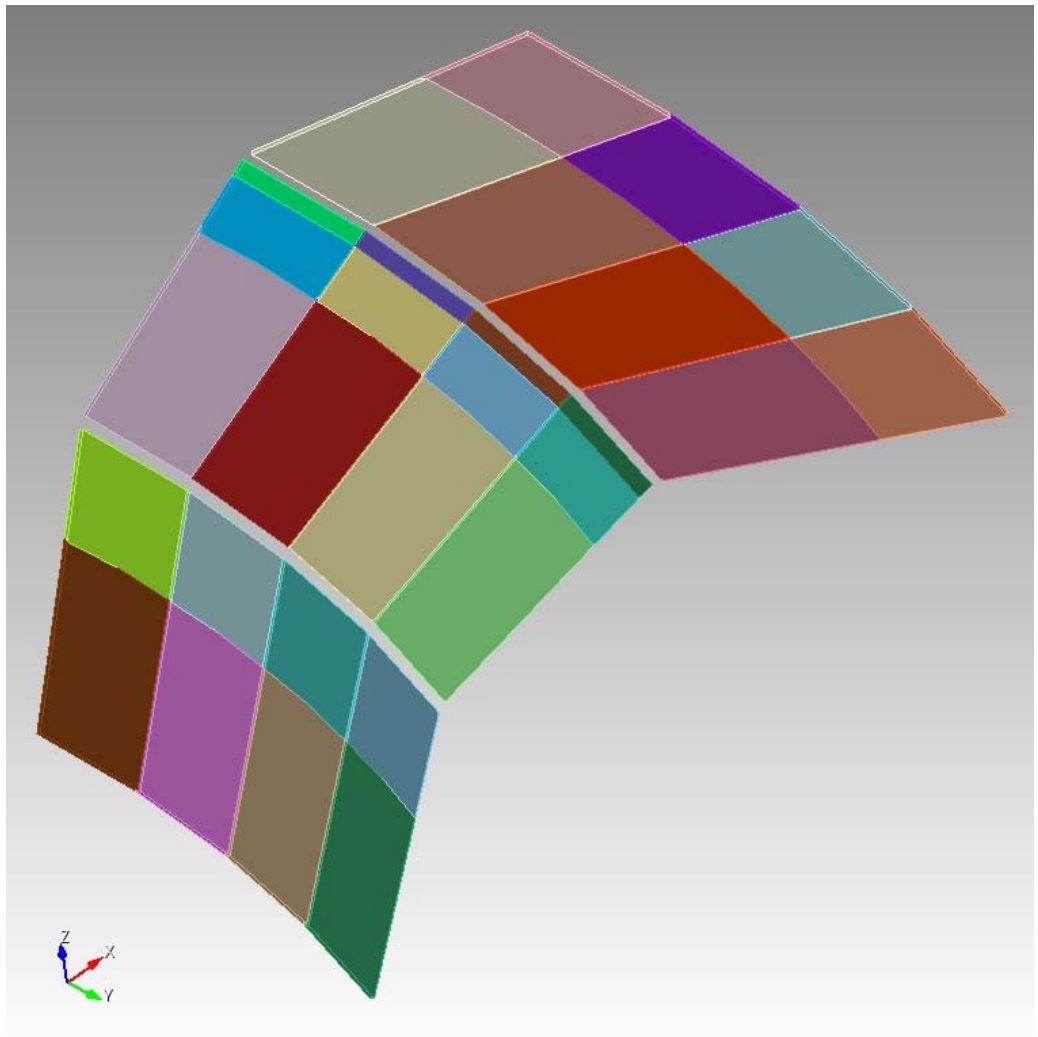
Plasma Wetting of FW 7, 8, 9



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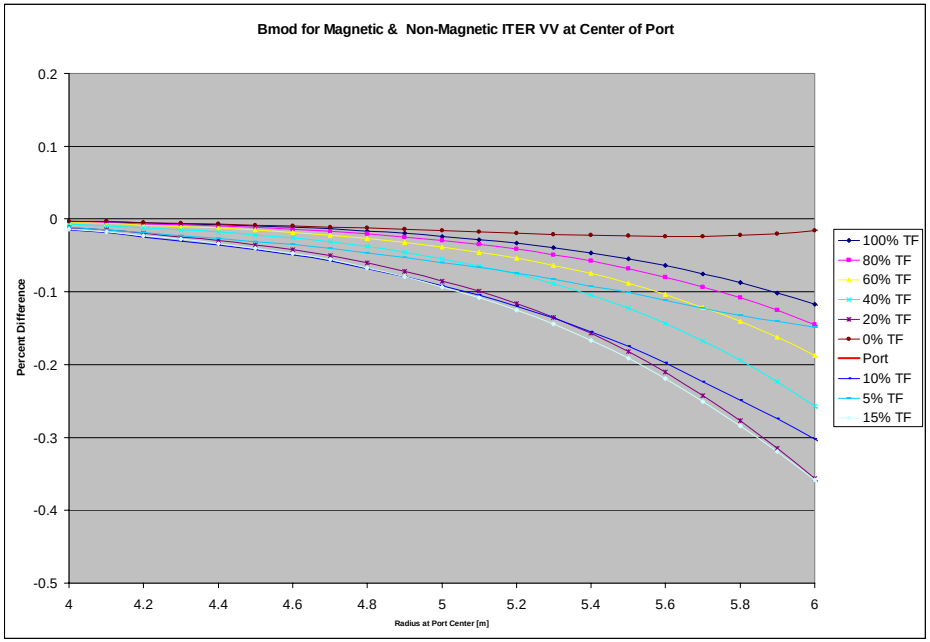
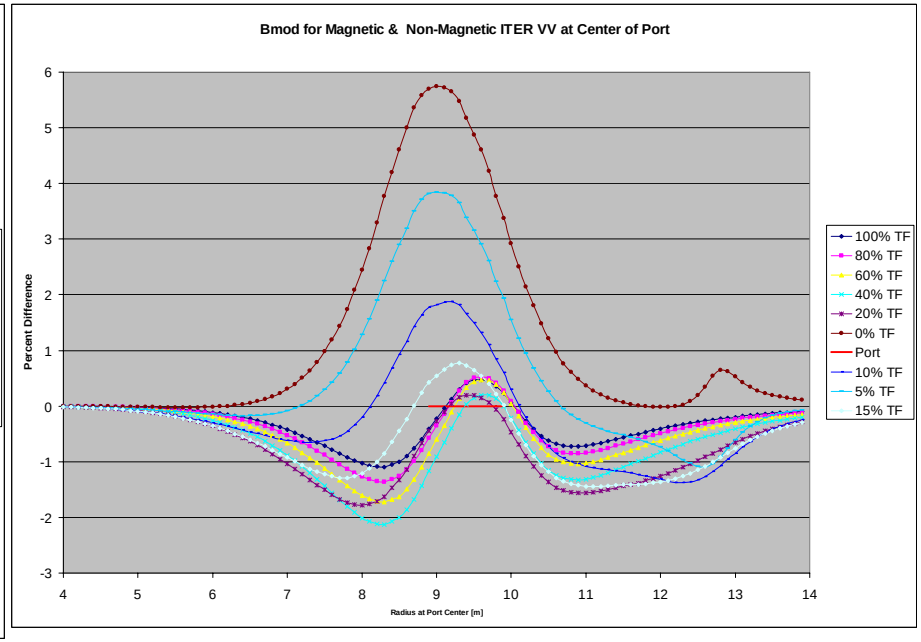
Error Fields Due to Ferritic Steel

- We supported the TBM project using base program funds and discovered an interesting aspect of using Ferritic steel
- Even though ITER fields are high enough to saturate Ferritic steel the material is still magnetized.
- We made a calculation with a Ferritic steel vessel and no TBM to see what error fields were generated in the plasma

Error Field Calculated





The field error is greater that 0.01% at all locations in the plasma even at full field. The error is 1% at the outer first wall.

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Summary

- Net Forces on ITER FW and Shield are caused by field gradients and are quite large
- Calculations of the plasma wetting of the First Wall can be used to sculpt the Wall to minimize heat flux peaking
- Use of Ferritic steel for tokamak structures must be carefully planned to avoid unacceptable field errors
  - Large gaps must be avoided
  - No localized regions with Ferritic