THE ANALYSIS OF THE ELECTROMAGNETIC LOADS ON SELECTED ITER BLANKET SHIELD MODULES DUE TO INDUCED EDDY AND HALO CURRENTS

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Overview

- **ITER Device**
  - **Overall System Model**
  - **Typical Blanket Model**

- **Plasma Disruption Scenarios**
  - **Basic description**

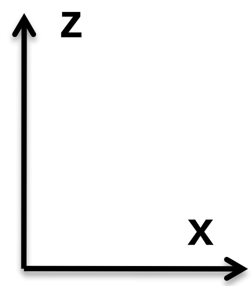
- **Electromagnetic Model**
  - **Eddy currents**
  - **Halo currents**

- **Results**
  - **Forces and Torques**
    - **Selected modules**
    - **Different disruption scenarios**

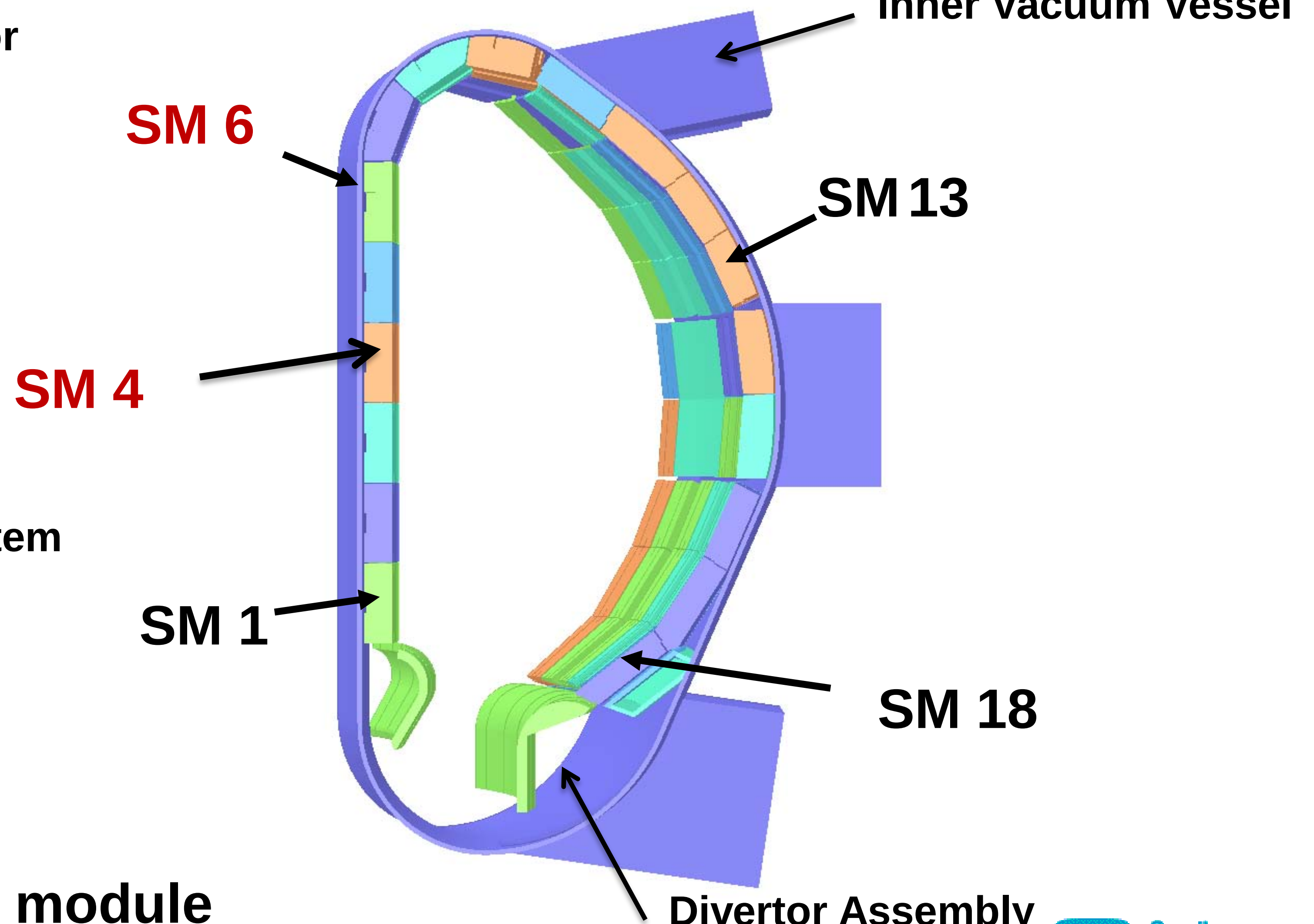
- **Conclusions**

ITER Device

20 degree sector

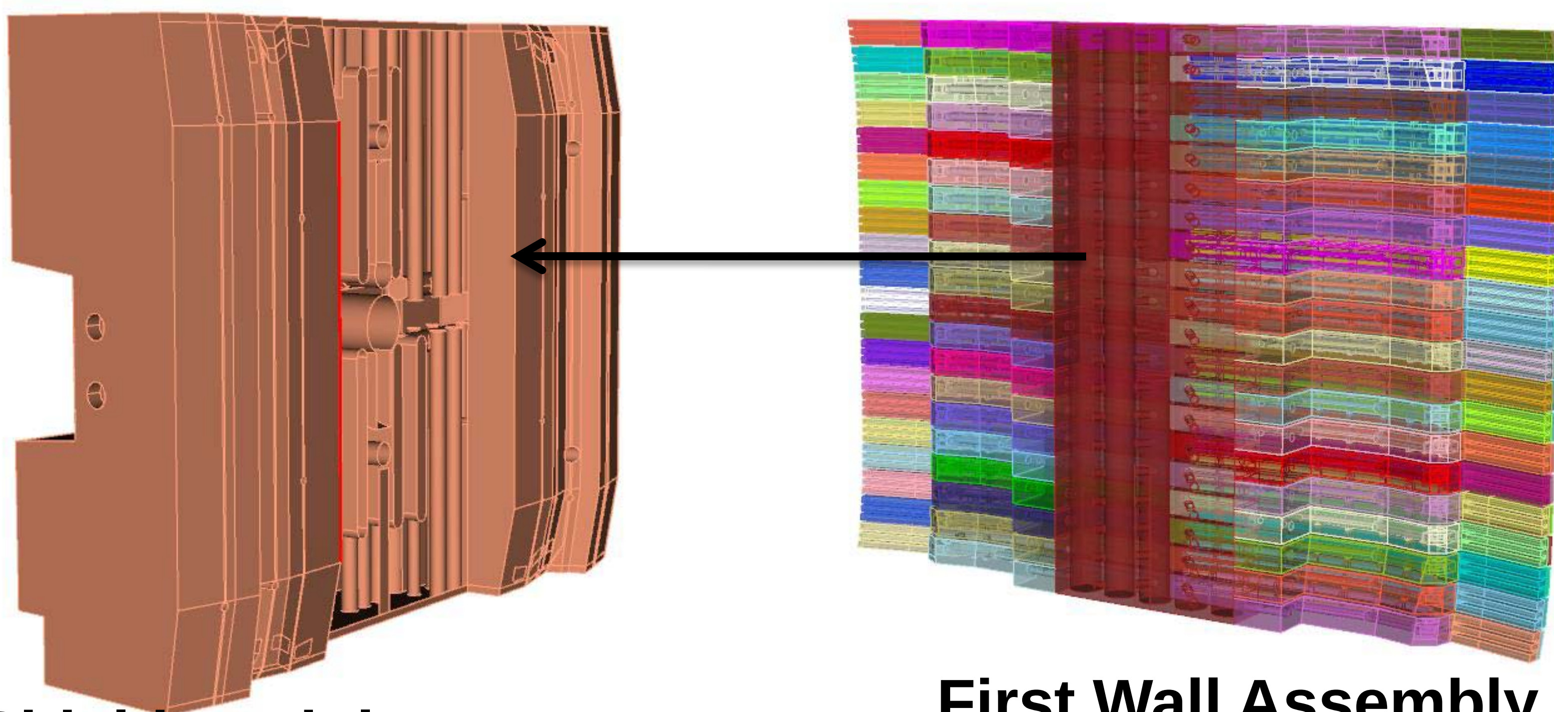


Coordinate system



SM – shield module
No First Wall

Example Blanket Module



Shield Module 4

First Wall Assembly 4

Key features – model contains cooling channels and eddy current slits

BM – shield module with First Wall Assembly

First wall assembly consists of CuCrZr face, SS fingers, SS beam

Plasma Disruption

- A 15 MA plasma current is flowing in the device, toroidal direction.
- Impurities disrupt plasma operation.
- Plasma current starts to decrease.
  - Centroid of this plasma moves - eddy currents are induced.
  - Flux surfaces contact blanket module - halo currents flow.

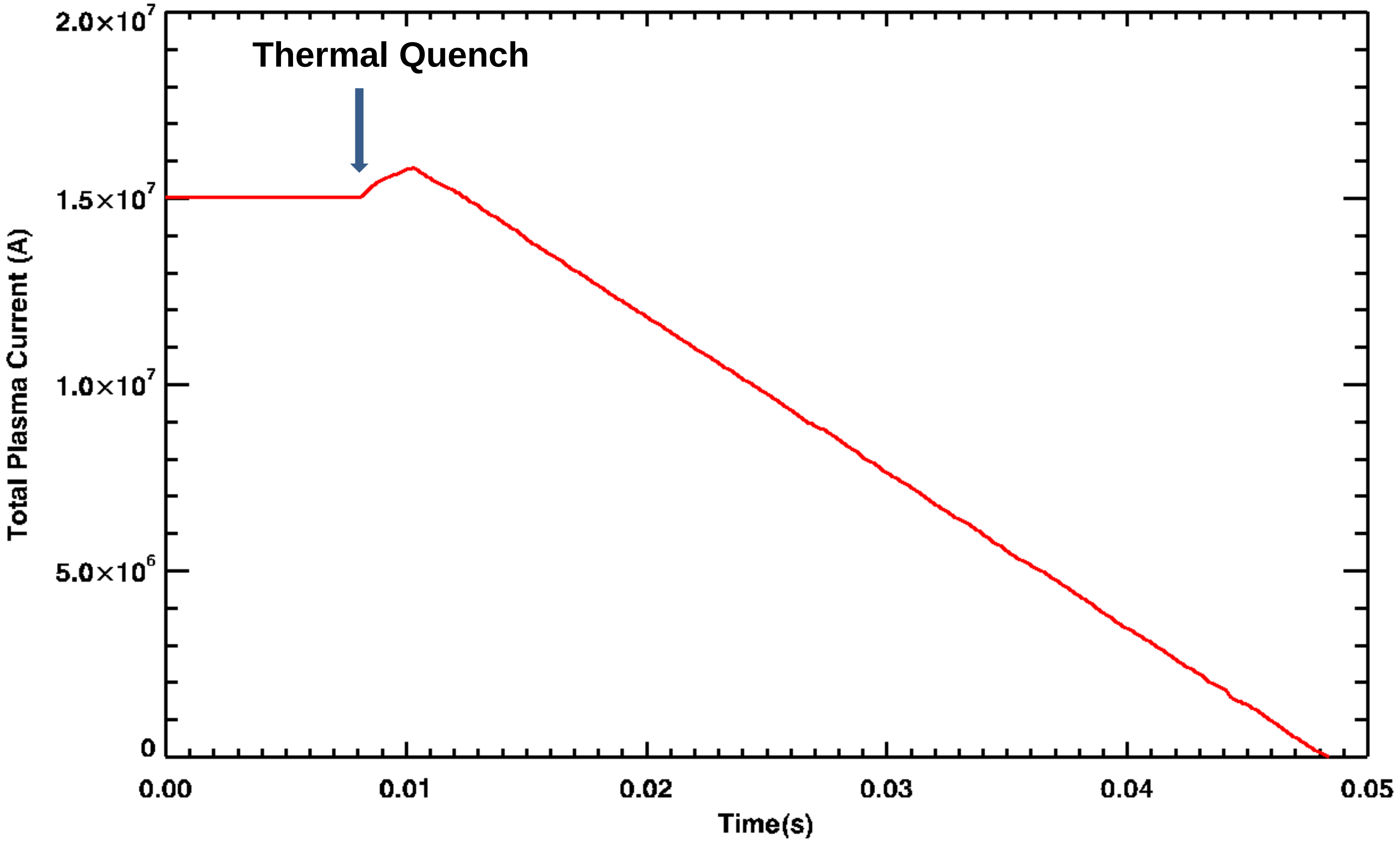
Plasma Disruption Modeling

for Eddy Currents

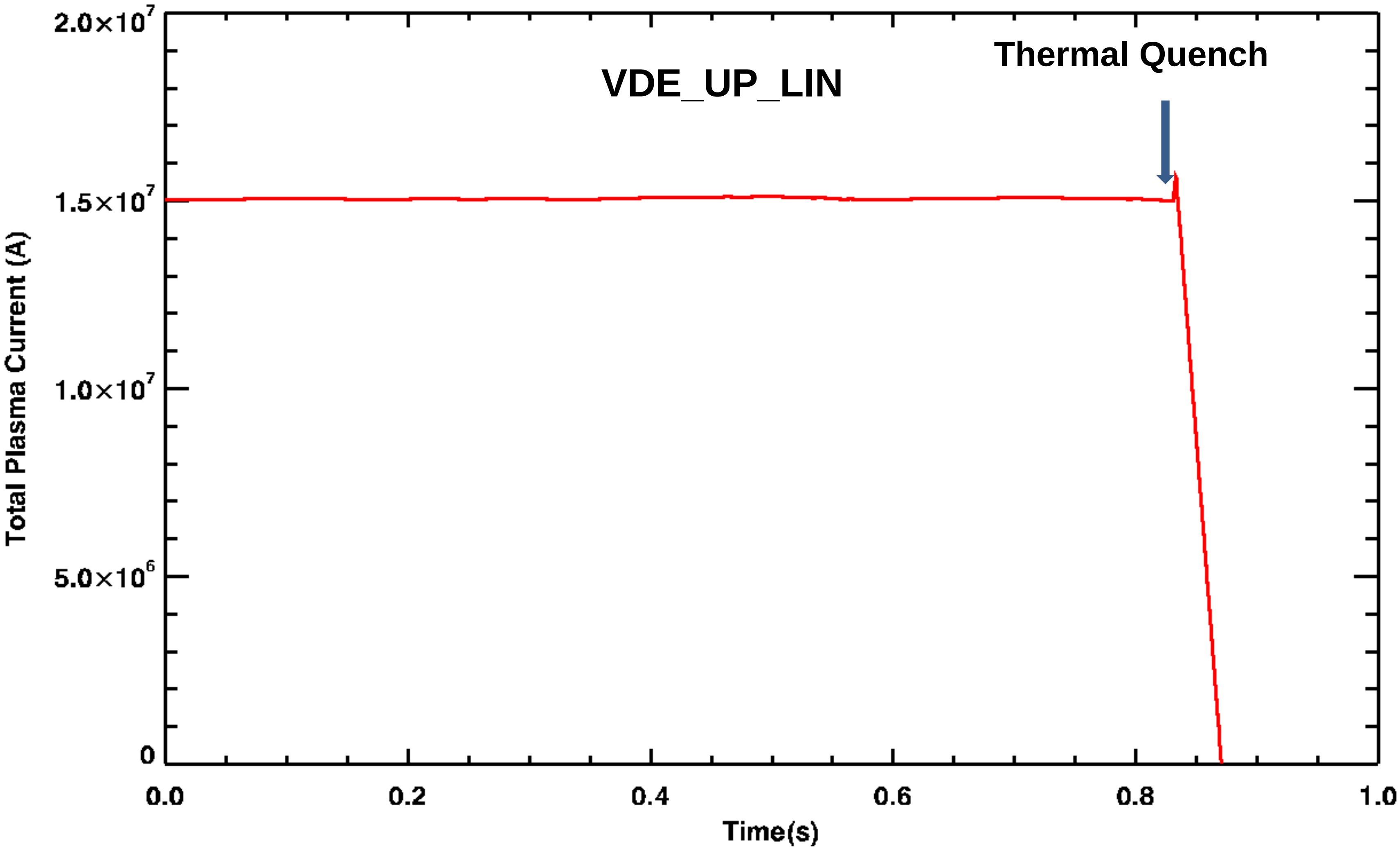
- **From DINA Simulations**
  - Prescribed by the International Organization
  - 20 different scenarios

- **Key Features**
  - Axisymmetric (2-D) description
  - Plasma current modeled by a finite number of filaments
    - Number of filaments vary with time
    - Position vary with time

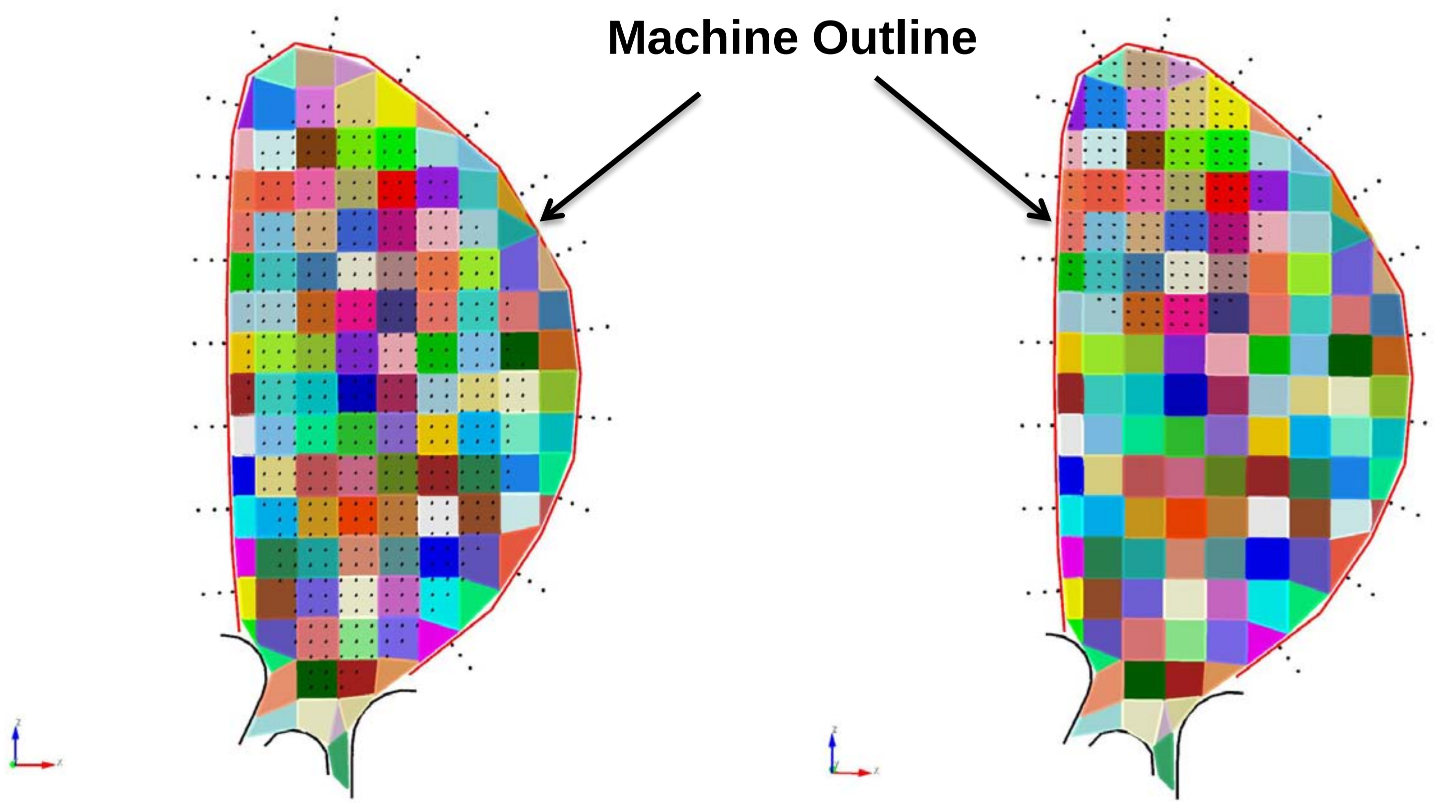
Plasma Disruption Current



Plasma Disruption Current



Plasma Disruption Modeling



T = 20 ms

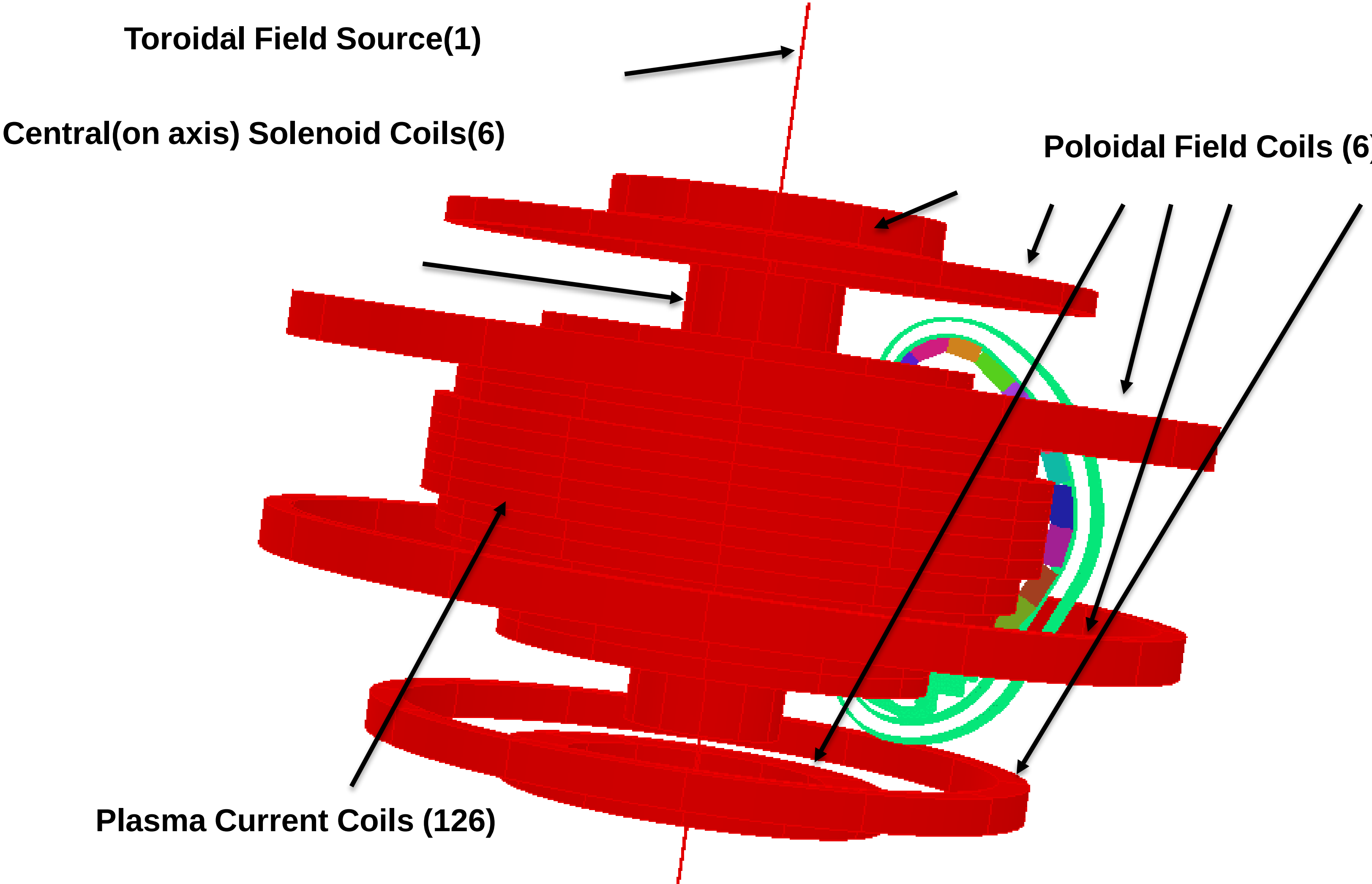
T = 36 ms

NOTE: Points inside machine outline(red curve) Dina filaments

Plasma Disruption Modeling

- Modeled by 126 solenoids.
  - Changed to 64.
- Each has a different time history.
- Models the time variation of the total current behavior.
- Models the movement of the plasma with time.

Electromagnetic Model

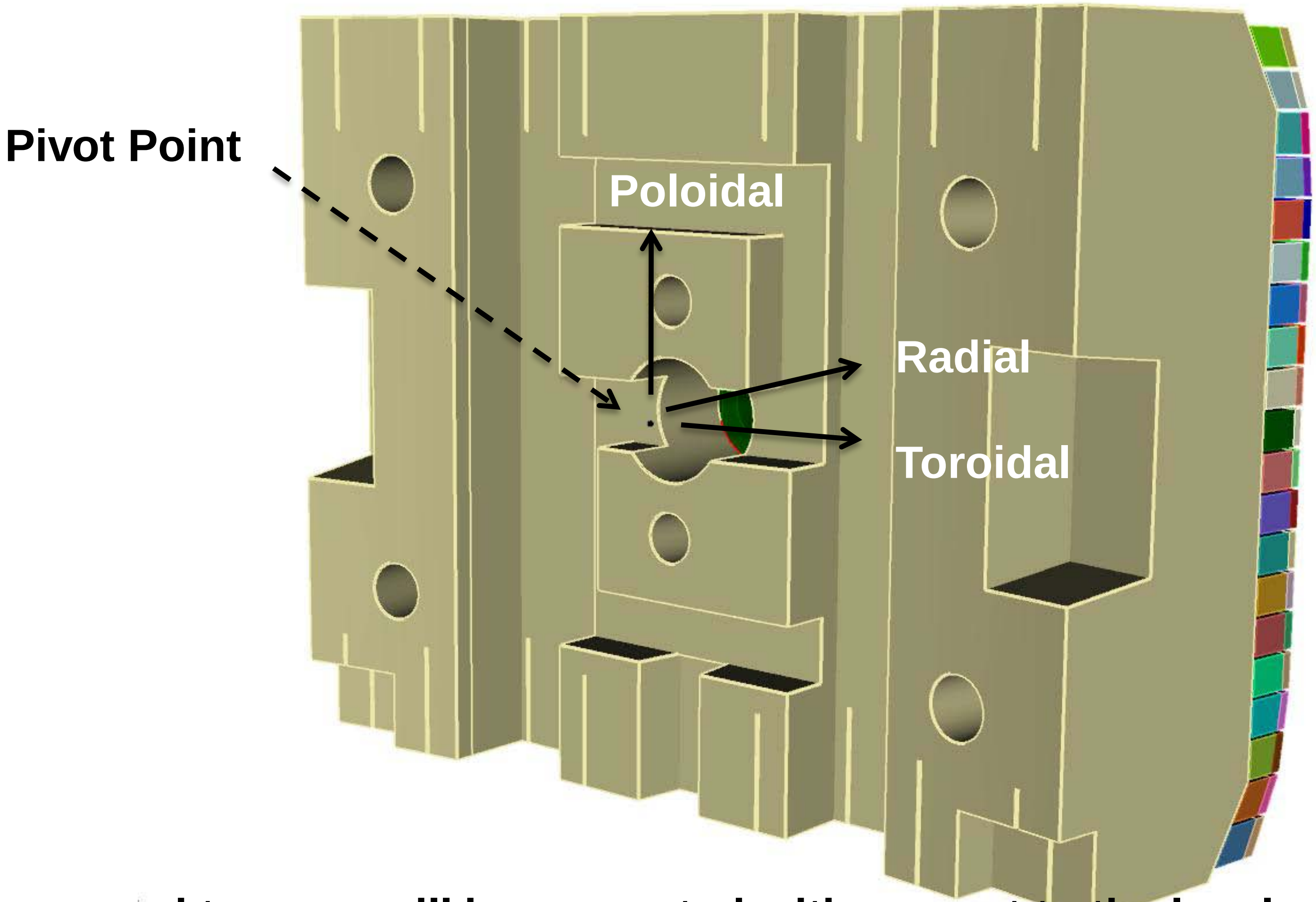


Electromagnetic Analysis
for Eddy Currents

- Twenty degree sector
  - Symmetry used.
  - Adjacent simplified modules are included with inner and outer vacuum vessels.

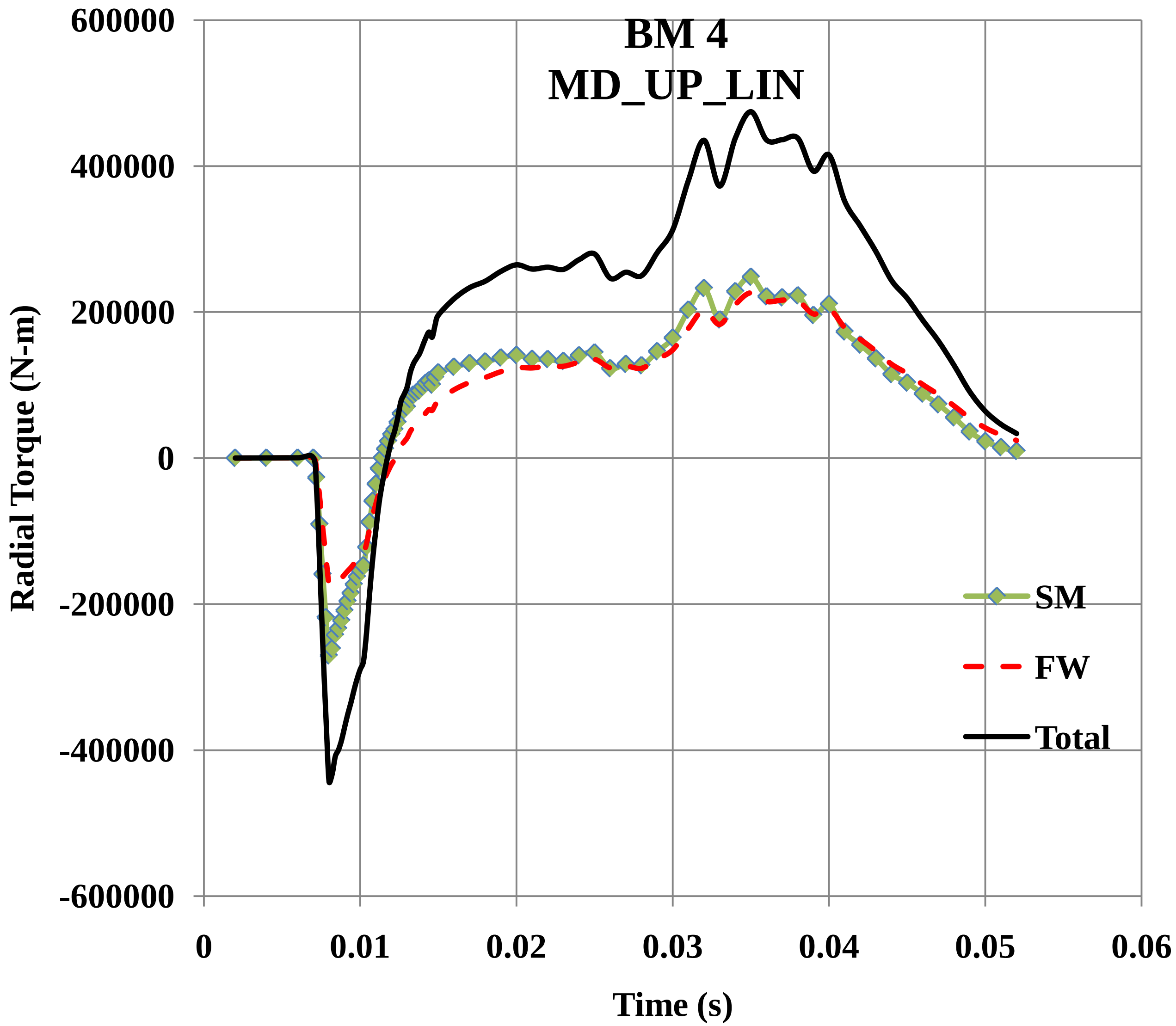
- Solved using the Opera-3d Software
  - Reduced potential formulation.
    - Currents are decoupled from the mesh
  - Forces and torques are computed in the model coordinate system.

Local Coordinate System

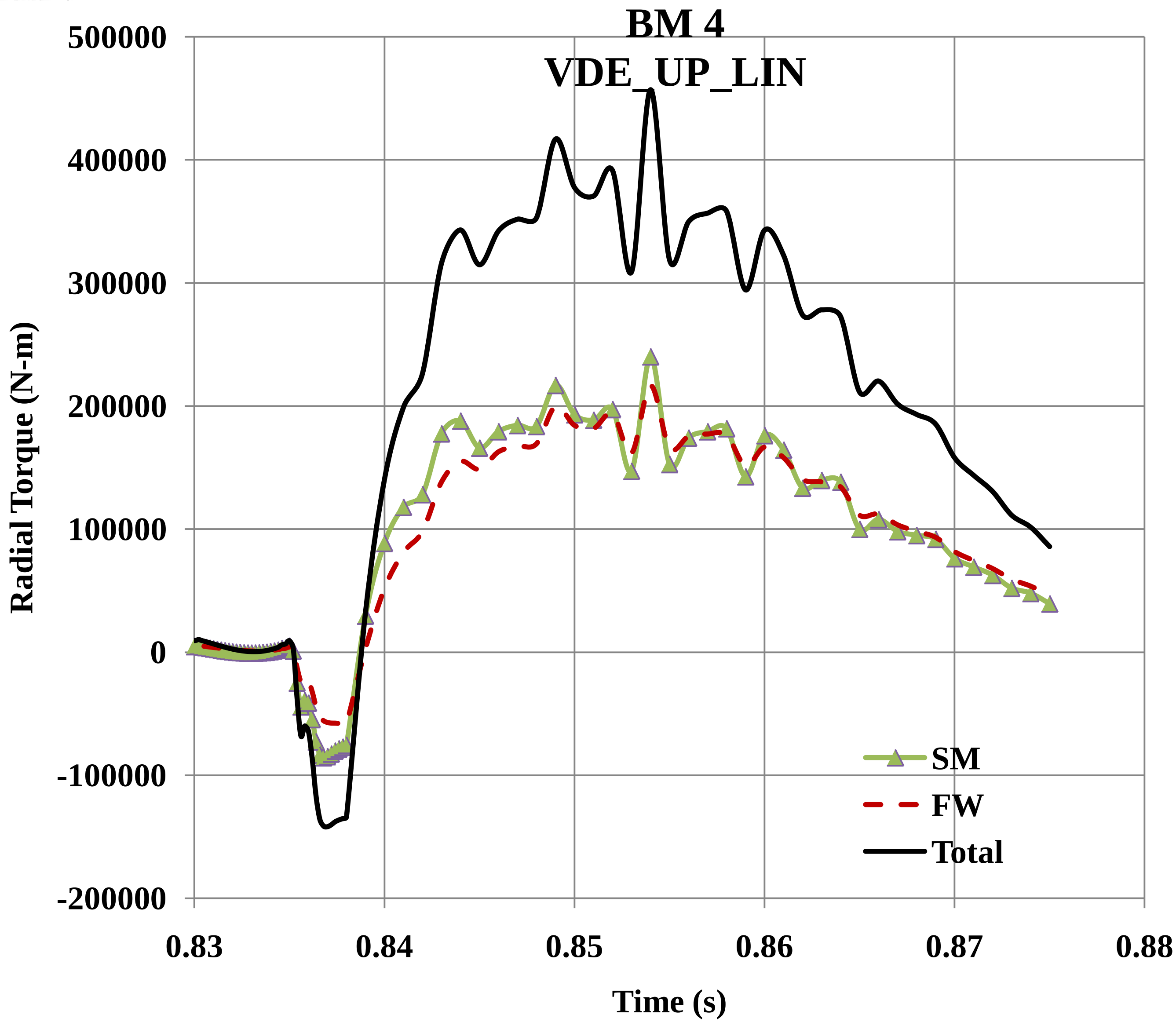


Forces and torques will be presented with respect to the local coordinate system for the module of interest

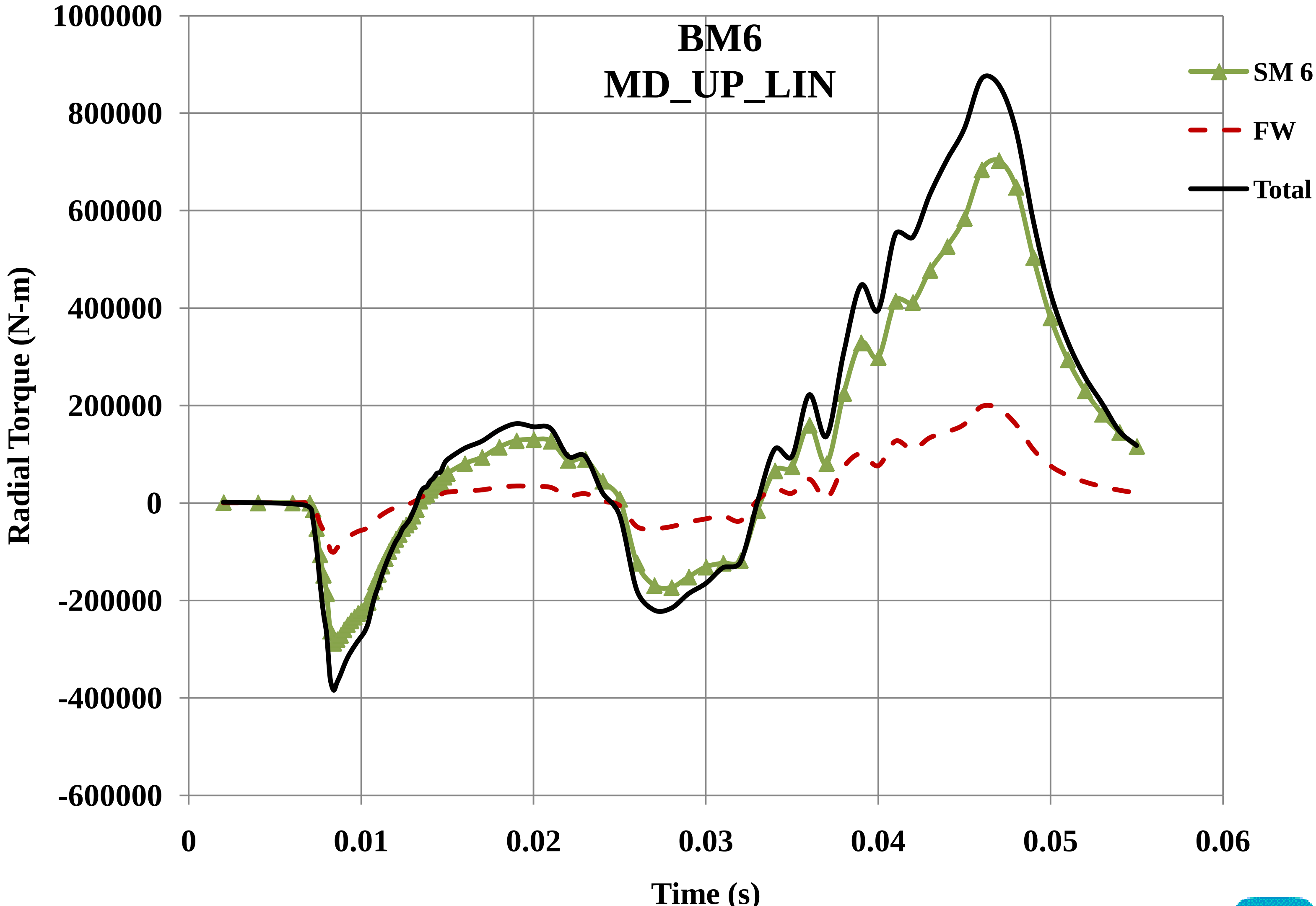
Radial Torque Comparisons



Radial Torque Comparisons



Radial Torque Comparisons



Electromagnetic Analysis
for Halo Currents

- **Occurs when the plasma flux surface intersects the in-vessel components.**

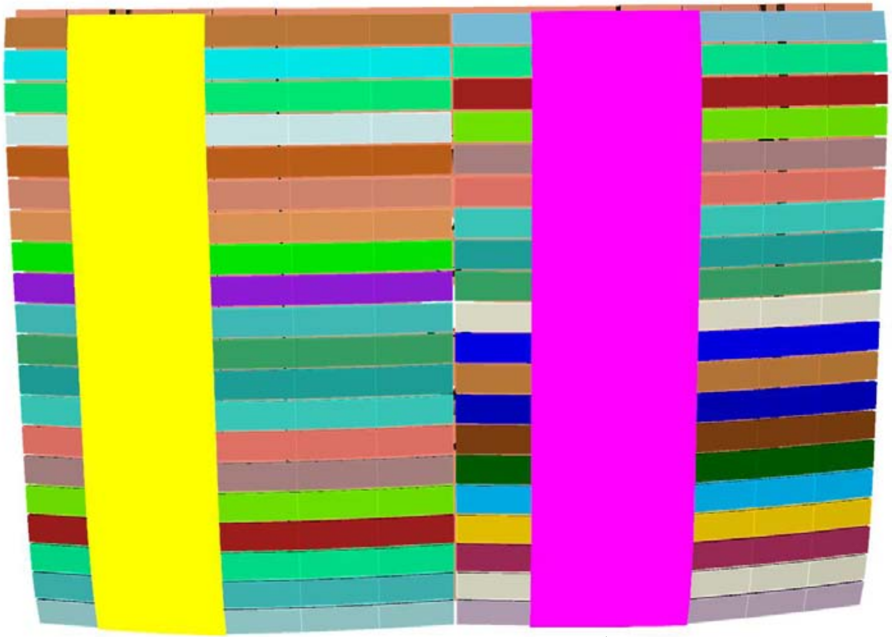
- **Behaves as direct current injection into the blanket module.**

- **The loads produced are in addition to those due to plasma disruption.**

Electromagnetic Analysis
for Halo Currents

- Current Flow Analysis on blanket module of interest.
  - Static analysis
    - Extract current to a TABLE file generated from an ABAQUS mesh.
- Extract Magnetic Flux density from disruption analyses.
  - To a TABLE file generated from an ABAQUS mesh.
- Calculate J x B combining the above data sets.
  - Time history of Halo included at this time
    - Direct multiplication of static data.

Halo Current Analysis – SM 4

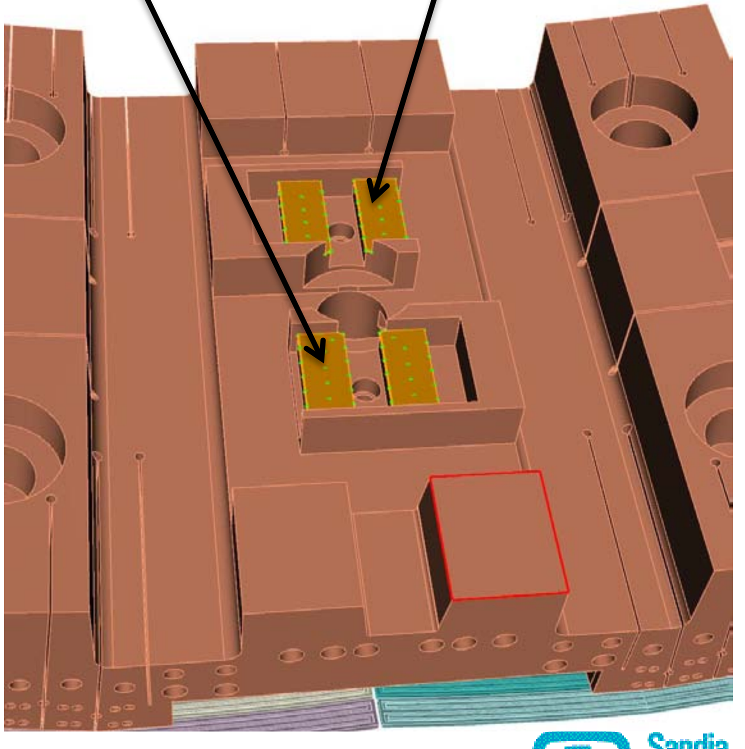


Voltage set on front of FW

Desired : I_{halo} = 136 kA

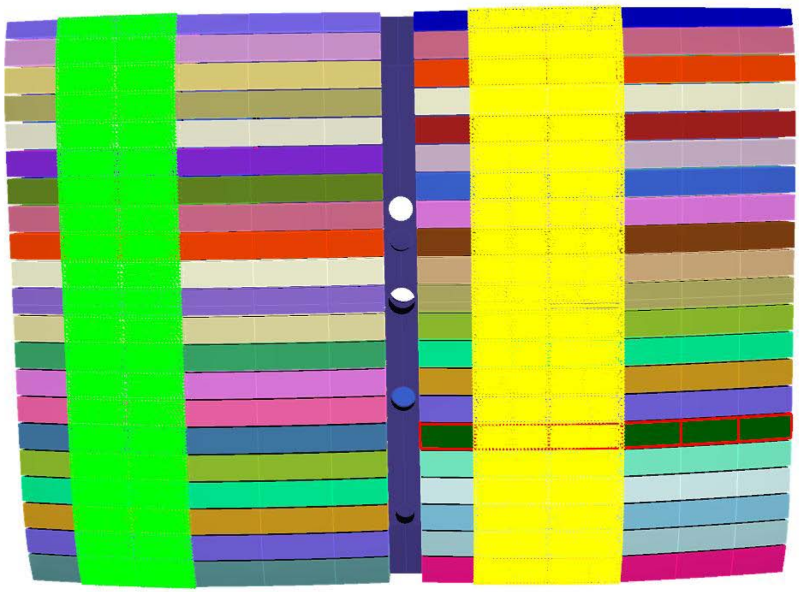
Calculated : I_{halo} = 142 kA

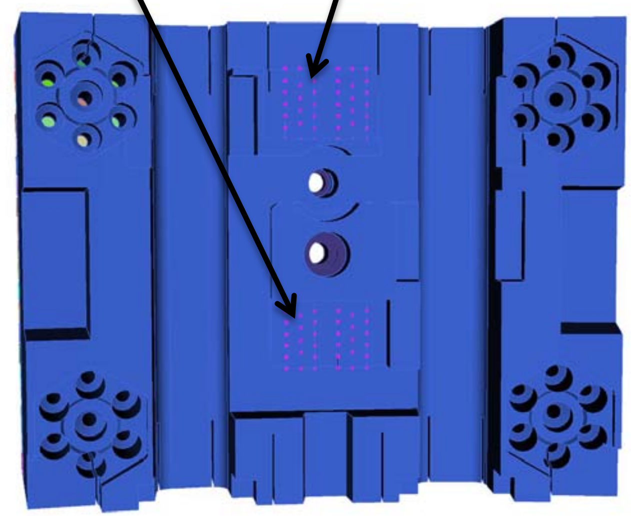
Voltage set on back of SM



Halo Current Analysis – SM 6

Voltage set on back of SM





Voltage set on front of FW

Desired : I_{halo} = 227 kA

Calculated : I_{halo} = 226.9 kA

Halo Current Results

RF BM 4

Module	F_r(kN)	F_p(kN)	F_t(kN)	T_r(kN-m)	T_p(kN-m)	T_t(kN-m)
BM 4	-43.2	-657.6	-15.3	6.6	7.7	-246.1
BM 6	-12.1	-1376.5	-87.2	16.7	38.1	-535.2

BM 6

	F_r(kN)	F_p(kN)	F_t(kN)	T_r(kN-m)	T_p(kN-m)	T_t(kN-m)
Total Loads	-12.1	-1376.5	-87.2	16.7	38.1	-535.2
FW	-11.8	-627.3	-41.9	5.5	20.0	-227.5
SM 06	-.28	-749.2	-45.3	11.2	18.1	-307.7

Conclusions

- **The electromagnetic forces and torques have been shown for two blanket modules of the ITER design.**
  - **Analysis procedure described.**

- **Largest component:**
  - **Eddy currents radial torque**
  - **Halo currents poloidal force**
    - **Due to interaction with the large toroidal field.**