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Transient Electromagnetic Analysis of Blanket Modules 14 and 15 in Different Sectors of the ITER Blanket System due to Plasma Disruption

J. D. Kotulski and R. S. Coats

jdkotul@sandia.gov

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Background

- **The plasma current in the ITER device may experience disruption due to the introduction of impurities or loss of control of the plasma.**

- **These disruption events induce eddy currents within the blanket system which result in large electromagnetic loads.**

Overview

- **This analysis reveals the modeling procedure used to predict the electromagnetic loads on the blanket modules(BM) due to plasma disruption.**
  - **Focus will be on the torque.**

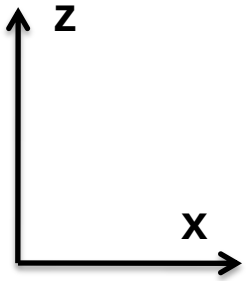
- **Two different configurations of BM's 14 and 15 will be considered.**

Overview(Cont'd)

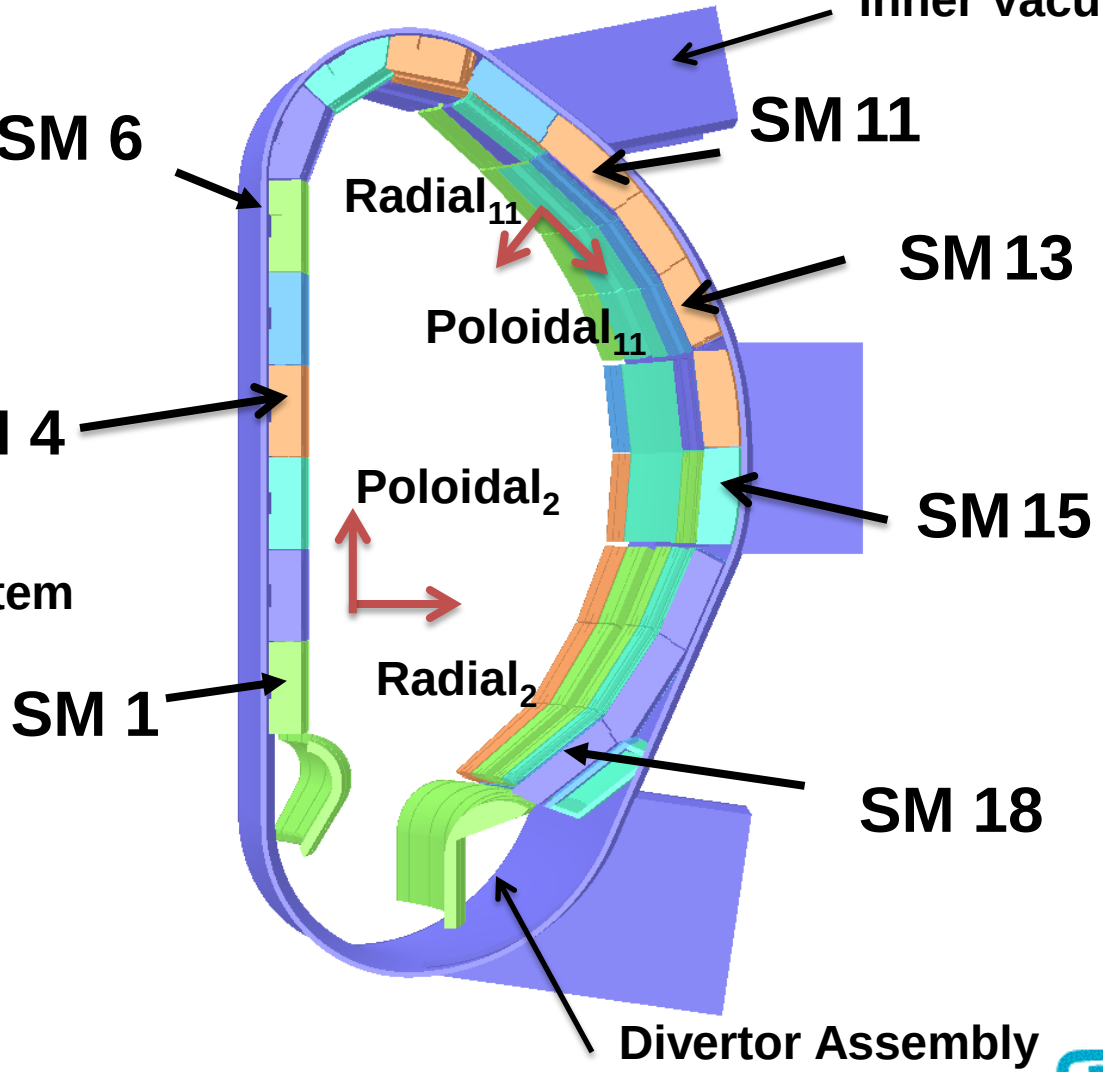
- **Blanket Modules 14 and 15**
  - **In two different sectors of the machine**
- **Plasma Disruption Scenarios**
  - **Basic description**
  - **Modeling procedure**
- **Electromagnetic Models**
- **Results**
  - **Electromagnetic loads**
- **Conclusions**

ITER Device

20 degree sector



Model Coordinate system



SM – shield module
No First Wall

Toroidal – out of paper

Plasma Disruption

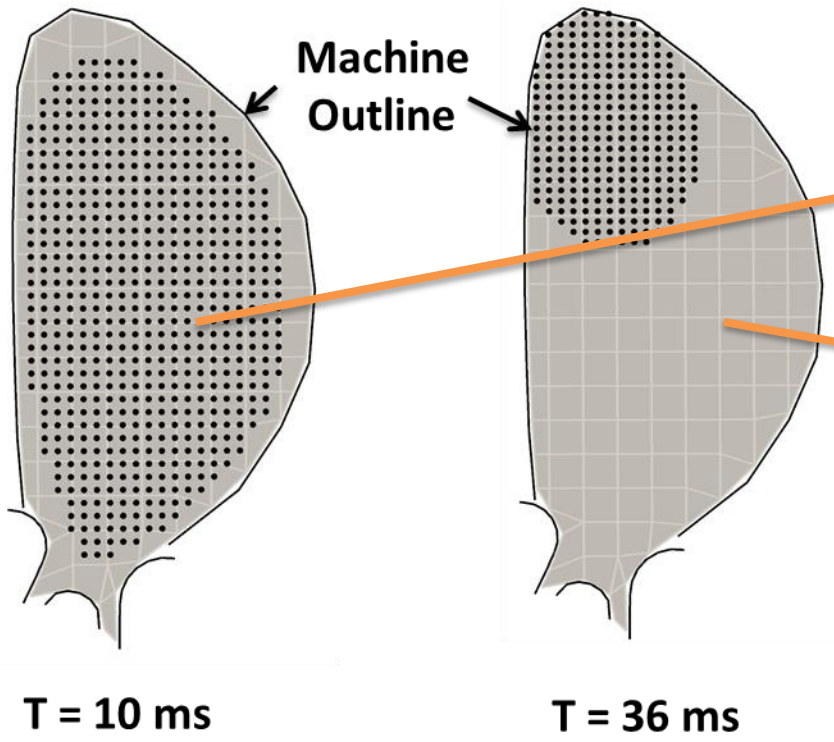
- A 15 MA plasma current is flowing in the device, toroidal direction.
- Plasma drifts then disrupted.
  - Due to impurities
  - Loss of stability
- Plasma current starts to decrease.
  - Centroid of this plasma moves - eddy currents are induced.

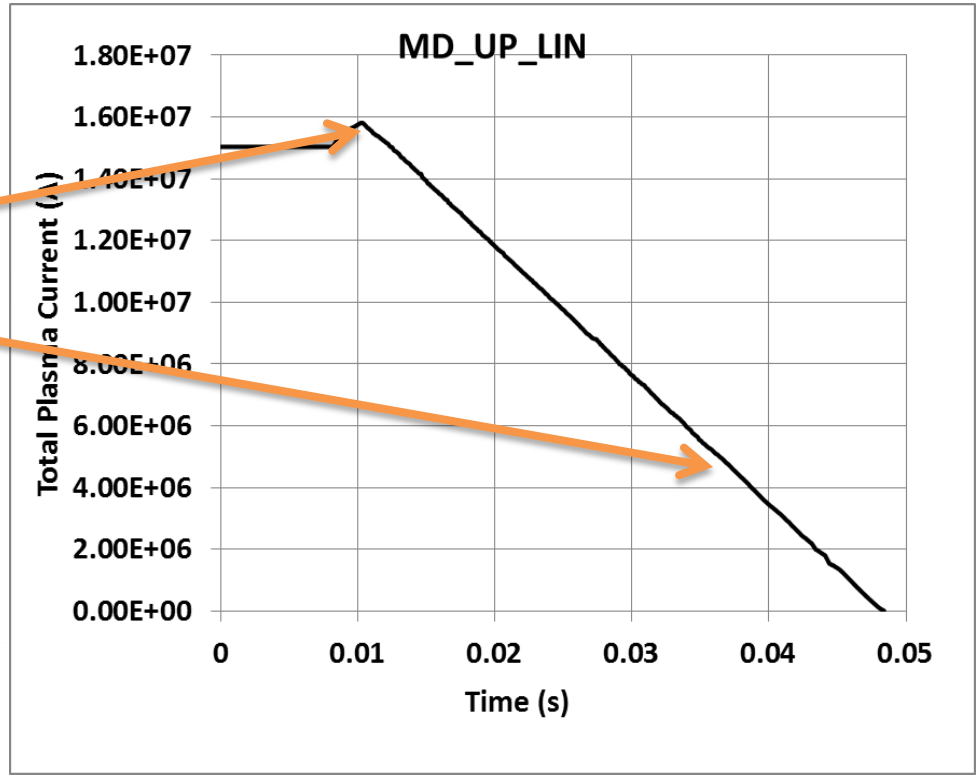
Plasma Disruption Modeling
for Eddy Currents

- From DINA Simulations
  - Prescribed by the International Organization
  - 20 different scenarios
    - MD – Major Disruption
    - VDE – Vertical Displacement Event
      - Plasma direction down(DW) or up (UP)
      - Plasma current decay linear (LIN) or exponential (EXP)
        - » MD_UP_LIN - Major disruption, upward moving, linear current decay

- 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 Modeling





DINA Filaments

Total plasma current

NOTE: Points shown are the Dina filament currents

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Plasma Disruption Modeling

- **Modeled by 64 stationary solenoids.**
  - **Using the equivalence principle.**
- **Each has a different time history.**
- **Models the time variation of the total current behavior.**
- **Models the movement of the plasma with time.**

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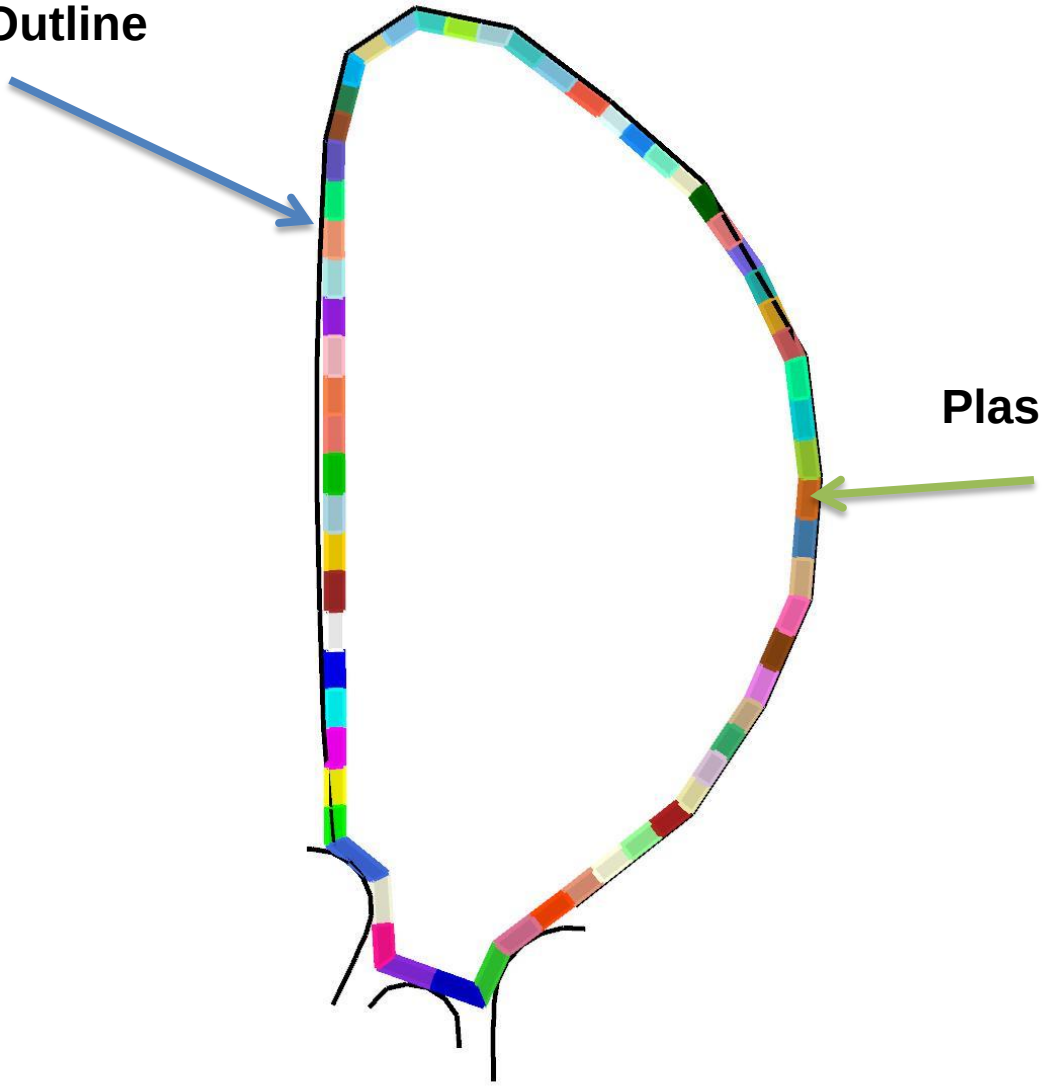
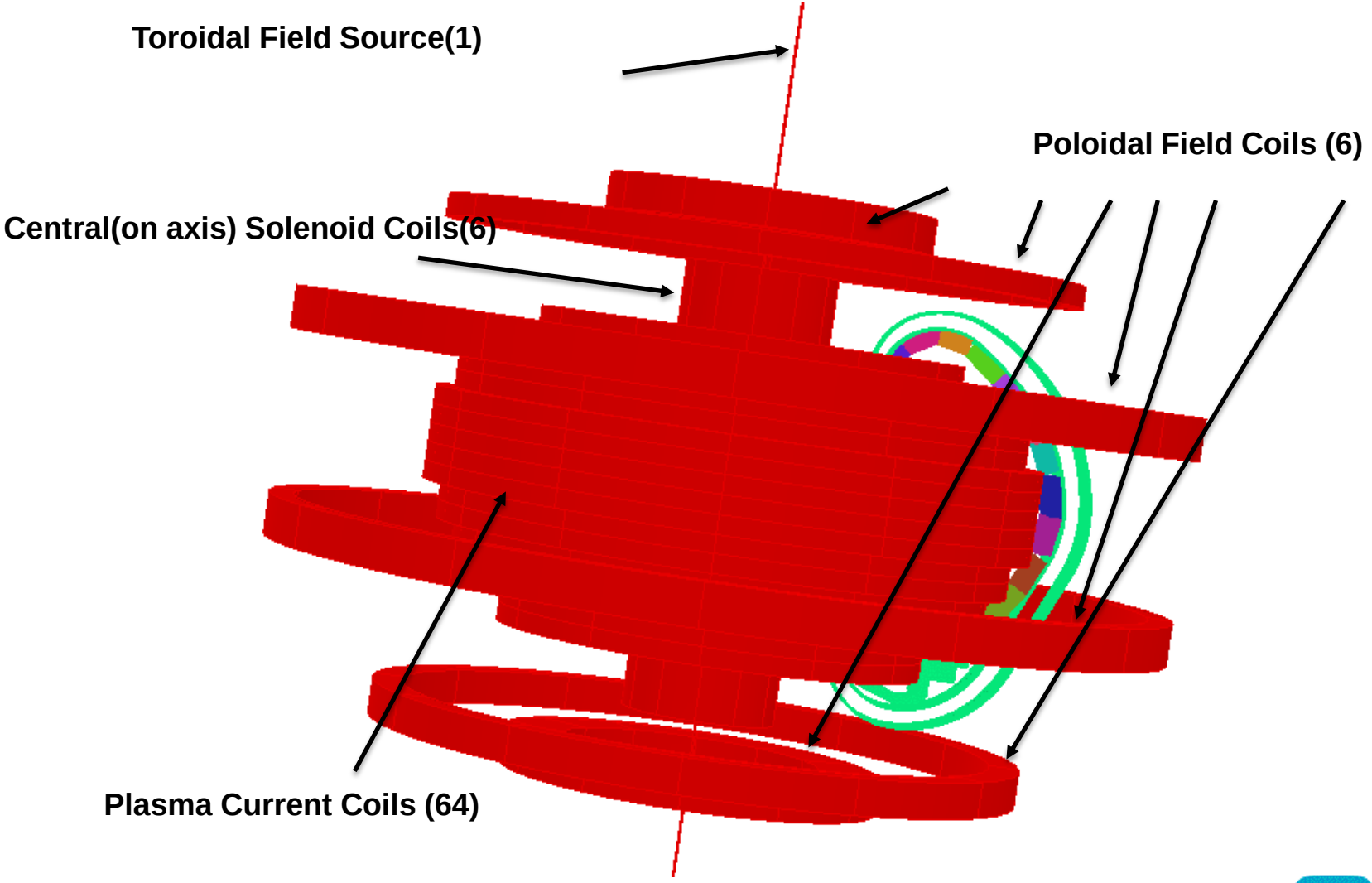
Plasma Disruption Modeling

Machine Outline



Plasma Conductors 64

Electromagnetic Model of Plasma Currents



General Modeling Notes

- For accurate results for a blanket module:
  - Nearest neighbors are included.
- Inner and outer vacuum vessels are included.
- Simulations performed with Opera-3d software.
  - Finite element model
    - 40 degree sector ~35 million elements
    - 20 degree sector ~19 million elements

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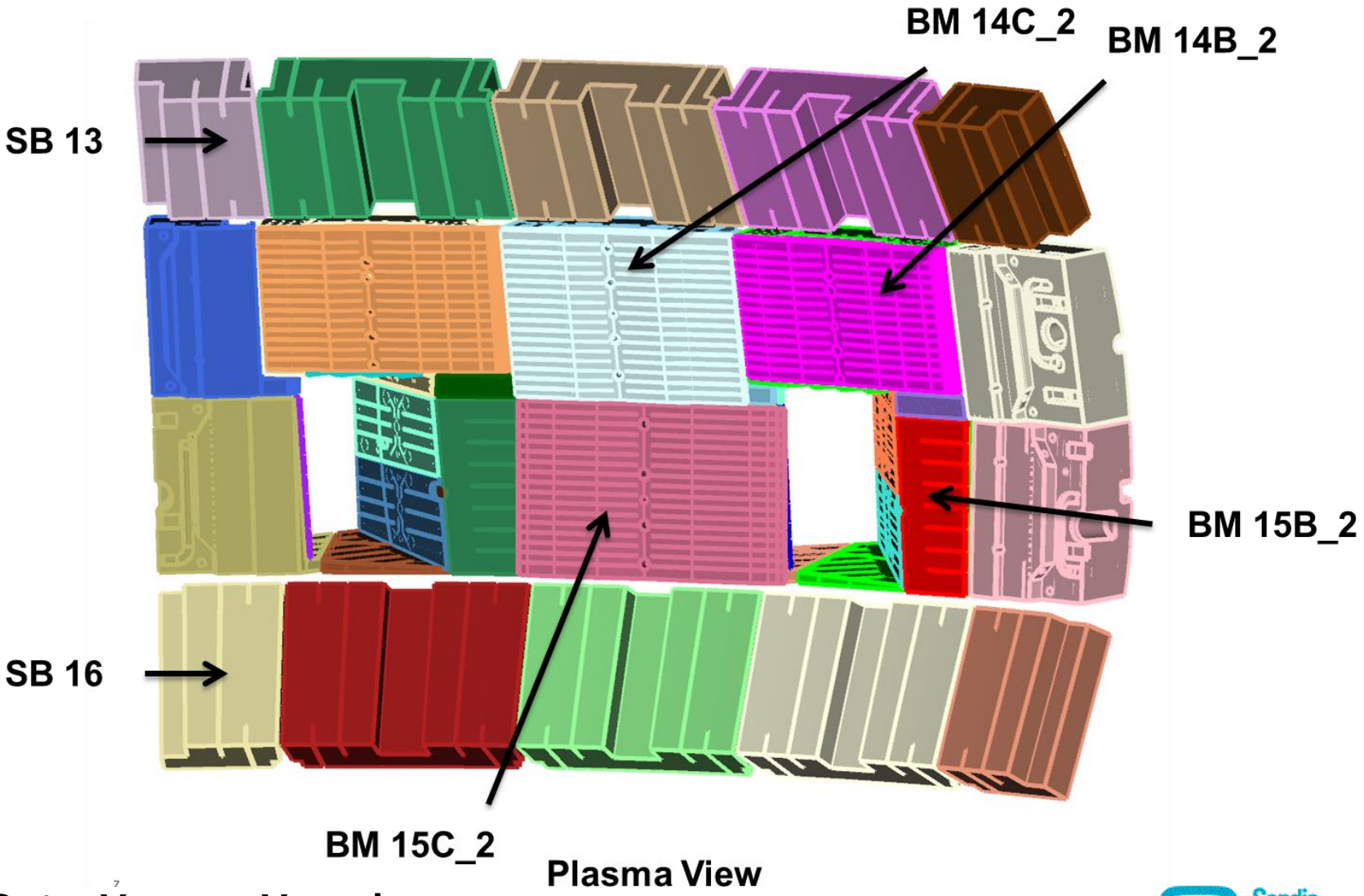
Solid Model for NBI Region

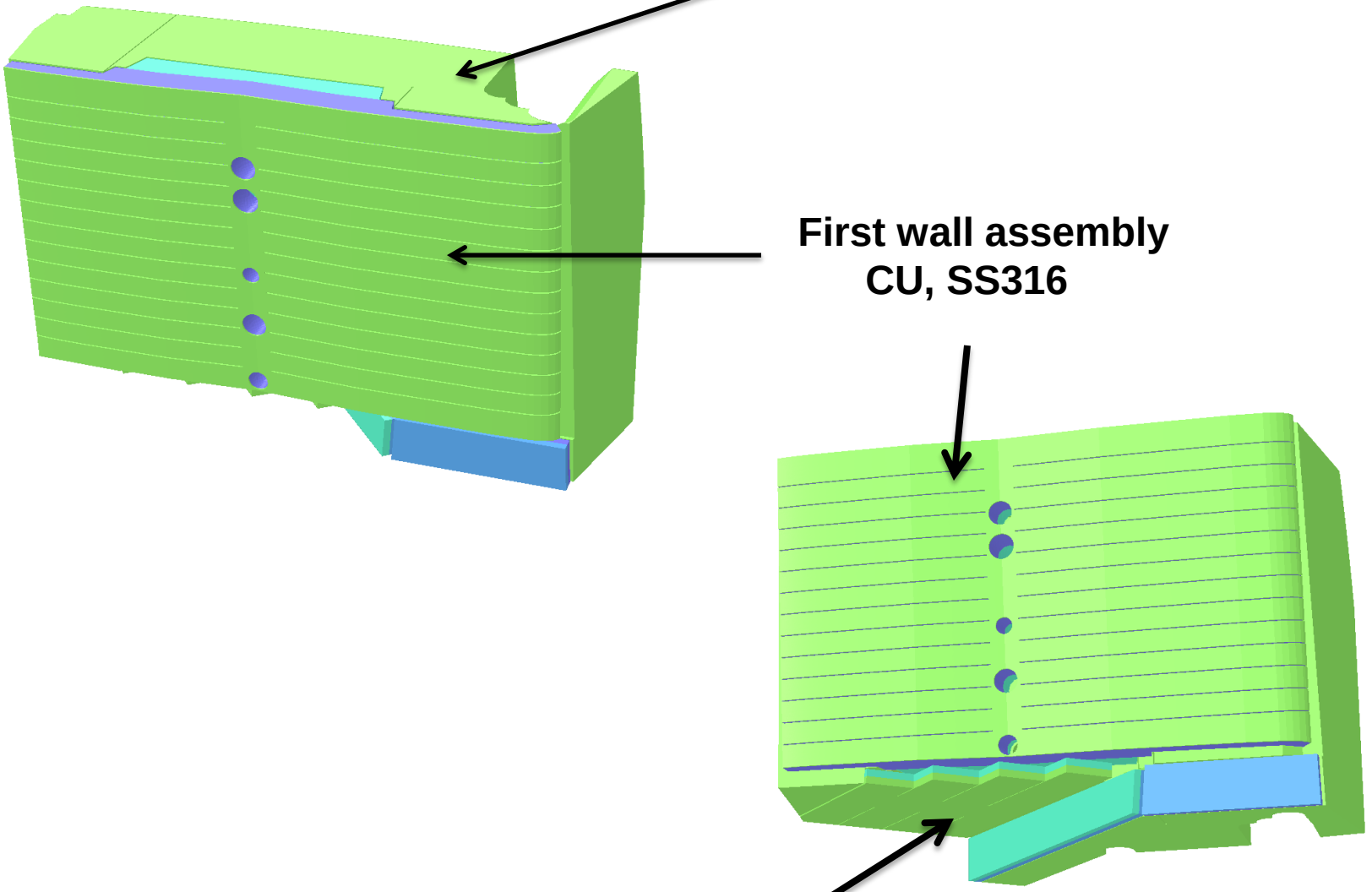
Model #1



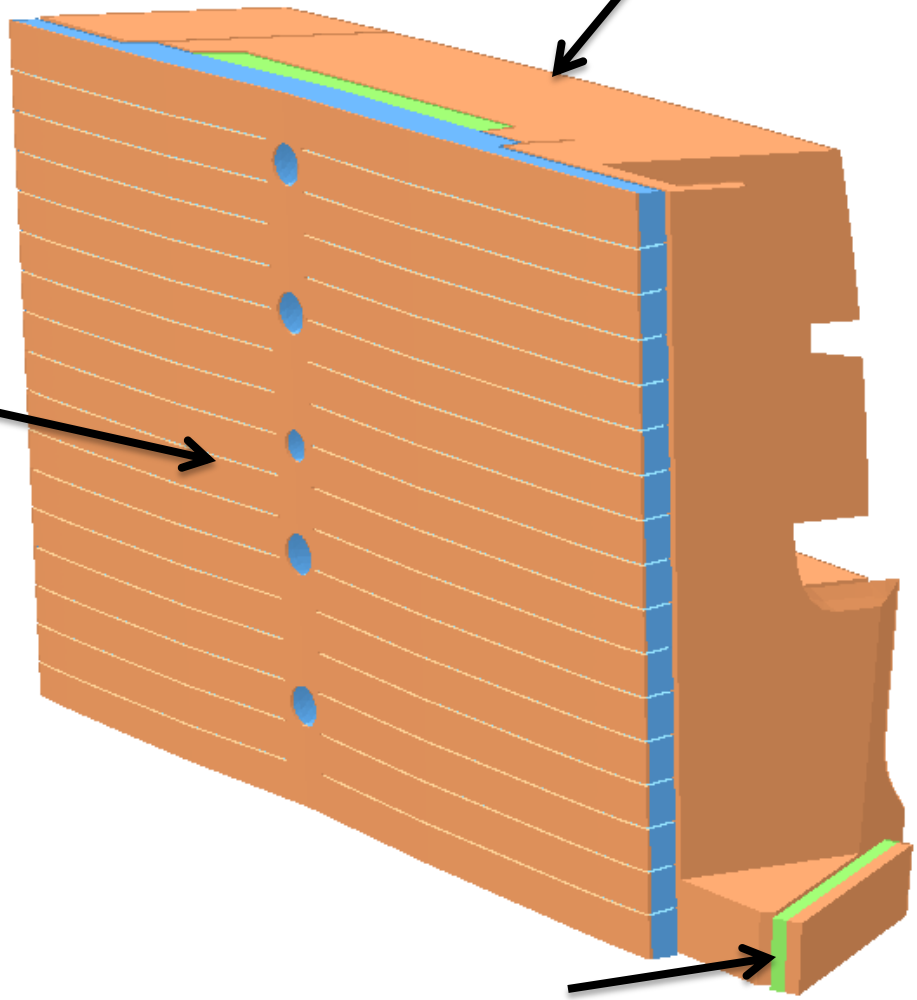
Inner / Outer Vacuum Vessel
Not shown

40 degree sector

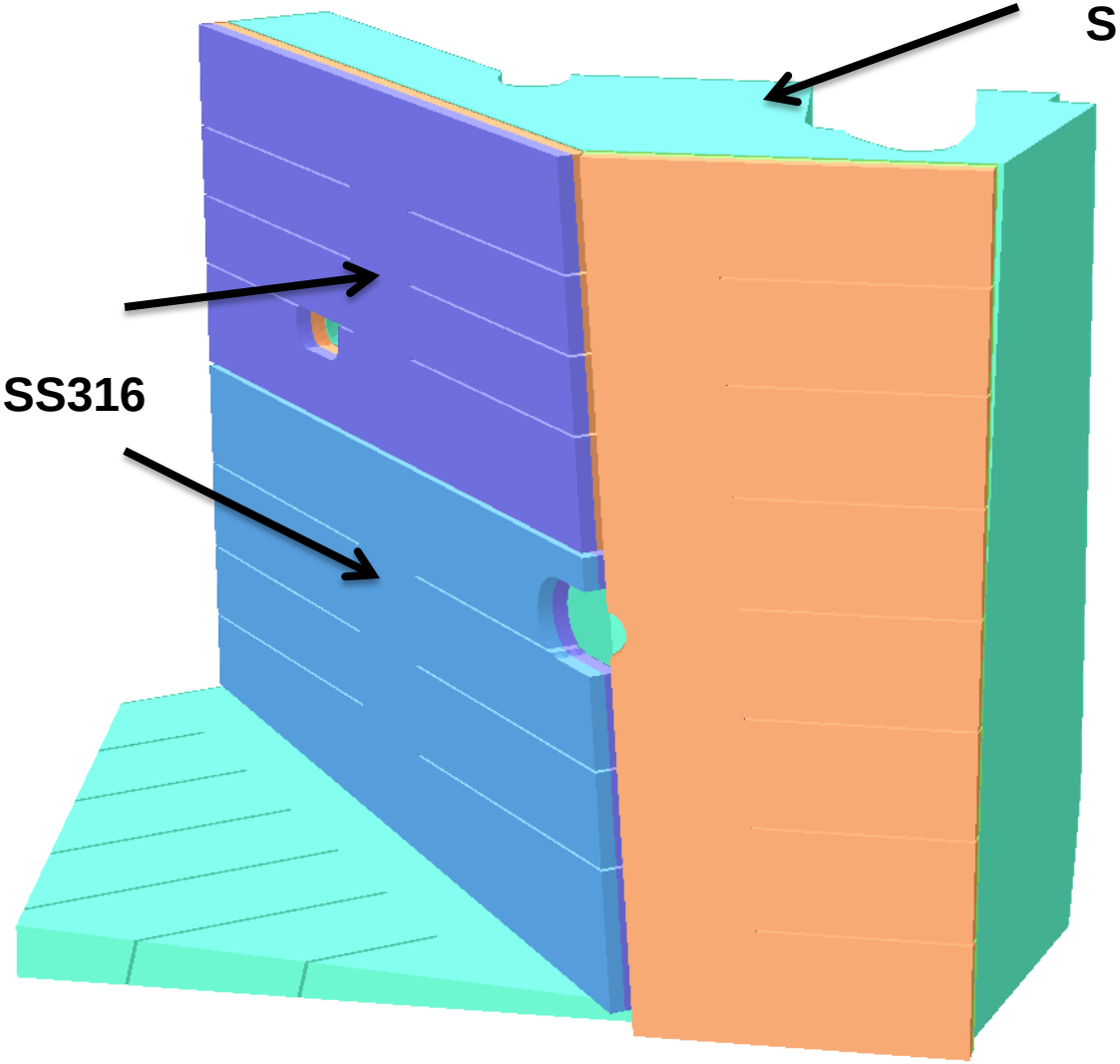
BM 14B_2


Shield block
First wall assembly
CU, SS316
Plates - CU on SS316

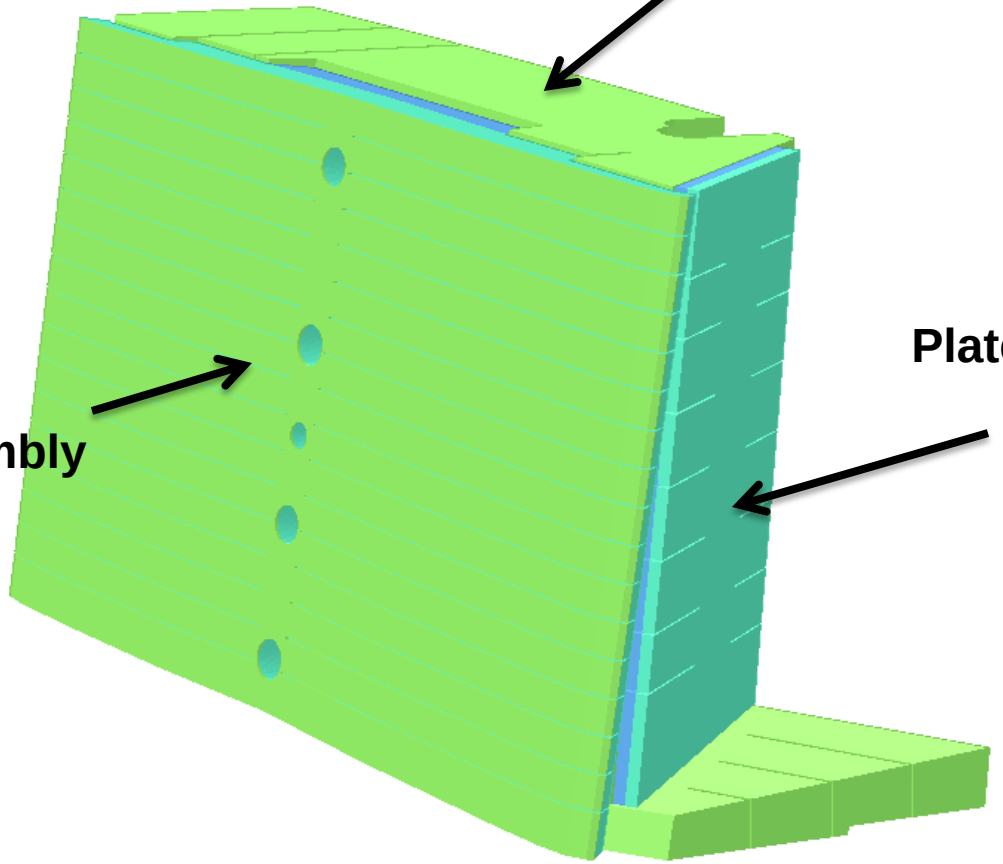
BM 14C_2


Shield block
First wall assembly
CU, SS316
Plates - CU on SS316

BM 15B_2



BM 15C_2

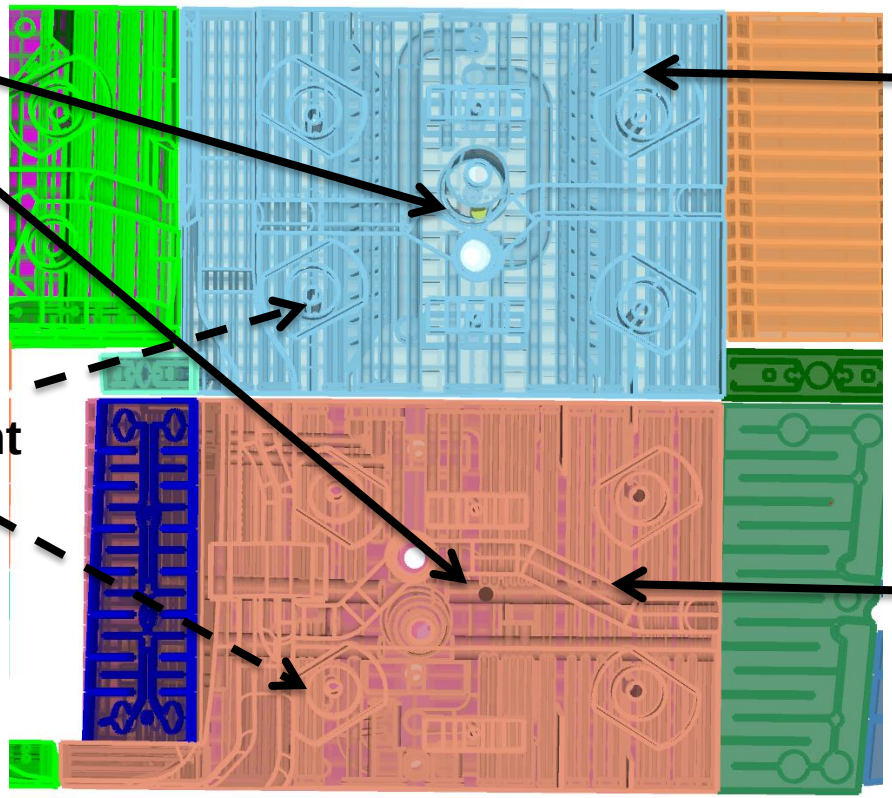

Shield block
Plates - CU on SS316
First wall assembly
CU, SS316

Electromagnetic Load Calculations

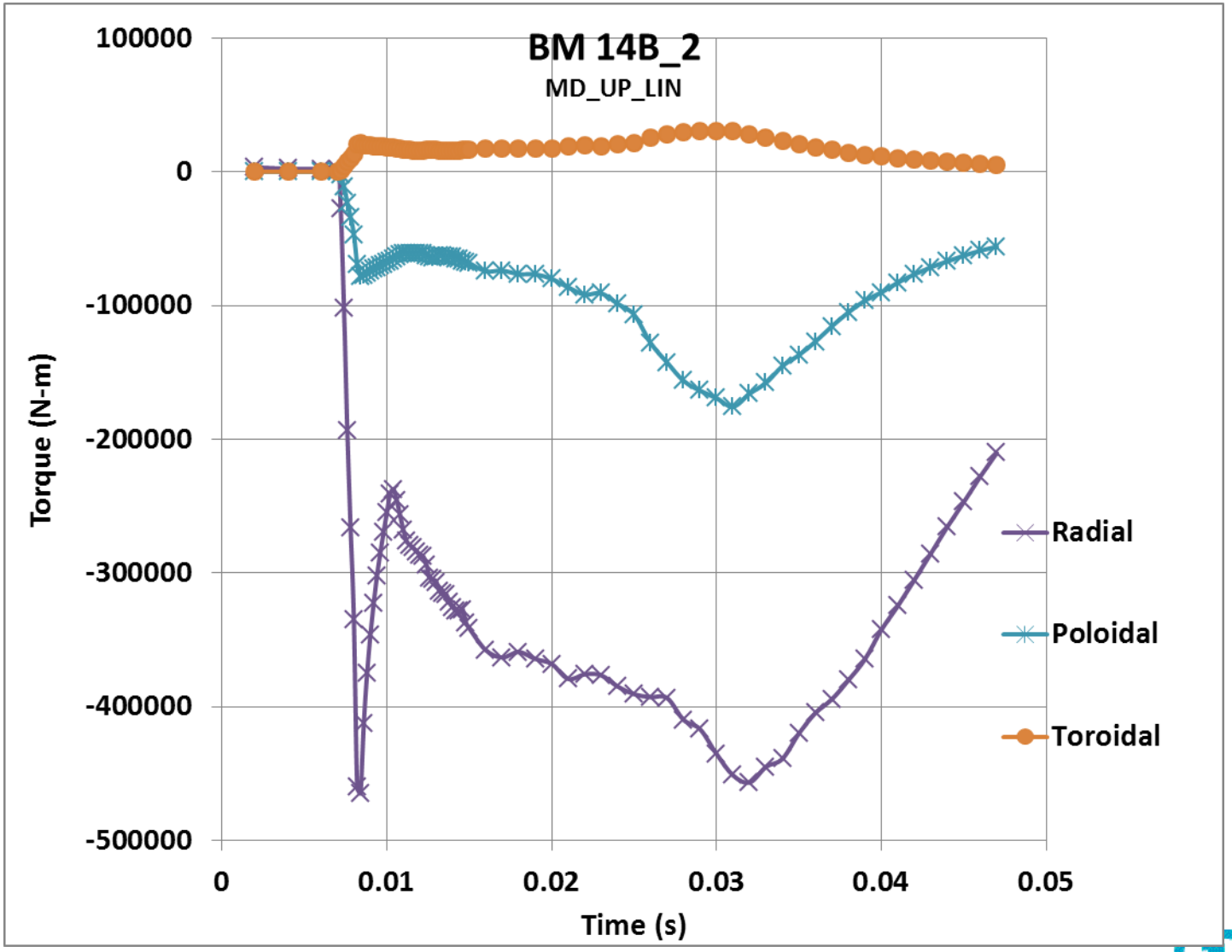
- **Calculated forces and torques transformed from the problem to the local coordinate system of a blanket module.**
  - **Radial direction : toward plasma**
  - **Toroidal direction : in direction of plasma flow**
  - **Poloidal direction : t x r**

Pivot Point Description

- **Pivot point calculated using flexible mount centroids.**



Results Model 1



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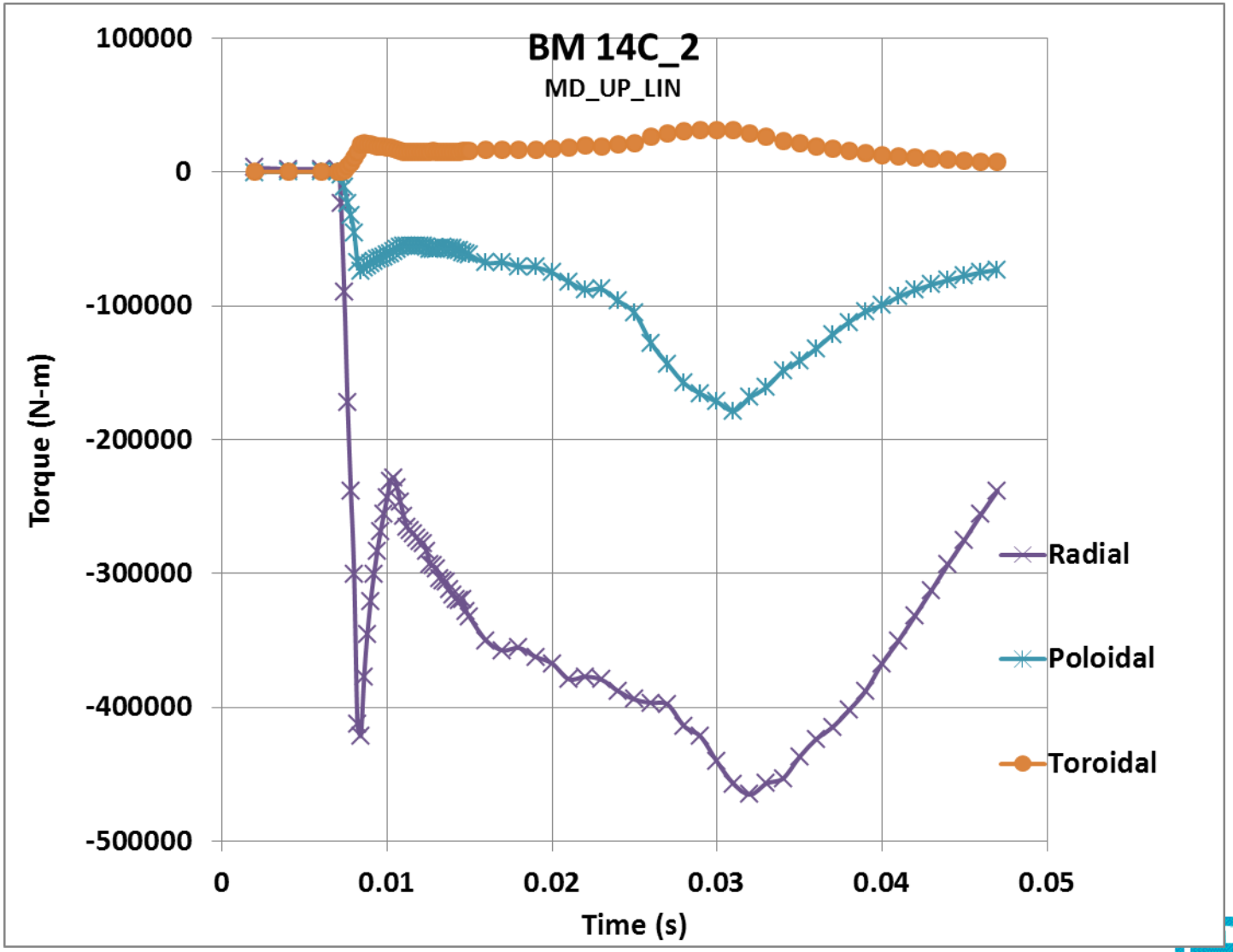
Results Model 1



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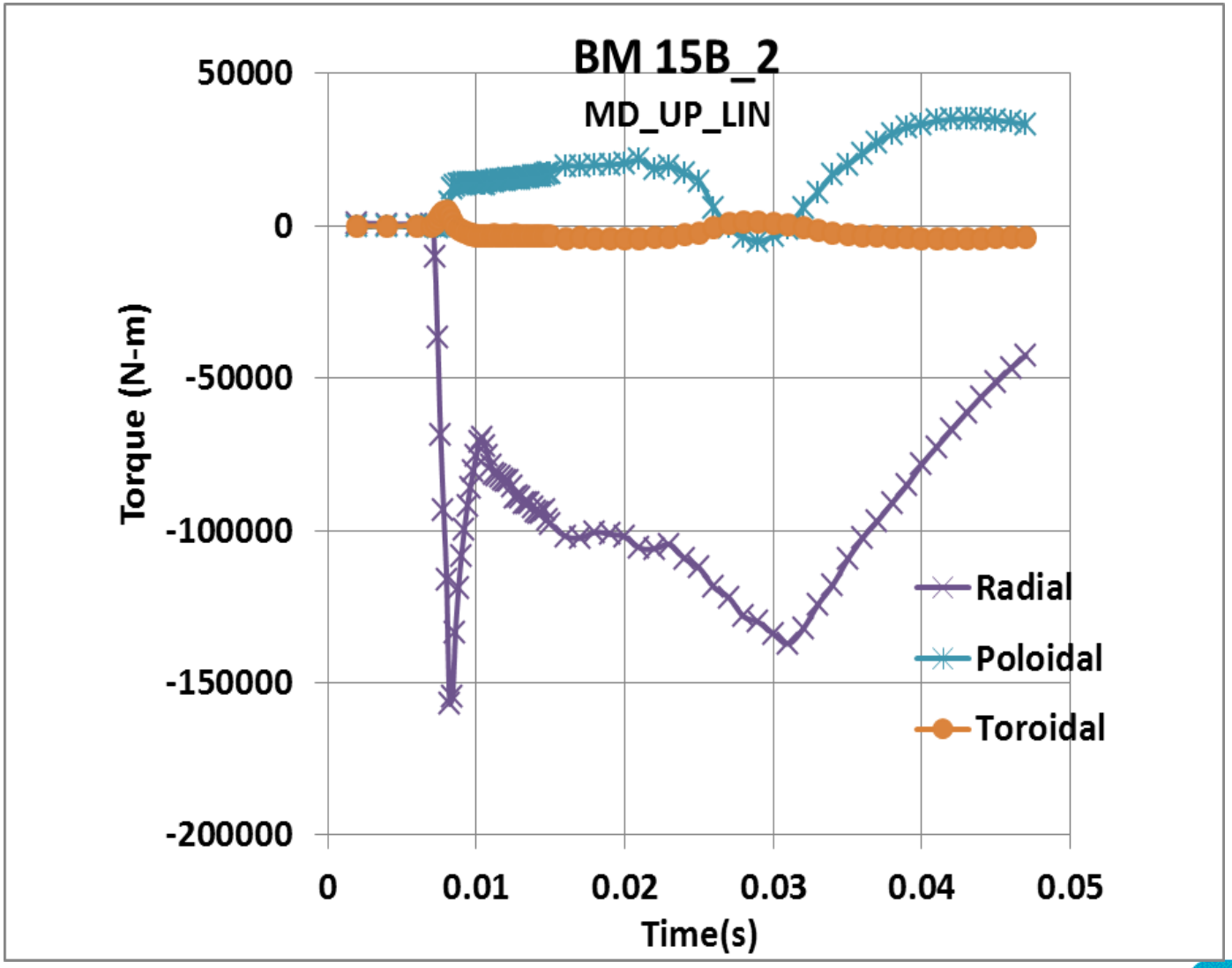
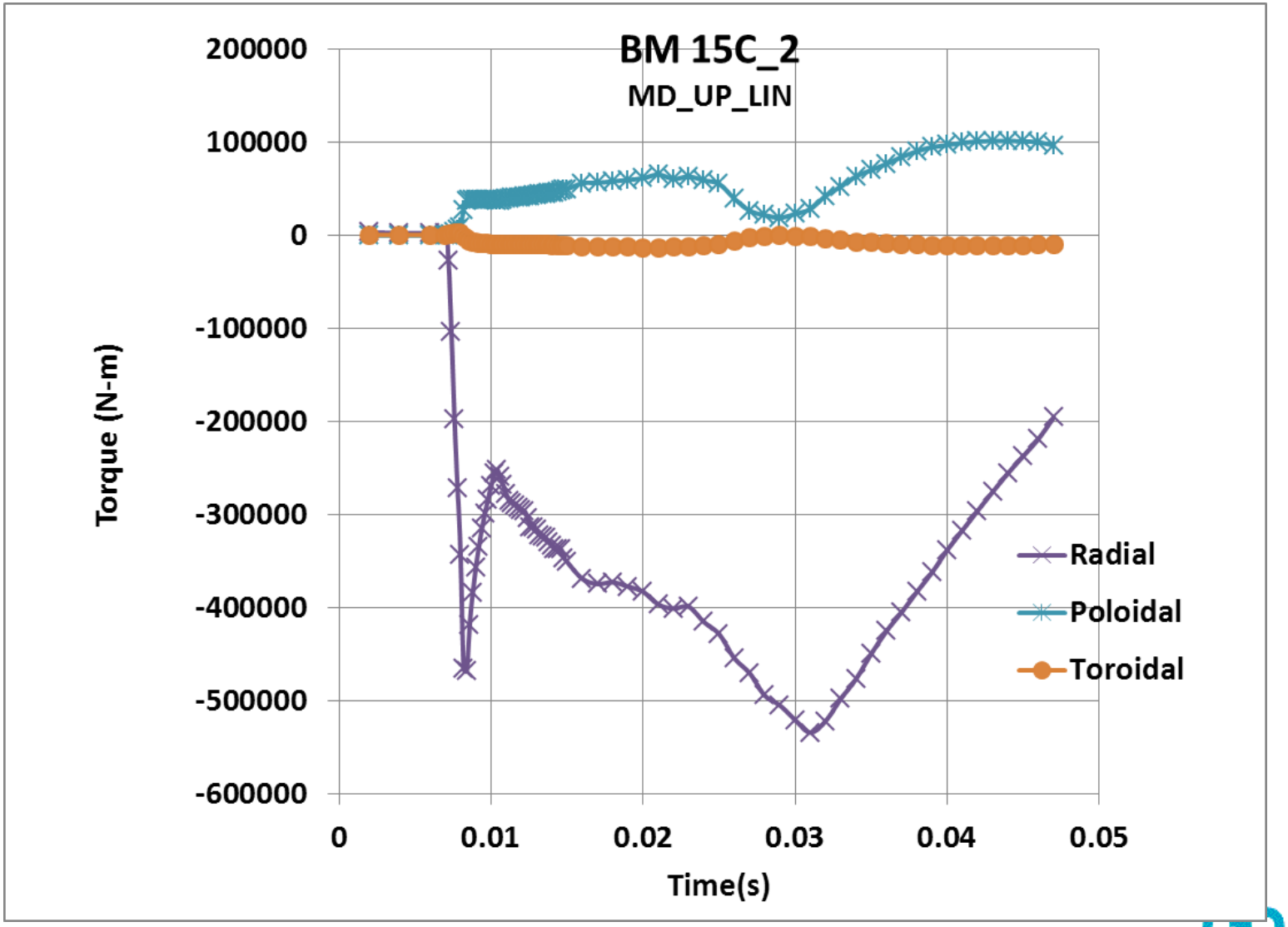
Results Model 1



Results Model 1



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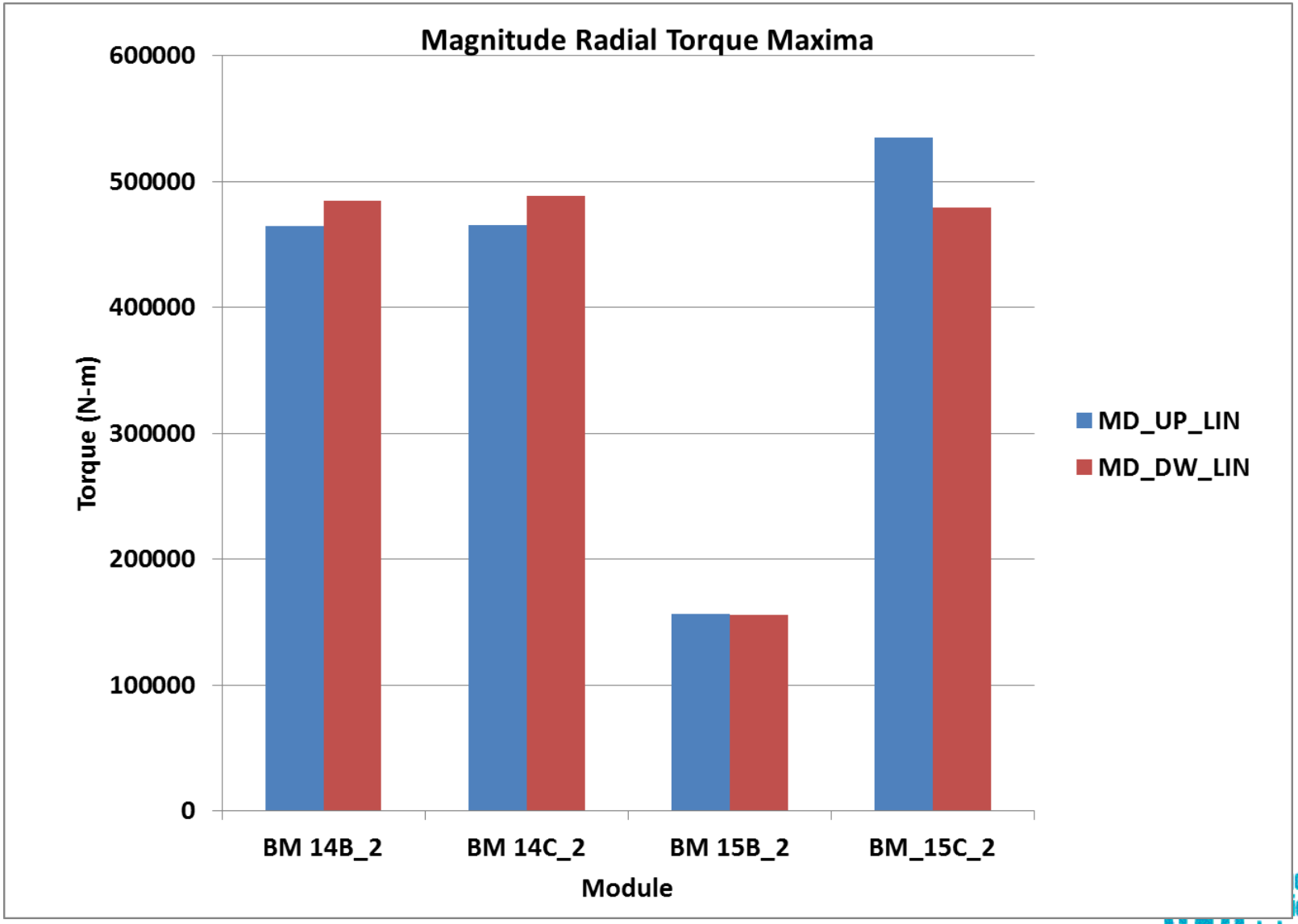
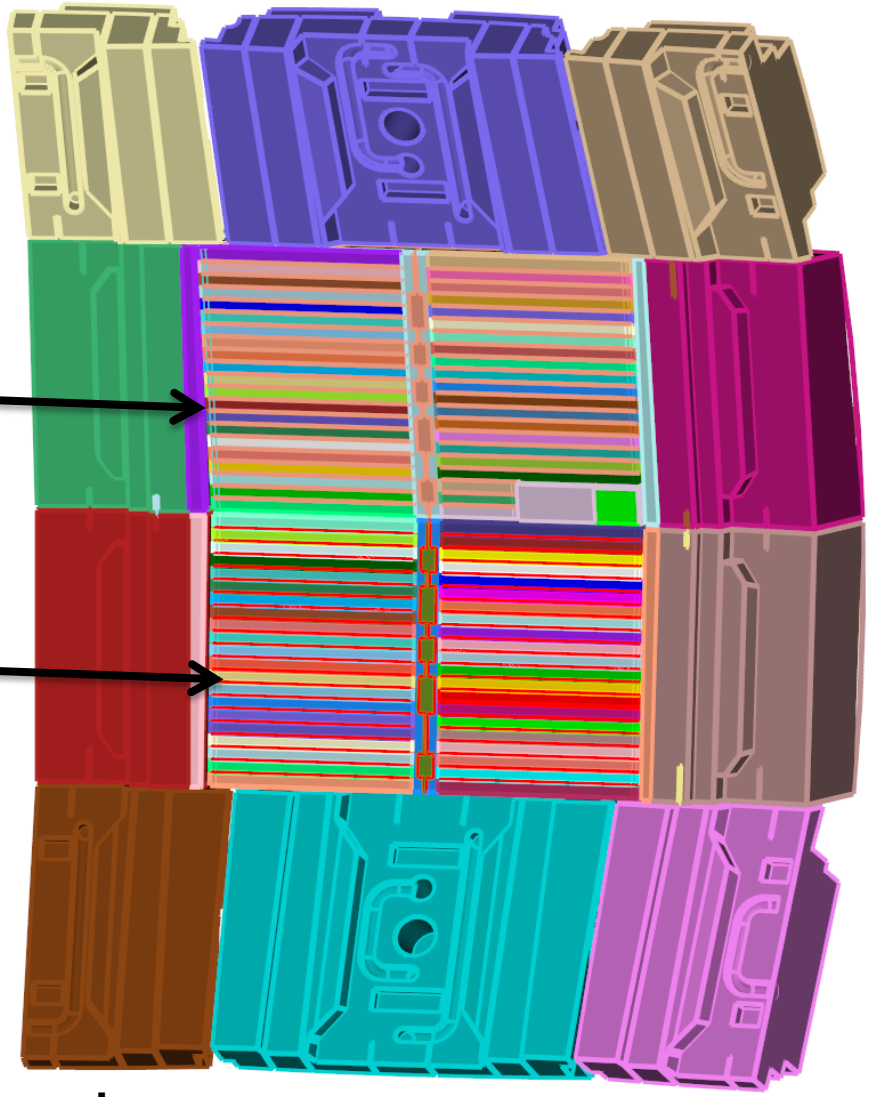
Load Comparisons



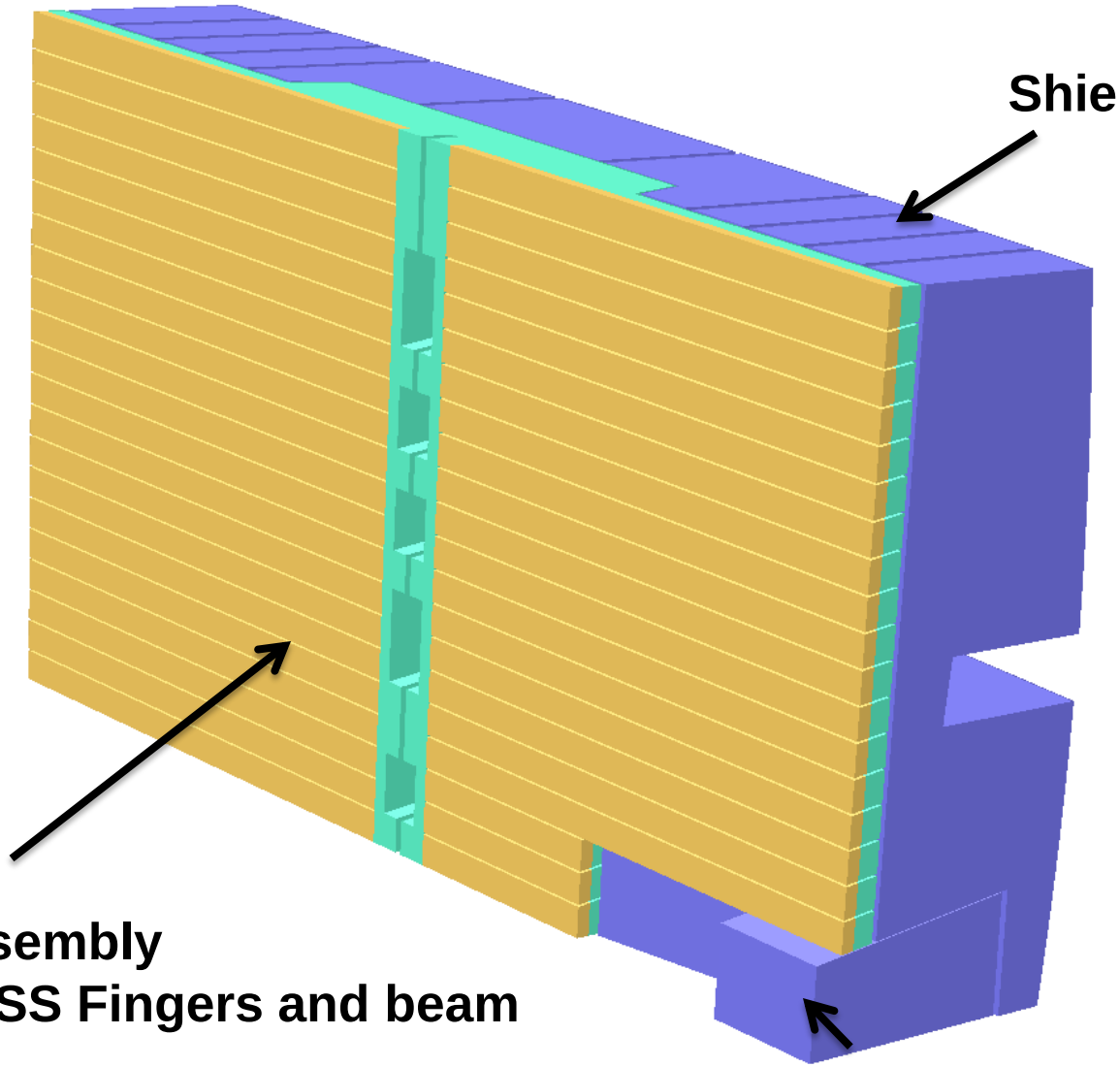
Model #2



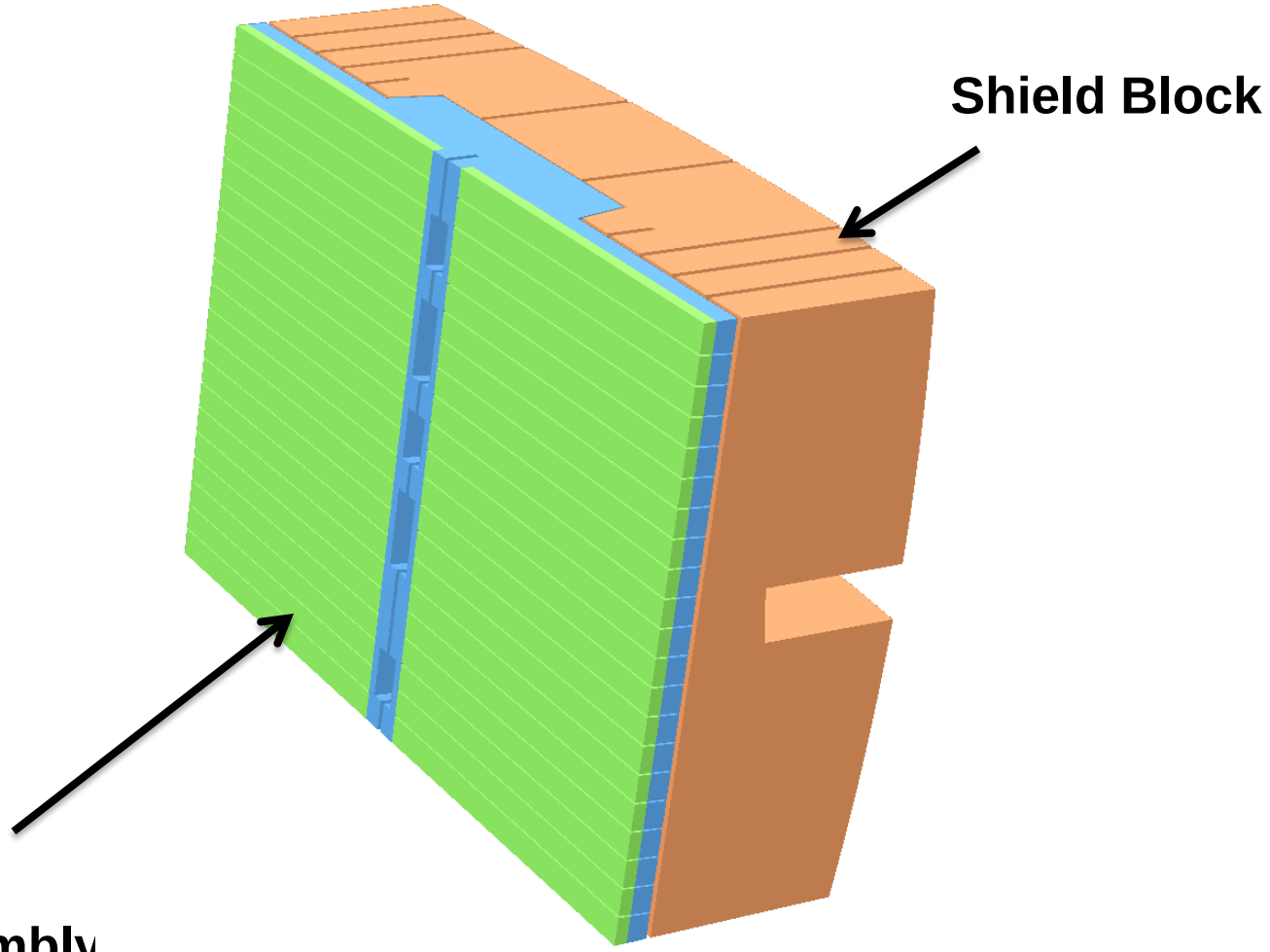
Inner / Outer Vacuum Vessel
Not shown

Plasma View 20 Degree Sector

BM 14_C07


Shield Block
First wall assembly
CU Fingers, SS Fingers and beam
Diagnostic Cover

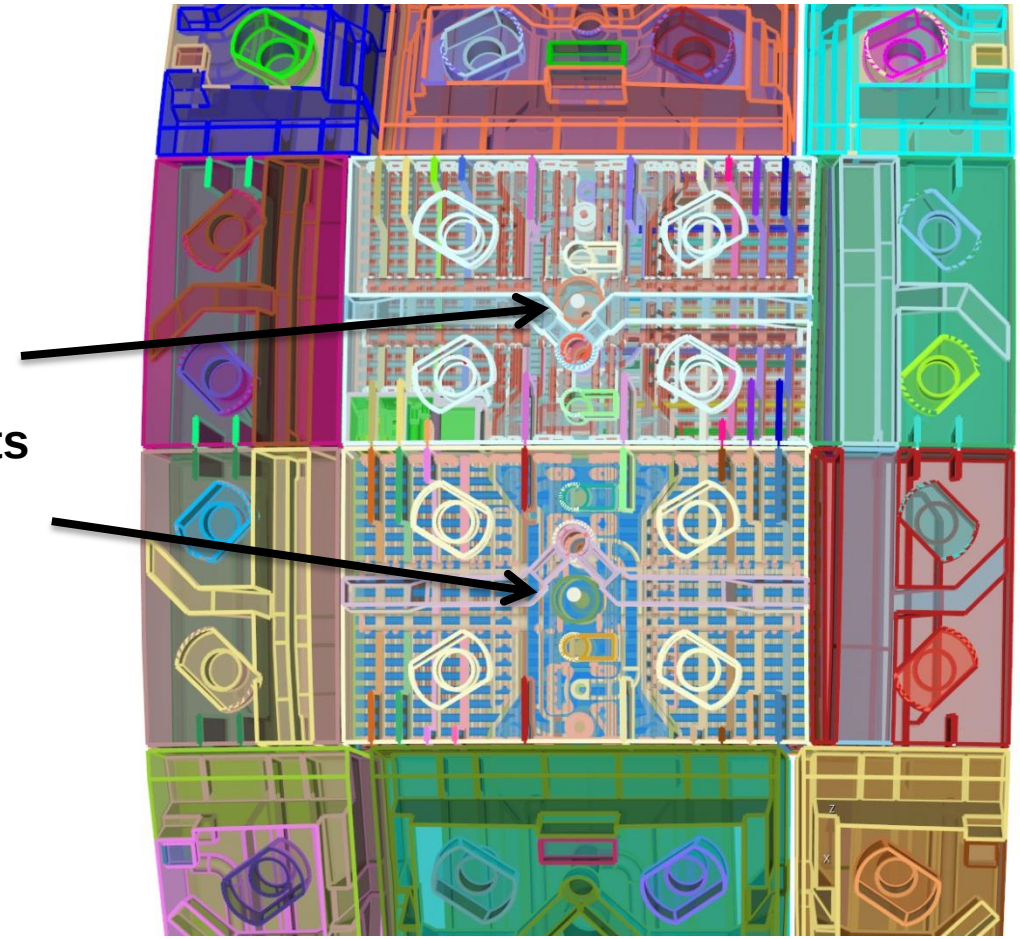
BM 15_C07



First wall assembly
CU Fingers, SS Fingers and beam

Pivot Points

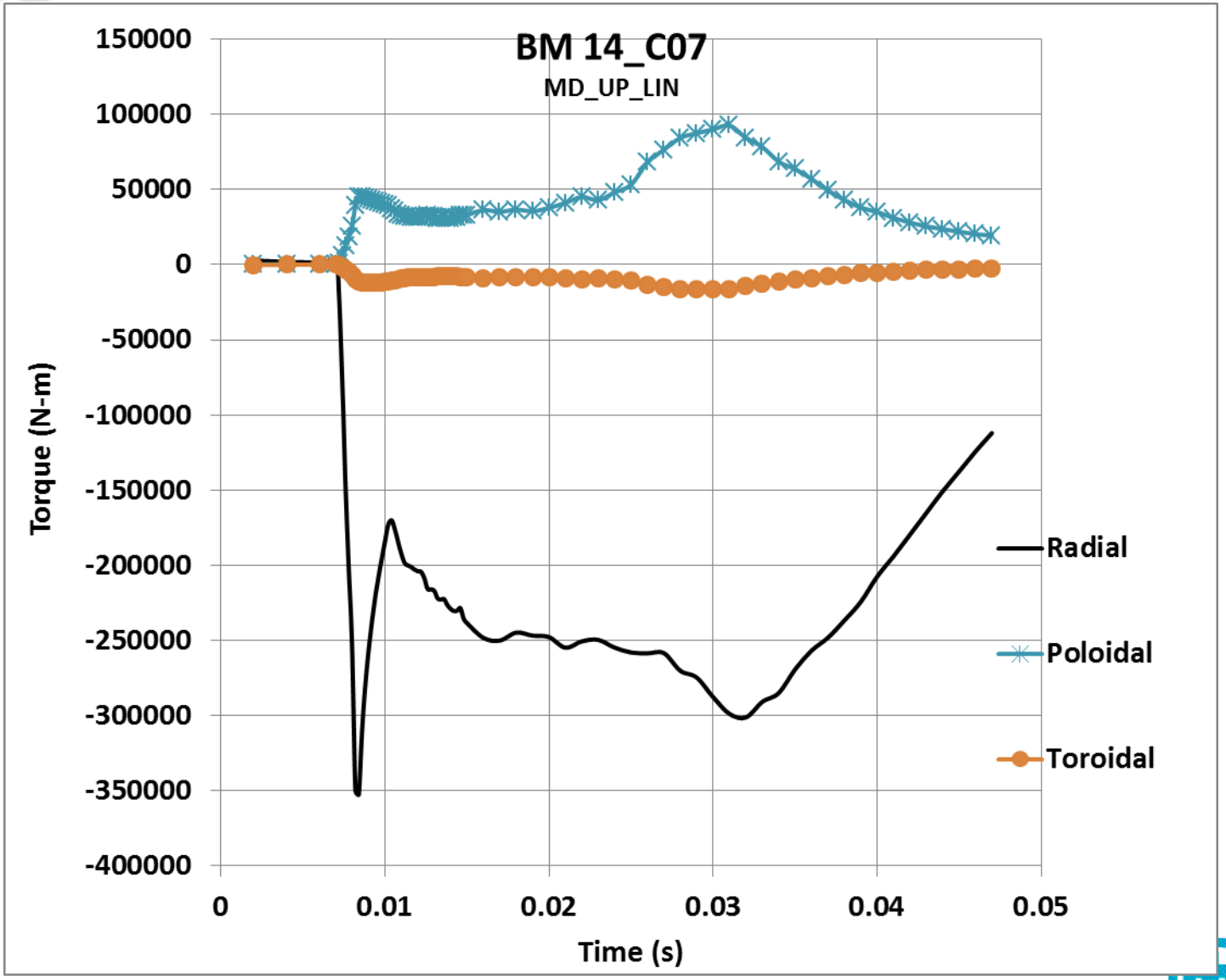
- **Pivot point calculated using flexible mount centroids.**



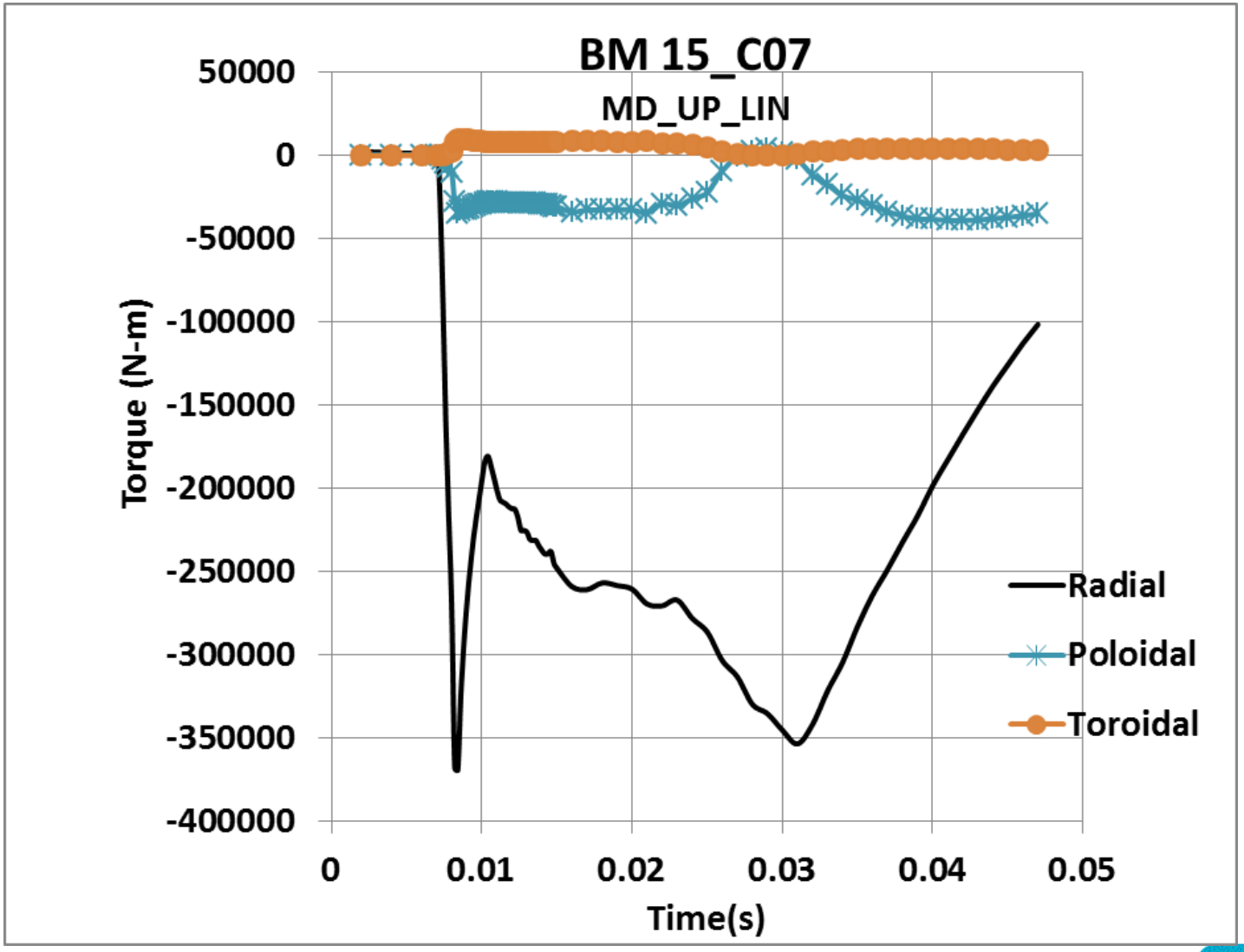
Pivot Points

Vacuum Vessel View

Results Model 2



Results Model 2



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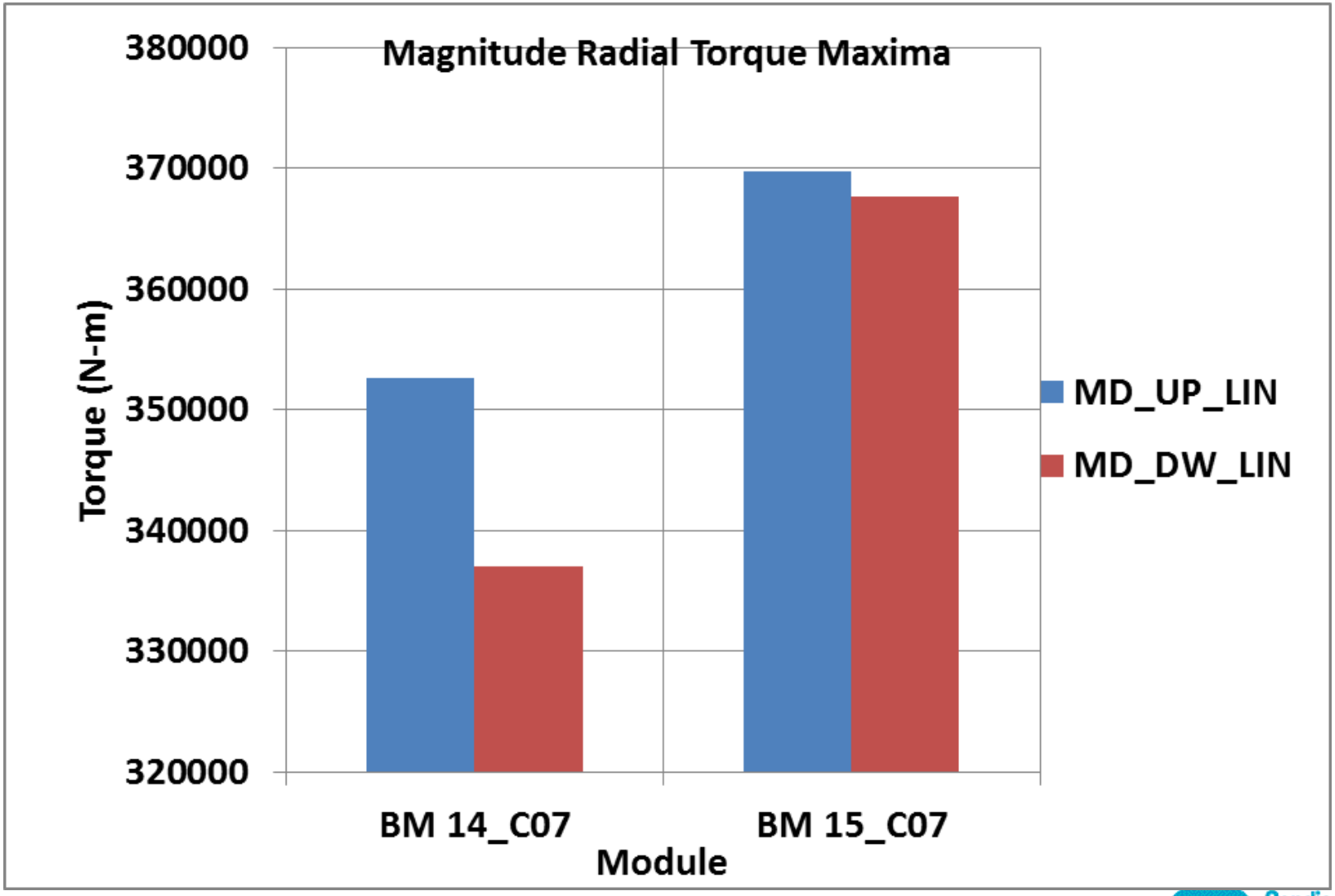
Load Comparisons



Conclusions(1)

- The analysis technique used to predict the electromagnetic loads on selected outboard blanket modules has been described.
  - Plasma disruption modeling
  - BM models
- The torques have been calculated for different plasma disruption events for these modules.
  - Forces calculated but not shown.

Conclusions(2)

- **The force distribution within the components of each blanket module is available.**
  - **For stress calculations**
- **Since each blanket module component has been separated electromagnetic loads have been calculated:**
  - **First wall to shield block**
  - **Plate attachments**

Acknowledgements

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- The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.