SAND2011-6600C

THE REDUCTION OF EDDY CURRENT LOADS DUE TO PLASMA DISRUPTION ON SELECTED ITER SHIELD MODULES THROUGH THE OPTIMIZATION OF EDDY CURRENT SLITS.

J. D. Kotulski, R. S. Coats, M. Ulrickson

jdkotul@sandia.gov

Sept. 2011

Sandia National Laboratories is a multi program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND2011-0439P
.

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.**
  - **These can be reduced by the proper placement of eddy current slits within the shield blocks.**

Overview

- This analysis reveals the modeling procedure used to predict the electromagnetic loads on the shield blocks due to plasma disruption.

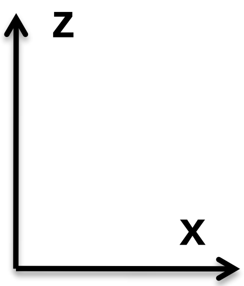
- In addition, a number of different slit configurations for a number of shield blocks have been considered to help guide the design of the shield blocks.

Overview(Cont'd)

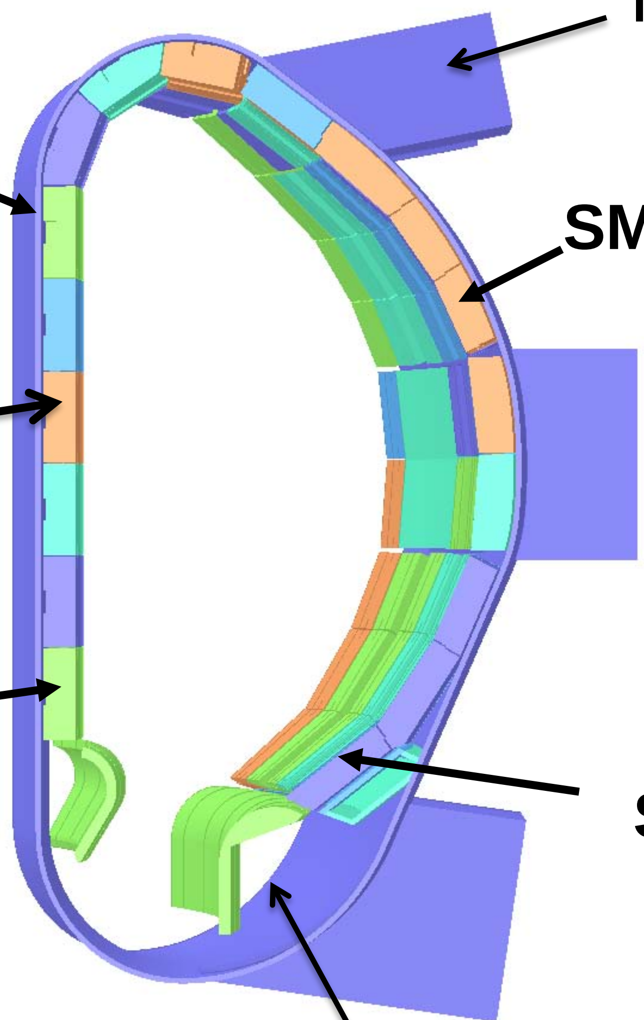
- **ITER Device**
  - **Overall System Model**
  - **Typical Blanket Module**
  - **Typical Shield Block**
- **Plasma Disruption Scenarios**
  - **Basic description**
  - **Modeling procedure**
- **Electromagnetic Model**
- **Results**
  - **Radial torque calculated for the different models.**
- **Conclusions**

ITER Device

20 degree sector



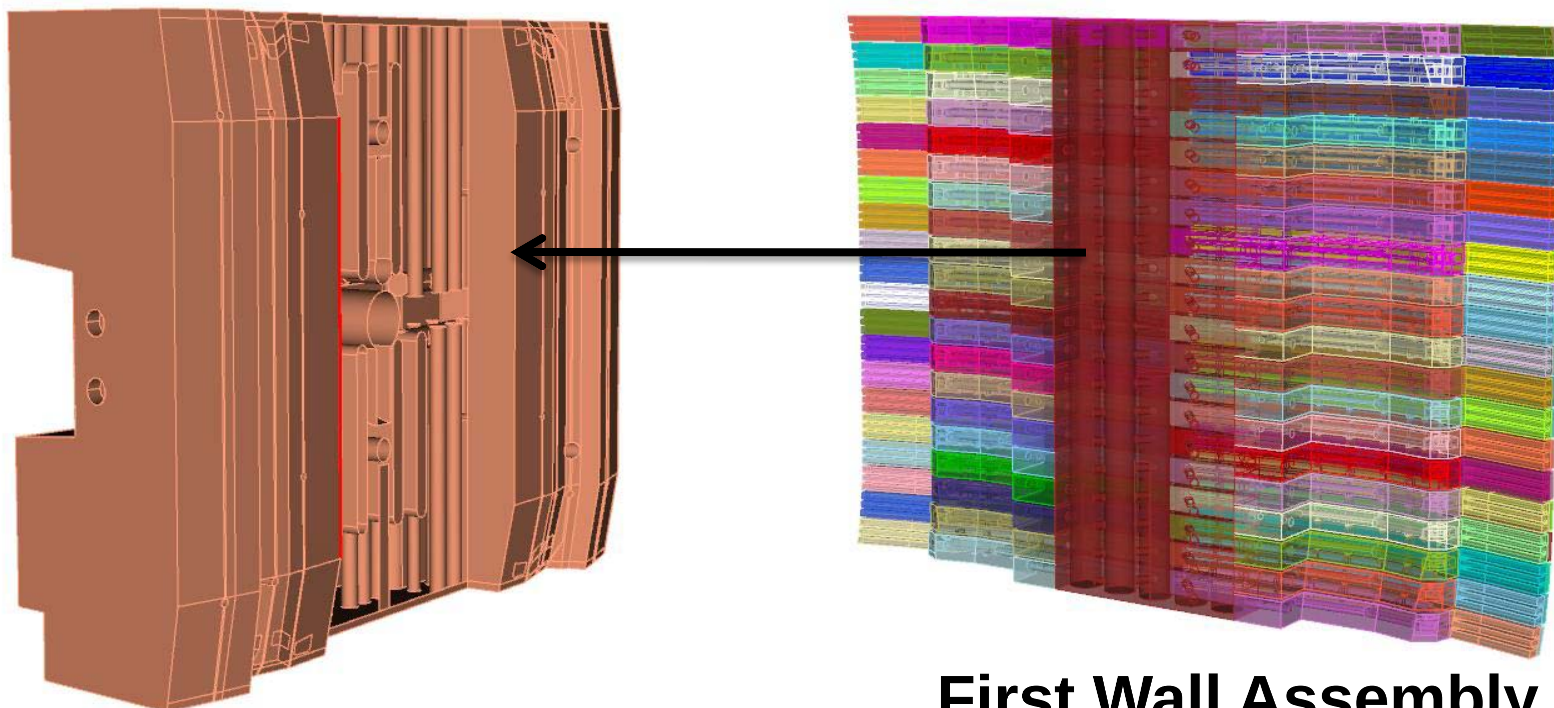
Coordinate system



SM – shield module

No First Wall

Example Blanket Module



First Wall Assembly 4

Shield Block 4

Key features – model contains cooling channels and eddy current slits

BM – shield block with First Wall Assembly

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

Plasma Disruption

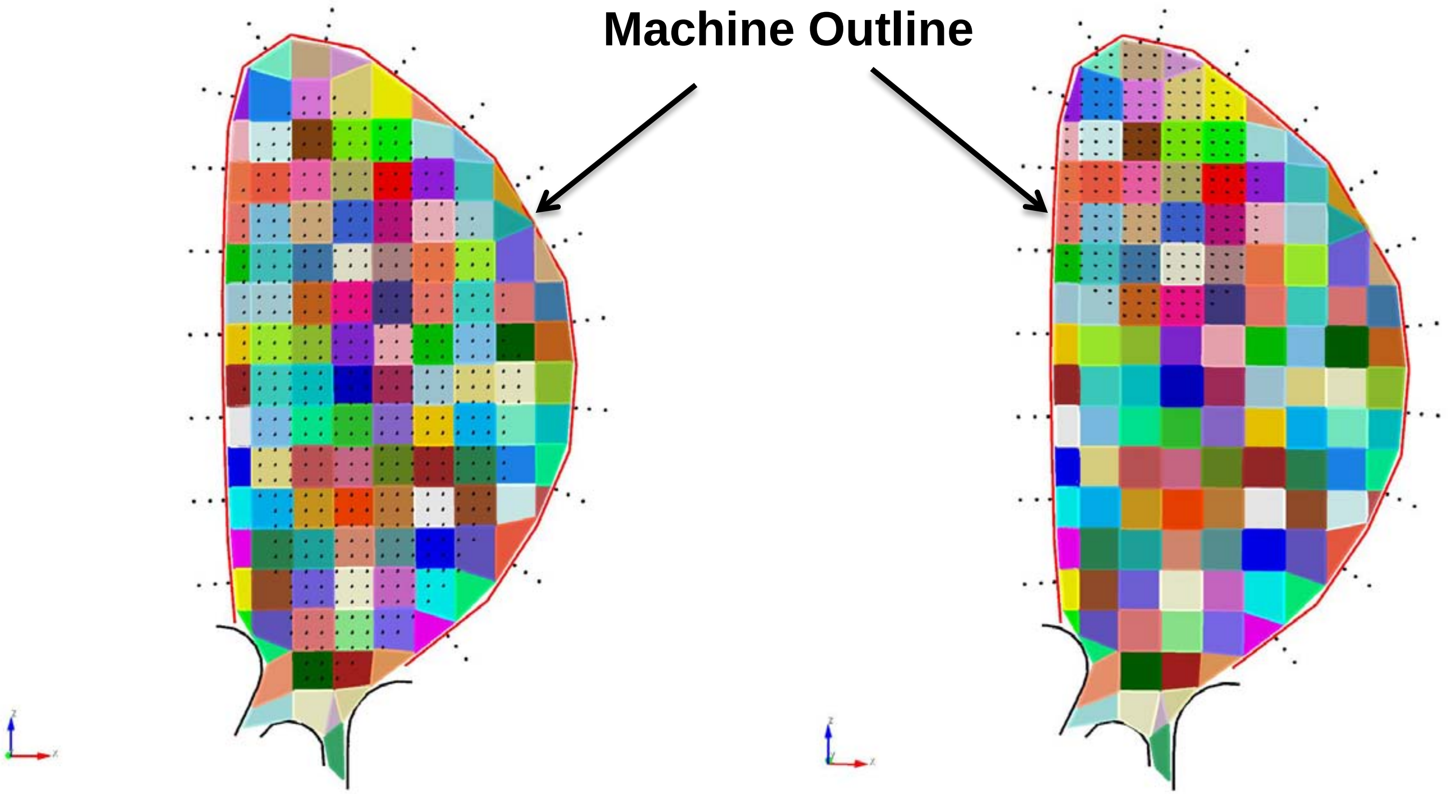
- A 15 MA plasma current is flowing in the device, toroidal direction.
- Impurities disrupt plasma operation.
- Plasma current starts to decrease.
  - Centroid of this plasma moves - eddy currents are induced.

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 Modeling



T = 20 ms

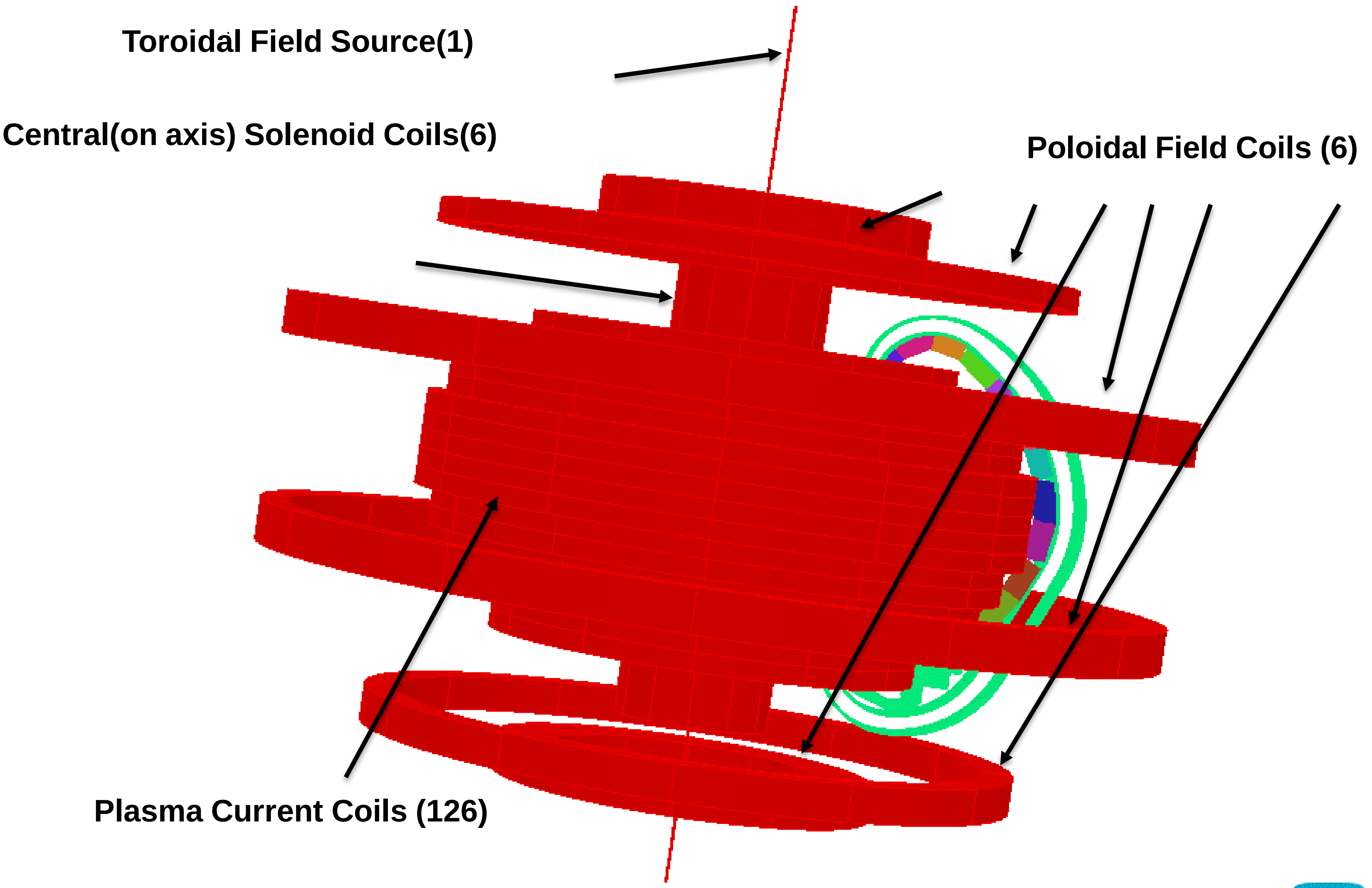
T = 36 ms

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.

Currents and Model



Electromagnetic Analysis

- **Performed using OPERA-3d**

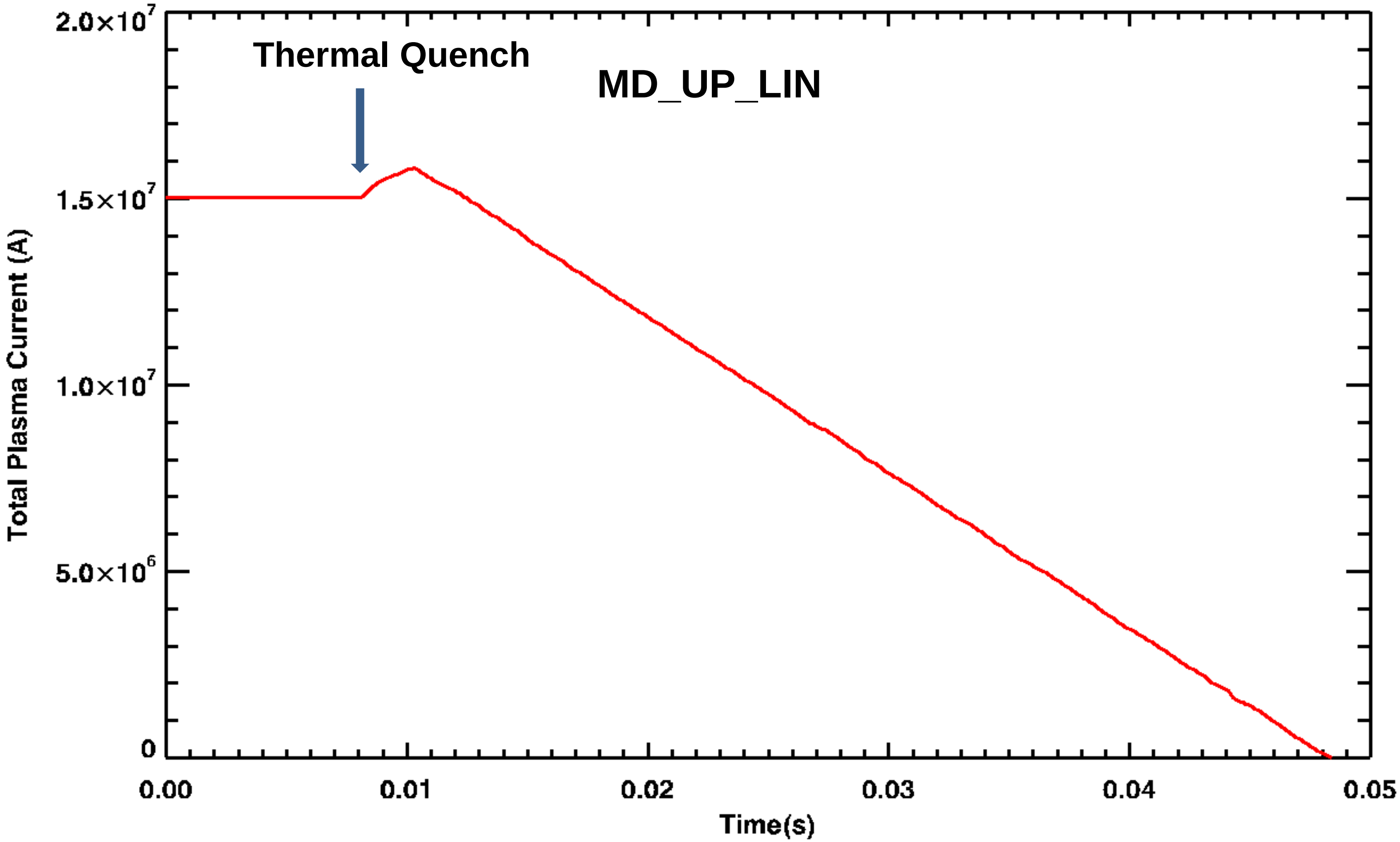
- **Key Features:**
  - **Transient solver**
  - **Symmetry**
  - **Reduced potential formulation**
    - **Currents decoupled from mesh**

Electromagnetic Modeling

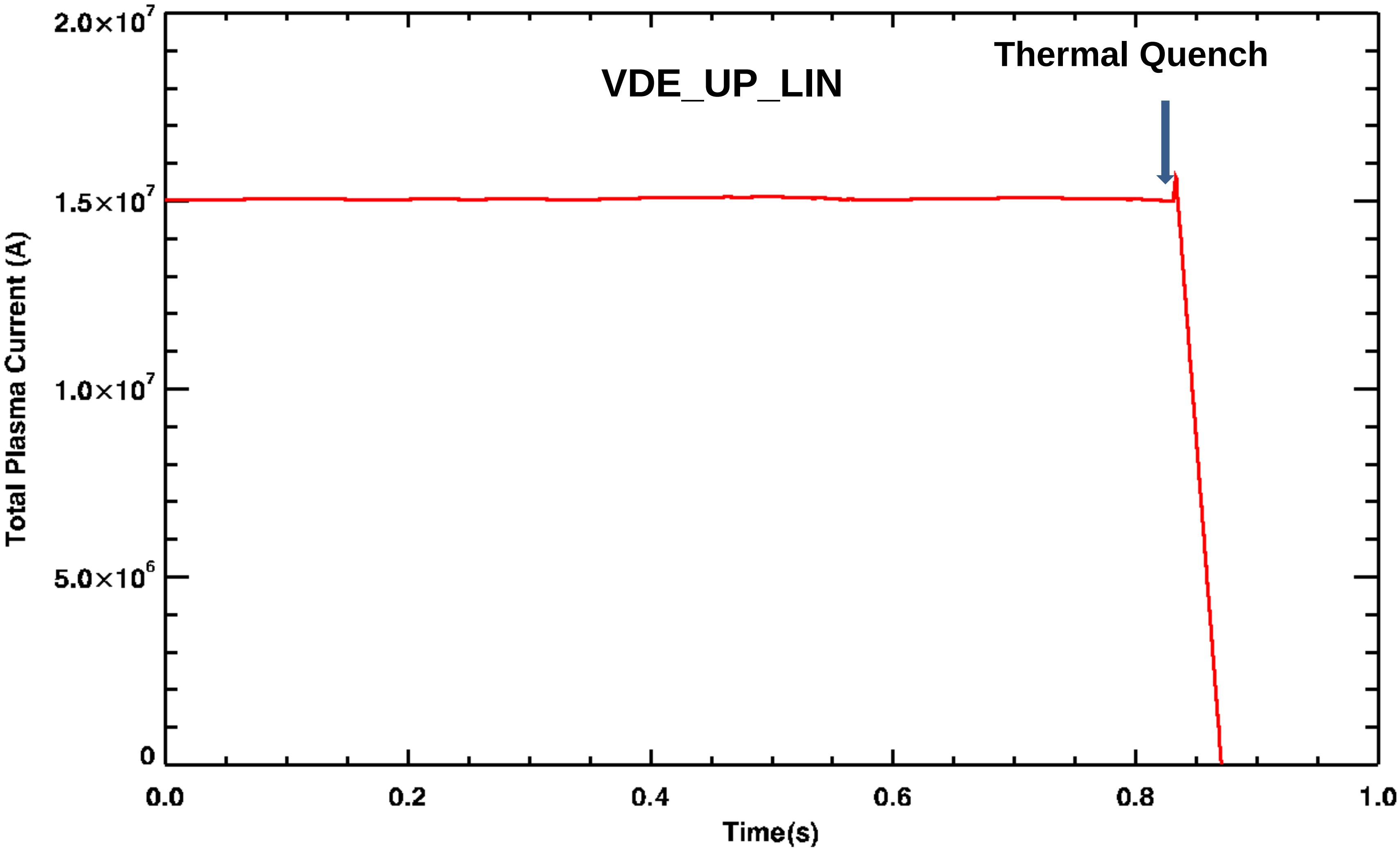
- **Solid model contains inner and outer vacuum vessel and:**
  - **Neighboring shield blocks**
  - **Simplified divertor for SB 1.**
- **Disruption scenario depends on location of module (most stressful EM loads):**
  - **SB 6 – VDE_UP_LIN**
    - **Vertical displacement event upward plasma motion, 36 ms decay**
  - **SB 4 – MD_UP_LIN**
    - **Major disruption event upward plasma motion, 36 ms decay**
  - **SB 1 – VDE_DW_LIN**
    - **Vertical displacement event downward plasma motion, 36 ms decay**

All modules contain cooling channels but not complete cooling circuits.

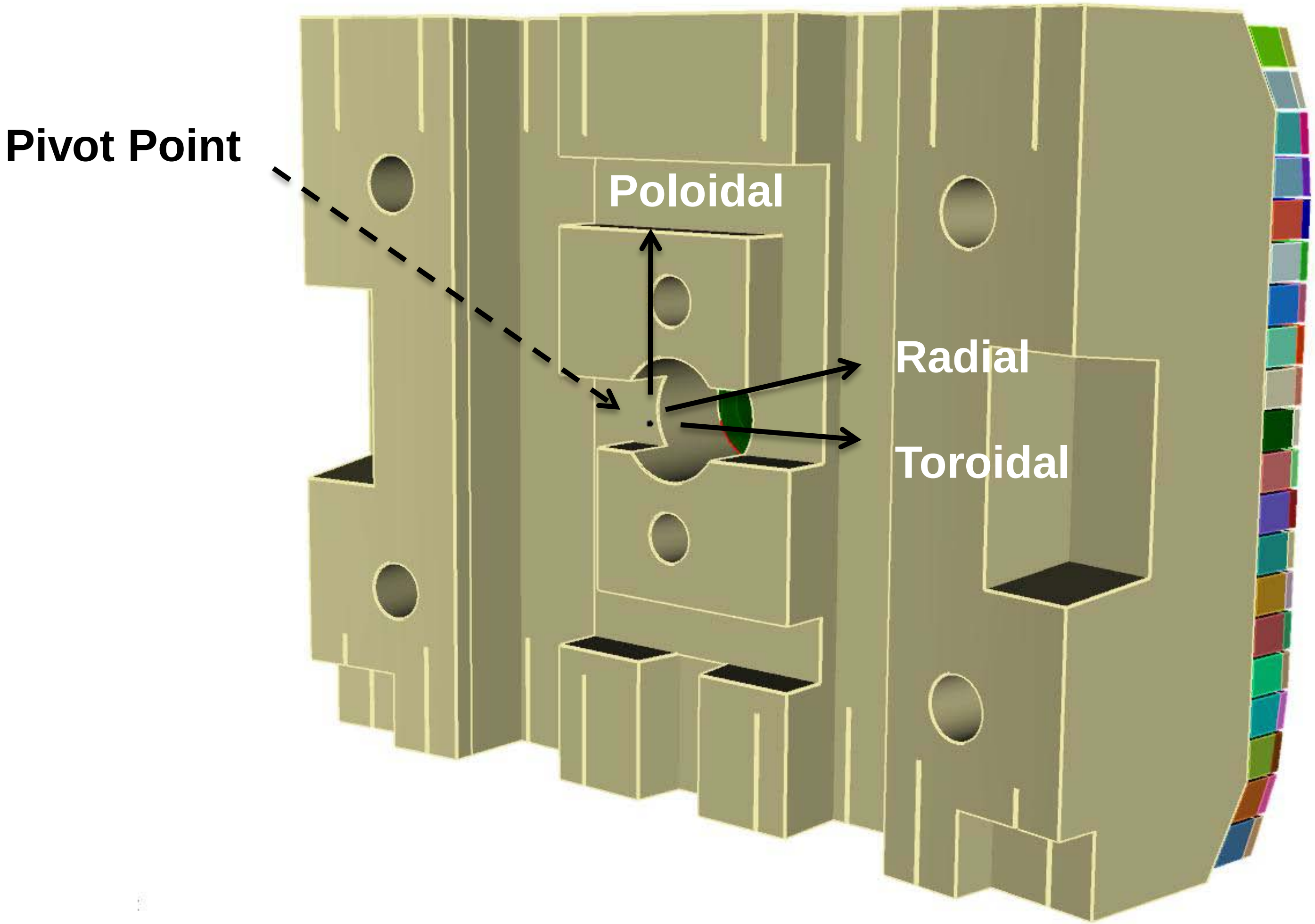
Plasma Disruption Current



Plasma Disruption Current

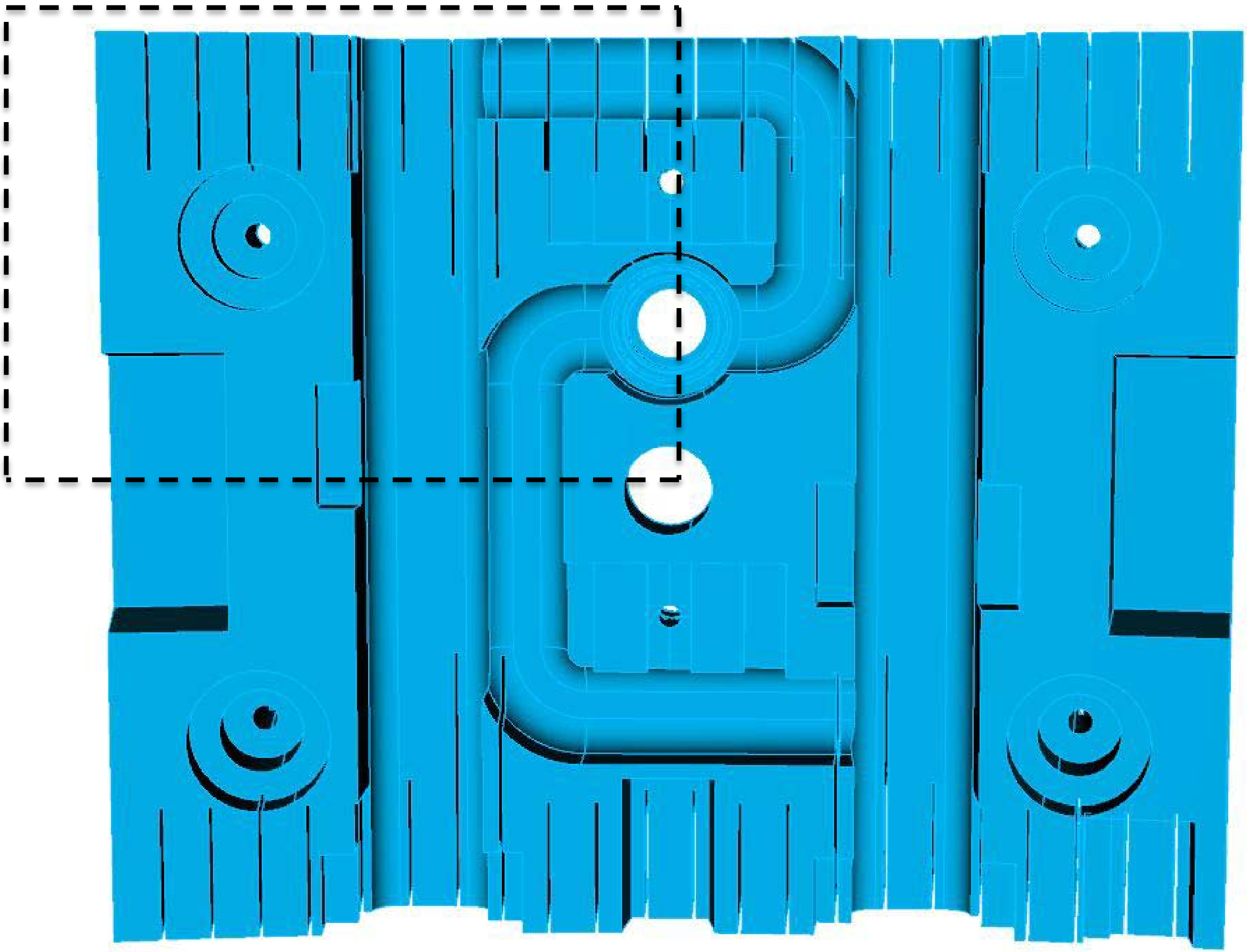


Local Coordinate System



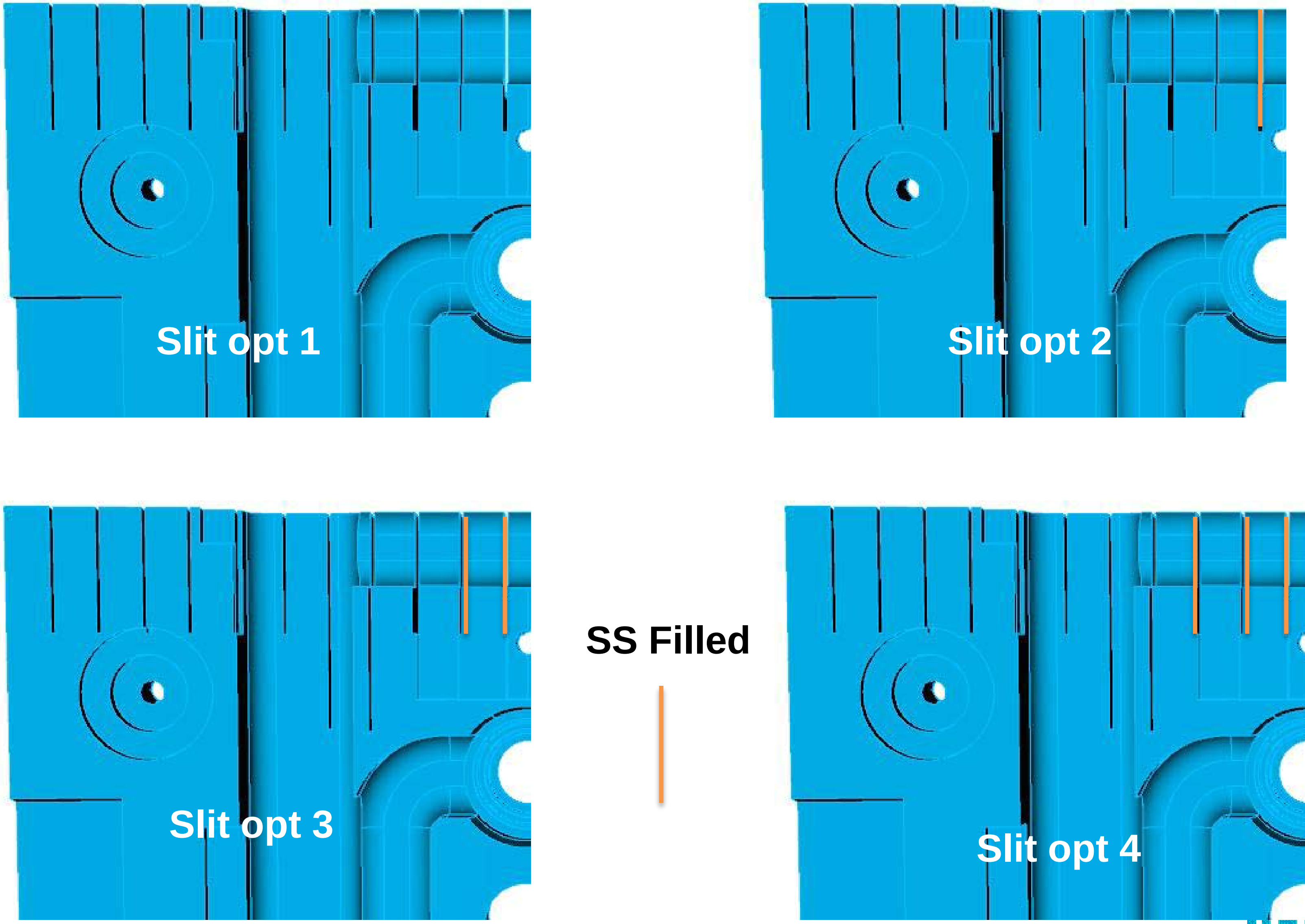
Torque results will be presented with respect to the local coordinate system for the module of interest

Geometry SB 4

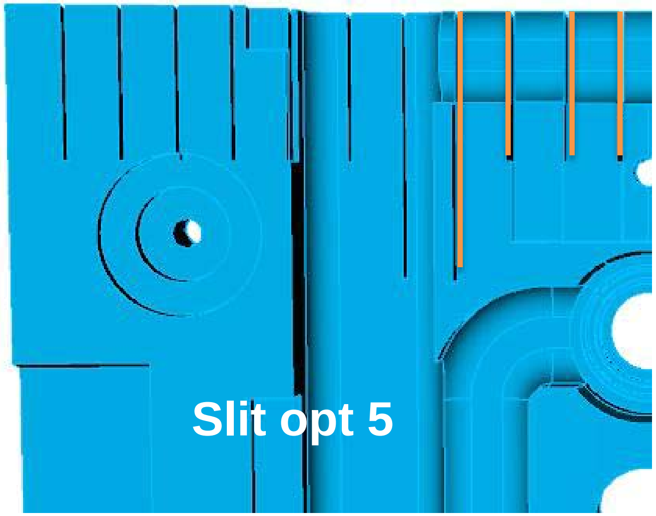


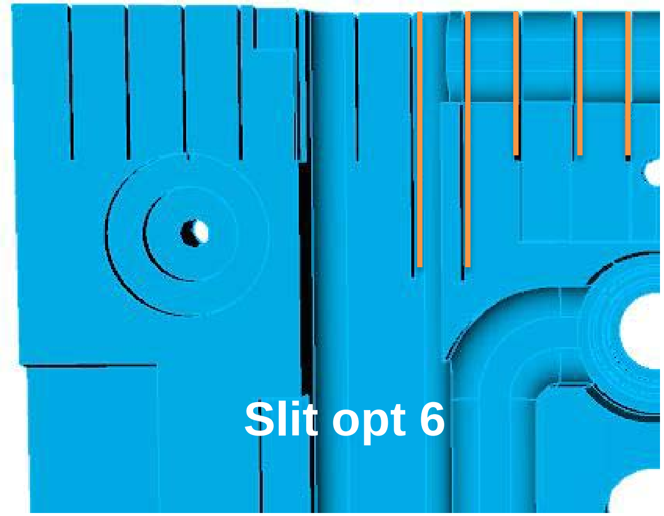
Shield Block 4 view from vacuum vessel

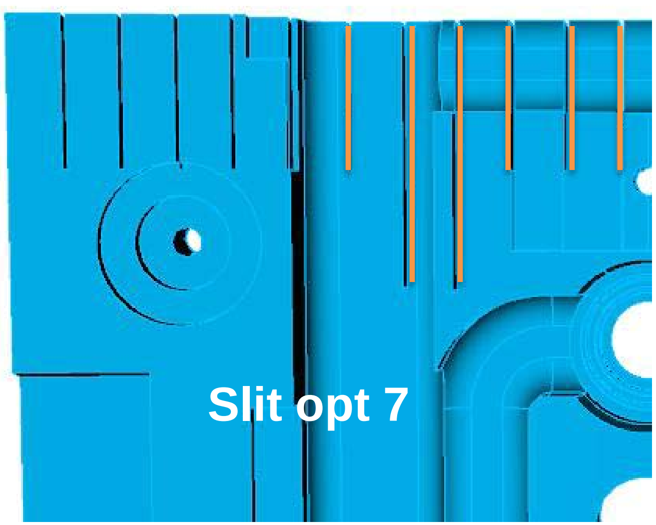
Geometry SB 4



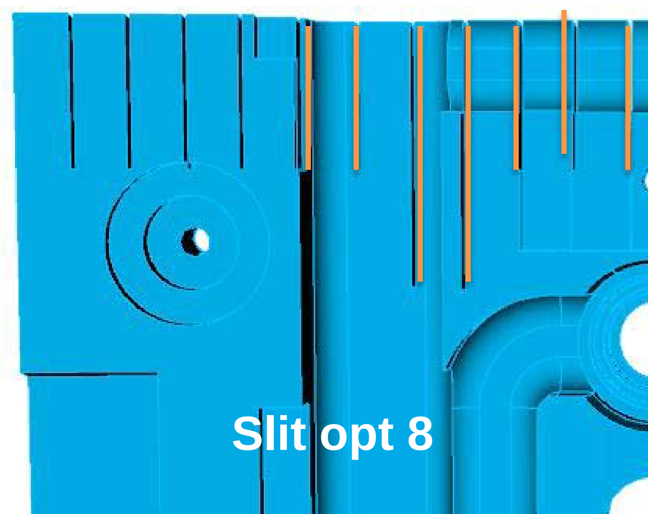
Geometry SB 4



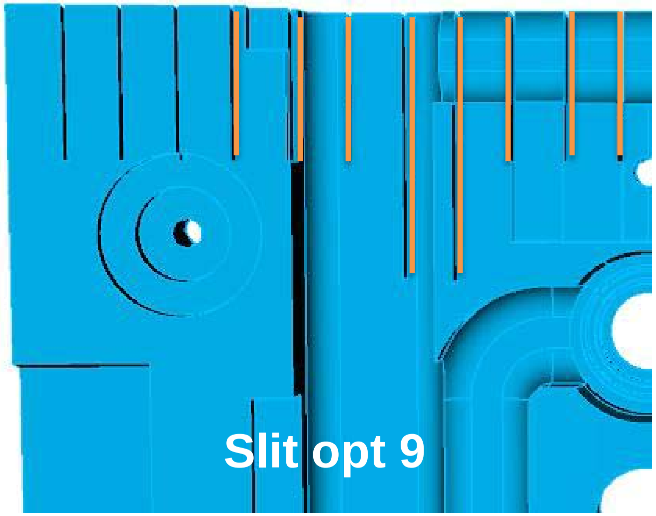




SS Filled



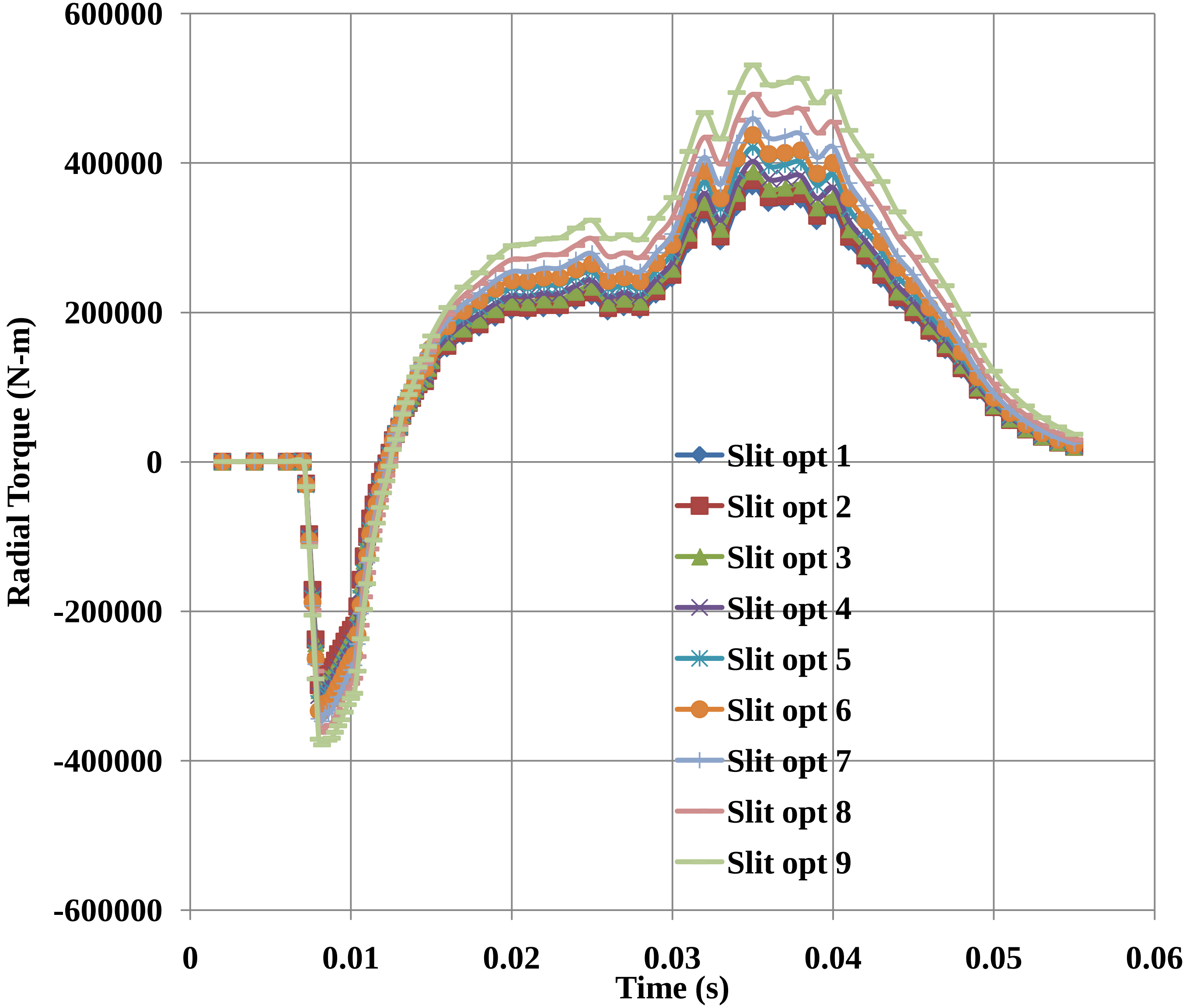
Geometry SB 4



SS Filled

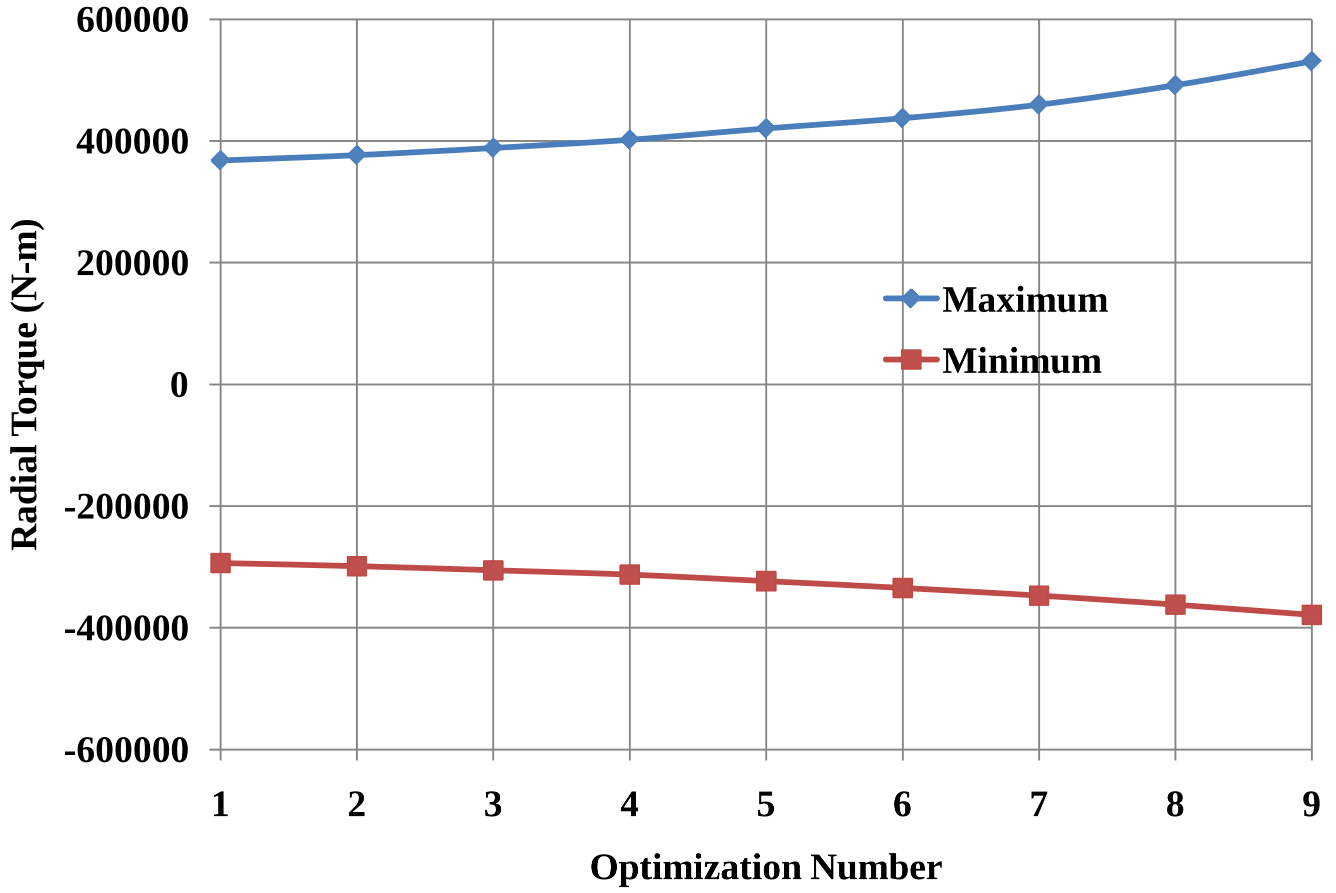
Results SB - 4

MD_UP_LIN

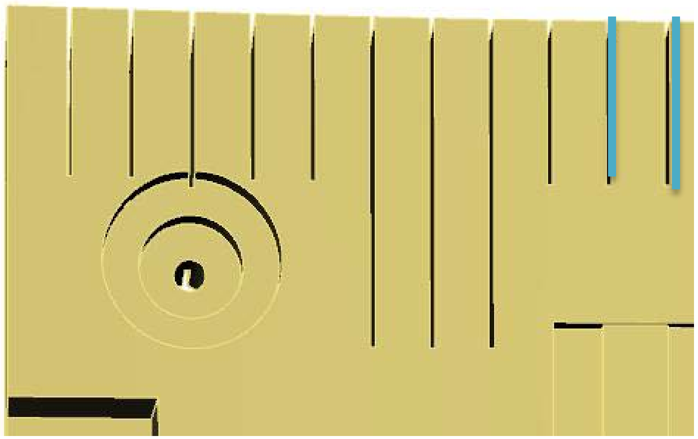


Results SB - 4

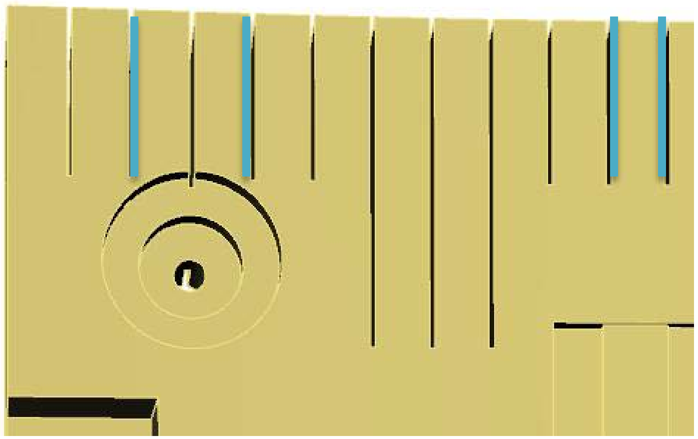
MD_UP_LIN



Geometry SB 1

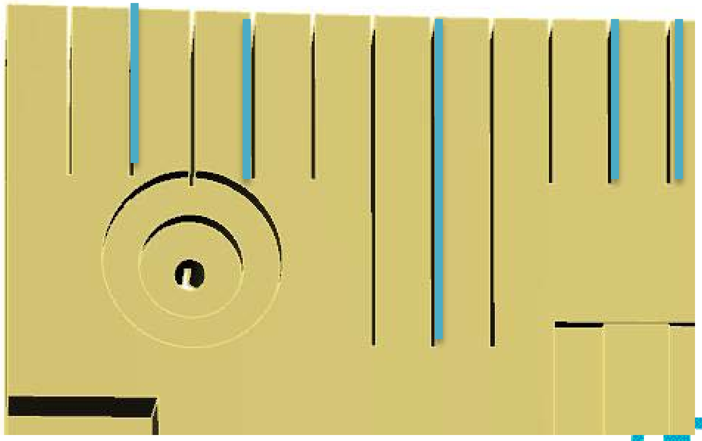


Opt 1 New



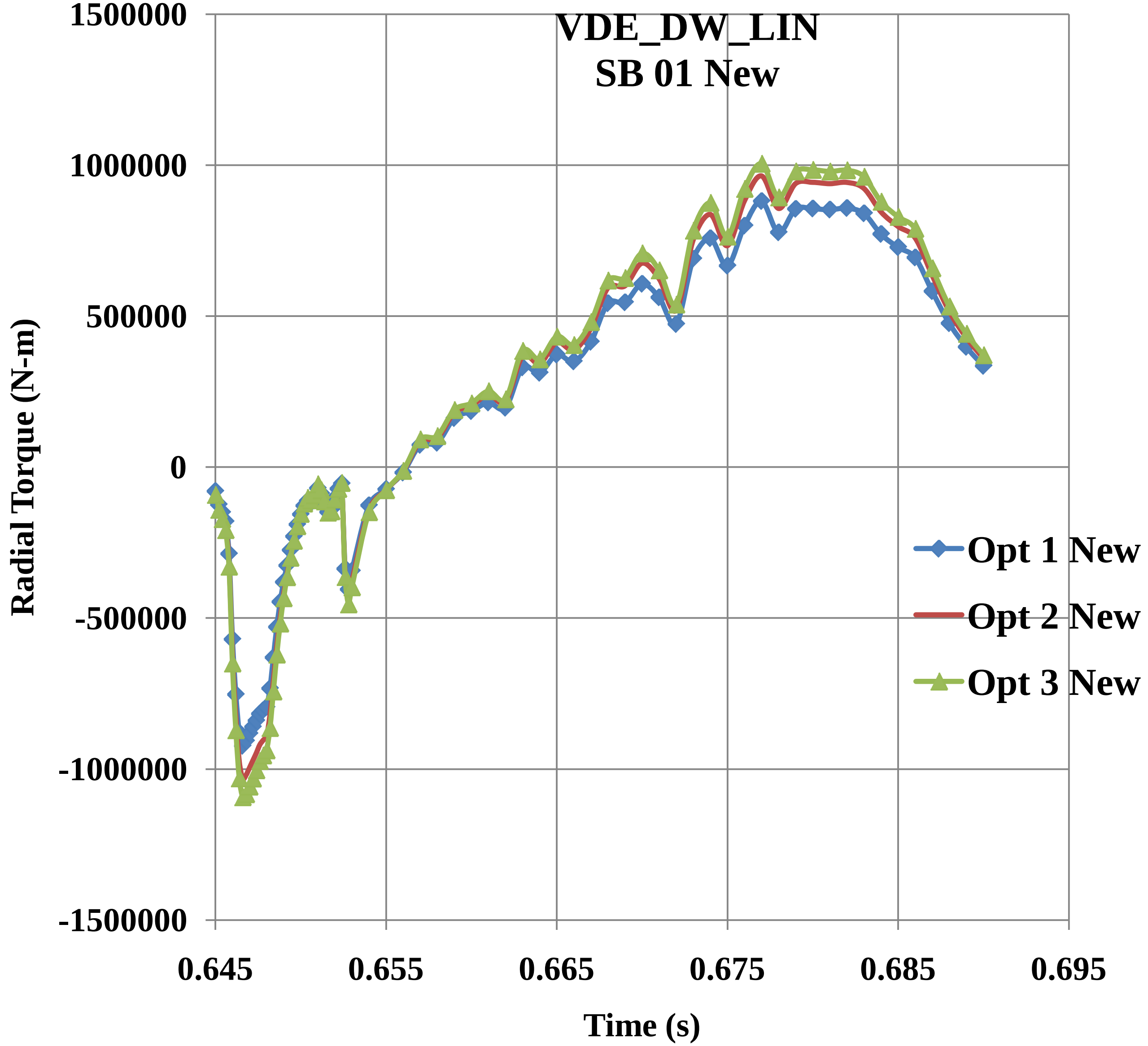
Opt 2 New

SS filled



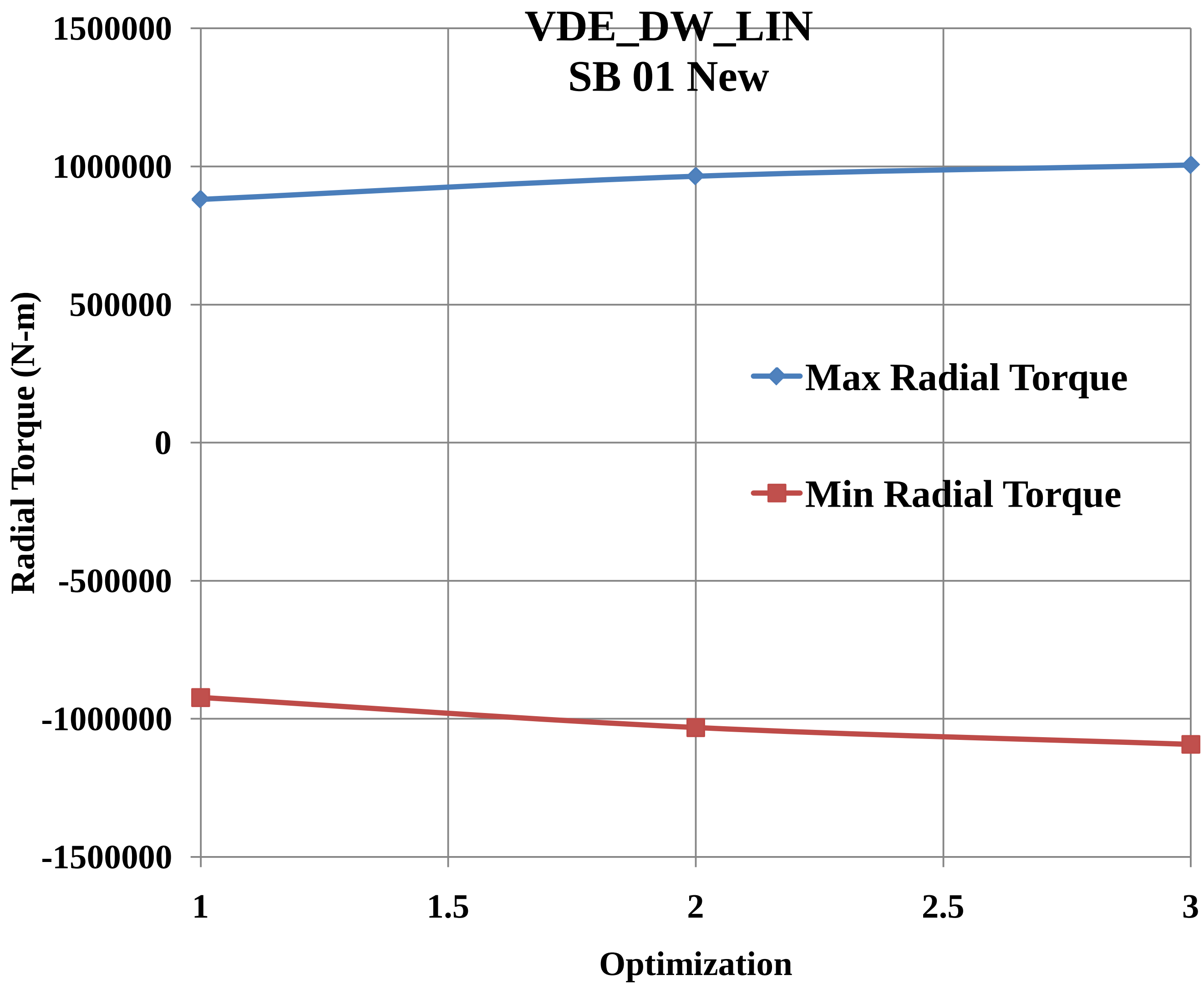
Opt 3 New

Results SB - 1



VDE_DW_LIN
SB 01 New
Radial Torque (N-m)
1500000
1000000
500000
0
-500000
-1000000
-1500000
0.645
0.655
0.665
0.675
0.685
0.695
Time (s)
Opt 1 New
Opt 2 New
Opt 3 New

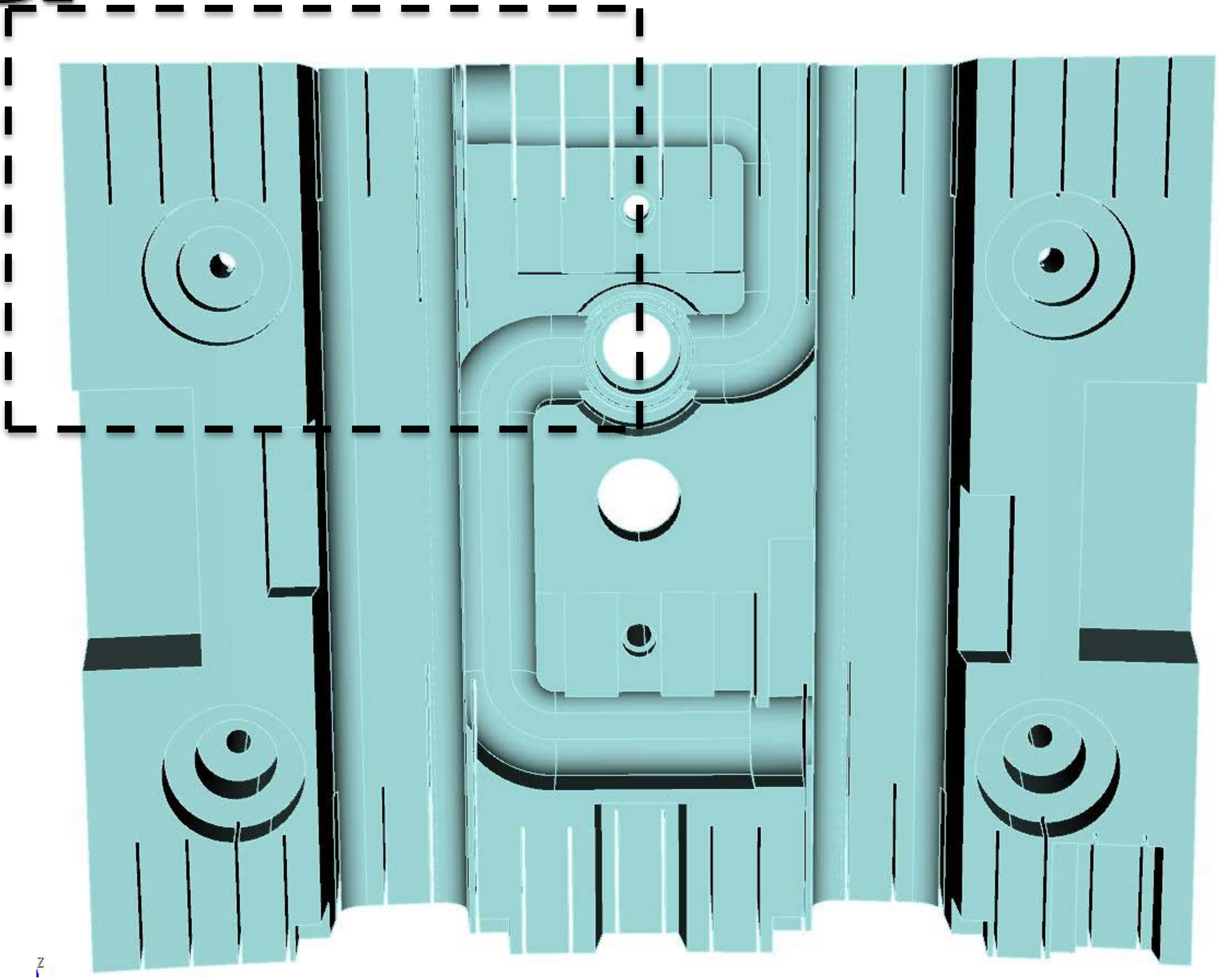
Results SB - 1



14% Change

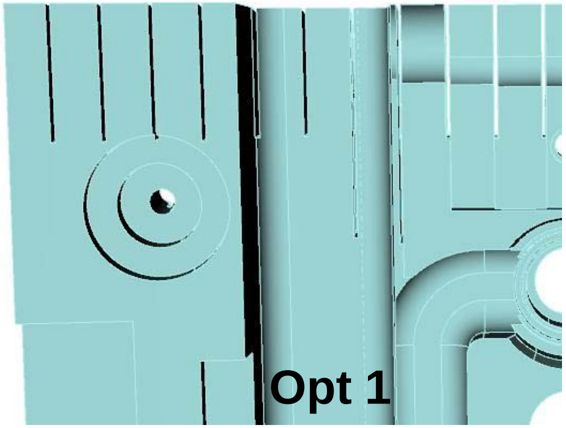
18% Change

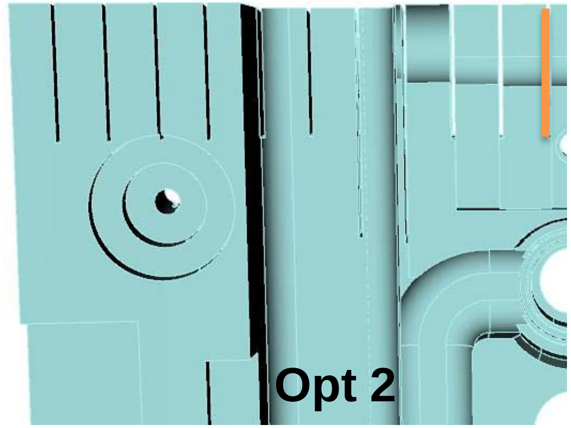
Geometry SB 6

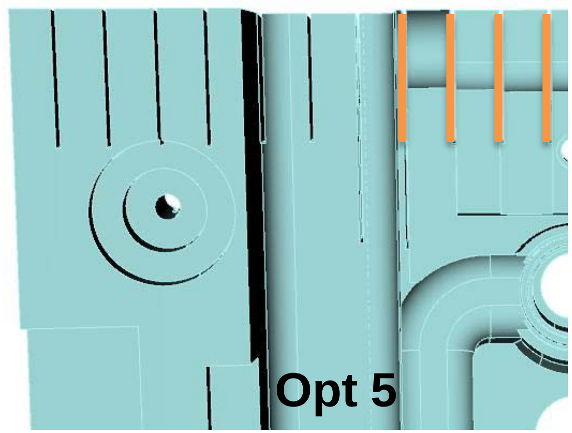


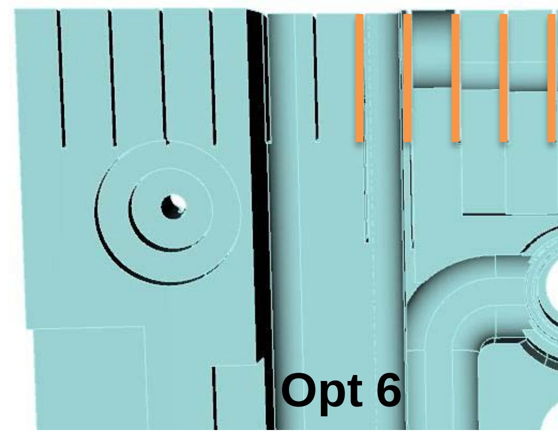
Vacuum vessel view

Geometry SB 6

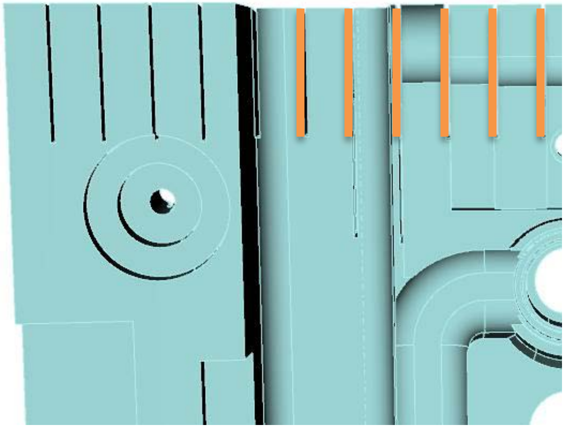








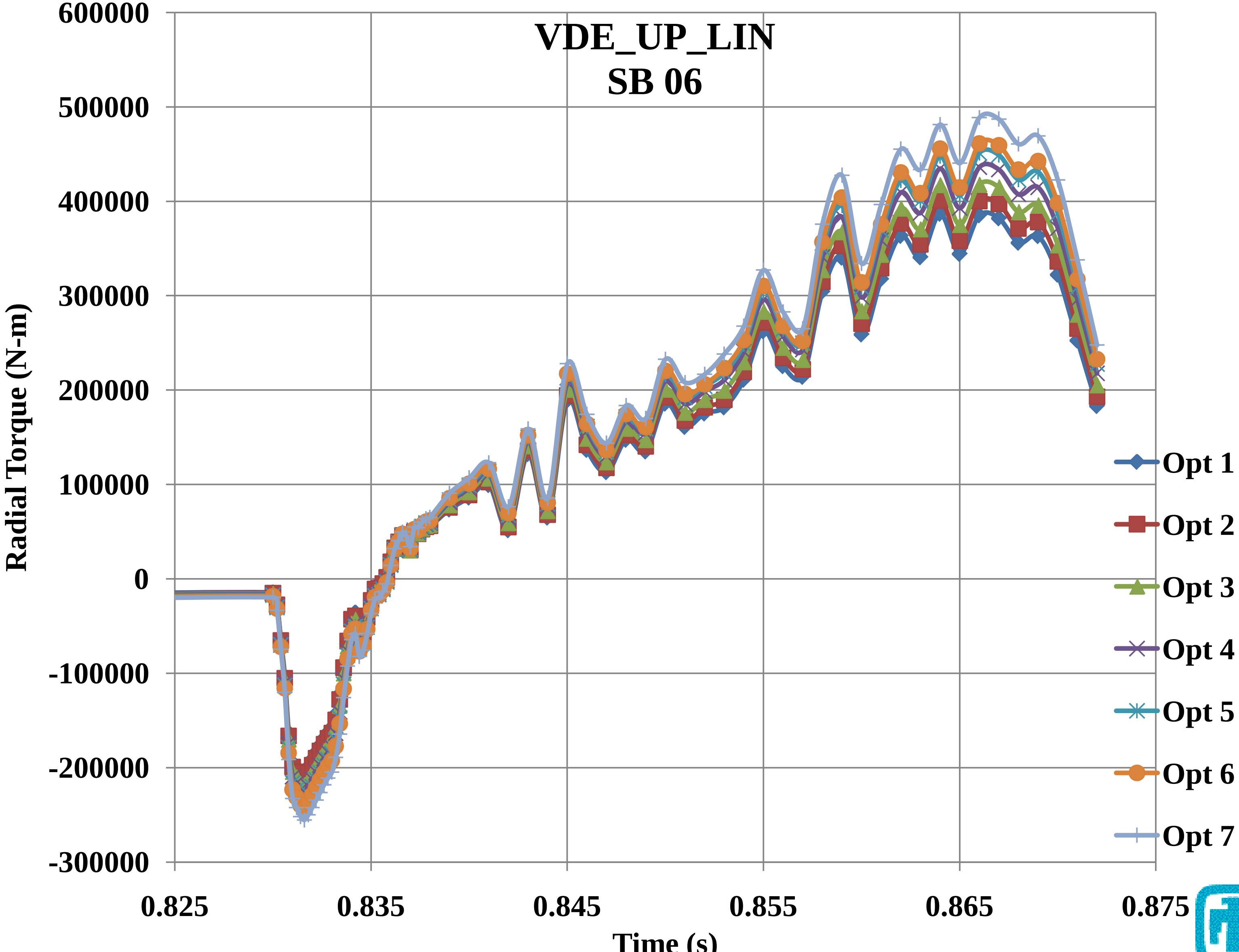
Geometry SB 6



SS filled

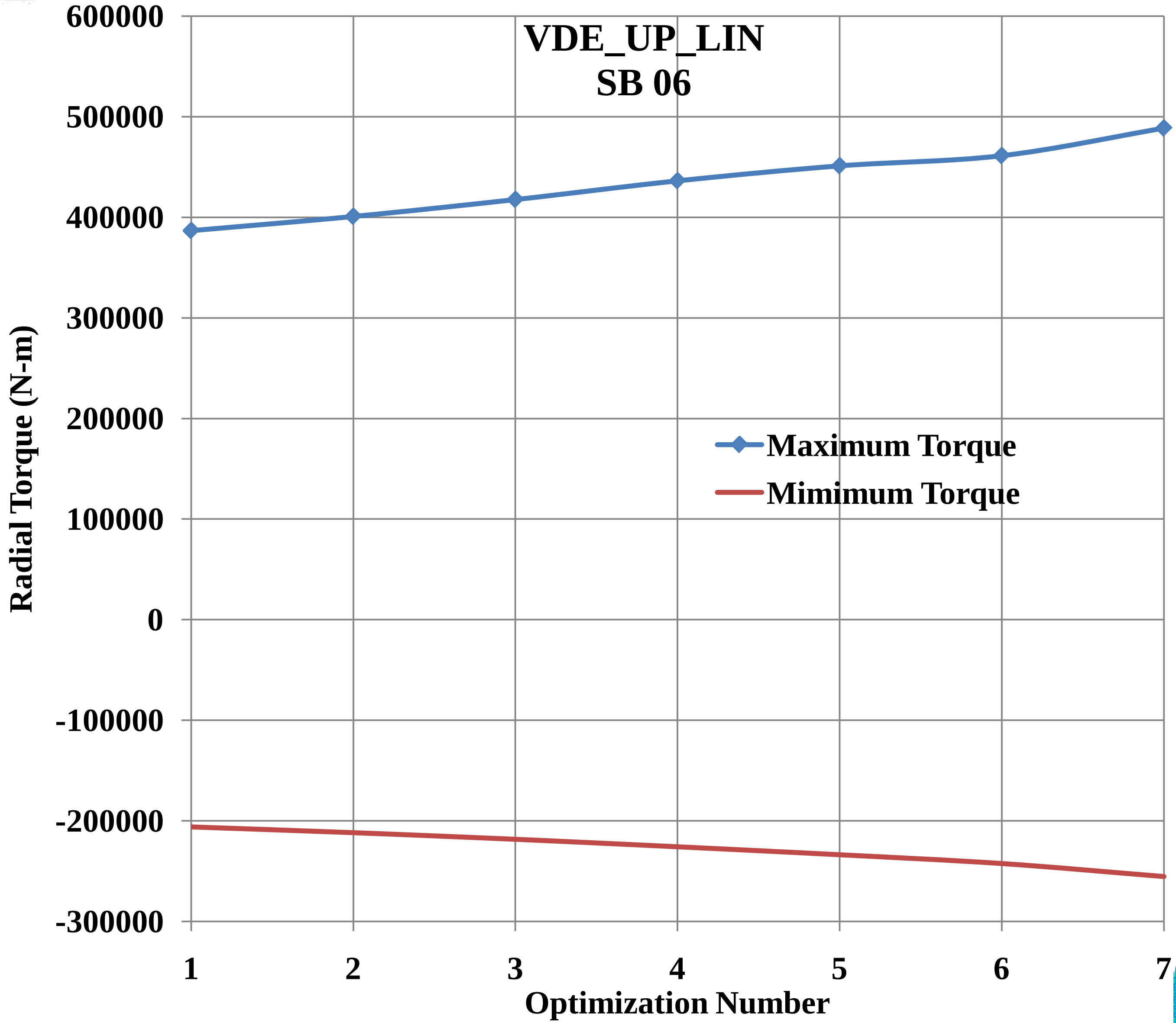
Opt 7

Results SB - 6



VDE_UP_LIN
SB 06
Radial Torque (N-m)
600000
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
0.825
0.835
0.845
0.855
0.865
0.875
Time (s)
Opt 1
Opt 2
Opt 3
Opt 4
Opt 5
Opt 6
Opt 7

Results SB - 6


VDE_UP_LIN
SB 06
Radial Torque (N-m)
600000
500000
400000
300000
200000
100000
0
-100000
-200000
-300000
1
2
3
4
5
6
7
Optimization Number
Maximum Torque
Mimimum Torque

Conclusions

- **Radial torque for blanket modules 1 , 4, and 6 under different slit configurations and disruption events have been computed.**
  - **The maximum radial torque occurs late in the disruption event.**
- **These results give guidance in placement and number of eddy current slits.**
  - **Must be combined with the necessary cooling requirements for the shield blocks.**
    - **Placement of cooling system.**