The ITER EC H&CD Upper Launcher: Methodology in the FEM Analyses of the Diamond Window Unit Subject to Seismic and Baking Loads

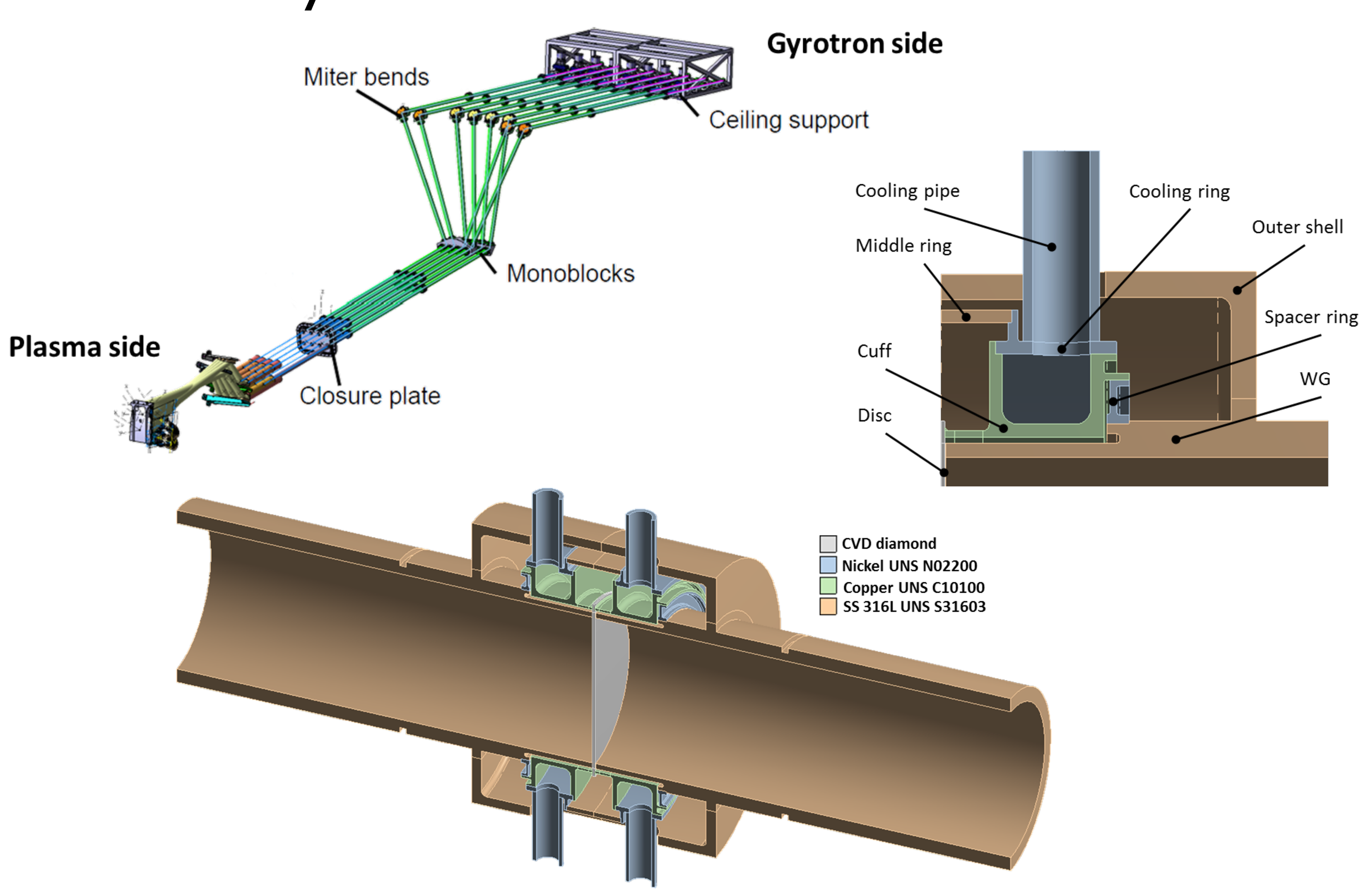
G. Aiello[a], M. Gagliardi[b], T.P. Goodman[c], A. Krause[c], A. Meier[a], G. Saibene[b], F. Sanchez[c], T. Scherer[a], S. Schreck[a], P. Spaeh[a], D. Strauss[a], A. Vaccaro[a]

[a]Karlsruhe Institute of Technology, Institute for Applied Materials, P.O. Box 3640, D-76021 Karlsruhe, Germany
[b]Fusion for Energy, C/Josep Pla 2, Torres Diagonal Litoral-B3, E-08019 Barcelona, Spain
[c]Centre de Recherches en Physique des Plasma, CRPP-EPFL, CH-1015 Lausanne, Switzerland

Introduction

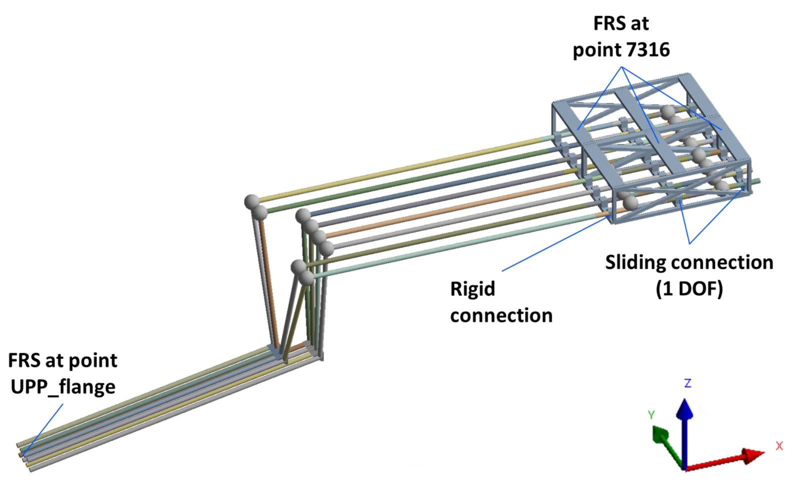
The torus diamond window unit is a sub-component of the EC H&CD UL forming a vacuum and tritium confinement boundary between the torus volume and the transmission lines (TLs) which guide microwave beams between 1 and 2 MW from the gyrotrons to the launcher. The unit is attached to the ex-vessel waveguides (WGs) assembly connected from one side to the ceiling of the ITER port cell by a frame (ceiling support frame) and to the UL port plug from the other side. Movements of the vacuum vessel (VV) due to baking, seismic and plasma disruption events, result in forces and moments acting on the units. Furthermore, during a seismic event, the unit is subject to additional loads induced by the oscillation of the support frame. An outer frame surrounding the unit is thus required to withstand these external loads and ensure the structural integrity and the confinement function of the unit. The load combination given by the stringent ITER SL-2 seismic event occurring during the VV baking is the design driver for the unit outer frame. A specific methodology was developed in this work to carry out the FEM analyses of the window unit with respect to this load combination. A two-step procedure was adopted to calculate first forces and moments acting on the units and then stresses and displacements of the units. Different design variants of the unit outer frame were investigated in order to find the optimum design solution.

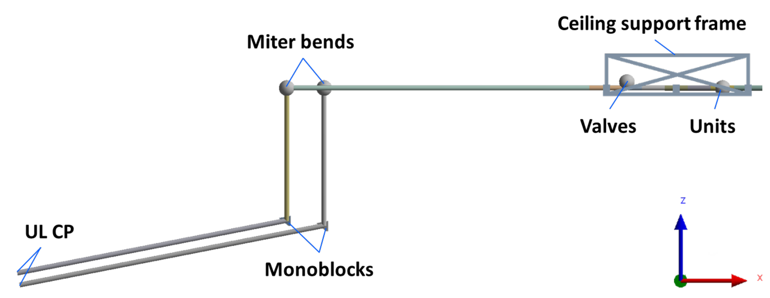
Geometry

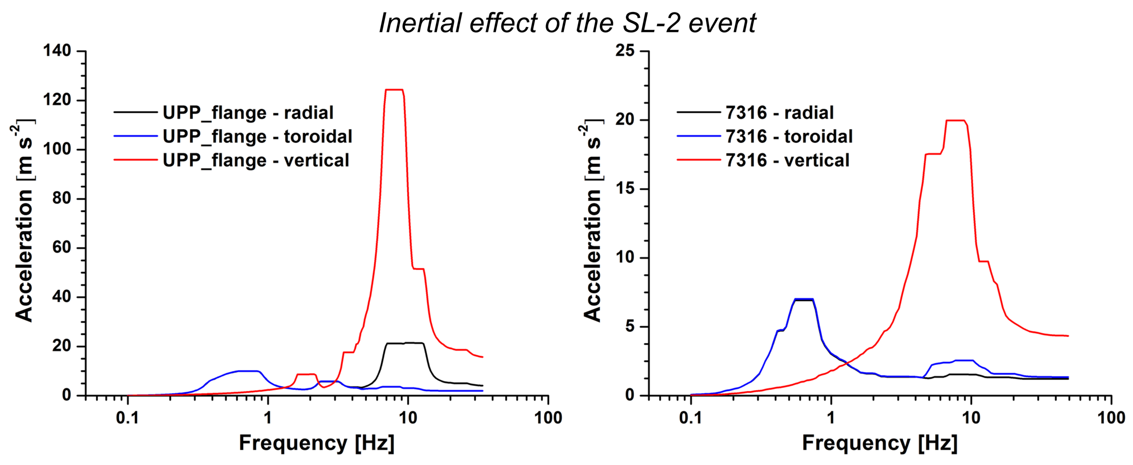


Methodology

First step of the analysis

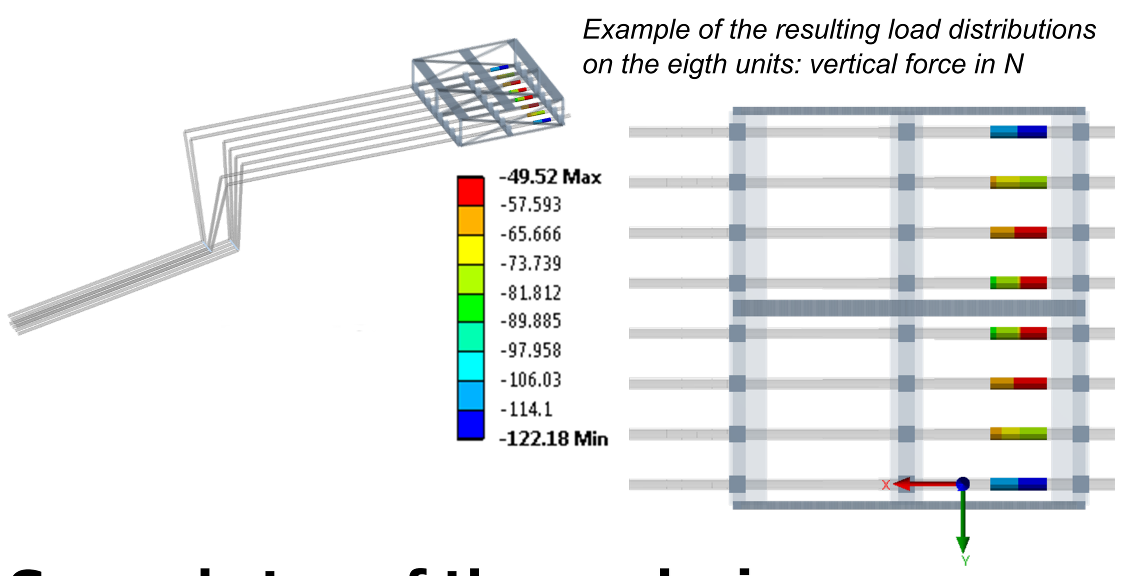






Kinematik effect of the SL-2 event

Seismic displacements at the UL CP	Values
Δx [mm]	6.29
Δy [mm]	4.6
Δz [mm]	5.84

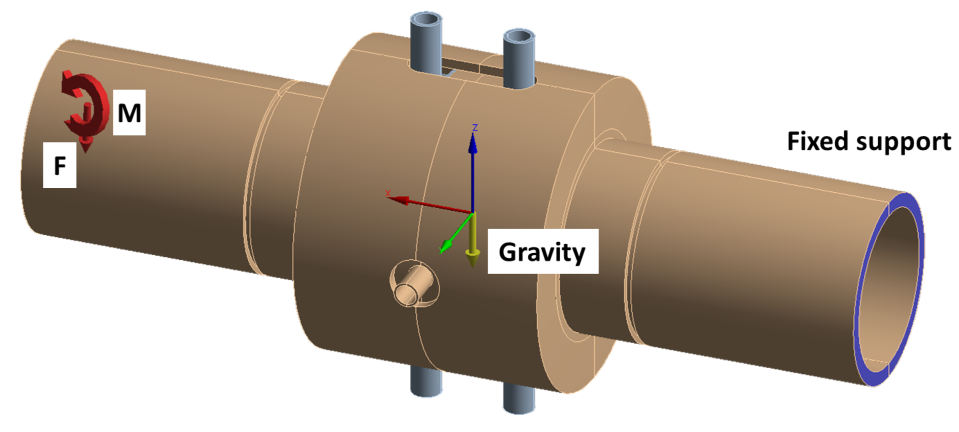


Effect due to the VV baking

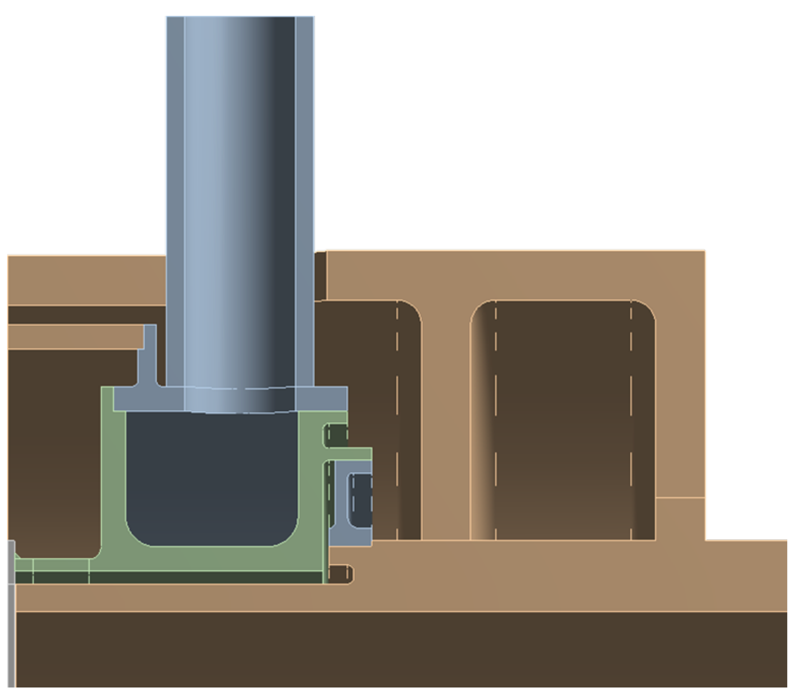
Displacements at the UL CP due to VV baking	Values
Δx [mm]	16.5
Δy [mm]	0
Δz [mm]	24.4

Second step of the analysis

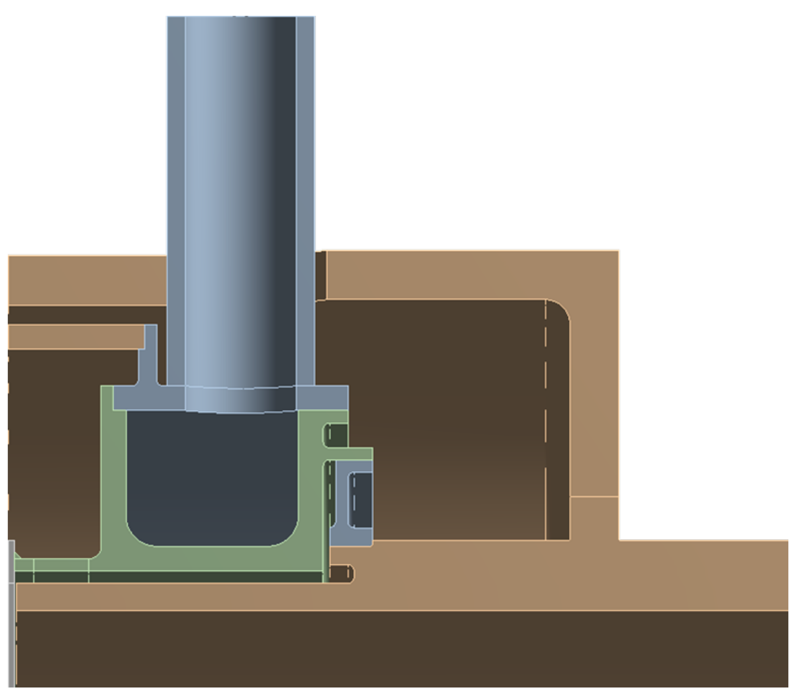
Type of loads	Maximum values
Axial force F_x [N]	12.3
Horizontal force F_y [N]	-19.8
Vertical force F_z [N]	-122.2
Axial torsion M_x [N m]	16.3
Horizontal bending M_y [N m]	34.7
Vertical bending M_z [N m]	6.3



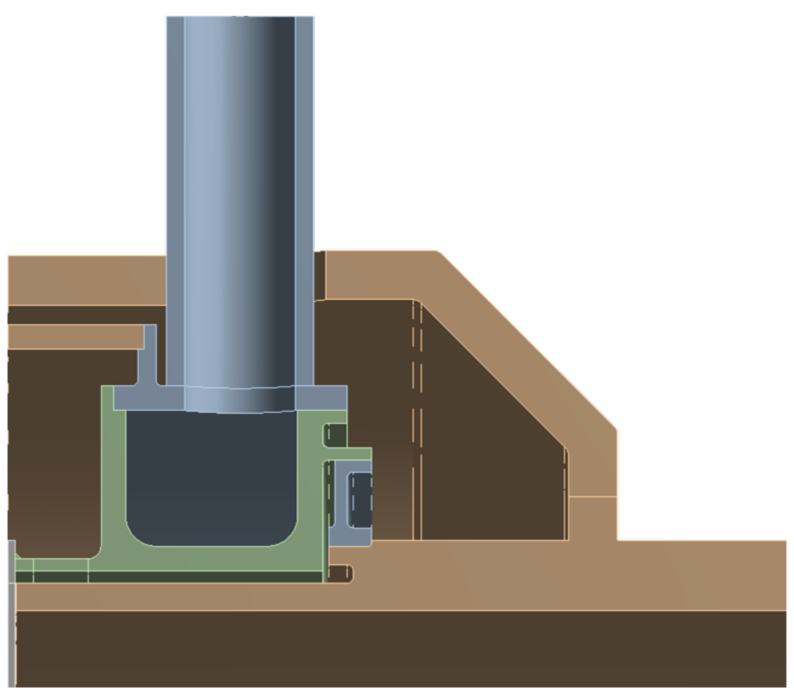
Design evolution of the window unit outer frame



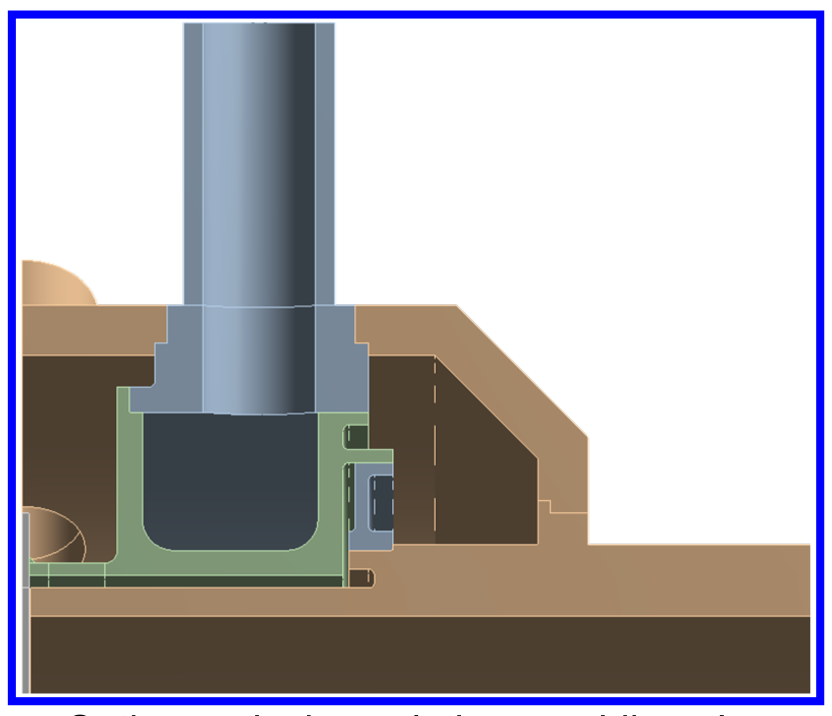
- Robust design due to very high loads acting on the unit in past design versions of the WGs assembly and their supports.
- Equivalent stress higher than 150 MPa.



- Outer frame formed by a 4 mm single wall shell.
- Equivalent stress of 73 MPa and disc-WG gap reduction of 12 μm.



- Outer frame formed by a 4 mm single wall with two 45° sides.
- Equivalent stress of 45 MPa and disc-WG gap reduction of 8 μm.



- Optimum design solution providing also a second tritium barrier and a real-time monitoring of all interspaces in the unit.
- Equivalent stress in the 20-24 MPa range and disc-WG gap reduction of 6 μm.

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