DarkSide-20k: Inner Detector Engineering Forum Meeting

DS-20k False Floor

April 19,2024

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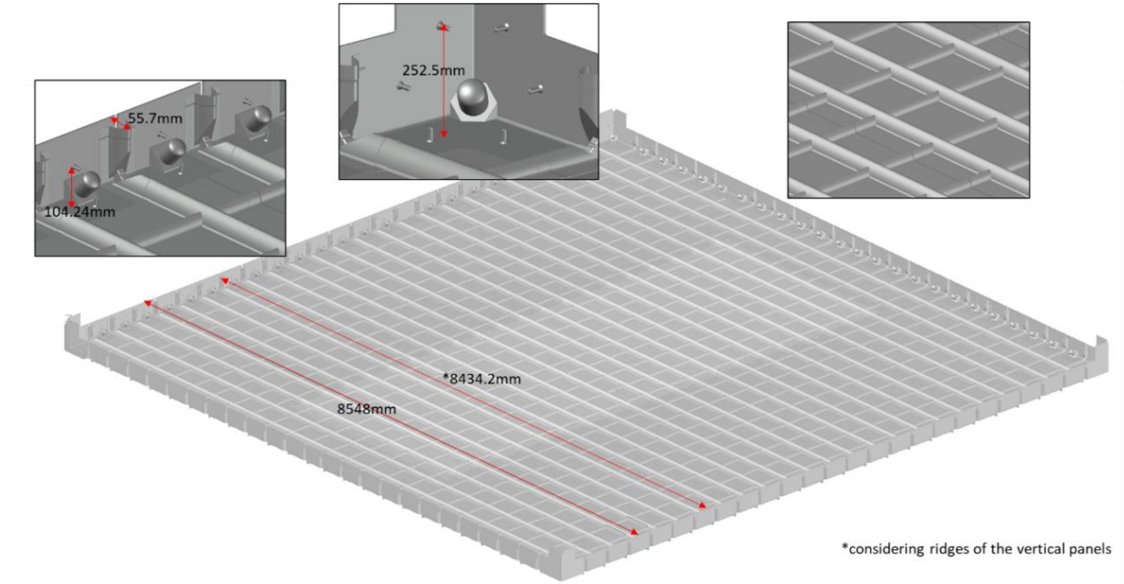
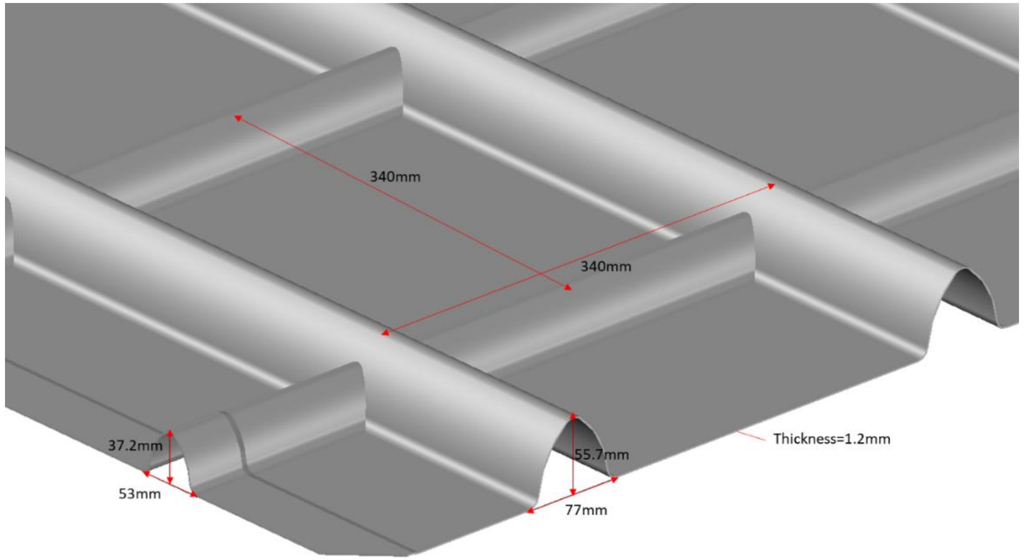
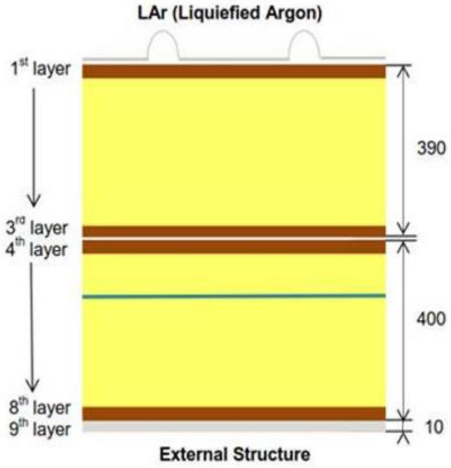
DS-20k false floor - Main notes

- It will be installed inside the cryostat, on the primary corrugated membrane
- It is required to withstand the loads associated with the installation phases of the detector inside the cryostat
- It will be installed immediately after the completion of the primary membrane
- It will be removed at the end of the fully assembly of the ID, with the Top Caps in place
- All the structural elements will be removed through the cryostat manhole (DN=700mm) before LAr filling.
- Welding or cuts are not permissible for the disassembly procedures inside the cryostat (for cleaning purposes). Therefore, only bolted and clamped connections are designed
- The system must be stiff enough to uniformly distribute the load, preventing cracks in the membrane
- SS upper covering is required for cleaning purpose
- Simultaneously, the SS plate should not be excessively thick to address economic and disassembly handling concerns
- A combined system made of SS plate 5 thick, 50x3/25x76 grating and IPE100 lattice beams has been designed. They will be clamped to each other to increase the efficiency of the system
- A maximum distance of about 1-2mm between adjacent SS plates will be ensured. Proper sealing made by silicon will also accommodate potential movements
- Tender procedure is currently being prepared

Geometrical features of the DS20k membrane

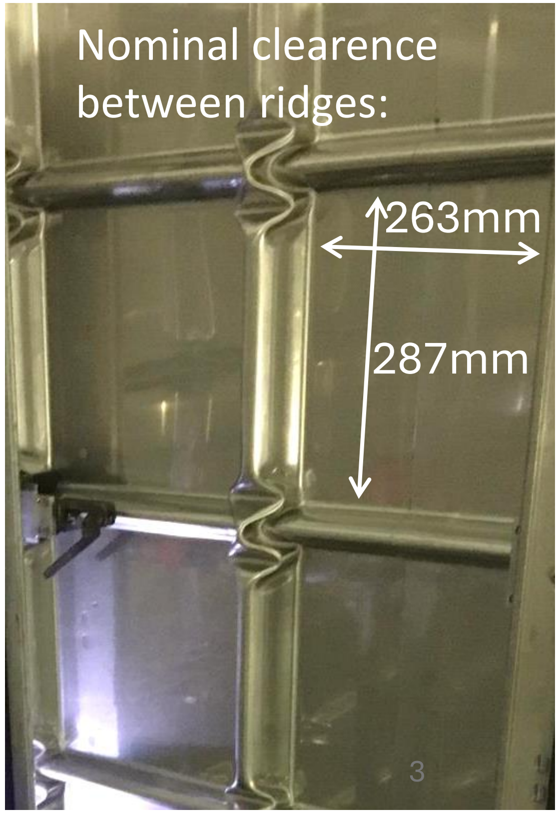




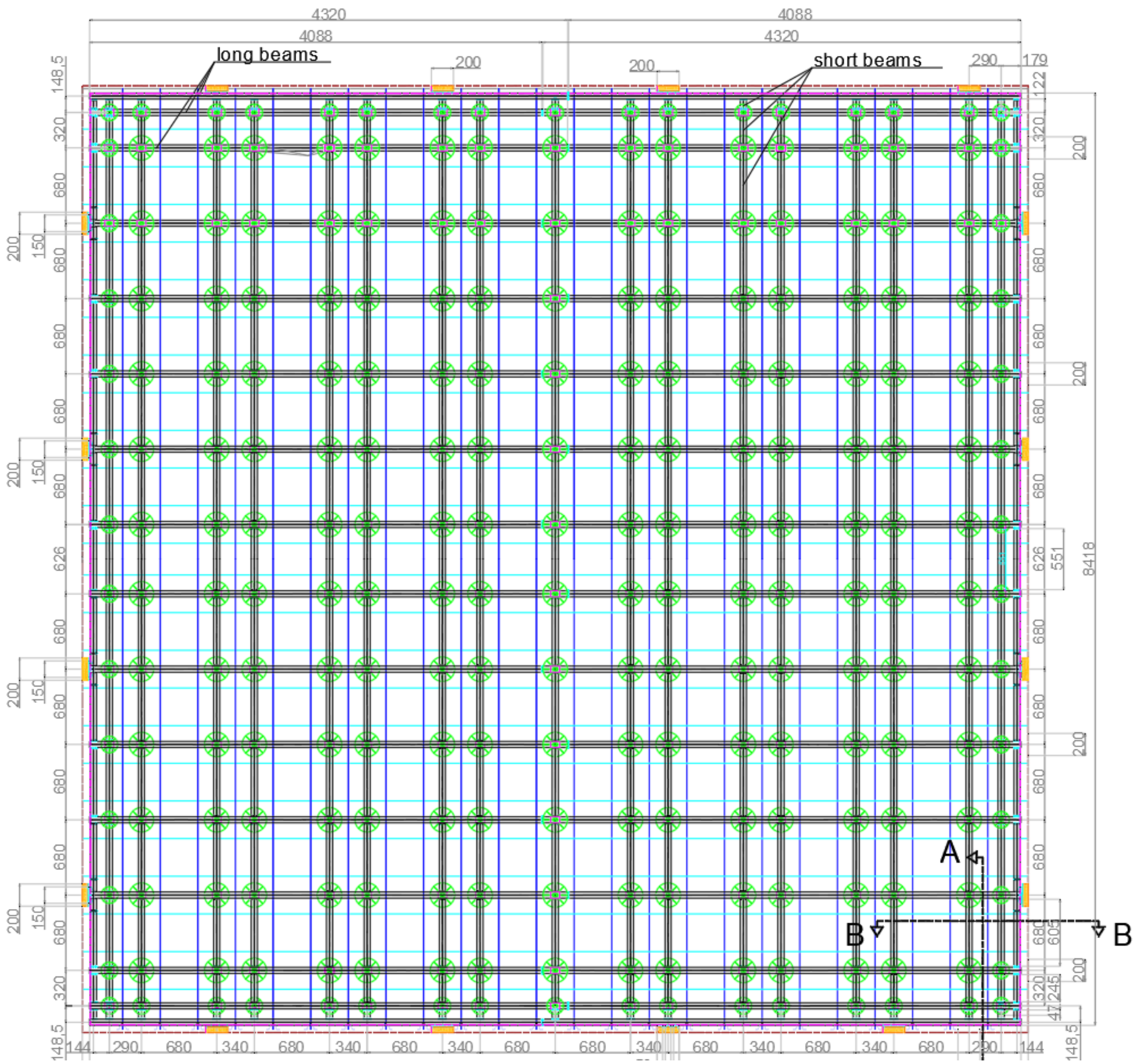


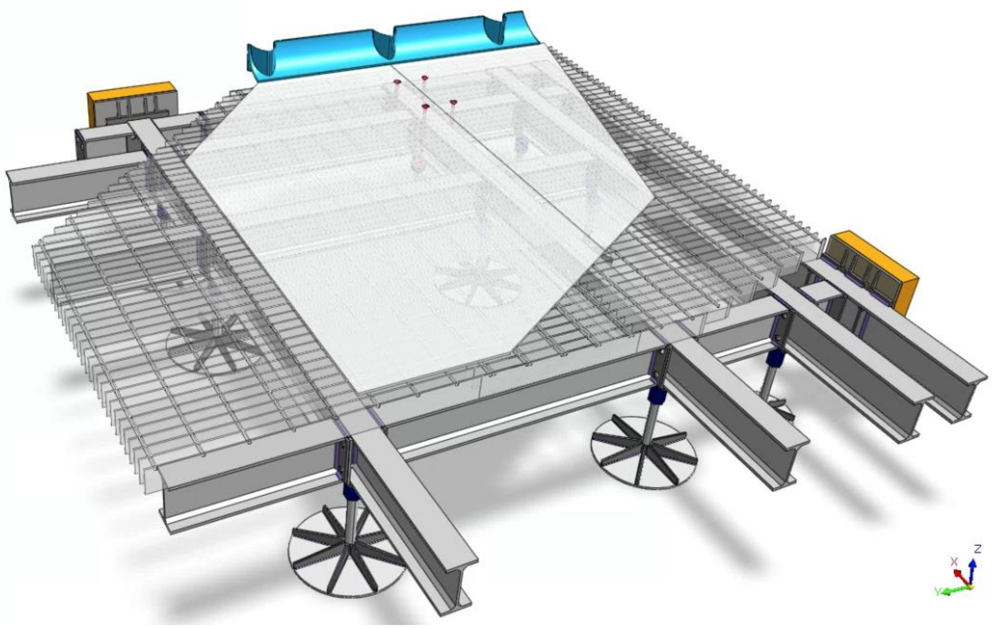
- 1st layer - Plywood (typical thickness = 12 mm)
- 2nd layer - Reinforced PU Foam (typical thickness = 366mm)
- 3rd layer - Plywood (typical thickness = 12 mm)
- 4th layer - Plywood (typical thickness = 12 mm)
- 5th layer - Reinforced PU Foam (typical thickness = 88mm)
- 6th layer - Secondary barrier (typical thickness = 0.6 mm)
- 7th layer - Reinforced PU Foam (typical thickness = 291 mm)
- 8th layer - Plywood (typical thickness = 9 mm)
- 9th layer - Mastic (typical thickness = 10 mm)

Vertical membrane:

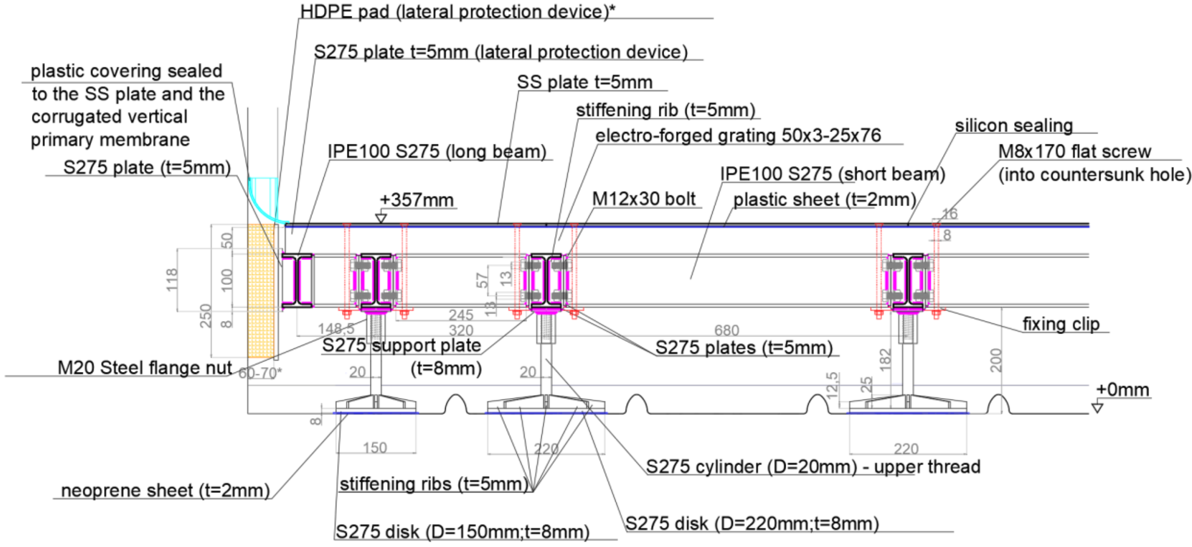


Geometrical features of the false-floor

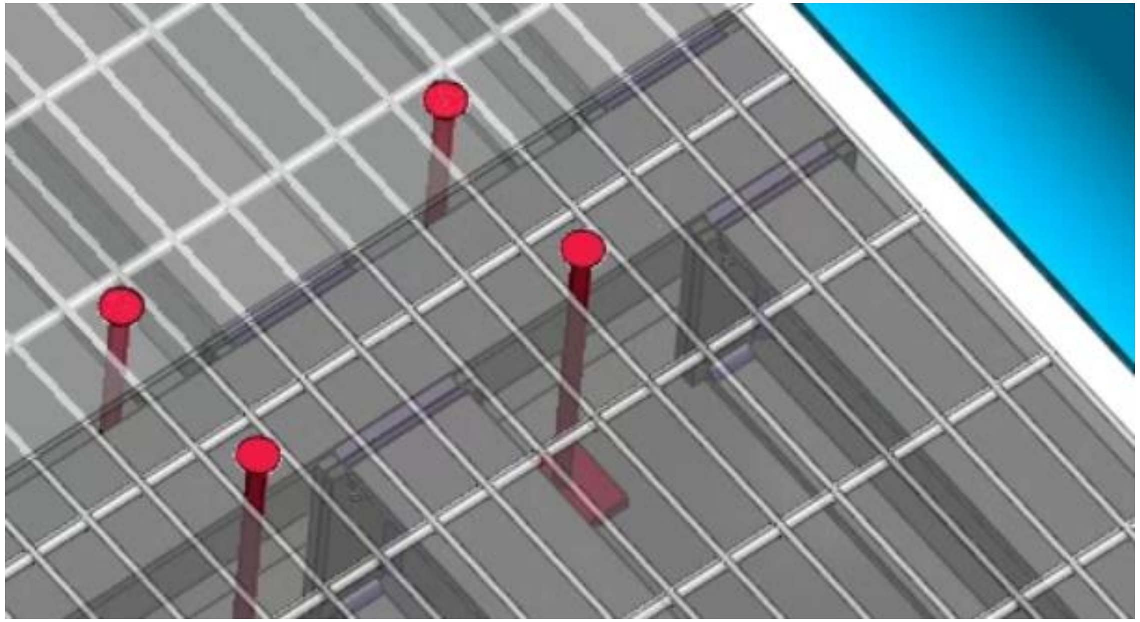


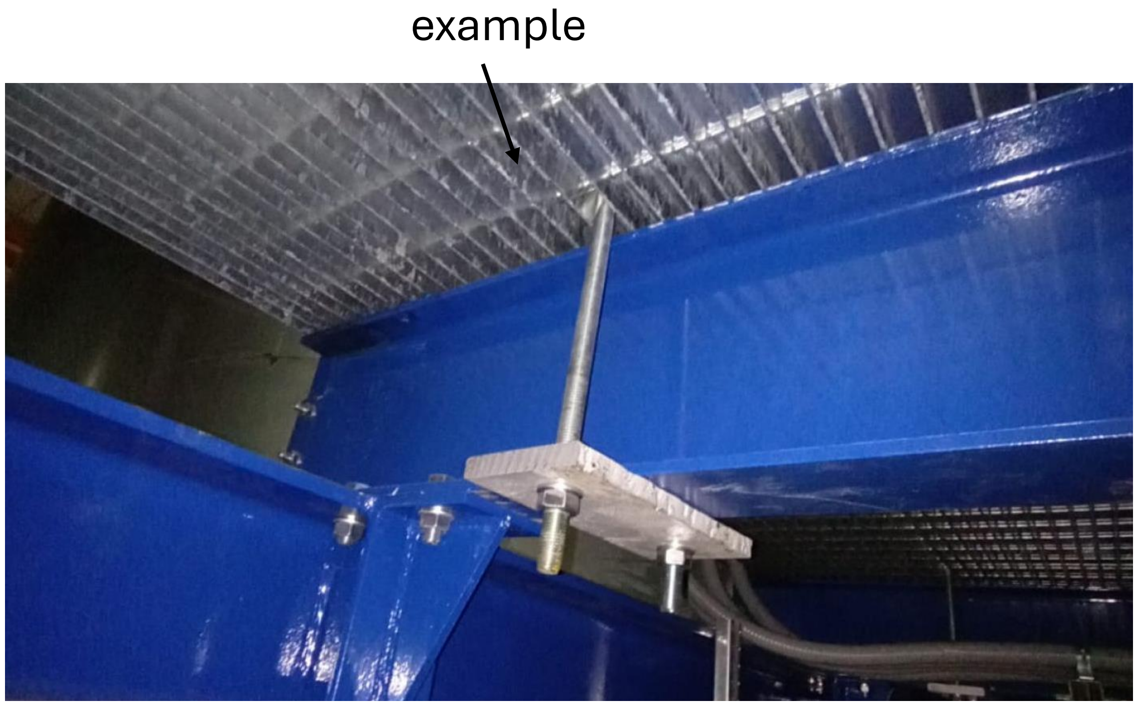


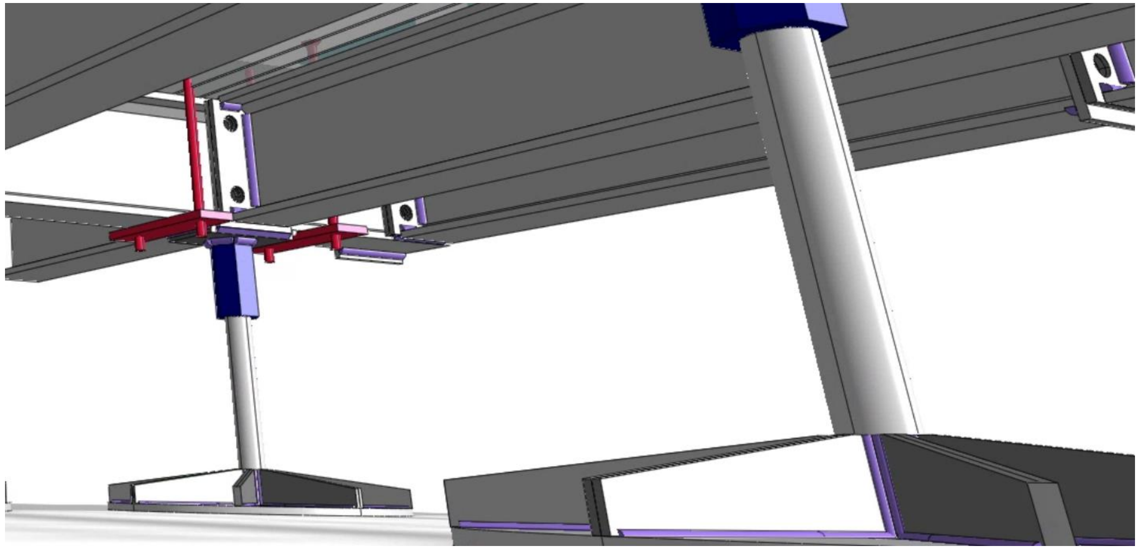
SECTION A-A

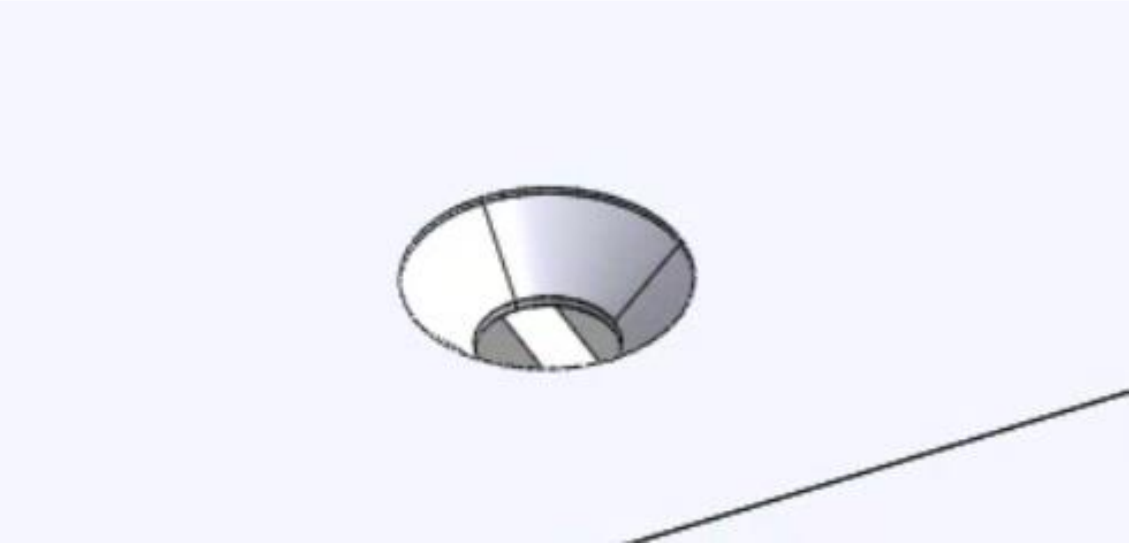


Details of the clamped solution

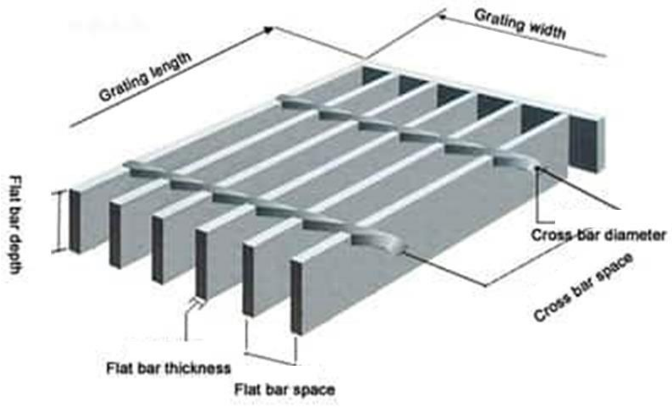








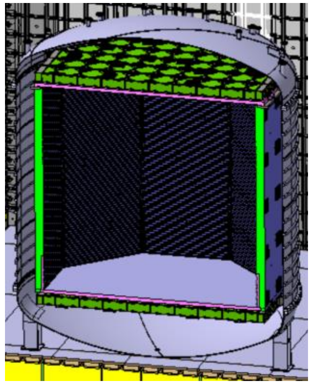
50x3 / 25x76



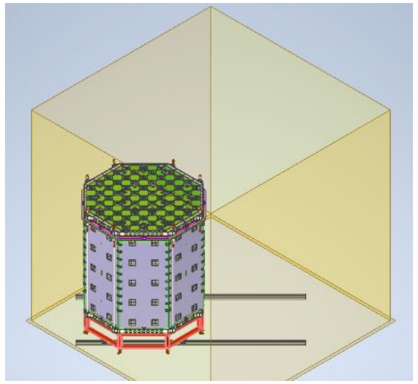
Flat bar depth: 50 mm
Flat bar thickness: 3 mm
Flat bar space: 25 mm
Cross bar space: 76 mm
Cross bar diameter: 6mm
Grating length/width : variable (max=680mm)
Material: S235Jr UNI EN10025
Weight: 53.90 kg/mq

UNI 11002-1

Class 1 [pedestrian load; i.e., 600kg/m2]	Class 2 [car load; i.e., 1000kg/(0.2mx0.2m)]	Class 3 [ligth truck load; 3000kg/(0.2mx0.4m)]	Class 4 [heavy truck load; 9000kg/(0.25mx0.6m)]
Lmax= 1924mm	Lmax= 928mm	Lmax= 476mm	Lmax= 349mm



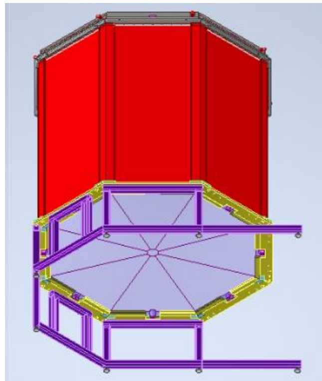
~28ton to 8 legs (footprint of 500 square mm)



~18ton to 2 c-shaped beams (currently with footprint of 90’’)

↓

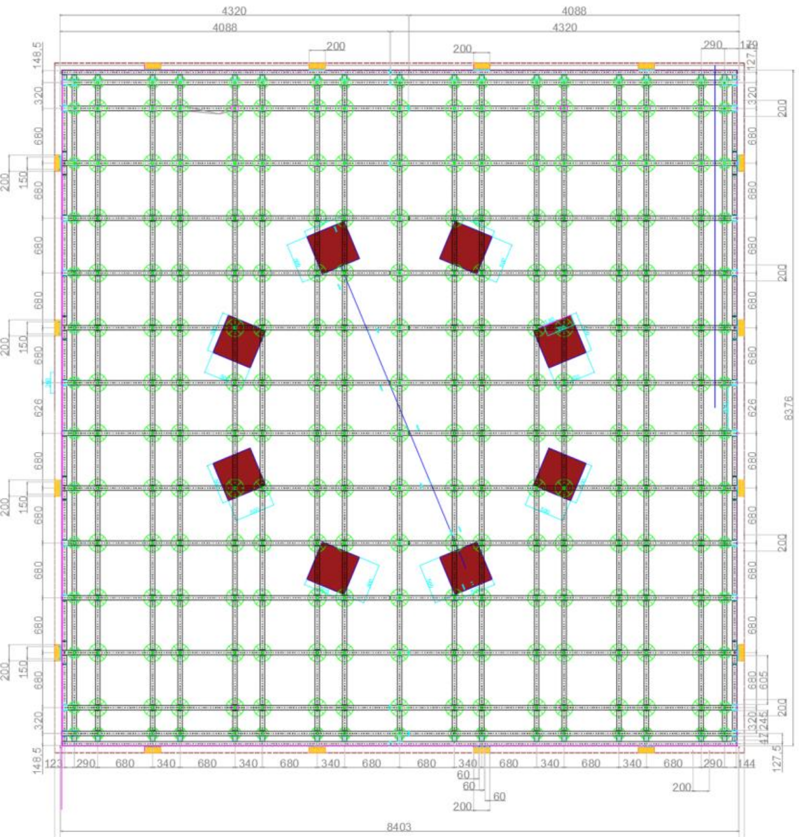
Recommended UPN240

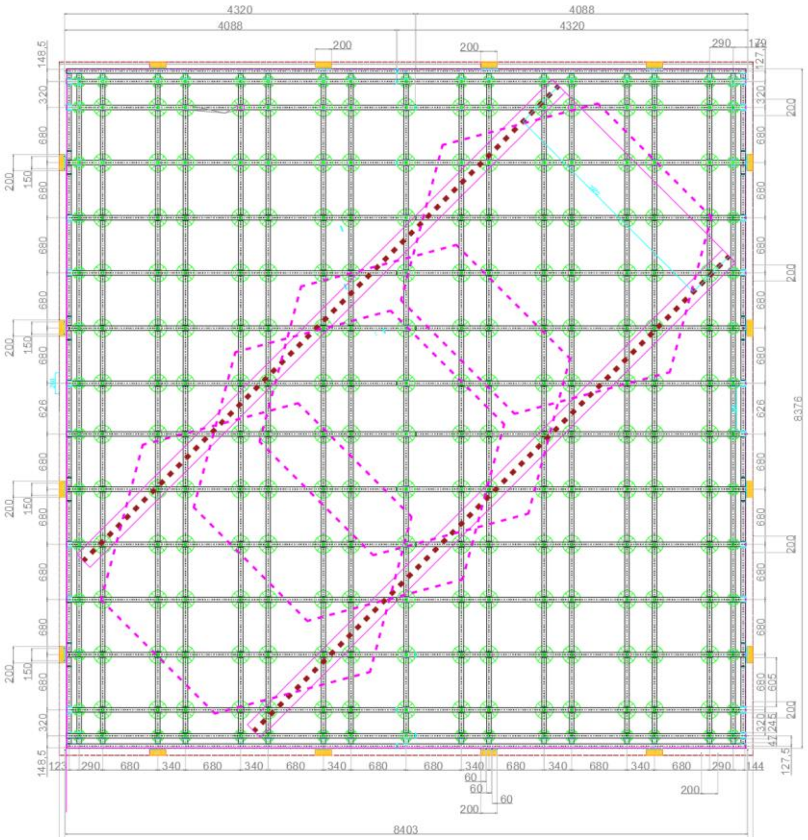


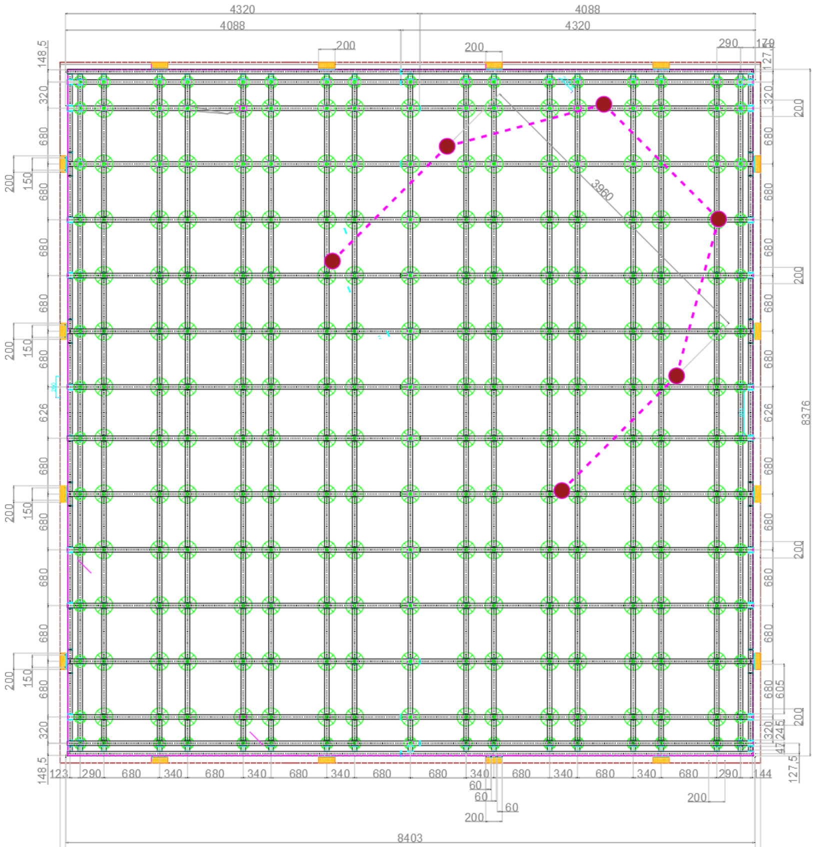
~17ton to 8 supports (currently with footprint of D=95mm)

↓

Recommended D=150mm



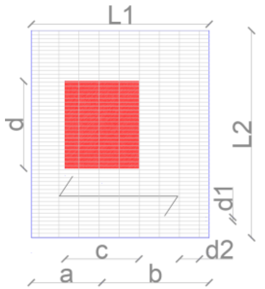




Manual calculation – grating

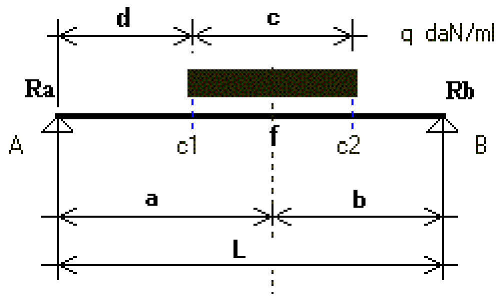
Grating	50x3-25x76		
h	50	mm	flat bar heigth
t	3	mm	flat bar thickness
d1	25	mm	flat bar space
d2	76	mm	cross bar space
L1	680	mm	
L2	680	mm	
E	210000	MPa	Young Modulus
fy	235	MPa	yielding design strength
n'	2.1	-	cross bar contrib. (productor table - f. of mesh grating)
γ_Q	1	-	design load coefficient
γ_0	1.05	-	design material coefficient
Ag	150	mm^2	single bar section area
W'	1250	mm^3	moudulus of resistance of a single bar
I'	31250	mm^4	Moment of Inertia of a single bar

not scaled scheme:



Uniform load case:

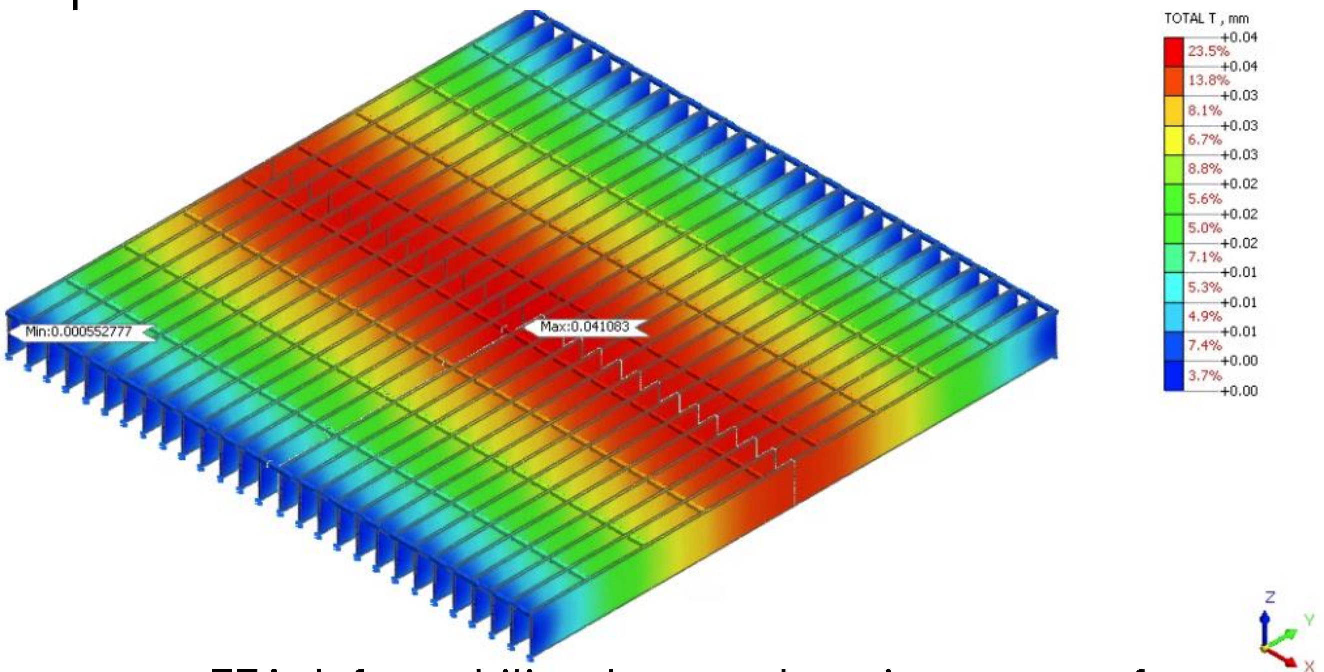
q	400.0	kg/m2	uniform load
q_ed	400.0	kg/m2	design uniform load
n	28.2	-	number of bar under load
N	30.30	-	(n'+n)
Q'_Ed	0.088	N/mm	distributed load on a single bar+
M_{max}	**5090.1**	N mm	Maximum moment
σ_{max}	**4.1**	MPa	Maximum stress
f_{max}	**0.037**	mm	(elastic field; i.e., γQ=1)



$$Mab = Mmax = \frac{q\,a\,b\,c\,(2\,L - c)}{2\,L^2}$$

$$f = \frac{q\,c}{384\,L\,E\,J}\,(L\,c^3 - 16\,a\,b\,c^2 + 128\,a^2\,b^2)$$

GRIGLIATO ELETTROSALDATO	
MAGLIA (mm)	n' = numero barre di collaborazione
11x76	2,7
15x76	2,5
17x76	2,4
22x76	2,3
25x76	2,1
30x100	1,9
34x76	1,7
44x44	1,5

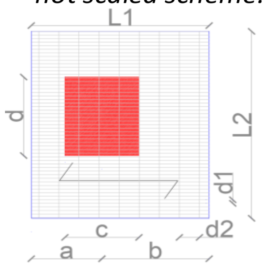


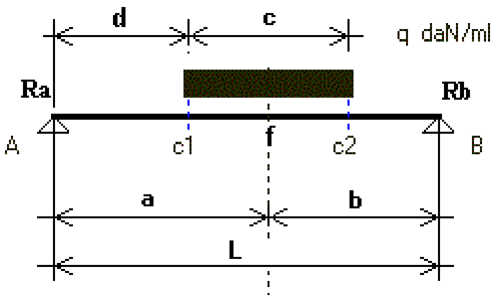
FEA deformability shows only an increment of about 10% with respect to manual calculations

Manual calculation – grating

Grating	50x3-25x76		
h	50	mm	flat bar heigth
t	3	mm	flat bar thickness
d1	25	mm	flat bar space
d2	76	mm	cross bar space
L1	680	mm	
L2	680	mm	
E	210000	MPa	Young Modulus
fy	235	MPa	yielding design strength
n'	2.1	-	cross bar contrib. (productor table - f. of mesh grating)
γ_Q	1	-	design load coefficient
γ_0	1.05	-	design material coefficient
Ag	150	mm^2	single bar section area
W'	1250	mm^3	moudulus of resistance of a single bar
I'	31250	mm^4	Moment of Inertia of a single bar

not scaled scheme:





$$Mab = Mmax = \frac{q\,a\,b\,c\,(2L - c)}{2L^2}$$

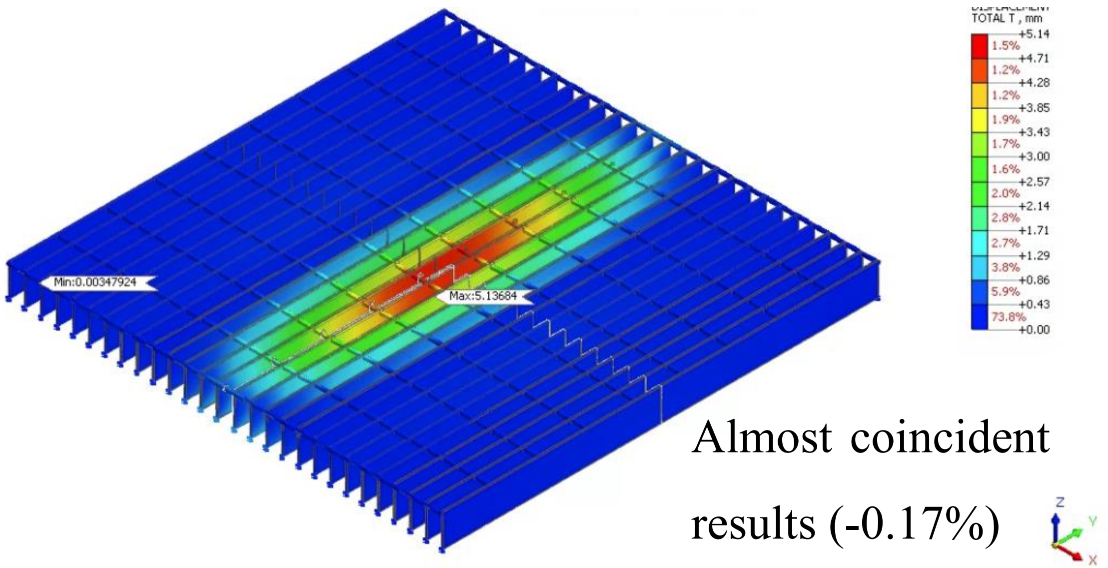
$$f = \frac{q\,c}{384\,L\,E\,J}\,(L\,c^3 - 16\,a\,b\,c^2 + 128\,a^2\,b^2)$$

GRIGLIATO ELETTROSALDATO	
MAGLIA (mm)	n' = numero barre di collaborazione
11x76	2,7
15x76	2,5
17x76	2,4
22x76	2,3
25x76	2,1
30x100	1,9
34x76	1,7
44x44	1,5

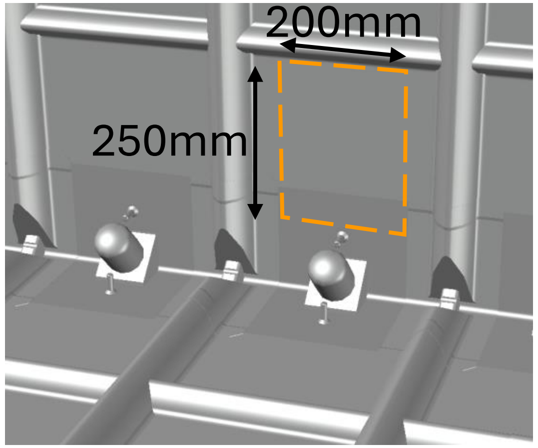
Partial load case (for validation purpose):

F	34335.0	N	= 3500 kg
a	340	mm	
b	340	mm	
c	680	mm	
d	25	mm	
F_{Ed}	34335.0	N	design force
fy_{Ed}	223.8	MPa	yielding design strength
n	2.0	-	number of bar under load
N	4.1	-	(n'+n)
Q'_{Ed}	12.315	N/mm	distributed load on a single bar
F'_{Ed}	8374.4	N	conc. load on a single bar
M_{max}	**711823.2**	N mm	Maximum moment
σ_{max}	**569.5**	MPa	Maximum stress
f_{max}	**5.225**	mm	(elastic field; i.e., γQ=1)

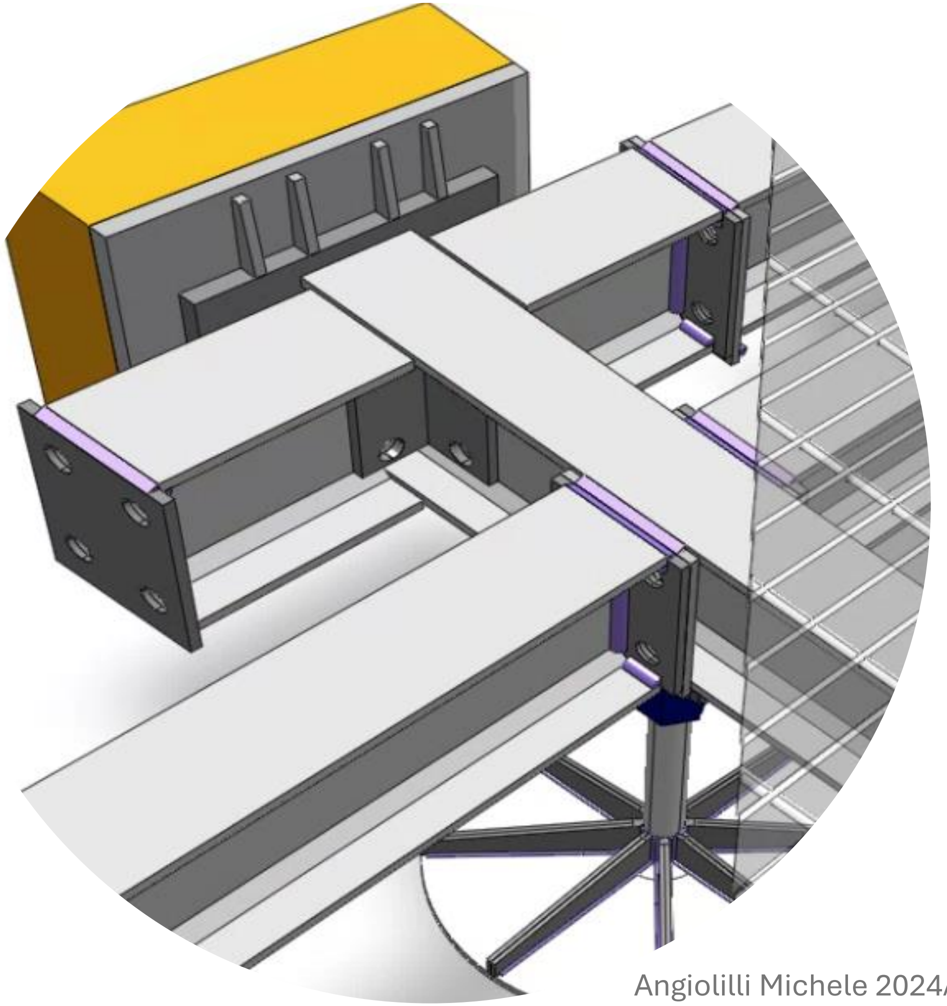
Load applied only to 2flat bars !

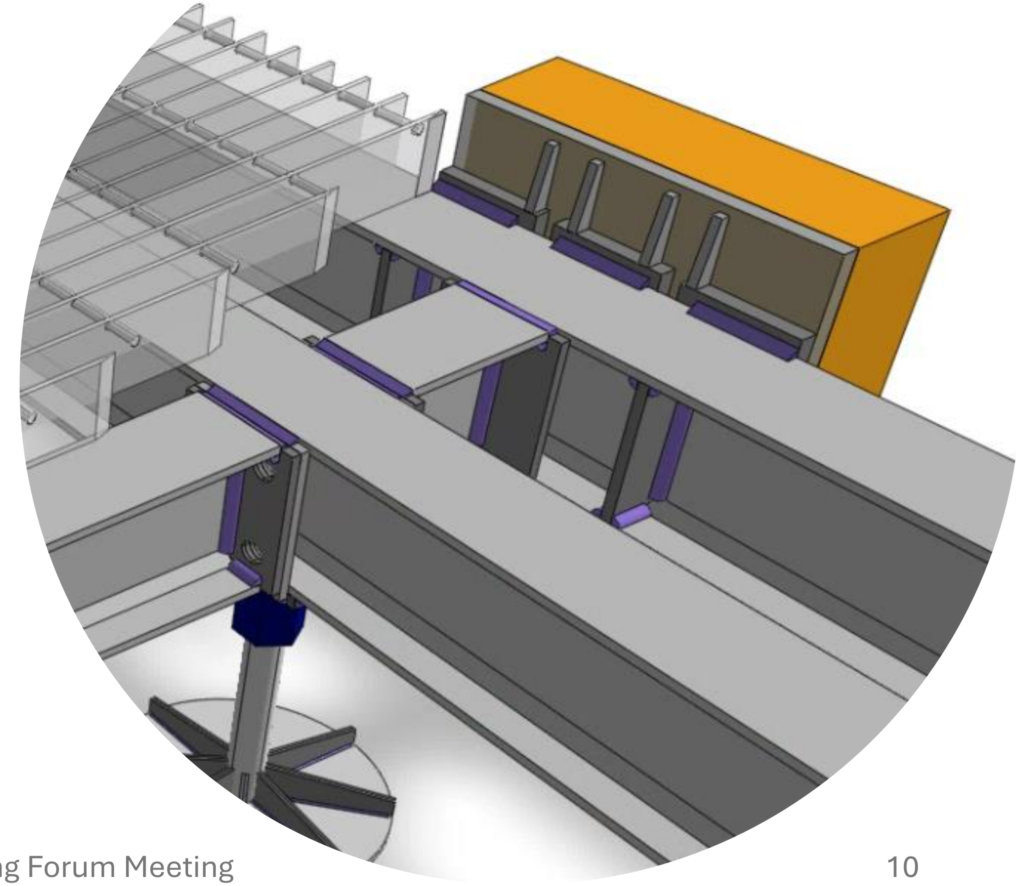


Almost coincident results (-0.17%)

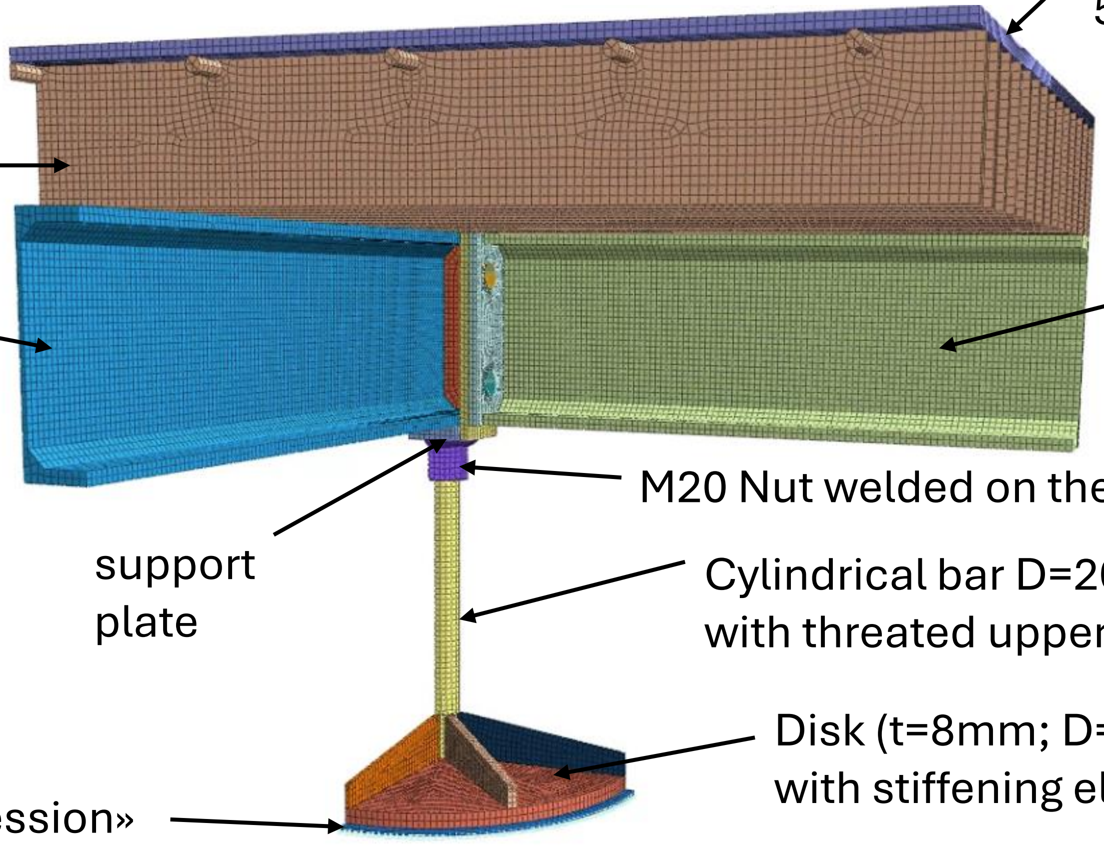


MAIN SCOPES:
- Avoid direct collision of the structure with ridges of the vertical membrane.
- Minimize pressure during horizontal actions, such as seismic events

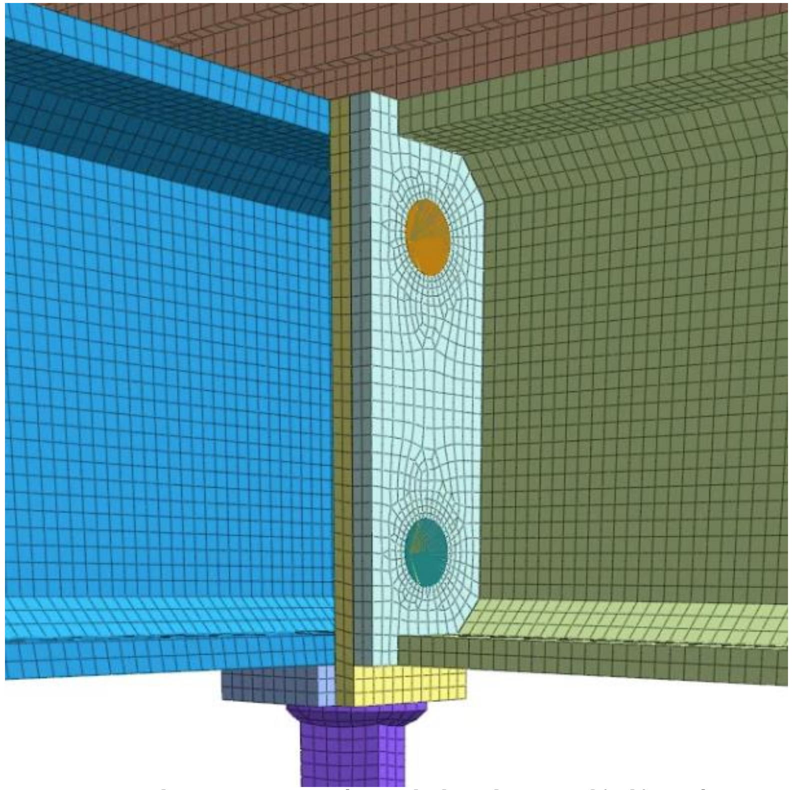




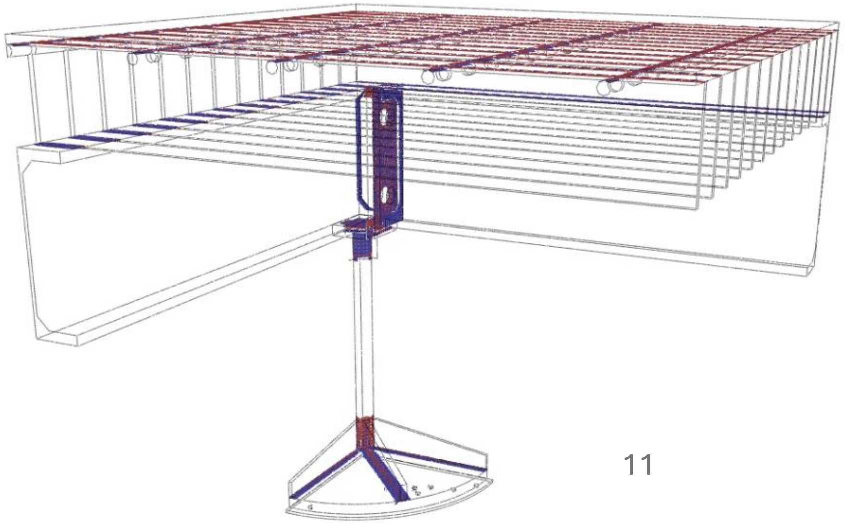
FEA – detailed model



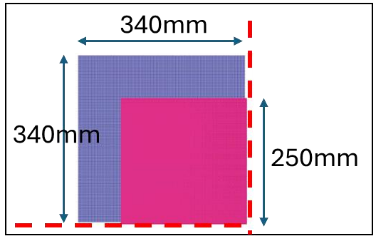
Detail of the bolted connection:



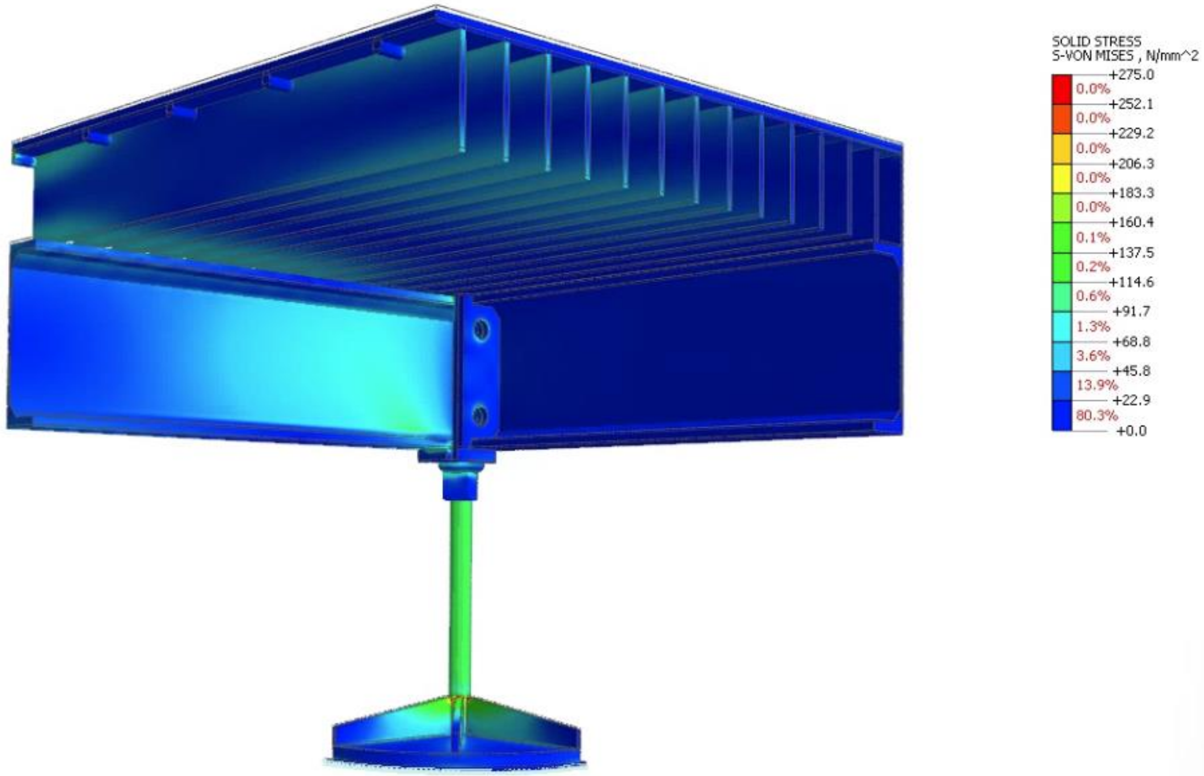
Contact elements (welded or sliding):



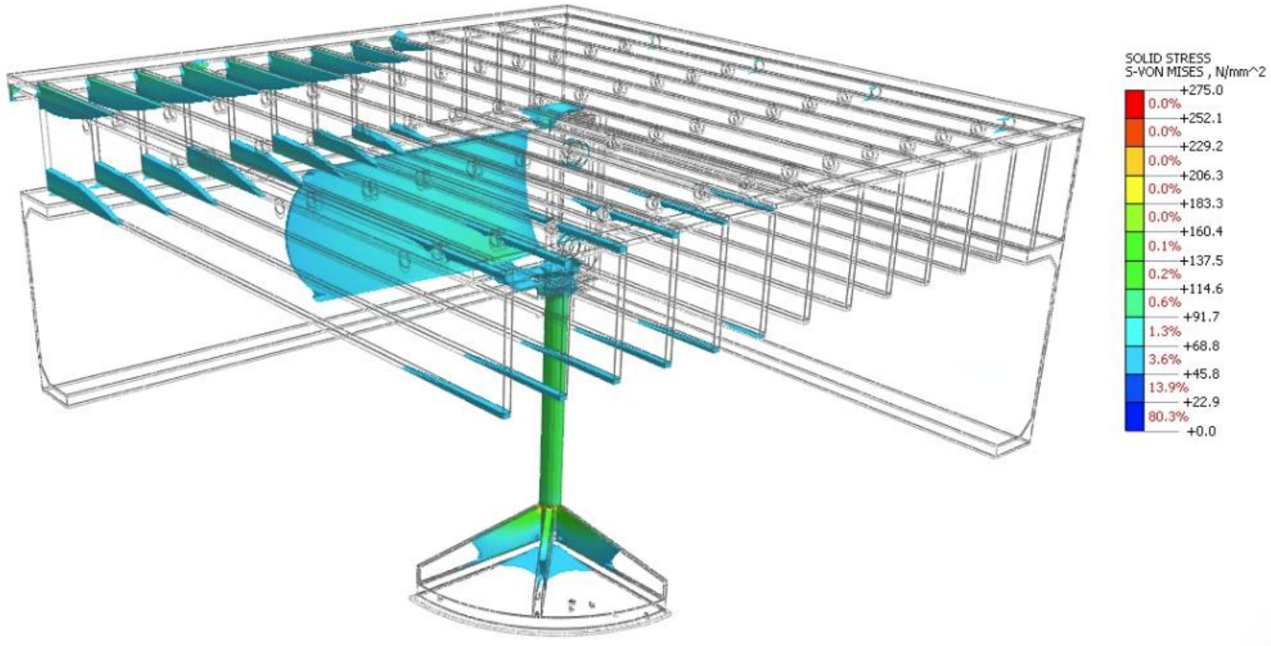
LC1: 3500kg from the vessel foot (500 square mm) on the center of the largest span (680 square mm)



Von Mises stress:



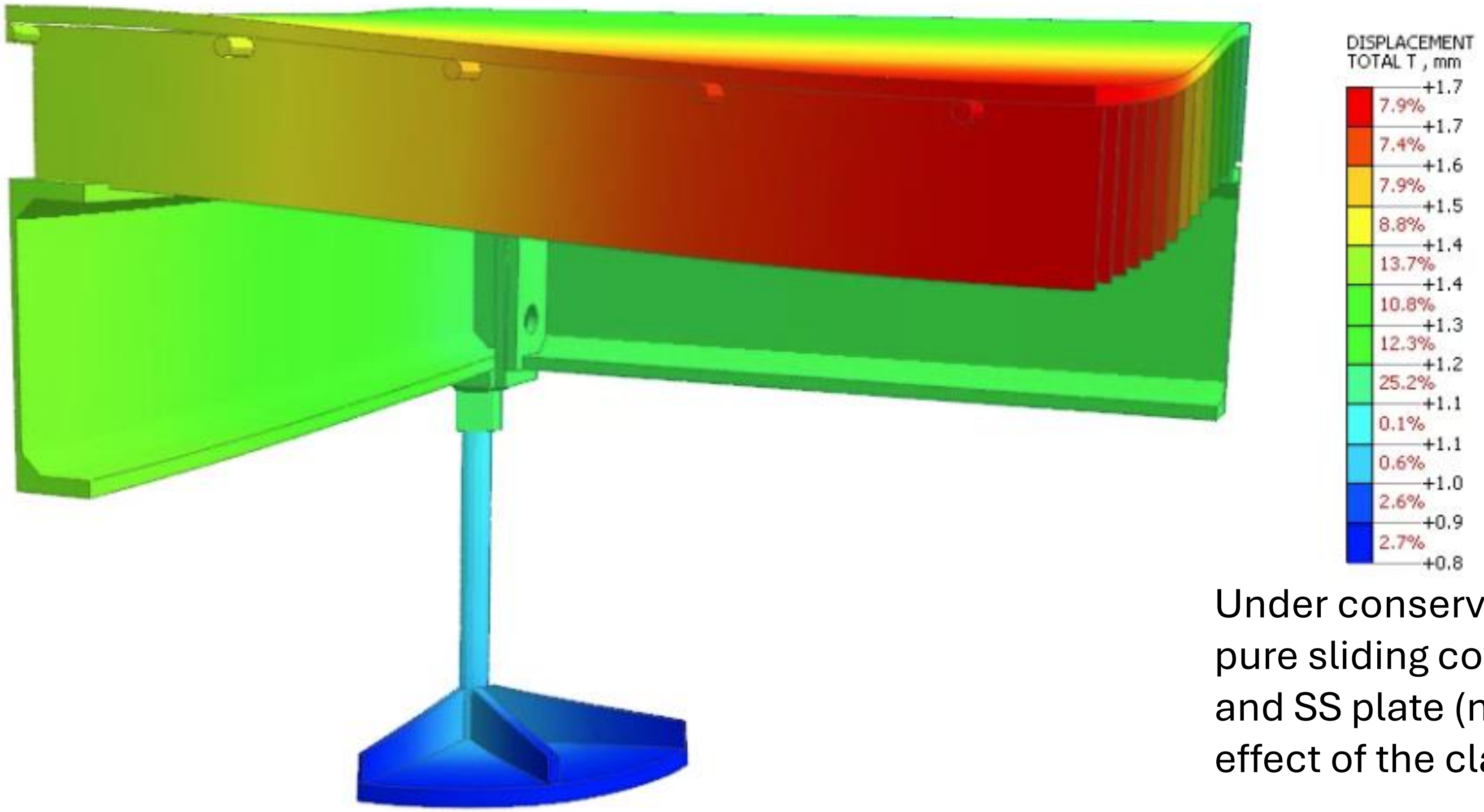
..making transparent the region with stress lower than 50MPa:



FEA – detailed model

LC1: 3500kg from the vessel foot (500 square mm) on the center of the largest span (680 square mm)

Dxyz displacement:



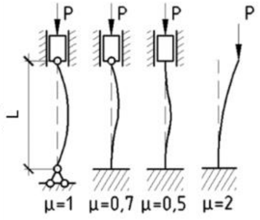
Under conservative assumption of pure sliding contact between grating and SS plate (neglecting confinement effect of the clamped connection)

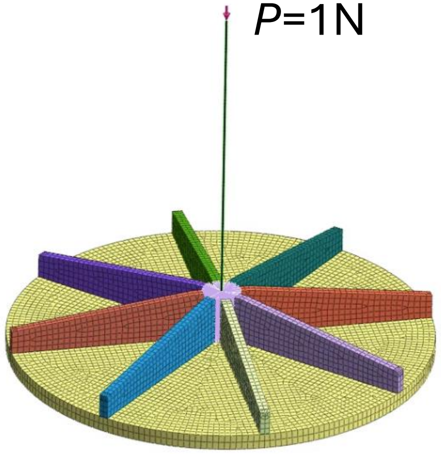
HDPE sheets 2-3mm thick under the Vessel legs are recommended

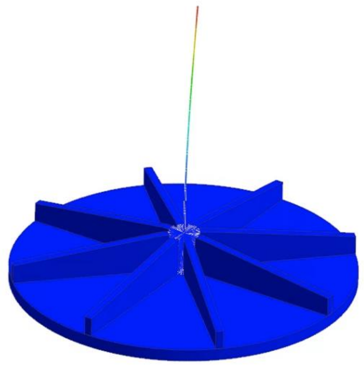
Eulero's approach:

Considering $l_0 = \mu L = 2L = 2*157mm$ (considering the presence of the stiffening ribs limiting the effective length of the cylindrical supports) and a second moment of inertia $I = \frac{\pi D^4}{64} = 7850mm^4$ one can compute a critical load N_{cr}:

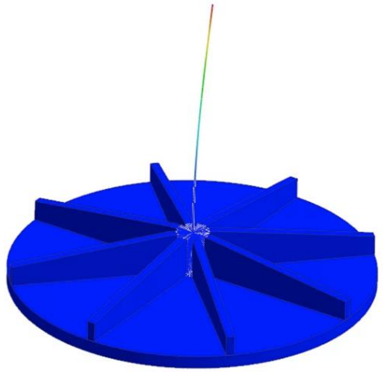
$$N_{cr} = \pi^2 \cdot \frac{EI}{l_0^2} = \frac{\pi^2}{4} \cdot \frac{EI}{L^2} = \frac{\pi^2}{4} \cdot \frac{210000 * 7850}{157^2} = 165017\ N$$



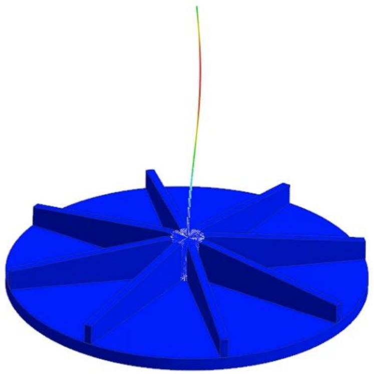




1°mode

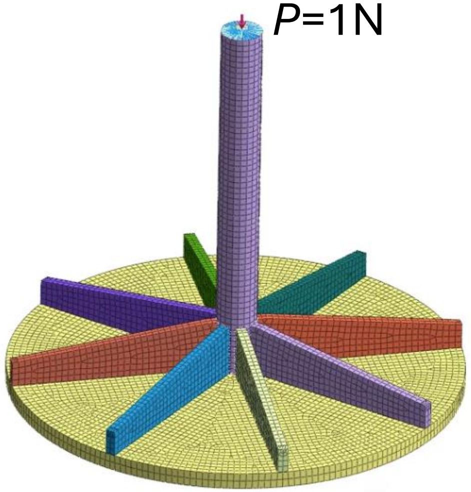


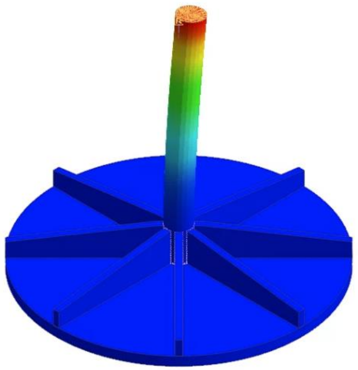
2°mode



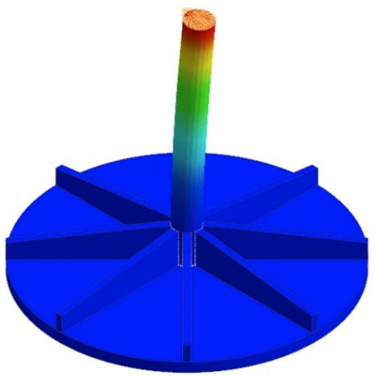
3°mode

MODE N.	EIGENVALUE
1	161,278
2	161,292
3	1,451,905

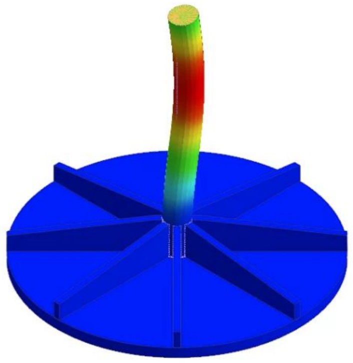




1°mode



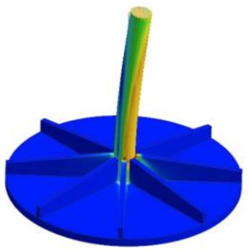
2°mode



3°mode

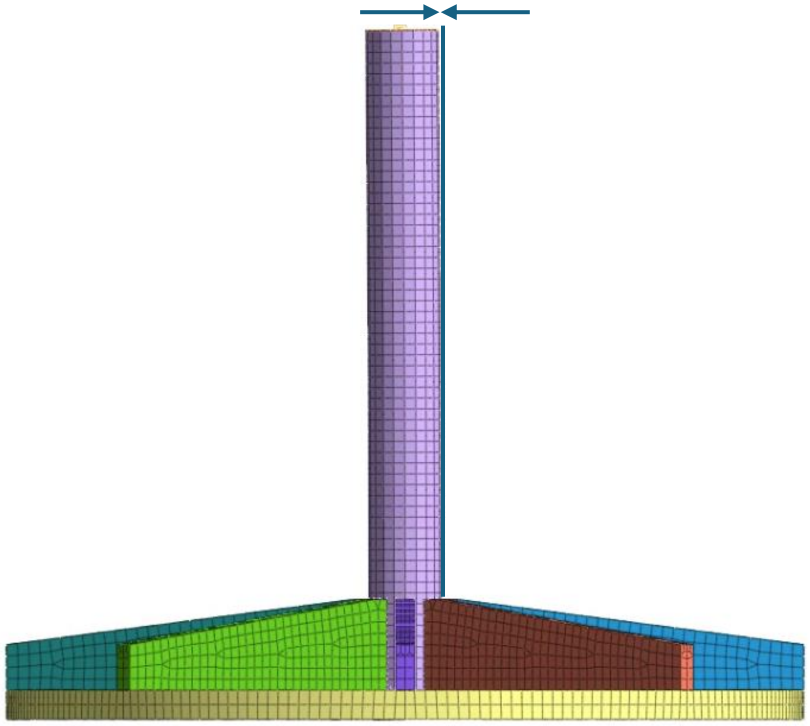
MODE N.	EIGENVALUE
1	139,311
2	139,458
3	1,216,335

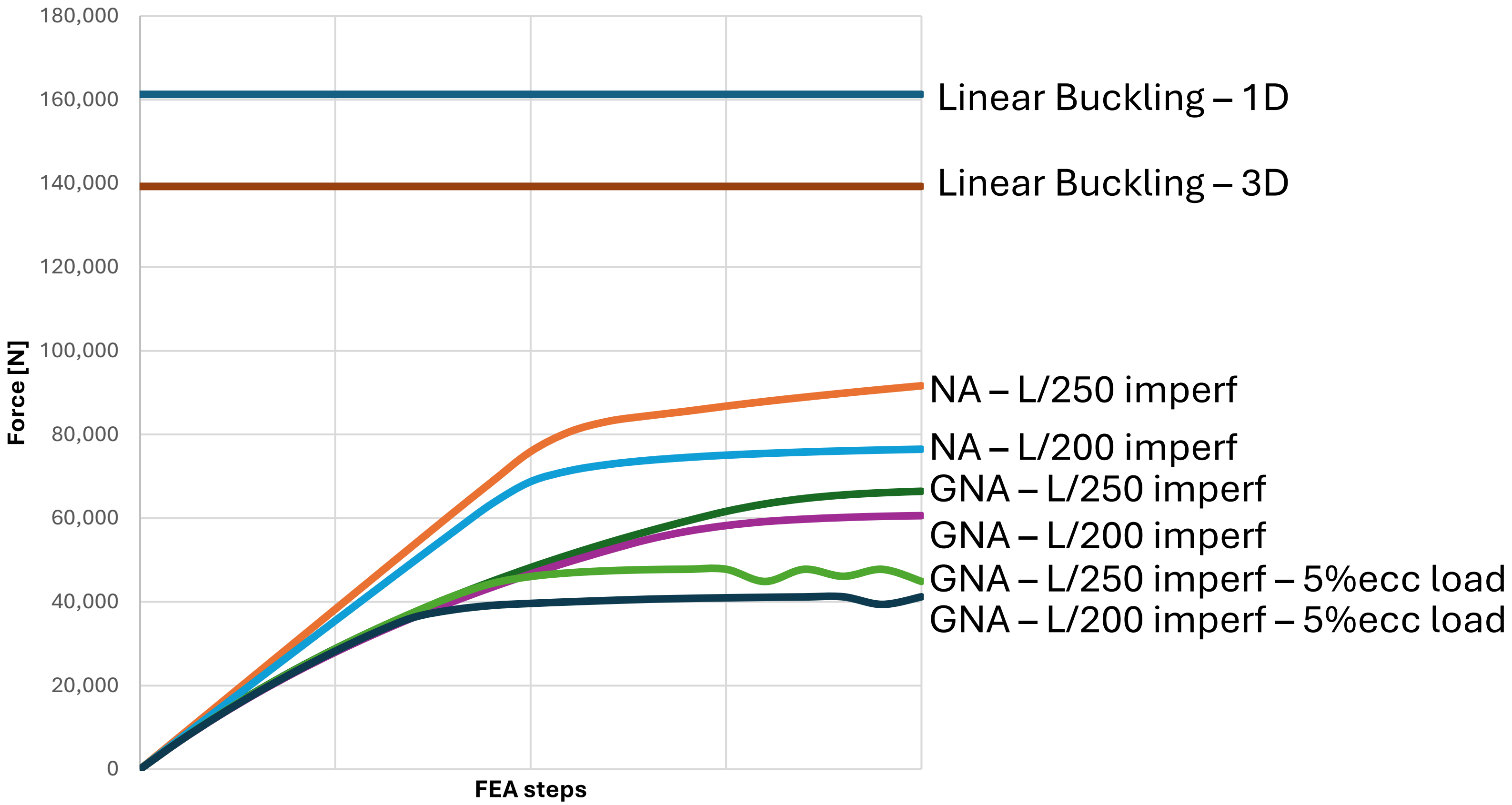
FEA – nonlinear buckling



Introduction of the effect of both imperfections and non-linearities:

- geometrical nonlinearity
- Non-linear material
- Assume geometric imperfections (either a small destabilizing load or an initial imperfection is necessary to initiate the solution of a desired buckling mode)
- Set incremental analysis





Manual calculation - buckling

linear buckling with imperfections and eccentricity according to NTC18/Eurocode:

The non-dimensional slenderness $\bar{\lambda}$ is computed as:

$$\bar{\lambda} = \sqrt{\frac{A\, f_{yk}}{N_{cr}}} = \sqrt{\frac{314 * 275}{165017}} = 0.723$$

$$\Phi = 0.5[1 + \alpha(\bar{\lambda} - 0.2) + \bar{\lambda}^2] = 0.5[1 + 0.49(0.723 - 0.2) + 0.723^2] = 0.889$$

Where α is the imperfection factor equal to 0.49 (see Tab. 4.2.VIII – NTC18)

The reduction factor for the relevant buckling mode χ can be computed as:

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \lambda^2}} = \frac{1}{0.889 + \sqrt{0.889^2 - 0.723^2}} = 0.711$$

The design value of resistance to normal force of the cylindrical support $N_{b_{R,d_{supp}}}$ can be computed as:

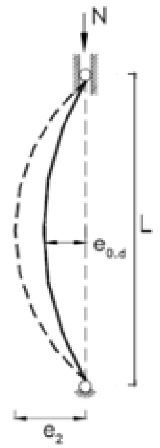
$$N_{b_{R,d_{supp}}} = \frac{\chi\, A\, f_{yk}}{\gamma_{M1}} = 0.711 * 314 * \frac{275}{1.05} = 58{,}471\, N$$

Therefore, the instability check is verified since:

$$\frac{N_{Ed_{supp}}}{N_{b_{R,d_{supp}}}} = 0.2 < 1$$

Anyhow, bucking cannot be totally neglected since $\frac{N_{Ed_{supp}}}{N_{Cr}} = 0.06 > 0.04$. FEA provides better responses on this phenomenon.

Finally, the design of the compressed member by considering imperfection effect is reported in the following. In particular, an equivalent eccentricity is considered as depicted in the figure.



From NTC18, k_δ is 0.06.

$$k_\gamma = (1 - k_\delta) + 2\, k_\delta \bar{\lambda} = (1 - 0.06) + 2 * 0.06 * 0.852 = 1.042 > 1$$

Considering $W_{el} = \frac{\pi D^3}{32} = 785 mm^3$

$$e_{0,d} = \frac{\alpha(\bar{\lambda} - 0.2) k_\gamma W_{el}}{A} = 0.49(0.852 - 0.2)1.042 * \frac{785}{314} = 0.83$$

The amplification of the deflection due to the initial imperfection of the member is called e_2 and is computed as:

$$e_2 = \frac{e_{0,d}}{1 - \frac{N_{b,Rd}}{N_{Cr}}} = \frac{0.83}{1 - \frac{44.5}{101.6}} = 1.48mm$$

Therefore, it is possible to verify the section as:

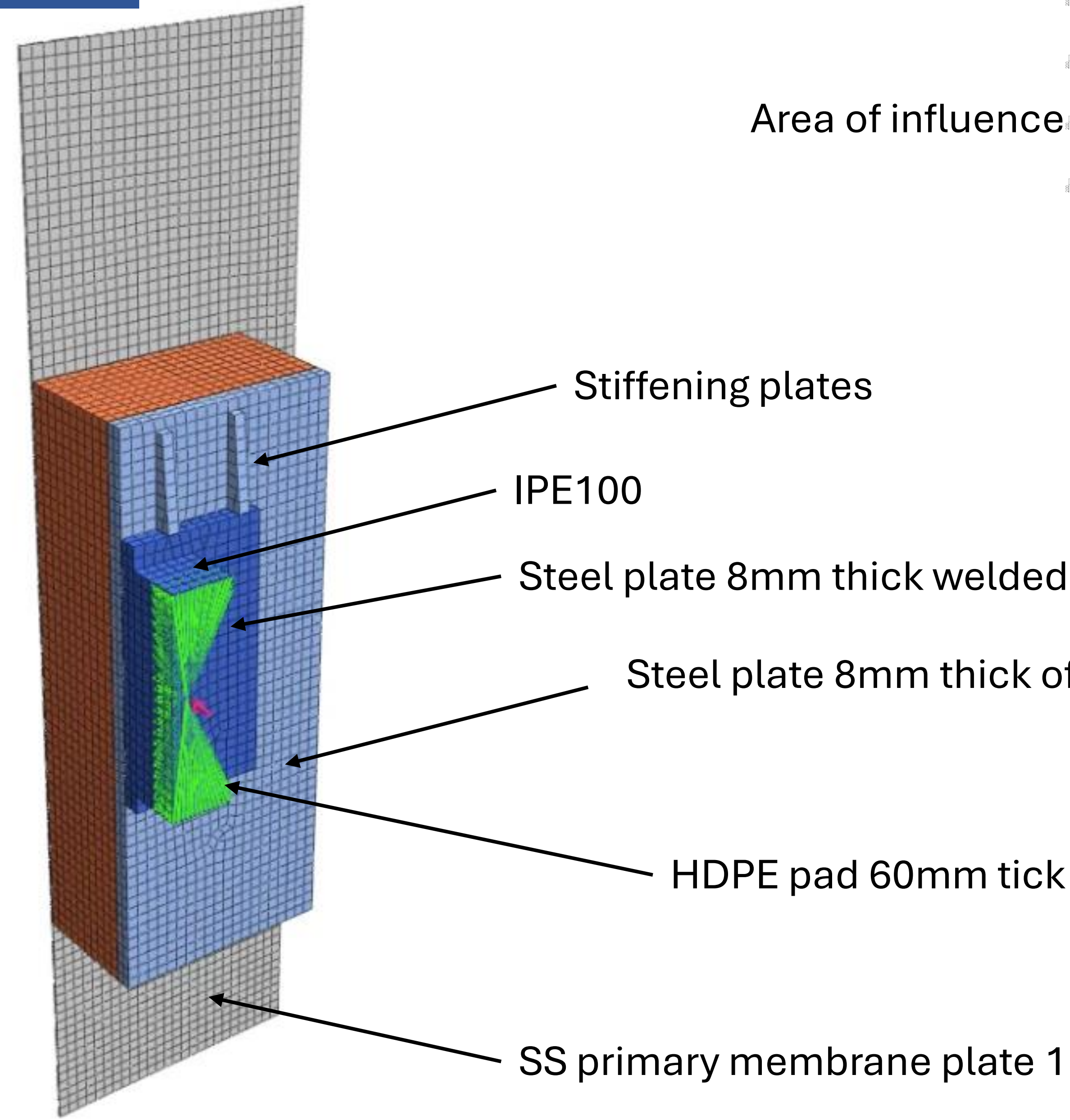
$$\frac{N}{A} + \frac{N\, e_2}{W_{el}} = 46.6MPa < fyd = 204.8$$

FEA – horizontal devices

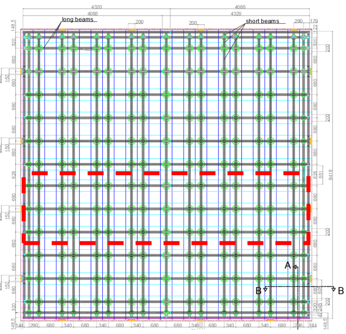
During seismic action, a maximum horizontal force of about 25kN is applied to a central device, which absorbe about 24% of the total load. Note that this is a conservative force value because:

- the seismic action occurs exactly when the entire assembly is placed on the false-floor
- The PGA rather than spectrum acceleration at T1, namely Sa(T1), is considered
- a modal decoupling between cryostat and false floor may occur with an increase of T1 and reduction of Sa(T1)
- The membrane is constrained with pinned connection neglecting the deformability of the insulation system

Spectral acceleration of 0.28g (see DOCDB LINK): https://darkside-docdb.fnal.gov/cgi-bin/private/RetrieveFile?docid=5469&filename=2024.04.04_angiolilli_EngMeeting.pdf&version=2

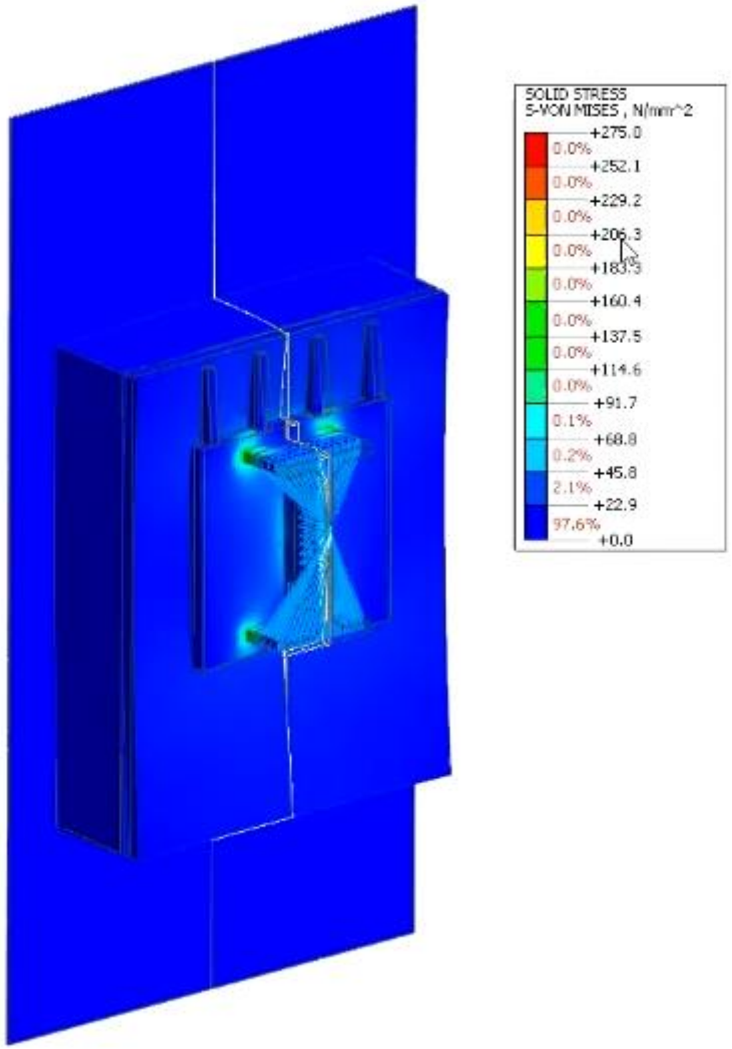


Area of influence

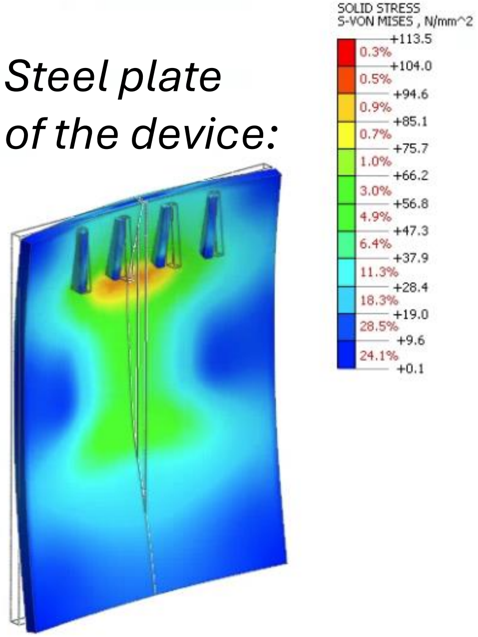


FEA – horizontal devices

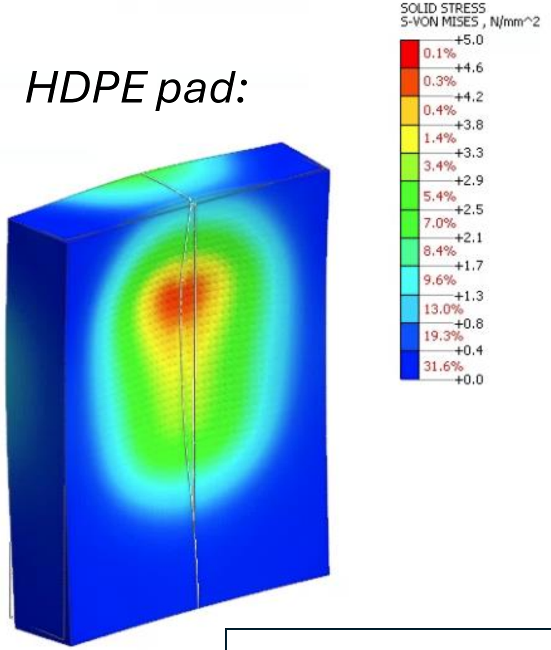
Von Mises stress- X100 deformation:



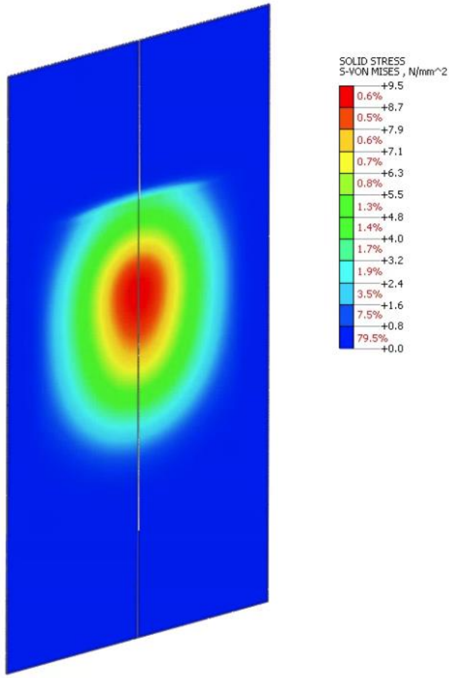
Steel plate of the device:



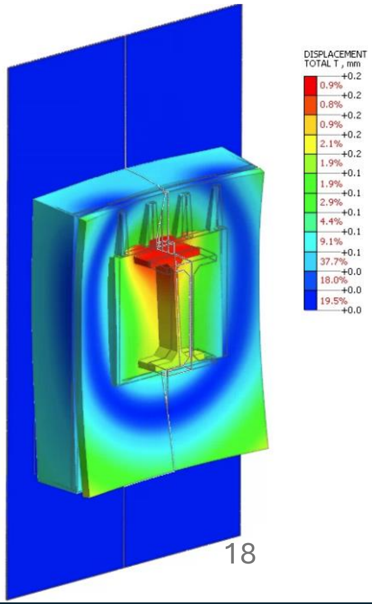
HDPE pad:



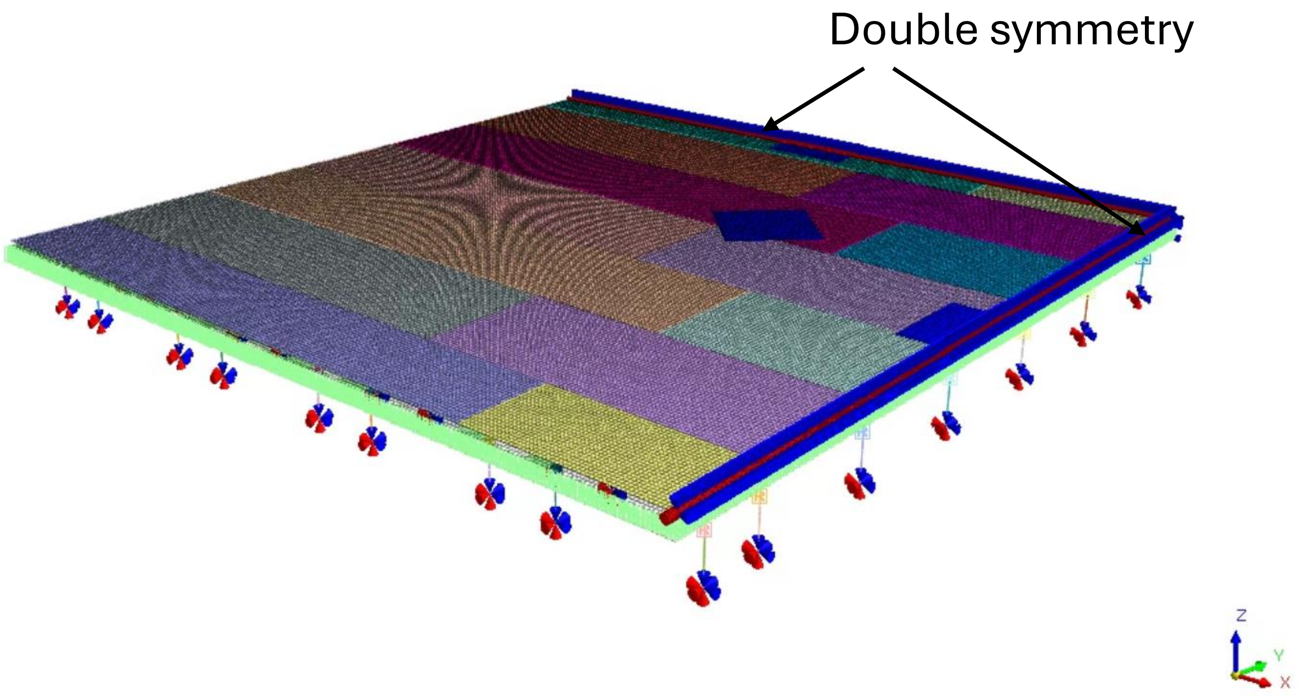
SS membrane:



deformability check of the horizontal device:

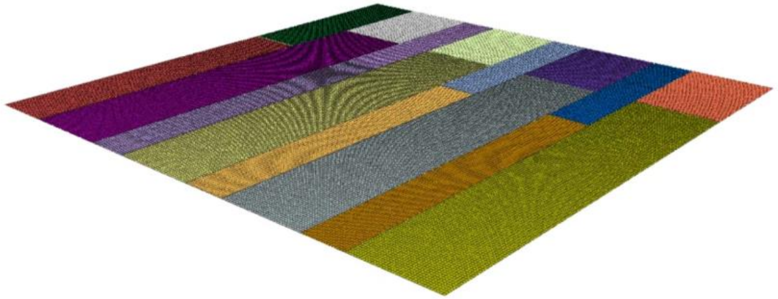


FEA – overall model

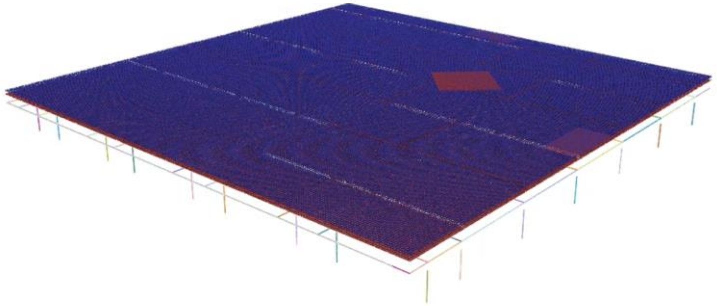


2D isotropic shell (SS plate):

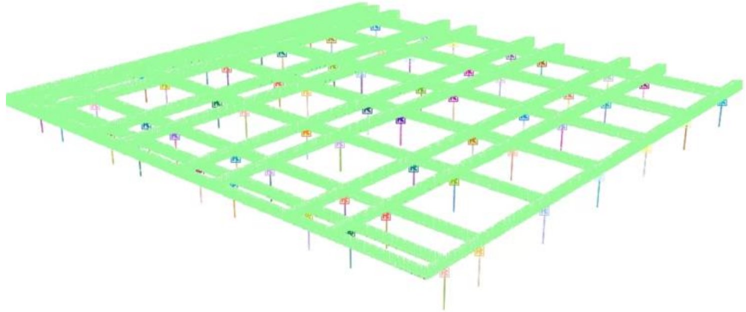
2D orthotropic shell (Grating) :



Contact elements (Sliding):

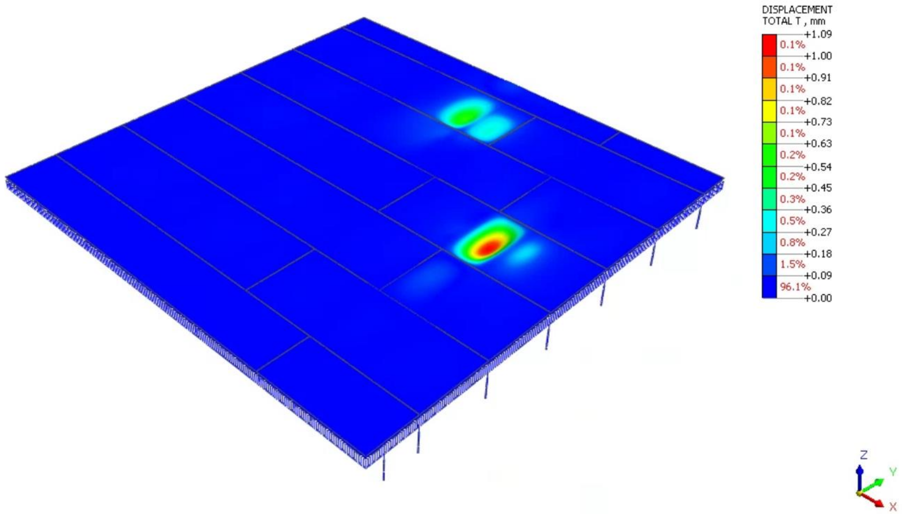


1D I-shaped beam & rigid links:



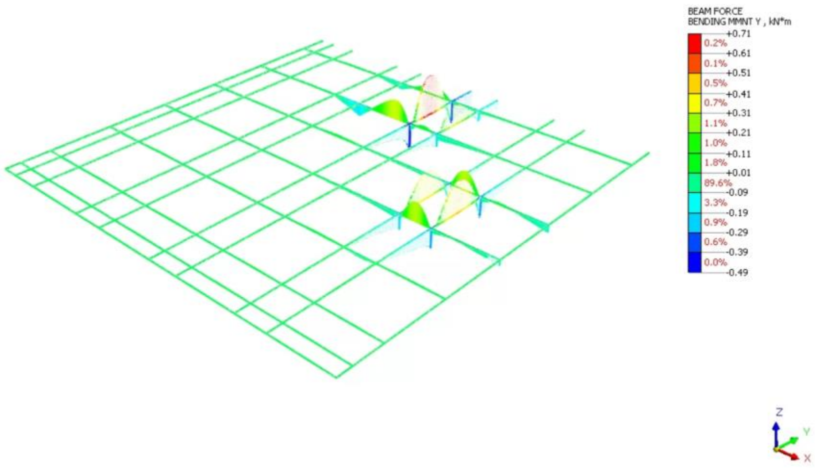
So far … Conservative assumption of neglecting clamped connection between IPE, grating and SS plate

Dxyz displacement:

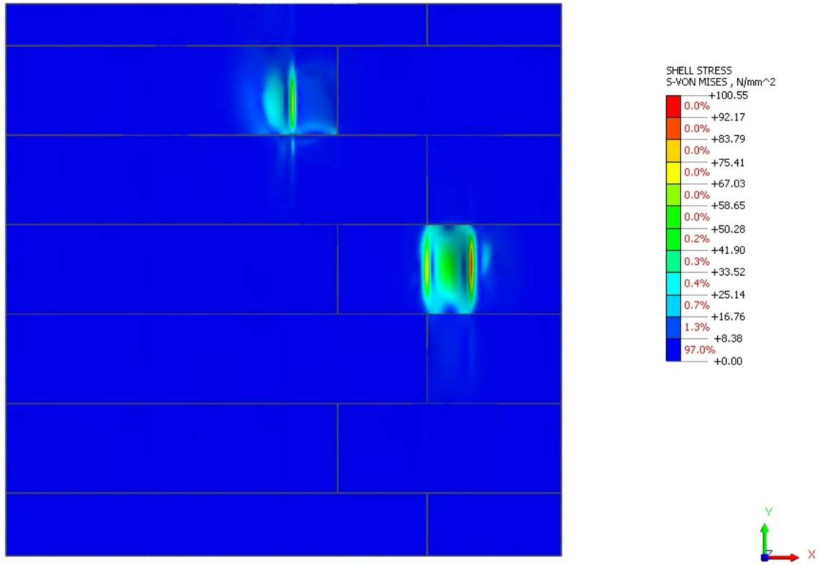


1.5 kN/m < maximum design moment of the IPE100:

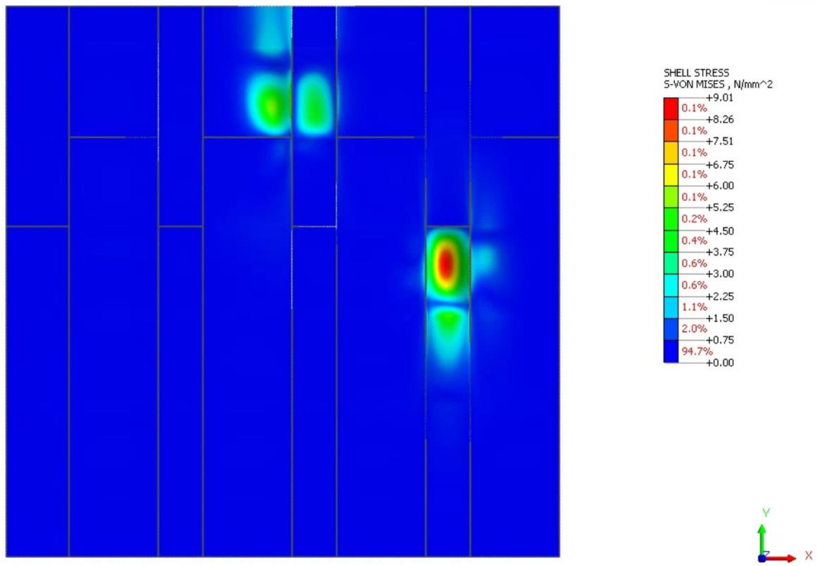
$M_{max}=\sigma/W_{el}$=275 MPa/(1.05*34000mm^3)=8.9kNm



Von Mises stress on SS plates:



Von Mises stress on the gratings:



Conservative assumption of neglecting clamped connection between IPE, grating and SS plate

“open” points

- On April 22nd, a preliminary discussion with the University of L’Aquila is scheduled to define the setup of the load test that will be performed at the the Company’s headquarter before to install it into cryostat

- Evaluation of the insertion of HDPM 2mm-thick between grating and SS plate (already quoted by the company about 3.5k€)

- Installation phase inside the criostat under discussion with the Company

- Evaluation of increasing the number of horizontal devices – check with GTT/CERN