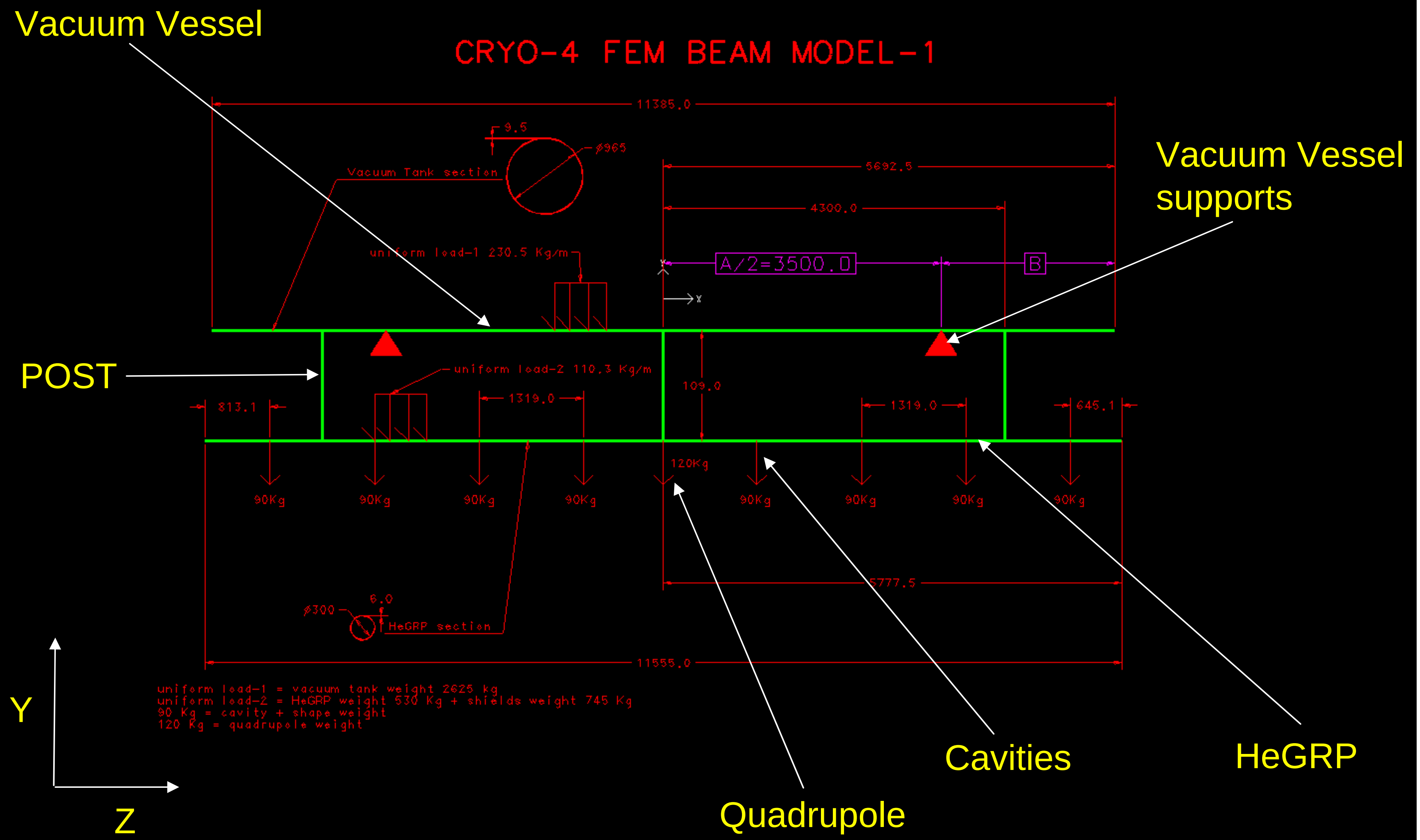
Mechanical studies of CRY-04

A.Basti INFN-PISA
in collaboration with INFN-Milano

Outline:

- We made a first simple FEM of CRY-4 module using beam elements.
  - We used the dimensions and weights of CRY-4 design supply by the INFN-Milano group (P.Pierini and N.Panzeri).
- We used this model to study the Vacuum Vessel support positions and the normal modes of vibration.
- Checks of ASME code compliance of Vacuum Vessel design.


Vacuum Vessel
CRYO-4 FEM BEAM MODEL-1
11385.0
9.5
ø965
Vacuum Tank section
5692.5
4300.0
uniform load-1 230.5 Kg/m
A/2=3500.0
B
Vacuum Vessel supports
POST
uniform load-2 110.3 Kg/m
813.1
1319.0
109.0
1319.0
645.1
120Kg
90Kg
90Kg
90Kg
90Kg
90Kg
90Kg
90Kg
90Kg
5777.5
6.0
ø300
HeGRP section
11555.0
uniform load-1 = vacuum tank weight 2625 kg
uniform load-2 = HeGRP weight 530 Kg + shields weight 745 Kg
90 Kg = cavity + shape weight
120 Kg = quadrupole weight
Cavities
HeGRP
Quadrupole
Y
Z

Vacuum Vessel Supports

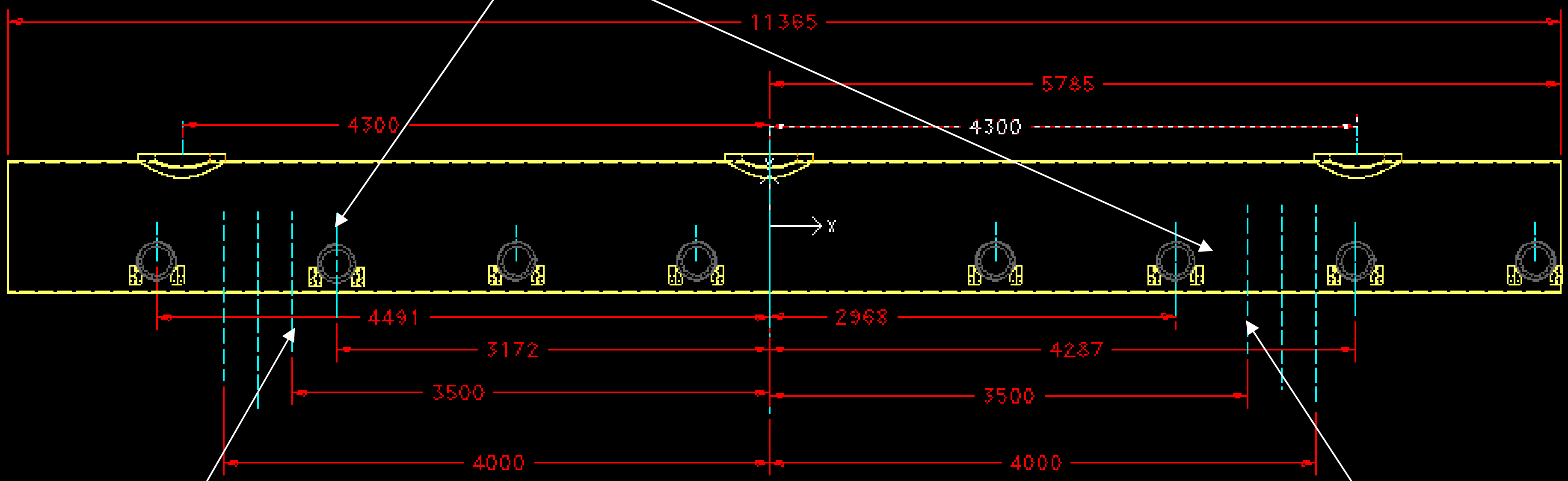
- Model:
  - Horizontal vessel.
  - Uniform vertical load applied (vessel weight + internal components).

- Solution:
  - two supports in symmetrical position with respect of central section. (isostatica solution, beam supported in two points).

- Optimization:
  - Max bending moment equal in the centre and support sections.

CRY-4 Vacuum Vessel design

Analytical solution A/2=3300 mm



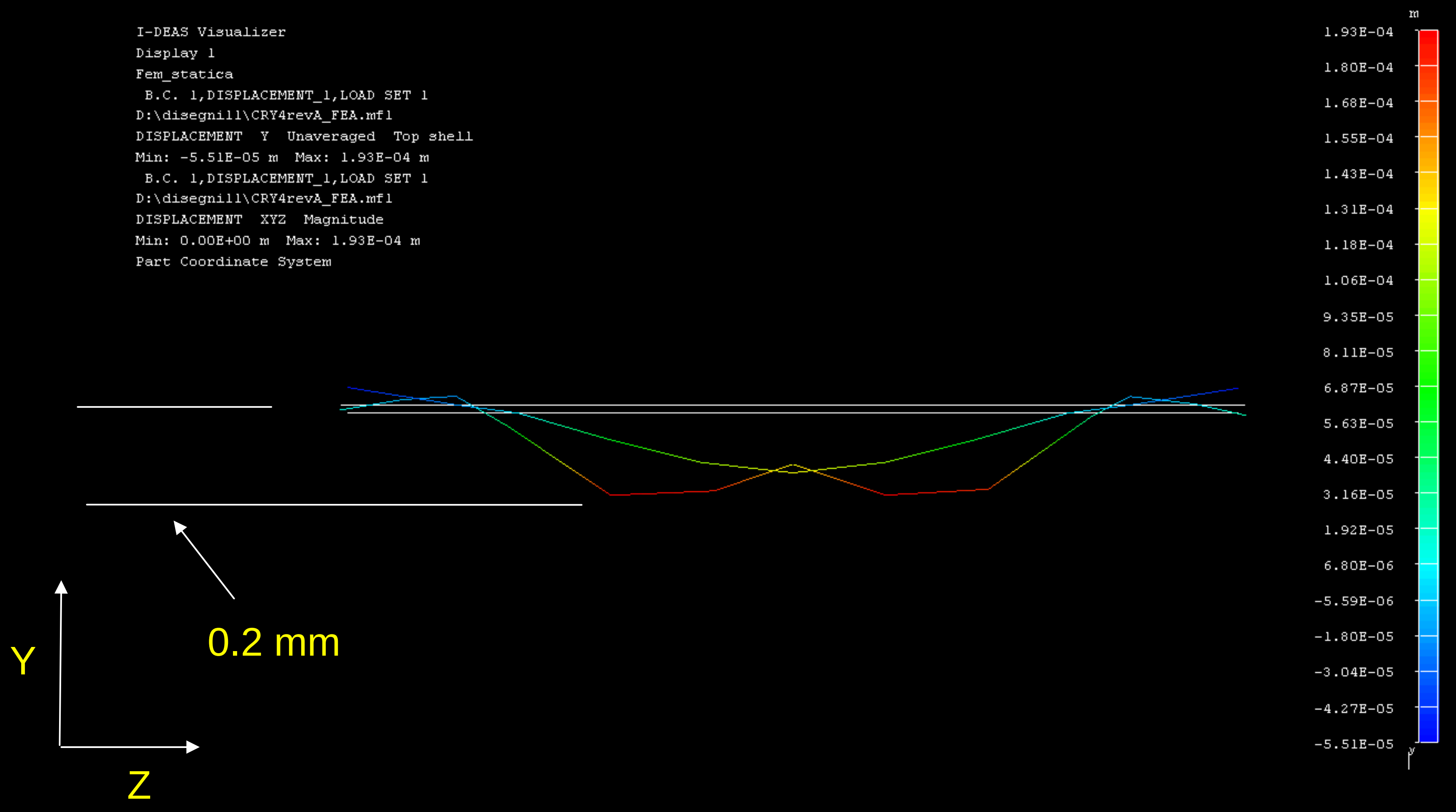
Vessel Support Position

Vessel Support Position

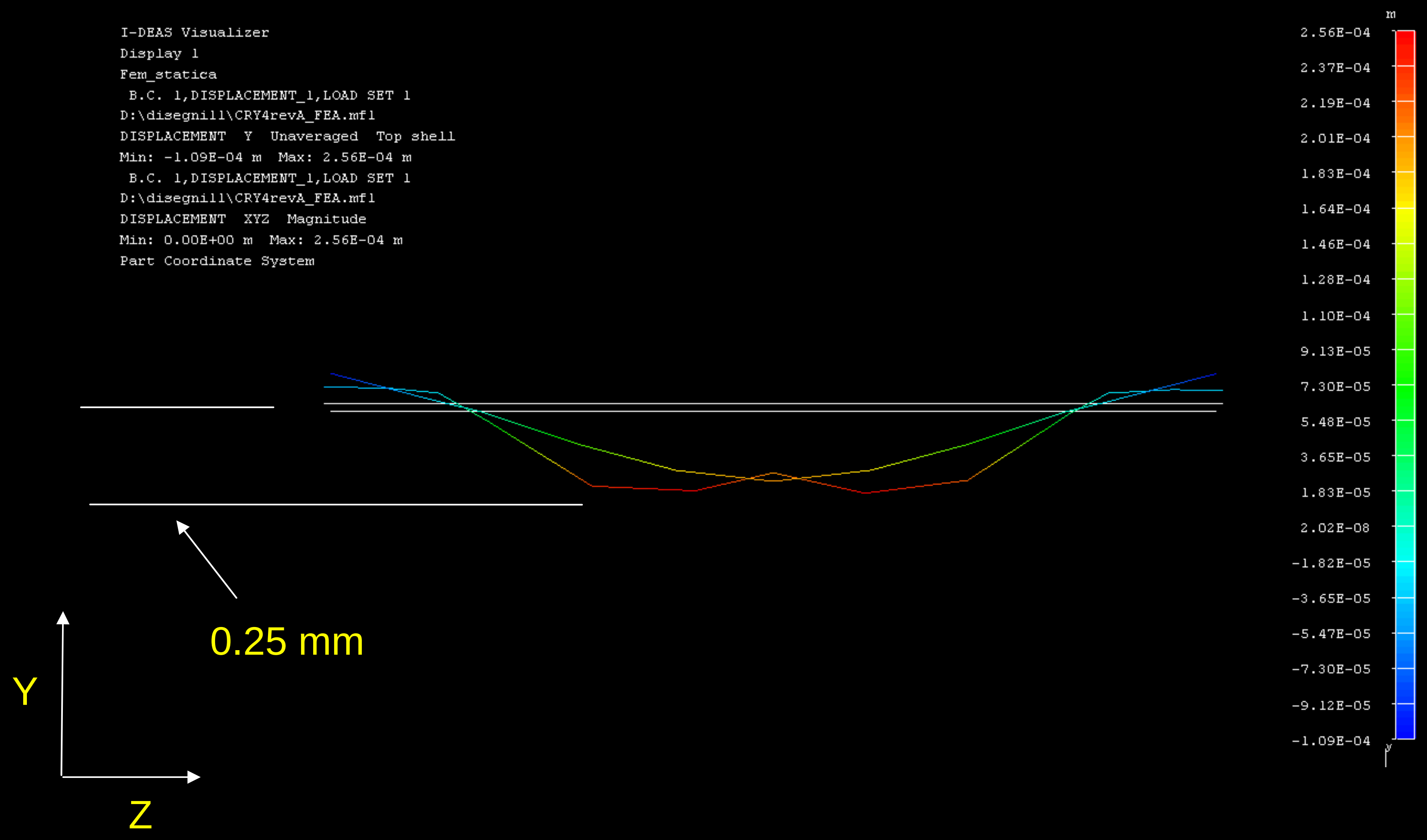
Using the FE model

- We use the FE beam model to calculate the displacements in the cases in which:
  - 1) we have only two support points,
  - at the distance from centre :
    - A/2 = 3500 mm
    - A/2 = 3750 mm
    - A/2 = 4000 mm
  - 2) We have three support points.
    - (one in the middle and two at 3500 from centre)

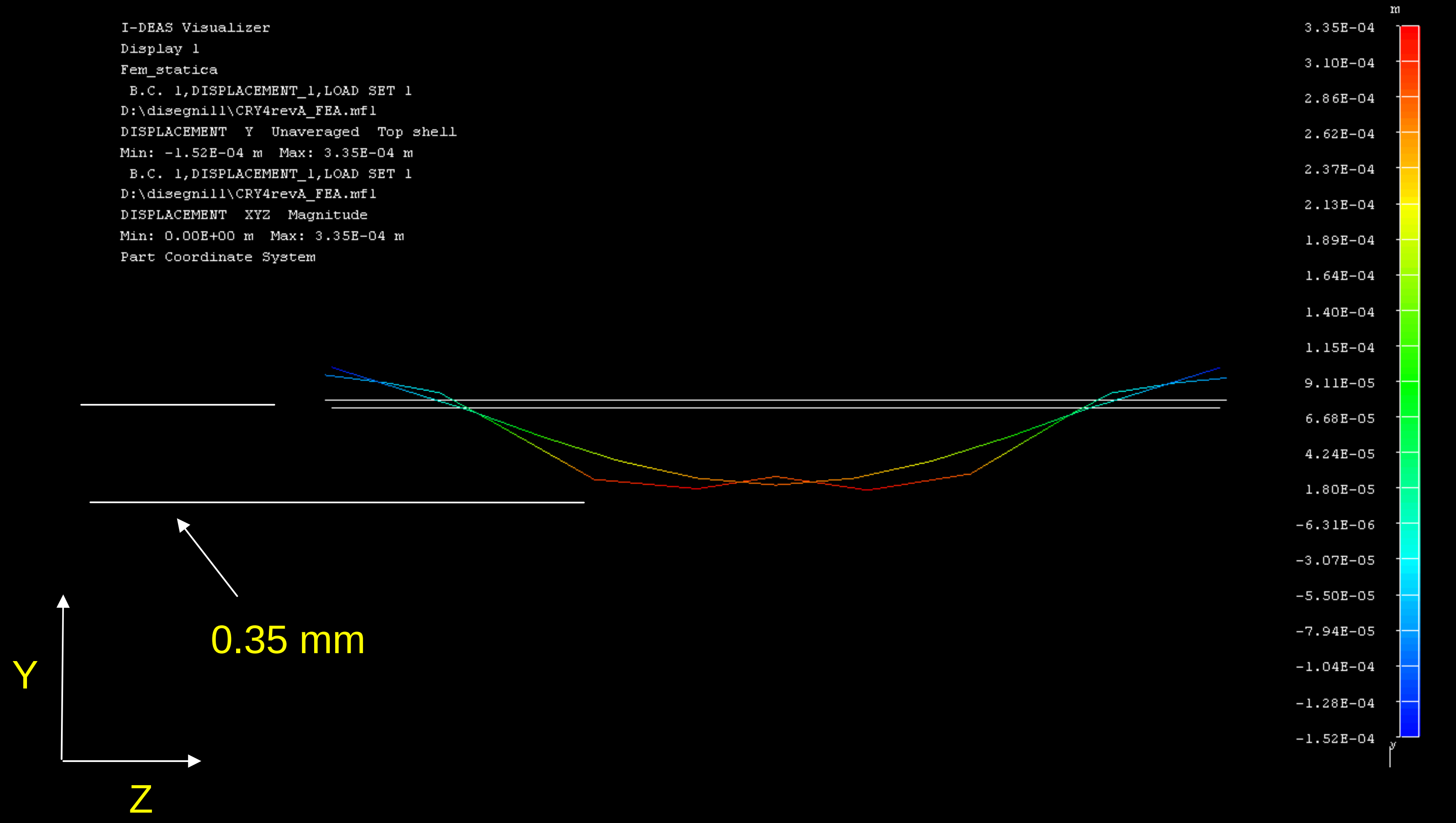
Displacements A/2=3500



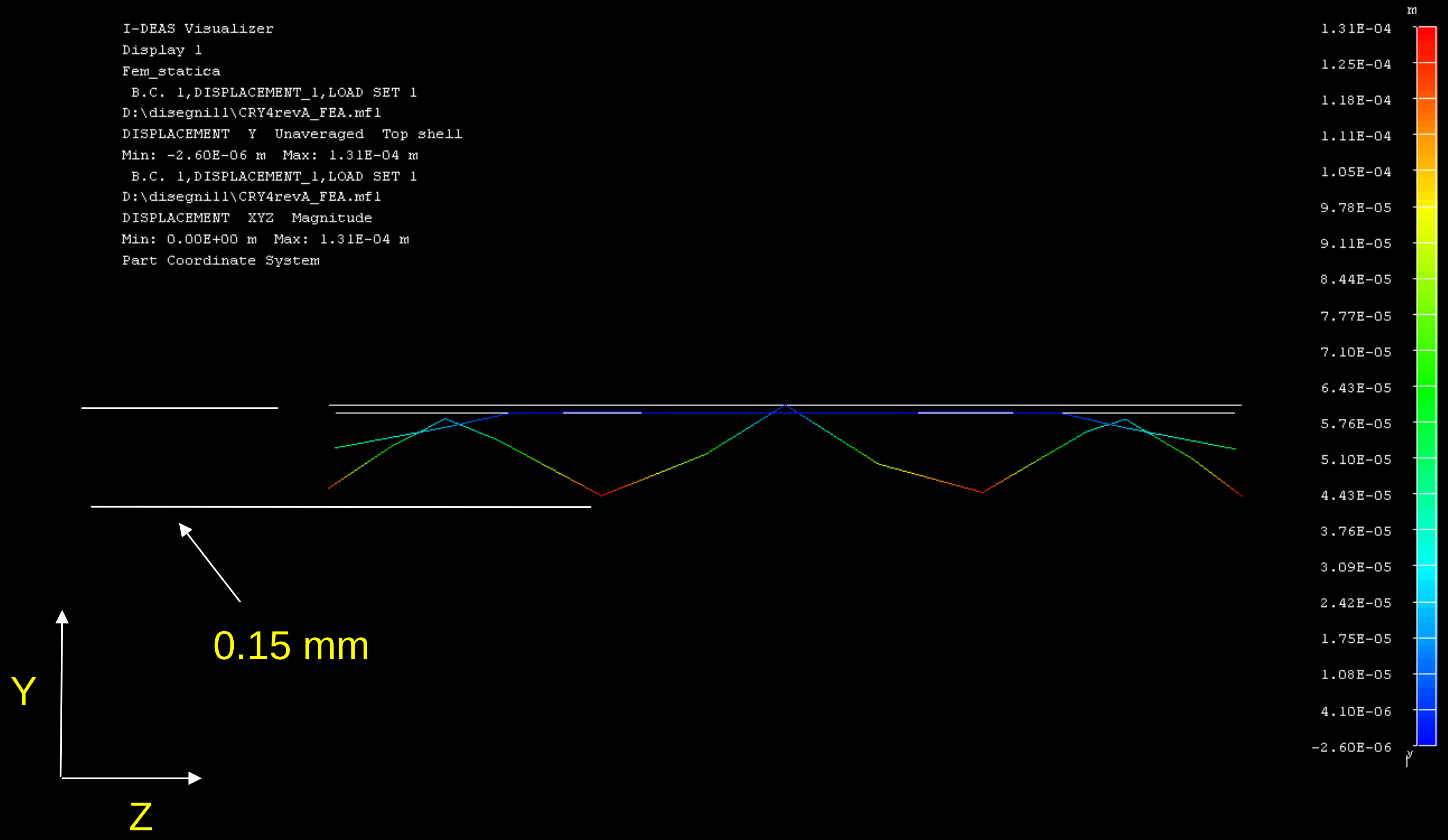
Displacements A/2=3750



Displacements A/2=4000



Displacements - 3 support points



FEM Results:

	Max displacements
A/2 = 3500 mm	0.19 mm
A/2 = 3750 mm	0.25 mm
A/2 = 4000 mm	0.33 mm
Three points (A/2=3500)	0.13 mm

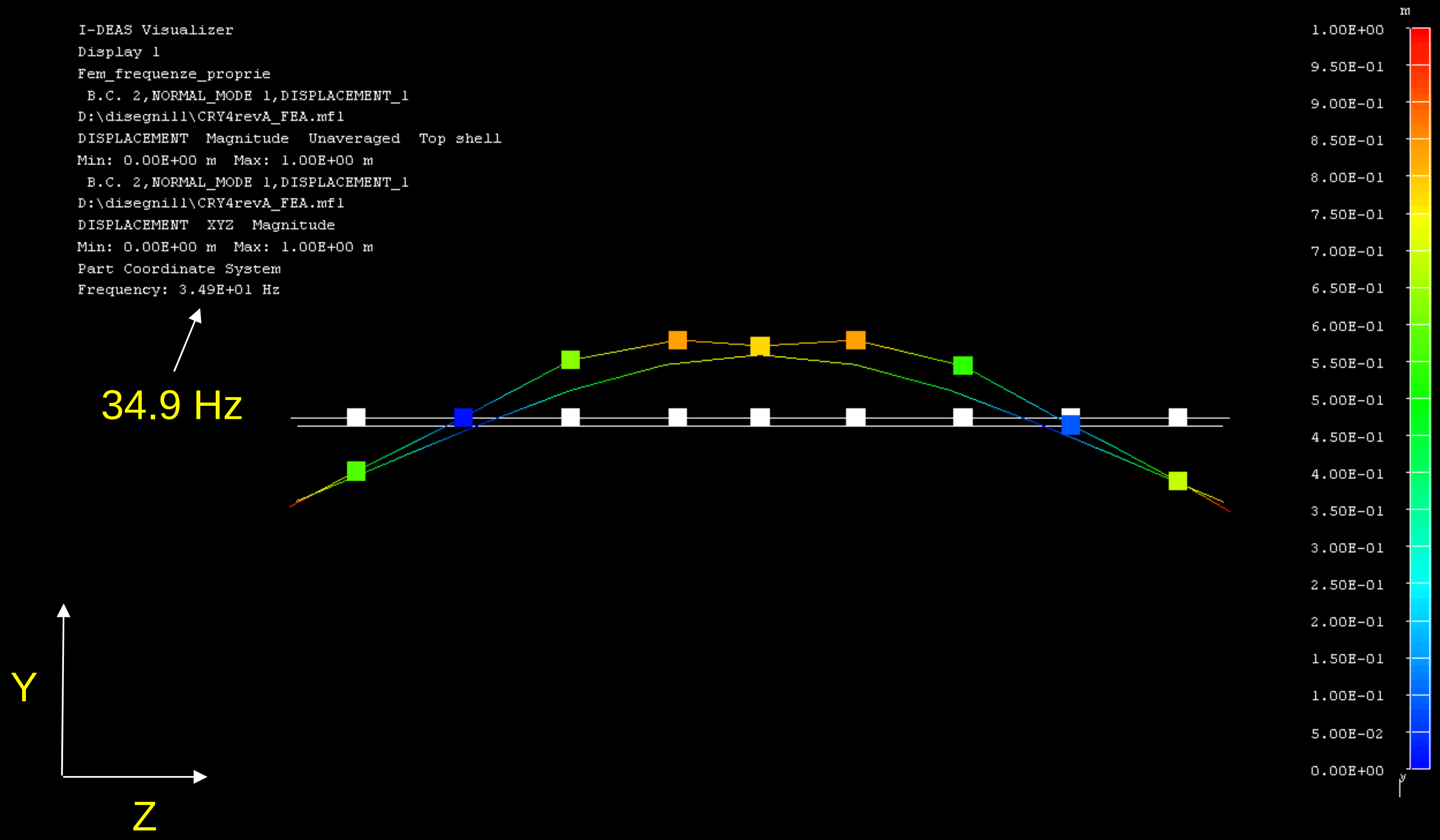
- The solution with three supports introduce several mechanical construction complication for a minimal gain.

Evaluation of normal mode of vibration

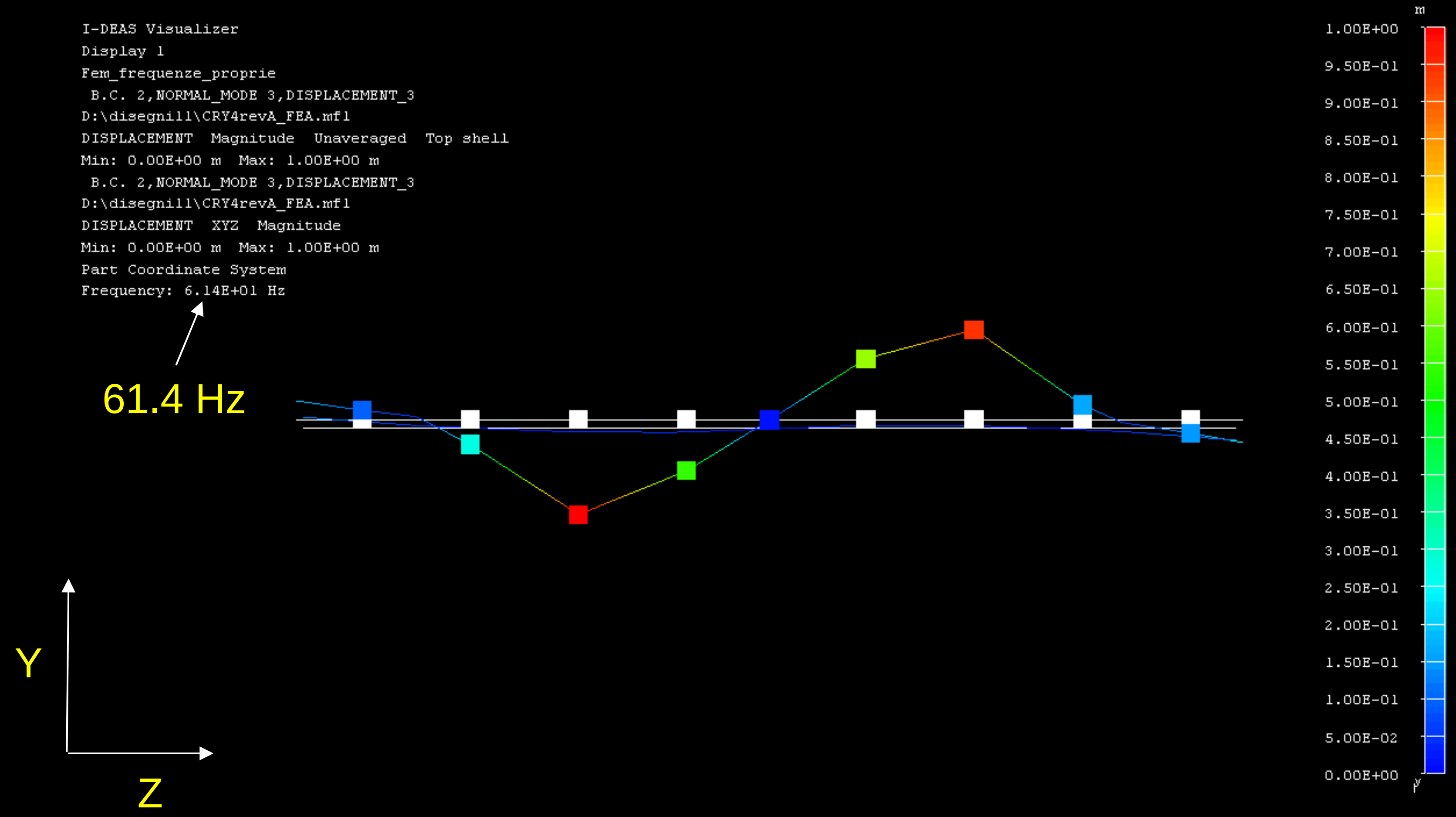
- We used the FE model to evaluate the normal modes in the case we have two support points (A/2=3500) and three support points.

- In the FE model we have replaced the concentrate forces in the HeGRP nodes with lumped masses.

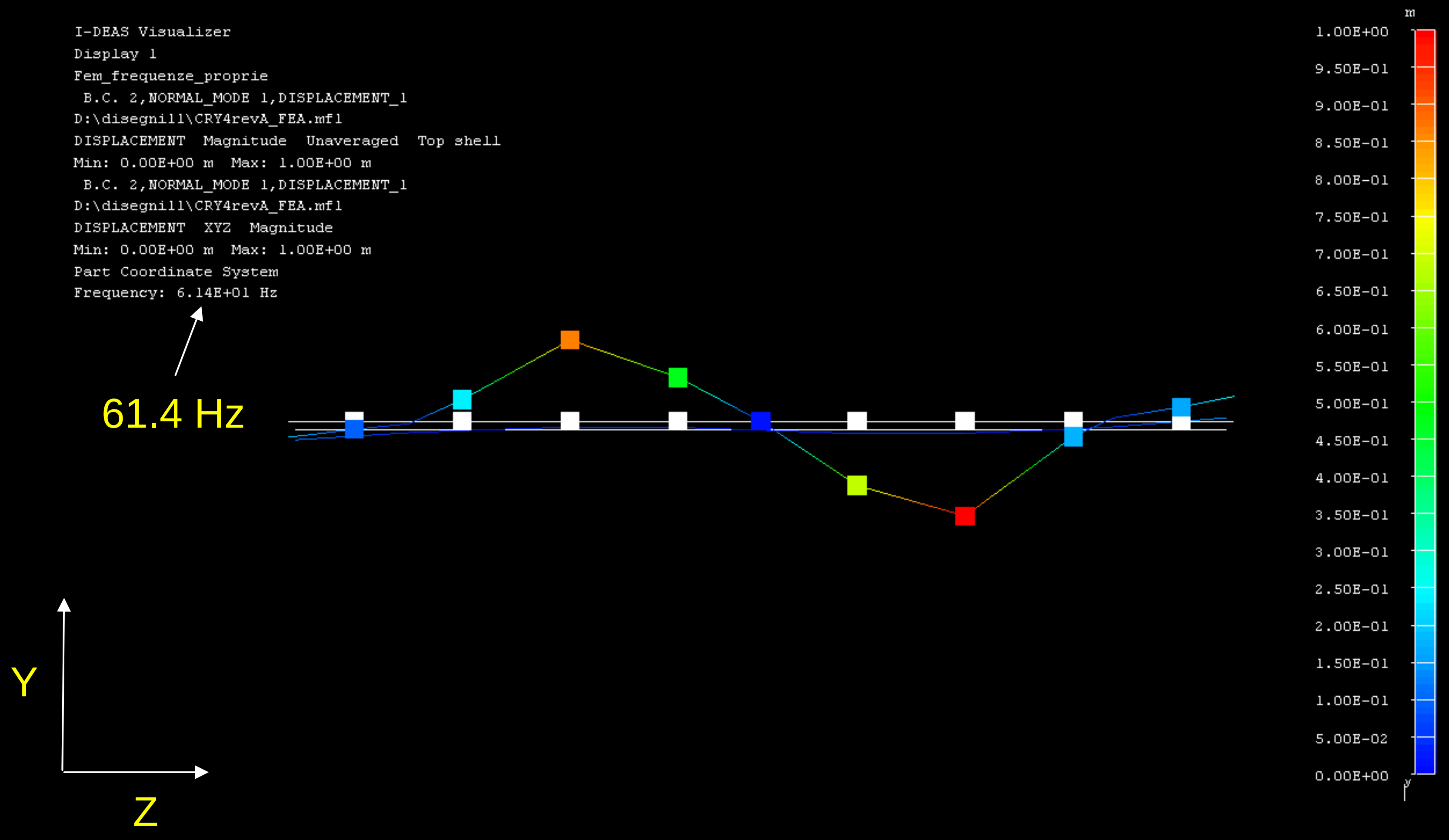
Normal Mode -1 (Y-Z plane) two support points



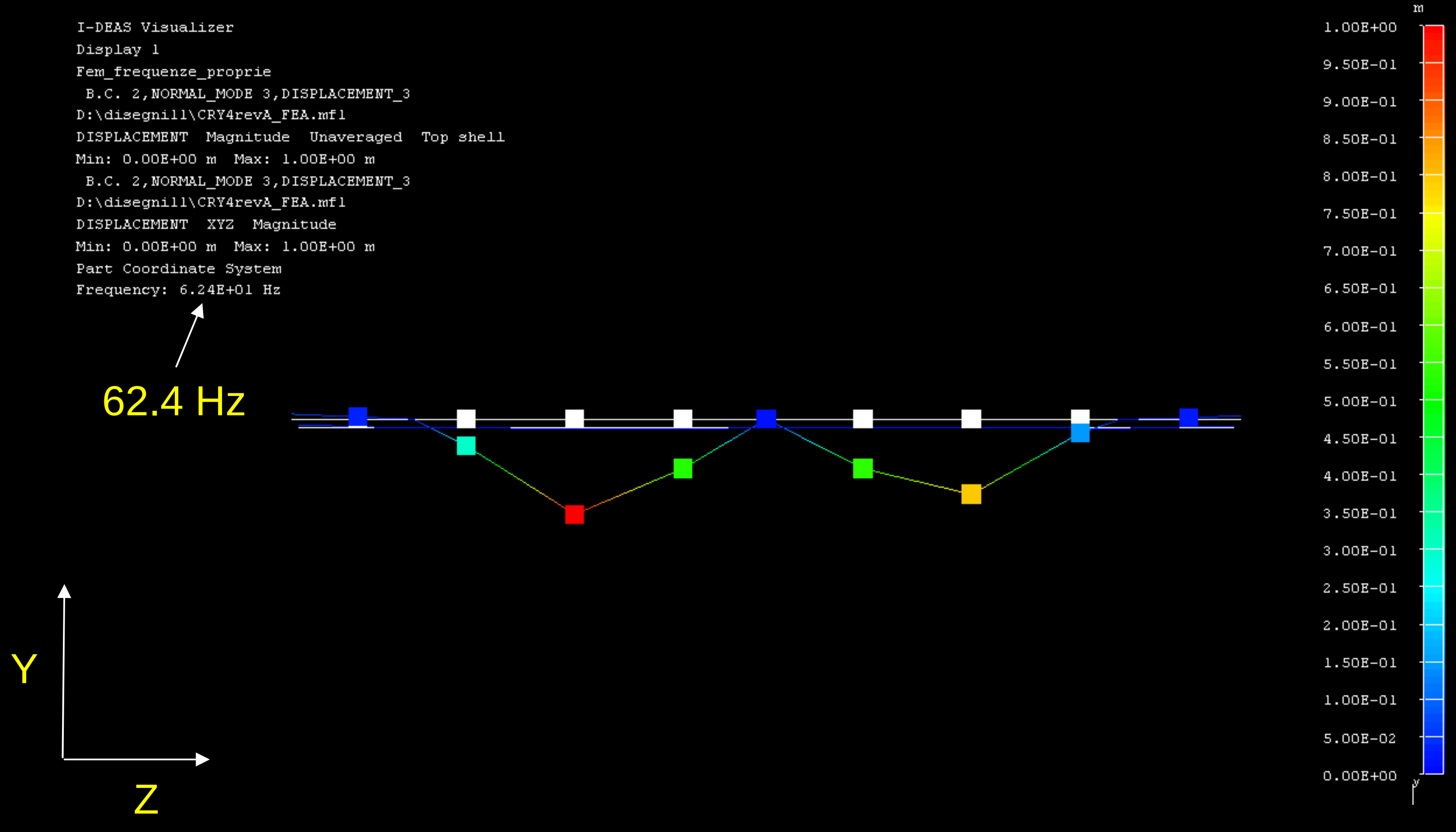
Normal Mode -3 (Y-Z plane) two support points



Normal Mode -1 (Y-Z plane) three support points



Normal Mode -3 (Y-Z plane) three support points



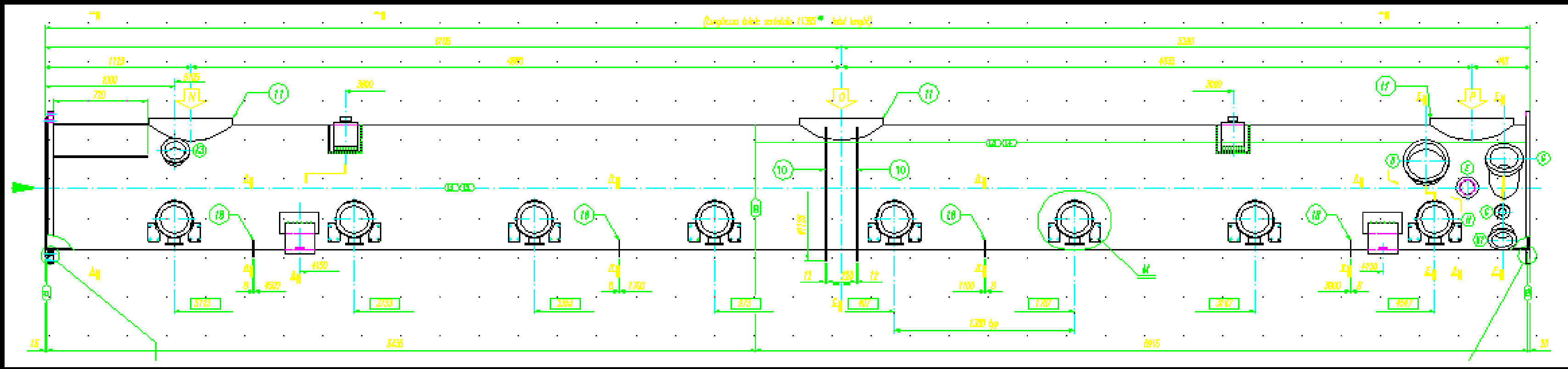
Normal Frequencies

Two supports			Three supports		
1	34.9 Hz	(Y-Z plane)	1	61.4 Hz	(Y-Z plane)
2	57.2 Hz	(X-Z plane)	2	62.3 Hz	(X-Z plane)
3	61.4 Hz	(Y-Z plane)	3	62.4 Hz	(Y-Z plane)
4	61.8 Hz	(X-Z plane)	4	62.5 Hz	(X-Z plane)
5	65.0 Hz	(Y-Z plane)	5	70.2 Hz	(Y-Z plane)
6	71.6 Hz	(X-Z plane)	6	75.4 Hz	(X-Z plane)
7	86.6 Hz	(Y-Z plane)	7	86.6 Hz	(Y-Z plane)
8	92.2 Hz	(X-Z plane)	8	98.0 Hz	(X-Z plane)
9	92.5 Hz	(Y-Z plane)	9	124 Hz	(Y-Z plane)
10	98.0 Hz	(X-Z plane)	10	134 Hz	(X-Z plane)

Checks of ASME code compliance of Vacuum Vessel design

- ASME Code Sect. VIII division 1.
- Reference drawing: Cry-3 module (released for prototype fabrication).
- Verifications done:
  - Max allowable pressure
  - Minimum thickness required for Vessel
  - Nozzle thickness check
  - Calculation of the opening reinforcing area

CRY-3 Vacuum Vessel design:



Material data:

(H II DIN 17155 corresponding SA516 gr. 60)

$Ys := 32 \cdot 10^{3} \cdot psi$	$Ys = 220.632 \times 10^{6}\, Pa$
$UTS := 60 \cdot 10^{3} \cdot psi$	$UTS = 413.685 \times 10^{6}\, Pa$
$E := 30 \cdot 10^{6} psi$	$E = 2.068 \times 10^{11}\, Pa$

Geometric data:

- Do = 952.6 mm Outer Diameter
- t = 9.52 mm Thickness
- L = 11385 mm Length

Results:

- Vacuum Vessel (considering the central ring as stiffener ring):
  - Maximum Pressure P_{max} = 2.46 atm (P = 1 atm)
  - Minimum Thickness T_{min} = 6.5 mm (t = 9.52 mm)

- Nozzle openings and reinforcing areas: (considering vessel extra thickness as reinforcing area)

Nozzle Type	D_i Internal Diameter [mm]	t Actual thickness [mm]	t_r Required thickness [mm]	A_d Available Area [mm^2]	A_r Required Area [mm^2]
C	64	3	0.2	235.28	208
D	290	5	0.7	983.3	942.5
E	108.2	3.05	0.3	367.26	351.65
G	213	5	0.9	920.92	880.75
H	278	5	0.8	1150	1125
K1, K3	158.3	5	0.5	590.57	514.48

Conclusion

- The FE beam model is an useful model to study the CRY-4 design.
- We can use the standard solution (two supports) to support the vacuum vessel (like in the CRY-3 design).
- To minimize the displacements the distance of these two supports from the centre must be 3500 mm:
  - the max. calculated displacements are below 0.2 mm.
    - Neglected local vessel deformations.
    - System can be realigned after the installation.
  - Three supports are not needed.
- Normal mode studies:
  - Concerns about normal modes close to 60 Hz.
  - Needed more investigations.
- Checks of ASME code compliance are almost completed.
  - Easy to repeat these calculations for other vessel design.