pfRICH top sensor plate structural simulation results – 22 Oct 2023

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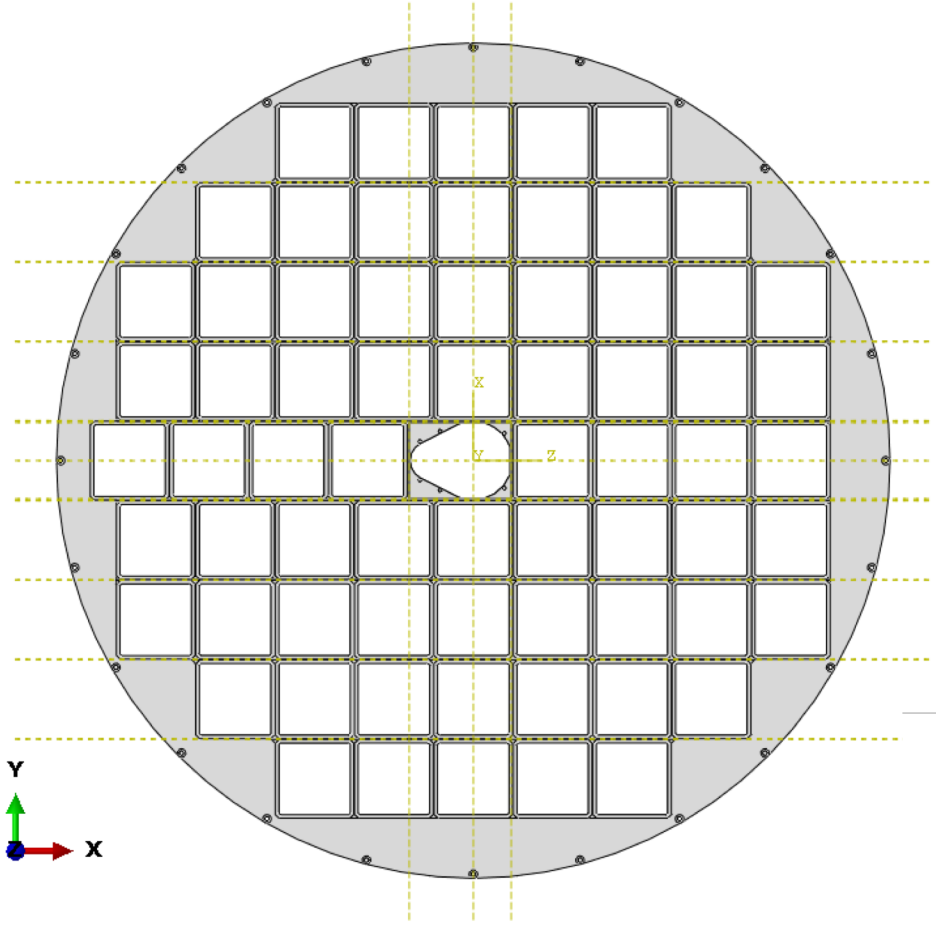
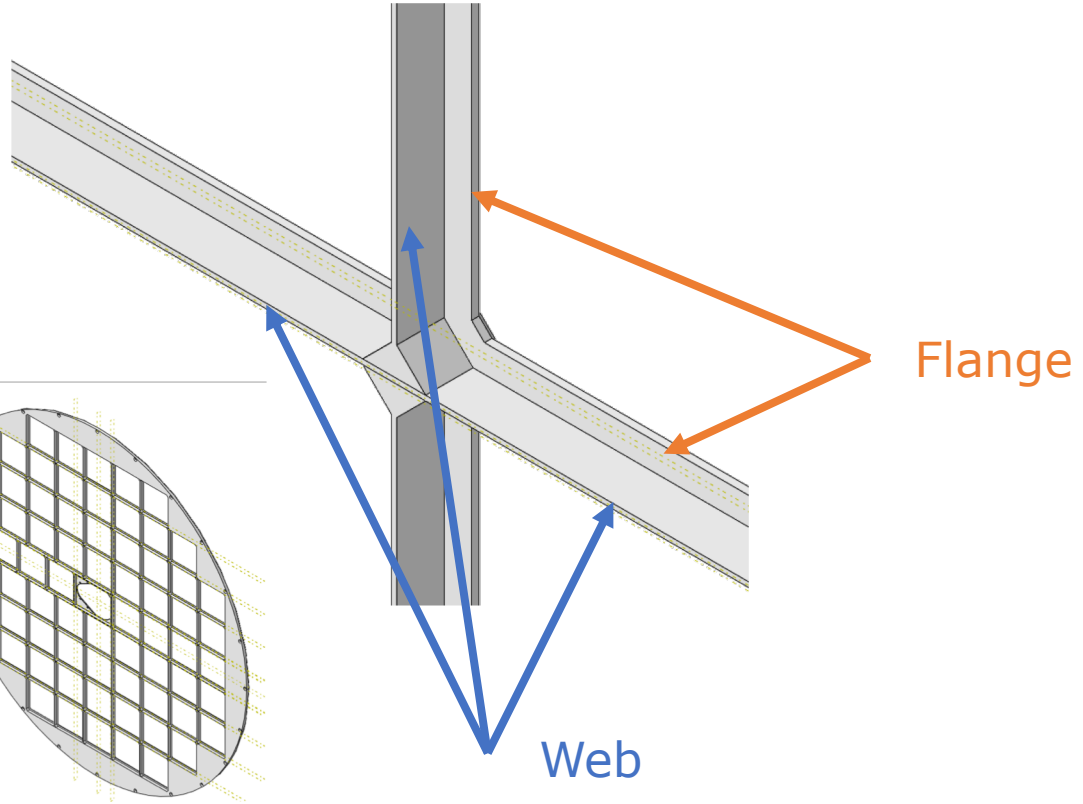
Geometry details



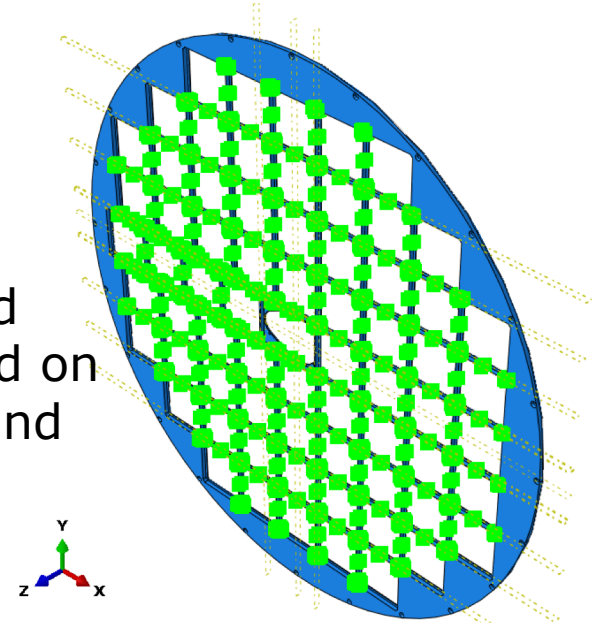
- As given in the CAD the web is 1 mm and the flange is 1.5 mm thick.
- Entire structure is envisioned to be made from CFRP laminates



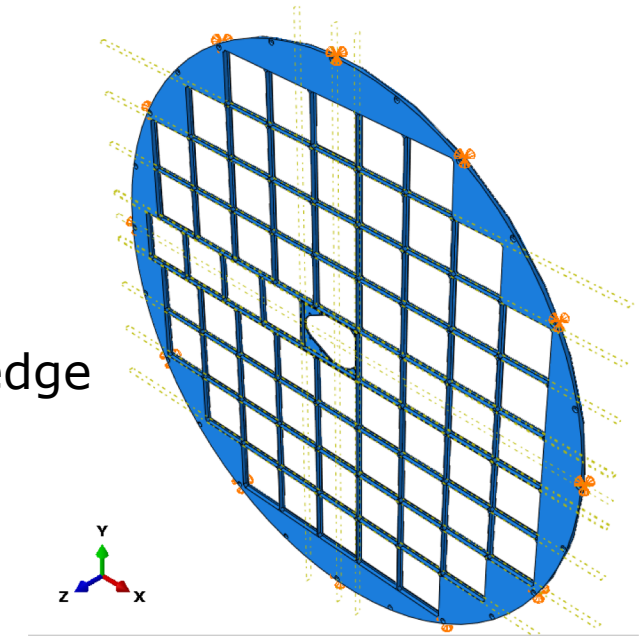
Details on material properties used and loading

- Layup used in [0/+45/-45/90/0]s which approximates the material properties
- Two iterations are tried out
  1. Standard modulus carbon fiber properties (AS4 / 8552 40 % RC)
  2. High modulus carbon fiber properties (M55j / Patz F6 39% RC)
- Nonstructural load of 97 kg is used for the 68 sensors, equally distributed on the web and flange for each condition
- BC – edge held with u1=u2=u3=0
- Simulation results are presented for both when pfRICH is held vertical (as installed) as well as horizontal (during assembly stage)

97 kg load distributed on the web and flange

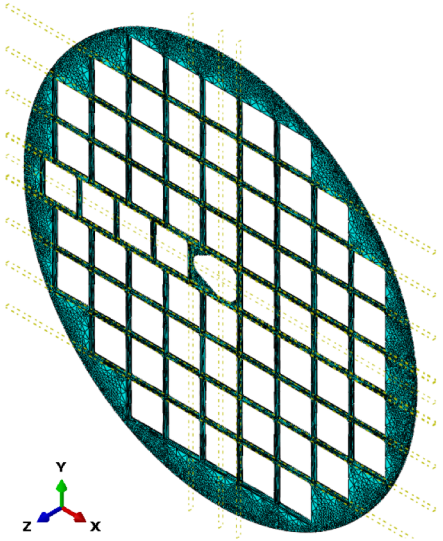


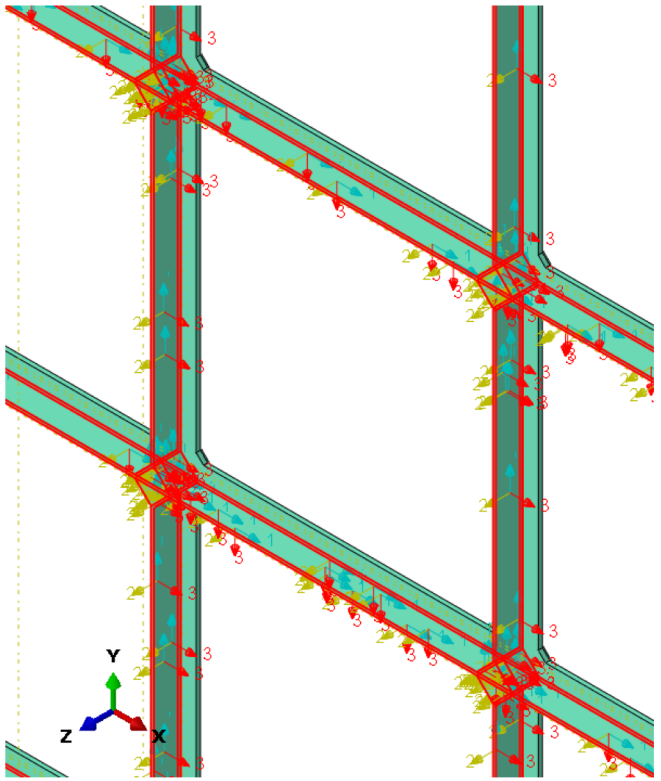
BC – edge
u1=0
u2=0
u3=0



Partition and mesh details

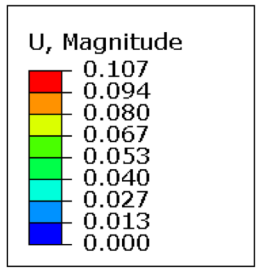
- Each rib and flange and web has independent orientation definition for closest to actual manufacturing approximation
- Base plate assumed to be a single layup and center hole cut from a single layup-
  - This is a 638 mm radius disc – at Purdue we have the capability to layup a ~1.5 m diameter disc and machine out the center section
  - Ribs, flanges and webs in the current model assume tie constraint (perfect load transfer) this approximation is okay for first order simulation results – needs to change to a kinematic coupling or constraint once the elaborate design is done.
- Tet-mesh used because of the intricate geometrical details
- Linear elements used – at least 2 elements through thickness for each cell
- 210390 linear tetrahedral elements of type C3D4



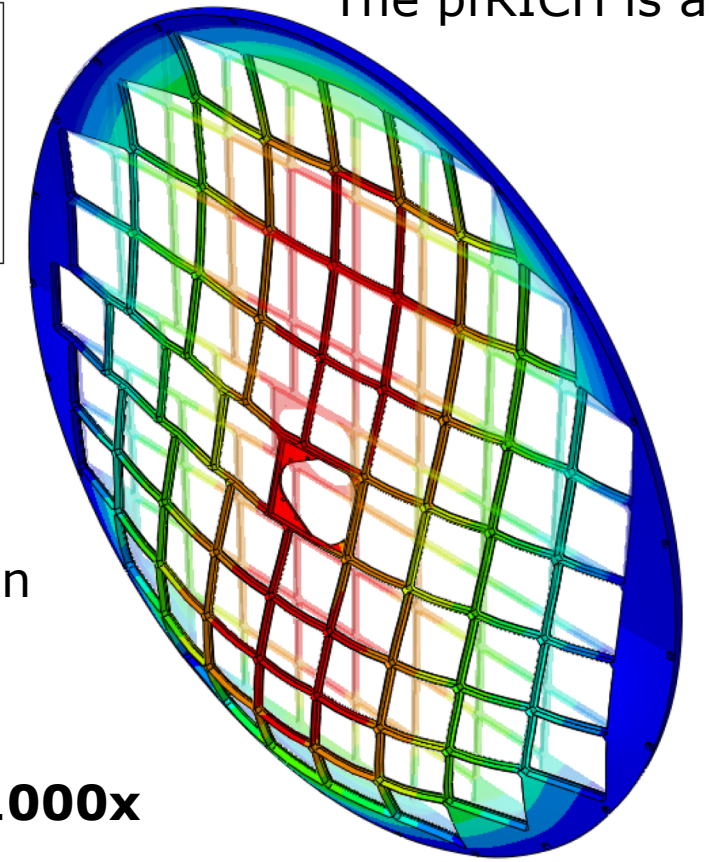


Results with standard modulus carbon fiber – AS4

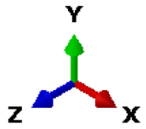
As installed configuration with web = 1mm and flange = 1.5 mm
The pfRICH is assumed to be assembled vertical as shown here.



Unit mm

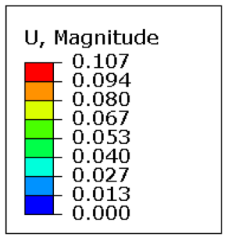


Gravity acting along –y direction

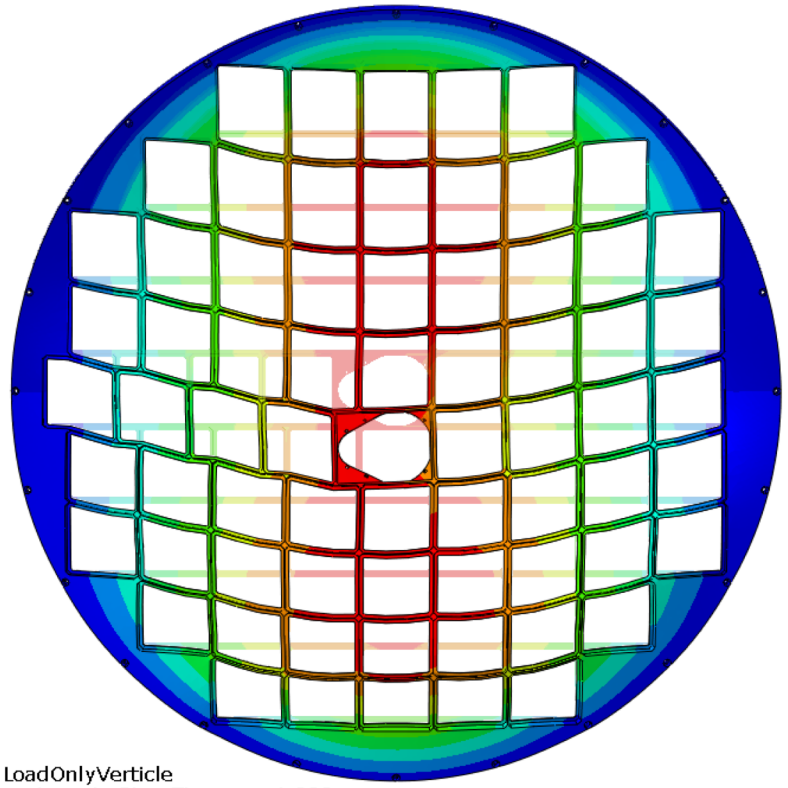


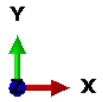
1000x

Step: LoadOnlyVerticle
Increment 1: Step Time = 1.000
Primary Var: U, Magnitude
Deformed Var: U Deformation Scale Factor: +1.000e+03



Unit mm





Step: LoadOnlyVerticle
Increment 1: Step Time = 1.000
Primary Var: U, Magnitude
Deformed Var: U Deformation Scale Factor: +1.000e+03

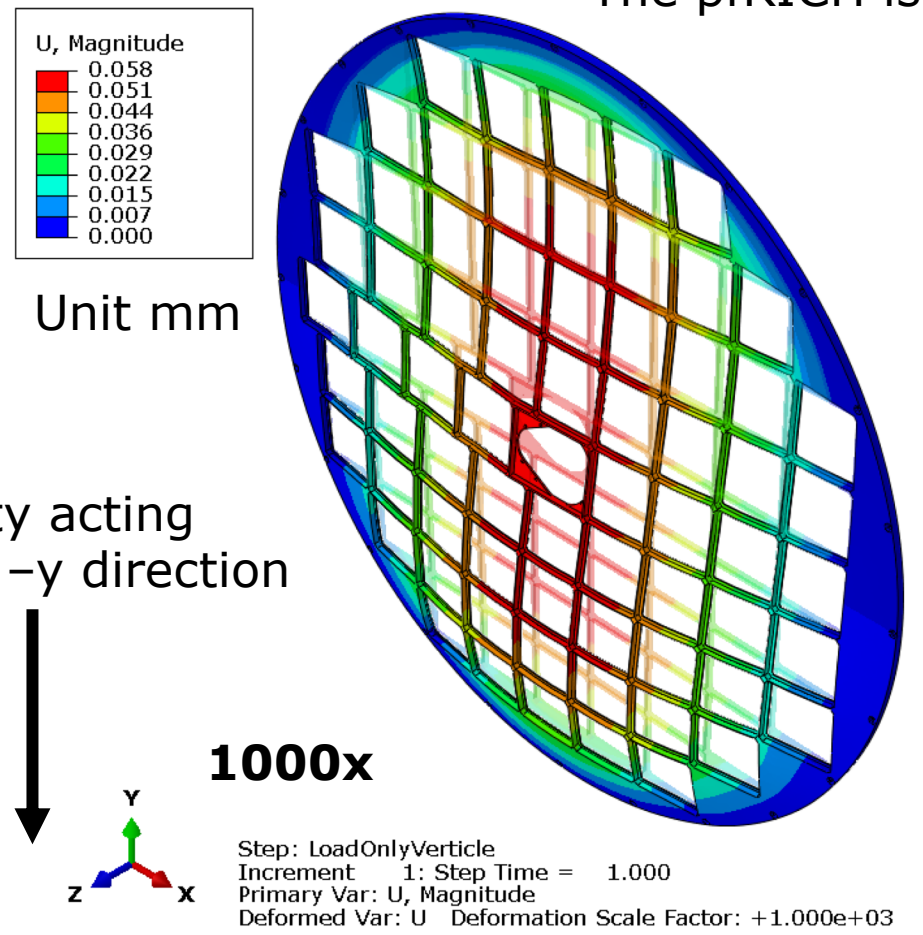
Gravity acting along –y direction

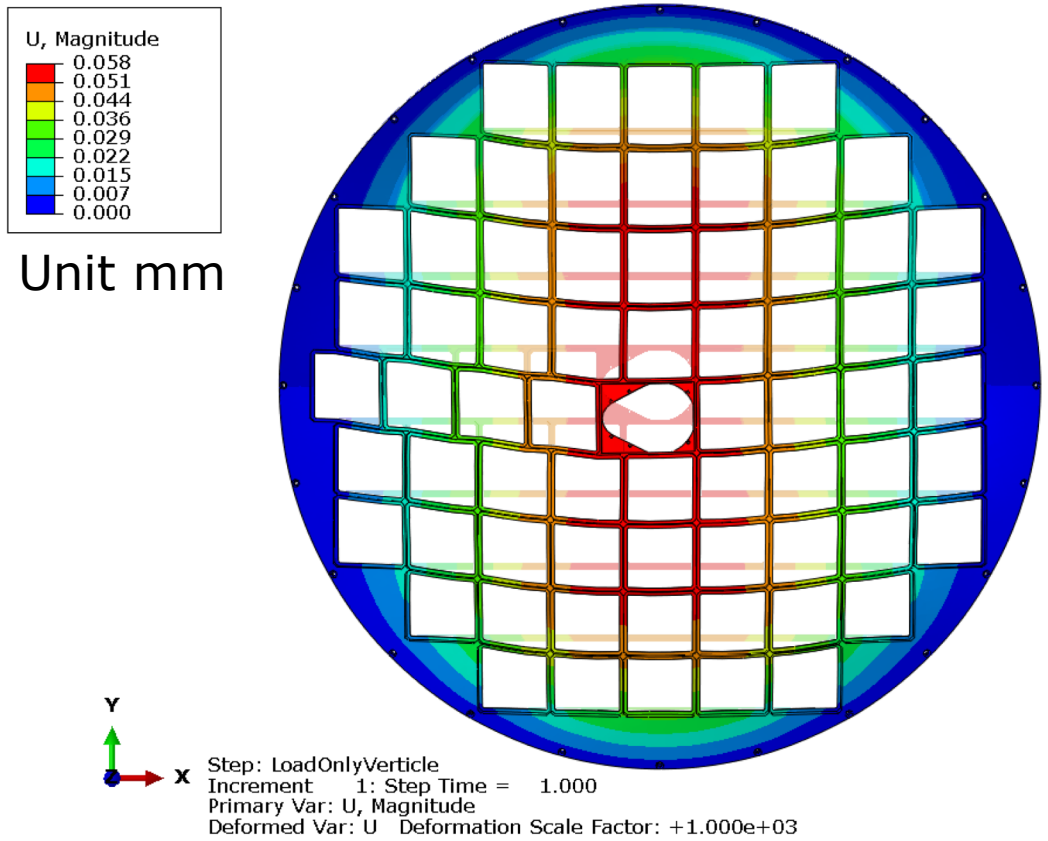
1000x the deformation shown to understand the trend in deformation

Caveat: this likely means the shape is held up by the sensor "elements" itself! An issue ?

Results with high modulus carbon fiber – M55j

As installed configuration with web = 1mm and flange = 1.5 mm
The pfRICH is assumed to be assembled vertical as shown here.





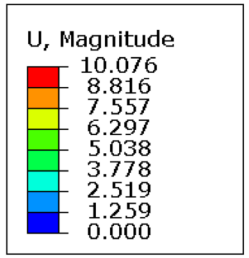
Caveat: this likely means the shape is held up by the sensor "elements" itself! An issue ?

1000x the deformation shown to understand the trend in deformation

Results with high modulus carbon fiber – M55j

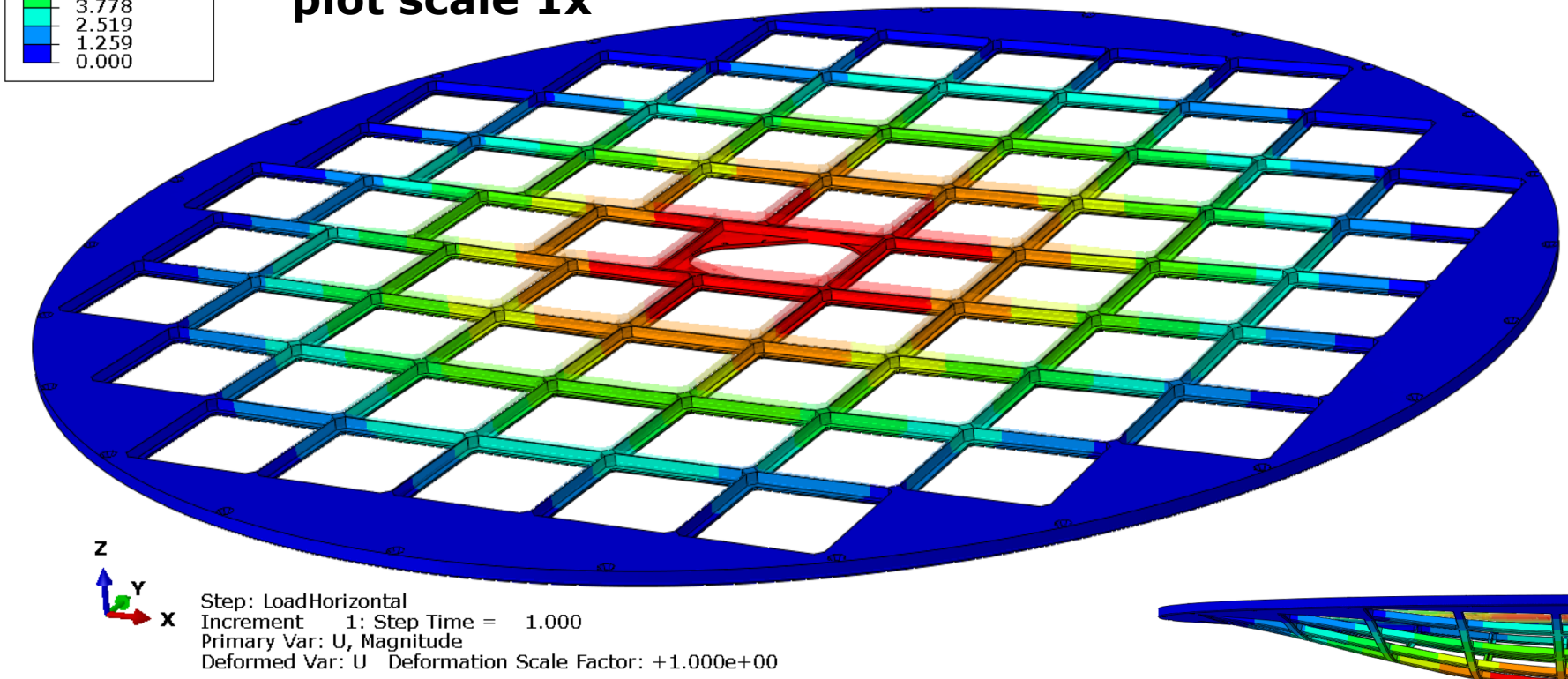
- Horizontal configuration with web = 1mm and flange = 1.5 mm. The pfRICH is assumed horizontal.
- **In this case the web and flange will break/snap**

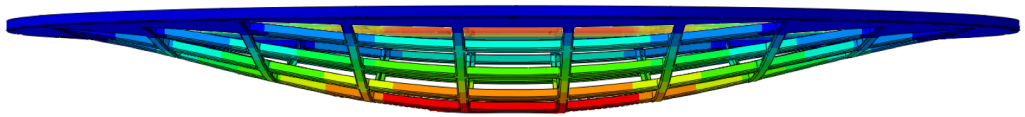
Unit mm



Deformation plot scale 1x

Gravity acting along –z direction



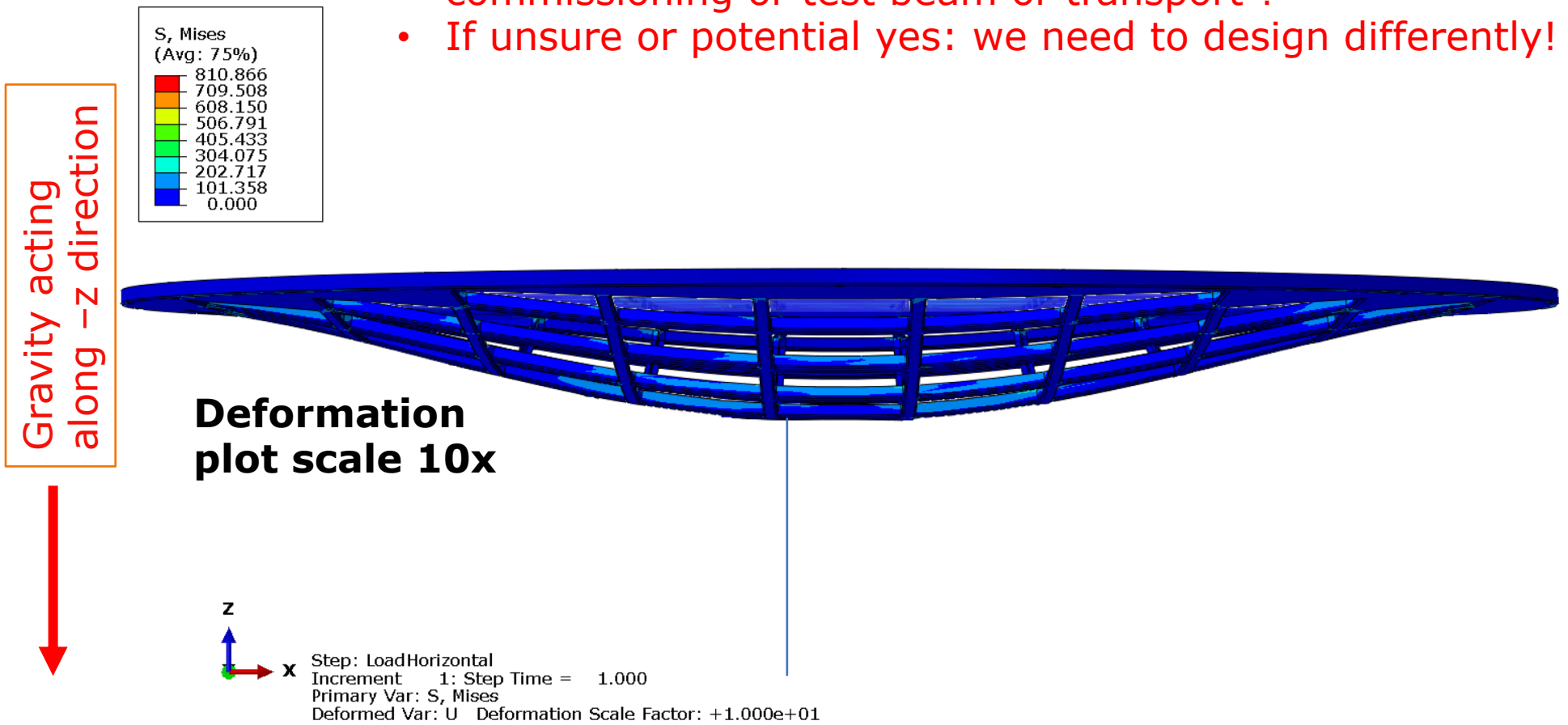


10x the deformation shown to understand the trend in deformation

Results with high modulus carbon fiber – M55j

- Horizontal configuration with web = 1mm and flange = 1.5 mm
- The pfRICH is assumed horizontal. In this case the web and flange will break/snap. Flexural strength for M55j ~ 1000 MPa – this is close to the breaking point
- Question is will pfRICH see this configuration of loading during commissioning or test beam or transport ?
- If unsure or potential yes: we need to design differently!

Unit mm



Next steps

1. Horizontal orientation is to weak a structure to support weight, vertical is ok-ish but pressure on sensor plates an issue ?
   - Horizontal configuration of loading during commissioning or test beam or transport ? If unsure or potential yes: we need to design differently
2. Creating CADs and FE models with web and flange thicknesses increased, ongoing:
   - Iterations on-going are as follows –
     - Web thickness = 2mm; flange = 1.5mm
     - Web thickness = 3.5mm; flange = 3 / 1.5mm ?!
3. Multiple option to stiffen the structure, e.g. more complicated ply layup – studies ongoing!
4. Emcal “wants” temps stable to 0.2C, no heating allowed! Room temp is ok ?! Light yield is best.

Caveats:

1. This simulation assumes perfect bonding between the vertical and horizontal rib structure. This is not true in reality – iterative FE model studies to understand effect of kinematic coupling on this will also be done simultaneously
2. Thermal simulation for 350 W and 500 W total heat from 68 sensor blocks being simulation with ambient temp assumed as -5 degree C and forced air convection cooling
   - Is active cooling even needed ? If really < 500 W for whole array it seems fairly low power density…might get away with dedicated paths in structure
   - Even easier if structure gets ”stiffened” up