Istituto Nazionale di Fisica Nucleare
SEZIONE DI FERRARA

[redacted]

dRICH

Mechanics

Alessandro Saputi – 10 May 2023

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- INFN-FE Mechanical Engineering Group
- dRICH Concept Design

Mechanical Engineering Group (INFN-Ferrara Departement & UNIFE)

The ME Group works in close collaboration with researchers, from the early concept of a detector/device to its construction.
The group includes a design office and a mechanical workshop facility with state-of-the-art equipment.
The design office performs mechanical design, advanced calculations, analyses and numerical simulations using computer-aided design (CAD) and computer-aided engineering (CAE) software.
The mechanical workshop core competencies are conventional and high-precision computer numerical control (CNC) machining, sheet metal forming, welding engineering, micrometric 3D metrology and additive manufacturing.

<u>Team:</u>
Federico Evangelisti, Michele Melchiorri: mechanical design
Stefano Squerzanti: mechanical design, CMM, AM
Michele Cavallina: mechanical workshop
Alessandro Saputi: head of ME Group

Mechanical Engineering Group: internal workshop facilities

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AM Lab

Design Office

Mechanical workshop

Store

Metrology Lab

Welding Lab & Carpenter shop

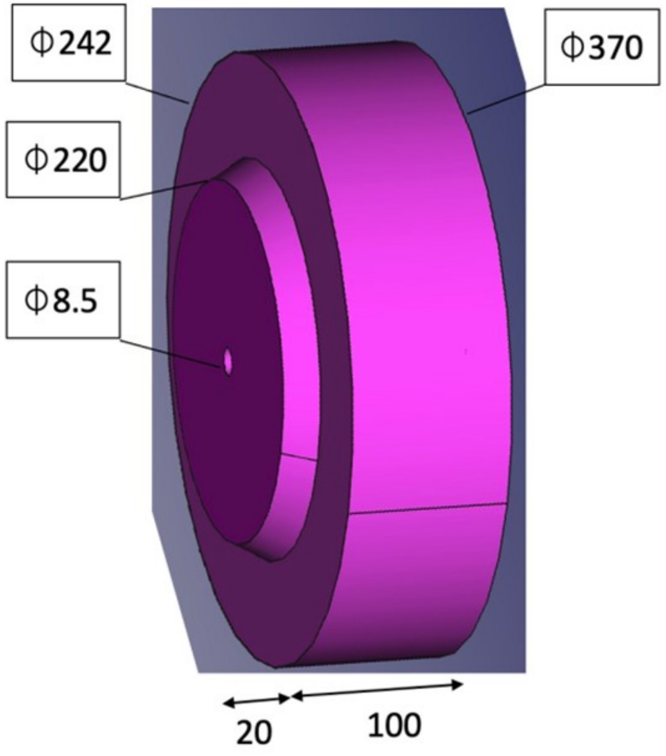
Carpentry workshop

dRICH: (preliminary) gas enclosure requirements

- The major functions of the gas enclosure are to provide containment for the dRICH gas radiator and to act as the stable frame for the optical components (the mirrors and aerogel).
- It must be light tight.
- To ensure the stability of the structure under the influence of the magnetic field.
- The enclosure must withstand a differential pressure (±3 mbar??) without compromising the mirror alignment.
- The minimum amount of material must be placed within the EPIC experiment acceptance limits.

- Envelope overall sizes: Φ3670 mm x 1130 mm
- Operating pressure up to 2.5 atm abs (~ 1.5 atm – gauge pressure)
- Operating temperature of 22 °C
- Gas mixture: C2F6 or Argon

dRICH vessel



dRICH: as a pressure vessel

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Operating pressure of 2.5 atm abs (~ 1.5 atm)

↓

Design pressures exceeding 15 psig (1 atm) are generally ASME labelled and considered ASME pressure vessels

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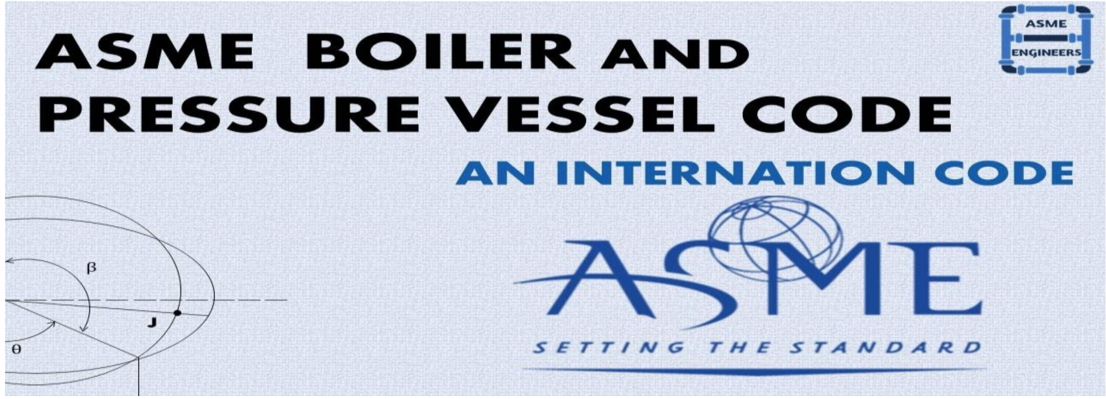
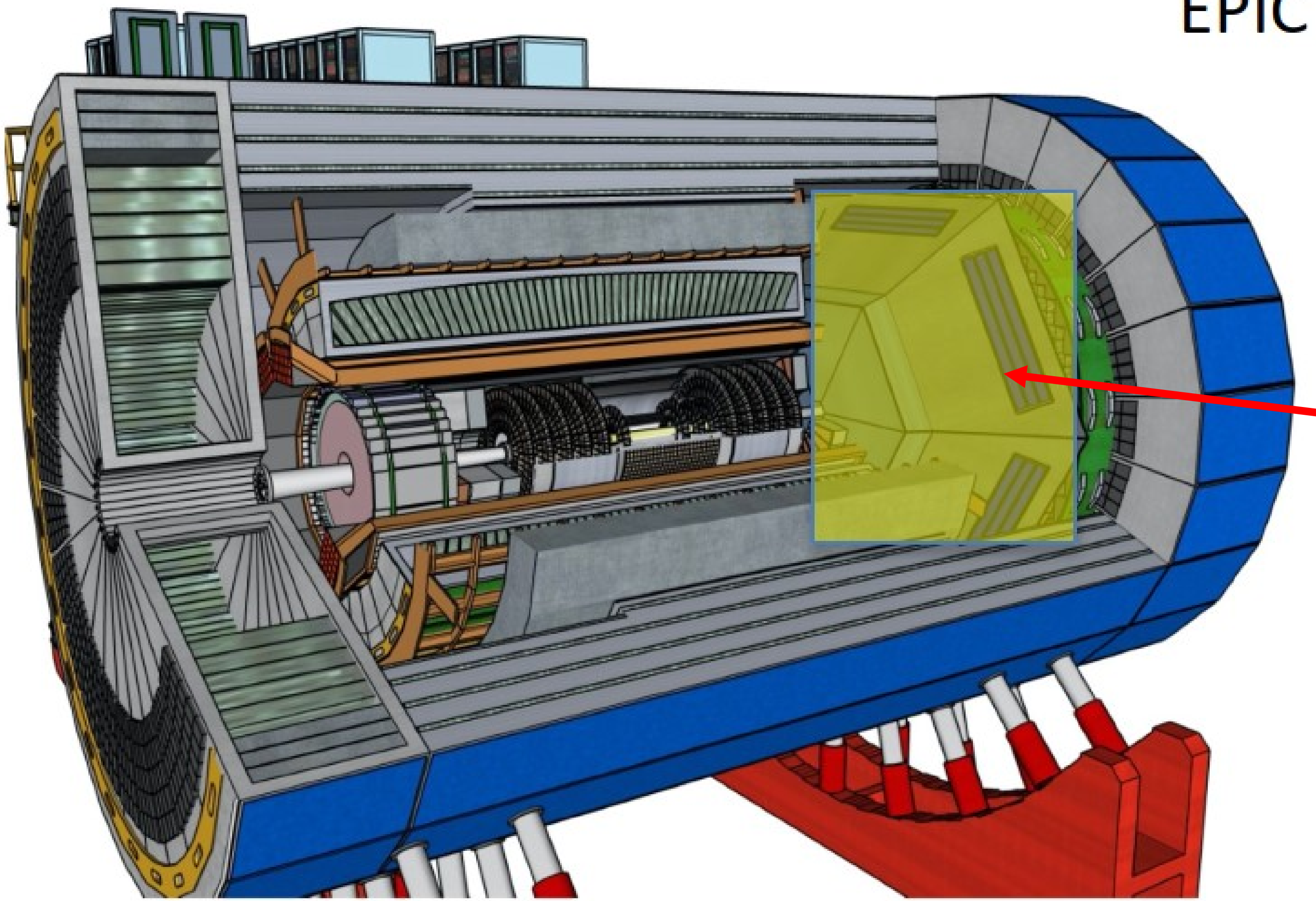
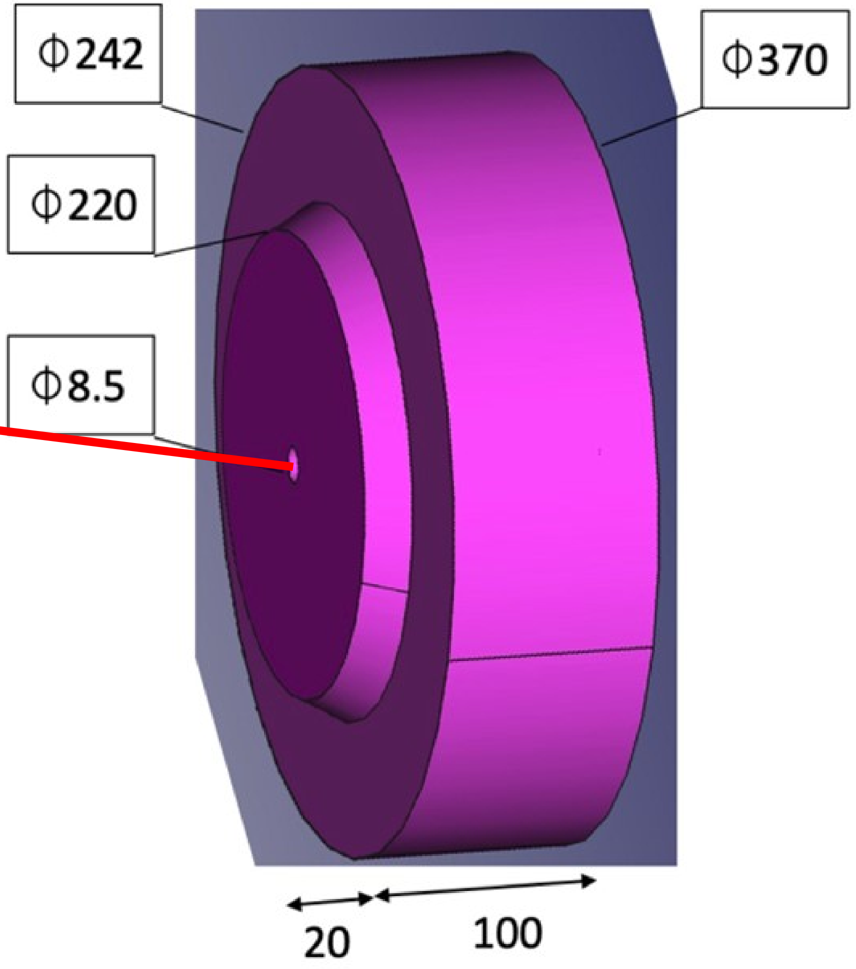


dRICH: concept design





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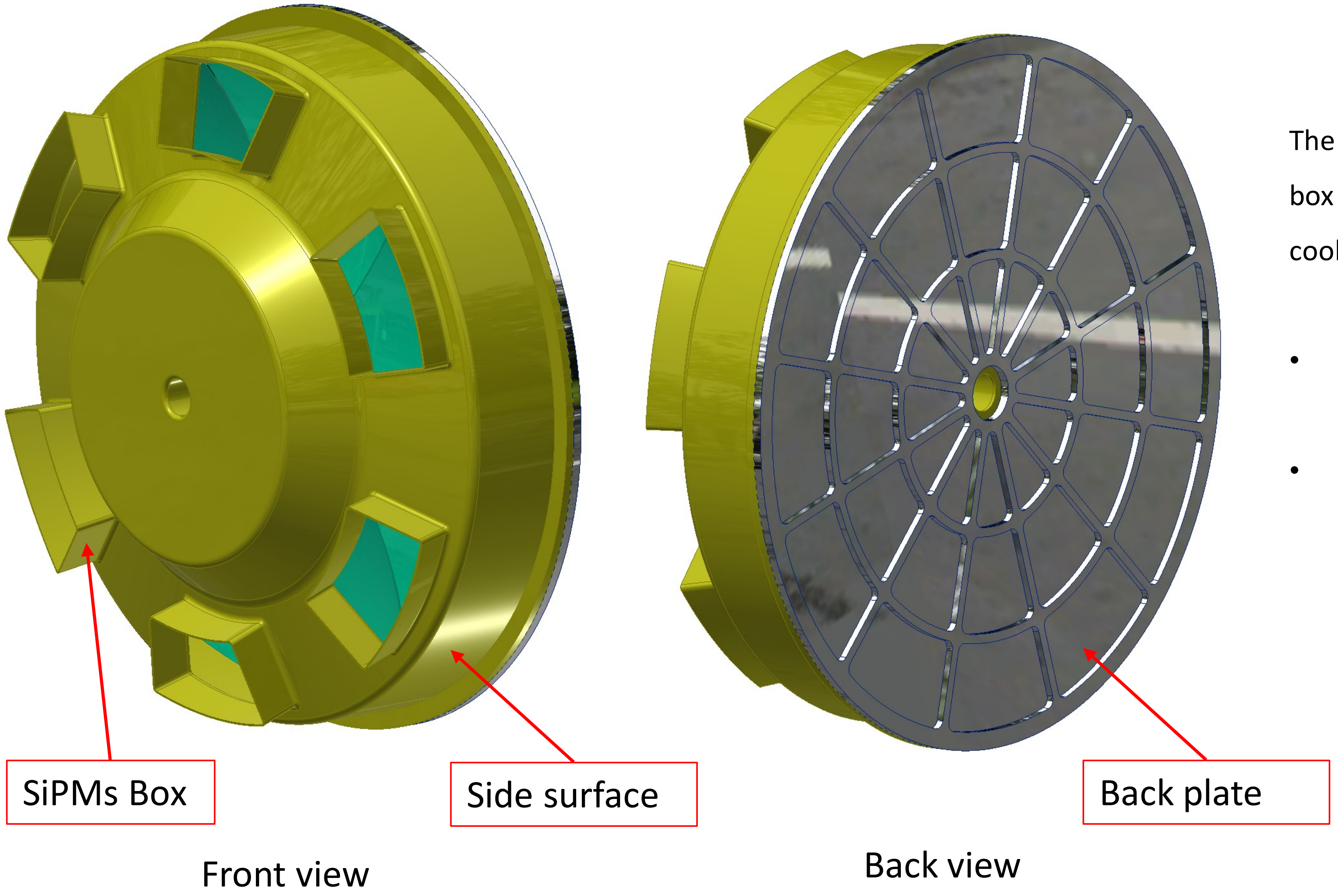


The gas enclosure is essentially a cylindrical box with six boxes that host SiPMs and cooling system.

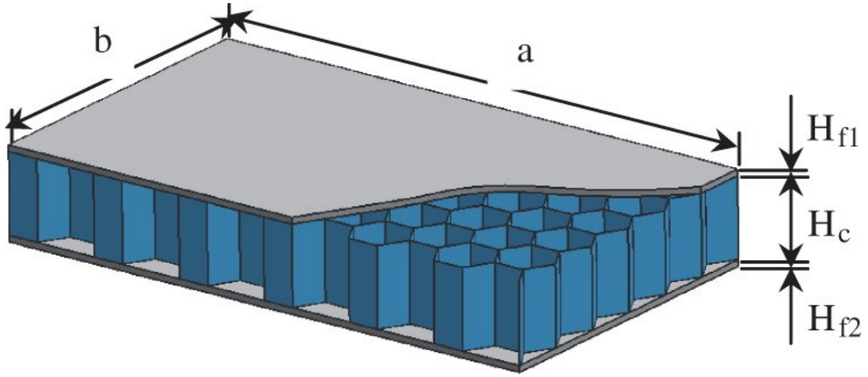
- The upstream face is closed by a plate which maintains the gas and light seal.
- The boxes are separated from gas volume by quartz windows (that allow Cherenkov photons to pass through to the SiPMs mounted behind).

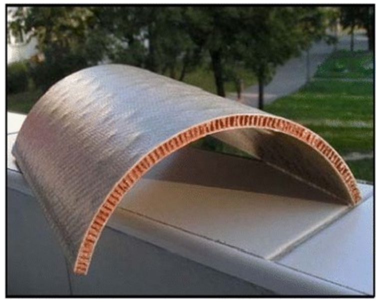
dRICH: concept design

Metal

CF laminate

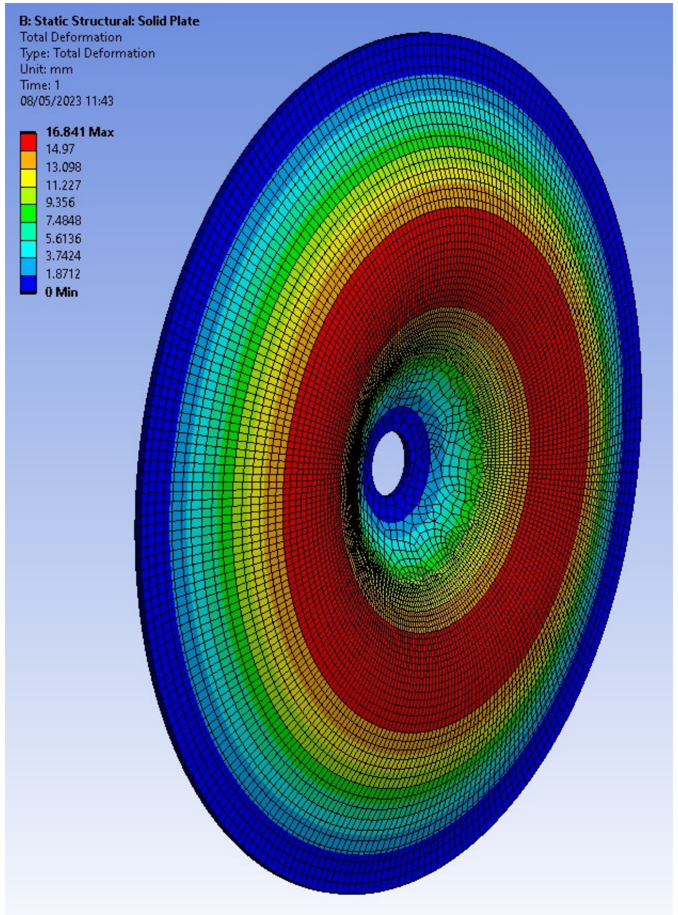
- Solid plate
- Ribbed plate



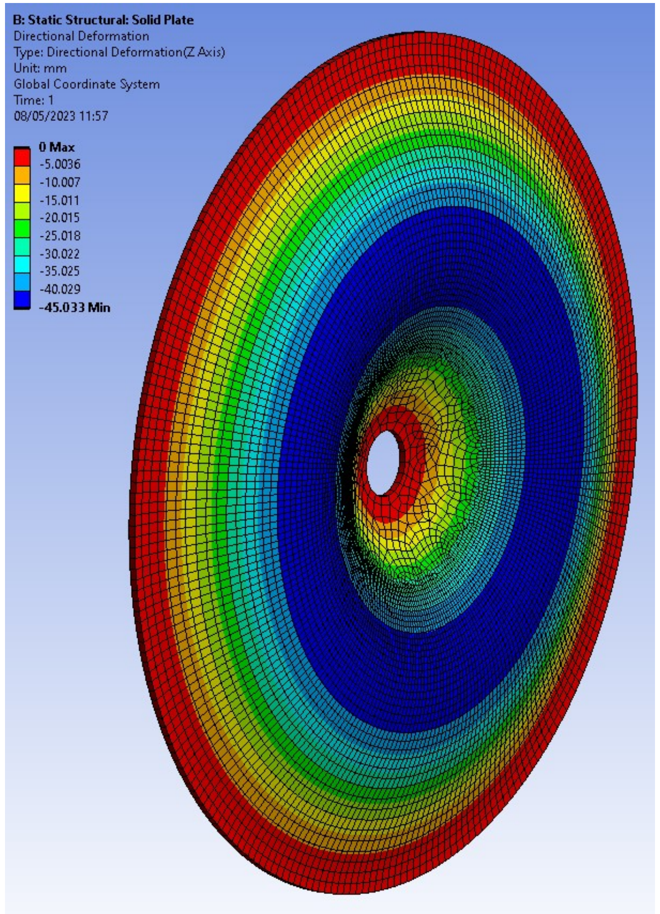


Sandwich structure

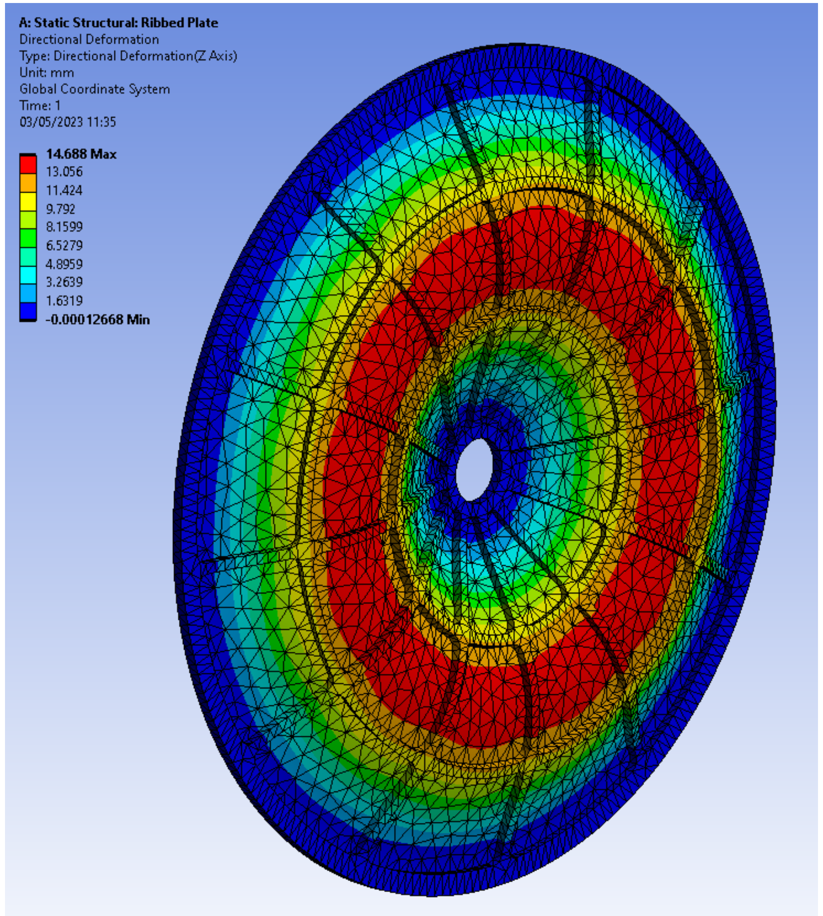
dRICH: concept design



Solid plate
Plate = 30 mm thick
Material = AISI 304



Solid plate
Plate = 30 mm thick
Material = Al



Ribbed plate
Plate = 10 mm thick
ribs = 50 mm thick
Material: AISI 304

dRICH: concept design

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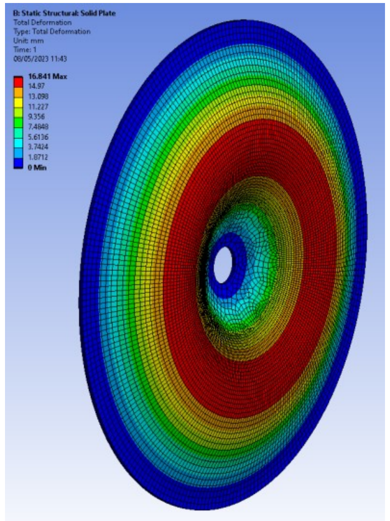
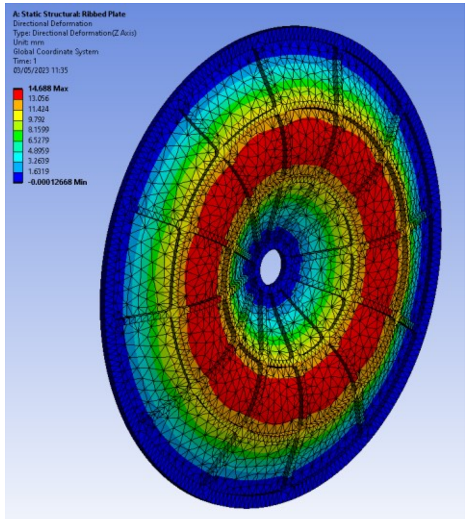


Sandwich plate
Plate = 50 mm thick

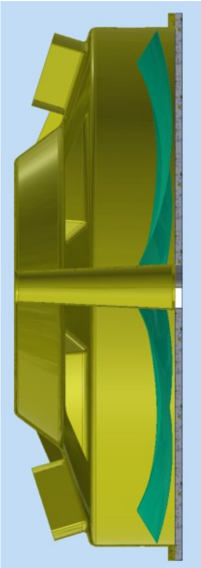


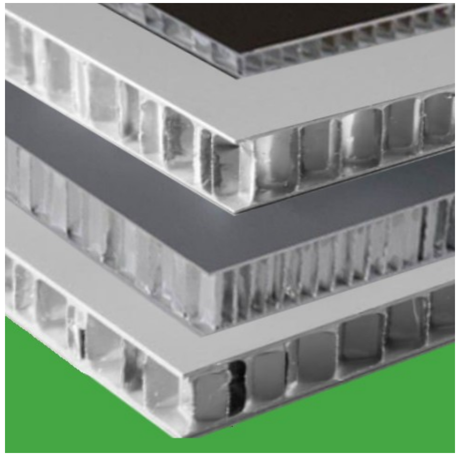
Ribbed sandwich plate
Plate = 30 mm thick
ribs = 30 mm thick

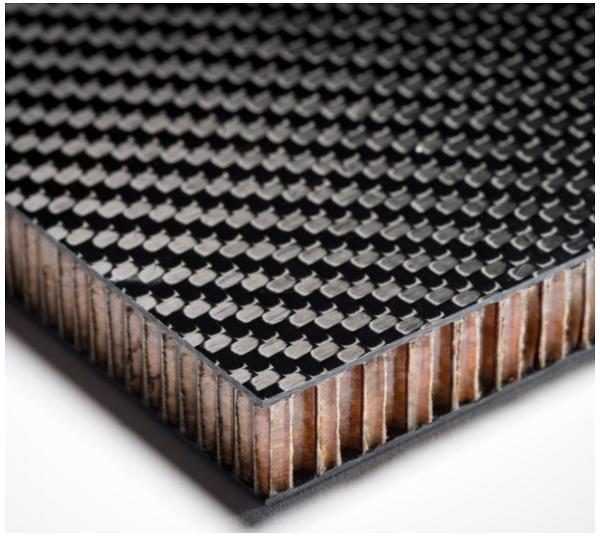
	Solid Metal Sheet	Sandwich Construction	Thicker Sandwich
	t	2t	4t
Relative Stiffness	100	700 7 times more rigid	3700 37 times more rigid!
Relative Strength	100	350 3.5 times as strong	925 9.25 times as strong!
Relative Weight	100	103 3% increase in weight	106 6% increase in weight

A striking example of how honeycomb stiffens a structure without materially increasing its weight.

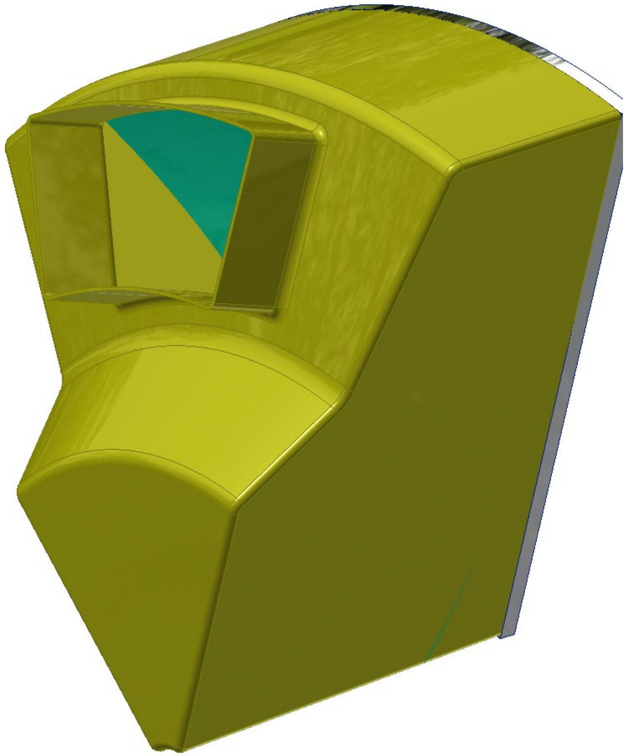
Sandwich plate
50÷120 mm thick
2 mm Al + 46÷116 mm honeycomb + 2 mm Al



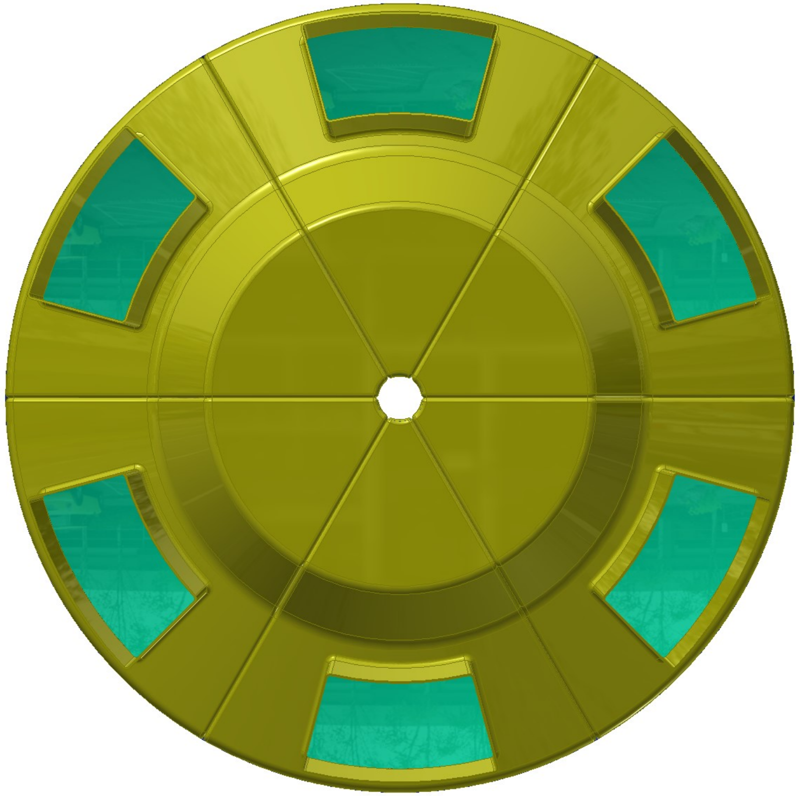




dRICH: concept design



Single Slice



Six Slices

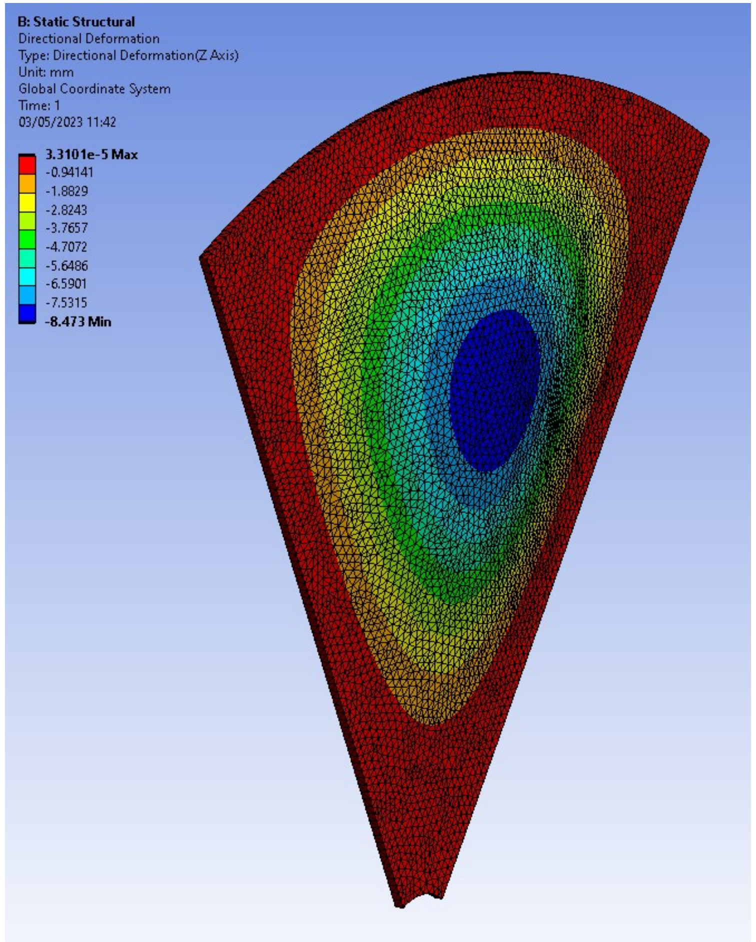
Disadvantages

- Reduction in the active area

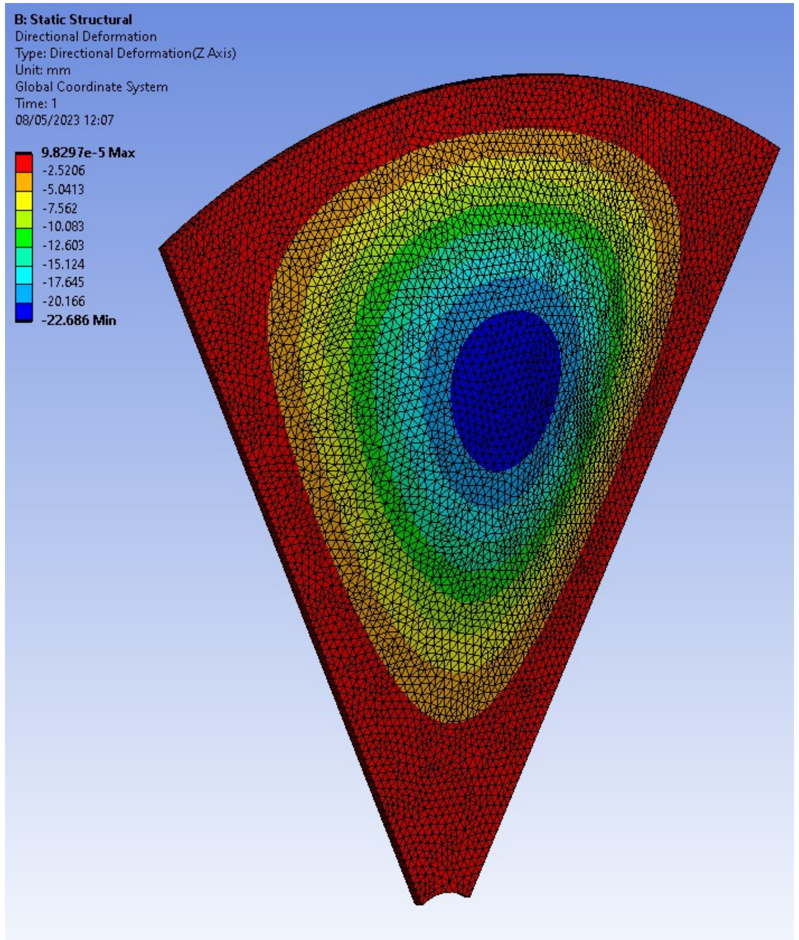
Advantages

- Lower gas volumes to be managed
- Partitioning of the gas volume
- Reduction of thickness of components
- An important advantage is that it can be "easily" built.

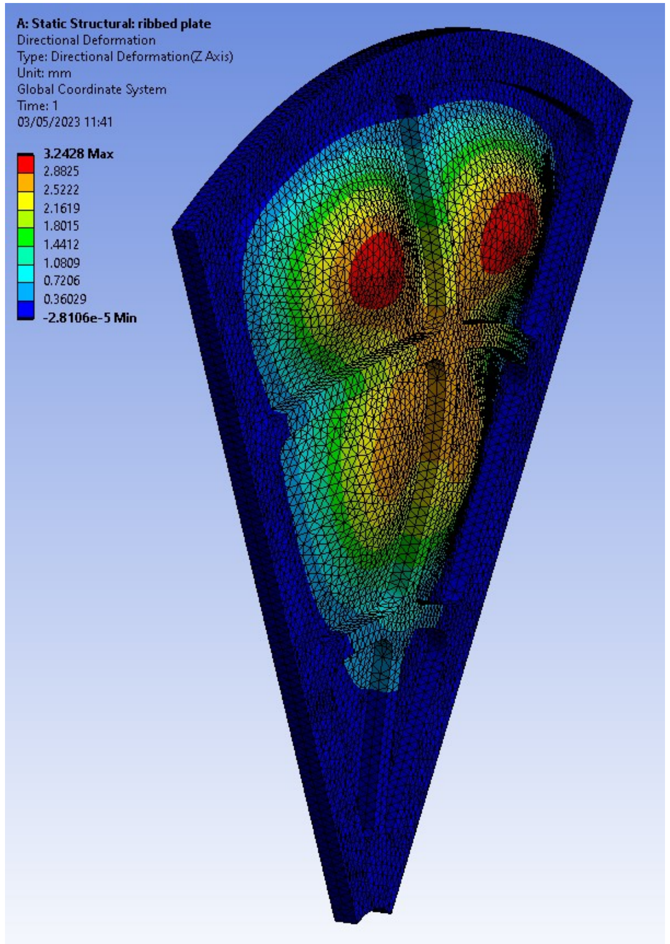
dRICH: concept design



Solid plate
Plate = 20 mm thick
Material = AISI 304

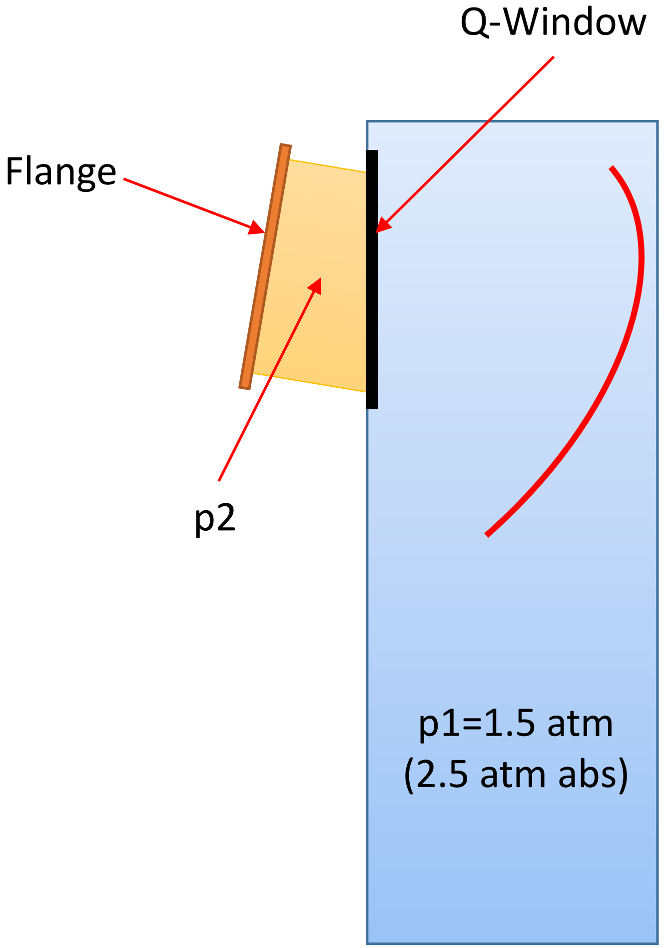


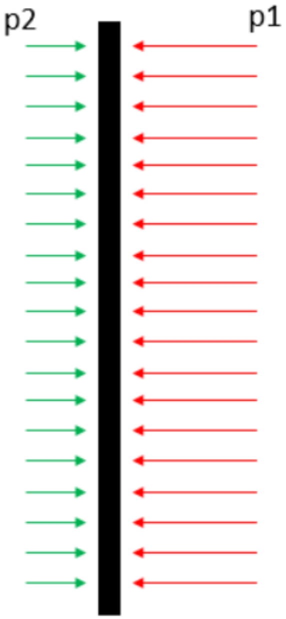
Solid plate
Plate = 20 mm thick
Material = Al

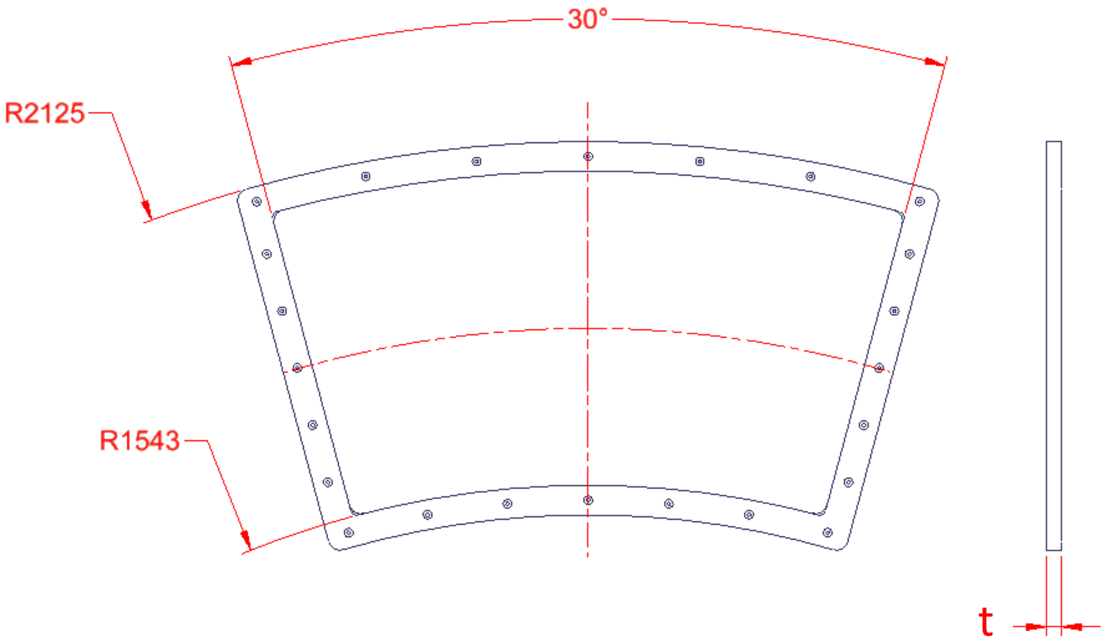


Ribbed plate
Plate = 10 mm thick
ribs = 50 mm thick
Material: AISI 304

dRICH: quartz windows



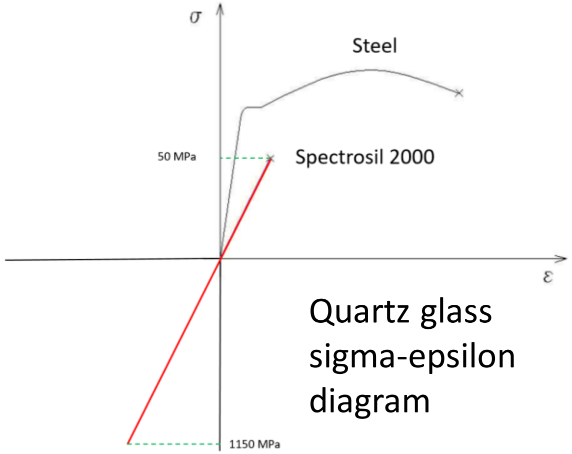




Two scenarios:

1. p2 = atm press.
2. p2 = p1 = 1.5 atm

Quartz windows: stress and strain calculation



Quartz glass sigma-epsilon diagram

Brittle material

$$S = \begin{bmatrix} \sigma_1 & 0 & 0 \\ 0 & \sigma_2 & 0 \\ 0 & 0 & \sigma_3 \end{bmatrix}$$

$$\sigma_1 \leq \sigma_{amm,t}$$

$$-\sigma_{amm,c} \leq \sigma_3$$

Galileo-Rankine strength criterion

$$\sigma_{amm}(allowable\ stress) = \frac{Strength\ of\ material}{SF\ (safety\ factor)}$$

SF (brittle material) = 2.5 ÷ 3

ASME pressure vessel code SF >= 3.5

Spectrosil 2000

Mechanical data		Suprasil®-family, Spectrosil® Infrasil® / HOQ®
Density	g/cm³	2,20
Mohs-hardness		5,5........6,5
Micro-hardness	N/mm²	8600........9800
Knoop-hardness	N/mm²	5800........6200
Modulus of elasticity (at 20°C)	N/mm²	7,0 · 10⁴
Modulus of torsion	N/mm²	3·10⁴
Poisson´s ratio		0,17
Compressive strength	N/mm²	1150
Tensile strength	N/mm²	50
Bending strength	N/mm²	67
Torsional strength	N/mm²	30
Sound velocity	m/s	5720

Brittle material

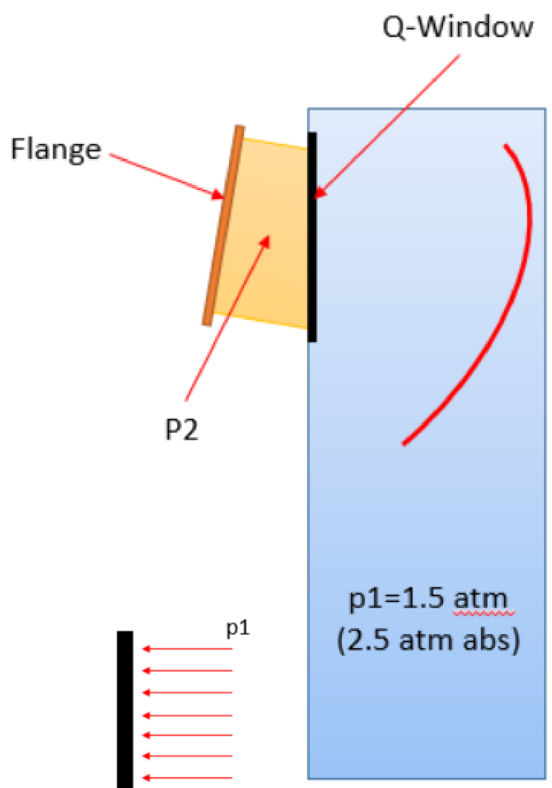
$$\sigma_{amm,c} = \frac{1150}{2} \cong 575\ {}^{N}/_{mm^2}$$

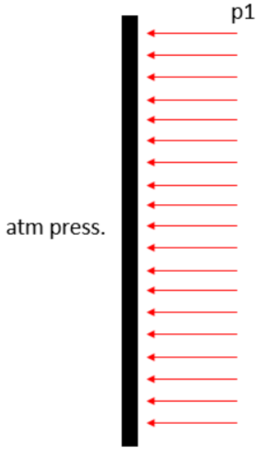
$$\sigma_{amm,c} = \frac{1150}{3.5} \cong 328\ {}^{N}/_{mm^2}$$

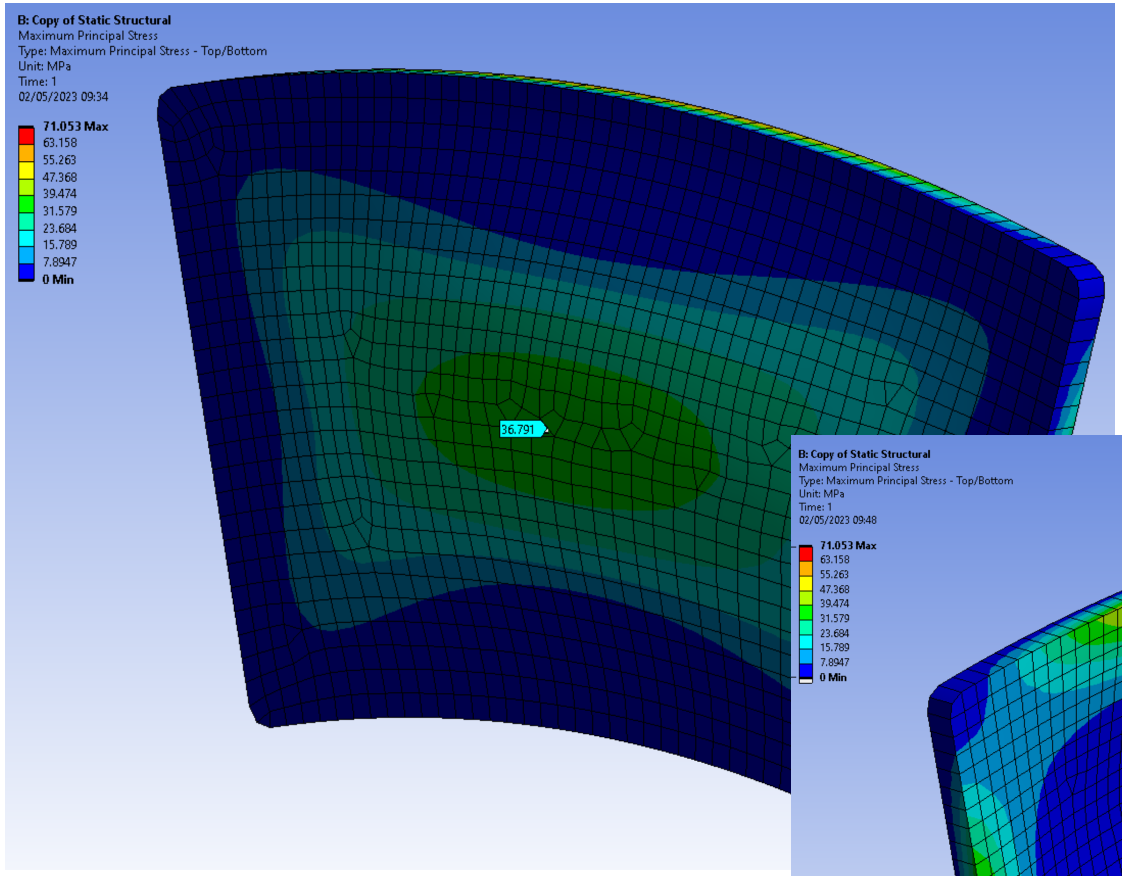
$$\sigma_{amm,t} = \frac{50}{2} \cong 25\ {}^{N}/_{mm^2}$$

$$\sigma_{amm,t} = \frac{50}{3.5} \cong 14\ {}^{N}/_{mm^2}$$

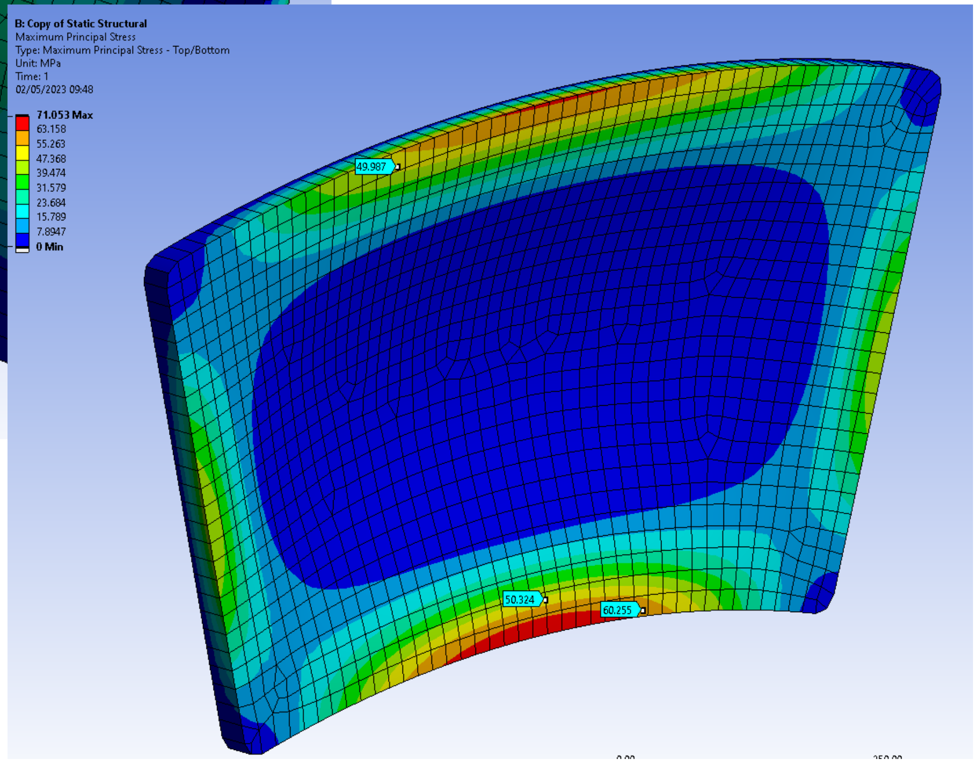
Quartz windows FEM: scenario 1





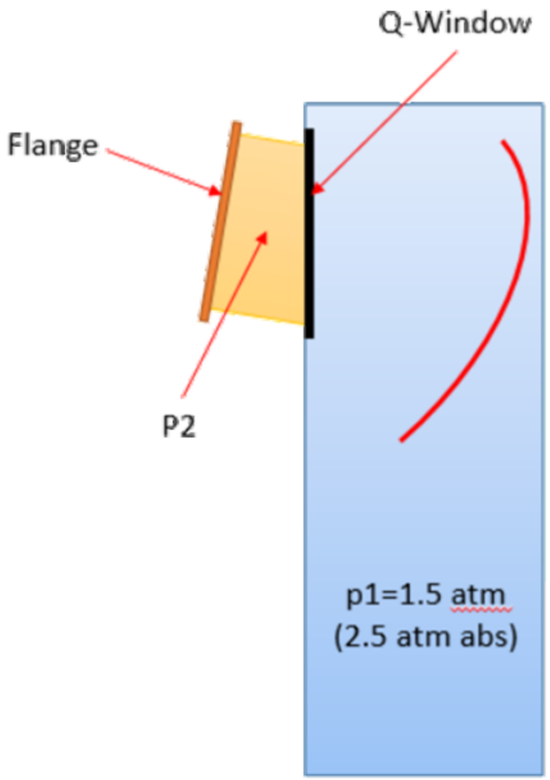


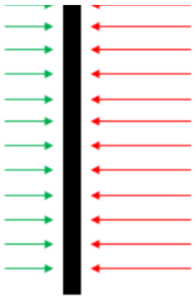
To be comply with ASME role, the Q-Window thickness should be 50/60 mm.
Maybe it is incompatible with the detector optics (??)

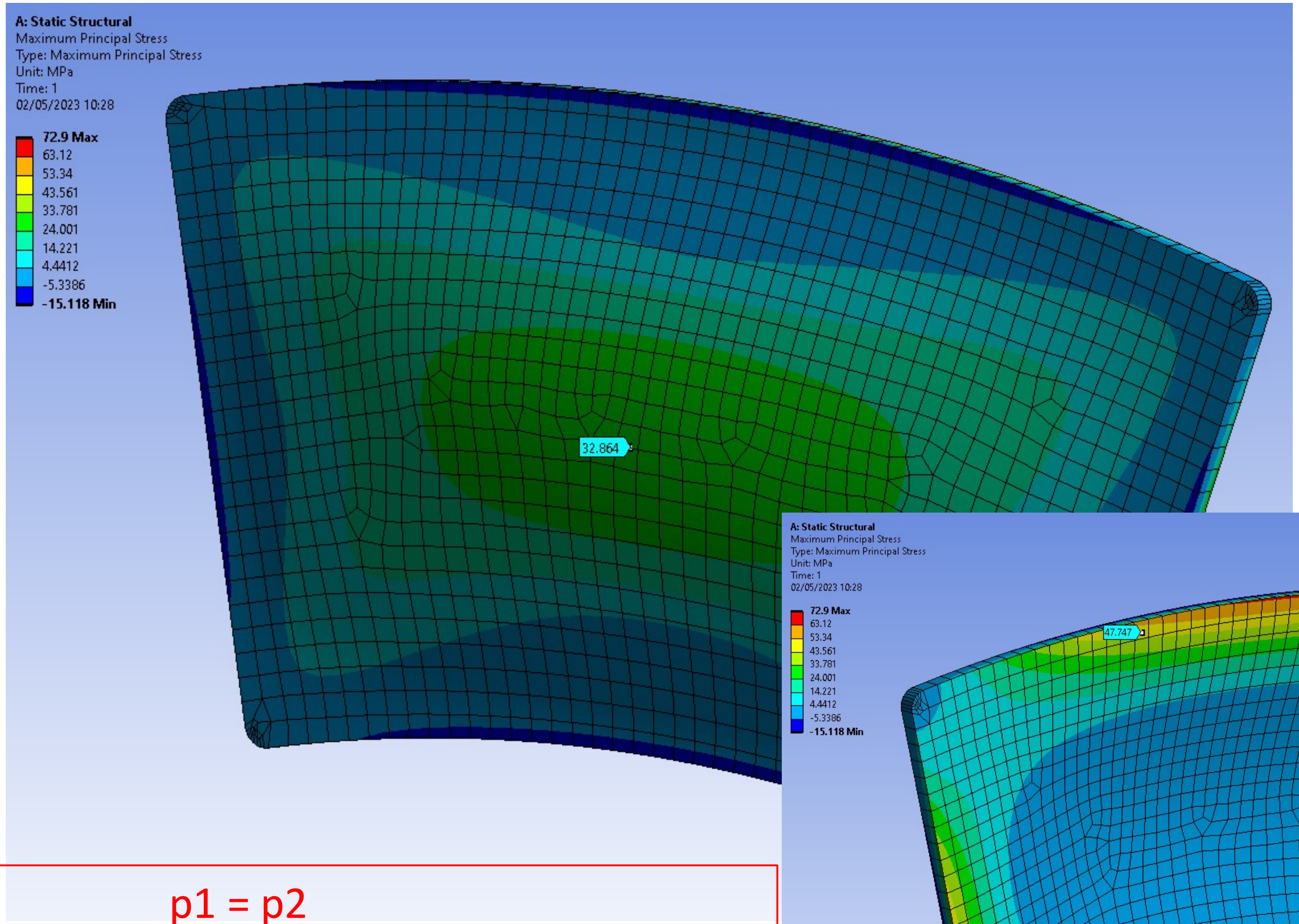


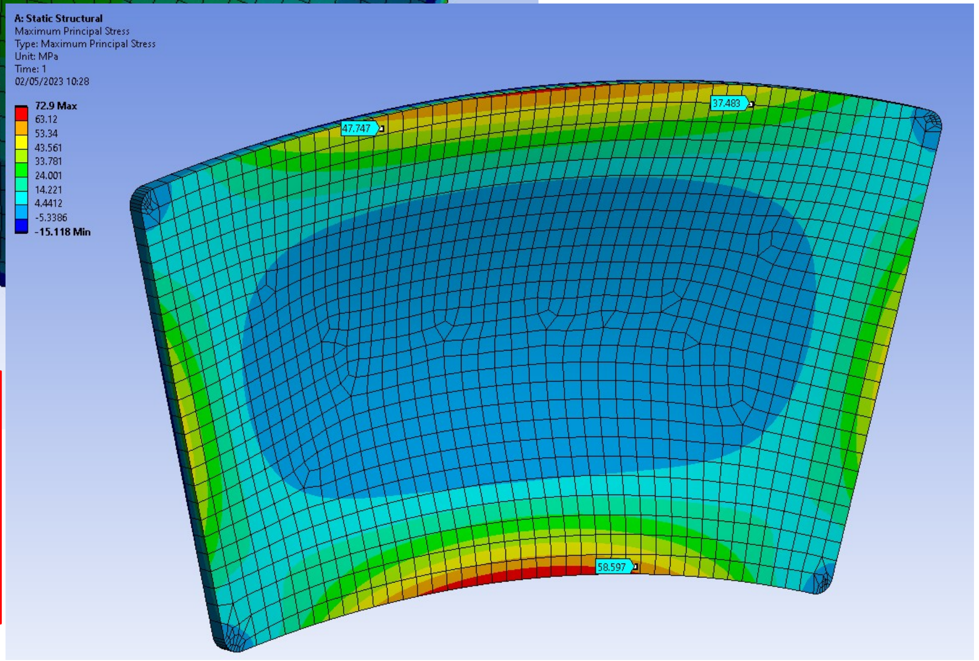
p1 > atm pressure (p2)
Q-Window thickness shall be greater than or equal to 30 mm

Quartz windows FEM: scenario 2









p1 = p2

Q-Window Thickness shall be greater than or equal to 20 mm because a pressure difference inside/outside greater than 0.1 atm can lead to the breakdown of Q-W

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Quartz windows: open points

- Effects of temperature: change of gas pressure, Q-W frame deformation
- Effects on the Q-W of main structure deformation
- Effects of pressure changes (control) during both gas enclosure filling and operation
- ....

dRICH: critical points

- Engineering of the gas enclosure: materials, construction technology.......
- Compliance with ASME/PED pressure vessel code
- Quartz Windows: stress
- Gas pressure control (pressure/temperature changes)

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