Istituto Nazionale di Fisica Nucleare
SEZIONE DI FERRARA

Brookhaven National Laboratory

Jefferson Lab

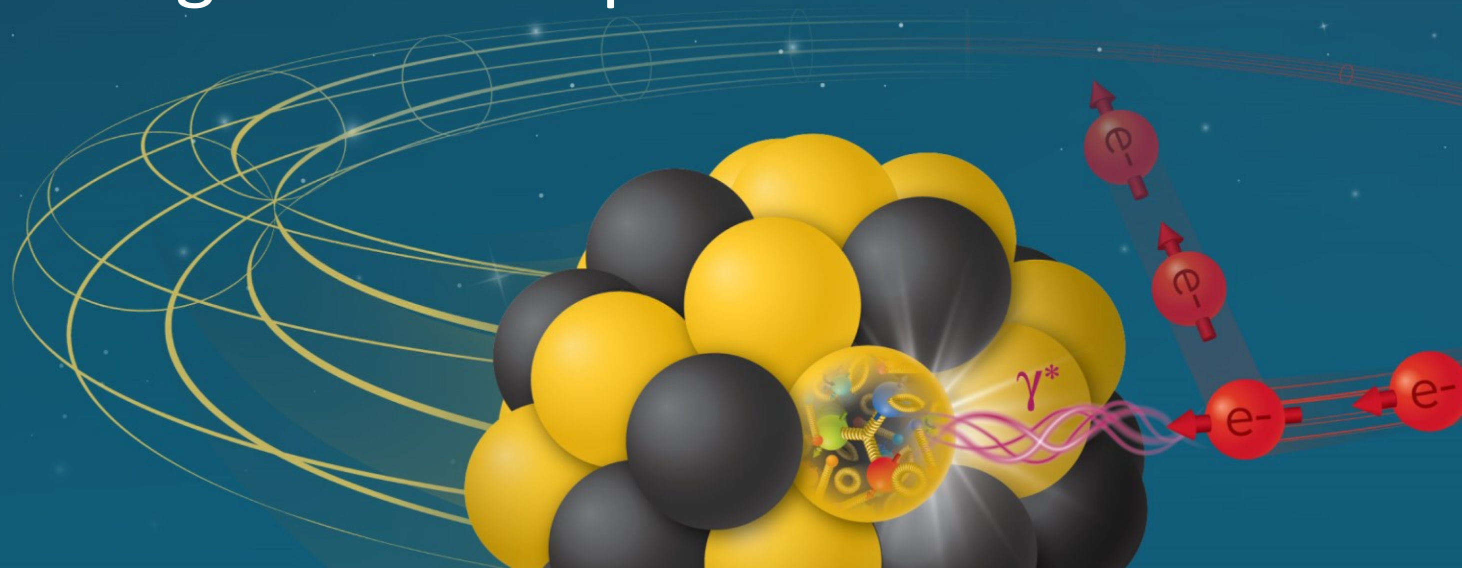
U.S. DEPARTMENT OF ENERGY

ePIC experiment
dRICH

dRICH Meeting
Mechanical Design Status Report

Alessandro Saputi – 19 February 2025

Electron-Ion Collider



Overview

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dRICH Mechanical Design
- Main requirements: position, clearance and envelope
- Components: vessel, detector box, aerogel
- Integration

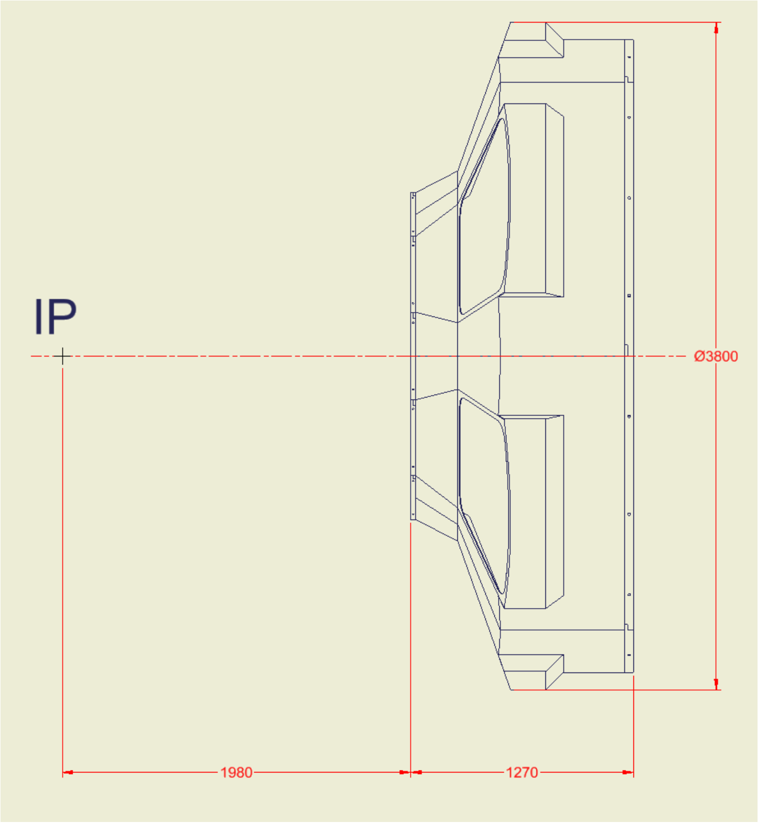
PCB Cooling
- Main requirements

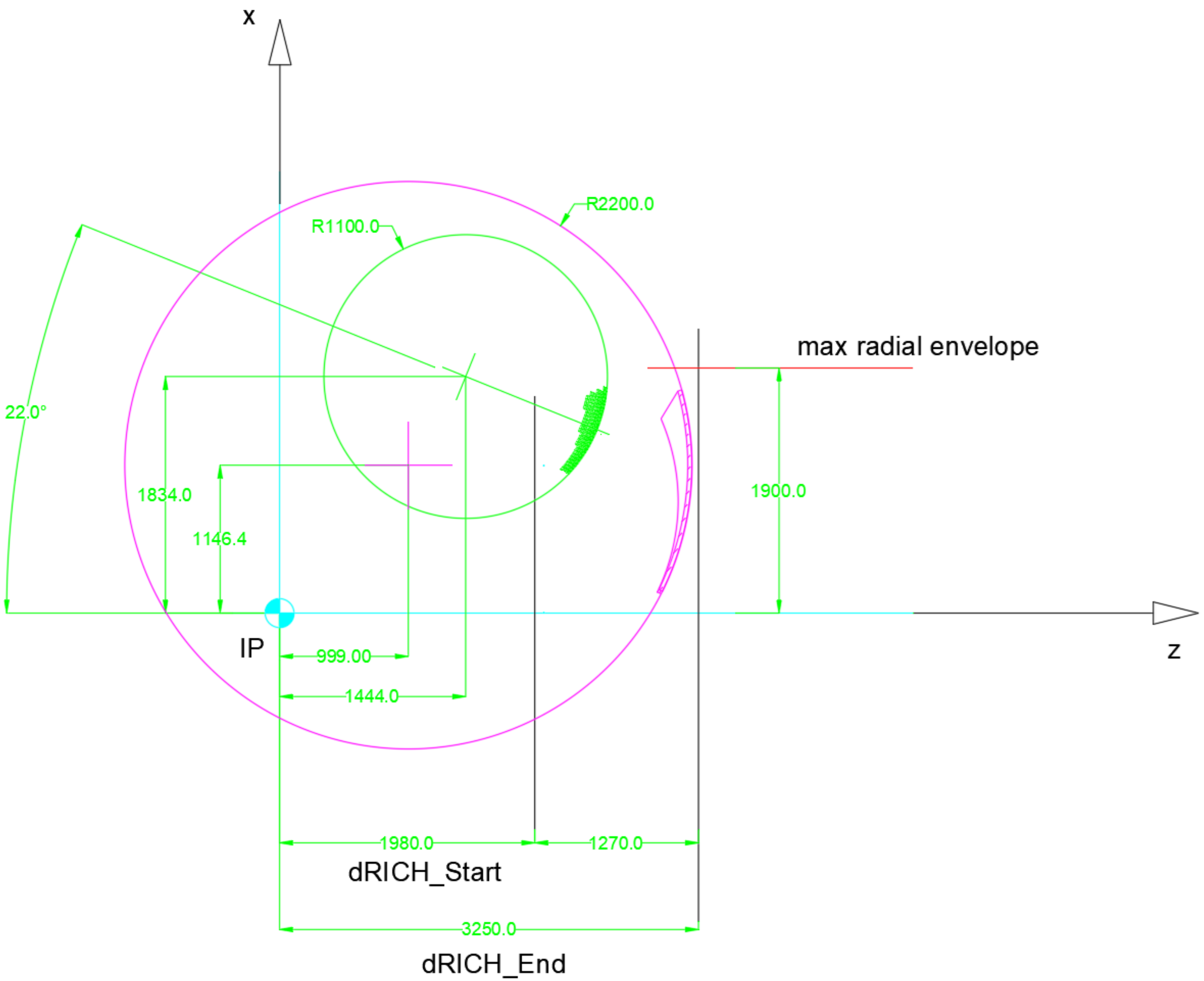
Prototype
- Design

Target R&D and Generic R&D
- Spectrometer Chamber
- High Pressure Chamber

dRICH: main requirements

- **Envelope overall size**: Ø3800 mm × 1270 mm
- **Operating pressure**: Up to 3 - 10 mbar
- **Operating temperature**: 22 °C
- **Gas mixture**: C_2F_6 - Nitrogen





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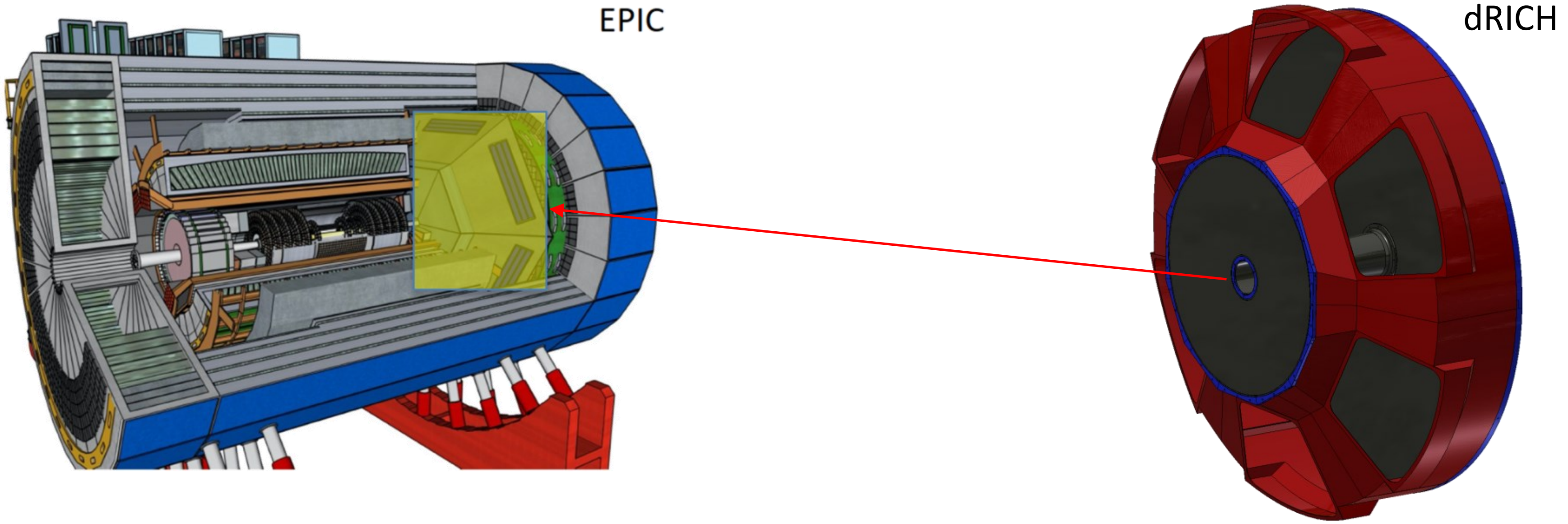
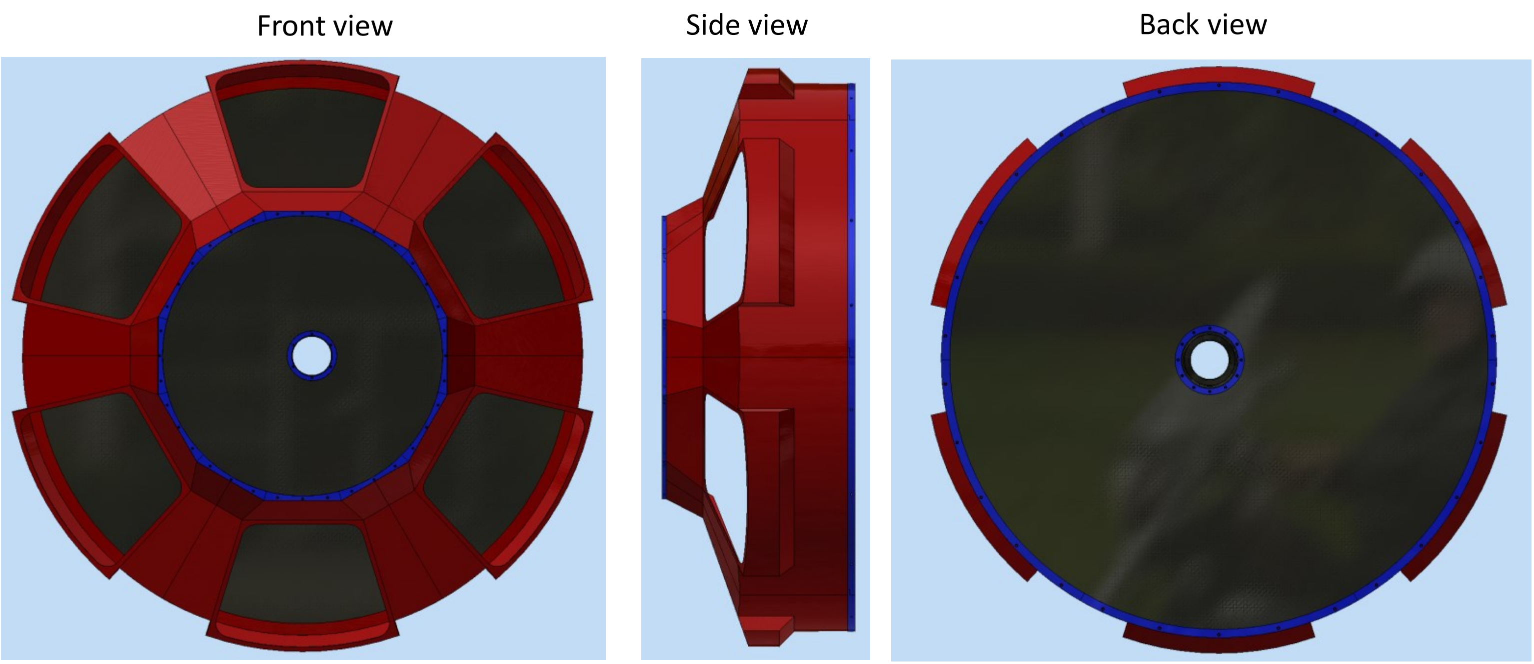
dRICH: main requirements

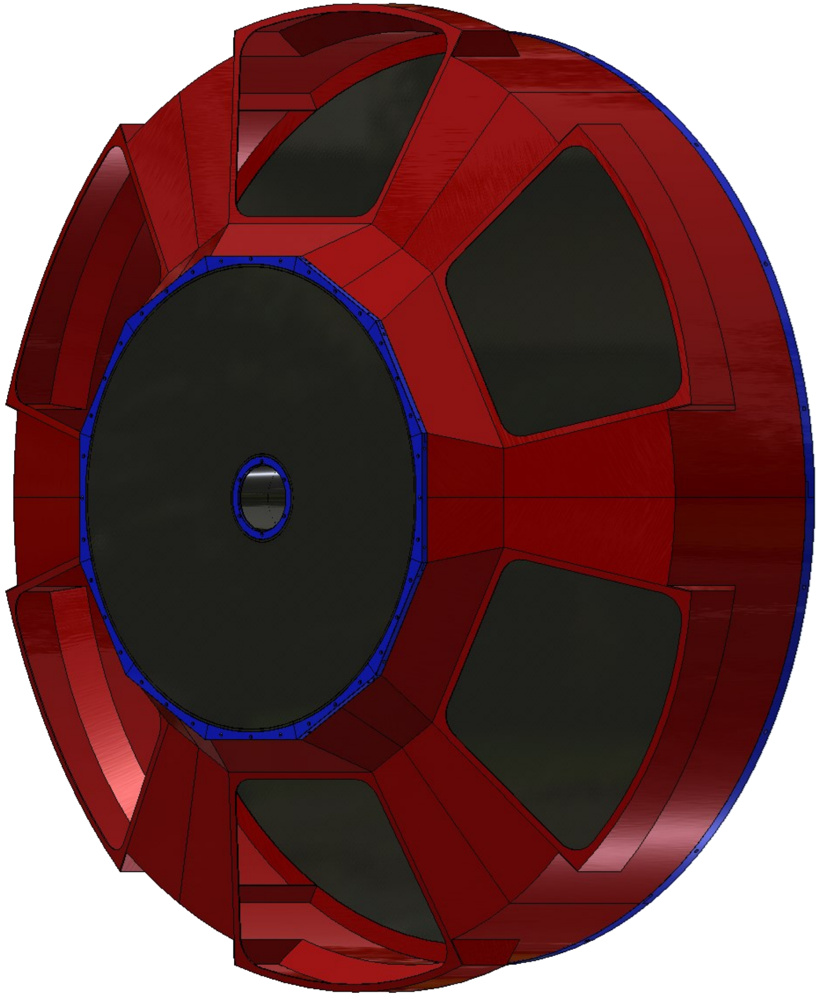
The major functions of the dRICH mechanical structure (gas enclosure) are to provide containment for the dRICH gas radiator and to act as a stable frame for the optical components (the mirrors and aerogel):

- It must be light-tight.
- It must ensure the stability of the structure under the influence of the magnetic field.
- The enclosure must withstand a differential pressure of 3-10 mbar without compromising the mirror alignment.
- The minimum amount of material must be placed within the ePIC experiment acceptance limits.



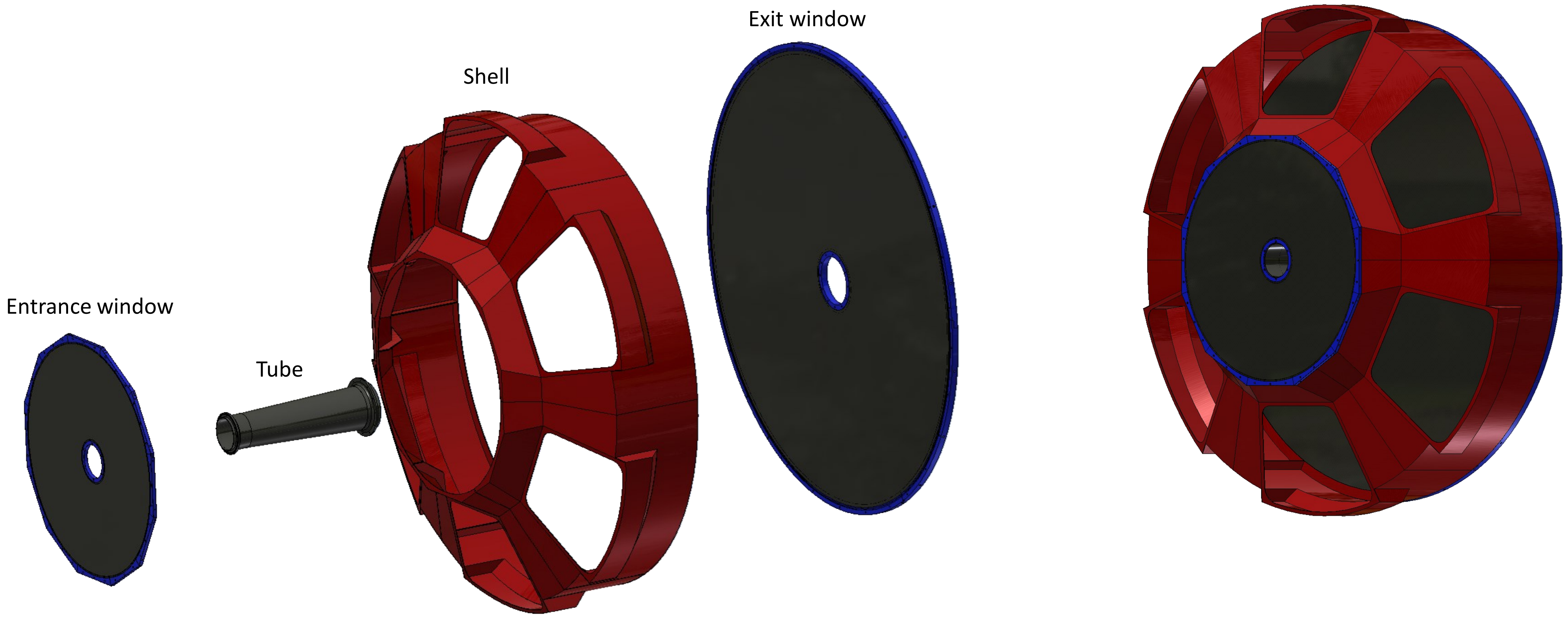
dRICH: mechanical preliminary design





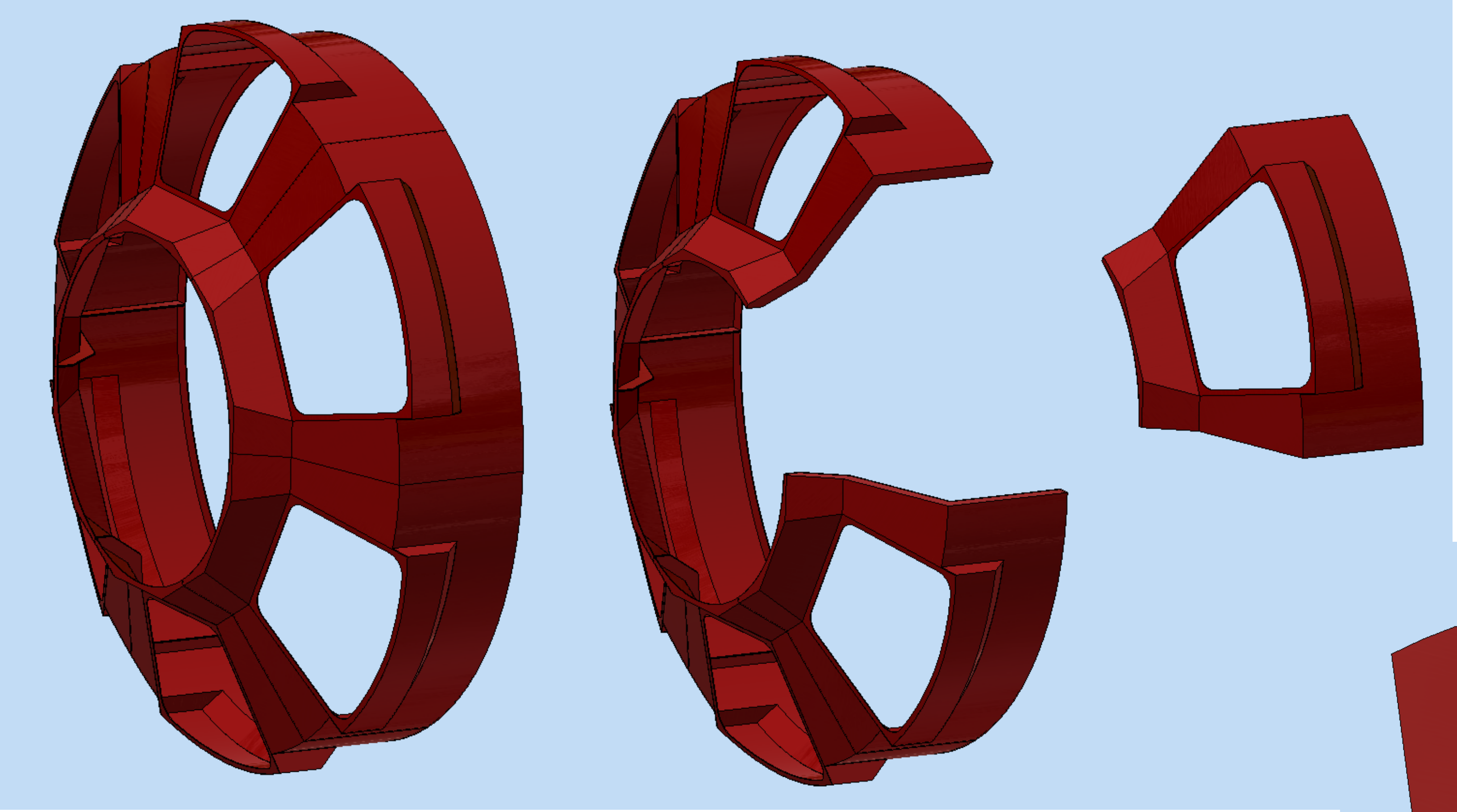
The gas enclosure is essentially a cylindrical box that hosts PDUs (including the cooling system), quartz windows, mirrors, and aerogel tiles.

dRICH: mechanical structure (gas enclosure)

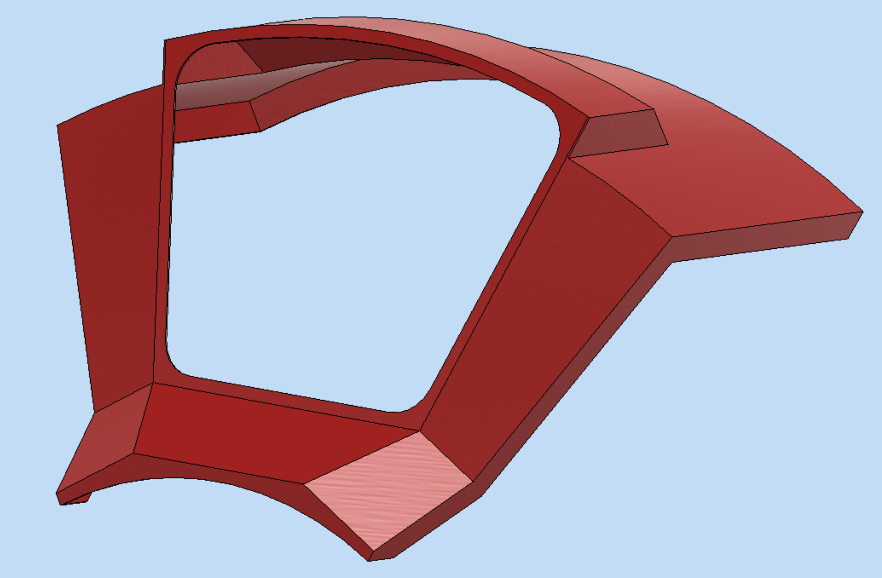


The mechanical structure (gas enclosure) is composed of six main components: the shell, the entrance and exit windows, the central tube, the detector boxes, and the quartz windows.

dRICH: shell

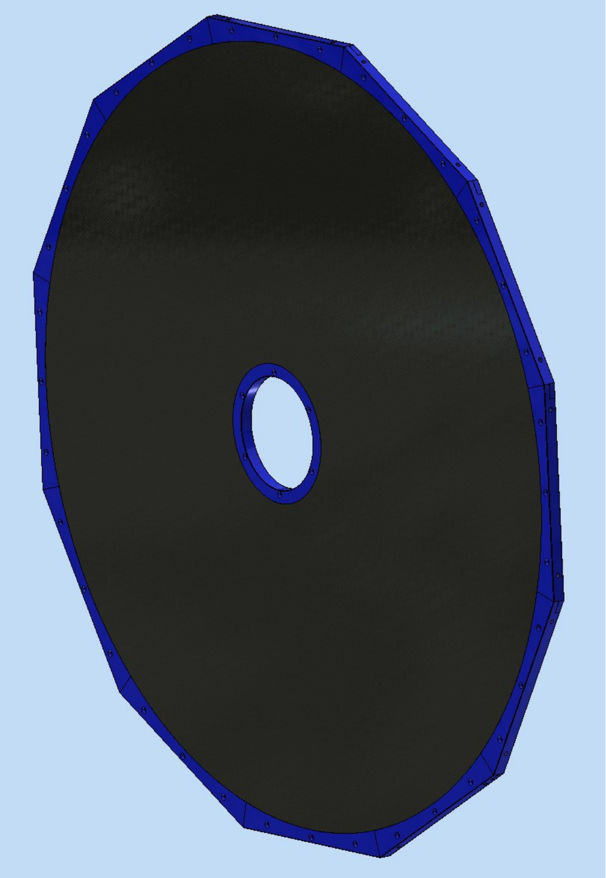


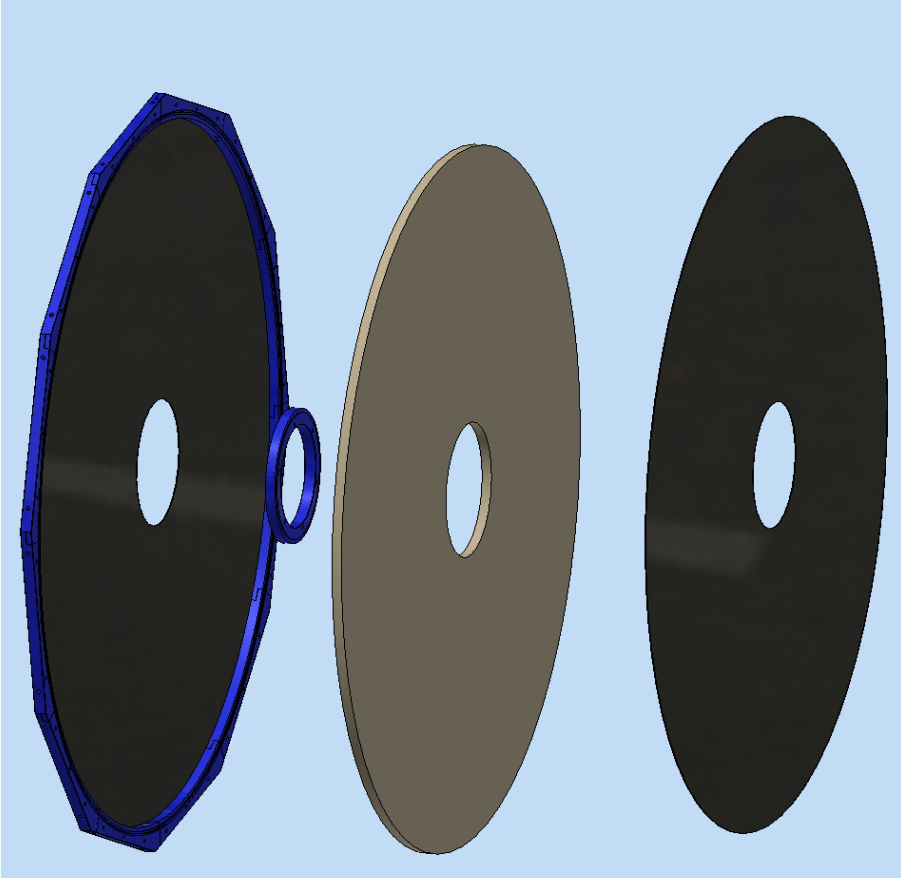
The shell will be made of an 10 mm thick carbon fibre epoxy composite. Each laminate will consist of six layers of balanced weave fabric, with fibres oriented at 0°/90° in one layer and ±45° in the adjacent layer.

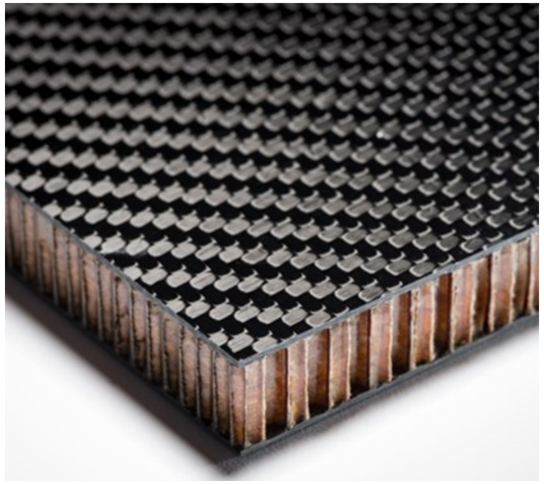


The shell is composed of six parts that are both bolted and glued together to ensure structural integrity.

dRICH: entrance windows



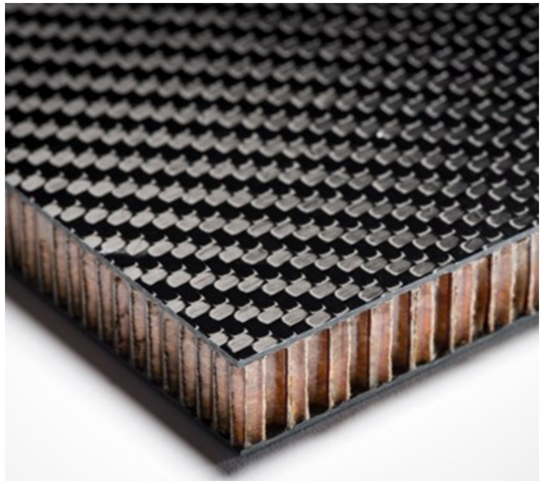




The Entrance Window will be a sandwich panel consisting of two carbon fiber-reinforced epoxy skins, each 2.28 mm thick, separated by a 25 mm thick Nomex honeycomb core. Each skin is composed of six layers of balanced weave laminate, with fibers oriented at 0°/90° in one layer and overlapped with ±45° in the adjacent layer.

The external sides are enclosed by two solid frames made of carbon fiber (CF) or aluminum.

dRICH: exit windows

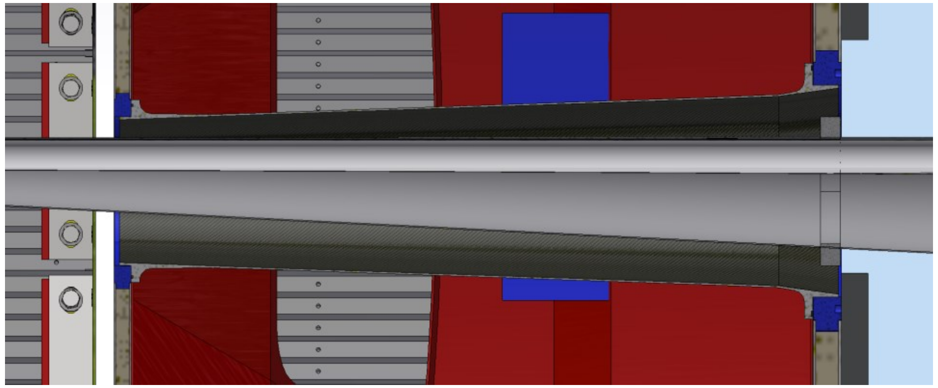


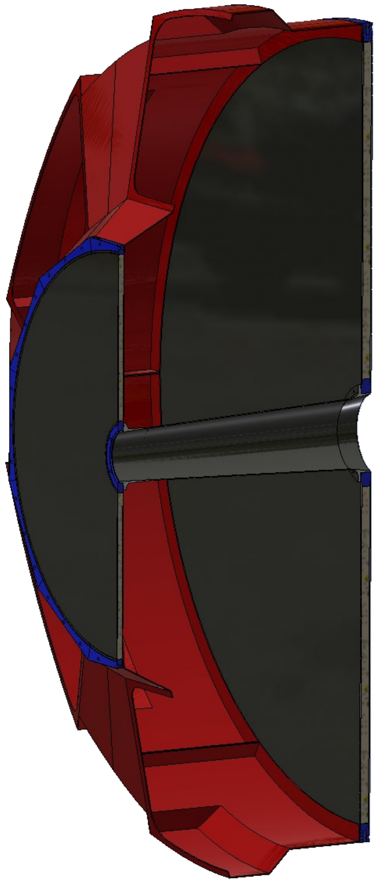
The Exit Window will be a sandwich panel consisting of two carbon fiber-reinforced epoxy skins, each 4.56 mm thick, separated by a 40 mm thick Nomex honeycomb core. Each skin is composed of six layers of balanced weave laminate, with fibers oriented at 0°/90° in one layer and overlapped with ±45° in the adjacent layer.

The external sides are enclosed by two solid frames made of carbon fiber (CF) or aluminum.

dRICH: central tube

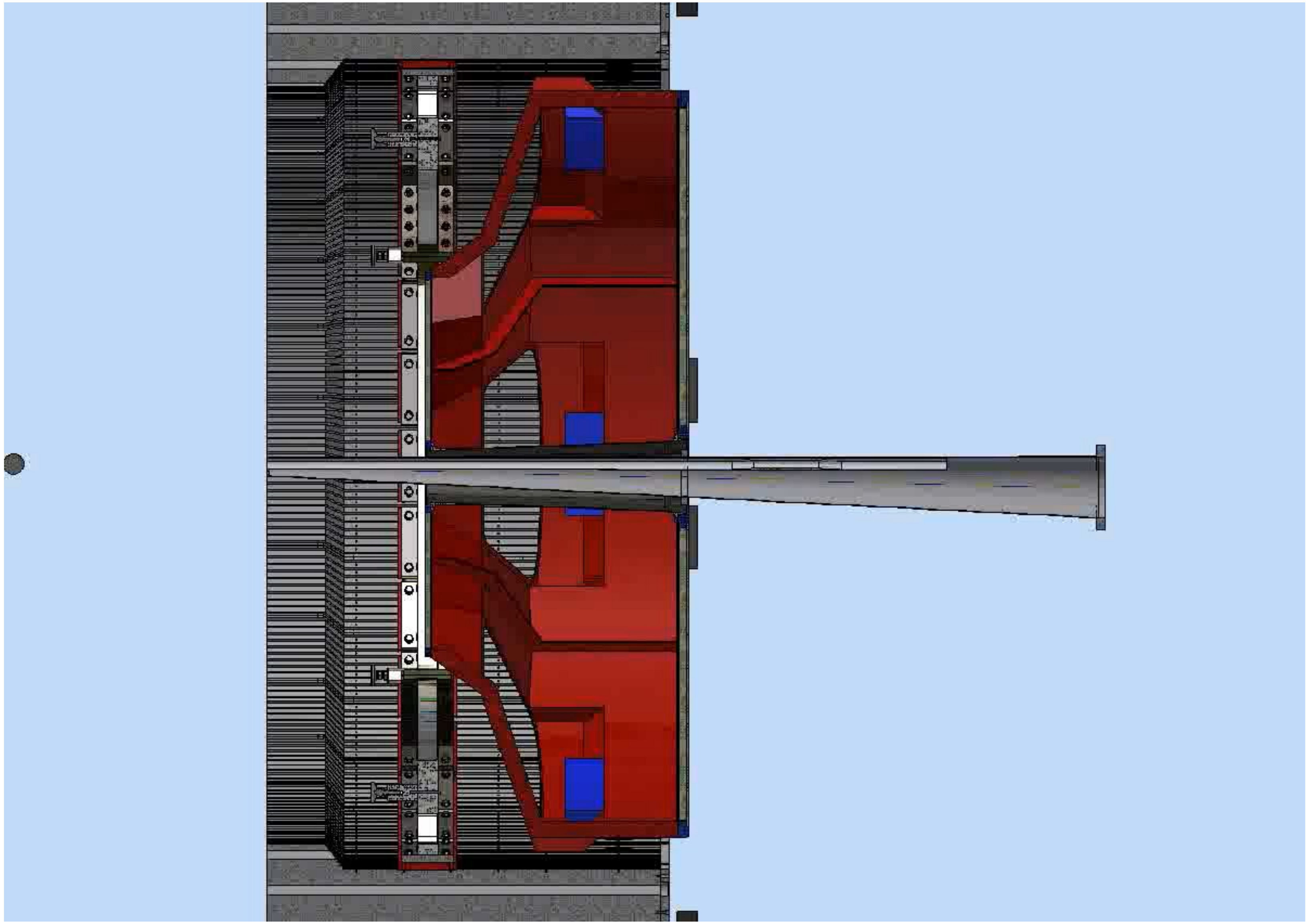
Central tube

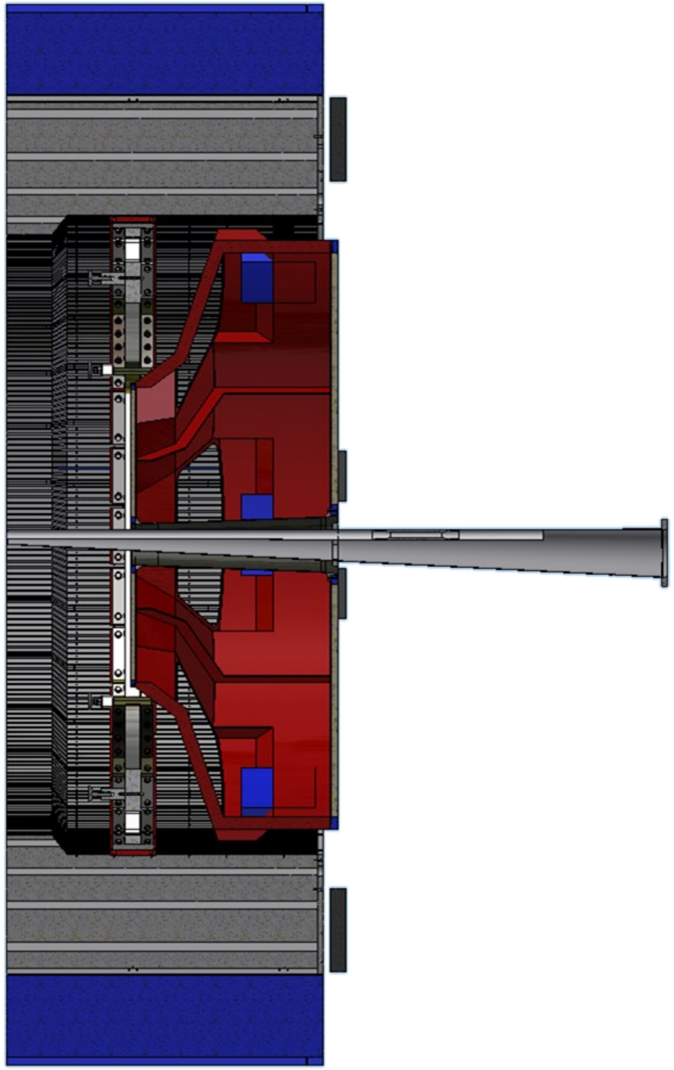




Both the entrance and exit windows are connected by the central tube. The central tube will be made of a 5 mm thick carbon fiber epoxy composite and will have an inside diameter of 260 mm at the entrance window, tapering to 370 mm at the exit window. This design ensures a radial separation between the vacuum chamber and the central tube.

dRICH: integration





dRICH: detector and detector box

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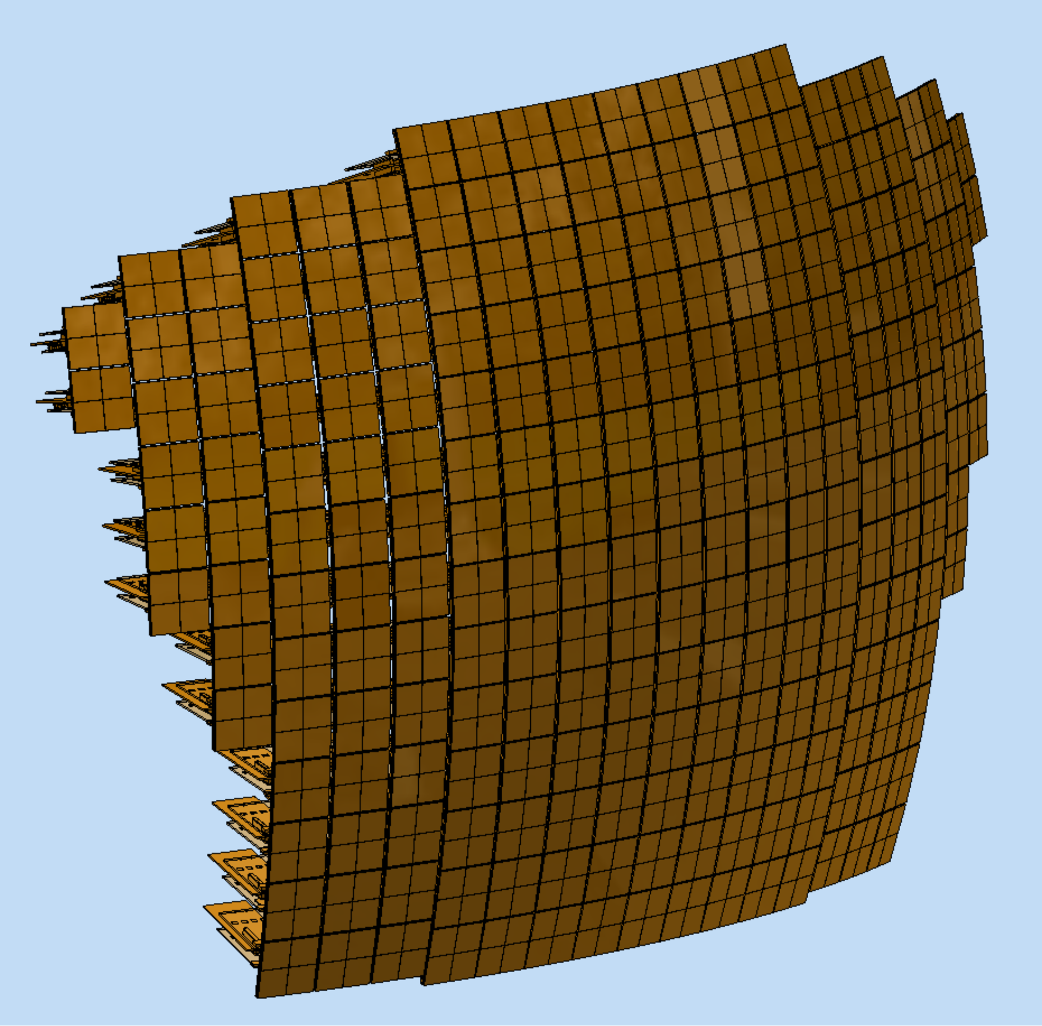
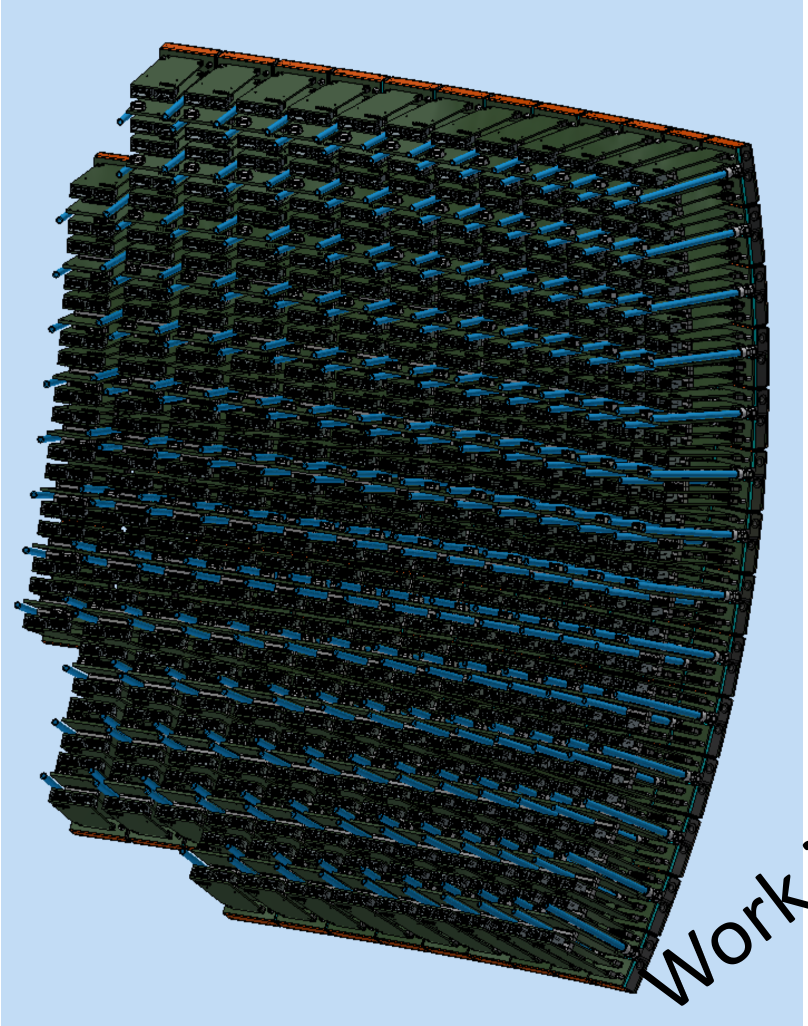
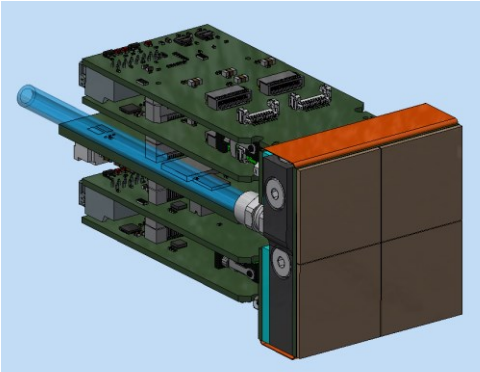
The detector is composed of 236 PDUs arranged on a sphere with a radius of 1100 mm







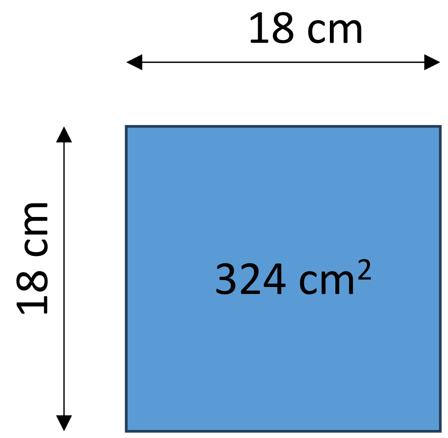
PDU designed by R.Preghenella

Work in progress

dRICH: aerogel layout

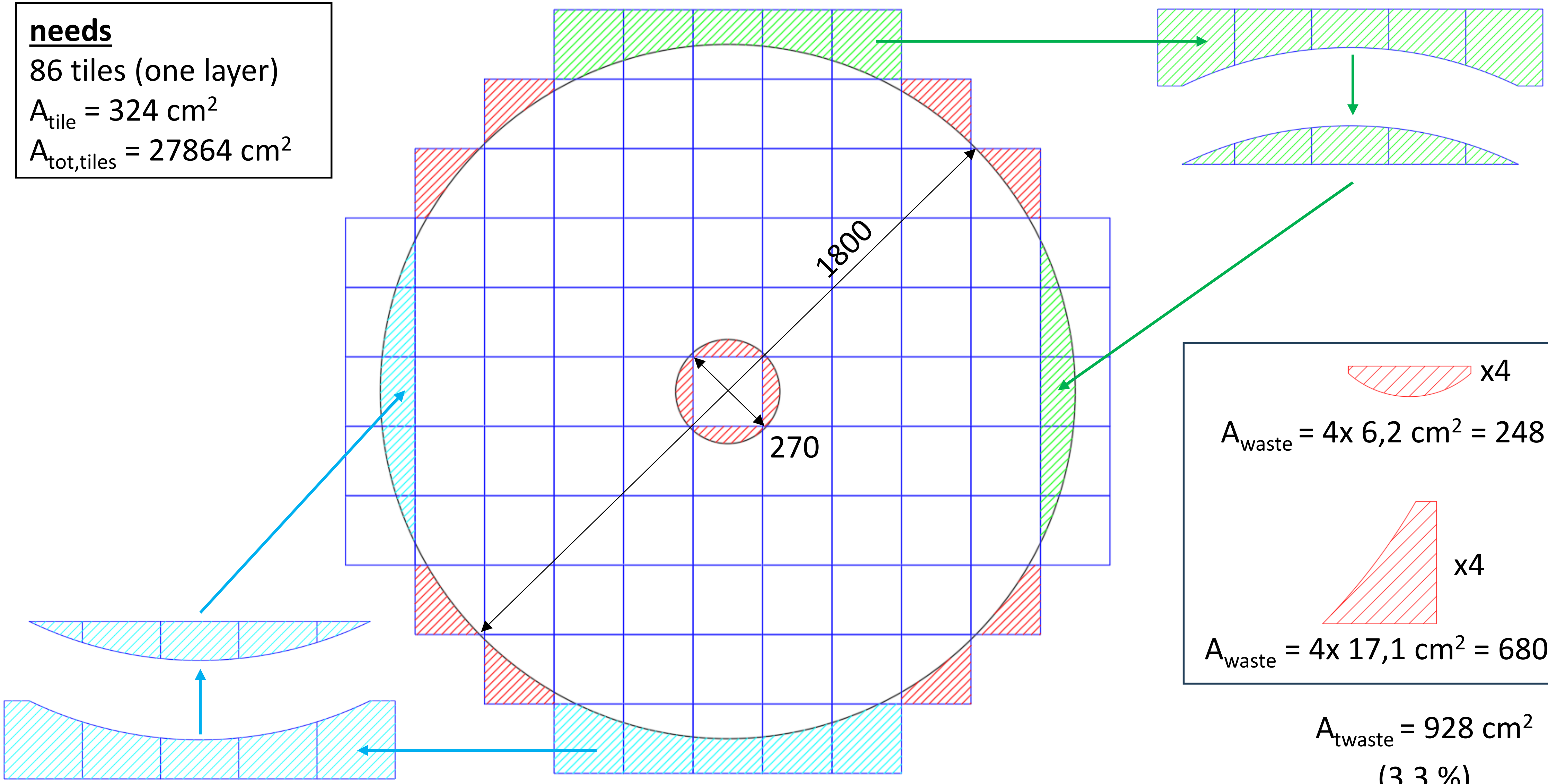
Aerogel Density ≈ 0.15 g/cm3.
Tile size = 180 mm x 180 mm - 20 mm thick

Requirements:
Aerogel Total Thickness 40 mm
Minimize dead space between the aerogel tiles
Light-tight material on the edges of the aerogel tiles



AEROGEL – Layout_A: nesting_A

needs
86 tiles (one layer)
A_{tile} = 324 cm^2
$A_{tot,tiles}$ = 27864 cm^2



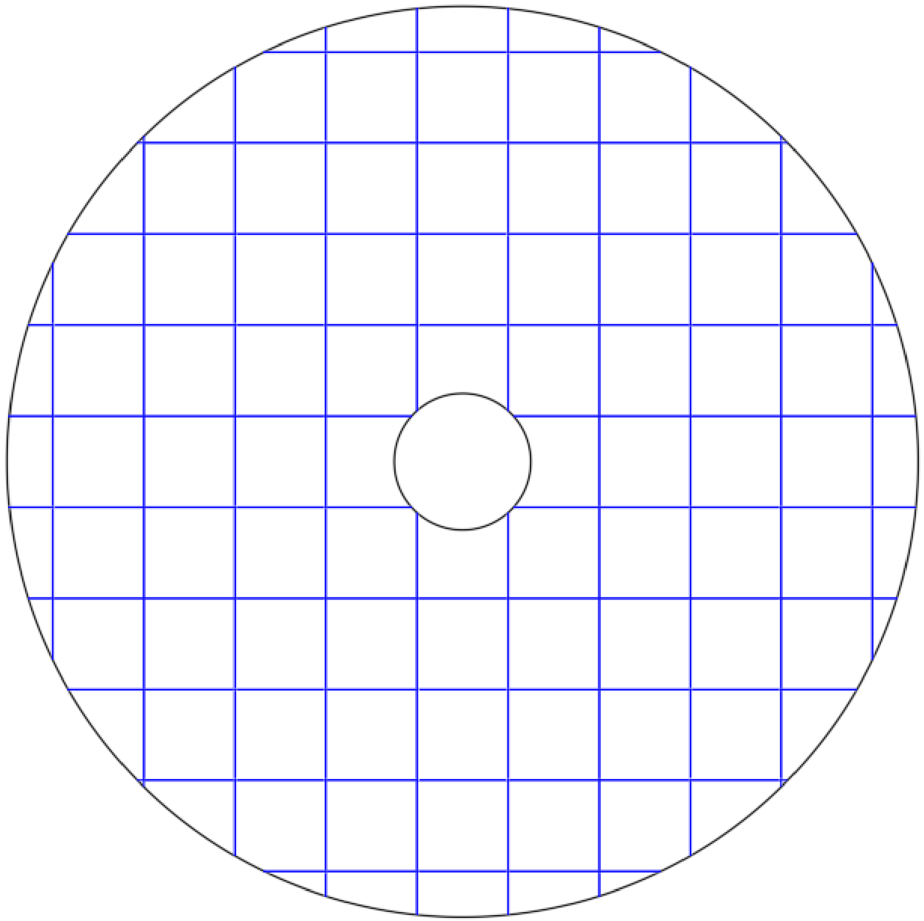
A_{waste} = 4x 6,2 cm^2 = 248 cm^2

A_{waste} = 4x 17,1 cm^2 = 680 cm^2

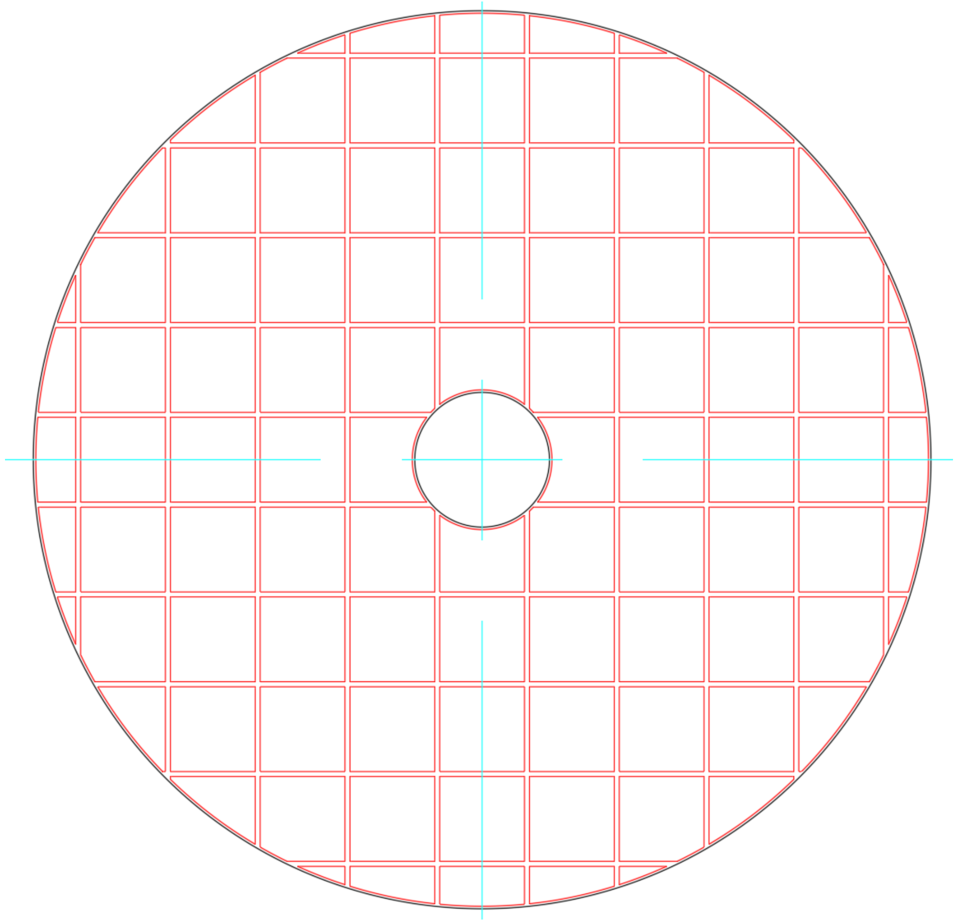
A_{twaste} = 928 cm^2

(3,3 %)

AEROGEL – Layout_A: Active Area and Dead Space



Nominal Active Area (A_n)= 24874 cm^2

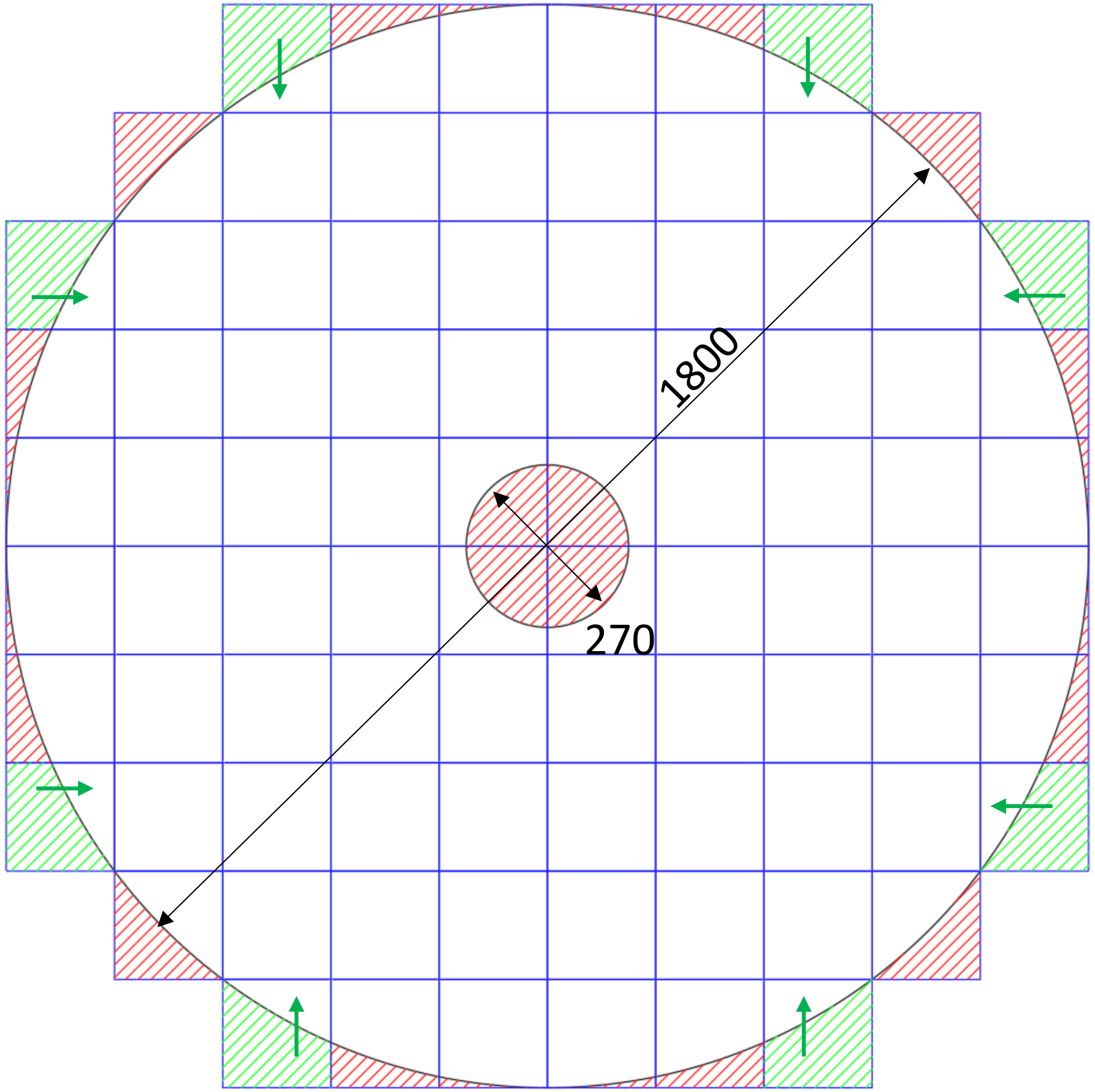


Active Area (A_a) = 21883,5 cm^2

Dead Active Area (A_{da}) = A_n – A_a = 2990,5 mm^2 (12%)

AEROGEL – Layout_B: nesting_B

84 tiles (one layer)
A_{tile} = 324 cm^2
$A_{tot,tiles}$ = 27216 cm^2



A_{twaste} = 1868 cm^2
(6,8 %)

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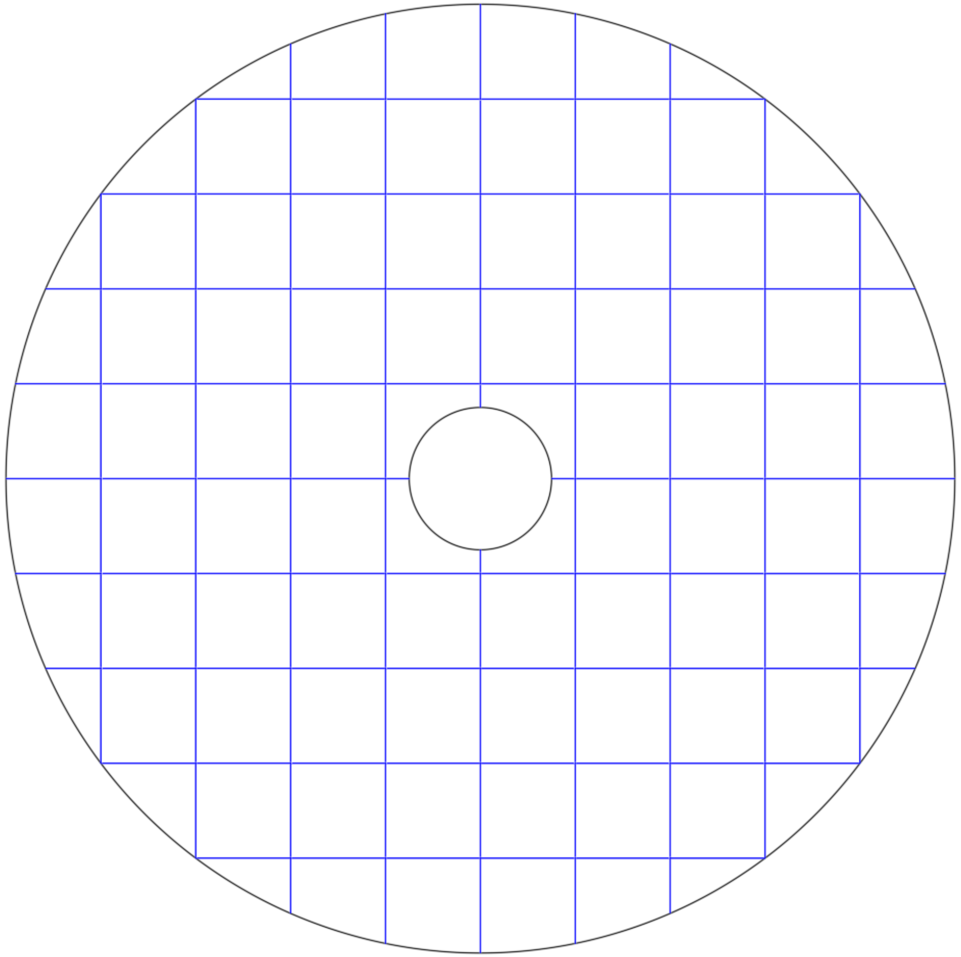
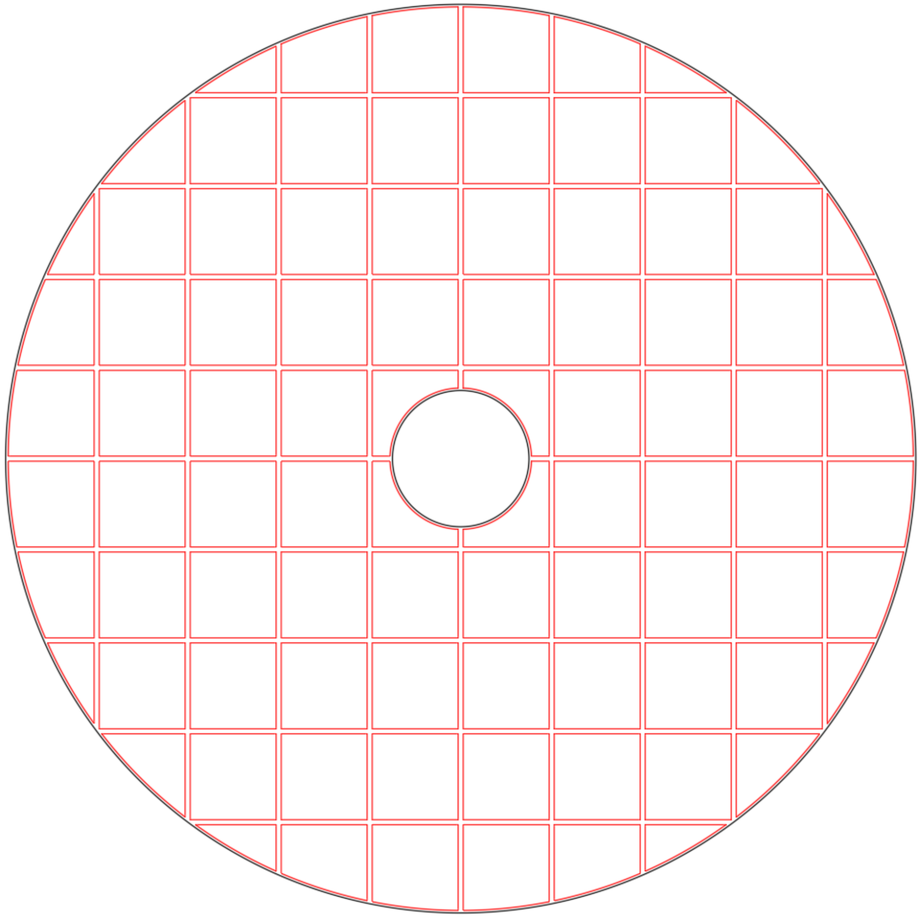
AEROGEL – Layout_B: Active Area and Dead Space



Nominal Active Area (A_n)= 24874 cm^2



Active Area (A_a) = 21368 cm^2
Dead Active Area (A_{da}) = $A_n - A_a$ = 3506 cm^2 (14%)

AEROGEL – Layout_C: nesting_C

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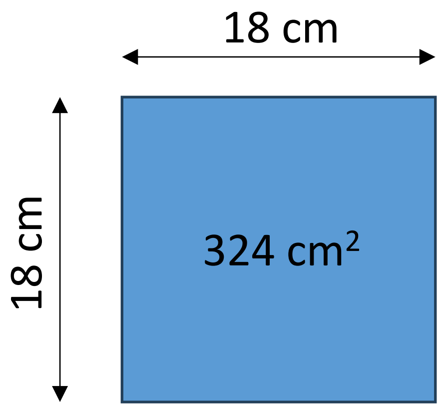
needs

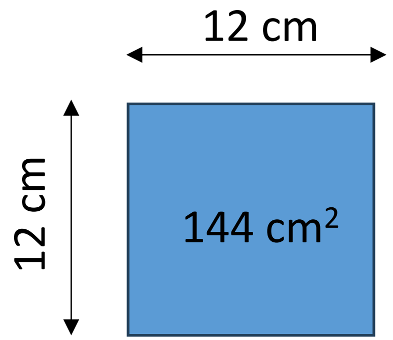
116 tiles (one layer)

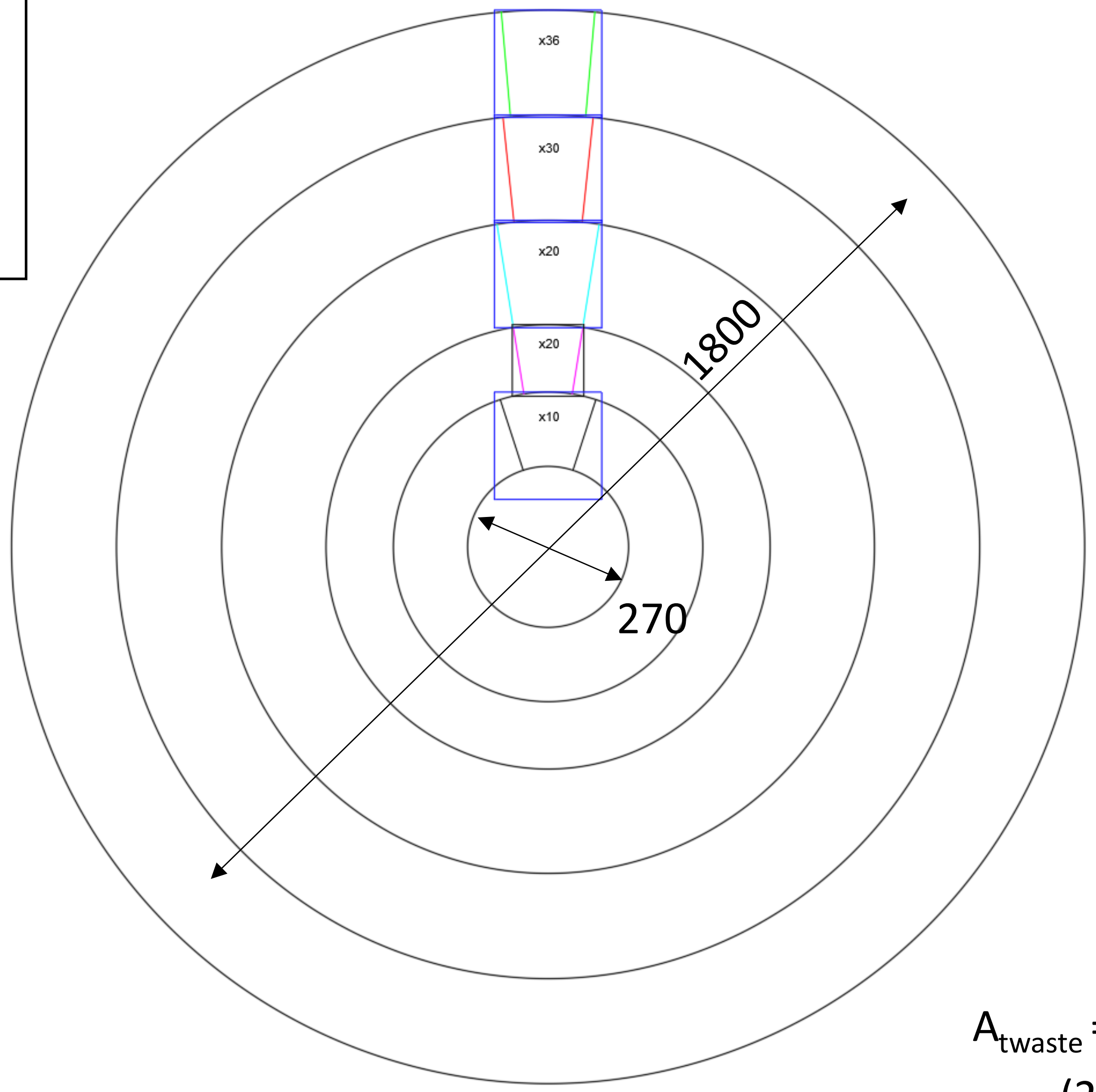
A_{tile} = 18cmx18cm = 324 cm^2

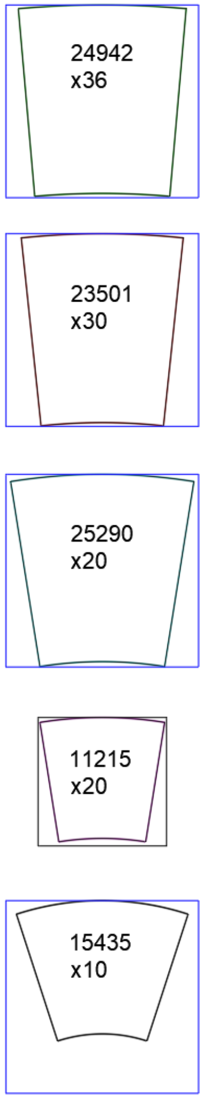
A_{tile} = 12cmx12cm = 144 cm^2

$A_{tot,tiles}$ = 33984 cm^2









A_{waste} = 2682 cm^2

A_{waste} = 2670 cm^2

A_{waste} = 1420 cm^2

A_{waste} = 640 cm^2

A_{waste} = 1700 cm^2

A_{twaste} = 9112 cm^2

(26,8 %)

AEROGEL – Layout_C: Active Area and Dead Space

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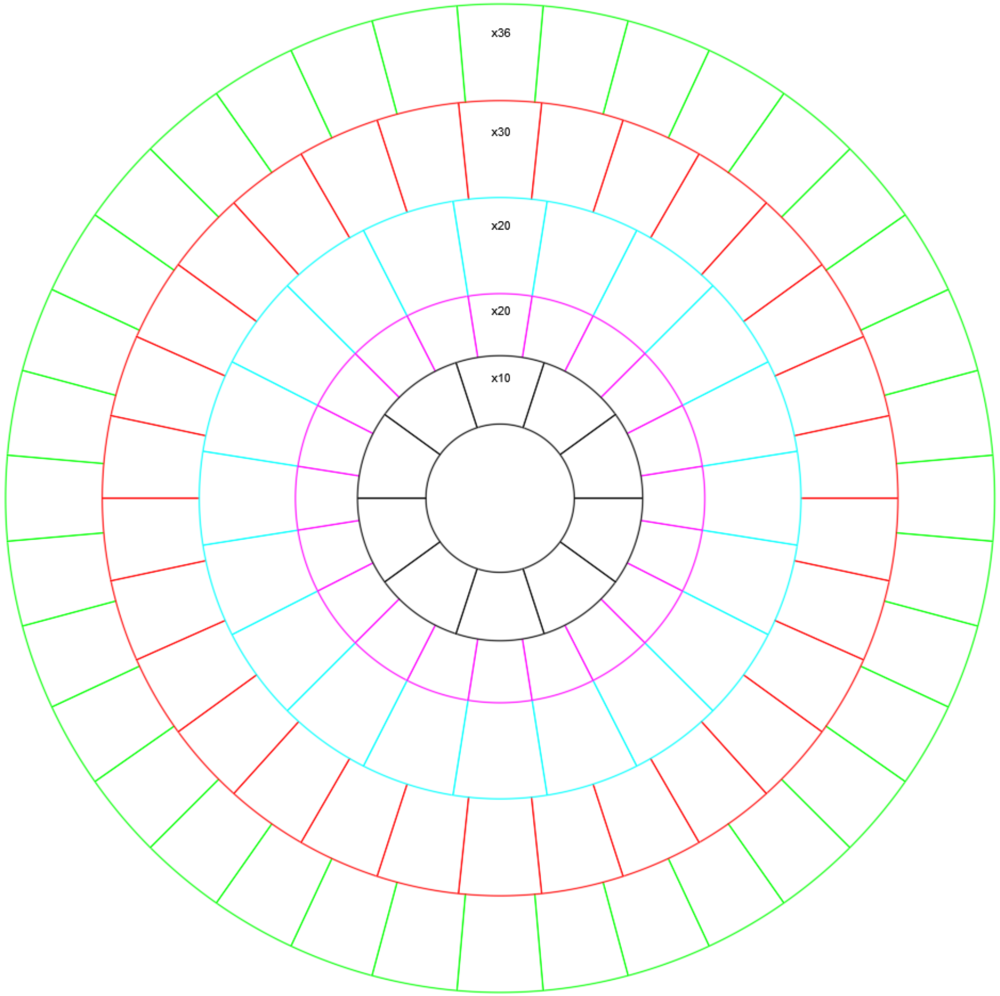
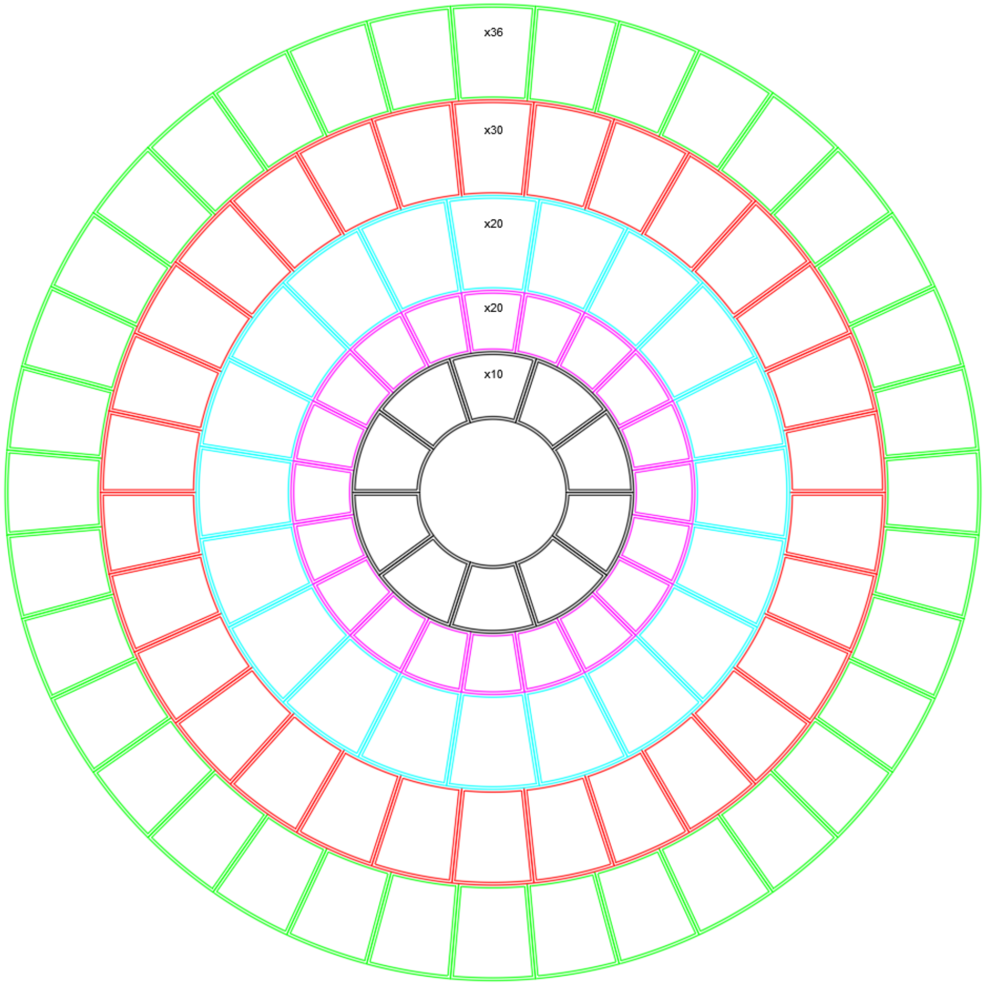


Nominal Active Area (A_n)= 24874 cm^2



Active Area (A_a) = 21605 cm^2

Dead Active Area (A_{da}) = $A_n - A_a$ = 3269 cm^2

(13,1%)

PDU and boards: cooling and thermal power

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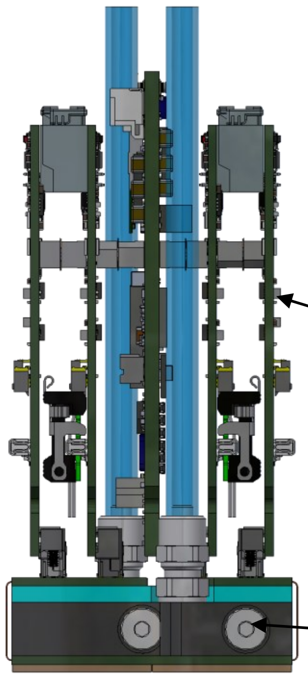
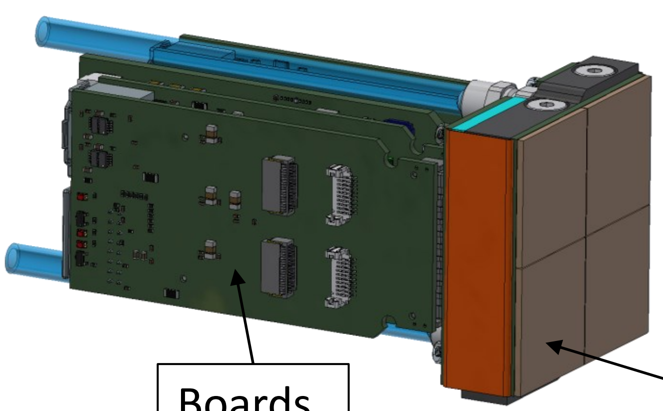


Designed and Engineered by Roberto Preghenella (INFN-BO)



dRICH PDU = 1200
Detector Box PDU = 242
dRICH Detector Boxes = 6

SiPM

P_{PDU} = 5 W (cooling power to be supplied to each PDU unit)
T_{SiPM} = -40°C (SiPM temperature)

P_{DT} = 242 × 5 W = 1210 W (cooling power to be supplied to each detector box)
P_{dRICH} = 6 x 1210 W = 7260 W (cooling power to be supplied to dRICH)

Electronic Boards

P_{boards} = 11 W (thermal power generated by each PDU unit)
T_{boards} = 30°C (maximum admissible boards temperature)

P_{BDT} = 242 × 11 W = 2662 W (thermal power generated by each detector box)
P_{dRICH} = 6 x 2662 W = 15972 W (thermal power generated by dRICH)

Detector Box: board's air cooling

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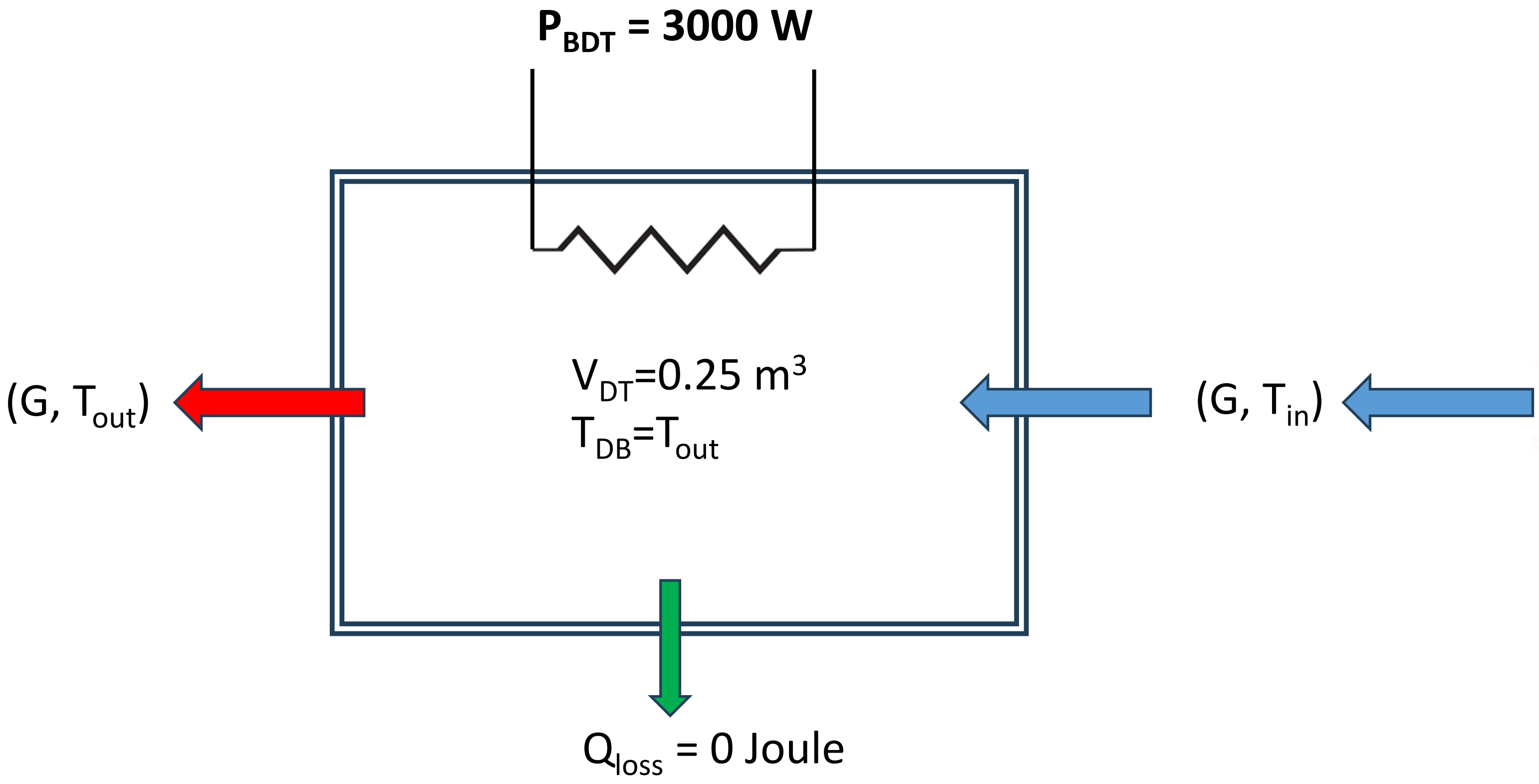
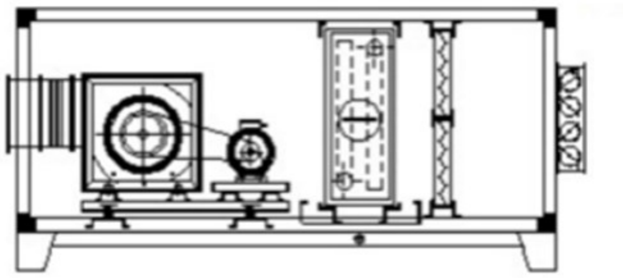
Hypothesis:
- Detector box perfectly insulated
- Thermal interaction with the SiPM cooling system not considered



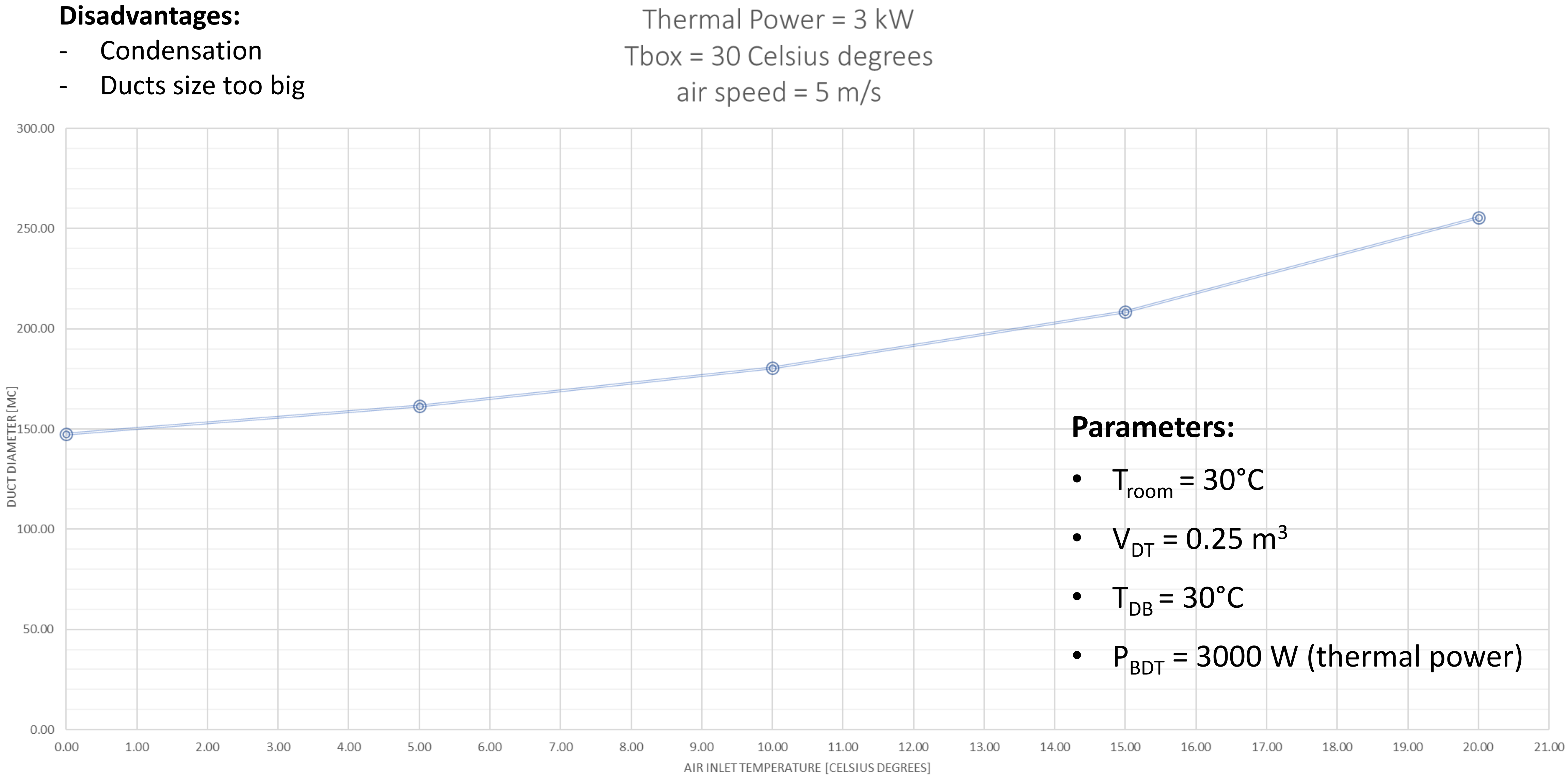
Disadvantages:
- Risk of condensation
- High noise
- High vibrations
- Big size of ducts



- External air intake
- Bag filter
- Cold coil
- Fan

Detector Box: board's air cooling

Disadvantages:
- Condensation
- Ducts size too big



Parameters:
- T_{room} = 30°C
- V_{DT} = 0.25 m^3
- T_{DB} = 30°C
- P_{BDT} = 3000 W (thermal power)

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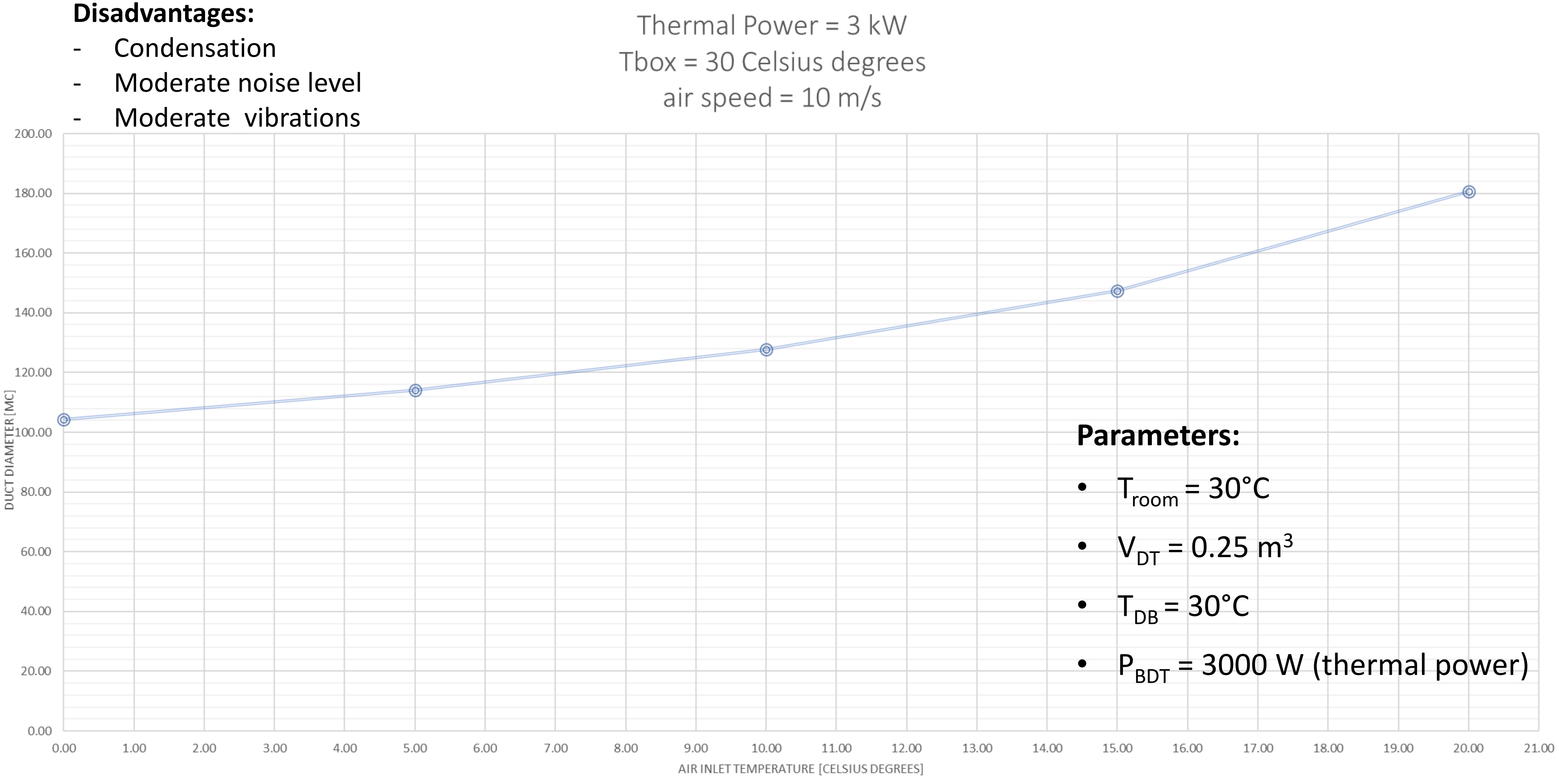
Detector Box: board's air cooling

Disadvantages:
- Condensation
- Moderate noise level
- Moderate vibrations



Parameters:
- T_{room} = 30°C
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- T_{DB} = 30°C
- P_{BDT} = 3000 W (thermal power)

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Detector Box: board's air cooling

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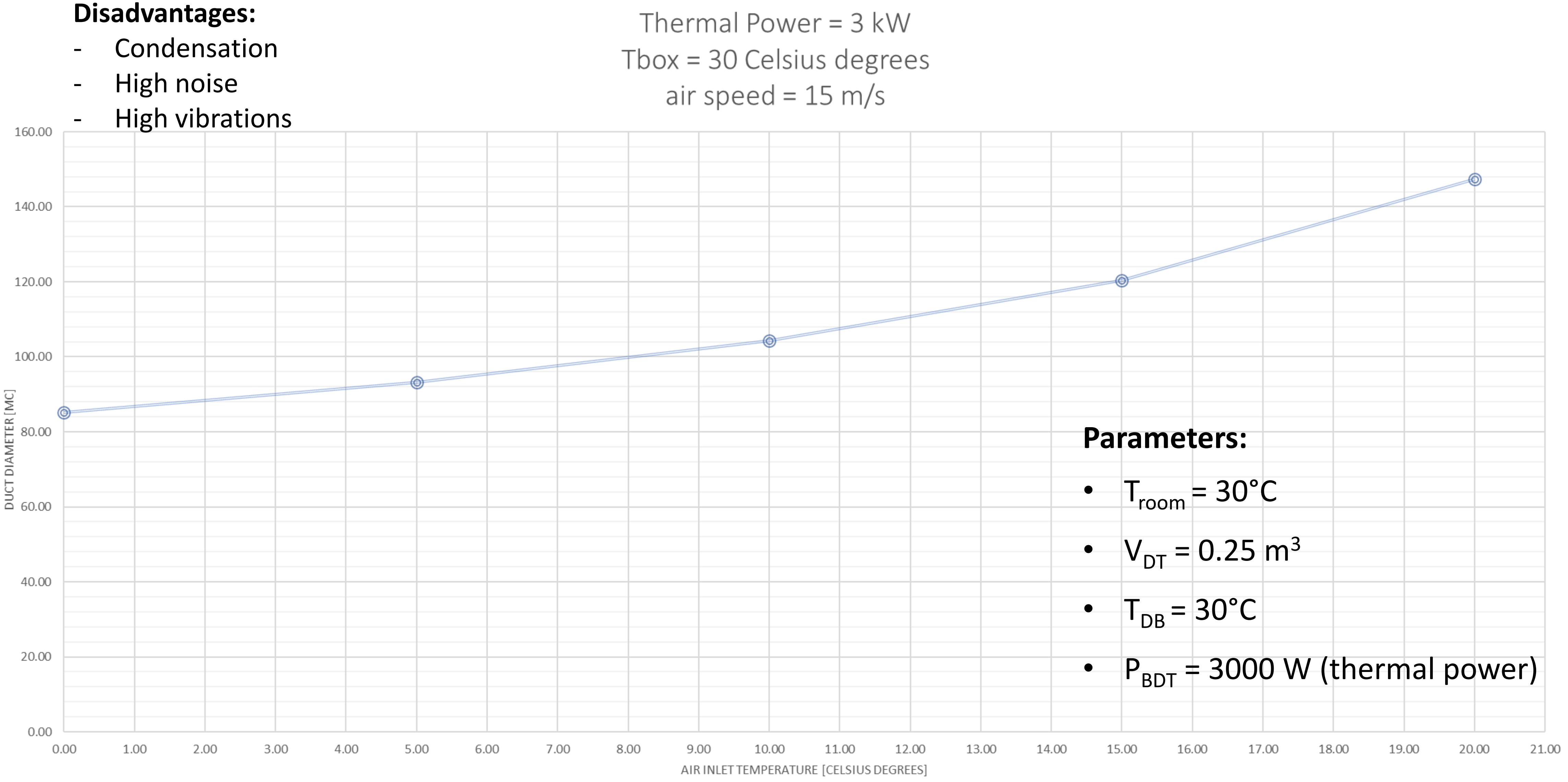
Disadvantages:
- Condensation
- High noise
- High vibrations



Parameters:
- T_{room} = 30°C
- V_{DT} = 0.25 m^3
- T_{DB} = 30°C
- P_{BDT} = 3000 W (thermal power)

Detector Box: board's air cooling

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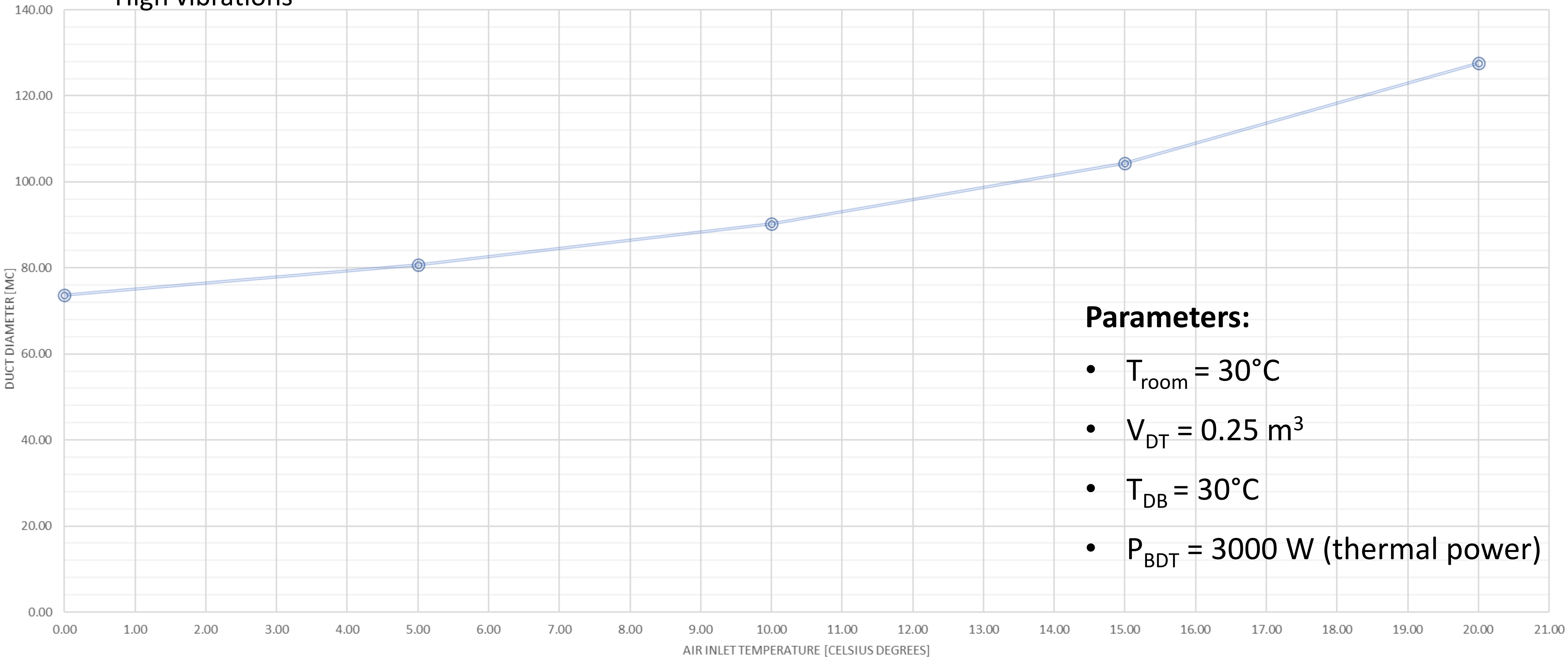
Disadvantages:
- Condensation
- High noise
- High vibrations

Thermal Power = 3 kW
Tbox = 30 Celsius degrees
air speed = 20 m/s



Parameters:
- T_{room} = 30°C
- V_{DT} = 0.25 m^3
- T_{DB} = 30°C
- P_{BDT} = 3000 W (thermal power)

Detector Box: board's cooling

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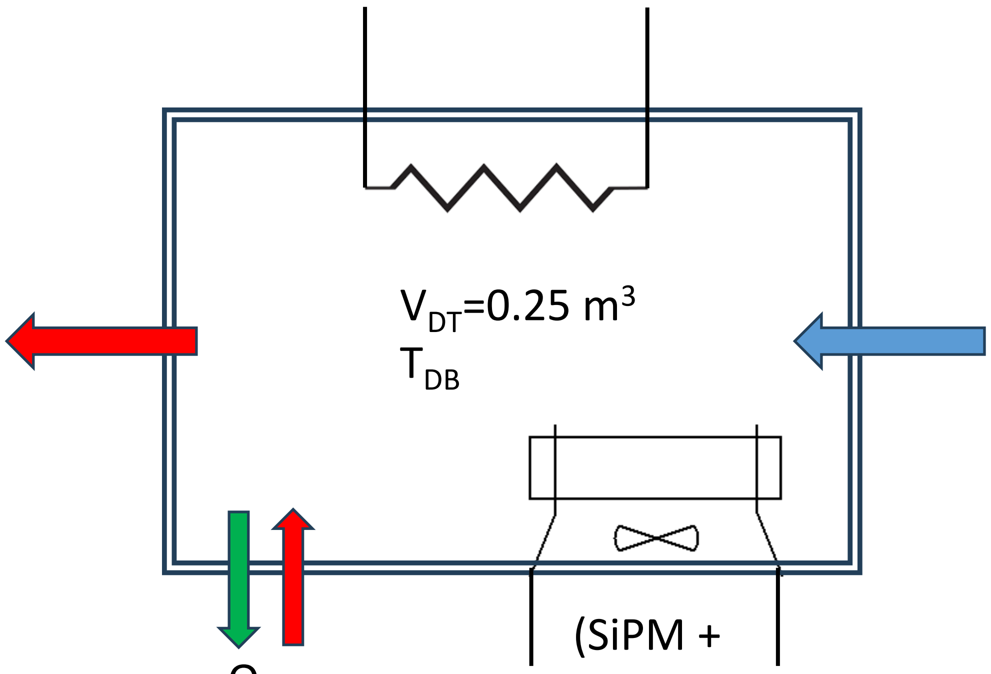
Hypothesis:

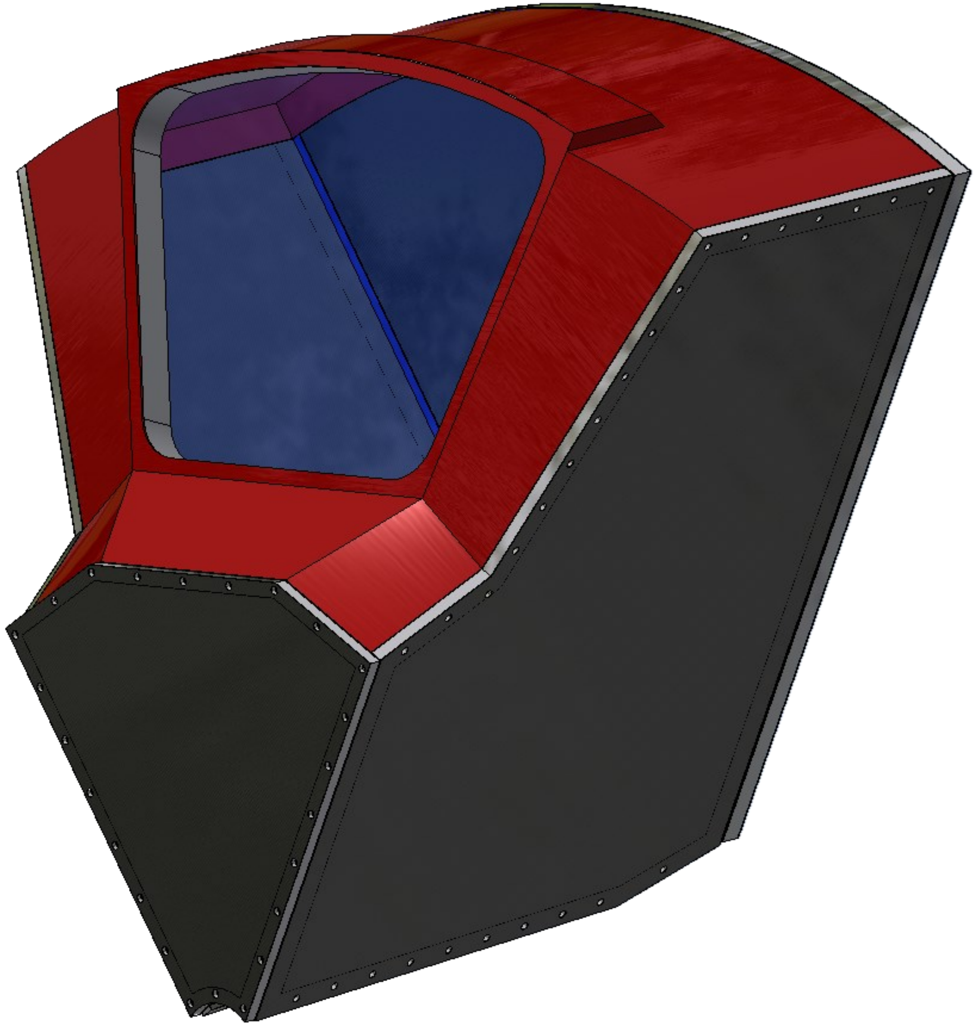
- Detector box no perfectly insulated
- Thermal interaction with the SiPM cooling system considered



Advantages:

- Low risk of condensation
- No noise
- low vibrations
- small size of pipes

dRICH: prototype



Single Slice
(one-sixth)

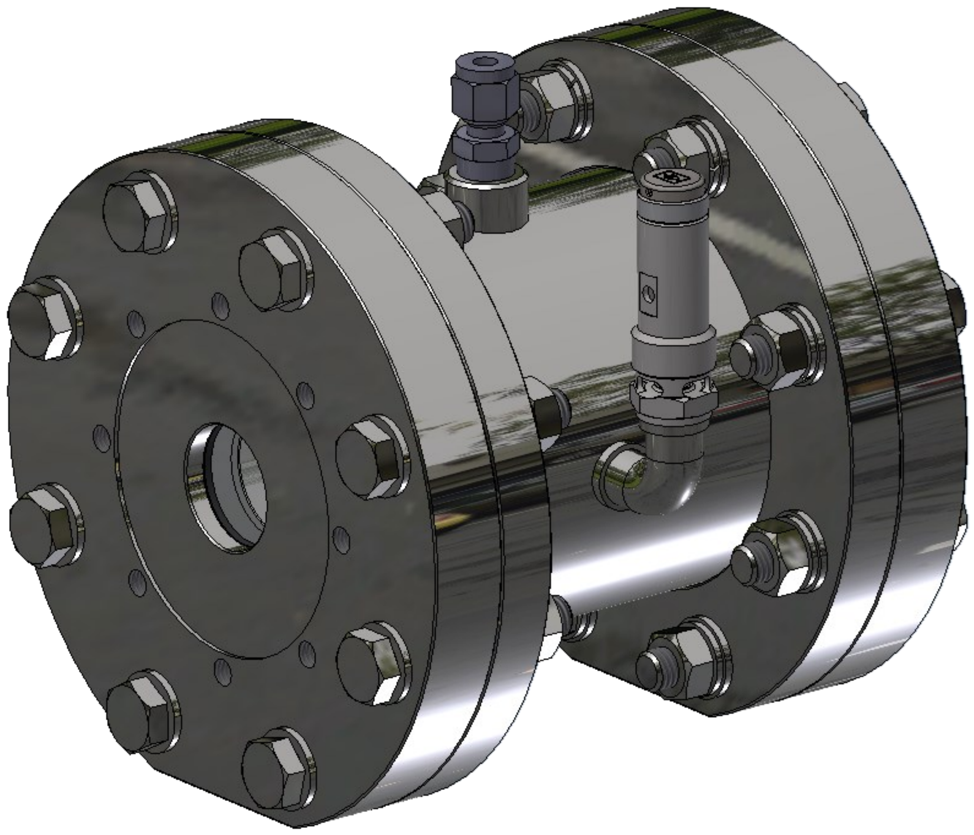
Full-scale (1:1) prototype representing one-sixth of the complete dRICH detector.

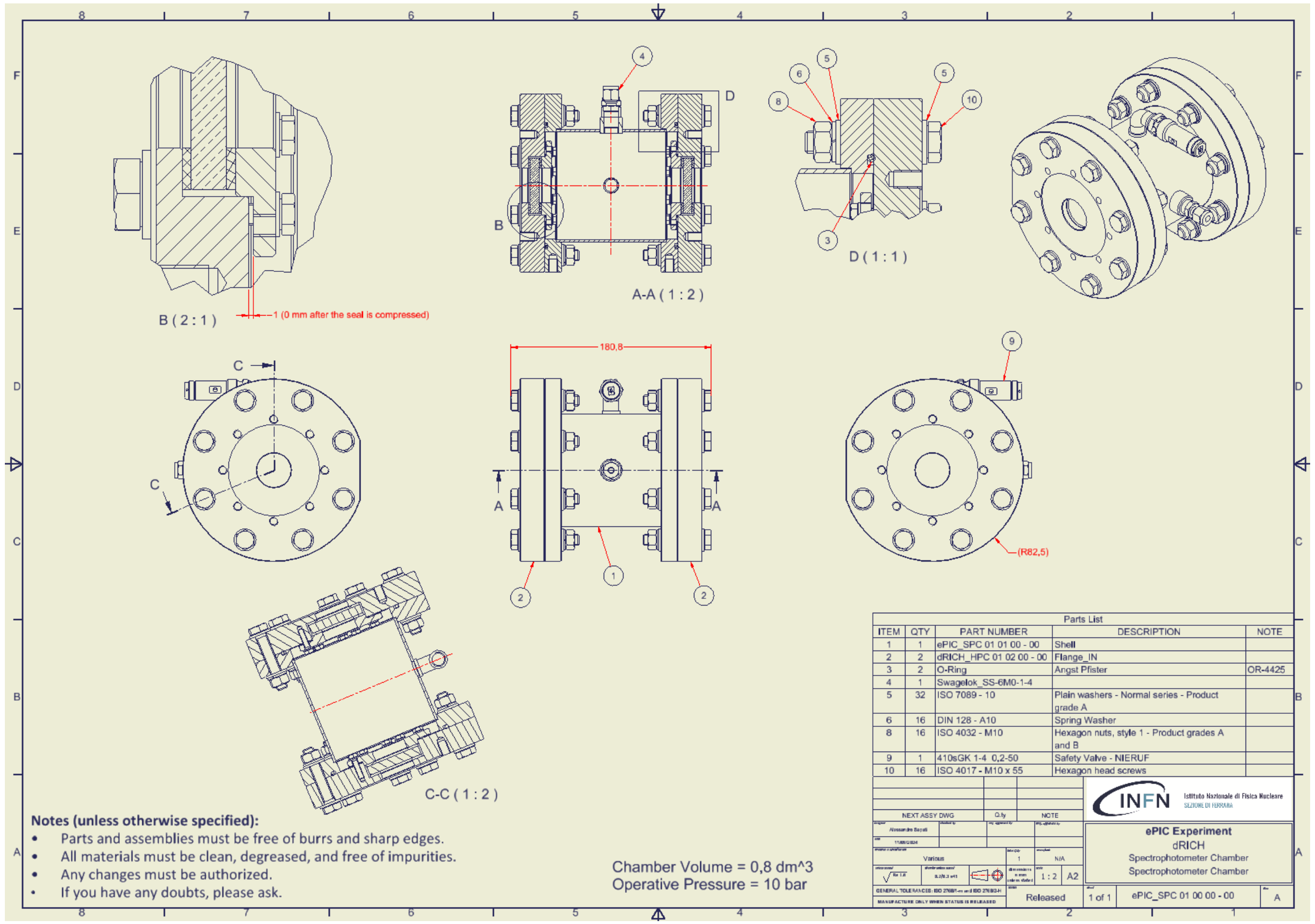
Status:

- The drawings are ready.
- The tender has been completed.
- Construction should start before the end of March 2025.

Spectrophotometer Chamber: target R&D

Design Pressure: 1,43 Mpa
Operative Pressure: 1 MPa



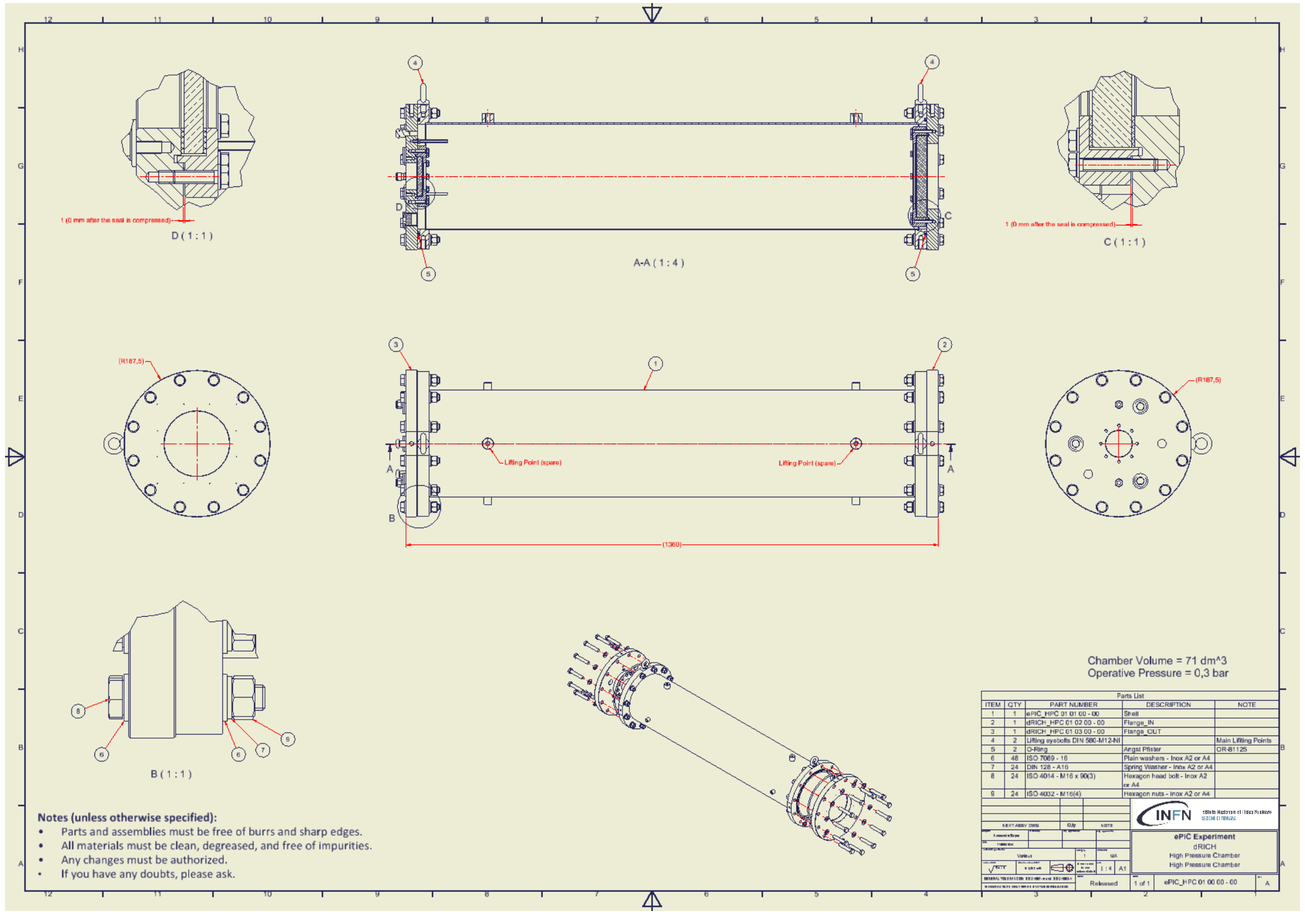


This chamber has been designed to study:

- Gas permeability of carbon fiber
- Gas transparency in the visible spectrum
- Gas-aerogel interactions

High Pressure Chamber: generic R&D

Design Pressure: 0,5 Mpa
Operative Pressure: 0,3 MPa

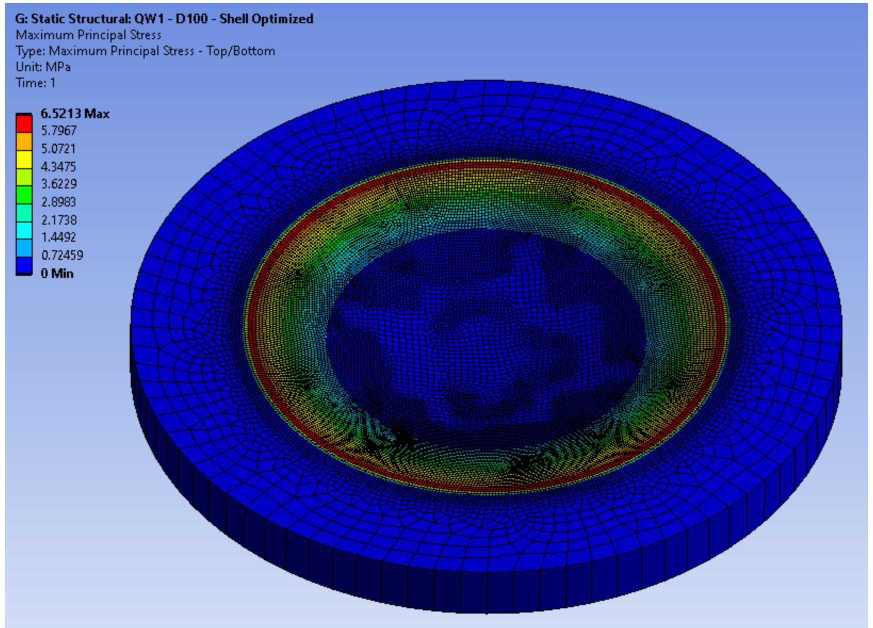


This chamber has been designed to study risk mitigation strategies for greenhouse gases.

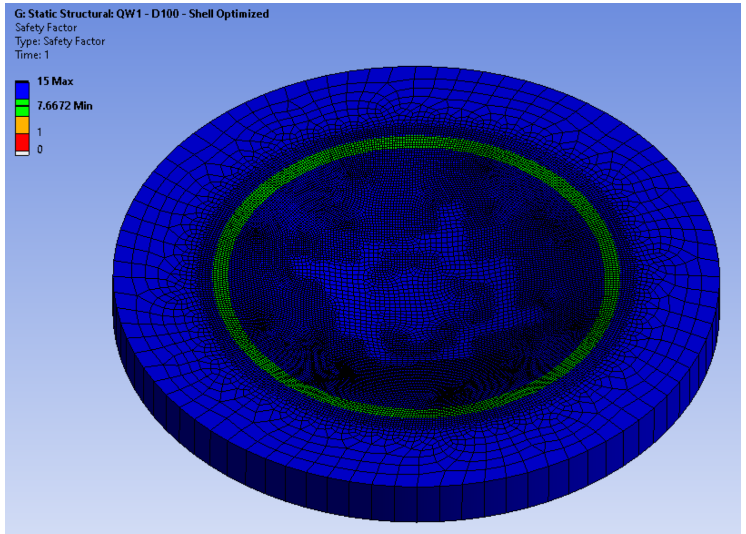
Quartz Window: stress&strain calculation - t_1=8 mm

- Thickness: **t_1=8 mm**;
- External diameter: D_1=100 mm
- Uniformly distributed (absolute) pressure over the entire surface (d_1=68mm): 0,5 MPa
- Constrains: Fixed along the edge surface

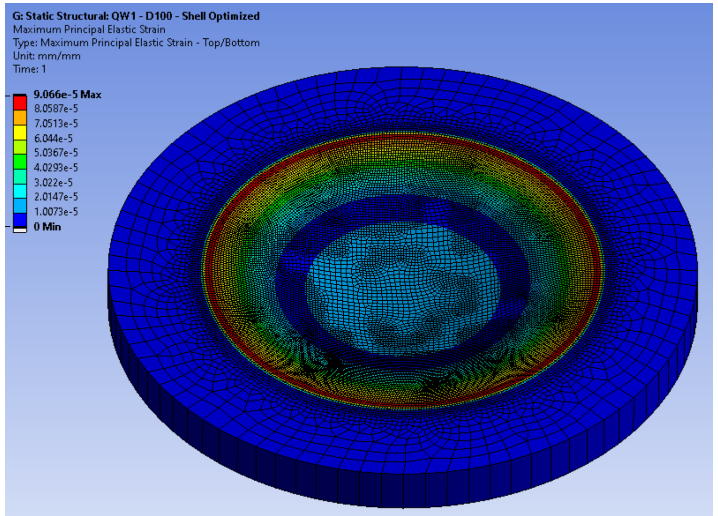
Maximum Principal Stress (S1)



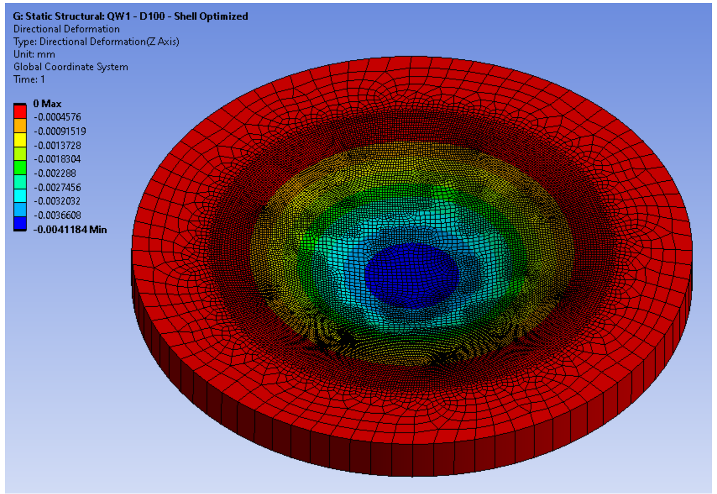
Safety Factor



Maximum Principal Strain



Deformation along Z Axis



- Maximum Principal Stress S1=6,5 MPa;
- Maximum Principal Strain = 0,00009
- Maximum Deformation along Z Axis = -0,004 mm
- Minimum Calculated Safety Factor SF_c = 7,6

$SF_c > 7$ → checked

Conclusions and NEXT Steps

- **Consolidation of the dRICH Mechanical Design**: refining and finalizing the mechanical design of the dRICH
- **Integration study of dRICH into the ePIC Apparatus:** fixing system, service integration……….
- **Study of the Extraction and Insertion System (Moving System):** design and optimization of the moving system used for the extraction and insertion of the dRICH detector within the ePIC apparatus
- **Structural Study of dRICH:** A detailed structural analysis of the dRICH detector will be conducted using Finite Element Method (FEM) simulations.

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