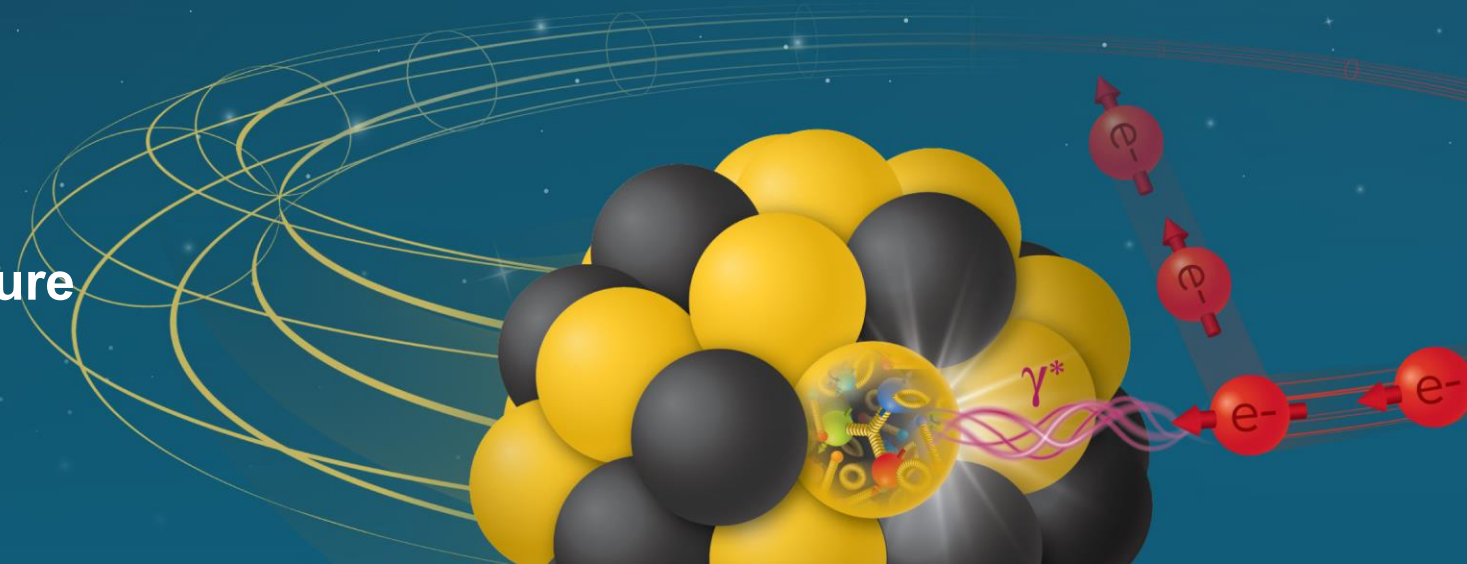
dRICH
Mechanical Design Status Report

Alessandro Saputi
Head of the Mechanical Engineering Group
INFN – Ferrara Division

PDR and Safety Review for ePIC
Integration, Installation and Infrastructure
Dec 8 & 9, 2025

Electron-Ion Collider



About Me

Alessandro Saputi

Current Project Role in ePIC

L5 Manager, Responsible for dRICH Mechanics, WBS 6.10.04.03 (Design, Integration, and Installation)

Relevant Experience

- 30 years of engineering experience in detector design
- 15+ years at CERN (Engineering Department and Experimental Physics Department)
- Design, analysis, and construction work on ATLAS, LHCb, Mu2e, DUNE, and several other projects

Highest Degree

Master's degree in Mechanical Engineering from "La Sapienza" University of Rome

Organization of the dRICH Mechanical Engineering Team

6.10.04.03 dRICH: Mechanics

- **Michele Melchiorri (INFN-FE):** *Mechanical Design*
- **Federico Evangelisti (INFN-FE):** *Mechanical Design*
- **Alex Eslinger (JLAB):** *Mechanical Design*
- **Stefano Squerzanti (INFN-FE):** *Mechanical Design, CMM measurement and quality control*
- **Francesco Noto (INFN-LNS):** *Mechanical Design*
- **Luca Barion (INFN-FE):** *Detector Design*
- **Carlo Mingioni (INFN-TO):** *Thermal Design*
- **Marco Nenni (INFN-TO):** *Thermal Design*
- **Michele Cavallina (INFN-FE):** *Mechanical Workshop*
- **Andrea Forlani (INFN-FE):** *Mechanical Workshop*
- **Alessandro Saputi (INFN-FE):** *Responsible for dRICH Mechanics*

Outline

dRICH Mechanical Design

- Main requirements: position, clearance and envelope
- Components: vessel, detector box….

dRICH Integration

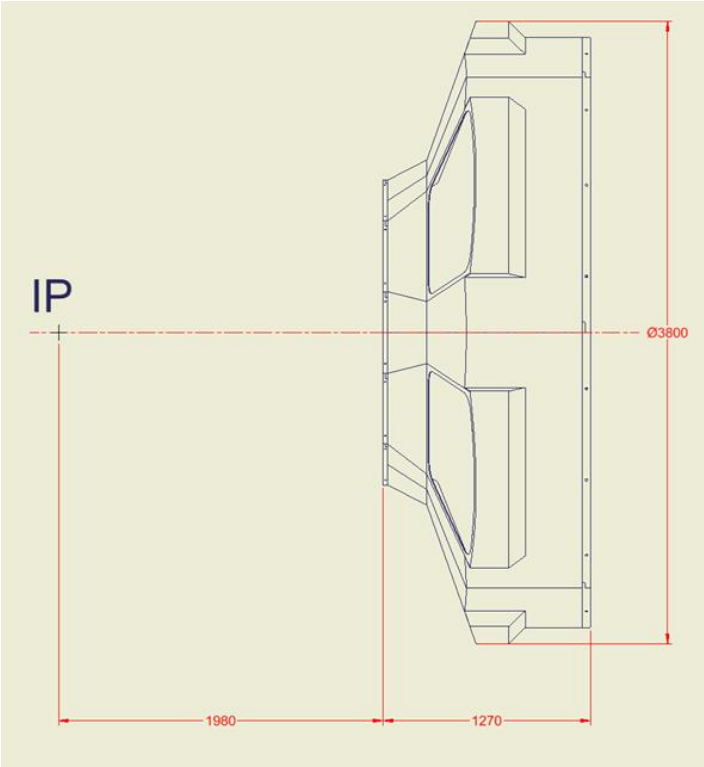
- Interface with ECAL structure
- Handling, Installation and moving system
- Access for ECAL maintenance

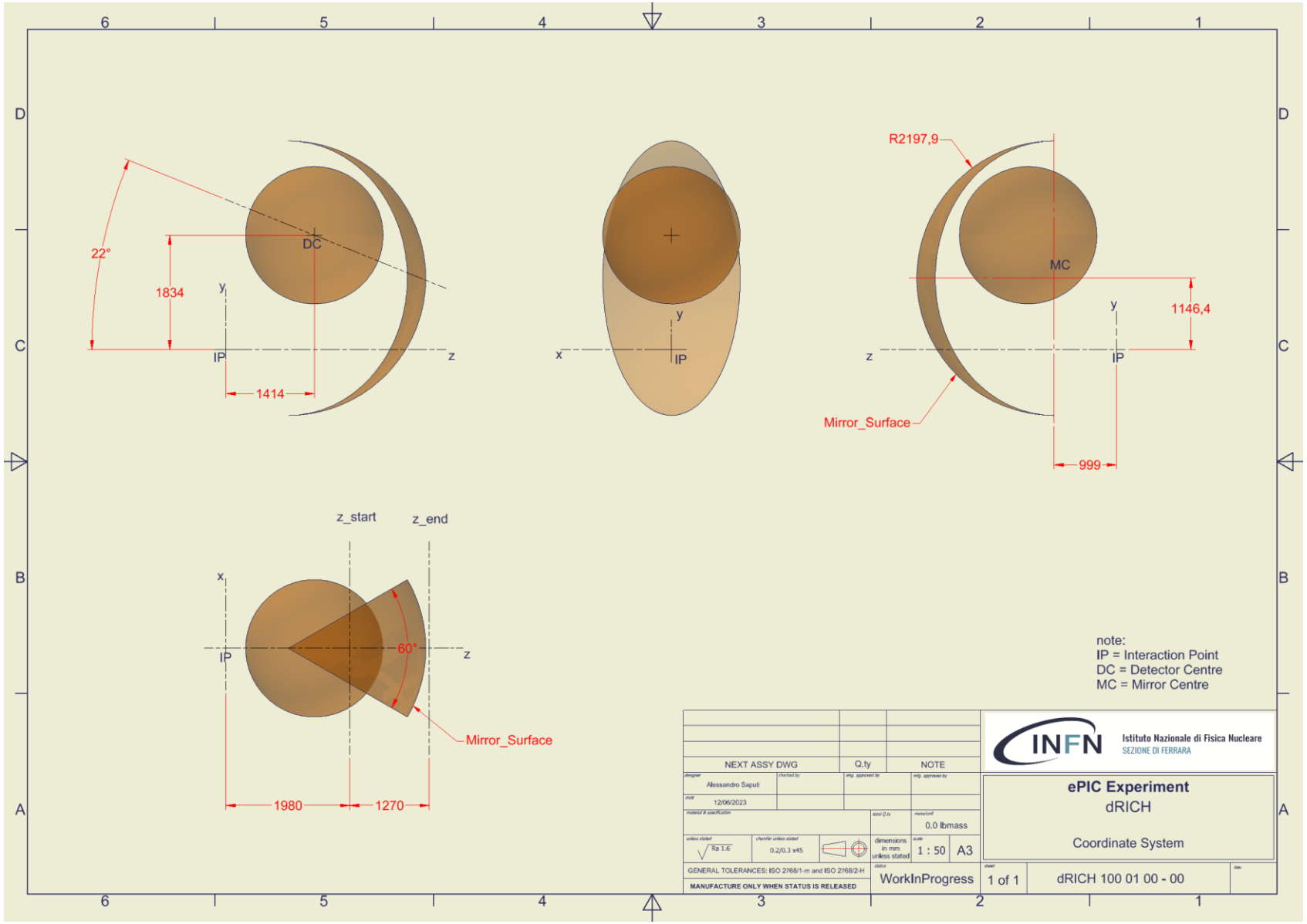
Conclusions and next steps

- Design Status
- Next Steps

dRICH: main requirements

- **Overall envelope diameter**: Ø3800 mm
- **Overall envelope length**: 1270 mm
- **Operating pressure**: from 3 to 10 mbar
- **Operating temperature**: 22 °C
- **Gas mixture**: C_2F_6 or Nitrogen

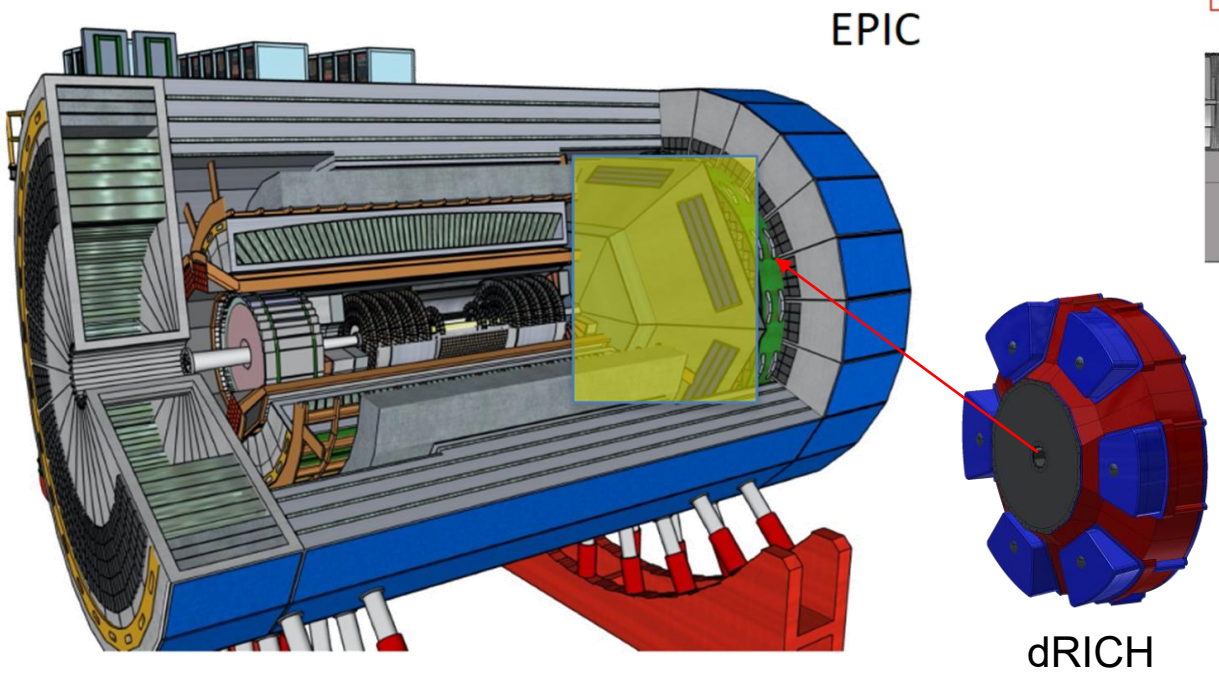


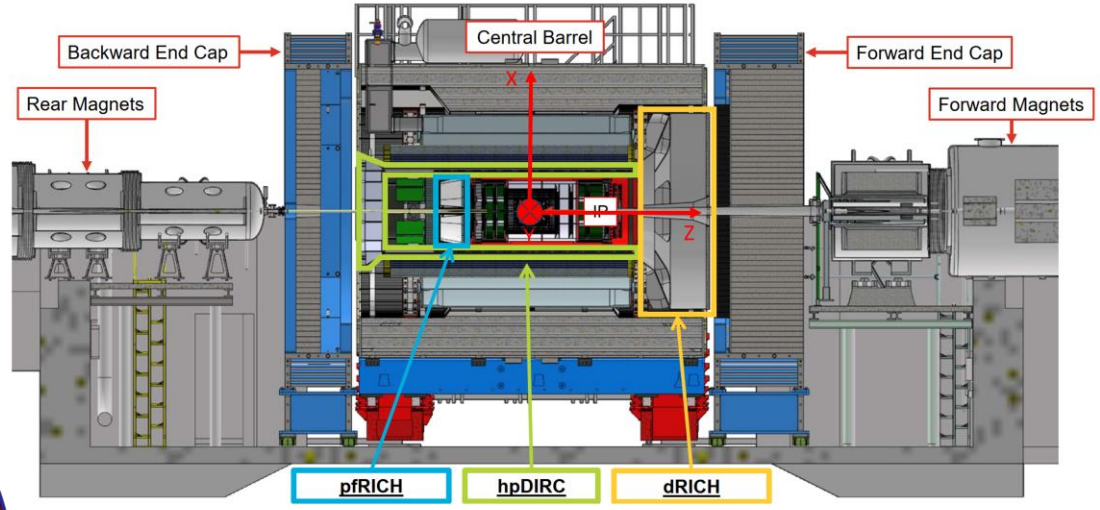


dRICH - mechanical structure : main requirements

It must:

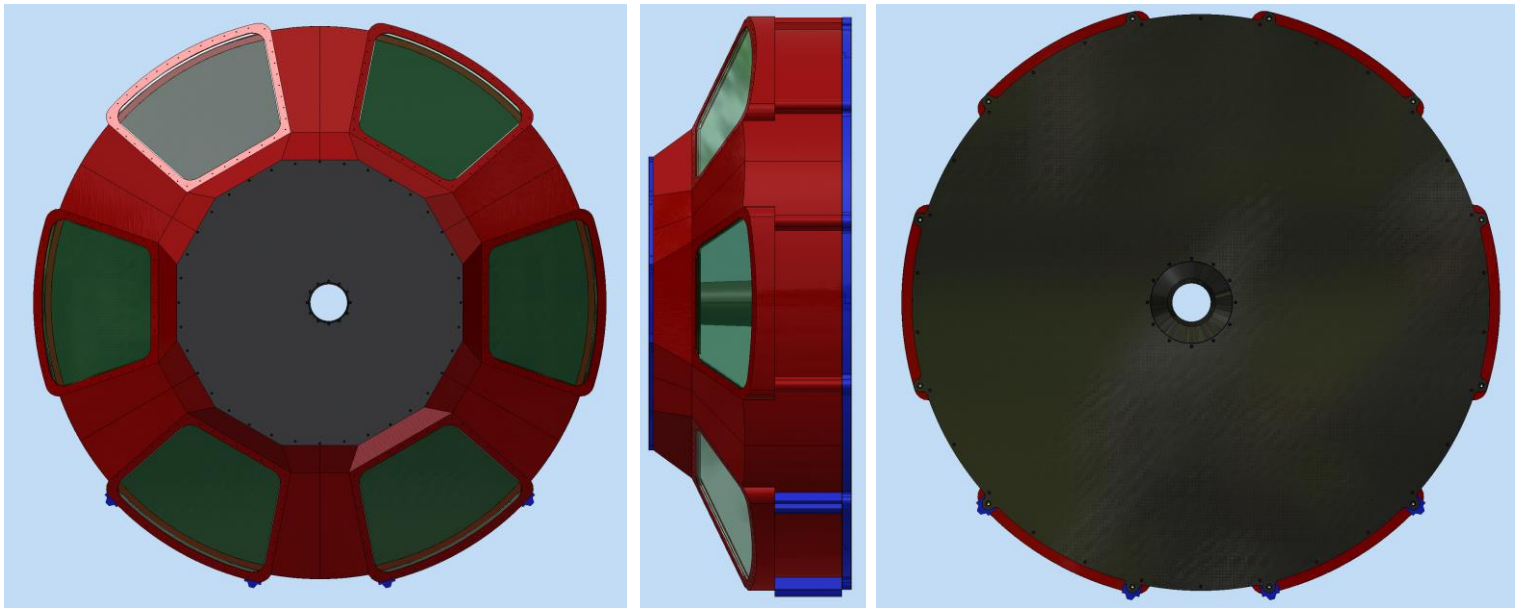
- Remain light-tight to avoid external interference.
- Stay structurally stable under the magnetic field.
- Withstand from 3 to 10 mbar pressure without affecting mirror alignment.
- Use minimal material, within the ePIC acceptance limits.

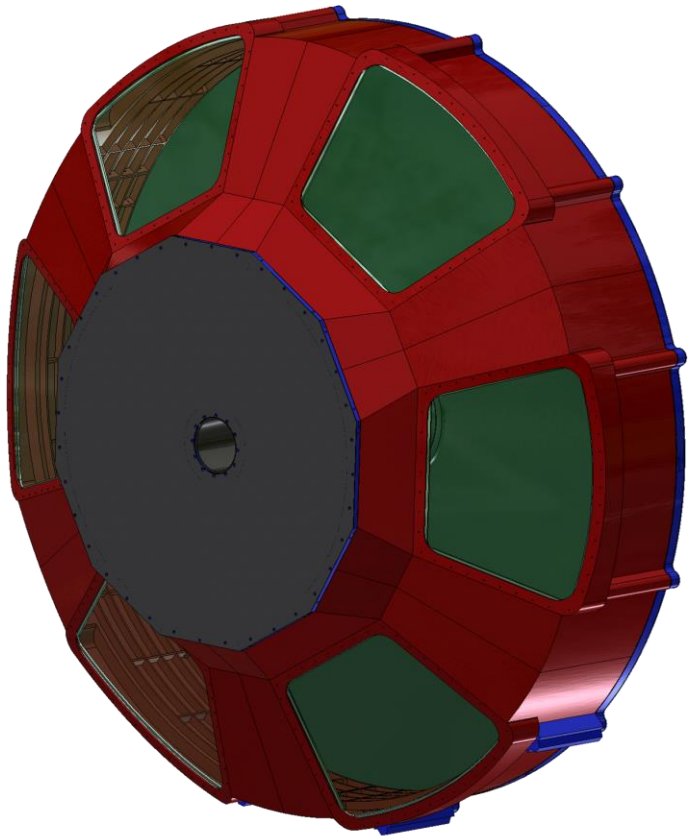




dRICH Gas Box: mechanical preliminary design

Front view | Side view | Back view

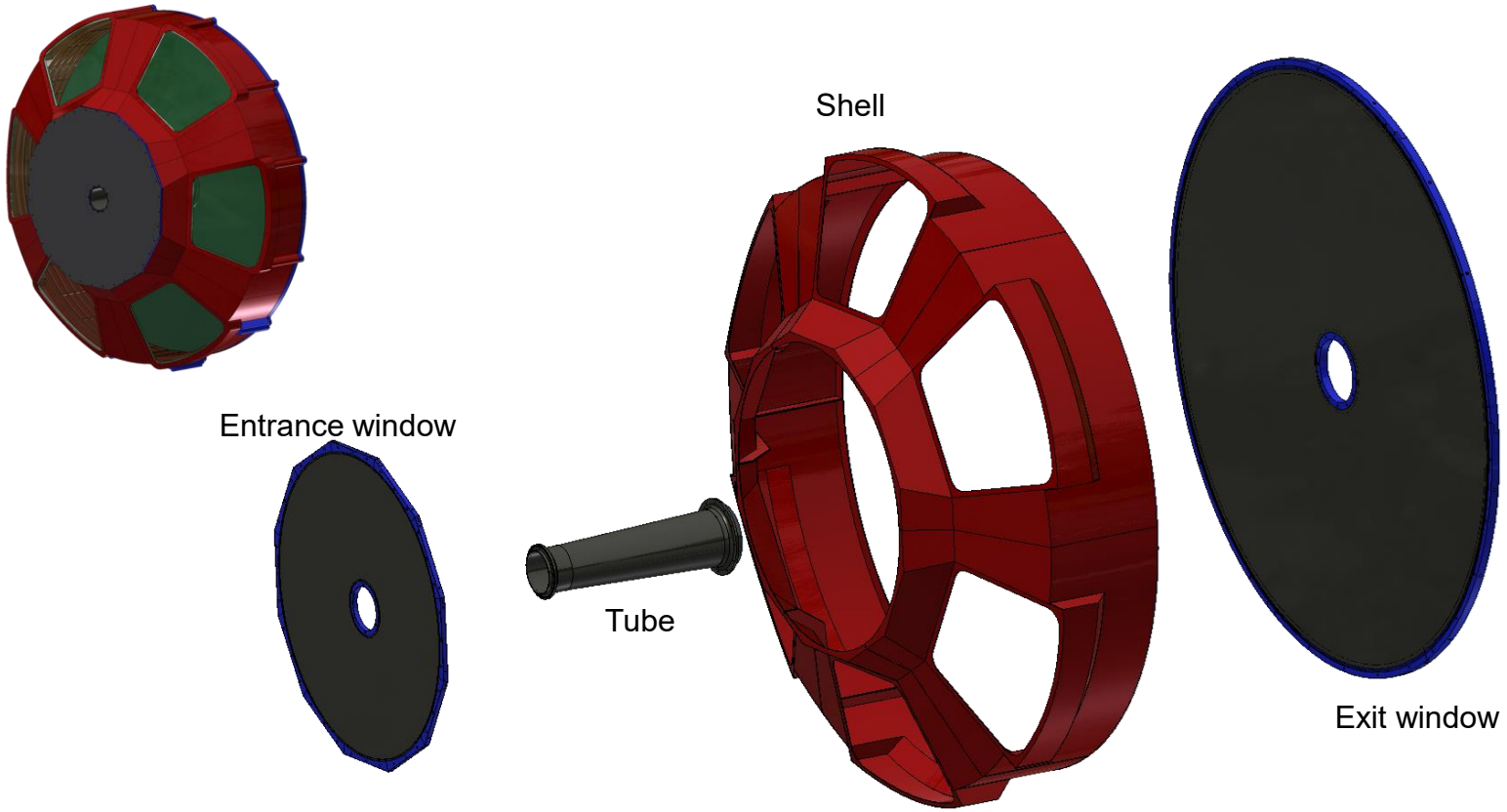


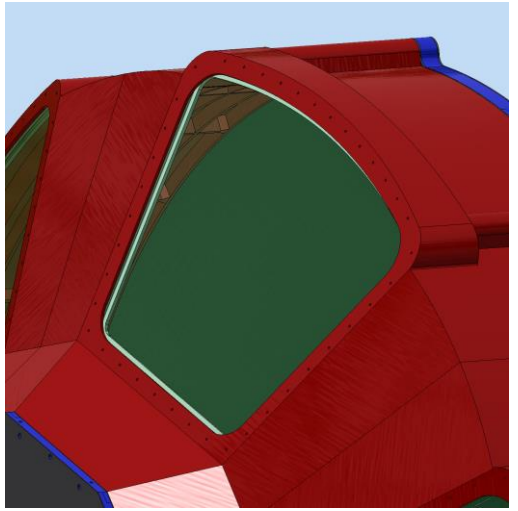


- Overall envelope diameter: Ø3800 mm
- Overall envelope length: 1270 mm
- Weight: ~2100 kg

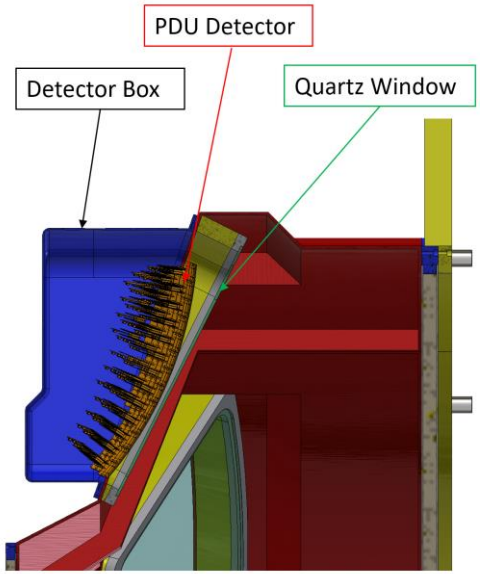
- The gas box: a cylindrical structure made of carbon fiber, housing mirrors and aerogel tiles.
- Carbon fiber: chosen for its combination of lightness and stiffness.

dRICH Gas Box: mechanical structure





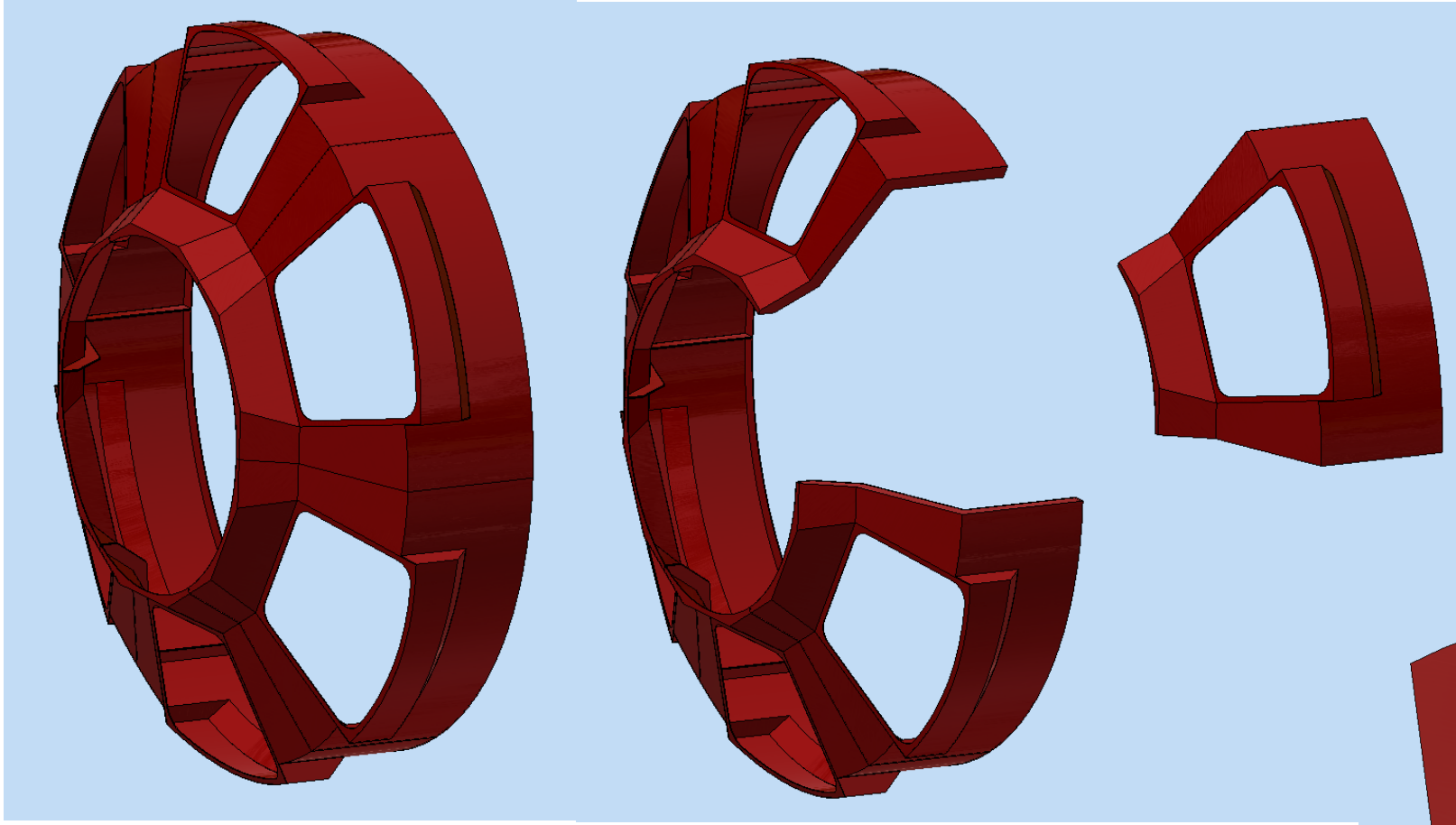
Quartz window (outside view)



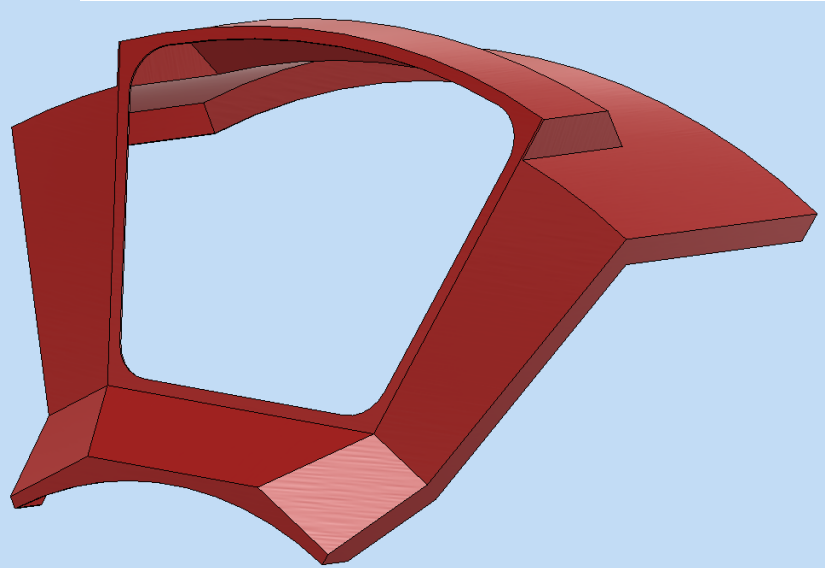
PDUs

- The mechanical structure (gas box) consists of six main components: the shell, the entrance and exit windows, the central tube, the detector boxes, and the quartz windows.
- All components forming the gas box are bolted together.
- Gas and light tightness are ensured by O-ring and gasket sealing.

dRICH: shell

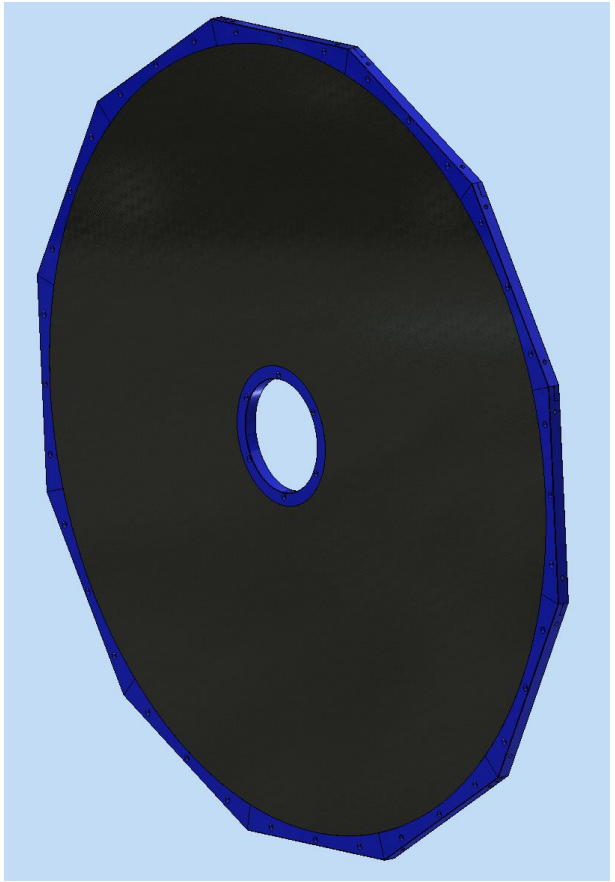


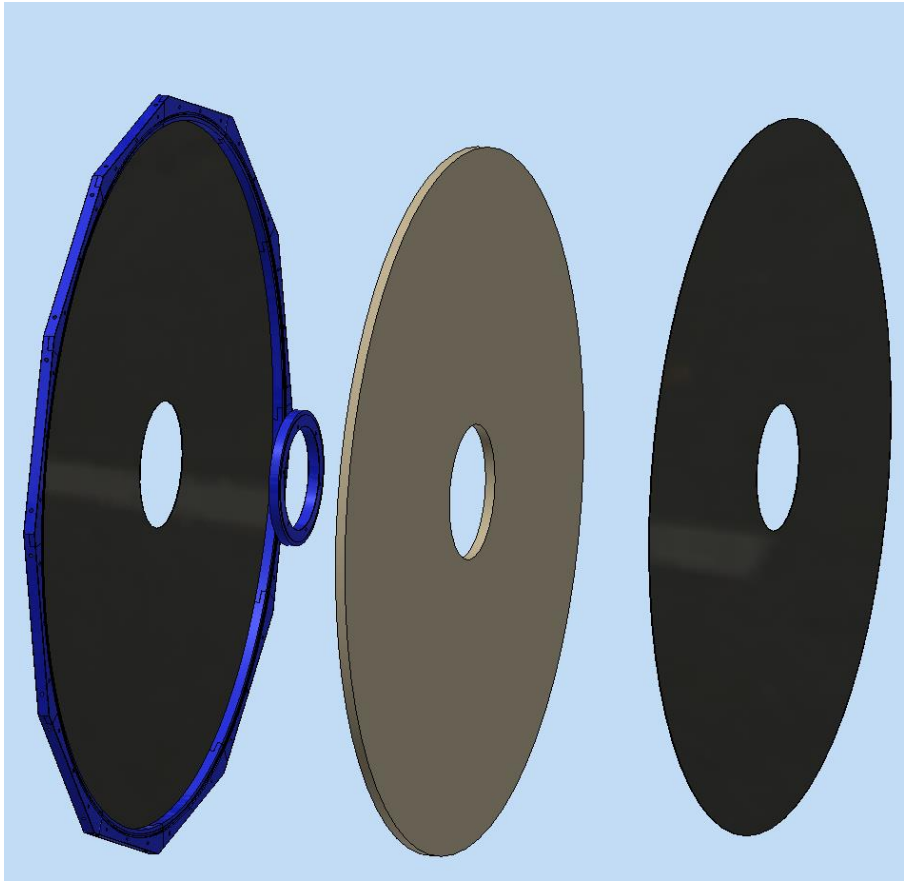
The shell will be made of an 10 mm thick carbon fibre epoxy composite. Each laminate will consist of six layers of balanced weave fabric, with fibres oriented at 0°/90° in one layer and ±45° in the adjacent layer.

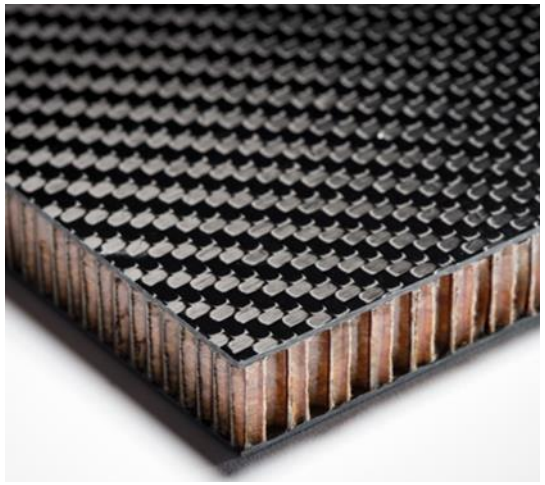


The shell is composed of six parts that are bolted and glued together to ensure structural integrity and the gas/light tightness.

dRICH: entrance windows

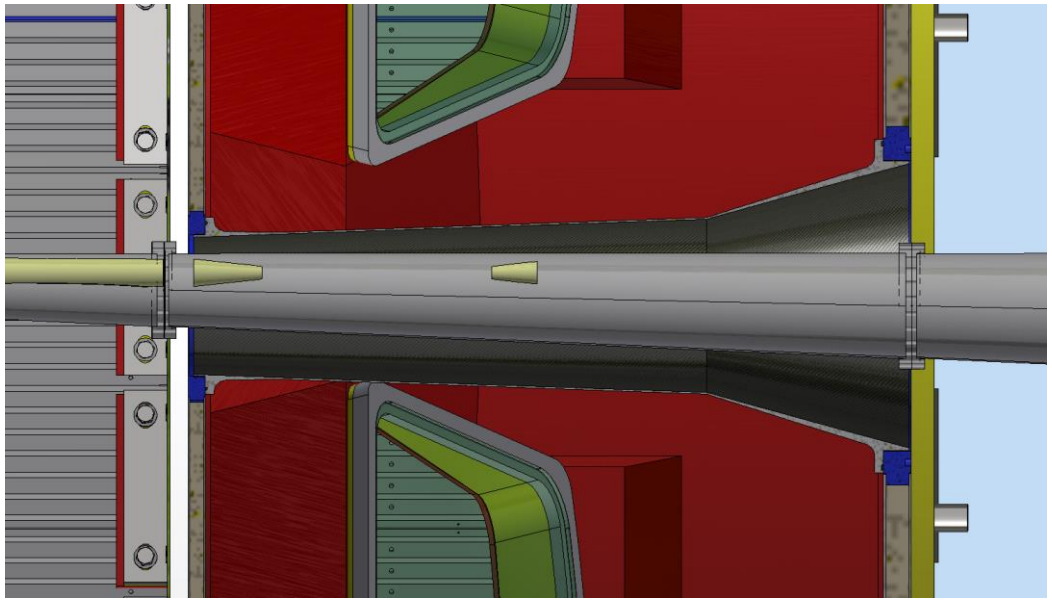


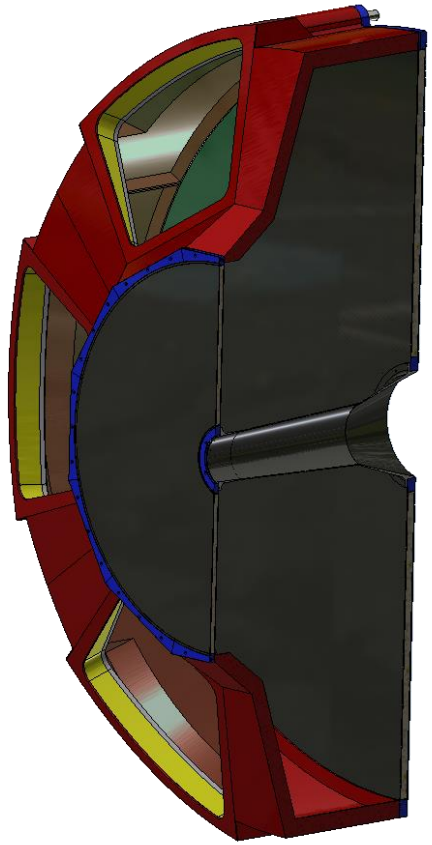




- The Entrance Window will be a sandwich panel consisting of two carbon fiber-reinforced epoxy skins, each 2.28 mm thick, separated by a 25 mm thick Nomex honeycomb core. Each skin is composed of six layers of balanced weave laminate, with fibers oriented at 0°/90° in one layer and overlapped with ±45°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

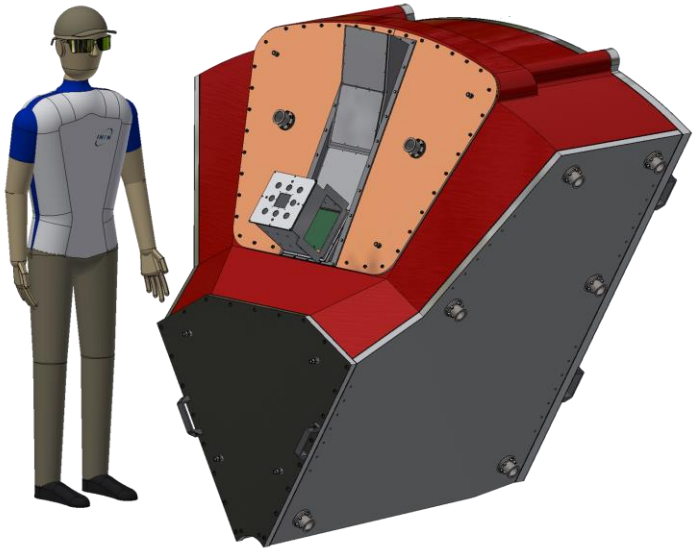
dRICH: central tube

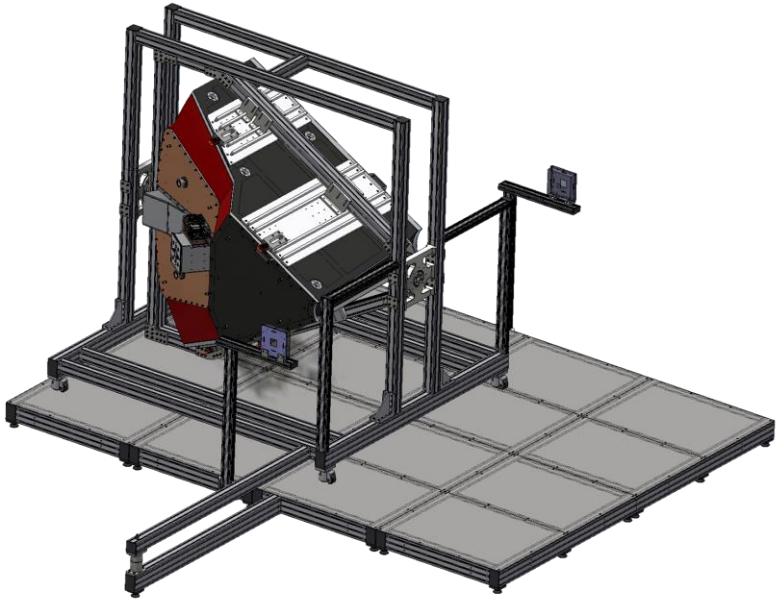


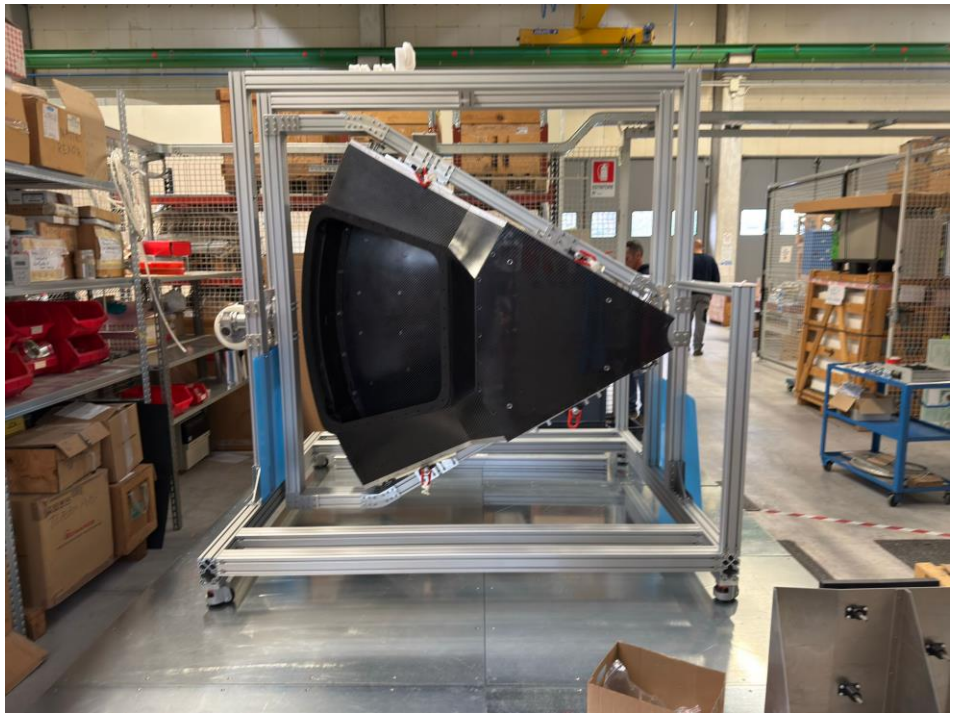


- Both the entrance and exit windows are connected by the central tube. The central tube will be made of a 5 mm thick carbon fiber epoxy composite and will have an inside diameter of 242 mm at the entrance window, tapering to 500 mm at the exit window.
- This design ensures a radial separation (10 mm minimum) between the vacuum chamber and the central tube.

dRICH: prototype







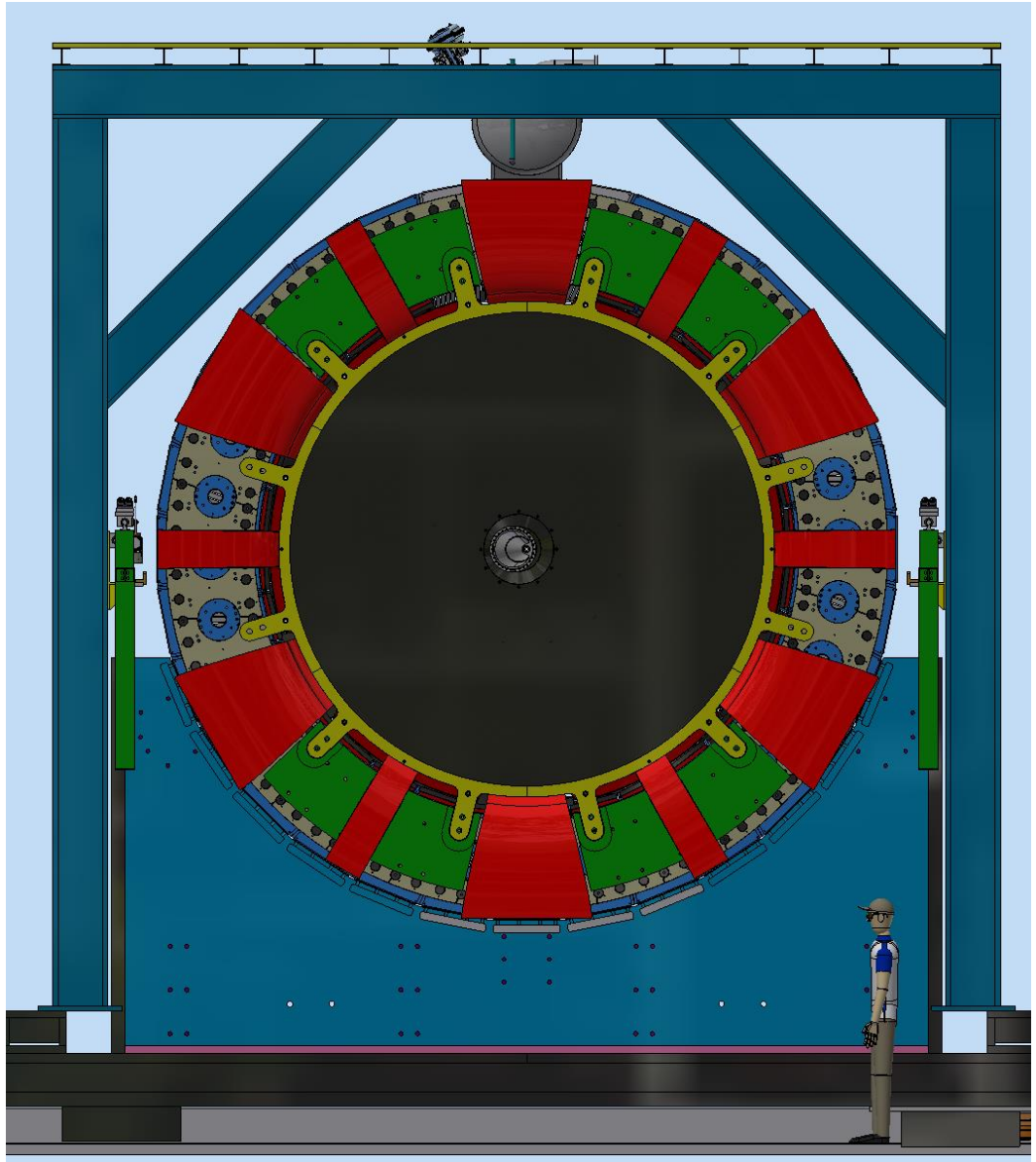
Building a **full-scale (1:1)** prototype representing one-sixth of the complete dRICH detector.

Purposes:

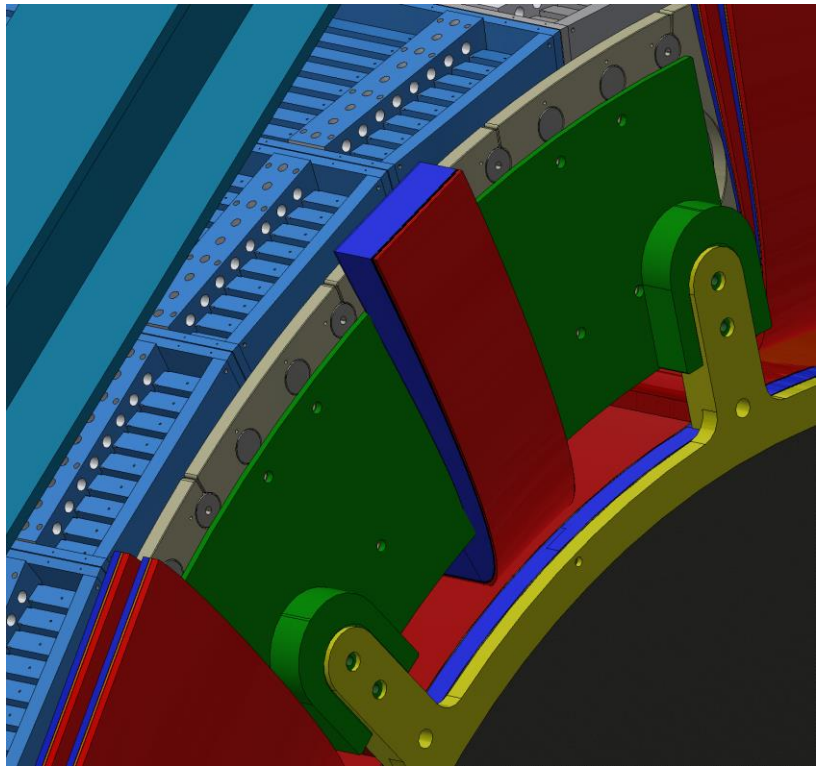
- **Validate the preliminary design**
- **Test beam:** study and optimize the performance of dRICH components

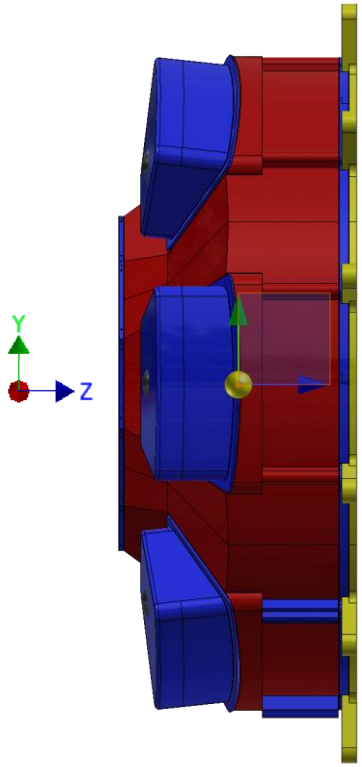
INTEGRATION and INSTALLATION

dRICH: integration with ePIC apparatus



- dRICH (yellow arms) bolted to green plates;
- Green plates bolted to the calorimeter structure (dog bone);
- Two-step mounting ensures solid mechanical support.



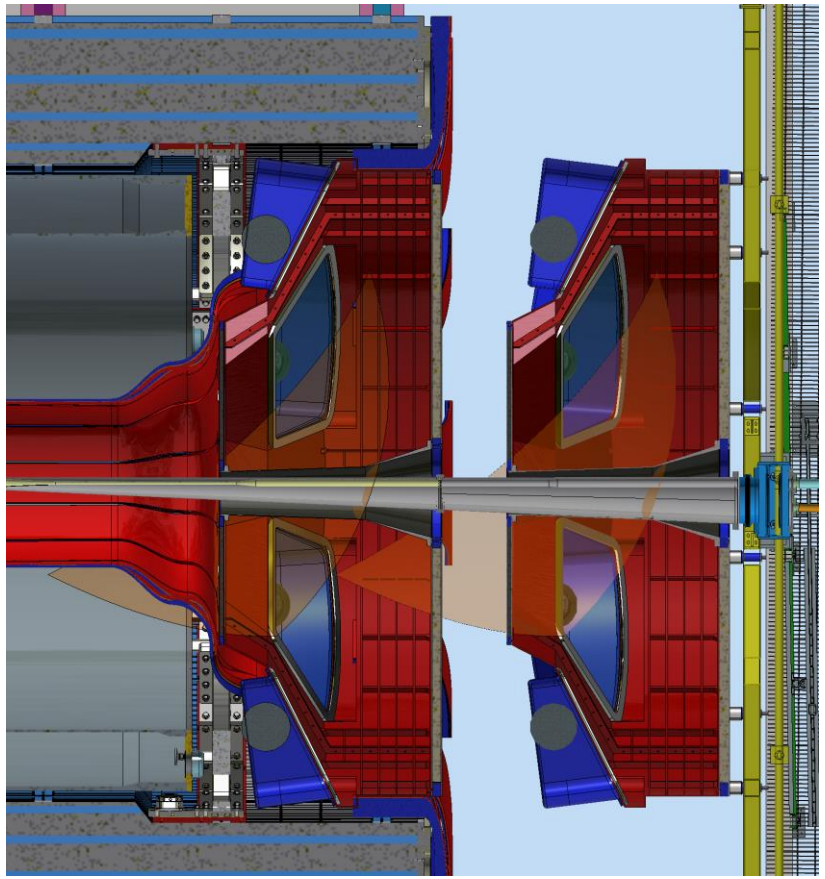


Maximum Y-direction deflection of the dRICH structure under design load: **0.1–0.5 mm**

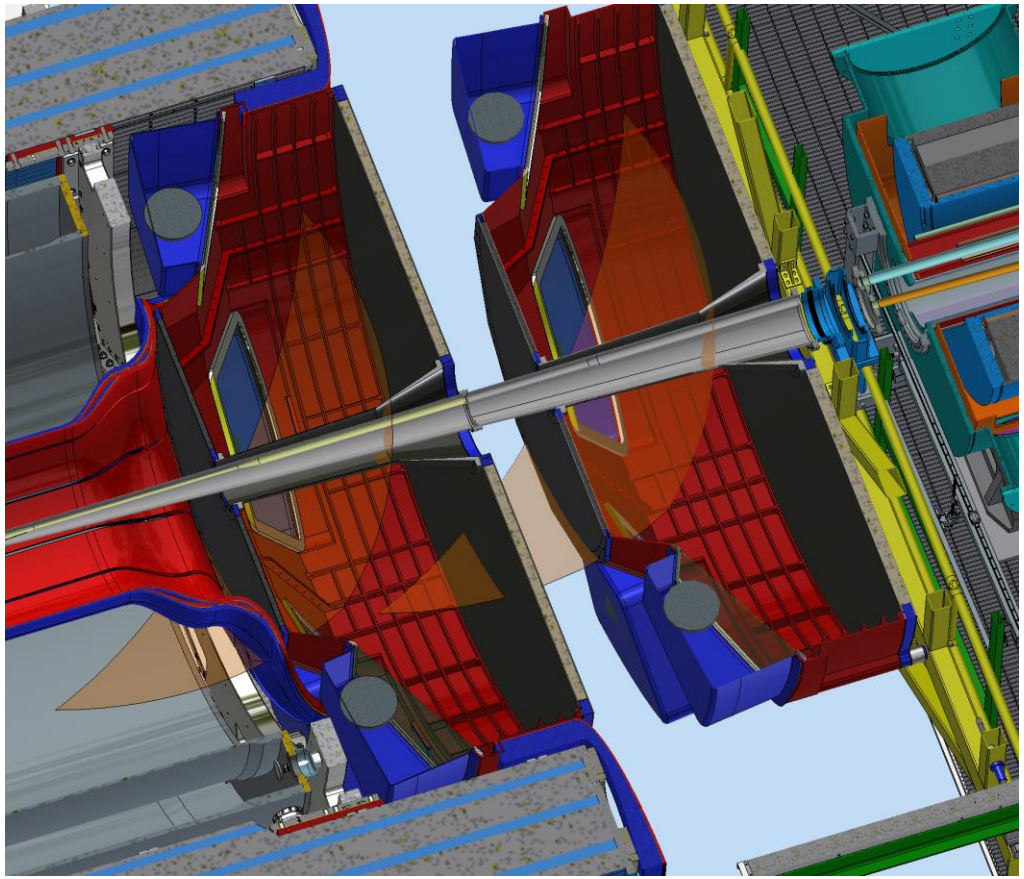
(analytically estimated; FEA analysis in progress)

dRICH: Clearance & Movement

Closed

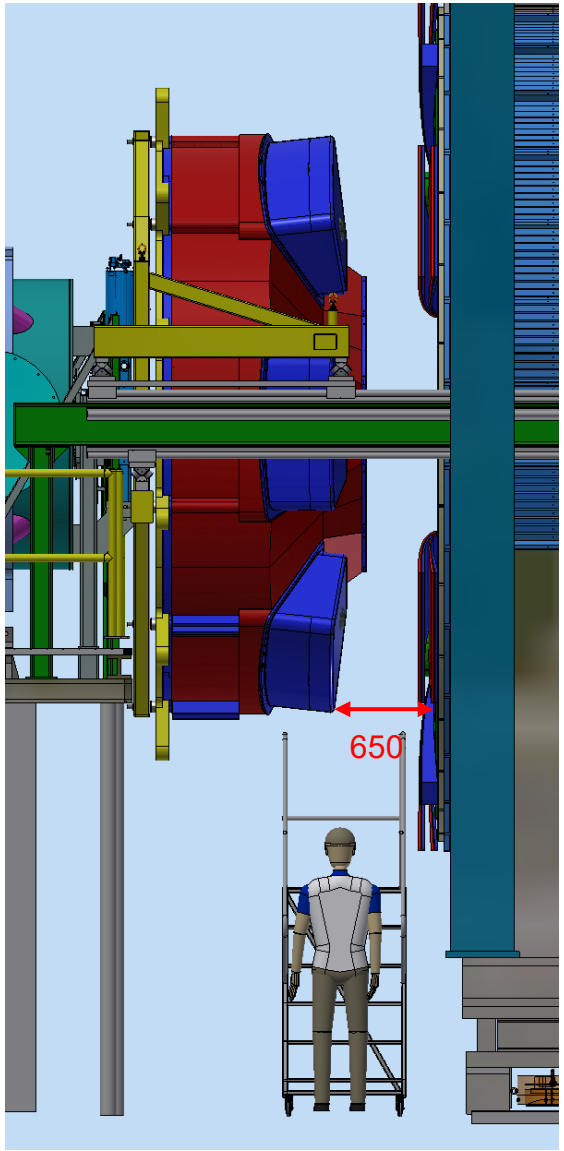


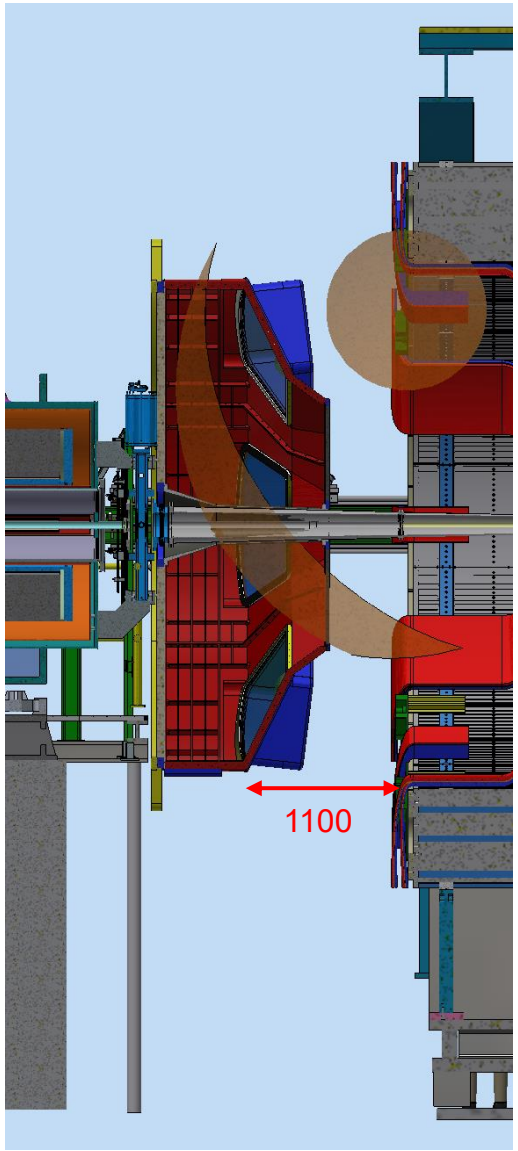
Open

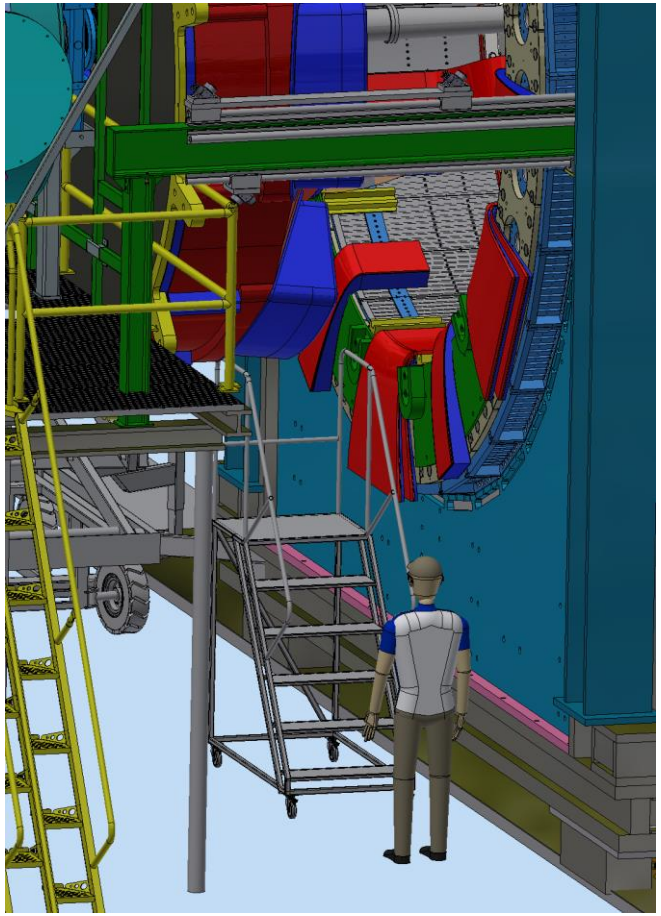


- No interference with the beam pipe (ensure at least 10 mm clearance) or with ECAL components
- Entrance/exit holes and central tube shape can be optimized

dRICH: access between dRich and ECAL (open position)

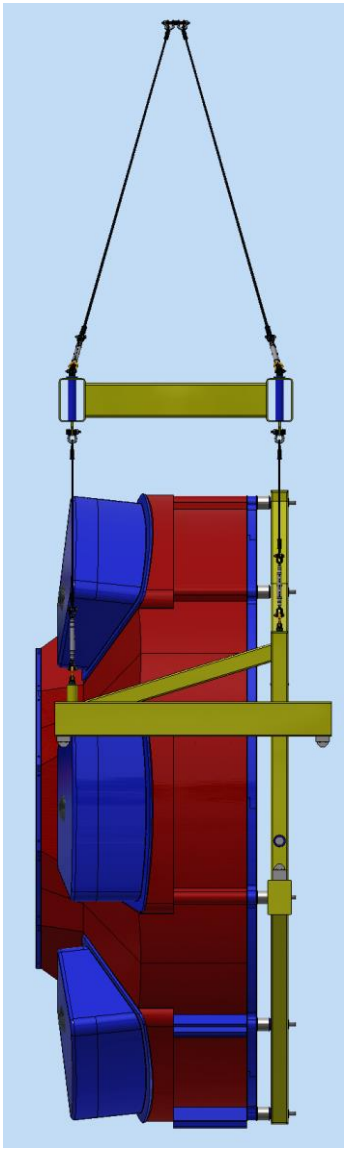


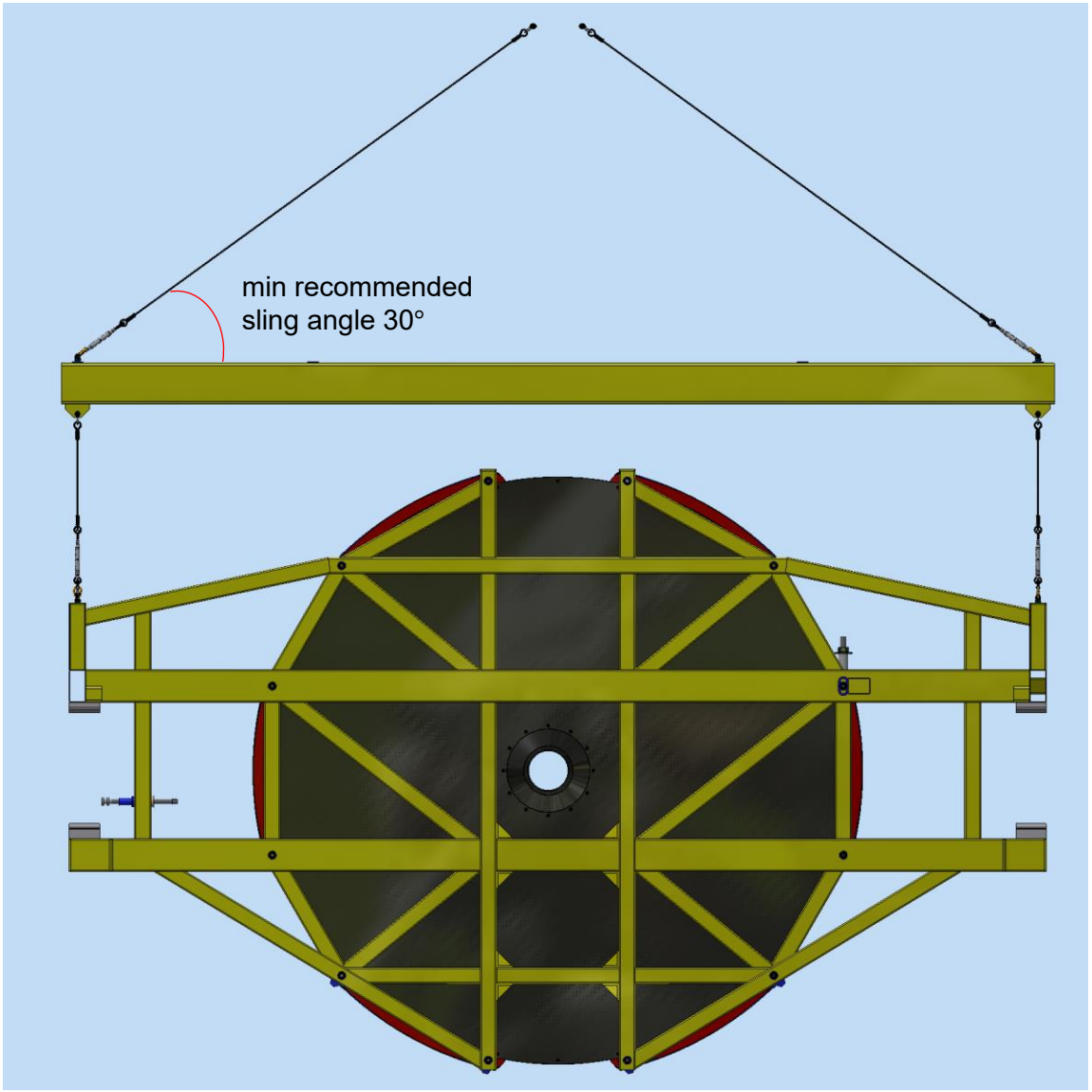


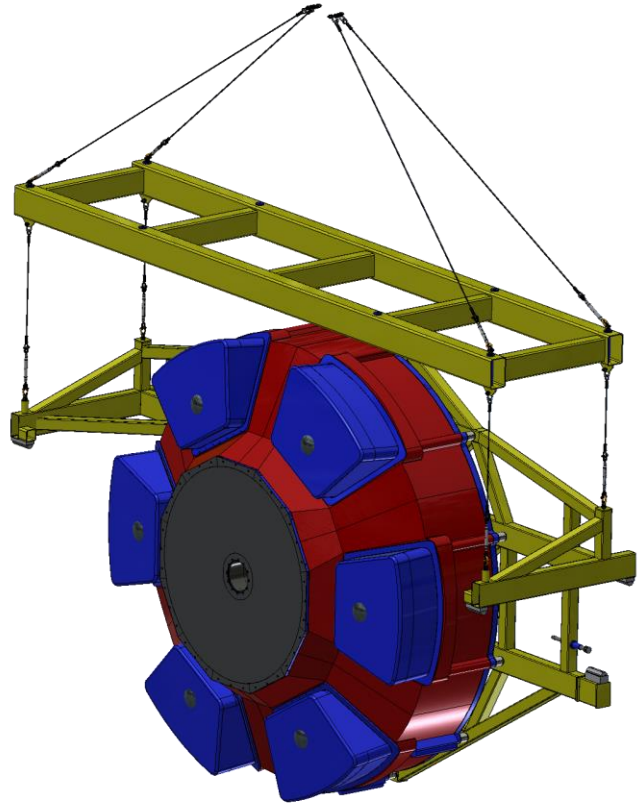


- Space checked for maintenance access
- ~650 mm minimum clearance available
- ~1100 mm maximum clearance available
- Enough room for safe entry and work

dRICH: lifting&handling tools

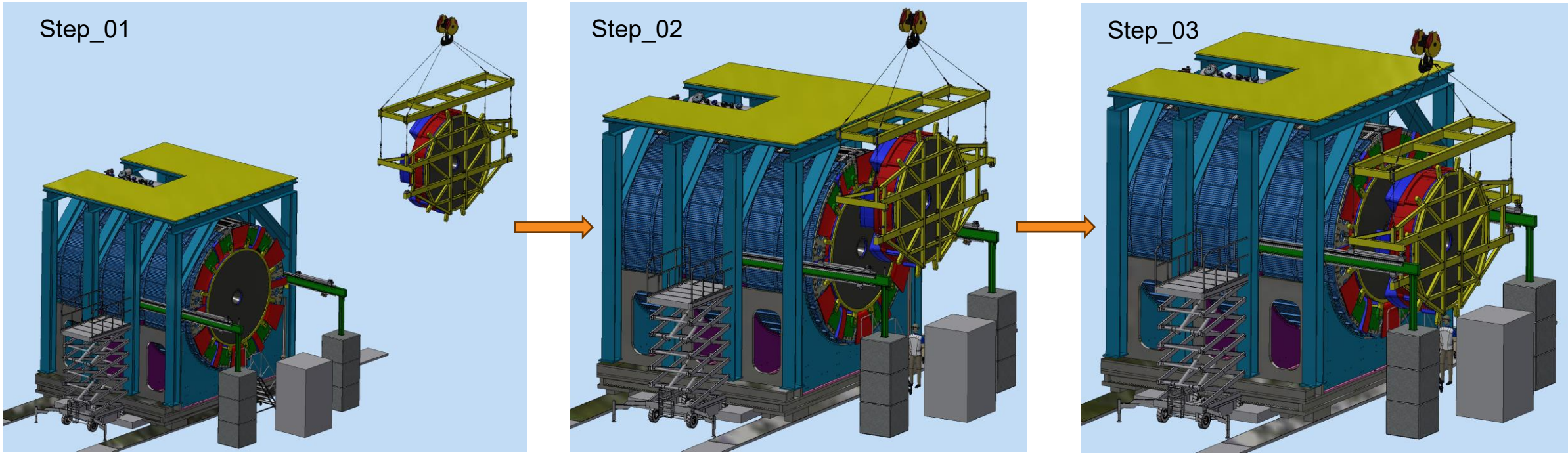


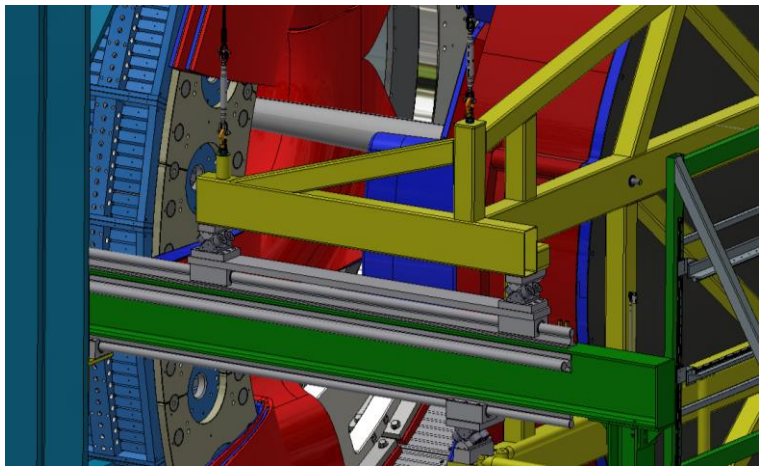


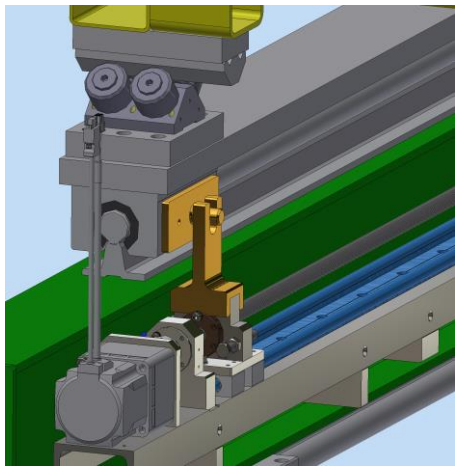


- Safe dRICH handling & installation concept
- Preliminary design for access and maintenance
- Tools under study: spreader frame + ECAL support frame

dRICH: handling, installation, and positioning (AH)

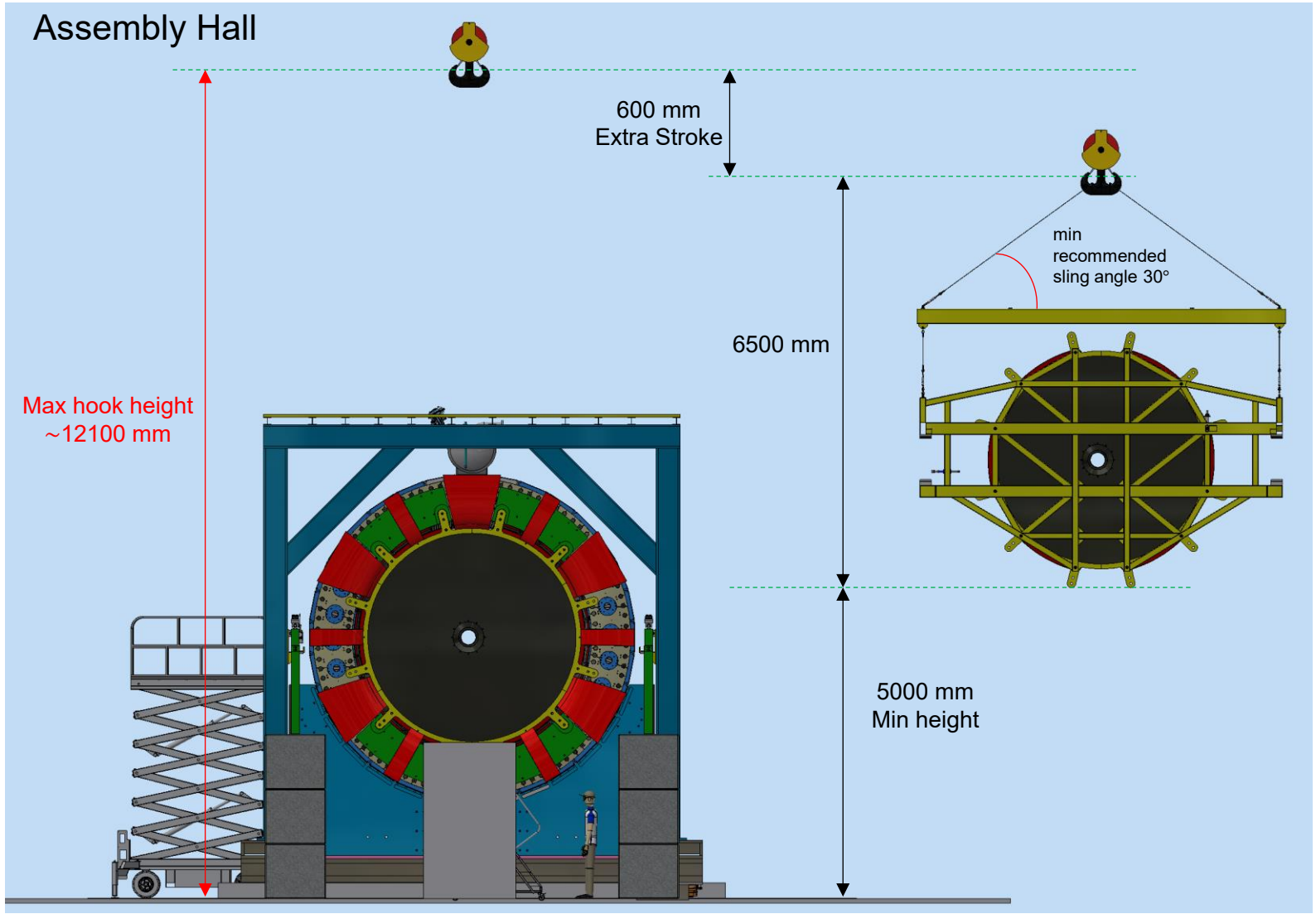


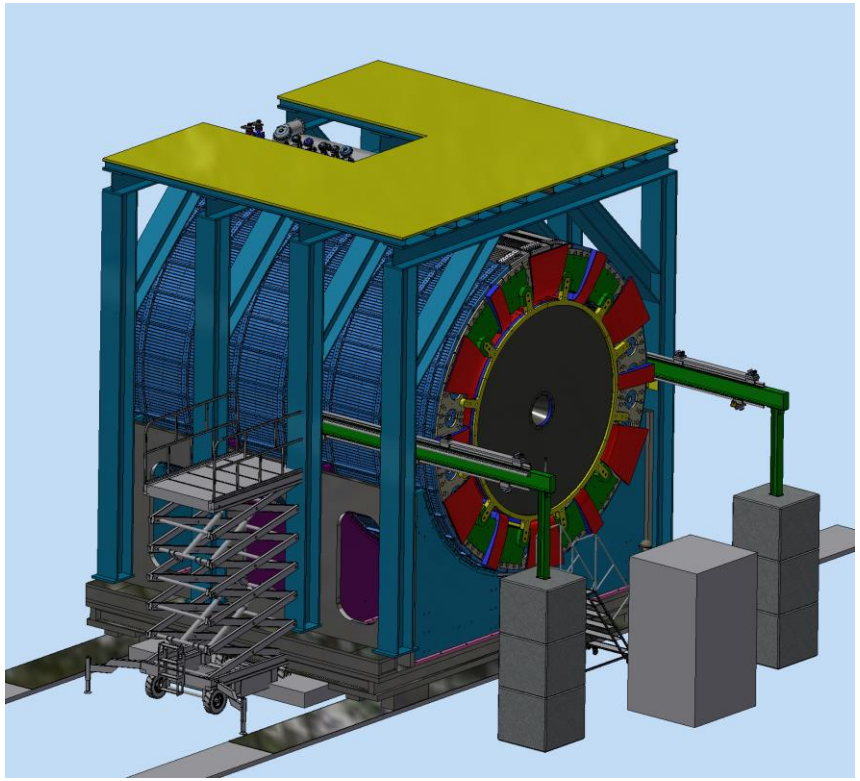


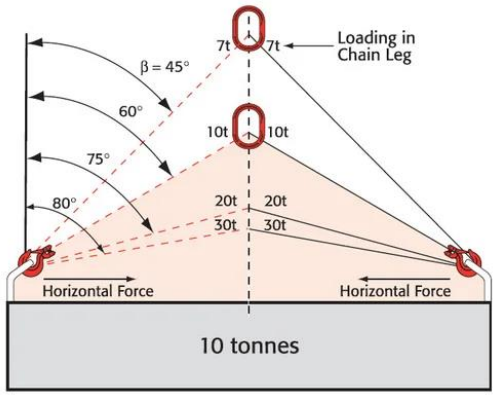


- dRICH moved from assembling workbenches to ePIC Detector using dedicated tools
- Aligned and seated on rails of ECAL support structure
- Final motion achieved with ball screw system for smooth, controlled movement and minimal shock

dRICH: handling inside Assembly Hall for installation

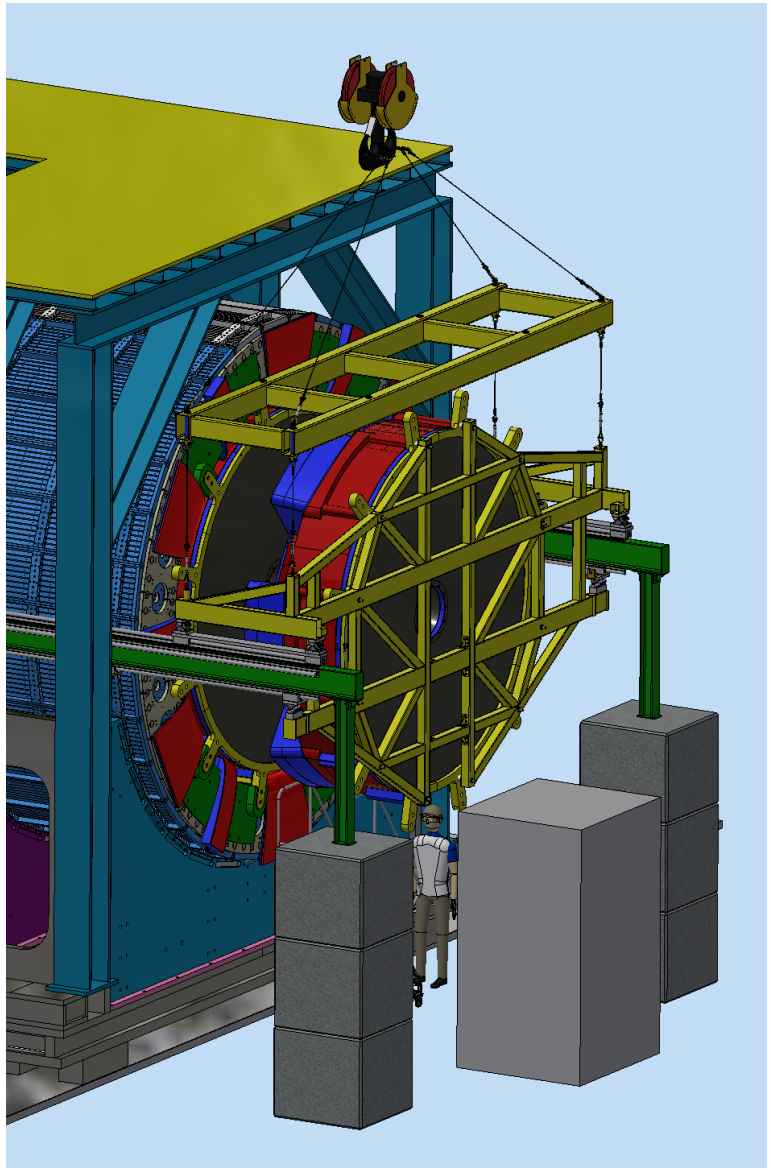


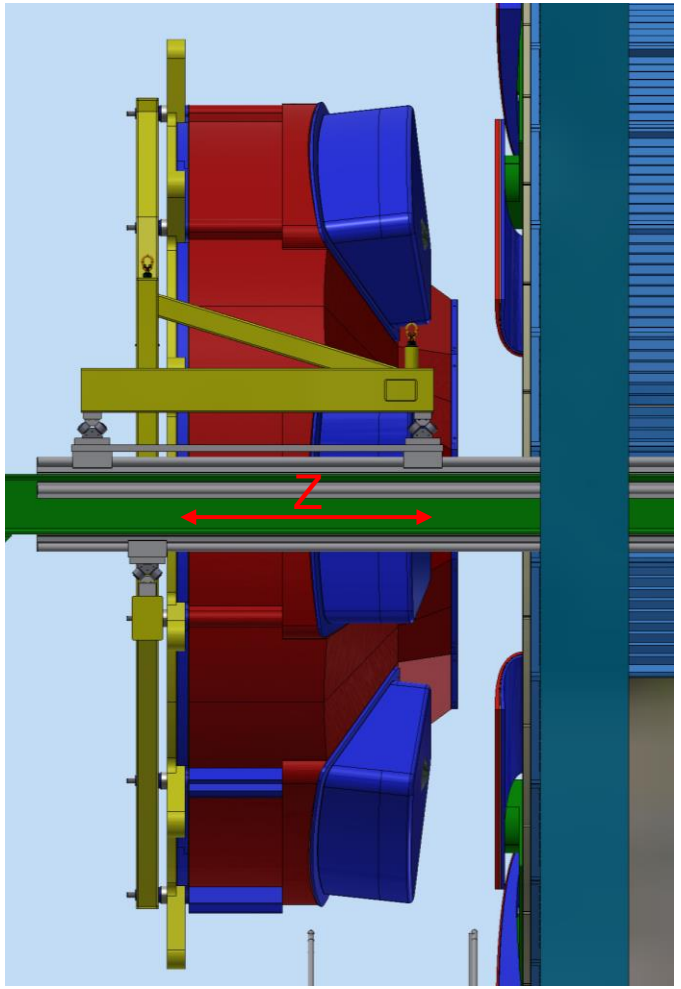


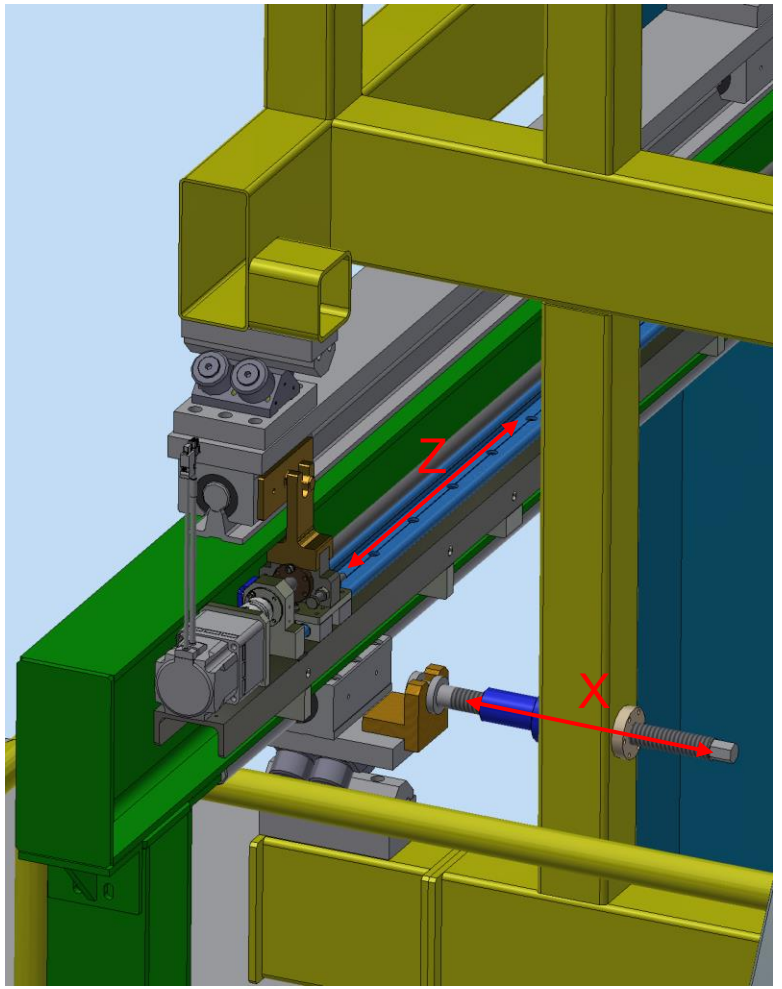


- Crane room enough to lift dRICH directly over rails
- Both left and right rails pulled out

dRICH: extraction/insertion (yellow frame functionality)

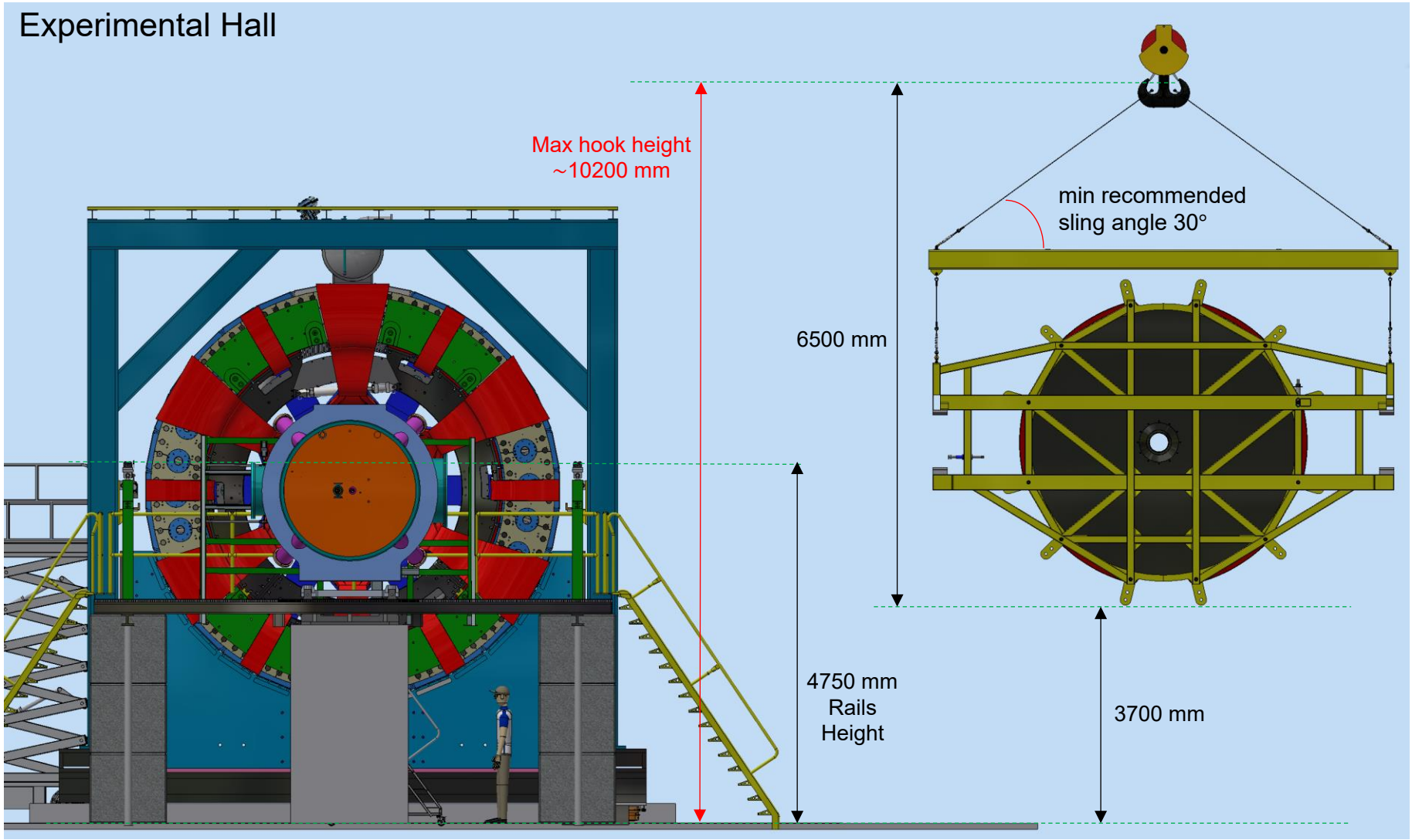


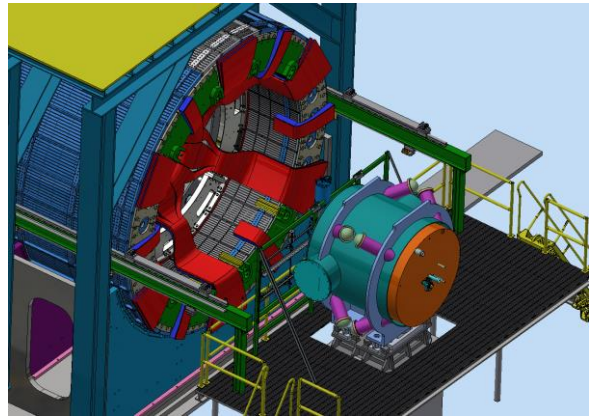


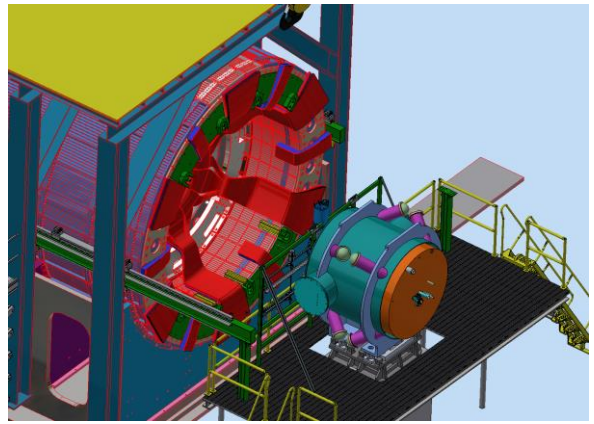


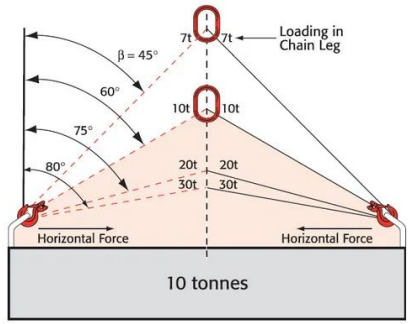
- Enables dRICH movement along and perpendicular to experiment axis
- Allows fine positioning during installation
- Perpendicular movement avoids collisions with the beam pipe

dRICH: handling inside Exp. Hall for maintenance



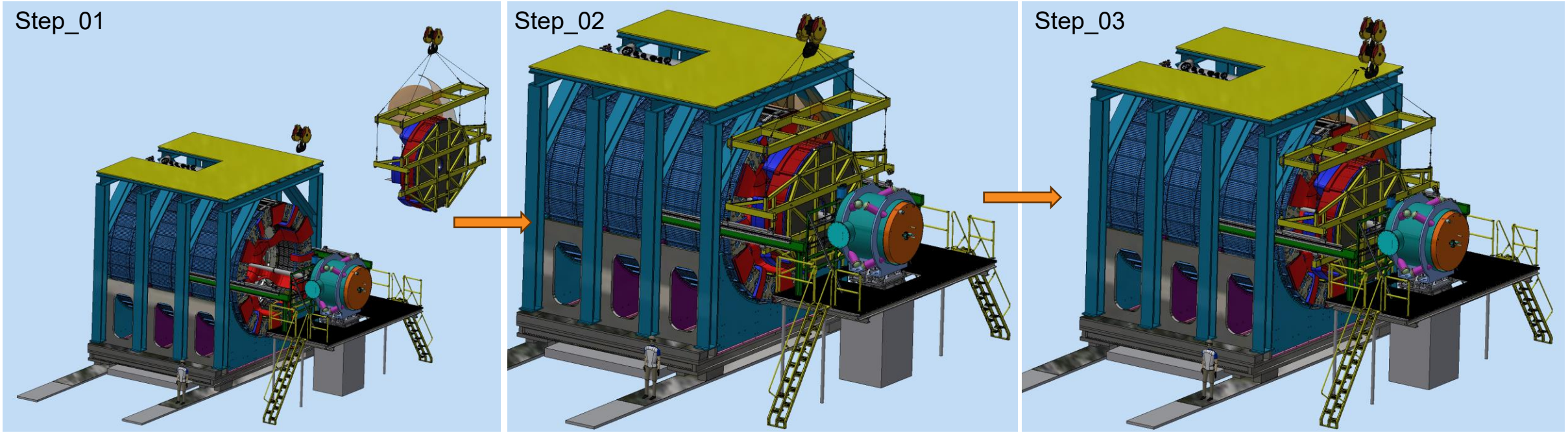


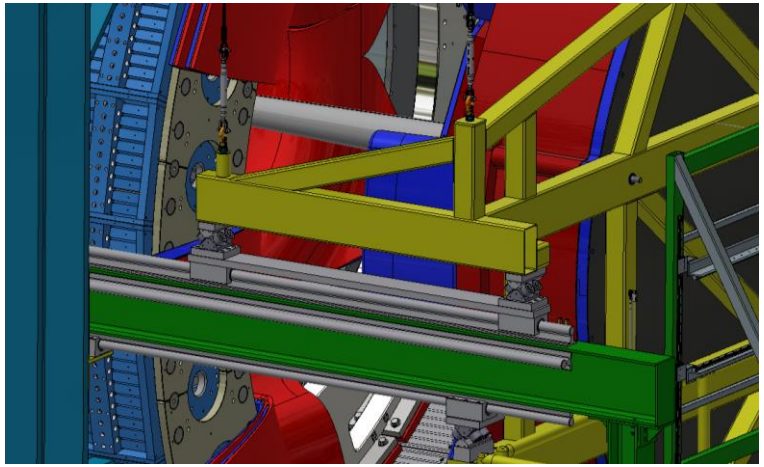


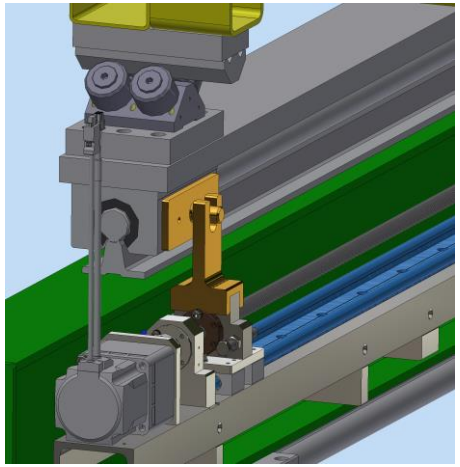


- Crane room too low to lift dRICH directly over rails
- Left rail pulled out first, right rail after dRICH is in front of ECAL

dRICH: handling, and positioning (Experimental Hall)







- dRICH moved from assembly area to installation site using dedicated tools
- Aligned and seated on rails of ECAL support structure
- Final motion achieved with ball screw system for smooth, controlled movement and minimal shock

Handling Tools: Preliminary Structural Considerations

Handling and Lifting systems must be comply with:

- ASME B30-20
- ASME BTH-1
- 29 CFR 1910 and 1926
- ePIC design guide

Documentation:

- Calculation and verification (through load test)
- Technical file (engineering report, usage and safety instructions)
- Certification

Handling Tools: Preliminary Structural Considerations

- The self-weight of the dRICH, and Handling Tool have been determined using Autodesk Inventor software, considering the nominal dimensions of the components and the material densities. To account for potential weight variations during the construction and fabrication, the estimated weights have been multiplied by a **contingency factor of 1,1**.

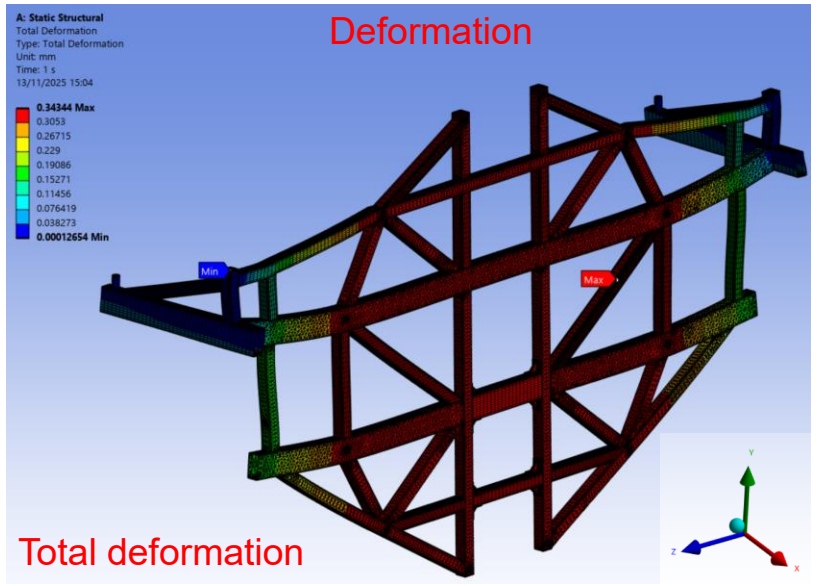
Calculated self-weight of the dRICH : **~2100 kg**

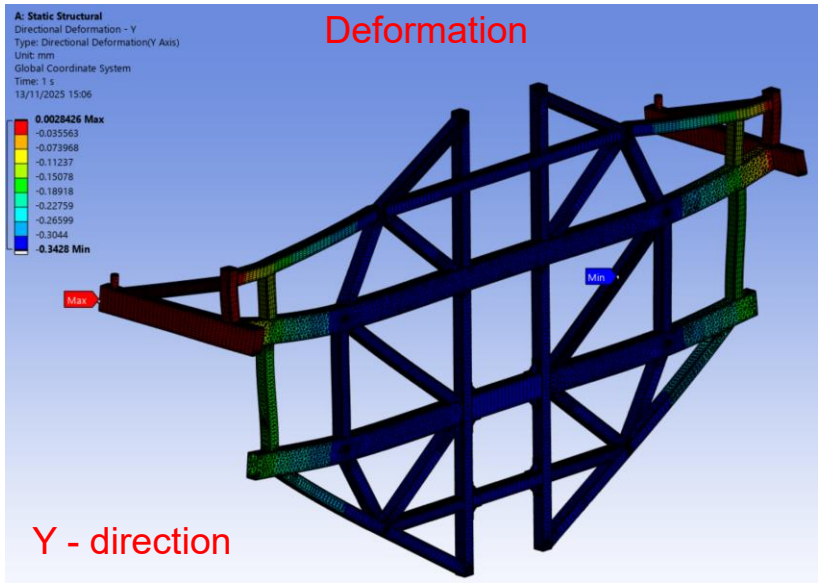
- To account for dynamic actions, a dynamic factor of **μ = 1.20** (ASME BTH-1-2017 – APPENDIX_C § C-1.3) has been applied to the Rated Load and to the Handling Tool Self-Weight.
- Since the Handling Tool shall be tested prior to its initial use (in accordance with ASME B30.20-2018, § 20-1.3.8.2), a factor of **ψ = 1.25** has been applied to the Rated Load and to the Handling Tool.

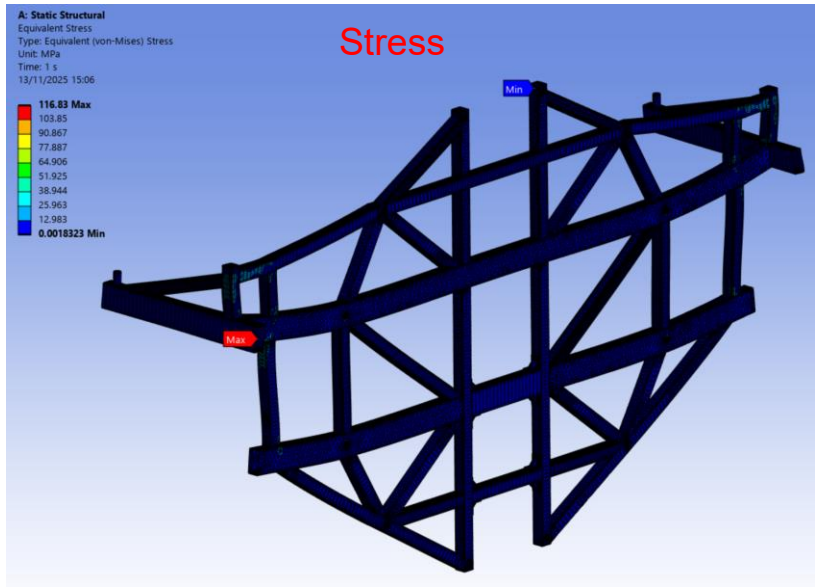
Design Load

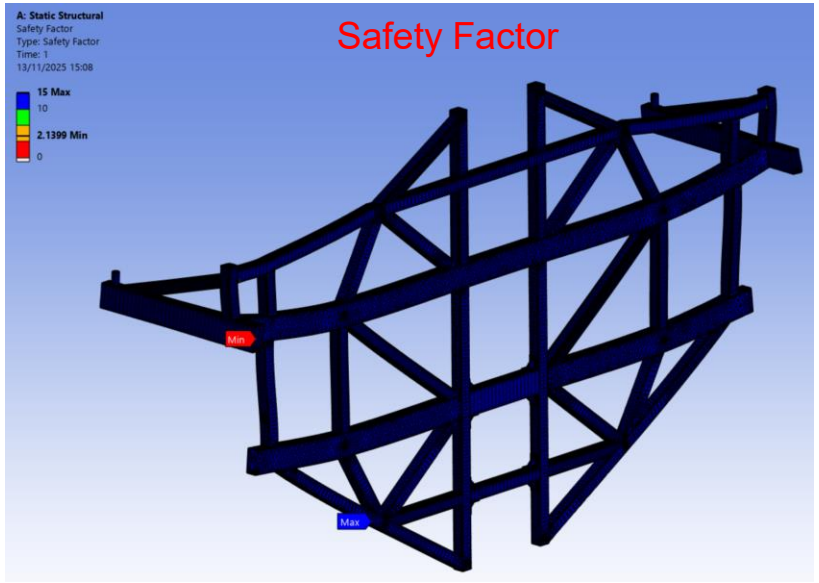
$$W_{DL} = \mu \times [(\psi \times W_{RL}) + SW_T] \sim \mathbf{40000\ N}$$

Handling tool: Preliminary Structural Considerations









Loads and Boundary conditions:

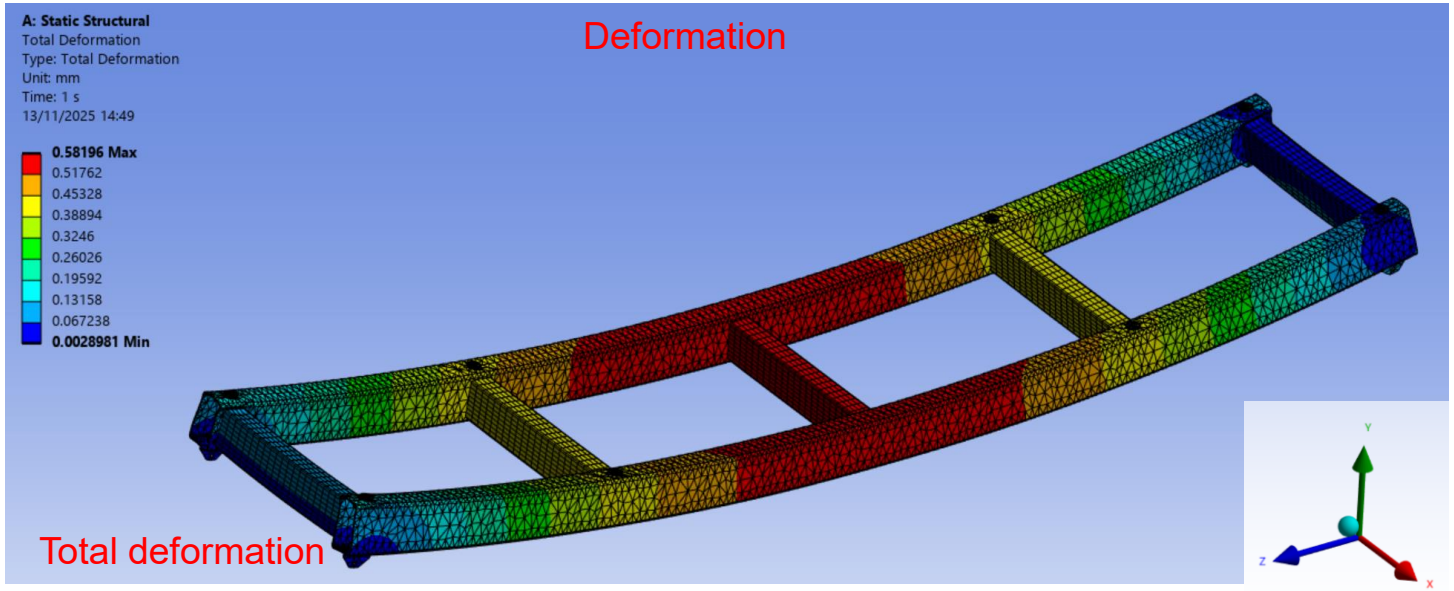
- Fixed at lifting points
- Detector and tools weight applied as load: 40 kN
- Gravity applied

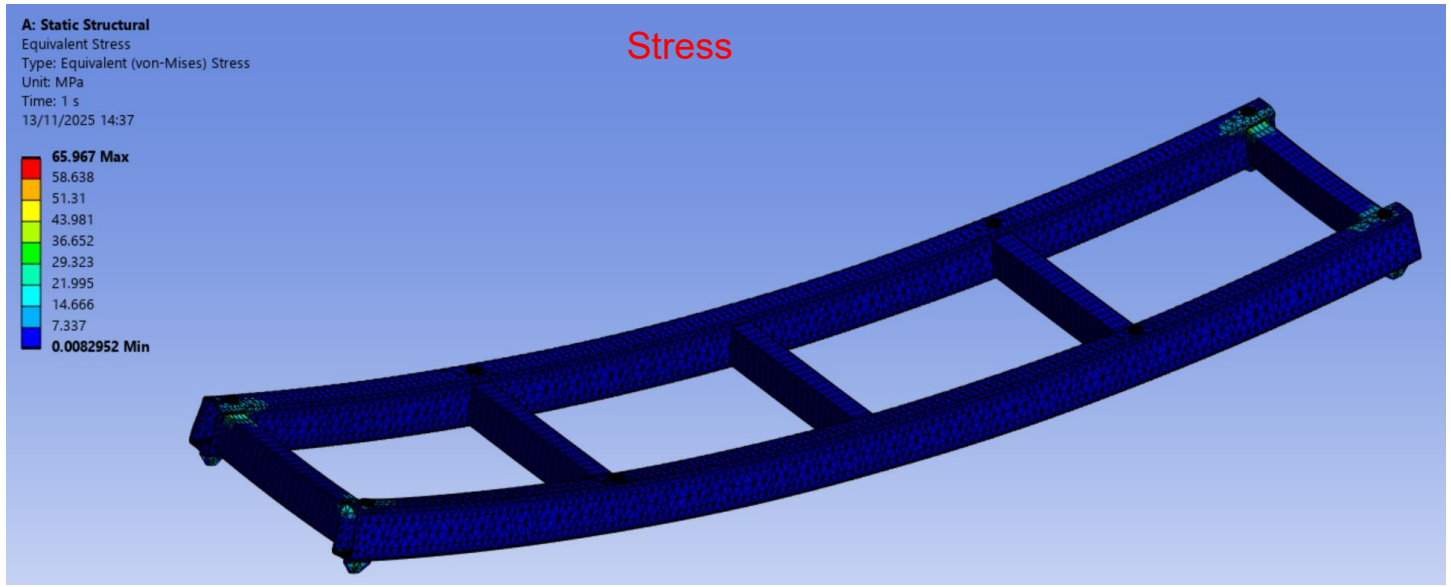
Results:

- Deformation very small: 0.35 mm
- Stress very low: 10 MPa (SF = 3)
- Highest stresses are singularities

Deformation and stress within limits → **tool suitable for use**

Spreader Frame: Preliminary Structural Considerations



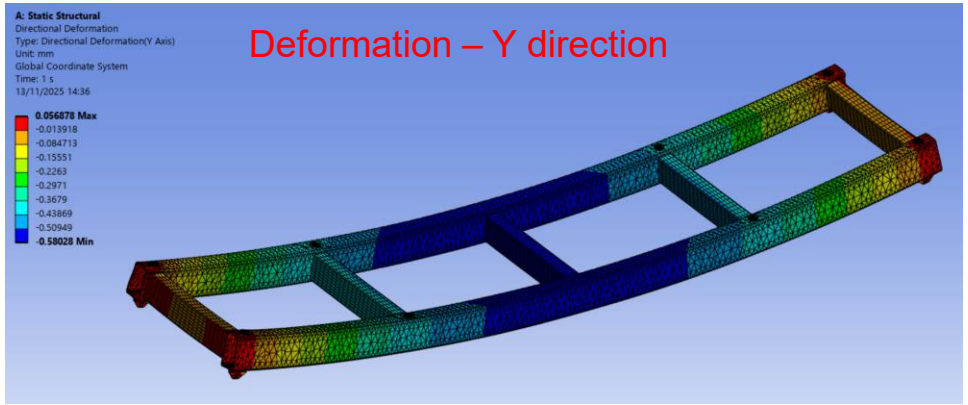


Loads and Boundary conditions:

- Fixed at lifting points
- Detector and tools weight applied as load: 40 kN
- Gravity applied

Results:

- Deformation very small: 0.6 mm
- Stress very low: 40 MPa (SF = 4)
- Highest stresses are singularities



Deformation and stress within limits
→ **tool suitable for use**

Conclusions and NEXT Steps

Design Status

- ***Detector design (dRICH):*** currently in a relatively advanced stage.
- **Tools design:** currently in an advanced stage.
- **Tools (handling and installation):** suitable for use in both the assembly hall and the experimental hall.
- **FEA simulations:** results are positive and meet the required technical standards.

Next Steps

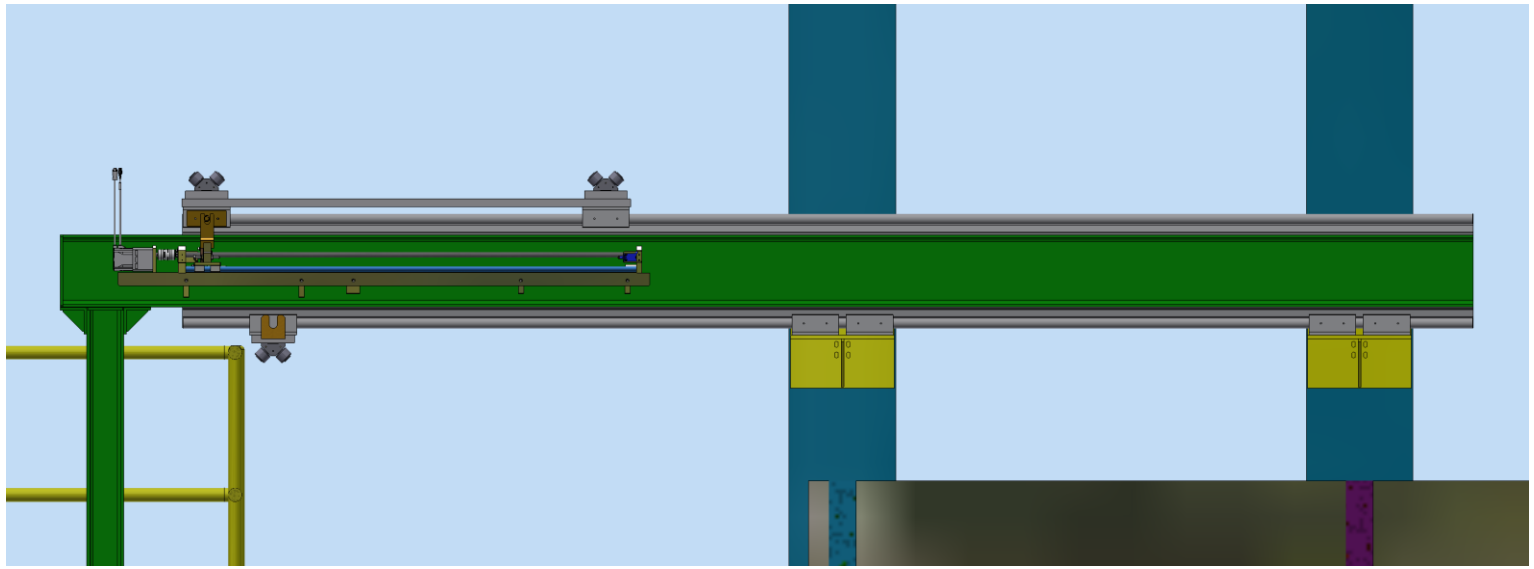
- **Consolidation of the dRICH mechanical design:** refining and finalizing the mechanical design of the dRICH.
- **Consolidation of the dRICH integration study into the ePIC apparatus:** finalizing the fixing systems and service integration.
- **Detailed study of the extraction and insertion system (moving system):** designing and optimizing the moving system used for extracting and inserting the dRICH detector within the ePIC apparatus.
- **Structural study of the dRICH:** performing a detailed structural analysis of the dRICH detector using FEM simulations.

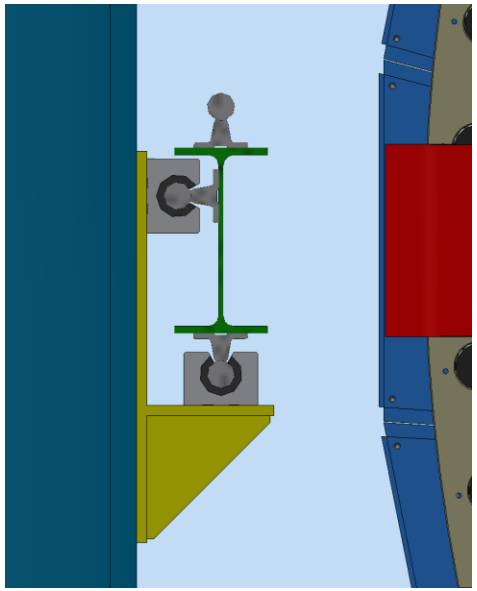
Questions?

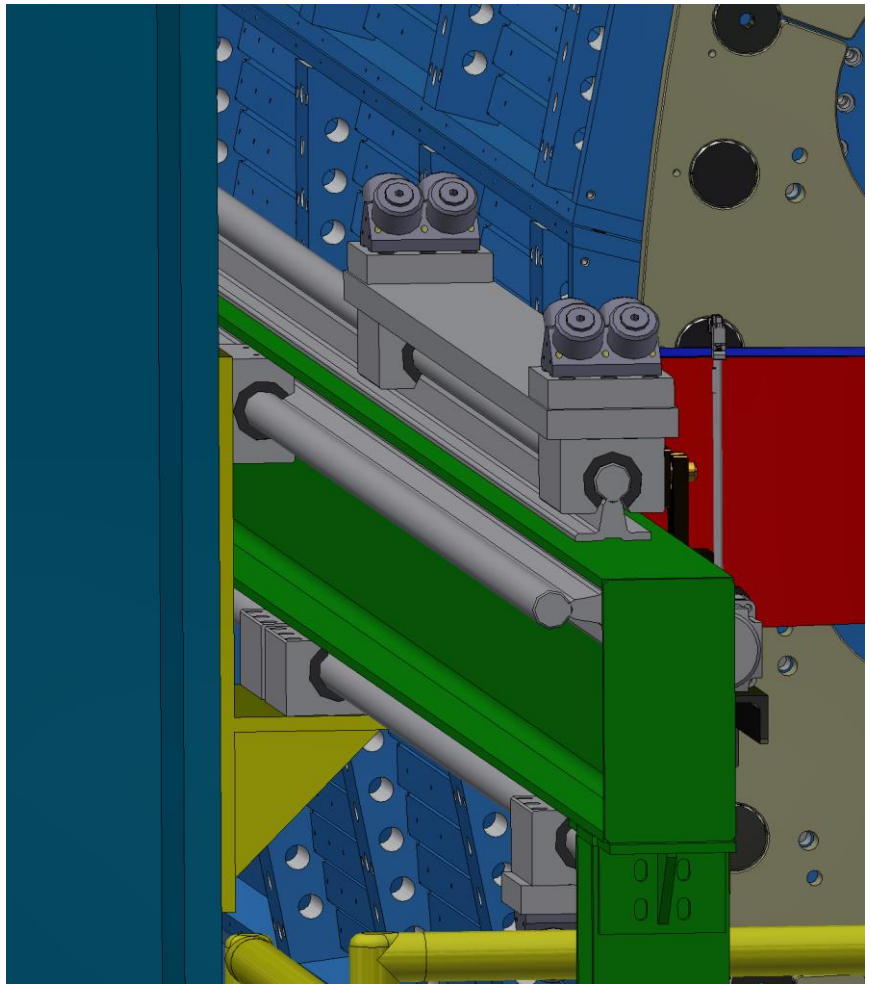

Thank You!!


BACK UP

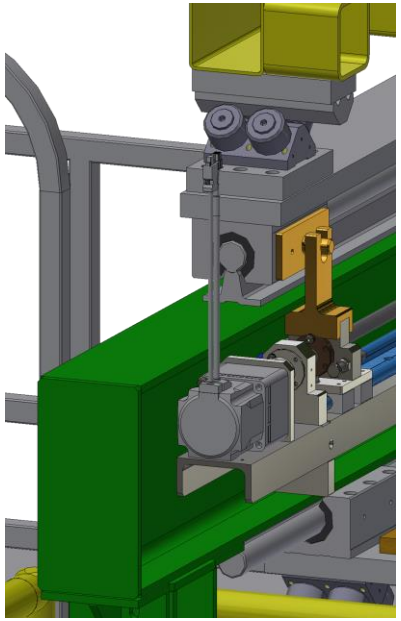
Rails

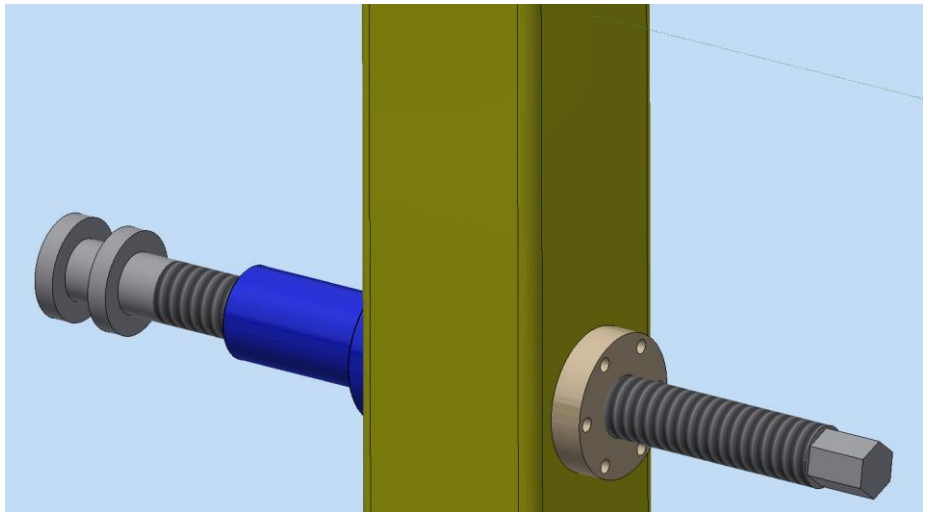


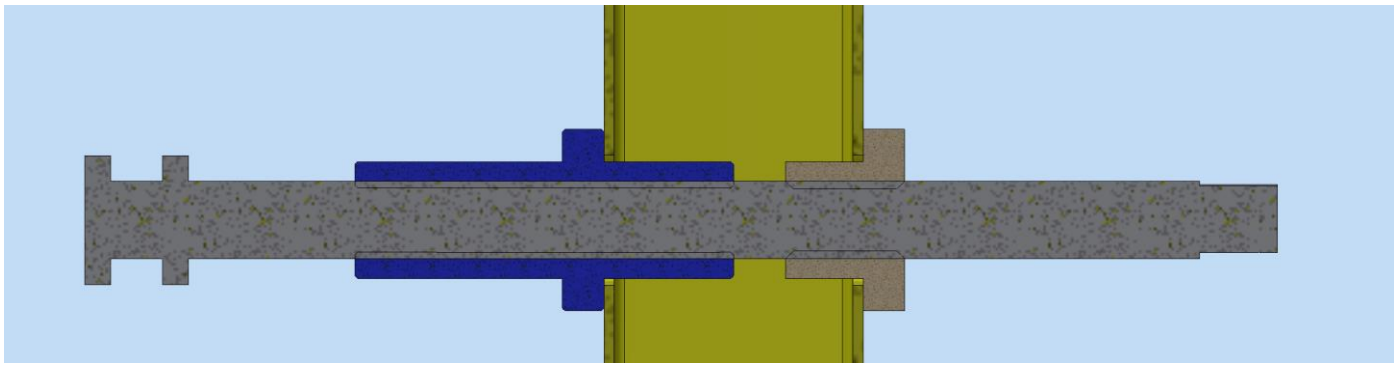




Approaching and Adjustment Systems



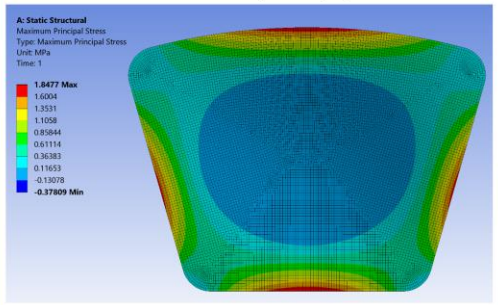




dRICH PDR

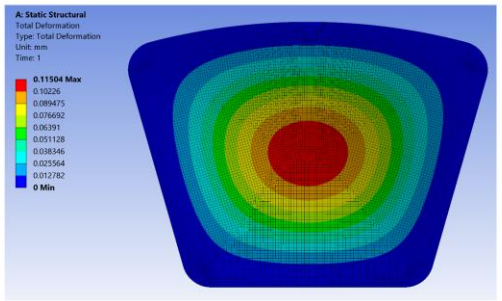
Quartz Window: FEA

Maximum Principal Stress (S1)



- Thickness: t_1=8 mm;
- Uniformly distributed (absolute) pressure over the entire surface: 0,0005 MPa (5 mbar)
- Constrains: Fixed along the edge surface

Deformation along Z Axis



- Maximum Principal Stress S1=1,9 MPa;
- Maximum Deformation along Z Axis = -0,11 mm
- Minimum Calculated Safety Factor SF_c = 15

$SF_c > 7$ ⟶ checked

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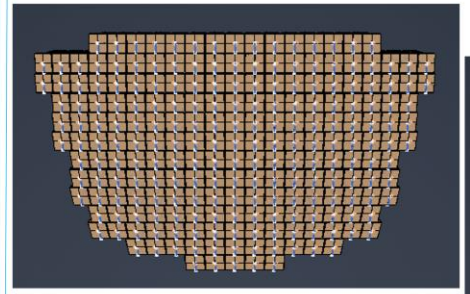
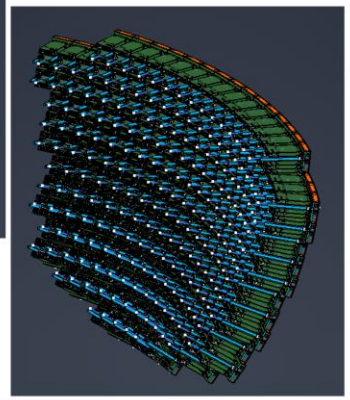
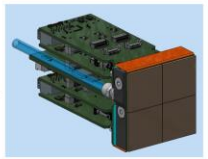
dRICH: PDU - detector

The detector is composed of 211 PDUs arranged on a sphere with a radius of 1100 mm







PDU designed by R.Preghenella

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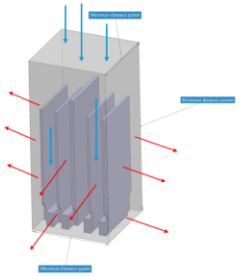
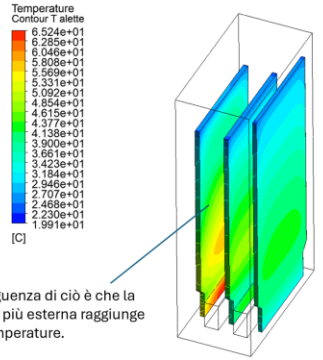
Detector Box: FEE cooling

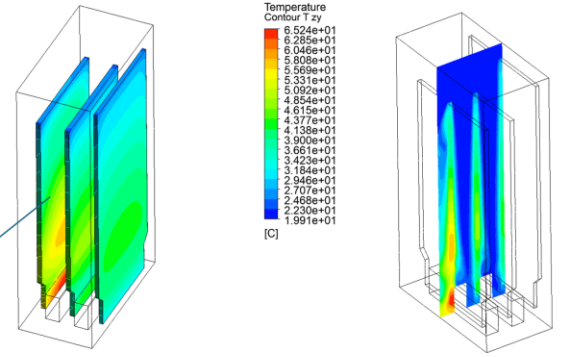


Condizioni su sezione inlet: v = 1 m/s, T = 20° C.

Singola PDU, aria dall'alto



Conseguenza di ciò è che la scheda più esterna raggiunge alte temperature.



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INFN – Ferrara Division Labs

Mechanical Workshop

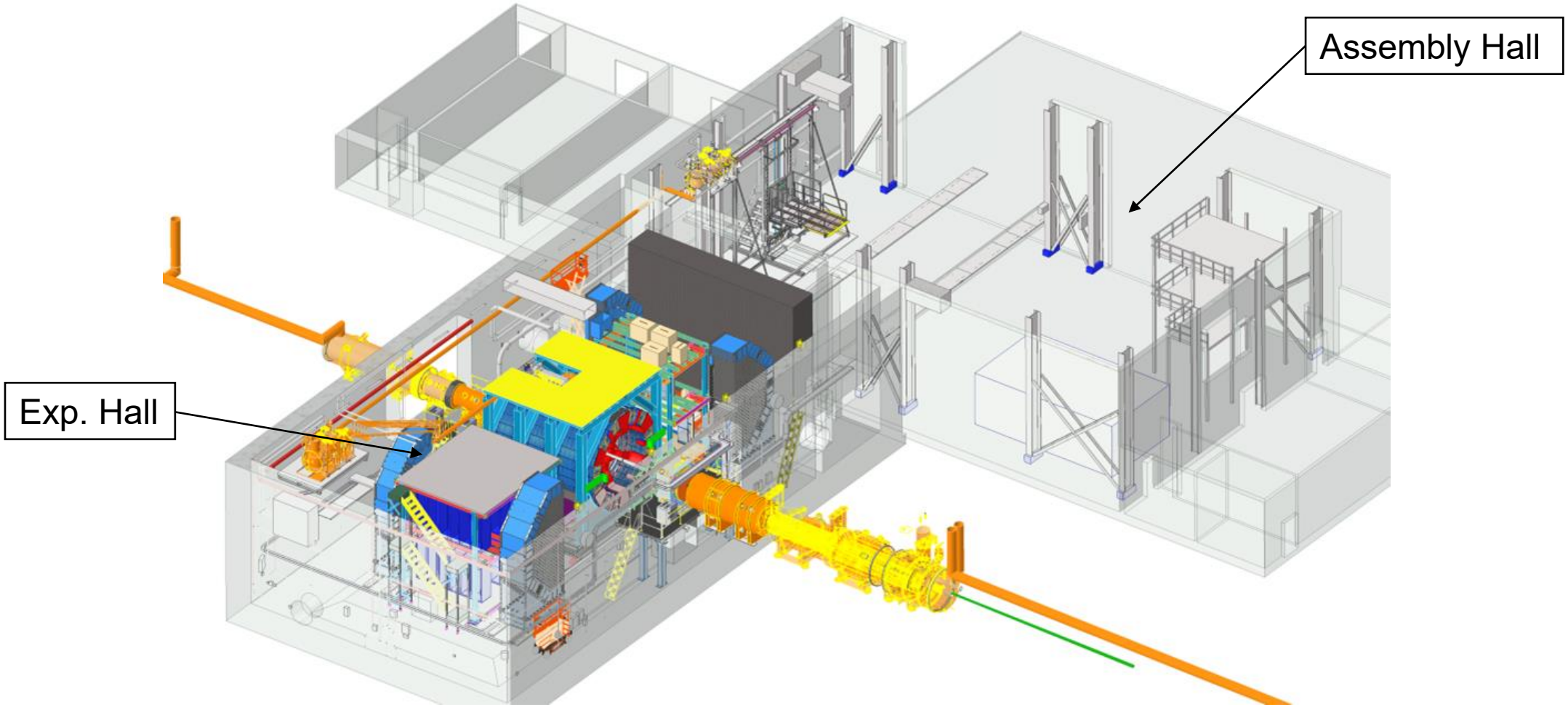
Welding Lab & Carpenter shop

Carpentry workshop

AM Lab

Metrology Lab

Experimental and Assembly Halls



dRICH: installation in the Assembly Hall