STRUCTURAL OPTIMIZATION AND EXPERIMENTAL VALIDATION OF A CFRP-NOMEX PRESSURE VESSEL FOR THE EPIC dRICH DETECTOR

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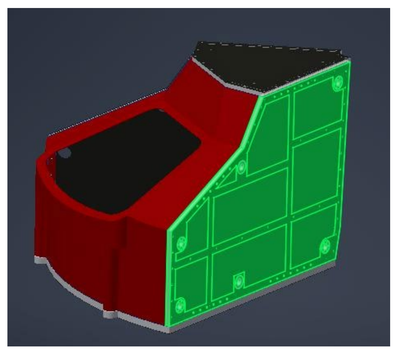
BACKGROUND & OBJECTIVE

The EPIC dual-radiator Ring Imaging Cherenkov (dRICH) detector requires a lightweight gas vessel with dimensional stability under pressure. This study evaluates a 1:10 CFRP-Nomex prototype.

OBJECTIVE

Validate the finite-element response experimentally and identify the sandwich layup that best controls deformation and stress from 0.2 to 0.5 MPa.

GEOMETRY & MATERIALS



Quarter-symmetry vessel model with monolithic CFRP zones and a curved sandwich panel.

Three layups compared

- Baseline: 4 mm Nomex core
- 5 mm core + 0.30 mm CFRP skins
- 3 mm core + 1.30 mm CFRP skins

NUMERICAL METHOD

Static structural FEM was performed in COMSOL Multiphysics on one quarter of the geometry. The model included anisotropic composite properties, bonded contacts, symmetry constraints and uniform internal pressure.

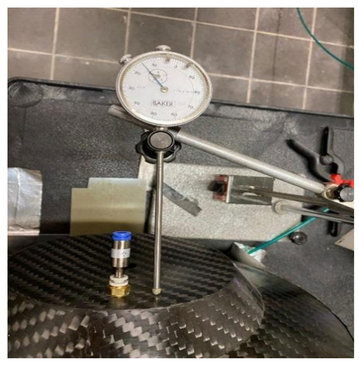
Outputs

- Directional deformation (Y)
- Von Mises equivalent stress
- Stress intensity
- Safety factor using a 2500 MPa reference limit

Disclosure: the numerical results originate from COMSOL Multiphysics, as reported in the thesis.

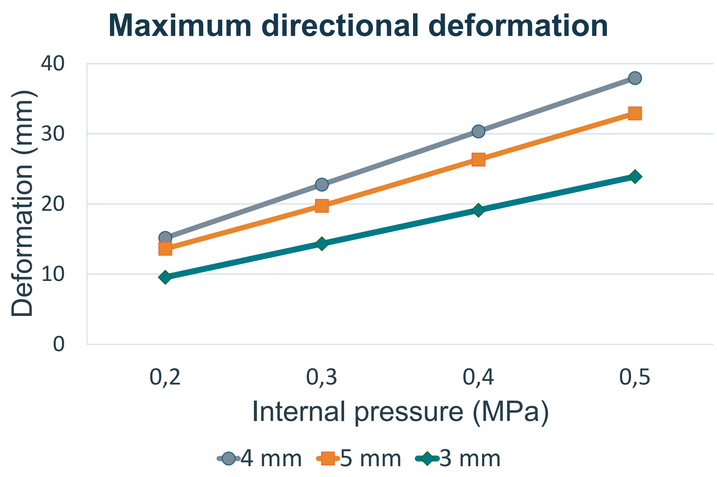
EXPERIMENTAL VALIDATION

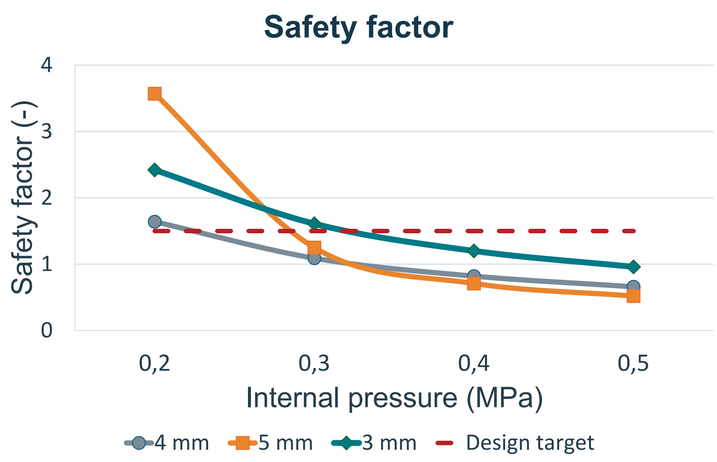




The prototype underwent 24 h and 48 h pressure cycles. A transducer, data logger and dial indicators monitored pressure and displacement. The deformation trend agreed with FEM predictions; local distress emerged near material transitions at higher pressure.

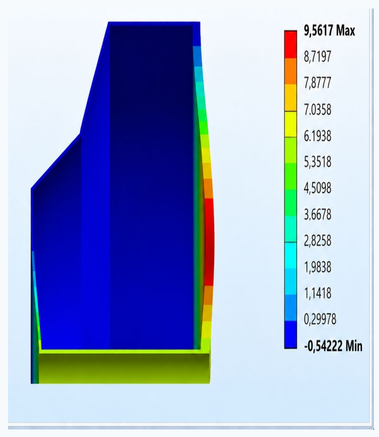
CONFIGURATION COMPARISON

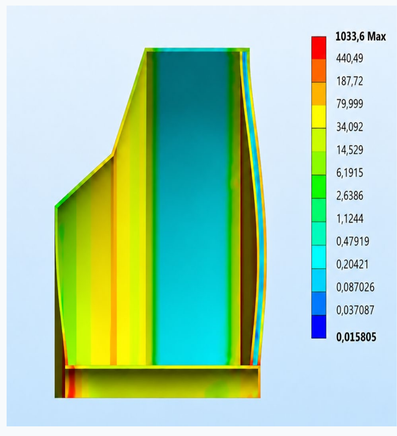




Correction: at 0.4 MPa, the 3 mm configuration has a safety factor of 1.20 and does not meet the stated target of 1.5.

OPTIMIZED RESPONSE





3 mm Nomex configuration at 0.2 MPa: maximum deformation 9.56 mm; equivalent stress 1033 MPa; safety factor 2.42.

KEY FINDINGS

- The 3 mm core with thicker CFRP skins produced the lowest deformation at every investigated pressure.
- At 0.3 MPa: 14.34 mm deformation, 1550 MPa equivalent stress and safety factor 1.61.
- No configuration met the target safety factor of 1.5 at 0.4 MPa.
- Interfaces and geometric transitions remained the critical regions.

CONCLUSION

The 3 mm Nomex core with 1.30 mm CFRP skins was the best-performing configuration tested. It improved stiffness and delayed loss of structural margin. Local reinforcement or geometry refinement is still required for operation at or above 0.4 MPa.

DESIGN IMPLICATIONS

Reinforce interfaces · refine transition geometry · reassess the pressure envelope after calibration.

REFERENCES & ACKNOWLEDGEMENTS

[1] G. M. Nicoletti, Structural Optimization of the dRICH Detector Shell for the EPIC Experiment, MSc Thesis, University of Catania, 2026.
[2] EPIC Collaboration, technical documentation for the Electron-Ion Collider detector.
[3] ASME Boiler and Pressure Vessel Code, Section VIII.

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EXPERIMENTAL EVOLUTION 2.5 bar: elastic response → 3.0 bar: visible bulging and first acoustic emissions → 3.5 bar: sealing loss and persistent deformation

STUDY MATRIX ¼ geometry · 4 pressure levels · 3 sandwich layups · 2 monitored zones

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