CERN

Development of High-density Signal Feedthroughs for Liquid Argon Calorimeters

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Workshop GranuLAr noble liquid Detectors

April 6 - 8, 2022

Outline

- Introduction
- High-density flanges
- Selection of components
- Experimental facility
- Experimental results
- Final design studies
- Conclusions

Introduction - Noble Liquid Calorimetry

- Noble liquid calorimetry is a well proven technology, successfully operated/operating in H1, NA48/62, ATLAS…
- Very promising candidate for future FCC experiments
- R&D direction: optimization for particle flow reconstruction on top of conventional calorimetry

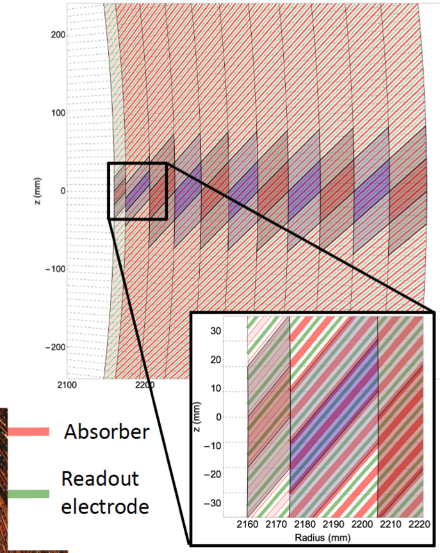
Higher granularity

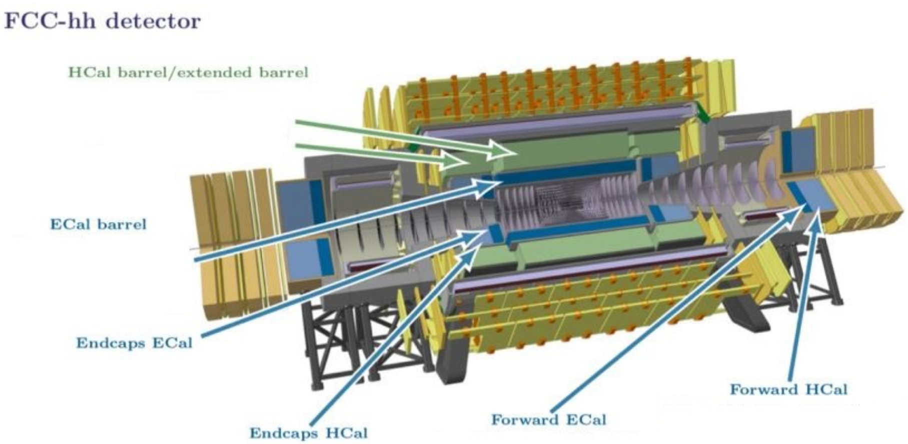
⇩

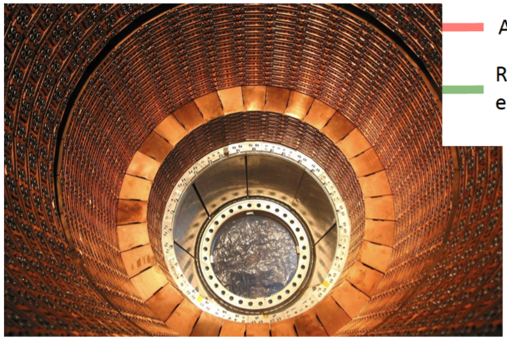
Higher number of read-out channels

⇩

Development of high-density signal feedthroughs



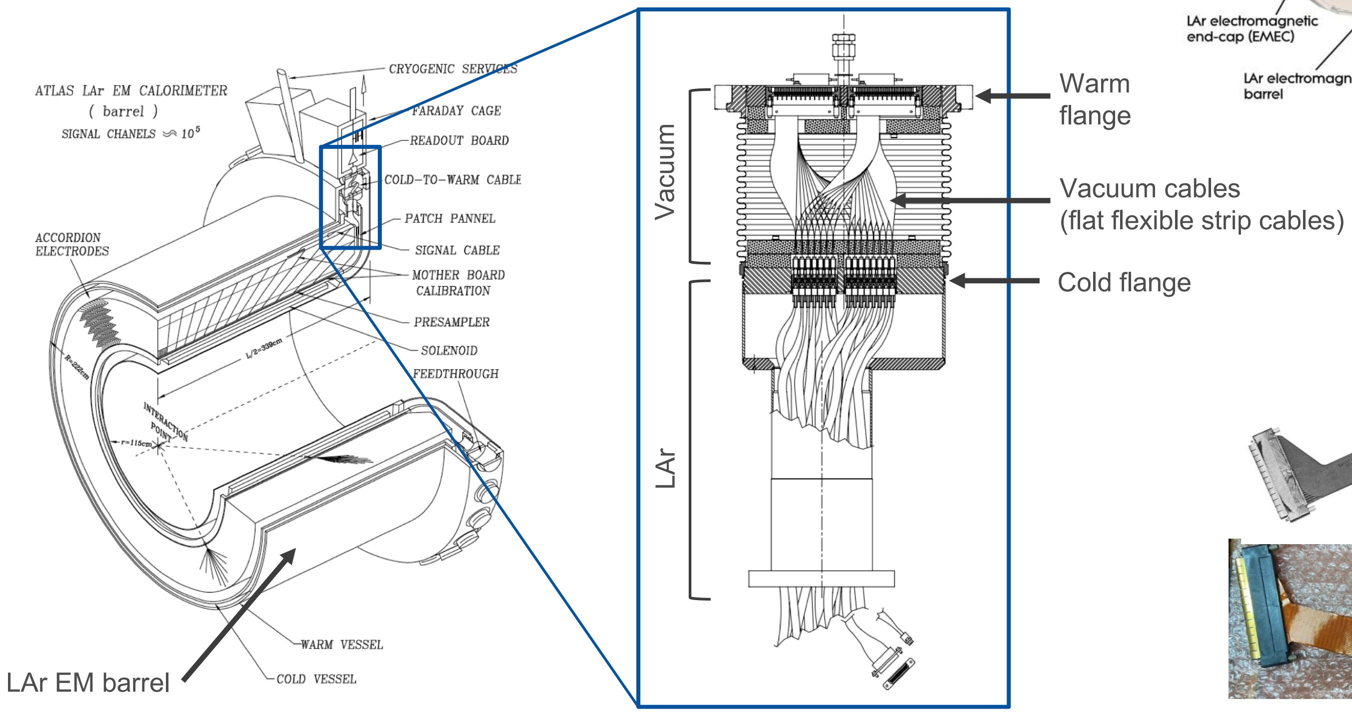


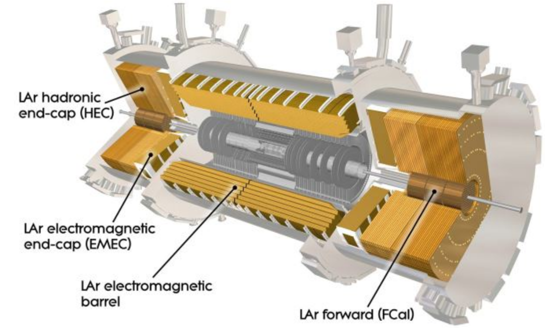


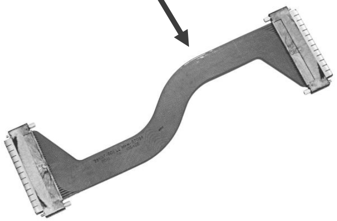
From: M. Aleksa, Calorimeters for the FCC-hh (https://arxiv.org/abs/1912.09962)

Introduction - The feedthroughs of ATLAS

- Reference: signal feedthroughs of the ATLAS LAr EM calorimeters







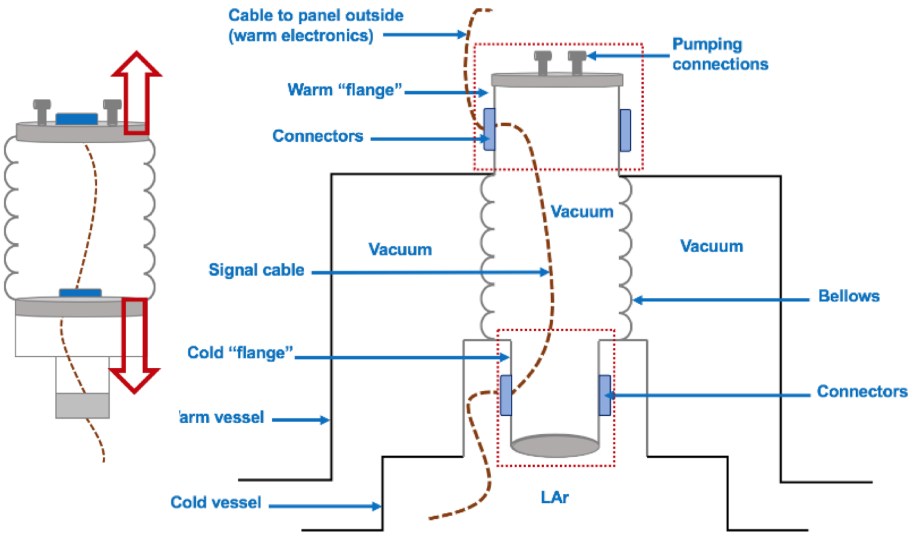
32 signal wires/cable

From: ATLAS LAr Unit, Liquid Argon Calorimeter – Technical Design Report
From: D. Makowiecki et al., Signal feedthroughs for the ATLAS barrel and endcap calorimeters

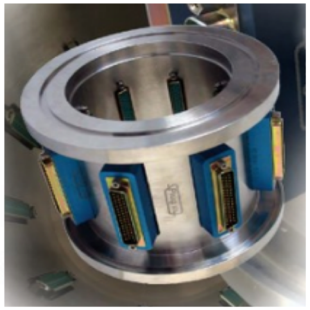
- Goal: 1920 wires/feedthrough (ATLAS) → ~20 000 wires/feedthrough (x10 more)

Introduction - 2 solutions considered

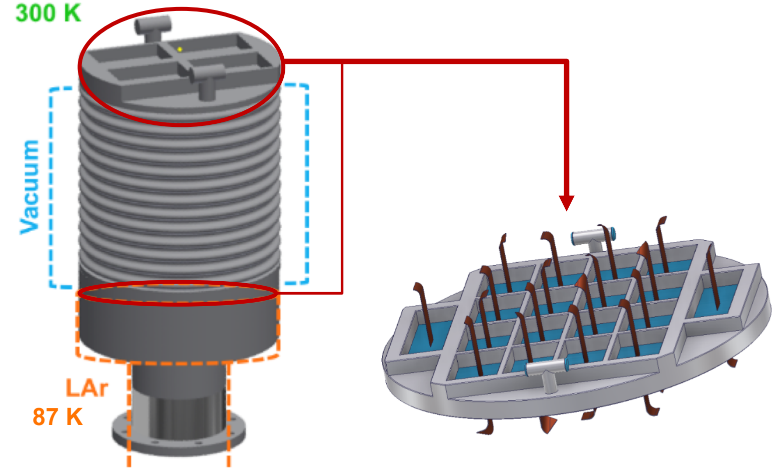
a) Large surface feedthroughs



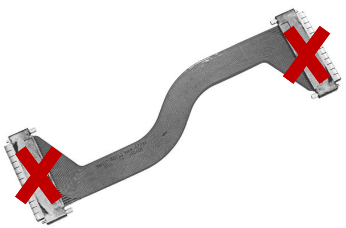
Higher number of connectors by using the available cylindrical surface



b) High-density flanges



Structures with high density of slits allowing the strip cables to pass → connectors-less solution



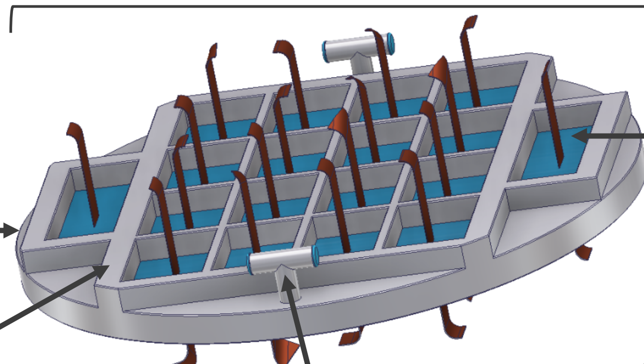
Connector x3 larger than strip cable

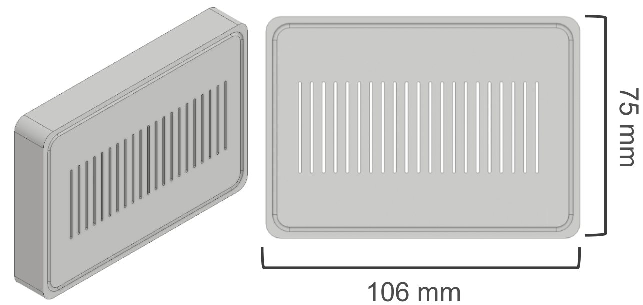
- Higher area dedicated to signal extraction
- Same design for warm and cold side

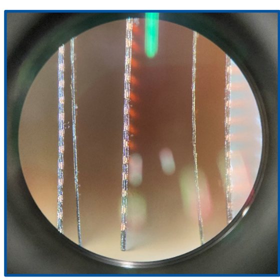
High-density flanges

- If the electronics sits outside of the cryostat (warm electronics), one needs high-density feedthroughs → high-density connector-less feedthroughs

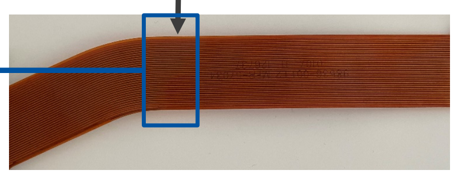
Conceptual design:







machined shielded strip cables
(microscope image)



32 signal wires/cable

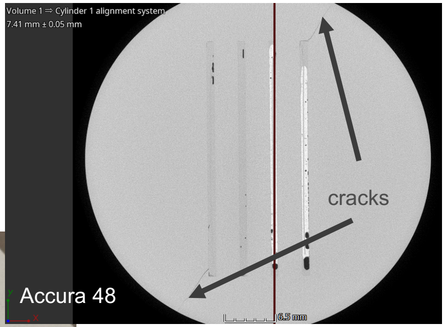
2 sealing solutions:

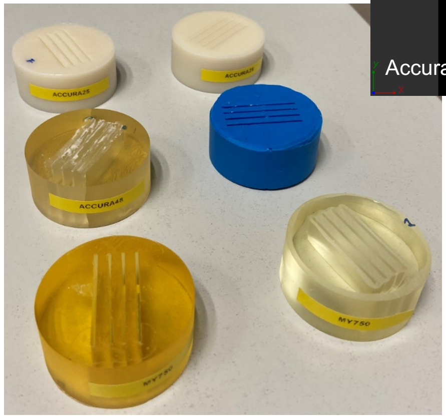
- seal between cable and structure
- seal between structure and body flange

Selection of components

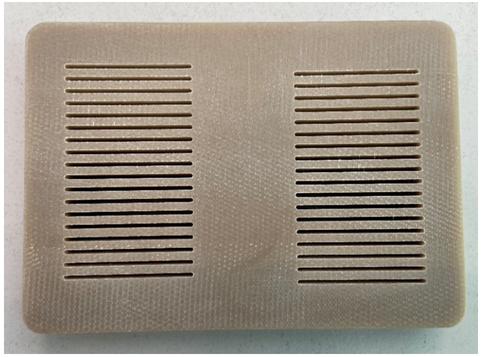
1. Structural material:

- Samples thermally shocked in LN_2 (77 K) + CT scans before and after
- Material candidates:
  - **Accura 25** (3D-printed epoxy resin)
  - Accura 48 (3D-printed epoxy resin) X
  - **Silastic M** (silicone rubber – 3D-printed mold)
  - **G10** (fiberglass laminate in epoxy resin)
  - **G11** (fiberglass laminate in epoxy resin)
  - **MY750** (araldite epoxy resin – 3D-printed mold)





- Main advantages:
  - Fabrication processes (mechanical and financial viability)
  - Lightness
  - Low conductivity

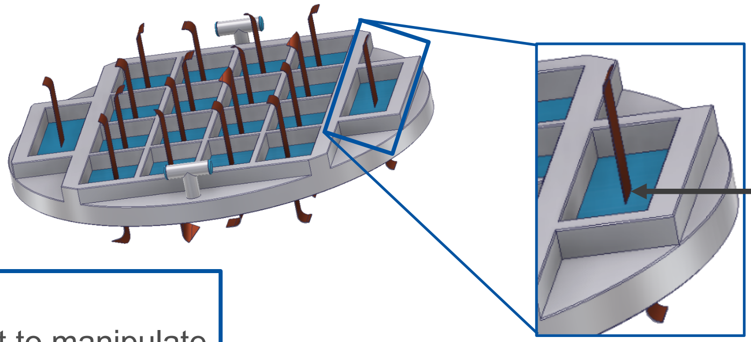


From CERN Polymer Laboratory

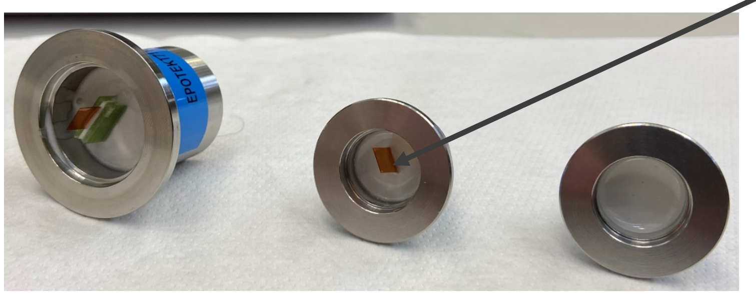
Selection of components

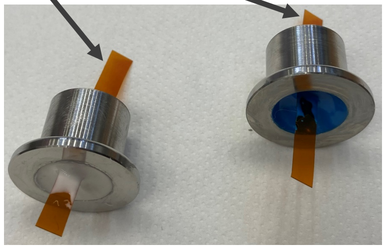
2. Seal between cable and structural material: glue/resin selection

- Samples thermally shocked in LN_2 (77 K) several times and leak tested at room temperature
- Glue/resin candidates:
  - DP 190
  - Eccobond 286
  - CAF-4
  - RESINPRO
  - **Epo-tek T7110** → easy to manipulate
  - **Araldite 2011** → more viscous and difficult to manipulate
  - Stycast



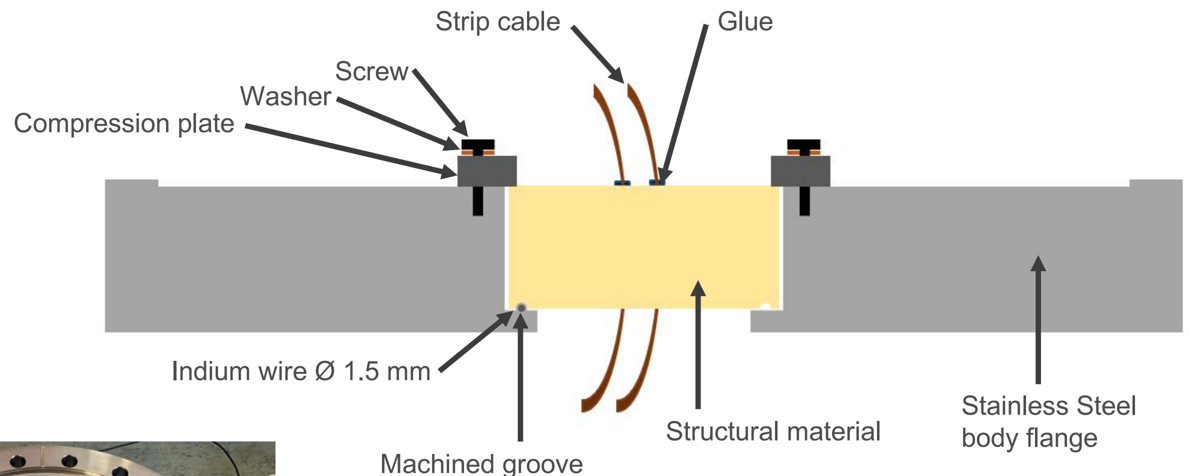
Flexible Kapton® strip



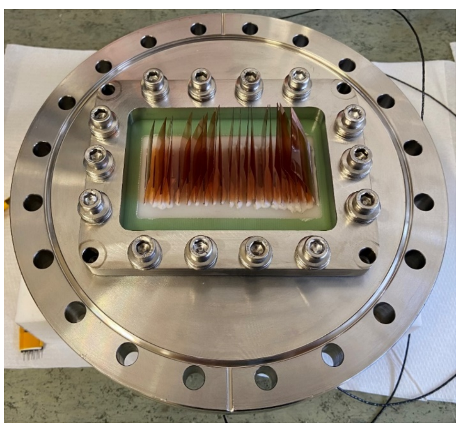


Selection of components

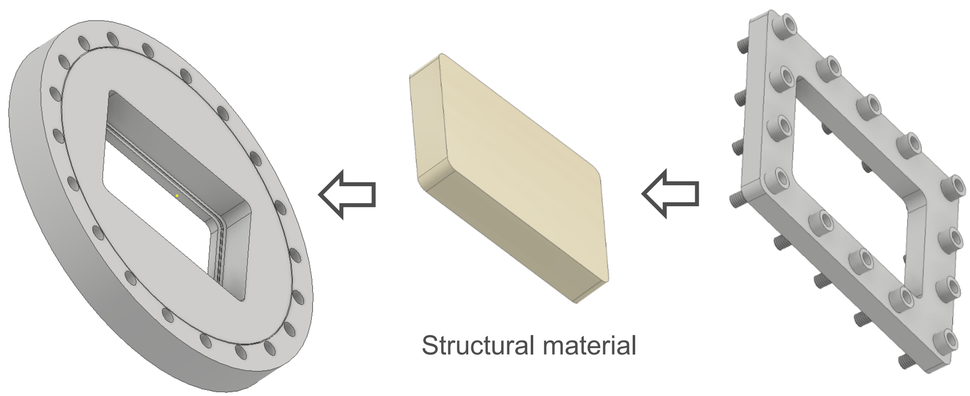
3. Seal between structural material and body flange: mechanical sealing solution



From COMPASS experiment - CERN



High-density flange sample to test



Stainless Steel body flange

Compression plate

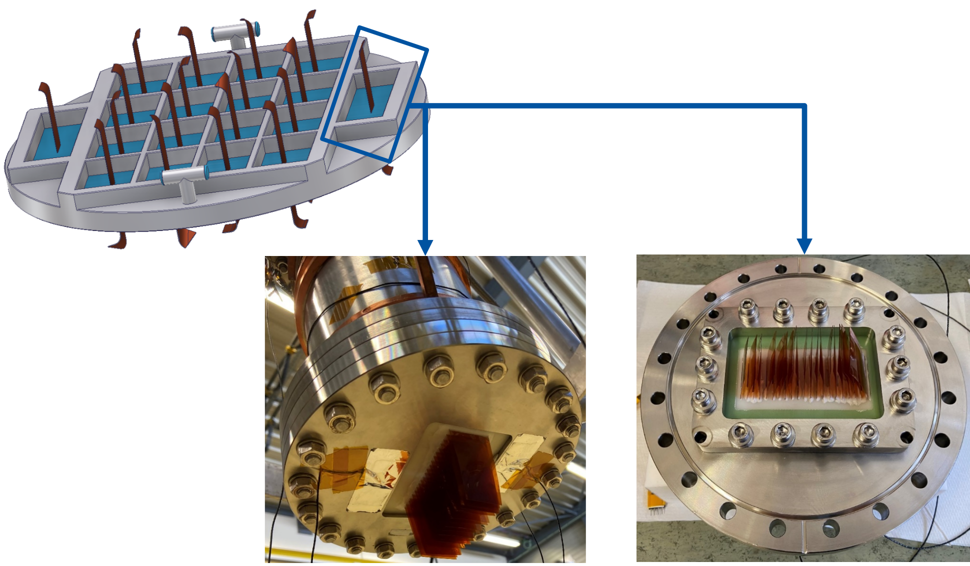
Experimental facility

- Experimental facility:
  - To perform pressure and leak test at room and low temperature

Test conditions:

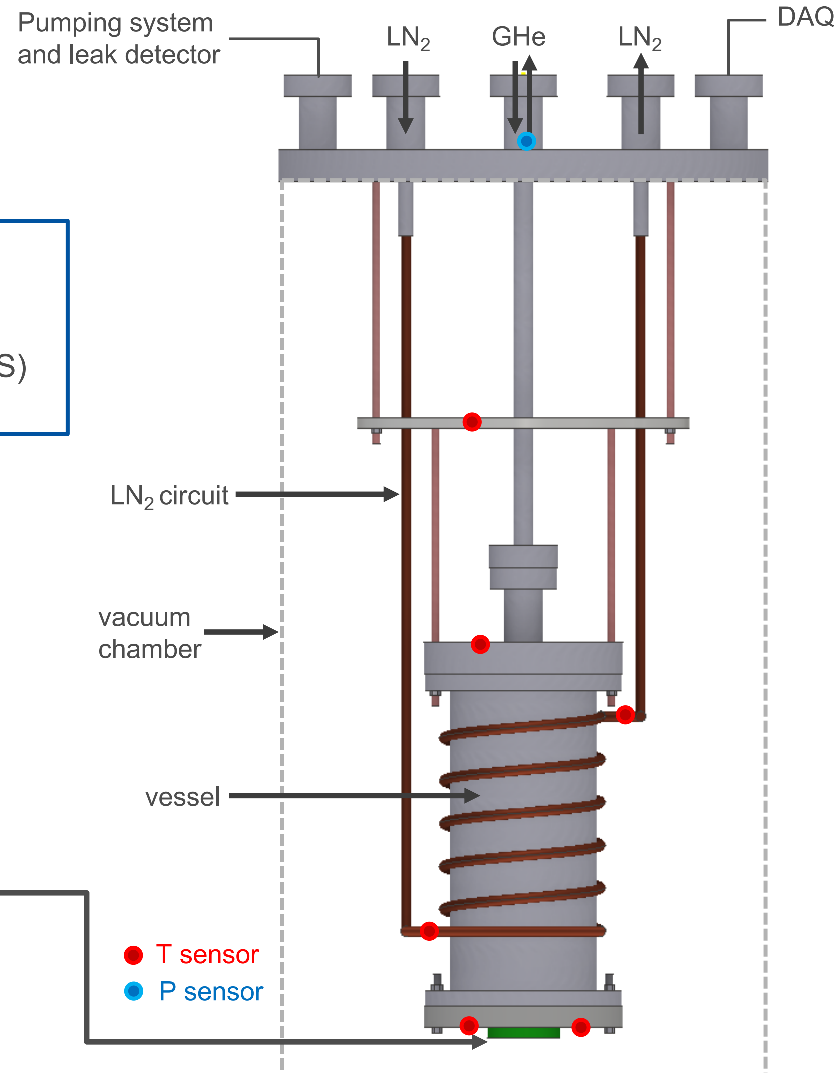
- Temperature: **87 K** (operating conditions ATLAS)
- Pressure: **3.5 bar** (breaking vacuum accident ATLAS)
- Leak-tightness: < 10^{-8} mbar.l/s

From: ATLAS LAr Unit, Liquid Argon Calorimeter – Technical Design Report

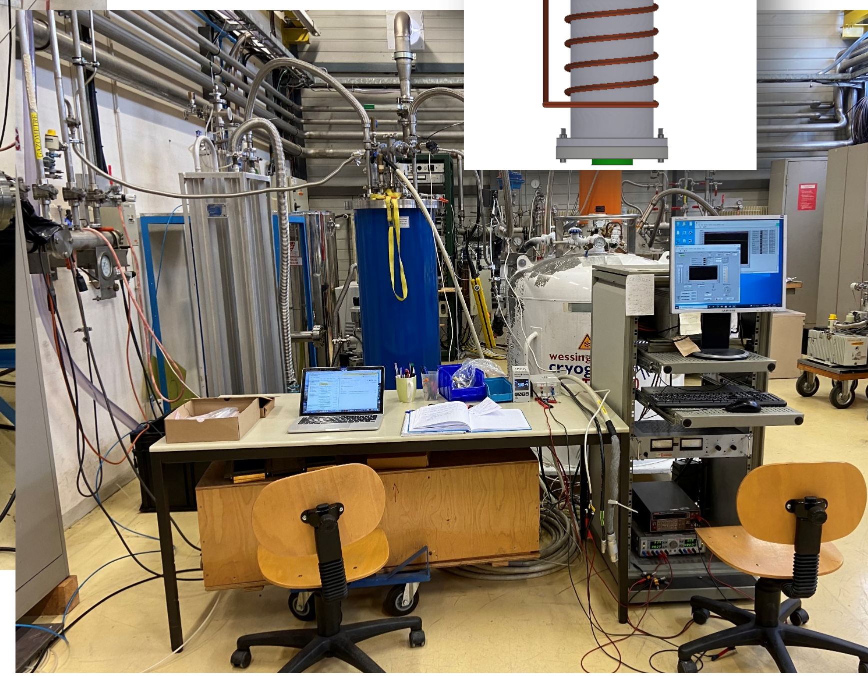


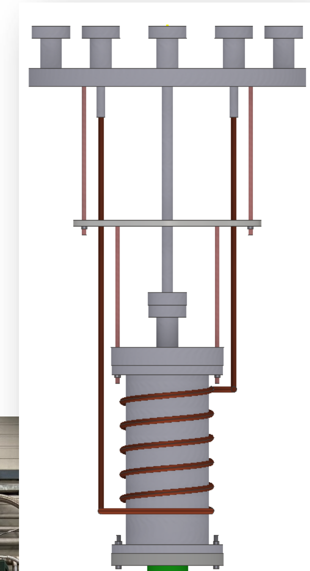
outer side

inner side



Experimental facility



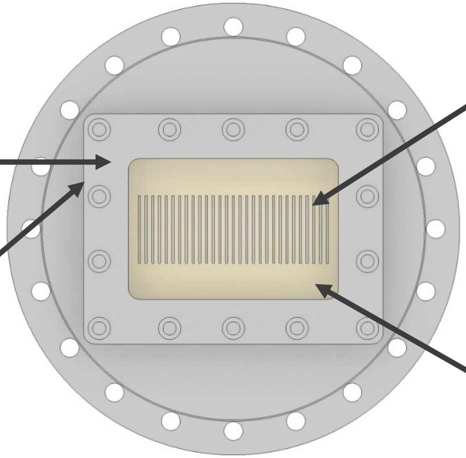


Experimental results - example

- Tests description:

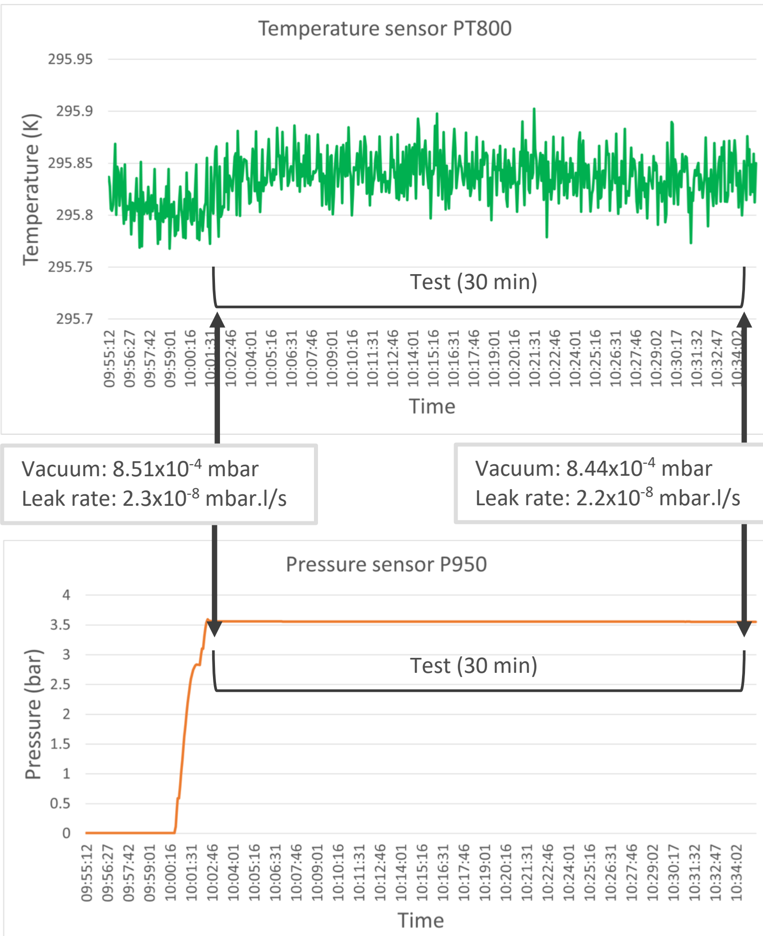
  1. Leak and pressure test at room T° (30 min)
  2. Cooling down process (~7 hours)
  3. Leak and pressure test at low T° (30 min)
  4. Warming up process (1-2 days)

- Example:

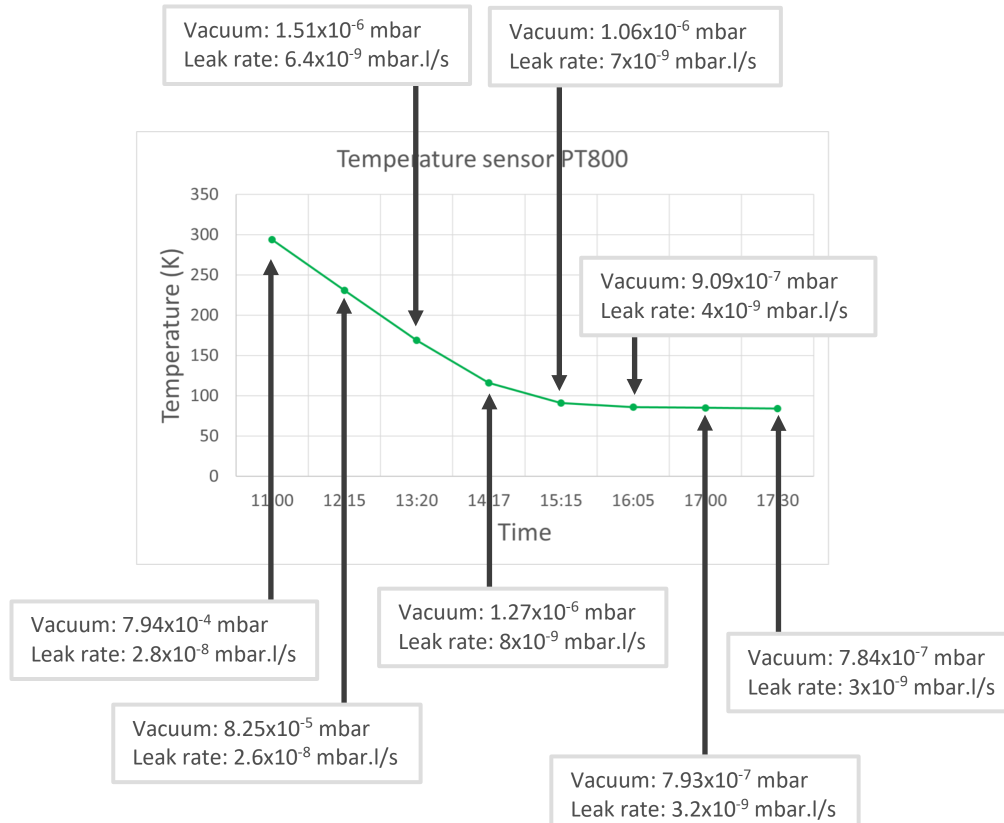


Experimental results - example

Step 1: Pressure and leak test at room T°

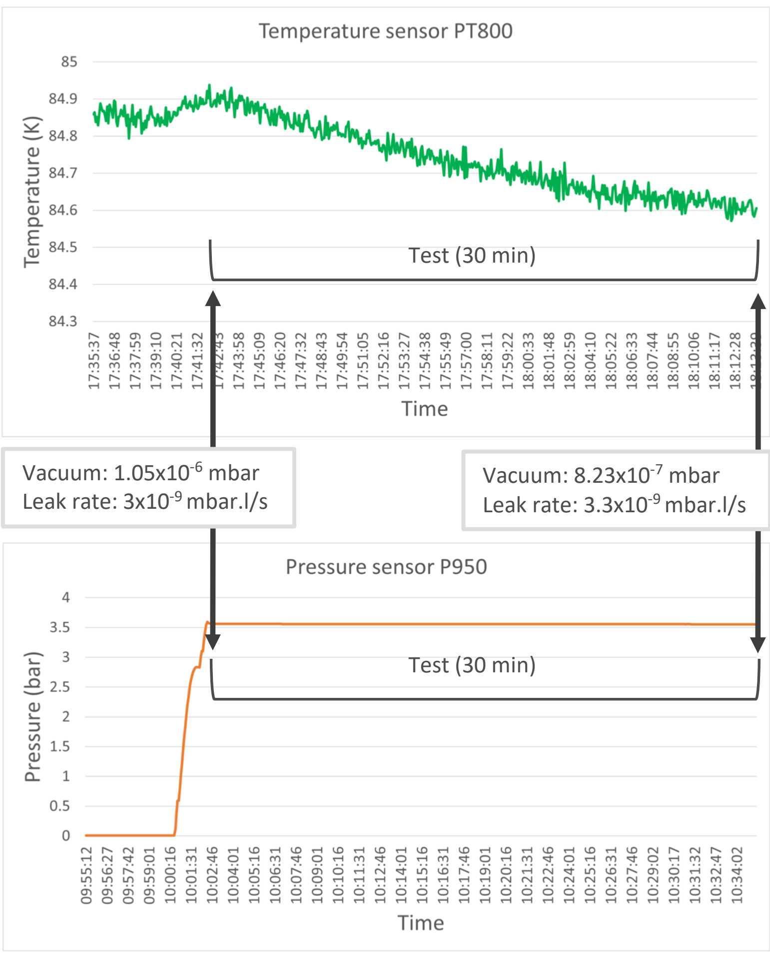


Step 2: Cooling down

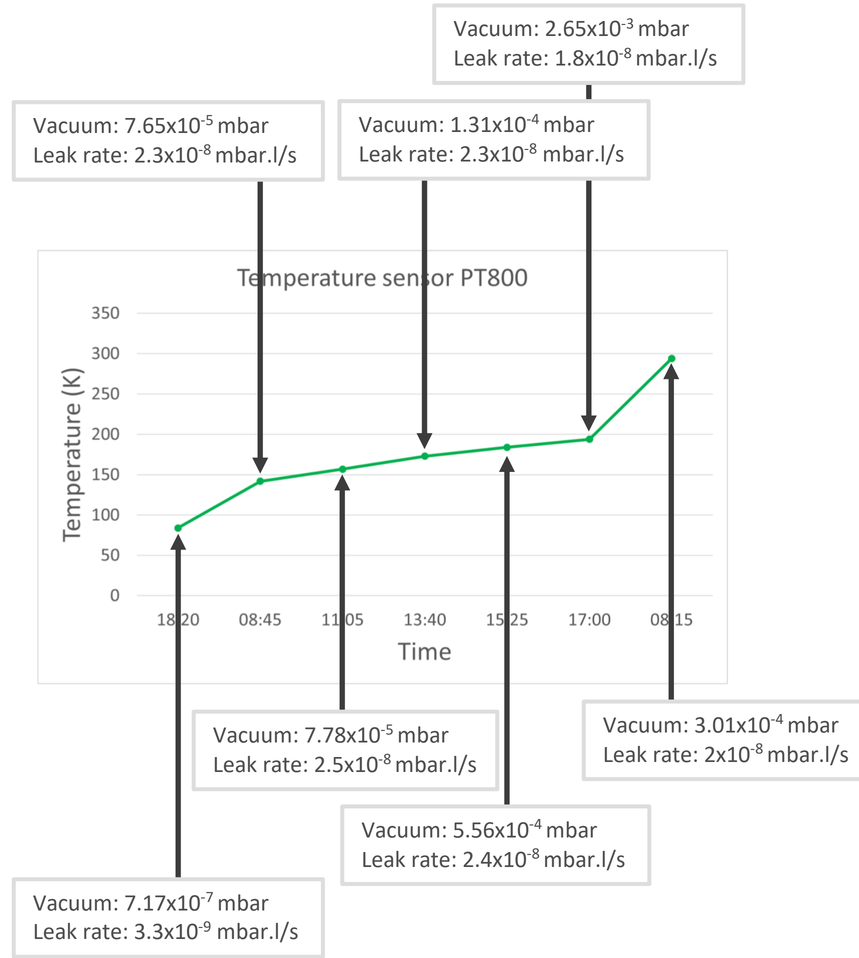


Experimental results - example

Step 3: Pressure and leak test at low T°



Step 4: Warming up



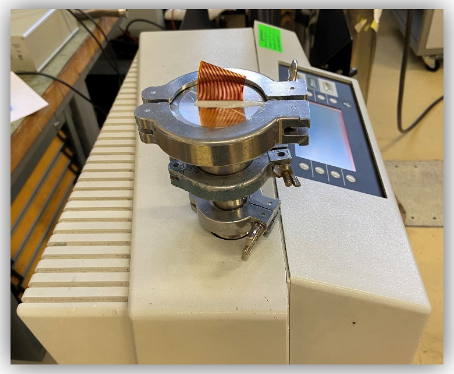
Experimental results - summary

- Summary of samples tested:

Sample	Experimental results
MY750 + Kapton strips + glue epo-tek + indium seal	Leaks detected
Accura25 + Kapton strips + glue epo-tek + indium seal	Leaks detected
G10 + Kapton strips + glue epo-tek + indium seal	**No leakage (2 cycles)**
G11 + Kapton strips + glue epo-tek + indium seal	**No leakage (2 cycles)**

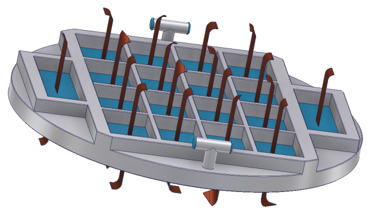

Sample A

- Strip cable of from ATLAS also tested:
  - Thermally shocked in LN_2 (77 K) up to 3 times and leak tested in stainless steel circular samples:
    Sample A (entire cable) → No leakage
    Sample B (cut piece of cable) → No leakage

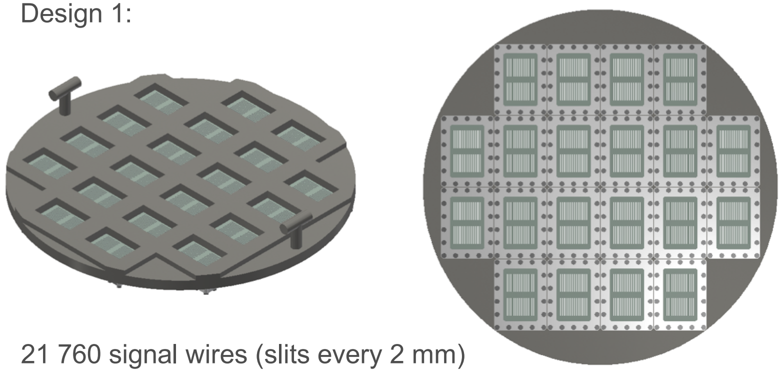

Sample B

Final design studies

- Up to 4 different flange designs studied
(going from 16 000 to 30 000 signal wires/flange)

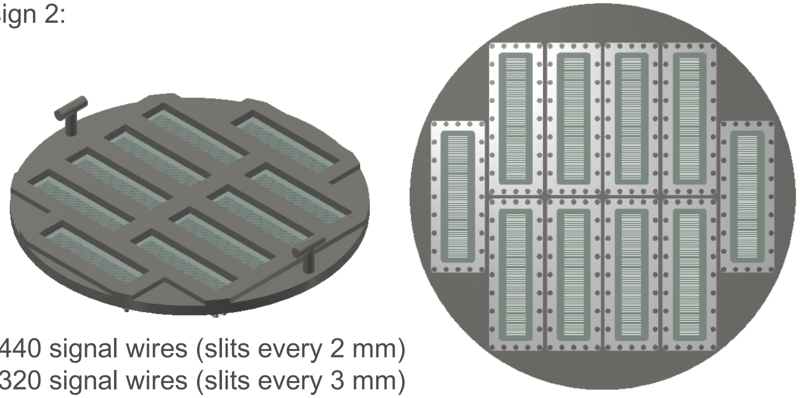


Design 1:



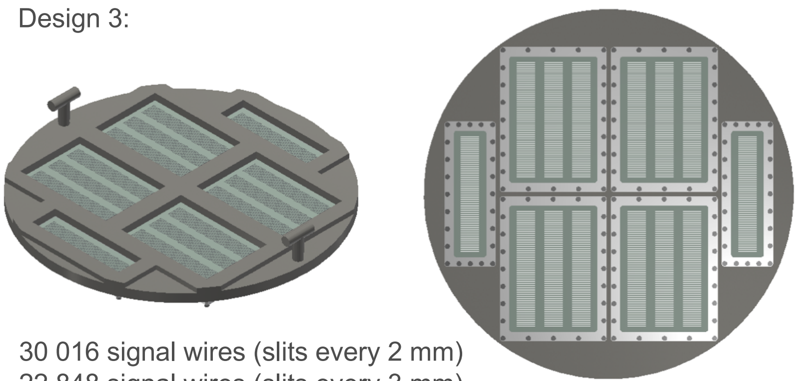
21 760 signal wires (slits every 2 mm)
16 640 signal wires (slits every 3 mm)

Design 2:



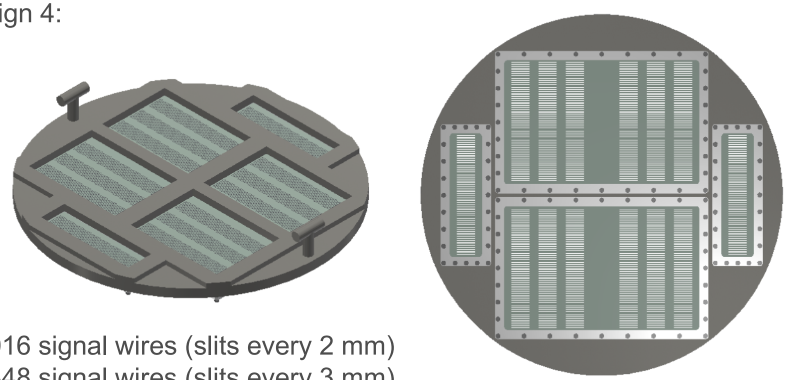
21 440 signal wires (slits every 2 mm)
16 320 signal wires (slits every 3 mm)

Design 3:



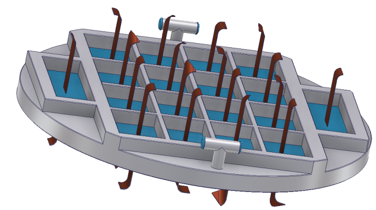
30 016 signal wires (slits every 2 mm)
22 848 signal wires (slits every 3 mm)

Design 4:

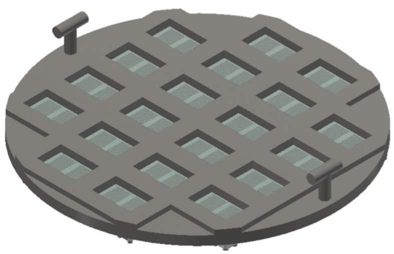


30 016 signal wires (slits every 2 mm)
22 848 signal wires (slits every 3 mm)

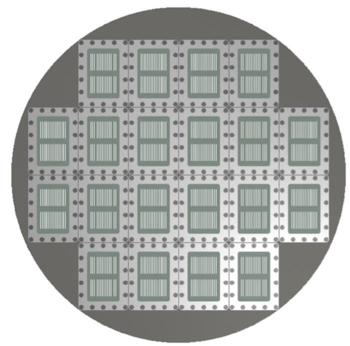
Final design studies



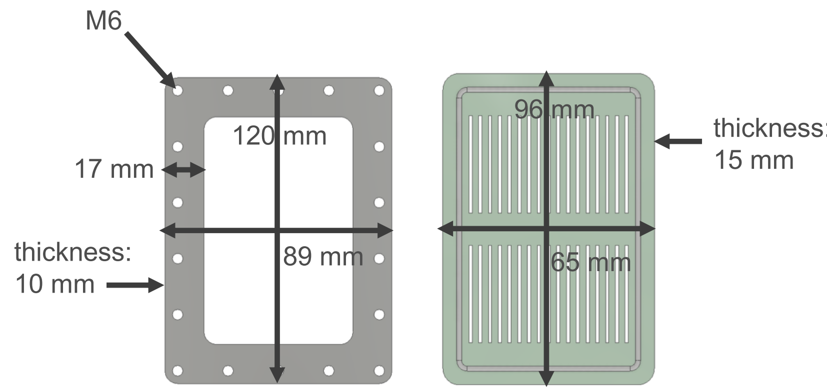
- 2 final designs selected:
  - Design 1: up to 21760 signal wires (2 mm)



Outer side

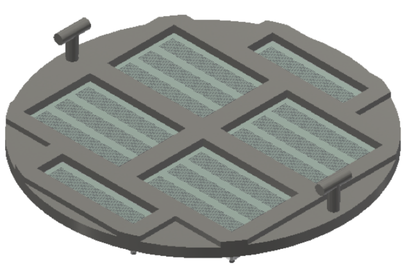


Inner side

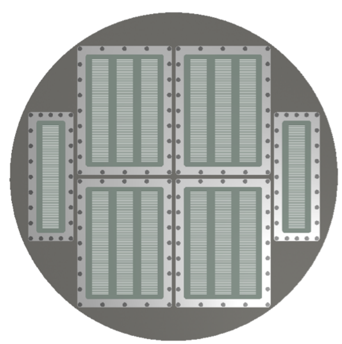


Optimized dimensions

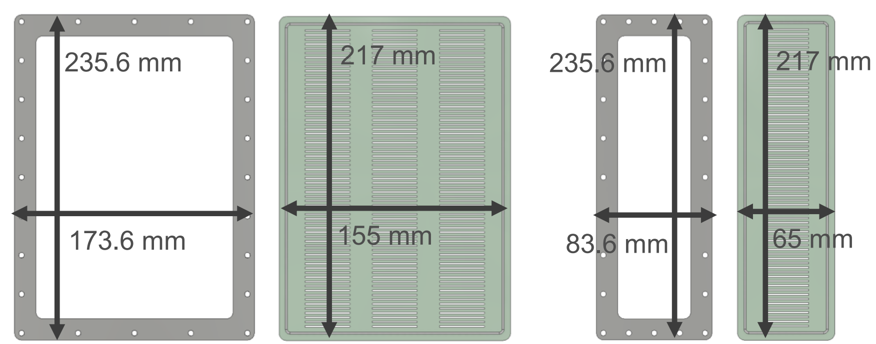
  - Design 3: up to 30 016 signal wires (2 mm)



Outer side



Inner side

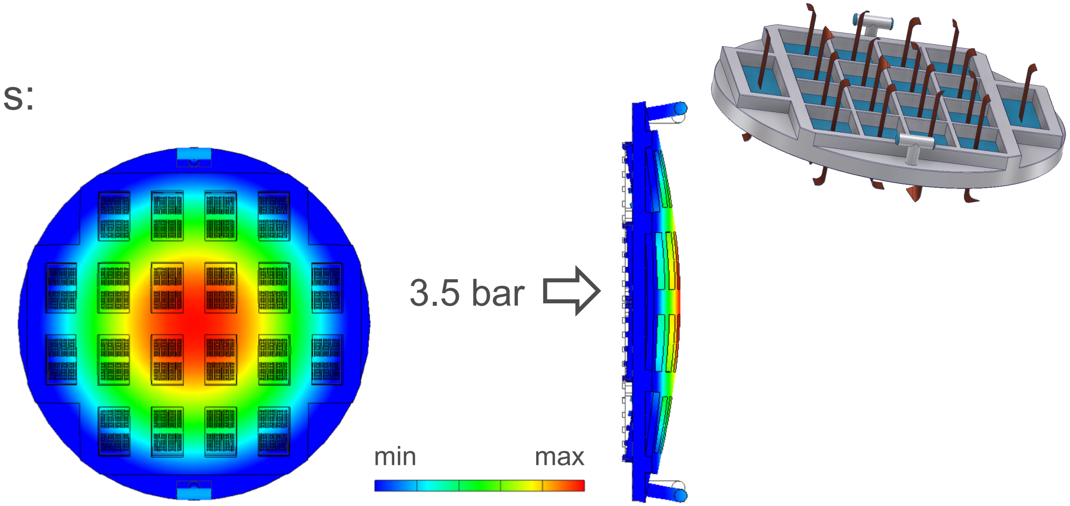


Optimized dimensions

Final design studies

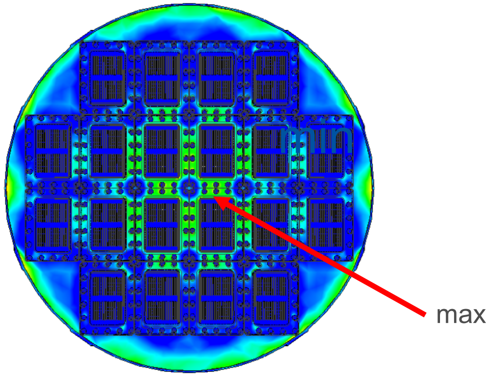
- Mechanical stress simulations:
  - Maximum deflection:

	295 K	77 K
Design 1	521.4 µm	474.8 µm
Design 3	760.3 µm	688.3 µm



  - Maximum Von Mises stress:

	295 K	77 K
Design 1	94.72 MPa	94.54 MPa
Design 3	140.6 MPa	140.1 MPa



Max. deflection: 0.76 mm (ATLAS FT 0.68 mm with ⌀ = 300 mm)
Max. Von Mises Stress: 140 MPa (below yield and tensile strength of components)

From: O. Reinicke (TUB Berlin)

Conclusions

Summary:

- Main components have been studied and selected
  (structural material, glue and mechanical seal)

  Rmk: also studies performed to analyse the failing samples (CTE measurements)

- Experimental setup has been designed and constructed to simulate extreme conditions
  in the LAr calorimeter (also used to test carbon fiber cryostat prototypes - internal collaboration)

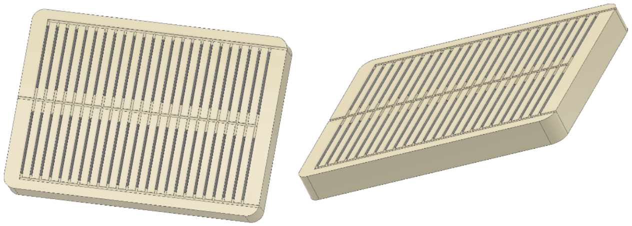
- Experimental tests have shown the validation of the concept (G10, G11 but also Stainless-Steel)
  (tests at “extreme” conditions: cooling down times, < 87K, GHe)

- Mechanical simulations have shown the viability of different flange designs

Conclusions

Future steps:

- Stablish standard protocols for the flange construction (surface treatments, gluing steps, capillary gluing, etc).



- Size optimization of different components (distance between slits, SS main grid size, etc.)

- Cable design and optimization
  (R&D ongoing on PCB electrodes design with noise and cross-talk mitigation – F. Brieuc)

- Other options:

  - High-density flange design with very thin connectors (~ 1.27 mm)
  - Other signal transfer technologies (increasing available surface, optical fibers, wireless solutions…)

Thank you for your attention!
Questions?