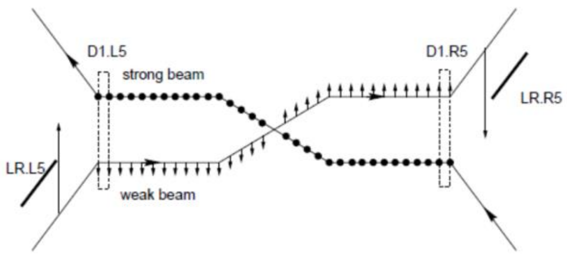

Possible Design of a Solid Wire BBLR Compensator

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with contributions from F. Carra, A. Dallocchio, S. Fartoukh, C. Fichera, M. Garlaschè, S. Mathot, F. Motschmann, Y. Papaphilippou, G. Sterbini, M. Timmins

8th HL-LHC Collaboration Meeting
CERN 18/10/2018

Context

- Beam-Beam Long-Range Compensators with physical wires are considered a valuable options for HL-LHC to increase dynamic aperture at small crossing angles
  - either in conjunction with Crab Cavities (HL-LHC round optics)
  - or as back-up solution (without Crab Cavities) with HL-LHC flat optics
- Requested in LHC Performance Workshop 2018 and 2018 HL-LHC Cost and Schedule:
  - Technical proposal for the HL-LHC wires integration by 2019-2020
- A space reservation of 4.5 m was made for both beams on either sides of IP1 and IP5

Initial Requirements (as understood)

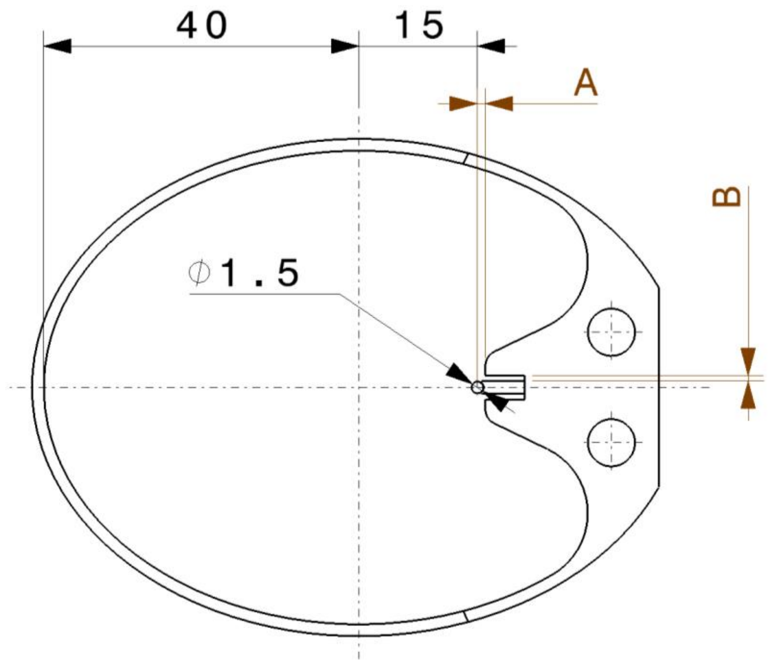
- **1 wire per beam** per side of IP1 and IP5 → **8 wires** (4 H-wires and 4 V-wires depending on IP1/5 crossing angle)
- **Single wire** positioned in a vacuum chamber
- **Round wire** cross-section
- Wire total active length **3 m**
- Up to **400 Am DC** per wire (may be 220 Am depending on the chosen configuration), **133 A**
- Lateral stroke of the chamber **~ 15 mm** (parking wire at ~ 30 mm from beam?)
- Energy deposited by beam halo / particle showers not taken into account (particle tracking and FLUKA required)

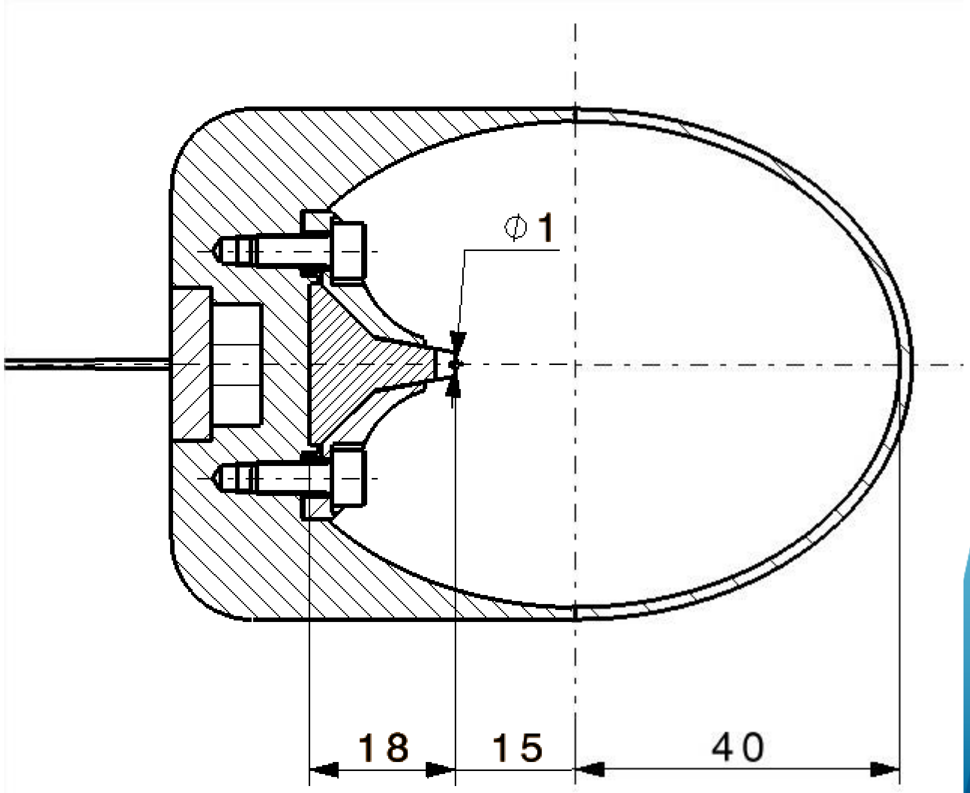
The Idea

- Use a slim, light design with a **thin, naked, metal** wire, allowing to move as close as possible to the beam, while minimizing interactions with beam particles.
- Bond the metal wire onto a support being both an **electrical insulator** and a **thermal conductor** (**ceramic**).
- Keep design simple and affordable, by using a **mobile vacuum chamber**, integral with wire, which can be shifted horizontally or vertically.
- To ease fabrication, assembling and installation, split the active length (3 m) in several **independent modules**, tentatively 3, **each 1 m long**, carrying up to **130 A**.
- Each module to be mounted and aligned on a **single support** structure, which can be integrally actuated.
- Exploit experience and know-how from collimators and TCTW, particularly for actuation system …

The Idea

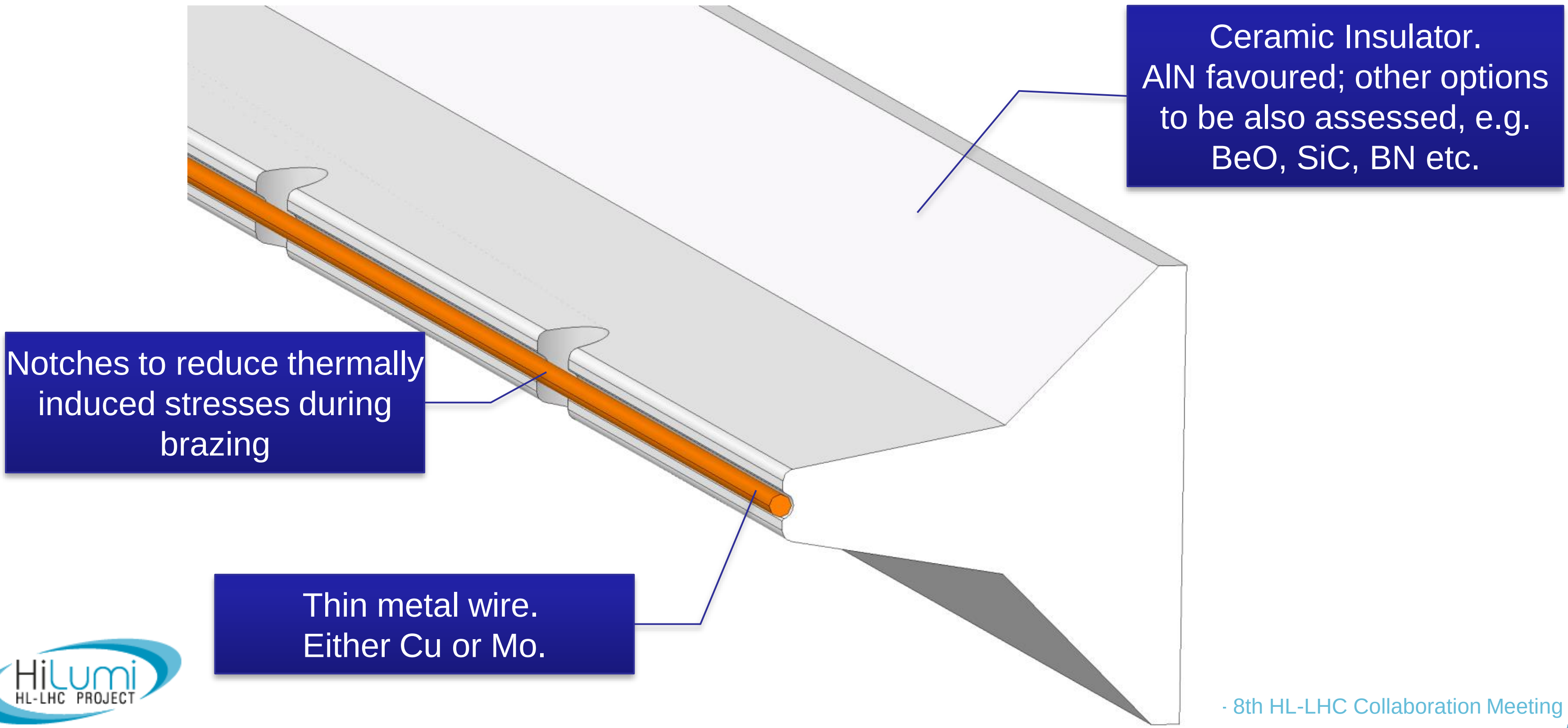
- A first concept presented by A. Rossi at Impedance WG on 1st June ’18.
- Initially ok with impedance, detailed analysis to follow when full design is ready.
- The initial concept posed several technological changes … concept evolved (and still evolving …)





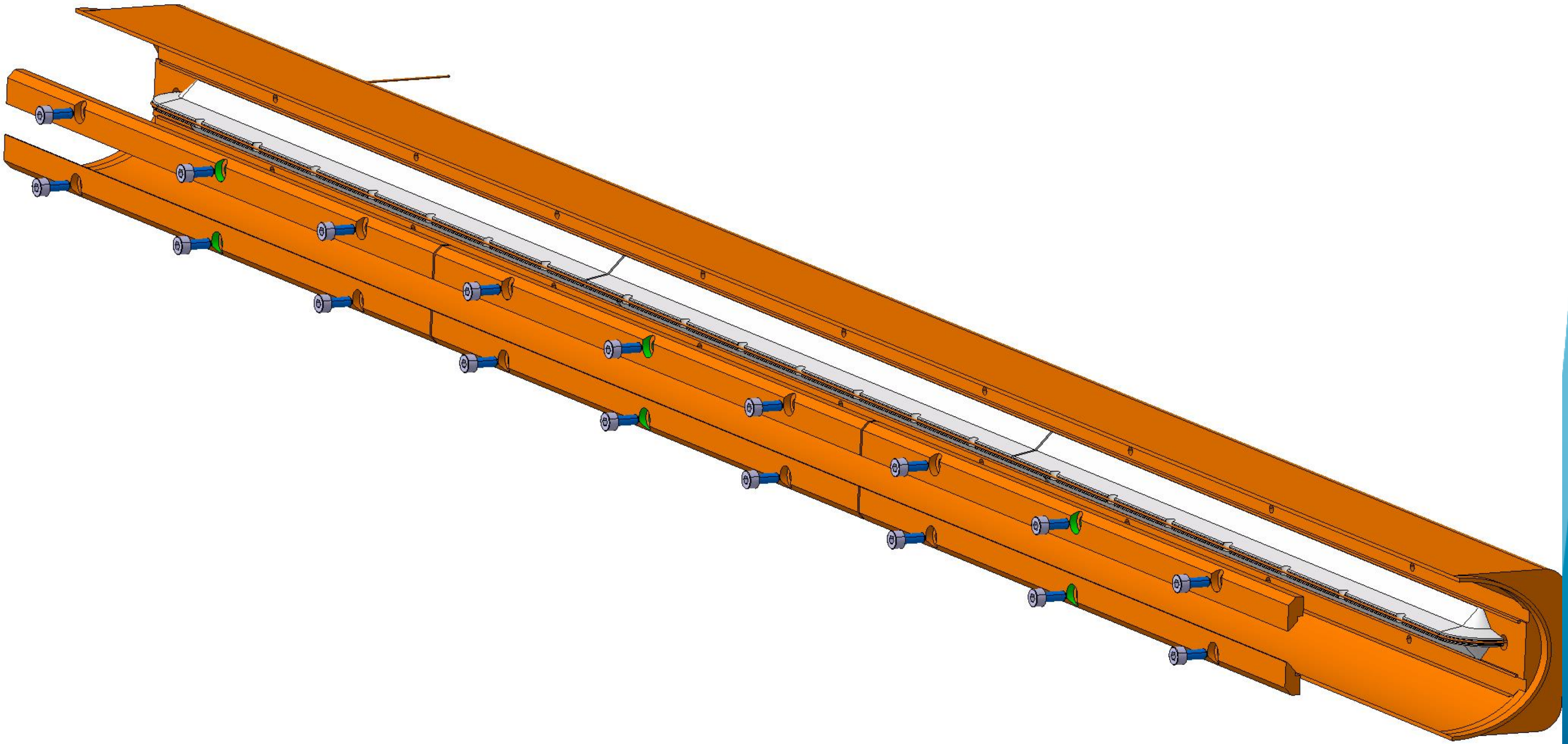
Main Design Features: Wire and Insulator

- Vacuum brazed solution. Dimensions of the insulator just preliminary.
- **Mo wire** has higher electrical resistivity compared to **Cu** (factor 3), but is **better matching** ceramic **CTE** and is refractory (higher robustness, similar density).
- Diameter **can hardly be smaller than 1 mm** for **technological reasons** (regardless of electrical current). Technological validation necessary …



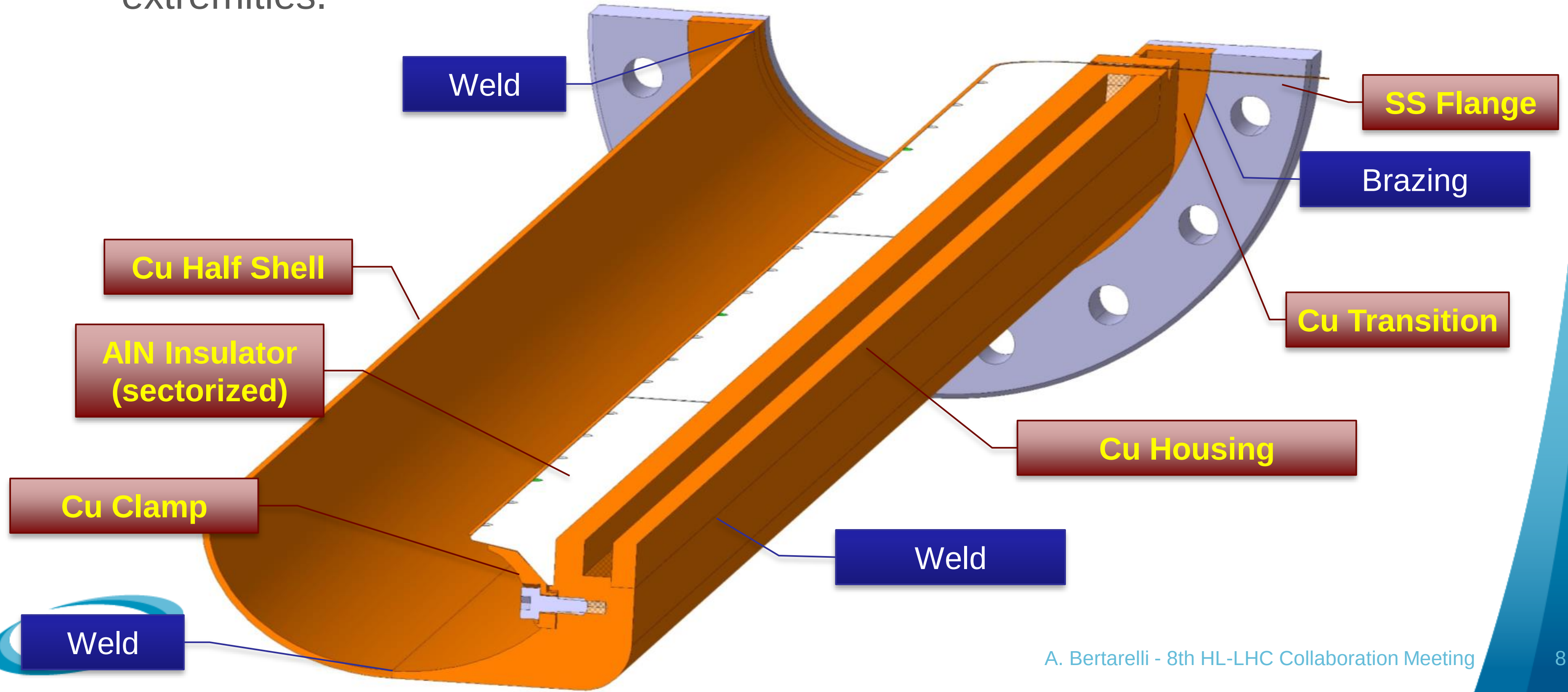
Main Design Features: Housing

- Insulator with wire is mechanically clamped to a Cu housing, via controlled-torque screws



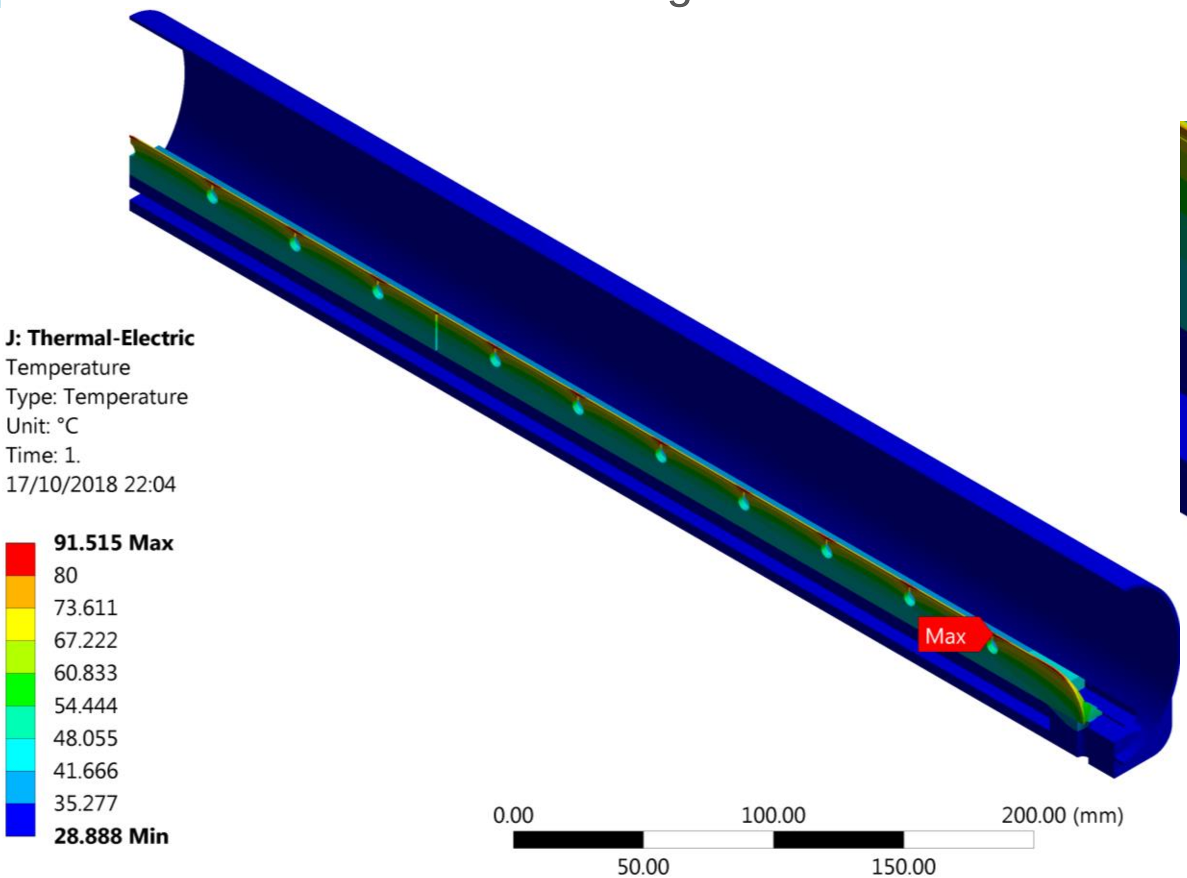
Main Design Features: Vacuum Chamber

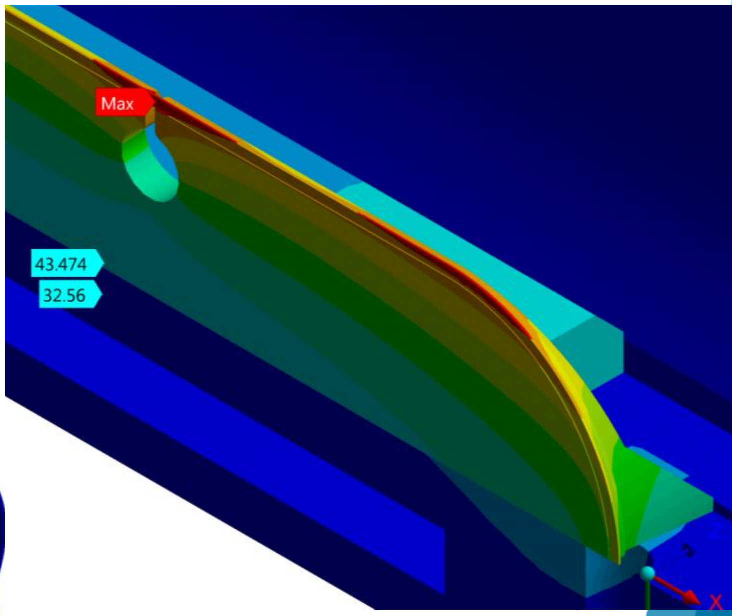
- Water cooling channel obtained by machining the housing and welding a circuit cover.
- Cu half-shell welded to the housing.
- Stainless steel flange brazed to copper and then welded to vacuum chamber.
- Total length: ~ 1200 mm. Welded bellows with RF fingers to be foreseen at extremities.



Engineering Parameters and Calculations

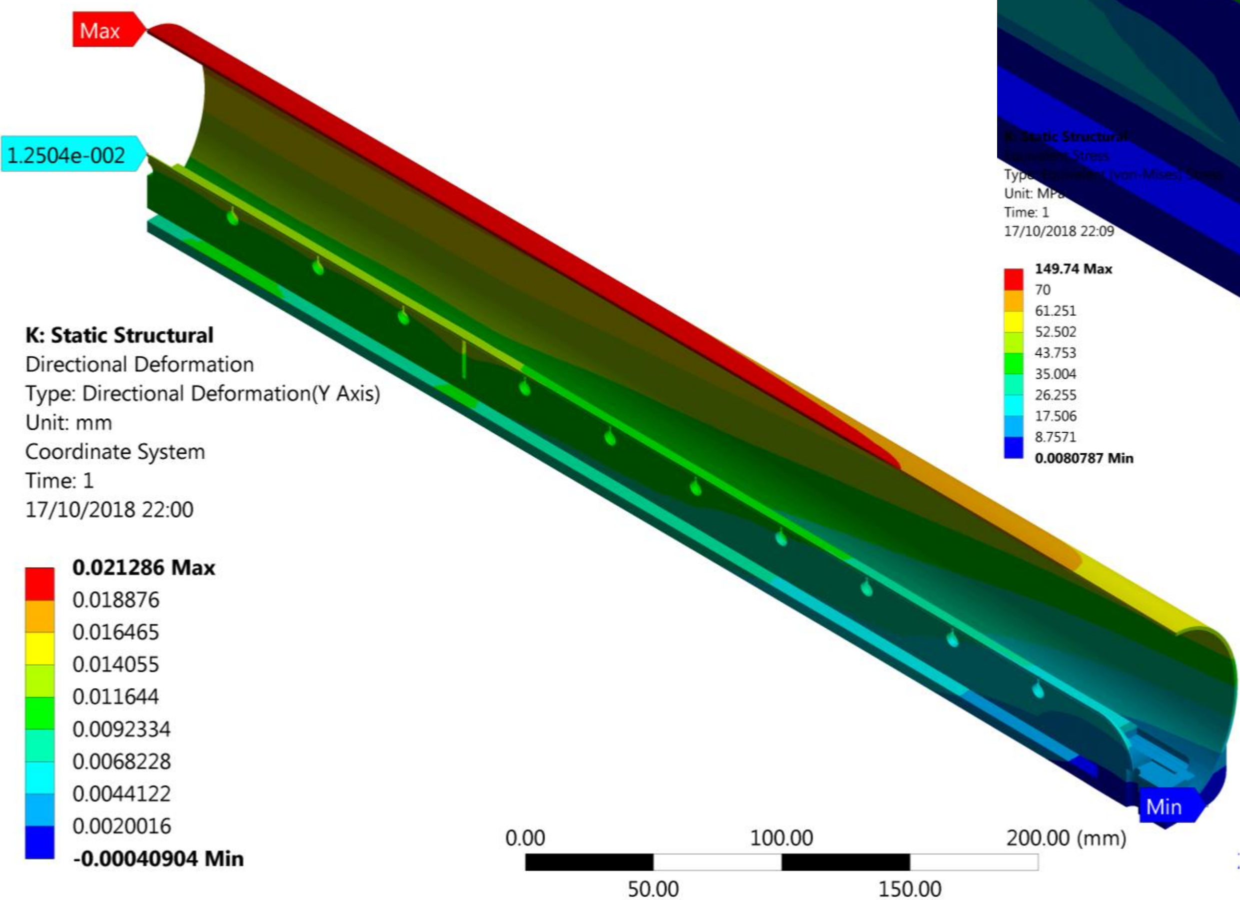
- With a ∅ 1 mm wire and 133 A per module, Joule-effect power to be dissipated is **~ 0.5 kW** in case of **Cu** and **~ 1.7 kW** in case of **Mo** (reminder: no beam losses included)
- Maximum temperature **~ 50 °C** in case of Cu, and **~ 100 °C** in case of Mo
- Water coolant circulating at **~ 3 m/s**

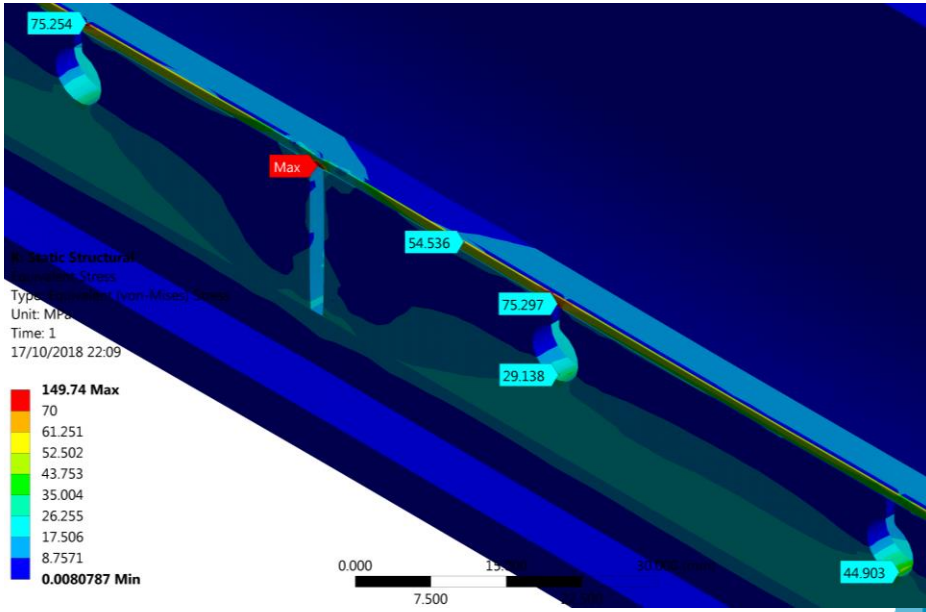




Engineering Parameters and Calculations

- Thermally-induced deformations appear limited (~ 20 µm) and stresses acceptable (~ 80 MPa in Mo, ~ 50 MPa in AlN)



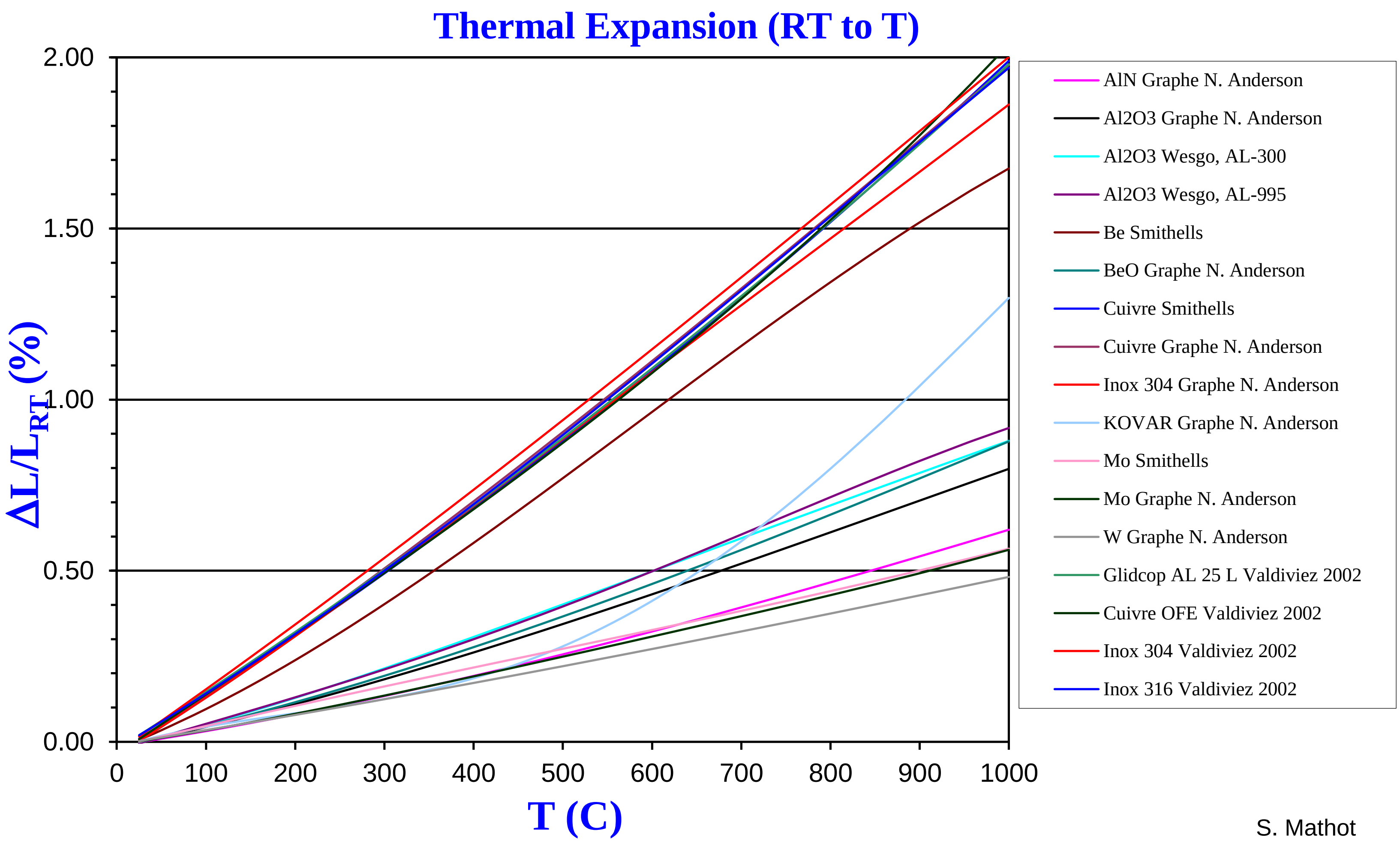


Outlook

- We are still at a brainstorming stage, exploring ideas, possibilities and specifications, concepts are evolving …
- Favoured concept is based on a simple, affordable mobile vacuum chamber with a solid metal wire.
- No showstoppers identified (yet?) for a thin Mo (or Cu) naked wire (Ø ≥ 1 mm) brazed onto a ceramic insulator.
- However, preliminary investigation **ignored several key physical and technological aspects** (e.g. beam losses, UHV aspects, RF impedance, transition feasibility, fabrication tolerances, bellows fatigue, RF fingers etc.) which should be the object of a proper design study.
- The manufacturing of a (small) demonstrator is paramount to validate the concept.

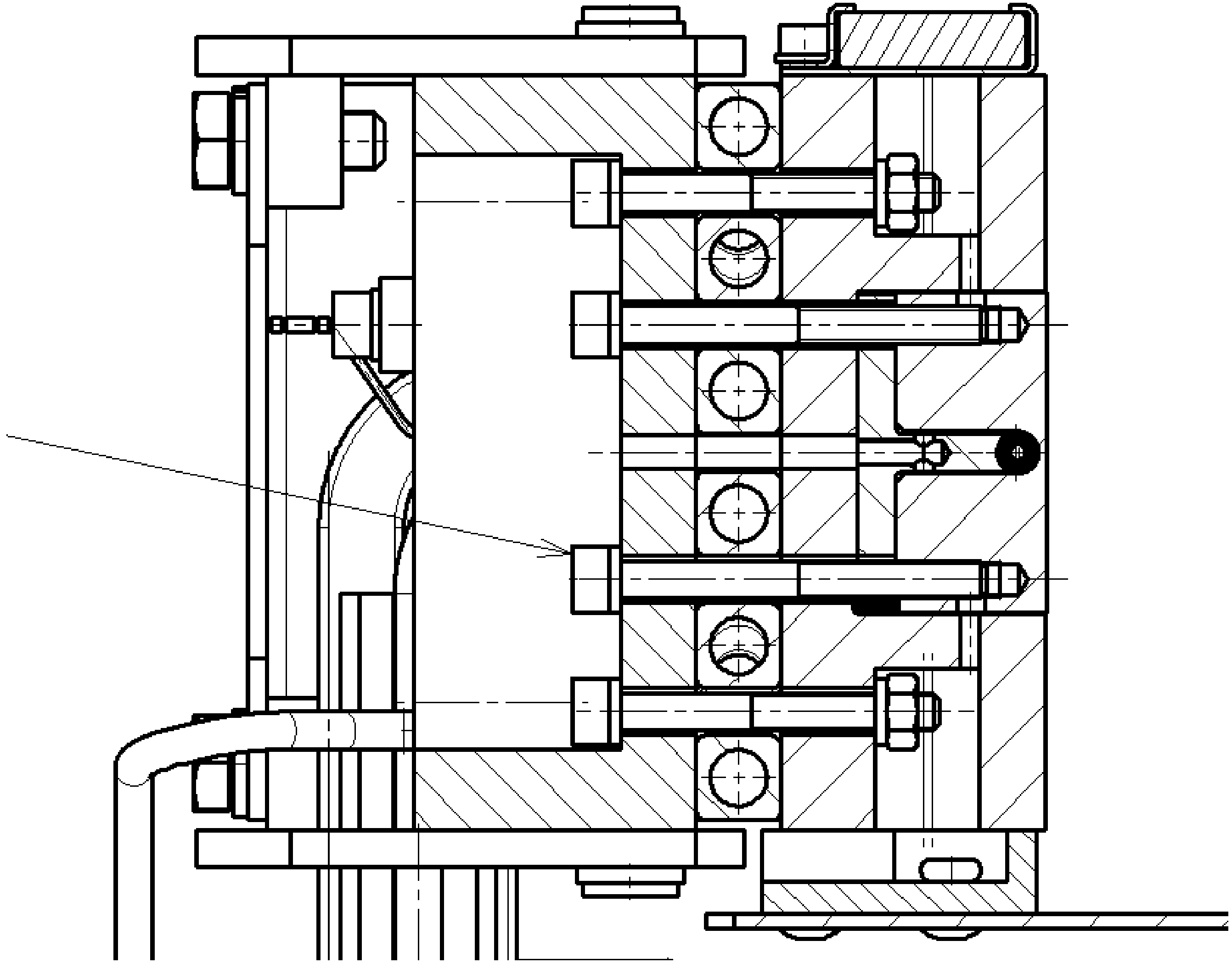
Thank you

Thermal Expansion

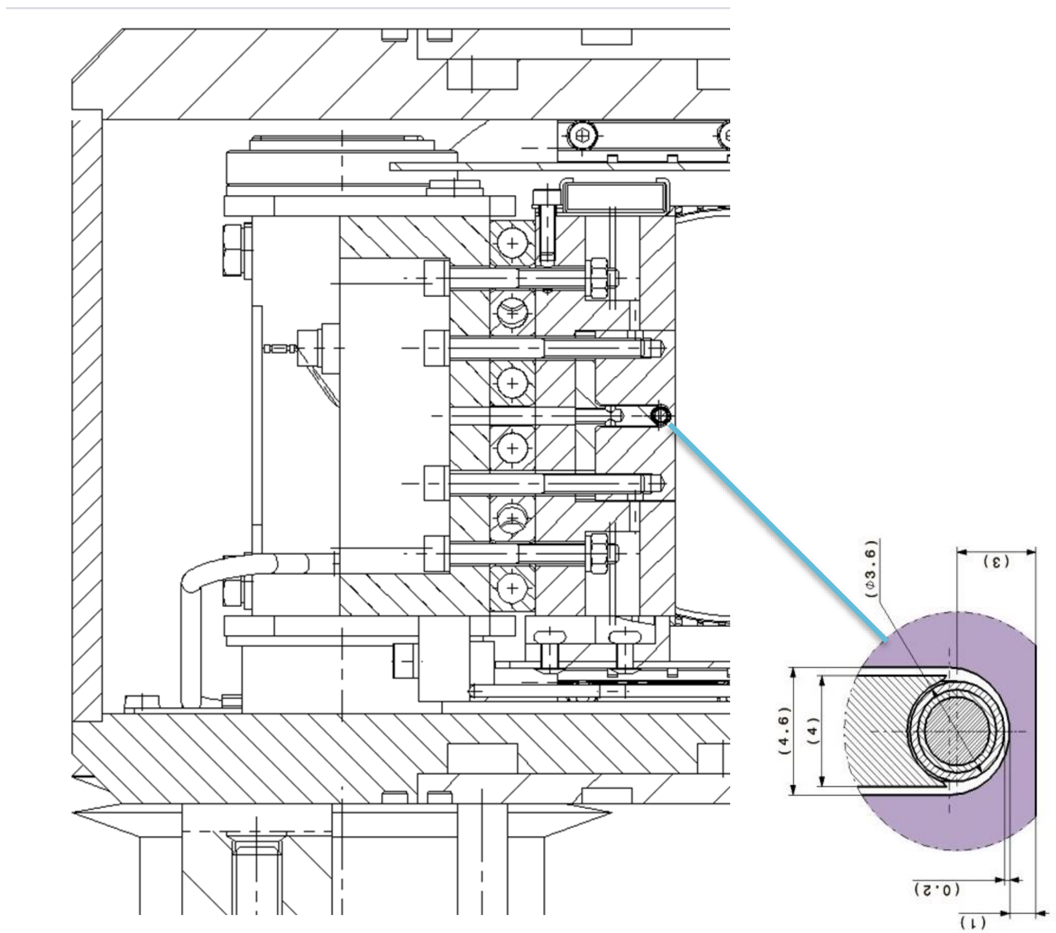


S. Mathot

TCTW Jaw Cross-section



TCTW Cross-section



Main Design Features: Vacuum Chamber