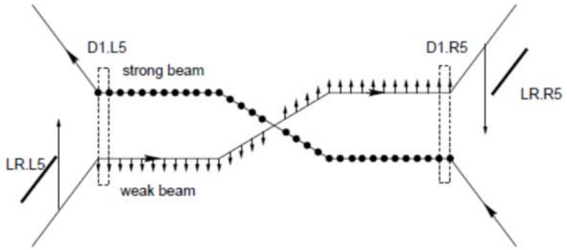

Preliminary hardware design of the Wire BBLRC for HL-LHC

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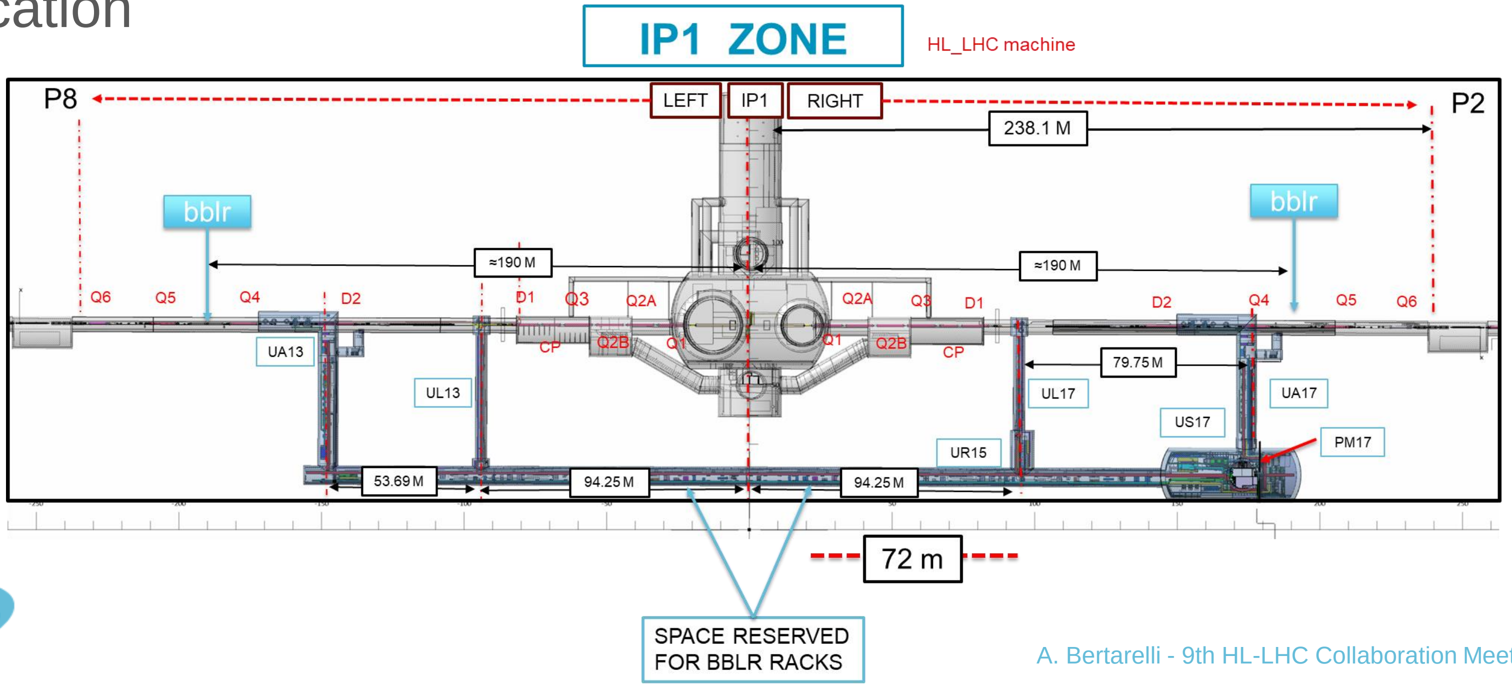
Context

- 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)
- A space reservation of 4.5 m on both beams was made on either sides of IP 1 and IP5, allowing 1 unit per beam per location



Initial Design Assumptions

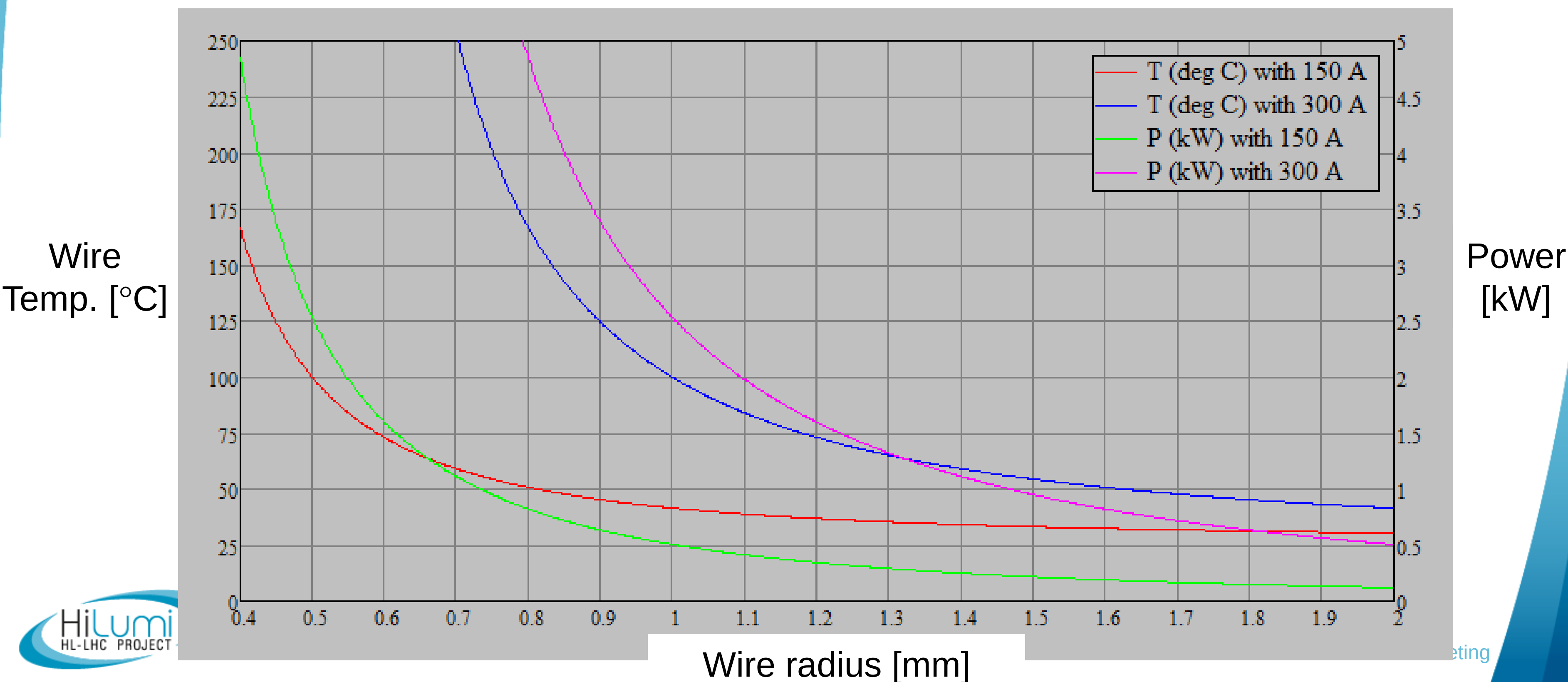
- These assumptions are a preliminary set of requirements defined for mechanical design purposes which may evolve or be scaled
  - **1 wire per beam** per side of IP1 and IP5 → **8 wires**
  - **Single wire** positioned in a vacuum chamber per beam
  - **Round wire** cross-section
  - Wire total active length **3 m**
  - **450 Am DC** per wire, i.e. **150 Am/m**
  - Wire entirely positioned in the shadow of Tertiary collimators (> 10.4 σ)
  - **Beam losses considered negligible**
  - **RF effects yet to be studied …**

The Idea

- Use a slim, light design with a **thin, bare, metal** wire, allowing to move as close as necessary 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**).
- To keep design simple and affordable, use a **mobile vacuum chamber**, integral with wire, which can be shifted horizontally and/or vertically. The cross-section should allow to host **two parallel chambers**, side by side on Beam 1 and 2
- To ease fabrication, assembling and installation, split the active length (3 m) in several **independent modules**, tentatively 3, **each 1 m long**
- Each module to be mounted and aligned on a **single support** structure, which can be integrally actuated.
- Exploit experience and know-how with collimators and TCTW, particularly for actuation system …

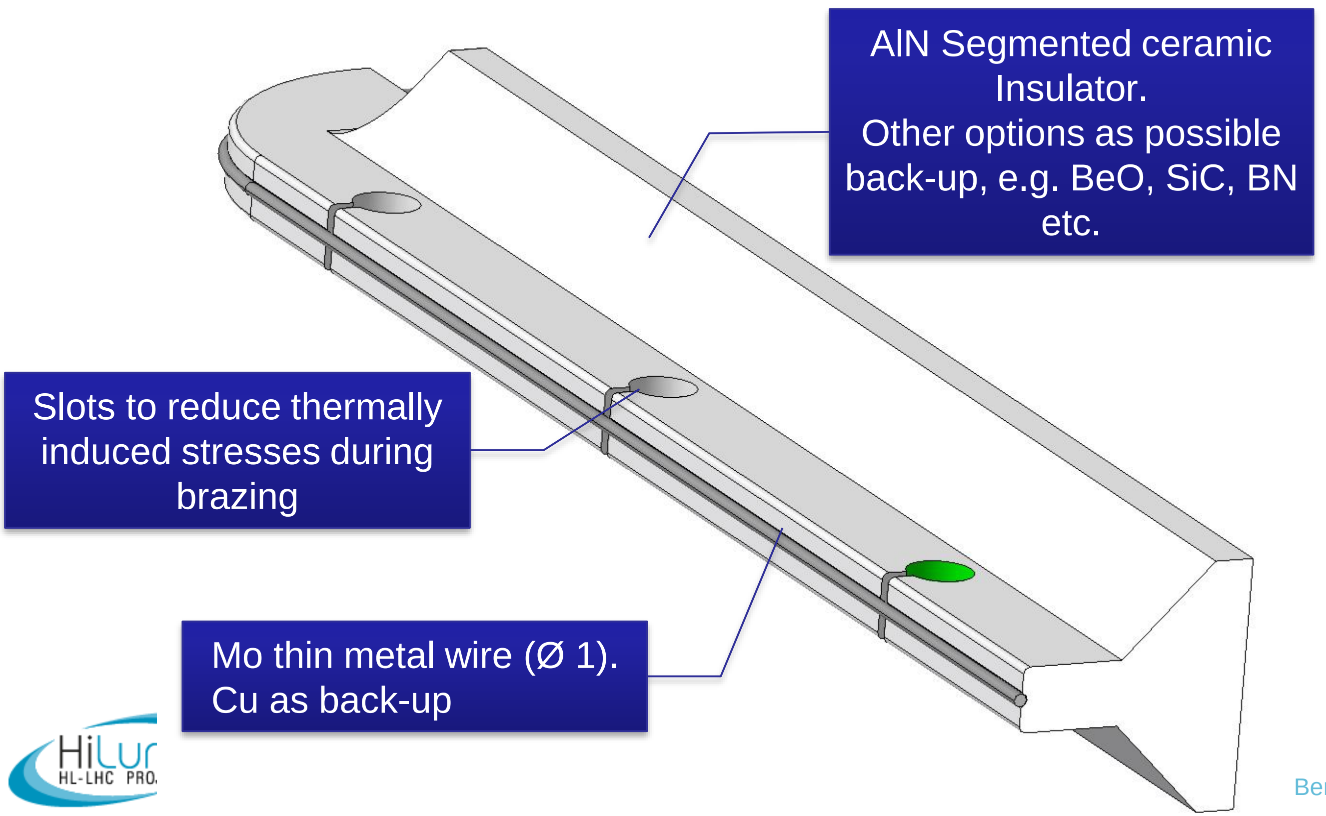
The Idea

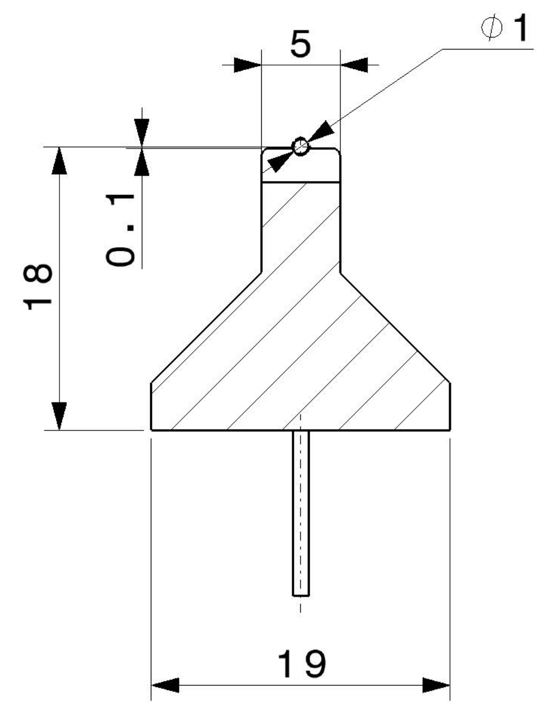
- How much current can the wire carry? It depends on its cross section …
  - A linear relationship exists between Current and Power (or max temperature) allowing a simple scaling of the design, if needed.
  - Mo wire used in the example below …



Main Design Features: Wire and Insulator

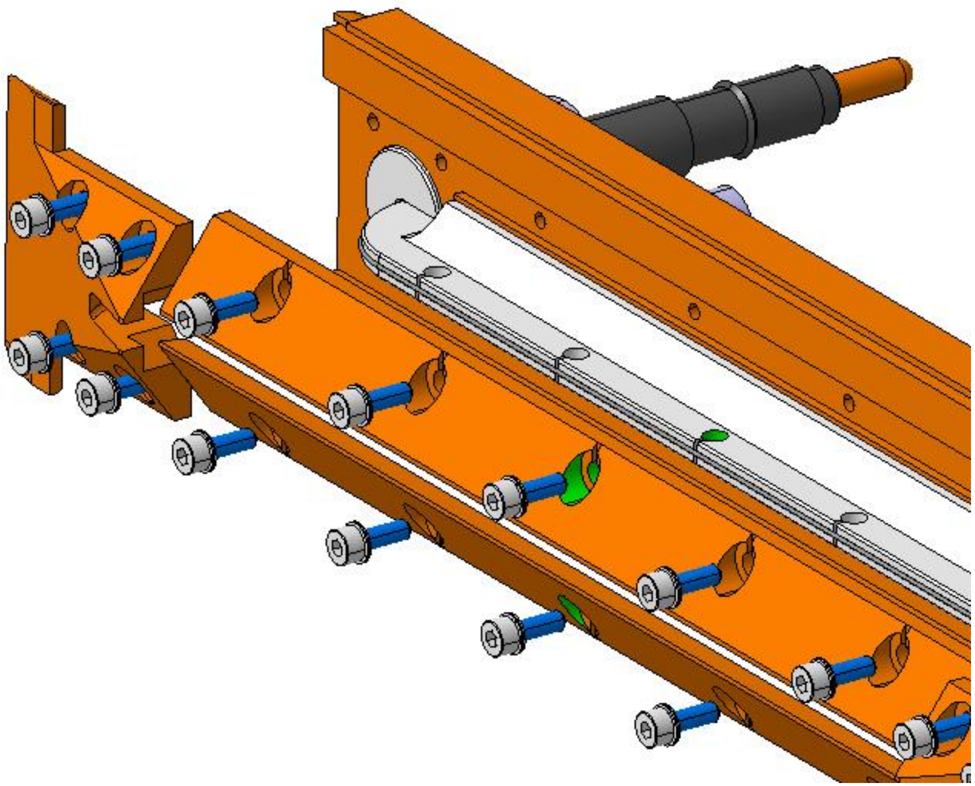
- To start, we assume a ∅**1 mm 1 m-long Mo** wire with **150 A** current
  - Vacuum brazed solution
  - **Mo wire** has higher electrical resistivity compared to **Cu** (back-up), but is **better matching** ceramic **CTE** and is refractory (higher robustness)
  - Diameter **can hardly be smaller than 1 mm** for **technological reasons** (regardless of electric current)

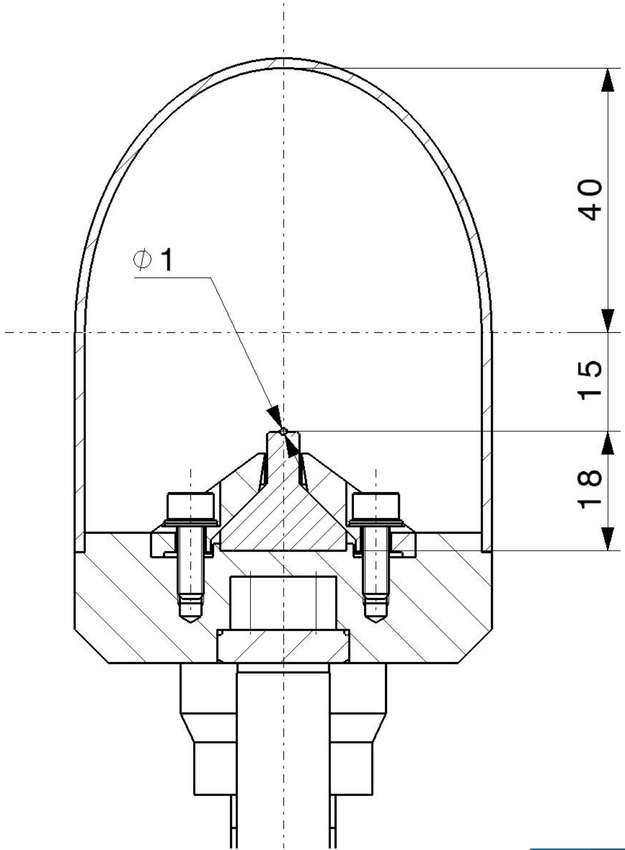




Main Design Features: Housing

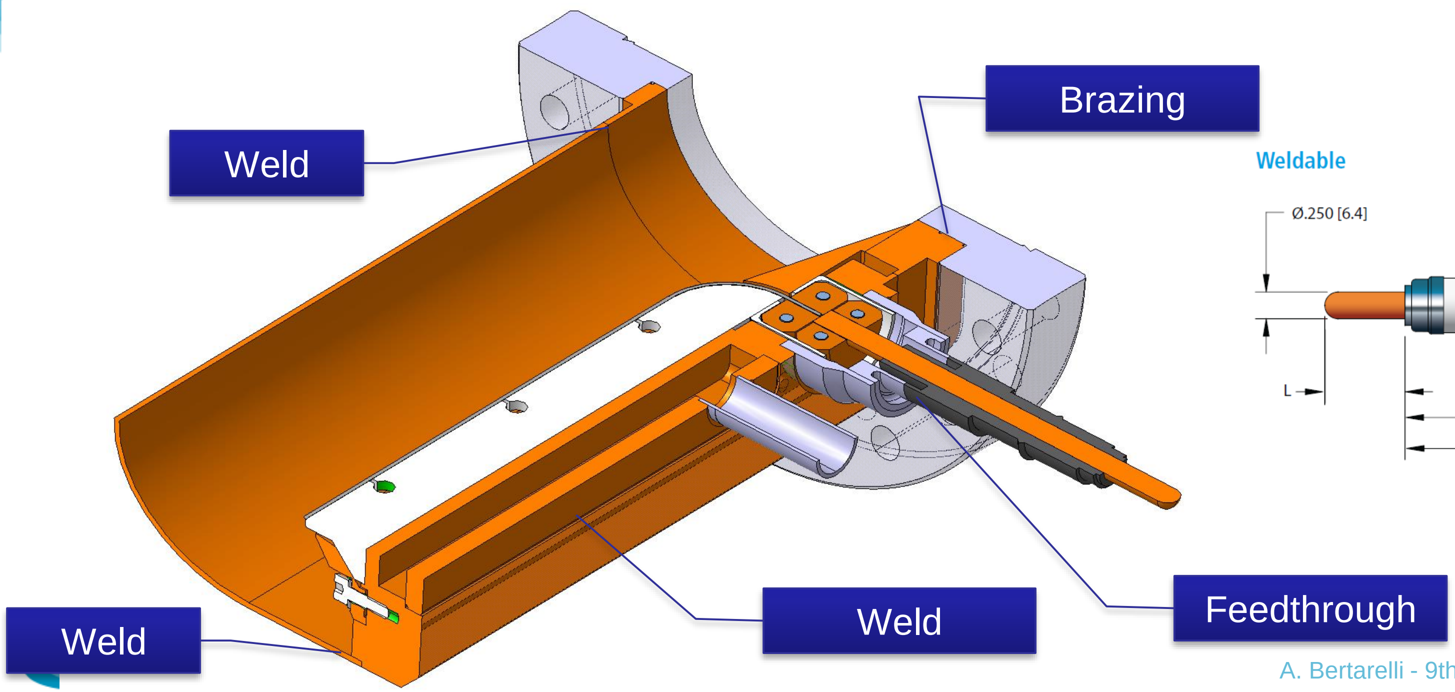
- Insulator with wire is mechanically clamped to a Cu-based housing, via controlled-torque screws
- Cu clamps to be designed to minimize RF impedance
- Wire active length 1 m; several insulator modules to be assembled (250 ÷ 300 mm long)

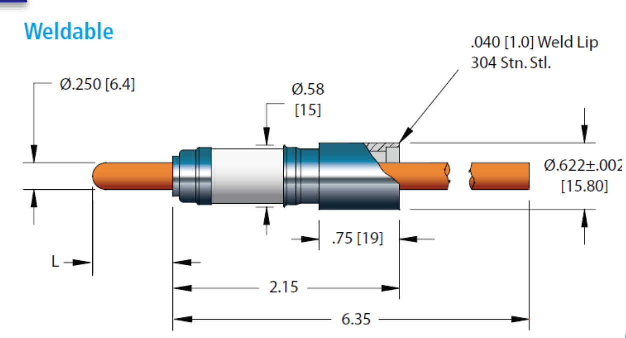




Main Design Features: Vacuum Chamber

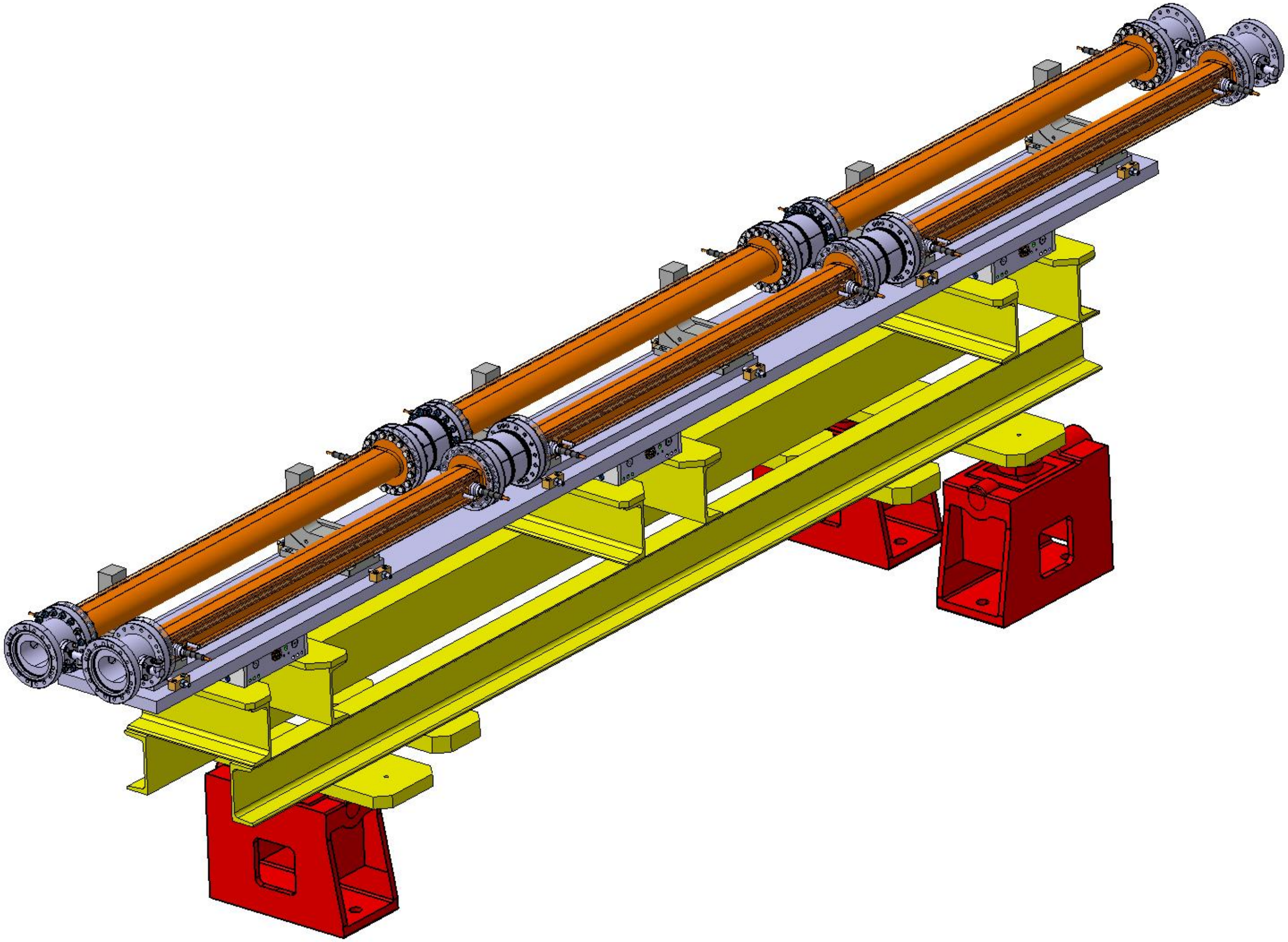
- Water cooling channel obtained by housing machining and cover welding.
- **Commercial feedthrough** connection carrying up to 185 A. If more current is needed, liquid-cooled feedthroughs should be adopted
- Cu half-shell welded to the housing
- Stainless steel flange brazed to copper and then welded to vacuum chamber.





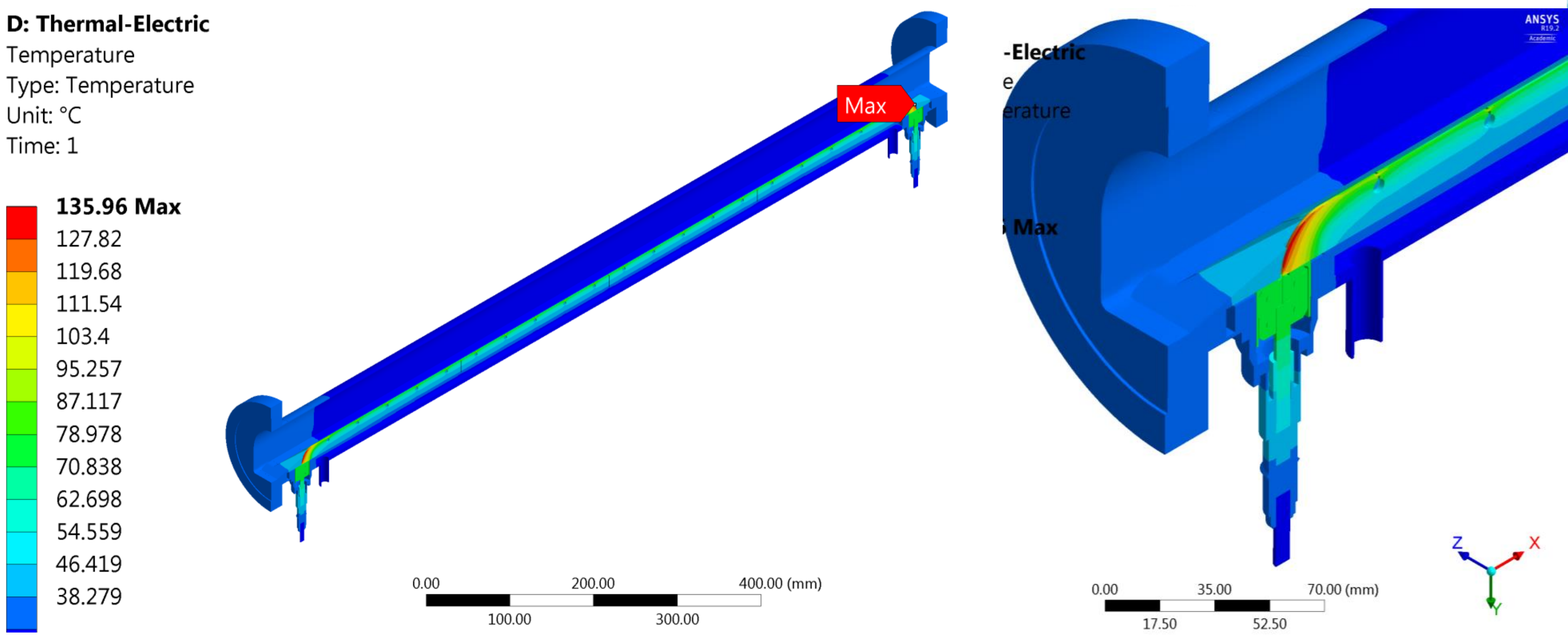
Possible Assembly Layout

- Conceptual layout with two parallel assemblies. For discussion only, many details missing, e.g. actuation system …



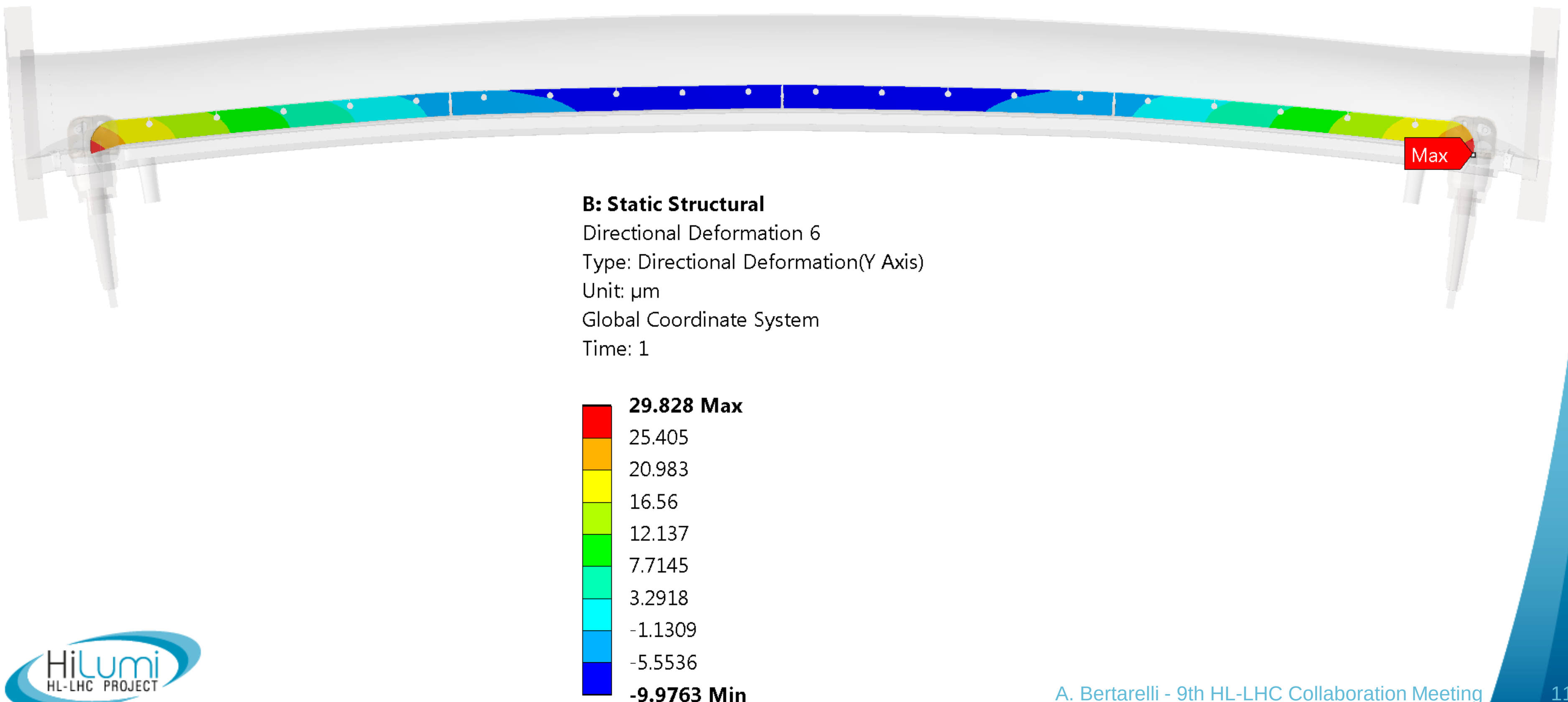
Numerical Simulations

- With a ∅ 1 mm **Mo** wire and **150 A per module**, Joule-effect power to be dissipated is **~ 2.1 kW** corresponding to **~ 14 V** (~ 90 mΩ)
- Maximum temperature **~ 90 °C** in straight wire (up to **~ 140 °C** in the end transitions)
- Water coolant circulating at **~ 1.5 m/s**, **~ 12 L/min**



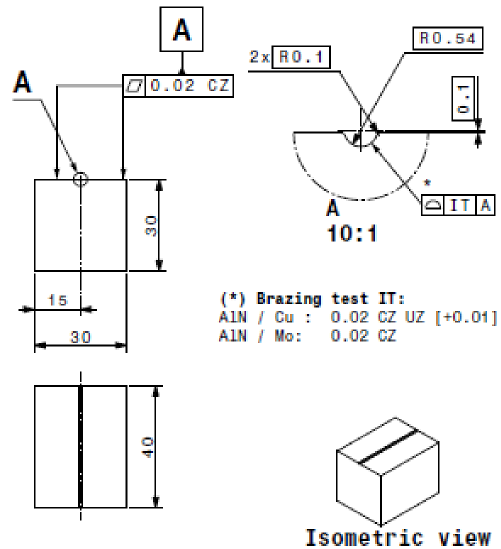
Numerical simulations

- Estimated deflection of the vacuum chamber in operating conditions is ~ 30 μm



Proof of Concept

- Vacuum Brazing is the most critical step in the process (a few mm gap between wire and cooler may induce a thermal runaway of hundreds degrees …) $\rightarrow$ proof of concept proposed
- AlN + Mo (and Cu as back-up) wire specimens ordered, to be brazed to verify feasibility and optimize brazing parameters. Specimens to be delivered in 6 weeks
- If results are ok a short demonstrator (290 mm long) will be built, brazed and assembles early 2020, to validate the process and check residual deformations …

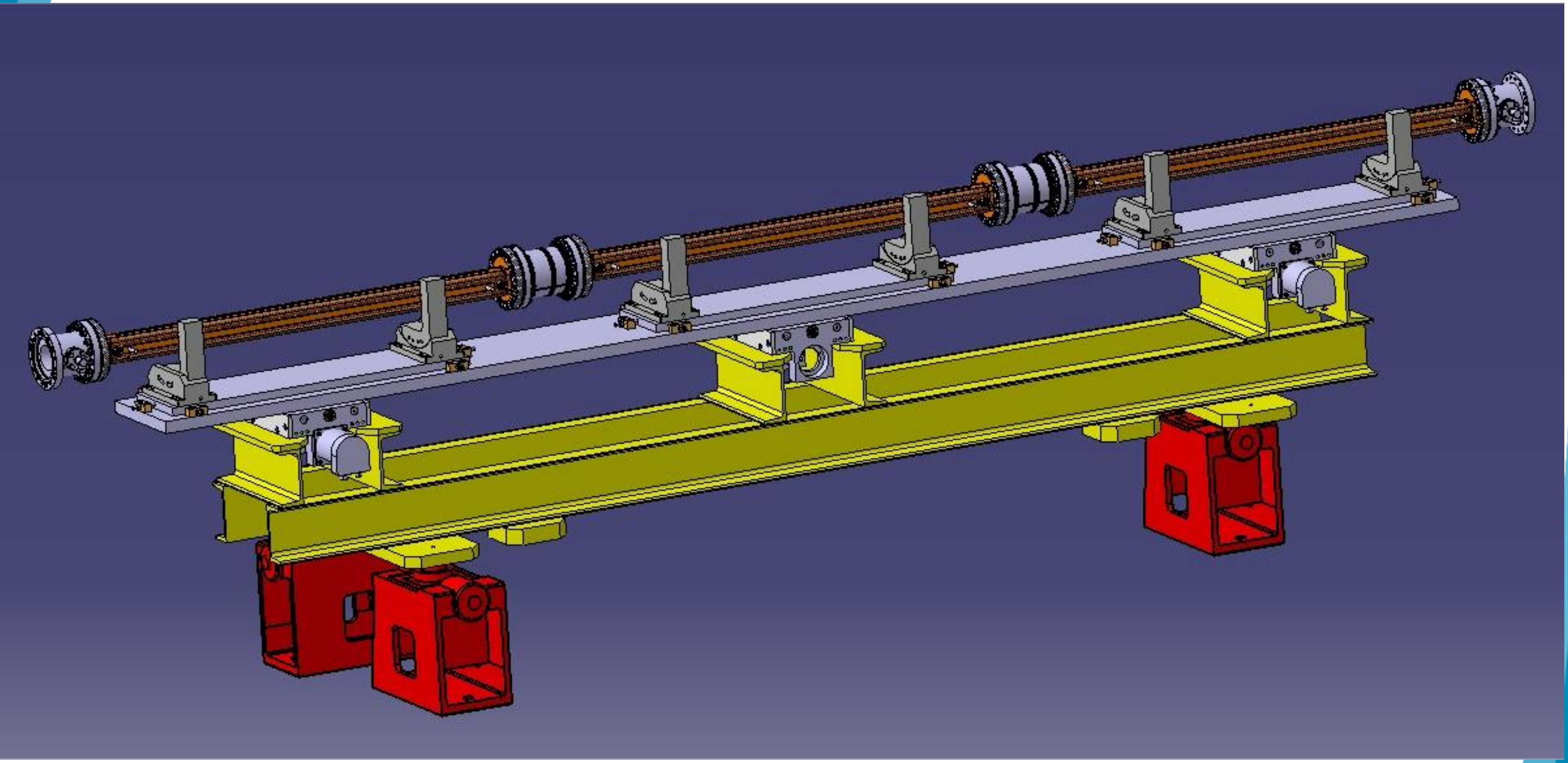


Outlook

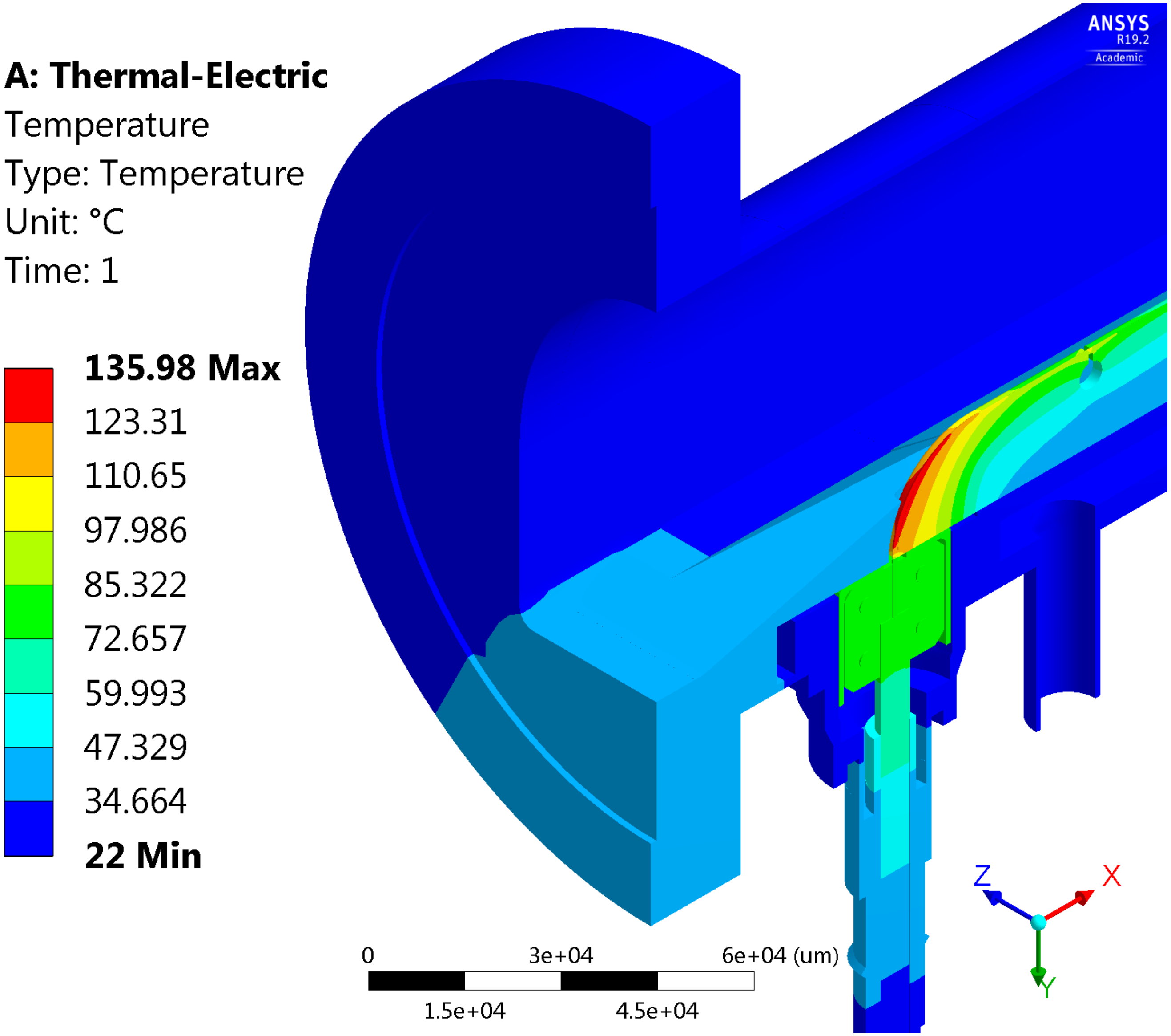
- A simple, low-cost, modular design is being explored, allowing a certain scalability as to number of modules, current and dimensions
- No showstoppers identified (yet?) for thin Mo naked wire (Ø ≥ 1 mm) brazed onto a ceramic insulator
- However, preliminary investigations ignored several key physical and technological aspects (e.g. beam and RF losses, mechanical feasibility, fabrication tolerances, UHV aspects etc.) which should be the object of a proper design study
- The manufacturing of a demonstrator is a fundamental step to validate the concept. A simplified demo is foreseen by early 2020
- A full-fledged design (number of modules, length, interfaces, motorization, integration …) should be launched after demonstrator proves this concept is viable

Thanks for your attention

Possible Layout



Numerical Simulations



Numerical Simulations