Advanced collimation design studies (TCT with wire, hollow e lens)

Diego Perini on behalf of the EN-MME design office

Summary

TTC with wire (a demonstrator)

- design issues
- test of components
- next steps

Hollow electron lens

- pre-design for HL-LHC
- next steps

TCT with wire

LHC Beam-Beam Compensator

Challenge: Embed an **electric wire in a TCTP collimator jaw** to compensate long-range Beam-Beam effects near interaction region

Concept: Insulated wire embedded in Tungsten jaw. Wire is pushed against jaw block by pushrod

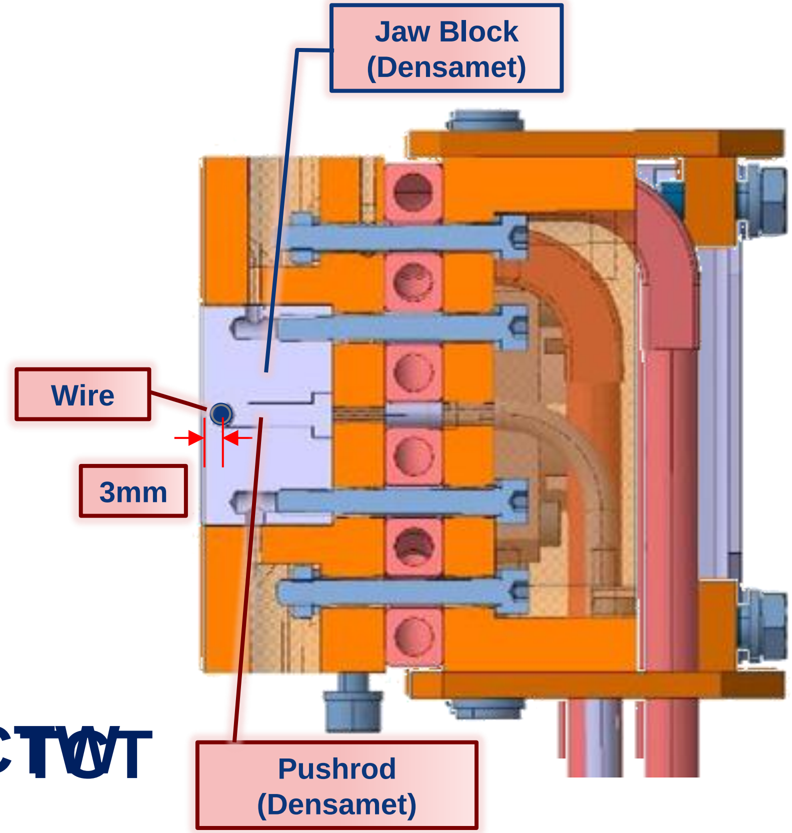
Requirements:

High DC current (up to 350 A)

Thin wire (Ø≤ 2.5 mm)

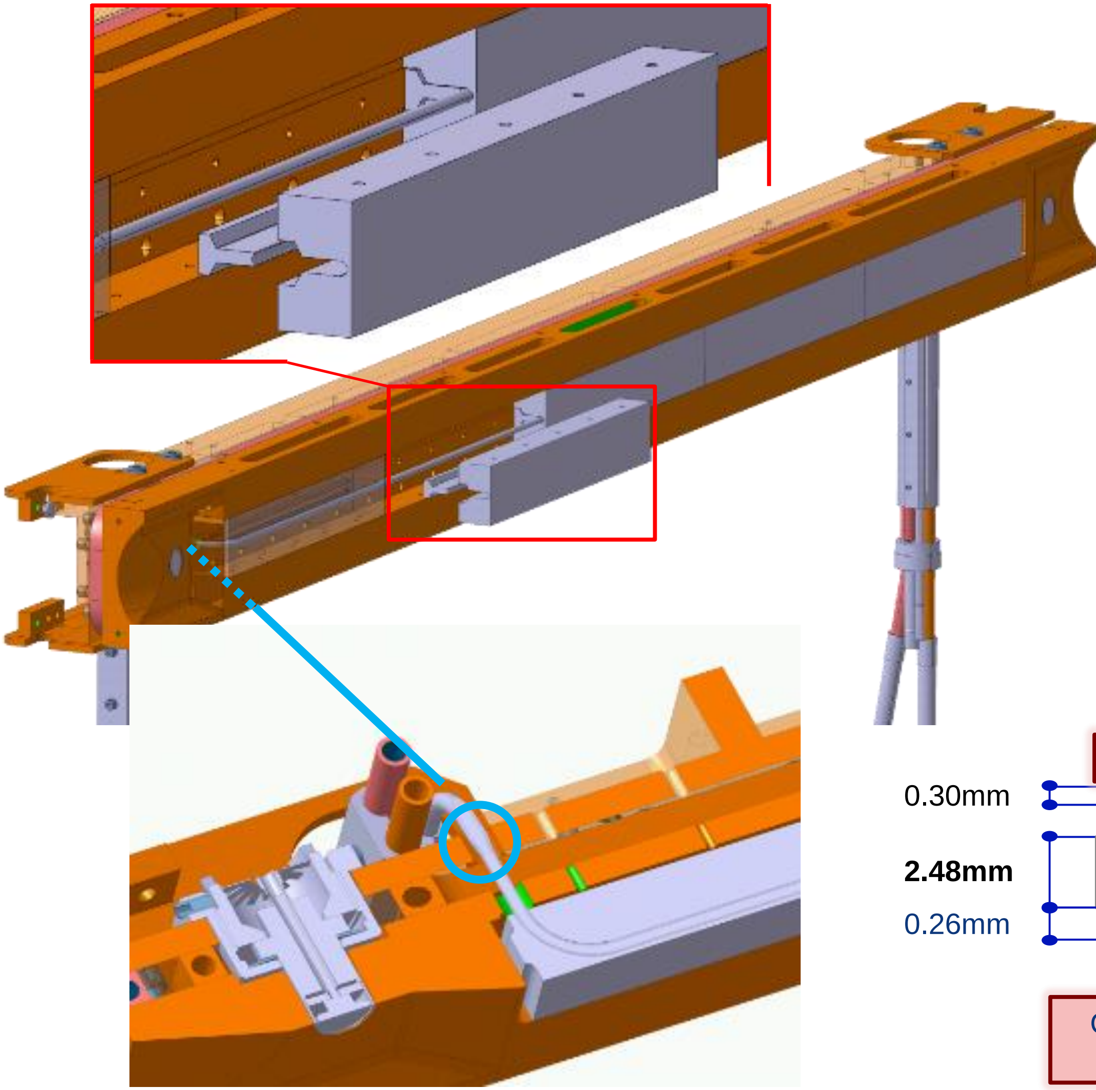
In-jaw wire (depth ≤ 3 mm)

Maintain TCTP complete functionality



TCTW

TCTW: New Features

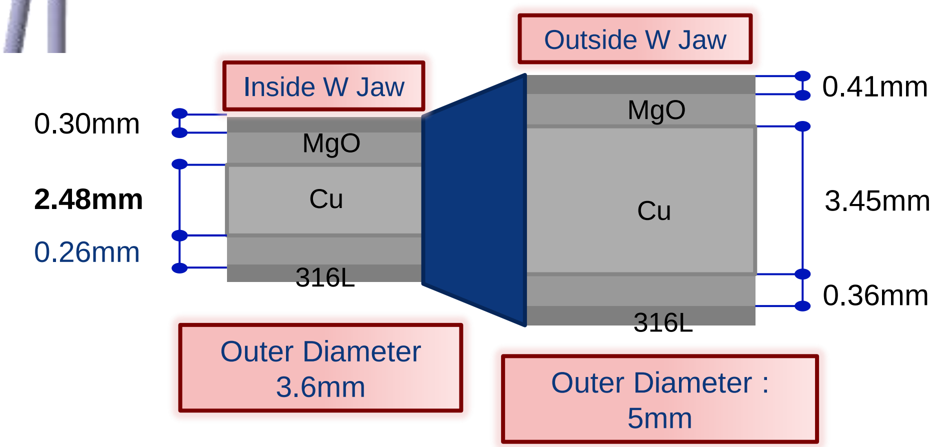


Wire Features:

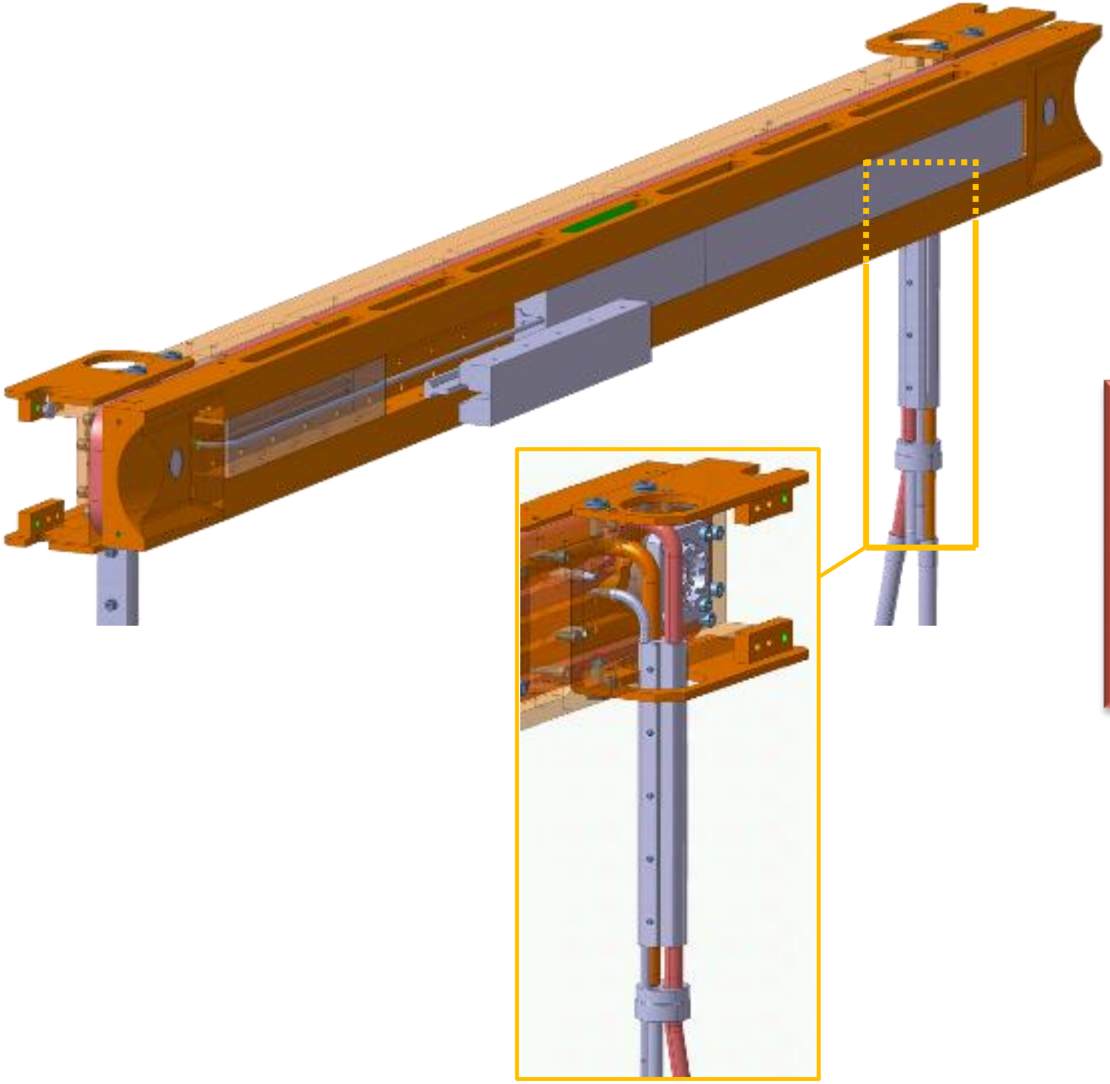
- 3 layers (Cu conductor, MgO insulator, 316L sheath)
- Maximum operating temperature : 300°C

Design optimized to minimize wire temperature:

Increased diameter (lower Joule effect) as soon as wire exits jaw



TCTW: New Features

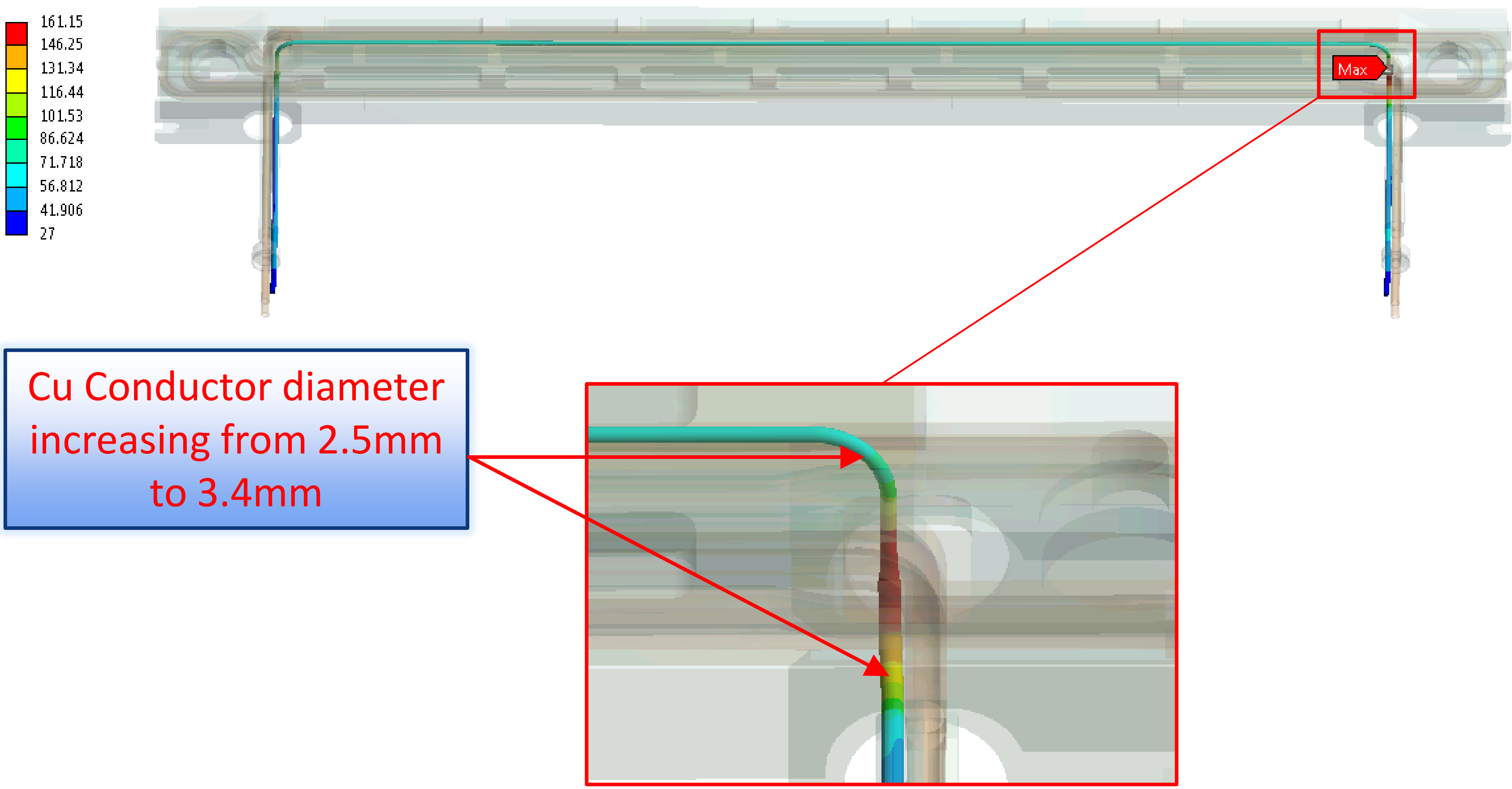


Design optimized to minimize wire temperature:

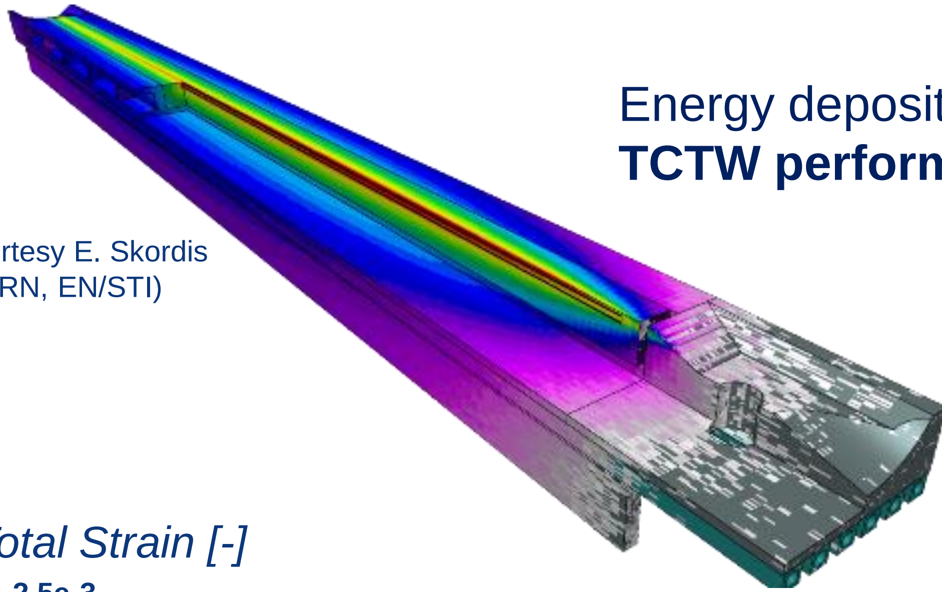
Dedicated cooling where wire is not cooled by direct contact with jaw

TCTW: Thermo-electrical Simulations

Optimization leads to **maximum temperature** (~161°C) well **below wire critical temperature**

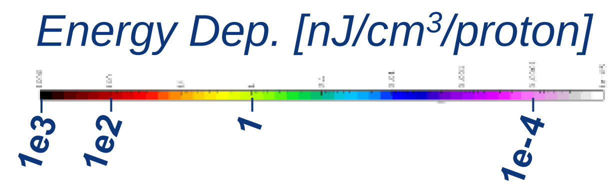


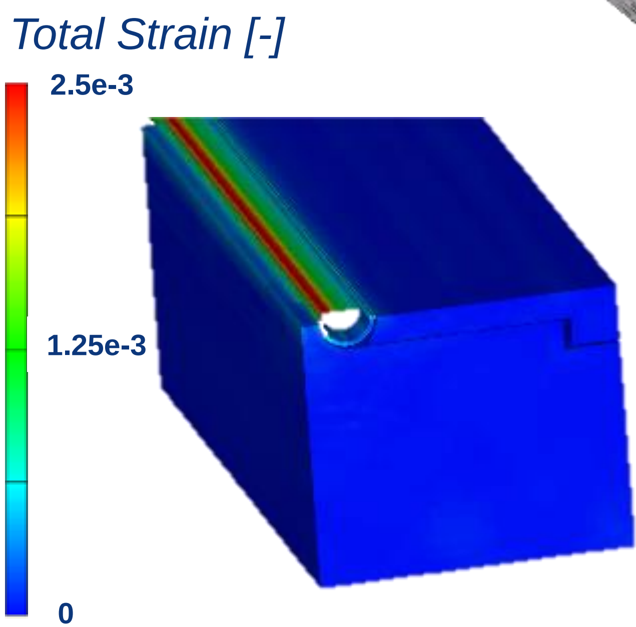
TCTW: Accident Scenarios



Courtesy E. Skordis
(CERN, EN/STI)

Energy deposition analyses for **benchmarking TCTW performance** against standard TCT





Thermo-mechanical analyses confirm that **TCT damage limits are also valid for TCTW**

Onset of plastic damage: I_b=5e9 [p^+]

TCTW: Wire-Jaw Interface

Wire position must be kept 3mm from jaw top surface for optimal beam compensation.

This is critical since one must simultaneously comply with different mechanical requirements:

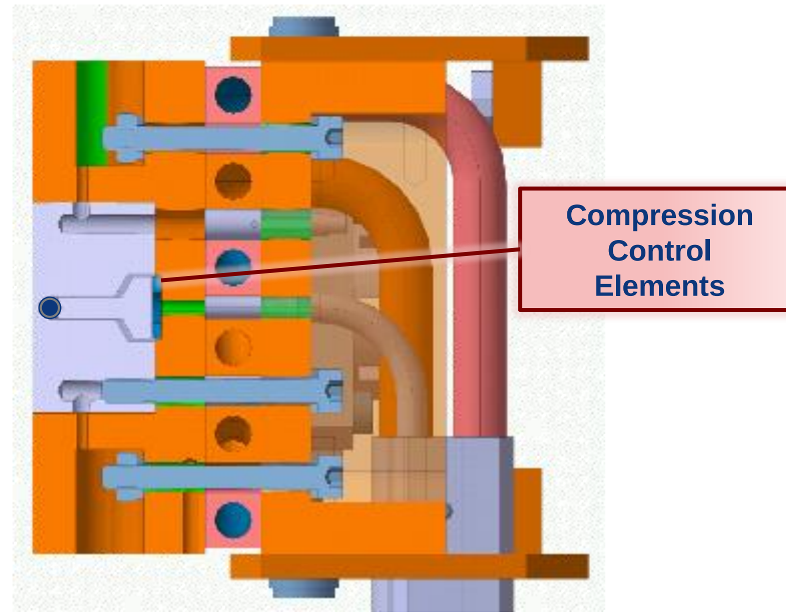
- Cable assemblability
- Jaw structural performance
- Cable thermal performance

TCTW: Wire-Jaw Interface

<u>Baseline design</u>: Wire pushed against jaw. Optimizing contact interface

Contact surface @ lowest position

Contact surface on V-shape

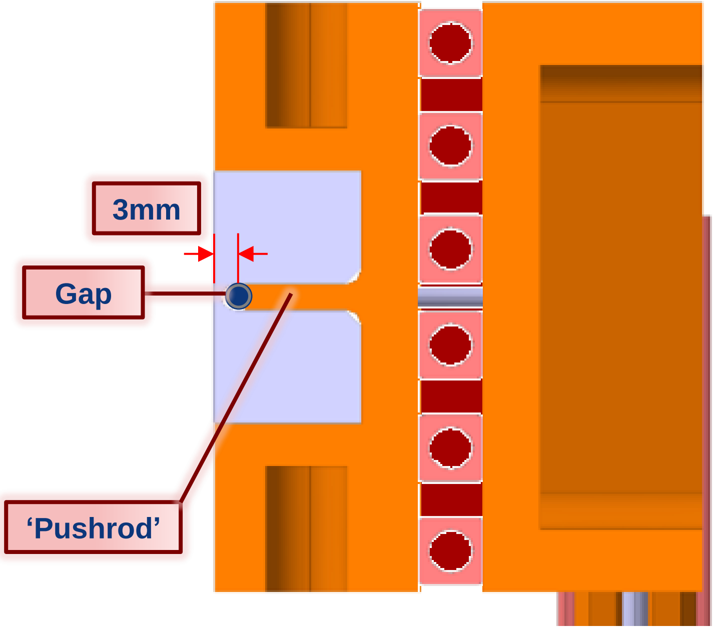


~25% reduction in jaw surface deformation

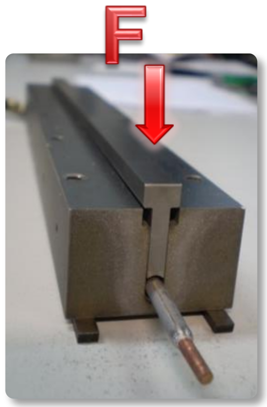
TCTW: Wire-Jaw Interface

Brazed design:

- Wire directly brazed to 'pushrod' (in Glidcop)
- Small gap between wire and jaw



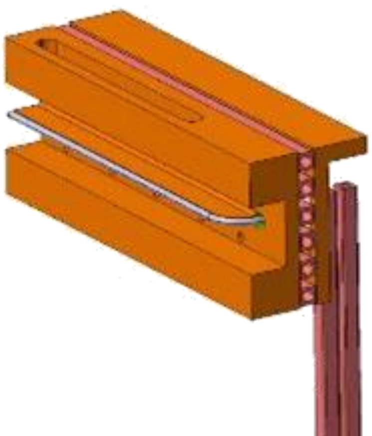
TCTW: Wire-Jaw Interface - Tests



Baseline design:

- Testing of jaw and wire under assembly compression load (both initial and V-Shape configurations)
- Characterization of Tungsten grade properties

Cable performance unaffected up to much higher loads than needed
Tungsten Properties slightly different from specification. Further tests ongoing



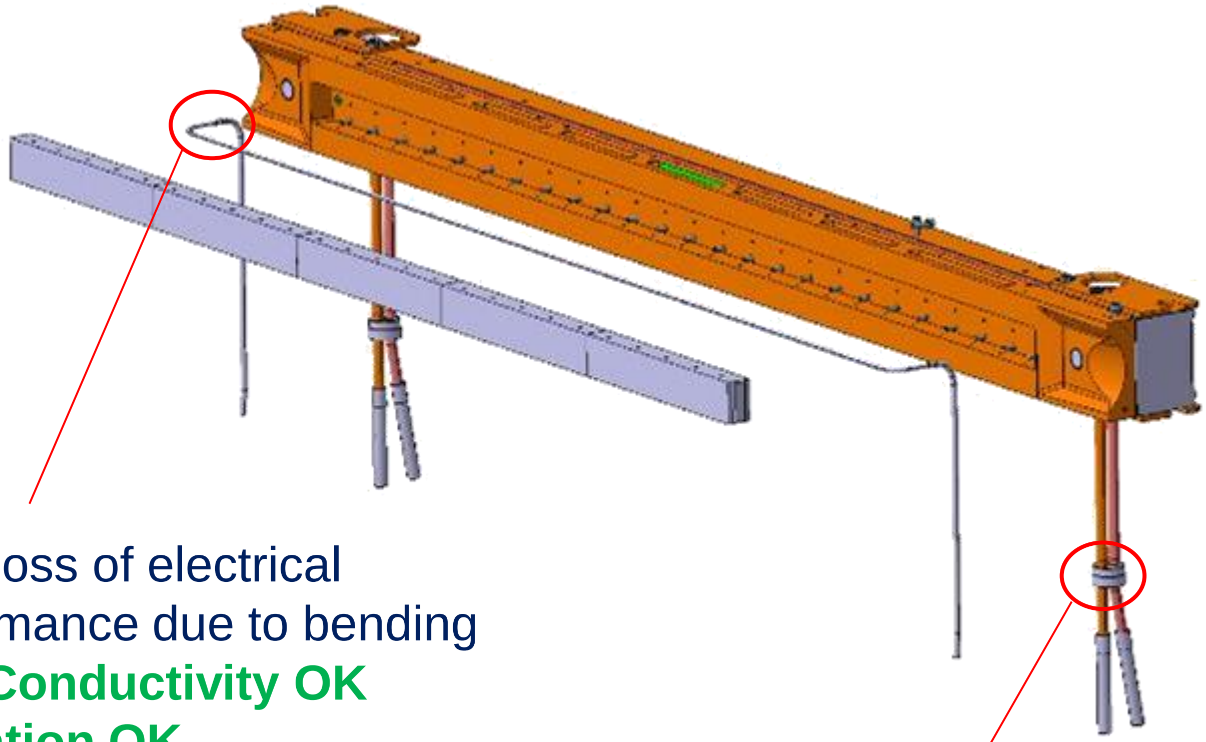
Brazed design:

- Testing feasibility of joining shaped wire to 'pushrod'

Mock-up machined and ready for brazing test

Choice between Baseline (V-Shape) and Brazed design by the end of the year

TCTW: Further Tests



Wire: loss of electrical performance due to bending
Wire Conductivity OK
Insulation OK

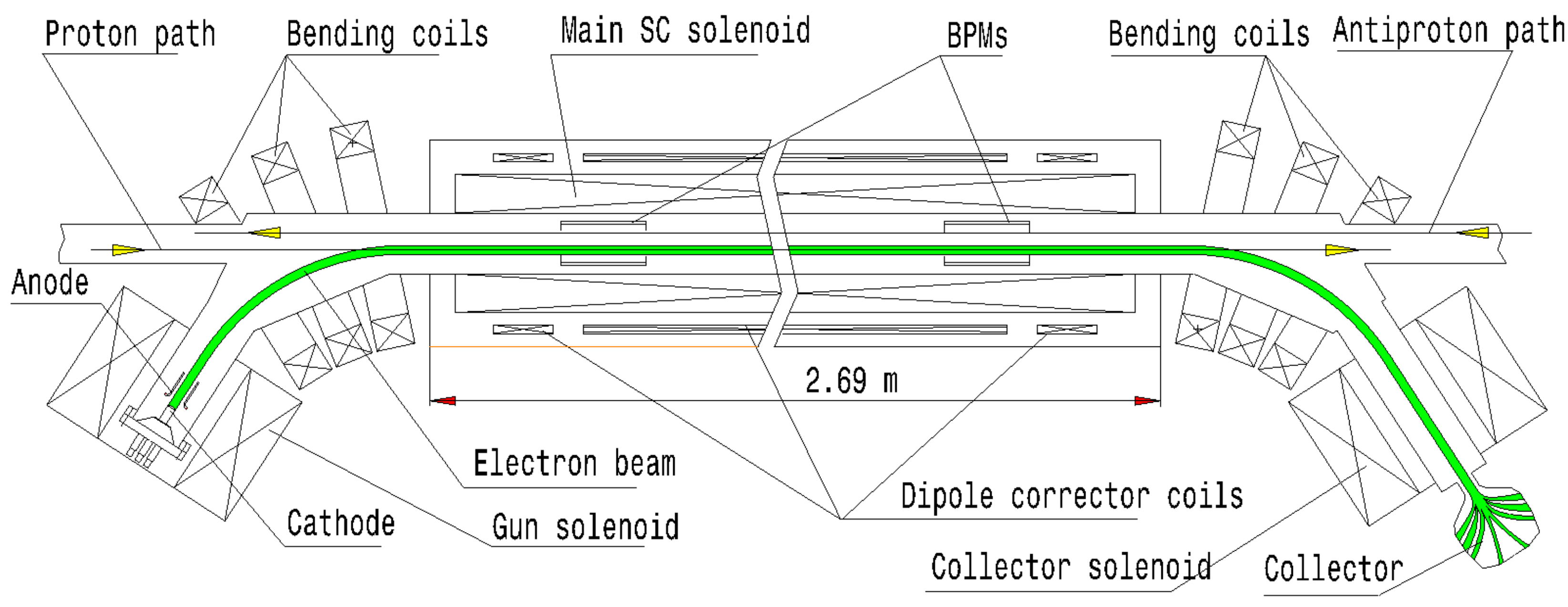
Multiple brazing of Tightness Cup to cooling tubes and BBC wire
OK

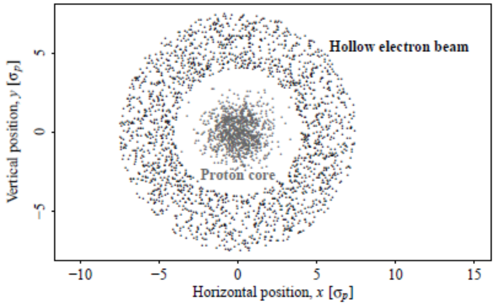
TCTW progress in a nutshell

- **Accidental scenarios** studied: **no change** with respect to standard TCTs damage limits.
- **Conceptual design is being tested and optimized** w.r.t. structural performance and fabrication (baseline VS. brazed option, **cable assembly feasibility**).
- **NEXT**: Finalizing design and assembly procedure.

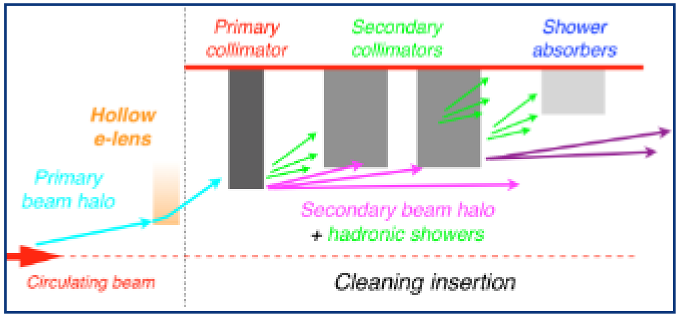
Hollow electron lens

Hollow Electron Lenses – A technique for halo control

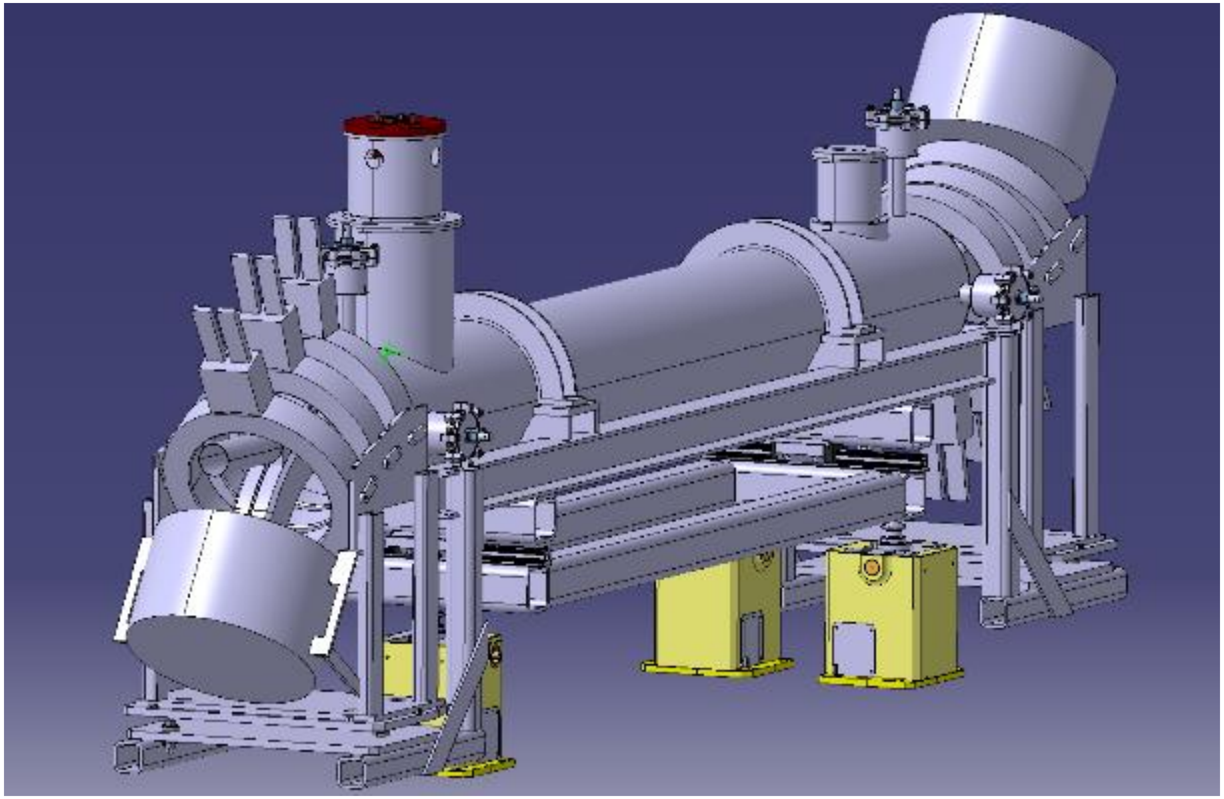




With axisymmetric electron distribution the beam core is unperturbed whereas the halo gets a smooth tuneable transverse kick. This device is a complement of the collimation system and will increase its efficiency.



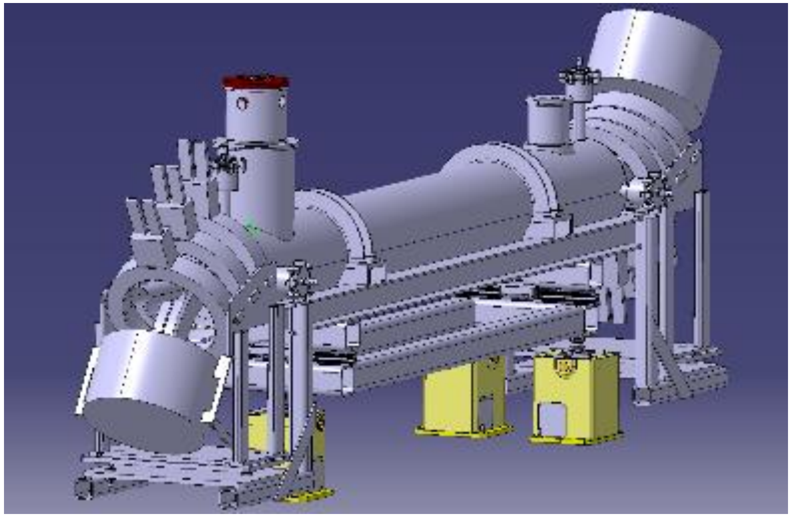
G. Stancari, V. Previtali, A. Valishev, R. Bruce, S. Redaelli, A. Rossi, and B. Salvachua Ferrando "Conceptual design of hollow electron lenses for beam halo control in the Large Hadron Collider".



HL-LHC configuration:

- 5 T field, 3-m-long superconducting solenoid (in parts)
- Cryostat
- Bending resistive coils
- Electron gun and collector (vertical – “S” shape)
- Vacuum chamber with insertions
- BPMs and diagnostic

Candidate locations for the electron lenses are RB-44 and RB-46 at Point 4, on each side of the interaction region IR4, which houses the accelerating cavities.
The beam to beam distance is 420 mm.



Functional main requirements

Beam-to-beam distance 420 mm → Compact construction.

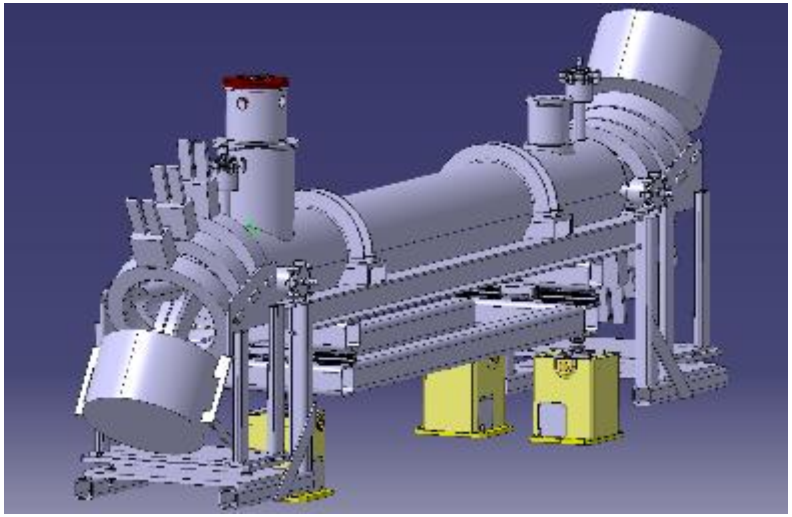
BPMs and related cables → Maximize vacuum chamber diameter.

Robust and reasonably simple (an often quenching 5 T solenoid is not a good idea).

Easy installation, maintenance, modifications.

Pre-design

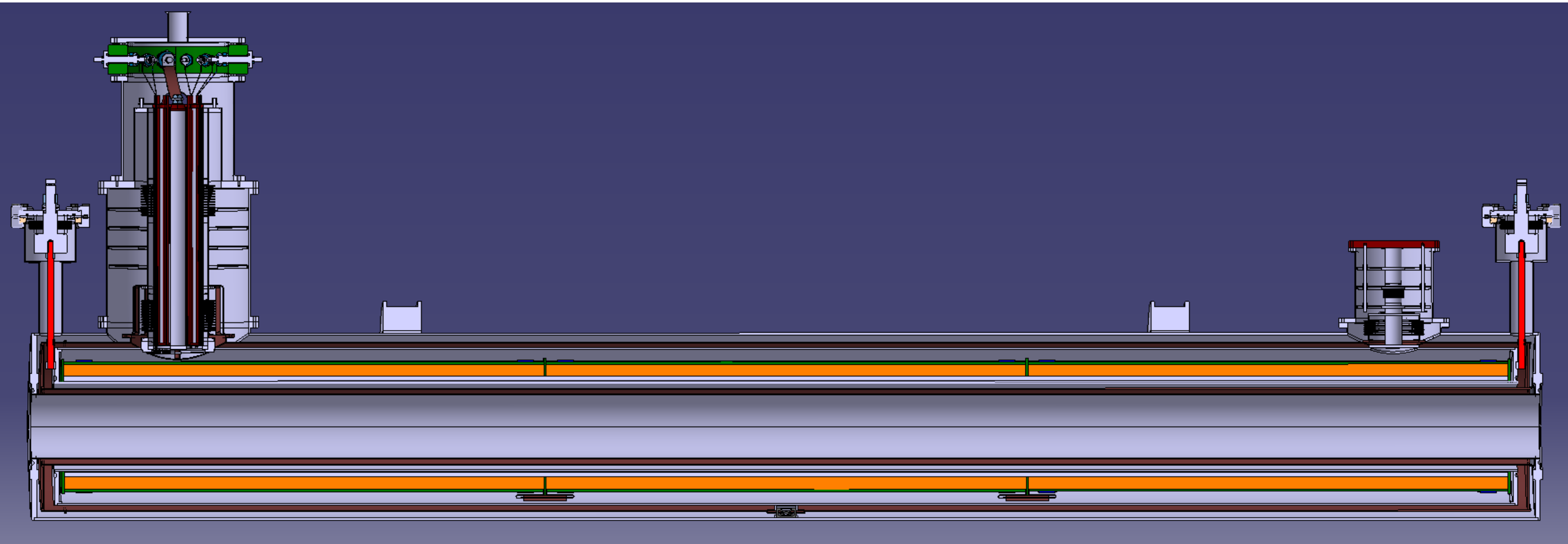
In collaboration with the Lapland University of Applied Sciences



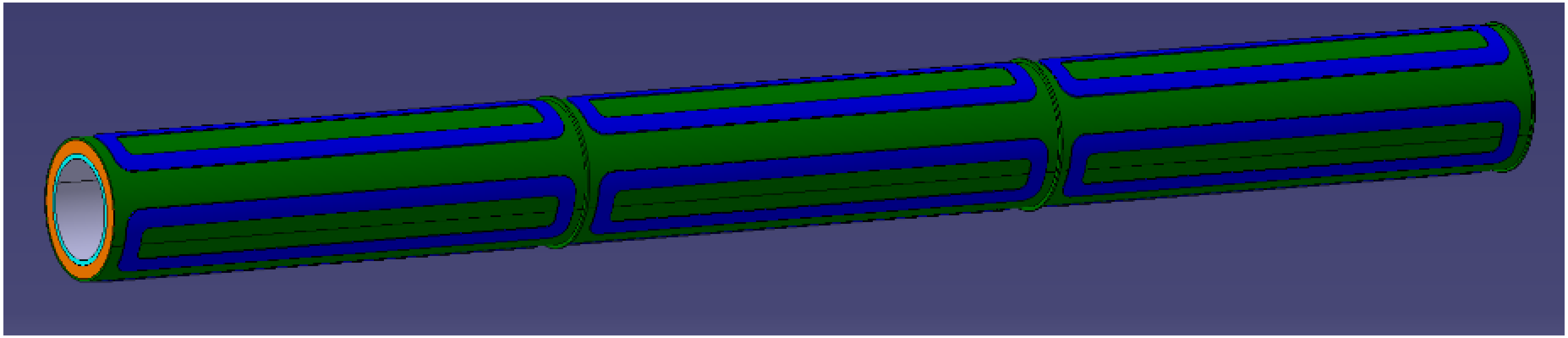
Olen tuli. Olen jää.
Olen myrsky. Olen tyven.
Olen luja ja herkkä.
Olen pohjoista tekoa.

Superconducting solenoid

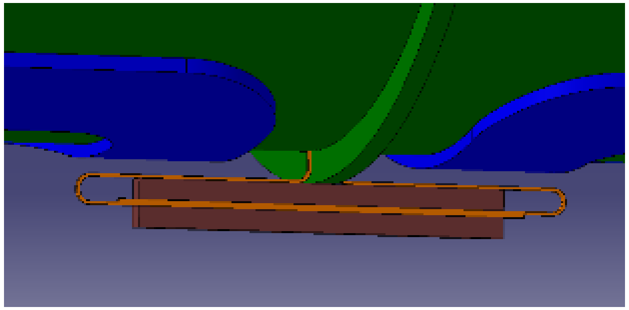
- Operation temperature: 4.2 K, current:about 250A, magnetic field: 5 Tesla. NMR type rectangular cable (~1.2 mm x 1 mm).
- Cooled by liquid helium.
- Two vessels: for liquid helium and vacuum. One thermal screen at 80K.
- The helium vessel is supported by permaglass bars in vertical and horizontal directions. The longitudinal fix point is in the centre.
- The main coils and the correction coils are inside the helium vessel



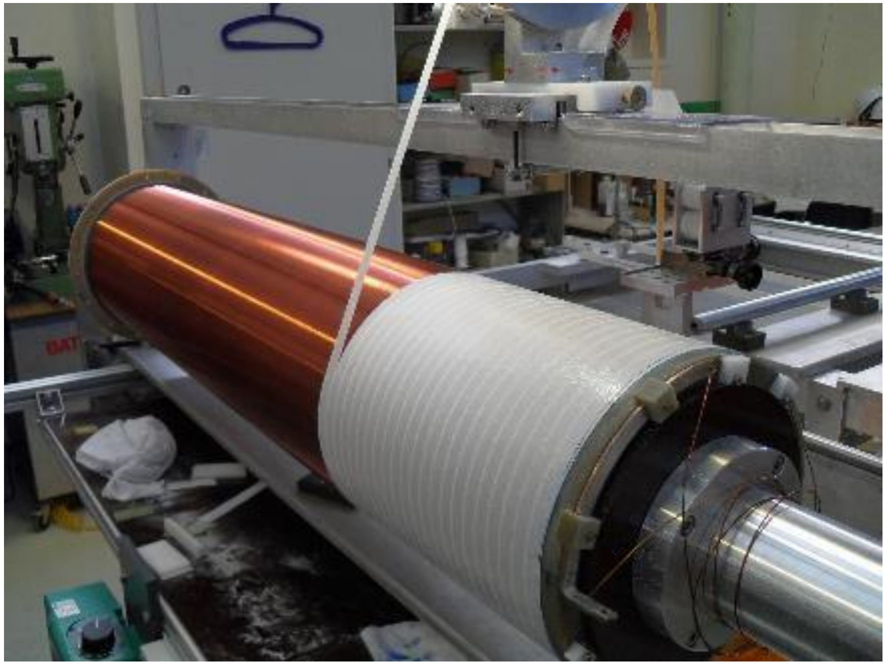
Coils

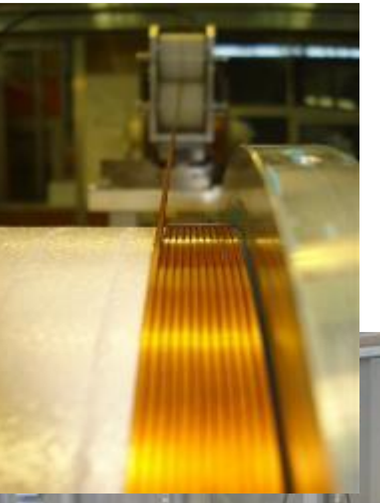


The main coils and the correction coils



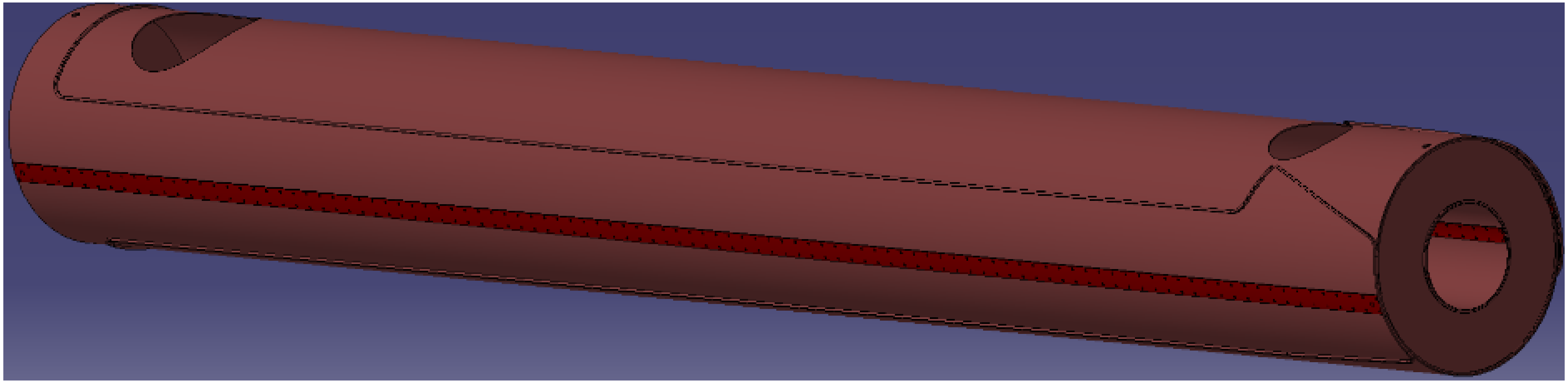
The power connection between the main coils



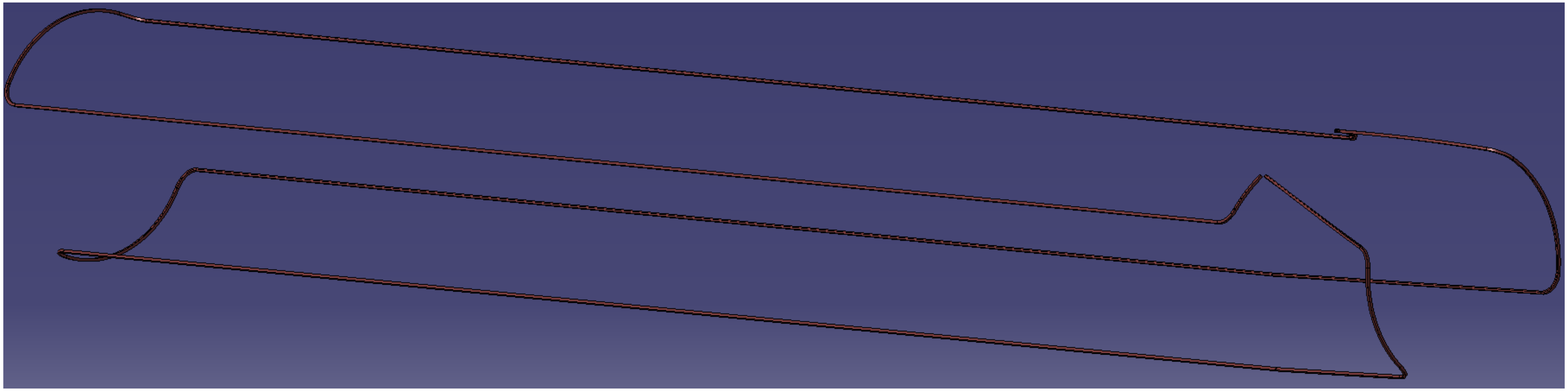


Two very similar solenoids were manufactured at CERN for the Aegis experiment.

Thermal screen

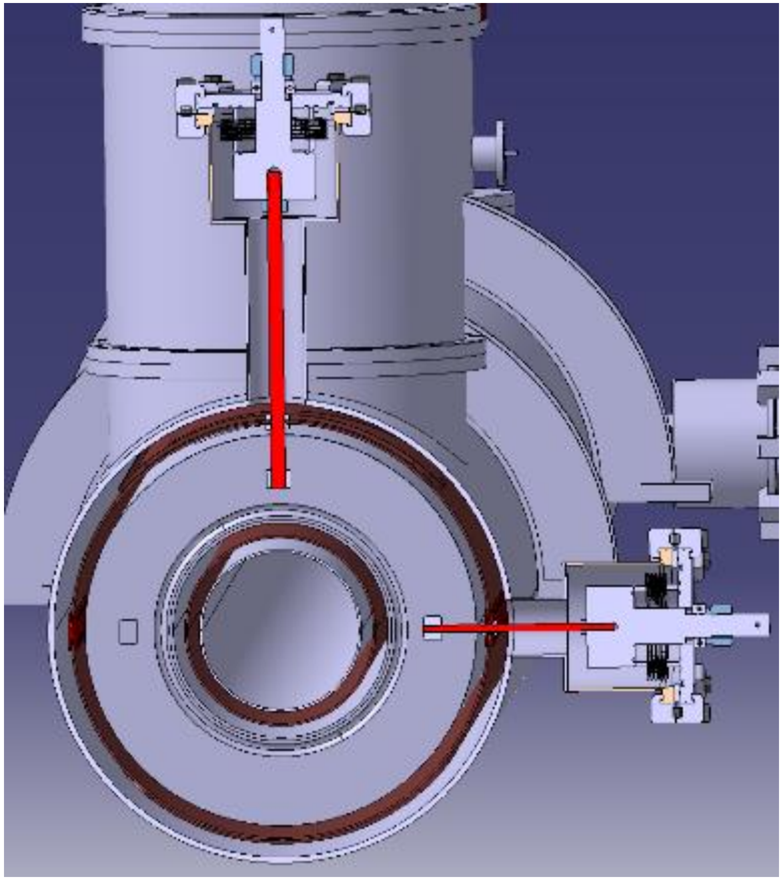


Thermal screen

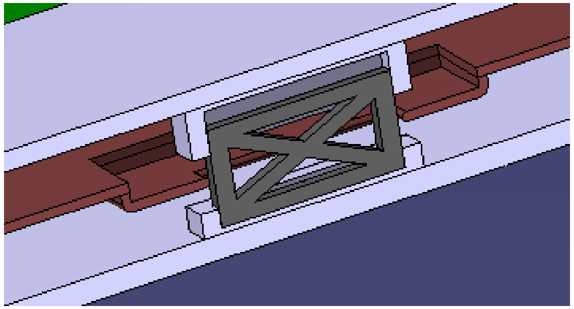


The helium gas pipes

Vessels’s supports

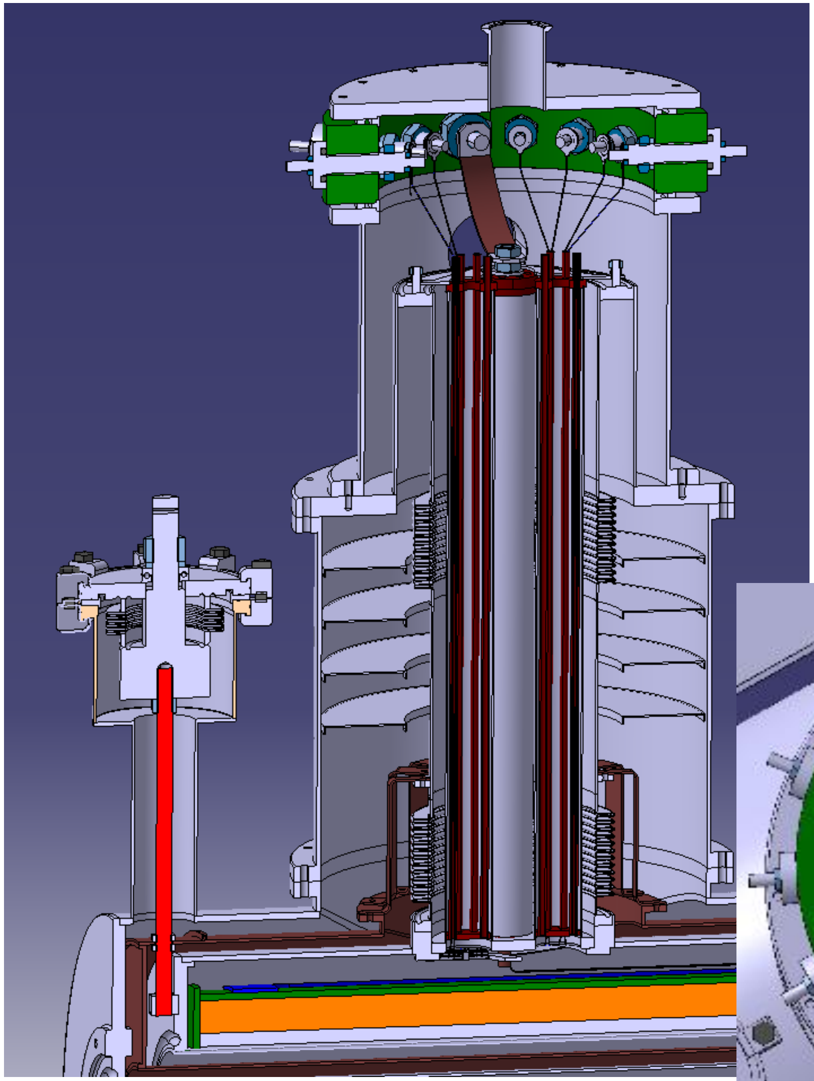


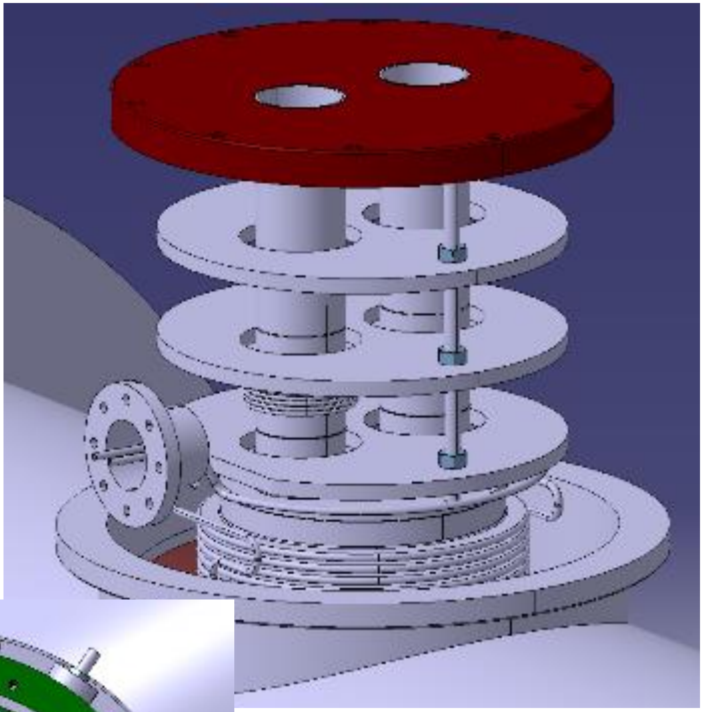
Suspension forvertical and horizontal directions



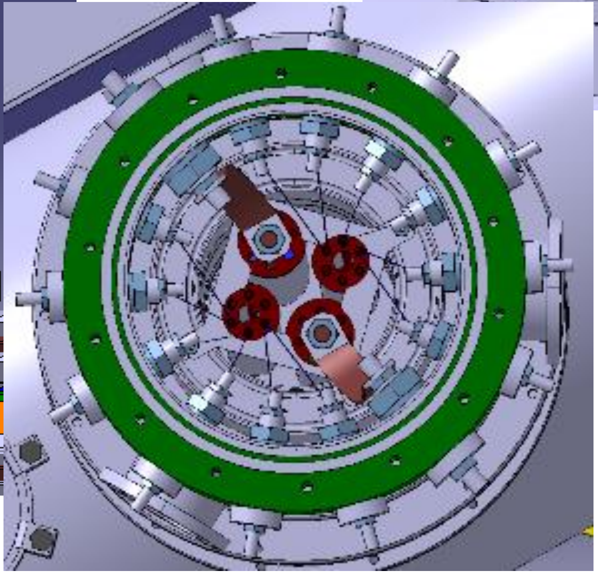
Fix point for axial direction

Power and helium supply





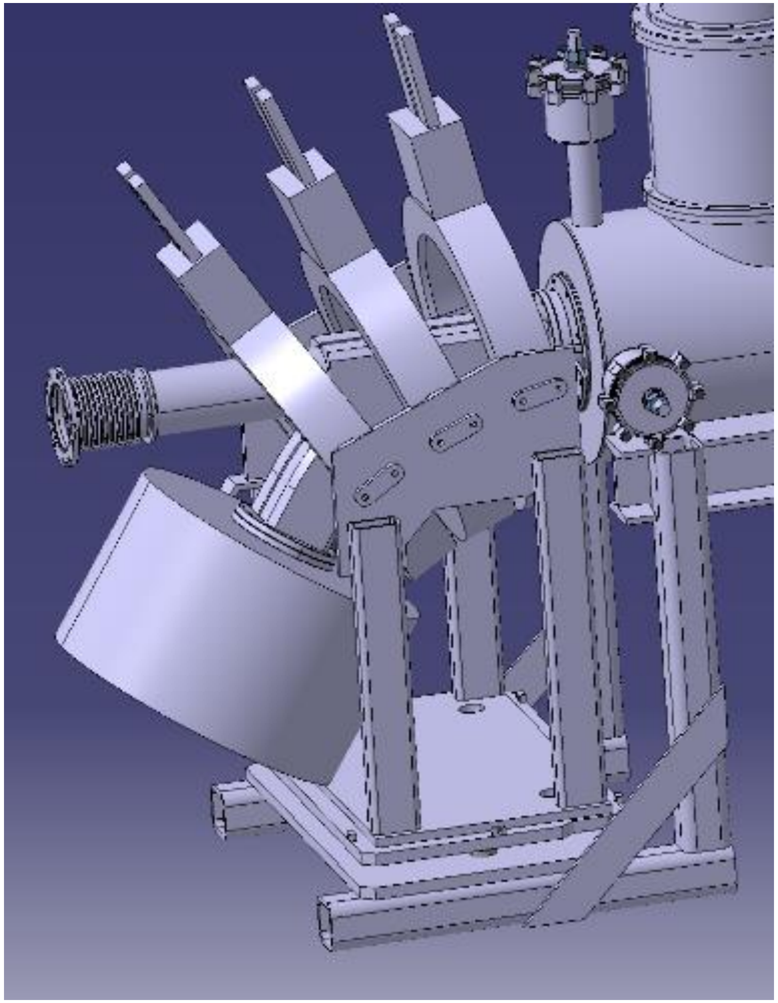
Supply for liquid and gas helium



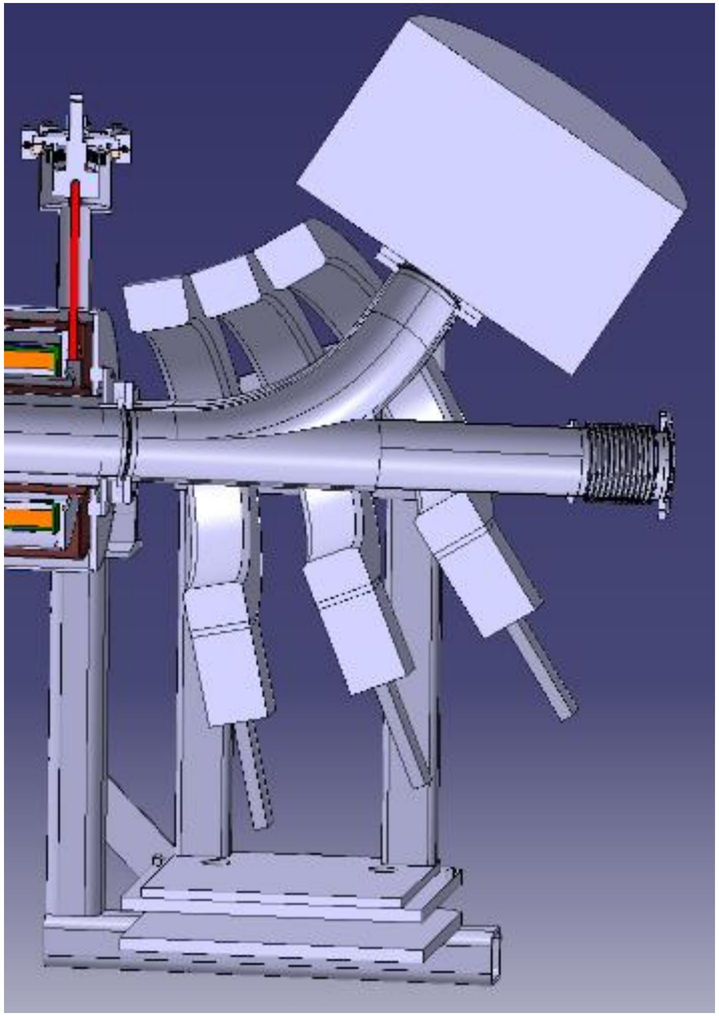
The connectors

The current leads

Toroid section



The gun side vacuum chamber and the toroid coils

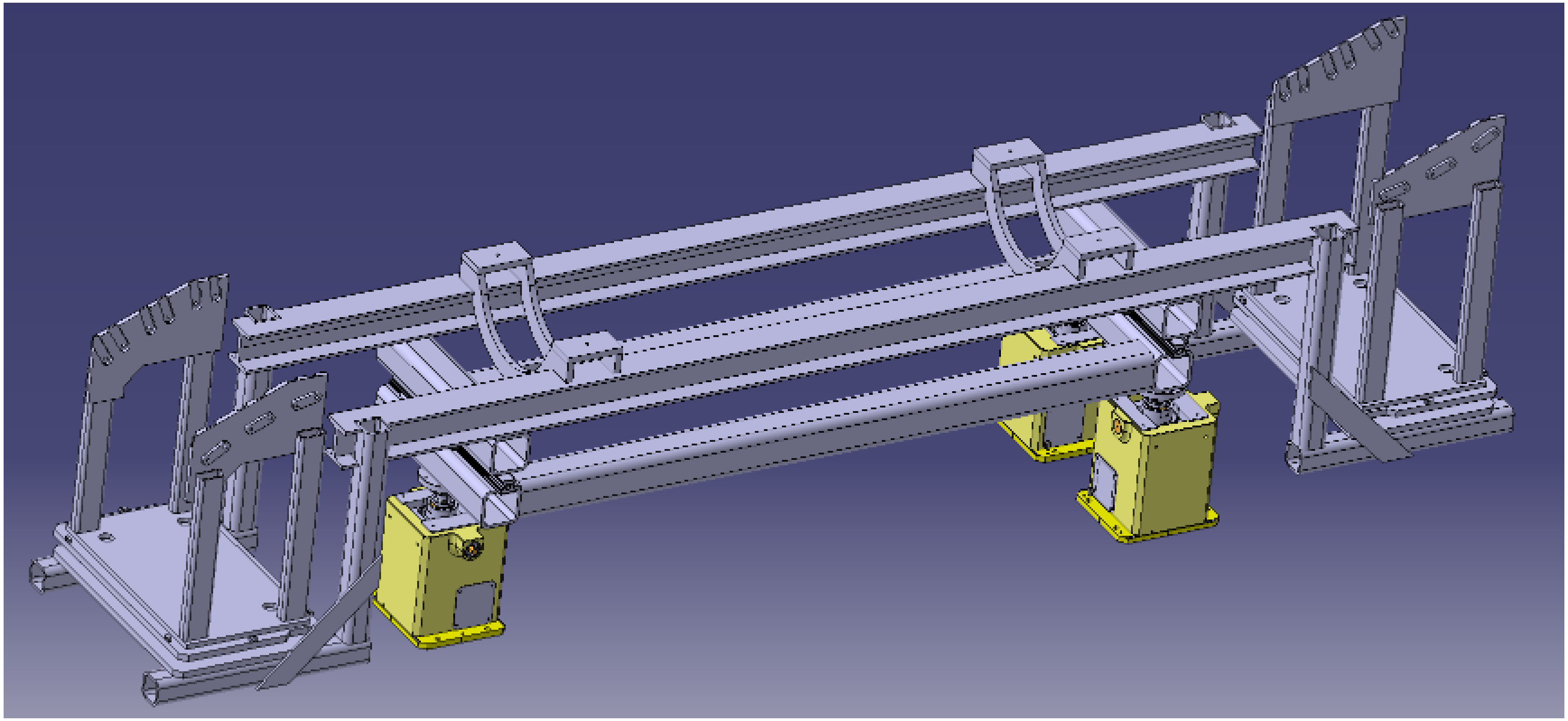


The collector side vacuum chamber and the toroid coils (section)

G. Stancari, V. Previtali, A. Valishev, R. Bruce, S. Redaelli, A. Rossi, and B. Salvachua Ferrando “Conceptual design of hollow electron lenses for beam halo control in the Large Hadron Collider”.

Assembly of the prototype (25 mm) hollow electron gun. The first photograph shows the base flange with electrical connections. In the second photo, one can see the hollow cathode with convex surface and the rim of the control electrode; both are surrounded by cylindrical heat shields. The mounting of the copper anode is shown in the third picture. The last picture shows the complete assembly.

Support frame



The support frame of the hollow electron lens.

Hollow electron lens status in a nutshell

- There is a first design based on the experience gained with similar applications built in the past.
- The goal is to have a device robust and as simple as possible.
- Next steps are the definition of the magnetic shielding and the optimization of the magnets.

Thank you for your attention