TCTW Collimator Design

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Workshop on Simulations and Measurements of Long Range Beam-beam Effects in the LHC
Lyon – *30 November, 2015*

Engineering Department

Outlook

- Introduction
- Design highlights
- Analyses of collimator robustness
- Testing
- Summary

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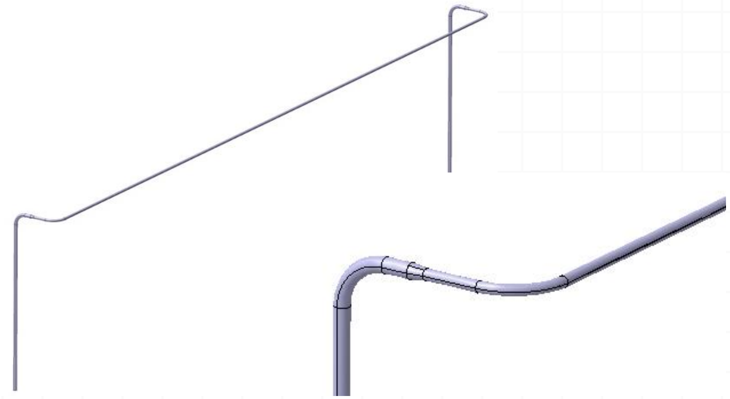
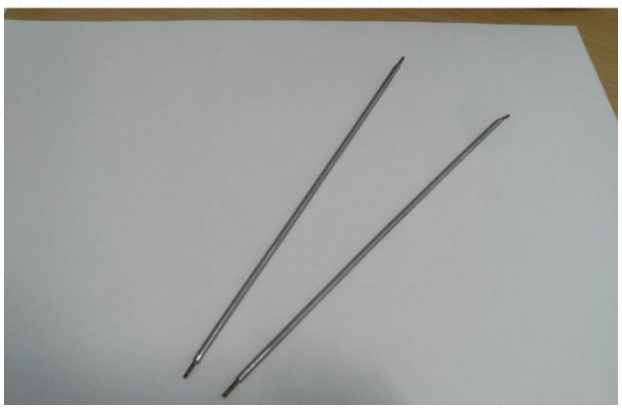
Introduction

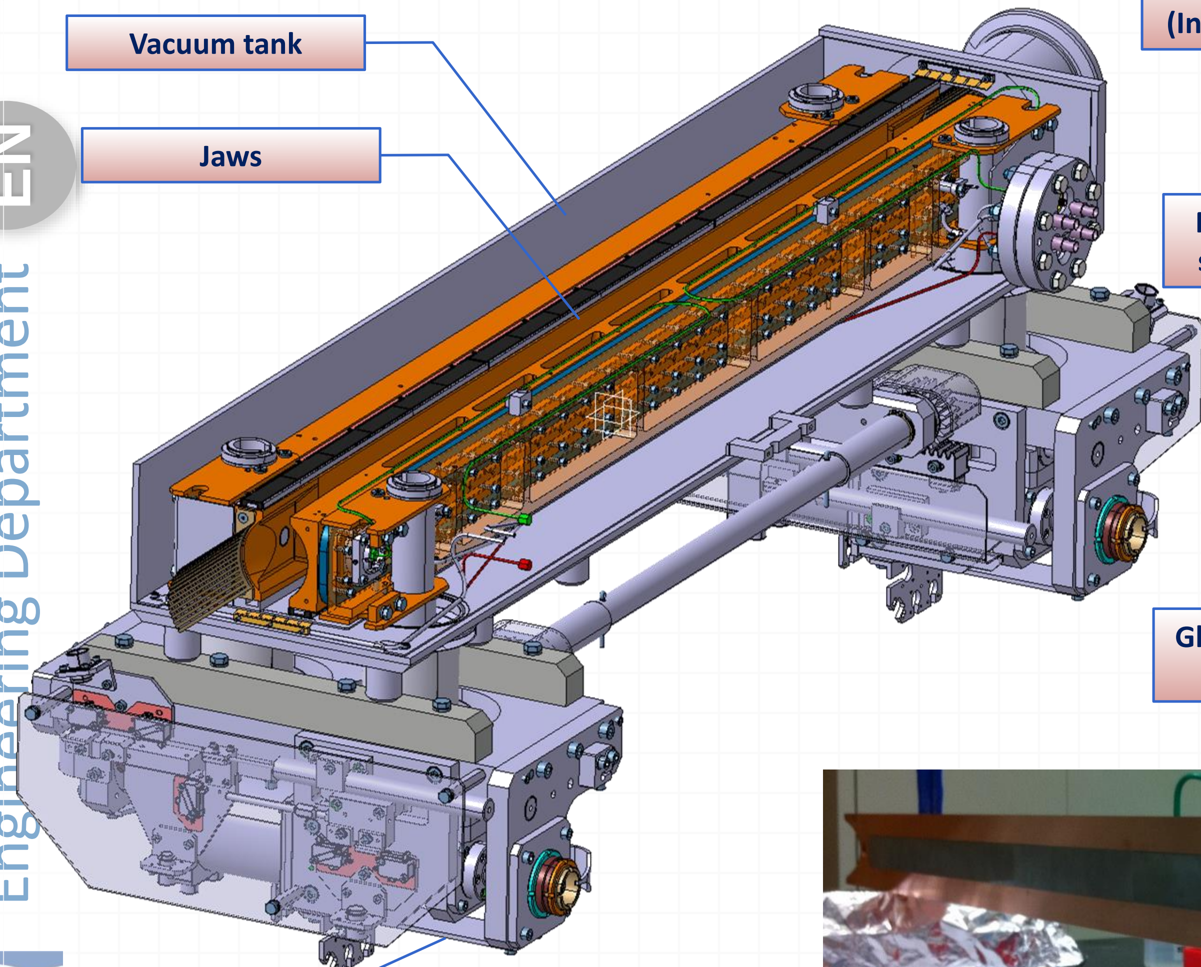
- **Challenge**: Embed an **electric wire in a TCTP collimator jaw** to compensate long-range Beam-Beam effects

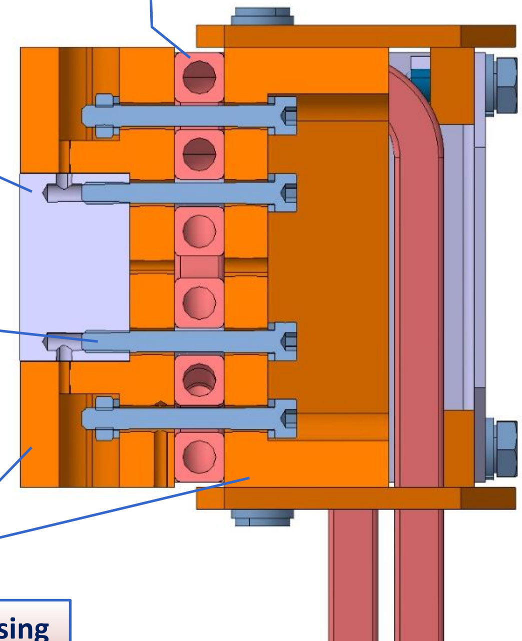


- **Requirements:**
- High DC current (up to 350 A)
- Thin wire ($Ø_{CU} \leq 2.5$ mm)
- In-jaw wire (depth ≤ 3 mm)
- **Maintain TCTP complete functionality!**



Standard TCTP Overview





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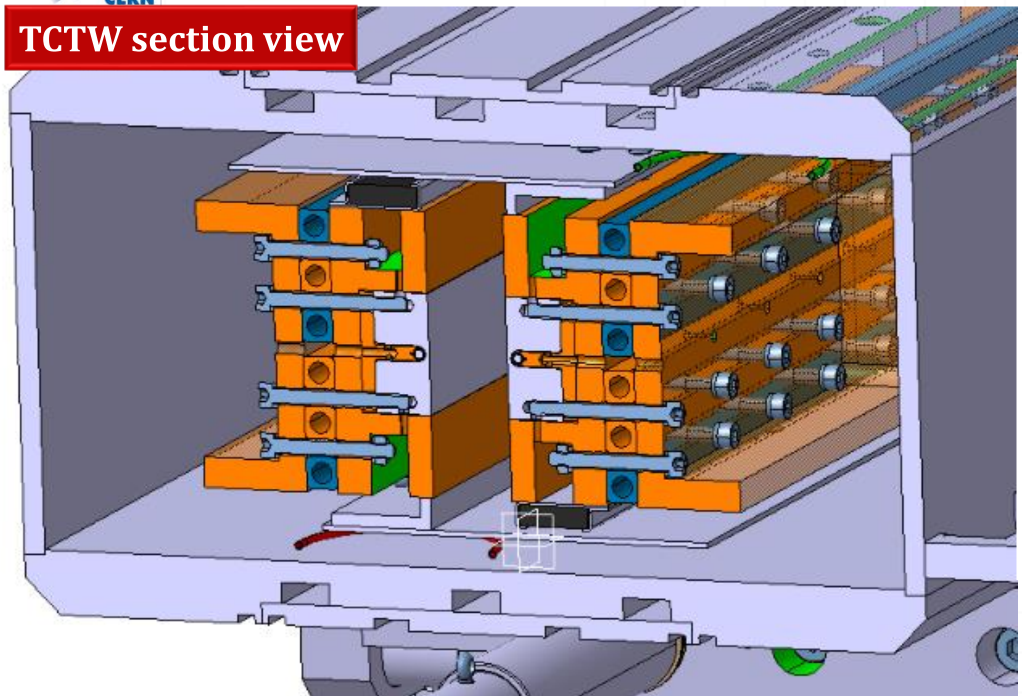
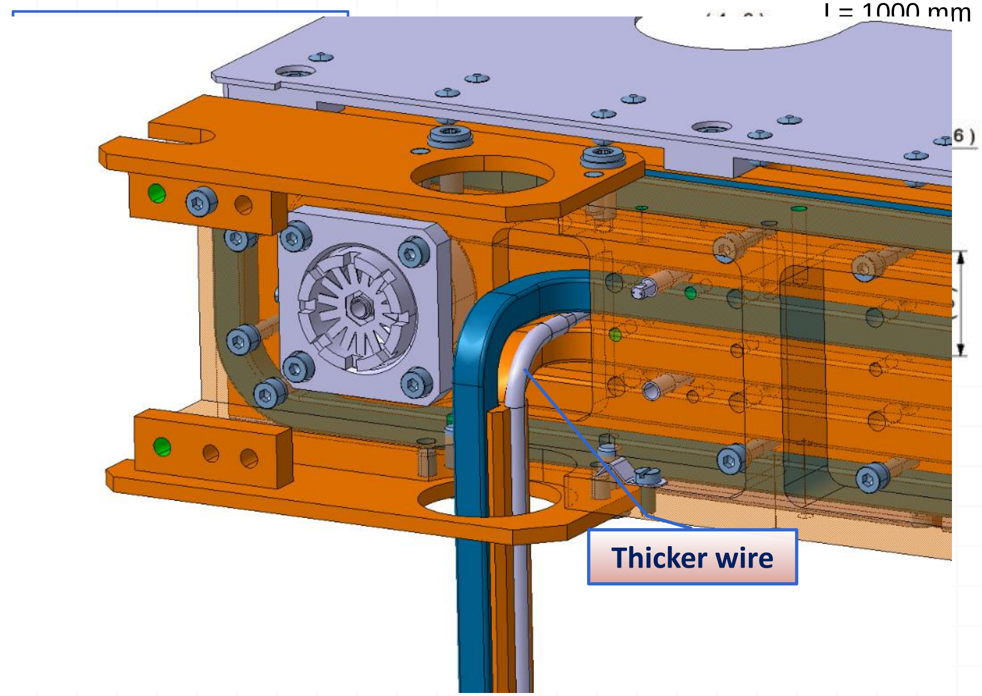
Wire-Embedded TCTW

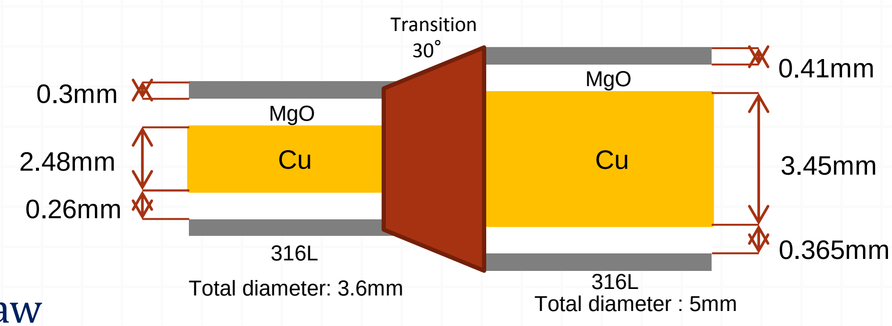




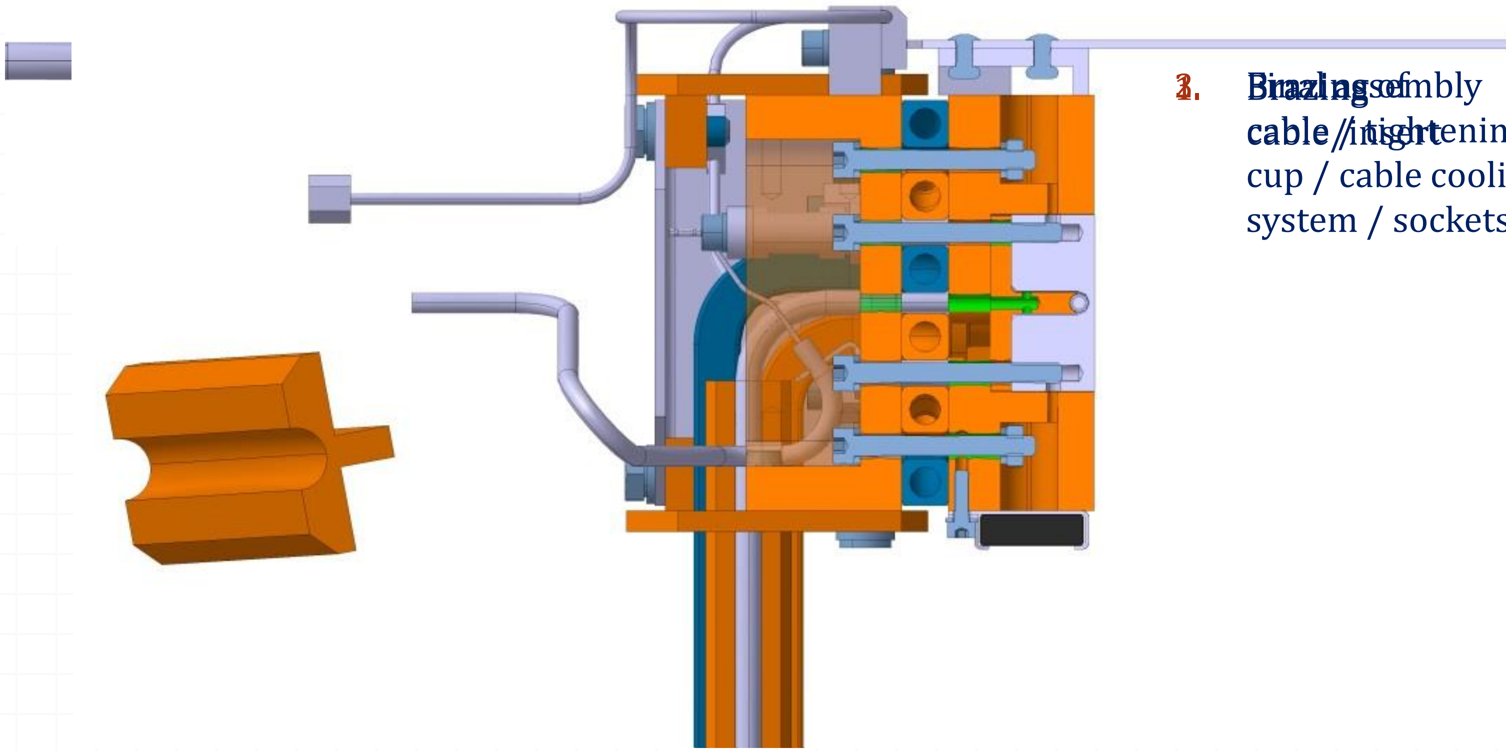
Engineer

- Wire is **brazed to a Glidcop “T shape”** support
- Tungsten block and “T” support **connected in series with the housing via screws**
- Brazing **maximizes wire cooling**
- **Increase of diameter** where the wire is not in direct contact with the jaw (extremities)
- Also **clamped to cooling pipes** when it’s not in the jaw

Cable Dimensions:



Jaw Assembling



- Brazing of cable / insert
- Final assembly / tightening cup / cable cooling system / sockets

Engineering Calculations

LHC Collimation Project CERN

HiLumi LARGE HADRON COLLIDER

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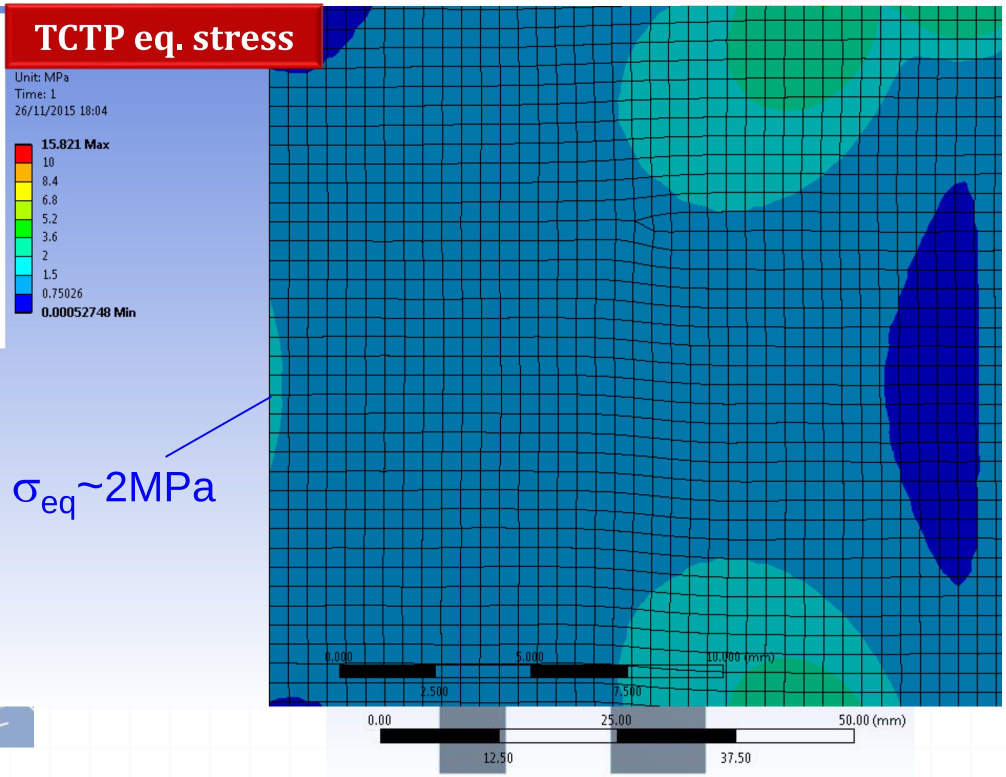
- The collimator resistance should be not jeopardized by the insertion of the wire
- Stresses on the **TCTW** have to be **comparable to those of a standard TCTP** for the following load cases:

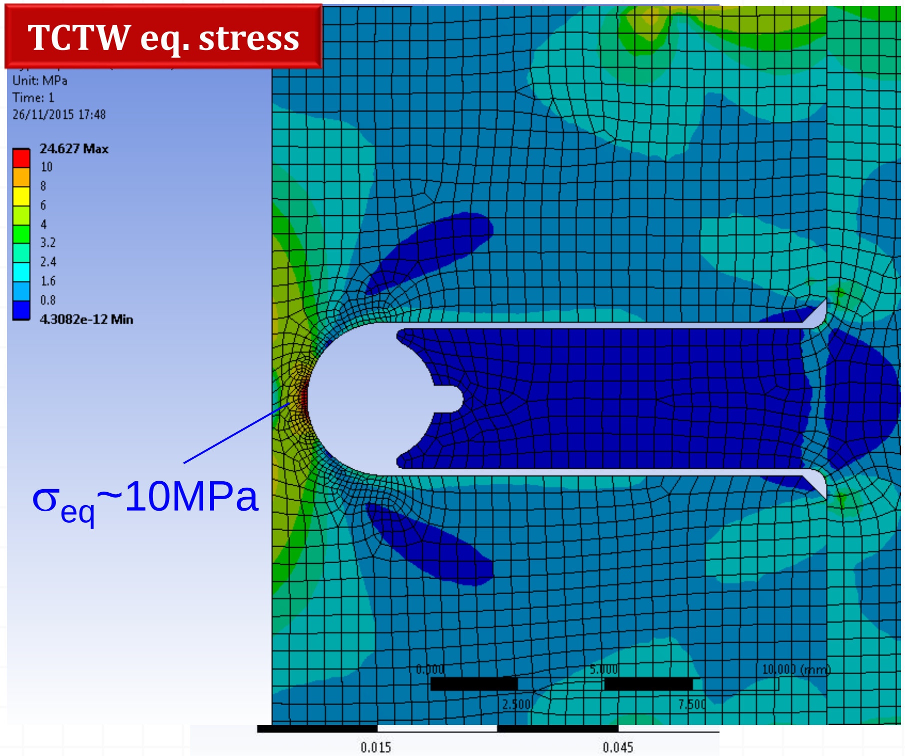
  1. **Assembling**
  2. **Nominal operation** – under beam slow losses
  3. **Accidental scenario** – asynchronous beam dump

Engineering Calculations

1. Assembling

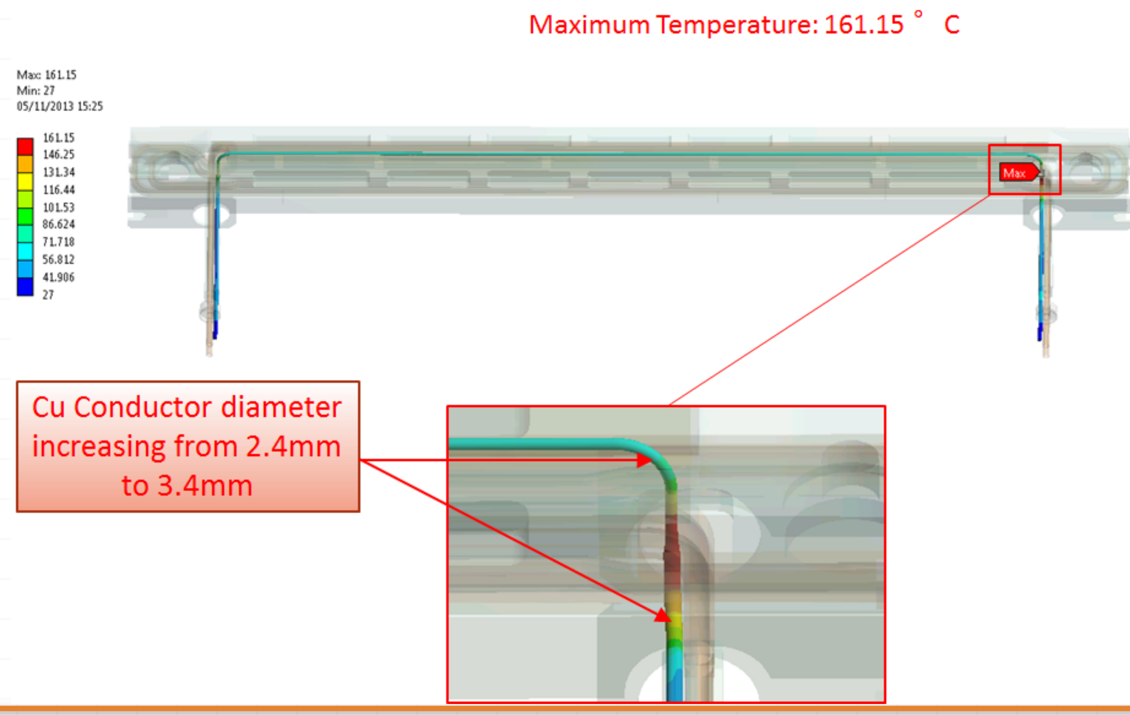
- Stresses on the Inermet block given by the fixing screws (1.5 kN/screw)
- Presence of the **gap wire/Wblock** prevents stress arise on the thin wall
- **Stresses negligible in both cases** (for reference, yield stress of Inermet is **650 MPa**)





2. Nominal operation – 1h beam life time

- In nominal operation, particles of the beam external halo transfer their energy to the collimator under the form of **thermal energy**, which induces thermal stresses and deflection
- Deformations are also induced by the **self-weight** (1m girder simply supported at the extremities)
- On top of that, during BBLRC-dedicated MD, a **strong joule effect** is produced on the wire (**1kW on a thin wire!)**



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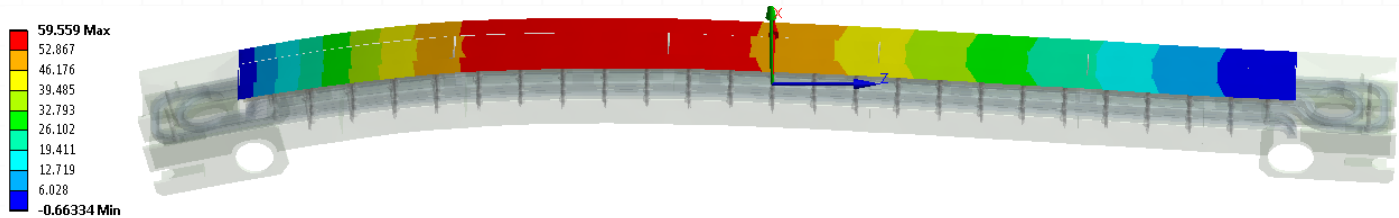
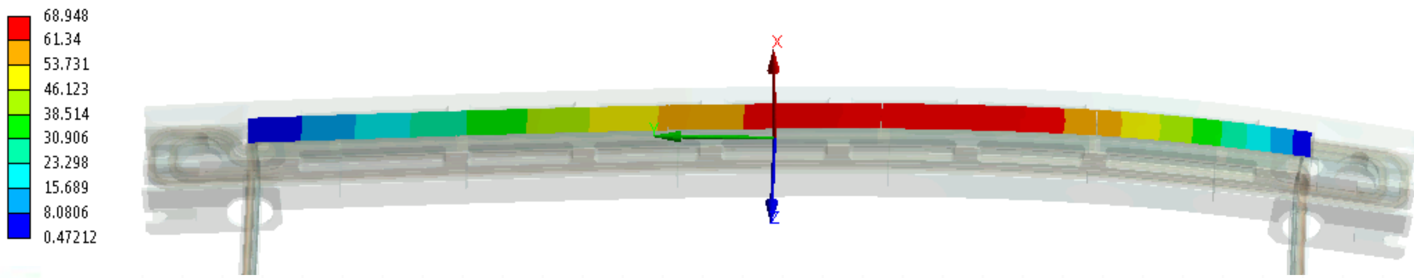
Engineering Calculations

2. Nominal operation – 1h beam life time

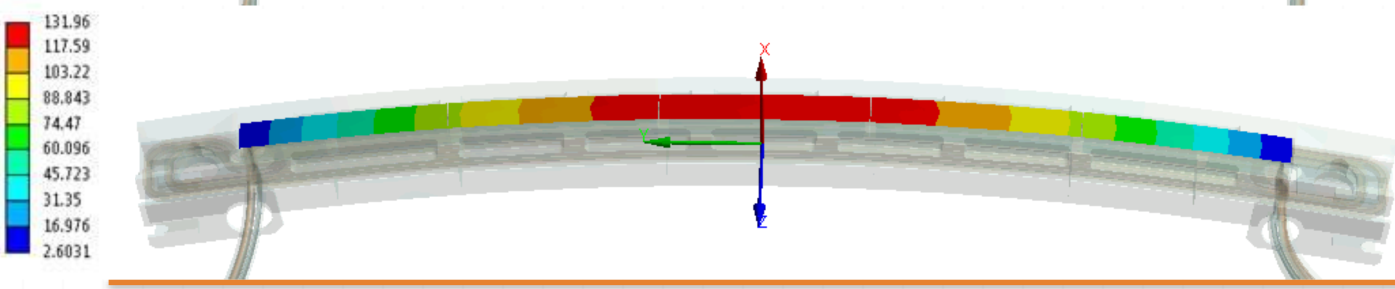
- **Thermal-induced sagitta** is comparable between TCTP and TCTW in nominal operation
- **Stresses are low in both cases**
- **Larger deformation** during MD given by **wire heating up by joule effect**



TCTP Collimator – Thermal deflection, beam heat generation only



TCTW Collimator – Thermal deflection, beam heat generation only



TCTW Collimator – Thermal deflection, wire heat generation only (joule effect)

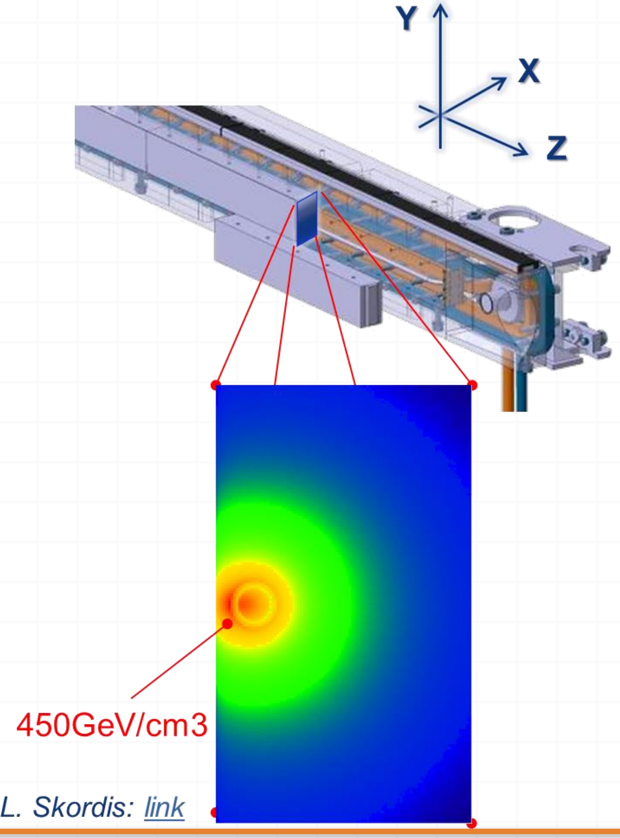
Engineering Calculations

3. Accidental scenario – asynchronous beam dump

- Target: same onset of damage between TCTP and TCTW
- At 7 TeV, this is estimated in 5E9 protons for TCTP
- Simulations repeated on TCTW for the following beam parameters (55 cm β* optics)

	Beam Energy [TeV]	Impacting Bunches	Impact Depth [mm]	Beam size $\sigma_x \times \sigma_y$ [mm]
	7.0	1	2	0.858 x 0.535

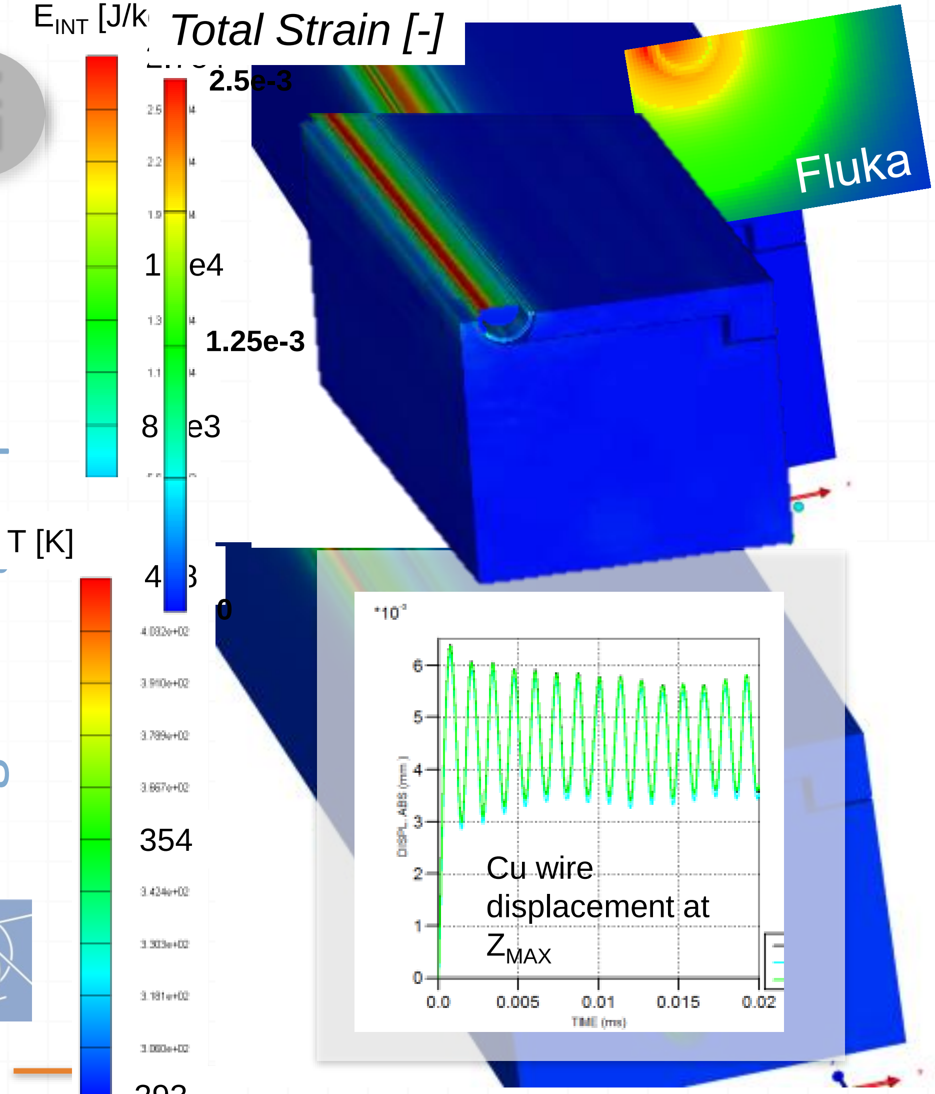
- **Peak deposition:**
  - Z: between blocks 1 & 2
  - X-Y: interface Inermet/wire



Courtesy L. Skordis: link

Engineering Calculations

3. Accidental scenario – asynchronous beam dump



		t ≈ 1ns	t = 20us
W	T [K]	428	
	σ_{vMises} [MPa]	-	260
	ε_plastic [-]	-	-
SS	T [K]	411	
	σ_{vMises} [MPa]	-	120
	ε_plastic [-]	-	-
Cu	T [K]	364	
	σ_{vMises} [MPa]	-	127
	ε_plastic [-]	-	0.5%

- **Threshold for the jaw is confirmed at 5E9 p**
- At this level, **moderate plastic deformation of the BBLRC wire**

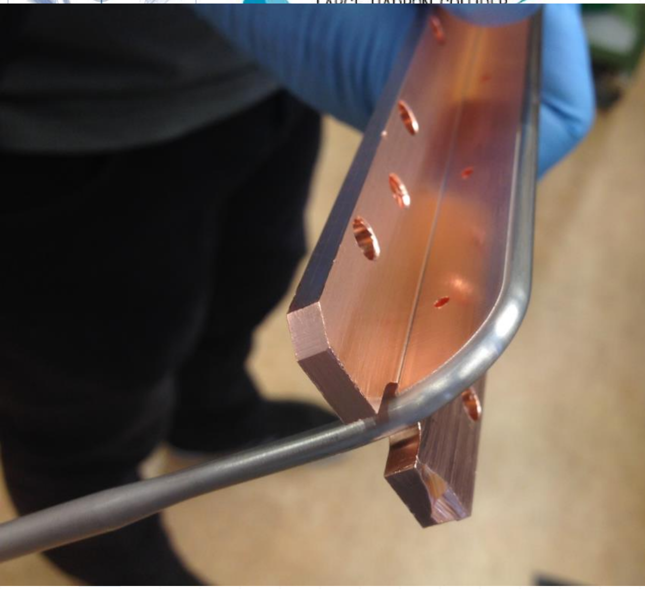
Testing

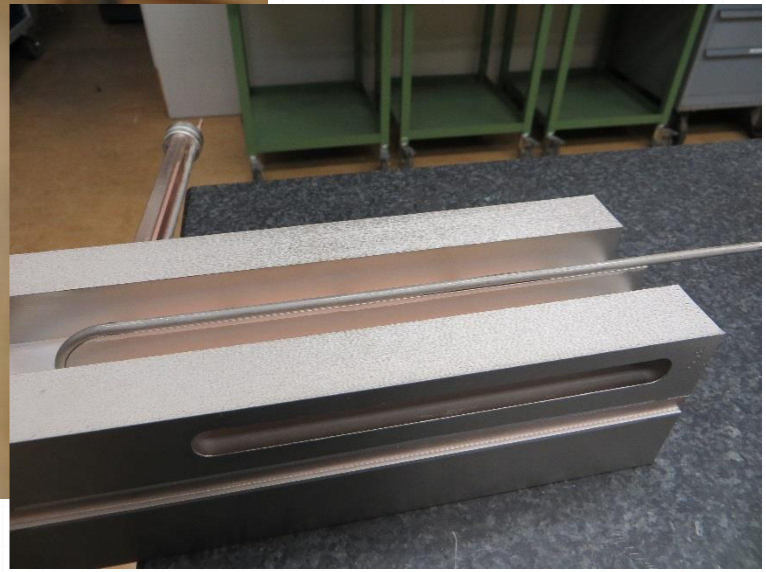
- The final configuration is the best solution found by **numerical and experimental means**
- Several laboratory tests to choose between different configurations (e.g. clamped BBLRC wire, brazed, different "T" shapes, etc.)
- Electrical functionality of wires during bending evaluated
- Testing of brazing wire/"T" support

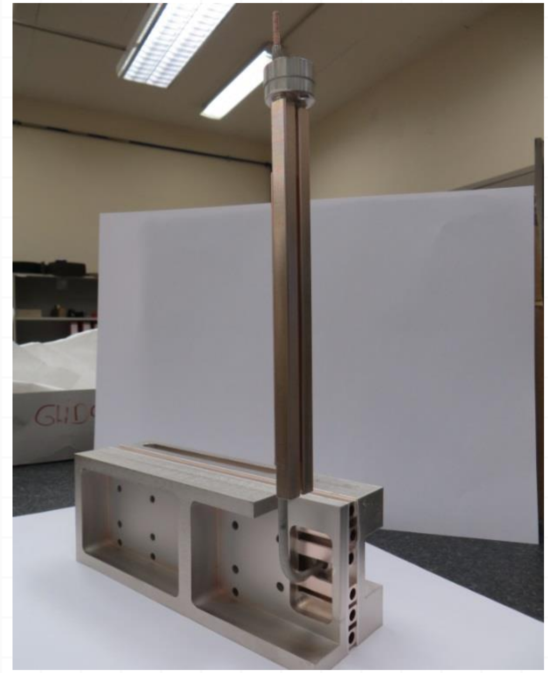
- Although for the final configuration stresses between TCTP and TCTW are comparable, **1 mm is the minimum thickness of W defined**
- **Too many risks** at lower thickness during machining, transport, manipulation (**W alloys are brittle!**)

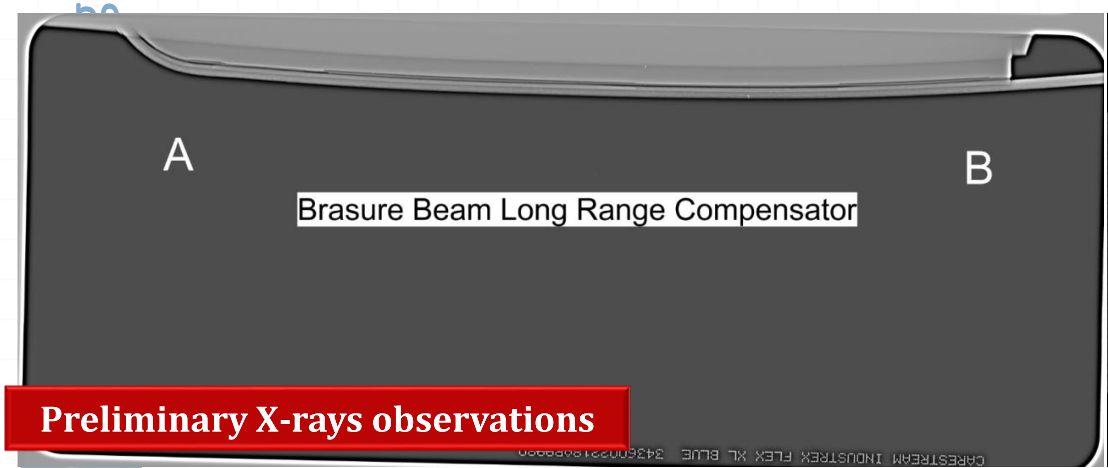
Testing

Brazing tests at CERN

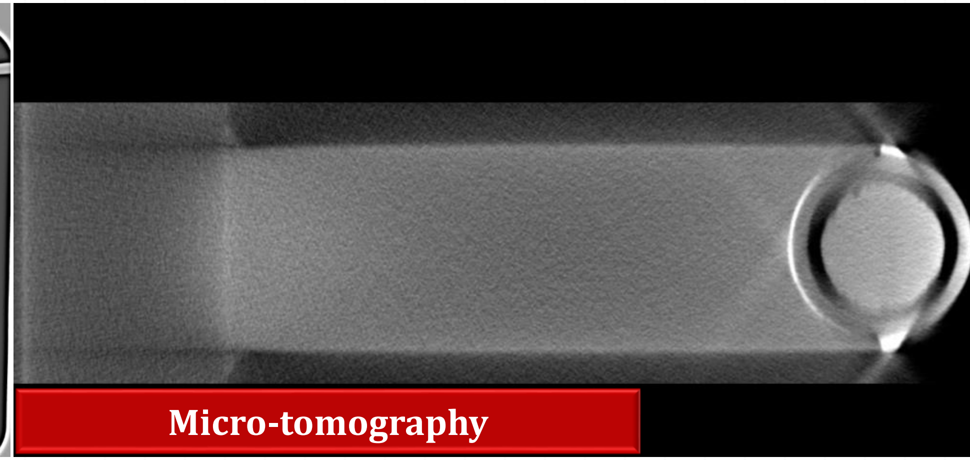






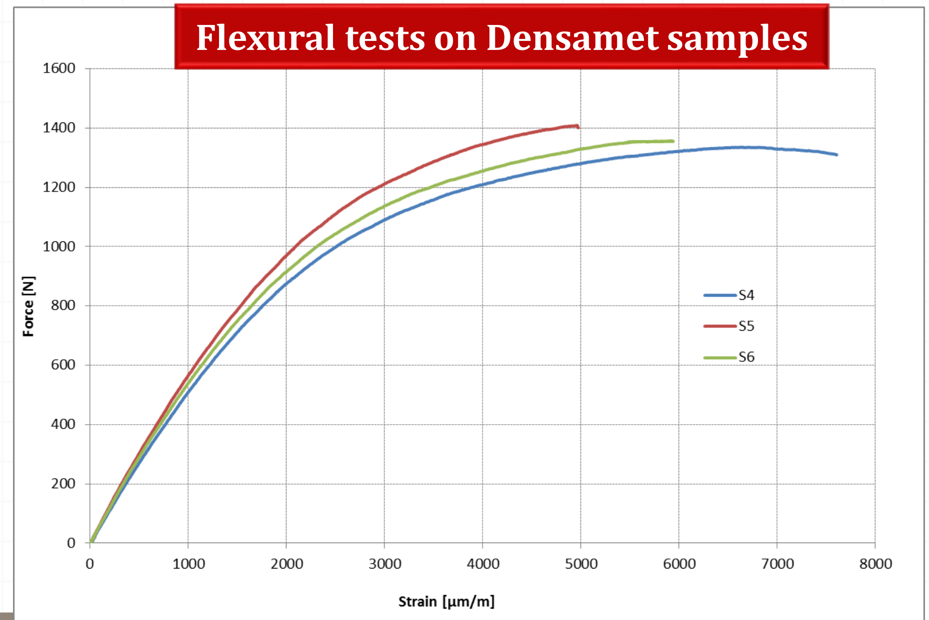


Preliminary X-rays observations

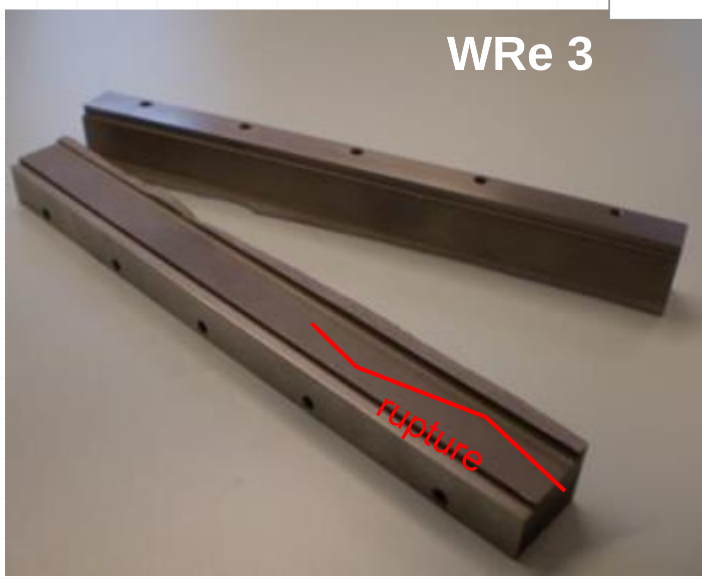


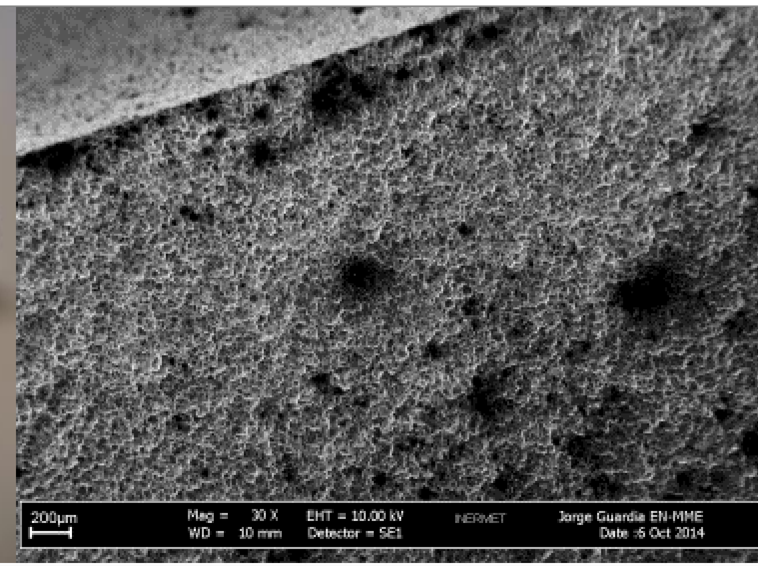
Micro-tomography

Testing



- Mechanical tests on preliminary configurations (clamped wire)
- EN/MME mechanical laboratory





Testing

- Influence of **bending process** on electrical performance of cables

NO influence on electrical resistivity √

BPM Cables tooling

Summary

- The design of a **tertiary collimator with embedded BBLRC (TCTW)** has been presented
- The TCTW maintains the complete functionality of a standard TCTP
- One of the main challenges is to evacuate the **very high heat load generated by joule effect** on the wire (**1 kW on the wire only** – higher than the design load of a full TCTP jaw!)
- This is done by **brazing the wire to a "T" shape insert**, and by **increasing the wire diameter and clamping it to the cooling pipes** when it's outside of the jaw
- Numerical calculations and experimental tests show that the TCTW accepts the same load scenarios of a TCTP without losing in safety
- Nevertheless, the **minimum thickness of the Inermet jaw has been defined in 1 mm**, to take into account possible accidental loads coming during transport and manipulation of the blocks, and to ease machining
- **Extensive R&D done on further aspects of BBLRC installation**: **bake-out** compatibility, **impedance and beam cleaning** analyses, development of **new LVDTs** less sensitive to EM effects from the wire
- Some open points to be analysed: radiation effects on the insulator, vacuum tests, influence of wire on BPM measurement, electrical acceptance tests, …

Backup slides