Phase II Collimators at CERN: design status and proposals

LHC Collimation

Phase II

Conceptual Review

2nd April, 2009

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on behalf of the Phase II Collimation design team

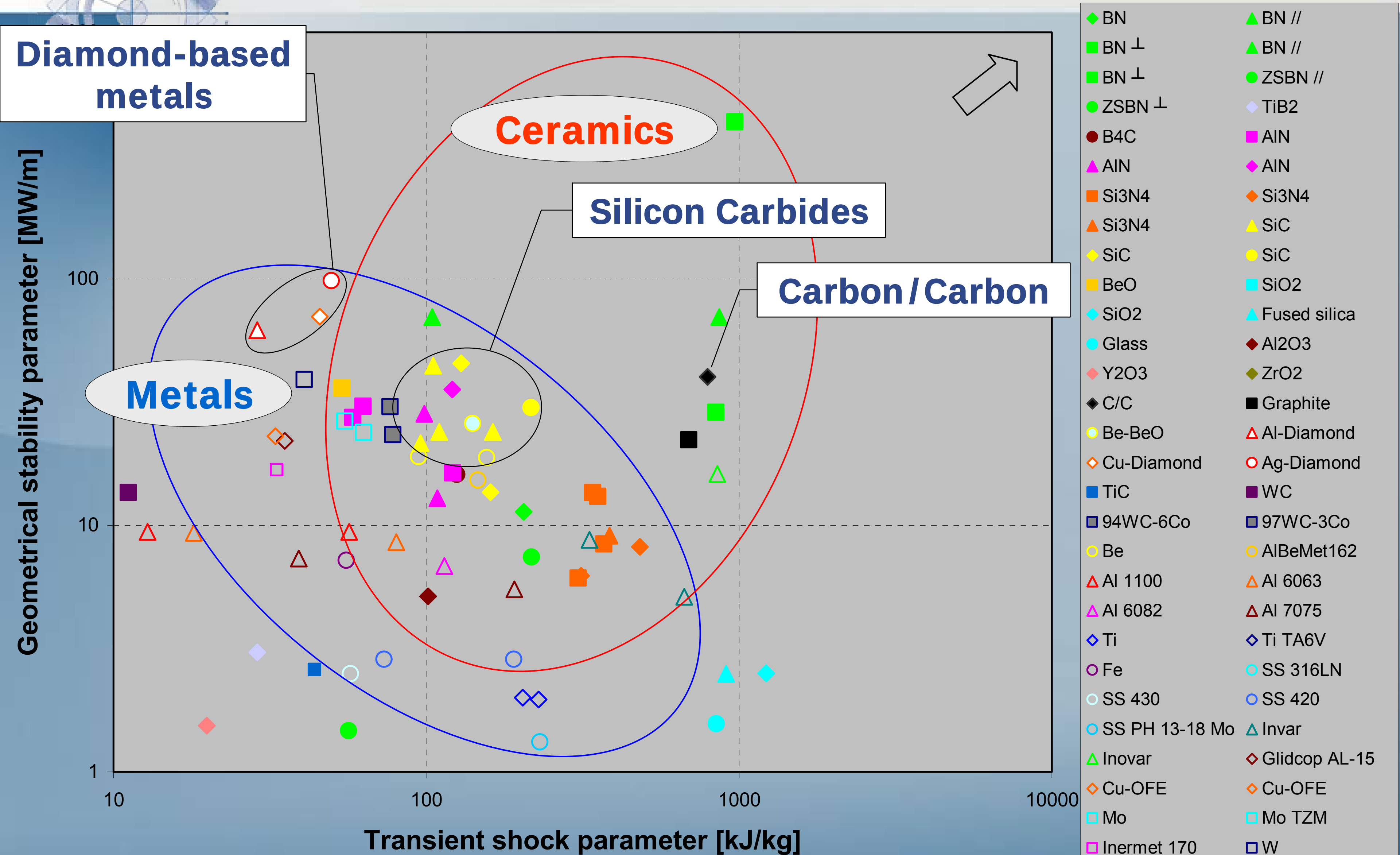
Phase II Design Strategy

- **First conceptual studies started in 2008.**
- **Keep Phase I design baseline (moveable jaws with 5 motors , i.e. 5 independent D.o.F. in a vacuum tank).**
- **Extended re-use of Phase I motorization, electronics and ancillary equipments** (Supports, Cabling, Water distribution circuits, Plug-ins…).
- **Focus on the re-design of the jaw assembly according to new requirements (**see **R. Assmann's** talk**)**.
- **Design optimization of some mechanical components** (e.g. mobile tables for the actuation system).
- **Rely on international collaborations for material R&D with European Institutes (EPFL, ARC, PoliTo, Kurchatov Inst. in the frame of FP7) and industries (Plansee AG …)**

Phase II Design Features

- Jaw design
  - Modular design (a common baseline for the jaw assembly allows the use of alternative materials for the jaw).
  - Back-stiffener concept to allow maximum geometrical stability (improves collimator efficiency).
  - Adjustable system to allow jaw flatness control and compensate gravity sag (2 versions being studied …)
  - Optimized internal cooling circuit to absorb higher heat-loads.
  - Integrated BPMs to minimize set-up time.
- Jaw materials (goals)
  - Tailored electrical conductivity to improve RF stability.
  - High thermo-mechanical stability and robustness.
  - Higher density (high-Z) to improve collimation efficiency.
  - Strong resistance to particle radiation.

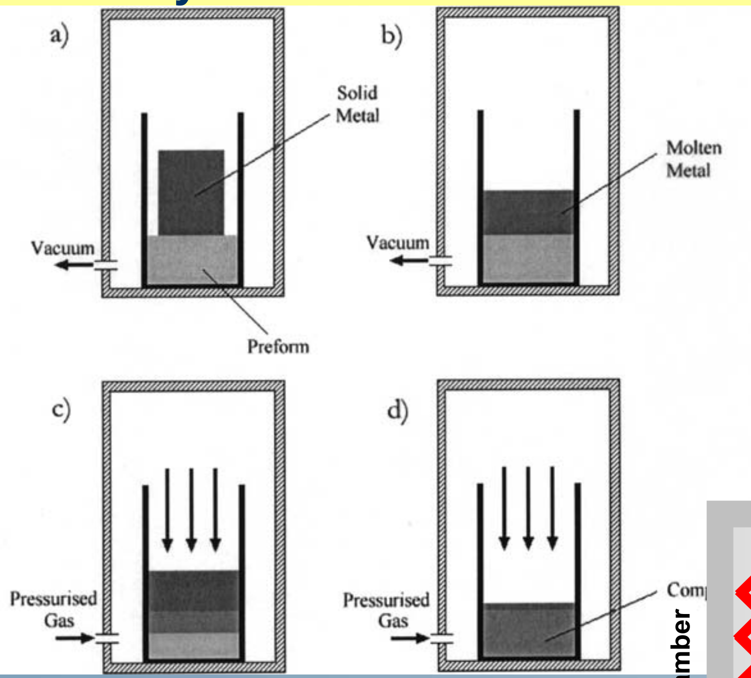
Phase II Collimator Materials

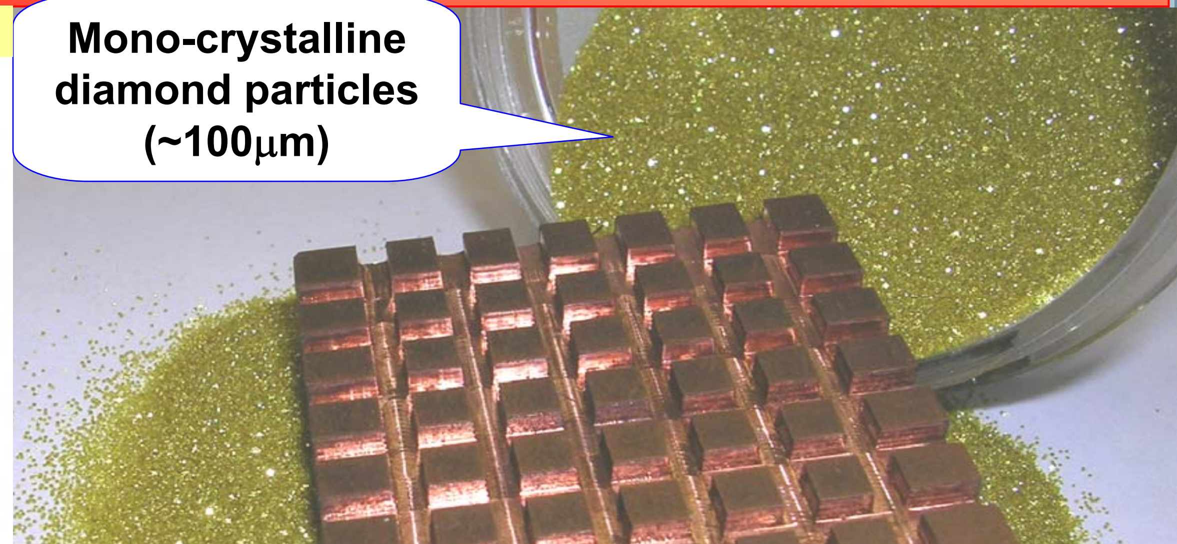


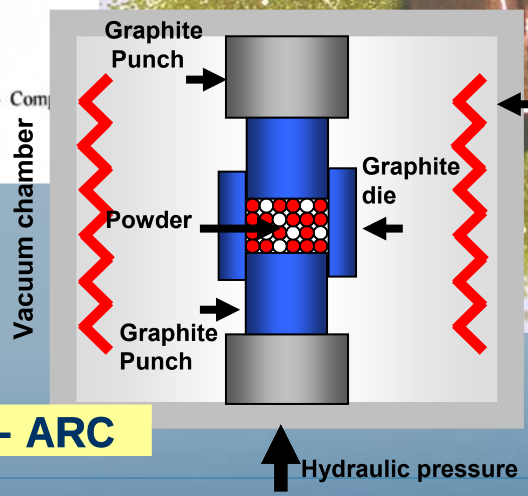
Phase II Collimator Materials

Diamond-metal composites are advanced thermal management materials usually obtained by liquid metal pressure infiltration or hot pressing…

Courtesy L. Weber – EPFL







Courtesy E. Neubauer – ARC

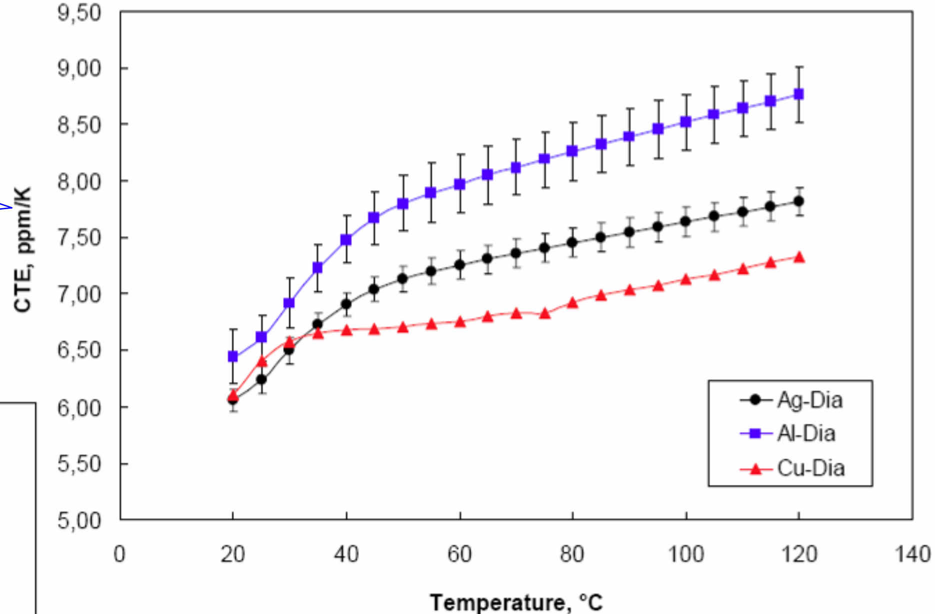
CERN Engineering Department

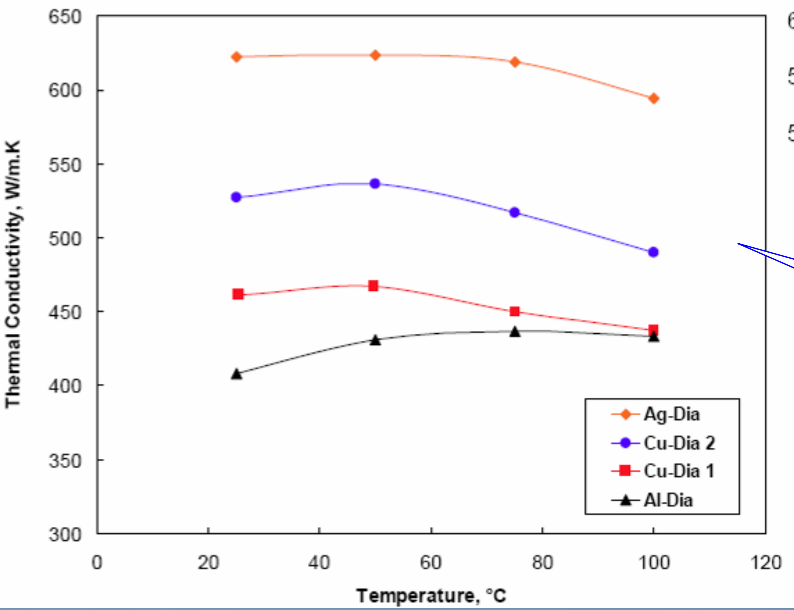
Phase II Collimator Materials

Diamond-metal composites combine excellent Thermal conductivity (higher than Cu) with particularly low CTE …

Coefficient of Thermal Expansion

(factor 2÷3 less than Cu)





Thermal conductivity

(factor 1.5÷2 more than Cu)

Source: Plansee AG – Reutte (AT)

Phase II Collimator Materials

Radiation hardness is a critical aspect for the lifetime of C-C jaws used for Phase I collimators …

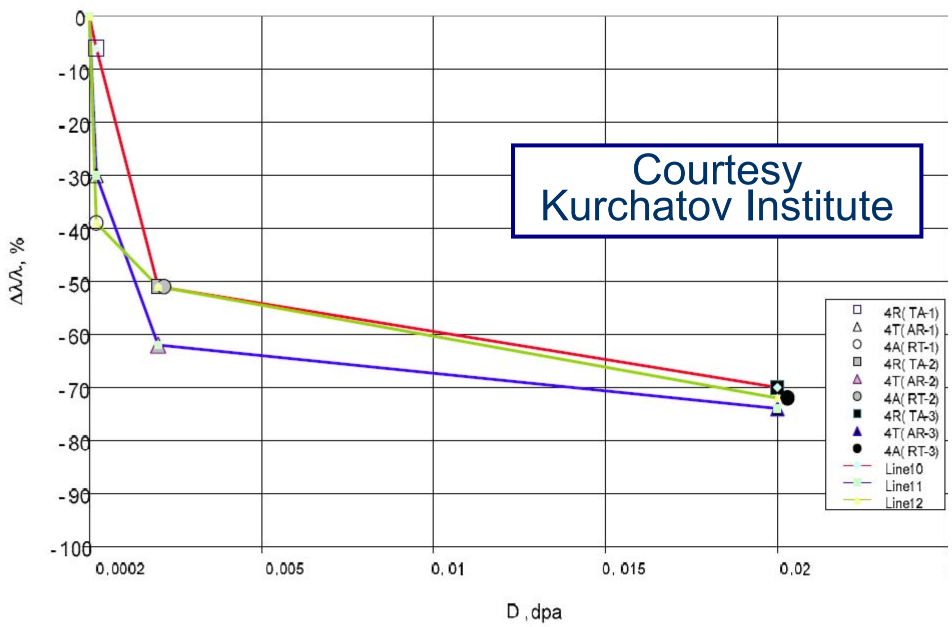


Fig.51. The relative change in thermal conductivity of samples for AC-150 material depending on the doses.

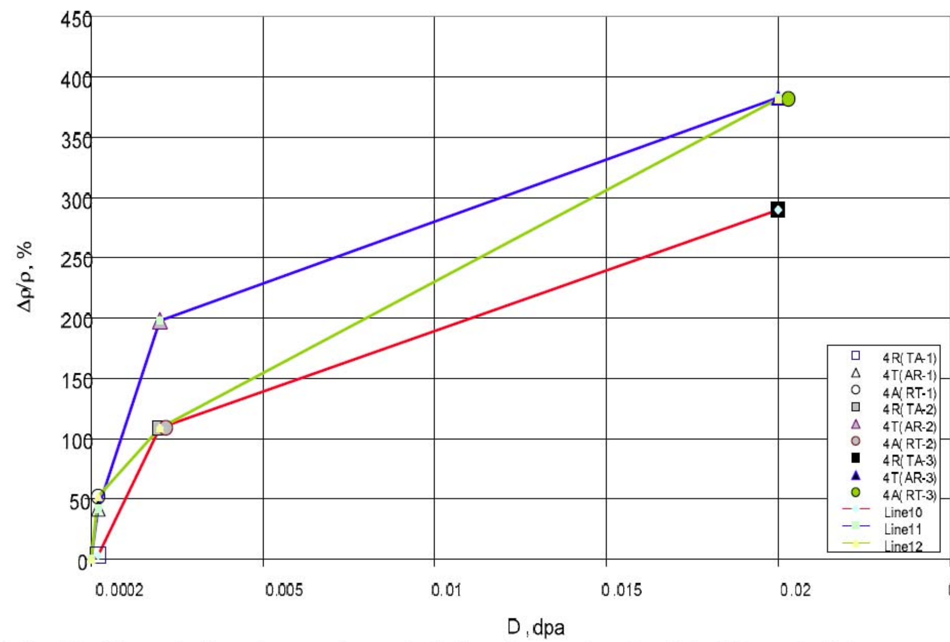


Fig. 50. The relative change in resistivity of samples for AC-150 material depending on the doses.

- According to data available in literature all potential materials (SiC, Copper, Diamond) exhibit good behaviour against radiation …
- Lower doses on surrounding equipment will extend lifetime of critical components (e.g. Warm Quadrupoles)

Phase II Design options

…depending on RF and cleaning efficiency specifications…

Possible alternative solutions for TCSM Equipped Jaw

Ceramic absorber with metallic (conductor) support

Solid metal jaw

Ceramic support with thin foil absorber (conductor)

Jaw absorber: Ceramic

1. 1-100 Ωm resistivity (SiC)
2. Few cm long tiles
3. ~10 mm thick
4. ~1 mm gap between tiles
5. CTE ~5 ppm

Jaw metal support

1. Good conductor
2. 1.2 m long monolithic
3. CTE matching ceramic's?

Metal-based jaw

1. 1.2 m long
2. Very good conductor on surface (e.g. Cu coating)
3. Bulk material should have low CTE (Metal – Diamond?)

Ceramic support

1. Low conducting material
2. Monolithic or brush-like

Thin-metal foil

1. Bonded to support
2. ~20-50 μm thick

Jaw Cooler & Pipes

1. Cooler Length ~300÷500mm
2. Brazed to metal support

Continuous pipes brazed to Jaw cooler (as Phase I)

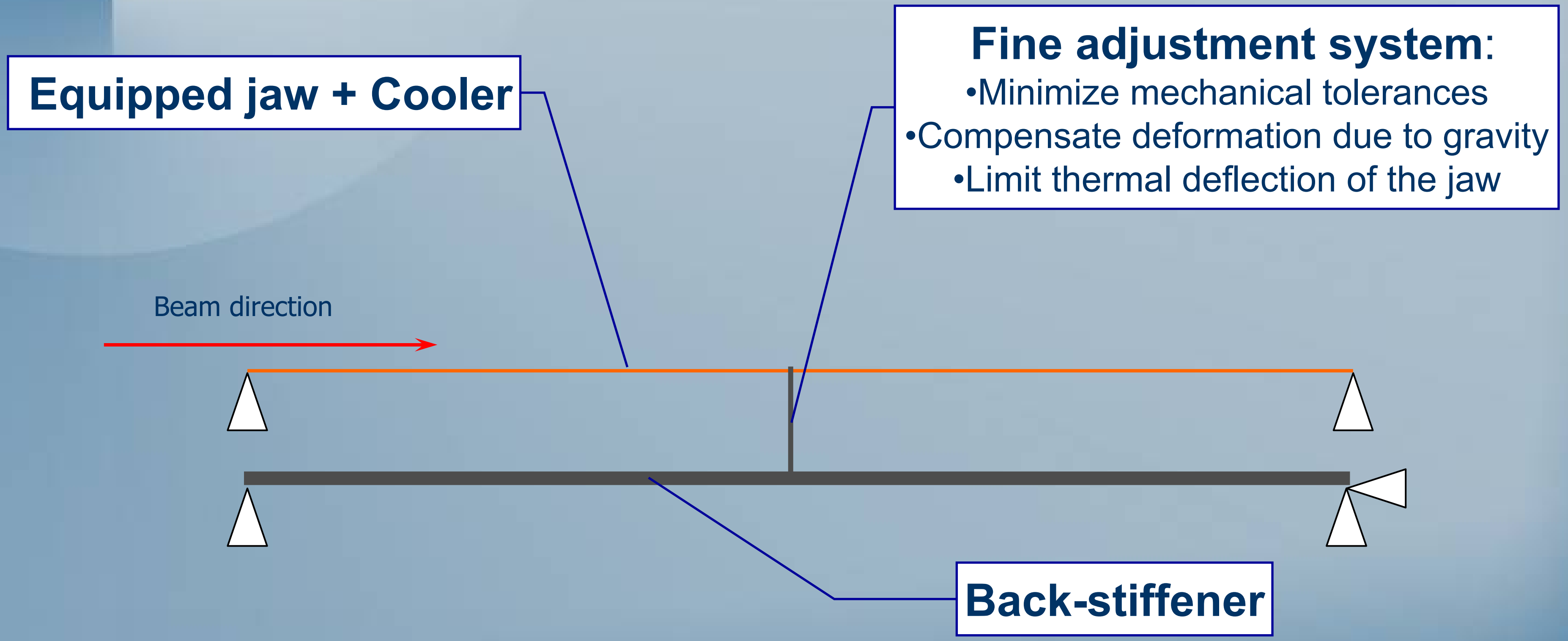
Embedded continuous pipes (back-casting)

Machined Circuit with brazed cover

Machined circuit sealed during casting

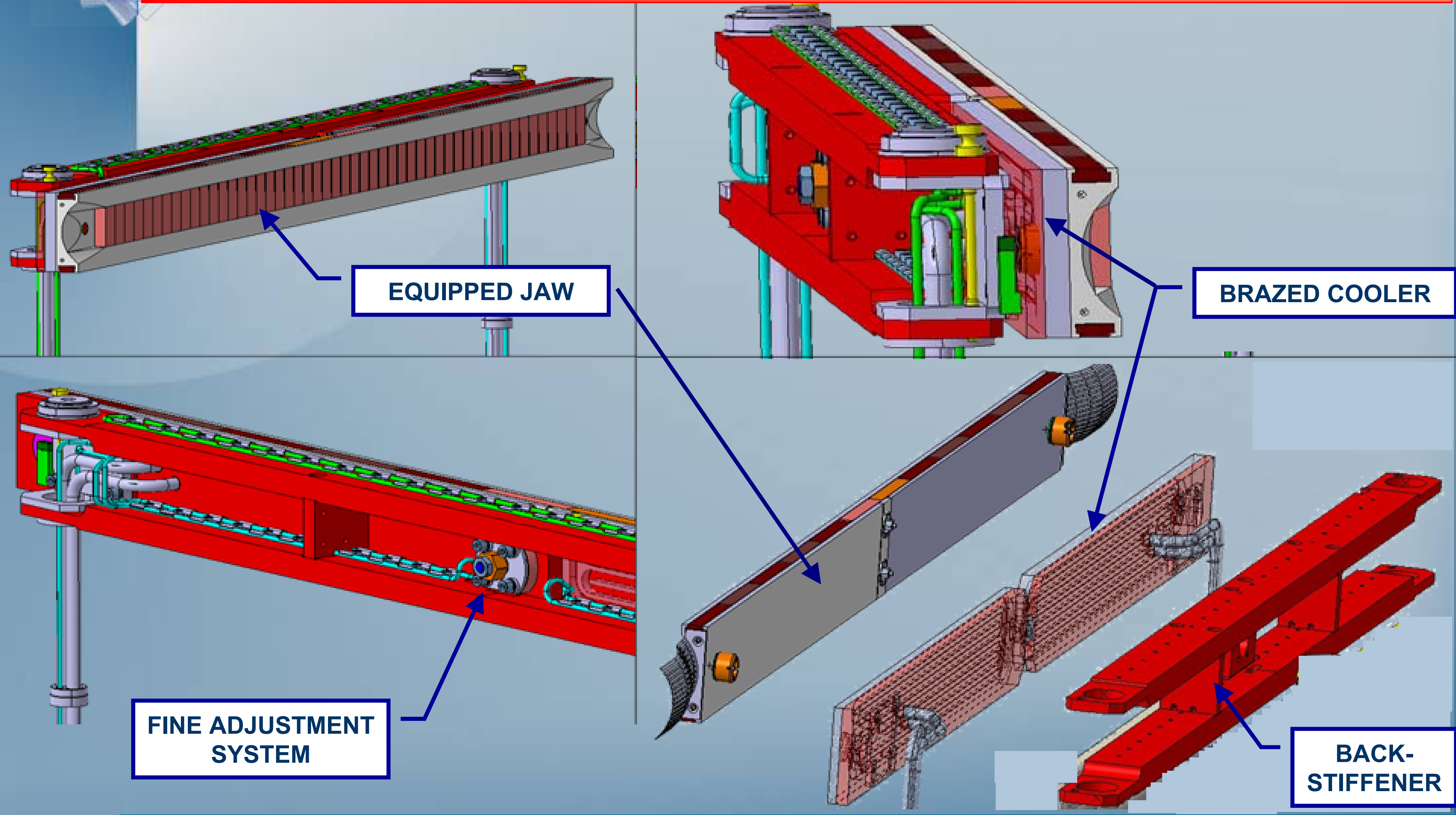
Phase II Design Baseline

Preliminary design is based on the concept of a rigid back stiffener remaining at almost uniform temperature and ensuring high **geometrical stability** to the jaw surface under thermal load.



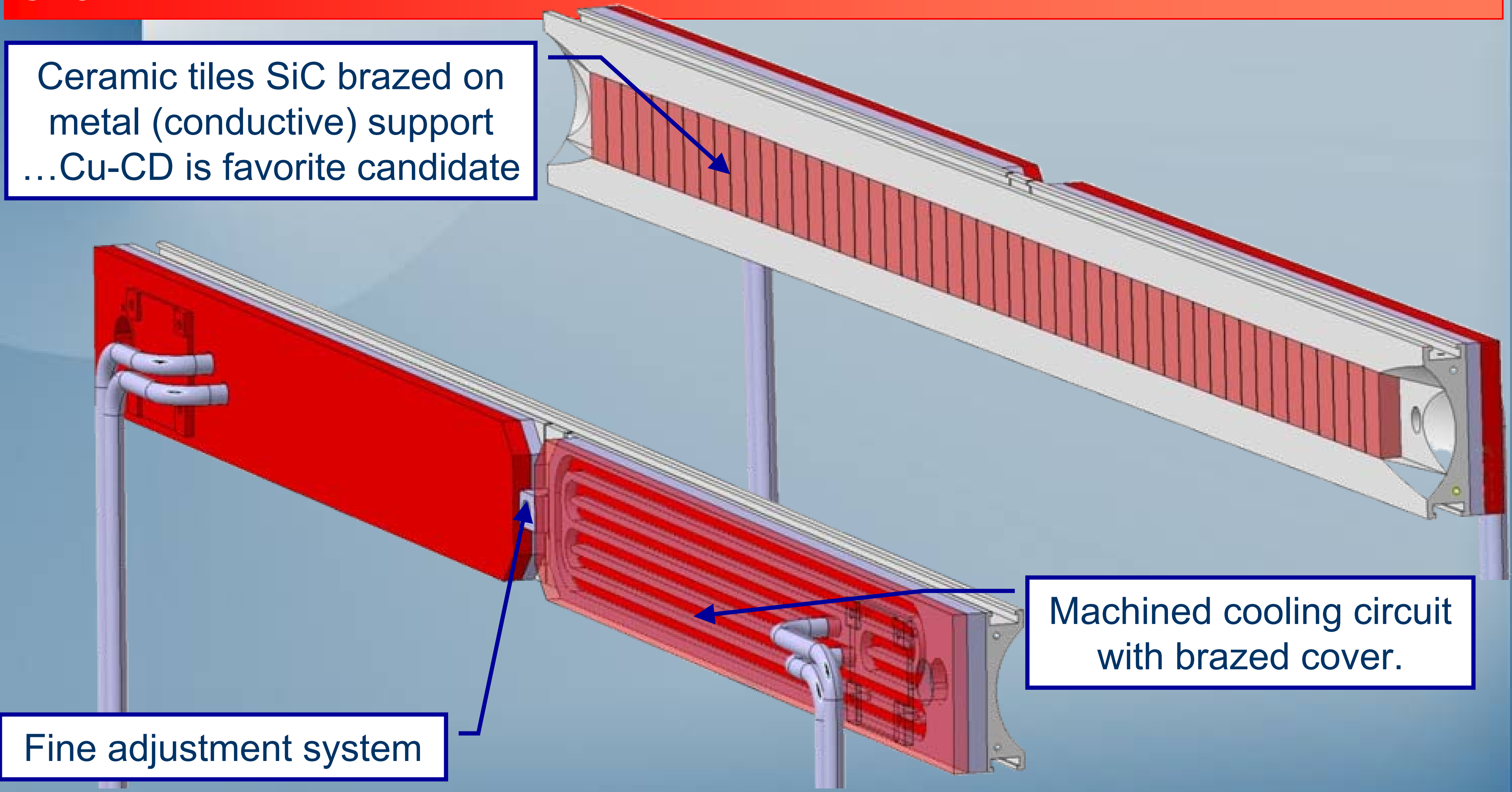
Phase II Design baseline (v1)

Modular concept to fit in alternative jaw materials ...



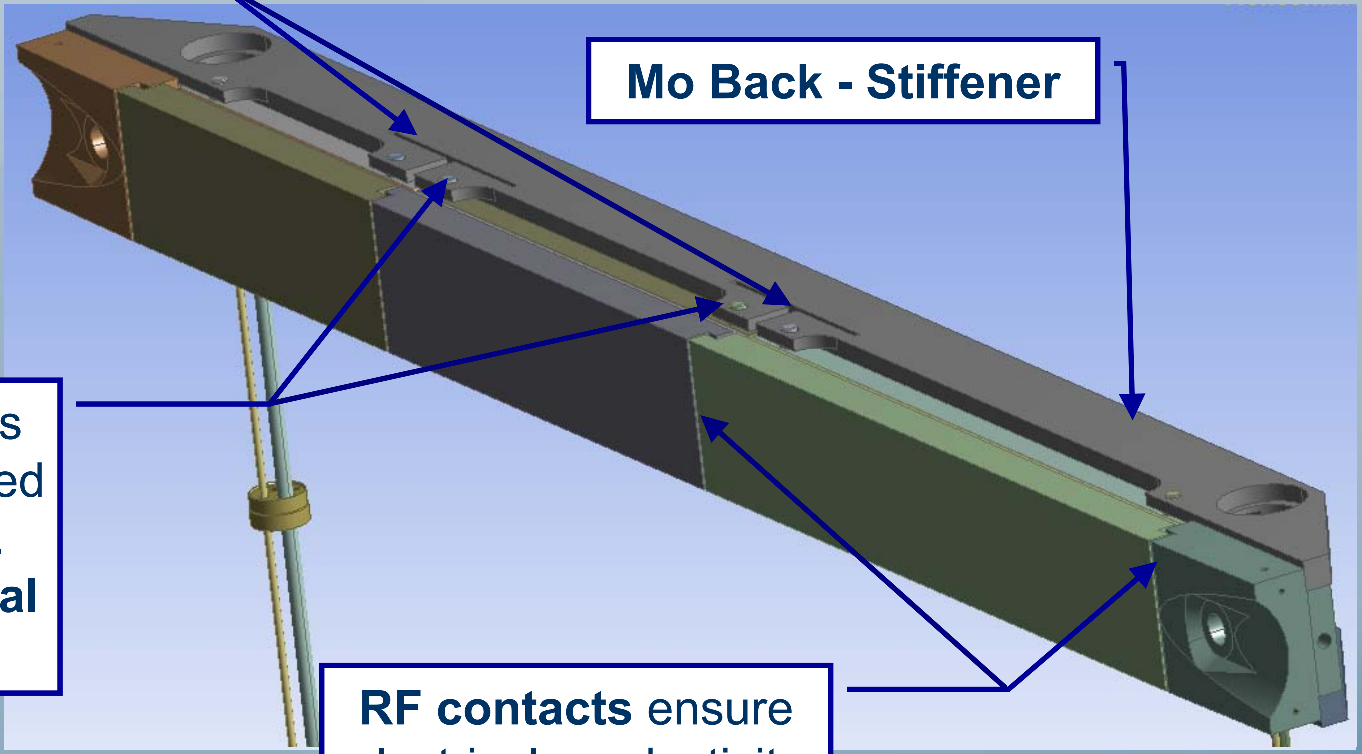
Equipped Jaw (v1)

1st version of equipped jaw (1 adjustable support) … SiC absorber shown …



Design Baseline (v2)

Alternative design of equipped jaw based on 2 intermediate adjustable supports …



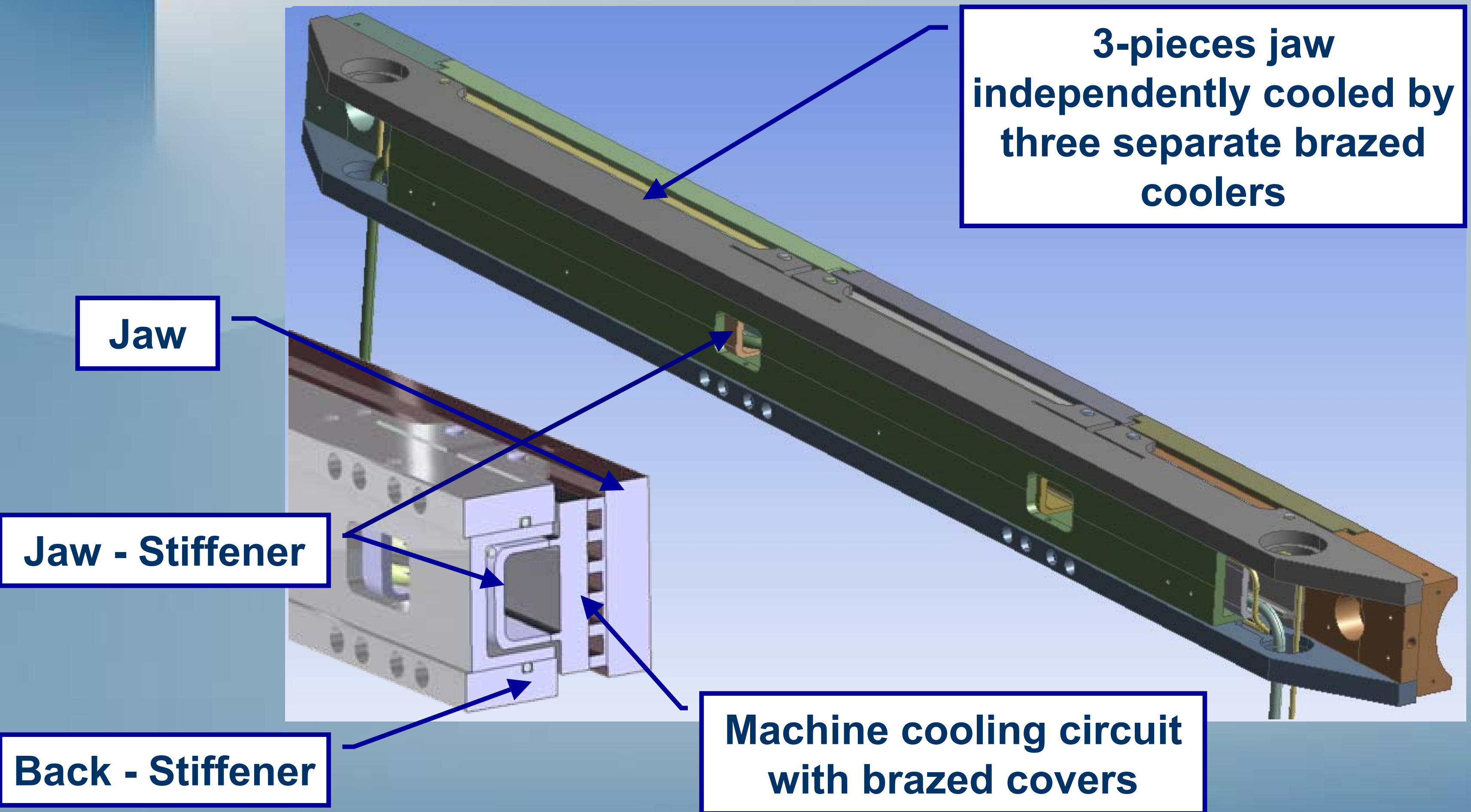
Fine adjustment system

Mo Back - Stiffener

Cut jaw: each piece is independently supported on the back stiffener. **Enhanced geometrical stability**

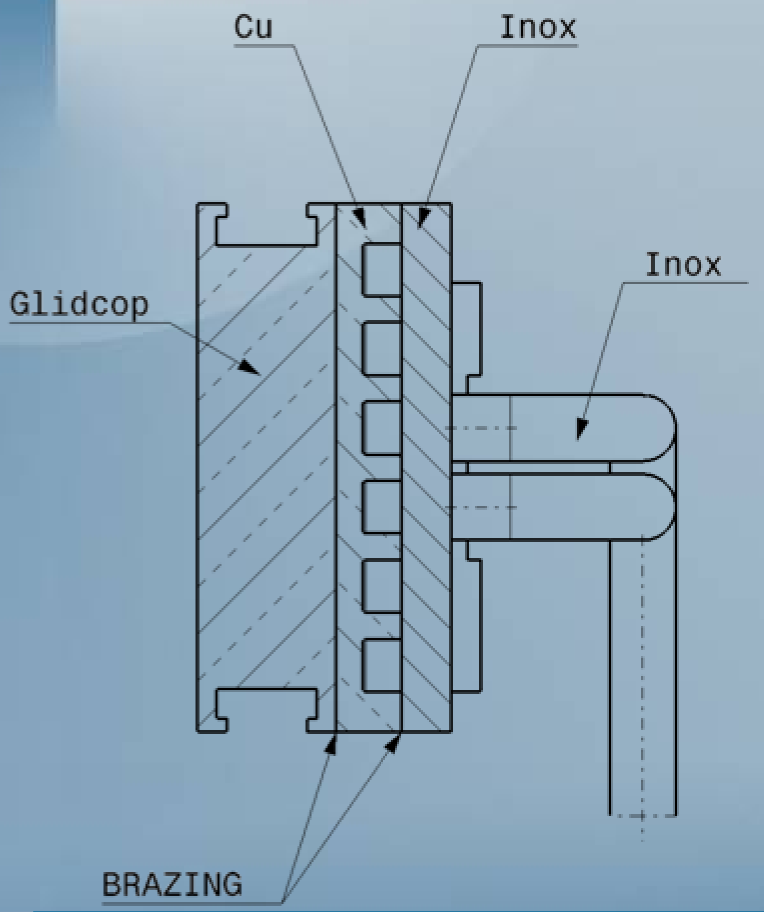
RF contacts ensure electrical conductivity between jaw pieces

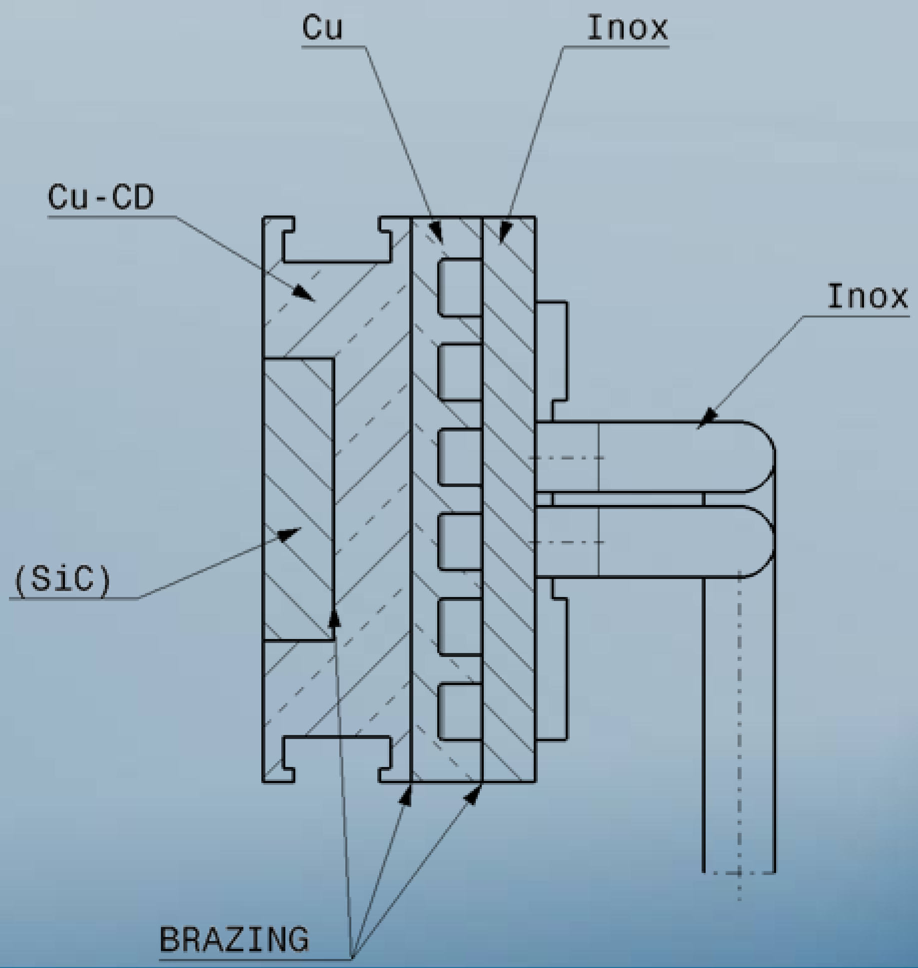
Design Baseline (v2)



Alternative Materials

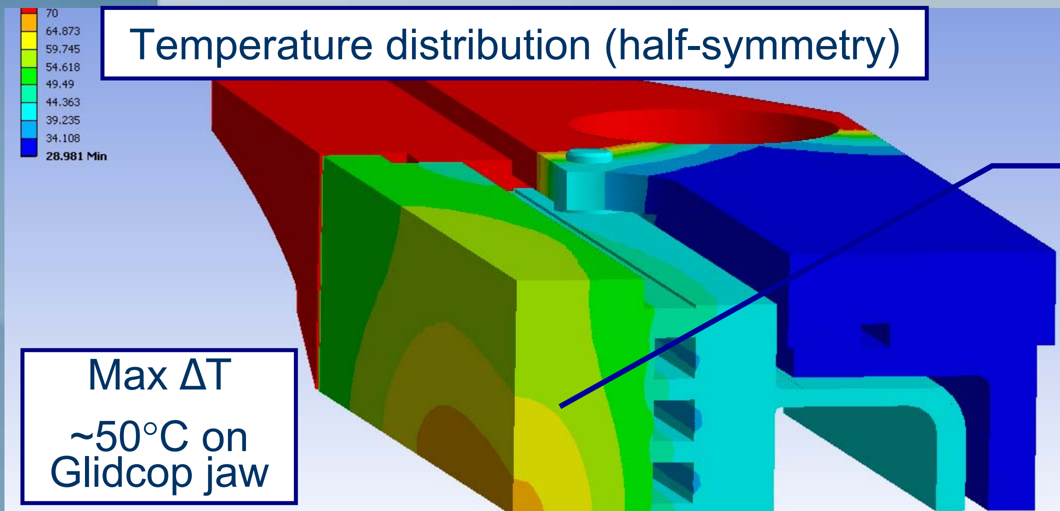
Metal jaw (high electrical conductivity) vs. **Ceramic jaw** (non-conductive) on metal conductive support...





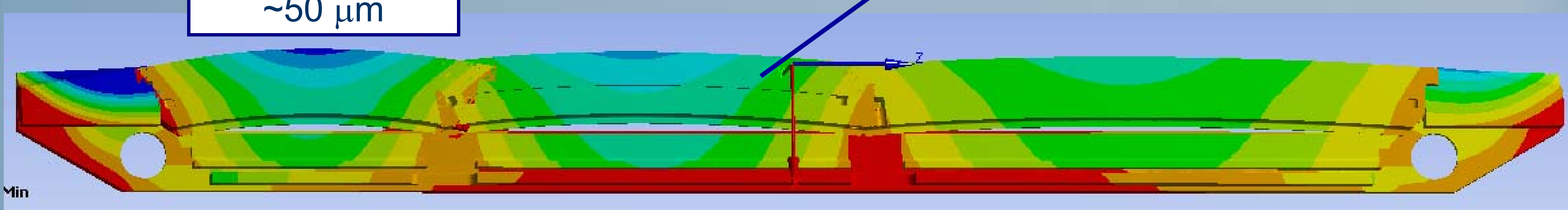
Thermo-mechanical analyses

Preliminary analyses show good geometrical stability.
Thermal deflection of Glidcop jaw with "design v.2" stays within 50μm with an active length of 1m (Steady-state case).



Temperature distribution
(1 hr Beam lifetime (τ) – 0.8x10^{11} p/s equivalent to ~20kW – Steady state)

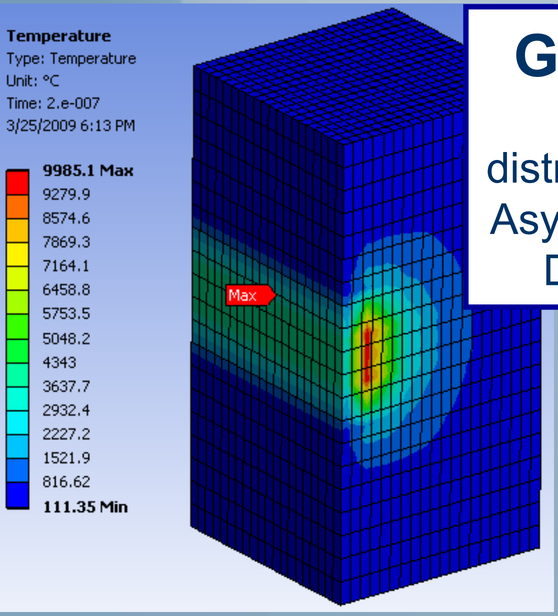
Max deflection
~50 μm



Thermal deflection
(Steady-state 1 hr τ)

Thermo-mechanical analyses

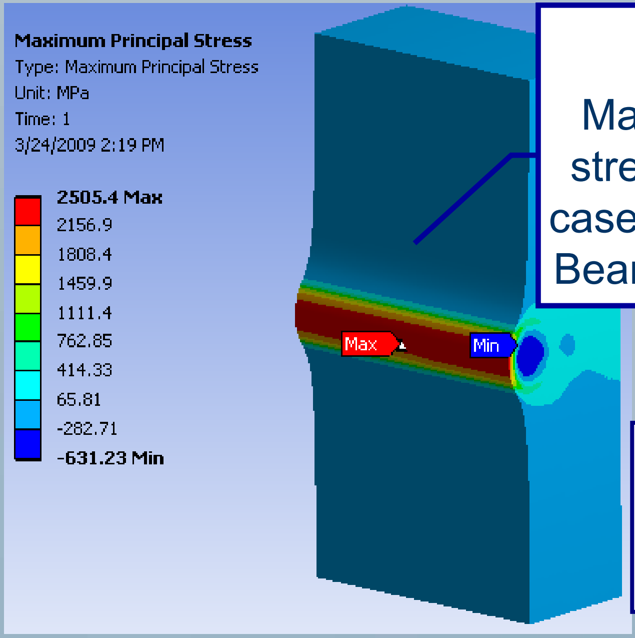
Preliminary simulations of direct 7 TeV beam impact (200 ns): SiC gives promising results (no melting as opposed to Glidcop jaw). **Simulations with hydrodynamic codes + dynamic characterization of the materials + HiRadMat tests are mandatory (See I. Efthymiopoulos talk).**



Glidcop Jaw

Temperature distribution in case of Asynchronous Beam Dump at 7 TeV

Max Pressure increase of cooling water: ~60bar



SiC Jaw

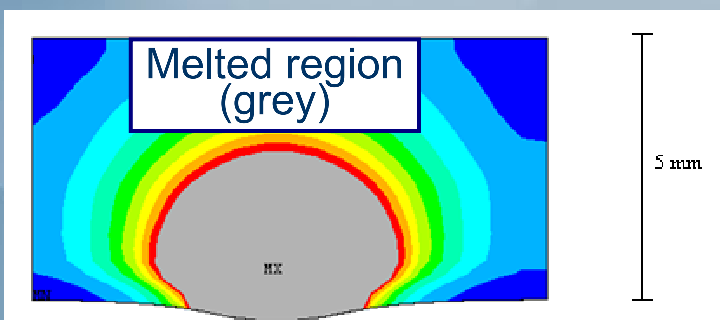
Maximum principal stress distribution in case of Asynchronous Beam Dump at 7 TeV

Max Pressure increase of cooling water: ~25bar

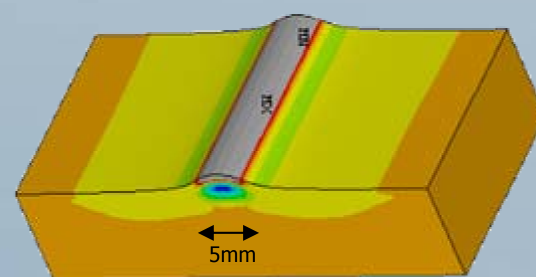
Thermo-mechanical analyses

Preliminary simulations of direct 7 TeV beam impact (200 ns): SiC gives promising results (no melting as opposed to Glidcop jaw). **Simulations with hydrodynamic codes + dynamic characterization of the materials + HiRadMat tests are mandatory (See I. Efthymiopoulos talk).**

Glidcop



SiC



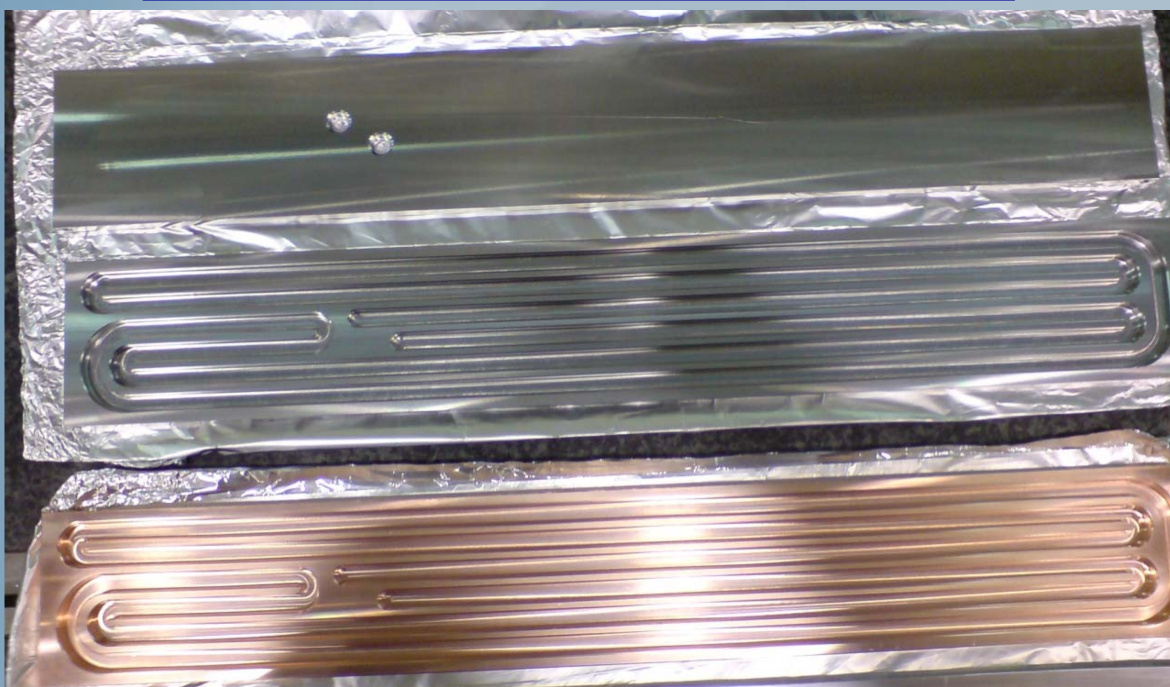
Affected region (grey):
Thermal stresses exceeding tensile strength

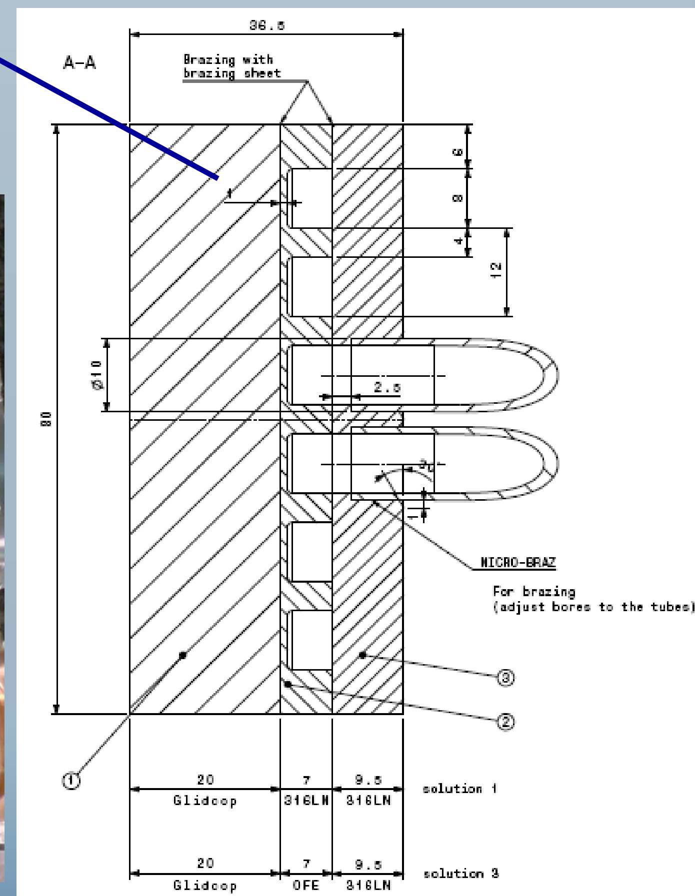
5th D.o.F. motor allows to move all the vacuum tank by ± 10mm.
Collimators should withstand up to 5 accidents.

Cooler prototype

Using high Z-material leads to higher energy deposition (up to a factor 5 increase w.r.t. Phase I). Higher cooling capacity is essential to ensure geometrical stability…

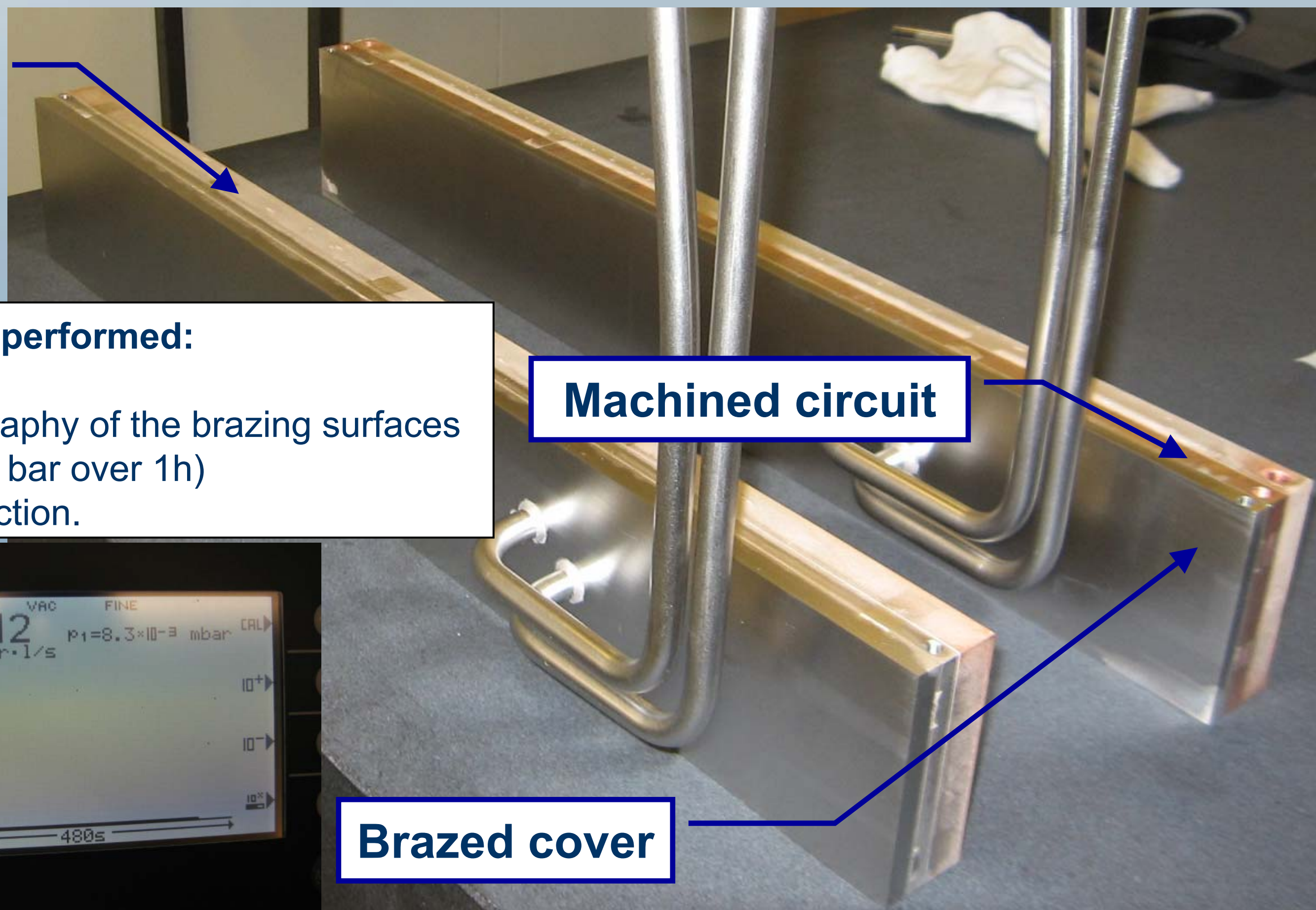
Two prototypes including **machined circuit**, **brazed cover** and jaw mock-up have been produced and successfully tested…



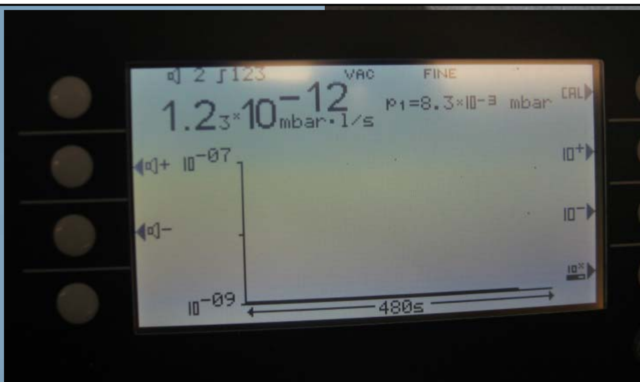


Cooler prototype

The goal is to define a complete and standardized procedure according to UHV specs. in order to **qualify the design**.



Test successfully performed:
- He leak detection
- Ultrasound cartography of the brazing surfaces
- Pressure test (100 bar over 1h)
- Final He leak detection.



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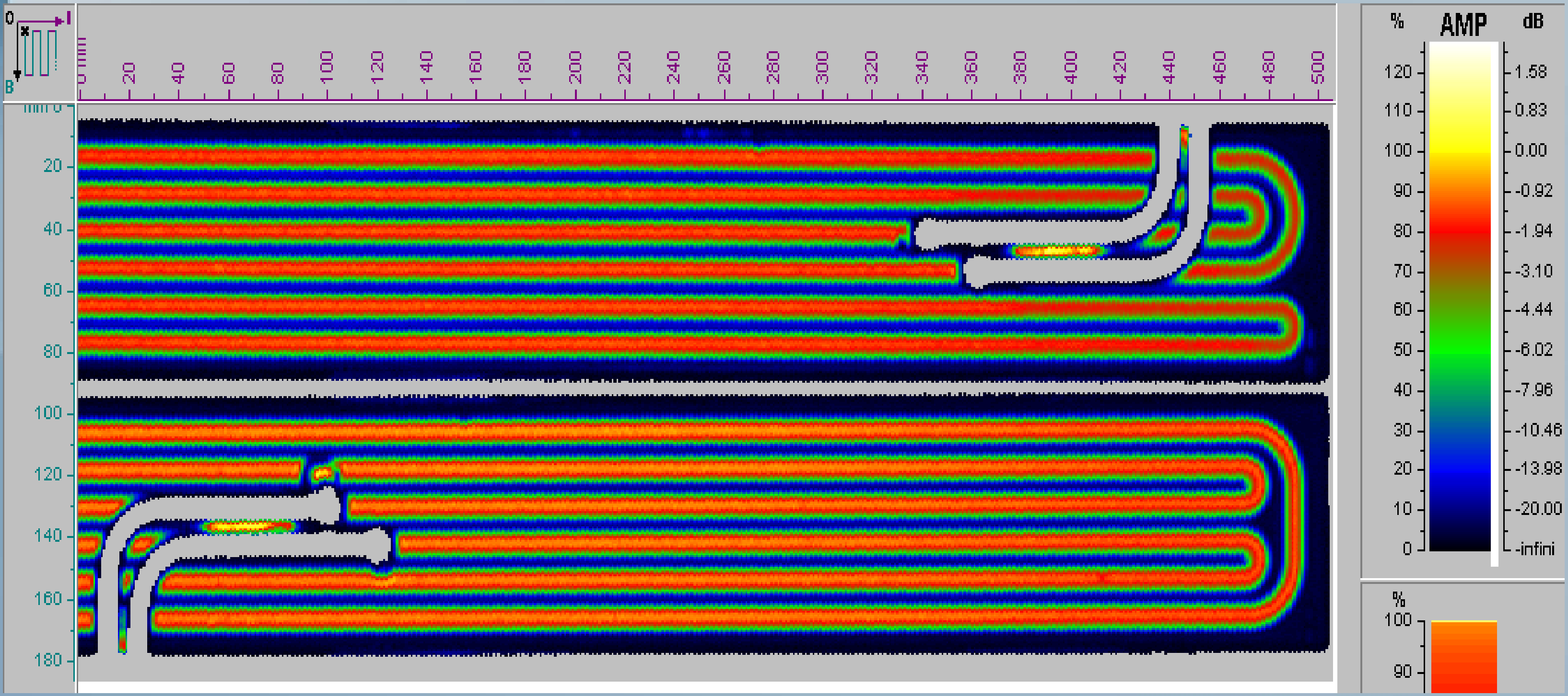
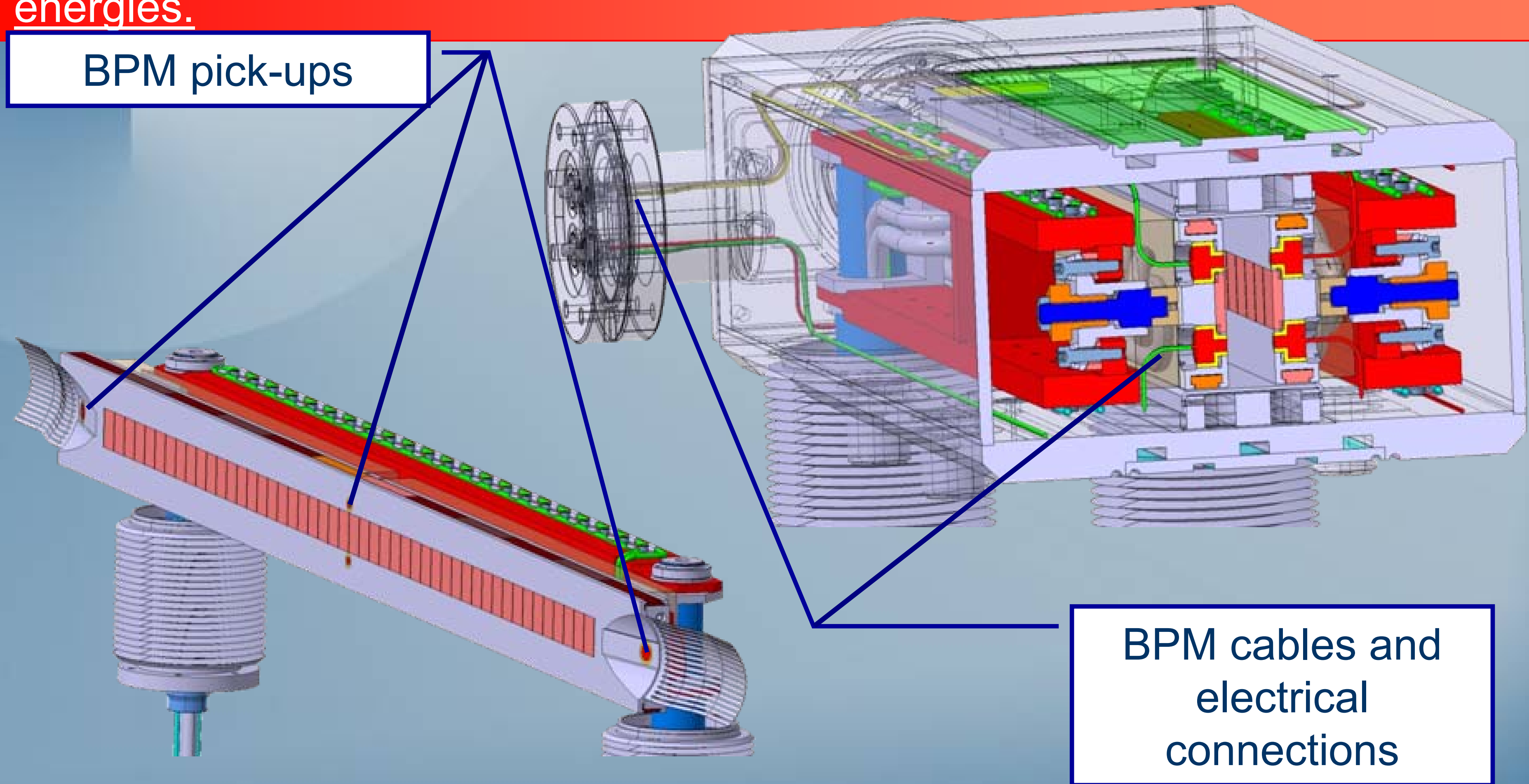


Ultrasound Cartography of Brazed Joint:
- No relevant defects found on either prototypes
- Brazing is leak-tight

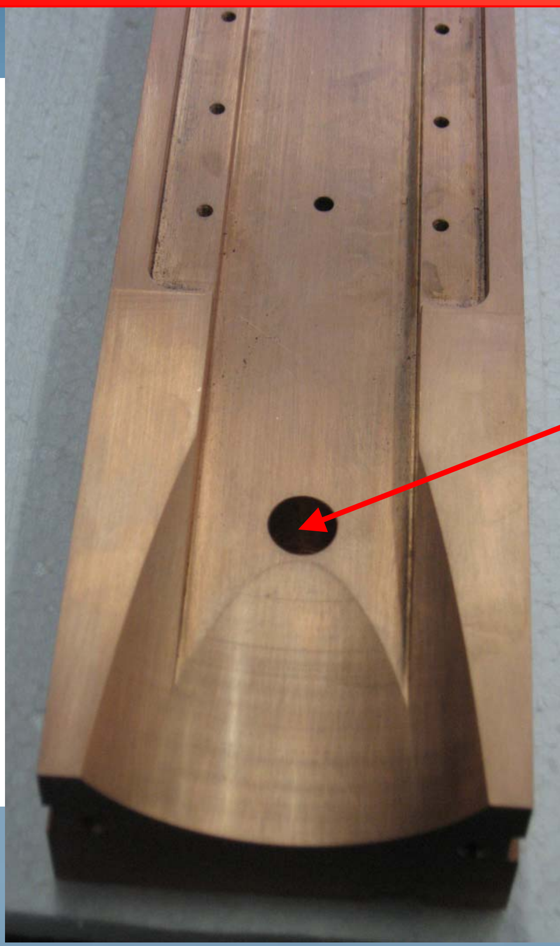
Operational efficiency

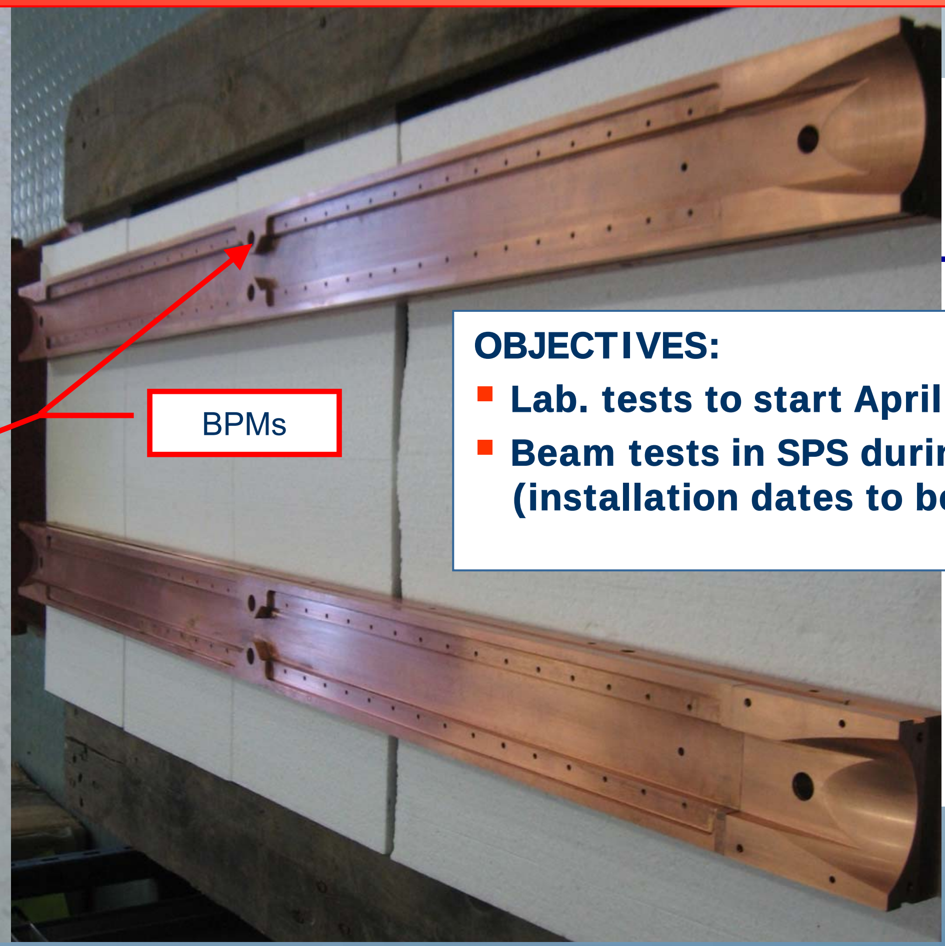
Integration of BPMs strongly influences the design of the whole system…
Reduce set-up time to ~1 min. Only way to set-up at high intensity and energies.

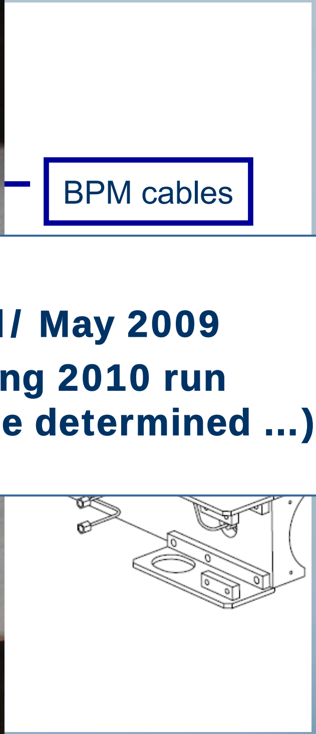


BPM functional prototype

Motivation: BPMs integration strongly influences the design of the whole system. A rapid testing in the SPS of the BPM embedded system is mandatory to validate the concept.





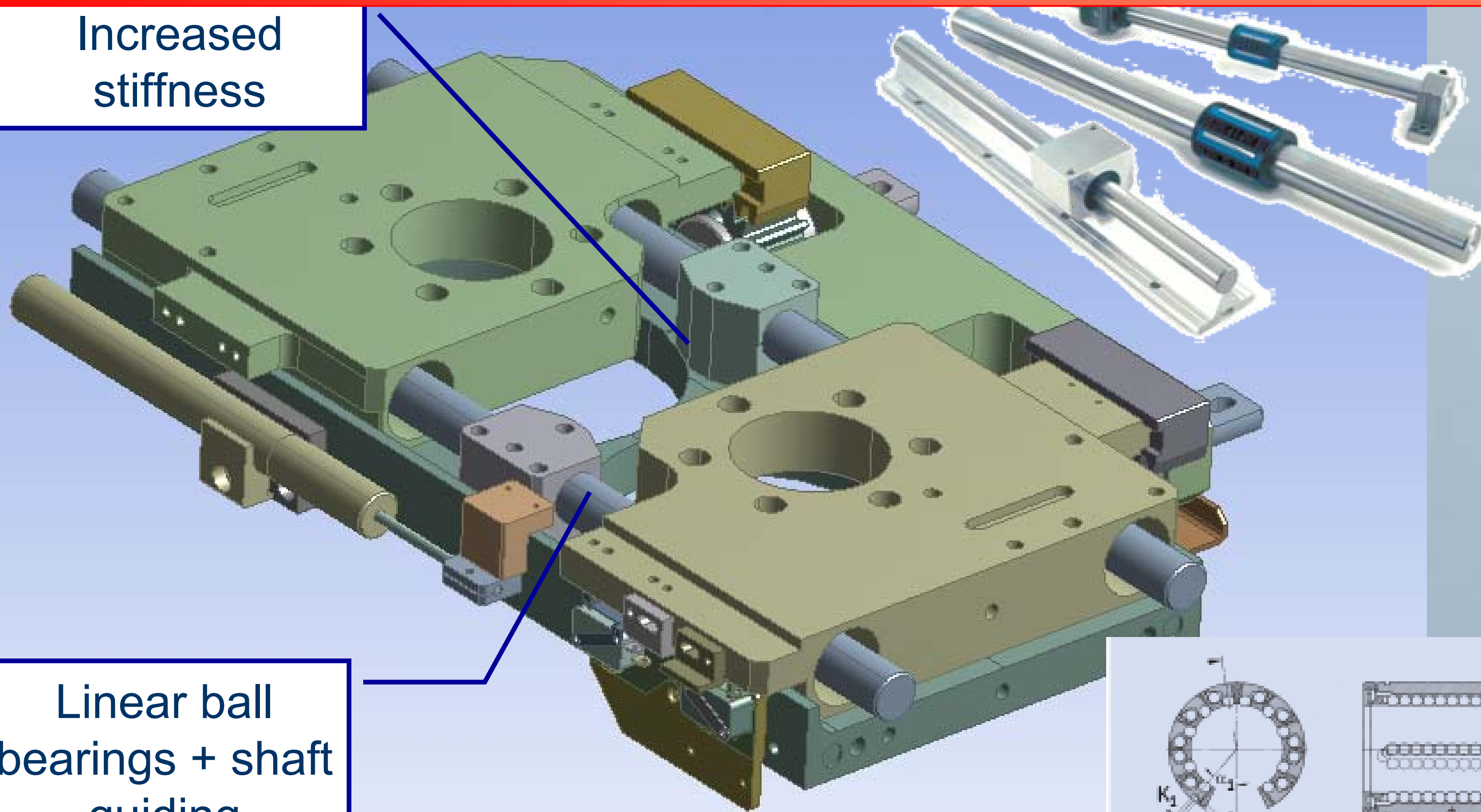


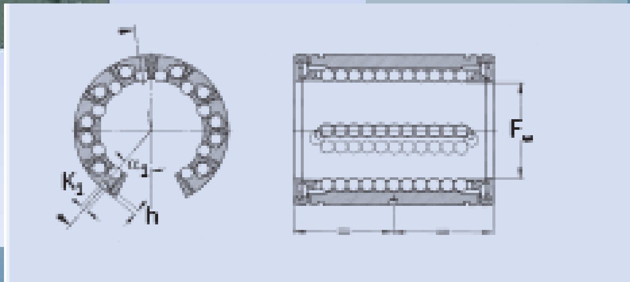
OBJECTIVES:

- **Lab. tests to start April/ May 2009**
- **Beam tests in SPS during 2010 run (installation dates to be determined ...)**

Mechanical Optimization

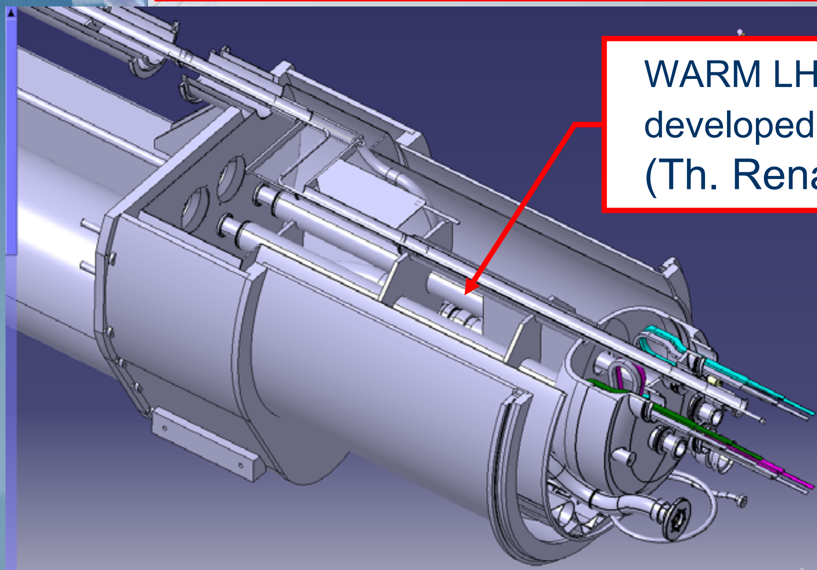
New stiffer design has been prototyped and is undergoing endurance tests ….





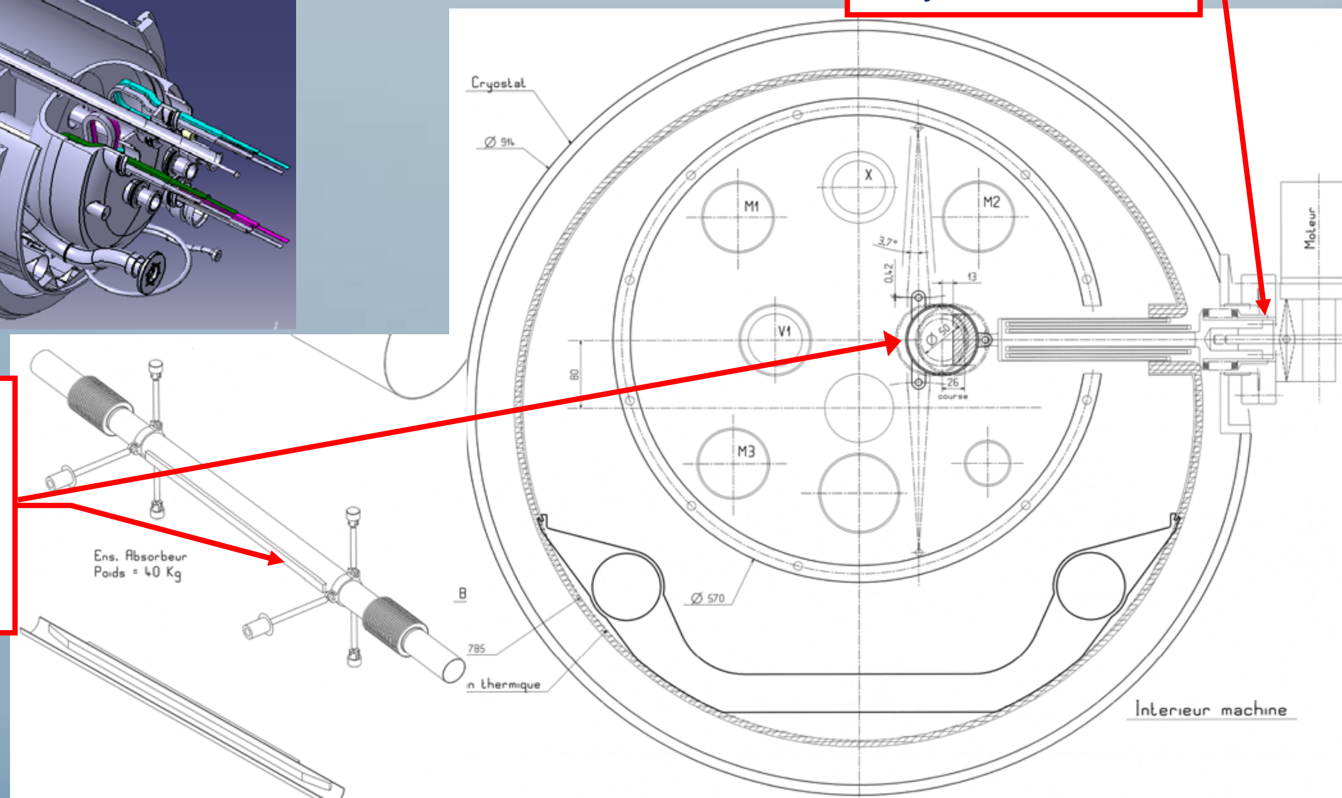
Cryogenic Collimators

Preliminary ideas at CERN …



WARM LHC Cold-warm transition developed for FP420 project. (Th. Renaglia EN-MME)

Warm Actuation system placed outside the cryostat

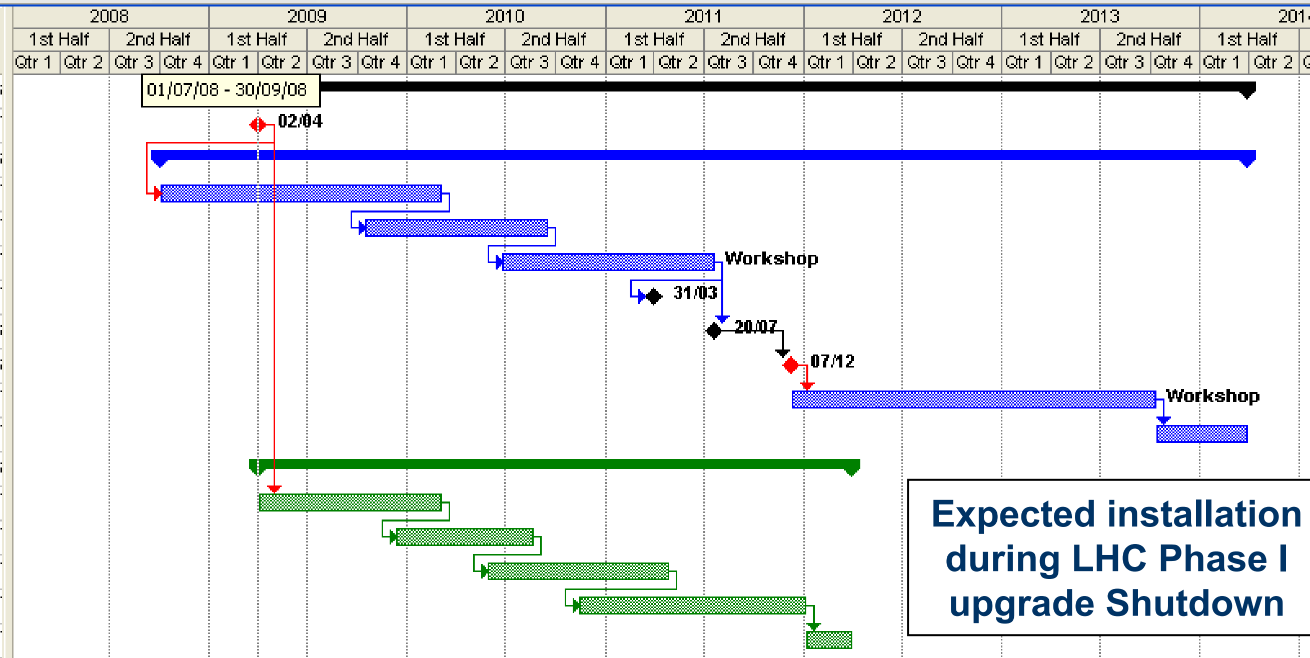


Possible Layout of a Cryogenic collimator @ ~50K: moveable beam pipe with integrated collimator jaw
(R. Perret EN-MME)

CERN Engineering Department

Planning and Resources

Task Name	Duration
PhaseII Collimation	**1420 days?**
Conceptual Review	0 days
PhaseII Collimators	**1420 days?**
PhaseII - Engineering, & Pre-study	18 mons?
Phase II - Design, Drafting & Material	12 mons?
PhaseII - Prototyping & Testing	14 mons
Phase II - Materials demostrators for H	0 days
Phase II - Prototype(s) Ready for HiRa	0 days
Phase II collimators - Construction	0 days
PhaseII - Production& Quality control	24 mons
PhaseII - Installation	6 mons
Cryogenic Collimators	**780 days?**
Tcryo - Engineering & Pre-study	12 mons
Tcryo - Design & Drafting	9 mons
Tcryo - Prototyping & Testing	12 mons?
Tcryo - Production	15 mons
Tcryo - Installation	3 mons



- **Phase II Collimators (assuming a series of 35 collimators)**
  - Engineering, Design, Prototyping and Testing (~ 24 months)
  - In-house (MME) production of a single type collimator; less critical components produced outside (e.g. tank + actuation system) (~ 24 months)
  - Resources critical
- **Cryogenic collimators (assuming a series of 8 collimators)**
  - Engineering, Design, Prototyping and Testing (~ 18 months??)
  - In-house (MME) production conceivable but very compressed (15 months???)
  - All resources to be found

Conclusions

- CERN design for Phase II collimators is an evolution of Phase I. Extensive redesign has been carried out on jaw assemblies to respond to new requirements.
- Preliminary jaw design is based on a modular concept, allowing different material options to be adopted.
- BPMs are integrated to reduce set-up time. Only way for set-up at high energies and intensities.
- Particular care devoted to flatness control, minimization of induced deflection, heat evacuation.
- Demonstrators are being built/tested to validate most critical aspects. Rapid tests of BPM demonstrator in SPS is fundamental.
- Ideas for possible solutions for Cryogenic collimators are being assessed within Phase II Design Team. Timing hard to estimate …
- Engineering, design and manufacturing of Phase II and Cryogenic collimators at CERN (EN-MME) is conceivable provided R&D effort is maintained (no contingency planning) and adequate resources are allocated.