# LHC Collimation PHASE II
# 10th Design Meeting - 19/09/2008

*Present:* Gonzalo Arnau Izquierdo, Arnaud Pierre Bouzoud, Roger Perret, Marc Timmins, Valentina Previtali, Ralph Assmann, Ivo Wevers, Luisella Lari, Oliver Aberle, Vasilis Vlachoudis, Francesco Cerutti, Fritz Caspers, Jeff Smith (SLAC), Alessandro Bertarelli (chairman), Alessandro Dallocchio (scientific secretary).

## 1. LARP Phase II Collimator: Engineering status. (J. Smith - SLAC)

*Smith* started his talk with a brief description of the design solution developed by SLAC team; the system is based on two rotatable cylindrical jaws (actually the jaw is not a cylinder but has 20 facets) so that a new surface can be exploited in case of beam impact. These are the main components of the jaw assembly:

- Hollow Molybdenum shaft (two parts brazed to a central Cu hub)
- Cu mandrel is brazed on the Cu hub region
- Cu pipe is wound in the mandrel grooves
- Jaw quadrants (Glidcop) are brazed over the mandrel.
- Geneva mechanism ensure the rotation of the jaw.

Thermo-mechanical calculations show that a good geometrical stability has been obtained (jaw deflection ~200 μm in case of nominal heat load, 1 hour beam life time) with the last design configuration (hollow molybdenum shaft + central hub). However, specification requirements (25μm) have not been achieved yet. Calculation concerning beam accident has been performed with a simplified model and the robustness of the collimator must be verified via real beam test.
*Bertarelli* asked if any beam dump detector is foreseen for the jaws; *Smith* explained that they are evaluating to include temperature probes or microphones to detect possible dumps on the collimator.

*Smith* focused on the brazing procedures they have used and showed the problem encountered during the realization of the prototype. Brazing between Mo hollow shafts and Cu central hub was critical: Mo shafts have fingers at its extremities in order compensate the difference of CTE between Mo and Cu.

A thermal test has been performed to verify the efficiency of the cooling system and the quality of the brazing. Experimental measurements are in good agreement with FEM simulations thus confirming that the cooling system works correctly and the validity of the manufacturing procedure.
A bake-out test has been performed but results are not yet available.

# 2. Design status, options and future outlook. (A. Bertarelli)

*Bertarelli* starded his talk with a summary of the objectives of the Phase II project and the scheduling of the activities. He focused on the guidelines followed during this R&D phase to develop the design:

- Modular concept to fit in alternative jaw materials (All-metal, Metal-diamond, Ceramics-metal, Thin foil etc.) and concepts (alternative cooling systems)
- Increase geometrical stability and precision (e.g. jaw flatness).
- Increase cooling capacity.
- Capitalize Phase I experience to improve existing design (e.g. new moving tables)
- Collaboration with external partners to identify, develop and test novel advanced materials (EPFL, Plansee, Politecnico di Torino, Kurchatov, BNL)
- Possibility to embed in jaw design Beam diagnostic devices (BPMs, BLM)

*Bertarelli* presented more in details the design principle of the jaw assembly based on rigid back-stiffener + equipped jaw with fine adjusting system.
Design of Mo back-stiffener is well defined while different options are still open for the equipped jaw (no definitive specifications available from RF studies and collimation efficiency studies → LHC operations necessary).
Concerning the jaw these are the proposed design solutions:

- Monolithic metallic jaw (Glidcop) – Studied.
- Monolithic Cu-diamond + Cu coating – Being studied.
  - Plansee available for advanced co-design (investment necessary?)
- Monolithic Al-diamond + Al coating – Being studied.
  - Collaboration with EPFL already launched: Development of Al-CD jaw + Al coating + Al-CD cooler with Zr or Inox pipes. Mock-up possibly available within few weeks.
- Ceramic tiles on metal support – Being studied.
  - Ongoing research of suitable ceramic materials following preliminary spec. by RF experts (SiC is expected to be a good candidate)
- Thin metal foil on low conducting support – To be studied.
  - Preliminary RF studies show that no major difference exists between monolithic metal jaw and thin metal foil bonded on low conducting support. Possible advantages in terms of robustness.

*Assmann* proposed to complete the list of design options with the evaluation of time/cost necessary to develop each solutions.
Another important remark made by *Assmann* concerns the collimation efficiency: given the last tracking studies, the cleaning efficiency could be improved by including an additional collimator in the SC area. This scenario entails that medium density materials can be considered for the jaws instead of high density materials.
*Caspers* remarked that a diamond coating with high electrical conductivity (instead of a thin metal foil) could be evaluated.

*Bertarelli* described the cooling system focusing on the proposed design solutions:

- Machined circuit with brazed covers (Glidcop or Cu-Diamond) – studied.
  - High cooling capacity, relatively easy production.
  - Not in line with UHV recommendations → …(Remark: Plansee developed and qualified a very similar solution for ITER project in a similar environment).
- Continuous bent pipes back-casted in metal diamond – being studied.
  - Plansee available for co-development using Ta or Nb pipes in Cu-CD (investment required?).
  - EPFL also working on this option using Zr or Inox pipes in Al-CD
- Machined circuit sealed during casting – To be studied.
- Continuous bent pipes brazed to jaw cooler – Derived from Phase I solution.

*Bertarelli* showed some details of the phase II RF system: no sliding contact thanks to ferrite blocks "coupled" with a metallic rail.
In the last part of the talk *Bertarelli* described the solutions developed to embed BPMs into the jaws. *Assmann* remarked that also BLM should be evaluated and proposed to contact PSI people, already experienced with setting-up of collimators based on BLM.

*Bertarelli* concluded with a list of actions necessary to complete the conceptual development and start the engineering studies:

- Tracking studies followed by Fluka analyses for all possible scenarios (nominal and accident), designs and jaw materials.
- Decision on cooling circuit solution (involving AT-VAC and SC-RP).
- Validate BPMs baseline to go ahead with Jaw design. Evaluate BPM possibilities.
- Consolidate contacts with interested institutes (Kurchatov, BNL) for irradiation studies on advanced materials.

*Assmann* commented that is not possible, at the moment, to perform tracking studies with the new proposed materials (e.g. ceramics, thin foil…) in order to assess the energy deposition in nominal working conditions. The evaluation of different materials must be based on FLUKA analyses in case of accident scenario (asynchronous beam dump).
*Assmann* made an important remark: both accident scenarios must be considered (direct beam impact on TCSM and impact on TCP with shower on TCSM). Collimators must be robust enough so that, after a beam impact, the damage is limited to the jaw without putting into danger the neighboring machine elements and the vacuum system. This means that water leaks into vacuum are not acceptable as well as major damages to the vacuum tank. Also the actuation system must keep its functionality so that the collimator jaws can be completely opened after a beam accident.

# 3. AOB

Concerning the action list, *Izquierdo* reported about tests on Molybdenum plates and pipes: mechanical properties of material have been measured while some machining tests will follow; Mo pipes cannot be bent here at CERN. *Arnau Izquierdo* is also in

charge of providing a bent cooling circuit (Inox) for EPFL in order to make a back-casting test with Al-CD. *Bertarelli* proposed to make the same test also with Zr pipes and *Perret* commented that Zr pipes can be probably supplied by CERCA. *Izquierdo* commented that a mock-up of a back casted cooling system (Al-CD + Inox pipes will be available within the end of October). *Bertarelli* asked if it is possible to have a mock-up with Al-CD in the core and pure Al on the surface.
*Bertarelli* remarked that it is also important to prepare a mock-up of the cooling system with the other configuration: machined pipes + brazed / welded covers. This is important to make tests and to establish a procedure of validation of this design so that could be possibly accepted by vacuum experts.

# 4. Action list.

| ACTION | MANAGED BY | OPENED | CLOSED |
|---|---|---|---|
| Study the metallurgical compatibility of Materials for cooling system | G. Arnau | 3/07/2008 | Closed |
| Prepare a summary of design solutions. | A. Bertarelli<br>A. Dallocchio | 17/07/2008 | Closed |
| Tests on Mo plate and tube: machining, welding, bending dimensional stability after baking out. | G. Favre<br>G. Arnau | 19/06/2008 | In progress |
| Identify one or more ceramics with the following properties:<br>Resistivity :1-100 Ωm<br>Diel. Const: as low as possible (up to 5)<br>Loss factor: < 1E-2<br>Brazeability to metal support.<br>High density | G. Arnau | 19/06/2008 | In progress |
| Once ceramic identified do brazing and machining tests | G. Arnau<br>G. Favre | 19/06/2008 | Standby |
| Thermo-mechanical calculations using Cu-diamond and Al-diamond to confirm its interest | A. Bertarelli<br>A. Dallocchio | 3/07/2008 | In progress |
| Contact BNL for radiation tests | G. Arnau | 3/07/2008 | To be done |
| Verify with R. Assmann the collimation efficiency in case of ceramic jaws. | A. Dallocchio | 17/07/2008 | To be done |
| Contact CADFEM to fix a “bug” found in ANSYS WORKBENCH | A. Dallocchio<br>A. Bertarelli | 05/09/2008 | To be done |
| Prepare a document for PLANSEE including design specifications of the back-stiffener | A. Bertarelli | 05/09/2008 | In Progress |
| Follow the preparation of a mockup of the cooler (EPFL): Inox pipes back-casted in Al-CD | G. Arnau<br>Izquierdo | 05/09/2008 | In Progress |
| Purchase Zr pipes (8mm id 10mm od) and prepare a bent cooling circuit for EPFL | G. Arnau<br>Izquierdo | 19/092008 | To be done |

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| Prepare a prototype of cooler: machined pipes + brazed / welded cover. | Bouzoud<br>Perret | 19/09/2008 | To be done |
| Contact PSI and B. Dehning for integration of BLM | Dallocchio | 19/09/2008 | In Progress |
| Energy deposition studies (FLUKA analyses) for different materials and design (accident scenarios including direct impact on TCSM + impact on TCP and shower on TCSM):<br>– Back-casted pipes solution:<br>1. Mo support , Tantalum or Niobium pipes, Cu-CD jaw, 1mm Cu coating on jaw surface.<br>2. Mo support , Tantalum or Niobium pipes, Cu-CD jaw support, Ceramic tiles.<br>3. Mo support , Tantalum or Niobium pipes, Cu-CD jaw support, Ceramic tiles, thin Cu foil (30μm) bonded to the ceramic tiles<br>– Machined pipe + brazed / welded covers:<br>4. Mo support , Glicop cooler and jaw suppor, Ceramic tiles. | L. Lari<br>F. Cerutti | 19/09/2008 | To be done |