Alessandro Dallocchio 04-09-2008

LHC Collimation PHASE II
8th Design Meeting - 17/07/2008

Present: Gonzalo Arnau Izquierdo, Arnaud Pierre Bouzoud, Gilles Favre, Wilhelmus Vollenberg, Ivo Wevers, Samuli Heikkinen, Fritz Caspers, Alessandro Bertarelli (chairman), Alessandro Dallocchio (scientific secretary).

1. Outcome of the 8th Specification Meeting. (A. Bertarelli)

Bertarelli reported the main issue coming from the last specification meeting: in order to improve the cleaning efficiency of the LHC collimation system, it was proposed to add a "special collimator" in the dispersion suppressor. This "cryogenic collimator" should ideally intercept beam losses where Phase II collimators are not sufficient, but needs to be placed in a cold region and some magnets must be shifted.
The design of this device will not be assigned to TS.

2. Status of material tests. (G. Arnau Izquierdo)

Gonzalo presented some details of material tests: samples of Molybdenum plates and pipes have been purchased in order to test mechanical properties of the material and to verify the feasibility of a cooling circuit made up of bended Mo pipes. Preliminary results of degassing tests of Cu-diamond and Al-diamond confirmed that the UHV compatibility is respected (more details can be found in the presentation).

3. Follow up of design solution. (A. Bouzoud)

Arnaud showed the last version of the design: the layout of the BPM cables has been defined in order to have four cables of equal length connected to the buttons placed in the middle of each jaw and other four cables of equal length connected to the buttons at the extremities. Each button include a regulation system that allow a fine positioning of the sensor with respect to the jaw surface.
Another improvement concerns the ferrite blocks now placed directly on the movable jaws (see figure 1); ferrite blocks ensure the RF continuity thanks to the metallic rails placed on top and bottom part of the vacuum tank. This solution prevents from sliding contact between components as it was for the RF fingers of Phase I collimators.
Arnaud presented the last version of the jaw: metallic support with ceramic tiles (figure 1) as it was proposed during a previous brainstorming meeting (19-06-2008).

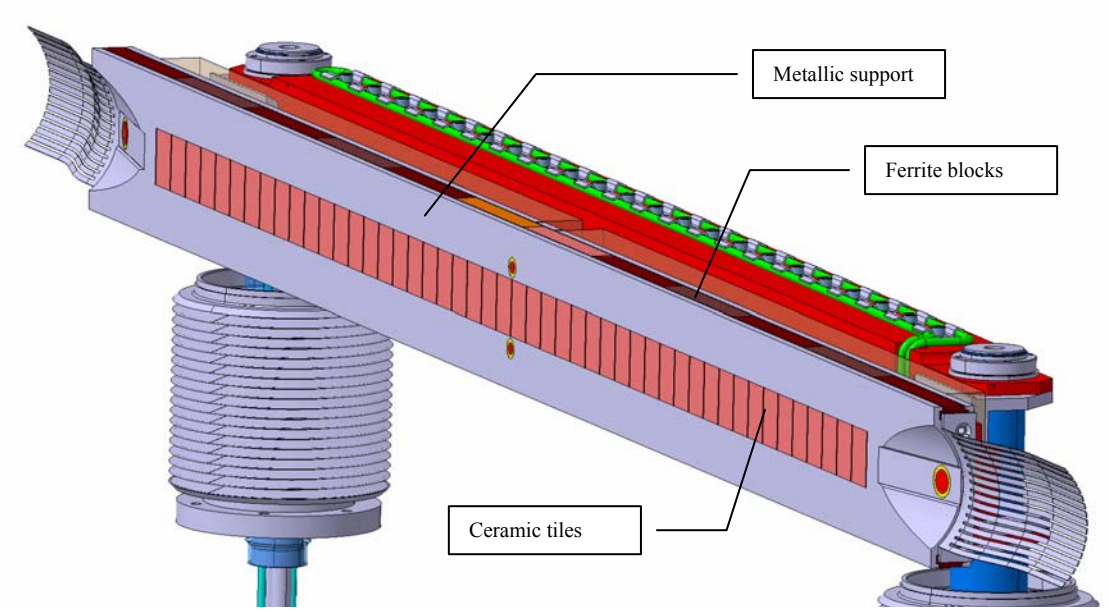

Figure 1: Collimator jaw made up ceramic tiles on metallic support. The jaw is equipped with BPM buttons and ferrite blocks.

4. AOB

Bertarelli showed some results of a structural calculation performed to assess the dimension of the grooves at the middle of the jaw (made to create a central flexible point where the adjustable screw is placed). Groove depth is 10mm and leads to a stiffness ratio 5÷6 between Mo back-stiffener and Cu-diamond jaw. A better performance, with a ratio ~10 is reached with a groove depth of 13mm. A definitive configuration will be found when thermo-mechanical analyses will be completed.
Caspers remarked the importance of a structural dynamic characterization of each material (in particular the structural damping): this is important in case of particle beam impact when the structure is possibly submitted to thermally induced vibrations.
Caspers proposed to evaluate another design solution for the collimator jaw: a thin metallic foil (20-50 μm) deposited on a support made up of low electrical conductivity material. This option could lead to high RF performances and needs to be studied.
Favre proposed to study a new design of the cooling system based on an upgraded version of the Phase I solution: bended pipes with external rectangular cross-section, brazed into longitudinal grooves (see figure 2).

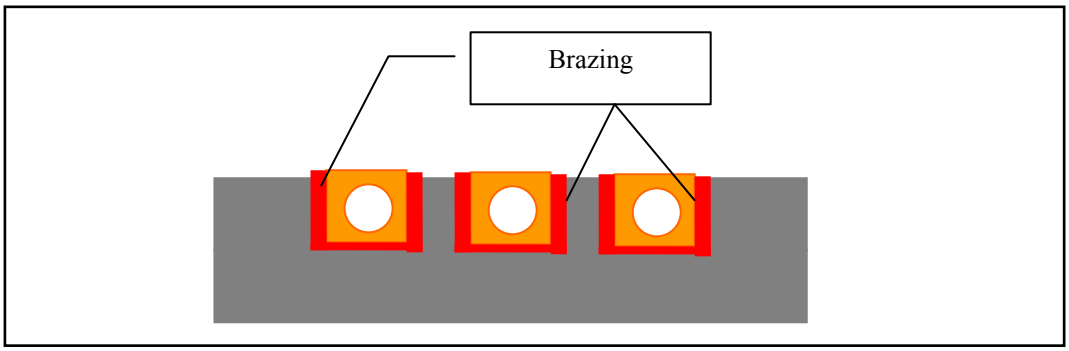

Figure 2: Scheme of a possible upgraded version of Phase I design of cooling pipes. Bended pipes with rectangular external cross-section brazed into longitudinal grooves. Red profiles represent the brazing region.

5. Action list

ACTION	MANAGED BY	OPENED	CLOSED
Verify potential problems relative to machining and brazing of Molybdenum	G. Favre	28/02/2008	In Progress
Verify the feasibility of the Molybdenum back stiffener (PLANSEE, PAM)	G. Arnau	24/04/2008	In Progress
Verify the feasibility of Molybdenum pipes (PLANSEE)	G. Arnau	24/04/2008	In Progress
Define specifications for metal-diamond samples to be used for RF tests	F. Caspers G. Izquierdo	24/04/2008	Standby
Supply of metal-diamond composite samples for UHV tests.	L. Weber	14/03/2008	closed
Validation of the metal-diamond materials to UHV requirements.	I. Wevers W. Vollenberg	14/03/2008	In Progress
Verify with R. Assmann the cleaning efficiency of a "comb" jaw.	A. Bertarelli A. Dallocchio	27/03/2008	Standby
Purchasing of Mo plate and Mo tube for tests	G. Arnau	19/06/2008	Closed
Tests on Mo plate and tube: machining, welding, bending dimensional stability after baking out.	G. Favre G. Arnau	19/06/2008	In Progress
Identify one or more ceramics with the following properties: Resistivity :1-100 Ωm Diel. Const: as low as possible (up to 5) Loss factor: < 1E-2 Brazability to metal support. High density	G. Arnau	19/06/2008	In progress
Once ceramic identified do brazing and machining tests	G. Arnau G. Favre	19/06/2008	Standby
Purchase of metal-diamond samples to do brazing tests and thick coating test	G. Arnau	19/06/2008	Standby
Mechanical calculations for: dimensioning the grooves dimension of the stud effect of gravity interest of locally doubling the rib plate	A. Bertarelli A. Dallocchio	3/07/2008	In progress
Thermo-mechanical calculations using Cu-diamond and Al-diamond to confirm its interest	A. Bertarelli A. Dallocchio	3/07/2008	Standby
Study the metallurgical compatibility of materials for cooling system	G. Arnau	3/07/2008	In progress
Contact Plansee and ARC for limitations of large size pieces of diamond composites	G. Arnau	3/07/2008	In progress
Contact BNL for radiation tests	G. Arnau	3/07/2008	
Prepare a summary of design solutions evaluated until now.	A. Bertarelli A. Dallocchio	17/07/2008	In progress

Verify with R. Assmann the collimation efficiency in case of ceramic jaws.	A. Dallocchio	17/07/2008	Standby

6. Outcome of material brainstorming meeting – 03/07/2008

Present: Said Atieh, Arnaud Pierre Bouzoud, Gilles Favre, Samuli Tapio Heikkinen, Wilhelmus Vollenberg, Ivo Wevers, Alessandro Bertarelli (chairman), Gonzalo Arnau Izquierdo (secretary)

Hors agenda:
Ludger Weber has excused his attendance and informs he will be absent till the 22nd of July. It is decided to propose a next meeting at EPFL or a visit to the laboratories if agreement from L.Weber.
Bertarelli informs that the job design has been extended until October; several solutions should be presented to the international review.

Follow up of design solutions

Bouzoud showed the follow up of design solutions.
Rib: the two long plates 15 mm thick are fixed with pins and screwed to the three transversal short plates (two spacers normal to the beam direction and one central supporting the adjustable system with the push/pull rod).
Bertarelli reports the results of a calculation based on the previous design version, the rigidity of the rib is a factor 5 to 6 that of the jaw which is considered not very satisfactory.
The adjustable system seats on a spherical support in the side of the rib.
In the jaw side it is fixed to a stud coming from one of the two half-jaws, the two half-jaws are fixed to a common jaw-base containing two grooves for reducing jaw stiffness. There is a concern about the stress level around the groves and in the stud possibly coming to plastic yield or creep, *Bertarelli* proposes to do a calculation for dimensioning the stud size and the depth of the grooves.
Favre suggests considering the possibility of doubling the long plate of the rib in given regions in order to increase its stiffness.
The central BPMs integrate elastic washers for positioning.
Ferrite plates 100 mm x 100 mm are clamped to top and bottom of the thank wall against back-plates of stainless steel. The clamps are made of bent CuBe sheet and large enough to cover the ferrite from the sight of the beam at the maximum aperture of the jaws. The possible need of transitions or contacts at the longitudinal extremities is to be studied.

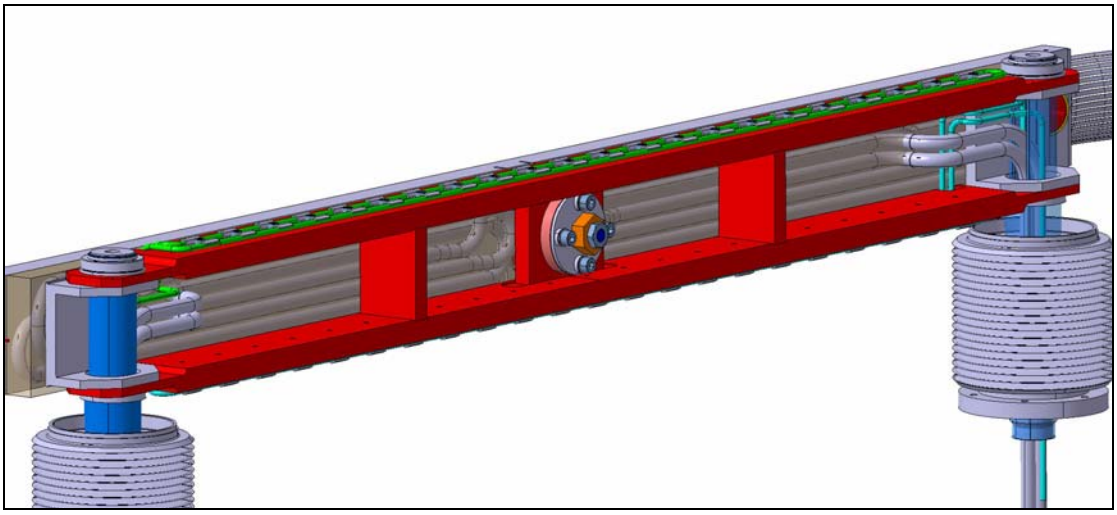

Figure 3: 3D view of the assembly of jaw and rib

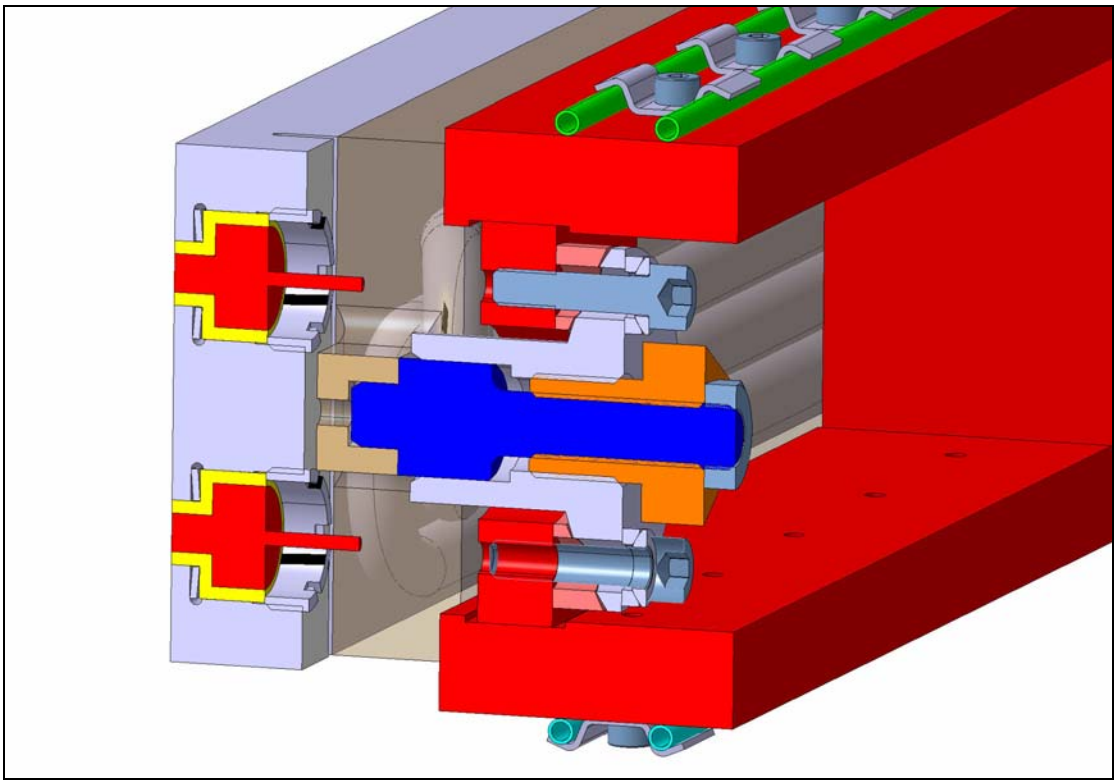

Figure 4: Cutaway of the adjustable system with spherical support in the jaw side and fixed to a stud of one of the cooling half-jaw (beige). Vertical groove in the jaw base for reducing the stiffness. Central BPMs integrating elastic washers for positioning.

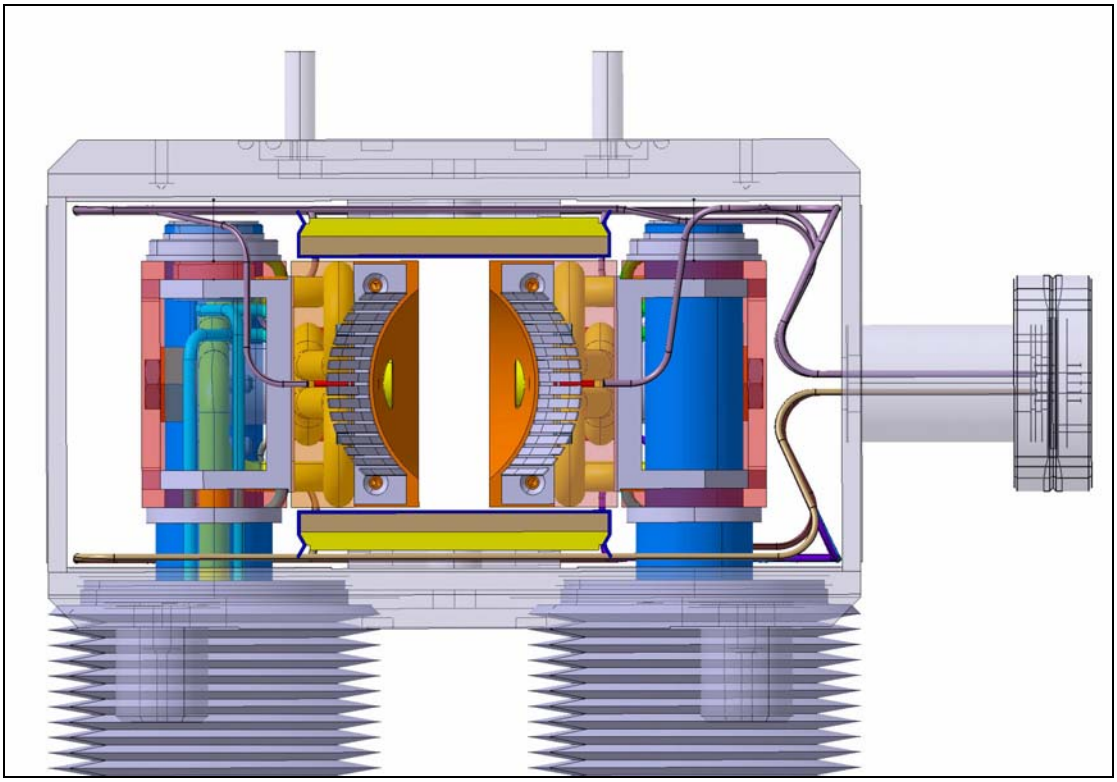

Figure 5: Face view of the tank with flange for cables on the right.

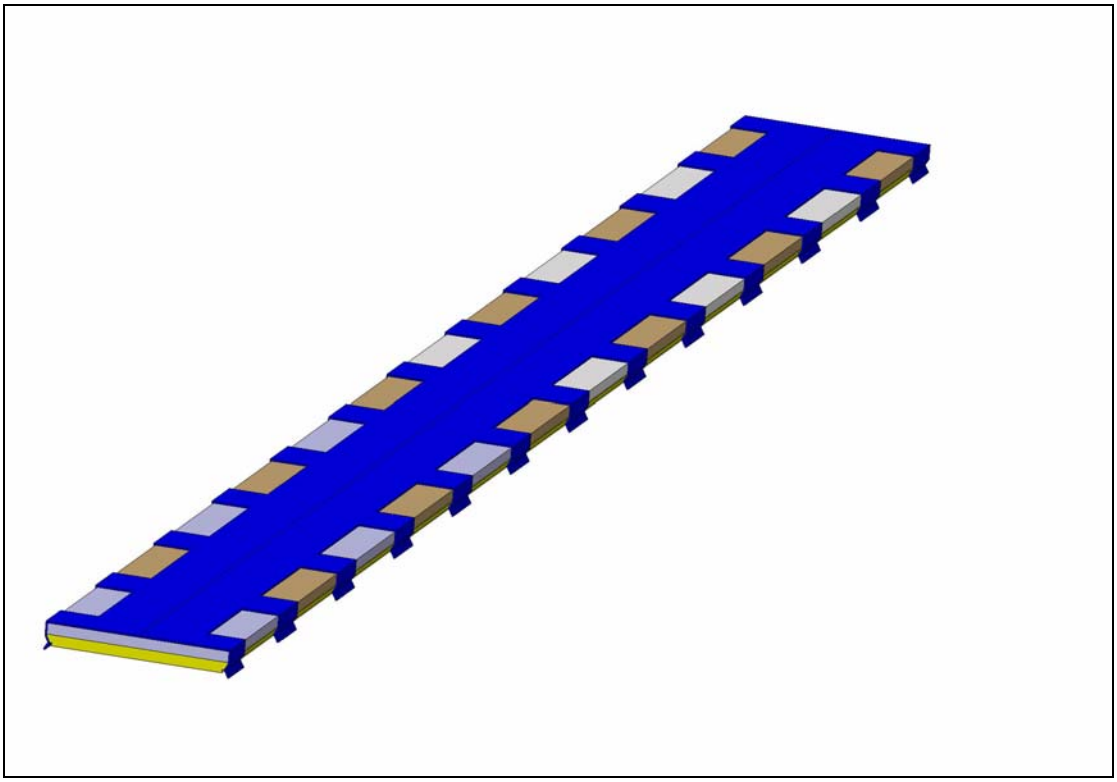

Figure 6: Assembly of ferrites (light blue and beige) hold with a CuBe clamp (blue).

Degassing tests

Wevers reports preliminary results of degassing tests made on ready-available samples of Cu-diamond (2E-12 torr l s^{-1} cm^{-2}) and Al-diamond (1E-11 torr l s^{-1} cm^{-2}) that are only two to three order of magnitude less good that metals commonly used in vacuum devices. A report will follow with detailed values, also tests on samples closer to the final manufacturing way and complementary tests for induced desorption are desirable, but those first results preliminarily indicate that materials are compatible with the use in ultra high vacuum environment.

Molybdenum material samples and tests

Arnau Izquierdo informs on the order of a plate 20x50x400 mm3 and about 2 m of tube OD10/ID8 for tests in the CERN workshops. *Favre* informs that machining, welding and pipe bending tests are foreseen.
Mechanical and metallographic characterization of raw material and welds are also foreseen.

Alternatives for the cooling circuit.

No new solution is proposed that complies with the requirement of no weld or brazed joint in the wall separating water and beam vacuum.
Concerning the embedded coil solution *Arnau Izquierdo* reminds the negative response of industry to produce the required coil because of the difficulty of the bending.
After some discussion on the limitations and interest of different combinations the grid shown in Fig. 5 is traced.

Figure 7: Table including different combination of materials for the cooling systems including fesibility and performances.

It is decided to perform deeper studies and trials for the higher score solutions:
Zr pipe in Al-diamond, inox pipe in Al-diamond, Mo pipe in Cu-diamond.
Those should include metallurgical compatibility and feasibility of the thigh bent coil.
The question is raised if Al-diamond can be brazed to copper or GlidCop, that may be necessary for solutions alternative to the embedded coil.

Thermo mechanical calculations to be done.

It was decided to perform mechanical calculations of relative rib/jaw stiffness and of stress in the midpoint of the jaw in order to determine depth of the grooves, size of the stud, effect of gravity, interest of locally doubling the rib plate.
It is important to do thermo-mechanical calculations in order to determine if the better performance expected from diamond composites may justify the difficulties of implementation and also if it is worth considering Al-diamond in spite of its low melting point and density.

Tests on Cu-diamond and Al-diamond.

Arnau Izquierdo proposes to, in collaboration with EPFL, contact back ARC and Plansee for defining the size limitations of diamond composites, and decide of trials to be done.
For the studies of irradiation damage *Bertarelli* suggest to contact the team from BNL that presented the talk in the Workshop of September 2007.

AOB

Atieh presented the software Granta CSE Selector for selection of materials associated to several databases. It will be available at CERN in some weeks.

7. Outcome of material brainstorming meeting – 19/06/2008

Present: Arnaud Pierre Bouzoud, Roger Perret, Fritz Caspers, Gilles Favre, Ivo Wevers, Gonzalo Arnau Izquierdo, Alessandro Dallocchio (chairman and scientific secretary).

Ceramics for the collimator jaw

Caspers explained that, due to the lack of manpower, it is not possible to organize at the moment a test campaign in order to assess RF performances of several ceramic materials. However, a list of properties useful to identify suitable materials was defined: resistivity (1-100 Ωm), dielectric constant (as low as possible, up to 5), loss factor ($< 1e^{-2}$), brazability to metal support, high density.
A possible design solution for a ceramic jaw was proposed: ceramic tiles (30x20 mm) spaced by a gap of 1 mm brazed over a metallic support.

Metal-Diamond

Wevers reported on the tests performed on Cu-diamond in order to assess its UHV behavior: positive results were obtained, Cu-Diamond is compliant with the UHV specifications required for CERN equipments. Al-Diamond will be also tested and a detailed report will be prepared. *Dallocchio* remarked that it is also important to perform test of brazability between metal-diamond and ceramics.

Follow-up of design solution

Bouzoud showed the new design of the back-stiffener: problems of assembling are solved thanks to a solution foreseeing 2 long plates with transversal ribs held together

by screws or weldings (instead of one-piece machined from a monolithic block of molybdenum).
Dallocchio proposed to buy samples of Mo plates in order to make tests of welding, machinability (milling, surface finishing, drilling…). *Gonzalo* remarked that it would be also necessary to perform tests of geometrical stability under thermal cycles as well as out-gassing tests after machining and welding.

8. Outcome of material brainstorming meeting – 02/06/2008

Present: Arnaud Pierre Bouzoud, Gilles Favre, Said Atieh, Wilhelmus Vollenberg, Gonzalo Arnau Izquierdo, Alessandro Bertarelli (chairman), Alessandro Dallocchio (scientific secretary).

Back stiffener

Perret raised an important remark concerning the design of the back stiffener: present configuration does not allow a correct assembly of the back stiffener and of the jaw + cooling circuit on the support shafts. The design of the Mo support should be changed. *Perret* proposed a different solution: instead of a one-piece stiffener machined from a monolithic bloc of Molybdenum, it is possible to use a beam made up of two long plates reinforced by transversal ribs. This option will be studied by *Bouzoud*.

Adjustable system

In order to improve the geometrical stability of the jaw assembly it was proposed to change the design of the control system at the middle of the jaw with the aim of reducing t the length of the adjustable screw; this should limit the thermal deformation of this component.
Present solution foresees that the adjustable screw acts directly on the jaw between the two cooling circuits; in a different way it is possible to link the back stiffener to one of the cooling circuits thanks to a stud with a needlepoint; the length of the screw can be appreciably reduced. This option will be studied by *Bouzoud.*

Cooling circuit

Bouzoud presented a new version of the embedded Mo pipes with larger bending radius, Gonzalo will submit the new design to PLANSEE in order to evaluate the feasibility of this solution.
Favre proposed to evaluate another solution for the cooling circuit based on the design of Phase I collimators. This option will be considered if the other solutions developed till now will not be successful.

9. Outcome of BPM integration brainstorming meeting – 15/05/2008

Present: Arnaud Pierre Bouzoud, Roger Perret, Marek Gasior, Rhodri Jones, Gilles Favre, Ahmed Cherif, Ivo Wevers, Wilhelmus Vollenberg, Gonzalo Arnau Izquierdo, Samuli Heikkinen, Fritz Caspers, Ralph Assmann, Alessandro Dallocchio (chairman and scientific secretary).

BPM buttons

Gasior and *Jones* proposed to increase the dimension of BPM buttons from 6 mm to 12 mm at least for those installed at the jaw extremities; in fact it is important that the BPM surface covers completely the particle beam. *Bouzoud* remarked that this change imply a modification of the tapering, moreover it will be possible to increase the BPM size only at the extremities of the jaw.
Caspers commented that minor changes to the surface of the tapering would not induce RF problems.
Jones explained that the two sensors at the middle of the jaw are necessarily coupled (the two buttons at the middle of each jaw work coupled by twos).

BPM cables

Jones shows a sample of BPM + co-axial cable. It is remarked that this type of cable behaves like a rigid pipe thus implying problems of positioning due to its high stiffness.
Gasior and *Jones* explained that the length of each cable must be precisely defined. Furthermore the cables of two buttons (one on each jaw) which are coupled, must have exactly the same length in order to obtain a correct signal. If it is not possible to use two equal cables, the difference can be electronically compensated (this solution could be difficult to realize and should be possibly avoided).
In conclusion, the preliminary configuration discussed during the meeting foresees a couple of BPM (one on each jaw) at the jaw extremities and two couples of BPM (two on each jaws) at the middle. The four buttons at the jaw extremities must have cables of the same length as well as the four BPM at the middle of each jaw.
Jones remarked that, being the cables connected to the movable jaws, a careful analysis of deformations and stresses must be done in order to assess possible problems, also a fatigue analysis must be performed.
Caspers proposed the use of flexible co-axial cables (ceramic pearl cables); this option will be considered if the standard BPM pipes cannot be used.
Perret raised a question concerning the electrical connections: there is no more space inside the plug-ins used for Phase I collimators. It was proposed to design dedicated flanges for the electrical connections of BPM.

AOB

Fritz proposed a modification to the design of RF contacts: the RF fingers at the extremities of the jaws remain the same while the RF rail can be replaced by a rail with ferrite blocks fixed on the tank or on the jaw assembly thus avoiding to have sliding part. This solution will be studied by *Bouzoud*.