LHC Collimation PHASE II
5th Design Meeting - 27/03/2008

Present: Gonzalo Arnau Izquierdo, Arnaud Pierre Bouzoud, Oliver Aberle, Samuli Tapio Heikkinen, Roger Perret, Ivo Wevers, Wihelmus Vollenberg, Elias Metral, Fritz Caspers, Alessandro Bertarelli (chairman), Alessandro Dallocchio (scientific secretary).

1. Phase II collimator design: RF issues (A. Bertarelli)

Bertarelli presented the current status of the design of Phase II collimators focusing on the concept of a back stiffener (C-shaped beam) that should ensure a good geometrical stability to the collimation jaw; presently two options are taken into account for the material of this component in order to match the RF specifications:

- Ceramics-made collimation jaw (high electrical resistivity)
- Metallic jaw (high electrical conductivity)

Bertarelli remarked that in both cases (conductive or insulating material) some RF issues need to be clarified in order to put forward the design of the jaw. Following questions were posed (more details can be found in the presentation):

1. Is it possible to choose between conductive and insulating materials? Which one gives better RF performance?
2. Requirements on electrical properties of conductive/insulating materials must be defined.
3. Should Electrical properties remain constant over the thickness of the jaw or is it possible to think about a thin (dimension must be specified) conductive/insulating layer bonded on a insulating/conductive support?
4. Geometrical requirements must be defined: jaw must be continuous? Adopting the solution of a jaw made up of tails, there are some restriction on the dimension of gaps between the tails?
5. Can Litz-wires actually improve RF performance? How they can be included in the collimator structure?

Bertarelli's presentation has been completed by a discussion where RF experts clarified some basic aspects relative to RF impedance.
First of all, *Metral* distinguished between coupled bunch instabilities (provoked by the impedance coming from a resistive wall placed near to the particle beam), and single bunch instabilities (usually related to abrupt discontinuities of the geometry of the beam pipe). As a general rule, geometrical discontinuities that could provoke local resonances should be avoided: smooth changes of cross-section, tapering…etc. must be used. Local resonances can be damped with ferrite components. In the LHC, single bunch instabilities are a minor problem with respect to the coupled bunch instabilities.
Metral remarked that LHC collimators, being the closest elements to the particle beam, have a strong resistive wall effect, therefore they give the largest contribution to the impedance of the machine and to the potential coupled bunch instabilities. Answering to the 1st question, Metral explained that, ideally, collimator jaws should

be made up of materials with infinite electrical conductivity (in order to cancel the resistive wall effect). In reality every material has a certain resistivity, thus the problem is more complex and, depending on the frequency of the beam, a conductive or insulating material should be used for the jaw in order to obtain better performances in terms of impedance. More details can be found in the next presentation.

2. EM Fields and Wake Forces of a Resistive Object (E. Metral)

Metral presented an analytical model for the calculation of transverse impedance for one graphite collimator (low resistivity $\rho=10^{-5}$ Ωm). The LHC works between 8 MHz and 2-3 GHz, in this range two different behaviors can be identified (more details on Metral's presentation):

- At high frequency the "classical thick wall" regime dominates; the impedance (both real and imaginary parts) decreases with the frequency and the slope of the curve depends on the resistivity of the material.
- At low frequency the "inductive bypass effect" dominates the real part of the impedance while the imaginary part presents a plateau whose value does not depend on the material.

Another important point is the strong dependency of the impedance on the "radius" ***b*** of the beam pipe (in this case ***b*** is the half gap between the collimator jaws): values of impedance dramatically decrease if ***b*** grows up. Concerning collimators it is clear that the gap between the jaw cannot be increased in order to reduce the effects of impedance.
Metral showed also how to calculate electromagnetic fields and wake forces close to the collimators r for perfect conductor and for resistive materials. Longitudinal (order of EM multipole m=0) and transverse (order of EM multipole m=1) case are considered.
Metral pointed out that the choice of the material for collimator jaws, in order to reduce the effects of impedance, strictly depends on the method will be used to stabilize the beam:

- Landau damping (octupoles): with this method it is important to decrease the imaginary part of the impedance (in order to reduce the real part of the tune shift). The imaginary part of transverse impedance given by collimators can be decreased by using high conductive materials (remark: in this way the Im part of the impedance goes down but the Re part grows up).
- Transverse feedback: with this method one should preferably decrease the real part of the impedance that means use an insulating material for the collimator jaw (Ceramics should be evaluated).

If we can rely on transverse feedback, the use of ceramics-made jaws could be useful.
First simulations (to be verified) show that high electrical resistivity (10^{16} Ωm) is necessary in order to obtain a low value of the real part of the impedance. *Caspers* remarked that such value of electrical resistivity requires a coating of Ruthenium oxide to be deposited on the jaw surface in order to compensate the effect of electrostatic charge.

The discussion focused on the solution proposed by *Caspers*: the use of Litz-wires with a "comb" configuration could artificially increase the collimator gap by forcing the image current to flow farer from the center of the beam.
Some details about the design of a potential "comb" jaw have been discussed:

- Good electrical conductor should be used (GLIDCOP)
- The length of the fingers of the comb should be established as a good compromise between the need of taking the image current far from the beam (long fingers) and the necessity of avoid resonances (*Caspers* explained that with 20mm fingers there is a resonances at 2-3 GHz). A good length of the fingers has been roughly estimated as 10mm.
- Maximum equivalent diameter of the fingers 5mm
- Gap between the fingers: ~2mm

In conclusion: more calculations will be done by *Metral* and *Caspers* in order to confirm the results obtained with ceramic materials.
Some tests are also foreseen to evaluate the performances of ceramic materials and "comb" jaws.
Metral remarked that the solution of a monolithic jaw with high conductive material cannot be abandoned: in fact, if it will be demonstrated that transverse feedback cannot be used to stabilize the beam, then Landau octupoles will be necessary and high conductive metallic jaws should be used.
The remaining questions posed by *Bertarelli* during his presentation will be examined by *Metral* and *Caspers* and will be discussed in the next CDM2.

3. Action list

- Provide to E. Metral properties of ceramics that can be potentially used
  (G. Izquierdo)

- Verify the feasibility of a "comb" jaw using GLIDCOP.
  (R. Perret)

- Verify with R. Assmann the cleaning efficiency of a "comb" jaw.
  (A. Bertarelli)

Next Phase II Design meeting will be on April 10th, 2008.
Room 376-1-016