2^{nd} Phase 2 Specification and Implementation Meeting

Present: O. Aberle, R. Assmann (chairman), G. Bellodi, A. Bertarelli, C. Bracco, M. Brugger, F. Caspers, F. Cerutti, A. Dallocchio, K. Kershaw, M. Mauri, A. Masi, E. Metral, L. Lari (scientific secretary), V. Previtali (scientific secretary), S. Redaelli, S. Roesler, L. Sarchiapone, W. Scandale, P. Strubin

Via telephone: E. Doyle, L. Keller, S. Lundgren, T. Markiewicz, J. Smith

1 Comments on the minutes of the last meeting

There were no comments.

2 General Information - R. Assmann

R. Assmann announced that a vacuum expert from AT/VAC will be participating regularly to the meeting.
R. Assmann mentioned that there will be a regular report from the LARP (LHC Accelerator Research Program) activities in the US in this meeting. The talks at CERN will also be linked at the SLAC web site for LARP.

3 Cleaning Efficiency - C. Bracco

C. Bracco presented the collimation system cleaning efficiency.
First presenting the status for phase 1, she showed that the predicted collimation performance reach for the "perfect" machine is $\sim 53\%$ of the nominal intensity considering the horizontal halo, and $\sim 38\%$ for the vertical halo. This assumes the published quench limits and the specified beam loss rates during LHC operation.
Further simulations were performed including imperfections of the machine (deformation and set-up errors of the jaws, mis-alignment of aperture and realistic orbit). The results indicate a factor 10 loss in efficiency due to the imperfections. Most severe is the misalignment of the aperture.

C. Bracco then reported on first phase 2 studies. Considering metallic jaw material (copper) for secondary collimators, C. Bracco showed that the performance reach in intensity would increase by about 50%. Almost 98%

of the particles lost in the cold aperture come directly from primaries collimators, where they experienced single diffractive scattering. This limits the achievable improvement with secondary collimators. This confirms the decision of the previous meeting to consider all possible solutions for a collimation upgrade (in addition to secondary collimators: higher efficiency primary collimators, magnetic collimators, cryogenic collimators, electron lens, crystals).

The goal to improve efficiency by a factor 10 in the collimation phase 2 upgrade was confirmed.

4 Impedance Constraints - E. Metral

E. Metral presented a review of impedance studies for collimators. A recent review of measurements was reported in the collimation working group (see link). After presenting theoretical expectations for LHC impedance, he showed the dependence of the imaginary and real part of the tune shift on the resistivity and the half gap of the collimator. E. Metral also presented results on possible beam stabilization with the transverse feedback, pointing out that further understanding is needed but hope exists.

E. Metral summarized the main input from impedance for design choices as follows:

- Opening the collimator gaps will always reduce both real and imaginary parts of the impedance.
- In case of using the octupoles to stabilize the beam with Landau damping, the imaginary part of impedance needs to be reduced, realistically by using good conductive materials.
- If the beam is stabilized with the transverse feedback, it is beneficial to reduce the real part of the impedance, for example by using a non-conductive jaw material, maybe even insulators. This is against the naive expectation.

F. Caspers pointed out that the problem must be reduced as much as possible at the source: if we would not succeed to damp the real part of the impedance with the feedback, the beam would blow up independent of the imaginary impedance.
R. Assmann asked if it is possible to reduce both imaginary and real parts of impedance without increasing the gaps. F. Caspers replied that in principle it is possible to reduce both, and he suggested to consider more “advanced”

materials like, for example, Litz-wires or ceramic materials. He identified additional information that is all placed on the web site of this meeting.
E. Metral asked to invite W. Hofle as expert of the transverse feedback system for future investigations.
S. Redaelli asked if it's possible to increase the contribution of the octupoles.
E. Metral did not think that much can be gained realistically.
R. Assmann commented that the increase of the imaginary part of the tune shift from better conducting materials is not very strong, i.e. about 20% for Cu, while the real part of the tune shift is reduced by more than a factor of two. The use of Cu for phase 2 (like pursued at SLAC) is therefore a promising path while not solving all issues. E. Metral agreed.

5 News on General Material Investigations - F. Caspers

F. Caspers reported on various paths of investigation he has been following:

- Litz wires: F. Caspers has been ordering samples of this material for tests. Litz wires are resembling a brush (conductance in the back with transverse wires to the front) and are molten into a glass-like material. They are used for ovens and might provide an elegant way to reduce impedance. It was agreed that a sample would also been given to N. Hilleret for outgassing tests. This concept resembles a photonic band gap structure.

- ITER research: Information on material reserach at ITER has been obtained from V. Barabash at ITER (see files 1, 2 at web site). The material will be reviewed and it was decided to invite V. Barabash to CERN.

6 Energy Deposition Constraints - F. Cerutti

F. Cerutti illustrated the physical quantities connected to the energy deposition evaluation.

- Radiation length: This is a measure of the penetration of the electro magnetic shower into the material. Its main dependencies are on the atomic number Z and the density ρ. It would be better to have a long radiation length in order to avoid a high localized energy deposition (low Z materials).

- Inelastic scattering length: This is a measure of probability of inelastic scattering in the material. Its main dependency is on the density. F.

Cerutti suggested that a short inelastic length increases the cleaning effect.
R. Assmann commented that in order to evaluate the cleaning efficiency, one has to take into account the multi-turn effect. In addition, a long inelastic scattering length helps to reduce single diffraction events in the primary collimators which is presently limiting the system performance.

- Moliere radius: This is a measure of the transverse dimension of the electro-magnetic shower. The dependence is on the density. A large Moliere radius is desirable (low density materials).

- Multiple Coulomb Scattering (MCS) angle: This is related to the angular distribution of primary particles after elastic scattering events. A high MCS angle is desirable (high Z material).

These different parameters require a careful trade-off as they are partly conflicting. On the basis of these evaluations, F. Cerutti showed the energy deposition (per mass unit) along the length of a collimator jaw for different collimator materials. The energy deposition depends strongly on the atomic number and on the density of the material. In particular the peak position of the energy density depends on the radiation length and λ. For low Z-density materials the peak is not reached within the length of a jaw. The shape of the impacting beam halo plays a major role in the energy deposition profile: the value of the peak itself depends strongly on it.
F. Cerutti concluded his presentation suggesting it should be investigated to use different Z materials at different positions in the collimation layout. In addition, a longitudinal multi-layer collimator might be an option worth to be investigated.
F. Caspers asked if the consequences of the shock waves were evaluated. R. Assmann replied that this argument will be studied in detail during the Phase 2 Design meetings and reported to the specification meeting. A. Bertarelli, chairman of Phase 2 Design meeting, confirmed.

7 Ion Collimation Constraints - G. Bellodi

G. Bellodi explained that the two stage collimation does not work as foreseen for the ions, because ions are affected by fragmentation and dissociation mostly in the primary collimators. These fragments do not receive a large transverse deflection while acting as strongly off-momentum ions. They do

then bypass all secondary collimators and absorbers in LSS7 and get lost in the first high disperion pointy in the downstream super-conducting arc.

G. Bellodi underlined the necessity to investigate other ideas to increase transverse deflection while avoiding fragmentation and dissociation. In particular she gave an overview on the possible solutions:

- High Z scrapers in high beta locations like at the triplets. This is not a good location for cleaning.

- Magnetic collimators which deflect particles with magnetic fields. F. Caspers commented that the such a magnetic collimator would probably be made out of permanent magnets which could loose their magnetization due to the higher temperatures in a collimator jaw. G. Bellodi replied that, given the lower intensity of the ions beam, this should not be a problem. R. Assmann added that simulations and magnetic field calculations could be necessary in the surface region of the jaws. F. Casper asked the order of magnitude of the magnetic field and A. Bertarelli asked its transverse dimension. G. Bellodi replied that the magnetic field should be around 0.2 T and have a transverse dimension of $\sim 100\mu m$. E. Metral agreed to calculate the magnetic fields at the jaw surface induced by the circulating beam.

- Electron lens. The solution of a hollow electron lens is potentially interesting, because it does not involve ion-matter interaction, no mechanical systems are involved and a fast cleaning time can be achieved. This is a "clean" method and easy to switch on and off. A non-hollow electron lens has already been tested and is now used operationally for abort gap cleaning at the TEVATRON. R. Assmann commented that the collimation team is in contact with V. Shiltsev (FNAL) in order to investigate the feasibility of using a hollow electron lens for scraping the LHC beam, both for protons and ions.

- Crystal collimation is another interesting option. The feasibility is being investigated in several ongoing experiments. In particular it is crucial to understand fragmentation and dissociation of ions in crystals.

A. Bertarelli asked if high Z materials are a good choice for the ion cleaning. G. Bellodi replied that high Z is preferred. R. Assmann underlined that the problems of radioactivity have to be evaluated.

8 AOB

S. Roesler and A. Bertarelli agreed to present their talks at the next meeting. The talk about "Materials used for bent crystals" by W. Scandale was deferred by 1 month.

9 Next Meeting

Next meeting will be held on Friday 22th February 2008.

Preliminary agenda:

- Minutes of previous meeting
- J. Smith: Update from SLAC/LARP work.
- S. Roesler: Radiation constraints.
- A. Bertarelli: Present candidate materials for phase 2 collimators.
- AOB