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Input on LHC collimation from the BI review

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The BI review took place on November 19 and 20, 2001. The collimation system was included into the review and was presented by talks from J.B. Jeanneret, G. Burtin, and R. Aßmann. This note summarizes some conclusions from this meeting and the following discussions.

<u>Presentations on the LHC collimation system</u>

We first list design options and issues which were not questioned, even if their presentation generated discussions.

- The need of two collimation insertions, one for betatron and one for momentum collimation. At RHIC the lack of momentum collimation has a negative impact on performance.
- The need of a two-stage system and its associated optics concepts.
- Efficiency versus quench prevention.
- Geometrical and mechanical parameters and their associated specifications, which were shown to match existing technology (leaving apart thermal and cooling issues). It was nevertheless emphasized that the primary/secondary retraction (n_1/n_2) shall be increased as much as possible, in order to reduce the sensitivity to beam errors (transient CO and beta-beating,…). This might imply a change of collimator location (the optimum phase advance depend on n_1/n_2). Otherwise preliminary robustness studies raised no fundamental objections.
- Quantitative radiation results for the present collimation system were not questioned.
- The presentations about destructive events (bad injections, dump erratic triggers) together with quantitative destruction limits were not questioned, but raised a robust debate. This most likely because these issues were raised openly only recently, such that no precise worked-out solutions exists as of today.

Now follows a list of open problems or issues which were raised either by the speakers or by the audience.

1. An **asynchronous self-trigger of one dump kicker module** would likely lead to severe damage of the collimation system with subsequent shutdown for repair. The estimation for such a failure is about once per year (it occurs about once a month at RHIC).
2. The collimation system is presently not protected against an **injection oscillation** of 4-5 σ amplitude that will lead to severe damage of the collimation system (for injection of more than 10 bunches or so) and subsequent repair shutdown. This is particularly dangerous because the transfer line will be operated in pulsed mode. It is under discussion to install collimators at the end of the transfer line to protect the collimators and other elements against such oscillations.
3. The impact of a **pilot bunch** on a collimator at 7 TeV will lead to some damage of the collimation system.
4. It is not evident that losses at 7 TeV can be kept below the collimator damage threshold of **$1.7\cdot10^{-5}$ of nominal intensity** (over ~10 turns) at all times. Questions here center on:
   - the population of the ***beam halo***,
   - beam losses during ***magnet trips***,
   - and the beam that escapes into the ***abort gap***.
5. It is not evident that losses at 450 GeV can be kept below the collimator damage threshold of **$2\cdot10^{-3}$ of nominal intensity** (over ~10 turns) at all times. Questions here center on:
   - beam losses during the ***start of the ramp*** (snap-back, beta-beating, emittance variation).
   - orbit changes during the ***ramp***.
   - perturbation of the circulating beam due to ***injection***.

6. The collimation system was designed for a "nominal" **beam lifetime** of 40 h. However, the collimation system must be operated for lower beam lifetimes (no damage/no spurious quenches). The consequences of lower beam lifetime are:
   - ***More particles*** impacting on the collimators.
   - ***More collimator heating*** than planned for (e.g. 6 kW at τ=4h instead of 600W at τ=40h).
   - More stringent requirements on ***cleaning efficiency*** (the margin factor will be reduced by a factor 10 for τ=4 h, i.e. from 60 down to 6).
7. The **deterioration of cleaning efficiency** was quantified for several imperfections:
   - The inefficiency doubles for a 10% ***transient beta beating***.
   - The inefficiency triples for a 150 μrad rms ***angle between beam and collimator*** jaw surface.
   - The inefficiency increases 20-fold for a ***reduction of the active length*** of secondary jaws from 50 cm to 10 cm (e.g. due to surface damage like observed at the HERA collimators).

   This list will be completed in the next weeks.
8. It was commented that the present estimates on **heating and damage** might be too optimistic compared to a full calculation, including stress limits and shock waves.
9. **Operational strategies** of collimation during injection, ramp, squeeze, and physics were already discussed, but need to be defined in detail.
10. The **compatibility** of the collimation requirements with other instrumentation and proposed measurements needs to be considered (e.g. kick measurements with several σ at 7 TeV).

<u>Preliminary conclusions on the LHC collimation system</u>

There was a general agreement that the present collimation system **does not correspond to all requirements** for operating the LHC with nominal parameters and realistic perturbations (e.g. poor lifetime at top energy).

A more robust collimation system would be required, that can **withstand the particle losses from known failure modes**, e.g. the asynchronous beam dumps.

The collimation system must be able to withstand **operating at low beam lifetimes**; e.g. beam dumps if the lifetime drops below 40 hours are not acceptable.

The systems should be designed to avoid frequent replacements of the collimator jaws, to limit **downtime** and **exposure of personnel to radiation**.

It was concluded that there is a **risk of cost over-run** for the collimation system, in view of the required changes. Innovative solutions must be considered to avoid this to the extent possible.

<u>Consequences for our work</u>

The work on an improved collimation system will be **centered around the LHC Beam Cleaning Study Group**, with a possible progress review in March 2002. The work in the **LHC Beam Cleaning Study Group** is done in collaboration with the Machine Protection WG, to avoid overlap / missing out important issues.

The **deadline to propose an improved cleaning system is about a year** and we will have to demonstrate the progress of our work towards this deadline.

We will **build on the expertise and the tools** developed for the design and study of the present LHC collimation system. However, more tools (e.g. detailed damage studies) are required and a fast turnaround for studies (~ weeks) is mandatory.

The present design of the collimation system provides the starting point, but we will have to **reconsider all design choices** and we must be open to **major changes** (for example low-Z jaw materials with a length of 1-2 meters, instead of 0.2-0.5 m long objects).

We will try to **identify and include all available expertise in- and outside of CERN** (experience in target design, absorber design, material science, particle-matter interaction, …).

Follow-up items

Some issues that were mentioned or discussed at the BI review will require follow-up within the Beam Cleaning Study Group:

1. Use of **quadrupolar BPM's** for fast online monitoring of the beam emittance and the beta beat, to allow collimation control during machine operation. Four BPM's are required to get both emittance and beta beat.
2. The definition of relevant time-scales for collimator damage (1 or 10 or 100 turns?) require detailed calculations of the **heat flow and cooling** in the collimator jaw.
3. Any change of the collimation design (more/less material) might have impact on the **radiation issues** in the collimation region. This will require close collaboration with the radiation protection group.
4. Useful **diagnostics in the collimation region** should be identified. Possible solutions include temperature sensors in the collimator jaws and measurements of the deposited charge.

Detailed work plan

A detailed work plan was discussed in a meeting of the Beam Cleaning Study Group. It is available on the web (http://www.cern.ch/lhc-collimation).