# 5th Meeting of the LHC Beam Cleaning Study Group 28.11.2001

Present: *R. Assmann (chairman), M. Brugger, H. Burkhardt, G. Burtin, B. Dehning, C. Fischer, M. Hayes, J.B. Jeanneret, R. Jung, V. Kain, M. Lamont, R. Schmidt,*

## 1) New member

R. Assmann introduced Markus Brugger from the radiation group (TIS/RP) as a new member of the LHC beam cleaning study group. Markus will do his PhD on the radiation issues in the cleaning insertions. He will be a much welcome help to our work.

## 2) Discussion of the input from the BI review (all)

The presentations on the LHC collimation system at the BI review are linked from our web page. The group discussed the input from the BI review, based on a draft from R. Assmann. There were many useful comments and additions. Everybody agreed on the conclusion that an improved LHC collimation system should be designed over the next one year. A common summary by R. Assmann and J.B. Jeanneret, including all comments, is appended in the minutes and available on our web page.

## 3) Discussion of a work plan (all)

The deadline for a final LHC collimation system is about one year (November 2002). This was stated at the BI review, amongst others based on requirements for the INB formalities. R. Jung commented that this deadline is already incompatible with a collimation system installed for operation in 2006. In view of the required changes and the short timeline, R. Assmann put together a possible work plan. This work plan would allow keeping the deadline, specifying a number of tasks with approximate deadlines and resources.

The work plan was discussed and many useful changes and additions were suggested. The present work plan is appended in the minutes and available from our web page. It is noted that not all tasks listed in the plan are done in the LHC Beam Cleaning Study Groups. Several tasks will be performed in other working groups or specific CERN groups. The plan will also evolve with our work.

In particular it was agreed to have a CERN wide meeting on beam absorbers and collimators on January 25th. The announcement is included in the minutes and available from our web page. The LHC Beam Cleaning Study Group will participate and specify the collimator requirements for this meeting, based on accelerator physics and operational scenarios.

## 4) Next meeting

Next meeting will take place 10h30 December 12th, 2001. B. 112, 4C17.

Geneva, 6 December, 2001

# Input on LHC collimation from the BI review

*R. Aßmann and J.B. Jeanneret*

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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.

Presentations on the LHC collimation system

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 $\sigma$ 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 **$1.7 \cdot 10^{-5}$ 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 **$2 \cdot 10^{-3}$ 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 $\tau$=4h instead of 600W at $\tau$=40h).
   - More stringent requirements on ***cleaning efficiency*** (the margin factor will be reduced by a factor 10 for $\tau$=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 $\sigma$ at 7 TeV).

Preliminary conclusions on the LHC collimation system

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.

Consequences for our work

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

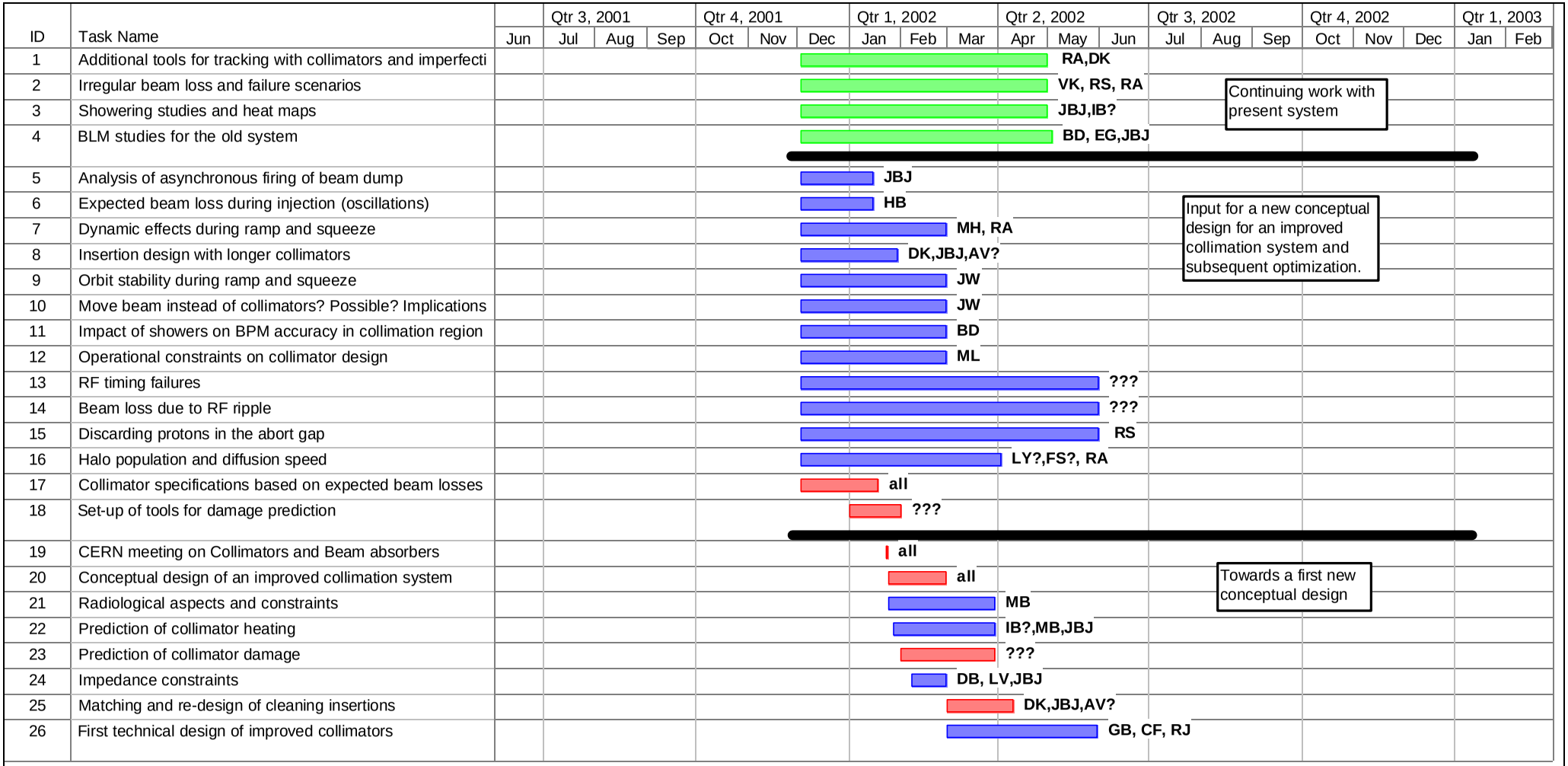
Some issues that were mentioned or discussed at the BI review will require follow-up within the Beam Cleaning Study Group:

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).

| ID | Task Name |
|---|---|
| 1 | Additional tools for tracking with collimators and imperfecti |
| 2 | Irregular beam loss and failure scenarios |
| 3 | Showering studies and heat maps |
| 4 | BLM studies for the old system |
| 5 | Analysis of asynchronous firing of beam dump |
| 6 | Expected beam loss during injection (oscillations) |
| 7 | Dynamic effects during ramp and squeeze |
| 8 | Insertion design with longer collimators |
| 9 | Orbit stability during ramp and squeeze |
| 10 | Move beam instead of collimators? Possible? Implications |
| 11 | Impact of showers on BPM accuracy in collimation region |
| 12 | Operational constraints on collimator design |
| 13 | RF timing failures |
| 14 | Beam loss due to RF ripple |
| 15 | Discarding protons in the abort gap |
| 16 | Halo population and diffusion speed |
| 17 | Collimator specifications based on expected beam losses |
| 18 | Set-up of tools for damage prediction |
| 19 | CERN meeting on Collimators and Beam absorbers |
| 20 | Conceptual design of an improved collimation system |
| 21 | Radiological aspects and constraints |
| 22 | Prediction of collimator heating |
| 23 | Prediction of collimator damage |
| 24 | Impedance constraints |
| 25 | Matching and re-design of cleaning insertions |
| 26 | First technical design of improved collimators |

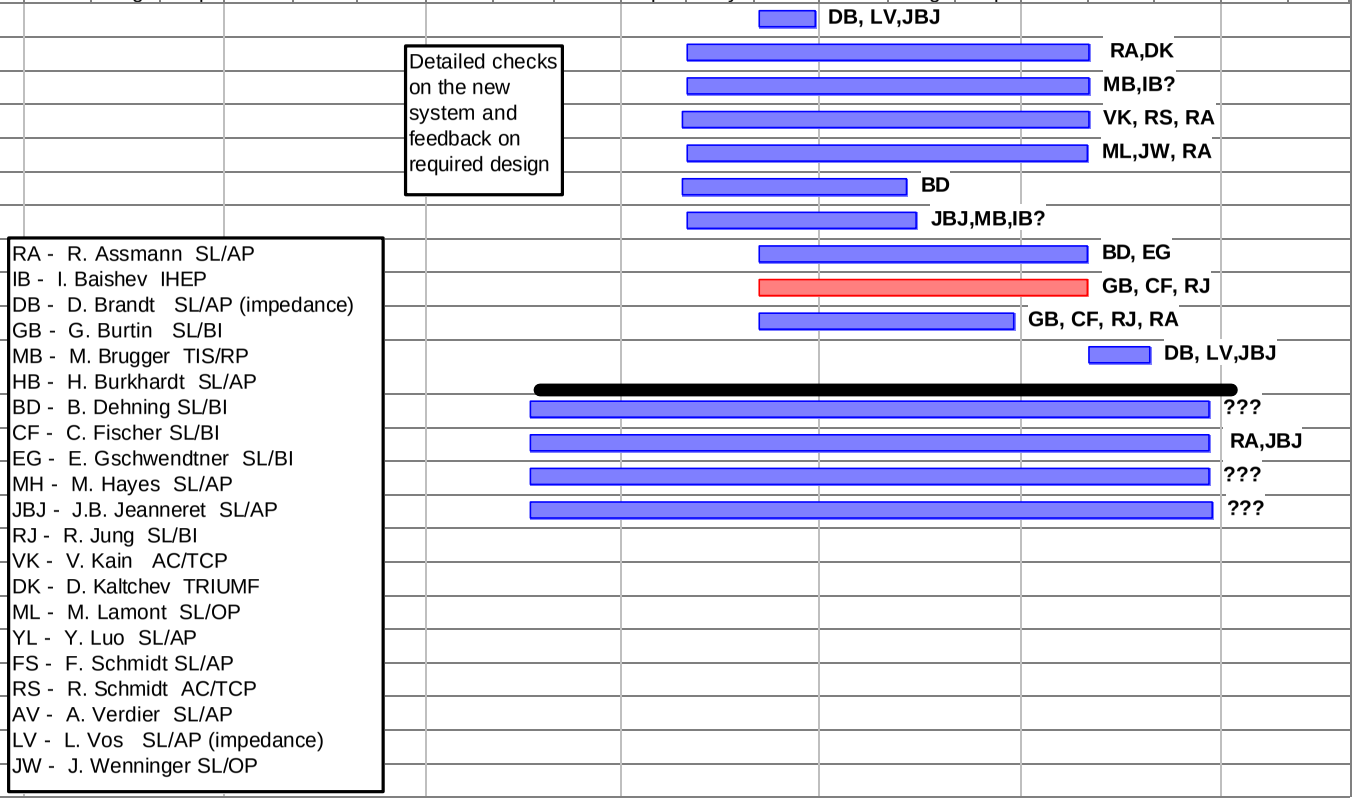



Project: bcsg2
Date: Thu 12/6/01

| | | |
|---|---|---|
| Task | Rolled Up Task | External Tasks |
| Progress | Rolled Up Milestone | Project Summary |
| Milestone | Rolled Up Progress | Group By Summary |
| Summary | Split | |

| ID | Task Name |
|---|---|
| 27 | Impedance review |
| 28 | Cleaning efficiency for the new system |
| 29 | Detailed prediction of activation in cleaning insertions |
| 30 | Response of new collimation to irregular beam loss and fai |
| 31 | Operation with the new system |
| 32 | Use of quadrupolar BPM's |
| 33 | Showering in the new collimator system |
| 34 | Beam loss monitor signals |
| 35 | Detailed design of collimators (incl feedback from detailed |
| 36 | Experimental tests of collimator design |
| 37 | Impedance review |
| 38 | Use of crystals |
| 39 | Machine experiments |
| 40 | Catastrophic beam loss scenario |
| 41 | Measure tertiary halo in collimation section directly |

Qtr 3, 2001: Jun | Jul | Aug | Sep
Qtr 4, 2001: Oct | Nov | Dec
Qtr 1, 2002: Jan | Feb | Mar
Qtr 2, 2002: Apr | May | Jun
Qtr 3, 2002: Jul | Aug | Sep
Qtr 4, 2002: Oct | Nov | Dec
Qtr 1, 2003: Jan | Feb




RA - R. Assmann SL/AP
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DB - D. Brandt SL/AP (impedance)
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MB - M. Brugger TIS/RP
HB - H. Burkhardt SL/AP
BD - B. Dehning SL/BI
CF - C. Fischer SL/BI
EG - E. Gschwendtner SL/BI
MH - M. Hayes SL/AP
JBJ - J.B. Jeanneret SL/AP
RJ - R. Jung SL/BI
VK - V. Kain AC/TCP
DK - D. Kaltchev TRIUMF
ML - M. Lamont SL/OP
YL - Y. Luo SL/AP
FS - F. Schmidt SL/AP
RS - R. Schmidt AC/TCP
AV - A. Verdier SL/AP
LV - L. Vos SL/AP (impedance)
JW - J. Wenninger SL/OP

Project: bcsg2
Date: Thu 12/6/01

Task | Progress | Milestone | Summary
Rolled Up Task | Rolled Up Milestone | Rolled Up Progress | Split
External Tasks | Project Summary | Group By Summary

Geneva, 6 December, 2001

## CERN Meeting on Collimators and Absorbers for the LHC Beam

The LHC collimation system is designed to passively protect the cold aperture in the LHC against energy deposition from direct particle impacts. Protons will be lost at the aperture limitation due to regular processes (diffusion, beam halo) and irregular events (failures). The high power of the LHC beams imposes many challenges for the design of the LHC collimation system.

In the recent LHC beam instrumentation review there was a general agreement that the robustness of the present collimation system should be improved in order to withstand the expected particle losses from known failure modes, e.g. asynchronous LHC beam dumps, and other failures.

At CERN, a large expertise in the field of "targets", "absorbers" and "collimators" exists. The aim of the meeting is to confront experts in the field of "targets" and "absorbers" with the specifications for the LHC collimators that are derived from accelerator physics and operation.

We therefore propose to address the following questions in a one-day meeting:

- What collimators / beam absorbers can stand the impact of part of LHC beam in case of equipment failure?

- What collimators can stand the heating by continuous loss of particles? What are the consequences for the beam intensities and lifetime?

**Proposed date and time:** Friday 25th January 2002, 9h-18h

**Location:** B. 40, R. 5-A01


**Organization:**

| | |
|---|---|
| R. Aßmann | Ralph.Assmann@cern.ch |
| C. Fischer | Claude.Fischer@cern.ch |
| J.B. Jeanneret | Bernard.Jeanneret@cern.ch |
| R. Schmidt | Rudiger.Schmidt@cern.ch |


**More on the LHC collimation system:** http://www.cern.ch/lhc-collimation

The participation is limited to 45 persons. Please send any requests and proposals to the organizers. In particular we would welcome:

- Proposals for short talks (10-20 min).
- Proposals for discussion topics.
- Proposals for other experts to be involved

Please see the preliminary lists of discussion topics and distribution below.

**Topics to be discussed:**

Specifications

- Specifications for primary collimators
- Specifications for secondary collimators (could be different from primary collimators)
- Overview on irregular beam loss at the collimators (failure scenarios)
- How many collimators are critical? All? or only a subset?

What materials should be used for the jaws?

- Mechanical properties
- Thermal properties
- Nuclear properties

What geometry should be used for the jaws?

- Shape
- Rectangular blocks, other shapes, is a Sandwich structure advisable and possible?

Cooling of the collimator jaws

- Active cooling
- Passive cooling

Radiological aspects for collimators

- Doses at the collimators
- Induced activity

Tools for studies of collimator design

- Nuclear cascade codes
- Codes for the calculation of mechanical stresses
- Codes for the calculation of thermal effects

What has been done / is being done at CERN outside the LHC collimation studies?

- Other absorbers for the LHC (TDI, absorbers in the dump area)
- Targets for other existing / planned machines (SPS beam dump, Neutrino Grand Sasso target, targets for Neutrino factories, …)
- Collimators at SPS and LEP
- Others?

Experimental validation of collimator design choices

- at the SPS
- at the PS
- outside CERN

The meeting will include several talks, and should allow for ample discussions. Brain-storming is encouraged, and we should be prepared to discuss alternative ideas (scattering foils, crystals, etc.).

Other aspects related to the design of the collimators should be kept in mind, such as cost, impedance of the collimators, impact on the machine layout.

**Distribution list**

- Members of the LHC Beam Cleaning Study Group (http://www.cern.ch/lhc-collimation)
- L.Evans DG/DI
- S.Myers SL/DI
- V.Mertens SL/BT, H.Schmickler SL/BI, F.Ruggiero SL/AP
- J.P.Koutchouk, B. Dehning SL/BI , L. Bruno, S. Peraire, B. Goddard SL/BT
- D.Brandt, L.Vos SL/AP
- T. Kurtyka, R.Valbuena EST/ME
- C.Johnson, J. Lettry, K.Schindl PS/PP, H.Schönauer PS/AE
- P.Sievers LHC/MTA, P. Bryant AC/TSC
- M. Brugger, S. Rösler, G.Stevenson TIS/RP
- P. Strubin LHC/VAC
- I. Baishev IHEP/Protvino
- D. Kaltchev TRIUMF
- N. Mokhov FNAL
- SL/EET