CERN Meeting on Absorbers and Collimators for the LHC Beam on 25.1.02

Preliminary Summary

R. Assmann, SL/AP

Complete summary being prepared by R. Assmann, C. Fischer, J.B. Jeanneret, R. Schmidt (meeting yesterday).
Goals:  
• Bring together the CERN expertise on collimators and absorbers.  
• Confront the requirements with this expertise.  
• Collect ideas on solutions and most urgent studies.

Part of the activity of the LHC Beam Cleaning Study Group.

Our input:

Preliminary Beam-based Specifications for the LHC Collimators


Keywords: Collimation, Beam Loss, Machine Protection

Response to our initiative: Strong interest and support
(~ 45-50 participants)

We asked for: Short talks (5-15 min) for quick summary of relevant experience and knowledge.

Great support from CERN experts… (all agreed to give a talk)

20 talks ranging from the ISR …

… over the Booster, ISOLDE, SPS, LEP…

… to the LHC.

- Requirements from the Beam Cleaning SG, Machine Protection, impedance, vacuum.
- Materials (from Be, C to fiber reinforced ceramics, Boron Nitride). Beryllium OK?!
- Technical solutions for handling the LHC beam for injection and dump.
- Experience with damage and fatigue.
- Computer tools.
- Possibilities for experimental tests.

Talks will be put on web. Valuable archive of CERN expertise…
The Challenge:

Talks explaining the challenge and the specific requirements:

J.B. Jeanneret
R. Schmidt
C. Fischer
R. Assmann

Complemented by talks on impedance and vacuum issues:

D. Brandt
N. Hilleret

Step from previous accelerators:

Factor 7 in proton energy
Factor 100 in stored beam energy

The powerful LHC beam must be handled in sensitive super-conducting environment!
Beam and Power Deposition During Regular Operation:

Lifetime reductions during machine cycle (ramp, squeeze, …) and tuning…

<table>
<thead>
<tr>
<th>Mode</th>
<th>Energy [TeV]</th>
<th>Duration [s]</th>
<th>Req. min. lifetime [h]</th>
<th>Beam deposition [protons/s]</th>
<th>Power deposition [kW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection</td>
<td>0.45</td>
<td>cont</td>
<td>1.0</td>
<td>$0.8 \times 10^{11}$</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.1</td>
<td>$8.2 \times 10^{11}$</td>
<td>60</td>
</tr>
<tr>
<td>Ramp</td>
<td>0.45-7.00</td>
<td>10</td>
<td>0.1-0.2</td>
<td>$8.2-4.1 \times 10^{11}$</td>
<td>60-465</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
<td>$\approx 1$</td>
<td>0.006</td>
<td>$1.3 \times 10^{13}$</td>
<td>1000</td>
</tr>
<tr>
<td>Top energy</td>
<td>7.00</td>
<td>cont</td>
<td>1.0</td>
<td>$0.8 \times 10^{11}$</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>0.2</td>
<td>$4.1 \times 10^{11}$</td>
<td>465</td>
</tr>
</tbody>
</table>

Most severe: Top energy (up to 0.5 MW) to be absorbed in collimators and downstream material. Dump beam below 0.2 h (top).

Ensure: Keep tolerance for collimation efficiency (~ 100 μm flatness). (important DIFFERENCE to BT absorbers)

R. Assmann
Cleaning Efficiency:

Quench levels of magnets require excellent cleaning of beam halo from injection all the way to top energy.

Good efficiency with “good” collimators (cannot run with damaged/deformed collimators)!
E.g.: tolerance on surface flatness: \( \sim 100 \, \mu m \)

R. Assmann
## Failures:

<table>
<thead>
<tr>
<th>Failure description</th>
<th>Beam energy [TeV]</th>
<th>Intensity deposit [protons]</th>
<th>Energy deposit [kJ]</th>
<th>Transverse dimensions [mm×mm]</th>
<th>Impact duration [ns]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection oscillation</td>
<td>0.45</td>
<td>$2.6 \times 10^{13}$</td>
<td>1875</td>
<td>$1.0 \times 1.0$</td>
<td>6250</td>
</tr>
<tr>
<td>Asynchronous beam dump</td>
<td>0.45</td>
<td>$1.1 \times 10^{12}$</td>
<td>78</td>
<td>$5.0 \times 1.0$</td>
<td>275</td>
</tr>
<tr>
<td>(all modules)</td>
<td>7.00</td>
<td>$2.8 \times 10^{11}$</td>
<td>311</td>
<td>$1.0 \times 0.2$</td>
<td>75</td>
</tr>
<tr>
<td>Asynchronous beam dump</td>
<td>0.45</td>
<td>$1.1 \times 10^{12}$</td>
<td>78</td>
<td>$5.0 \times 1.0$</td>
<td>275</td>
</tr>
<tr>
<td>(1 out of 15 modules)</td>
<td>7.00</td>
<td>$6.0 \times 10^{11}$</td>
<td>667</td>
<td>$1.0 \times 0.2$</td>
<td>150</td>
</tr>
</tbody>
</table>

About 6 full LHC bunches:
- 0.2% of LHC beam
- 30% of HERA-p beam
- 2200% of LEP2 beam

**Our goal:**
Collimator jaws that can withstand this beam impact.
Preliminary summary: (final summary from JBJ, RS, CF, RA)

- Preliminary beam-based requirements presented as a **basis for hardware choices**. (Propose a talk in LCC on this issue in 4 weeks time).

- Several materials appear promising (**Be**, **C**, Boron Nitride, fiber reinforced ceramics?, diamond coating?). Would coating or plating be an option for collimators?

- Worries on materials (toxicity, brittleness, conductivity, **shock resistance**, **flatness control**, dust, thermal expansion, surface cracks, fatigue). Careful trade-off required.

- Damage mechanics (**shock waves, fatigue**) are crucial! Tools and expertise available…

- Experimental tests (**tests with beam**) are mandatory: ISOLDE, SPS?

- Collaborate with **vacuum** group on choice of material!

- **Do not consider constraints from impedance** for now (coating for insulator).

- Think on methods to **find damaged collimator** (tomography, RF, temp., beam based,…).

- Protection of LHC collimators require **TCDQ (BT) at 10σ**! Ensure consistency!

- Other concepts: wire septum, non-linear collimation, increased beta functions?
The damage/deformation and fatigue of collimators will depend on the machine running:

- Collimation depth (aperture)
- Machine protection (beam dump)
- Intensities, bunch schemes
- Beam lifetimes
- Flashes of beam loss (start of ramp)
- Failures

Close interconnection between: accelerator physics, operational scenarios, machine protection, radiation issues, collimator hardware design

Beam Cleaning Study Group + further collimation meetings?