Review of the Collimation System with Asymmetric Settings

A. Mereghetti, D. Kodjaandreev, on behalf of the LHC Collimation Team and LHC Impedance Team
Outline

• Introduction
• Simulations for HL-LHC:
  • Cleaning inefficiency
    • IR7 TCPs single-sided
    • IR7 TCSGs single-sided
    • Load on TCLD
  • Octupole current
• Benchmark of simulation results
• Conclusions
Introduction

• In the context of the HL-LHC project, the IR7 collimation system will undergo a substantial upgrade, in order to properly handle the HL-LHC beams in terms of:
  • Cleaning performance;
  • Impedance;
  • Collimator robustness;
• The impedance upgrade of the LHC collimation system is aimed at reducing the impedance from IR7 collimators:
  • to grant enough margin in octupole current to compensate for other sources of beam instability;
  • IR7 graphite collimators are responsible for a significant fraction of impedance at flat top energy;
  • Impedance upgrade achieved exchanging:
    • 2 (out of 3) IR7 TCP collimators per beam with MoGr ones;
    • 11 (all) IR7 TCSG collimators per beam with Mo-coated, MoGr ones;

Upgrade actually performed in two stages:
• LS2: TCPs and 4 TCSGs per beam;
• LS3: remaining 7 TCSGs per beam

Impedance estimation (plots on the left):
• 100 turns^{-1};
• Q’=10;
• εn=2.0 μm;
• Nb=2.3 10^{11};
Introduction (II)

- Are there other collimator schemes that could help in reducing further impedance? At which cost in terms of cleaning performance the impedance reduction can be achieved?
- Single sided collimation:
  - Firstly explored in simulations by R. Bruce + deployed in recent ion runs to mitigate background issues in ALICE;
  - Take advantage of multi-turn nature of halo-cleaning in circular accelerators;
  - …at the expenses of a lower cleaning performance in single pass (a-priori);
- Work presented here has been carried out by D. Kodjaandreev under my supervision:
  - Exploring TCP and TCSG single-sided;
  - Evaluating cleaning inefficiency and impact on impedance;

Overall reduction of W impedance per single collimator by ~2
Simulation Settings

- Classical SixTrack simulations for cleaning studies:
  - Pencil beam on primary collimator of concern:
    - Cleaning plane: flat distribution, $5.72 \pm 0.02 \sigma$
    - Non-cleaning plane: Gaussian distribution
    - Monochromatic beam @7TeV
  - ~8M beam particles
- HL-LHC optics V1.3, $\beta^* = 15\text{cm}$, parallel separation on
- TCLD still in cell 8!

<table>
<thead>
<tr>
<th>IR</th>
<th>Coll Family</th>
<th>Settings (3.5(\mu\text{m}) [\sigma]</th>
<th>Settings (2.5(\mu\text{m}) [\sigma]</th>
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<tr>
<td>IR7</td>
<td>TCP / TCSG / TCLA / TCLD</td>
<td>5.7 / 7.7 / 10 / 12</td>
<td>6.74 / 9.11 / 11.8 / 14.2</td>
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<tr>
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<td>TCP / TCSG / TCLA</td>
<td>15 / 18 / 20</td>
<td>17.8 / 21.3 / 23.7</td>
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<td>TCDQ / TCSP</td>
<td>9 / 8.5</td>
<td>10.6 / 10.1</td>
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<td>TCT / TCL</td>
<td>10.9 / 12</td>
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<tr>
<td>IR2/8</td>
<td>TCT</td>
<td>30</td>
<td>35.5</td>
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</tbody>
</table>
Single-Sided TCPs - Configurations

- Considered two configurations:
  - Driven by the orientation of the skew TCP;
  - Single-sided TCPs chosen such that no quadrant is left uncovered;
- Expectations:
  - Losses in IR7 DS are dominated by single diffractive events in TCP jaws, and appear at locations where dispersion gets large;
  - The two configurations may not give the same cleaning inefficiency in the IR7 DS;
Single-Sided TCPs - Results

- Cluster Total: cleaning inefficiency integrated in each cluster (load on cryo-cooling);
- Cluster Peak: peak in cluster (risk of a local quench);
- Ratios wrt DRY run, i.e. no changes made to the collimators;
- B1H:
  - C1 performs way better than C2;
  - C1 performs better than DRY!
- B1V: almost insensitive to single-sided TCPs;

Cluster 4 found in arc, upstream of IR8

C1 on B1 is a good candidate for deployment, and give room to compensate for possible loss of performance from single-sided TCSGs.
Single-Sided TCPs – Results (II)

- **B2H:**
  - C2 performs way better than C1 (reversed situation wrt B1H);
  - C2 performs better than DRY (as it was happening with C1 on B1H);
- **B2V:** almost insensitive to single-sided TCPs (as for B1V);
- C2 on B2 is a good candidate for deployment, and give room to compensate for possible loss of performance from single-sided TCSGs.

TCSG configurations in B1(B2) will be explored with C1(C2) to compensate for possible increase in leakage due to single-sided TCSGs;
Single-Sided TCSGs - Configurations

- Use C1 in B1 and C2 in B2;
- Mainly explored 2 sets of configurations:
  - Take the four TCSGs with largest contribution to impedance:
    - A6L7, B5L7, D4L7*, B4L7* in B1 (for B2, take slots symmetric around IP7):
    - Brute-force scan, to identify most promising configuration of single-sided TCSGs;
    - Each configuration will be denoted by a series of 4 N/P, indicating which jaw is active on the selected collimator → e.g. C1+PPPP;
  - Make all but 2 TCSG collimators (i.e. A5L7 and B5R7) single-sided:
    - Single-sided jaws selected based on paths of particles out-scattered by TCPs;
    - Labelled as “MANY” configuration hereafter;

* Slots with TCSPM installation during LS2
• B1H: all configurations perform better than DRY (and are almost equivalent in terms of total) → relevant role of the TCLD in catching the leakage from IR7;
• B1V: only few configurations perform better than DRY;
• Decided to take PPPP: almost no worsening wrt DRY;
• B2: same key messages as those from B1:
  • H plane sensitive to choice of TCP config;
  • The chosen configuration has a very limit loss in performance wrt DRY;
Load on TCLD

• Load on TCLD wrt DRY
• Single-sided configurations change the load on the TCLD in case of B1H, less in the other beams/planes;
• In case, endep studies with Fluka could be run to verify load on downstream magnets;
Octupole Current

- Stability diagrams:
  - Significant changes when applying single-sided collimation in the case of LHC (expected: CFC collimators);
  - Limited gain (few 10A) in case of HL-LHC (expected: Mo-coated MoGr jaws effective);
  - To be noted the gain at Q’=10, where we typically show octupole current plots;
Benchmark of Results

- MD2901, carried out on 25\textsuperscript{th} July from 02:00 AM to 09:00 AM (7h);
- Aim:
  - to verify with beam different configurations of single-sided collimation;
  - to collect data for benchmarking simulations;
- Two ramps:
  - 1\textsuperscript{st} one: validation of configurations via loss maps (cleaning inefficiency);
    - One nominal bunch with several pilots;
  - 2\textsuperscript{nd} one: validation of configurations via tune-shift measurements (impedance);
  - Some troubles with measurement set-up:
    - ADT was not kicking on all beams/planes;
    - Issues with data saving from ADT obsBox;
    - High intensity bunch in B1 (~1.8E11) was unstable at FT \(\rightarrow\) could not take DRY as reference config. against which measure tune-shifts;
- Dedicated set of simulations (both cleaning and impedance)
  - Tested TCSG configurations different from those of HL-LHC;
  - While C1/C2 do not change, ranking of TCSG configuration changes wrt HL-LHC (due to absence of TCLD);
  - Concept does not change!
• Trends in simulation and measurements in very good agreement on B1;
• B2 results require further investigations, since if the general trend of simulations and measurements is there, peaks and valleys are in counter-phase;
• Some loss maps were also inserted in activity MD1653 – got the same results;
Impedance Measurements

- Many configurations explored + problems with ObsBox data;
- For the moment, only treatment of the high sensitivity gated BBQ data from Timber:
  - Method less precise than kicking method;
  - Tune-shift in the order of $10^{-4}$ – consistent with simulations;
  - Large spread in the measured tune values;

Analysis of ObsBox data still to be done, but results from BBQ seem encouraging;

Courtesy of D. Amorim
Conclusions

• Single-sided collimation for HL-LHC explored in terms of cleaning inefficiency and impedance;
  • Evaluations done with optics V1.3 and TCLDs in cell 8;
• Cleaning-wise:
  • TCP configurations:
    • due to the nature of losses in the IR7 DS, the choice of TCP configuration is important, especially for losses on the horizontal plane;
    • one configuration even provides better cleaning than the other one;
  • TCSG configurations:
    • In general, they spoil the cleaning inefficiency;
    • It was possible to identify a configuration with marginal loss of performance;
• Potential for deployment in Run III:
  • In the configuration with 4 TCSG single-sided, two slots will be already upgraded in LS2, whereas the other two will be kept as TCSG → potential gain for Run III;
  • Single sided collimation could be of interest also for “hybrid” scenarios where TCSPMs are installed in the TCSM slots – i.e. one jaw of TCSG out, together with the opposite one of the TCSPM immediately downstream;
Conclusions

- Impedance-wise:
  - Gain for HL-LHC limited to few 10A in terms of octupole current – more important if Q’=10, i.e. ~80A;
  - Could be interesting to test in simulations hybrid scenarios of interleaved TCSG-TCSPM single-sided collimation;

- Outlook:
  - Address implications by closed orbit distortions;
  - Evaluate effects of offsets/misalignments and multipolar errors (non linear optics);
  - Assess endep-related figures (i.e. power on downstream magnets and collimators);
Thanks!