Incoherent beam-beam effects and lifetime optimisation

8th Evian Workshop, 12-14 December 2017

D. Pellegrini

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Outline

• Recap of DA sensitivity from weak-strong beam-beam simulations (tune, chromaticity, octupoles) with sixtrack.
• Predictions and effects on DA during 2017:
  • 30 cm beta*,
  • 8b4e filling scheme,
  • crossing angle anti-levelling.
• Correlation between DA and lifetime
• Comments on computing and instrumentations
• High sensitivity to tune adjustments, 1-2 \( \sigma \) DA lost within a few 1e-3 trims.
• First test performed at the end of 2016, immediate lifetime improvement.
• Tune optimisation routinely applied in 2017, e.g. after crossing angle steps.
• Care not to excessively approach the diagonal to avoid instabilities.
• Optimised tunes are now considered a “must” for lifetime and DA studies.
Impact of tunes (II)

Optimised tunes can allow as much as 30 μrad reduction of half crossing angle (2 σ BB separation @ 40cm) → 10% increase in peak luminosity
Chromaticity and Octupoles

- 1 σ DA for ~10 units of chromaticity.
- Limited impact (< 0.5 σ) of octupoles in the range usually exploited: 300-500 Å.
- Demonstrated lifetime improvement for telescope-enhanced negative octupoles (MD 2269, S. Fartoukh et al.)
Octupole raise during the run

- On Oct 2 octupoles where raised to improve beam stability.
- Check the effective cross section (losses normalised to luminosity) on few fills before and after.
Octupole raise during the run

- Small increase of losses at the beginning of the fill (within the uncertainty), compatibly with simulations.
- No long term effect on losses.

N. Karastathis
Reduction of $\beta^*$

- Xing maintained at 150 $\mu$rad leveraging on tune optimisations.
- Beam-beam separation reduced from 10 to 8.5 $\sigma$. 
Beam-Beam with 8b4e

Min DA, ATS \( \beta^*=30 \text{cm} \), \((Q_x,Q_y)=(62.313,60.317)\)
\( \epsilon=2.5 \mu\text{m}, Q'=15, l_{\text{MO}}=510 \text{A} \)

LHC 2017; 8b4e\(_8\); \( \beta^*=30 \text{ cm} \); \( Q=(.314, .320) \)
\( l_{\text{MO}}=330 \text{ A}; Q'=15; \epsilon=2.5 \mu\text{m}; \) Min DA.

DA recovered also thanks to the 8b4e beam (worst case shown here), having less long range beam-beam encounters.
Different 8b4e classes

- Precise predictions also for 8b4e trains.
- The bunches in the front of the 8b mini-trains suffer more.
- Observed both in MDs and simulations.

Courtesy M. Hostettler
From MD 2201 G. Sterbini et al.
Crossing angle anti-leveling

- **Idea:** follow the intensity decay with the crossing angle along the iso-DA curve.
- **Act on the geometric reduction factor, for more luminosity.**
- **Agreed on 10 μrad steps performed at 2, 4, 8 h into the fill.**
- **Potential for introducing extra losses if not done properly (steps too aggressive or taken too early, unforeseen emittance blowup...)**
Anti-leveling with extra losses

- Luminosity integrated with measured (fill 6054) or fitted cross section for intensity decay, with or without crossing angle steps.
- Slightly aggressive crossing steps
- ~3% gain of integrated luminosity compared to ideal 5%.

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The effective cross section (loss rate normalised with luminosity) is kept constant over the year across the various configurations.

Difference between the two beams under investigation.

More in S. Papadopoulou’s talk.
Lifetime vs DA with 8b4e

Idea: feed the machine settings and beam measurements along MDs with significant lifetime degradation to DA simulations.

Observe correlations between DA and lifetime.

Burnoff lifetime ≈ 25 h
Lifetime vs DA with 8b4e

- Linear scale for DA, logarithmic for lifetime
- In agreement with:
  \[ \frac{I(t)}{I_0} = 1 - e^{-DA^2(t)/2} \]
  (M. Giovannozzi, PRST-AB, 2012)

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Tune and Luminosity optimisation

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Tune and Luminosity optimisation

Burnoff lifetime ≈ 25 h
Lifetime vs DA with 8b4e

- Linear scale for DA, logarithmic for lifetime
- In agreement with:
  \[-e^{-DA^2(t)/2} \frac{I(t)}{I_0} = 1\]
  (M. Giovannozzi, PRST-AB, 2012)

### Tune and Luminosity optimisation

- Chromaticity and octupoles reduction

### Cross section steps

<table>
<thead>
<tr>
<th>Crossing Angle (°)</th>
<th>Time [h]</th>
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</thead>
<tbody>
<tr>
<td>150</td>
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</tr>
<tr>
<td>130</td>
<td>1.5</td>
</tr>
<tr>
<td>110</td>
<td>2.0</td>
</tr>
<tr>
<td>100</td>
<td>2.5</td>
</tr>
<tr>
<td>90</td>
<td>3.0</td>
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</tbody>
</table>

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Lifetime vs DA with 8b4e

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Tune and Luminosity optimisation

Crossing angle relaxation
- Cannot well reproduce.
- Need lifetime simulations taking into account particles lost previously.
- Possible degradation of the core.

Chromaticity and octupoles reduction
Exercise repeated for MD 2201, observing BCMS beams.

Burnoff lifetime ≈ 25 h
Good agreement between 8b4e and BCMS (non-pacman):

- **4 σ**: give a lifetime equivalent to burnoff.
- **5 σ**: grants lifetimes of ~100 h. Minimum target for operation if well in control.
- **6 σ**: suitable for studies further in the future in presence of larger uncertainties.
Summary

• Assessed **sensitivity** to tunes, chromaticity and octupoles, with both operational experience and simulations.

• Spot-on **predictions** of the crossing angle requirements in various scenarios, including anti-levelling.

• Better understanding on DA and lifetime **correlations** and DA targets.
Comments on Computing

- DA plots massively relying on the CERN computing resources (~1 year CPU time/plot).
- Greatly suffered from the switch to HTCondor.
- Follow up by ABP-CWG, slow improvements along 2017.
- Ticket system not always effective, profited from having a direct line with IT specialists (thank you Ben Jones!).
- Still some issues from time to time (authentication, scheduler reachability) being reported, but definitely bearable.
Comments on Instrumentation

**Outstanding** performance of the instrumentation:

• Inputs from many instruments: fBCT, BSRT, Luminosity Monitor, BLM, BBQ, Schottky.
• Relatively easy access with pyTimber and pjLSA.

But few wishes:

• **Tune** determination in collision difficult, trims are often performed almost “blindly”.
• Transverse profile **tail** knowledge (up to ~6 σ) would be desirable for guiding lifetime simulations (coronagraph?).
Thank you!