Task 2.5: Beam-beam studies
D. Banfi, J. Barranco, T. Pieloni, A. Valishev

Very-Preliminary results for RLIUP scenarios
<table>
<thead>
<tr>
<th>$\beta_1, \beta_2$</th>
<th>30, 7.5 cm</th>
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<tbody>
<tr>
<td>$\sigma_z$</td>
<td>7.5 cm</td>
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<tr>
<td>$\varepsilon_x, \varepsilon_y$</td>
<td>2.5 $\mu$m</td>
</tr>
<tr>
<td>$N_b$</td>
<td>2736</td>
</tr>
<tr>
<td>Collisions at</td>
<td>IP1, IP5</td>
</tr>
<tr>
<td>$N_p \times 10^{11}$</td>
<td>x-angle (mrad)</td>
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<tr>
<td>----------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>1.0</td>
<td>300</td>
</tr>
<tr>
<td>1.2</td>
<td>300</td>
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<tr>
<td>1.0</td>
<td>350</td>
</tr>
<tr>
<td>1.2</td>
<td>350</td>
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<td>350</td>
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<tr>
<td>1.4</td>
<td>400</td>
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<tr>
<td>1.8</td>
<td>400</td>
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<td>2.2</td>
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<tr>
<td>1.6</td>
<td>450</td>
</tr>
<tr>
<td>1.8</td>
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<td>2.0</td>
<td>450</td>
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<td>1.6</td>
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<td>1.8</td>
<td>500</td>
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<td>2.0</td>
<td>500</td>
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<tr>
<td>2.2</td>
<td>550</td>
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</table>
Possible scenarios at 7 TeV:

<table>
<thead>
<tr>
<th></th>
<th>N_{b\text{coll}} [10^{11}]</th>
<th>\epsilon_{\text{coll}} [\mu m]</th>
<th>Coll. Bunches IP1,5</th>
<th>Min \beta^* (xing/sep) [cm]</th>
<th>B-B Sep [\sigma]</th>
<th>Xing angle [\mu rad]</th>
<th>L_{\text{peak}} [10^{34} \text{ cm}^{-2} \text{s}^{-1}]</th>
<th>L_{\text{lev}} [10^{34} \text{ cm}^{-2} \text{s}^{-1}]</th>
<th>\tau_{\text{lumi}} [h]</th>
<th>Lev. time [h]</th>
<th>Opt. Fill length [h]</th>
<th>Machin e eff. 6 h fills [%]</th>
<th>Machin e eff. opt. fill length [%]</th>
<th>Avg. Peak-pile-up density [ev./mm]</th>
<th>Target int. Lumi [fb^{-1}/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIC</td>
<td>1.45</td>
<td>1.8</td>
<td>2592</td>
<td>40/20</td>
<td>12</td>
<td>308</td>
<td>4.34</td>
<td>-</td>
<td>7.09</td>
<td>-</td>
<td>6</td>
<td>26.8</td>
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<td>1.45</td>
<td>70</td>
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<tr>
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<td>2.22</td>
<td>2736</td>
<td>40/20</td>
<td>12</td>
<td>341</td>
<td>3.72</td>
<td>-</td>
<td>9.26</td>
<td>-</td>
<td>6.8</td>
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<tr>
<td>US1</td>
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<td>2.62</td>
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<td>40/20</td>
<td>10</td>
<td>309</td>
<td>7.95</td>
<td>5.06</td>
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<tr>
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<td>10</td>
<td>466</td>
<td>16.3</td>
<td>5.06</td>
<td>4.72</td>
<td>6.4</td>
<td>8</td>
<td>57.8</td>
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<tr>
<td>US2</td>
<td>2.2</td>
<td>2.5</td>
<td>2736</td>
<td>15/15</td>
<td>10</td>
<td>490</td>
<td>19.8</td>
<td>5.06</td>
<td>4.71</td>
<td>8.41</td>
<td>9.75</td>
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<tr>
<td>US2</td>
<td>2.2</td>
<td>2.5</td>
<td>2736</td>
<td>30/7.5</td>
<td>10</td>
<td>348</td>
<td>18.6</td>
<td>5.06</td>
<td>5.04</td>
<td>8.08</td>
<td>9.58</td>
<td>57.8</td>
<td>51.6</td>
<td>&lt;1.24</td>
<td>270</td>
</tr>
</tbody>
</table>

- Bunch length 7.55cm, could be increased to 10cm for pile-up density or more with 2nd harmonic system
- \beta^* = 40 cm could be relaxed to gain aperture and pile-up density
- B-B sep being evaluated
Beam-beam Task 2.5

- Is there any filling scheme among those proposed for BCMS that could pose problems for beam-beam effects?
- What is the required beam-beam separation for flat optics and no BBLR?
- What is the dependence on intensity?
- BBLR position vs emittance, flat beam crossing angle with BBLR. Is it compatible with collimation?
**Filling schemes 25 ns**

<table>
<thead>
<tr>
<th>Filling scheme</th>
<th>Total</th>
<th>IP1-5</th>
<th>IP2</th>
<th>IP8</th>
</tr>
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<tbody>
<tr>
<td>BCMS: 48b 6 Ps inj, 12 SPS inj</td>
<td>2604</td>
<td>2592</td>
<td>2288</td>
<td>2396</td>
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<tr>
<td>Standard: 72b 4 Ps inj, 12 SPS inj</td>
<td>2748</td>
<td>2736</td>
<td>2452</td>
<td>2524</td>
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</tbody>
</table>

In case of instabilities could be problematic! Except if we take head-on collision in IP2 or IP8

Beta* leveling in IP8 but is 1 head-on stability enough? To be tested

Ratio nominal/pacman different needs considerations for optimization/wire
LHC running 2012

LHC runs always above 8 $\sigma$ DA with imperfections!
We have heavy losses at DA of 3-4 $\sigma$
What do we define as GOOD POINT 6 $\sigma$ or 8 $\sigma$ to have some margin?

8-7 $\sigma$ DA for nominal intensity, nom $\sigma$
1 $\sigma$ reduction for Intensity increase
1.1-1.6 $10^{11}$ ppb
Beam-beam DA studies

PIC & US1 scenarios (simulations still running)
• DA with beam-beam only (4D&5slices and 6D)
• **No imperfections**
• No tune scans = no optimization

US2
• DA with beam-beam (4D&5slices and 6D)
• DA with imperfections
• Tune scans on-going for 30/7.5 cm Optic
PIC: Beam-beam interactions only

40/20 Optics 4D/5 slices BB

To be evaluated for scenarios crossing angles

Missing interesting points simulations still running, SORRY!
PIC&US1: Beam-beam interactions only

Very Preliminary!
Missing interesting points
simulations still running,
SORRY!

PIC1: 15.8 $\sigma$ first encounter
PIC2: 14.6 $\sigma$ first encounter
US1: 15 $\sigma$ first encounter?

PIC1: 8 $\sigma$ DA
PIC2: 6.7 $\sigma$ DA
US1: 5.7 $\sigma$ DA
Preliminary results show:

- Larger DA if $\beta^*$ sep plane larger
- Leveling with $\beta^*$ should aim to separation plane to improve DA!
- Sharper improvement with larger $\beta^*$ sep plane
- Tune scan needed!
Comparison between 4D&5 slices BB and 6D Hirata beam-beam tracking
Tune scan needed!
PIC: Beam-beam interactions only

40/10 Optics 4D/5 slices BB 390 $\mu$rad

10.9 $\sigma$ first encounter

Missing interesting points simulations still running, SORRY!
Crossing angle can be reduced thinking to level with beta*!
Simulations still running, SORRY!
15 cm round optics

15/15 Optics 4D/5 slices BB

13.8 $\sigma$ first encounter

12.5 $\sigma$ first encounter

Smaller US2 $a : 6.5 \sigma$ DA
Energy 6.5 TeV separation reduced 0.5 $\sigma$
15 cm round optics 6D BB

15/15 Optics 6D BB

14.0 $\sigma$ first encounter

13 $\sigma$ first encounter

6 D requires a bit more, Energy scaling also!
15 cm round optics

Need to understand deep at 2.2 e11 ppb
Is it real? Simulations on-going!
Need also Imperfections!
No margin at 550 $\mu$rad 10% Intensity variation will require 580 $\mu$rad crossing angle
Same discussion for larger emittances
This case at 7 TeV at 6.5 TeV you need 0.7 sigma more (570 $\mu$rad)
No margin at 550 \( \mu \text{rad} \) 10% Intensity variation will require 580 \( \mu \text{rad} \) crossing angle
Same discussion for larger emittances
This case at 7 TeV at 6.5 TeV you need 0.7 sigma more (570 \( \mu \text{rad} \))
More than 17 $\sigma$ first encounter

Needs still some understanding! Tune scan on-going and FMA
Nedd more separation
This case at 7 TeV at 6.5 TeV you need 0.7 sigma more (570 $\mu$rad)
Beam-beam interactions only!

30/7.5 Optics 2.2 e11 ppb

Need to clarify the 4D and 6D differences!
FMA studies on-going!
Imperfections have strong impact!
Results are new, need check! Passive compensation tune shift? Tune scan could help understanding.

30/7.5 Optics 540 µrad

15cm Optics 590 µrad
Flat 30/7.5 Intensity scans

All scenarios are at the limit!
Here no margin!

16.5 σ first encounter for 4D simulations
18 σ first encounter for 6D simulations

• NEEDS studies to understand this effect
• NEEDS tune scan (on-going)
• Leveling in Sep plane (Larger beta in sep plane) could IMPROVE
**BB Long range wire compensation**

15 cm round Optics HL-LHC
590 \(\mu\)rad crossing angle

FMA and footprints tool in Sixtrack!
Need official release to make them available to everyone
BB Long range wire compensation

1 Wire next to TCT IP5
1 Wire next to TCL IP1

A wire exist in Sixtrack by Bela Erdelyi and Tanaji Sen (Benchmarked versus F. Zimmermann)
Testing On-going preliminary results showed

Need wire implemented in MADX for matching tune shift!
Need MADX to Sixtrack conversion!
Summary

- Several results for BB only
- Preliminary results need a decision in what to define as DA minimum to define separations!
- For flat options larger separations seems needed
- Imperfections are important for low beta optics, needs some studies!
- Leveling with separation plane should improve things! Relex separation incrossing plane by larger beta in sep plane!
- Past studies suggest tune scan could improve, ongoing!
- Wire studies are possible, need implementations in MADX now!
- Not shown here: diffusion rates and footprints. Analysis ongoing!