LHCb upgrade: minimum crossing angle from Beam-Beam: Preliminary tracking results

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Simulations set-up

Optics configurations (beam 1):
- Optics version HLLHCV1.2
- $\beta^*$ of 15 cm in IR1/5, 10 m in IR2, 3 and 1 m in IR8
- Tunes of 62.31 and 60.32
- Crossing (half-)angles: 295 $\mu$rad in IR1/5, -170 $\mu$rad in IR2, -250 $\mu$rad, -200 $\mu$rad, -150 $\mu$rad and -50 $\mu$rad in IR8 (external)
- LHCb Spectrometer polarity + and –
- Separation: 0 in IR1/5/8, 2 mm in IR2
- Chromaticity of 3
- Multi-pole errors and Landau octupoles switched off
- Emittance 2.5$\mu$rad
- Intensities: $1.1 \times 10^{11}$ and $2.2 \times 10^{11}$
- Crab cavities switched off and on
Crabs off - Positive polarity

- Different $\beta^*$ in IR8 does not affect significantly the DA
- Only for high-intensity of $2.2e11$, DA < $6 \sigma$
- Different $\beta^*$ in IR8 does not affect significantly the DA, for negative spectrometer polarity as well
- Only for high-intensity of $2.2e11$, $DA < 6 \sigma$
Crabs off - summary

- Overall, slightly higher DA from negative spectrometer polarity (IR8 total crossing angle increase)

![Graph showing dynamic aperture for different Nb and beta values with positive and negative polarities.](image-url)
Crabs on - Positive polarity

- Minor impact on DA for crab-cavities switched on
Crabs on– Negative polarity

- For negative spectrometer polarity, $DA > 6 \sigma$ for all intensities
Crabs on - summary

- Overall higher DA (average and minimum) for negative polarity

![Graph showing Crabs on summary with data points for different Nb and beta values.](image)

- Nb=1.1e11, $\beta^*=3m$
- Nb=2.2e11, $\beta^*=3m$
- Nb=1.1e11, $\beta^*=1m$
- Nb=2.2e11, $\beta^*=1m$
Crossing-angle scan

- Clear degradation of DA below -150 µrad, getting better for -100 µrad and worse for -50 µrad (following total crossing angle, which passes from -15 to +35 and finally +85 µrad)
- Only for crossing angle of 50µrad, DA close to 6σ

\[ N_b = 1.1e11, \beta^* = 3m, + \text{ polarity} \]
Crossing-angle scan

- Clear degradation of DA below -150µrad
- For crossing angle below -100µrad, DA < 6σ

\[ Nb = 1.1e11, \beta^* = 1m, + polarity \]
Crossing-angle scan

- DA not affected until external crossing angle of 50 µrad, (i.e. -185 µrad of total crossing angle)
- Only for crossing angle below 50 µrad, DA close to 6σ

\[ Nb = 1.1e11, \beta^* = 3m, - polarity \]
Crossing-angle scan

- Clear degradation of DA below 100 µrad (total crossing angle of -235 µrad)
- Finner scan is needed to identify the limit

Nb = 1.1e11, β* = 1m, - polarity
Summary – next steps

- Mild impact on DA between $\beta^*$ of 3m and 1m in IR8
  - For both spectrometer polarities and the nominal external crossing angle of 250 $\mu$rad
  - For both nominal and peak intensities,
  - With and without crab cavities
  - DA always above 6 $\sigma$, for nominal intensity

- Negative polarity provides always higher DA, due to total crossing angle increase

- Crossing angle scan:
  - From the preliminary analysis, there is an important DA degradation when external crossing angle is reduced to below 100 $\mu$rad (especially for positive polarity)

- Next steps:
  - Missing cases (for 2.2e11, $\beta^* = 2$m), alternative crossing scheme
  - Inclusion of other non-lineararities (octupoles, multi-pole errors)
  - Detailed beam dynamics analysis with other indicators
Thanks for your attention