Impact of LHCb upgrade II on ATLAS/CMS

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Thanks to G. Iadarola

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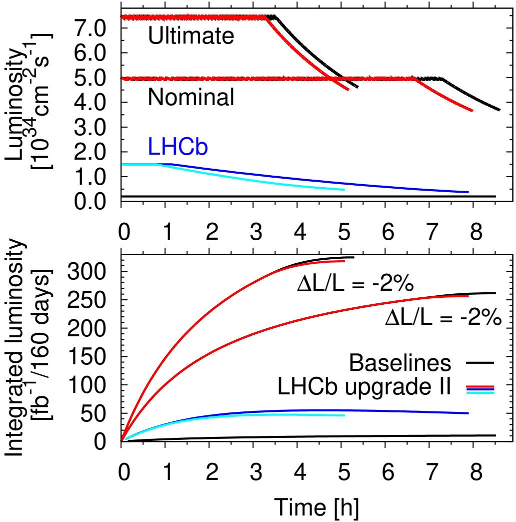
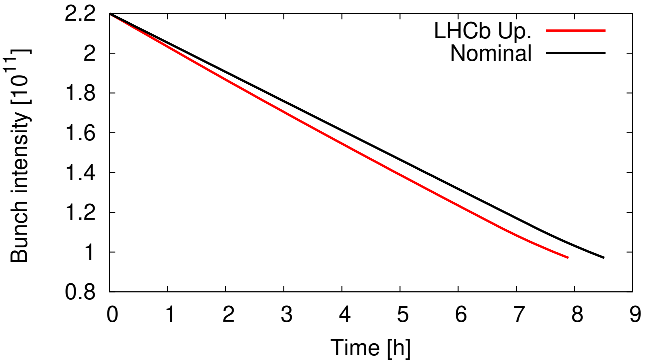


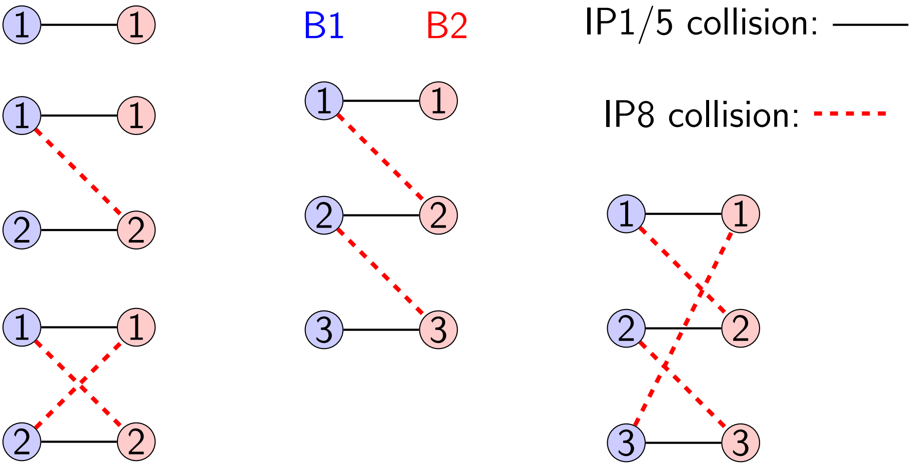
LHCb upgrade II would reduce ATLAS/CMS integrated luminosity by 2% for both Nominal and Ultimate.

Impact on bunch population

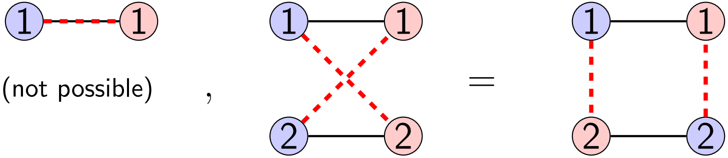
Increasing LHCb luminosity to 1.5×10^{34} cm^{-2}s^{-1} comes with *a priori* a small impact on IP1&5 performance but introduces bunch-by-bunch variations



Collision patterns up to 3 bunches

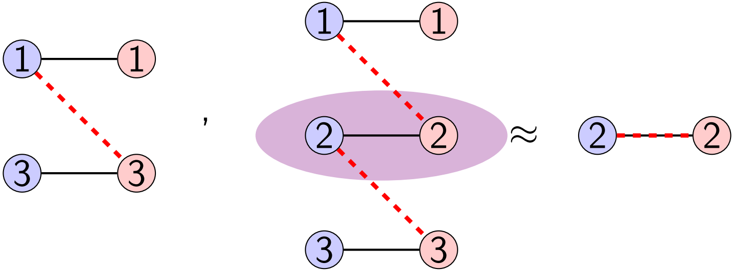


Type 1: **cycle** graph



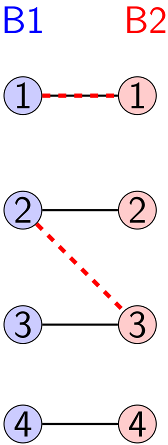
All bunches in any cycle graph (any number of bunches) will follow the same burn-off (ignoring initial variations).

Type 2: **string** graph



All bunches in string graphs have different burn-off but it is a good approximation to consider internal bunches as loops.

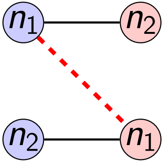
Filling schemes: Standard & BCMS



	Standard	BCMS
1–1	2376	2017
2–2	186	345
3–3	186	345
4–4	0	29

Numbers from: G. Iadarola, HL-LHC filling schemes, 172 WP2

Analytical equations for the simulation code

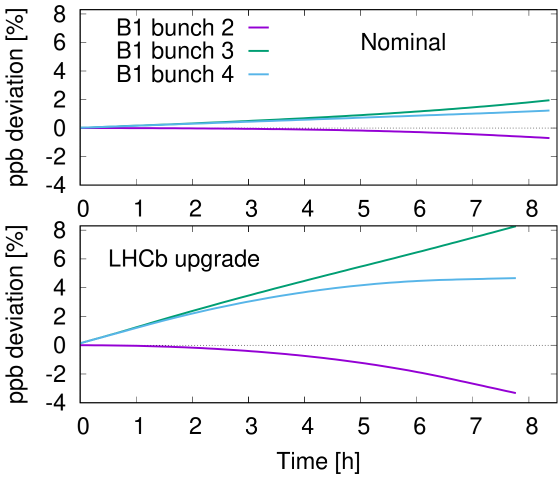


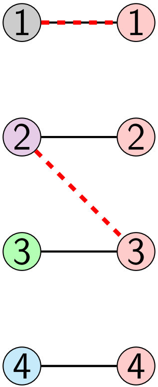
$$\frac{\mathrm{d}n_1}{\mathrm{d}t} = -\sigma n_1 n_2 \; - \sigma_8 n_1^2 \,, \qquad \frac{\mathrm{d}n_2}{\mathrm{d}t} = -\sigma n_1 n_2 \;\;.$$

Defining $n_r = \frac{n_{1,0}}{n_{2,0}}$, $\sigma_r = \frac{\sigma_8}{\sigma} \ll 1$ and $\chi = n_r(1-\sigma_r) - 1$, gives:

$$\begin{aligned} n_1(t) &= n_2(t) n_r \mathrm{e}^{\sigma n_{2,0}\chi t} \\ n_2(t) &= n_{2,0}\frac{\chi}{n_r \mathrm{e}^{\sigma n_{2,0}\chi t} - \sigma_r n_r - 1} \;\;. \end{aligned}$$

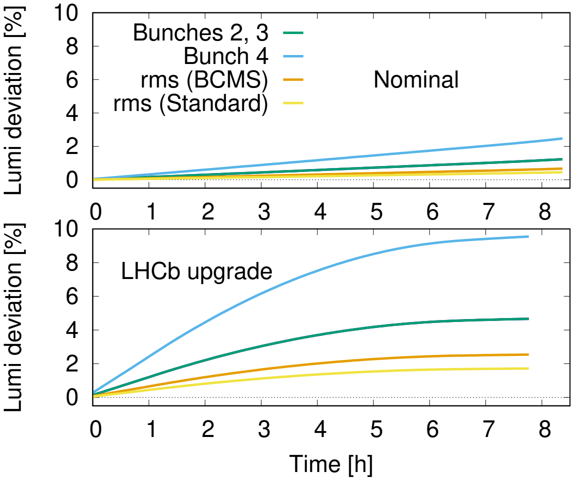
PPB: HL-LHC Nominal & LHCb upgrade

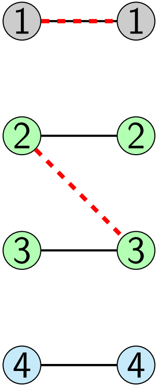




Worst bunch here is 3 in the string of 2 bunches.

Lumi: HL-LHC Nominal & LHCb upgrade





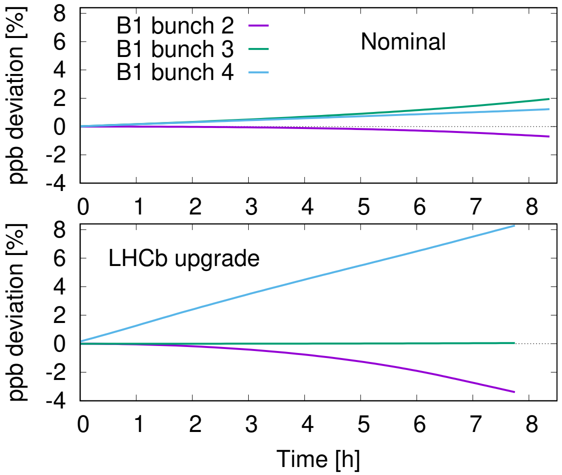
Maximum lumi difference of 10%, rms of about 2%. Is this an issue?

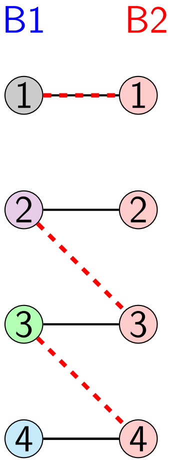
Summary & outlook

- LHCb upgrade II implies a luminosity loss of about 2% for ATLAS/CMS for both nominal and ultimate leveling.
- It introduces bunch-to-bunch luminosity variations from burn-off,
- maximum difference of 10% and rms of about 2%.
- Tolerance was set to 10% rms and injectors could take most of it with 3% rms on bunch intensity and 9% on emittance.
- In 25th EDQ CMS requested a write-up of this effect.
- Need to simulate fills with initial fluctuations from injectors. Other mechanisms to increase bbb variations?
- Will this effect be significant in Run 3? LHCb @ 2×10^{33}, IP1/5 @ 1-2×10^{34}.

Extra slides

String: HL-LHC Nominal & LHCb upgrade





Analytical solution for asymmetric collisions

It is possible to solve the differential equations for burn-off with unequal bunch charges and constant emittance (single IP):

$$\frac{\mathrm{d}n_1}{\mathrm{d}t} = -\sigma_r n_1 n_2 \quad , \qquad \frac{\mathrm{d}n_2}{\mathrm{d}t} = -\sigma_r n_1 n_2 \quad .$$

giving, for $n_{1,0} > n_{2,0}$:

$$\begin{aligned} n_1(t) &= \frac{n_{1,0}\mathrm{e}^{\sigma_r(n_{1,0}-n_{2,0})t}}{\frac{n_{1,0}}{n_{1,0}-n_{2,0}}(\mathrm{e}^{\sigma_r(n_{1,0}-n_{2,0})t}-1)+1} \quad , \\ n_2(t) &= \frac{n_{2,0}}{\frac{n_{1,0}}{n_{1,0}-n_{2,0}}(\mathrm{e}^{\sigma_r(n_{1,0}-n_{2,0})t}-1)+1} \quad . \end{aligned}$$

Burn-off amplification of bunch charge ratio

The ratio n_1/n_2 computed from previous eqs. gives:

$$\frac{n_1(t)}{n_2(t)} = \frac{n_{1,0}}{n_{2,0}} \mathrm{e}^{\sigma_r (n_{1,0} - n_{2,0}) t} \quad ,$$

featuring an exponential divergence!

Therefore the interplay between bunch-by-bunch variations generated by the injectors, IP8 and the exponential amplificaion is of concern.