Performance updates & A first simple model for comparison between SPS flat bottom duration & LHC injection

Performance Results

Reference

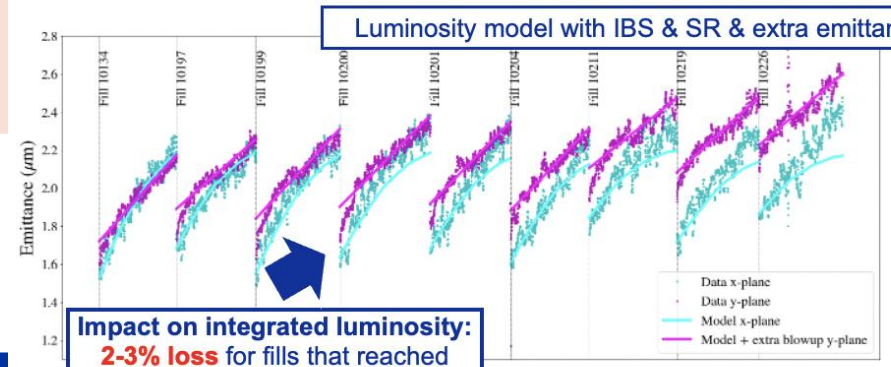
Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics [2]	# colliding IP1/5 bunches [3]	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²) [4]	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8 (1.6)	30	30	off	101	20	6 **[1]**	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2031	0.5	2.2	25	25	on	132	15	136	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2032	0.5	2.2	20	20	on	132	10	154	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2033	0.5	2.2	20	20	on	132	10	152	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
5	2036	0.5	2.2	15	15	on	132	15	152	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2037	0.5	2.2	15	15	on	132	10	195	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2038	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2039	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2040	0.5	2.2	15	15	on	132	15	165	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2041	0.5	2.2	15	15	on	132	10	203	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise

[1]: Reaching 1.6e11 ppb and not 1.8e11 ppb at the end of 2030.
[2]: Same numbers of days as DMR M. Zerlauth, 29 days of ions per year in Run4 and 25 days/year in Run5.
[3]: 25ns_2760b_2748_2492_2574_288bpi_13inj_800ns_bs200ns
[4]: Not considering LHCb upgrade after LS4, up to 3% loss of integrated lumi for ATLAS/CMS.

Reference

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics [2]	# colliding IP1/5 bunches [3]	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²) [4]	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8 (1.6)	30	30	off	101	20	6 **[1]**	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2031	0.5	2.2	25	25	on	132	15	136	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2032	0.5	2.2	20	20	on	132	10	154	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2033	0.5	2.2	20	20	on	132	10	152	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
5	2036	0.5	2.2	15	15	on	132	15	152	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2037	0.5	2.2	15	15	on	132	10	195	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2038	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
	2039	0.5	2.2	15							2574	2.5	H/V	250	2	110	Extra V 0.04 + CC noise
														:50	2	110	Extra V 0.04 + CC noise
														:50	2	110	Extra V 0.04 + CC noise

Emittance growth at collisions



$$\left(\frac{d\epsilon}{dt}\right)_{CC} \approx 0.115\,\mu\text{m/h} \cdot \frac{V_{CC}^2}{(6.8\,\text{MV})^2}\frac{15\,\text{cm}}{\beta^*}$$

Variations

Flat optics

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	**30**	**30**	off	101	20	6	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04
	2031	0.5	2.2	**25**	**25**	on	132	15	136	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
	2032	0.5	2.2	**20→8**	**20→18**	on	132	10	154	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
	2033	0.5	2.2	**20→8**	**20→18**	on	132	10	152	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
5	2036	0.5	2.2	**15→8**	**15→18**	on	132	15	152	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
	2037	0.5	2.2	**15→8**	**15→18**	on	132	10	195	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
	2038	0.5	2.2	**15→8**	**15→18**	on	132	10	198	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
	2039	0.5	2.2	**15→8**	**15→18**	on	132	10	198	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
	2040	0.5	2.2	**15→8**	**15→18**	on	132	15	165	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise
	2041	0.5	2.2	**15→8**	**15→18**	on	132	10	203	2748	2574	2.5	**H/V→V/H**	250	2	110	Extra V 0.04 + CC noise

Variations

Smaller initial emittance at start of SB (~12%)

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (µm)	IP1/5 crossing plane	IP1/5 φ/2 (µrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	30	30	off	101	20	6	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04
	2031	0.5	2.2	25	25	on	132	15	136	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
	2032	0.5	2.2	20	20	on	132	10	154	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
	2033	0.5	2.2	20	20	on	132	10	152	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
5	2036	0.5	2.2	15	15	on	132	15	152	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
	2037	0.5	2.2	15	15	on	132	10	195	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
	2038	0.5	2.2	15	15	on	132	10	198	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
	2039	0.5	2.2	15	15	on	132	10	198	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
	2040	0.5	2.2	15	15	on	132	15	165	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise
	2041	0.5	2.2	15	15	on	132	10	203	2748	2574	**2.5→2.2**	H/V	250	2	110	Extra V 0.04 + CC noise

Variations

Nominal BCMS

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	30	30	off	101	20	6	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04
	2031	0.5	2.2	25	25	on	132	15	136	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
	2032	0.5	2.2	20	20	on	132	10	154	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
	2033	0.5	2.2	20	20	on	132	10	152	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
5	2036	0.5	2.2	15	15	on	132	15	152	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
	2037	0.5	2.2	15	15	on	132	10	195	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
	2038	0.5	2.2	15	15	on	132	10	198	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
	2039	0.5	2.2	15	15	on	132	10	198	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
	2040	0.5	2.2	15	15	on	132	15	165	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise
	2041	0.5	2.2	15	15	on	132	10	203	2748→2736	2574→2370	2.5→2.2	H/V	250	2	110	Extra V 0.04 + CC noise

Variations

Reduced losses

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	30	30	off	101	20	6	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04
	2031	0.5	2.2	25	25	on	132	15	136	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2032	0.5	2.2	20	20	on	132	10	154	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2033	0.5	2.2	20	20	on	132	10	152	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
5	2036	0.5	2.2	15	15	on	132	15	152	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2037	0.5	2.2	15	15	on	132	10	195	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2038	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2039	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2040	0.5	2.2	15	15	on	132	15	165	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2041	0.5	2.2	15	15	on	132	10	203	2748	2574	2.5	H/V	250	2	**110→90**	Extra V 0.04 + CC noise

Variations

"Low-tail" BCMS

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	30	30	off	101	20	6	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04
	2031	0.5	2.2	25	25	on	132	15	136	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2032	0.5	2.2	20	20	on	132	10	154	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2033	0.5	2.2	20	20	on	132	10	152	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
5	2036	0.5	2.2	15	15	on	132	15	152	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2037	0.5	2.2	15	15	on	132	10	195	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2038	0.5	2.2	15	15	on	132	10	198	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2039	0.5	2.2	15	15	on	132	10	198	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2040	0.5	2.2	15	15	on	132	15	165	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise
	2041	0.5	2.2	15	15	on	132	10	203	**2748→2736**	**2574→2370**	**2.5→2.2**	H/V	250	2	**110→90**	Extra V 0.04 + CC noise

Variations

CC emittance growth fully mitigated

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	30	30	off	101	20	6	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2031	0.5	2.2	25	25	on	132	15	136	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2032	0.5	2.2	20	20	on	132	10	154	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2033	0.5	2.2	20	20	on	132	10	152	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
5	2036	0.5	2.2	15	15	on	132	15	152	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2037	0.5	2.2	15	15	on	132	10	195	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2038	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2039	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	Extra V 0.04 +
	2040	0.5	2.2	15	15	on	132	15	165	2748	2574	2.5	H/V	250	2	110	Extra V 0.04
	2041	0.5	2.2	15	15	on	132	10	203	2748	2574	2.5	H/V	250	2	110	Extra V 0.04

Variations

V emittance growth fully mitigated

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	30	30	off	101	20	6	2748	2574	2.5	H/V	250	2	110	-
	2031	0.5	2.2	25	25	on	132	15	136	2748	2574	2.5	H/V	250	2	110	CC noise
	2032	0.5	2.2	20	20	on	132	10	154	2748	2574	2.5	H/V	250	2	110	CC noise
	2033	0.5	2.2	20	20	on	132	10	152	2748	2574	2.5	H/V	250	2	110	CC noise
5	2036	0.5	2.2	15	15	on	132	15	152	2748	2574	2.5	H/V	250	2	110	CC noise
	2037	0.5	2.2	15	15	on	132	10	195	2748	2574	2.5	H/V	250	2	110	CC noise
	2038	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	CC noise
	2039	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	CC noise
	2040	0.5	2.2	15	15	on	132	15	165	2748	2574	2.5	H/V	250	2	110	CC noise
	2041	0.5	2.2	15	15	on	132	10	203	2748	2574	2.5	H/V	250	2	110	CC noise

Variations

All sources of emittance growth at collisions fully mitigated, V emittance shrinking

Run	Year	Efficiency	Bunch intensity (1e11 ppb)	$\beta_{//}^*$ (cm)	β_x^* (cm)	CC	PU_{max}	Days Intensity ramp-up	Days Proton physics	# colliding IP1/5 bunches	# colliding IP8 bunches	Emit start of SB (μm)	IP1/5 crossing plane	IP1/5 φ/2 (μrad)	LHCb L_{peak} (1e33 Hz/cm²)	Losses (mb)	Emittance growth (um/h)
4	2030	0.5	1.8	30	30	off	101	20	6	2748	2574	2.5	H/V	250	2	110	-
	2031	0.5	2.2	25	25	on	132	15	136	2748	2574	2.5	H/V	250	2	110	-
	2032	0.5	2.2	20	20	on	132	10	154	2748	2574	2.5	H/V	250	2	110	-
	2033	0.5	2.2	20	20	on	132	10	152	2748	2574	2.5	H/V	250	2	110	-
5	2036	0.5	2.2	15	15	on	132	15	152	2748	2574	2.5	H/V	250	2	110	-
	2037	0.5	2.2	15	15	on	132	10	195	2748	2574	2.5	H/V	250	2	110	-
	2038	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	-
	2039	0.5	2.2	15	15	on	132	10	198	2748	2574	2.5	H/V	250	2	110	-
	2040	0.5	2.2	15	15	on	132	15	165	2748	2574	2.5	H/V	250	2	110	-
	2041	0.5	2.2	15	15	on	132	10	203	2748	2574	2.5	H/V	250	2	110	-

Reference:

Round optics, 110 mb losses, 2.5 μm initial emittance at SB, 4x72b standard, emittance growth from CC noise and extra in V of Run3 (0.04 μm/h)

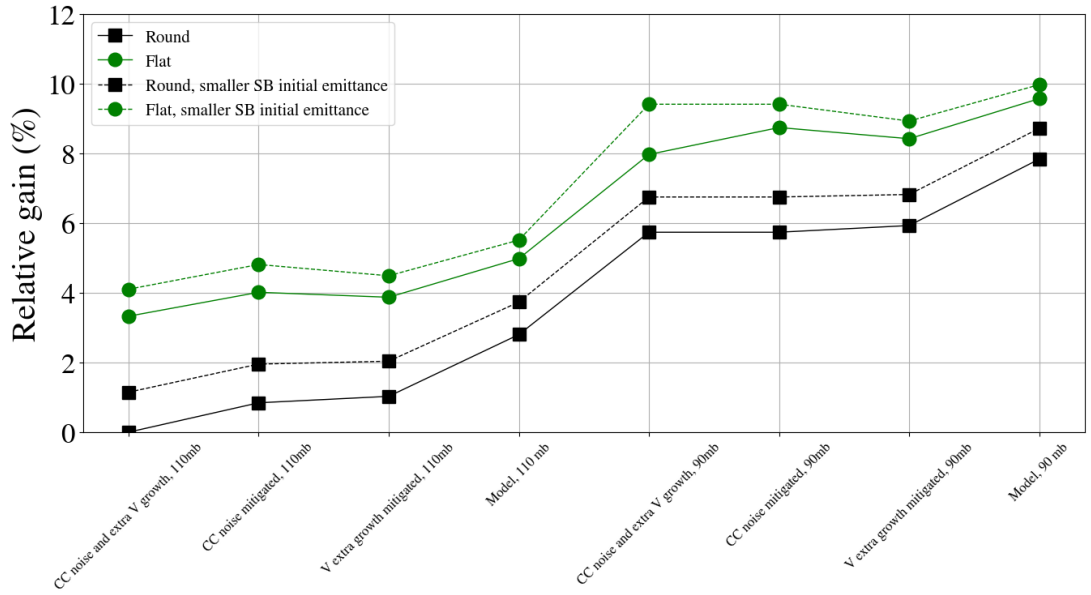
Variations:

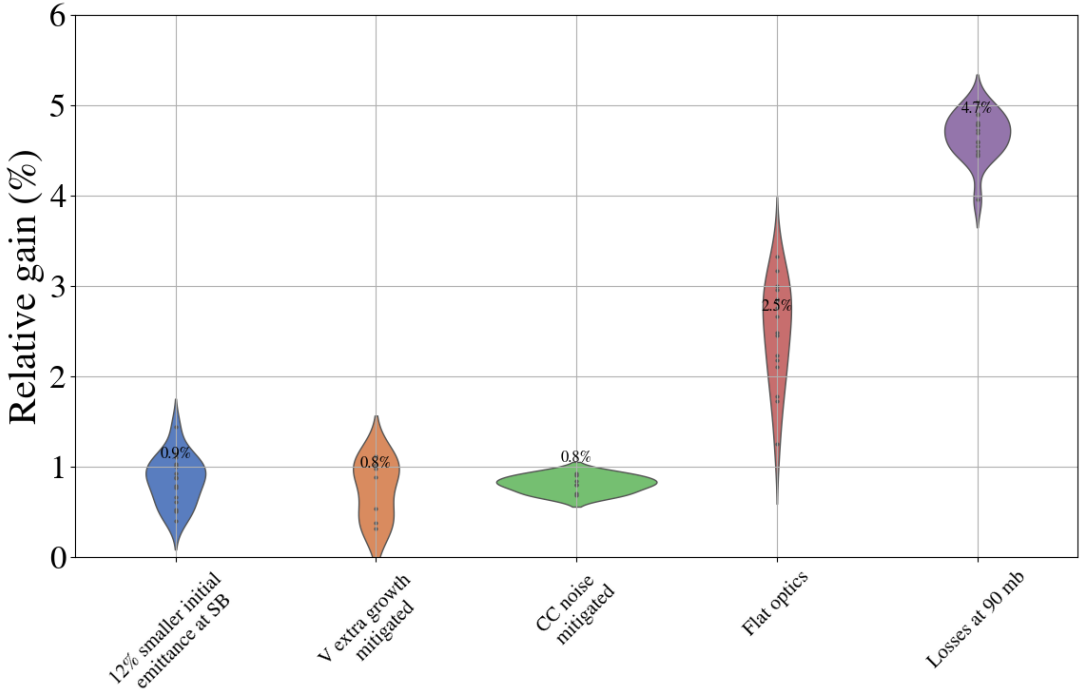
- Flat optics
- Loss reduction to 90 mb
- 2.2 μm initial emittance at SB
- CC noise fully mitigated
- V extra growth fully mitigated
- Nominal BCMS: smaller initial emittance, BCMS filling scheme
- "Low-tail" BCMS: smaller initial emittance, BCMS filling scheme, 90 mb
- **All possible combinations**

Relative yearly & total integrated luminosity

Run	Year	Reference (fb^{-1})	Flat optics	CC noise growth fully mitigated	V emittance growth fully mitigated	Smaller initial emittance at SB	Losses to 90 mb from 110 mb	Nominal BCMS	"Low-tail" BCMS	1. "Low-tail" BCMS & 2. fully mitigated emittance growth at collisions & 3. Flat optics	1. "Low-tail" BCMS & 2. Flat optics
4	2030	**9.2**	0%	0%	4.1%	4.9%	5%	4.6%	10%	14.9%	10%
	2031	**204.9**	0%	1%	1.5%	1.8%	5.2%	1.5%	6.7%	9.4%	6.4%
	2032	**235.9**	6.6%	0.9%	1.2%	1.3%	5%	1.1%	6%	12.9%	11.7%
	2033	**232.9**	6.6%	0.9%	1.2%	1.3%	5%	1.1%	6%	12.9%	11.7%
5	2036	**211.9**	2.9%	0.8%	0.9%	1%	4.7%	0.8%	5.5%	9.2%	7.9%
	2037	**273**	2.8%	0.8%	0.9%	1%	4.7%	0.8%	5.3%	8.8%	7.6%
	2038	**277.6**	2.7%	0.8%	0.9%	1%	4.7%	0.8%	5.3%	8.8%	7.6%
	2039	**277.6**	2.7%	0.8%	0.9%	1%	4.7%	0.8%	5.3%	8.8%	7.6%
	2040	**229.1**	2.9%	0.8%	0.9%	1%	4.7%	0.8%	5.4%	9.1%	7.9%
	2041	**283.9**	2.7%	0.8%	0.9%	1%	4.7%	0.8%	5.3%	8.8%	7.6%
		2236.2	**3.3%**	**0.8%**	**1%**	**1.1%**	**4.8%**	**0.9%**	**5.6%**	**9.8%**	**8.4%**

Relative gain in integrated luminosity





Simple model SPS FB vs LHC injection

	3x36	3x36 + dedicated filling (6s)	3x36 + dedicated filling (9s)	5x36	5x36 + dedicated filling (6s)	5x36 + dedicated filling (9s)	4x72b	4x72b + dedicated filling (9s)	4x72b + dedicated filling (6s)
Bunch intensity (1e11 ppb)	1.6	1.6	1.6	1.6	1.6	1.6	2.3	2.3	2.3
SPS supercycle (s)	36	30	27	43.2	37.2	34.2	39.6	33.6	30.6
Time between B1 injections (s)	72	60	54	86.4	74.4	68.4	79.2	67.2	61.2
Number of injections for IP1/5 colliding bunches	23	23	23	15	15	15	12	12	12
Emittance at start of LHC injection (µm)	1.3	1.3	1.3	1.3	1.3	1.3	2.1	2.1	2.1
Minimum time spent at LHC injection for IP1/5 colliding bunches (mins)	27.6	23 (-4.6 mins)	20.7 (-6.9 mins)	21.6 (-6 mins)	18.6 (-9 min/-3 min)	17.1 (-10.5 min/-4.5 min)	15.84	13.44 (-2.4 mins)	12.24 (-3.4 mins)
Emittance growth due to IBS and unknown blowup (µm/h)	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7
Average/Max emittance at the end of LHC injection	1.47/ 1.62	1.44/1.57	1.43/1.54	1.43/1.55	1.42/1.52	1.41 /1.5	2.2/2.28	2.18/2.26	2.18/2.24
Number of IP1/5 colliding bunches	2340	2340	2340	2484	2484	2484	2748	2748	2748
Turn-around (h)	2.5	2.42	2.385	2.5	2.45	2.425	2.5	2.46	2.44

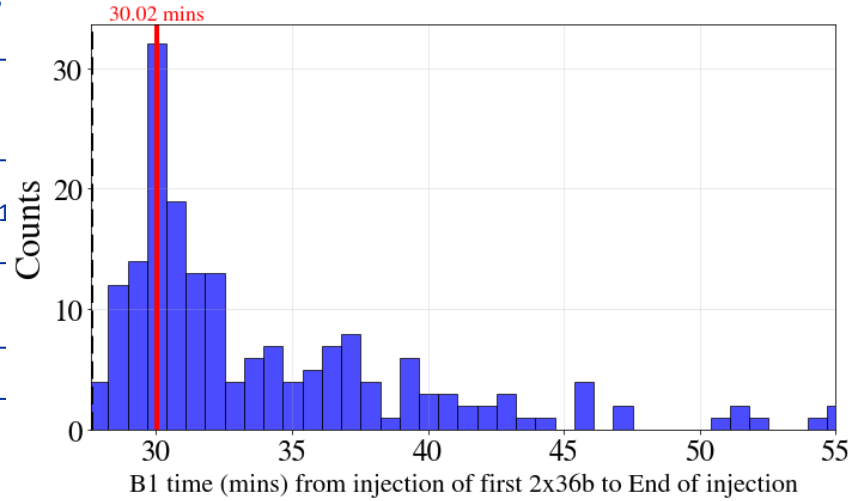
Simple model SPS FB vs LHC injection

	3x36	3x36 + dedicated filling (6s)	3x36 + dedicated filling (9s)	5x36	5x36 + dedicated filling (6s)	5x36 + dedicated filling (9s)	4x72b	4x72b + dedicated filling (9s)	4x72b + dedicated filling (6s)
Bunch intensity (1e11 ppb)	1.6	1.6	1.6	1.6	1.6	1.6	2.3	2.3	2.3
SPS supercycle (s)	36	30	27	43.2	37.2	34.2	39.6	33.6	30.6
Time between B1 injections (s)	72	60	54	86.4	74.4	68.4	79.2	67.2	61.2
Number of injections for IP1/5 colliding bunches	23	Measured by Ingrid		15	15	15	12	12	12
Emittance at start of LHC injection (µm)	1.3	1.3	1.3	1.3	1.3	1.3	2.1	2.1	2.1
Minimum time spent at LHC injection for IP1/5 colliding bunches (mins)	27.6	23 (-4.6 mins)	20.7 (-6.9 mins)	21.6 (-6 mins)	18.6 (-9 min/-3 min)	17.1 (-10.5 min/-4.5 min)	15.84	13.44 (-2.4 mins)	12.24 (-3.4 mins)
Emittance growth due to IBS and unknown blowup (µm/h)	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7
Average/Max emittance at the end of LHC injection	1.47/ 1.62	1.44/1.57	1.43/1.54	1.43/1.55	1.42/1.52	1.41 /1.5	2.2/2.28	2.18/2.26	2.18/2.24
Number of IP1/5 colliding bunches	2340	2340	2340	2484	2484	2484	2748	2748	2748
Turn-around (h)	2.5	2.42	2.385	2.5	2.45	2.425	2.5	2.46	2.44

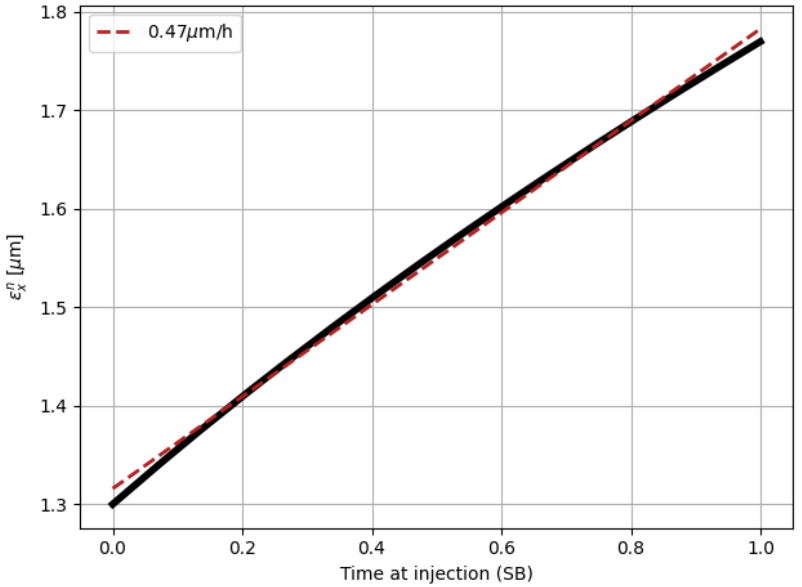
Simple model SPS FB vs LHC injection

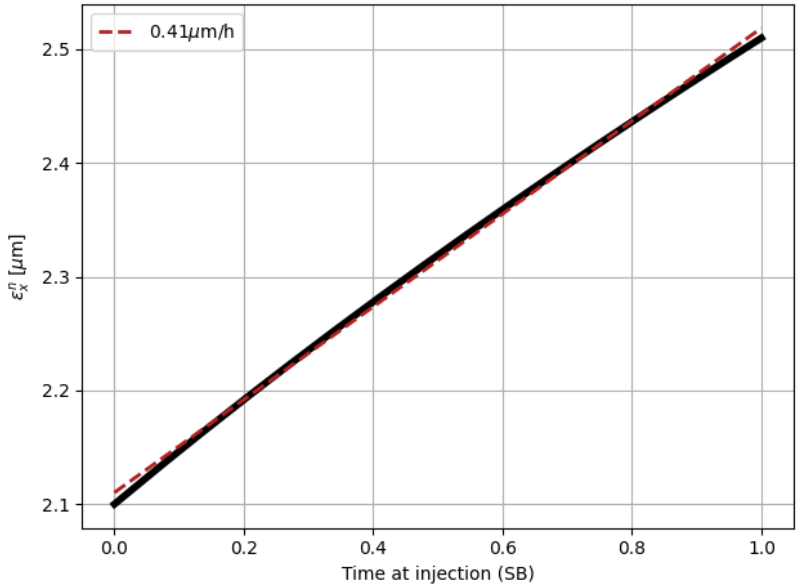
	3x36	3x36 + dedicated filling (6s)	3x36 + dedicated filling (9s)	5x36	5x36 + dedicated filling (6s)	5x36 + dedicated filling (9s)	4x72b	4x72b + dedicated filling (9s)	4x72b + dedicated filling (6s)
Bunch intensity (1e11 ppb)	1.6	1.6	1.6	1.6	1.6	1.6	2.3	2.3	2.3
SPS supercycle (s)	36	30	27	43.2	37.2	34.2	39.6	33.6	30.6
Time between B1 injections (s)	72	60	54	86.4	74.4	68.4	79.2	67.2	61.2
Number of injections for IP1/5 colliding bunches	23	23	23	15	15	15	12	12	12
Emittance at start of LHC injection (µm)	1.3	1.3				1.3	2.1	2.1	2.1
Minimum time spent at LHC injection for IP1/5 colliding bunches (mins)	27.6	23 (4.6 mins)	20.7 (6.9 mins)	21.6	18.0	17.1 10.5 min/-4.5 min)	15.84	13.44 (-2.4 mins)	12.24 (-3.4 mins)
Emittance growth due to IBS and unknown blowup (µm/h)	~0.7					~0.7	~0.7	~0.7	~0.7
Average/Max emittance at the end of LHC injection	1.47/ 1.62	1				1.41 /1.5	2.2/2.28	2.18/2.26	2.18/2.24
Number of IP1/5 colliding bunches	2340					2484	2748	2748	2748
Turn-around (h)	2.5					2.425	2.5	2.46	2.44

Statistics from 2024, time between 2x36b injected and end of injection



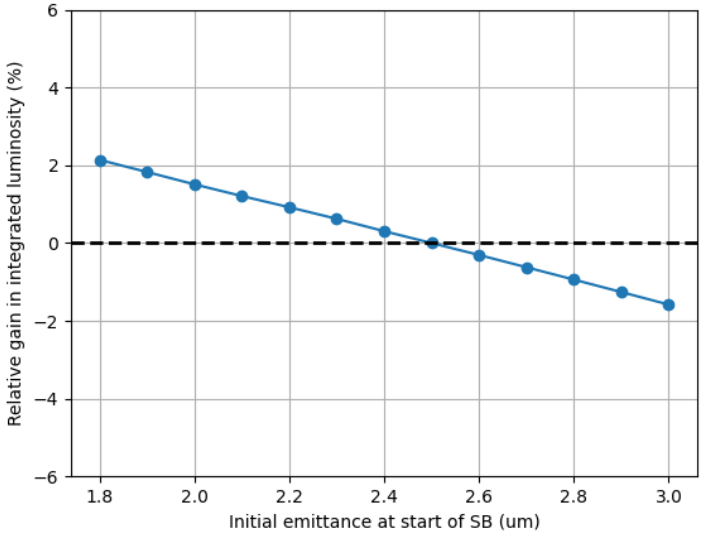
Simple model SPS FB vs LHC injection

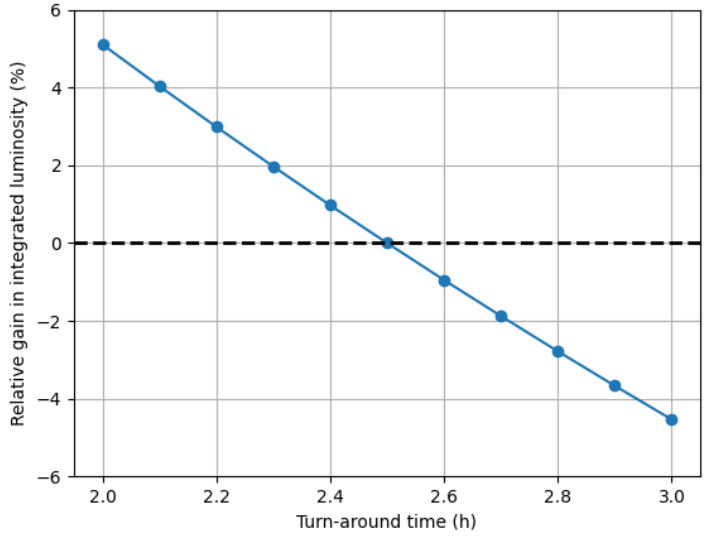




Bunch intensity (1e11 ppb)									2.3
SPS supercycle (s)									30.6
Time between B1 injections (s									61.2
Number of injections for IP1/5 colliding bunches									12
Emittance at start of LHC injecti (μm)									2.1
Minimum time spent at LHC injection for IP1/5 colliding bunches (mins)	27.6	23 (-4.6 mins)	20.7 (-6.9 mins)	(-6 mins)	(-9 min/-3 min)	(-10.5 min/-4.5 min)	15.84	13.44 (-2.4 mins)	12.24 (-3.4 mins)
Emittance growth due to IBS and unknown blowup (μm/h)	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7
Average/Max emittance at the end of LHC injection	1.47/ 1.62	1.44/1.57	1.43/1.54	1.43/1.55	1.42/1.52	1.41 /1.5	2.2/2.28	2.18/2.26	2.18/2.24
Number of IP1/5 colliding bunches	2340	2340	2340	2484	2484	2484	2748	2748	2748
Turn-around (h)	2.5	2.42	2.385	2.5	2.45	2.425	2.5	2.46	2.44

Simple model SPS FB vs LHC injection



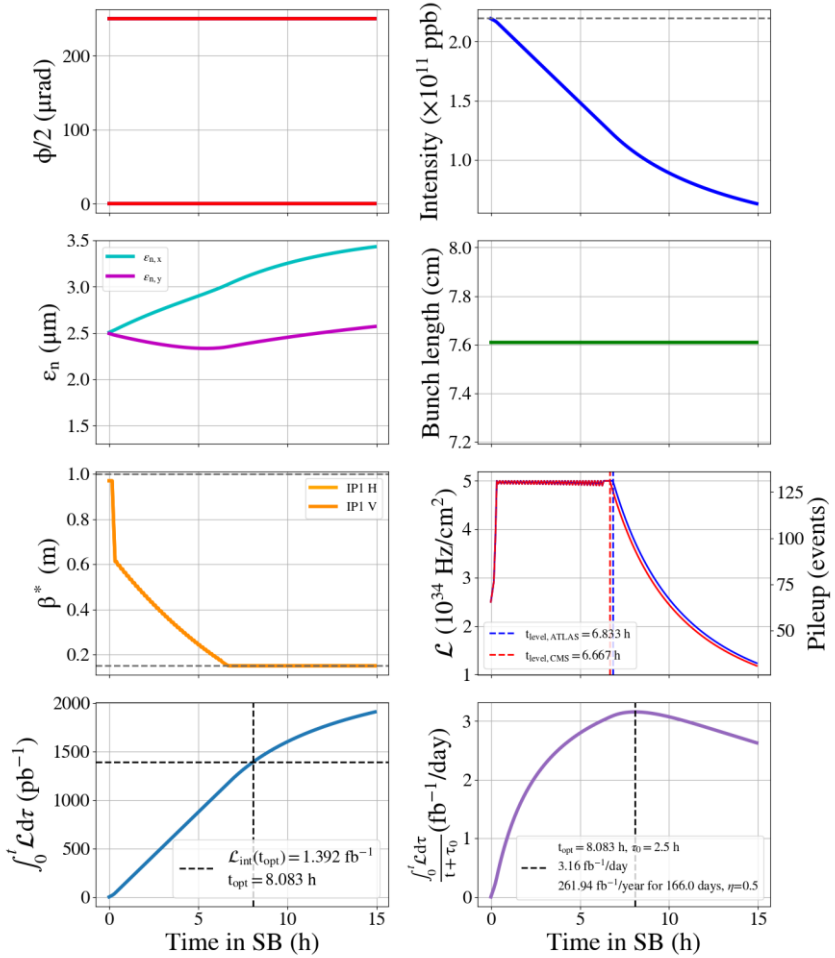


	3x3								4x72b + dedicated filling (6s)
Bunch intensity (1e11 ppb)	1.								2.3
SPS supercycle (s)	3(								30.6
Time between B1 injections (s)	7:								61.2
Number of injections for IP1/5 colliding bunches	2:								12
Emittance at start of LHC injection (μm)	1.								2.1
Minimum time spent at LHC injection for IP1/5 colliding bunches (mins)	27								12.24 (-3.4 mins)
Emittance growth due to IBS and unknown blowup (μm/h)	~0.7	~0.7	~0.7	~0.7	~0.7	~0.7			
Average/Max emittance at the end of LHC injection	1.47/ 1.62	1.44/1.57	1.43/1.54	1.43/1.55	1.42/1.52	1.41 /1.5	2.2/2.28	2.18/2.26	2.18/2.24
Number of IP1/5 colliding bunches	2340	2340	2340	2484	2484	2484	2748	2748	2748
Turn-around (h)	2.5	2.42	2.385	2.5	2.45	2.425	2.5	2.46	2.44

~ 1% smaller emittance at end of injection

Backup

With CC noise



With CC noise & extra V