Parameter update

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What needs to be updated and why?

- Number of bunches & IP1/5 collisions for 25 ns

→ two filling scheme: standard and BCMS (see Appendix 1)

- Take into account the RF curvature of the crab-cavity in the (generalized) geometric loss factor (see Appendix 2)

- Add a few new entries, e.g. for beam energy, PU density, parameters at injection SPS exit)....

- The total number of PU is now (re-)calculated more precisely with an inelastic cross-section of 85 mb (also for nominal), while 100 mb is still assumed for calculating the proton burn off and the resulting levelling time

- The RF parameters (bunch length, energy spread) are reported more precisely following the LHC DR (Vol. 1, Tab. 2.2, p. 4) for a Gaussian bunch (slightly pessimistic for IBS, PU density).

Proposed modif's 1/2

Parameter	Nominal LHC (design report)	HL-LHC 25ns (standard)	HL-LHC 25 ns (BCMS)	HL-LHC 50ns
Beam energy in collision [TeV]	7	7	7	7
N_b	1.15E+11	2.2E+11	2.2E11	3.5E+11
n_b	2808	2748[1]	2604	1404
Number of collisions at IP1 and IP5	2808	2736	2592	1404
N_{tot}	3.2E+14	6.0E+14	5.7E+14	4.9E+14
beam current [A]	0.58	1.09	1.03	0.89
x-ing angle [µrad]	285	590	590	590
beam separation [σ]	9.4	12.5	12.5	11.4
β^* [m]	0.55	0.15	0.15	0.15
ε_n [µm]	3.75	2.50	2.50	3
ε_L [eVs]	2.50	2.50	2.50	2.50
r.m.s. energy spread	1.13E-04	1.13E-04	1.13E-04	1.13E-04
r.m.s. bunch length [m]	7.55E-02	7.55E-02	7.55E-02	7.55E-02
IBS horizontal [h]	80 -> 106	18.5	18.5	17.2
IBS longitudinal [h]	61 -> 60	20.4	20.4	16.1
Piwinski angle	0.65	3.14	3.14	2.87
Geometric loss factor R0 without crab-cavity	0.836	0.305	0.305	0.331
Geometric loss factor R1 with crab-cavity	(0.981)	**0.829**	**0.829**	**0.838**
beam-beam / IP without Crab Cavity	3.1E-03	3.3E-03	3.3E-03	4.7E-03
beam-beam / IP with Crab cavity	3.8E-03	1.1E-02	1.1E-02	1.4E-02
Peak Luminosity without ~~levelling and~~ crab-cavity [$cm^{-2}\ s^{-1}$]	1.00E+34	7.18E+34	6.80E+34	8.44E+34
Virtual Luminosity with crab-cavity: Lpeak*R1/R0 [$cm^{-2}\ s^{-1}$]	(1.18E+34)	19.54E+34	18.52E+34	21.38E+34
Events / crossing without levelling w/o crab-cavity	27	198	198	454
Levelled Luminosity [$cm^{-2}\ s^{-1}$]	-	5.00E+34	5.00E34	2.50E+34
Events / crossing (with levelling and crab-cavities for HL-LHC)	27	138	146	135
Peak line density of pile up event [evt/mm] (max over stable beam)	0.21	1.25	1.31	1.20
Levelling time [h] (assuming no emittance growth)	-	8.3	7.6	18.0

Proposed modif's – 2/2

Parameter	Nominal LHC (design report)	HL-LHC 25ns (standard)	HL-LHC 25 ns (BCMS)	HL-LHC 50ns
Number of collisions at IP2 /IP8	2808	2452/2524	2288/2396	0/1404
N_b at SPS extraction[2]	1.2E+11	2.3E+11	2.3E11	3.68E+11
n_b / injection	288	288	288	144
N_{tot}	3.46E+13	6.62E+13	6.62E+13	5.30E+13
ε_n at SPS extraction [µm][3]	3.40	2.30	2.30	2.70

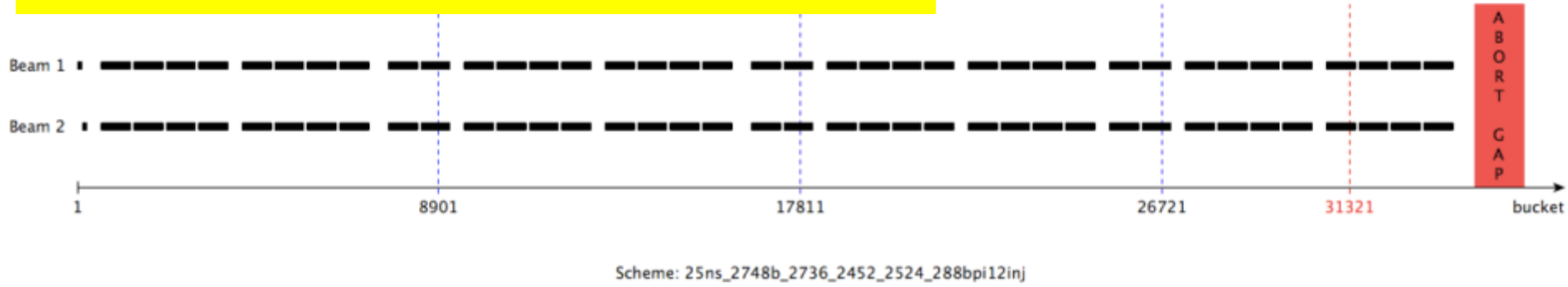
[1]Assuming one less batch from PS for machine protection (pilot, TL steering with 12 nominal bunches) and non-colliding bunches for experiments (background studies,…)

[2]An intensity loss of 5% distributed along the cycle is assumed during the LHC cycle from SPS extraction to collisions in the LHC.

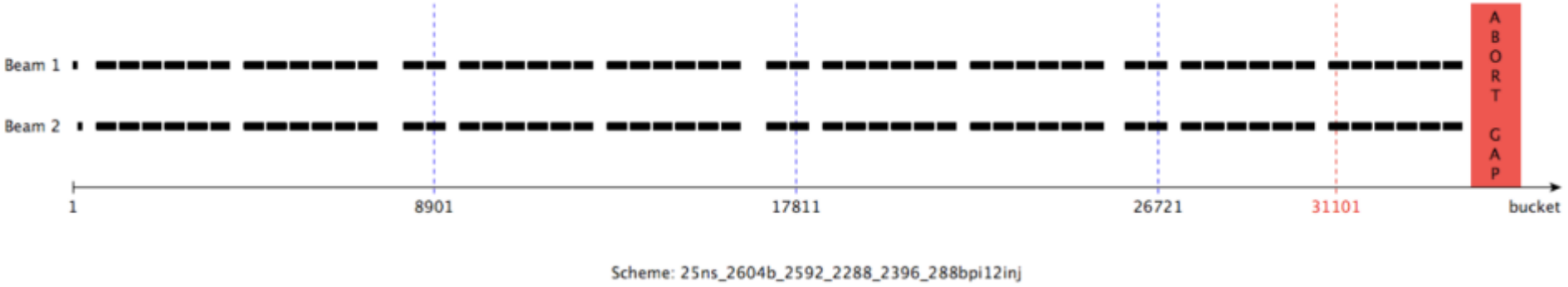
[3]A transverse emittance blow-up of 10 to 15 % on the average of the H/V emittance in addition to that expected from Intra-Beam Scattering (IBS).

Appendix1: 25 ns filling scheme

Standard: 2748 bunches, 2736 collisions at IP1 and IP5



BCMS: 2604 bunches, 2592 collisions at IP1 and IP5



Courtesy of G. Arduini

Appendix2: some formulae (1/2)

- Mathematical formulation for the 2D lumi density

$$\frac{\partial^2 L}{\partial z \partial t} = L_0 \frac{2c}{R} \times k(z;t) \times \rho(z-ct)\rho(z+ct)$$

with

→ L_0: Instantaneous lumi, e.g. 5E34 when levelling

→ ρ: Normalized longitudinal distribution ($\int du\, \rho(u) \equiv 1$)

→ $0 \leq k(z;t) \leq 1$: **kernel function** depending on β*, X-angle, crab-cavity settings (see next slide)

→ R : Generalized luminosity loss factor defined such that $\iint \frac{\partial^2 L}{\partial z \partial t} \equiv L_0$

$$R = 2c \times \iint dz dt\, k(z;t) \times \rho(z-ct)\rho(z+ct) \leq 1$$

Appendix2: some formulae (2/2)

→ The **kernel function** with CCs in crossing-plane (no CK scheme) and hour glass effect

$$k(z;t) = \frac{\exp\left\{-\left[\frac{\Theta_X z - \frac{\alpha_X}{\omega/c}\cos(\omega t)\,\sin(\omega z/c)}{\beta_X\sqrt{[1+(z/\beta_X)^2]}}\right]^2\right\}}{\sqrt{[1+(z/\beta_X)^2][1+(z/\beta_{||})^2]}}$$

With

→ Θ_X: Normalized half-crossing angle (in units of σ)

→ α_X: Normalized rotation induced by the crab-cavity ($\alpha_X = \Theta_X$ for full crabbing)

→ β_X and $\beta_{||}$: beta* in the crossing and parallel separation plane

→ $\omega = 2\pi \times 400\ \mathrm{MHz}$: crab-cavity frequency