


Update of HL-LHC parameters

R. Tomás, L. Medina for WP2

September 29, 2016

HL-LHC current table (link)

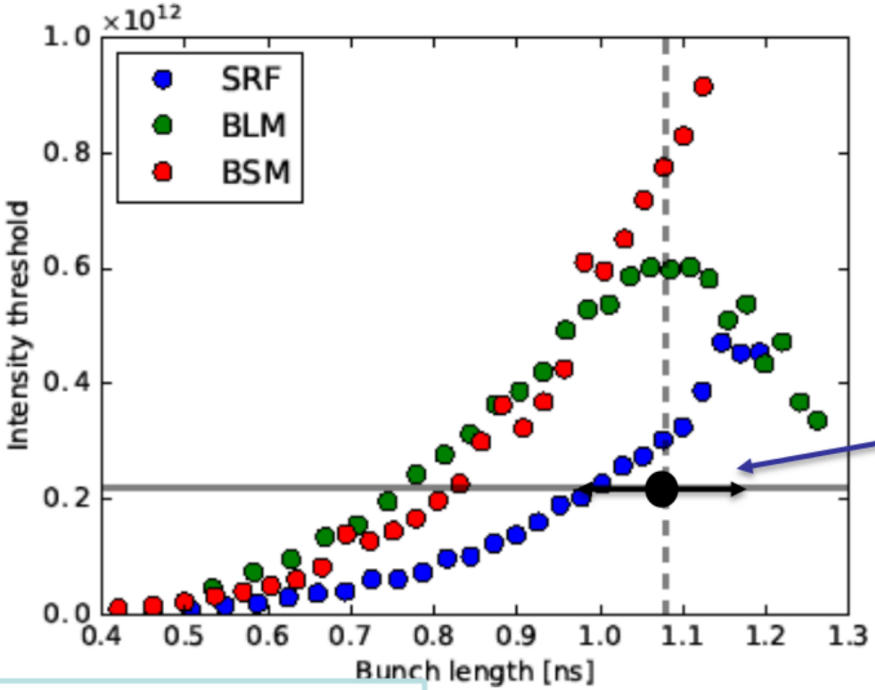
Parameter	Nominal LHC (design	HL-LHC 25ns (standard)	HL-LHC 25ns (BCMS) [9]	HL-LHC 8b+4e [12]
Beam energy in collision [TeV]	7	7	7	7
N_b	1.15E+11	2.2E+11	2.2E+11	2.3E+11
n_b	2808	2748	2604	1968
Number of collisions in IP1 and IP5 [1]	2808	2736	2592	1960
N_{tot}	3.2E+14	6.0E+14	5.7E+14	4.5E+14
beam current [A]	0.58	1.09	1.03	0.82
x-ing angle [µrad]	285	590	590	554 [10]
beam separation [σ] [11]	9.4	12.5	12.5	12.5 [10]
β^* [m]	0.55	0.15	0.15	0.15
ε_n [µm]	3.75	2.50	2.50	2.20
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	13.1
IBS longitudinal [h]	61 -> 60	20.4	20.4	17.6
Piwinski parameter	0.65	3.14	3.14	3.14
Total loss factor R0 without crab-cavity	0.836	0.305	0.305	0.304
Total loss factor R1 with crab-cavity [13]	(0.981)	0.829	0.829	0.828
beam-beam / IP without Crab Cavity	3.1E-03	3.3E-03	3.3E-03	3.9E-03
beam-beam / IP with Crab cavity [13]	3.8E-03	1.1E-02	1.1E-02	1.3E-02
Peak Luminosity without crab-cavity [cm^{-2} s^{-1}]	1.00E+34	7.18E+34	6.80E+34	6.38E+34
Virtual Luminosity with crab-cavity: Lpeak*R1/R0	(1.18E+34)	19.54E+34	18.52E+34	17.40E+34
Events / crossing without levelling and without crab-cavity	27	198	198	246
Levelled Luminosity [cm^{-2} s^{-1}]	-	5.00E+34 [5]	5.00E+34	3.63E+34
Events / crossing (with leveling and crab-cavities for	27	138	146	140
Peak line density of pile up event [event/mm] (max over	0.21	1.25	1.31	1.28
Leveling time [h] (assuming no emittance growth) [8, 13]	-	8.3	7.6	9.5

What changed?

- ★ Rebaselining: β^*=20 cm, 2 CCs, crossing angle reduces to keep separation of 12.5σ. Peak pile up density enforced $\leq$ 1.3 mm^{-1}
- ★ RF needs margin in the bunch length to ensure stability $\rightarrow$ 1.2 ns (σ =9 cm)

E. Shaposhnikova, 78th WP2 Meeting

Longitudinal beam stability in HL-LHC
400 MHz & (400 MHz + 800 MHz) RF



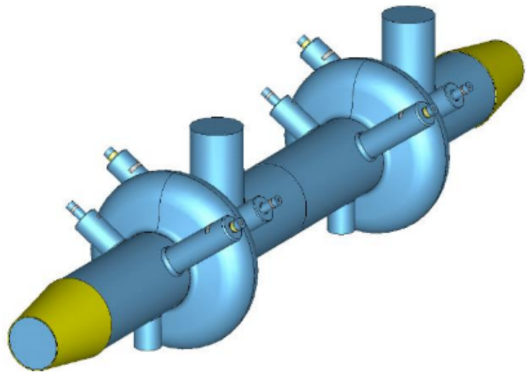
J. E. Muller, PhD thesis

E=7 TeV, V_{400} = 16 MV, V_{800} = 4 MV
ImZ/n ~ 0.11 Ohm (N. Biancacci et al.)
→ 1.0 ns bunches are unstable
→ Voltage of 4 MV @ 800 MHz would be sufficient for stability of bunches > 0.85 ns (as now)

10% spread in bunch length

- Controlled longitudinal BUP, if done too close to instability threshold, may excite dipole motion
- SR leads to bunch shrinkage

→ 1.3 ns nominal average bunch length in a single



Cavity design: T. Roggen & Y. Shashkov

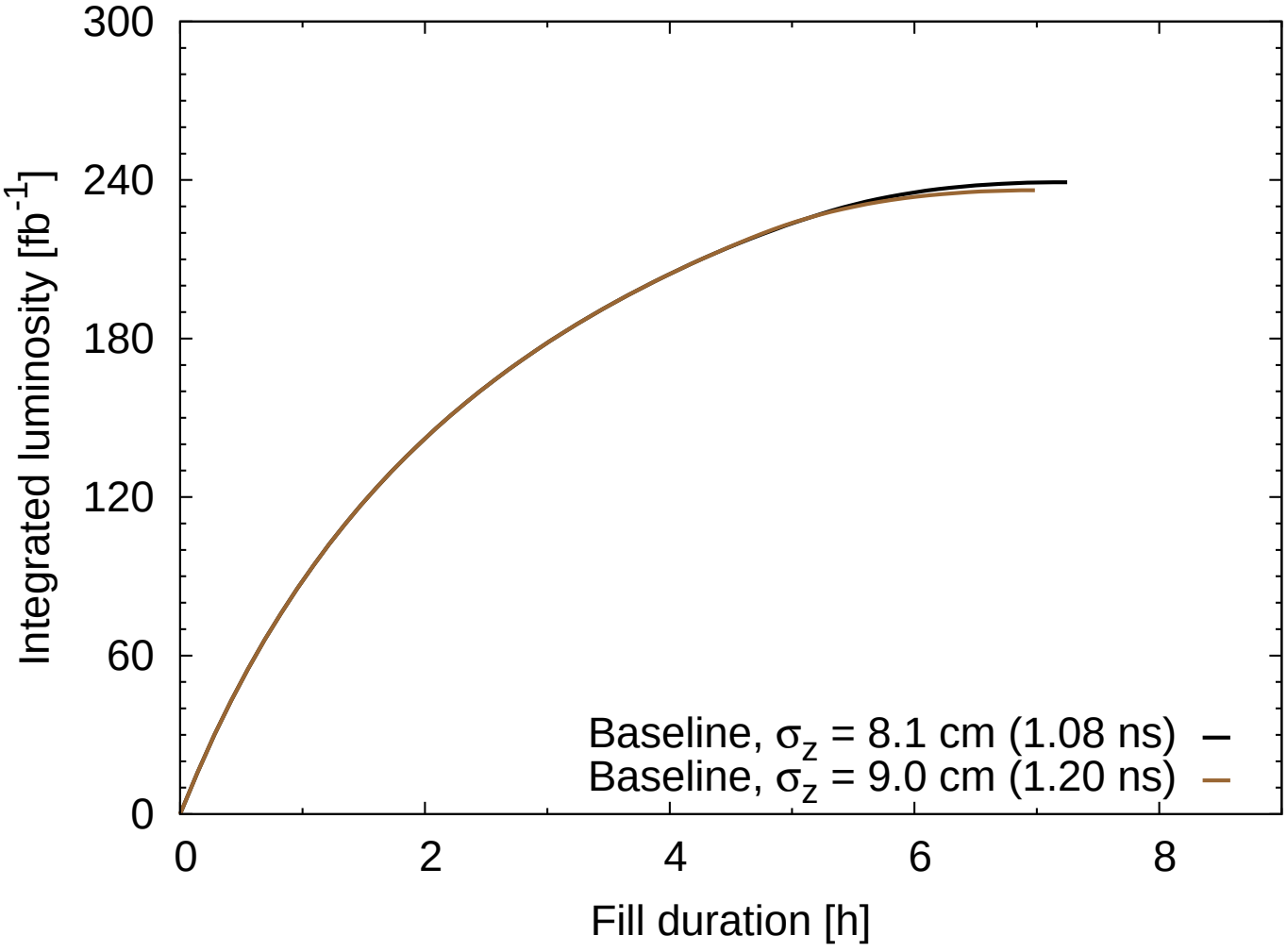
Parameter table I

	Base	8b+4e
E [TeV]	7	7
N_b [10^{11}]	2.2	2.3
$n_{bunches}$	2748	1968
IP1&5 colls	2736	1960
N_{tot} [10^{14}]	6.04	4.53
beam current [A]	1.10	0.82
x-sing angle [μrad]	512	480
beam separation [σ]	12.5	12.5
β^* [m]	0.2	0.2
ϵ_n [μm]	2.5	2.5
ϵ_L [eVs]	2.5	2.5
E spread [10^{-4}]	1.08	1.08
bunch length [cm]	8.1	8.1
IBS horizontal [h]	18.8	13.6
IBS longitudinal [h]	20.6	16.9
Piwinski parameter	2.5	2.5

Parameter table II

	base	8b+4e
Loss factor no CC	0.37	0.37
Loss factor with CC	0.71	0.74
beam-beam no CC [10^{-3}]	3.9	4.7
beam-beam with CC [10^{-2}]	0.89	1.1
Peak Lumi without CC [$cm^{-2}s^{-1}10^{34}$]	6.52	5.8
Virtual lumi with CC [$cm^{-2}s^{-1}10^{35}$]	1.26	1.16
Pile-up without lev CC	172	213
Leveled lumi [$cm^{-2}s^{-1}10^{34}$]	5.3	3.8
Pile-up with lev CC	140	140
Peak pile-up density	1.3	1.3
Leveling time [h]	5.3	6.2
Number of collisions IP2/IP8	2452/2524	1163/1868
N_b at injection [10^{11}]	2.3	2.4
n_b per injection	288	224
N_{tot} per injection [10^{13}]	6.6	5.4
Emittance at injection [μm]	2	1.7

Effect of bunch length 1.08⟶1.2ns



Luminosity loss of 1.3%

Parameter table I (1.2ns)

	Base	8b+4e
E [TeV]	7	7
N_b [10^{11}]	2.2	2.3
$n_{bunches}$	2748	1968
IP1&5 colls	2736	1960
N_{tot} [10^{14}]	6.04	4.53
beam current [A]	1.10	0.82
x-sing angle [μrad]	512	480
beam separation [σ]	12.5	12.5
β^* [m]	0.2	0.2
ϵ_n [μm]	2.5	2.5
ϵ_L [eVs]	3	3
E spread [10^{-4}]	1.2	1.2
bunch length [cm]	9.0	9.0
IBS horizontal [h]	22.1	16.1
IBS longitudinal [h]	29.5	24.2
Piwinski parameter	2.8	2.8

Parameter table II (1.2ns)

	base	8b+4e
Loss factor no CC	0.34	0.34
Loss factor with CC	0.67	0.69
beam-beam no CC [10^{-3}]	3.6	4.3
beam-beam with CC [10^{-2}]	0.86	1.1
Peak Lumi without CC [$cm^{-2}s^{-1}10^{34}$]	5.95	5.3
Virtual lumi with CC [$cm^{-2}s^{-1}10^{35}$]	1.17	1.09
Pile-up without lev CC	157	195
Leveled lumi [$cm^{-2}s^{-1}10^{34}$]	5.3	3.8
Pile-up with lev CC	140	140
Peak pile-up density	1.3	1.3
Leveling time [h]	4.7	5.9
Number of collisions IP2/IP8	2452/2524	1163/1868
N_b at injection [10^{11}]	2.3	2.4
n_b per injection	288	224
N_{tot} per injection [10^{13}]	6.6	5.4
Emittance at injection [μm]	2	1.7