

Table 7: Summary comparison table of the key parameters between the different sextupole lattice options for HL-LHC.

Parameters	Baseline	No MS10	No MS14F	No MS14F & MS14D
Q_x, Q_y	62.31, 60.32	62.31, 60.32	62.31, 60.32	62.31, 60.32
$\beta_{x,y}^*$ (IP1-5) [cm]	15	15	15	15
$\Delta\mu_x^{IP1-5}$ B1/B2 [2π]	31.430 / 31.275	31.378 / 31.275	31.425 / 31.278	31.380 / 31.275
$\Delta\mu_y^{IP1-5}$ B1/B2 [2π]	30.381 / 30.919	30.330 / 30.369	30.761 / 30.421	30.381 / 30.919
Q_x/ϵ_x (MO = -570 A) B1/B2 [10^5m^{-1}]	-3.69 / -4.10	-3.56 / -3.81	-3.95 / -4.21	-3.91 / -4.24
Q_y/ϵ_y (MO = -570 A) B1/B2 [10^5m^{-1}]	-3.33 / -3.35	-3.21 / -3.27	-3.41 / -3.37	-3.35 / -3.39
Q_x/ϵ_y (MO = -570 A) B1/B2 [10^5m^{-1}]	1.59 / 1.64	1.55 / 1.75	1.85 / 1.85	1.59 / 1.61
Horizontal chrom. β -beating IP 1/2/5/8 IP 3/4/6/7 $\delta_p=3\times 10^{-4}$ (Beam 1) [%]	0.6 /0.005/ 1.0 /1.7 0.9/0.4/1.8/1.1	0.8 /0.003/ 1.3 /1.7 0.9/0.3/1.2/1.5	0.2 /0.3/ 1.8 /0.8 1.5/2.0/1.8/2.4	0.1 /0.5/ 0.9 /2.2 1.2/1.0/0.5/2.2
Horizontal chrom. β -beating IP 1/2/5/8 IP 3/4/6/7 $\delta_p=3\times 10^{-4}$ (Beam 2) [%]	0.9 /1.2/ 0.2 /0.4 0.4/0.3/0.2/1.7	0.3 /0.3/ 1.1 /0.2 0.3/1.4/1.0/1.0	0.8 /2.6/ 2.2 /2.7 2.8/0.06/2.2/3.5	1.0 /1.4/ 0.3 /0.4 0.4/0.2/0.01/1.6
Vertical chrom. β -beating IP 1/2/5/8 IP 3/4/6/7 $\delta_p=3\times 10^{-4}$ (Beam 1) [%]	0.3 /0.7/ 0.8 /1.9 0.7/0.5/2.4/0.2	1.4 /2.3/ 2.5 /2.2 2.4/1.4/3.6/3.0	2.3 /0.08/ 0.5 /2.7 0.3/0.8/3.0/4.2	3.7 /4.0/ 4.6 /2.8 4.2/1.0/6.4/5.8
Vertical chrom. β -beating IP 1/2/5/8 IP 3/4/6/7 $\delta_p=3\times 10^{-4}$ (Beam 2) [%]	2.0 /1.6/ 0.9 /0.6 0.9/2.3/1.2/1.6	0.4 /2.2/ 2.2 /2.1 1.3/1.4/0.9/1.7	0.1 /0.7/ 1.5 /0.03 0.4/1.2/0.2/0.2	4.2 /3.1/ 1.7 /2.1 3.4/1.7/1.7/0.5
Average DA (B1/B2) 60 seeds, 10^5 turns, with field imperfections, MO=-570 A $Q'=15$, Xing = 295 μrad [σ]	12.9 / 12.2	11.5 / 11.2	12.0 / 12.5	12.4 / 12.1
Minimum DA (B1/B2) 60 seeds, 10^5 turns, with field imperfections, MO=-570 A $Q'=15$, Xing = 295 μrad [σ]	10.9 / 10.4	9.0 / 8.6	9.5 / 10.0	10.1 / 10.0

Table 8: Summary comparison table between the different sextupole lattice options for HL-LHC.

Optics	Pros	Cons
Baseline	<ul style="list-style-type: none"> • Gain of 20% of sextupole strength • Largest DA solution for HL-LHC 	<ul style="list-style-type: none"> • Installation of 4 additional sextupole • Large hardware modification
No MS10	<ul style="list-style-type: none"> • Same sext. configuration as LHC • No intervention required 	<ul style="list-style-type: none"> • Large geometrical aberrations • Worst DA solution • Max. $\Delta DA_{\min} = -1.9\sigma$ w.r.t to Baseline
No MS14F	<ul style="list-style-type: none"> • No installation required (2 sext. unplugged) • Better DA than No MS10 	<ul style="list-style-type: none"> • Change in optics ($\Delta\mu_y^{IR1\&5} = -\frac{\pi}{2}$) • Max. $\Delta DA_{\min} = -1.4\sigma$ w.r.t to Baseline
No MS14F & MS14D	<ul style="list-style-type: none"> • No installation required (4 sext. unplugged) • No change in optics • Best DA solution without MS10 	<ul style="list-style-type: none"> • +20% in total sextupole strength required • Worst vertical Chromatic β-beating • Max. $\Delta DA_{\min} = -0.8\sigma$ w.r.t to Baseline

Table 9: IR6 main parameters comparison for the different proposed optics.

Param. B1 / B2	Target values	Baseline	No MS14F	No MS14F&MS14D
$\Delta\mu_{x,\text{MKD-TCDQ}}$ [°]	$90^\circ \pm 4^\circ$	86.3 / 93.6	91.5 / 93.6	86.3 / 93.6
β_y^{TCDQ} [m]	≥ 200	238.3 / 260.6	283.2 / 200.0	238.3 / 271.0
β_x^{TCDQ} [m]	-	736.4 / 473.3	513.9 / 460.0	736.4 / 474.6
β_y^{TCDQ} [m]	≥ 145	180.5 / 145.0	145.0 / 176.2	180.5 / 145.0
$ \text{D}_{x,\text{TCDQ}} $ [m]	-	0.6 / 0.4	0.02 / 0.38	0.5 / 0.42
$\text{Gap}_{\text{TCDQ},\text{min}}$ [mm]	≥ 3	4.0 / 3.05	3.3 / 2.99	4.0 / 3.05
β_x^{TDE} [km]	≥ 4	6.37 / 4.92	5.06 / 4.83	6.37 / 4.93
β_y^{TDE} [km]	≥ 3.2	3.36 / 7.23	8.2 / 6.33	3.36 / 7.72
$(\beta_x\beta_y)^{\frac{1}{2}}_{\text{TDE}}$ [km]	≥ 4.5	4.62 / 5.98	6.44 / 5.53	4.62 / 6.17
$ \Delta\mu_{x,\text{MKD-TCT,IP1}} $ [°]	≤ 20	19.8 / 18.8	9.8 / 18.6	5.0 / 19.6
$ \Delta\mu_{x,\text{MKD-TCT,IP5}} $ [°]	≤ 30	29.5 / 31.4	36 / 30.1	29.5 / 31.9
Q5.L6 [T/m]	160	163 / -164	160 / -162	163 / -165
Q5.R6 [T/m]	160	-159 / 151	-161 / 151	-159 / 152