Flat beam options

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main reference: S. Fartoukh, Breaching the Phase I optics limitations for the HL-LHC, Chamonix workshop, 2011.

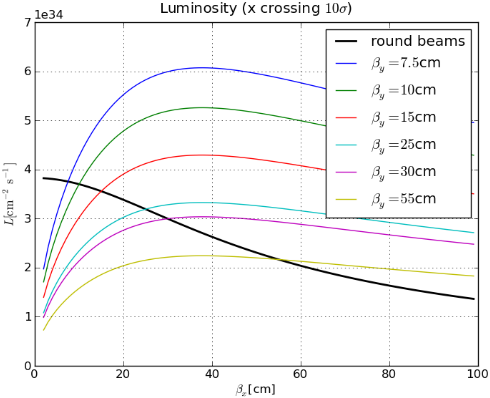
Luminosity formula

$$L = L_0 F_{\mathrm{geo}} F_{\mathrm{hr}} \qquad L_0 = \frac{N_b^2 n_b f_{\mathrm{rev}}}{4\pi\epsilon\sqrt{\beta_x^* \beta_y^*}} \qquad F_{\mathrm{geo}} = \frac{1}{\sqrt{1 + \left(\frac{\sigma_z d_{\mathrm{s}}}{2\beta_x^*}\right)^2}}$$

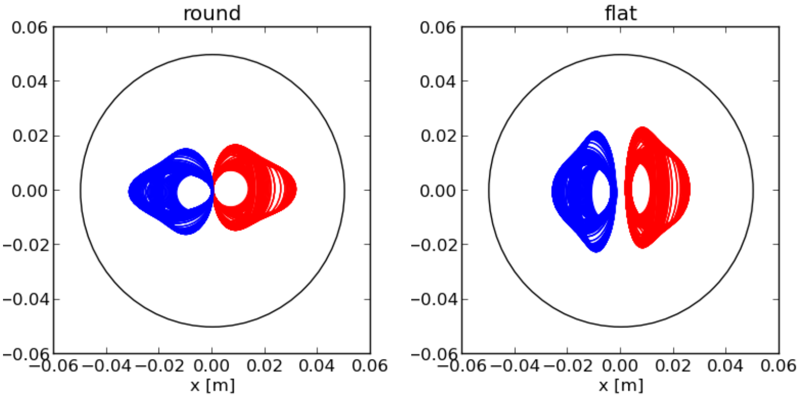
$$\theta_{\mathrm{c}} = d_{\mathrm{s}}\sqrt{\epsilon/\beta_x^*} \qquad \sigma = \sqrt{\epsilon\beta}$$

Round beam saturation

For low β^* in the crossing plane, the increase of the crossing angle limits the gain in luminosity.



Efficient use of the aperture



5σ projection in the triplet area for β^*=(15cm,15cm) and (7.5cm,30cm).

Low β^* for HL-LHC

$$L = L_0 F_{\text{geo}} F_{\text{hr}} \qquad L_0 = \frac{N_b^2 n_b f_{\text{rev}}}{4\pi\epsilon\sqrt{\beta_x^*\beta_y^*}} \qquad F_{\text{geo}} = \frac{1}{\sqrt{1+\left(\frac{\sigma_z d_{\text{s}}}{2\beta_x^*}\right)^2}}$$

$$\theta_{\text{c}} = d_{\text{s}}\sqrt{\epsilon/\beta_x^*} \qquad \sigma = \sqrt{\epsilon\beta}$$

quantity	unit	25ns	25ns flat
f_{rev}	Hz	11245.5	11245.5
N_b	10^{11}	2.2	2.2
n_b		2808	2808
σ_z	cm	7.55	7.55
ϵ	$\mu\text{rad}/\gamma$	2.5	2.5
β^*	cm	15	7.5/30
d_{s}		12.5	15
θ_c	μrad	590	500
F_{geo}		0.300	0.49
L_0	$10^{34}/(\text{cm}^2\,\text{s})$	24.1	24.1
L	$10^{34}/(\text{cm}^2\,\text{s})$	7.3	10.8

round beams reach

ap. [1] [mm]	grad [T/m]	lengths [2] [m]	β^* [cm]	α [σ]	N1 [3] [ppb]	N2 [4] [ppb]	t [5] [h]
140	150	8.00, 6.8	15.0	5	2.01E11	1.29E11	5.64
140	150	8.00, 6.8	32.5, 7.5	6.5	1.73E11	n/a	n/a
140	150	8.00, 6.8	33.0, 9.0	10	2.10E11	1.80E11	2.4
140	100	10.5, 8.8	19.0	5	2.05E11	1.42E11	4.89
140	100	10.5, 8.8	33.5, 10.0	6.5	1.83E11	n/a	n/a
140	100	10.5, 8.8	34.3, 12.0	9.5	2.18E11	1.91E11	2.2

[1] without shielding

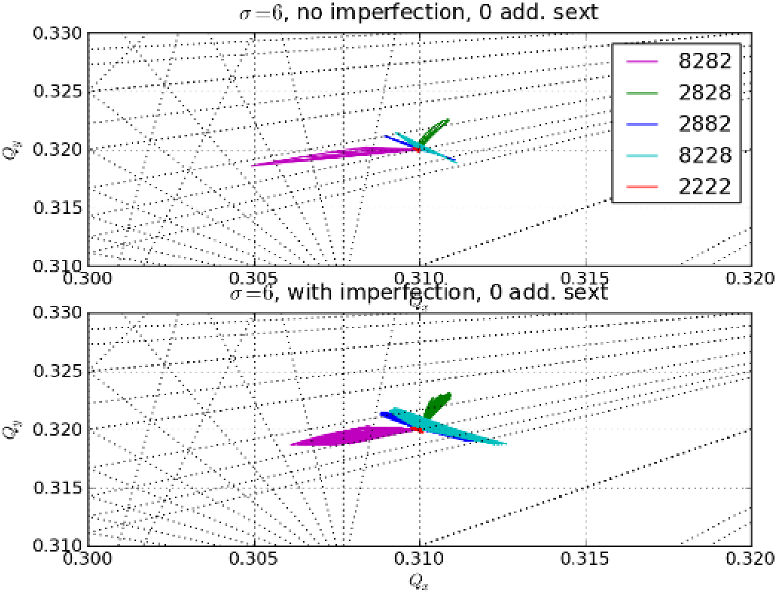
[2] Length of Q1-Q3, Q2a-Q2b

[3] Bunch intensity (and otherwise nominal parameters) at the beginning of the leveling (5σ half crossing angle) to reach $5 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

[4] Bunch intensity (and otherwise nominal parameters) at the end of the leveling (head-on) to reach $5 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

[5] leveling time

Optics implications



Optics implications

	Minimum DA (σ)		
Optics	no sext. layout change	+1 sext.	-1 sext.
2828	7.6	9.3	9.3
2882	8.3	**11.0**	**11.4**
8228	9.9	**11.3**	**10.8**
8282	11.1	8.9	8.8

Conclusion

- flat β^* makes an efficient use of the aperture for luminosity
- cannot fully restore the geometric loss factor
- the ATS optics enable the production of the very low β^* although geometric aberration are enhanced compared to an equivalent round optics
- the h-v crossing does not fully compensate the LR beam beam effect, larger beam beam separation needed.
- backup solution in case crab cavities cannot meet the requirements