increasing the LHC luminosity by reducing the transverse emittance
-
Roland’s proposal

fundamental equations of LHC performance

$$\Delta Q_{bb} \cong -\frac{N_b}{\varepsilon_N} \frac{r_p}{2\pi\sqrt{1+\phi^2}}$$

$$\phi = \theta\sigma_Z /(2\sigma^*)$$

$$L = \frac{f_{rev}\gamma}{2r_p} n_b \frac{1}{\beta^*} N_b \Delta Q_{bb} F_{profile} F_{hg}$$

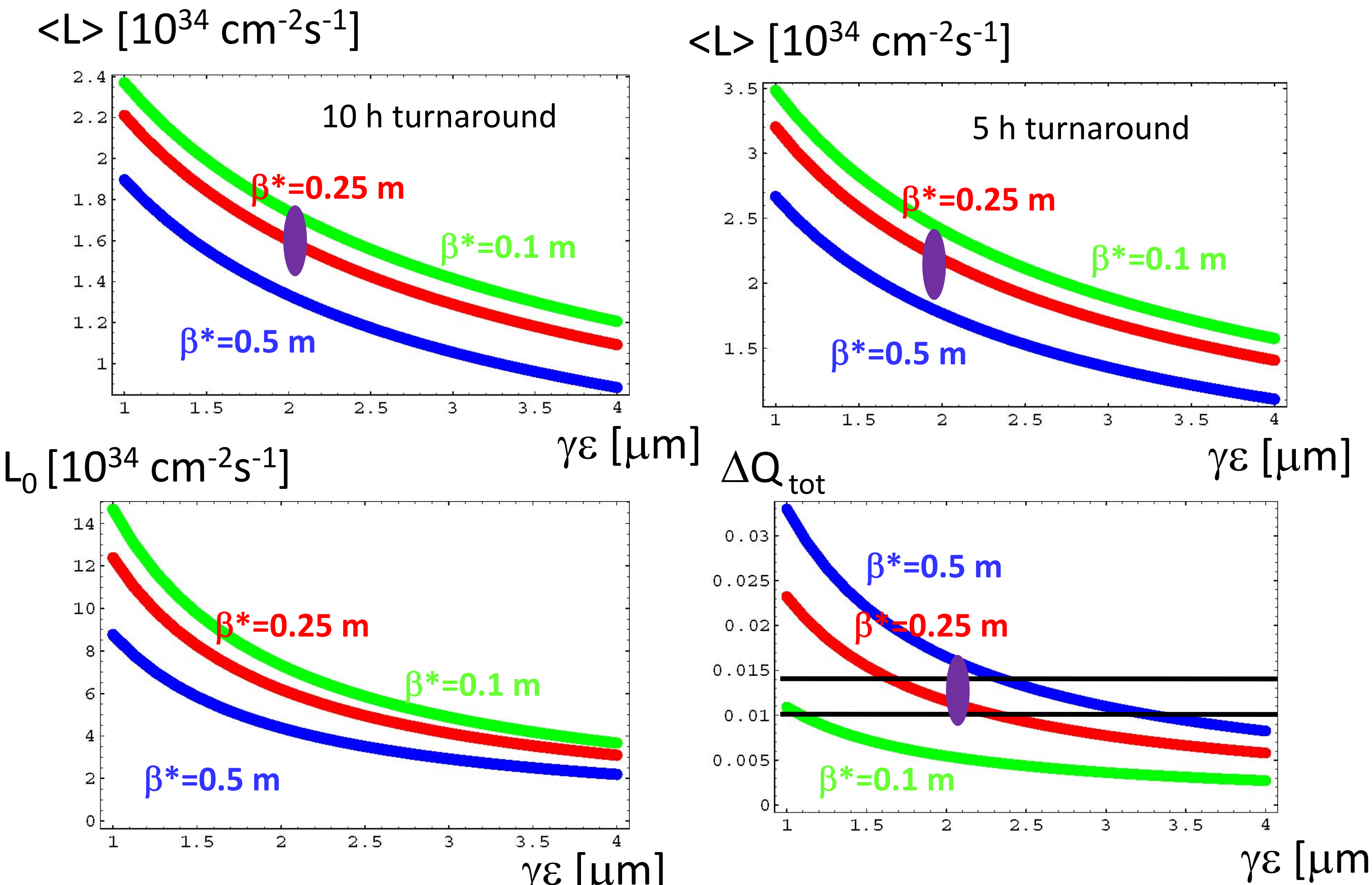
basic idea: reduce ε to compensate for larger Piwinski angle and get the full benefit of phase-1 (or phase-2 IR) upgrade); at the same time the smaller emittance relaxes aperture constraints

→ possible implications for the injection design

Roland's example parameter sets

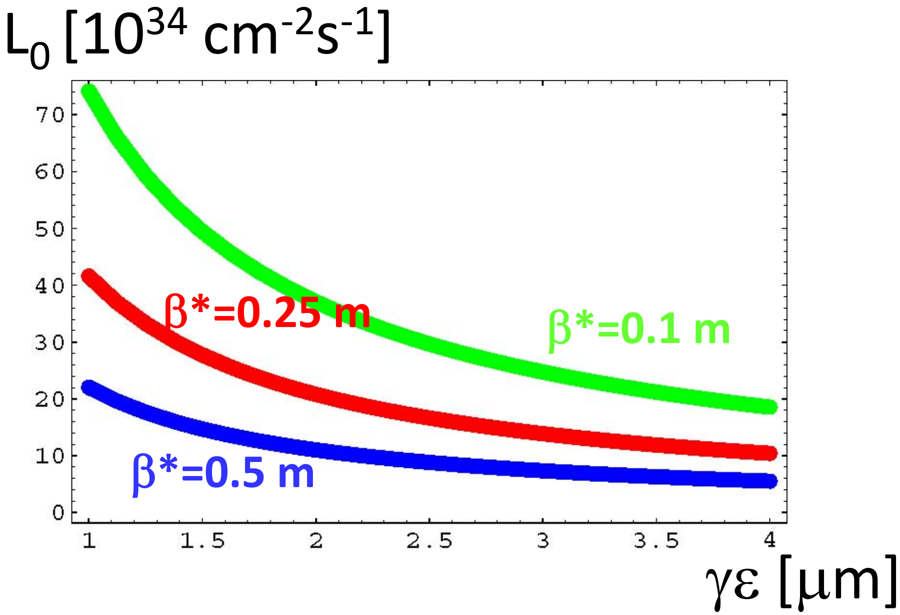
	1	2	3	4	5	6
	Nominal	**Nominal with IR phase 1**	**Nominal with IR phase 1 and reduced emittance**	**Ultimate**	**Ultimate with β*=0.25 m**	**Ultimate with β*=0.25 m and reduced emittance**
N_b (x 10^{11})	1.15	1.15	1.15	1.70	1.70	1.70
ε_N (μm)	3.75	3.75	**2.54**	3.75	3.75	**2.60**
β^*	0.55	0.25	0.25	0.50	0.25	0.25
σ^* (μm)	16.58	11.18	9.20	15.81	11.18	9.31
Crossing angle (mrad)	0.285	0.440	**0.360**	0.315	0.440	**0.365**
σ_z (mm)	75.50	75.50	75.50	75.50	75.50	75.50
ϕ (Piwinski angle)	0.65	1.49	**1.48**	0.75	1.49	**1.48**
ΔQ_{bb} head-on	1.00	0.67	**0.99**	1.42	0.99	**1.43**
Luminosity	1.00	1.47	**2.18**	2.30	3.22	**4.65**
Luminosity lifetime (h)	22.00	14.95	**10.08**	14.13	10.11	**6.99**

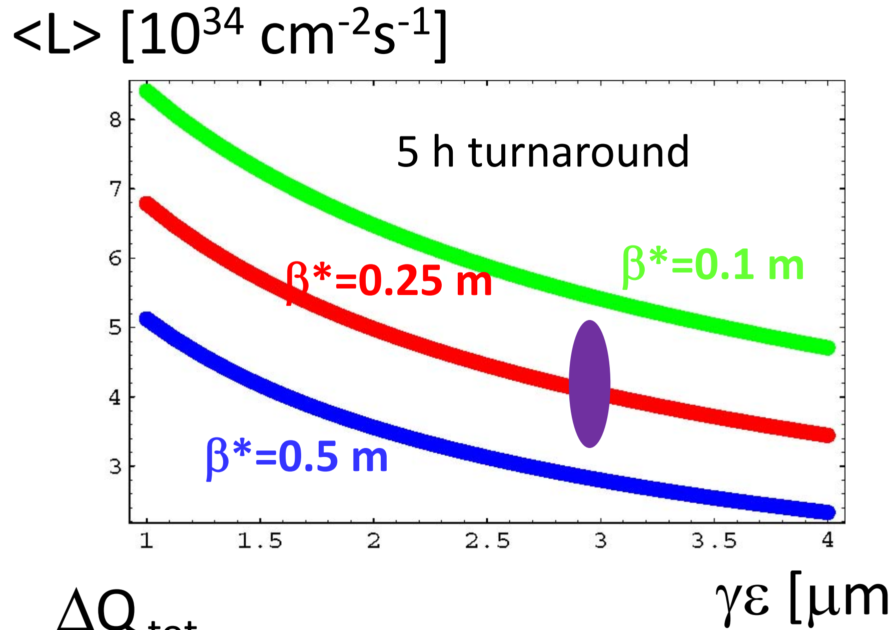
ultimate Gaussian bunches for phase 1 and 2



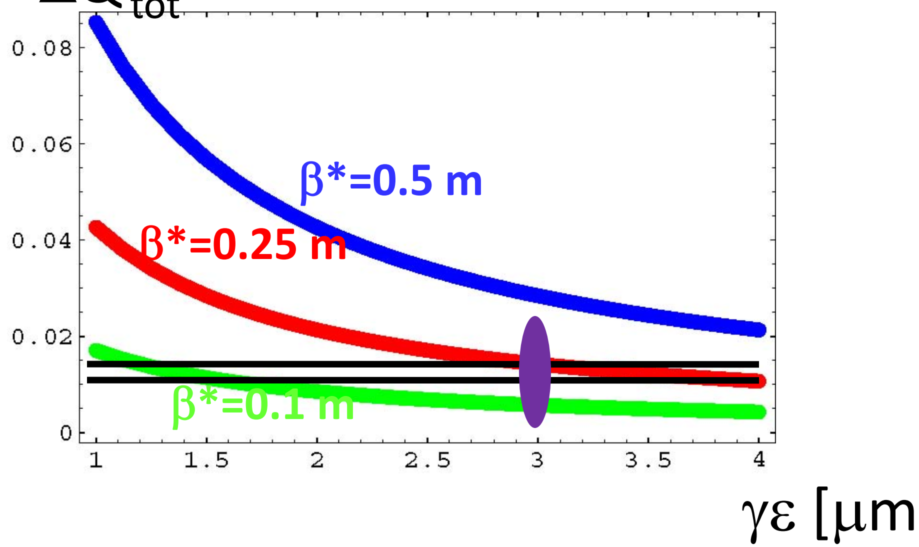
2808 bunches with 7.55 cm length, ultimate bunch intensity 1.7×10^{11}, 9.5 σ sep.

long flat bunches for phase 2





1404 bunches with 41 cm full length, bunch intensity 4.9×10^{11}, 8.5 σ sep.



conclusions

- for Gaussian ultimate bunches and β^*~0.1-0.25 m, emittance reduction from 3.75 to **2 micron yields ~40-50% higher integrated luminosity**; a smaller emittance reduction to **2.6 micron gives ~22-27% av. luminosity increase**
- for long flat bunches and β^*~0.25, emittance can be reduced only to 3 micron (tune shift limit), and the luminosity gain here is 13%

conclusions cont'd

- for comparison the luminosity gain from crab cavities would be 40-91% for β^*~0.25-0.1 m