A Luminosity Leveling Method for LHC using an Early Separation Scheme

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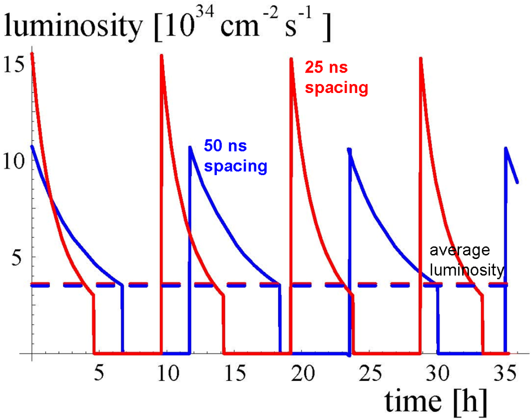
Outline

1. Introduction and Concept
   - The luminosity leveling need
   - Using the early separation scheme for leveling
   - The luminosity model
2. The Luminosity Leveling Insertion
   - The hardware layout considered
   - The dynamic range of the θ_c
3. Scenarios, Performance and Side effects
   - Scenarios ad performance
   - The integrated magnetic field request
   - Possible side effects

A LHC Luminosity Upgrade perspective.



Courtesy of W. Scandale and F. Zimmermann
[1, *"Two scenarios for the LHC Luminosity Upgrade"*]

WHY to level the luminosity?

Since...

"Experiments prefer more constant luminosity, less pile up at the start of run, higher luminosity at end."

[1, *"Two scenarios for the LHC Luminosity Upgrade"*]

and from the machine perspective, there is the energy deposition issue: 1.8 kW of debris at nominal luminosity.

...it is already proposed to level the luminosity...

- squeezing β^*
- varying the bunch length.

[1, *"Two scenarios for the LHC Luminosity Upgrade"*]

HOW to level the luminosity?

Here we proposed...

- to vary the θ_c for leveling the luminosity using the Early Separation Scheme.

[2, "An Early Beam Separation Scheme for the LHC Luminosity Upgrade"]

It should be a very **clean** and very **flexible** control system.

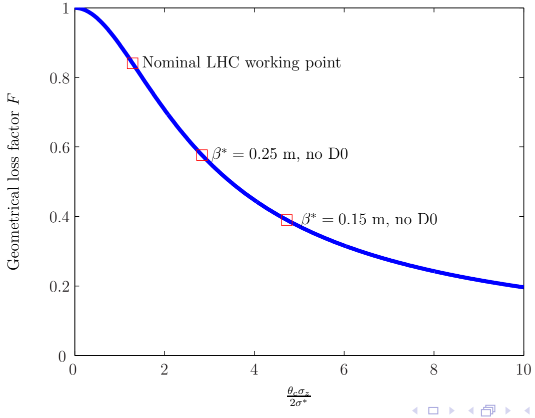
- NO chromaticity correction variation
- NO sextupoles feed-down
- NO closed orbit variation around the machine.

But...

We need to install dipoles in the detector.

Why varying the θ_c...

$$L(\theta_c) = \frac{f_{rev} n_b N_b^2}{4\pi\sigma^{*2}} F(\theta_c) \quad \text{where} \quad F(\theta_c) \approx \frac{1}{\sqrt{1 + \left(\frac{\theta_c \sigma_z}{2\ \sigma^*}\right)^2}}$$



The model of luminosity we used.

We implemented the following three processes

- the protons burning

$$\dot{N}_b(t) = -\frac{\sigma \; n_{exp}}{n_b} L(t)$$

- the intra beam scattering [3, "Handbook of Accelerator Physics and Engineering"]

$$\dot{\epsilon}(t) = \frac{1}{\tau_{IBS}} \frac{N_b(t)}{N_{IBS}} \epsilon(t)$$

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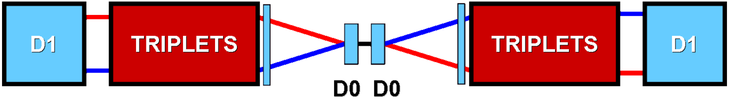
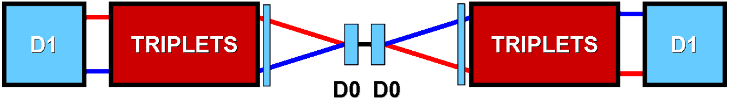


- θ_1 is the kick provided by the dipole at the position l_1 from the IP
- θ_2 is the kick provided by the orbit corrector at the position l_2 from the IP

A simple geometrical approach...

$$\theta_1 = atan\left(\frac{l_2\ tan(\frac{\theta_{tripl}}{2}) - l_1\ tan(\frac{\theta_c}{2})}{l_2 - l_1}\right) - \frac{\theta_c}{2}$$

$$\theta_2 = \frac{\theta_{tripl}}{2} - \frac{\theta_c}{2} - \theta_1$$



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The dynamic range of the θ_c

Lower limit...

- encounters at reduced distance
- position of the dipoles

Upper limit...

- synchro-betatron coupling (to be investigated)
- strength of dipoles

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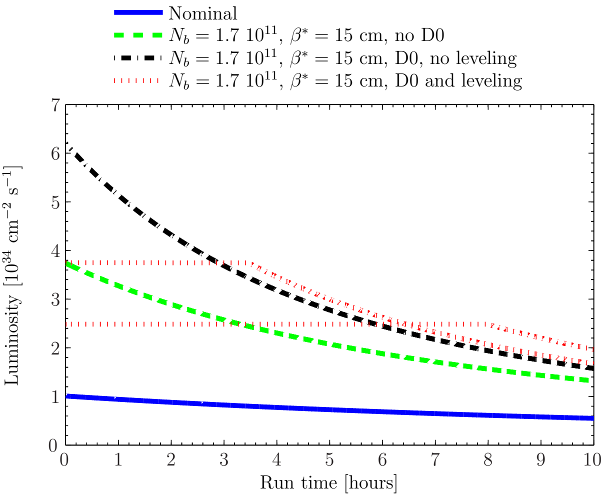
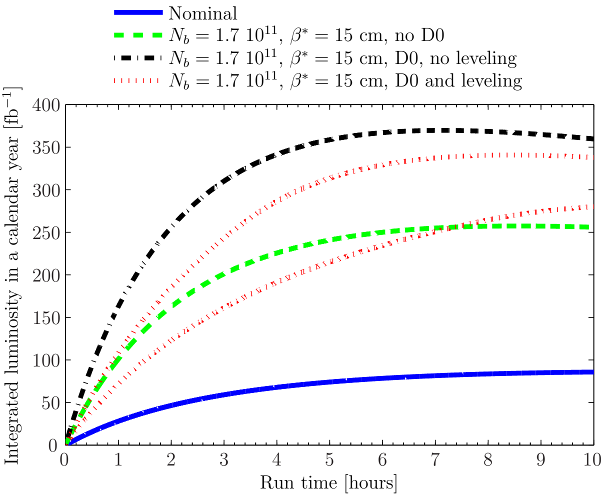
The instantaneous luminosity.



The integrated luminosity.



General consideration

The leveling has a “moderate analytical cost” in term of integrated luminosity.

		Peak L [10^{34} cm^{-2} s^{-1}]	Integrated L [fb^{-1}]
Nominal scenario		1.01	86.37
$\beta^* = 0.15$ m	no D0	3.74	257.37
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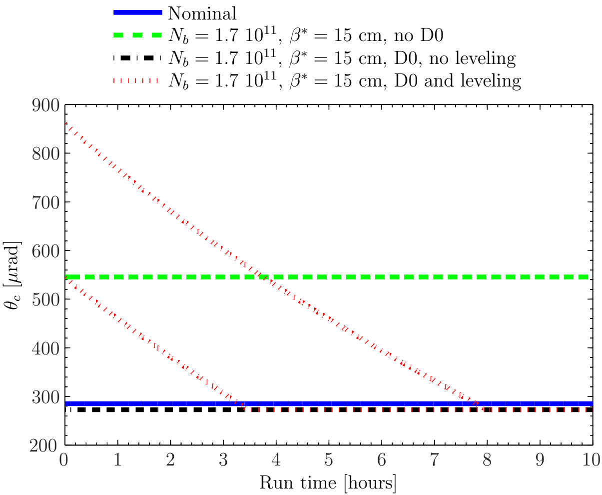
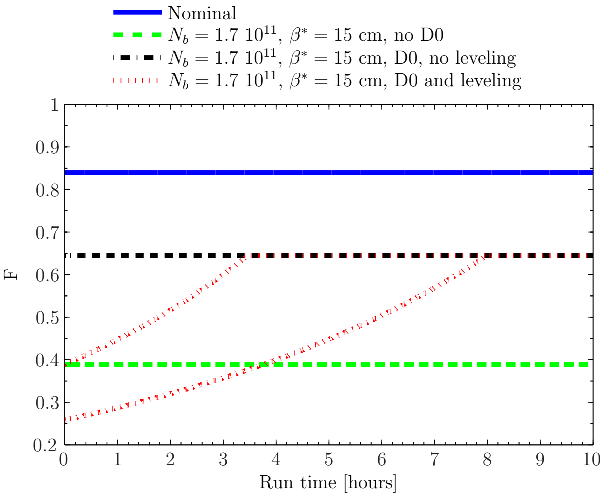
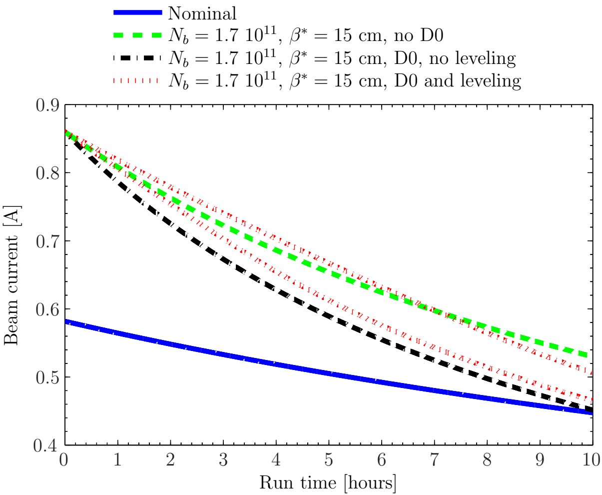
The crossing angle.



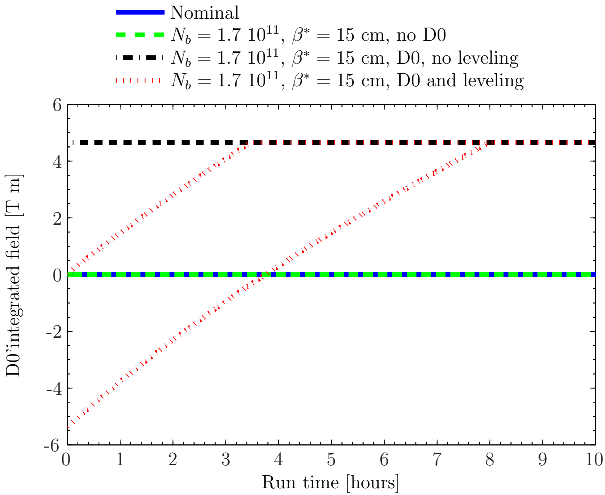
The geometrical loss factor.



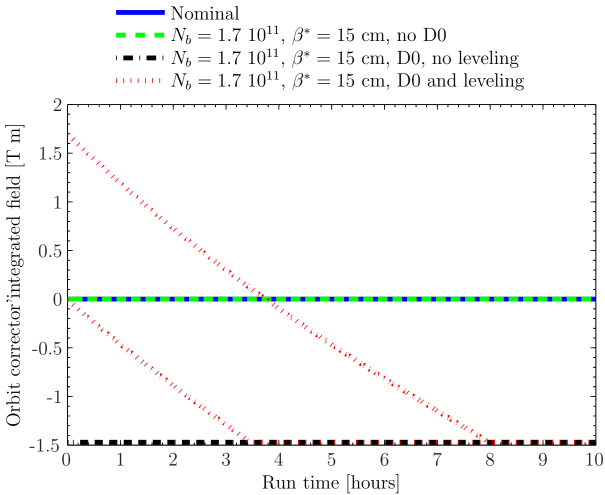
The beam current.



The dipole working condition.



The orbit corrector working condition.



Possible side effects.

We focus on

- the distance between the beams
- the longitudinal size of the luminous region

$$\frac{1}{\sigma_{lum}} \approx \sqrt{\frac{2}{\sigma_z^2} + \frac{\theta_c^2}{2\ \sigma^{*2}}}$$

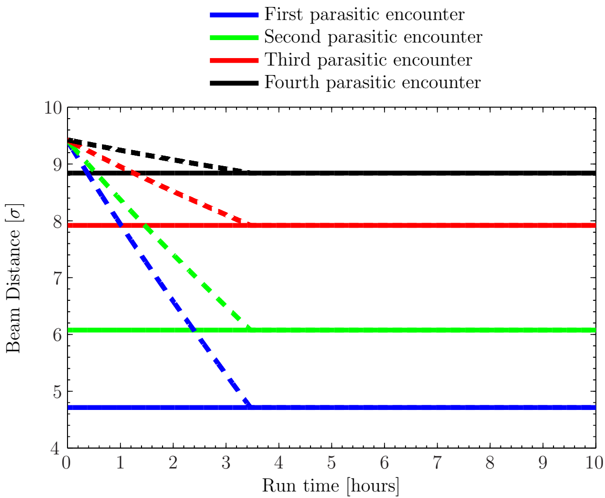
[1, *"Two scenarios for the LHC Luminosity Upgrade"*]

- the tune shift due to head-on collisions

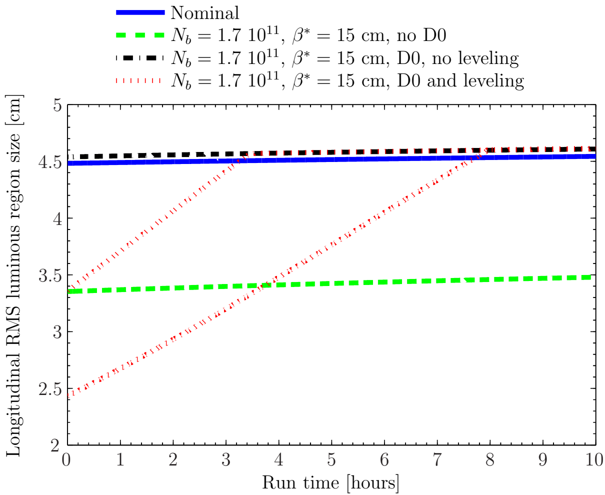
$$\xi = \frac{N_b r_p}{4\pi\epsilon_n} F$$

[4, "LHC Luminosity and Energy Upgrade"].

Distance between the beams



The longitudinal size of the luminous region.



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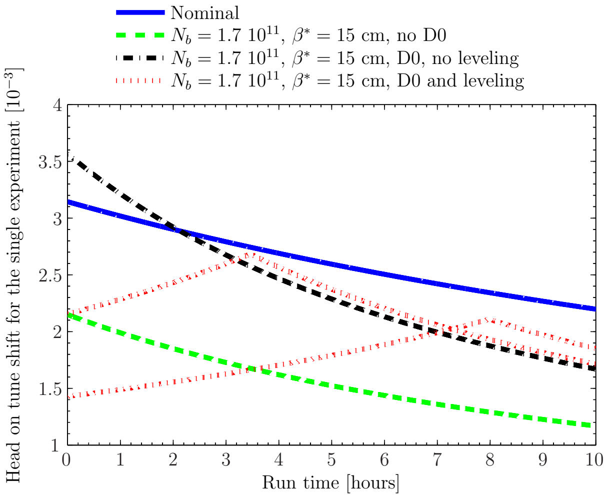

Summary

- We proposed a method for luminosity leveling using the θ_c fully compatible with the Early Separation Scheme (and/or Crab Cavities).

Pros

- Clean to implement
- With flexibility.

Cons

- Dipoles in the detectors
- BB effect to understand better.

References

- F. Zimmermann and W. Scandale, *“Two scenarios for the LHC Luminosity Upgrade”*, PAF/POFPA meeting, 13 February 2007, CERN.
- J.-P. Koutchouk and G. Sterbini, *“An Early Beam Separation Scheme for the LHC Luminosity Upgrade”*, EPAC06 Proceedings, Edinburgh.
- A.W. Chao and M. Tigner, *“Handbook of Accelerator Physics and Engineering”*, World Scientific Publishing Co. Pte. Ltd. , 2006.
- O. Brüning and al., *“LHC Luminosity and Energy Upgrade: a Feasibility Study”*, LHC Project Report 626, December 2002, Geneva.