Studies of decelerator tolerances.

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October 10, 2012

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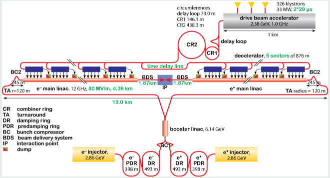
Introduction

Motivation

- Determine tolerances of the drive beam with respect to delivered beam from the DB complex.
- Try and inject interesting types of beams.
- Investigate “worst case” - first decelerator section.
- Main goals:
  - Keep 3σ envelope (“the envelope”) below 3mm.
  - Preserve machine efficiency.

Layout



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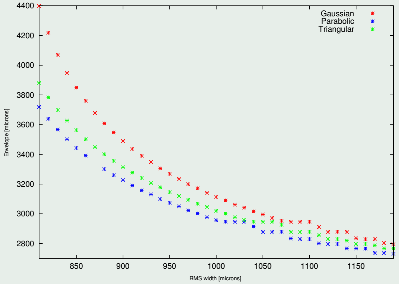
Beam shaping

- Inject bunches of various longitudinal shapes (form factors) - vary RMS width.
- Gaussian, parabolic, triangular bunches injected. For each the charge is set to zero outside 3σ, $\sqrt{5}\sigma$ and $\sqrt{6}\sigma$, respectively.



- Some structure in the the envelope, that seems not to be a numerical artefact.
- The efficiency drops slightly with other bunch shapes

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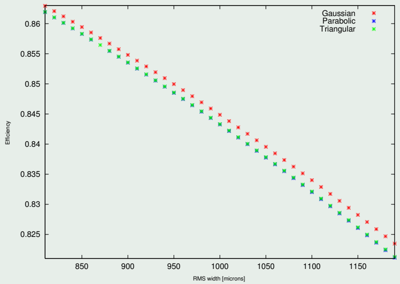

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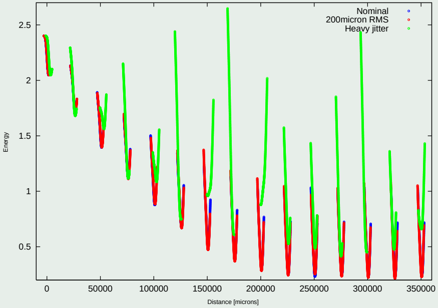
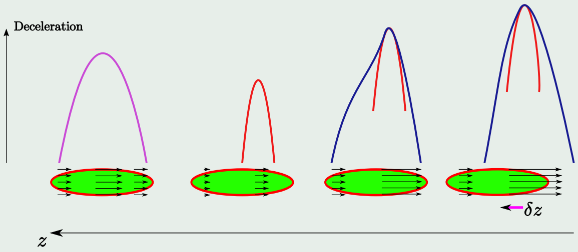
Starting point

Phase jitters

- Observation:
  - With even small longitudinal jitters ($\sim 200\mu m$ RMS), some parts of bunches become more decelerated than nominally.
  - With very large jitters, some particles recive accelerating kicks instead of deceleration.
  - Source of more deceleration?

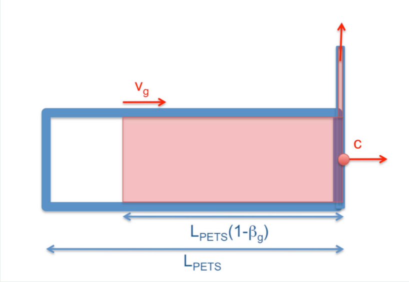


Longitudinal wakefield



- The decelerating wake is the sum of single- and multi-bunch effects.
- The multi-bunch wake peaks at the center of a bunch.
- The single-bunch wake peaks towards the rear of the bunch.

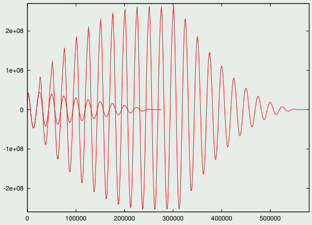
Longitudinal wakefield

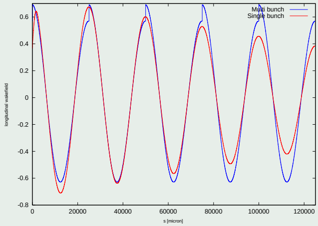


- Three players in the wakefield:
  1.) Emitting slice,
  2.) Field, (velocity $c\beta_g$)
  3.) Pickup slice - distance d away
- $$z_1(t) = ct$$
  $$z_2(t) = \beta_g ct$$
  $$z_3(t) = ct - d$$
- $$z_2 = z_3 \Rightarrow ct_{catch-up} = d/(1-\beta_g)$$
- $$z_3 = \beta_g d/(1-\beta_g)$$
- The trailing charge only feels the field during a distance
  $$L_{eff} = L_{pets} - \beta_g d/(1-\beta_g)$$

Longitudinal wakefield

- Longitudinal wakefield for a (longitudinal delta function) charge.
-
$$W_l(d) \propto \begin{cases} \left(L_{pets} - \frac{\beta d}{1-\beta}\right) \cos\left(\frac{2\pi d}{\lambda}\right) & , \quad \text{for } [d > 0] \bigcap [L_{pets} - \frac{\beta d}{1-\beta}] > 0 \\ 0 & , \quad \text{otherwise} \end{cases}$$
- Fill time of $\sim$10 bunches.
- Effect of bunch n on bunch $n + k$ decreases linearly in k.
- Distance from maximum of multi bunch wakefield to maximum of single bunch is 1637μm.
- Expect 7% extra deceleration from a bunch displaced by that amount from field calculation.





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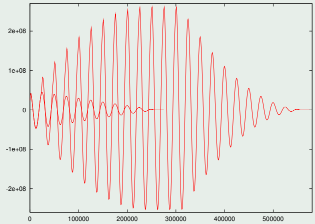

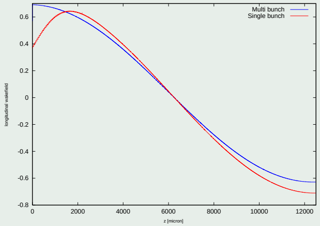

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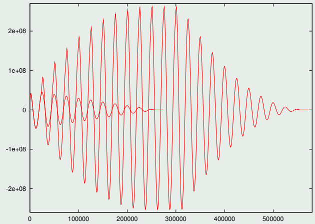
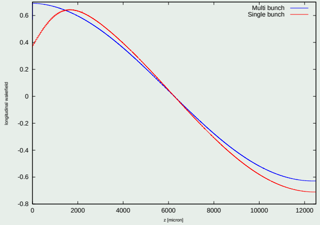
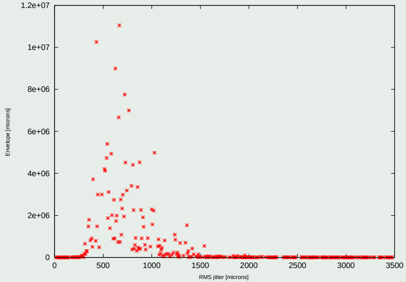




- The envelope of the beam blows up for phase-jittered beams - up to unphysical “meter-scales”.
- Even with small jitters, the envelope is unacceptable.
- It is confirmed that the excess deceleration is constant throughout the machine - and in the range 0-3.5%
- Some jitters are worse than others - 400-1000μm. above that magnitude of jitter, decoherence of the wake occurs.
- How about “freak” bunches - bunches that have got very large displacements?



Increasing RMS jitter:
Nominal $\rightarrow$ Enhanced single bunch effects $\rightarrow$ decoherence.

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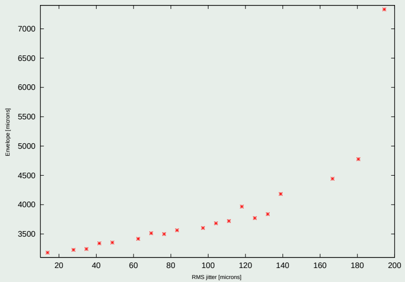

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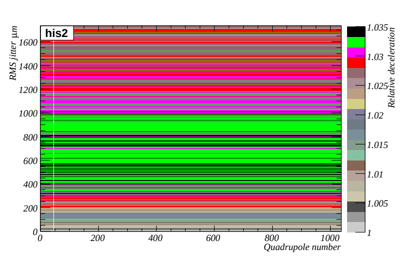

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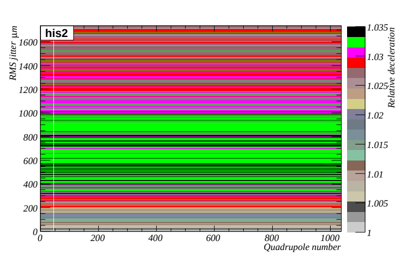

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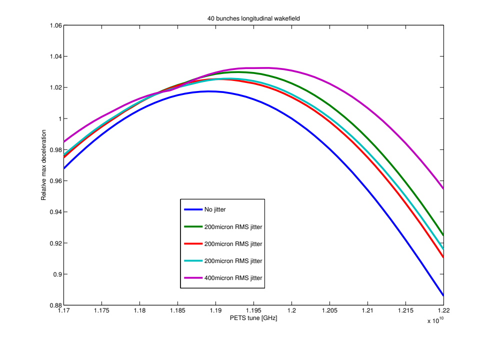
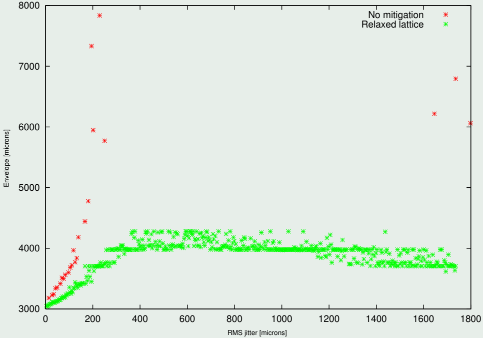
Detuning the cavities?

- Try to detune the cavities away from (towards?) the wakefield enhancement.
- Observe the maximum field.
- Detuning does not decrease sensitivity to jitter (possibly even worse).
- The effect of detuning on machine efficiency has not been studied.



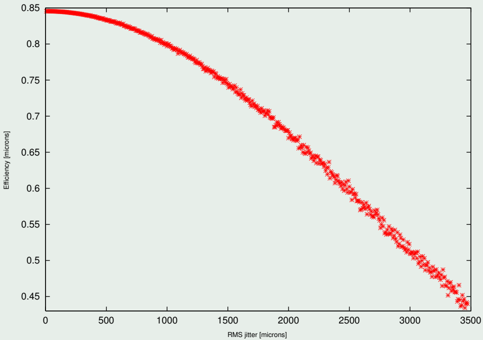
Tapering the lattice

- Relaxing the quadrupole gradient towards the end of the lattice helps.
- This is very preliminary, and can certainly be optimized further.



Efficiencies

- Efficiency: $\eta = \frac{E_0 - \frac{\sum_i E_i N_i}{\sum_i N_i}}{E_0}$ - E_i, N_i measured at the end of decelerator.
- With relatively small changes in efficiency, very large changes in envelope (with nominal lattice) can occur.



Content

Further studies

- Extract info from CTF3 on phase jitter/bunch shape?
- More work for the "worst case" displacement (1637μm).
- More work on optimizing the lattice to cope with jitter and longitudinal displacement.
- Need to optimize parameters with a constraint on the machine efficiency.
- Additional understanding of the interplay between detuning and phase jitter.
- Optimization for "worst case" is worse than for jitters: 3.5% extra deceleration $\rightarrow \sim$7% extra deceleration. Can "worst case" occur?