Introduction

The combined effect of wakefields and dispersion in the main linac and beam-beam interaction at the IP has been shown to be able to result in a severe luminosity loss in spite of a very small emittance growth

R. Brinkmann, O. Napoly, D. Schulte: PAC 2001

e.g. 1% emittance growth can result in 20% luminosity loss

Content

Beam-Beam Interaction

Bunches at the IP produce a very strong electromagnetic field because of the high particle density

therefore beam-beam forces are huge

they are focusing

convenient is the disruption parameter $D_{x,y}$

$$D_{x,y} = \frac{2Nr_e\sigma_z}{\gamma\sigma_{x,y}(\sigma_x + \sigma_y)} = \frac{\sigma_z}{f_{x,y}}$$

normally

$D_x \ll 1$: bunch acts as a thin lens

$D_y \gg 1$: particles from other bunch start to oscillate

beneficial: $\mathcal{L} = H_D \mathcal{L}_{\text{geom}}$

but two stream instability

Luminosity and Disruption

$$\mathcal{L} \propto \frac{n_b f_{rep} N^2}{\sigma_x \sigma_y} \propto P_{beam} \frac{N}{\sigma_x \sigma_y}$$

$$D_y \propto \frac{N \sigma_z}{\sigma_x \sigma_y}$$

$$\mathcal{L} \propto P_{beam} D_y \frac{1}{\sigma_z}$$

$$\mathcal{L} \approx H_D \times 1.74 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1} \frac{P_{beam}}{\mathrm{MW}} D_y \frac{\mu\mathrm{m}}{\sigma_z}$$

$\Rightarrow$ if one has a long bunch and high luminosity one needs to have a large disruption parameter

here, D_y is nominal disruption parameter,

effective one is usually larger

Project Parameters

name		TESLA	NLC	CLIC
$\epsilon_{y,DR}$	$[\mathrm{nm}]$	20	20	5
$\epsilon_{y,BDS}$	$[\mathrm{nm}]$	30	30	10
N	$[10^9]$	20	7.5	4
σ_x^*	$[\mathrm{nm}]$	553	243	202
$\sigma_{y,DR}^*$	$[\mathrm{nm}]$	4.2	2.3	(1.1)
$\sigma_{y,IP}^*$	$[\mathrm{nm}]$	5	3	(1.5)
$\sigma^a st_z$	$[\mu\mathrm{m}]$	300	110	35
$D_{y,DR}$		28.9	16.5	7

emittance grows along the machines due to

- wakefield effects
- dispersion

shape change may have

- no correlation in z
- correlation in z

disruption calculated with $\epsilon_{y,DR}$

disruption is highest in TESLA

$\Rightarrow$ concentrate on this case

Simulation Procedure

Main linac and BDS are simulated with PLACET including

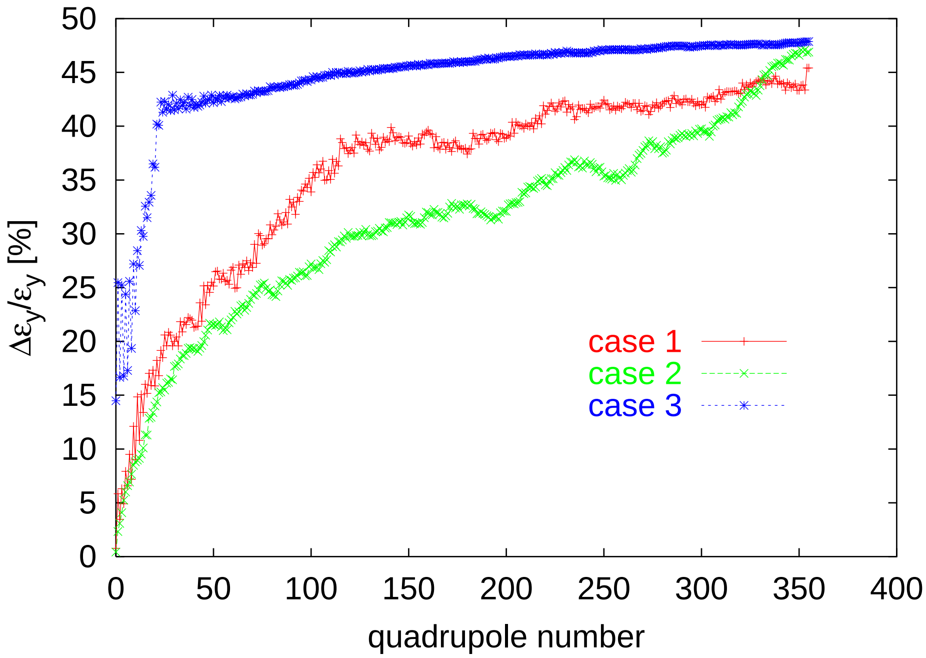
- initial misalignments
- beam-based alignment
- dynamic errors

beam-beam interaction is simulated with GUINEA-PIG

a problem arises from the instable collision

- computational parameters (e.g. number of macro particles and slices) affect results

Static Emittance Growth



Static alignment procedure for TESLA is changing

a simplified model is used to produce the budgeted emittance growth

- single error (BPM position, cavity offset or cavity angle)
- error mixture

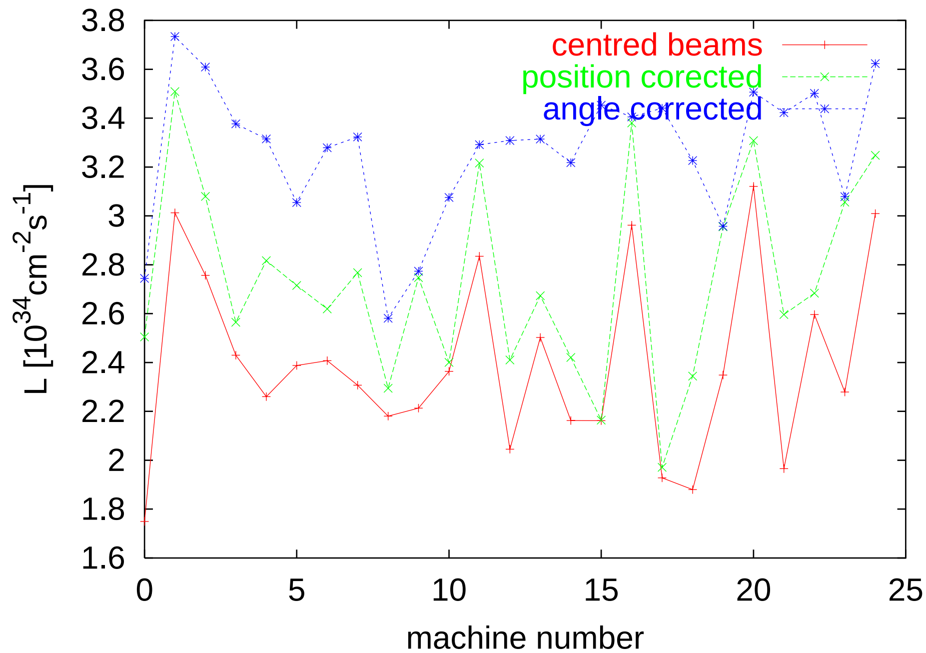
single error tests whether different errors give similar results

mixture should be a better representation of alignment result

single errors are ($35\mu m$,$1150\mu m$,$750\mu rad$)

mixture is ($25\mu m$,$600\mu m$,$300\mu rad$)

Static Collision Optimisation



Dynamic effects are completely ignored

first offset is scanned to maximise luminosity

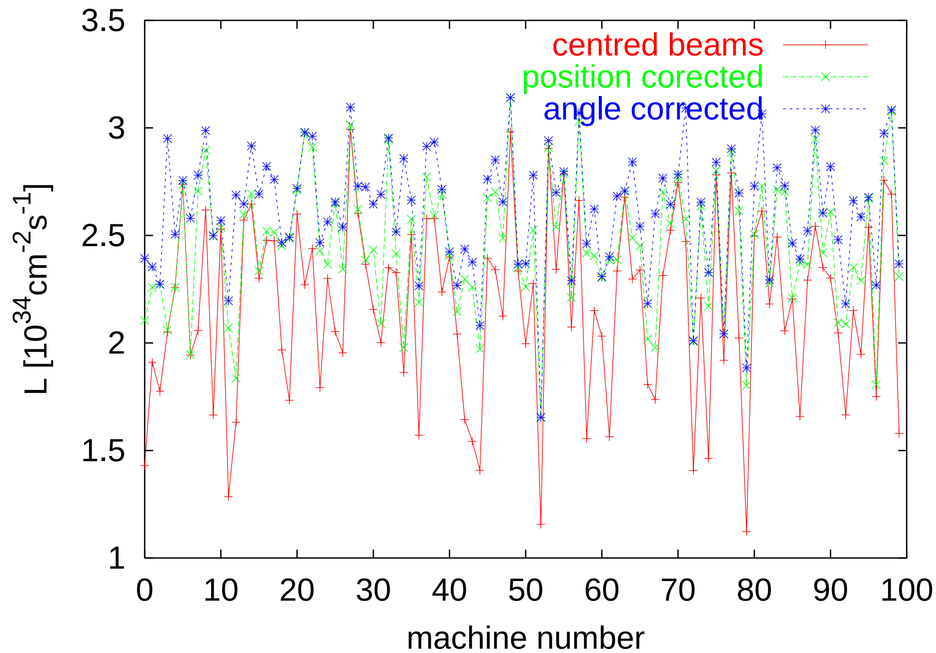
then crossing angle is introduced

significant increase of luminosity in both steps

optimisation	BPM pos.	cav. pos	cav angle	mixture
	$\mathcal{L}\ [10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$			
none	2.4	2.1	2.1	2.2
offset	2.7	2.8	2.7	2.5
angle	3.3	3.4	3.2	3.3

better than expected (with no waist shift 3.0)

Lower Disruption Machines

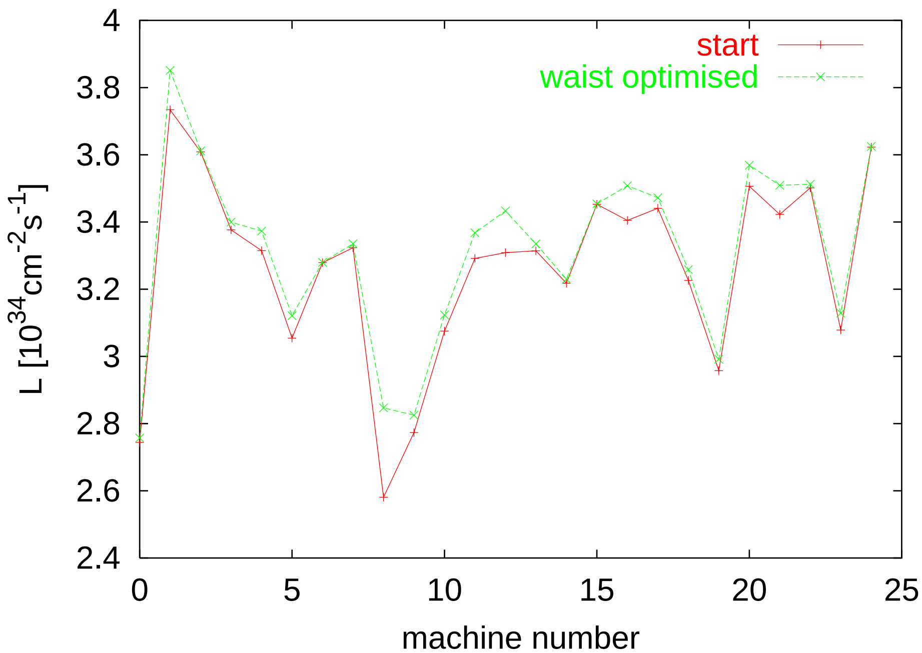


Improvement much smaller (CLIC shown in plot)

main contribution from offset optimisation

optimisation	NLC $\mathcal{L}$ $[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	CLIC $\mathcal{L}$ $[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$
none	1.8	2.2
offset	2.1	2.5
angle	2.2	2.6

Waist Optimisation



In TESLA, waist optimisation obtained $\approx 15\%$ luminosity for straight beams

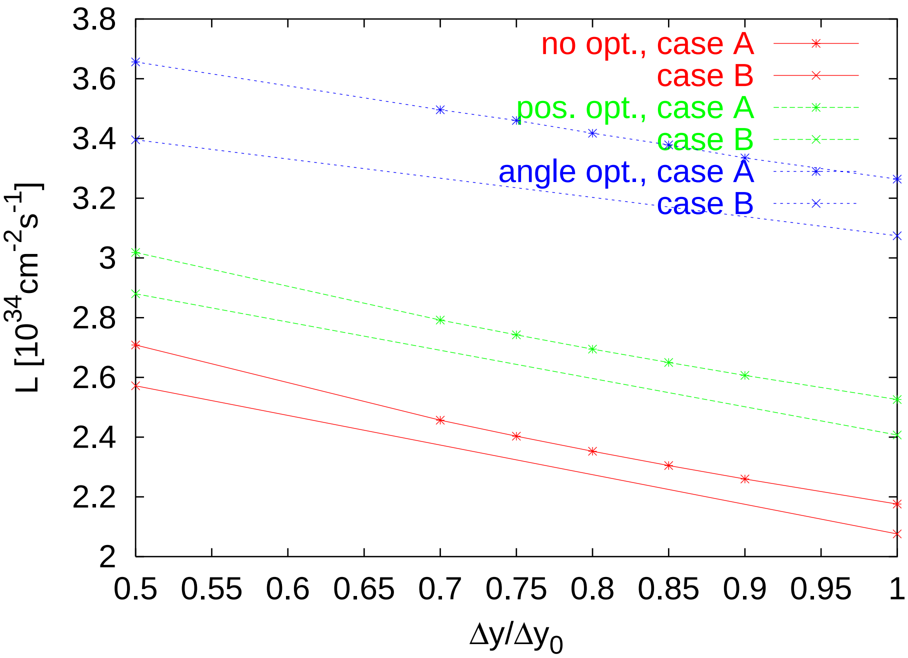
first both waist are moved symmetrically than anti-symmetrically

usually not very efficient with bananas

$\Rightarrow$ small average gain

$\Rightarrow$ but almost 10% in one case

Dependence on Computational Parameter



The same 25 machines where used, misalignments are scaled

case A has

- 72000 macro particles
- 72 slices

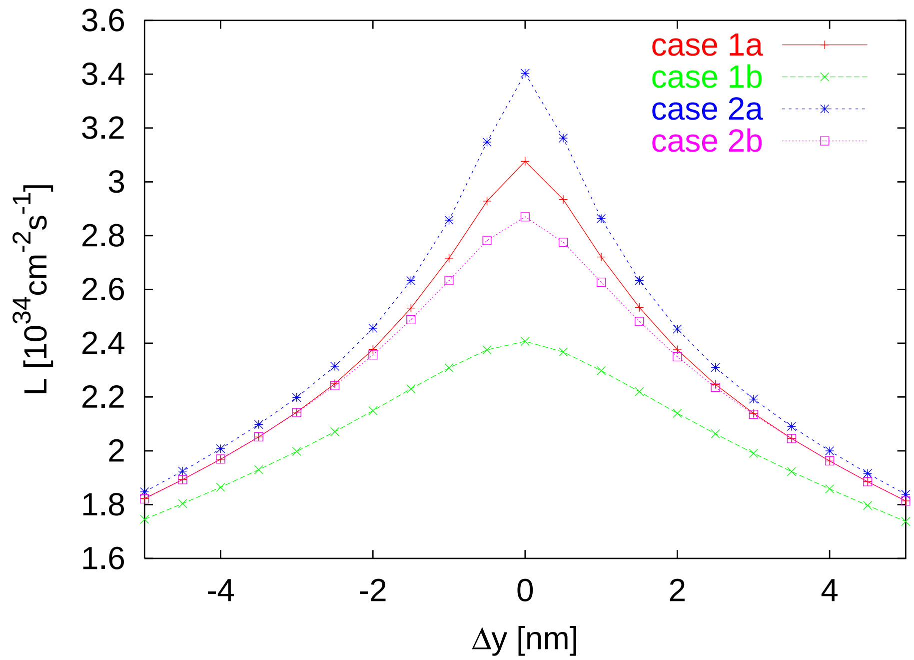
case B has

- 24000 macro particles
- 24 slices

results differ significantly

largest difference at full optimisation

Sensitivity to Offsets



Small number of particles (case B)

case 1: 100% of misalignment applied

a: offset and angle optimised

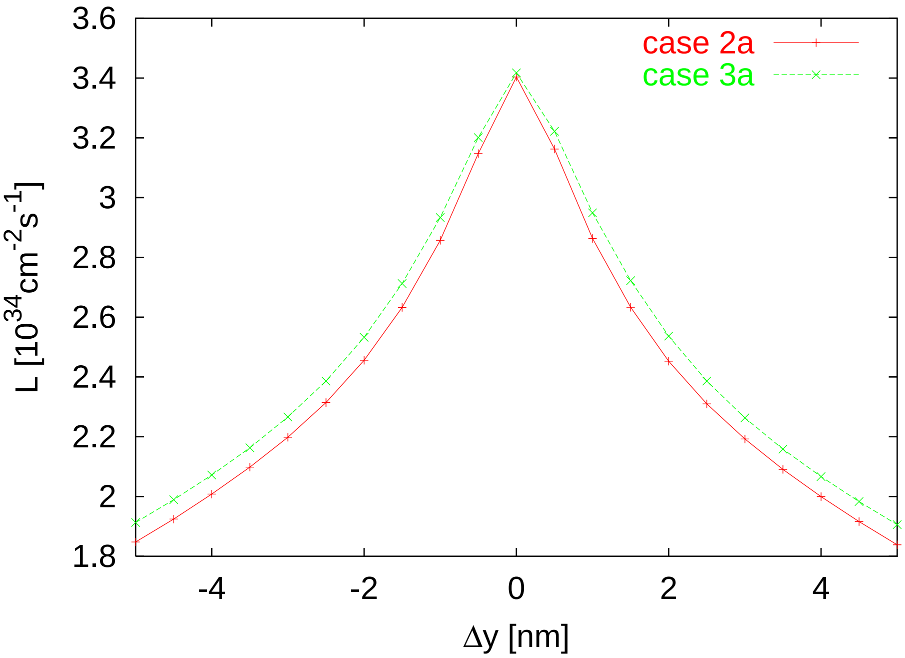
b: only offset optimised

case 2: 50% of misalignment applied

averaged sensitivity of 25 machines

$\Rightarrow$ the higher the luminosity the tighter the tolerance

Sensitivity (cont.)



Different misalignments lead to same luminosity

case 2: 50% (case B)

case 3: 85% (case A)

$\Rightarrow$ sensitivity to offset does not seem to change dramatically

$\Rightarrow$ using faster simulations may be OK

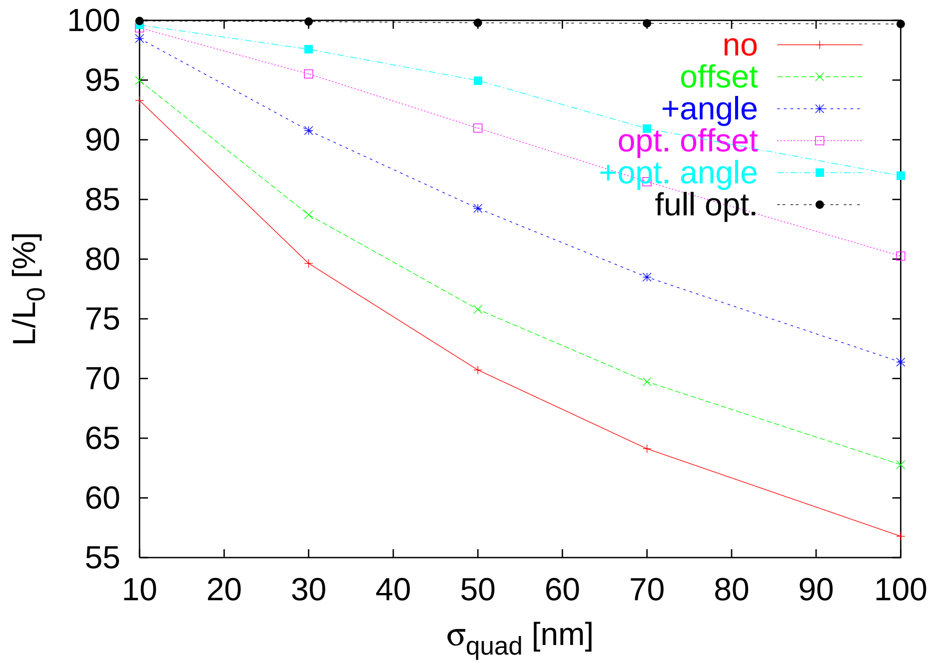
Error Sources

Position Δy and angle $\Delta y'$ errors at IP exist

three main regions of error sources exist

- everything before the linac
  - couples into Δy, $\Delta y'$, amounts $\Delta y/\sigma_y$ and $\Delta y'/\sigma_{y'}$ may differ
- the linac
  - equally into Δy, $\Delta y'$
- beam delivery system
  - more Δy

Linac Quadrupole Jitter

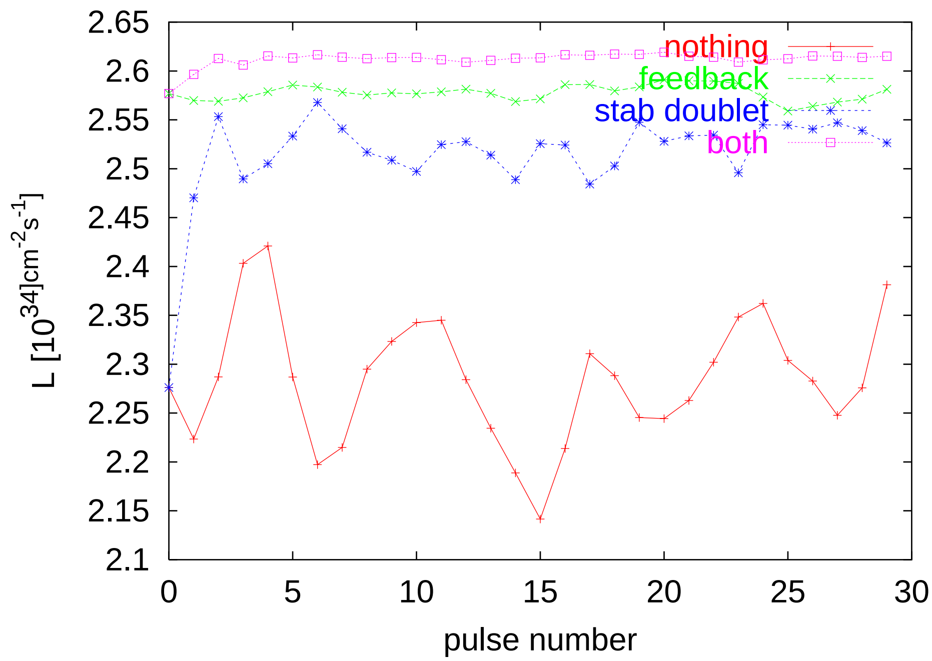


Six cases considered

- no correction
- correcting offset
- correcting angle and offset
- varying offset to maximise luminosity
- varying offset and angle to maximise luminosity
- also correcting beam angle and offset before BDS

$\Rightarrow$ sometimes it is not only the banana

Feedback and Ground Motion



Medium severe ground motion used (following A. Seryi)

in CLIC (shown) $\Delta t = 5\,\mathrm{ms}$ between pulses

slow feedbacks with gain $g = 0.04$ assumed

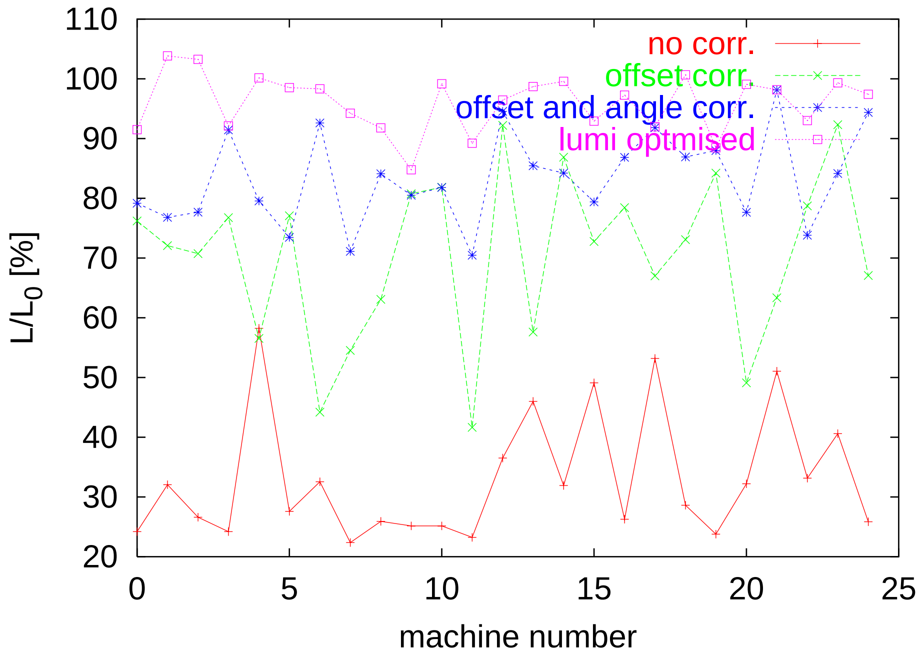
in TESLA $\Delta t = 200\,\mathrm{ms}$

more severe ground motion

$\Rightarrow$ loss at first pulse after complete optimisation is large ($> 50\%$)

but intra-pulse feedback can easily be used

Intra-Pulse Feedback



Severe ground motion used (following A. Seryi)

slow feedbacks included (idealised)

$\mathcal{L}/\mathcal{L}_0$ [%]:

gain (slow)	0.01	0.02	0.04
no feedback	26.0	29.1	33.0
offset feedb.	63.7	66.2	70.3
+angle feedb.	78.5	81.4	83.4
+lumi opt. w. offset	86.4	89.7	91.8
+lumi opt. w. angle	92.4	95.1	96.0

large gain from minimising offset at IP

Conclusion

The static effect can be (almost) cured

optimise beam offsets and angles at IP

cure of dynamic effects

- centroid offsets: BPM based feedbacks

  in TESLA pulse-to-pulse is not sufficient

  $\Rightarrow$ intra-pulse feedback

- banana effects: luminosity based feedbacks

$\Rightarrow$ require fast luminosity measurment

intra-pulse feedback is interesting for TESLA

because of banana effect

non-IP feedbacks are also important