Luminosity tuning bumps in the CLIC main linac

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Introduction

- BBA required to preserve beam emittance along the CLIC main linac.
- Ballistic alignment method aligns BPMs and Quadrupoles (removes dispersion). Accelerating structures aligned using BPMs incorporated into them.
- Due to wakefield kicks from misaligned accelerating structures, the remaining emittance growth is still unacceptable (~380%). Target is < 100%.
- Emittance/luminosity tuning bumps have to be used as a final stage of beam-based correction.

Prealignment

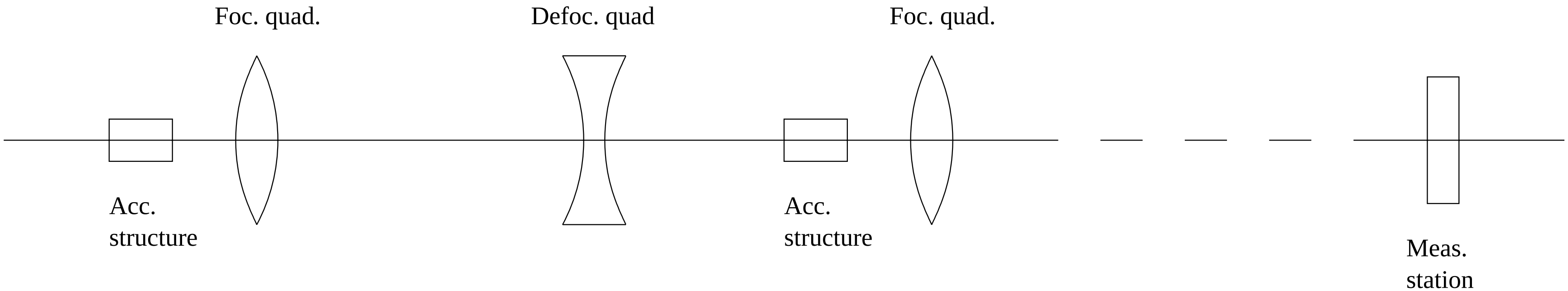
- 50 ”machines” for each side of the IP are created using Placet:
  - Elements are initially scattered according to a normal distribution.
  - Ballistic alignment is applied and acc. structures aligned.
- Average remaining emittance growth for these machines is ~380%.

Element	σ
Quads	50 μm
Acc. structures	10 μm
Acc. struct. realignment	10 μm
Acc. struct. vert. angle	10 μrad
Bpms	10 μm

Wakefields

- Offset accelerating structures cause wakefield kicks to the beam.
- Emittance growth due to these effects cannot be completely avoided using BBA.
- By transversely offsetting some structures along the linac the integrated wakefield kicks from all misaligned structures can be partly cancelled.

Emittance/luminosity tuning bumps



- Consists of two accelerating structures that can be moved transversally.
- Positioned close to focusing quadrupoles (where β_y is high and the effective wakefield kick strong).
- Followed by a transverse position feedback.
- Measurement station to evaluate the effect of the structure offsets.

Emittance/luminosity tuning bumps

- Measurement stations traditionally measure emittance after each bump. In this case one single station (at IP) measures luminosity.
- Ideal phase advance between the two structures of a bump is 90°. In this case it is instead 72°, i.e. the phase advance per FODO cell.
- Each bump controlled by two knobs.
  - Knob 1: Both structures offset by same amount.
  - Knob 2: Structures offset be same amount in opposite directions.
- In reality more than 10 bumps needed to avoid large structure offsets.

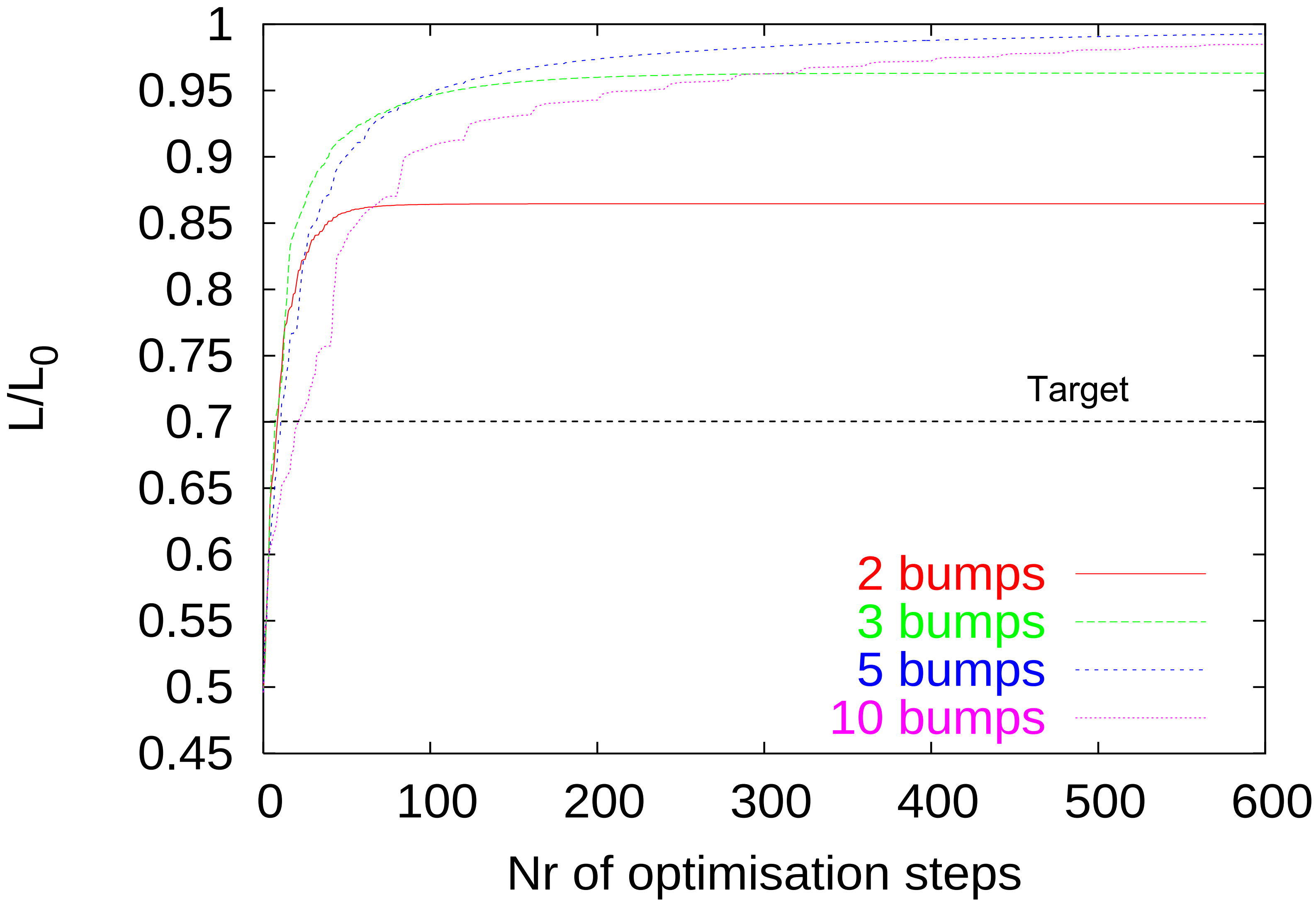
Performed simulations

- Function optimisation
  - Upper limit for the performance of the bumps.
- Realistic optimisation
  - Viable optimisation method.
  - With and without noise.
- Including BDS (Guineapig for luminosity calculation)
  - Preliminary results.
- Using wide laserwire
  - Simplified luminosity measurement.

Function optimisation

- Initial particle coordinates at IP calculated for the electron and positron beam.
- Response of these particles to knob adjustments calculated.
- Luminosity calculated as the envelope of two upright ellipses. Offset and angle of the beams set to zero.
- Expressions for luminosity as a function of each of the knobs are obtained.
- Brent’s method used to optimise one knob after the other.

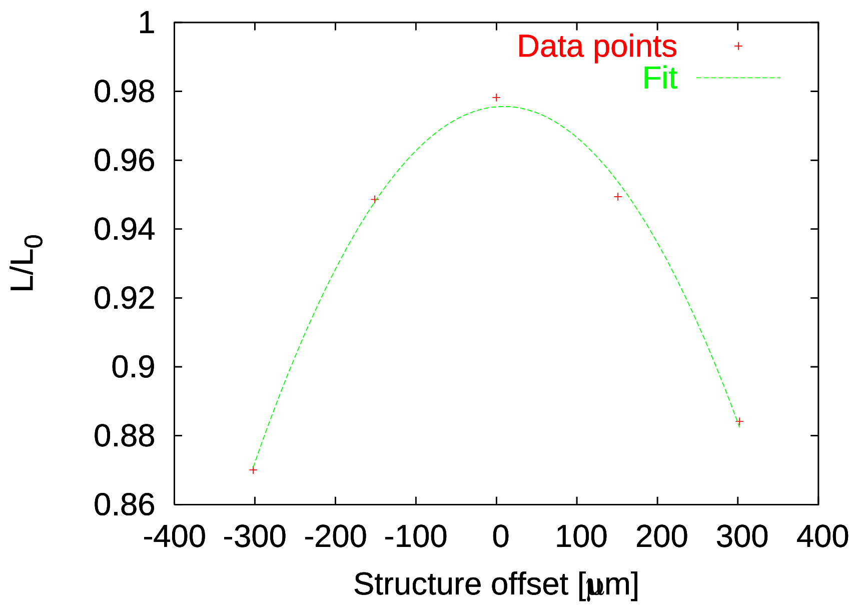
Function optimisation (results)



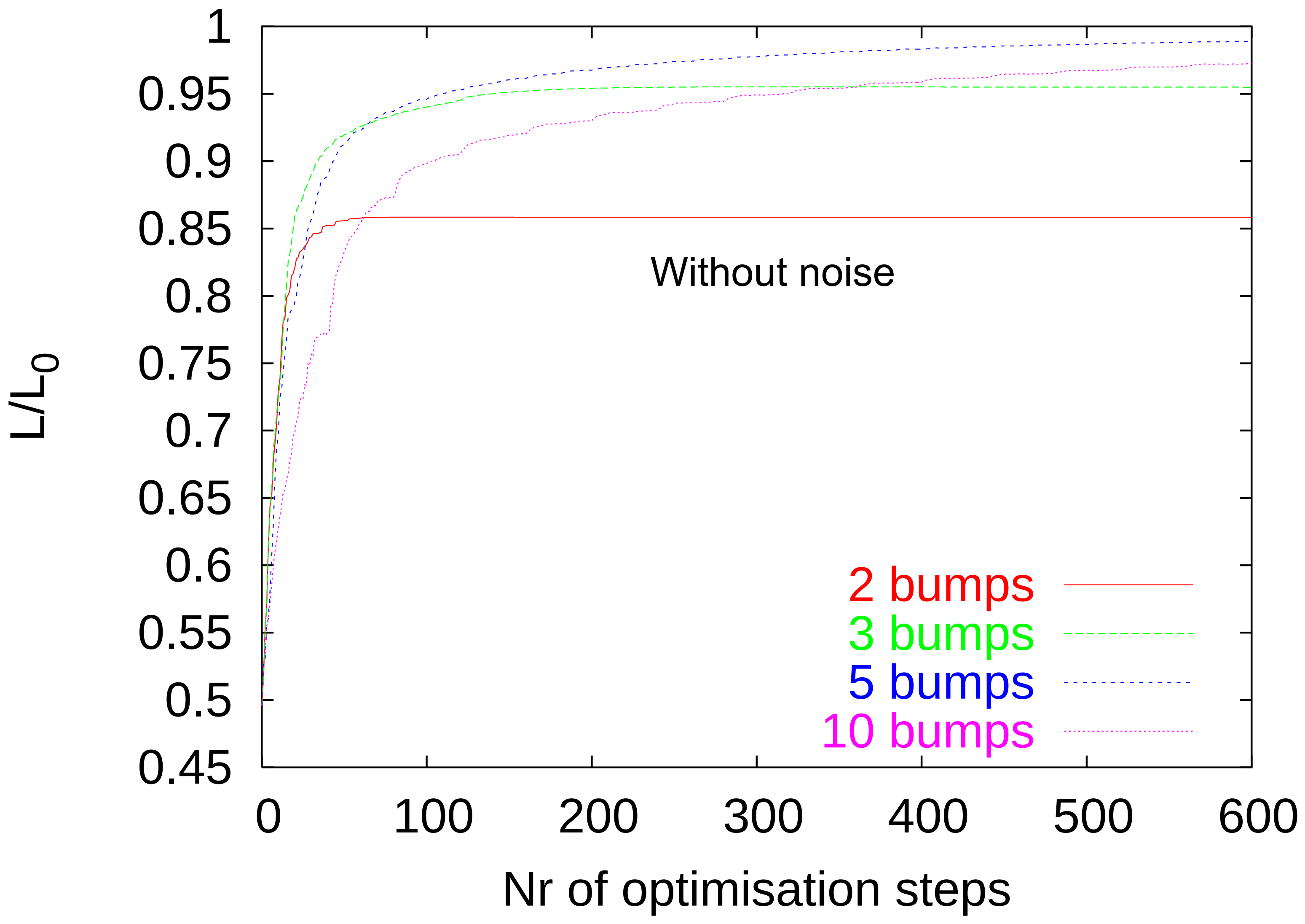
Realistic optimisation

- Carried out in the same way as the function optimisation except that:
  - optimisation of knob settings is carried out by fitting a second-order polynomial to luminosity data for five knob settings.
  - simulations were performed with and without noise in the luminosity measurement.

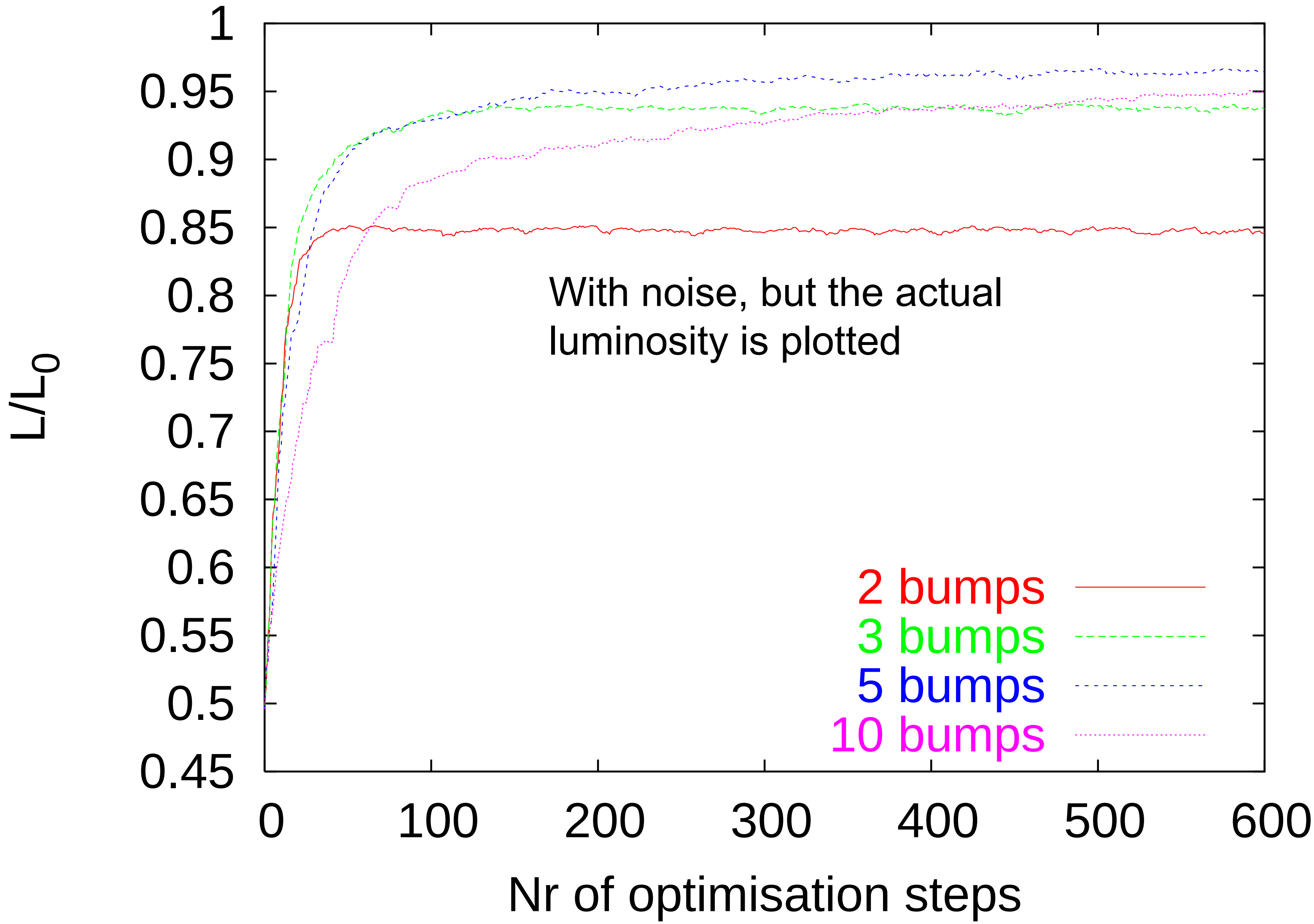
    (Gaussian distribution, σ = 3%, truncated at 3σ.)



Realistic optimisation (results)

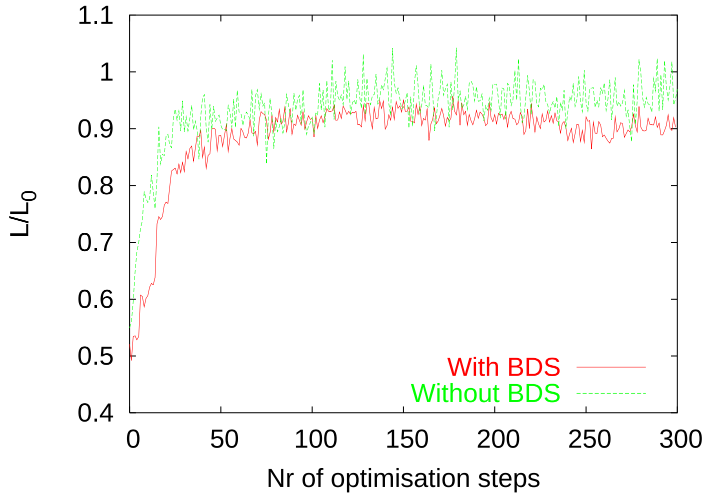


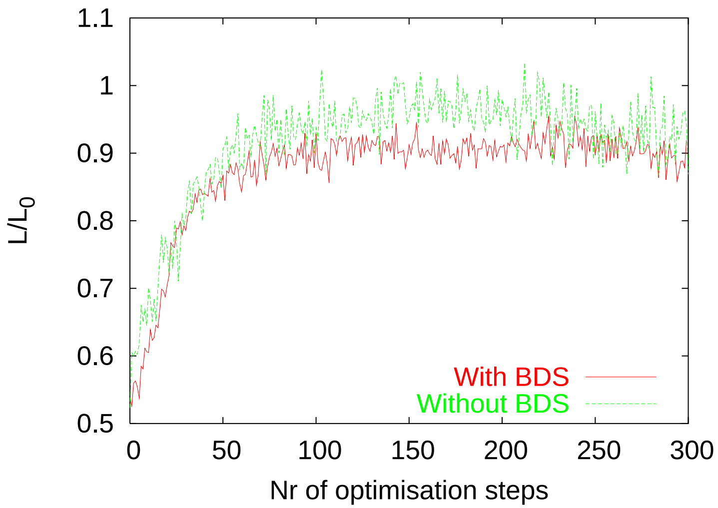
Realistic optimisation (results)

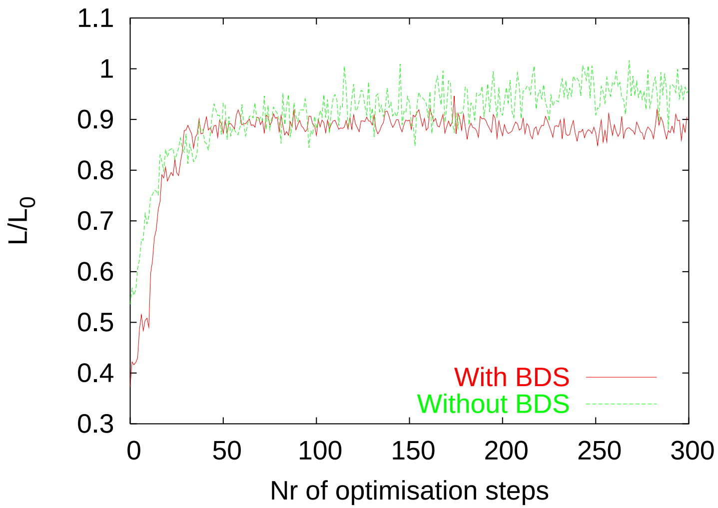


Including BDS

- Same method again, but:
  - BDS included.
  - Guineapig used to calculate luminosity.
- Comp. to prev. method with noise. 3 machines, 5 bumps.



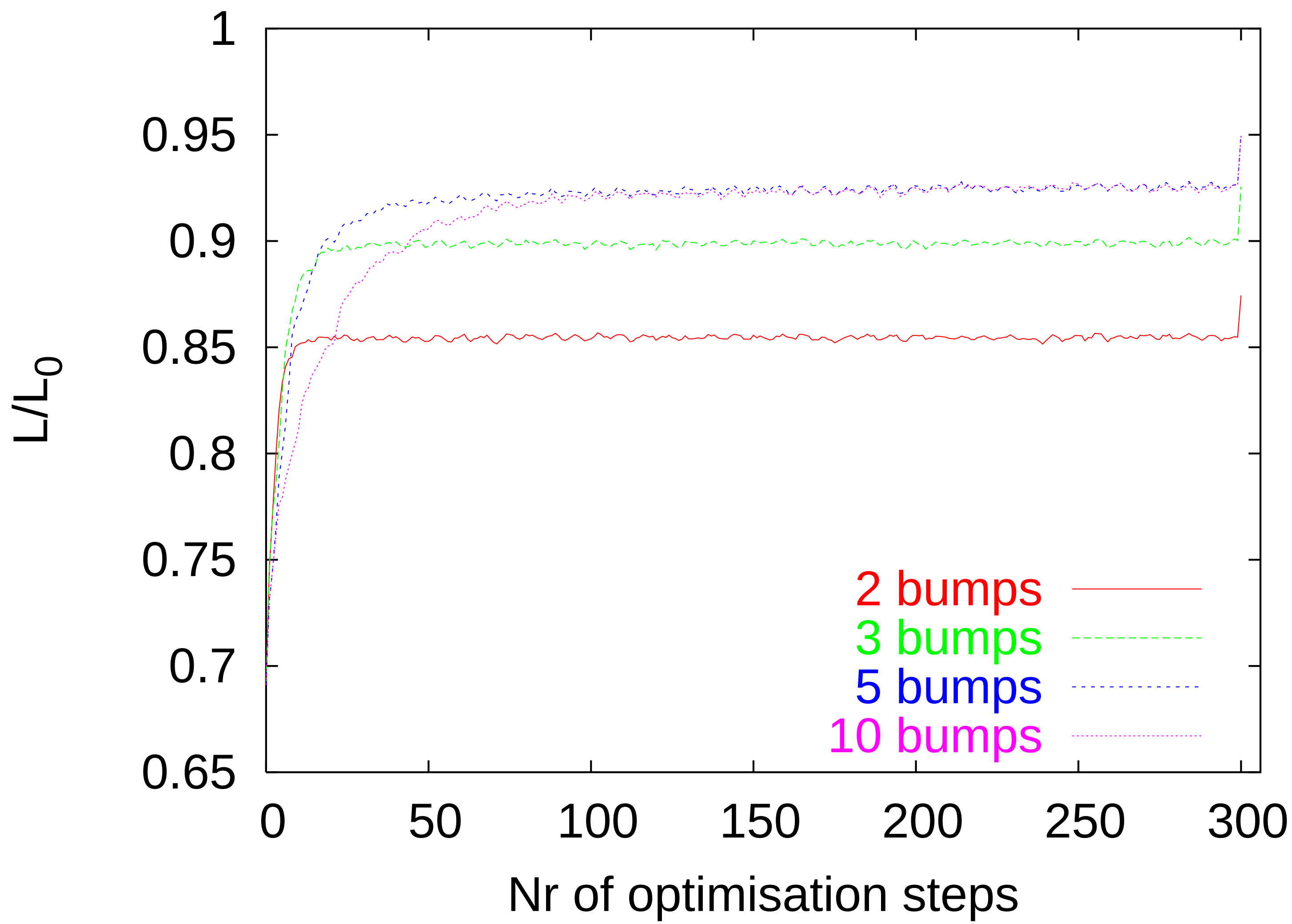




Using wide laserwire

- Only optimisation on one side.
- Two laserwires used to emulate collision with a perfect beam.
  - Laserwires have a gaussian transverse profile with a size representing the target beam.
  - Laserwires are separated by a betatron phase advance of 90° to measure on both phases.
- During the first and last optimisation step the positions of the laserwires are adjusted. (see later slide)

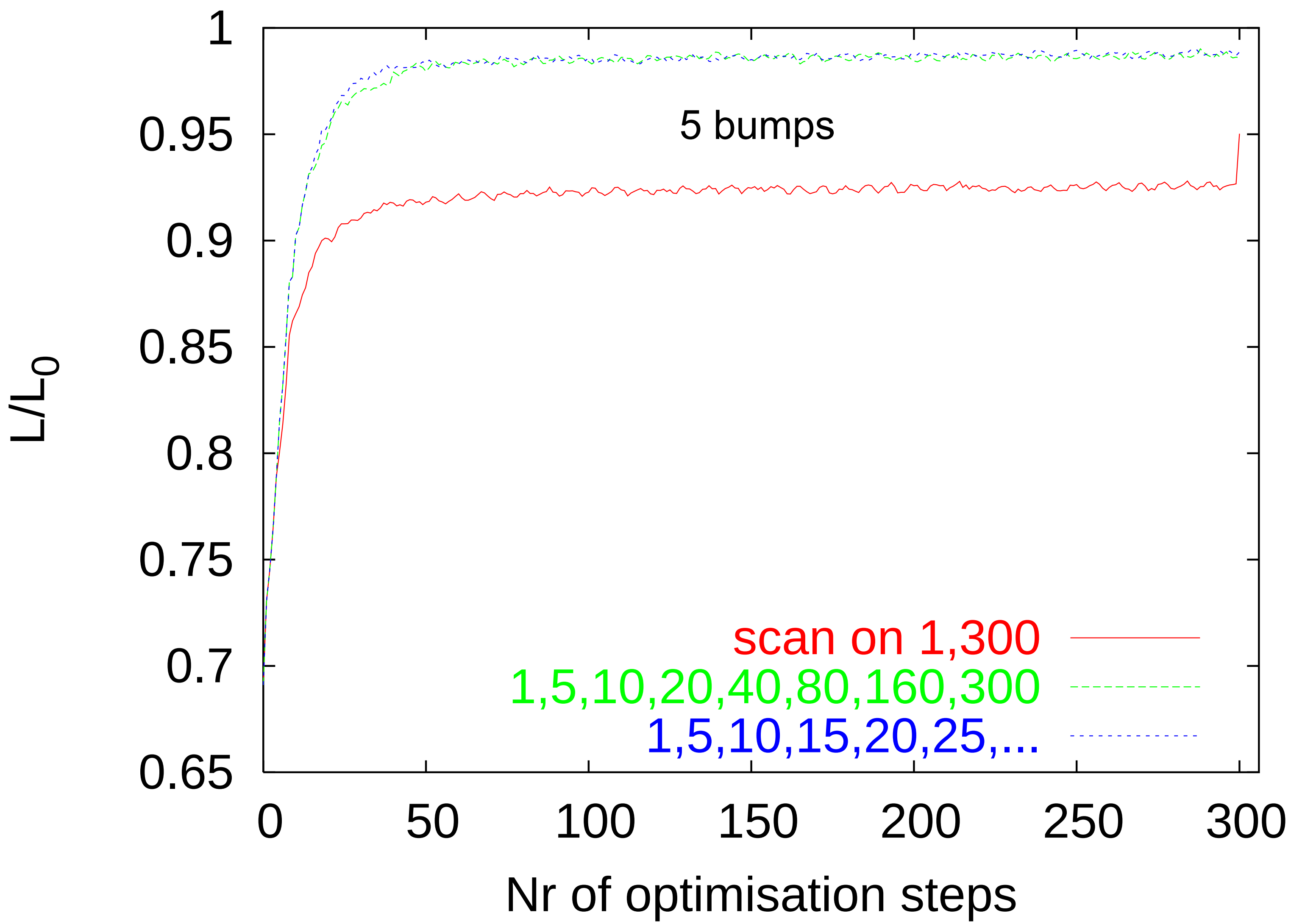
Using wide laserwire (results)



Using wide laserwire (cont.)

- Obtained results show that the laserwire position has to be continously adjusted.
- Optimum laserwire position found by fitting a second-order polynomial to five measurement points.
- Adjustment of laserwire position is carried for each of the knobsettings tested during an optimisation step.
- Two ”schemes” tested:
  - Adjustments on every fifth optimisation step.
  - Adjustments on step 1, 5, 10, 20, 40, 80, 160, 300

Using wide laserwire (results 2)



Conclusions

- Luminosity tuning bumps work well.
  - In an ideal situation, almost all luminosity can be recovered using 5 or 10 bumps.
  - More realistic tests show that almost 97% can be recovered when noise is added to luminosity measurement. (σ = 3%)
- Novel way of using laserwire give good results.
  - Beam-laser luminosity can be used as a tuning signal.
  - Laserwire position has to be adjusted from time to time.
- Realistic simulations (linac + BDS, Guineapig) show that ~90% of luminosity can be recovered using 5 bumps.
  - Target value is 70%.