Tuning bumps in the main linac

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Introduction

- Dispersion bump as a complement to Dispersion Free Steering.
- TESLA linac lattice misaligned according to TRC scheme.
- Two methods of DFS tested.

- After grad-grad: $\Delta\epsilon_y(90\%) \approx 55nm$

- After energy-grad: $\Delta\epsilon_y(90\%) \approx 25nm$

- Target is $\Delta\epsilon_y(90\%) < 10nm$

Misalignment Model

- TRC model

- $\sigma_{quad} = 300\,\mu\text{m}$

- $\sigma_{cav} = 300\,\mu\text{m}$

- $\sigma'_{cav} = 200\,\mu\text{radian}$

- $\sigma_{bpm} = 200\,\mu\text{m}$

- $\sigma_{res} = 10\,\mu\text{m}$

- $\sigma_{module} = 200\,\mu\text{m}$

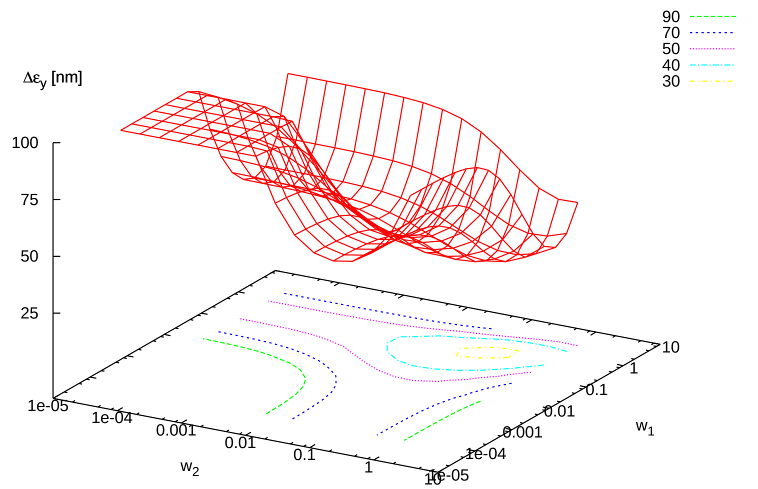
Dispersion Free Steering

- Two DFS methods

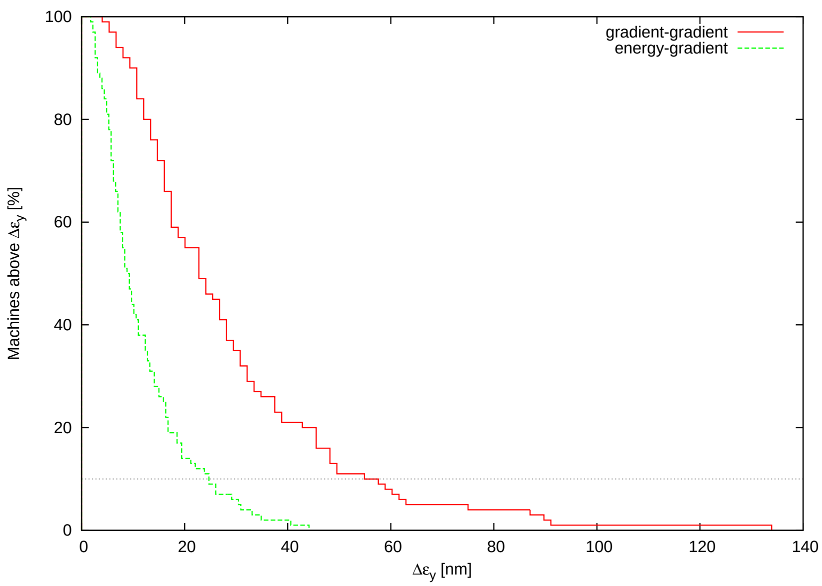
DFS method	Beam 1	Beam 2	Beam 3
gradient-gradient	nominal	10% lower gradient	20% lower gradient
energy-gradient	nominal	20% lower gradient	20% lower energy

Results of DFS

- Optimal weights for DFS.



- After DFS. BPM$_{res} = 10\mu m$ (not very different in case of 5, 2, 1 μm.)

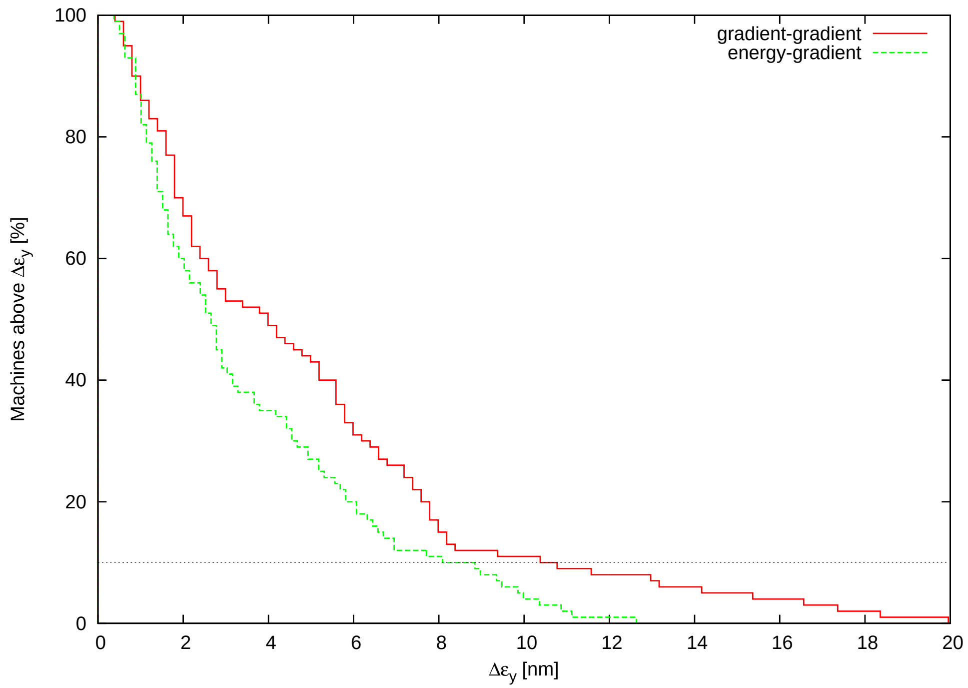


Dispersion bumps

- Each bump controlled by two knobs. One adjusting the dispersion and one adjusting dispersion derivative.
- Bumps were implemented as a change of the particle coordinates at a given point.
- Brents method was used for optimisation of the knobs.
- Procedure iterated until convergence.
- For each bump setup, 100 machines were simulated.
- Laserwires were used to evaluate the effect of the bumps.

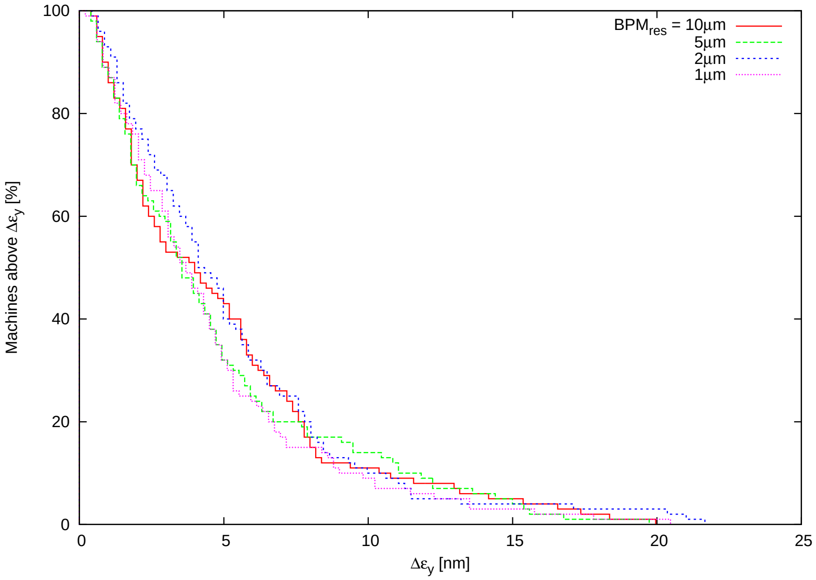
Using two dispersion bumps

- One bump in beginning and one in the end. BPM$_{res} = 10\mu m$.
- Two bumps enough to bring emittance close to target.

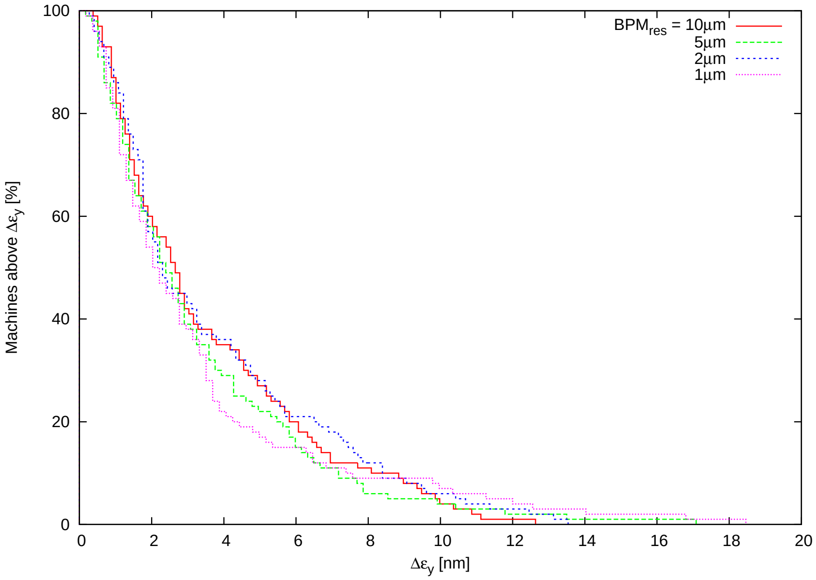


Effect of BPM resolution

- Gradient-gradient method.

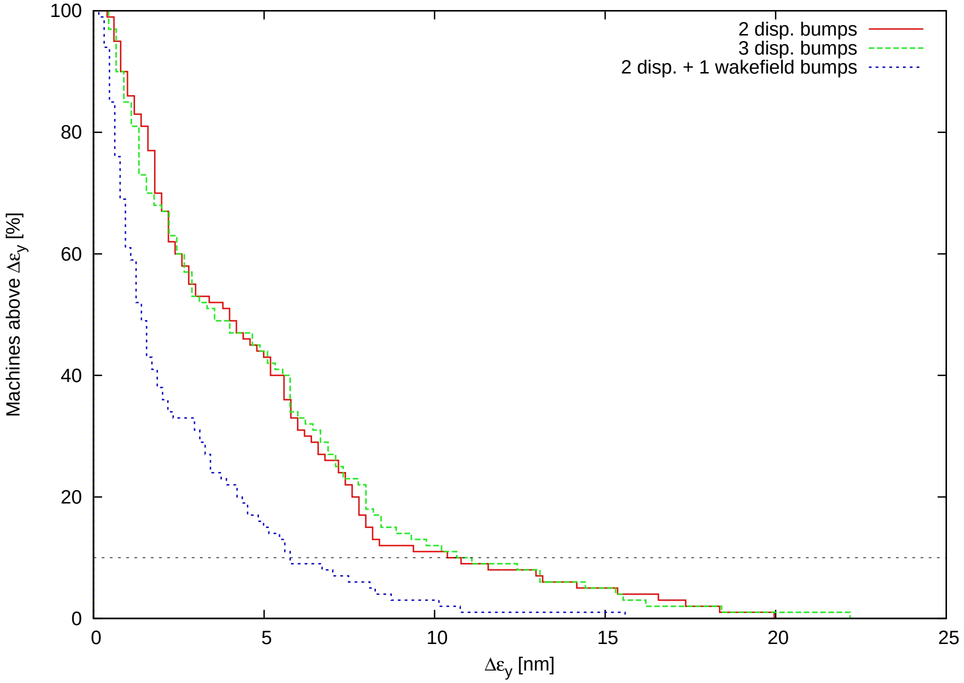


- Energy-gradient method.



Adding a third dispersion bump

- A third dispersion bump in the middle of the linac does not improve performance.
- Instead the use of a wakefield bump was tested (see next slides)



Wakefield bumps

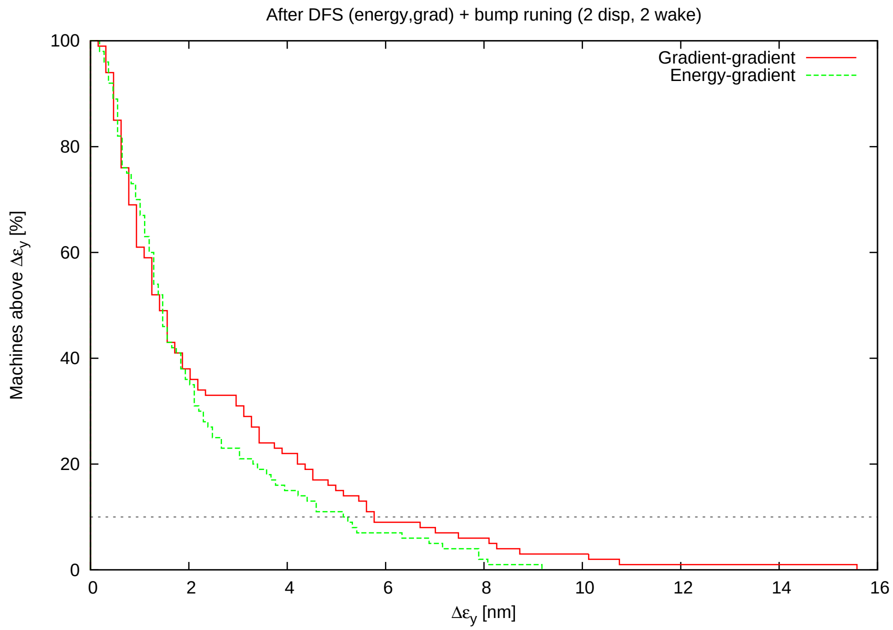
- Controlled by two knobs. One knob offsets one quadrupole by an amount Δy and another quadrupole 360 degrees later by an amount $-\Delta y K_1/K_2$ to kick the beam back into its orbit. Second knob acts on the beam at a phase 60 degrees from the other.
- The pairs of quadrupoles are positioned after a third and two thirds of the linac respectively.
- Same optimisation method as before was used.

Two dispersion and one wakefield bump

- Both methods of DFS now fulfil the emittance requirements.

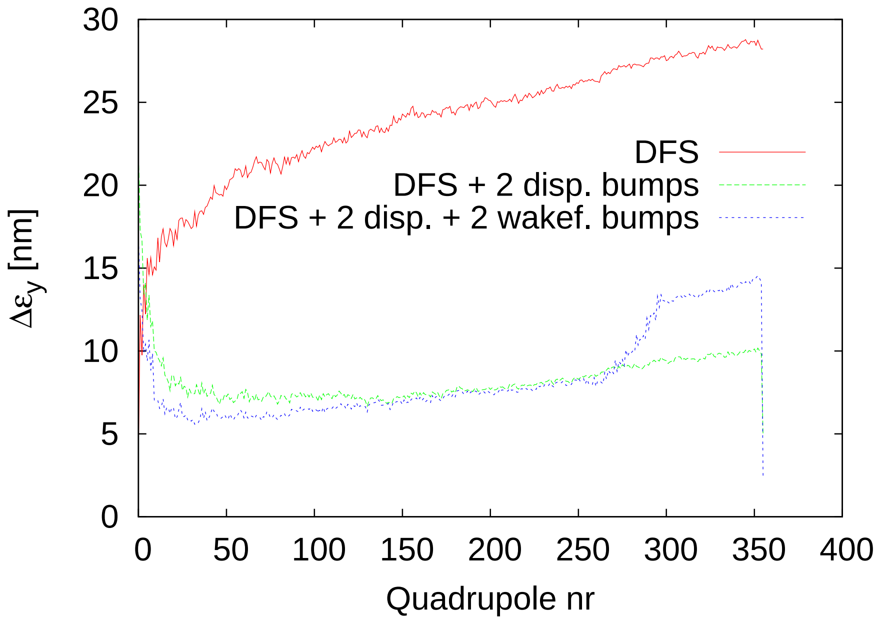
- Gradient-gradient: $\Delta\sigma_y(90\%) \approx 6nm$

- Energy-gradient: $\Delta\sigma_y(90\%) \approx 5nm$



Emittance along the linac

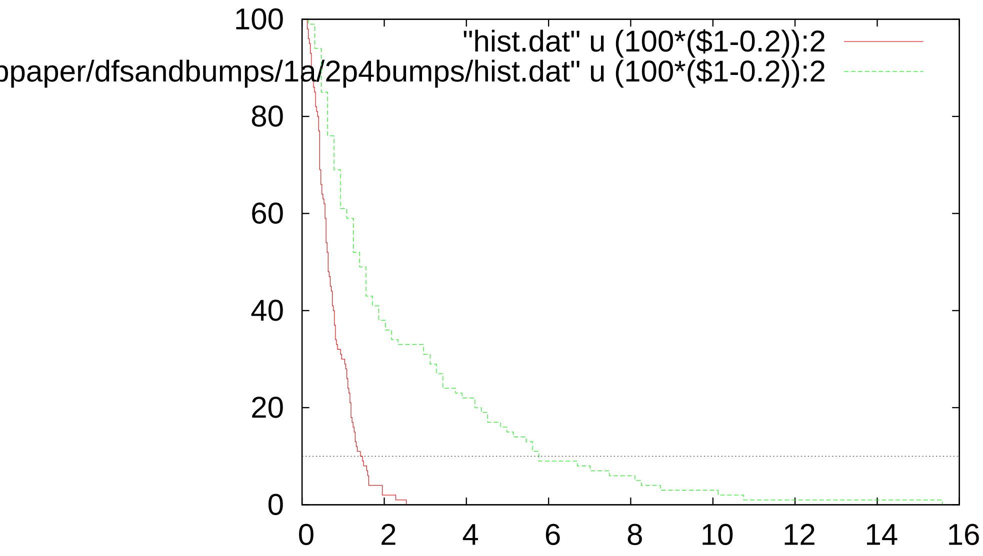
- Wakefield bump gives rise to dispersion that might be better to remove as fast as possible.
- Position of the quadrupole pairs modified to get better performance. Move closer to each other.



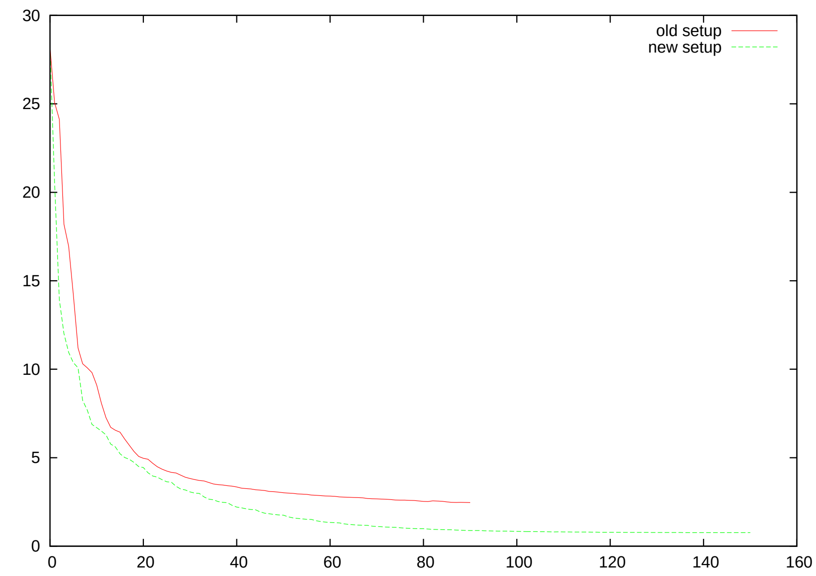
Two dispersion and one wakefield bump (new setup)

- Far better emittance than the target.
- Worst case simulated, i.e. gradient-gradient DFS, BPM$_{res} = 10\mu m$

- $\%$ of machines above $\Delta\epsilon_y$

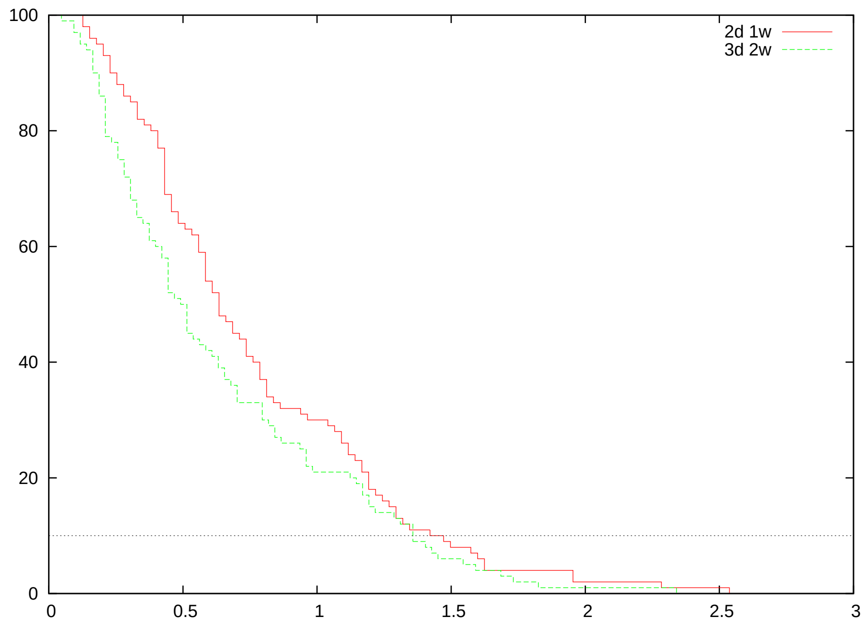


- $\Delta\epsilon_y$ vs optimisation steps



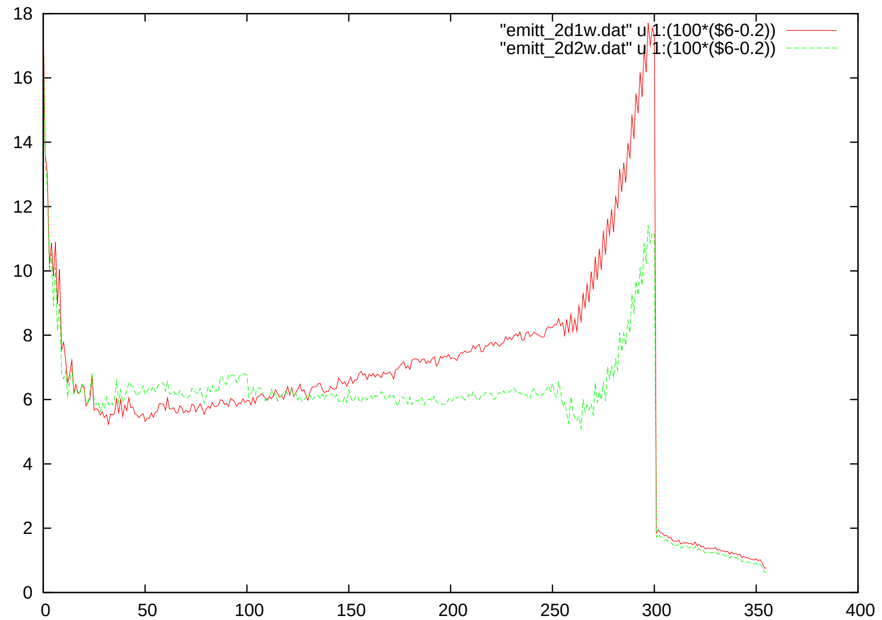
Three dispersion and two wakefield bumps

- With another wakefield and dispersion bump the final emittance is only slightly improved.



Comparison

- 2 dispersion + 1 wakefield bump compared to 3 dispersion + 2 wakefield bumps.
- The already low emittance growth is reduced by 15%
- The emittance along the linac looks nicer.



Robustness

- Only preliminary results (4 machines simulated)
- Final states of machines after DFS and bump tuning used.
- Sensitivity to variations in bunch charge and phase studied.
- Effect of RF grad. and bunch length should be studied.

- charge $\sigma = 5\%$

machine nr	orig. ϵ	mean ϵ	proj. ϵ
1	20.1577	20.1635	20.1679
2	20.2084	20.2141	20.2171
3	20.2434	20.2549	20.2665
4	20.0419	20.0429	20.0416

- phase $\sigma = 1^o$

machine nr	orig. ϵ	mean ϵ	proj. ϵ
1	20.1577	20.3447	22.3215
2	20.2084	20.3127	21.3749
3	20.2434	20.4338	24.5214
4	20.0419	20.0654	20.3069

Conclusion

- DFS steering does not reach emittance target on its own.
- Dispersion bumps very effecient (2 bumps seems enough).
- Dispersion bumps + wakefield bumps give very good results. $\Delta\epsilon_y < 1.5nm$.
- Extra wakefield and dispersion bump improves results slightly.
- For final state linac seems quite robust, not sensitive to bunch charge variations, projected emittance affected by phase variations.

Ongoing studies, future work

- Some simulations have been performed to find the optimal position of bumps. More work needed.
- To get faster knob convergence independant knobs ate needed. Some work done already, but much more needed.
- Real bumps/knobs should be designed.
- Further studies of robustness needed. Might be sensitive to phase variations. What about RF grad, bunch length, ground motion, quadrupole jitter, klystron failure?