Australian Government

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Bunch Compressor Optimization

Compact Light Glasgow Virtual Meeting

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On behalf of WP6

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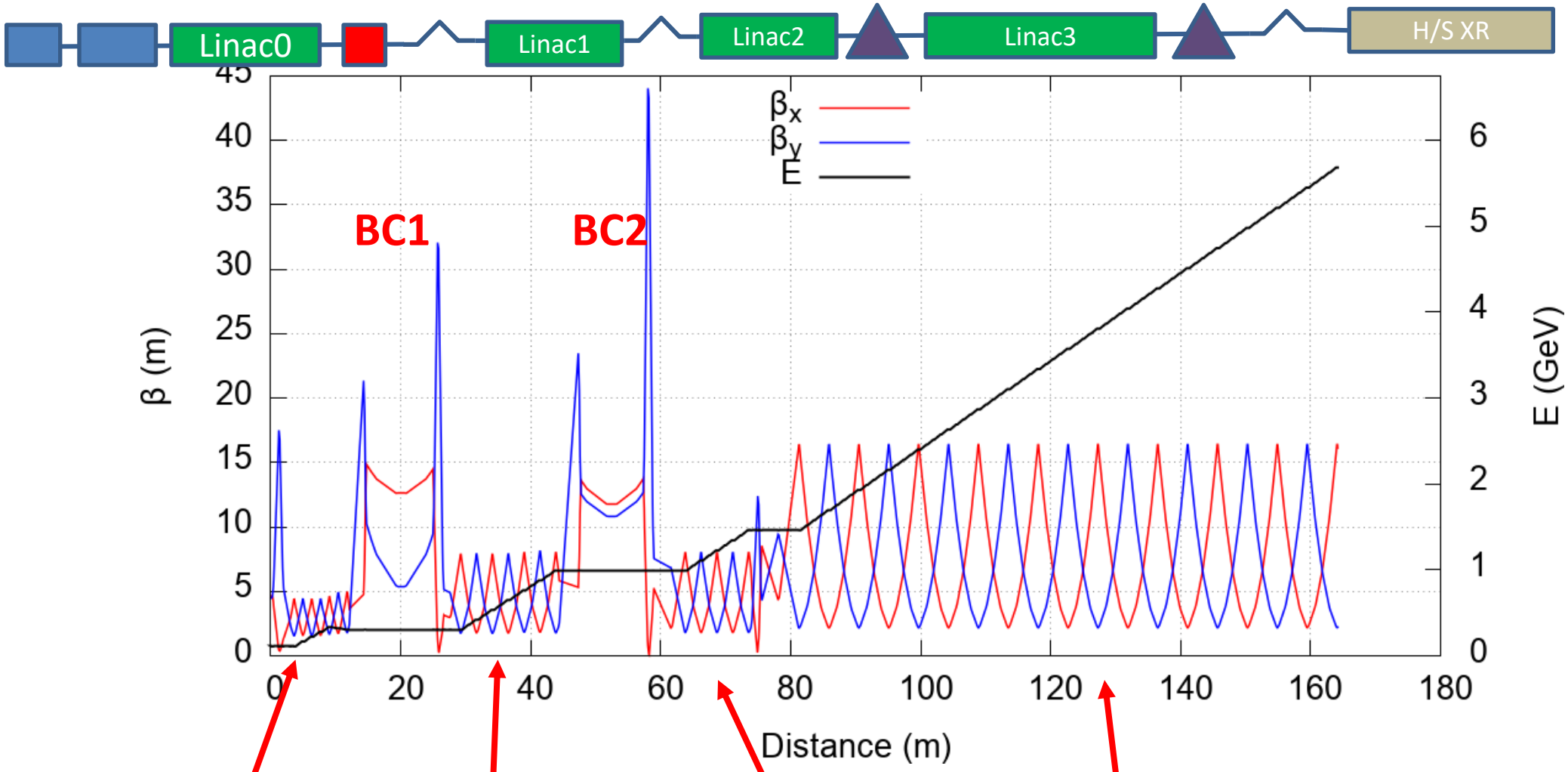

Linac0
1-str beween
quads

Linac1
2-str beween
quads

Linac2
2-str beween
quads

Linac3
4-str beween
quads

A. Aksoy

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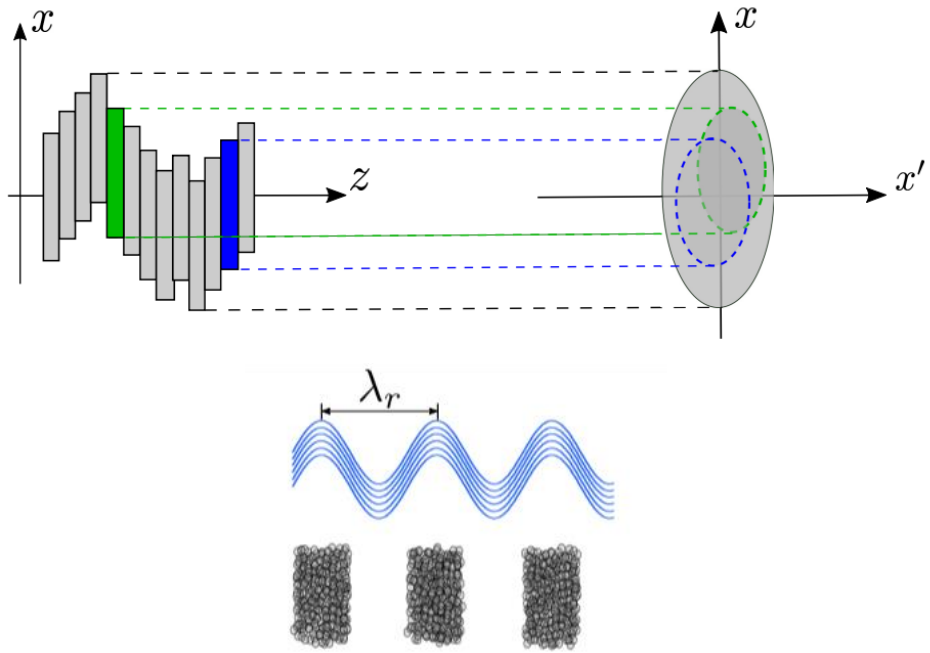
CSR and Bunch Compressors

- Coherent Synchrotron Radiation (CSR) will be produced if a bunch through a dipole has a bunch length shorter than the wavelength of emitted radiation.
- For a bunch passing through a BC, CSR can impact the quality of the beam by:
  - Causing significant emittance growth
  - Increasing the projected emittance
  - Causing micro-bunching instabilities



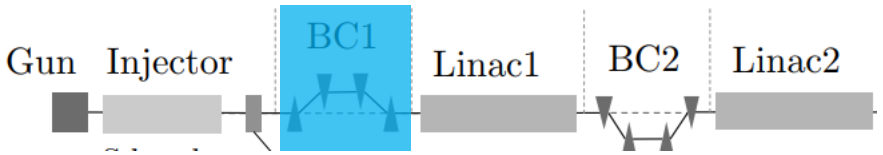
Micro-bunching Instabilities

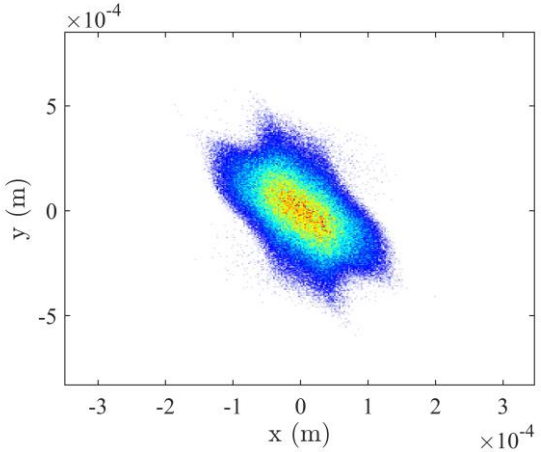
- Fragmentation of the longitudinal phase space
- CSR, longitudinal wakefields and longitudinal space-charge (LSC) can contribute to M-B.I.
- Impact FEL performance indirectly by instability induced energy spreading

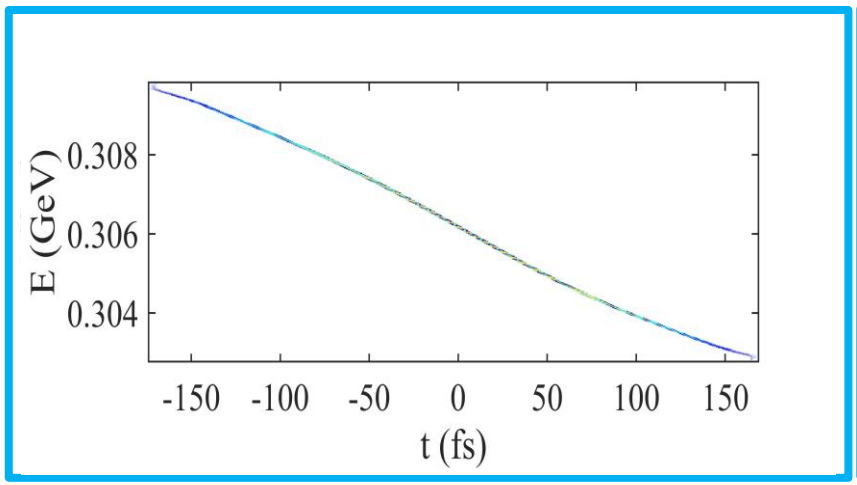
Energy spread and longitudinal phase space through BC1 and BC2

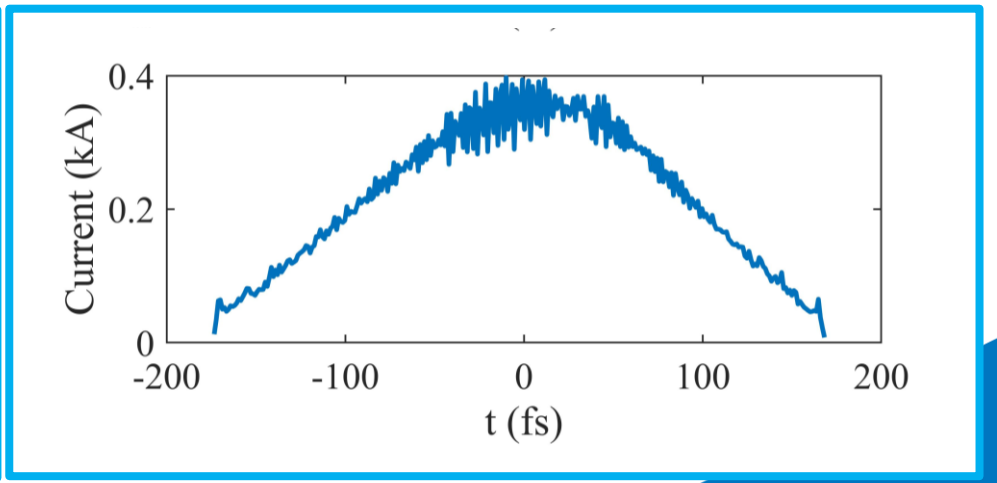
- Slice energy spread is small initially but grows due to CSR or LSC driven instabilities

End of BC1





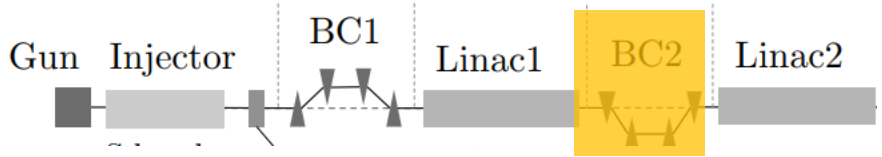


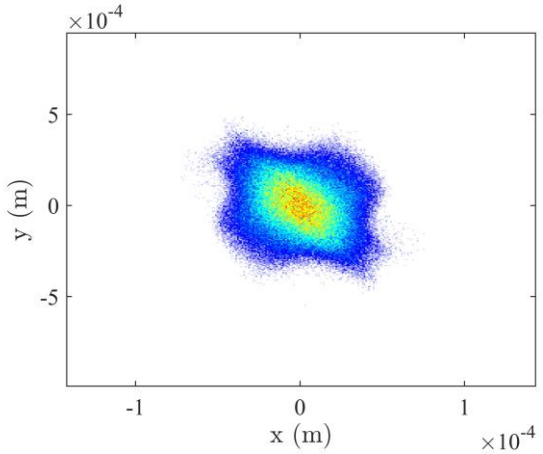


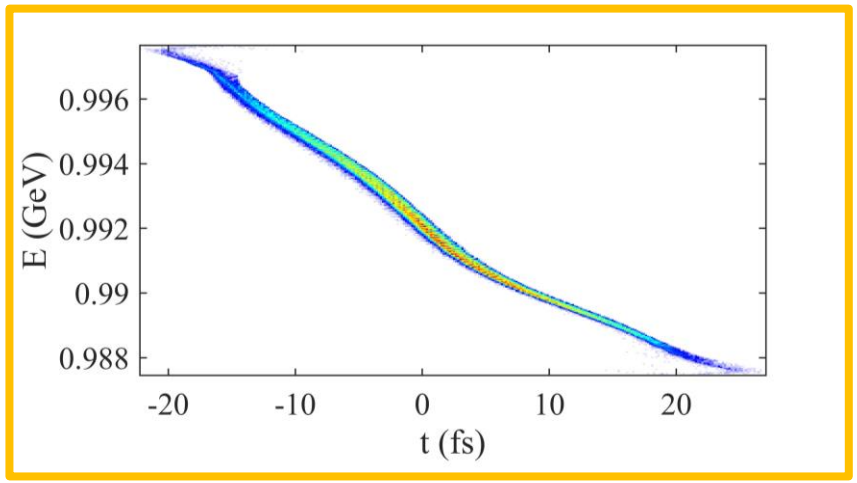
Energy spread and longitudinal phase space through BC1 and BC2

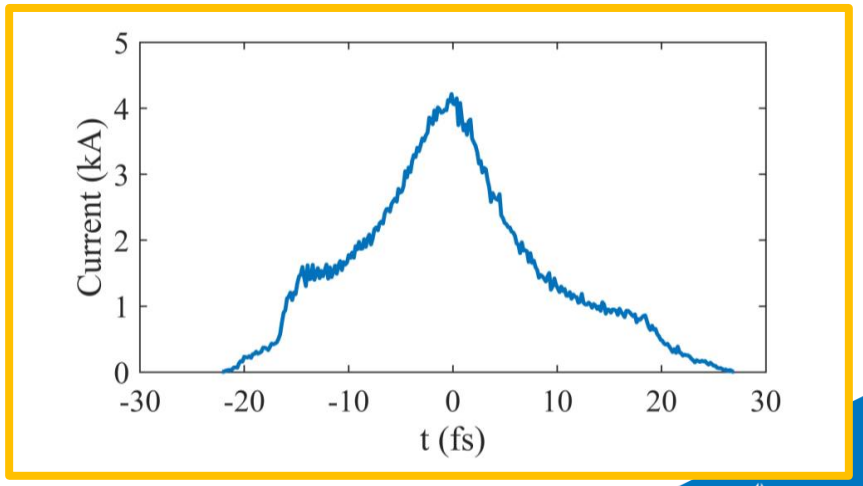
- Slice energy spread is small initially but grows due to CSR or LSC driven instabilities

End of BC2









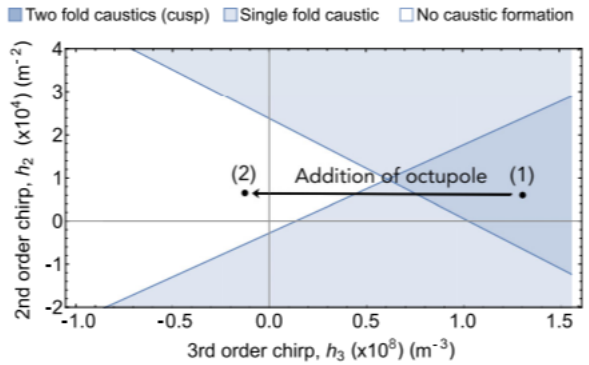
Optical Linearization to reduce emittance growth

- Use sextupoles and octupoles in the bunch compressor to achieve linear compression
  - T_{566} and U_{5666} are control variables

$$h_2 R_{56} + h_1^2 T_{566} = 0$$
$$h_3 R_{56} + 2h_1 h_2 T_{566} + h_1^3 U_{5666} = 0$$

$$T_{566} = -\frac{h_2 R_{56}}{h_1^2}$$

$$U_{5666} = \frac{2h_2^2 R_{56} - h_1 h_3 R_{56}}{h_1^4}$$



T. K. Charles, D. M Paganin, A. Latina, M. J. Boland and R. T. Dowd, Phys. Rev. AB, 30, 030705, 2017.

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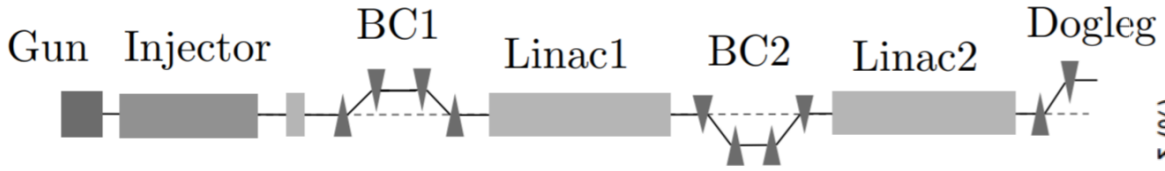
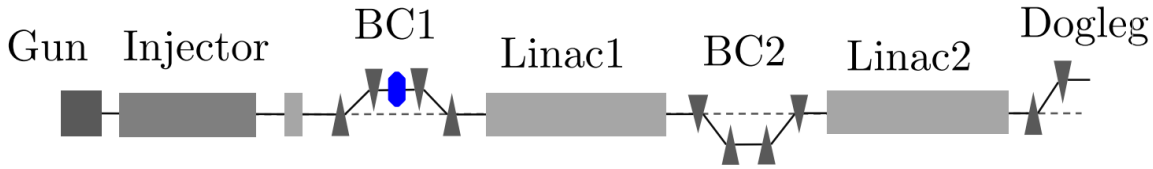
Use magnets to adjust 2nd order dispersion

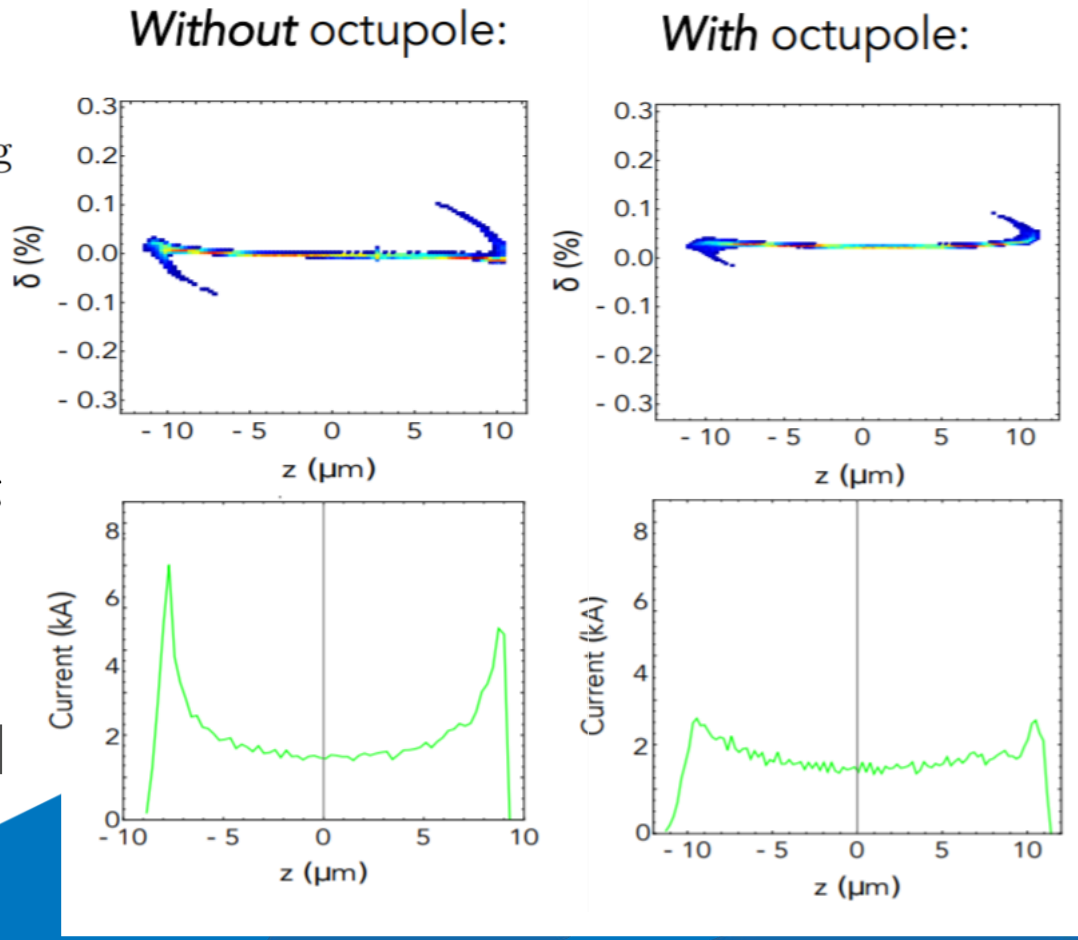
- Baseline



- Add octupole to BC1



- 49% reduction in the CSR-induced emittance growth



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T. K. Charles, D. M Paganin, A. Latina, M. J. Boland and R. T. Dowd, Phys. Rev. AB, 30, 030705, 2017.

Laser Heater to suppress instabilities

- See Simone Di Mitri's talk
- Aim: reduce instability susceptibility by increasing the energy spread
- A laser heater introduces longitudinal energy mixing with the bunch before the bunch enters the BC
  - Add a correlated microstructure to the beam phase space
    - This is removed when the beam traverses through the transport line

Z. Huang, G. Stupakov, NIM A, 2018

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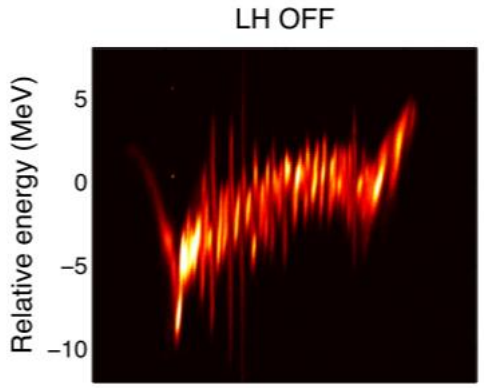

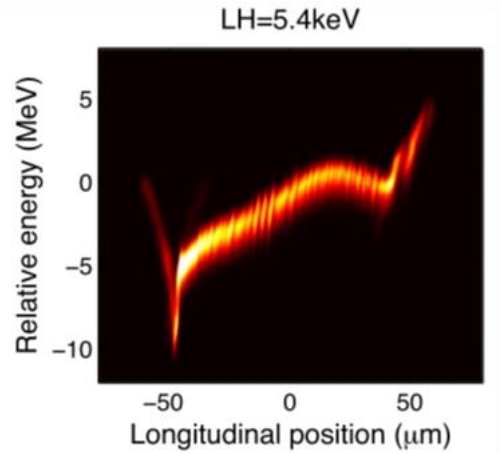

Z. Huang, G. Stupakov, NIM A, 2018

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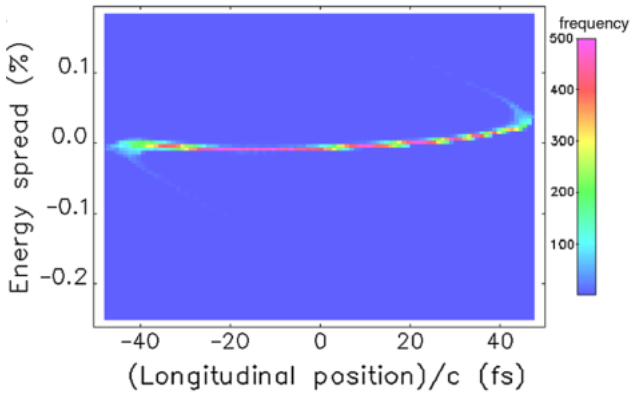
Laser Heater to suppress instabilities

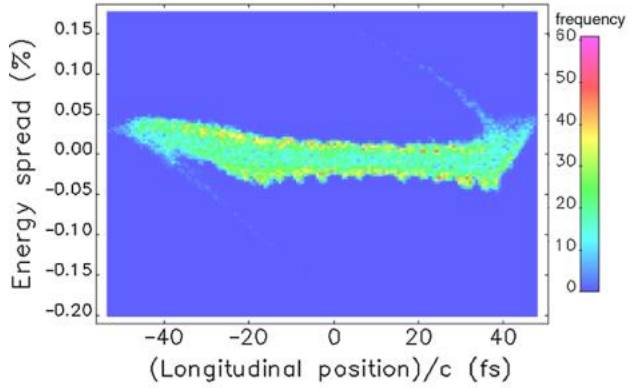
- Increases uncorrelated energy spread
- Leads to strong Landau damping
- Adding LH improves the gain length by 30% (LCLS FEL)

(Huang *et al. Phys. Rev.*, 2010)

No Heating



Laser Heater On



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Results and Current work

Optimization procedure

1. Optimize R56, using bending angles of chicane and drifts
2. Optimize the T566/U5666 term and minimize the emittance of the design
3. Constrain $\eta x/\eta xp = 0$ and symmetric at either end of the BCs
4. Place a scanner element before BC1 to scan and minimise the $\beta x,y$ functions to the final BC dipole. This will minimise the CSR.

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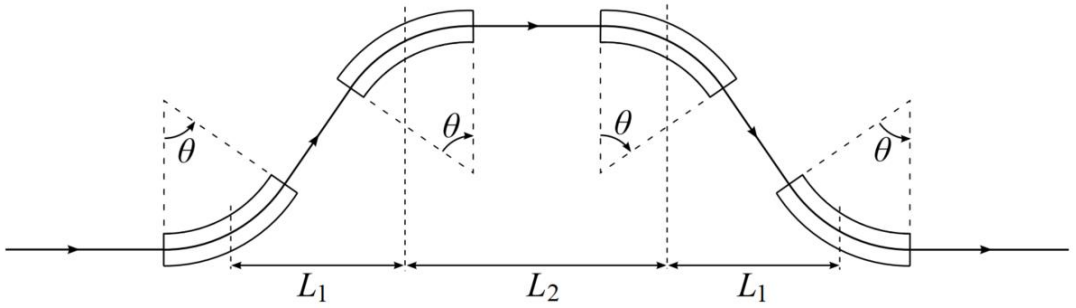

A. Wolski, Beam Dynamics, 2014

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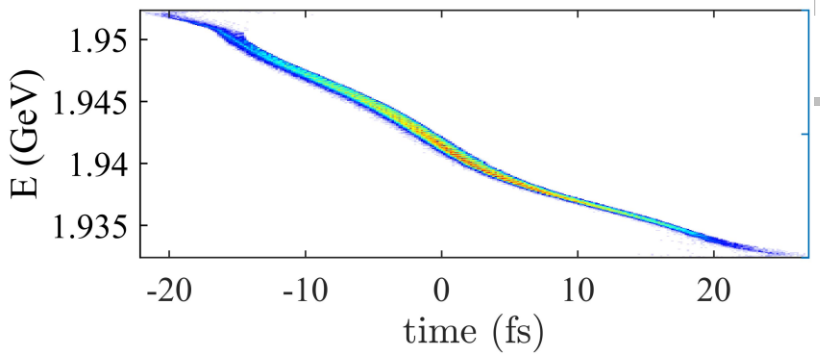

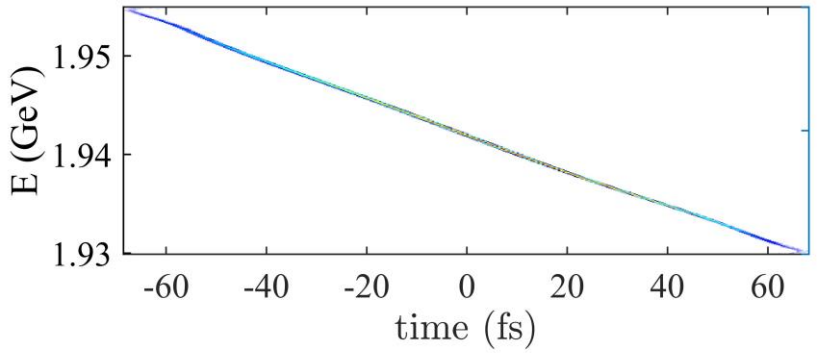

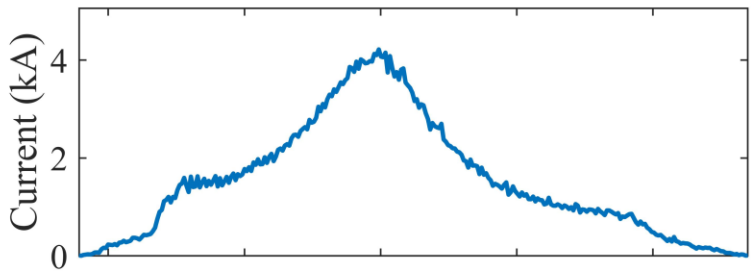

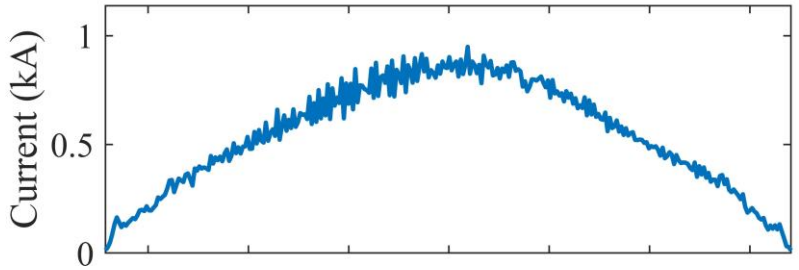

Current Work

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Current Work

- Initial β/α optical functions have a impact on the growth of the projected emittance imposed by CSR
- Next step: scans of beta functions to determine the optimal solution for BC1 and BC2
- Addition of laser heater?

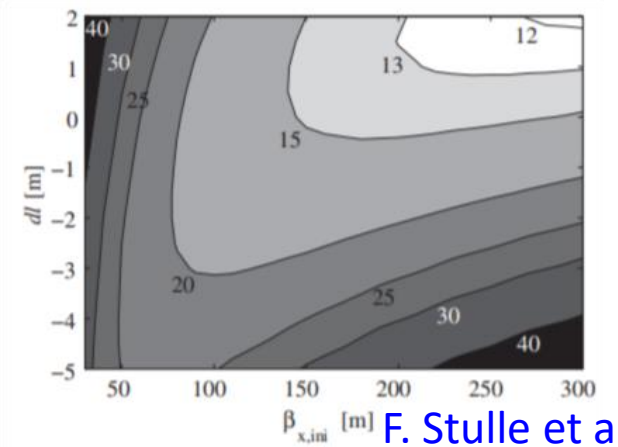

FIG. 9. Contour plot of the emittance growth in a C-chicane versus dipole shift dl and initial beta function $\beta_{x,ini}$.

F. Stulle et al, Phys Rev. Acc. And Beams, 2007

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Thank you

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