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NLS

Re-circulating Linac Option

Deepa Angal-Kalinin & Peter Williams

ASTeC, STFC, Daresbury Laboratory & The Cockcroft Institute

ASTeC Science & Technology Facilities Council

The Cockcroft Institute of Accelerator Science and Technology

Re-circulating Linac Design

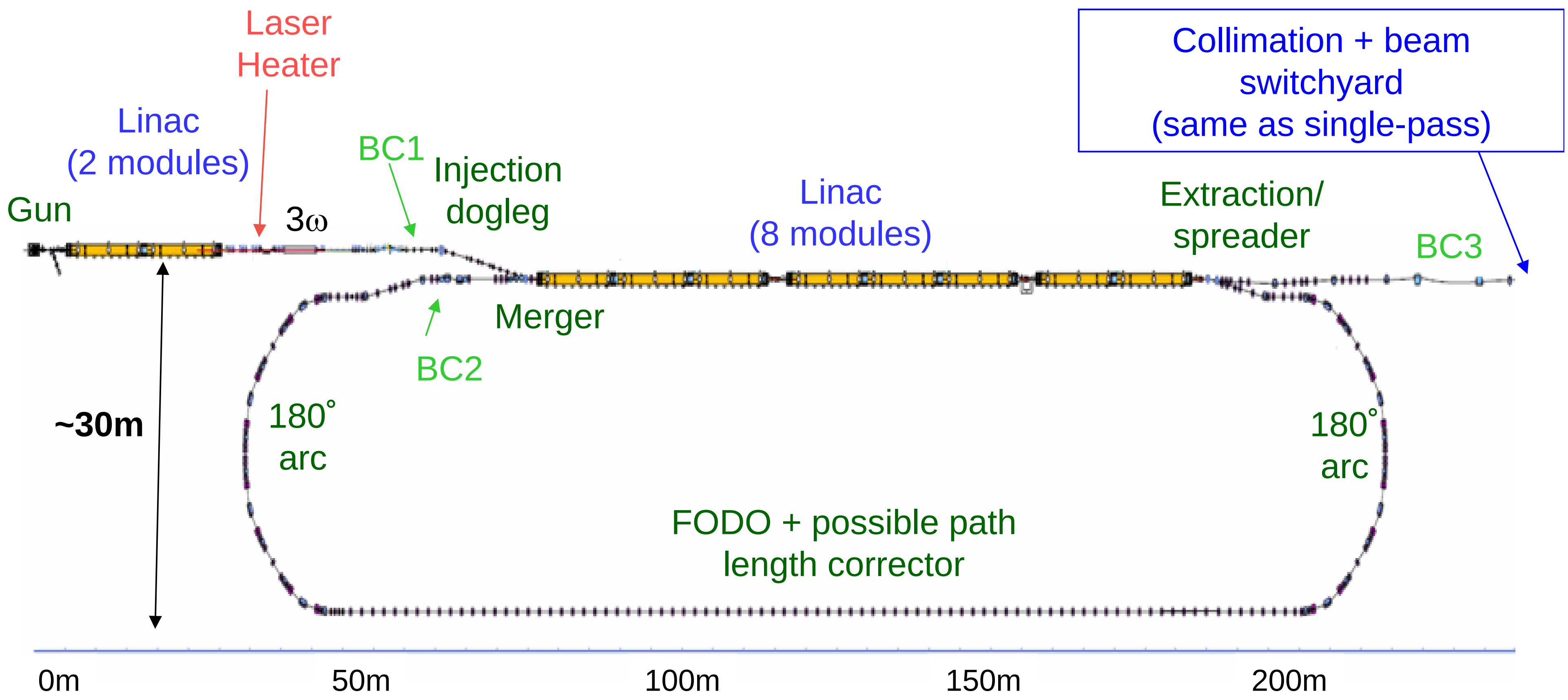
- ❑ High repetition rate requirements of NLS need SCRF Linac
  => re-circulation reduces capital and running cost

- ❑ Technical feasibility of re-circulating linac option is under investigation compared to straight through Linac baseline option

- ❑ Possibility to extract at different energies (1.2GeV and 2.2 GeV) & natural upgrade path to higher energies

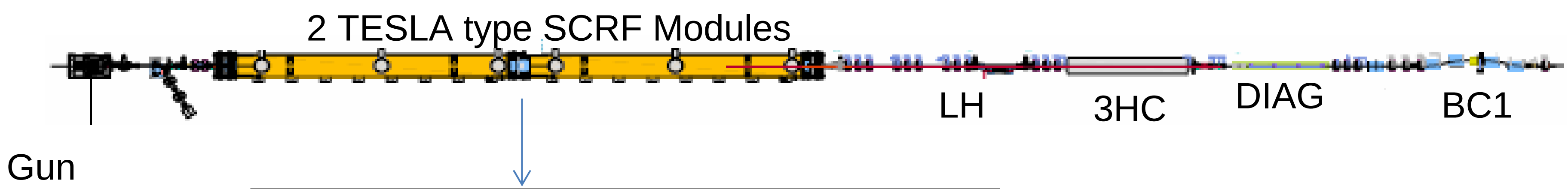
- ❑Additional issues compared to straight through option
  - ❑Combining and separating different energy beams
  - ❑CSR and ISR in the arcs, mergers/combiners & extraction
  - ❑Bunch compression and linearisation scheme restricted
  - ❑Jitter tolerances due to extra transport?

Re-circulation Linac Layout



Inject at ~200 MeV, two passes through 1 GeV

Injector, Linac module, LH, 3HC, BC1

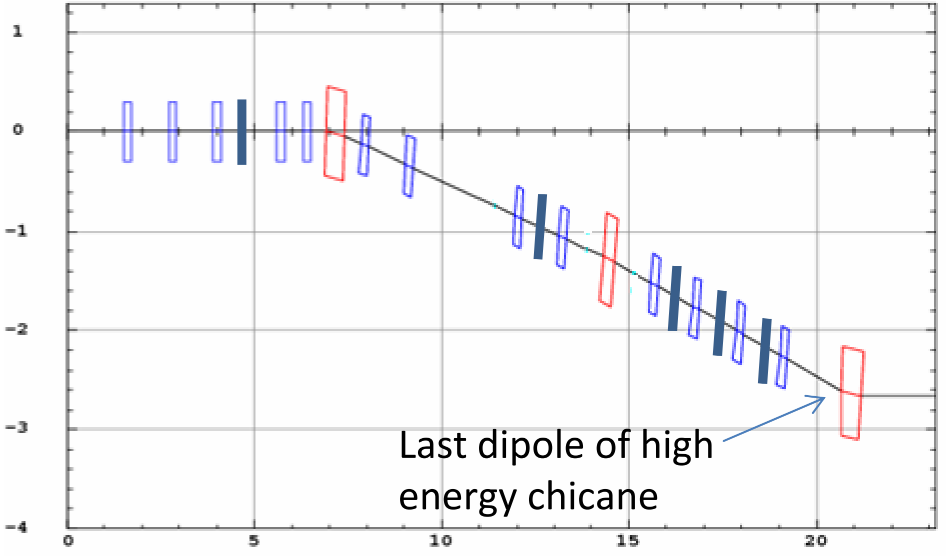


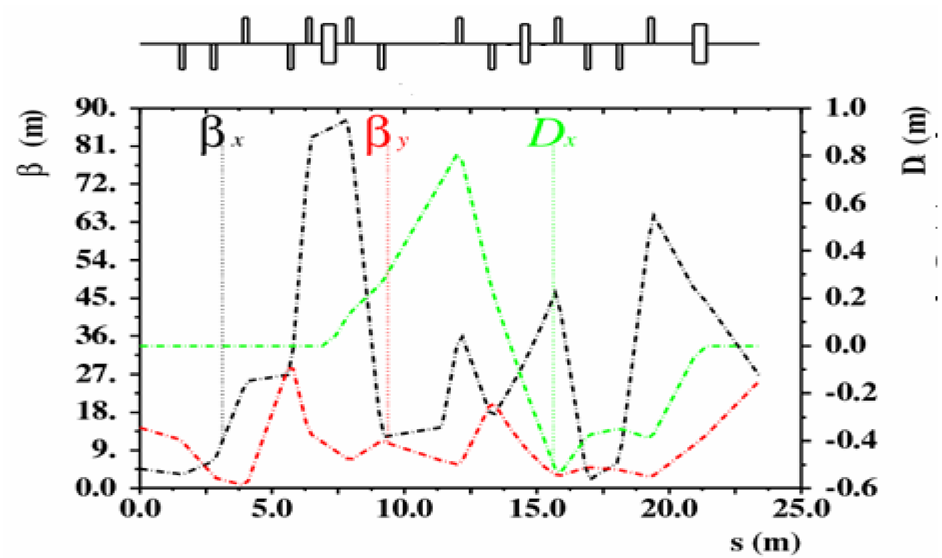
200 pC,18 ps FW, 135 MeV

Normalised emittance 0.3 mm. mrad

- ❑Choice of beam energy at injection > 200 MeV for minimising longitudinal space charge & optimum accelerating modules.
- ❑LH place holder. Reduced need due to incoherent energy spread from the arcs.

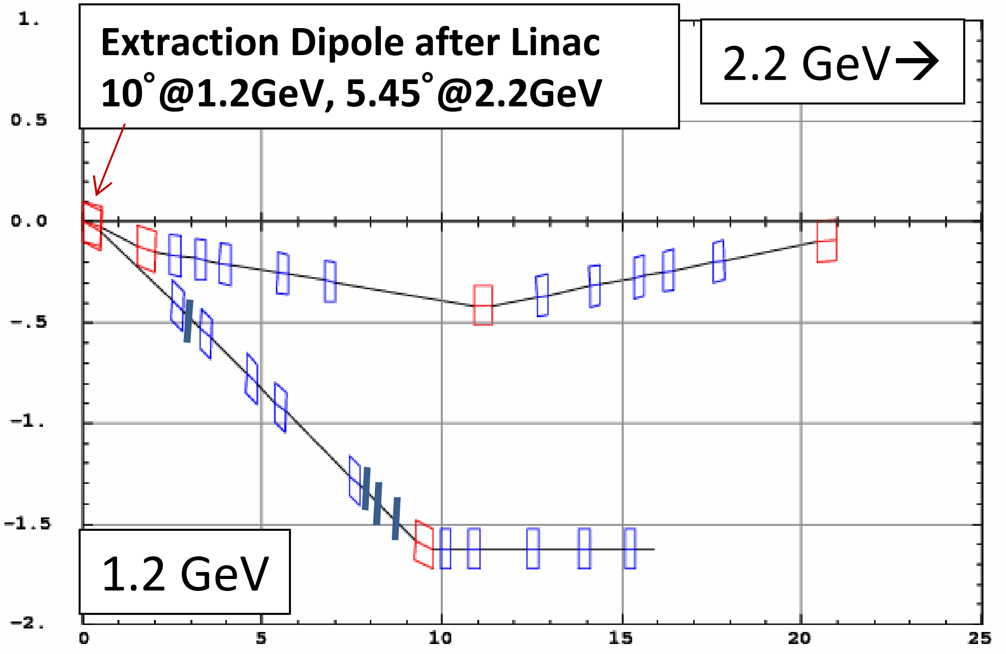
Injection Dogleg





- ❑Need to merge with the high energy beam; Ratio of energies = 6
- ❑ Achromatic and isochronous dogleg design
- ❑ Optimised number, locations and strengths of sextupoles (energy spread~0.9%)using 'Simplex algorithm' to minimise the emittance growth due to chromatic effects.

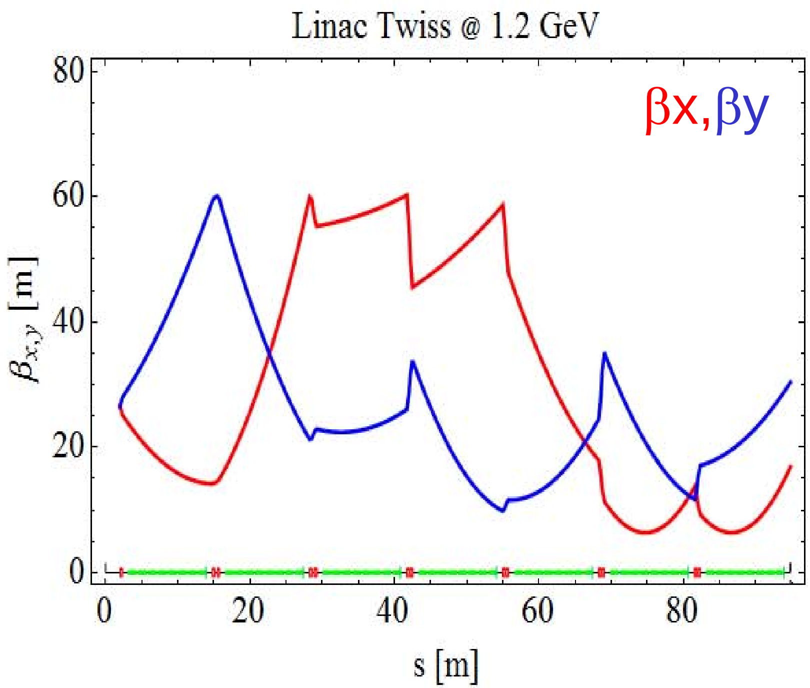
Beam Extraction

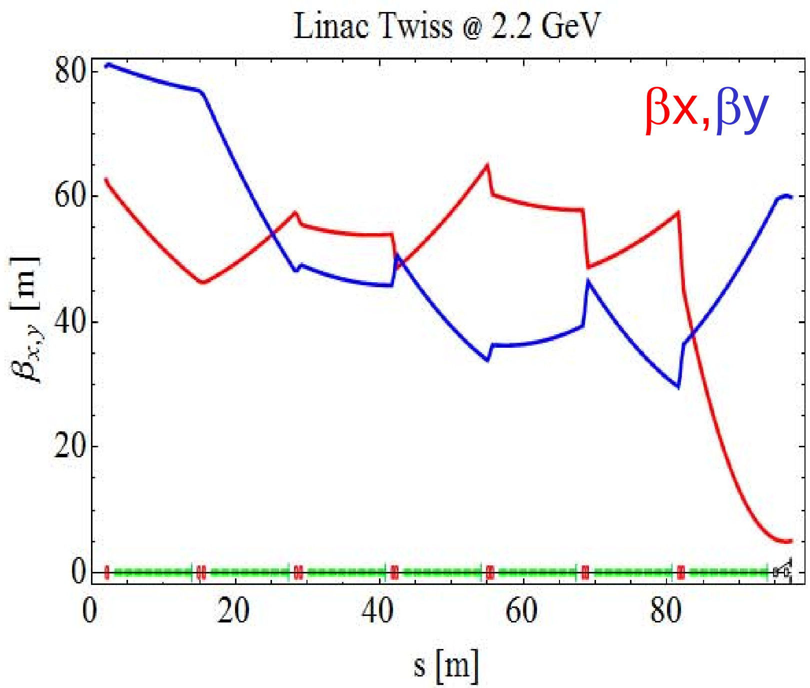


- ❑ First dipole after the Linac separates 1.2 and 2.2 GeV beams.
- ❑ 1.2 GeV beam is matched into the arc.
- ❑ R56 = 5 mm for matching to arcs and 0.002 mm for extraction.
- ❑ Optimised locations and strengths of sextupoles in matching to the arc (energy spread~0.4%) to minimise on emittances.

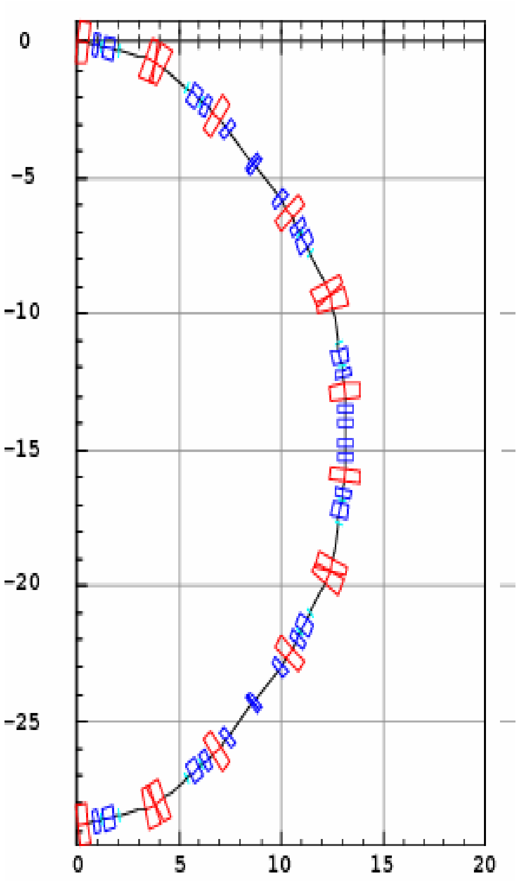
Re-circulation Linac

- ❑ 8 TESLA type cavities, maximum gradient 17.5 MV/m
- ❑ FODO between cavities optimised at two different energies to minimise CSR blow up in first extraction dipole whilst simultaneously keeping 1.2 GeV twiss sensible.





Arc Design

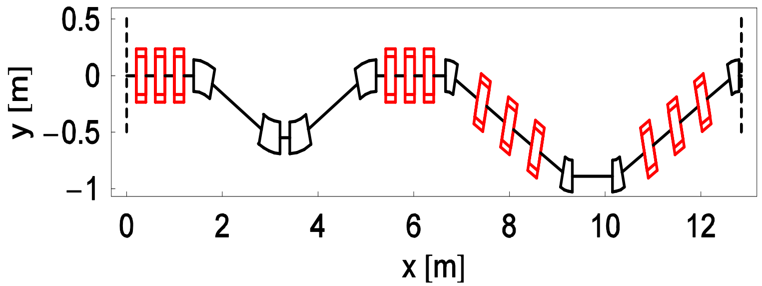


- ❑ Considered arcs from 4GLS, BESSY, LUX & DLS low-alpha **– BESSY best**
  - ❑ Four triple bend achromats, low dispersion
  - ❑ Wider footprint, non-isochronous
  - ❑ ISR emittance growth from both arcs 3.6%
  - ❑ Energy spread due to ISR ~5×10^{-5} ; useful for suppression of microbunching
  - ❑ Two sextupole families to correct the chromaticities

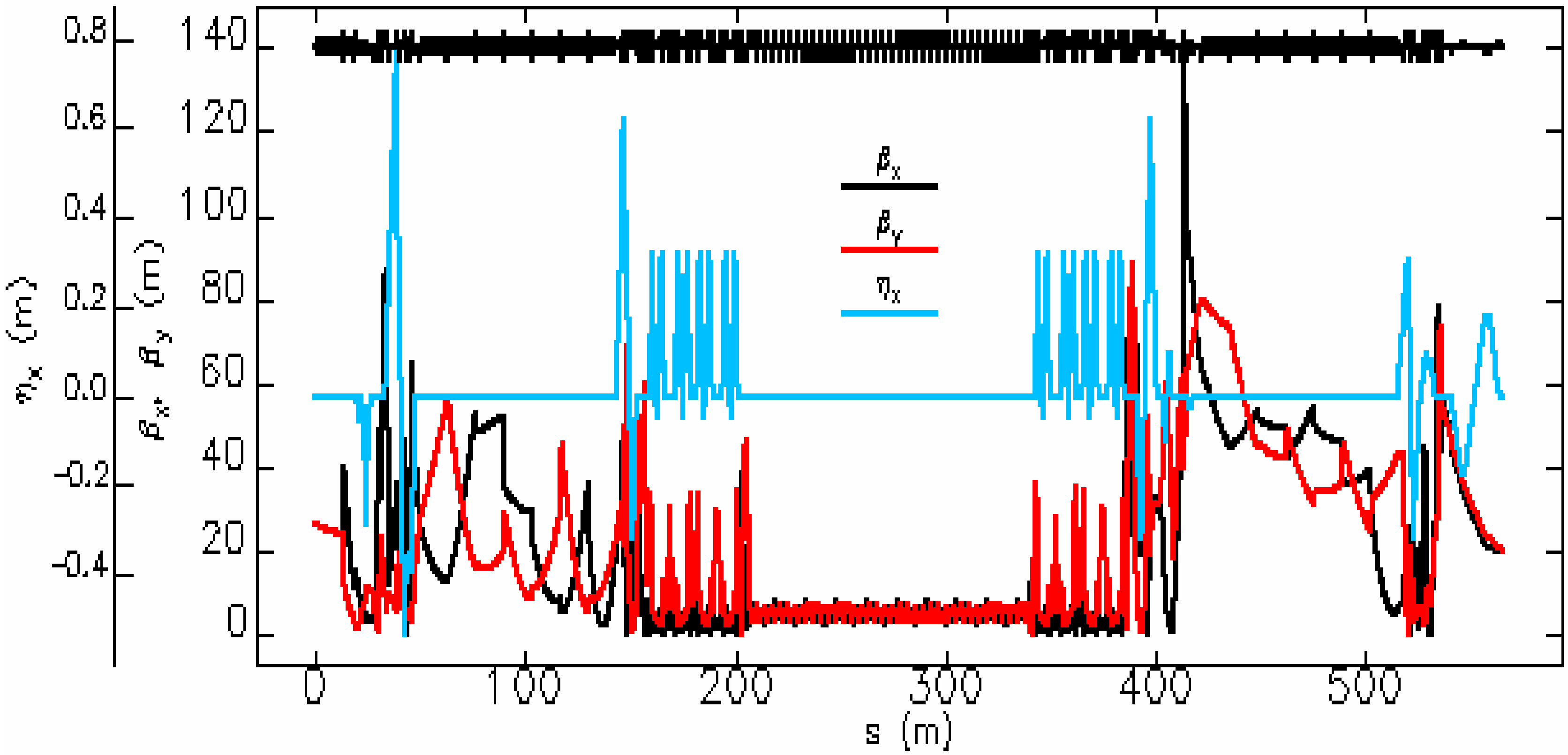
Return pass

- ❑ Return transport connecting arcs is simple FODO-cells with phase advance of 45°. Possible to include few screens to study the beam properties at 1.2 GeV.
- ❑ Plan to have isochronous path length adjuster. 4GLS design, based on moving girders - would give independent phase control on second pass of linac (this control has been assumed in the simulations)

Path length corrector



Machine Optics (start to BC3 exit)



Design optimisation

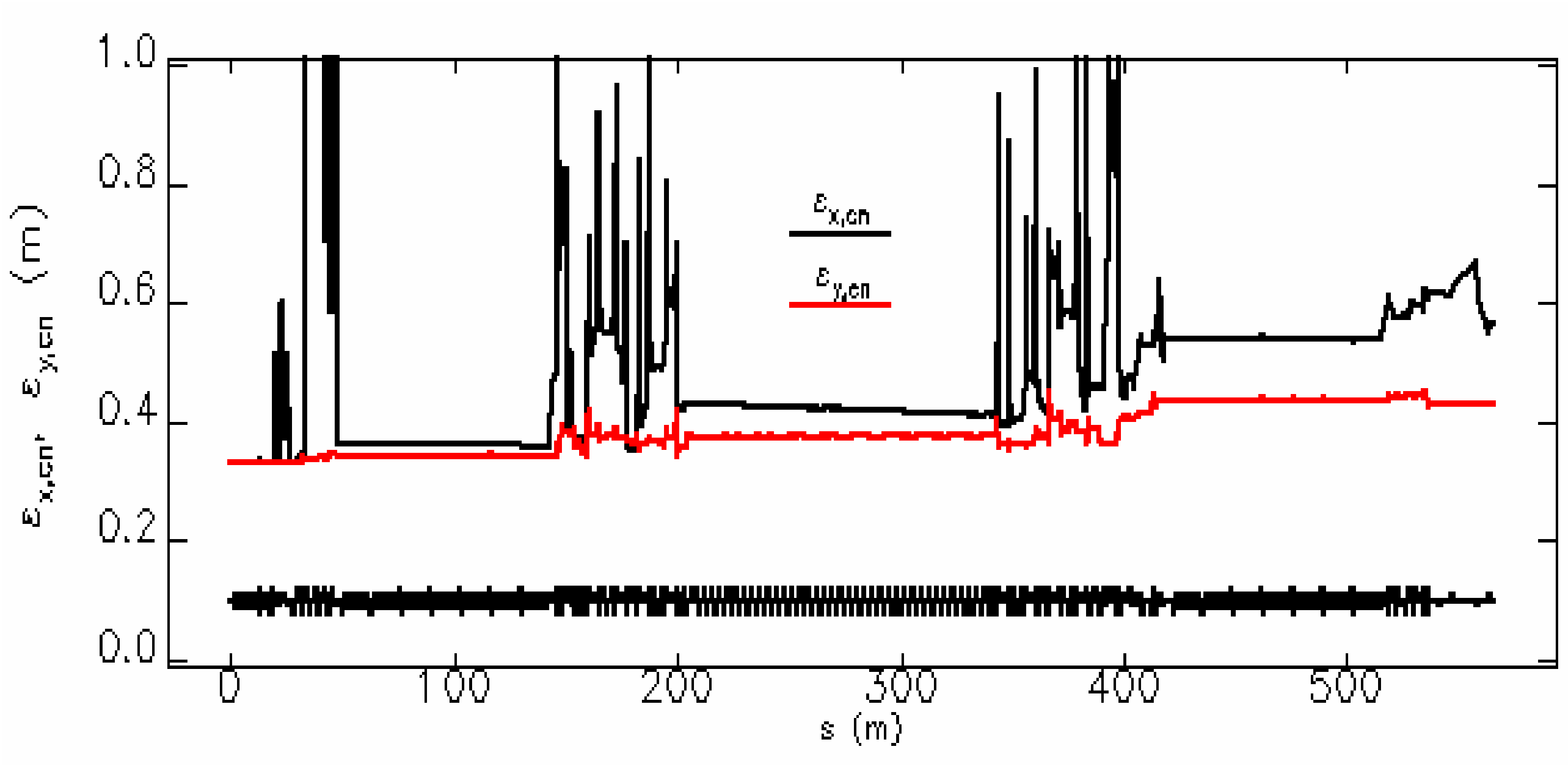
❑ Need constant slice parameters on a length of 100 fs – or longer to accommodate the seed pulse and jitter

❑ No residual (or very small) energy chirp

❑Tracking using ELEGANT from 135 MeV including CSR, ISR and Linac wakefields.

❑Manual longitudinal optimisation to progressively compress, whilst keeping bunch above 2ps through arcs and minimising projected energy spread at end, most compression is at BC2.

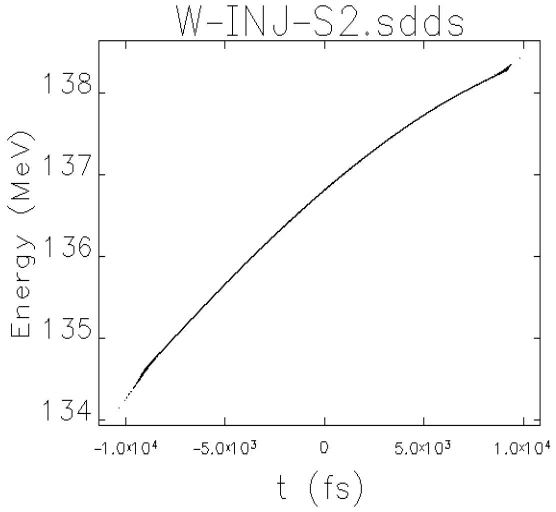
Simulation results : projected emittances

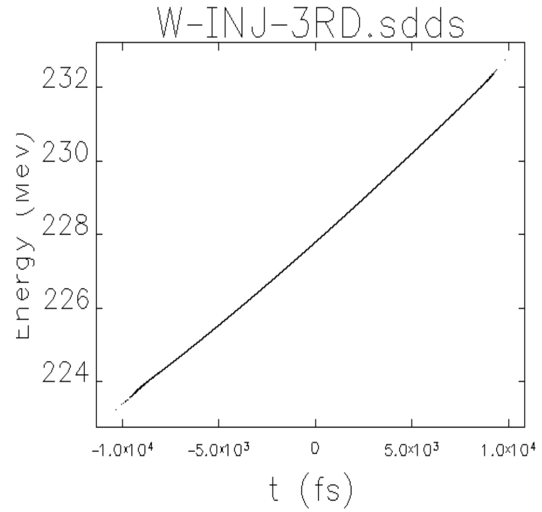


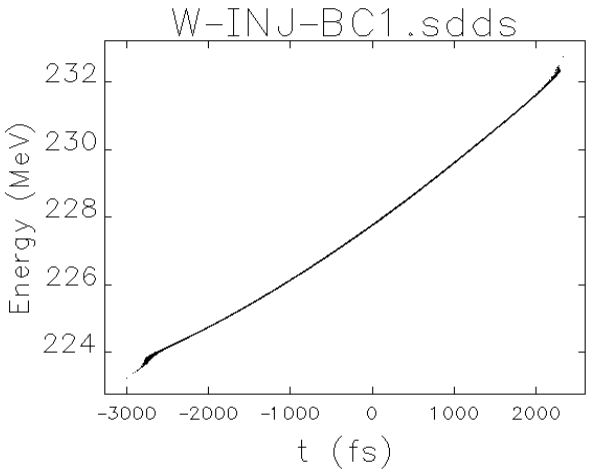
Final normalised projected emittances in x/y = 0.56/0.43 mm.mrad

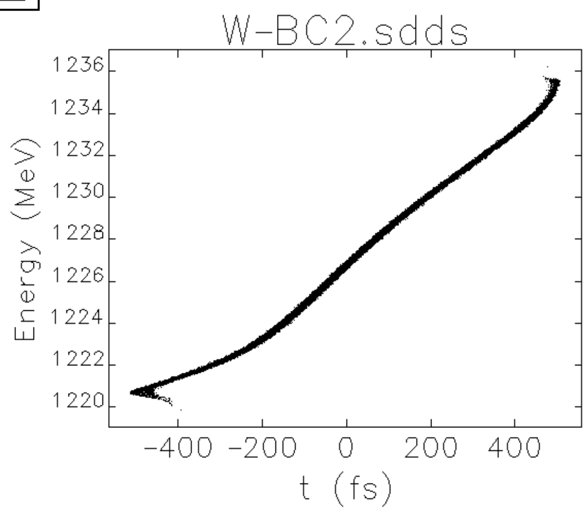
Bunch evolution : 100 k particle tracking

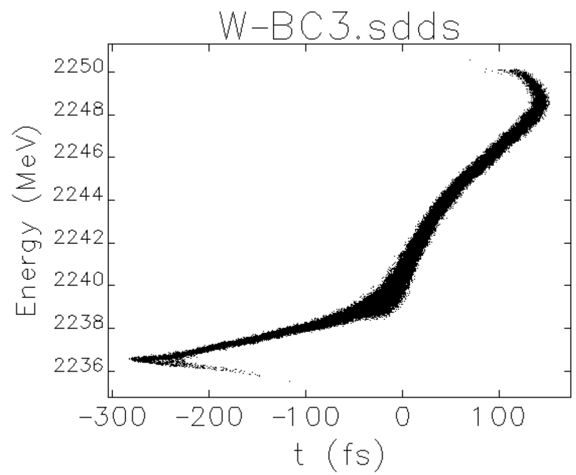
Position	Variable	Value
3ω lineariser (CW)	E	15.0 MV/m
3ω lineariser	ϕ	$+162.1°$
Injector	ϕ	$-25.1°$
Linac first pass	ϕ	$-10.0°$
Linac second pass	ϕ	$0°$
First compressor	R_{56}	122 mm
Arcs (full 360°)	R_{56}	37.3 mm
Second compressor	R_{56}	29.4 mm
Third compressor	R_{56}	42.2 mm



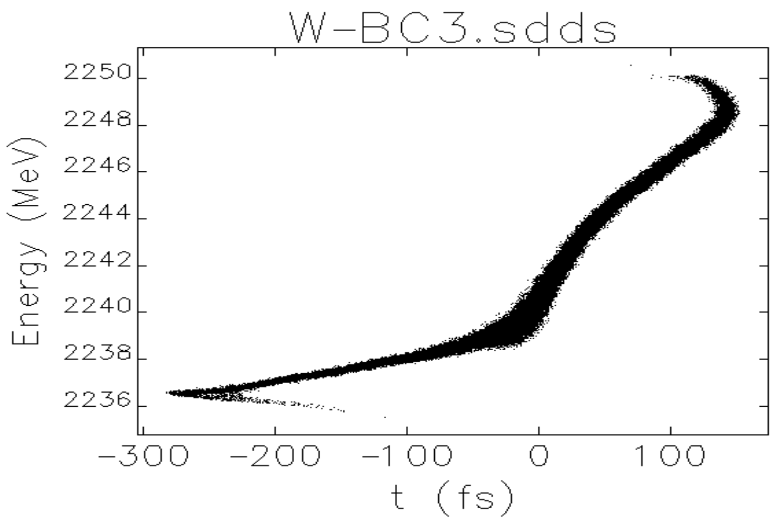


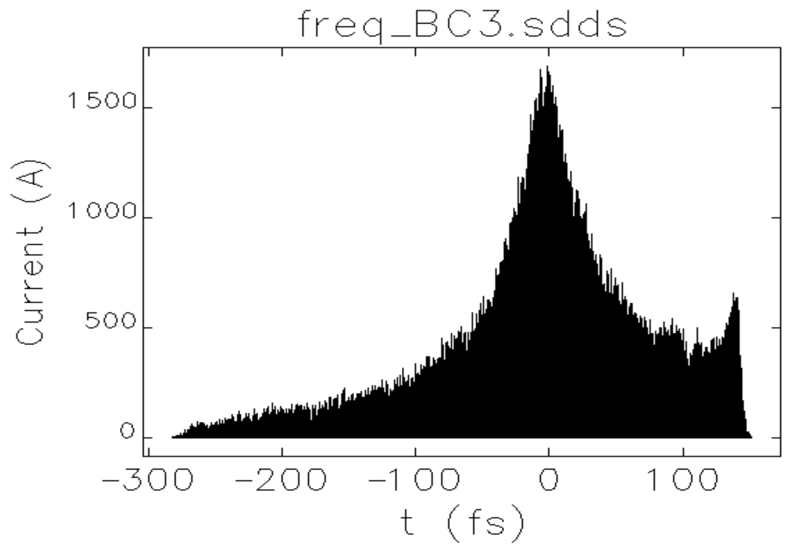


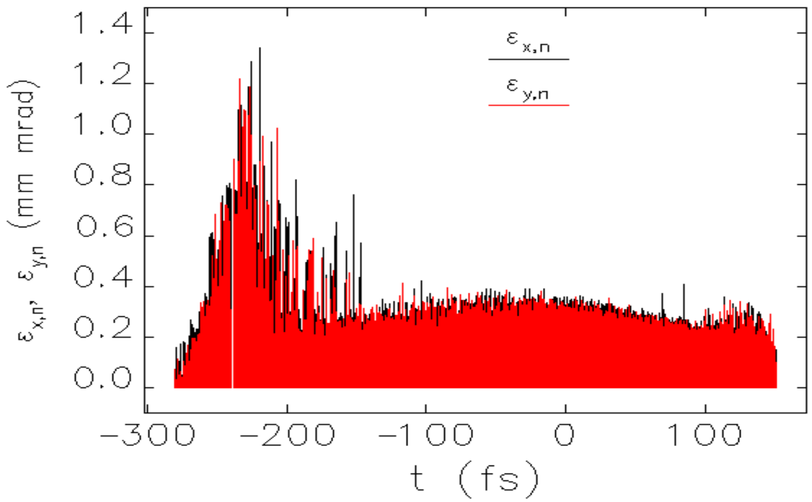


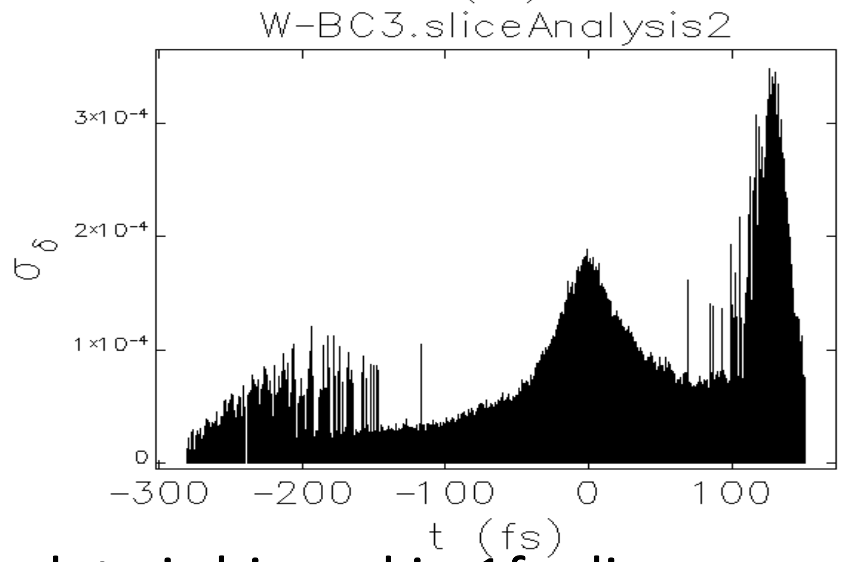


Bunch Parameters at the exit of BC3









Tracked 100k particles. The data is binned in 1fs slices.

Summary

- The re-circulator design is very close to achieving simultaneous bunch properties required for the FEL operation.
- Presently working on automatic optimisation to tailor bunch to "flat top" at 1kA and obtain less energy chirp on the bunch.
- Next steps
  - to include collimation + beam switchyard (same design as the straight through Linac baseline option)
  - estimate the jitter tolerances
  - pass a bunch through FEL simulations

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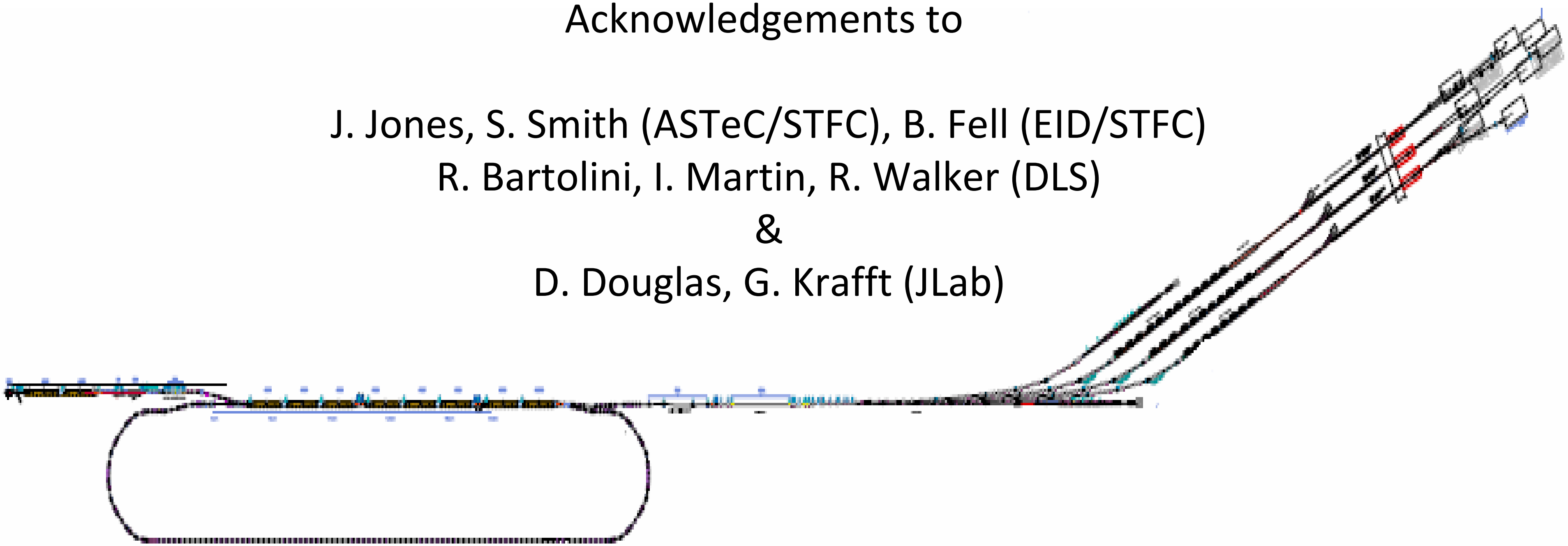

Thank you for your attention