Update on the DBRC's studies

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CLIC beam physics meeting

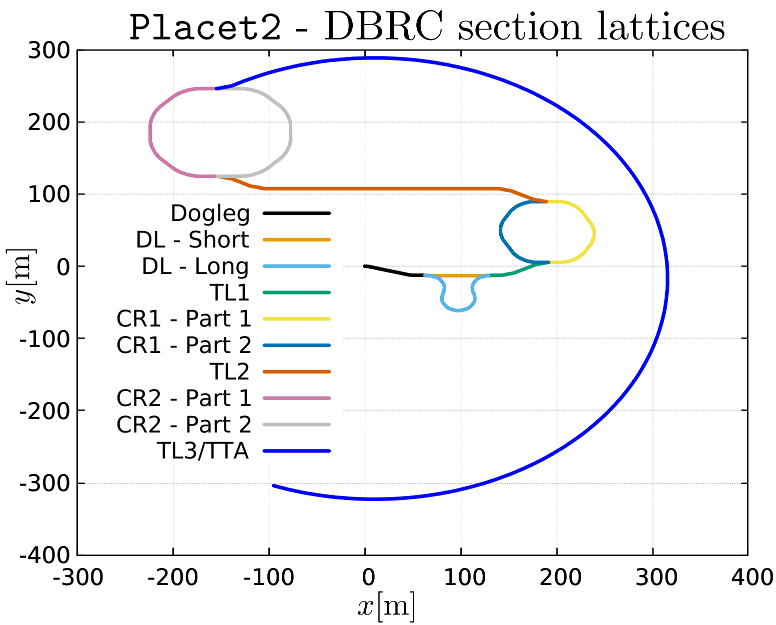
Outline

DBRC review

The Drive Beam Recombination Complex

The DBRC is located between the drive beam linac and the deceleration sectors

It's role is to combine the drive beam by a factor 24× into high frequency pulses



122 bunches 4.2 A
0.49975 GHz $2\text{ns} \equiv 60\text{cm}$
244 ns between bunches

2928 bunches 100 A
11.994 GHz $83\text{ps} \equiv 2.5\text{cm}$
244 ns between bunches

70760 bunches ($\equiv 142\mu$s) train

5.9 μs

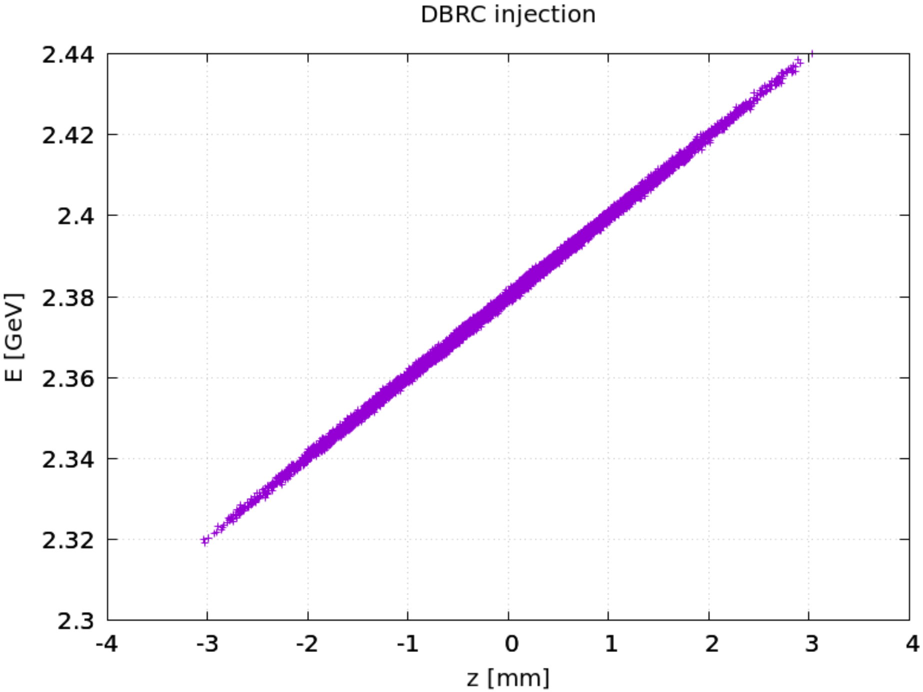
"Nominal" Parameters

Injection Parameters:

$$E^* = 2.0/2.38\,\text{GeV}$$
$$\delta = 0.85\,\%$$
$$\sigma_z = 1\,\text{mm}$$
$$\varepsilon_x = 100\,\mu\text{m}$$
$$\varepsilon_y = 100\,\mu\text{m}$$

Extraction Parameters:

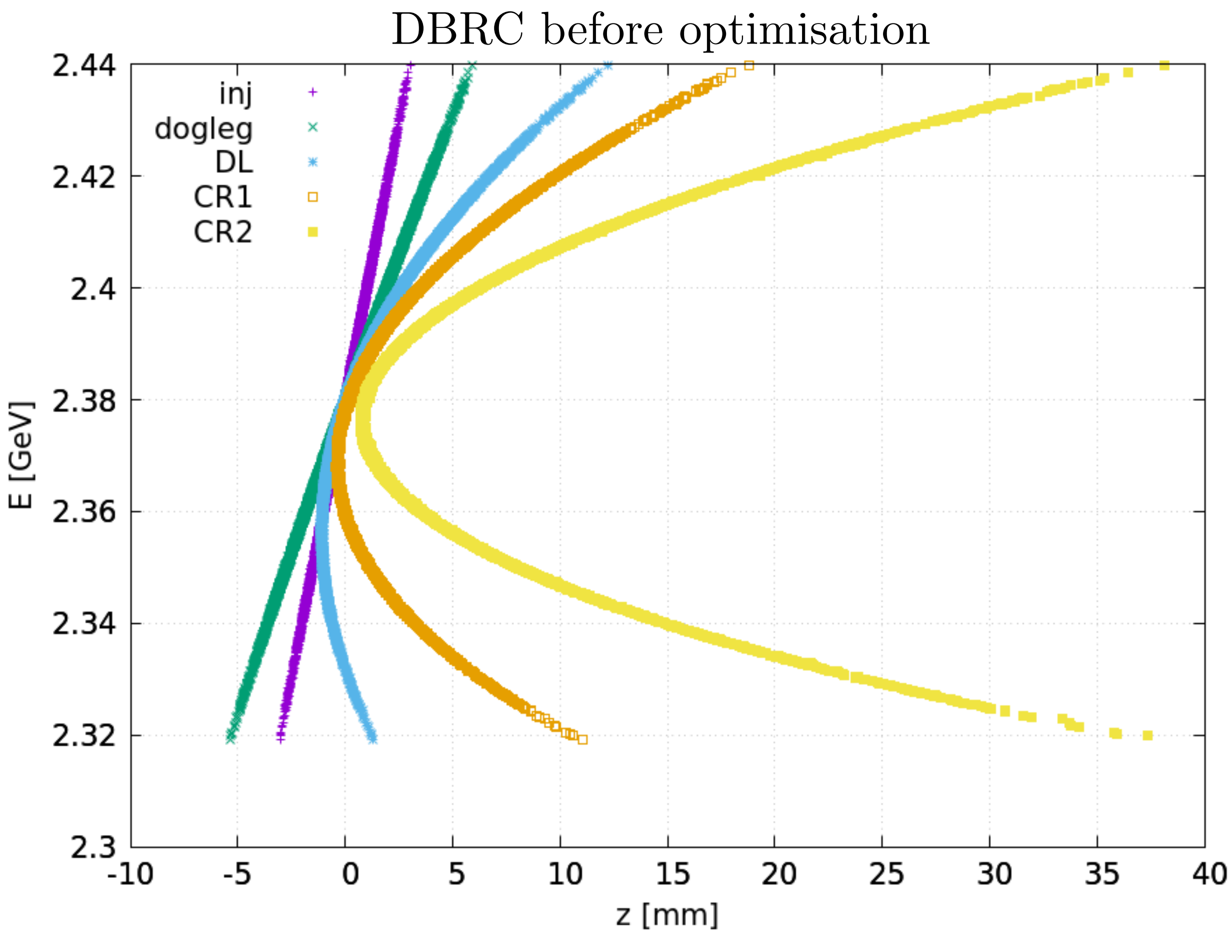
$$\varepsilon_x < 150\,\mu\text{m}$$
$$\varepsilon_y < 150\,\mu\text{m}$$



* DBRC results presented were generated for 2.38 GeV

Longitudinal challenges

Longitudinal challenges



Source of the longitudinal issues

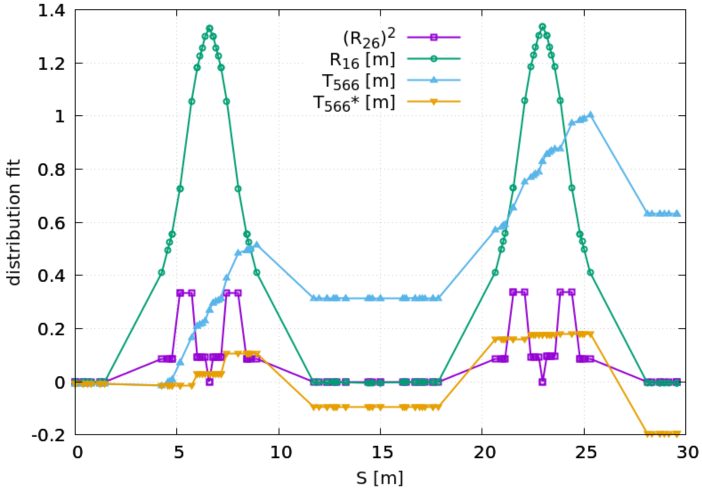
$$z\left(s\right) = z + R_{56}\delta + T_{566}\delta^2$$

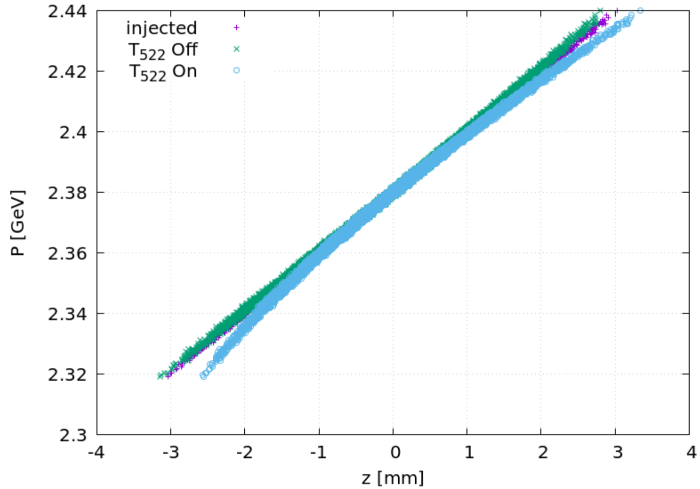
$$T_{566_{[n]}} = \sum_i R_{5i_{[n]}} T_{i66_{[n-1]}} + \sum_{ij} T_{5ij_{[n]}} R_{i6_{[n-1]}} R_{i6_{[n-1]}}$$

$$T_{566_{[n]}} \sim T_{566_{[n-1]}} + \left(R_{26_{[n-1]}}\right)^2 T_{522_{[n]}}$$

$$T_{522_{[\mathrm{Drift}]}} = \frac{L}{2}$$

Placet2 was updated to track individual tensor elements





* If $T_{522} = T_{544} = 0$

T_{566} optimisation - Technique

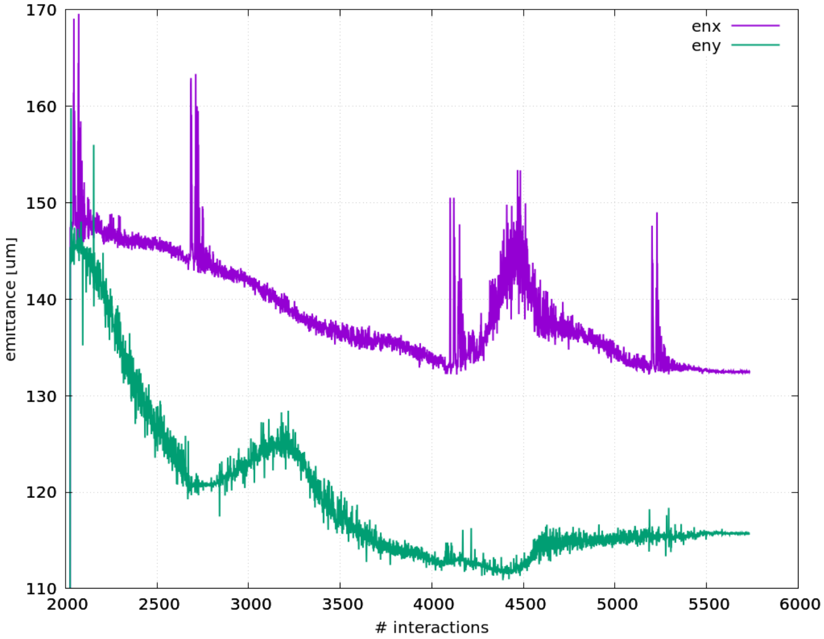
Correction with sextupoles in dispersive regions

API to `Octave` to access Nelder-Mead's simplex

Define sextupole families (7-40) and minimize $w_1 \varepsilon_x + w_2 \varepsilon_y + w_3 T_{566}{}^*$

Takes a lot of fine tuning
Takes a lot of time

Ex: Latest CR2 4x optimisation



* In reality minimizing the error of a linear fit is more efficient

Impact of synchrotron radiation

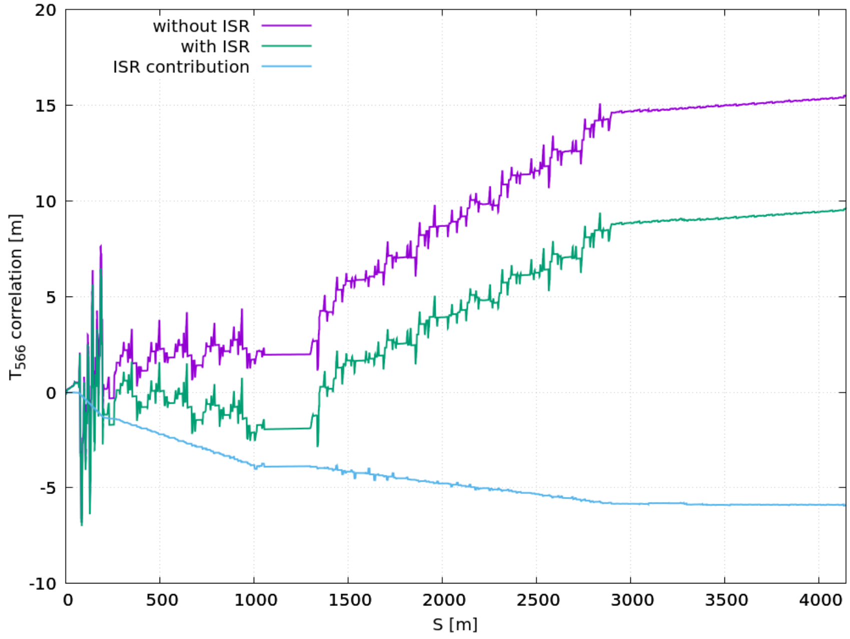
Impact of synchrotron radiation

The lattice was optimized with ISR

Tracking without ISR actually increases T_{566}

This does not mean that ISR is beneficial

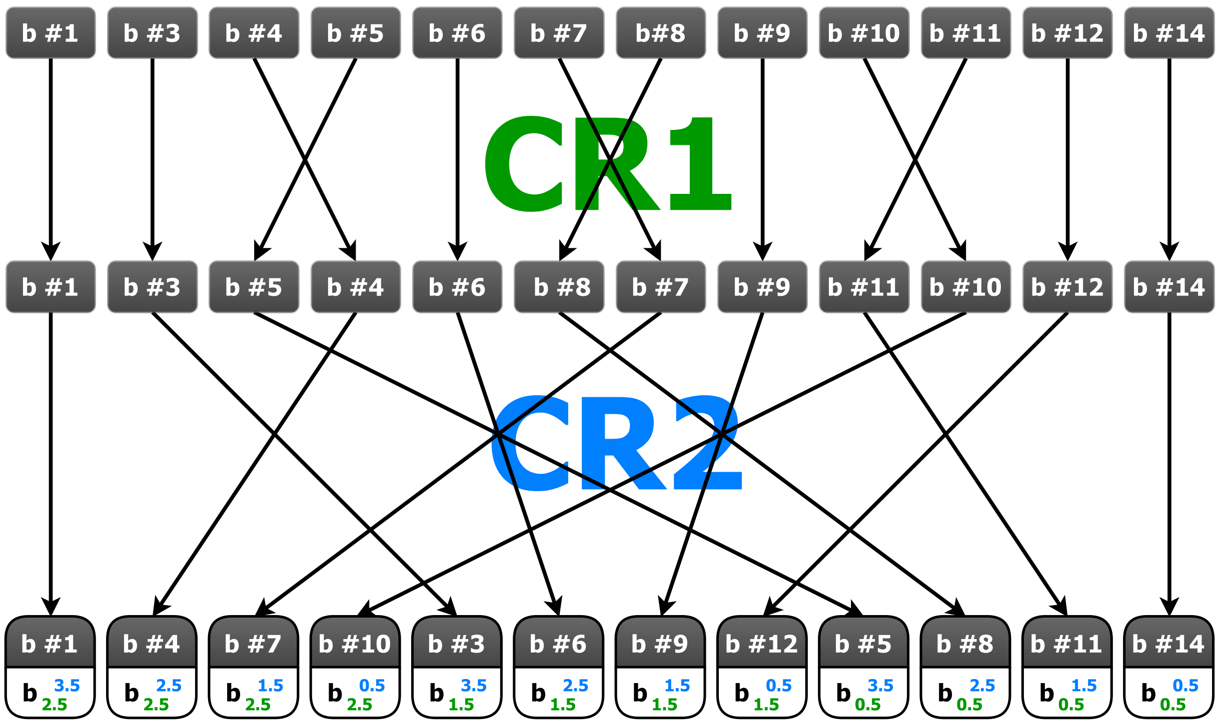
Simply that the solutions for both models are very different



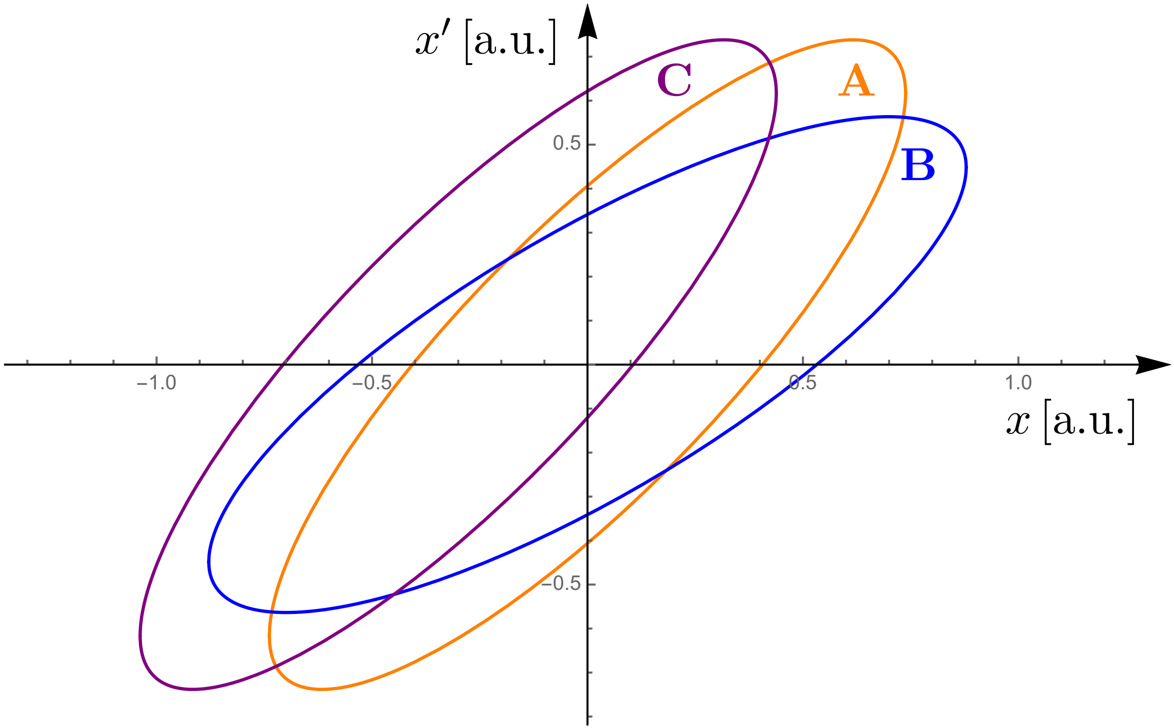
Results - emittance: 100 μm

Notation

We are tracking 12 bunch "families" differentiated by the number of turns they take in CR1 and CR2: $\mathbf{b}_{CR1}^{CR2}$



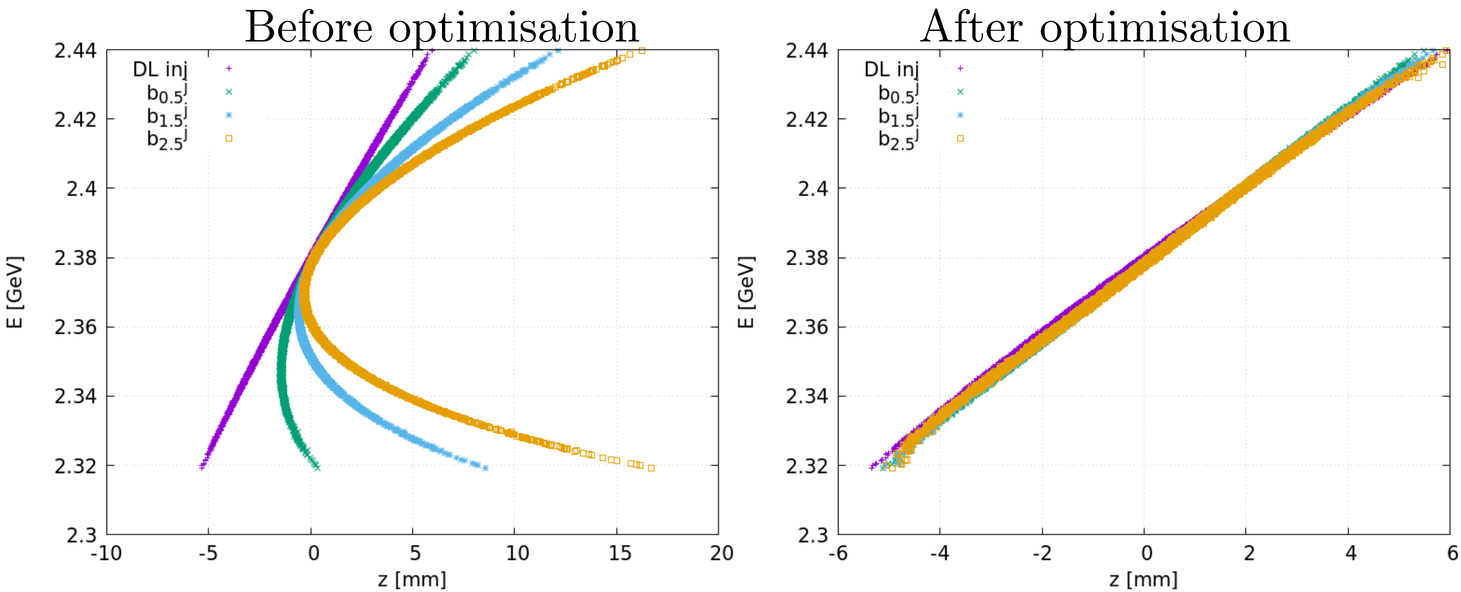
Notation



Targeting $\langle \varepsilon \rangle$ does not ensure twiss and centre-orbit match
We project all bunches on top of one-another and compute $\tilde{\varepsilon}$

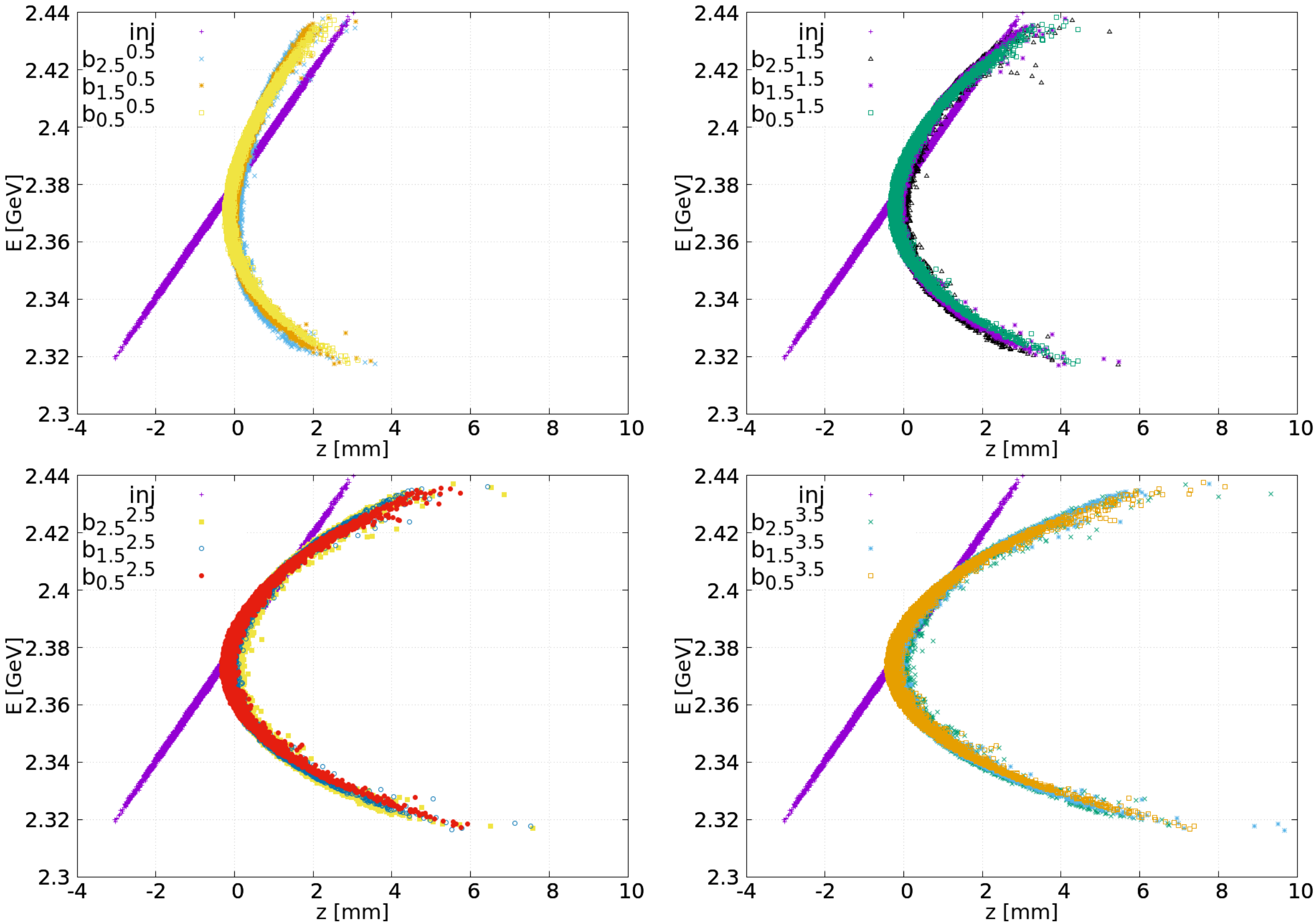
$$\tilde{\varepsilon} \geq \langle \varepsilon \rangle$$

100 μm results - CR1



Emittance [μm]	$b_{0.5}^j$	$b_{1.5}^j$	$b_{2.5}^j$	$\langle \varepsilon_i \rangle$	$\tilde{\varepsilon}_i$
Horizontal	132	121	132	128	136
Vertical	116	113	130	119	122

100 μm results - Extraction

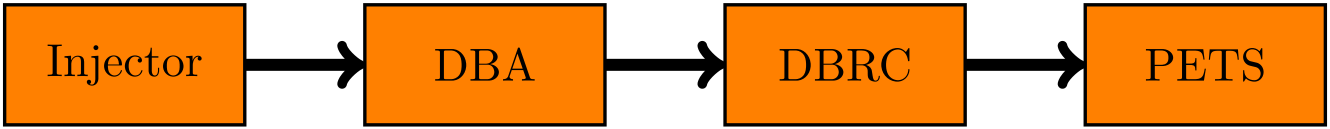


100 μm results - Extraction

Bunch	S_{total} [m]	ε_x [μm]	ε_y [μm]	T_{566} [m]	σ_z [mm]
${b_{2.5}}^{3.5}$	4145	212	143	9.6	0.93
${b_{2.5}}^{2.5}$	3706	220	135	7.3	0.72
${b_{2.5}}^{1.5}$	3267	177	134	5.1	0.52
${b_{2.5}}^{0.5}$	2828	147	128	2.8	0.32
${b_{1.5}}^{3.5}$	3853	125	128	10	0.97
${b_{1.5}}^{2.5}$	3414	134	123	7.8	0.76
${b_{1.5}}^{1.5}$	2975	115	121	5.6	0.56
${b_{1.5}}^{0.5}$	2536	116	117	3.3	0.36
${b_{0.5}}^{3.5}$	3560	146	127	11	1.04
${b_{0.5}}^{2.5}$	3121	147	124	8.4	0.82
${b_{0.5}}^{1.5}$	2682	143	122	6.2	0.62
${b_{0.5}}^{0.5}$	2243	128	116	4.0	0.42
${b_i}^j$	–	157	127	–	–

Results - emittance: 80 μm

80 μm injection



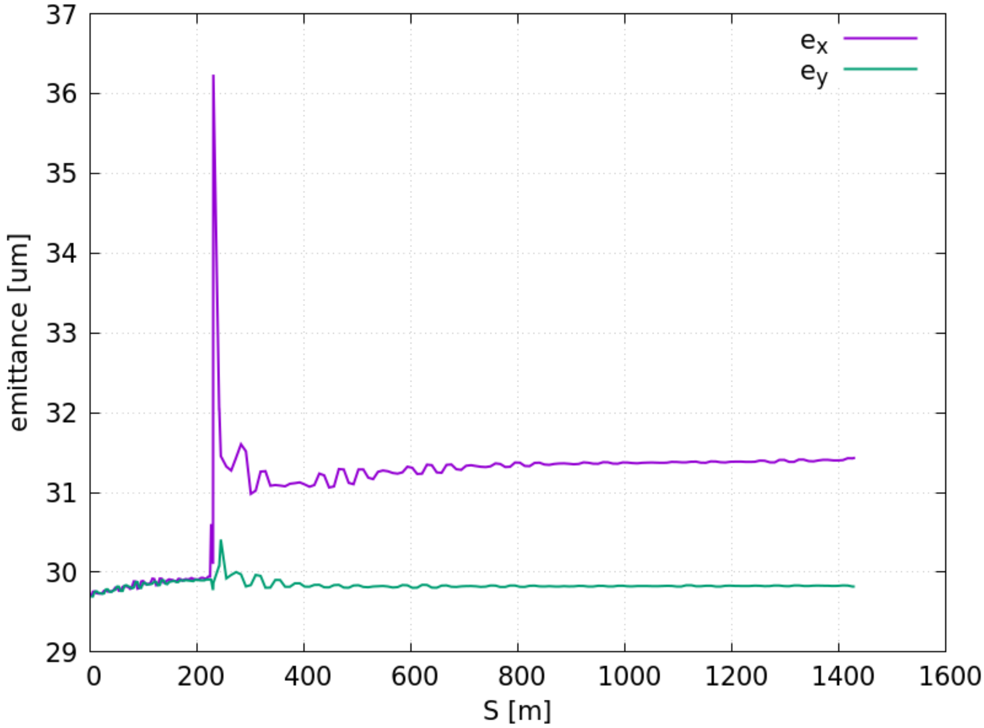
- The DBRC's target emittance is fixed at < 150 μm by the PETS
- Is it possible to achieve lower than 100 μm at injection?
- Avni Aksoy presented promising results in the last CLICWS [2]
- Avni was kind enough to provide us with his scripts

DBA simulation parameters

DBA simulation parameters:	
Initial energy (MeV)	50
Final energy (GeV)	2
Initial Energy Spread (%)	1.0*
Bunch Charge (nC)	8.4
Initial emittance (μm)	30
BPM resolution (μm)	10
Misalignment errors - Quad. and Acc. (μm rms)	200
Pitch errors - Acc. (μrad rms)	200

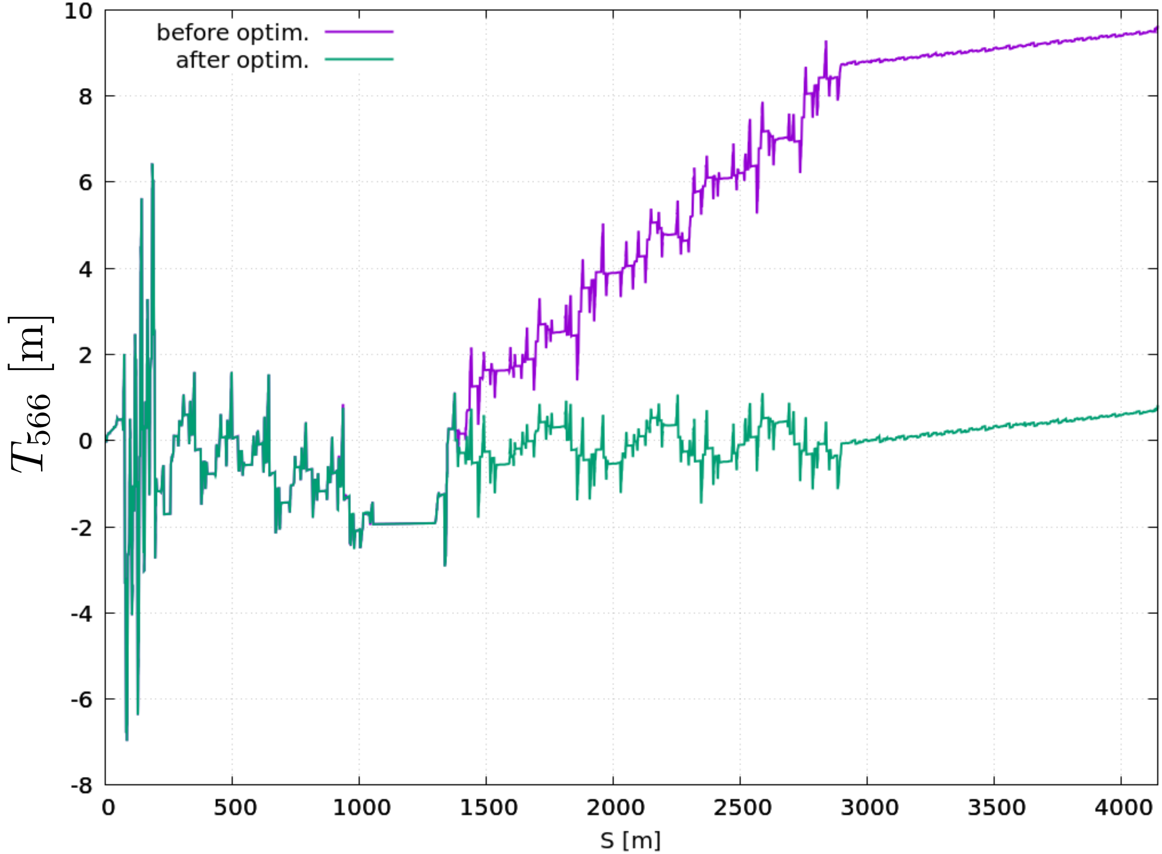
* Previously 0.2%, increased based on results from [3]

DBA simulations (WFS)

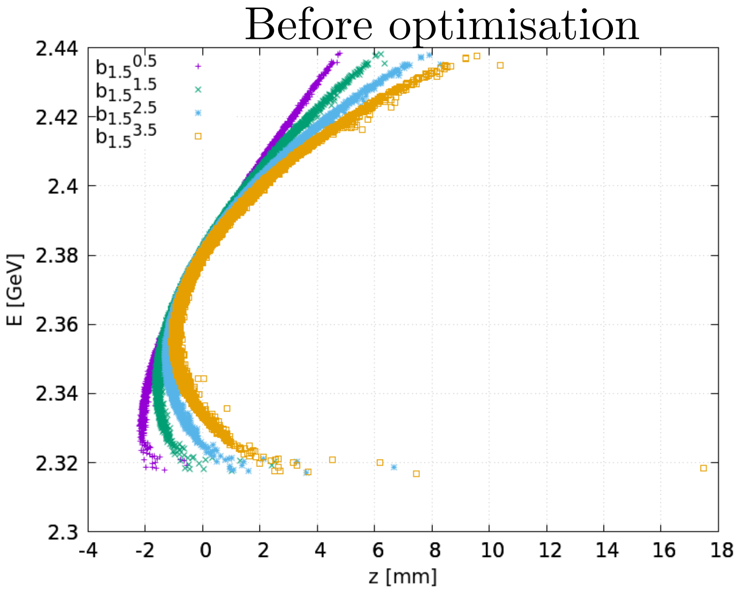


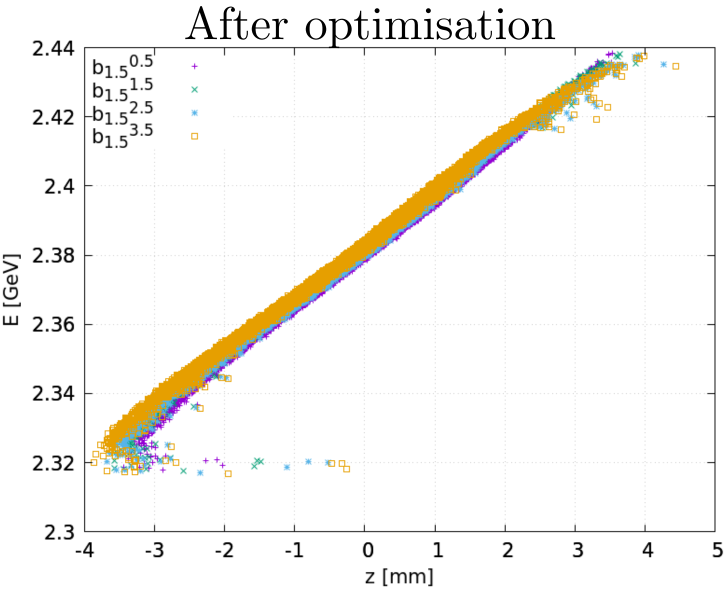
- Average final emittance: $\varepsilon_x = 31\ \mu\text{m}$, $\varepsilon_y = 30\ \mu\text{m}$
- Final energy spread of $0.836\% \pm 0.004\%$

80 μm results - T_{566} correction



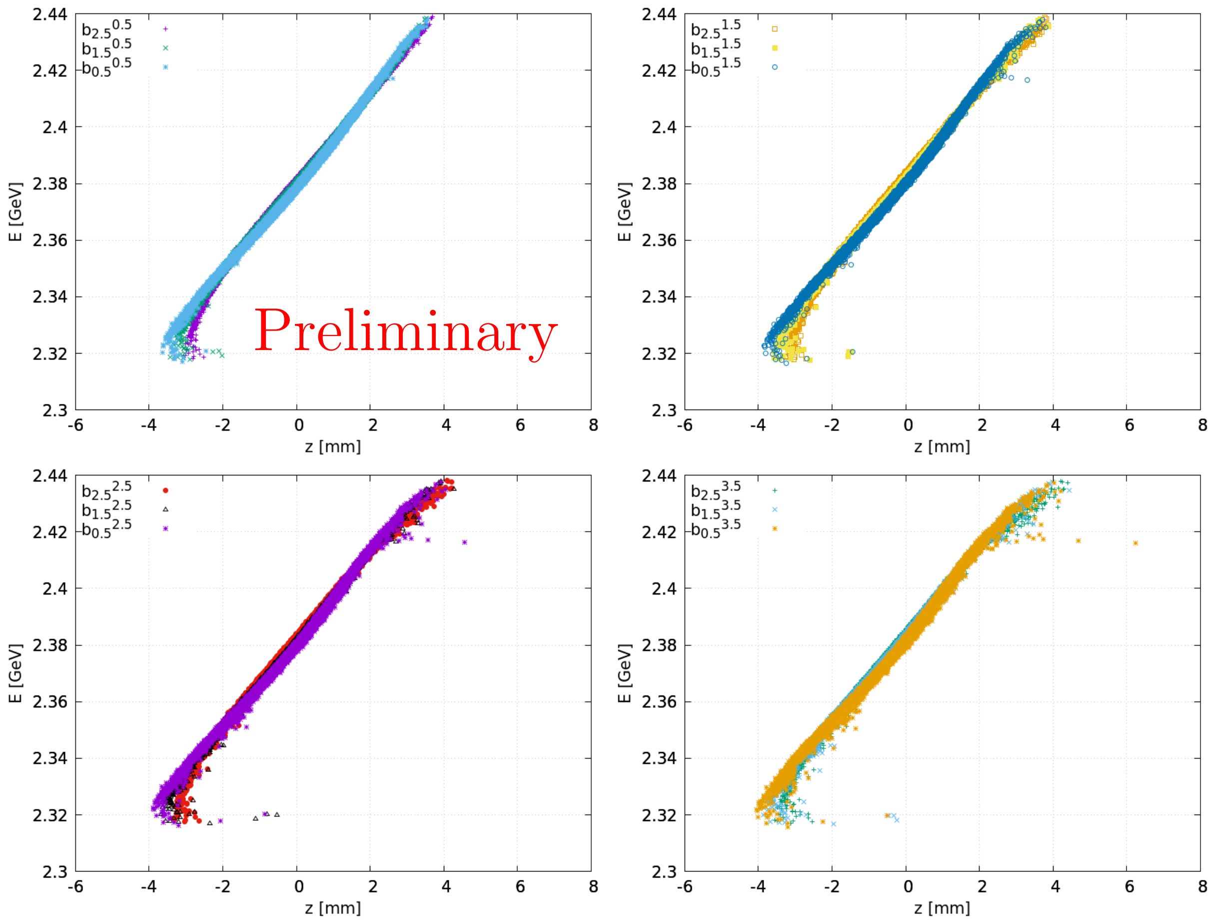
80 μm results - CR2 (4x)





Emittance [μm]	$b_{1.5}^{0.5}$	$b_{1.5}^{1.5}$	$b_{1.5}^{2.5}$	$b_{1.5}^{3.5}$	$\langle \varepsilon_i \rangle$	$\tilde{\varepsilon}_i$
Horizontal	125	119	122	153	130	132
Vertical	102	113	119	128	116	116

80 μm results - CR2 (12x)



Conclusions and Outlook

Conclusions

- At 100 μm emittance:
  - `Placet2` was updated to track tensor elements
  - We confirmed the inside of the arcs as the main source of T_{566}
  - ISR is significant for T_{566} growth
  - It doesn't appear possible to address the longitudinal challenges without changing the lattice (ex: extra sextupoles)
- At 80 μm emittance:
  - CR2 was optimised to correct T_{566} while maintaining the emittance under the budget ($\varepsilon_x = 132$ μm, $\varepsilon_y = 116$ μm)
- DBA results ($\varepsilon_x = 31$ μm, $\varepsilon_y = 30$ μm) allow for the reduction

Outlook

- DBRC
  - Test the lattice at 2 GeV
  - Try to close T_{566} "locally" at the DL' and CRs' arcs
  - Optimise the TTA
  - Optimise full recombination at 80 μm (?)
  - Would 50 μm be an option?
  - Implement misalignments and BBA techniques
- DBI+DBA
  - Can we get a realistic distribution for the DBRC?
- Decelerators
  - Compute form factor for the DBRC's distributions
  - Set up simulations for off-center beams (Xianfcong's work)
- `Placet2`
  - CSR? PETS?
  - Parallelization, LXplus, etc...

Bibliography

- C. Biscari *et al.*, "CLIC Drive Beam Frequency Multiplication System Design", Particle accelerator. Proceedings, 23rd Conference, PAC'09, Vancouver, Canada (2009).
- A. Aksoy, "Drive Beam Linac Optimisation", CLICWS2018, Geneva, Switzerland (2018).
- Hajari, Sh Sanaye and Shaker, H and Doebert, S, "Beam dynamics design of the Compact Linear Collider Drive Beam injector", Nucl. Instrum. Methods Phys. Res., A, 799 (2015).