Update on the PLACET2 Drive Beam simulations

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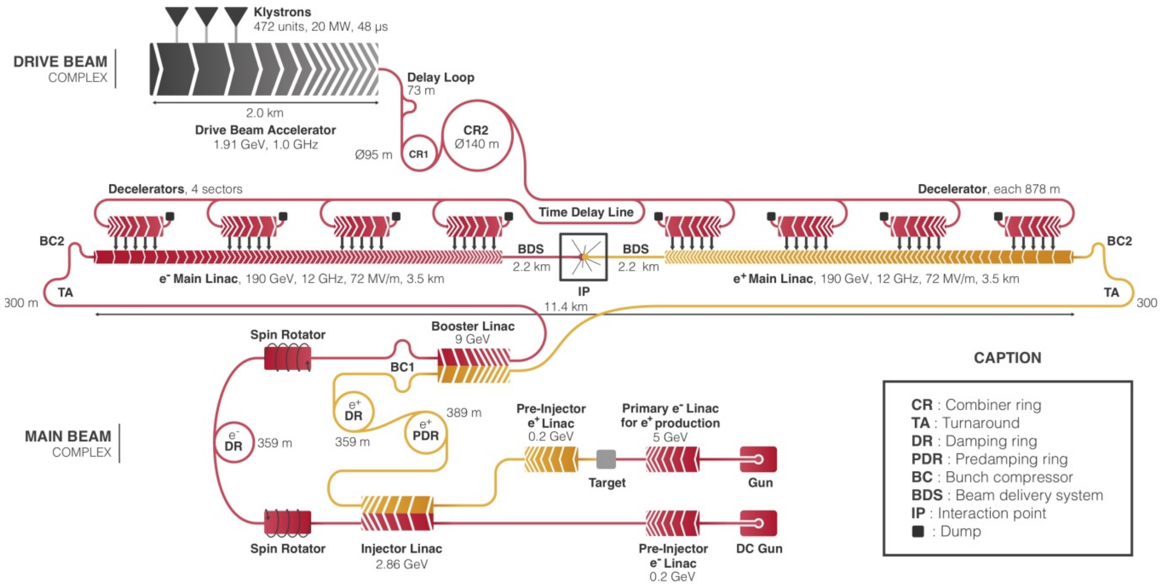
Outline

Drive-Beam complex overview



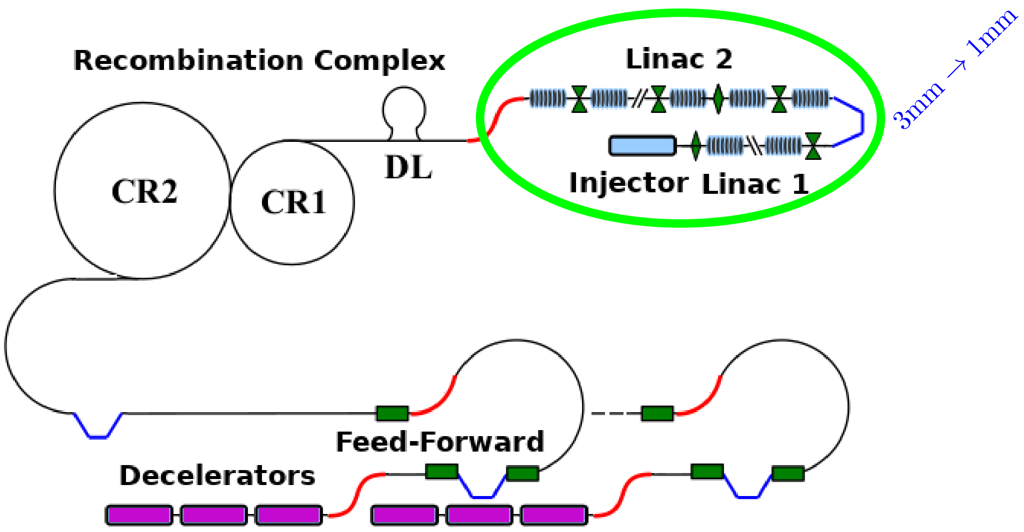
Challenges:

Complex 24× pulse compression

High charge beam induces coherent synchrotron radiation (CSR)

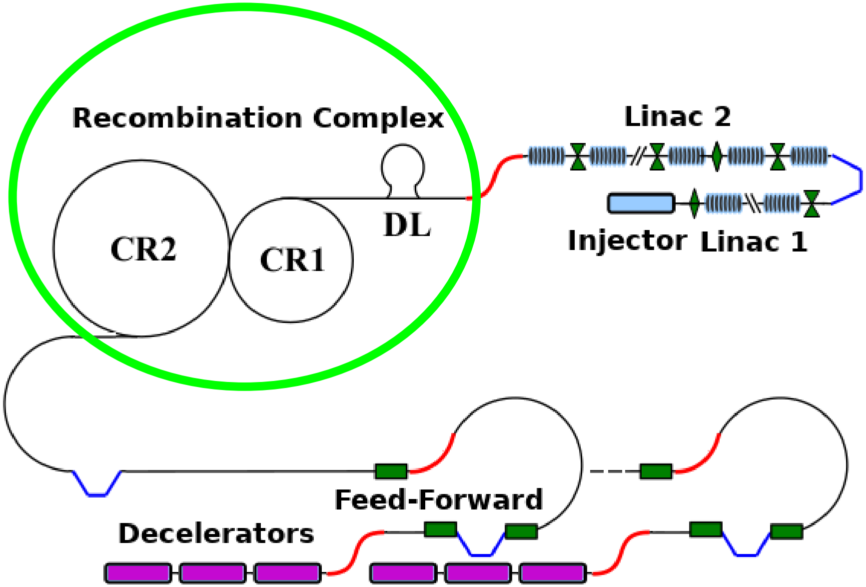
Strict bunch length (1mm) and phase (0.2°) stability requirements

Drive-Beam accelerator

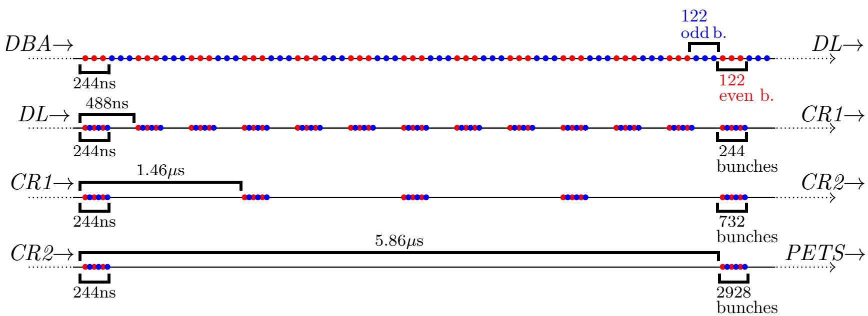


Accelerate the Drive-Beam to 1.9 GeV
Compress it to $\sigma_z = 1\,\text{mm}$
Provide the energy chirp required for longitudinal gymnastics downstream

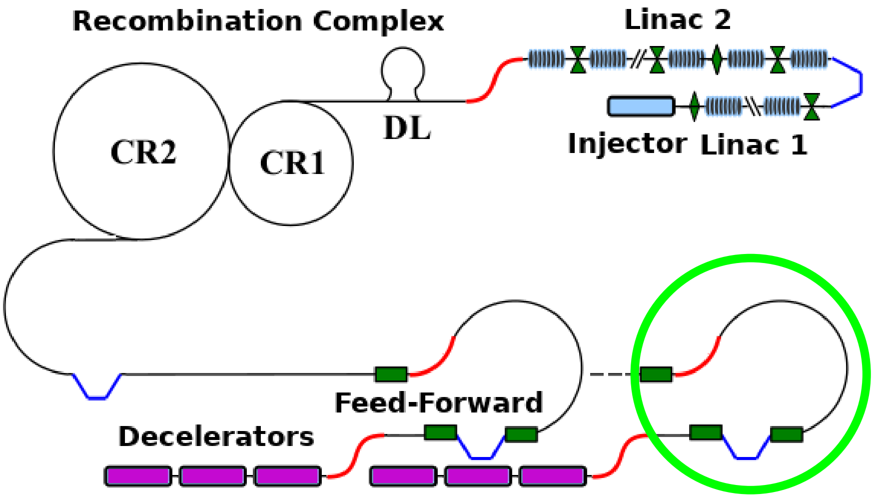
Recombination complex

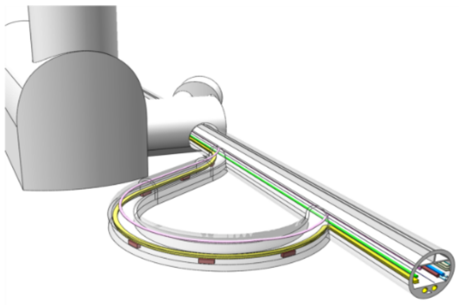


Interleaves 24 pulses composed of 122 bunches each, increasing the frequency and current by a factor 24



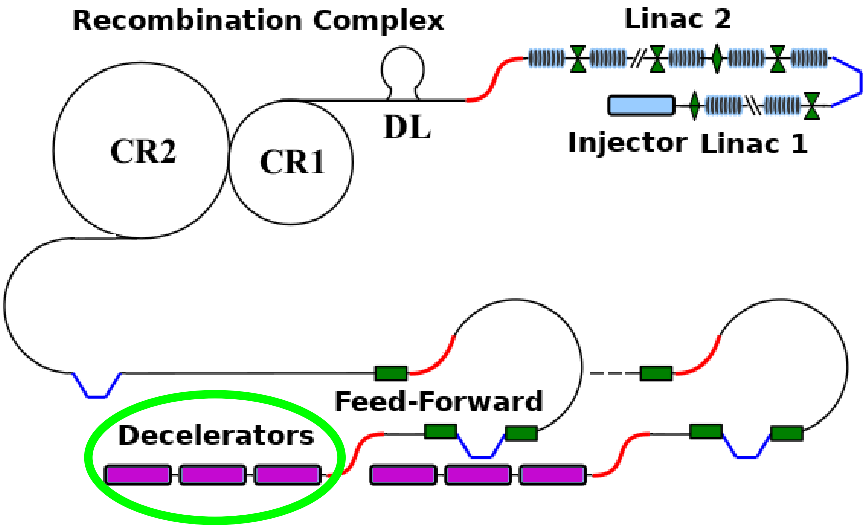
Phase stabilisation feed-forward

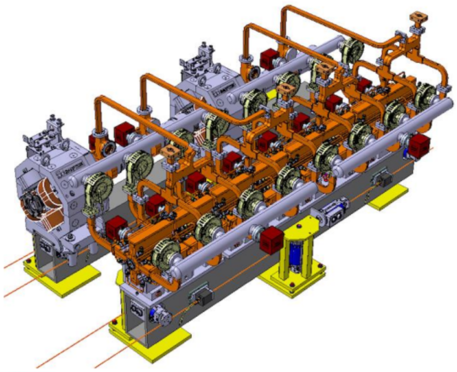




Takes advantage of the turnaround loops to correct phase instabilities
This is done in a chicane that also compresses the beam

Decelerators





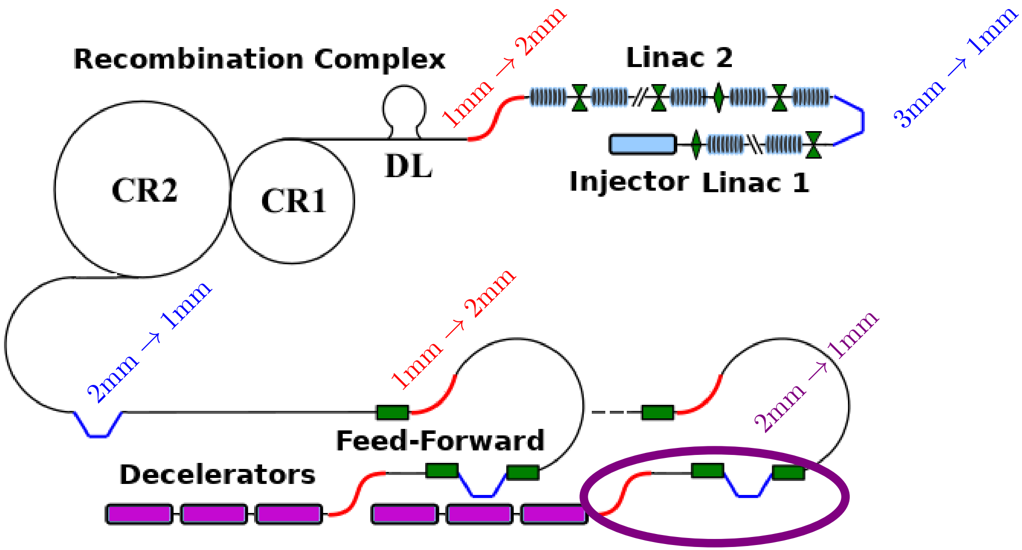
Decelerator requirements:

1 mm bunch length

1% bunch length stability

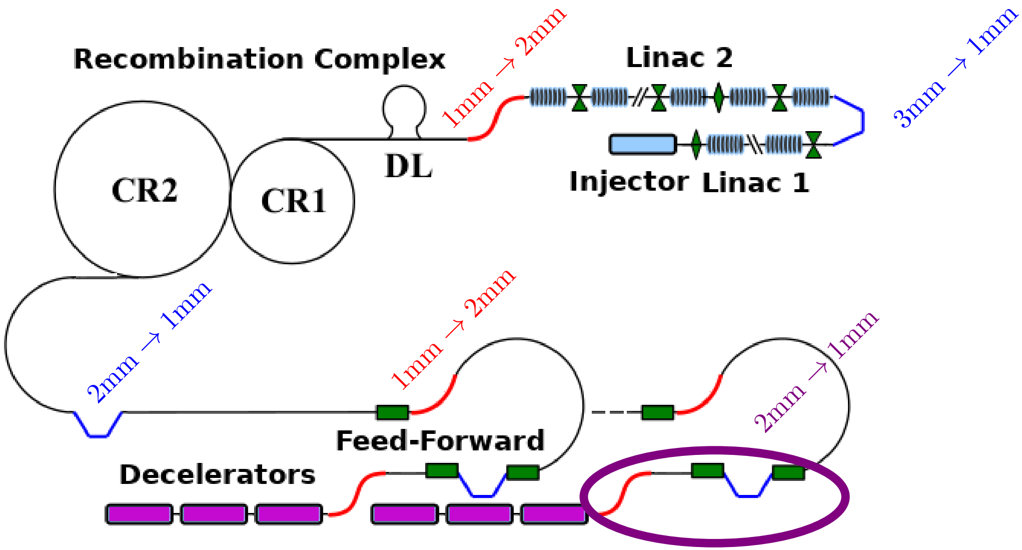
0.2°phase stability at 12 GHz

Longitudinal dynamics



After Linac 1, $\sigma_z = 1\,\mathrm{mm}$ to meet decelerator requirements
In bending sectors with high CSR, $\sigma_z = 2\,\mathrm{mm}$ to mitigate the effect

Longitudinal dynamics

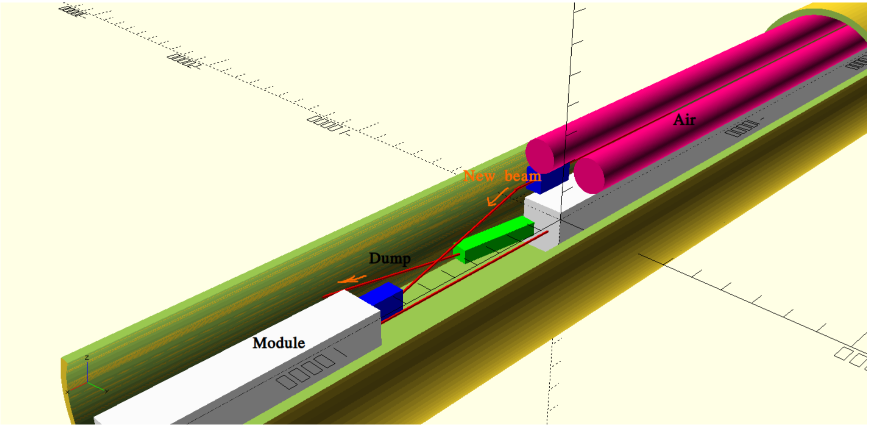


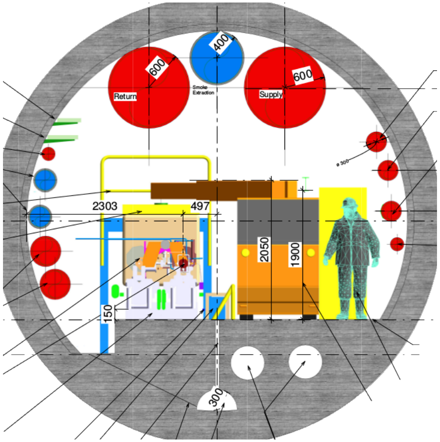
After Linac 1, $\sigma_z = 1\,\text{mm}$ to meet decelerator requirements
In bending sectors with high CSR, $\sigma_z = 2\,\text{mm}$ to mitigate the effect
Linac 2 imprints an energy chirp (δ_{corr}) to perform this gymnastics

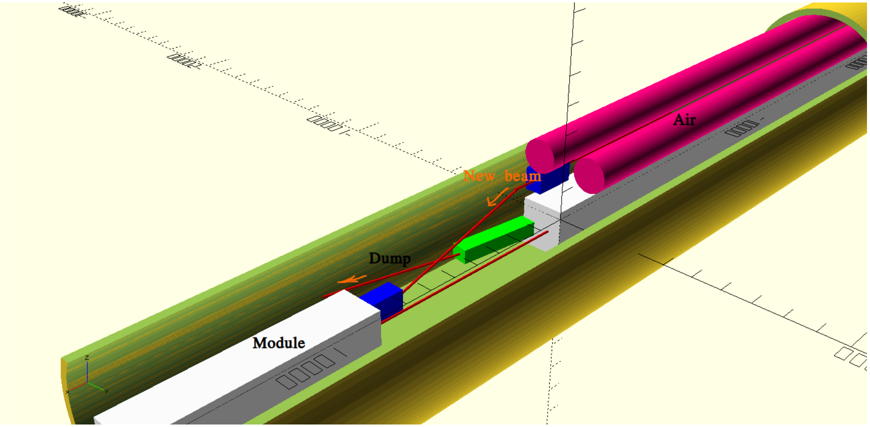
$$z = z_0 + R_{56}\delta_{\text{corr}}$$

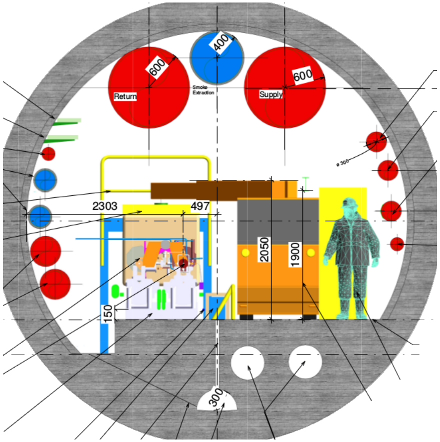
$R_{56} > 0$ for arcs and doglegs
$R_{56} < 0$ for chicanes

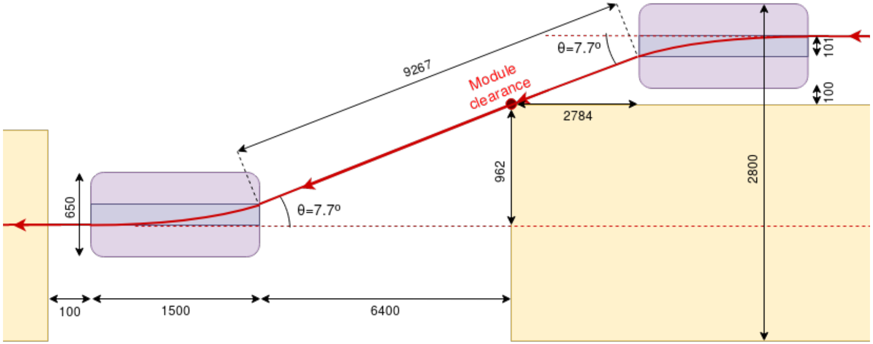
Decelerators injection











Vertical dogleg:

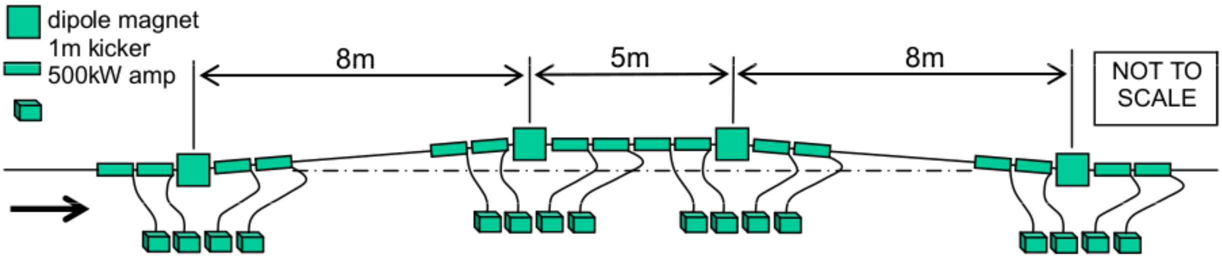
$\theta = 7.67°$

$B = 0.71\,\mathrm{T}$

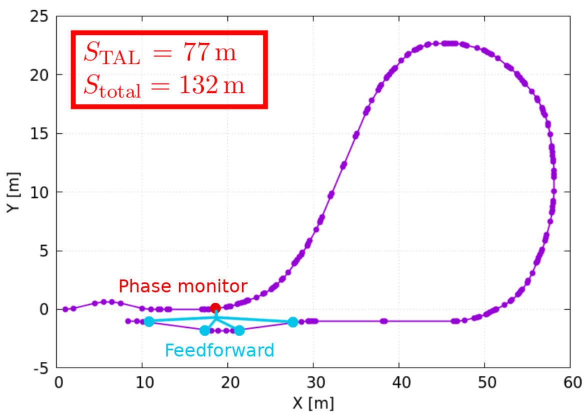
$R_{56} = 8.97\,\mathrm{mm}$

$$R_{56} = 2L_b\left(1 - \frac{\sin\theta}{\theta}\right)$$

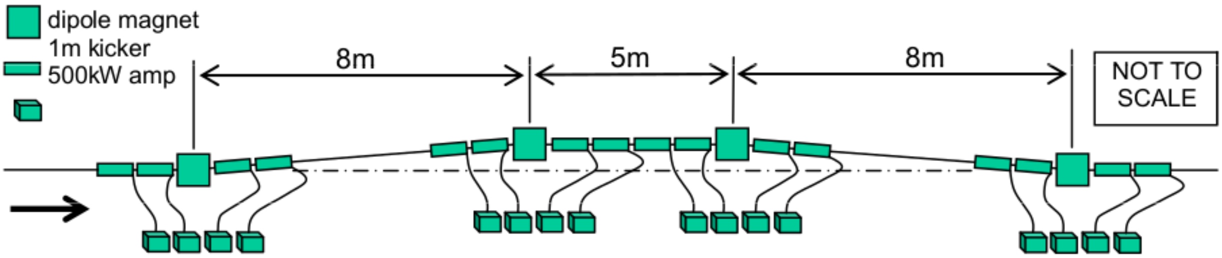
Feed-Forward phase correction



$$\Delta_z = 4L_d \csc\theta\,(\sec\theta - 1)\,k_4 + 2\tan\theta\left(L_a \sec^2\theta\, k_4 + (L_a\sec\theta - L_k)\,k_3\right)$$



Feed-Forward phase correction



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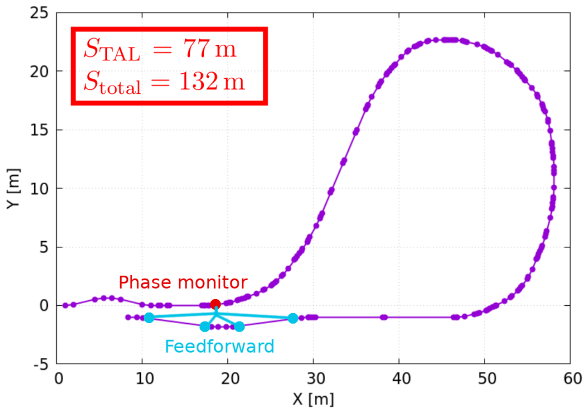


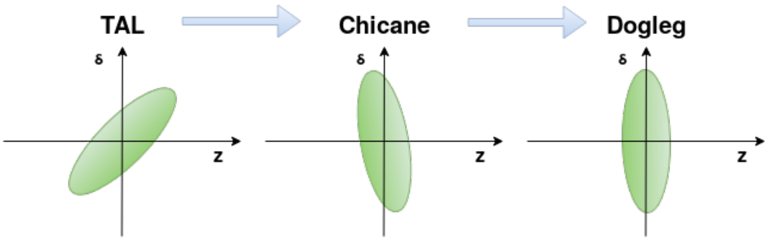
CDR chicane specifications:

- $\theta = 0.09\,\mathrm{rad}$
- $L_b = 1.001\,\mathrm{m}$
- $L_1 = 7.03\,\mathrm{m}$
- $R_{56} = -12.5\,\mathrm{cm}$

Longitudinal requirements – FF chicane + dogleg

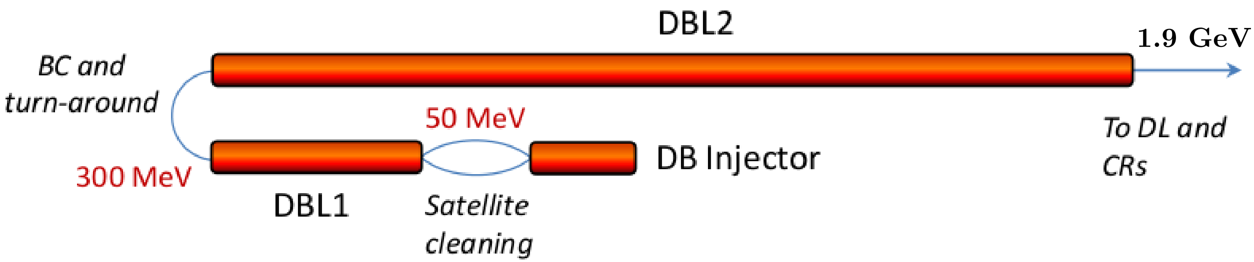
The combination of these two systems establishes the required δ_{corr}

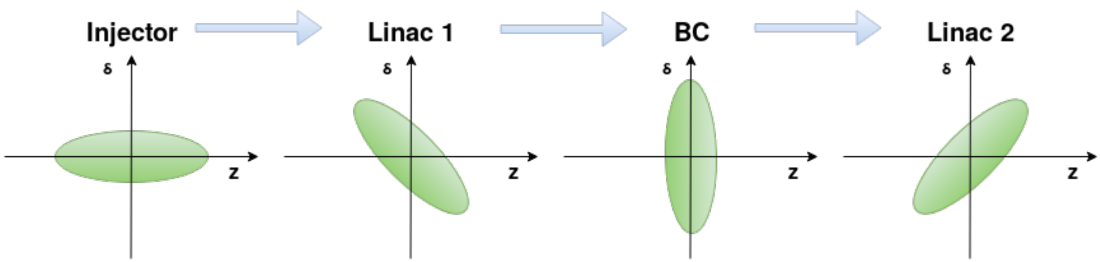
$$R^{\text{chicane+dogleg}} = R^{\text{dg}} R^{\text{chicane}} \qquad R_{56} = R_{56}^{\text{dg}} + R_{56}^{\text{chicane}}$$



$$R_{56} = -11.6\,\text{cm}$$
$$\delta_{\text{corr}} = 0.86\%$$

Drive-Beam accelerator

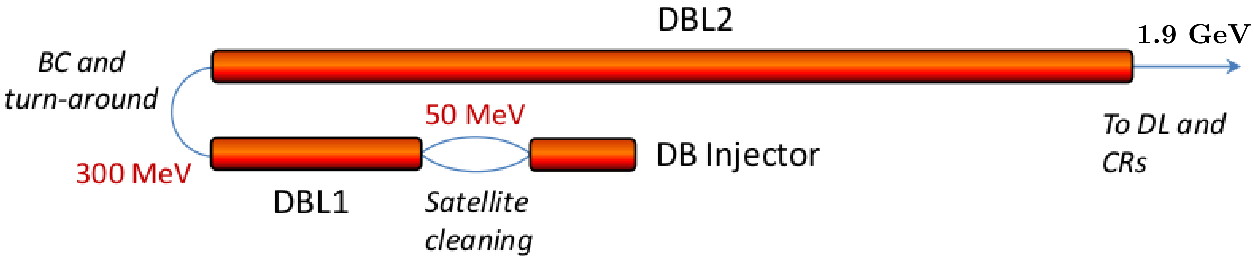


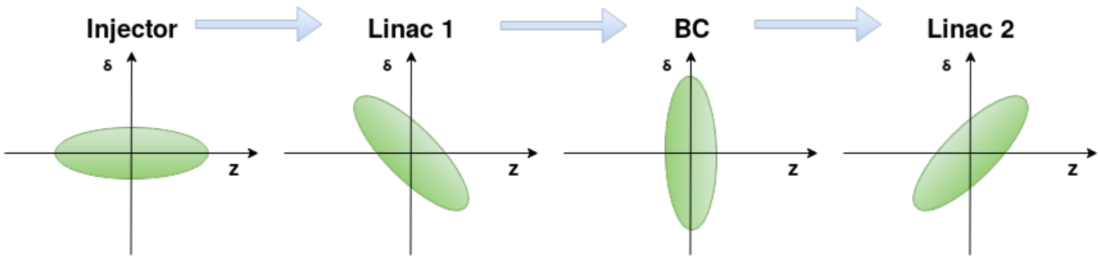


Bunch compressor arc: $R_{56} = 60\,\mathrm{cm}$

$\delta_{\mathrm{corr}} = 0.86\%$ after Linac 2

Drive-Beam accelerator





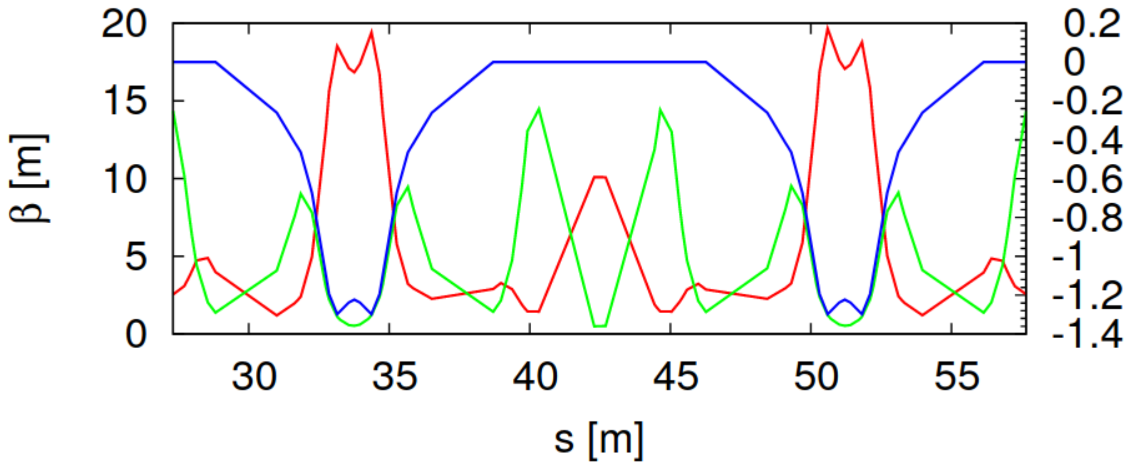
Bunch compressor arc: $R_{56} = 60\,\text{cm}$

$\delta_{\text{corr}} = 0.86\%$ after Linac 2

Lattice currently under revision to add the turnaround bunch compressor and update of the accelerator structures

Combiner Ring Arcs

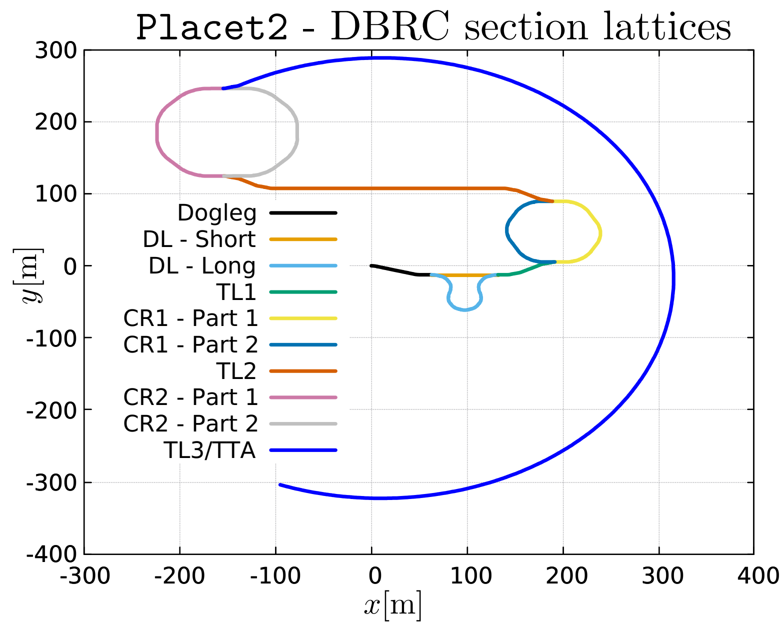
In order to maintain first and second order isochronicity the delay loop and combiner ring have complex arc cells composed of 8 combined function bending magnets and several sextupoles to correct chromatic effects

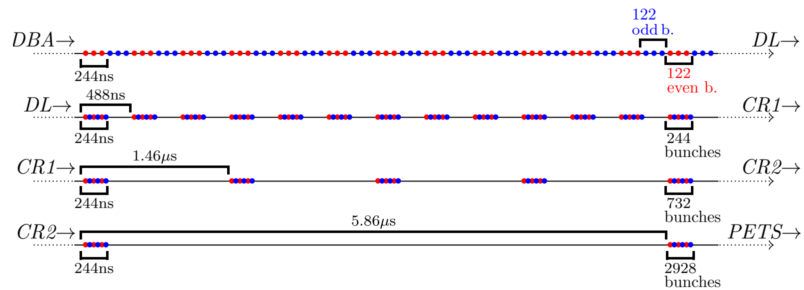


Emittance preservation is challenging due to non-linearities and CSR effects

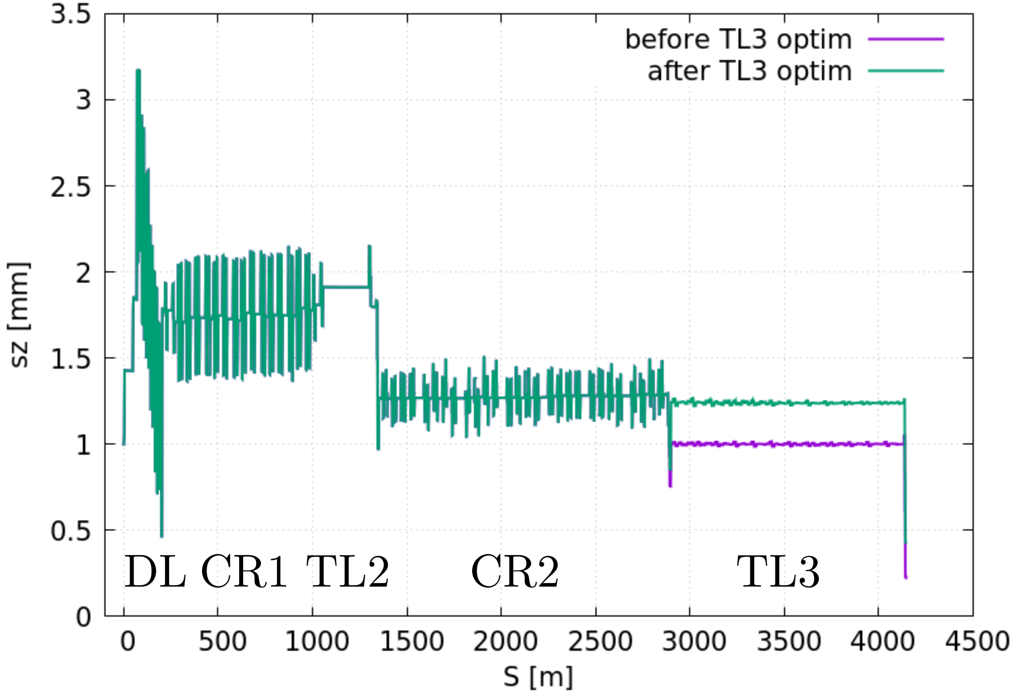
Tracking recirculating machines – PLACET2

- Multi-particle tracking
- Allows for complex machine topologies
- Tracking and interleaving multiple bunches
- Easy to add new elements and arbitrary thin kicks
- Modern, flexible and user-friendly
- Short and long range wakefields
- Synchrotron radiation



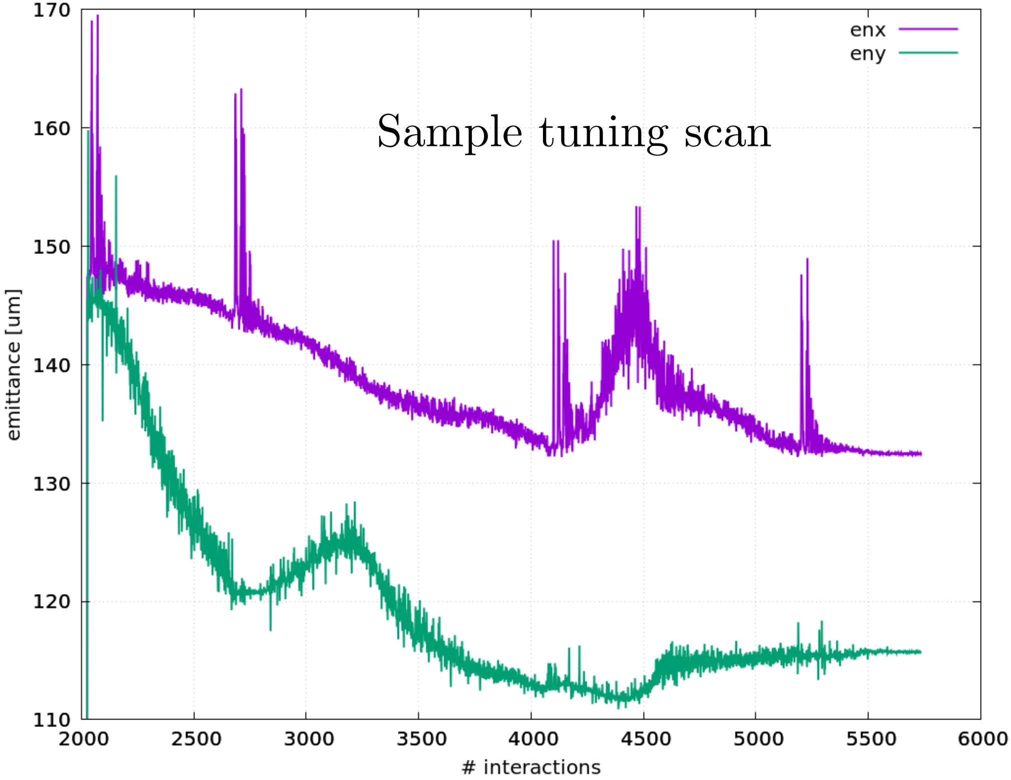


Enforcing isochronicity in the recombination complex transfer lines



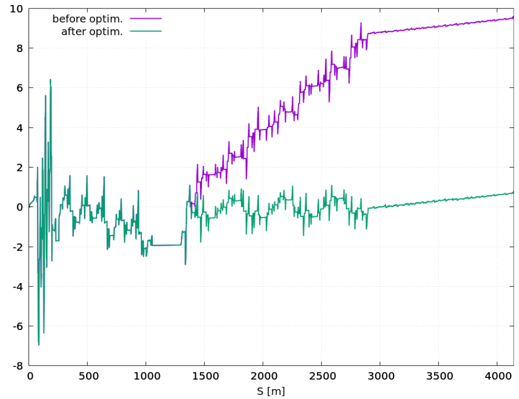
Tracking recirculating machines – PLACET2

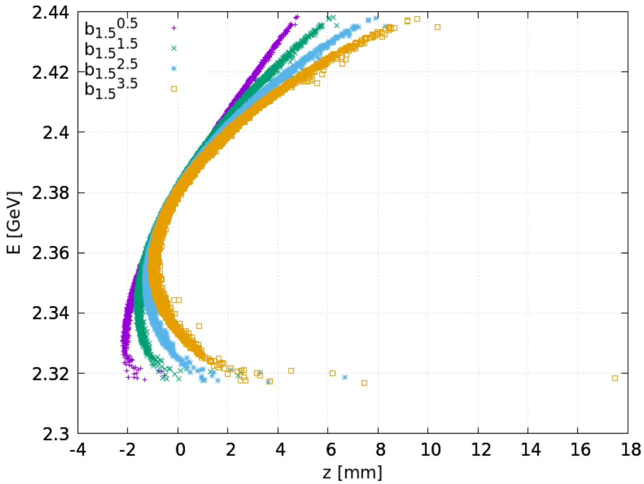
Reducing the design full train emittance growth through iterative sextupole tuning

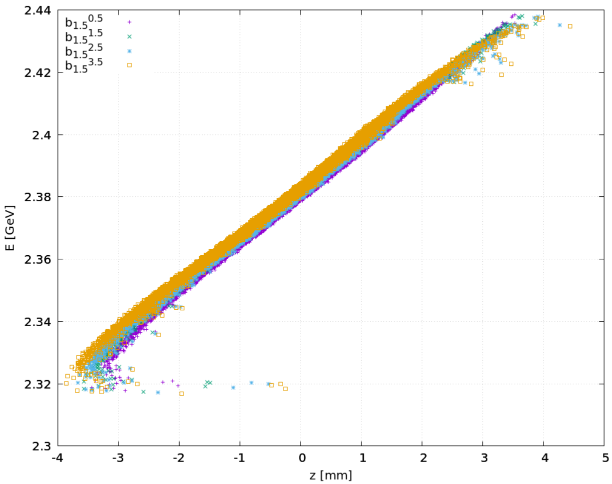


Tracking recirculating machines – PLACET2

Removing second order effects from the combiner ring arcs







Conclusions

Drive-Beam studies:

- We've presented the various sectors of the Drive-Beam complex
- Designed decelerator injection dogleg ($R_{56} = 9\,\mathrm{mm}$)
- Established longitudinal parameters ($\delta_{\mathrm{corr}} = 0.86\%$)
- Enforced isochronicity of TL3
- Enforced second order isochronicity in the combiner rings

PLACET2 developments/new features:

- 3D surveying of the machine layout
- Tracking with loses and defining apertures
- Different macro-particle weights
- Twiss and emittance tracking in dispersive sectors
- Tracking of first and second order moments

Outlook

Drive-Beam performance optimization and design updates:

- Enforce isochronicity of TL2
- Update DBA lattice (bunch compressor and new structures)
- Perform start-to-end simulations and consolidate the design
- Evaluate lattice tolerances to static and dynamic effects
- Beam-based alignment simulations

PLACET2 ongoing/future work:

- Decelerators
- CSR implementation
- Tracking of arbitrary particles
- Combined simulation of the entire CLIC machine

Thank you for your time