The Compact Linear Collider's Drive-Beam complex: How to power electrons up to 1.5 TeV

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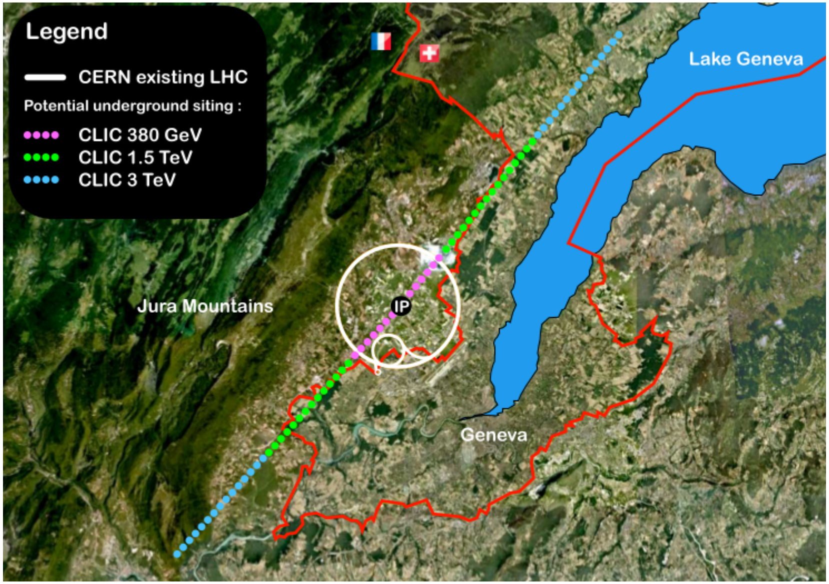
Outline

Introduction

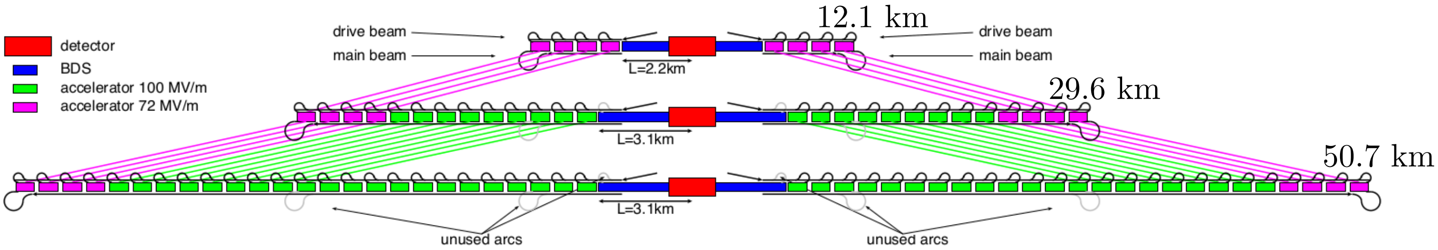
The Compact Linear Collider



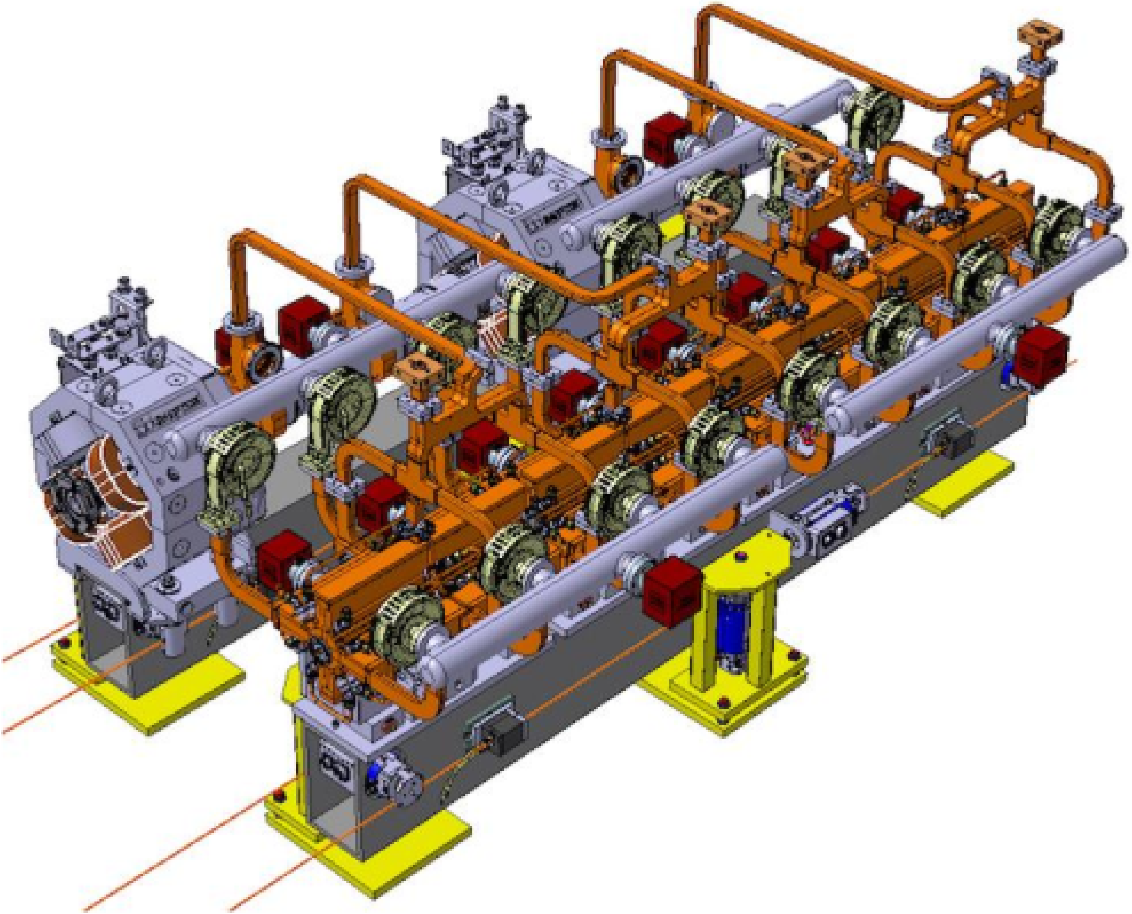
First stage: 380 GeV

Second stage: 1.5 TeV

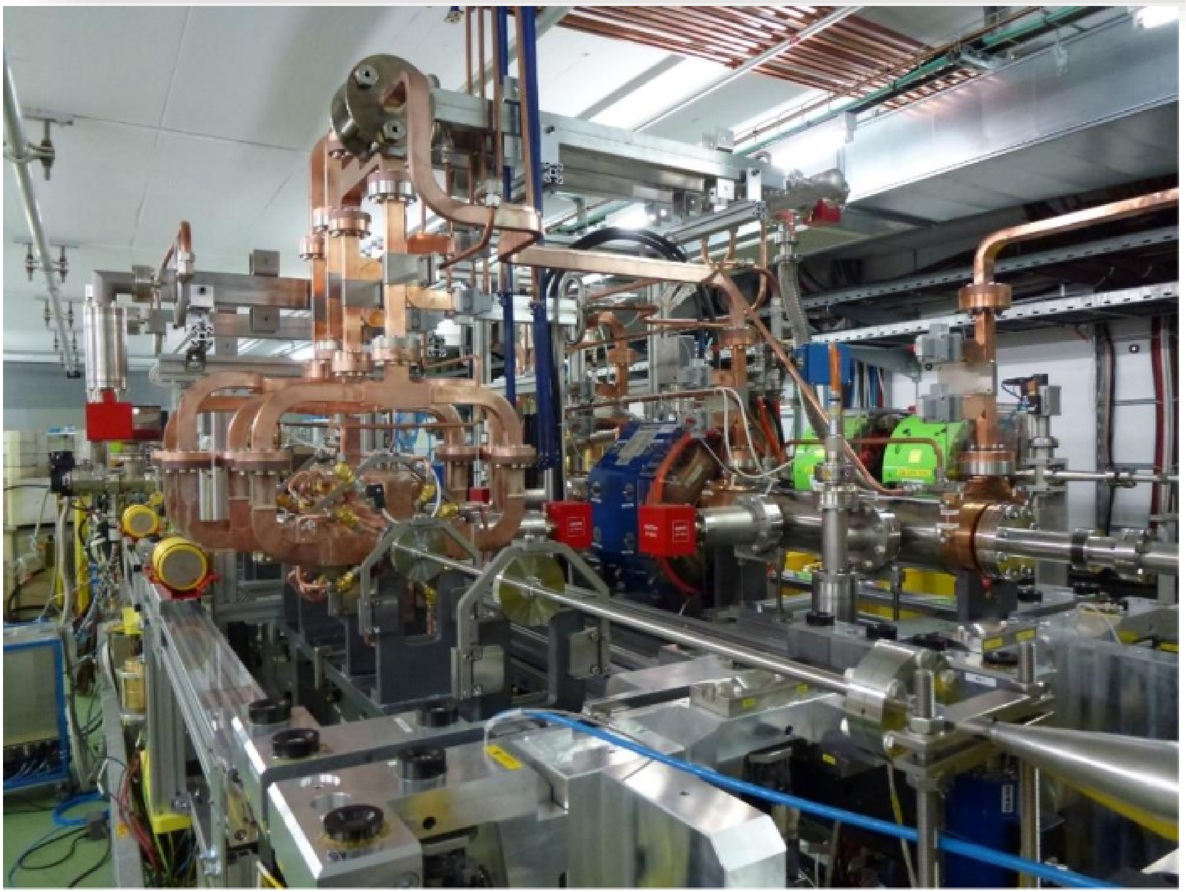
Third Stage: 3 TeV



Two-beam acceleration

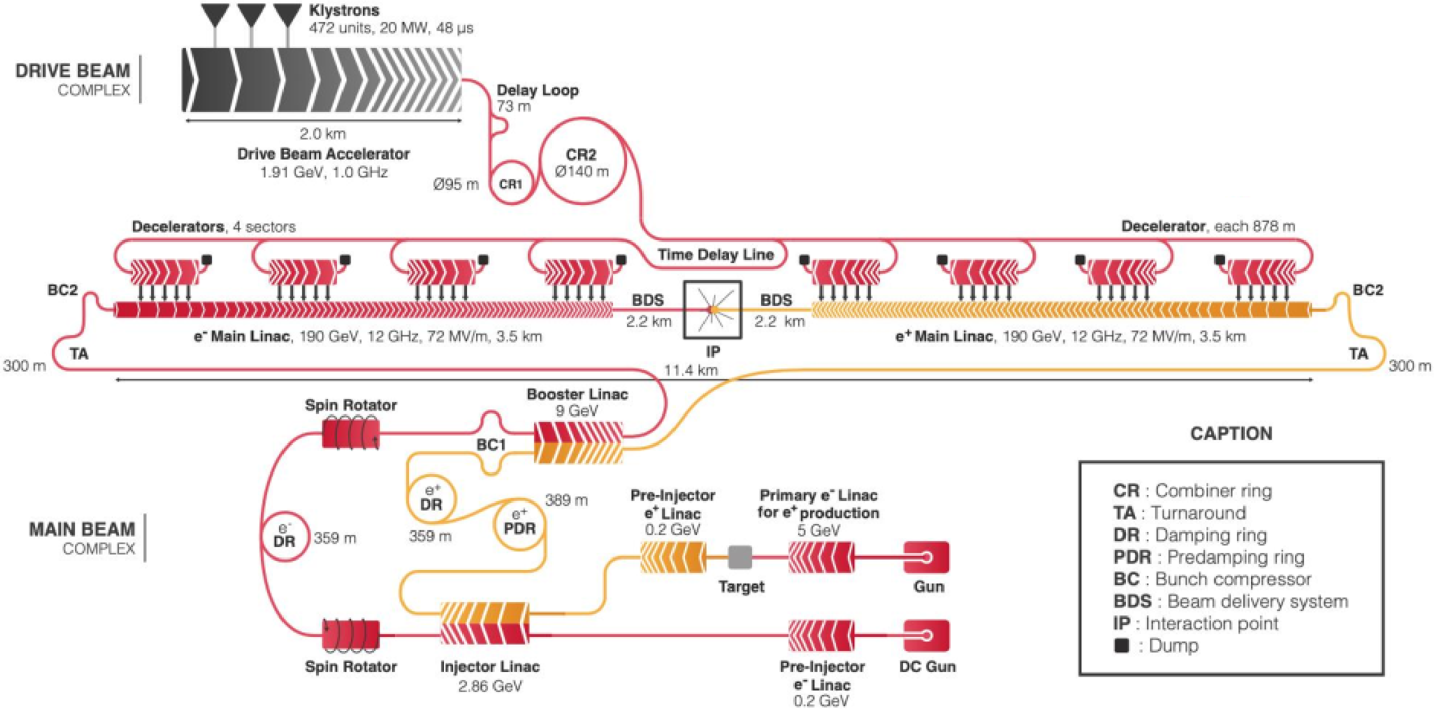


Two-beam module

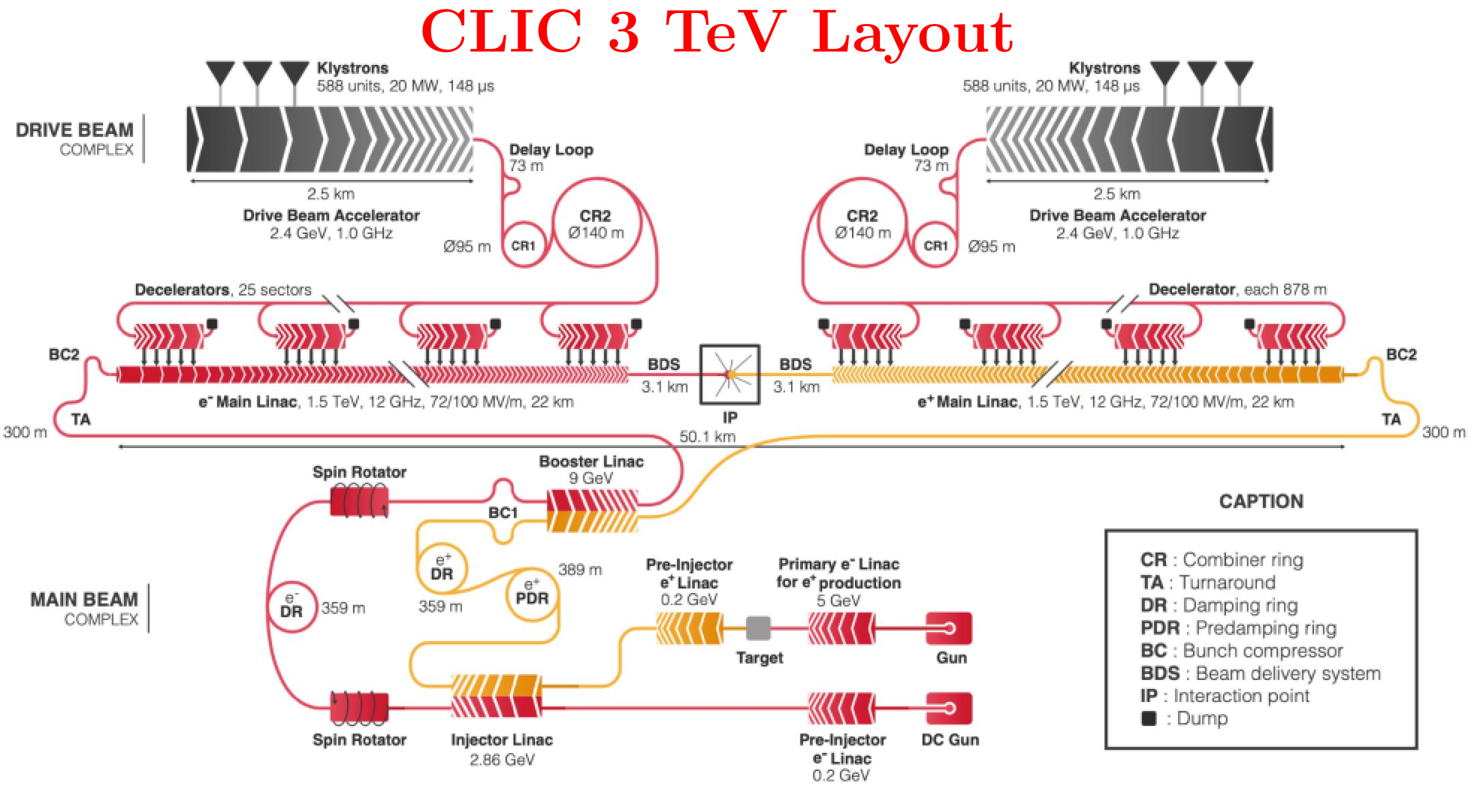


The Compact Linear Collider: 1st stage

CLIC 380 GeV Layout



The Compact Linear Collider: 3rd stage



System description

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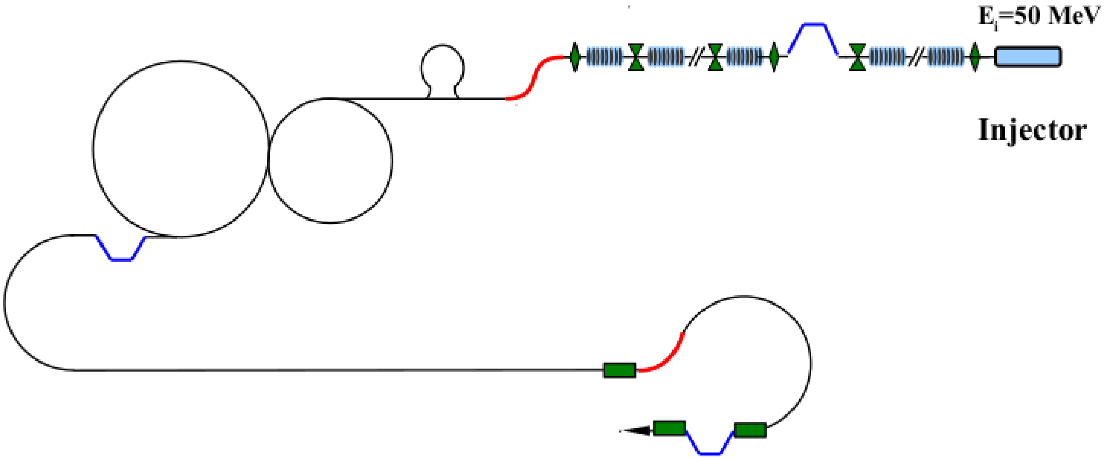

Sectors of the complex:

Drive-beam injector: Produces a 4.2A, 0.5GHz electron beam

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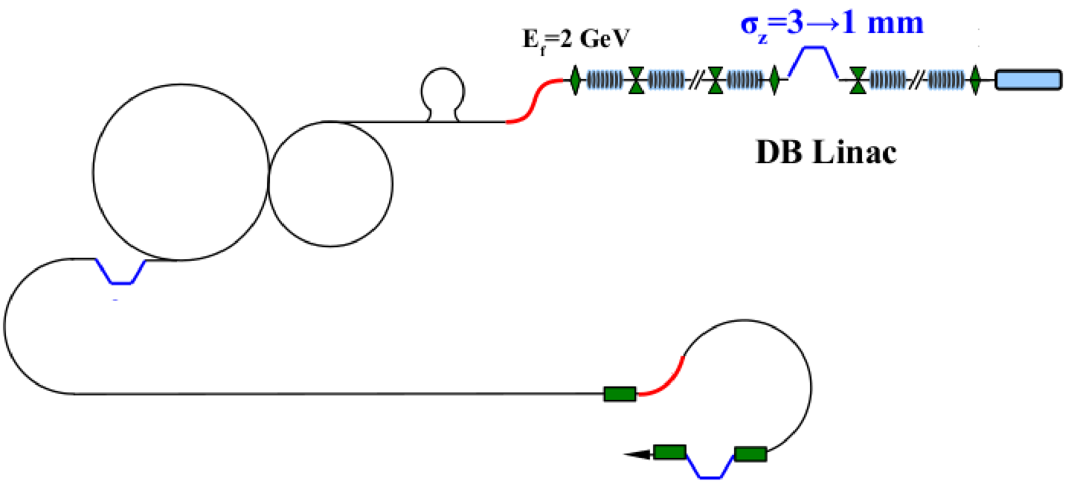

Sectors of the complex:

Drive-beam injector: Produces a 4.2A, 0.5GHz electron beam

Drive-beam accelerator: Increases beam energy to 1.9GeV/2.4GeV

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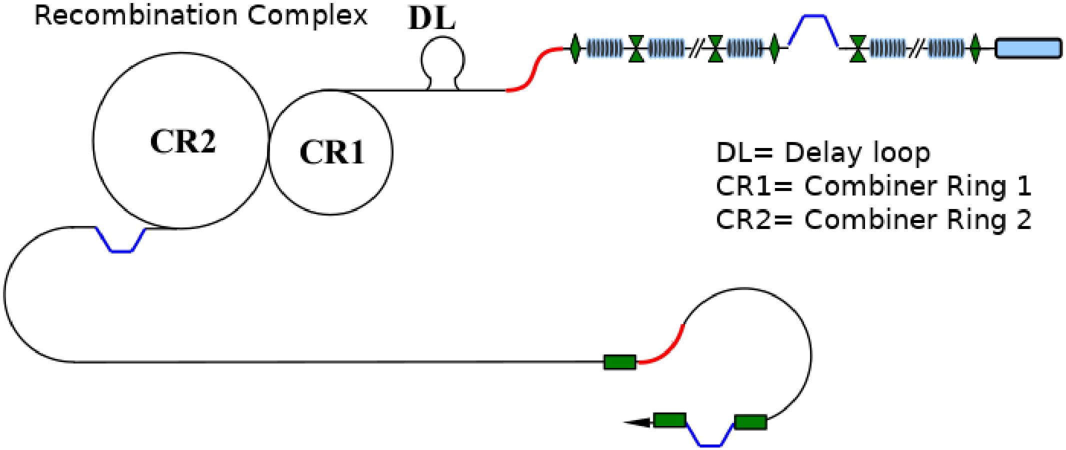

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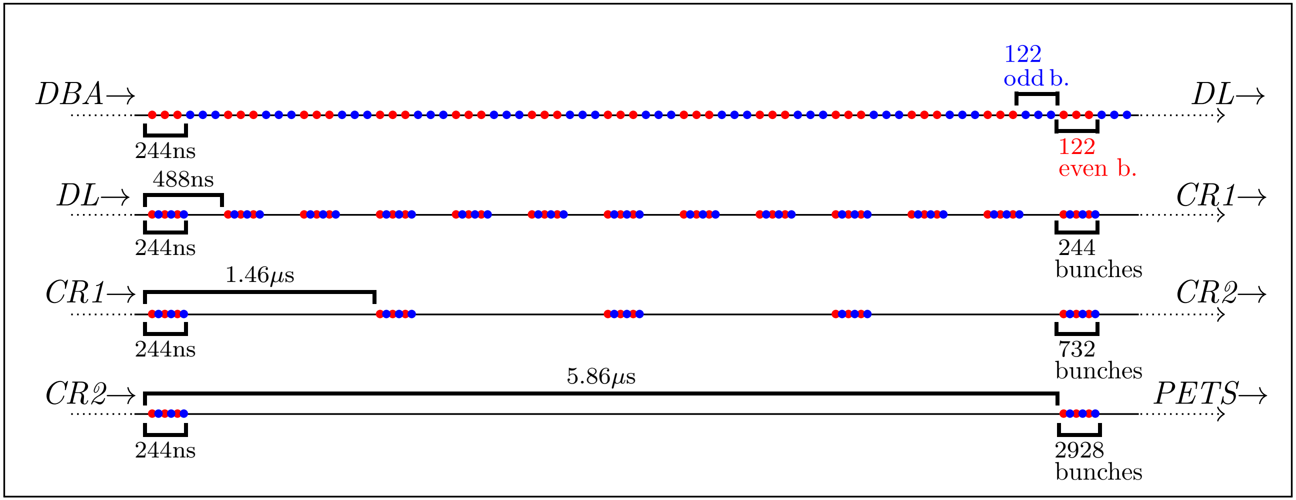
Recombination complex: Increases the frequency to 12GHz (101A)

System description: Recombination complex

http://ctf3-tbts.web.cern.ch/ctf3-tbts/slides/lemmings6.mpg

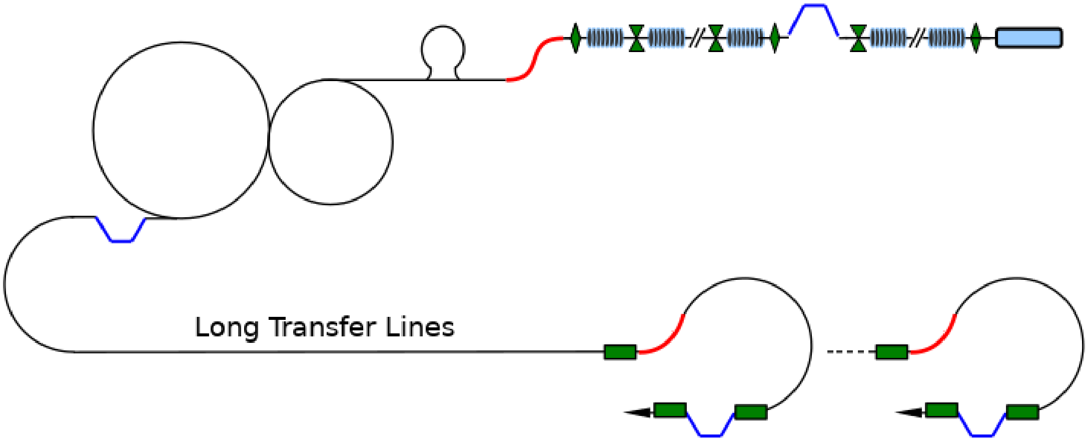
Recombination complex: Summary of operations



Injection: 0.5 GHz, 4.2 A

Extraction: 12 GHz, 101 A

System description



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Long transfer lines: Transport the beam down to the main linac tunnel

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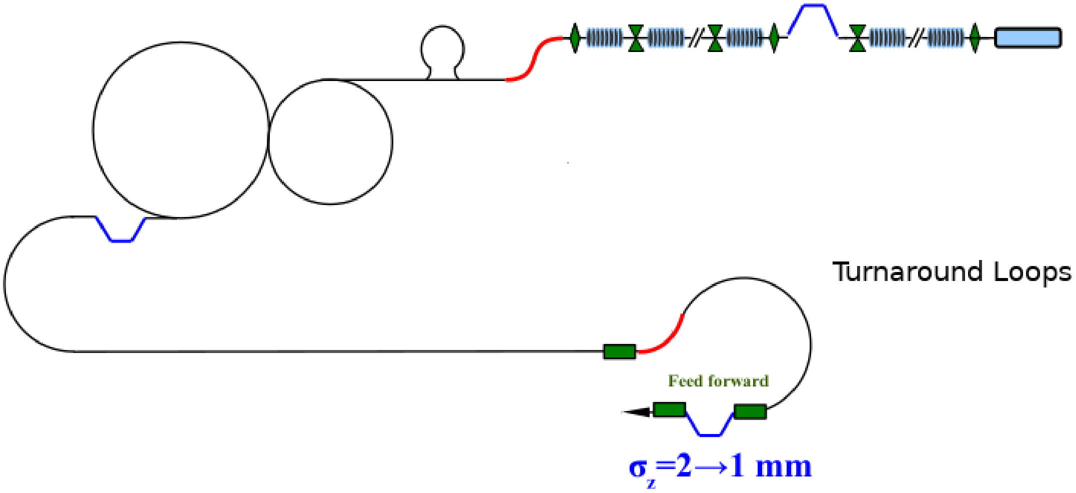

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Turnaround Loops: Turn the beam, house the feed-forward system

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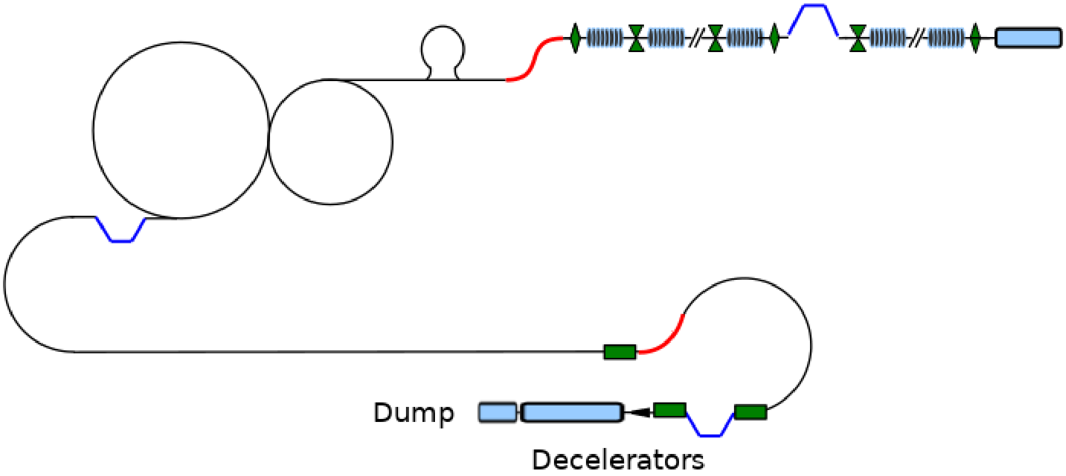

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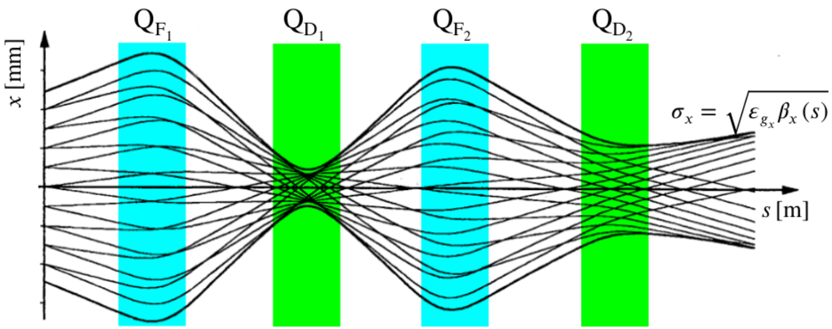
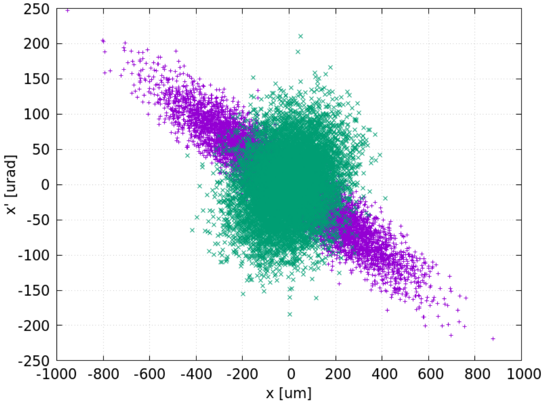
Decelerators: Extract power from the beam

Design challenges

Beam emittance





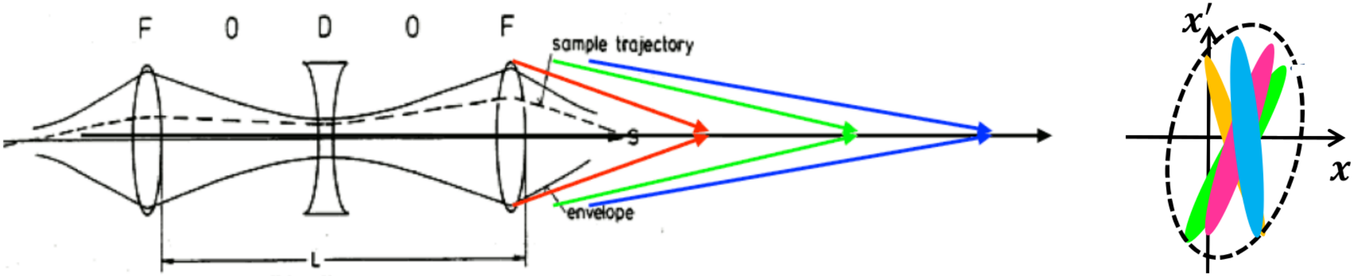
In phase-space, particles rotate around the reference orbit in an ellipse

The shape of the ellipse changes, but its area remains the same

Emittance growth: Chromatics effects

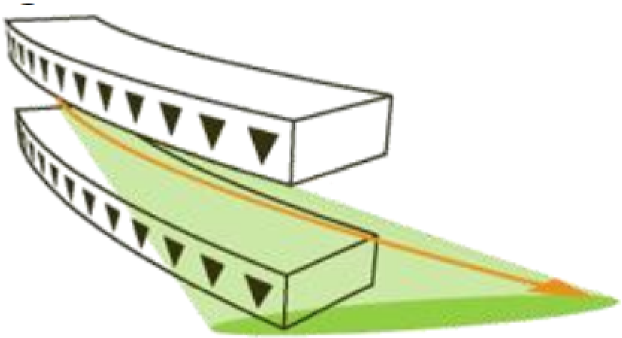
The evolution of phase-space ellipse is defined by the lattice optics

However, particles with different momentum ”see” different optics



Projecting the different momentum slices in the phase-space show how the bunch overall emittance increases

Emittance growth: Synchrotron radiation



Incoherent synchrotron radiation:

If $\lambda \ll \sigma_z$

$$E_{\text{Loss}} \propto \frac{{\color{red}N}\gamma^4\theta^2}{L_{\text{b}}}$$

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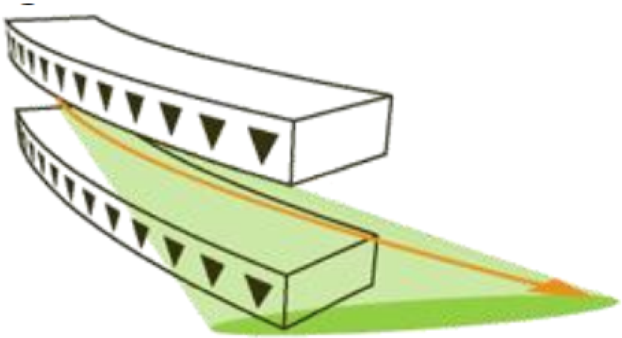

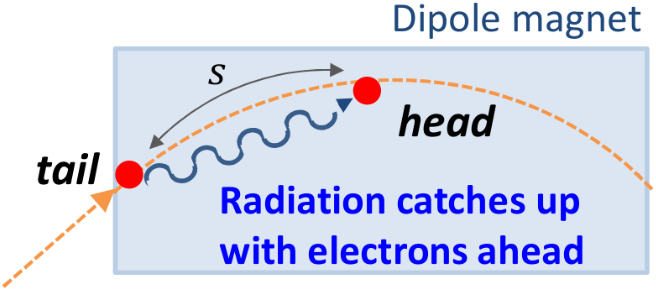

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Coherent synchrotron radiation:

If $\lambda \simeq \sigma_z$

$$E_{\text{Loss}} \propto \frac{\color{red}{N^2}\theta^{2/3}L_{\text{b}}^{1/3}}{\sigma_z^{4/3}}$$

PETS requirements: Bunch length = 1 mm

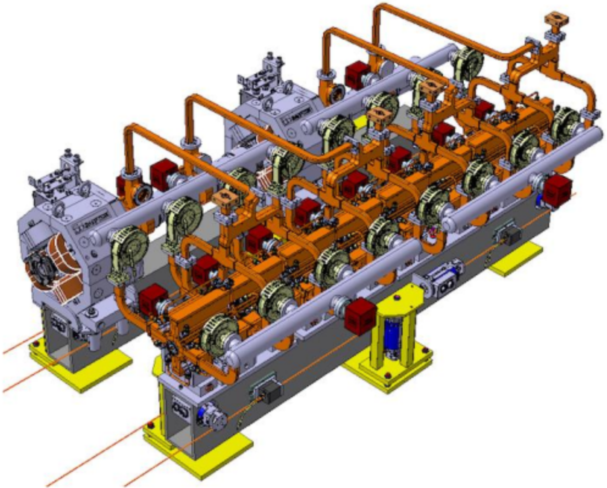
In the power extraction structures (PETS), the extracted power depends on the longitudinal charge distribution through the form factor

$$F\left(\lambda\right) = \int_{-\infty}^{+\infty} dz' \lambda\left(z'\right) \cos\left(\frac{\omega_{RF}}{c} z'\right) \sim \exp\left(-\frac{\sigma_z^2 \omega_{\mathrm{RF}}^2}{2c^2}\right)$$

$\Rightarrow$ changes in σ_z

$\Rightarrow$ decreased RF power for the main linac

$\Rightarrow$ decreased luminosity



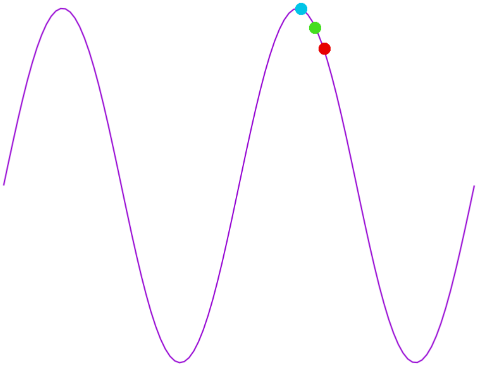
PETS requirements: Phase stability

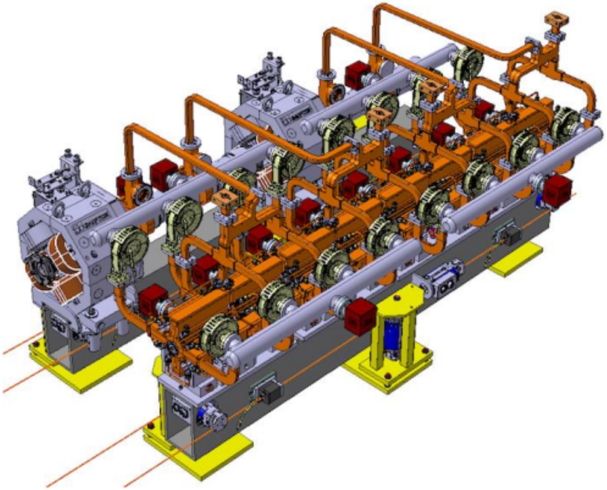
If the main-beam and RF synchronization jitters, the main-beam energy jitters as well, which affects luminosity

To keep luminosity loses $< 1\%$,

we need $< 0.2°$phase-error between the main-beam and the RF.

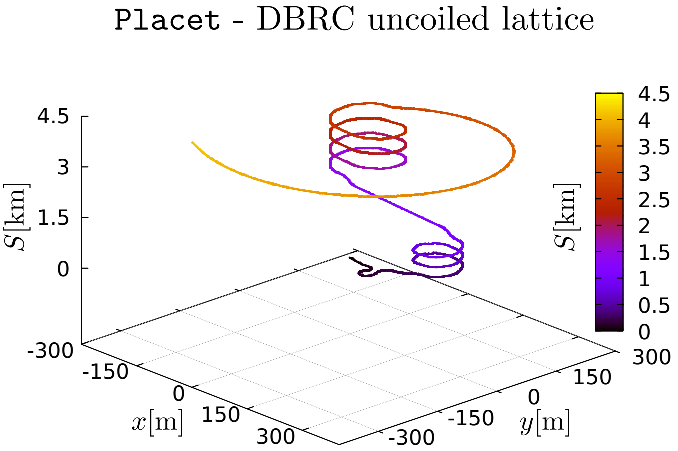
$\Rightarrow \quad \sim 46\,\text{fs}$ synchronization between main-beam and drive-beam

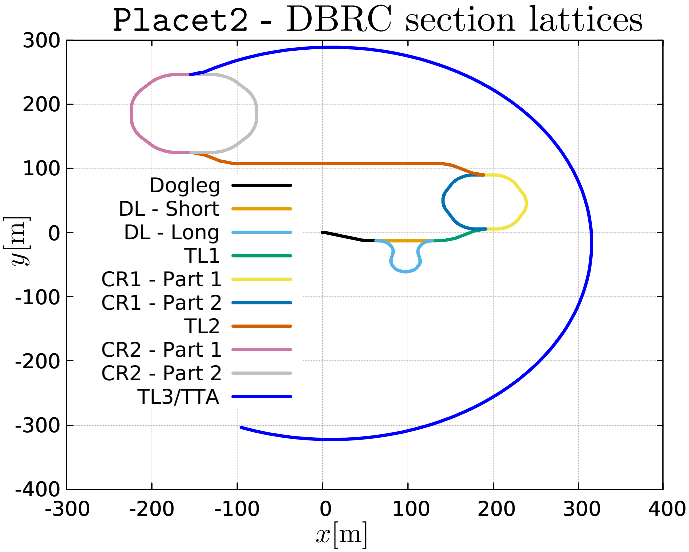




My role in the project

Tracking code: Placet2


`Placet` - DBRC uncoiled lattice


`Placet2` - DBRC section lattices

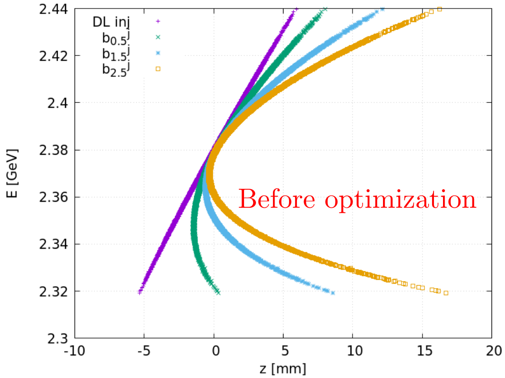
⇒ Multiparticle, Multibunch tracking

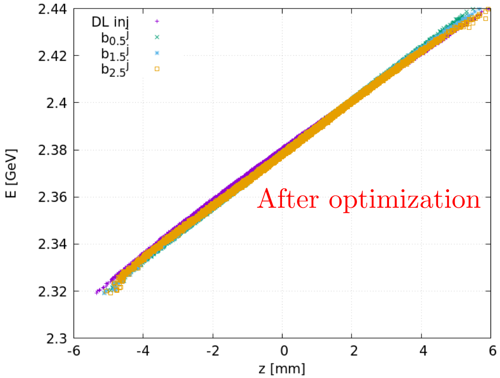
⇒ Developed with re-circulating machines in mind

⇒ Interfaces to **Octave** and **Python**

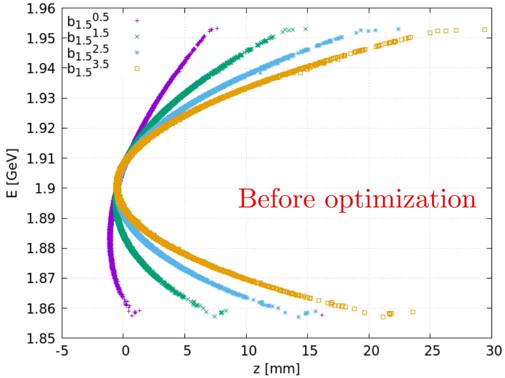
Combiner Rings: 2nd order matching

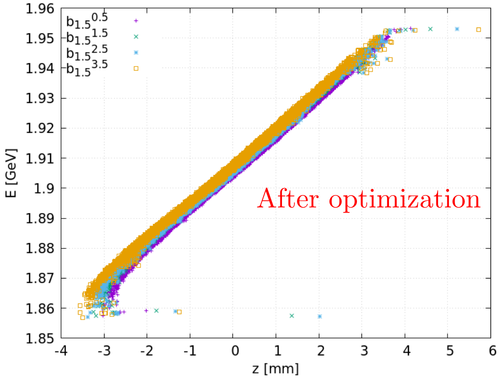
CR1:



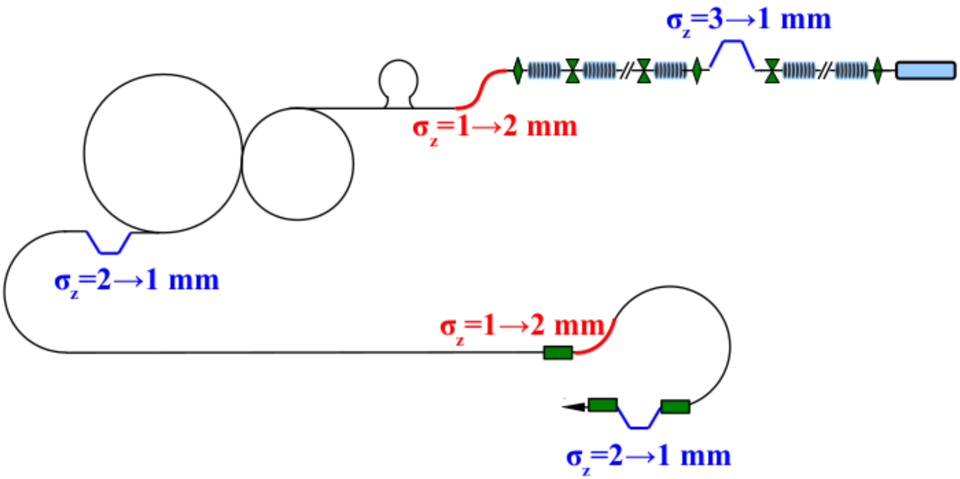


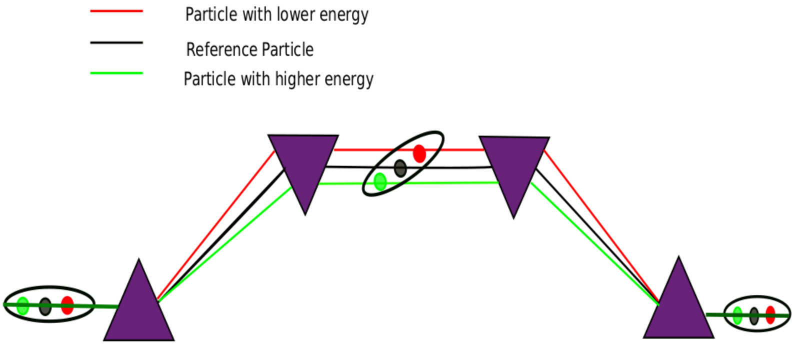
CR2:



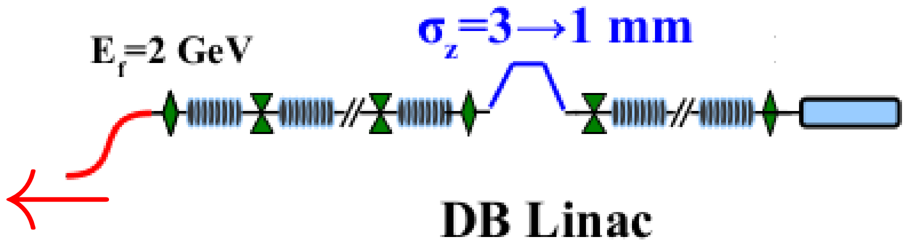


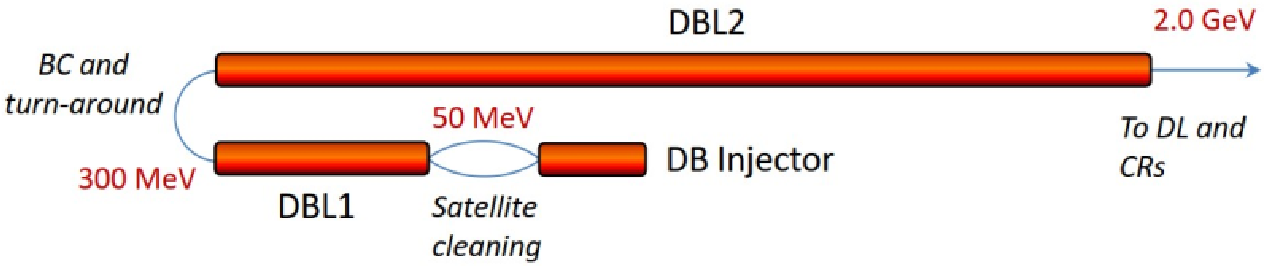
Bunch compression and decompression





Drive-beam accelerator

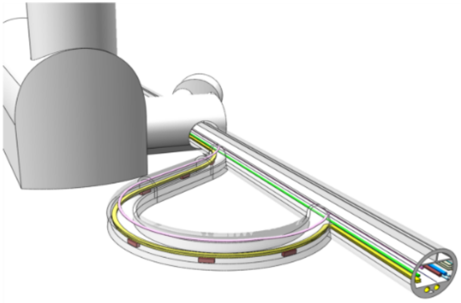


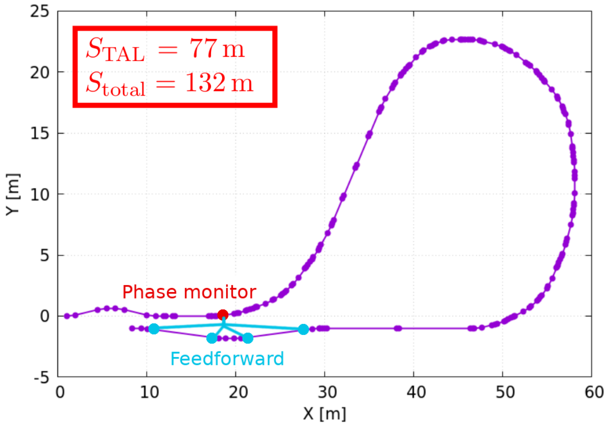


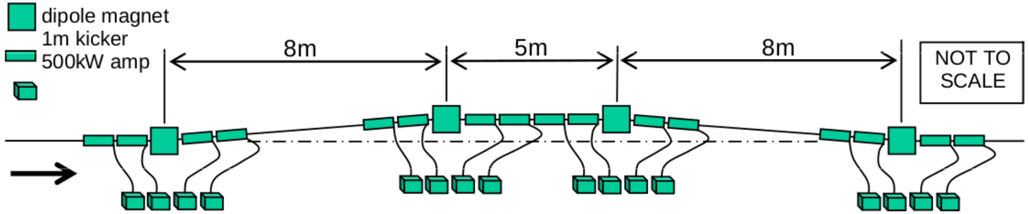
⇒ Design a bunch-compressor chicane to reduce the footprint

⇒ Match the linacs to the required energy chirp

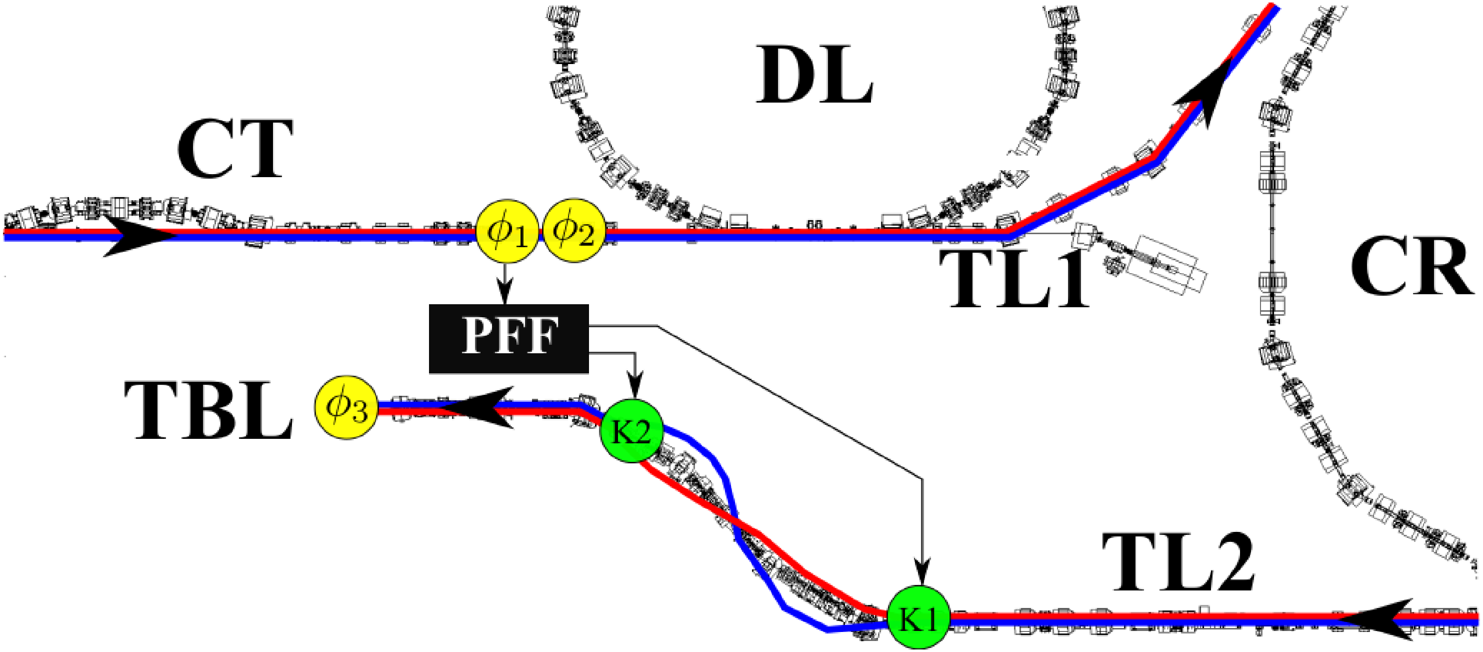
Turnaround loops and the feed-forward system





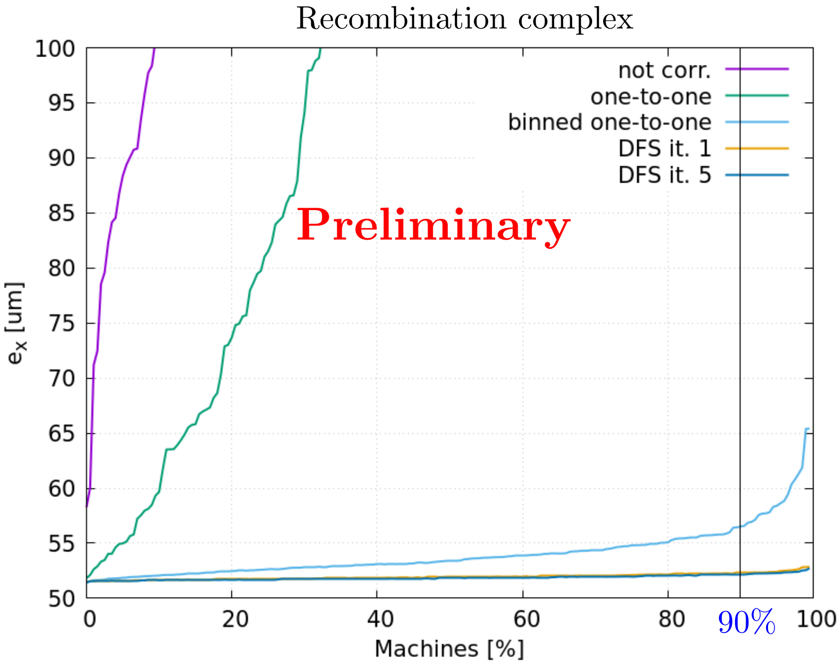


Feed-forward prototype at CTF3



Misalignments and beam-based alignment

Step one: Misalign machine to reproduce realistic conditions
Step two: Generate (imperfect) beam position monitor readouts
Step three: Apply beam-based correction techniques
Step four: Ensure that 90% of simulated machines fulfill specifications



Project outlook

Outlook

⇒ Match turnaround to tunnel geometry (includes vertical dogleg)

⇒ Design the bunch compressor arc for the DB accelerator

⇒ Update Linacs 1 and 2 to match required energy chirps

⇒ Design and track a full lattice of the long transfer lines

⇒ Update Placet2 to model CSR and the decelerators

⇒ Look at machines where CSR experiments could be made

⇒ Extend beam-based alignment methods to address re-circulation

⇒ ...

⇒ Integrate complete realistic simulations of the entire machine

⇒ Start digging (?)

CLIC's Drive-Beam

Thank you