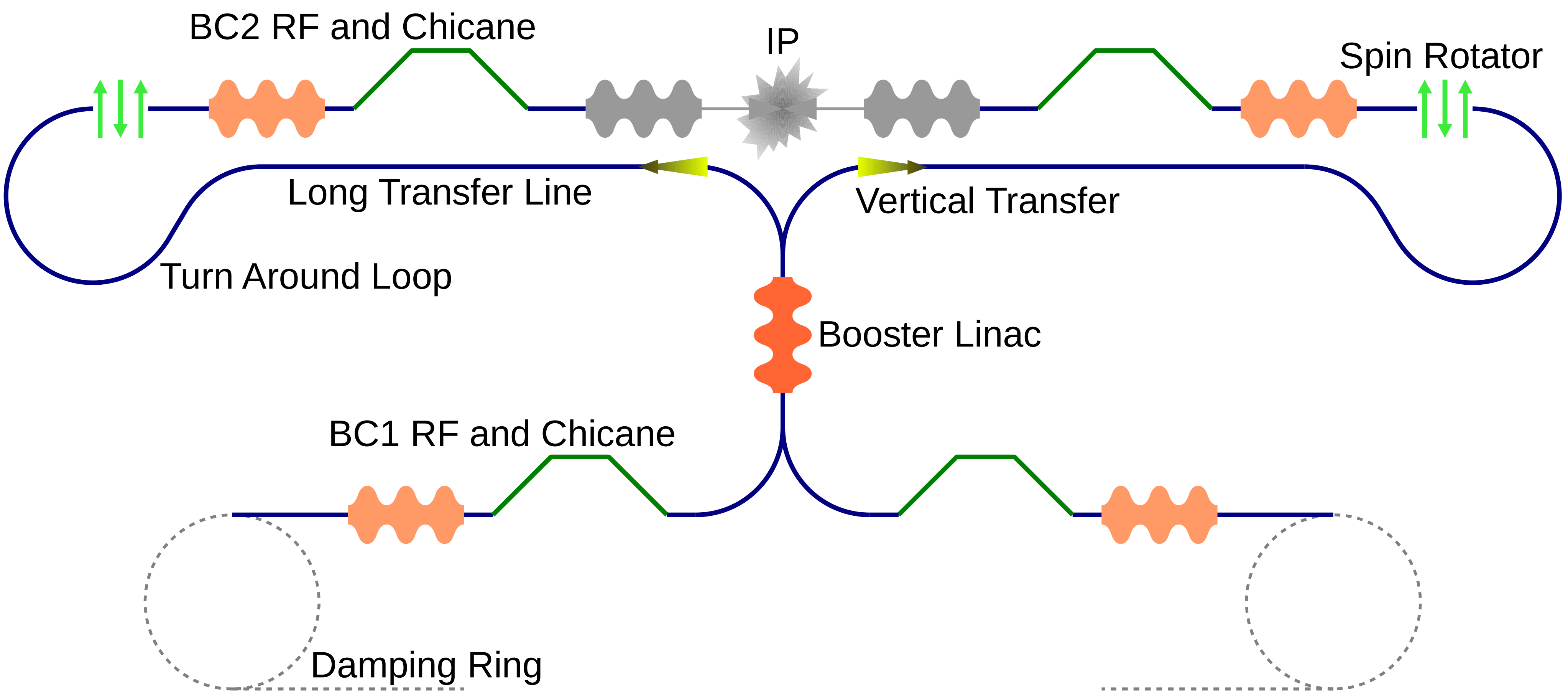
The CLIC Main Beam RTML

- Overview
- Main Systems and Beam Dynamics Challenges
  i.e. Bunch Compressor 1, Booster Linac,
  Vertical Transfer, Long Transfer Line,
  Turn Around Loop, Spin Rotator,
  Bunch Compressor 2
- Integrated Simulations
  i.e. from entrance of BC1 to exit of BC2
- RTML @ CLIC500
- Future Plans

Overview



not shown: Diagnostics, Collimation, Coupling Correction, Dispersion Correction, Spectrometers and Dumps

Overview

The RTML has to:

- ➔ transport the beams to the outer ends of the site
- ➔ match incoming beam parameters to main linac requirements
- ➔ guarantee acceptable jitter level, e.g. via feedback (and feed-forward)
- ➔ characterize the pulses (or even individual bunches)

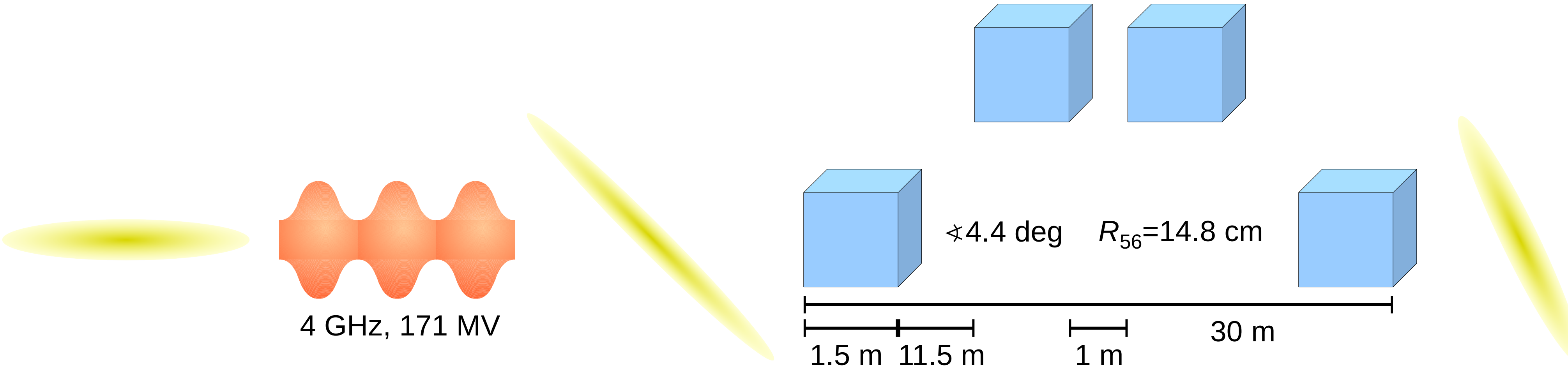
Property	Symbol	Value	Unit
Electron energy	E_0	2.86	GeV
Bunch charge	Q_0	0.65	nC
Bunch length	σ_s	1400	µm
Total energy spread	$\sigma_{E,tot} / E_0$	0.1	%
Normalized emittance	$\varepsilon_{n,x}$	500	nm rad
	$\varepsilon_{n,y}$	5	nm rad

@ Exit of Damping Rings

Property	Symbol	Value	Unit
Electron energy	E_0	8	GeV
Bunch charge	Q_0	>0.6	nC
Bunch length	σ_s	44	µm
Total energy spread	$\sigma_{E,tot} / E_0$	<1.5	%
Normalized emittance	$\varepsilon_{n,x}$	<600	nm rad
	$\varepsilon_{n,y}$	<10	nm rad

@ Entrance of Main Linac

Bunch Compressor 1 (new)



E_0	2.86	GeV
σ_s	1400	µm
$\sigma_{E,unc}/E_0$	0.1	%
$1/E_0\ dE/ds$	0	1/m
$\sigma_{E,tot}/E_0$	0.1	%

E_0	2.86	GeV
σ_s	1400	µm
$\sigma_{E,unc}/E_0$	0.1	%
$1/E_0\ dE/ds$	-4.95	1/m
$\sigma_{E,tot}/E_0$	0.7	%

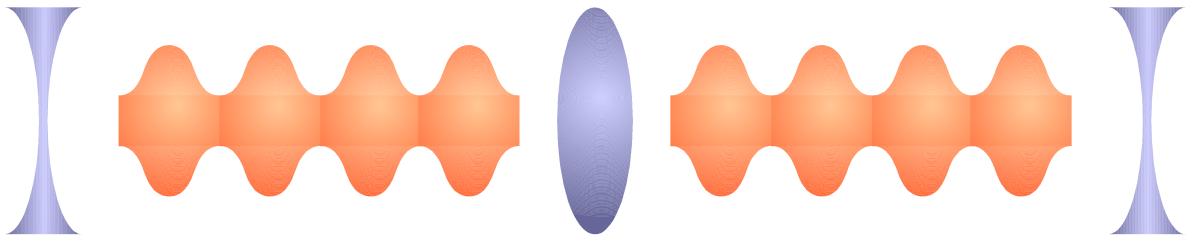
E_0	2.86	GeV
σ_s	400	µm
$\sigma_{E,unc}/E_0$	0.35	%
$1/E_0\ dE/ds$	-15.2	1/m
$\sigma_{E,tot}/E_0$	0.7	%

To improve performance of BC1:

- ➔ longer final bunch (reduces CSR in all beam lines up to BC2)
- ➔ larger than necessary energy chirp (under-compression), i.e. less R_{56} => less CSR (the induced chirp would allow a compression to 200 µm)

Booster Linac

by D. Wang



4 GHz, 5.14 GV (or 6.14 GV)

E_0	2.86	GeV
σ_s	400	µm
$\sigma_{E,unc}/E_0$	0.35	%
$1/E_0\ dE/ds$	-15.2	1/m
$\sigma_{E,tot}/E_0$	0.7	%

E_0	8 (9?)	GeV
σ_s	400	µm
$\sigma_{E,unc}/E_0$	0.13	%
$1/E_0\ dE/ds$	-5.42	1/m
$\sigma_{E,tot}/E_0$	0.25	%

Optimized with respect to wake fields and impact of misalignment

- ➔ FODO lattice with 30 m average beta function
- ➔ 12 m of cavities between two quadrupoles,
  other schemes were also investigated and show similar performance
- ➔ 240 m total length
- ➔ due to the long bunches a non-negligible RF curvature is induced

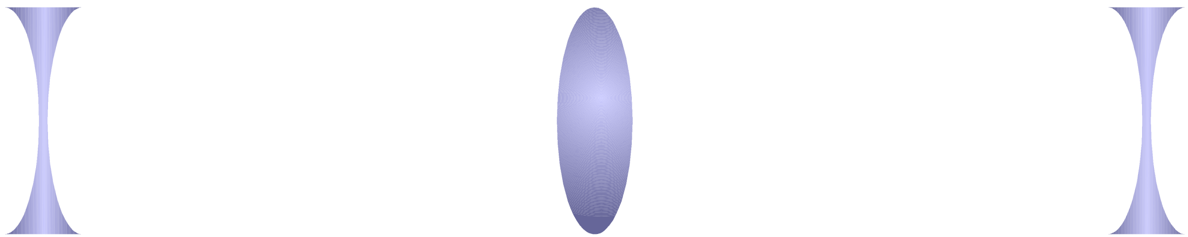
Vertical Transfer

?

CSR is expected to be the main challenge.
We hope that due to the long bunches (400 µm) it is mitigated.
But this needs to be confirmed!

Long Transfer Line

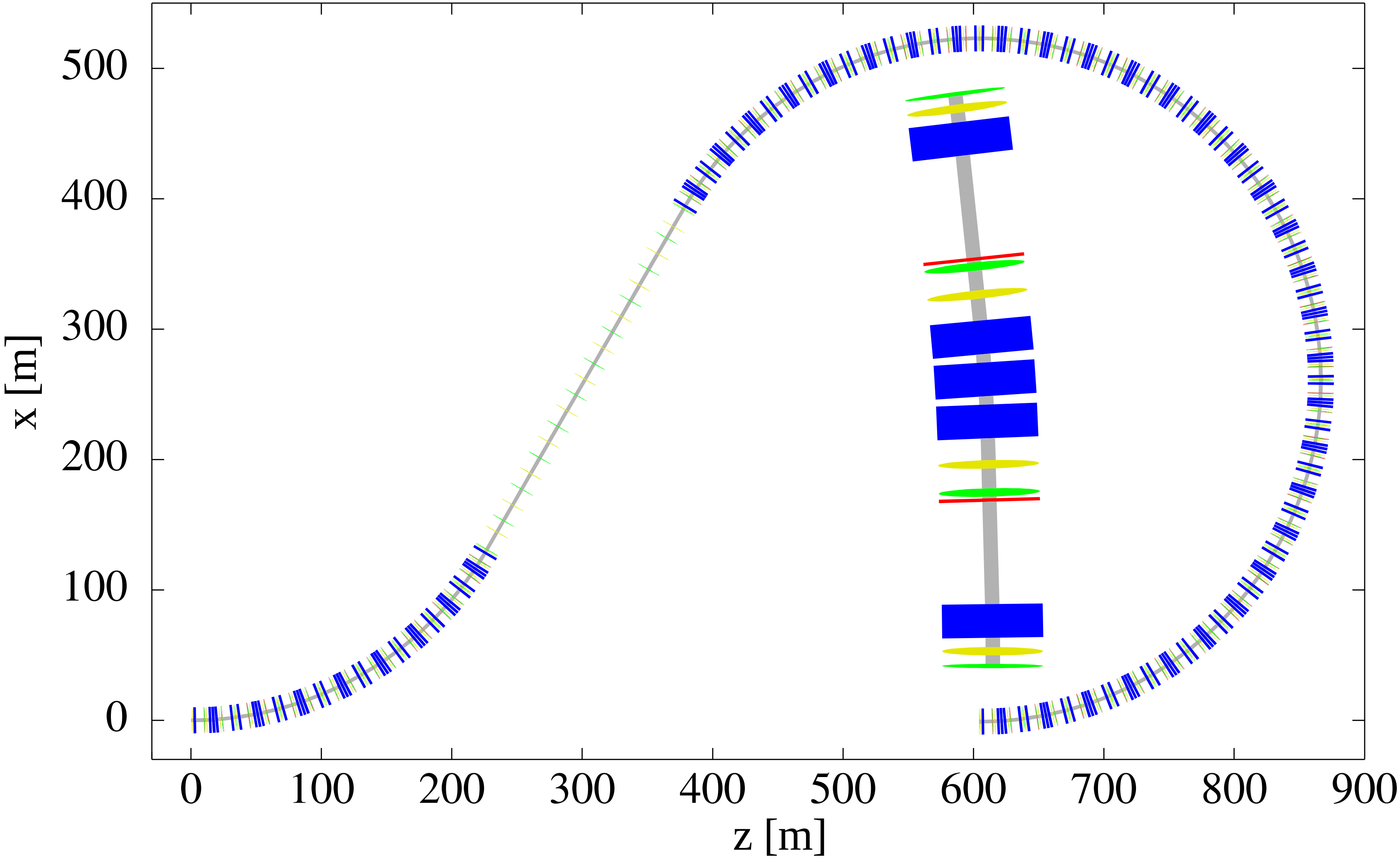
by B. Jeanneret



21 km FODO lattice, very weak quadrupoles (k_1<0.01 1/m^2)

- huge average beta function, >600 m
- low k_1 helps to suppress chromatic dilutions
- utilizes a large beam pipe of 10 cm diameter to reduce resistive wall wakes
- fast beam ion instability is an issue,
  vacuum level of 0.1 nTorr required (G. Rumolo)
- magnetic stray fields are being investigated (J. Snuverink)

Turn Around Loop



Turn Around Loop

The turn around loop profits from the new compression scheme in two ways:

- CSR was already small and is now really negligible
- the energy spread is smaller,
  i.e. chromatic errors of the quadrupoles are weaker

The only challenge left is ISR:

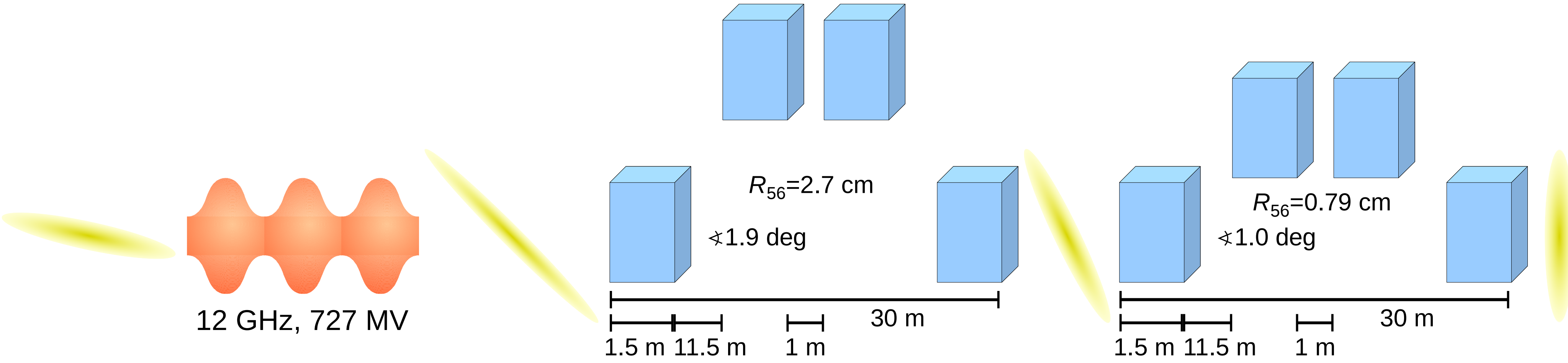
- ISR in the turn around loop was the motivation to reduce
  the electron energy after the booster linac to 8 GeV
- but main linac would have to start 1 GeV earlier, which is unfavorable
- Optimization has to be done

Spin Rotator

?

We hope to be able to use the ILC Spin Rotator as a basis
and adapt it to the CLIC parameters.
But this needs to be confirmed!

Bunch Compressor 2 (new)



E_0	8	GeV
σ_s	400	µm
$\sigma_{E,unc}/E_0$	0.13	%
$1/E_0\ dE/ds$	-5.42	1/m
$\sigma_{E,tot}/E_0$	0.25	%

E_0	8	GeV
σ_s	400	µm
$\sigma_{E,unc}/E_0$	0.13	%
$1/E_0\ dE/ds$	-28.3	1/m
$\sigma_{E,tot}/E_0$	1.14	%

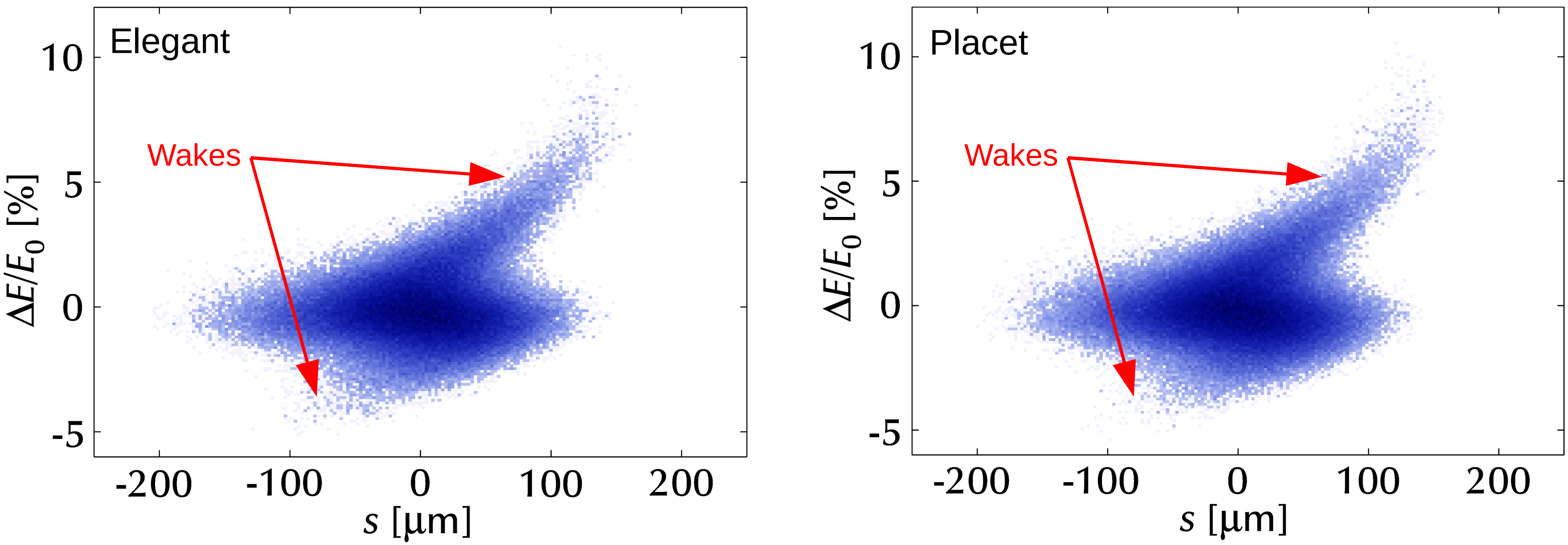
E_0	8	GeV
σ_s	100	µm
$\sigma_{E,unc}/E_0$	0.5	%
$1/E_0\ dE/ds$	-102	1/m
$\sigma_{E,tot}/E_0$	1.14	%

E_0	8	GeV
σ_s	44	µm
$\sigma_{E,unc}/E_0$	1.14	%
$1/E_0\ dE/ds$	0	1/m
$\sigma_{E,tot}/E_0$	1.14	%

To improve performance of BC2:

- ➔ utilize double chicane
- ➔ reduce bend angles where bunches are shortest, i.e. less CSR
- ➔ gain a lot flexibility to adapt to different parameter sets
- ➔ due to longer initial bunches less RF required, i.e. less wake fields

Integrated Simulations (old)

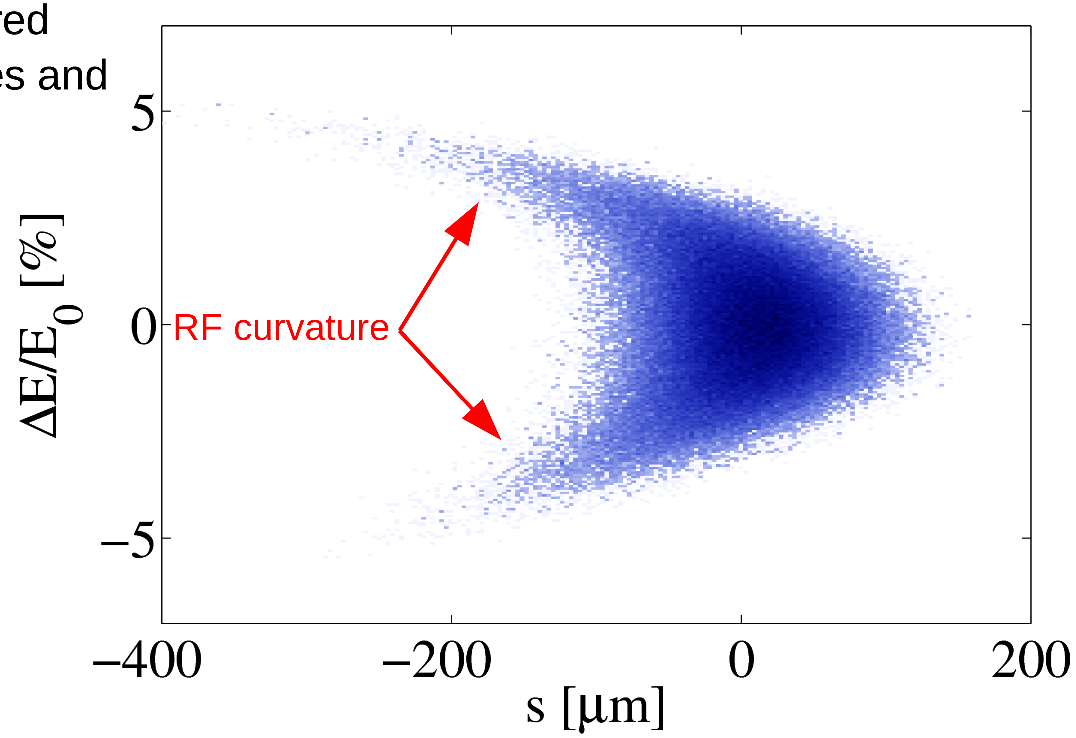


- In the simulations BC1, booster linac, long transfer line, turn around loop and BC2 are connected by simple optics matching sections.
- ISR, wake fields and chromatic effects lead to an emittance growth in the horizontal plane of $\Delta\varepsilon_{n,x}$ = 50 nm rad (Elegant) and $\Delta\varepsilon_{n,x}$ = 60 nm rad (Placet).
- If only CSR is considered the emittance growth is $\Delta\varepsilon_{n,x}$ = 200 nm rad (Elegant).
- Emittance in the vertical plane is always unchanged.

Integrated Simulations (new)

Since the CSR induced emittance growth was unacceptably large the bunch compression system had been revised:

- less compression in BC1
- two BC2 chicanes with different R_{56} (single RF)
- reduced CSR emittance growth to $\Delta\varepsilon_{n,x}$ = 20 nm rad (Elegant)
- but now the booster linac induces non-negligible RF curvature
- this must be taken into account in the setup of BC2 RF and chicanes, otherwise the final bunch length would be too large, i.e. larger energy chirp but less R_{56} required (values on previous slides are ideal values and not corrected according to the impact of RF curvature or wake fields)



RTML @ CLIC500

	3 TeV	500 GeV
Bunch charge	0.65 nC	1.2 nC
Initial bunch length	1400 μm	1400 μm
Final bunch length	44 μm	~70 μm
Emittance budget x	100 nm rad	500 nm rad
Emittance budget y	5 nm rad	5 nm rad

RTML specifications are the same for nominal and conservative parameter sets.

- ➔ Doubling the charge is a major issue.
  But longer final bunch and larger horizontal emittance budget help.
- ➔ An RTML which is suitable for the 3 TeV case (normal charge) could also be suitable for the 500 GeV case (double charge).
- ➔ No upgrade would be required, neither from conservative to nominal parameters nor from 500 GeV to 3 TeV. This is used as a design objective.
  (Clearly, the length of the long transfer line has to be adjusted, but this is of minor importance for beam dynamics.)
- ➔ In the old layout CSR emittance growth was unacceptable ($\Delta\varepsilon_{n,x}$ = 800 nm rad), but the new layout seems to be promising!

Future Plans

- First simulations of the new RTML are very promising, they will be refined and all important effects, i.e. ISR, CSR and wake fields, will be taken into account.
- To mitigate RF curvature in the booster linac we will check if it is possible to compress in BC1 to 300 µm.
- Simulate RTML for 500 GeV parameters.
- Explore tolerances on static and dynamic imperfections and their mitigation including misalignment, magnetic field errors and stray fields, jitter of incoming beam parameters.
- Evaluate vacuum requirements.
- Study requirements for feedback and feed-forward system.
- The lattice of the turn around loop is not optimal and should be revised, but for the moment it seems to be acceptable.
- We need to study the vertical transfer and the spin rotator.