Bunch Compressors and Turn Around Loops for CLIC

PSI worked on Beam Lines for

Main Beam and Drive Beam:

- -> Tasks and Parameters Overview
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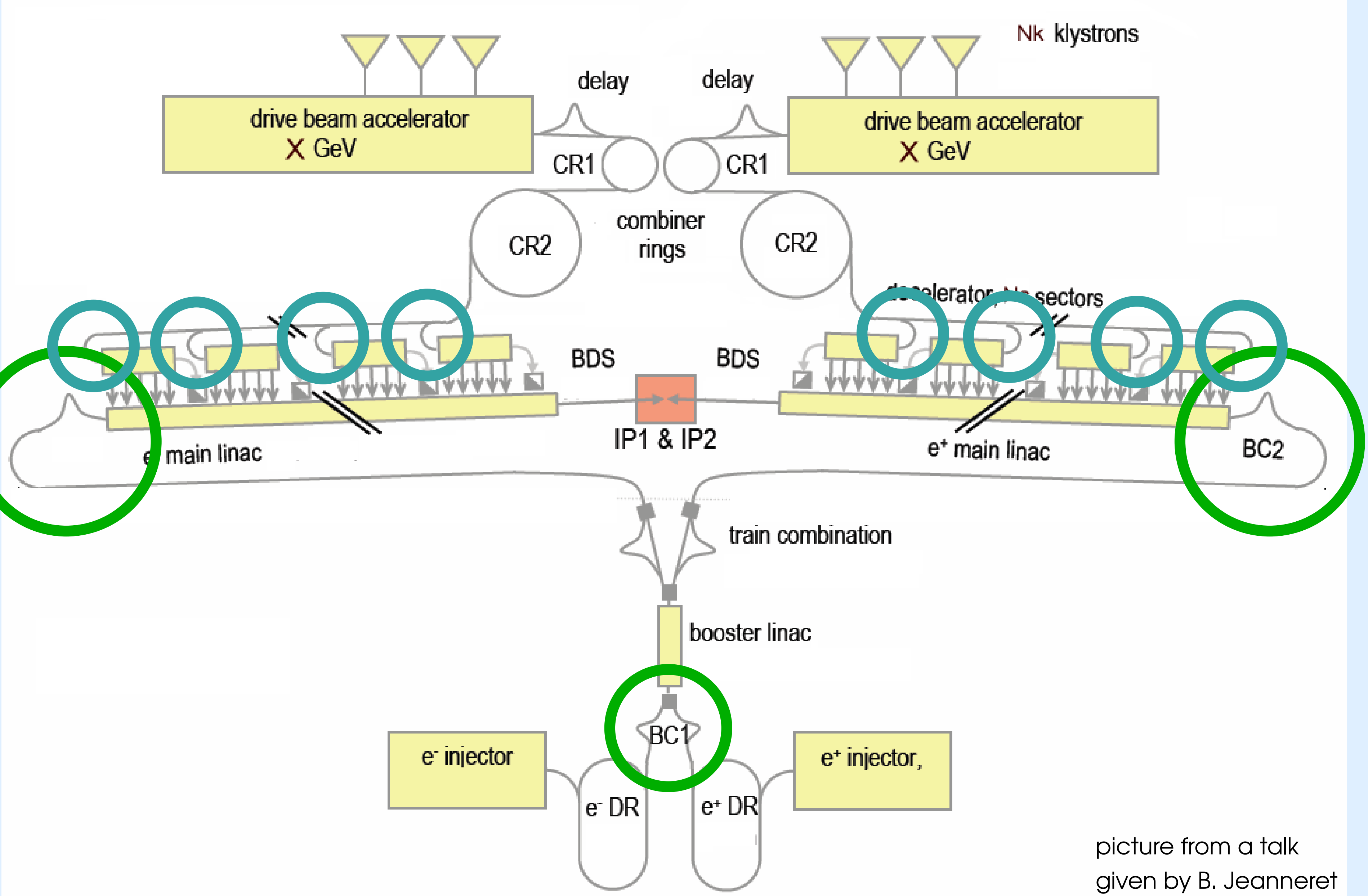
for details see EUROTeV-Report-2008-025
(available soon)

PSI's Tasks within the EUROTeV Collaboration



picture from a talk
given by B. Jeanneret

Tasks Overview

Main Beam:

-> Bunch Compression at 2.424 GeV

-> Turn Around Loop at 9 GeV

-> Bunch Compression at 9 GeV

=> distinct beam lines,
each will be build two times

Drive Beam:

-> Bunch Compression

-> Phase / Energy Error Measurement

-> Turn Around Loop

-> Bunch Compression

-> Phase Correction

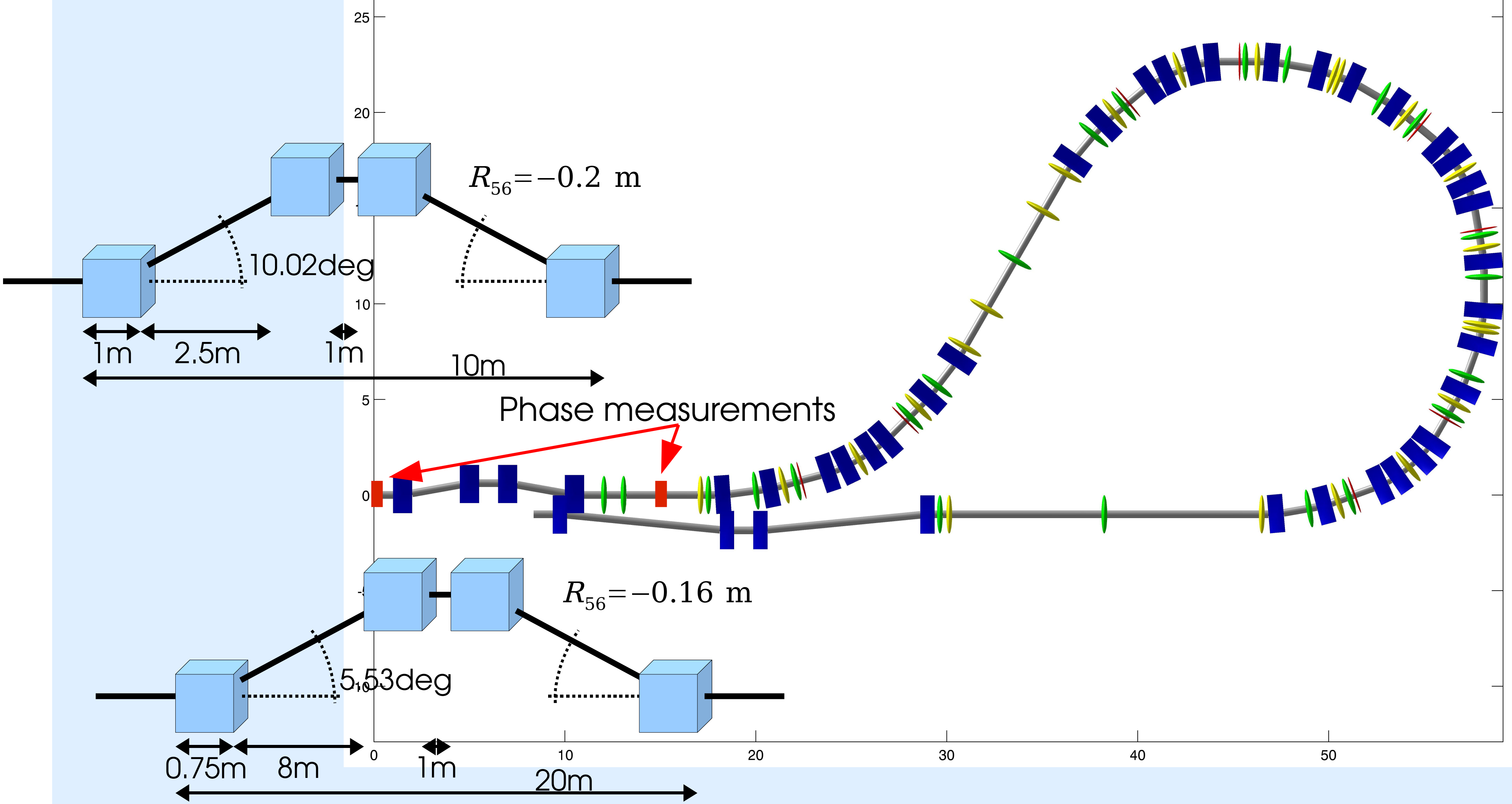
=> integral beam line,
will be build 2 x 24 = 48 times

Drive Beam Tasks Overview

Bunch Compressor Chicane 10 m

Turn Around Loop 77 m = 1x 60deg arc + matching + 3x 80deg arc

Bunch Compressor Chicane 20 m



Design Considerations / Constraints

Bunch Compressors BC1 and BC2:

-> BC1 is not only a bunch compressor, but is also used to convert an incoming energy jitter into a measurable phase jitter

-> for the energy jitter measurement its R_{56} should not be too small:

$$\Delta\phi \approx \frac{2\pi}{\lambda_{\mathrm{RF}}} R_{56} \frac{\Delta E}{E_0}$$

-> the phase error measured in front of the loop is corrected in BC2 by changing the path length of the bunch

-> its R_{56}, i.e. the bending angles, should be large enough to allow the usage of weak correction kickers:

$$\Delta l \approx \frac{2}{3}\left(3\, l_{12} + 2\, l_{\mathrm{B}}\right)\alpha_0 \Delta\alpha$$

-> the influence of ISR is small due to the huge beam emittance and the rather low electron energy

-> CSR is also rather easy to control due to the huge beam emittance

Design Considerations / Constraints

Turn Around Loop:

-> the turn around loop has to be achromatic and should be isochronous

-> it has to be compact and simple since 2x 24 loops are required

-> the $R_{56}(s)$ should stay small since the bunch has an energy chirp,
it might be compressed to short lengths, i.e. it might radiate a lot CSR

-> this is the main complication for the lattice design,
a trade-off has to be made between $R_{56}(s)$, $T_{566}(s)$ and chromaticity

-> the influence of ISR is small due to the huge beam emittance
and the rather low electron energy

-> CSR is also rather easy to control due to the huge beam emittance

Simulation Results, 1D CSR

Specification
in front of BC1:

$E_0 = 2.424$ GeV

$Q_0 = 7.8$ nC

$\sigma_s = 2000$ µm

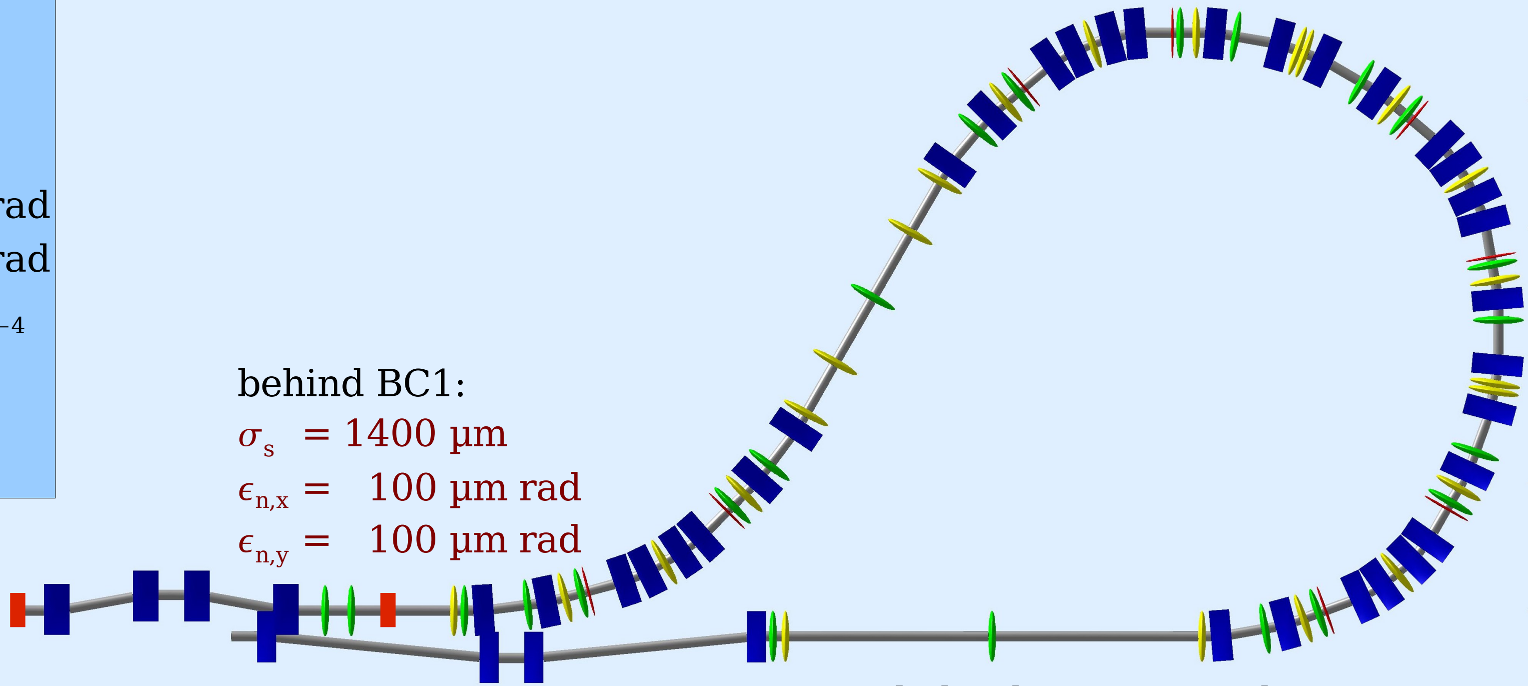
$I_{peak} = 466$ A

$\epsilon_{n,x} = 100$ µm rad

$\epsilon_{n,y} = 100$ µm rad

$\frac{\sigma_{E,unc}}{E_0} = 2.5 \times 10^{-4}$

$\frac{1}{E_0}\frac{dE}{ds} = -1.47\ \mathrm{m}^{-1}$



behind BC1:

$\sigma_s = 1400$ µm

$\epsilon_{n,x} = 100$ µm rad

$\epsilon_{n,y} = 100$ µm rad

behind Turn Around Loop:

$\sigma_s = 1400$ µm

$\epsilon_{n,x} = 102$ µm rad

$\epsilon_{n,y} = 100$ µm rad

Specification
behind BC2:

Specification		Simulation
σ_s	$= 1000$ µm	1000 µm
I_{peak}	$= 933$ A	940 A
$\epsilon_{n,x}$	< 110 µm rad	103 µm rad
$\epsilon_{n,y}$	< 110 µm rad	100 µm rad
$\frac{\sigma_{E,tot}}{E_0}$	$< 5 \times 10^{-3}$	2.7×10^{-3}

Simulation Results, 1D CSR

Specification in front of BC1:

$E_0 = 2.424$ GeV

$Q_0 = 7.8$ nC

$\sigma_s = 2000$ µm

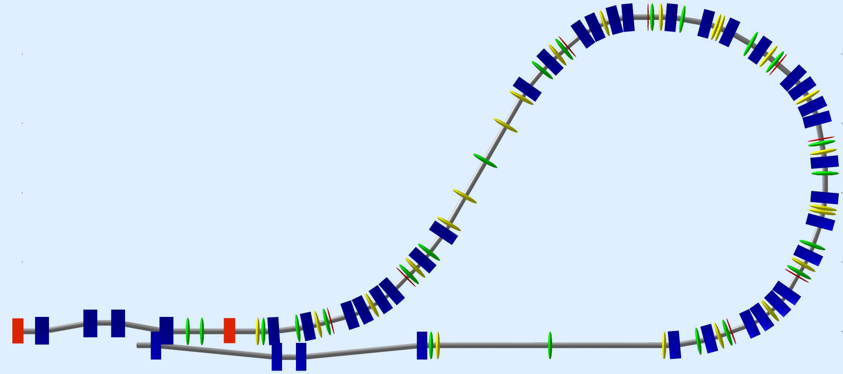
$I_{peak} = 466$ A

$\epsilon_{n,x} = 100$ µm rad

$\epsilon_{n,y} = 100$ µm rad

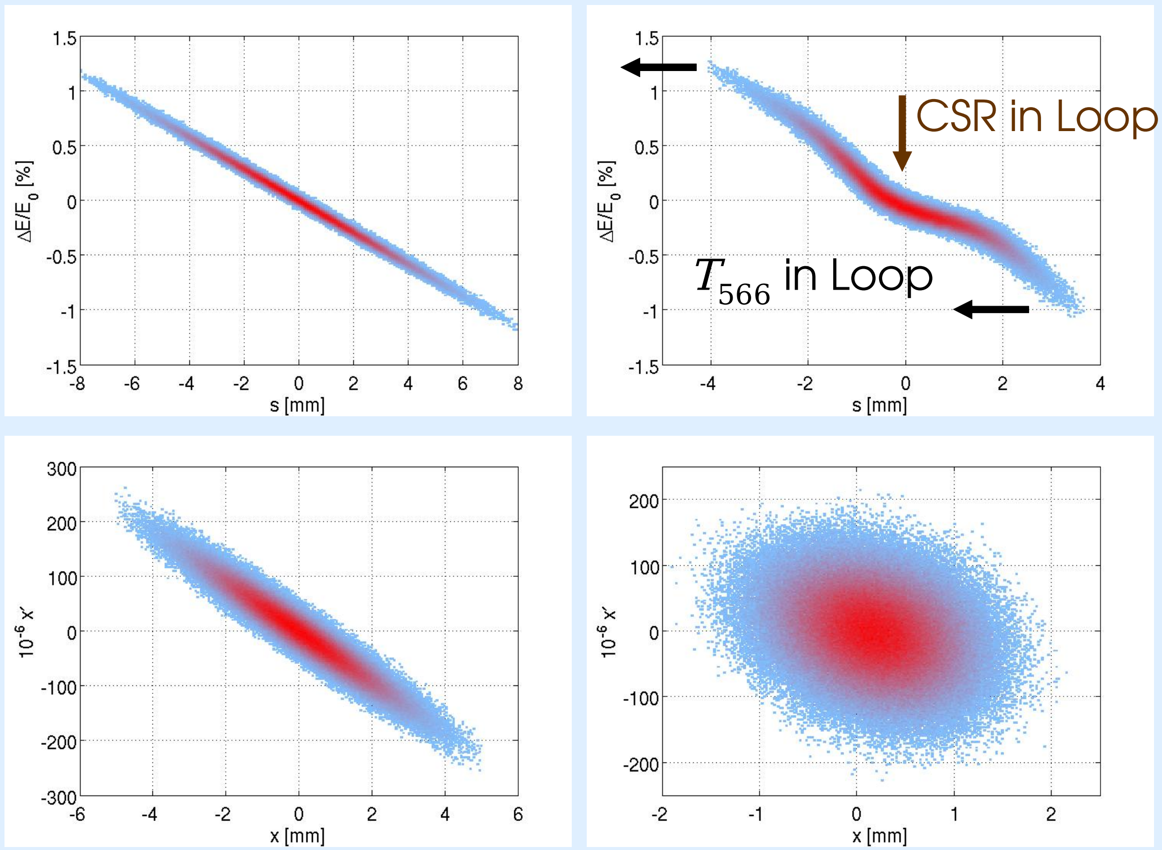
$$\frac{\sigma_{E,unc}}{E_0} = 2.5 \times 10^{-4}$$

$$\frac{1}{E_0}\frac{dE}{ds} = -1.47 \text{ m}^{-1}$$



longitudinal phase space

transverse phase space



initial

final

$\sigma_s = 1000$ µm

$I_{peak} = 940$ A

$\epsilon_{n,x} = 103$ µm rad

$\epsilon_{n,y} = 100$ µm rad

$$\frac{\sigma_{E,tot}}{E_0} = 0.27\ \%$$

Limitations

Utilizing BC1 for the conversion of energy errors to measurable phase errors and utilizing BC2 for the correction of phase errors has side-effects:

-> high demand on the accuracy of the phase measurement since the conversion factor is small (< 0.1 deg)

-> a small bunch length jitter will be induced in BC2 due to the phase correction, i.e. due to the $\Delta\alpha$ produced by the kickers, R_{56} will vary by two times the requested path length tuning.

Due to the compact layout of the Turn Around Loop and the small R_{56}(s) other parameters are not optimal:

-> distortions like chromaticity and T_{566} are large, e.g. $T_{566,\mathrm{Loop}} = 2.8\ \mathrm{m}$, energy acceptance limited $< 1\%\ \mathrm{RMS}$, it is hard to find good positions for sextupoles

Drive Beam Tasks Status / Summary

Drive Beam Chicanes and Turn Around Loop (based on Oct 2007 parameters):

-> design of loop and chicanes for bunch compression and phase feed-forward using a Gaussian charge distribution and linear energy chirp, optimize with respect to chromaticity, ISR and CSR using a 1D CSR model ✓

-> confirm results using 3D CSR models
...BCs and a single arc of the loop have been simulated ✓

-> investigate CSR micro-bunch instability in chicanes ✓

-> use a more realistic charge distribution including effects of wakefields, RF curvature,...
...phase space distribution including effects of RF and combiner rings not yet available, study postponed ✗

-> study influence of imperfections (energy jitter, alignment errors, ...)
...alignment and magnet strength errors studied
...more detailed study postponed ✓