Bunch Compressors and Turn Around Loop for the CLIC Drive Beam

-> Parameter Overview

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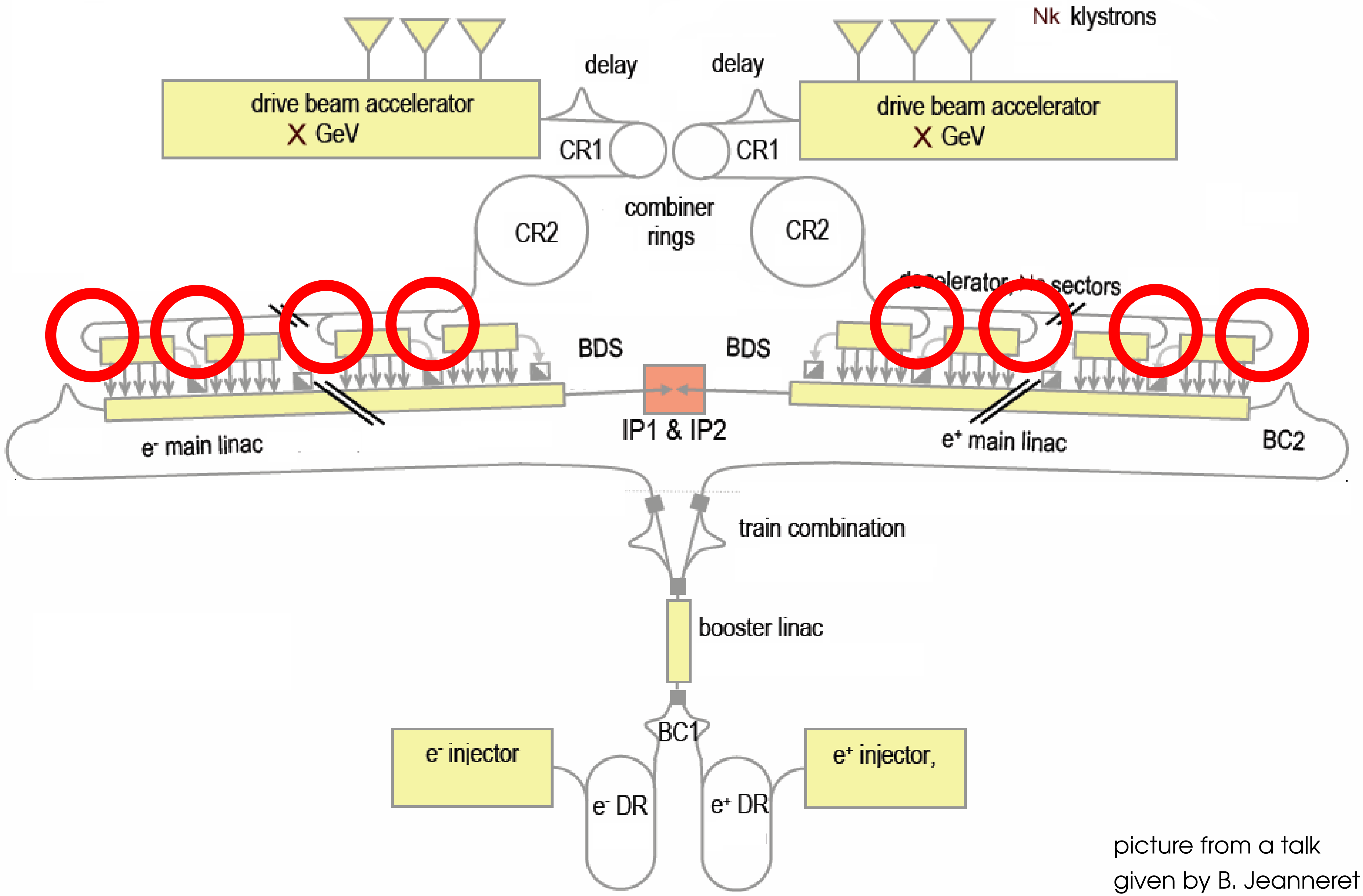
My Tasks for the CLIC Drive Beam

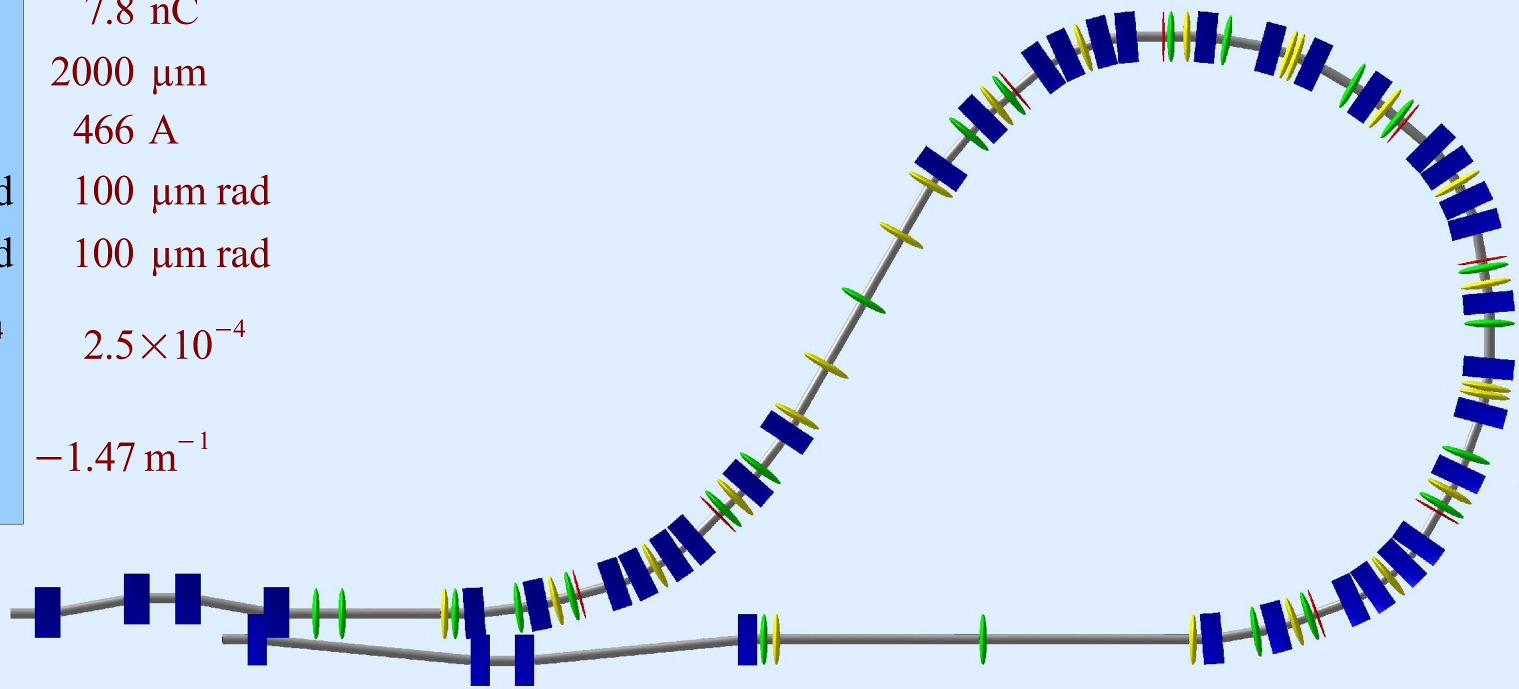


picture from a talk
given by B. Jeanneret

Old (30 GHz) vs. New (12 GHz) Drive Beam Parameters

Specification in front of BC1:

E_0	$= 2\ \text{GeV}$	$2.424\ \text{GeV}$
Q_0	$= 10\ \text{nC}$	$7.8\ \text{nC}$
σ_s	$= 4000\ \mu\text{m}$	$2000\ \mu\text{m}$
I_{peak}	$= 300\ \text{A}$	$466\ \text{A}$
$\epsilon_{n,x}$	$= 100\ \mu\text{m rad}$	$100\ \mu\text{m rad}$
$\epsilon_{n,y}$	$= 100\ \mu\text{m rad}$	$100\ \mu\text{m rad}$
$\frac{\sigma_{E,unc}}{E_0}$	$= 2.5 \times 10^{-4}$	2.5×10^{-4}
$\frac{1}{E_0}\frac{dE}{ds}$	$= -2.56\ \text{m}^{-1}$	$-1.47\ \text{m}^{-1}$



Specification behind BC2:

σ_s	$= 400\ \mu\text{m}$	$1000\ \mu\text{m}$
I_{peak}	$= 3000\ \text{A}$	$933\ \text{A}$
$\epsilon_{n,x}$	$< 110\ \mu\text{m rad}$	$110\ \mu\text{m rad}$
$\epsilon_{n,y}$	$< 110\ \mu\text{m rad}$	$110\ \mu\text{m rad}$
$\frac{\sigma_{E,tot}}{E_0}$	$< 1\ \%$	5×10^{-3}

Design Considerations / Constraints

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

-> its has to be compact and simple since about 2x 26 loops are required

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

-> its R_{56} should be large enough to allow the usage of weak correction kickers:

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

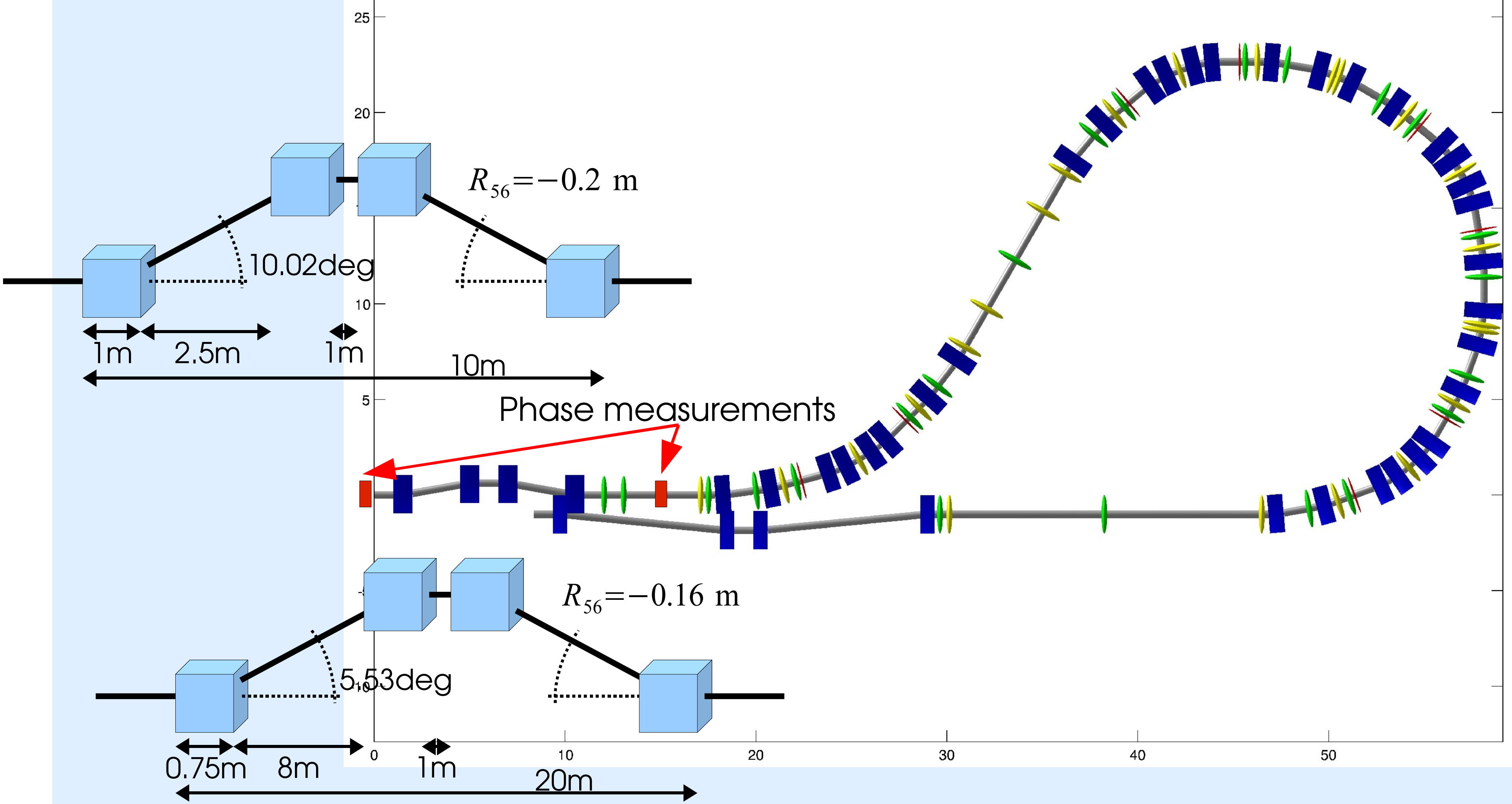
-> still ISR, CSR and chromaticity have to be small

Beam Line Overview

Bunch Compressor Chicane 10 m

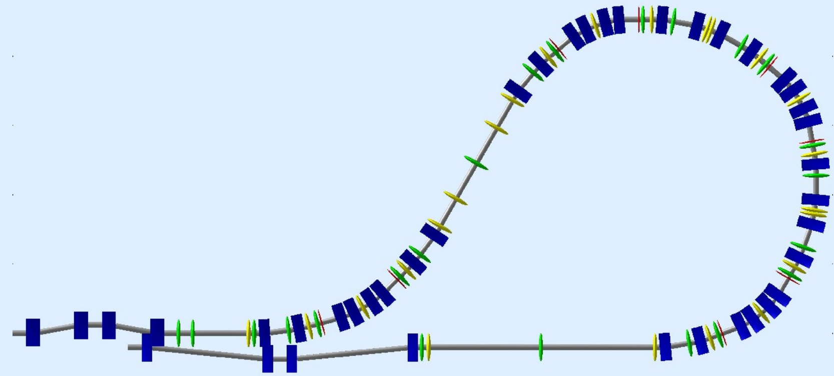
Turn Around Loop 77 m = 1x 60deg arc + matching + 3x 80deg arc

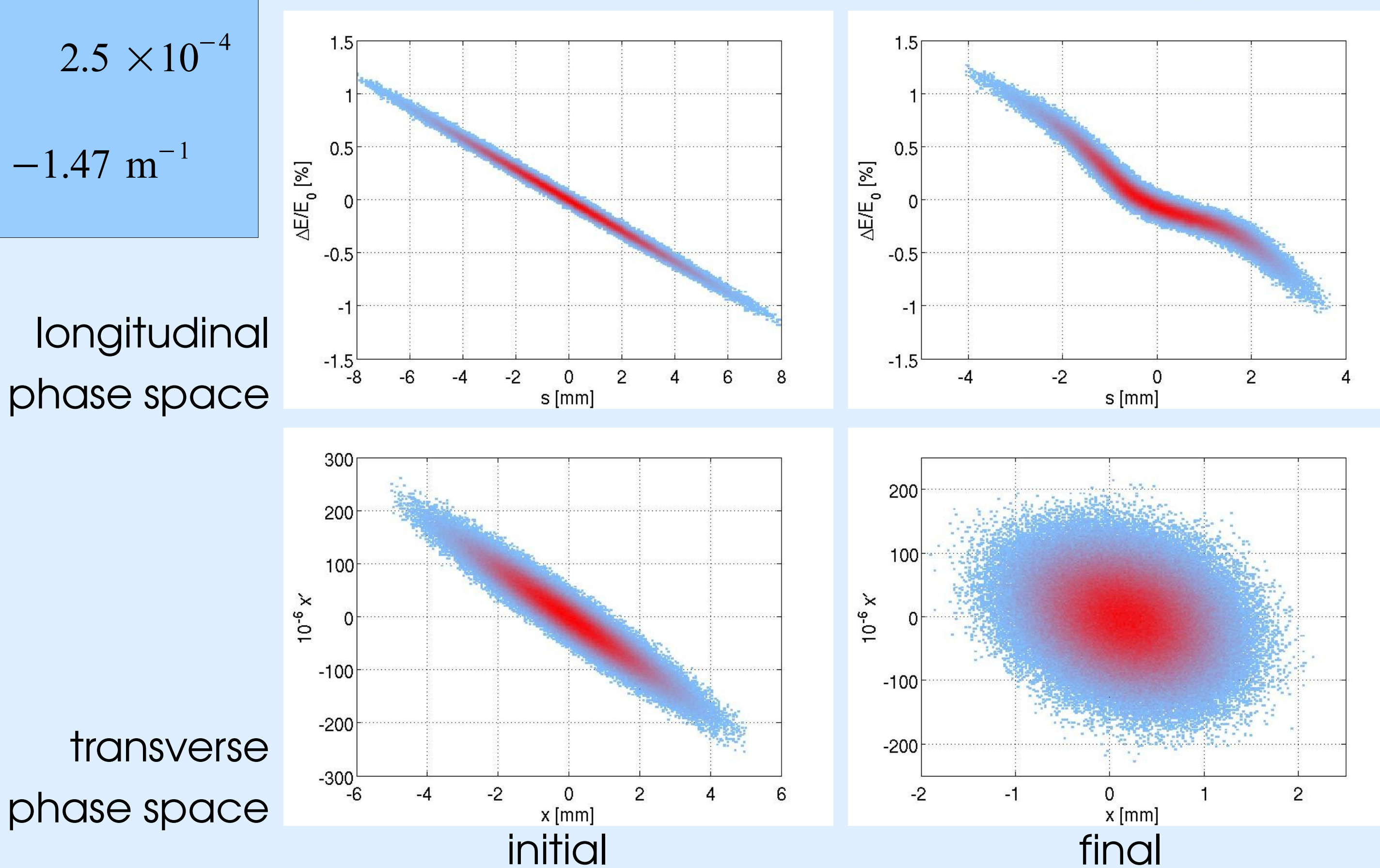
Bunch Compressor Chicane 20 m



Simulation Results, 1D CSR

$$E_0 = 2.424\ \text{GeV}$$
$$Q_0 = 7.8\ \text{nC}$$
$$\sigma_s = 2000\ \mu\text{m}$$
$$I_{peak} = 466\ \text{A}$$
$$\epsilon_{n,x} = 100\ \mu\text{m rad}$$
$$\epsilon_{n,y} = 100\ \mu\text{m rad}$$
$$\frac{\sigma_{E,unc}}{E_0} = 2.5 \times 10^{-4}$$
$$\frac{1}{E_0}\frac{dE}{ds} = -1.47\ \text{m}^{-1}$$





$$\sigma_s = 1000\ \mu\text{m}$$
$$I_{peak} = 940\ \text{A}$$
$$\epsilon_{n,x} = 104\ \mu\text{m rad}$$
$$\epsilon_{n,y} = 100\ \mu\text{m rad}$$
$$\frac{\sigma_{E,tot}}{E_0} = 0.27\ \%$$

Simulation Results, 1D CSR

Specification in front of BC1:

$E_0 = 2.424$ GeV

$Q_0 = 7.8$ nC

$\sigma_s = 2000$ µm

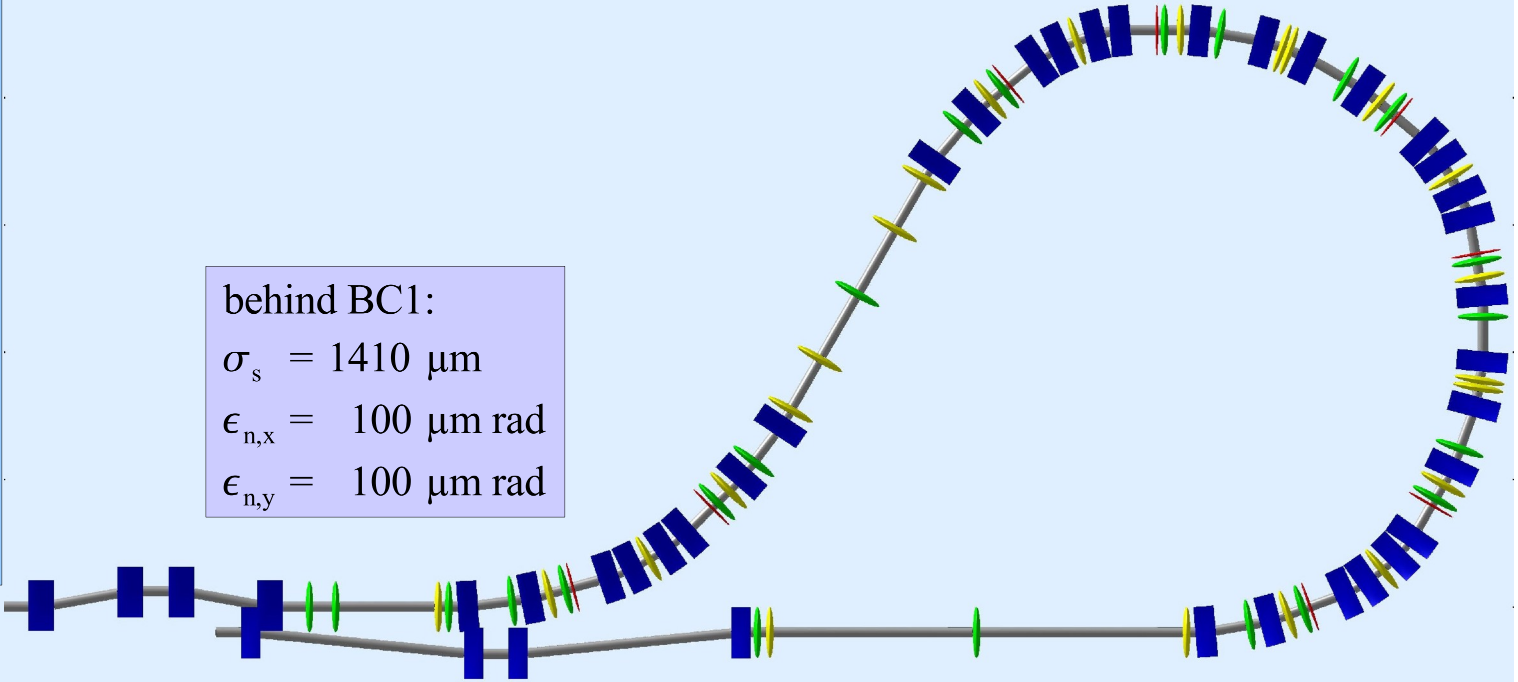
$I_{peak} = 466$ A

$\epsilon_{n,x} = 100$ 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:

$\sigma_s = 1410$ µm

$\epsilon_{n,x} = 100$ µm rad

$\epsilon_{n,y} = 100$ µm rad

Specification behind BC2:

$\sigma_s = 1000$ µm

$I_{peak} = 933$ A

$\epsilon_{n,x} < 110$ µm rad

$\epsilon_{n,y} < 110$ µm rad

$\frac{\sigma_{E,tot}}{E_0} < 5 \times 10^{-3}$

behind BC2:

$\sigma_s = 1000$ µm

$I_{peak} = 940$ A

$\epsilon_{n,x} = 104$ µm rad

$\epsilon_{n,y} = 100$ µm rad

$\frac{\sigma_{E,tot}}{E_0} = 2.7 \times 10^{-3}$

behind loop:

$\sigma_s = 1410$ µm

$\epsilon_{n,x} = 102$ µm rad

$\epsilon_{n,y} = 100$ µm rad

Limitations

-> using BC1 for the conversion of energy jitter to phase jitter puts a high demand on the accuracy of the phase measurement since the conversion factor is small, example:

$$R_{56}=0.2\ \text{m},\ f=12\,\text{GHz},\ \Delta E/E_0=10^{-5} \Rightarrow \Delta\phi\approx 0.03\ \text{deg}$$

-> due to the compact design of the loop higher order distortions like chromaticity and T_{566} are not optimal ($T_{566,\text{Loop}} = 2.8$ m), i.e. the energy acceptance is limited $< 1\%$

-> 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:

$$\Delta\sigma_s \approx \frac{4}{3}\frac{\sigma_E}{E_0}\left(3\,l_{12}+2\,l_B\right)\alpha_0\,\Delta\alpha$$

example:

$$l_{12}=8\ \text{m},\ l_B=0.75\,\text{m},\ \sigma_E/E_0=0.3\,\%,$$
$$\alpha_0=5.5\ \text{deg},\ \Delta\alpha=3.5\ \text{mdeg} \Rightarrow \Delta\sigma_s\approx 0.6\ \mu\text{m}$$

Summary / Outlook

-> Required parameter set for 12 GHz frequency complete

-> Electron beam parameters adjusted to match new specifications

-> Beam lines were not changed for new parameters

-> Performed simulations of chicanes and the loop including ISR and CSR

-> ISR in chicanes and loop has no major impact

-> Chromaticity of the loop is o.k., as long as energy spread is not too high, also high T_{566} is problematic, i.e. energy spread limited < 1%

-> Main source of emittance growth is CSR

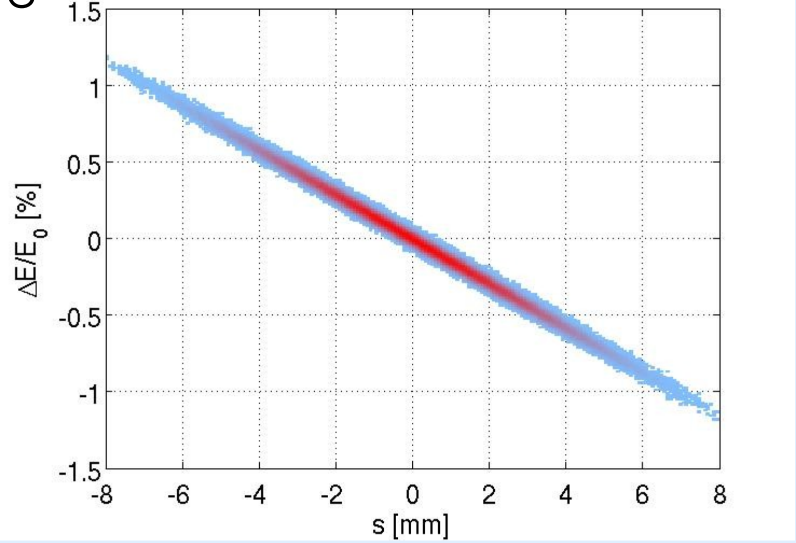
-> Start 3D CSR simulations for BC1 and BC2, 3D CSR (using CSRTrack or TraFiC4) in loop seems unrealistic for the moment, option could be CSR model developed by R. Talman

-> Try to get more realistic initial charge distributions

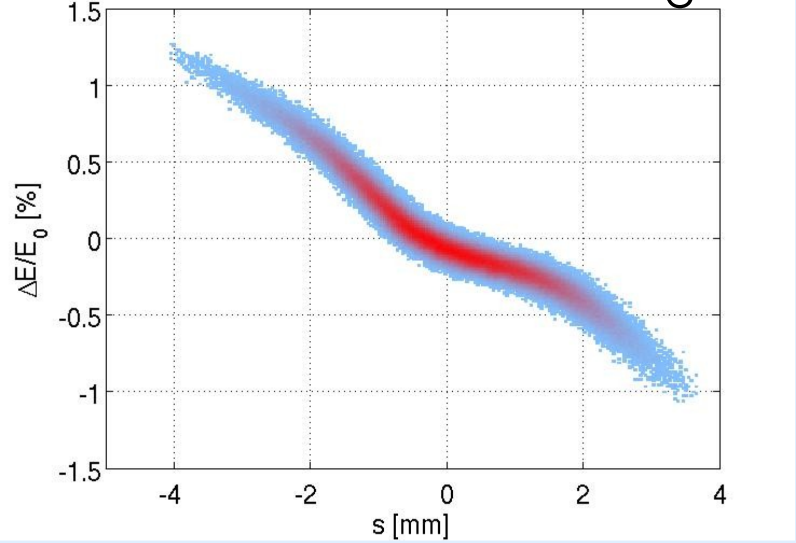
-> For the moment no layout changes are planned, unless someone requests changes or by chance I find some optimizations

1D CSR Simulation Results using new Parameters

longitudinal

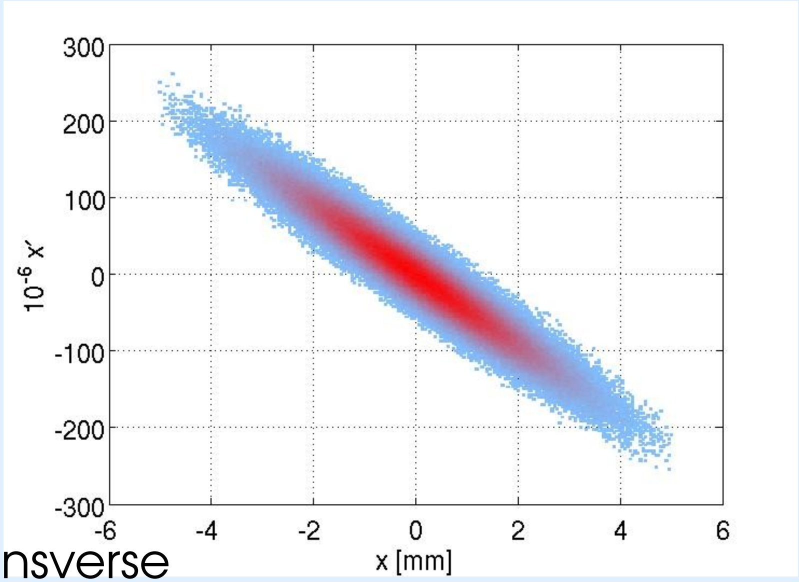


longitudinal

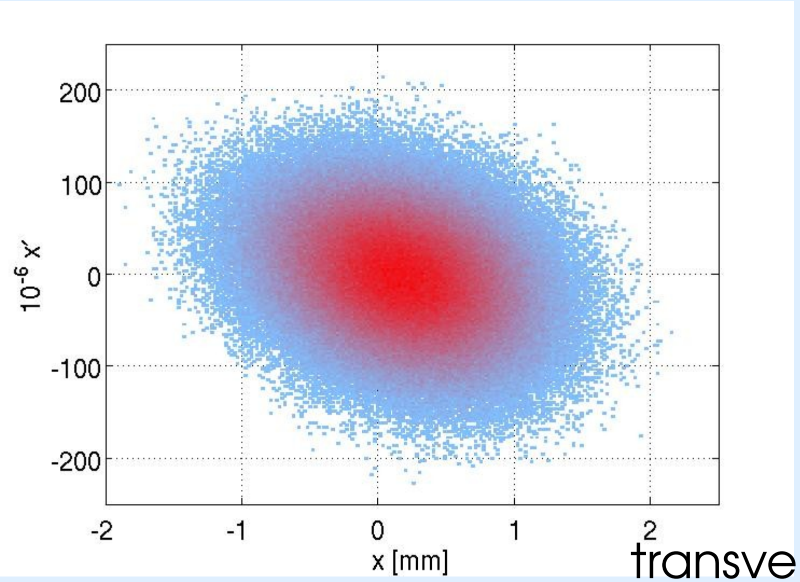


initial phase space distributions

final phase space distributions

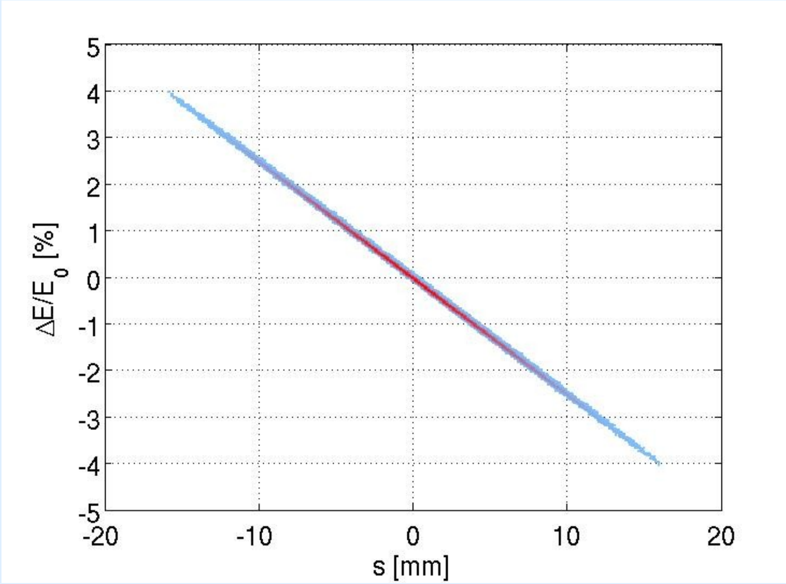


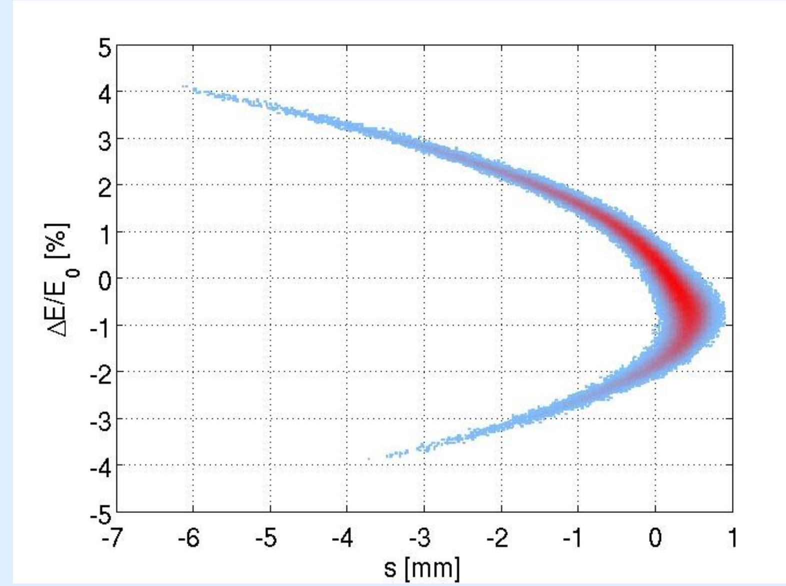
transverse



transverse

1D CSR Simulation Results using old Parameters





initial longitudinal phase space distribution

final longitudinal phase space distribution