PAUL SCHERRER INSTITUT

Bunch Compressors and Turn Around Loops for CLIC

PSI worked on Beam Lines for

Main Beam and Drive Beam:

-> Tasks and Parameters Overview

-> Design Considerations / Constraints

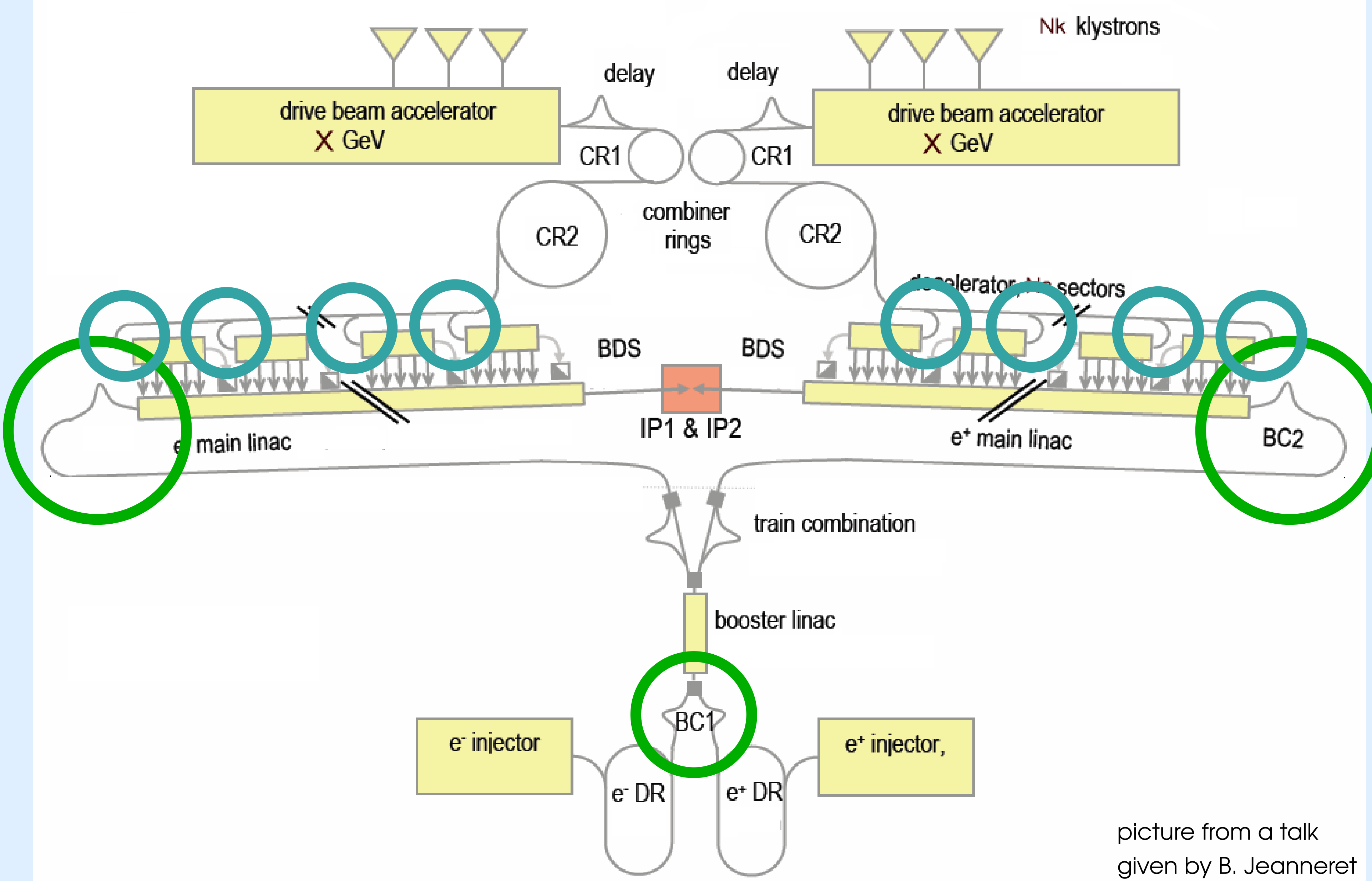
-> Beam Line Overview

-> Simulation Results

-> Status / Summary

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 Compressor at 2.424 GeV

-> Turn Around Loop at 9 GeV

-> Bunch Compressor at 9 GeV

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

Drive Beam:

-> Bunch Compressor

-> Phase / Energy Error Measurement

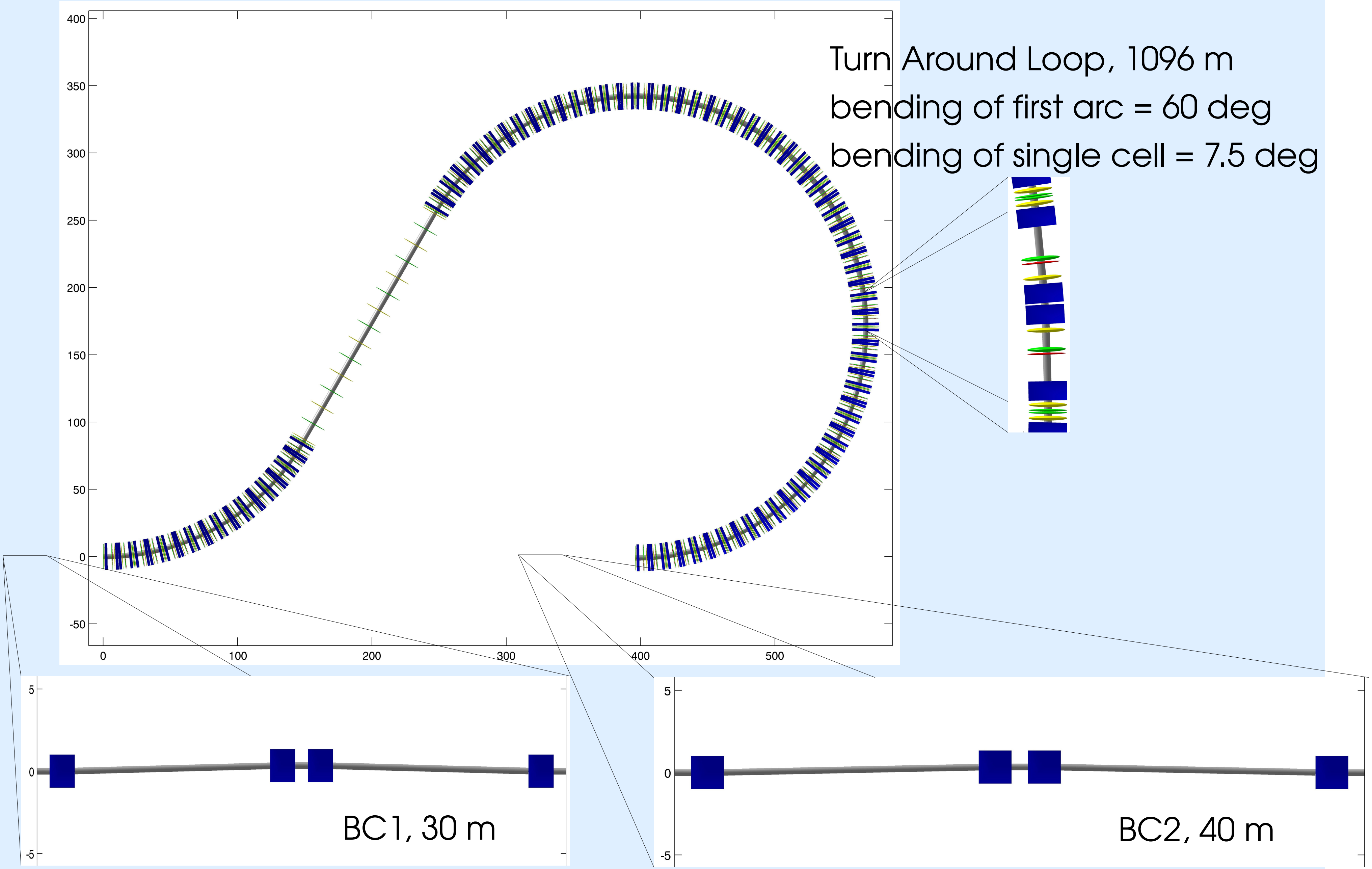
-> Turn Around Loop

-> Bunch Compressor

-> Phase Correction

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

Main Beam Tasks Overview



Design Considerations / Constraints

Bunch Compressors BC1 and BC2:

-> perform full compression in both chicanes (i.e. get upright phase space ellipses),
full compression in BC1 requested but not mandatory,
full compression definitely required in BC2

-> as long as full compression is achieved in both BCs, the bunch compression system can be fully characterized by the two R_{56} values and the energy chirps,
i.e. by a set of 4 independent parameters

-> initial bunch length, final bunch length and initial uncorrelated energy spread are fixed!
only one free parameter is left: e.g. intermediate bunch length between BC1 and BC2.

-> R_{56} of BC2 can only be reduced by compressing stronger in BC1
not by increasing energy chirp, stronger compression in BC1 only by using
higher energy chirp and lower R_{56}, i.e. intermediate bunch length gets smaller

-> several effects influence the choice of the intermediate bunch length:
- wake fields and RF curvature in the booster linac
- wake fields and space charge fields in the transport line
- chromaticity (due to changing energy chirp) and CSR in the turn around loop
- CSR in BC1 and BC2

Design Considerations / Constraints

Turn Around Loop:

-> based on CERN 2000-008, chapter 2.2.5 and CLIC Note 292

-> main complication: high beam energy and consequently strong ISR emittance growth

-> CSR and chromaticity can be controlled by good layout

-> minimize overall bending of the beam, a turn around loop just needs a 180 deg arc and a dog leg to correct transverse offset (i.e. first bending 90 deg in one direction and then 270 deg in the other is unnecessary)

-> loop should be as short as possible

-> since bunch energy spread in loop is solely uncorrelated we don't care about R_{56}(s) (compare drive beam)

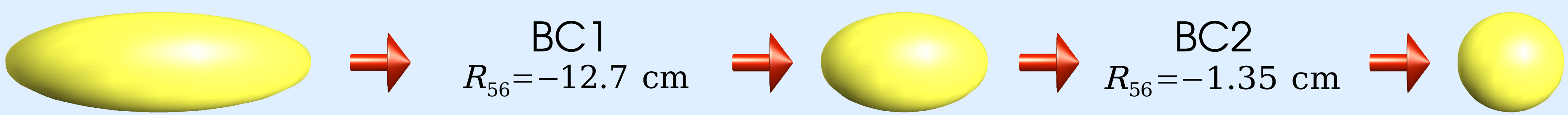
Parameters

Specification in front of BC1:

$E_0 = 2.424$ GeV
$Q_0 = 0.65$ nC
$\sigma_s = 1500$ µm
$I_{peak} = 52$ A
$\epsilon_{n,x} = 510$ nm rad
$\epsilon_{n,y} = 5$ nm rad
$\frac{\sigma_{E,unc}}{E_0} = 0.137$ %
$\frac{1}{E_0}\frac{dE}{ds} = -7.8\ \mathrm{m}^{-1}$

in front of BC2:

$E_0 = 9$ GeV
$Q_0 = 0.65$ nC
$\sigma_s = 175$ µm
$I_{peak} = 450$ A
$\epsilon_{n,x} < 580$ nm rad
$\epsilon_{n,y} < 6$ nm rad
$\frac{\sigma_{E,unc}}{E_0} = 0.32$ %
$\frac{1}{E_0}\frac{dE}{ds} = -69.6\ \mathrm{m}^{-1}$



behind BC1:

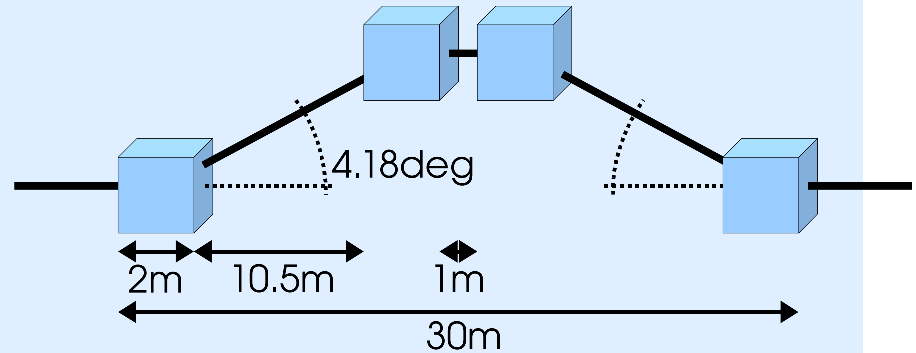
	Design	Result	
σ_s	$= 175$ µm	178 µm	
I_{peak}	$= 450$ A	450 A	
$\epsilon_{n,x}$	< 520 nm rad	538 nm rad	no shielding
		515 nm rad	with shielding
$\epsilon_{n,y}$	< 5 nm rad	5 nm rad	
$\frac{\sigma_{E,tot}}{E_0}$	$= 1.17$ %	1.2 %	

Specification behind BC2:

	Specification	Result
σ_s	$= 44$ µm	44 µm
I_{peak}	$= 1800$ A	1800 A
$\epsilon_{n,x}$	< 600 nm rad	600 nm rad
		587 nm rad
$\epsilon_{n,y}$	< 10 nm rad	6 nm rad
$\frac{\sigma_{E,tot}}{E_0}$	< 1.5 %	1.3 %

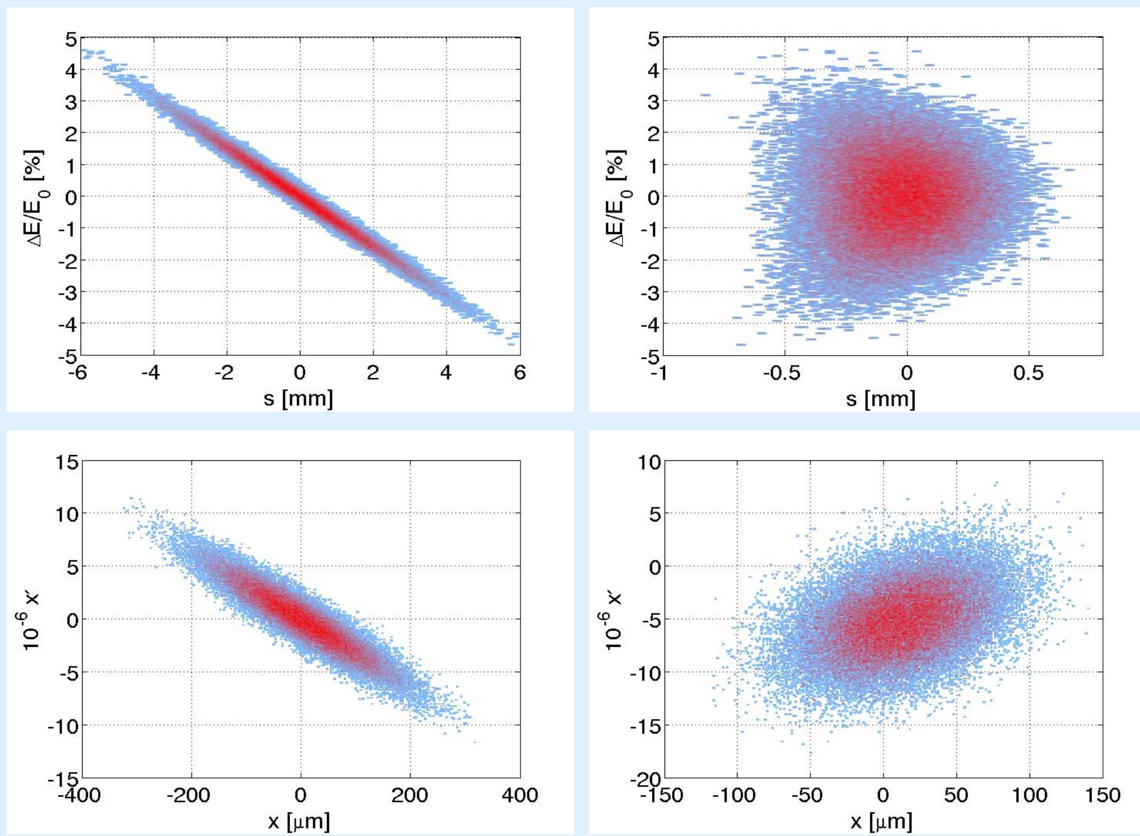
BC1 Simulation Results, 1D CSR

$E_0 = 2.424$ GeV
$Q_0 = 0.65$ nC
$\sigma_s = 1500$ µm
$I_{peak} = 52$ A
$\epsilon_{n,x} = 510$ nm rad
$\epsilon_{n,y} = 5$ nm rad
$\frac{\sigma_{E,unc}}{E_0} = 0.137$ %
$\frac{1}{E_0}\frac{dE}{ds} = -7.8\ \mathrm{m}^{-1}$



longitudinal phase space

transverse phase space



initial

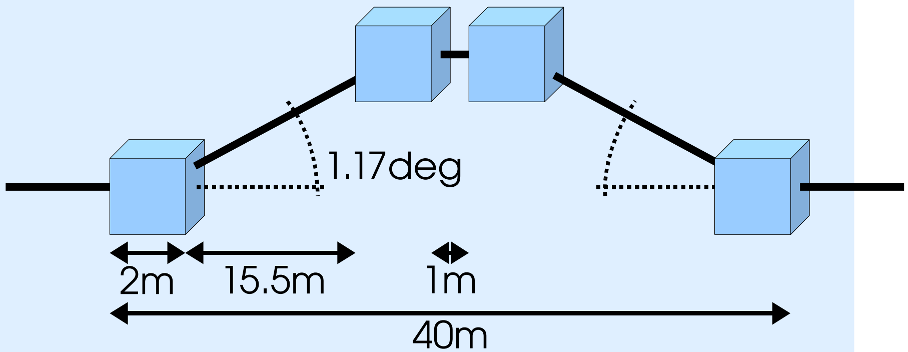
final

$\sigma_s = 175$ µm
$I_{peak} = 450$ A
$\epsilon_{n,x} = 538$ nm rad
$\epsilon_{n,y} = 5$ nm rad
$\frac{\sigma_{E,tot}}{E_0} = 1.2$ %

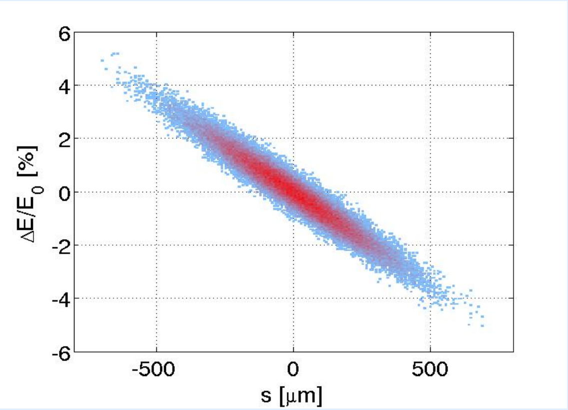
515 nm rad
with shielding

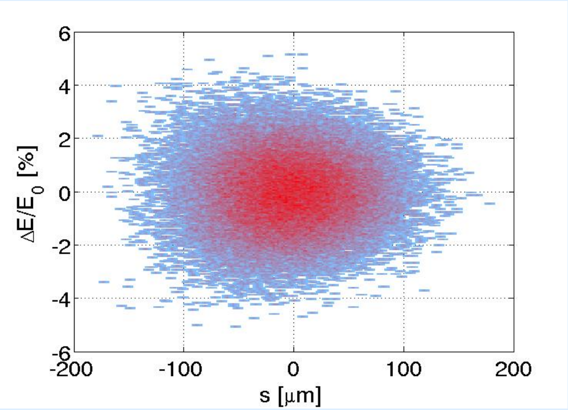
BC2 Simulation Results, 1D CSR

$$E_0 = 9\ \text{GeV}$$
$$Q_0 = 0.65\ \text{nC}$$
$$\sigma_s = 175\ \mu\text{m}$$
$$I_{peak} = 450\ \text{A}$$
$$\epsilon_{n,x} = 580\ \text{nm rad}$$
$$\epsilon_{n,y} = 6\ \text{nm rad}$$
$$\frac{\sigma_{E,unc}}{E_0} = 0.3\ \%$$
$$\frac{1}{E_0}\frac{dE}{ds} = -69.6\ \text{m}^{-1}$$

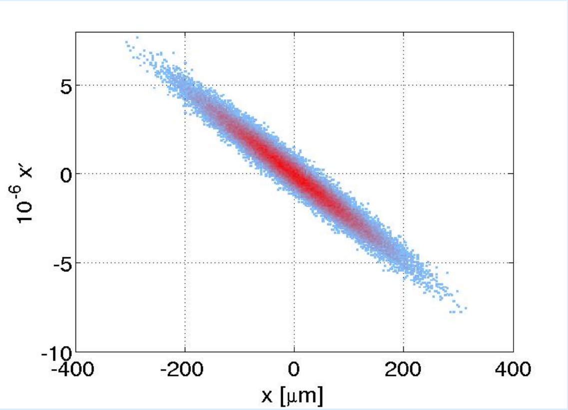


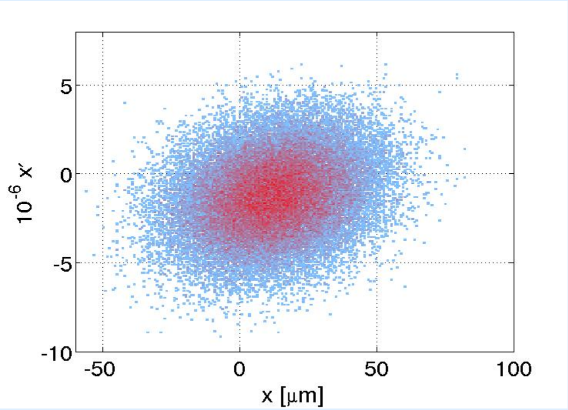
longitudinal phase space





transverse phase space





initial

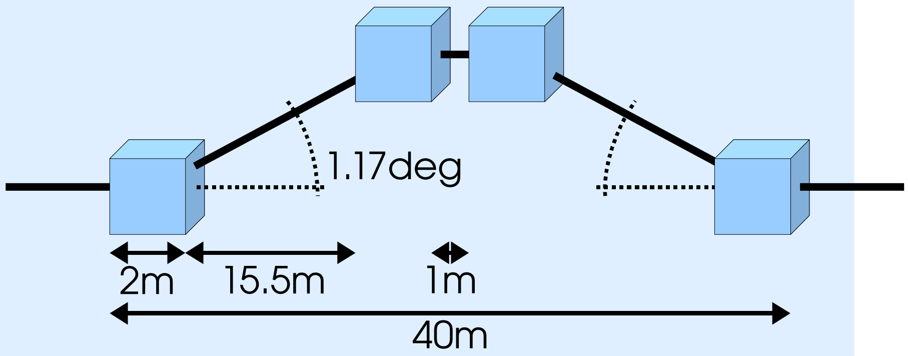
final

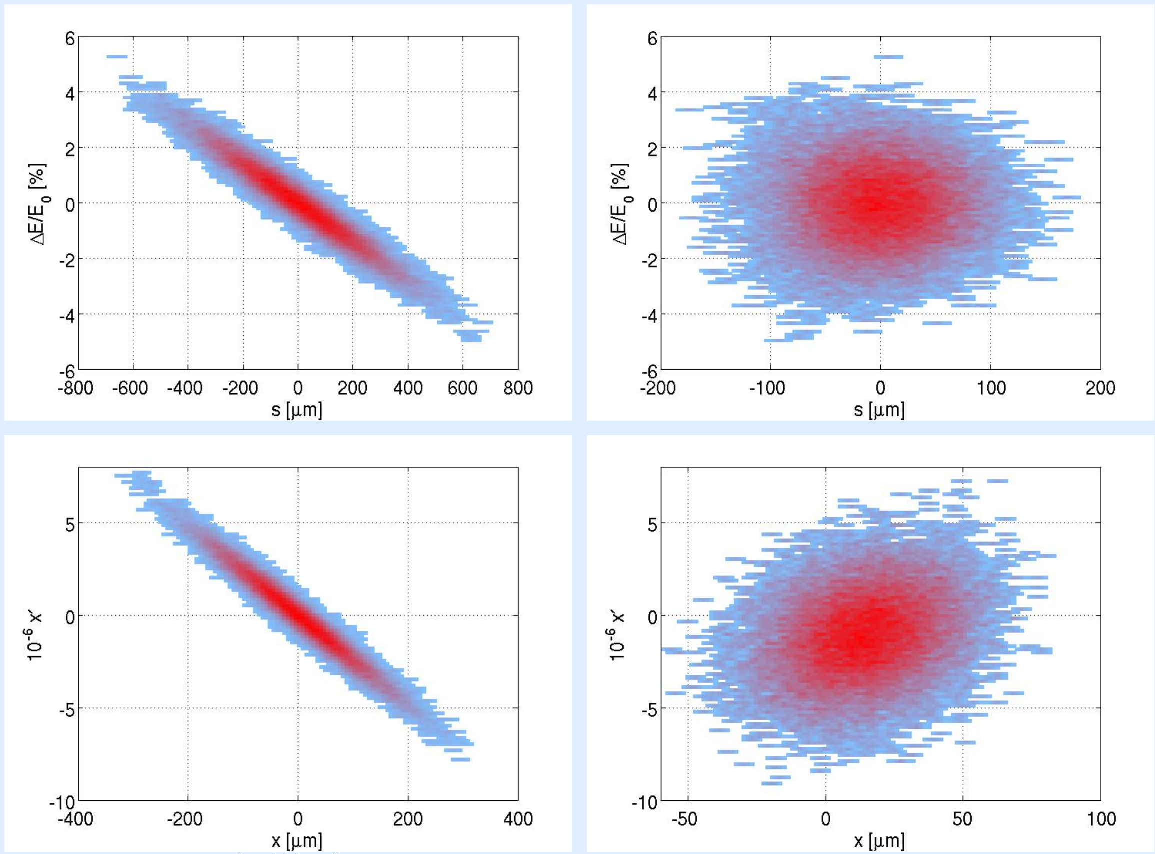
$$\sigma_s = 44\ \mu\text{m}$$
$$I_{peak} = 1800\ \text{A}$$
$$\epsilon_{n,x} = 600\ \text{nm rad}$$
$$\epsilon_{n,y} = 6\ \text{nm rad}$$
$$\frac{\sigma_{E,tot}}{E_0} = 1.3\ \%$$

587 nm rad with shielding

BC2 Simulation Result, 3D CSR

$$E_0 = 9\ \mathrm{GeV}$$
$$Q_0 = 0.65\ \mathrm{nC}$$
$$\sigma_s = 175\ \mu\mathrm{m}$$
$$I_{\mathrm{peak}} = 450\ \mathrm{A}$$
$$\epsilon_{n,x} = 580\ \mathrm{nm\ rad}$$
$$\epsilon_{n,y} = 6\ \mathrm{nm\ rad}$$
$$\frac{\sigma_{E,\mathrm{unc}}}{E_0} = 0.3\ \%$$
$$\frac{1}{E_0}\frac{dE}{ds} = -69.6\ \mathrm{m}^{-1}$$





longitudinal phase space

transverse phase space

initial

final

$$\sigma_s = 44\ \mu\mathrm{m}$$
$$I_{\mathrm{peak}} = 1800\ \mathrm{A}$$
$$\epsilon_{n,x} = 600\ \mathrm{nm\ rad}$$
$$\epsilon_{n,y} = 6\ \mathrm{nm\ rad}$$
$$\frac{\sigma_{E,\mathrm{tot}}}{E_0} = 1.3\ \%$$

Turn Around Loop Simulation Results, 1D CSR

$E_0 = 9$ GeV

$Q_0 = 0.65$ nC

$\sigma_s = 175$ µm

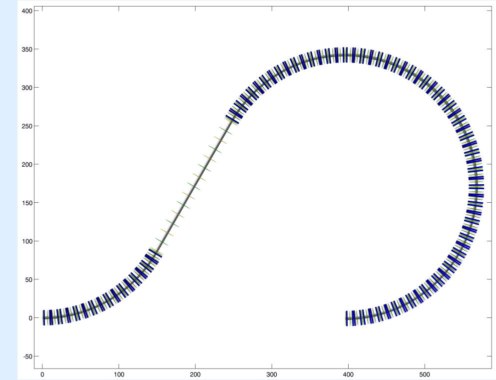
$I_{peak} = 450$ A

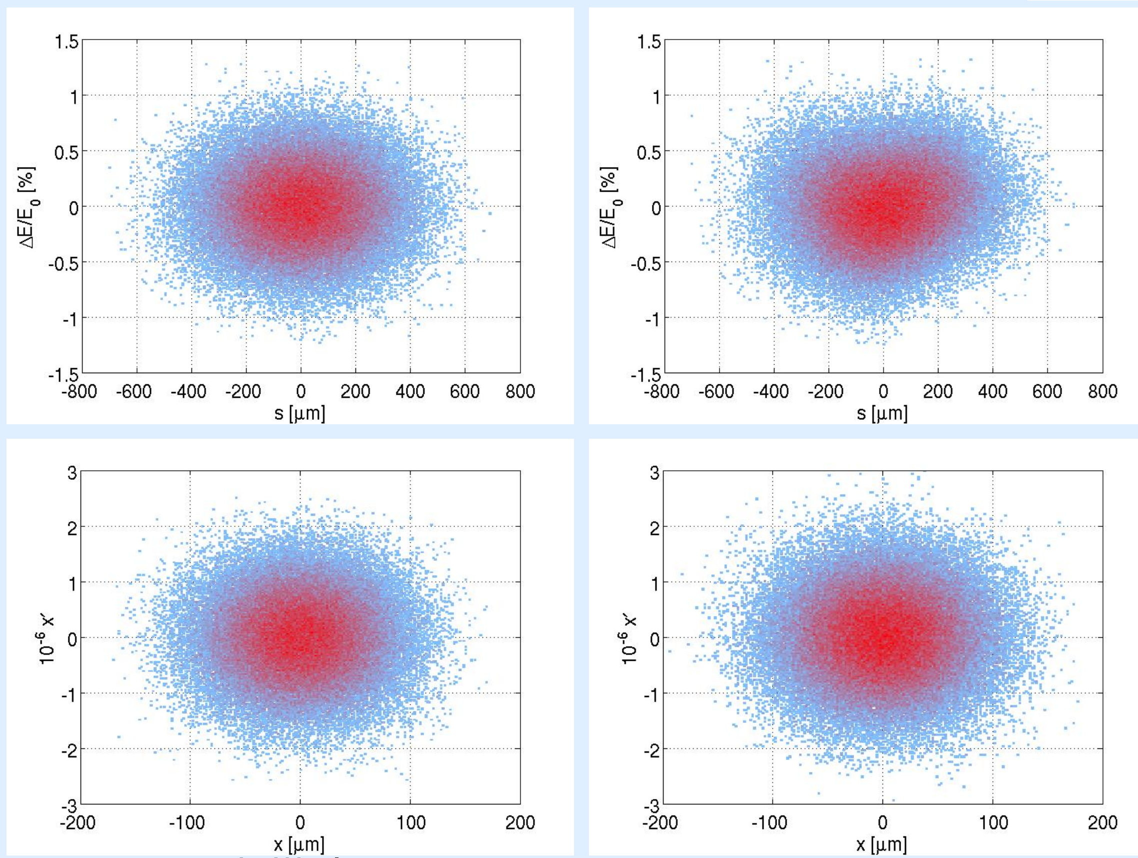
$\epsilon_{n,x} = 520$ nm rad

$\epsilon_{n,y} = 5$ nm rad

$\frac{\sigma_{E,unc}}{E_0} = 0.3$ %

$\frac{1}{E_0}\frac{dE}{ds} = 0.0\ m^{-1}$





longitudinal phase space

transverse phase space

initial

final

$\sigma_s = 175$ µm

$I_{peak} = 450$ A

$\epsilon_{n,x} = 580$ nm rad

$\epsilon_{n,y} = 5$ nm rad

$\frac{\sigma_{E,tot}}{E_0} = 0.3$ %

Main Beam Tasks Status / Summary

Main Beam BC1 and BC2 (based on Oct 2007 parameters):

-> design BC1 and BC2 using a Gaussian charge distribution and linear energy chirp, optimize with respect to ISR and CSR using a 1D CSR model ✓

-> confirm results using 3D CSR model ✓

-> investigate CSR micro-bunch instability ✓

-> use a more realistic charge distribution including effects of wakefields, RF curvature, etc.
...RF curvature included, wakefields missing
...details have to be studied within start-to-end simulations ✓ (dotted)

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

Main Beam Tasks Status / Summary

Main Beam 9GeV Turn Around Loop (based on Oct 2007 parameters):

-> design a loop 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 model
...3D simulations performed for single arc cell ✓

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