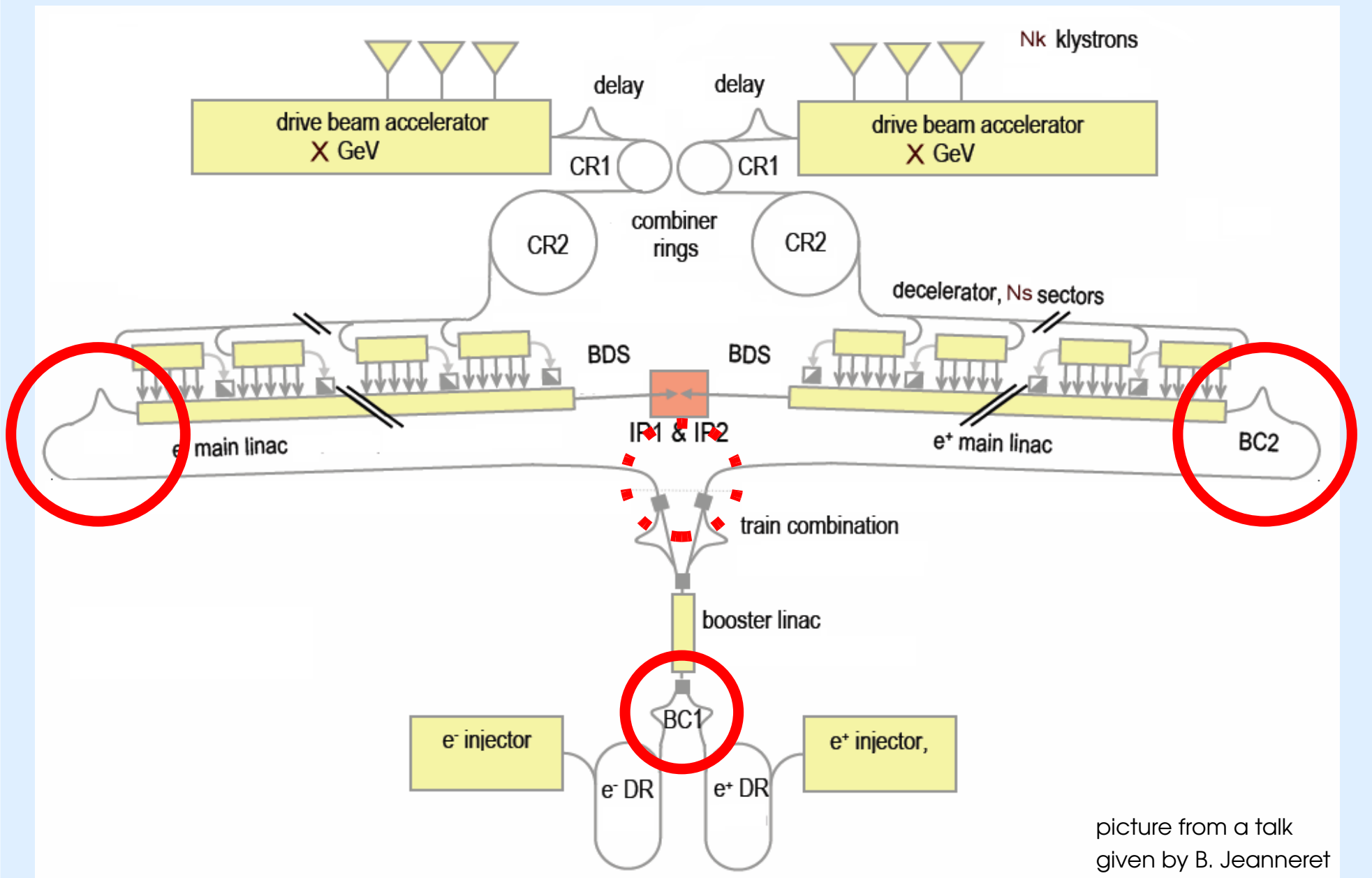# Bunch Compressors and Turn Around Loop
for the CLIC Main Beam

-> Parameter Overview

-> Design Considerations / Constraints

-> Beam Line Overview

-> Simulation Results

-> Summary / Outlook

picture from a talk
given by B. Jeanneret

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

Specification
in front of BC1:

E_0	=	2.424 GeV	
Q_0	=	0.41 nC	0.67 nC
σ_s	=	1500 μm	
I_{peak}	=	33 A	53 A
$\epsilon_{n,x}$	=	550 nm rad	430 nm rad
$\epsilon_{n,y}$	=	3 nm rad	4 nm rad
$\dfrac{\sigma_{E,unc}}{E_0}$	=	0.13 %	0.137 %
$\dfrac{1}{E_0}\dfrac{dE}{ds}$	=	-5.2 m^{-1}	-7.8 m^{-1}

in front of BC2:

E_0	=	9 GeV	
Q_0	=	0.41 nC	0.67 nC
σ_s	=	250 μm	175 μm
I_{peak}	=	200 A	460 A
$\epsilon_{n,x}$	<	570 nm rad	
$\epsilon_{n,y}$	<	4 nm rad	
$\dfrac{\sigma_{E,unc}}{E_0}$	=	0.2 %	0.32 %
$\dfrac{1}{E_0}\dfrac{dE}{ds}$	=	-70.5 m^{-1}	-69.6 m^{-1}
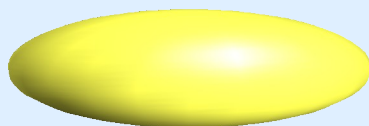
BC1
$R_{56} = -19.2$ cm
$R_{56} = -12.7$ cm

BC2
$R_{56} = -1.4$ cm
$R_{56} = -1.35$ cm
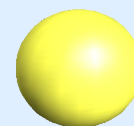
behind BC1:

σ_s	=	250 μm	175 μm
I_{peak}	=	200 A	460 A
$\epsilon_{n,x}$	<	570 nm rad	450 nm rad
$\epsilon_{n,y}$	<	4 nm rad	4 nm rad
$\dfrac{\sigma_{E,tot}}{E_0}$	=	0.8 %	1.17 %

Specification
behind BC2:

|			
σ_s	=	30 μm	44 μm
I_{peak}	=	1670 A	1820 A
$\epsilon_{n,x}$	<	600 nm rad	
$\epsilon_{n,y}$	<	5 nm rad	10 nm rad
$\dfrac{\sigma_{E,tot}}{E_0}$	=	1.8 %	1.26 %

Bunch Compressors BC1 and BC2:

-> perform full compression in both chicanes (i.e. get upright ellipses), then in both chicanes the required R_{56} and the energy chirp depend only on the bunch length behind BC1

-> several effects influence the choice of this bunch length:
- wake fields in the booster linac and the transport line
- chromaticity and CSR in the turn around loop
- CSR in BC1 and BC2

-> full optimization of BC2 was performed for old CLIC parameters, BC1 was partially optimized

-> decided not to change the chicane layouts too much for the new parameters

Important boundary condition:

- -> full compression in BC1 requested, but not mandatory
- -> definitely full compression in BC2 needed

As long as full compression is requested in both BCs:

- -> the R_{56} values and the energy chirps are coupled between both chicanes
- -> 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}
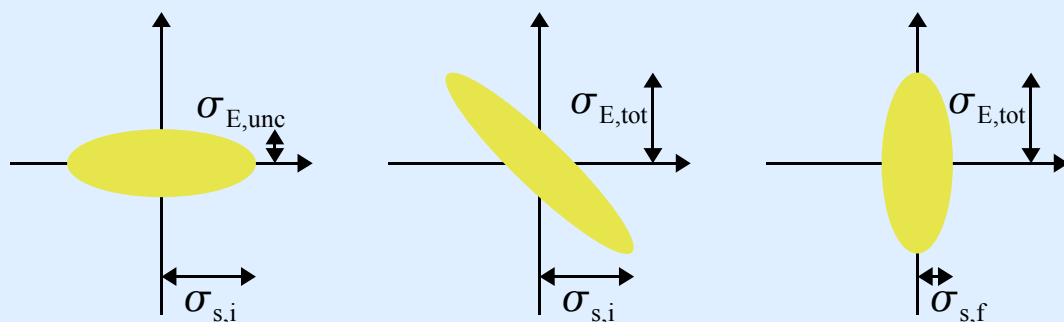
$$\sigma_{s,f} = \sqrt{\left(1 - \frac{1}{E_0}\frac{dE}{ds}R_{56}\right)\sigma_{s,i}^2 + R_{56}^2\left(\frac{\sigma_{E,unc}}{E_0}\right)^2}$$

$$\sigma_{E,tot} = \sqrt{\sigma_{E,unc}^2 + \sigma_{s,i}^2\left(\frac{1}{E_0}\frac{dE}{ds}\right)^2}$$

$\epsilon_{long} = \sigma_{s,f}\,\sigma_{E,tot}$ only for full compression !!!

Turn Around Loop:

-> based on CLIC CDR (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 bending of the beam,
a turn around loop loop just needs a 180 deg arc and a dog leg to
correct transverse offset (i.e. first bending 90 deg in one direction
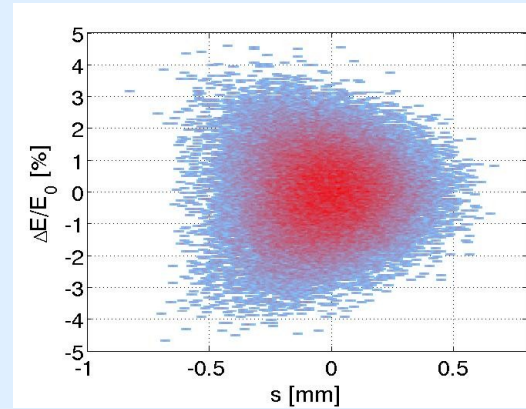and then 270 deg in the other is unnecessary)
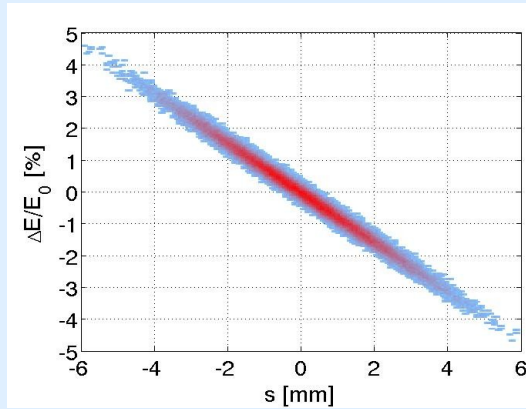
-> loop should be as short as possible

Turn Around Loop, 1096 m
bending of first arc = 60 deg

BC1, 30 m

BC2, 40 m
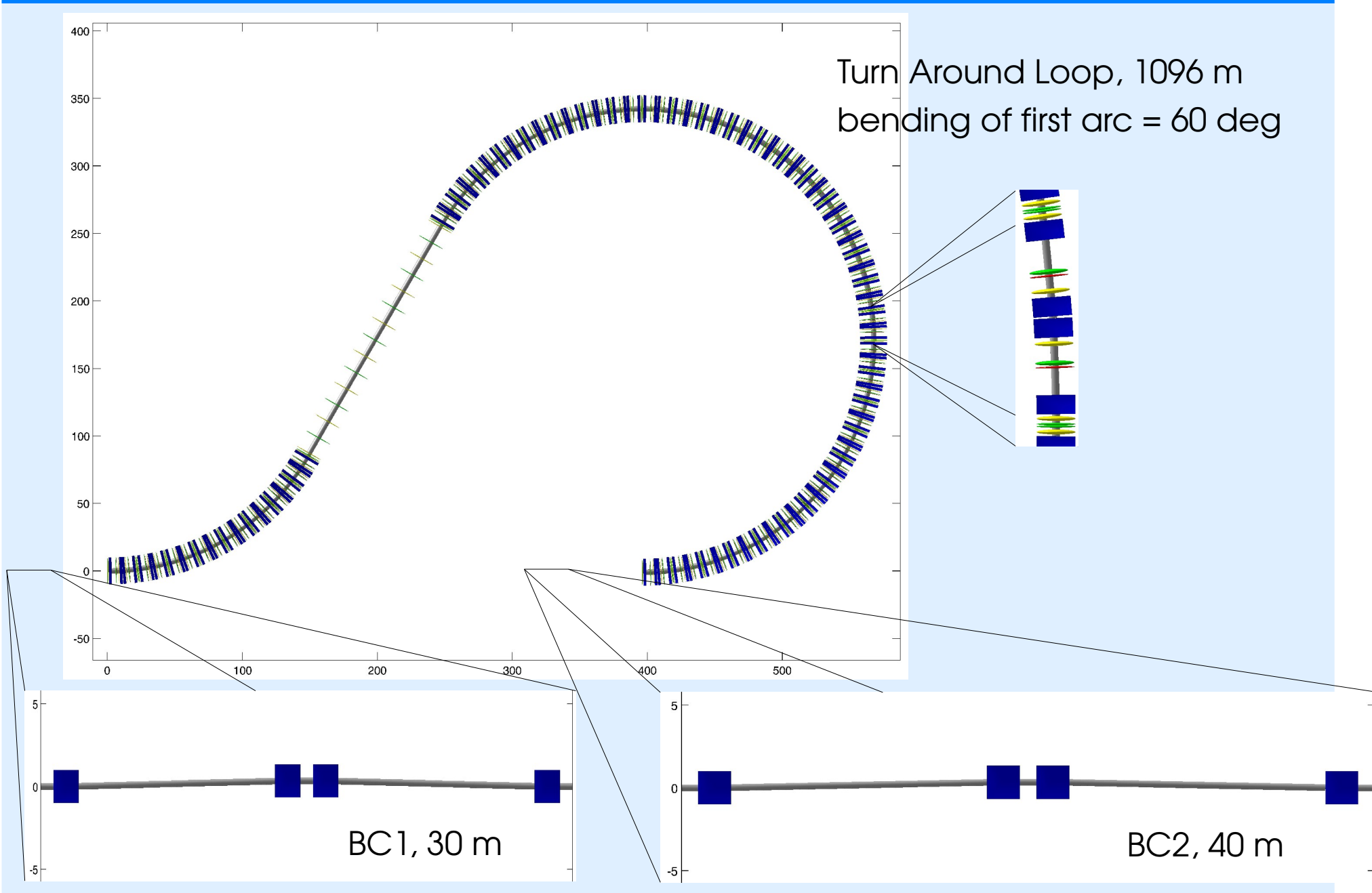
BC1 Simulation Results, 1D CSR

E_0 = 2.4 GeV

Q_0 = 0.67 nC

σ_s = 1500 µm

I_{peak} = 53 A

$\epsilon_{n,x}$ = 400 nm rad

$\epsilon_{n,y}$ = 4 nm rad

$\dfrac{\sigma_{E,unc}}{E_0}$ = 0.14 %

$\dfrac{1}{E_0}\dfrac{dE}{ds}$ = −7.8 m^{-1}
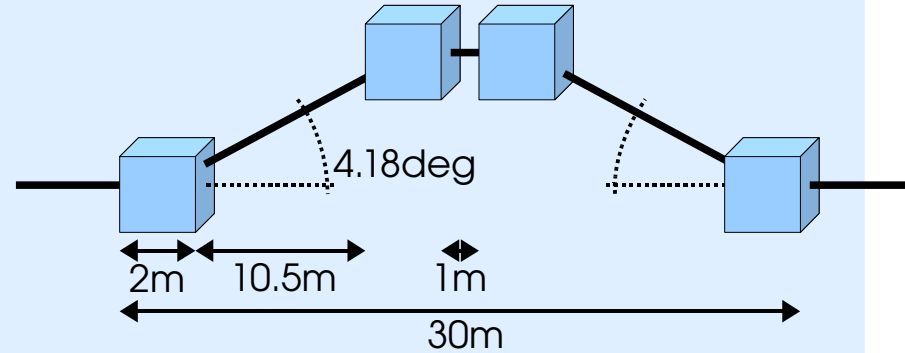
4.18deg

2m 10.5m 1m

30m

longitudinal phase space

transverse phase space
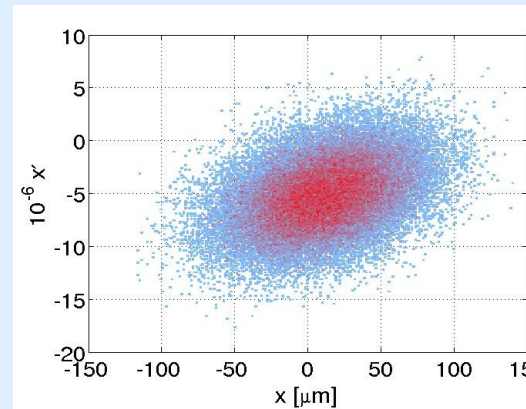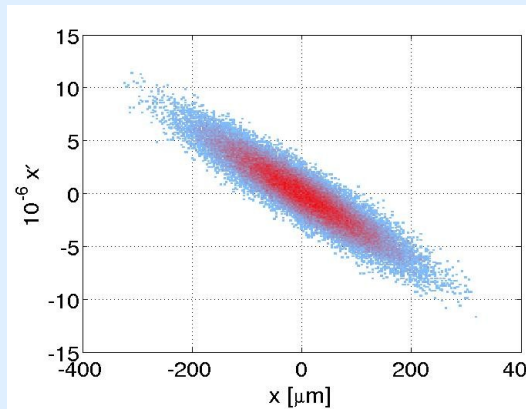
initial

final

σ_s = 178 µm

I_{peak} = 450 A

$\epsilon_{n,x}$ = 440 nm rad

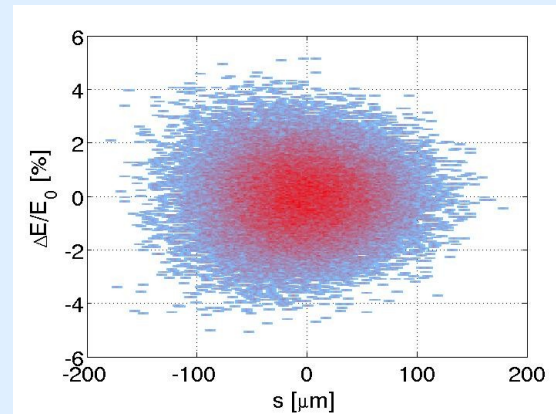$\epsilon_{n,y}$ = 4 nm rad

$\dfrac{\sigma_{E,tot}}{E_0}$ = 1.2 %

405 nm rad with shielding

BC2 Simulation Results, 1D CSR

$$E_0 = 9 \text{ GeV}$$
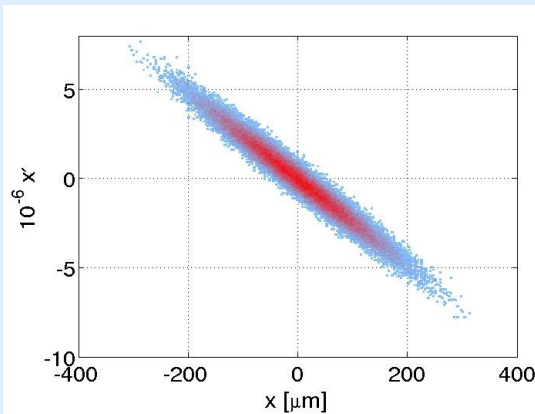$$Q_0 = 0.67 \text{ nC}$$
$$\sigma_s = 175 \text{ μm}$$
$$I_{peak} = 460 \text{ A}$$
$$\epsilon_{n,x} = 570 \text{ nm rad}$$
$$\epsilon_{n,y} = 4 \text{ nm rad}$$
$$\frac{\sigma_{E,unc}}{E_0} = 0.3 \text{ \%}$$
$$\frac{1}{E_0}\frac{dE}{ds} = -69.6 \text{ m}^{-1}$$

1.17deg

2m 15.5m 1m

40m

longitudinal phase space

transverse phase space

initial

final

$$\sigma_s = 44 \text{ μm}$$
$$I_{peak} = 1820 \text{ A}$$
$$\epsilon_{n,x} = 595 \text{ nm rad}$$
$$\epsilon_{n,y} = 4 \text{ nm rad}$$
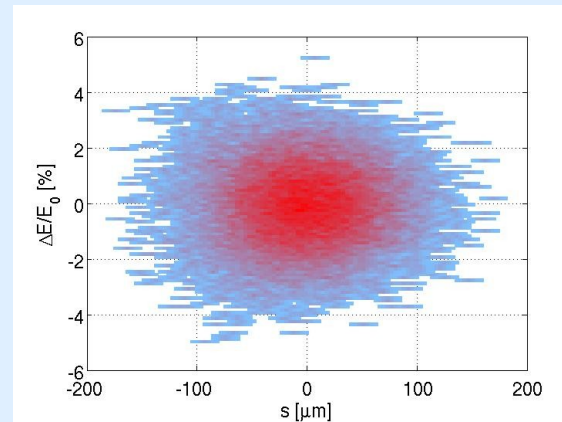$$\frac{\sigma_{E,tot}}{E_0} = 1.3 \text{ \%}$$
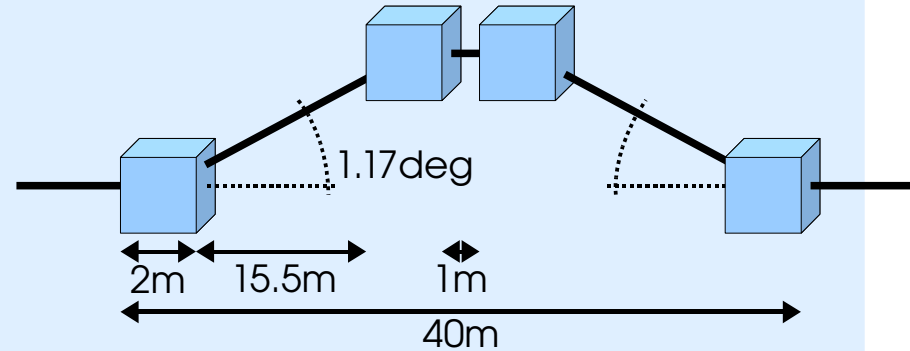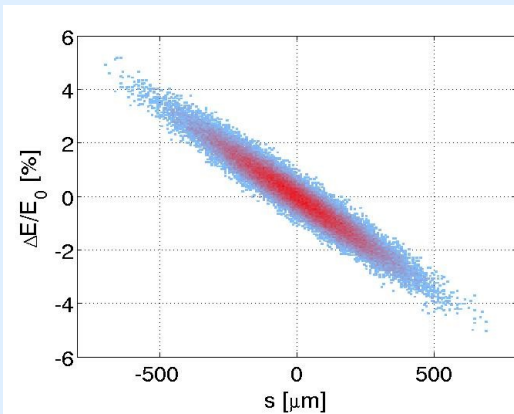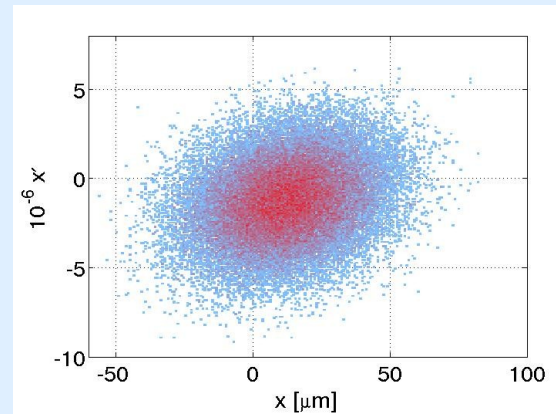
577 nm rad with shielding

First BC2 Simulation Results using 3D CSR

E_0 = 9 GeV
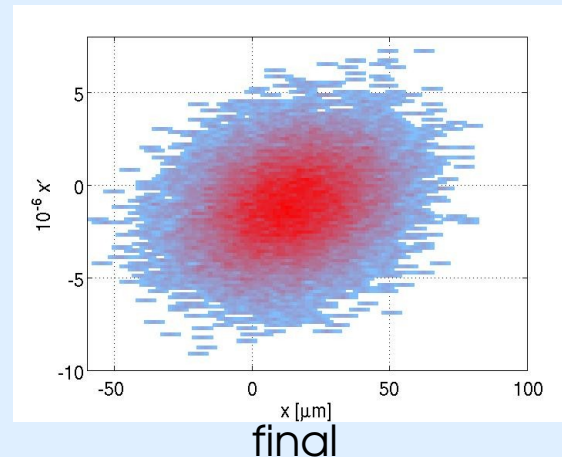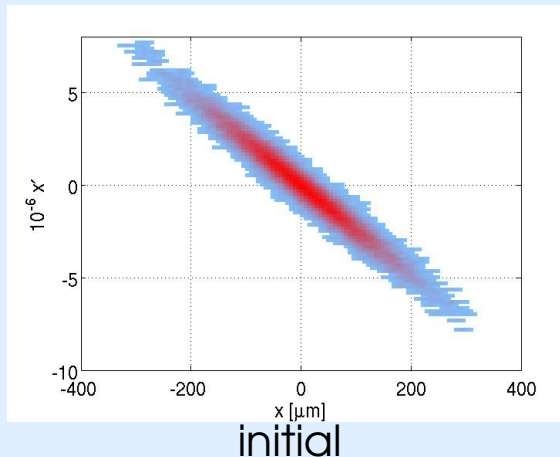
Q_0 = 0.67 nC

σ_s = 175 μm

I_{peak} = 460 A

$\epsilon_{n,x}$ = 570 nm rad

$\epsilon_{n,y}$ = 4 nm rad

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

$\dfrac{1}{E_0}\dfrac{dE}{ds}$ = −69.6 m^{-1}

1.17deg

2m 15.5m 1m

40m

σ_s = 44 μm

I_{peak} = 1820 A

$\epsilon_{n,x}$ = 595 nm rad

$\epsilon_{n,y}$ = 4 nm rad

$\dfrac{\sigma_{E,tot}}{E_0}$ = 1.3 %

longitudinal phase space

transverse phase space

initial

final

Frank Stulle, CLIC Workshop, October 2007
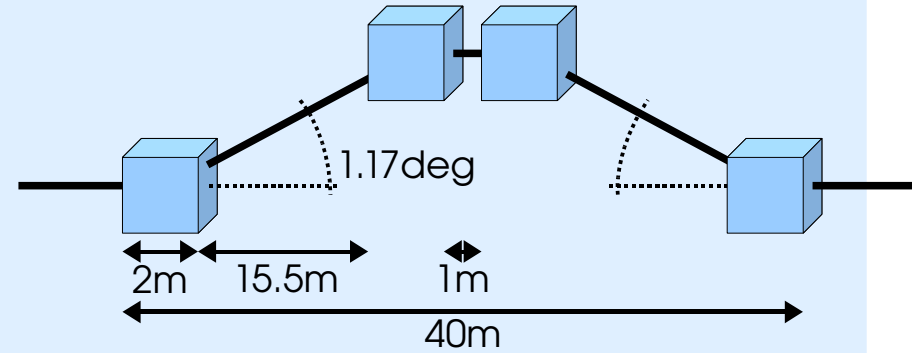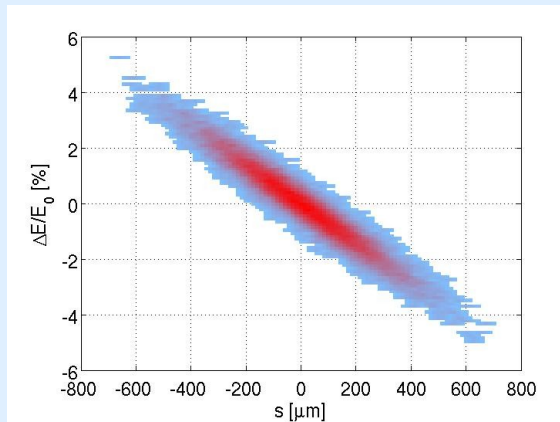
Turn Around Loop Simulation Results, 1D CSR

$E_0 \quad = \quad 9 \text{ GeV}$

$Q_0 \quad = 0.67 \text{ nC}$

$\sigma_s \quad = \quad 175 \text{ μm}$

$I_{peak} \quad = \quad 460 \text{ A}$

$\epsilon_{n,x} \quad = \quad 500 \text{ nm rad}$

$\epsilon_{n,y} \quad = \quad 4 \text{ nm rad}$

$\dfrac{\sigma_{E,unc}}{E_0} \quad = 0.32 \text{ \%}$

$\dfrac{1}{E_0}\dfrac{dE}{ds} \quad = \quad 0.0 \text{ m}^{-1}$
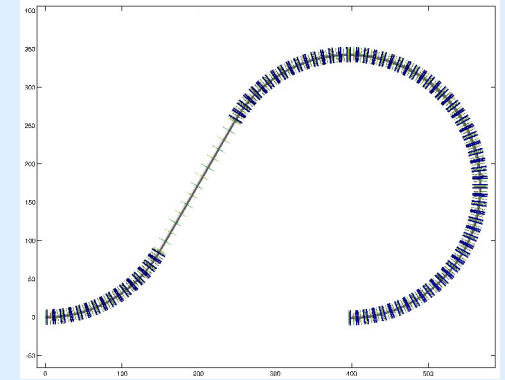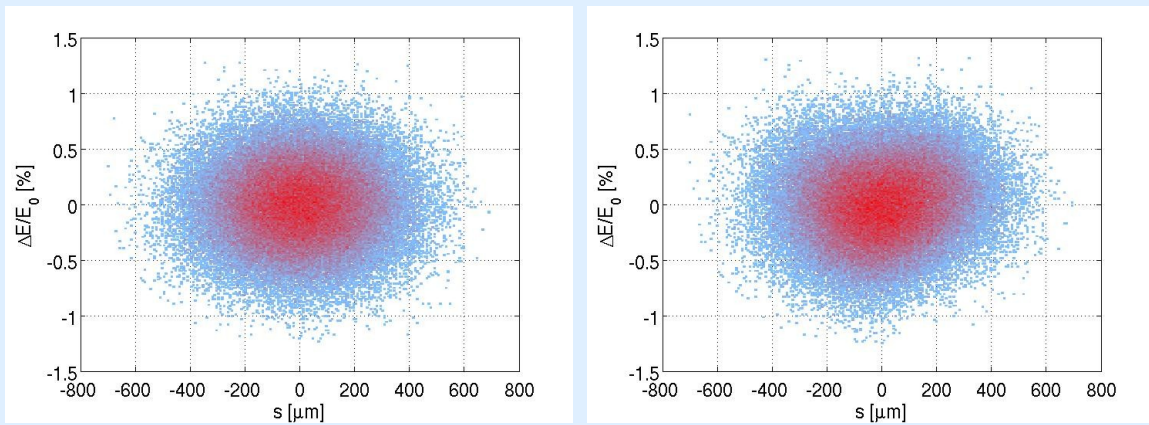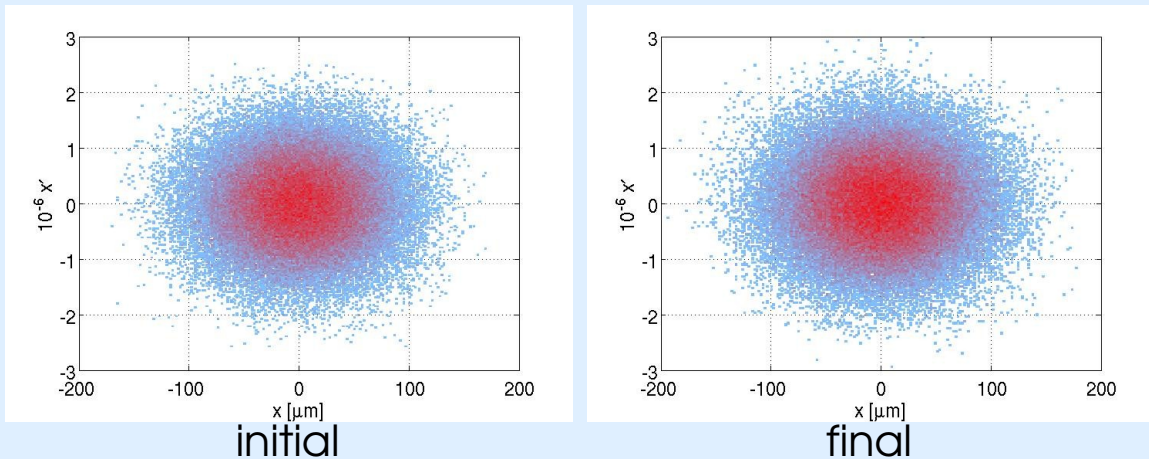
$\sigma_s \quad = \quad 175 \text{ μm}$

$I_{peak} \quad = \quad 460 \text{ A}$

$\epsilon_{n,x} \quad = \quad 560 \text{ nm rad}$

$\epsilon_{n,y} \quad = \quad 4 \text{ nm rad}$

$\dfrac{\sigma_{E,tot}}{E_0} = 0.32 \text{ \%}$

longitudinal phase space

transverse phase space

initial

final

-> Required parameter set for 12 GHz frequency complete

-> Chicane and electron beam parameters adjusted to match new specifications

-> Created layout of Turn Around Loop

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

-> CSR in chicanes is important as long as no shielding effects due to
   the vacuum chamber are considered, in the loop CSR has no major impact

-> Chromaticity of the loop is o.k., as long as energy spread is not too high

-> Main source of emittance growth in the loop is ISR

-> First 3D CSR simulations of BC2 are very promising

-> Continue 3D CSR simulations for BC2 and start with BC1,
   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

Turn Around Loop 1151 m

bending of first arc = 45deg

BC1, 30 m

BC2, 40 m