Impact of new CLIC Parameters on Bunch Compressors and Turn Around Loop

Main Beam Bunch Compressors:

- Status before parameter change
- Old vs. new parameters
- Discussion of new parameters and first simulation results
- Summary and outlook

Drive Beam Bunch Compressors,
Turn Around Loop and Phase Feed-Forward:

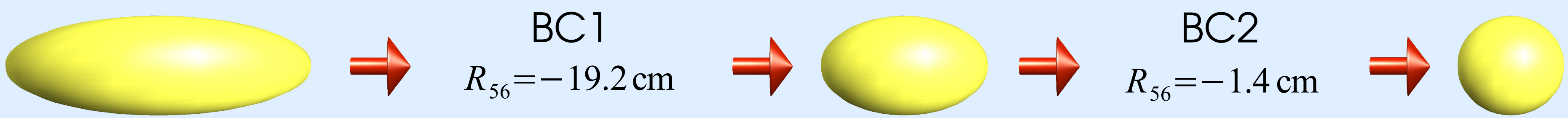
- Status before parameter change
- Old vs. new parameters
- Discussion of new parameters and first simulation results
- Summary and outlook

Frank Stulle, CLIC Meeting 20.07.2007

Status before Parameter Change

$$\begin{aligned} E_0 &= 2.4\ \text{GeV} \\ Q_0 &= 0.41\ \text{nC} \\ \sigma_s &= 1500\ \mu\text{m} \\ I_{\text{peak}} &= 33\ \text{A} \\ \epsilon_{n,x} &= 550\ \text{nm rad} \\ \epsilon_{n,y} &= 3\ \text{nm rad} \\ \frac{\sigma_{E,\text{unc}}}{E_0} &= 0.13\ \% \\ \frac{1}{E_0}\frac{dE}{ds} &= -5.2\ \text{m}^{-1} \end{aligned}$$

$$\begin{aligned} E_0 &= 9\ \text{GeV} \\ Q_0 &= 0.41\ \text{nC} \\ \sigma_s &= 250\ \mu\text{m} \\ I_{\text{peak}} &= 200\ \text{A} \\ \epsilon_{n,x} &= 570\ \text{nm rad} \\ \epsilon_{n,y} &= 4\ \text{nm rad} \\ \frac{\sigma_{E,\text{unc}}}{E_0} &= 0.2\ \% \\ \frac{1}{E_0}\frac{dE}{ds} &= -70.5\ \text{m}^{-1} \end{aligned}$$



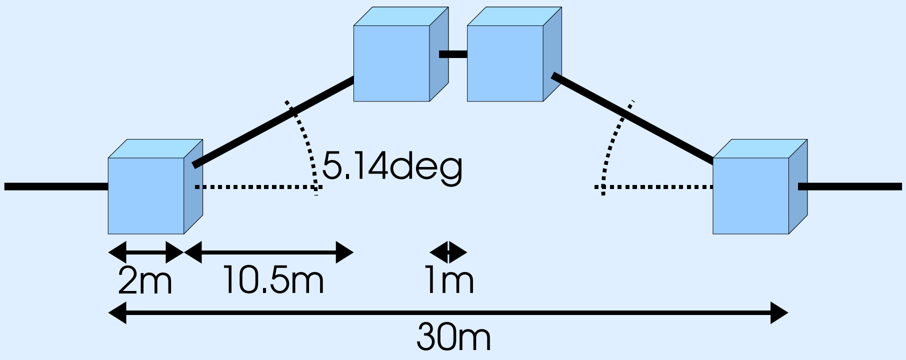
$$\begin{aligned} \sigma_s &= 250\ \mu\text{m} \\ I_{\text{peak}} &= 200\ \text{A} \\ \epsilon_{n,x} &< 570\ \text{nm rad} \\ \epsilon_{n,y} &< 4\ \text{nm rad} \\ \frac{\sigma_{E,\text{tot}}}{E_0} &< 0.8\ \% \end{aligned}$$

$$\begin{aligned} \sigma_s &= 30\ \mu\text{m} \\ I_{\text{peak}} &= 1670\ \text{A} \\ \epsilon_{n,x} &< 600\ \text{nm rad} \\ \epsilon_{n,y} &< 5\ \text{nm rad} \\ \frac{\sigma_{E,\text{tot}}}{E_0} &< 2\ \% \end{aligned}$$

Status before Parameter Change

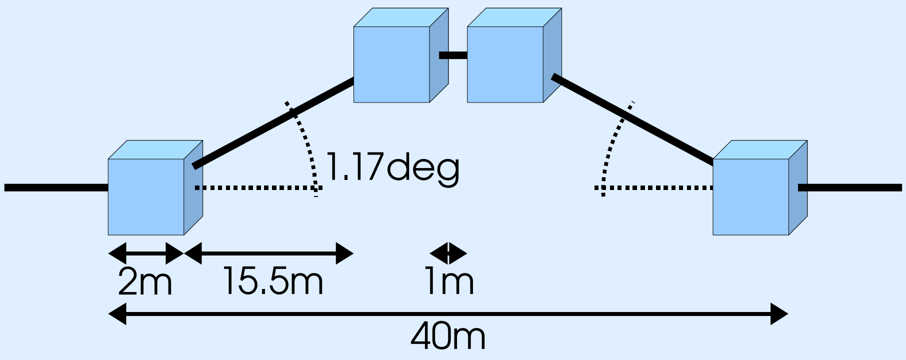
"quick" layout of BC1:

- not fully optimized
- might require shielding to reach emittance goal
- $\Delta\varepsilon$=20 nm rad without shielding
- $\Delta\varepsilon$=5 nm rad in 1cm high chamber
- R_{56}=–0.192 m



"final" layout of BC2:

- fully optimized
- does not require shielding
- $\Delta\varepsilon$=10 nm rad without shielding
- R_{56}=–0.014 m



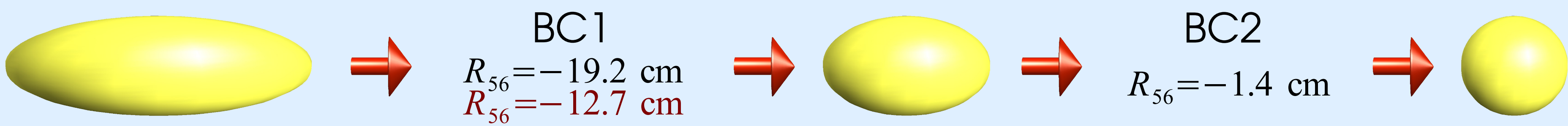
Status before Parameter Change

- Layout work almost finished,
  only minor adjustments remaining
- Starting to perform 3D simulation to confirm results,
  stuck for some time because neither CSRTrack (3D)
  nor TraFiC4 were working properly, but now TraFiC4 is running
- Preparing integration in Start-to-End simulations
  (including studies of more realistic charge distributions)
- but then parameters changed...

New Main Beam Parameters

E_0	$= 2.4$ 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
$\frac{\sigma_{E,unc}}{E_0}$	$= 0.13$ %	0.14 %
$\frac{1}{E_0}\frac{dE}{ds}$	$= -5.2\ \mathrm{m}^{-1}$	$-7.8\ \mathrm{m}^{-1}$

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	
$\frac{\sigma_{E,unc}}{E_0}$	$= 0.2$ %	0.3 %
$\frac{1}{E_0}\frac{dE}{ds}$	$= -70.5\ \mathrm{m}^{-1}$	$-69.6\ \mathrm{m}^{-1}$



σ_s	$= 250$ µm	175 µm
I_{peak}	$= 200$ A	460 A
$\epsilon_{n,x}$	< 570 nm rad	
$\epsilon_{n,y}$	< 4 nm rad	
$\frac{\sigma_{E,tot}}{E_0}$	< 0.8 %	1.2 %

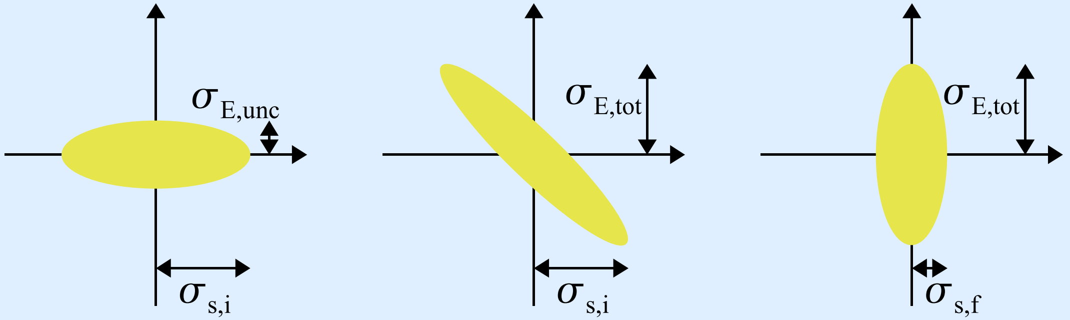
σ_s	$= 30$ µm	44 µm
I_{peak}	$= 1670$ A	1820 A
$\epsilon_{n,x}$	< 600 nm rad	
$\epsilon_{n,y}$	< 5 nm rad	10 nm rad
$\frac{\sigma_{E,tot}}{E_0}$	< 2 %	1.6 %

Additional boundary conditions:

- (may be) full compression in BC1
- definitely (?) full compression in BC2

As long as full compression is requested in both BCs:

- values of R_{56} and 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 !!!

New Main Beam Parameters

Impact of new parameters on BCs:

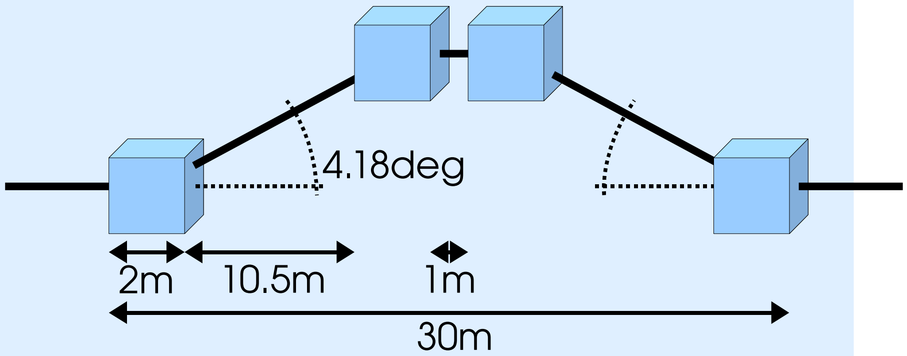
- higher charge => higher peak current despite larger $\sigma_{s,f}$
- expect stronger CSR, when R_{56} in BC2 unchanged
- current choice: R_{56} in BC1 smaller, in BC2 unchanged, but both can be made smaller when compressing even more in BC1
- this will increase energy spread in turn around loop
- shorter bunches in booster linac accumulate less RF curvature, but produce larger wakefields

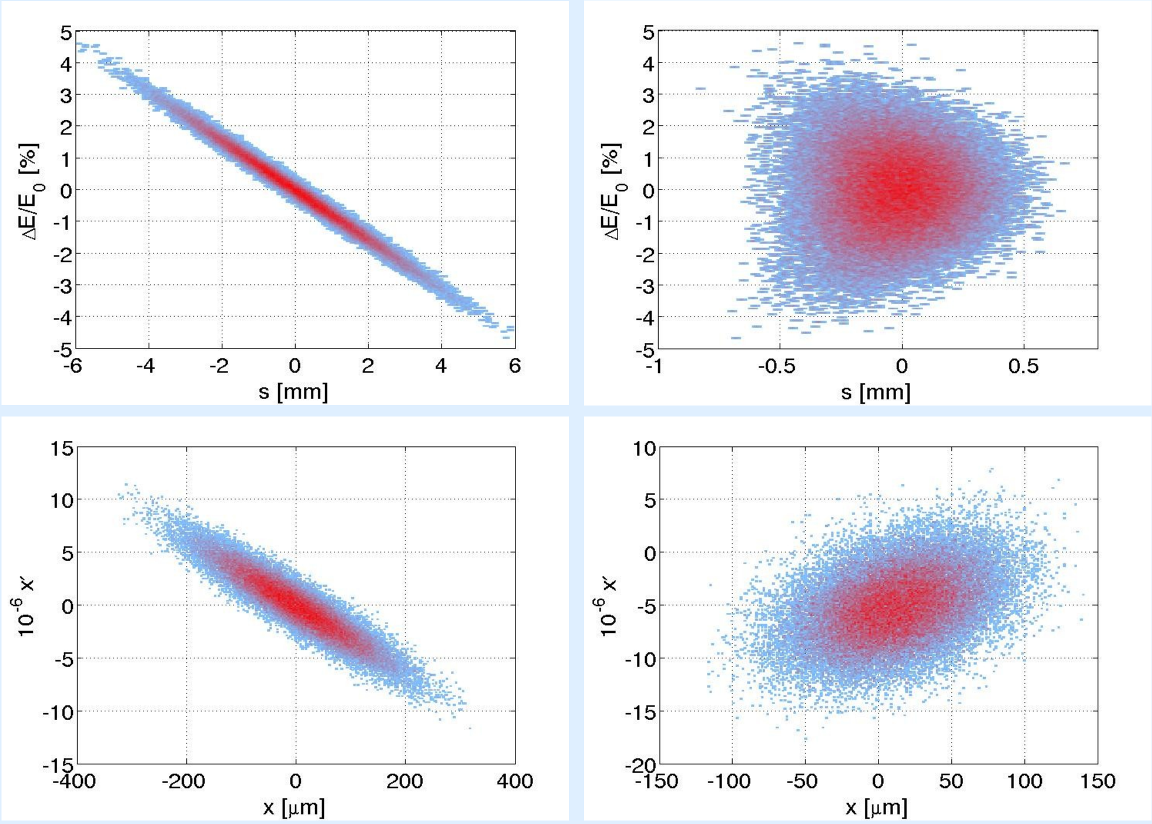
Open questions:

- emittance budget
- maximum allowed wakefields in booster linac, i.e. minimum bunch length after BC1
- maximum allowed energy spread in turn around
- full compression in BC1 and BC2

First Simulation Results for new BC1 parameters

$$E_0 = 2.4\ \text{GeV}$$
$$Q_0 = 0.67\ \text{nC}$$
$$\sigma_s = 1500\ \mu\text{m}$$
$$I_{peak} = 53\ \text{A}$$
$$\epsilon_{n,x} = 400\ \text{nm rad}$$
$$\epsilon_{n,y} = 4\ \text{nm rad}$$
$$\frac{\sigma_{E,unc}}{E_0} = 0.14\ \%$$
$$\frac{1}{E_0}\frac{dE}{ds} = -7.8\ \text{m}^{-1}$$





longitudinal phase space

transverse phase space

initial

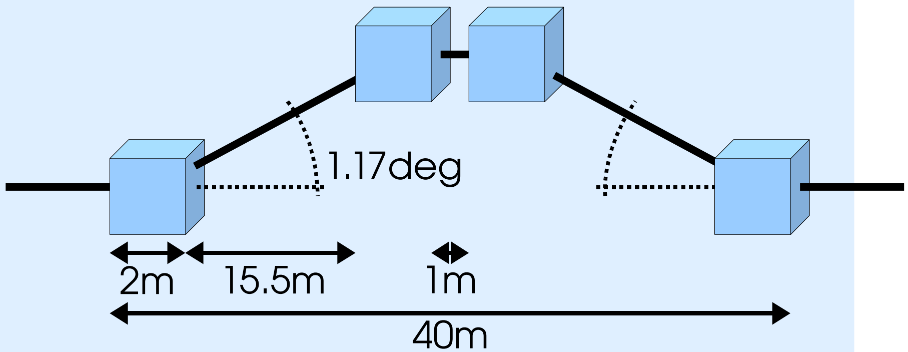
final

$$\sigma_s = 178\ \mu\text{m}$$
$$I_{peak} = 450\ \text{A}$$
$$\epsilon_{n,x} = 440\ \text{nm rad}$$
$$\epsilon_{n,y} = 4\ \text{nm rad}$$
$$\frac{\sigma_{E,tot}}{E_0} = 1.2\ \%$$

405 nm rad with shielding

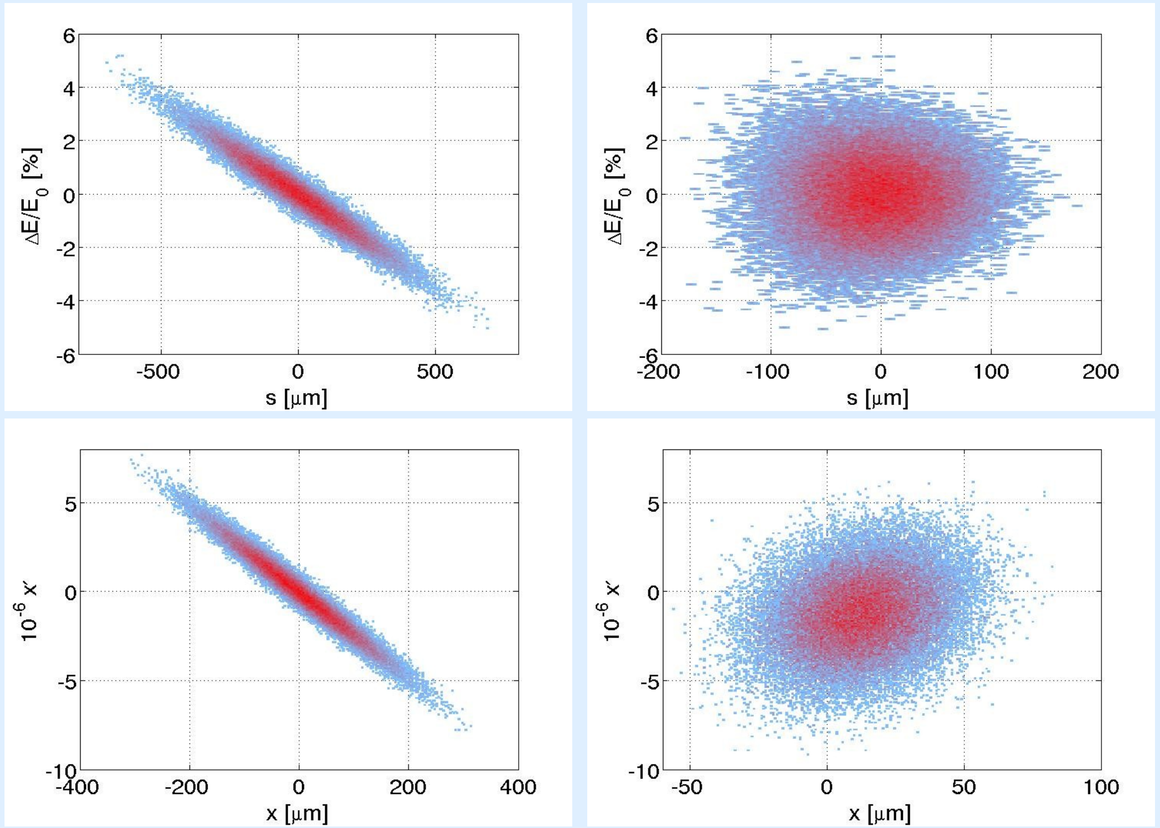
First Simulation Results for new BC2 parameters

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



longitudinal phase space

transverse phase space



initial final

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

577 nm rad
with shielding

Summary / Outlook

- Using the old parameters the design of BC1 and BC2 was almost finished
- But new CLIC parameters require some adjustments
- Full compression in BC1 and BC2 requires unfavourable setup
- Higher charge / peak current leads to higher CSR emittance growth
- Shielding effect helps in both chicanes
- No major changes expected

- Re-optimization of layout and optics on the way
- Preparing integration in Start-to-End simulations
  (including studies of more realistic charge distributions)
- 3D simulations will come soon

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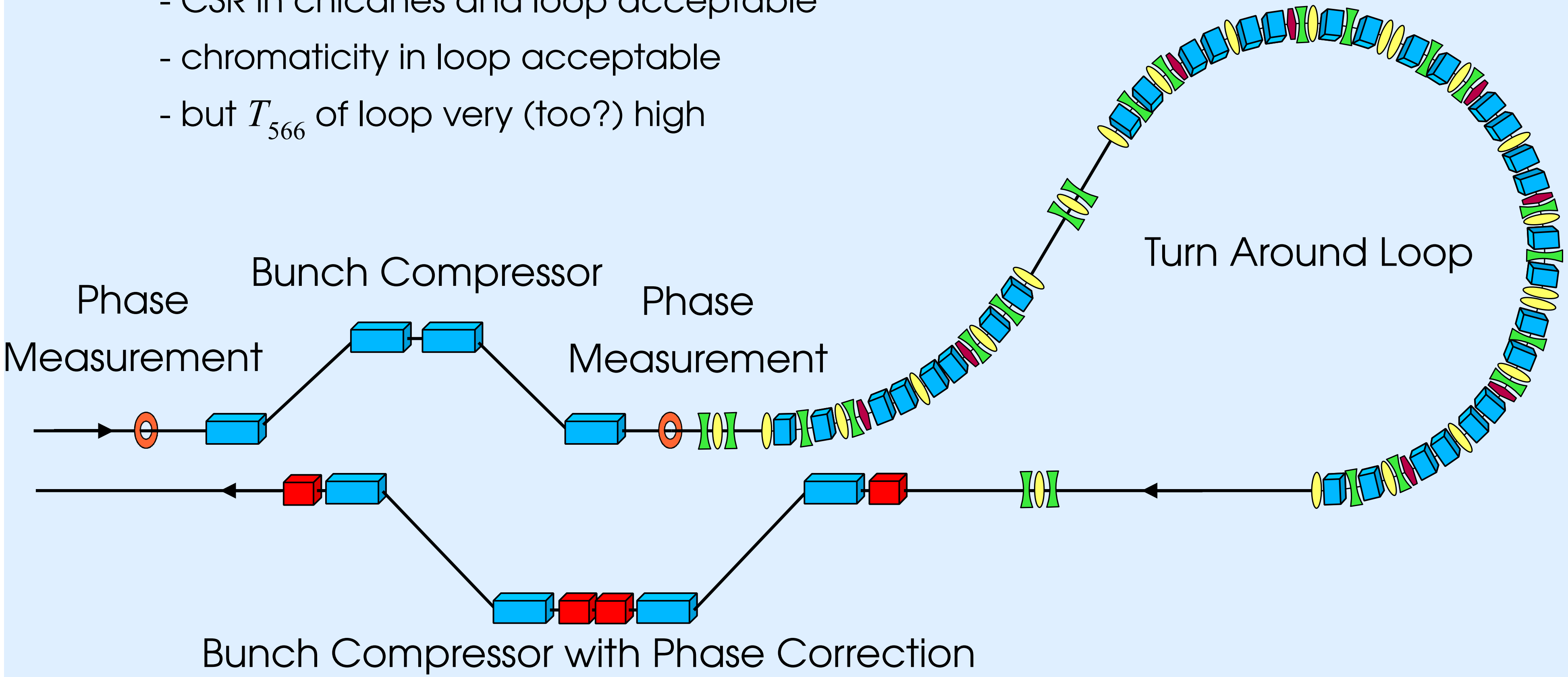
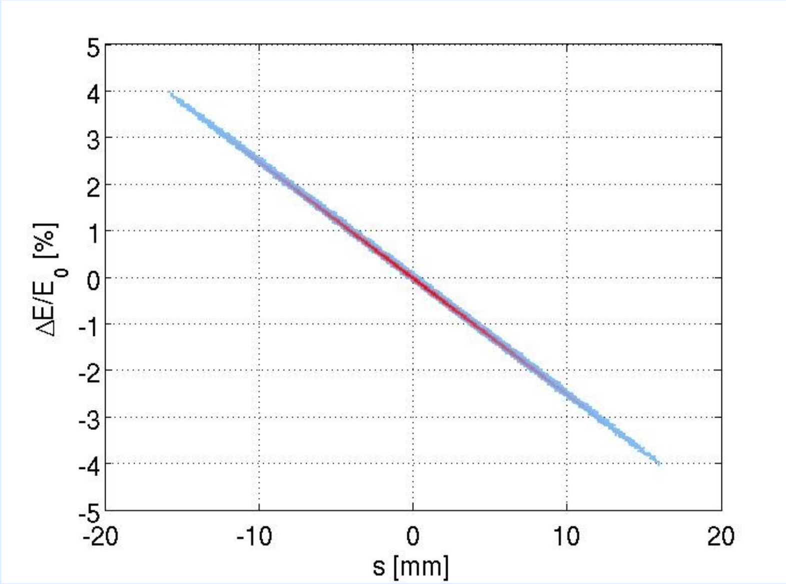
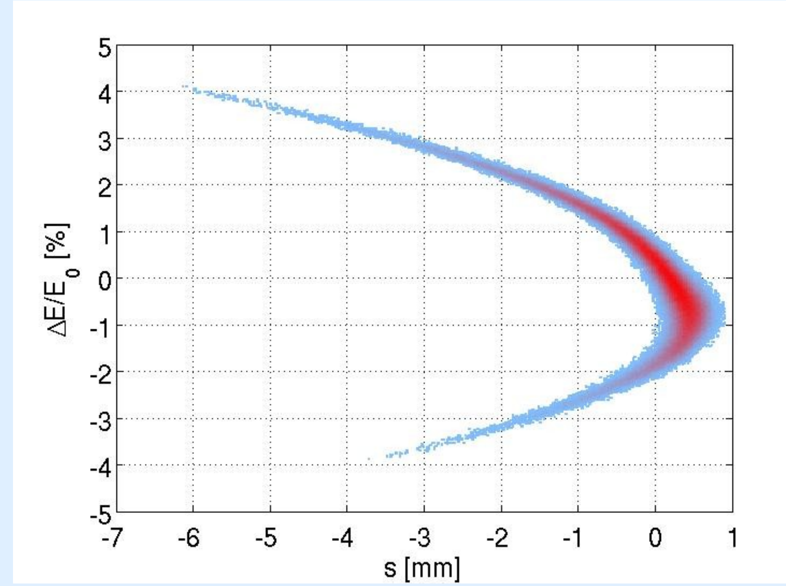
Current layout of beam line:

- total length $130\ \mathrm{m}$ (1st phase measurement to last dipole)
- first chicane $10\ \mathrm{m}$, turn around loop $77\ \mathrm{m}$, second chicane $20\ \mathrm{m}$
- partially optimized
- CSR in chicanes and loop acceptable
- chromaticity in loop acceptable
- but T_{566} of loop very (too?) high



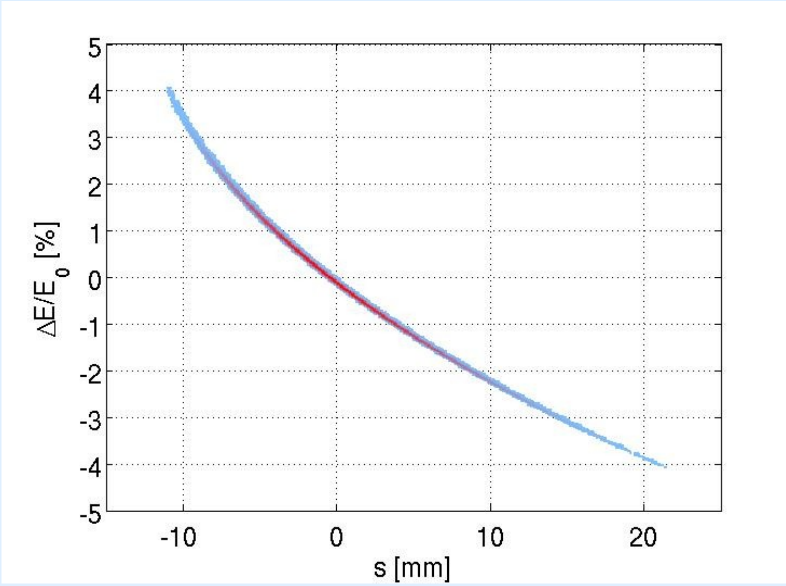
Status before Parameter Change

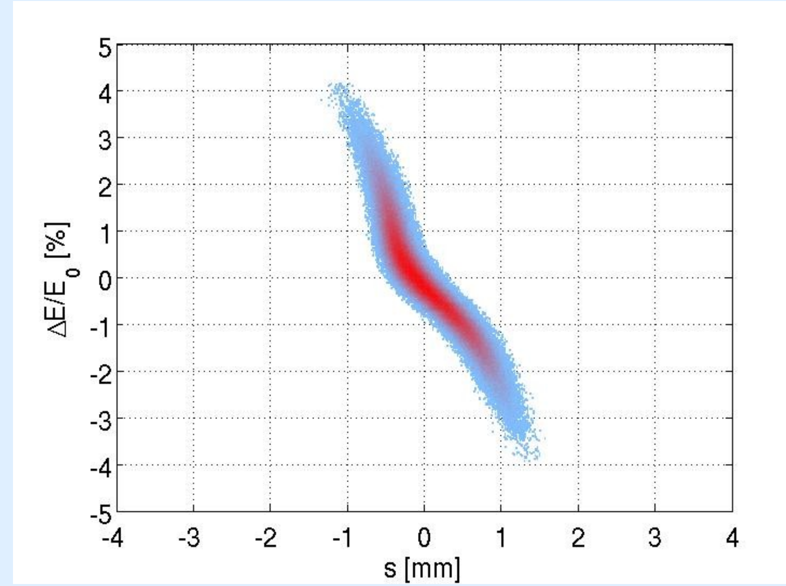




initial longitudinal phase space distribution

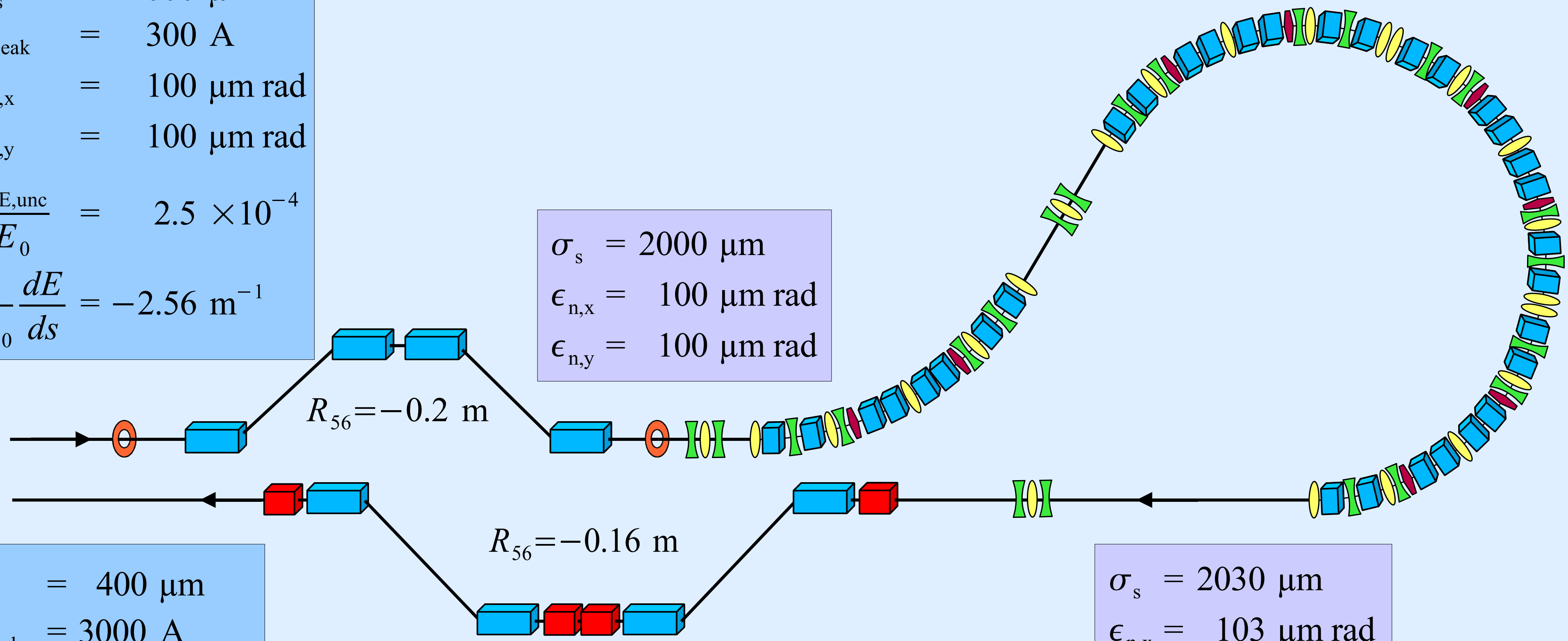
final longitudinal phase space distribution





Status before Parameter Change

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



$$\sigma_s = 2000\ \mu\text{m}$$
$$\epsilon_{n,x} = 100\ \mu\text{m rad}$$
$$\epsilon_{n,y} = 100\ \mu\text{m rad}$$

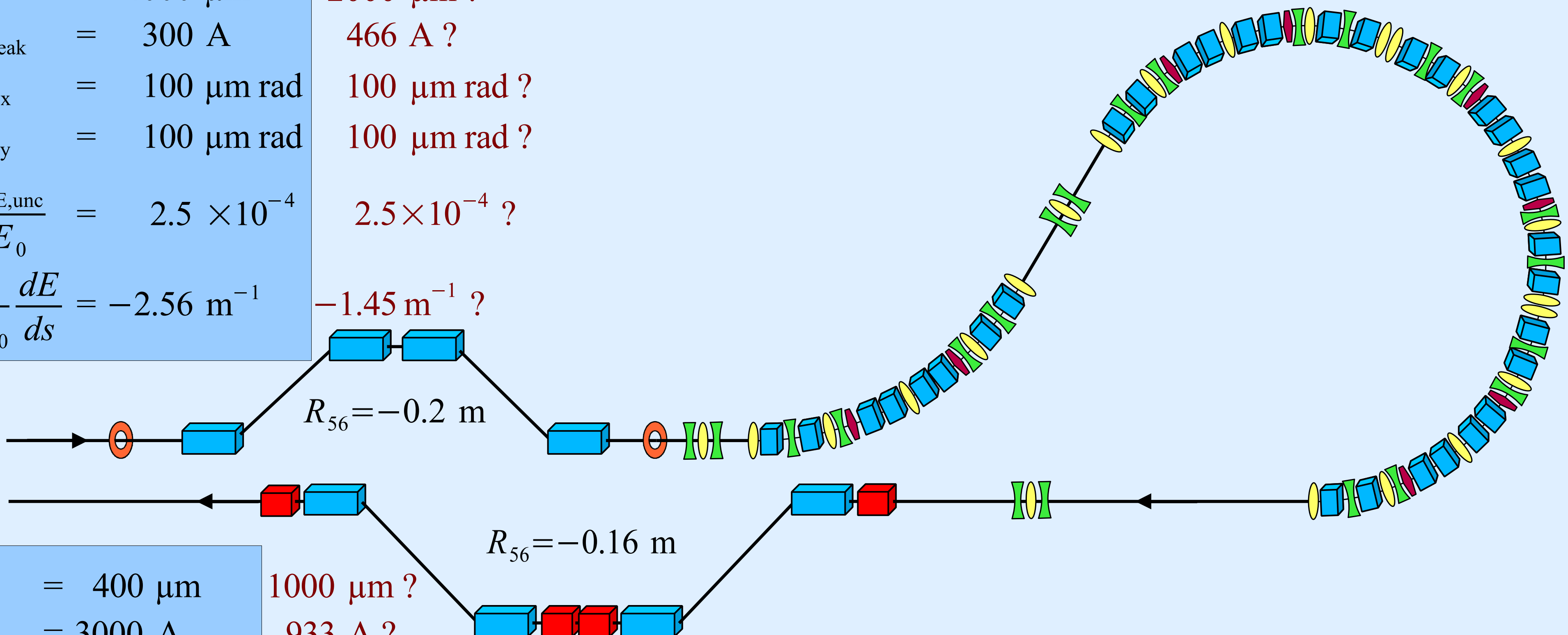
$$\sigma_s = 2030\ \mu\text{m}$$
$$\epsilon_{n,x} = 103\ \mu\text{m rad}$$
$$\epsilon_{n,y} = 101\ \mu\text{m rad}$$

$$\sigma_s = 590\ /\ 400\ \mu\text{m}$$
$$I_{peak} = 4300\ /\ 3600\ \text{A}$$
$$\epsilon_{n,x} = 110\ /\ 105\ \mu\text{m rad}$$
$$\epsilon_{n,y} = 101\ /\ 101\ \mu\text{m rad}$$

$$\sigma_s = 400\ \mu\text{m}$$
$$I_{peak} = 3000\ \text{A}$$
$$\epsilon_{n,x} < 110\ \mu\text{m rad}$$
$$\epsilon_{n,y} < 110\ \mu\text{m rad}$$
$$\frac{\sigma_{E,tot}}{E_0} < 1\ \%$$

New Drive Beam Parameters

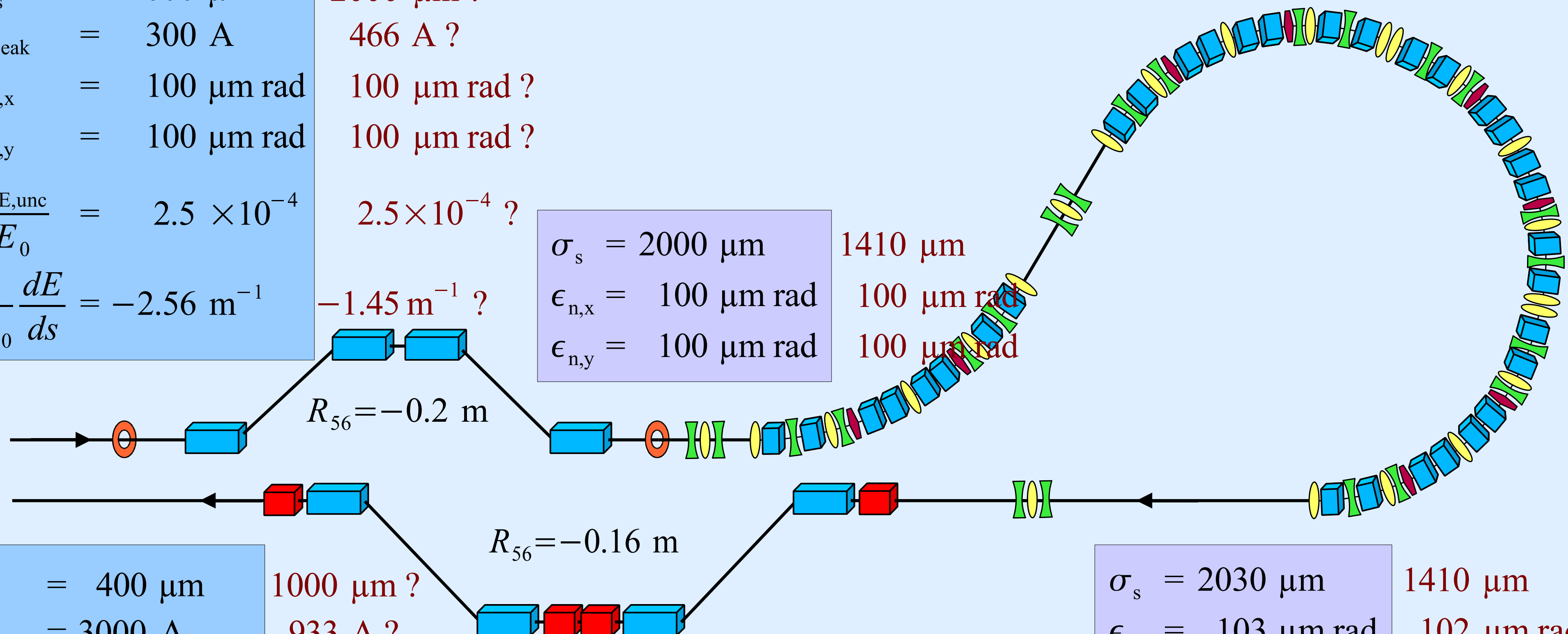
E_0	$= 2\ \text{GeV}$	$2.4\ \text{GeV}$?
Q_0	$= 10\ \text{nC}$	$7.8\ \text{nC}$?
σ_s	$= 4000\ \mu\text{m}$	$2000\ \mu\text{m}$?
I_{peak}	$= 300\ \text{A}$	$466\ \text{A}$?
$\epsilon_{n,x}$	$= 100\ \mu\text{m rad}$	$100\ \mu\text{m rad}$?
$\epsilon_{n,y}$	$= 100\ \mu\text{m rad}$	$100\ \mu\text{m rad}$?
$\frac{\sigma_{E,\text{unc}}}{E_0}$	$= 2.5 \times 10^{-4}$	2.5×10^{-4} ?
$\frac{1}{E_0}\frac{dE}{ds}$	$= -2.56\ \text{m}^{-1}$	$-1.45\ \text{m}^{-1}$?



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

New Drive Beam Parameters

E_0 = 2 GeV		2.4 GeV ?
Q_0 = 10 nC		7.8 nC ?
σ_s = 4000 μm		2000 μm ?
I_{peak} = 300 A		466 A ?
$\epsilon_{n,x}$ = 100 μm rad		100 μm rad ?
$\epsilon_{n,y}$ = 100 μm rad		100 μm rad ?
$\frac{\sigma_{E,unc}}{E_0} = 2.5\times10^{-4}$		2.5×10^{-4} ?
$\frac{1}{E_0}\frac{dE}{ds} = -2.56\ \text{m}^{-1}$		$-1.45\ \text{m}^{-1}$?



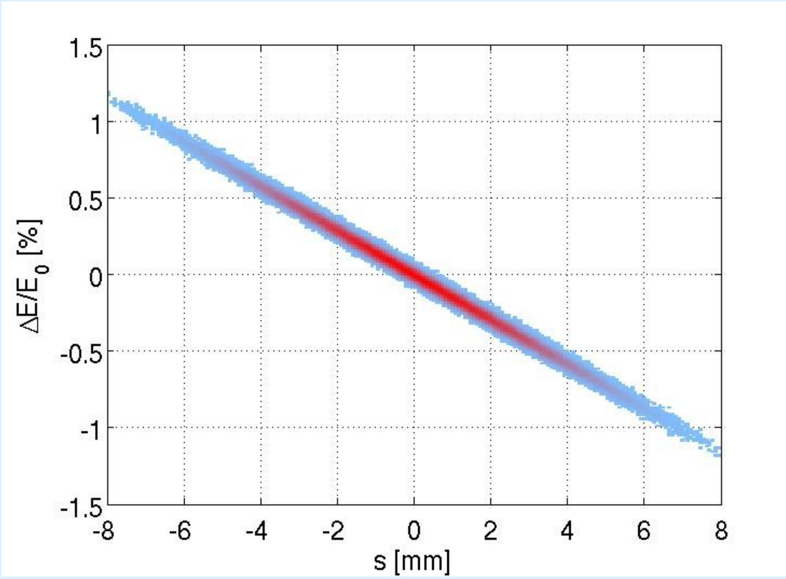
σ_s = 2000 μm	1410 μm
$\epsilon_{n,x}$ = 100 μm rad	100 μm rad
$\epsilon_{n,y}$ = 100 μm rad	100 μm rad

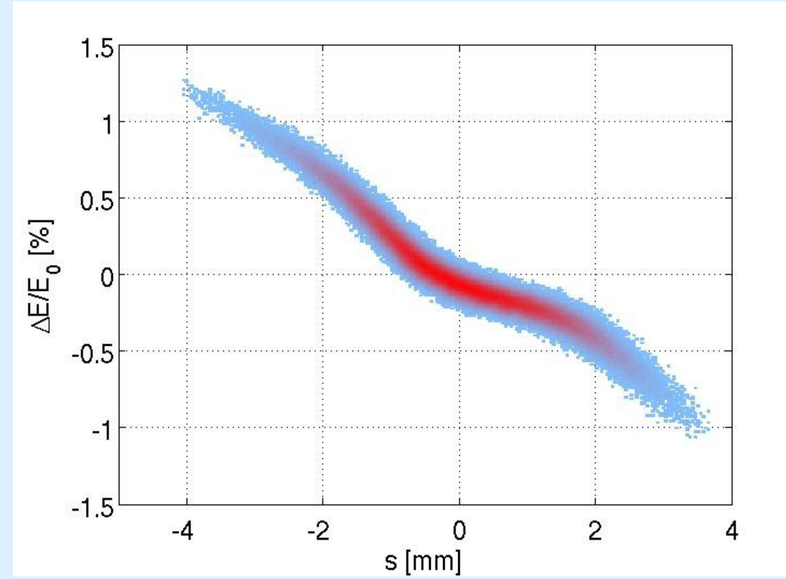
σ_s = 2030 μm	1410 μm
$\epsilon_{n,x}$ = 103 μm rad	102 μm rad
$\epsilon_{n,y}$ = 101 μm rad	100 μm rad

σ_s = 590 / 400 μm	1000 μm
I_{peak} = 4300 / 3600 A	910 A
$\epsilon_{n,x}$ = 110 / 105 μm rad	104 μm rad
$\epsilon_{n,y}$ = 101 / 101 μm rad	100 μm rad
$\frac{\sigma_{E,tot}}{E_0}$ = 0.96 %	2.7×10^{-3}

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

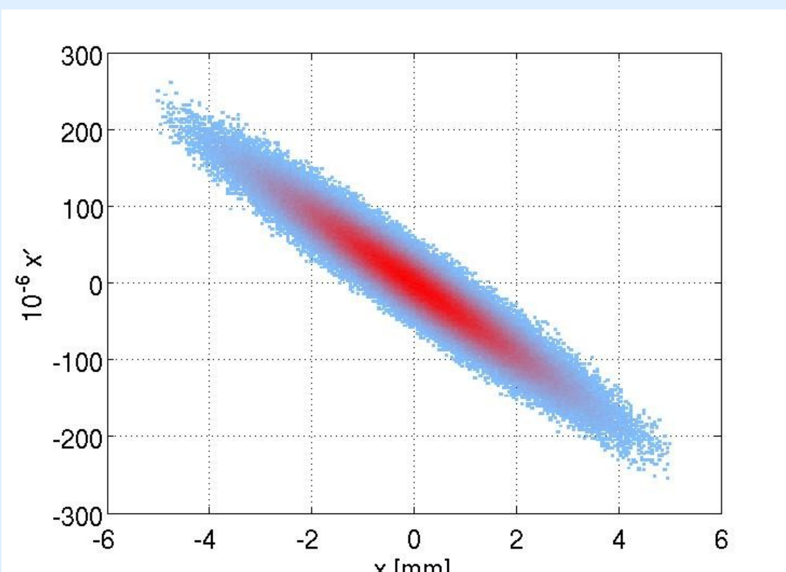
First Simulation Results using new Parameters

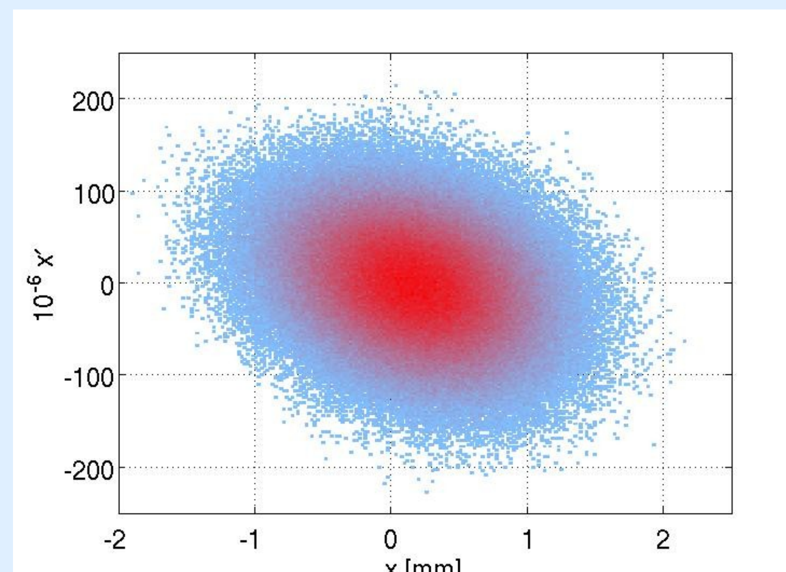




initial phase space distributions

final phase space distributions





First Simulation Results using new Parameters

- New parameters are better in terms of CSR emittance growth and chromaticity
- Lower energy spread reduces longitudinal non-linearities a lot
- Some freedom to distribute compression over both chicanes, but bunch should not be too short in turn around loop
- No impact on energy measurement as long as R_{56} of first chicane unchanged

Open questions:

- new parameters
- required bunch shape / rms bunch length / peak current in decelerator (depends also on incoming beam)
- accuracy of phase/energy measurement and correction
- 3^{rd}-harmonic cavity in front of chicanes

Summary / Outlook

- Design of drive Beam bunch compression, turn around and phase feed-forward pretty much advanced before parameter change
- Most important question was, if T_{566} is acceptable
- First simulations show that new parameters are favourable
- Especially lower total energy spread is good
- Hardware setup unchanged for new simulations, only electron beam parameters changed
- Some freedom to distribute compression

- Fix new parameters and other specifications
- Integrate in Start-to-End simulations (including studies of more realistic charge distributions)
- Try 3D simulations including CSR