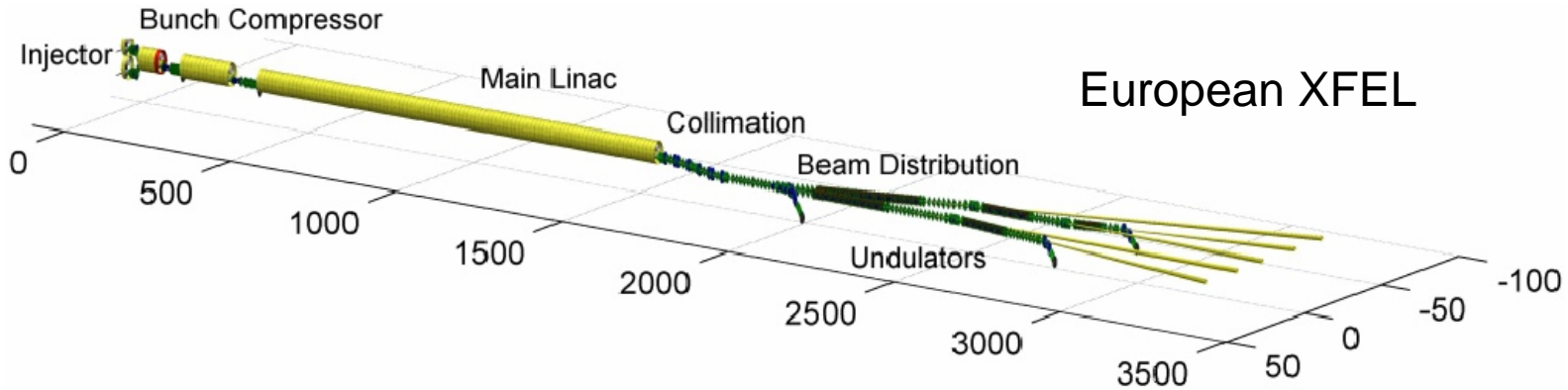
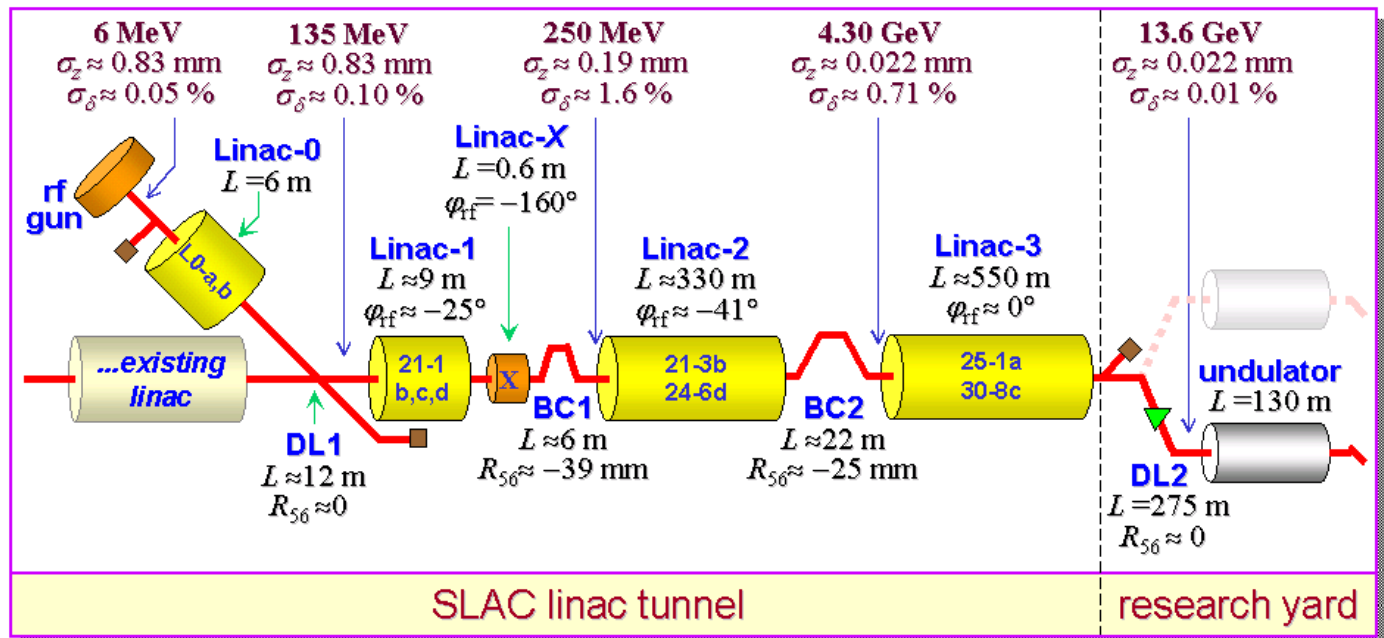


LCLS and European FEL



LCLS



bunch compression in LCLS and European FEL
(1nC scenario)

European XFEL

gun → 1nC $I_{\text{peak}} \sim 50\text{A}$ $\sim 7\text{MeV}$

1 x module → 130MeV

dogleg

$z \sim 43\text{-}53\text{m}$

4 x module + 2 x module-3rd → 500MeV
chirp $\sim 10\text{MeV}/\sigma$

bc1 (r56 $\sim 100\text{mm}$) → $\sim 1\text{kA}$

$z \sim 144\text{-}164\text{m}$

12 x module → 2GeV

chirp $\sim 10\text{MeV}/\sigma$

bc2 (r56 $\sim 18\text{mm}$) → $\sim 5\text{kA}$

$z \sim 357\text{-}377\text{m}$

main linac → 17.5GeV

LCLS

gun → 1nC $I_{\text{av}} \sim 100\text{A}$ $\sim 6\text{MeV}$

linac 0 → 135MeV

bend

$z \sim 18\text{m}$

linac 1 + 4th harm. → 250MeV
chirp $\sim 5\text{MeV}/\sigma$

bc1 (r56=39mm) → $\sim 450\text{A}$

$z \sim 31\text{-}38\text{m}$

linac 2 → 4.3GeV

chirp $\sim 30\text{MeV}/\sigma$

bc2 (r56=25mm) → $\sim 4\text{kA}$

$z \sim 397\text{-}422\text{m}$

linac 3 → 13.6GeV



parameter sensitivity:

LCLS
100A → 4kA

without self fields

E_i	4 MeV			
E_1	250 MeV	$C_1 = 4.5$		
E_2	2 GeV			
$f_1=f_2$	4.3 GHz	$C_2 = 8.88$	$I \rightarrow 0.9 I$	
f_3	11.40 GHz		$I \rightarrow 1.1 I$	
U_1, φ_1	283.58 MeV	17.38 deg	0.375 MeV	0.2 deg
U_2, φ_2	24.67 MeV	-176.925 deg	-0.28 MeV	-0.45 deg
$r_{56,a}$	-39 mm			
U_3, φ_3	4.547 GeV	27.05 deg	-23 MeV	0.18 deg
$r_{56,b}$	-25 mm			



parameter sensitivity: European XFEL – parameters 1
50A → 5kA

without self fields

E_i 4 MeV

E_1 500 MeV $C_1 = 20$

E_2 2 GeV

$f_1=f_2$ 1.3 GHz $C_2 = 5$

f_3 3.9 GHz

$I \rightarrow 0.9 I$

$I \rightarrow 1.1 I$

U_1, φ_1 621.77 MeV 21.336 deg -0.32 MeV 0.0117 deg

U_2, φ_2 83.36 MeV -166.947 deg -0.468 MeV -0.035 deg

$r_{56,a}$ -103.3 mm

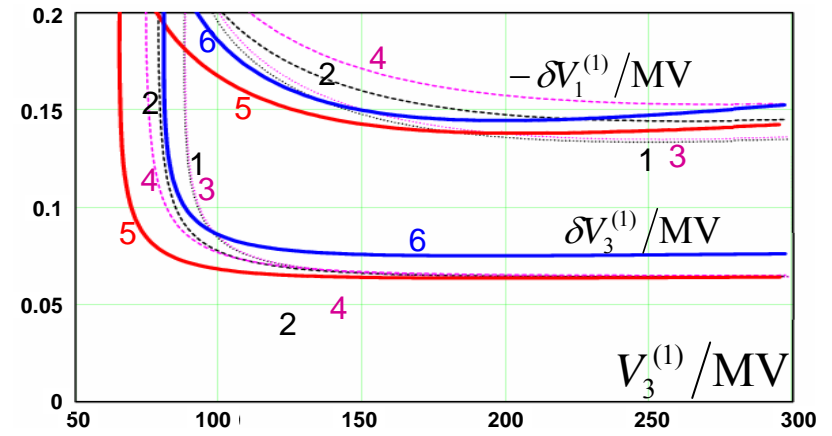
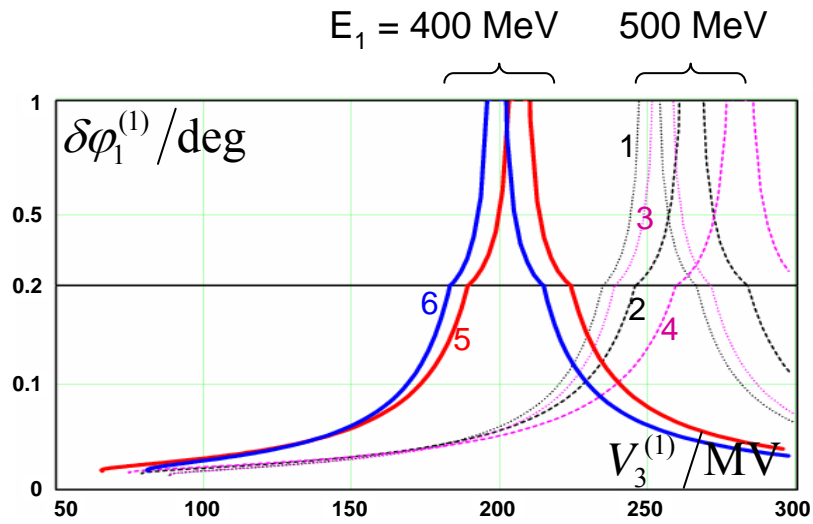
U_3, φ_3 1.596 GeV 20.000 deg -16.9 MeV 1.06 deg

$r_{56,b}$ -14.9 mm



parameter sensitivity:

European XFEL
increase 3rd harm. rf



parameter sensitivity:

European XFEL – parameters 2

50A → 5kA

without self fields

+ C1, + chirp from L2

E_i 4 MeV

E_1 500 MeV $C_1 = 10$

E_2 2 GeV

$f_1=f_2$ 1.3 GHz $C_2 = 10$ $I \rightarrow 0.9 I$

f_3 3.9 GHz $I \rightarrow 1.1 I$

U_1, φ_1 616.60 MeV 20.531 deg -0.92 MeV -0.021 deg

U_2, φ_2 83.60 MeV -166.927 deg -0.383 MeV -0.057 deg

$r_{56,a}$ -103.3 mm

U_3, φ_3 2.000 GeV 41.100 deg -11.1 MeV 0.233 deg

$r_{56,b}$ -22.5 mm



parameter sensitivity: European XFEL – parameters 3
50A → 5kA

without self fields

+ E1, ++ chirp from L2

E_i	4 MeV			
E_1	400 MeV	$C_1 = 10$		
E_2	2 GeV			
$f_1=f_2$	1.3 GHz	$C_2 = 10$	$I \rightarrow 0.9 I$	
f_3	3.9 GHz		$I \rightarrow 1.1 I$	
U_1, φ_1	495.35 MeV	21.35 deg	...	-0.025 deg
U_2, φ_2	67.70 MeV	-164.942 deg
$r_{56,a}$	-103.3 mm			
U_3, φ_3	2.287 GeV	45.594 deg
$r_{56,b}$	-22.5 mm			



parameter sensitivity: European XFEL – parameters 4
50A → 5kA

without self fields

+ U3

E_i	4 MeV			
E_1	400 MeV	$C_1 = 10$		
E_2	2 GeV			
$f_1=f_2$	1.3 GHz	$C_2 = 10$		$I \rightarrow 0.9 I$
f_3	3.9 GHz			$I \rightarrow 1.1 I$
U_1, φ_1	471.14 MeV	21.35 deg	0.48 -0.383 MeV	0.039 -0.033 deg
U_2, φ_2	99.01 MeV	131.30 deg	0.12 -0.095 MeV	0.10 -0.084 deg
$r_{56,a}$	-103.3 mm			
U_3, φ_3	2.287 GeV	45.594 deg	15.3 -12.5 MeV	0.192 -0.24 deg
$r_{56,b}$	-26.2 mm			



parameter sensitivity:

European XFEL – parameters 5

50A → 5kA

without self fields

- r56, +++ chirp from L2

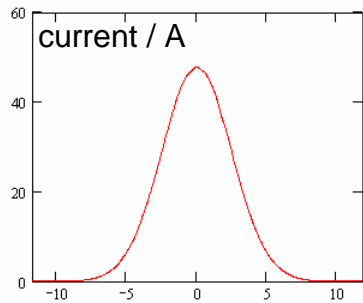
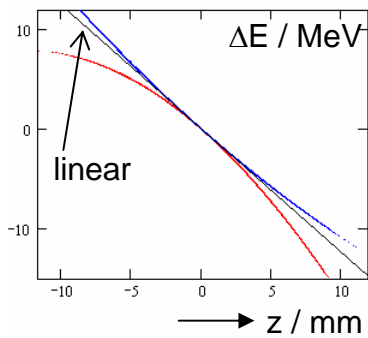
E_i	4 MeV			
E_1	400 MeV	$C_1 = 10$		
E_2	2 GeV			
$f_1=f_2$	1.3 GHz	$C_2 = 10$	$I \rightarrow 0.9 I$	
f_3	3.9 GHz		$I \rightarrow 1.1 I$	
U_1, φ_1	484.77 MeV	5.73 deg	0.41 -0.330 MeV	0.040 -0.033 deg
U_2, φ_2	100.05 MeV	149.67 deg	0.127 -0.155 MeV	0.105 -0.085 deg
$r_{56,a}$	-65.9 mm			
U_3, φ_3	2.263 GeV	45.00 deg	15.3 -14.5 MeV	0.20 -0.25 deg
$r_{56,b}$	-18.3 mm			



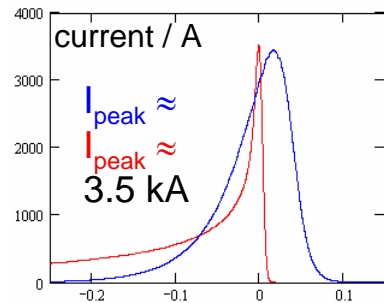
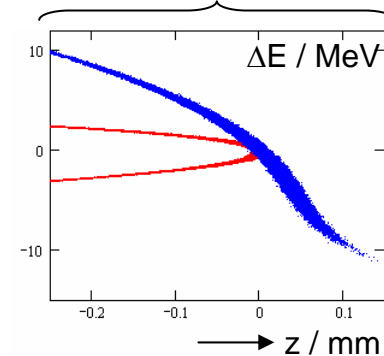
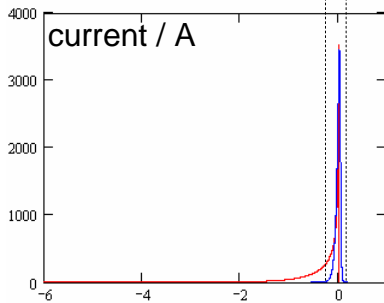
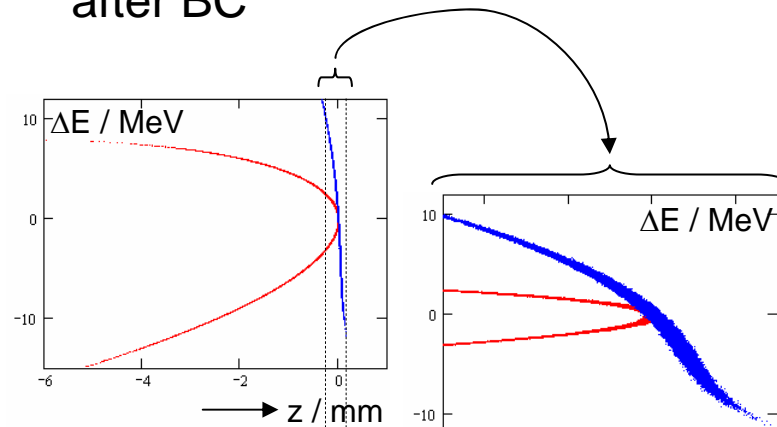
linearized \leftrightarrow 'rollover' compression
(in principle)

'controlled' or linearized compression
'rollover' compression

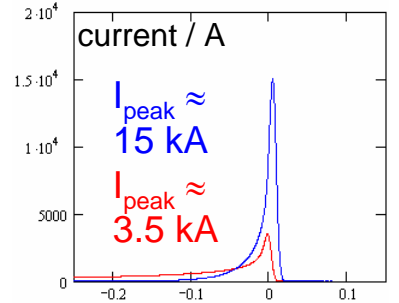
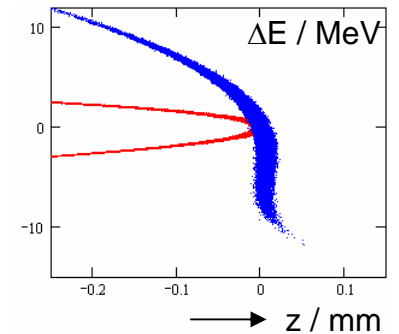
before BC

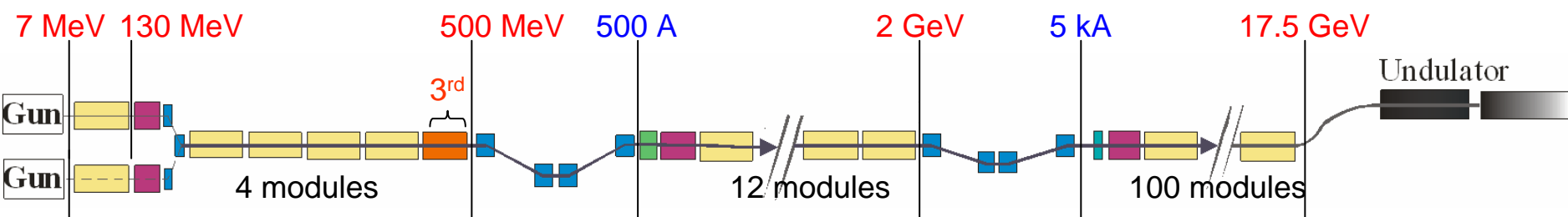


after BC



lost control:
magnet strength
changed by 0.5%





$\delta E_1 = 10 \text{ keV}$
(heater)

$C_1 = 10$

$\delta E_2 = 100 \text{ keV}$

$C_2 = \text{full}$

$r_{56}^{(2)} \delta E_2 = 10 \mu\text{m}$

$r_{56}^{(1)} = -0.1 \text{ m}$

(500 MeV)

$$e'_1 = \frac{-9}{\text{m}} \longrightarrow e' = \frac{-90}{\text{m}}$$

$r_{56}^{(2)} = -0.2 \text{ m}$

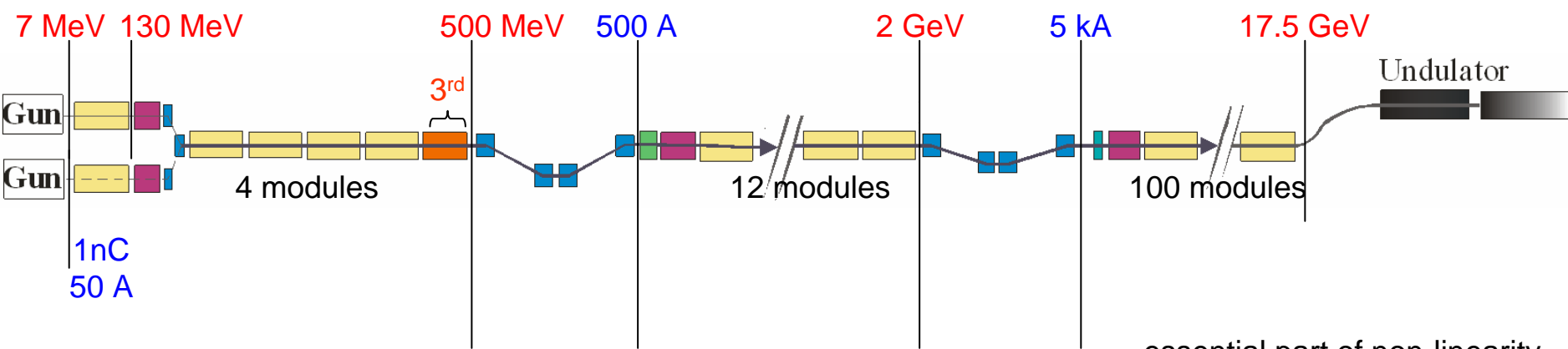
(2 GeV)

$$e' = \frac{-22.5}{\text{m}} + e'_{L2} = \frac{1}{r_{56}^{(2)}}$$

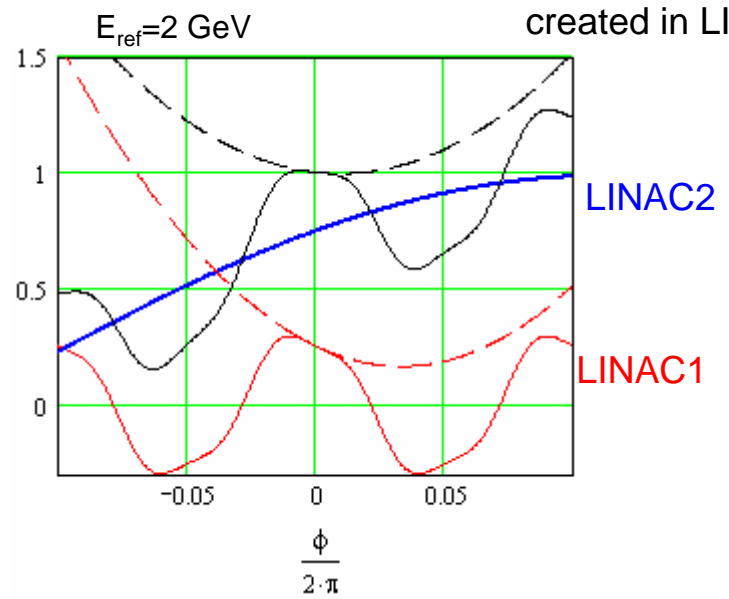
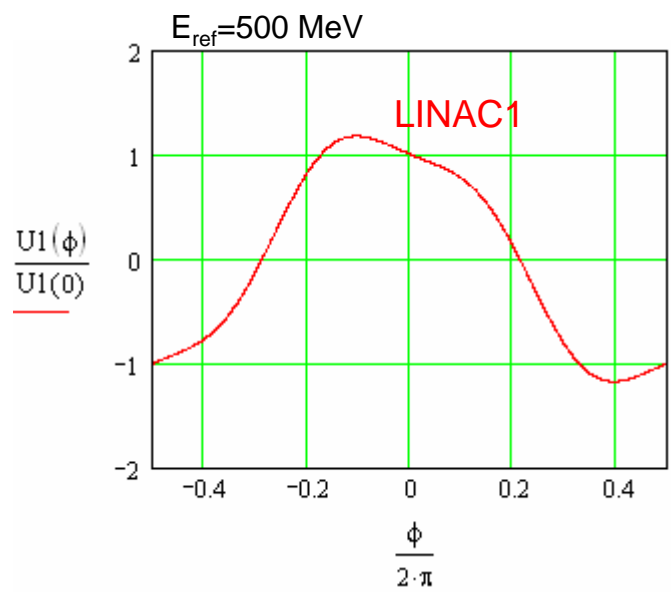
$$e'_{L2} = \frac{+17.5}{\text{m}} = \frac{1.5 \text{ GeV}}{2 \text{ GeV}} k \tan \varphi_{L2}$$

$\varphi_{L2} = 40.5 \text{ deg}$
 $U_{L2} = 1.973 \text{ GV}$





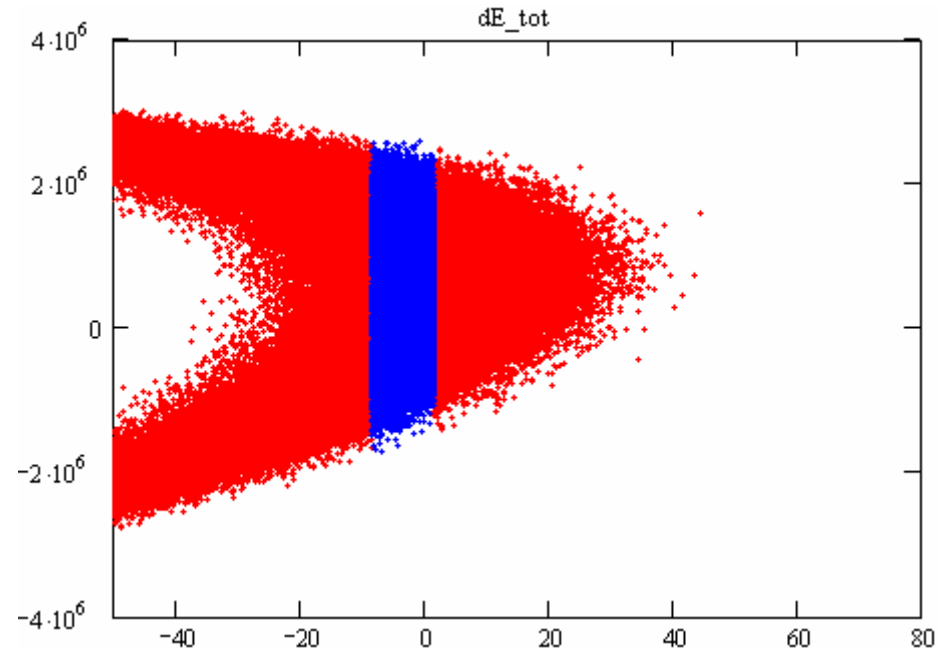
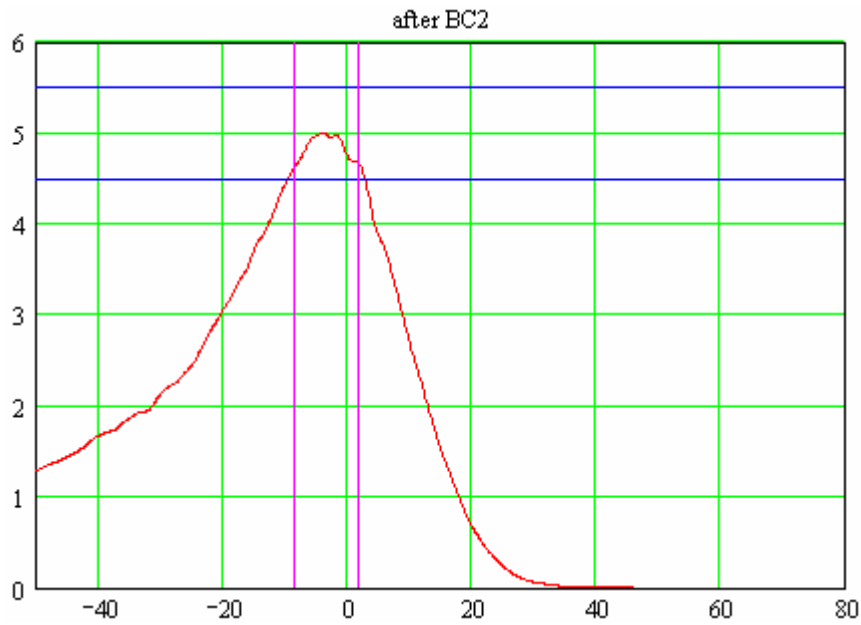
essential part of non-linearity created in LINAC1 !



parameter sensitivity:

European XFEL – parameters 6
50A → 5kA

without self fields



rms energy spread = 0.88 MeV



parameter sensitivity: European XFEL – parameters 6
50A → 5kA

without self fields

E_i	4 MeV			
E_1	500 MeV	$C_1 = 10$		
E_2	2 GeV			
$f_1=f_2$	1.3 GHz	$C_2 = \text{full}$	$I \rightarrow 0.9 I$	
f_3	3.9 GHz		$I \rightarrow 1.1 I$	
U_1, φ_1	607.07 MeV	17.773 deg	-1.15 ... 1.3 MeV	-0.06 ... 0.048 deg
U_2, φ_2	73.40 MeV	-174.978 deg	-0.65 .. 1.15 MeV	-0.13 ... 0.18 deg
$r_{56,a}$	-100 mm			
U_3, φ_3	1.973 GeV	-40.500 deg	<30 ... >30 MeV	-2.2 ... >2.5 deg
$r_{56,b}$	-200 mm			

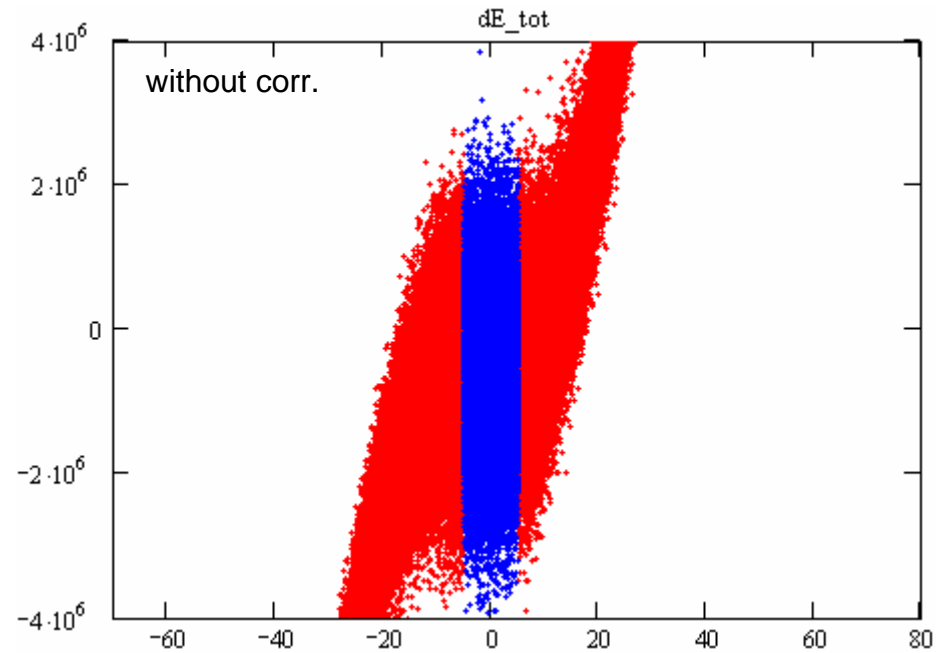
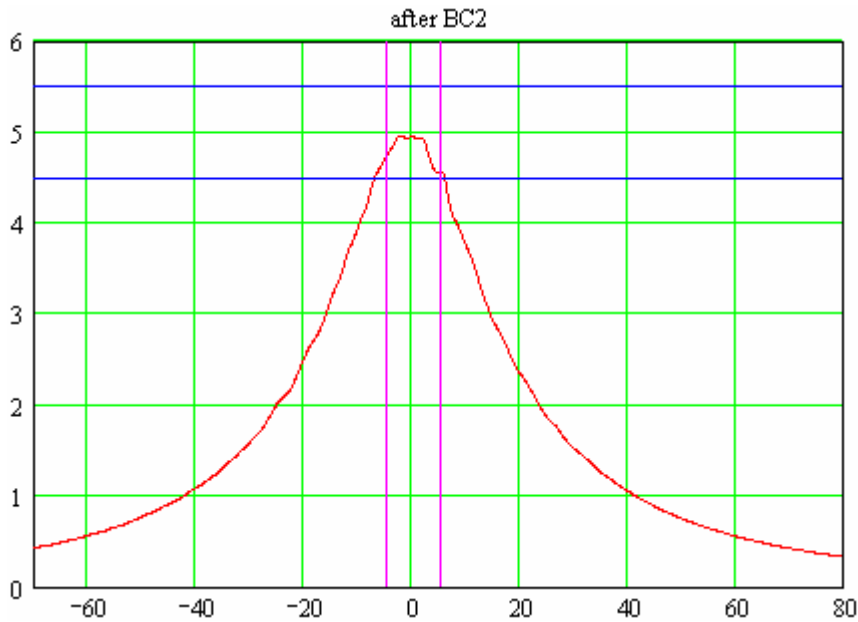
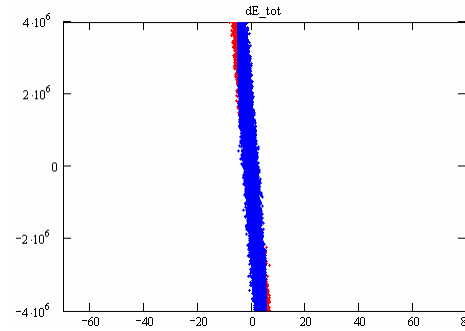


parameter sensitivity:

European XFEL – parameters 5

50A → 5kA

without self fields



$$a2w = 1.999 \times 10^9$$

$$a2rms = 9.748 \times 10^5$$

