Proposal on testing x-band bunch compression at NLCTA

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SLAC NATIONAL ACCELERATOR LABORATORY

Motivation and simulation conditions

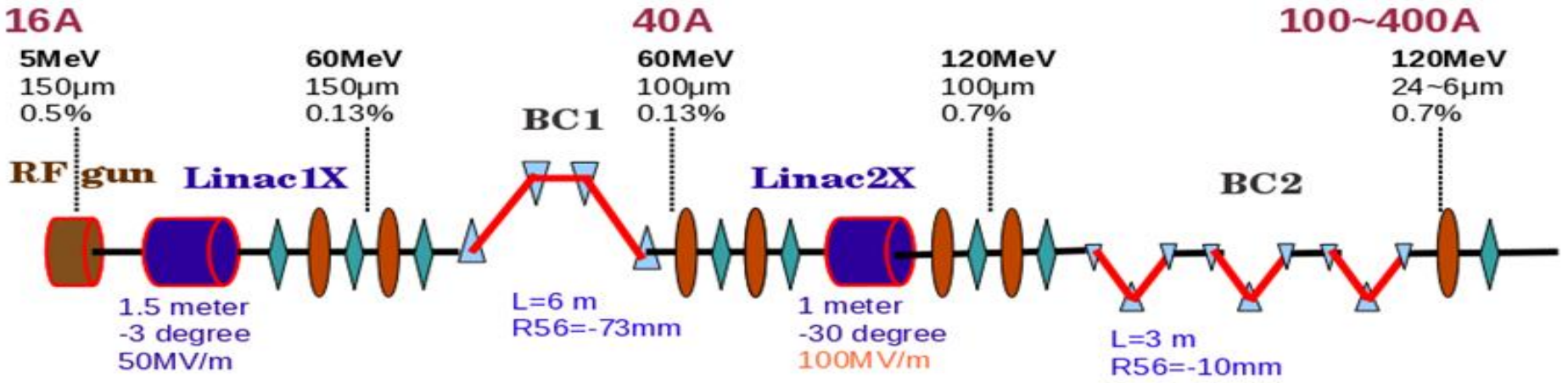
Motivation for future X-band FELs

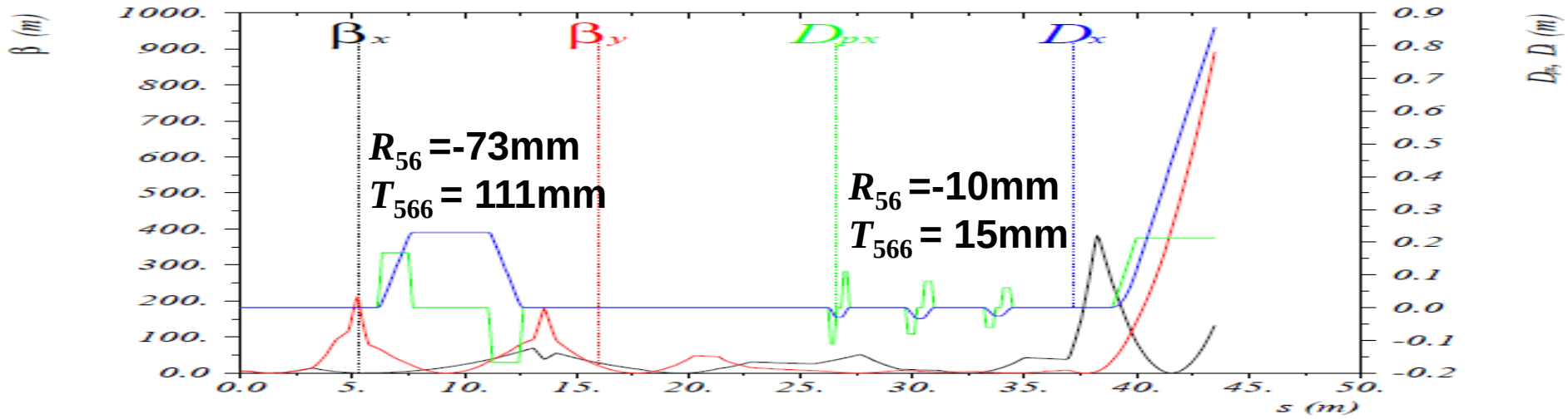
- Demonstrate effective bunch compression (10 to 20 times) with x-band RF
  - **Scheme 1: use normal chicane + positive RF chirp (current NLCTA)**
  - Scheme 2: use optics w/ higher order dispersion + positive/negative RF chirp (need to install 4/6 sextupoles in the big chicane)
- Investigate tolerances on timing jitter, misalignment etc.; emittance growth

Simulation condition:

- ✓In Elegant, transverse and longitudinal wake of X-band cavities, 1D coherent synchrotron radiation (CSR) and ISR, longitudinal space charge (LSC)
- ✓CSRDRIFT between all bends with the "USE_STUPAKOV" option
- ✓CSR induced steering removed by 'center' element in Elegant
- ✓0.5 million macro-particles
- ✓For scheme 1, current operating optics
- ✓For scheme 2, new optics
- ✓20 pC beam at 5MeV, 0.5ps RMS bunch length, 6e-3 RMS energy spread, 1 mm.mrad transverse emittance
- ✓Beam energy: 60 MeV at BC1, 120 MeV at BC2

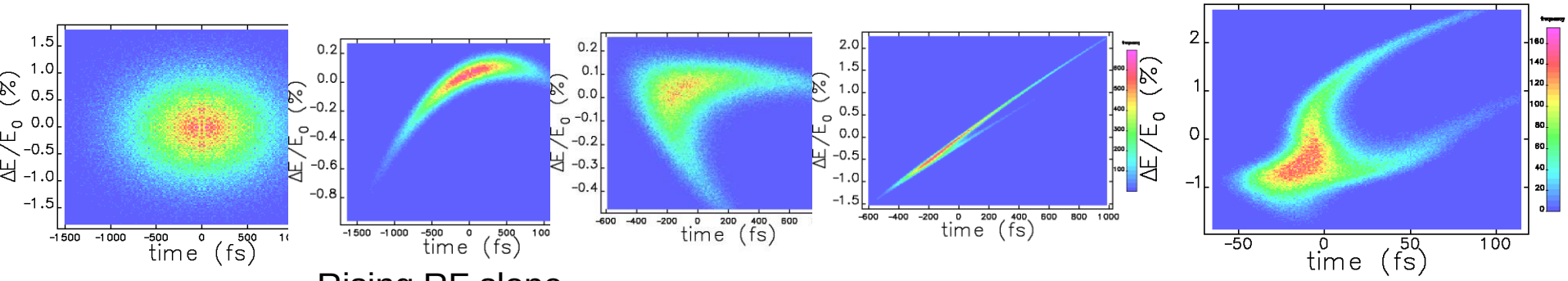
NLCTA optics (current configuration)



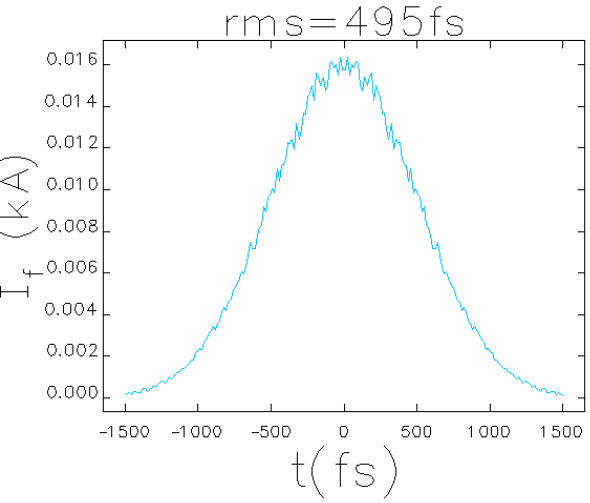


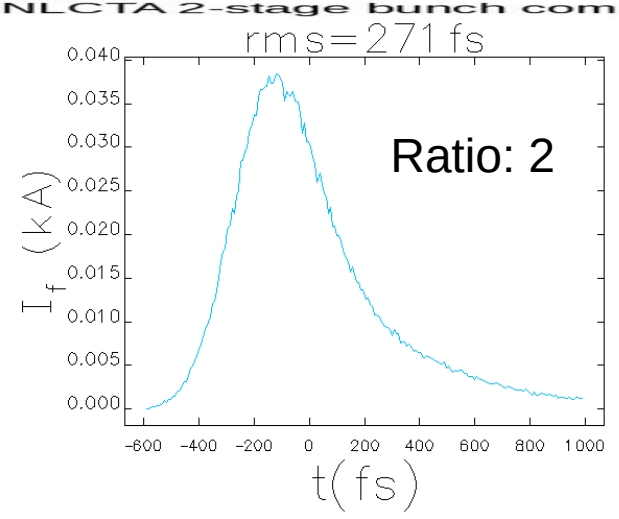
Scheme 1 (1) L-phase, current and bunch length

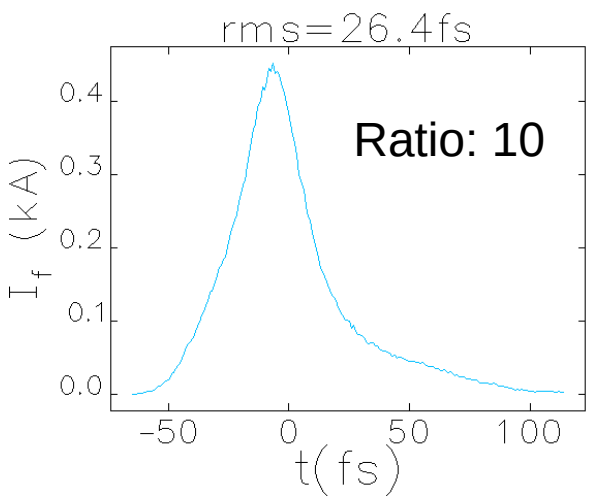
Initial Linac1 BC1 Linac2 BC2



Rising RF slope

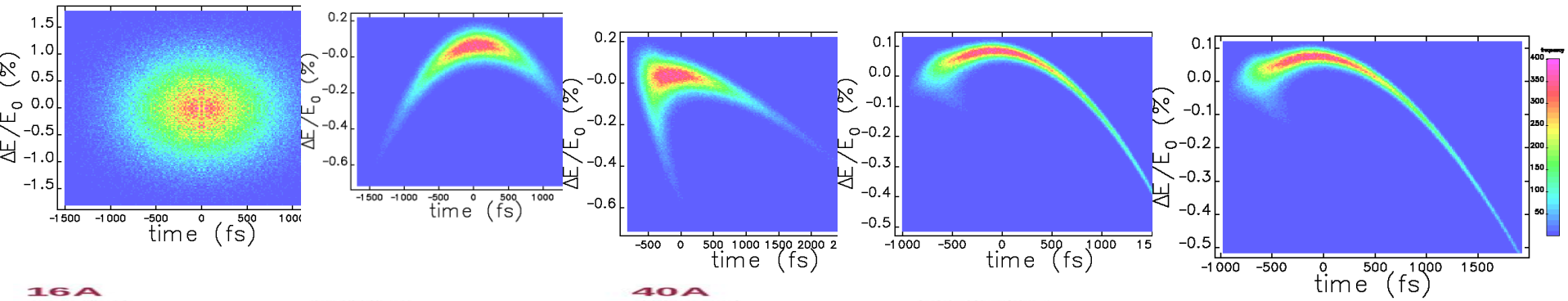


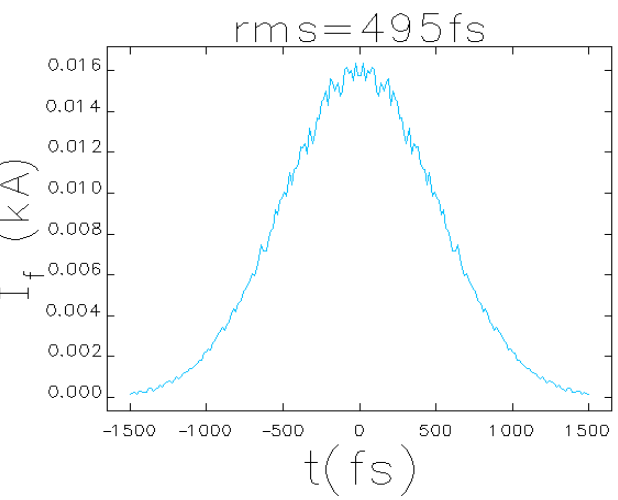


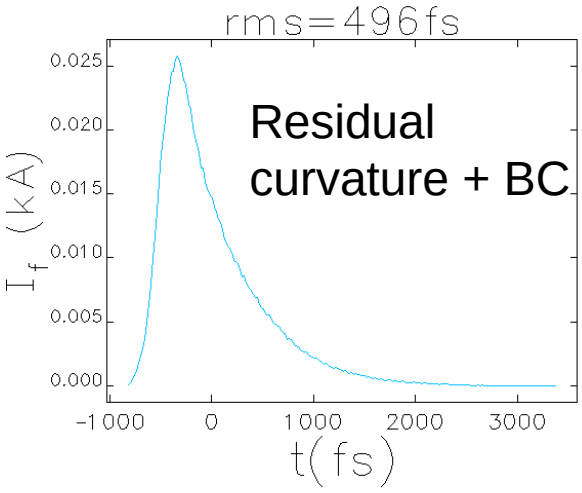


Scheme 1 (2) no compression, on crest

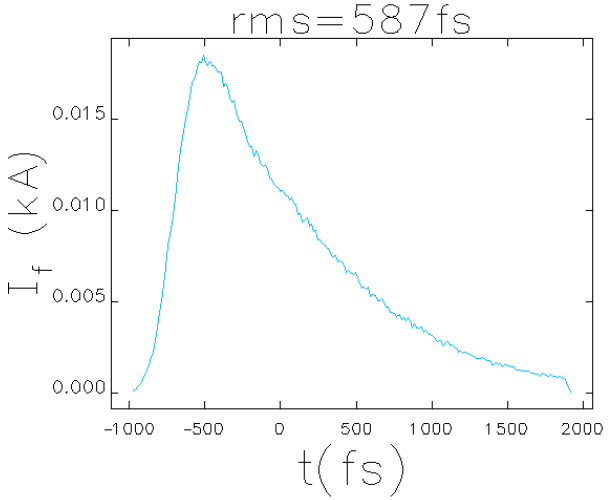
Initial Linac1 BC1 Linac2 BC2



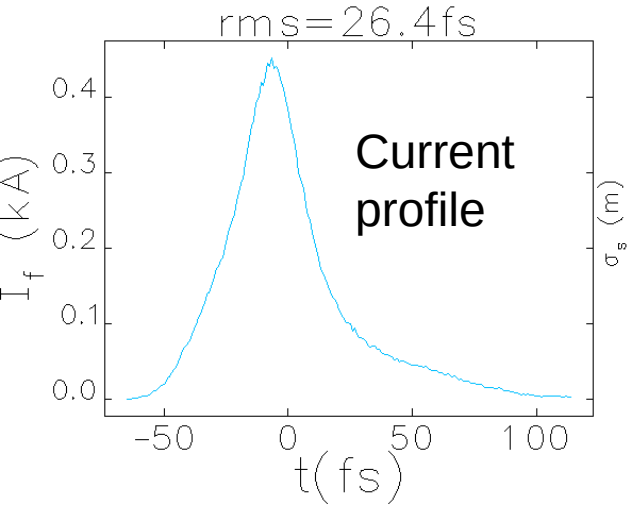


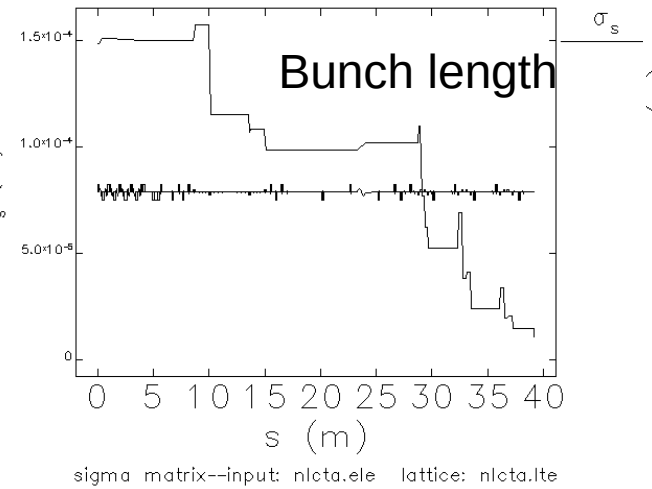


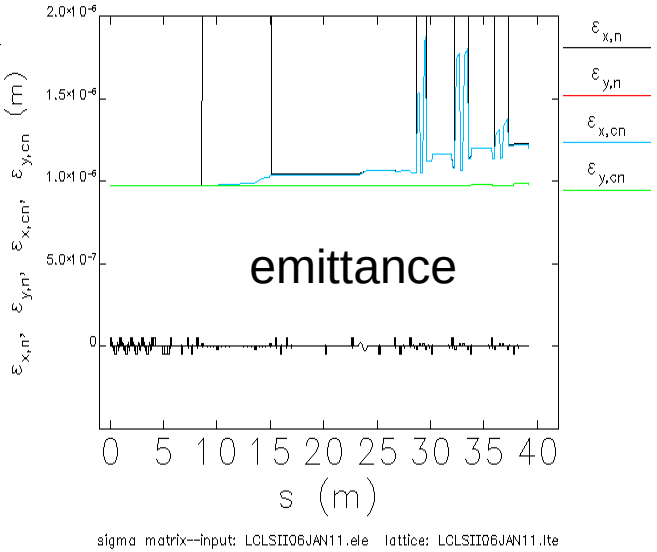
Residual curvature + BC



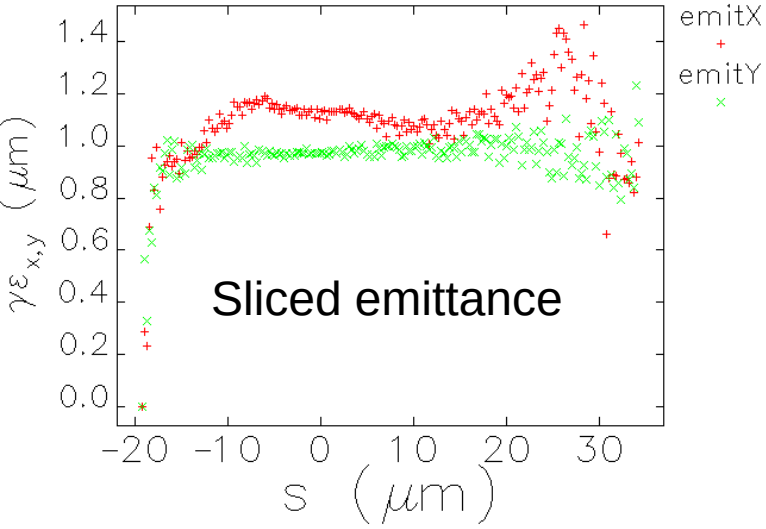
Scheme 1 (3) 2 stage 20 times BC, linac end

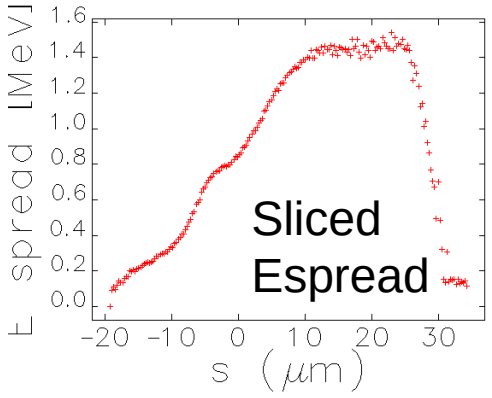


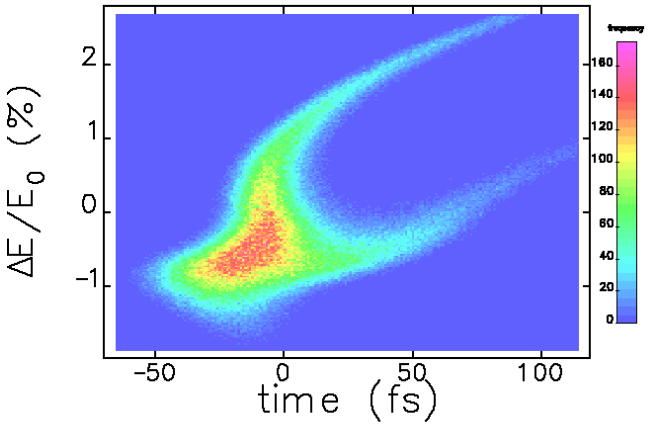




enx=1.21um
eny=0.98um

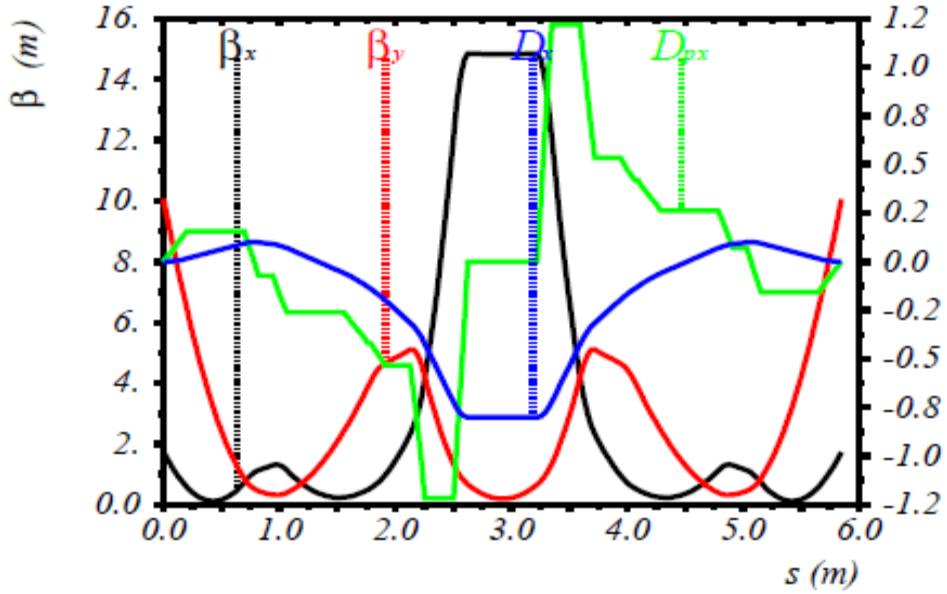


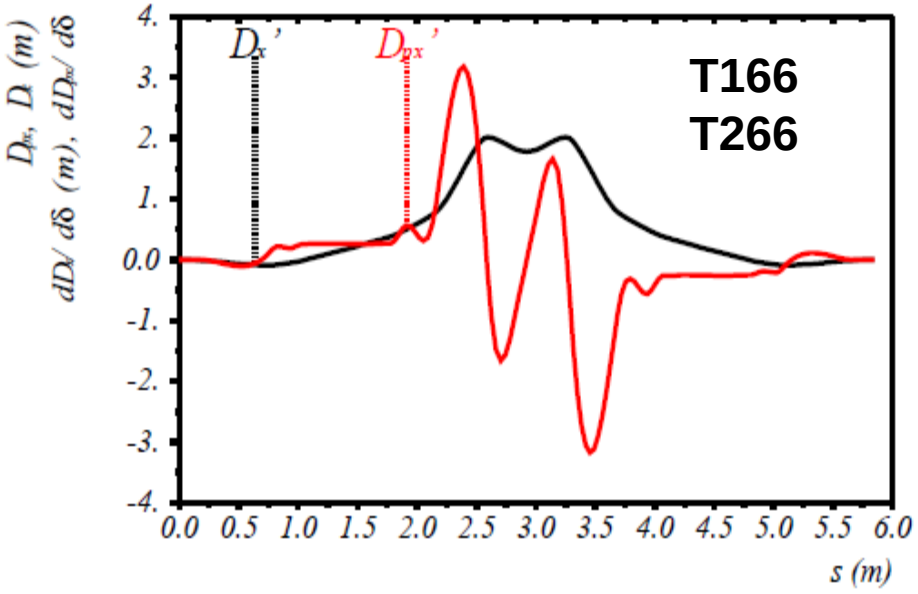




Scheme 2 (1) optics

Install 4/6 sextupoles in the big chicane, at 60 MeV



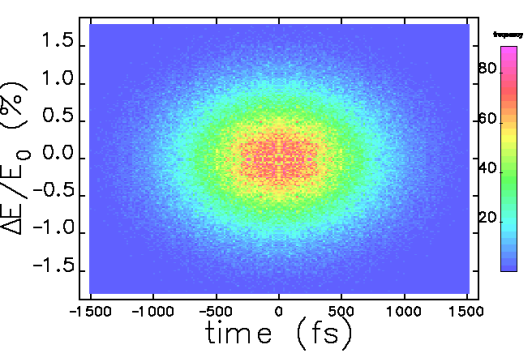


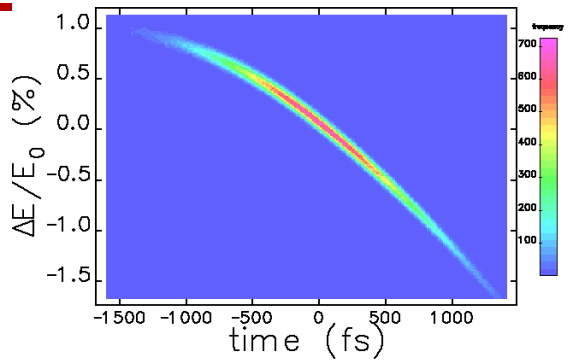
Chicane w/ quadrupole+sextupole, **6 meters long**
R_{56} tunable, T_{566} tunable

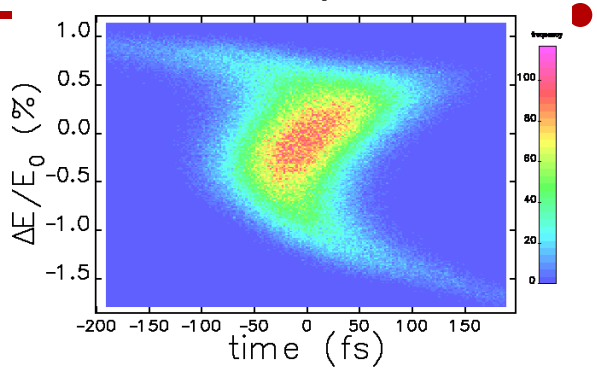
K1_Q < 18 (0.13m Quad)
K2_S < 70 (0.1m sextupole)

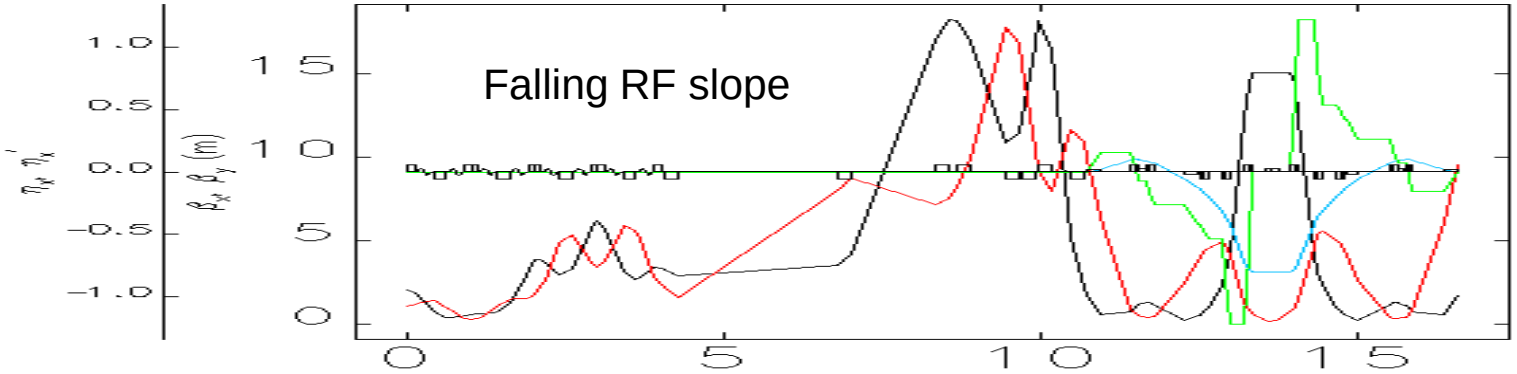
Scheme 2 (2) L phase and current

Over compression

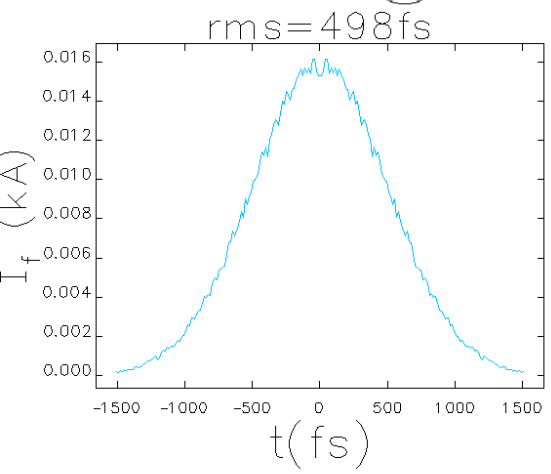


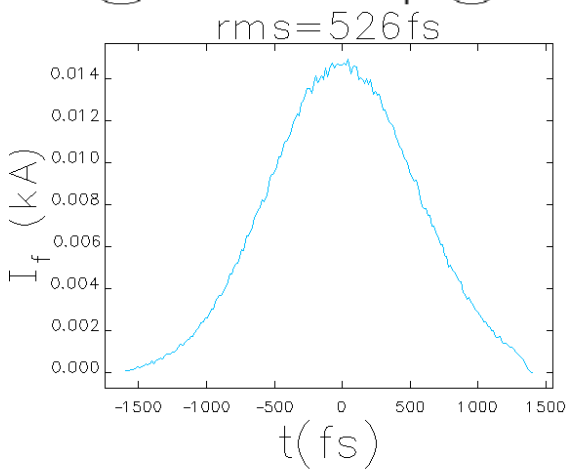


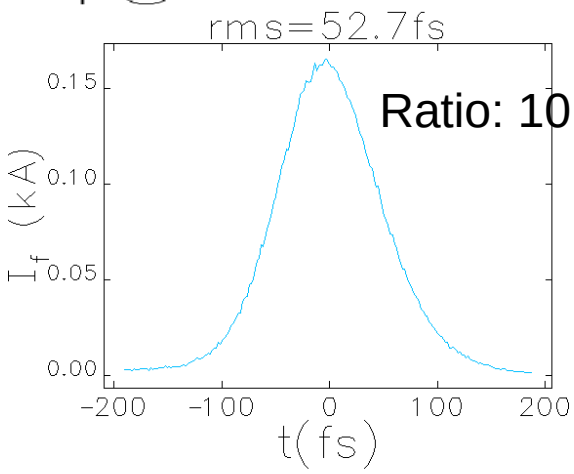




R56=0.03m
T566=0.6m

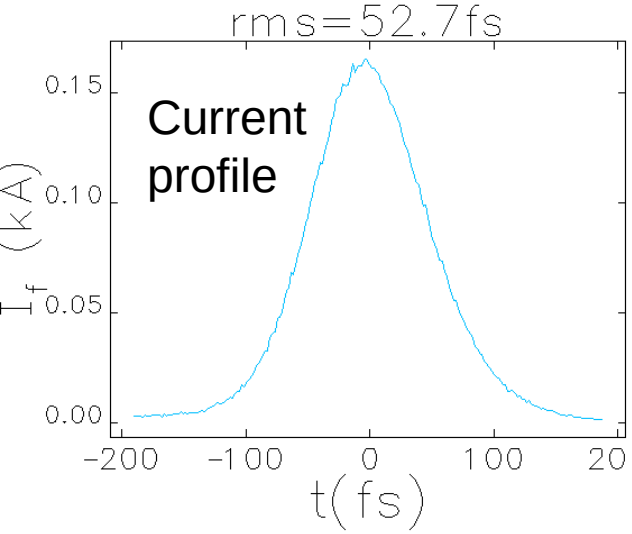


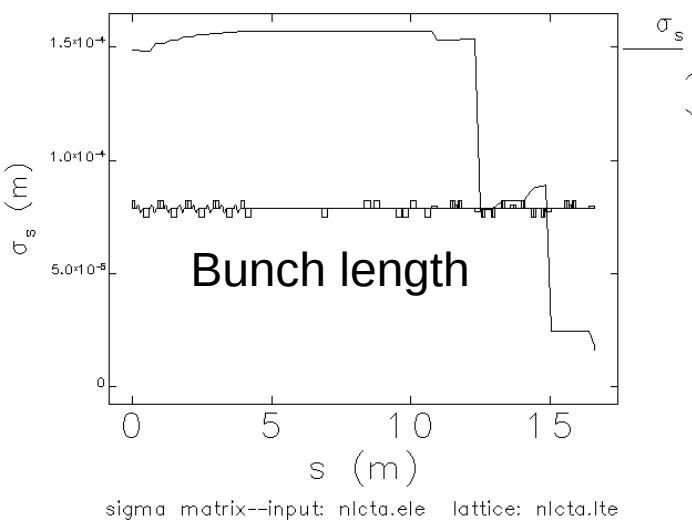


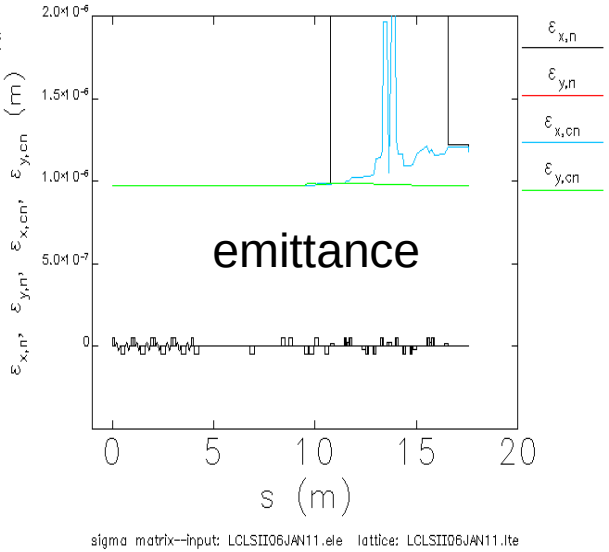


Ratio: 10

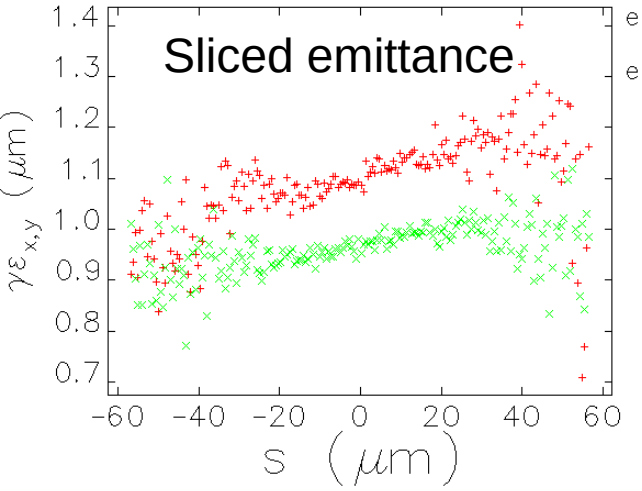
Scheme 2 (3) 1 stage 10 times BC, linac end

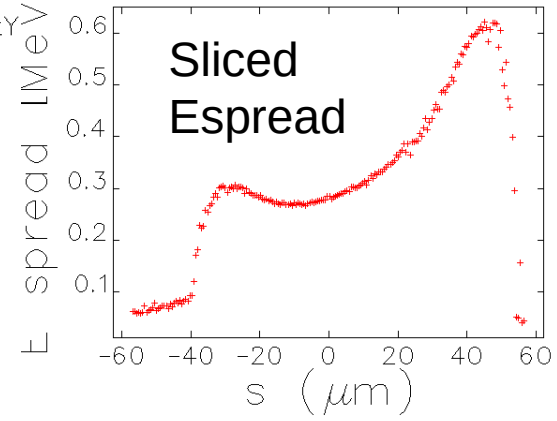


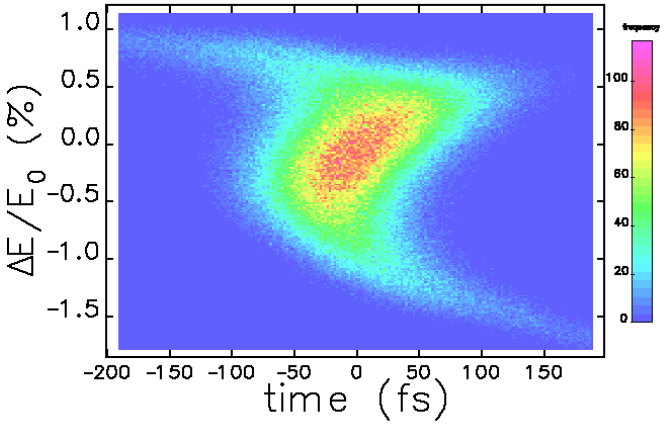




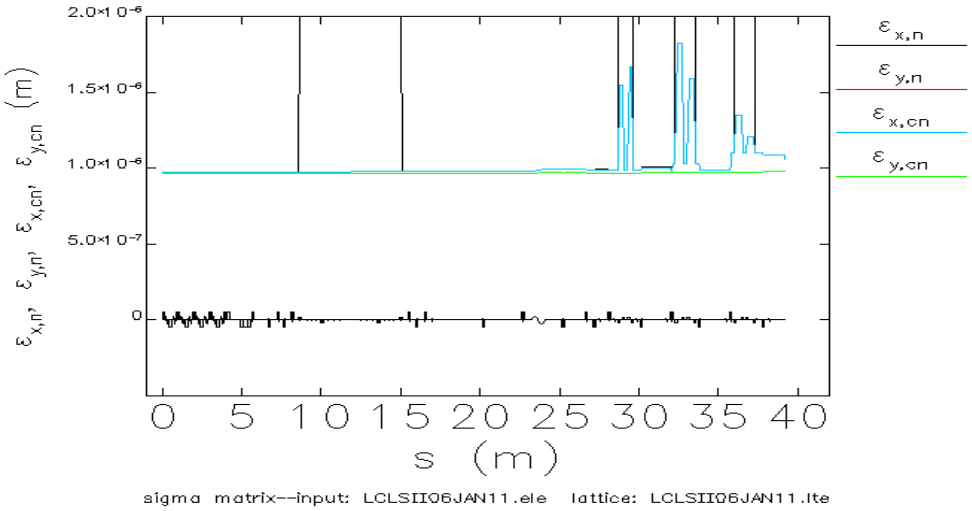
enx=1.20um
eny=0.97um



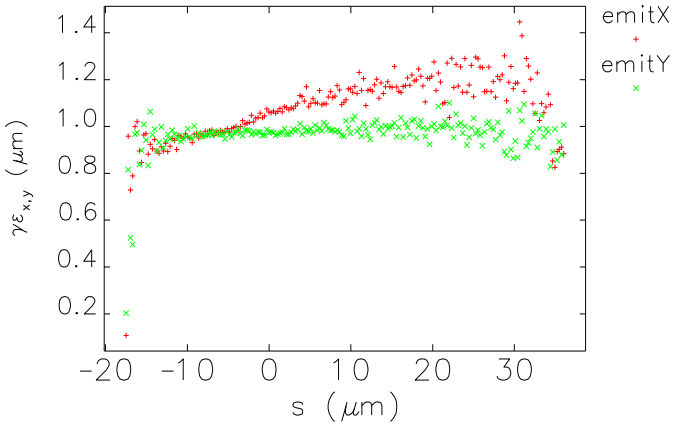




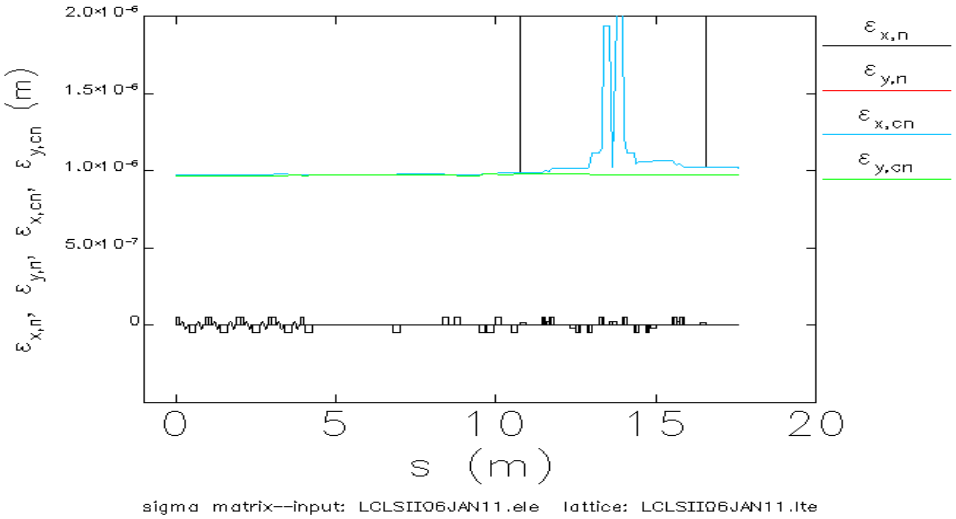
Effect of CSR, scheme1&2



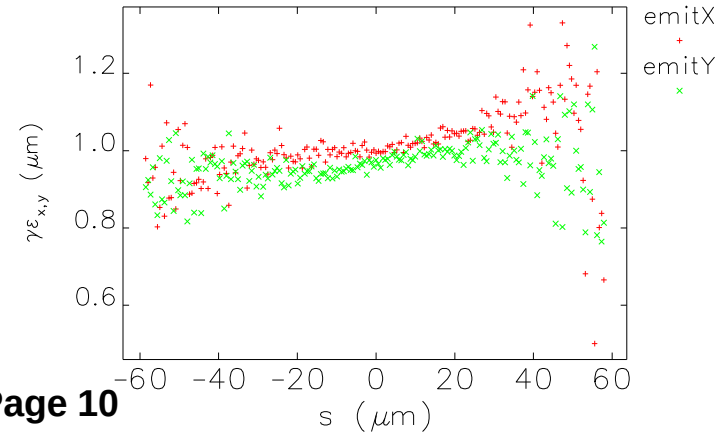
scheme1



CSR=0 in all bends and CSRDRIFT



scheme2

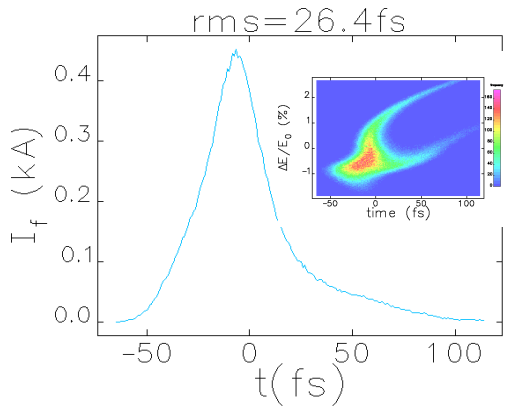


Effect of timing jitter, scheme1&2

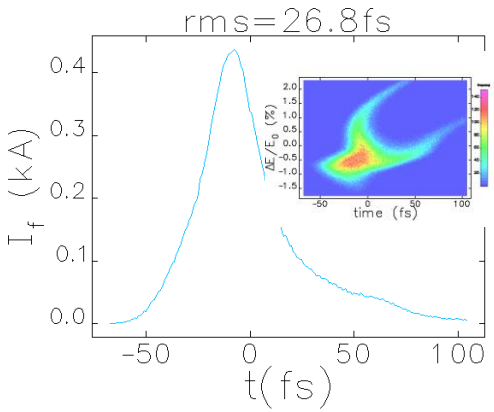
Timing jitter between **laser** and **RF** (assumed same for two RF sections)

scheme1

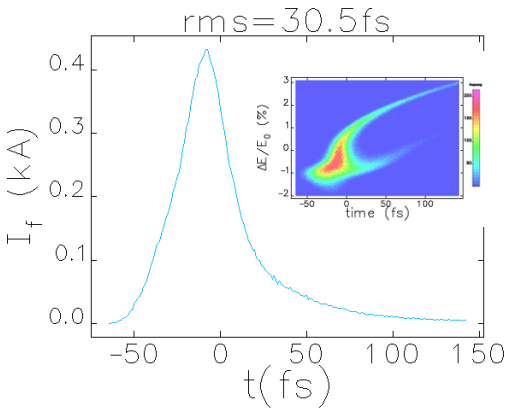
On phase

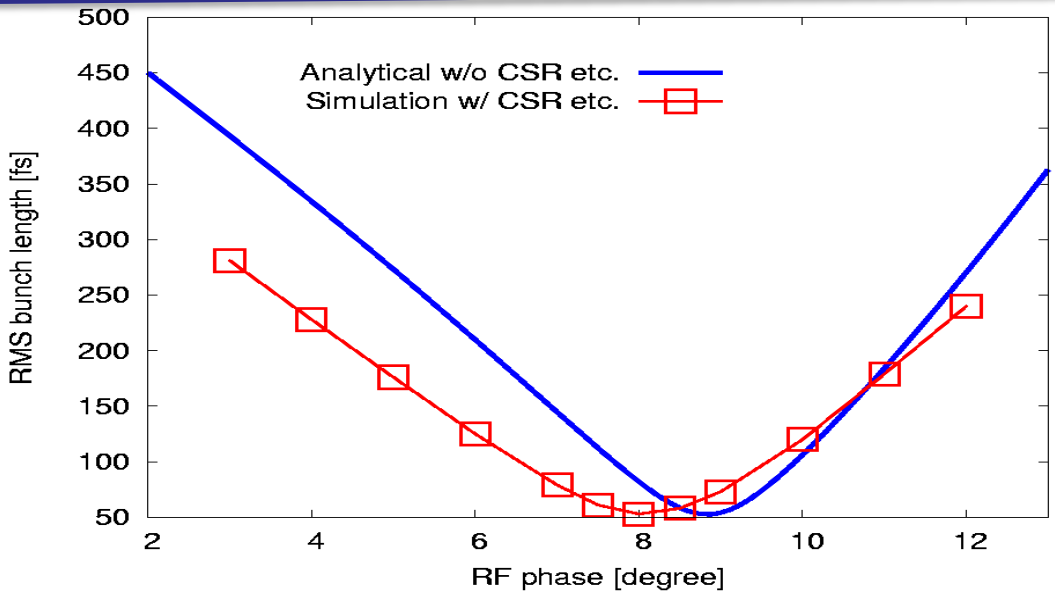


+ 115 fs (0.5 degree)



- 115 fs



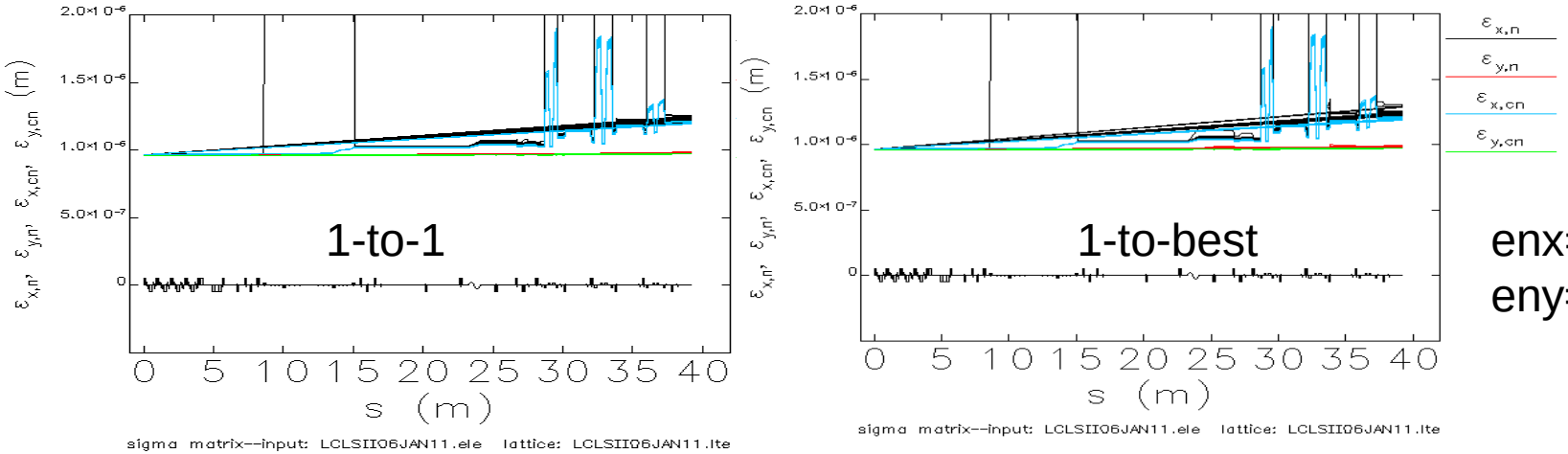


Deviation between analytical formulae and simulation due to:

- ❖Approximation in analytical model, neglected terms
- ❖Collective effects in simulation

scheme2

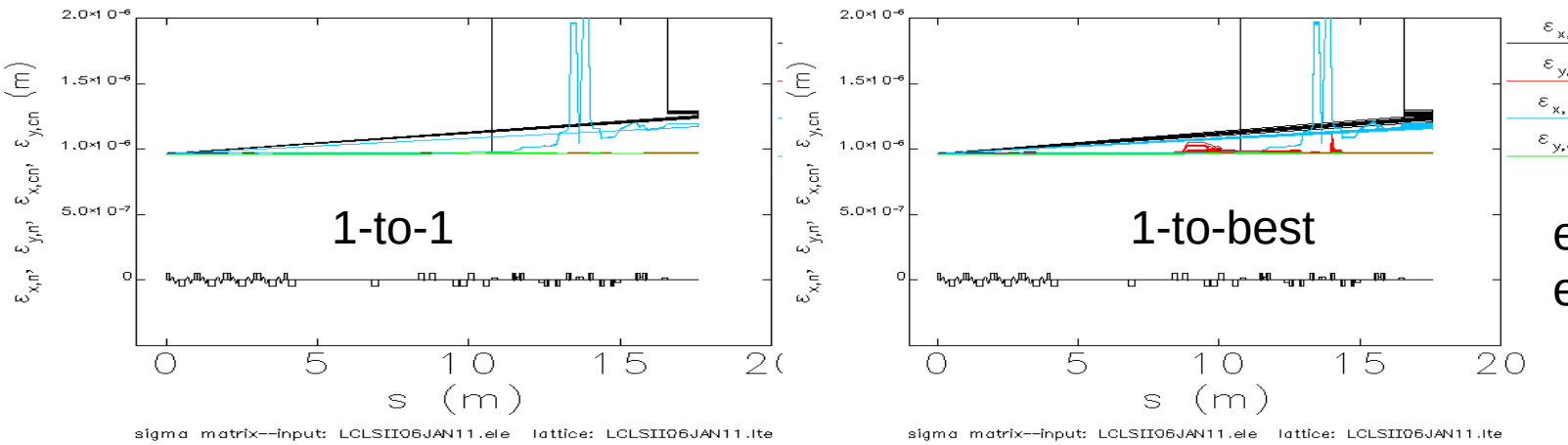
Effect of Quad+ACC alignment, scheme1&2



scheme1

enx=1.23um
eny=0.97um

Quad, ACC, Quad-BPM offset RMS=200um (x&y); Quad roll RMS=200urad
20 seeds



scheme2

enx=1.24um
eny=0.97um

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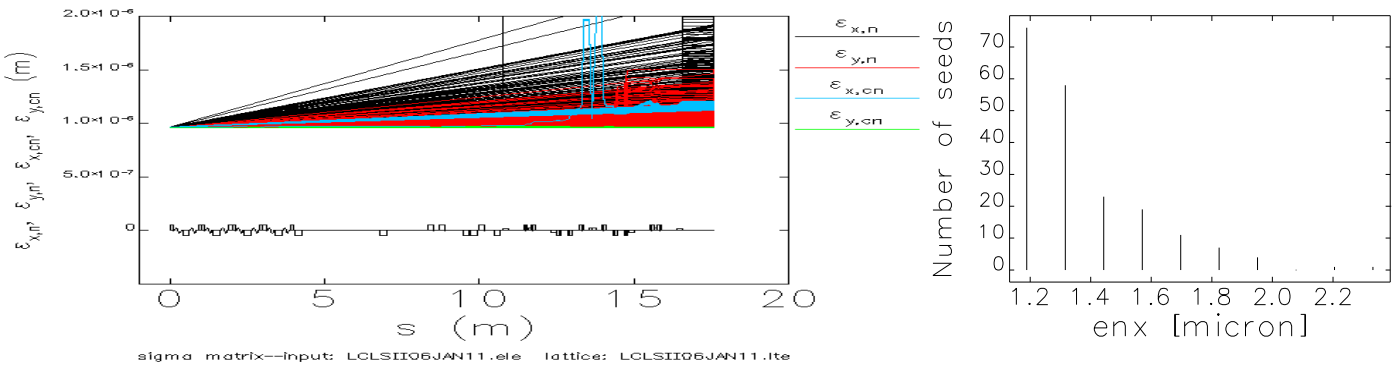
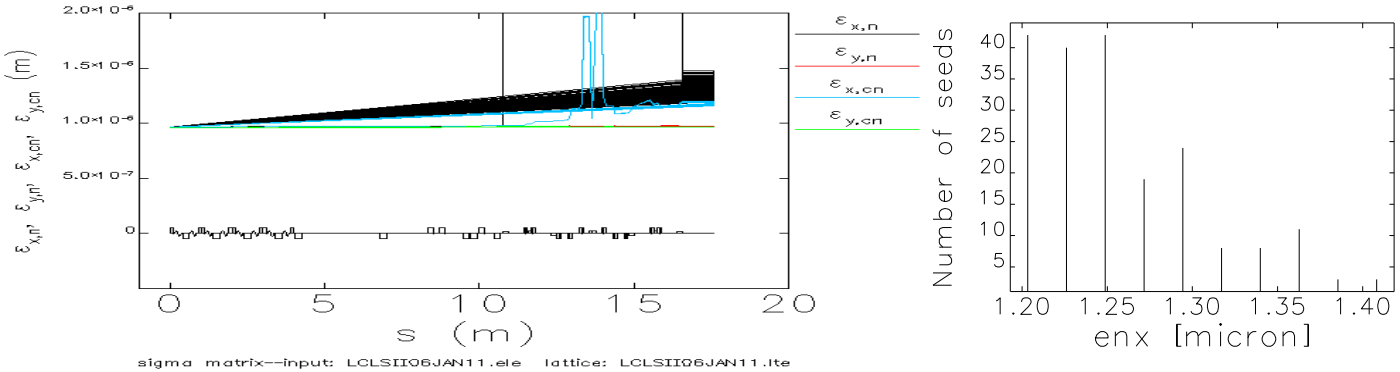
enx0=1.20um eny0=0.97um

Effect of BC Quad+Sext alignment, scheme2



No correction
enx=1.36um
eny=1.04um



1-to-1
enx=1.26um
eny=0.97um

Quad, **Sextupole**, Quad-BPM offset RMS=200um (x&y)
Quad, **Sextupole**, roll RMS=200urad
200 seeds

enx0=1.20um eny0=0.97um

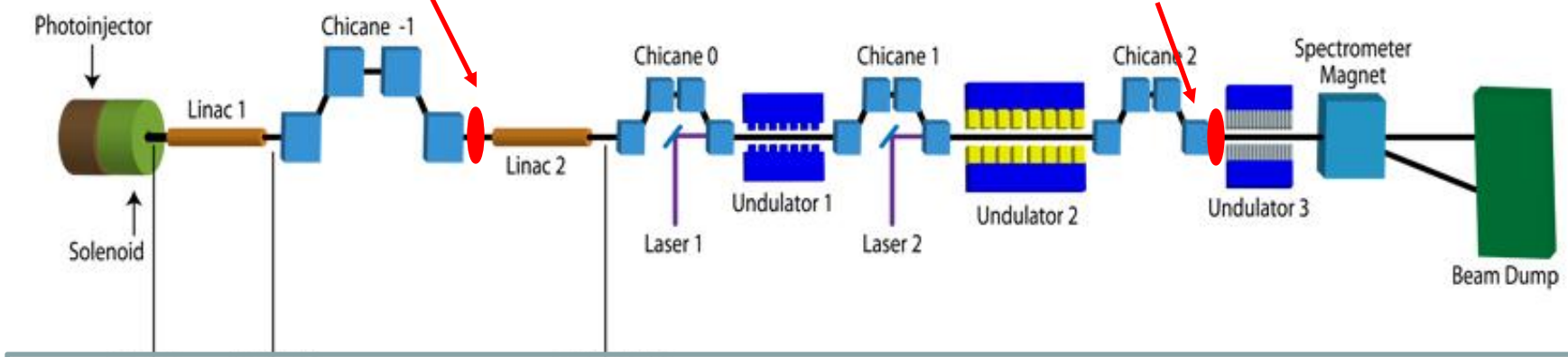
Bunch length diagnostics

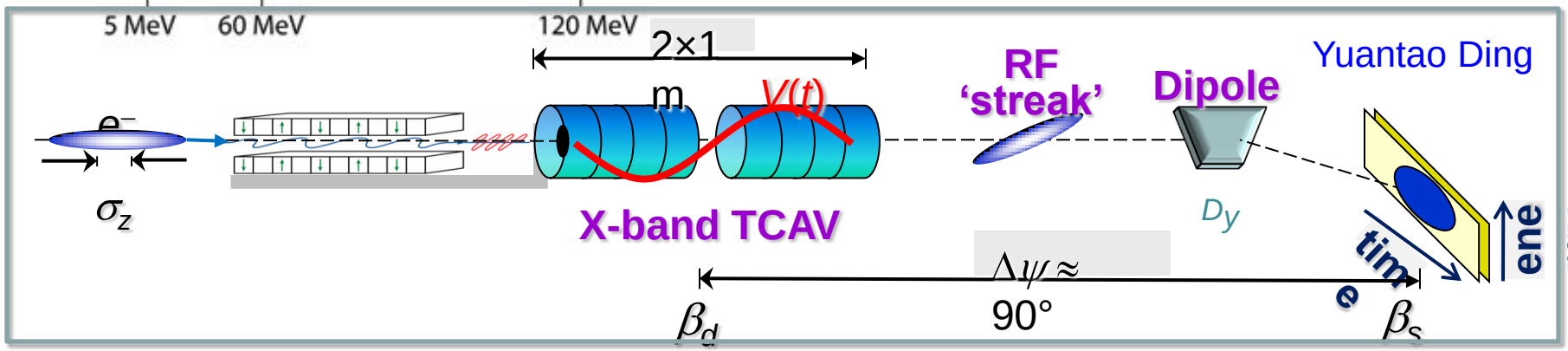
X-band transverse deflecting cavity

TCAV1 to increase σ_E

Dao Xiang

TCAV2 to measure slice parameters





$$\sigma_x^2 = \sigma_{x0}^2 + \beta_d \beta_s \sigma_z^2 \left(\frac{k_{RF} e V_0}{E_s} \sin \Delta\psi \cos\phi \right)^2$$

$$\sigma_y^2 = \sigma_{y0}^2 + (D_y \delta)^2$$

High resolution,
~ few fs;

Summary

- Two bunch compression schemes proposed at NLCTA
- 10-20 times compression ratio
- Tolerances acceptable in simulation
- Measured by X-band TCAV

	Initial	Scheme 1	Scheme 2
Energy [MeV]	5	120	60
Bunch length [fs]	500	26	50
Peak current [A]	15	450	160
Emittance x/y [um]	1/1	1.2/1	1.2/1
Energy spread [%]	0.6	0.8	0.5

I would like to thank the following people for their great help and useful discussions:

C. Adolphsen , K. Bane, A. Chao, Y. Cai, Y. Ding, J. England, P. Emma, Z. Huang, C. Limborg, Y. Jiao, Y. Nosochkov, T. Raubenheimer, M. Woodley, W. Wan, J. Wu

Thank you for your patience!