LCLS Tracking Studies

- CSR micro-bunching in compressors
- Superconducting wiggler can reduce effect
- FEL gain evaluation after system tracking

Paul Emma

January 17, 2002

CSR Workshop

ICFA Beam Dynamics Panel Mini-Workshop

FUTURE LIGHT SOURCES

UCLA

Advanced Photon Source

Los Alamos

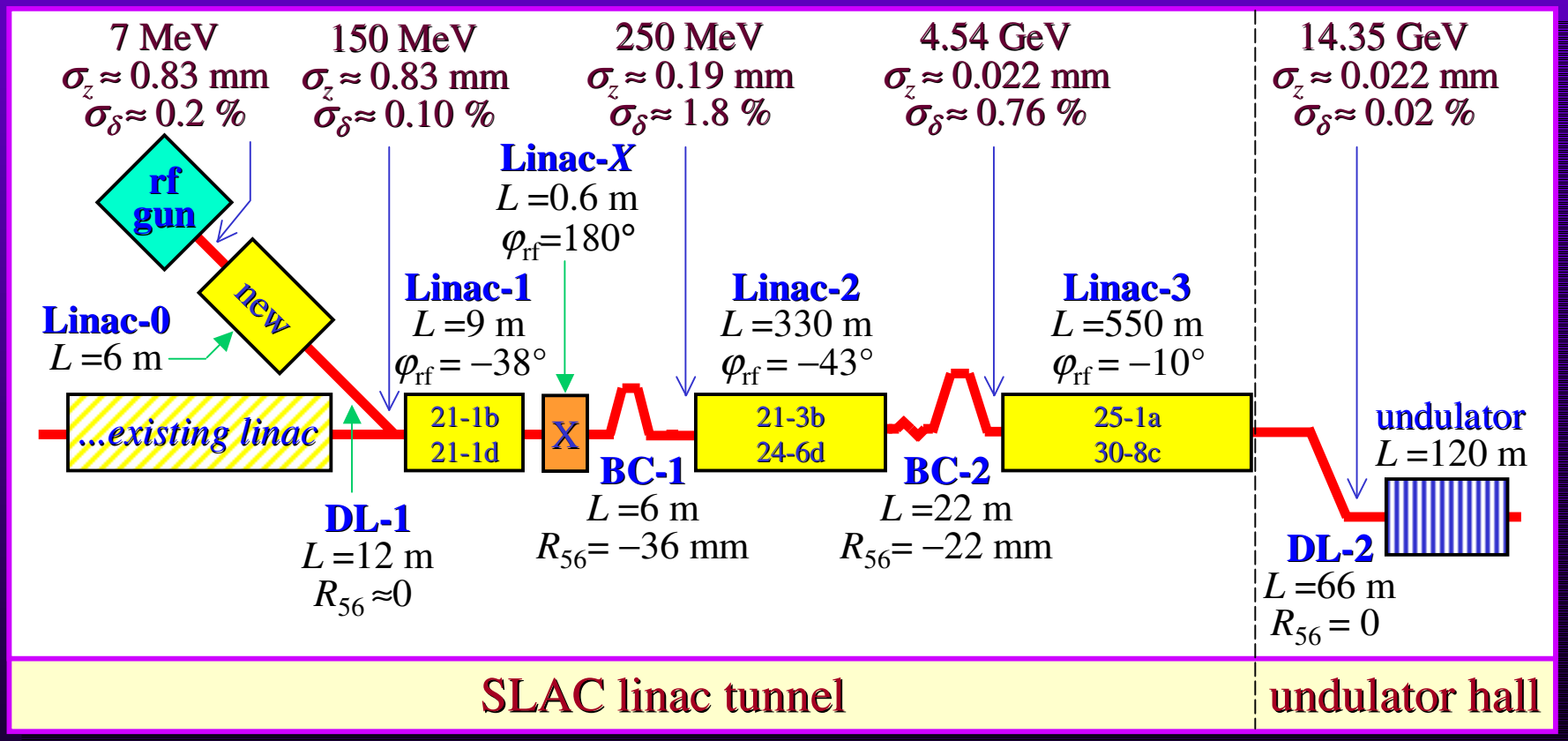
BROOKHAVEN NATIONAL LABORATORY

Stanford Linear Accelerator Center

SSRL

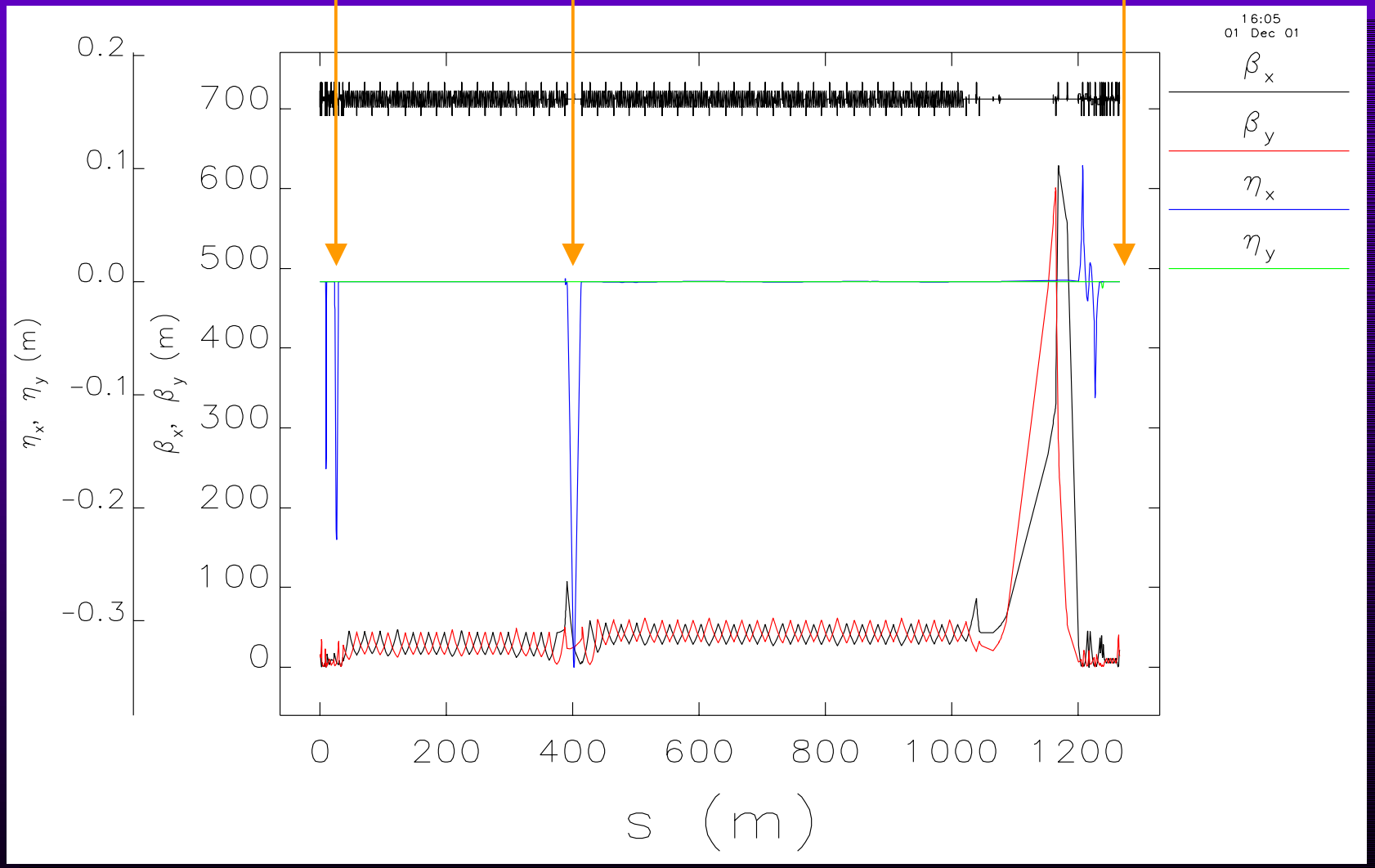
LLNL

LCLS Accelerator and Compressor Schematic

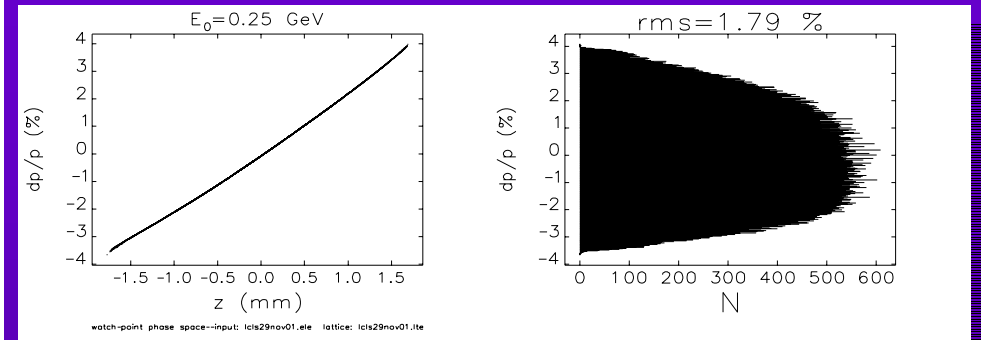


(12/01/01)

LCLS Linac Layout



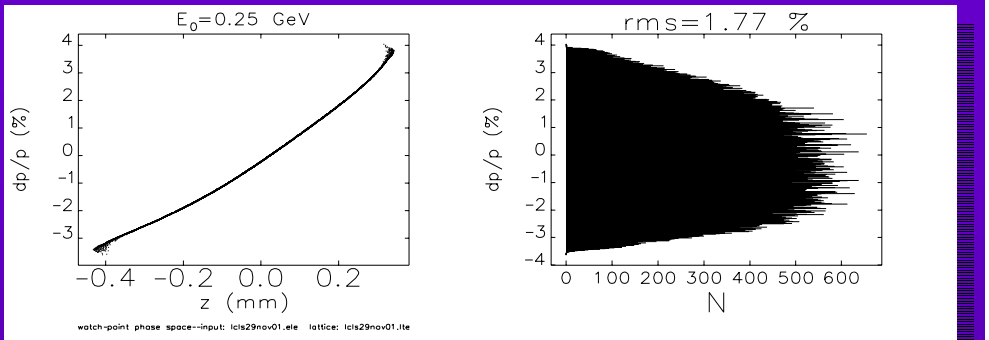
Compression Evolution using *Elegant**



before BC1

$E = 250$ MeV

$\sigma_z \approx 830\ \mu$m

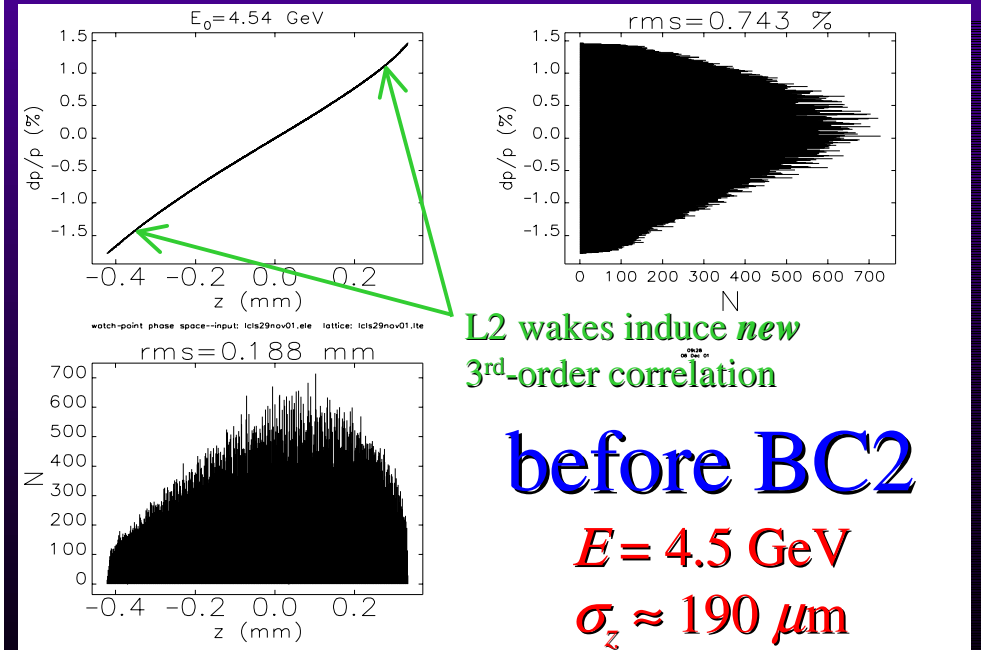


after BC1

$E = 250$ MeV

$\sigma_z \approx 190\ \mu$m

under-compression of head & tail from 3rd-order term

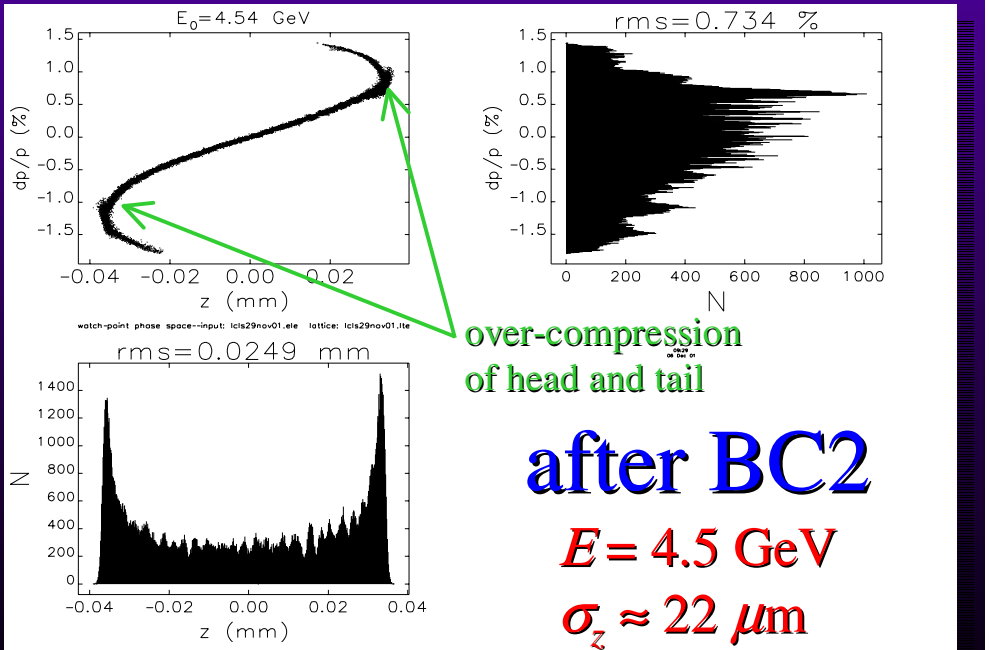


L2 wakes induce *new* 3rd-order correlation

before BC2

$E = 4.5$ GeV

$\sigma_z \approx 190\ \mu$m



over-compression of head and tail

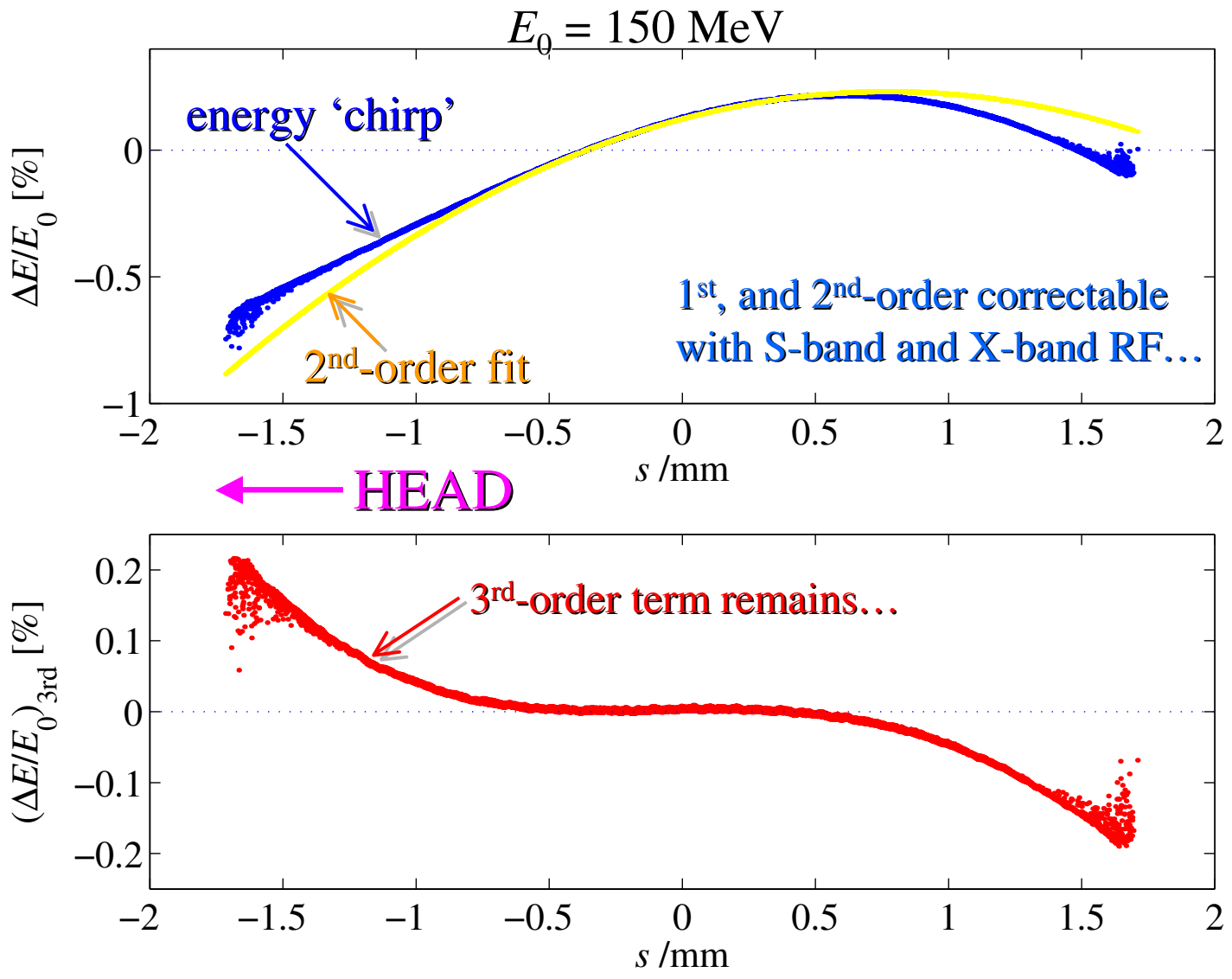
after BC2

$E = 4.5$ GeV

$\sigma_z \approx 22\ \mu$m

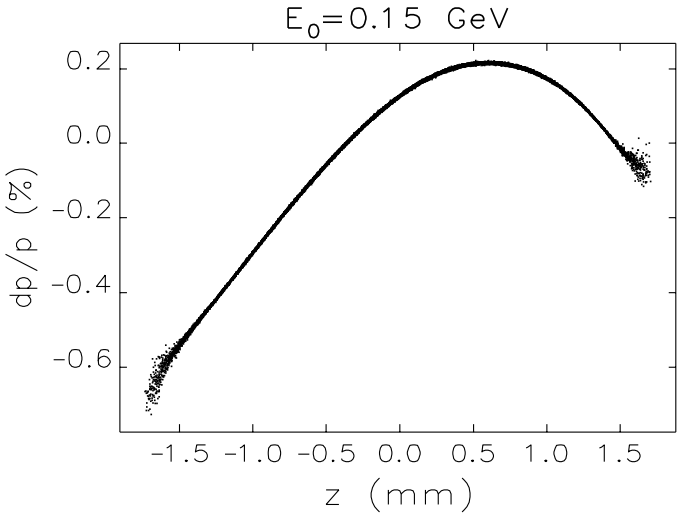
* written by M. Borland, ANL/APS

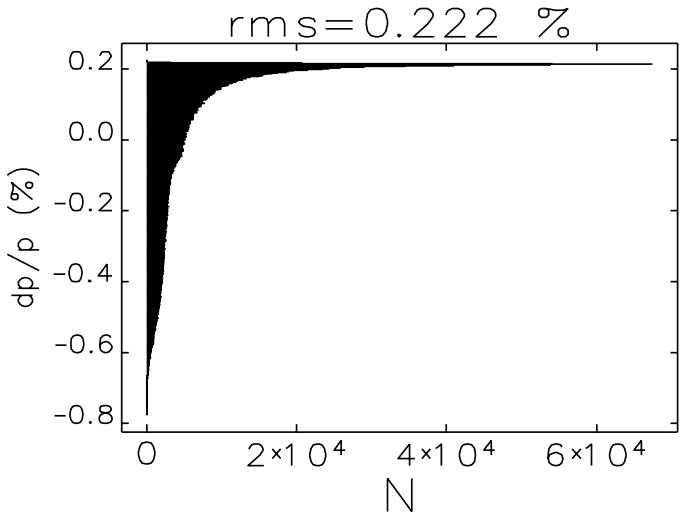
3rd-order energy-time correlation from injector

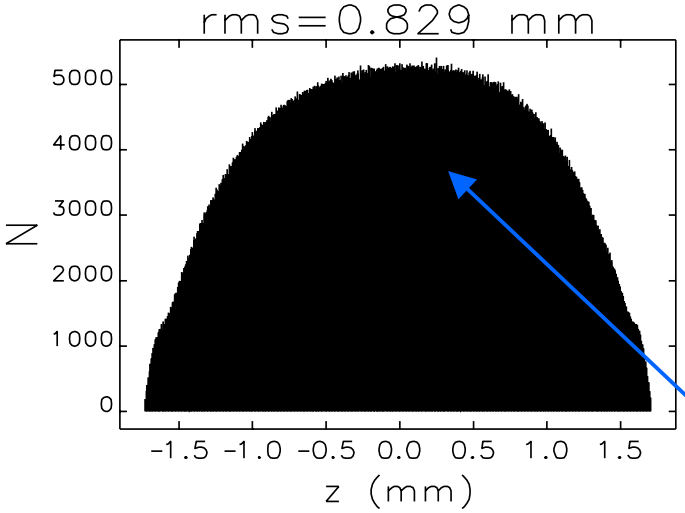


3rd-order term generated with space charge and $\lambda'(s)$ in gun-to-linac drift (C. Limborg)

Smoothed Parmela dist. input to LCLS





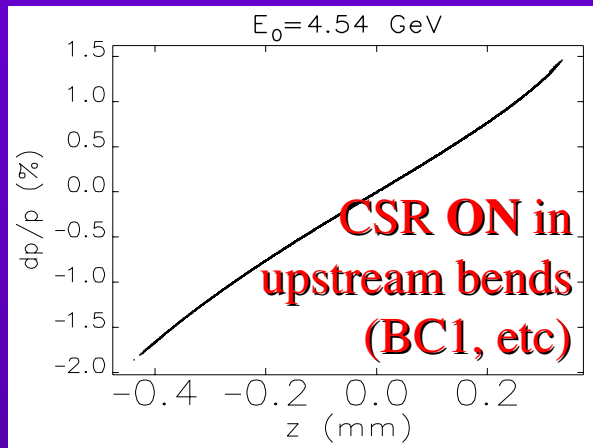


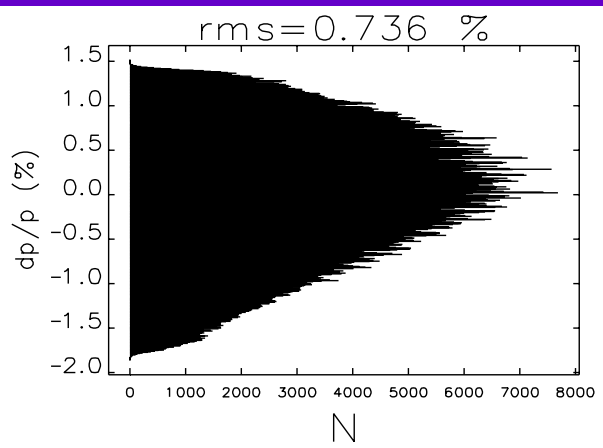
$N = 2\times10^6$

plus temporal smoothing

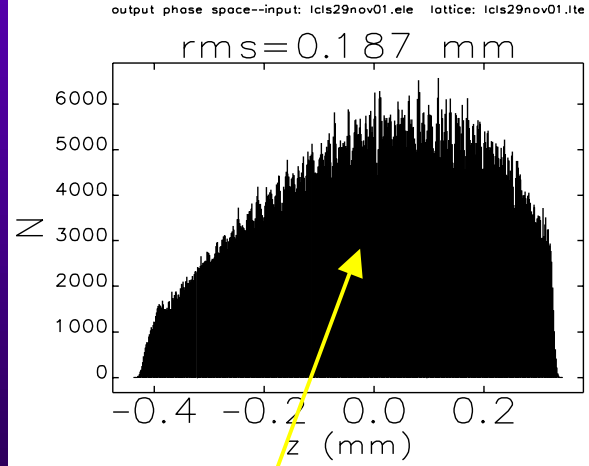
at 150 MeV, before any bends

LCLS bunch tracked to start of BC2

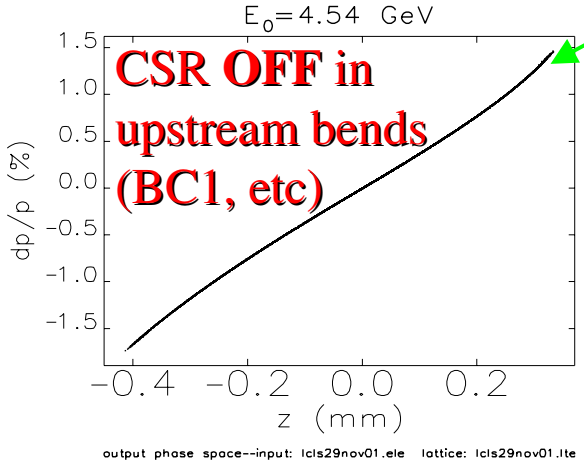


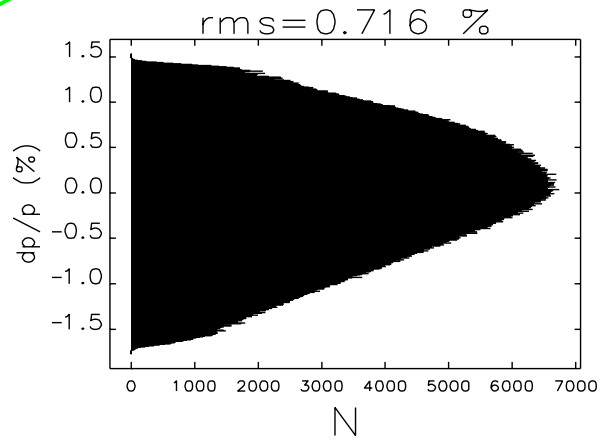


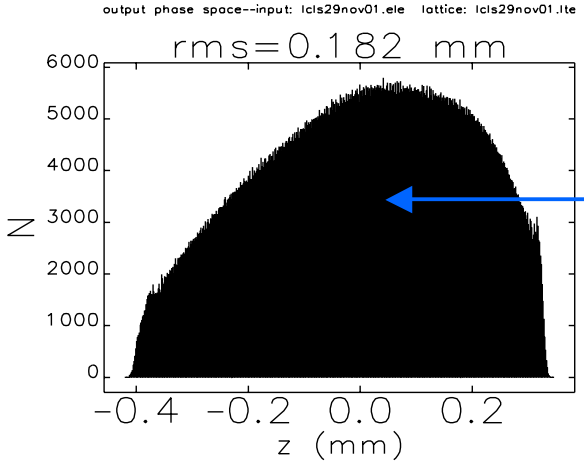
cubic correlation term generates head/tail spikes at end of chicane



CSR in BC1 causes microbunching at entrance to BC2

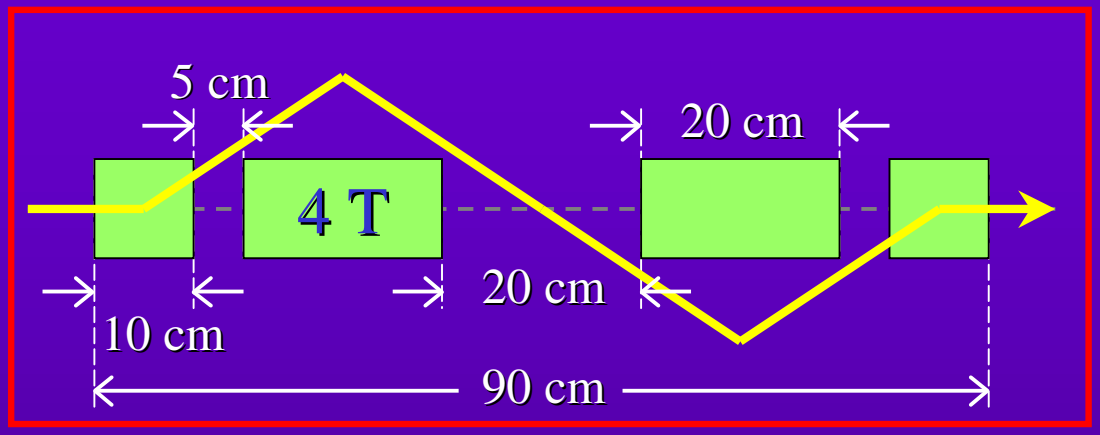






…otherwise have smooth dist. at BC2 entrance

Superconducting Wiggler in *LCLS*…



Add Super-Conducting wiggler prior to BC2 to increase incoherent energy spread (×10)

At BC2:

$E_0 = 4.54$ GeV

$\sigma_E/E_0 \approx 3\times10^{-5}$

$\Delta\varepsilon_x/\varepsilon_{x0} \approx 7\%$

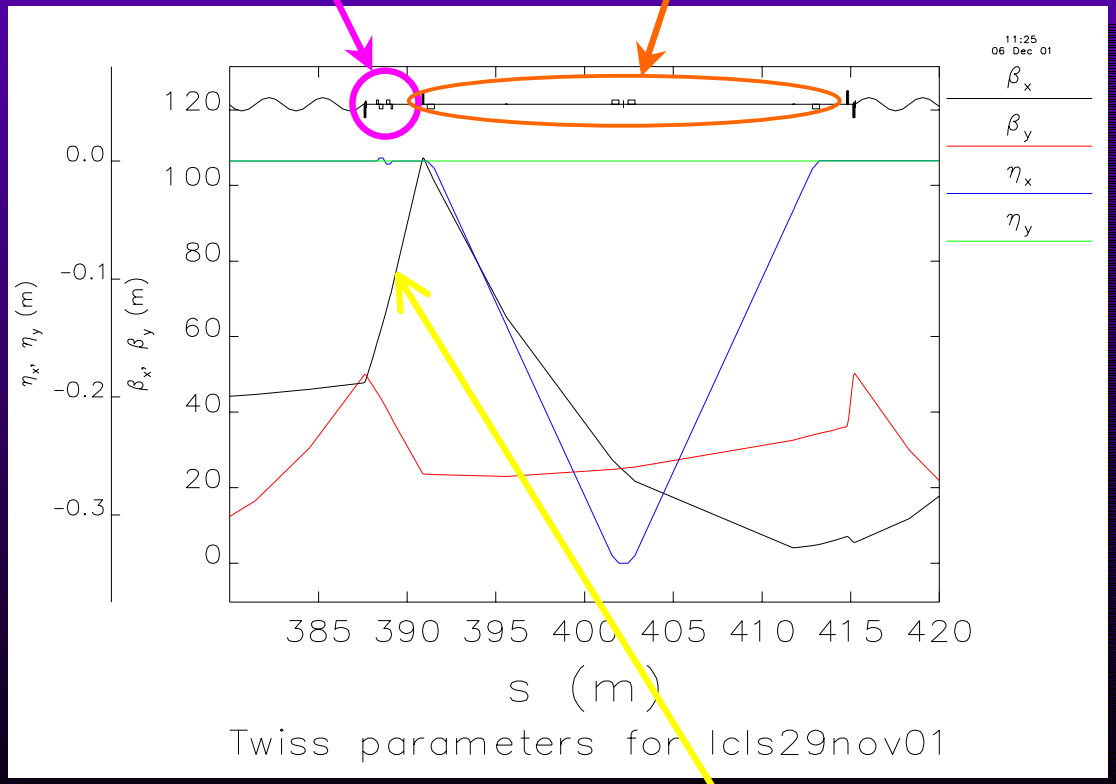
At Undulator:

$E_1 = 14.3$ GeV

$\sigma_{z0} \approx 195\ \mu$m

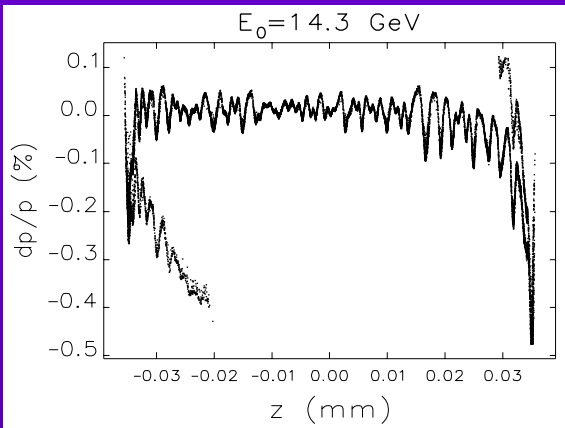
$\sigma_{z1} \approx 22\ \mu$m

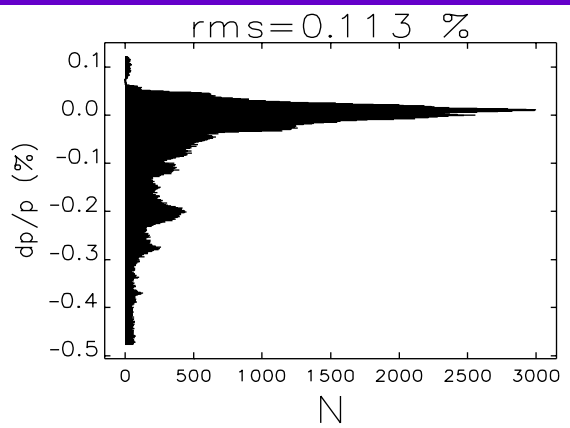
$(\sigma_{z0}/\sigma_{z1})\sigma_E/E_1 \approx 8.4\times10^{-5}$



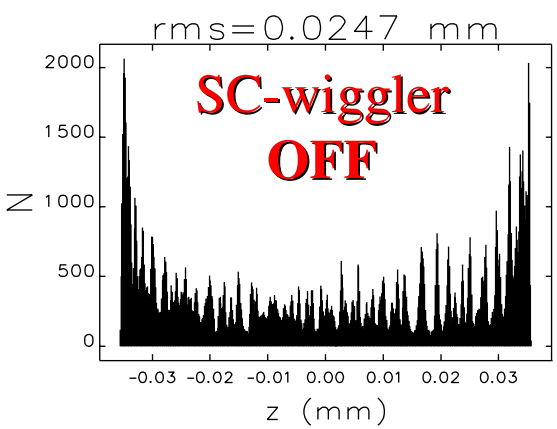
wiggler field limited by β-function

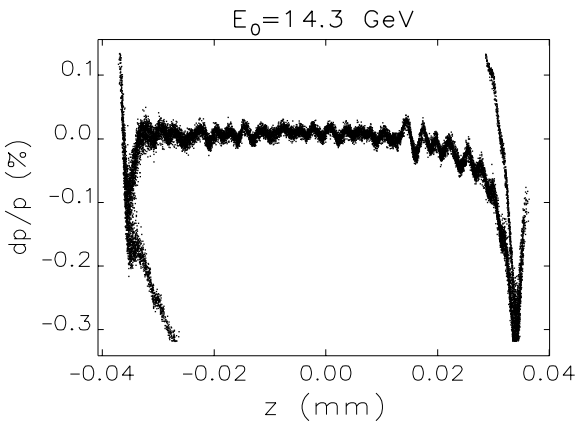
Superconducting wiggler **OFF**

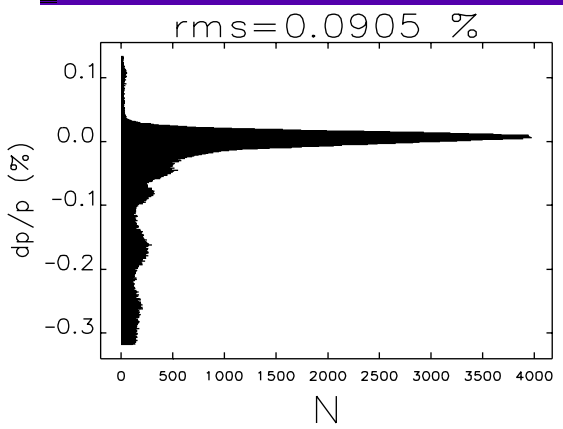




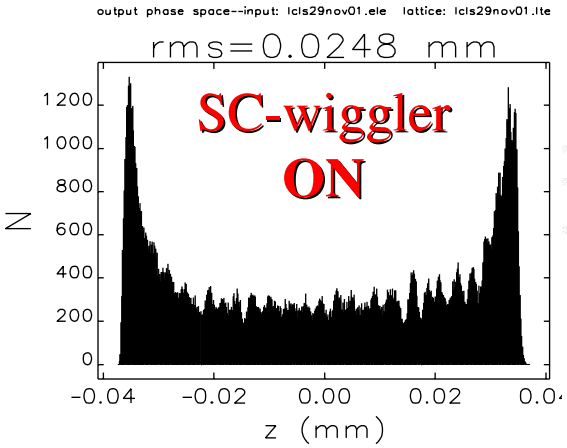
Using Stupakov CSR model (based on Saldin et. al.) and *Elegant* tracking

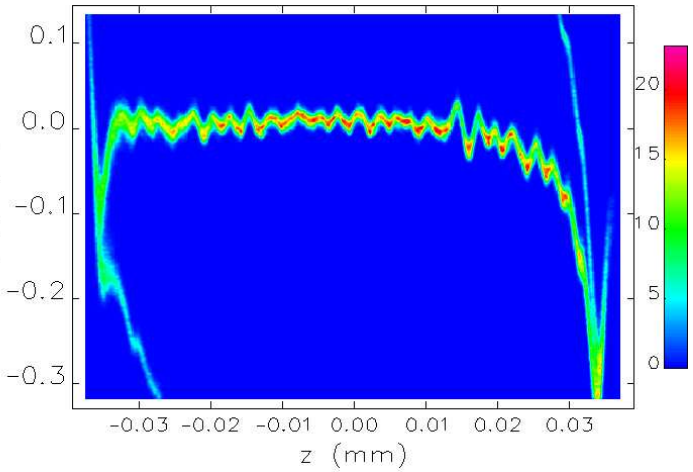




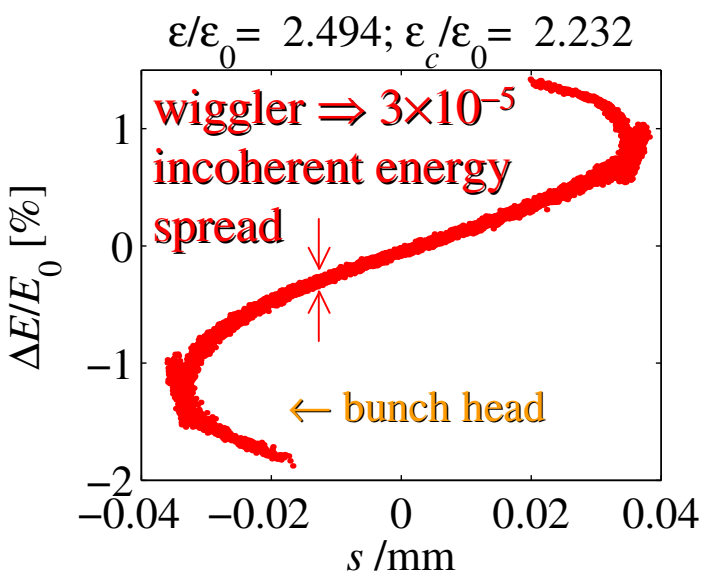


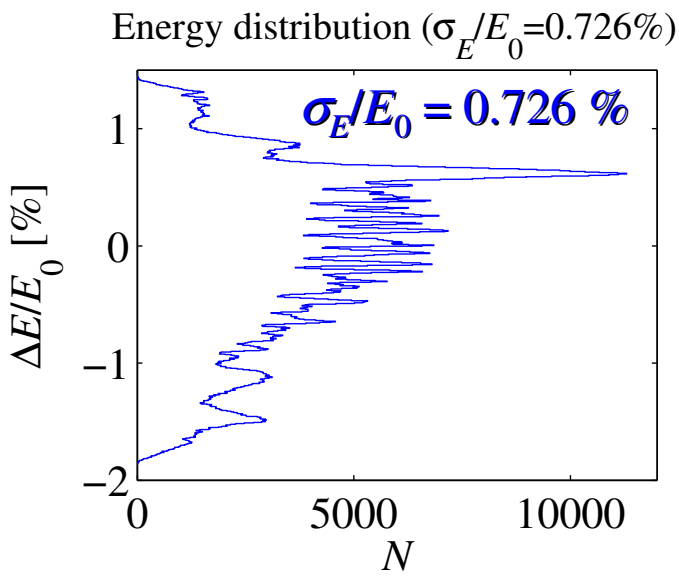
CSR may still be over-estimated in present tracking

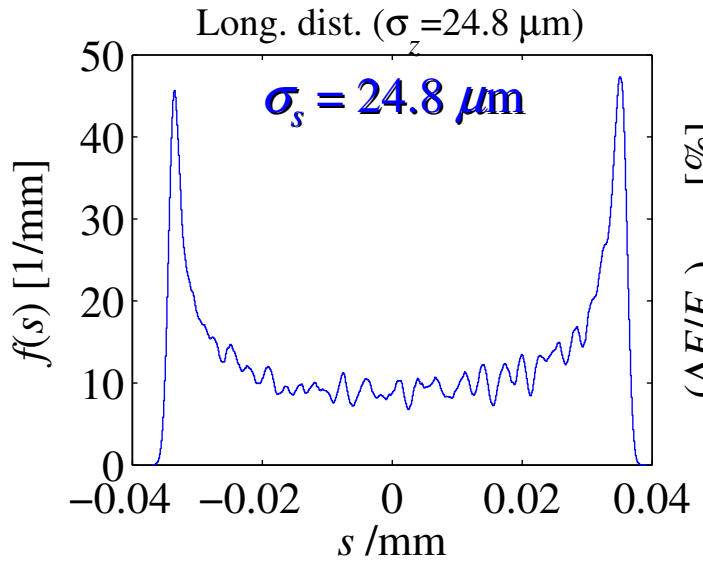


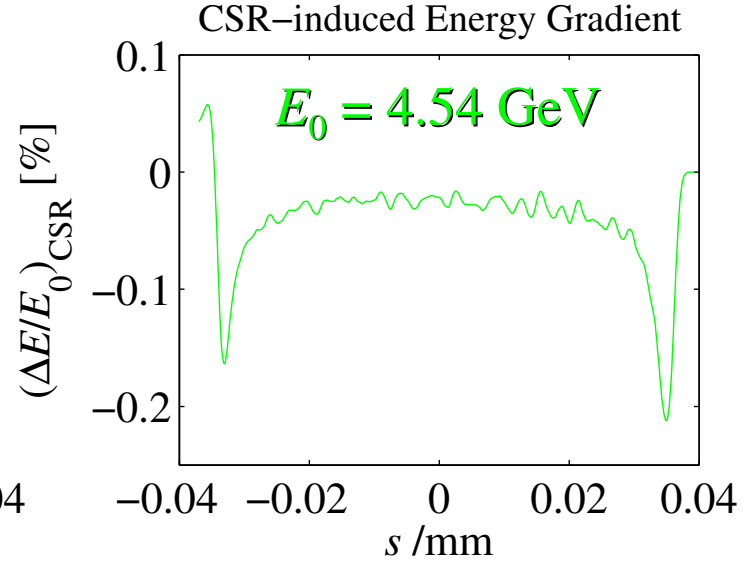


LCLS Distribution After BC2 Chicane
(SC-wiggler ON, CSR ON in upstream bends)

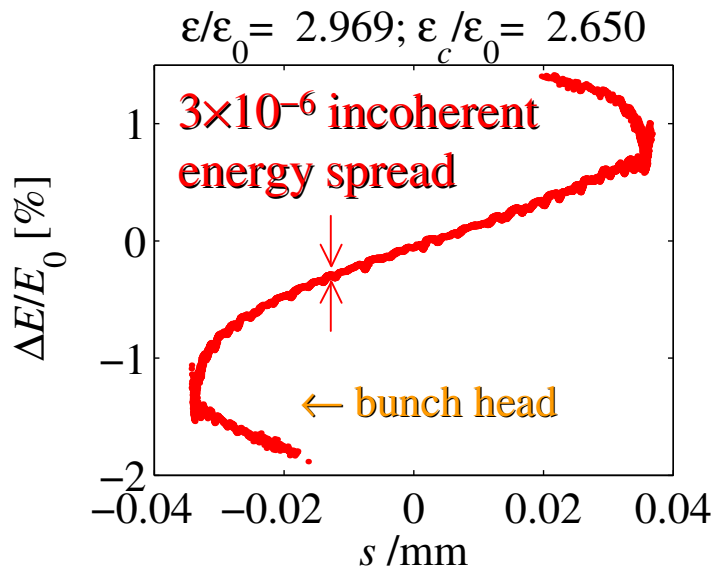


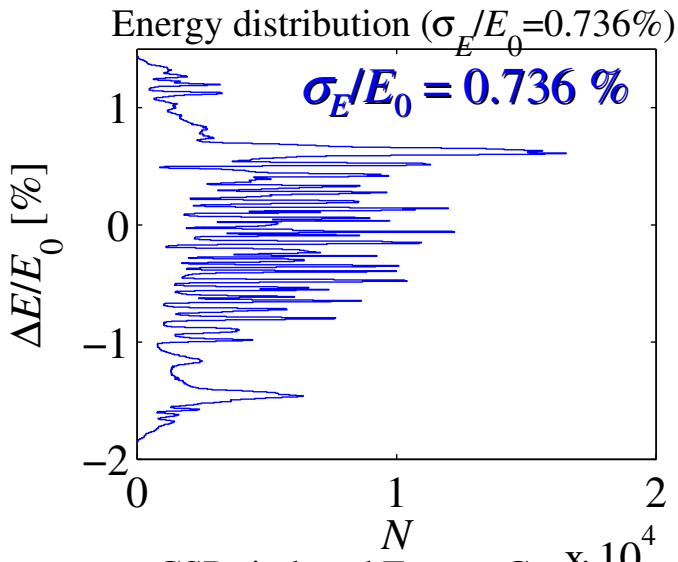


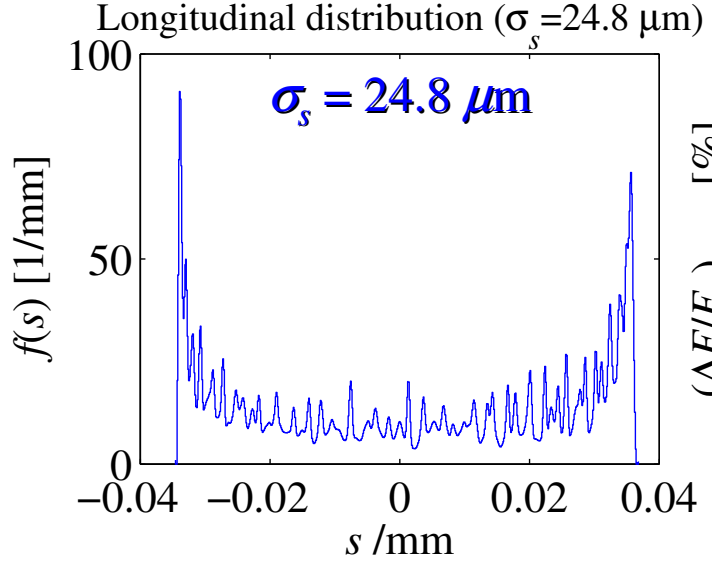


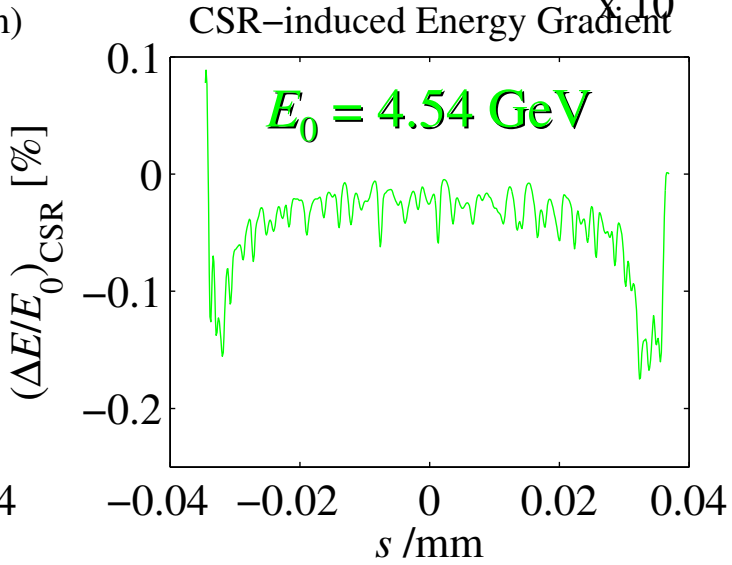


LCLS Distribution After BC2 Chicane
(SC-wiggler OFF, CSR ON in upstream bends)

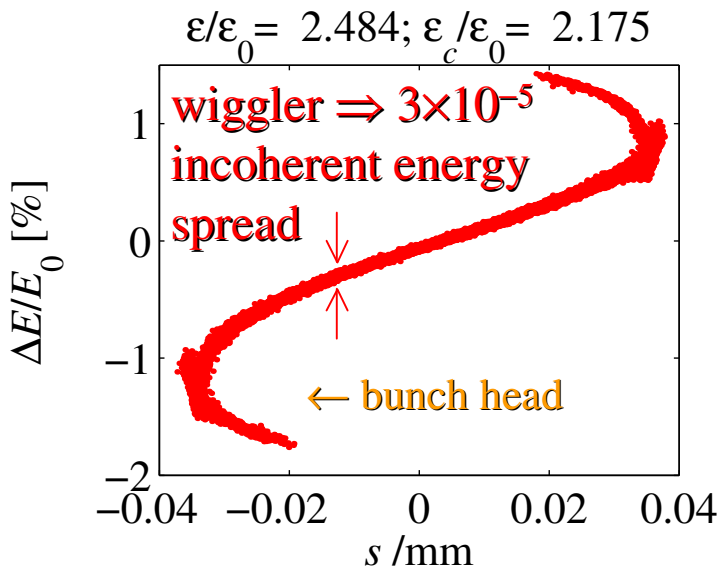


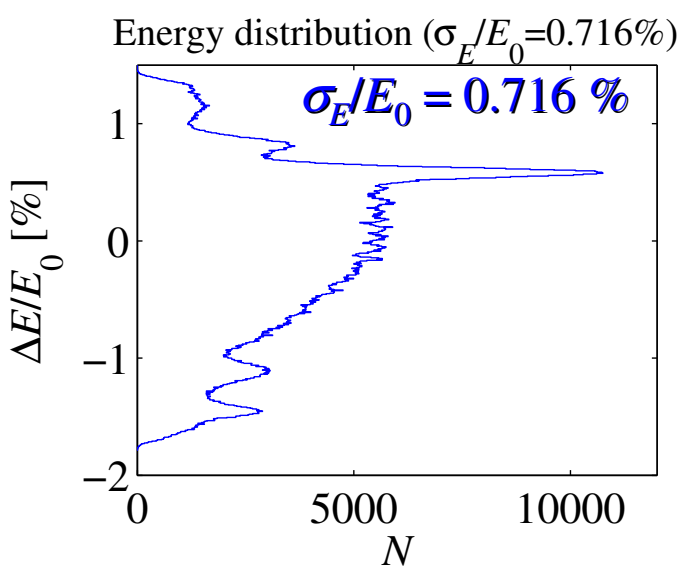


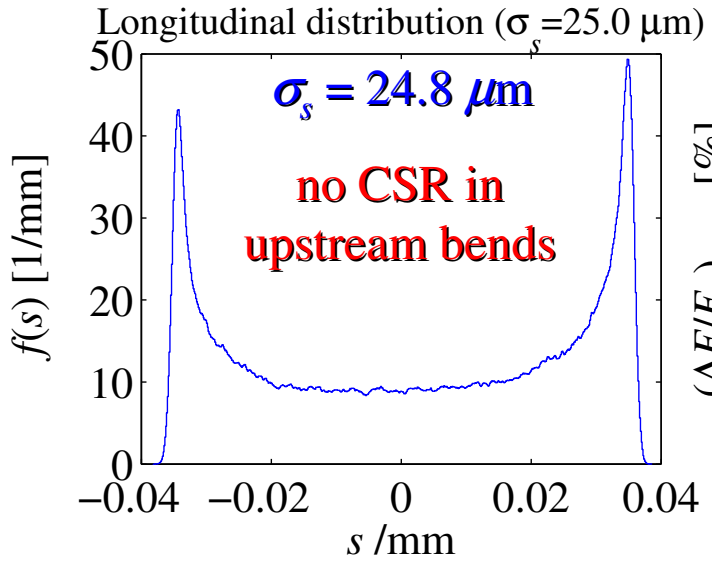


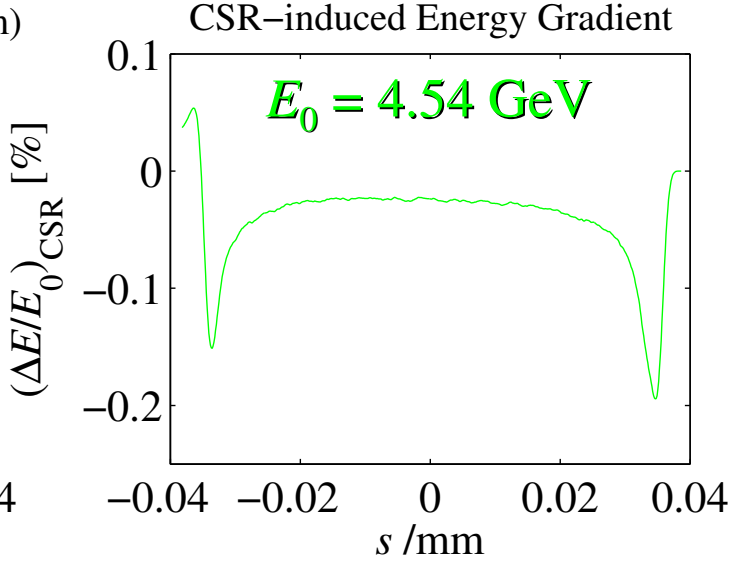


LCLS Distribution After BC2 Chicane
(SC-wiggler ON and CSR OFF in upstream bends)

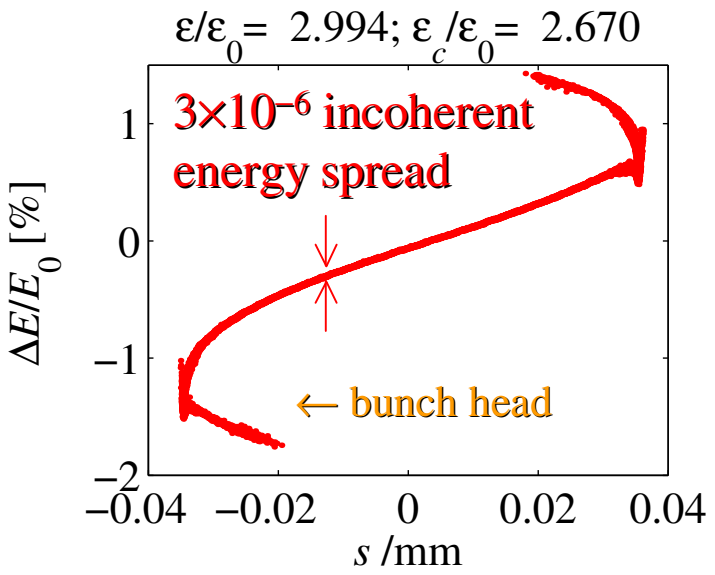


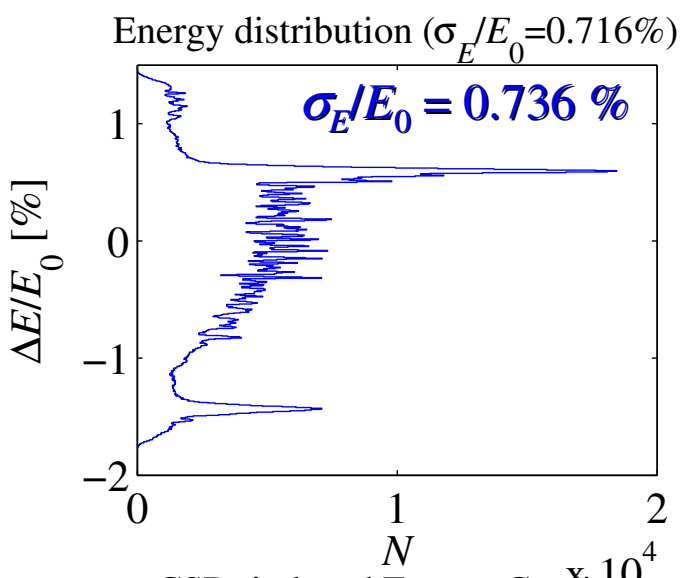


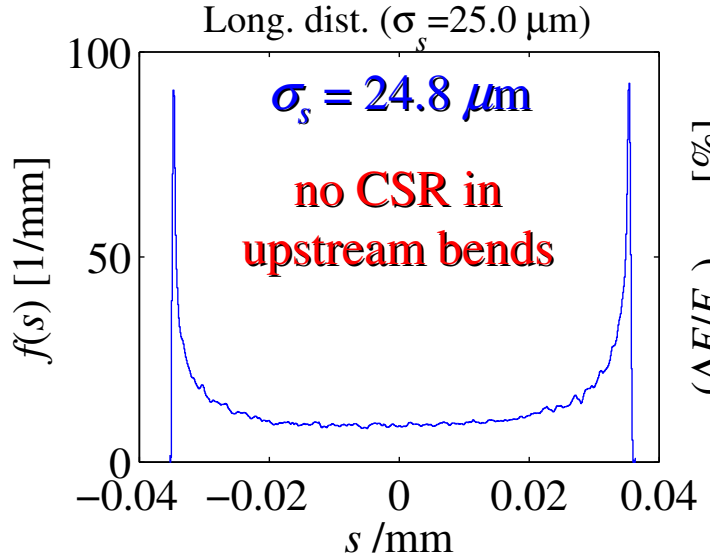


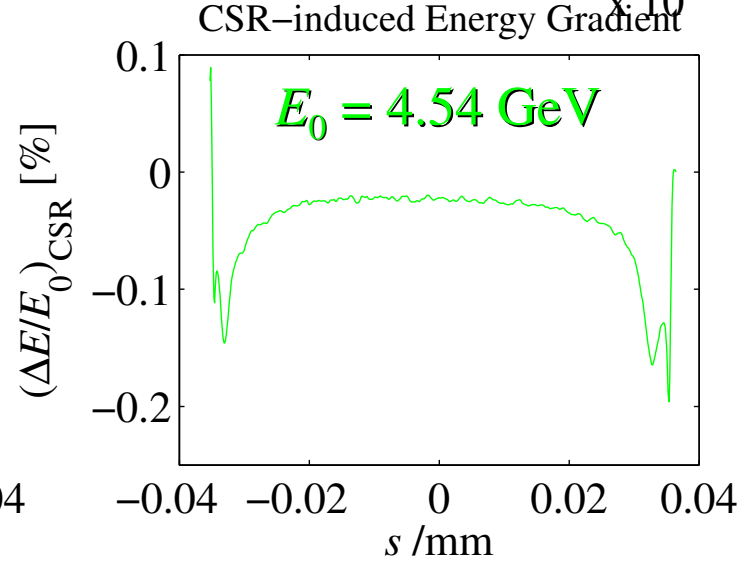


LCLS Distribution After BC2 Chicane
(SC-wiggler OFF, CSR OFF in upstream bends)

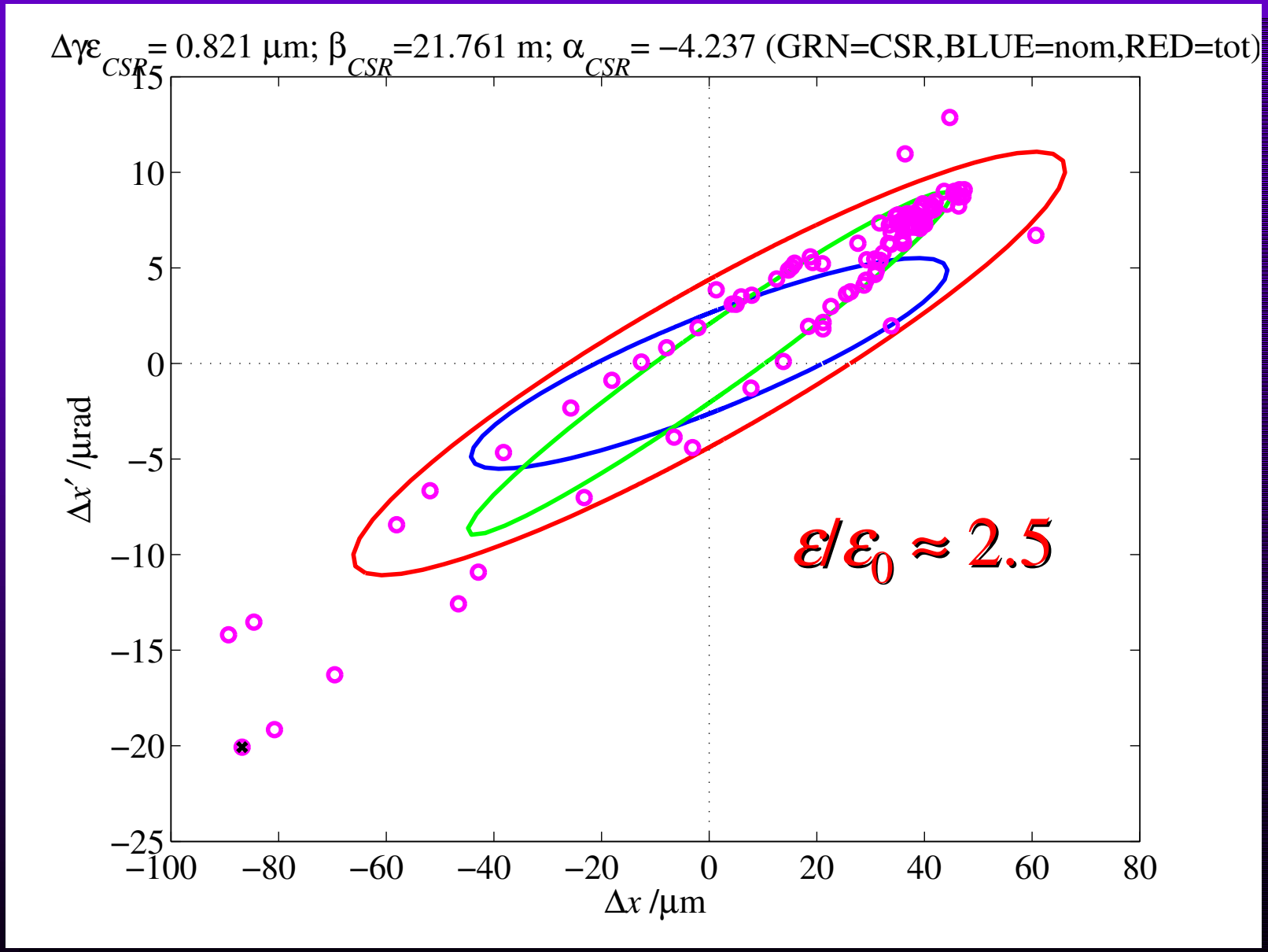




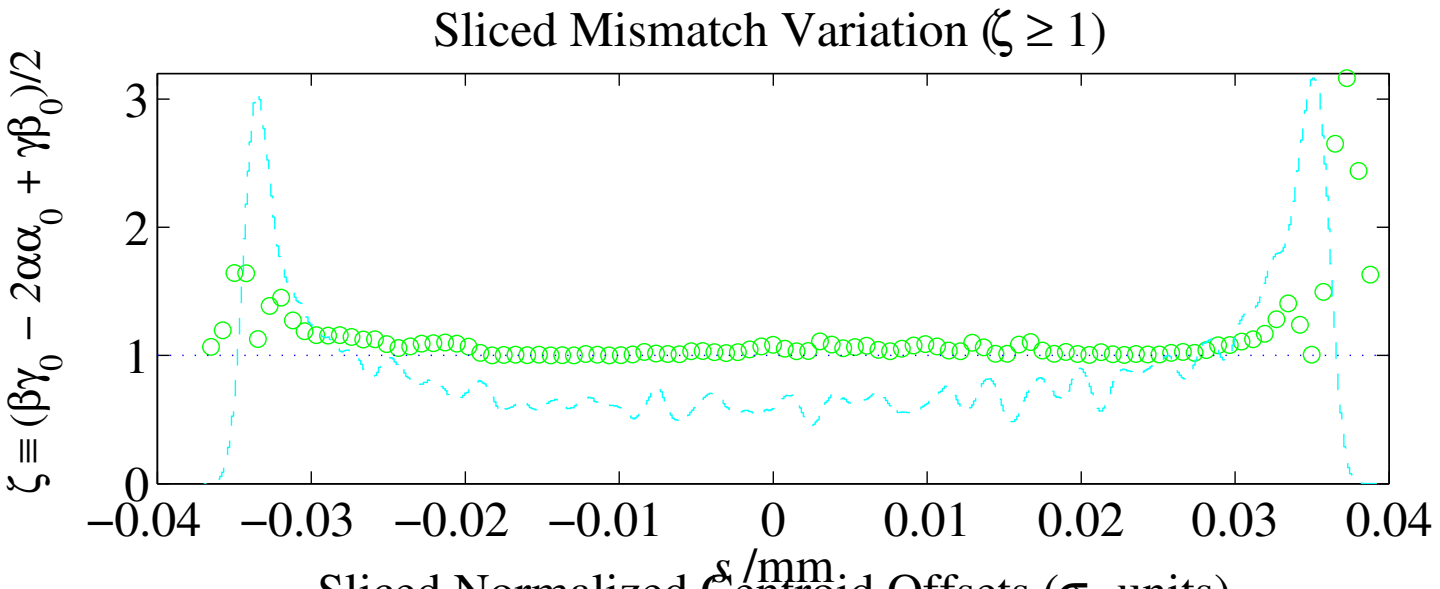


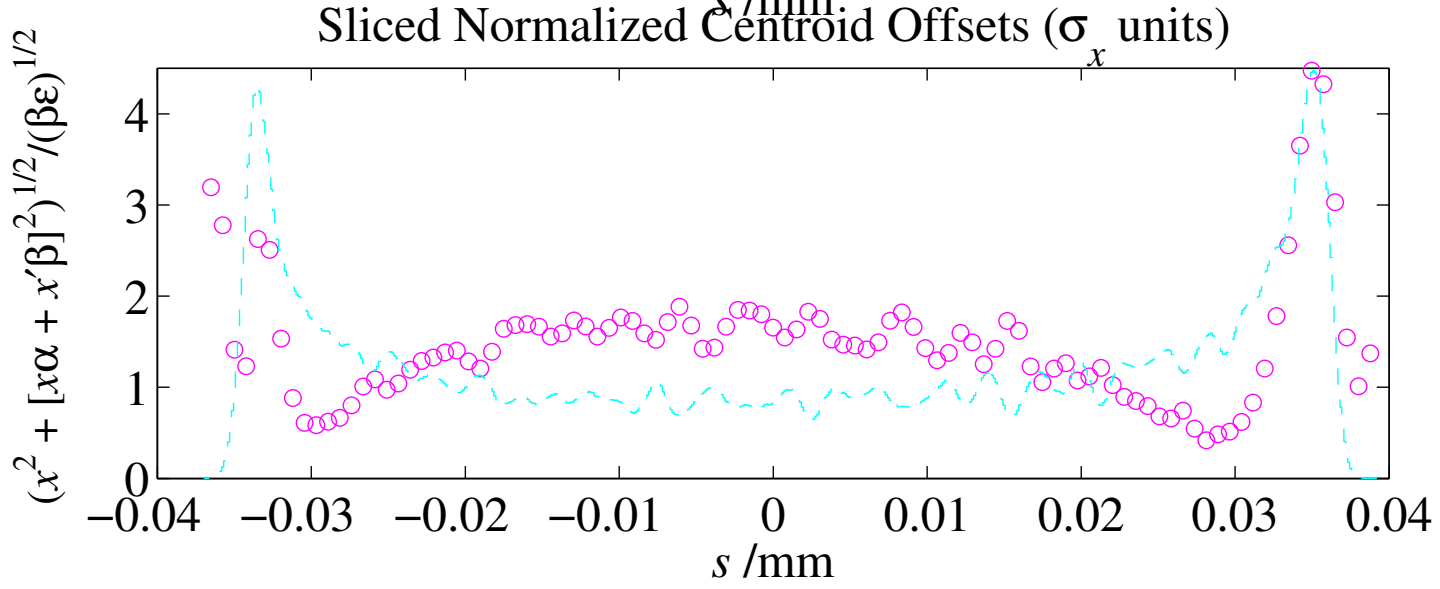


Final x-x' Phase Space (LCLS input)

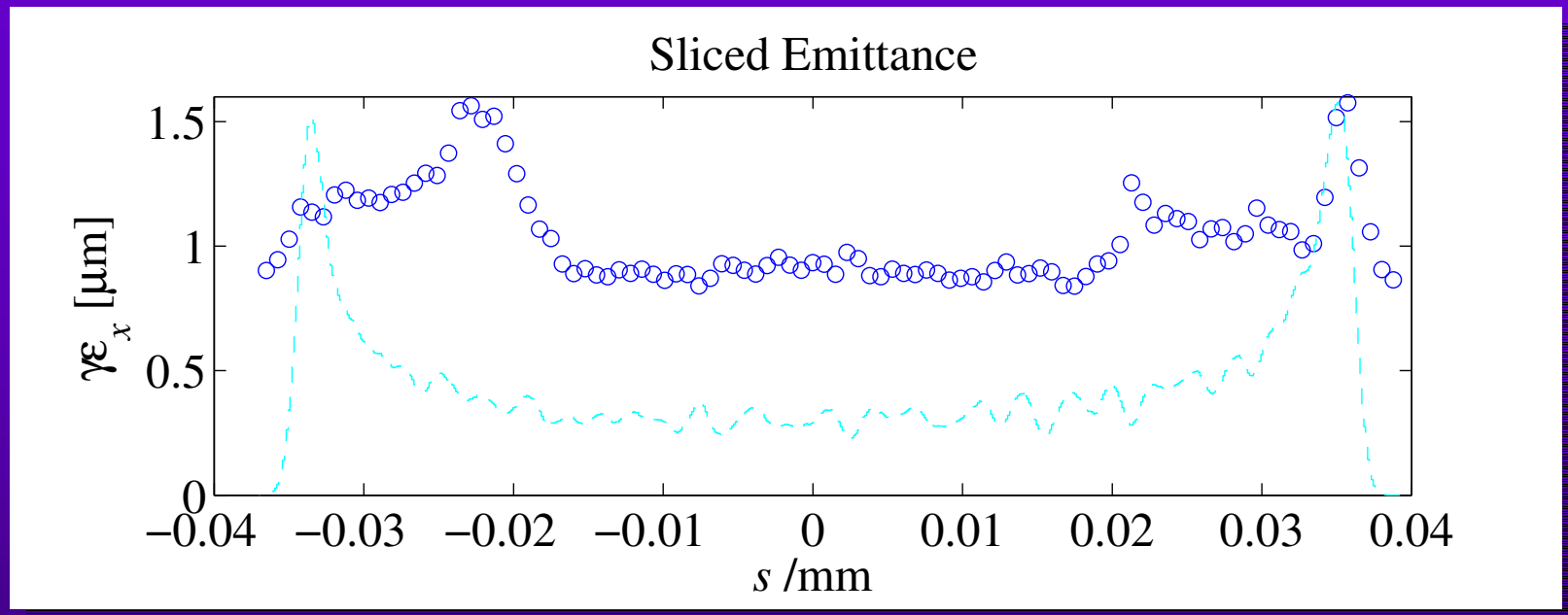


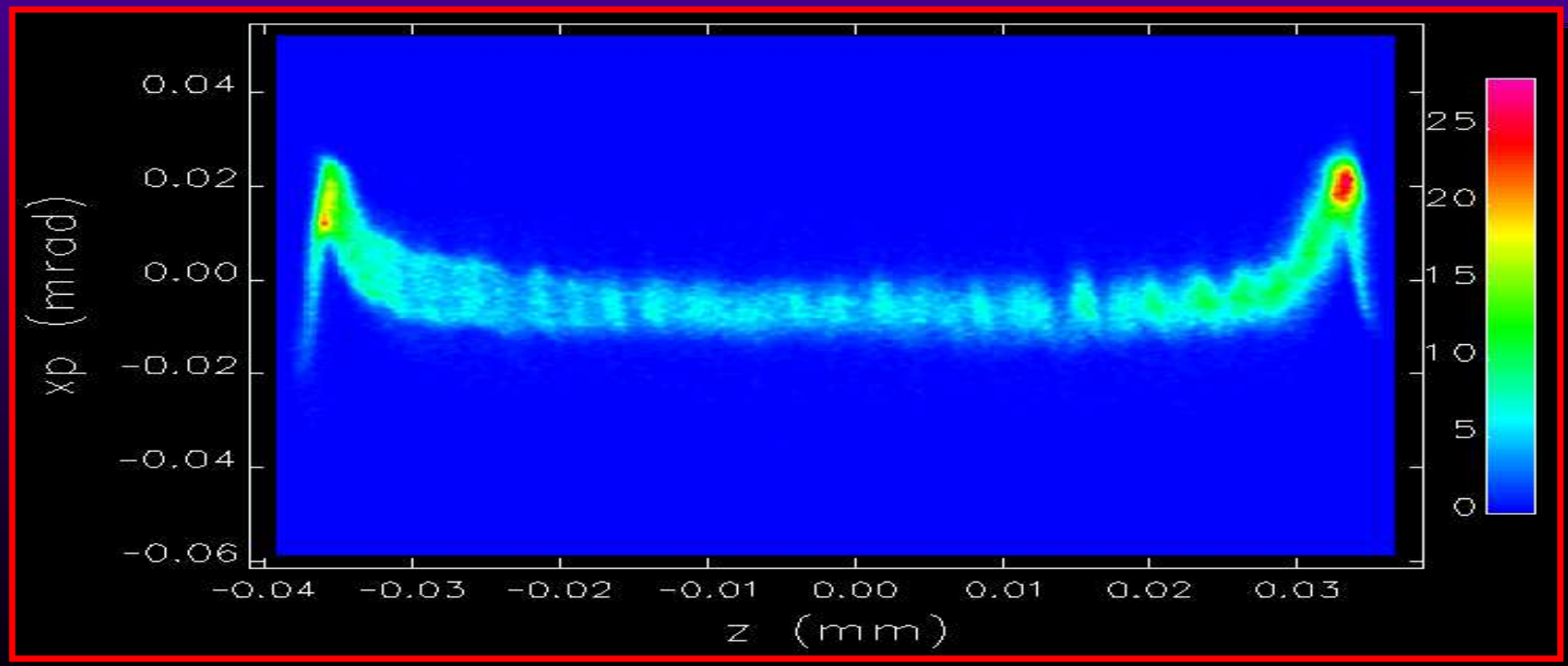
Slice Mismatch and Oscillation (LCLS Input)



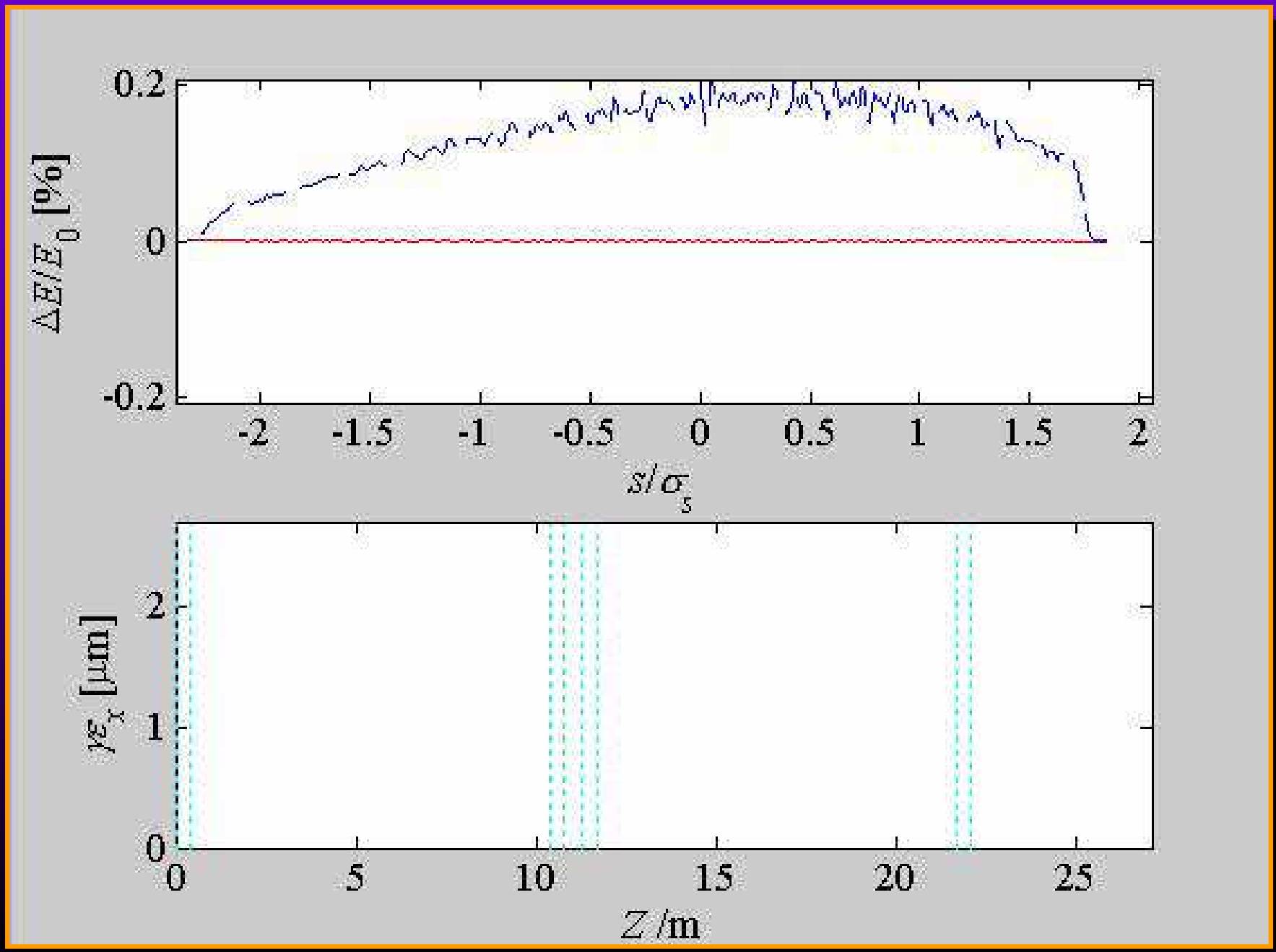


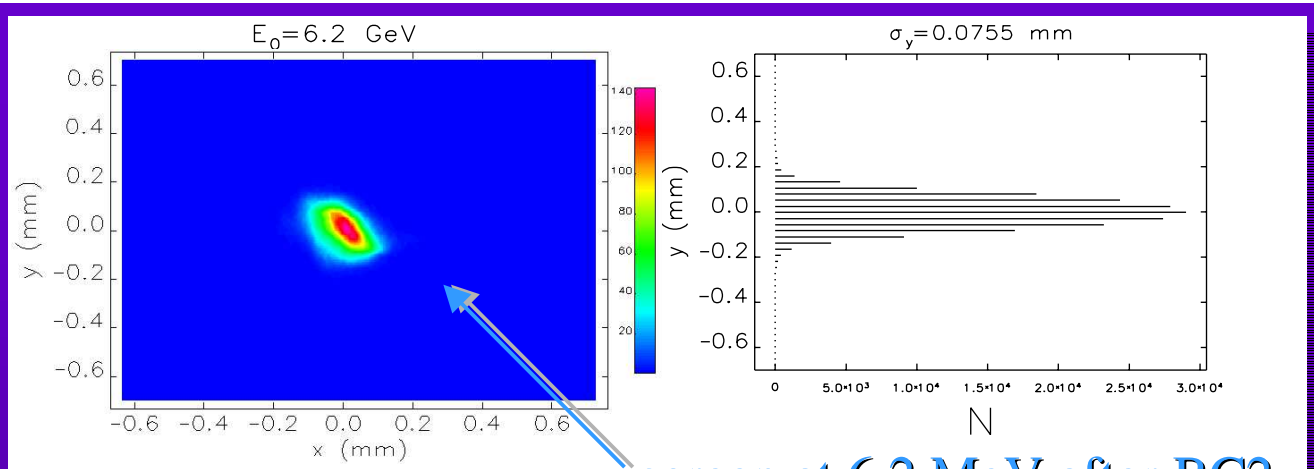
Slice Emittance (LCLS)

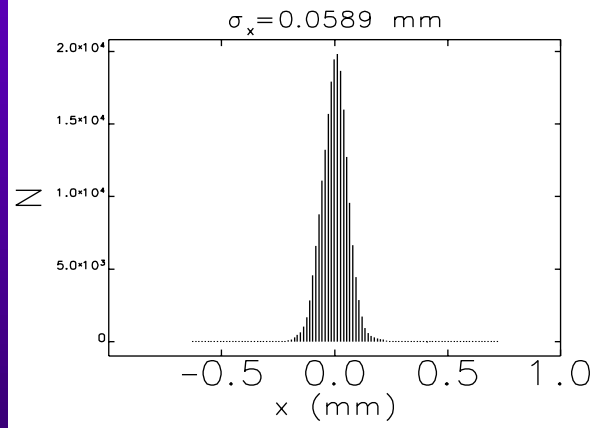




LCLS BC2 CSR-integrated-wake (tracked dist.)

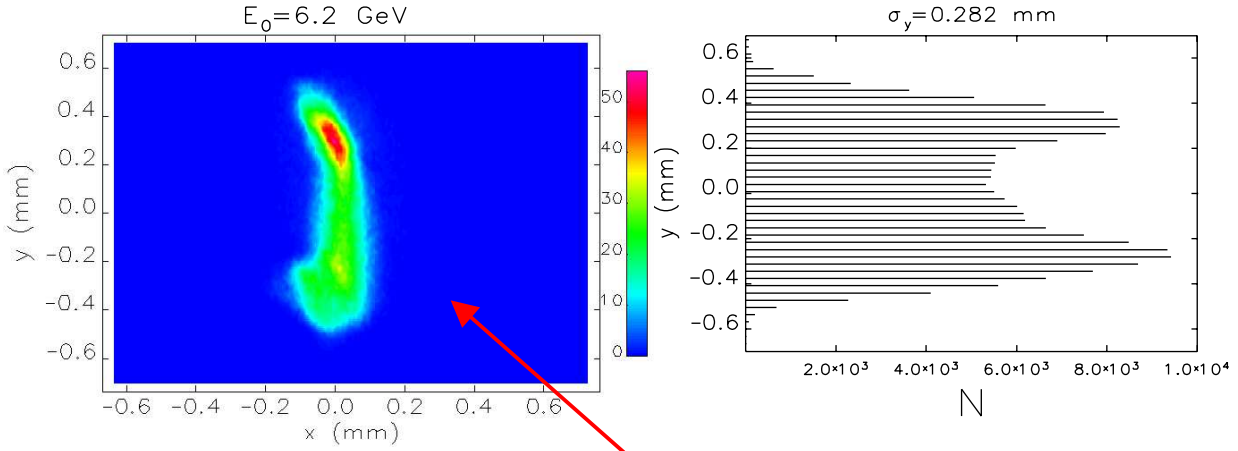


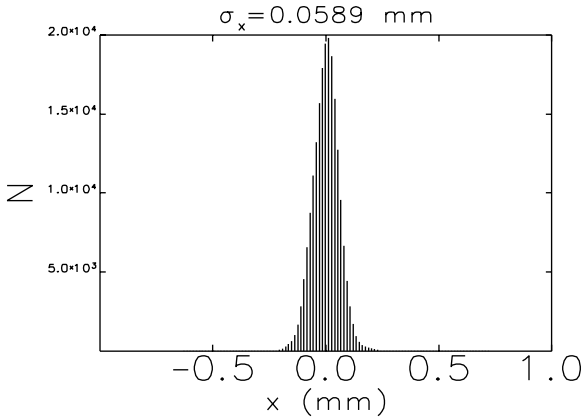




screen at 6.2 MeV after BC2 with transverse-RF **OFF**

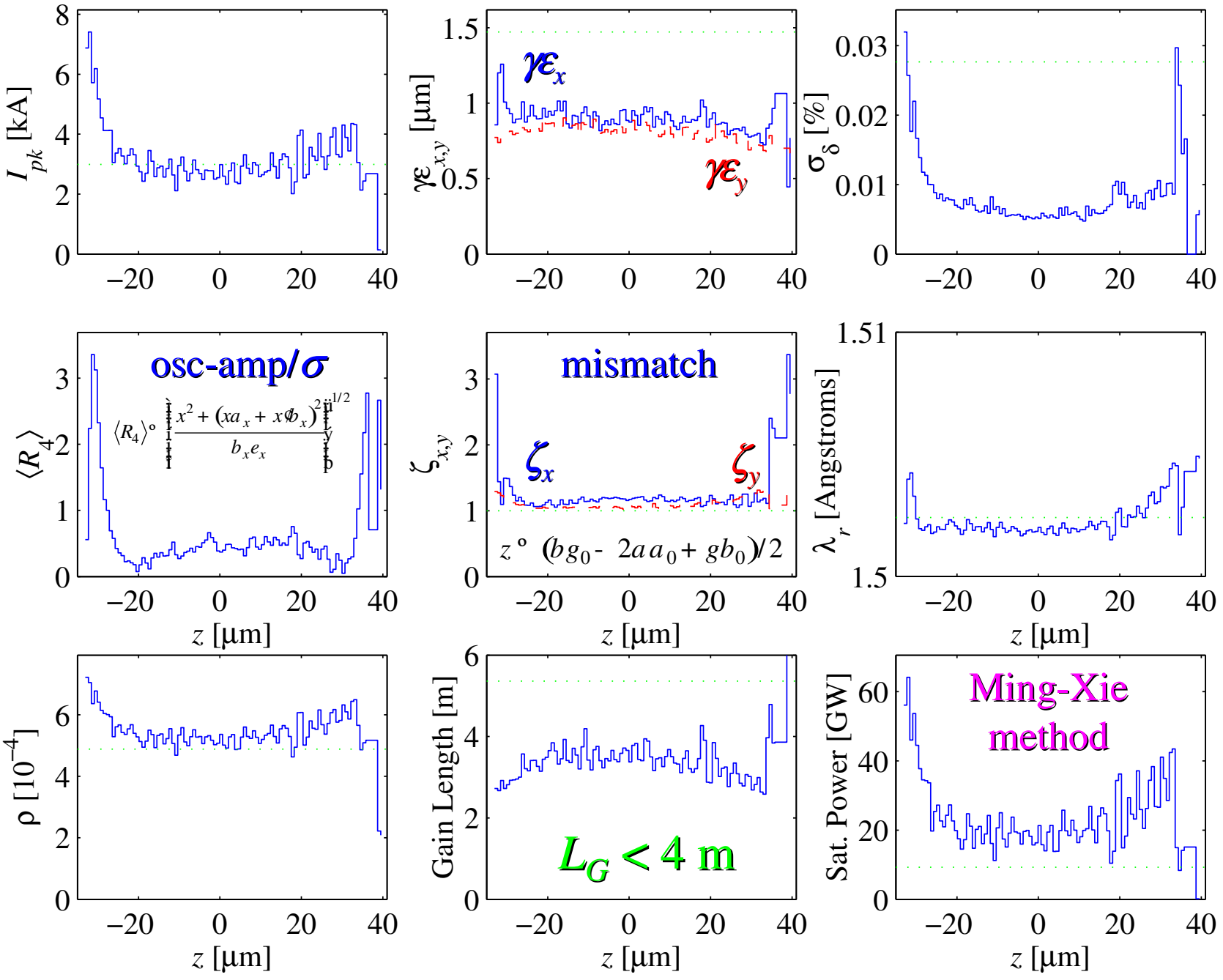
Transverse RF deflector used to diagnose 'slice' emittance after BC2





Transverse RF ON (*V* = 20 MV)

Sliced Beam After Injector and Linac Tracking



Summary

- New awareness of CSR micro-bunching and new design optimization
- Projected emittance doubles over linac, but slice parameters allow $L_G < 4$ m
- Projected emittance growth presents a diagnostics and tuning challenge (use transverse RF)
- Stability studies and ***Genesis*** results $\rightarrow$ (see M. Borland talk…)