LCLS Linac Update

- CSR micro-bunching requires new compressors
- Superconducting wiggler reduces CSR effects
- New full-system tracking studies

Paul Emma

December 10, 2001

***LCLS* Technical Advisory Committee Meeting**

SLAC

UCLA

Advanced Photon Source

Los Alamos

BROOKHAVEN NATIONAL LABORATORY

Stanford Linear Accelerator Center

SSRL

LLNL

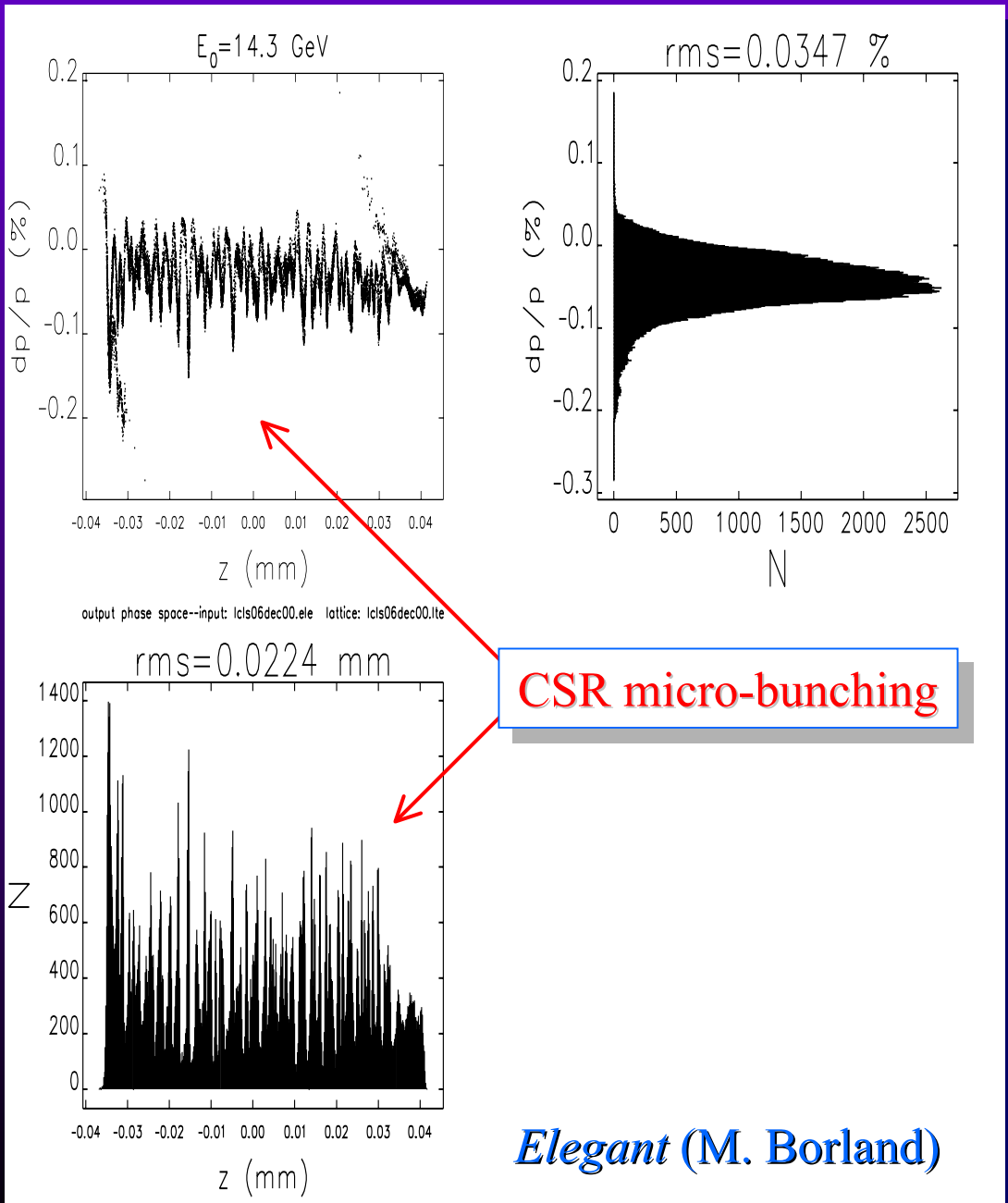
At Last TAC (Jan. 2001)…

- X-band RF introduced at BC1 to linearize compression
- CDR linac Chapter-7 finished
- Start-to-end simulations encouraging…

Since then…

- Borland finds CSR micro-bunching effect in chicanes → emittance growth much worse
- Stupakov/Emma (using Saldin et al.) develop more accurate bend-exit CSR model for use in tracking
- Double-chicanes replaced with single-chicanes
- Super-conducting wiggler at BC2 reduces micro-bunching by raising incoherent energy spread
- Start-to-end simulations encouraging again, but projected emittance growth worse than at last TAC

Tracking June-2001 design with June-2001 CSR model

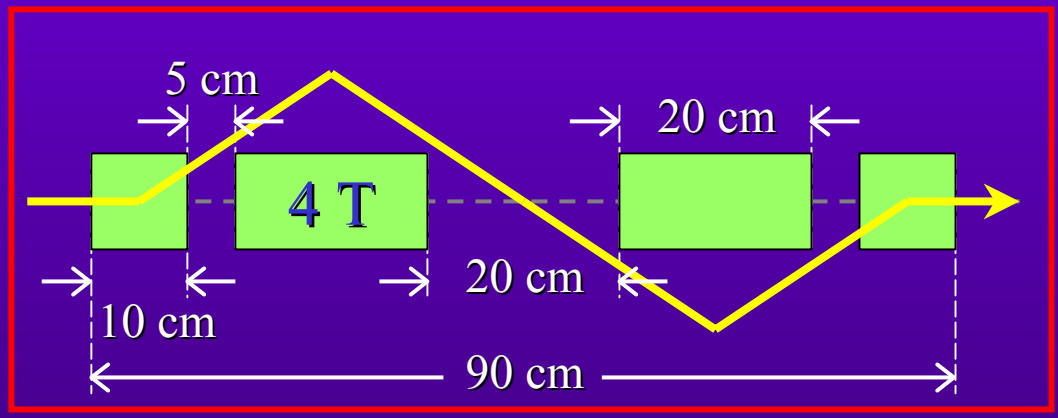


- Previous runs used too much $f(t)$ smoothing
- …and too large slice-energy spread
- Micro-bunching ruins slice emittance and energy spread (PAC2001)…

however…

- ***Elegant*** over-estimated CSR after bend-exit
- Single-chicanes generate less micro-bunching
- SC-wiggler added to BC2
- DL2 bends reduced to $\theta/2$
- New design with new CSR model is much better…

Superconducting Wiggler in *LCLS*…



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

At BC2:

$E_0 = 4.54$ GeV

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

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

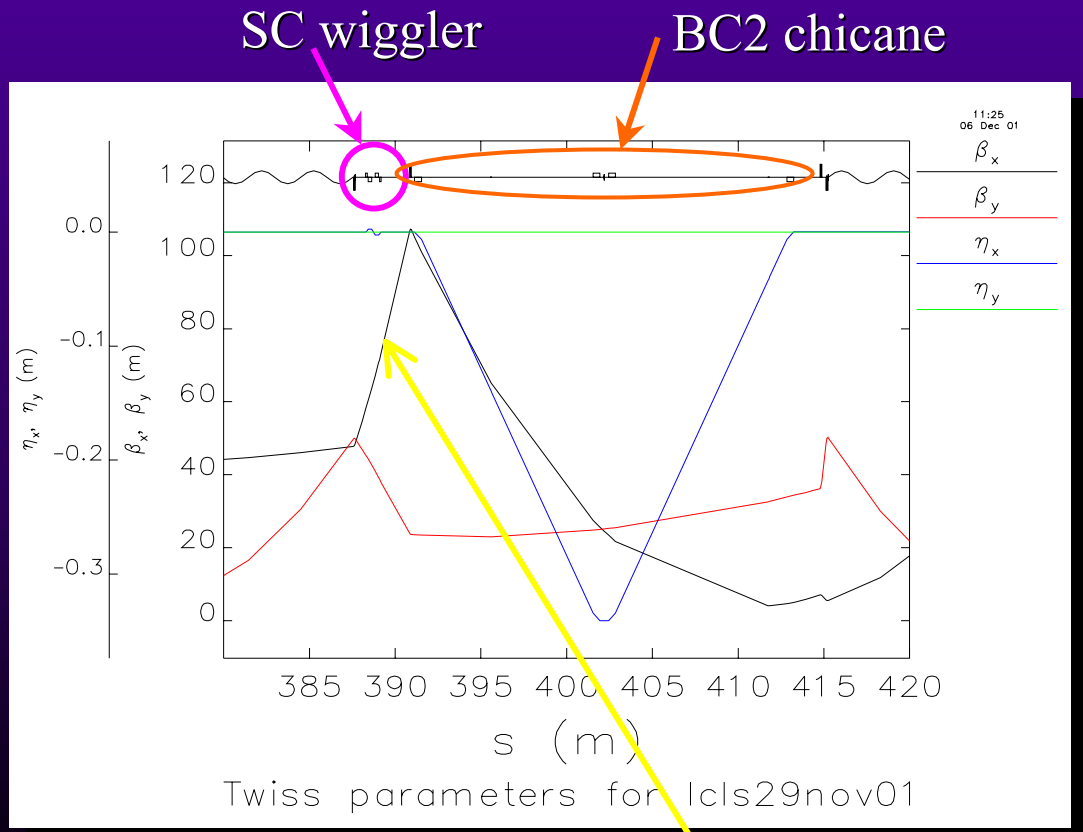
At Undulator:

$E_1 = 14.3$ GeV

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

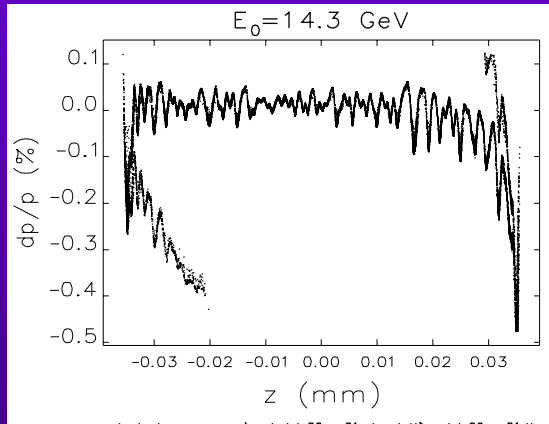
$\sigma_{z1} \approx 22\ \mu$m

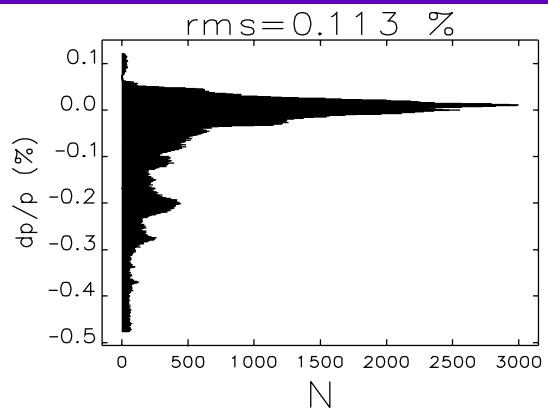
$(\sigma_{z0}/\sigma_{z1})\sigma_E/E_1 \approx 8.4\times10^{-5}$



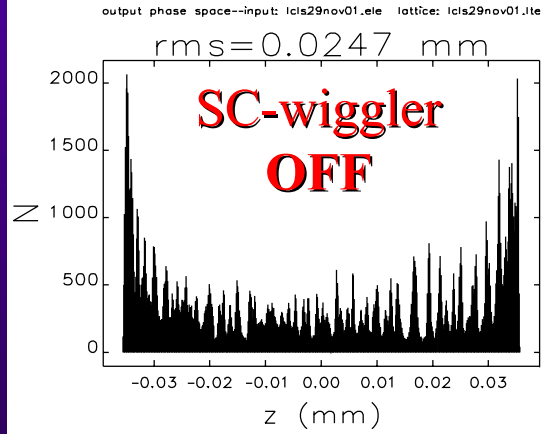
wiggler field limited by β-function

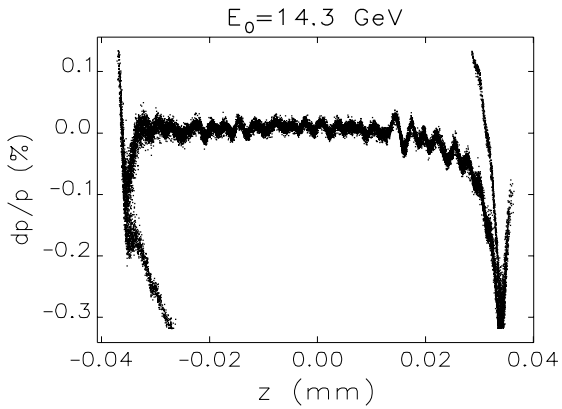
Superconducting wiggler **OFF**

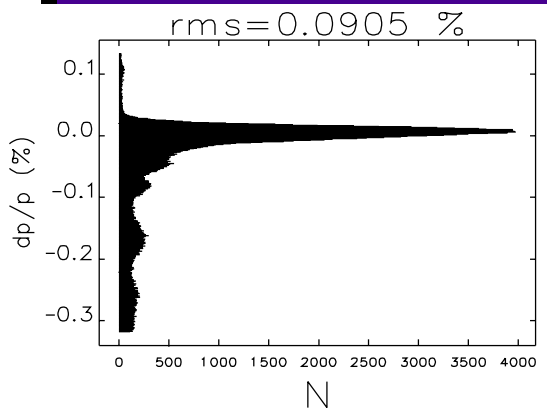




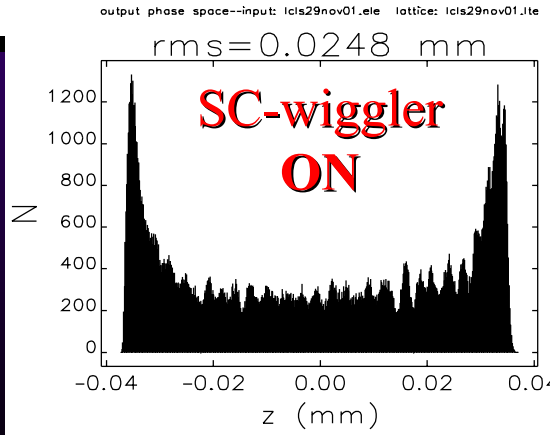
Using Stupakov CSR model and new design in *Elegant* tracking

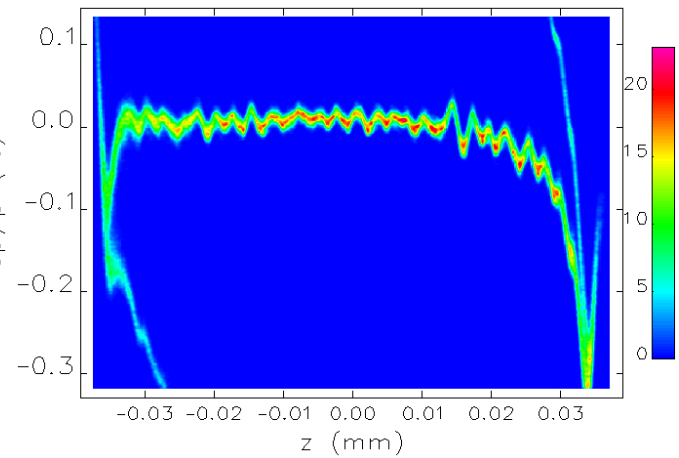




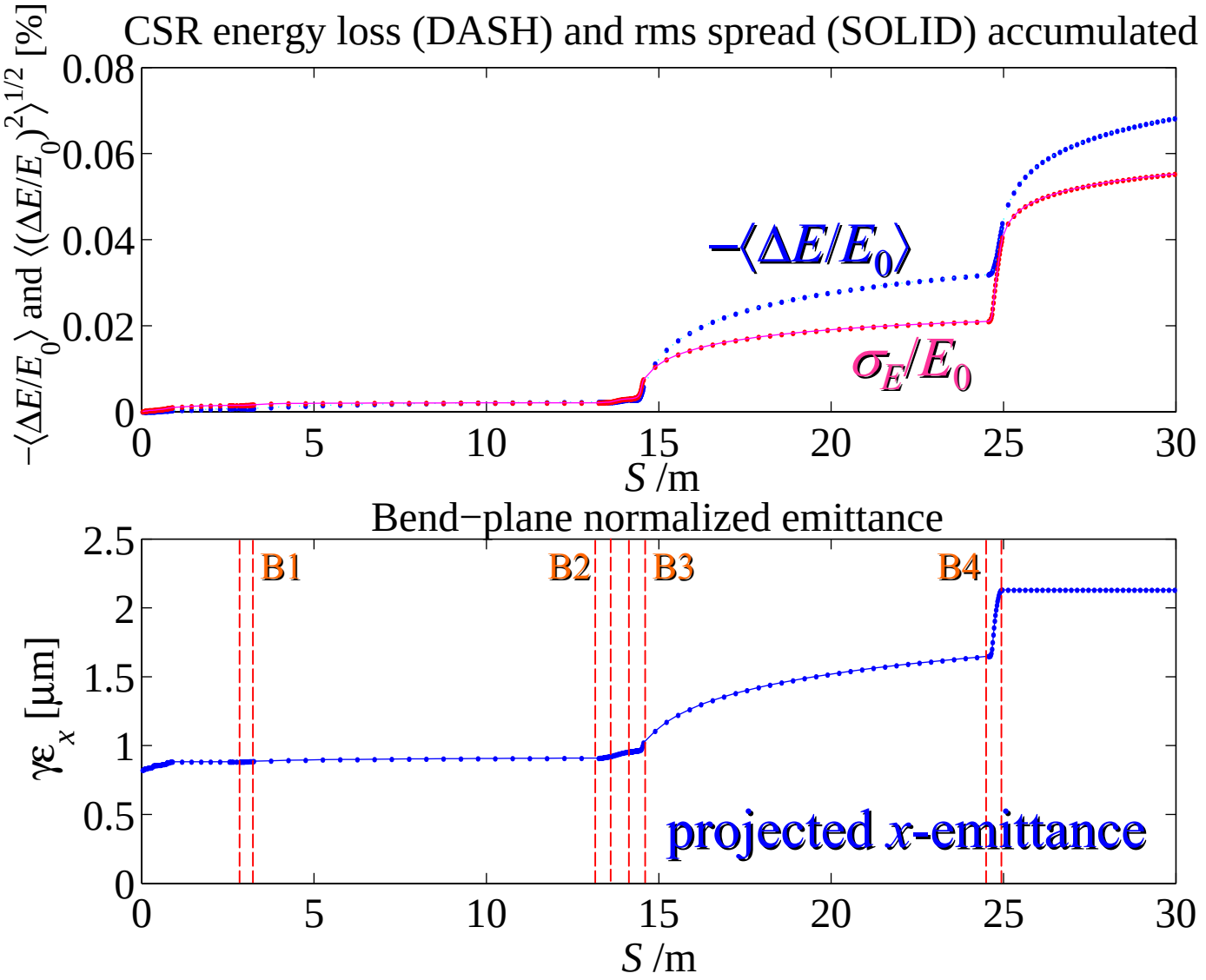


CSR may still be over-estimated in present tracking

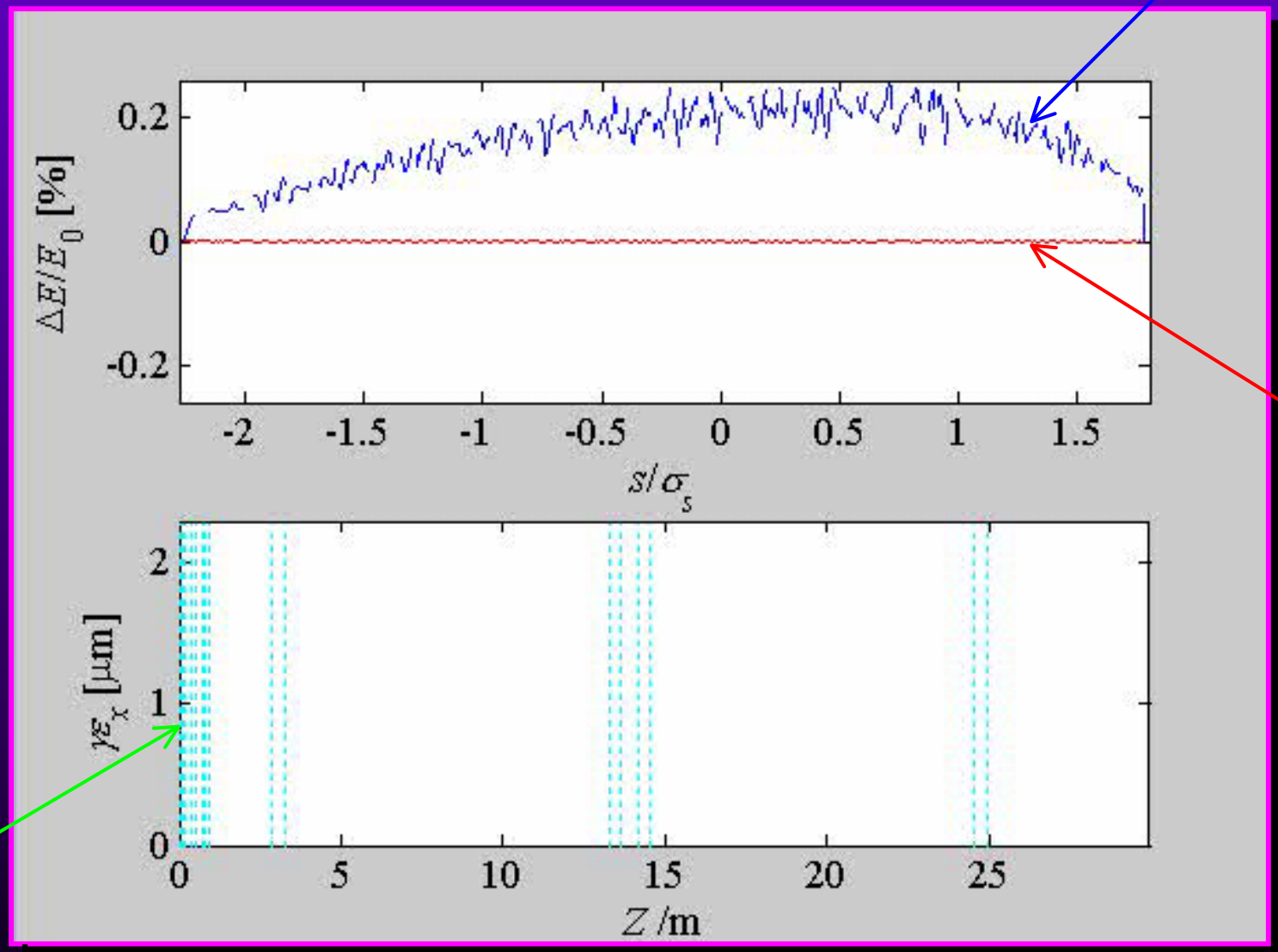




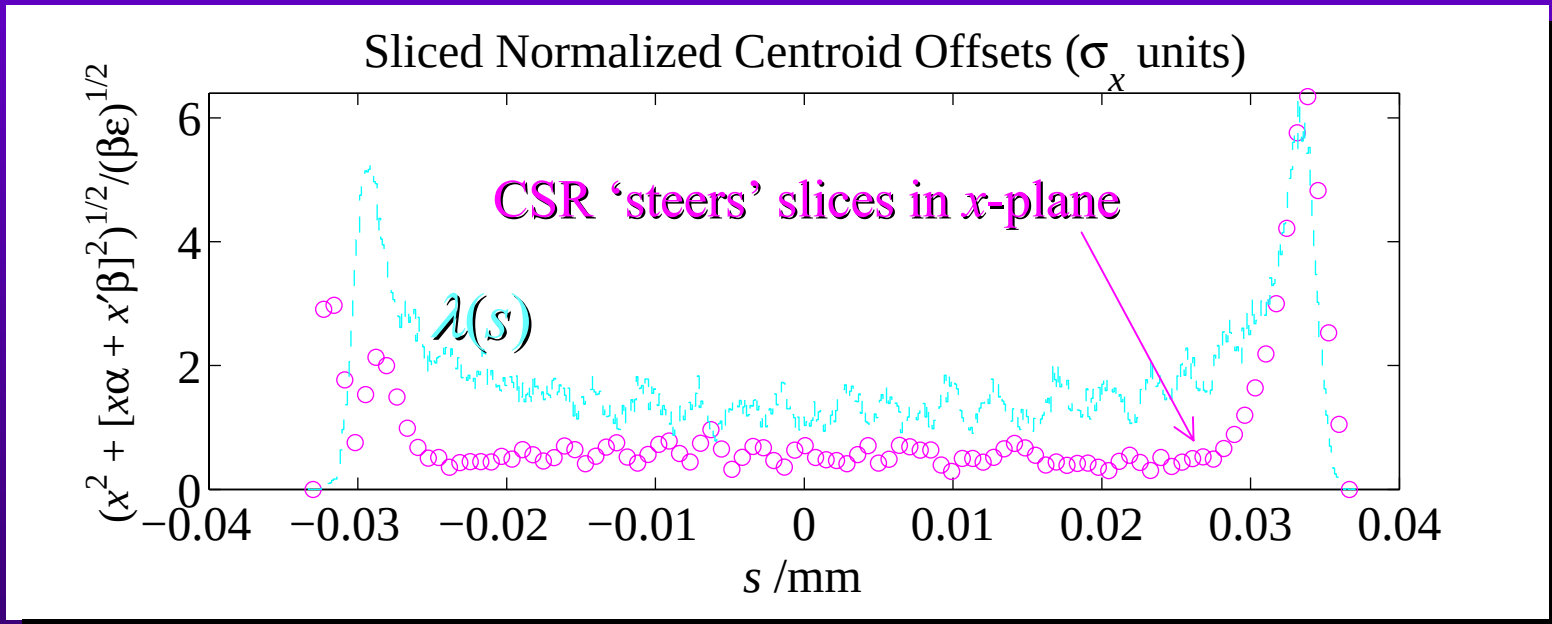
CSR Generated in BC2

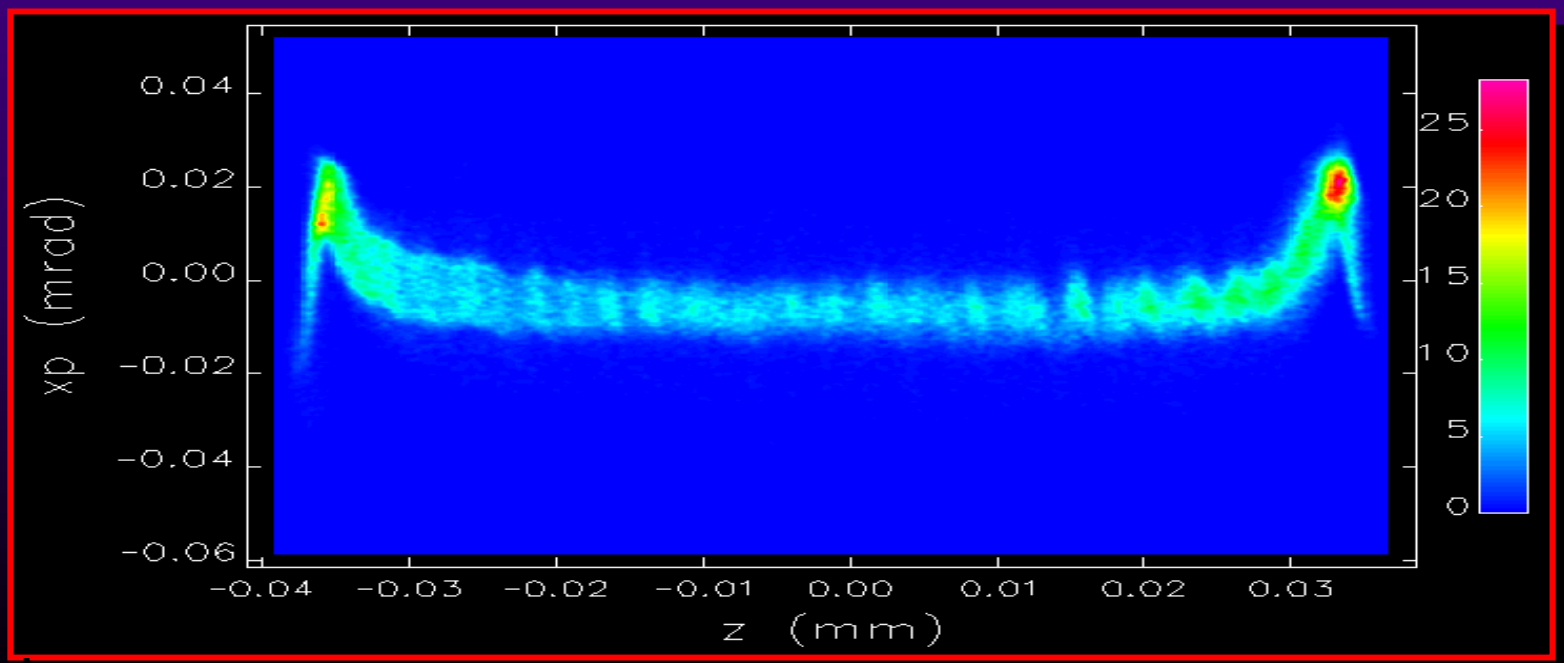


CSR Generated in BC2

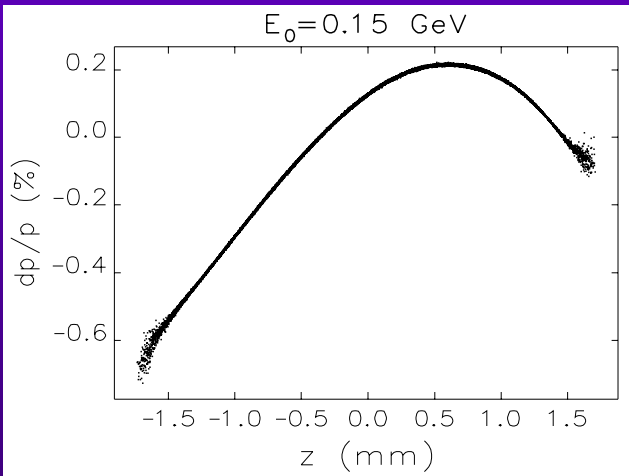


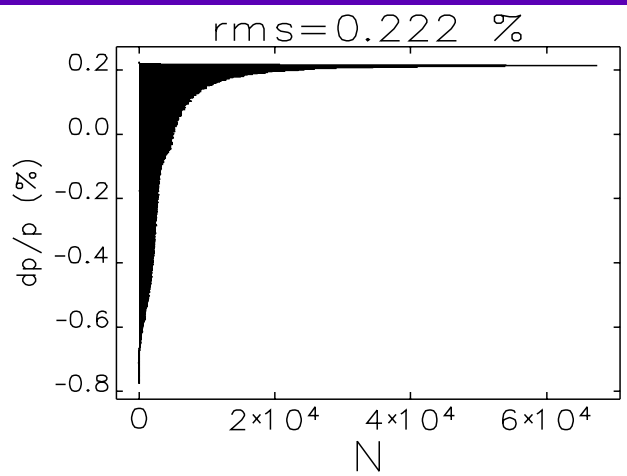
CSR Generated in BC2

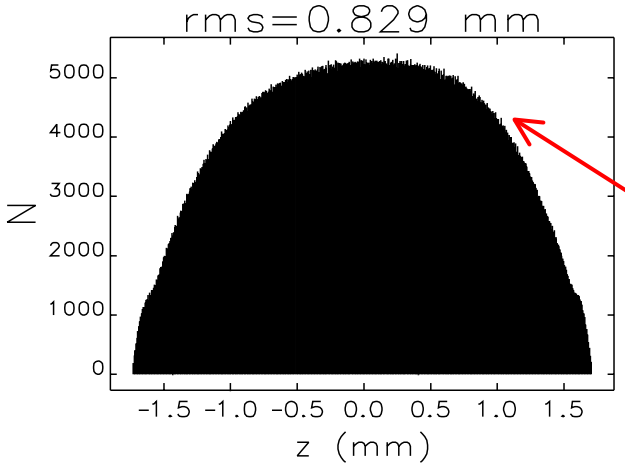




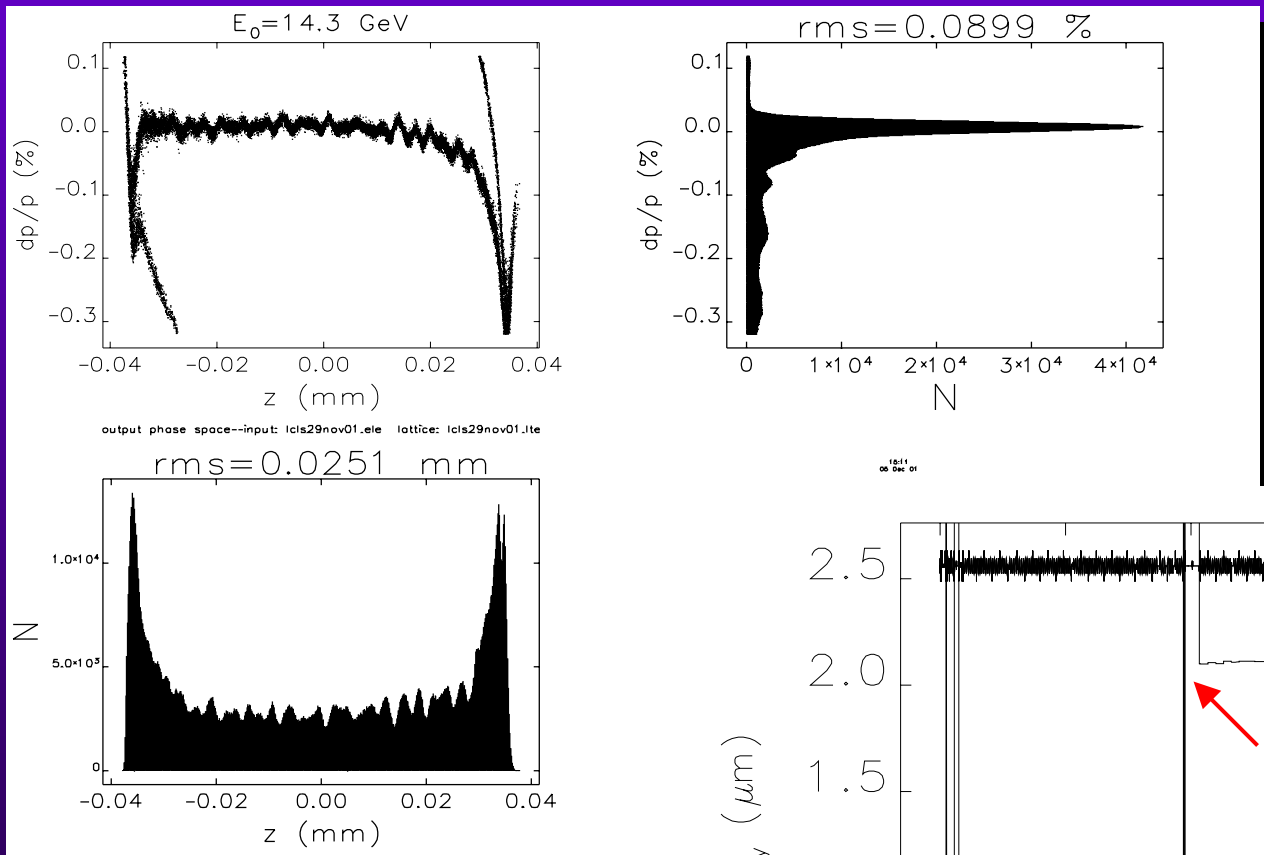
Study CSR for much smoother input distributions…



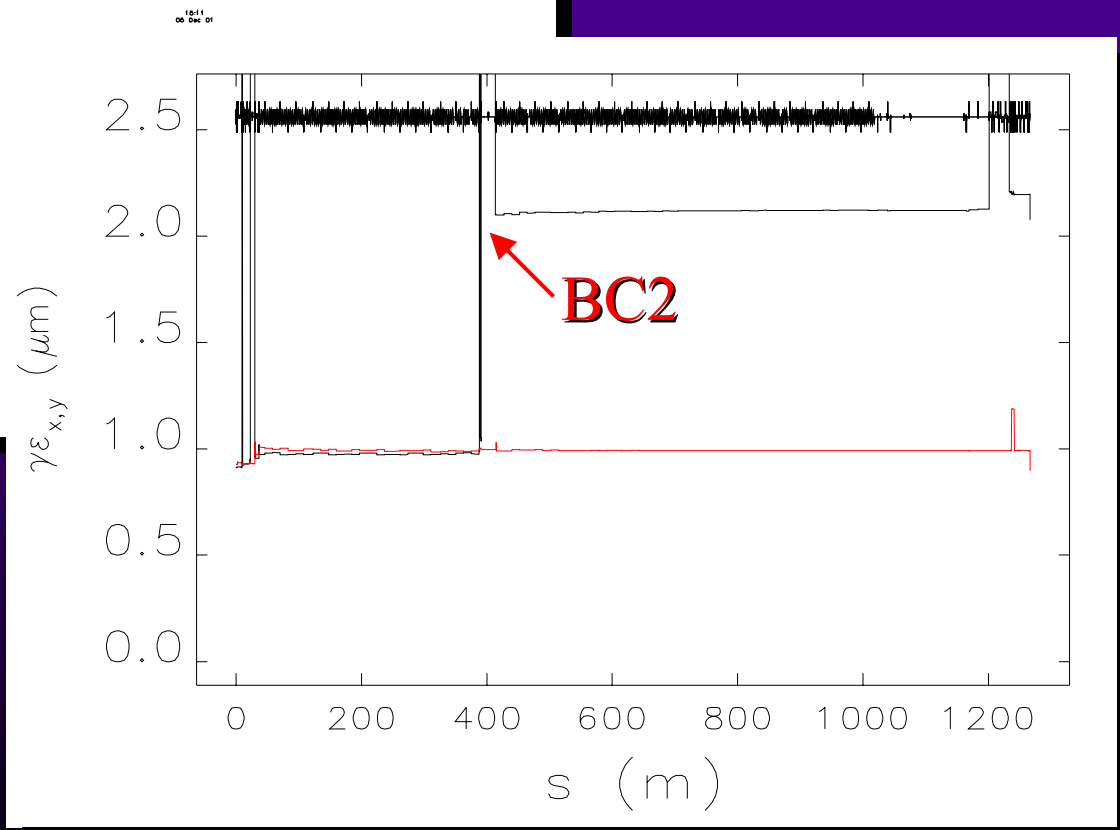




Parmela output…
(C. Limborg, 29-Nov-01)
smoothed and extended to 2×10^6 particles

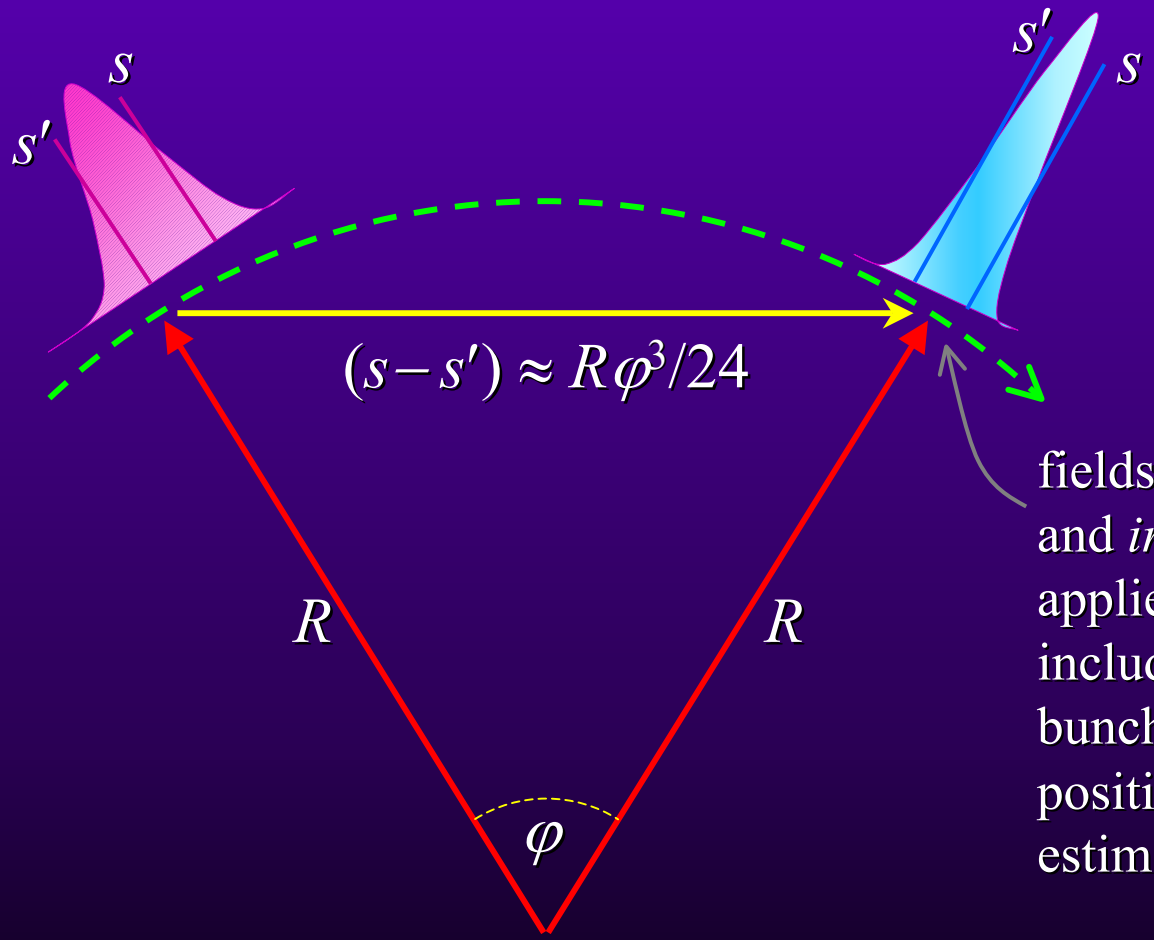


Track again with 2×10^6 macro-particles and with smoothing applied…



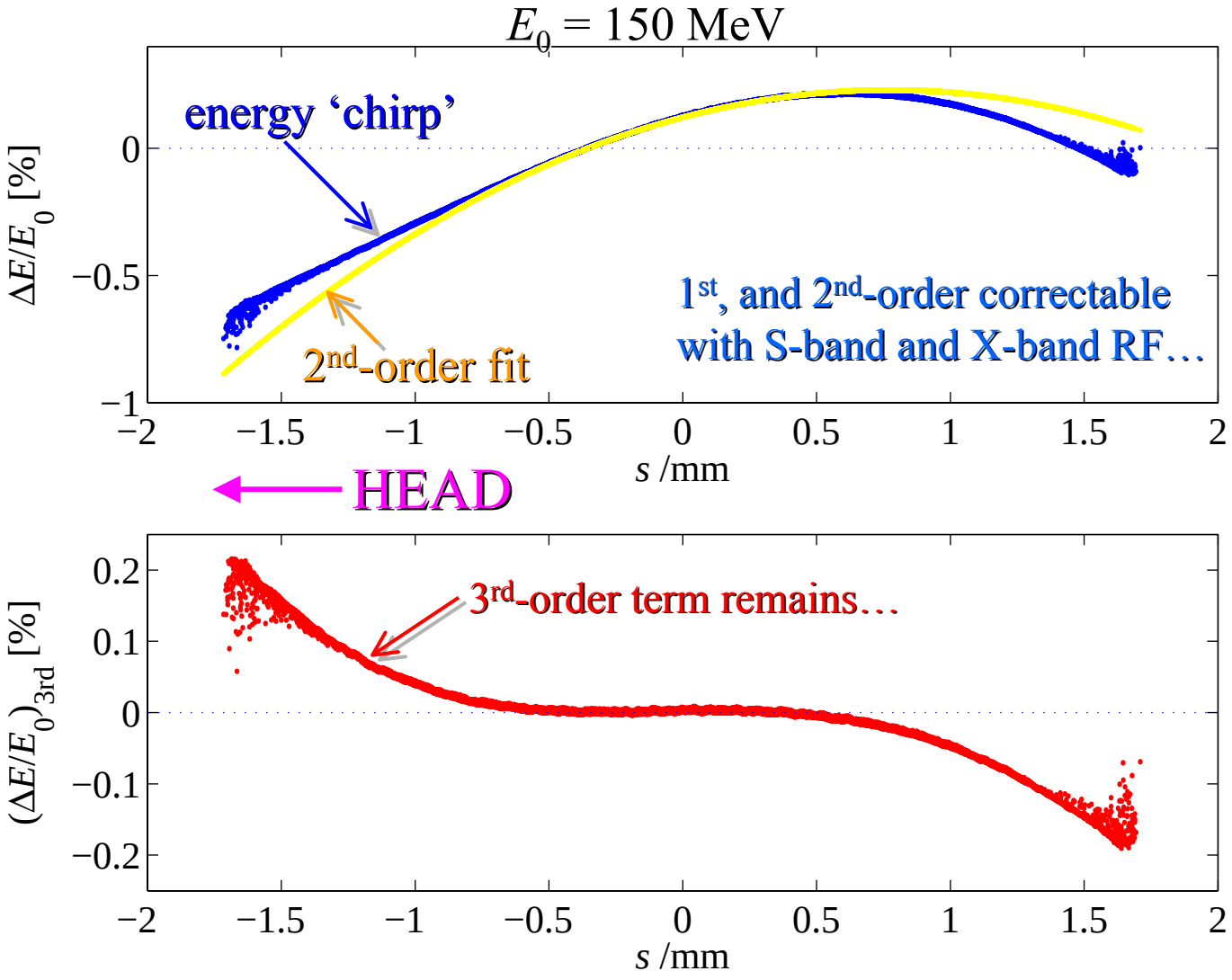
…numerical noise from Parmela run not significant contributor to micro-bunching

CSR may be over-estimated in present tracking…



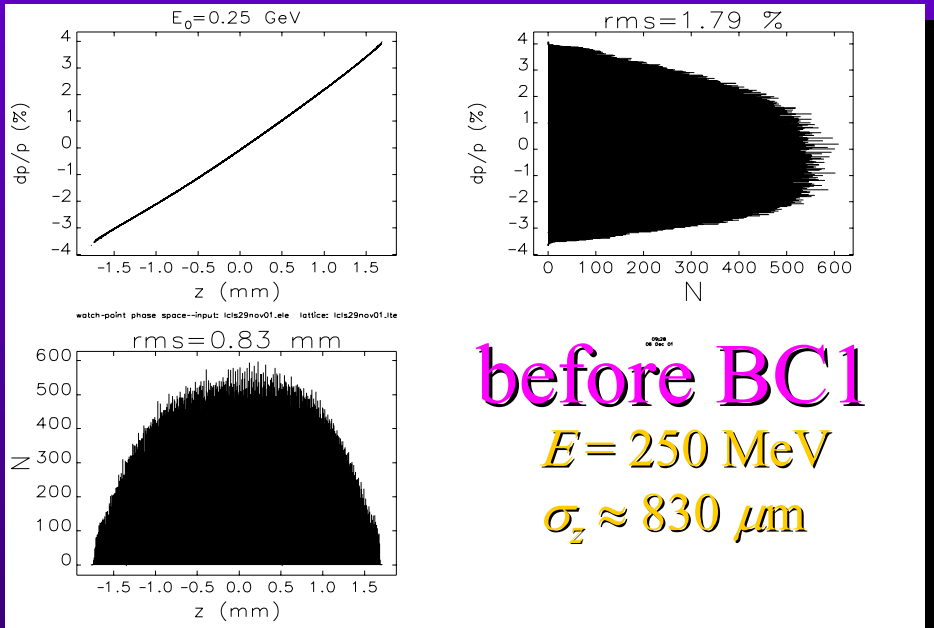
fields evaluated and *immediately* applied, without including longer bunch at retarded position → over-estimate?

3rd-order energy-time correlation from injector



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

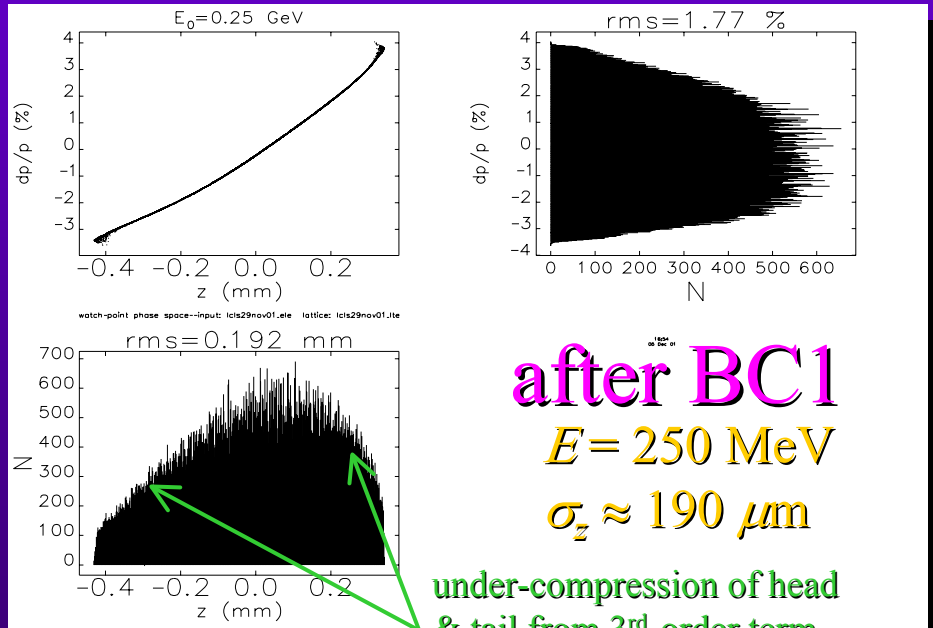
Compression Evolution



before BC1

$E = 250$ MeV

$\sigma_z \approx 830\ \mu$m

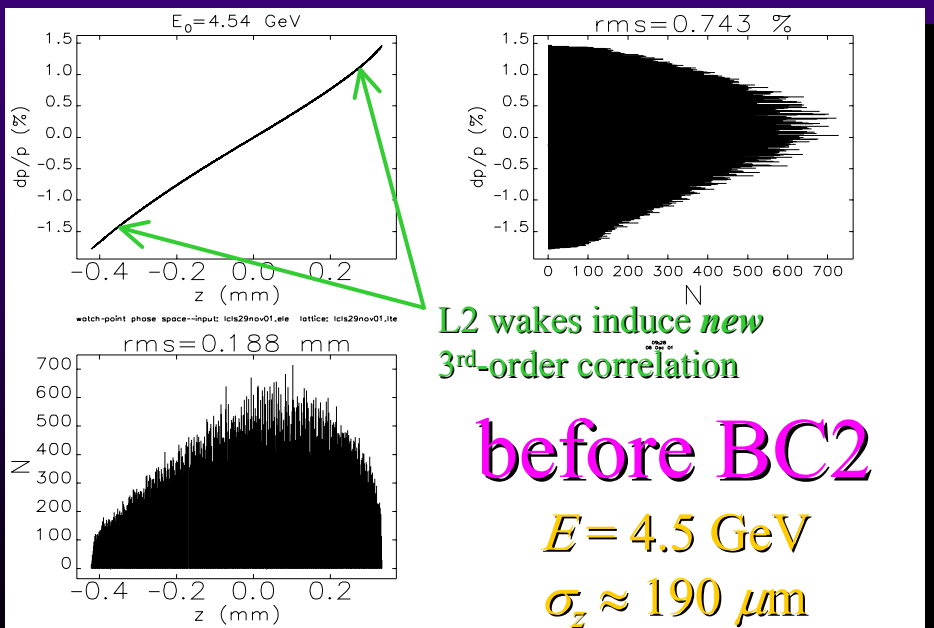


after BC1

$E = 250$ MeV

$\sigma_z \approx 190\ \mu$m

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

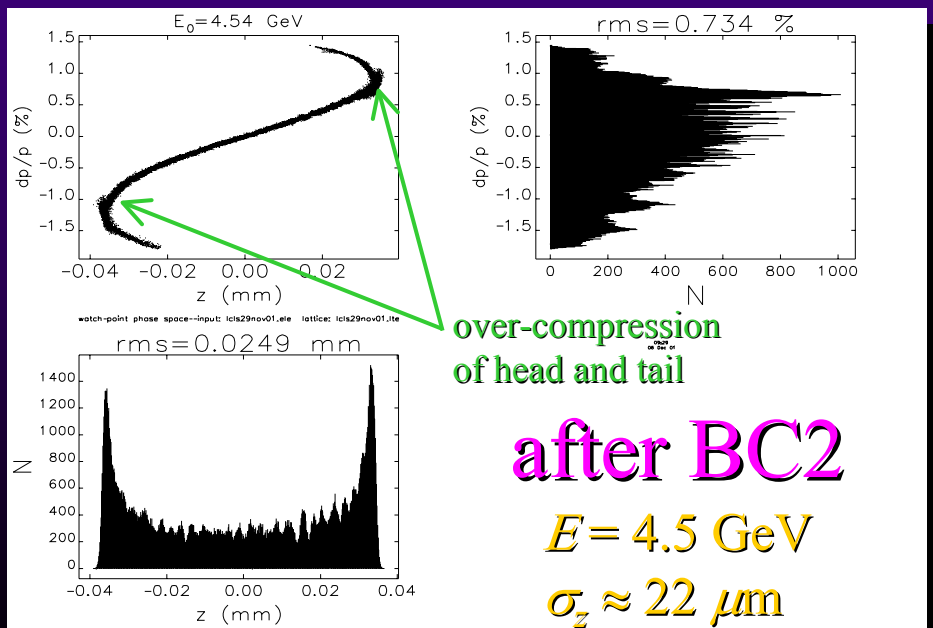


L2 wakes induce *new* 3rd-order correlation

before BC2

$E = 4.5$ GeV

$\sigma_z \approx 190\ \mu$m



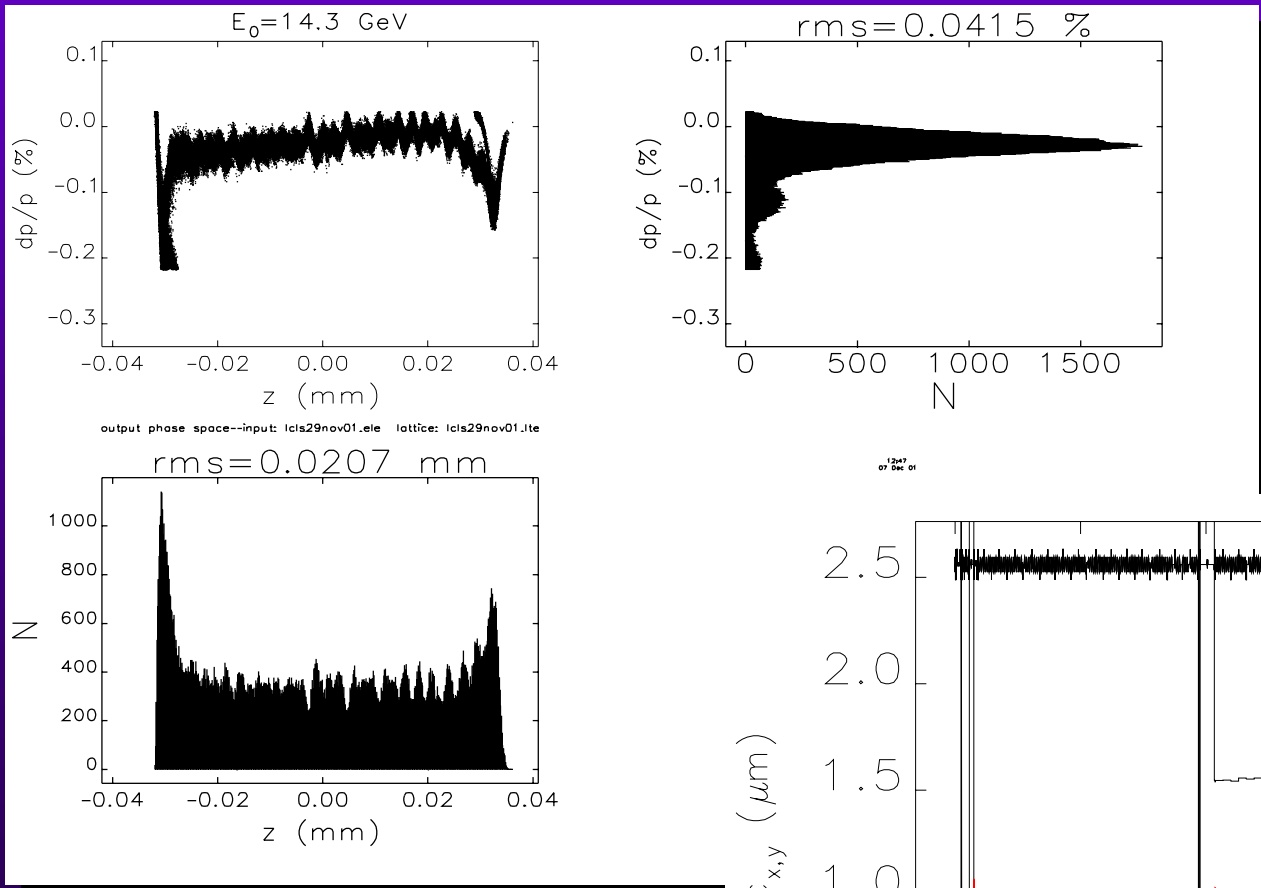
over-compression of head and tail

after BC2

$E = 4.5$ GeV

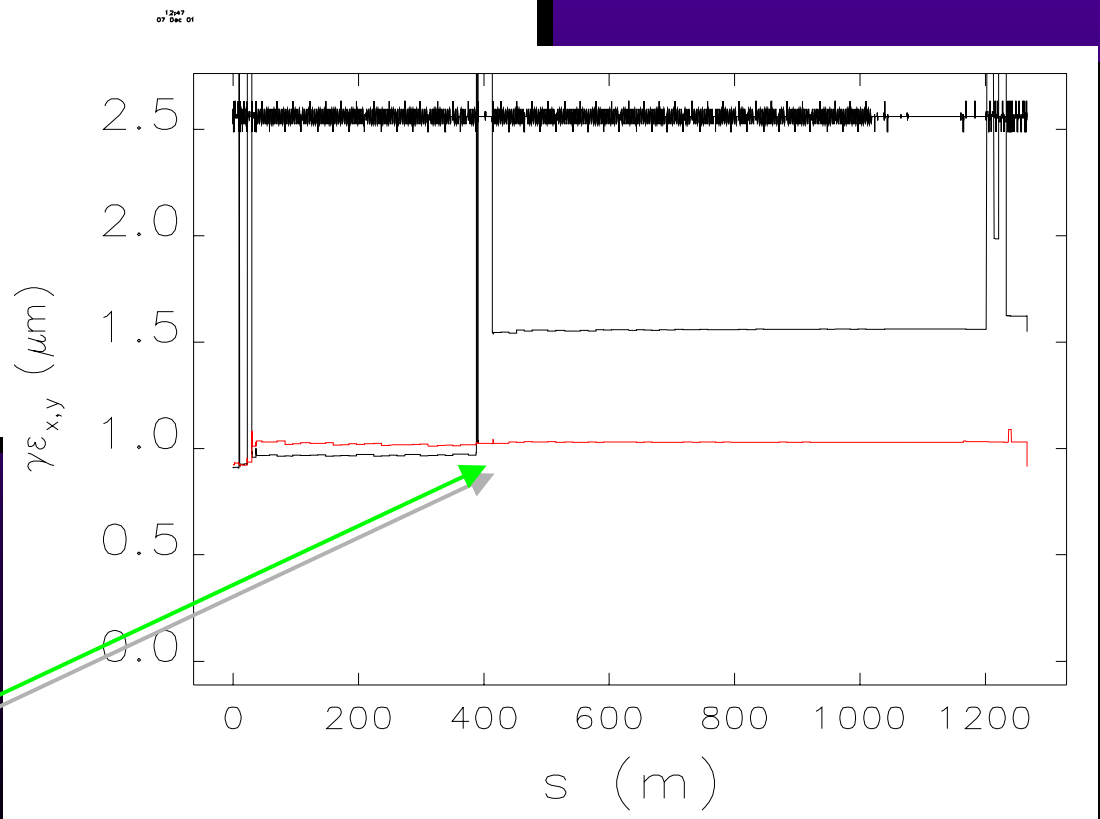
$\sigma_z \approx 22\ \mu$m

Now flip injector's temporal distribution and re-track *LCLS*…

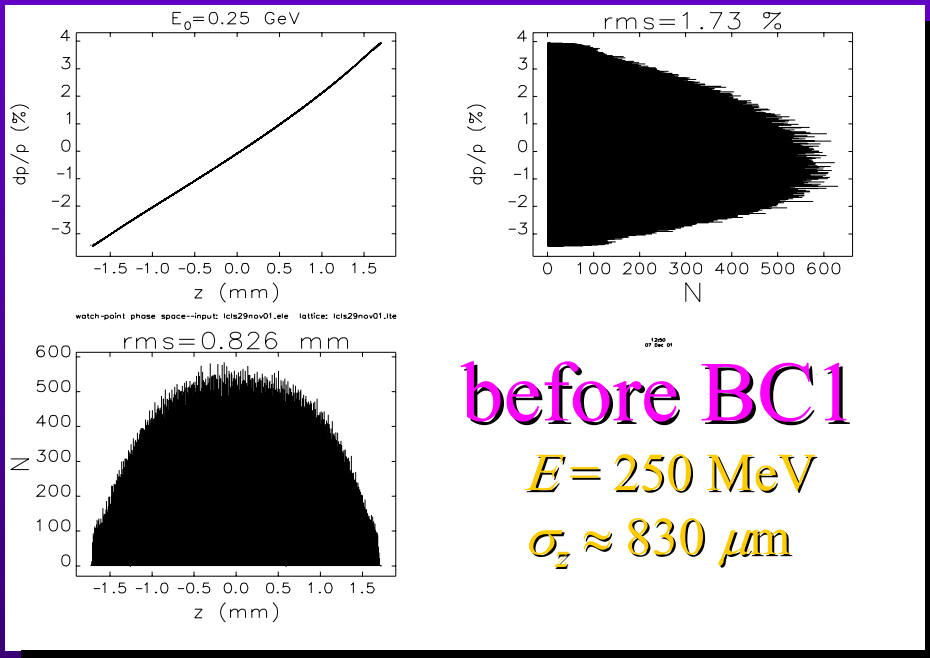


…with reversed 3rd-order injector *E-t* correlation

CSR emittance growth much reduced ($2\ \mu m \rightarrow 1.5\ \mu m$)



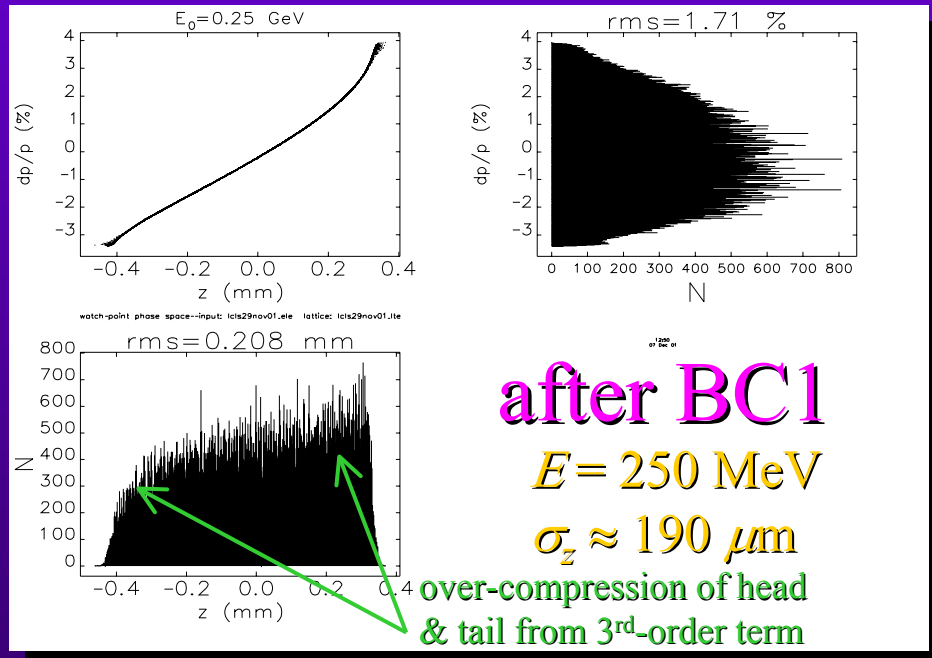
Compression evolution (with reversed 3rd-order injector *E*-*t* correlation)



before BC1

$E = 250$ MeV

$\sigma_z \approx 830\ \mu$m

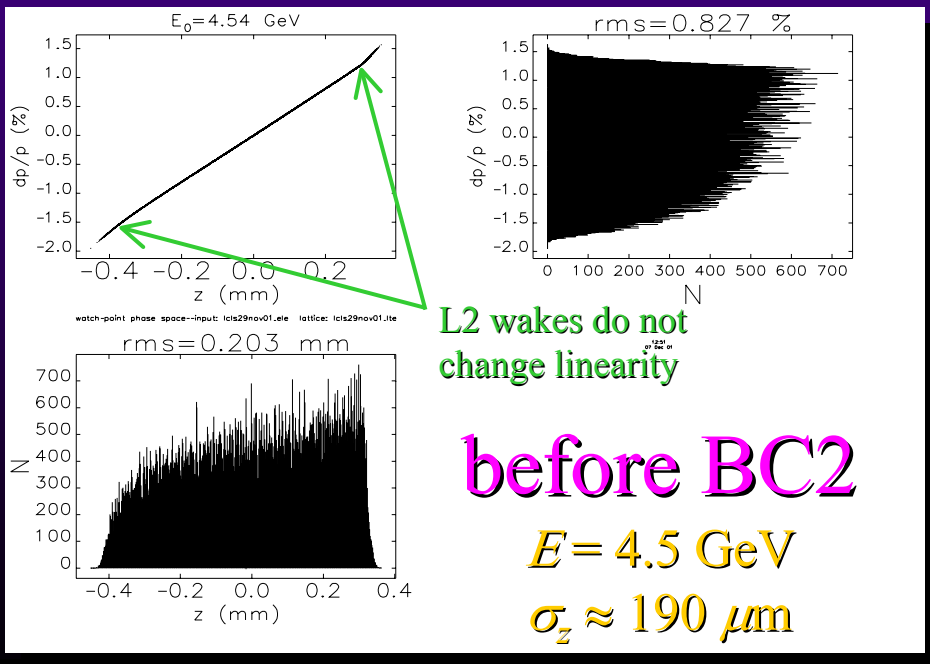


after BC1

$E = 250$ MeV

$\sigma_z \approx 190\ \mu$m

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

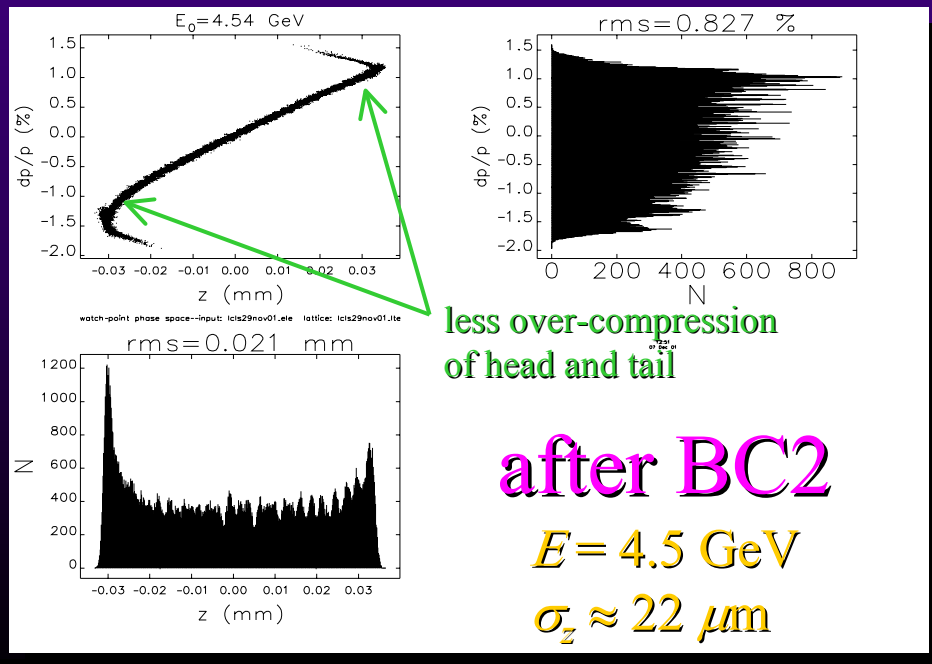


L2 wakes do not change linearity

before BC2

$E = 4.5$ GeV

$\sigma_z \approx 190\ \mu$m



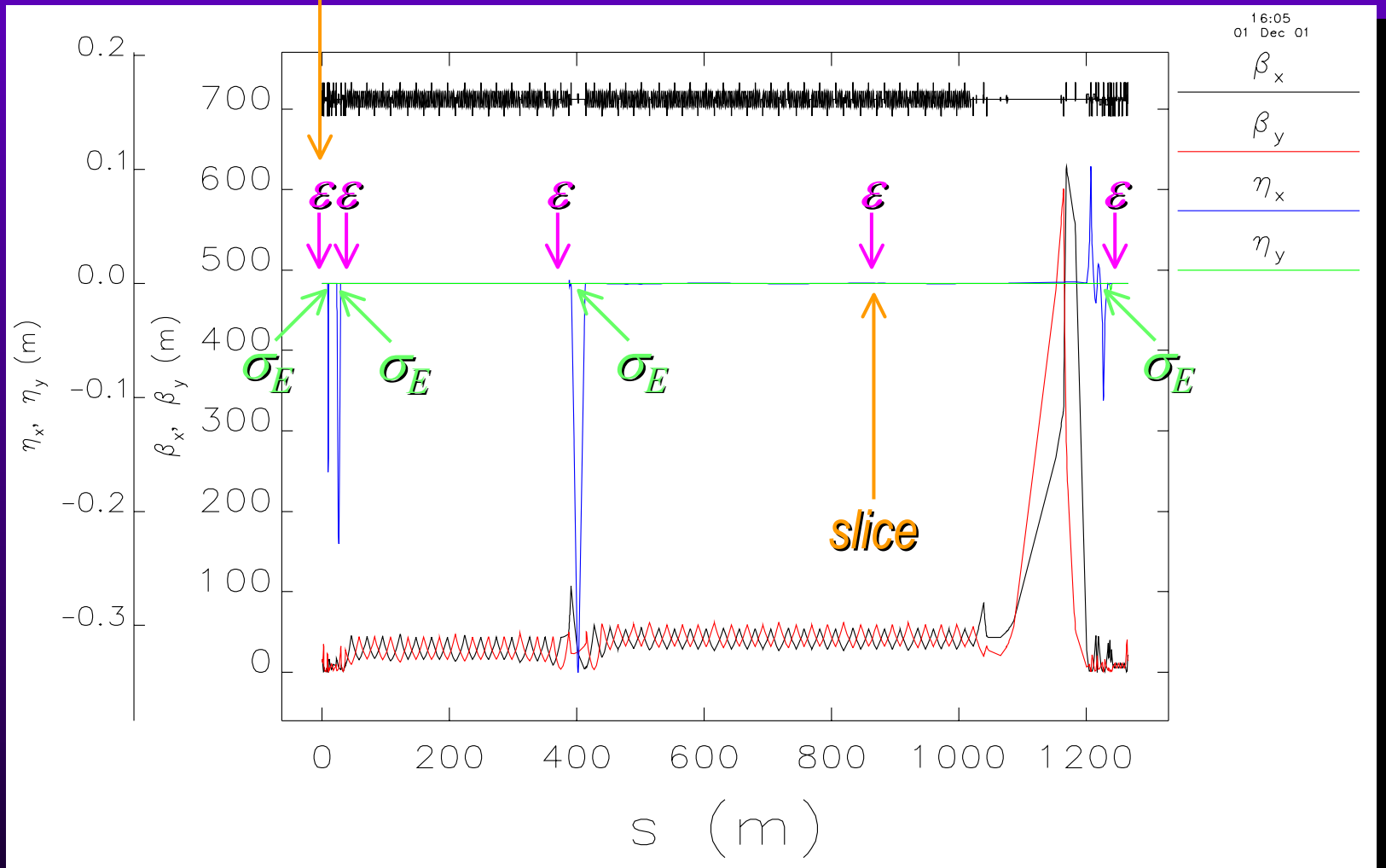
less over-compression of head and tail

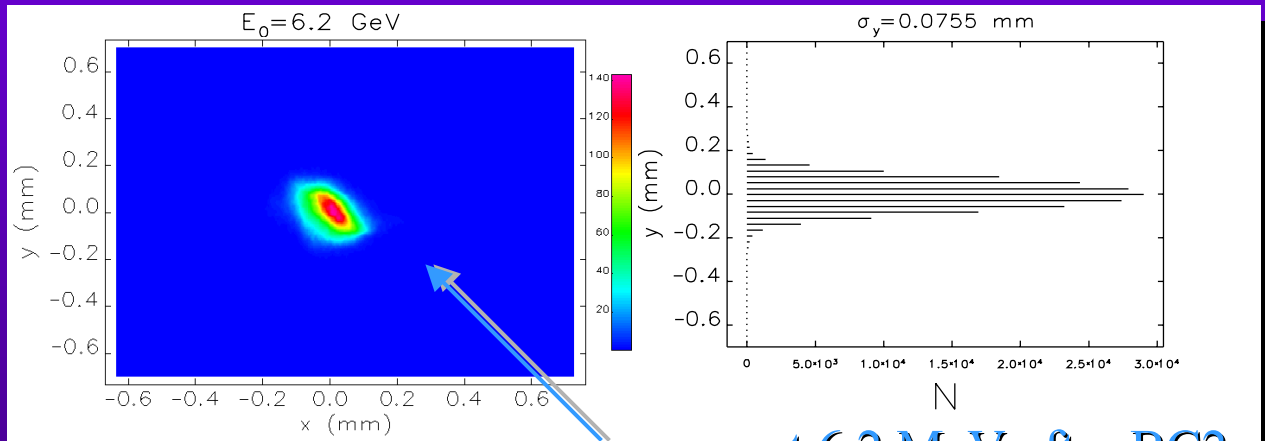
after BC2

$E = 4.5$ GeV

$\sigma_z \approx 22\ \mu$m

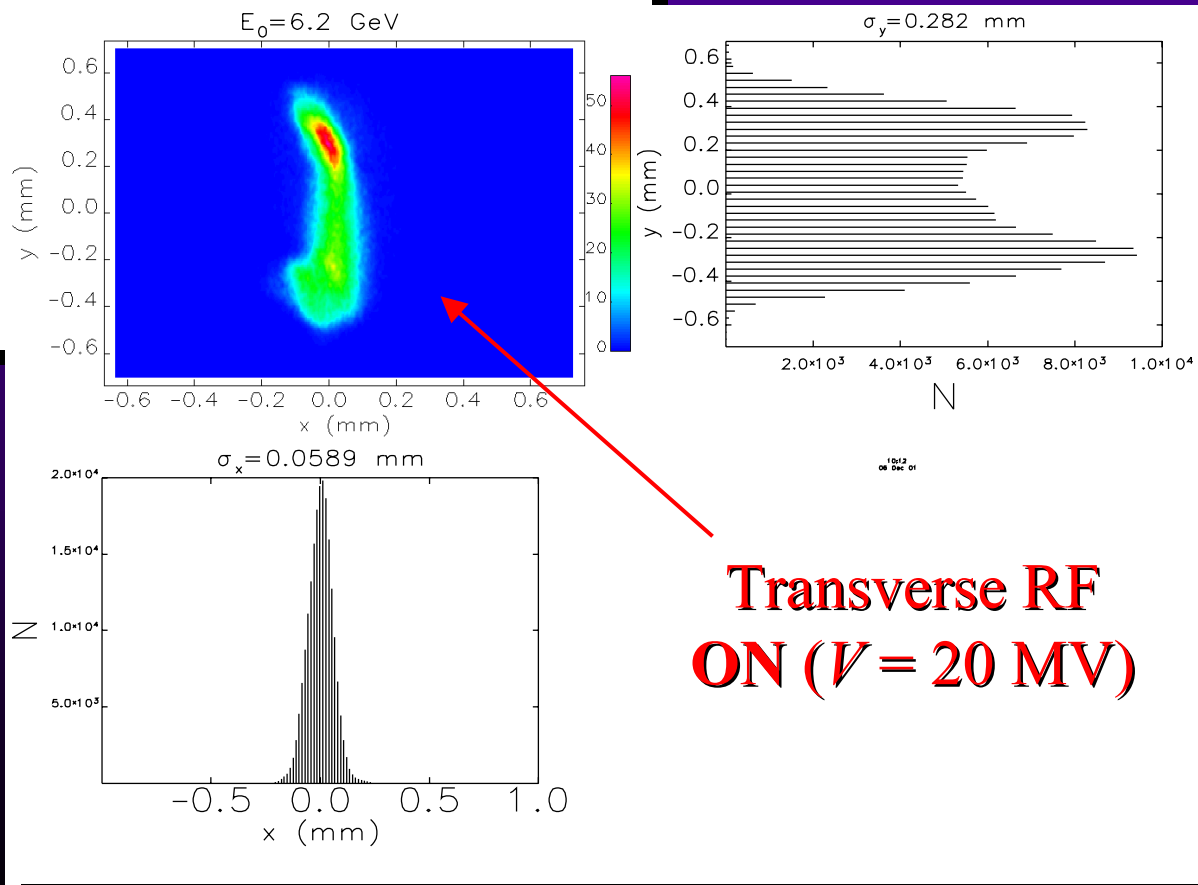
Diagnostics





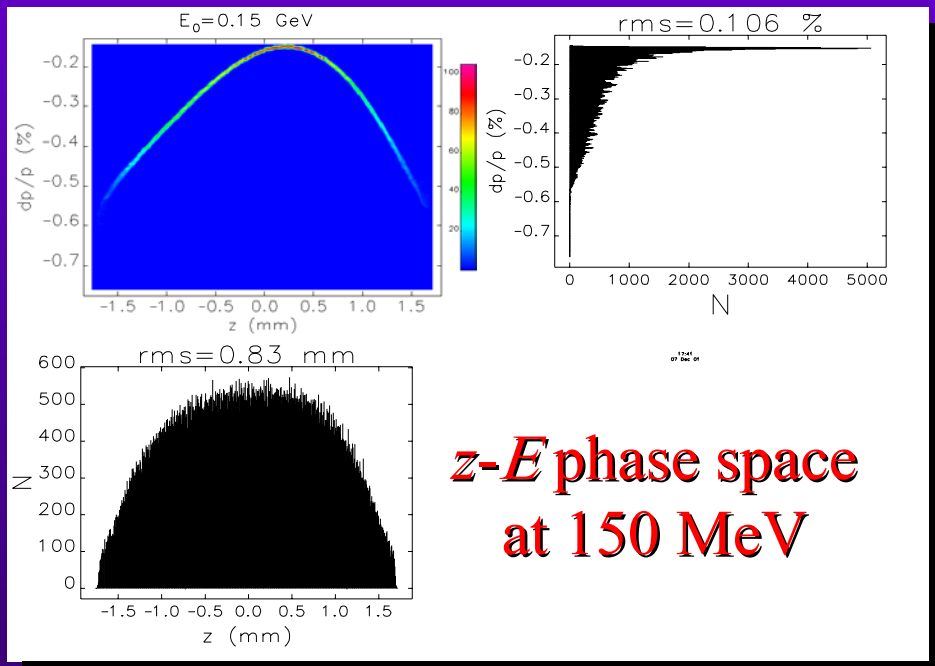
screen at 6.2 MeV after BC2
with transverse-RF **OFF**

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

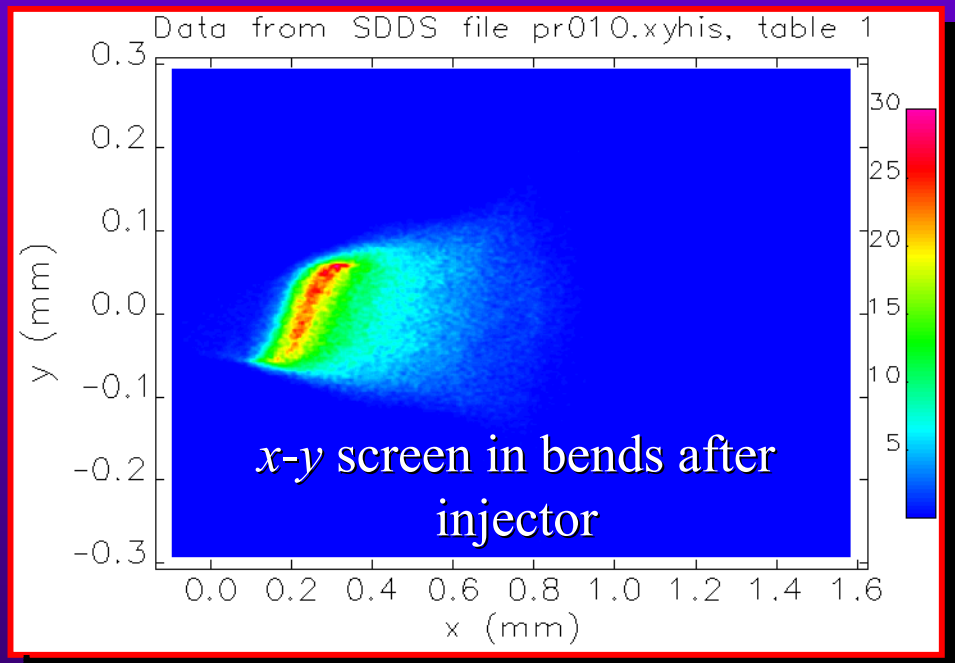


Transverse RF ON (V = 20 MV)

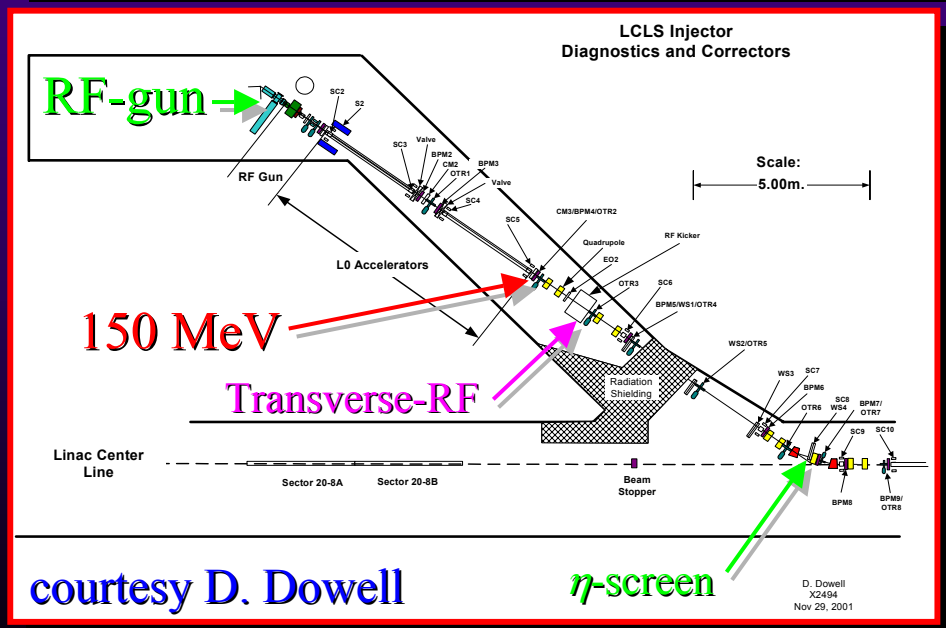
Transverse RF cavity at 150 MeV

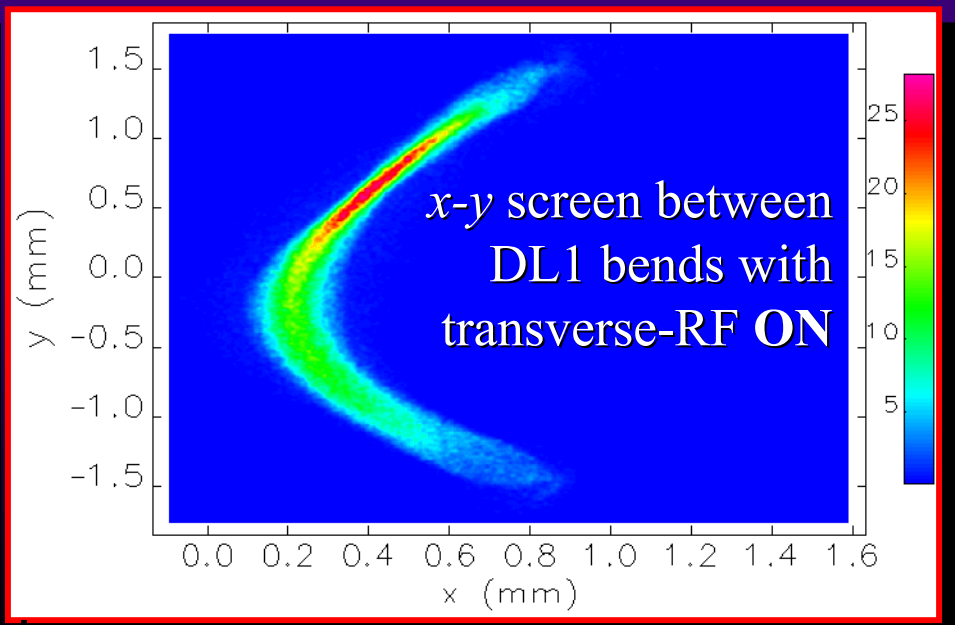


z-E phase space at 150 MeV



x-y screen in bends after injector

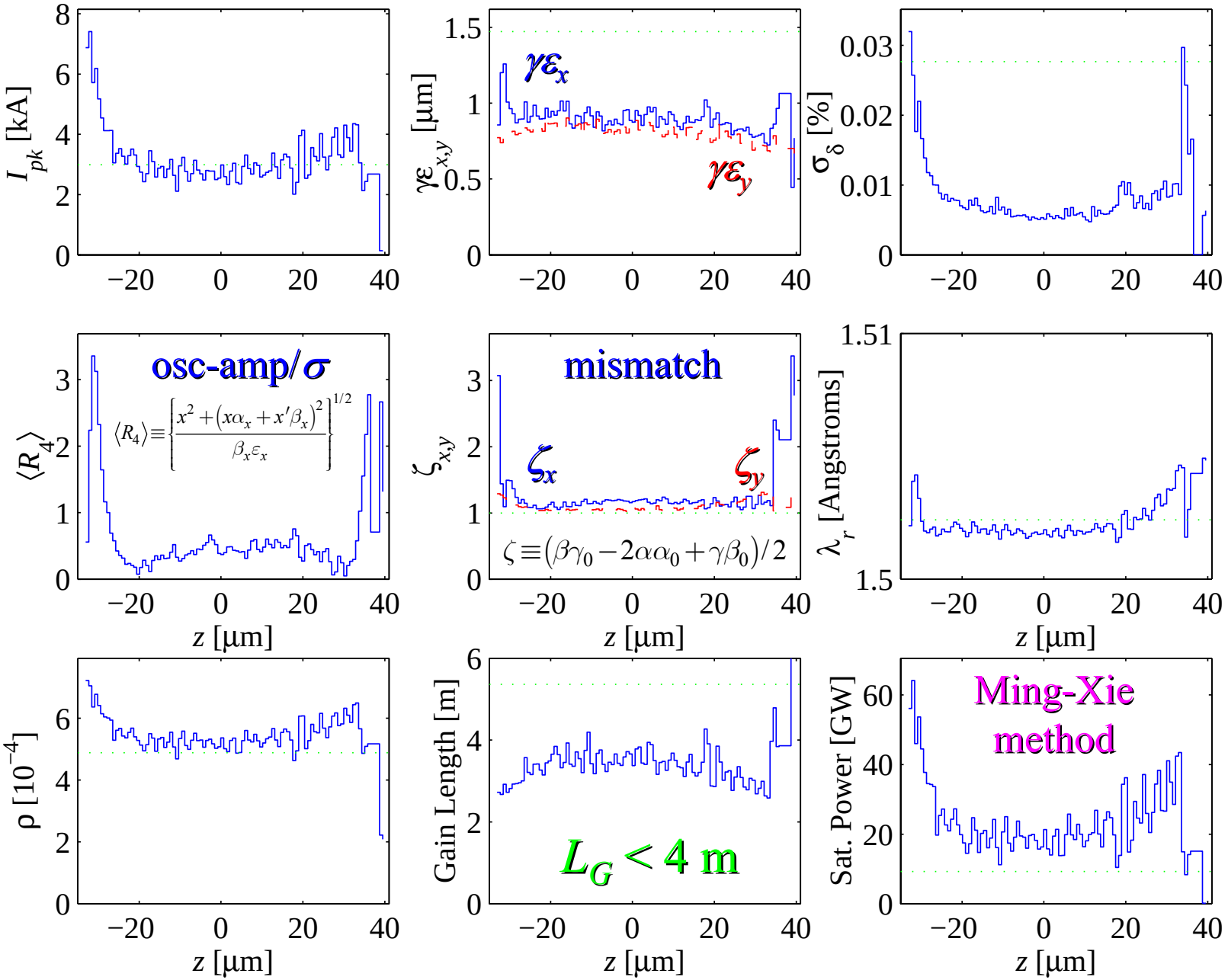




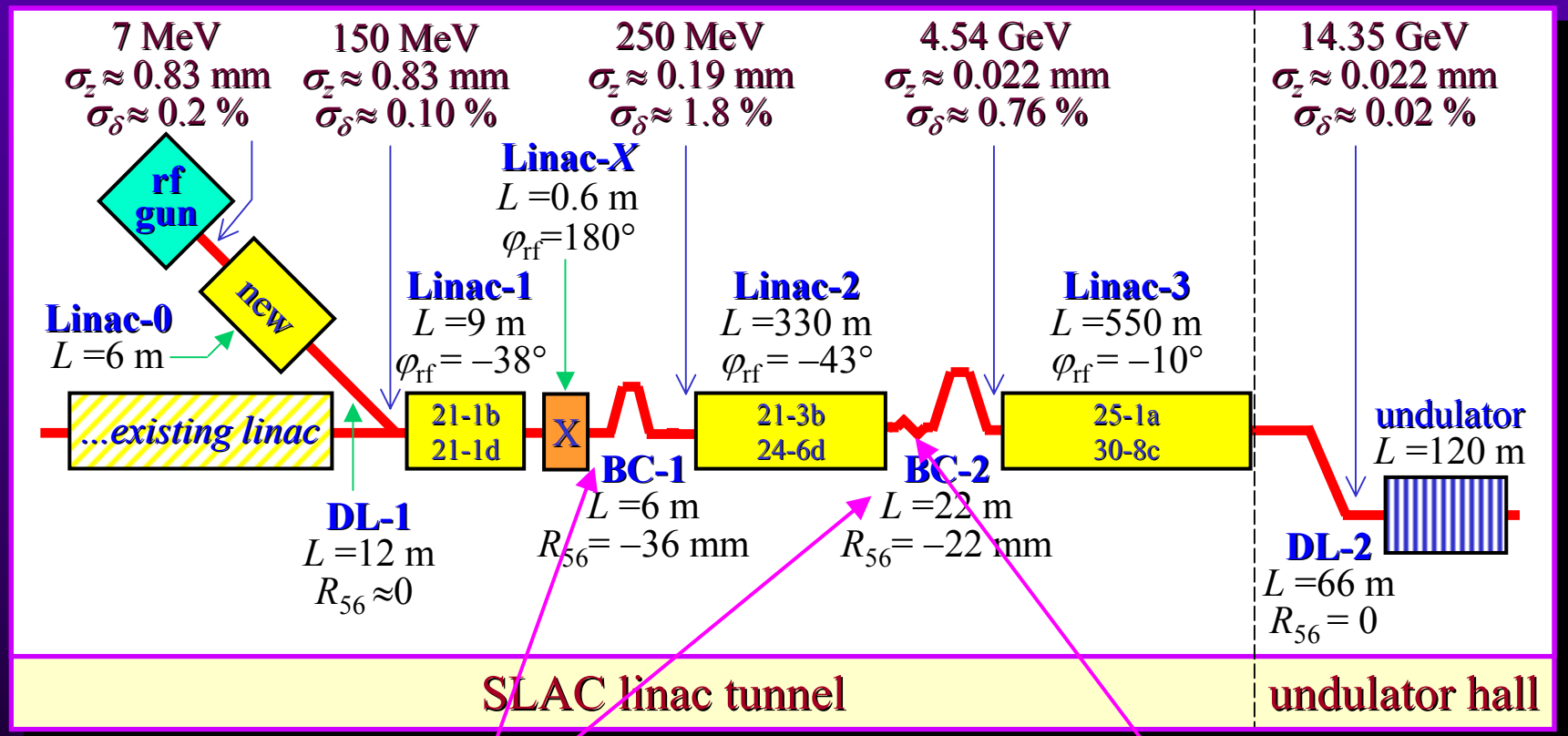
x-y screen between DL1 bends with transverse-RF **ON**

$L = 55$ cm, $V = 1$ MV, $P \approx 1.3$ MW

Sliced Beam After Injector and Linac Tracking



LCLS Accelerator and Compressor Schematic



single-chicanes

(12/01/01)

SC-wiggler

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 → (see M. Borland talk…)

Thanks to M. Borland for ***Elegant*** and ***SDDS-Toolkit***