Integration of layout components for beam dynamics control

S. Di Mitri (1.0 hr.)

Credits:
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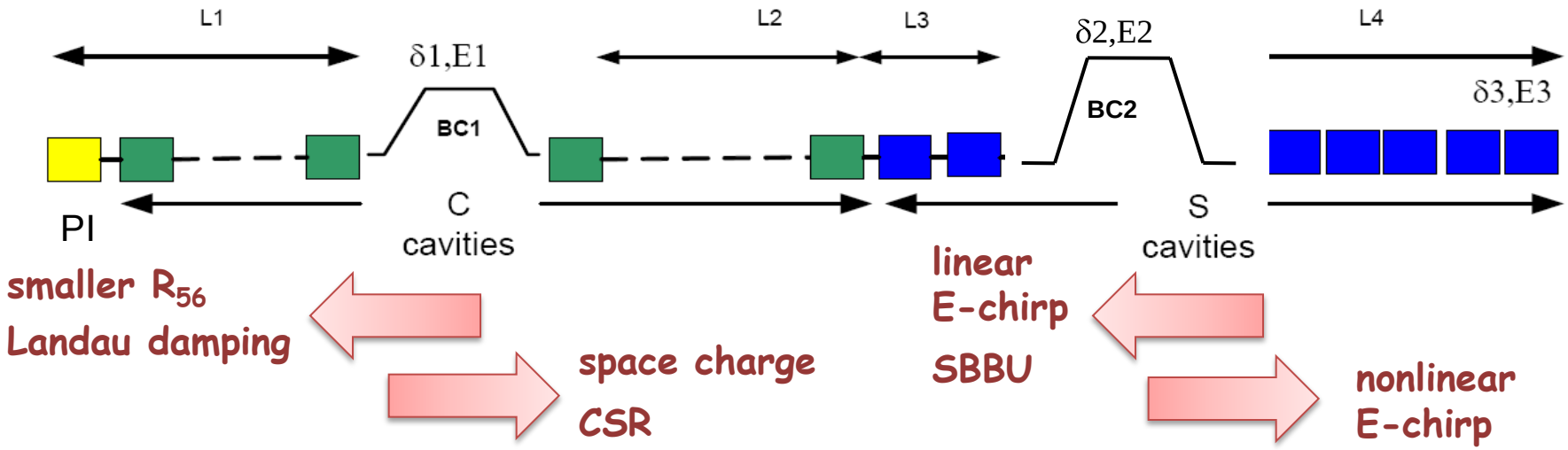
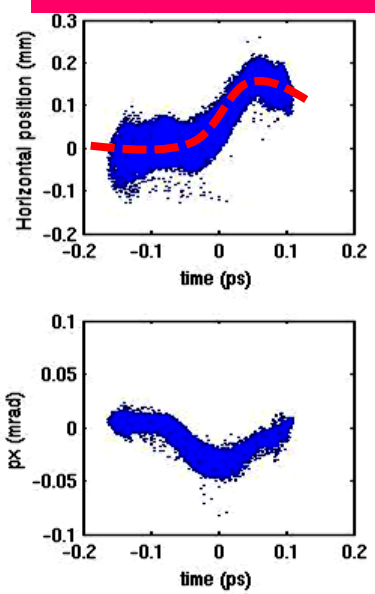
COMPRESSION – Energy, Geometry, Optics

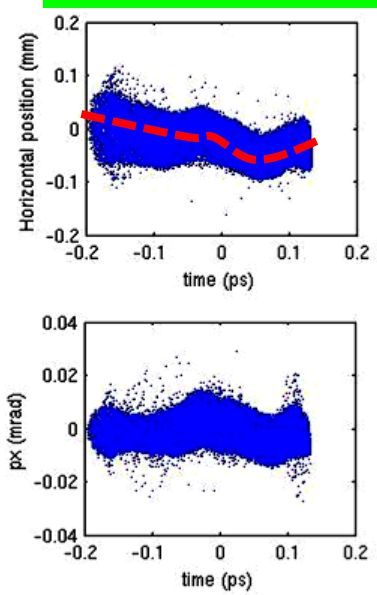
Pictures by M. Cornacchia, R. Bartolini et al. S. Di Mitri et al., PRST-AB 15, 020701 (2012)

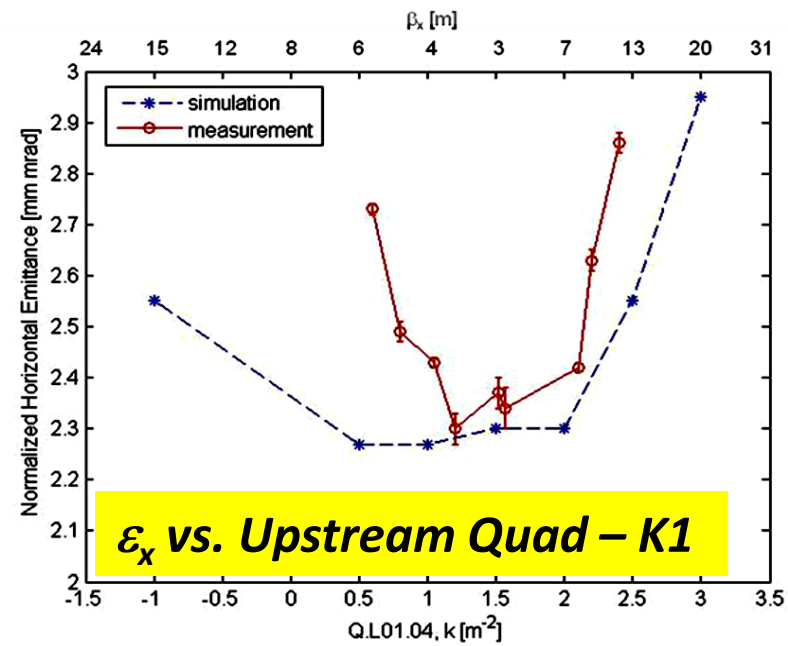


***C-type* chicane**



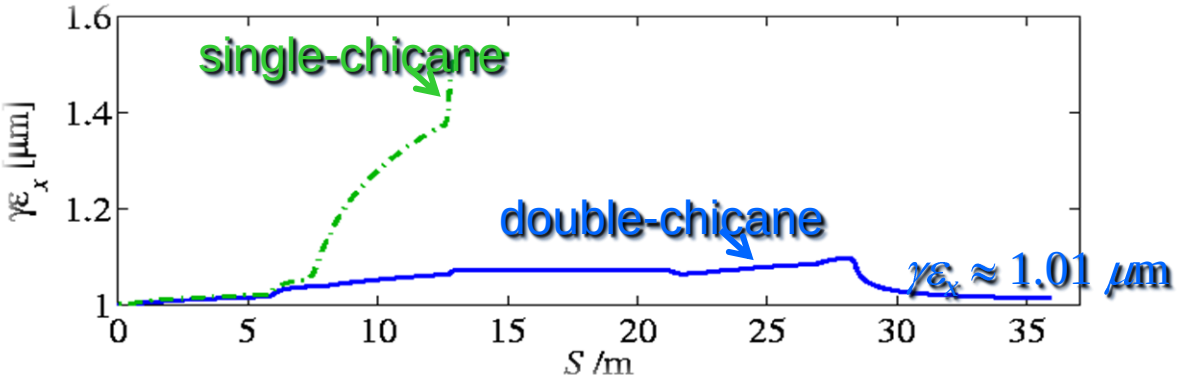
***S-type* chicane**



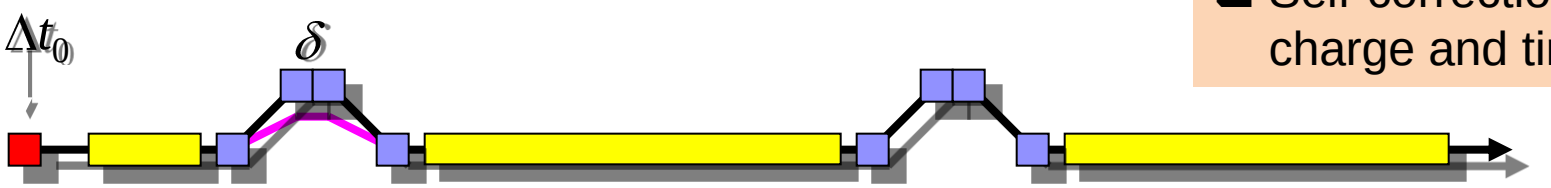


COMPRESSION – Stages

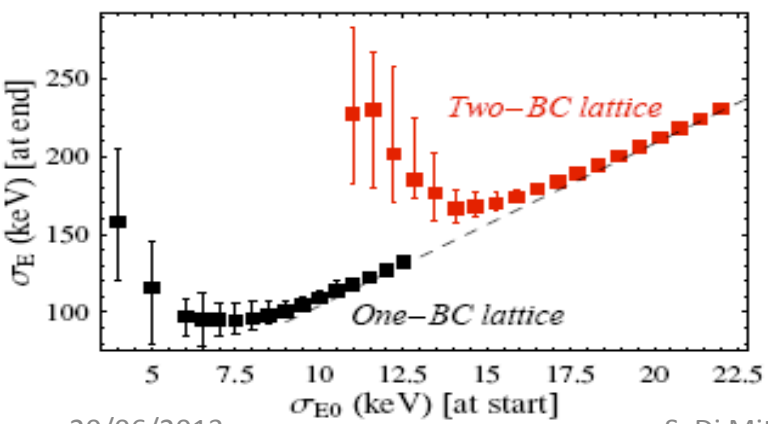
Pictures courtesy of
P. Emma, M. Venturini



- CSR-induced ε-growth minimized.
- RF tols relaxed.
- Self-correction against charge and time jitter.



late arrival, higher energy, less chirp → longer bunch, less wake, more chirp → ~same bunch length

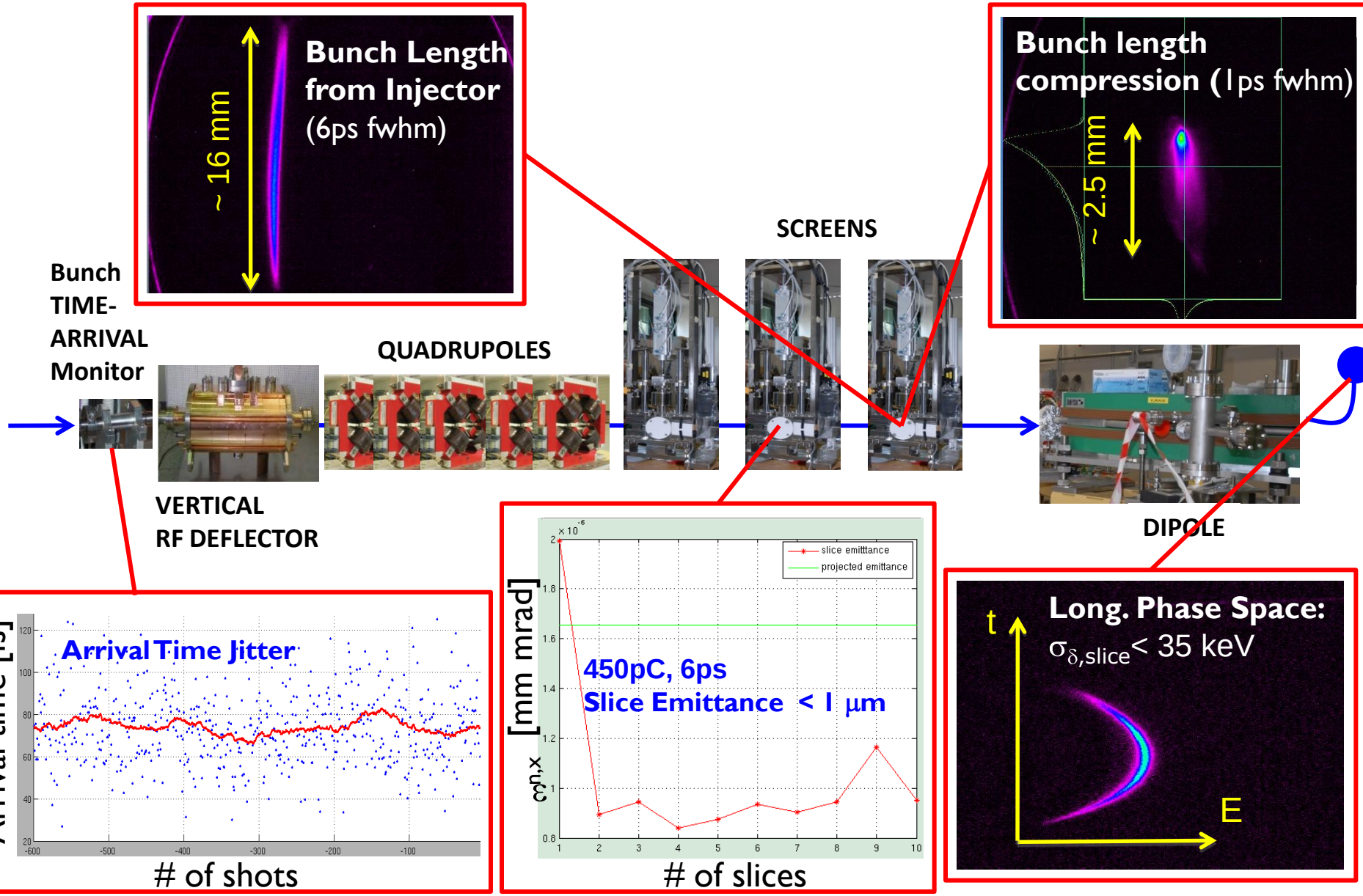


- Microbunching instability has larger gain → stronger heating required → higher slice energy spread at the end

M. Venturini et.al., PRST-AB, 10, 054403(2007)

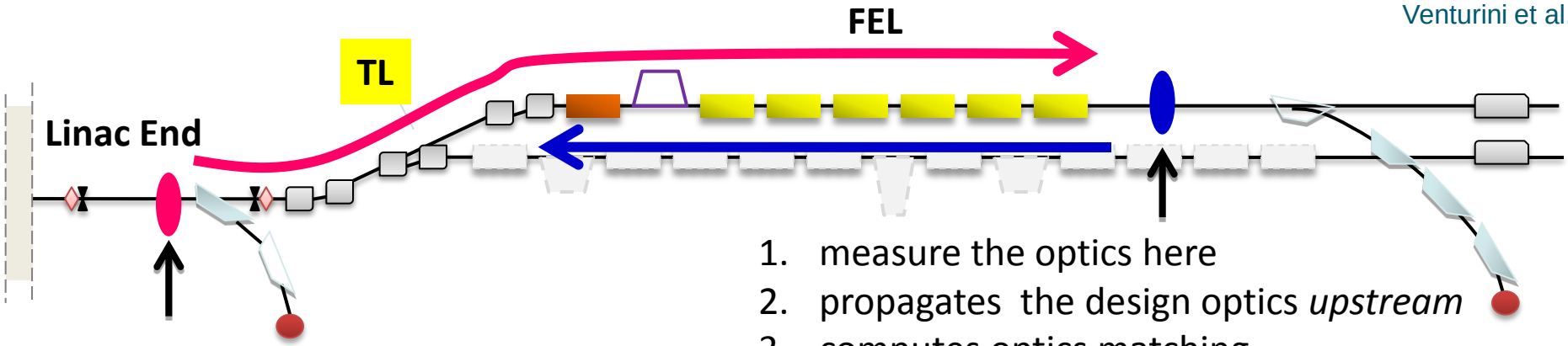
e-BEAM DIAGNOSTICS

Pictures courtesy of
G. Penco et al.



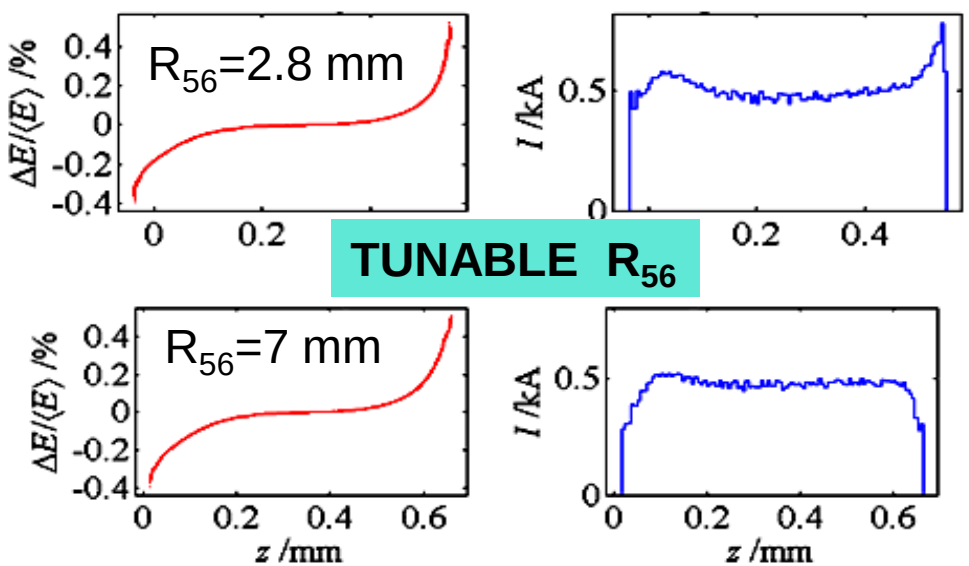
TRANSFER LINE

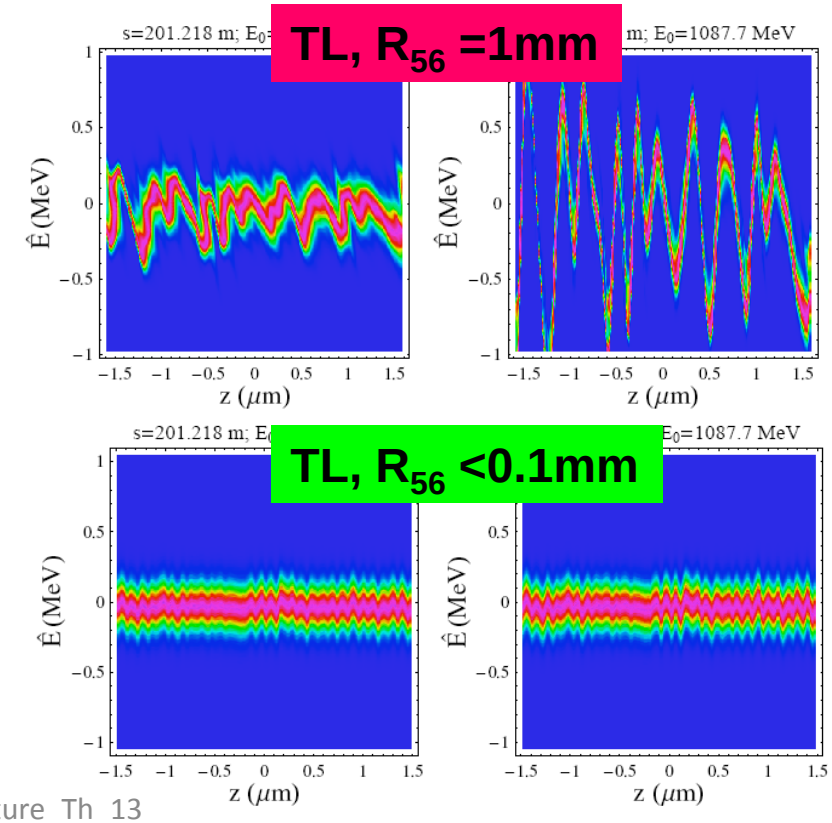
Pictures courtesy of M. Cornacchia, M. Venturini et al.



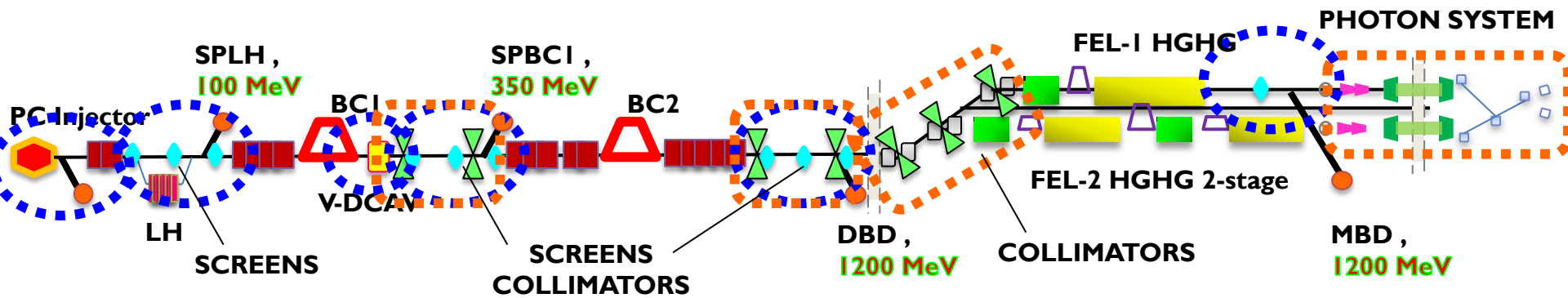
1. measure the optics here
2. propagates the design optics *upstream*
3. computes optics matching

1. measure the optics here
2. computes optics matching here
3. propagates the design optics *downstream*

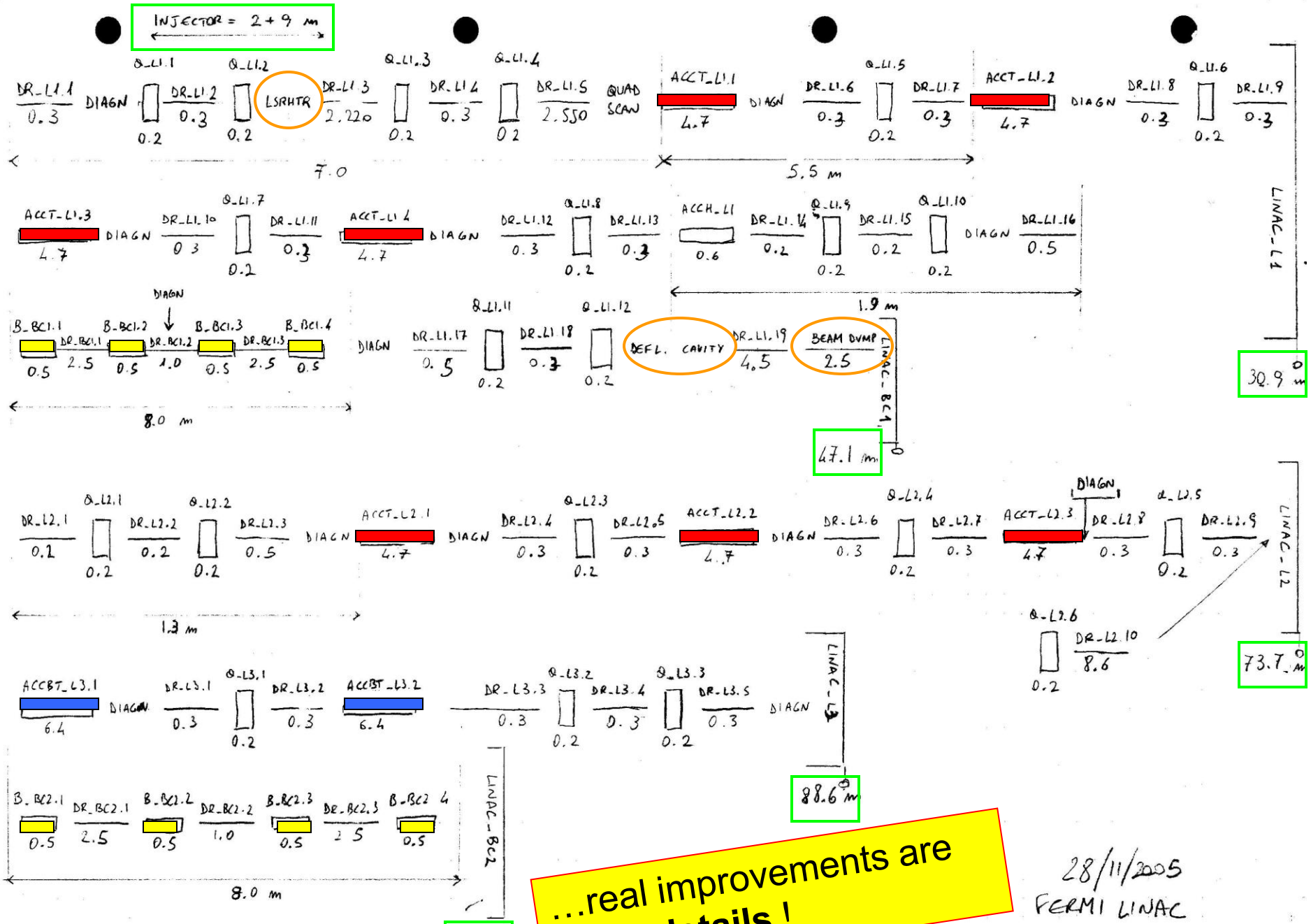




Layout Summing Up (Example)



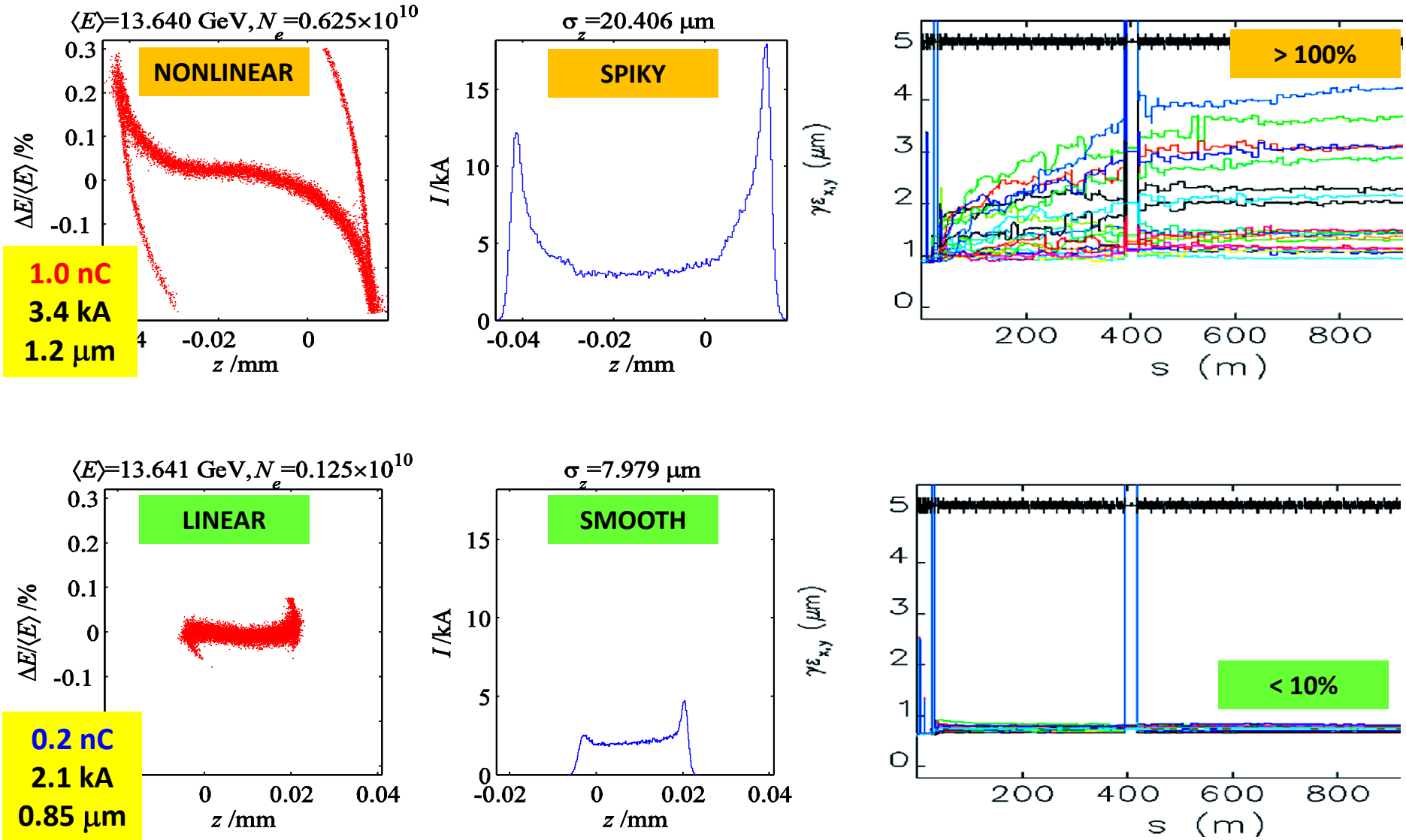
- RF Photo-cathode Gun and Injector + up to1.35 GeV Linac
- 2 Magnetic Bunch Length Compressors + 2 Bunch Length Monitors
- RF Vertical Deflector for time-resolved measurements
- 4 optics Diagnostic Stations + 5 Spectrometers
- 3 Collimation sections
- Planar and APPLE-II type Undulators + RF BPMs + γ/e- Screens + Quad-movers
- Photon Diagnostics Hutch + X-ray Transport + 3 Beamlines



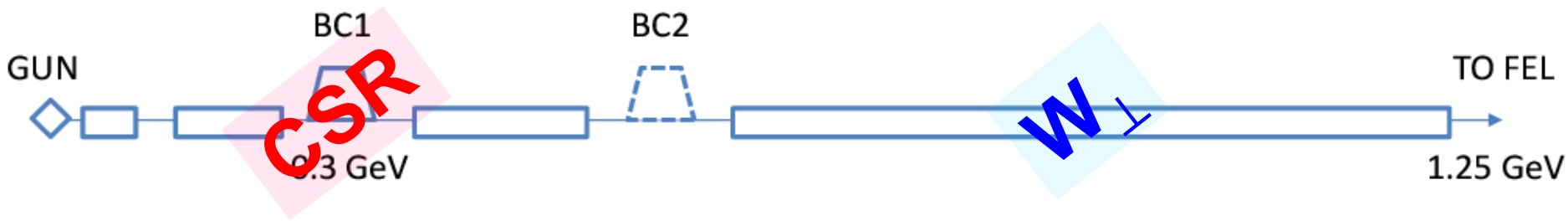
…real improvements are in the **details** !

Which beam?

Pictures courtesy of P. Emma



T–X–Y Coupled Dynamics



$$\Delta\gamma_0\varepsilon_{i,0} \cong \gamma_0\varepsilon_{i,0}\left[\sqrt{1+\frac{\breve{\beta}\theta^2\sigma_{\delta,CSR}^2}{\varepsilon_{i,0}}}-1\right] \equiv \gamma_0\varepsilon_{i,0}\left[\sqrt{1+X_{CSR}}-1\right]$$

$$\sigma_{\delta,CSR} \propto \frac{Q}{\gamma}\left(\frac{C}{\sigma_{z,0}}\right)^{\alpha>1}$$

- **CSR** in magnetic compressors affects the projected **emittance** (in the bending plane): the effect is **stronger** for **shorter bunches**.

$$\Delta\gamma_f\varepsilon_{f,0} \cong \gamma_f\varepsilon_{f,0}\left[\sqrt{1+2\left(\frac{\pi r_e}{Z_0 ce}\right)^2\frac{Q^2\overline{W}_\perp^{\,2}(\sigma_z)L_{FODO}L_{tot}\overline{\beta}}{\gamma_f\varepsilon_{f,0}\sqrt{\gamma_0\gamma_f}}\Delta^2}-1\right] \equiv \gamma_f\varepsilon_{f,0}\left[\sqrt{1+X_W}-1\right]$$

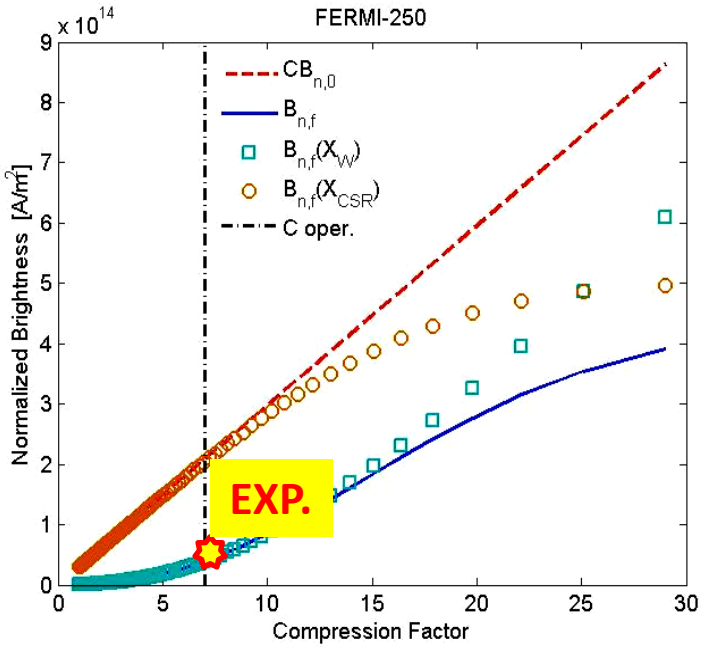
- **$W_\perp$** in the linac affects the projected **emittance** (in both planes): the effect is **stronger** for **longer bunches**.

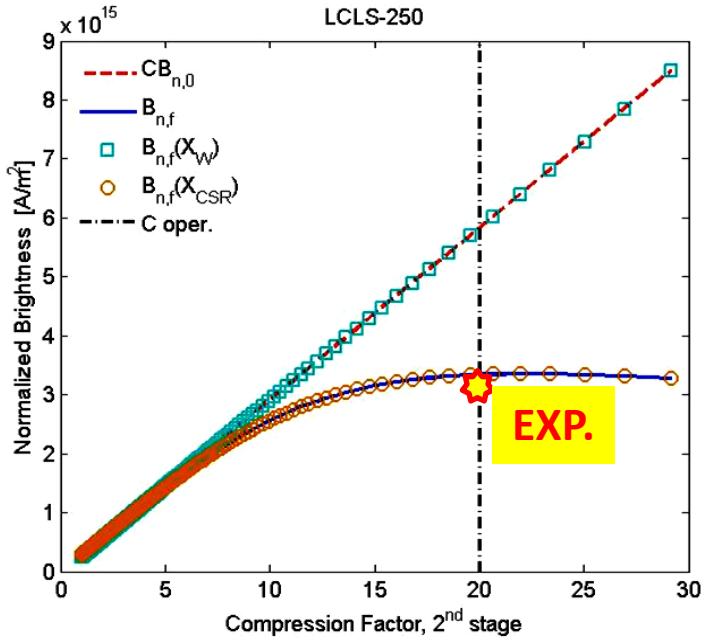
4-D Brightness

S. Di Mitri, PRST-AB 16, 050701 (2013)

- ✓ *Assume* the CSR effect is dominated by the emission in the second half of the chicane (shorter bunch region).
- ✓ *Assume* $W_\perp$ effect is dominated by the random misalignment of acc. structures (over magnet offsets and spurious dispersion).

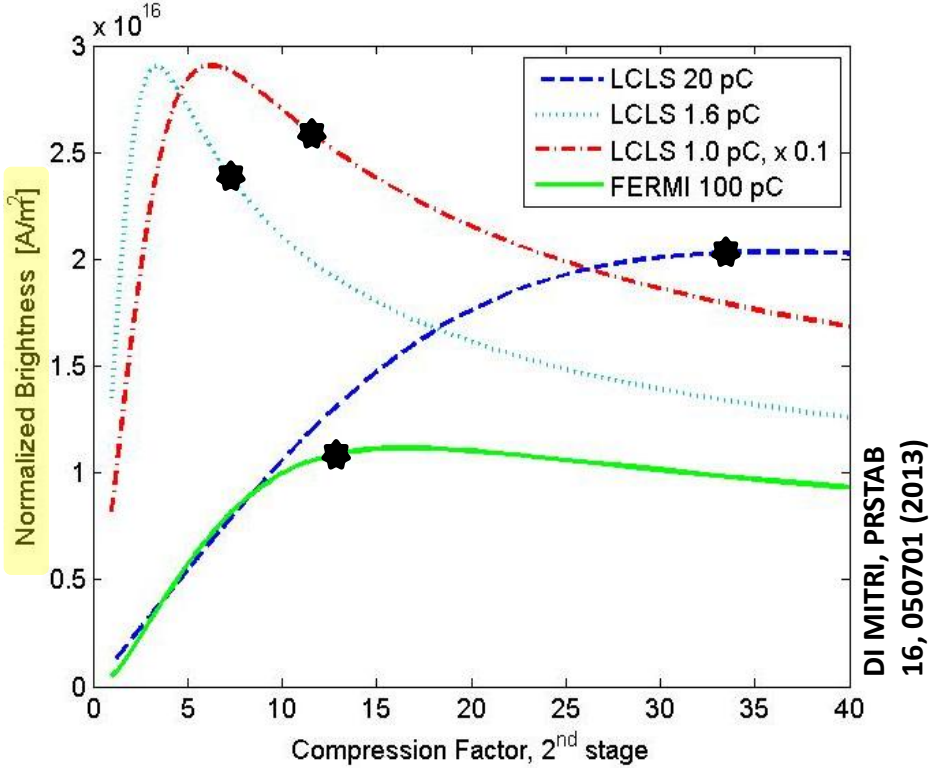
$$B_{n,f} \equiv \frac{I}{\gamma_f^2 \varepsilon_{x,f} \varepsilon_{y,f}} = \frac{CI_0}{\gamma_0 \varepsilon_{i,0}^2 \sqrt{(1+X_W)(1+X_{CSR}+X_W)}} \equiv \frac{CB_{n,0}}{\sqrt{(1+X_W)(1+X_{CSR}+X_W)}}$$

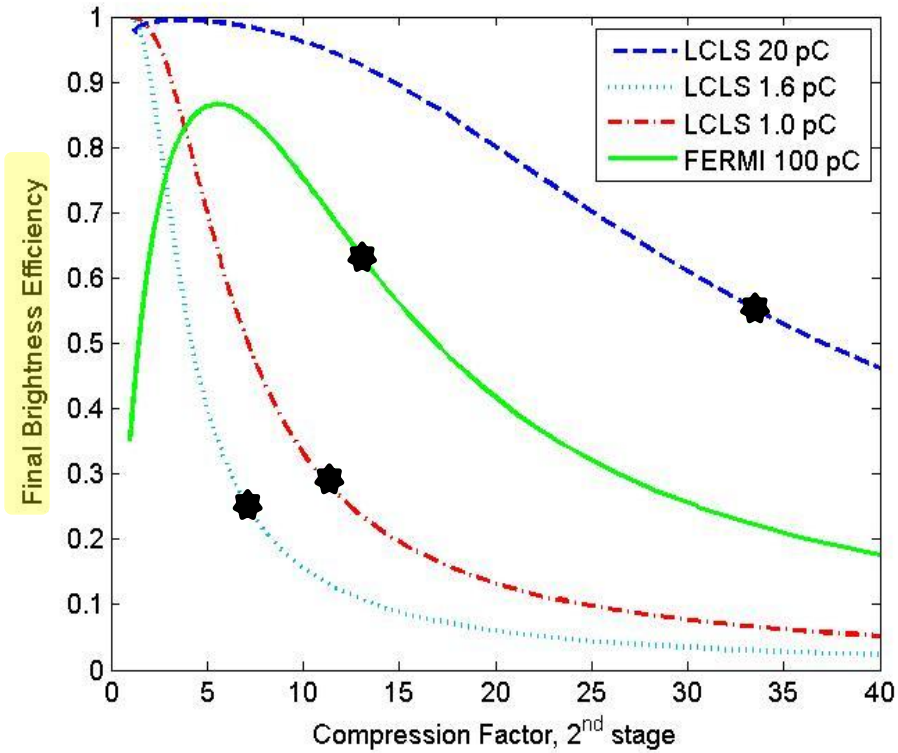




Brightness Optimization

S. Di Mitri, PRST-AB 16, 050701 (2013)





- Compression factor fixed to reach 1.5kA and maximize $B_{n,f}/CB_{n,0}$.
- Fast analytical tool for guidance towards optimum working point (design) or brightness optimization (in already existing facilities).