CSR in x-ray ERLs

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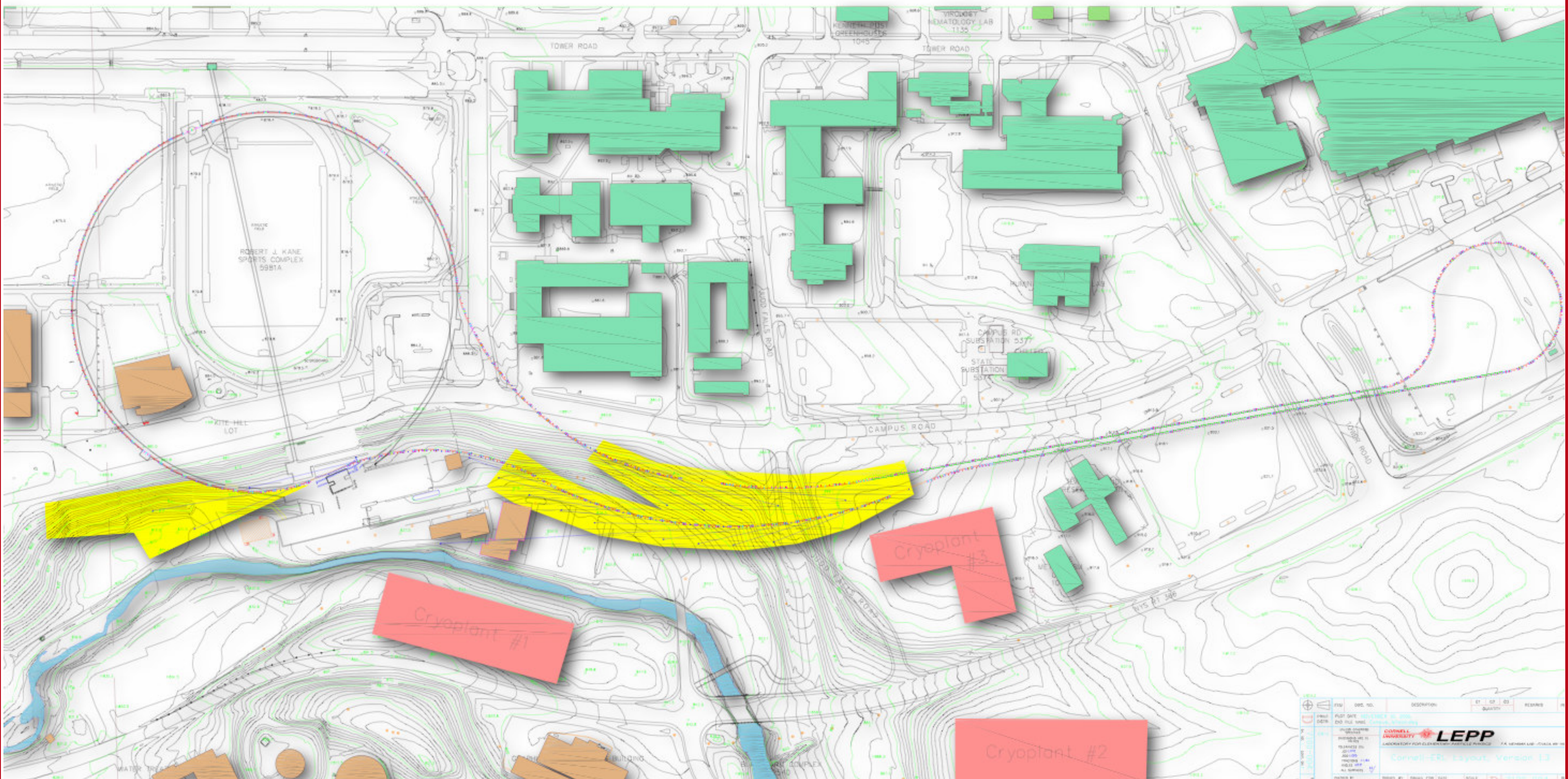

Short bunches after loops?

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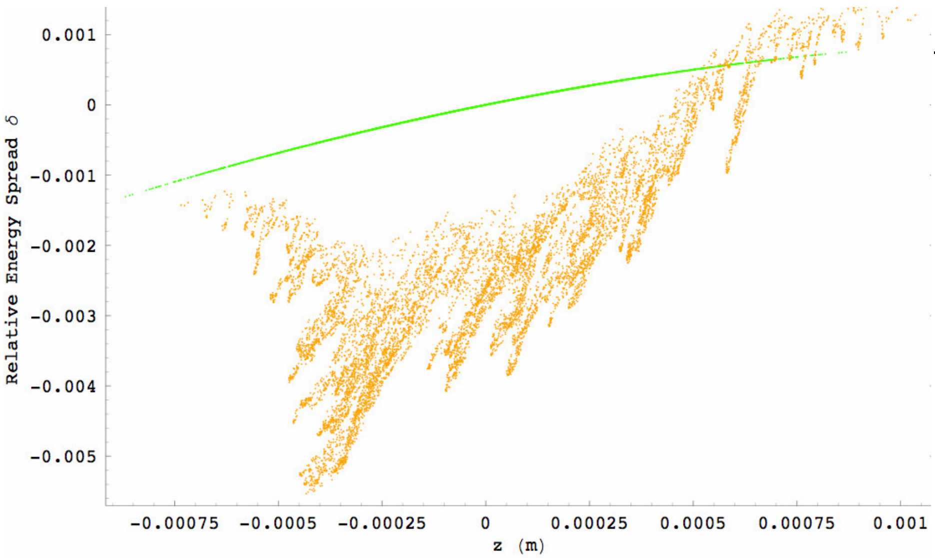
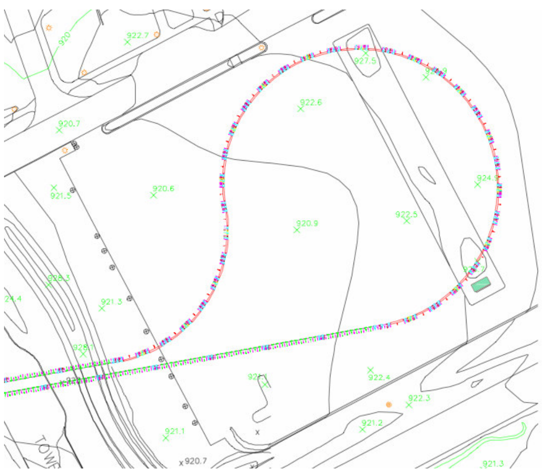
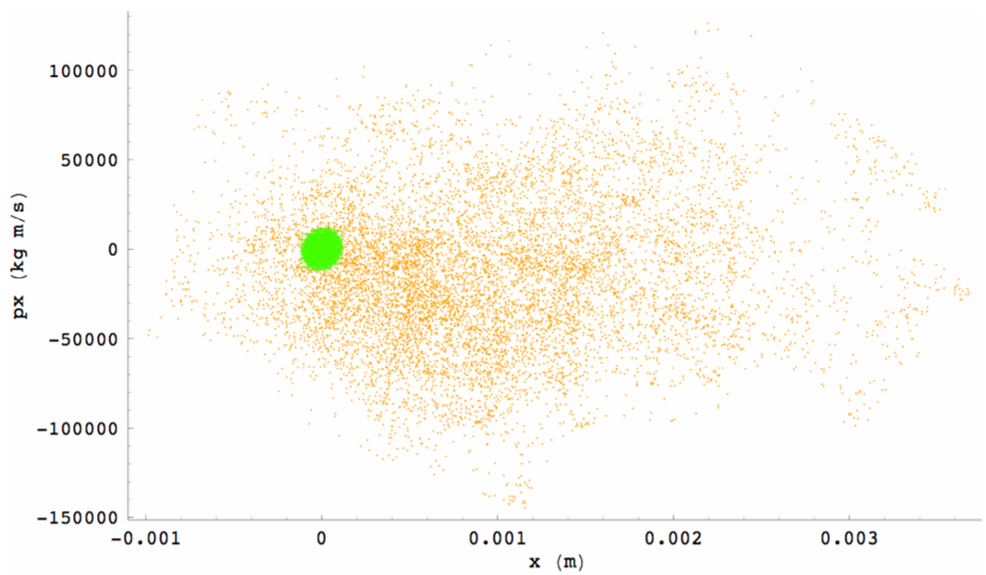


ERL Turnaround

- 1ps long bunch
- 1nC charge
- 0.3 mm-mrad normalized emittance





ELEGANT and TAO used here

Extremely short bunches in ERLs

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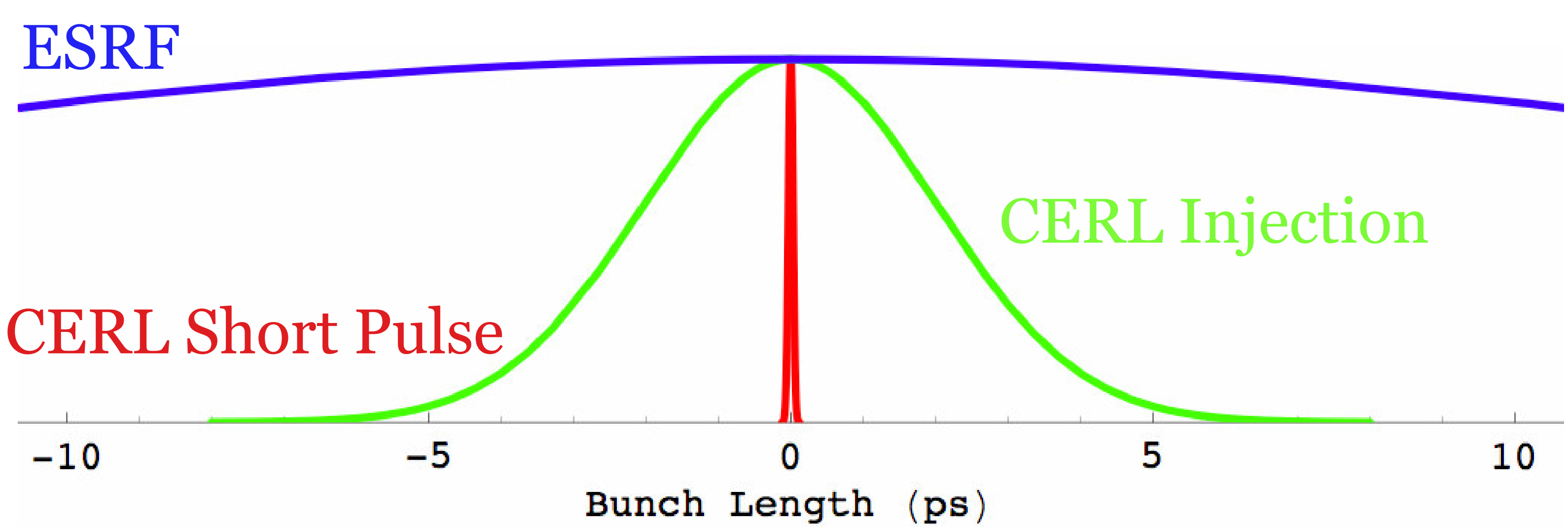
(1) Provide only rather low bunch charges (e.g. Wisconsin-FEL)

(2) Make short low current bunches in one linac (e.g. SPPS) and do not energy recover, but dump.

(3) Make short high current bunches in one linac and use immediately, then energy recover.



CSR for the ERL turn around for 2ps bunches

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Bending radius: 7.6m

Number of bends: 24 bends of 1m length, 12 bends of 2m length

Phase advance chosen to cancel CSR kicks:
After each achromat, the horizontal phase advance is 3π.

Iincoherent radiation:
emittance growth = 20% of the 0.08 mm mrad of high sp. brightness mode B
energy spread growth = 2.1e-5, irrelevant even after deceleration

Coherent radiation:

	mode A	mode B	mode C
Emittance grwoth	1%	0.2%	1%
Energy spread growth	$4\ 10^{-5}$	10^{-6}	1%

CSR in ERL bends

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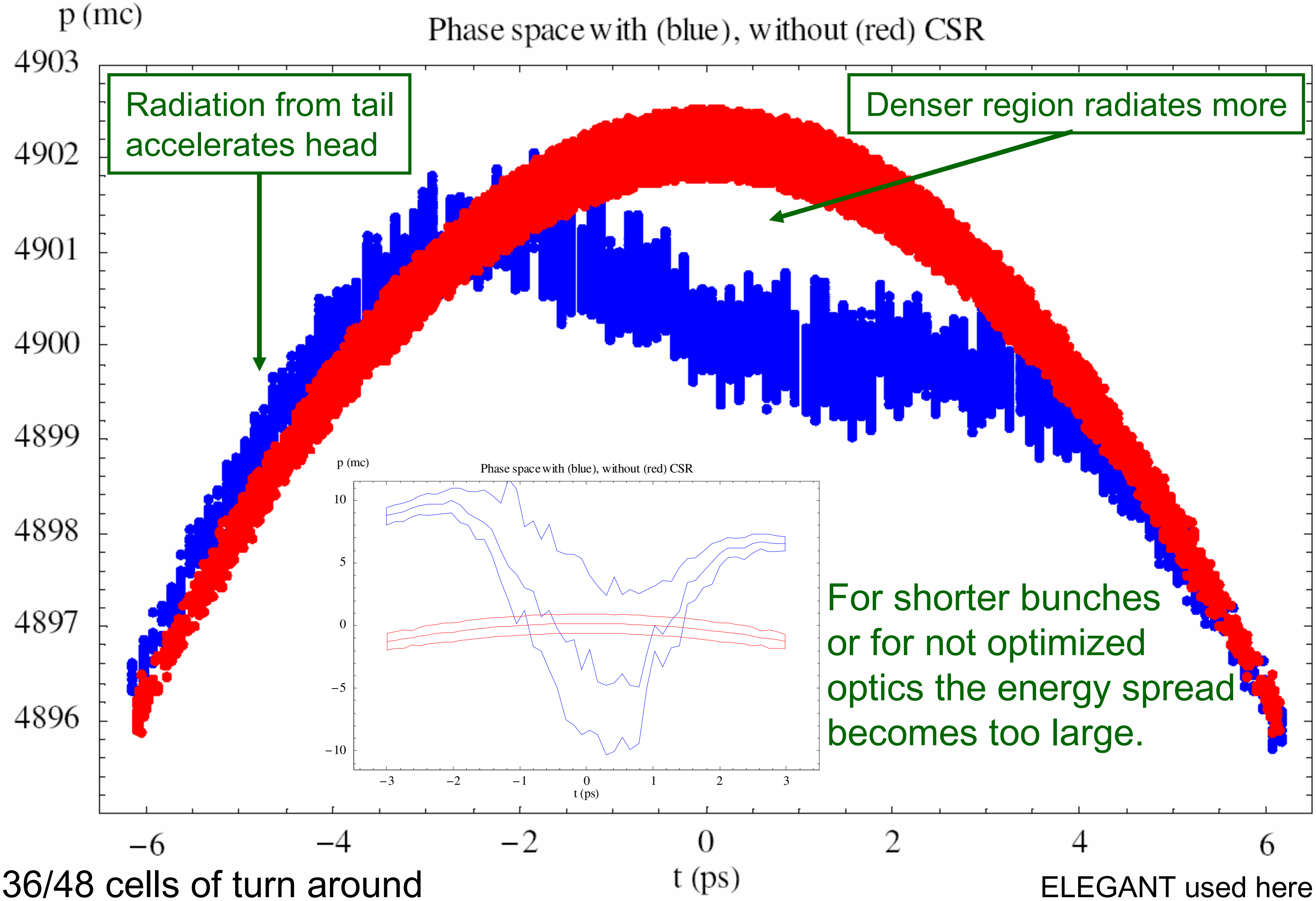

After 36/48 cells of turn around

ELEGANT used here

CSR in ERL bends

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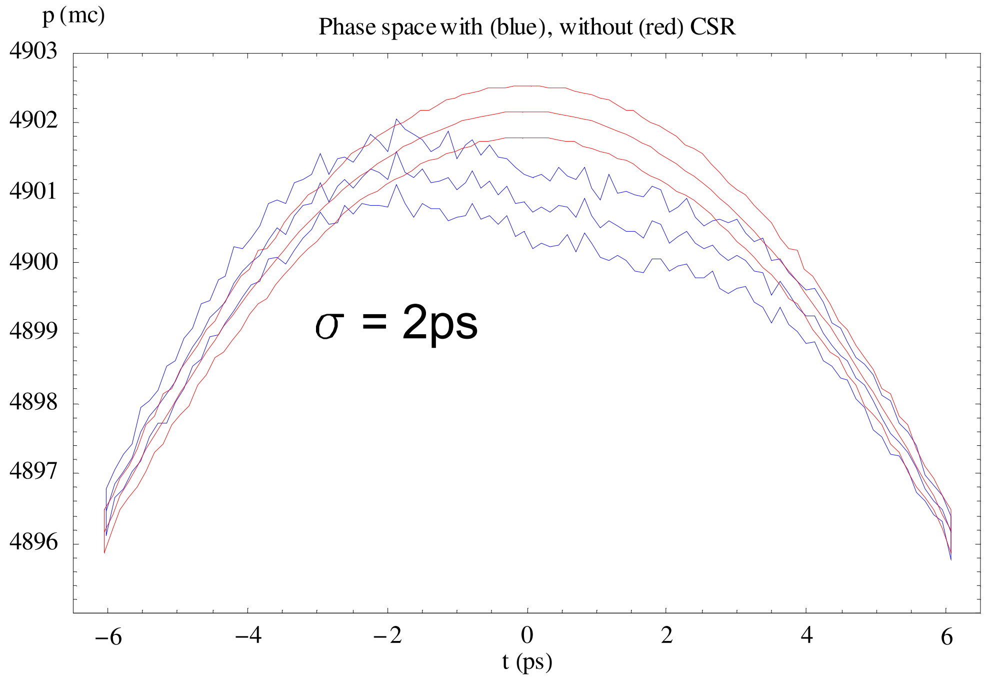

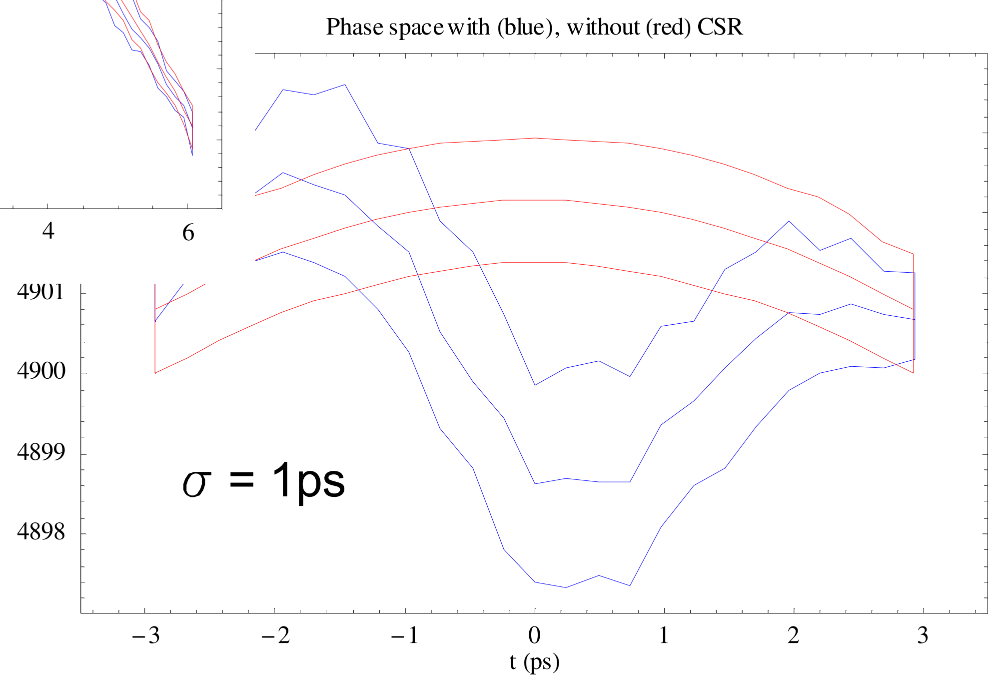

After 24/48 cells

ELEGANT used here

CSR bunch compression with decapoles

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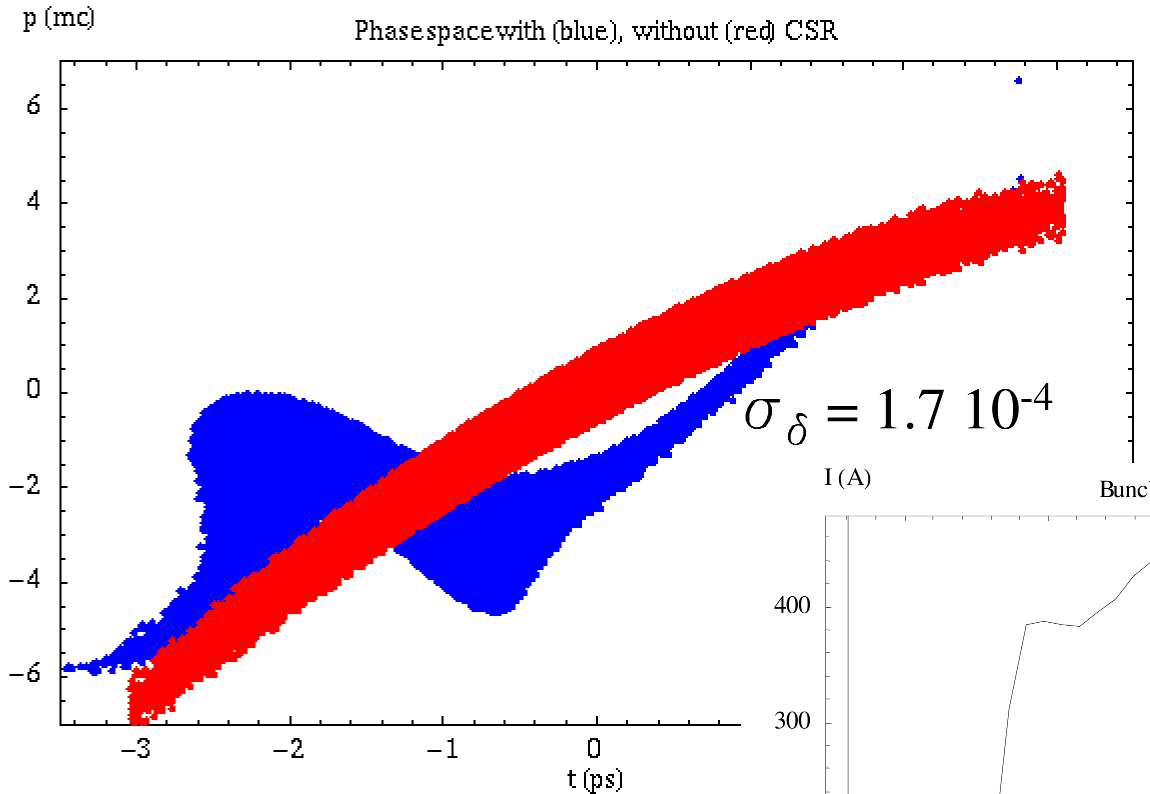

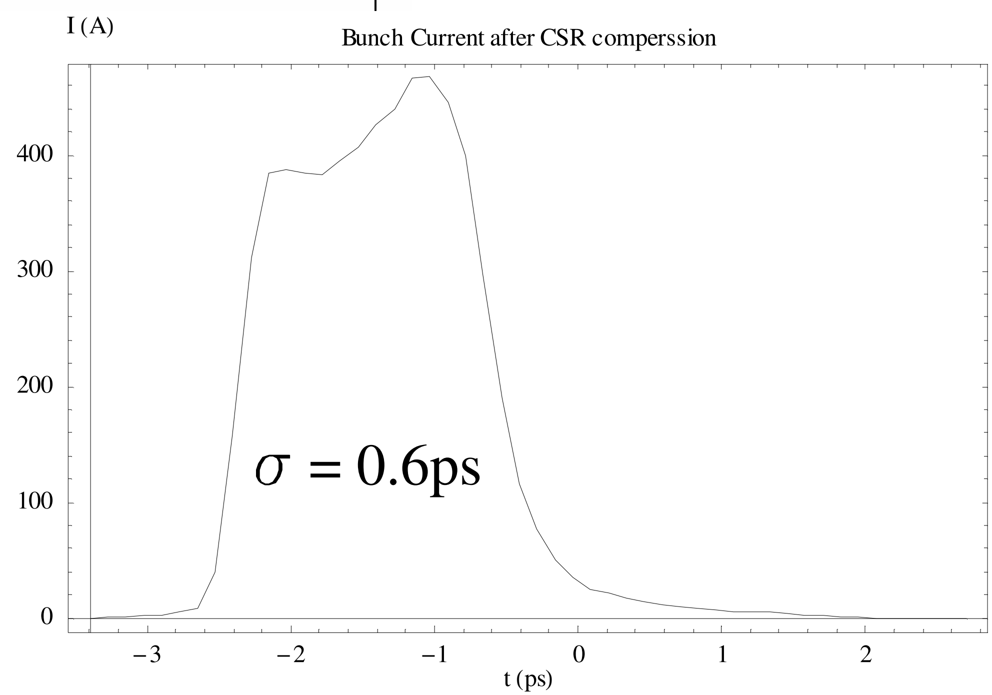

After turn around

Shielding of CSR in the turn around

- A 1.5cm vertical gap reduces the total CSR power by a factor of 130 for a Gaussian beam with σt = 1ps.

- For the large TA, 2.5cm vertical gap reduces the CSR power by 22.

Note for ERL mergers:
For a 10MeV merger, a 1cm gap would shield CSR in the full frequency range for bends with R > 1.4m !

Agoh/Yakoya Mesh (2004)

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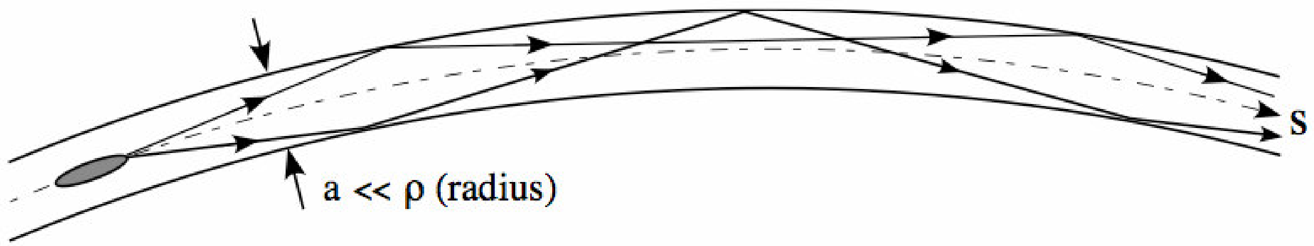
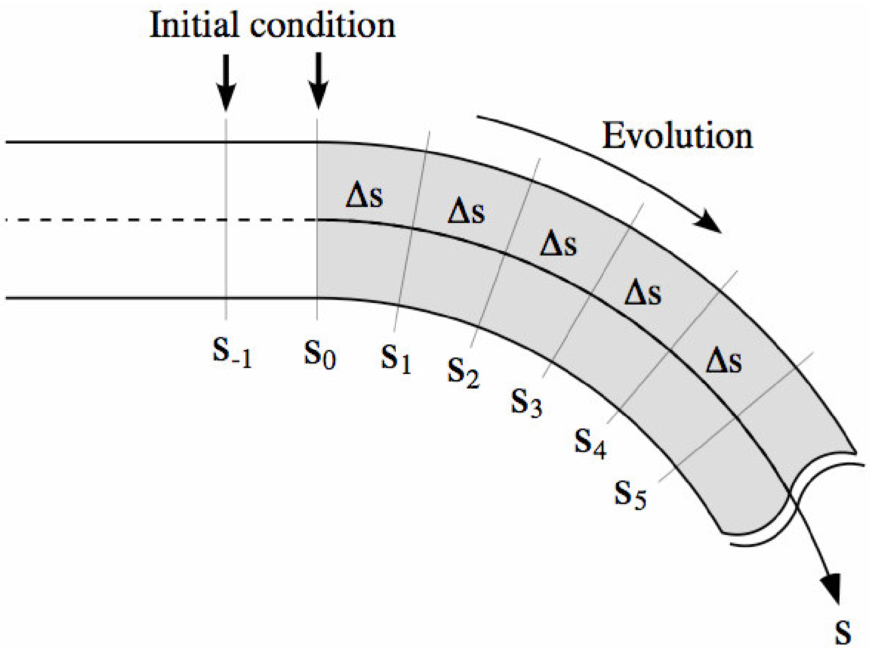
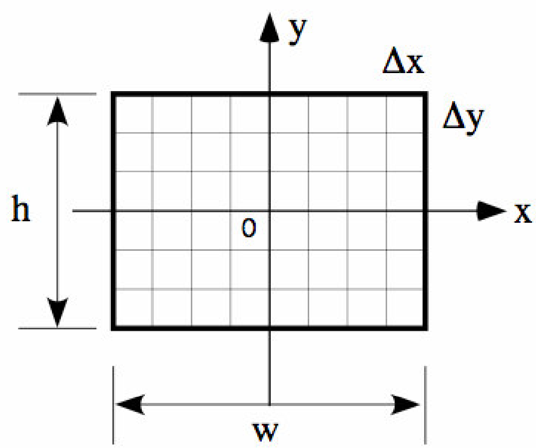


- Approximate Maxwell's Equations
- Discretize Space, Fourier Transform Time
- Propagate Fields, Construct CSR Wake





rectangular cross section
(boundary condition)

CSR energy loss and energy spread

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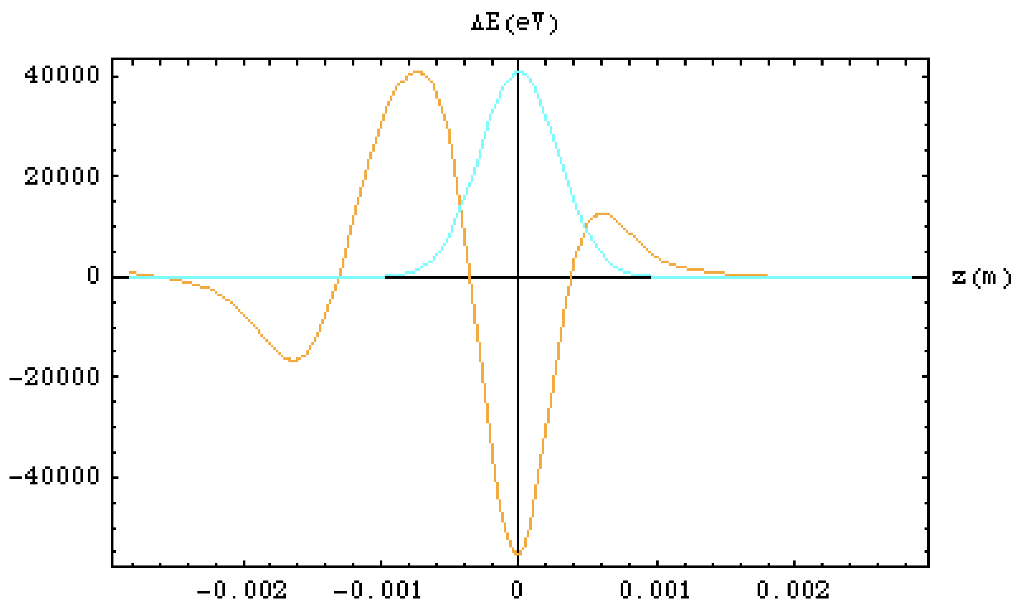
- The mesh code computes the longitudinal CSR wake
- Integrating the bunch over it leads to energy loss and energy spread



Name: 55_0.000283137m_X_0.025m, Charge = $1. \times 10^{-9}$ Coulombs, σz = 0.000283137m

Width = 0.025m Height = 0.025m

Bend Length = 1.m, Bend Radius = 7.63944m, Angle = 0.1309 = 7.5 Degrees

Averaged ΔE = -26541.6 eV

RMS ΔE = 26059.6 eV

Power shielding vs. wake-field shielding

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Phys. Rev. ST AB 7, 054403

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS, VOLUME 7, 054403 (2004)

Calculation of coherent synchrotron radiation using mesh

T. Agoh and K. Yokoya

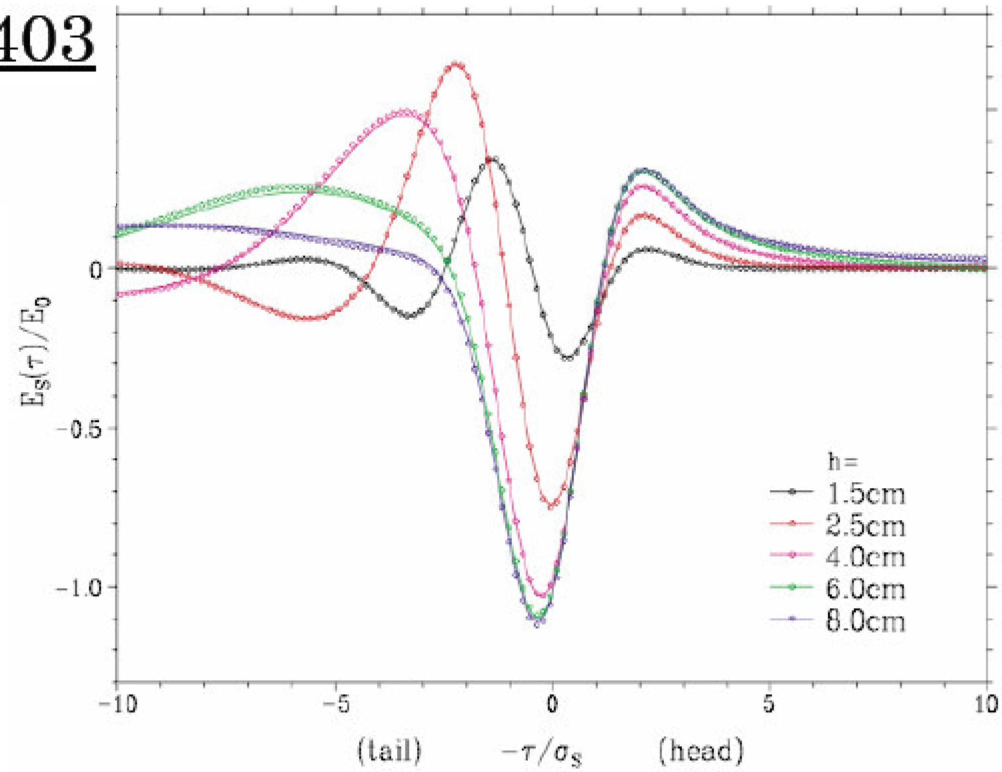
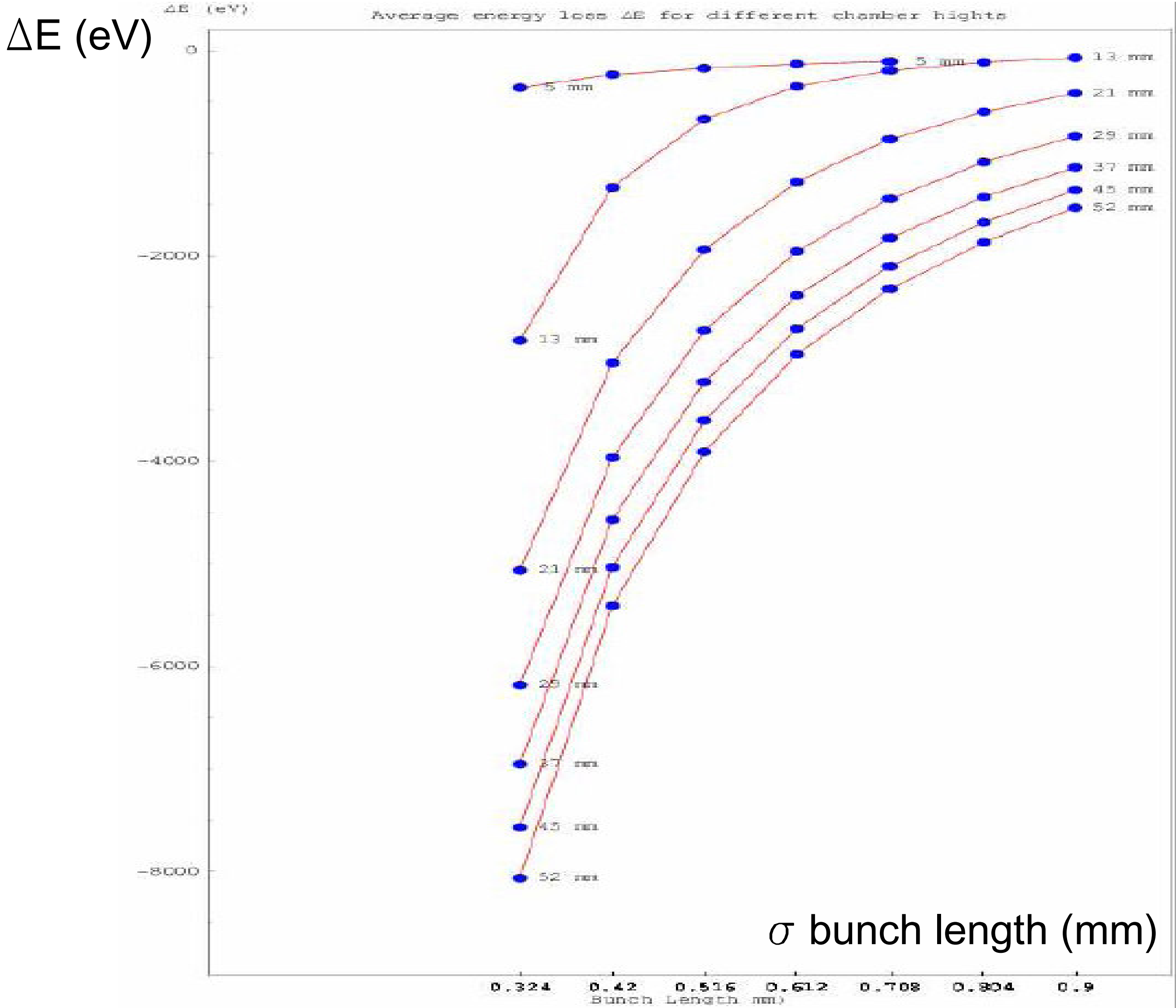


FIG. 2. (Color) The longitudinal electric field E_s in steady state at $x = y = 0$ between infinite parallel plates. Warnock's formula is plotted with solid lines. The dots are the simulation results. The different colors show the gap between the two horizontal parallel plates, $h = 1.5$ cm (black), 2.5 cm (red), 4 cm (magenta), 6 cm (green), and 8 cm (blue), respectively. The width of the chamber is $w = 50$ cm and the length of the magnet is 3 m. (bending radius: 10m)

There are parameter ranges for which the CSR power is strongly suppressed by a vertical aperture, but the CSR energy spread does not change much

→ We need detailed CSR wake understanding → measurements !

CSR energy loss supression



Wake-field shielding at Wilson

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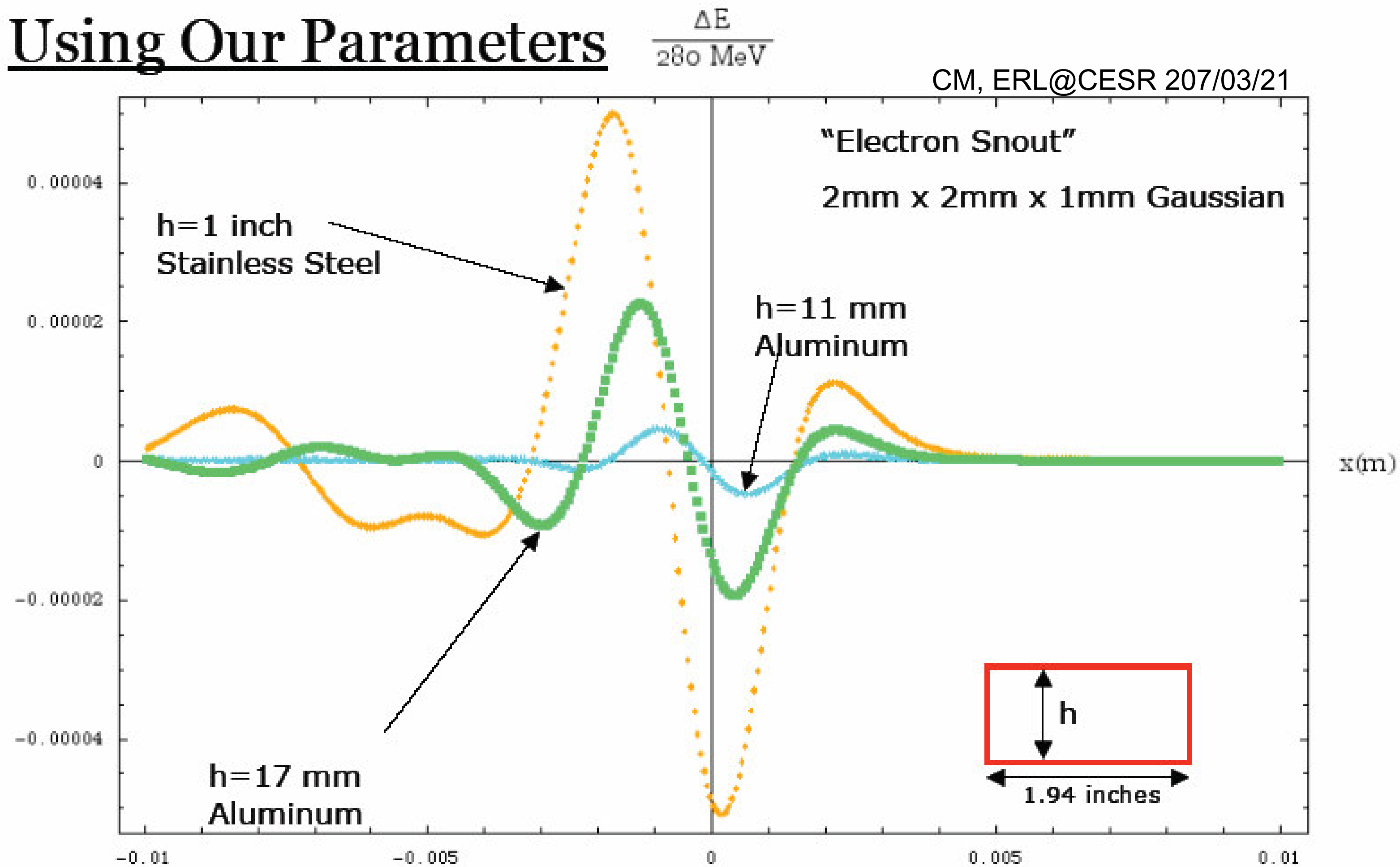
Using Our Parameters



For parameters of the analyzer magnet in the Wilson linac, the wake potential does get suppressed by shielding. But the CSR energy spread is too small to be measured.

CSR energy loss and spread in the TA

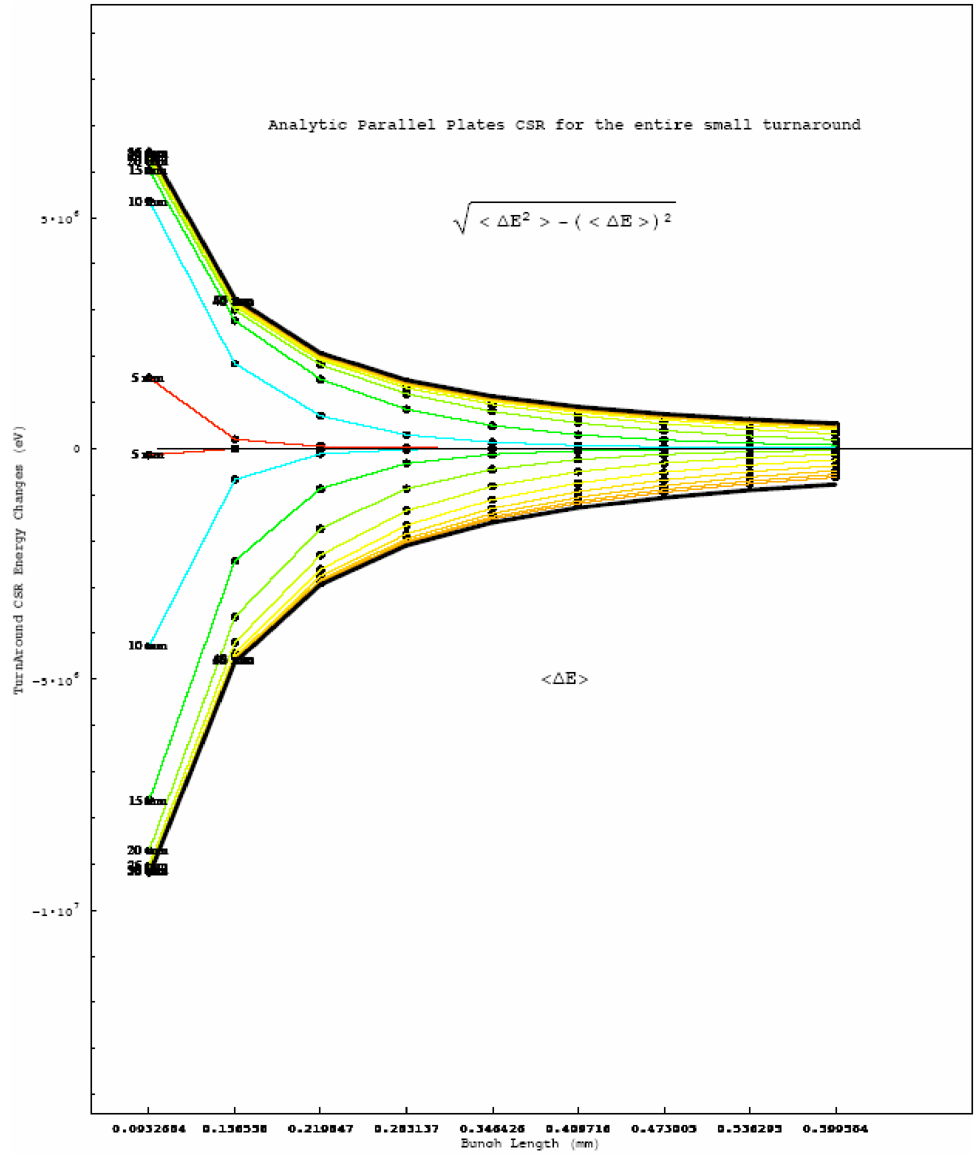
CHESS & LEPP

Analytic formalism due to Warnock (1991)

Computes the steady state radioactive Greensfunction in frequency space for zero potential at the vacuum chamber and integrates over the bunch distribution to obtain the CSR wake field.

Conclusion:

In the steady state, i.e. for very long magnets, the energy spread in the turn around would be suppressed by chamber walls.



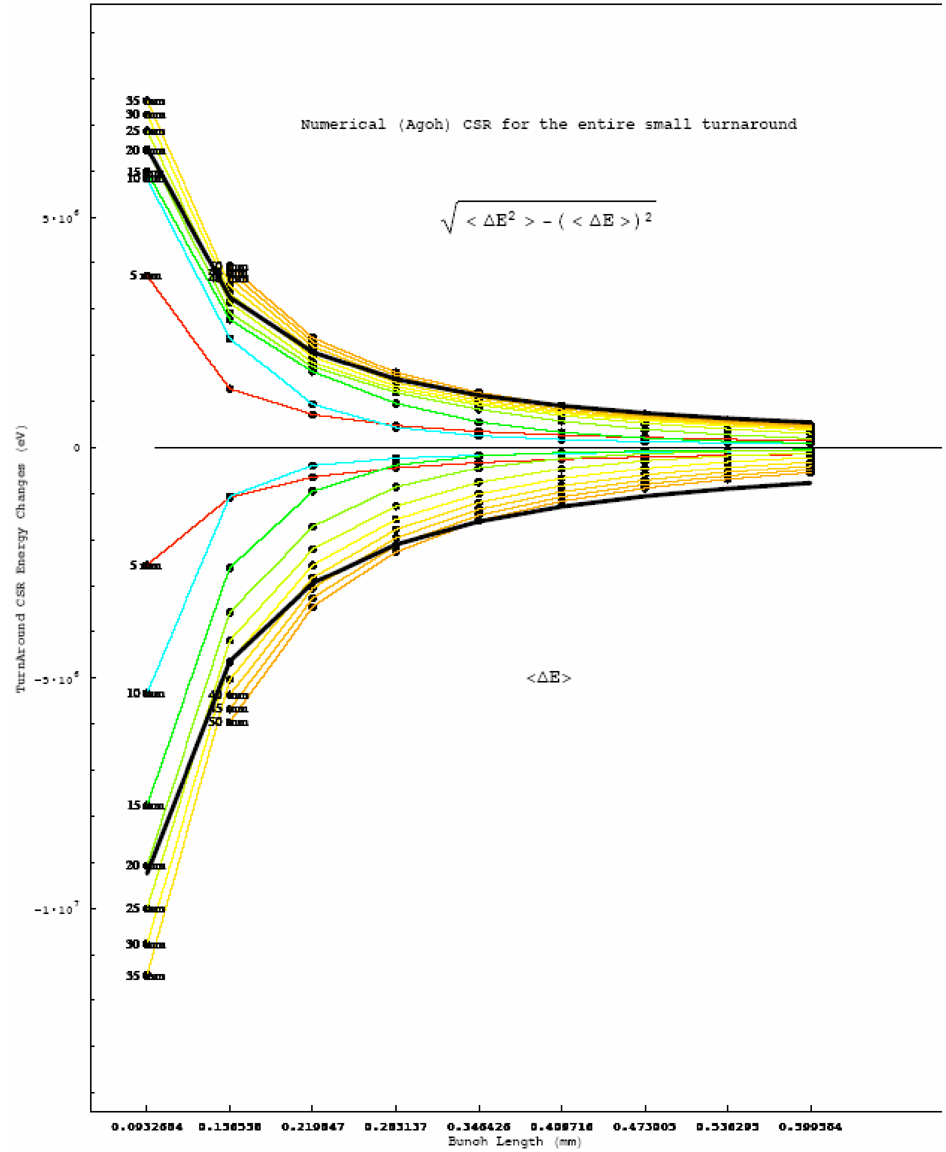
CSR energy loss and spread in the TA

CHESS & LEPP

Numerical formalism due to Yokoya&Agoh (2004):

Conclusion:
Also for magnets of realistic length, the energy spread in the turn around would be suppressed by chamber walls.

Warning:
Chambers of 1cm diameter will have to be studied for wake field effects.



Conclusion

(1) Unshielded CSR in macroscopic bends of an ERL limits the bunch length to about 1ps.

(2) Beam-dynamics compensation of CSR seems infeasible.

(3) Suppression of CSR by chamber walls can suppress the emitted energy and the phase-space dilution.

(4) Future analysis:
   (1) Experimental verification of shielding is needed.
   (2) Simulations do not include microbunching – which can lead to bunchlets with unshielded radiation. The feasibility of experiments at JLAB is now being analyzed.

CSR in ERL bends

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PHYSICAL REVIEW E VOLUME 57, NUMBER 3 MARCH 1998

Suppression and enhancement of coherent synchrotron radiation in the presence of two parallel conducting plates

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(Received 16 April 1997)

CSR in ERL bends

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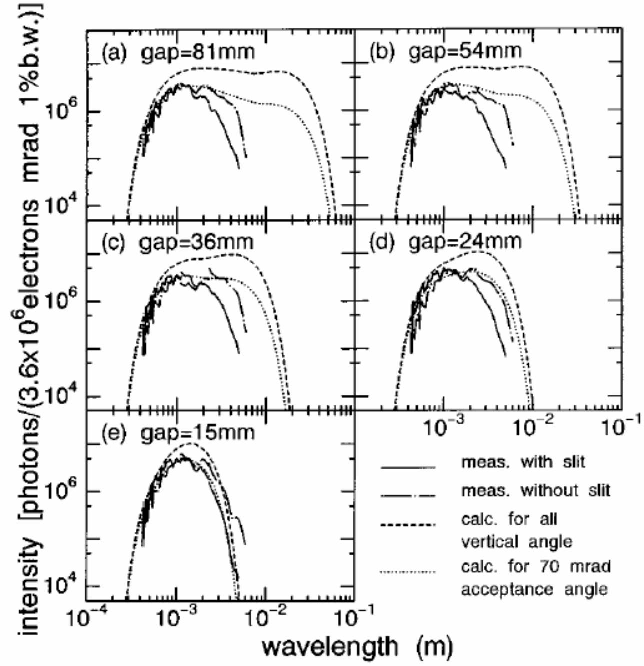

FIG. 5. Spectra of coherent synchrotron radiation for gaps between the metallic plates from 81 down to 15 mm. The solid lines are the measured spectra with the slit and the dash-dotted lines are those without it. The dashed lines are the spectra calculated with the theory of Nodvick and Saxon and the dotted lines are those with an acceptance angle of 70 mrad. In this calculation, the bunch shape is assumed to be the Gaussian shape with the bunch length (FWHM) of 0.3 mm.

CSR in ERL bends

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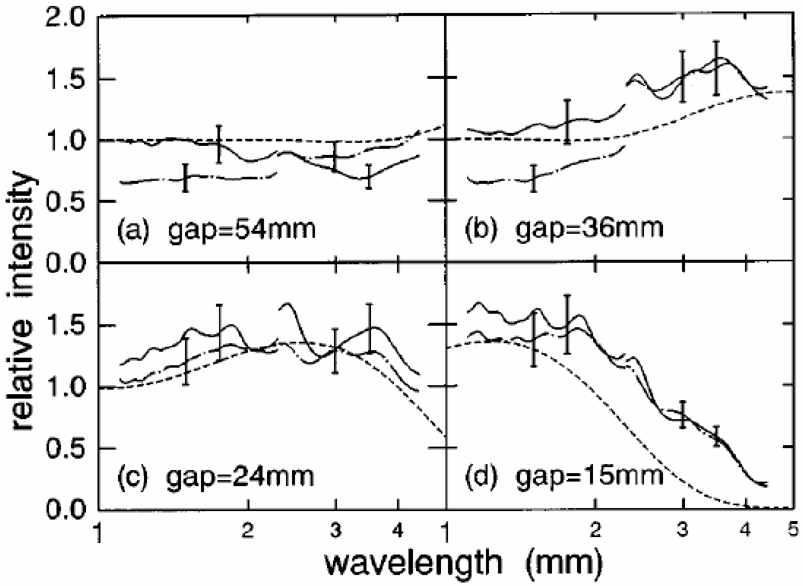
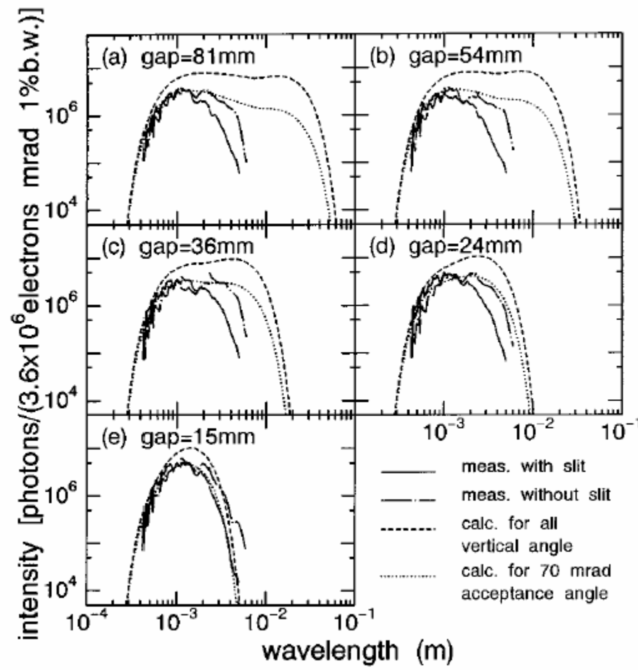


FIG. 7. Spectrum ratios of coherent synchrotron radiation for gaps from 54 to 15 mm relative to the reference spectrum at gap =81 mm. The solid lines show measured spectra with the slit and the dash-dotted lines show those without it. The dashed lines show spectra calculated with the theory of Nodvick and Saxon.



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CSR in ERL bends

CHESS & LEPP

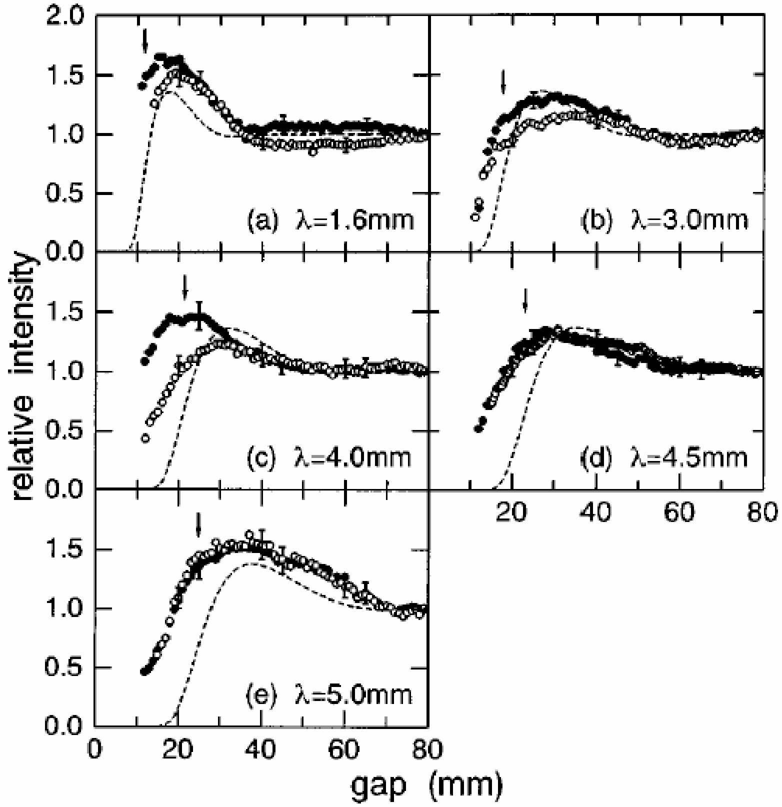
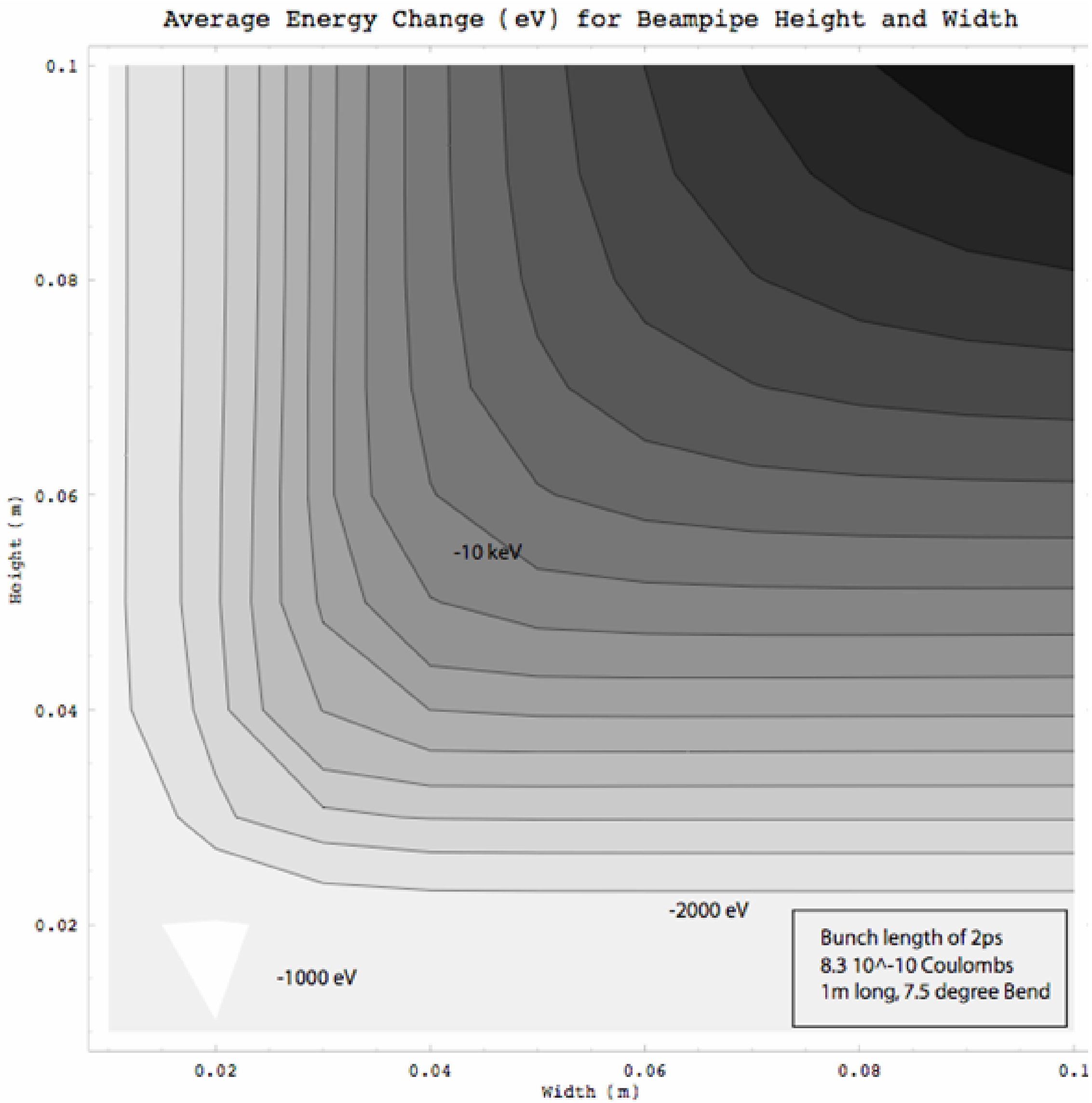


FIG. 8. Relative intensities of coherent synchrotron radiation as a function of the gap between the metallic plates for wavelengths from 1.6 to 5.0 mm. The intensities are normalized with the intensity at the gap of 80 mm for each wavelength. The solid circles denote intensities measured with the slit for cutting stray light and the open circles without it. The dashed lines are calculated values. The arrows indicate the critical wavelengths given by Eq. (5).

Shielding by vertical and horizontal walls

CHESS & LEPP



CSR Energy Loss

Yokoya&Agoh code used here