Status report

CSR SHIELDING EXPERIMENT

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Outline

- Motivation/expectation from proposal
- Experimental setup and results
- Conclusions and future plans

Motivation (from A. Fedotov talk)

CSR (without taking into account beam pipe shielding effect) 9

Gaussian longitudinal distribution:

- relative energy loss: $< p - p_0 / p_0 >= -0.35 \dfrac{r_e N_e L_{eff}}{\gamma (R^2 \sigma_{es}{}^4)^{1/3}}$

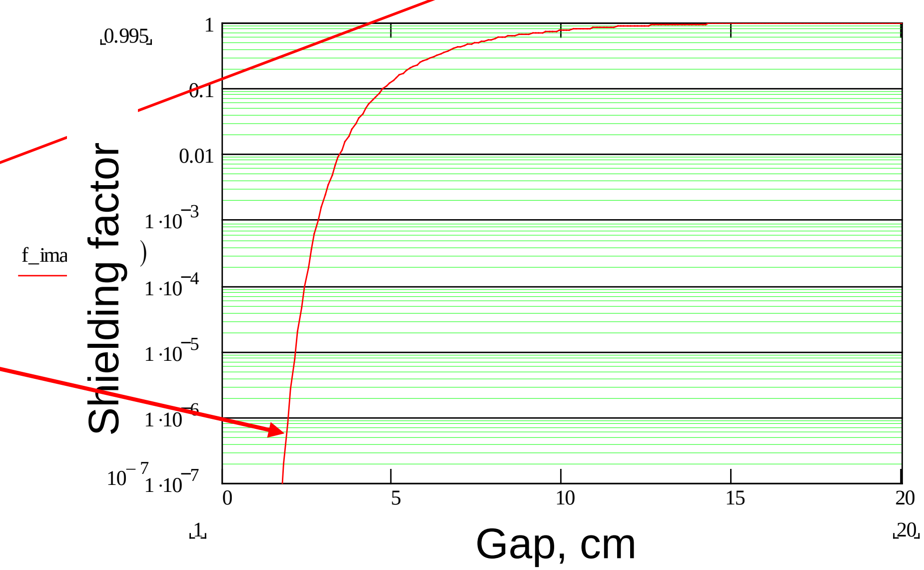
- increase in relative rms energy spread: $\sigma_p = 0.22 \dfrac{r_e N_e L_{eff}}{\gamma (R^2 \sigma_{es}{}^4)^{1/3}}$

- Since it takes place in a dispersive region, the transverse phase-space distribution is also affected and beam emittance increases.

MEeIC - CSR effect after passing 10 arcs with local bending radius of 6.2m and 1 arc with 7.2m 10

	rms bunch length σ_s=2mm (no shielding)	σ_s=4mm (no shielding)	σ_s=2mm (h=2cm)	σ_s=2mm (h=1cm)
-ΔE, MeV	8	3.2	2.1e-5	8e-18
-ΔE/E	0.011	4.3e-3		
ΔE_{rms}, MeV	5.7	2.26		
$(\Delta E/E)_{rms}$	7.7e-3	3.1e-3		
Shielding suppression factor $=P_{coh}$(with shielding)/P_{coh}(without shielding)			2.6e-6	1e-18

The shielding suppressing factor from theory for MEeIC parameters and 2 cm vacuum chamber is 2.6e-6!!!!



How good is our understanding of CSR shielding?

- The theoretical aspects of CSR shielding is described in many papers

Some (partial) history of some theoretical work on shielding:

1. J. Schwinger (1945), L. Schiff (1946); Nodvick and Saxon (1954).
2. R. Warnock (1990-91) – also for rectangular chamber
3. S. Heifets, A. Michailichenko (1991).
4. S. Kheifets and B. Zotter (1995) – overview of previous results and simple formulas for estimates.
5. Murphy, Krinsky, Gluckstern (1996) – using image-charges method.
6. R. Li, C. Bohn, J. Bisognano (1997) – review of Kheifets-Zotter/corrections and comparison with several more rigorous methods.

More recent work:

7. Stupakov et al. (2003)
8. Agoh, Yokoya (2004)
9. Sagan, Hoffstaetter (2008)
10. C. Mayes and G. Hoffstaetter (2009)

- But experimentally... Hmmm not much

Dedicated experiments on CSR shielding

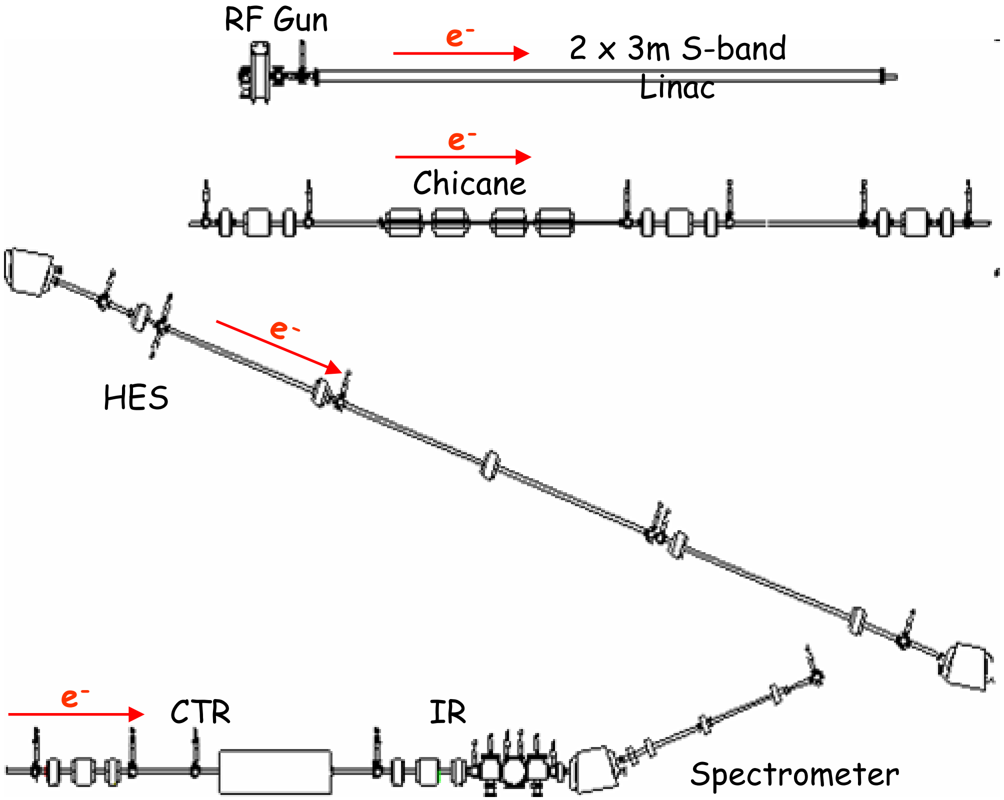
- H. Braun et al. (2001) – experiments at CLIC test facility CTF-II.
- Kato et al. (Phys. Rev. E, 1998).

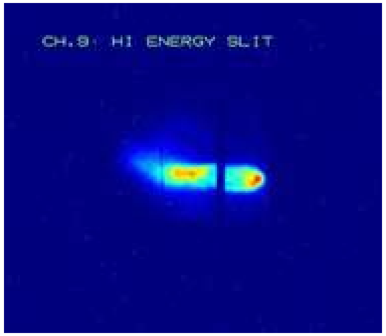
Some Issues

1. One experiment did not show expected theoretical reduction (with shielding) in energy loss due to CSR.
2. Another experiment studied synchrotron radiation rather than effects on the beam – also some issue were reported, like disagreement with theory for small gap sizes, etc.
3. While there seems to be is a clear picture about suppression of CSR power loss with shielding, effect of shielding on energy spread is less transparent.
4. Transient effects.

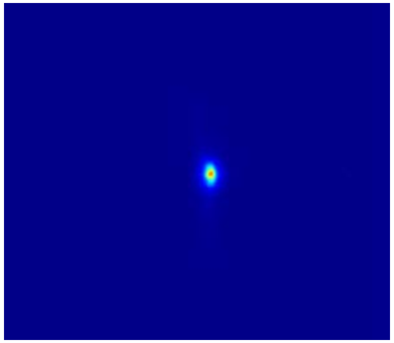
Simple, well-controlled experiment is desired to address these issues. ATF@BNL is ideally suited for such an experiment.

Experimental Layout





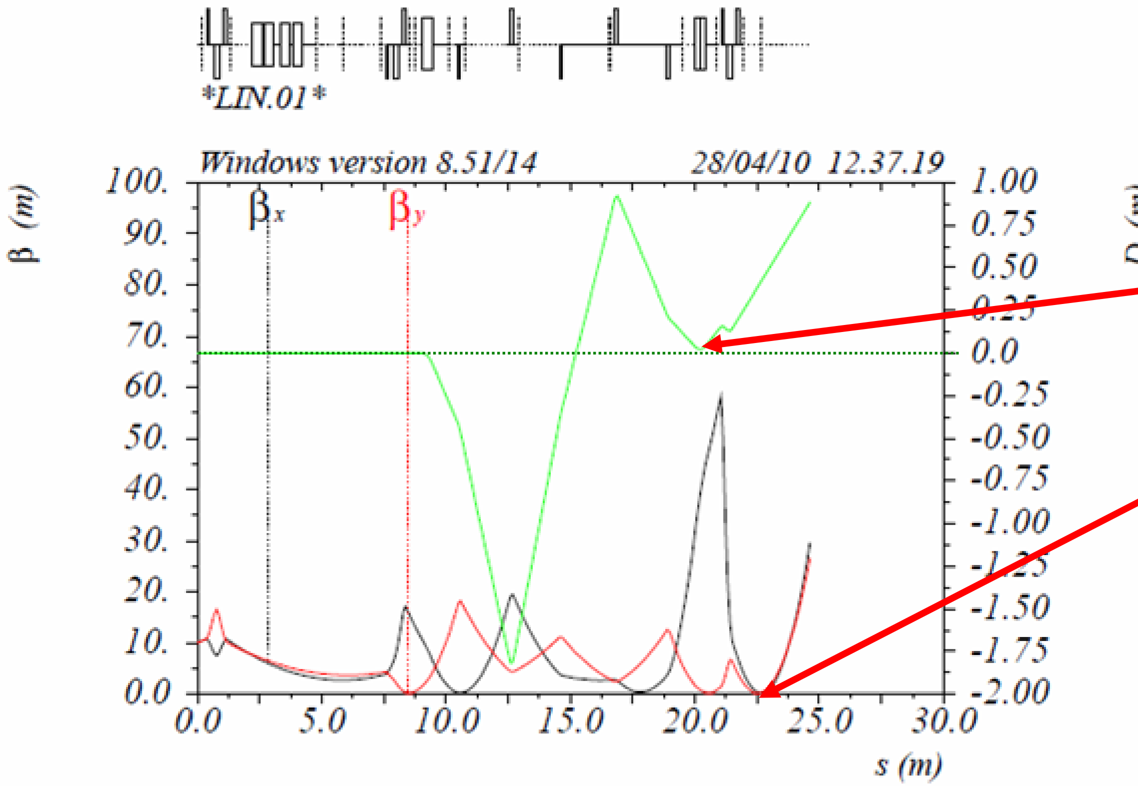
HES image



BPM/flag image

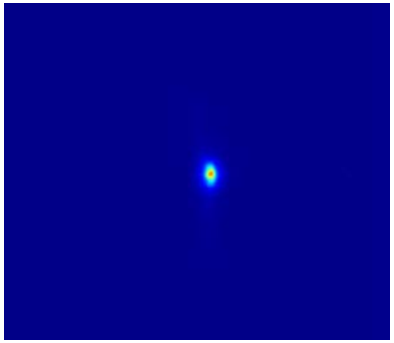
Photocathode gun, solenoid lens, accelerating section, dogleg with energy defining slit, beam position monitor (flag) together with distributed quadrupole triplets are essential elements of CSR shielding experiment beamline setup.

Optic functions configuration



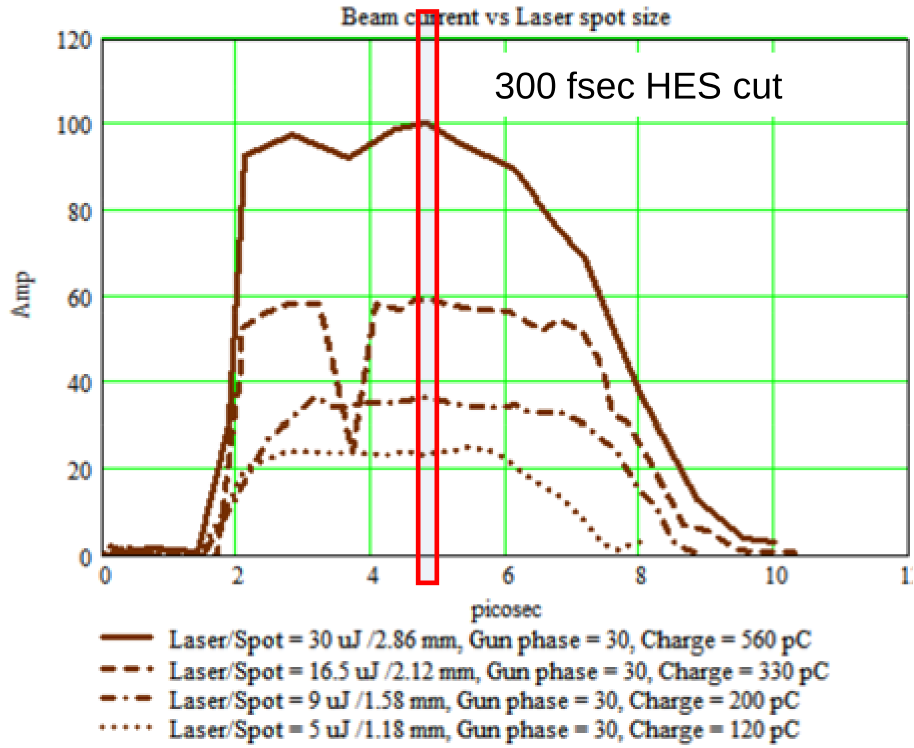
Dispersion function minimized in the dipole where shielding plates are installed.

Horizontal and vertical beta-functions minimized at the observation BPM where CSR and Resistive Wakes effects are measured.



BPM/flag image

Charge per bunch and peak current controlled by changing the laser spot size

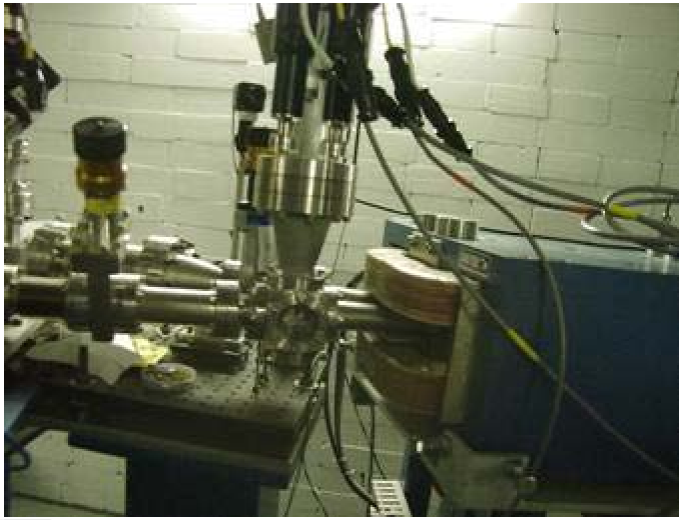


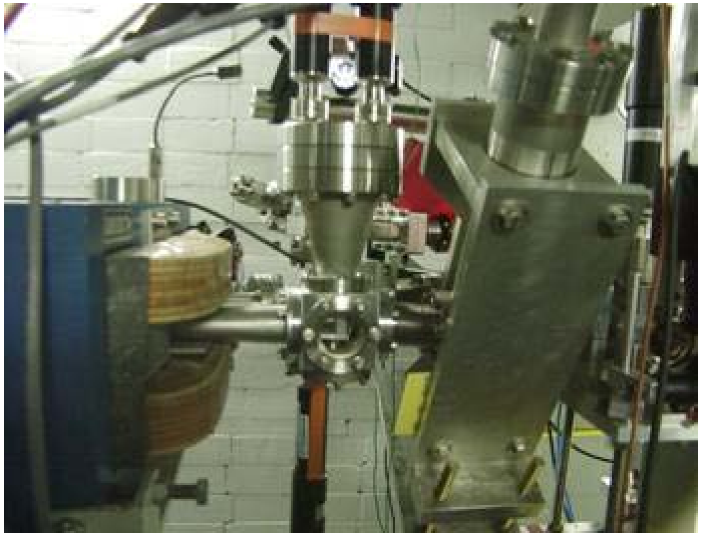
Longitudinal bunch profile for different laser spot size (charge per bunch, current)

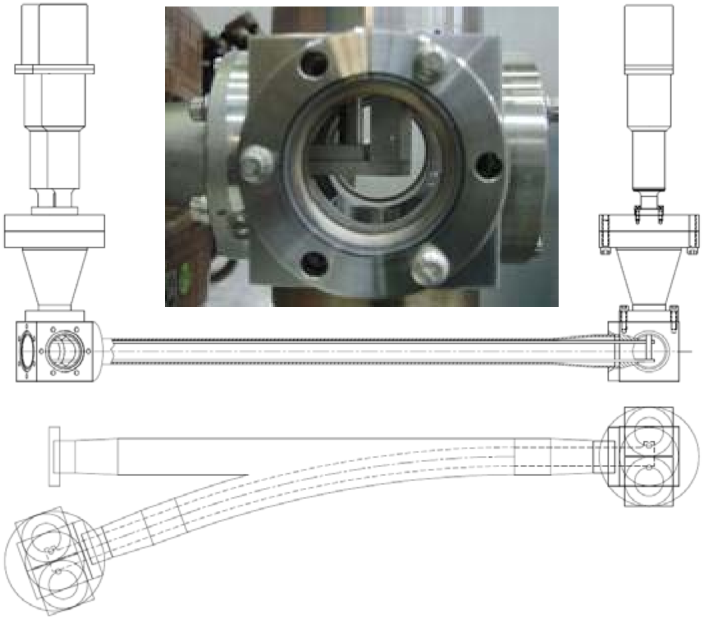
Beam current vs laser spot size

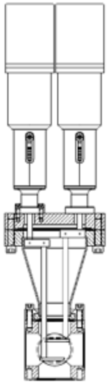
Bunch longitudinal profile stays the same for current from 20A to 100A

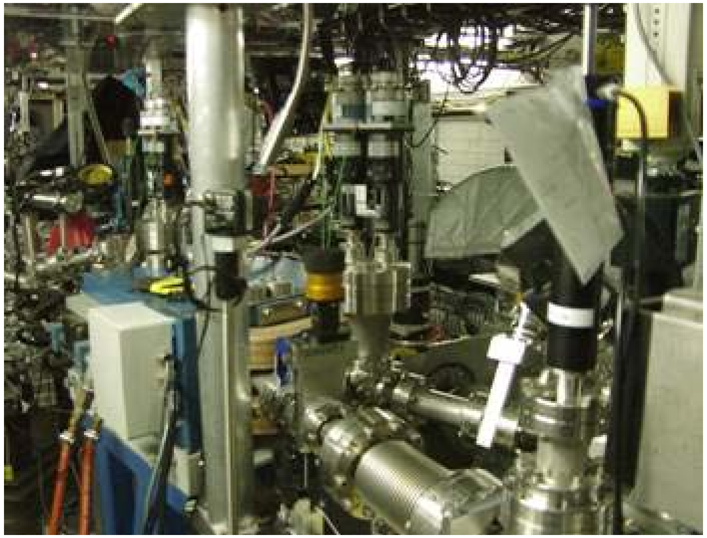
CSR shielding experiment plates











•Two plates with adjustable gap were installed into dipole vacuum chamber

CSR shielding test beam and system parameters

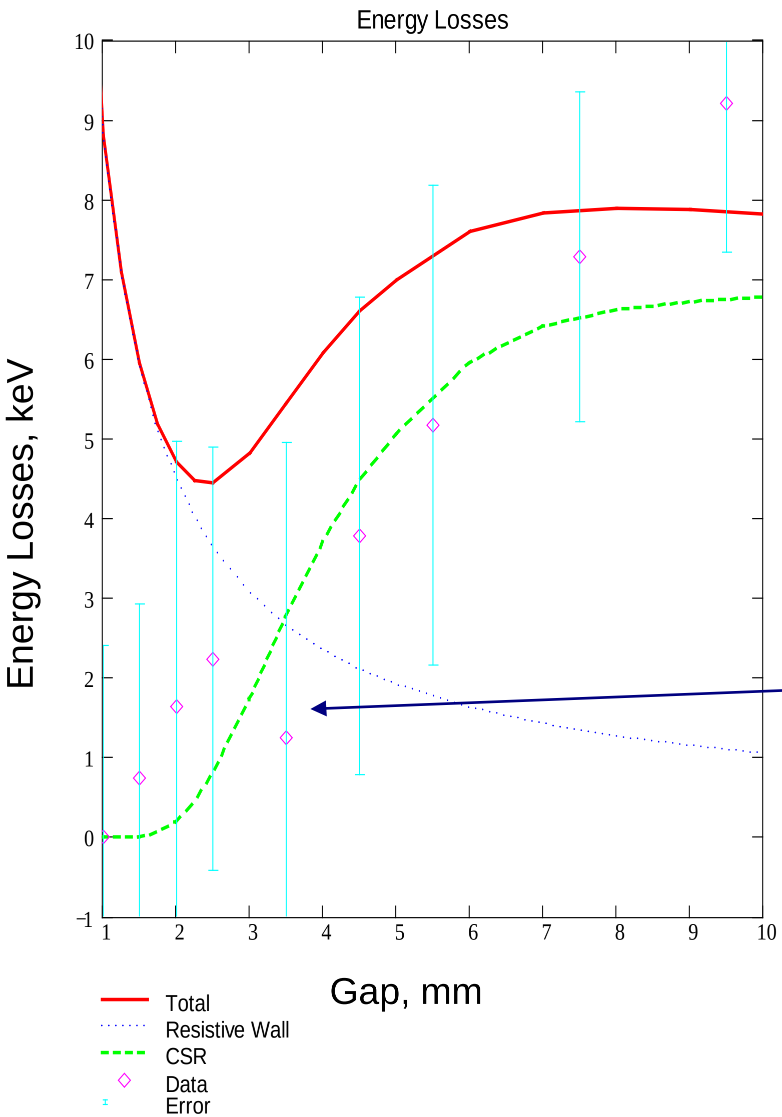
	Bunch profiles	
	Gaussian	Flat top
Energy, MeV	50	50
Beam Current, A	40	100
Bunch length, fsec	180*)	300
Bunch charge, pC	12	30
Banding Radius, m	1.14	1.14
Banding length, cm	40	40
CSR energy losses no shielding, keV	6.8	51.5
Gap changes, mm	1-10	1-10

*) RMS size

Vacuum chamber gap effect to the energy losses

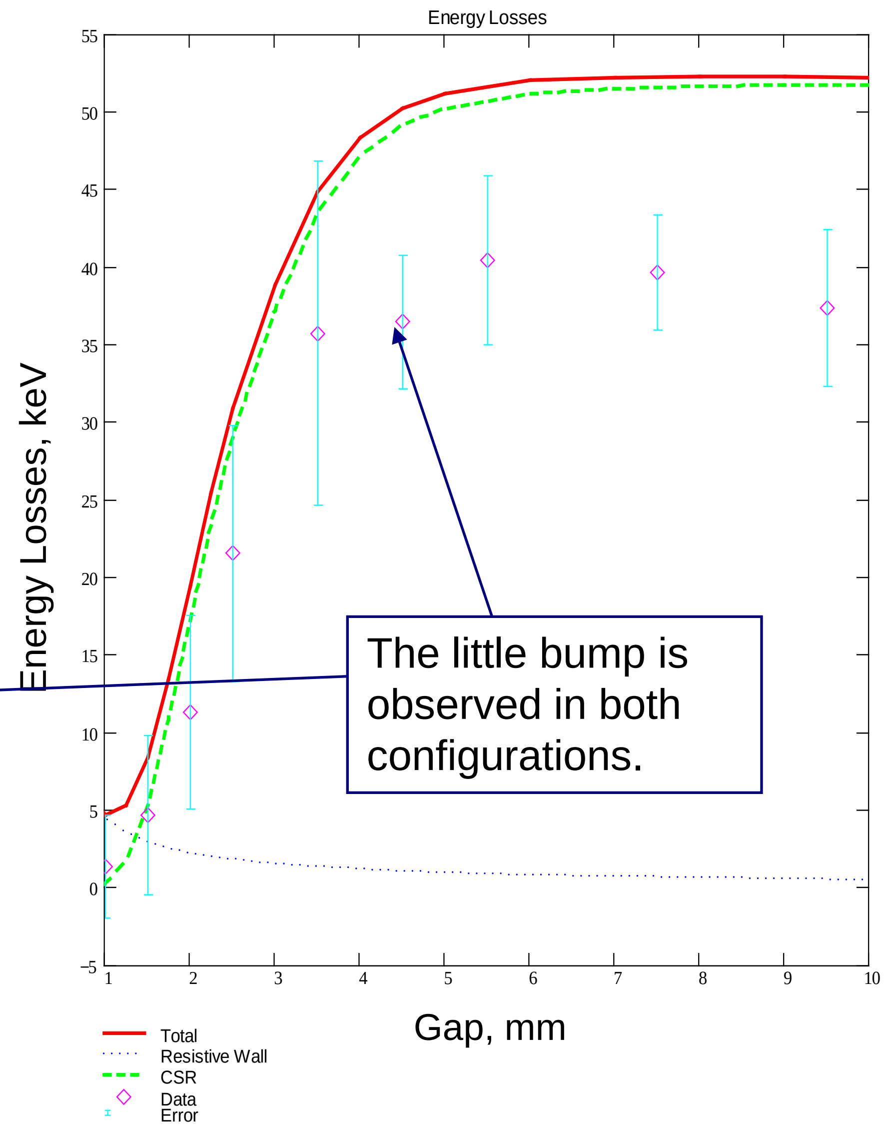
300fs FWHM Gaussian, 40A

$I = 40\,A \quad Q = 1.2 \times 10^{-11}\,C \quad \frac{\sigma s}{c \cdot 10^{-15}\,sec} = 179.524$



300fs FWHM “Square”, 100A

$I = 100\,A \quad Q = 3 \times 10^{-11}\,C \quad \frac{dT}{10^{-15}\,sec} = 300$



The little bump is observed in both configurations.

Future plans for CSR shielding experiment

- Recent improvement of RF phase stability from 2° to the order of 0.1° will reduce shot to shot bunch charge/current/energy fluctuations

  => cleans up the error bars
- Reduce of dipole magnet entrance and exit energy changes effects by zeroing dispersion from bending magnet entrance to the flag location (qudrupoles after the dipole will help)

- Reduce an energy loss due to surface roughness by polishing the plates
- Will compress the bunch to increase the peak current by chicane

Conclusion

- Studies the suppression of the energy loss due to CSR on presence of vacuum chamber were conducted.
- To observe the shielding effect the sets of “good” beam parameters established
- Effects of energy changes for different bunch profiles are measured. It’s in well agreement with theoretical model.
- The observed little bump can be a result of other wake field- or transient-effects not included in simple model. Needs more studies.
- Wake fields effects are essential for CSR shielding test bunch parameters.
- More measurements should be carry out with recent upgrade of RF feed back system and polished plates
- The energy spread due to CSR and vacuum chamber shielding studies will continue