COLLECTIVE EFFECTS AND LASER PROFILE OPTIMIZATION FOR HIGH BRIGHTNESS BEAM GENERATION AT APS-LEA

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ABSTRACT

- The Linac Extension Area (LEA) at the Advanced Photon Source (APS) is a testbed, in the BeamNetUS network, capable of delivering high-brightness electron beams with sub-micrometer emittances and adjustable charge from 100 pC to 1.5 nC for advanced accelerator research and development. [1,2]
- In this work, we present initial beam dynamics simulations of beam transport to LEA that capture collective effects for a range of laser profile settings.
- Near the photocathode, 3D space-charge forces are modeled self-consistently using ASTRA [3] to capture emittance growth during the low-energy phase of acceleration.
- CSR-induced energy spread and emittance dilution in the bunch compressor are evaluated using a fully 3D self-consistent integrator [4] that accounts for transverse effects. In particular, we demonstrate the need to capture 3D effects in the bunch compressor. The code is interleaved with ELEGANT [5]

BACKGROUND/MOTIVATION

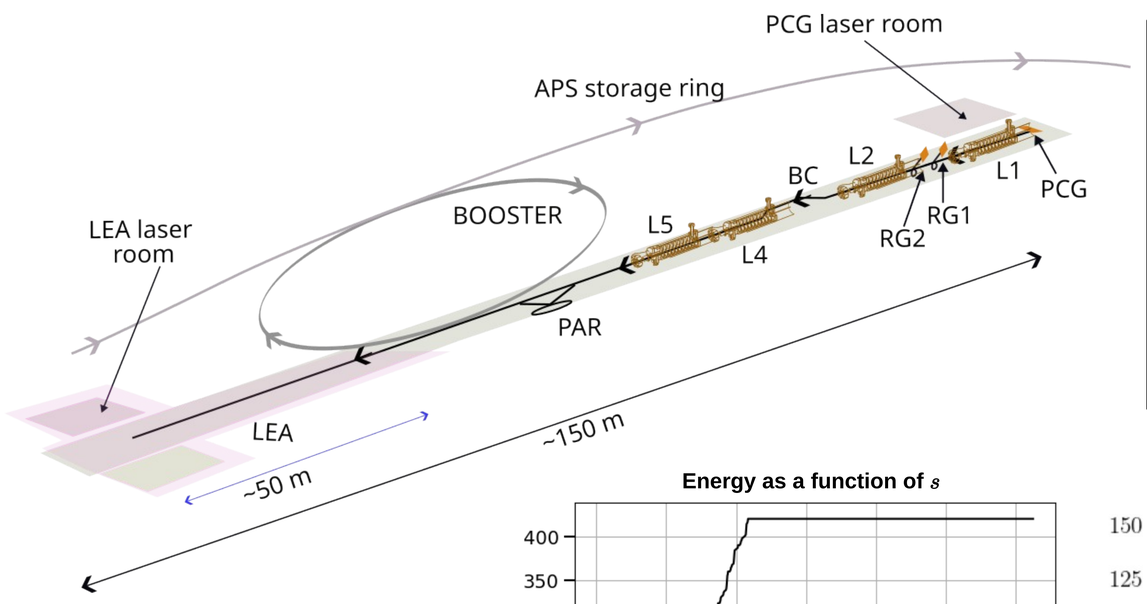
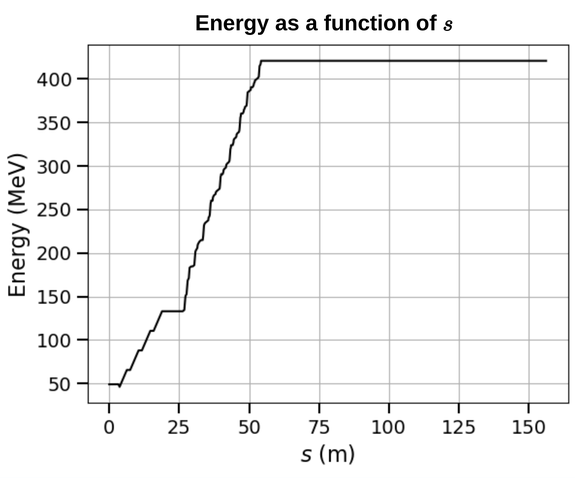


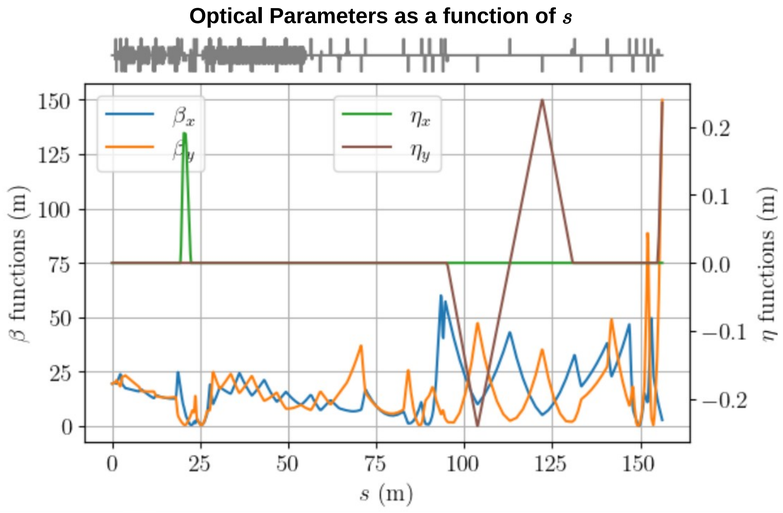
Figure: Overview of the APS injection complex chain. “PCG”, “RG”, “L”, and “BC” refer to the photocathode RF gun, thermionic RF gun, LINACs, and bunch compressor chicane, respectively. (Fig from [2])

- The recent installation of a new photocathode drive laser (capable of operating in high charge mode for direct injection to the Booster, or high brightness for delivery to LEA for R&D) has improved the reliability of photoinjector operations at the APS.
- In this work, we characterize the transport of a high brightness beam to LEA for different laser profile configurations (spot size and pulse length).
- The space charge effect in the PCG places an upper limit on the amount of charge that can feasibly be injected at the gun.
- CSR in the dipoles bunch compressor likewise place an upper limit on the achievable peak current.

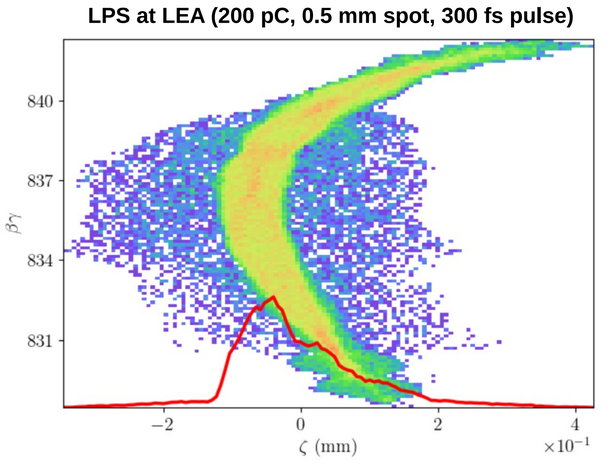
Energy as a function of s



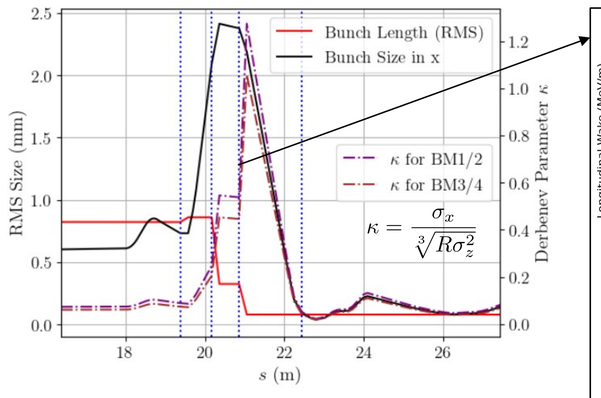
Optical Parameters as a function of s



LPS at LEA (200 pC, 0.5 mm spot, 300 fs pulse)

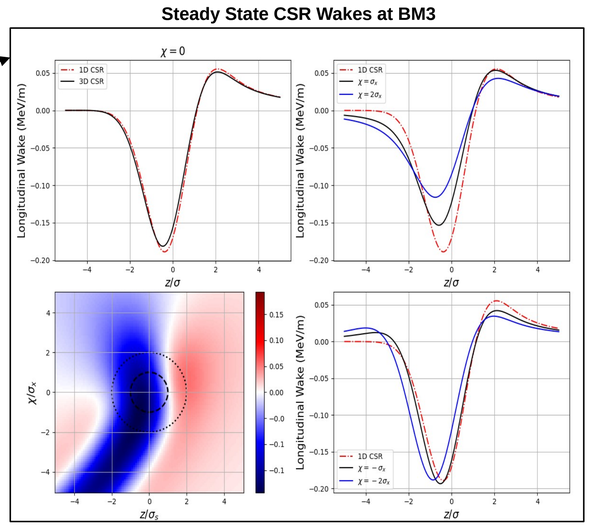


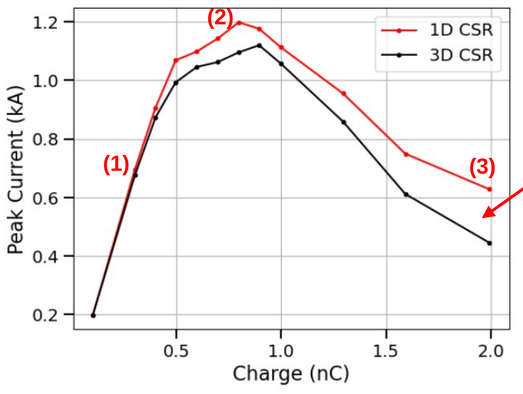
CSR IN THE BUNCH COMPRESSOR



As the beam moves through the bunch compressor, the transverse size increases through BM 2-3, causing the Derbenev parameter κ to get large.

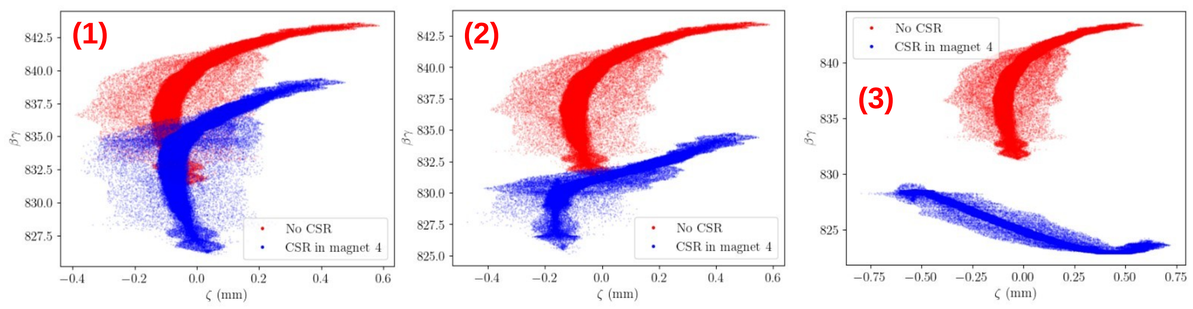
Steady State CSR Wakes at BM3



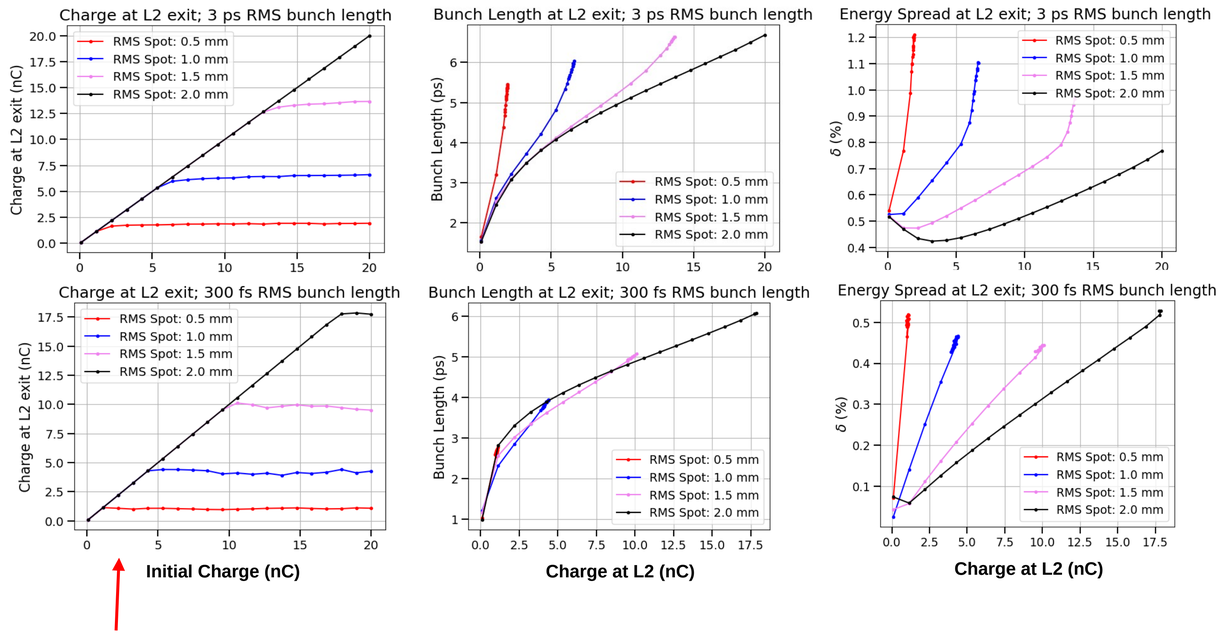


- In this regime, 1D CSR models are on the edge of their validity.
- Note how 3D CSR diverges dramatically off-axis. (ref. T33 and WG5 on 07/30 for details)
- At LEA, these effects cause a noticeable drop in peak current.

The CSR effect is strongest in BM4 and lengthens bunch with increasing charge, as shown in the scatterplots. (1D CSR only in BM4)



SPACE CHARGE & LASER PROFILE OPTIMIZATION



- Image charge forces at the PCG imposes an upper limit on the amount of charge that can be injected.
- For low bunch lengths, there are additional wall losses due to space charge blowout.

- These effects also result in bunch lengthening/energy spread for small spot sizes.
- The image charge forces are stronger when the bunch is concentrated in a small spot, which leads to deceleration and phase mismatch.
- There’s generally more wiggle room to optimize with the larger spot.

- We performed initial transport simulations and lattice optimizations for different laser shapes in the PCG.
- All simulations were performed with ASTRA through the cathode and L1, and ELEGANT for the rest of the beamline.

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