

Laser Heater as a Beam Shaping Tool at FACET-II



Facility for Advanced
Accelerator Experimental Tests

From Microbunching Instability
Suppression to Multi-Spike Current
Profiles

Anna Kinderman

UC Santa Cruz PhD Student

Motivation

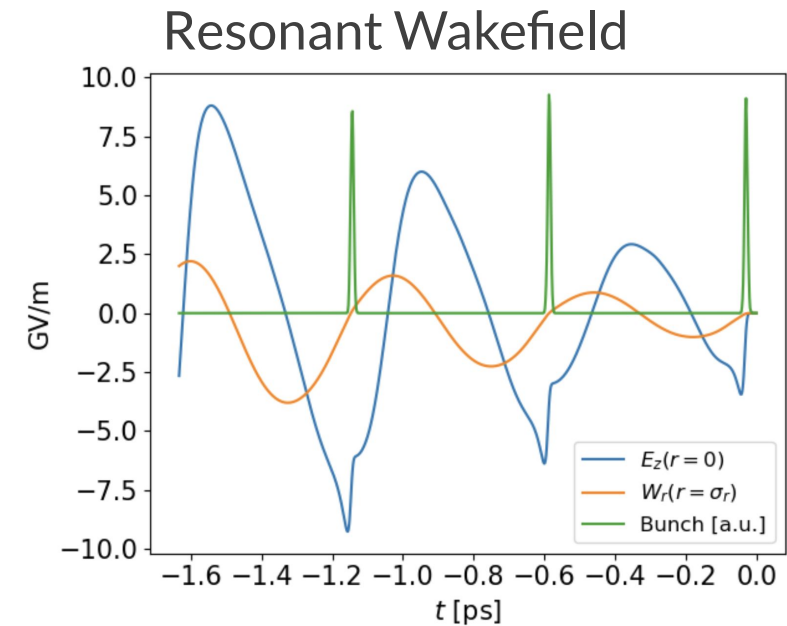
- 2-3 driver bunches, spaced by plasma period to generate resonant excitation of nonlinear plasma wakefields (BeamNetUS, PI: L. Verra)
- Allow for live tunable, clean separations (100-150um) between current spikes

Resonant Excitation of Plasma Wakefields with a Train of Relativistic Particle Bunches

Jul 27, 2026, 2:30 PM
20m
Legacy B (Luskin)

To be considered for W... A3-Working group # 3

Building off this work...

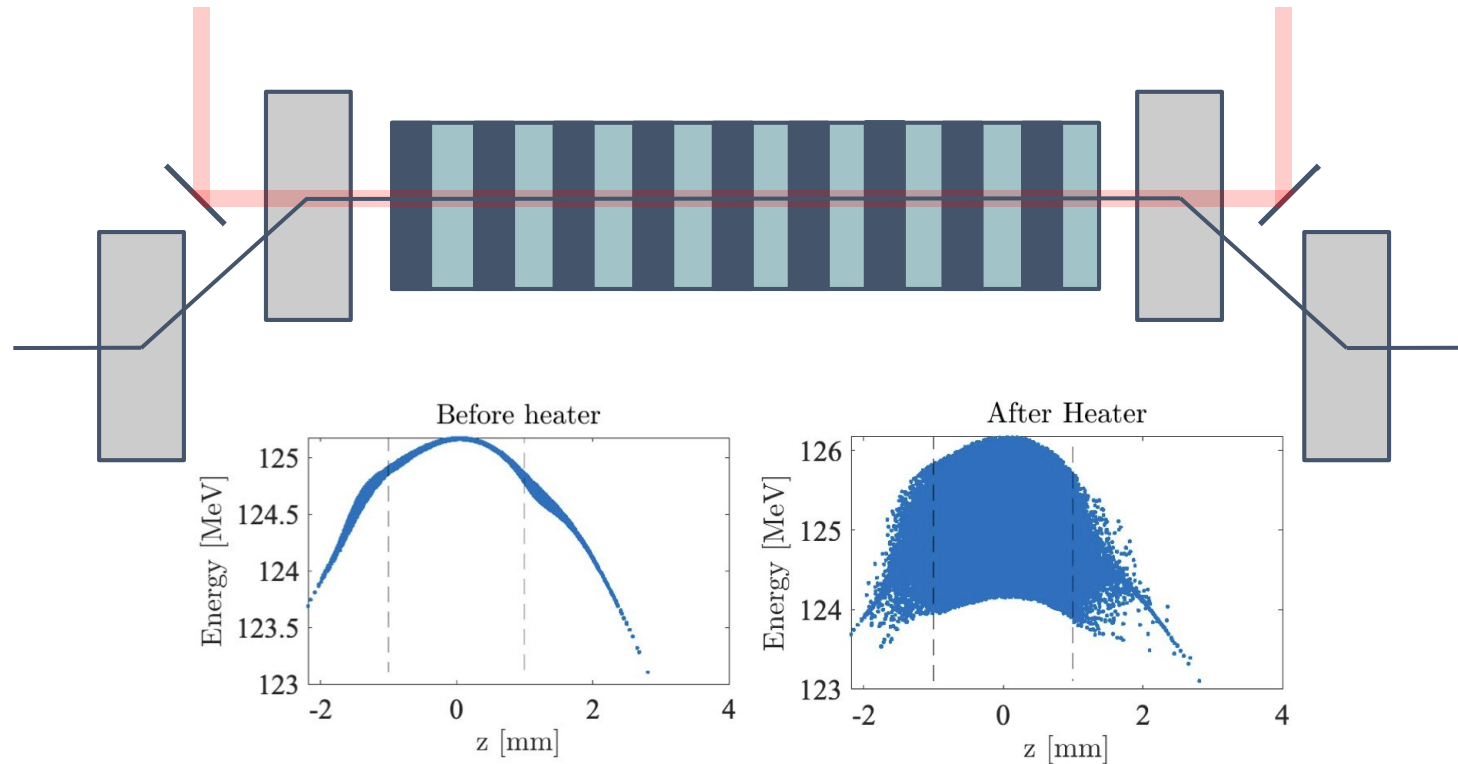


Work in preparation for a BeamNetUS experiment this fall...

Laser Heater at FACET-II

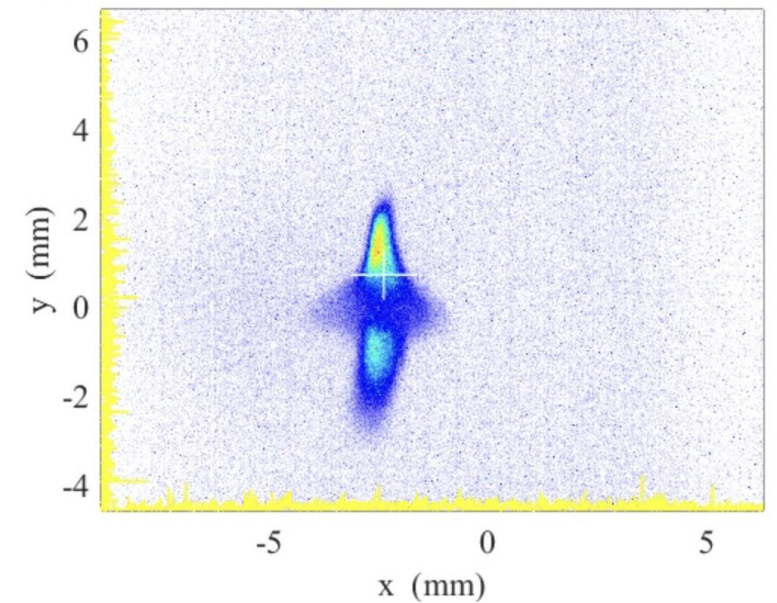
- Laser Heater System: Chicane, Undulator, IR Laser

- Damp microbunching
- Control current at IP
- Suppress CSR + emittance growth



C. Emma, LH Commissioning in 2023

Heated electron beam shortly after LH



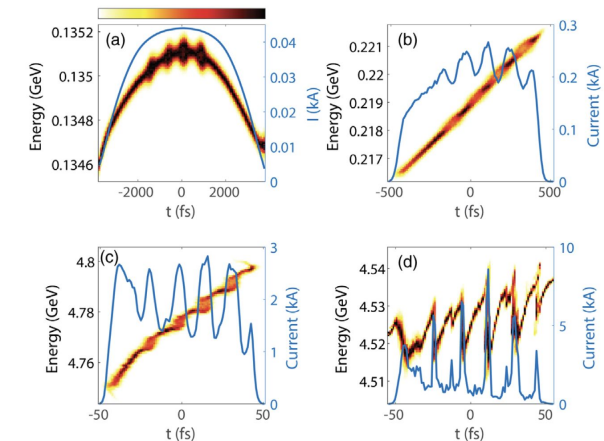
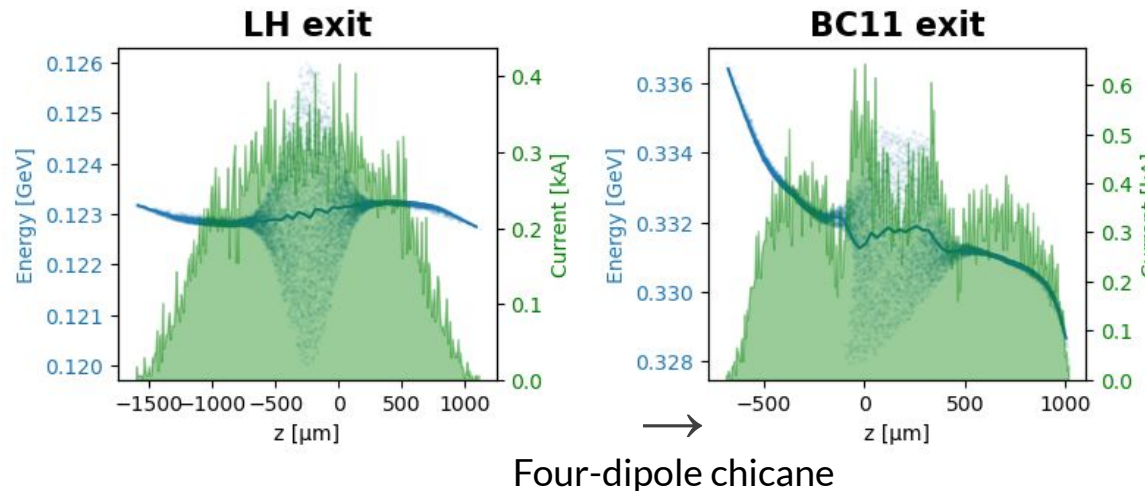
The laser heater imparts a smooth energy modulation across the beam

Background & Theory

- LH energy modulation $\rightarrow$ Current modulation (kinetic model, D. Cesar et al. 2021)

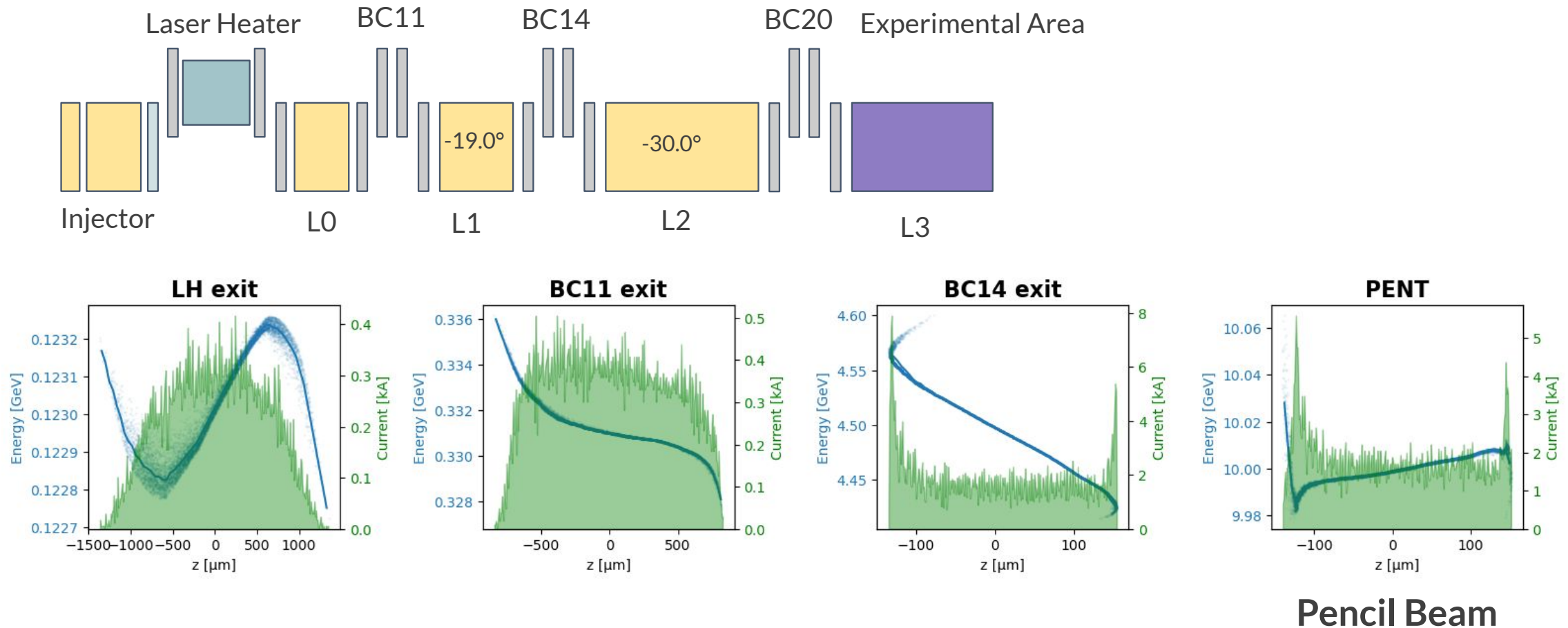
$$I(s) = I_0 \sum_{n=0}^{\infty} \left(\frac{R_{56}^n}{2^n n!} \right)^2 \frac{\partial^{2n}}{\partial s^{2n}} A^{2n}(s) \quad n_1 \text{ term gives the leading order modulation}$$

- Analytical backtracking: chirp sources add linearly (Sudar & Ding 2022)
- At FACET-II: LH-driven high current spike, ~ 0.1 MA, demonstrated experimentally (C. Emma et al. 2025)



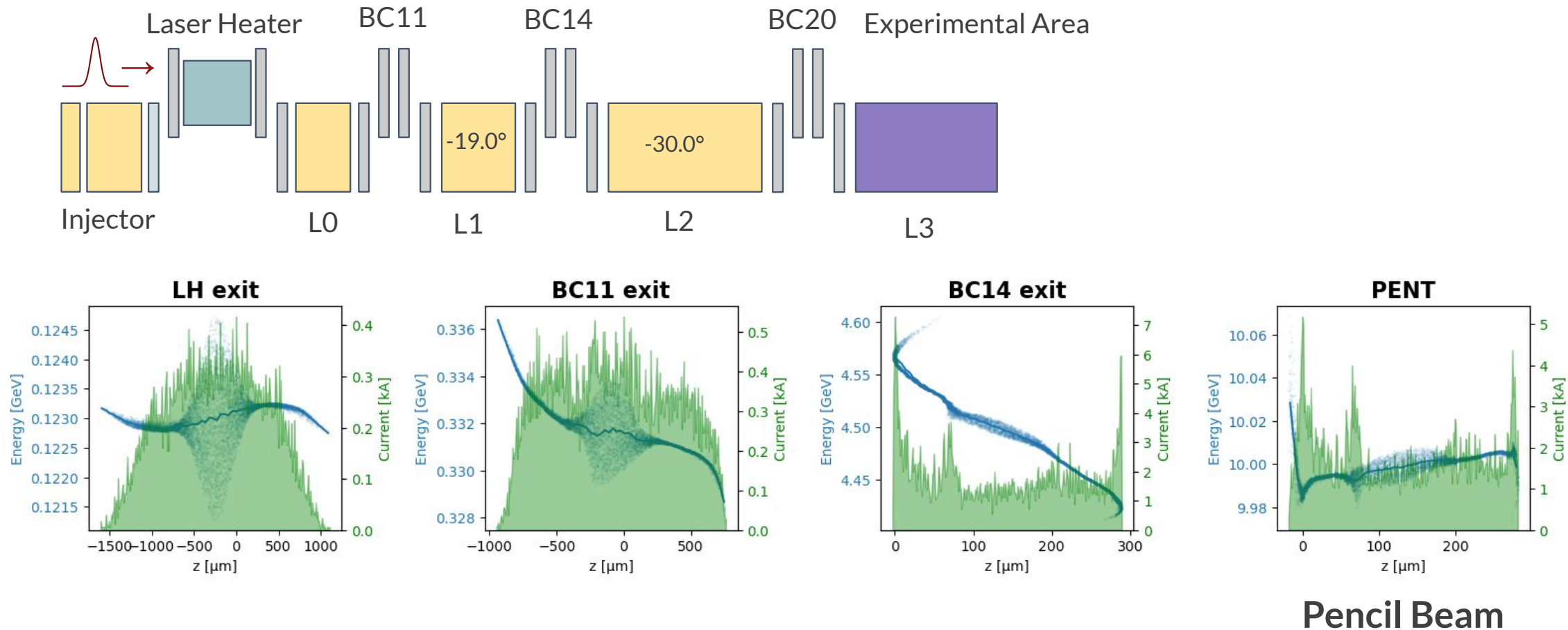
LCLS-II beamline simulation
(D. Cesar et al. 2021)

S2E Simulations - Single Pulse



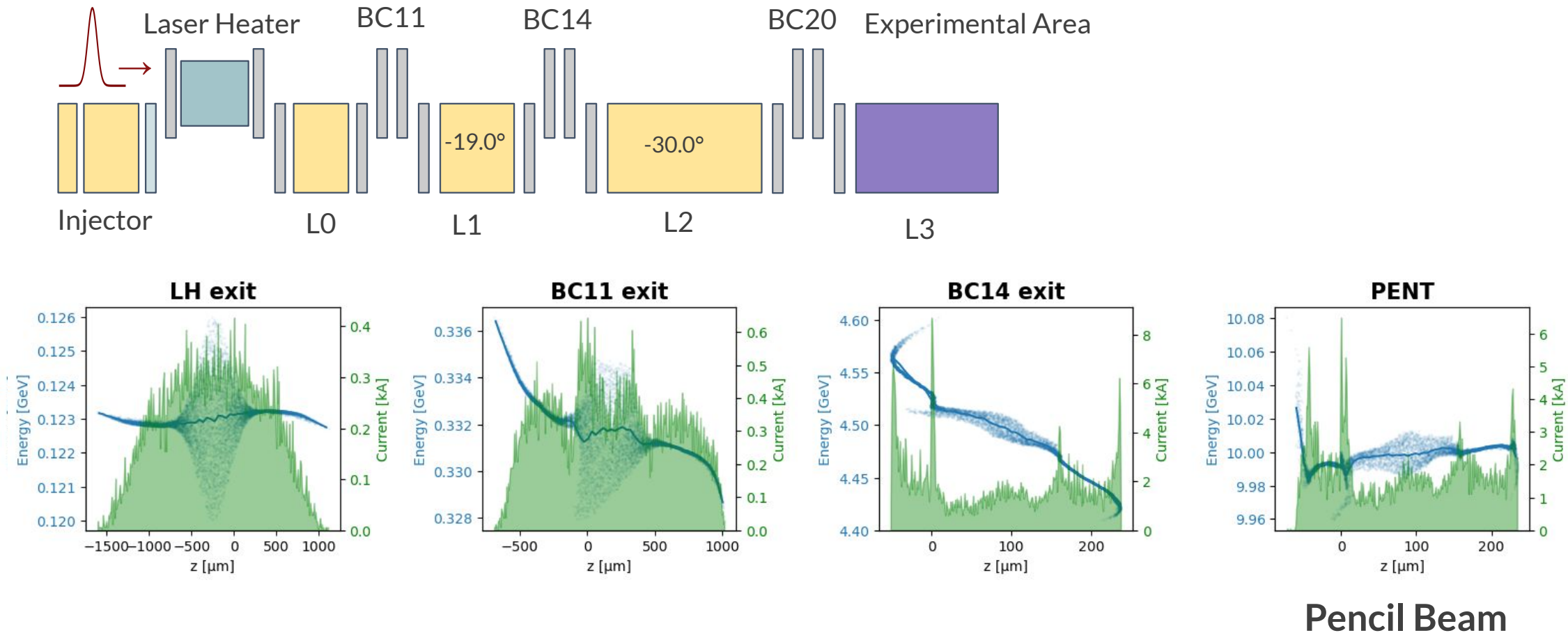
Phase space and current development across linac without LH pulse

S2E Simulations - Single Pulse



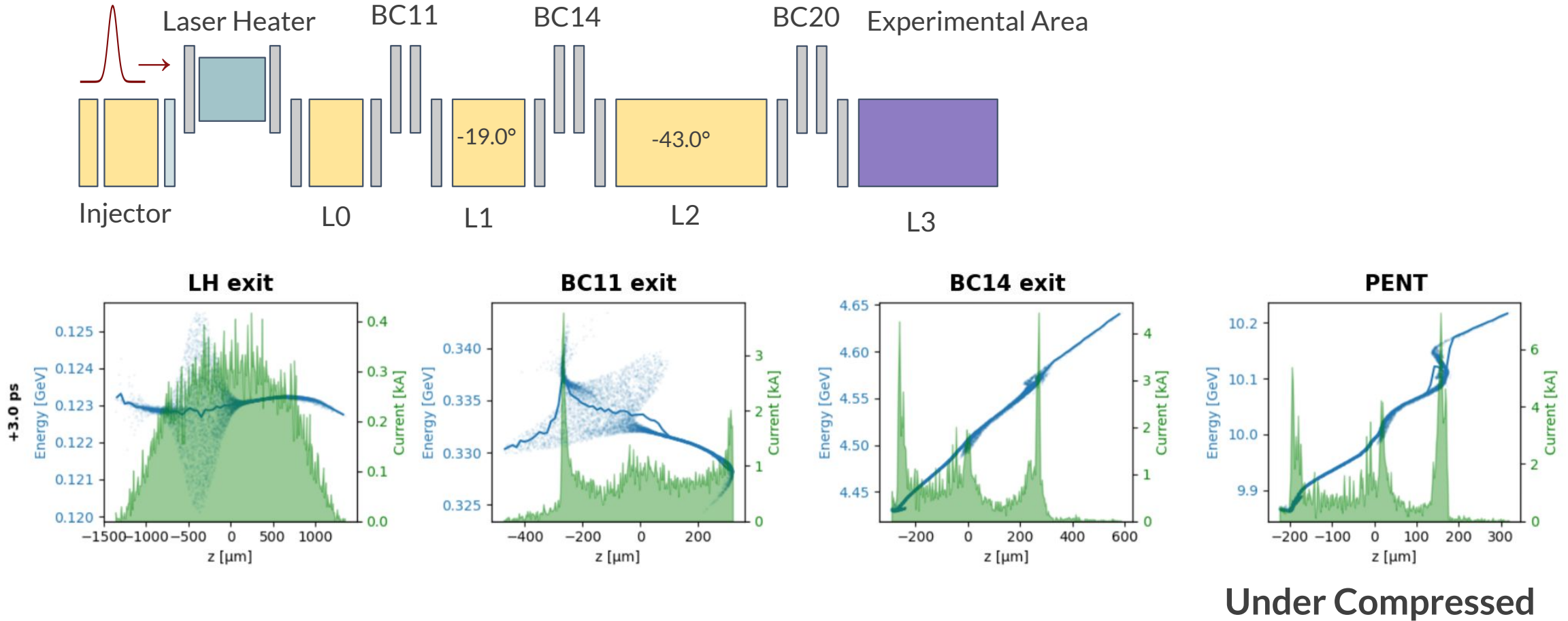
Phase space and current development across linac with 3mJ LH pulse

S2E Simulations - Single Pulse



Phase space and current development across linac with 5mJ LH pulse

S2E Simulations - Single Pulse

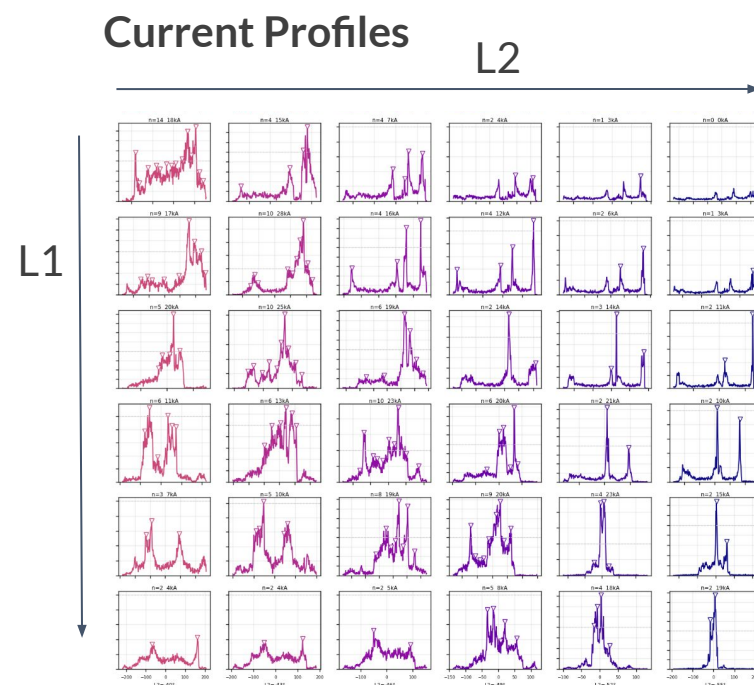
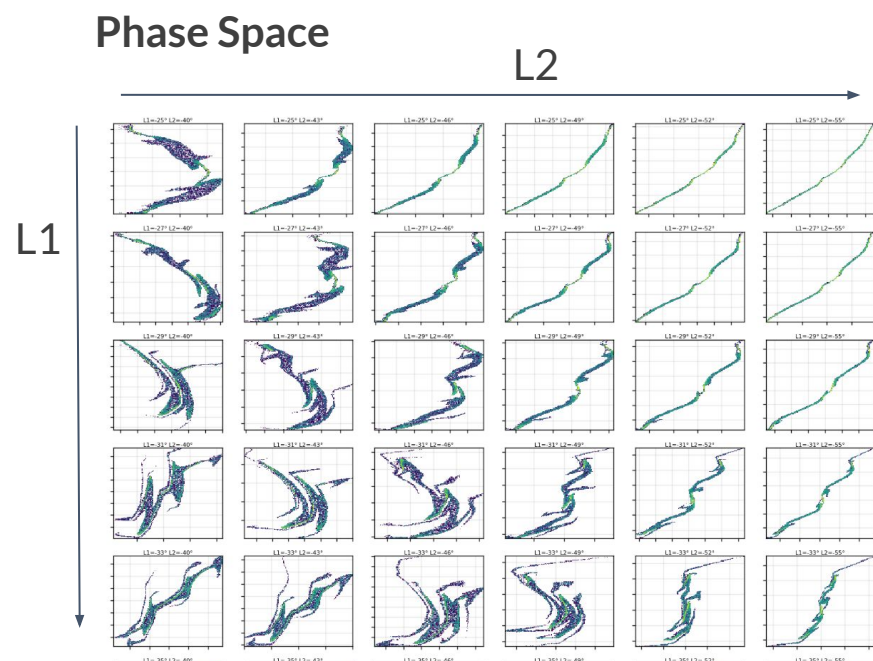
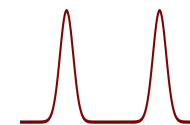


Phase space and current development across linac with 5mJ LH pulse

Parameter Scans

- Free parameters: L1/L2 RF phase, LH power, pulse width, spacing, overall delay
- Supplemental search method: Bayesian optimization *Xopt*

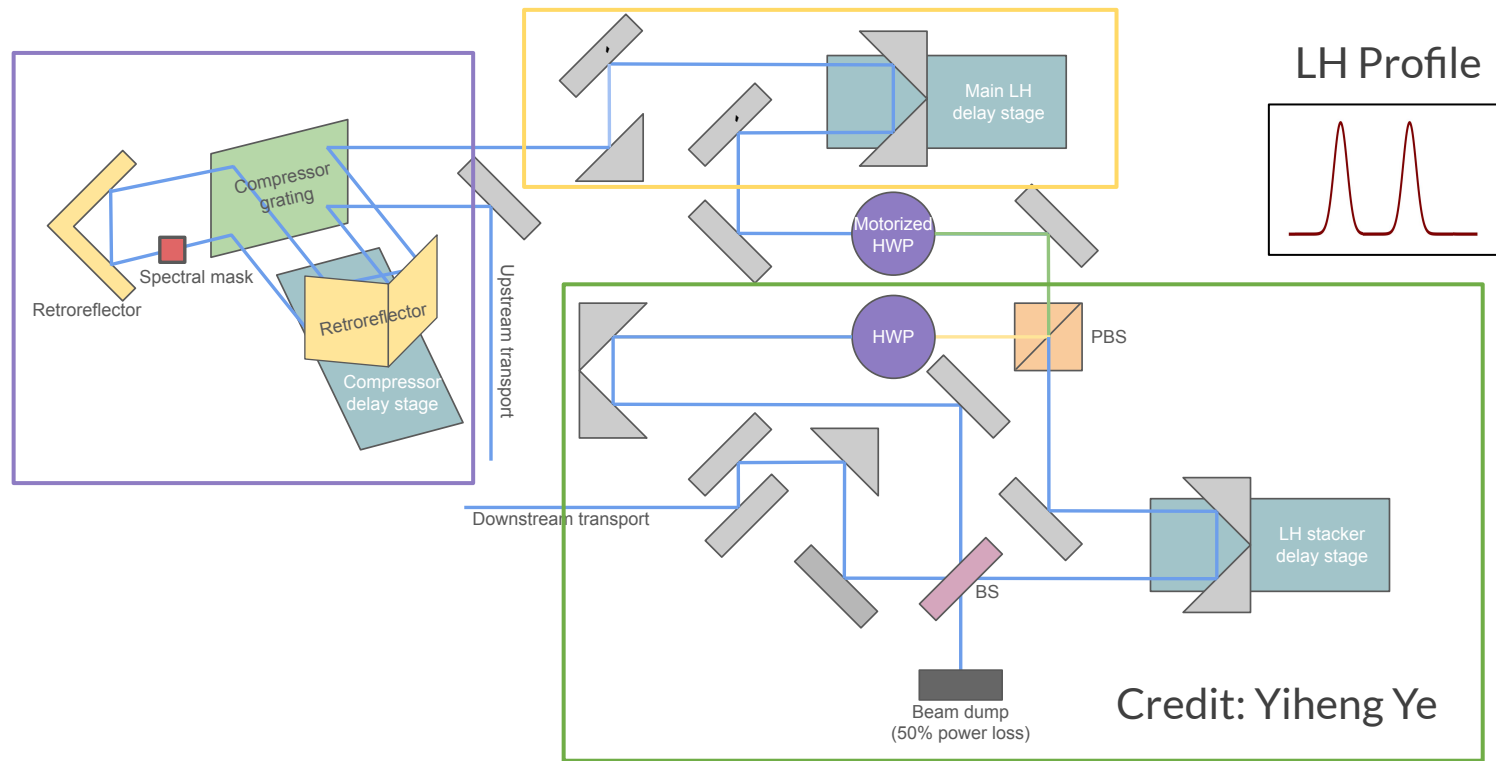
LH Profile



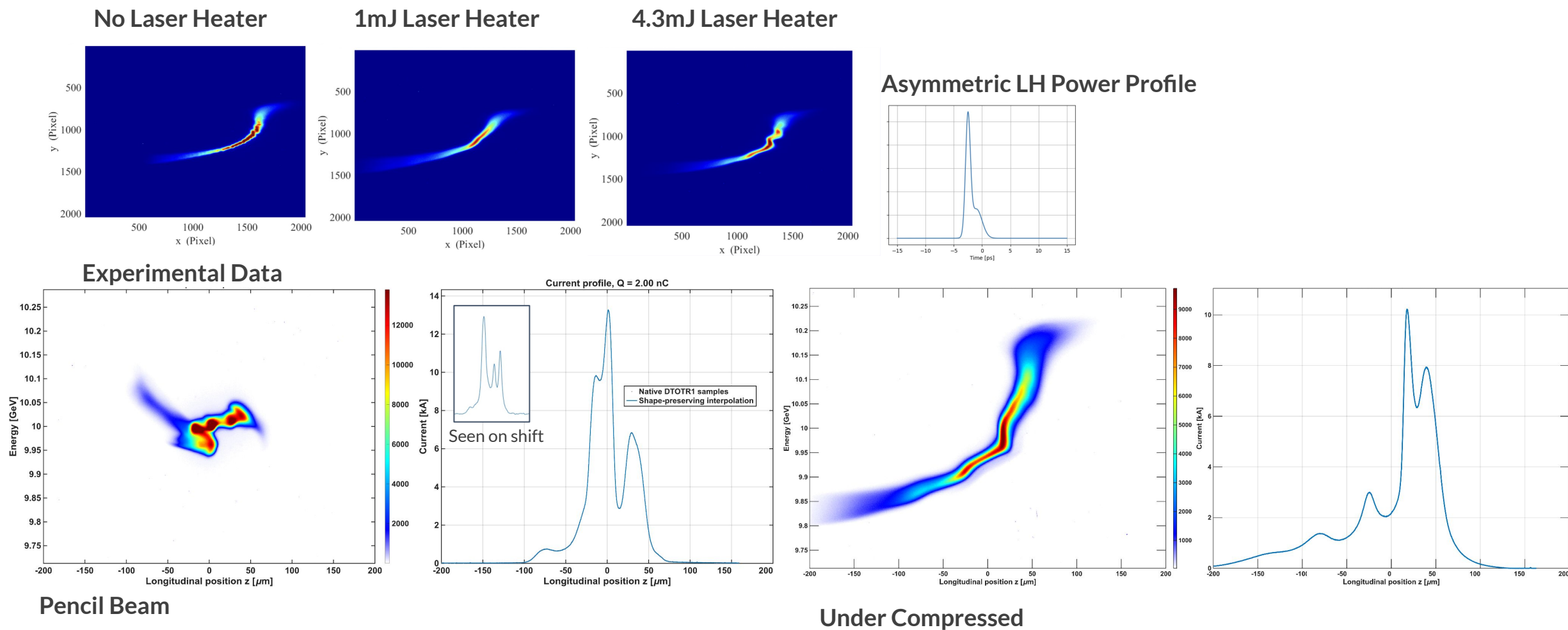
Current profiles are highly RF phase dependent

LH Pulse Stacker

- Pulse stacker: spectral mask + grating compressor sets pulse duration; HWP/PBS splits into two independently-delayed, independently-weighted arms; recombine into a single beam with two sub-pulses

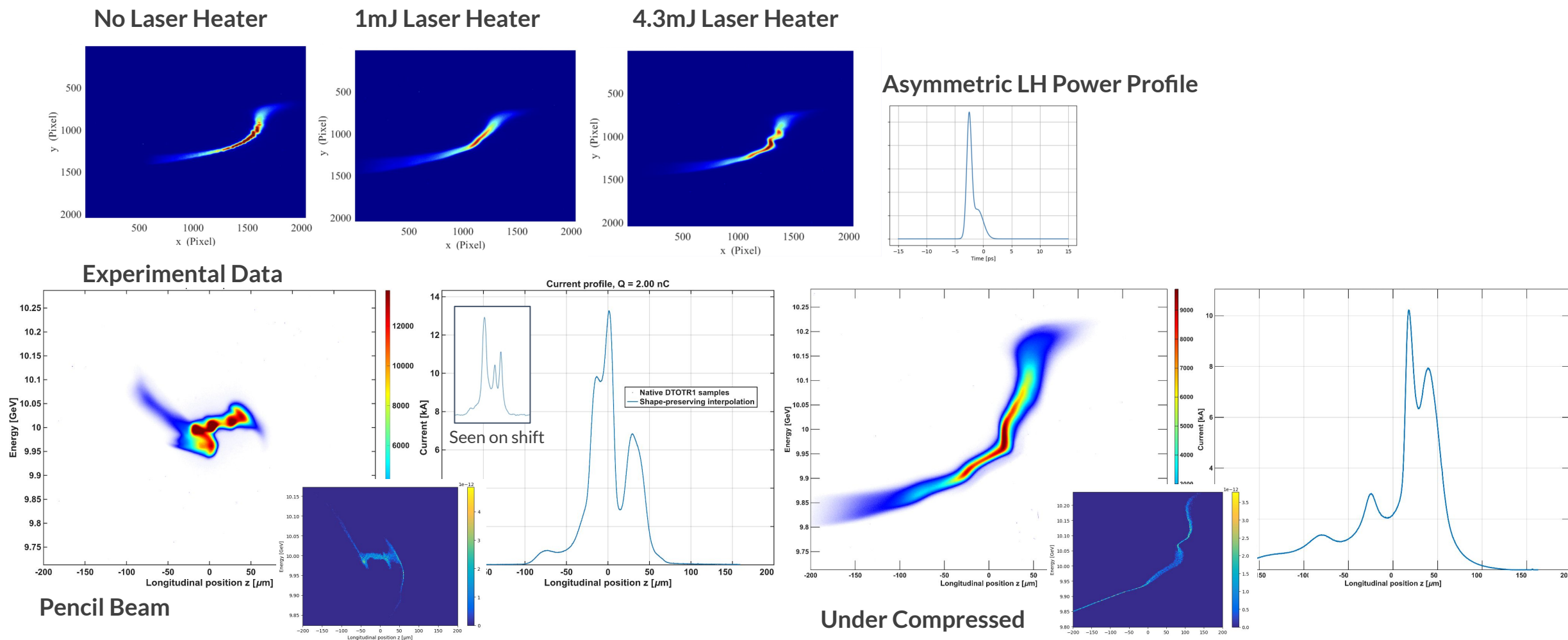


Laser Heater Commissioning



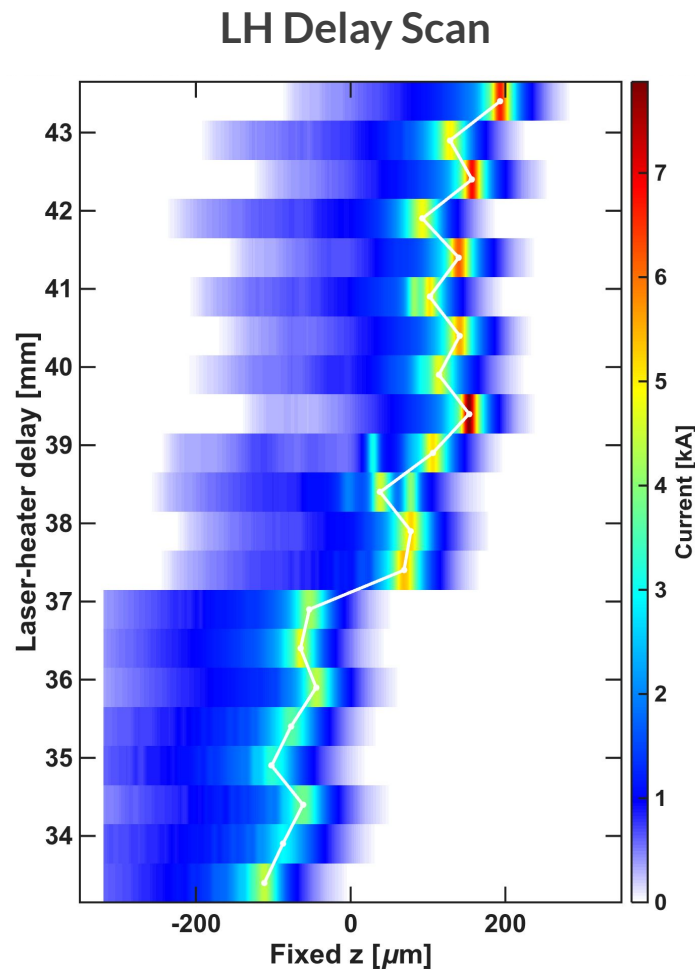
Current spikes generated with asymmetric LH profile and ~ 1 ps gaussian LH pulse

Laser Heater Commissioning

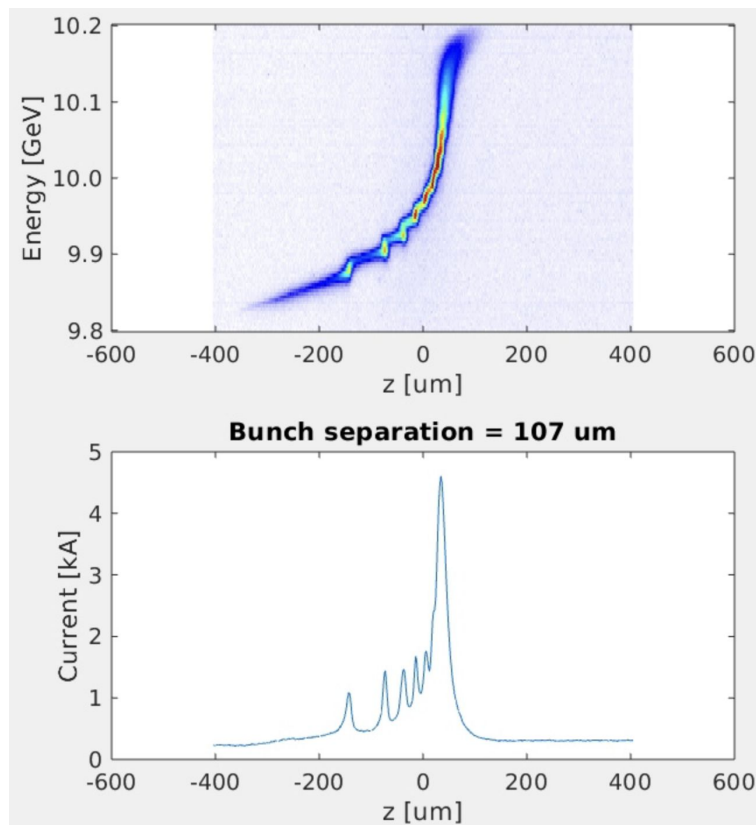


Strong agreement between experimental data and FACET-II S2E simulations

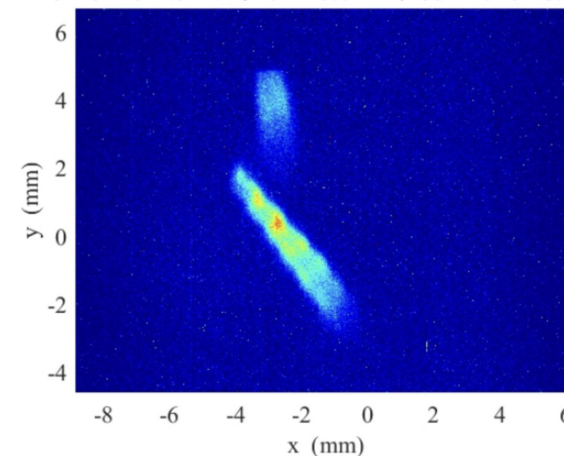
Laser Heater Commissioning



Spike Train Seeding, Two LH Pulses



Profile Monitor PROF:IN10:711 29-Jun-2026 18:38:46



- Two-bunch mode:
independent driver/witness
heating confirmed on
PR01711
- Interference observed at
specific LH pulse separations

Moveable current spike that tracks with LH pulse delay

Future Work

- Develop analytical models to understand coupled nature of collective effects (CSR, wakefields, space charge) and better understand how this impacts current profile reproducibility
- Full experimental L1/L2 scan with two LH pulses of 2ps separation, 3mJ LH energy
- **BeamNetUS proposal target: 2-3 equal drivers (spaced by plasma wavelength) + smaller witness spike**

Optimistic for the future beamtime in October!

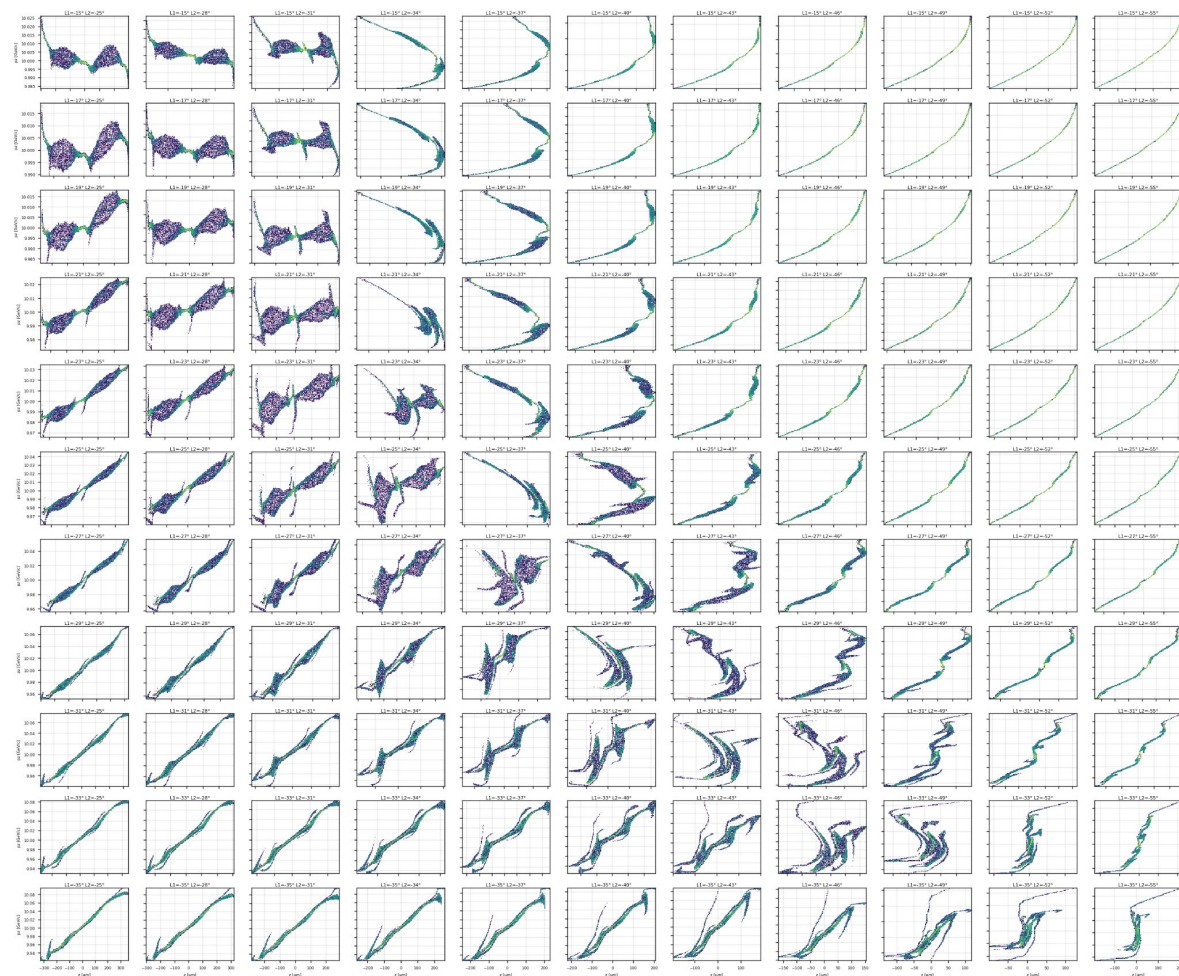
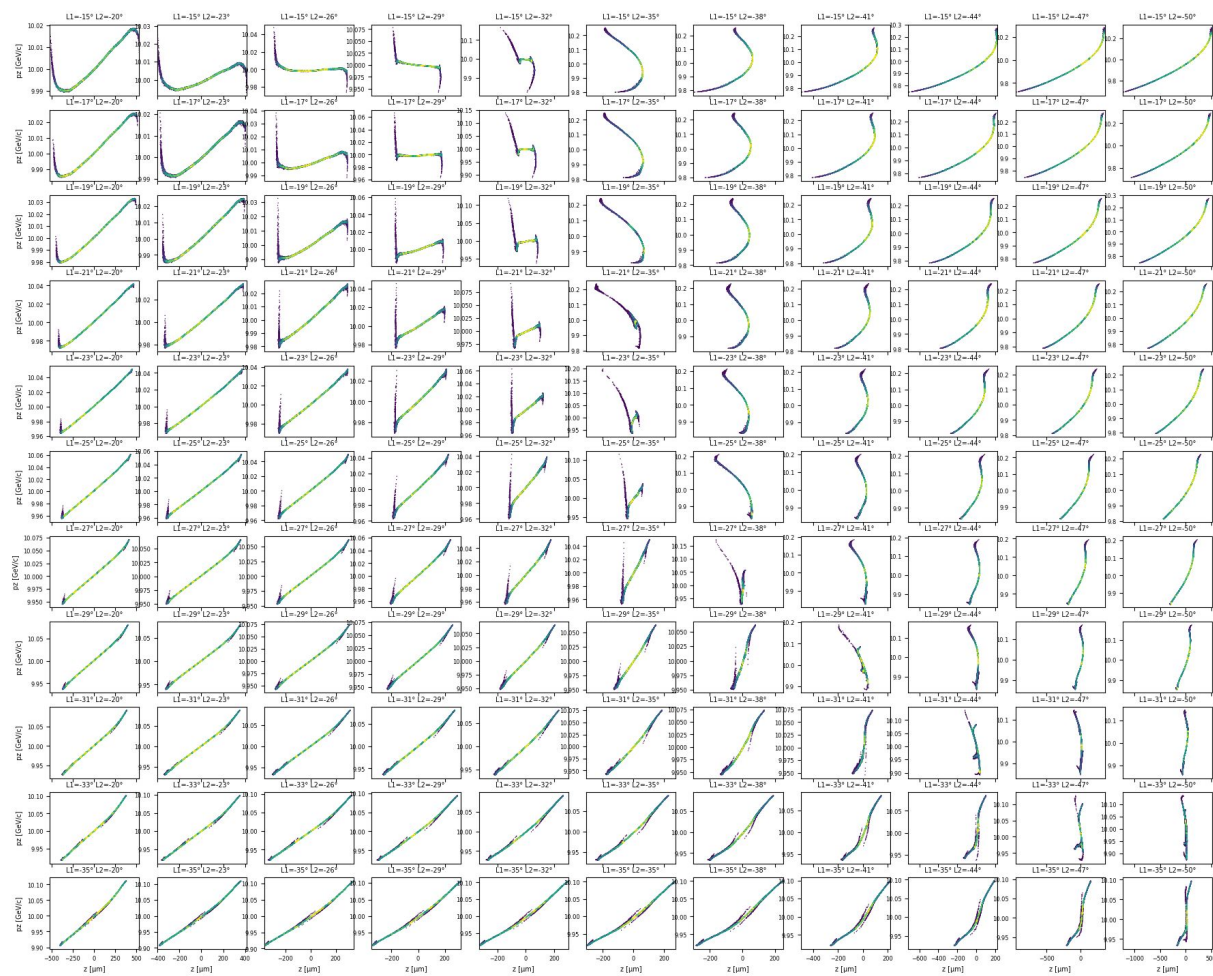
Future Work

- Develop analytical models to understand coupled nature of collective effects (CSR, wakefields, space charge) and better understand how this impacts current profile reproducibility
- Full experimental L1/L2 scan with two LH pulses of 2ps separation, 3mJ LH energy
- **BeamNetUS proposal target: 2-3 equal drivers (spaced by plasma wavelength) + smaller witness spike**

Thank you for listening!

Optimistic for the future beamtime in October!

A Complicated Phase Space



A Complicated Phase Space

