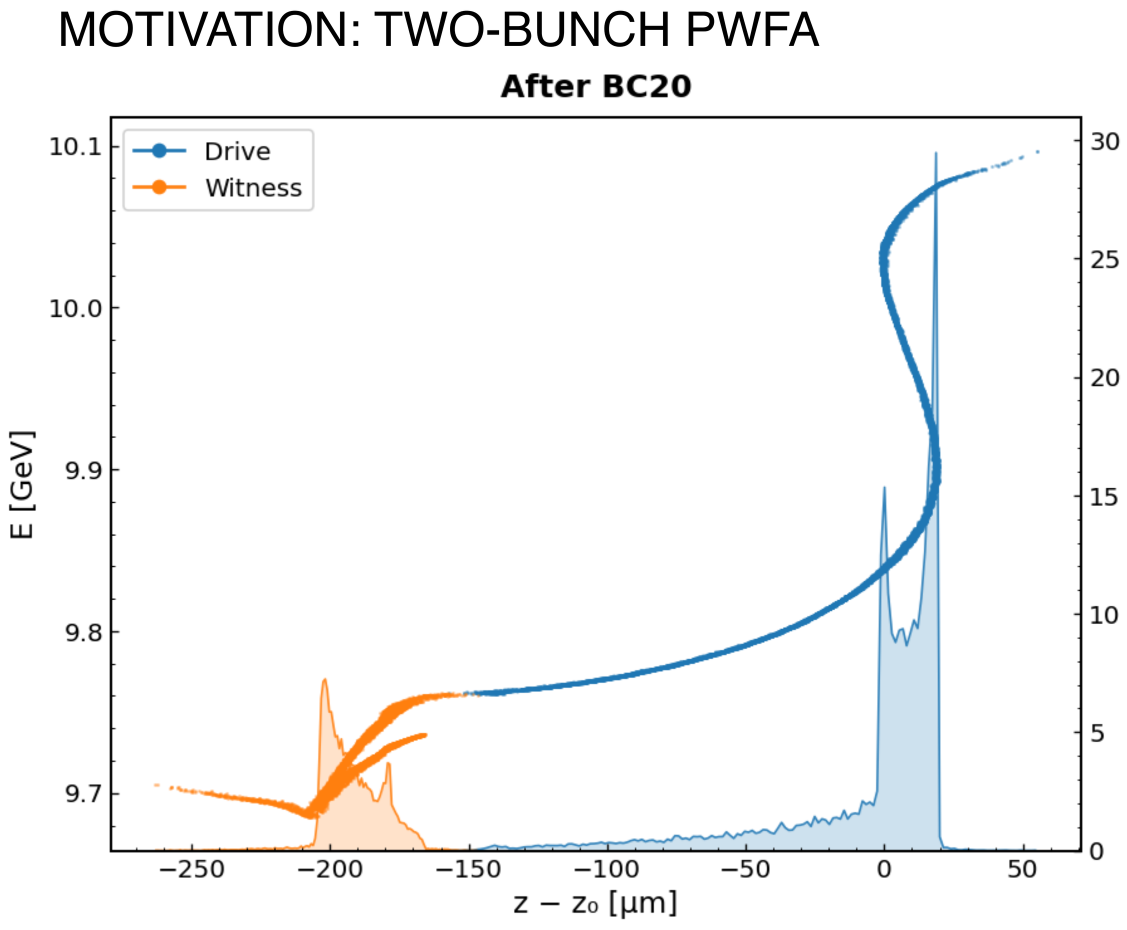
Tunable Photocathode Two-Bunch Mode for Advanced Accelerator Application

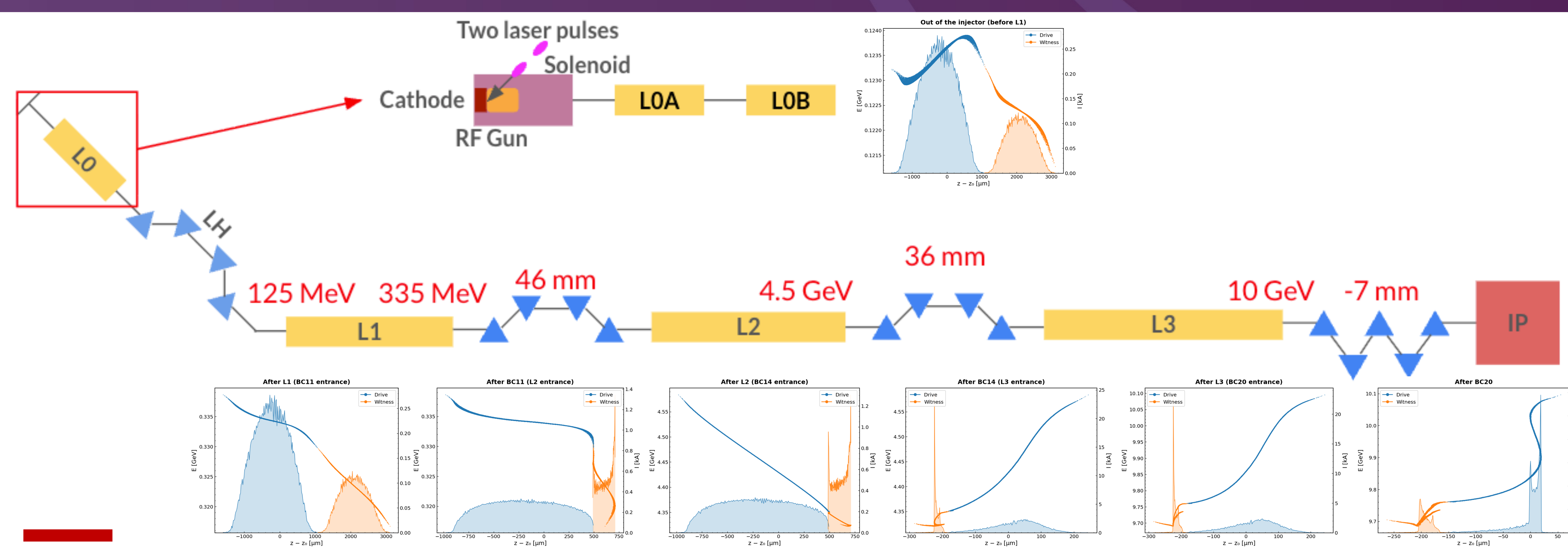
Yiheng Ye[1] - yihengy@slac.stanford.edu, Zack Buschmann[1], Claudio Emma[1], Spencer Gessner[1], Mark Hogan[1], Alexander Knetsch[1], Ryan Loney[1], Nathan Majernik[1], Brendan O'Shea[1], Marcellus Parker[1], Sharon Perez[1], Ivan Rajkovic[1], Doug Storey[1], Kelly Swanson[1], Junzhi Wang[1], Gerald Yocky[1]

1. SLAC National Accelerator Laboratory

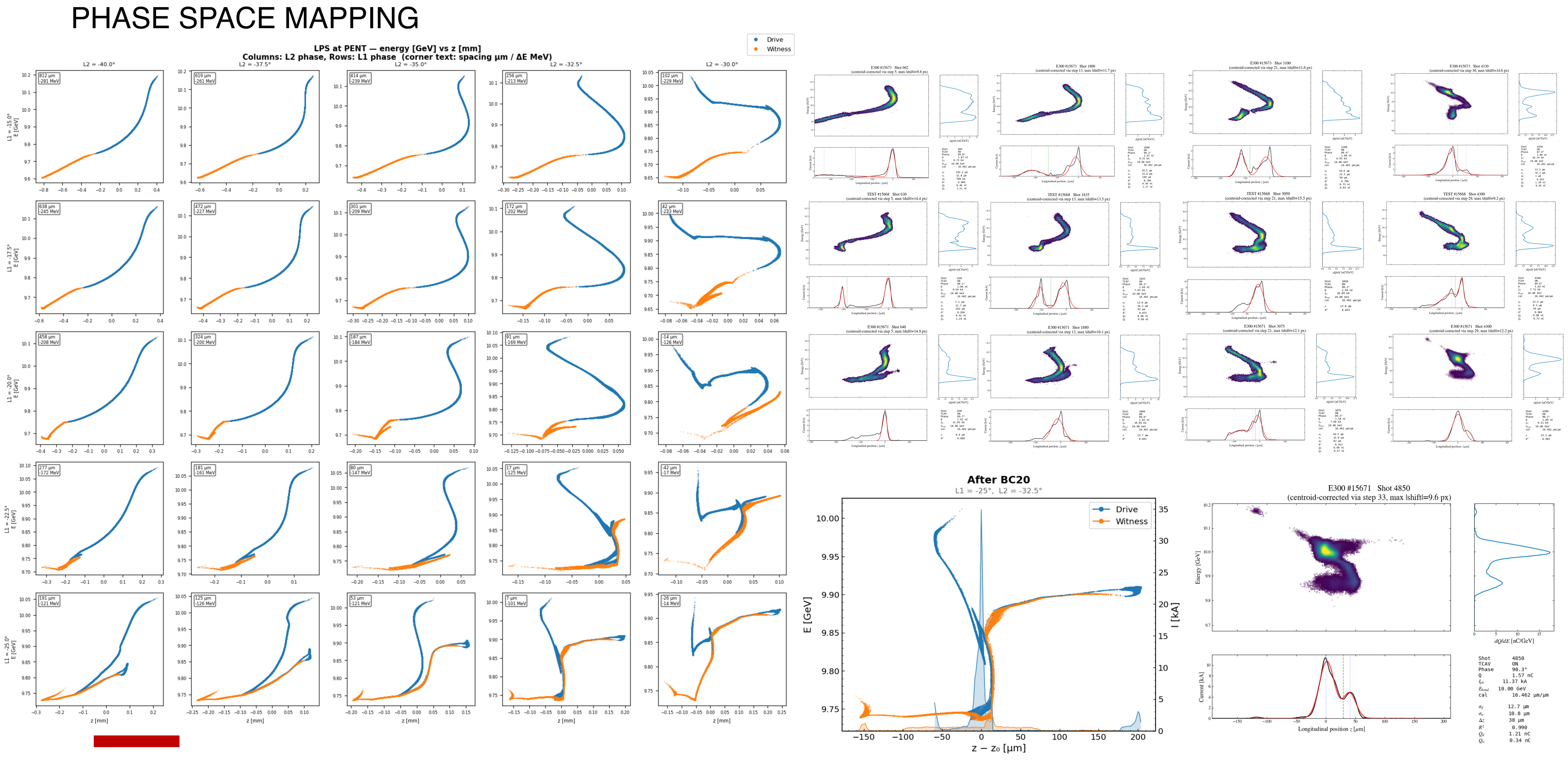
MOTIVATION: TWO-BUNCH PWFA



- One of the primary goals of PWFA at FACET-II
  - Collider-quality PWFA
    - >30% energy transfer efficiency
    - multi-GeV/m energy gain (10+ GeV)
    - maintaining <1% energy spread
    - minimal emittance growth
- Drive bunch requirements
  - High current
  - Good transverse properties
- Witness bunch requirements
  - Correct spacing behind the drive
  - Correct current profile to beam-load the wake
  - Matched spot size to the plasma



PHASE SPACE MAPPING



ANALYTICAL TRACKING

$$g_i^{(n)} = \underbrace{\frac{E_{n-1}}{E_n}\frac{g_i^{(n-1)}}{C_i^{(n-1)}}}_{\text{inherited}} + \underbrace{k\left(1-\frac{E_{n-1}}{E_n}\right)\frac{\sin\varphi_i^{(n)}}{\cos\varphi_n}}_{\text{RF}} + \underbrace{\frac{B\ell_n}{E_n}\frac{N_i}{L_i^{(n-1)}}\, e^{-\sqrt{L_i^{(n-1)}/2s_0}}}_{\text{self-wake}}$$

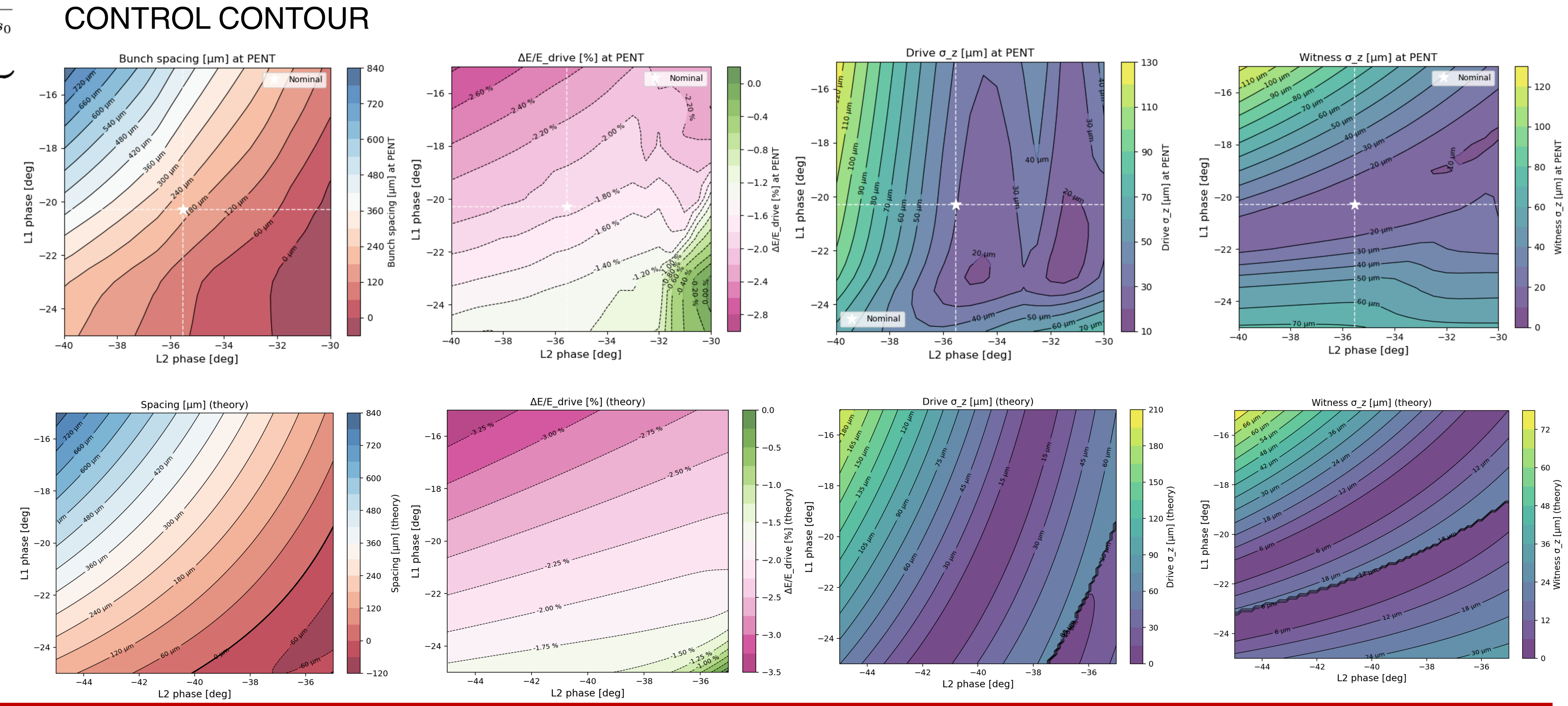
$$\Delta E^{(n)} = \Delta E^{(n-1)} + (E_n - E_{n-1})\, k\Delta z^{(n-1)} \tan\varphi_n + \Delta E_w^{(n)}$$

$$\Delta E_w^{(n)} = \underbrace{\mathrm{sgn}(\Delta z)\, B\ell_n N_L\, e^{-\sqrt{|\Delta z|/s_0}}}_{\text{cross kick}} - \underbrace{B\,\ell_n\left(N_d\Lambda_d - N_w\Lambda_w\right)}_{\text{loss differential}}$$

$$C_i^{(n)} = 1 + g_i^{(n)} R_{56}^{(n)}, \qquad \sigma_i^{(n)} = \left|C_i^{(n)}\right| \sigma_i^{(n-1)}$$

$$\Delta z^{(n)} = \Delta z^{(n-1)} + \frac{R_{56}^{(n)}}{E_n}\,\Delta E^{(n)}$$

CONTROL CONTOUR



CONCLUSION

- We demonstrate the quasi-independent tunability of drive-witness pair in photocathode two-bunch mode with nano-Coulomb, asymmetric bunch charge
- We use analytic theory to understand the RF chirp offset+wakefield dominated longitudinal dynamics

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