E338 (PAX) Plans for FY26

FACET-II PWFA Collaboration meeting

SLAC National Accelerator Laboratory

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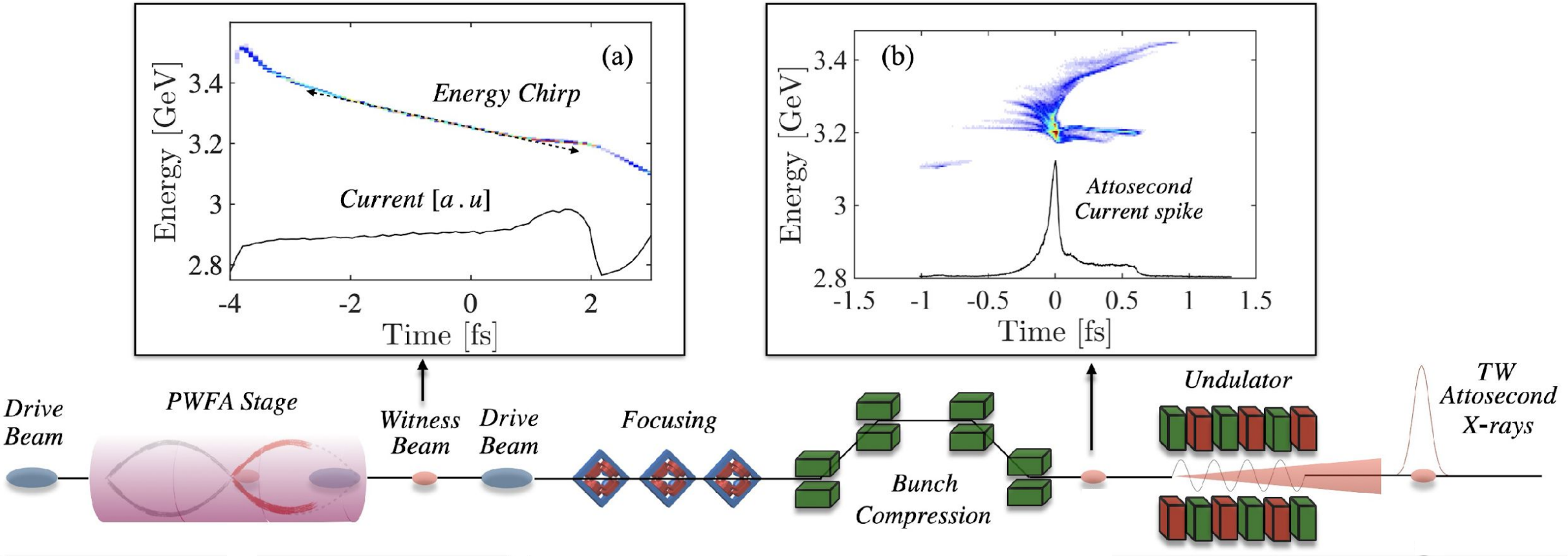
FACET-II

SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

Concept for scaling to shorter wavelengths R. Hessami et al., PRAB (2024)

PAX concept: a Plasma-driven Attosecond X-ray Source



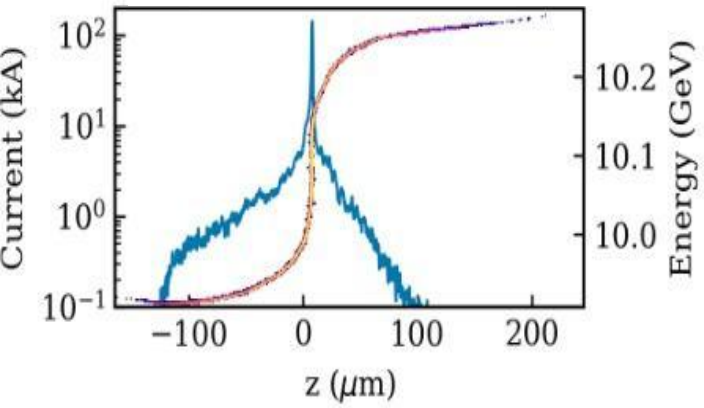
C. Emma et al., APL Photonics, **6**, 076107 (2021)

Large chirp, small slice energy spread make PWFA beams ideal for post-compression & coherent emission

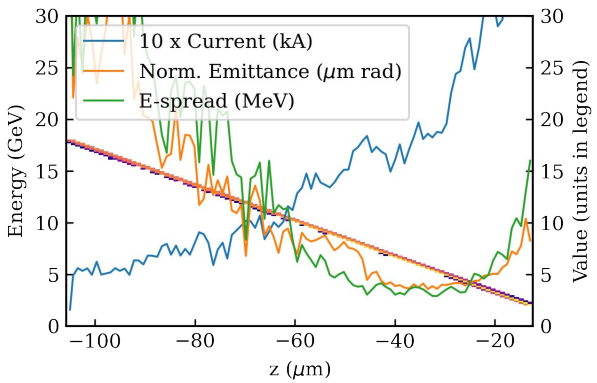
E338 Experimental goals at FACET-II

Science Goals
1. Demonstrate post-plasma sub-fs compression of e- beam
2. Measure + characterize XUV CSR for compressed e- beam down to 100 nm
3. Using plasma-injector, compress + measure coherent XUV down to 50 nm

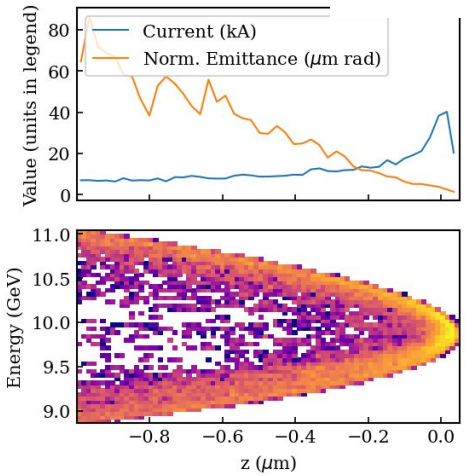
Before Plasma

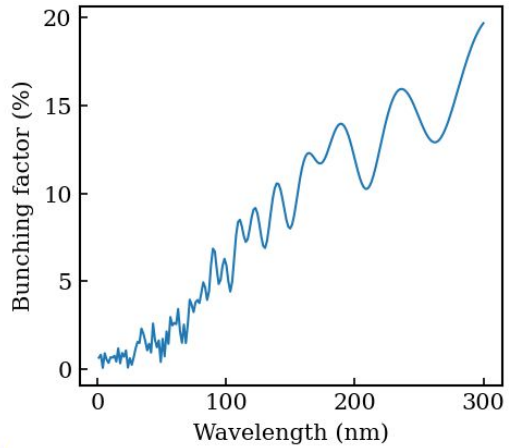


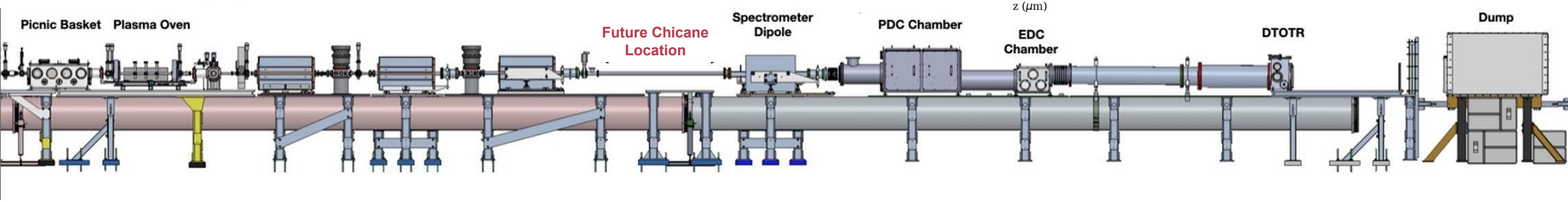
After Plasma



After Chicane





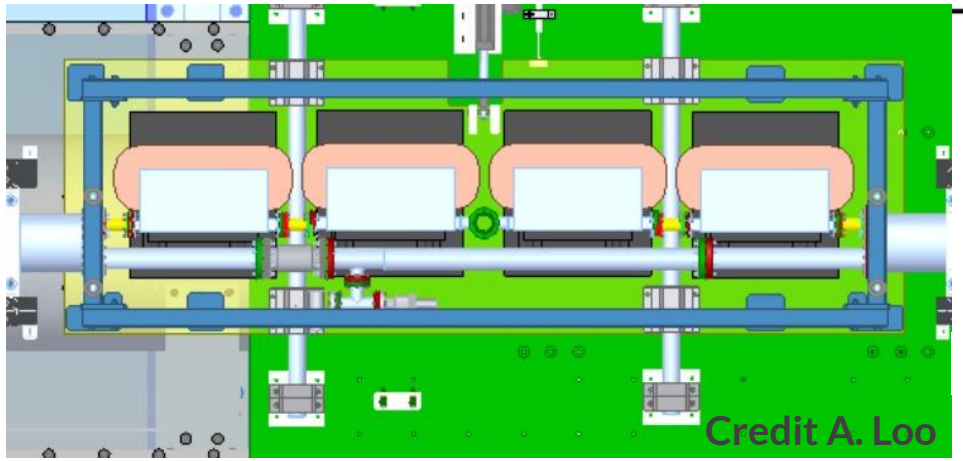


E338 Experimental setup and diagnostics

Plasma Sources

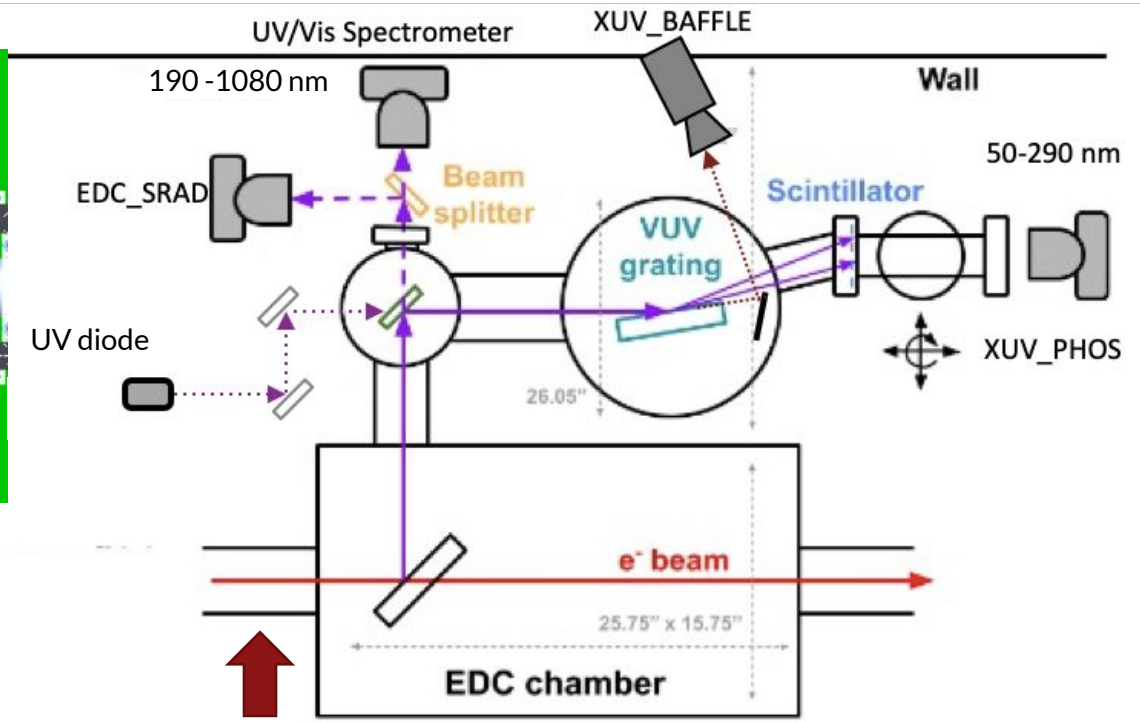
- Gas Jet
$n_e = 10^{18} – 10^{20}$ cm^{-3}
- Li Oven
ne = $10^{16} – 10^{17}$ cm^{-3}
- Static fill

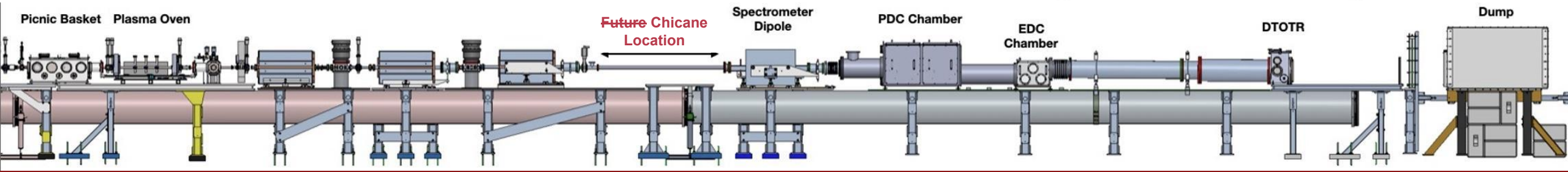
Chicane + bypass line



Spectral Measurement Setup

Confluence

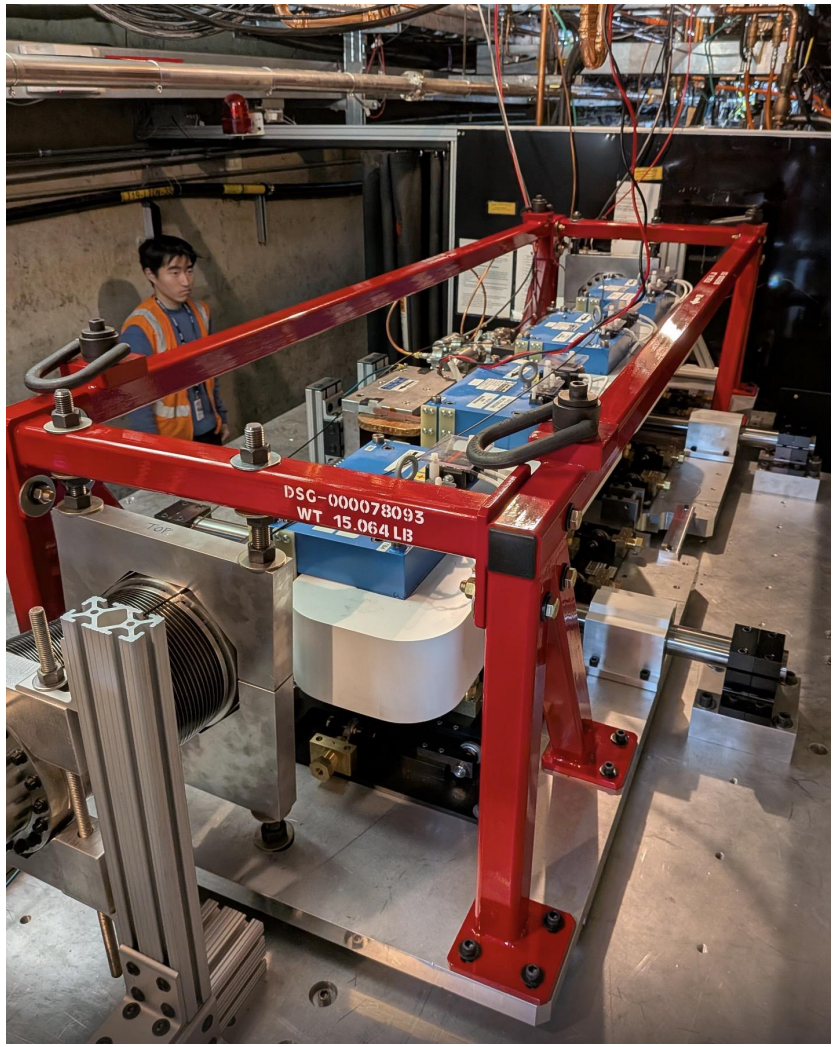


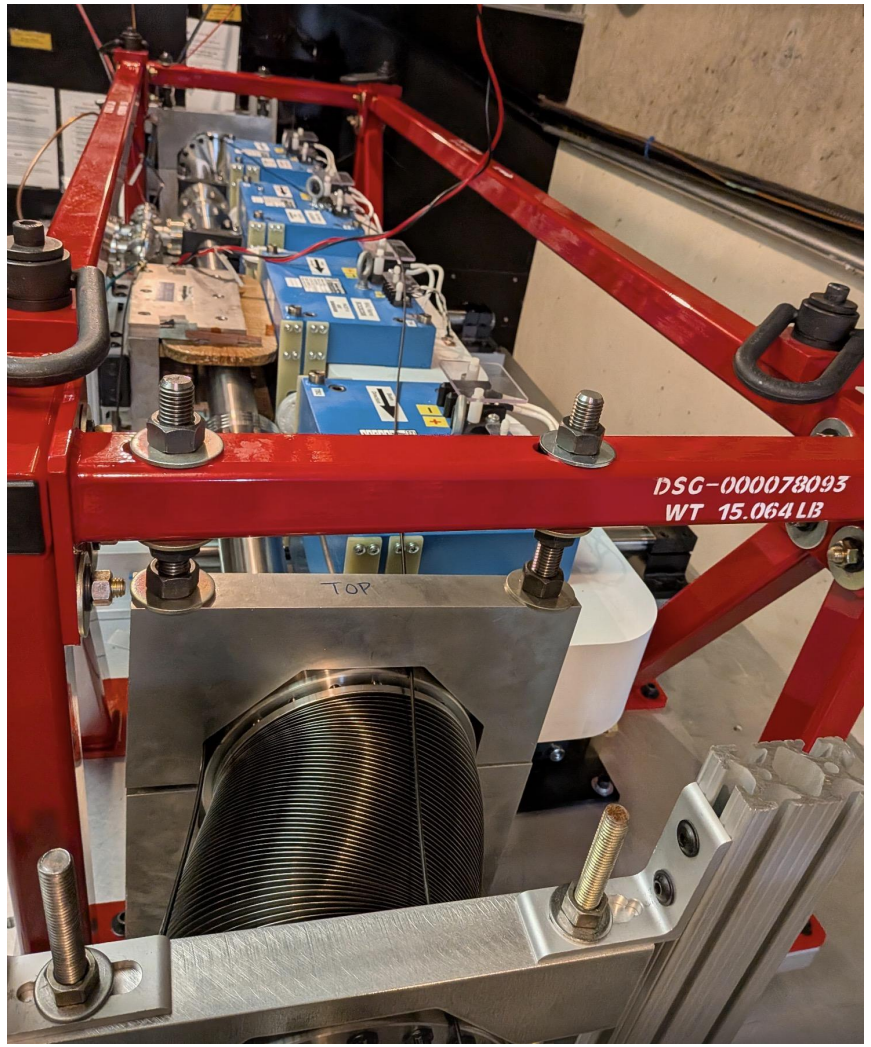


Radiation setup detects broadband spectral content to map bunching factor of fully-compressed e-beam

Chicane installation status and plans

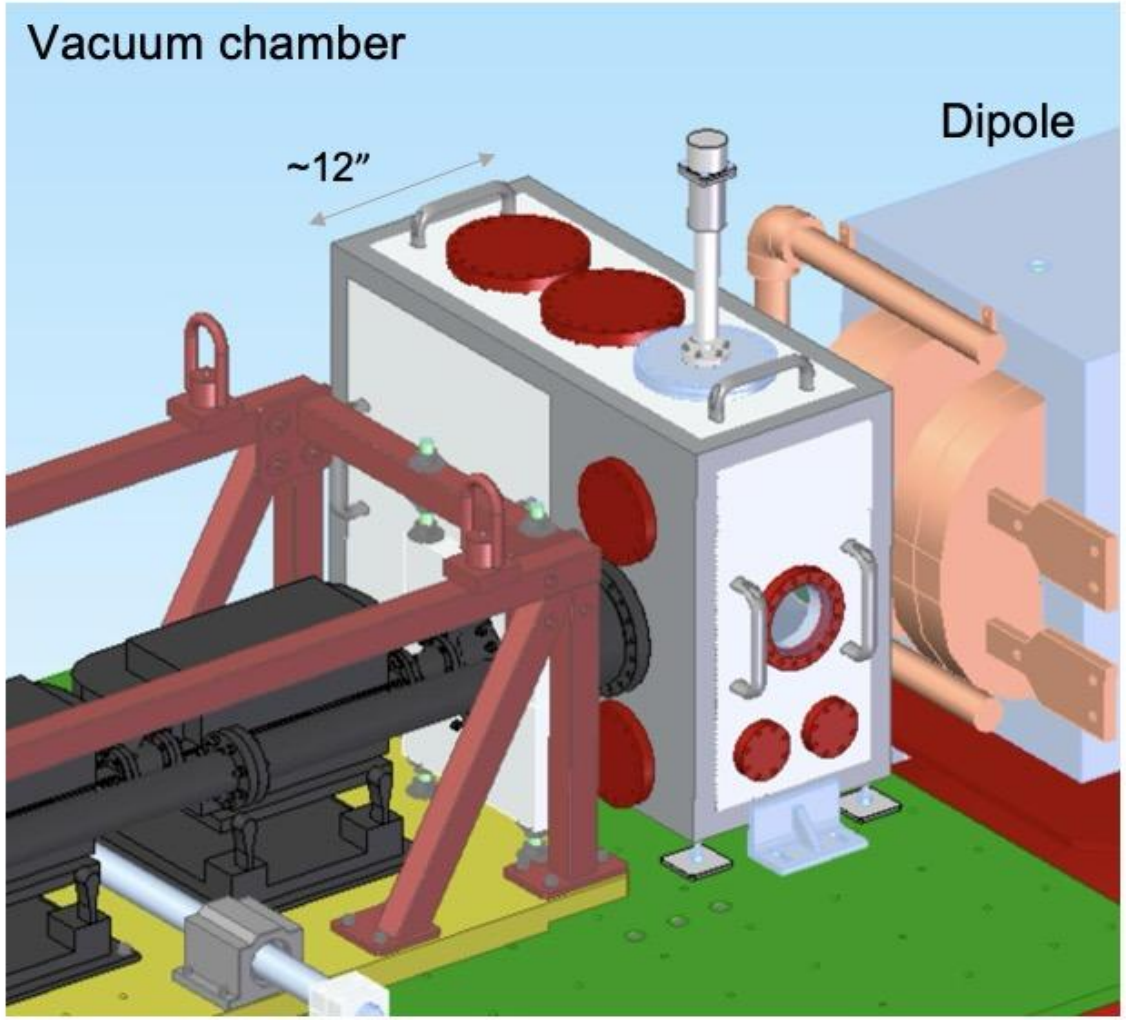
- Chicane installed between Q2D and dump dipole
- Mover table allows remote transition from chicane to bypass line
- Dipoles powered in pairs to enable net deflection of beam
- YAG screen between dipoles 2 and 3
- First beam time with chicane planned for this week.





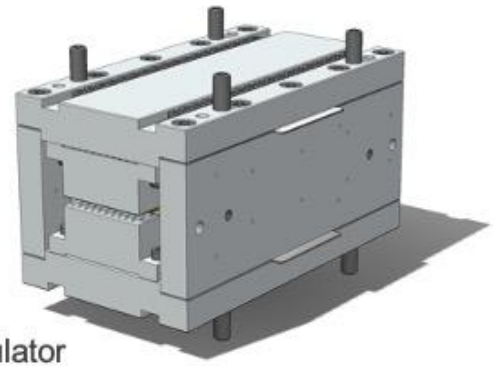
Chicane installed on beamline. Ready to see first beam.

Post-chicane chamber



Chamber can support:

- Gas jets
- Solid targets
- OTR screens
- Undulators
- Others?



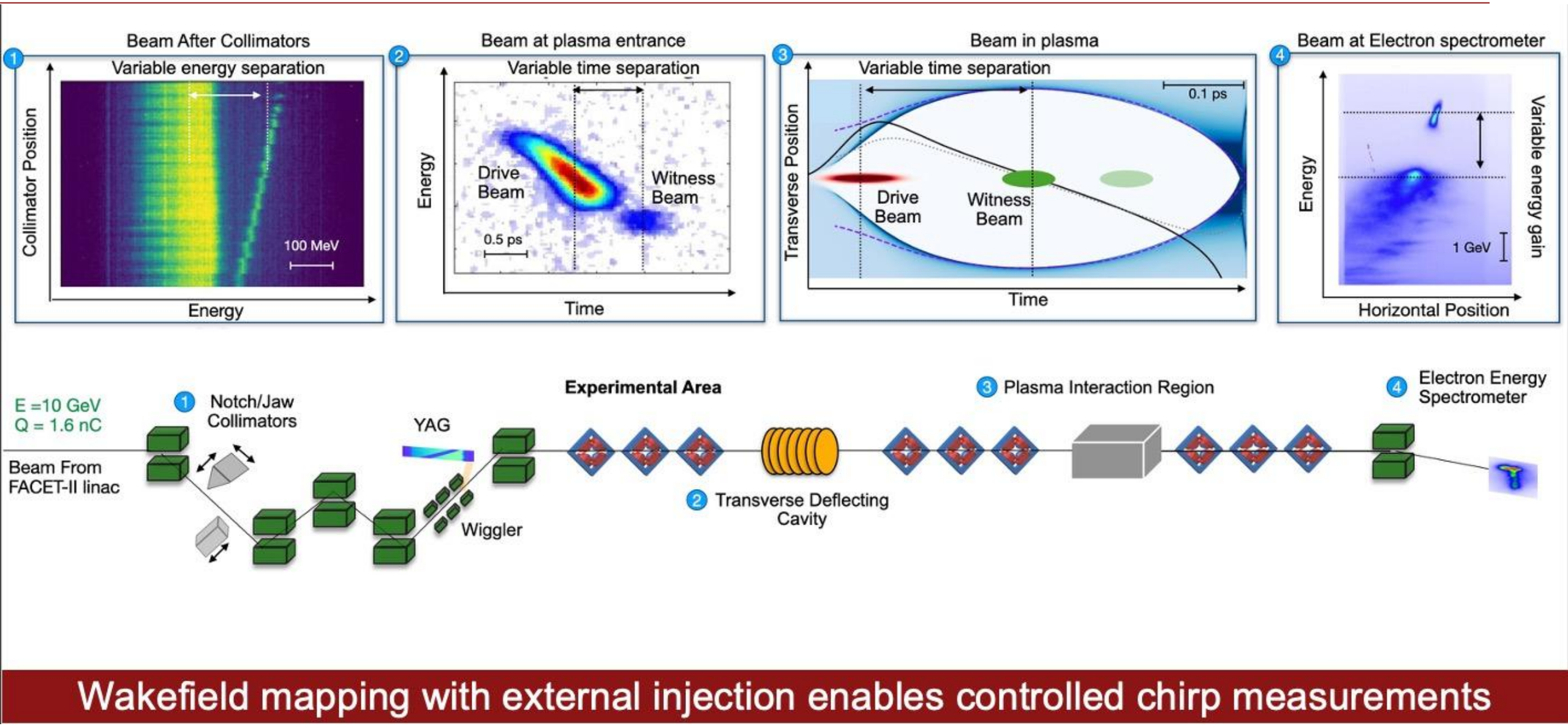
Compact undulator

Status

- Quotes obtained from vendors
- Installation expected in summer 2026 downtime.

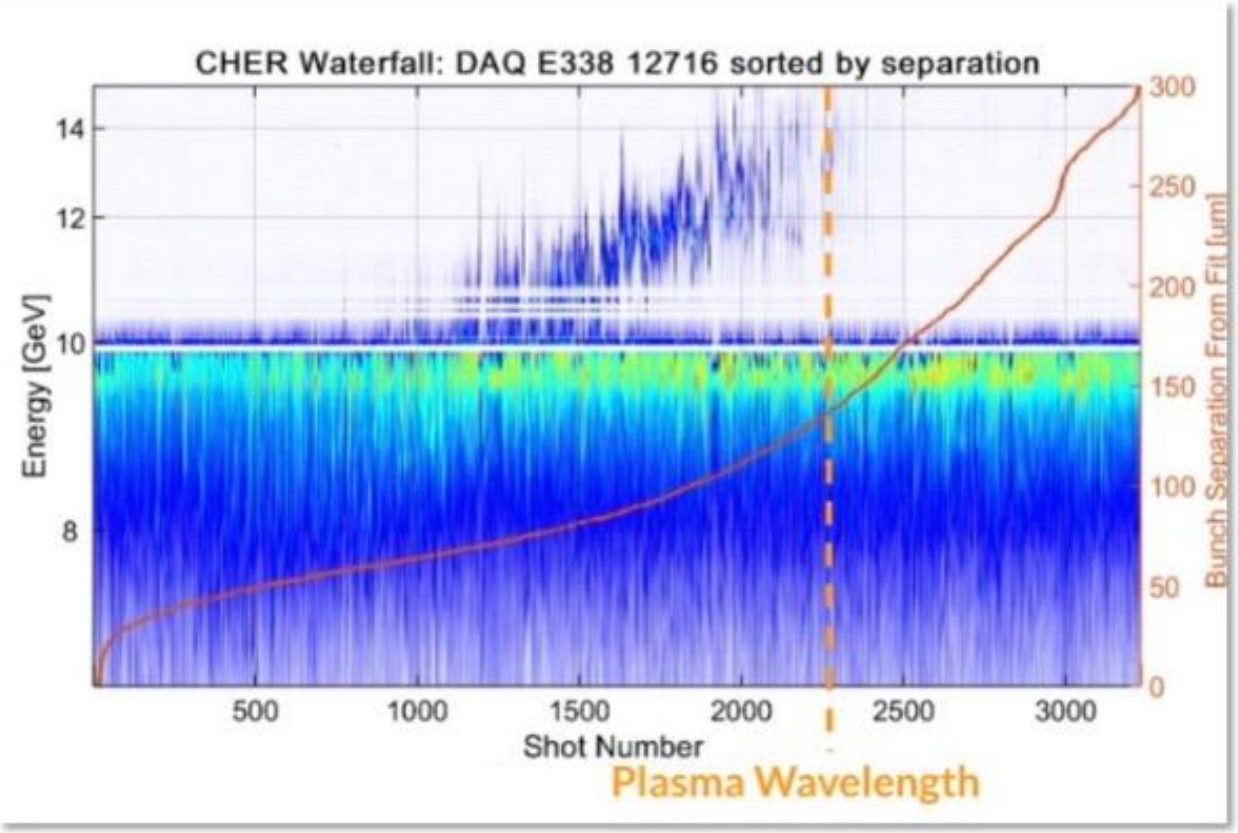
Post-chicane chamber designed, ideally available for experiments in Fall 2026

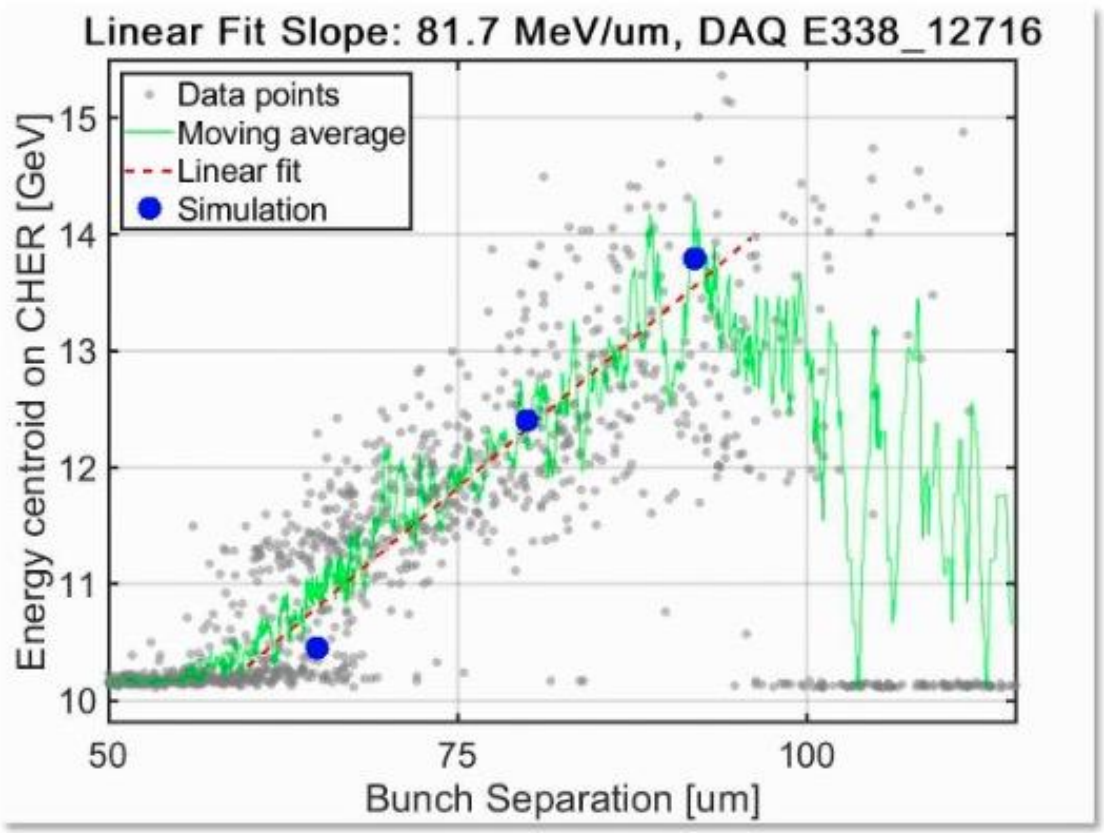
E338 FY25 results - chirped beam generation



Wakefield mapping with external injection enables controlled chirp measurements

E338 FY25 results - chirped beam generation

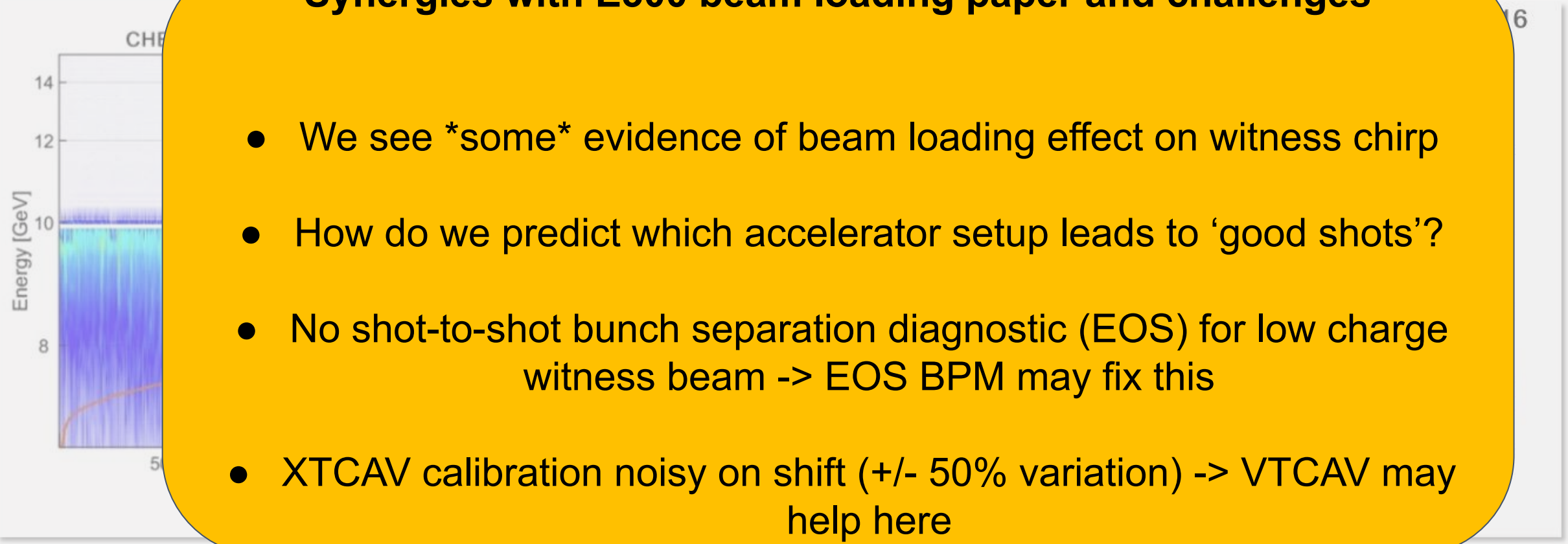




50-80 % charge capture obtained for separations giving 1-2 GeV energy gain

Chirped beams with external injection good for first plasma compression experiments

E338 FY25 results - chirped beam generation



Synergies with E300 beam loading paper and challenges

- We see *some* evidence of beam loading effect on witness chirp
- How do we predict which accelerator setup leads to ‘good shots’?
- No shot-to-shot bunch separation diagnostic (EOS) for low charge witness beam -> EOS BPM may fix this
- XTCAV calibration noisy on shift (+/- 50% variation) -> VTCAV may help here

50-80 % charge capture obtained for separations giving 1-2 GeV energy gain

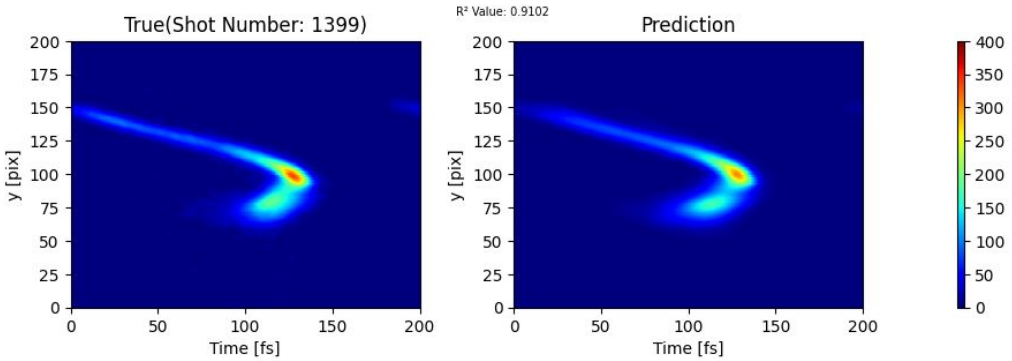
Chirped beams with external injection good for first plasma compression experiments

Virtual TCAV

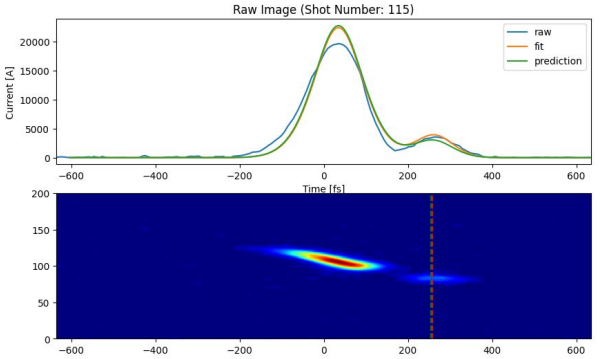
Status

- Virtual tcav prediction used for post-shift analysis in single/two bunch configs
- ML model allows “tuning” of LPS by changing PV values
- Requires training w tcav (~30 mins) during shift
- Goal is deployment of live VTCAV GUI this run - synergy w Sheldon’s ML BSA work

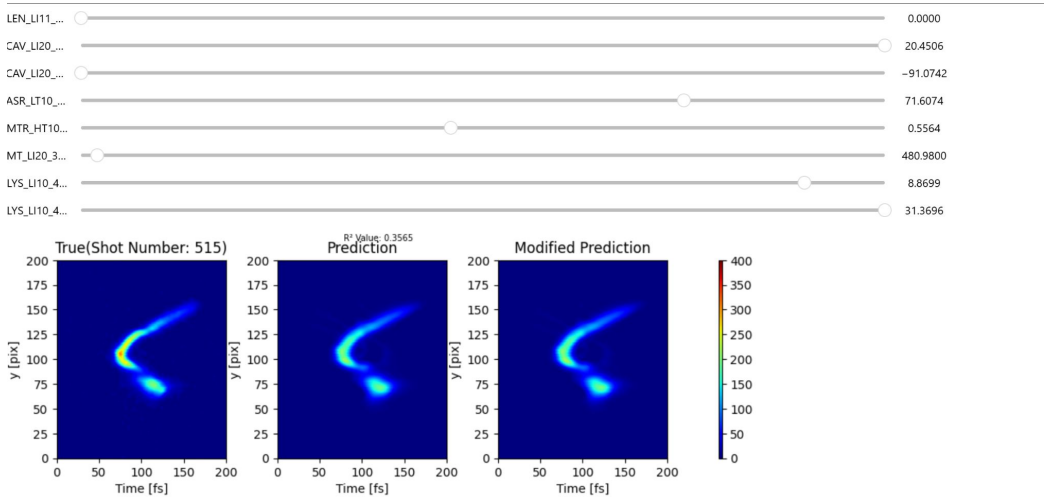
Two bunch prediction



Single bunch notch prediction



Two bunch LPS “tuning”



Virtual TCAV used for post-analysis, live GUI for on-shift feedback is work in progress

E338 FY26 plans

- Commission chicane with beam (no plasma) - February
- First external injection plasma-based compression experiments with chicane (Li oven, static fill, gas jet) - March/April
  - Goal is to see an effect on CSR spectrum as we scan dipole peak field
  - Shot-to-shot bunch separation diagnostic (EOS) highly desirable esp for single bunch notched with low charge witness.
- Optimize beam and plasma configuration for shortest bunch generation - May/June
  - Optimize plasma source **synergy with E301**
  - Internally vs externally injected beam **synergy with E304**
  - For external injection, Li oven vs static fill and single bunch notch vs two bunch from photocathode
- **How does this fit into broader E-300 program?**
- Final compressed bunch performance will depend on beam matching/transverse quality coming out of the plasma. We are interested in contributing to analysis, optimization of slice beam properties at plasma entrance.

Goal for this run is to demonstrate the plasma compression conceptually

Acknowledgments

Collaborators

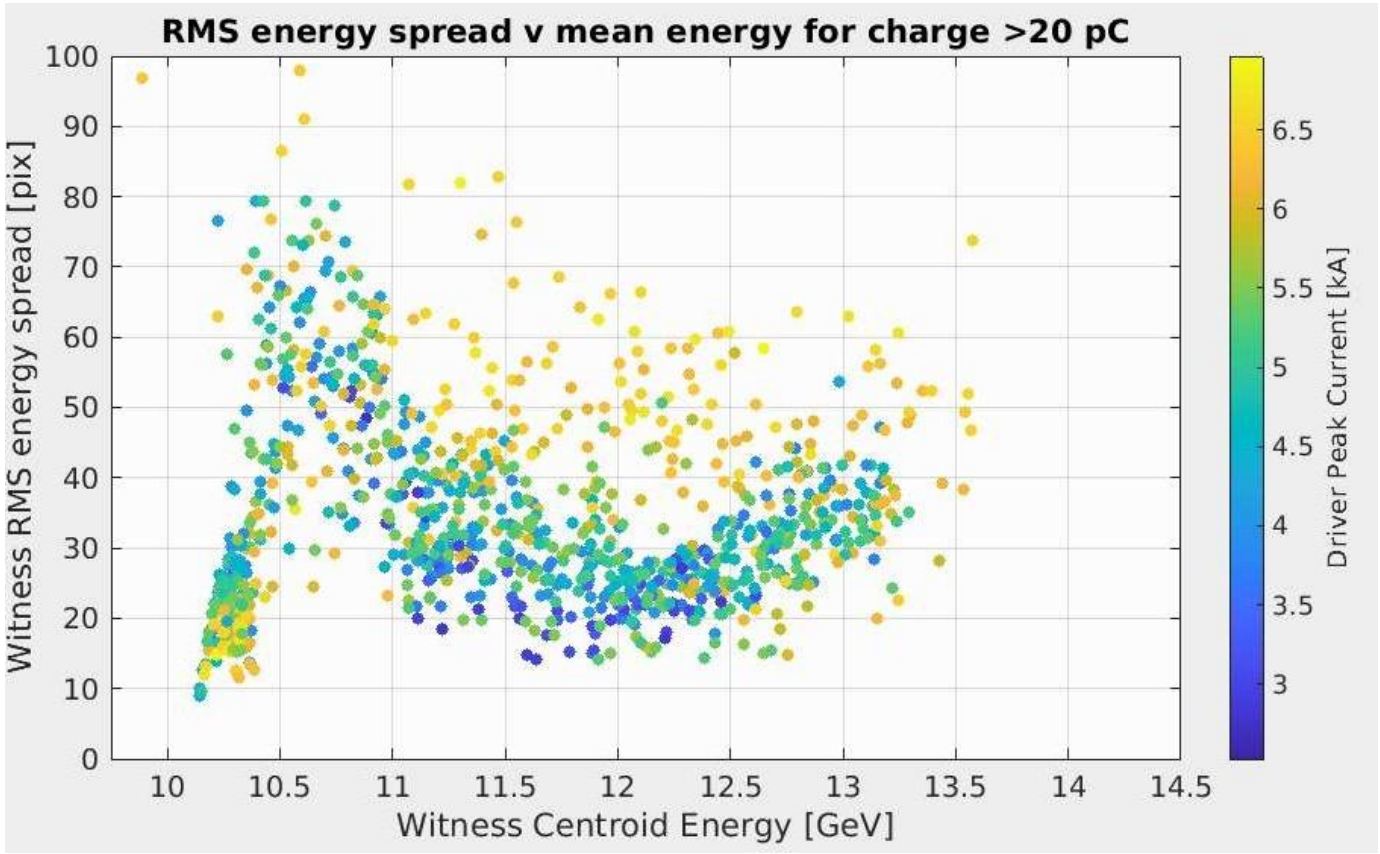
- **SLAC**: R. Hessami, K. Larsen, R. Robles, K. Swanson, C. Emma, A. Marinelli, FACET-II AARD & Beam Physics groups
- **UCLA**: A. Fisher, P. Musumeci, C. Zhang, C. Joshi, K. Marsh
- **Experimental Collaborations with:** E-300, E-304, E310, …

- ***Special thanks to:*** D. Storey, A. Loo, D. McCormick, J. Cruz, I. Rajkovic for chicane installation work, S. Corde + Sheldon for writing notch + jaw scan function

Thank you for your attention

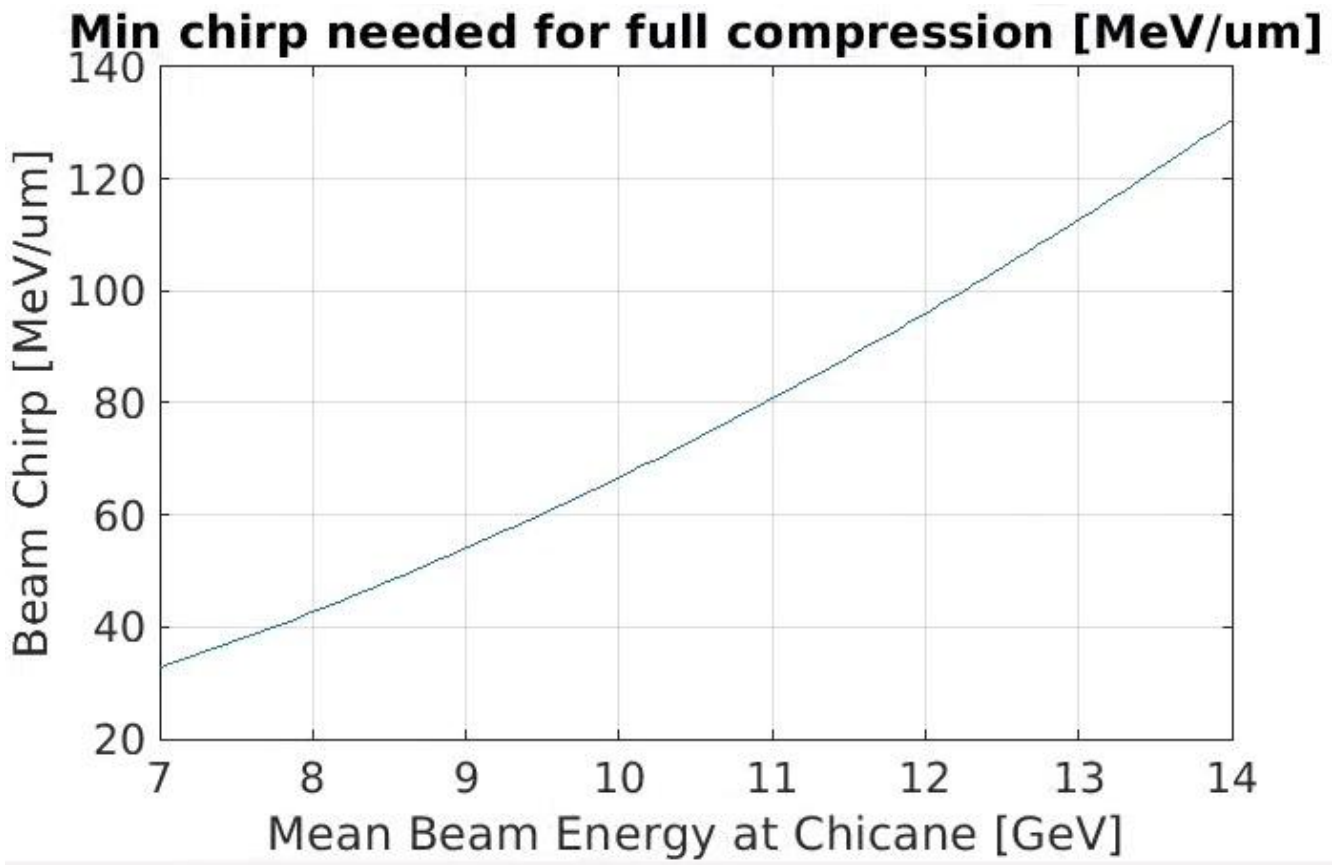
Backup Slides

E338 FY25 results - wakefield mapping and beam loading



Preliminary analysis shows some evidence of beam loading on the energy spread vs position in bubble

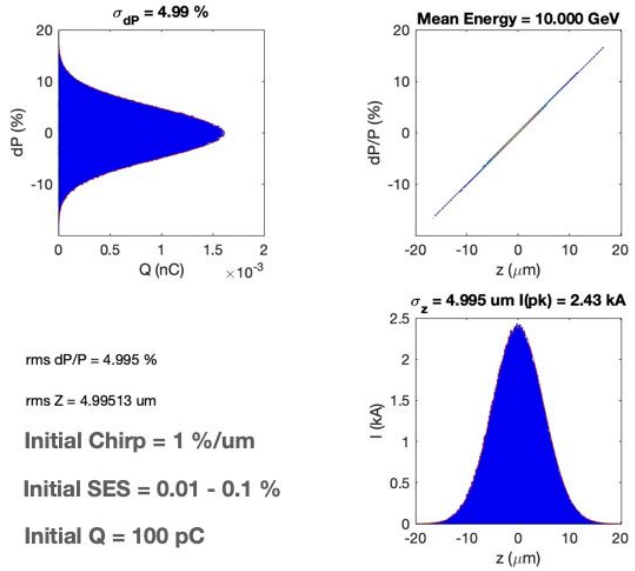
Chirp required for full compression



Assumes our chicane runs at max R56 of 150 um at 10 GeV and that full compression is achieved when |chirp| = 1/R56

PAX first E300-like experiments: tolerances to beam emittance and SES

LPS at exit of plasma



rms dP/P = 4.995 %

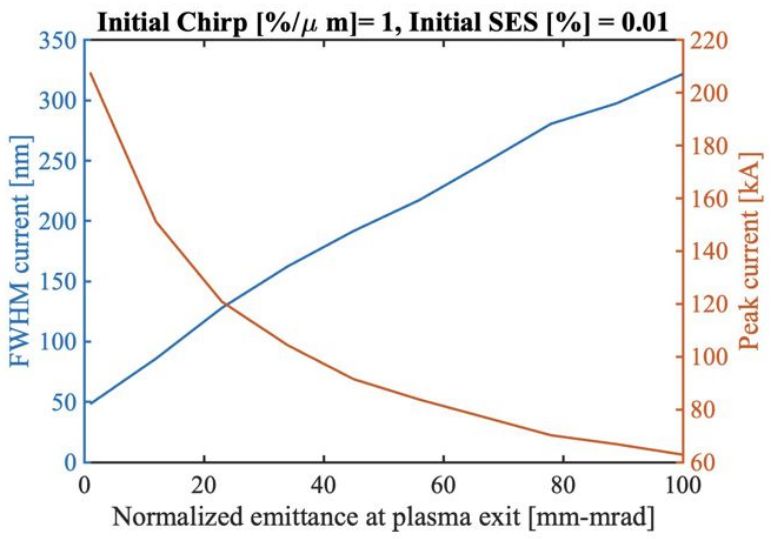
rms Z = 4.99513 um

Initial Chirp = 1 %/um

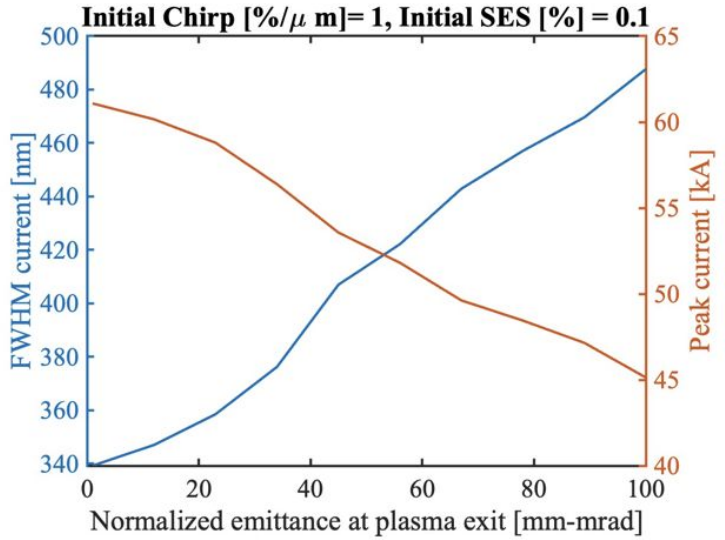
Initial SES = 0.01 - 0.1 %

Initial Q = 100 pC

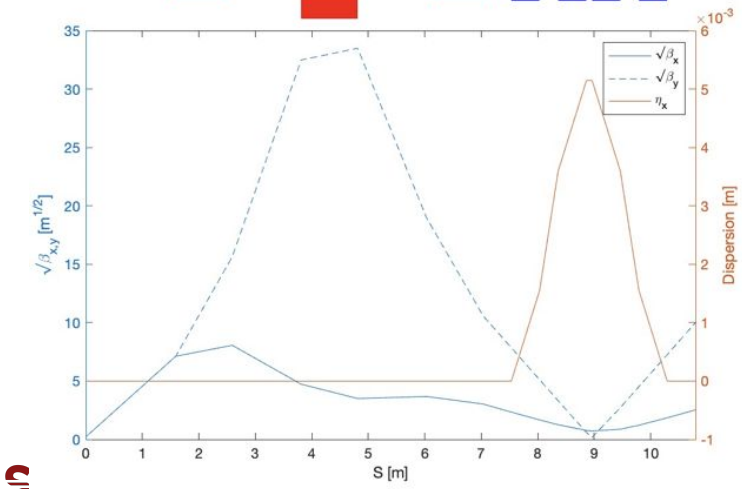
Output beam parameters after chicane

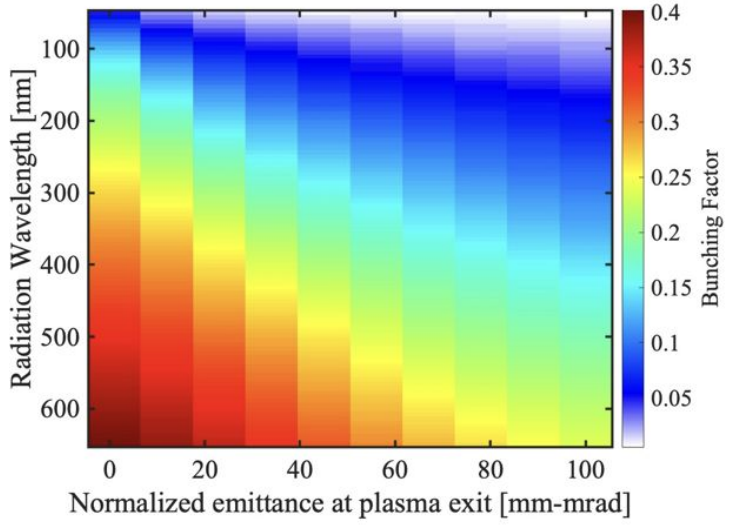


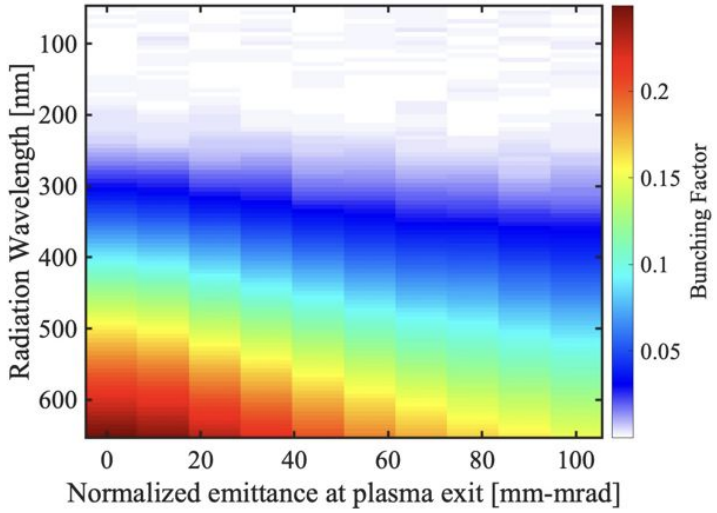
Output beam parameters after chicane



Focusing triplet and post-plasma chicane

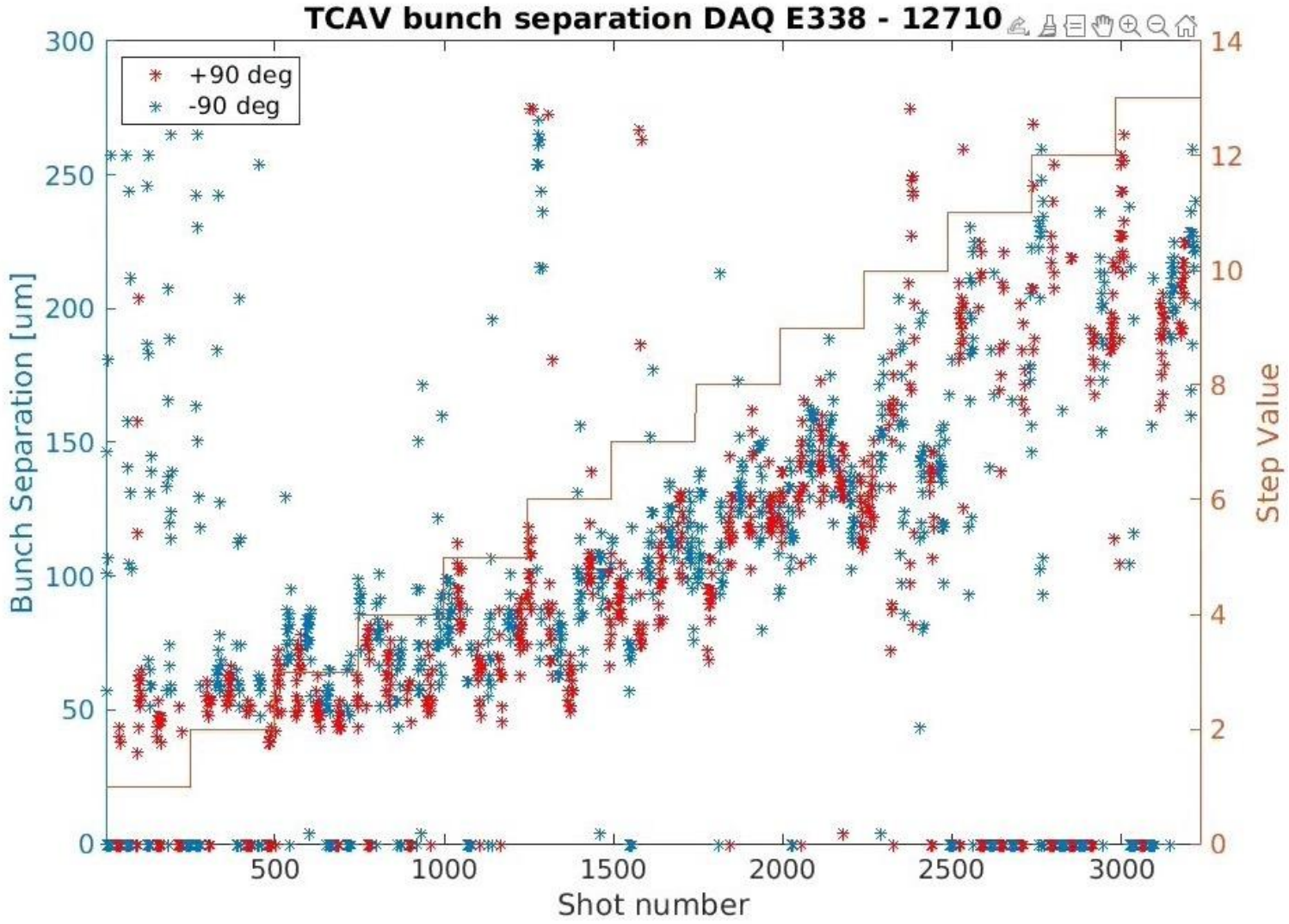






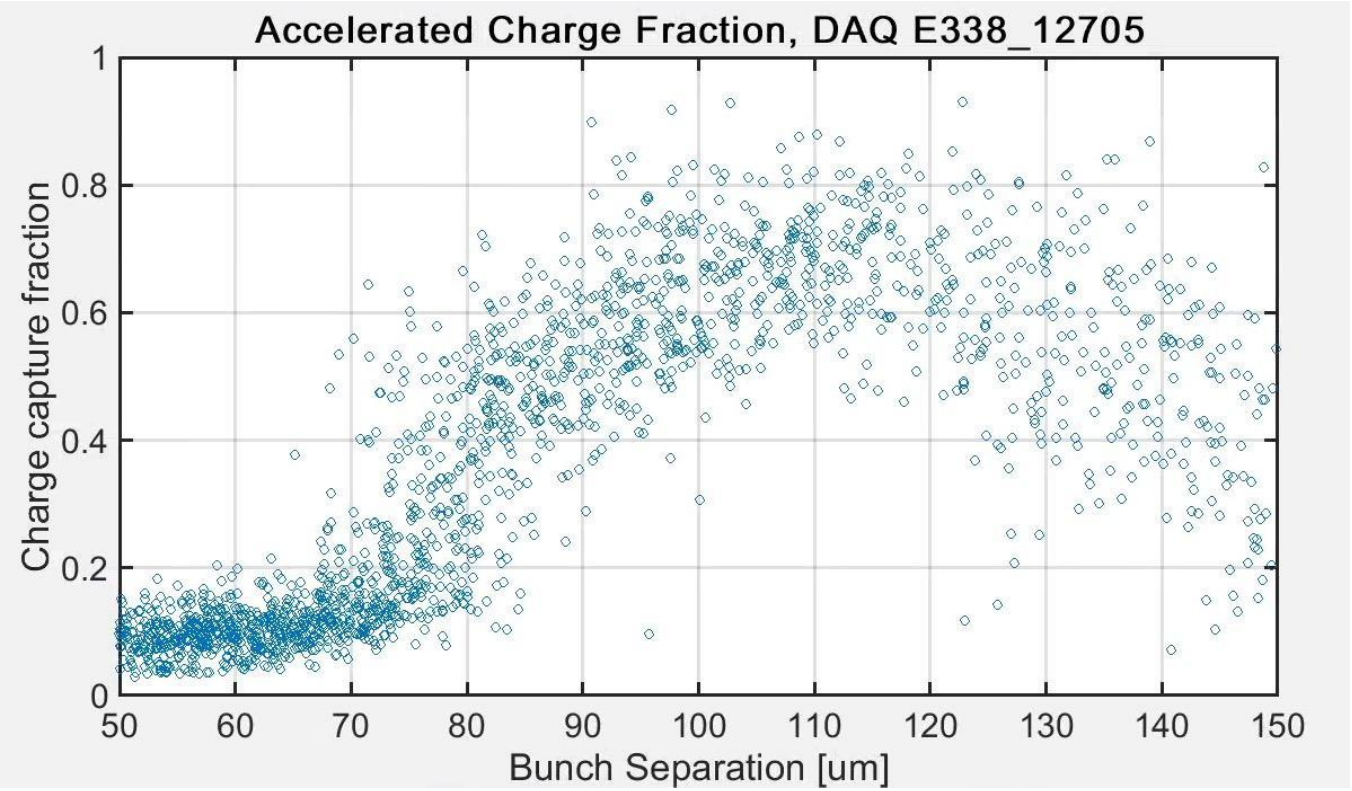
XTCAV reconstruction notes

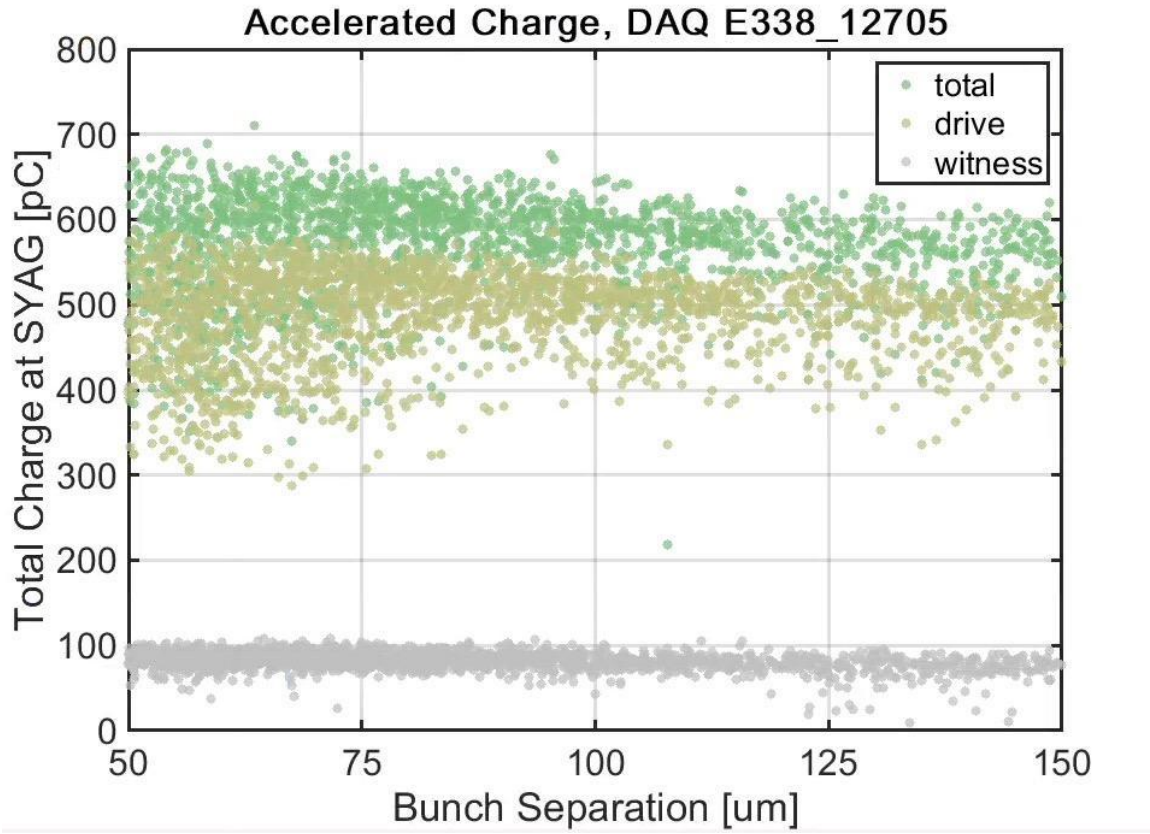
Bunch separation from each zero crossing fairly consistent during 2D notch + jaw and BLEN scan



Accelerated Charge

Oven at 4 Torr, n_p = 3.5e16

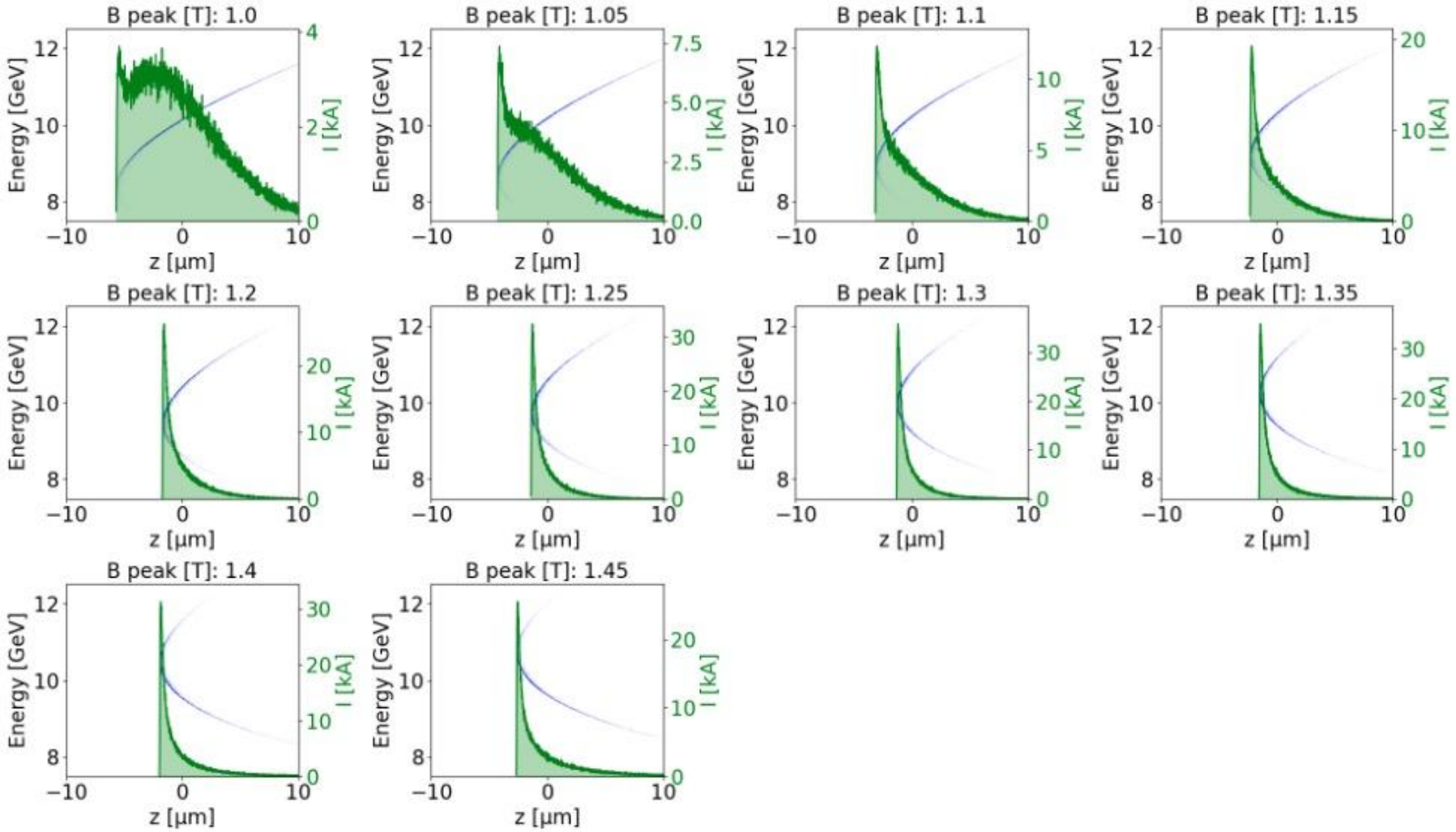




Good charge capture (>60%) obtained for bunch separations at 1-2 GeV energy gain

Simulations for ‘first experiments’

Assumes **100um** emittance, 100 pC, 0.7%/um chirp at plasma exit



Magnetic field scan enables compression of beam from ‘under’ to ‘over’ compressed configuration

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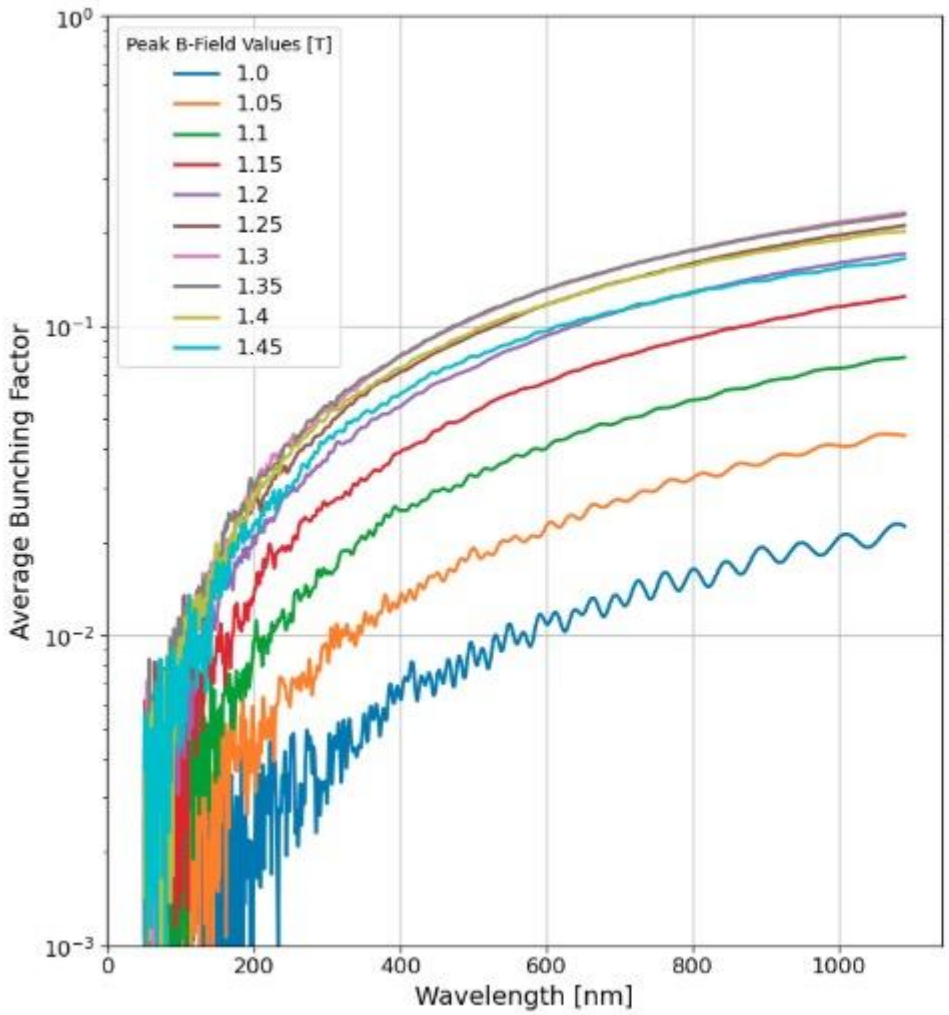

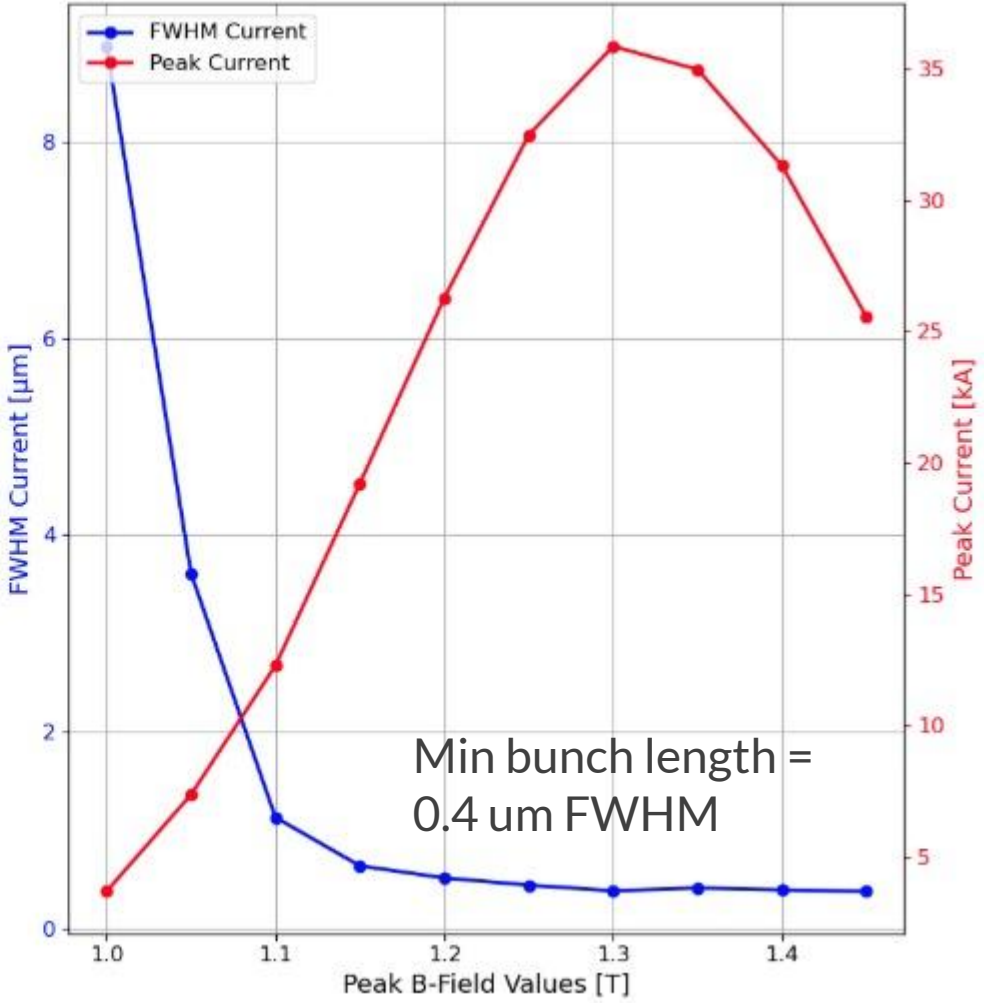

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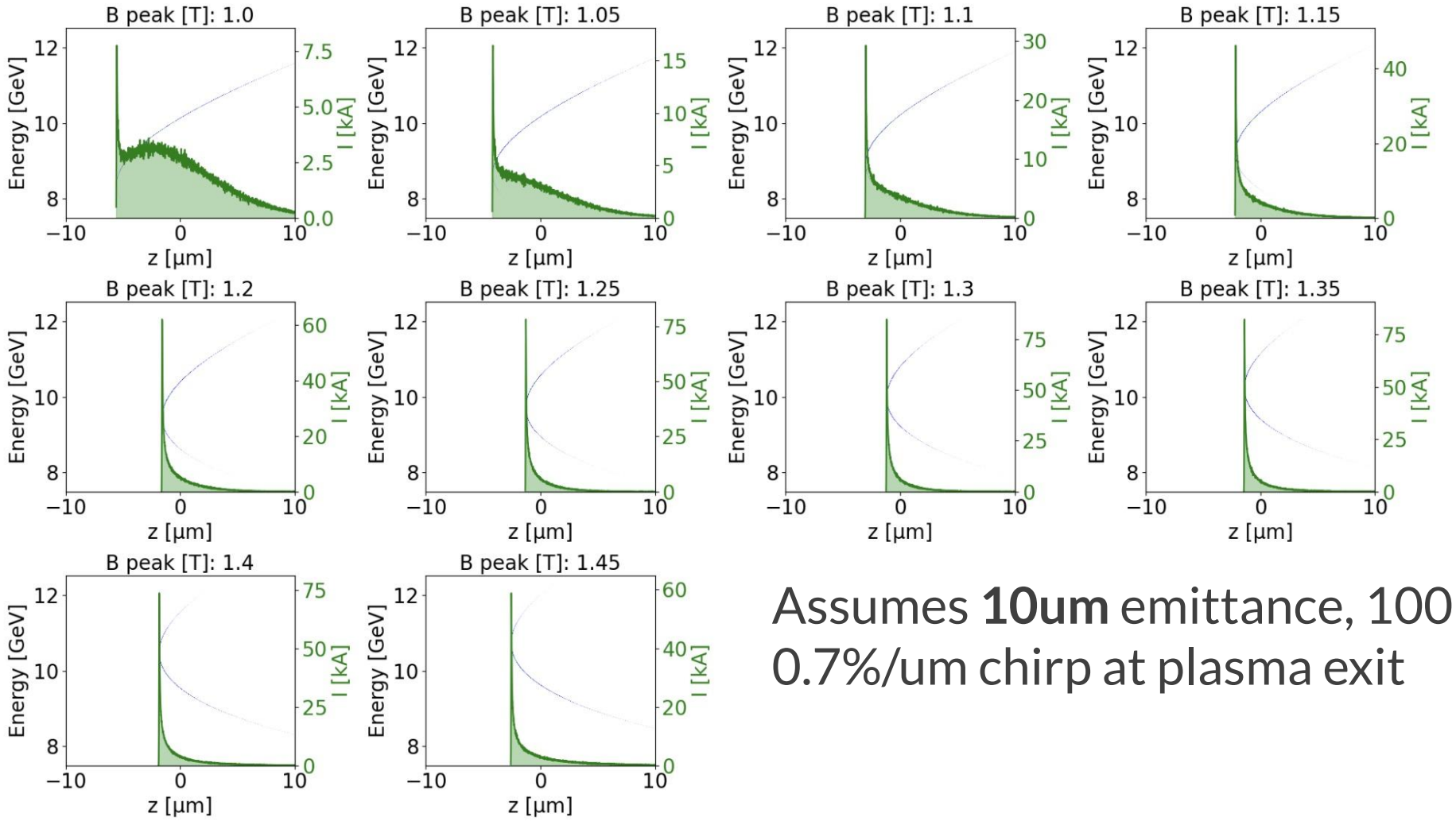

Assumes **10um** emittance, 100 pC, 0.7%/um chirp at plasma exit

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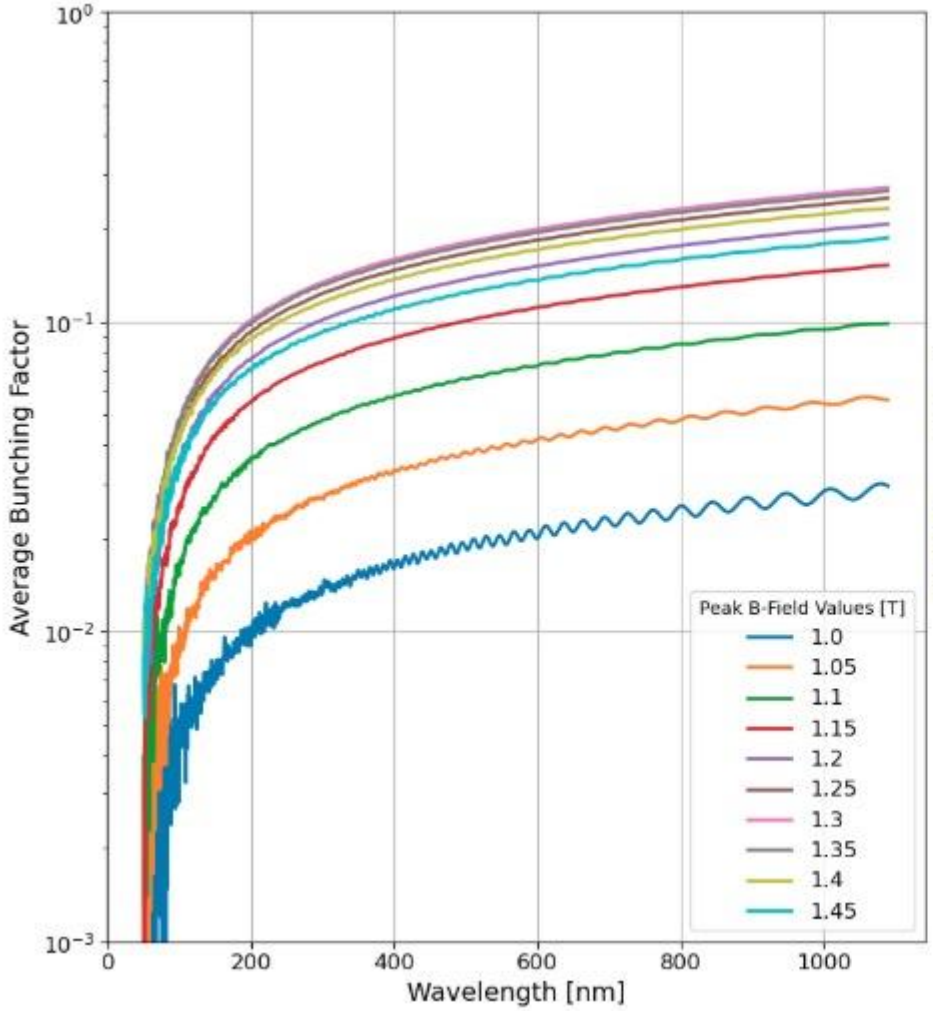

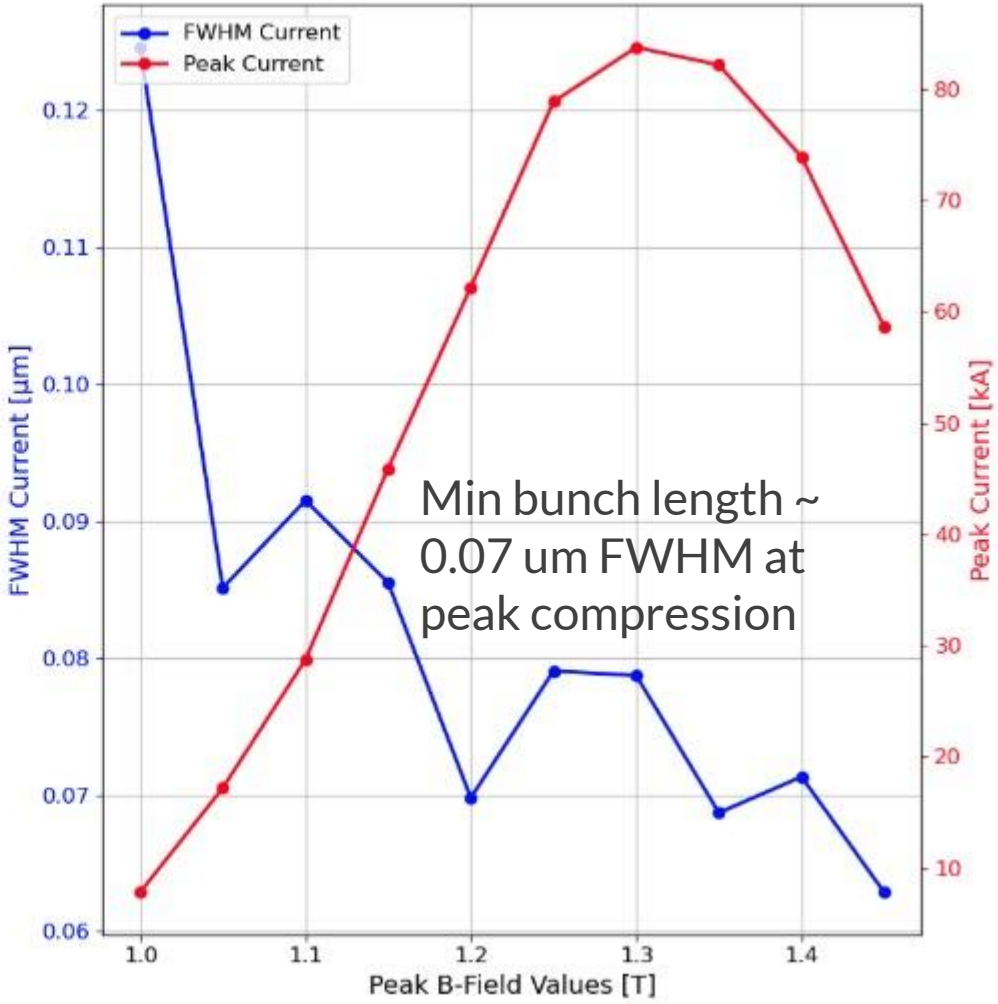

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