E338 Outlook for FY27

FACET-II Long term planning meeting

July 10th, 2026

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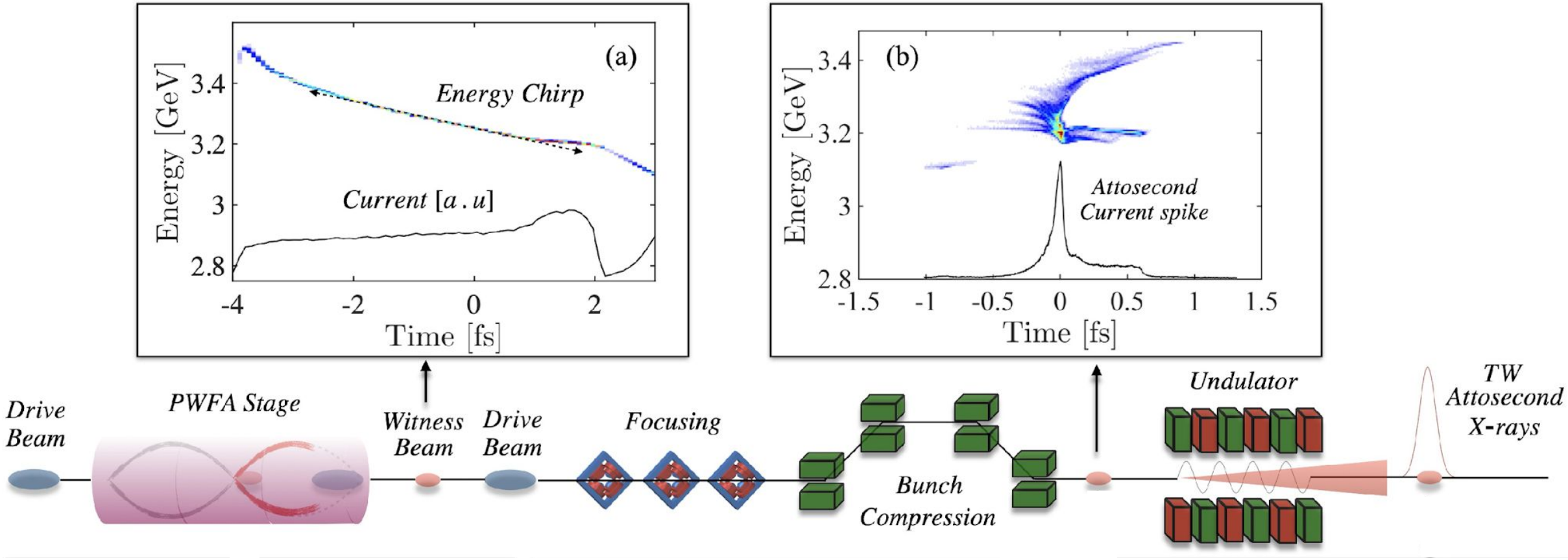
FACET-II

SLAC NATIONAL ACCELERATOR LABORATORY

Overview + science goals

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

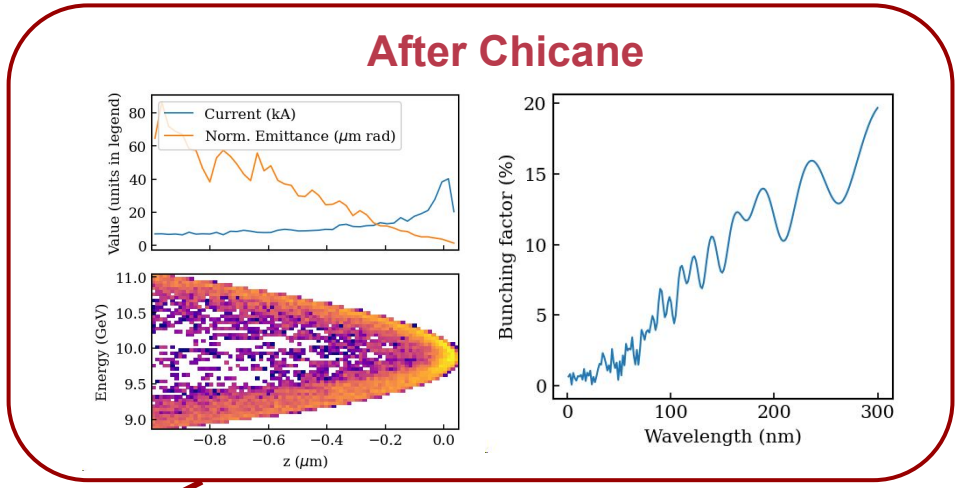


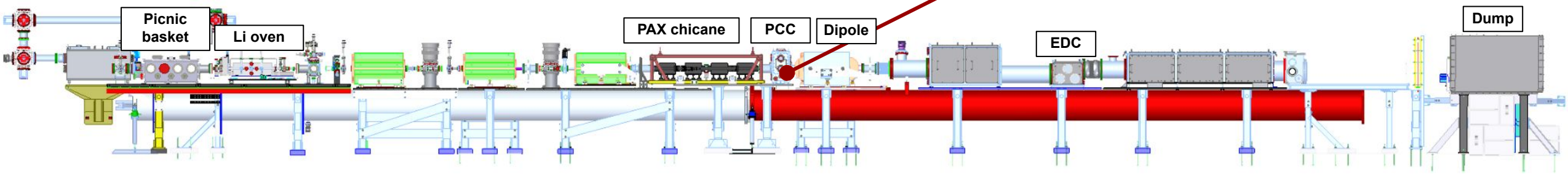
C. Emma et al., APL Photonics, **6**, 076107 (2021)
R. Hessami et al., PRAB, **27**, 070701(2024)
K. K. Swanson, et al., PRAB, **29**, 052802 (2026)

Experimental goals at FACET-II

Science Goals

1. Demonstrate post-plasma, sub-fs compression of externally injected witness beam by measuring UV-Vis CSR
2. Measure + characterize XUV CSR for compressed beam down to 100 nm
3. Compress + measure XUV CSR of plasma-injected beams down to 50 nm





Experimental setup and diagnostics

Plasma Sources

- Gas Jet

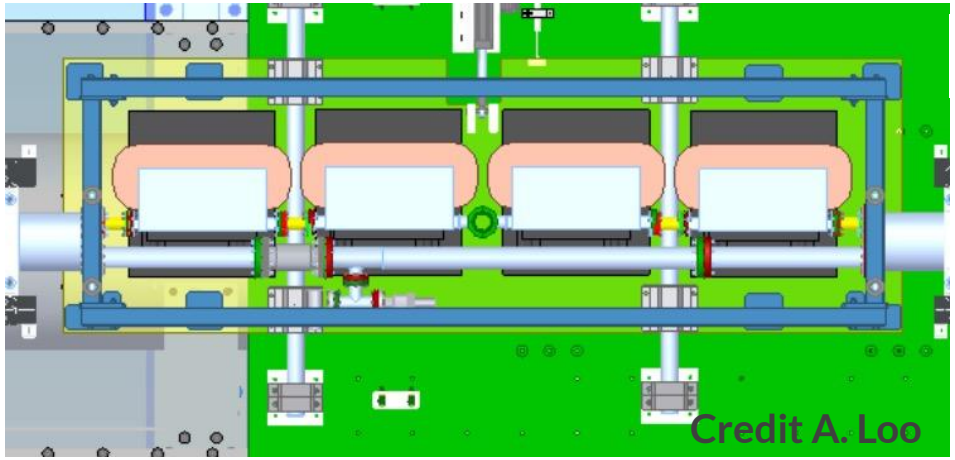
$n_e = 10^{18} – 10^{20}$ cm^{-3}

- Li Oven

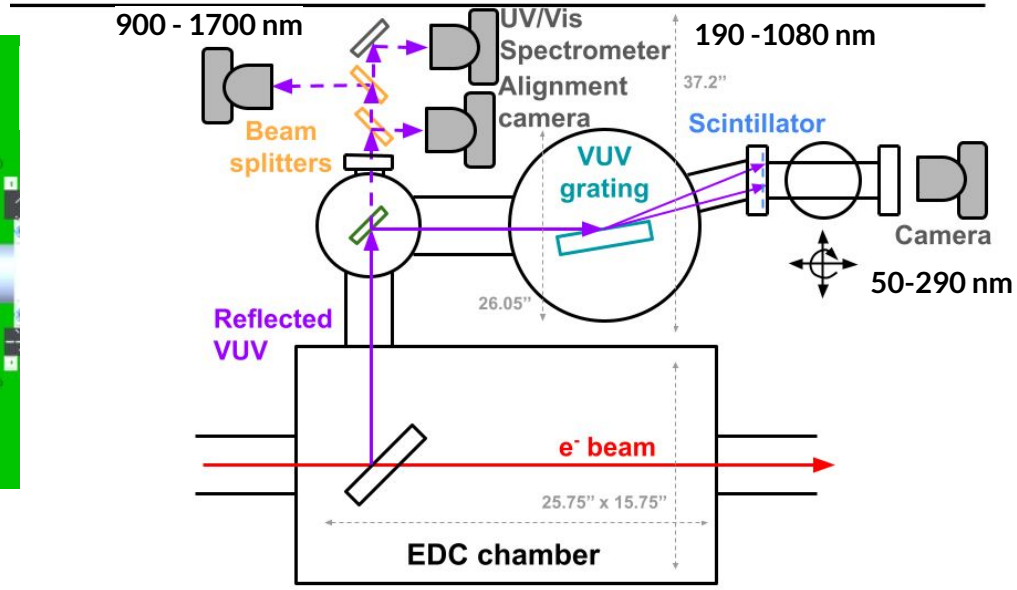
$ne = 10^{16} – 10^{17}$ cm^{-3}

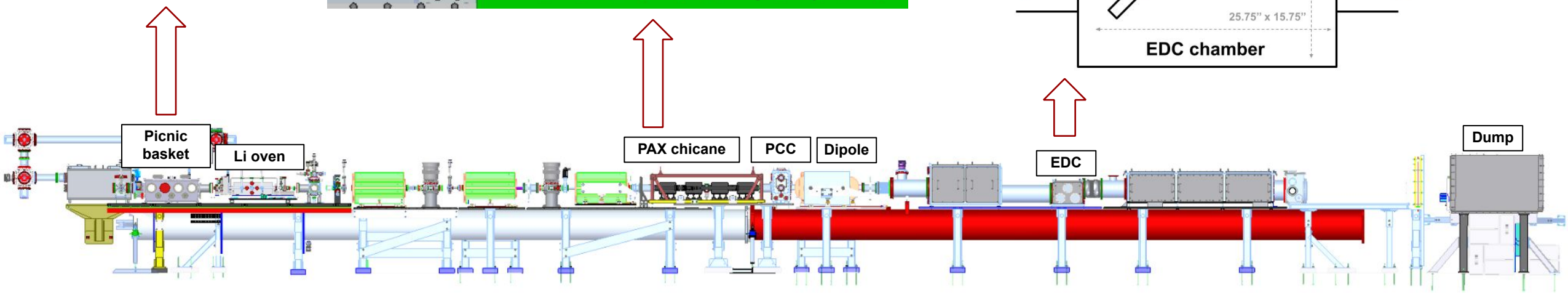
- Static fill

Chicane + bypass line



Spectral Measurement Setup





Spectrometer setup detects broadband radiation to map bunching factor of fully-compressed e-beam

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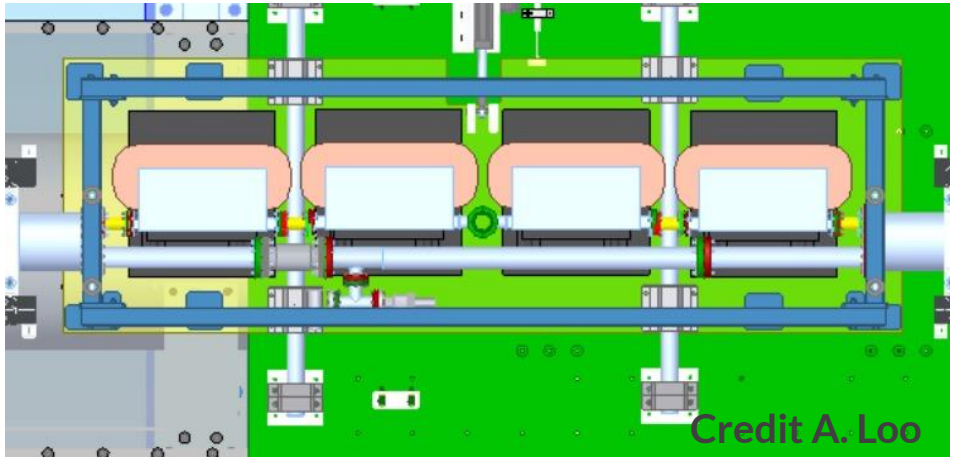

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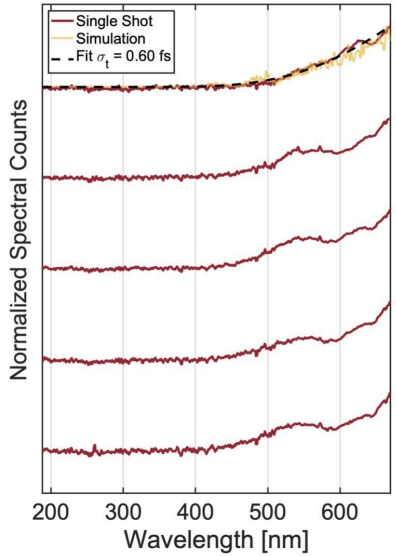
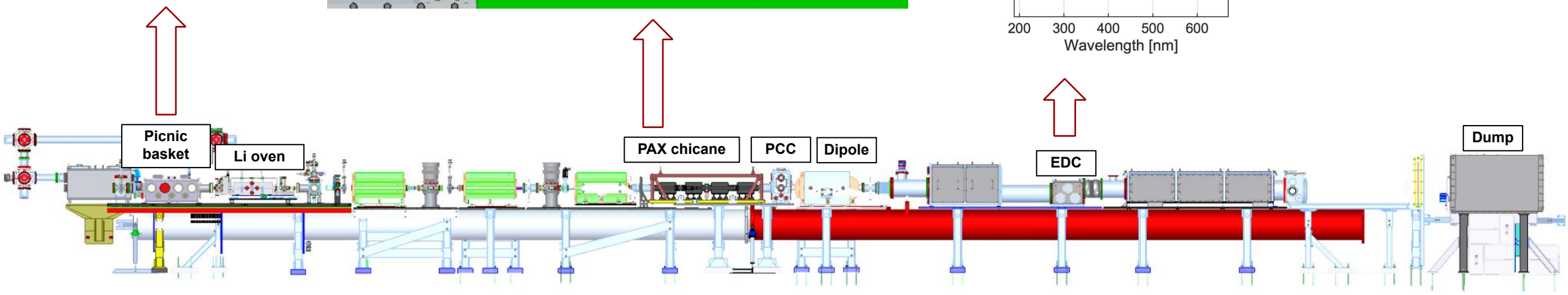


Expected UV-Vis signal from laser heater studies

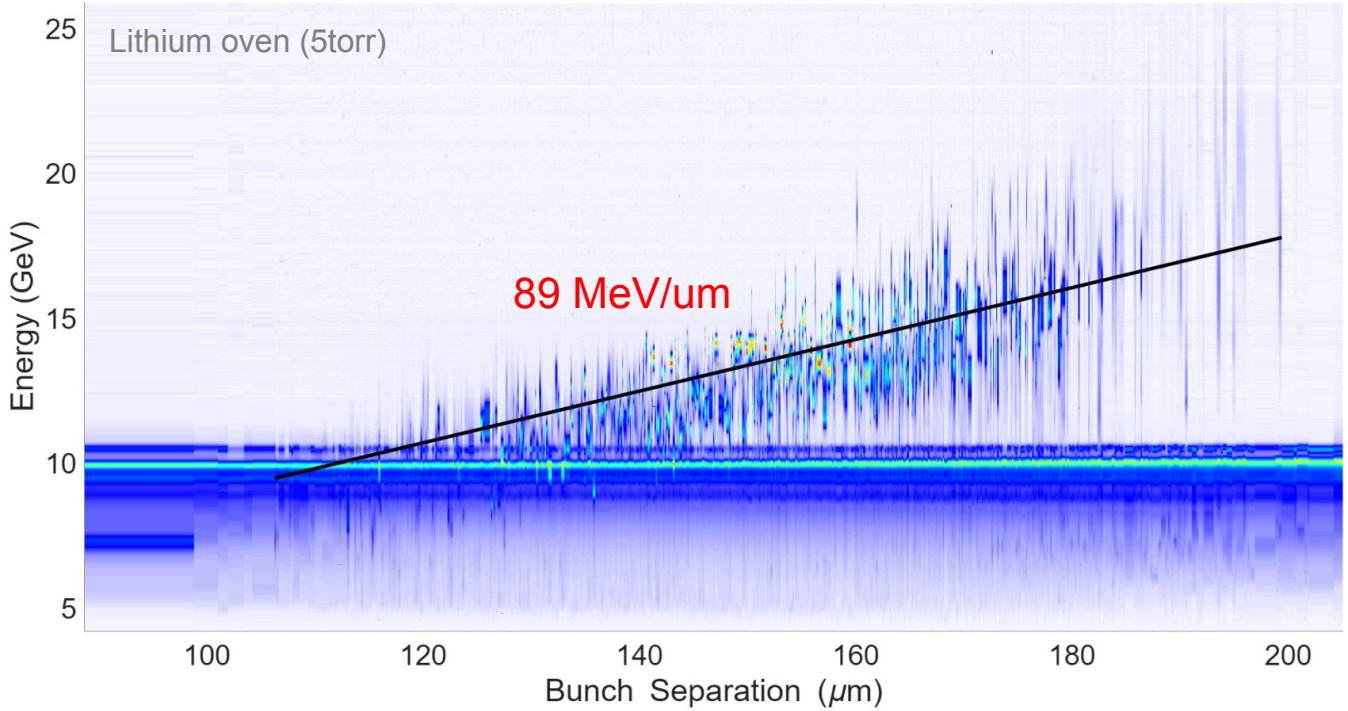


Spectrometer setup detects broadband radiation to map bunching factor of fully-compressed e-beam

What we did in FY26

What worked

- Measured chirps O(10-100 MeV/um) with different beam/plasma configurations
- Installed and commissioned PAX chicane, including YAG screen and spoiler
- Observed signals on UV-Vis spectrometer related to beam-plasma interaction



Measured chirps in all plasma/beam combinations:

- Li oven (3-8 torr) and He static fill
- Single bunch notched and two bunches

Measured chirps consistent with simulations/theory on multiple shifts, although not on every shift. More analysis is needed to determine what other parameters are contributing.

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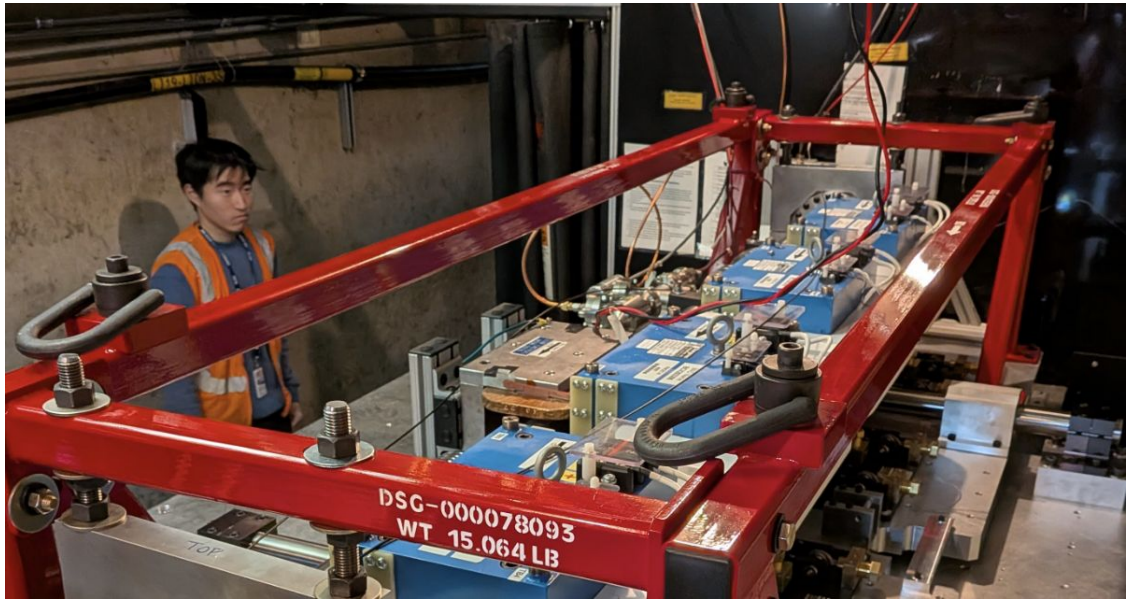

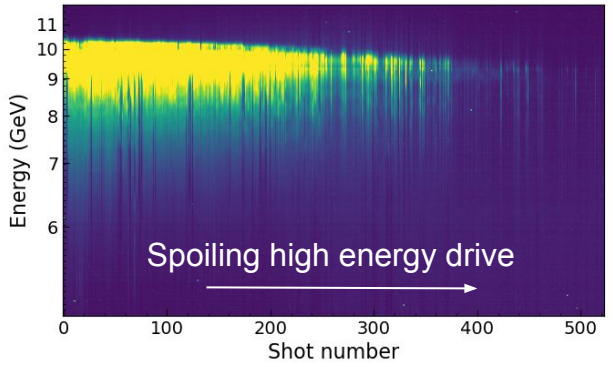

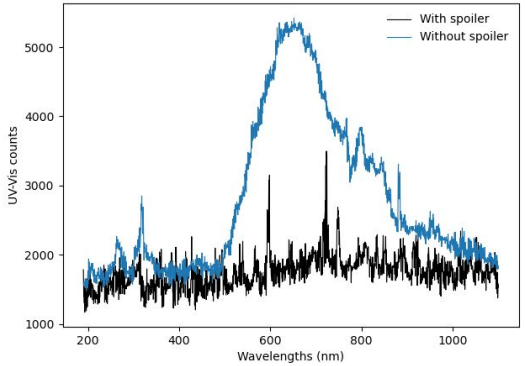

Successful commissioning of the chicane enabled first experimental studies of plasma based compression.

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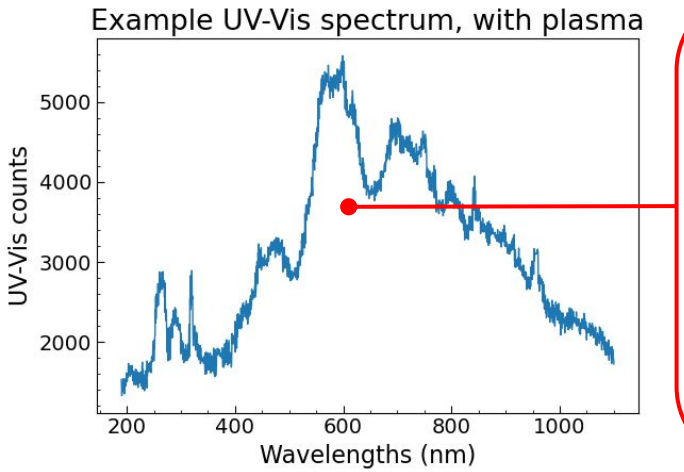
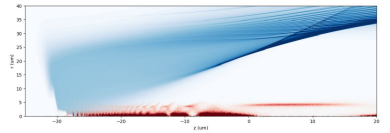
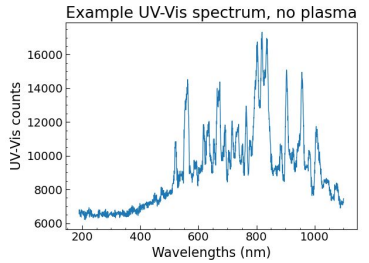
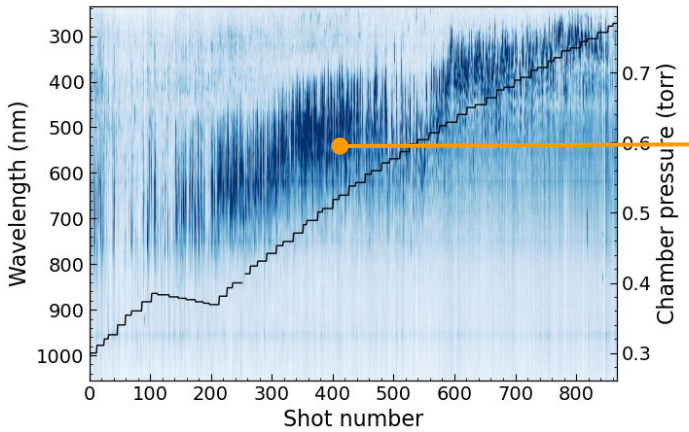


Broadband feature centered around 600 nm consistently observed across different beam/plasma conditions







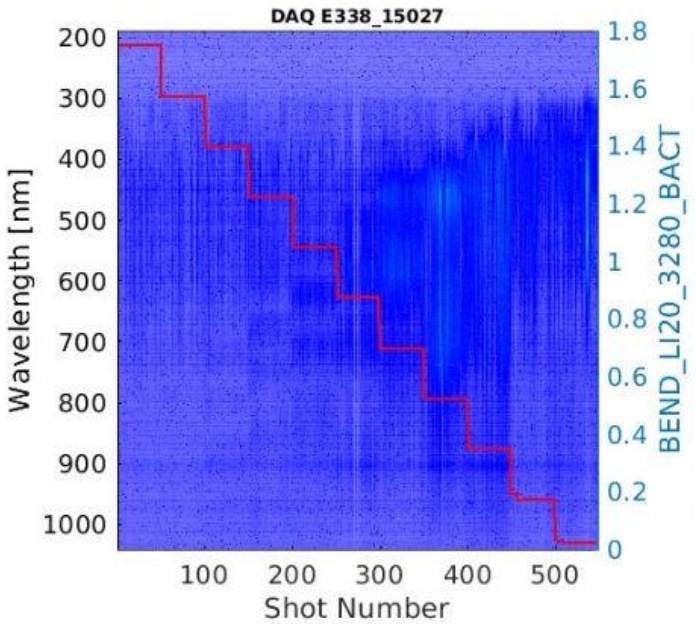
Short wavelength, narrowband peak with dependence on plasma density (E304 shift)

Distinctive features on UV-Vis spectrometer probe interesting beam structures but more analysis is required to better understand.

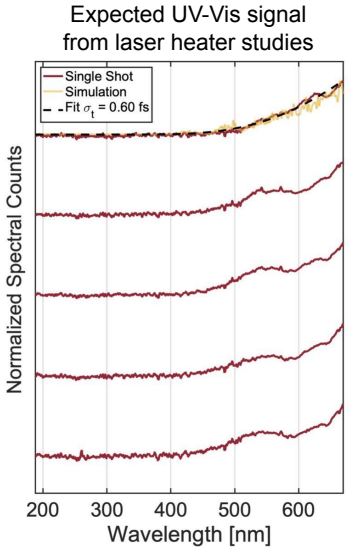
What we haven’t gotten to work yet

Compression after PAX chicane:

- External injection
  - No evidence of longitudinal compression on diagnostics despite sufficient chirp
  - Except for maybe one shift in helium static fill (analysis in progress)
  - Hypothesis: transverse effects broadening bunch
- Plasma injection (in collaboration with E304)
  - No evidence of longitudinal compression on diagnostics
  - Hypothesis: beamloading reducing chirp



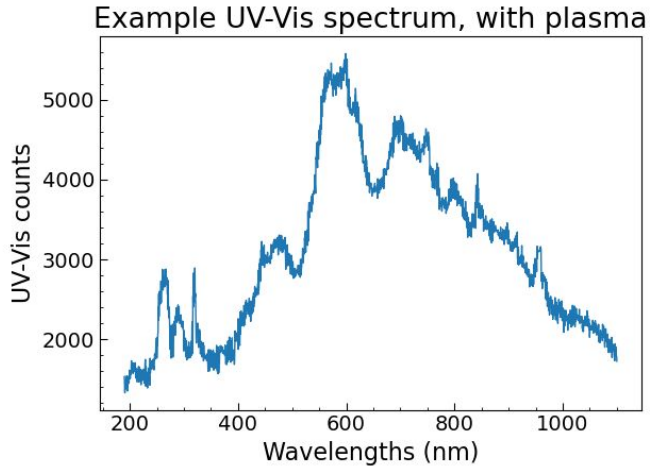
Observations: Little to no signal at large wavelengths, broadband peak which changes with R56, more intense at lower magnetic fields

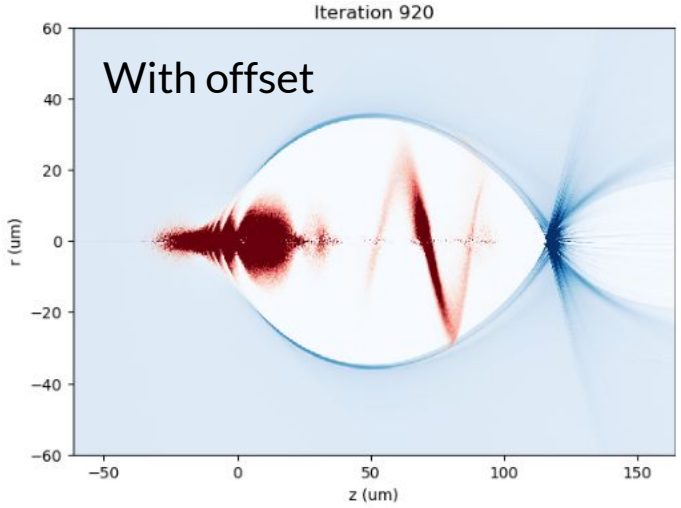


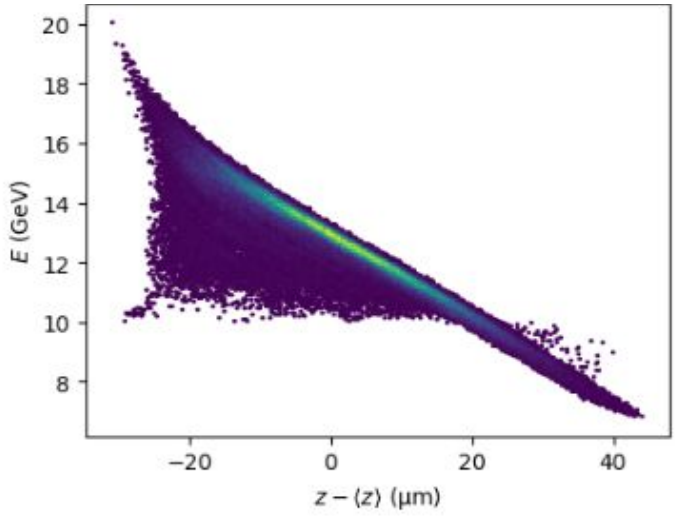
Have not yet observed obvious signs of compression but more analysis required.

Measurements/analysis we wanted to do but haven't gotten to yet

- What is the consistent broadband peak on UV-Vis spectrometer and why does it consistently appear at small magnetic fields in PAX chicane?
- How does the chirp depend on beam parameters?
  - Why do we measure smaller than expected chirps on some shifts?
- How much do transverse effects impact compression?







E338 publications timeline

Experiment	Result	Timeline for getting data	Needs
E338/E300	Longitudinal wakefield mapping and strongly chirped beam generation	Have some, maybe all we need?	
E338	Spectral diagnostics of beam-plasma interaction	Have data, need to analyze	
E338/SPARC	Post-plasma compression at SPARC	Have data, need to analyze	
E338	Post-plasma compression at FACET	Fall 2027	
E338	XUV coherent undulator radiation from plasma-compressed beams	Fall 2027	Undulator

Plans for FY27

Improvements for next run

- Diagnostics:
  - XUV spectrometer improvements - improved signal collection, Andor XUV/x-ray camera
  - Additional 1-2 um spectrometer - currently installed but not integrated with DAQ
- Spoiler - installed in time for the last shift
- Improved matching into the plasma (M12/M34 scans are slow and backpropagation of twiss parameters unsuccessful).
- Plasma targets:
  - Static fill with potentially longer ramps
  - Plasma injection (density downramp gas jet, Trojan horse)

Improved transverse beam quality + diagnostic upgrades will help observation of compression signal.

Compression of plasma-injected beams

Challenge	Benefits of plasma injection
Betatron oscillations causing slice energy spread and emittance growth	Matched in plasma bubble
Emittance-induced slippage after plasma	Smaller emittance
Chromatic aberrations in post-plasma quadrupoles	Smaller bunch duration leading to smaller energy spread
Higher order compression	Smaller bunch duration leading to smaller energy spread
Beamloading	Lower charge possible
Nonlinear chirp	Lower charge possible

Compress beams from partner experiments:

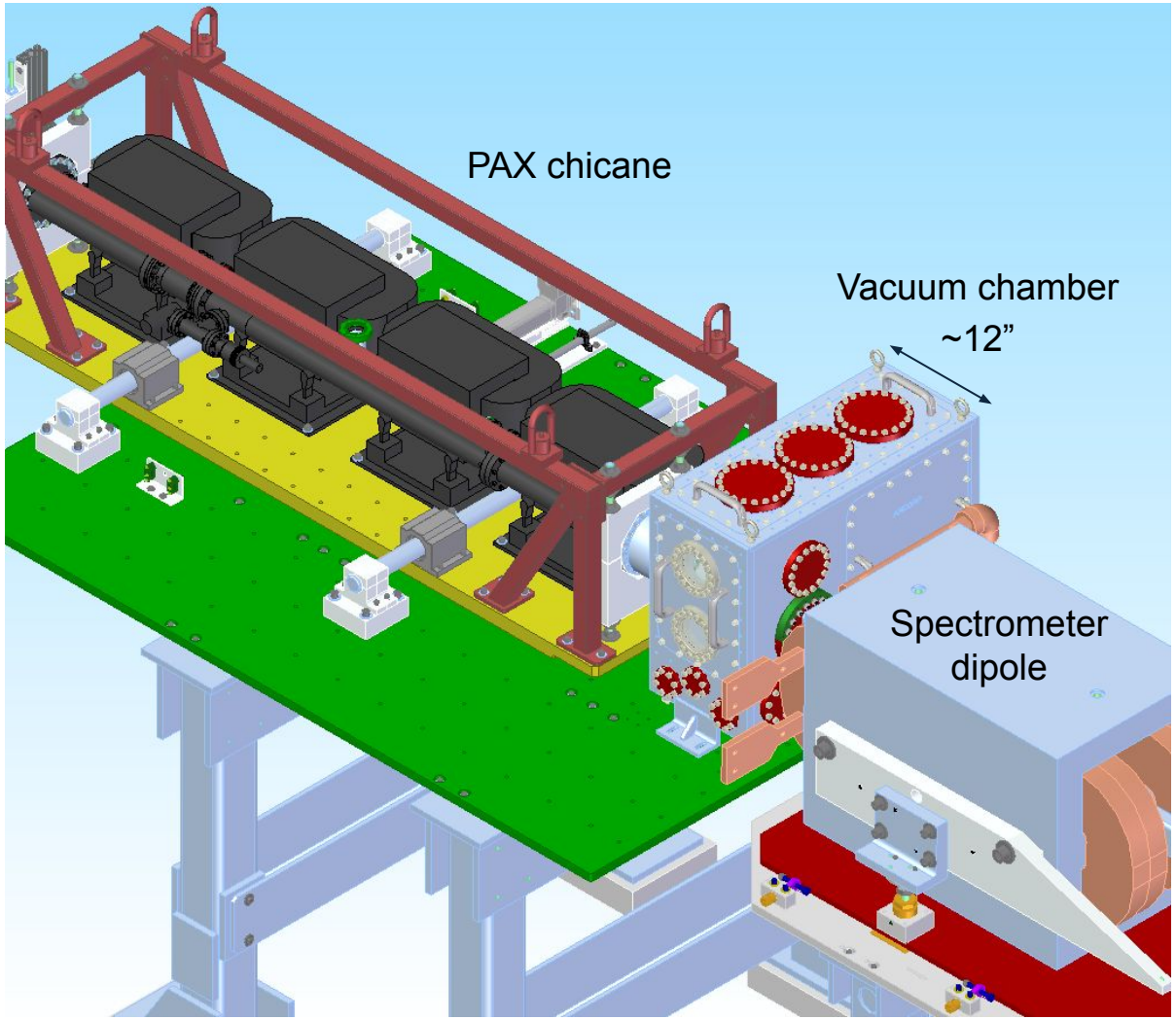
- Trojan horse
- Density downramp gas jet (E304)

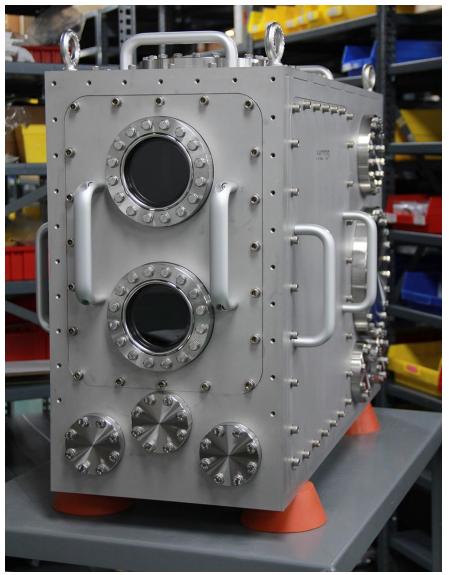
Challenges:

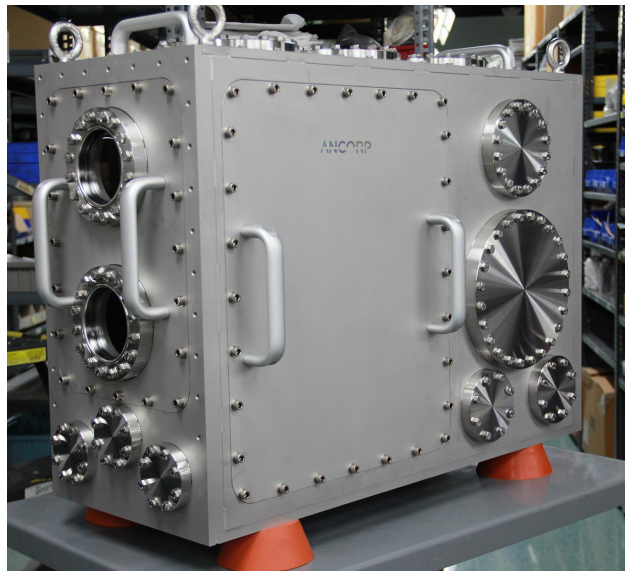
- How to measure chirp
- Low charge difficult to measure on diagnostics

Plasma injection helps suppress other effects which broaden the compressed bunch.

Post-chicane chamber







Chamber can support:

- OTR screen
- Gas jets (e.g. strong-field atomic physics: Federico, David)
- Solid targets (e.g. multifoil interactions: Yann, Sebastien)
- Undulators (e.g. beam diagnostics: E338, Trojan horse)
- Others?

Post-chicane chamber to be installed this summer!

Summary

- **What are your high-level scientific goals?**
  - Plasma compression of FACET photoinjector e-beams ~ 100 nm bunching.
  - Compression of plasma injected e-beams < 50 nm generating attosecond XUV pulses.
- **What data do you have and what analysis has been done?**
  - Chirped beams generated with Li oven and static fill, sufficient for compression with chicane.
  - Attempted compression in chicane for different plasma and beam conditions. Analysis ongoing.
- **What went well?**
  - Commissioning of PAX chicane with YAG screen and spoiler.
  - Improved diagnostics (e.g. EOS and VTCAV for bunch separation, improved optics for spectrometers, new tools for transverse beam parameters).
- **What could go better?**
  - Detection of beam-produced signal on spectrometers corresponding to compression.
  - Improved matching into the plasma (M12/M34 scans are slow and backpropagation of twiss parameters unsuccessful).
- **Outlook for next run? Positive!**
  - Plan for plasma injection
  - Further investigate external injection with spoiler

With the improved diagnostics and tools, E338 is well-positioned to measure compressed bunches next run!

Acknowledgments

Collaborators

- **SLAC**: R. Hessami, A. Kinderman, K. Larsen, J. Park, 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, E-310, …

- ***Special thanks to**:* Alex, Elena, and Junzhi for the laser and EOS operation; Sheldon and Yiheng for the beam optimization tools; Juan, Doug S. and Doug M. for the chicane installation; Alysson for the spoiler design, and Chaojie for the gas jet operation.