PAX (E338), ECA, Laser Heater and ML (E327)

Claudio
FACET-II Long Term Planning meeting
August 22, 2024

PAX (E338)
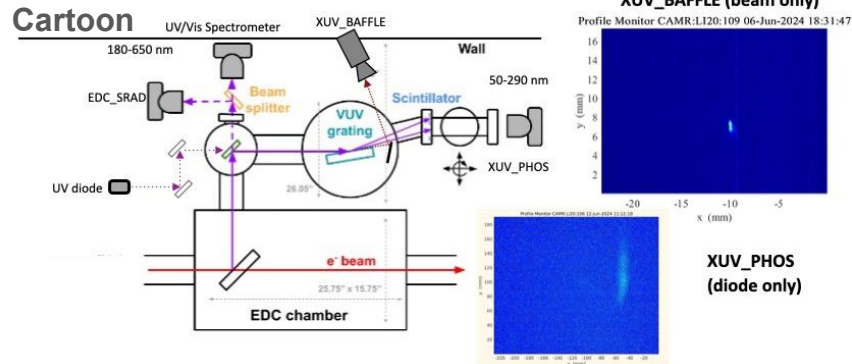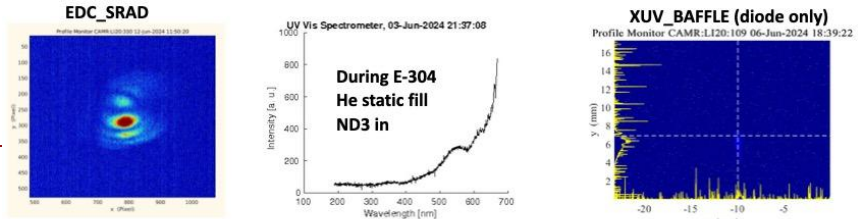
Beam time: 2 shifts + parasitic time
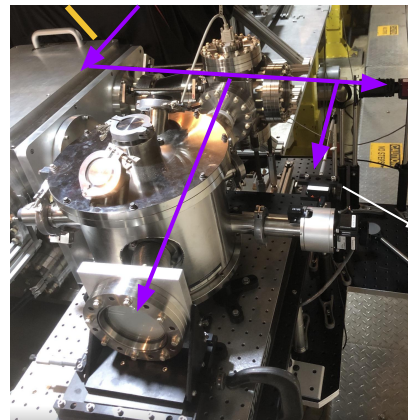
What worked

- Installed all radiation diagnostics in the tunnel. Commissioned UV-Vis spectrometer + remote alignment of XUV spec.
- UV-vis spec has been useful for e.g. E300 He wakes, E304, LH shaping
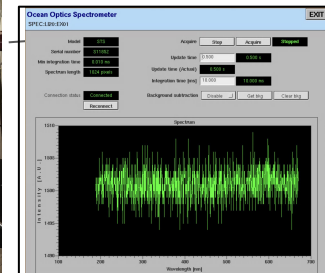- Chicane PO awarded, timeline for delivery ~9 months

What didn't work

- UV-vis spec acquisition with DAQ
- Still don't understand the donut pattern on EDC_SRAD
- No 50-290 nm radiation seen on XUV spectrometer
- No effect seen during 'offset-compression' shift

EDC_SRAD

UV Vis Spectrometer, 03-Jun-2024 21:37:08

During E-304 He static fill ND3 in

XUV_BAFFLE (diode only)
Profile Monitor CAMR:LI20:109 06-Jun-2024 18:39:22

Cartoon

XUV_BAFFLE (beam only)
Profile Monitor CAMR:LI20:109 06-Jun-2024 18:31:47
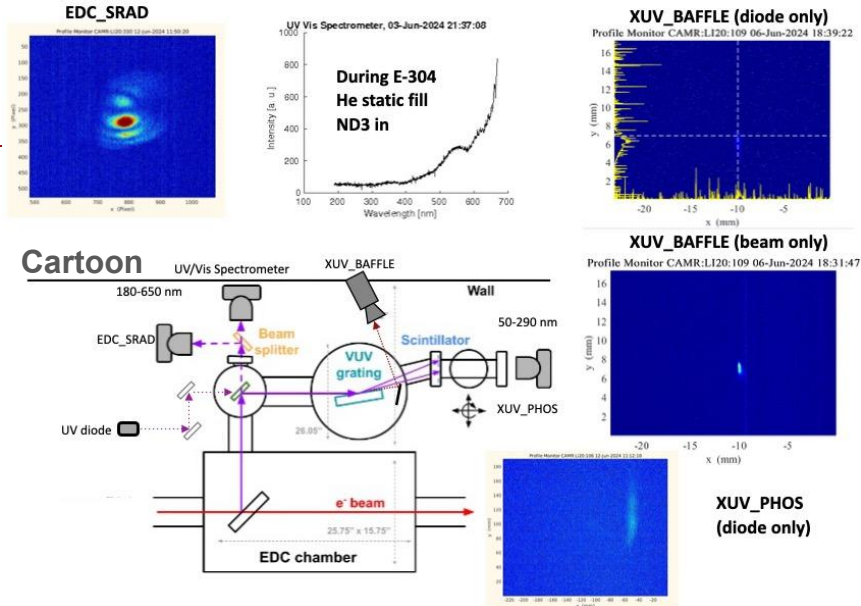
XUV_PHOS (diode only)

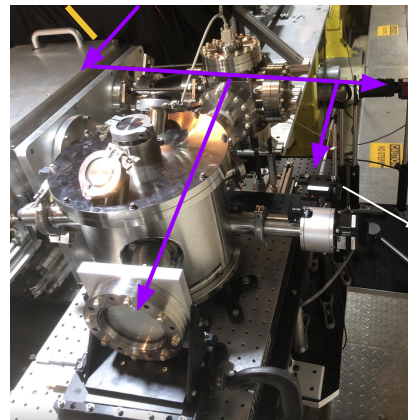**As built**

UV-Vis spectrometer GUI

PAX (E338)

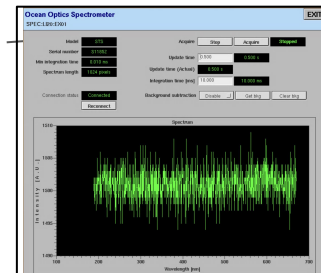**Goals for the coming run (and beyond)**

- Oct - Dec 2024:
    - Reconfigure optics, optimize for collection efficiency of UV-Vis & XUV.
    - Benchmark CSR energy from simulation with measured energy and spectra
    - Commission BSA data acquisition of UV-Vis spec.
    - Make shorter current spikes (<1fs) e.g. with cathode laser shaping.
    - Commission XUV spectrometer with beam.
- Summer 2025:
    - Install chicane mover, support structure, bellows, commission mover stage
    - Install chicane dipoles, bypass line, profile monitor.
- Beyond summer 2025:
    - First post-plasma compression experiments.
    - Experiments with photoinjector/plasma injector beams exploring post-plasma compression.
   - Install undulator and measure coherent undulator radiation with post-plasma compressed beams


EDC_SRAD

UV Vis Spectrometer, 03-Jun-2024 21:37:08

During E-304
He static fill
ND3 in

XUV_BAFFLE (diode only)
Profile Monitor CAMR:LI20:109 06-Jun-2024 18:39:22

Cartoon

UV/Vis Spectrometer

XUV_BAFFLE

Wall

180-650 nm

EDC_SRAD

Beam splitter

VUV grating

Scintillator

50-290 nm

XUV_PHOS

UV diode

e⁻ beam

EDC chamber

25.75 x 15.75"

XUV_BAFFLE (beam only)
Profile Monitor CAMR:LI20:109 06-Jun-2024 18:31:47

XUV_PHOS (diode only)

As built

UV-Vis spectrometer GUI

Ocean Optics Spectrometer

ECA - Extreme beam experiments at FACET-II

Multi-purpose, post-chicane interaction chamber currently under design.

Vacuum chamber

~15cm

Dipole

Chicane
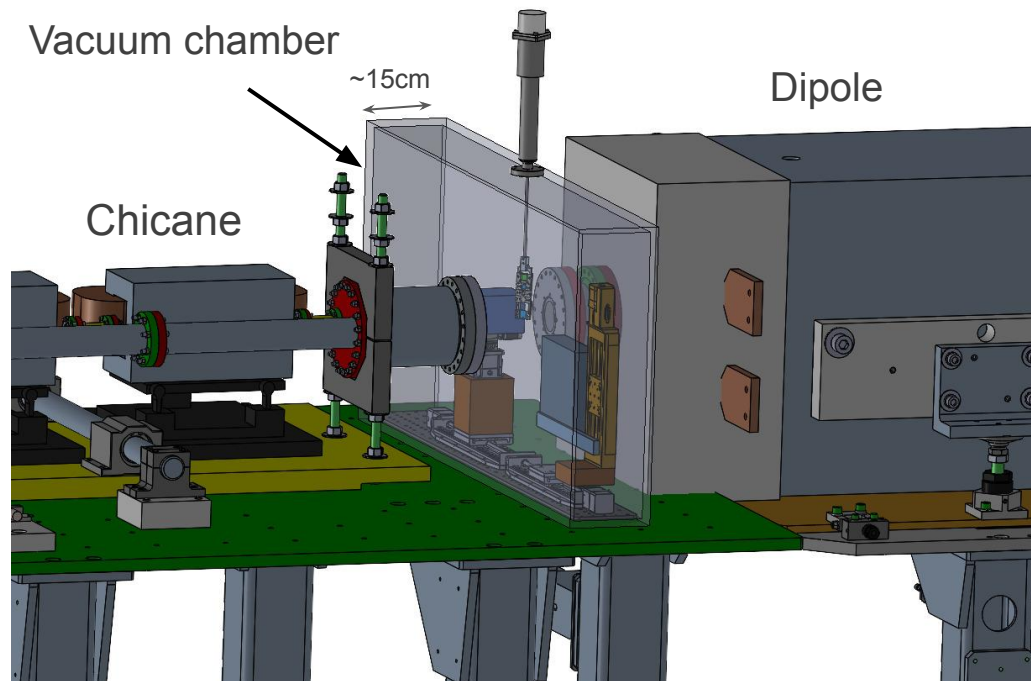
Elements trying to include:

- Numerous viewports
- Gas jets
- Solid targets
- OTR ladder
- Undulator
- Others?

LANL undulator

~14cm
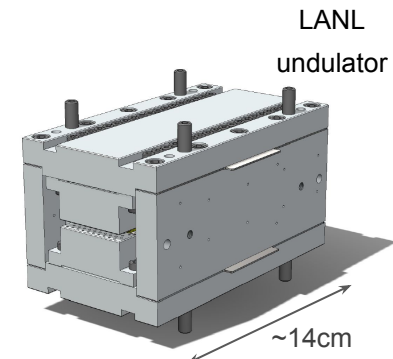
Stakeholders will be consulted during design process

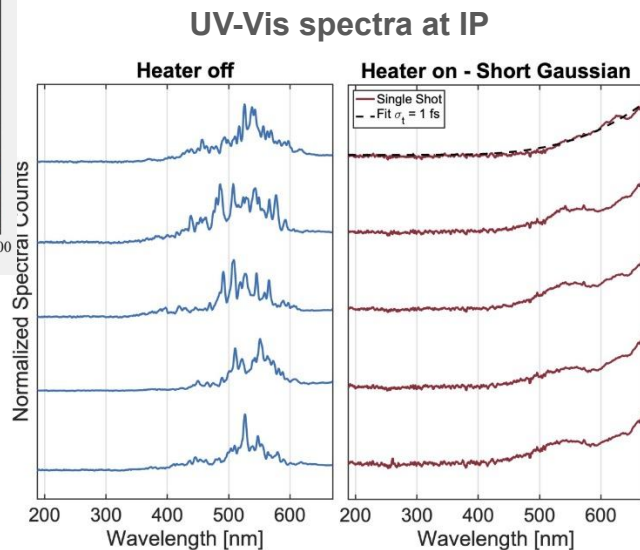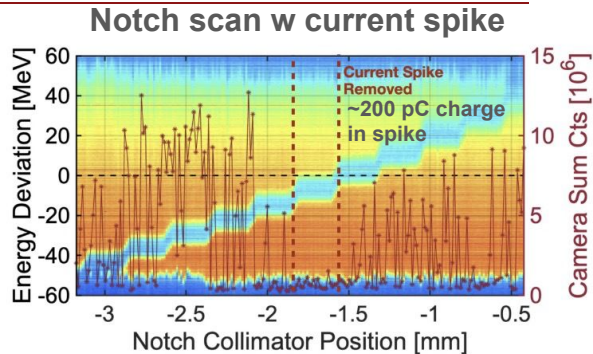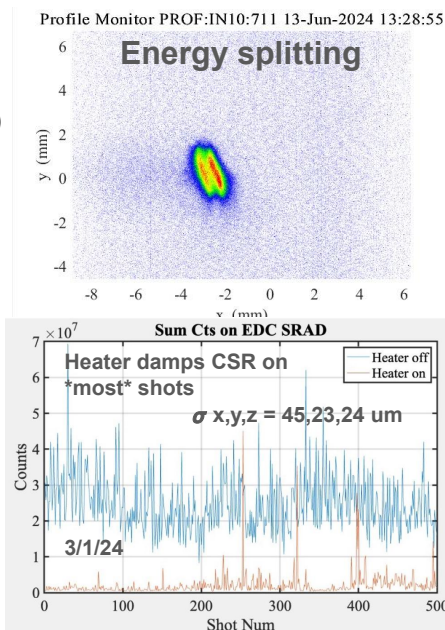# Laser Heater

What worked (since last run)

- LH *mostly* suppressed ionization of He buffer gas for E300*
- LH can seed generation of current spikes (see backup slide) used for E304, PWFA -> wakeless shifts
- LH stays aligned for days at a time

What didn't work.

- COTR/ionization persistent on some shots at IP
- LH takes expert to align (~15 mins)
  - Foil damage impedes feedback
- When beam/laser spots aren't matched we see 'splitting' effect (can this drive MBI?)

Goals for the coming run

- Finish last commissioning task for LH:
  - Get useful data of S20 current variation in single/two bunch mode with heater on/off (needs better XTCAV)
  - Fix LH auto-aligner (if deemed a priority)
- Understand MBI (theory, sims) + get data to inform if we want another laser for the LH
- Test transverse shaping (LG01 mode) for enhanced MBI suppression a-la LCLS
- Explore further current profile shaping (train of spikes, doorstop profiles?)

Profile Monitor PROF:IN10:711 13-Jun-2024 13:28:55

Energy splitting

Sum Cts on EDC SRAD

Heater damps CSR on *most* shots

σ x,y,z = 45,23,24 um

3/1/24

Heater off / Heater on

Notch scan w current spike

Current Spike Removed ~200 pC charge in spike

Notch Collimator Position [mm]

UV-Vis spectra at IP

Heater off

Heater on - Short Gaussian

Single Shot / Fit σ_t = 1 fs

Normalized Spectral Counts

Wavelength [nm]

Publications

	High level science goals	First publications	How to get from here to there
E-338	Attosecond XUV pulses from plasma compressed e-beams	• Rafi harmonics paper published in [PRAB](#) • Spectral diagnostics of beam-plasma interaction with short current spikes (mid impact, 0.5-1 yr) • Plasma based attosecond e- beam compression (1-2 yrs) • Attosecond coherent XUV undulator radiation (2-3 yrs)	**Need BSA UV-Vis spectra, need to measure XUV spectra from beam** **Need to install chicane** **Need to install undulator**
Laser heater	-Suppress MBI -Control I_pk -Create custom current profiles	• Ultra-high current beam generation with LH shaping (in progress) • Summary of LH commissioning results (tech note)	***Maybe need better data on LH shaped current (e.g. w BSA spectra)*** **Emittance vs LH energy data** **S20 I_pk vs LH energy data**

# ML Experiments - E327

What worked (since last run)

- Nothing new.

What didn't work.

- No dedicated beam time.
- XTCAV resolution limit means the usefulness of the virtual diagnostic in S20 is limited.

Goals for the coming run

- Demonstrate prediction with S15 TCAV
- Get useful data out of XTCAV
- Focus on robustness (quantify accuracy over multiple shifts), multiple beam configurations (single + two bunch), **improved XTCAV resolution**
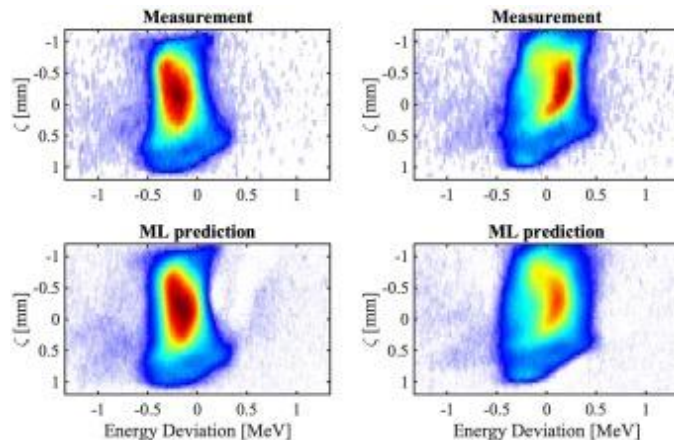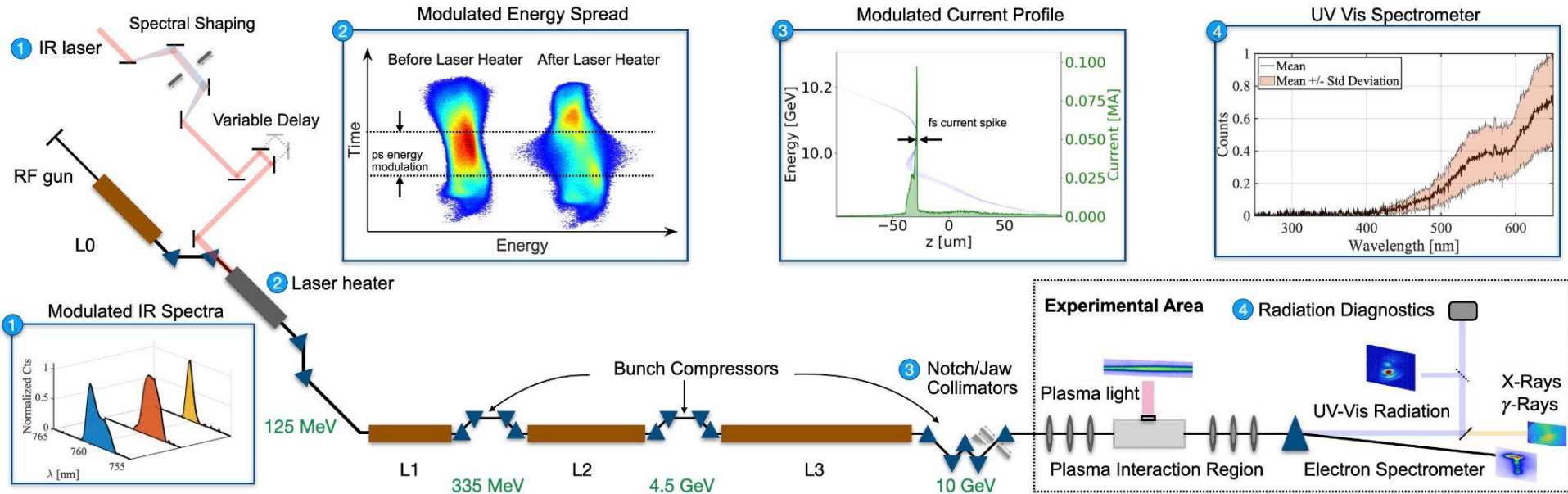

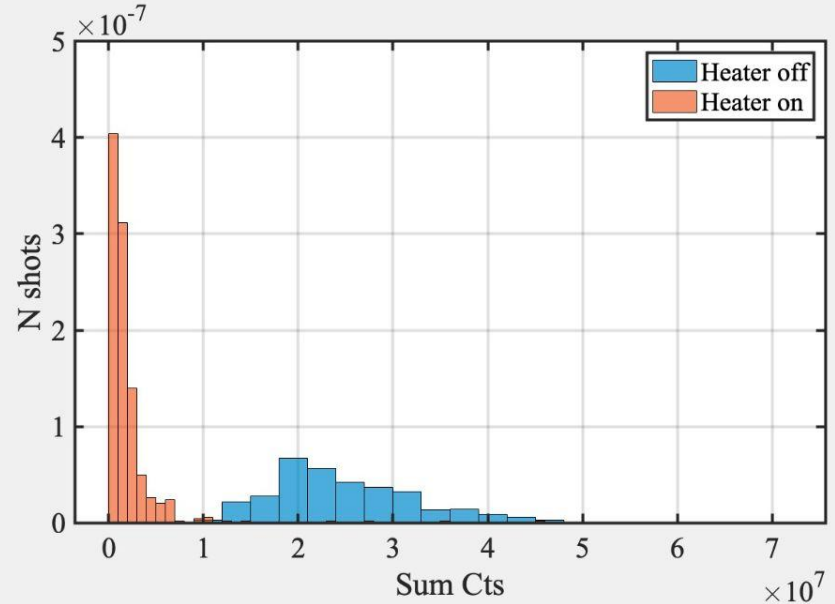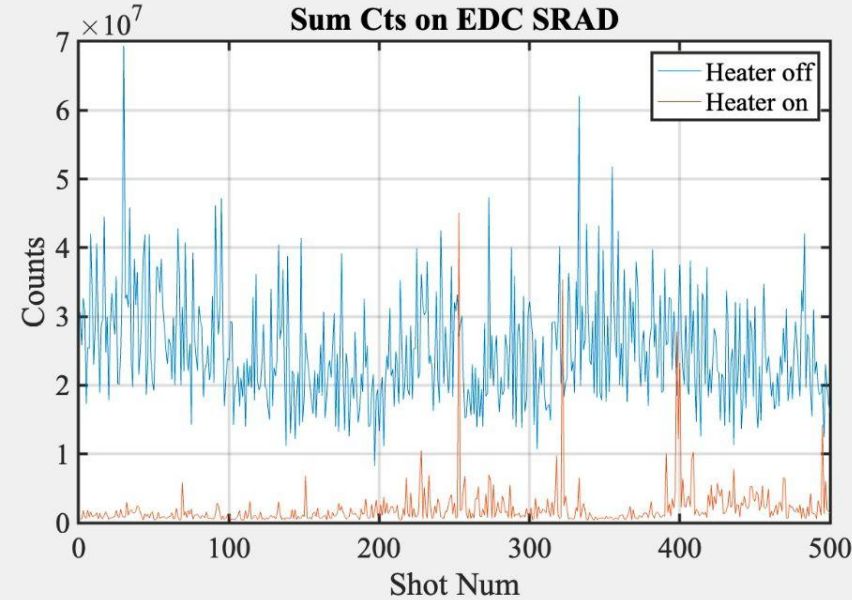Sector 10 LH off/on
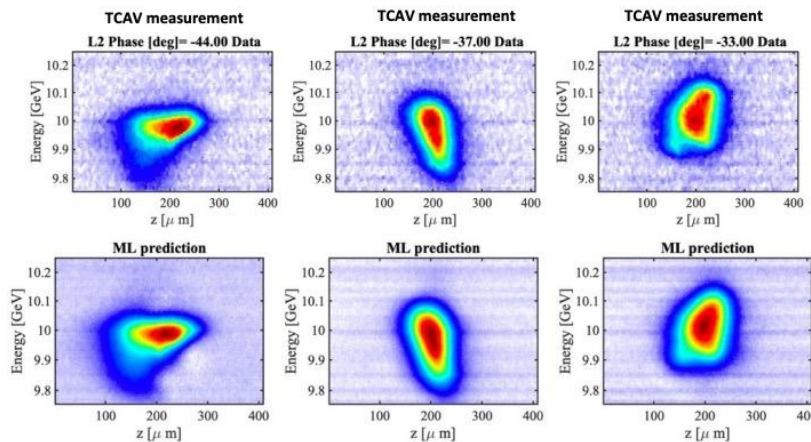
Sector 20

Publications

	High level science goals	First publications	How to get from here to there
E-327	Virtual XTCAV	● Virtual LPS prediction on single-shot multi-location for ultra-high current beams (??)	**Need to improve XTCAV resolution**

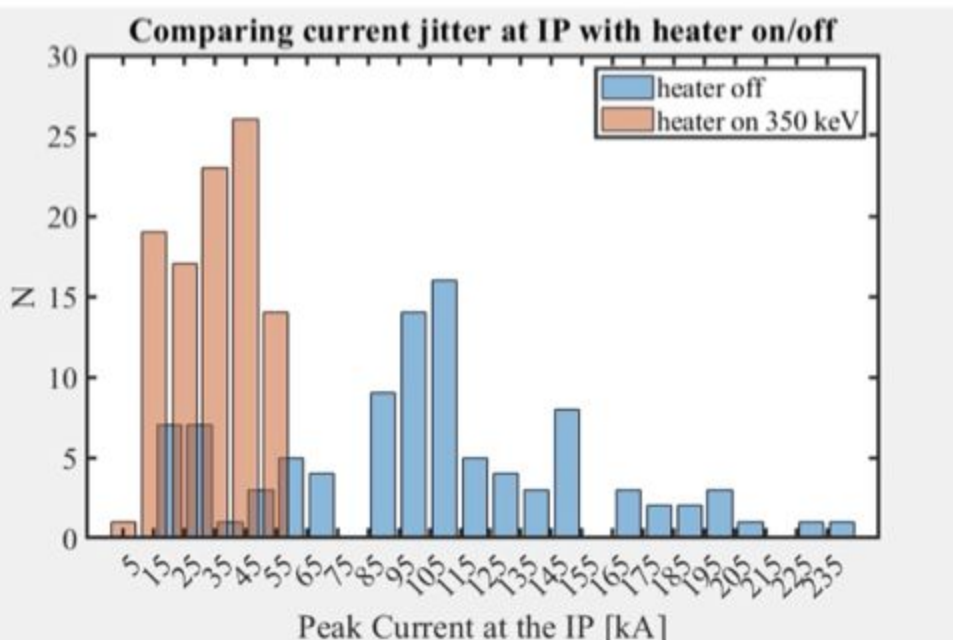# Backup

Laser heater seeded current spike

EDC_SRAD counts with heater on/off

Similar trend observed in past during LH commissioning. LH damps the coherent radiation by an order of magnitude on average. Some shots with COTR still persist.

Starting point for the jitter scans is the 2nC single bunch simulation shown in the slides.
Jitter parameters are L1 and L2 RF phase (±0.25 deg) and amplitude (±0.1 %)

Jitter scans - single bunch current variation with LH on/off at 350 keV

Current profile examples heater off

Current profile examples heater on

The laser heater reduces fluctuations of the peak current at the IP
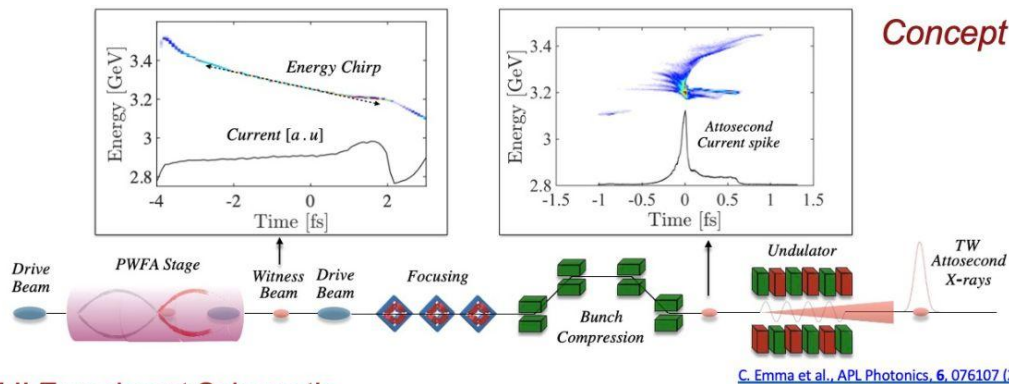
SLAC
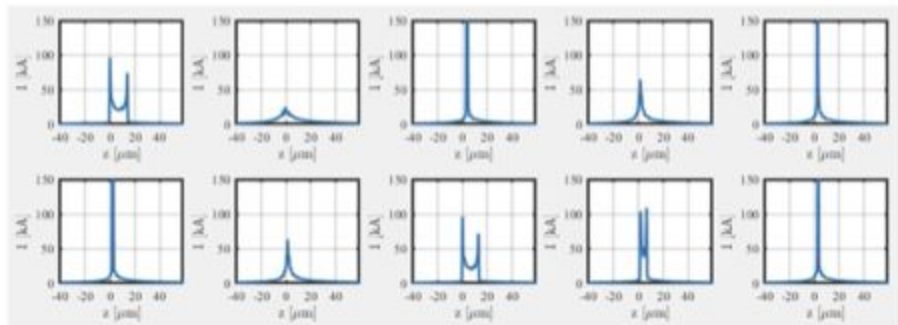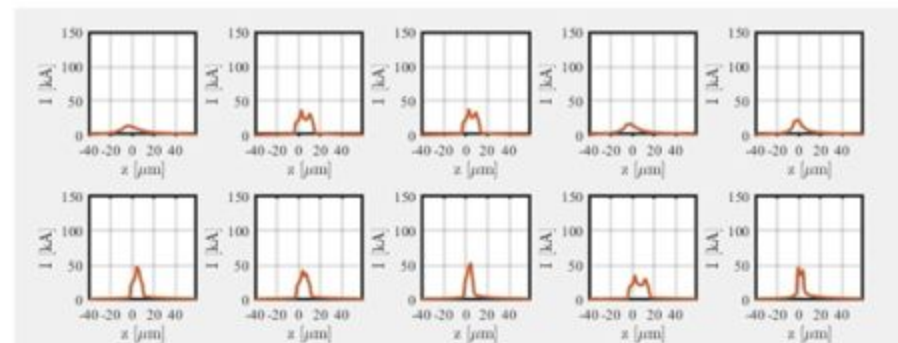
PAX at FACET-II - one slide summary

Science Goals

Demonstrate post-plasma sub-fs compression of e- beams

Measure + characterize XUV CSR for compressed e- beam down to 50-100 nm

Using beams from plasma injector, compress + measure coherent XUV at 50 nm or below

Concept

Energy Chirp

Current [a.u]

Attosecond Current spike

Drive Beam — PWFA Stage — Witness Beam — Drive Beam — Focusing — Bunch Compression — Undulator — TW Attosecond X-rays

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

FACET-II Experiment Schematic

Chicane + bypass line design
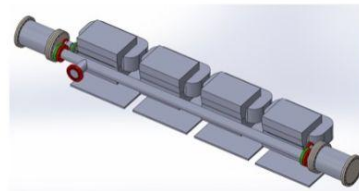
Spectral Measurement Setup

Plasma Sources

- Gas Jet
  $n_e = 1e18 - 1e20$ cm^-3

- Li Oven
  $n_e = 1e16$ cm^-3

190-650nm

Alignment camera

Wall

UV/Vis spectrometer

Beam splitter

VUV grating

Scintillator

37.2°

Au

Reflected VUV

26.05°

50-200nm

Camera

e- beam

25.75" x 15.75"

EDC chamber

Phased Approach

First stage will chirp + compress beams from FACET-II photoinjector

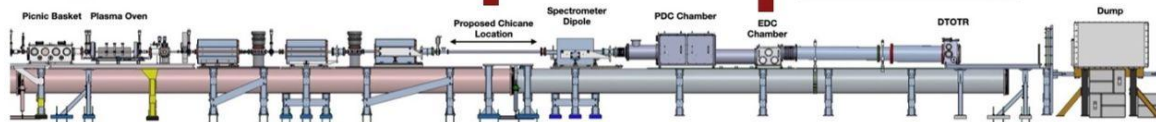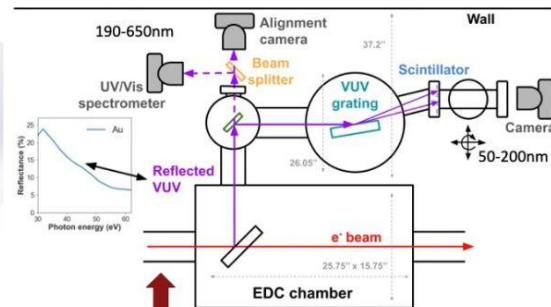Second stage will compress ultra-high brightness beams generated from plasma injector

Publication timeline

Picnic Basket   Plasma Oven   Proposed Chicane Location   Spectrometer Dipole   PDC Chamber   EDC Chamber   DTOTR   Dump

Experiment	Result	Journal	Timeline for getting data	Needs
E338	Spectral diagnostics of beam-plasma interaction	PRAB	Summer 2024	
E338	Attosecond beams	Nature (or Nat. Phot)	Spring 2025	Chicane
E338	XUV undulator radiation	Nature (or Nat. Phot)	Spring 2026	Chicane, undulator

ML Experiments - E331

A. Edelen

2nC injector tuning
20x faster than regular BO
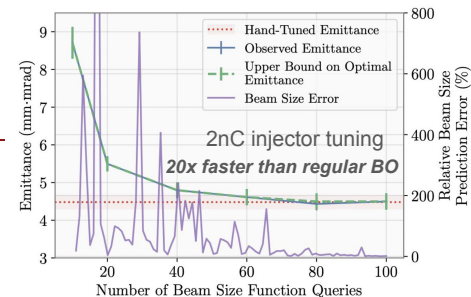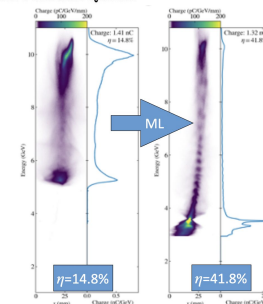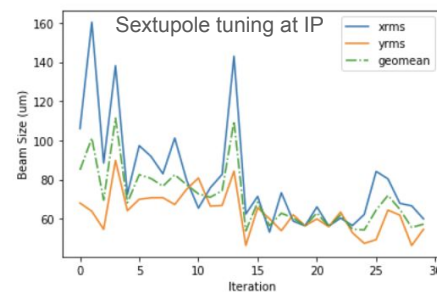
What worked (since last run)

- Emittance tuning demo in injector (BAX - 20x faster than vanilla BO)
- Sextupole tuning demo and integration into E300
- Smart data gathering for ML system modeling / model calibration (to use in tuning) - Bayesian Exploration
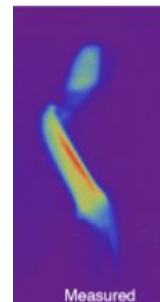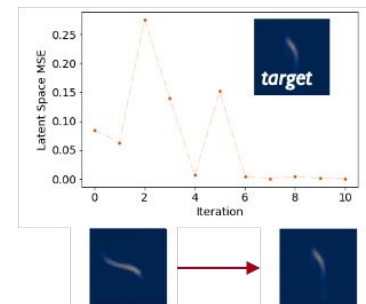
What didn't work

- Challenges with data acquisition (e.g. wirescan GUI not server mode – human in the loop to take measurement)
- For E300 tuning, simple metrics worked but need more refinement (algorithm will do exactly what objectives/constraints specify ….)

Goals for the coming run

- Expand tuning scope (driven by operations need)
    - Emittance tuning to downstream (emittance preservation)
    - Multiple objectives /constraints in tuning (e.g. emittance / losses, LPS) → want suggestions on what would be highest impact for operation
- Two-bunch tuning / LPS tuning ML development
    - Have approaches to try (need to set up with diagnostics/PVs to adjust)
    - Need to prototype w/ previous data (e.g. image analysis) and simulations
    - Need XTCAV or other diagnostics we want to use for metrics ready
    - Incorporate additional diagnostics / objectives / constraints (e.g. LPS plus keep losses low, examine spectra?)
- Model-based ML tuning – priors for BO and model-based RL
    - Path to faster/higher-precision tuning by adjusting more variables together across machine
    - Incorporate calibrated injector model into tuning
    - Extend model calibration downstream (e.g. up to IP)
- Improve integration with plasma metrics (help enable further use in experiments)
    - Need to refine diagnostic analysis/setup for objectives/constraints

Sextupole tuning at IP

R. Ariniello

target

Measured

N. Majernik