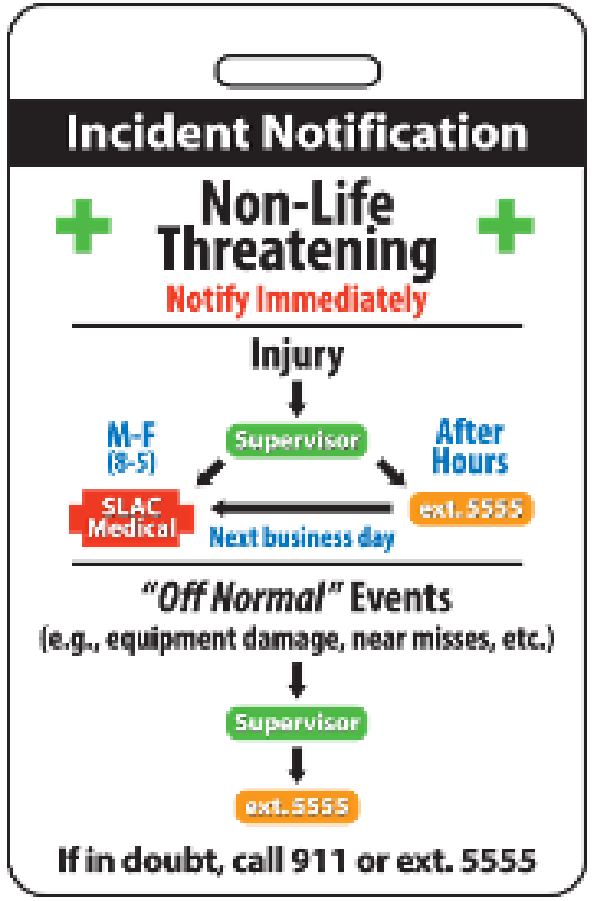
In case of an emergency

Fire

- Evacuate: Be aware of building exits
- Follow building residents to the assembly area
- Do not leave until you are accounted for and have been directed to leave

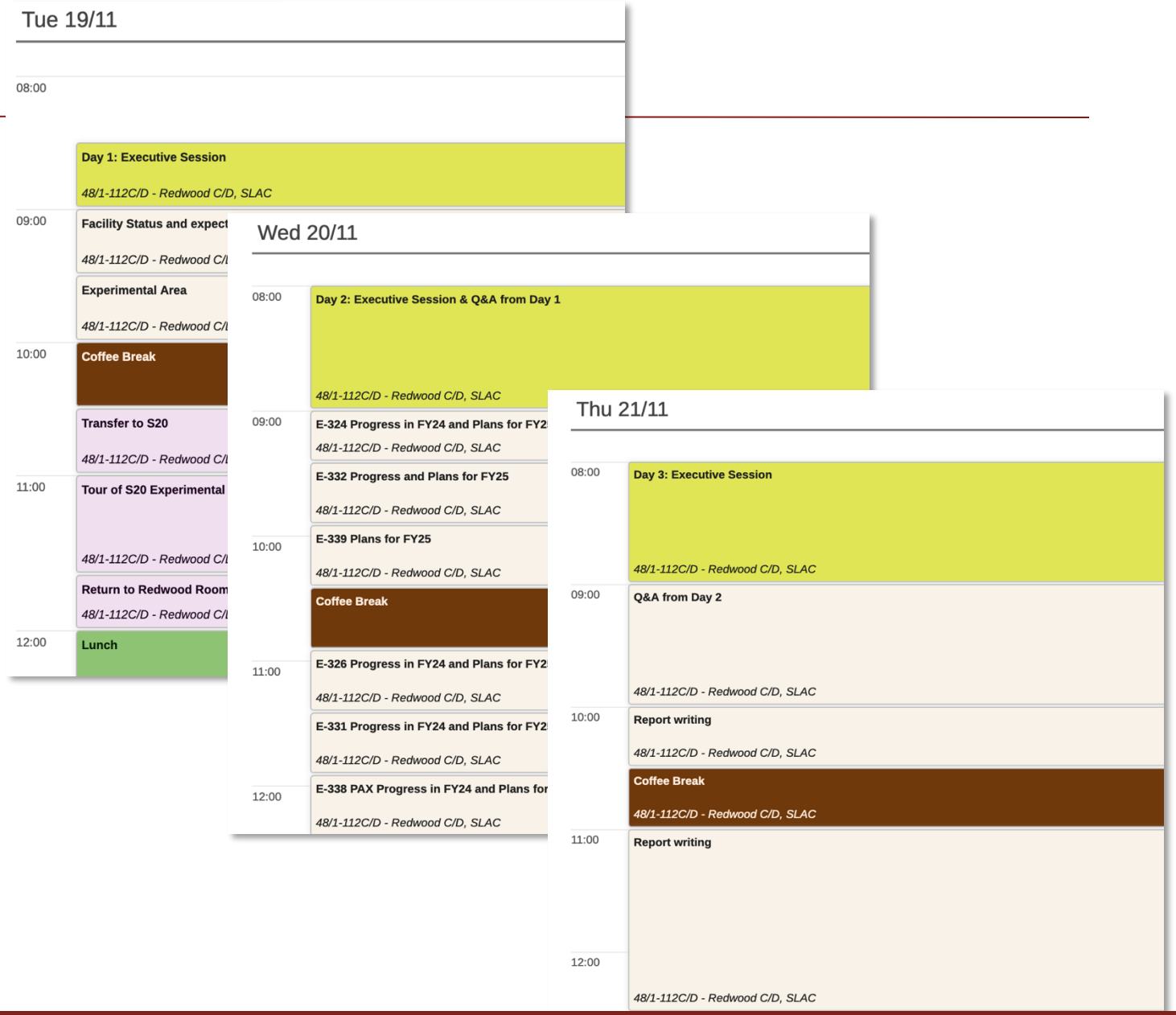
Earthquake

- Remain in building: Duck, cover, and hold position
- When shaking stops: Evacuate building via a safe route to the assembly area
- Do not leave until you are accounted for and have been directed to leave



Agenda/Format

- Tuesday morning: FACET-II overview and tours
- Tuesday afternoon: science and reception at Dutch Goose
- Wednesday morning: science
- Wednesday afternoon: new science and reception in building 52
- Thursday morning: Q&A with committee
- Lunch is provided for all in-person attendees on Tuesday and Wednesday
- Coffee and snacks are provided during breaks
- **Microphones are very sensitive**, zoom will hear every side conversation and every candy wrapper



Discussions between the presentations are just as important as the presentations

Facility Status and Expectations for FY25

FACET-II

Facility for Advanced Accelerator Experimental Tests

Brendan O'Shea / Lead Scientist / Advanced Accelerator Research Department Head

2024 FACET-II PAC & User Meeting

SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

FACET-II Major Events and Timeline Through FY24

- Major hardware installation completed by OCT 2019
- Installation Complete: AUG 2020
- Start FACET-II Commissioning: SEP 2020
- Threshold KPP and CD-4: SEP 2021
- 2022 : Objective KPP and previous PAC
- 2023 : FACET-II accelerator off from DEC 2022 to JUL 2023
- 2024 : First full year of User Programs

E300 11/15/24

FY23 began with half a year of downtime, in the remainder we returned the machine to good performance which enabled a successful FY24 campaign

Science in 2024

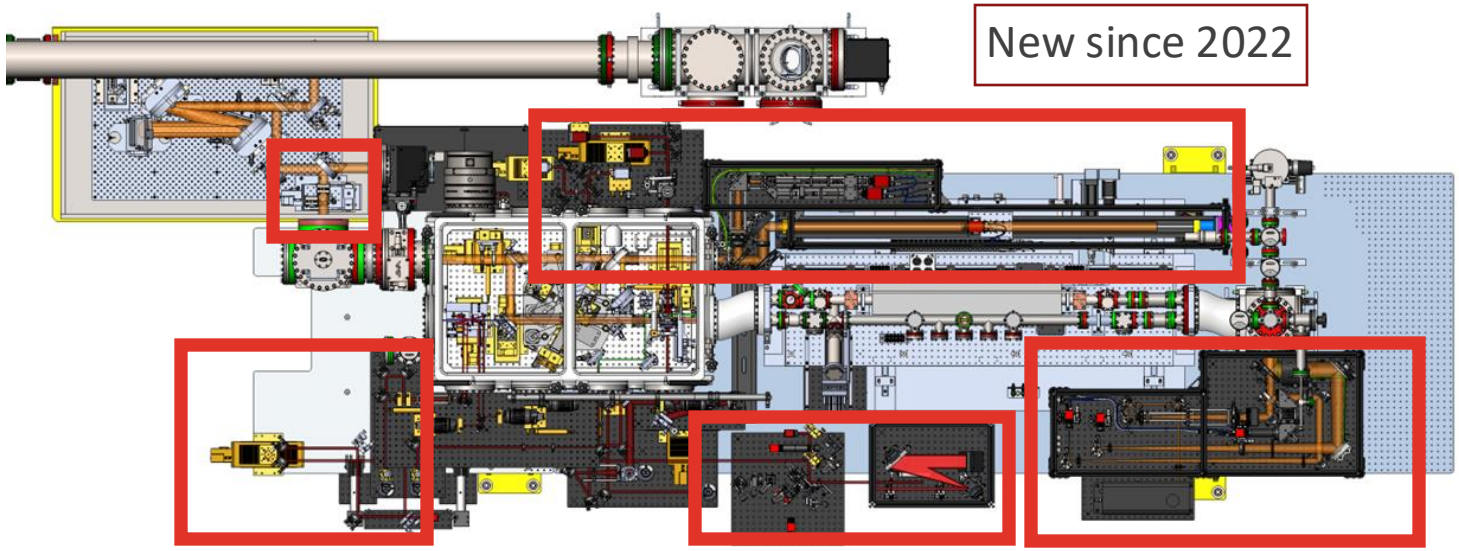
- High-efficiency PWFA using both single and two bunches (E300/Joshi + E301/Litos)
- High-brightness beam generation (E304/Zhang + E310/Sutherland)
- Laboratory Astrophysics (E305/Corde)
- SFQED (E320/Reis)
- Machine Learning / Artificial Intelligence (E326/O'Shea + E331/Edelen)
- Extreme Beams (E338/Marinelli + E332/Giljohann)
- Plasma Science (E324/Downer + E339/Sahai)

Experiment	Status	Topic
E300	Published	Diagnostics and first PWFA interactions FACET-II
E300	Published	Generation of meter scale hydrogen plasmas and efficient pump depletion
E300	Collect final data in Spring 2025	Mapping of wakefields using two bunches
E300	Collect data in Spring 2025	Pump depletion and emittance preservation
E301	Data in hand	Generation of wide plasma for PWFA in noble gases
E301	Collect final data in Spring 2025	Refraction effects in Li plasmas
E304	Collect final data in Fall 2024	Density down ramp injection
E305	Published	Spatiotemporal dynamics of ultrarelativistic beam-plasma instabilities
E305	Published	Probing strong-field QED in beam-plasma collisions
E305	Data in hand	Observation of the transition between wakeless and blowout regime
E320	Collect final data in Spring 2025	Observe change from perturbative QED to non-perturbative
E320	Collect data in Spring 2025	Measure change in rate of positron production between perturbative and non-perturbative regimes
E326	Data in hand	Single shot, non-intercepting diagnostic
E332	Data in hand	Demonstrate transition radiation focusing using multiple foils
E338	Submitted	Generation of short bunches using laser heater
E338	Collect data in Fall 2024	Spectral characterization of short bunches

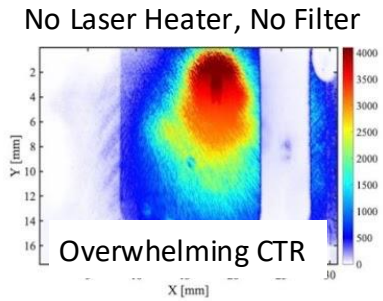
FACET-II will build on the success of FY24 and deliver great science in FY25

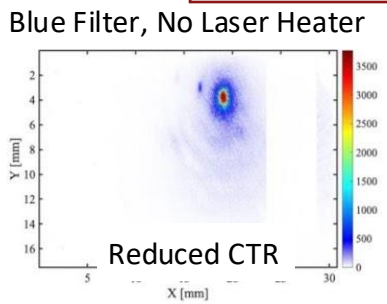
FACET-II Machine Configuration

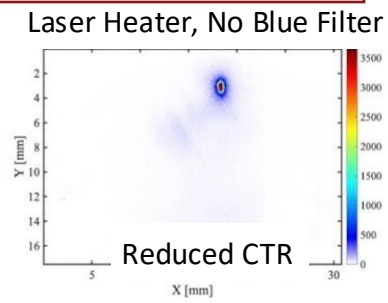
- Three beam configurations: Long bunch, short bunch and two bunch
- Six laser lines: S20 Main Laser, S20 EOS, S20 Ionizer, S20 Plasma imaging, S10 UV and S10 Laser Heater
- Three plasma sources: Lithium oven, gas jet (multiple nozzles), static fill. Gases: hydrogen, helium, argon, mixtures
- ~100 CCD cameras, 5 CMOS cameras, data acquisition software capable of capturing ~10,000+ images in single data set
- 62 movers, 113 pico motors

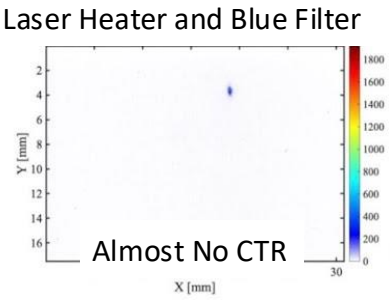


Laser heater commissioned





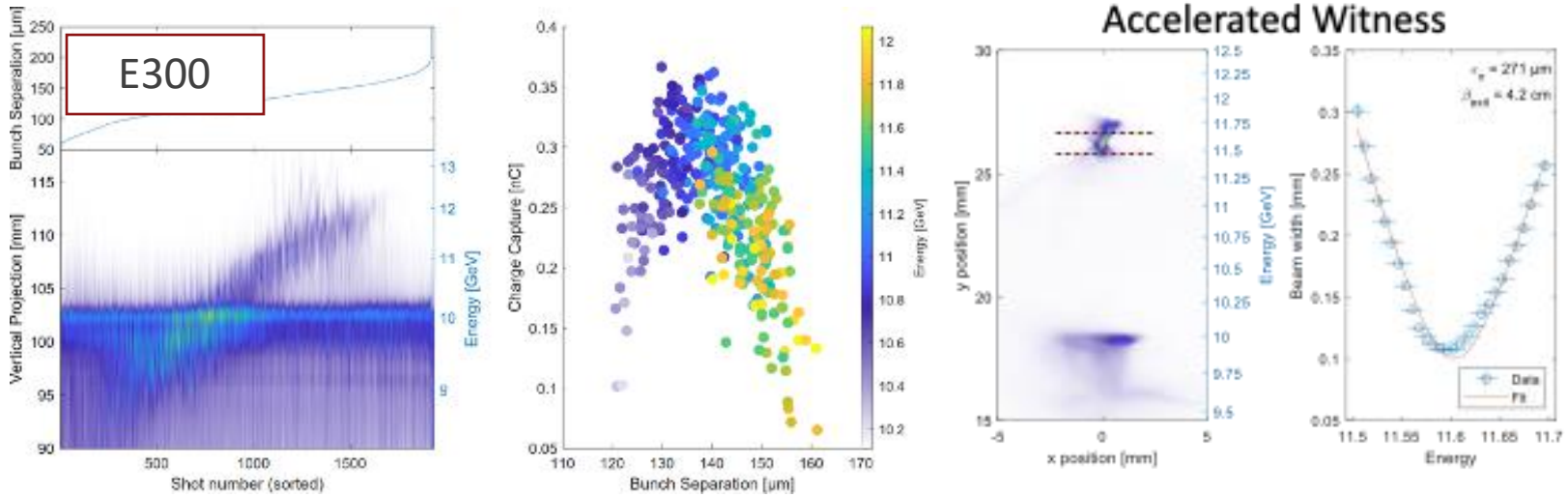


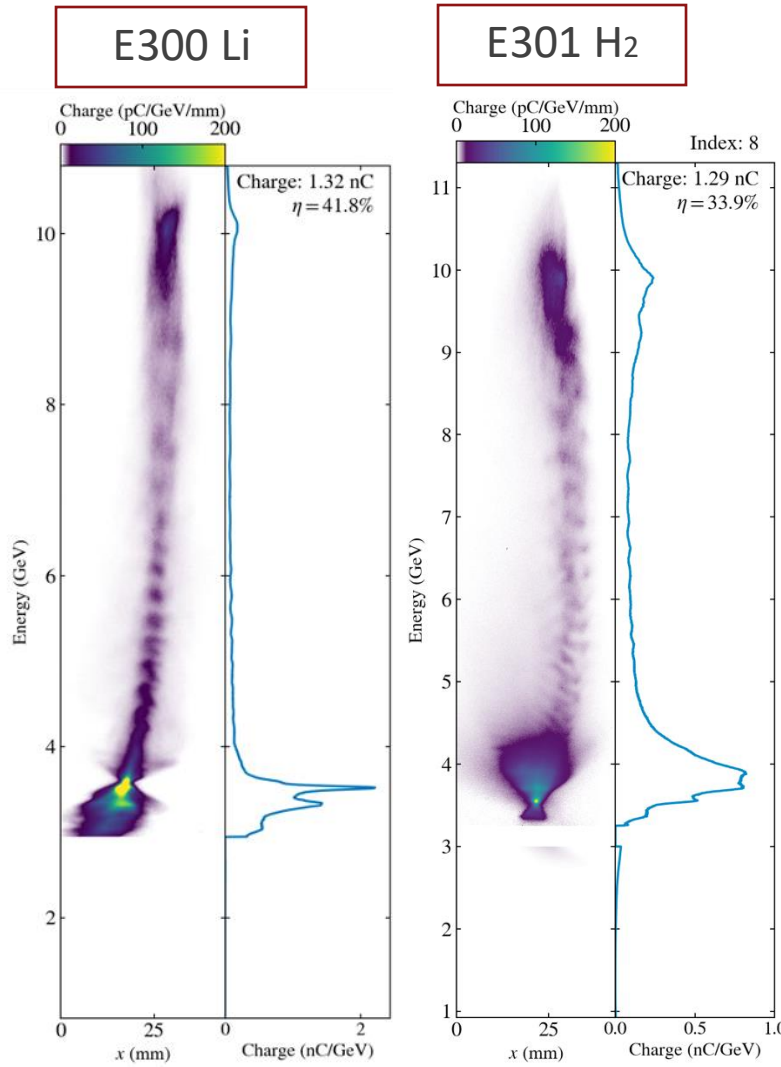


Strong User collaboration required to efficiently utilize limited, in demand IP real estate

Two bunch and short bunch PWFA experiments

- Introduced two bunch capability in April 2024
  - 3 to 5% overall efficiency (14% drive-to-wake, 35% wake-to-witness), 2.5 GeV/m over 40 cm
  - Near complete capture of the witness at the optimal bunch spacing
- Single bunch: drive-to-wake efficiency of 35%
- Collaboration critical to develop diagnostic and AI tools



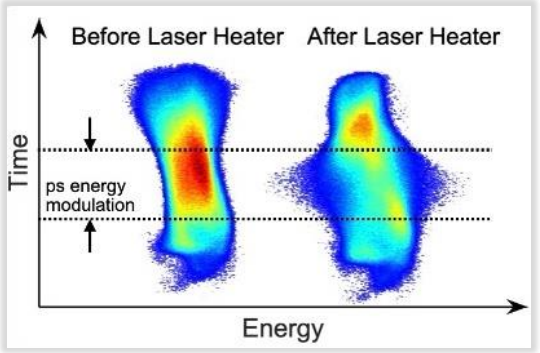


Significant progress on demonstration of a single high-quality PWFA stage

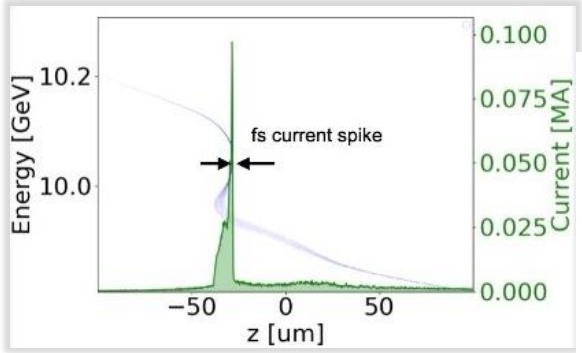
FACET-II can produce extreme beams

- Laser heater shaping generates ~1 fs, 100 kA beam
- Tunable current spike amplitude and location
- New proposal to study wakeless transition
- Downramp injection demonstration
- Measured micrometer scale emittance
- Brightness boost of 25-50x over FACET-II Beam

E338 + Laser Heater

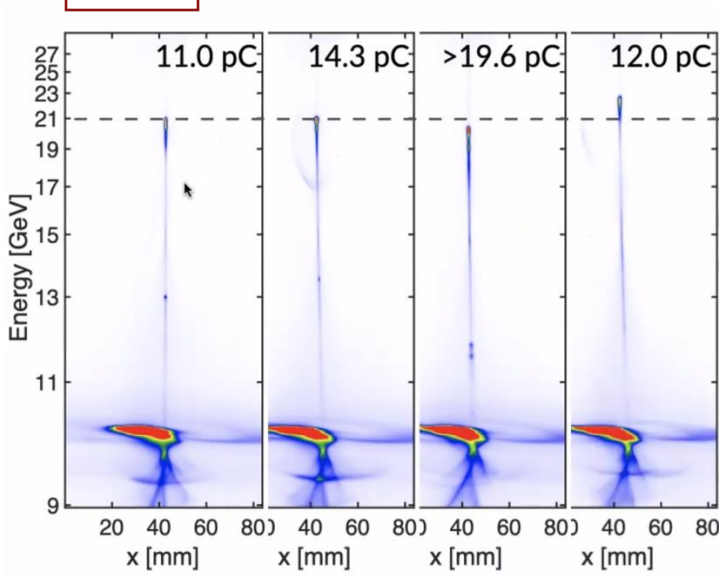


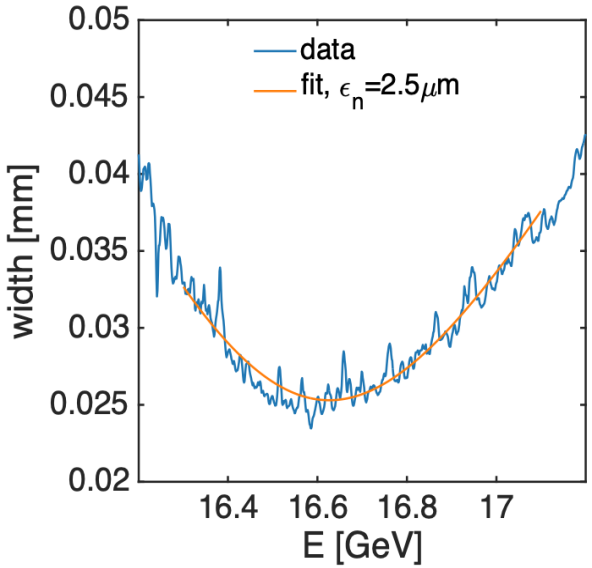
Modulated Energy Spread



Modulated Current Profile

E304





FACET-II delivers 10 GeV electron beams with unprecedented intensities

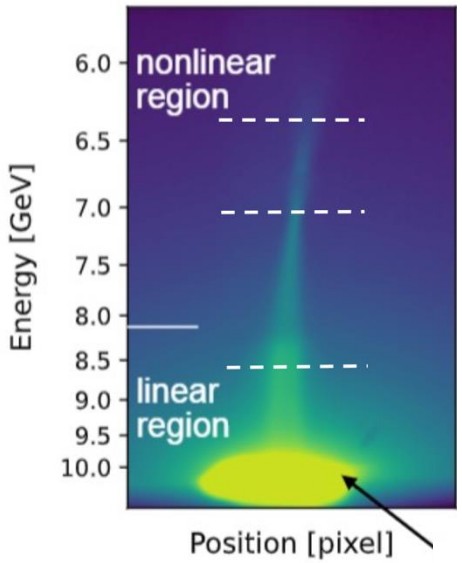
From extreme beams to frontier physics

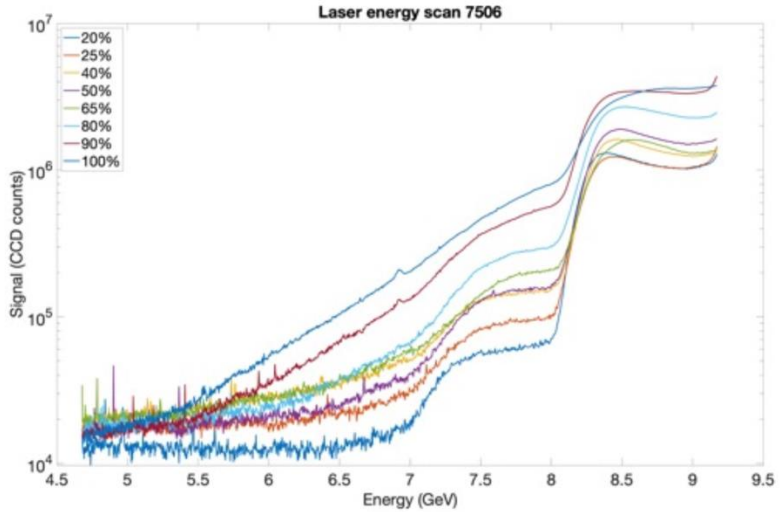
- Laser-beam collision produces field approaching critical field
- SMOS Camera and ”goose” trigger
- Gas jet + EOS used to time laser to electron beam

E320

$$\chi = \frac{E\hbar\omega}{{m_e}^2}(1 + cos\theta)a_0$$

Laser timed

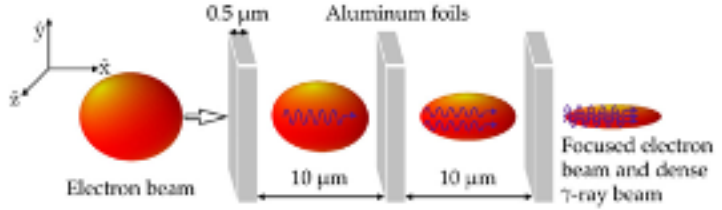


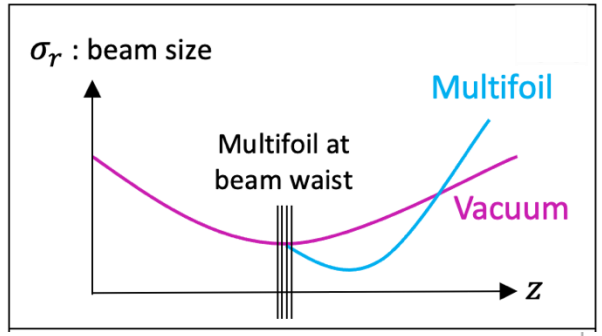


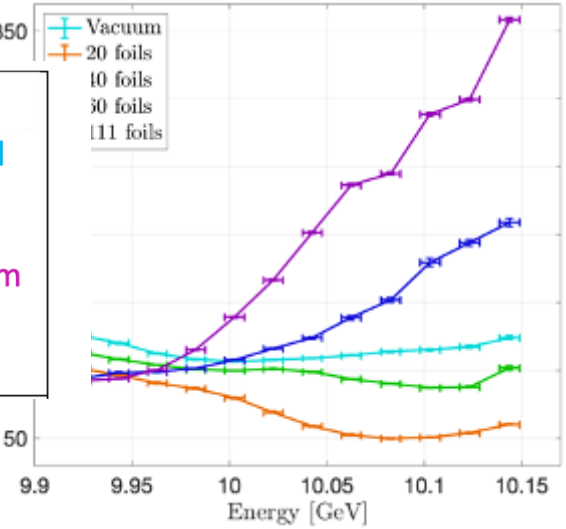
e-beam

- Path to focusing electron beams to solid density
- Facility + Users together develop method to scan foil

E332



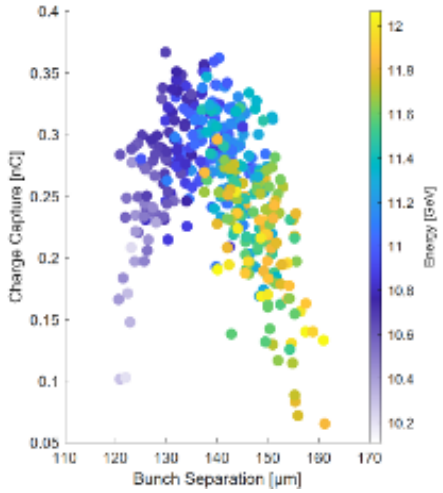


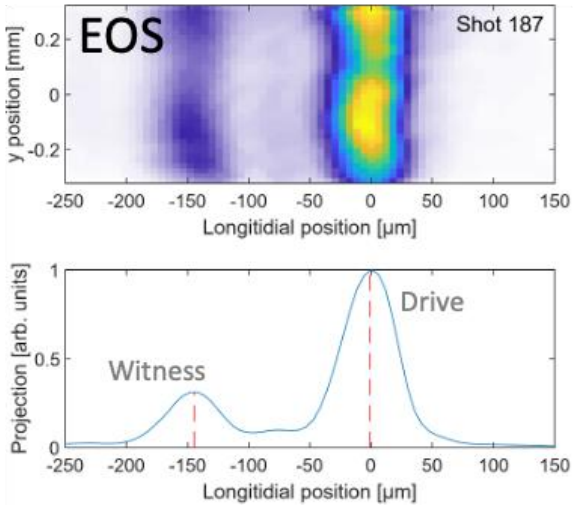


Techniques developed for one experiment quickly spread to others

Diagnostics and Artificial Intelligence

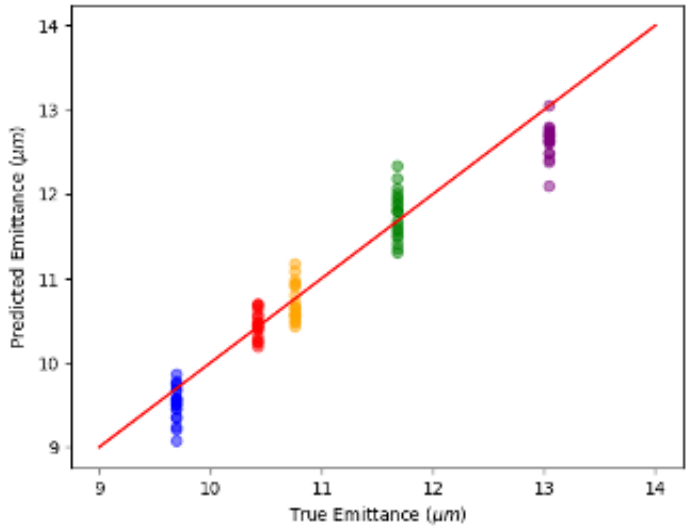
- High intensity beams destroy intercepting diagnostics
  - cannot be used during experiments
- Solution virtual and non-intercepting diagnostics
- Plasma is best diagnostic for extreme beams
- New proposal on ML powered diagnostic



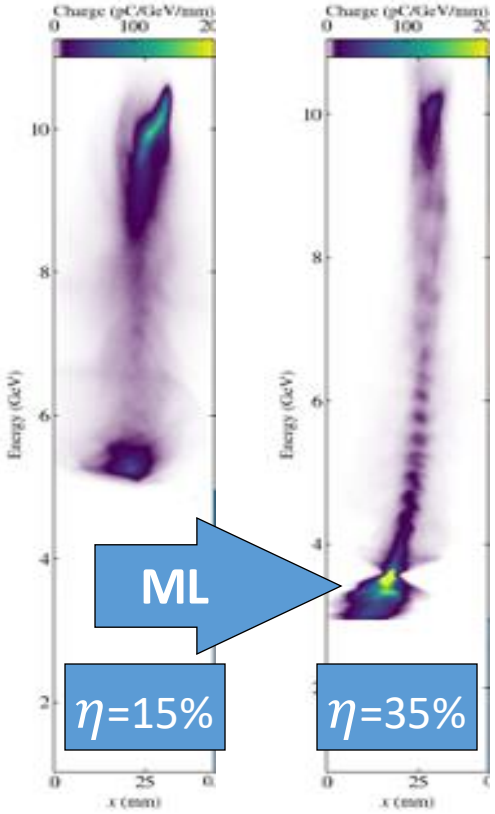


E326

True vs Predicted Emittance



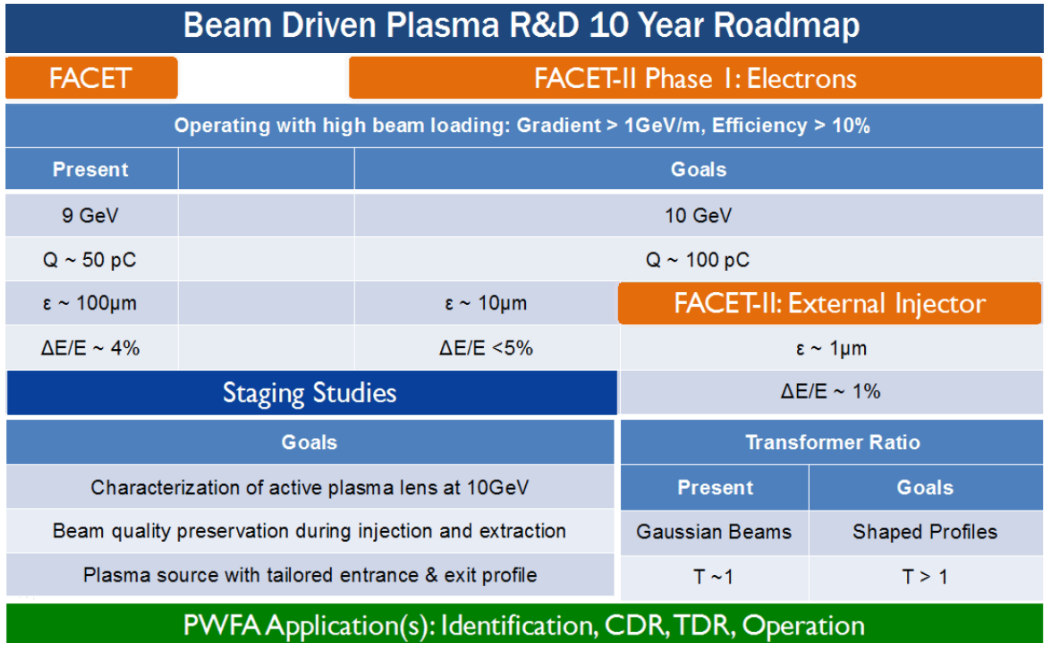
E300+E331



High charge, current, and quality require new diagnostics and control methods

AAC Roadmap, Snowmass + P5

- AAC Roadmap published in 2016
- HEP community updated goals via Snowmass 2021
  - Mark Hogan AF6 Convener on Advanced Acceleration
  - Spencer Gessner part of Collider Implementation Task Force
- P5 Report issued in DEC 2023
- FACET-II response to P5
  - 10 TeV Collider Study (Gessner and Osterhoff [LBL])
  - Development of two proposals covering four technical challenges for FCC-ee



Particle Physics Project Prioritization Panel

"**Support vigorous R&D** toward a cost-effective 10 TeV pCM collider based on proton, muon, or possible **wakefield technologies**."

"Wakefield concepts for a collider are in the early stages of development. **A critical next step is the delivery of an end-to-end design concept**, including cost scales, with self-consistent parameters throughout. "

In FY24 FACET-II attended to milestones in 2016 AAC roadmap and began responding to P5

Summary

- High-efficiency PWFA and plasma sources
- High-brightness and extreme beam generation
- Frontier physics
- Artificial intelligence control and diagnostics
- Collider directed R&D

- The user community is >40% students and postdocs
- New users start in one collaboration and quickly find themselves in many more

The last User meeting was 2018.

Do not miss this year's photo!

Ambitious users make FACET-II a place to do impactful science

FACET-II | Facility for Advanced Accelerator Experimental Tests

Thank You!