FACET-II

Facility for Advanced Accelerator Experimental Tests

E300

FACET-II Long Term Planning Meeting

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SLAC NATIONAL ACCELERATOR LABORATORY

Stanford University | U.S. DEPARTMENT OF ENERGY

E300 high-level scientific goals

Goals of the E300 collaboration – as stated in 2024 PAC meeting:

- Demonstration of a single stage with the beam parameters required for a future plasma-based collider or light source
  - Net energy transfer of 40%
  - Minimize energy spread growth in trailing bunch
    - Understand factors that cause energy spread to increase
  - Minimize emittance growth in trailing bunch
    - Understand factors that cause emittance growth – mismatch, alignment error
  - Conserve charge of trailing bunch

Main activities towards these goals in FY25

- New Li oven
- Operated in “Notched 2 bunch” and “Two bunch from cathode” modes
- Many new diagnostics and procedures developed:
  - Nathan’s two bunch linac setup: Google Doc
  - Li oven operations manual: Confluence
  - Two bunch tune up for PWFA: Confluence

- Broad summary of progress, data analysis to date, etc: PWFA Collab. Indico

Very short summary of results

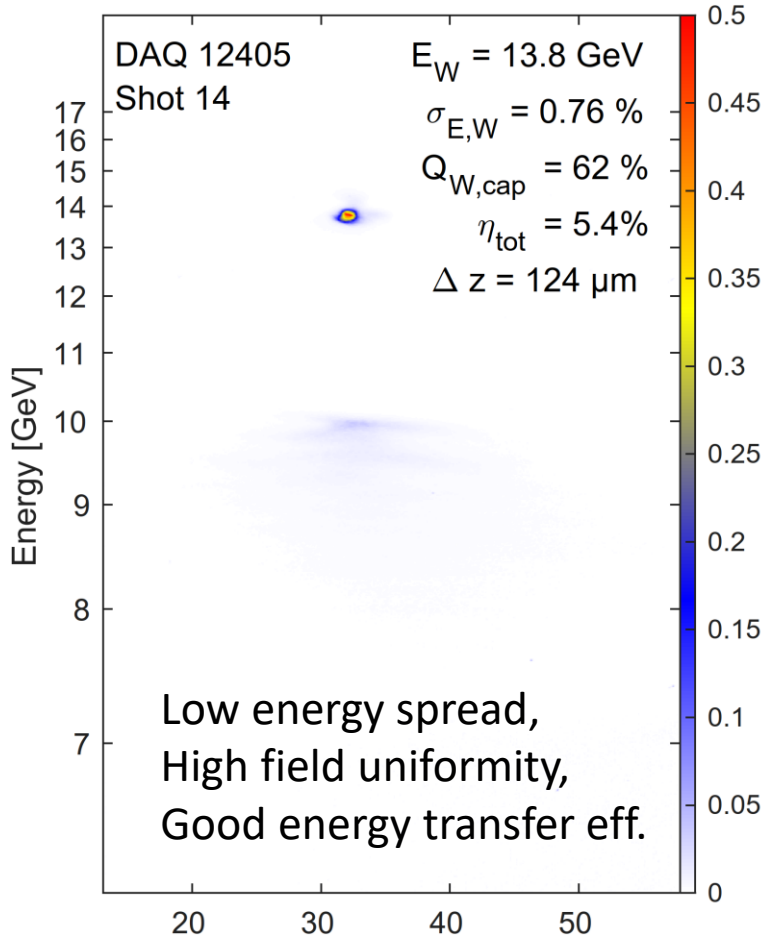
- Achieved multi-GeV (up to ~16 GeV) witness acceleration with low energy spread
- Total efficiencies of 5-6%, maybe higher
- Progress towards matching, emittance - TBD

- **Goals stated from PAC:**

Parameter	Units	2016 AAC	FACET-II results 2024	FY25
Emittance (post plasma)	μm	10	>200*	>200
Energy Spread	%	<5	4	<5
Energy Gain	GeV	10	1.5	3
Total Efficiency	%	>10	4	10
Gradient	GV/m	>1	2.5	5
Charge	pC	~100	~100	>100
Plasma Source			40 cm Li Oven	40 cm

Achieved simultaneously? (Work in progress)

- TBD
- < 1% total *~2-3% field uniformity*
- ~4 GeV optimally
- 5%
- 9.5 GeV/m
- 180 pC
- 40cm oven, 5 Torr



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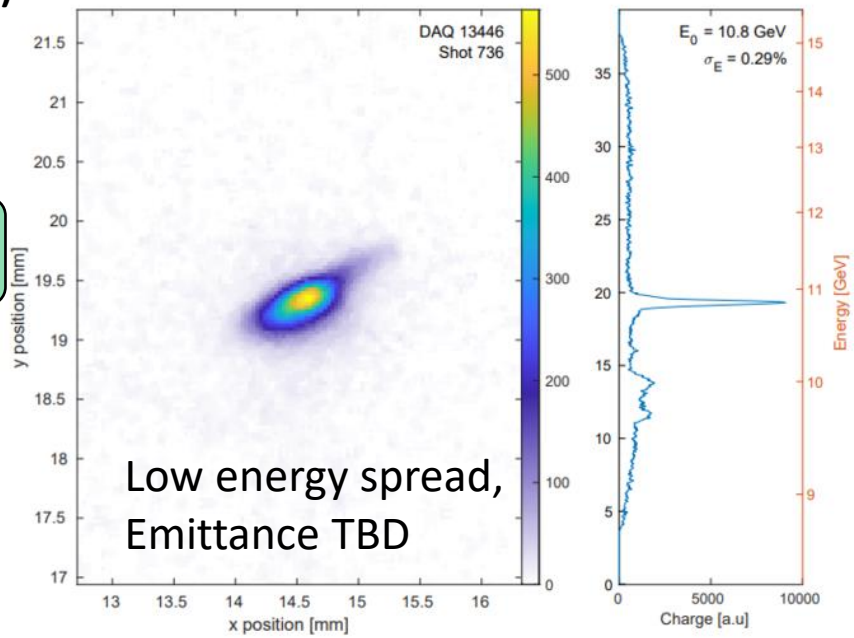
Energy Spread	%	<5	4	<5	< 1% total *~2-3% field uniformity*
Energy Gain	GeV	10	1.5	3	~4 GeV optimally
Total Efficiency	%	>10	4	10	5%
Gradient	GV/m	>1	2.5	5	9.5 GeV/m
Charge	pC	~100	~100	>100	180 pC
Plasma Source			40 cm Li Oven	40 cm	40cm oven, 5 Torr



Publication plans

- **Mapping of wakefields using 2 bunches** *(Goal stated last year)*
  - Retook better data with characterized oven, notched 2 bunch config, with E338
  - Aiming to co-publish with E338

- **Drive to wake, pump depletion with emittance preservation** *(Goal stated last year)*
  - No significant progress towards this. Only a single E300 shift dedicated to single bunch this year
  - Work towards this is being published in E301 paper instead

- **Beam dynamics in non-optimal matching conditions/self matching of drive beam** *(Goal stated last year)*
  - There was some analysis/simulation work done last year… but again, no time devoted to single bunch studies

- **Multi-GeV witness acceleration with high field uniformity**
  - Max 6-7 GeV acceleration with highest field uniformity, closer to 1-4 GeV acceleration with better charge capture
  - Importance of beam loading: Optimal beam loading vs over/under loaded from notched 2 bunch studies

- ***Matching*** *– depends on what the data says??*
  - Work towards matching. Depends on what we find from changing density and beta* = 10, 25, 50cm

What are out next high-level goals

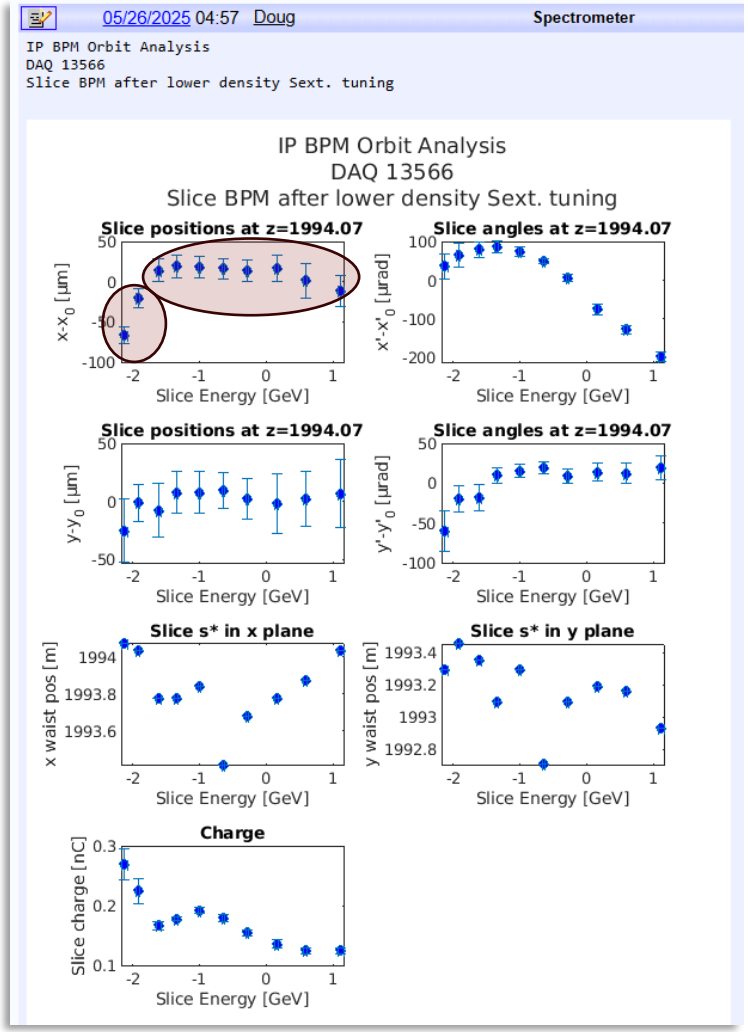
Parameter	Units	2016 AAC	FACET-II results 2024	FY25			FY26	FY27
Emittance (post plasma)	μm	10	>200*	>200	TBD	Matching, alignment, removing dispersion, etc	20	10
Energy Spread	%	<5	4	<5	< 1% total		<5	<5
Energy Gain	GeV	10	1.5	3	4 (<6) GeV		4.5	9
Total Efficiency	%	>10	4	10	5%	Factor of 2-3 improvement	15	15
Gradient	GV/m	>1	2.5	5	9.5 GeV/m		5	5
Charge	pC	~100	~100	>100	180 pC	Improve “charge capture”	>100	>100
Plasma Source			40 cm Li Oven	40 cm	40cm oven, 5 Torr	Longer oven in current space	60 cm	New Source

How do we keep improving?

- **Improve matching, beam quality, and drive/witness transverse alignment**
  - Sextupoles:
    - Centered on nominal beam orbit → Task: More than MD time?
    - Reliable/repeatable movers → Task: investigations from controls group. Is this happening?
    - Sextupole tuning while maintaining IP orbit
  - IP diagnostics
    - Dispersion tuning – we have many tools, are we using them in the most effective way?
    - Jitter tool
    - EOS → EOS BPM
  - Operation at smaller beta
  - Linac emittance growth
    - Linac BBA?
    - Other improvements?

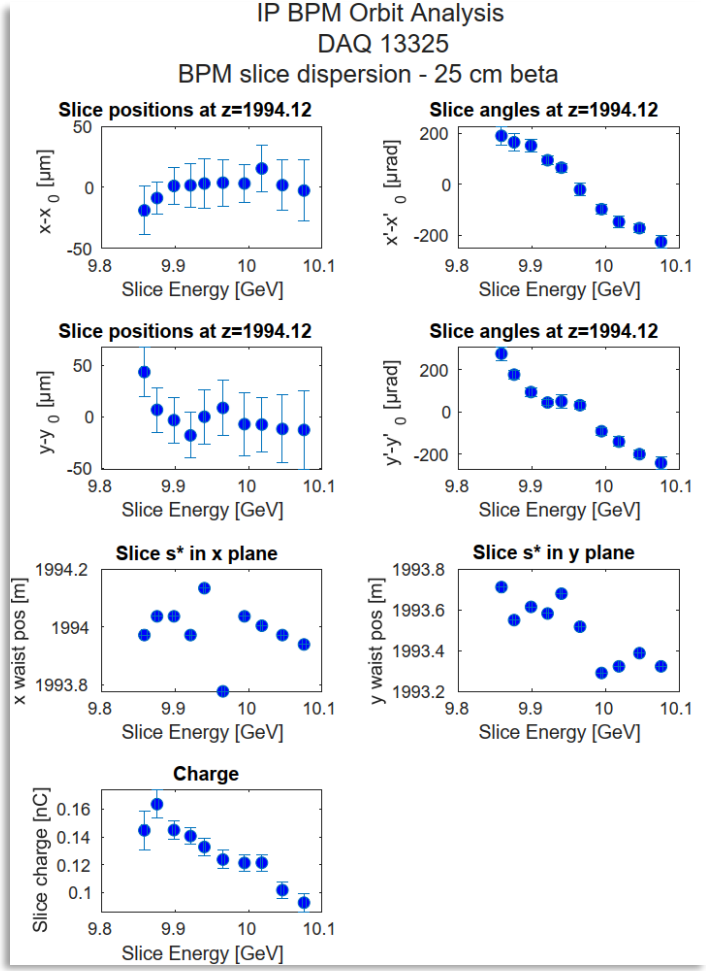
Transverse tuning

A bad beam with drive/witness offset



Sextupoles

Slightly better beam, but lots of dispersion’



???

An even better beam

How do we keep improving?

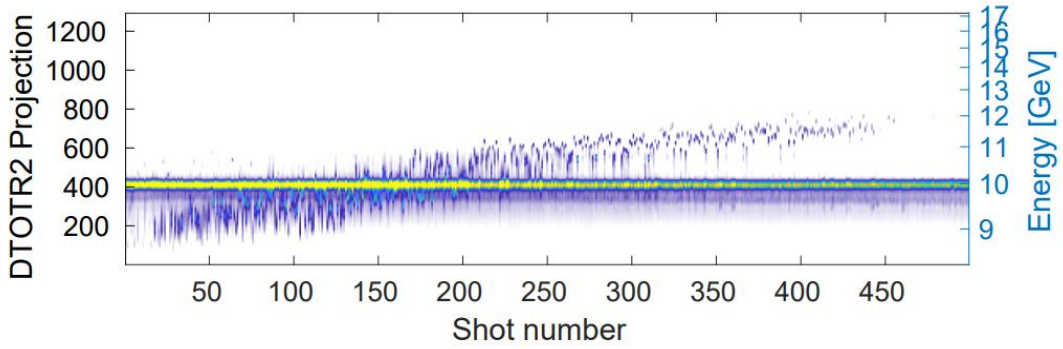
- **SVAC line**
  - Linac at 30 Hz
  - Reduced rate to oven → lower risk, more tuning with oven

- **Longitudinal setup**
  - XTCAV
    - More kick → Task: shorten input cable to klystron (Doug/Juan make a shelf, AMRF to move equipment)
      Task: Continue RF conditioning to get from 20 to ~24+ MV
    - More repeatable TCAV measurements
      - New GUI → Task – underway
      - New analysis codes (Reliable calibrations, TCAV off deconvolution, etc)
  - TCAV3
  - S20 Pyro → Task: fix the window, other work required?

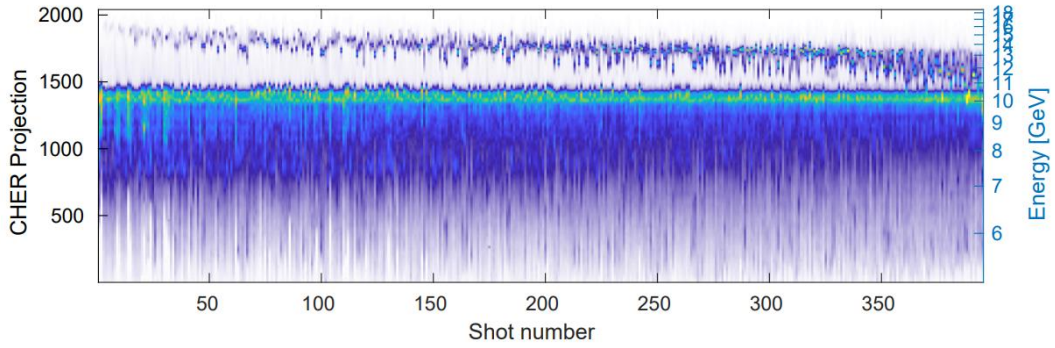
Longitudinal improvements in 2025

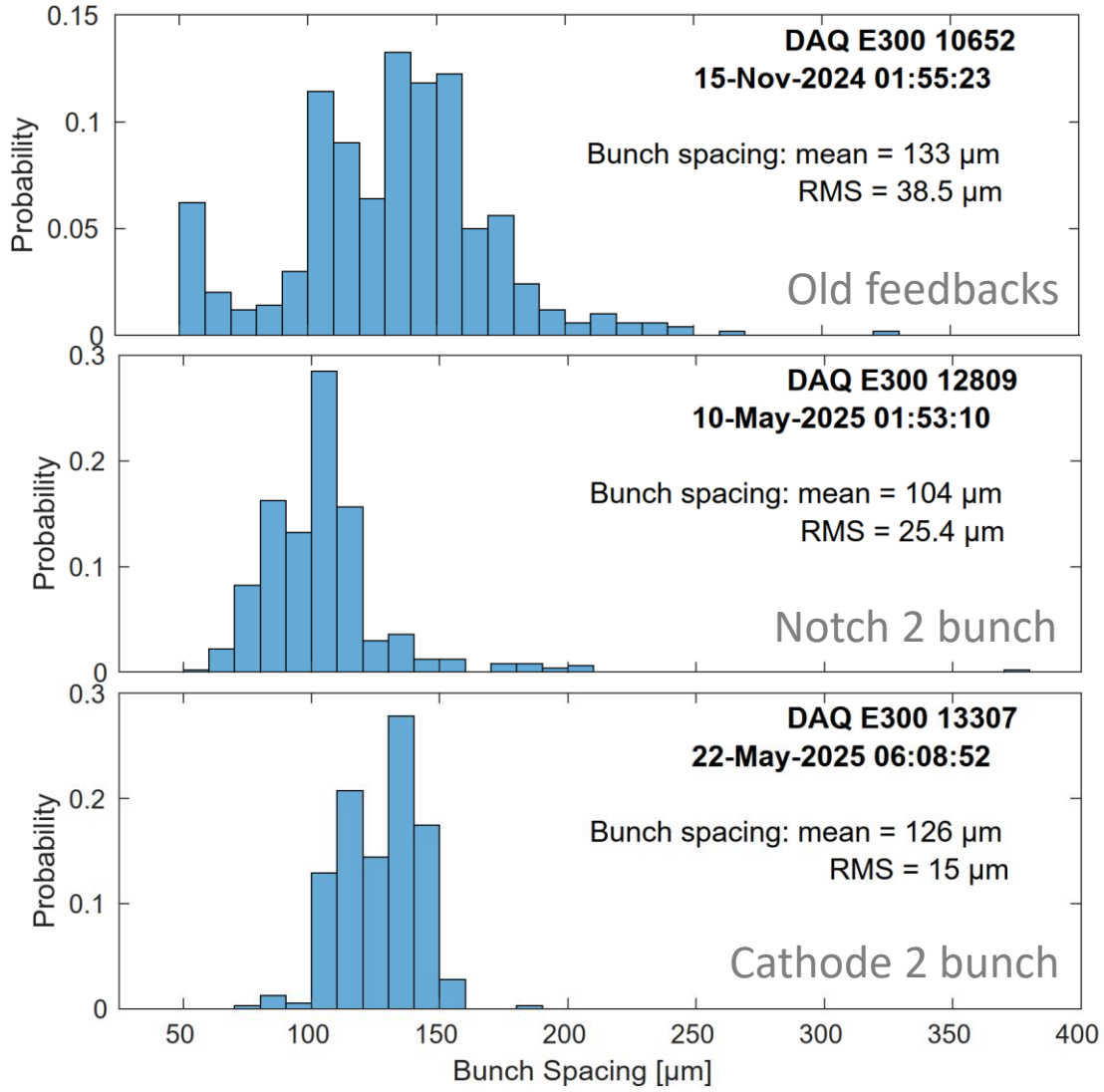
- Improvements from last year
  - L1 LLRF upgrades
  - Updated longitudinal feedbacks**

Old feedbacks



New feedbacks





Plasma Sources

- Li oven
  - More stable performance this year with better heat management (and maybe more stable beam)
    - Max drive to wake energy transfers ~25-30%
      → ~50 Watts going into the oven
    - Able to manage heater power to keep oven stable
    - But – ability to run at lower rate would reduce risk
  - Longer oven
    - Only decelerating down to about 5 GeV
    - 60cm oven should get us closer to pump depletion (2-3 GeV) and up our total efficiency
      - Space should already exist for this

- Discharge source - Development underway
- Long gas jets?

- New chamber for non-oven plasma sources
  - "Global" design effort, hot-swapable vacuum chamber?

What worked well?

- Quick single → 2 bunch switchover (and back)
- Standard tuning procedure to get to a decent starting point: Confluence
- “24” hour operation in 2 bunch mode
  - But this gets tiring very fast
- Notched 2 bunches
- Pace of the addition/adoption of new tools
- More people able/willing to manage the oven (Can use even more)
- Laser pre-ionized Li oven (~mm-scale plasma channel) → Task: Stop laser autoaligner from burning Be window