

E301 & E333

Summary of Progress and Results from FY25

July 23, 2025

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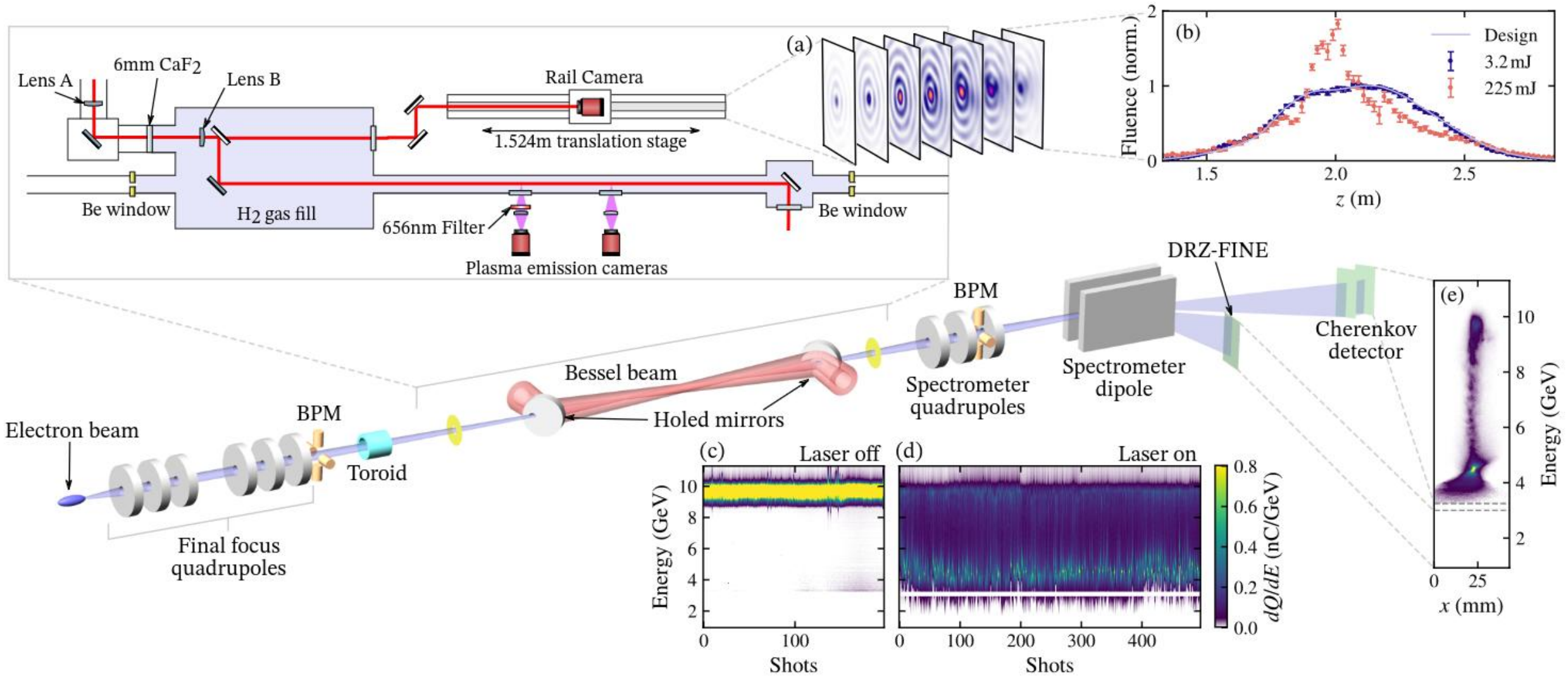
on behalf of the E301 Collaboration

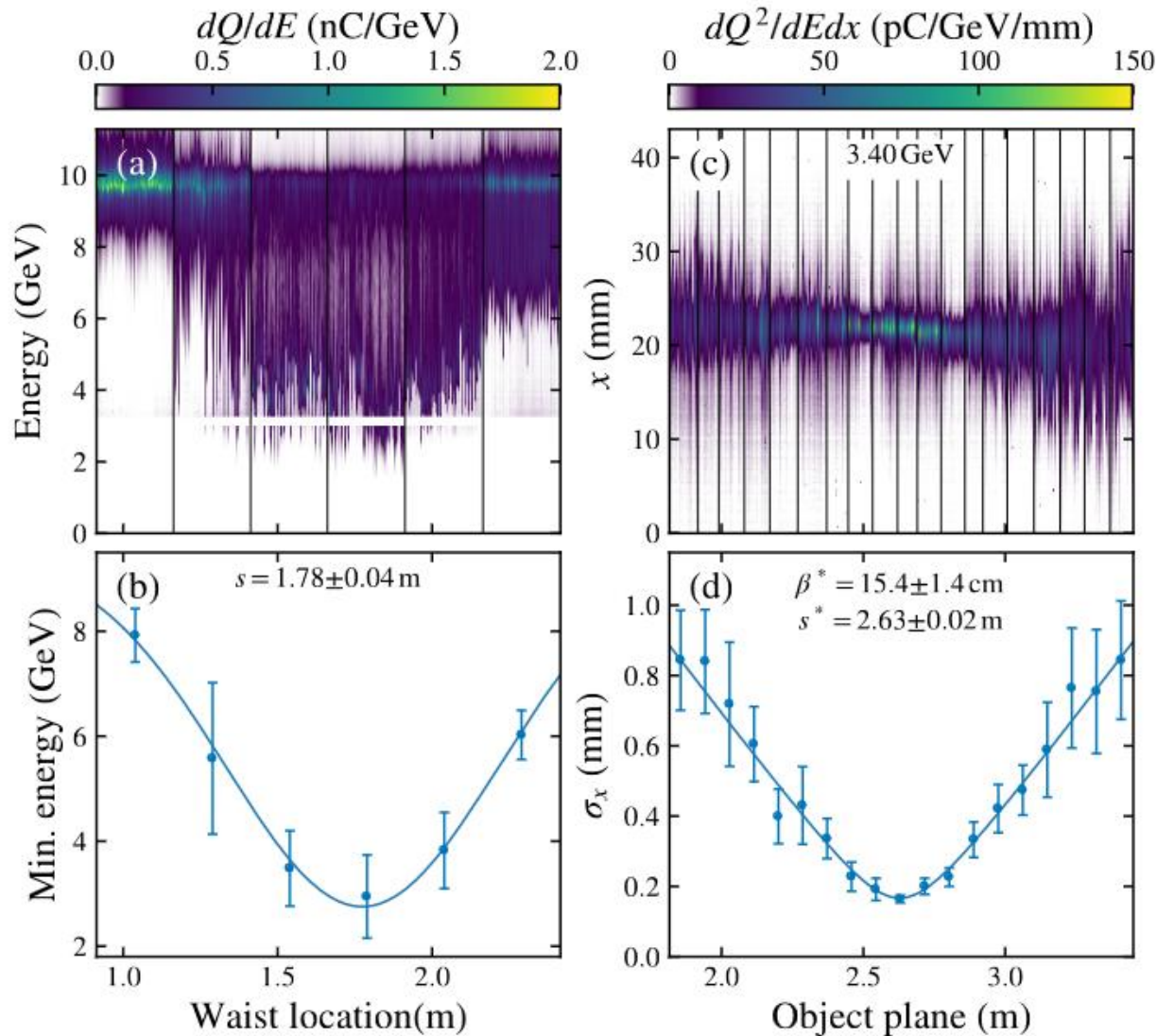
University of Colorado, Boulder

- Achieving high performance PWFA in a **laser ionized plasma source**
 - To achieve collider required energy deposited -> Oven has suffered overheating and lithium loss when trying to increase the drive-to-wake energy transfer.
 - Controllable plasma geometry -> Emittance preservation, plasma shaping for positron acceleration (E333)
- High efficiency PWFA
 - Drive to wake efficiency
 - Wake to witness efficiency
 - Charge preservation
 - Energy spread preservation
 - Emittance preservation

Experimentally demonstrate high performance PWFA in a laser ionized plasma source

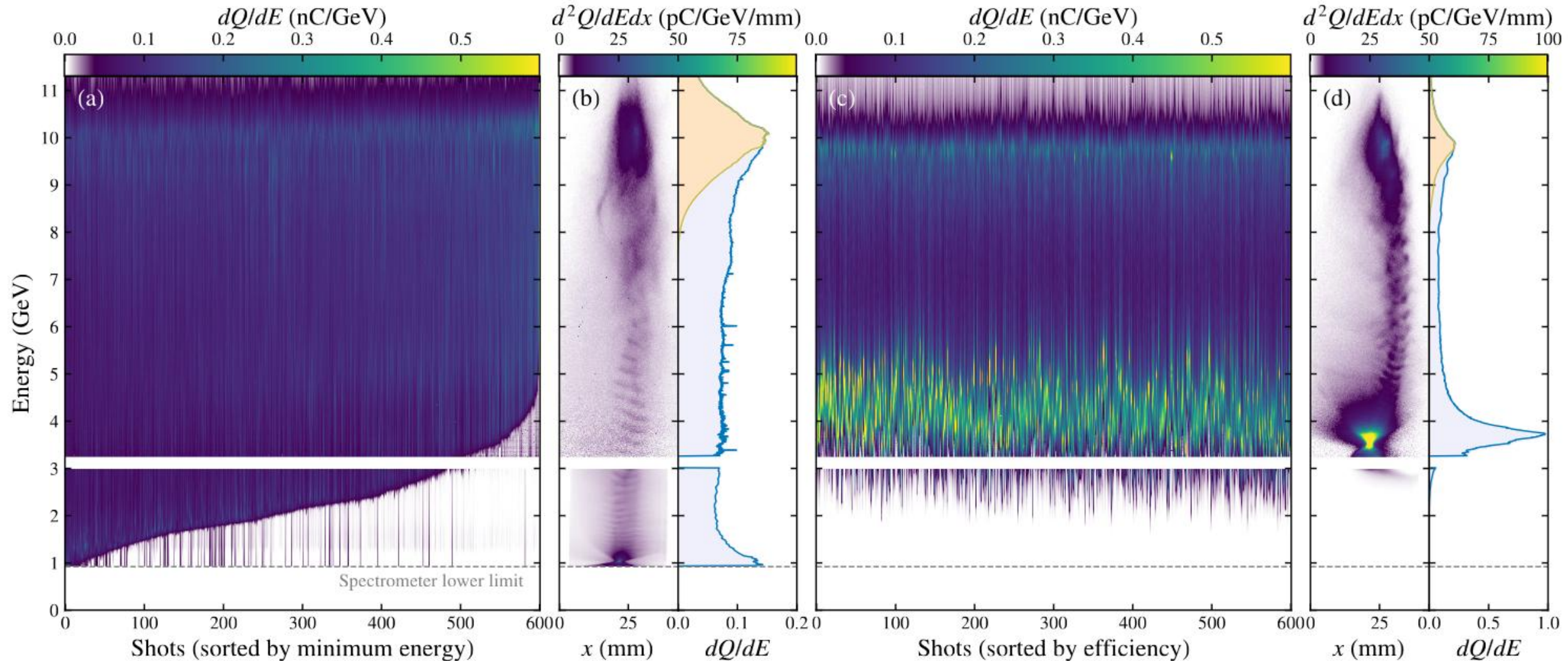
E301 Experimental Setup



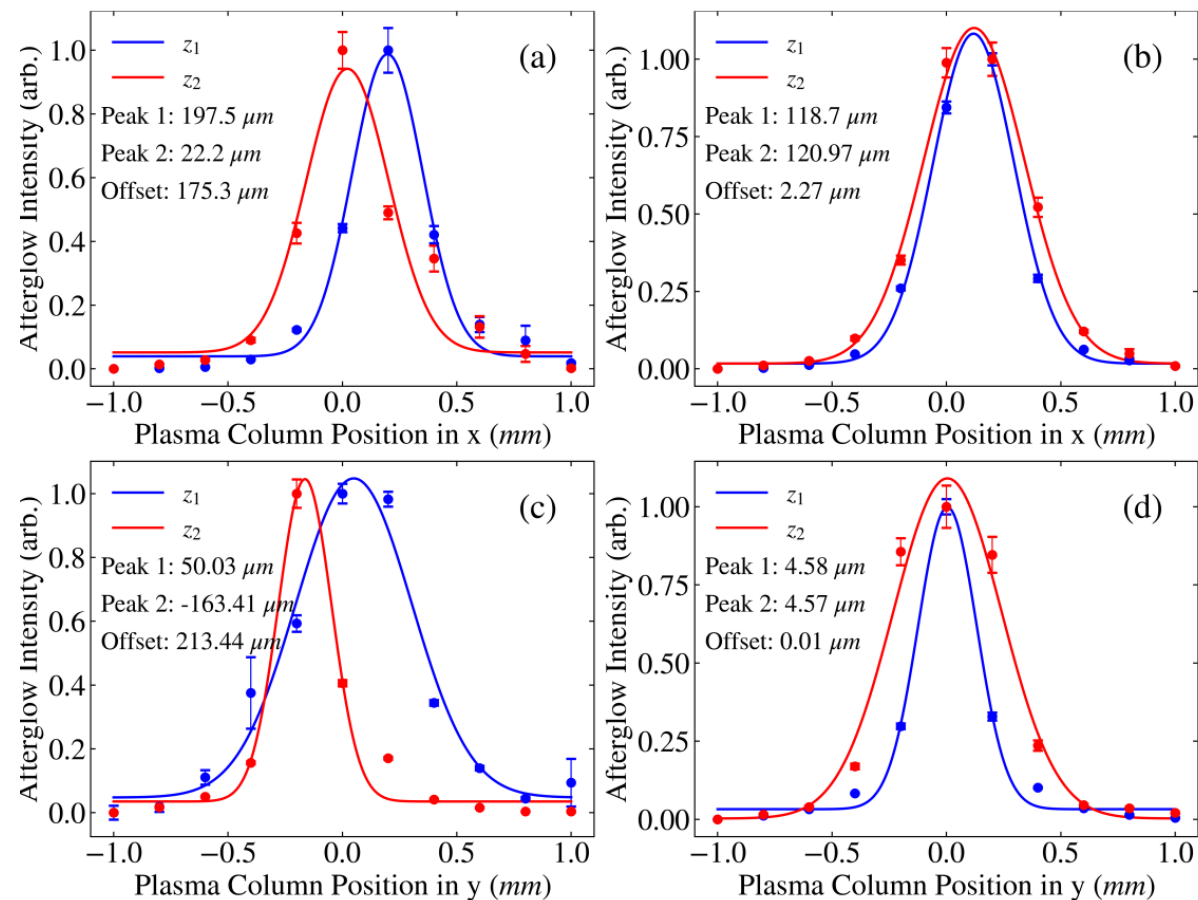
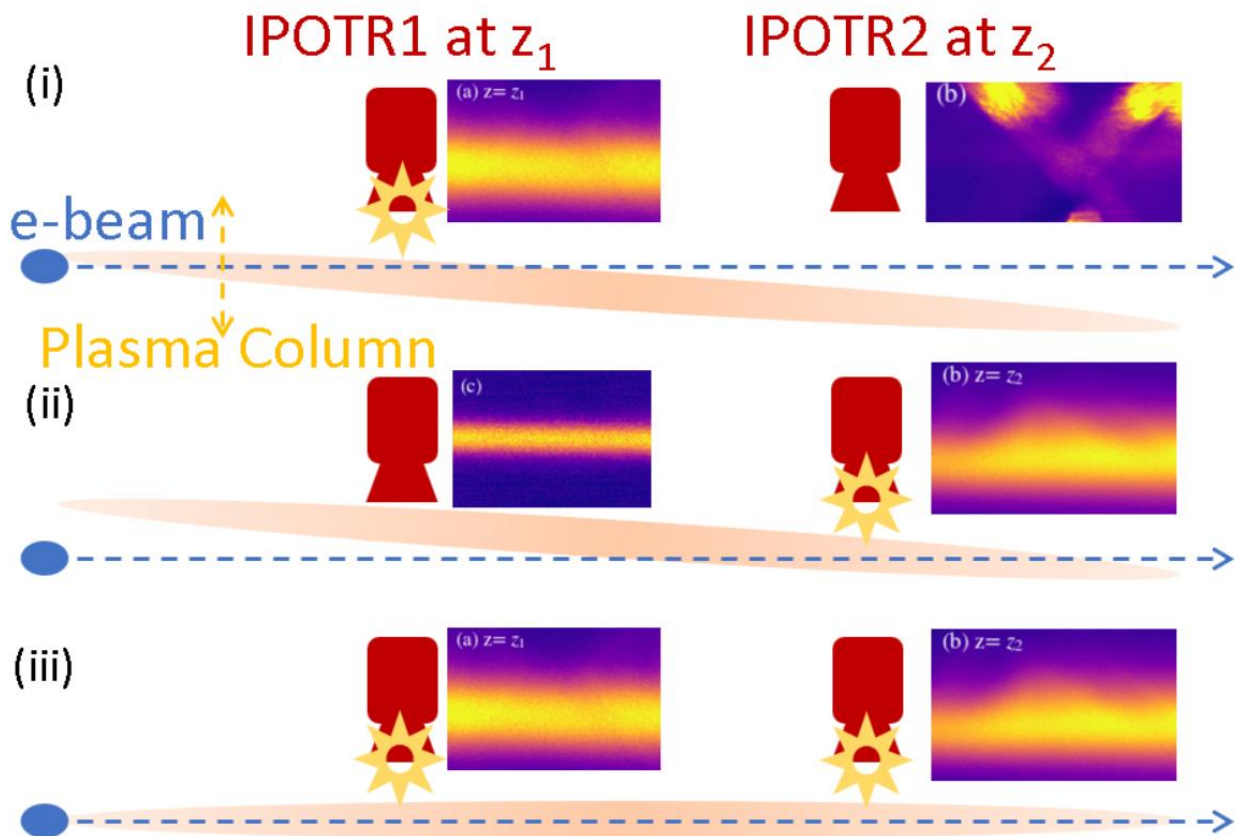


- The optimum waist location approximately corresponds to the start of the plasma. This is because the interaction is maximized when the waist is co-located with the virtual-waist of the plasma's matched beta function, which corresponds to approximately the center of the plasma entrance ramp.
- Plasma density: $4.5e16$ cm³
- Plasma length: 85cm
- Plasma starting position: 1995m

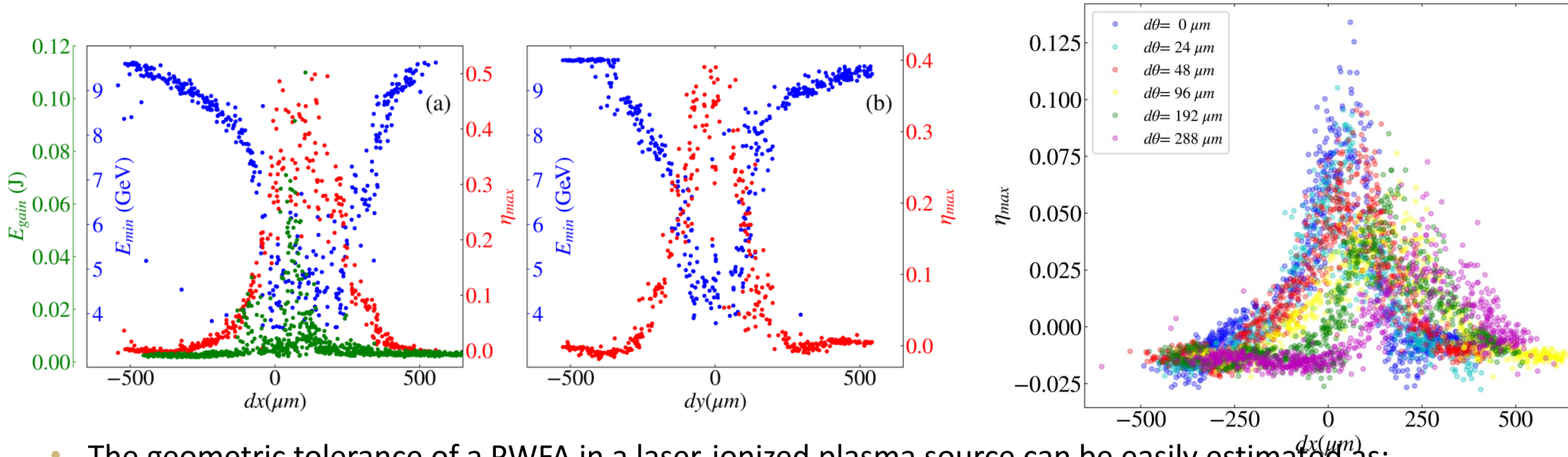
FY24 Results – Energy depletion, High Drive-to-wake energy transfer efficiency



- Depletion of significant charge below the spectrometer's lower limit of 0.93 GeV
- High efficiency: $35 \pm 3\%$ drive-to-wake efficiency



We are able to consistently and efficiently align the plasma to the electron beam to within 10 μm offset, 10 μrad tilt.



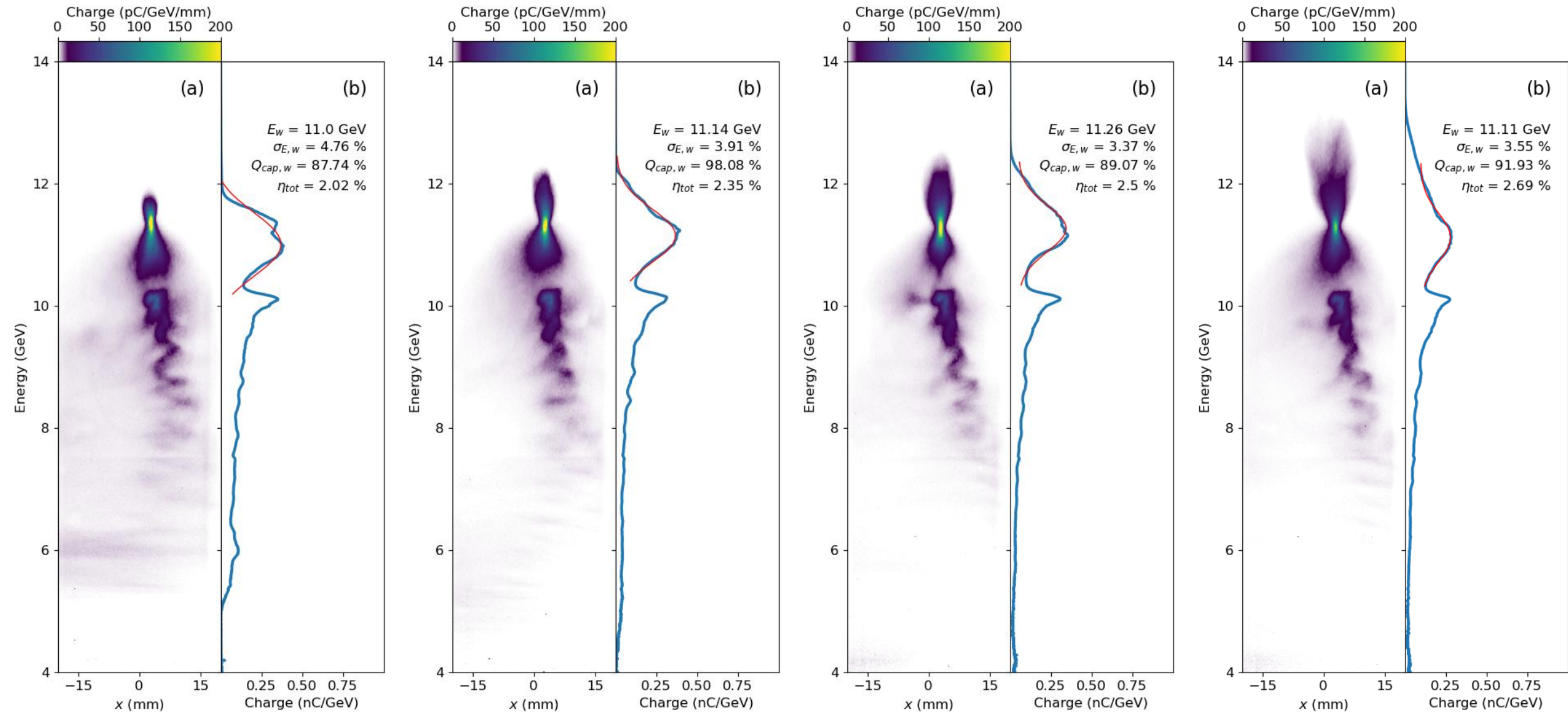
- The geometric tolerance of a PWFA in a laser-ionized plasma source can be easily estimated as:

$$dr + L \sin(d\theta) \leq 2(R_p - r_b)$$

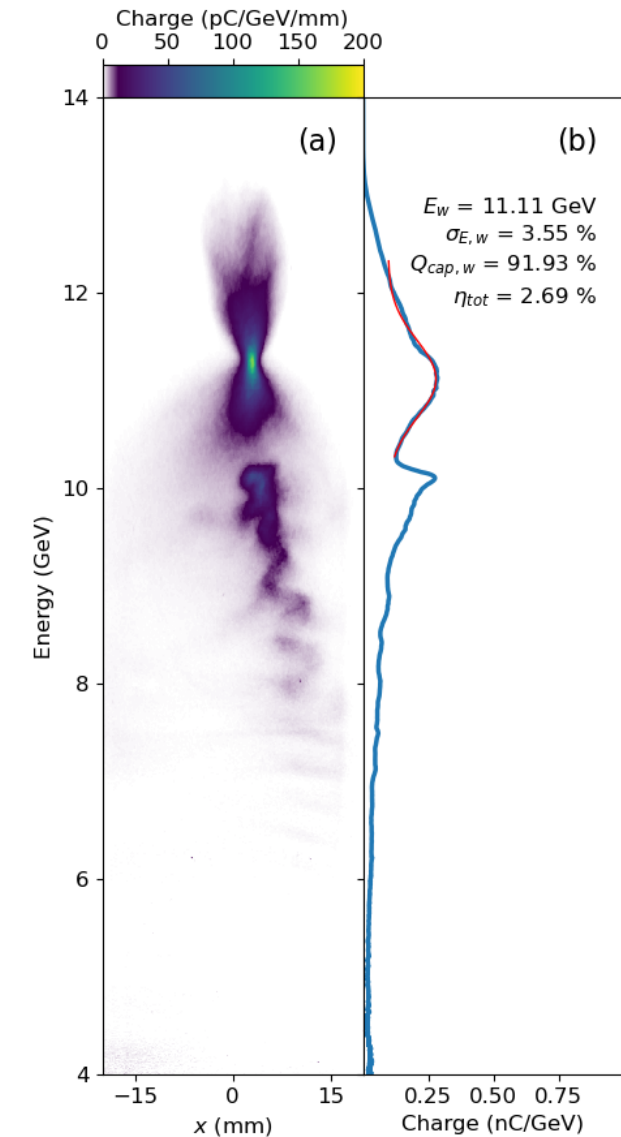
- Previous studies have shown that a mis-aligned drive beam can be attracted into the plasma column, which suggests that the alignment tolerance may be greater than that predicted by the simple geometric argument.

Both the transverse and angular tolerances are consistent with the geometric calculation.

FY25 Results – Good Performance PWFA

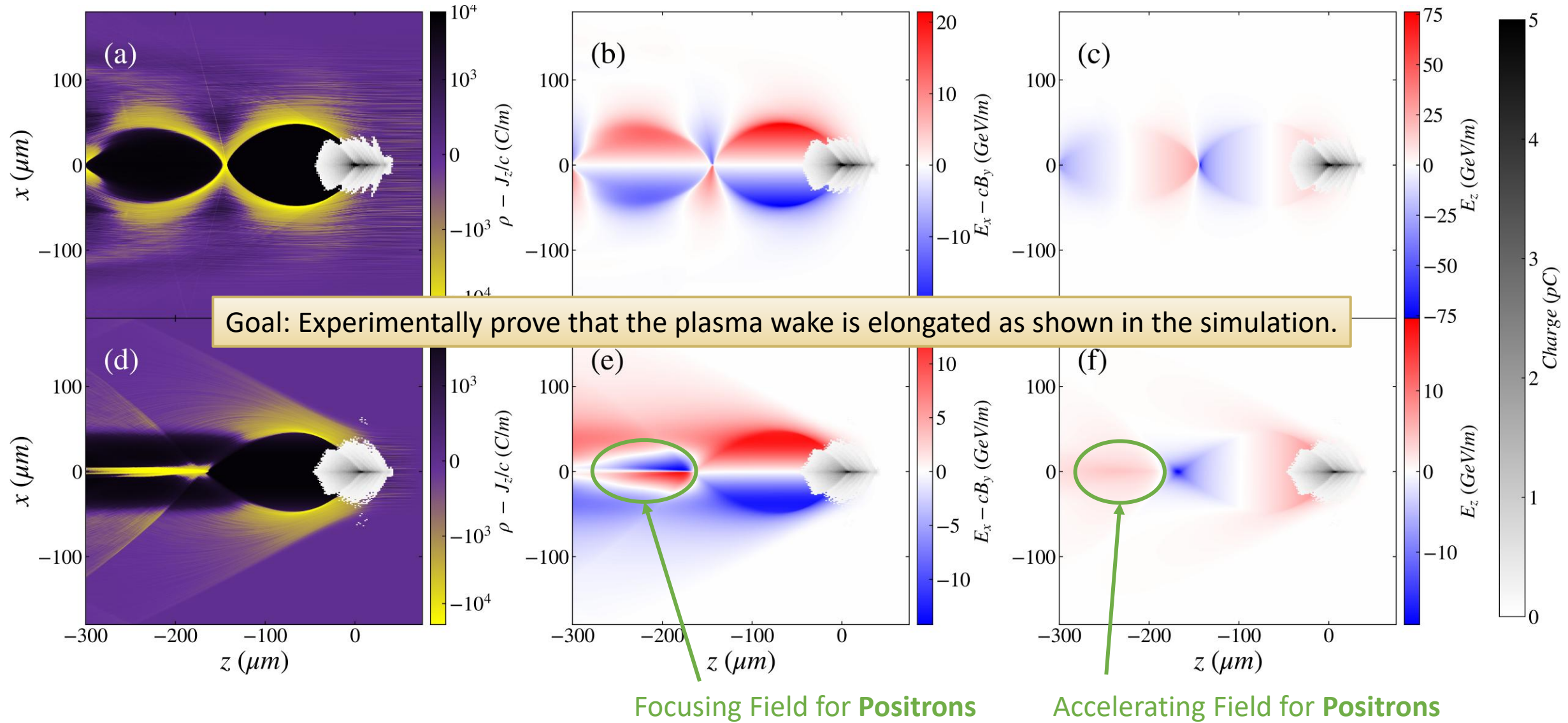


- E_w : Witness energy, calculated by fitting the witness beam using a Gaussian profile
- $\sigma_{E,w}$: Energy spread, rms spread/ E_w
- Q_{tot} : from BPM3156, which is calibrated with TORO2452 (can be noisy)
- Drive/witness ratio: SYAG brightness
- Incoming drive/witness charge: $Q_{tot} * \text{Drive/witness ratio}$
- Visible witness charge: charge above 10.4GeV
- $Q_{cap,w}$: Witness beam charge capture, visible witness charge /incoming witness charge
- η_{tot} : Total efficiency, drive energy gain/ (incoming drive charge*10GeV)

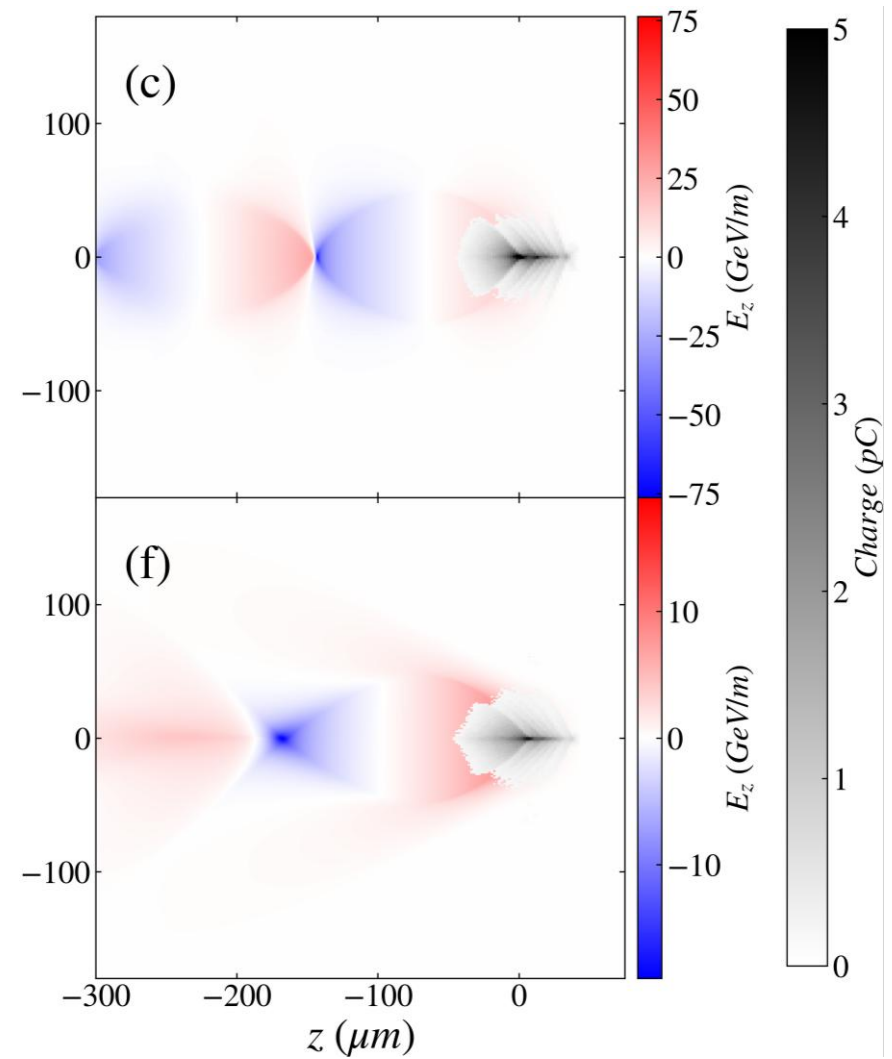
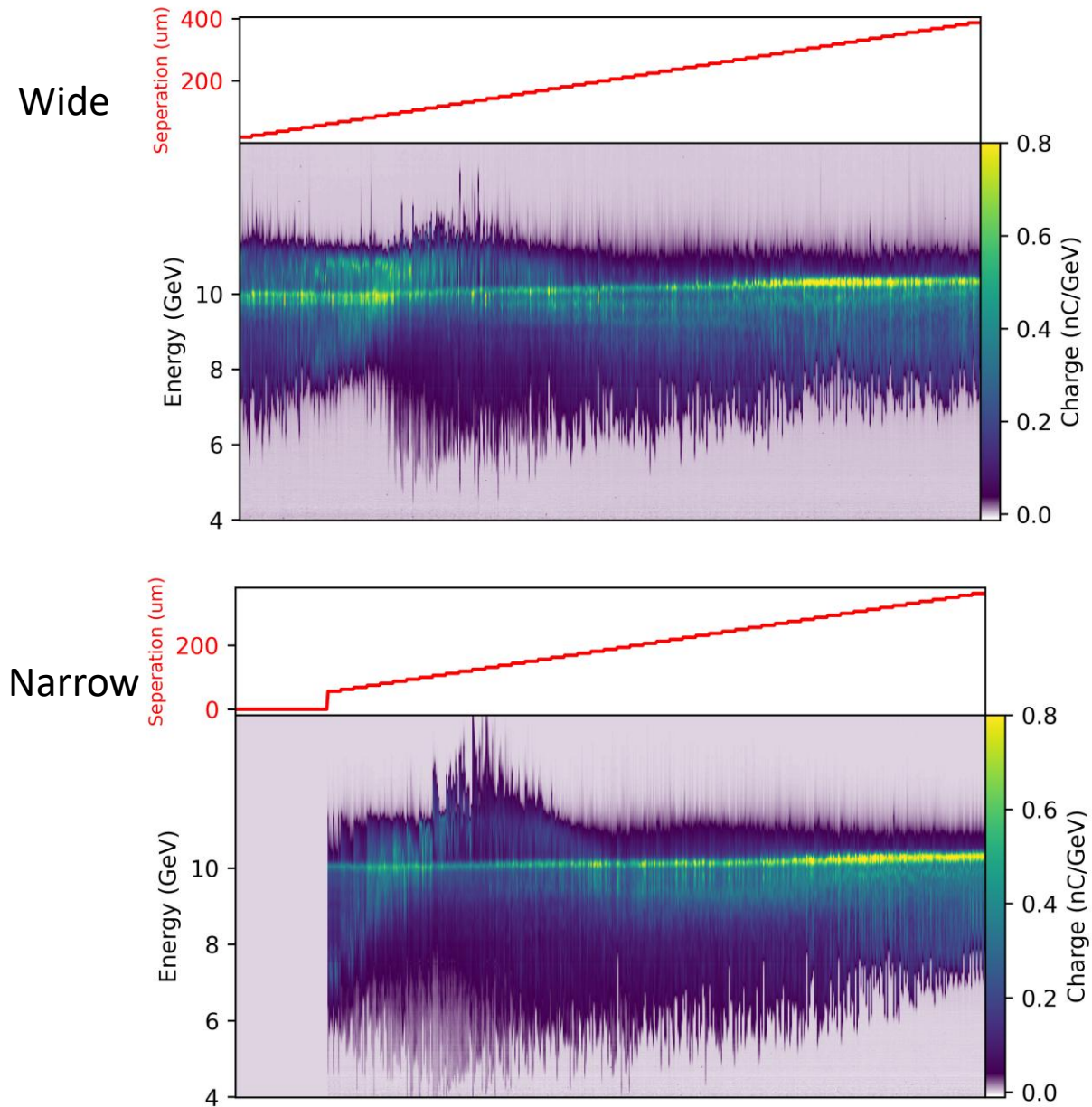


- Process all dataset
- Be careful about SYAG charge calibration
- Re-do CHER energy/charge calibration (currently using the calibration data taken 3 weeks before the experiment)
- Compare with drive only data (we only have a limited number of shots, might not find matches)

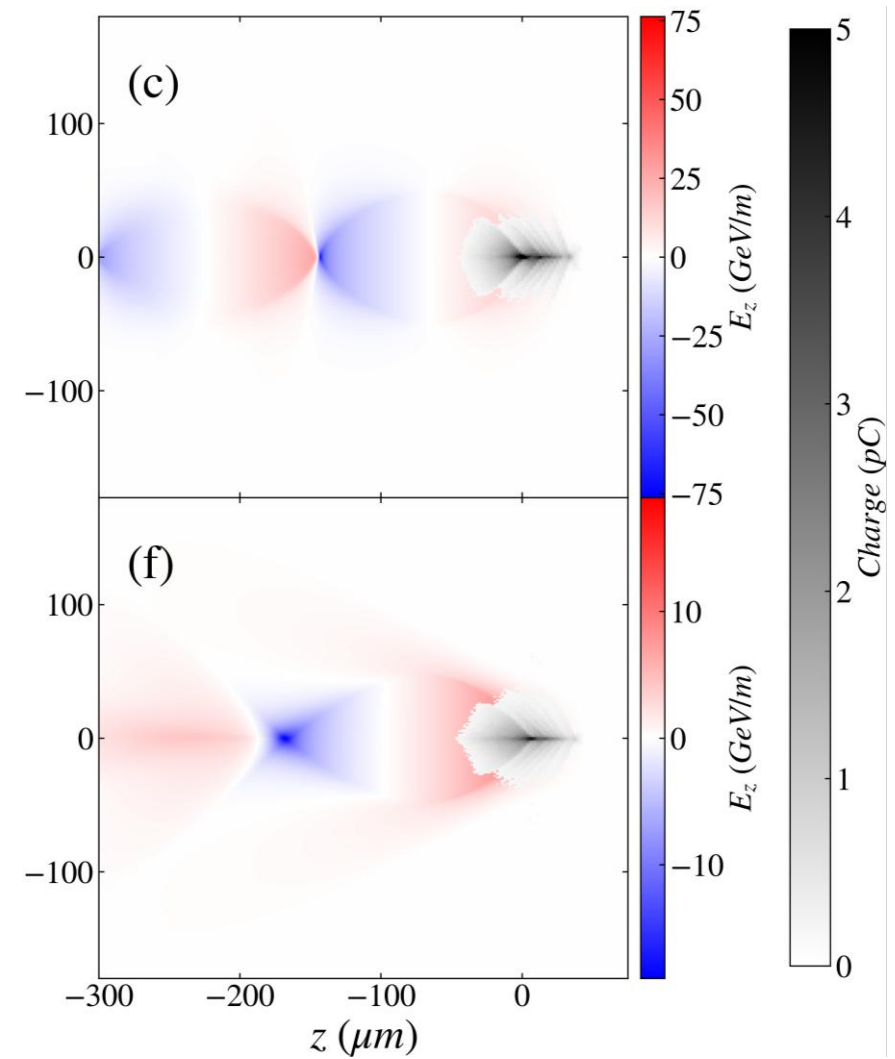
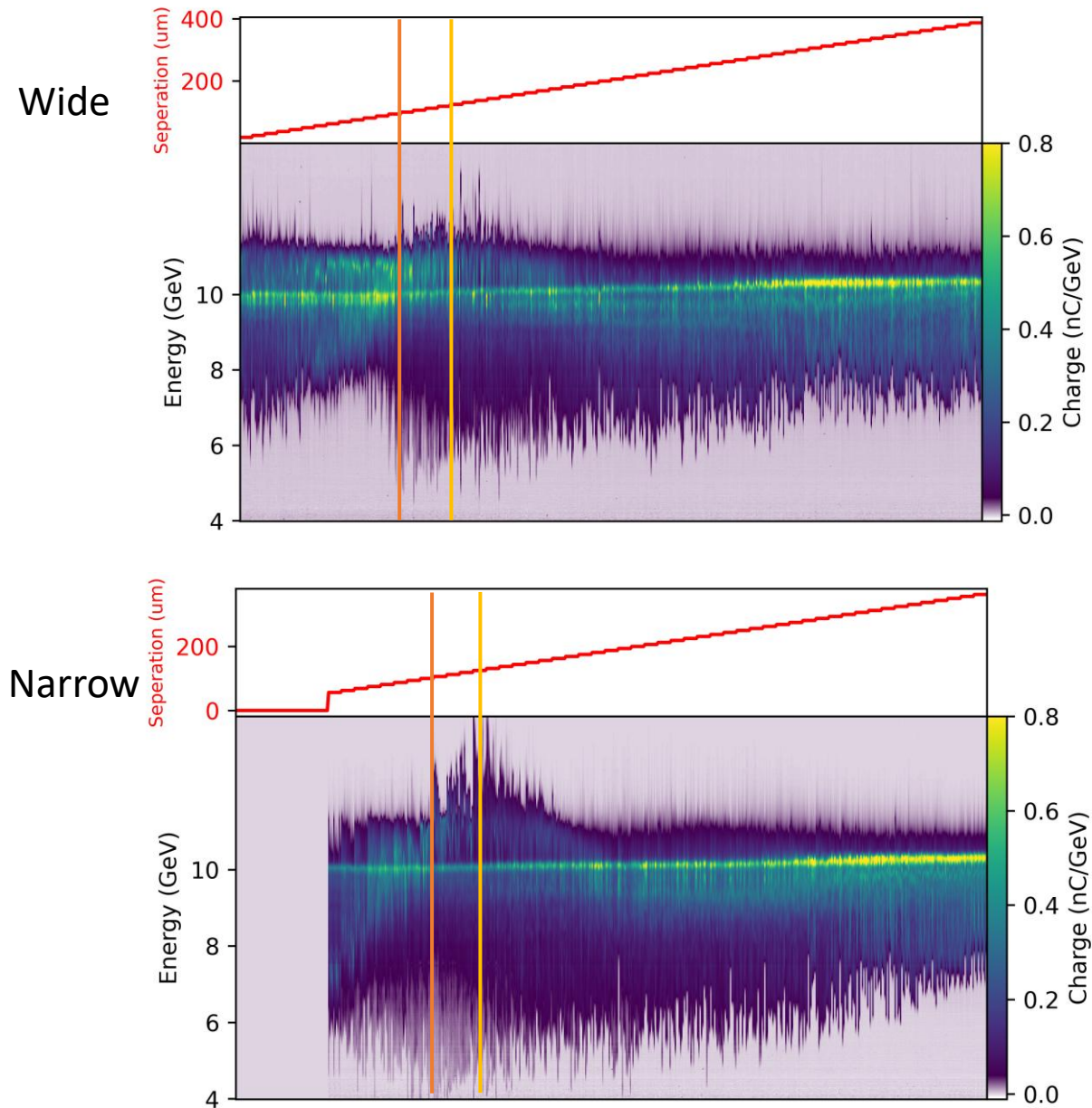
E333 High-level Scientific Goals



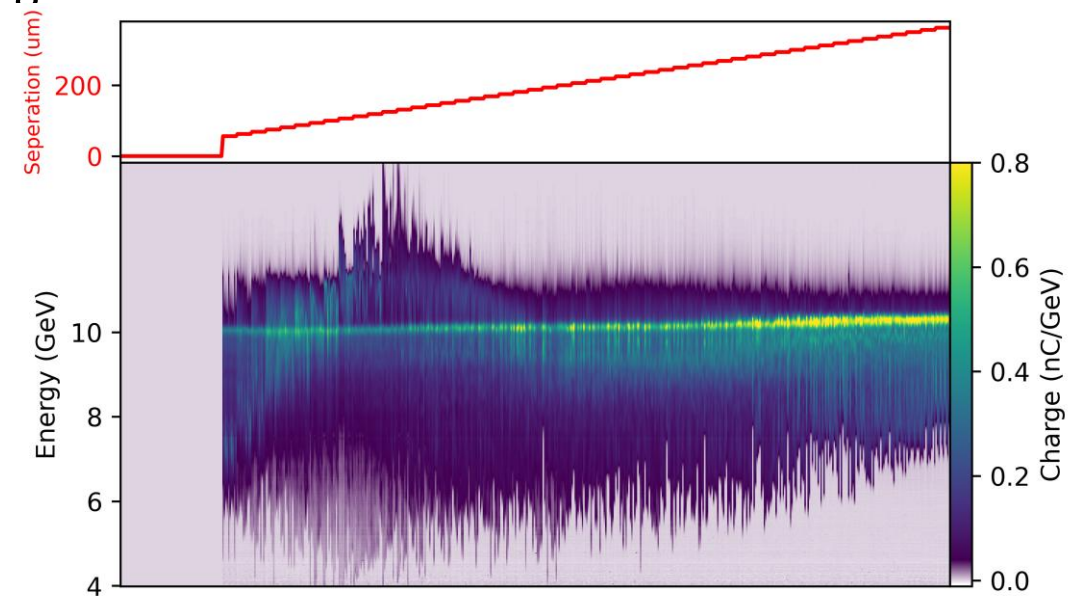
FY25 Results – Elongated Wake



FY25 Results – Elongated Wake



- Update data selection method and create a cleaner result
- Better define various longitudinal regime with corresponding longitudinal wake
- Apply updated E301 calibration
- Examine missing charge to define the defocusing regime between the first and second wake
- Understand different behaviors of the acceleration charge in wide and narrow plasma



- “Drive beam depletion with multi-Joule energy transfer in a plasma wakefield accelerator” PRAB, final editing stage
- “Alignment Method and Tolerance of a Plasma Wakefield Accelerator in a Laser-ionized Plasma Source” PRAB, final editing stage
- “First Experimental Measurement of the Plasma Wake Structure in a Narrow Plasma Column” PRL, perfecting data analysis
- “TBD” (A paper presenting the E301 PWFA result focusing on being the first high quality PWFA in a laser-ionized plasma source) PRL(?), PRAB, perfecting data analysis

Questions?

Drive/Witness Ratio from SYAG

