E304 Progress, Status and Plans for first Experiments

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on behalf of the E300 Collaboration

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Science goals: definition of success and target time for each goal

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E304: generate low emittance beams using downramp trapping in PWFA

Year 1-2

Demonstrate downramp trapping

- Driver significant energy loss
- Evidence of injection (charge excess)
- trapped electron signal on the dump table

Year 2-3

Systematic study of the injection

- E>1 GeV to make the beam to the dump table
- Make emittance measurements using laser/ beam ionization
- Reach the limit of the diagnostic (>1 μm)

Year 3

Generate measure ultralow emittance beams

- Measure ultralow emittance (<1 μm)
- E>1 GeV
- $\delta E/E<\sim 1\%$
- $\varepsilon_n<\sim 1\ \mu m$
- $I>\sim 5$ kA

Experimental timeline

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- Experimental design: Dec, 2020 for the first run
- Installation plan: E305 will install the apparatus, E304 will only need to change nozzles
- Ready for experimental safety review: review docs submitted
- Ready for commissioning: Anytime after installation
  - Beam requirements: E=10 GeV, $\sigma_r < 20\ \mu$m, $\sigma_z <\sim 30\ \mu$m, $\varepsilon_n < 20\ \mu$m, Q > 1 nC (I > 4 kA)
- first science: demonstrate injection and understand emittance dependence on the driver/plasma parameters
  - Beam requirements: E=10 GeV, $\sigma_r \sim \sigma_z < 10\ \mu$m, $\varepsilon_n < 10\ \mu$m, Q>1 nC (I>12 kA)
- 2nd phase of the program: generating ultralow emittance beams
  - Prerequisites: E=10 GeV, $\sigma_r \sim 4\ \mu$m β~5-10 cm (same as E300), $\sigma_z < 10\ \mu$m, $\varepsilon_n < 10\ \mu$m, Q>1 nC (I>12 kA)
  - Date: year 2 and 3 (2022-2023)

Experimental layout

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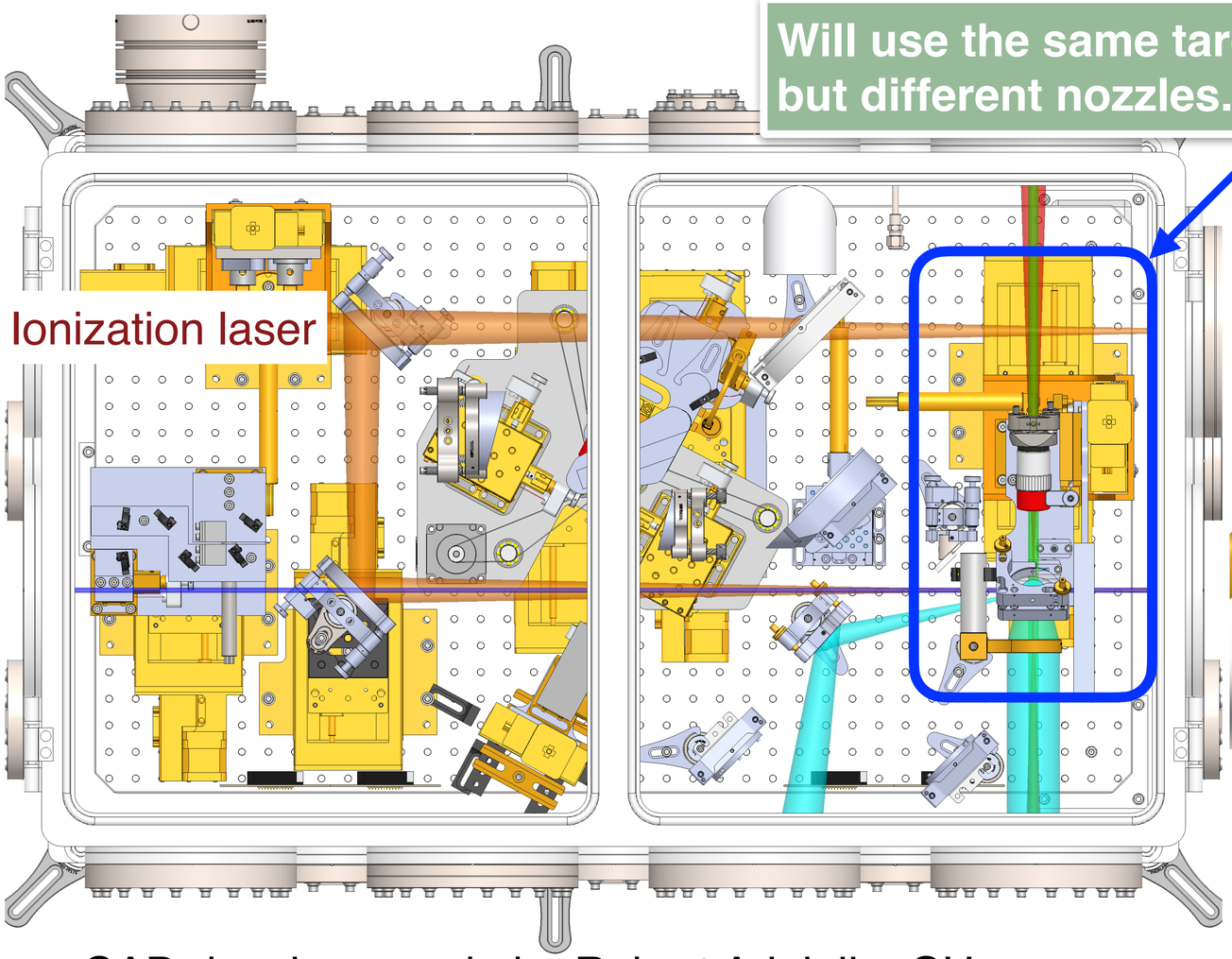
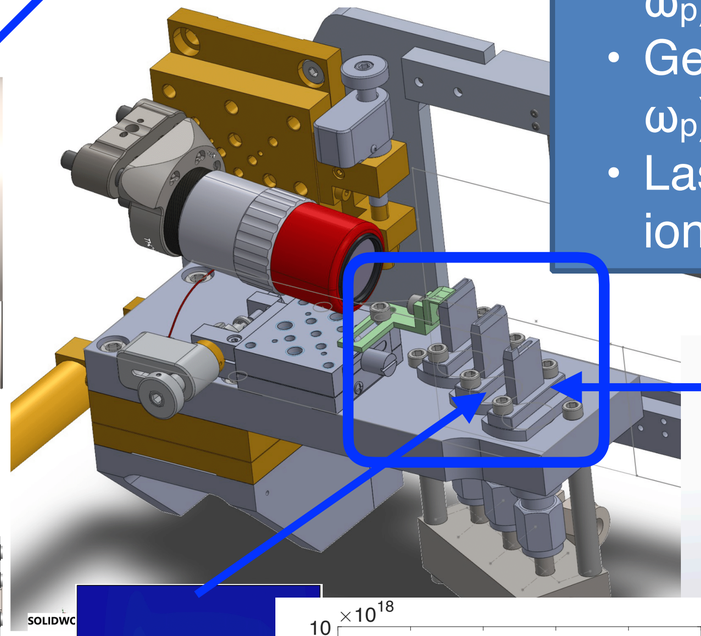
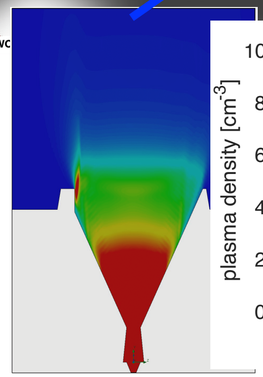
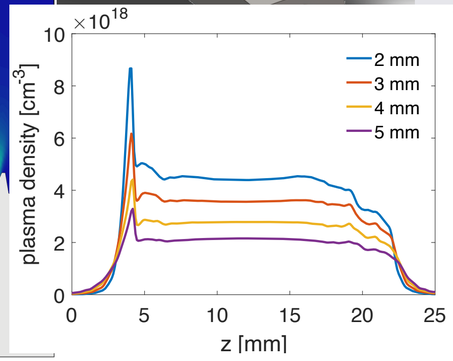


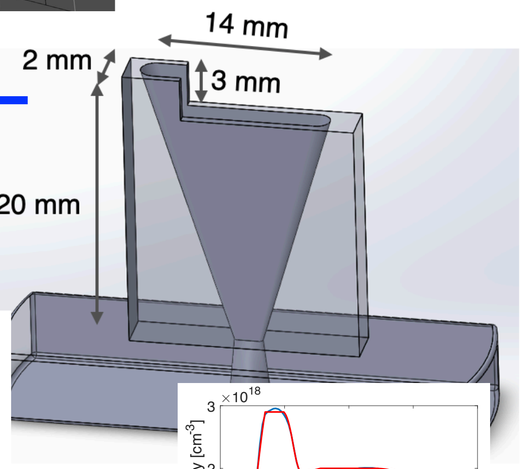
Will use the same target assembly as E305 but different nozzles.

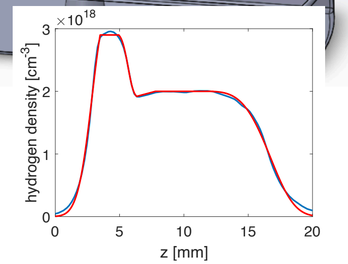
- E304 plasma source:
  - Sharp downramp (~10 c/ ω_p) by shock front
  - Gentle downramp (~100 c/ ω_p) by structured nozzle
  - Laser ionization & beam ionization











CAD drawings made by Robert Ariniello, CU

Diagnostics and observables

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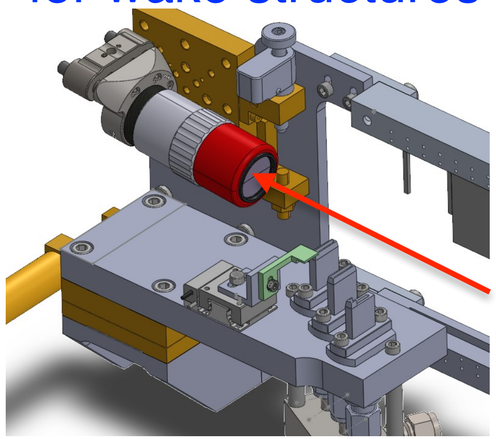
Driver

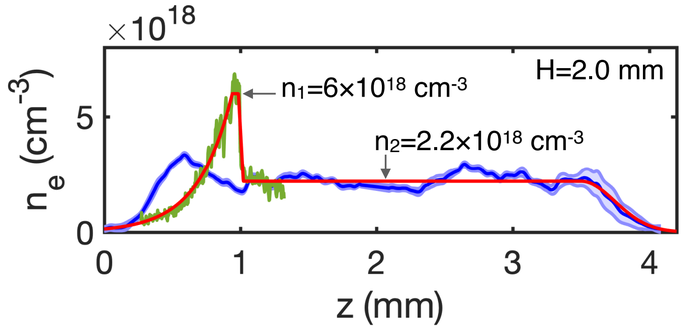
- Same as E300
- EOS-BPM
  - Bunch length
  - Charge
  - Position

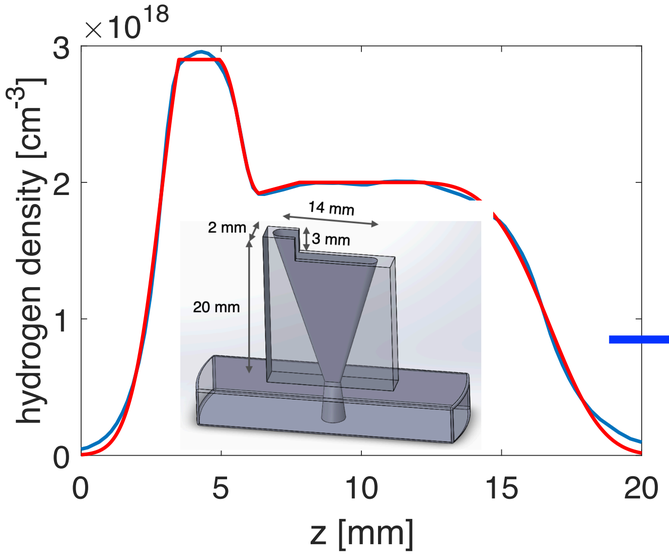
- Online shadowgraphy for wake structures



Plasma source

- Offline calibration of the density profile before installation

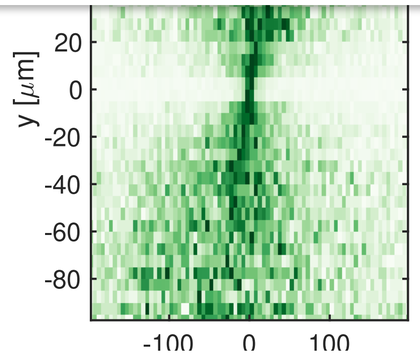


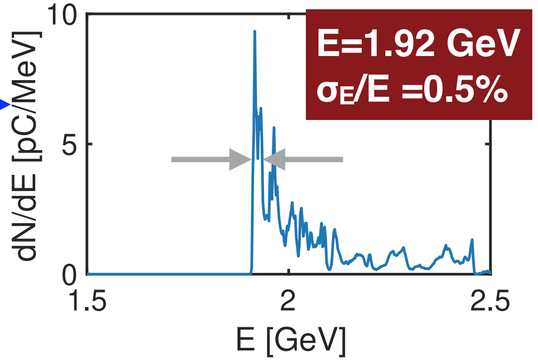


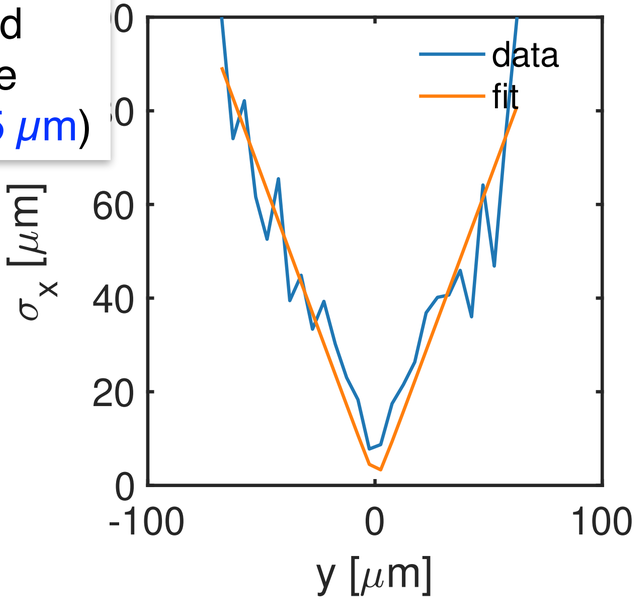
Injected bunch

- Imaging spectrometer for characterizing the energy, charge and emittance of the injected bunch

The injected bunch is tracked from the IP to the dump table (DTOTR1 detector, σ_{reso}~4.5 μm)







Fit: $\varepsilon_n \approx 1.5$ μm; Simulation:
~1.7 μm (projected)
~0.5 μm (slice)

Potential future evolution of the experiment

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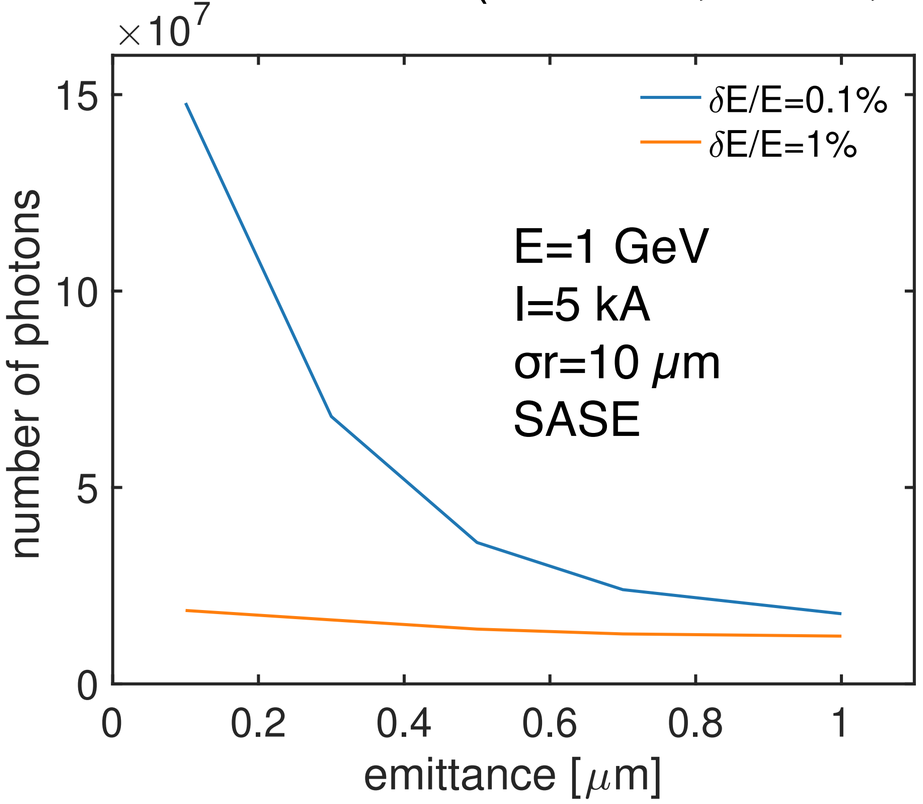
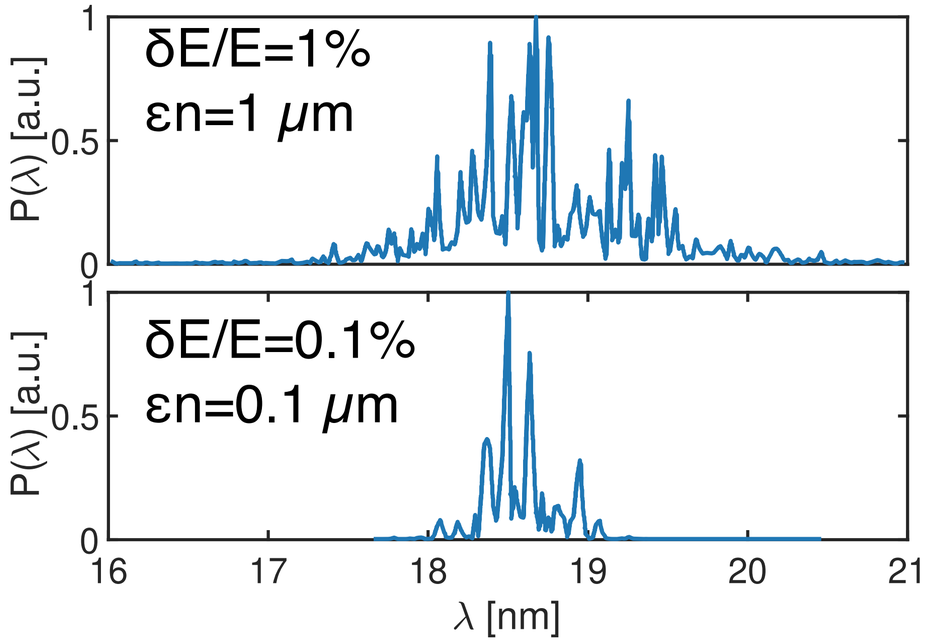
A short undulator as a potential diagnostic for ultralow emittance (year 3 and beyond)

Genesis simulation

A short (2 m) undulator as a beam characterization tool (λu=3 cm, K=2.8, N_{period}=66)





- Driver beam radiates at different wavelength (E>7 GeV, εn>5 μm, δE/E~1%)

Desired facility upgrades

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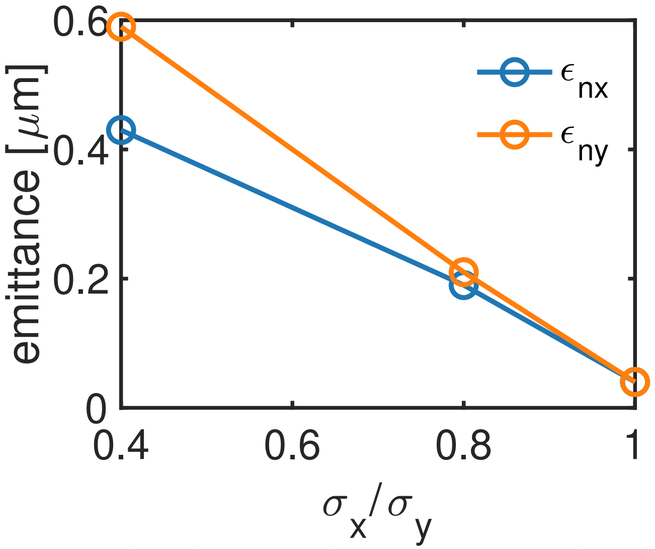
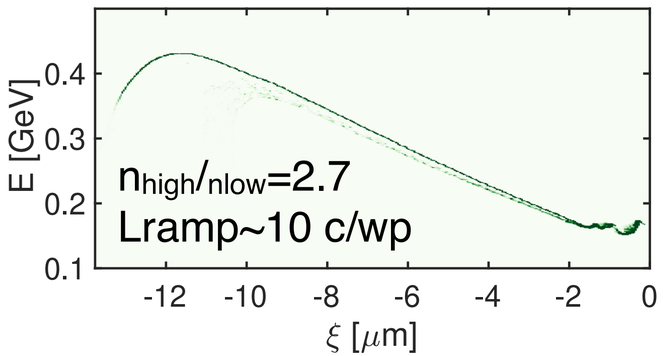
The items listed here do not affect the proposed E304 experimental plan;
But they will provide more controllability and diagnostics for future upgraded experiments;

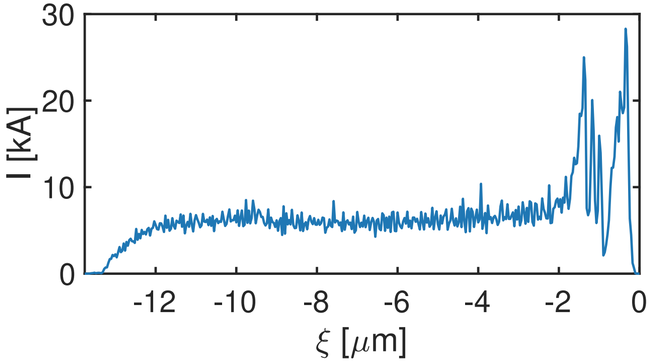
- Ability to deliver and characterize round beams at IP (critical for generating beams with tens of nm emittance) (year 2 and 3)
- A short undulator after the picnic basket as a emittance diagnostic (year 3 and beyond)
- Downstream deflecting cavity for characterizing the longitudinal phase space of the injected bunch (year 3 and beyond, or use other novel methods)



Asymmetric driver leads to emittance increase

A sharp downramp is capable of generating bunches with large linear chirps.





Collaborations

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X. Xu, M. Hogan, V. Yakimenko, FACET-II staff

Sebastien Corde's group

Mike Litos' group

Thank you for your attention