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E305 summary: filamentation instability

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on behalf of E305 collaboration
July 10, 2026

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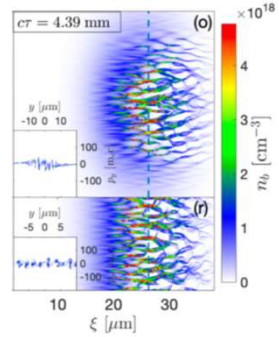
E305 recap/scientific goals

What are we trying to do?

Obtain clean observations of **beam-plasma instabilities** in a pressure scan showing transition from:

- Plasma lensing (affect Twiss parameters, but not much energy loss/gain) at the lowest pressures (less than 10 psi)
- **PWFA** with energy loss/gain (sub-GeV) at intermediate pressures (tens to hundreds of psi)
- Linear regime and **filamentation** (suppression of energy loss/gain and gamma rays) at highest pressures (thousands of psi)



P. San Miguel Claveria et al., **PRR** 2022

E305 recap/scientific goals

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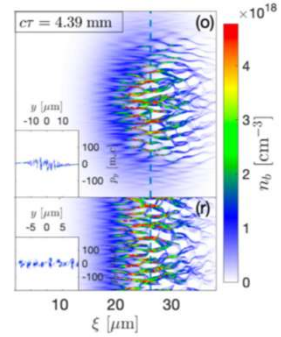
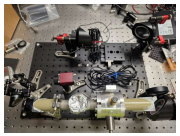
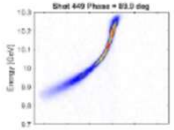


P. San Miguel Claveria et al., **PRR** 2022

What was implemented in the spring 2026 shifts?



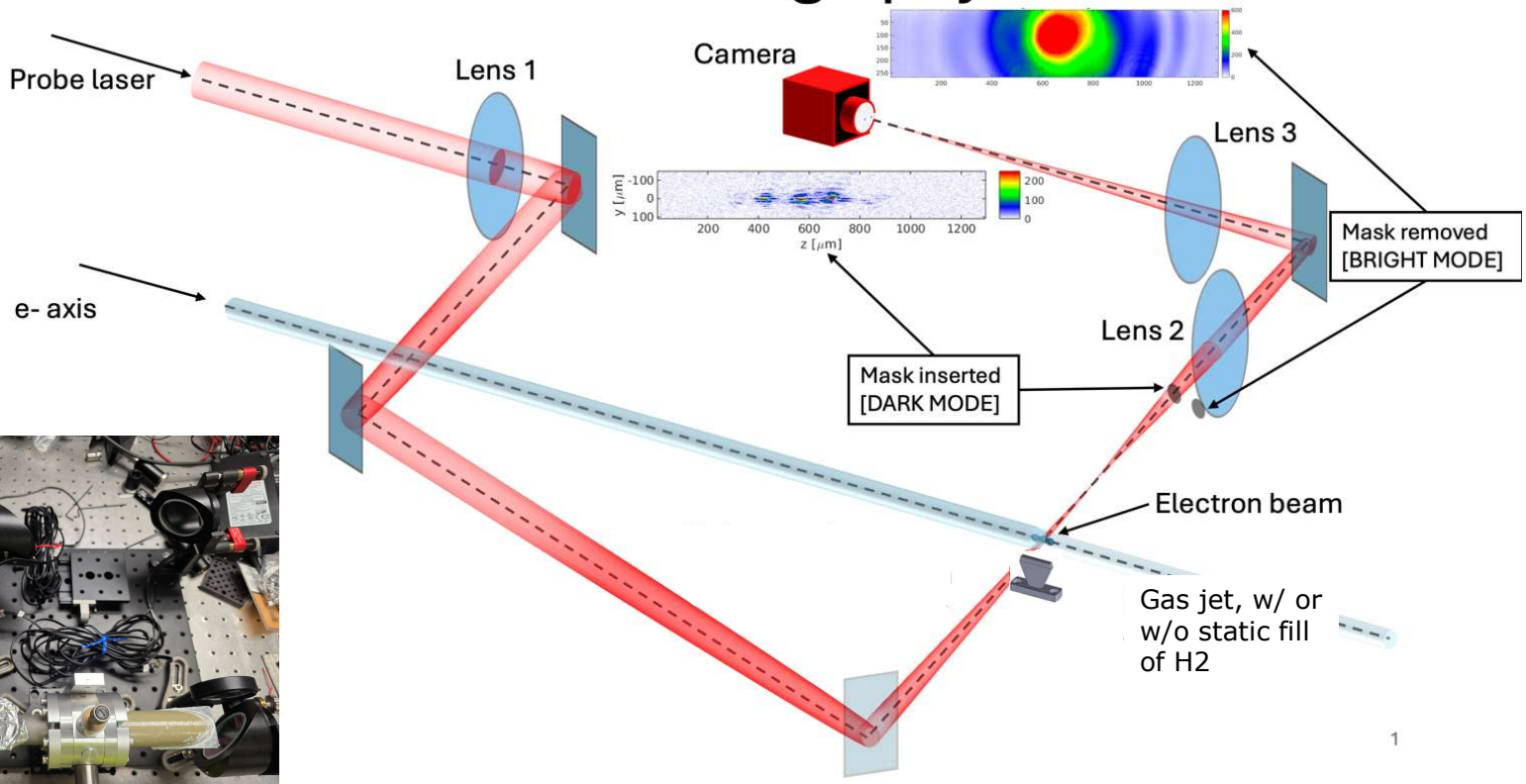


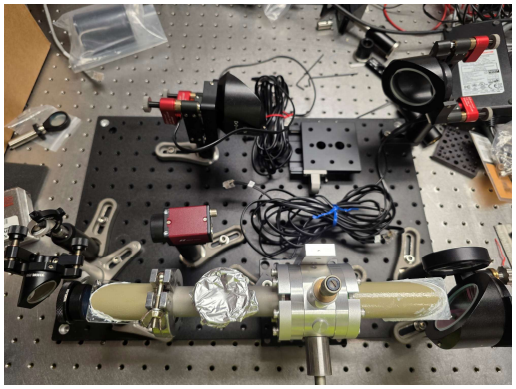
- 2cm nozzle with 0.5mm width – close to highest density
- **Dark-field shadowgraphy**, same setup as E340
- First time using clean chirped electron beam; correlation between energy & longitudinal position

Dark-field shadowgraphy

+E305

E340: Dark-field shadowgraphy at SLAC





E305 2025/26 summary

E305 shifts March 2026

Results:

- **Successfully implemented** dark-field shadowgraphy

- **Parameter scan** studies: low to high gas jet pressure, residual pressure (self-focusing), laser/beam ionization, etc; observation of **spatial modulations**

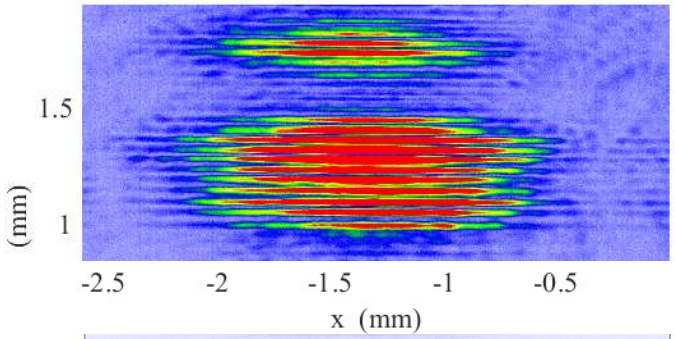
- Preliminary DTOTR beam spectra & divergence analysis; **head-to-tail** dynamics identified

Shadowgraphy results

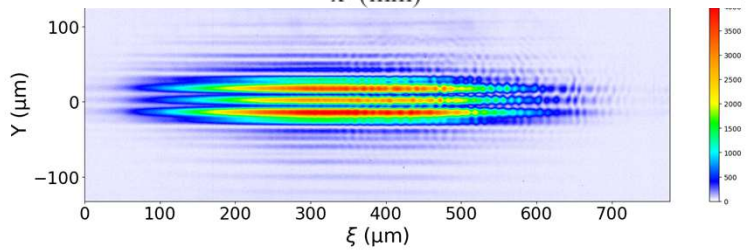
Shadowgraphy results

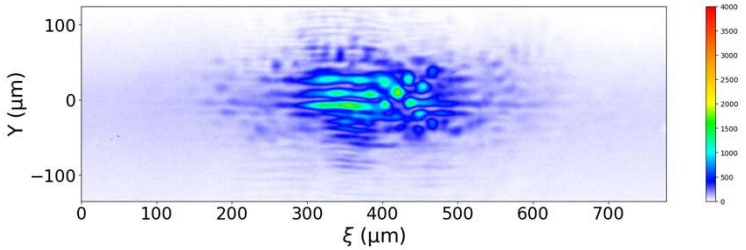
Beam propagates to the left

Laser ionized

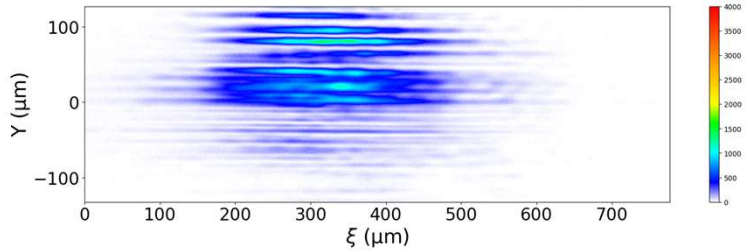


Beam ionized



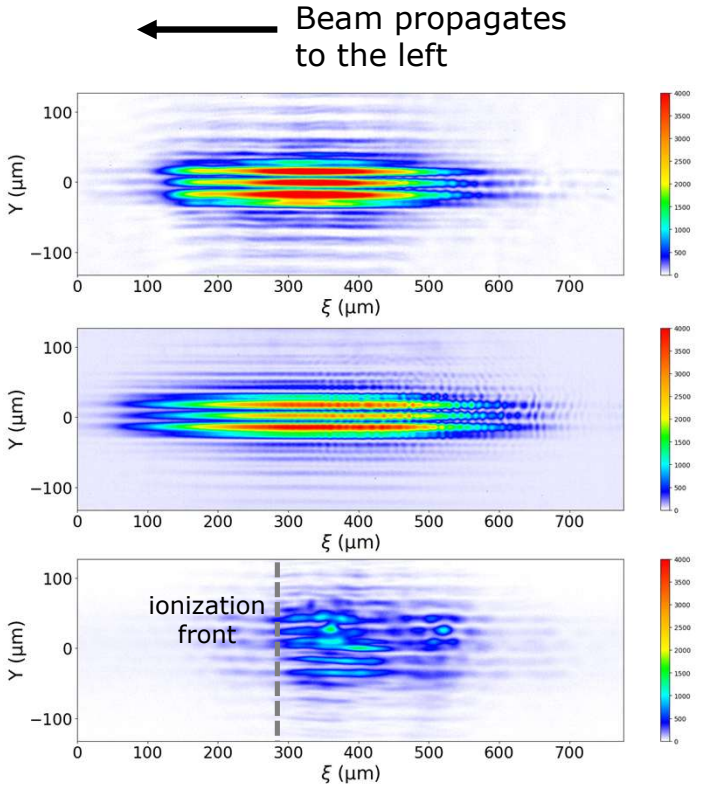


Laser+beam



Shadowgraphy results

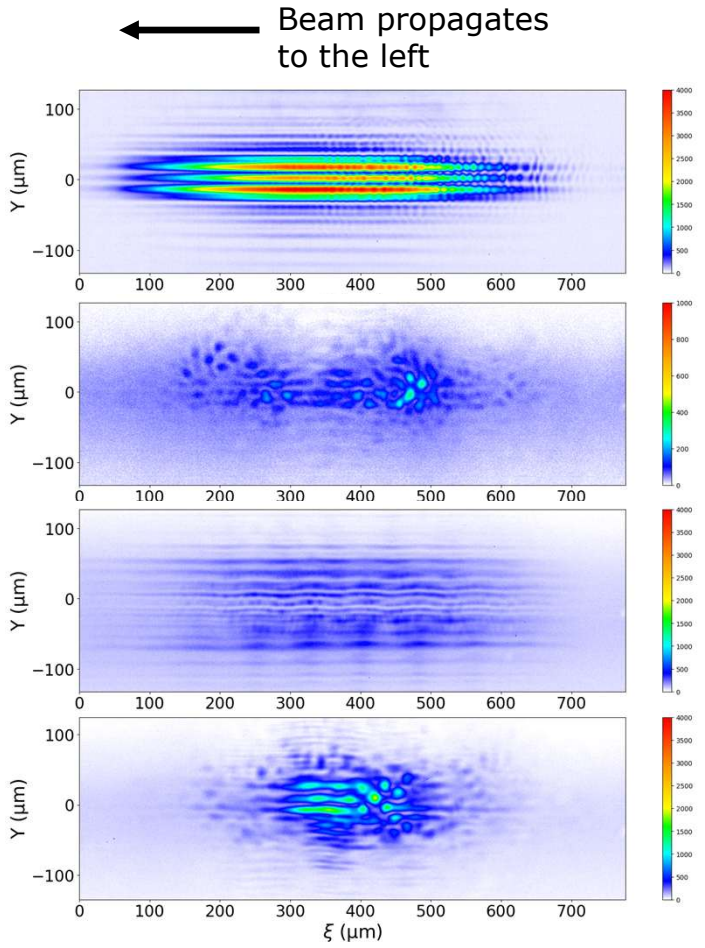
Beam-ionized plasma: three regimes identified



Gas pressure	residual pressure
100 psi	(not determined)
1200 psi	0.3 torr
1200 psi	0 (one shot every 30s)

Beam position (ionization front) was observed but not tracked for all shots; would hugely benefit from **better EOS2 timing**

Beam tuning



BC11	BC14	Residual
7500	15000	0.3 torr
5500	15000	0.3 torr
4500	20000	0.3 torr
3500	10000	0

Sensitivity to beam parameters

More systematic studies needed to understand drivers of instability

DTOTR density scan analysis

Density scan analysis

Courtesy: Pablo

Plasma density scan (laser-ionized H_2):

- gas jet height: 0.5mm – 30mm from beam axis
- gas jet backing pressure: 1200-100 psi

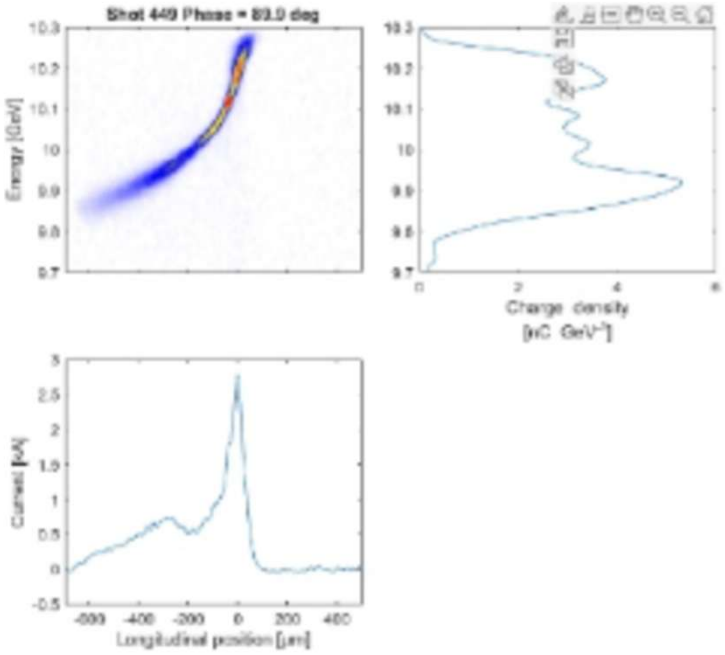
- No residual backing pressure (1shot/30s)

Chirped long beam:

- 500um long beam
- High energies at front
- Low energies at the rear

DTOTR2

- Energy-resolved divergence
- Spatiotemporal measurement



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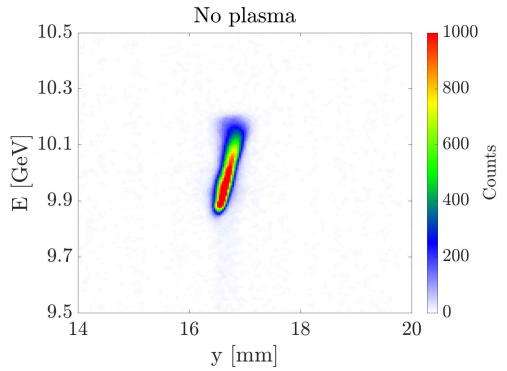
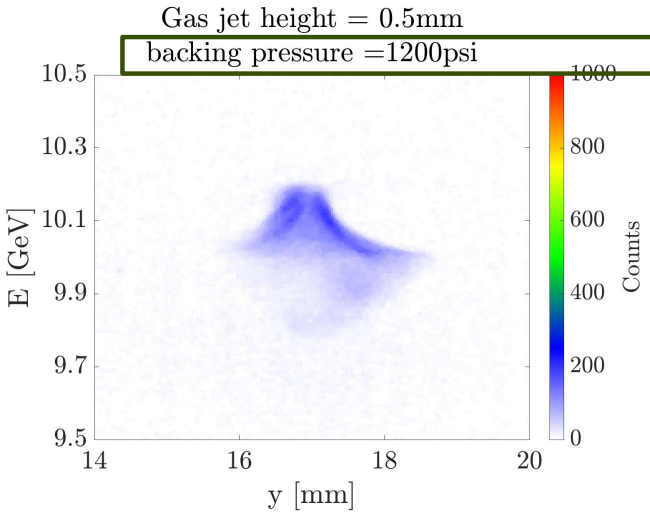
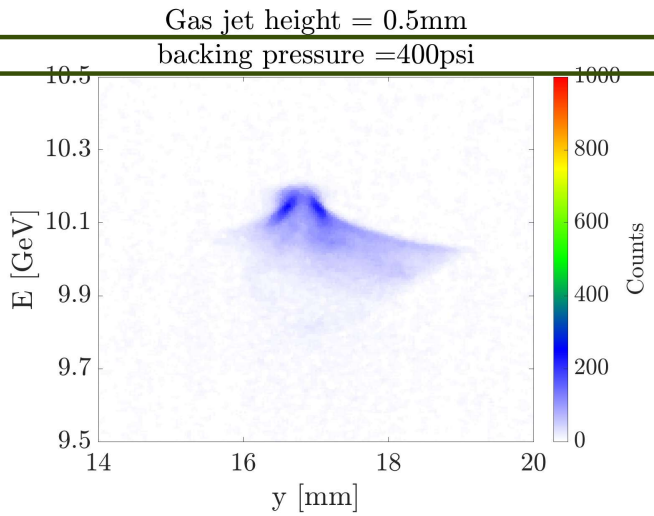
Plasma density scan (laser-ionized H_2):

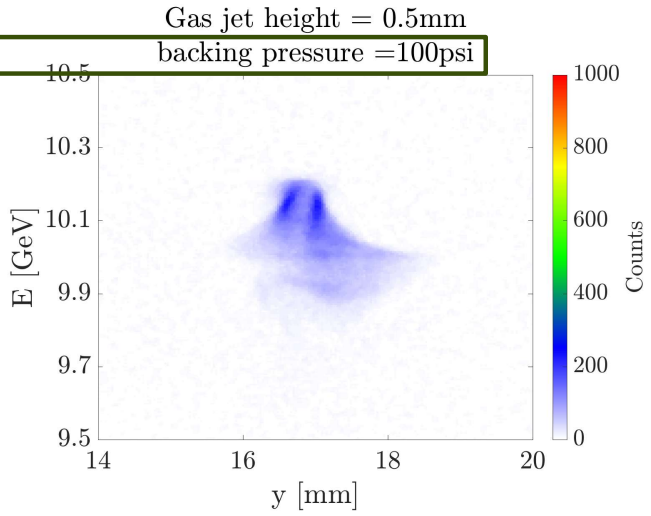
DTOTR2 raw images

(Calibration still preliminary)









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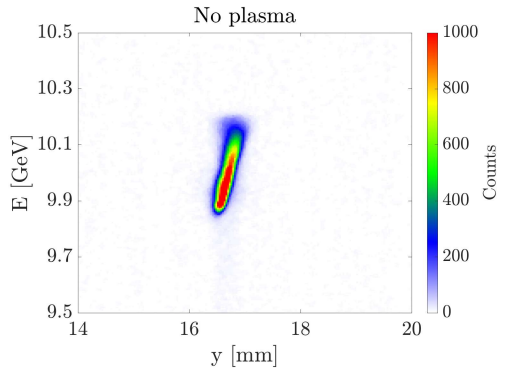
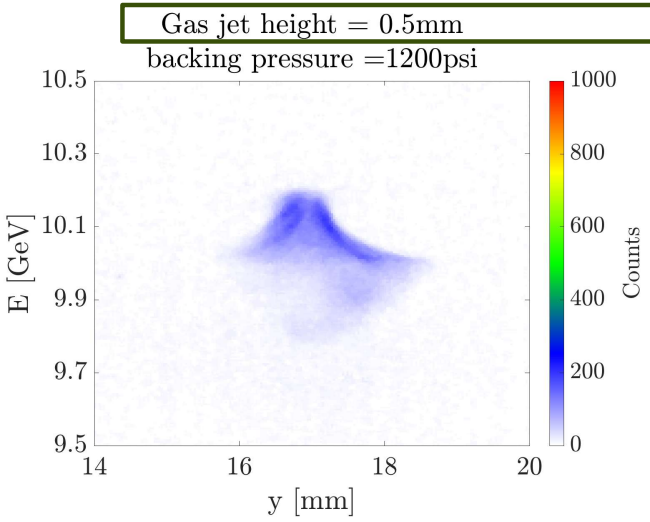
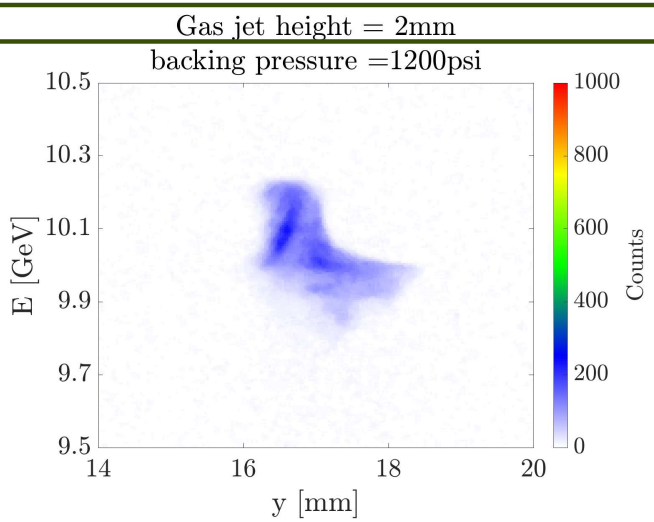
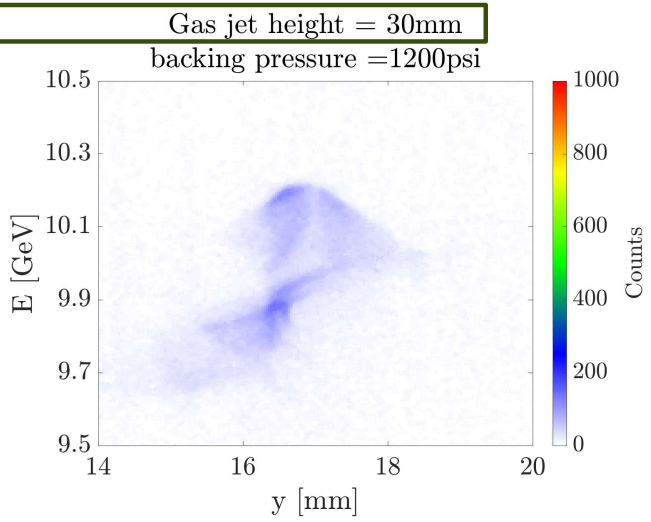






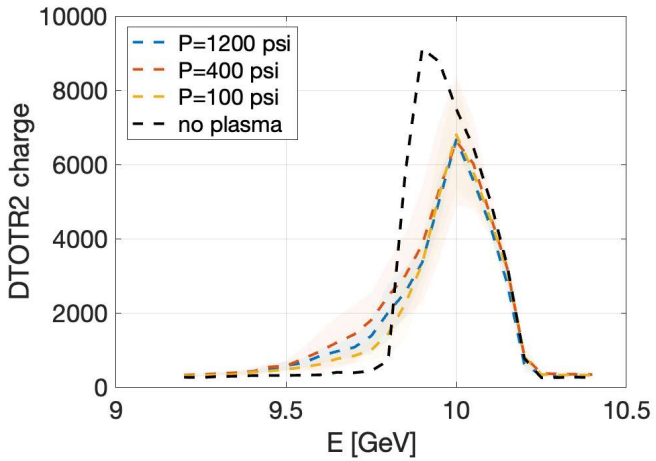


Density scan analysis

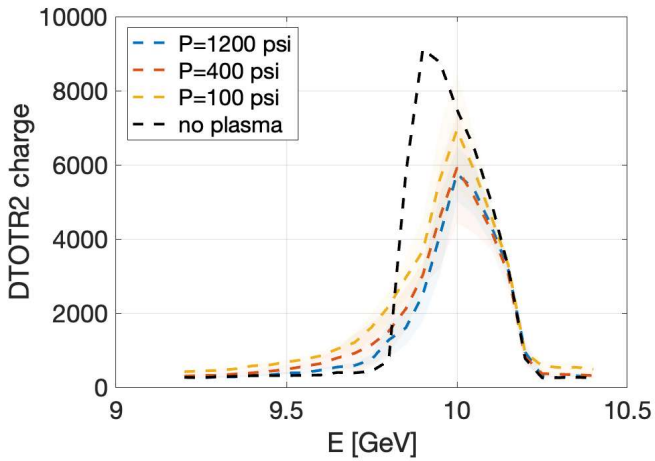
Courtesy: Pablo

DTOTR2 electron spectra & charge loss

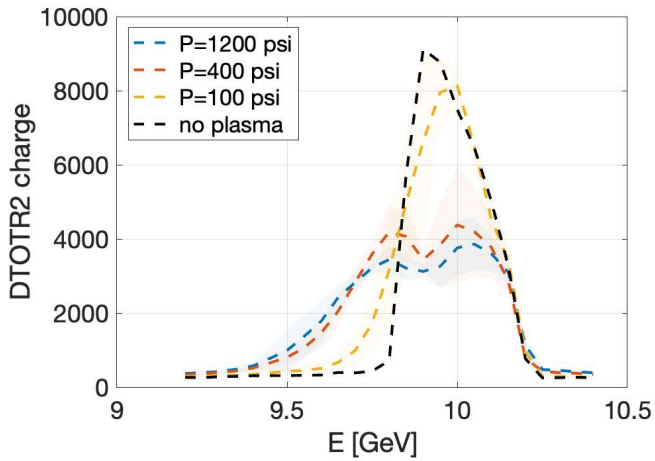
Gas jet height: 0.5 mm



Gas jet height: 2 mm



Gas jet height: 30 mm

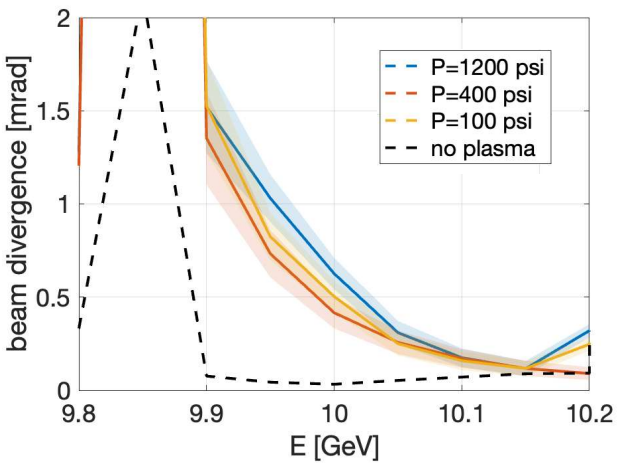


Density scan analysis

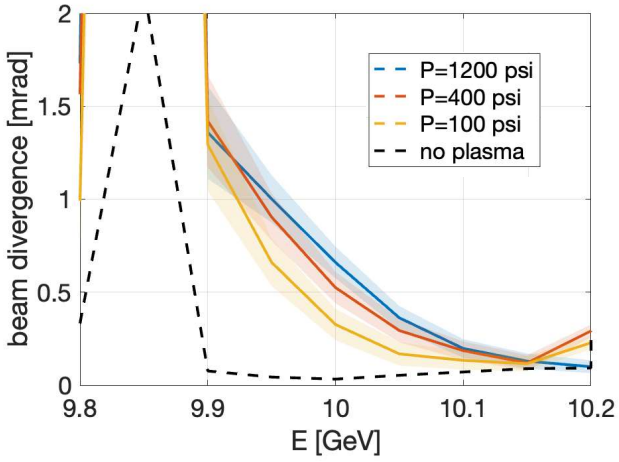
Courtesy: Pablo

DTOTR2 Energy-resolved divergence

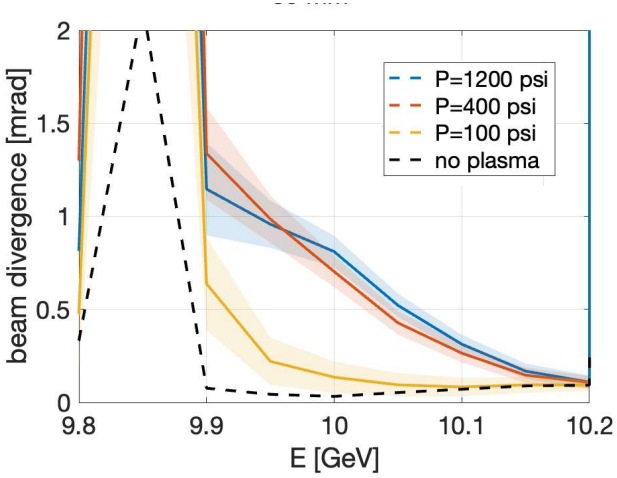
Gas jet height: 0.5 mm



Gas jet height: 2 mm



Gas jet height: 30 mm



Strong divergence correlation with energy (in chirped beam: from **head to tail**; no so strong correlation with plasma density)

Summary & outlook

What goals can we achieve for FY27 run for high-profile publication?

- Improved **timing scans** to gain precise information of beam position (achieved in June E340 shifts)
- Distinguish between two types of instability mechanisms:
  - **Pure plasma instabilities**: energy deposited by the beam turns plasma unstable; **temporal** dependence but **not on propagation distance**
  - **Beam-plasma instabilities**: clear evidence of **growth during propagation**
- Understand what is driving growth of beam divergence; **beam divergence sensitivity to instabilities**

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What to be implemented for these runs:

- Shorter slit nozzle (higher density) and probe from start to end of gas jet
- More systematic parameter scans: timing, probe position, pressure
- More extensive with simulation (in progress)

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Thank you!

Questions …

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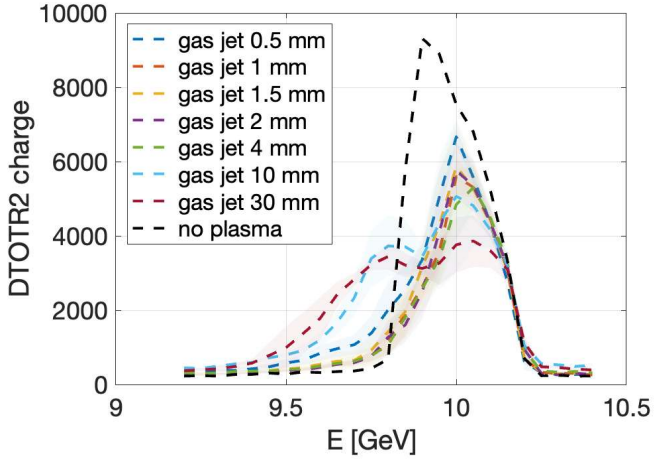
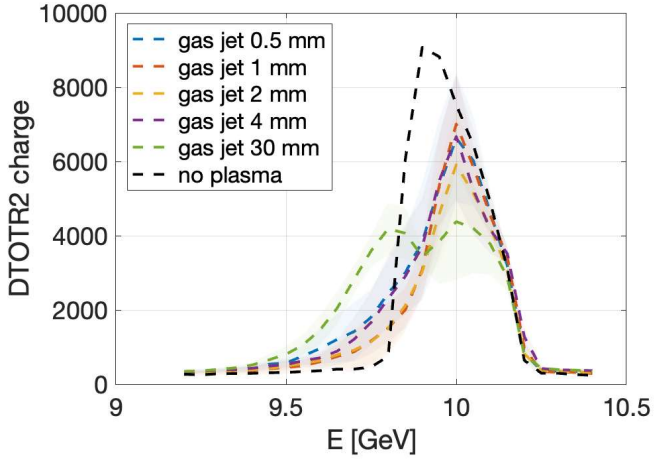
Density scan analysis

DTOTR2 charge loss (bis)

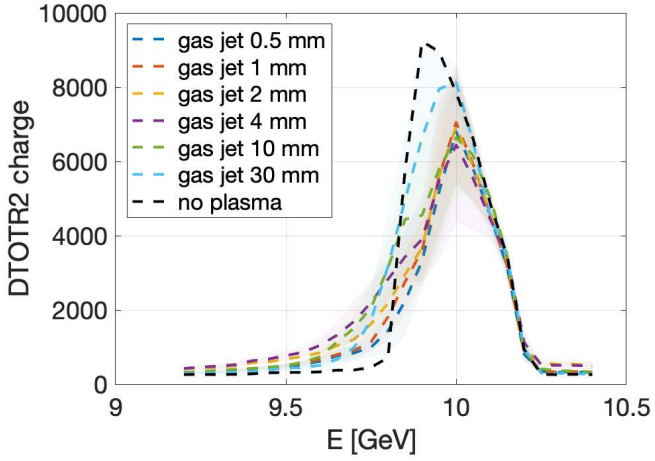
Gas jet pressure: 1200psi



Gas jet pressure: 400psi

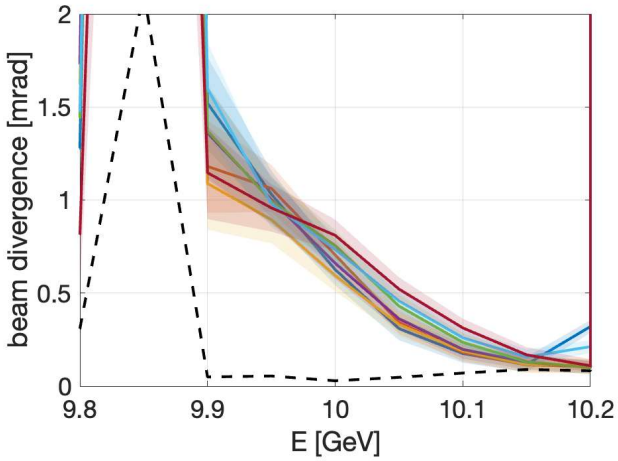


Gas jet pressure: 100psi

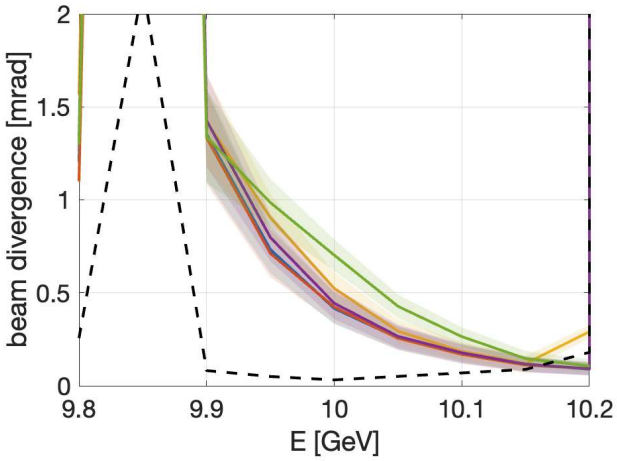


DTOTR2 Energy-resolved divergence (bis)

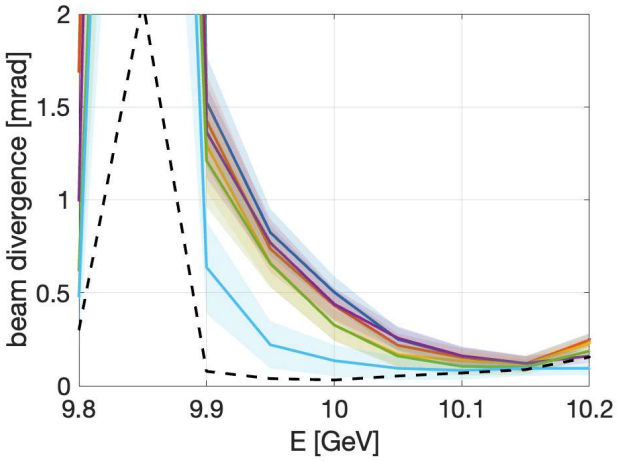
Gas jet pressure: 1200psi



Gas jet pressure: 400psi

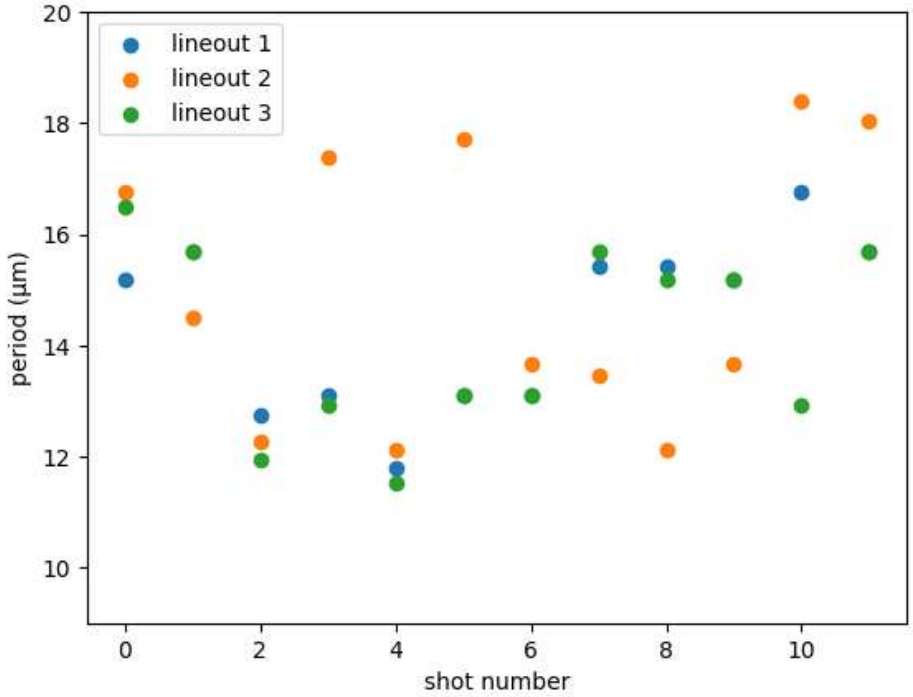


Gas jet pressure: 100psi



Modulation periods

100 psi



1200 psi