X-2 ION-MOTION EXPERIMENT (ARD NOV 12–15)

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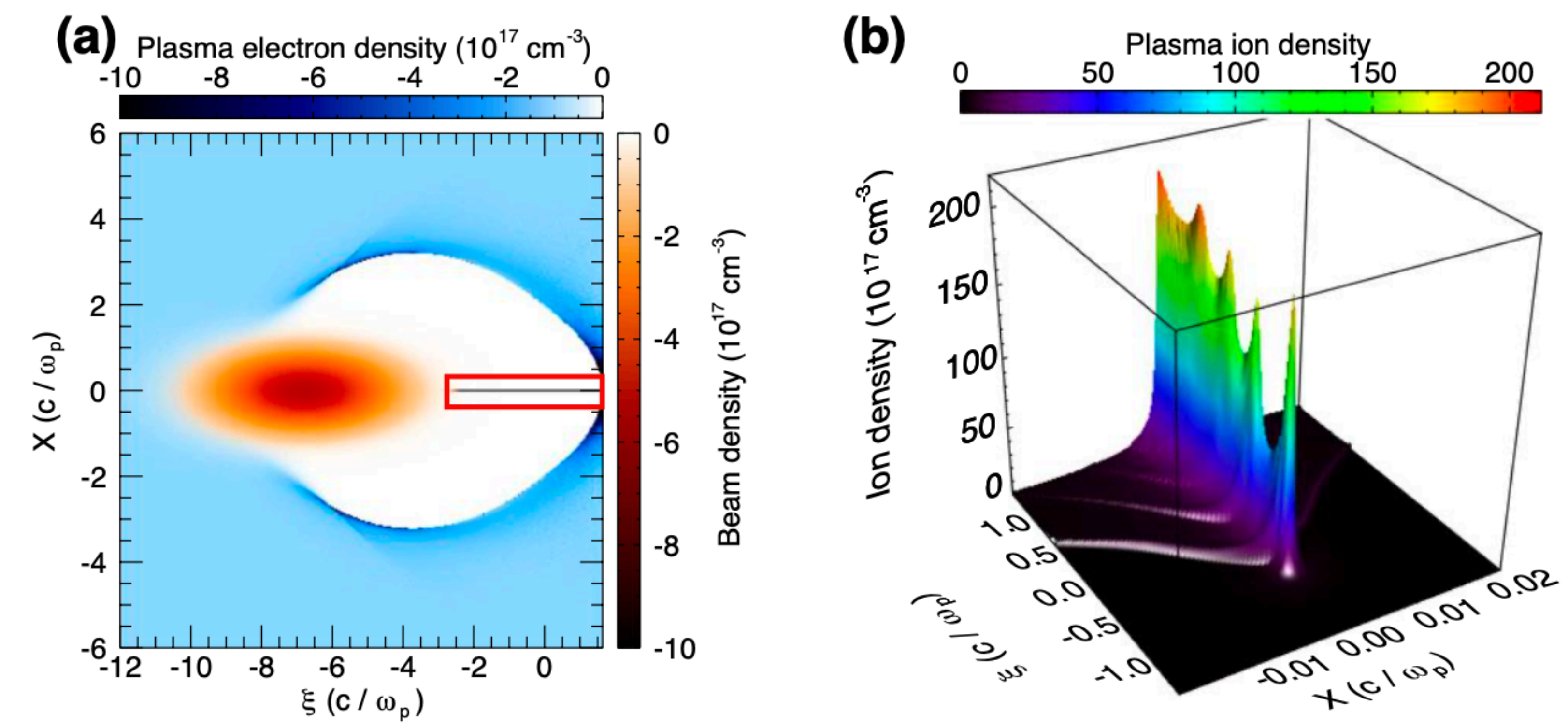
Planned experiment for the ARD shift Nov 12–15

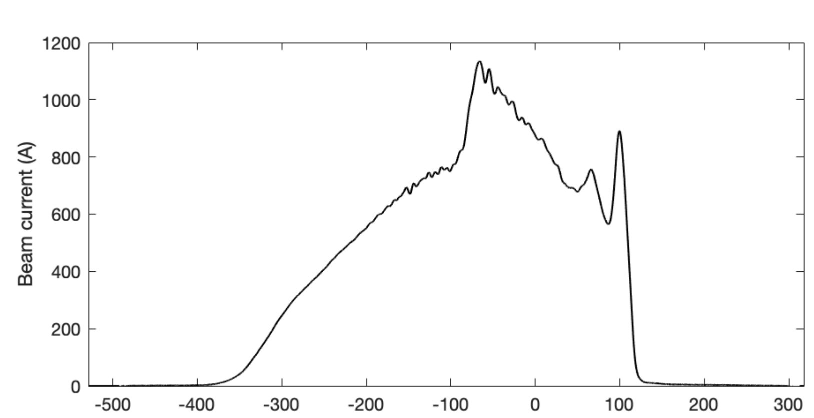
- What: **Observe emittance growth due to ion motion inside the plasma cavity.**
- Why?
  - An on-axis ion spike gives nonlinear focusing fields, resulting in emittance growth.
- How?
  - Using a tightly focused beam (semi-matched)
  - Hydrogen plasma
  - Argon plasma (as a control; expecting no ion motion)
  - Observable: emittance vs. energy gain (a proxy for the z-location)
    - *(object plane scan for different energies on a spectrometer)*
- Big question: Can it be done at FLASHForward?
  - Using Rosenzweig's ion-phase-advance formula: maybe…
  - Severin performed HiPACE++ simulations to check.



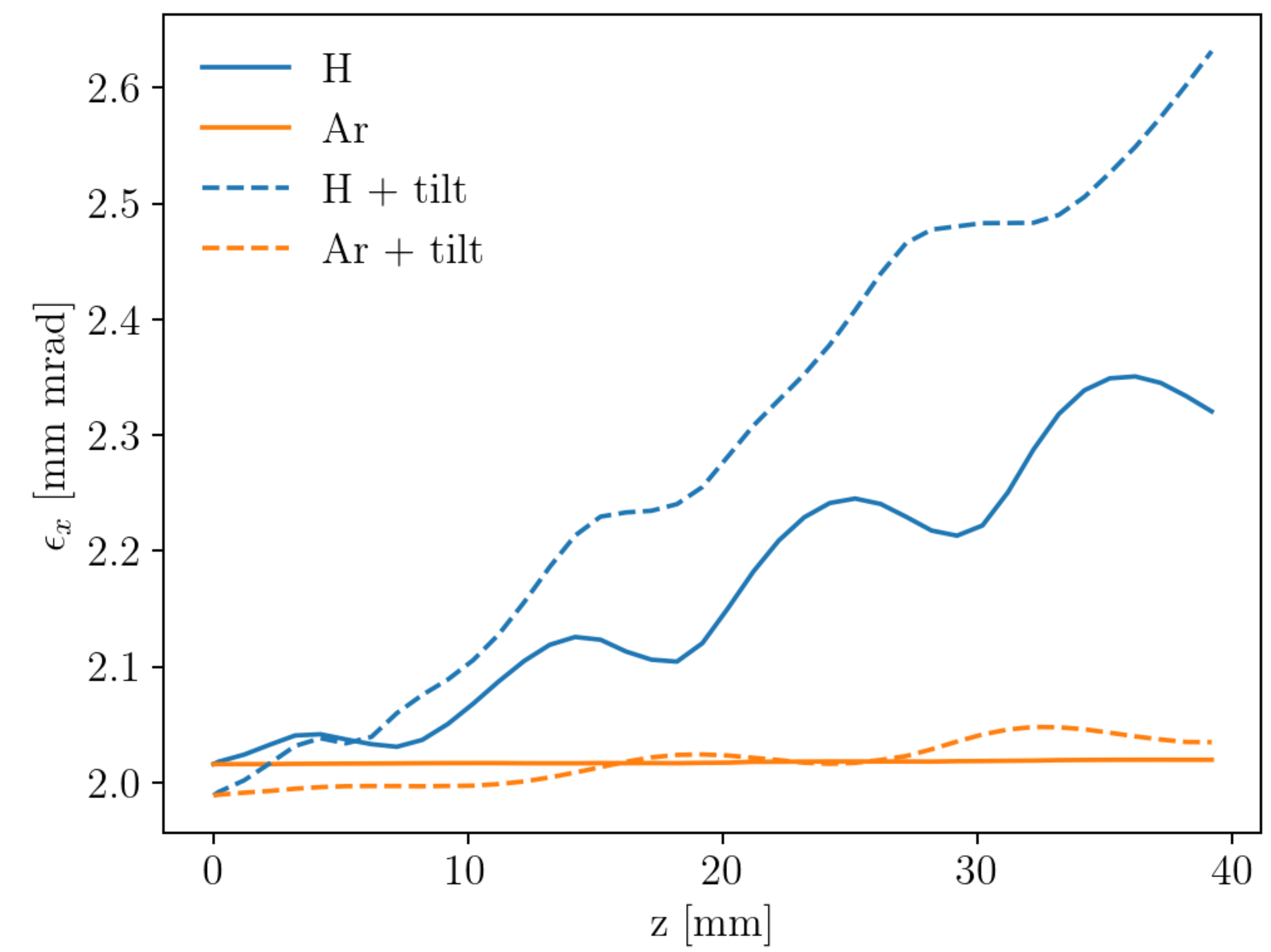
$$\Delta\phi_i \simeq \sqrt{\frac{2\pi r_p Z_i N \sigma_z}{A\epsilon_n}}(r_e n_0 \gamma)^{1/4}$$

SIMULATIONS USING DIFFERENT BEAM SIZES (SIMULATED BY SEVERIN USING HIPACE++)

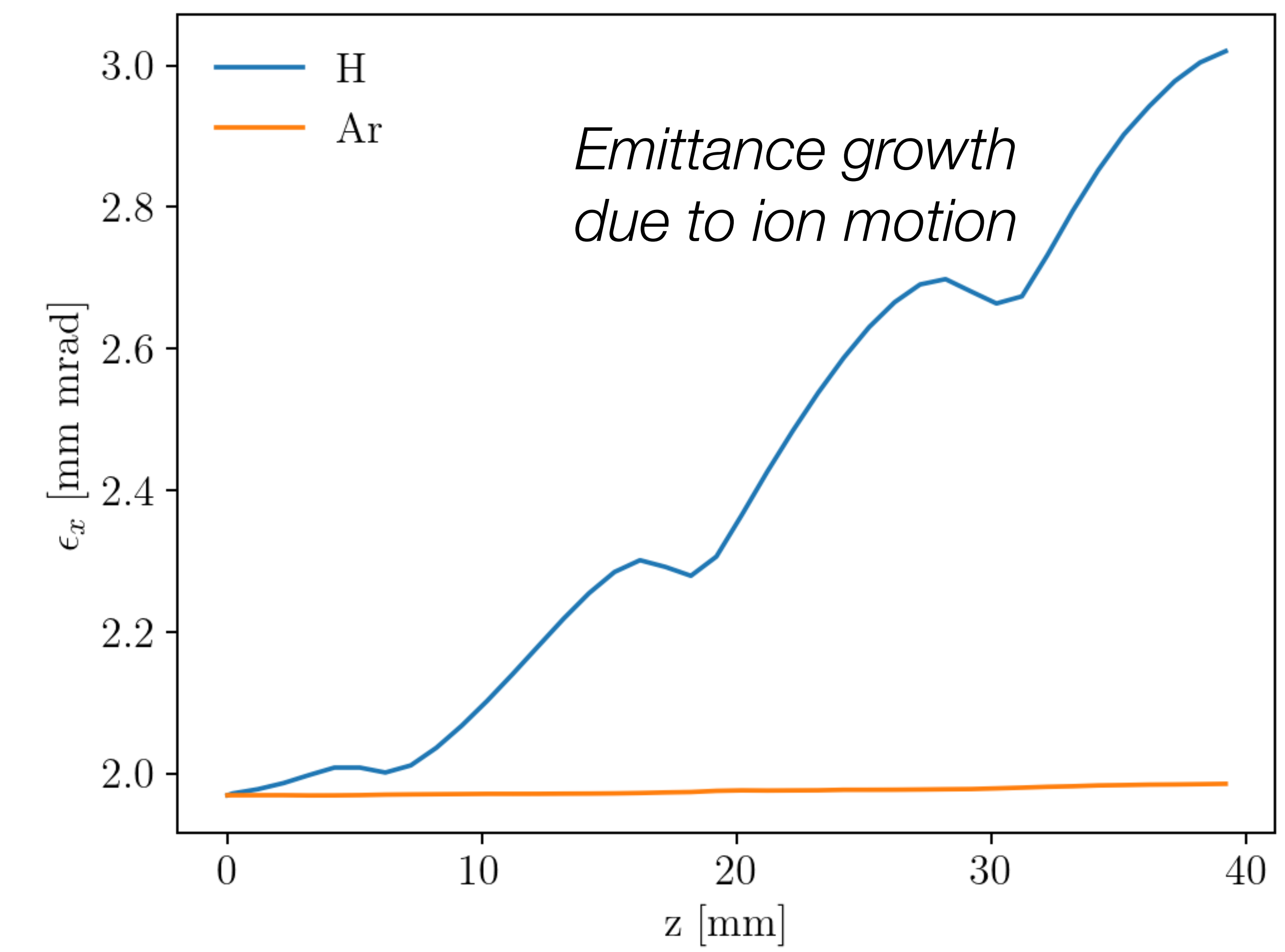
- The answer is yes, if the beam size is small enough.
    - *Matched: 2 μm rms*
- Simulation:
    - 1 GeV, 1 nC charge
    - ~1 kA peak current
    - 7x10^{15} cm^{-3}, 40 mm long
    - 2 mm mrad emittance
    - 0.4% energy spread
- Shown:
    - Slice emittance at the tail



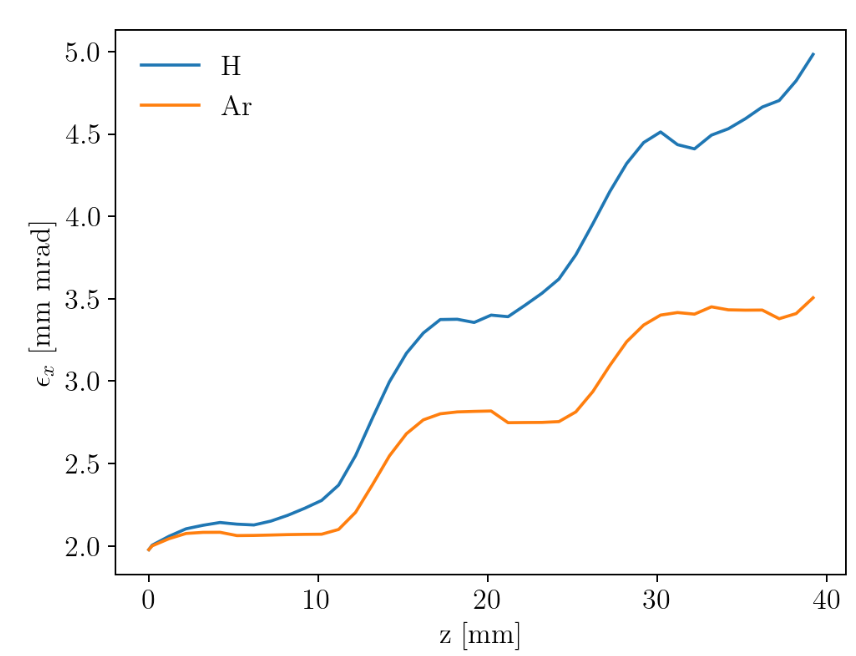
3 μm rms



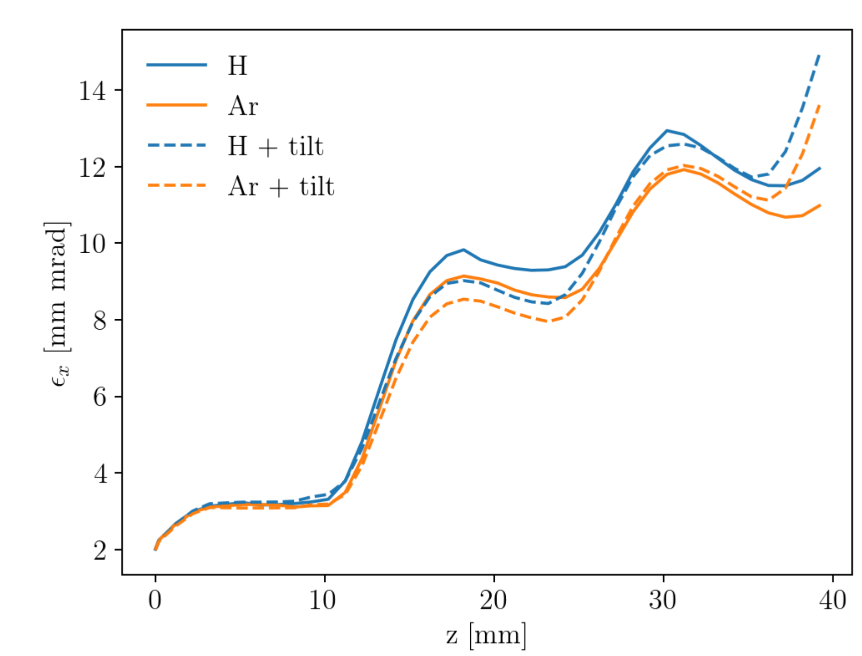
5 μm rms



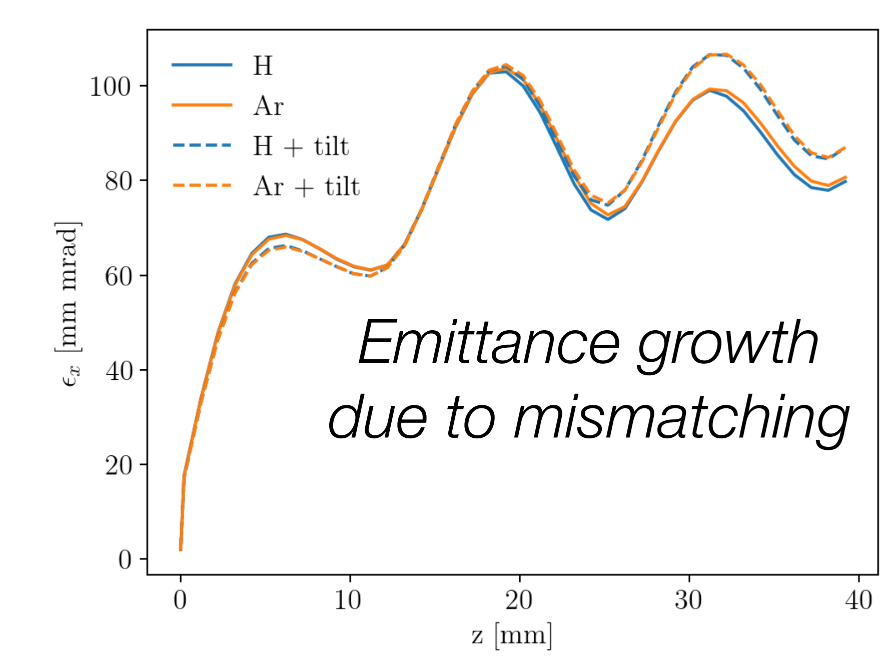
8 μm rms



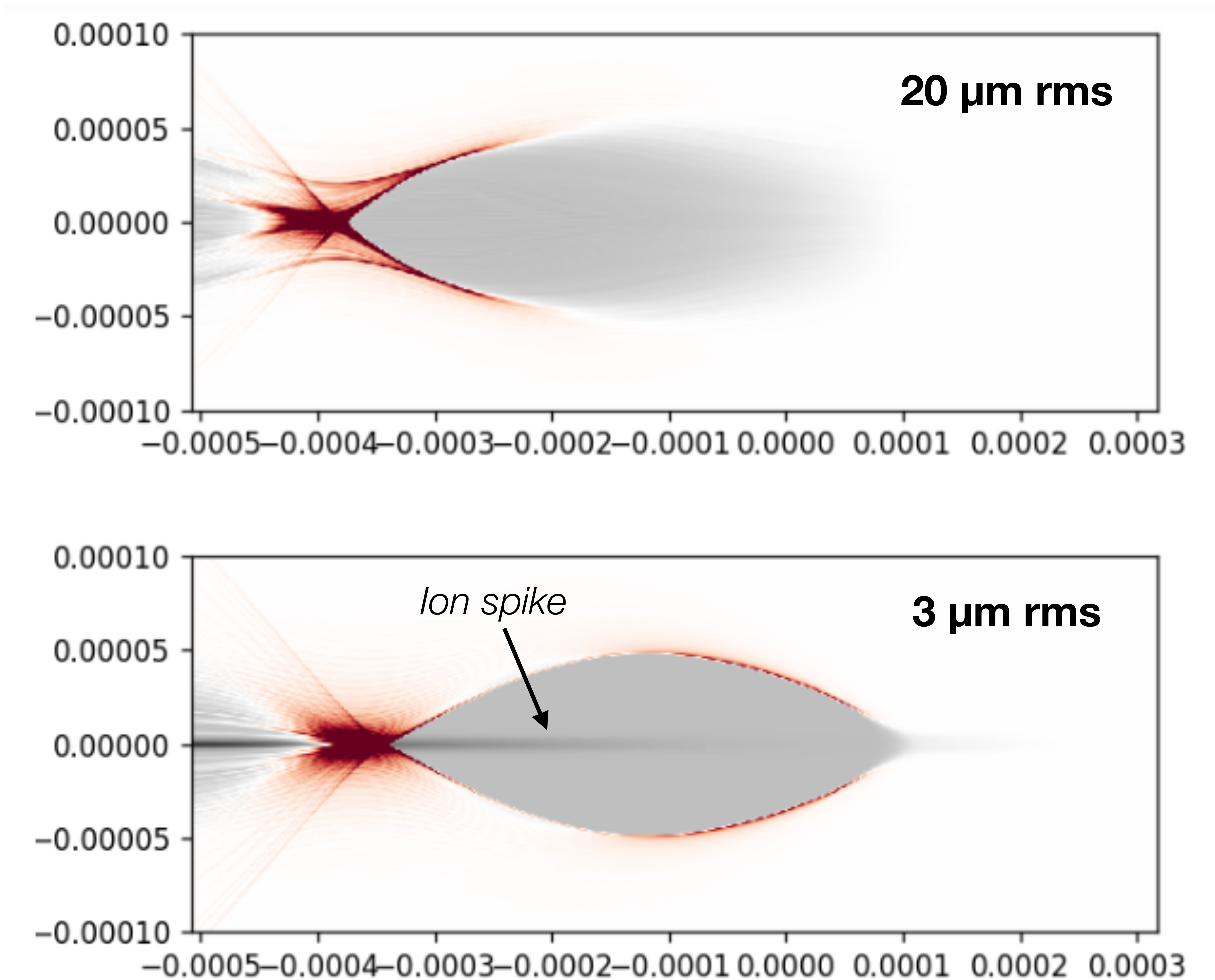
10 μm rms



20 μm rms

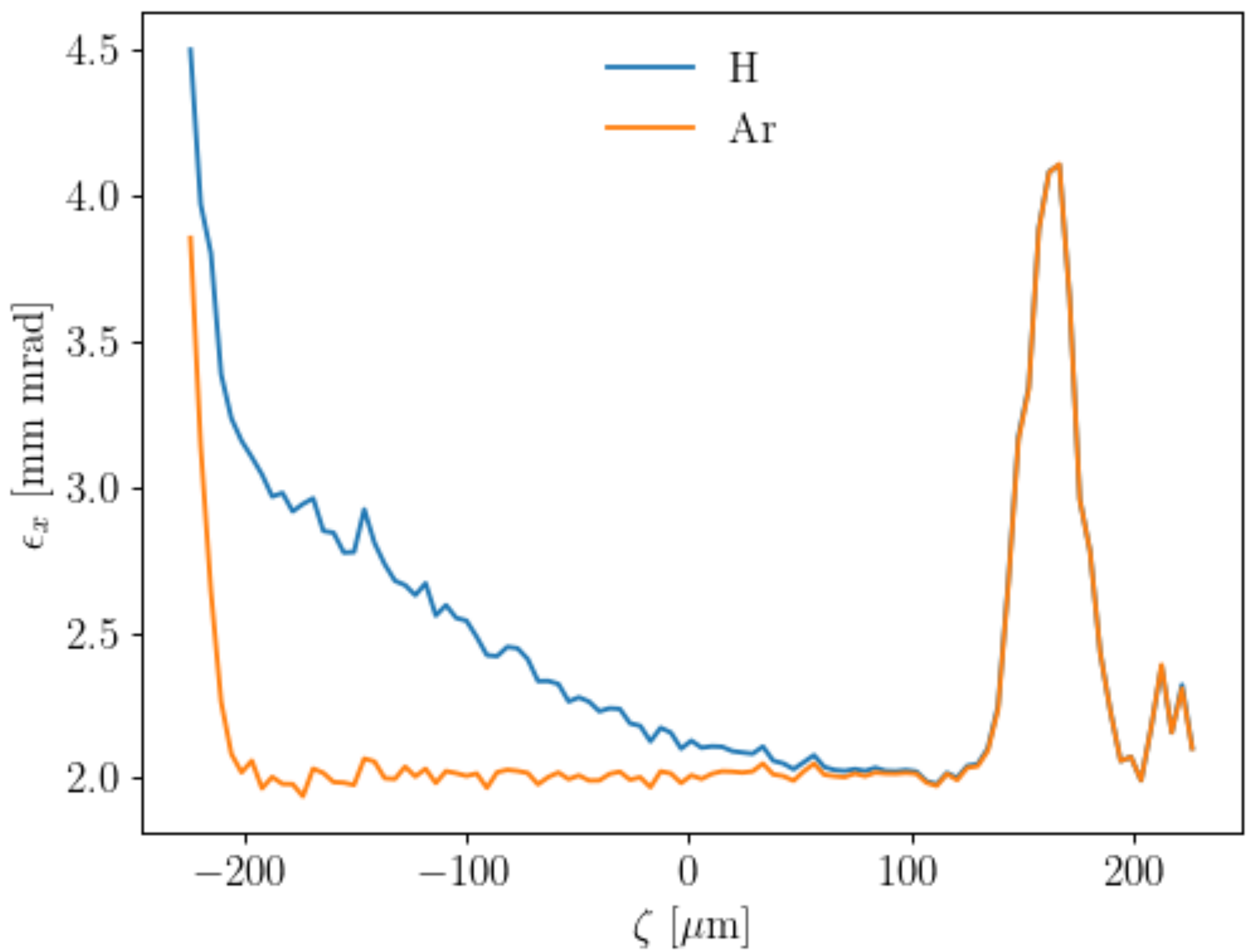


Cross section of the plasma cavity



GROWING EMITTANCE TOWARDS THE BEAM TAIL

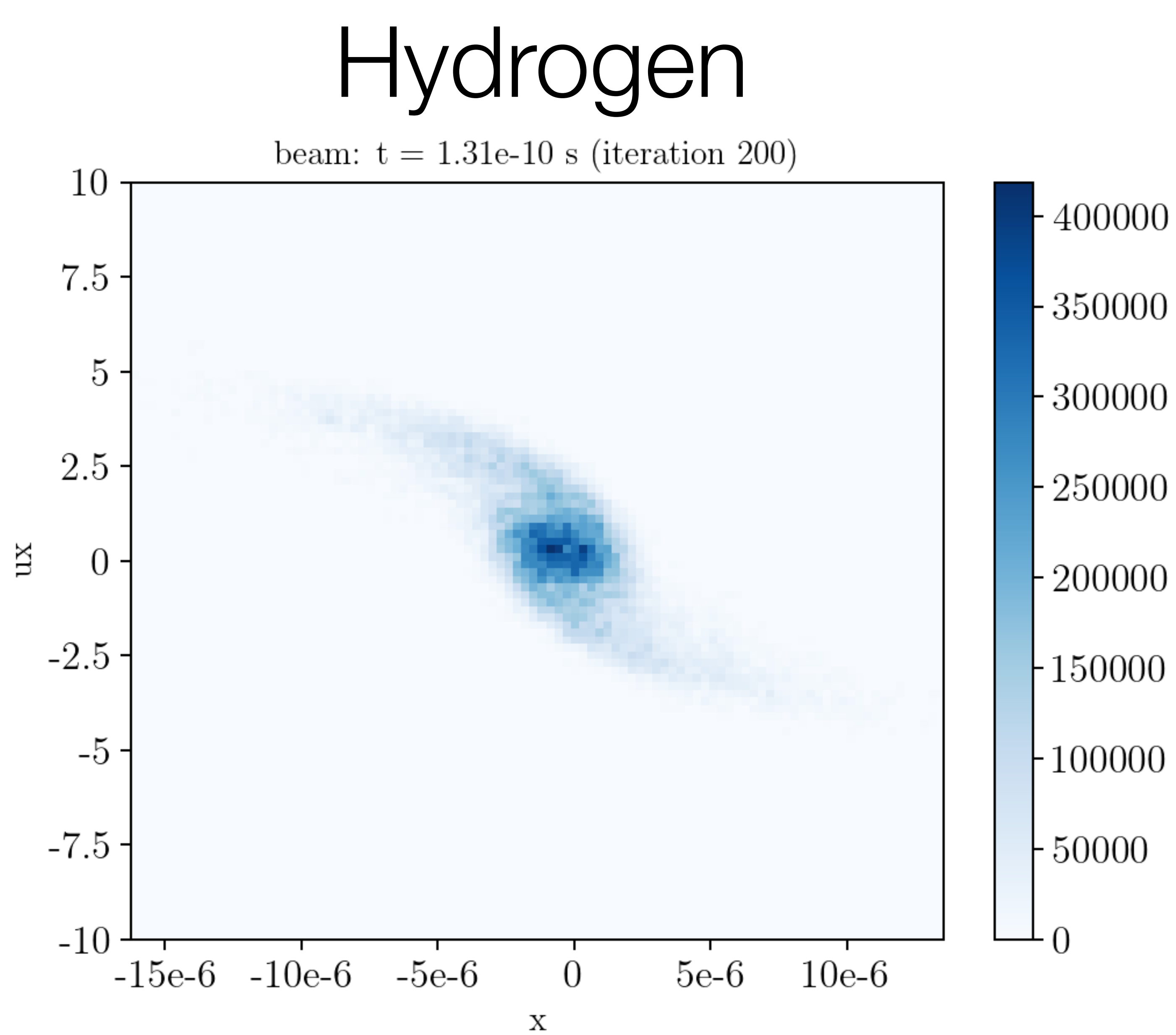
> Main observable:

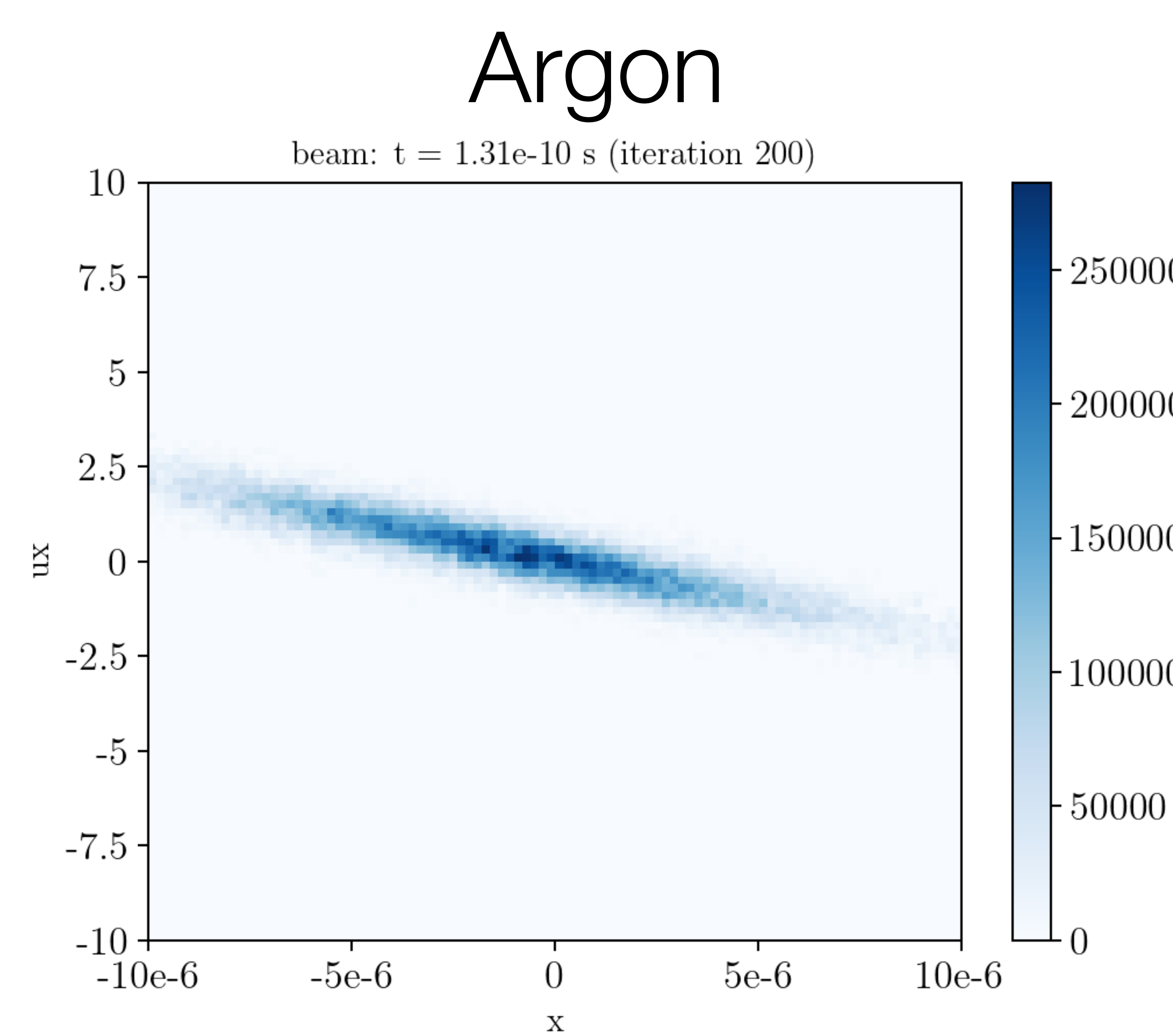


Non-Gaussian transverse phase space in hydrogen due to ion motion

- Looking at a slice towards the tail, we see clear evidence of nonlinear focusing:
  - A galaxy-shaped phase space (hydrogen) shows that focusing is stronger closer to the axis (like in a galaxy).
  - In argon, a regular bivariate Gaussian distribution is observed.

Simulations with a 5 µm rms beam size:





> In conclusion — we should be able to observe emittance growth due to ion motion!