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In-Bubble Ion Motion Measurements

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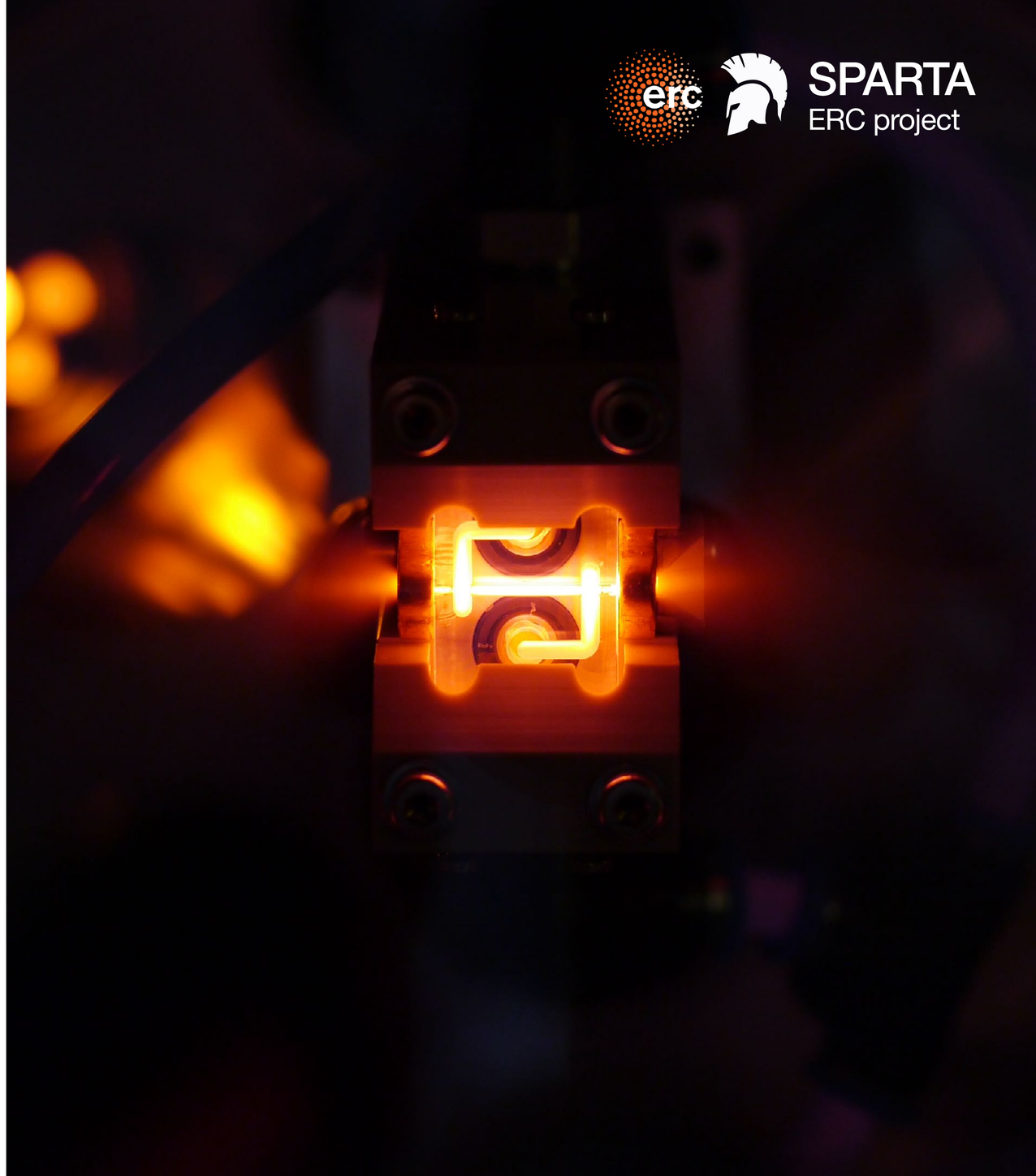
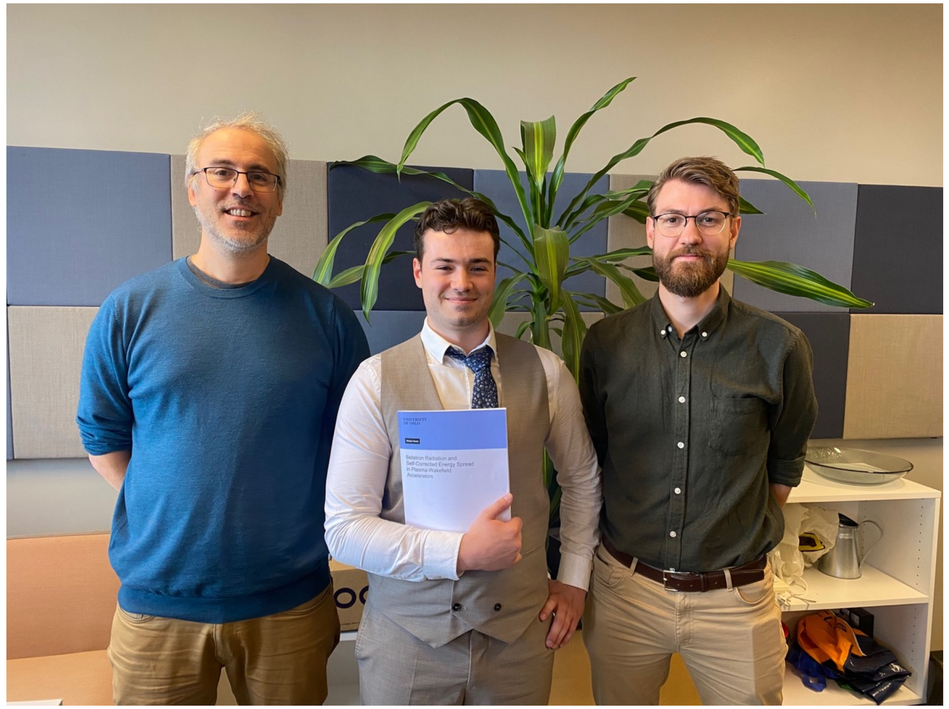


SPARTA
ERC project

About me

- Bachelor in energy physics from Norwegian university of life sciences.
- Masters in Plasma Wakefield acceleration from university of Oslo
- Started a PhD with the SPARTA project in the same field in the same place this August.



Ion motion

Blessing or a curse?

- Rosenzweig et al. pointed out that ion motion is not negligible for sufficiently dense beams [1].

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

- This causes non-linear focusing, and consequently emittance growth. This has been shown in simulations [2].

- But, simulations have also shown that ion motion can suppress beam hosing [3].

[1] Rosenzweig et al. Phys. Rev. Lett. 2005

[2] An et al. Phys. Rev. Lett. 2017

[3] Mehrling et al. Phys. Rev. Lett. 2018

Ion motion

Depends on beam and plasma density

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

- $\sqrt{\frac{Z}{A}}$ Is the root if ionization number over mass.
- The ions move more for lighter gas species, and when using denser beams
- For argon, A=40.
- Assuming 1 ionized electron of the argon plasma, the phase advance is more than 6 times larger for hydrogen (with A,Z=1). With the same beam density.

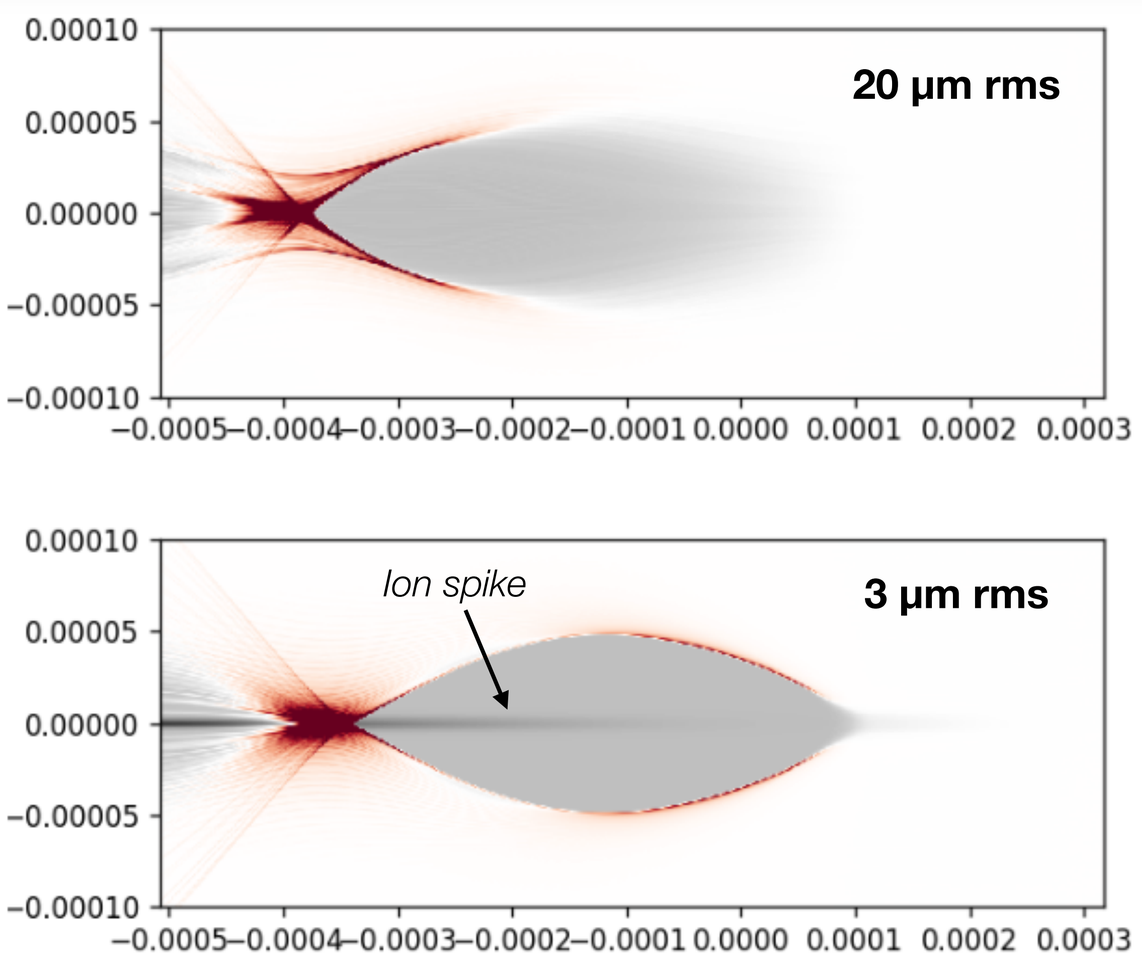


Figure by Severin Diederich

What we are expecting

- We expect that the ion spike grows towards the back of the bubble.
- We want to measure the emittances longitudinally along the beam.
- The idea: accelerate the back half of the beam, and separate the beam based on energy.

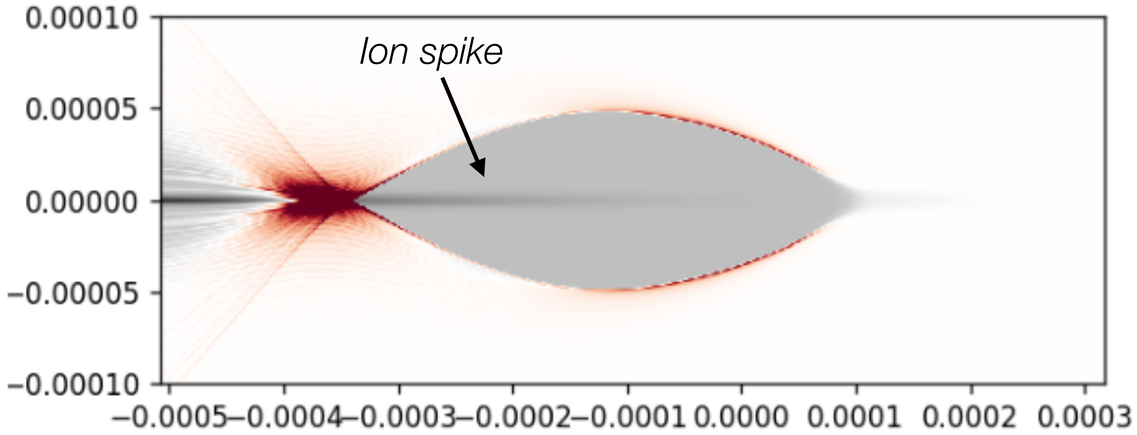


Figure by Severin Diederich

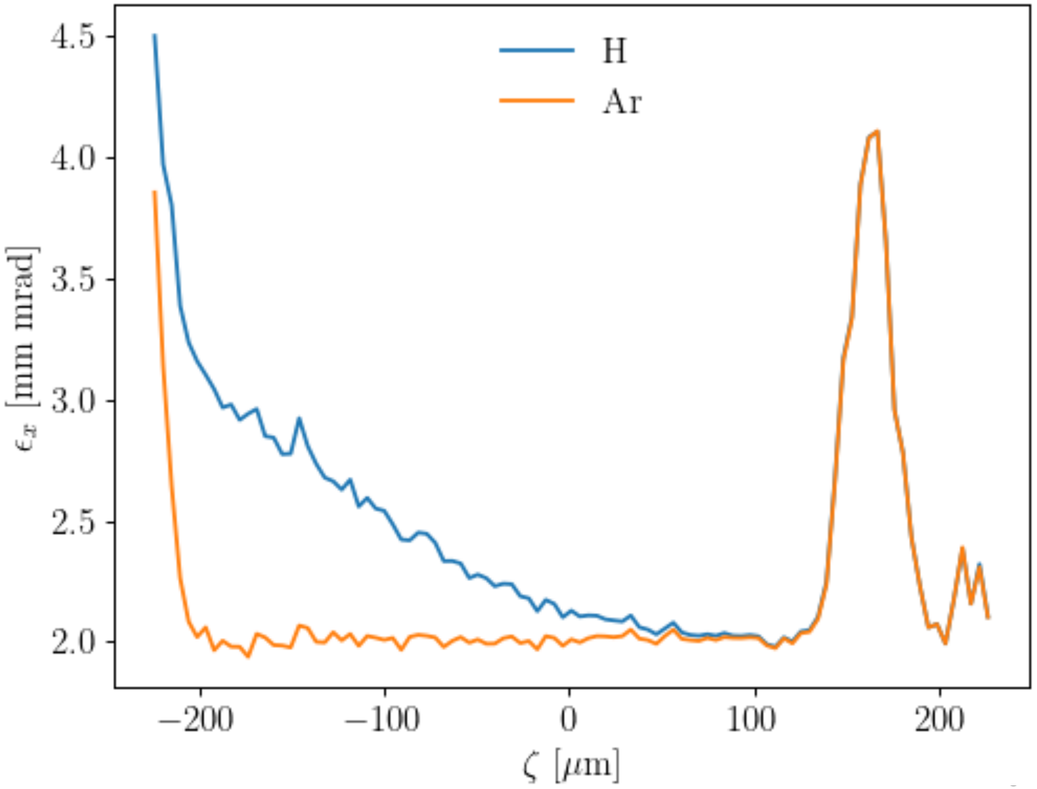
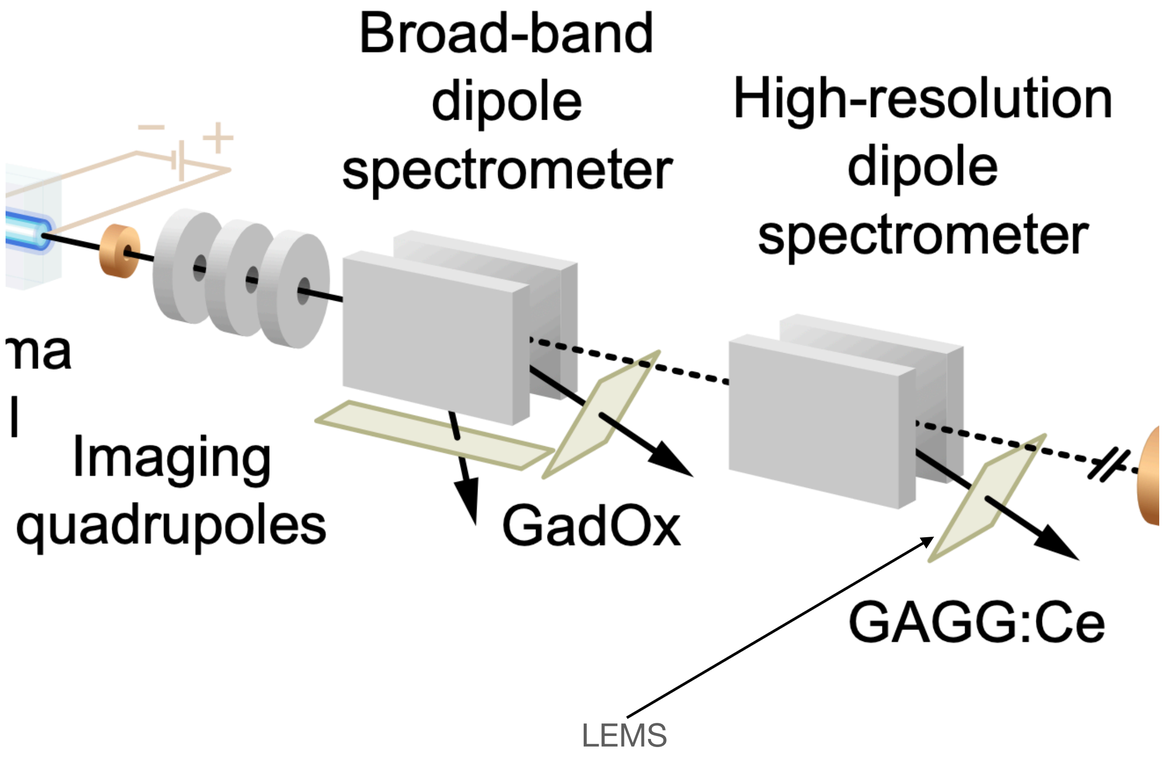


Figure by Severin Diederich

Experimental concept and setup

- We are trying to show the effects of ion motion in the first wake.
- The drive beam is so long that the tail is accelerated. I.e there is no witness beam
- Using a quadrupole triplet and a spectrometer, we can separate energy slices and measure their transverse sizes.
- Since the tail is accelerated, it is easy to identify at a BPM.

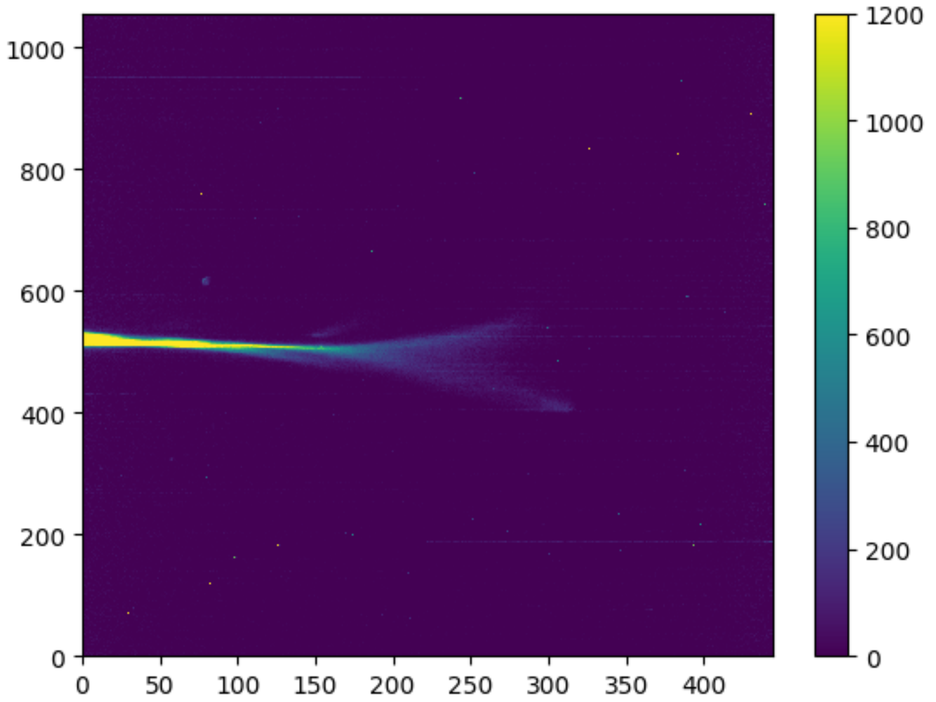


From the thesis of Felipe Peña [4]

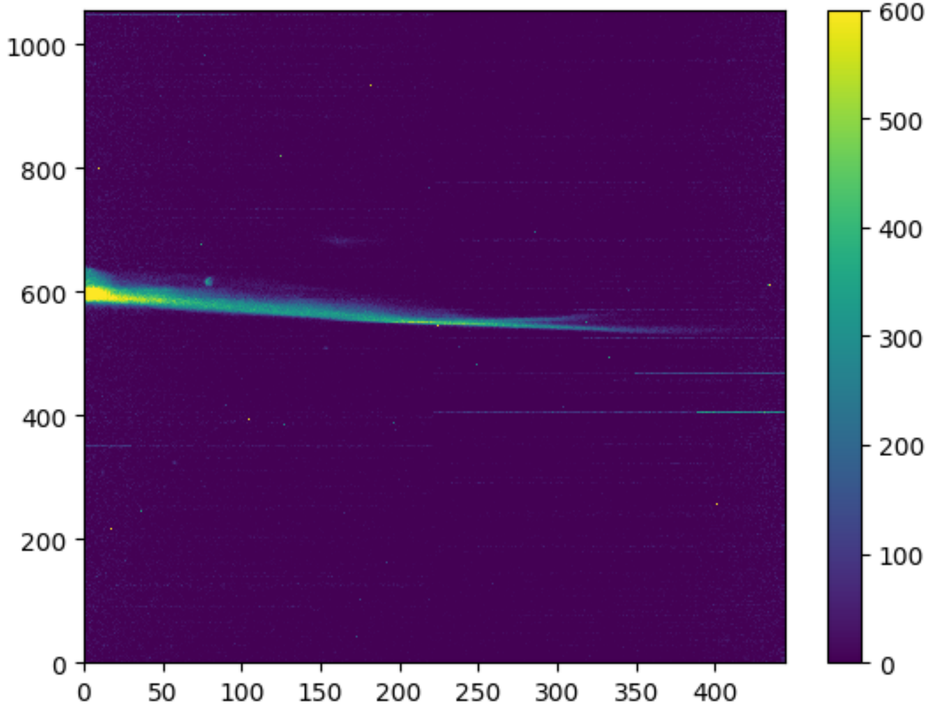
[4] Peña. PhD thesis, U. Hamburg. 2024

Argon vs Hydrogen

First pictures



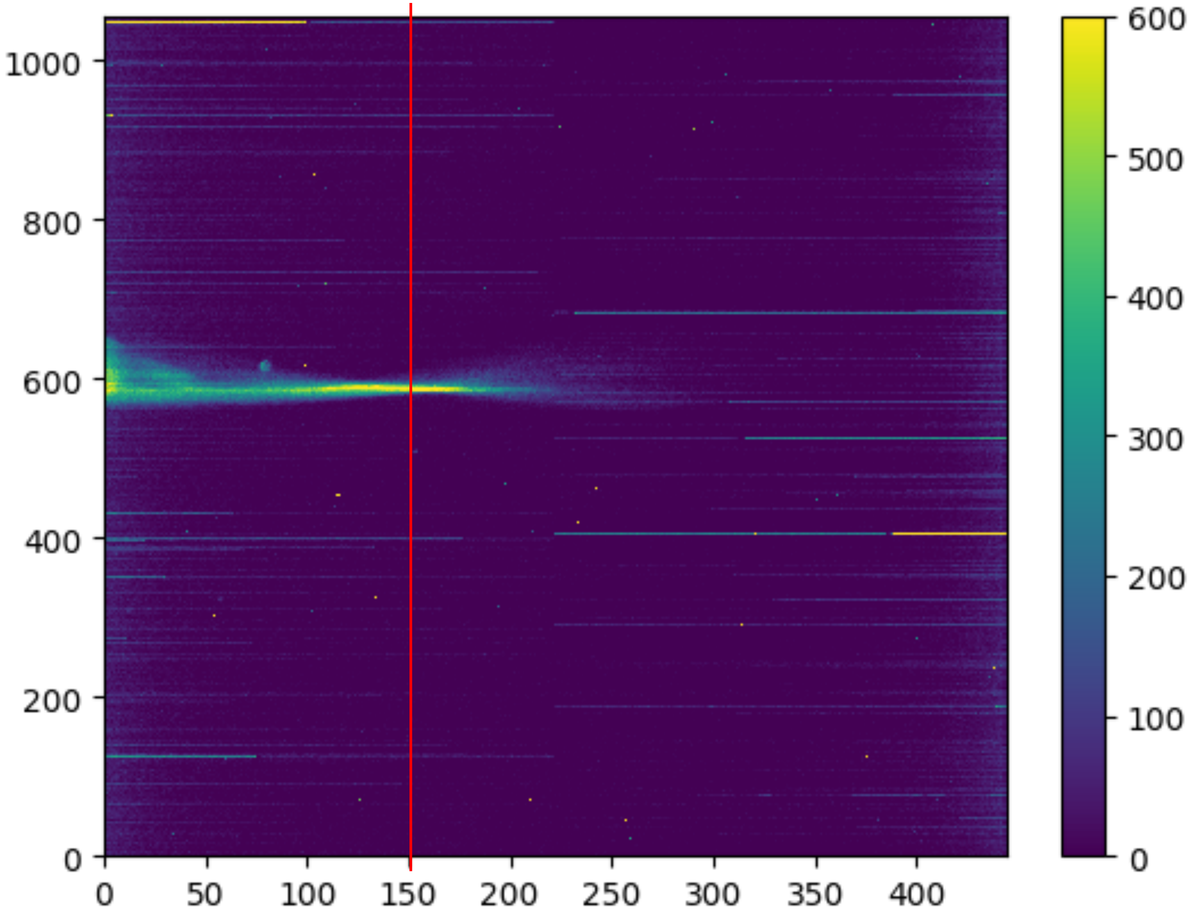
Hydrogen



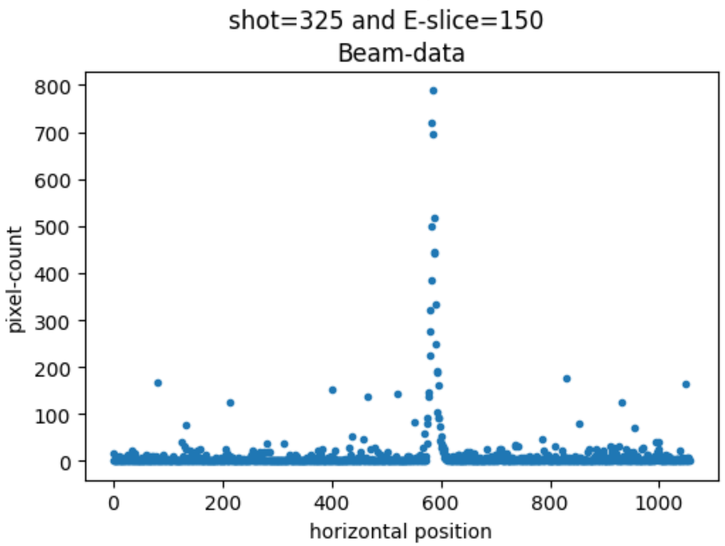
Argon

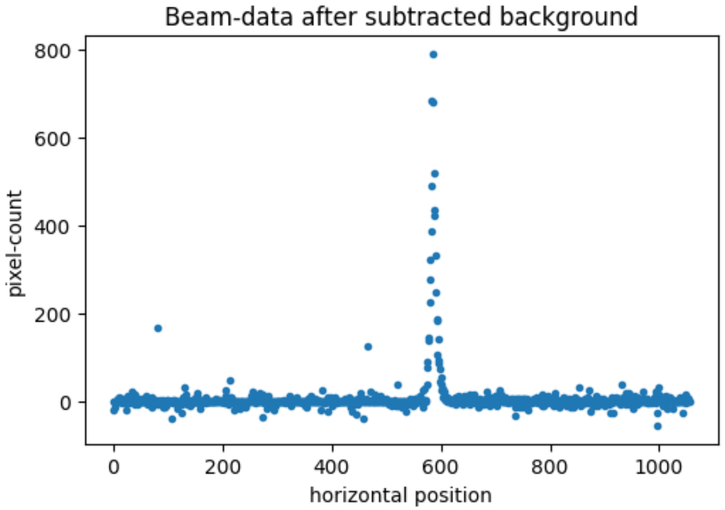
Analysis

Getting to know the dataset



Argon, shot 325

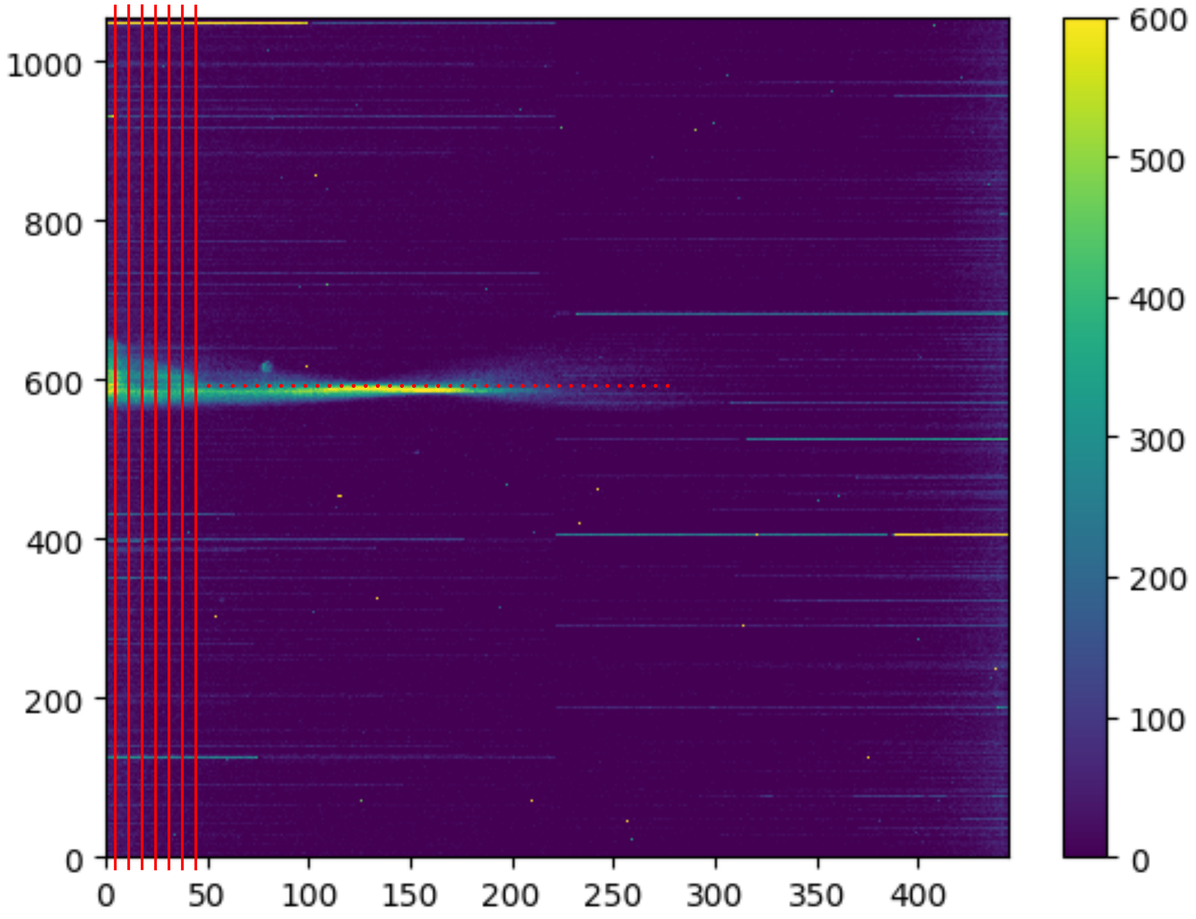




Pixel counts along the horizontal axis of the figure to the left.

Next steps

Getting the same plots, cleaning the data, and calculate the beam sizes for different slices.
Repeat for different shots to get emittance for the different energies.



Shot 325

Concluding remarks

- When we have the energy-emittance plots, we can compare emittance in hydrogen and argon.

- If we see a distinct difference, we will reconstruct the 6D phase space using longitudinal phase space (TDS) and transverse phase space measurements (LEMS and BPMs). Then use this in a HiPACE++ simulation to compare.

- Hopefully, we can conclude that ion motion is present in light plasmas, and use it as a mitigation mechanism for transverse instabilities.

Acknowledgements

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