How does Ion Motion affect SMI

(What do we expect when testing the 10 m Long Discharge Plasma Source with different gases (ions)?)

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Background

- **A 10 m long discharge plasma source has been installed in AWAKE**
- **The AWAKE experimental team is preparing a three week long experimental run (starting May 1st 2023)**
- **Physics: SMI (no laser or electron beam seeding)**
- **Discharge plasma allows for different ion species:**
  - Helium (Z = 4)
  - Argon (Z = 40)
  - Xenon (Z = 131)
  - Previously: (Rubidium (Z = 87))
- **➔ Simulation study using LCODE (2D-cylindrical) to see how ion motion affects the development of SMI and expectations for the experiments**

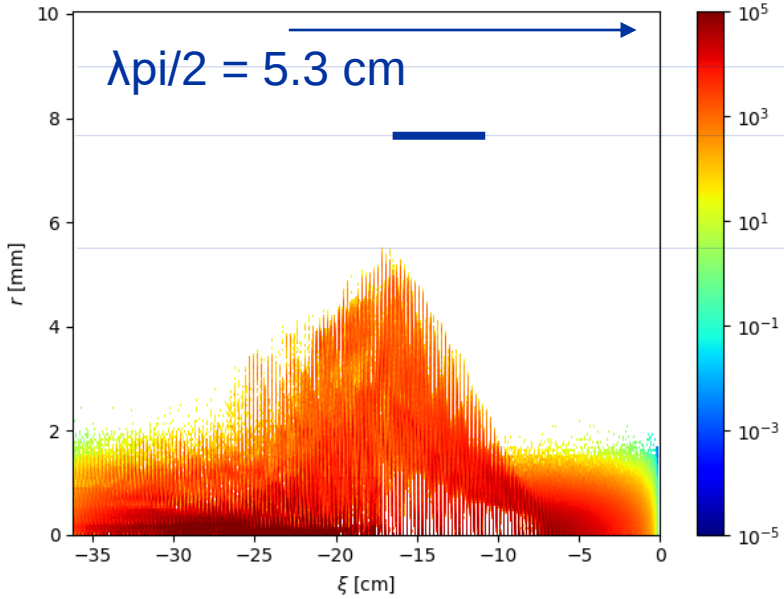
Simulation Details

- **Code: LCODE, 2D cylindrical**
- **Imitate SMI; Bunch length 250 ps (sin2 profile, cut at +650ps), 3e11 protons**
  - Warning: Seed amplitude in the experiment could be different, leading to earlier or later SM saturation
- **Plasma: 7e14, 10m- long, uniform in r and z**
  - Warning: Plasma might not be uniform

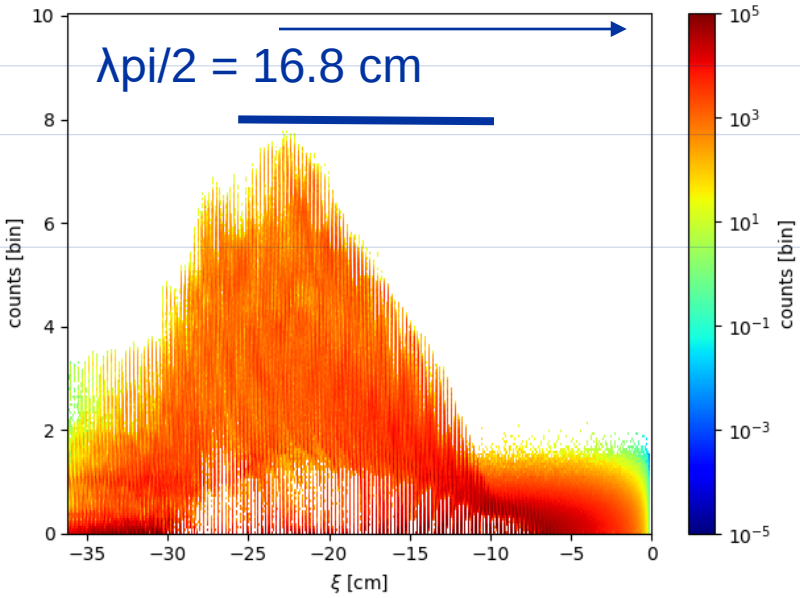
Gas Species Affects SMI Development

Note the logarithmic color scale

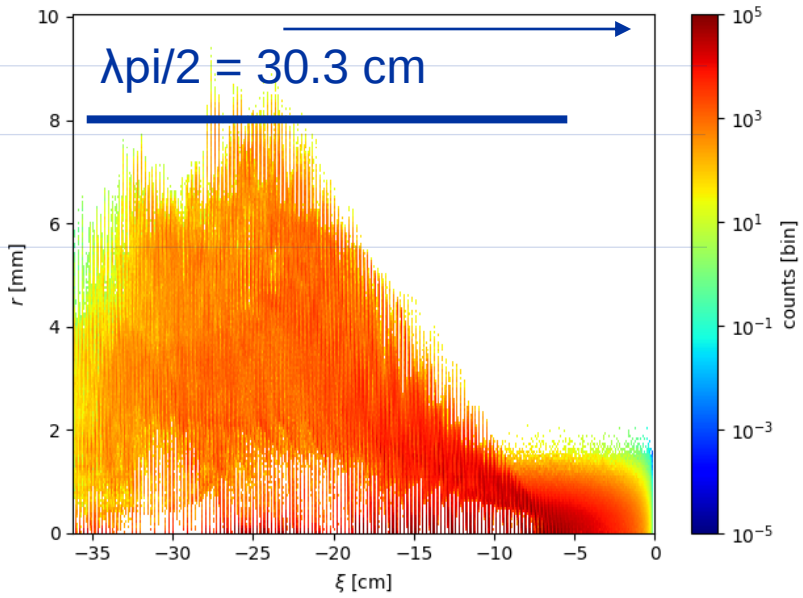
Helium (Z=4)



Argon (Z=40)



Xenon (Z=131)



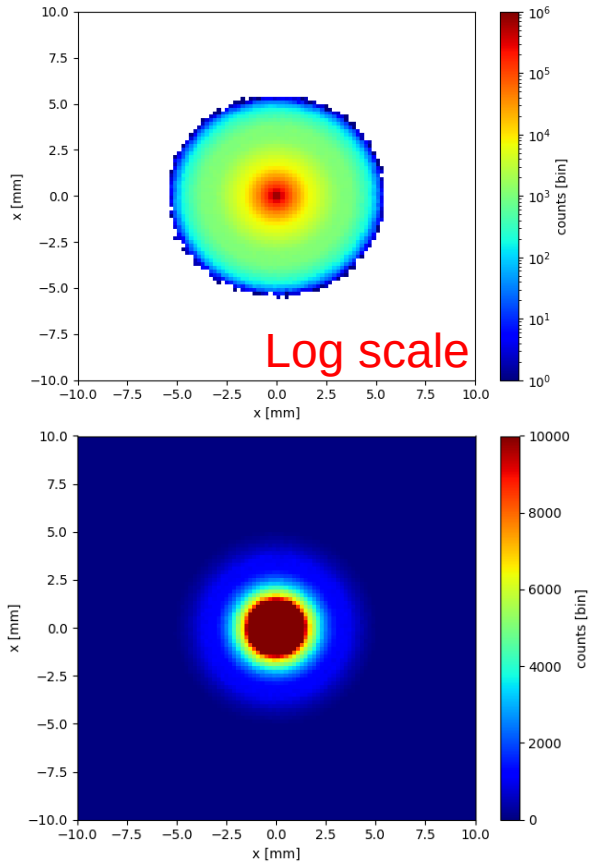
Higher ion mass allows for longer wakefield growth along the bunch and higher field amplitudes at large xi.

Experimental signature on the streak camera: longer bunch trains the for higher ion masses

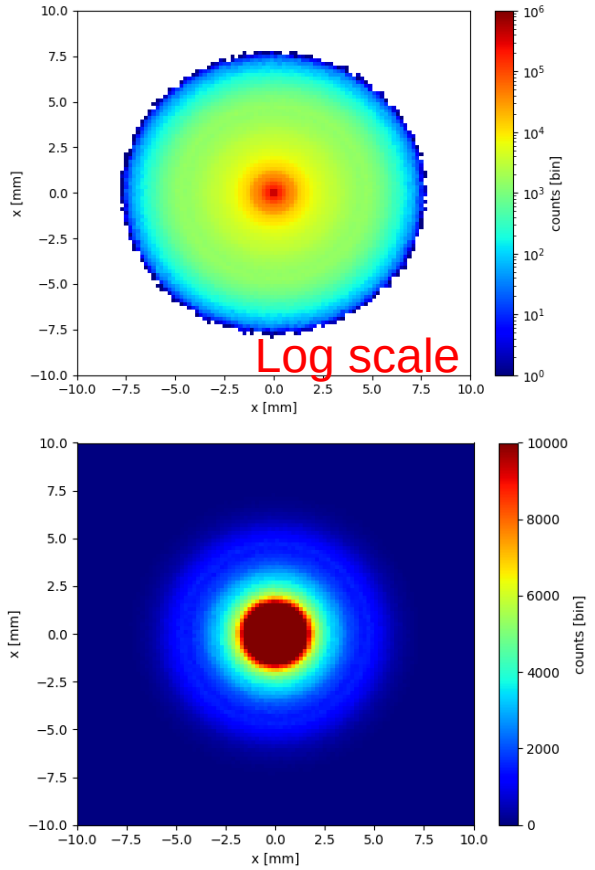
Gas Species Affects Distribution of Defocused Protons

Transverse distribution at the plasma exit → translates to the IS in a self-similar way

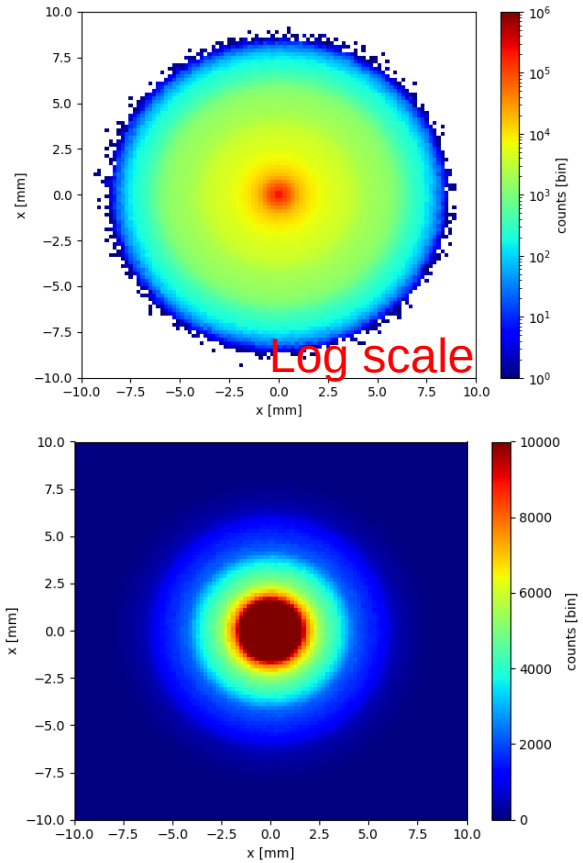
Helium



Argon



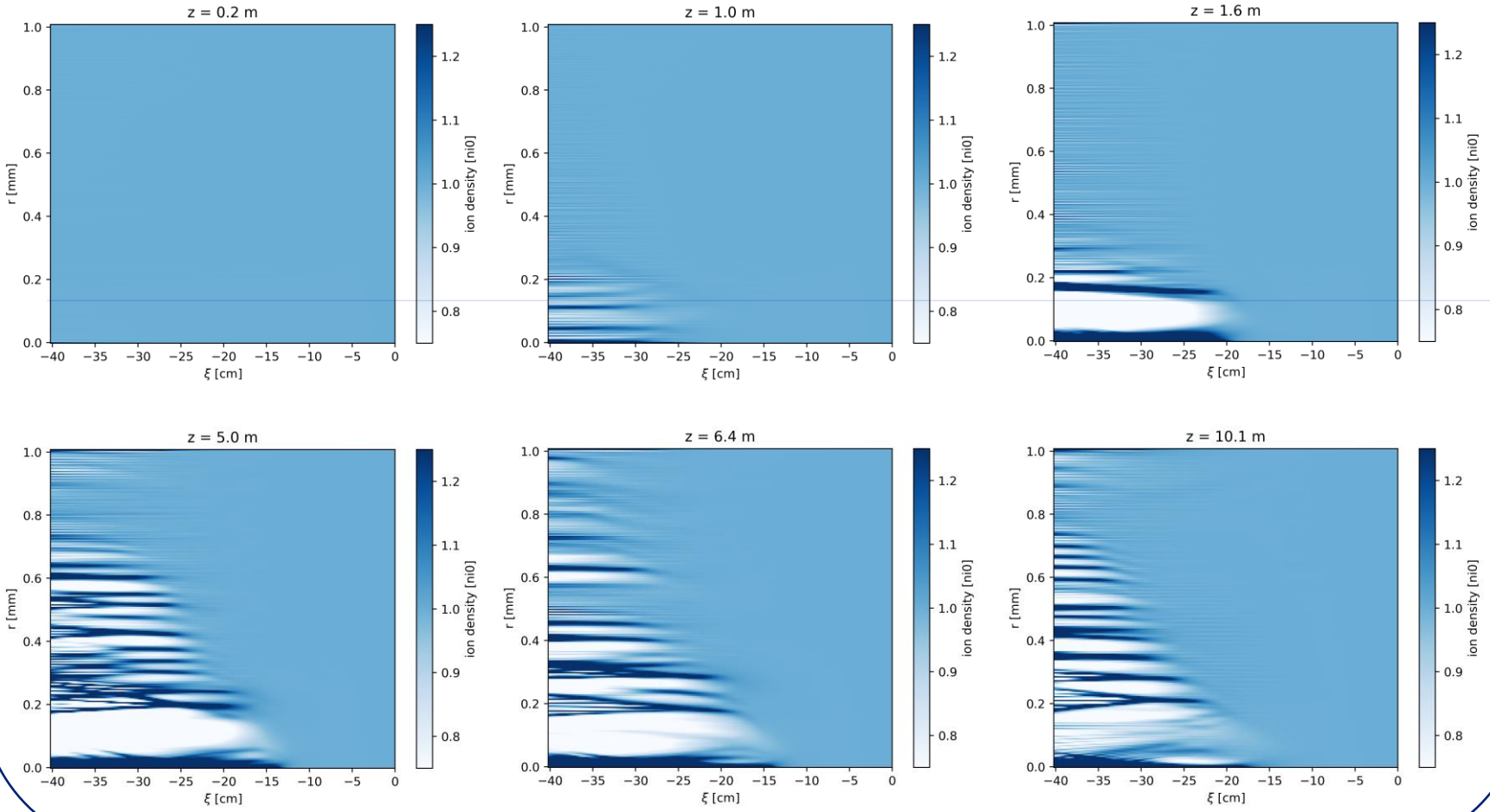
Xenon

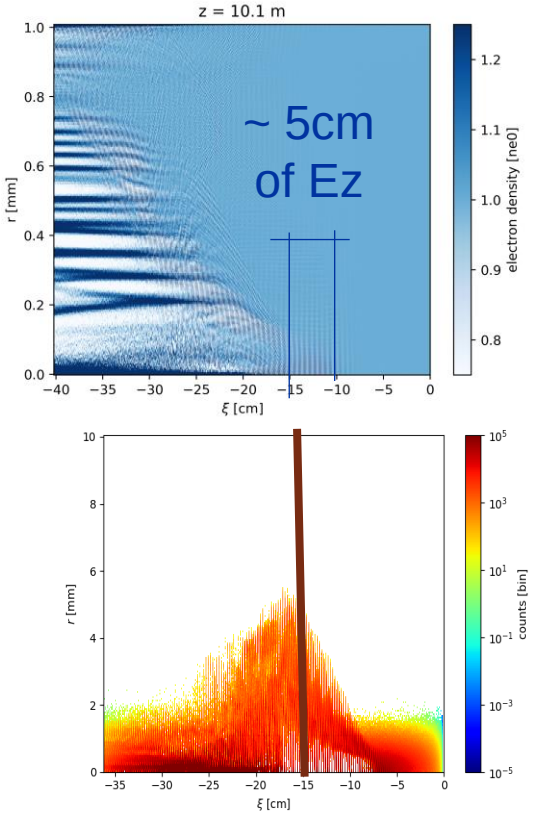


Measurement of transverse, time-integrated images: Larger defocusing for heavier ions. → Difference between Helium and Xenon should be visible for these beam and plasma parameters.

Ion Motion in Helium

Ion density along the 10m plasma





Ion motion interferes with wakefields(Ez) significantly after a duration of ~λpi/2.

Summary & Conclusions

- Discharge plasma source will allow testing of different gas (plasma ion) species
  - → study the effect of ion motion on SMI development
  - Expected to interfere with wakefields ~half an ion plasma frequency

- Simulations suggest that the effect should be measurable for nominal AWAKE bunch and plasma parameters
  - Streak camera: duration of the micro-bunch train (longer for higher Z ions)
  - Imaging stations: transverse extend of the defocused protons (larger for higher Z ions)

- Experimental outcome may be different due to:
  - Different initial seed level
  - Reduced plasma density uniformity
  - → trends are expected to remain the same

- We have already observed SMI at lower bunch populations in a test run last week → hopeful for a good data set during the May run