LhARA fortnightly Meeting

Summary of recent work on the plasma lens

8th February 2022

Titus Dascalu

Initial plan for experiments at Swansea

A – Validation: confined electron plasmas **vs.** PIC simulations (VSim[†])

- → **predictions** on the confinement of an electron plasma in the **next design** iteration of the Gabor lens.

B – Development:

- Investigate the experimental limitations of the existing trap

C – New measurement:

- Measure focusing of positron beam by electron cloud

Current status

ongoing

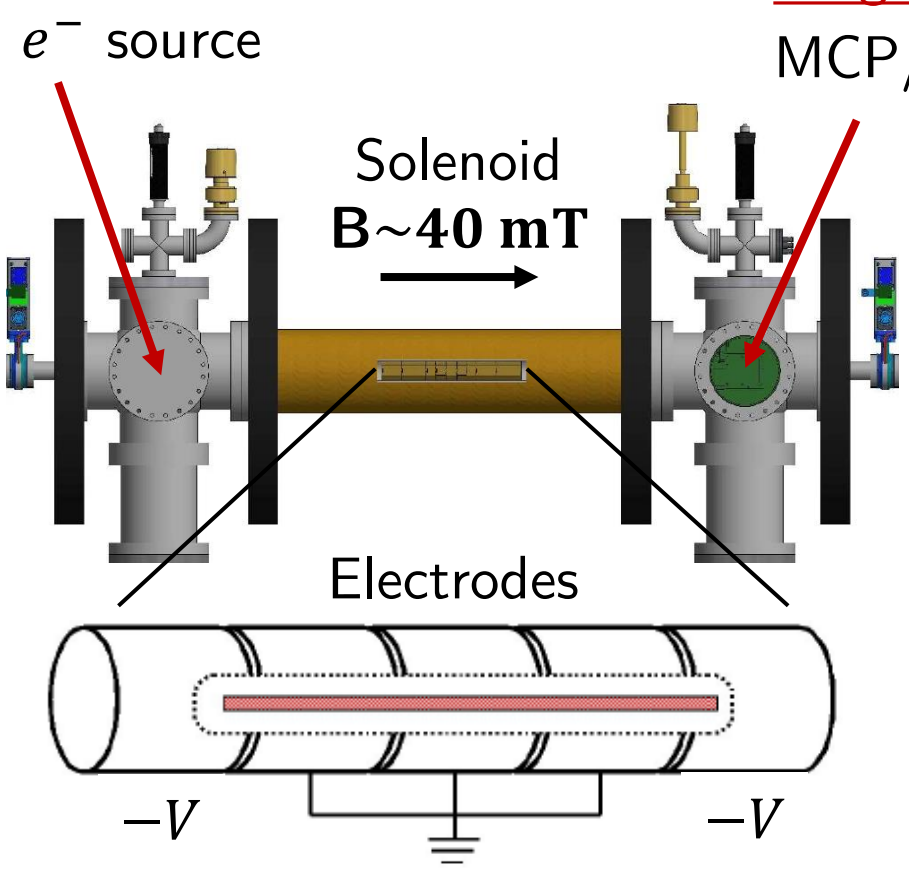
Observed e^- density lower than expected

↓

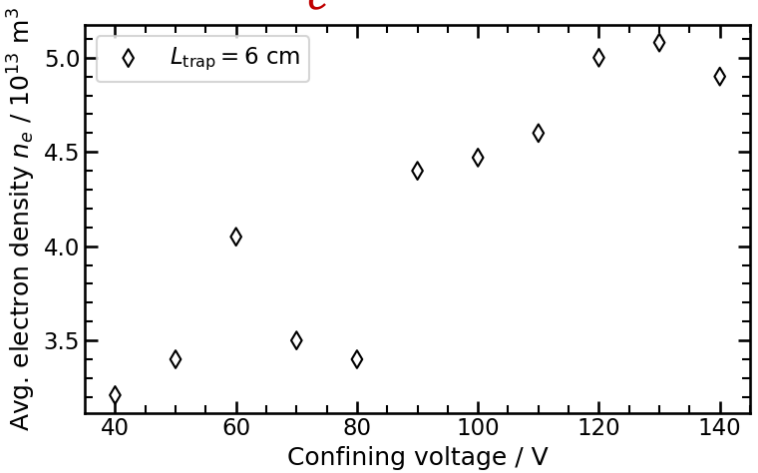
Single-particle regime

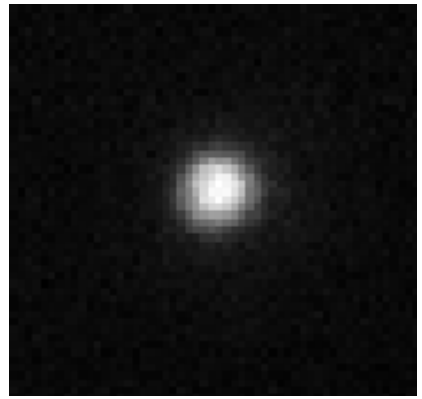
[†] Chet Nieter and John R Cary. Vorpal: a versatile plasma simulation code. Journal of Computational Physics, 196(2):448–473, 2004.

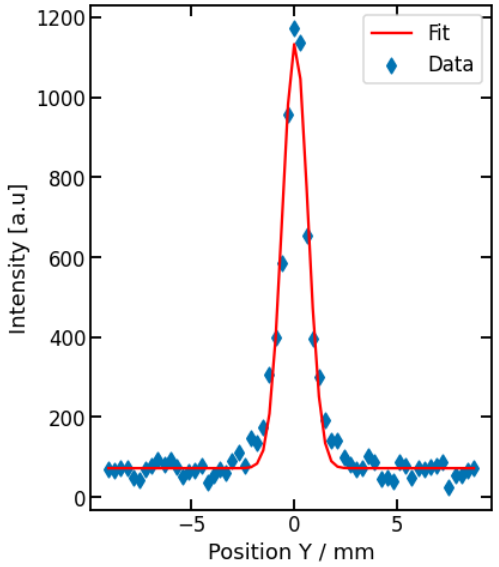
Electron plasma parameters



$n_e \sim 3\text{–}5 \times 10^{13}\ \mathrm{m}^{-3}$







$\sigma_{x,y} \sim 0.3\ \mathrm{mm}$

Ptcl. number	$\leq 1 \times 10^7$
Plasma length L_p	3– 20 cm
Plasma radius r_p	~0.3 mm
Debye length λ_D	~1 mm

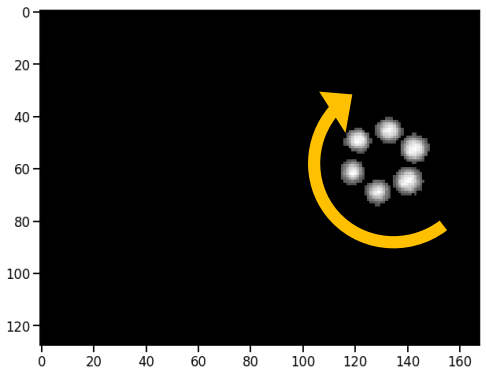
Plasma behaviour for $\lambda_D \ll r_p, L_p$

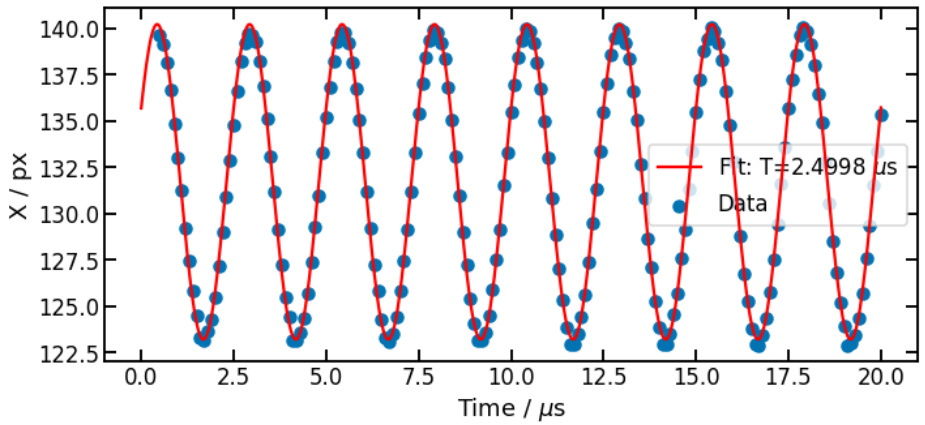
Single-particle motion

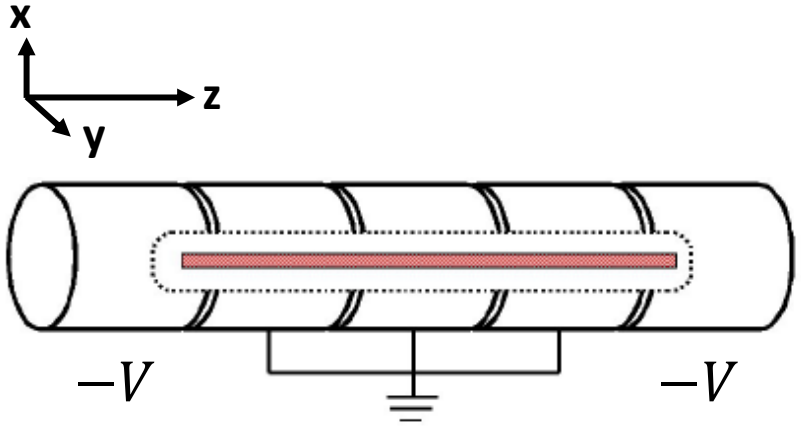
- Axial motion (~5–25 MHz)
- Modified cyclotron motion (~1 GHz)
- Magnetron rotation (~5–500 kHz)
  $\mathbf{E} \times \mathbf{B}$ drift

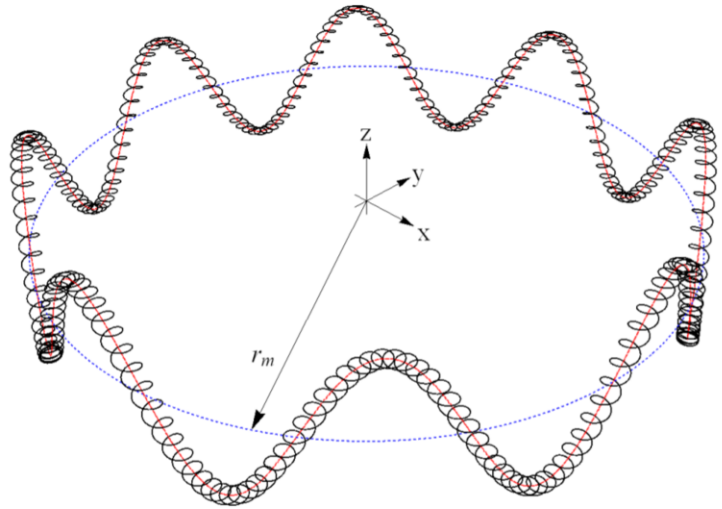
$$\omega_m = \omega_c / 2 - \sqrt{(\omega_c / 2)^2 - \omega_z^2 / 2}$$

$\omega_c = eB/m_e$; $\omega_z = \omega_z(V;\ \text{electrode geometry})$





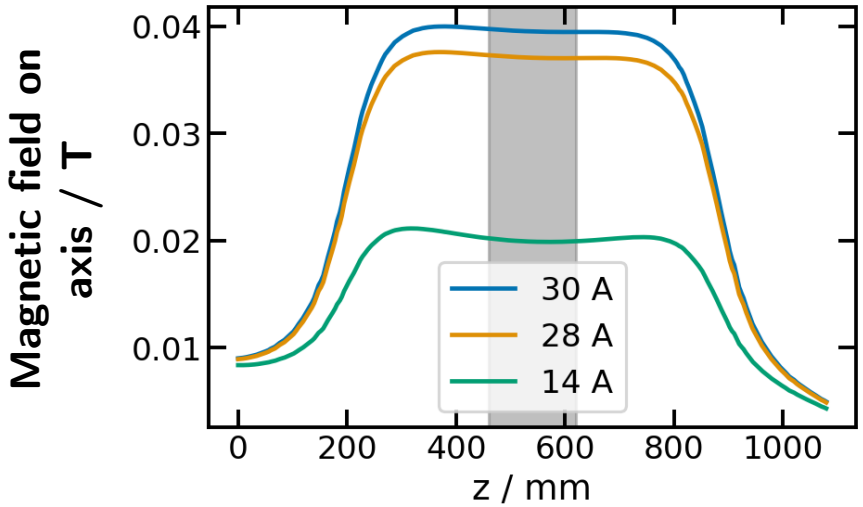




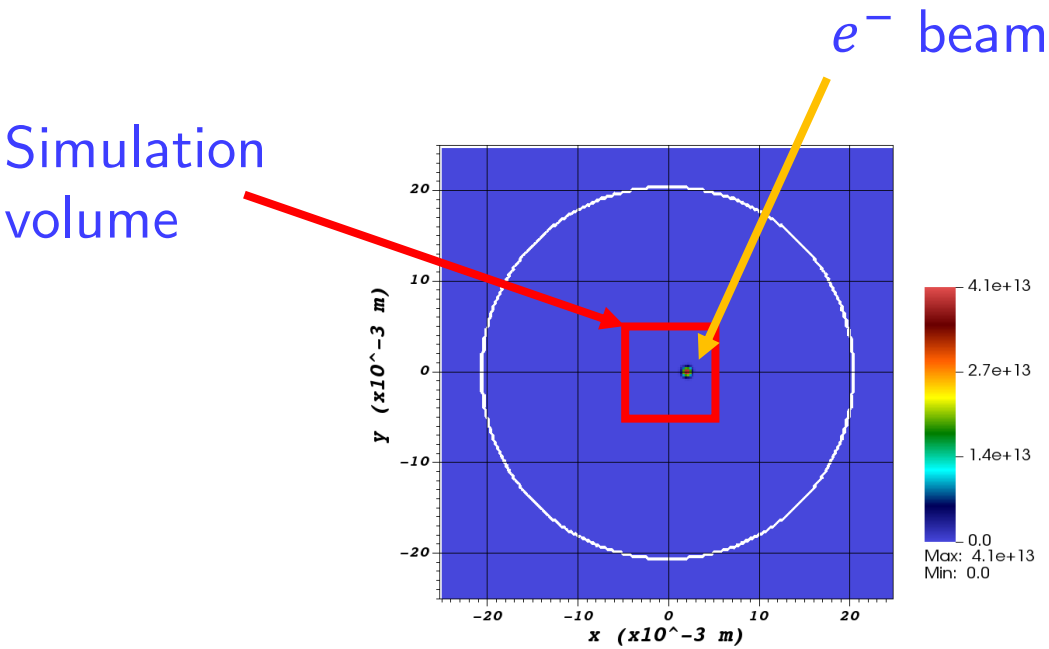
A. Deller, PhD Thesis, Swansea University, 2013

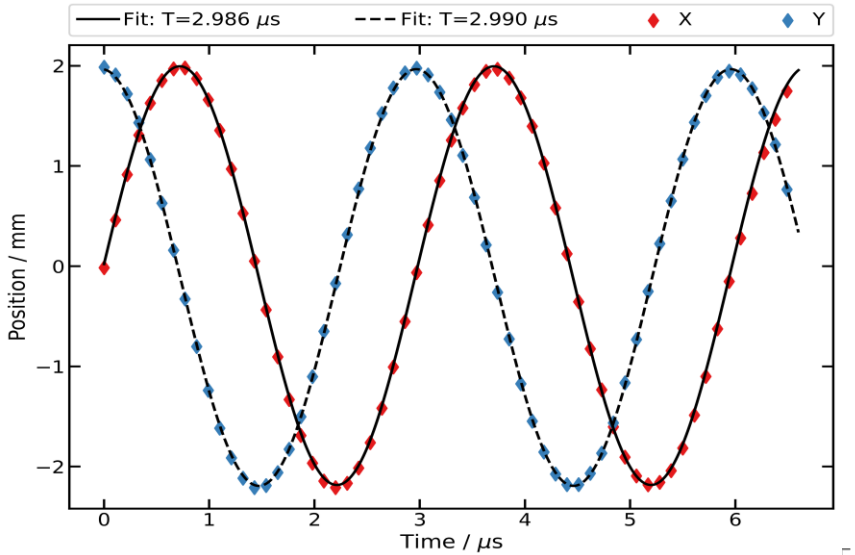
Progress in PIC simulations

- Factor of ~10 improvement in CPU time
  - reduction of simulation volume
  - single calculation of the trapping fields
- Model longitudinal variation in the magnetic field



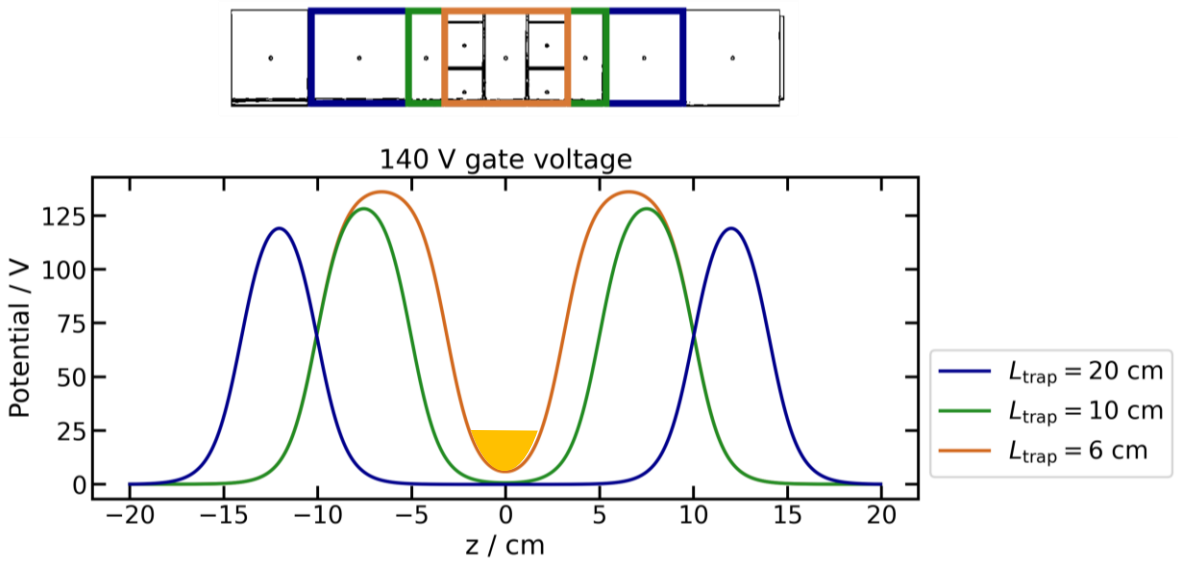
- Particles are loaded more realistically based on the
  - Beam-catching technique
  - Calculated confining potential

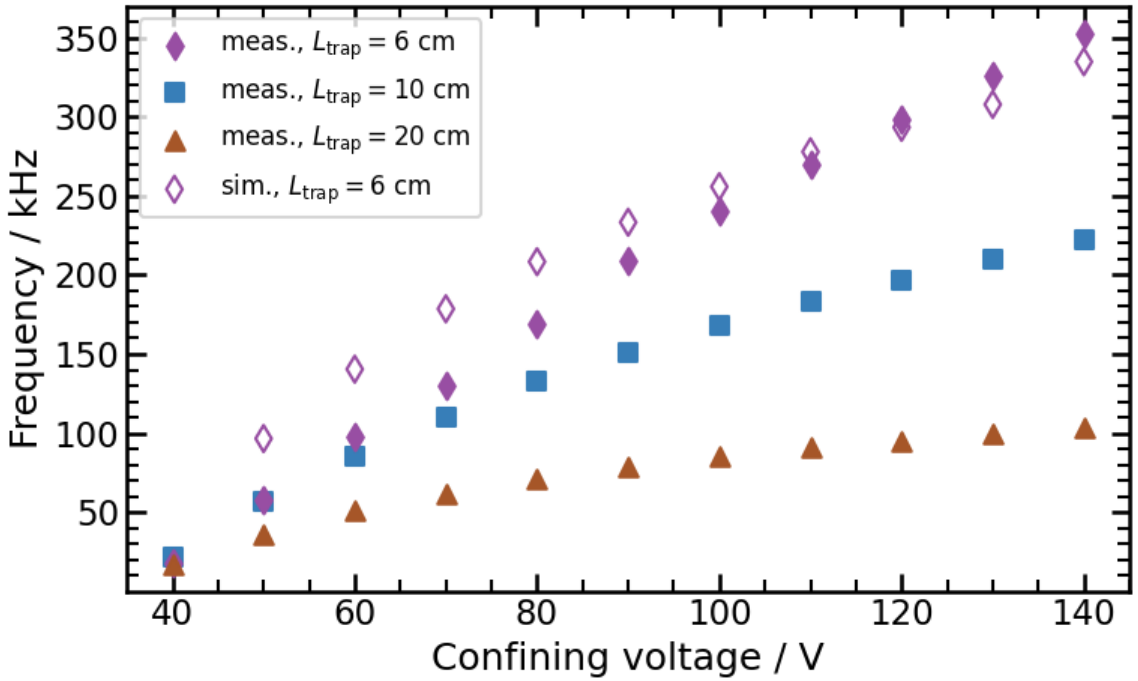




Main results and comparison to simulation (1)

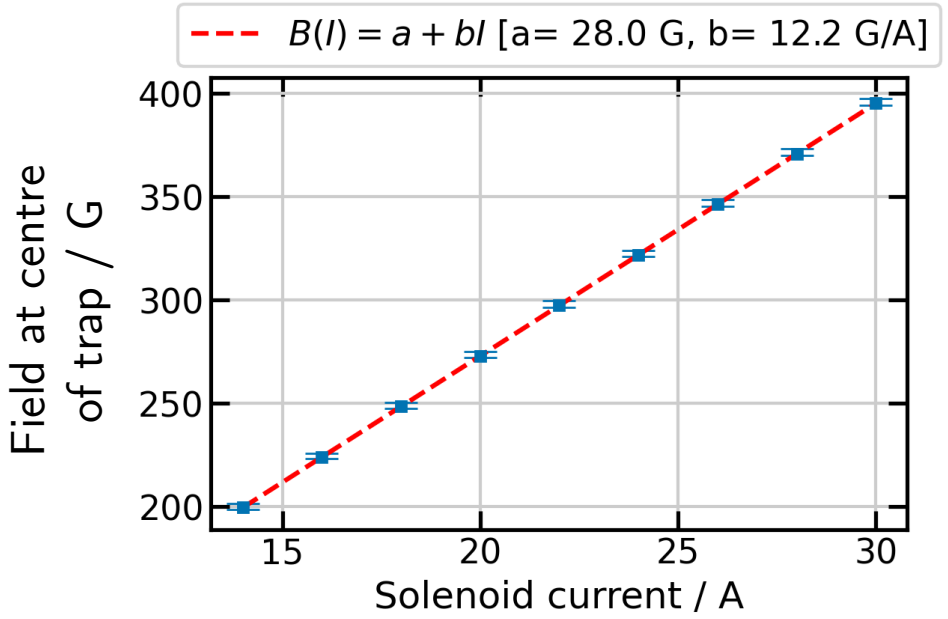
- Magnetron frequency ω_m measured under various trapping conditions
  - Change in plasma length & voltage applied on end electrodes

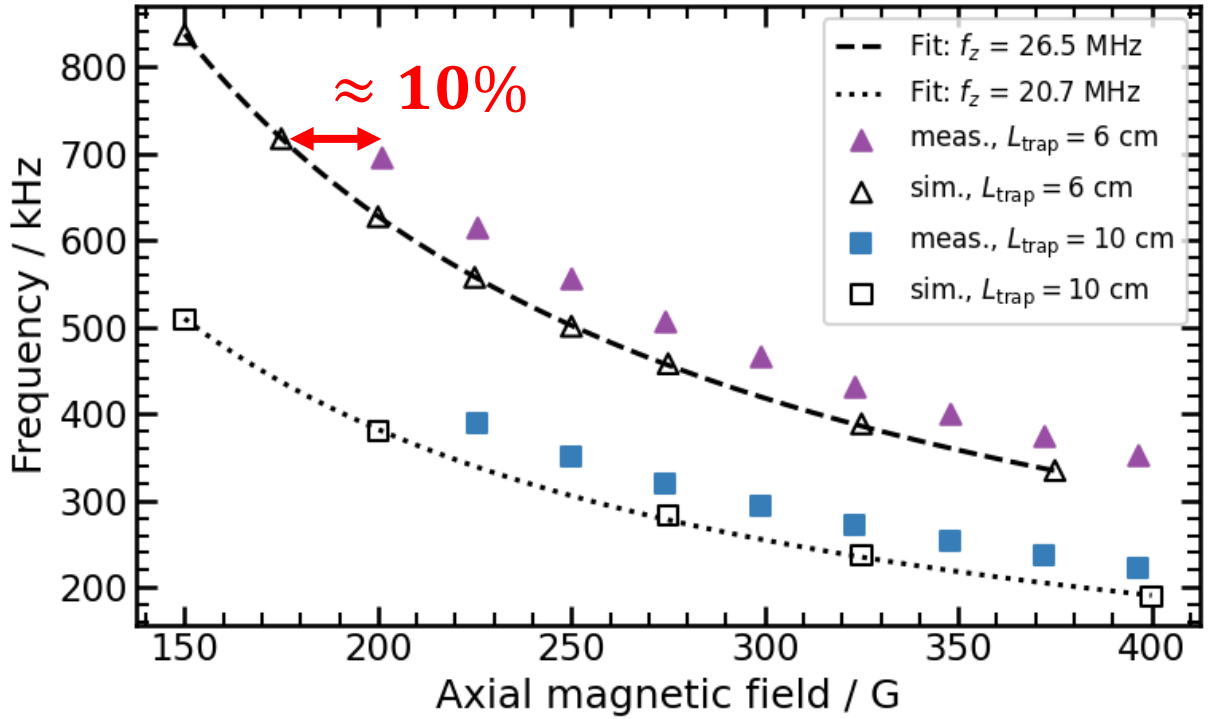




Main results and comparison to simulation (2)

- Magnetron frequency ω_m measured under various trapping conditions
  - Change in the current through the solenoid





Recent probing of the solenoid field (C. Baker)
→ 10% lower than expected from model (consistent with discrepancy above)

Next steps

- Repeat previous sets of simulations to include the new information about the solenoid field

- Modification/replacement of the source for higher emission current (C. Baker)
  - Larger beam collimator → larger beam diameter & more electrons trapped
  - Replace linear filament with single loop/multiple loops lamp filament

- Second round of measurements with "good" plasma ($r_p \gg \lambda_D$)
  - Single-particle motion → plasma behaviour
    - Magnetron motion → diocotron motion
      - Image charges induced in the conducting walls
      - Plasma space-charge

(to be compared to PIC simulations)

Thank you for listening!