

Proton and ion capture

Gabor lens

- The focal length (f) of the Gabor lens:

$$\frac{1}{f} = \frac{e^2 n_e l}{4\epsilon_0 U}$$

where e is electric charge of the electron

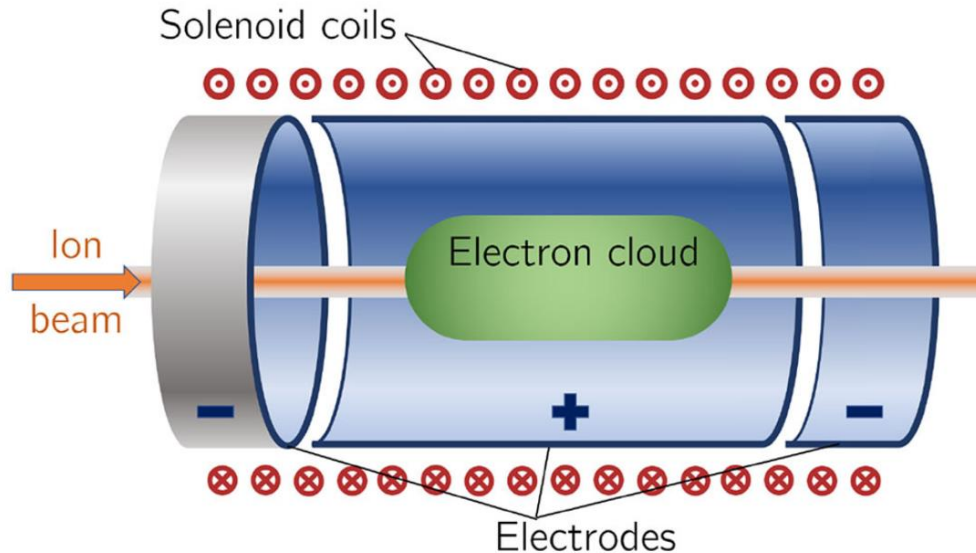
n_e is the plasma density

l is the length of the plasma

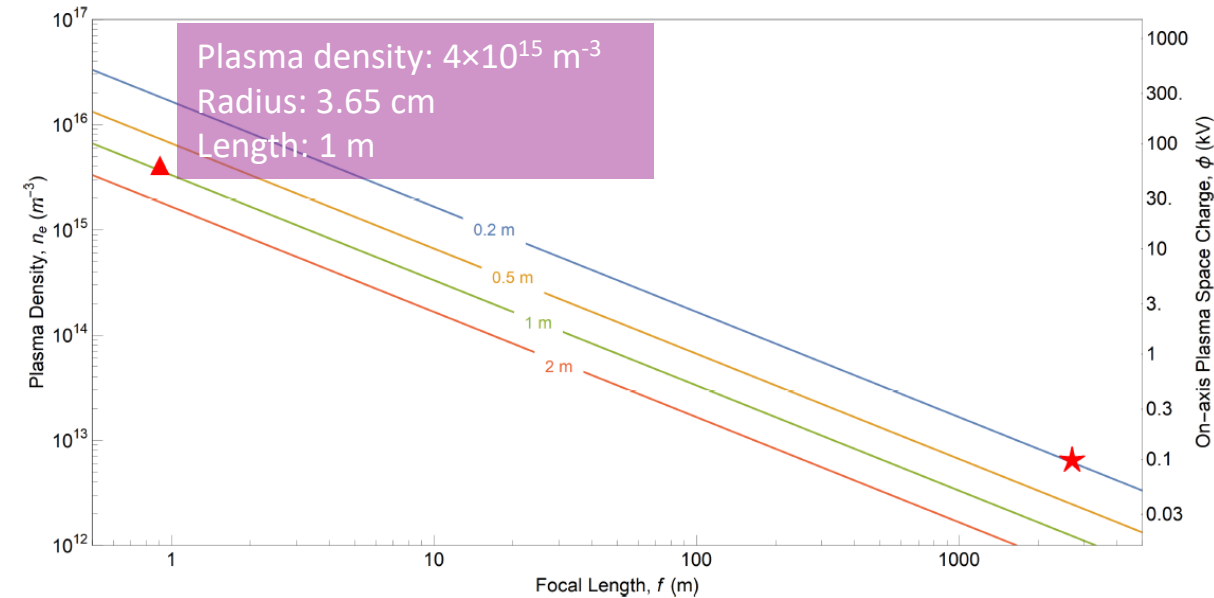
ϵ_0 is the permittivity of free space

U is the kinetic energy of the positively charge particle.

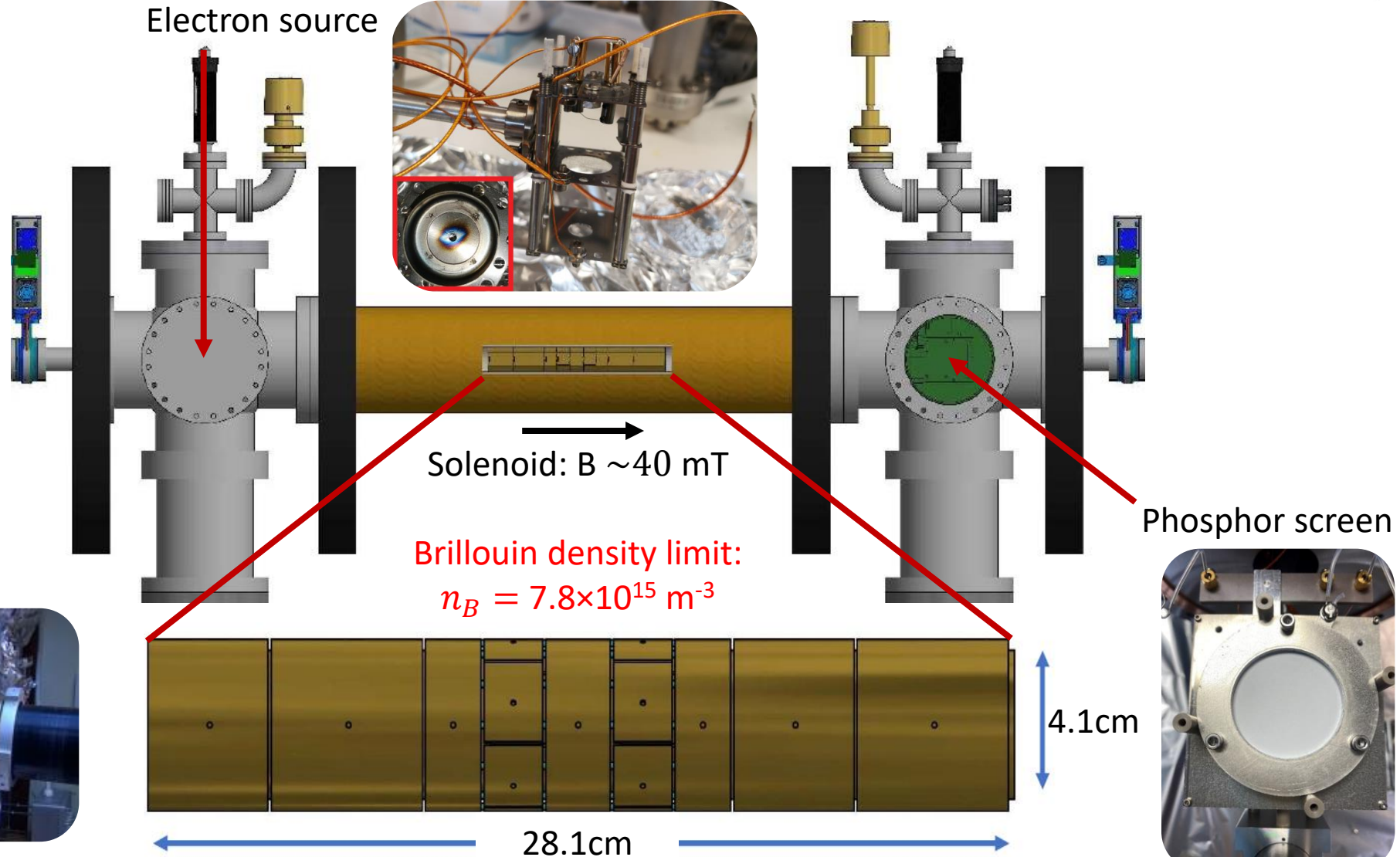
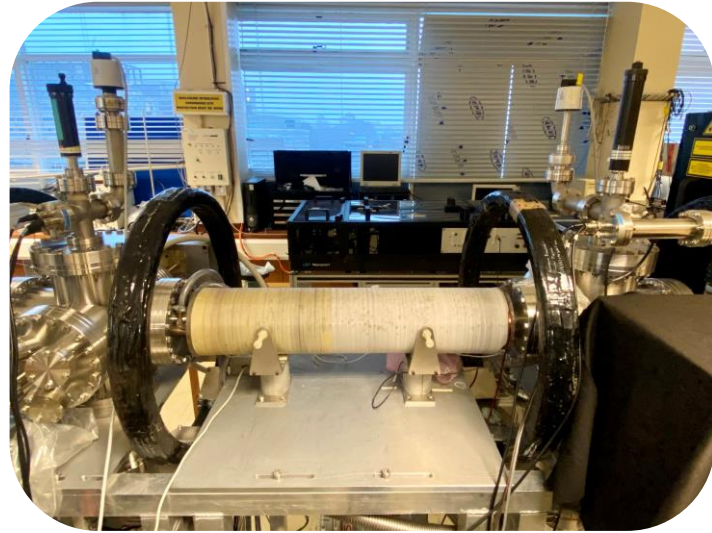
- Penning-Malmberg trap



Aymar, G., Becker, T., Boogert, S., Borghesi, M., Bingham, R., Brenner, C., ... & Xiao, R. (2020). LhARA: the laser-hybrid accelerator for radiobiological applications. *Frontiers in Physics*, 8, 567738.

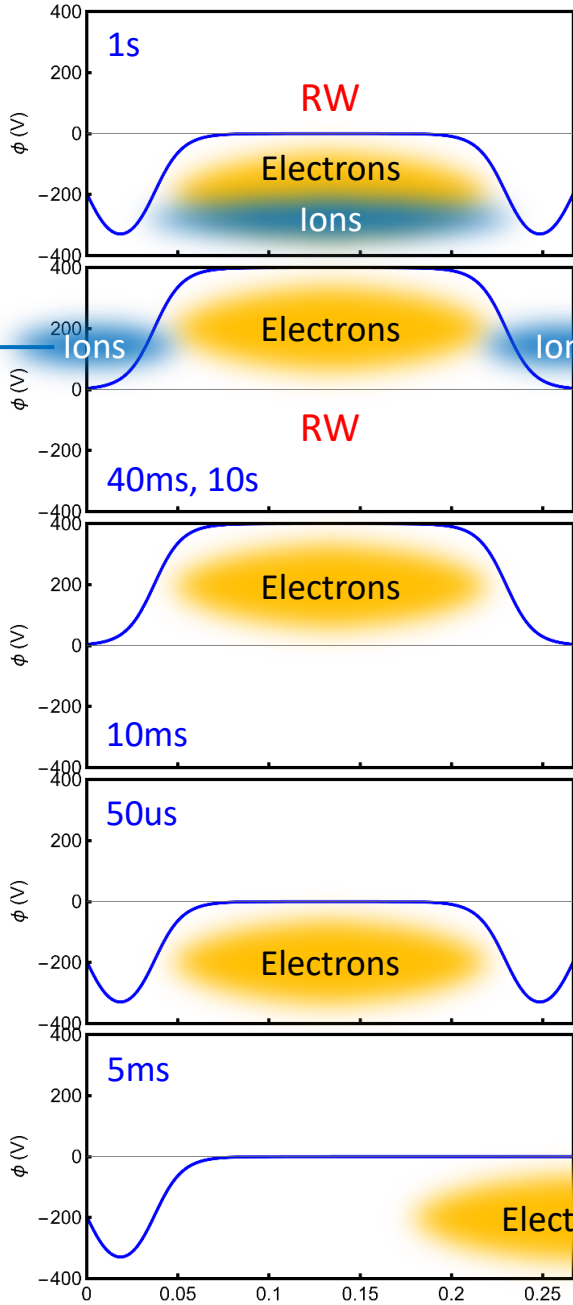


Experimental setup

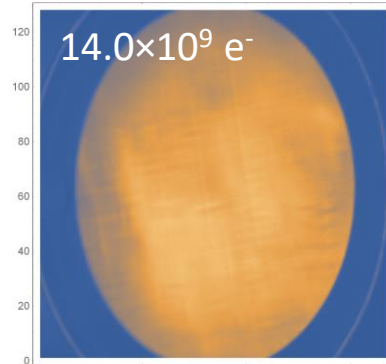


Previous results (HV trap)

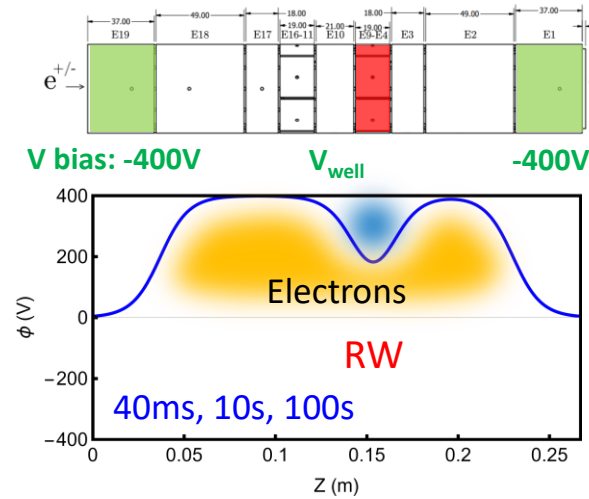
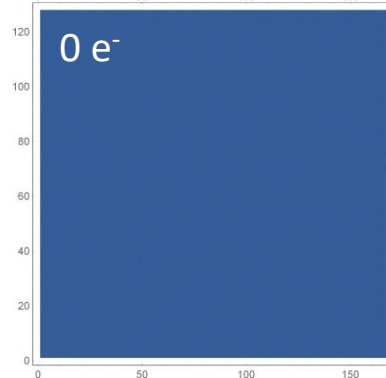
- Rotating wall (RW)
- Cooling gas (CO_2)



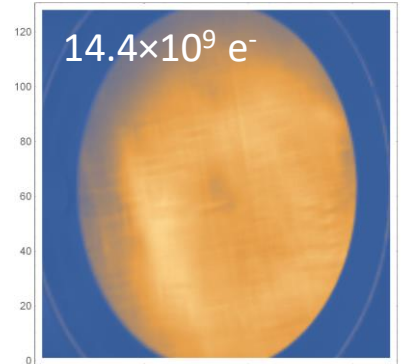
40 ms



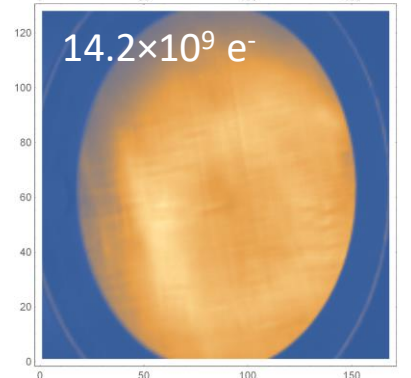
10 s



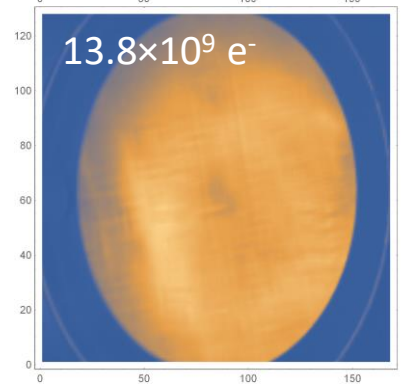
40 ms



10 s



100 s



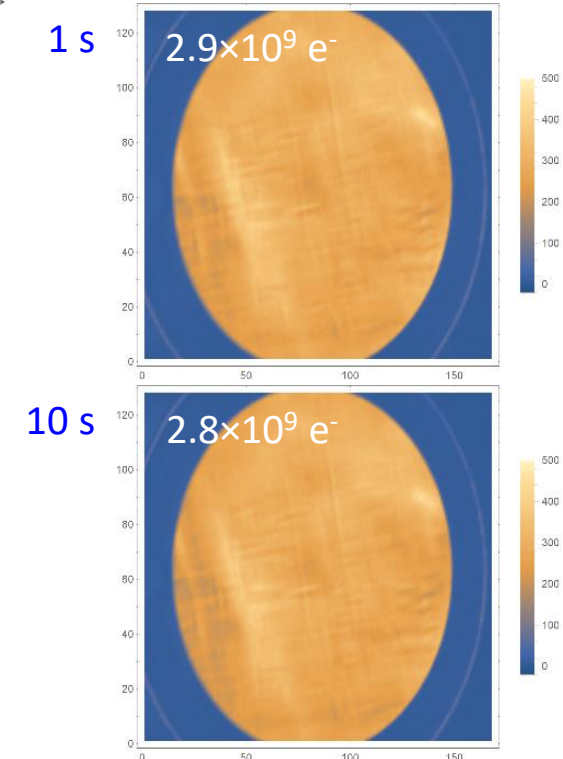
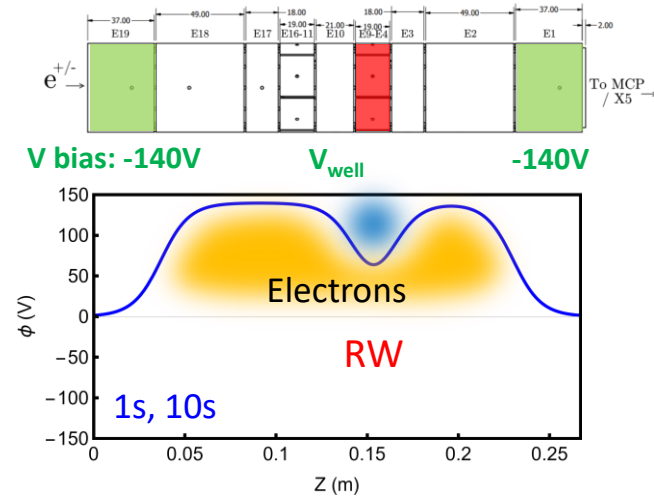
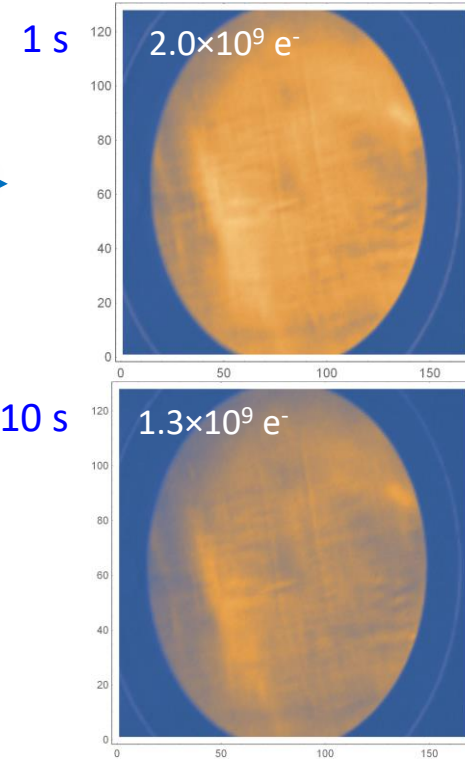
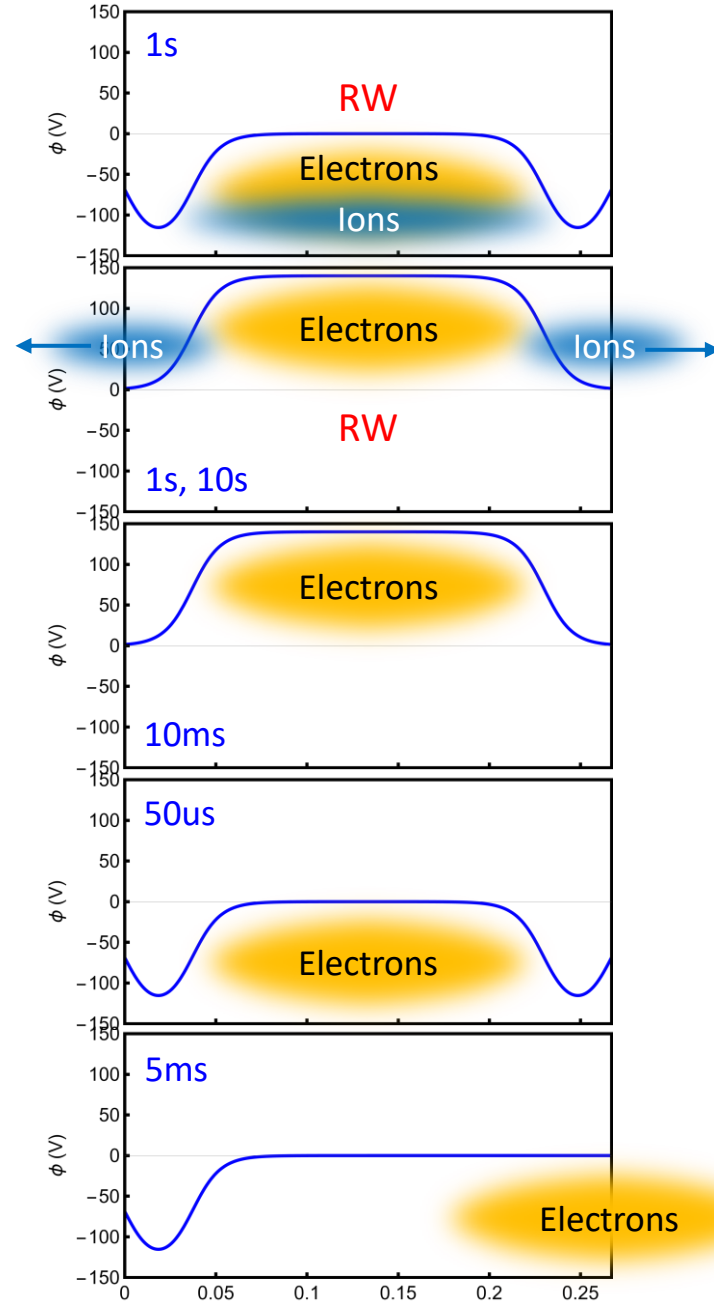
Electrons

HV Amplifiers (± 400 V)

—*Malfunctioning*



Switch to ± 140 V amplifiers



1. The plasma contains a high electron number.
 - Caused by ionization between RW field and CO₂ cooling gas.
 - Influenced by a dimple in the trap.
2. The plasma remains stable as long as the RW is applied.
 - Likely due to the dimple that confines trapped ions.

Simplify the experiment

1. The plasma contains a high electron number.

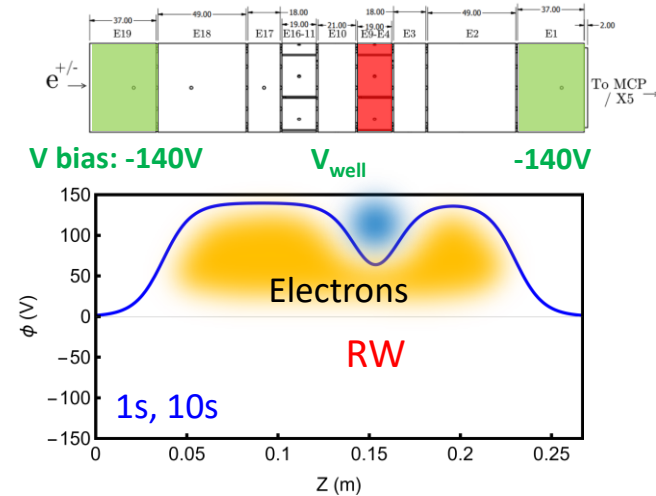
- Caused by ionization between RW field and CO₂ cooling gas.
- Influenced by a dimple in the trap.

2. The plasma remains stable as long as the RW is applied.

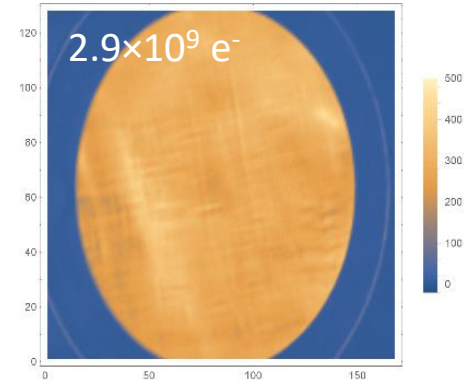
- Likely due to the dimple that confines trapped ions.

To simplify the experiment:

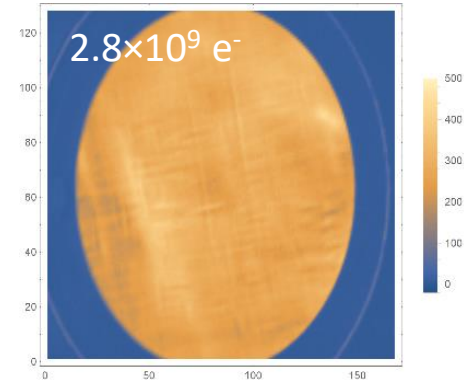
1. Apply an oscillating field to E2 or E18.
2. Create a dimple on E3, E4-9, E10, E11-16, or E17.



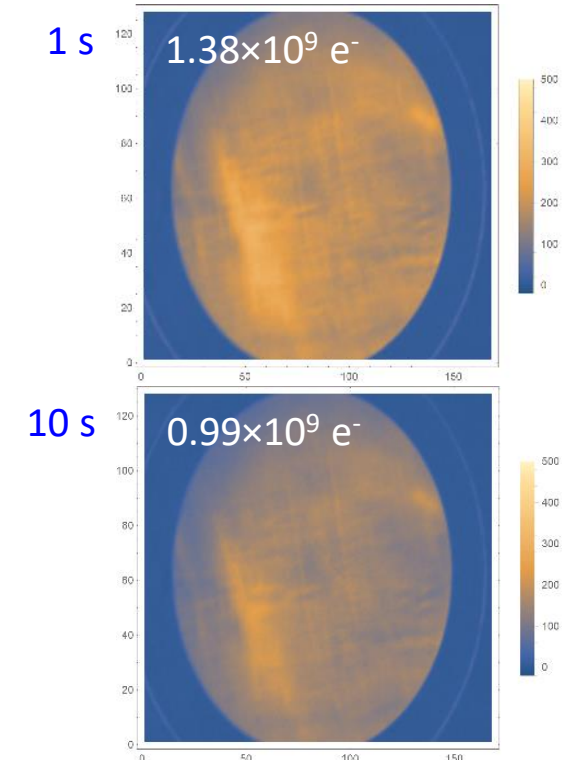
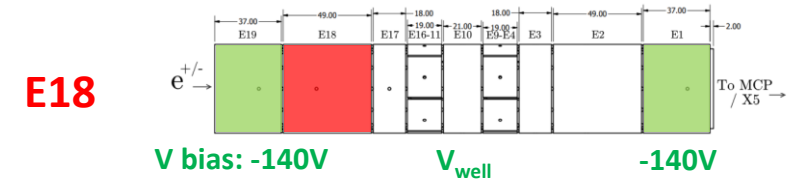
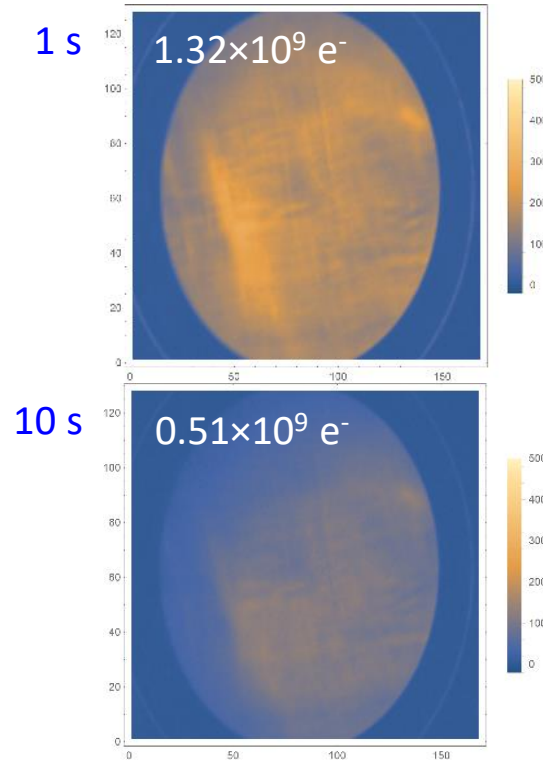
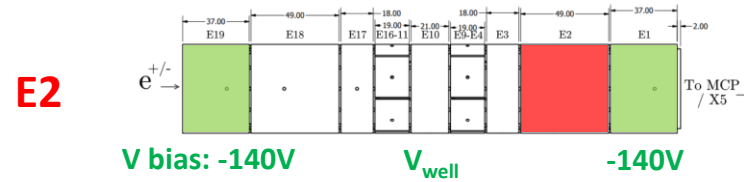
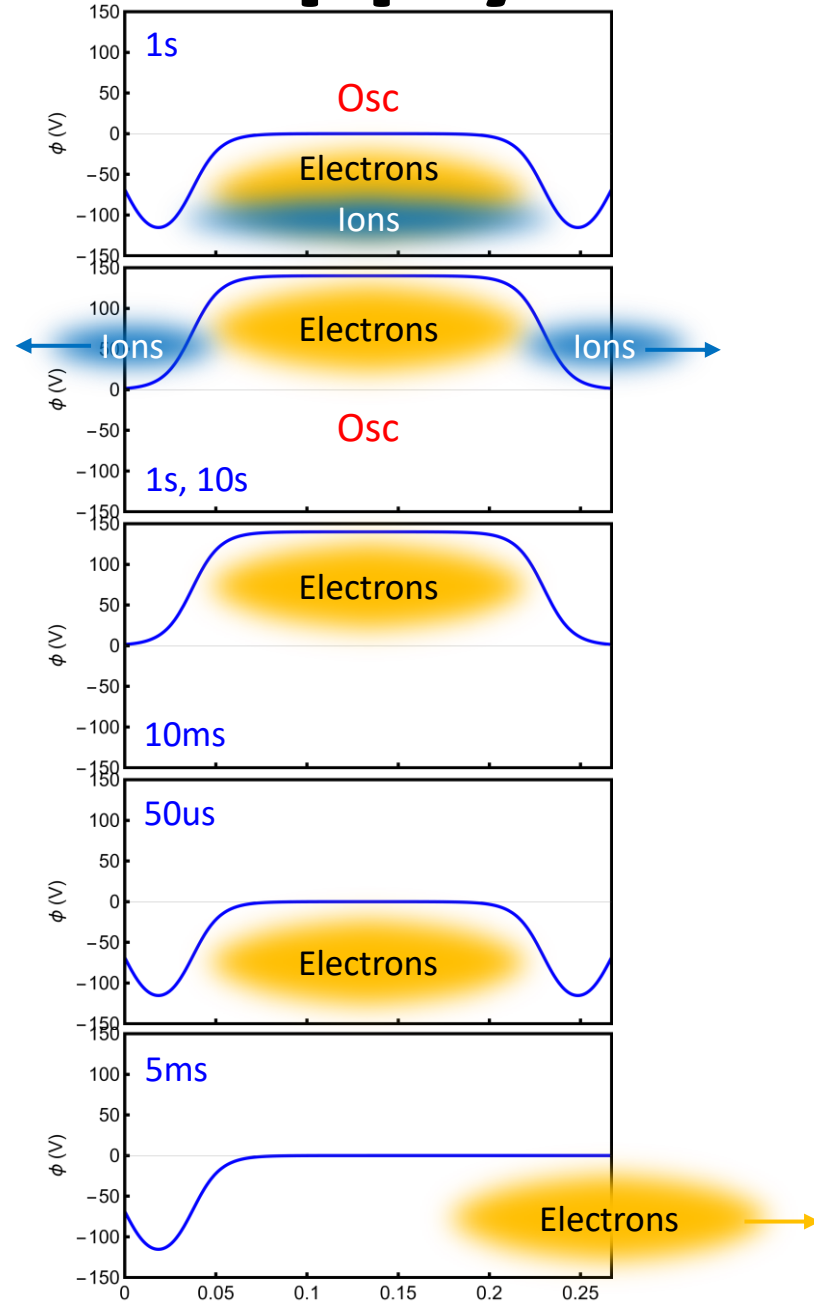
1 s



10 s



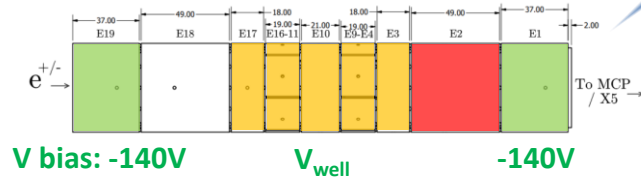
1. Apply an oscillating field



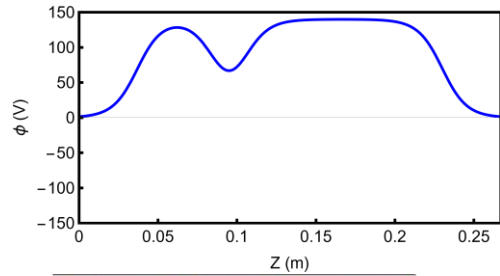
2. Osc (E2) + Dimple



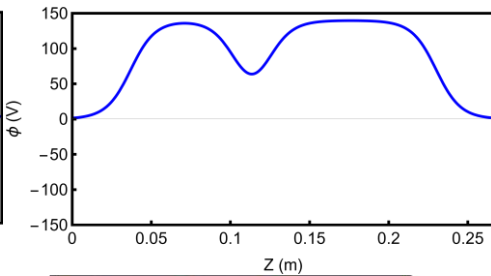
E2



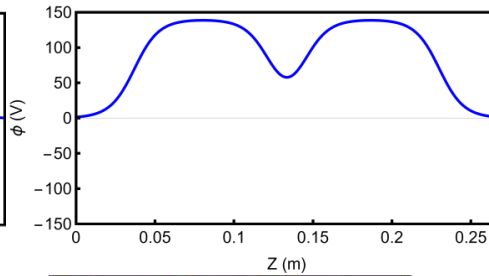
Dimple (E17)



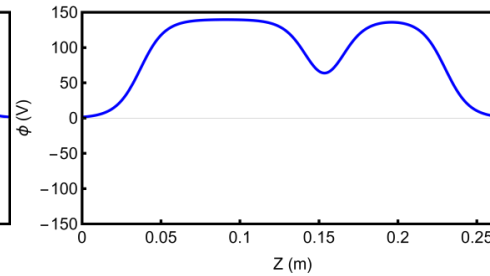
Dimple (E11-16)



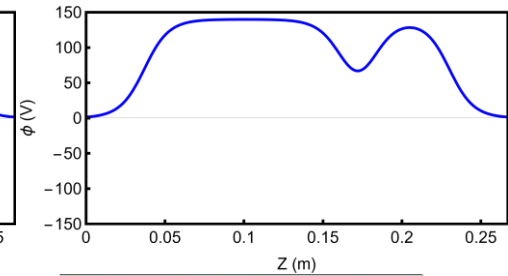
Dimple (E10)



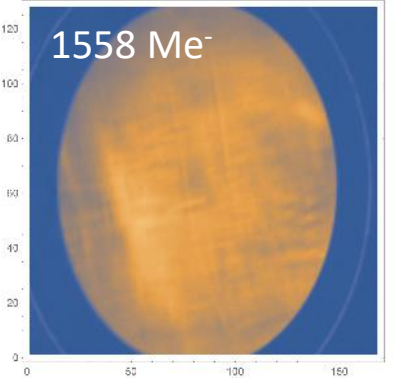
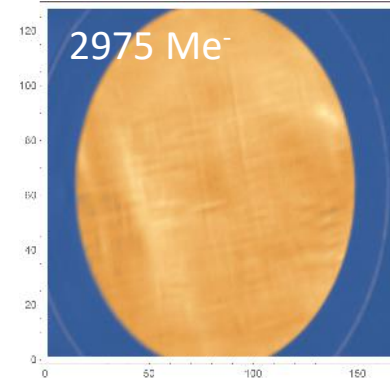
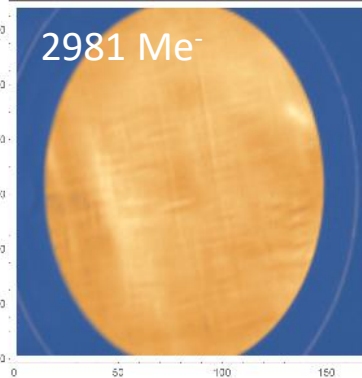
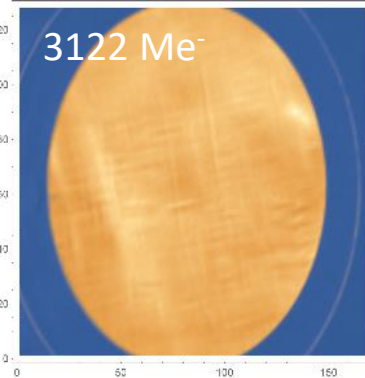
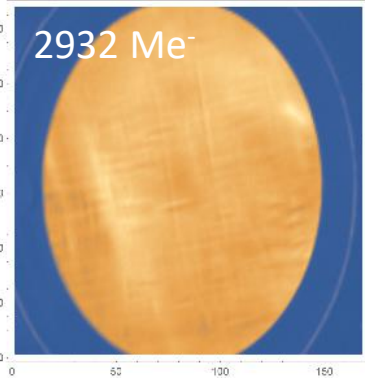
Dimple (E4-9)



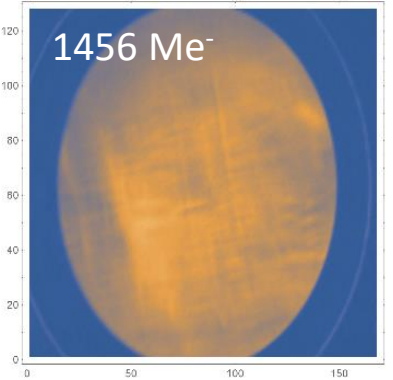
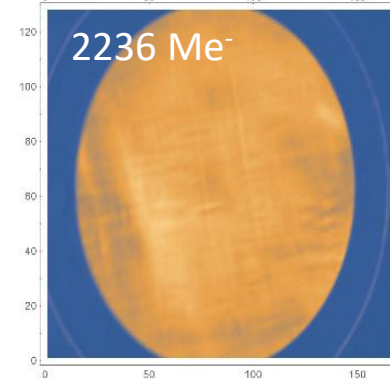
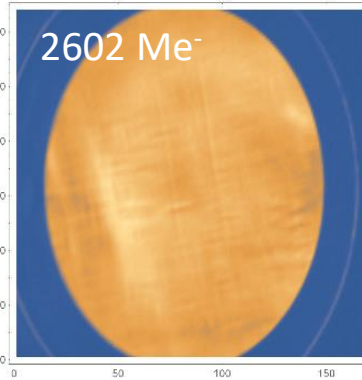
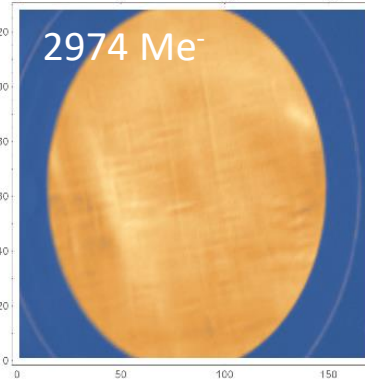
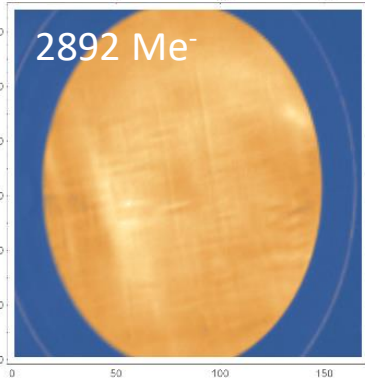
Dimple (E3)



1 s



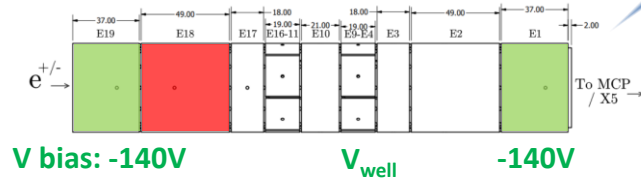
10 s



2. Osc (E18) + Dimple



E18

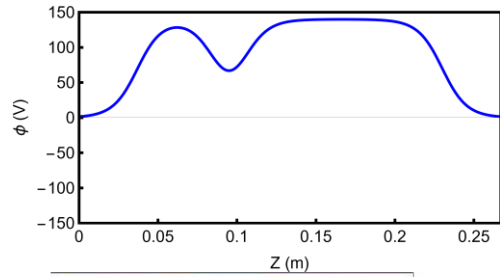


$V_{\text{bias}}: -140\text{V}$

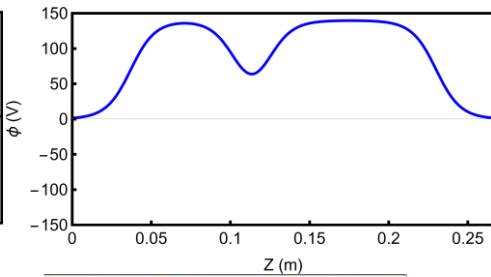
V_{well}

-140V

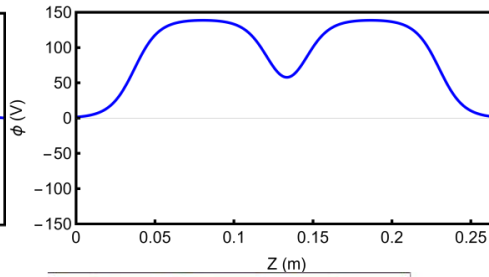
Dimple (E17)



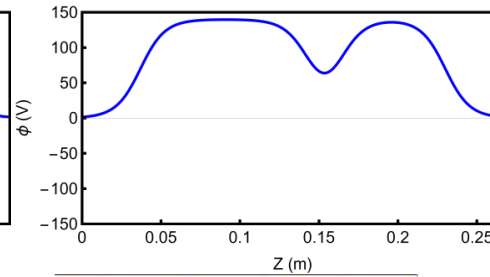
Dimple (E11-16)



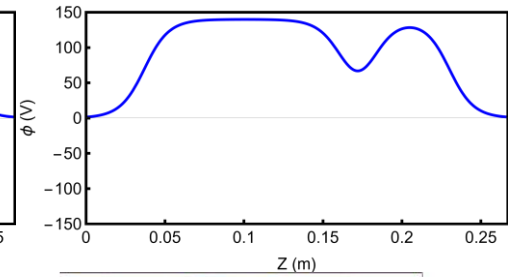
Dimple (E10)



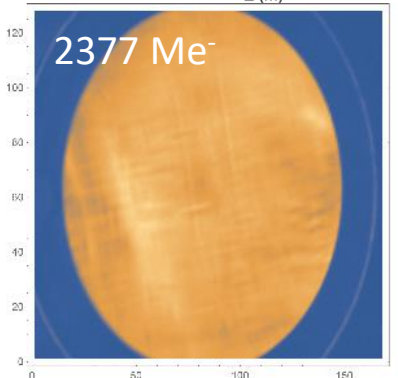
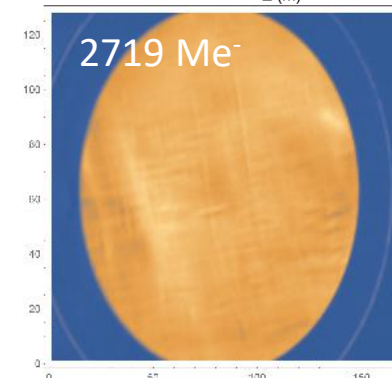
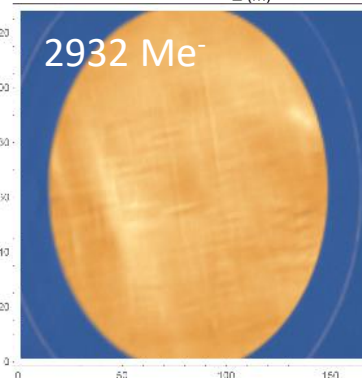
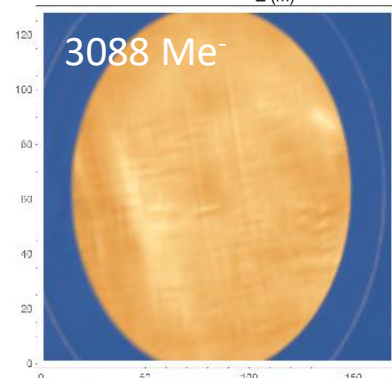
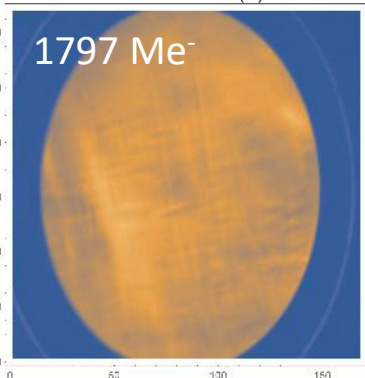
Dimple (E4-9)



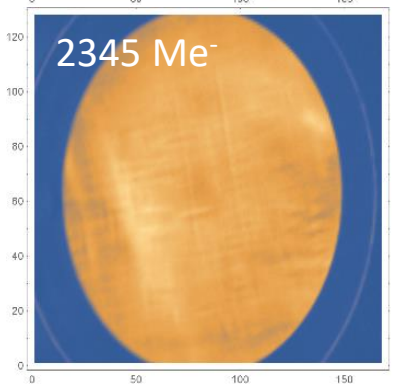
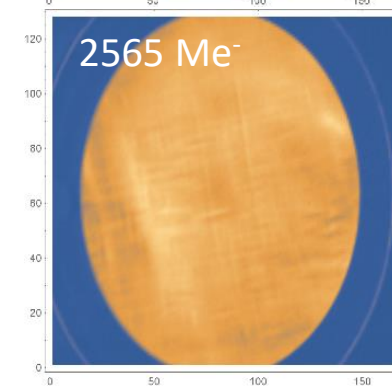
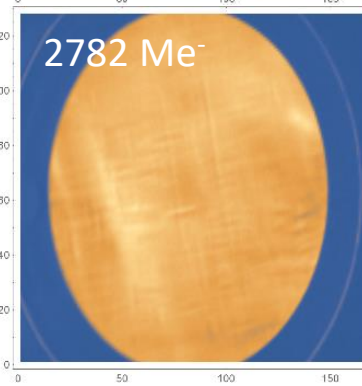
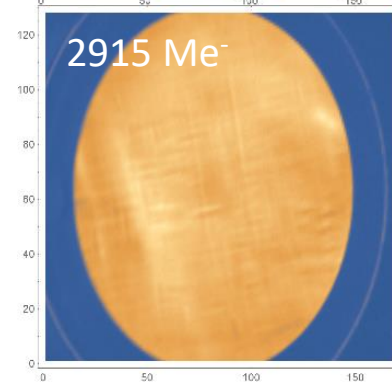
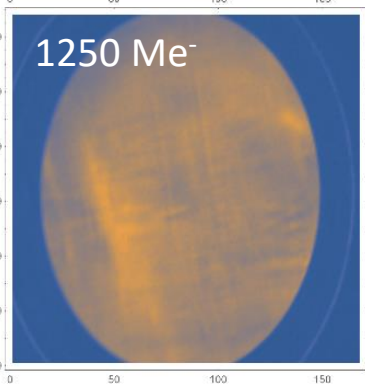
Dimple (E3)



1 s



10 s

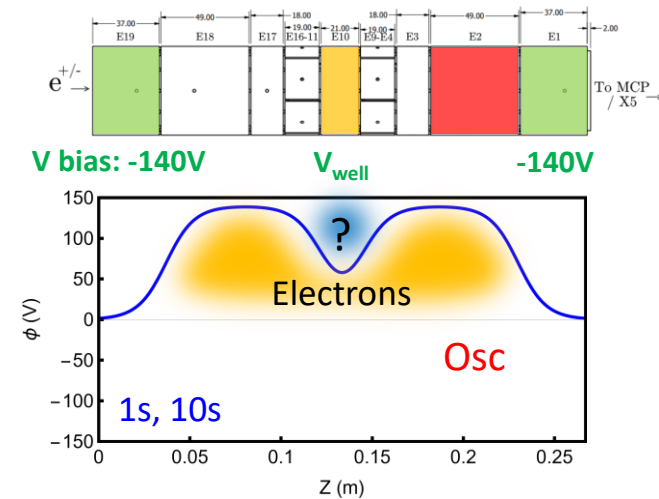


Discussions

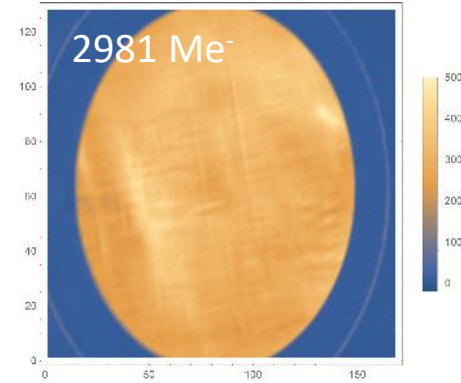
- The oscillating field alone can generate a plasma; however, the resulting electron density is low, and the plasma lacks stability.
- The dimple is essential for producing a stable, high-density plasma.

Question:

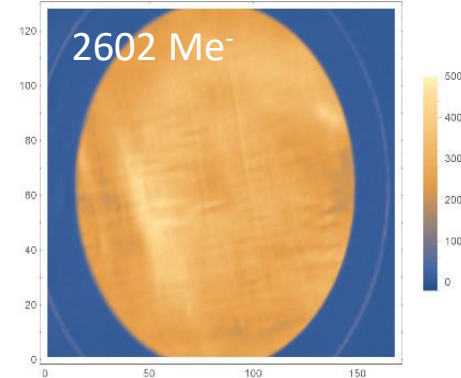
- What is the underlying mechanism by which the dimple contributes to the stability and high-density of the plasma? Is it due to the dimple or the trapped ions or both the dimple and trapped ions?



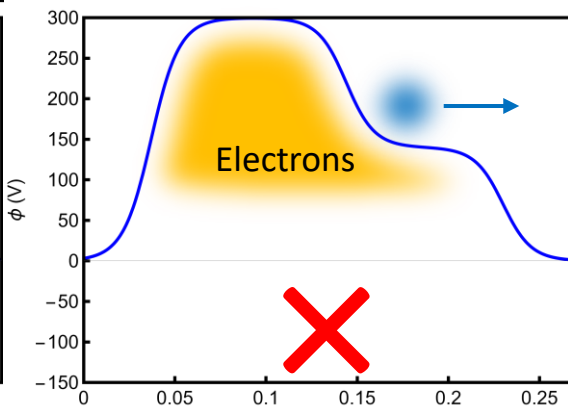
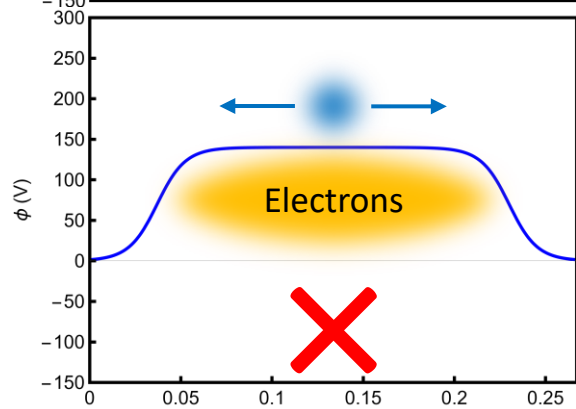
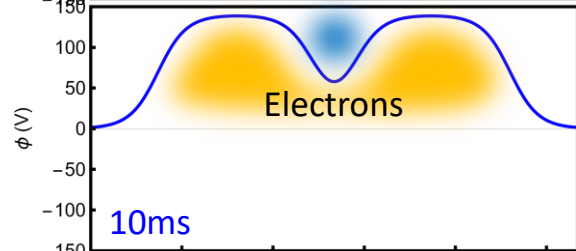
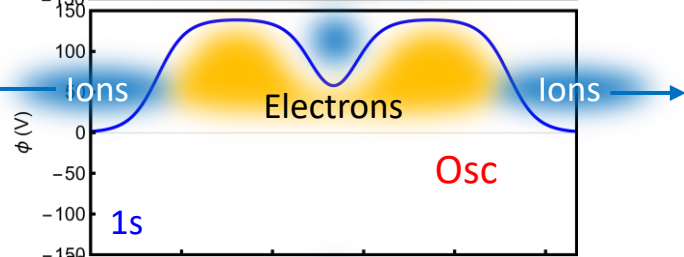
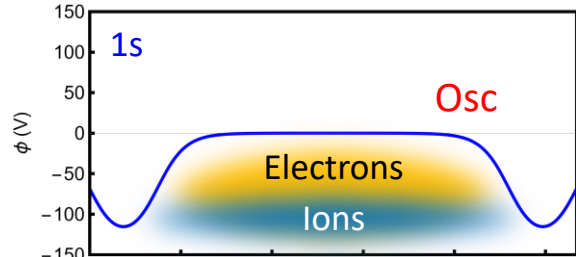
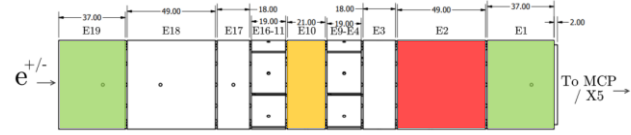
1 s



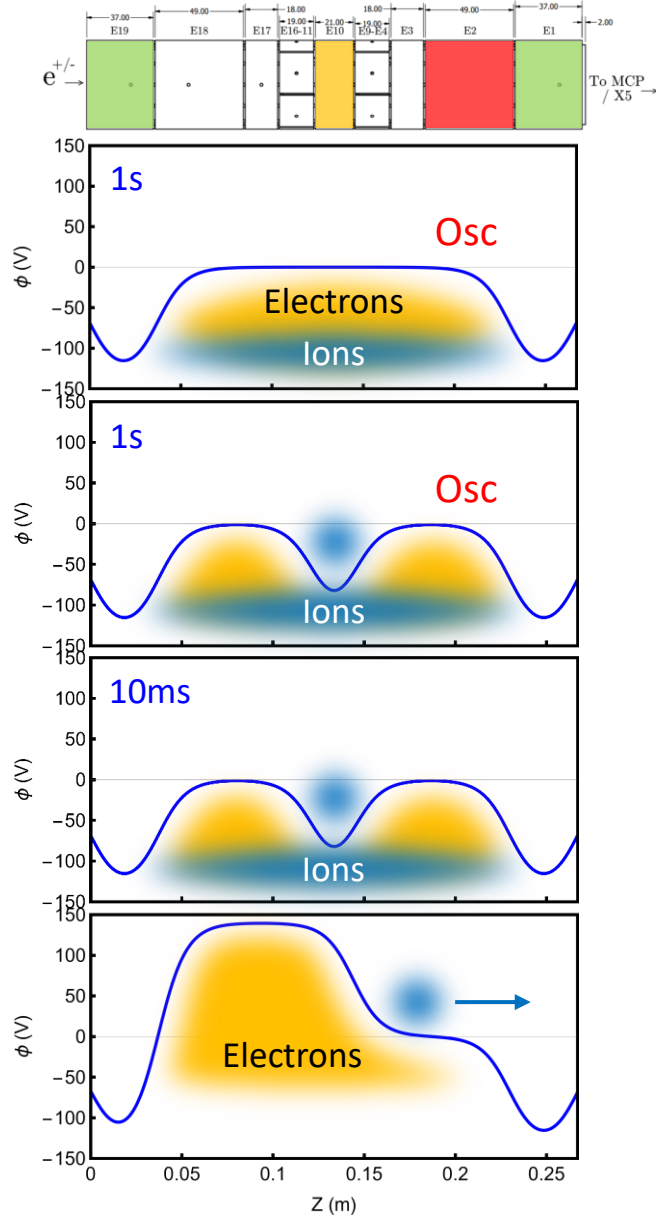
10 s



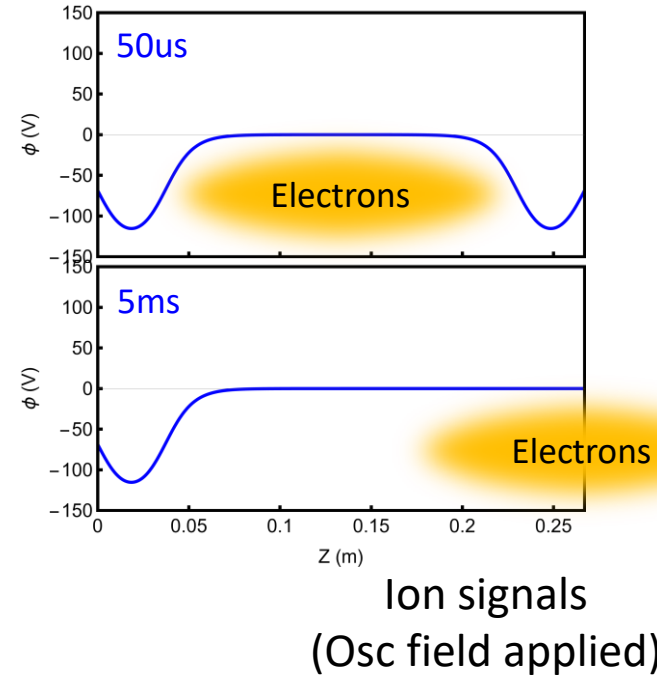
Ion detection



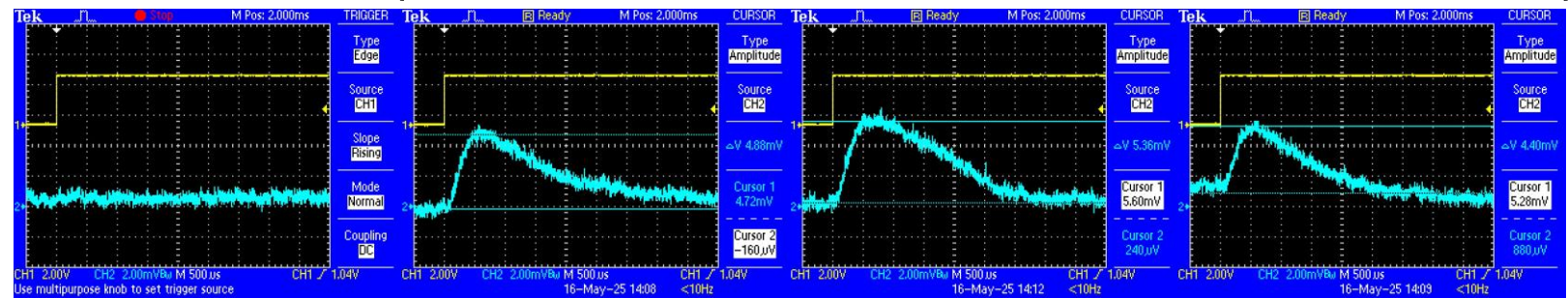
Ion detection



Background signal
(Turn off Osc field)

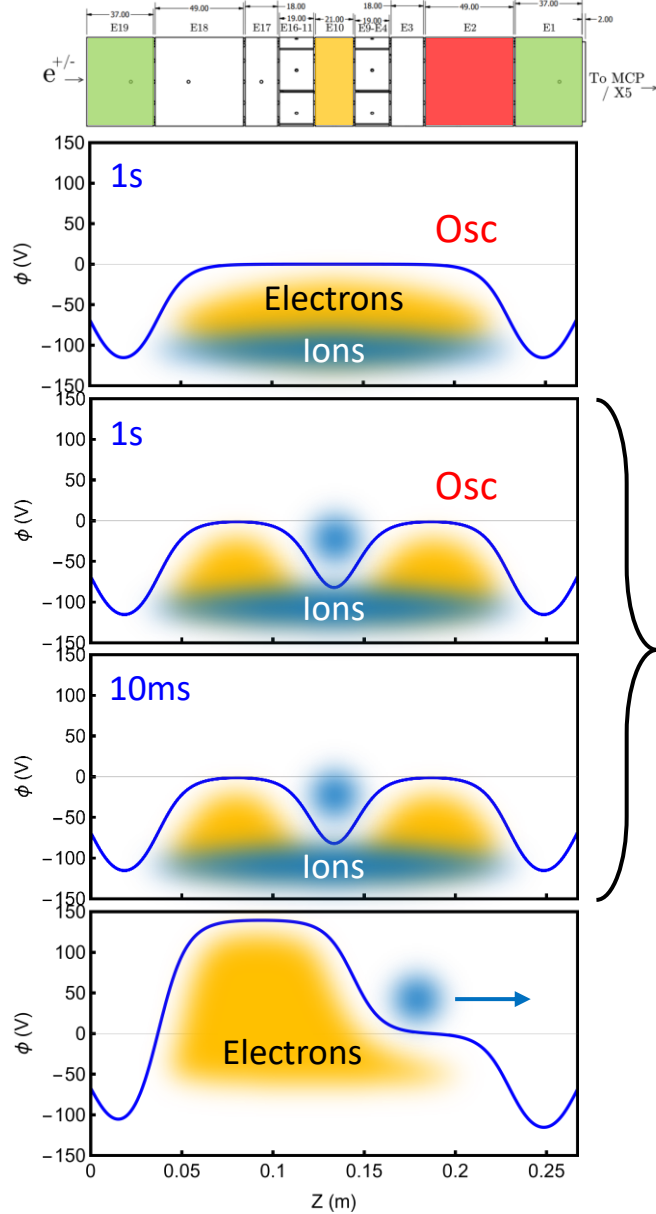


Ion signals
(Osc field applied)

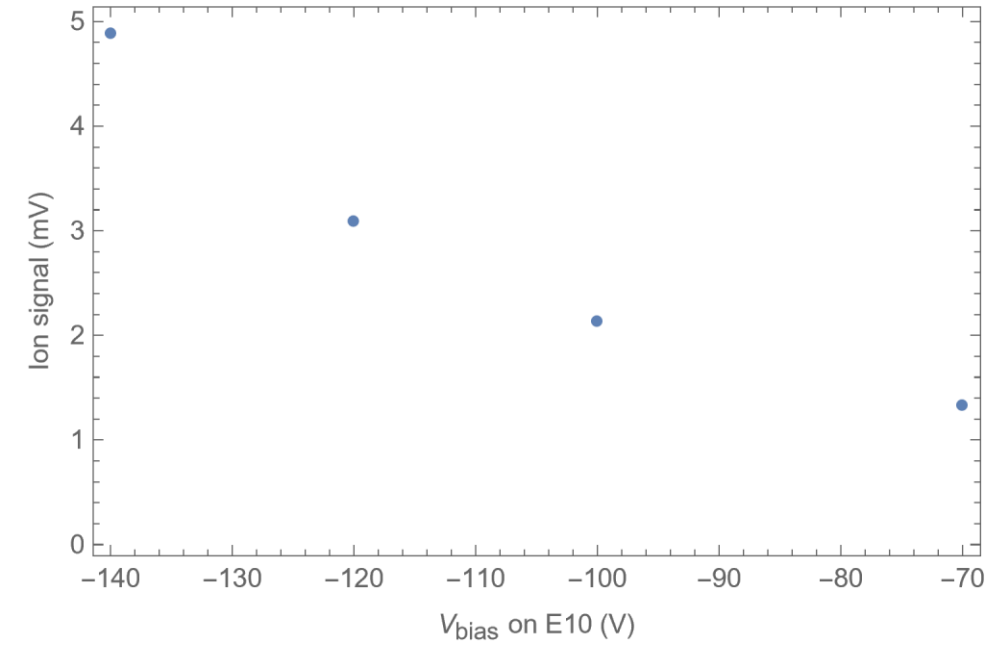
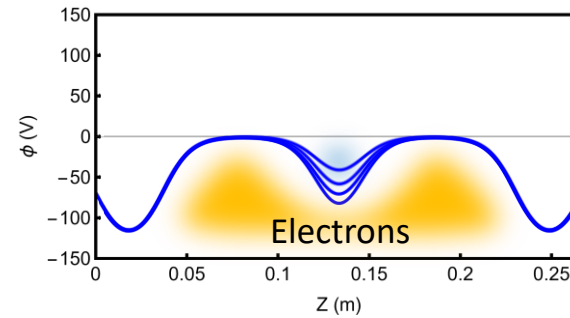


Dimple: -140V, Voltage amplitude: 4.88 mV (29.2 M ions)

Ion detection



V_{bias} (E10): -140, -120, -100, -70 V



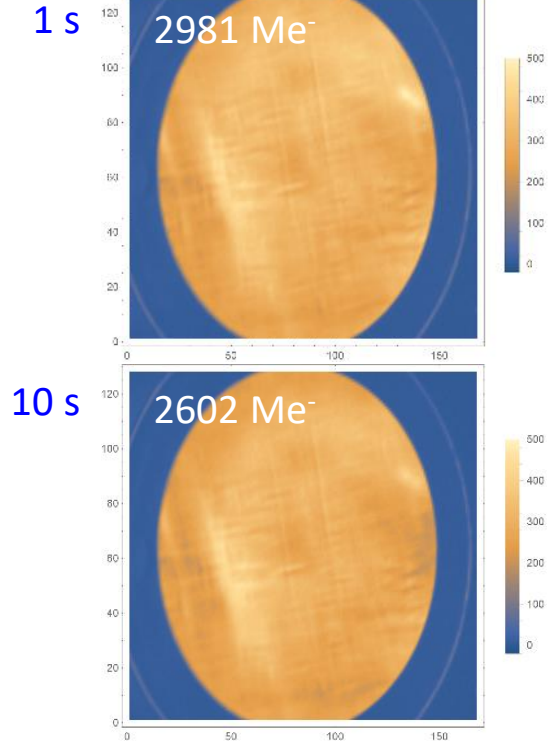
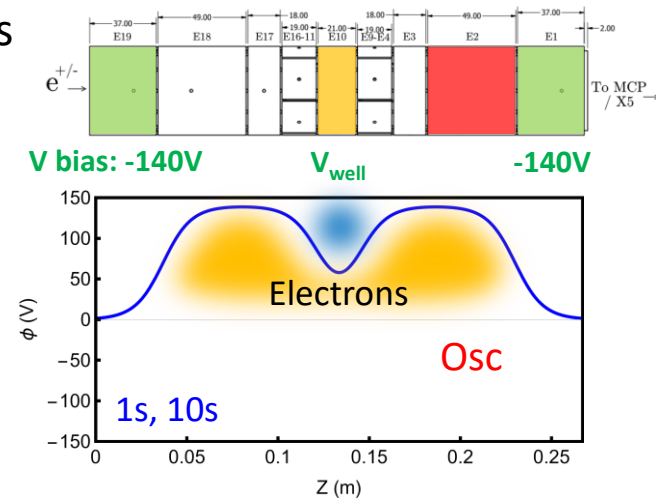
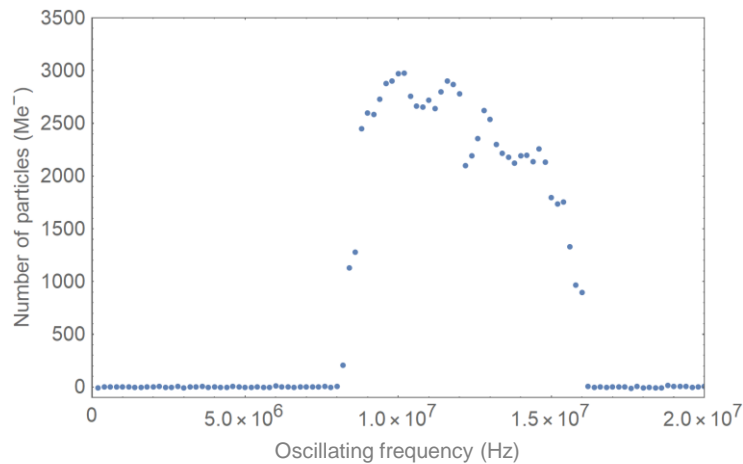
Conclusion and outlook

To generate a stable and high-density plasma, two key components are required:

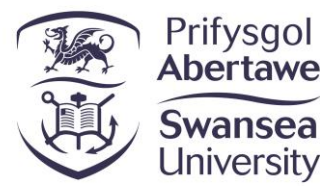
1. **Oscillating electric field**
2. **Dimple that traps ions**

Next steps ...

- Further investigation on dimple and trapped ions.
- Investigate the plasma mode.
- Use numerical simulation to verify our diagnostics.



WP3 Personnel



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J. Wurtele

B. Bingham

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A. Knoll

E. Bennet



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