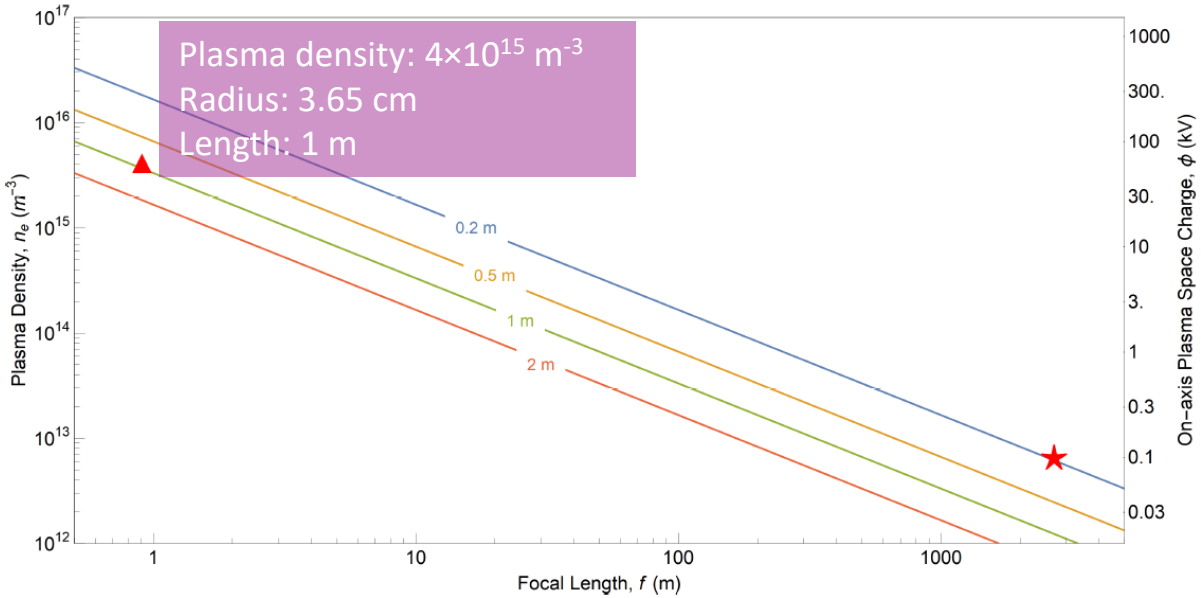
Proton and ion capture

Gabor lens

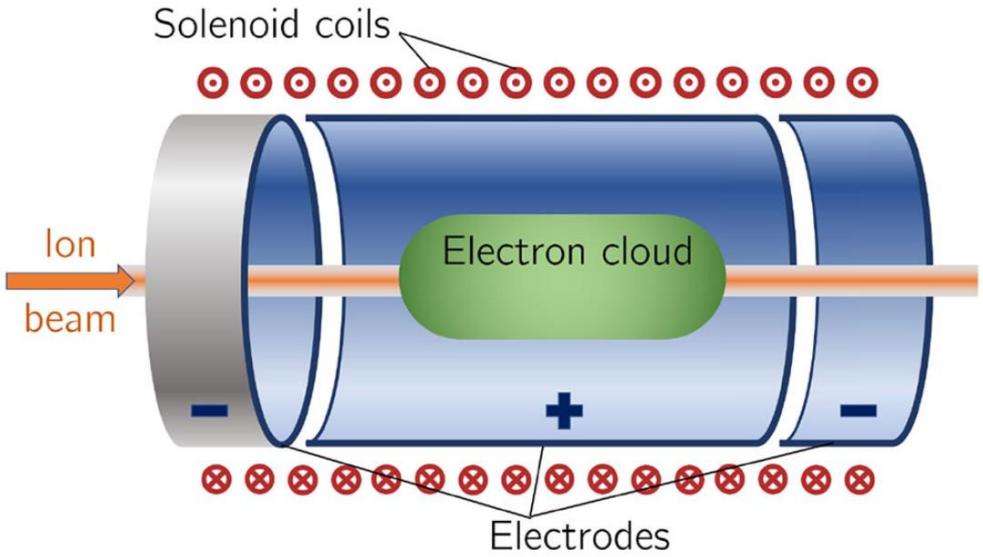
- **The focal length (f) of the Gabor lens:**

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

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.

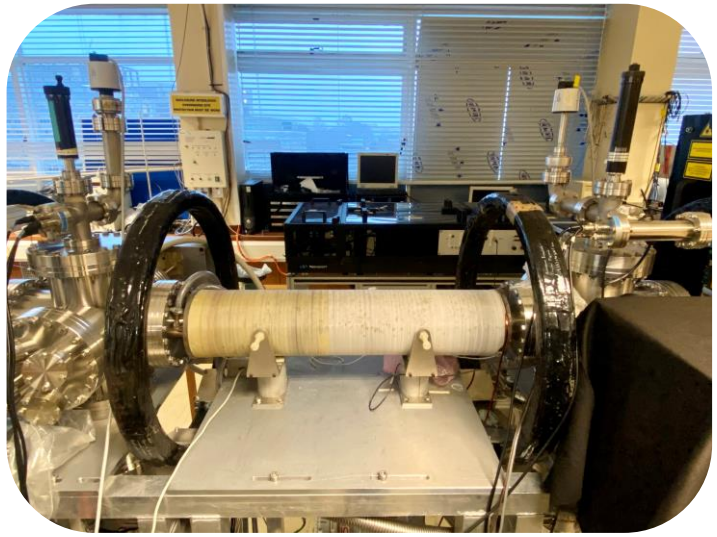


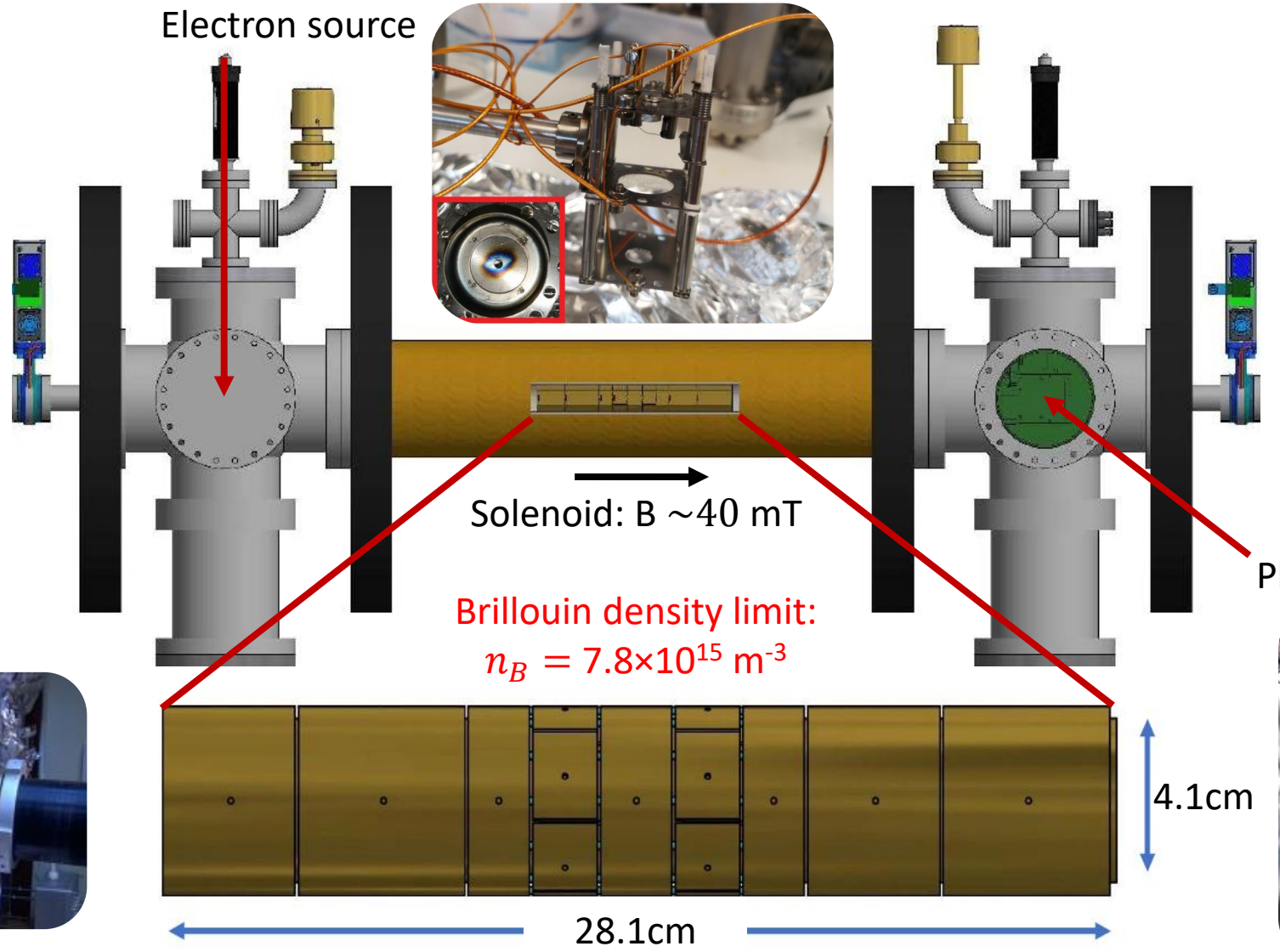
- **Penning-Malmberg trap**

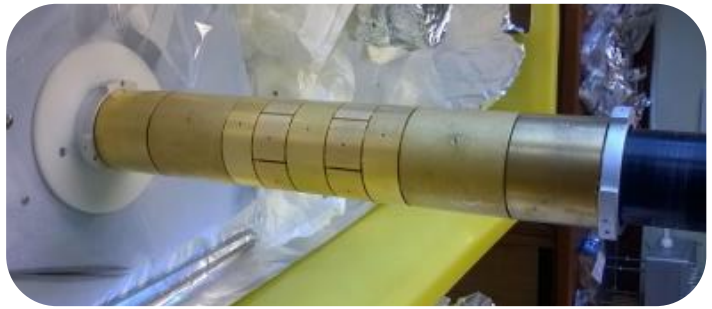


Aymar, G., Becker, T., Boogert, S., Borghesi, M., Bingham, R., Brenner, C., ... & Xiao, R. (2020). LhARA: the laser-hybrid accelerator for radiobiological applications. Frontiers in Physics, 8, 567738.

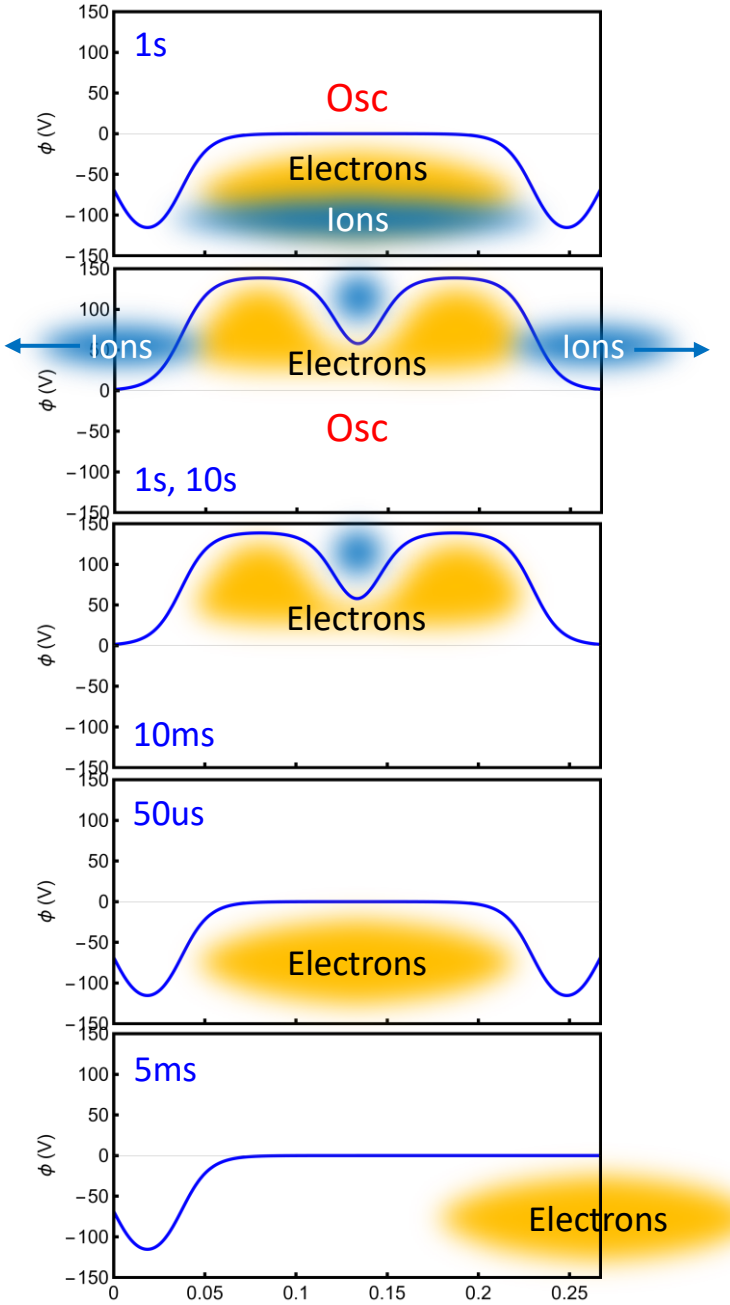
Experimental setup





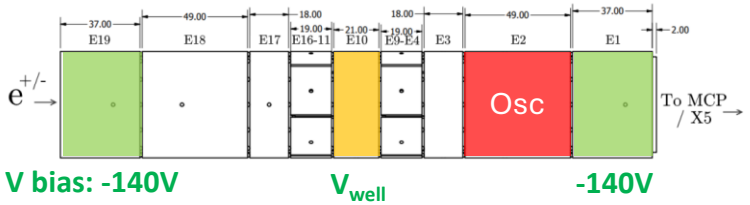


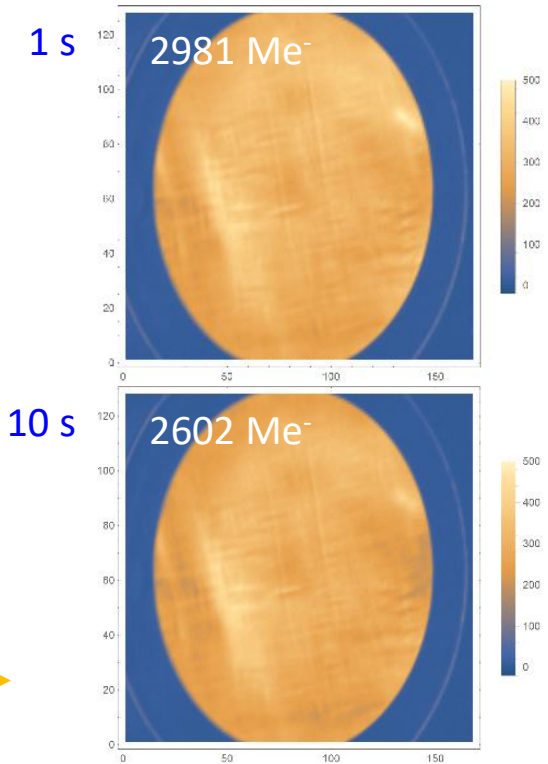
Previous results (-140V trap)



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

1. **Ionization:** Oscillating electric field (Osc) + Background gas
2. **Dimple that traps ions**





CO_2 → Ar

Polyatomic molecule — Monatomic

- Cause dissociation (breaking apart the molecule), generating secondary species like CO, O_2, or carbon-based ions that may affect plasma behaviour and diagnostics.

Documentation of plasma results with/without CO_2 gas

Seed Plasma (without CO_2)

1. N(t): Number of particles vs. load time
2. Lifetime: Number of particles vs. hold time
3. Temperature
4. Mode

Lens Plasma

Cooling gas: CO_2 (fixed pressure)

Oscillating field: applied to E2

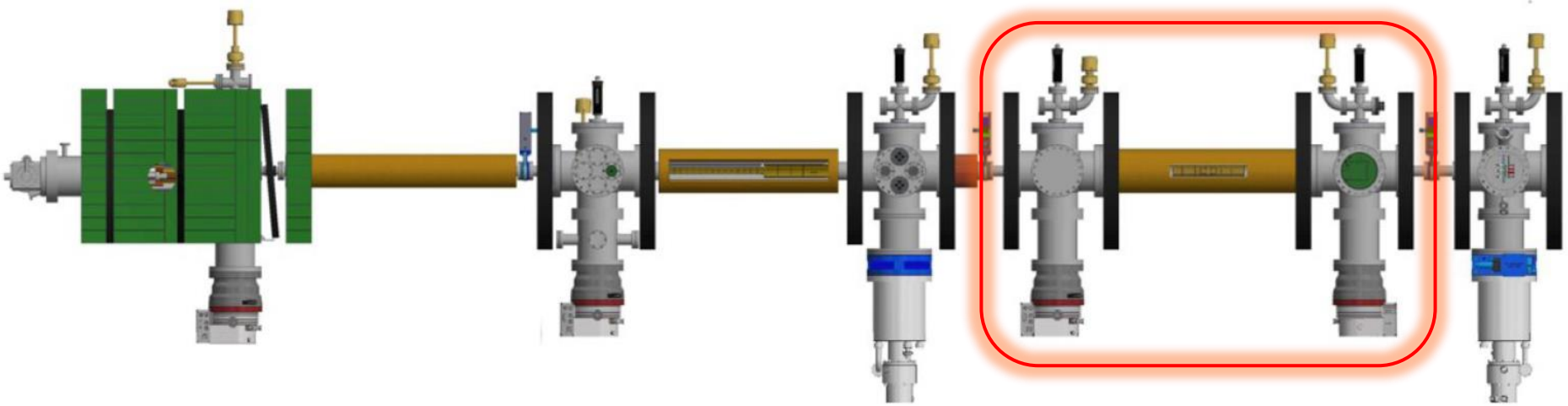
1. N(t): Number of particles vs. load time
2. Stability: Number of particles vs. hold time (oscillating field on)
3. T(t): Temperature vs. time during oscillating field application
4. Lifetime: Number of particles vs. hold time (oscillating field off)
5. Mode

Documentation of plasma results with/without CO_2 gas

Seed Plasma (without CO_2)

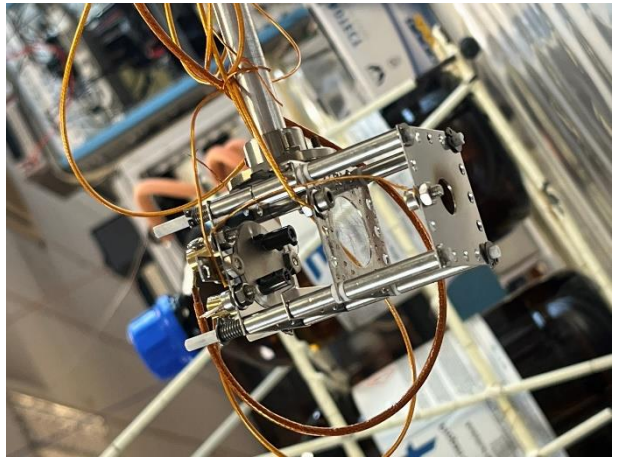
1. N(t): Number of particles vs. load time
2. Lifetime: Number of particles vs. hold time
3. Temperature
4. Mode

Swansea positron beamline



E-gun: Investigation and improvements

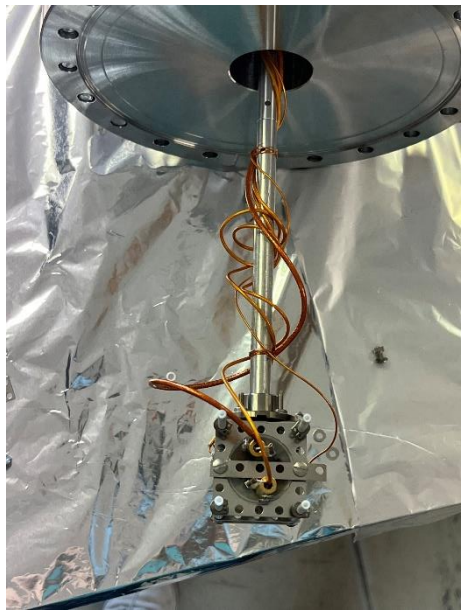
Before:

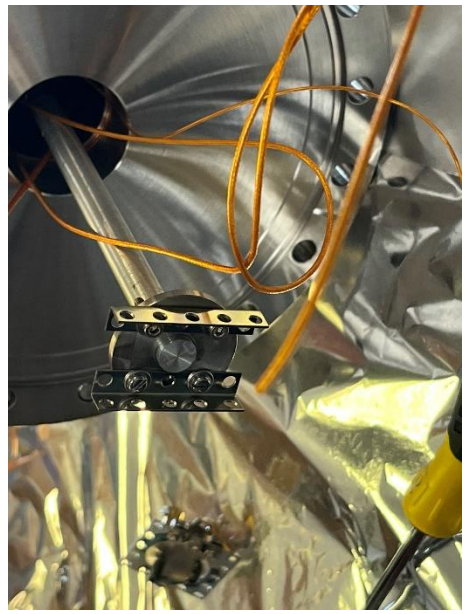


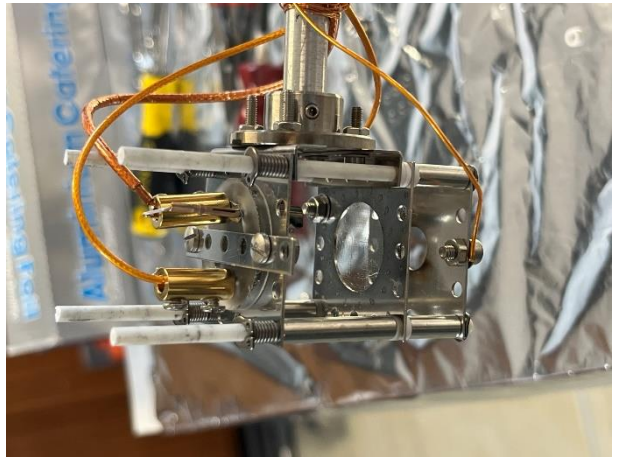
Findings:

1. Loose Wires
2. Unstable Mounting

After:







Improvements Implemented:

1. Wire Management
2. Enhanced Mechanical Stability

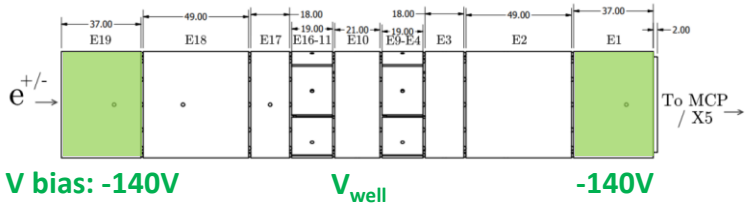
Plasma results without CO_2 gas

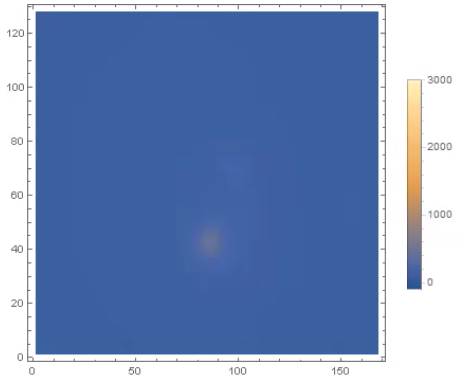
Seed Plasma (without CO_2)

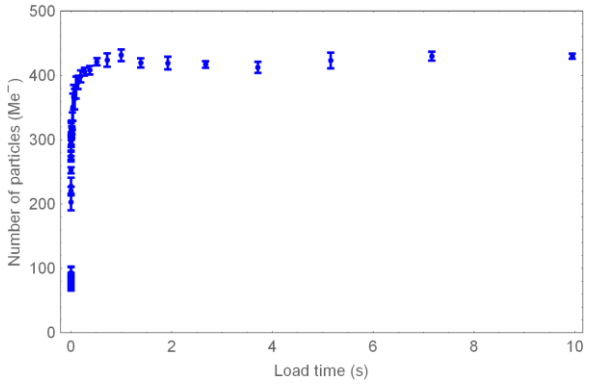
1. N(t): Number of particles vs. load time
2. Lifetime: Number of particles vs. hold time
3. Temperature
4. Mode

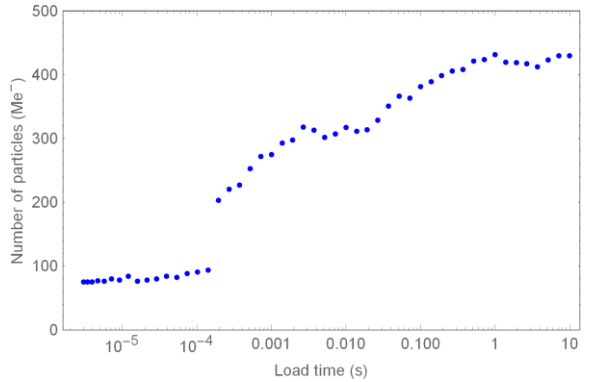
Experimental sequence (Trap depth: -140V)

1) Load: 3us-10s
2) Hold: 20us
3) Dump + Trigger digitizer/CAM: 5ms









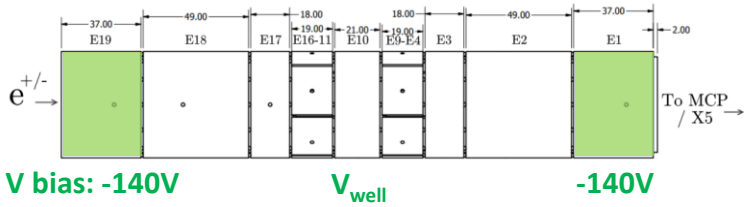
Plasma results without CO_2 gas

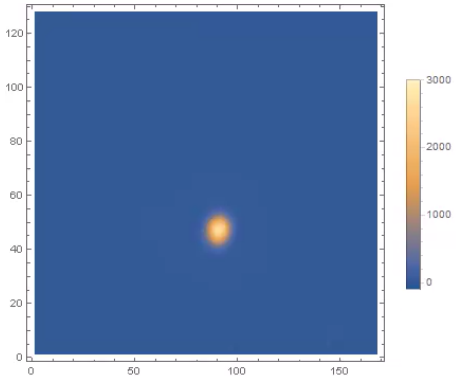
Seed Plasma (without CO_2)

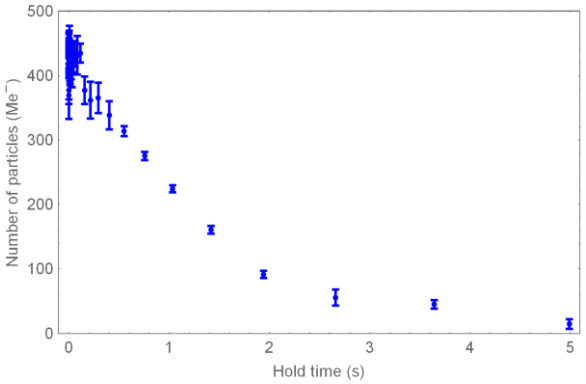
1. N(t): Number of particles vs. load time
2. Lifetime: Number of particles vs. hold time
3. Temperature
4. Mode

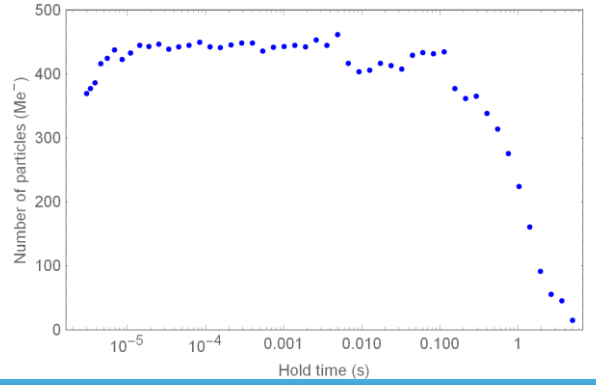
Experimental sequence (Trap depth: -140V)

1) Load: 1s
2) Hold: 3us-5s
3) Dump + Trigger digitizer/CAM: 5ms









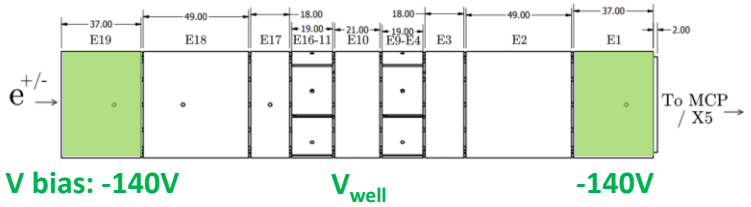
Plasma results without CO_2 gas

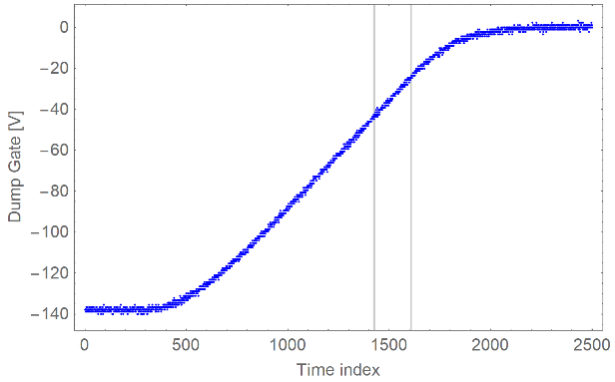
Seed Plasma (without CO_2)

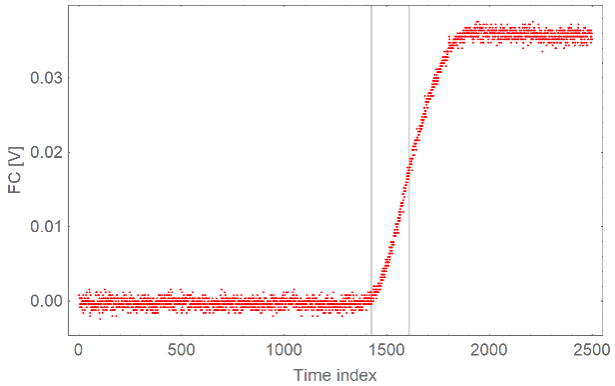
1. N(t): Number of particles vs. load time
2. Lifetime: Number of particles vs. hold time
3. Temperature
4. Mode

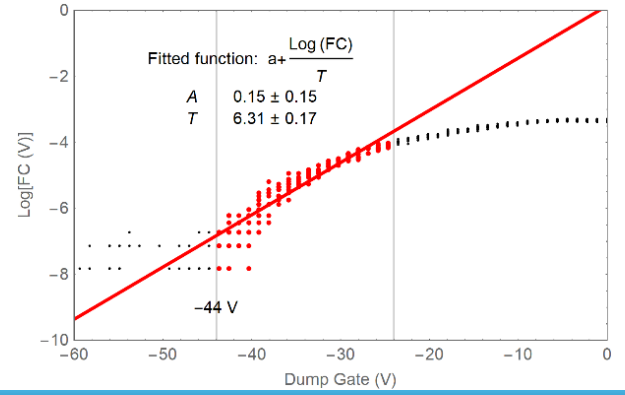
Experimental sequence (Trap depth: -140V)

1) Load: 1s
2) Hold: 20us
3) Dump + Trigger digitizer/CAM: 5ms









Plasma results with CO_2 gas

Lens Plasma

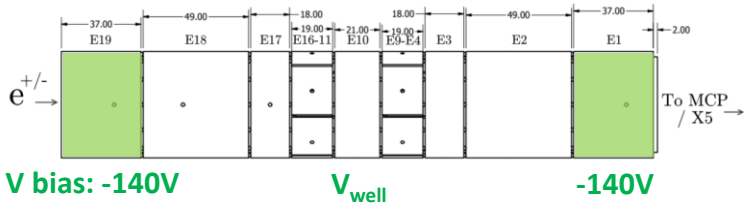
Cooling gas: CO_2 (fixed pressure)

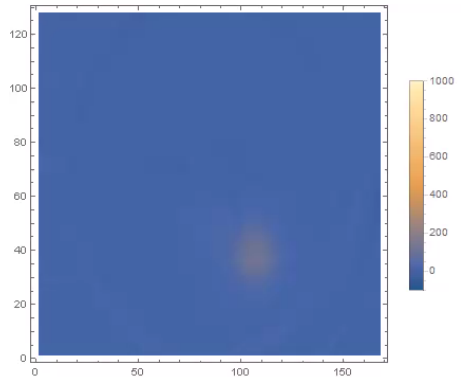
Oscillating field: applied to E2

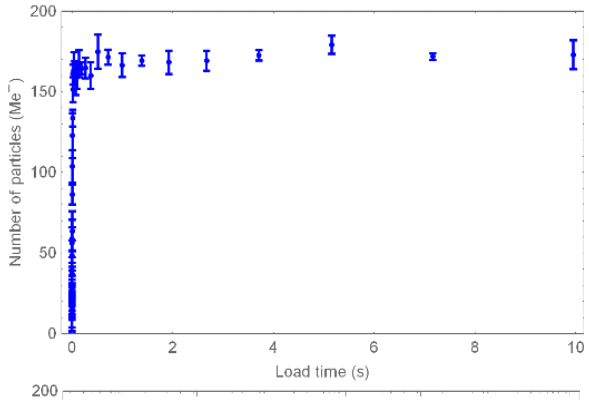
1. N(t): Number of particles vs. load time
2. Stability: Number of particles vs. hold time (oscillating field on)
3. T(t): Temperature vs. time during oscillating field application
4. Lifetime: Number of particles vs. hold time (oscillating field off)
5. Mode

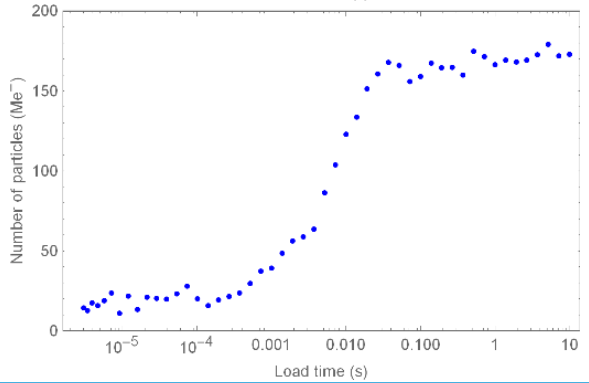
Experimental sequence (Trap depth: -140V)

1) Load: 3us-10s
2) Hold: 20us
3) Dump + Trigger digitizer/CAM: 5ms









Plasma results with CO_2 gas

Lens Plasma

Cooling gas: CO_2 (fixed pressure)

Oscillating field: applied to E2

1. N(t): Number of particles vs. load time
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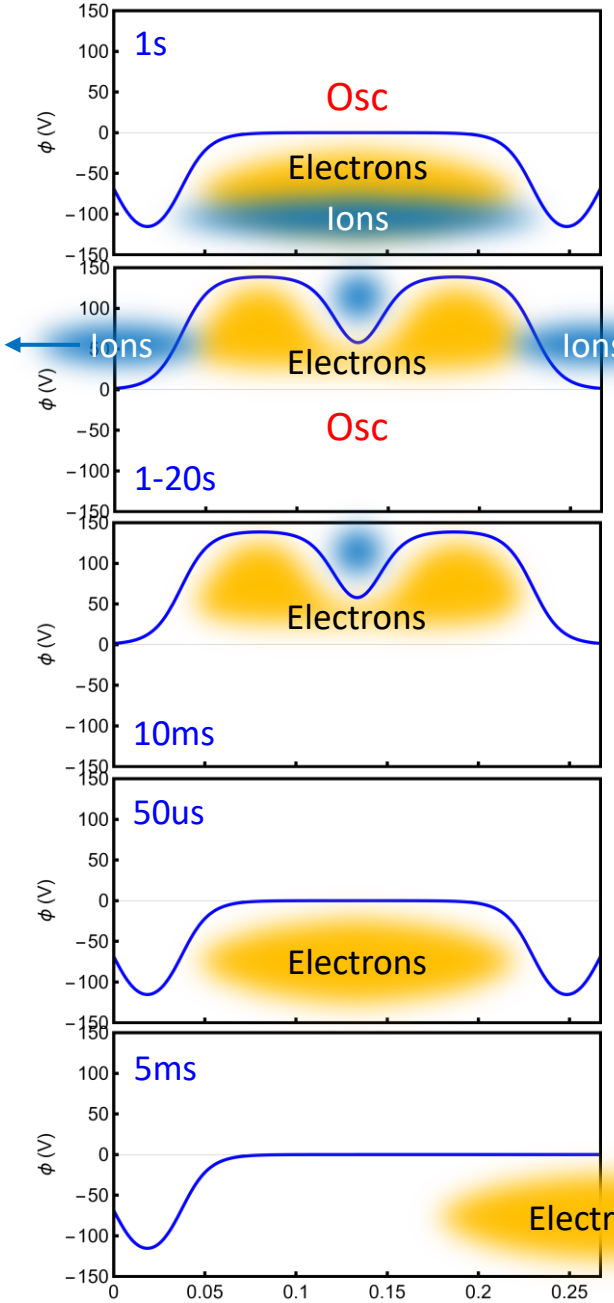
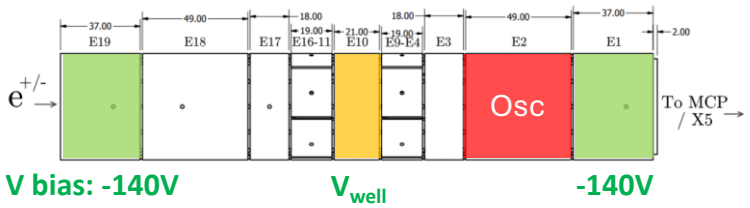
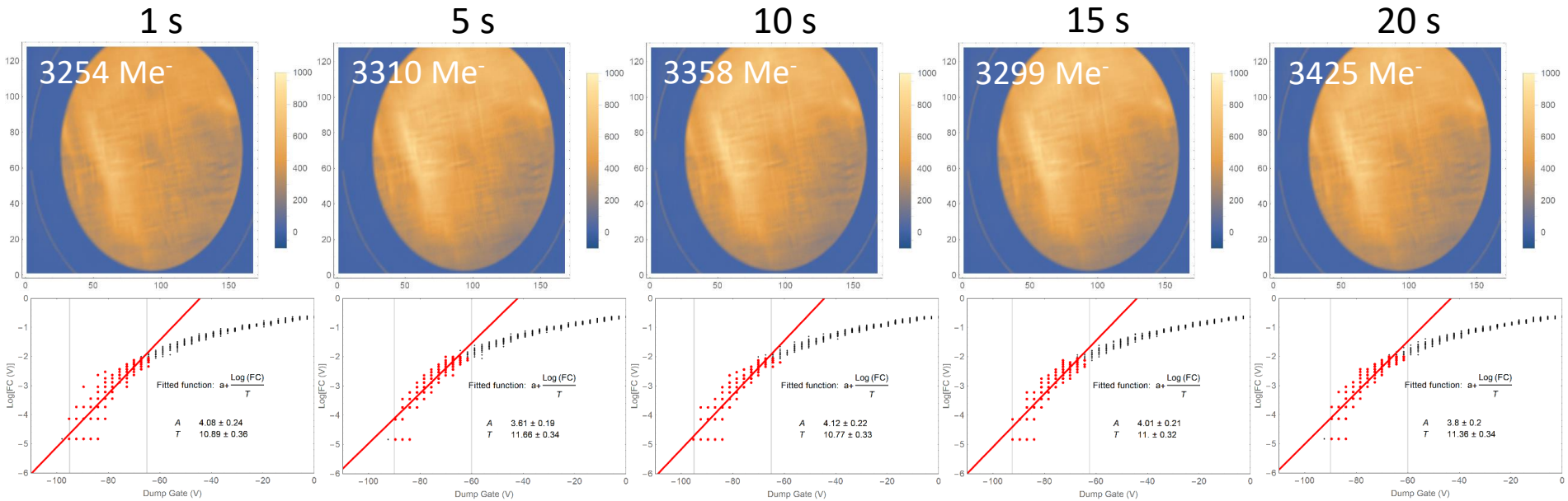
4. Lifetime: Number of particles vs. hold time (oscillating field off)
5. Mode

Plasma results with CO_2 gas







Plasma results with CO_2 gas

Lens Plasma

Cooling gas: CO_2 (fixed pressure)

Oscillating field: applied to E2

1. N(t): Number of particles vs. load time
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3. T(t): Temperature vs. time during oscillating field application
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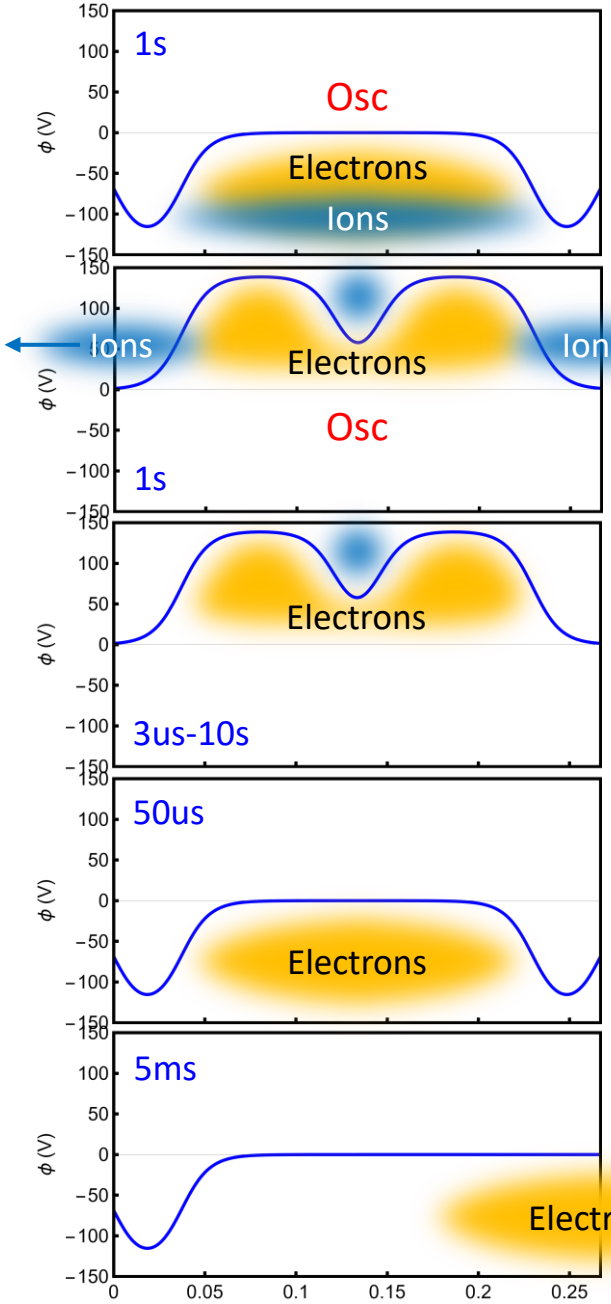
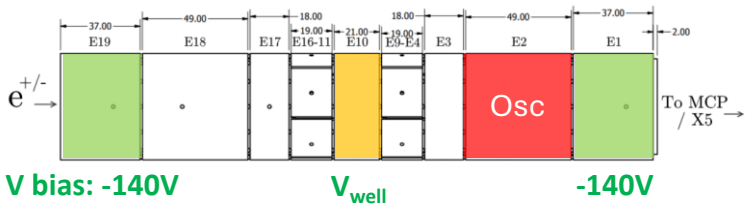
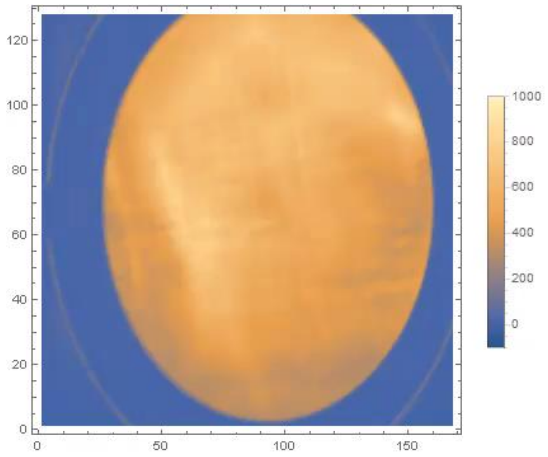
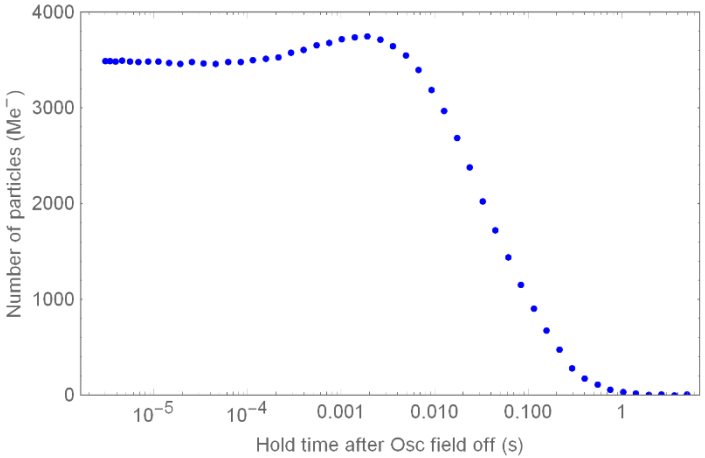
Plasma results with CO_2 gas



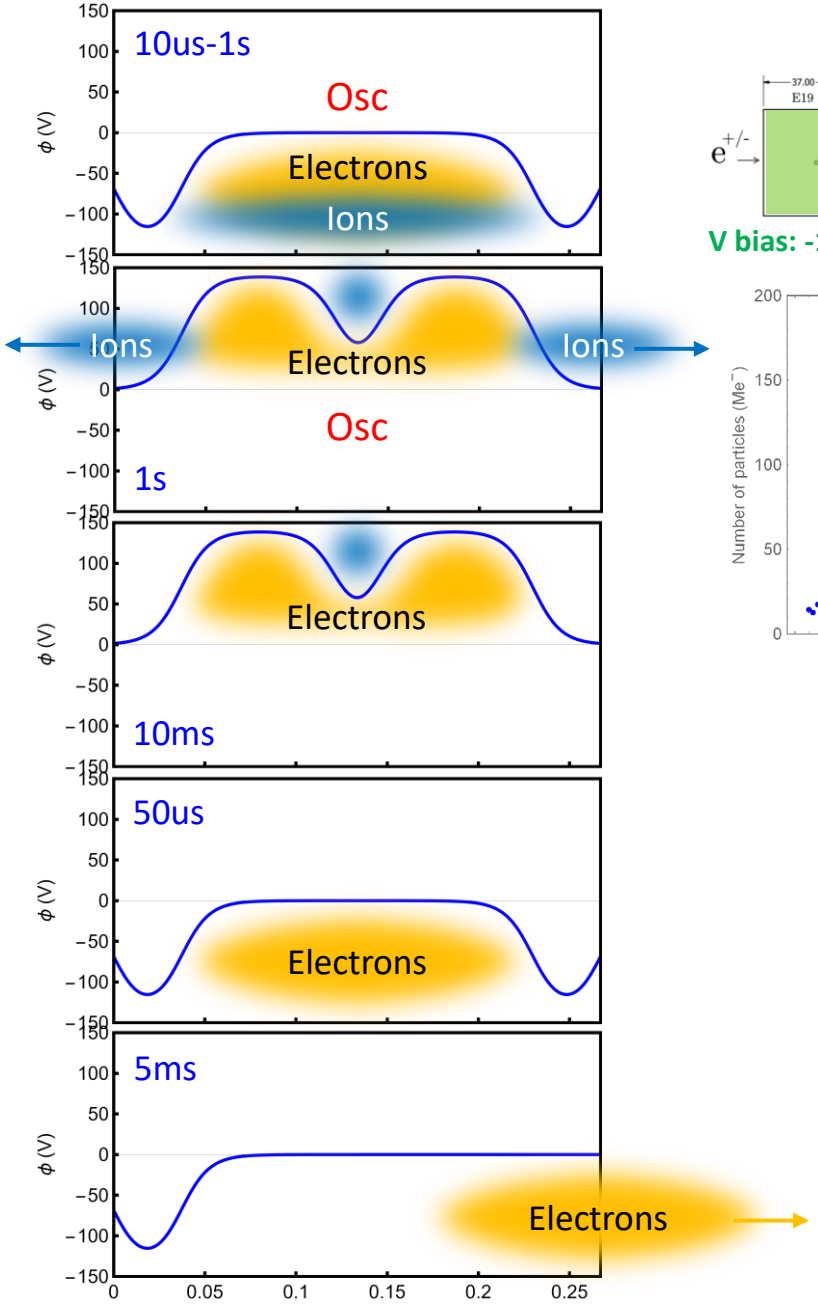


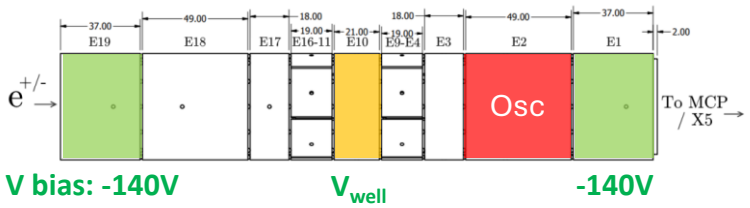


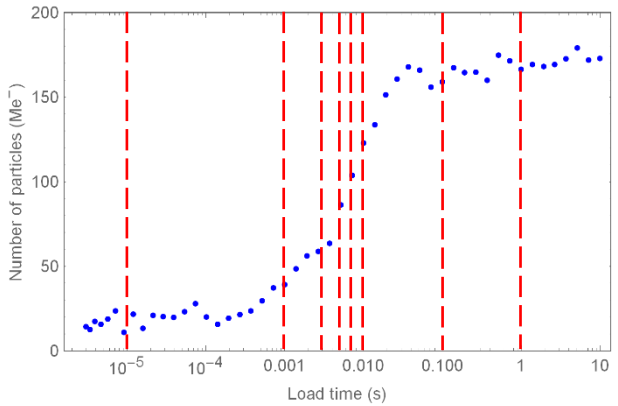


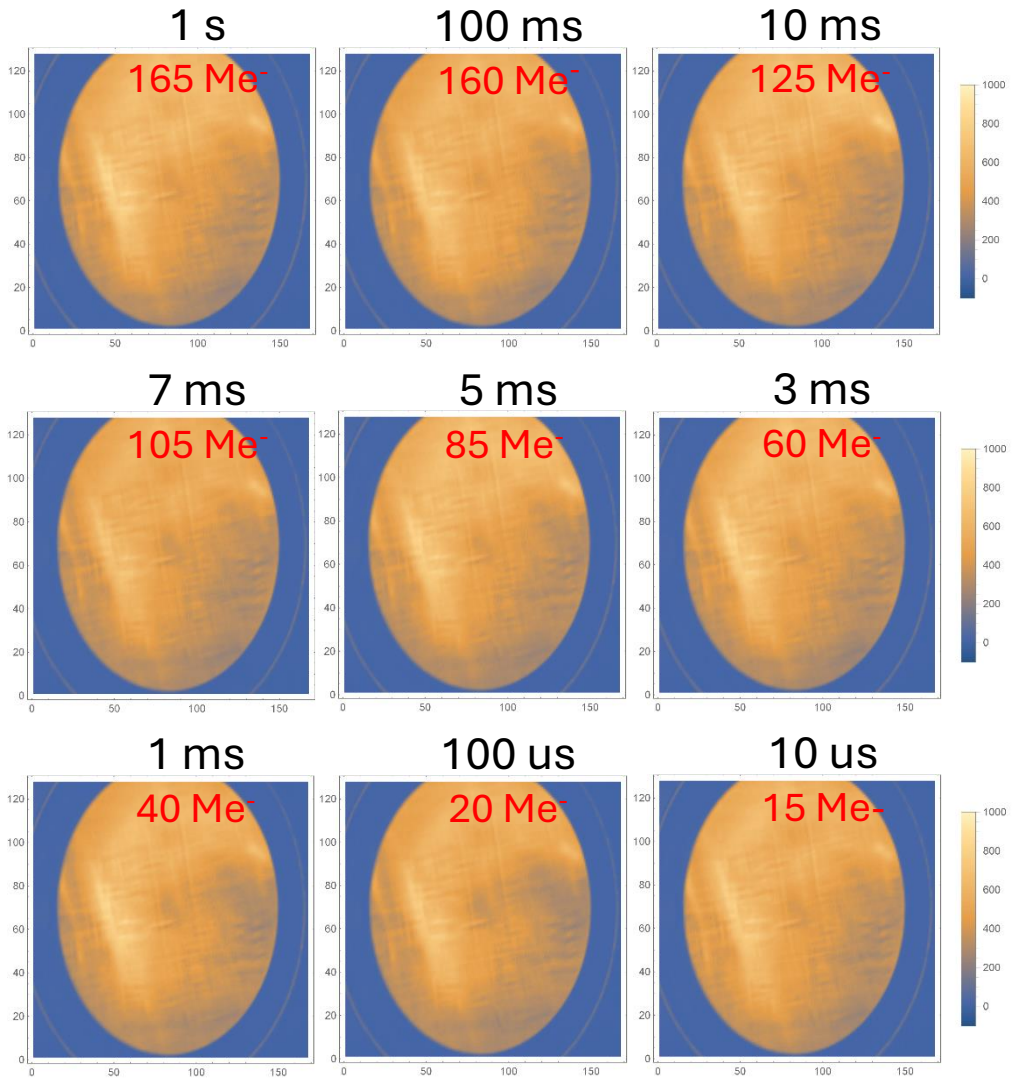
What is the minimum number of seed electrons needed in the trap to produce this plasma?

Plasma results with CO_2 gas









Conclusion and outlook

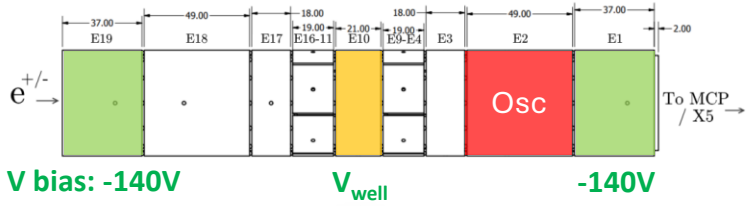
To generate a stable and high-density plasma, two key components are required:

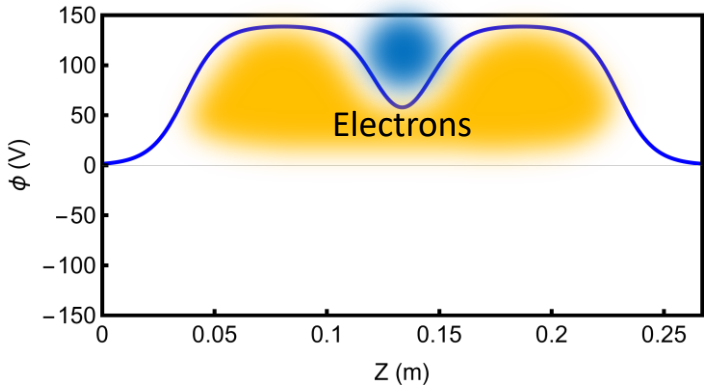
1. **Ionization:** Oscillating electric field (Osc) + Background gas
2. **Dimple that traps ions**

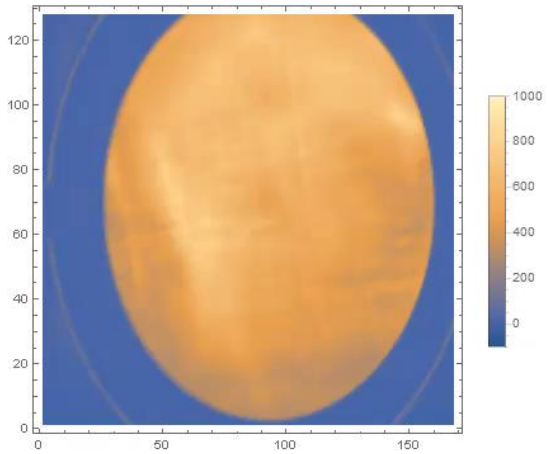
Notably, this plasma can be initiated using a very small number of seed electrons.

Next steps …

- Investigate plasma modes.
- Resume experiments using the high-voltage (HV) amplifiers.
- Conduct the experiments using Ar instead of CO_2.
- Use numerical simulation to verify our diagnostics.







WP3 Personnel

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