# Measuring Coulomb Explosion Ions from OMEGA EP Interactions

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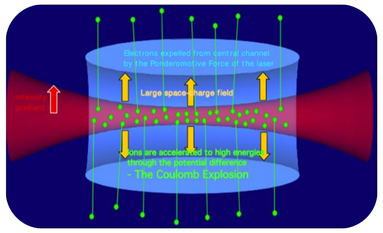
## Motivation

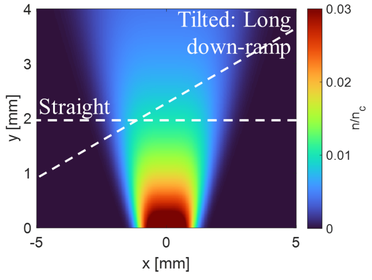
- Direct laser acceleration (DLA) can generate electron beams with high charge to produce secondary radiation sources [1]
- OMEGA EP experiments were designed to optimize the DLA of electrons in an underdense He plasma
- The channel formed in these experiments is key to understanding electron acceleration. The strong transverse electric field in the channel accelerates the He ions radially through a Coulomb explosion [2], making it an interesting complementary measurement for understanding the field strengths inside the channel.

## Coulomb Explosion




- Electrons wiggle outward ponderomotively, creating a channel (blue).
- Ions (green) in the channel explode outward as they repel each other and feel an electrostatic impulse force in the direction perpendicular to the laser axis. This is the "**Coulomb explosion**".
- It is anticipated that the ion energy may be proportional to the ponderomotive potential.

## Omega EP Experiments





He Gas Jet, Straight Nozzle


He Gas Jet, Tilted Nozzle

- A 1 ps pulse was fired at a He gas target in the geometries shown on the right to create the channel.
- Plasma density, laser energy, and nozzle angle are varied for each shot.

## Diagnostics

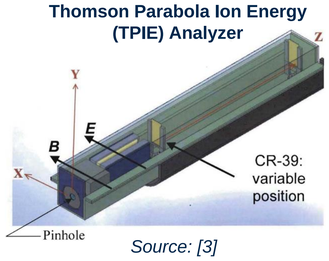
### Ion Energy

$$E_{ion} = \frac{1}{2m}\left(q\overrightarrow{B_x}L_B\left[\frac{L_B}{2}+l_b\right]\right)^2\frac{1}{y^2}$$

Where m = mass, q = charge, $\vec{B}$ = magnetic field strength, $L_B$ = length of magnet, $l_b$ = distance from edge of magnet to detector, and y = ion deflection distance

Note: $E_{ion} \propto \frac{q}{m} \propto \frac{1}{y^2}$

**Thomson Parabola Ion Energy (TPIE) Analyzer**



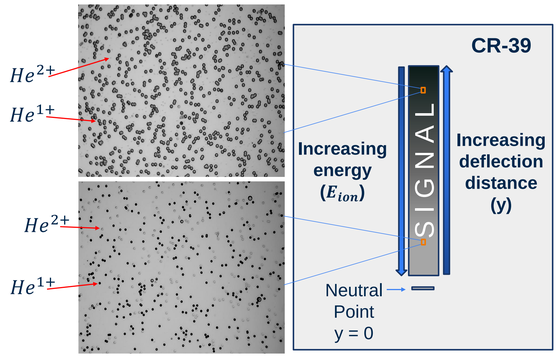

*Source: [3]*

- Note: No $\vec{E}$ field applied due to use of gas jet in chamber.

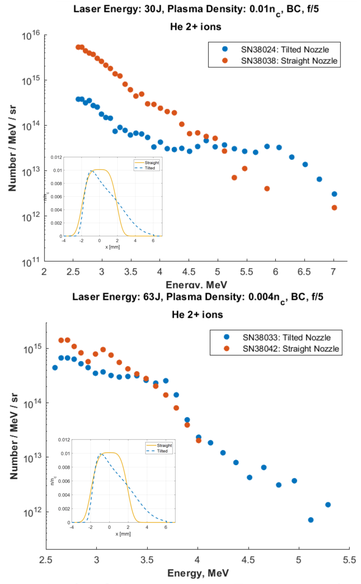
## Experimental Results

**For a particular position:** smaller pits → higher energy species

**For a particular energy:** Higher $\frac{q}{m}$ → greater y-deflection distance

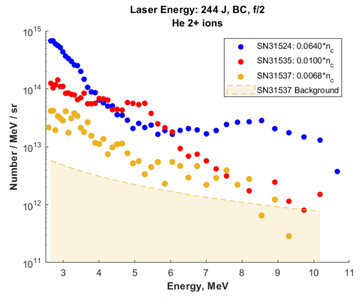



### Density Gradient Scans




Angle of Measurement: Transverse plane

### Plasma Density Scan

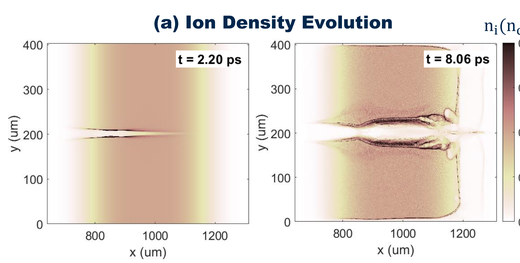



Angle of Measurement: 27˚ forward from transverse axis

- Tilted nozzles tend to lead to a plateau structure
- The straight nozzle shows a greater number of ions measured
- Increasing the plasma density gives:
  - (a) Greater # ions observed
  - (b) Longer plateau

## Simulation: Osiris 4.0

**(a) Ion Density Evolution**

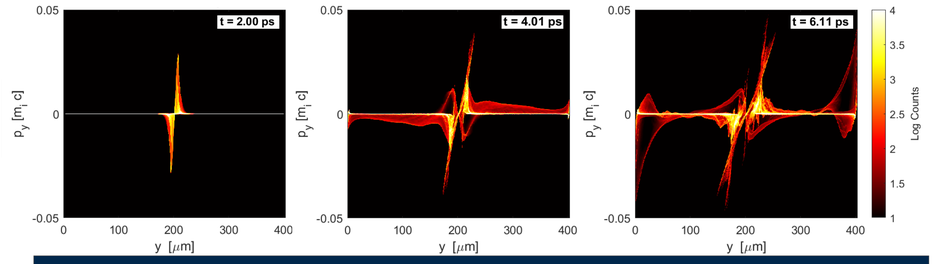



**Simulation Parameters:**
**Pulse Duration** = 1 ps
$a_0 = 6$ $n_e = 0.01 n_c$

**(a):** Ion density evolution as laser first penetrates gas plume (2.20 ps) and the ripple effect after pulse exits plume (8.06 ps).

**(b):** Phase space plots $p_y$ vs. $y$ show the radial acceleration of the ions

**(b) Ion Phase Space Evolution**




## Conclusions & Future Work

- The results from these shots indicate that **higher densities** allow for **higher ion energies**.
- Additionally, **the plateau** in the trends appear to **signify the presence of shocks**, as in [4].
- The **highest energies are measured** in S/N: 31524, where the ion measurement is taken **at an angle of 27˚** from the transverse axis in the forward direction, which also agrees with the simulation results shown in [4] specifying that during higher density shots, ions are preferentially accelerated slightly forward.
- Next steps are to identify trends in the ion data as the experimental parameters are changed and compare to simulation.

## Acknowledgements

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## References

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