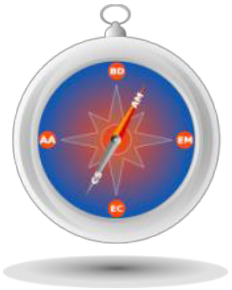
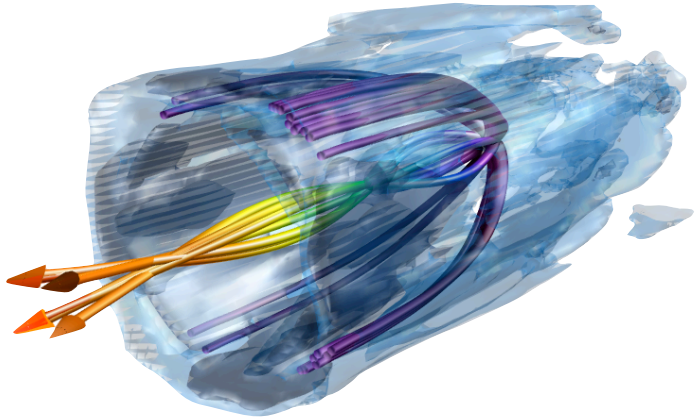
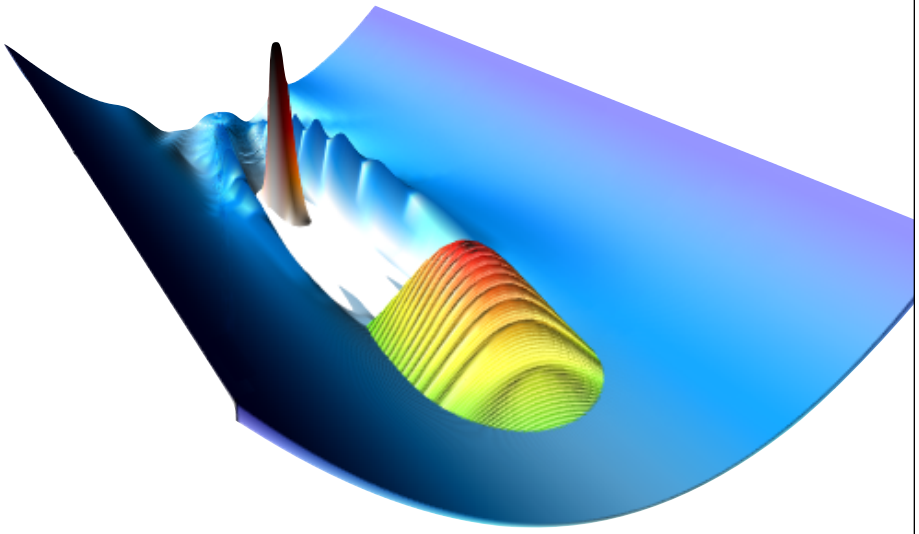
Ionization induced trapping in LWFA





UCLA



Generalized trapping condition

Assume wake moves at v_ϕ

$$\bar{H} = \gamma - v_\phi p_z - \psi$$

is an approximate constant of motion

$$\boxed{\therefore \;\; \gamma - v_\phi p_z = 1 + \Delta\psi}$$

$$\Delta\psi = \psi - \psi_i$$

Trapping occurs when $v_z = v_\phi$

$$\boxed{\therefore \;\; |\Delta\psi| > 1 - \frac{\sqrt{1 + p_\perp^2}}{\gamma_\phi}}$$

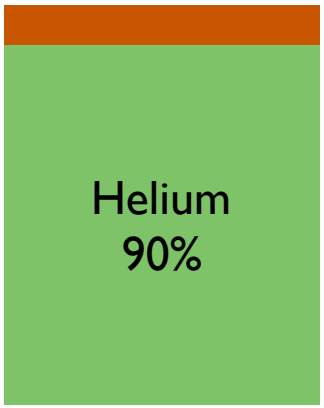
is trapping condition

- Fully 3D
- Useful for preionzed and self-ionized.
- Injection using ionization can lead to:
  - Better emittance: electrons are born on axis
  - lower energy spread: staging
  - Better control: gas mixtures, stages,...

A new method for LWFA electron injection

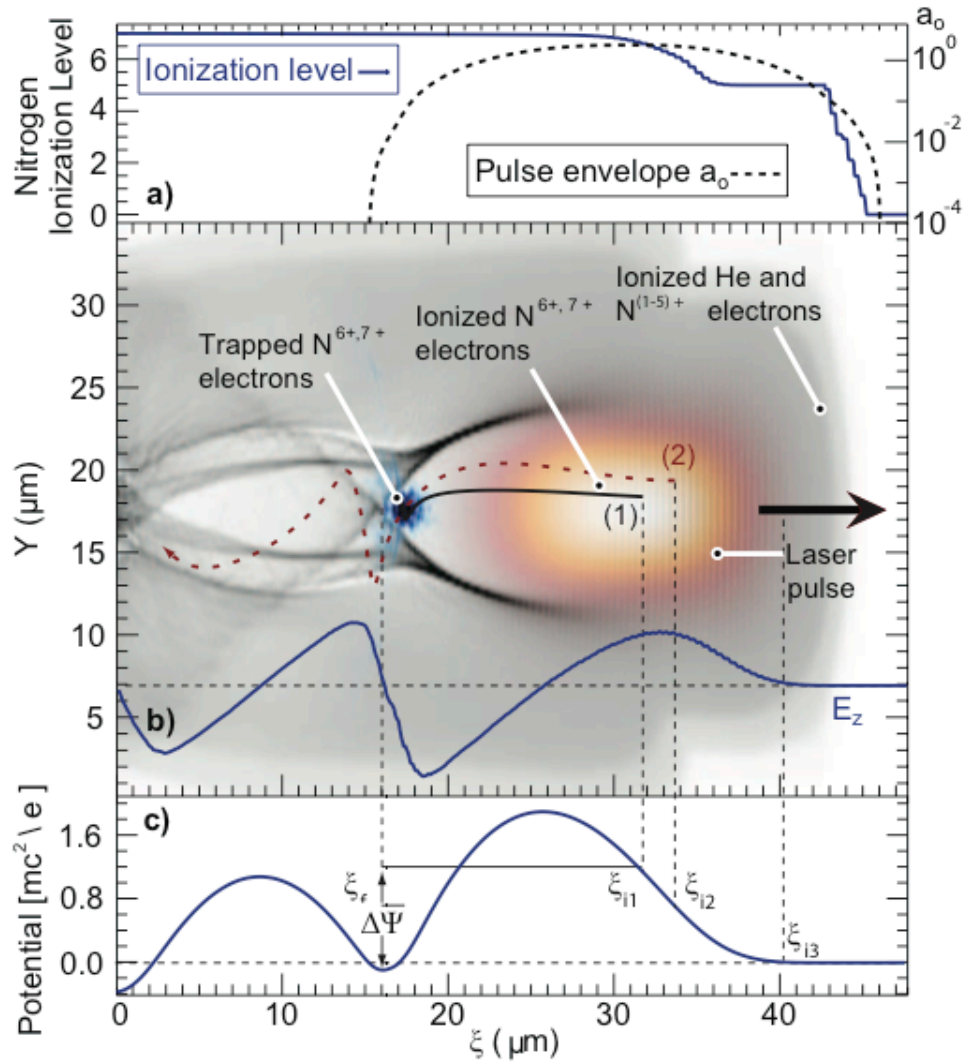
A.Pak et al submitted Phys Rev Lett (2009)

Gas mix

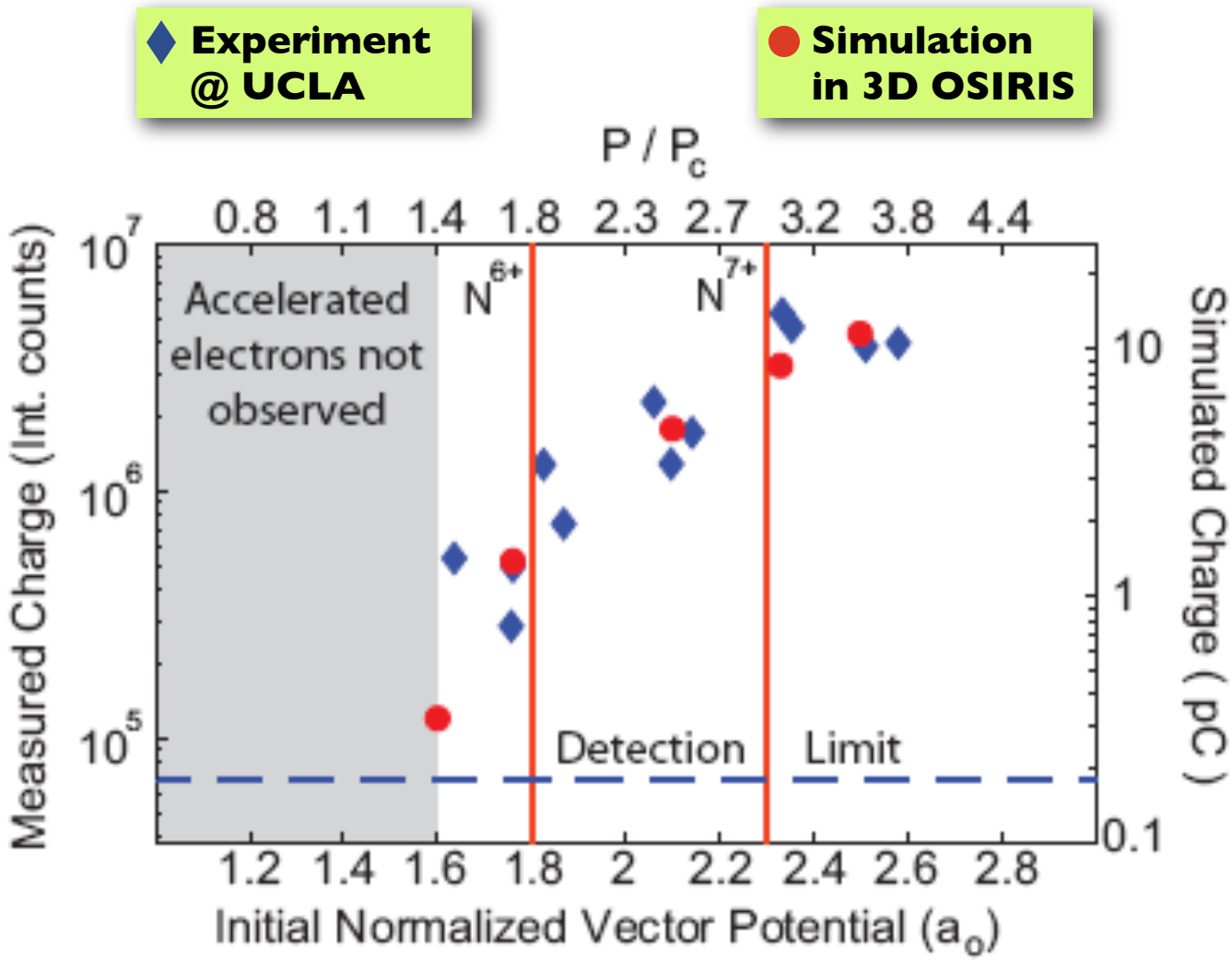


- The two He electrons and the first 5 (L-shell) N electrons form the wake
- The 6th (K shell) nitrogen electron is ionized in the wake and trapped more easily by the wake potential than the electrons that support the wake.
- Ionization trapping reduces the wake amplitude and therefore the laser power

Ionization induced trapping



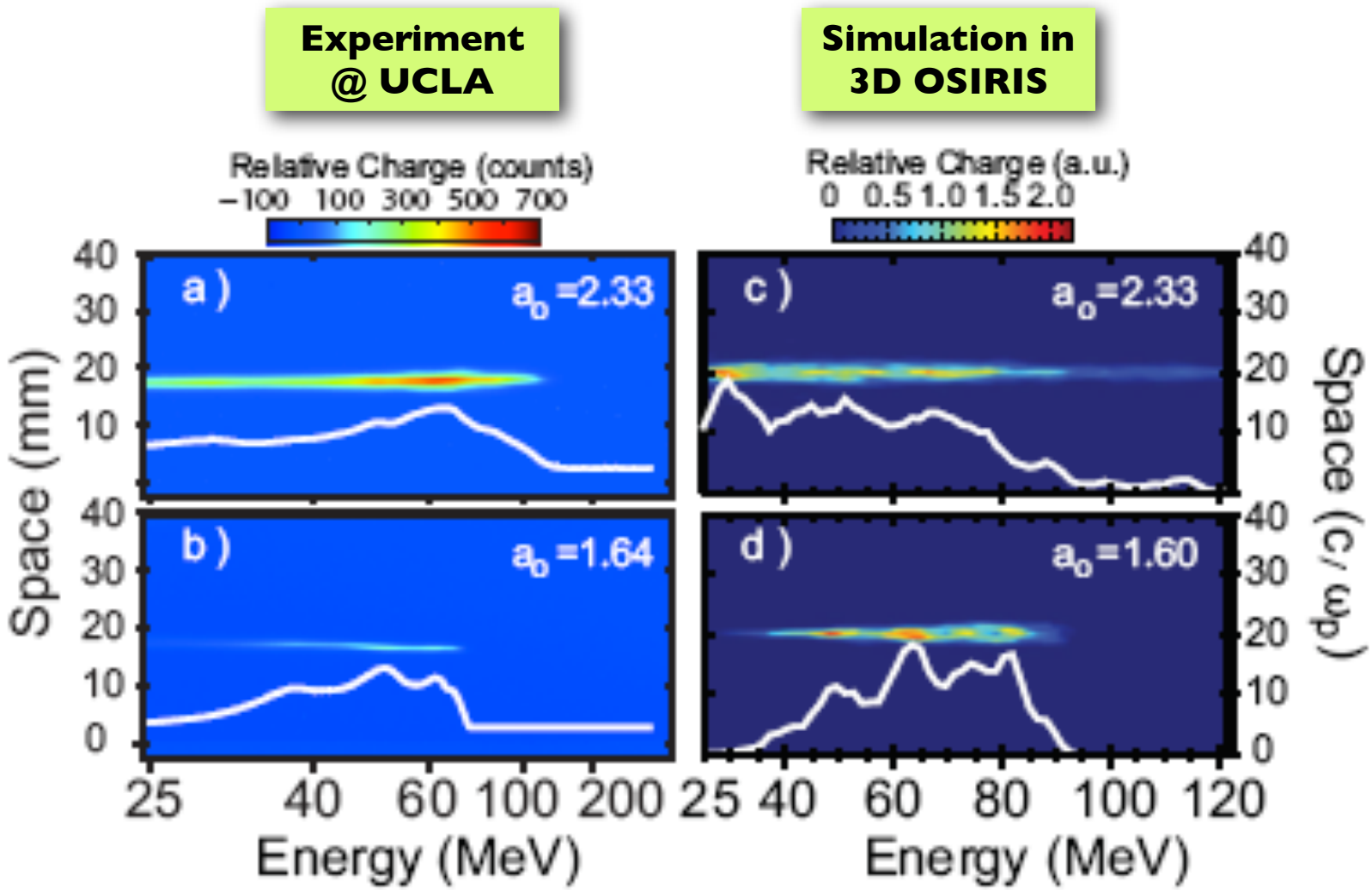
Threshold condition consistent with ionization induced trapping in LWFA



9:1 He:N_2 Plasma

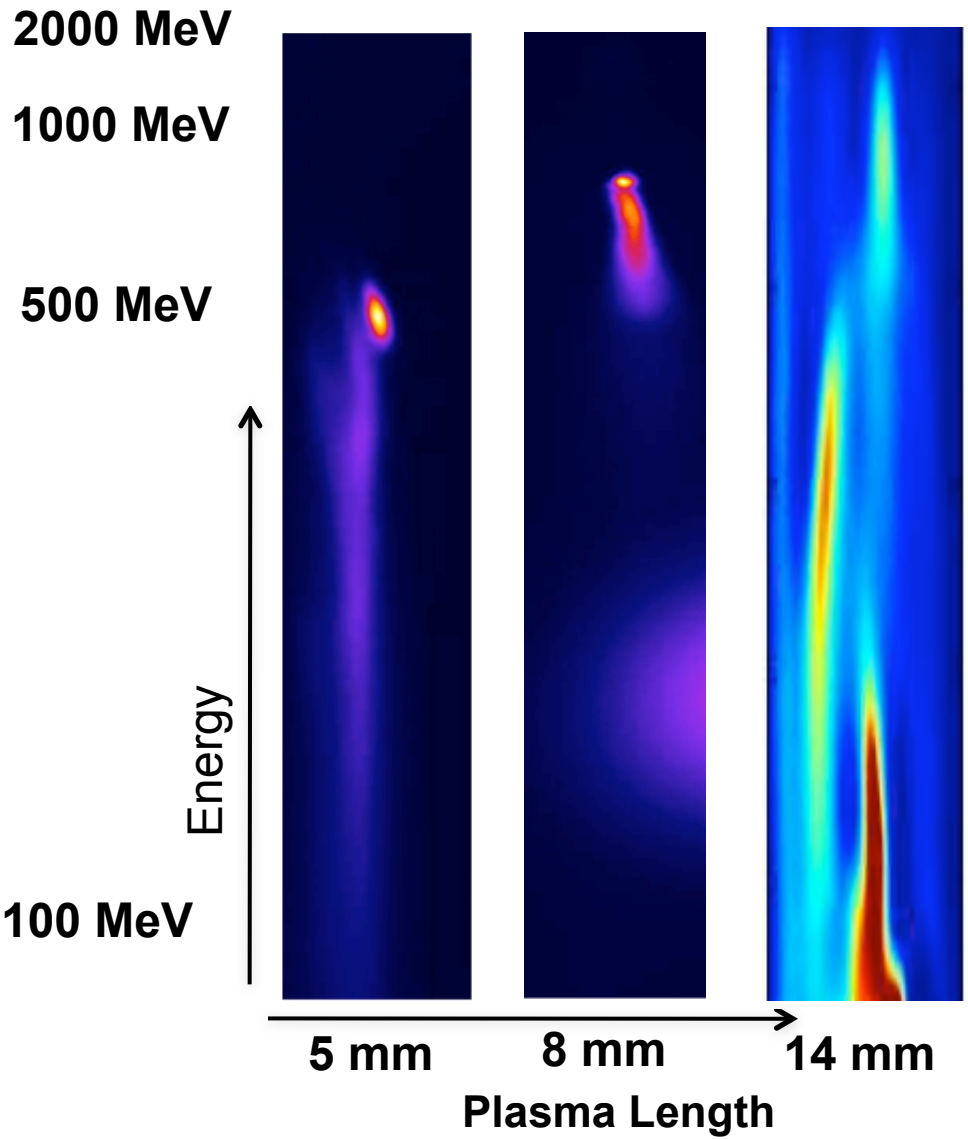
No charge below ao of 2.3 in pure He plasma

Tunnel ionization of Nitrogen K-shell electrons into a LWFA wake

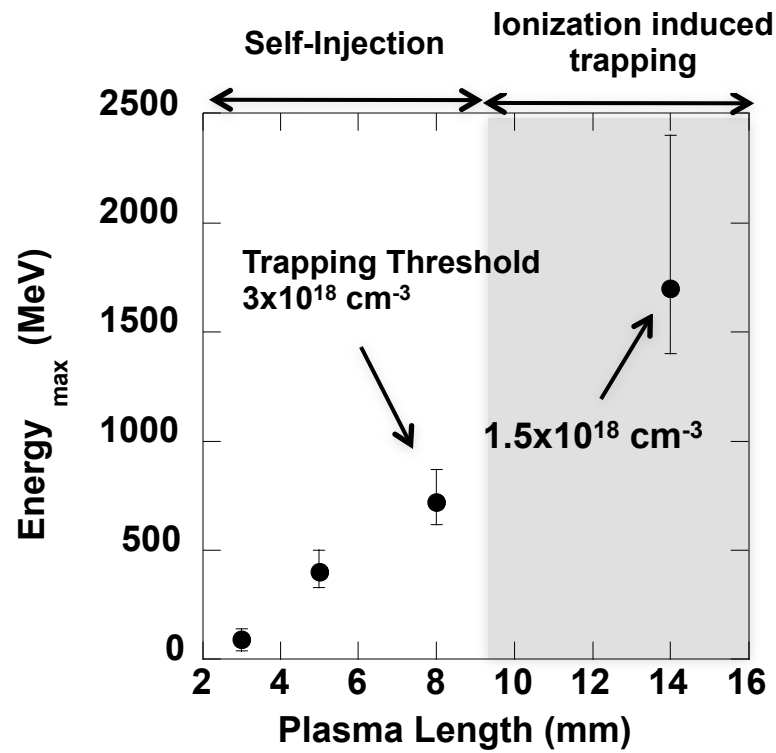


9:1 He:N_2 Plasma

This collaboration has pushed the limits of energy gain in LWFA while demonstrating the limitations of self-injection



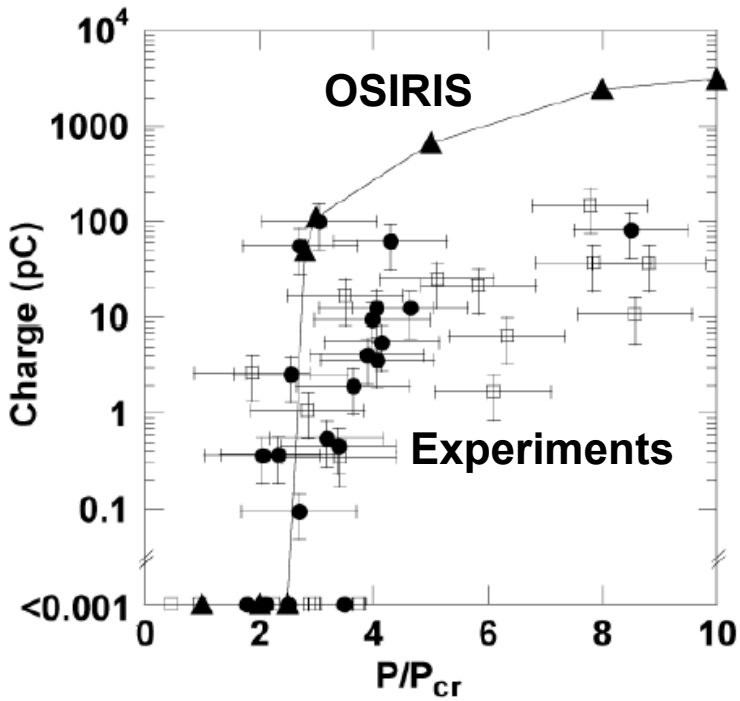
The electron energy is measured as a function of plasma length



The density is reduced to match the plasma length to the dephasing length

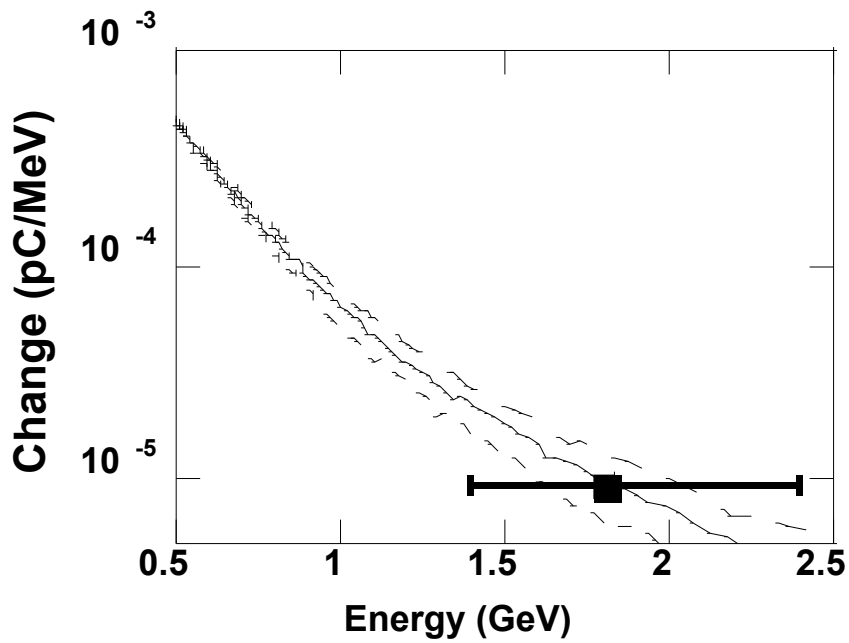
The self-injection threshold limits acceleration to less than 1 GeV: OSIRIS simulations are being used to interpret the experiment

A self-injection threshold was measured to be at $3x10^{18}$ cm^{-3}



This threshold density limits the dephasing length and acceleration to less than 1 GeV

Adding trace amounts of CO_2 leads to continuous injection at low densities $1.5x10^{18}$ cm^{-3}

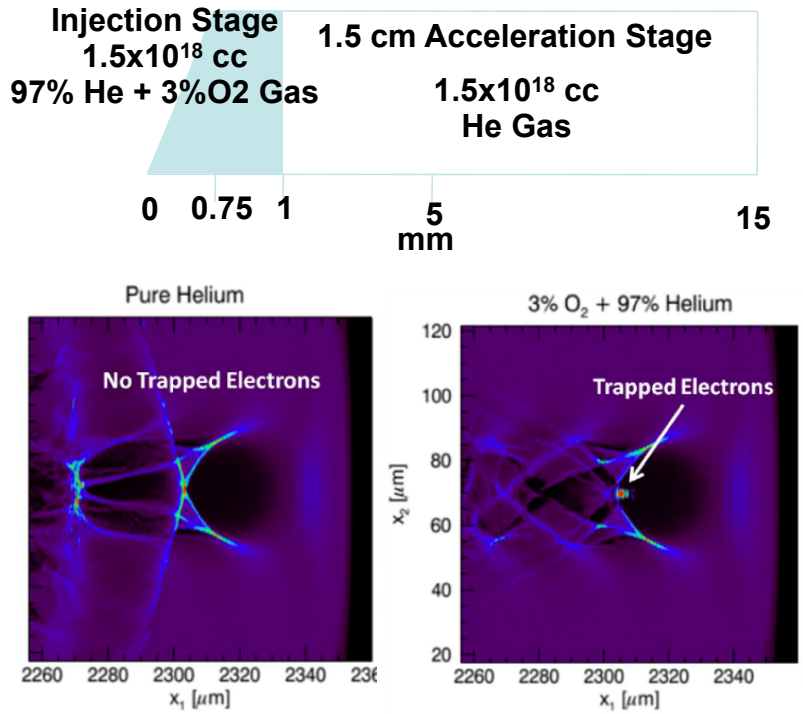


2.5 pC of charge is accelerated beyond 1 GeV

*Froula et.al., PRL Submitted 2009

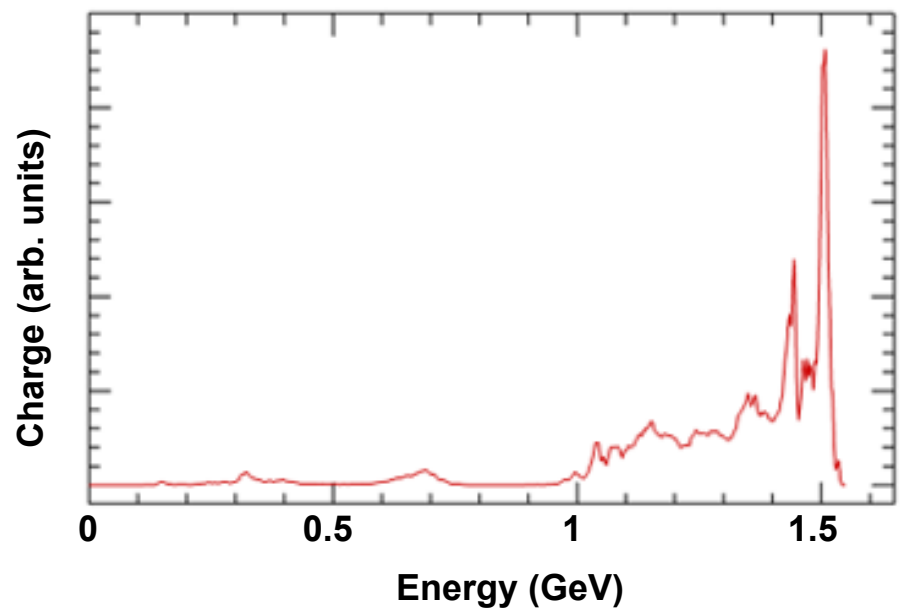
Two-stage simulations demonstrate monoenergetic 1.5 GeV electron beams using the Callisto laser conditions

OSIRIS simulations were used to design a two-stage density profile for future Callisto experiments



No self-injection occurs at these conditions; trace amounts of O_2 provide injection

Two-stage injector produces a 1.5 GeV monoenergetic electron beam



Callisto experimental parameters were used in this simulation