Laser Guiding At Relativistic Intensities And Wakefield Particle Acceleration In Plasma Channels

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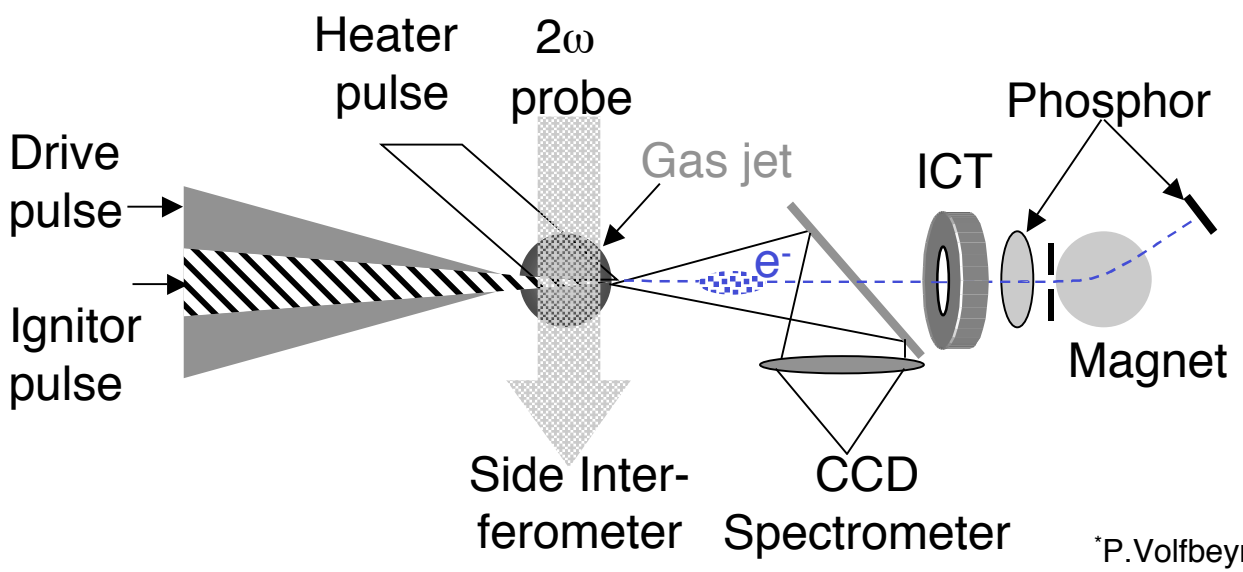
Plasma Channel Guided Laser Wakefield Accelerator
l'OASIS laboratory - LBNL

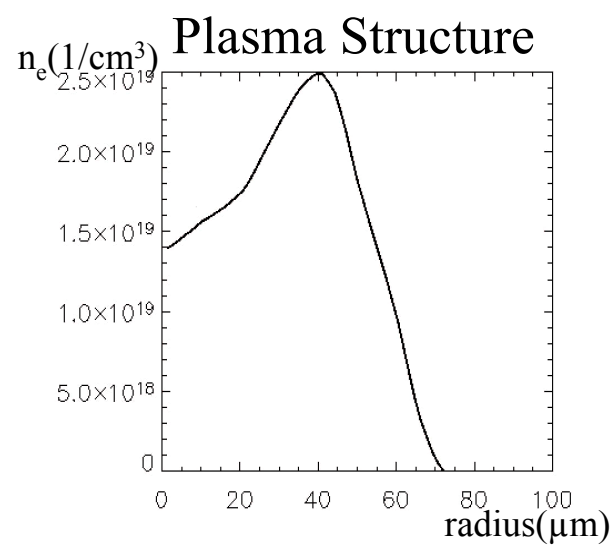
Laser wakefield acceleration experiments conducted in plasma channels

- Guiding of relativistic pulses
- Effect of guiding on wakefield acceleration of electrons.
- Self modulated regime to allow self trapping: λ_p ~7μm, pulse ~ 18μm, a_o~2

PIC simulations using VORPAL have been used to

- model experiments
- probe phase space and mechanisms for beam formation
- assist in interpretation and design

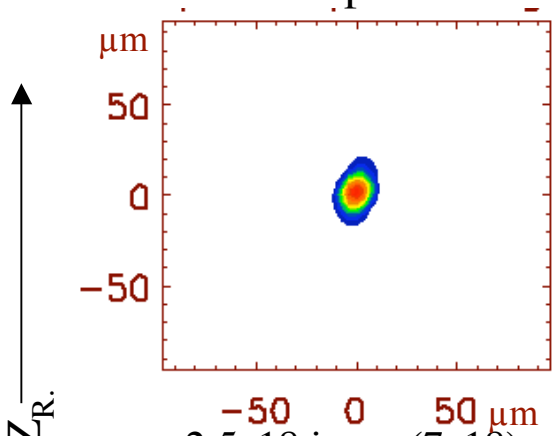




*P.Volfbeyn, E.Esarey, W.Leemans, Phys. Plasmas 1999

Guided Unaberrated Modes at Relativistic Intensity

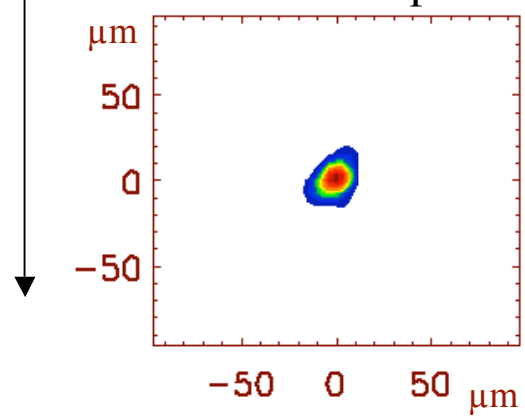
Guide Input Mode



2.5e18 input (7e18)

>10 Z_R

Guide Output



35% guided,Output >1e18W/cm^2

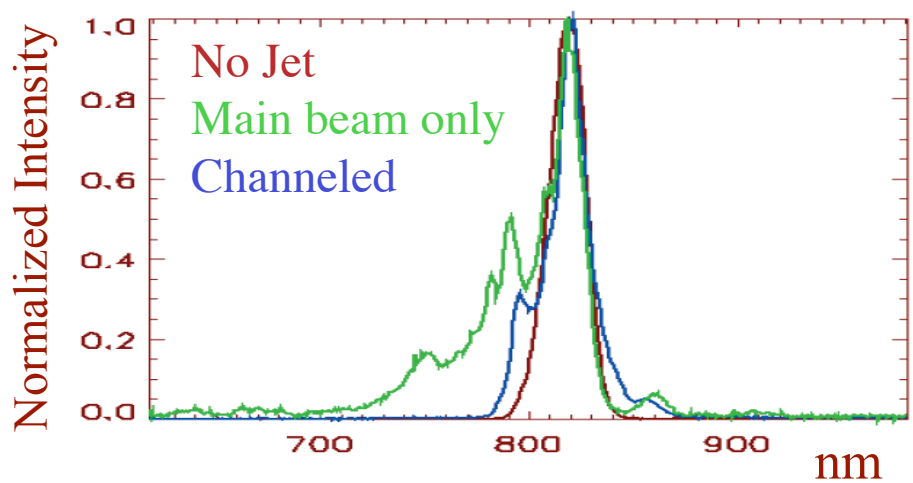
Output mode unaberrated at 4 TW

Output $a_0 \sim 1$

30% reduction in transmission vs. low power

Guide profile adjusted for self guiding

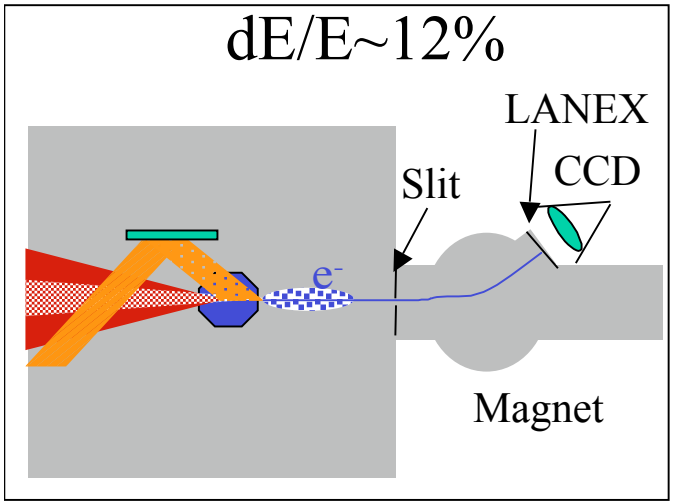
Spectral structure verifies laser confinement

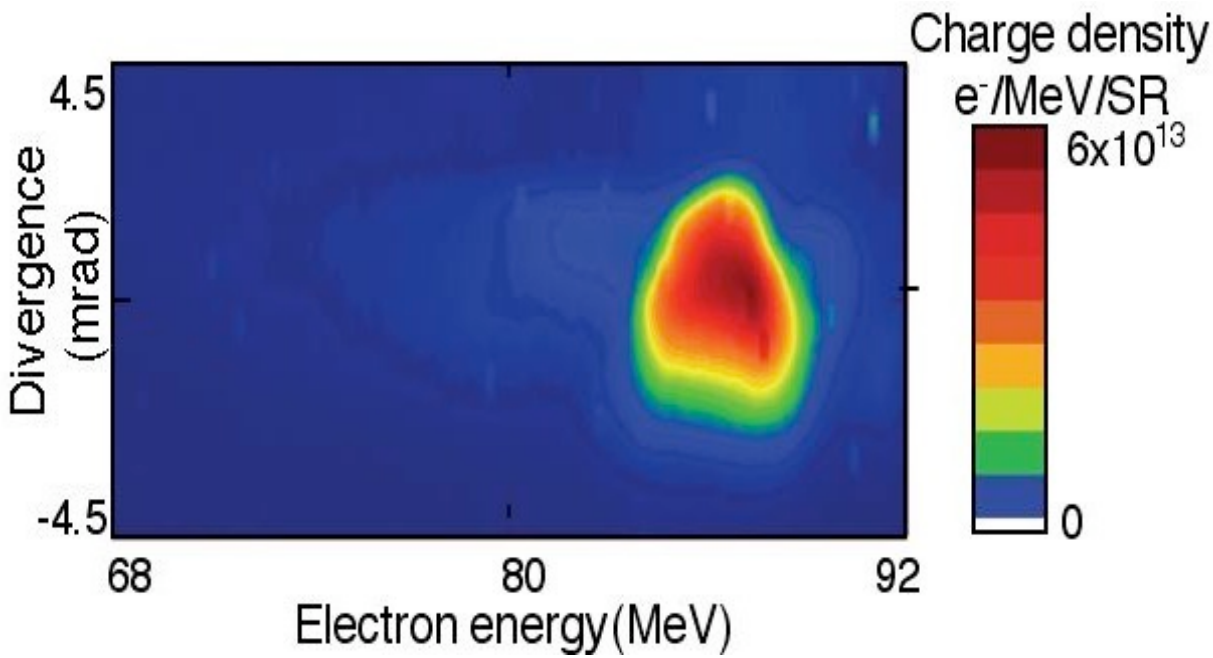


PIC Simulations reproduce depletion, indicate $E_{dephase} \sim 200$MeV - Injection platform.

Intense Beams with Low Energy Spread and High Energy from Channeled Accelerator

Magnetic Spectrometer





High quality, intese beams

2e9 electrons	Divergence 3mrad
Energy Spread<4MeV	Normalized Geometric Emittance 2π mm-mrad

Beams observed up to 3e9 @ 78MeV

Peak energy 150-170 MeV, with 1e9 electrons.

Stability needs to be addressed

Simulations used to probe physics of beam formation

Increased beam energy was anticipated

High quality beams are surprising without control of injection

Simulations allow probing of phase space and analysis of beam formation

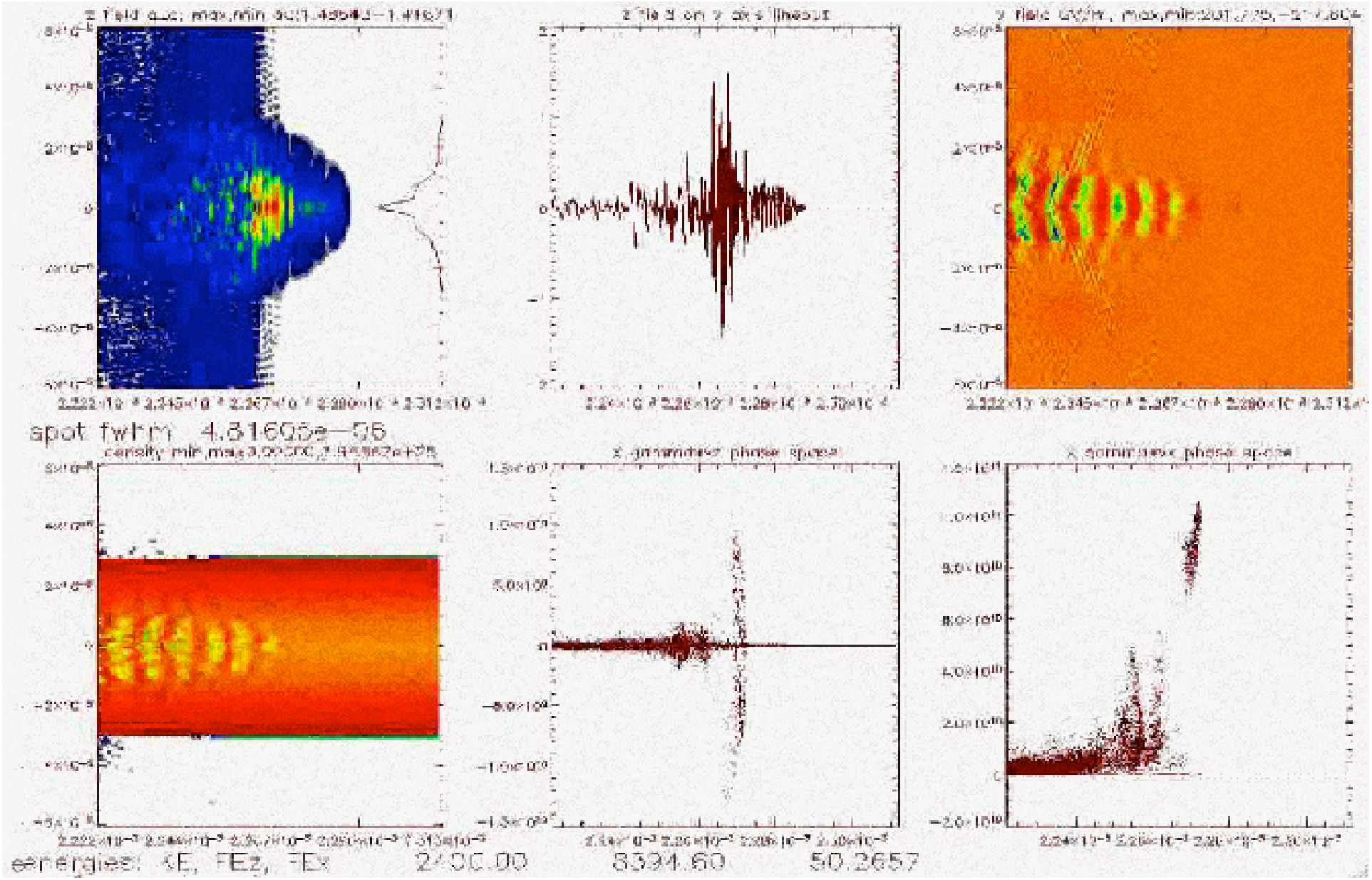
Particle in cell simulations using VORPAL code for experimental parameters

- a_o~ 2, 55fs FWHM gaussian or sin pulse
- n_e~ 2 E 19 cm^{-3}
- 2d moving window 90x120μm
- 1800x300cells -> 16x2 cells/wavelength
- 5-30 particles/cell -> up to 1.6E7 particles
- partial transverse load (now with ramped sides)

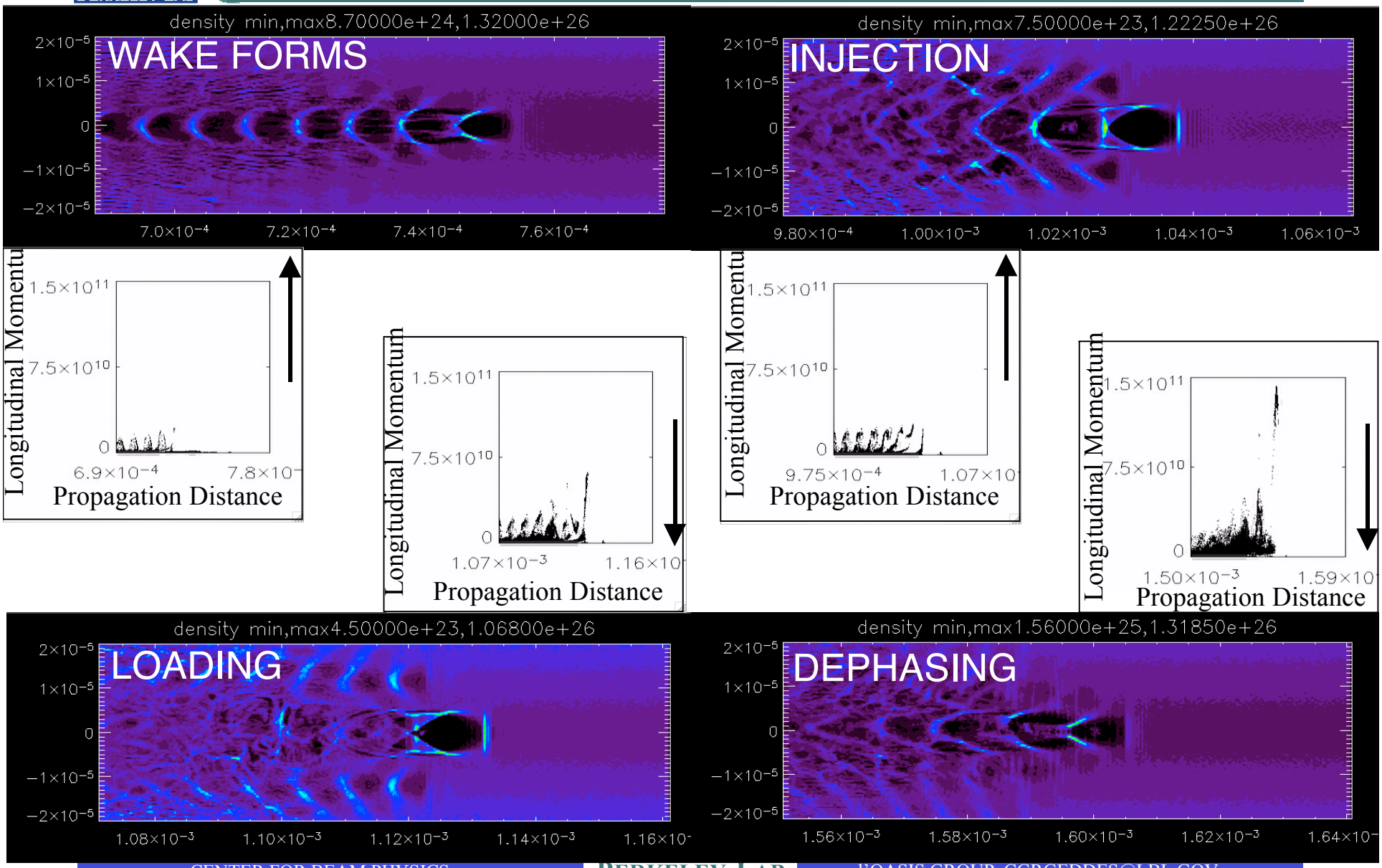
Small runs to home in on desired space, now beginning large runs

- high resolution to address resolution effects - so far look moderate
- 3d runs

Wake Evolution and Dephasing Yield
Low Energy Spread Beams in PIC Simulations



Formation of high quality beams by beam loading and dephasing



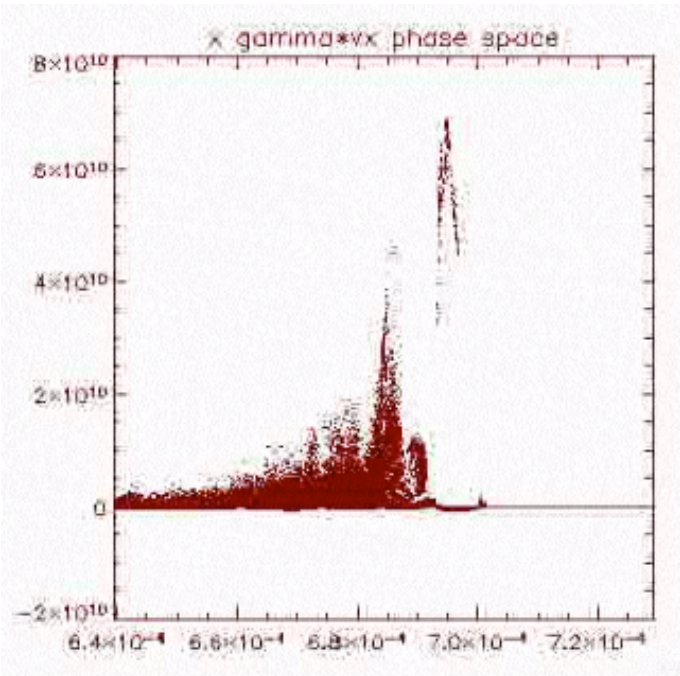
Effects of resolution are modest

Large simulations on Seaborg beginning

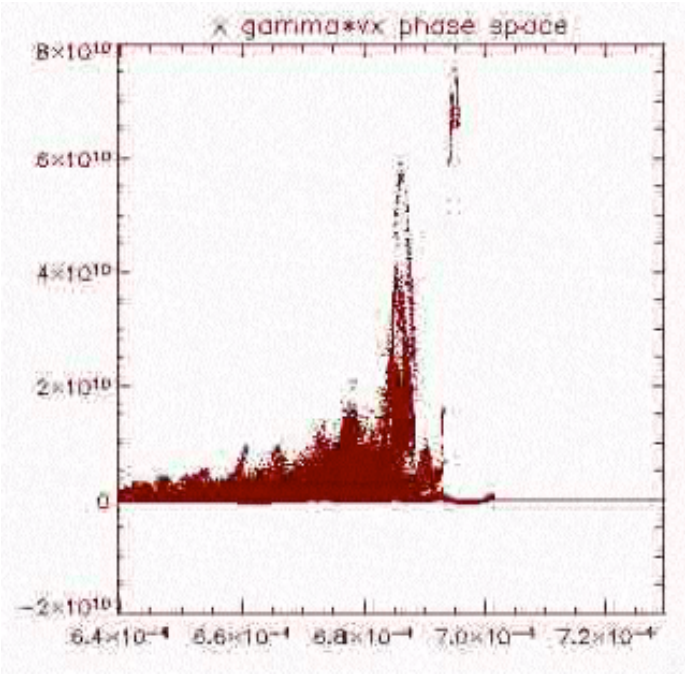
First indications: resolution has small impact -> reasonable regime

a_0=2, n_e=3e19cm^{-3}, unchanneled

16x 2 cells/λ, 5ppc

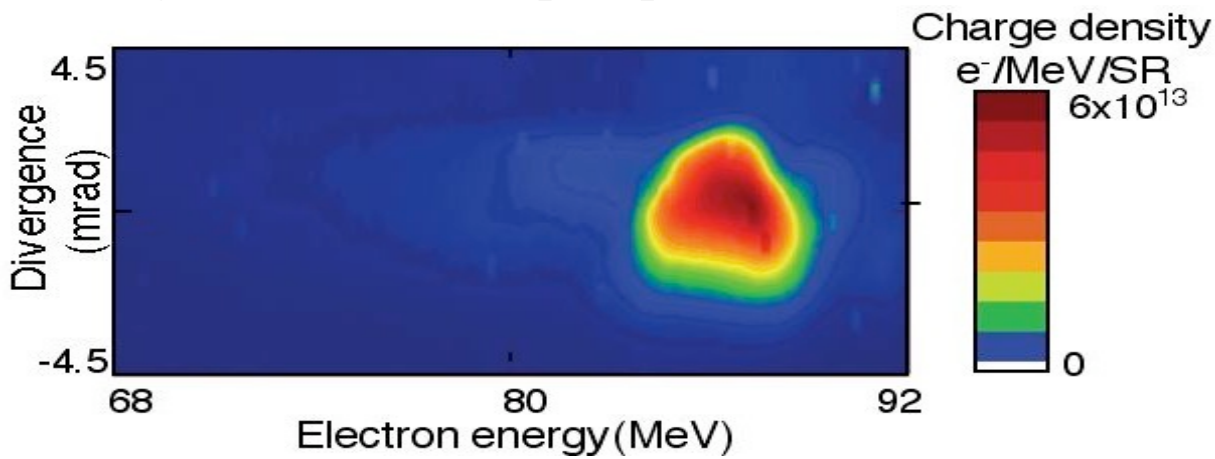


32x 4 cells/λ, 5ppc



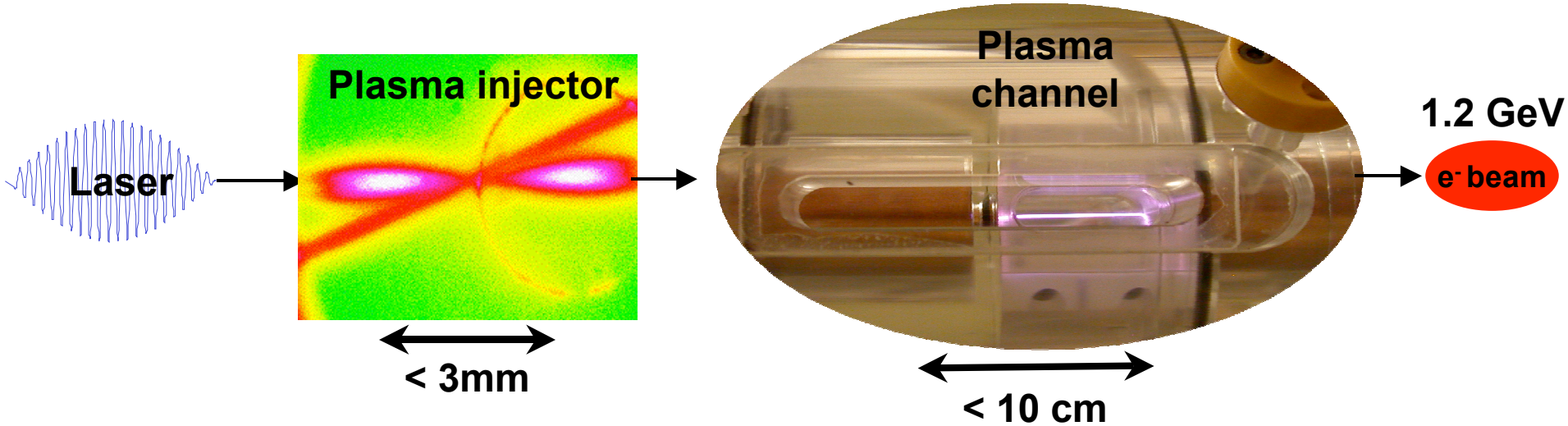
Channeled Laser Accelerators Produce Intense High Quality Electron Beams

- Demonstrated
  - Guided relativistic intensities by density channel
  - Enhancement of accelerator output with guided beam
  - Tuning of accelerator by dephasing
- Simulations used in concert with experiment
  - Matching of experimental and simulation results
  - Mechanisms underlying accelerator output & optimization
  - What effects are important? New launchers, loaders, evaluated.
  - Continuing work: optical spectrum, particle tracking…
- Prospect for new generation of compact particle sources



Other modeling efforts under way

Laser Upgrade + Injector + Capillary plasma channel -> GeV Stage



Modeling of space charge effects on electron beam propagation

G.Fubiani, Ji Qiang *et al.*, in preparation

3-D relativistic point-to-point-interaction code

- Calculates space charge force on one macroparticle from all others
- modification of energy spectrum from beam expansion