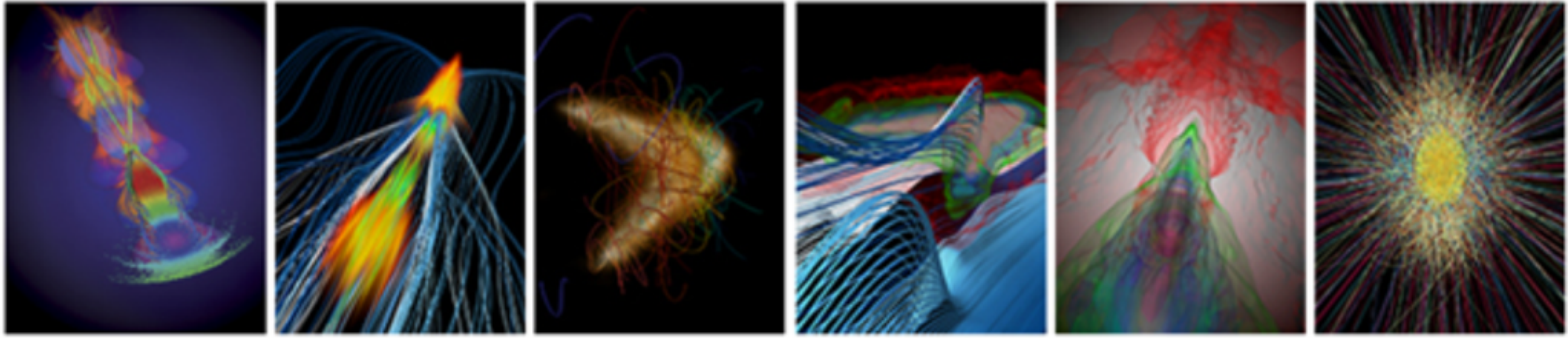

Modeling Plasma Wake Field Accelerator

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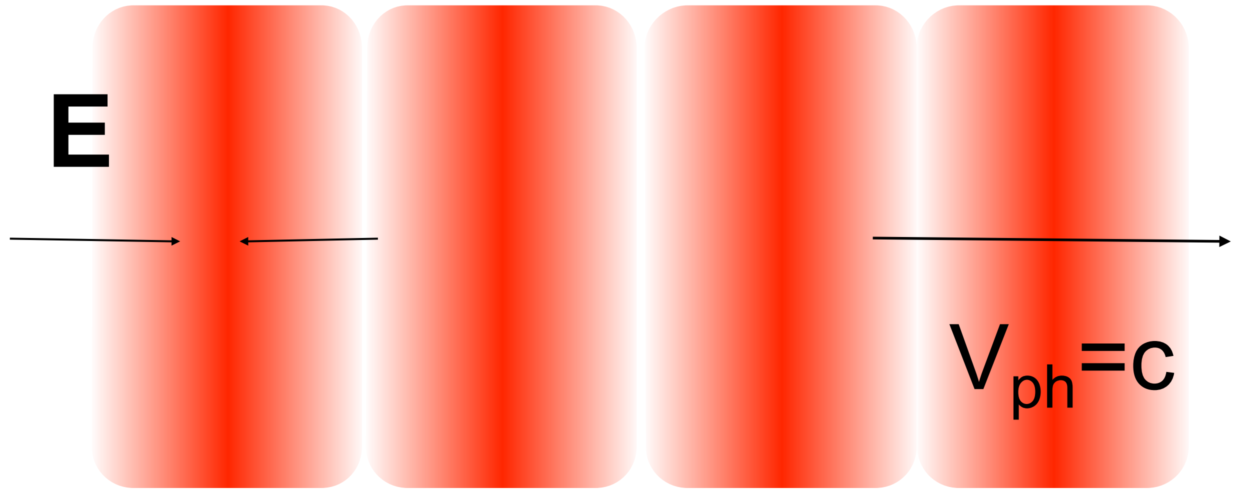
U.S. DEPARTMENT OF ENERGY | Office of Science

PICKSC
http://picksc.idre.ucla.edu

Why Plasma?



1-D plasma density wave

Gauss' Law

$$\nabla \bullet E \sim ik_p E = -4\pi e n_1$$

$$k_p = \omega_p / V_{ph} \approx \omega_p / c$$

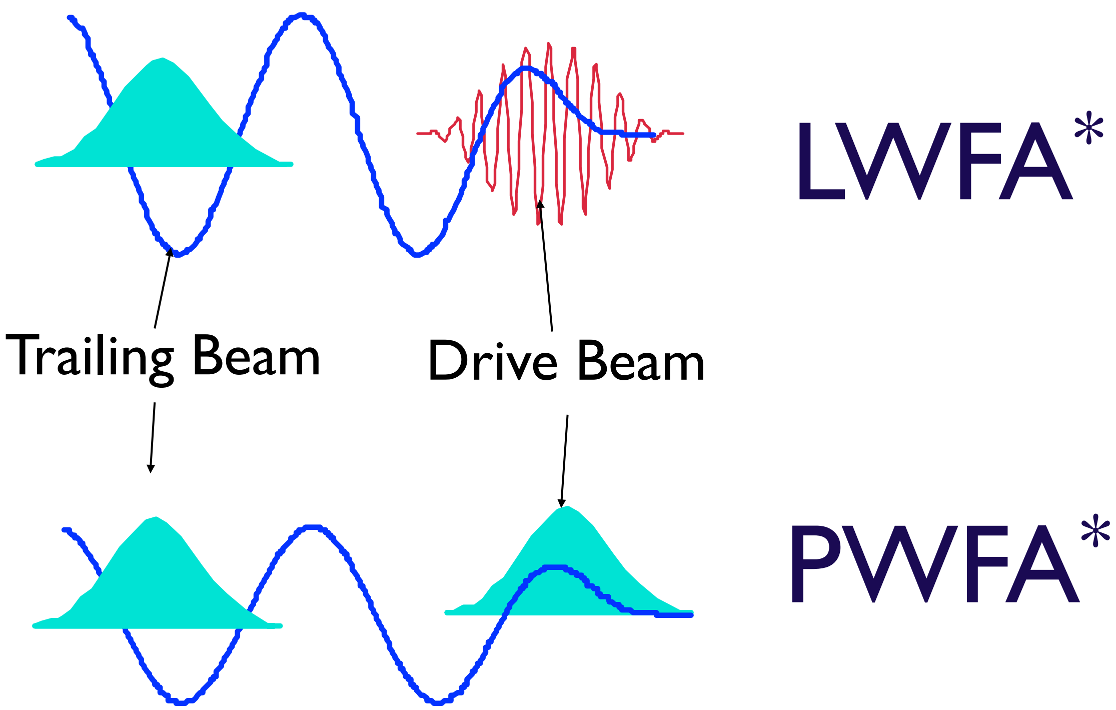
$$n_1 \sim n_o$$

$$\Rightarrow eE \sim 4\pi e n_o e^2 c / \omega_p = mc\omega_p$$

$$or \quad eE \sim \sqrt{\frac{n_o}{10^{16} cm^{-3}}} 10\, GeV/m$$

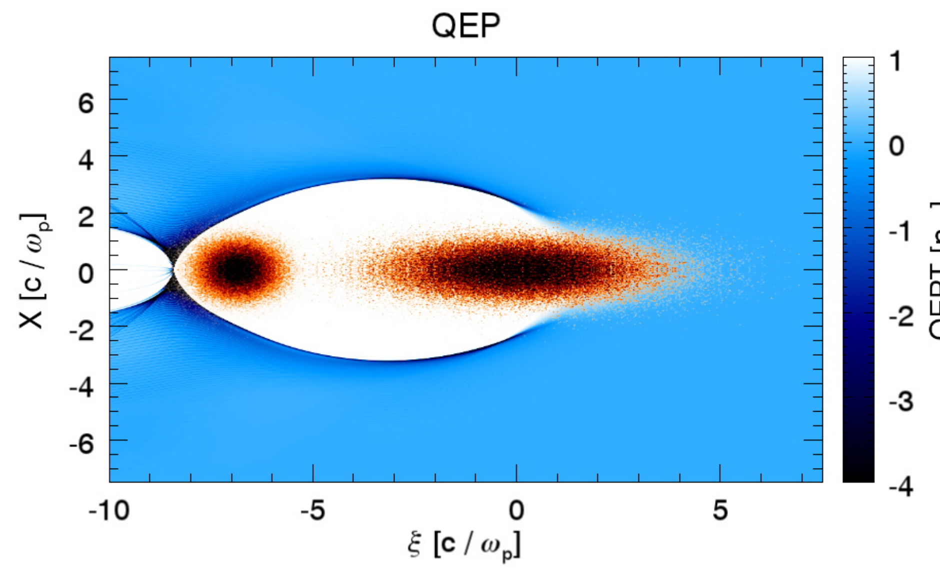
~1000 times larger than the conventional accelerators

How to Make a Plasma Wake Field?

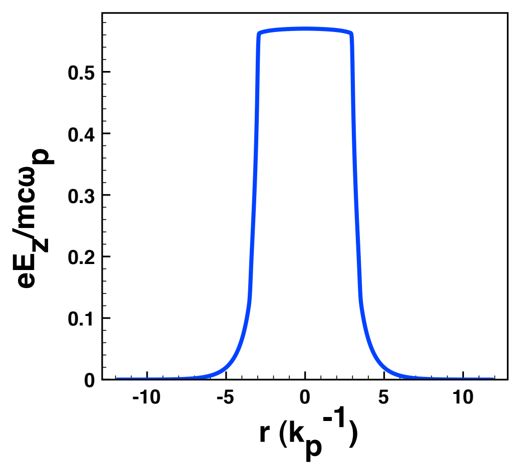


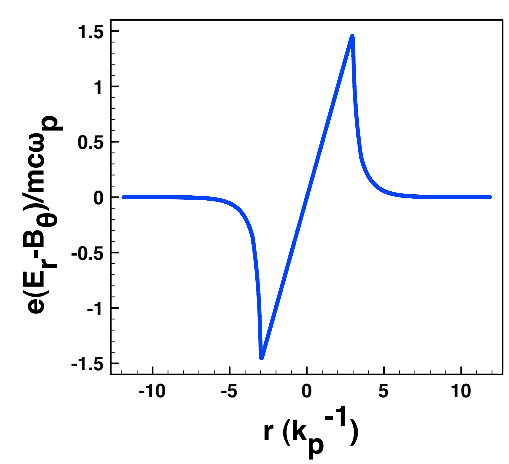
- Wake: phase velocity = driver velocity (V_g or V_{beam})

Nonlinear Process



Blow-out Regime[1,2]





LWFA: Tajima and Dawson 1979
PWFA: Chen, Dawson et al., 1985

***J. B. Rosenzweig, et. al., Phys. Rev. A 44, R6189 (1991)**
***W. Lu, et. al., Phys. Rev. Lett. 96, 165002 (2006)**

Plasma Based Accelerator Research is at the Forefront of Science

Plasma simulation has greatly impacted on PBA research.

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Simulation of PWFA

Beam Particles: $10^8 \sim 10^9$

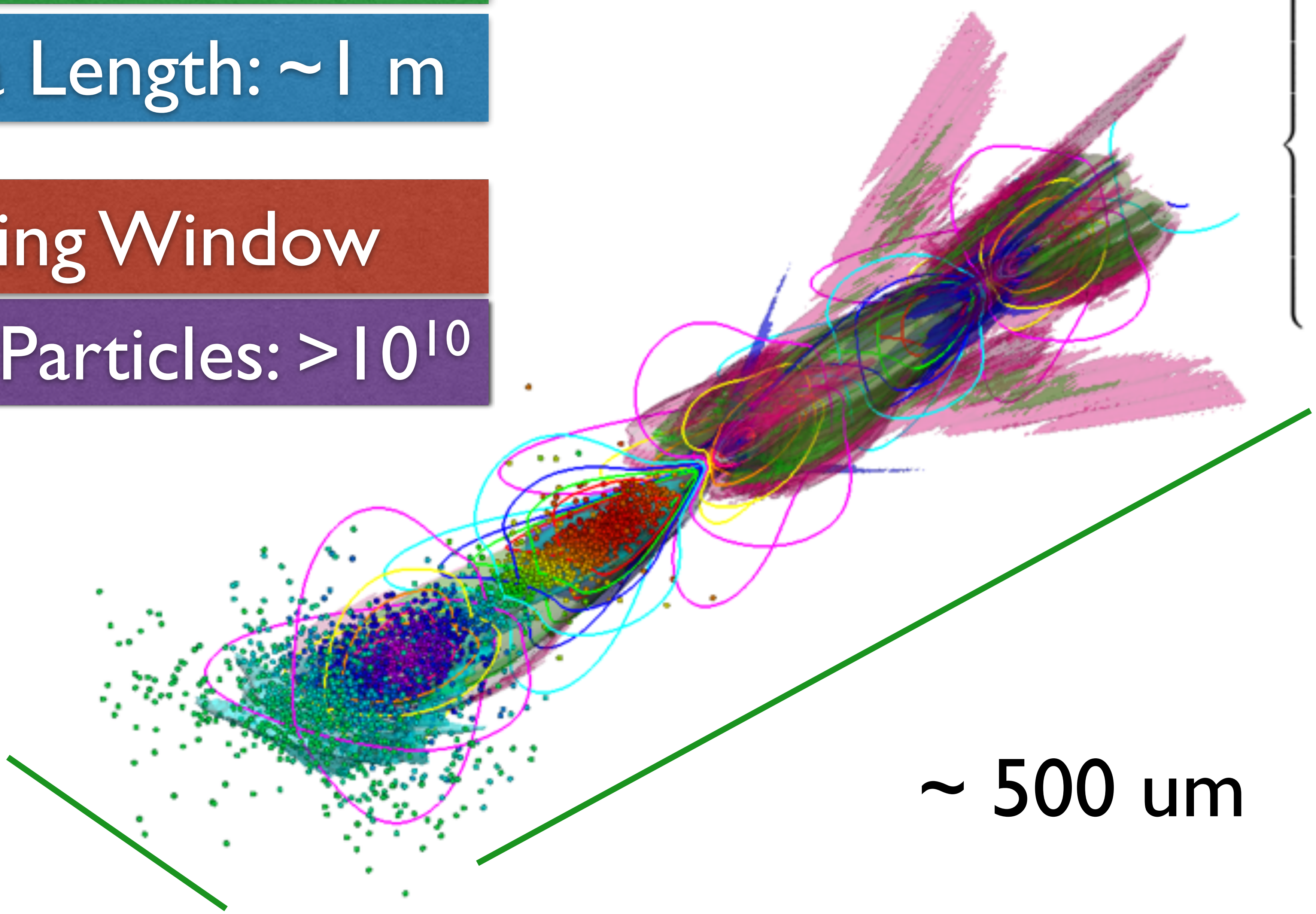
Plasma Length: ~1 m

Moving Window

Plasma Particles: $>10^{10}$

Maxwell's Eqns

$$\begin{cases} \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \\ \nabla \times \vec{B} = \frac{\partial \vec{E}}{\partial t} + \vec{J} \\ \nabla \cdot \vec{E} = \rho \\ \nabla \cdot \vec{B} = 0 \end{cases}$$



~ 500 um

~ 500 um

All particles move self-consistently

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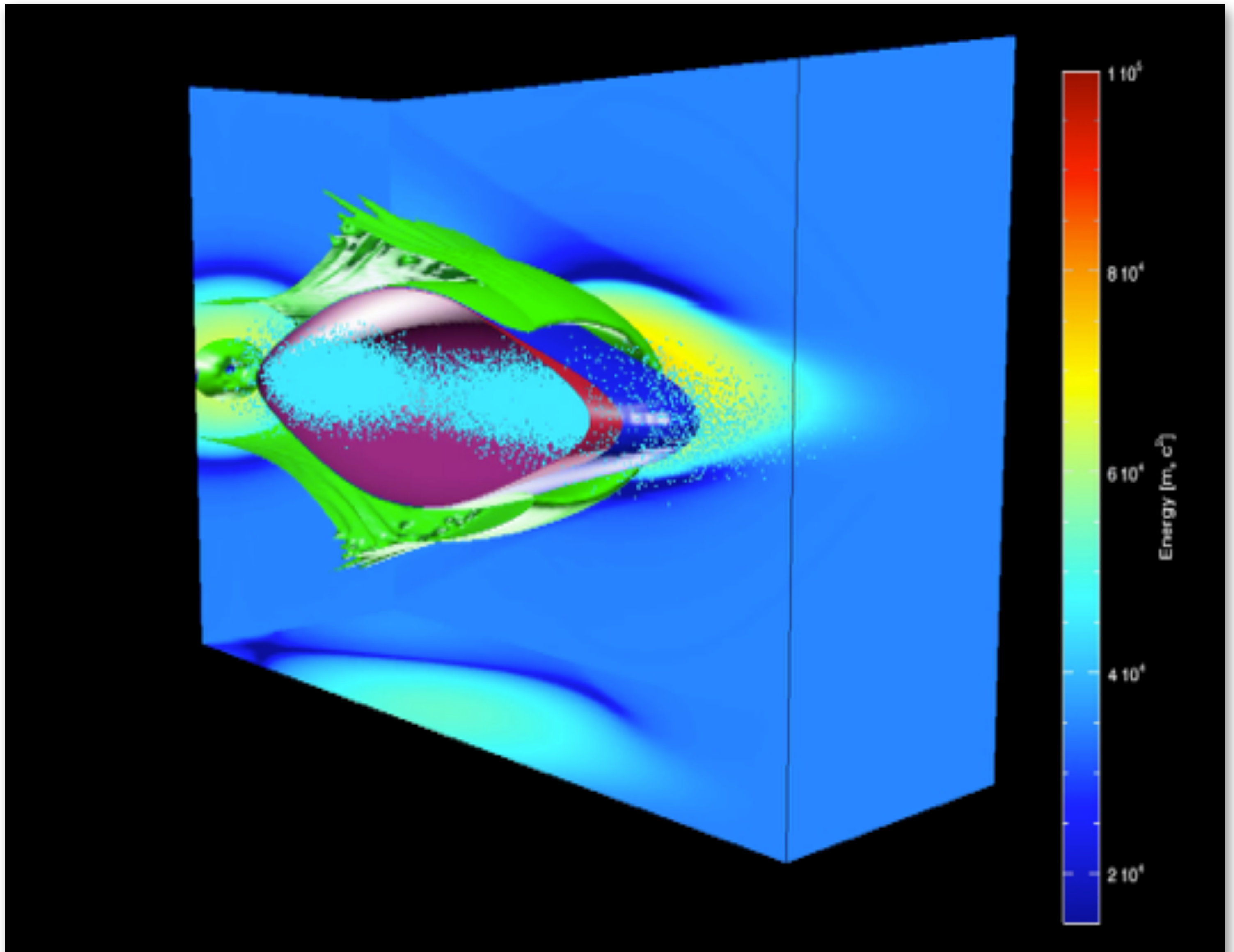
Box and Cell Size



3D or 2D r-z with moving window

Box Size: Large Enough to minimize the boundary effects.

Cell Size: Resolve the plasma wave length.

$<=0.05k_p^{-1}$

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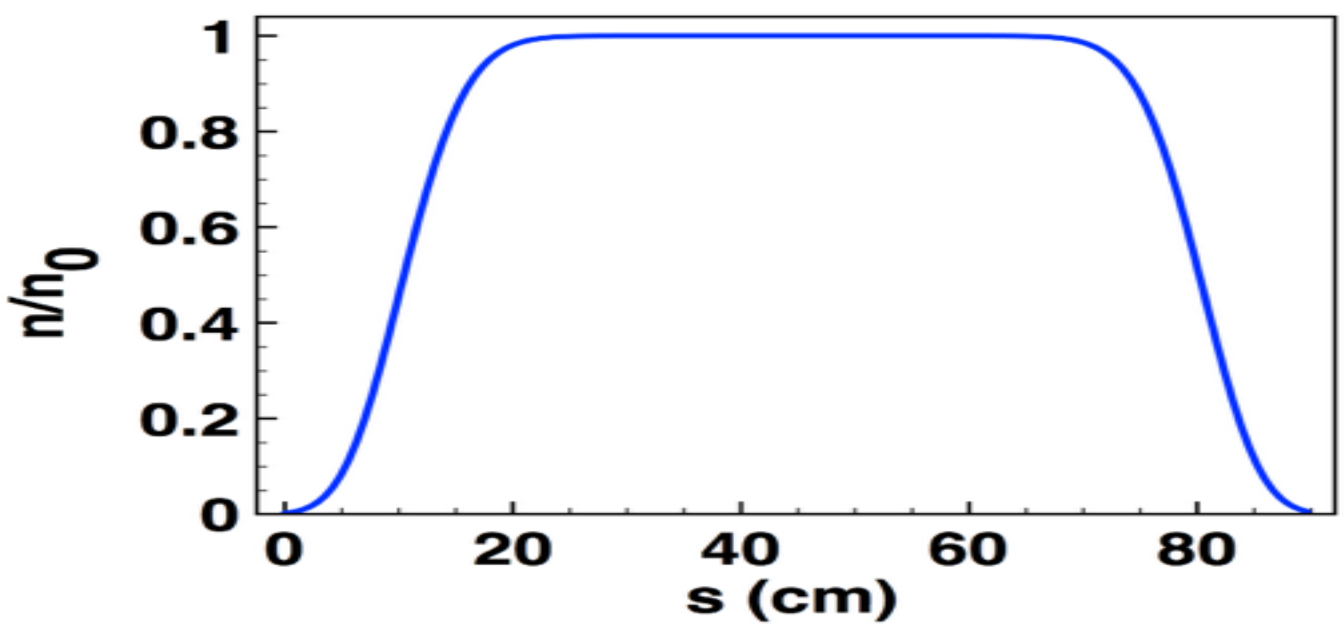
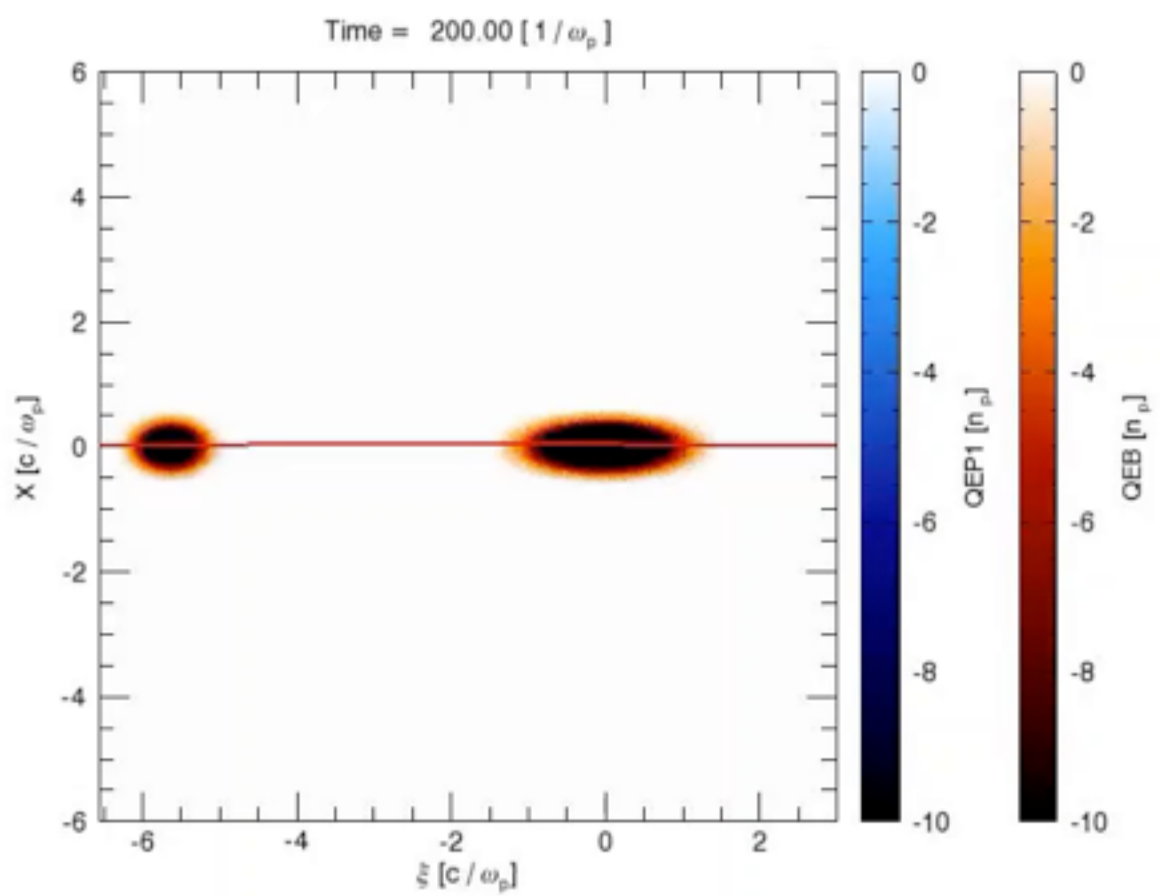
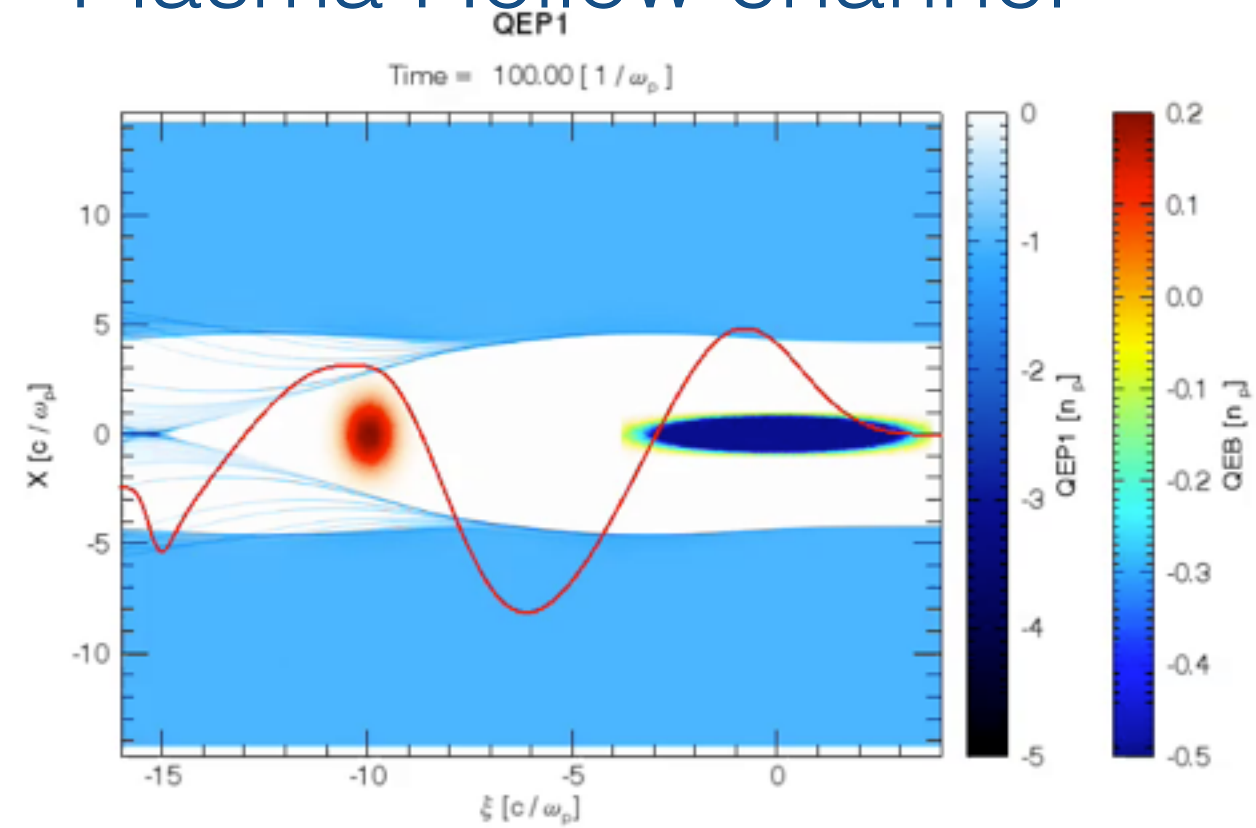
Plasma

Plasma Density Profile





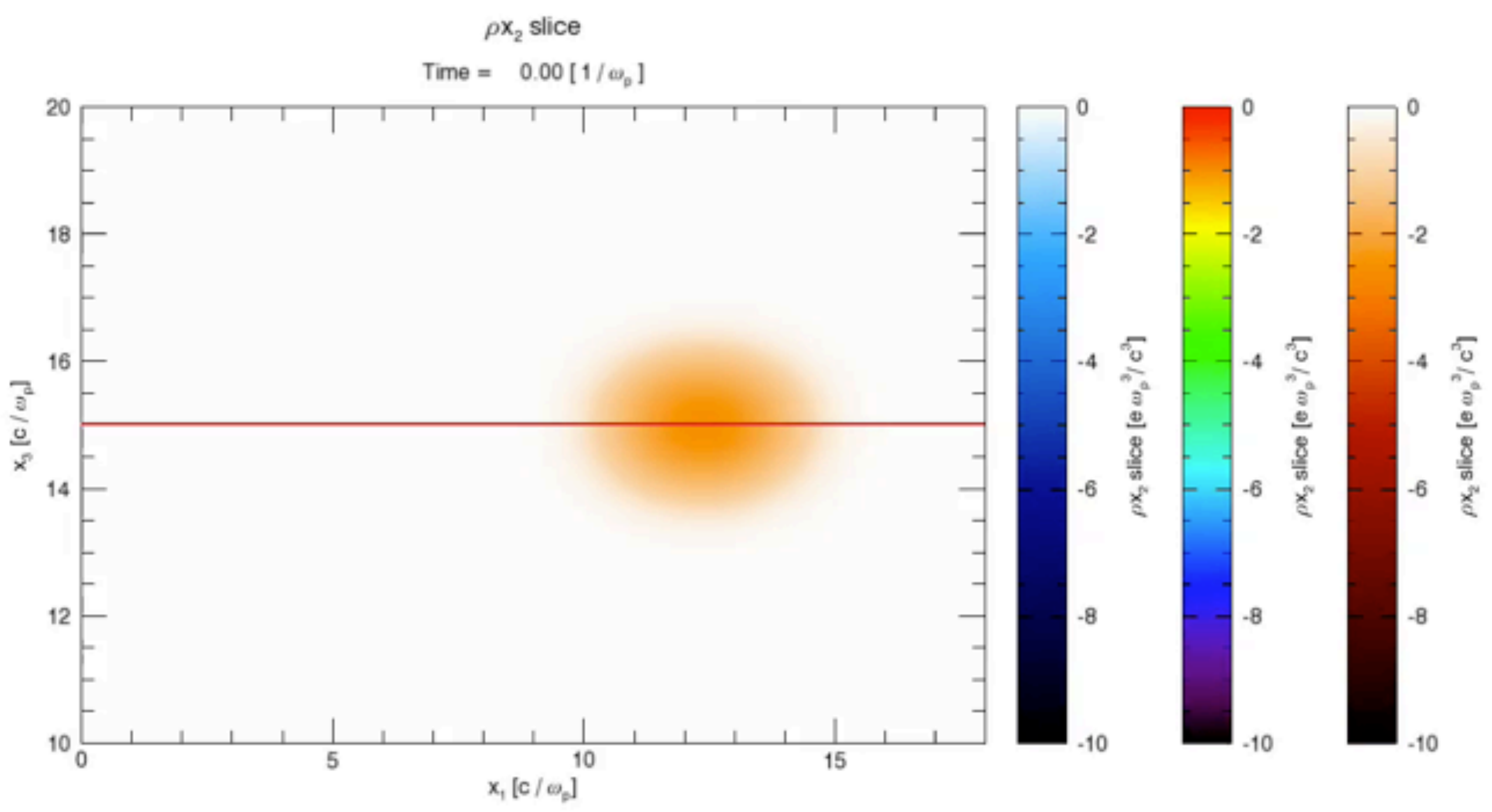
Plasma Hollow channel



Define the density profile using math function.

Plasma

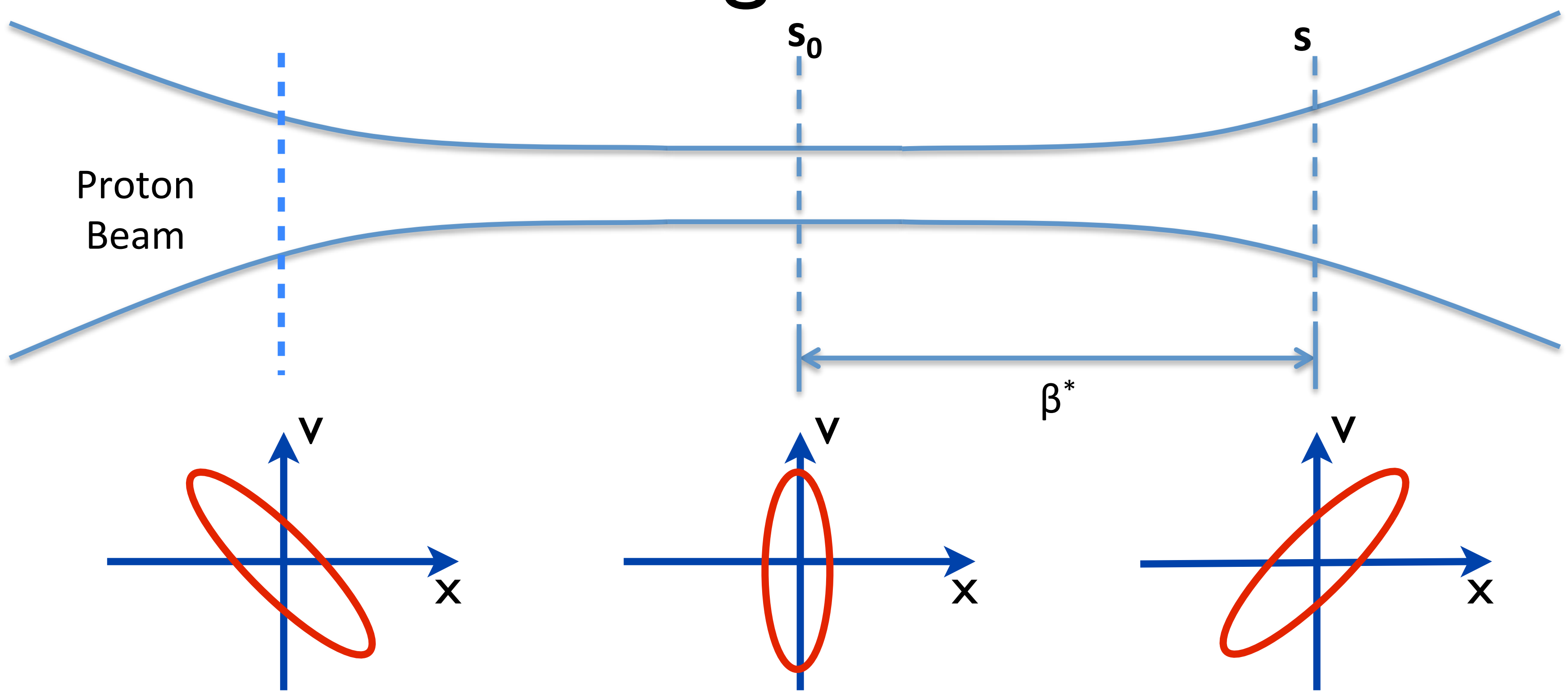
Field Ionized Plasma



Neutral Species

Initialize The Beam With A Focal Length

The focal length of the beam



$$\beta^* = \gamma \frac{\sigma_r^2}{\epsilon_N} \qquad \sigma_r = \sigma_{r0}\sqrt{1 + (s - s_0)^2/\beta^{*2}}$$

Twiss Parameter: $\gamma x'^2 + 2\alpha x x' + \beta x^2 = \epsilon$

In the Vacuum: $\gamma = \frac{1}{\beta^*}, \quad \beta = \beta^*(1 + \alpha^2), \quad \alpha = -\frac{s - s_0}{\beta^*}$

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Initialize The Beam With A Focal Length

Beam Density: $$n_b = n_{b0} \exp(-\frac{r^2}{2\sigma_r^2}) \exp(-\frac{z^2}{2\sigma_z^2})$$

Transverse Phase Space: $$\sim \exp(-\frac{x^2}{2\sigma_{x0}^2}) \exp(-\frac{v^2}{2\sigma_{v0}^2})$$

Transverse Phase Space at $s^*=z-z_0$: $$\sim \exp(-\frac{(x - vs^*/c)^2}{2\sigma_{x0}^2}) \exp(-\frac{v^2}{2\sigma_{v0}^2})$$

$$\sim \exp\left[-\frac{x^2}{2\sigma_{x0}^2(1 + s^{*2}/\beta^{*2})}\right] \exp\left[-\frac{(v - \frac{s^* cx}{\beta^{*2}+s^{*2}})^2}{2\sigma_{v0}^2/(1 + s^{*2}/\beta^{*2})}\right]$$

$$\bar{\sigma}_x = \sigma_{x0}\sqrt{1 + s^{*2}/\beta^{*2}} \qquad \bar{\sigma}_v = \sigma_{v0}/\sqrt{1 + s^{*2}/\beta^{*2}}$$

Good for Osiris Initialization!

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QuickPIC Open Source

Boundary Condition

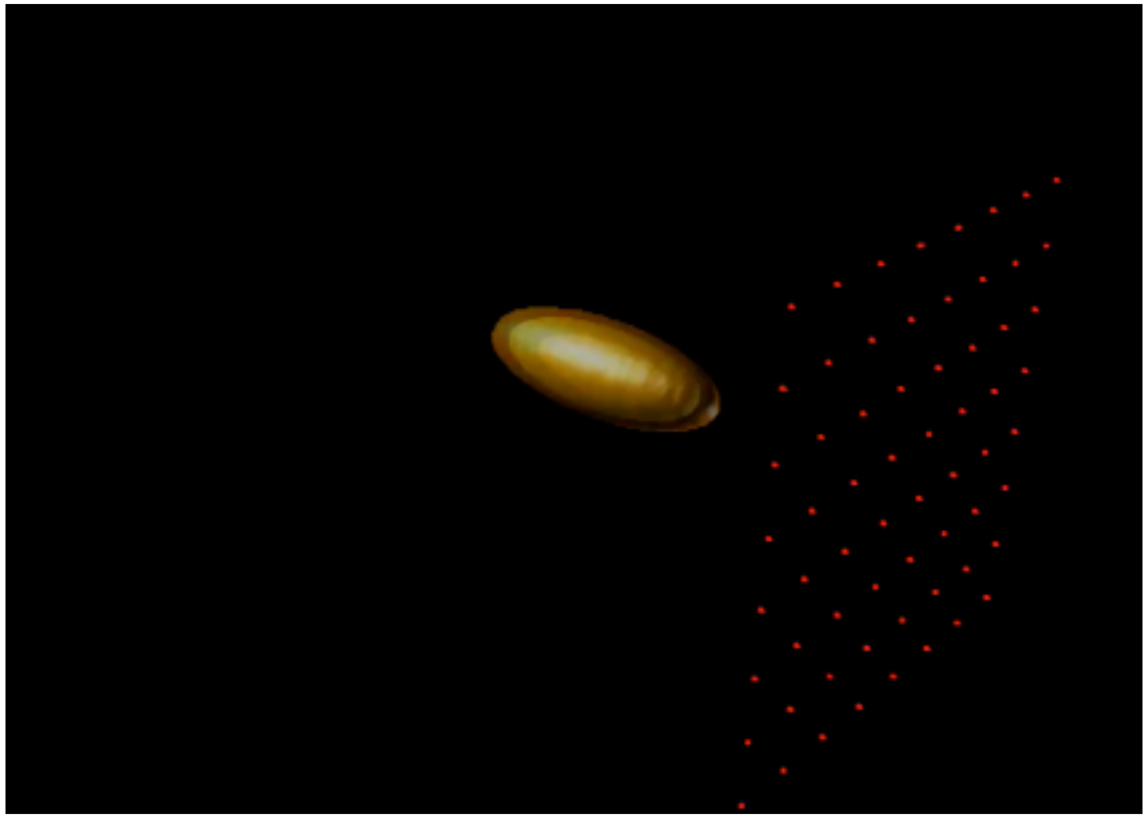
Conducting

Interpolation Order

1st

MPI or Shared Memory

MPI + OpenMP



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Fortran 2003
Object Oriented

Fortran 77
Fortran 90

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