Overview of Recent CIFS-Relevant Research

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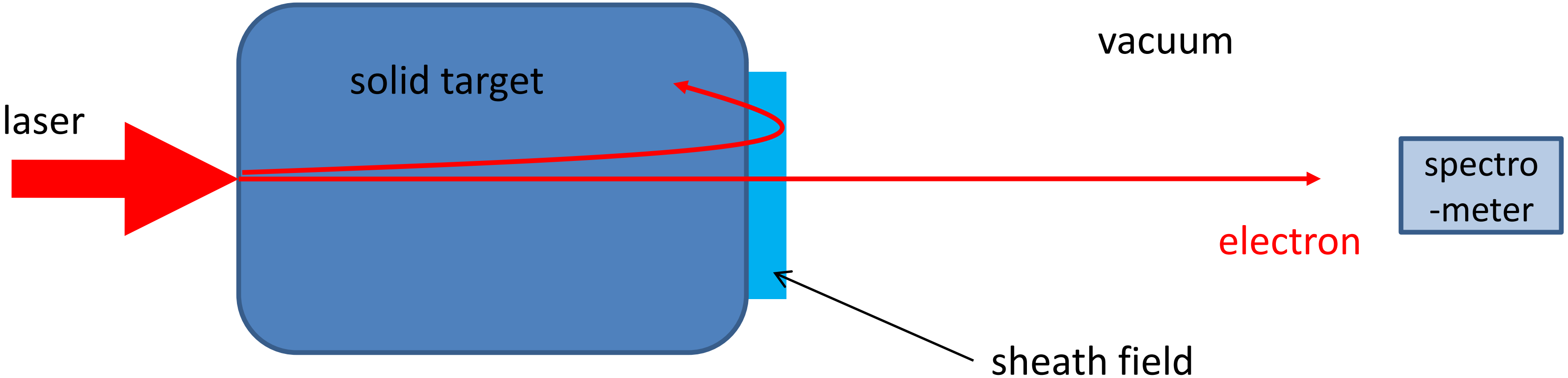
Problem of measuring fast electron energy



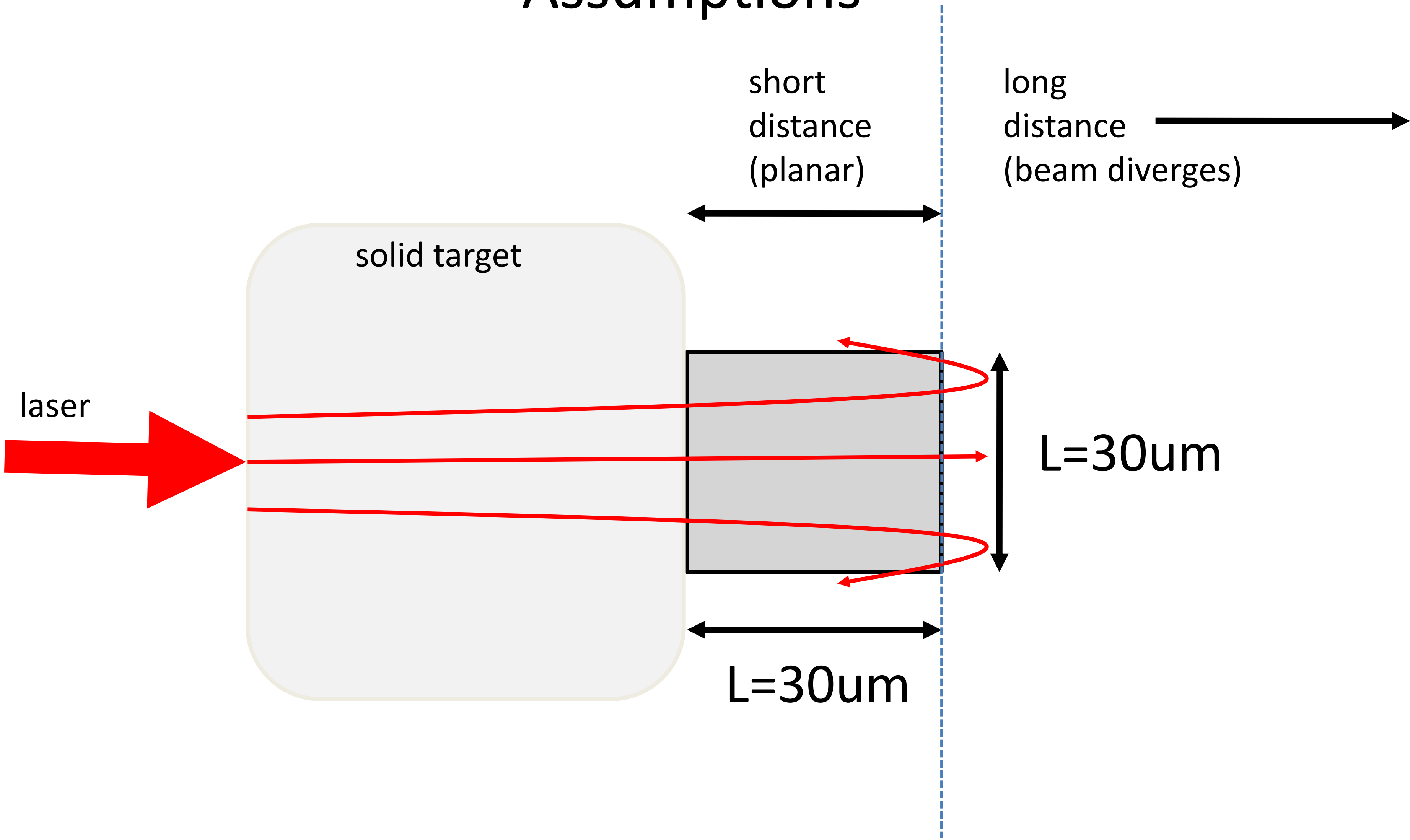
Energy at the spectrometer

Two opinions:

(a) Only higher energy electrons reach the spectrometer, so it measures an energy that's *too high*.

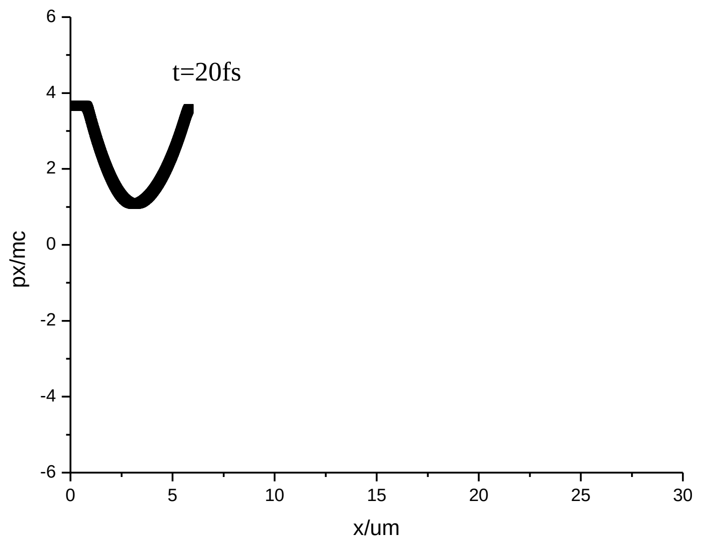
(b) The average electron loses energy when it moves through the sheath, so it measures an energy that's *too low*.

Assumptions

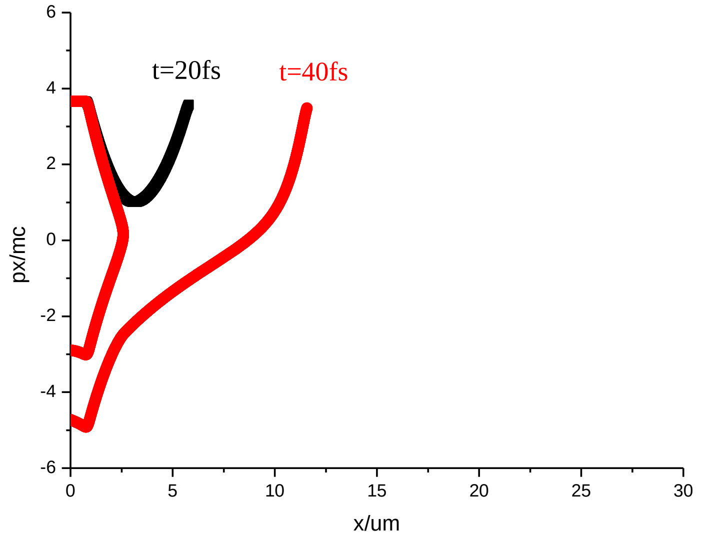


- Planar geometry is OK at small distances
- Divergent (e.g. spherical) geometry applies at large distances

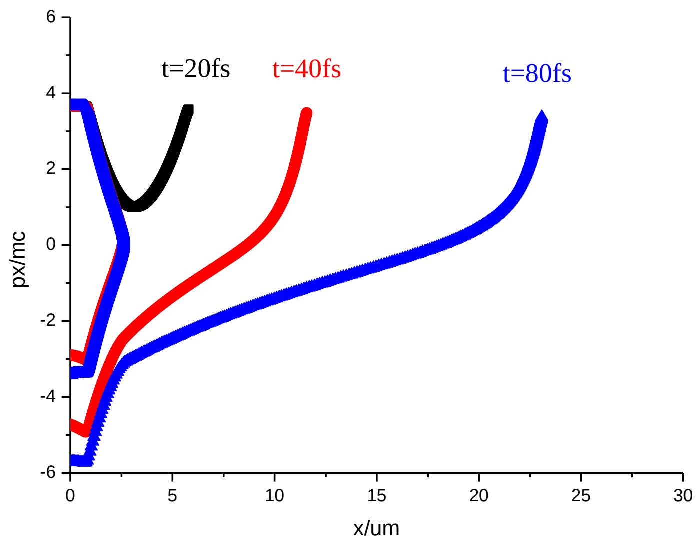
Simple particle simulation



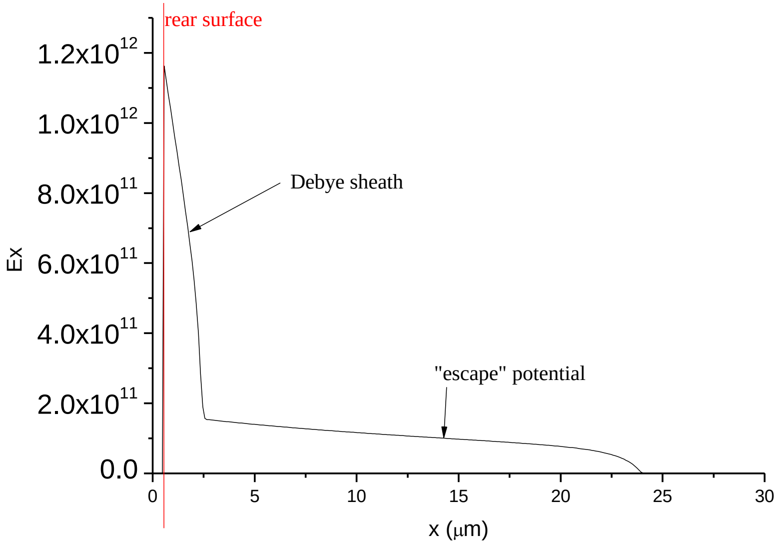
Why is the vacuum energy lower?



Why is the vacuum energy lower?



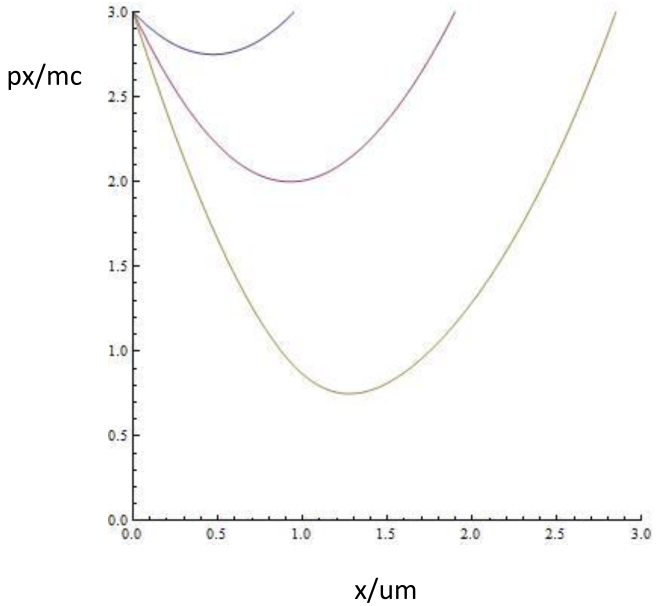
Electric field



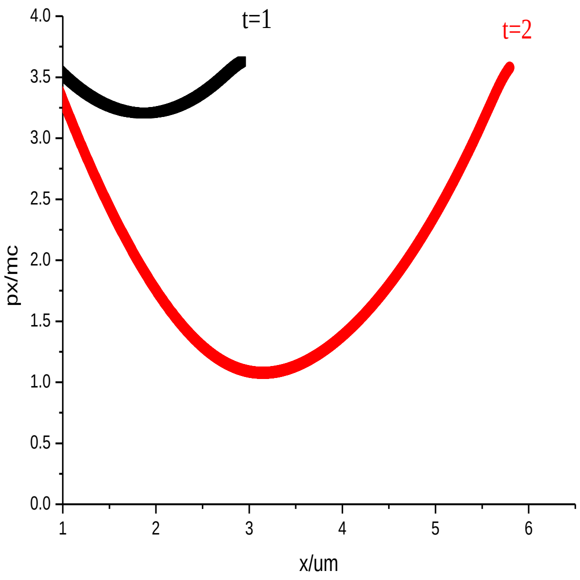
Continuous electron model

$$p(\tau,t) = p_0 - j_0\tau(t-\tau)$$

$$x(\tau,t) = \frac{\sqrt{1+p_0^2} - \sqrt{1+p_0^2 + j_0^2\tau^2(t-\tau)^2 + 2p_0 j_0\tau(t-\tau)}}{j_0\tau}$$

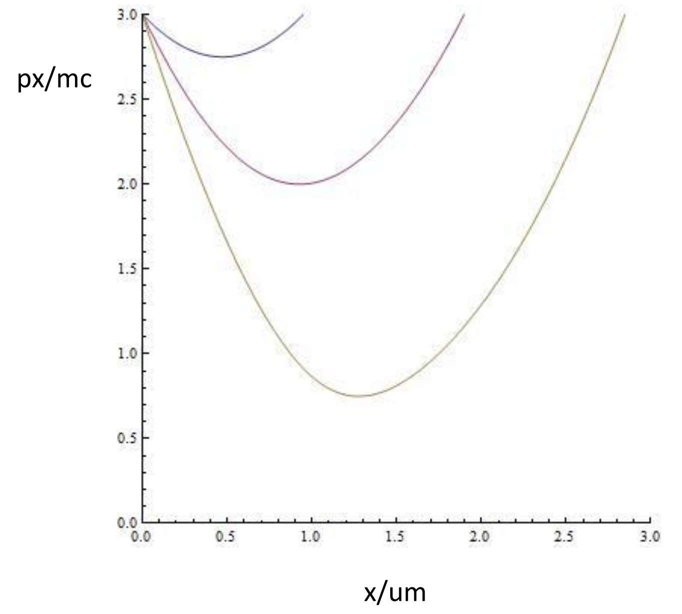


theory



simulation

Continuous electron model



$$p(\tau, t) = p_0 - j_0 \tau (t - \tau)$$

Expand around τ=0 for small τ and large t

$$p \approx p_0 + const \times \tau$$

$f(p) \approx const \qquad p < p_0$

$f(p) \approx 0 \qquad p > p_0$

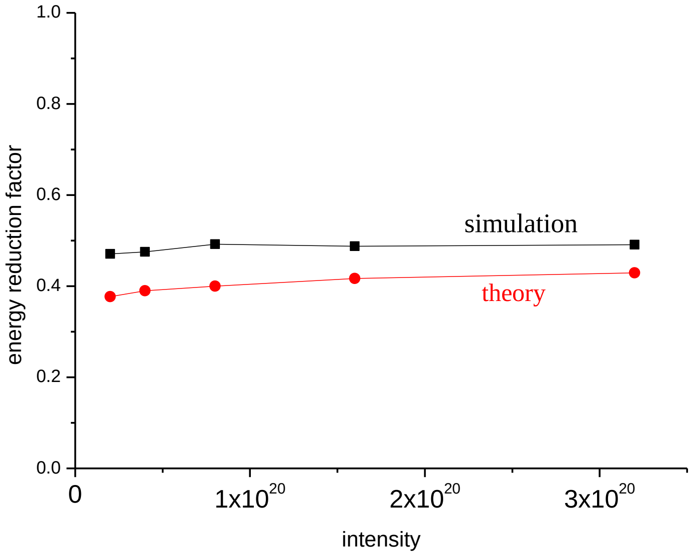
near the front of the electron stream

$$\Rightarrow \langle E \rangle = mc^2 \int_0^{p_0} (\gamma(p) - 1) f(p) dp = \frac{1}{2}(\sqrt{1 + p_0^2} - 1) + \frac{\mathrm{arcsinh}(p_0)}{p_0}$$

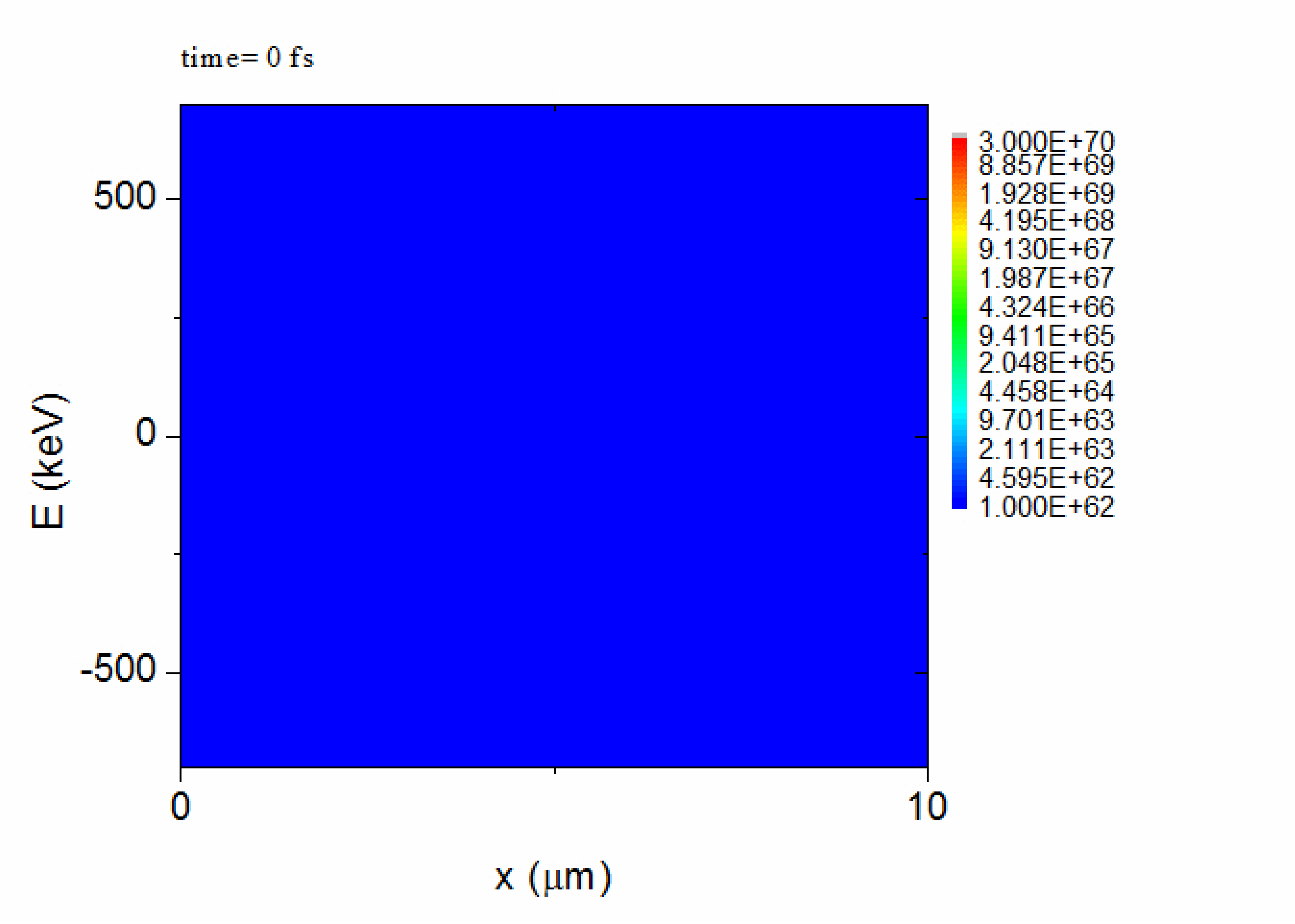
$$\frac{\langle E \rangle}{E_{injected}} = \frac{\langle E \rangle}{\sqrt{1 + p_0^2} - 1} \approx \frac{1}{2}$$ (ultra-relativistic limit)

Continuous electron model

$$\left\langle E \right\rangle_{vac} \approx \frac{1}{2} E_{injected}$$

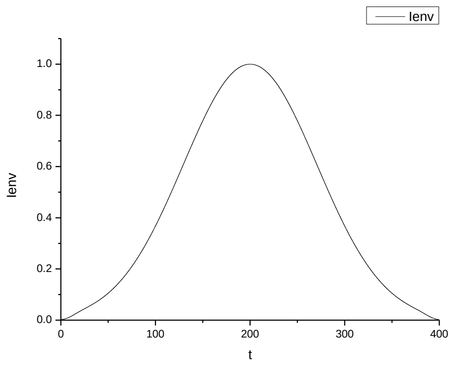


“Realistic” distributions?

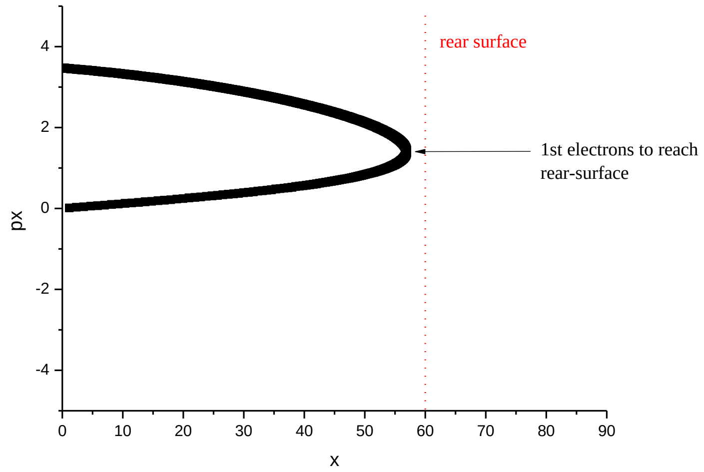


(Vlasov simulation)

Transport in target

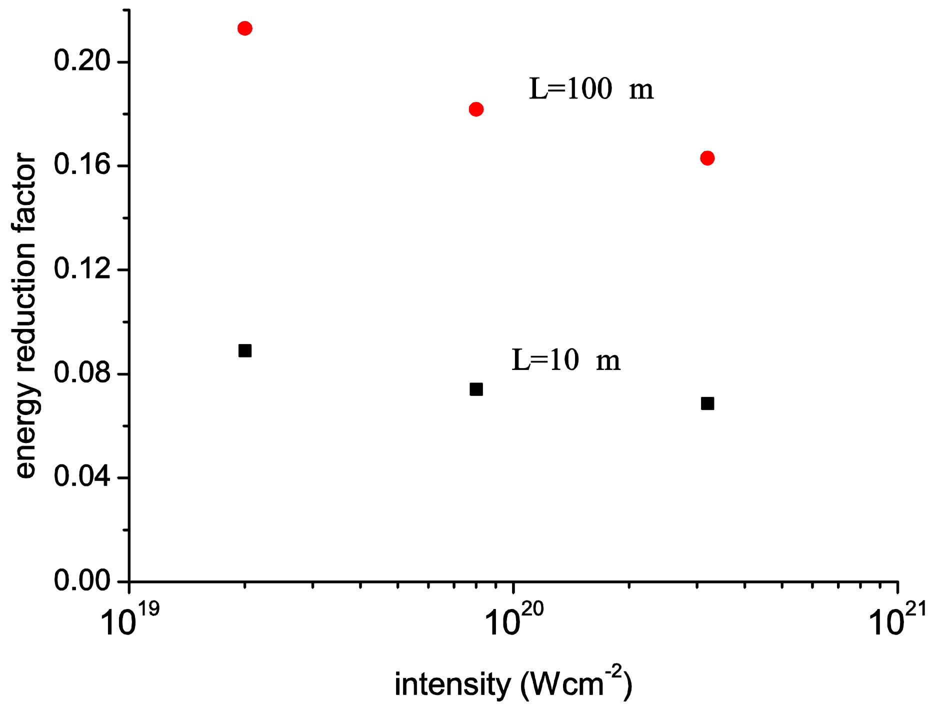


$$\langle E \rangle \approx 0.6\left\{\sqrt{1+\frac{I\lambda^2}{1.3\times10^{18}Wcm^{-2}}}-1\right\}mc^2$$



$$E_{\text{vac}} \approx \frac{1}{2}\left(\frac{1}{2}E_{\text{target}}\right)$$

Some results



Full Vlasov simulation (including transport through target).
Best to use short pulses and thick targets.

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Two opinions:

~~(a) Only higher energy electrons reach the spectrometer, so it measures an energy that's *too high*.~~

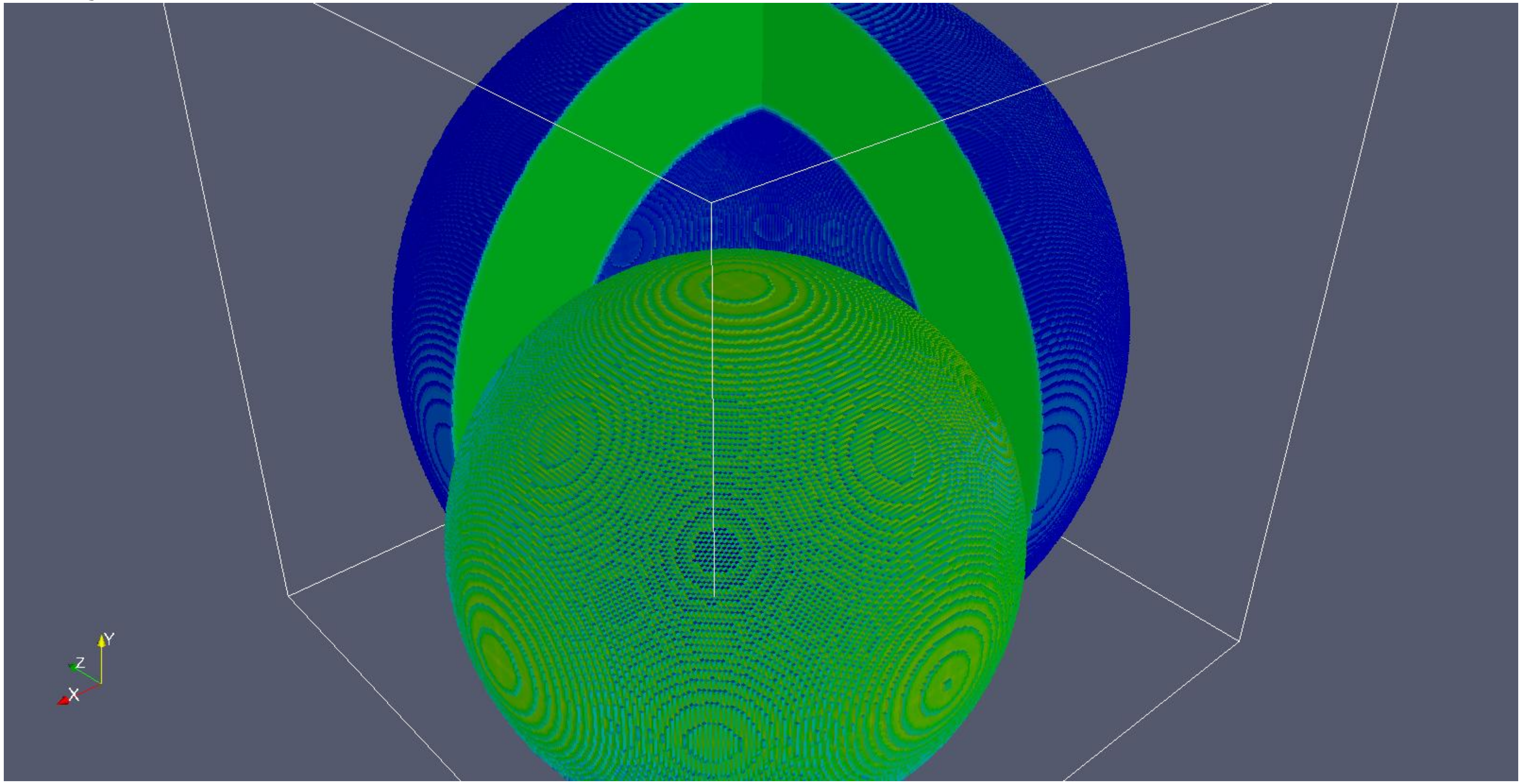
~~(b) The average electron loses energy when it moves through the sheath, so it measures an energy that's *too low*.~~

(c) The first electrons to reach the rear surface are the only ones able to escape so the measured energy is lower. Furthermore these electrons lose more energy as they *generate* the "escape sheath".

3D Gorgon - Capsule Calculations (J. Chittenden & S. Taylor)

DT ice ball with gaseous hotspot, 2μm spatial resolution – initiated during the coast phase with velocity $4x10^5$ m/s

Density of main fuel



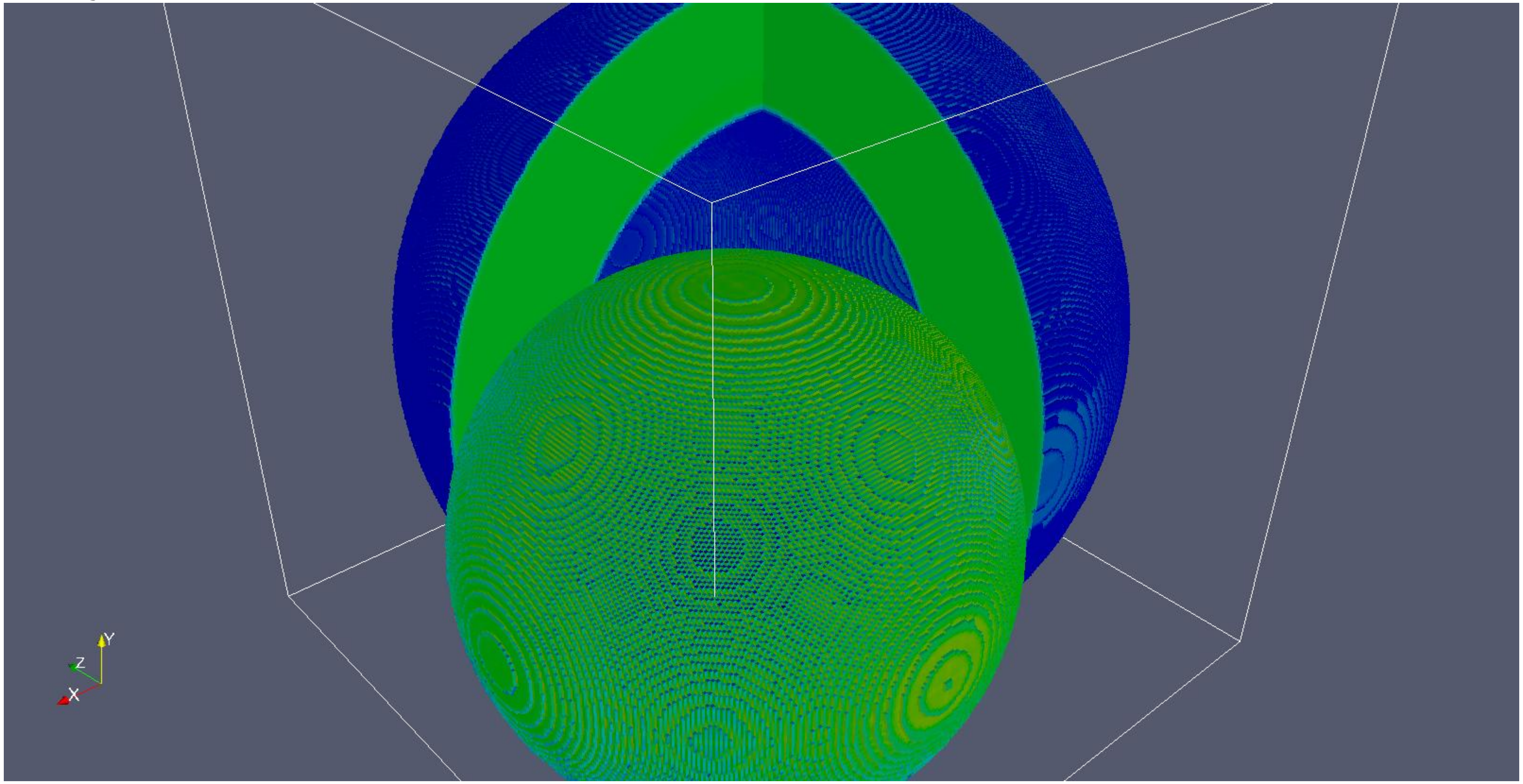
Temperature of Hotspot

Unperturbed 1D test problem – local alpha deposition model "clean yield" ~ 10MJ

3D Gorgon - Capsule Calculations (J. Chittenden & S. Taylor)

DT ice ball with gaseous hotspot,
2μm spatial resolution
– initiated during the coast phase
with velocity $4x10^5$ m/s

Density of main fuel



Temperature of Hotspot

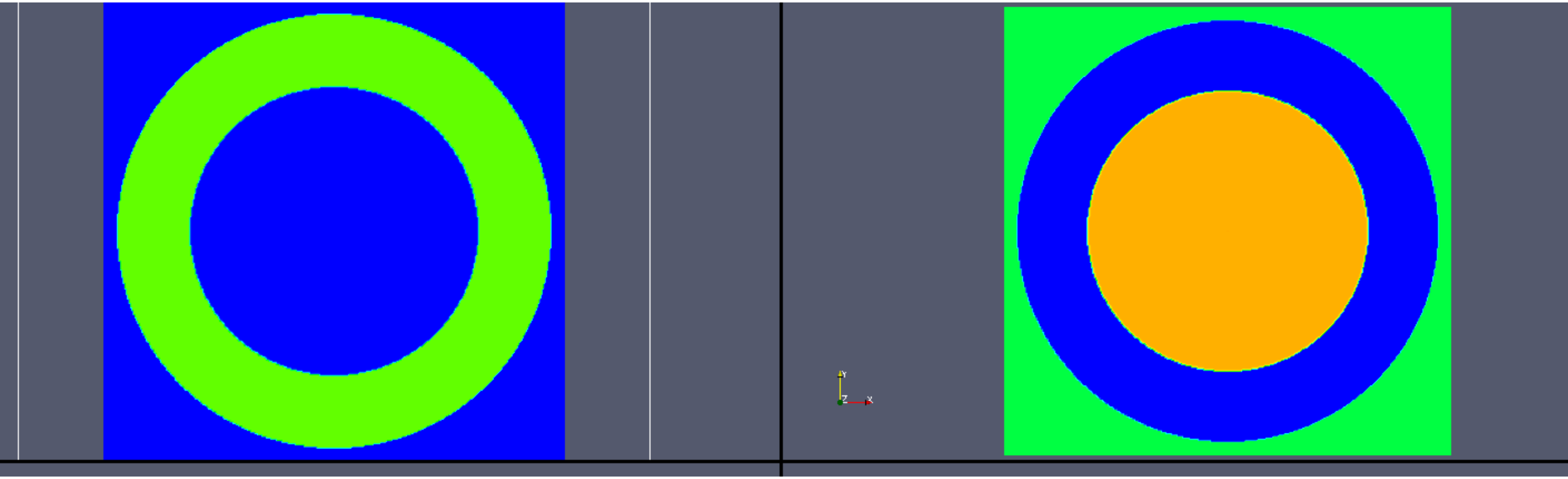
4,2 mode Legendre polynomial –
local alpha deposition model
"yield over clean" ~ 1%

3D Gorgon - Capsule Calculations (J. Chittenden & S. Taylor)

DT ice ball with gaseous hotspot,
2μm spatial resolution
– initiated during the coast phase
with velocity $4x10^5$ m/s

Density

Temperature



Next we will try noise perturbation to generate a more realistically asymmetric hotspot.

8,16 mode Legendre polynomial
– local alpha deposition model
"yield over clean" ~ 10%

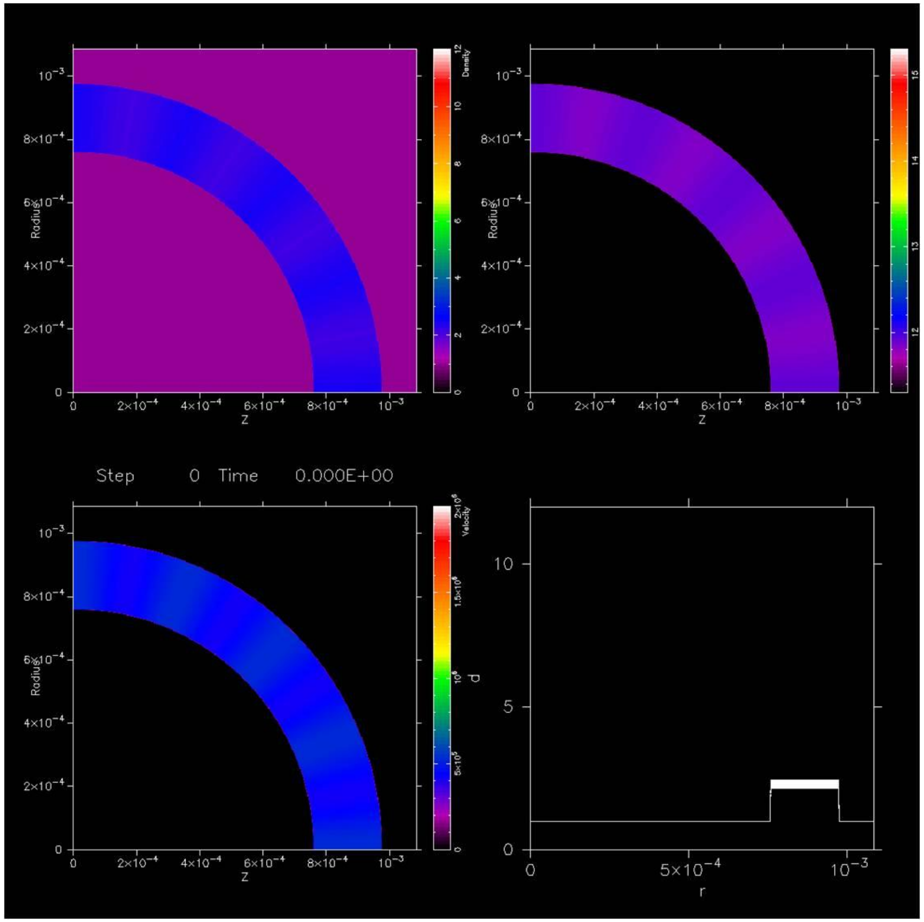
The main purpose of these calculations is to provide a target for studies of non-local alpha transport in inhomogenous burning plasma

Zeus 2D (C.Davie & R.G.Evans)

- Zeus maintains spherical symmetry very well for an ideal converging shock.
- Converging spherical shock with small perturbation in driving pressure. Single T Eulerian.

density

T

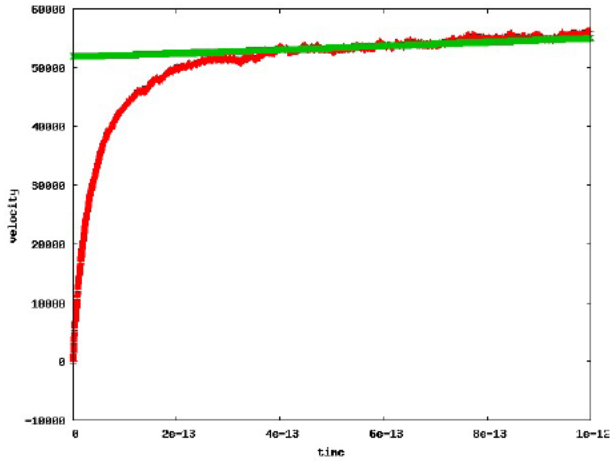


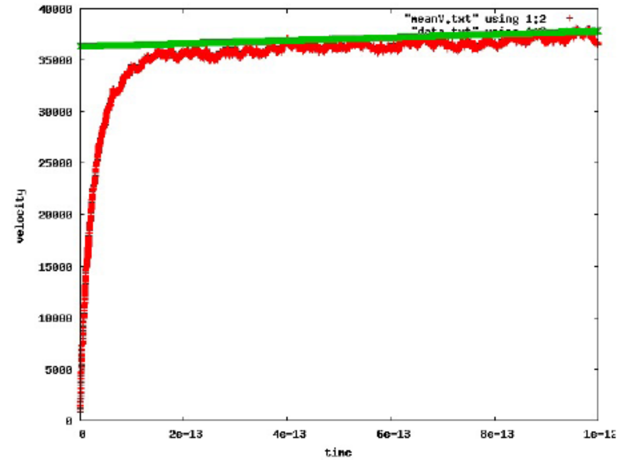
velocity

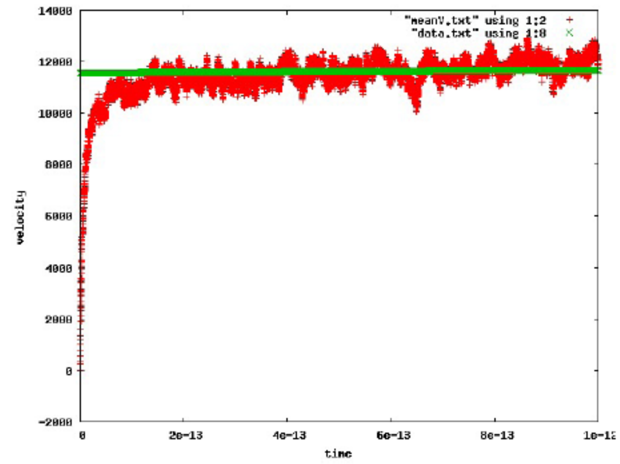
density vs radius for all the cells so the dispersion of the points shows the departure from ideal sphericity.

Although the shock wave distorts markedly near the bounce it rapidly recovers its sphericity in the outgoing phase. This contributes to the robustness of shock ignition since the burn is initiated by the return shock in the DT shell rather than in a central hot spot.

PIC Simulations (EPOCH) of Dense Targets Collisions







$T = 1 \times 10^5$ K

$E = 1 \times 10^7$

$n_e = 1 \times 10^{26}$

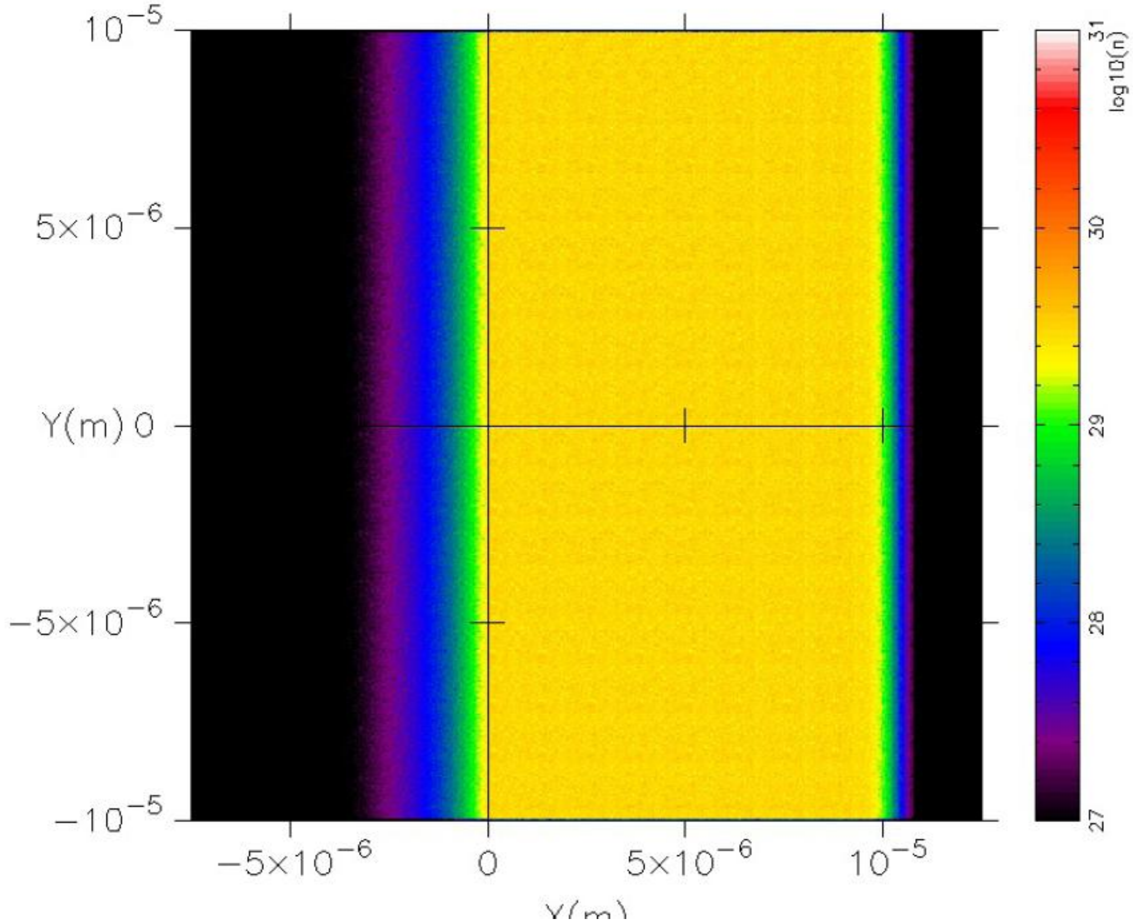
$dt = 1 \times 10^{-16}$

$\tau \approx 1 \times 10^{-14}$

~1million particles (per cell)

PIC Simulations (EPOCH) of Dense Targets

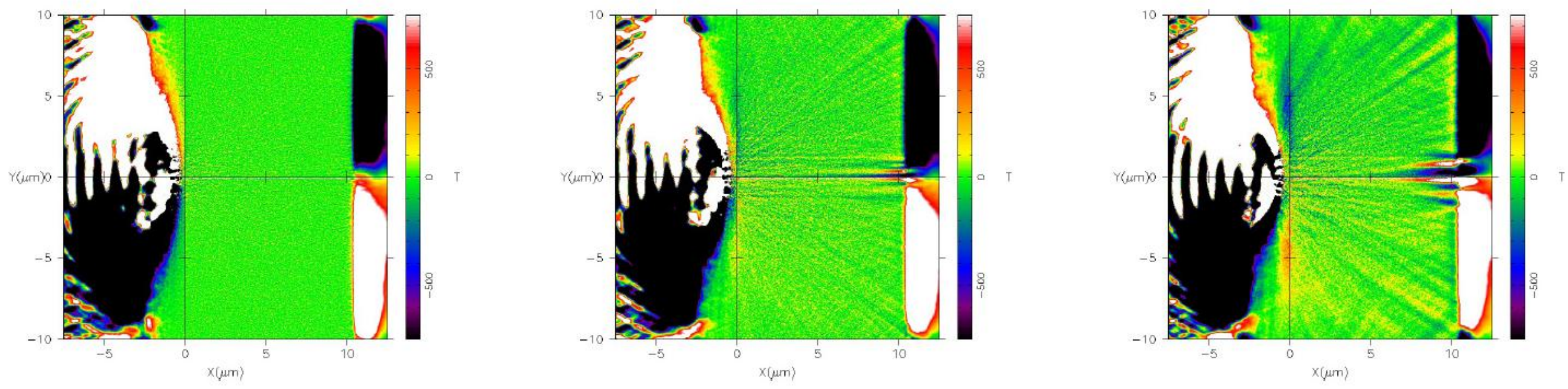
- 3072×3072 cells
- $20\mu m \times 20\mu m$
- $density = 1g/cc$
- $T = 100eV$
- dt$\approx 7.66 \times 10^{-18}$s
- dx$=6 \times 10^{-9}$m
- 2×10^{9} particles
- $5\mu m$ laser spotsize
- $I = 5 \times 10^{19} Wcm^{-2}$



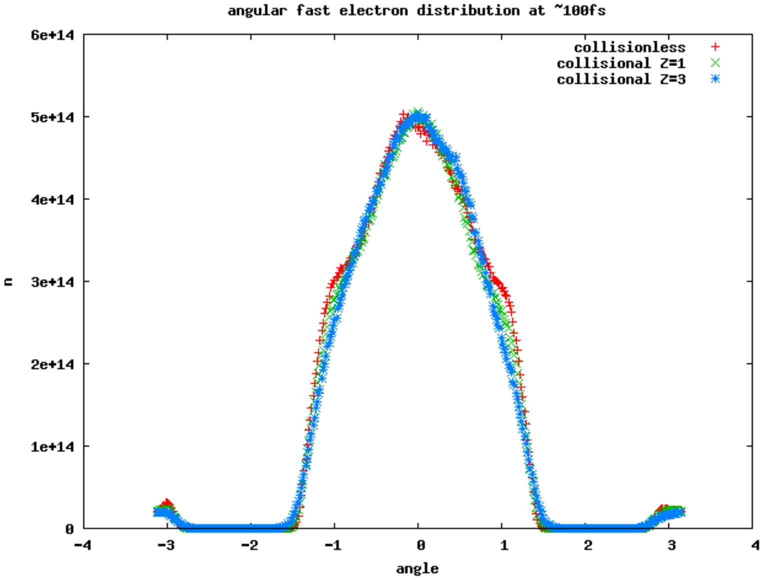
Magnetic Field (time-av) at 200fs

Monte-Carlo collisions give a resistive magnetic field.

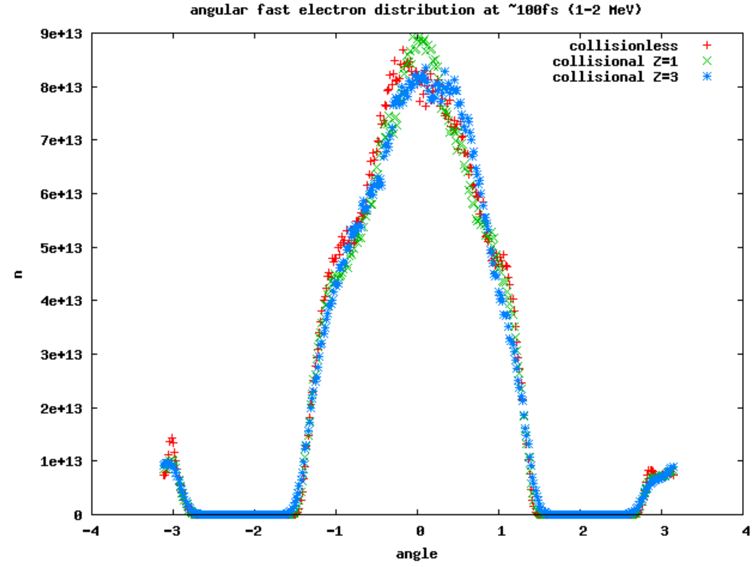
Collisionless Z=1 Collisional Z=3 Collisional

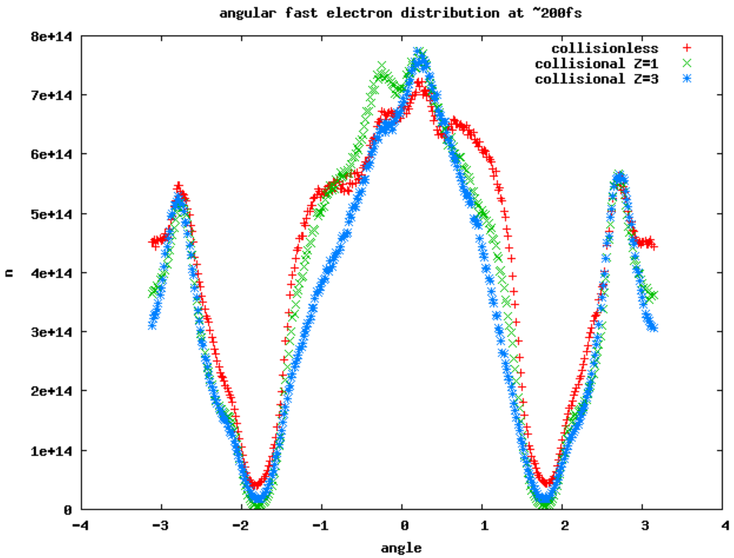


Fast Electron Divergence

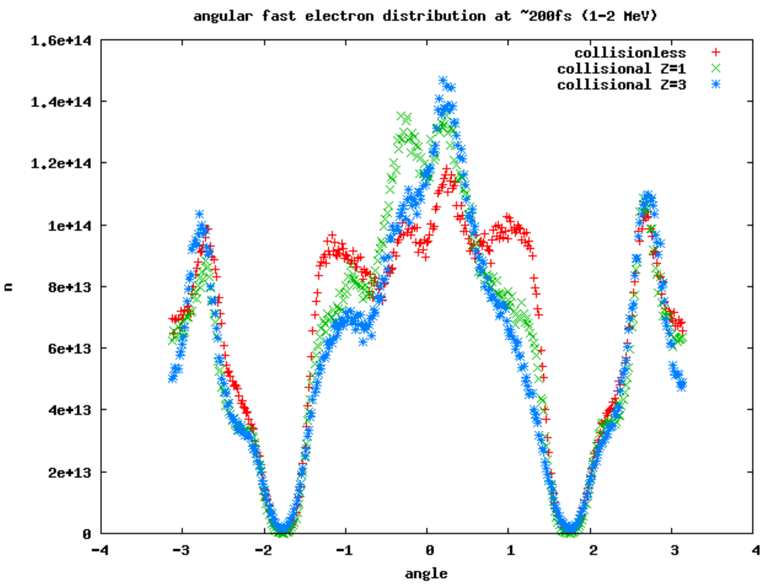


100fs





200fs



All electrons

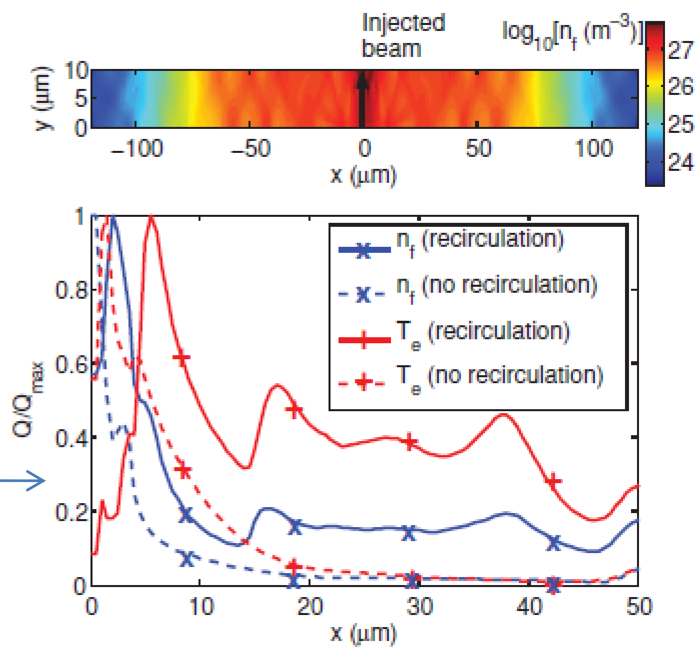
Fast electrons (1-2MeV)

VFP Simulations of Rear-Surface Effects

(C.Ridgers & M.Sherlock)

Experimentally, we probe the target rear surface. Can we infer the correct divergence angle from rear surface measurements?

Along target rear surface



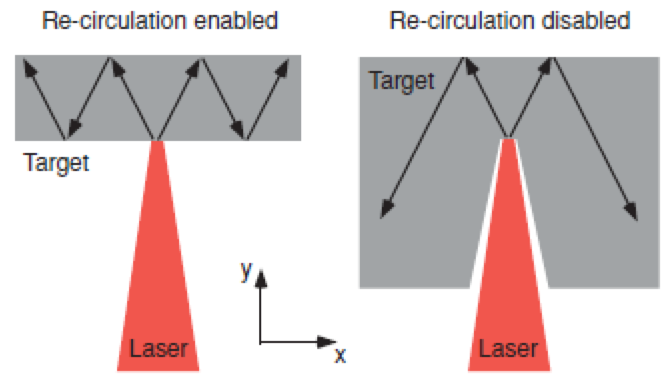


FIG. 1. (Color online) The two types of targets considered in this paper.

- •Density and temperature give conflicting evidence
- •A better estimate of divergence is gained from targets that suppress refluxing.

Summary

- Fast electron energy measured at spectrometer is too low.
- Need to suppress refluxing to get a better understanding of fast electron divergence.
- Collisions in PIC codes do not significantly modify the beam divergence.
- 3D implosion simulations are underway to investigate the effect of non-local alpha-energy deposition in non-uniform hotspots.
- 2D implosion simulations show shock waves that are initially distorted can recover their symmetry after the bounce.