Short pulse modelling in PPD

N. J. Sircombe, M. G. Ramsay, D. A. Chapman,
S. J. Hughes, D. J. Swatton.
nathan.sircombe@awe.co.uk

www.awe.co.uk

Outline

- Background
- Short pulse LPI
- Transport
- Plans for short pulse modelling

Background

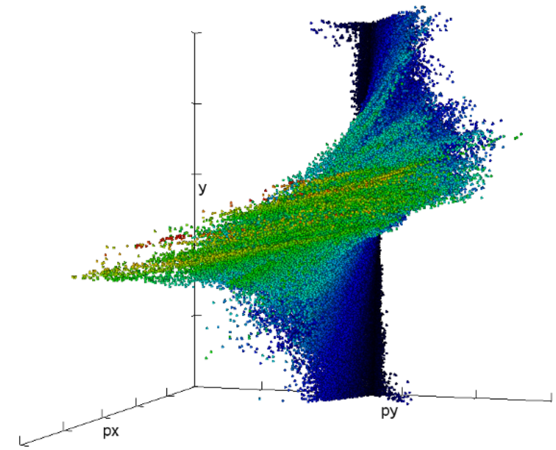
- The twin petawatt arms on ORION will provide a means to heat matter to extreme temperatures and allow us to study its properties.
- The mechanisms by which the short pulse laser delivers its energy, how this energy is distributed and how it is transported into the material are complex and interdependent.

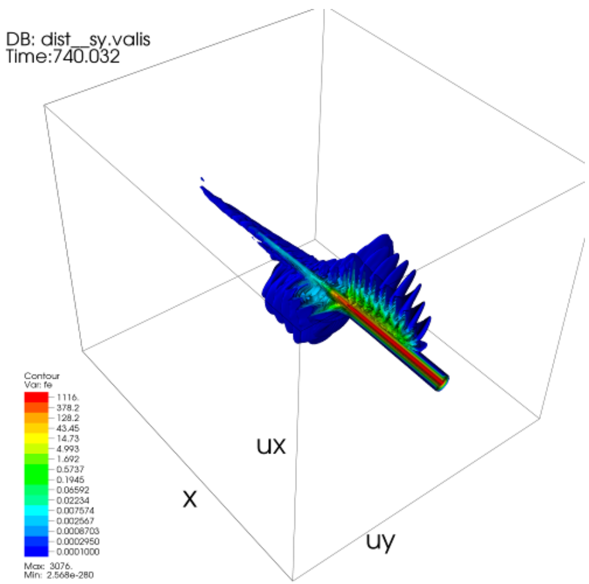
Background

- Currently there is a reliance on a number of empirical relations, which may be limited to a specific target configuration or laser system.
- A more predictive modelling capability will help us to…
  - Understand, challenge or support these assumptions
  - Optimise experiments to make the best use of ORION's available short-pulse capability.
- There are clear similarities between the problems faced in predicting the outcome of full-scale ORION experiments and developing a fast ignition point design

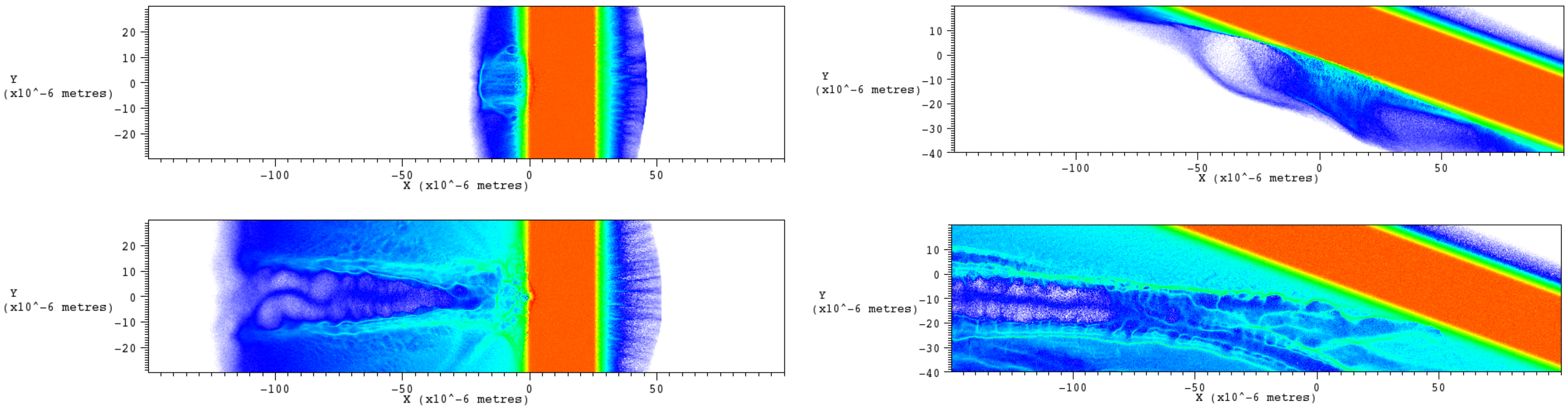
Short pulse LPI

- Modelling interaction of SP laser in
  - Planar targets
    - Variety of plasma profiles, target angles
  - Cone geometry
    - Effect of low-density cone fill
    - Effect of 'missing' cone tip
- Using PIC codes and direct Vlasov solvers
  - CCPP PIC code – EPOCH
    - Developed by C. S. Brady (CFSA Warwick)
  - Direct, 2D, Vlasov – VALIS
    - Developed with T. D. Arber (CFSA Warwick)



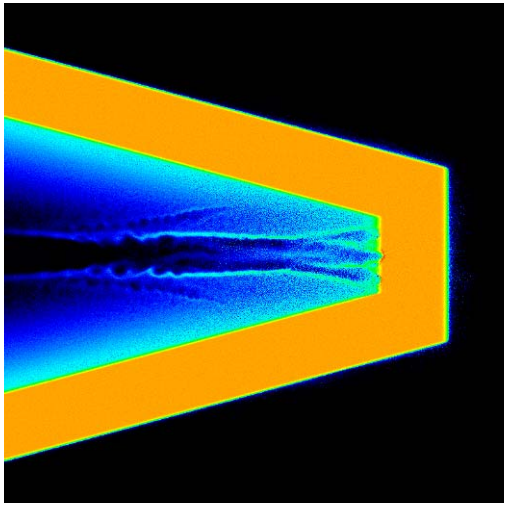


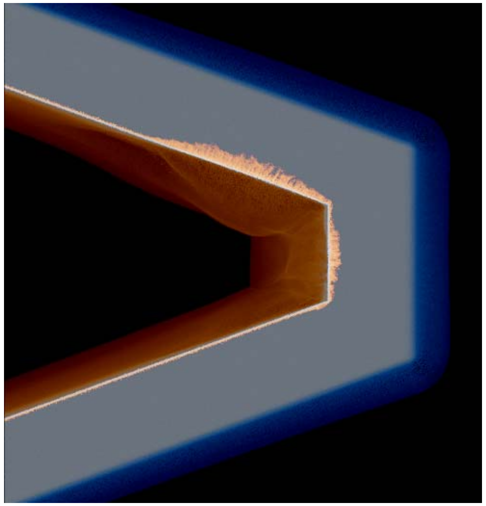
Hot electron generation in planar targets

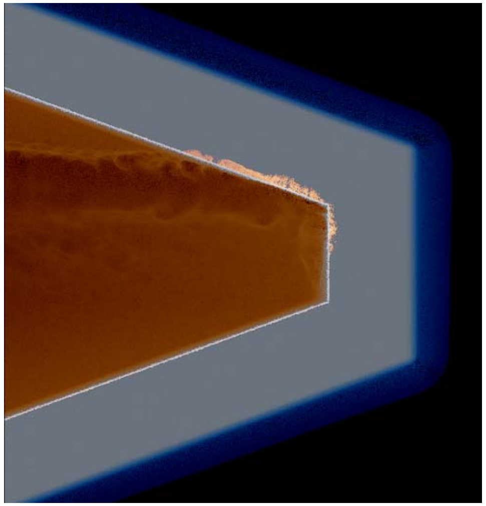


- Characterise energy spectrum of hot electrons in experiments fielded on Omega
- To produce radiographic source from bremsstrahlung
- With and without a long-pulse created 'pre plasma'
  - Intended to improve absorption and generation of hot electrons
  - …but low density pre-plasma generates very high energy electrons
  - Potential problem for FI (e.g. foam filled cones, fuel 'jets' entering the cone etc.)
- Bremsstrahlung radiation can be modelled using EPOCH particle probe data as a source in MCNPx

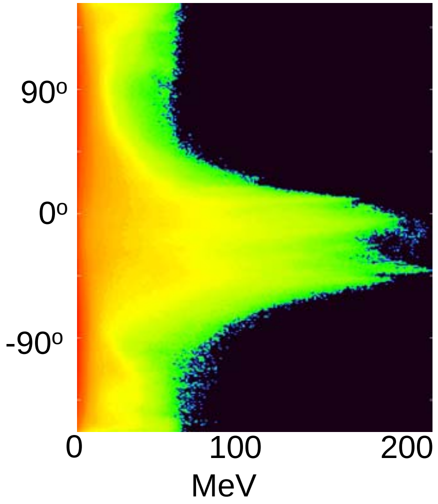
2D 'Cone' Geometries

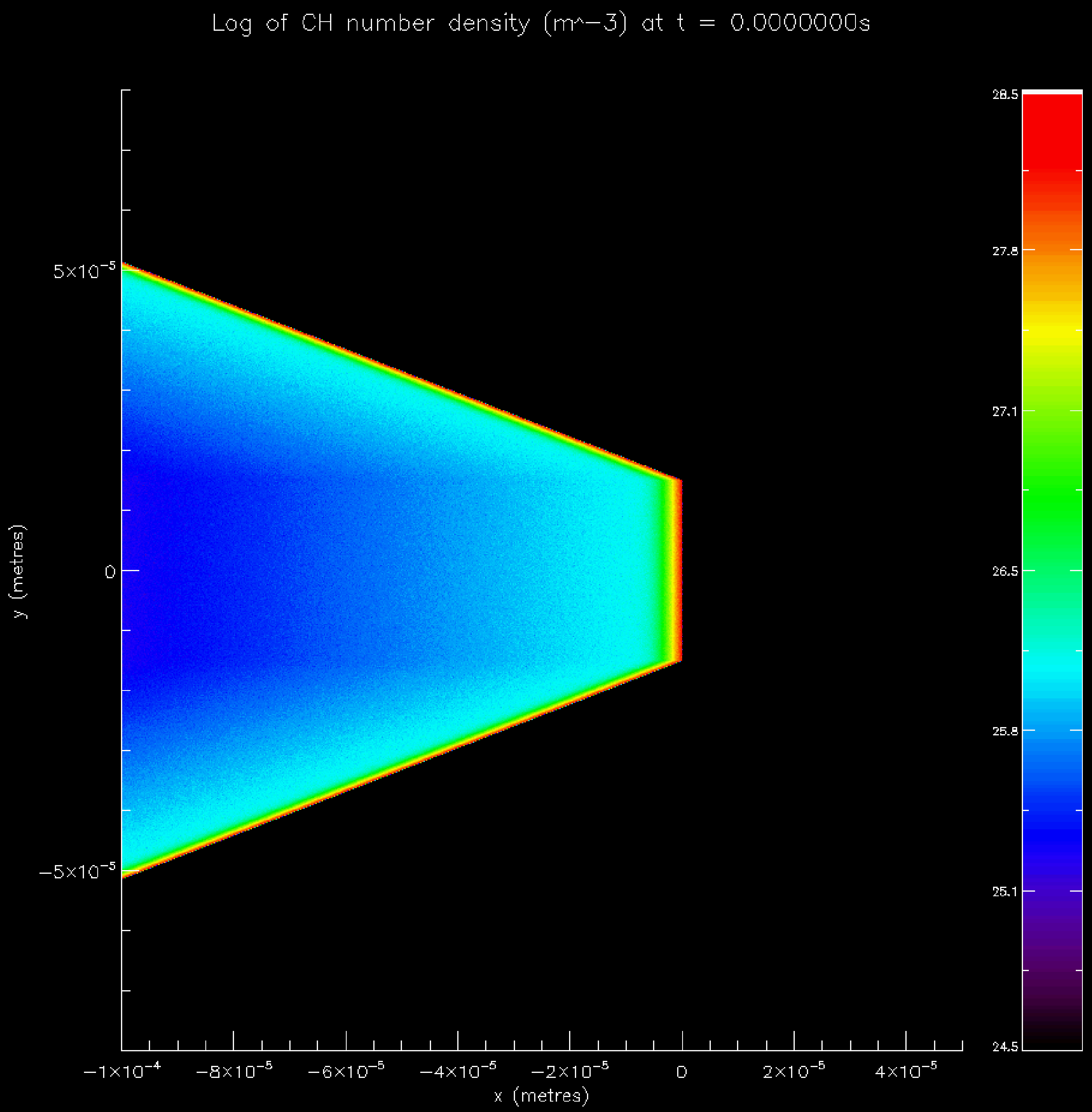






- In a full 2D cone geometry, the presence of a long scale length pre-plasma:
  - allows more energy to be coupled into hot electrons
  - produces higher energy electrons
  - produces a more divergent beam
  - creates a larger effective hot electron source, as the beam is refracted.
- If the short pulse laser misses the cone tip the pre-plasma has a detrimental effect
  - Produces a hot electron beam which is divergent
  - originates over a larger area
  - not directed at the assembled fuel.

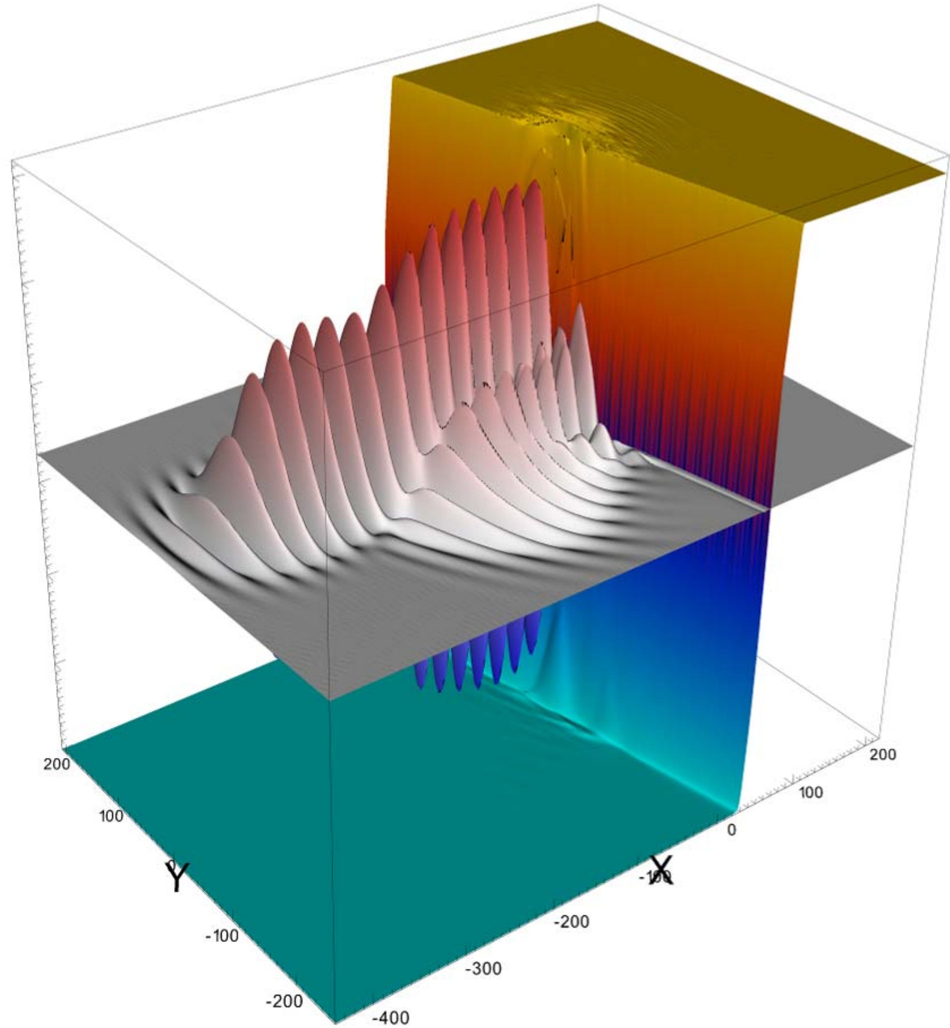




Log of CH number density (m^−3) at t = 0.0000000s
y (metres)
5×10^−5
0
−5×10^−5
x (metres)
−1×10^−4
−8×10^−5
−6×10^−5
−4×10^−5
−2×10^−5
0
2×10^−5
4×10^−5
28.5
27.8
27.1
26.5
25.8
25.1
24.5

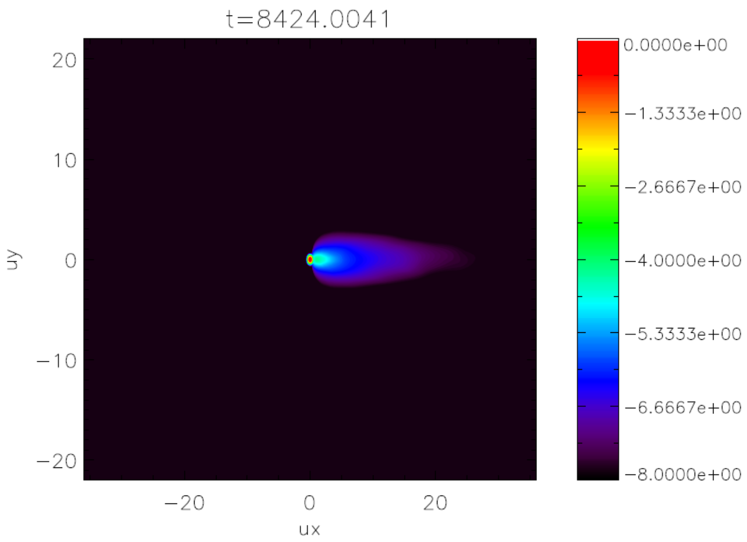
VALIS

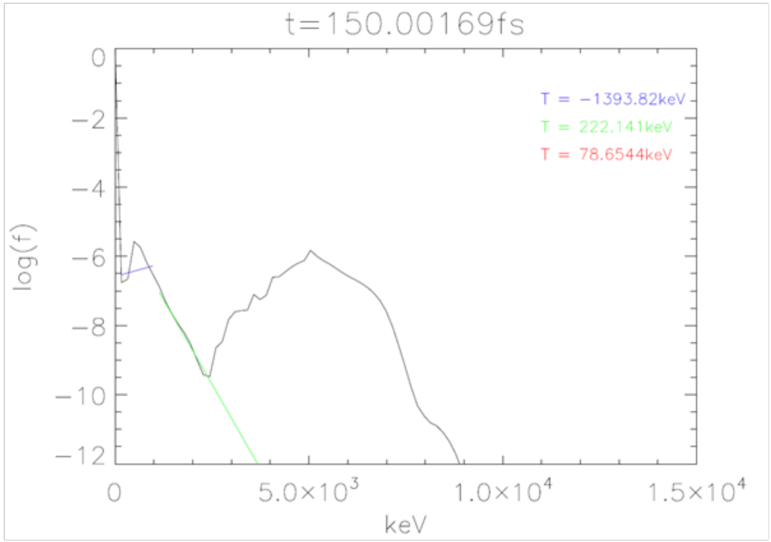
- 2D2P Direct Vlasov Solver
- Explicit, Conservative, Split scheme using PPM advection
- Laser boundaries for LPI
- Domain decomposition over 4D (2D2P) phase space
- *N.J. Sircombe and T.D. Arber, J. Comp. Phys. 228, 4773, (2009)*



Hot electrons from short scale length plasmas

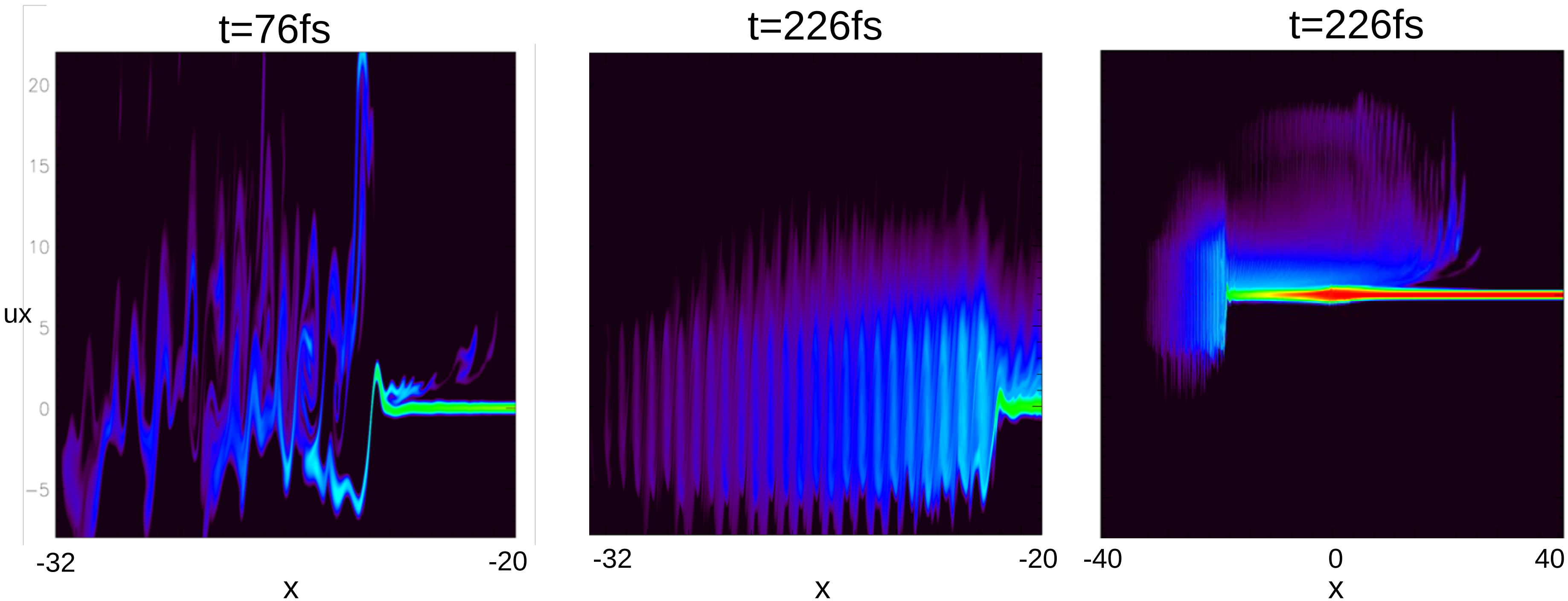
- 500nc, 3.5 micron scale length plasma ramp
- 1.37e20W/cm^2 from LH boundary
- System size
  - 80 microns in space, +/- 24$\beta\gamma$ in momentum
  - (nx, npx, npy) = (8192, 200, 220)
- Estimate T_{hot} Using fit to Boltzmann distribution over three energy ranges*
  - [0.1, 1), [1,5) and [5,10] MeV
- 'Head' of electron 'beam' not well described by Boltzmann dist.





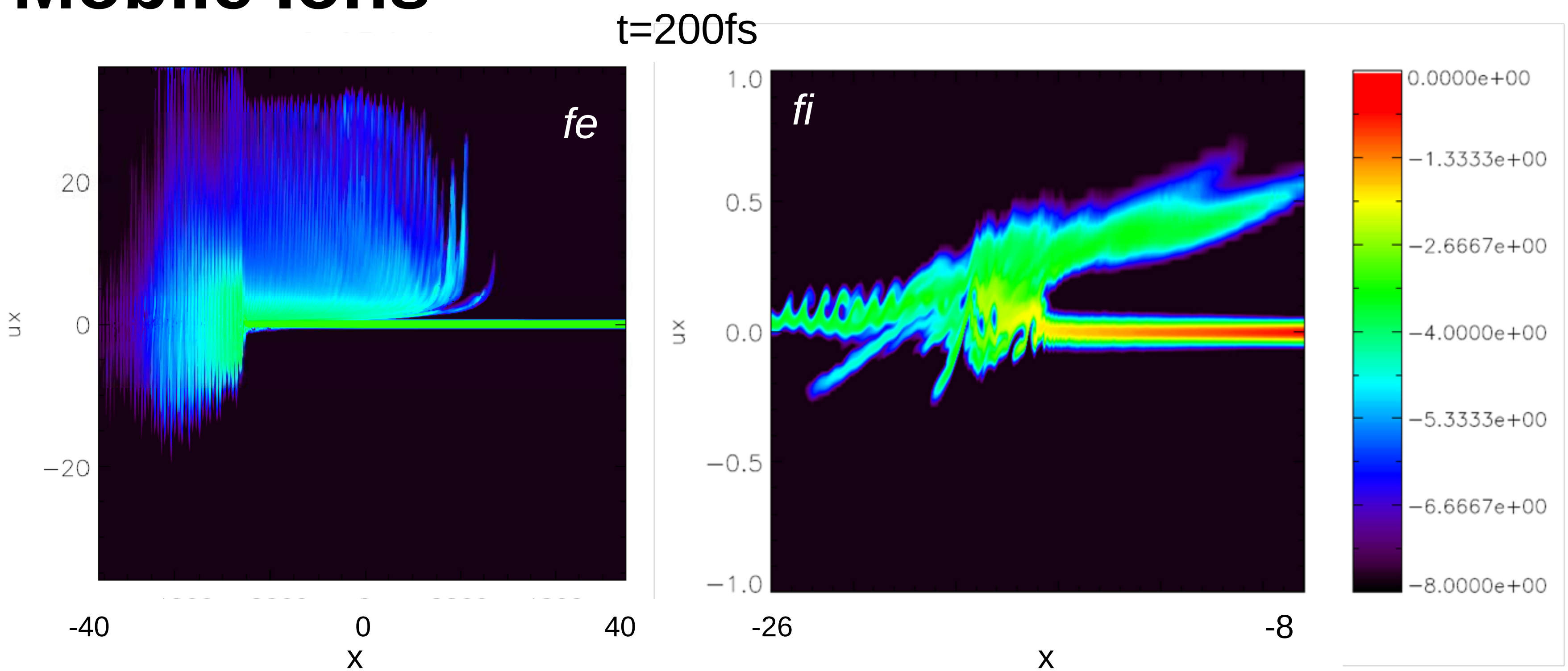
* Not an ideal solution! see M. Sherlock PoP (2009)

(x,ux) phase space (immobile ions)



- T_{hot} peaks and falls
  - 7.3 MeV at 200fs, 1.5MeV at 400fs
- Apparent 'steady state' by 200fs

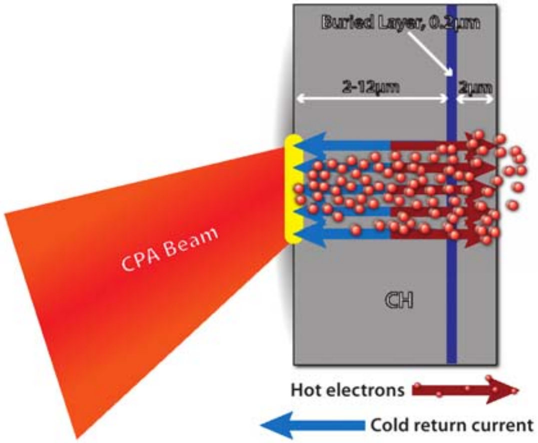
Mobile Ions

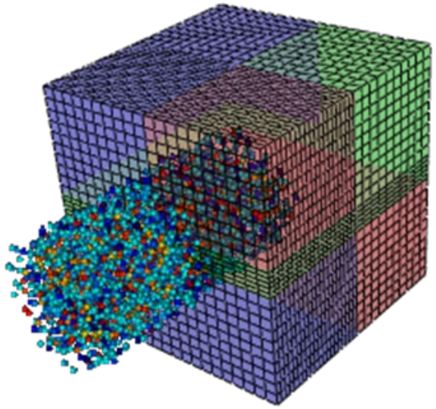


- Preliminary results with mobile ions
- Profile steepening, ion acceleration at front surface
- Evidence of IAW, ion trapping in pre-plasma

Transport

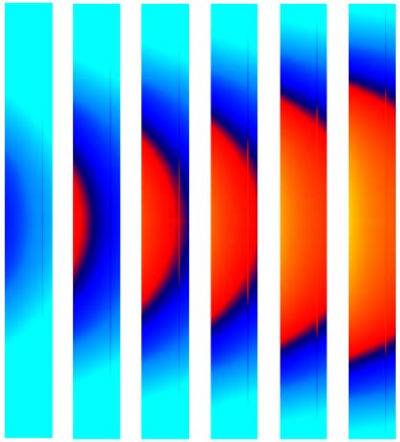
- Modelling hot electron transport in solid density targets using THOR II
- Explicit Monte Carlo Vlasov-Fokker-Planck solver in 2D3P or 3D3P
- Eulerian grid
- Self-consistent fields via return current argument

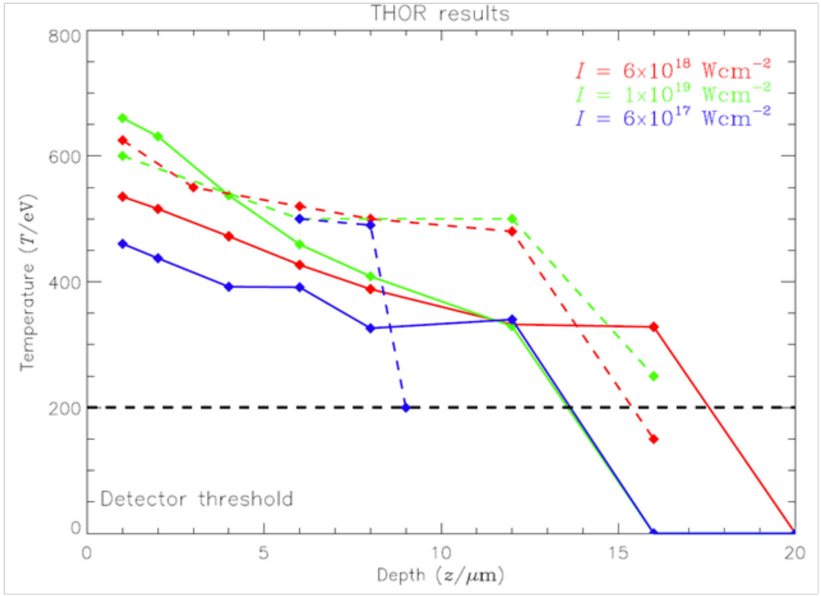




Buried Layer modelling

- Range of intensities
- Al layer buried at various depths in CH target
- Lee-More resistivity model for metals, capped Spitzer model in plastic
- Absorption based on Ping et al. PRL
- Beg-scaling for hot electron energies
- Fixed divergence angle



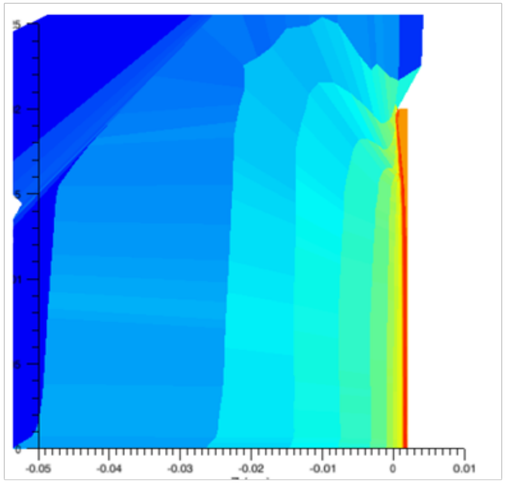


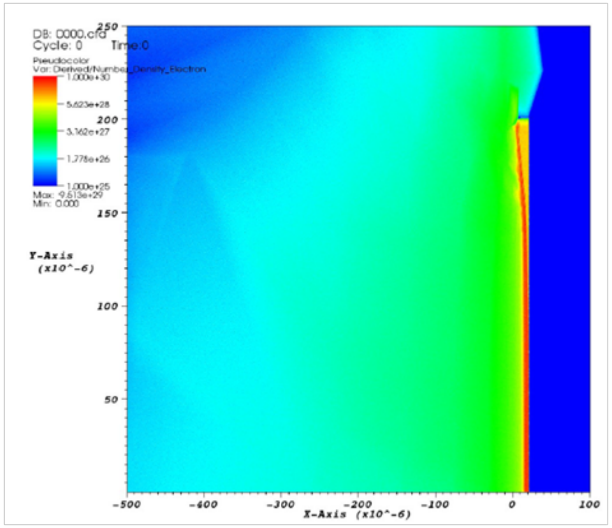
Plans

- Overarching aim is to provide a predictive short pulse modelling capability in support of ORION experiments
- Requires that we
  - Scale existing models to larger systems, higher densities and 3D
  - Couple hydro and kinetic models
  - Add additional physics

Integrated modelling

- Plan to couple transport models into hydro codes
- Early stages of using hydro code data as an initial condition in EPOCH
- Currently looking at characterising hot electron source using EPOCH/VALIS over wide parameter range to replace empirical scaling
- Aim to model…
  - LP interaction, target compression, pre-pulse effects in CORVUS.
  - Short pulse interaction, hot electron generation in EPOCH using density & temperature from CORVUS
  - Hot electron transport and target heating in THOR using hot electrons from EPOCH and density / temp from CORVUS.





Areas of interest

- SP absorption and subsequent transport in realistic, ORION / HiPER scale targets
- Additional physics for kinetic codes
  - Collision operators
  - Ionisation
  - Hybrid models
- Optimisation of kinetic algorithms and parallel communications
  - Ready for future HPC on many 10,000’s of cores
  - AMR-Vlasov

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