Modification of laser driven ion beams by using the double-pulse drive technique

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Central Laser Facility, RAL

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Scottish Universities Physics Alliance

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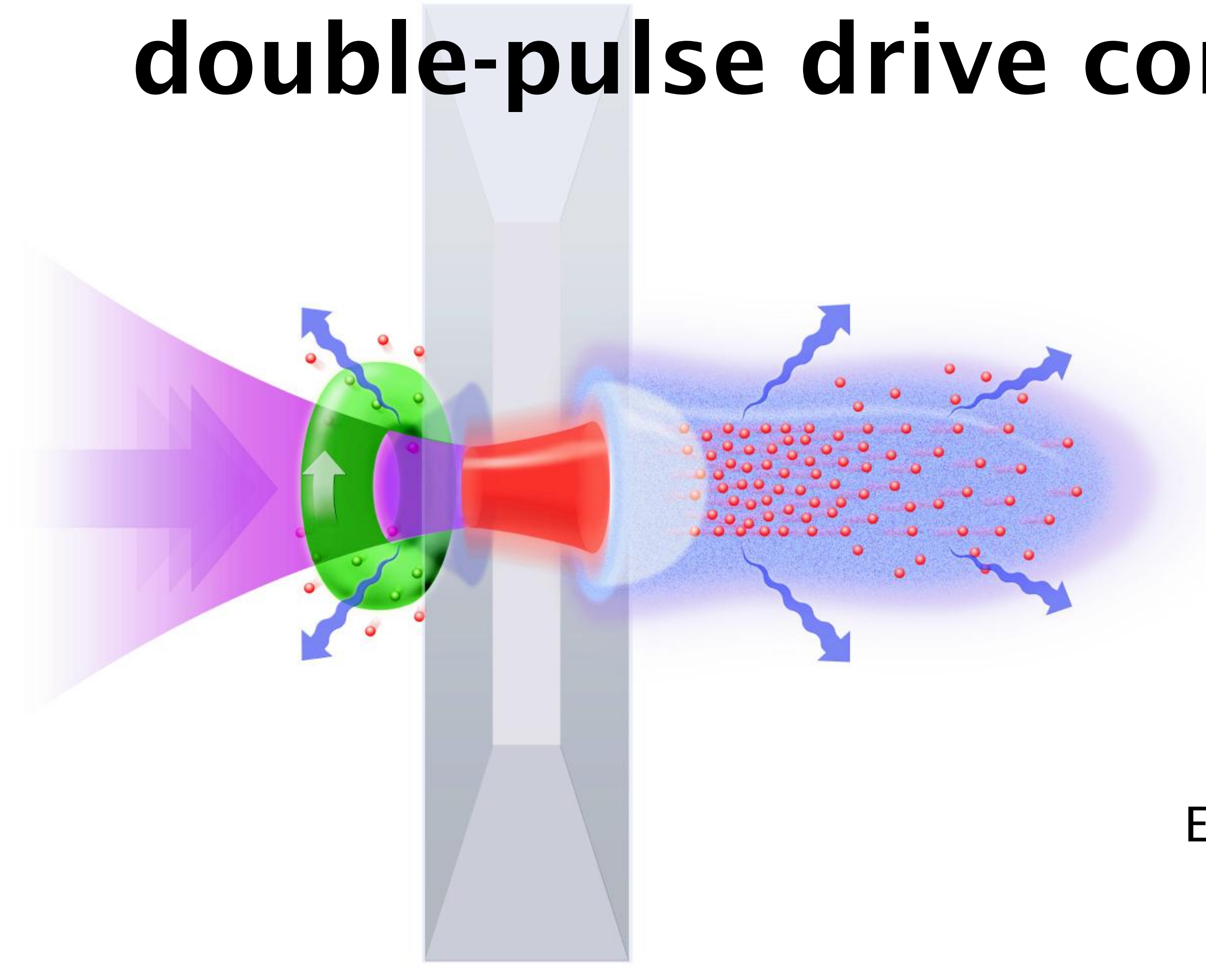
Ion acceleration driven by a double-pulse drive configuration



How is it useful?

What is it?

How does it work?

Experimental results

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Laser-plasma accelerators

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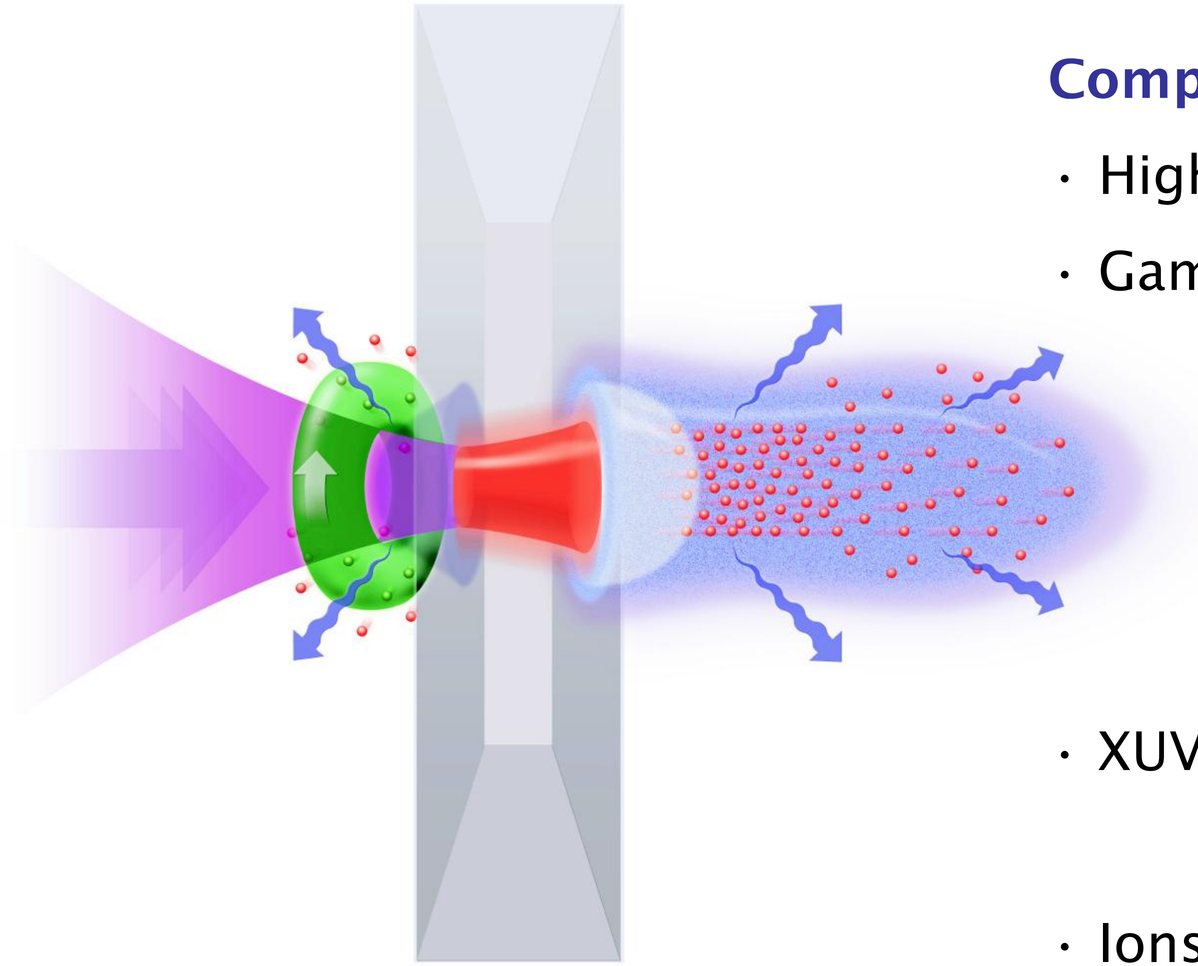

Compact, bright sources of:

- High energy electrons
- Gamma rays
- XUV and x-ray radiation
- Ions

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Applications

$E_p > \sim 100$ MeV

Ion beam cancer therapy
Proton probing (field measurements)
Radiography (density measurements)
Injection into conventional accelerators
Production of isotopes
Fast ignition fusion
Proton heating
Industrial (lithography)

$E_p \sim 10$ MeV

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$E_p \sim 10$ MeV

High flux of medium energy (3-15 MeV) protons

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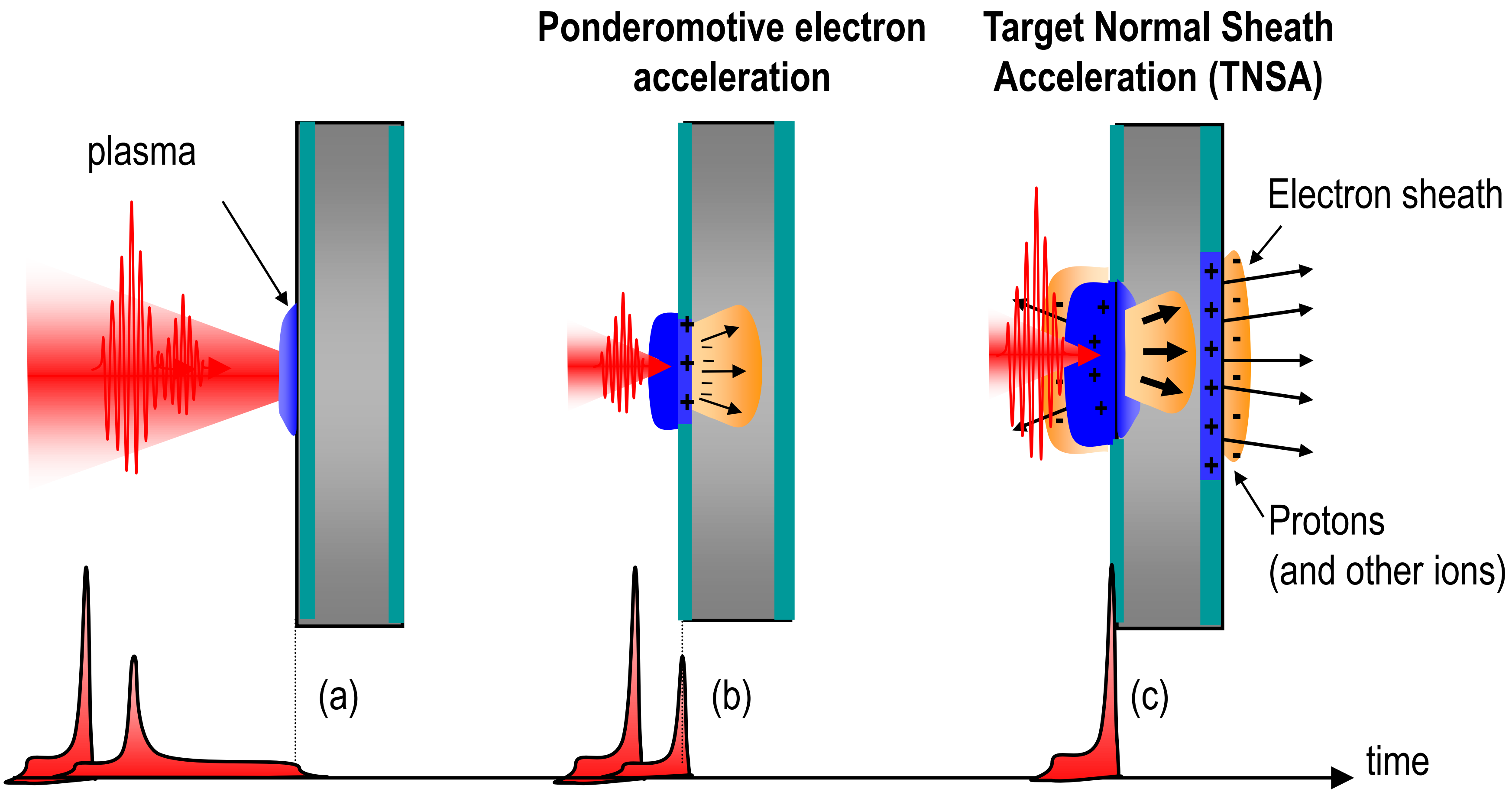
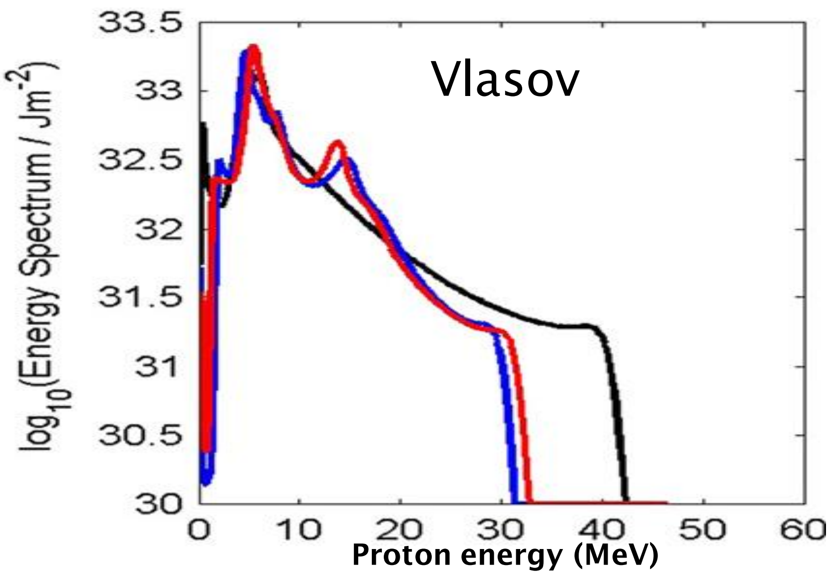
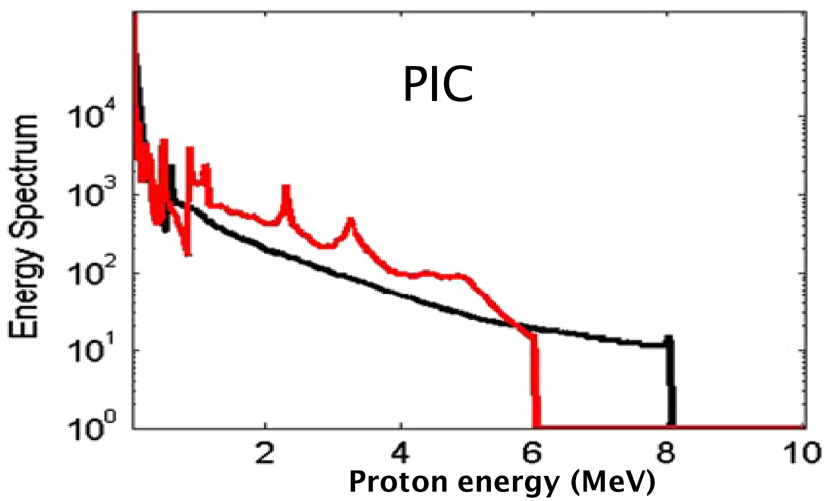
Double pulse mechanism



Multi-Pulse Sheath Acceleration (MPSA)

“Spectral control in proton acceleration with multiple laser pulses”,
A.P.L.Robinson *et al*, Plasma Phys. Control. Fusion 49 (2007) 373–384

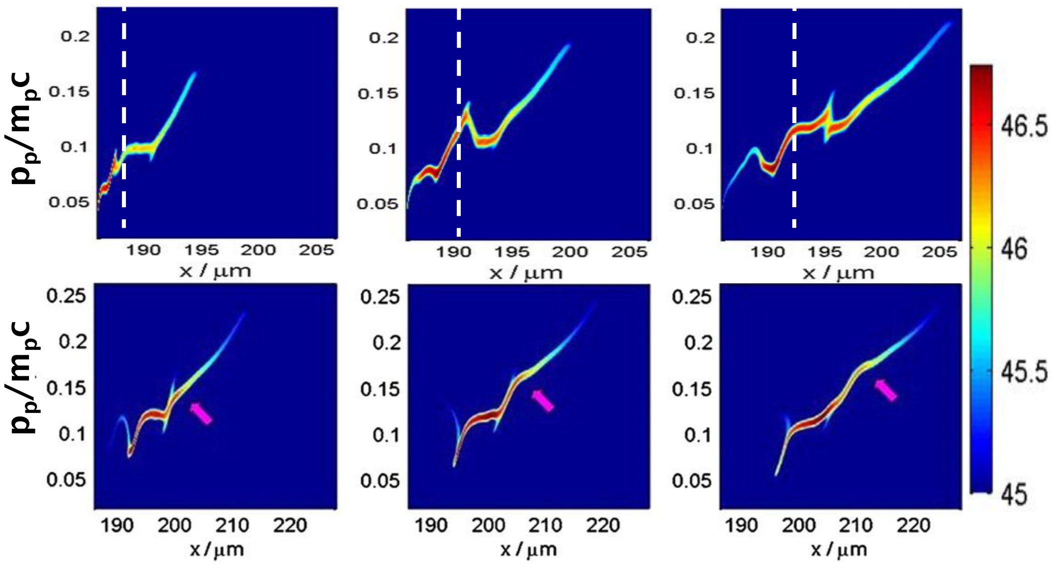




single drive pulse

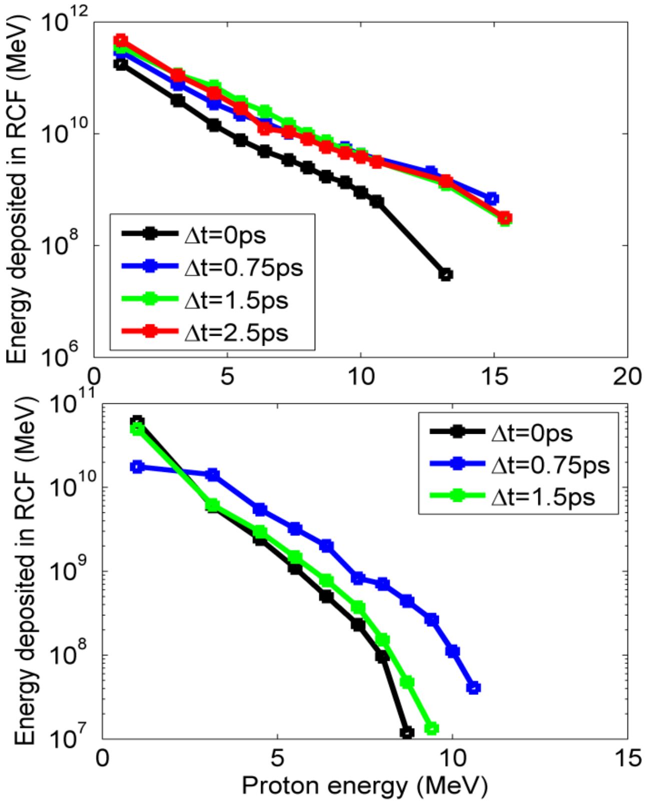
double drive pulse

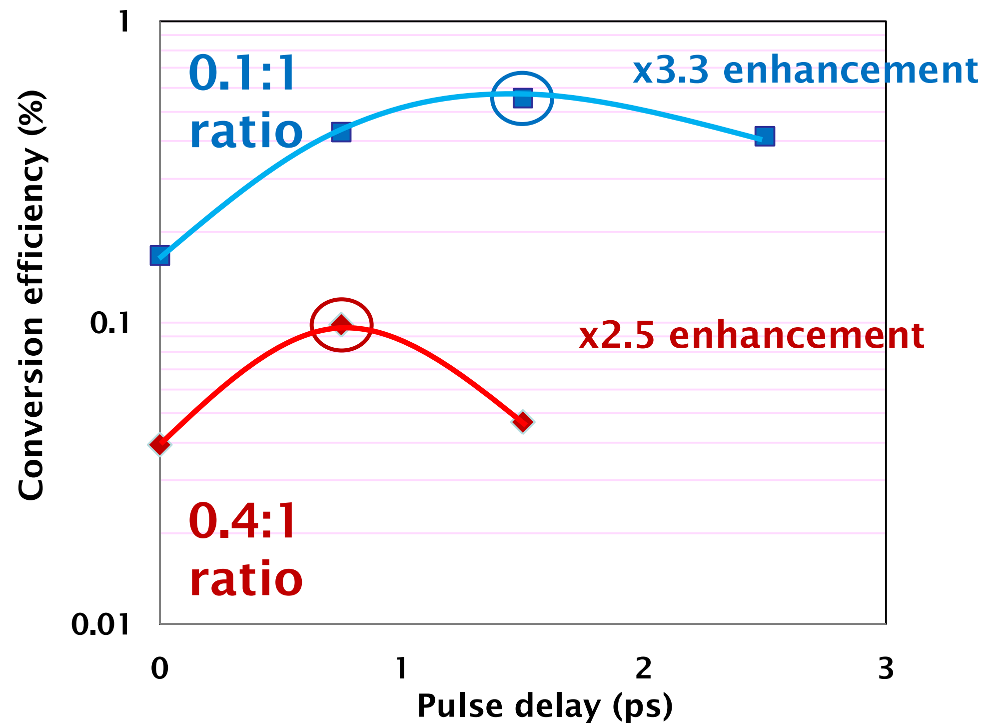
Multi-Pulse Sheath Acceleration (MPSA)



- controlled initial pulse initiates TNSA of ions and protons
- density modulation of protons builds up ahead carbon front
- increase in T_e caused by 2^{nd} (main) drive pulse
- surge of higher energy protons across ion front
- high accelerating fields at ion/proton boundary

"Spectral enhancement in the double pulse regime of laser proton acceleration", K.Markey *et al,* PRL, 105, 195008, (2010)

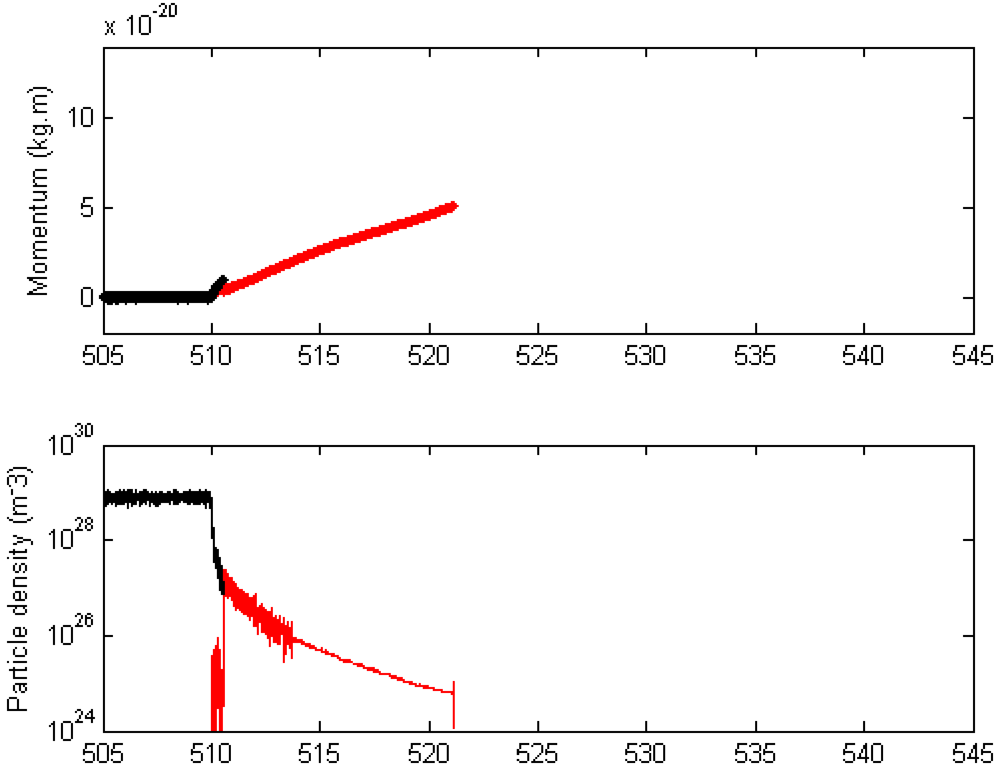




100 μm Au foils, Vulcan Petawatt, high contrast (with plasma mirror)

1D PIC simulations

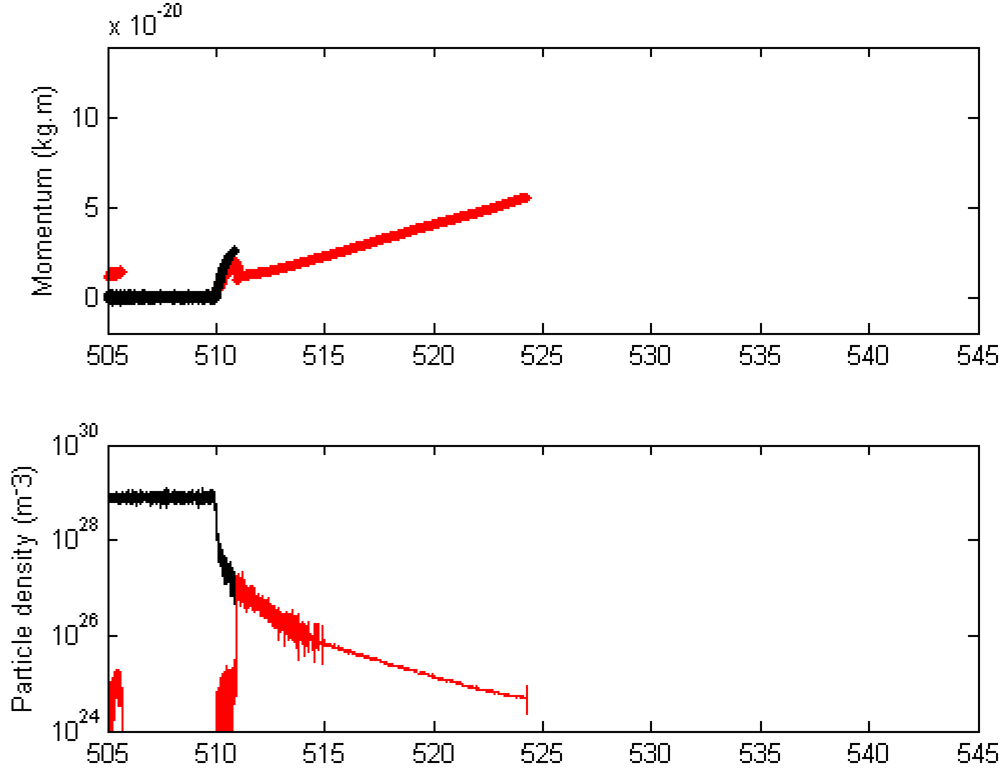
$t = t_0$-250fs



- **Protons**
- **Ions**

1D PIC simulations

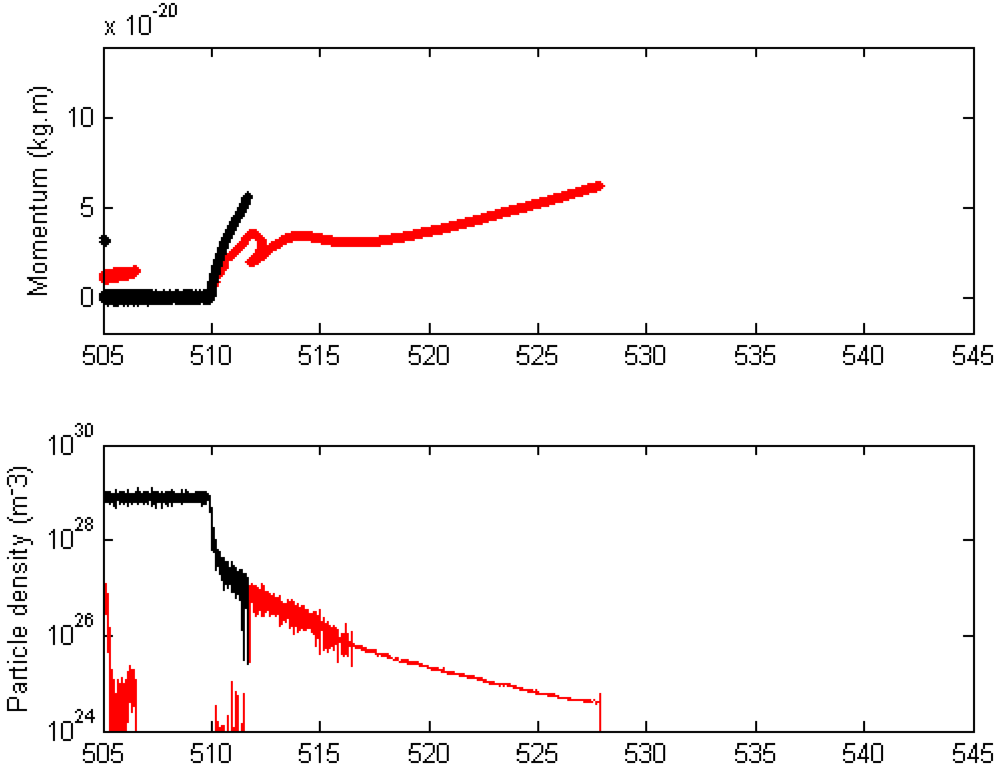
$t = t_0$-150fs



- **Protons**
- **Ions**

1D PIC simulations

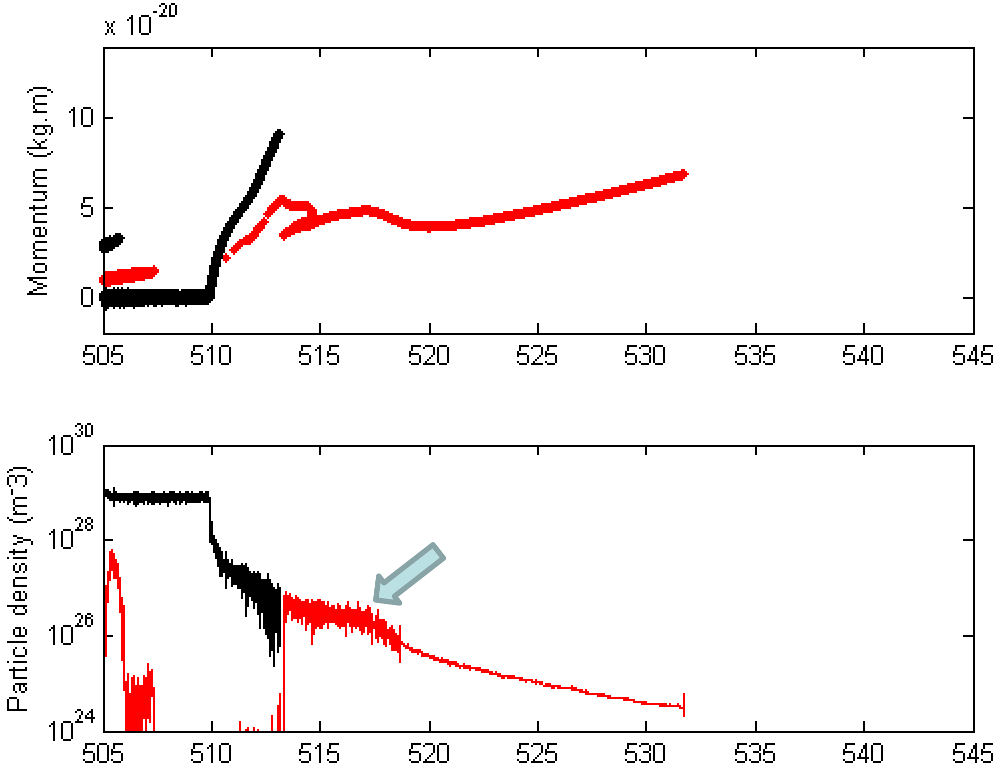
$t = t_0$-50fs



- **Protons**
- **Ions**

1D PIC simulations

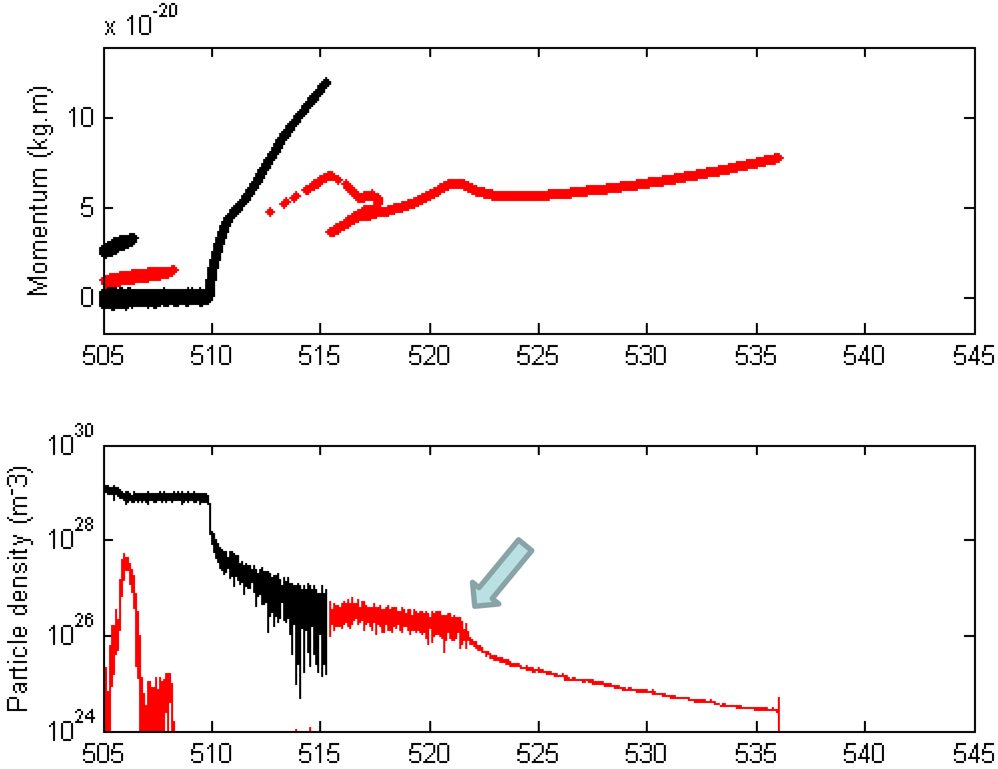
$t = t_0 + 50fs$



- **Protons**
- **Ions**

1D PIC simulations

$t = t_0 + 150fs$



- **Protons**
- **Ions**

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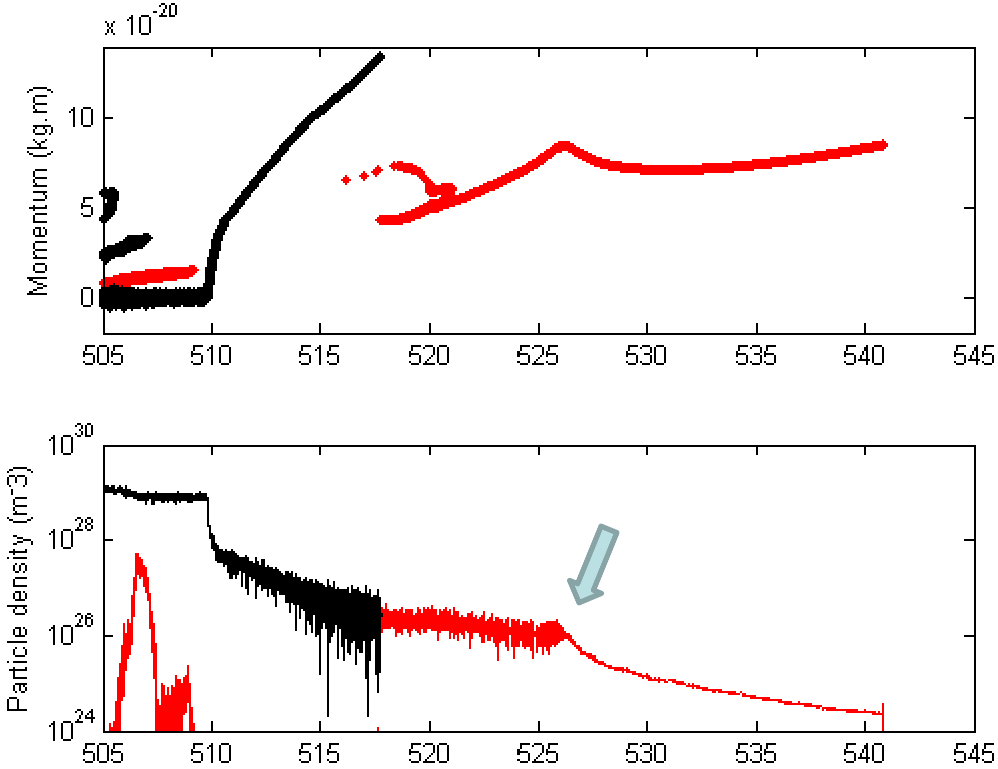
1D PIC simulations

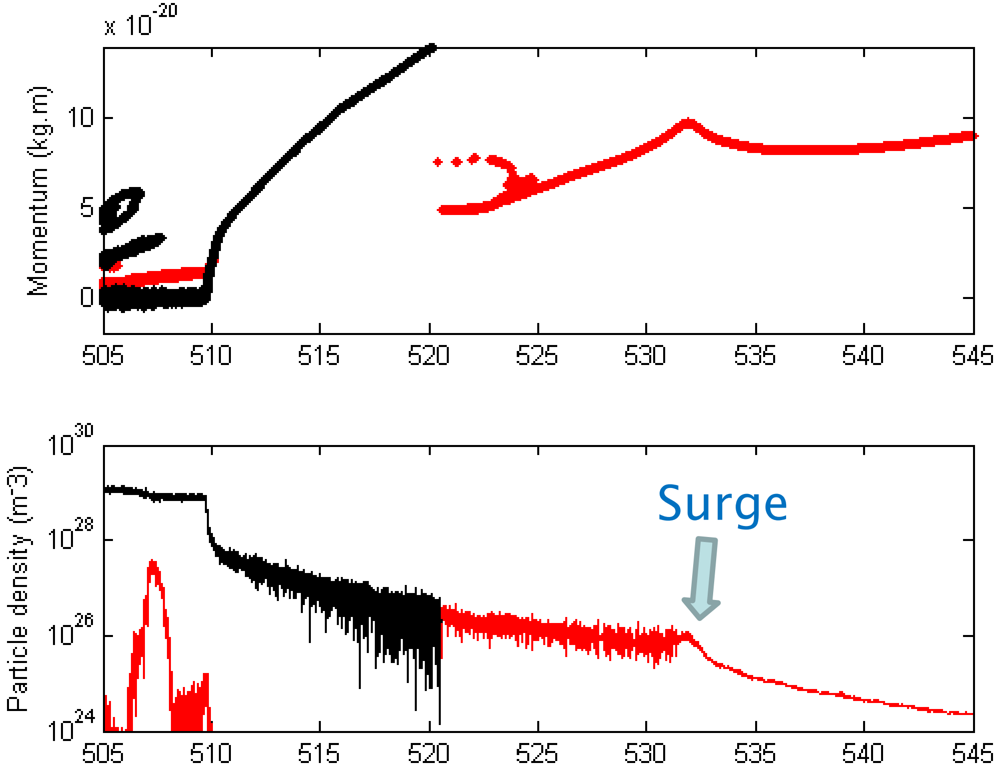
$t = t_0 + 250fs$



- **Protons**
- **Ions**

1D PIC simulations

t = t_0+350fs



- **Protons**
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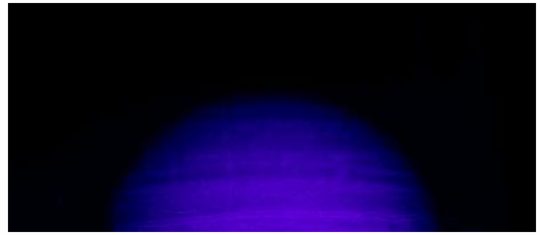
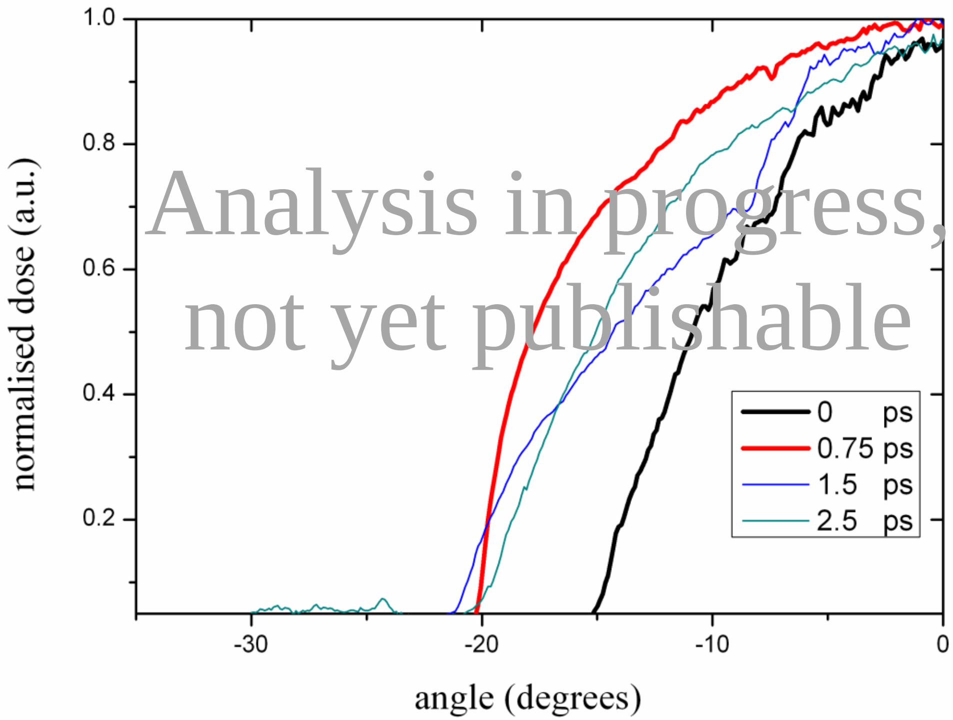
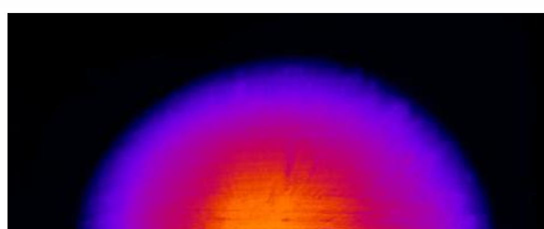
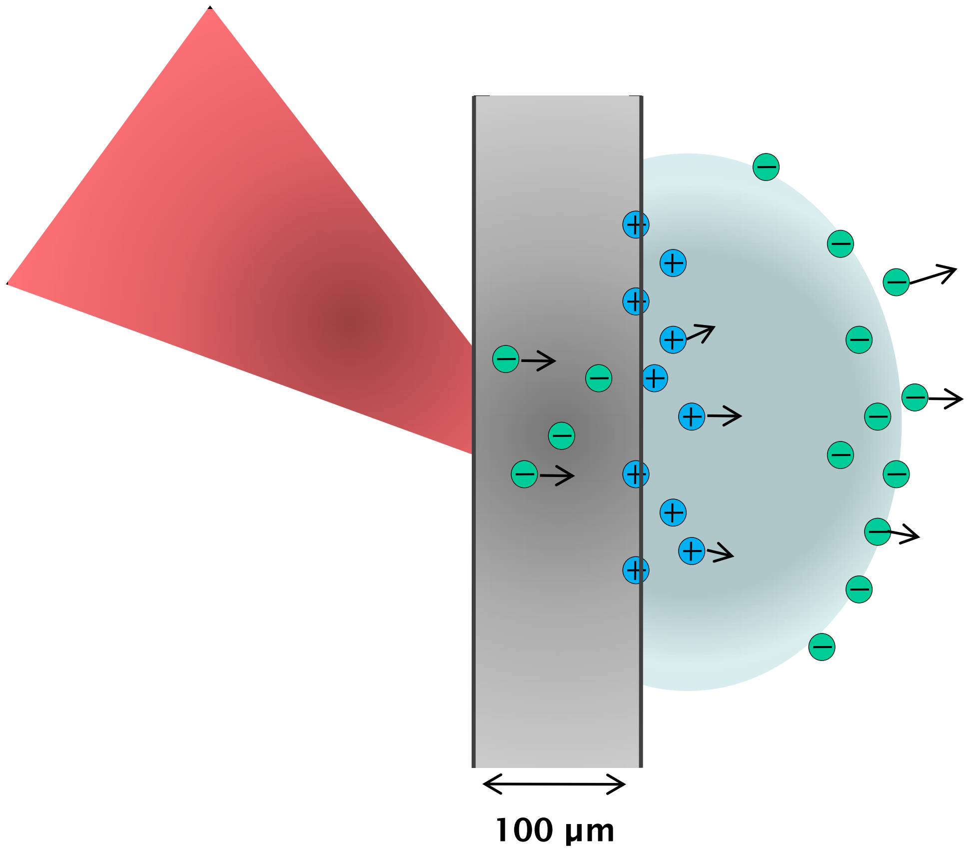






Recirculation and multi pulses?



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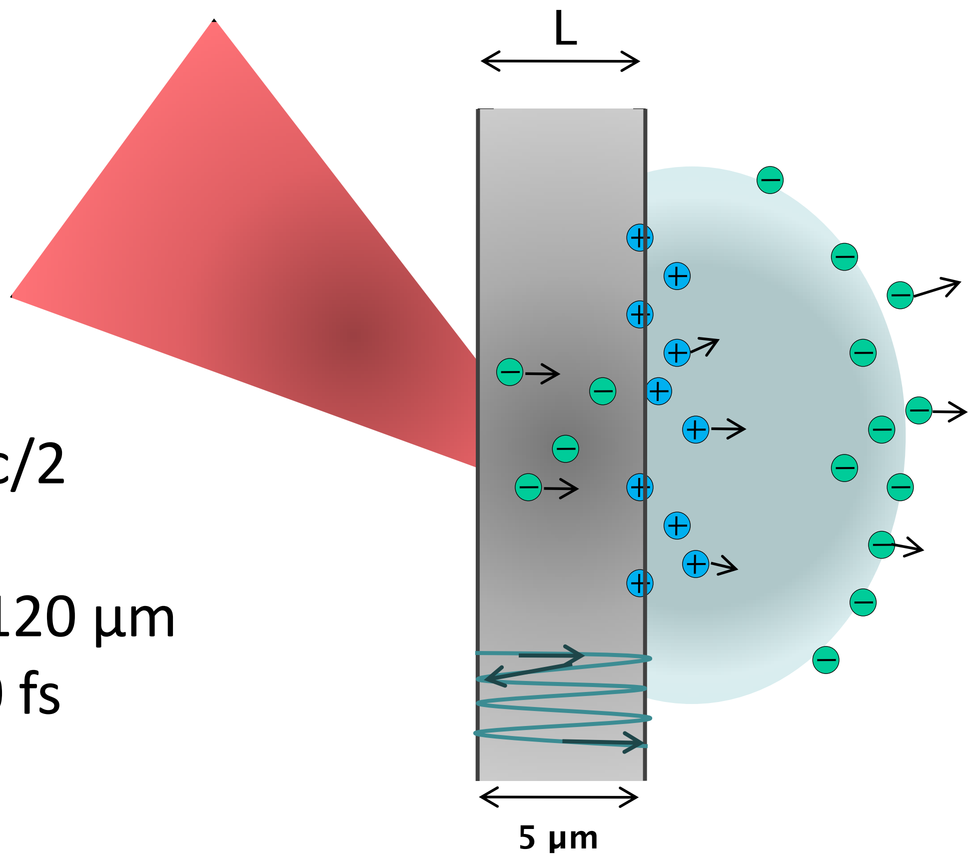
Recirculation and multi pulses?



For $L < \tau_L c/2$

where L is 120 µm
for τ_L ~ 800 fs

Recirculation of electrons

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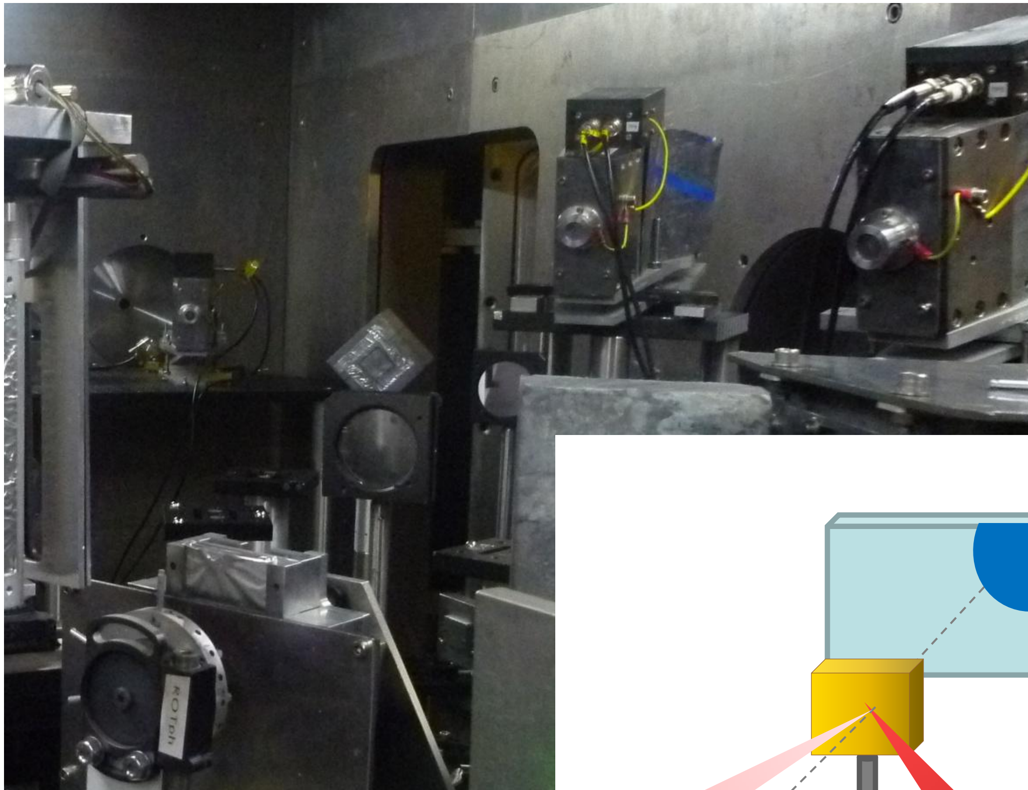
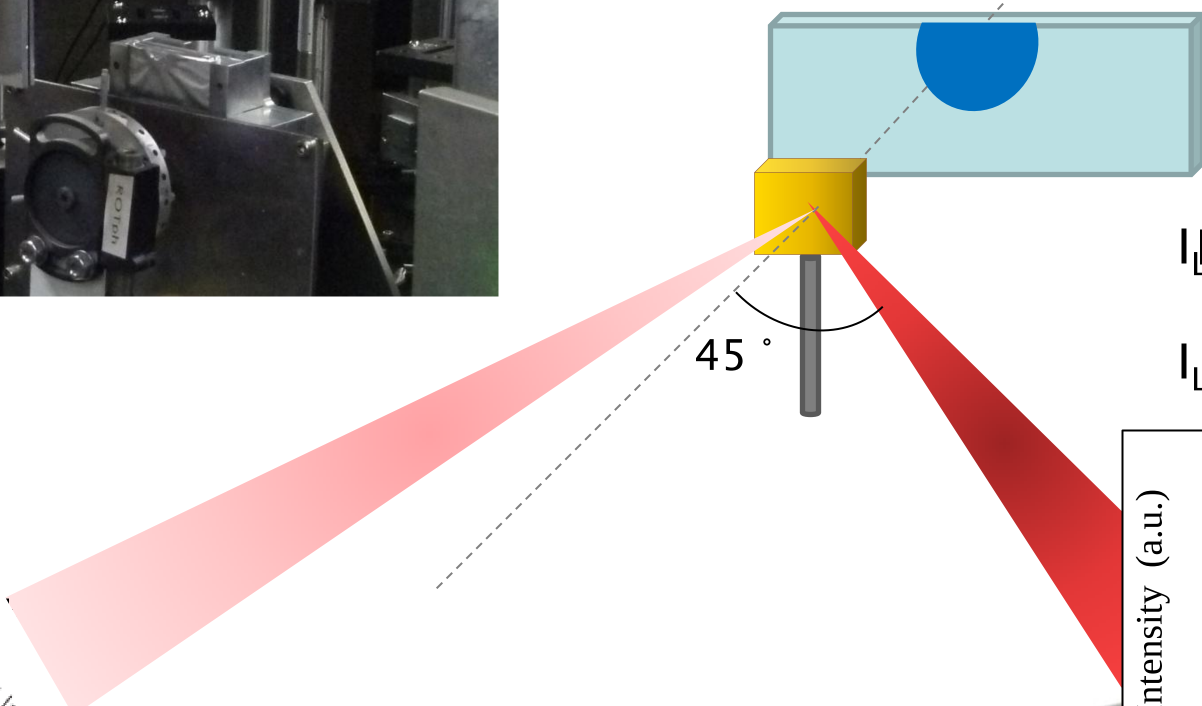
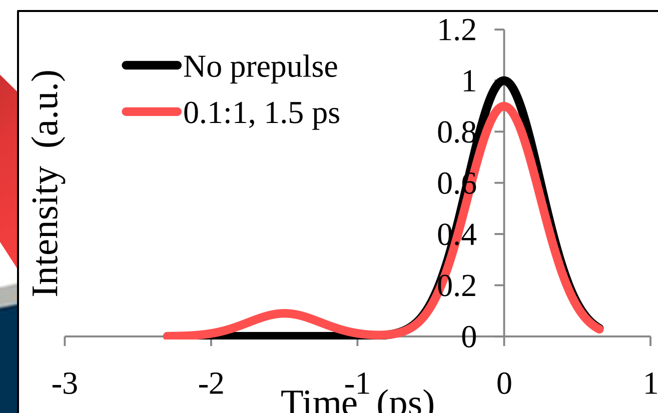


Calibrated radiochromic film (RCF) stack



$I_L \sim 3.2 \times 10^{18}\ W/cm^2$
and
$I_{L2} \sim 2.9 \times 10^{19}\ W/cm^2$



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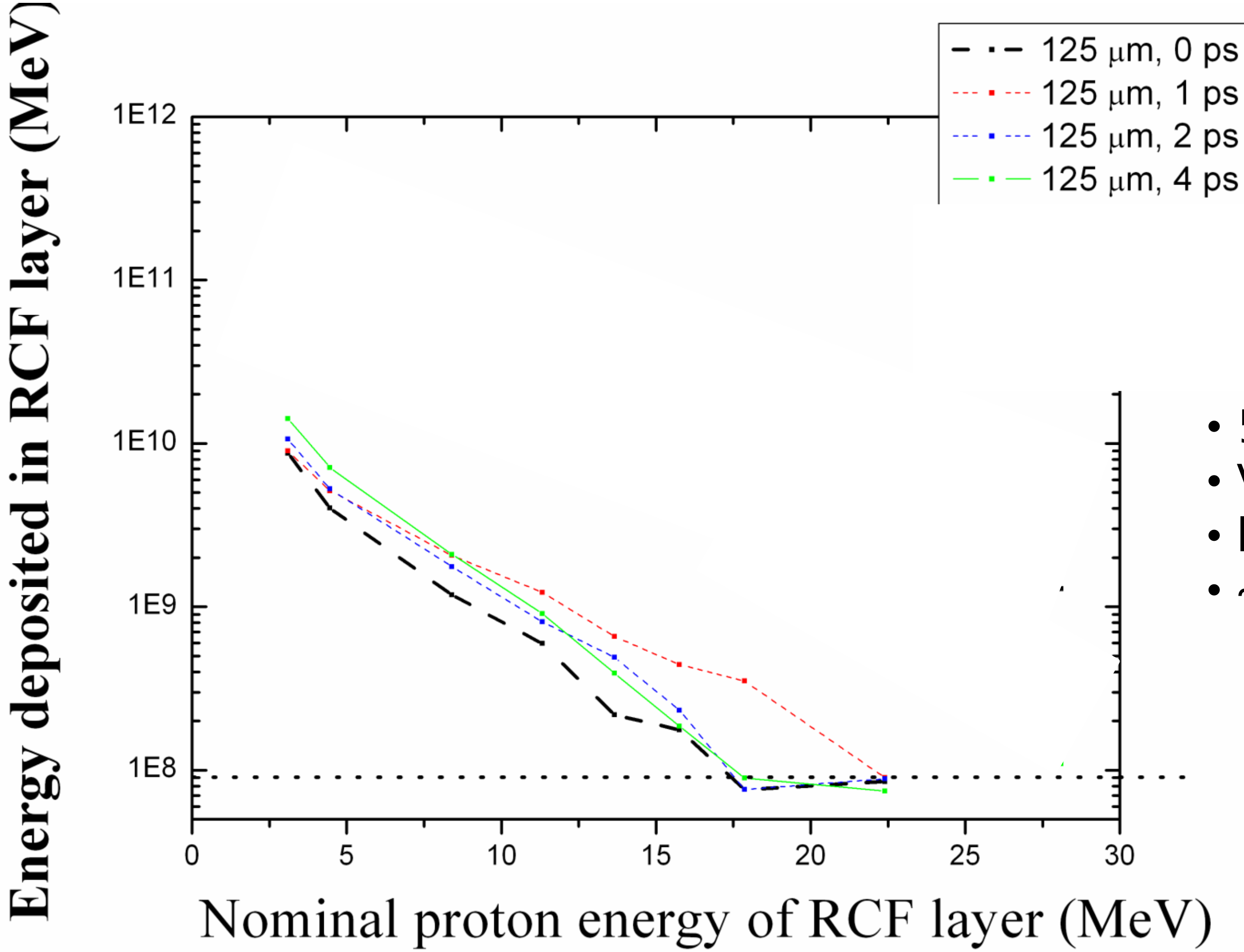
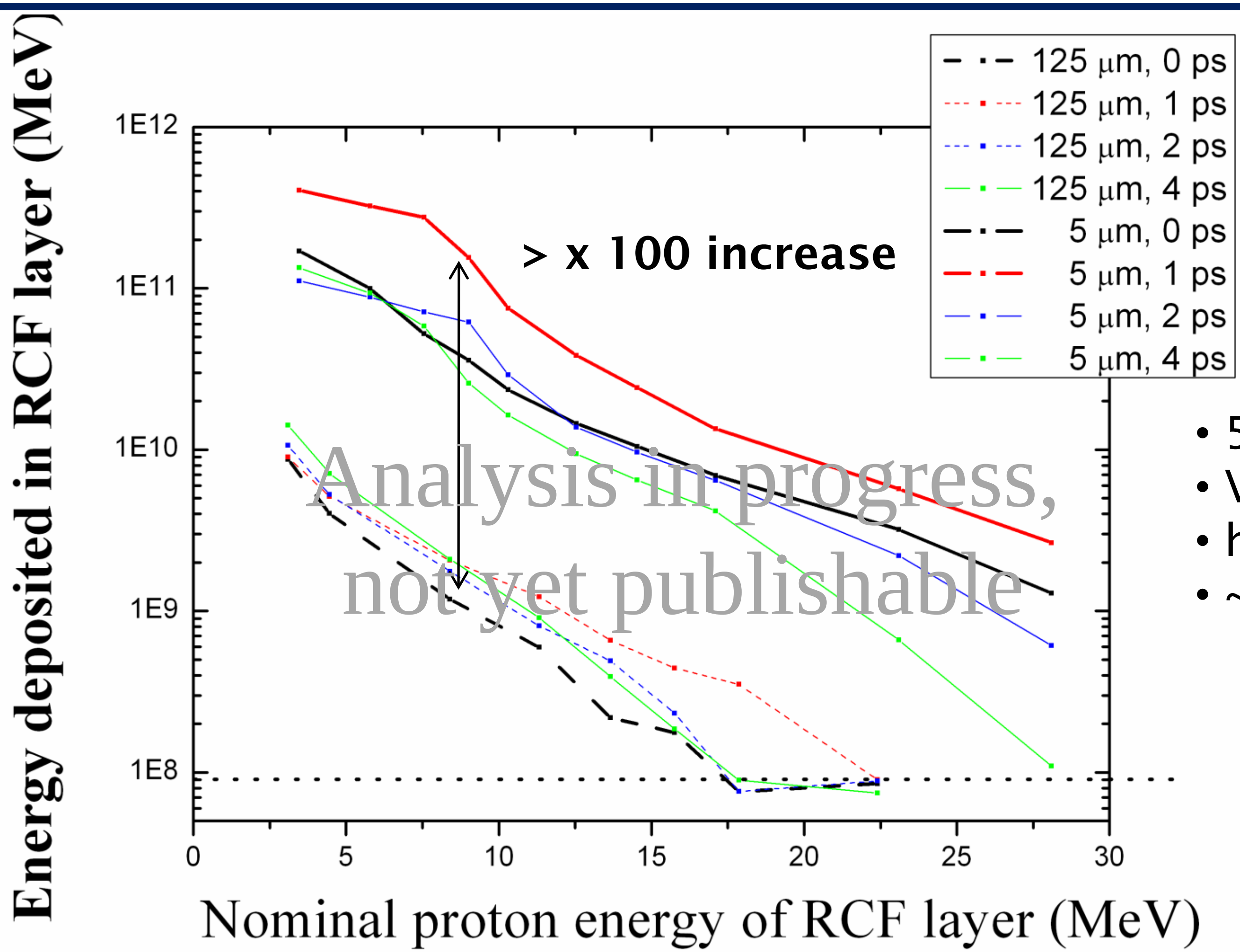
Using thin foils to enhance conversion efficiency



- 5 µm Au foils
- Vulcan Petawatt
- high contrast
- ~180 J on target

Using thin foils to enhance conversion efficiency



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Development of MPSA technique

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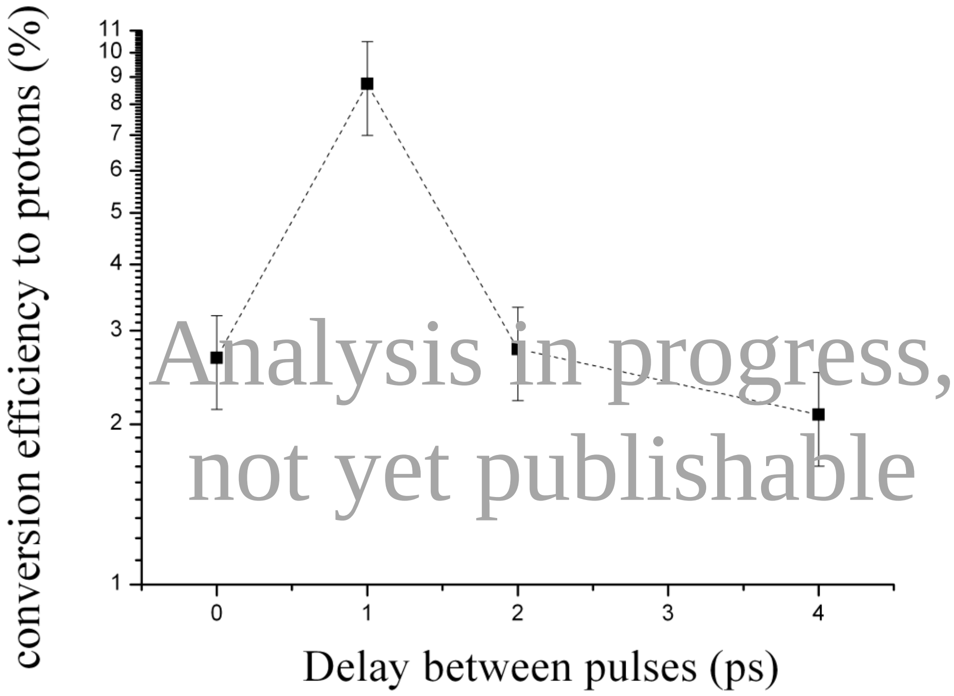
Spectral enhancement using the double pulse technique demonstrating:

• significant flux enhancement in the thin foil (refluxing) regime for lower energy protons

• increase in laser-to-proton conversion efficiency compared to thicker foils



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Development of MPSA technique

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Spectral enhancement using the double pulse technique demonstrating:

• significant proton flux enhancement in the thin foil (refluxing) regime for lower energy protons

• increase in laser-to-proton conversion efficiency compared to thicker foils

Future direction:

• investigate the double pulse technique for ultrashort laser system parameters

• conduct 2D PIC simulations to study the evolution of the sheath field on the rear surface

CLF central laser facility

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Thank you

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