Target Configurations for Laser-Driven Fusion Reaction

Wei YU

Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences

The rate of fusion reaction per unit volume:

$$P = n_i^2 (\overline{\sigma v})$$

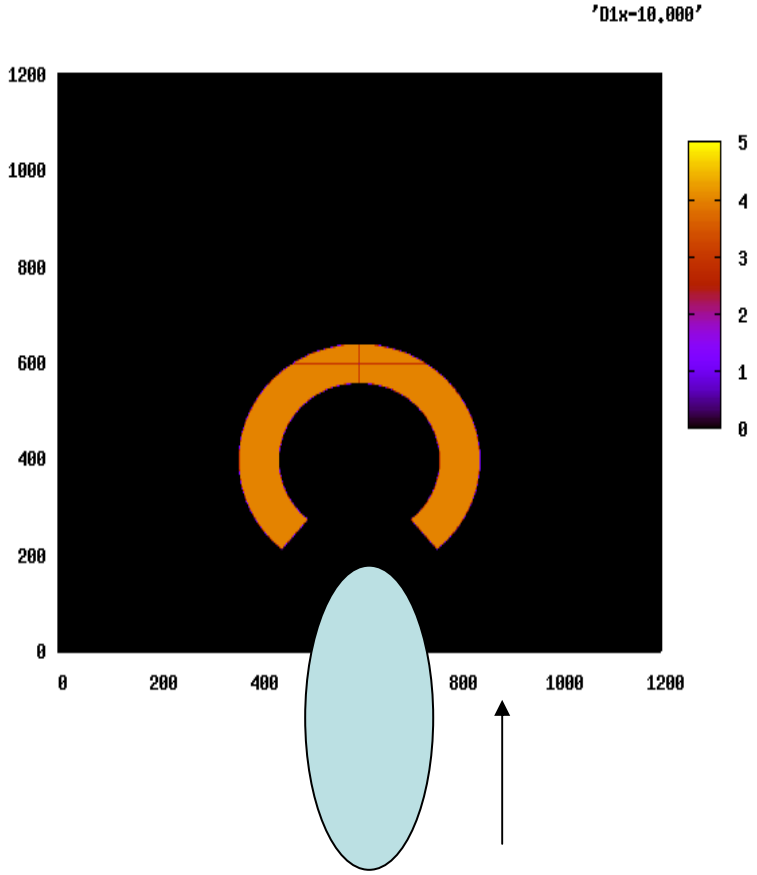
n_i: ion density, $(\overline{\sigma v})$: the reactivity, it reaches maximum as ion temperature $T_i = 1.25\ \mathrm{MeV}$ for DD reaction and $T_i = 64\ \mathrm{KeV}$ for DT reaction.

The key issue: a proper target configuration that can lead to high concentration of ions at the appropriate temperature.

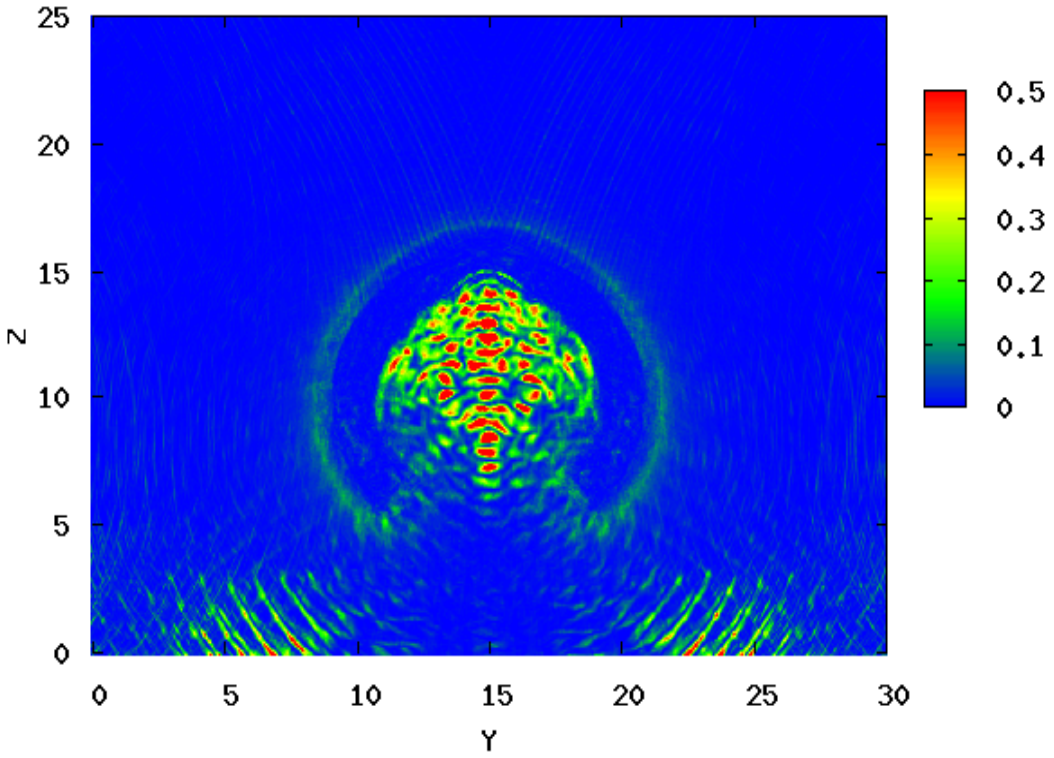
1, Laser-driven ion focusing in a shell target

laser strength: a0=5,
duration: 20T,
spot size: 2 λ,

density: 4 nc,
inner radius: 4 λ
outer radius: 6 λ
40 degree opening.

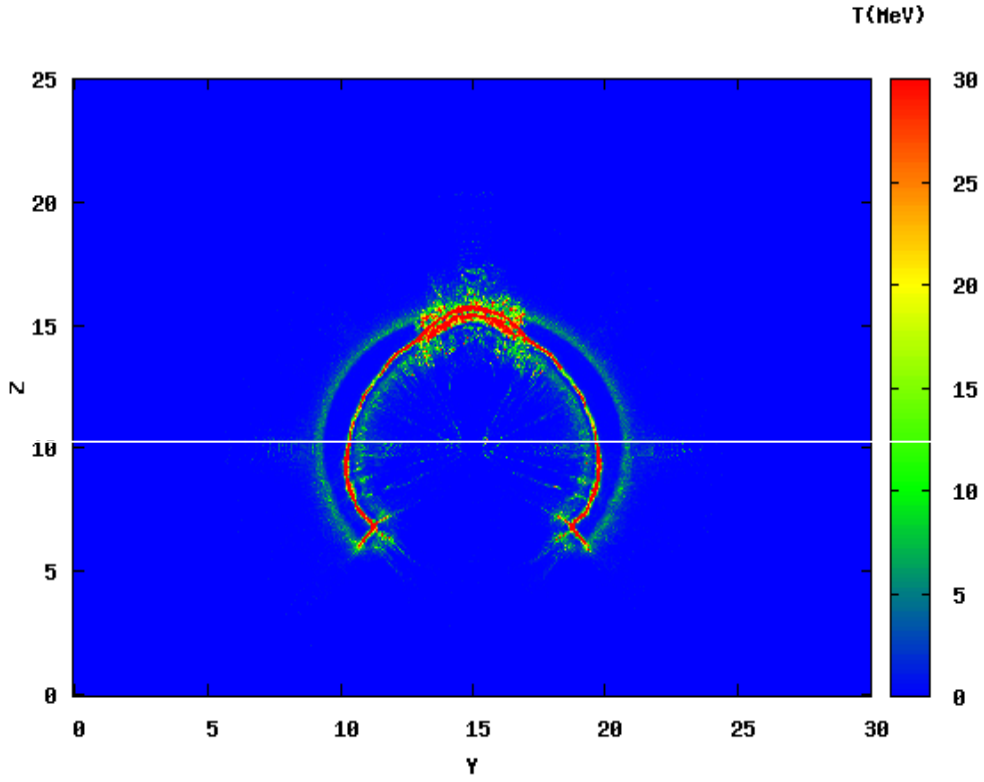


EM energy density t=50T



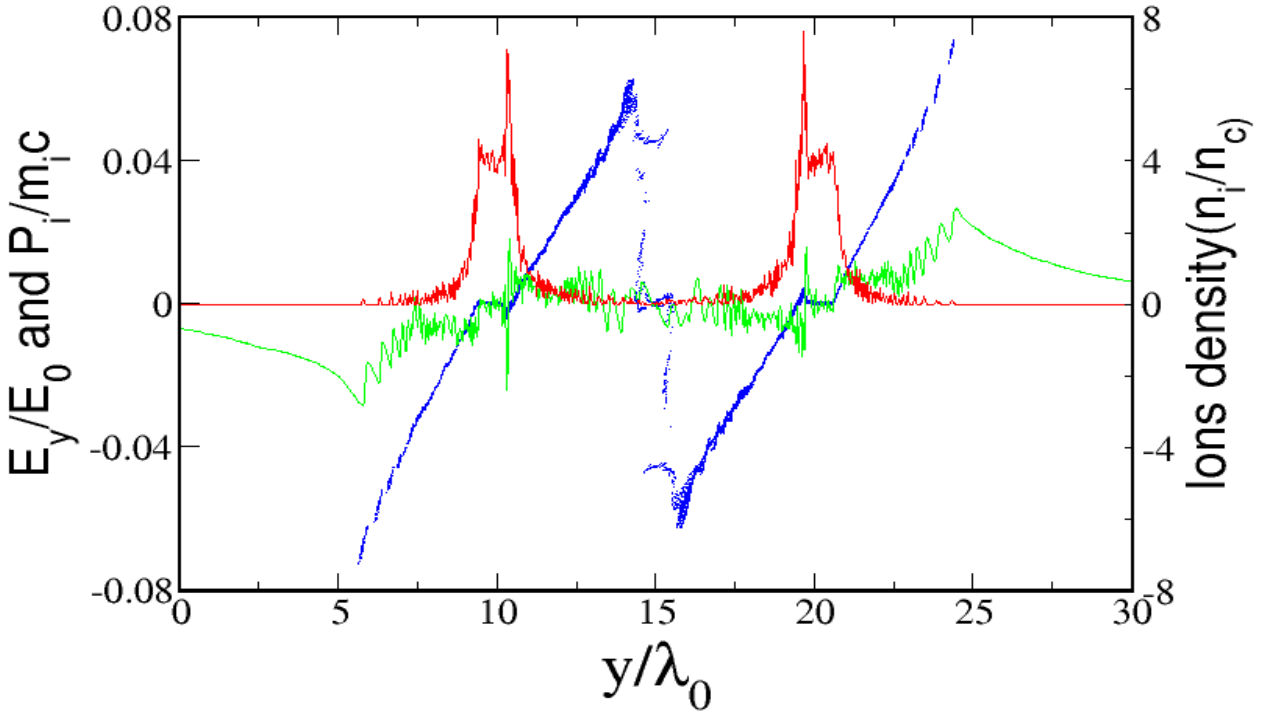
Incident laser fills the cavity

Ion temperature at t=100T



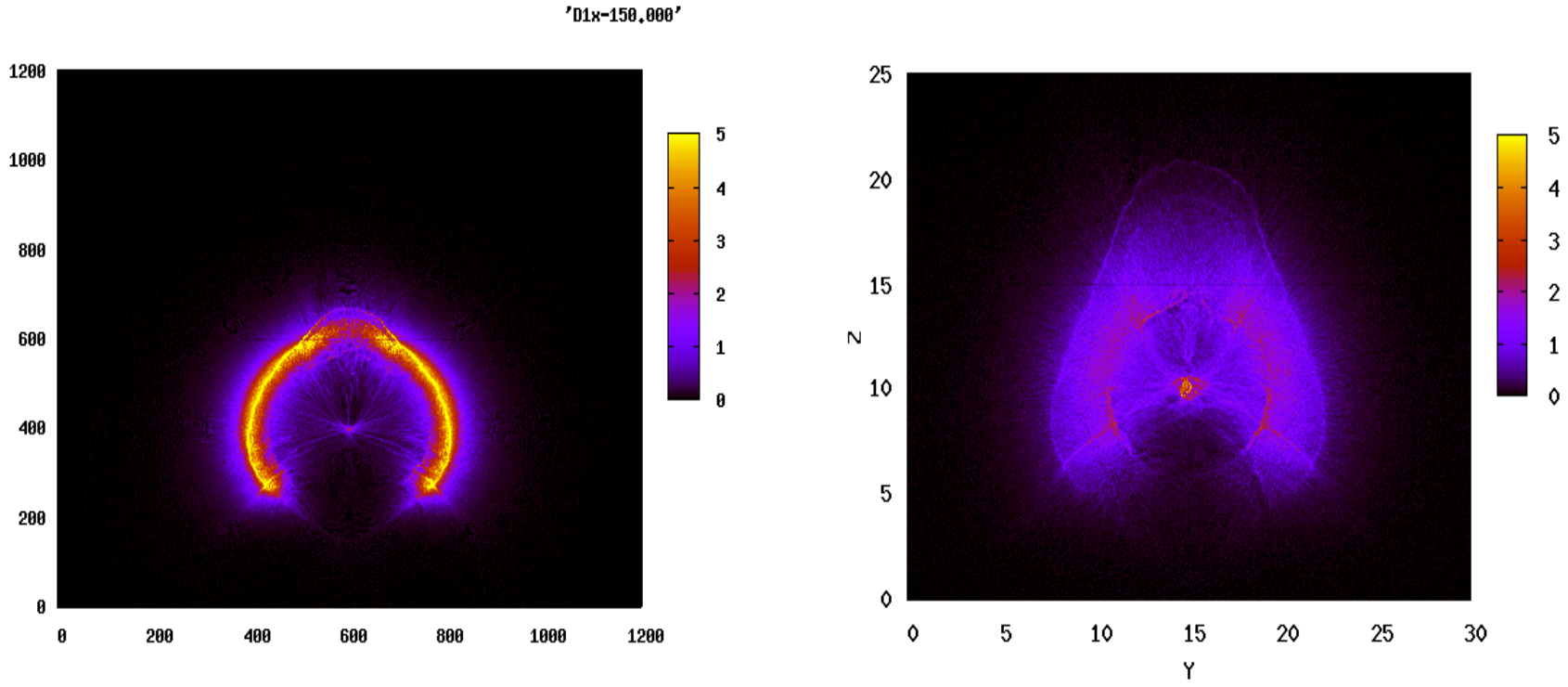
The shell target is heated by laser from inside

Ion density (red), momentum (blue), and space charge field (green) at z=10 and t=100T



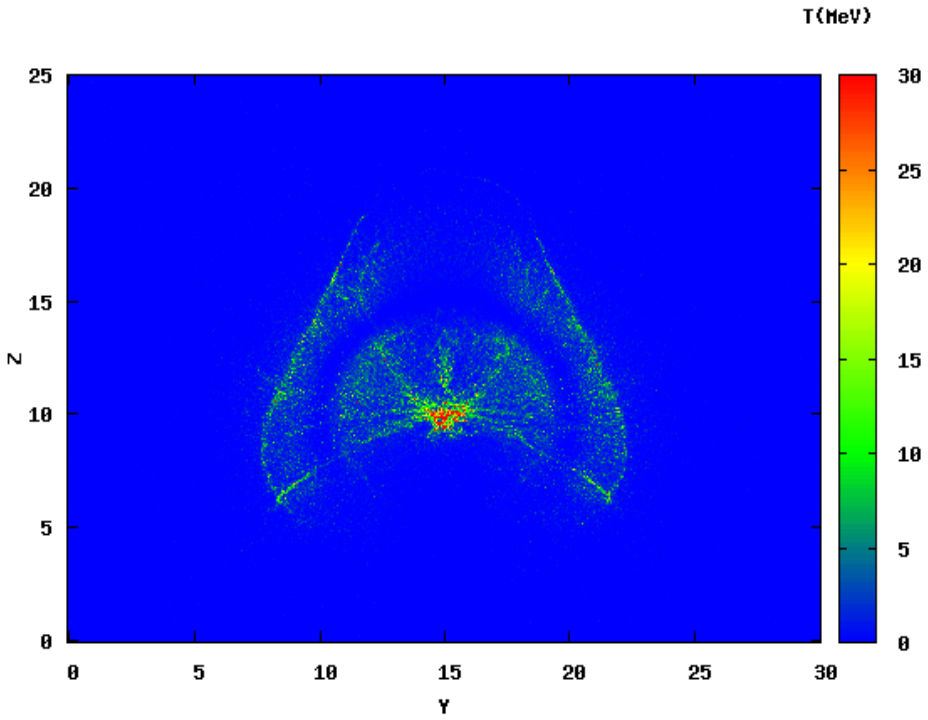
Strong inward expansion of laser-heated plasma

Ion density at t=150T and 300T



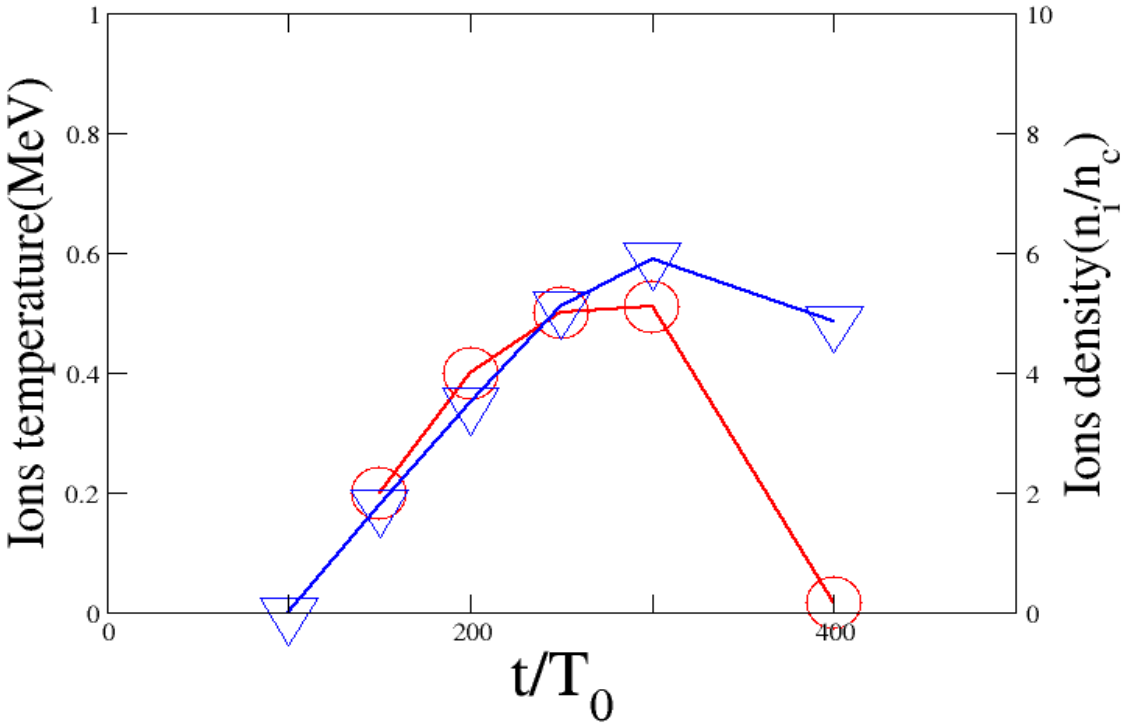
Inward expanding ions slow down at the center, leading to a sharp ion peak. The shell itself almost disappears

Ion temperature at t=300T



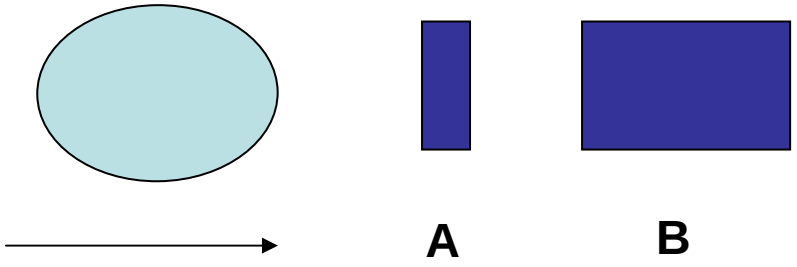
As inward expanding ions slows down, the energy deposition makes the ion peak rapidly heated.

Time evolution of ion density and temperature at shell center



High concentration of high-temperature ions

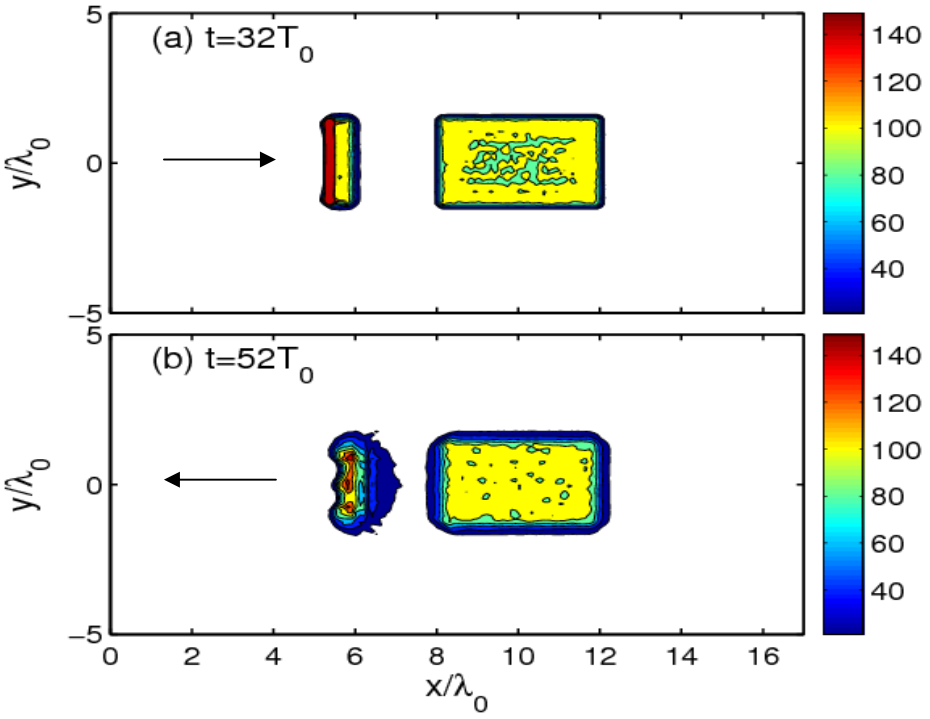
2, Impact of laser-accelerated micron-size projectile with plasma



laser strength: a0=40 $(I = 2.2\times10^{21}\mathrm{W}/cm^2)$
spot radius: 5 λ **pulse width: 10** λ

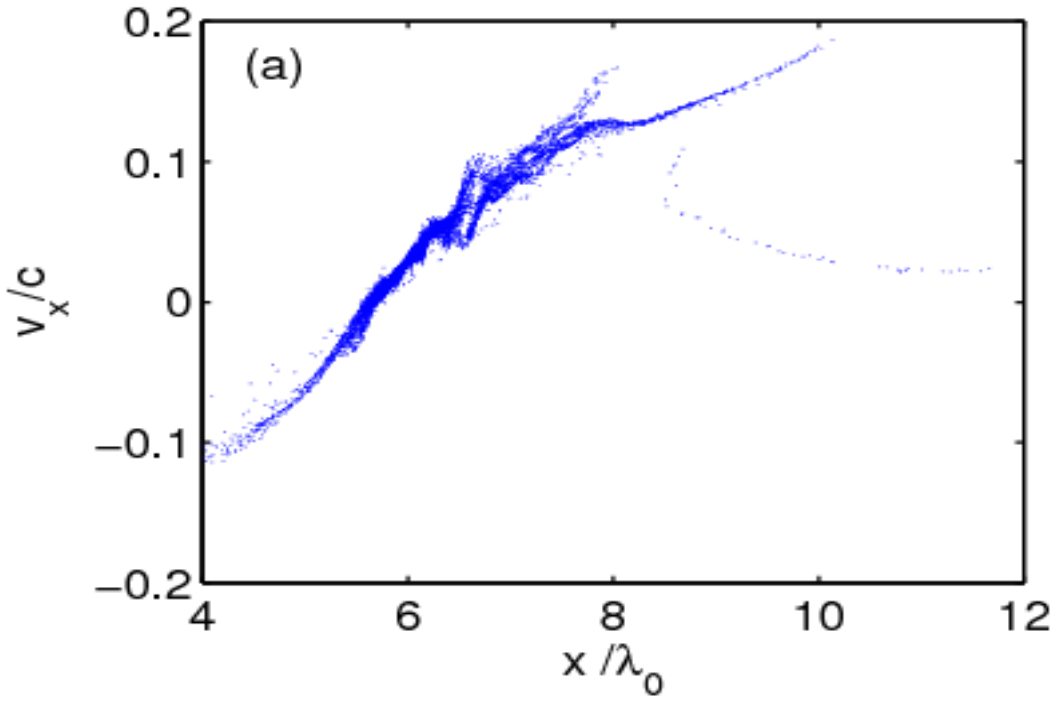
size of targets: A(3 λ **X 1** λ **) and B(3** λ **X 4** λ **) .**
target density: 100nc
interval between two targets: 2 λ **.**

Ion density at t=32T and 52T



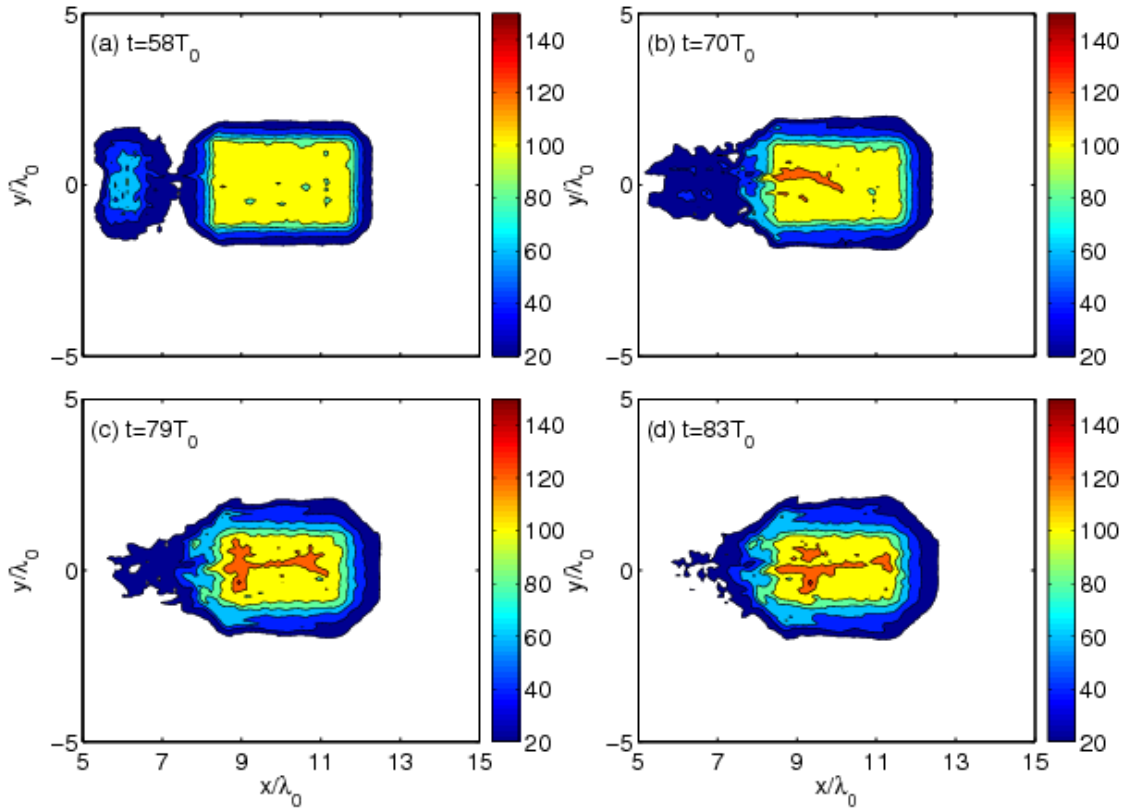
Target A is effectively accelerated [PRE 72, 046401(2005)]
Blocked by A, target B is almost not influenced.

Target A: the longitudinal ion velocity at t=52T.



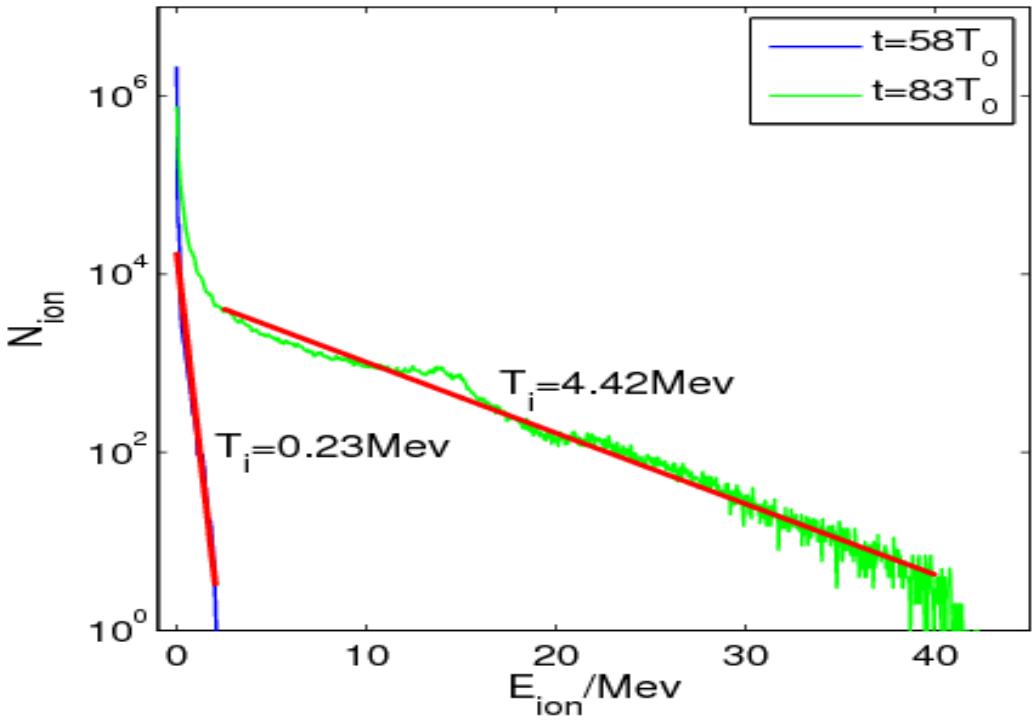
Most ions are accelerated to >0.1c (>5MeV), although some ions leave behind and some move back.

Impact: ion density at t=58T, 70T, 79T and 83T



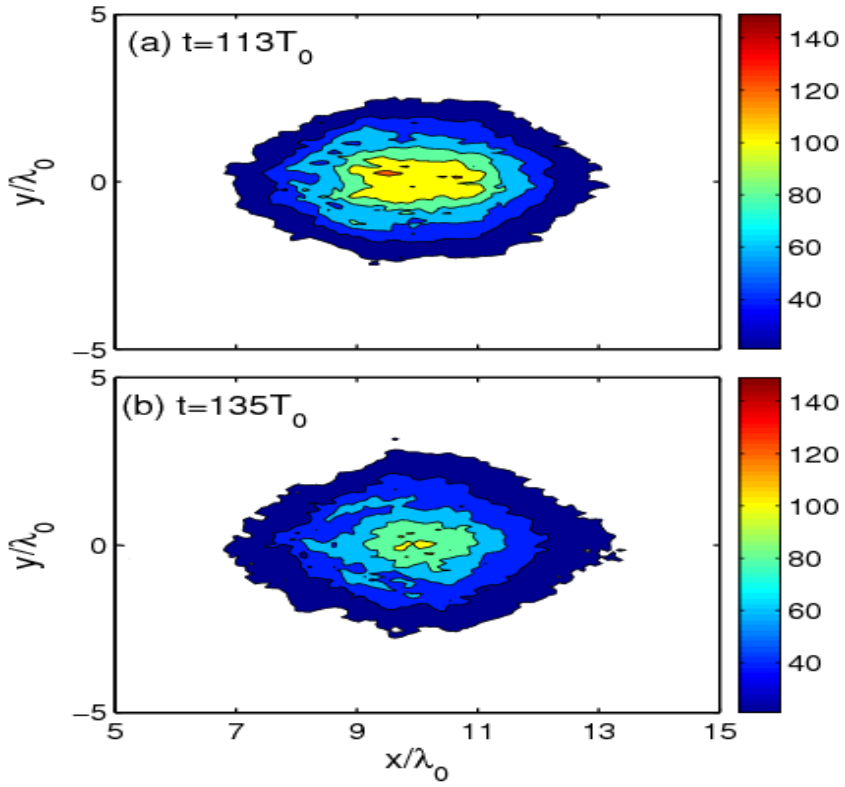
Ions in target A enter target B and stop inside
Target B does not move significantly.

Ion energy distribution in B at 58*T* and 83*T*, i.e. before and after impact.



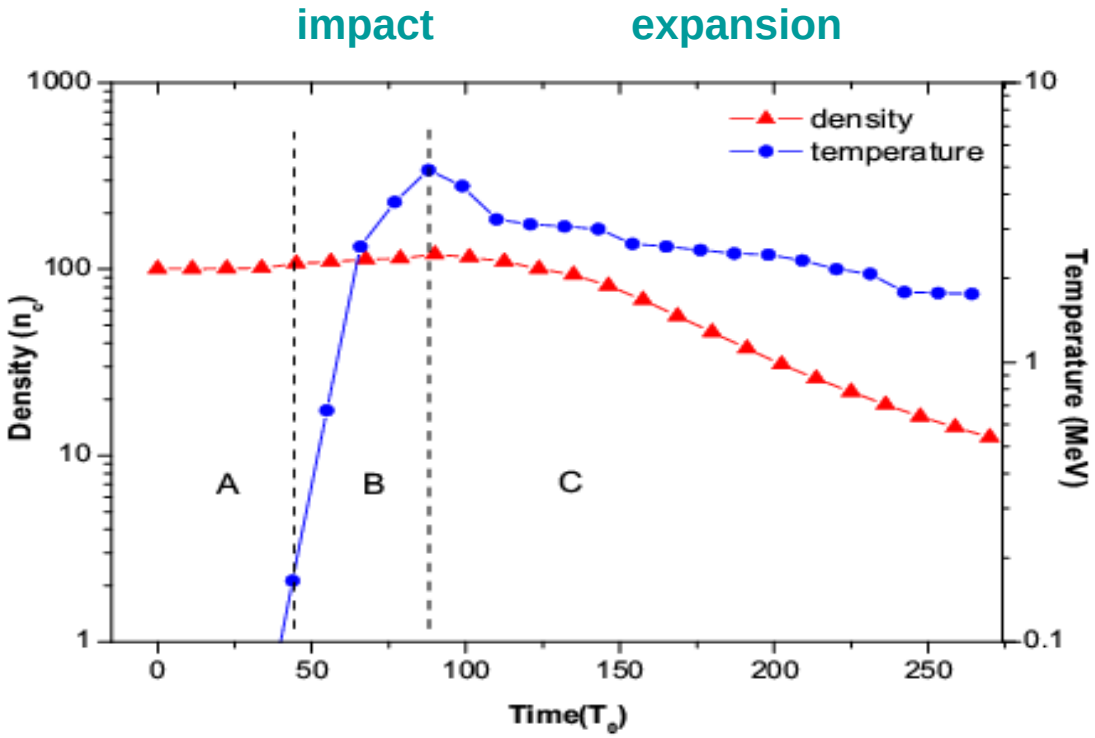
With the kinetic energy of A deposited, target B is rapidly heated after impact.

Expansion: ion density at t=113T and 135T



The resulting high-density, high-temperature plasma bunch expands outward.

Time evolution of ion density and temperature



Plasma bunch of 1-4.68MeV temperature and 10-130nc density.

Thanks