Ion Acceleration Mechanisms in LFEX Multi-short Pulse Laser Experiments

４ビーム PW LFEX レーザーによるイオン加速実験の検証

イオンの加速機構は？　TNSA + Others

1. 強度変調
2. プレプラズマ
3. P 加速　v.s. D 加速

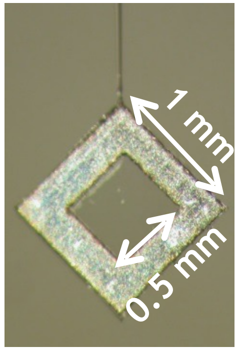
In collaboration with T.Asahina, A.Iwata, A.Yogo, et al.

Laser Plasma Simulation W.S., 2017.1.11 , at ILE, Osaka University

Experimental Set-up

Thin-foil target

0.4 ~ 20 μm-thick Al/C_8D_8



Focal spot size

70 μm in diameter

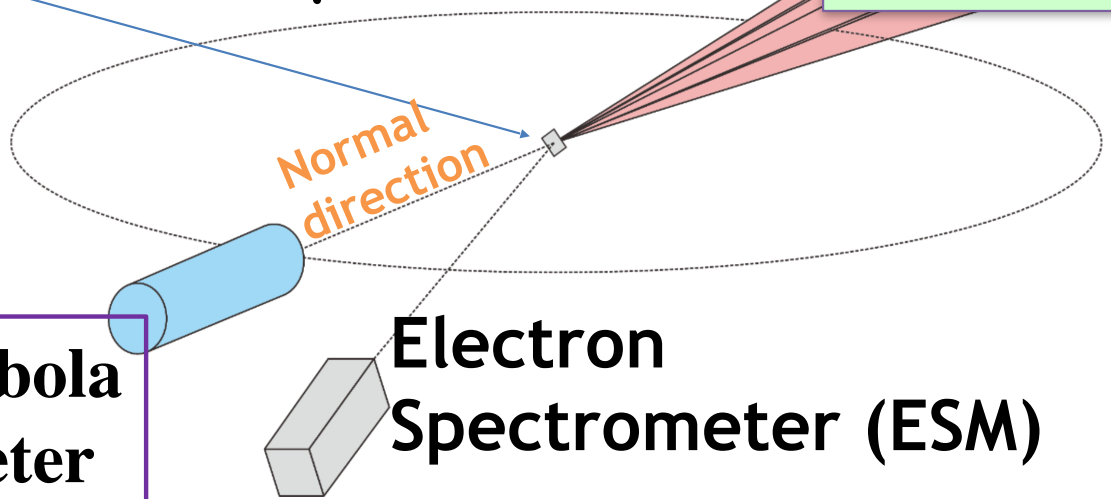
LFEX beams

Pulse duration: 1.5 ~6 ps

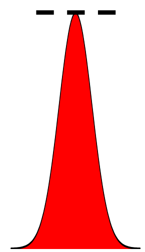
Energy: 1 kJ on target

Intensity: 0.2~1.2X10^{19} Wcm^{-2}

4 beams in total.

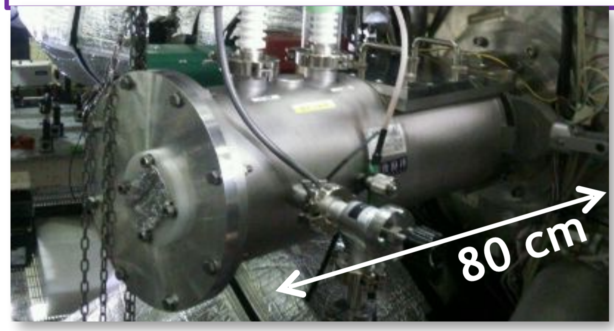


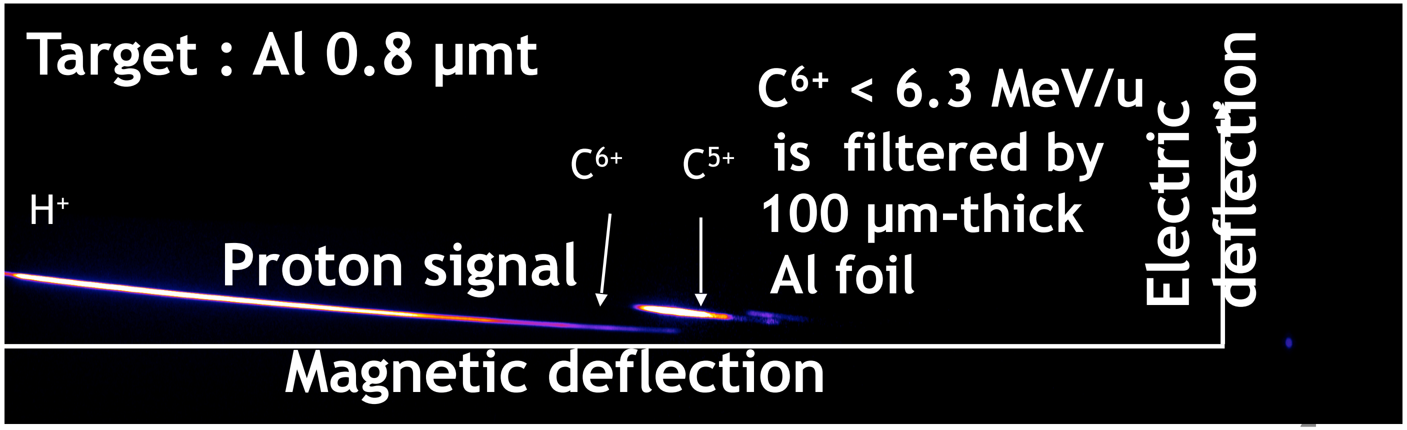
0.3X4X10^{19} Wcm^{-2}



1.5 ps (FWHM)

Thomson parabola Ion spectrometer

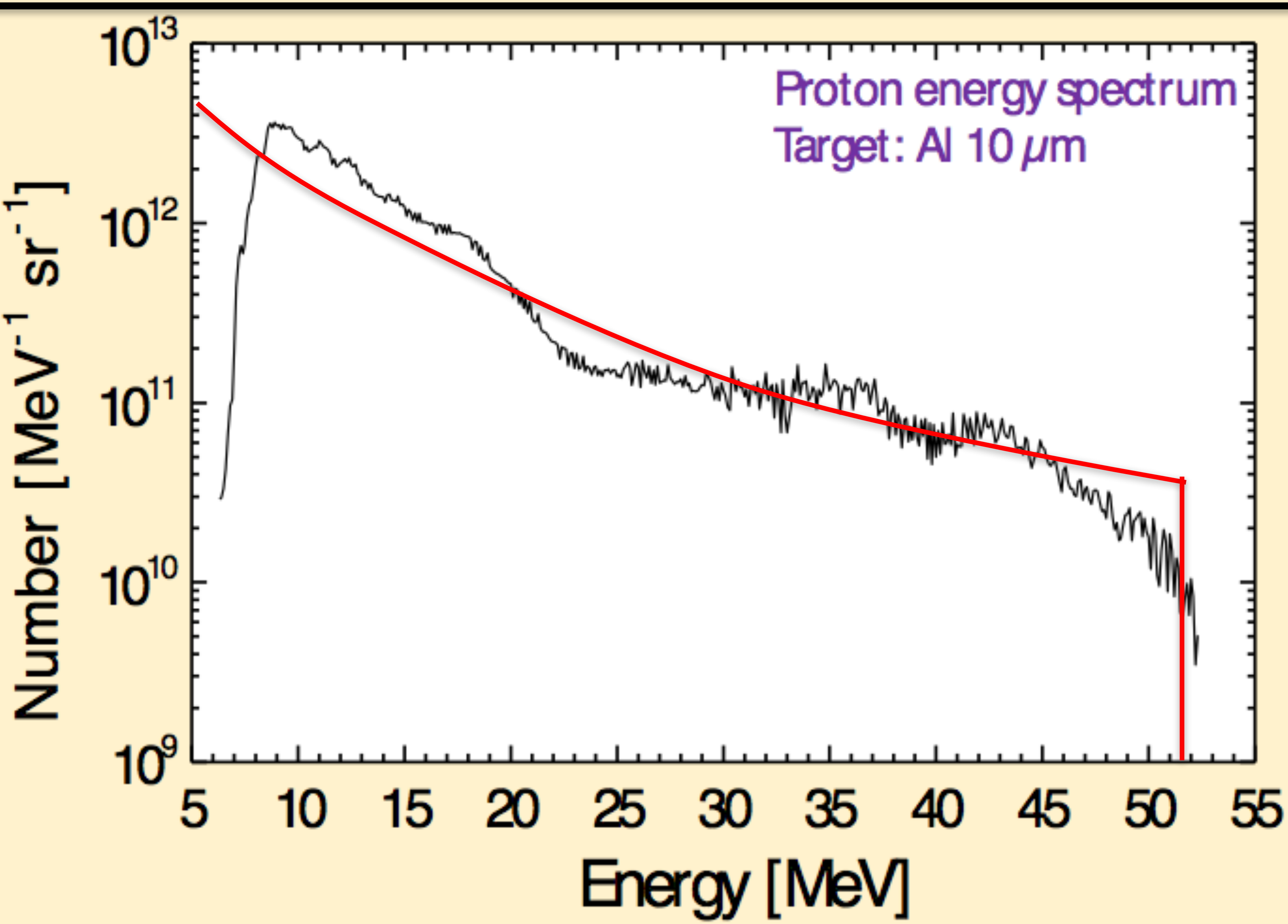




ILE OSAKA

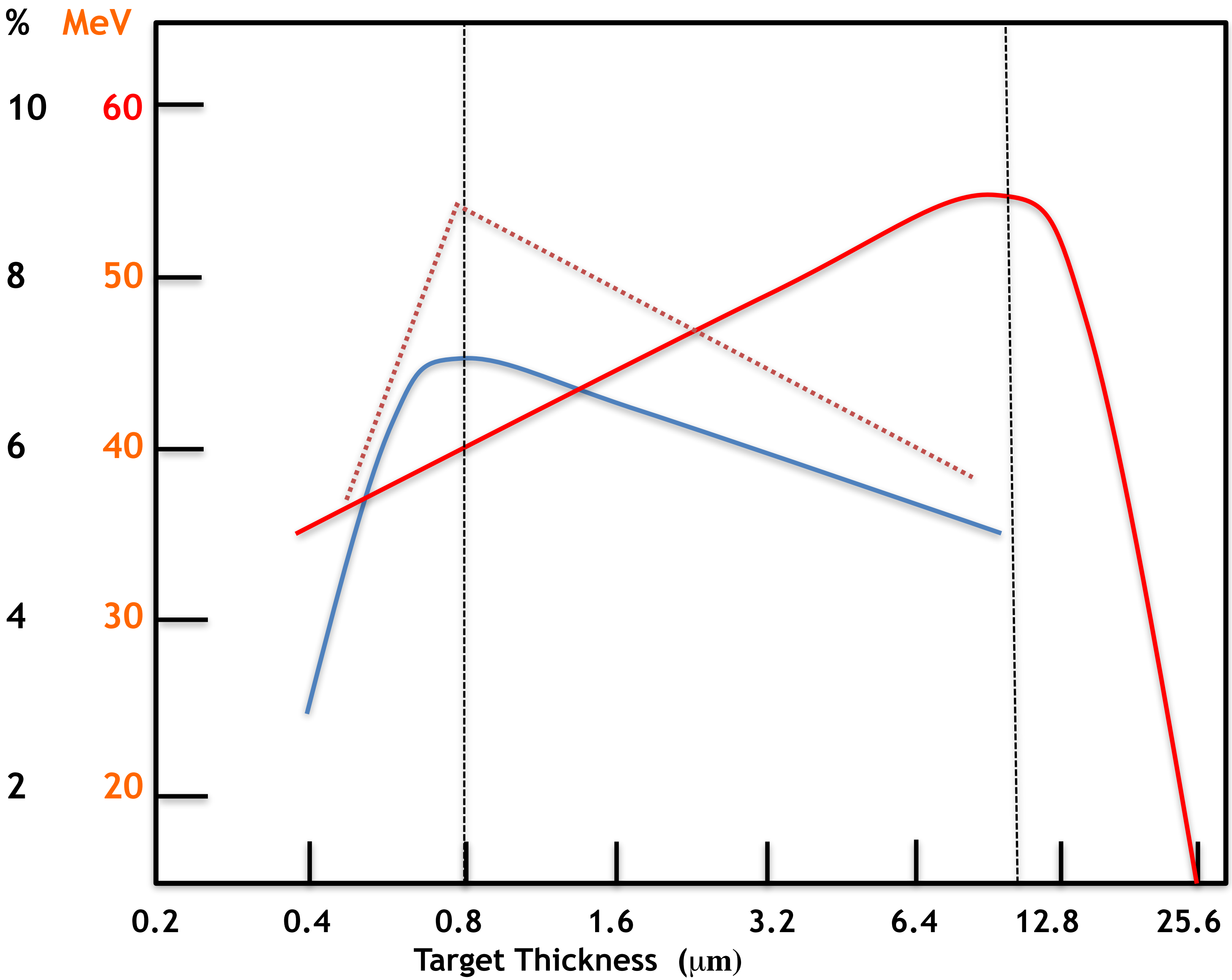
Maximum Proton Energy: 52 MeV

LFEX:1.5 ps kJ laser experiments after A.Yogo, JIFT W.S. 2016



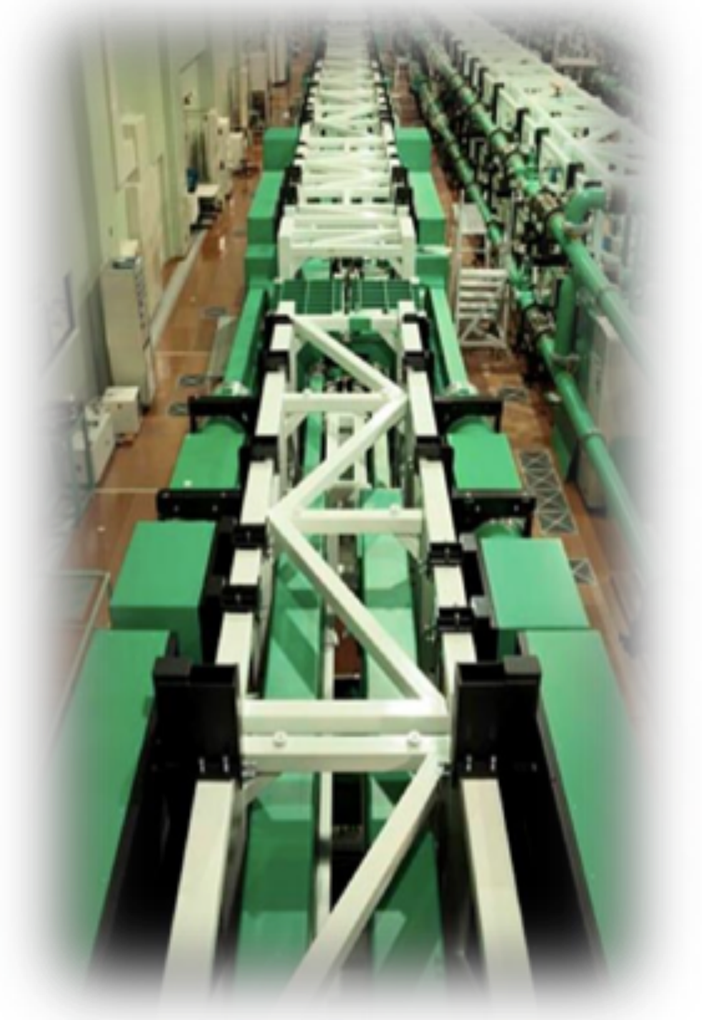
Conversion efficiency> 4% to protons of energy > 6 MeV

Target Thickness Dependence of Efficiency and Maximum ProtonEnergy

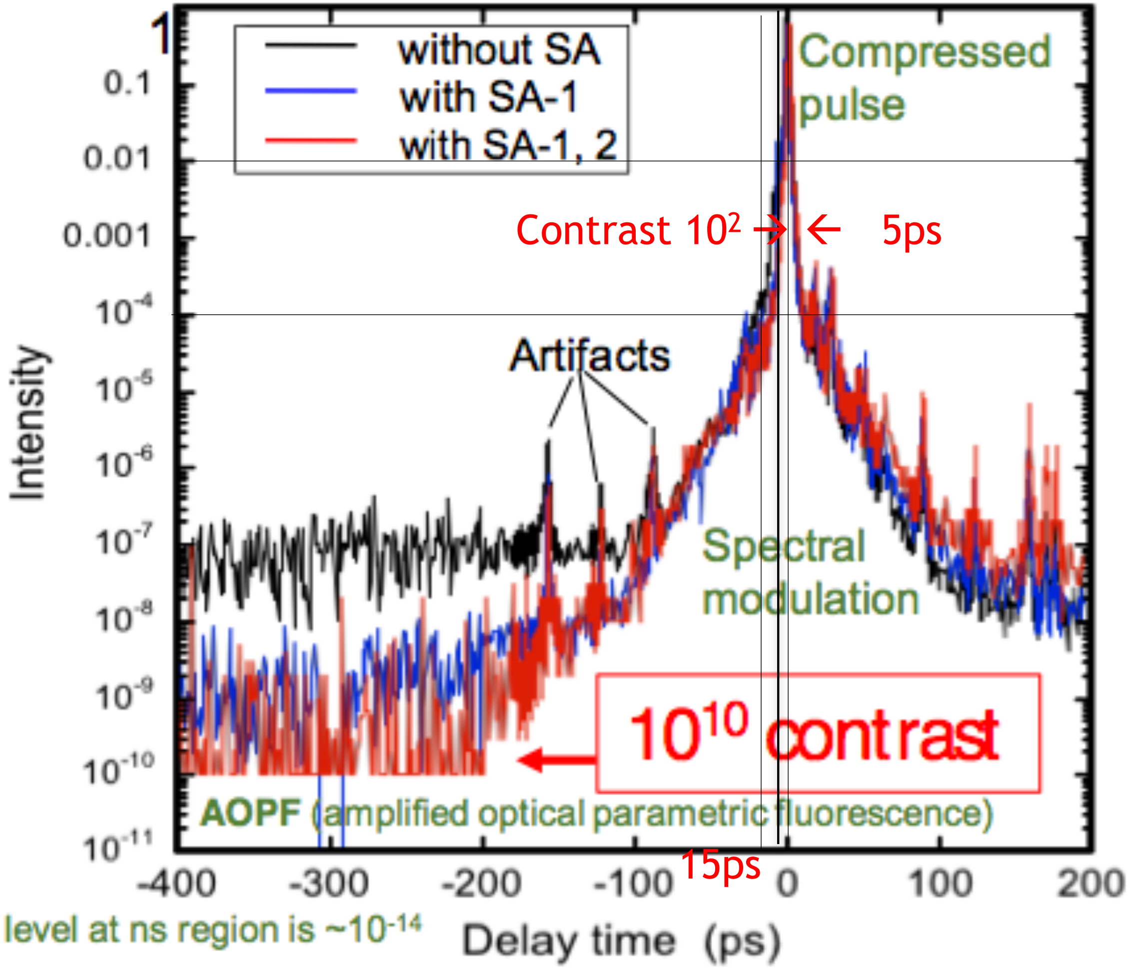


Ion acceleration has been carried out with LFEX –Up grade (High Contrast, kJ/ps pulse)

LFEX at ILE



Pulse contrast measured at the front end



Target plasma density profile at the main pulse

$a = a_0 \exp[(t - t_p)/t_p]$

$a_0 = 0.25$, $t_p = 5$ ps

$T_e = a^2 mc^2/2$: ponderomotive scaling

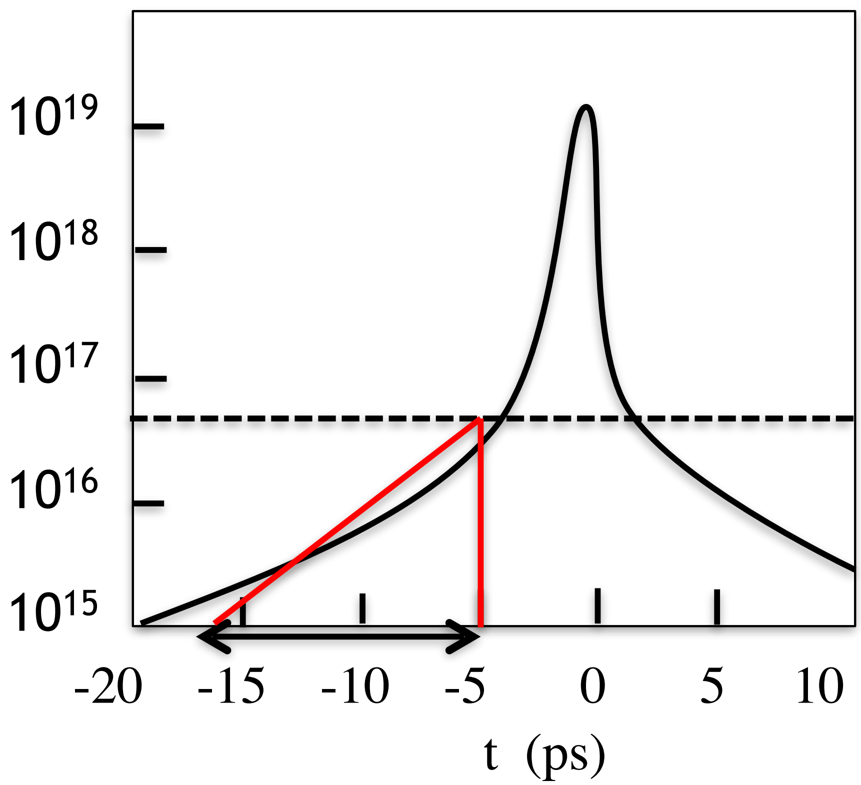
t =	-15	-10	-5	ps
T_e =	2	6	16	keV

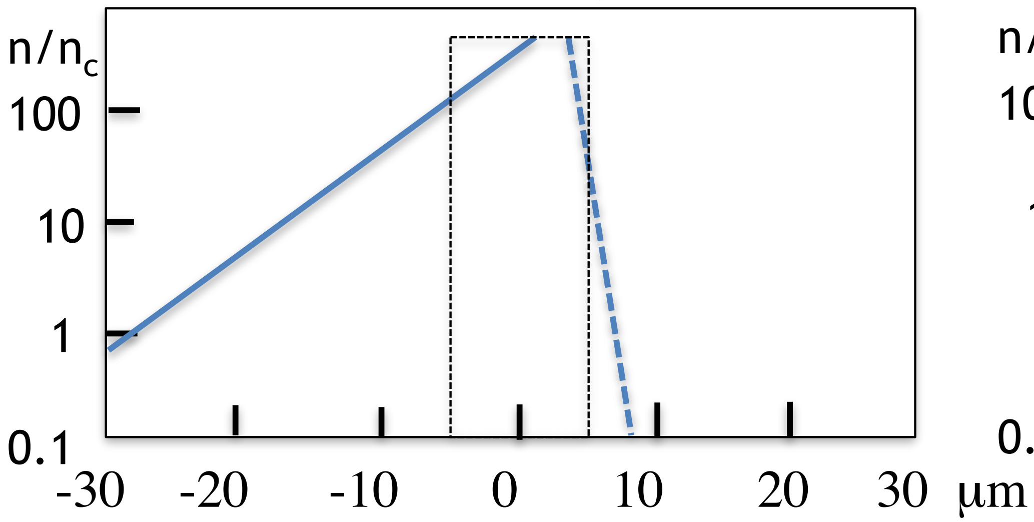
Heat wave penetration depth: $(l_{mfp} v_e t_p)^{1/2} \sim 10\mu m$

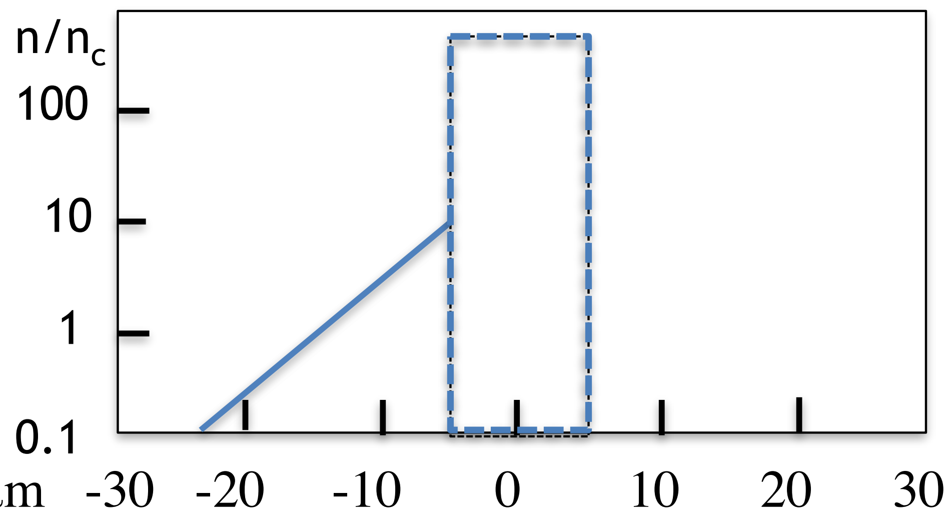
$$L_p = \int_{-15ps}^{t_p} (ZT_e/M)^{1/2}\, dt \sim t_p a_0 5\times10^8 \text{ cm/sec}$$

$\sim 6\ \mu m$

PIC of Radiation Hydro?

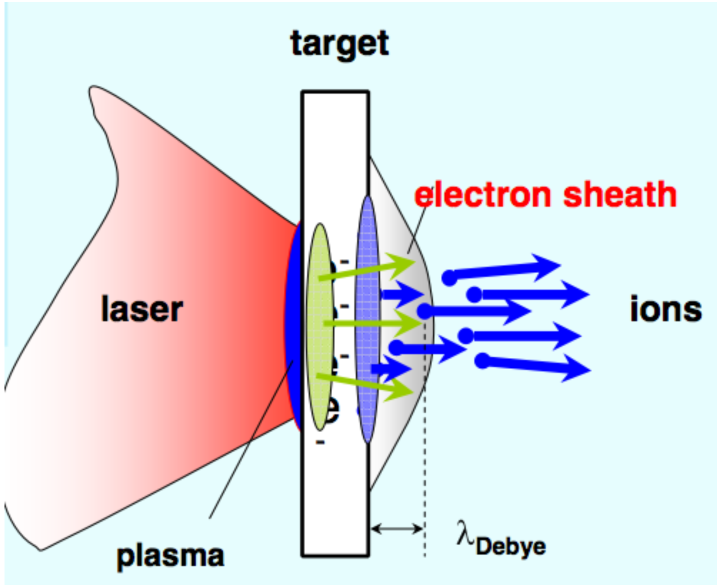






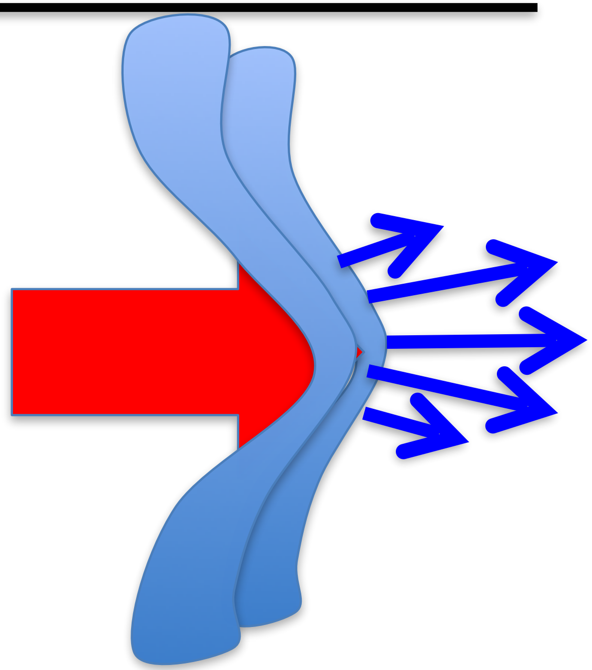
Mechanisms of Laser Ion Acceleration

TNSA
+CSA



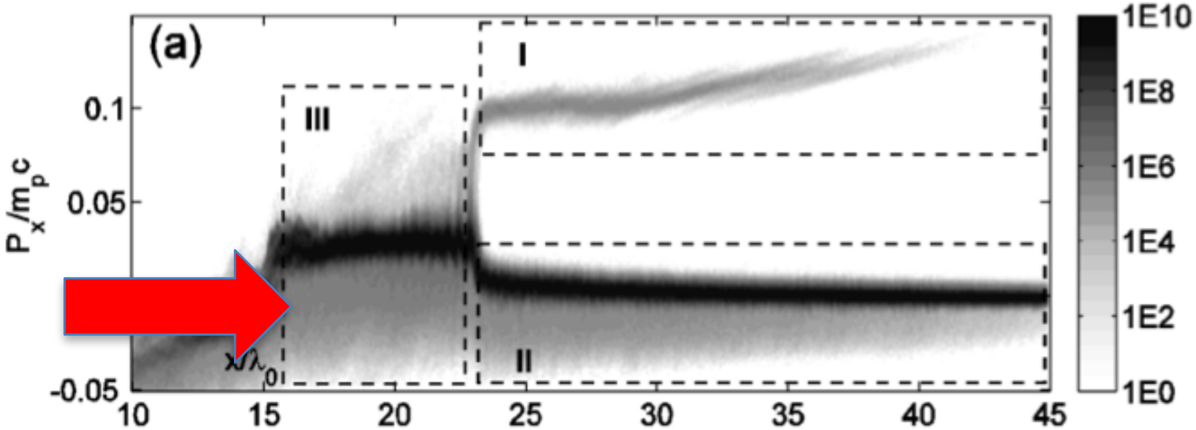
Dense thick foil

RPA
BOA
MDA
CSA



NRCD foil

Ion Acceleration in NRCD plasmas Collision-less Shock Acceleration (CSA)

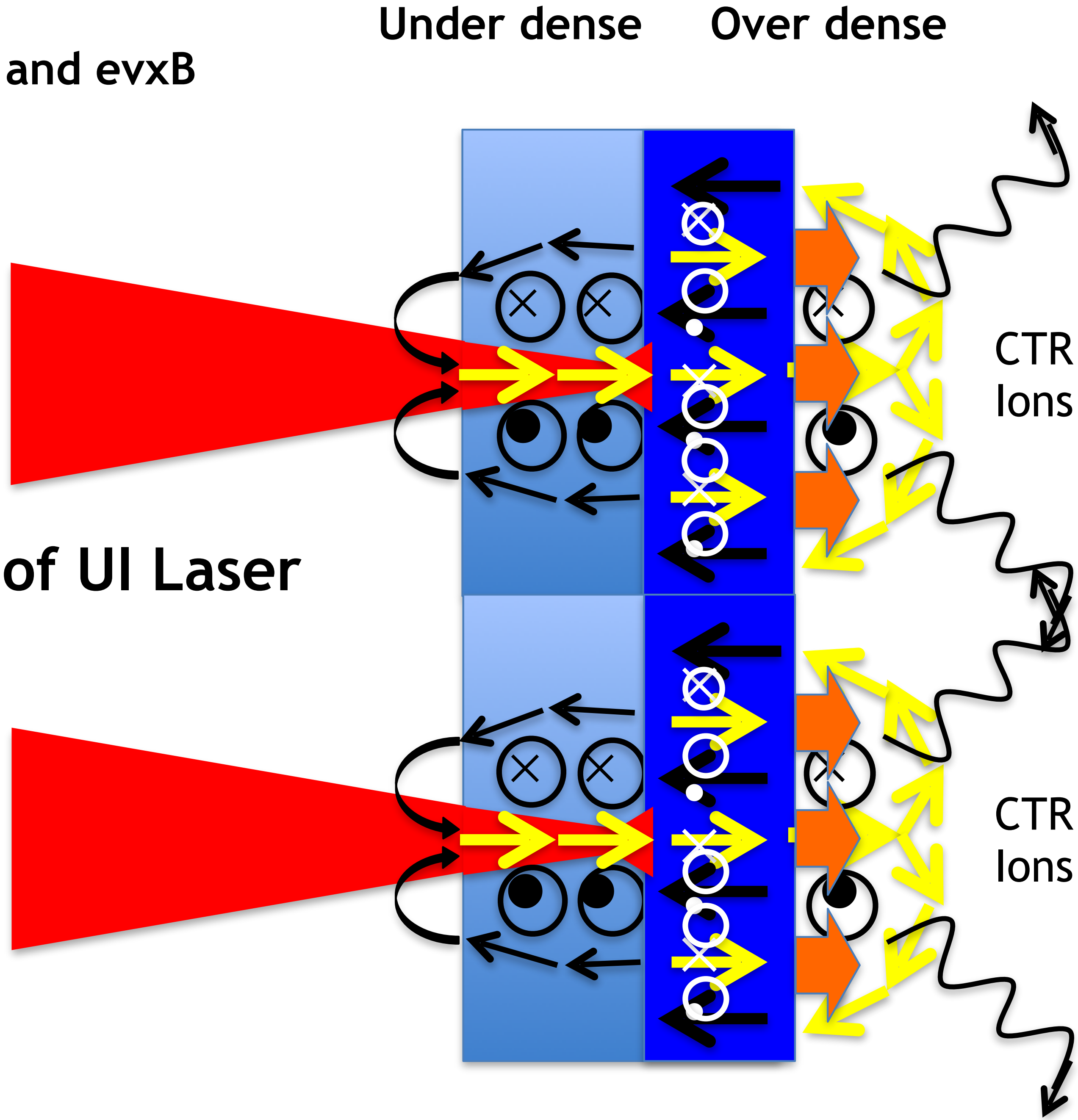


Low density thick foil

Electro-magnetic phenomena in URCD and NRCD plasmas

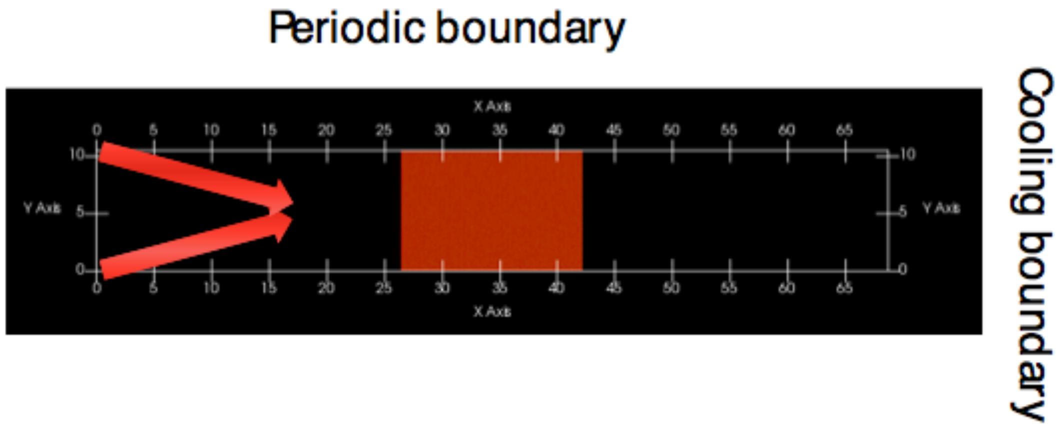
EM forces on electron : eE and evxB
are comparable.
Electrostatic and Inductive
E-fields accelerate ions

Intensity modulation of UI Laser



計算条件

- ターゲット
  - Carbon
  - 温度 1.3 keV
  - 密度 $10n_{cr}$
- レーザー
  - 波長 1.05 μm
  - FWHM = 350 fs
  - 1×10^{19} W/cm^2, 入射角±5.7°（2本）

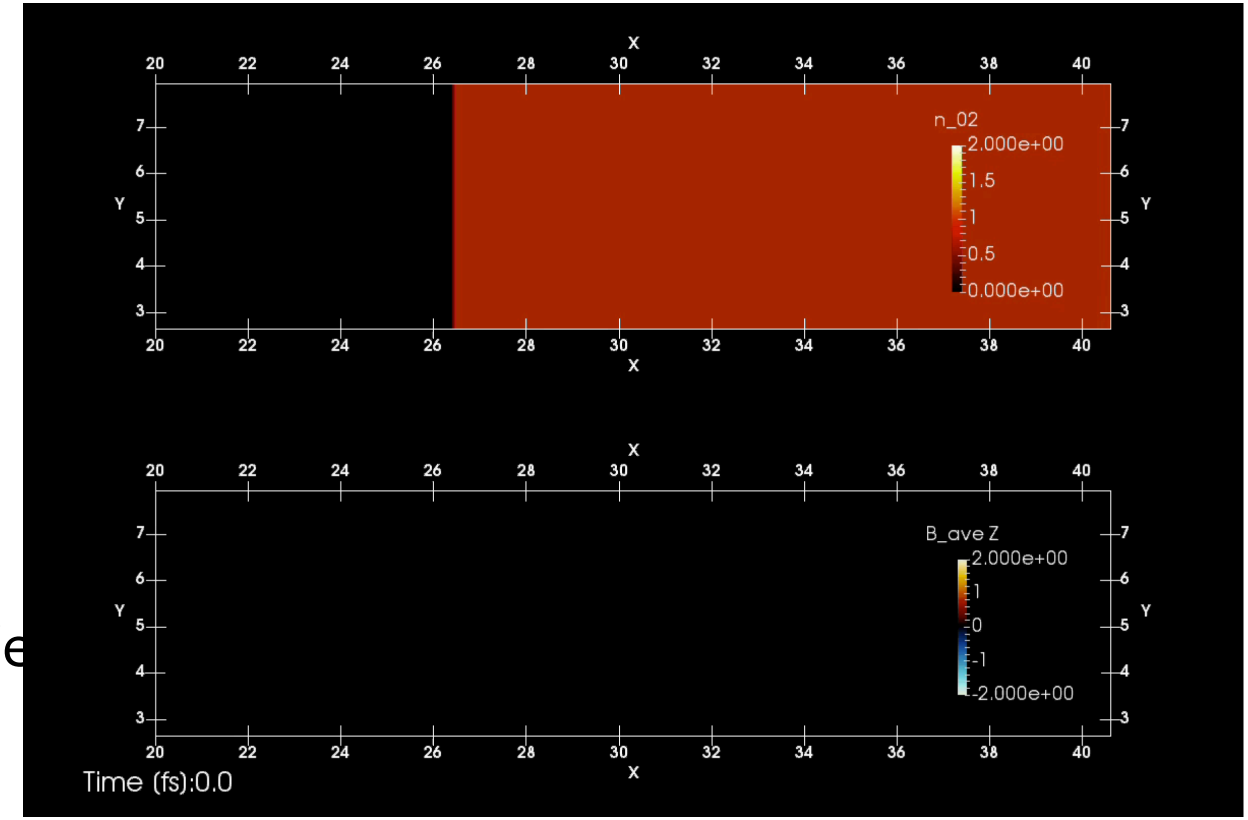


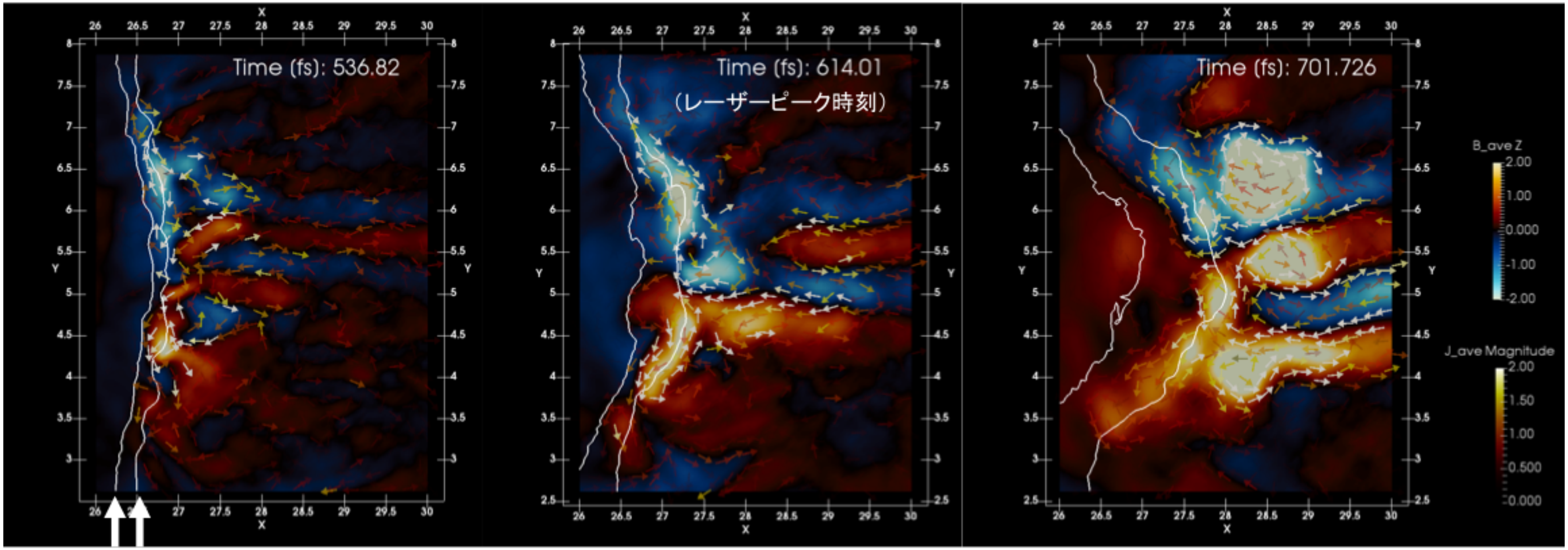
レーザーピークの -525 fs より計算開始

ターゲット表面と内部に磁場が生成した

n_e [$10n_{cr}$]

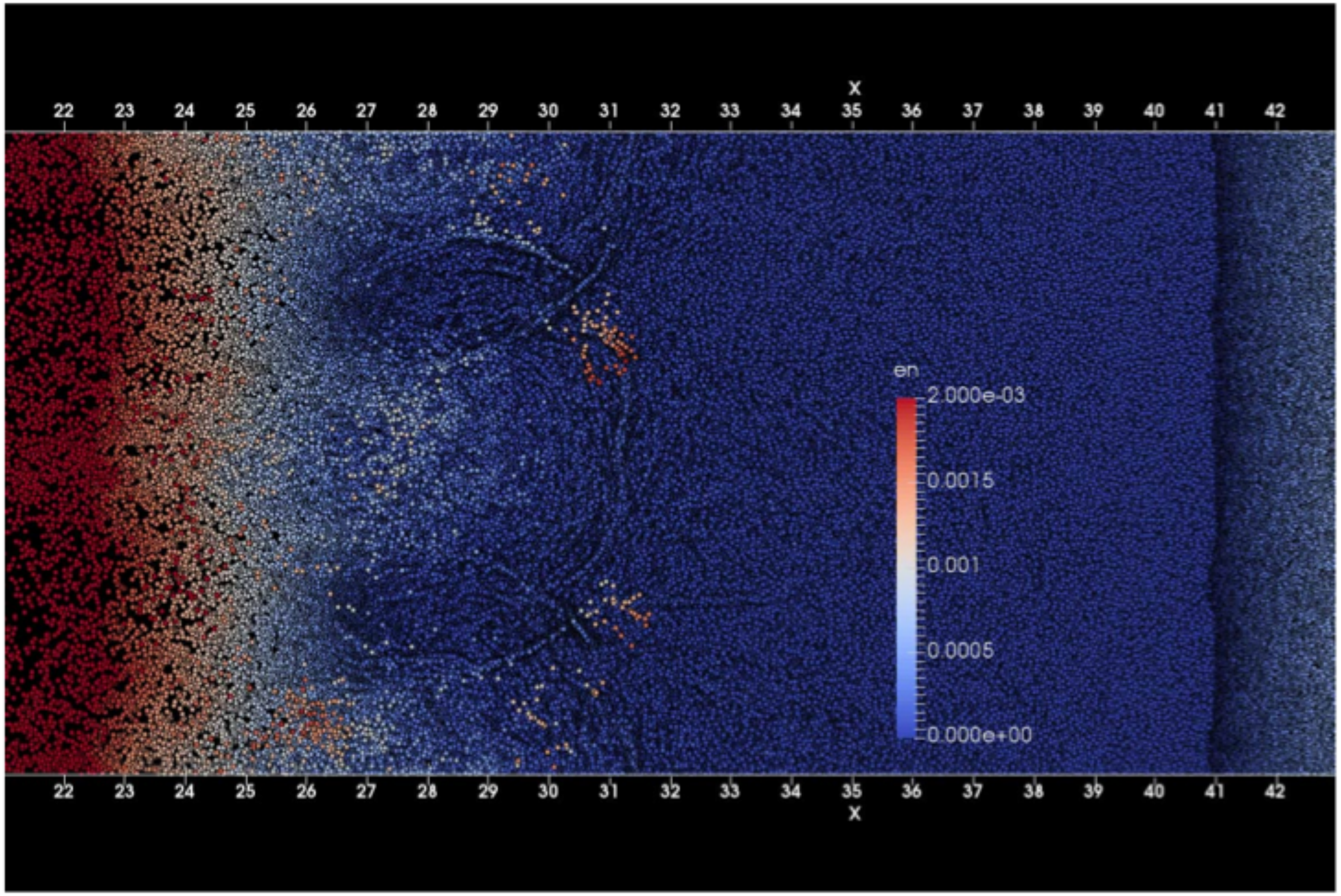
B_z [$m_e\omega_L/e$

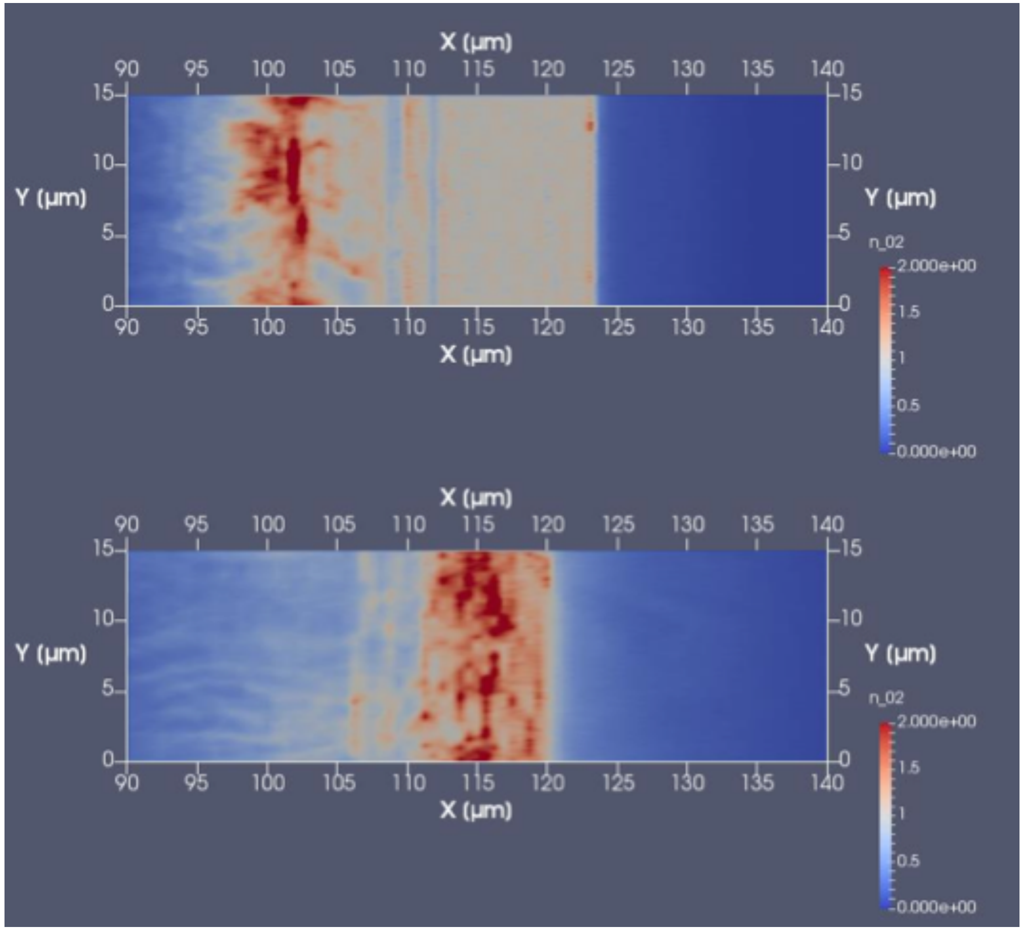
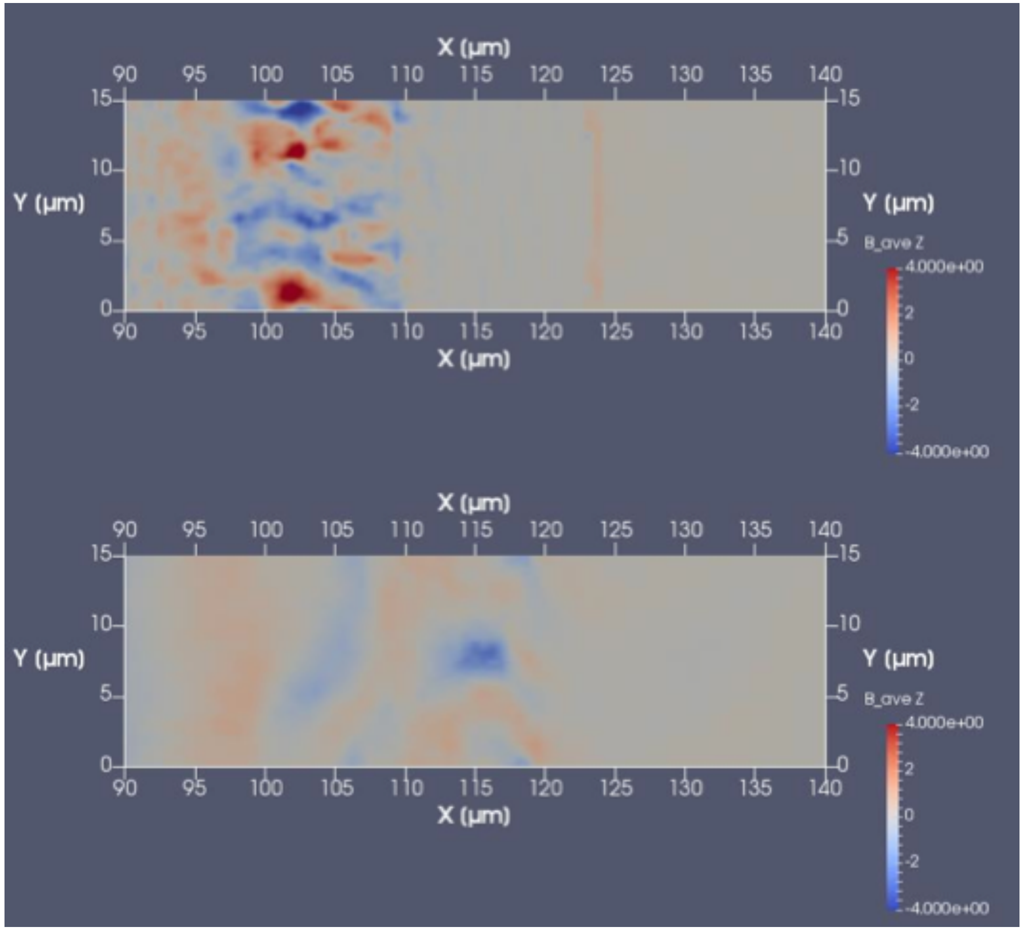



Time (fs): 536.82
Time (fs): 614.01
（レーザーピーク時刻）
Time (fs): 701.726
X
Y
B_ave Z
2.00
1.00
0.000
-1.00
-2.00
J_ave Magnitude
2.00
1.50
1.00
0.500
0.000

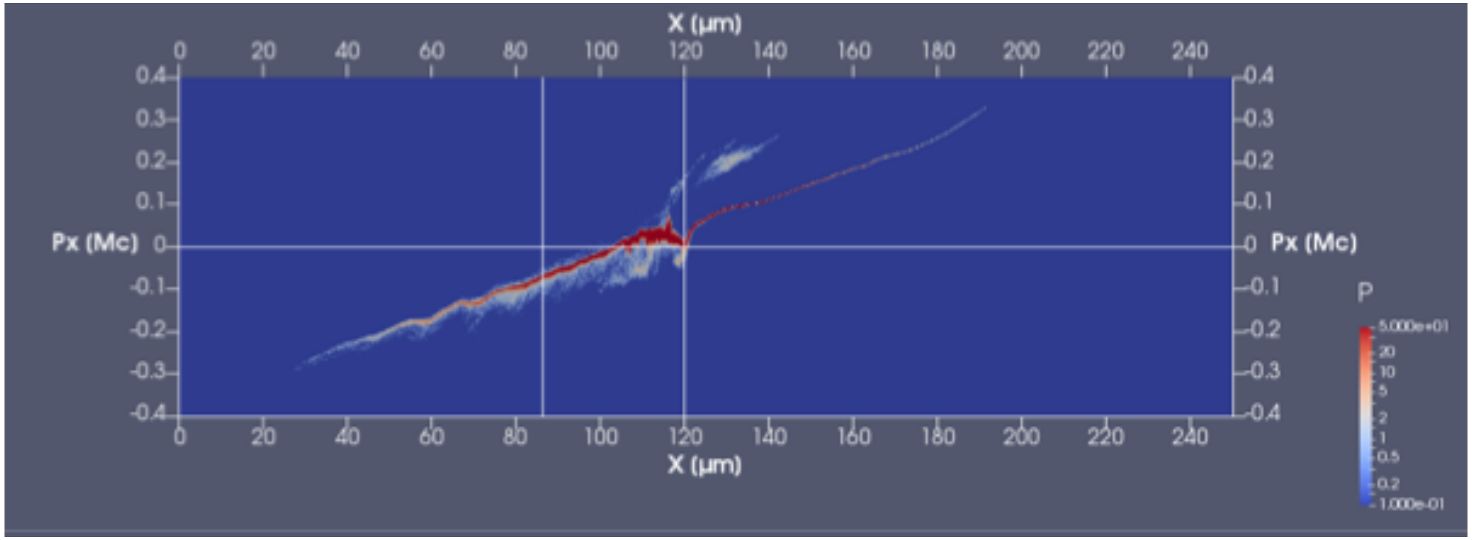
密度 n_{cr}, $5n_{cr}$

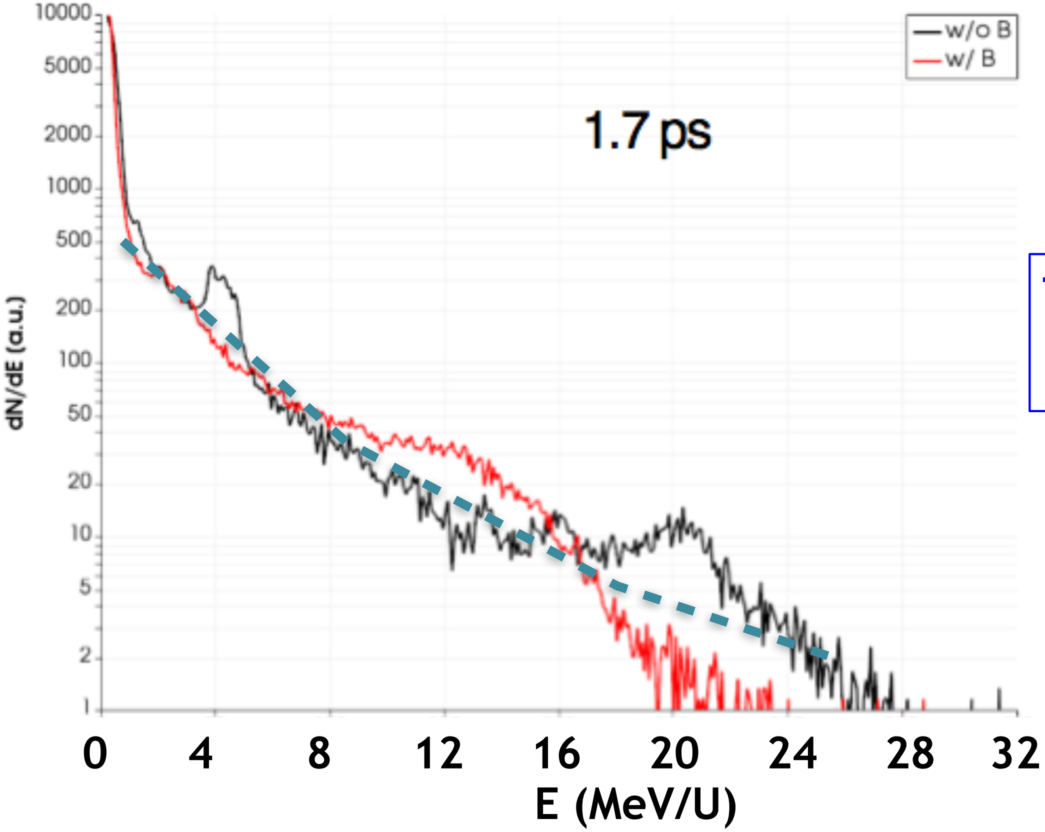
衝撃波が重なる部分ではイオンが20 MeV程度まで加速された




X (μm)
Y (μm)
n_02
2.000e+00
1.5
1
0.5
0.000e+00

X (μm)
Y (μm)
B_ave Z
4.000e+00
2
0
-2
-4.000e+00

Ion Phase Space Distribution and Energy Spectra





TNSA Energy Spectrum
~ $EXP[-(E/E_0)^{1/2}]$, E_0=1 MeV

Summary and Questions

1. **Plasma profile produced by ~20ps pedestal ?**

2. **Self-focusing and filamentation are triggered by laser intensity modulation.**

3. **Radiation pressure driven shocks in NRCD plasmas are important?**

4. **Modification of proton energy spectra from TNSA?**
   Time dependent electron temperature effects,
   Colliding multiple shocks, Collision-less shock, or ?

5. **Mechanisms of separation of proton and deuteron energy are due to,**
   Localization of proton, Large laser spot effect, others?