LaB'17

Ion Acceleration from the Modulated Electric and Magnetic Fields by Bundled Picosecond Laser Beams

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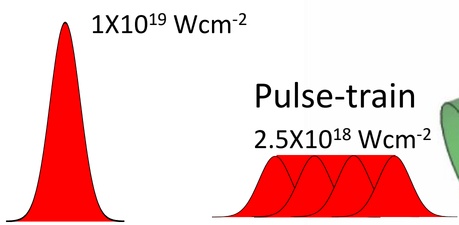
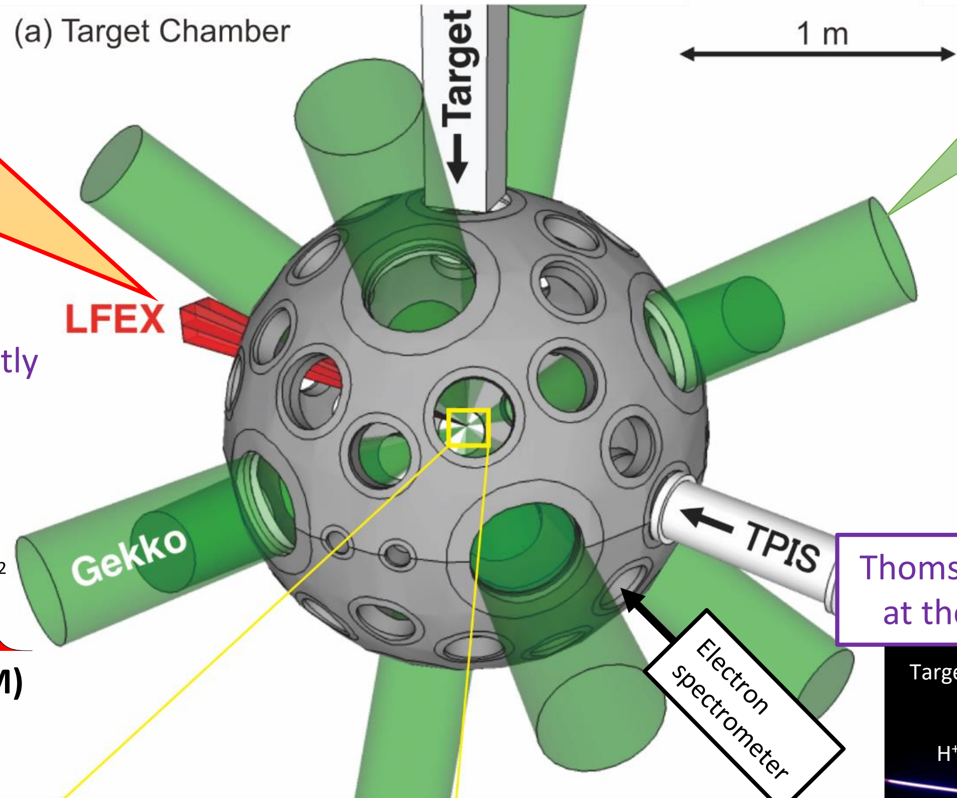
Experimental conditions

Ion energy distributions are measured at the rear side of thin-foil targets.

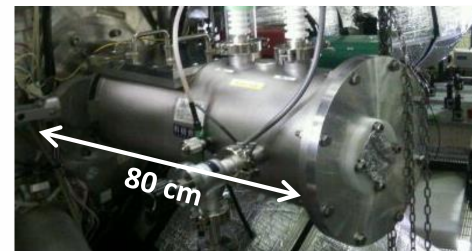
LFEX: ps laser
1.5 ps, 1 kJ on target
1.2×10^{19} Wcm^{-2}
60 μm spot (FWHM)
4 beams in total.

The arrival timing of 4 LFEX beams can be set independently of each other.

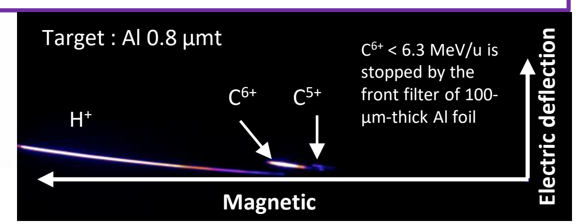




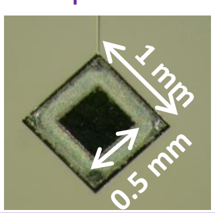
Gekko-XII: ns laser for fuel implosion
12 beams in total.



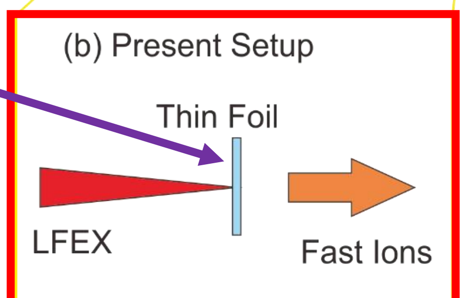
Thomson parabola Ion spectrometer at the laser propagation direction

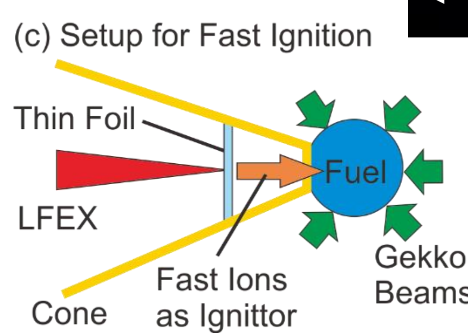


Thin-foil target
5 or 10-μm-thick AL



Spot size >> target thickness
(60 μm) (5-10 μm)





Electron energy spectra are measured simultaneously with ions.

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Experimental conditions

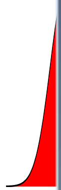
Ion energy … foil targets.

The arrangement of the beams is 2X2

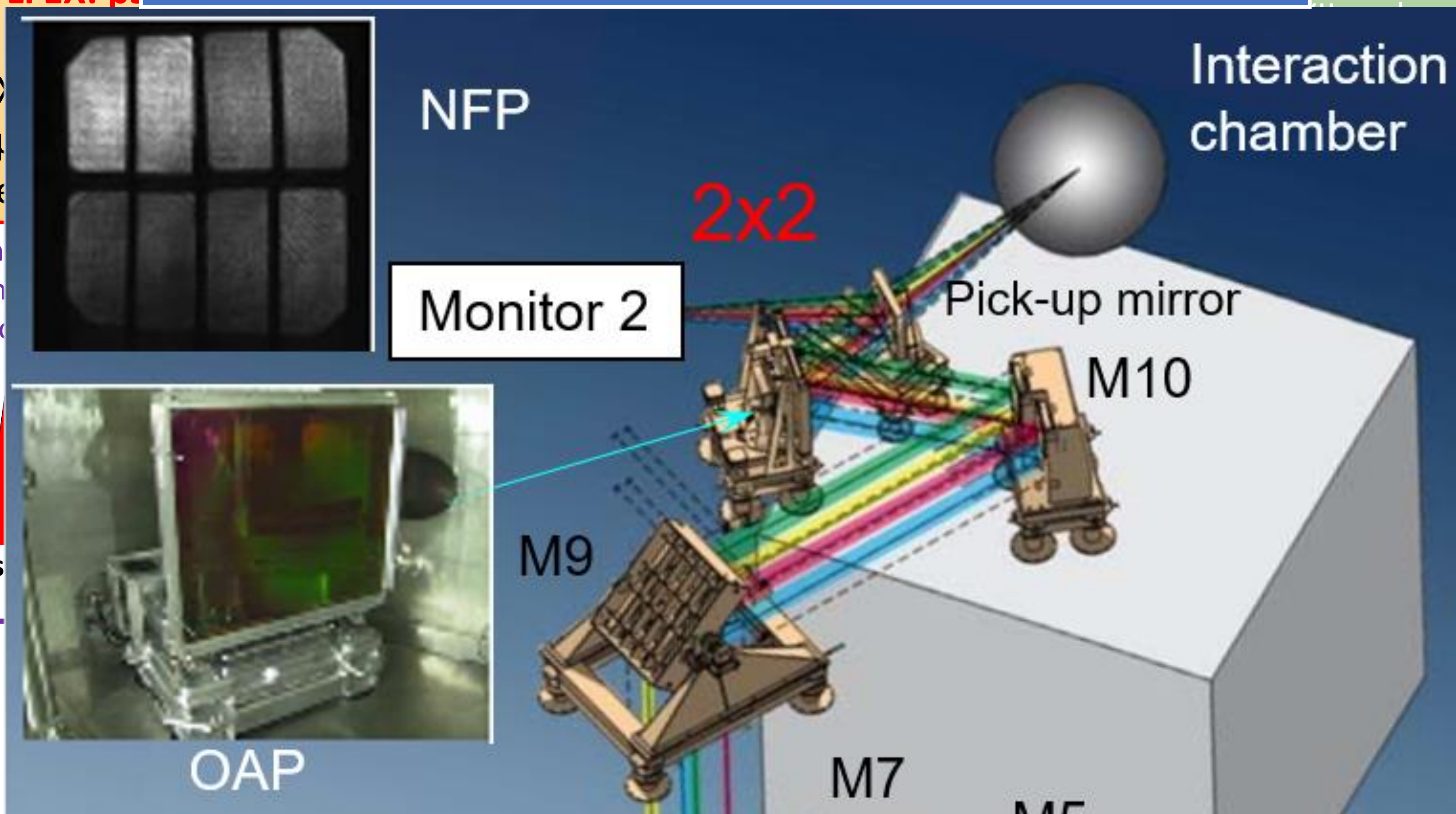
LFEX: ps

1.5
1.2X
60 μ
4 be

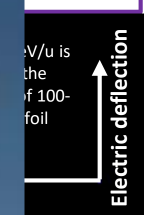
The a
beam
of eac



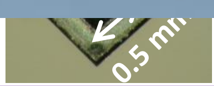
1.5 ps

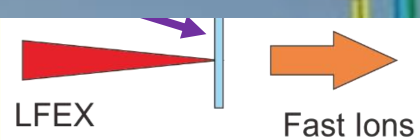


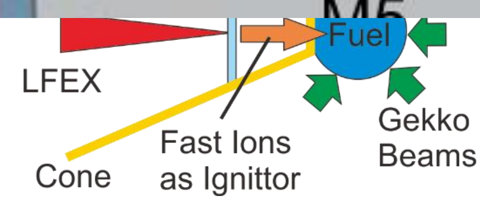
meter
ction



5







a are measured simultaneously with ions.

Spot size >> target thickness
(60 μm) (5-10 μm)

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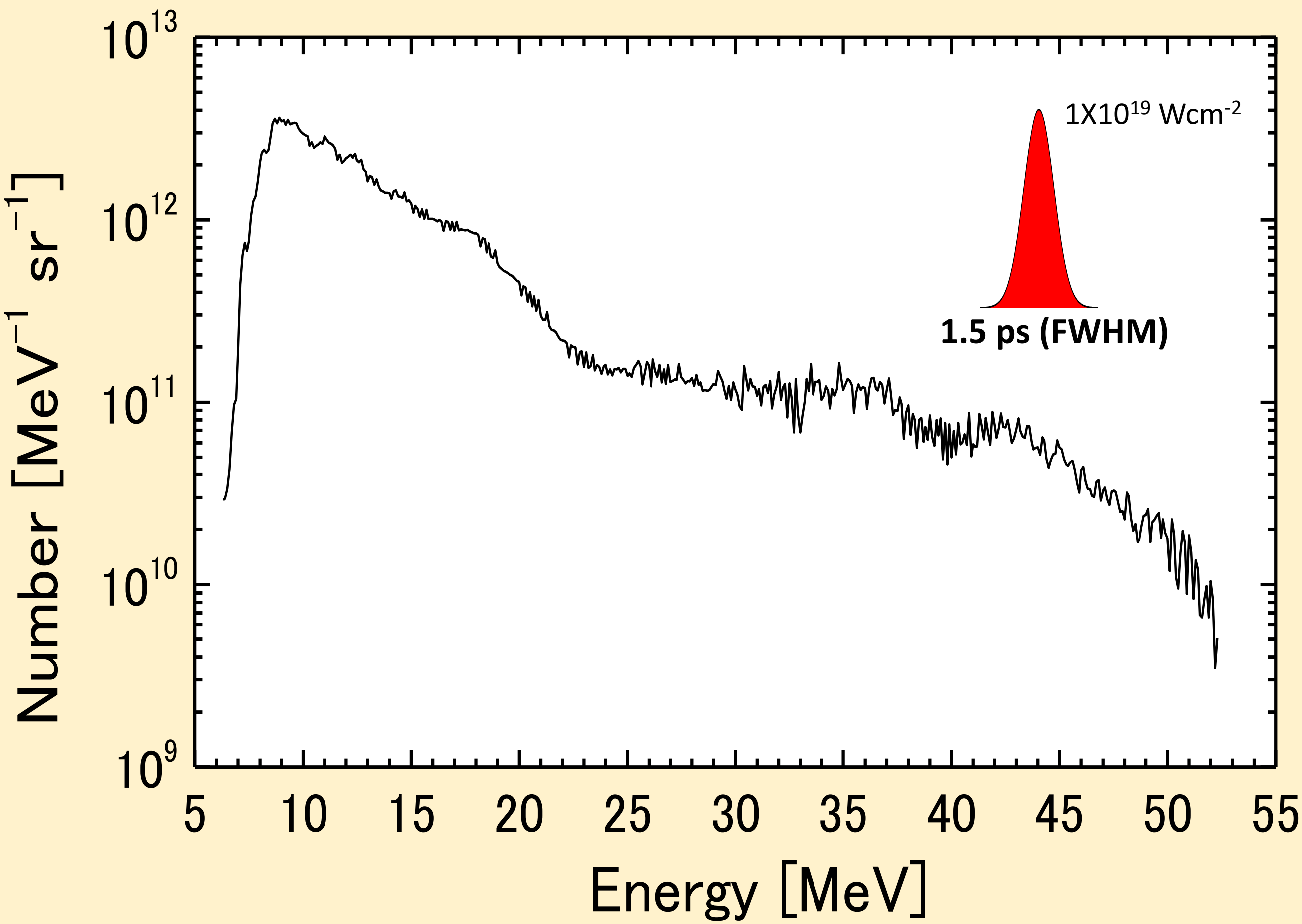
Experimental conditions

Ion en… targets.

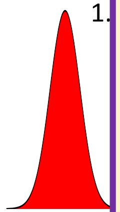
Maximum Proton Energy 52 MeV with $1.2X10^{19}$ Wcm^{-2}

Energy Conversion Efficiency into Protons (>6 MeV): 4 %

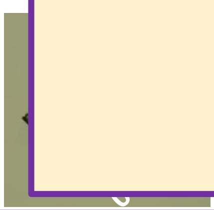


LFE…
1.5 ps,…
1.2X10…
60 µm…
4 bean…

The arriv…
beams ca…
of each o…

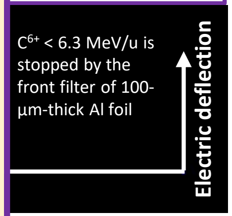


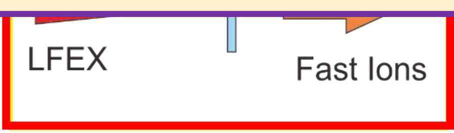
Th…
5 or 1…

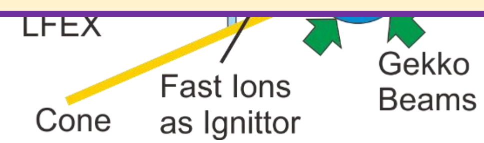


…laser
…osion
…total.

…pectrometer
…n direction

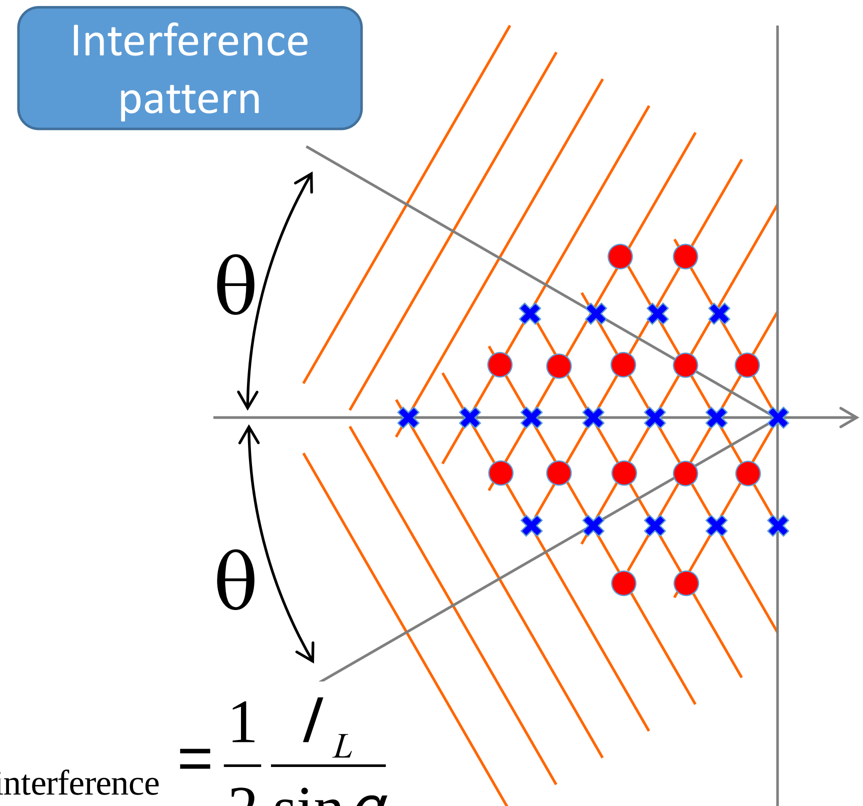






Spot size >> target thickness
(60 µm) (5-10 µm)

EM field modification due to the interference between the beams



$$l_{\text{interference}} = \frac{1}{2}\frac{\lambda_L}{\sin\theta}$$

- When the multi-beams are irradiated from different incident angles, the laser intensity is enhanced at specified points (●) due to the interference.

- Case of the LFEX laser

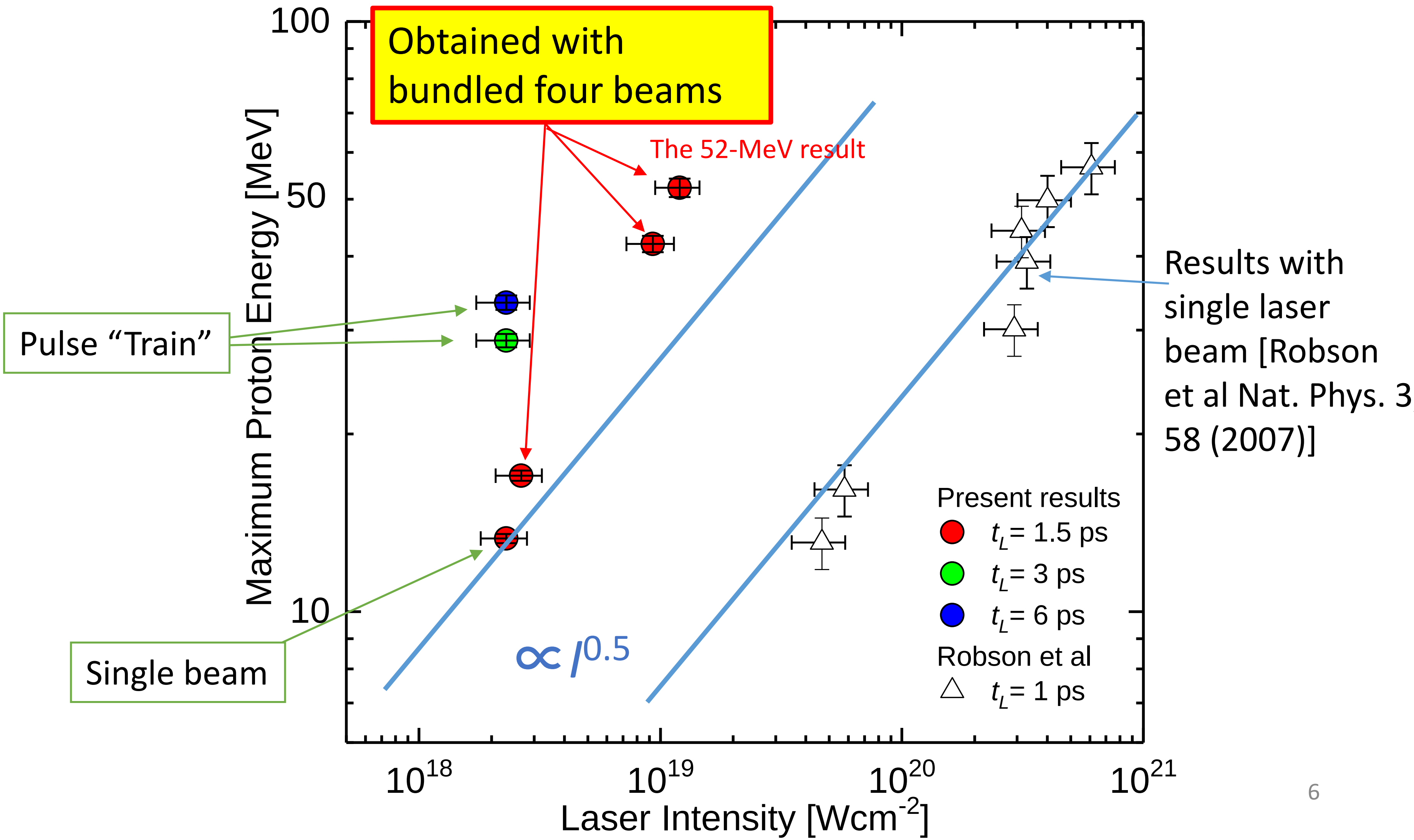
  $\theta = 2.86^\circ \quad \rightarrow \quad l = 10.0\ \mu m$

  $\Rightarrow$ The distance between the interference patterns is smaller than our laser focal spot size.

Can the beam interference make any influence on the ion acceleration?

The maximum proton energy

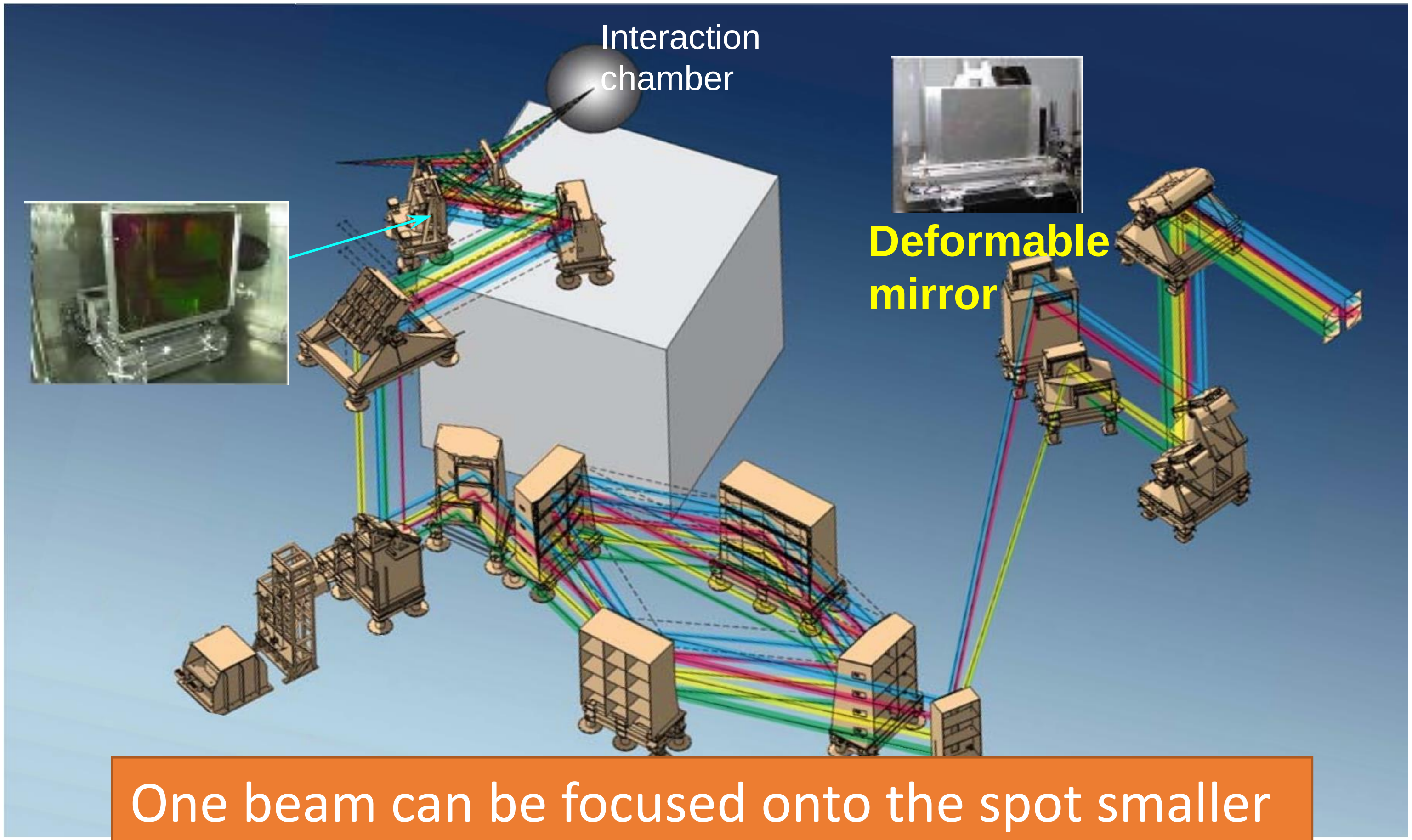
Scaling on the laser intensity



The maximum proton energy

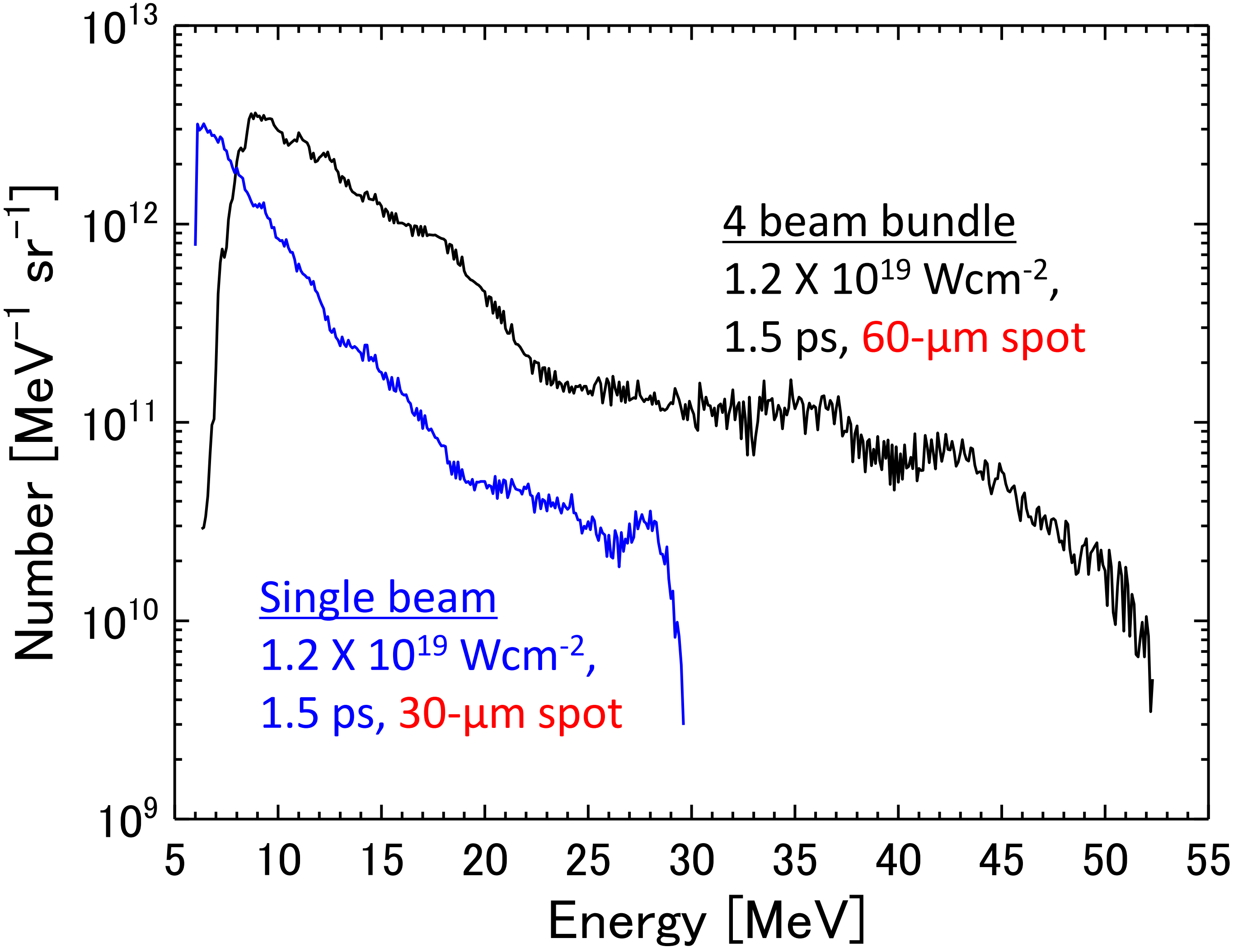
Comparison with single beam case.

Deformable mirror is installed on one beam out of the 4 beams after the main amplifire.

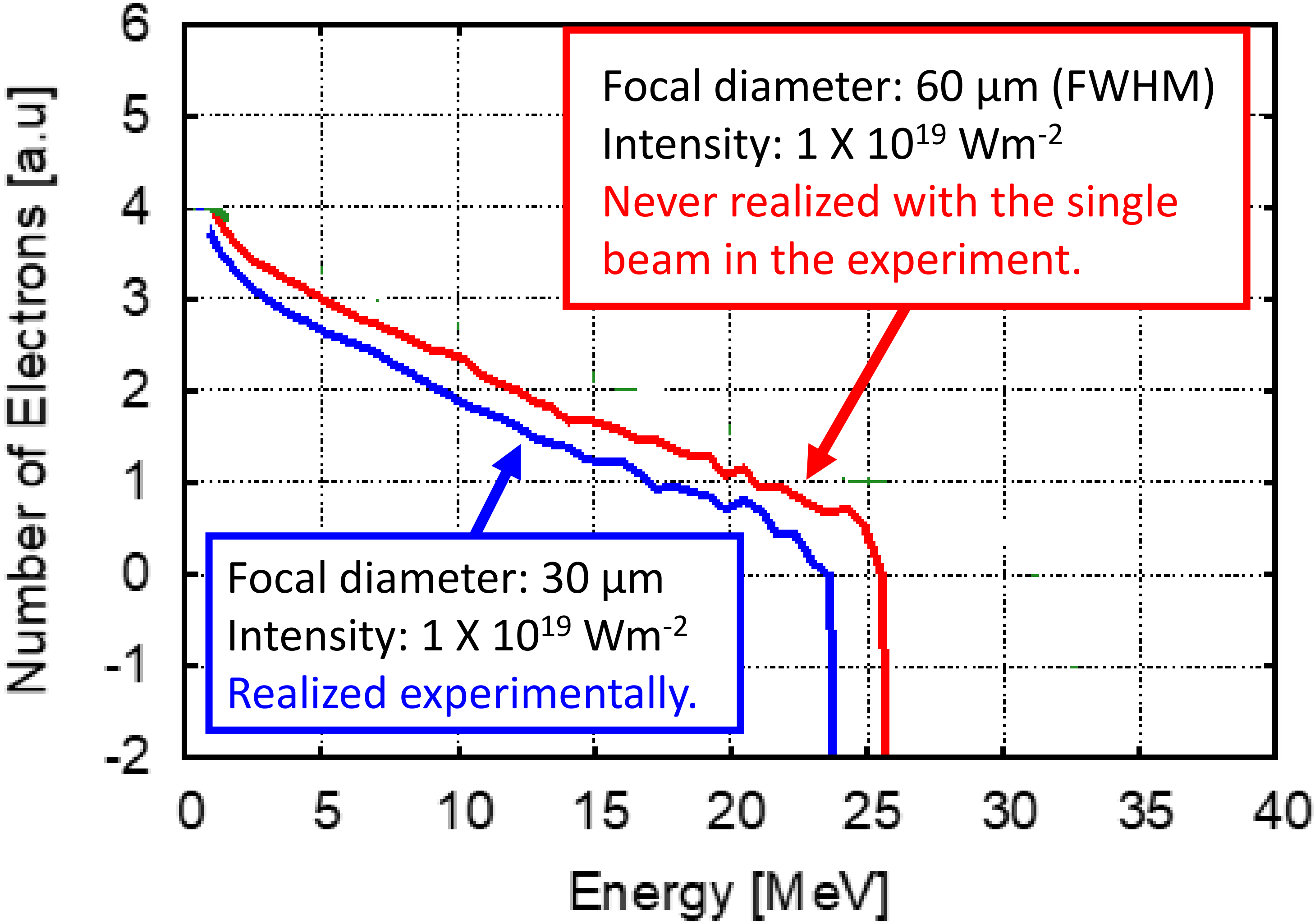


One beam can be focused onto the spot smaller than the other 3 beams.

The maximum proton energy
Comparison with single beam case.



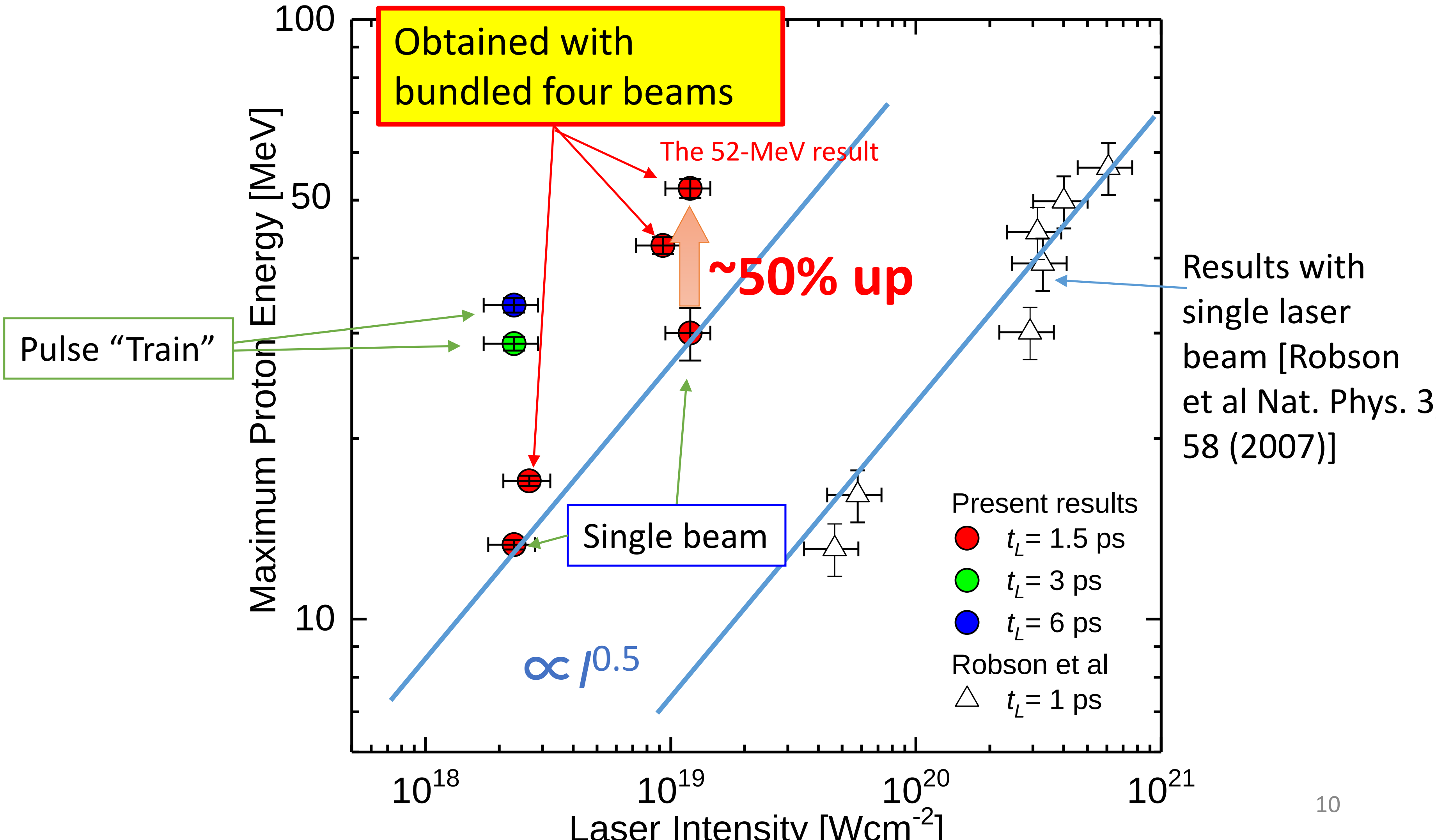
Proton energy obtained with 30 µm spot is not seriously different from that of 60 µm spot in the single beam casein our PIC simulation.



(i) The maximum proton energy

Scaling on the laser intensity

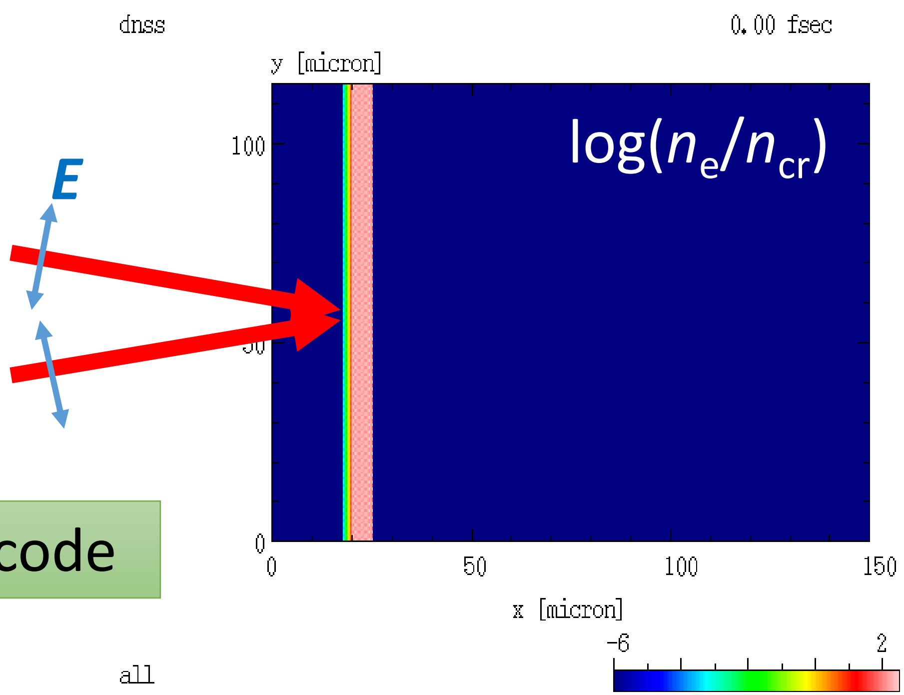
50% enhancement from the scaling line of the single beam incidence.



2D PIC Simulation involving Interference effects

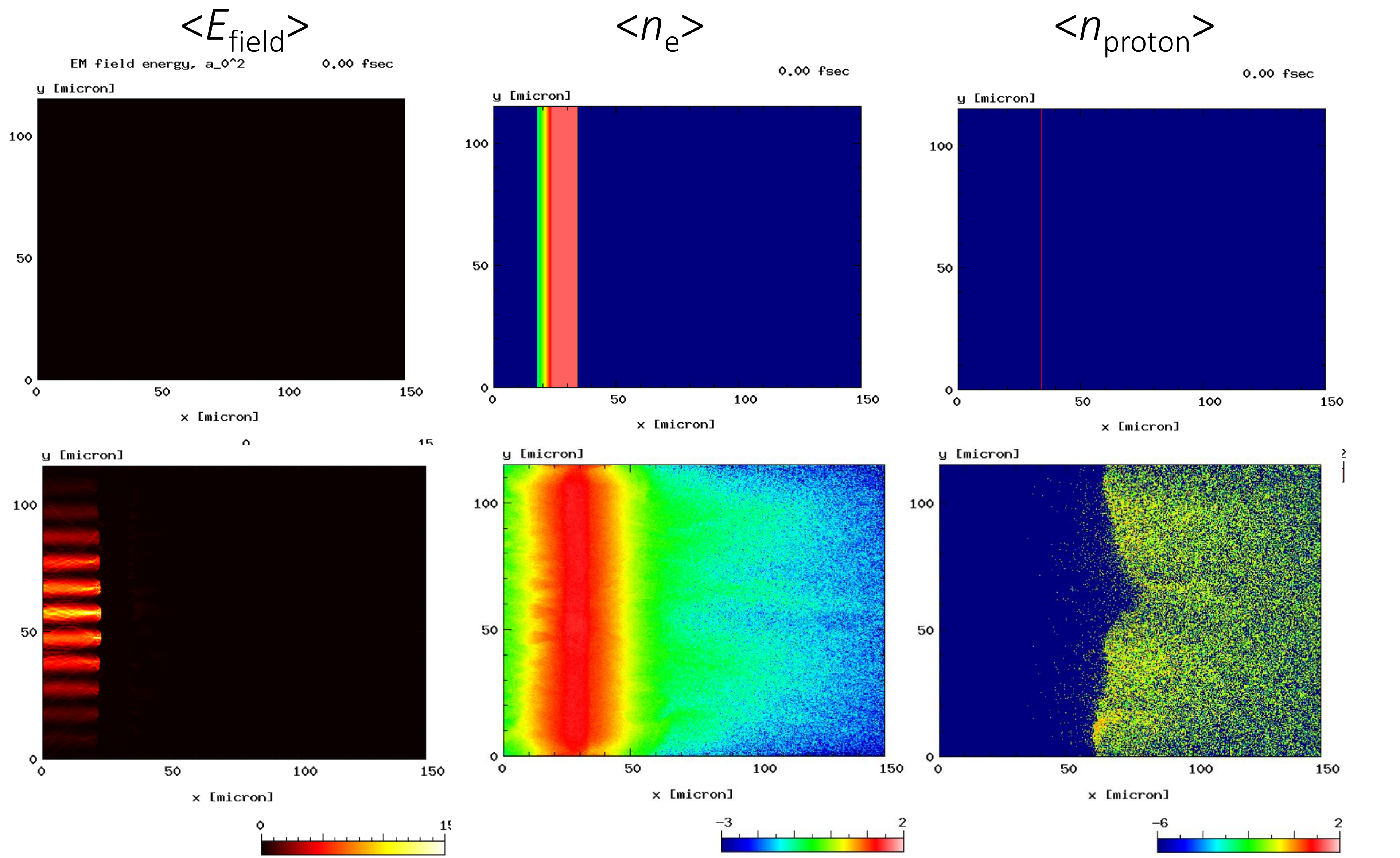
- Laser paremters
  - I_0 = 5.0 × 10^{18} W/cm^2 X 2 beams
    (In the experiment, 2.5e18 W/cm^2X4 beams)
  - λ_L = 1.0 μm
  - θ = ±2.86°
  - Temporally Gaussian
    - τ_{FWHM} = 500τ_{lsr} = ~1.5 ps
  - Spatially Gaussian
    - Φ_{FWHM} = 50 μm

- Al + rear H plasmas
  - n_e = 0.1~40n_{cr}
  - Exponential Al preplasma of L_{pre} = 1 μm from 0.1 to 40n_{cr} and 40n_{cr} flat plasma
  - $d_{rear\ H\ plasma}$ = 200 nm



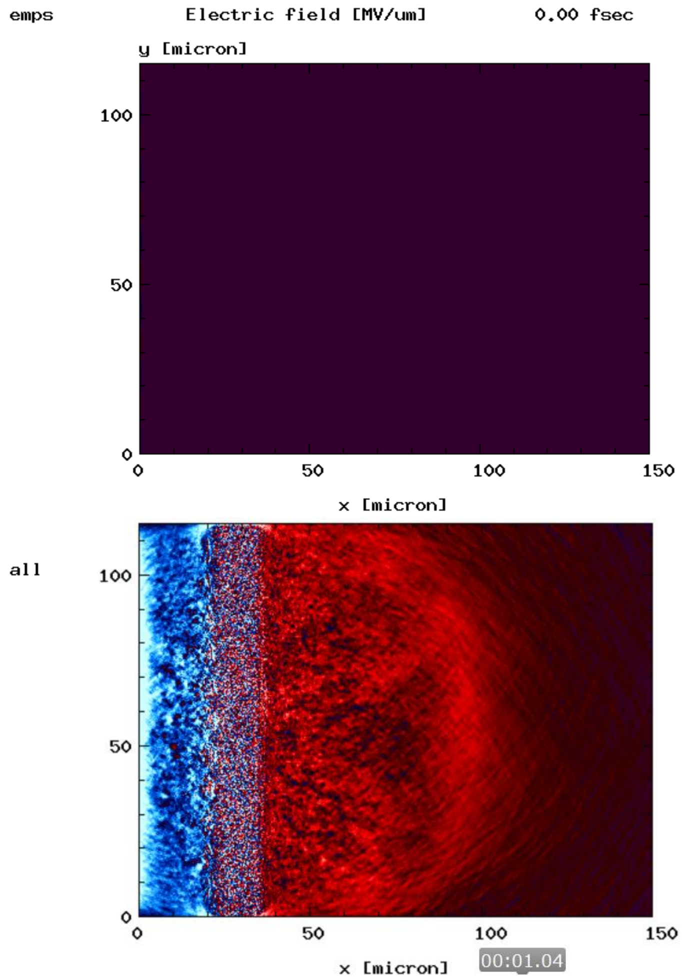
Calculated by Dr. Hata with PICLS-code

2D PIC Simulation involving Interference effects (preliminary)

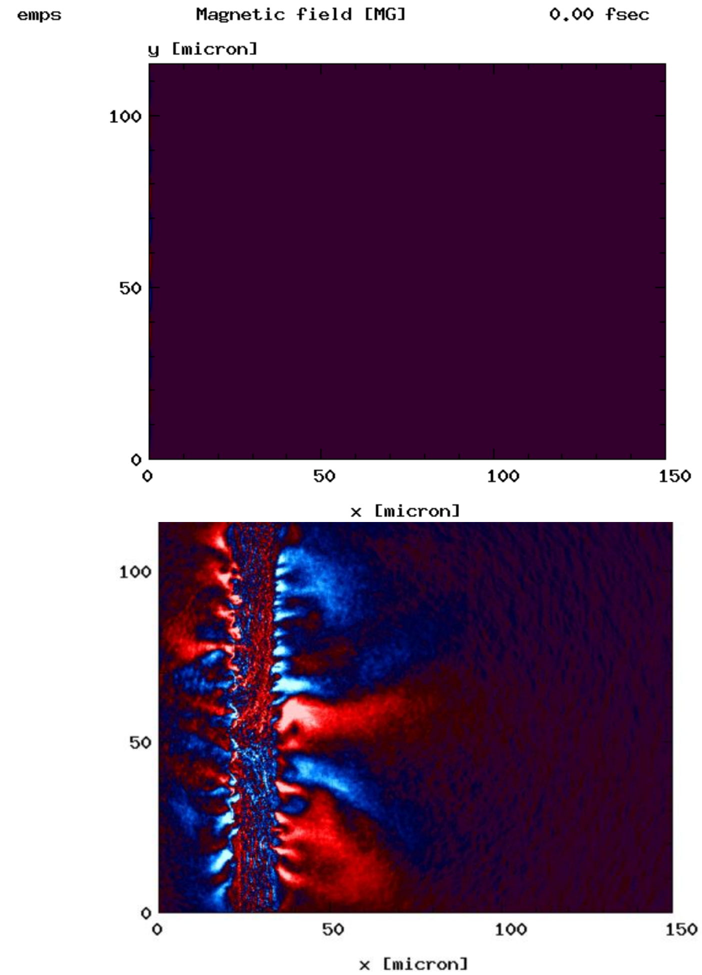


2D PIC Simulation involving Interference effects (preliminary)

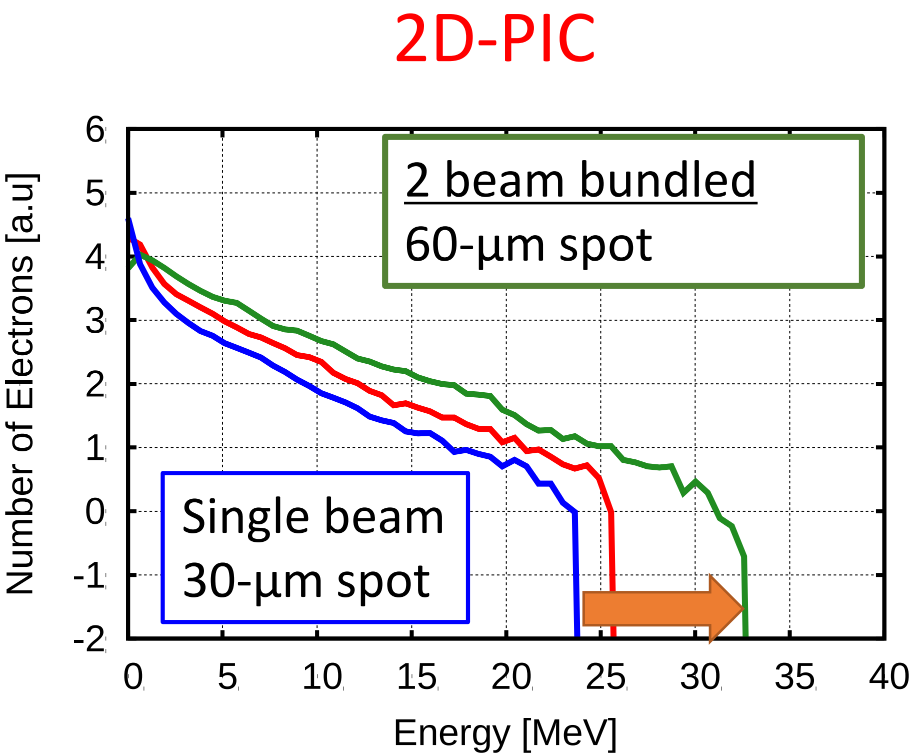
$\langle E_x \rangle$ [MV/um]

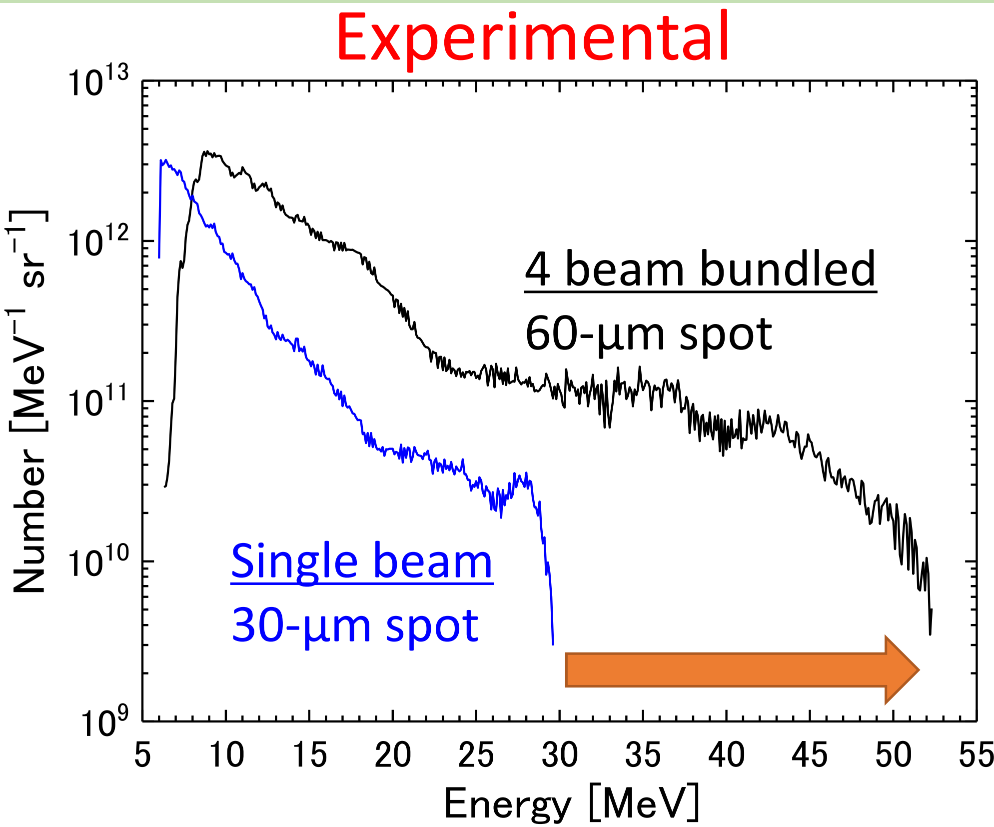


$\langle B_z \rangle$ [MG]



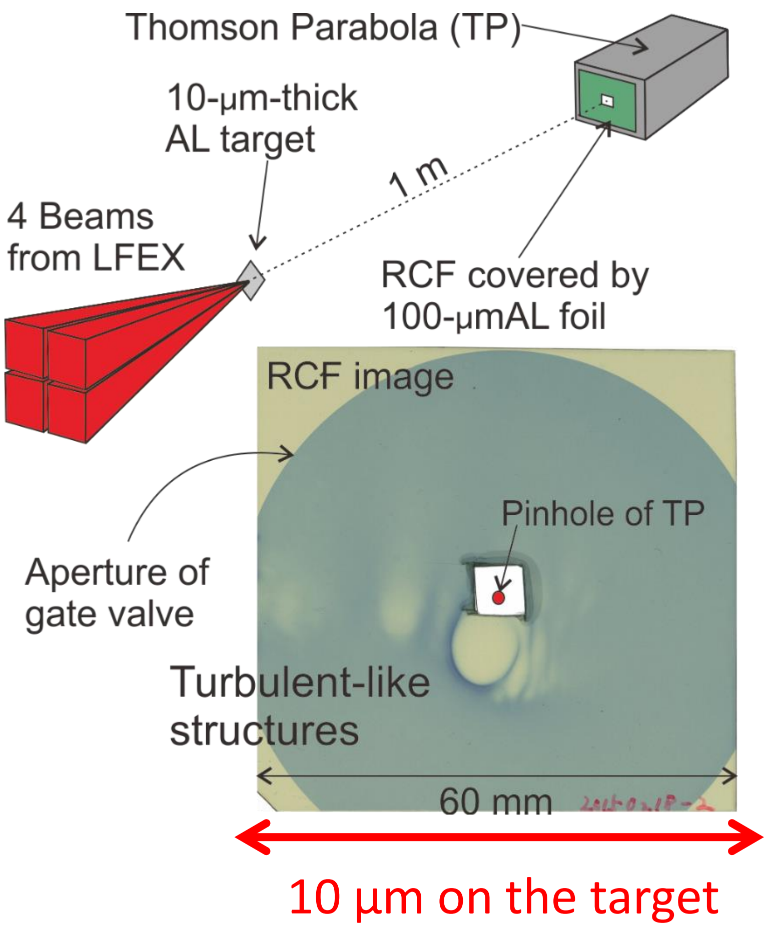
2D PIC Simulation involving Interference effects qualitatively agrees with the experimental results on the proton energy enhancement.



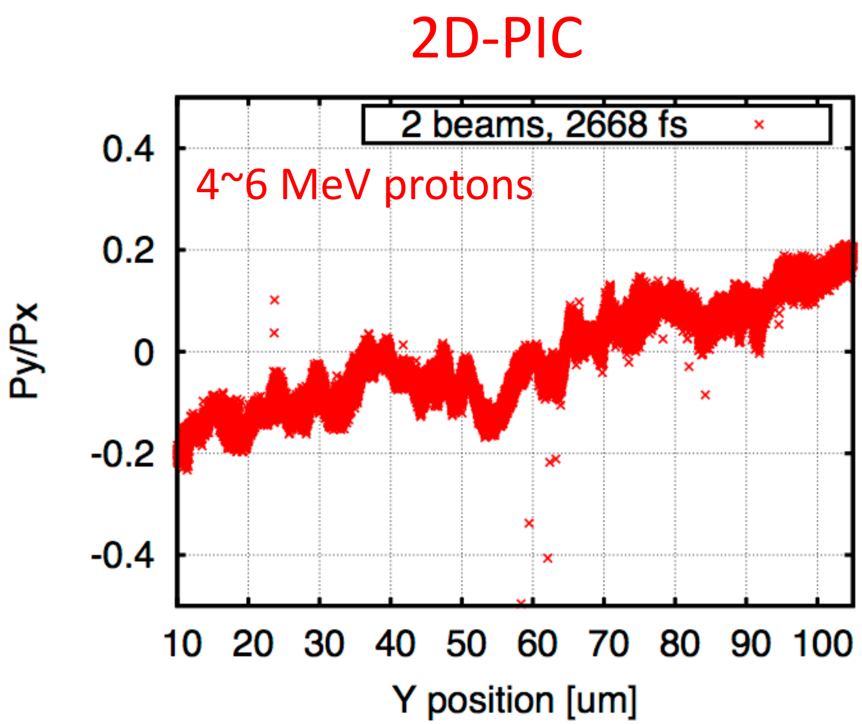


The modulated laser fields induce localized electric and magnetic fields, and also make a beneficial effect for enhancing the ion energy owning to the high absorption efficiency due to the modulation.

Evidence of the modulated electric and magnetic field ?



Recorded proton's energy: ~ 5MeV
Magnification ~ X6500
(Assuming the cone angle to be 40º)



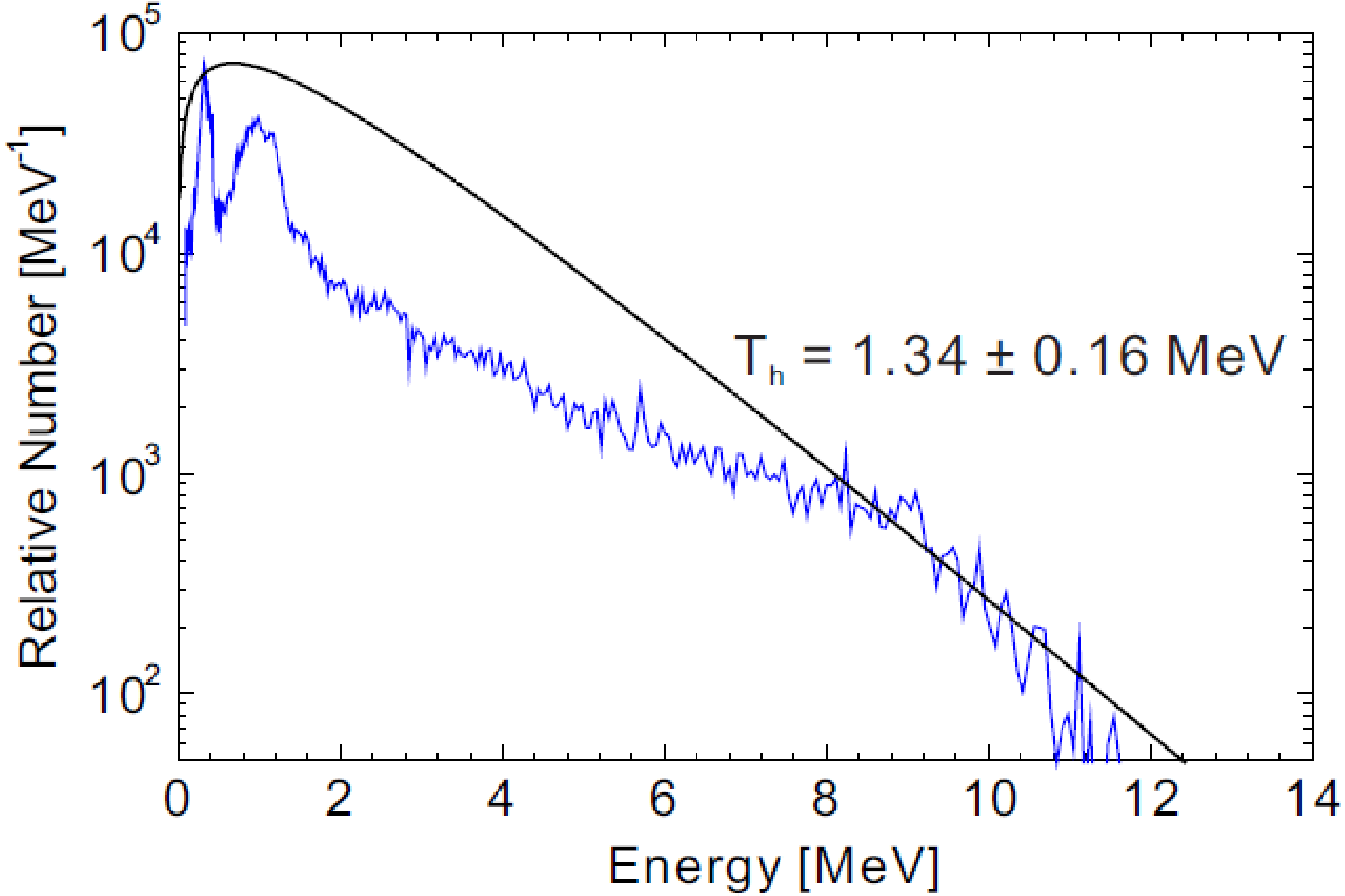
3 - 5 modulations are seen in the distance of 10 μm both for the experiment and simulation.

Summary

We demonstrated the laser-ion acceleration by bundled picosecond laser beams experimentally. 50-MeV protons were achieved from a typical thin aluminum target with 1.2×10^{19} Wcm^{-2} as total laser intensity of four bundled beams.

We confirmed by experiments and simulations that 50% enhancement of the proton energy is realized by the bundled beams.

This result can be attributed to the interference effects, which appear in multiple laser beams focused on the target with small angle each other. The modulated laser fields induce localized electric and magnetic fields also on the rear side, which make a beneficial effect for enhancing the ion energy owning to the high absorption efficiency due to the modulation.



Relative Number [MeV-1]
Energy [MeV]
T_h = 1.34 ± 0.16 MeV
10^5
10^4
10^3
10^2
0
2
4
6
8
10
12
14