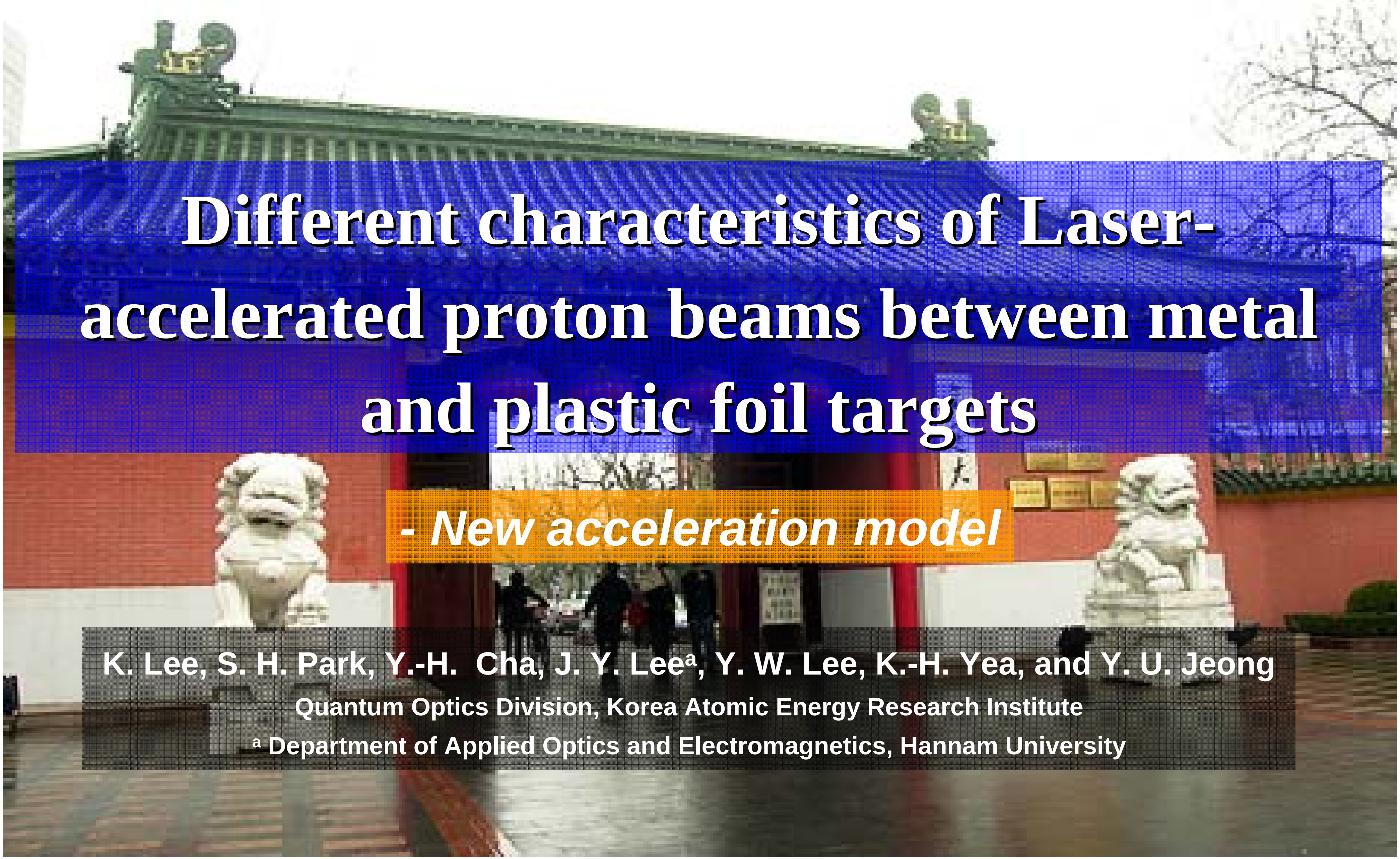
2008 ICUIL, Tongli, Shanghai

2008. 10. 27 ~ 10. 31

韓國原子力研究院
Korea Atomic Energy Research Institute



Different characteristics of Laser-accelerated proton beams between metal and plastic foil targets

- New acceleration model

K. Lee, S. H. Park, Y.-H. Cha, J. Y. Lee[a], Y. W. Lee, K.-H. Yea, and Y. U. Jeong

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[a] Department of Applied Optics and Electromagnetics, Hannam University

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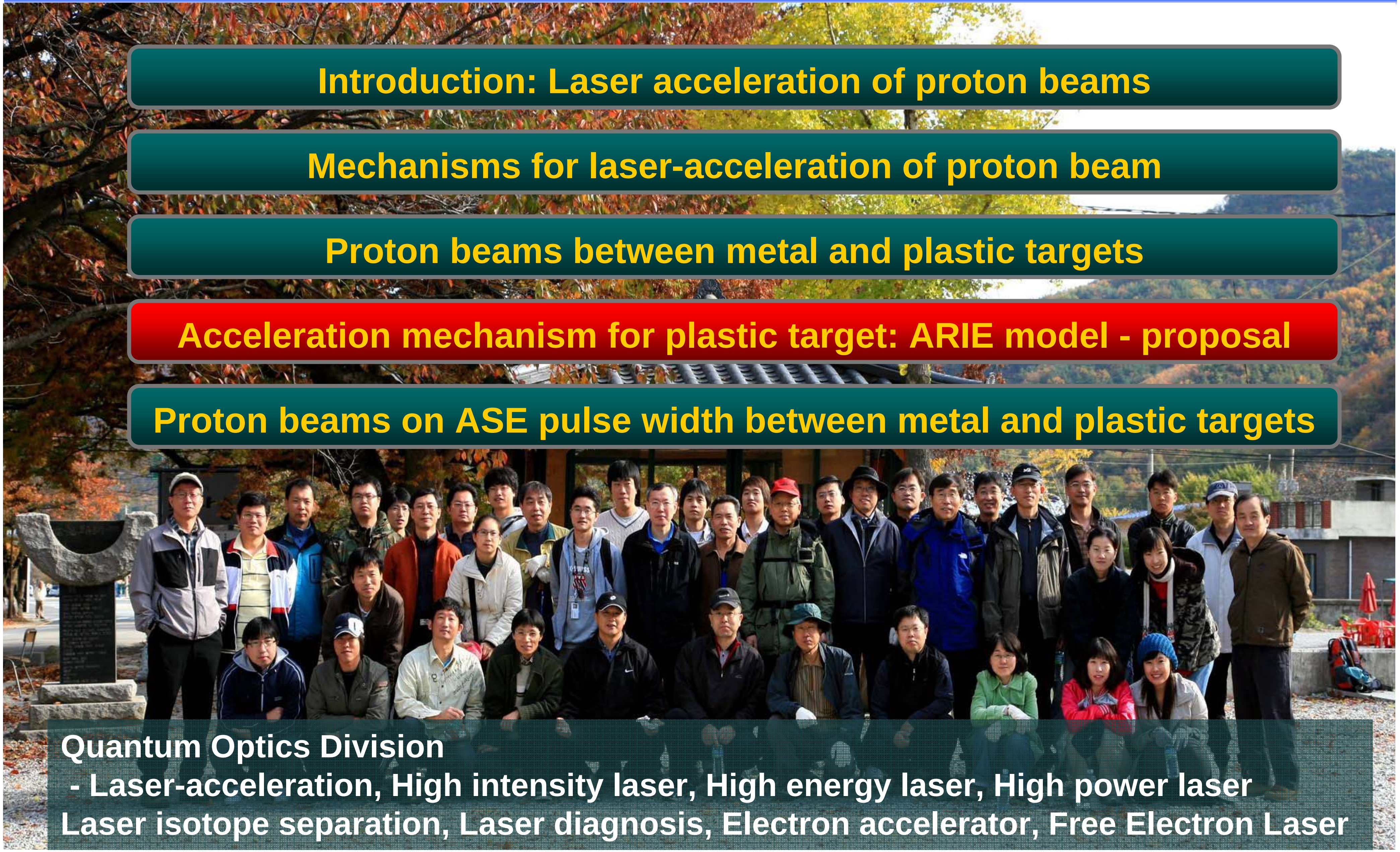


Quantum Optics Division

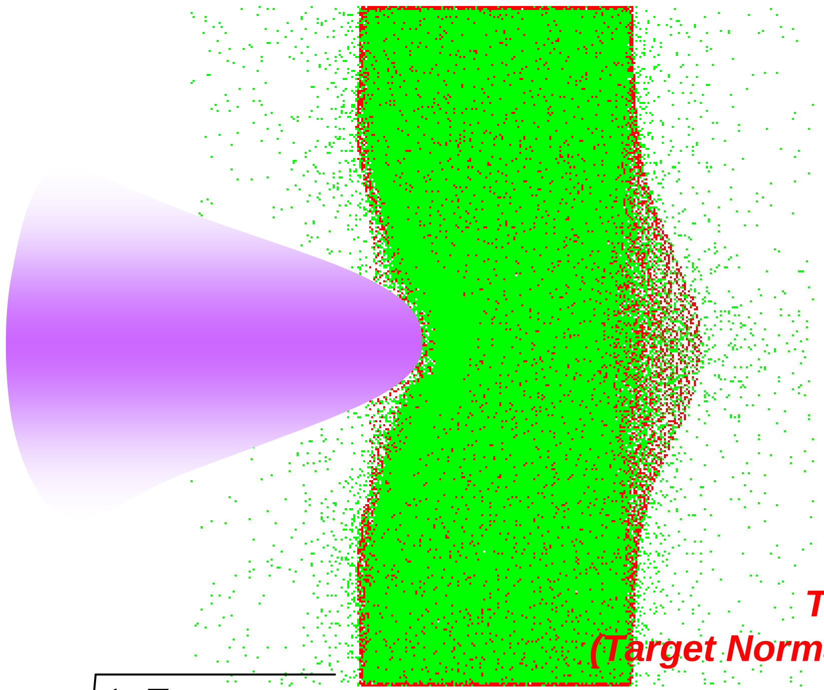
- Laser-acceleration, High intensity laser, High energy laser, High power laser

Laser isotope separation, Laser diagnosis, Electron accelerator, Free Electron Laser

Laser induced acceleration of ion beams

- ***Mechanisms***

:relativistic intensity (a>1), overdense (n_e>n_c (ω_p> ω_L))



TNSA (Target Normal Sheath Accel.)

$$\frac{u_s}{c} = \sqrt{\frac{1}{2}\frac{Zm_e}{M_i}\frac{n_c}{n_e}a_o^2}$$

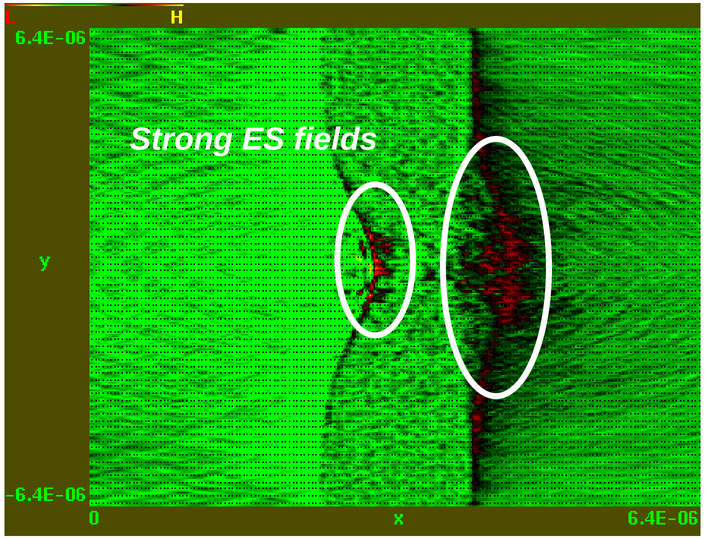
Isothermal expansion model

Mora, PRL 90, 185002 (2003)

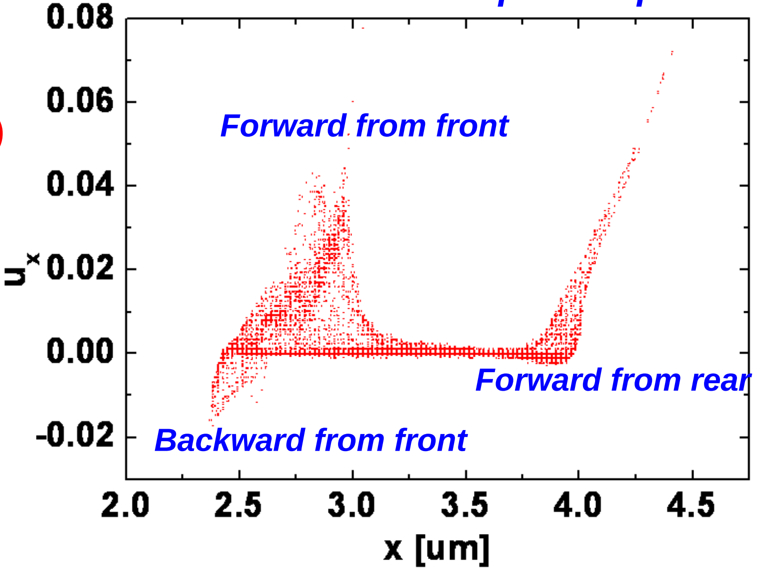
$$E_{es}^{peak} = \sqrt{\frac{2}{e_E}} \times \sqrt{4\pi n_o T_e}$$

$$E_{\max} \approx 2T_e \ln^2\left(\frac{\omega_{pi}t}{\sqrt{2e_E}} + \sqrt{\frac{\omega_{pi}^2 t^2}{2e_E} + 1}\right)$$

Electrostatic field

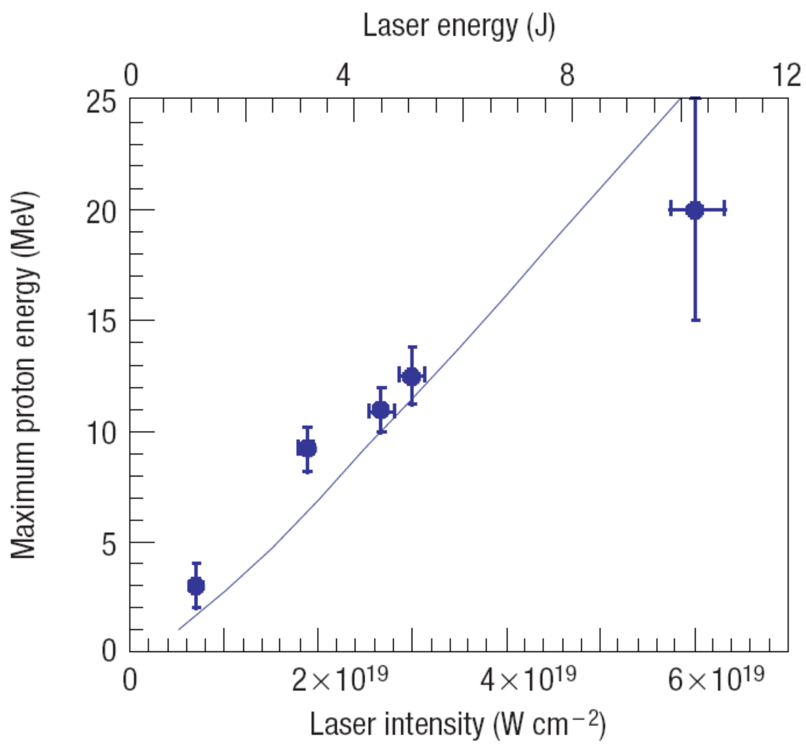


Proton X-Vx phase space

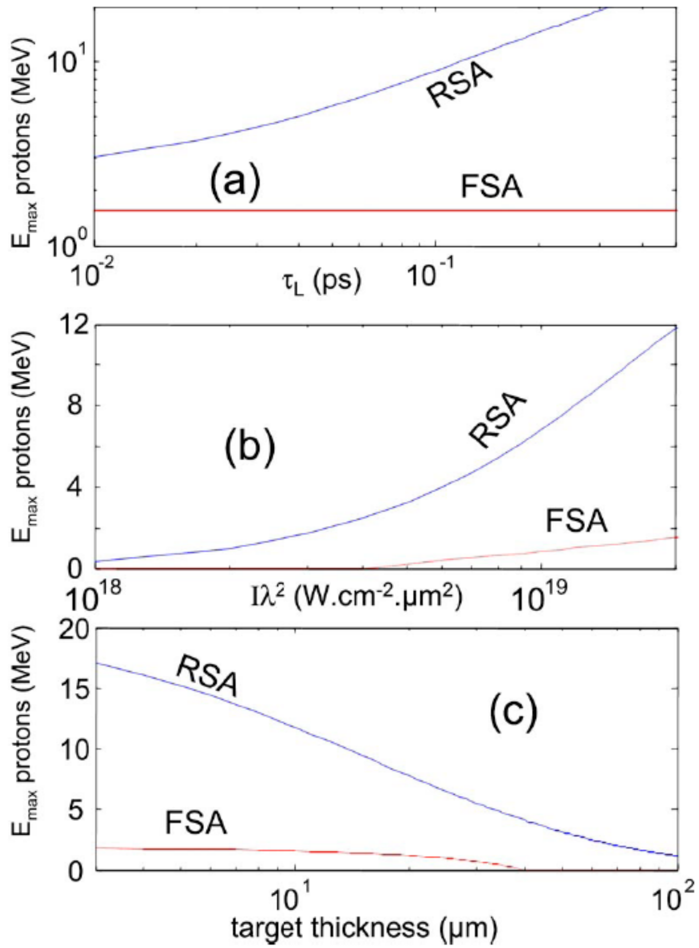


Rear Side Accel. is dominant for metal target

J. Fuchs et al., Nature Phys. 2, 48, (2006)



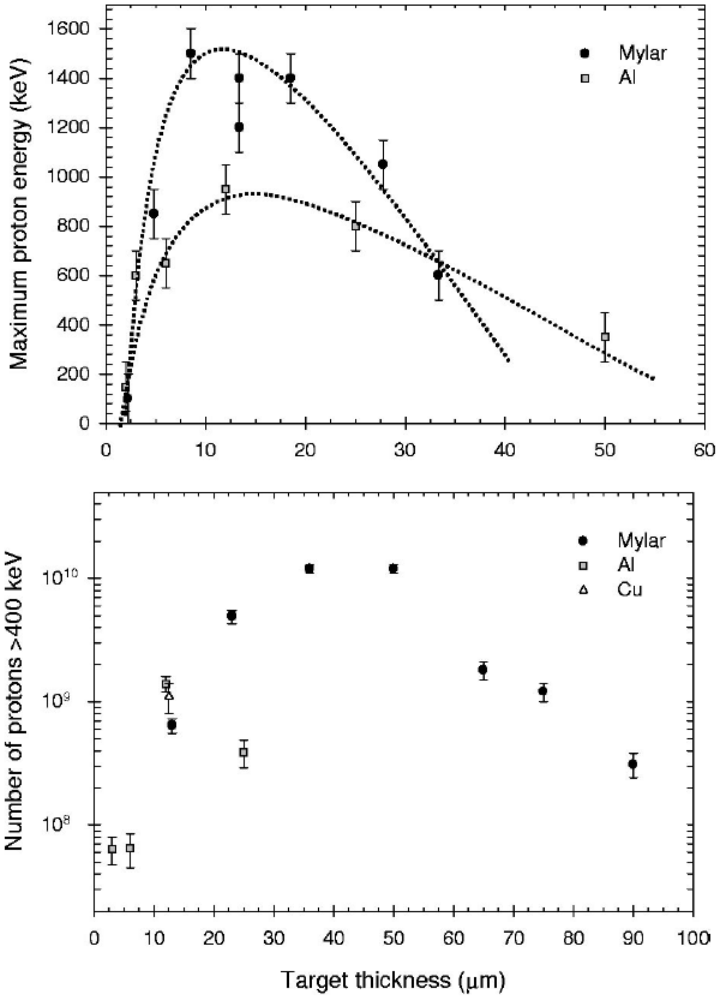
J. Fuchs et al., POP 14, 053105 (2007)



Observation of more intense proton beam from plastic targets

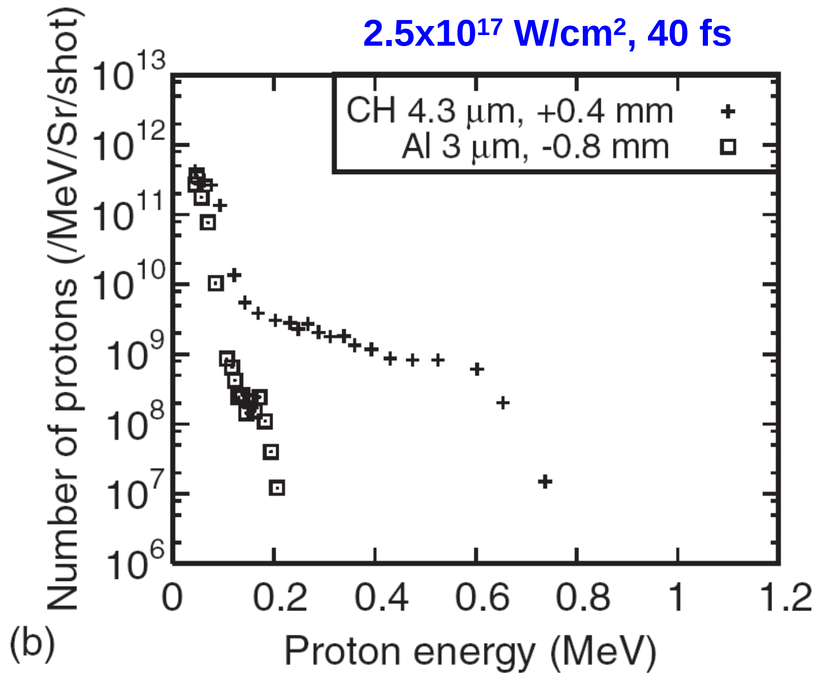
Spencer et al., PRE 67, 046402 (2003)

7x10^{18} W/cm^2, 60 fs

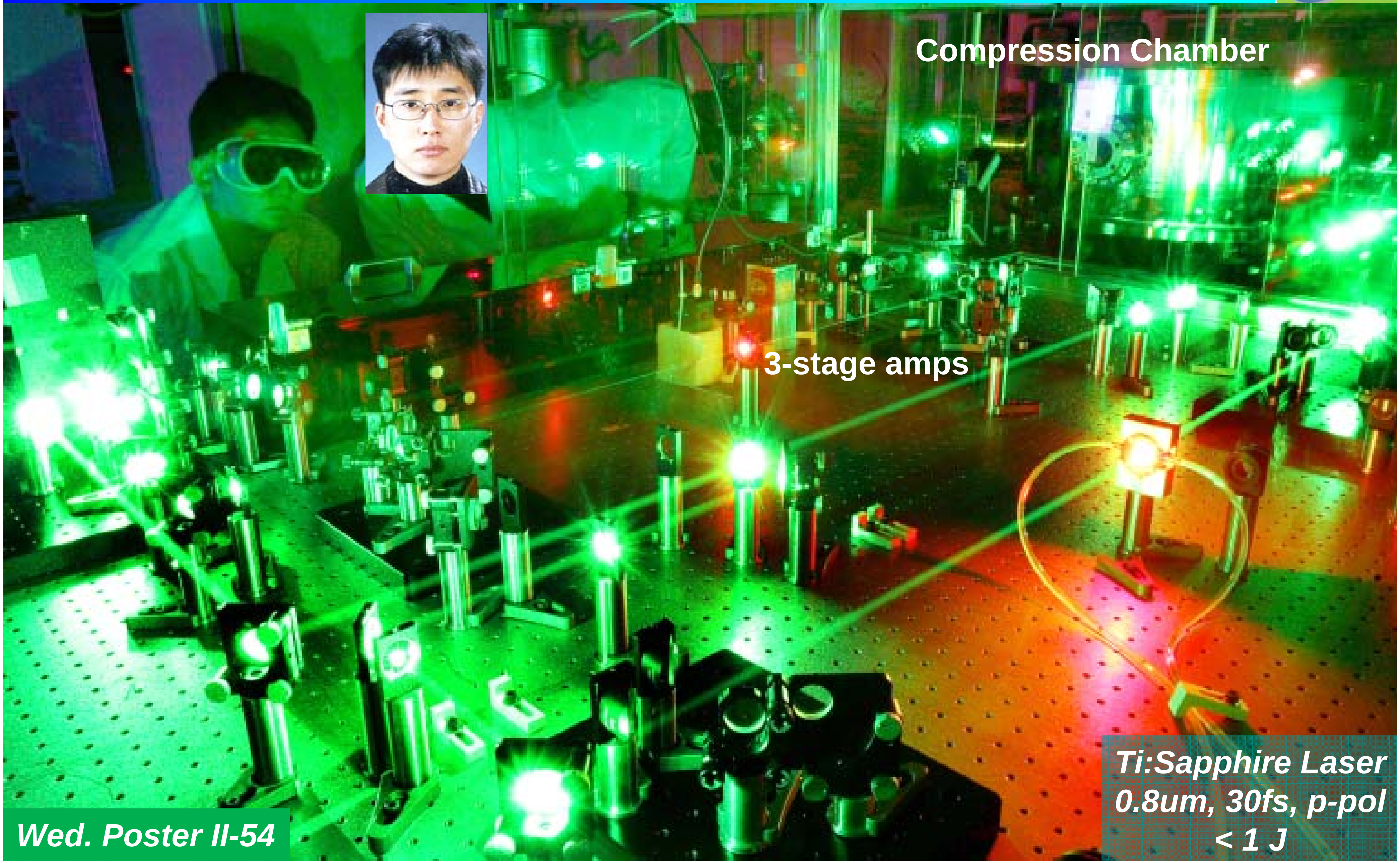


Y. Wada, JJAP 44, 3299 (2005)

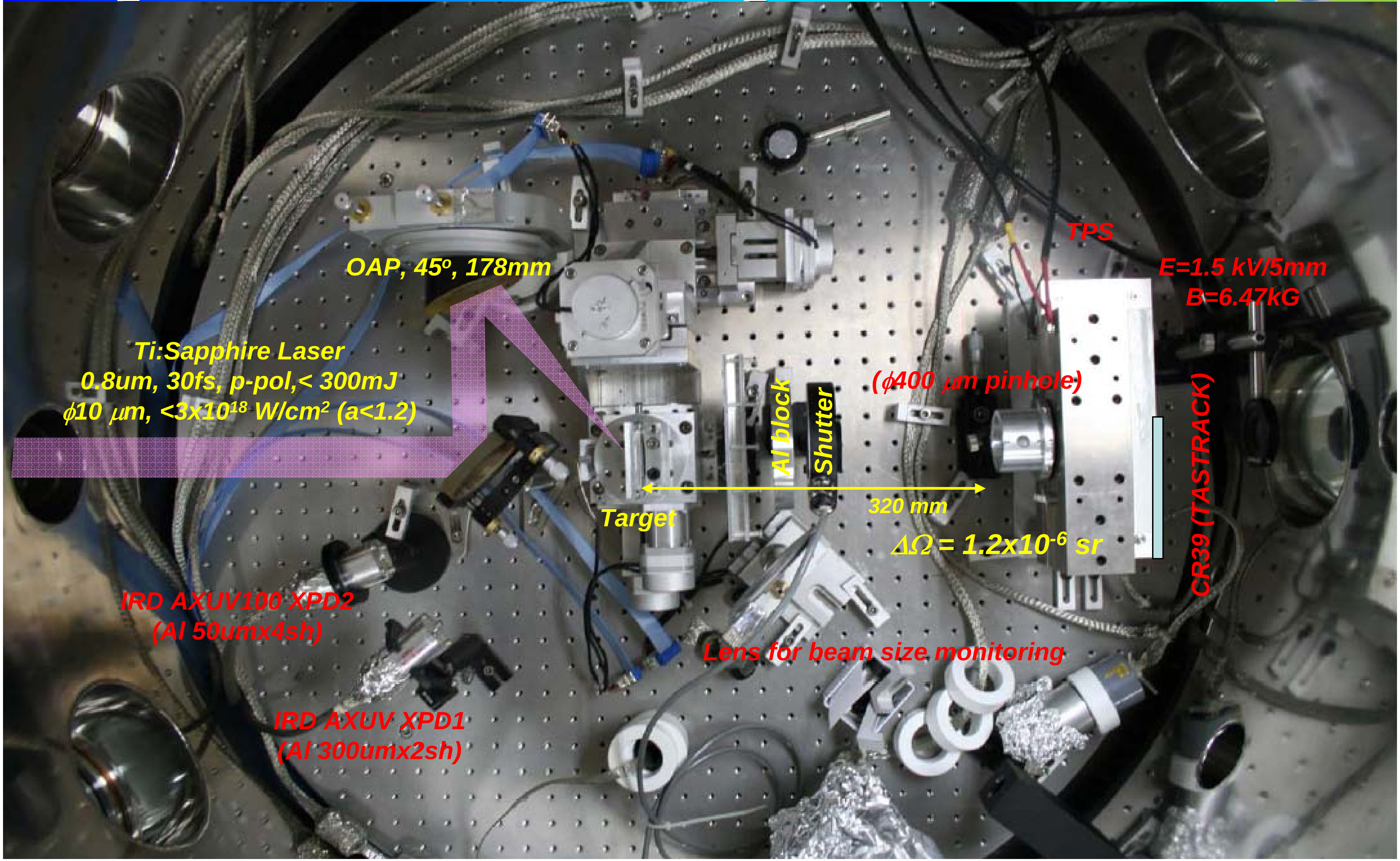
2.5x10^{17} W/cm^2, 40 fs



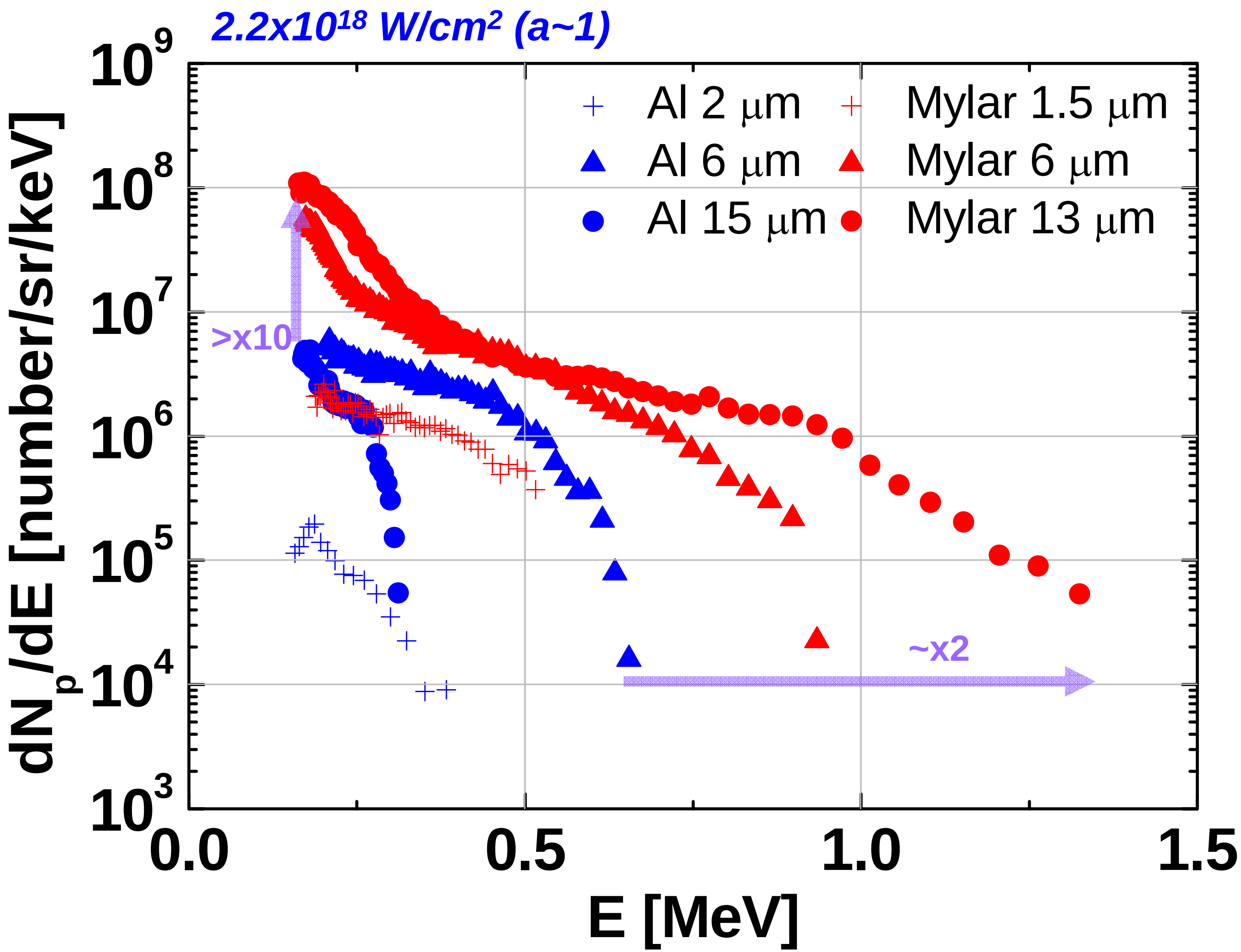
KAERI Table-top 30 TW Laser



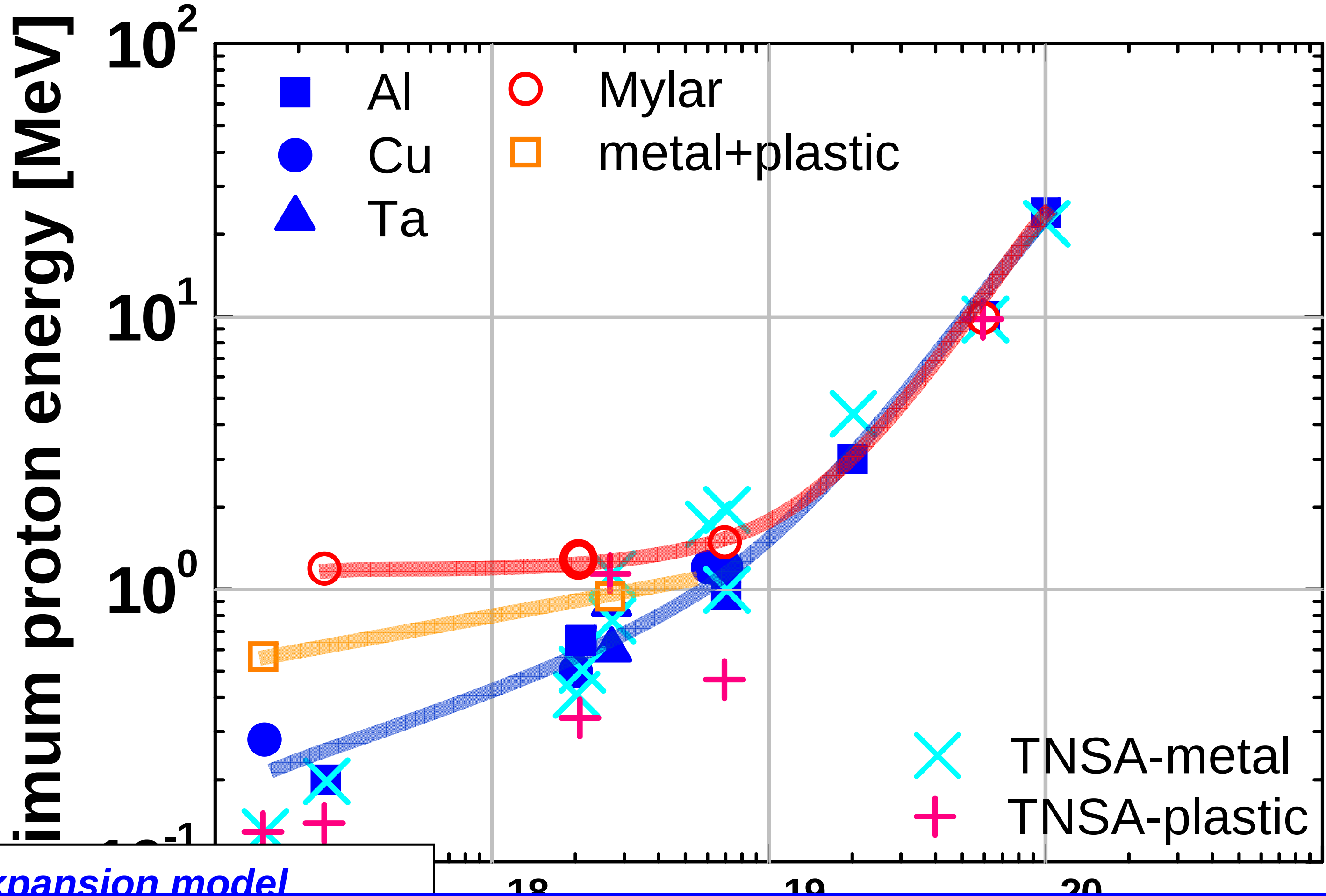
Experimental Set-Up I



Proton beams on target materials



Anomalous behavior of Plastic target



Schreiber2006
Ffritzler2003
Spencer2003
Wada2005
Kishimura2004
Yogo2006
Fuiji2003
Fukumi2005
Oishi2005
Mackinnon2002
(30-100fs)

Isothermal expansion model

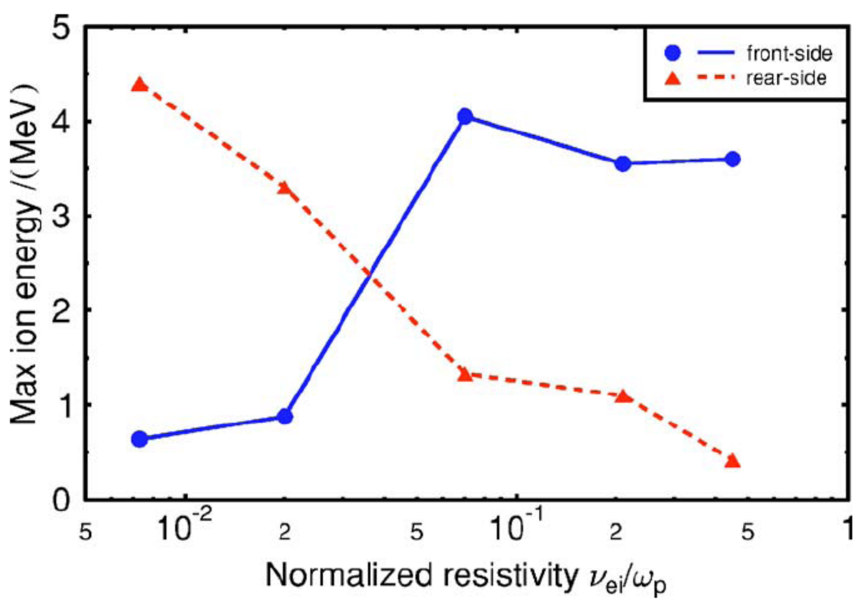
- ***Protons from Mylar target have higher maximum energies in 10^{17}-10^{19} W/cm^2***
- ***For Mylar targets, there are large discrepancies between exp. and model.***
- ***Metals coated with plastic place between Mylar and metal.***
- ***These investigations require new acceleration mechanisms for plastic target.***

Anomalous behavior of Plastic target

1. Comment of a bulk acceleration by Spencer et al.

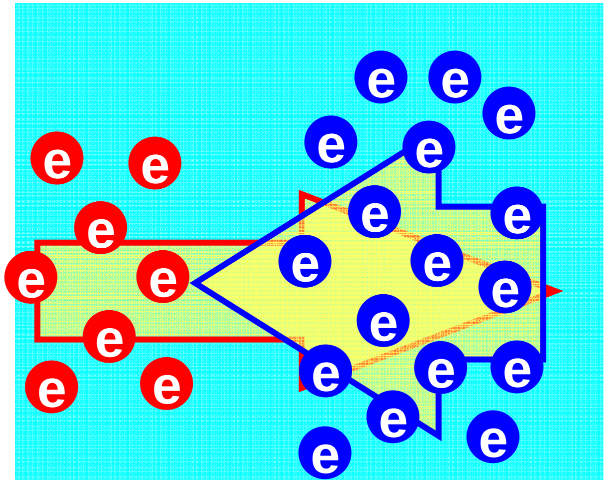
2. Initial high plasma resistivity of plastic target

- ***High resistivity of initially unionized plastic target is seriously underestimated by the plasma model –*** *Key et al., POP **5**, 1966 (1998).*
- ***Spatial disruption of electron flow inside insulator target –*** *Fuchs et al., PRL **91**, 255002 (2003).*
- ***As target resistivity increases, front side acceleration becomes dominant –*** *Gibbon PRE 72, 026441 (2005).*
- ***Inhibition of hot electron transport by resistively induced electric field – Bell et al.***



Inhibition of hot electron transport by Resistively Induced Electric field

Bell et al., PPCF 39, 653 (1997)



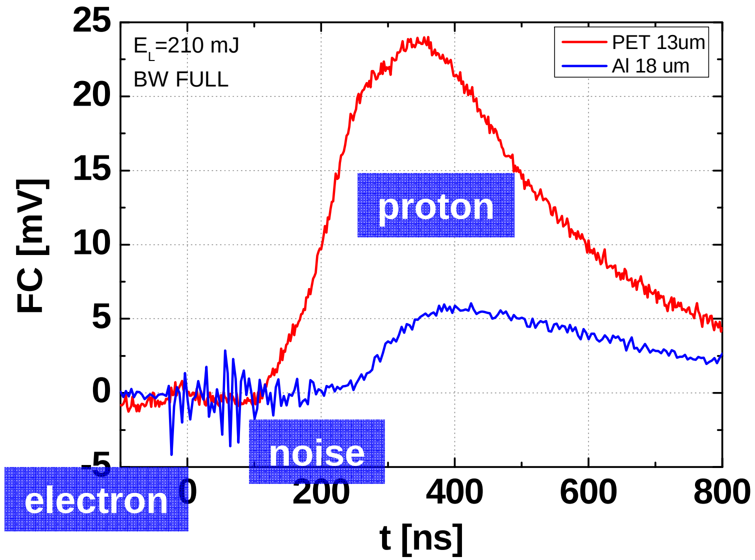
$J_h \sim n_h ec$ $\qquad J_{return} \sim n_{th} e v_{th} \sim E_r/\eta$

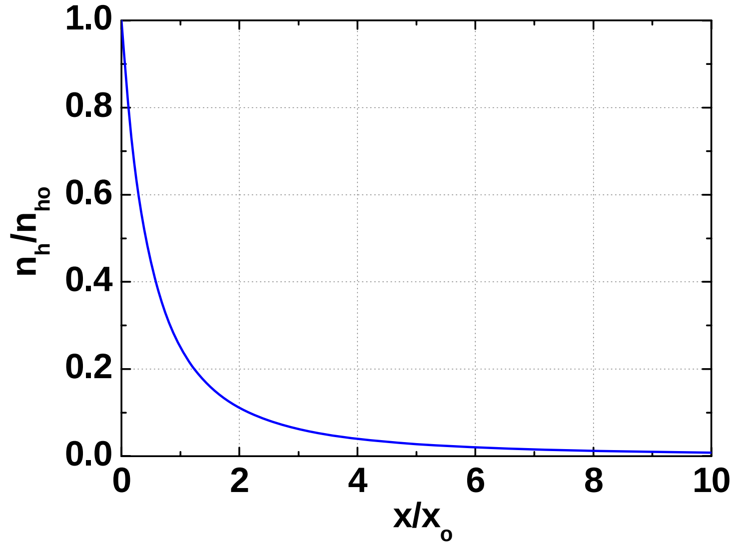
$$n_h = n_{ho}\left(\frac{t}{\tau_L}\right)\left(\frac{x_o}{x+x_o}\right)^2,$$

$$n_{ho} = 1.4\times10^{20}\,\eta\,\frac{I_{abs}^2\tau_L}{T_h^3}\left[cm^{-3}\right],$$

$$x_o = 300\,\frac{T_h^2}{\eta I_{abs}}\left[\mu m\right]$$

10^{18} W/cm^2, ps, MeV, $\mu\Omega m$





ARIE model

Acceleration by Resistively Induced Electric field

K. Lee et al., PRE 78, (2008)

$E_r = \eta J_{return} \sim \eta J_h \sim \eta n_h e v_h$

$$T_h = m_e c^2 \left(\sqrt{1+a^2} - 1 \right)$$

$$E_r = E_o \left(\frac{t}{\tau_L} \right) \left(\frac{x_o}{x + x_o} \right)^2,$$

$$E_o = \eta e c n_{ho} \frac{a}{\sqrt{1+a^2}},$$

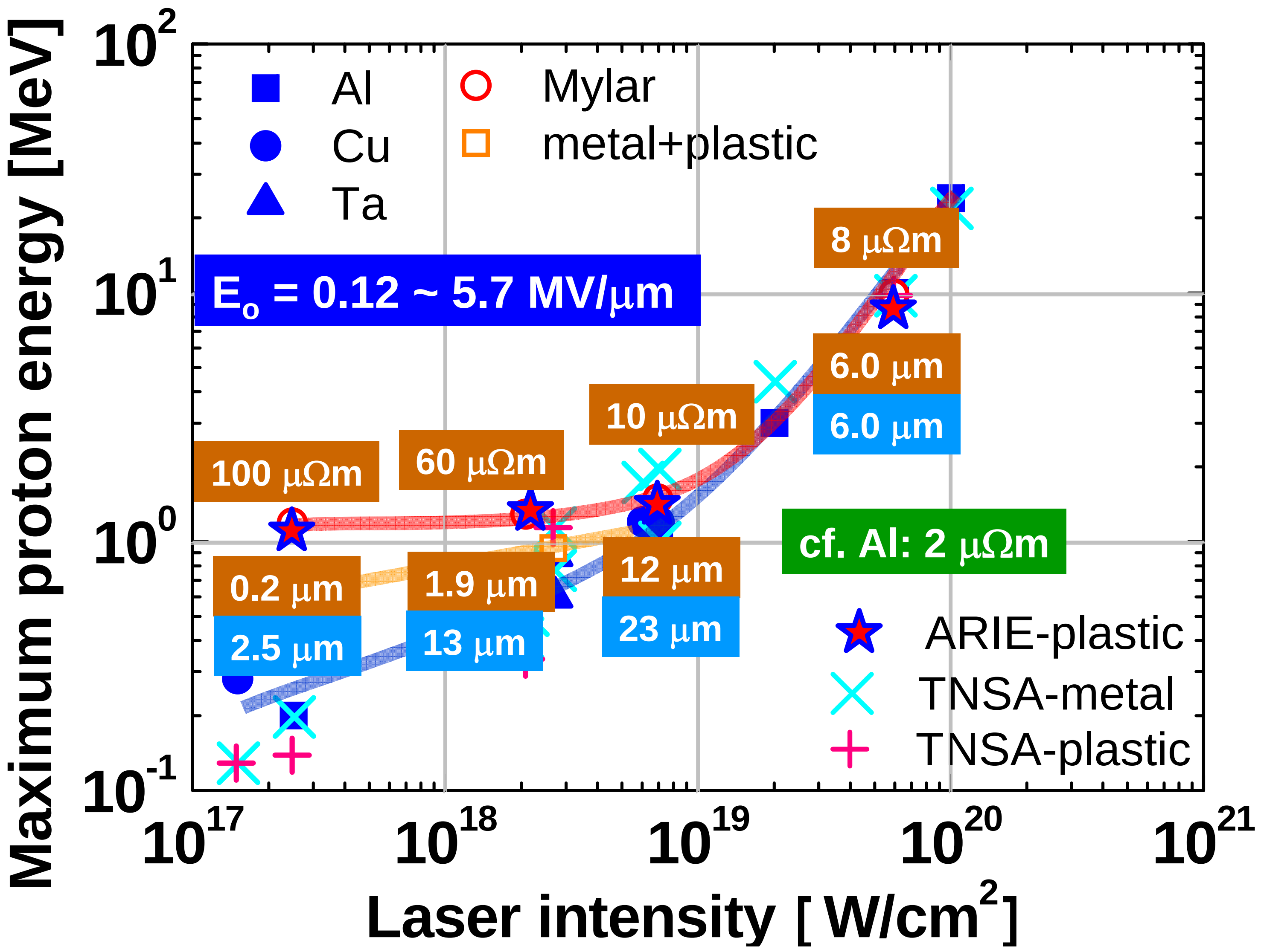
Assumption: - V_h from T_h
- Proton is accelerated after $t=\tau_L$,
- E_r is kept static during acceleration.
- Maximum proton energy from x=0

$$E_p^{\max} = e E_o x_o$$

$$\approx 2 \frac{\eta f I \tau_L}{T_h} \frac{a}{\sqrt{1+a^2}} [MeV]$$

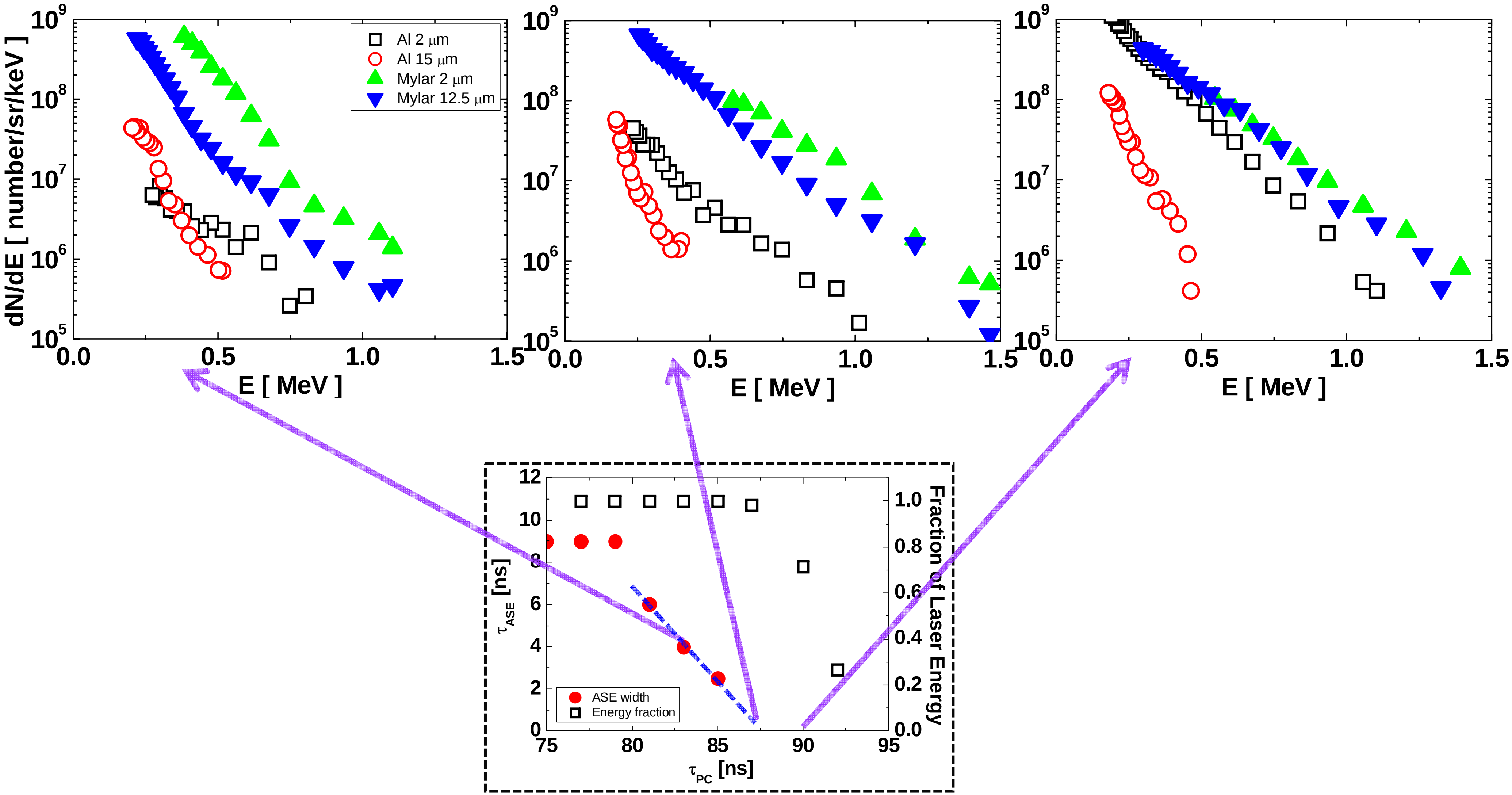
1. Linear dependence on resistivity
   - ARIE gets dominant for plastic target of which resistivity considered to be high
2. Bulk acceleration: Higher number of protons
3. *But it is difficult to determine plasma resistivity in a self consistent way*

Anomalous behavior of Plastic target

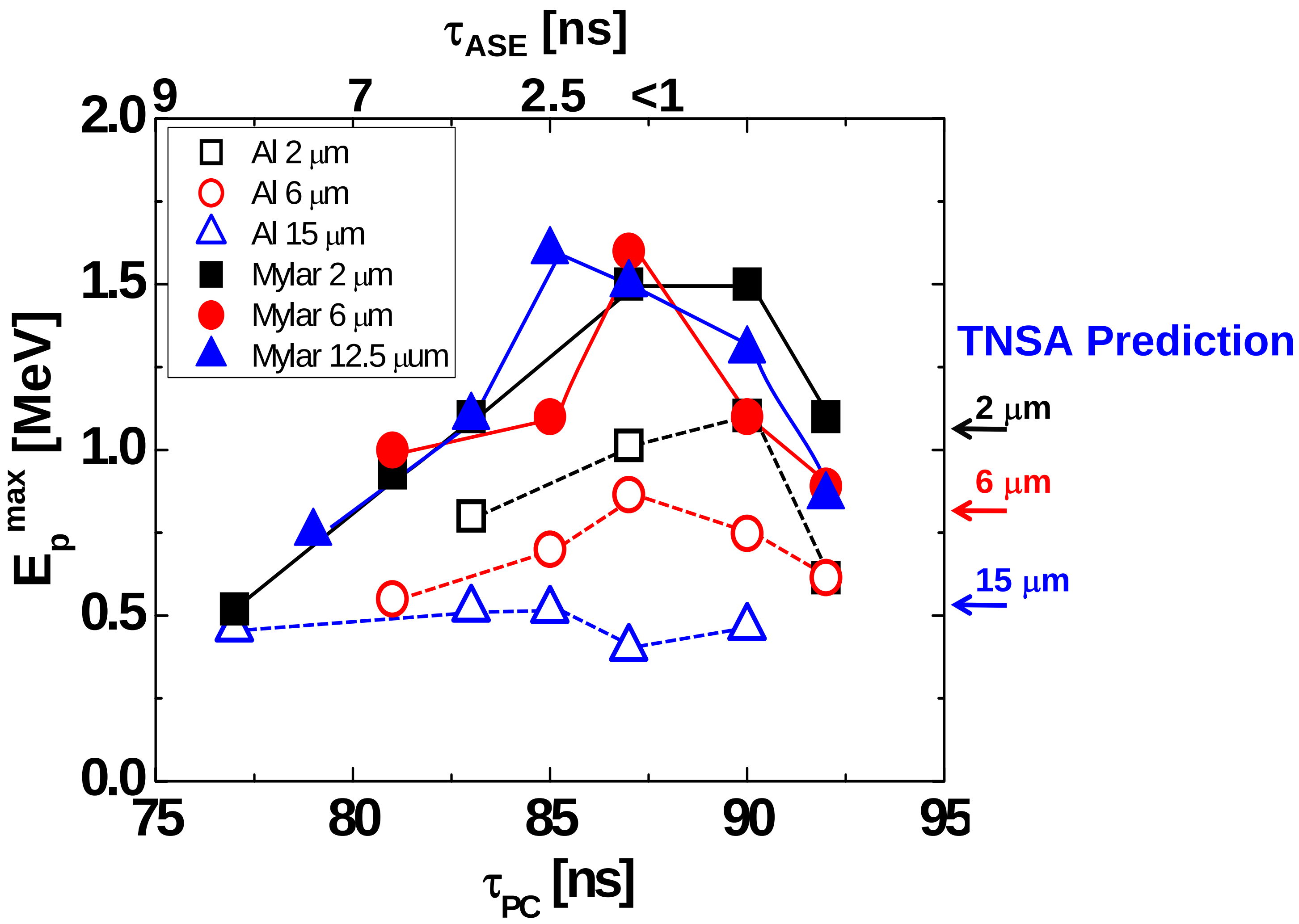


Proton Spectrum on Pre-pulse

2.4x10^{18} W/cm^2



Maximum Proton energies on Pre-pulse



Summary

- ***Proton beams generated from metal and plastic targets are compared,***
- ***which shows distinct differences.***
- ***An acceleration model, ARIE is proposed to account for more intense proton beams from plastic targets.***
- ***An effect of the ASE pulse width on the proton generation is also compared between metal and plastic targets,***
- ***which also show clear differences and in the case of plastic targets, it also can be addressed from the ARIE model***
- ***We are preparing a scheme utilizing such an acceleration mechanism for more efficient generation of the proton beams.***

Thank for your attention !

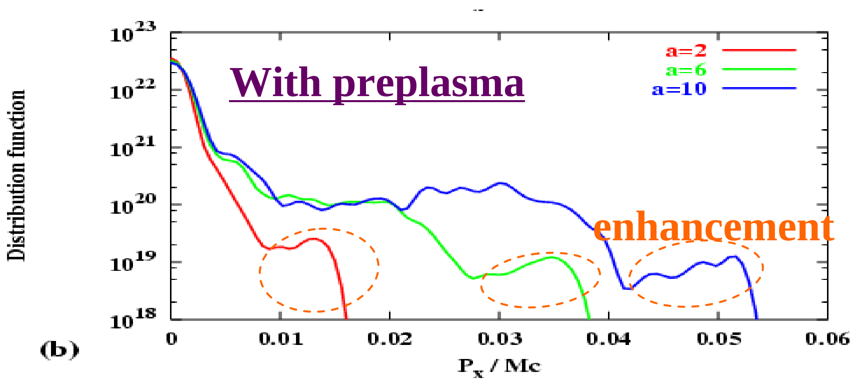
and

I cowardly invite you to the SOLS 2008 !

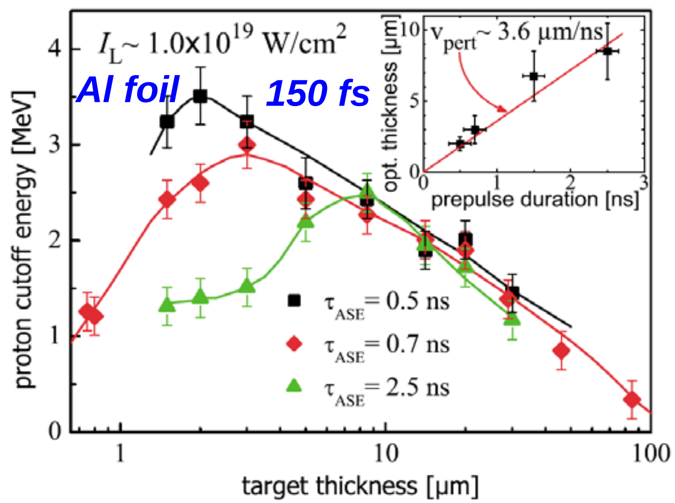
Proton beams on a laser prepulse

H. J. Lee et al. POP 11, 1726 (2004)

2D PIC simulation

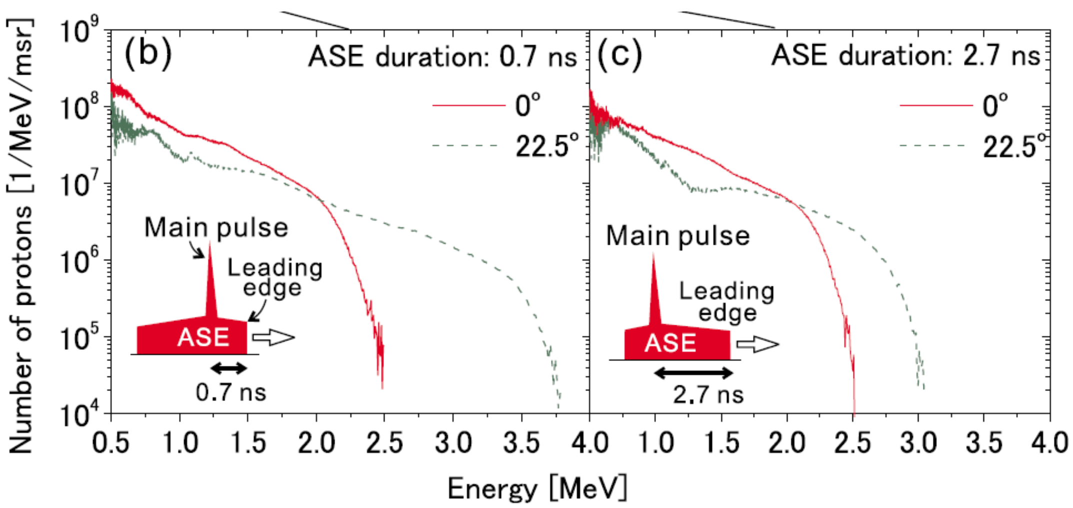


MPI, Kaluza et al. PRL 93, 045003 (2004)

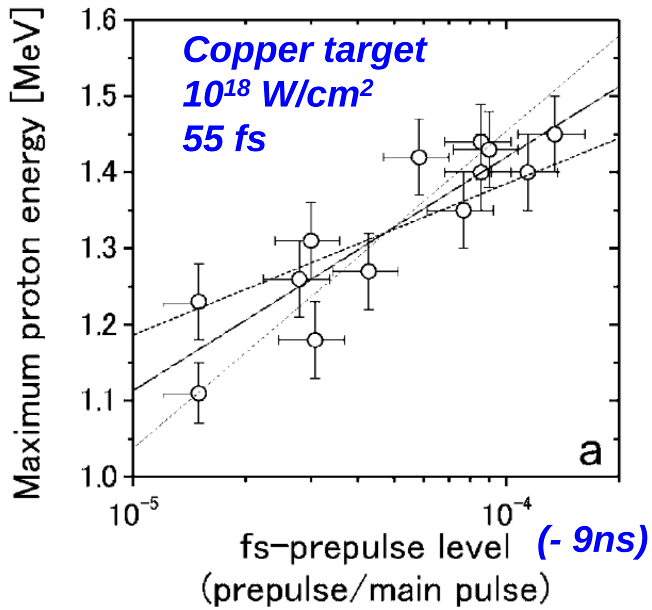


Yogo et al. PRE 77, 016401 (2008)

Polyimid target, 10^{19} W/cm^2, 45 fs

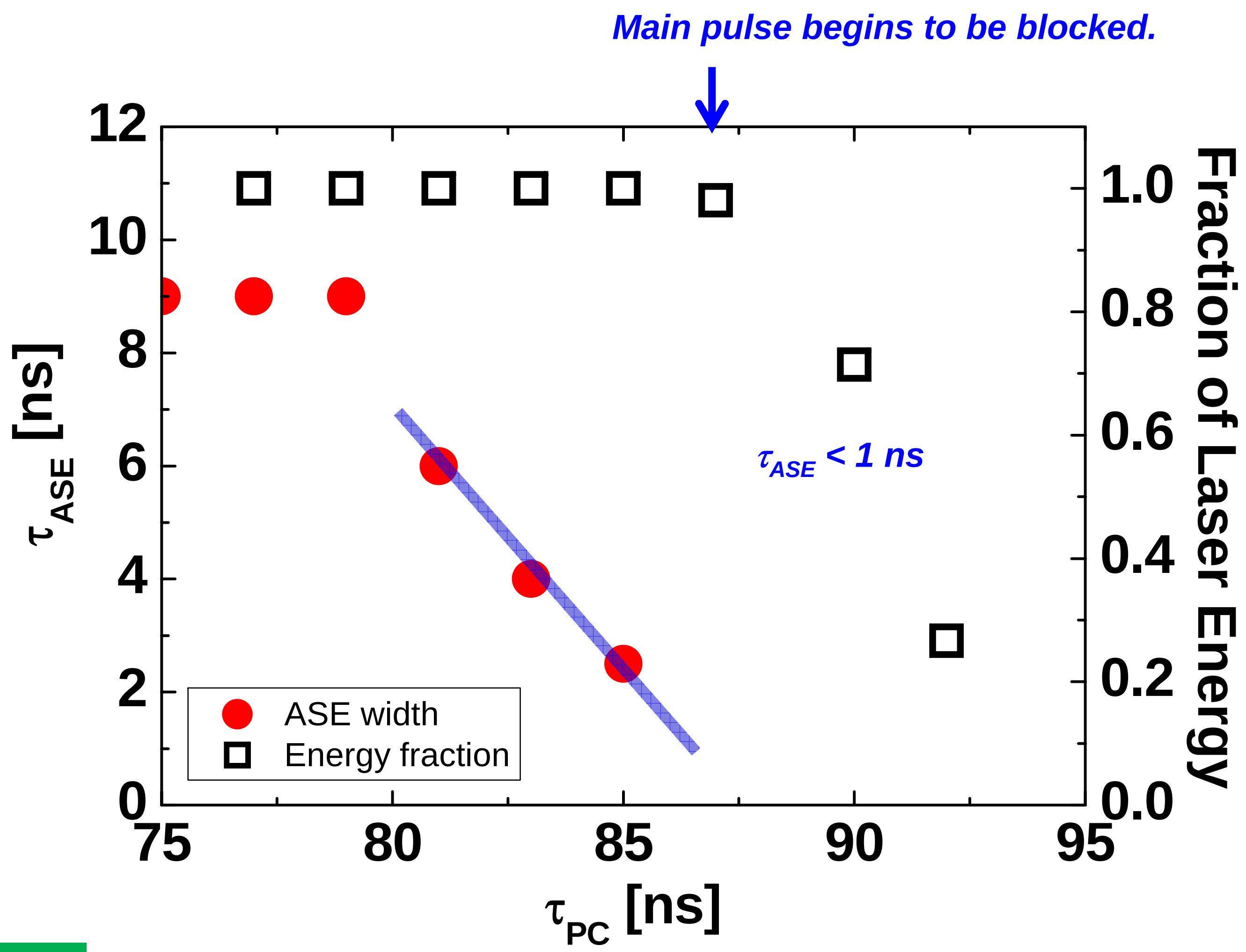


Yogo et al. POP 14, 043104 (2007)



Laser Prepulse (ASE)

Control of ASE pulse width by changing pulse picker opening time installed after a pre-amplifier

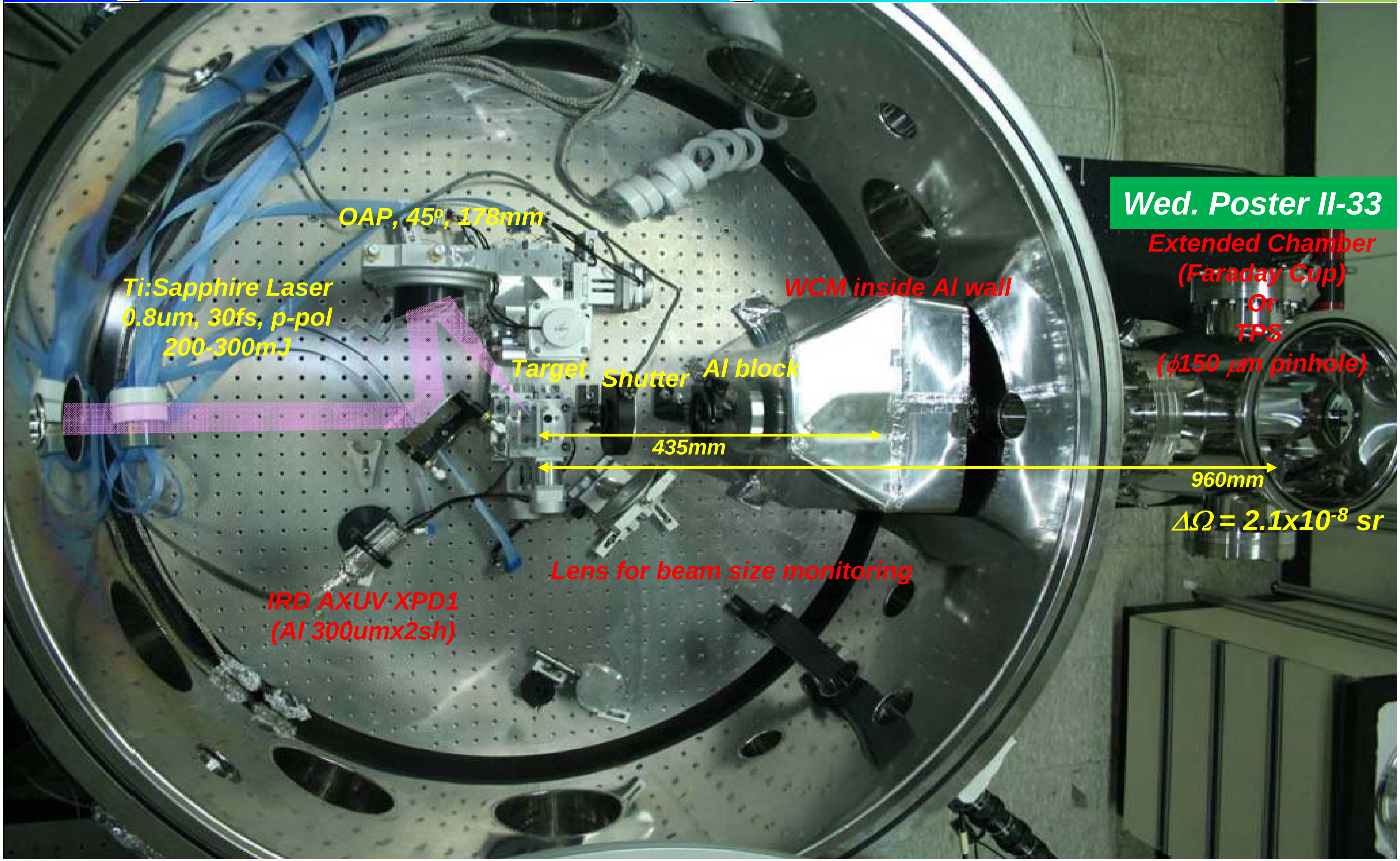


Wed. Poster II-54

- *For measurement of the contrast ratio*

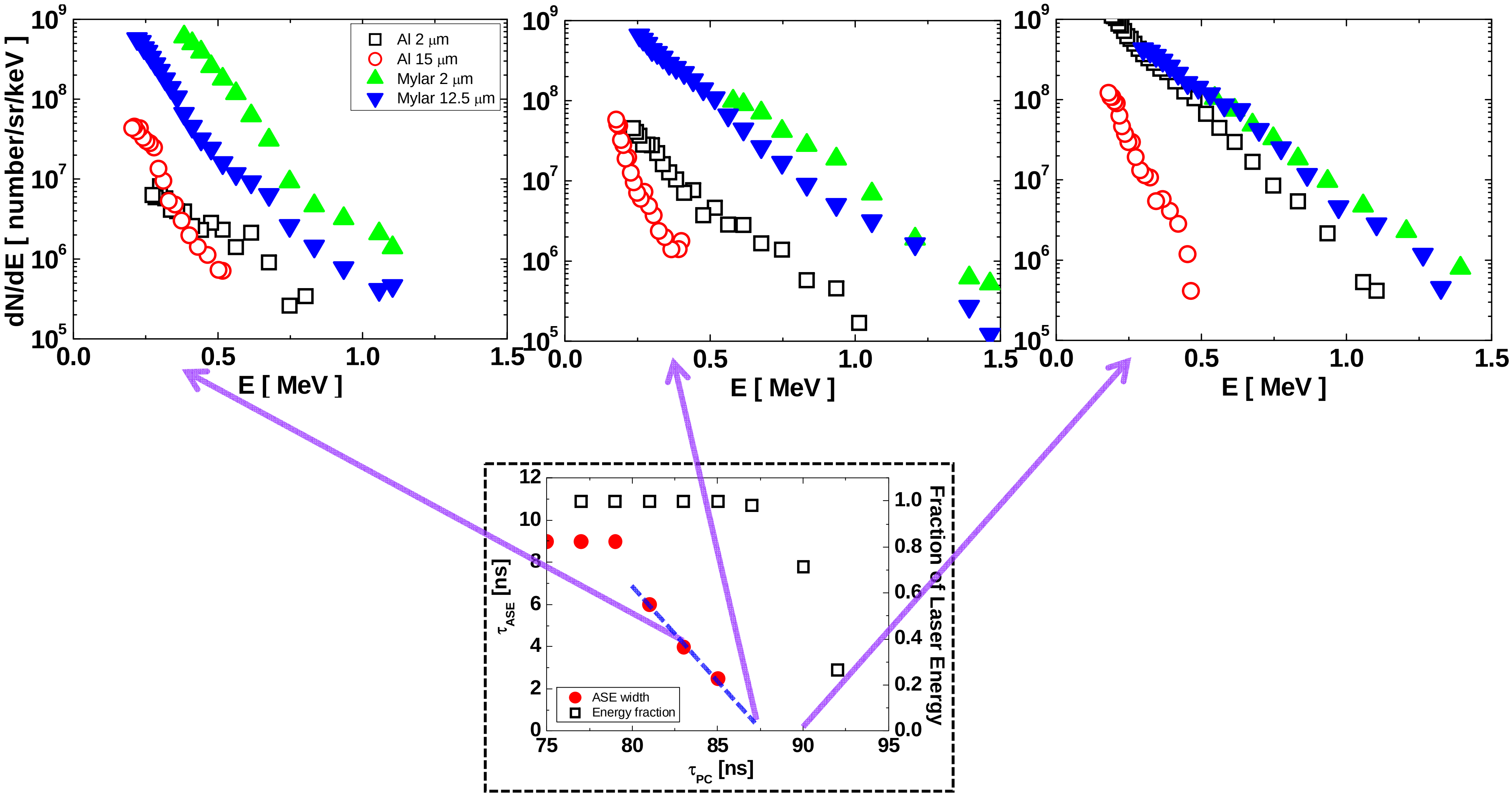
Y. H. Cha et al., Appl. Opt. 46, 6854 (2007)

Experimental Set-up

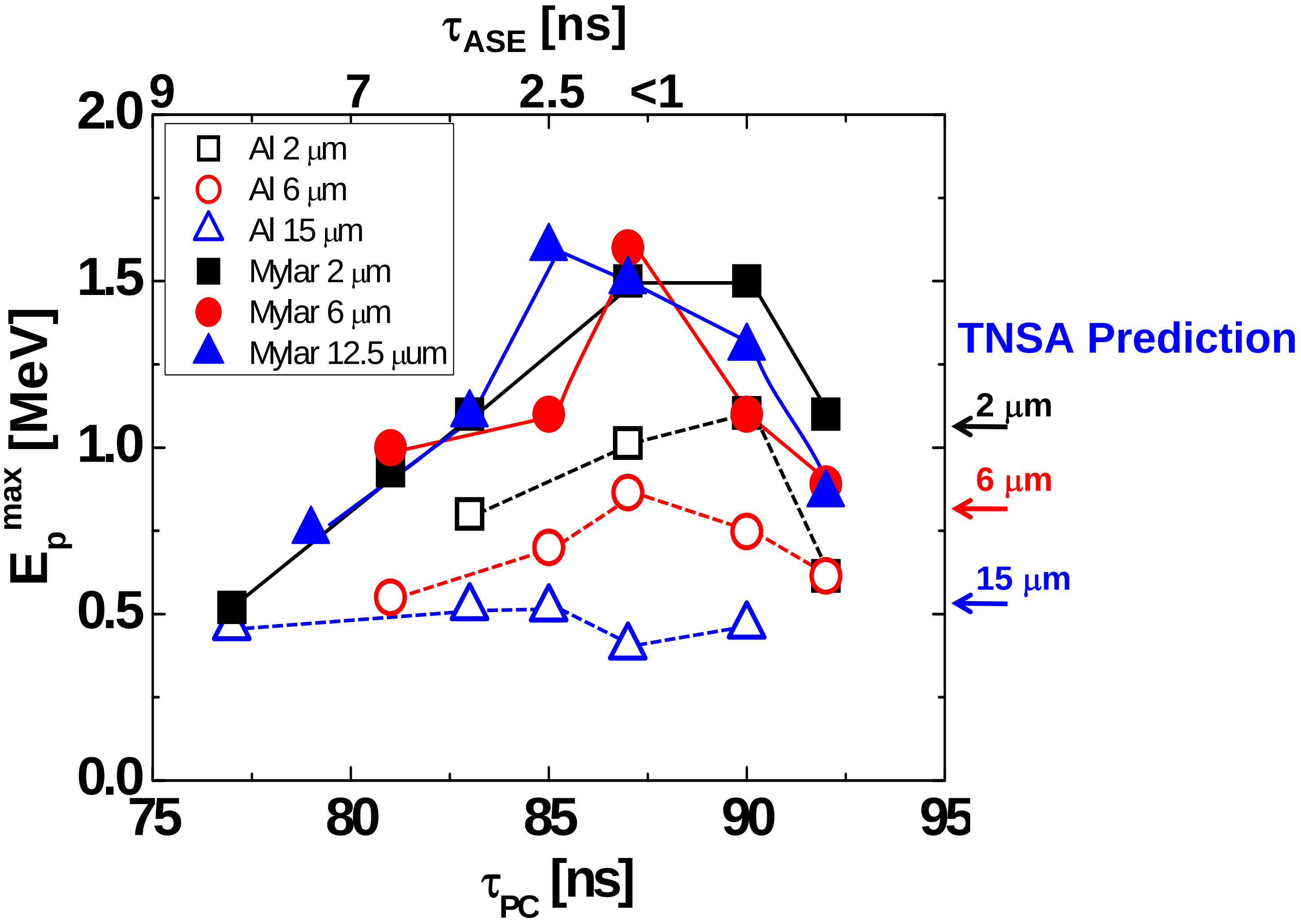


Proton Spectrum on Pre-pulse

2.4×10^{18} W/cm^2

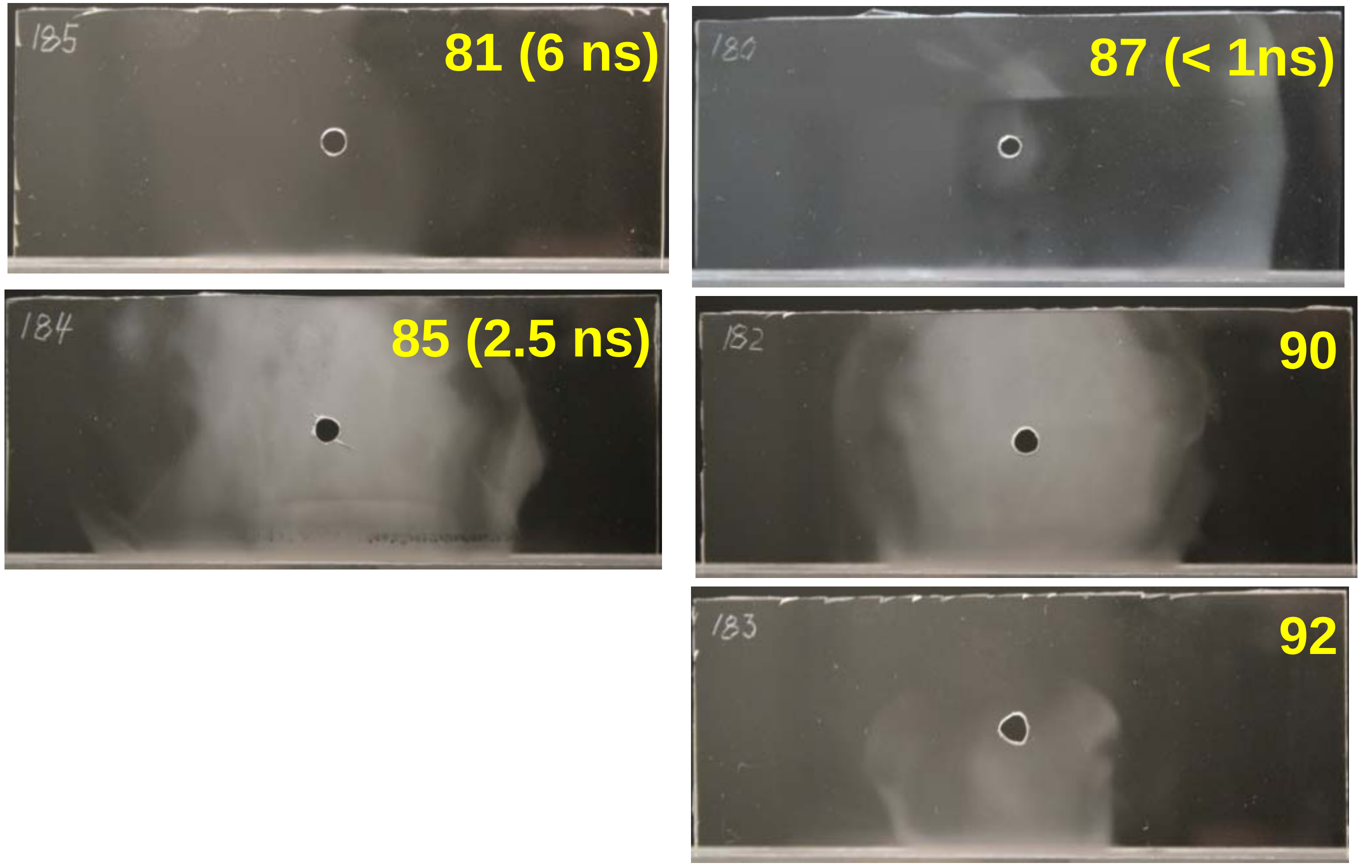


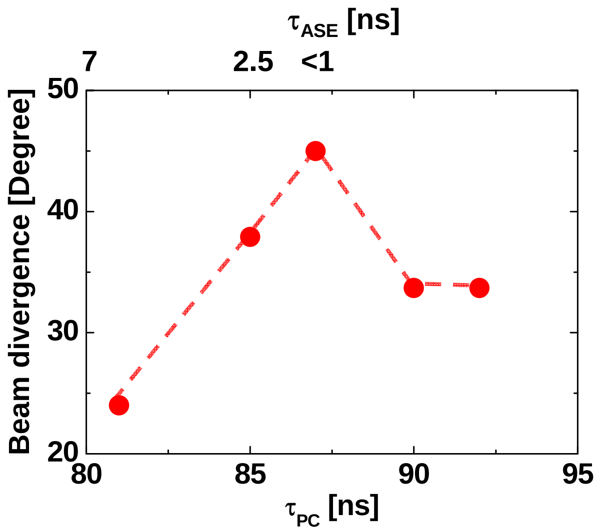
Maximum Proton energies on Pre-pulse



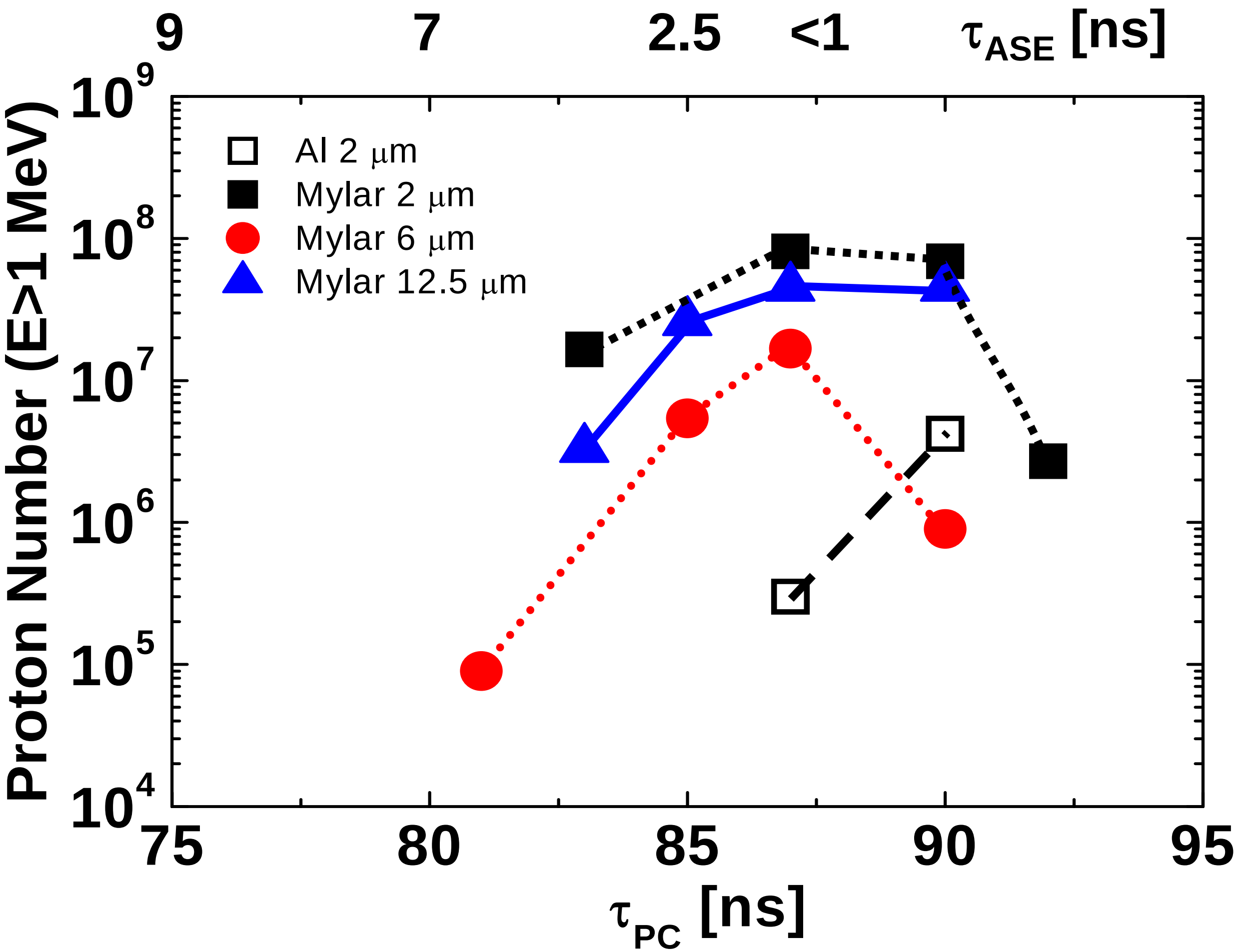
Proton beam divergence on Pre-pulse

Target: Mylar 6 um
CR39: 9 cm away from target with 13 um-thick Mylar filter (E > 0.8 MeV)





Proton number generated on Pre-pulse



- *Energy efficiency for E > 0.5 MeV was estimated to be 1 %*

Summary

- ***Proton beams generated from metal and plastic targets are compared,***
- ***which shows distinct differences.***
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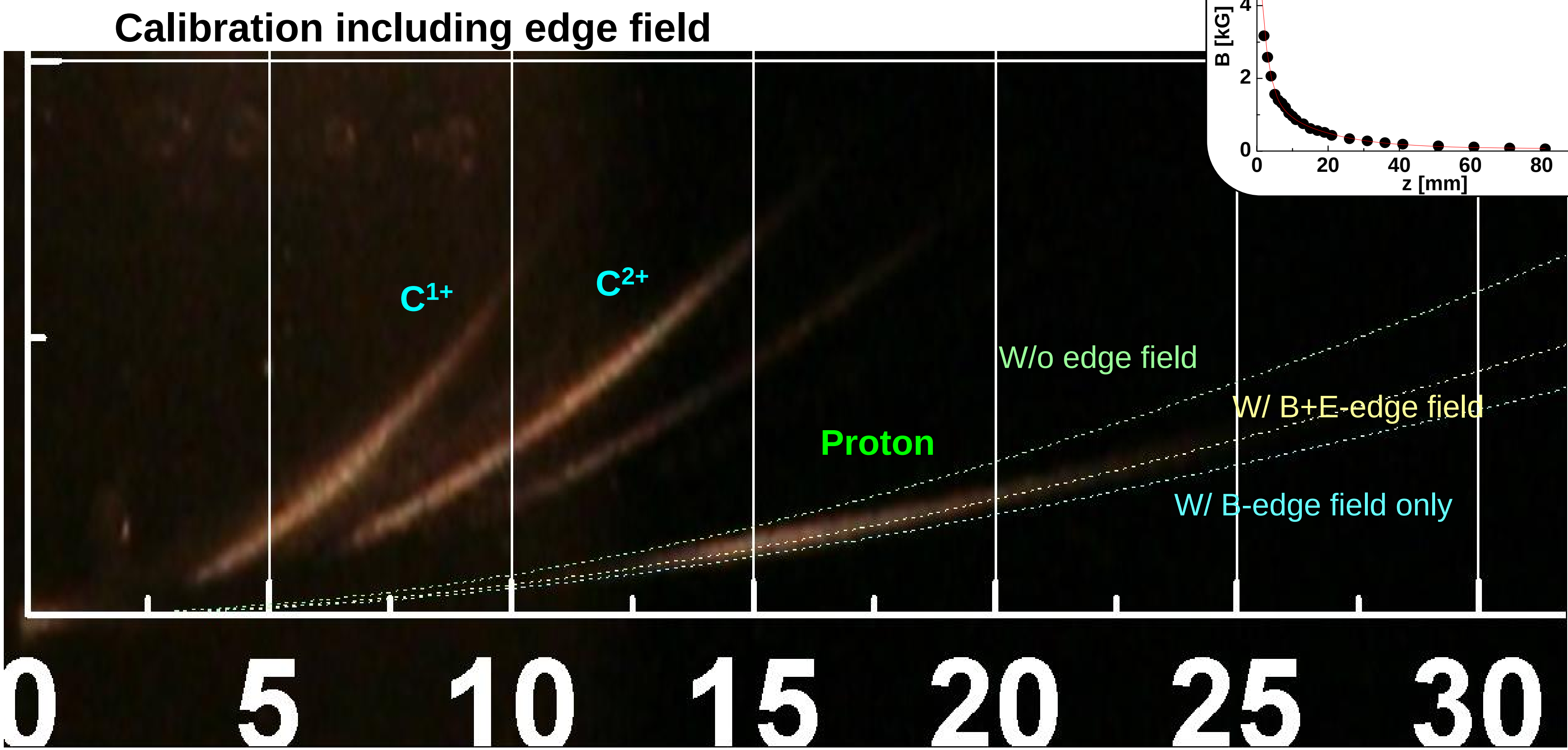
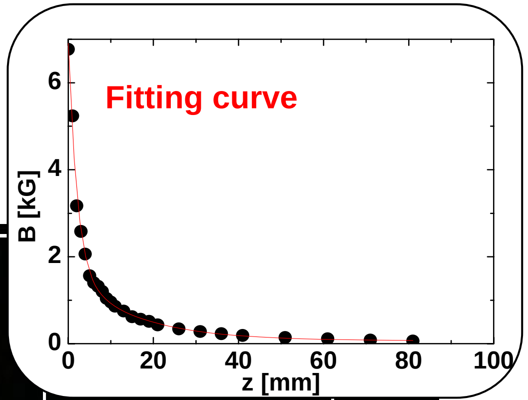
- ***An effect of the ASE pulse width on the proton generation is also compared between metal and plastic targets,***
- ***which also show clear differences and in the case of plastic targets, it also can be addressed from the ARIE model***
- ***We are preparing a scheme utilizing such an acceleration mechanism for more efficient generation of the proton beams.***

Thomson Parabola Exp.

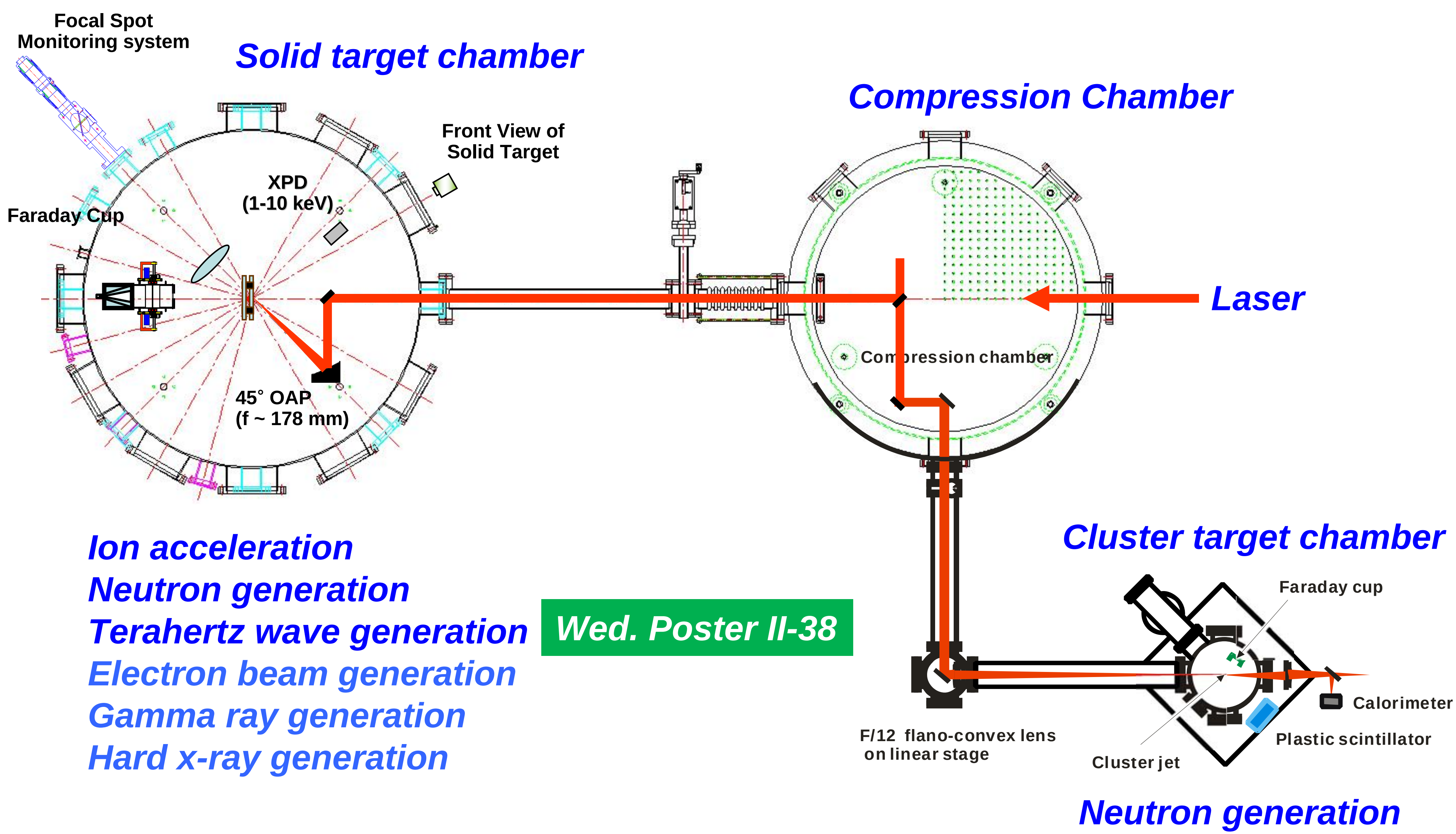
Ion TPS traces on a CR39 detector





J. Y. Lee et al., JKPS 51, 426 (2007)

Target Chambers at KAERI



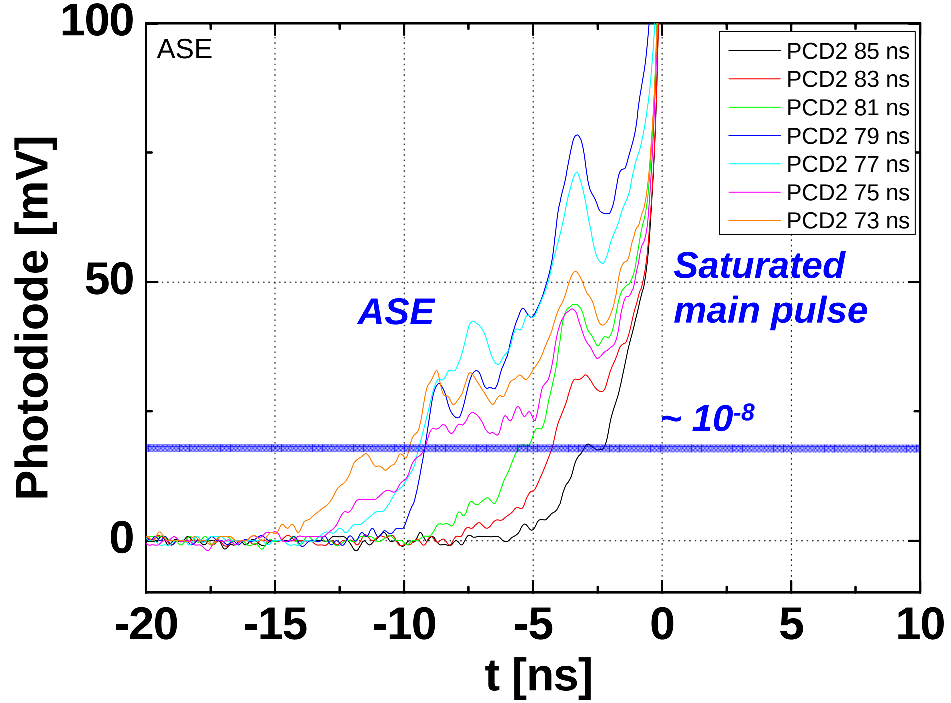
Ion acceleration
Neutron generation
Terahertz wave generation
Electron beam generation
Gamma ray generation
Hard x-ray generation

Wed. Poster II-38

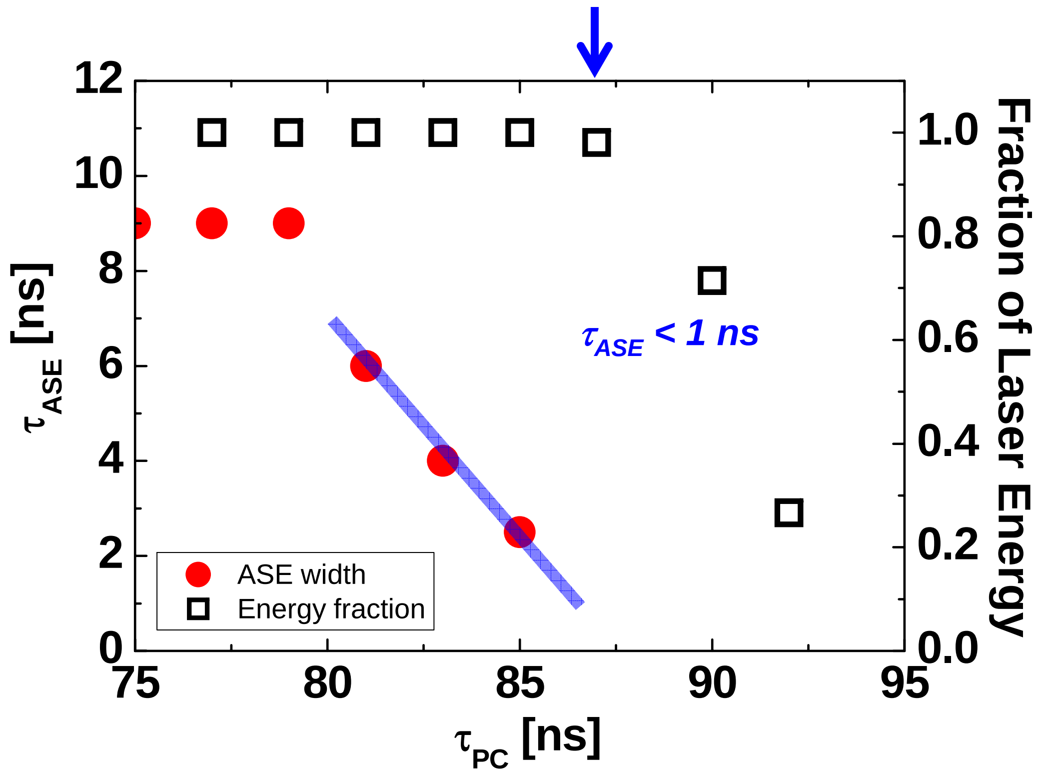
Laser Prepulse (ASE)

Control of ASE pulse width by changing pulse picker opening time installed after a pre-amplifier

Before compression
Fast-photodiode signal (200 ps rising time)



Main pulse begins to be blocked.

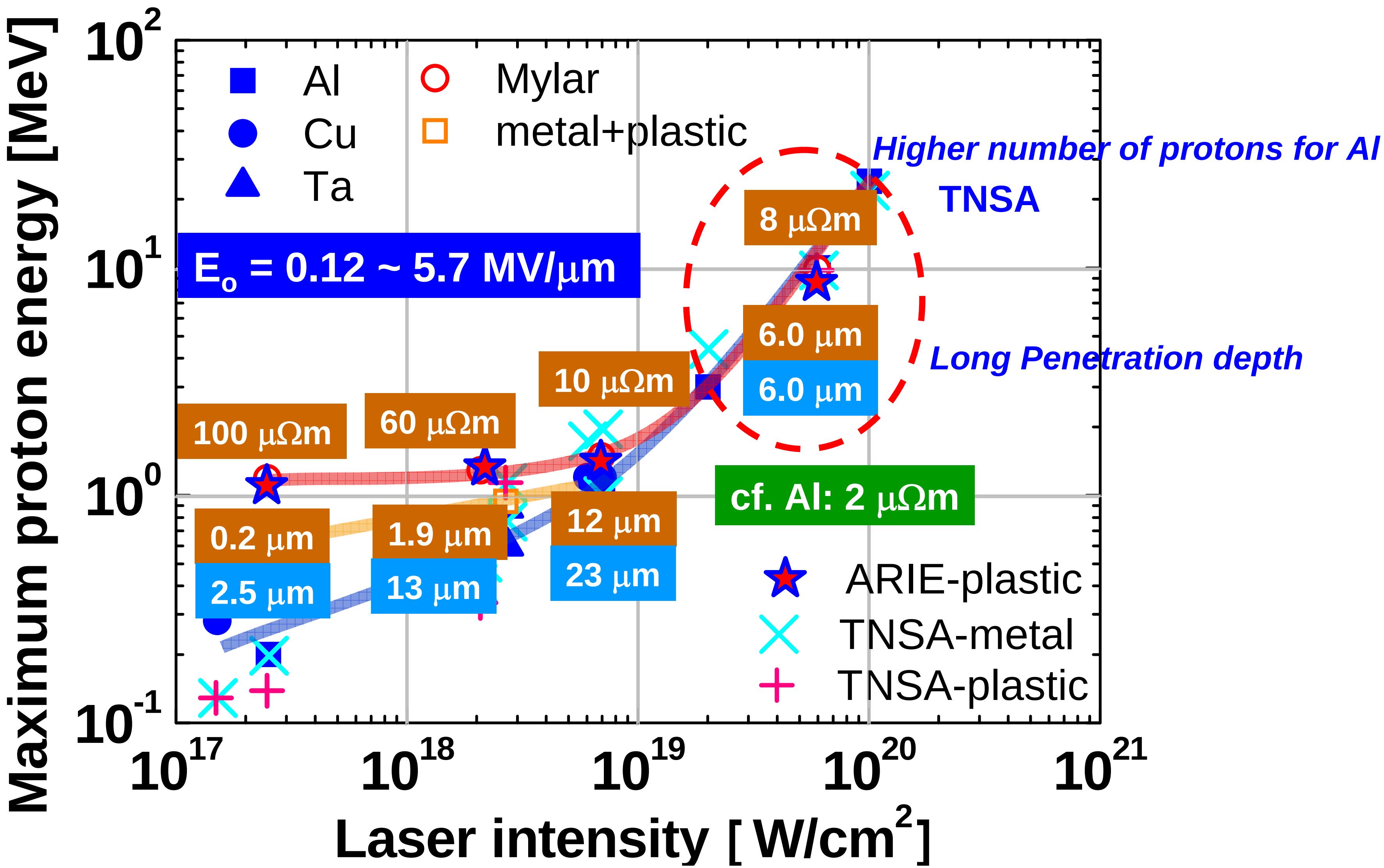


Wed. Poster II-54

• Contrast ratio ~ 10^{-8} at 10 ns measured by a simple method developed at KAERI.

Y. H. Cha et al., Appl. Opt. 46, 6854 (2007)

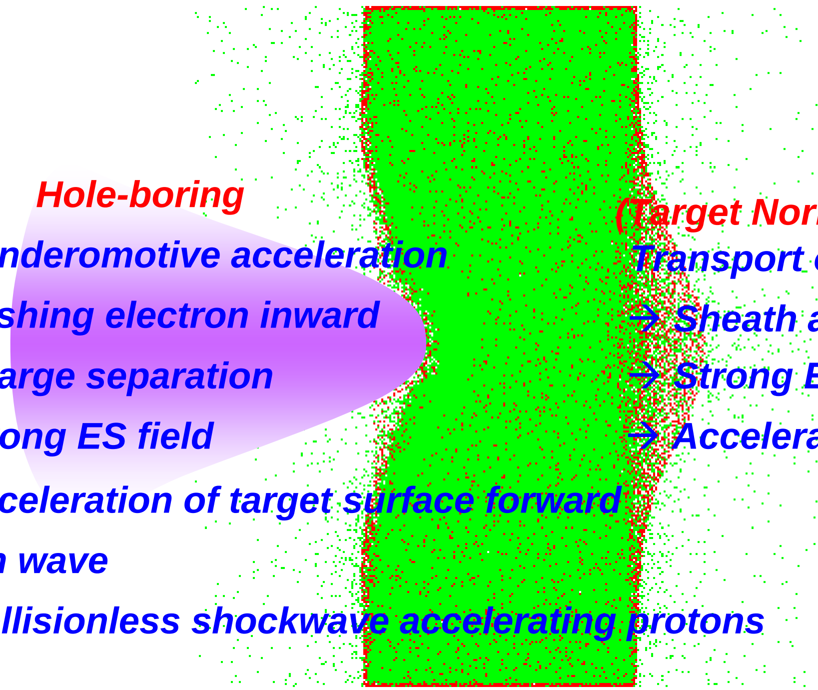
Anomalous behavior of Plastic target



Laser induced acceleration of ion beams

- ***Mechanisms***

:relativistic intensity (a>1), overdense ($n_e > n_c$ ($\omega_p > \omega_L$))



Hole-boring

Ponderomotive acceleration

→ Pushing electron inward

→ Charge separation

→ Strong ES field

→ Acceleration of target surface forward

→ Ion wave

→ Collisionless shockwave accelerating protons

TNSA

(Target Normal Sheath Accel.)

Transport of electron bunch

→ Sheath at the back of target

→ Strong ES field

→ Acceleration of protons

$$\frac{u_s}{c} = \sqrt{\frac{1}{2}\frac{Zm_e}{M_i}\frac{n_c}{n_e}a_o^2}$$

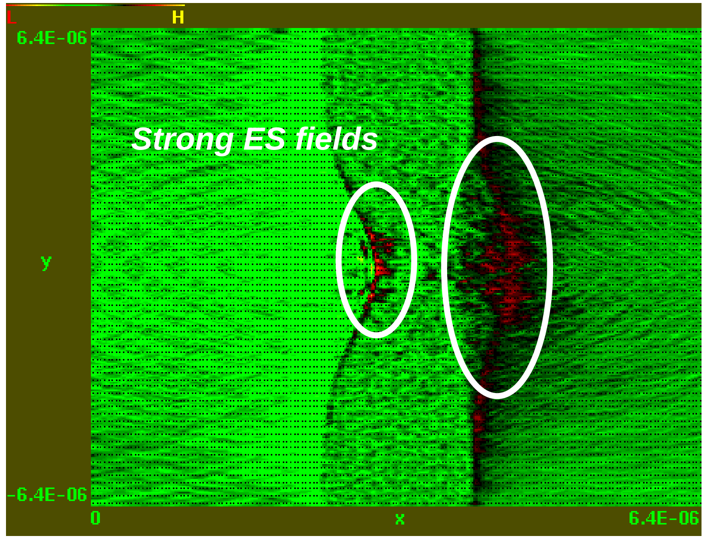
Isothermal expansion model

Mora, PRL 90, 185002 (2003)

$$E_{es}^{peak} = \sqrt{\frac{2}{e_E}} \times \sqrt{4\pi n_o T_e}$$

$$E_{\max} \approx 2T_e \ln^2\left(\frac{\omega_{pi} t}{\sqrt{2e_E}} + \sqrt{\frac{\omega_{pi}^2 t^2}{2e_E} + 1}\right)$$

Electrostatic field



Proton X-Vx phase space