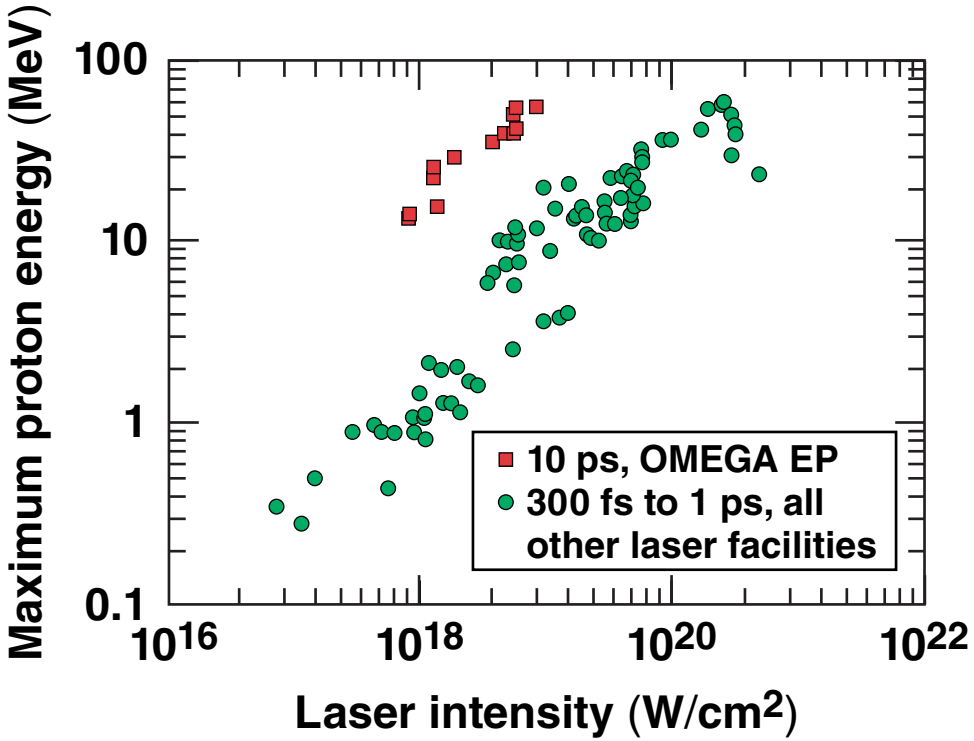
Measurements of Proton Generation with Intense Kilojoule Laser Pulses on OMEGA EP



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Summary

Protons with a maximum energy of 55 MeV are produced by kilojoule, 10-ps laser pulses on OMEGA EP

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- Scaling of laser-driven proton beams is important for beam optimization and potential applications from fundamental scientific research to practical medical treatment
- The maximum proton energy $(E_p)_{max}$ scales as the square root of the laser energy
- The laser-to-proton energy-conversion efficiency η_{L-p} scales as the laser energy, with about 2% to 3% for a typical kJ shot
- $(E_p)_{max}$ and η_{L-p} increase with laser-pulse duration at fixed intensities

Collaborators

P. M. Nilson, W. Theobald, C. Stoeckl, C. Dorrer, T. C. Sangster, and D. D. Meyerhofer

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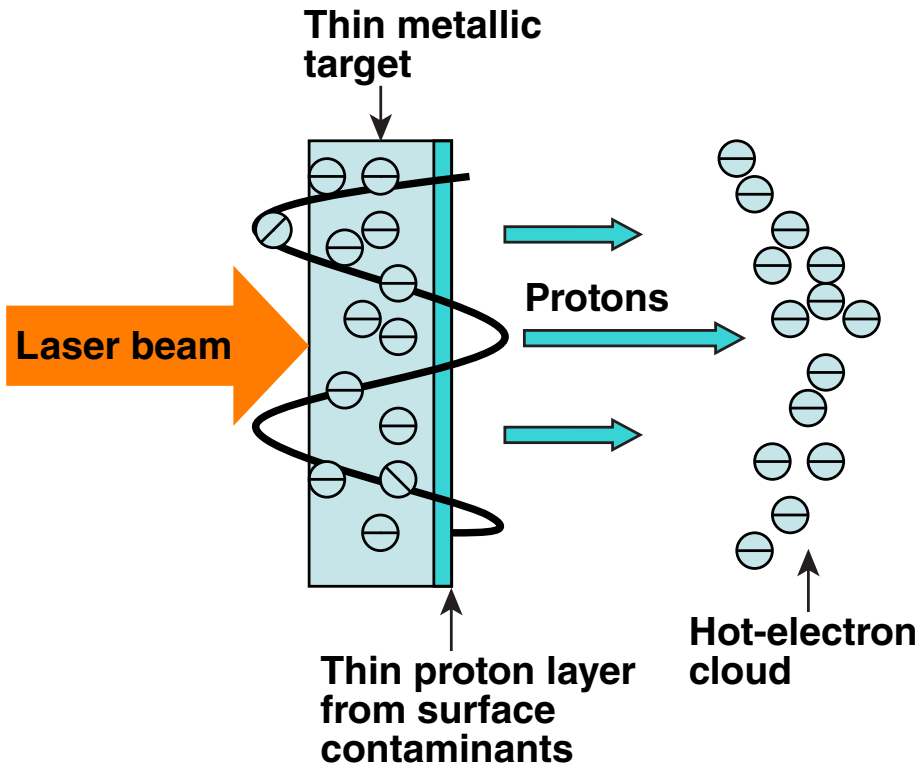
Target normal-sheath acceleration (TNSA)* generates MeV proton beams in intense laser–solid interaction

- Hot electrons escape from the rear side of the target
- An electrostatic field is built up, with field gradient on the order of MeV/μm
- Protons are accelerated to tens of MeV



Laser-driven protons are ultrabright, extremely laminar, collimated, and have high peak energy and short burst duration.

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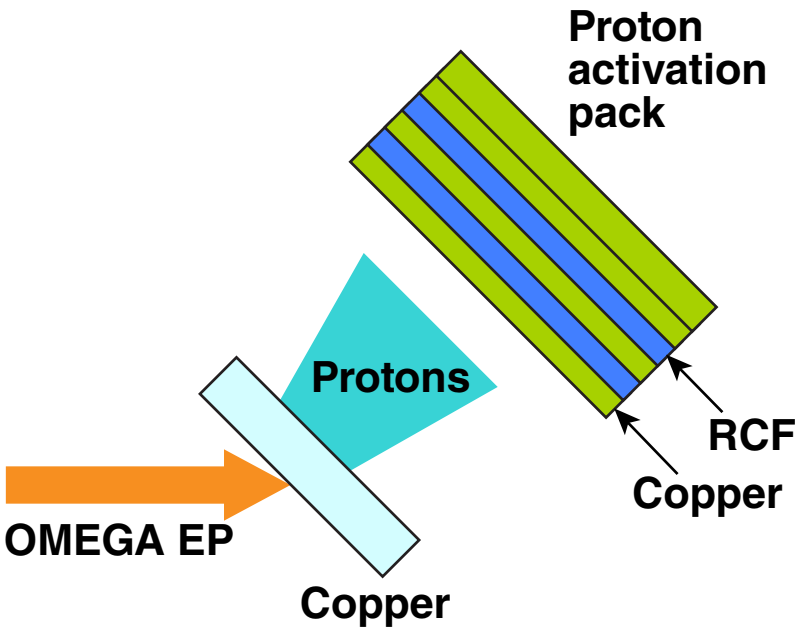
*S. C. Wilks *et al.*, Phys. Plasmas 8, 542 (2001).

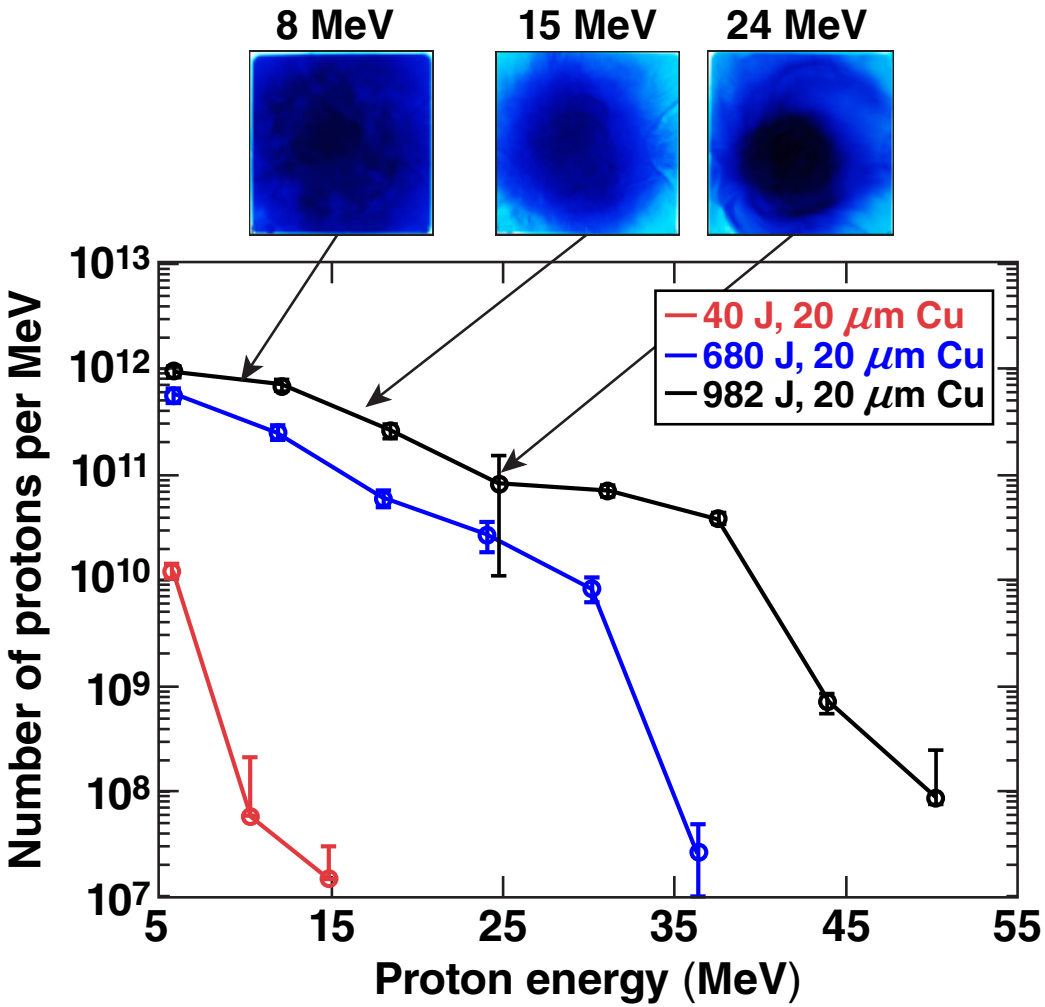
Experiments were performed on OMEGA EP to characterize energetic protons

Focal spot (R_{80})	20 ~ 25 μm
Laser energy	40 J ~ 1500 J
Intensity (average within R_{80})	0.25 ~ 8 × 10^{18} W/cm^2
Intensity contrast	~10^8
Targets	500 μm^2 × 20 μm Cu/Cu+Al/Cu+CH 500 μm^2 × 50 μm Cu



Nuclear activation of copper stacks determines the energy spectrum of the forward-accelerated protons

- Radiochromic film shows proton beam profile
- ^{63}Cu (p, n) ^{63}Zn
  ^{65}Cu (p, 3n) ^{63}Zn
- Coincidence counter was absolutely calibrated using point source Na_{22}
- Response functions using stopping power* and cross-section data**
- This is an iterative method to recover the energy spectrum



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* http://physics.nist.gov/Star.
** http://www.nndc.bnl.gov/exfor/.

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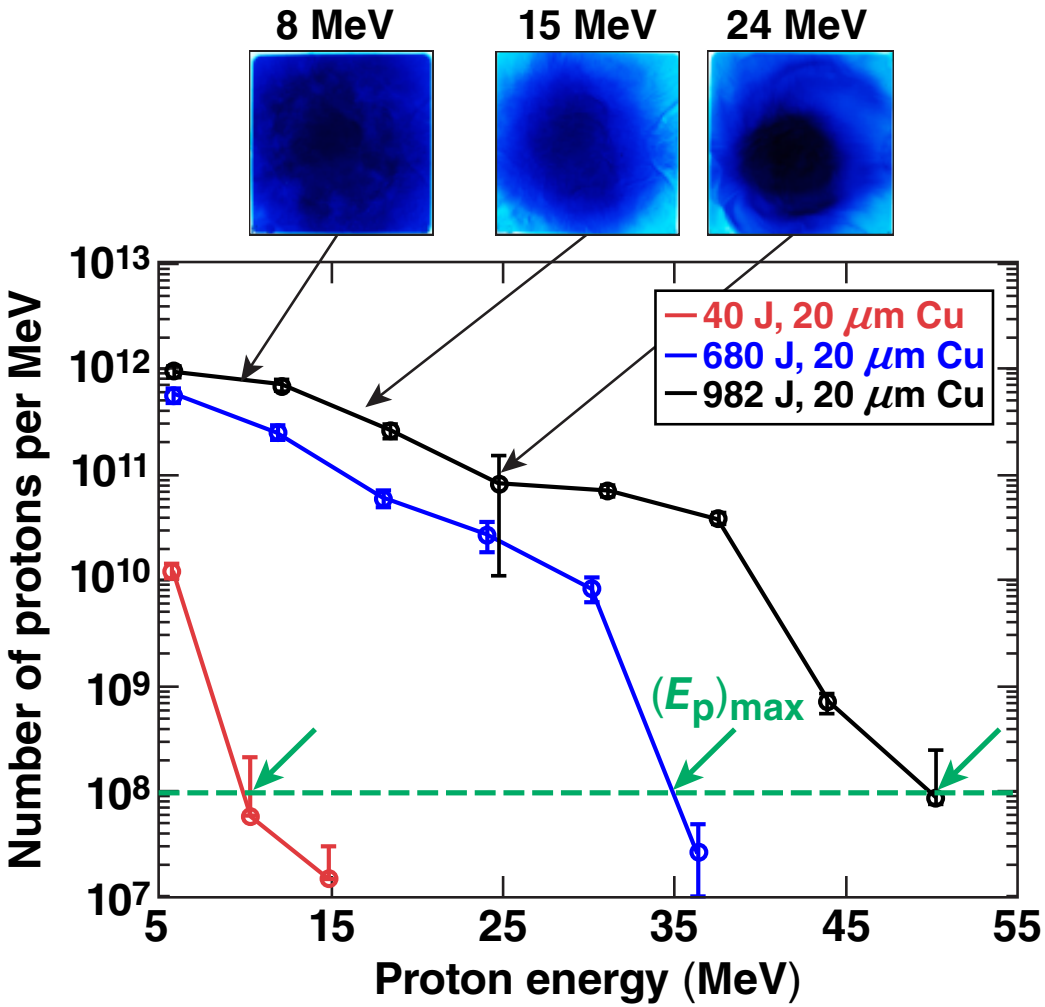

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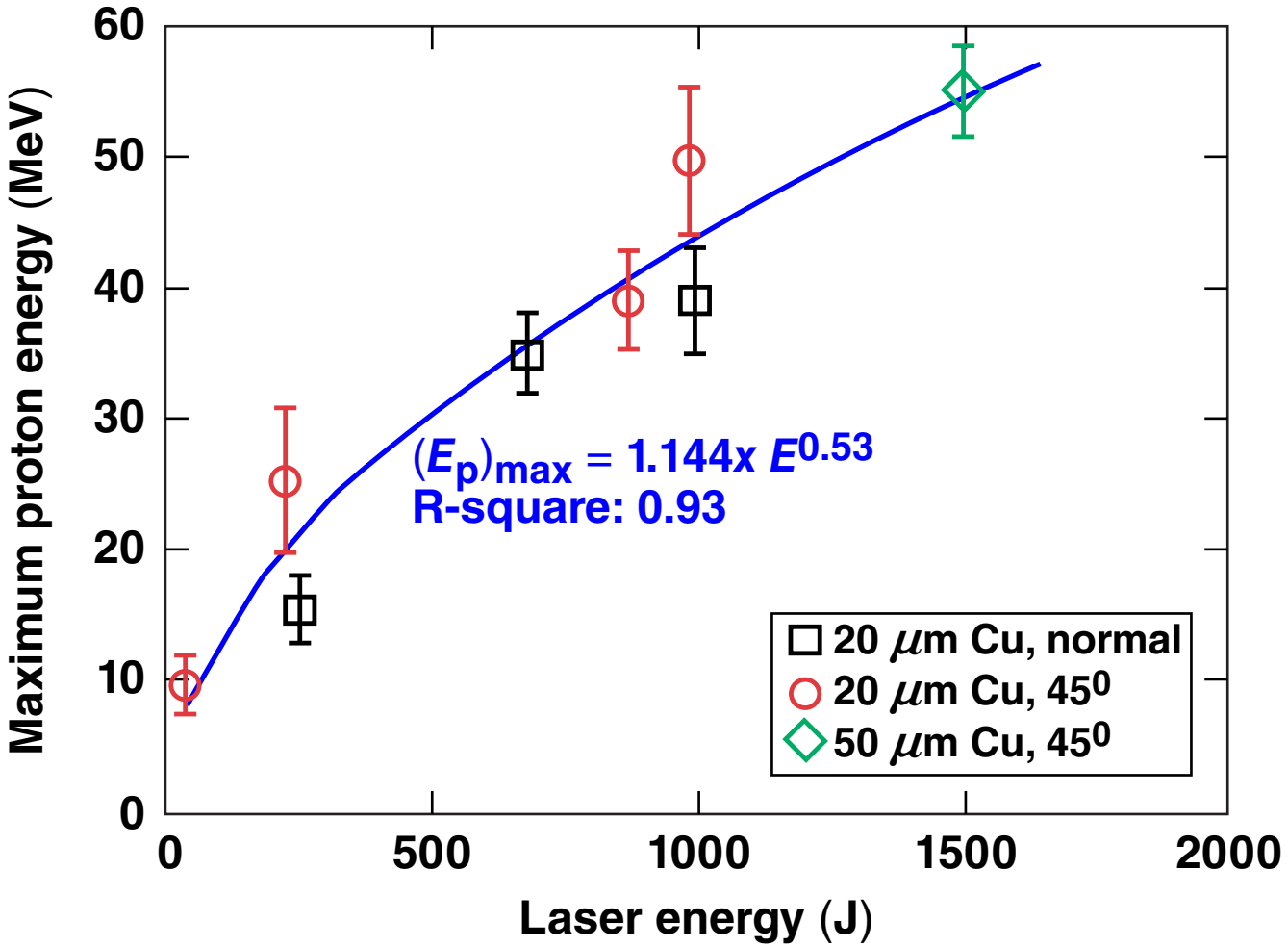
The maximum proton energy $(E_p)_{max}$ scales as the square root of the laser energy



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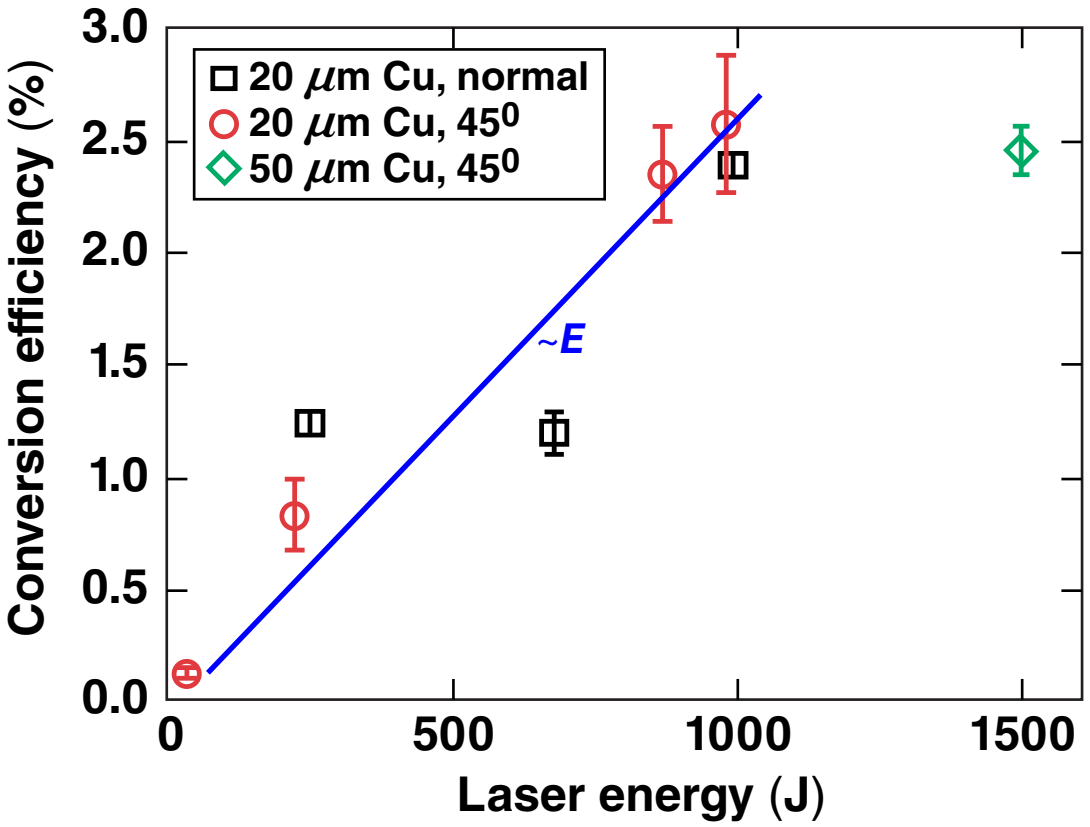
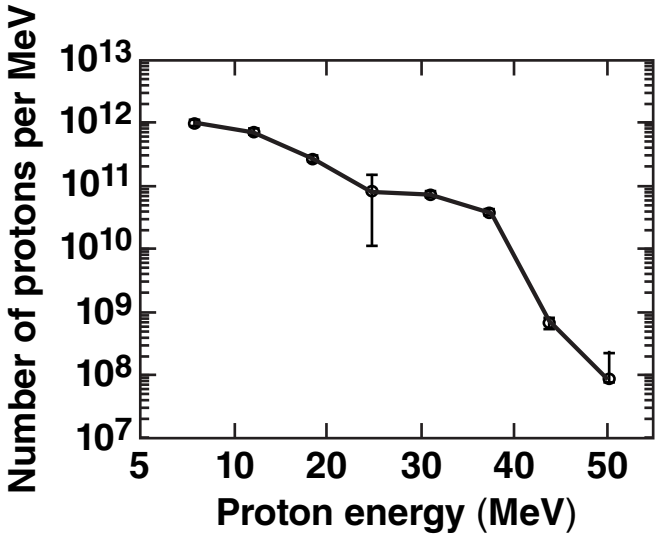
The laser-to-proton energy-conversion efficiency η_{L-p} is proportional to the laser energy





η_{L-p} ~ 2% to 3% for a typical 1-kJ, 10-ps shot.

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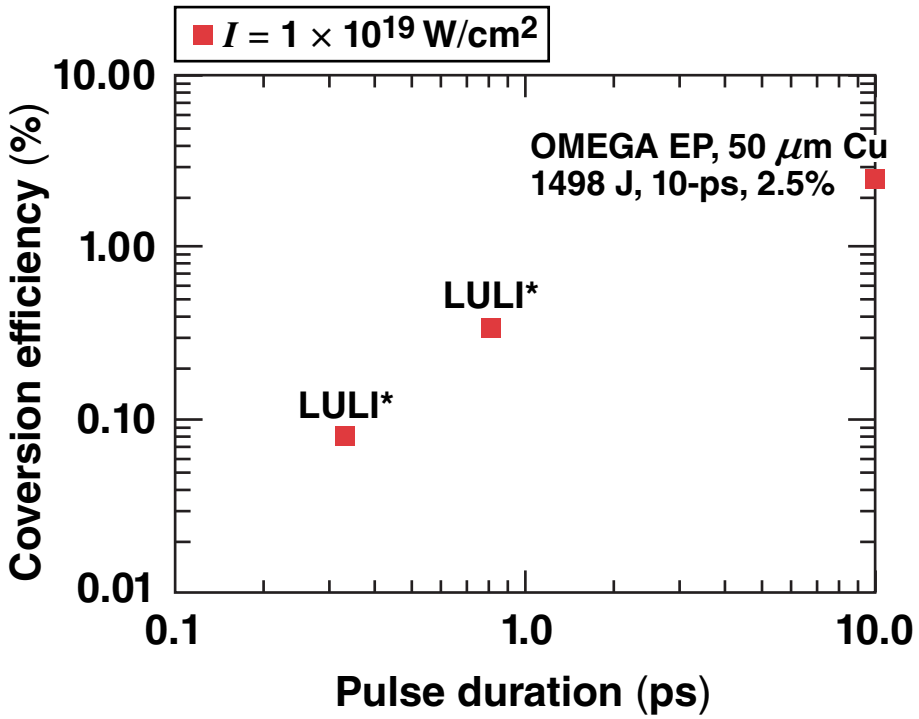
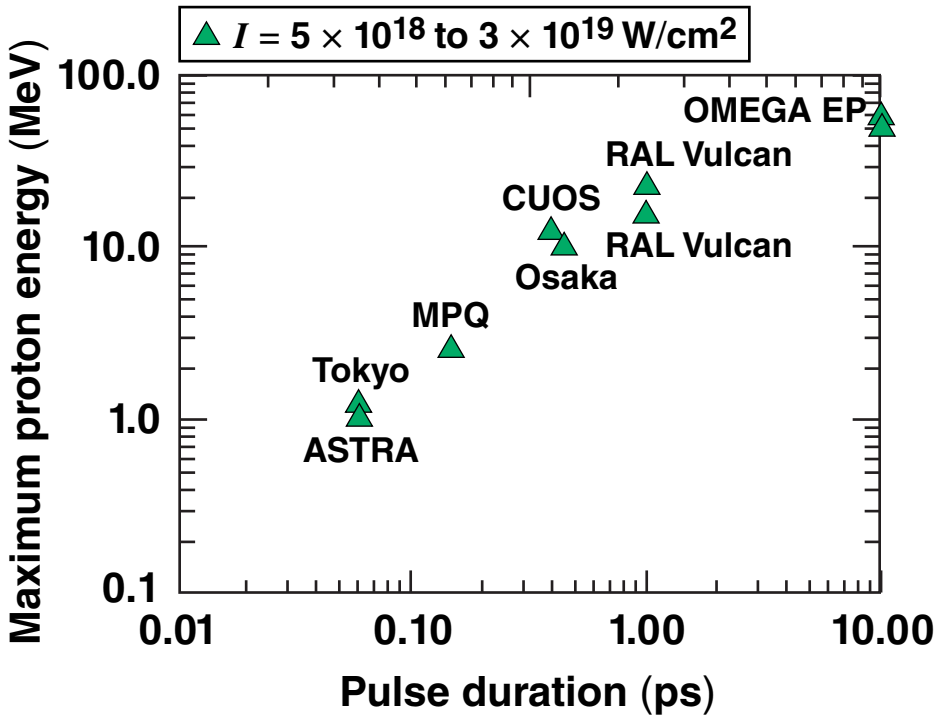
Both the conversion efficiency and $(E_p)_{max}$ increase with pulse duration at fixed intensities





*J. Fuchs *et al.*, Nature Phys. 2, 48 (2006).
**M. Borghesi *et al.*, Fusion Sci. and Tech. 49, 412 (2006) and the references therein.

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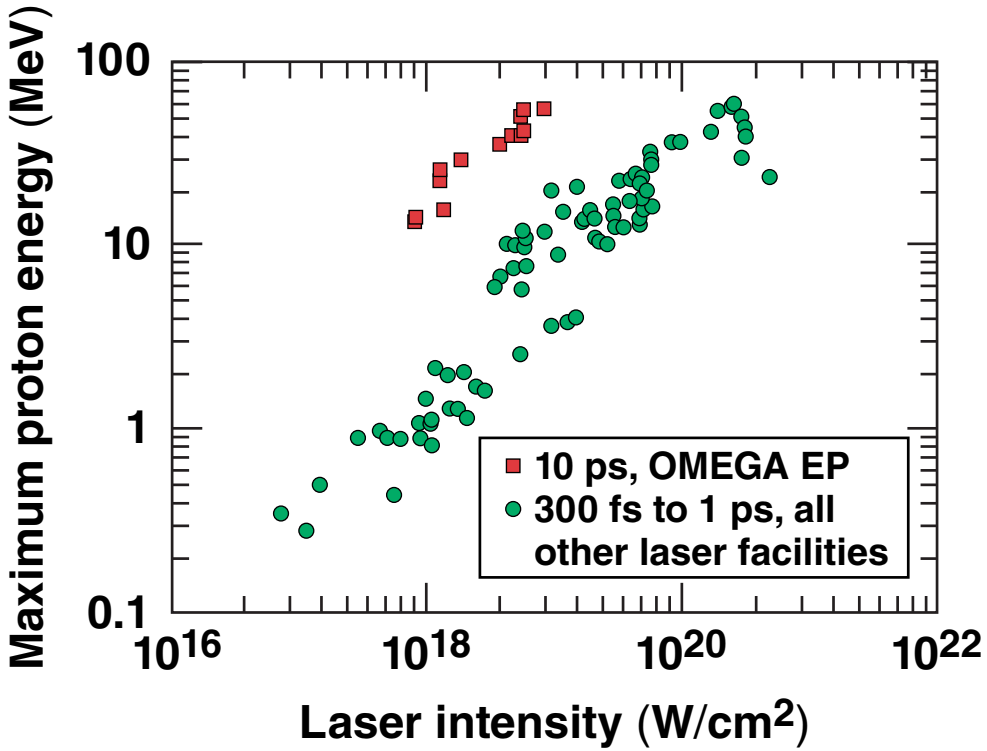
$(E_p)_{max}$ grows faster with laser intensity on OMEGA EP than in previous experiments*



The highest $(E_p)_{max}$ achieved on OMEGA EP is 55 MeV.

*E. L. Clark *et al.*, Phys. Rev. Lett. 85, 1654 (2000).
K. Krushelnick *et al.*, Phys. Plasmas 7, 2055 (2000).
R. A. Snavely *et al.*., Phys. Rev. Lett. 85, 2945 (2000).
M. Borghesi *et al.*, Fusion Sci. Technol. 49, 412 (2005) and the references therein.
K. Flippo *et al.*, J. Phys.: Conf. Ser. 244, 022033 (2010) and the references therein.

Summary/Conclusions

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