SAND2007-4271C

Laser Generated Ion Beams

in the Context of Sandia's HEDP Mission

Laser Plasma Accelerator Workshop

Angra do Heroismo ,Terceira Island, Azores

July 10, 2007

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Sandia National Laboratories

(Z-Backlighter Facility)

SNL Approval: xxx

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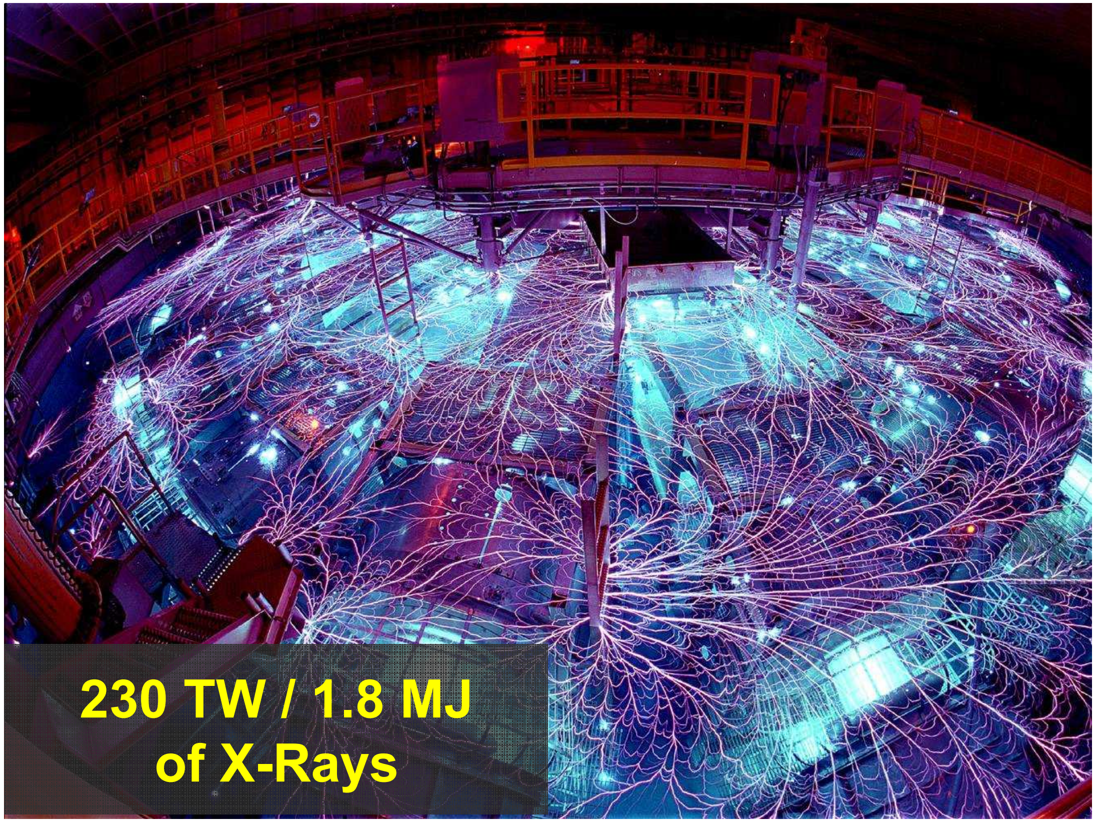
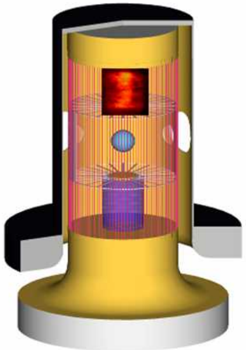
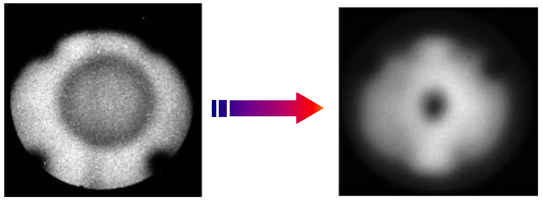
HEDP on Z





X-ray driven deuterium capsule compression in a hohlraum.



8×10^{10} neutrons
$T_{hohlr.} = 220$ eV
CR > 14 (40 g/cm^3)

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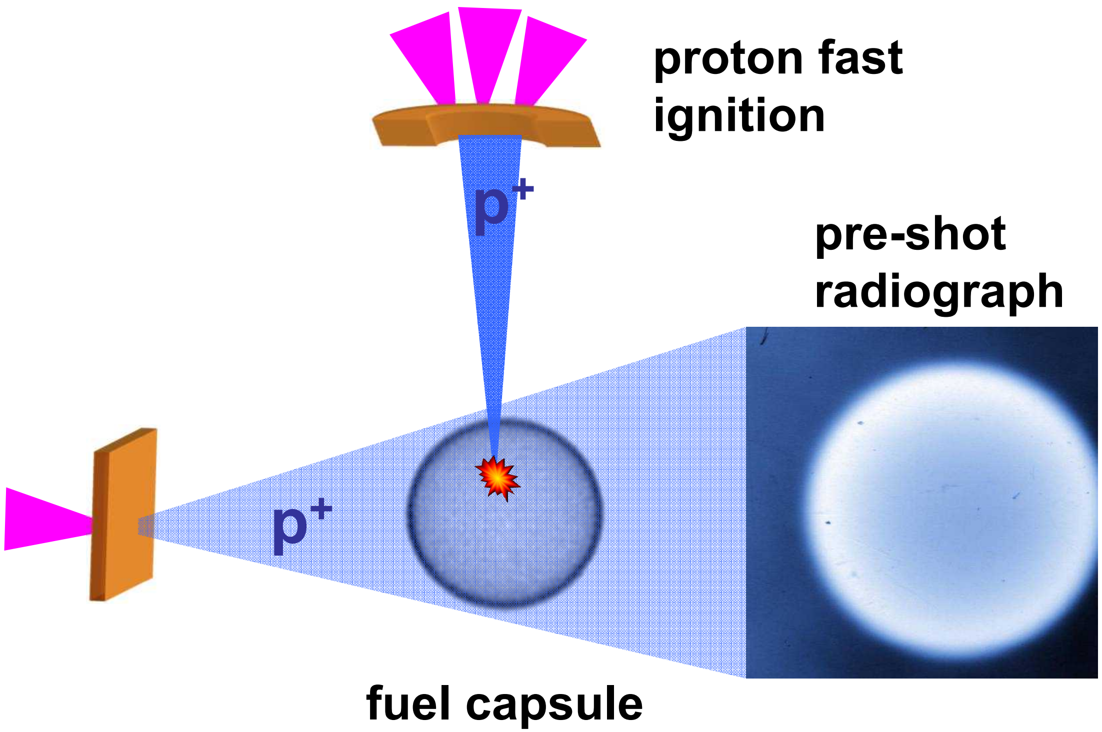
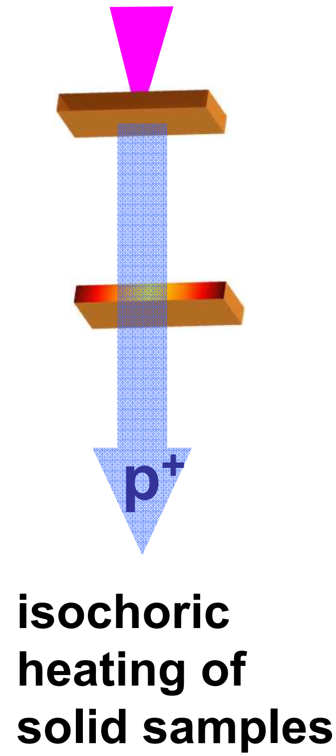
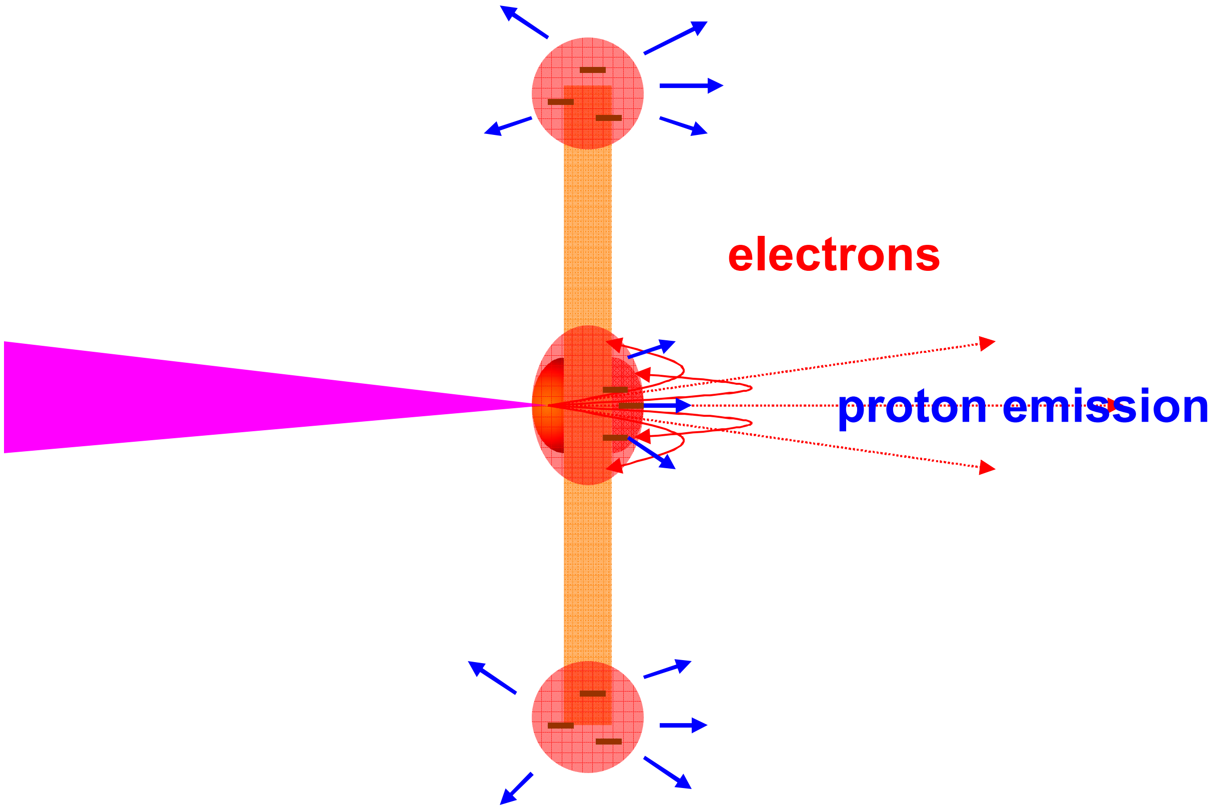
Where do ions figure in?





Edge Emission

(Concept: McKenna et al.: PRL 98, 145001, 2007)



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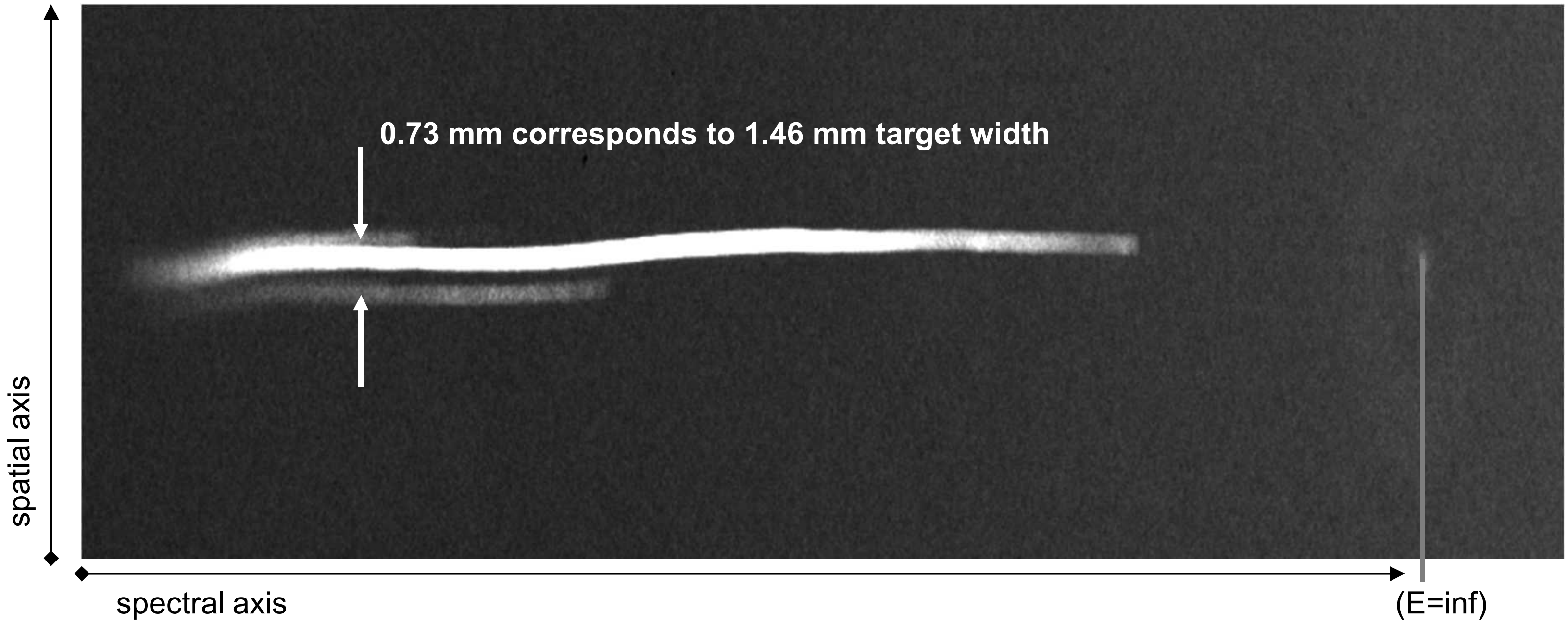
Edge Emission

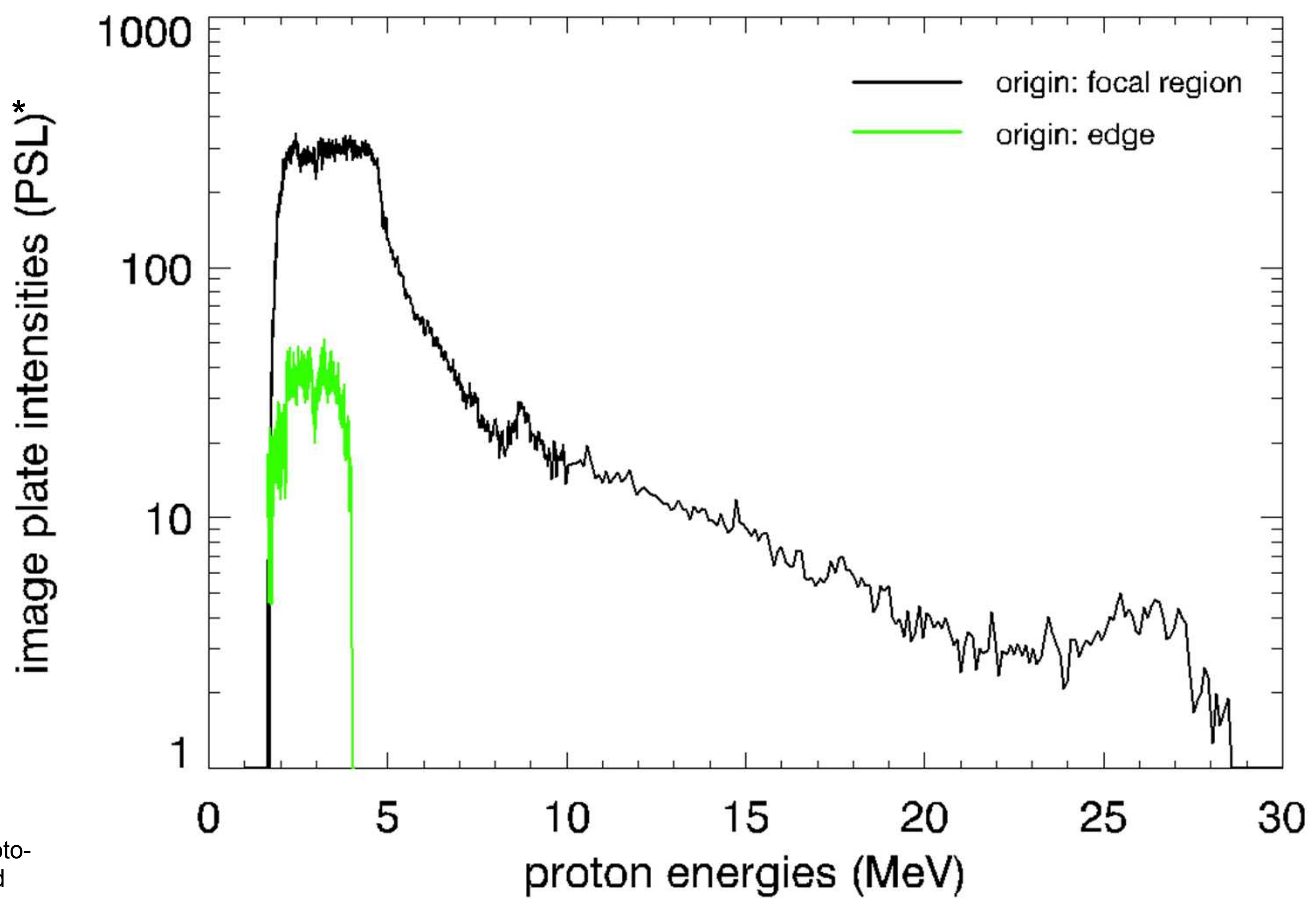
Proton Traces on B-Spectrometer



Low energy protons are emitted from the edges of the target foil and leave parallel ghost images on the image plate behind the Thomson parabola. Similar to X-ray emission, the intensity is substantial due to field enhancement at an edge. The entrance pinhole of the spectrometer projects a 1:2 demagnified 1D-image of the source.

Edge Emission

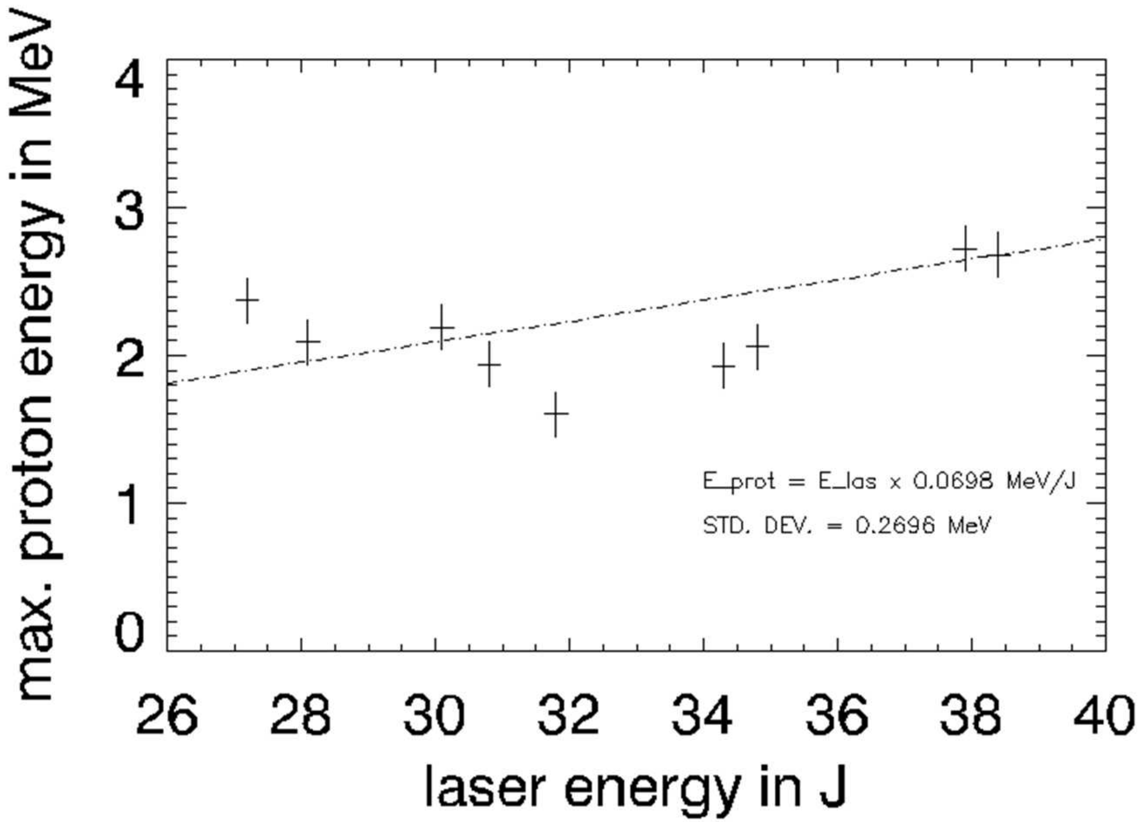
Comparison with Main Proton Trace



*PSL: photo-stimulated luminescence

Edge Emission

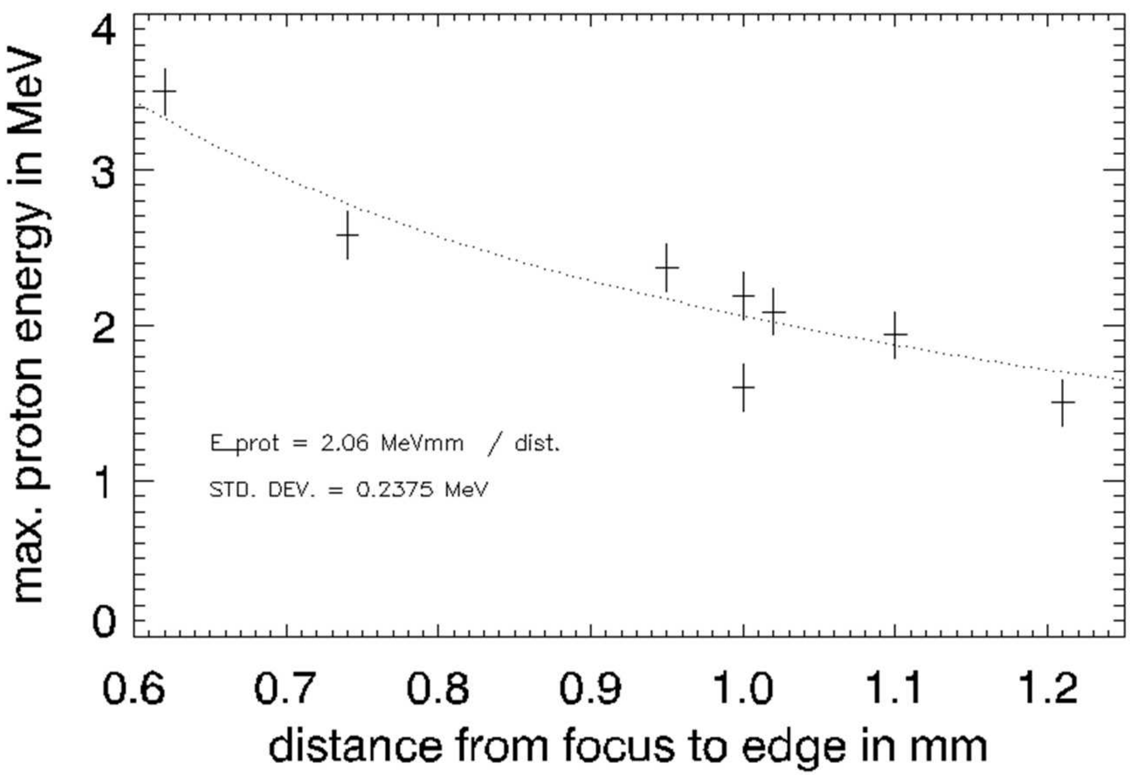
Dependence on Laser Energy



Evaluation of shots with a distance from focus to edge of 1mm ± 10%

Edge Emission

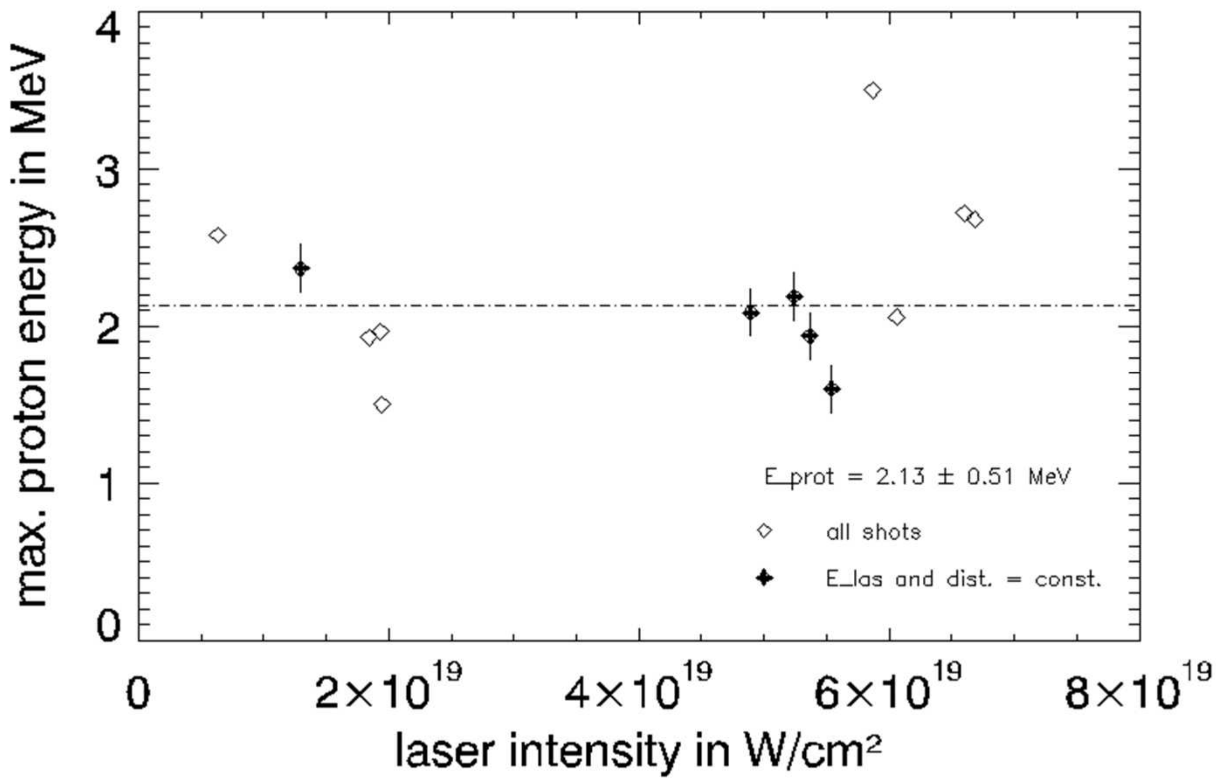
Dependence on Focus Position



Evaluation of shots with a laser energy of 30.5 J ± 10%

Edge Emission

Dependence on Laser Intensity



No obvious dependence of max. proton energy on laser intensity!

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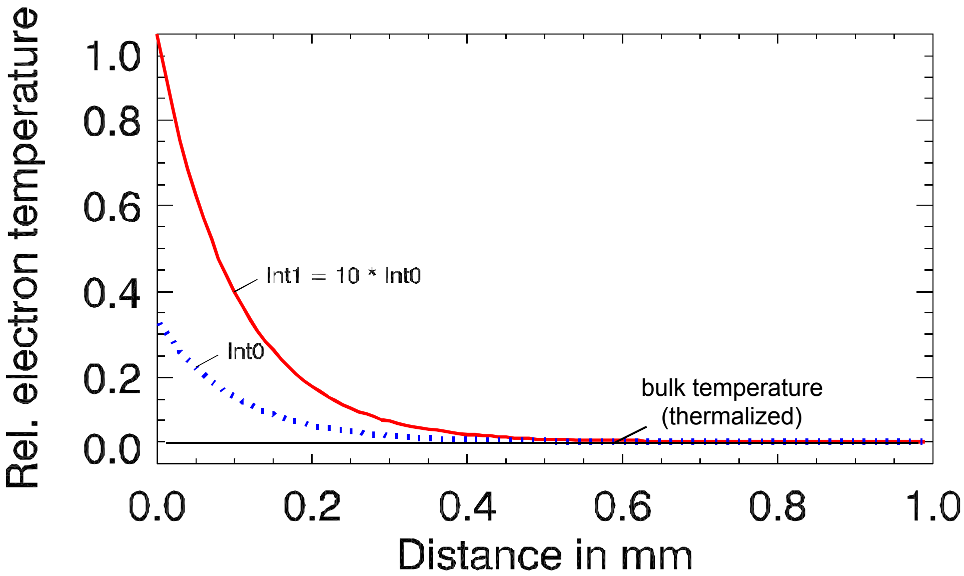
Edge Emission

Explanation: Thermalized electrons ?



Electrons cool along the target:

$$T_e \infty T_0 * e^{-x/c} + T_{bulk}$$

This example: $c = 0.1$ mm

$T_{bulk} = 0.05$

$E_{max}(p^+) = F(T_e, n_e)$

T_e: electr. temp.

n_e: electr. density

$E_{max}(p^+)$ is:

- independent of $T_{e,0} \infty I^{1/2}$
- proportional to $n_e \infty E_{laser}$
- proportional to $n_e \infty 1/d$
- dependent on T_{bulk} (∞E_{las}?)

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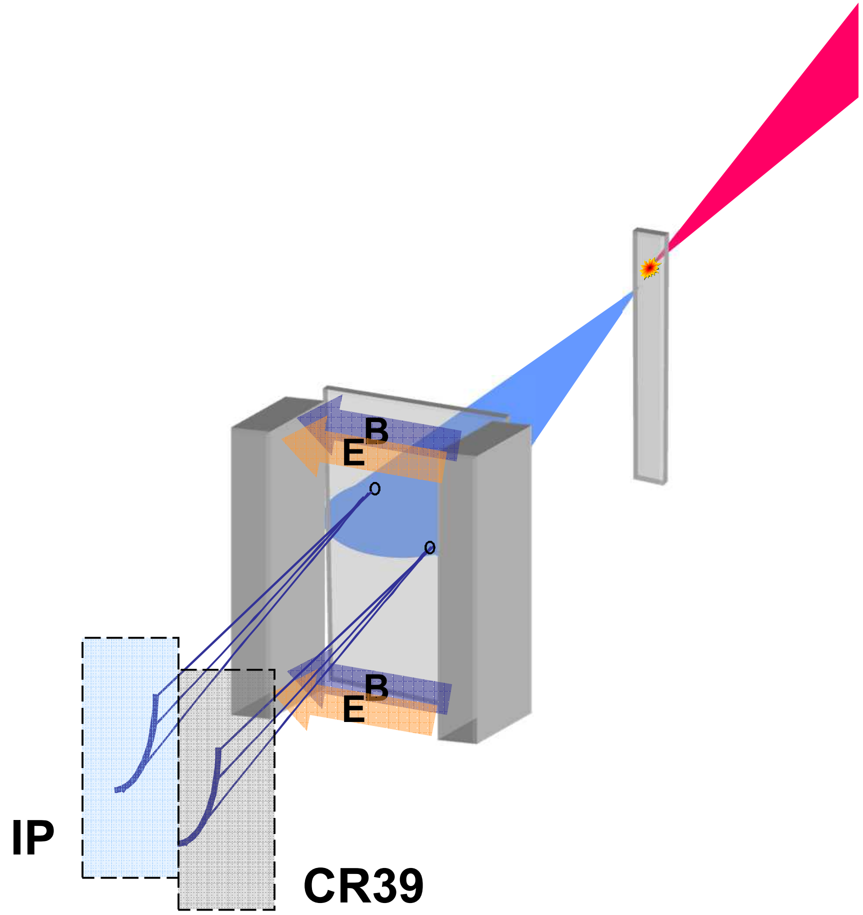
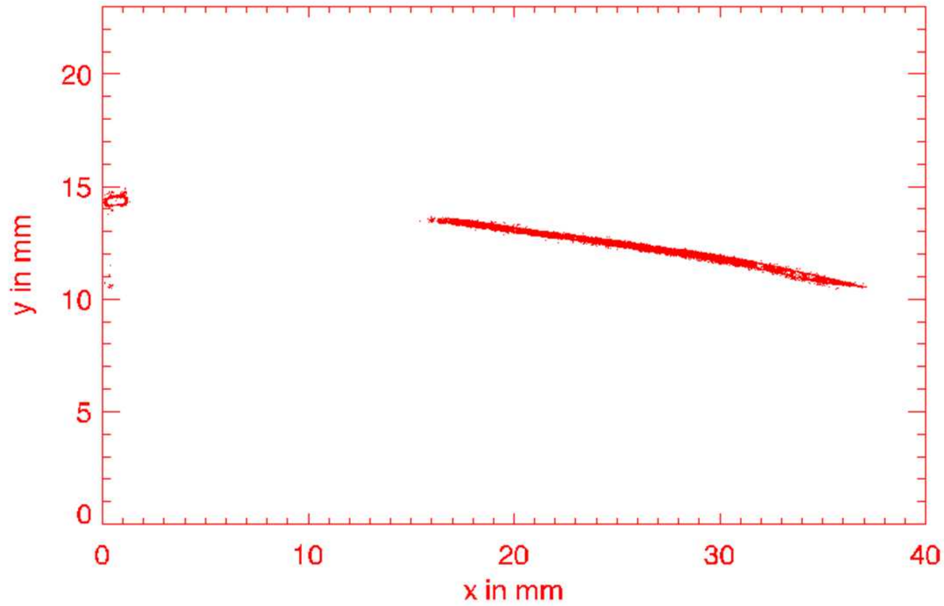
Calibrating Image Plates

Two-Pinhole Thomson Parabola

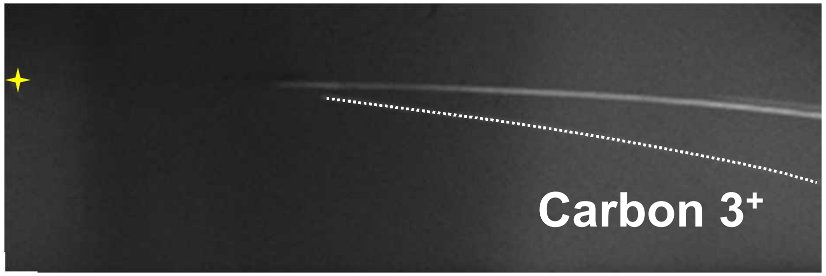


Calibrating Image Plates

CR39 vs. IP



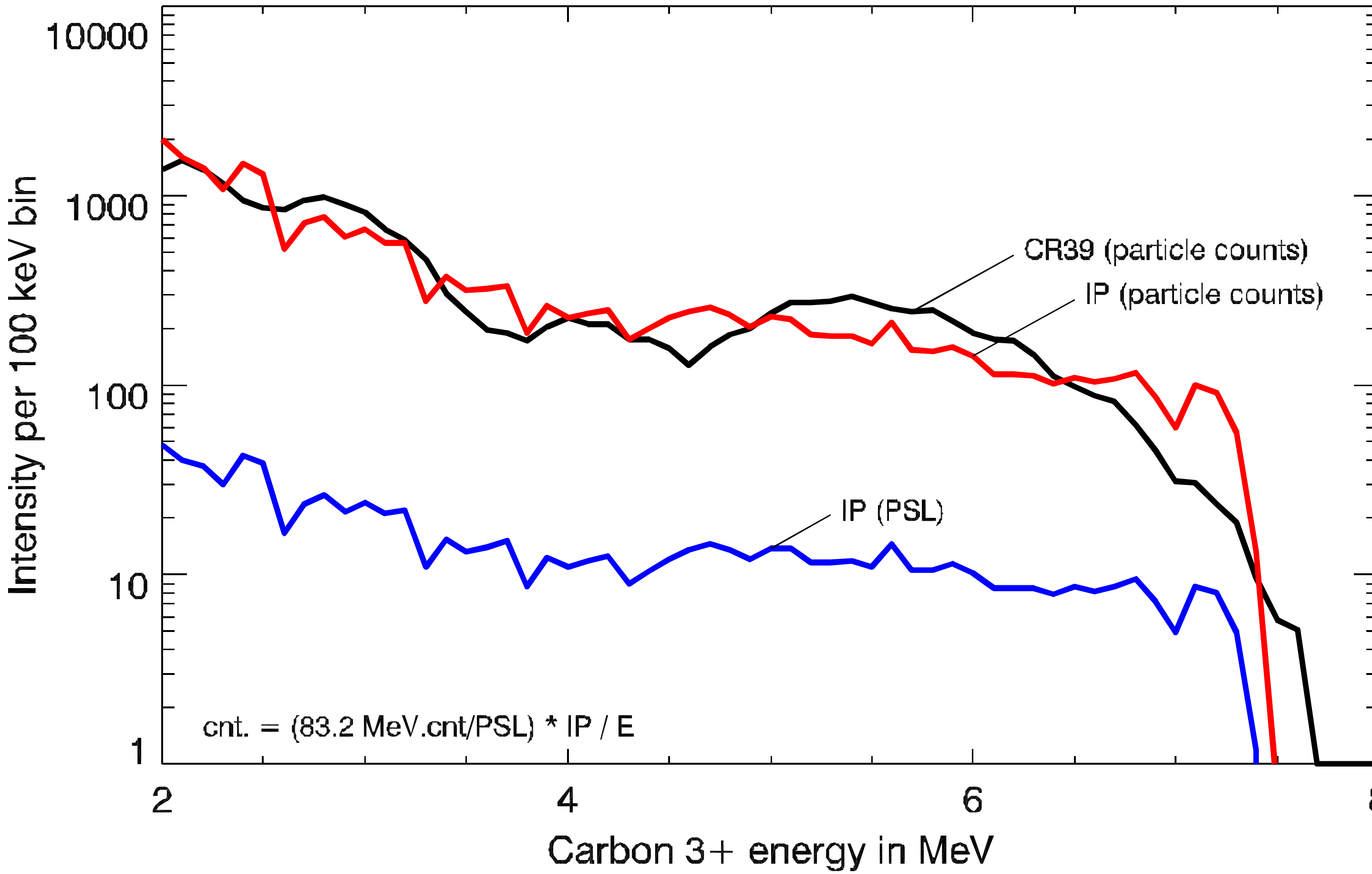
CR39



IP

Calibrating Image Plates

CR39 vs. IP

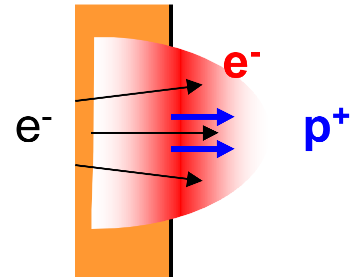


MEAN relative deviation: Δ(cnts)/cnts = 37%

Proton Energy Scaling Laws

for Target Normal Sheath Acceleration

How does the electron sheath form and accelerate protons?
- Two entirely different approaches:



ARTICLES

Laser-driven proton scaling laws and new paths towards energy increase

J. FUCHS[1,2*], P. ANTICI[1,2,3,4], E. D'HUMIÈRES[5], E. LEFEBVRE[5], M. BORGHESI[6], E. BRAMBRINK[1], C. A. CECCHETTI[6], M. KALUZA[7], V. MALKA[8], M. MANCLOSSI[8,9], S. MEYRONEINC[10], P. MORA[11], J. SCHREIBER[7], T. TONCIAN[12], H. PÉPIN[3] AND P. AUDEBERT[1]

Fuchs *et al.*:Nature Physics 2, 48 (2006)

Concept: Isothermal expansion into vacuum

PRL 97, 045005 (2006) PHYSICAL REVIEW LETTERS week ending 28 JULY 2006

Analytical Model for Ion Acceleration by High-Intensity Laser Pulses

J. Schreiber,[1,2,*] F. Bell,[1] F. Grüner,[1] U. Schramm,[1] M. Geissler,[2] M. Schnürer,[3] S. Ter-Avetisyan,[3] B. M. Hegelich,[4] J. Cobble,[4] E. Brambrink,[5] J. Fuchs,[5] P. Audebert,[5] and D. Habs[1]

Schreiber *et al.*: PRL 97, 045005 (2006)

Concept: Electrostatic field acceleration

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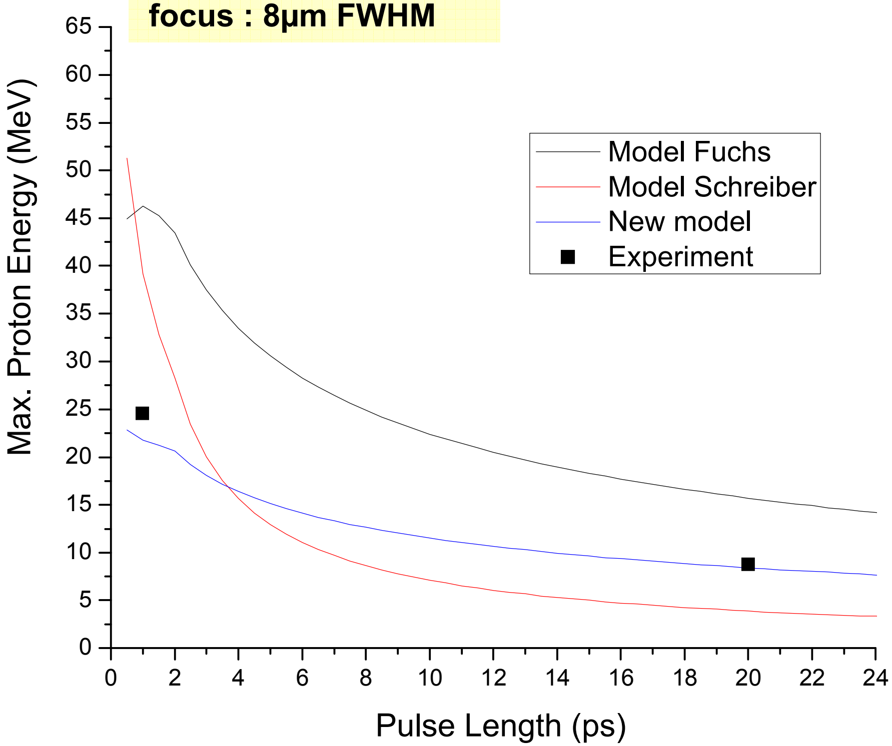
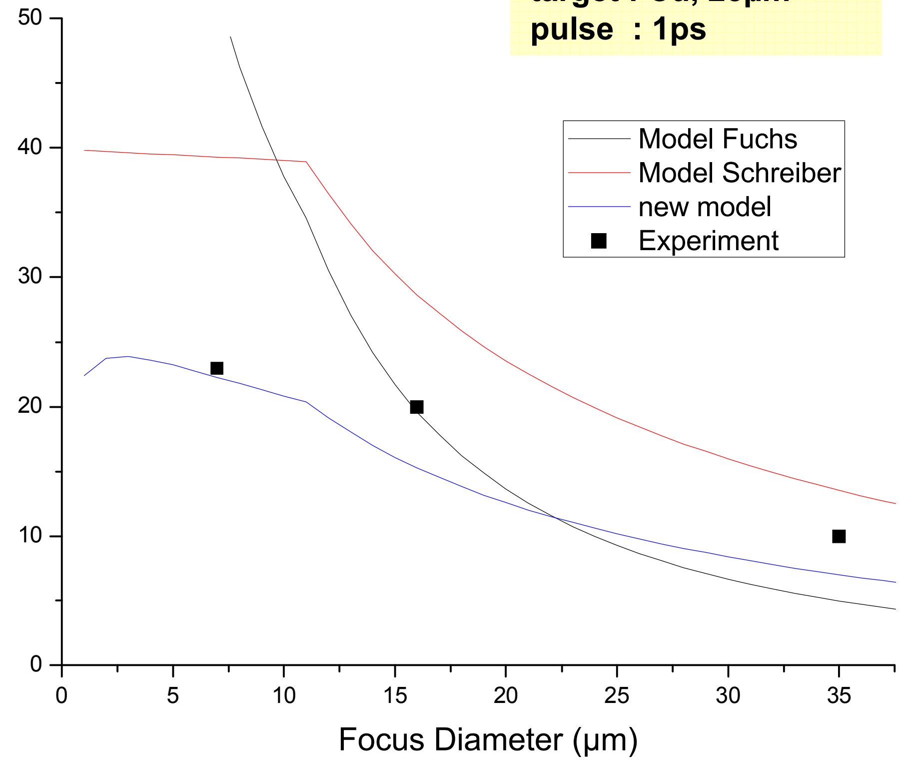
Proton Energy Scaling Laws

A modified model

E_{laser} :40J
target : Cu, 25µm
focus : 8µm FWHM



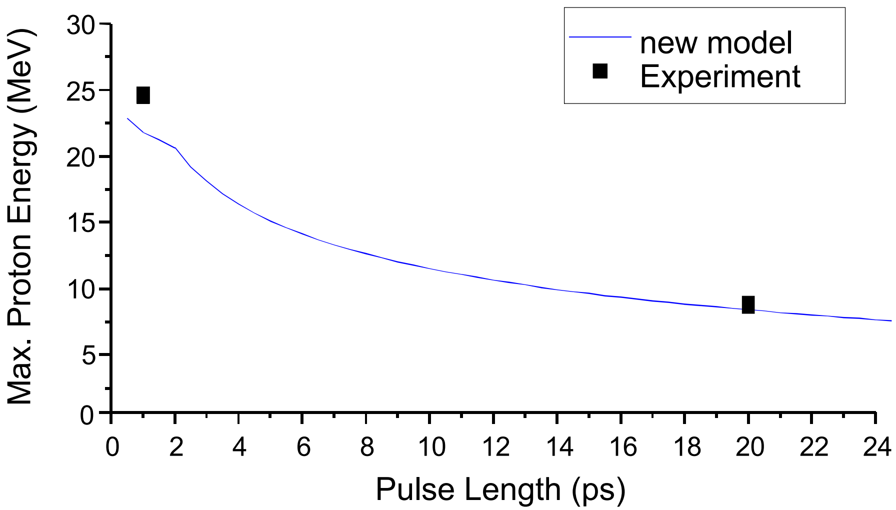
E_{laser} :40J
target : Cu, 25µm
pulse : 1ps

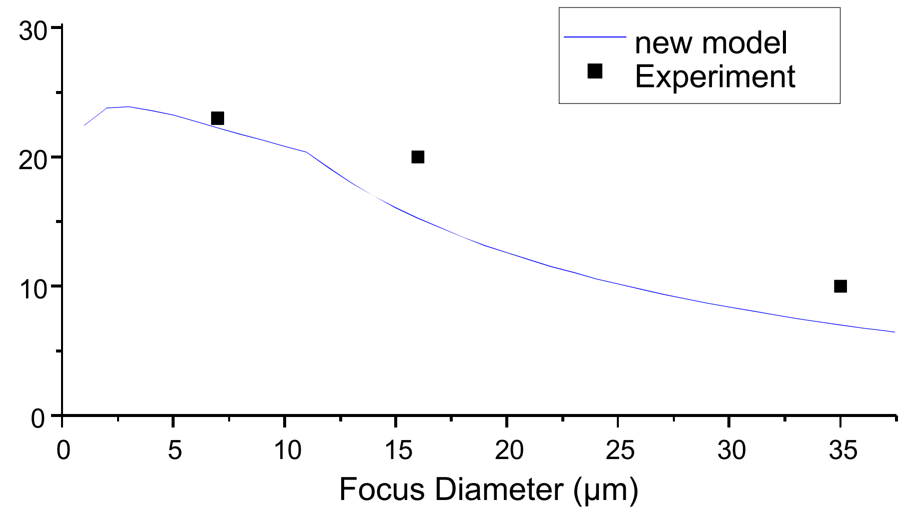


- **Established models disagree strongly.**
- **Established models do not match data.**
- **No critical dependence on focus or pulse width!!**

Proton Energy Scaling Laws

A modified model





- **Electron recirculation has been taken into account.**
- **Electrons cool down due to radiation and collisions, real acceleration time.**
- **Additional empirical energy loss process in the first 100 fs (instability?)**
- **Published data from other experiments are also well reproduced.**

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Summary

- E_{max} of edge emission protons seems independent from laser intensity (thermalization?). It increases linearly with laser energy and decrases linearly with edge distance from focus: Proportionality with electron density.

- Image plates respond linear to the energy deposited by charged particles.

- TNSA protons scale differently than assumed. Intensities seem less significant; the expansion and cooling/energy loss of electrons are important.