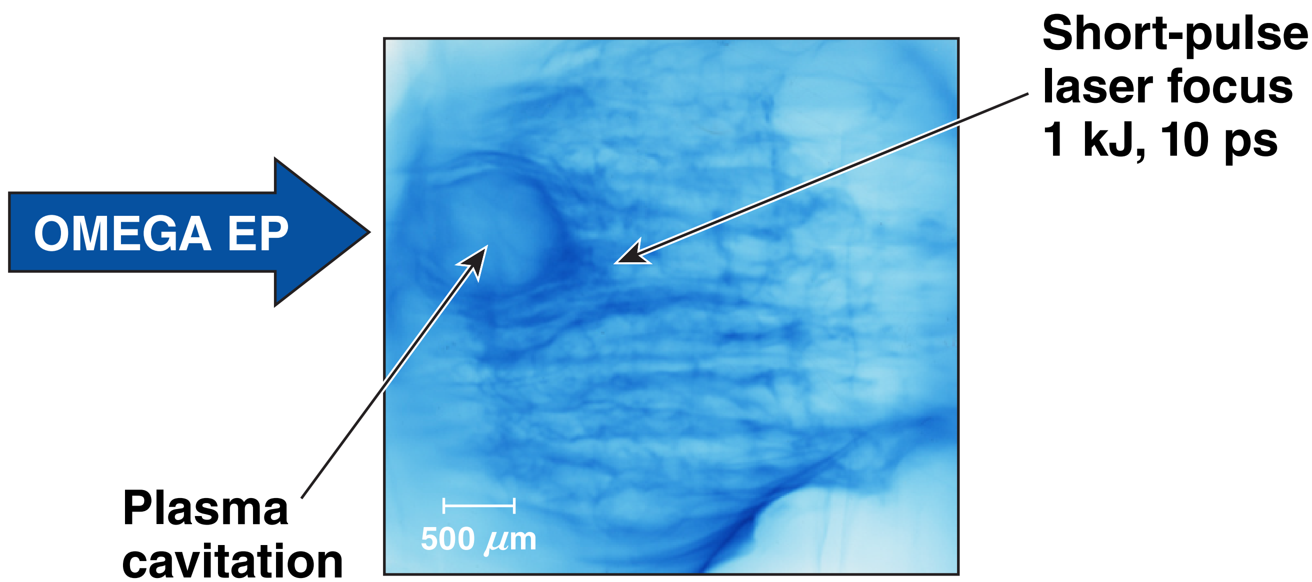
Initial Channeling Studies of a Kilojoule-Class Laser in Long-Scale-Length Plasma



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53rd Annual Meeting of the
American Physical Society
Division of Plasma Physics
Salt Lake City, UT
14–18 November 2011

Summary

Fast-ignition–relevant channeling experiments on OMEGA EP have been conducted using a 1-kJ, 10-ps pulse incident on a large preformed plasma

- Picosecond time-resolved images of channel formation are obtained by proton radiography in a 60-ps window
- Focusing at the density 5×10^{18} cm^{-3} in from the target showed the best penetration into the plasma
- No significant energy coupling was observed for focusing positions closer to the target surface
- About 0.5% of short-pulse laser energy was converted into protons (>15 MeV)

Collaborators

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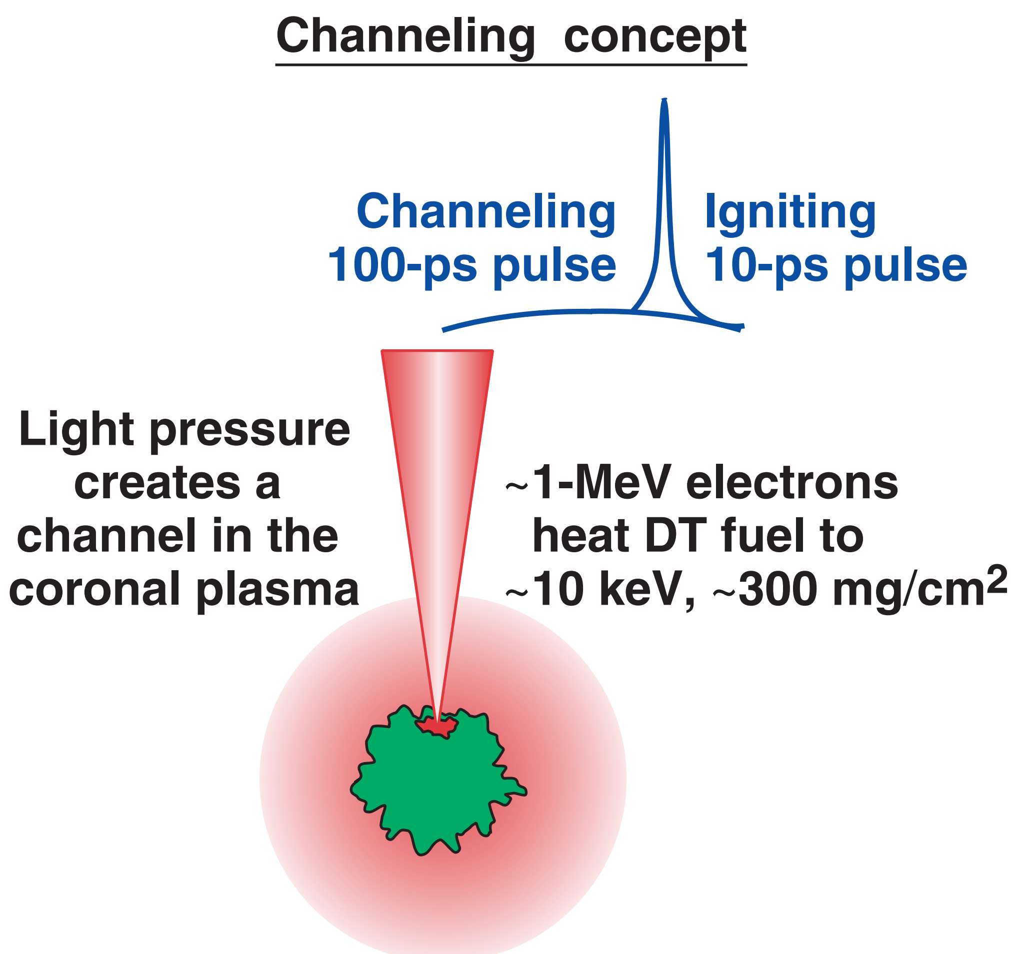
Channeling is one part of a process to deliver localized energy deposition to a compressed core for fast ignition*



Channeling for fast ignition relies on a well-developed understanding of

- channel penetrating velocity
- channel expansion velocity
- residual plasma left in channel

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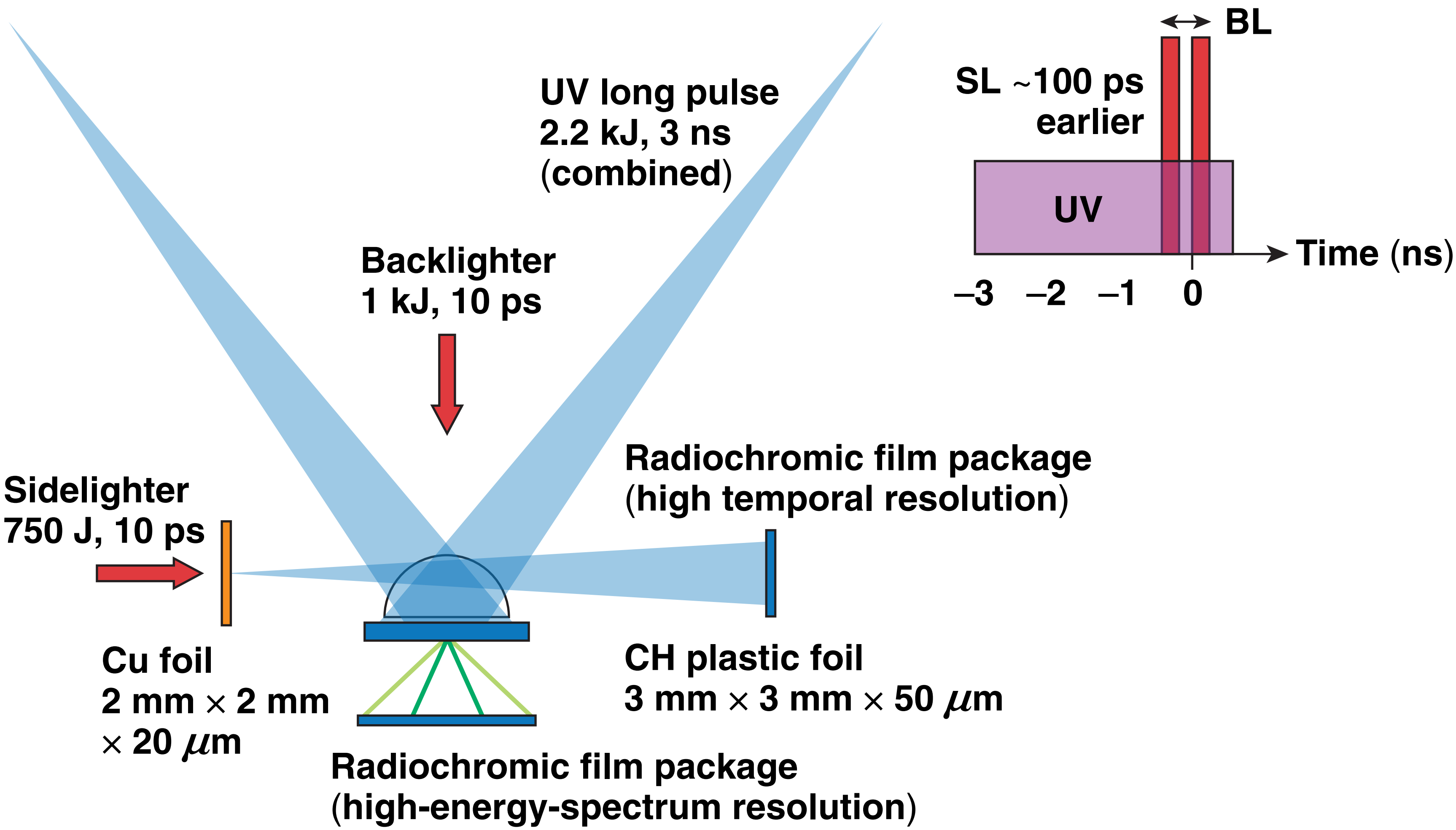
*M. Tabak *et al*., Phys. Plasmas 1, 1626 (1994).

The beam configuration of OMEGA EP allows a fast-ignition–relevant channeling experiment to be performed



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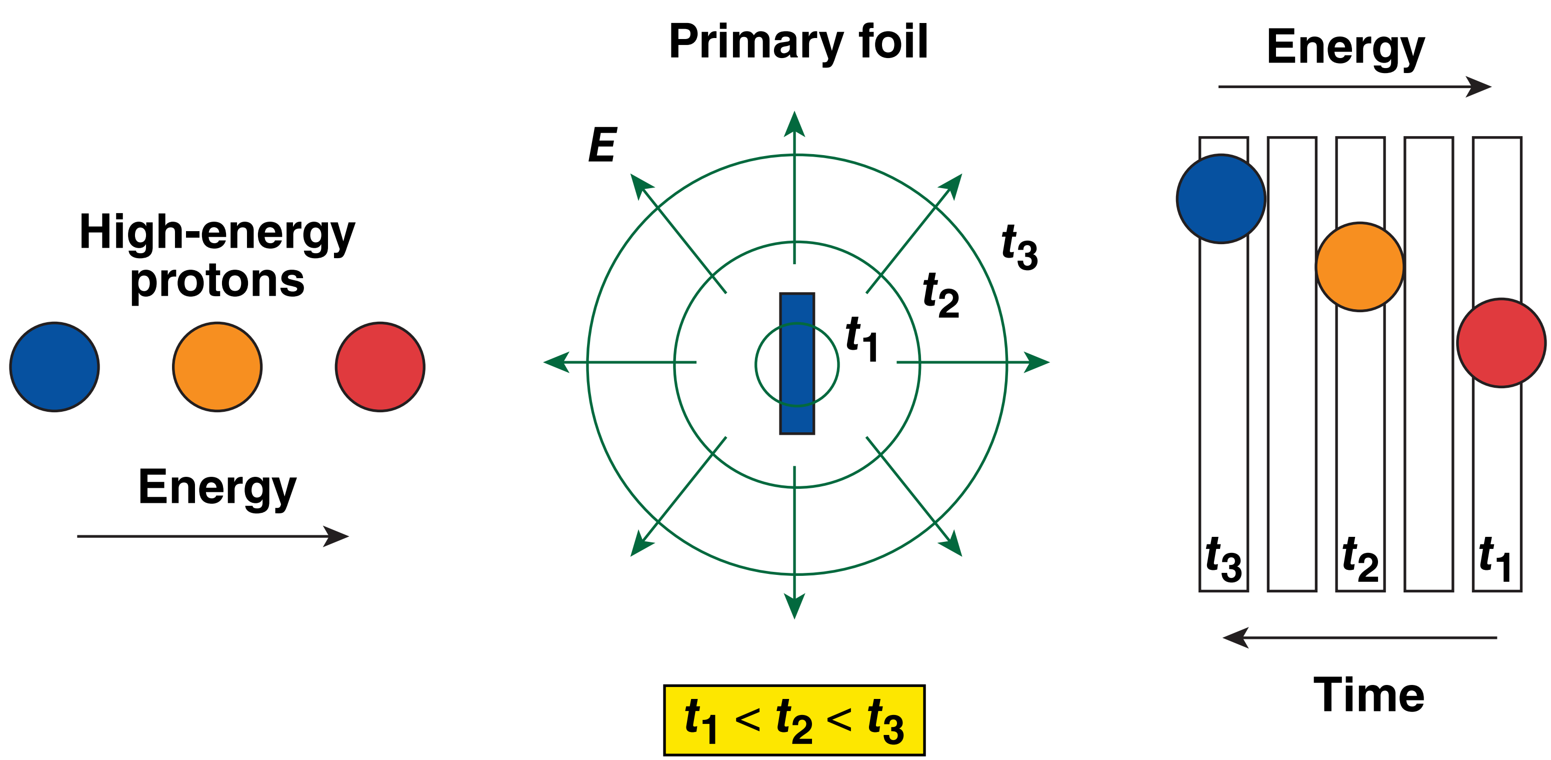
Time-of-flight dispersion and a filtered stack detector produces a multiframe imaging capability



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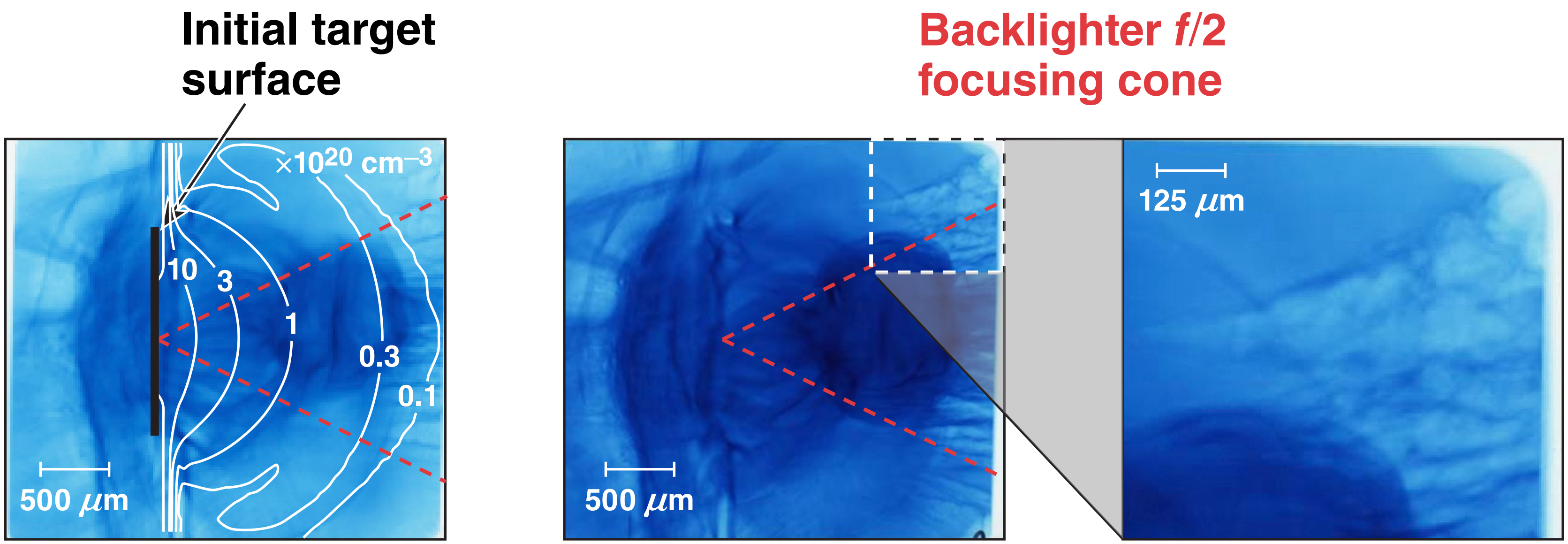
M. Borghesi *et al*., Phys. Plasmas 9, 2214 (2002).

Focusing the laser deep into the plasma led to beam breakup through filamentation



$T = t_0 + 5$ ps

$T = t_0 + 12$ ps

$T = t_0 + 12$ ps (magnified region)

Orthogonal view

Filaments evident up to 0.1 n_c. Filaments are inhibited on axis.

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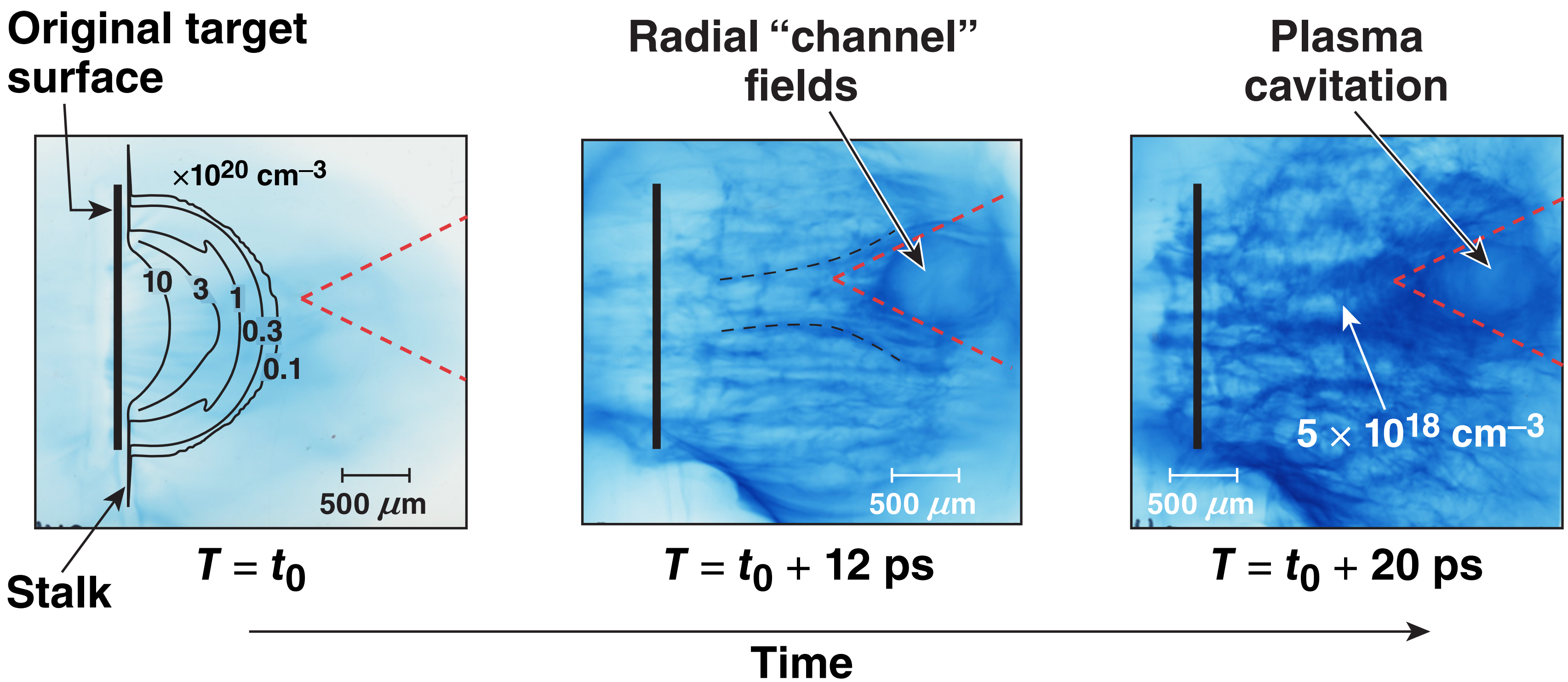
When the laser focused 1.2 mm in front of the original target surface, a large plasma cavitation was observed to develop over ~20 ps



<u>Orthogonal view</u>

- Nominal focus position at $n_e \sim 5 \times 10^{18}$ cm^{-3}
- Super-penetration* studies suggest cavitation depth is sensitive to the plasma density at laser focus

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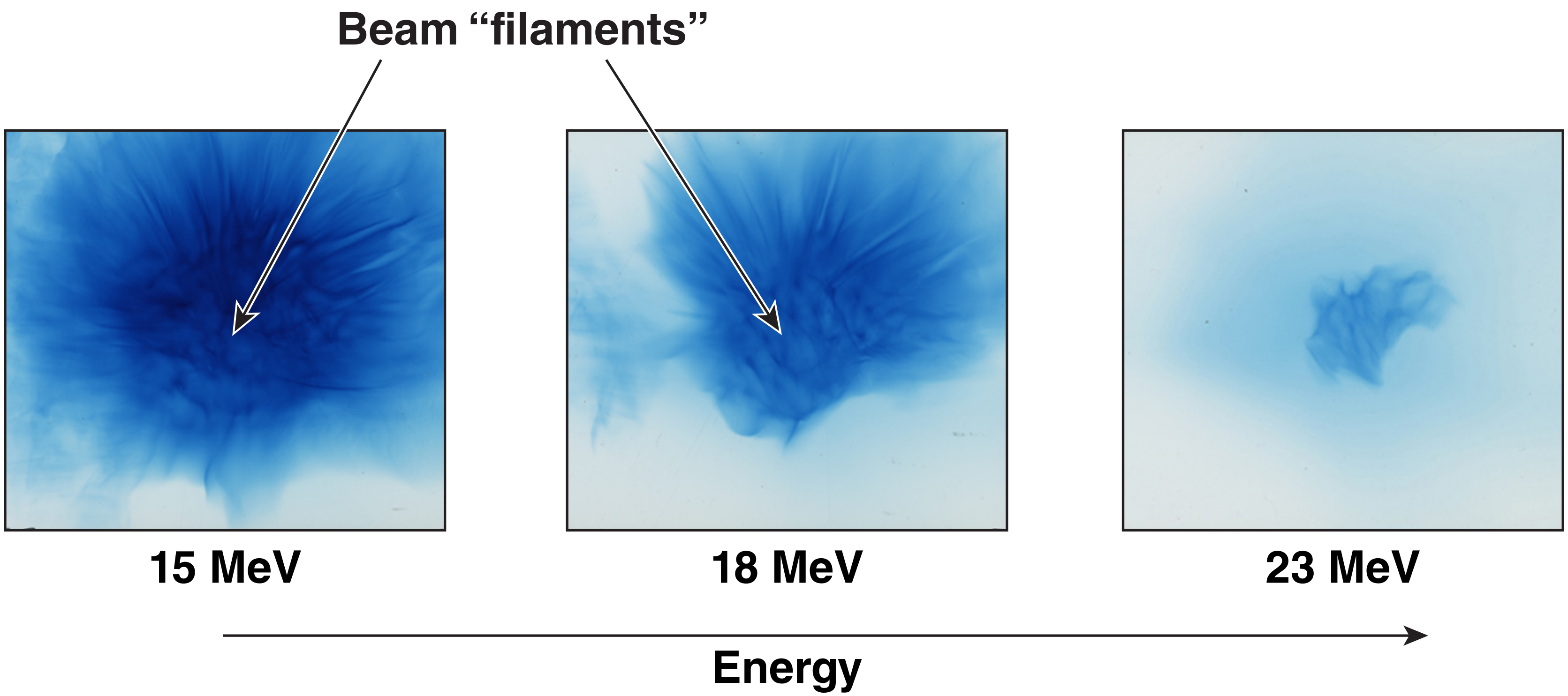
*K. A. Tanaka *et al*., Phys. Plasmas 7, 2014 (2000).

A strong proton signal in the channeling direction was observed indicating energy transport into the dense plasma

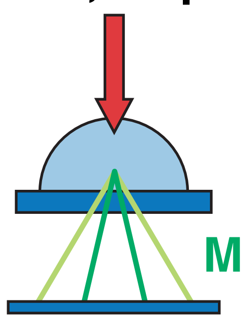


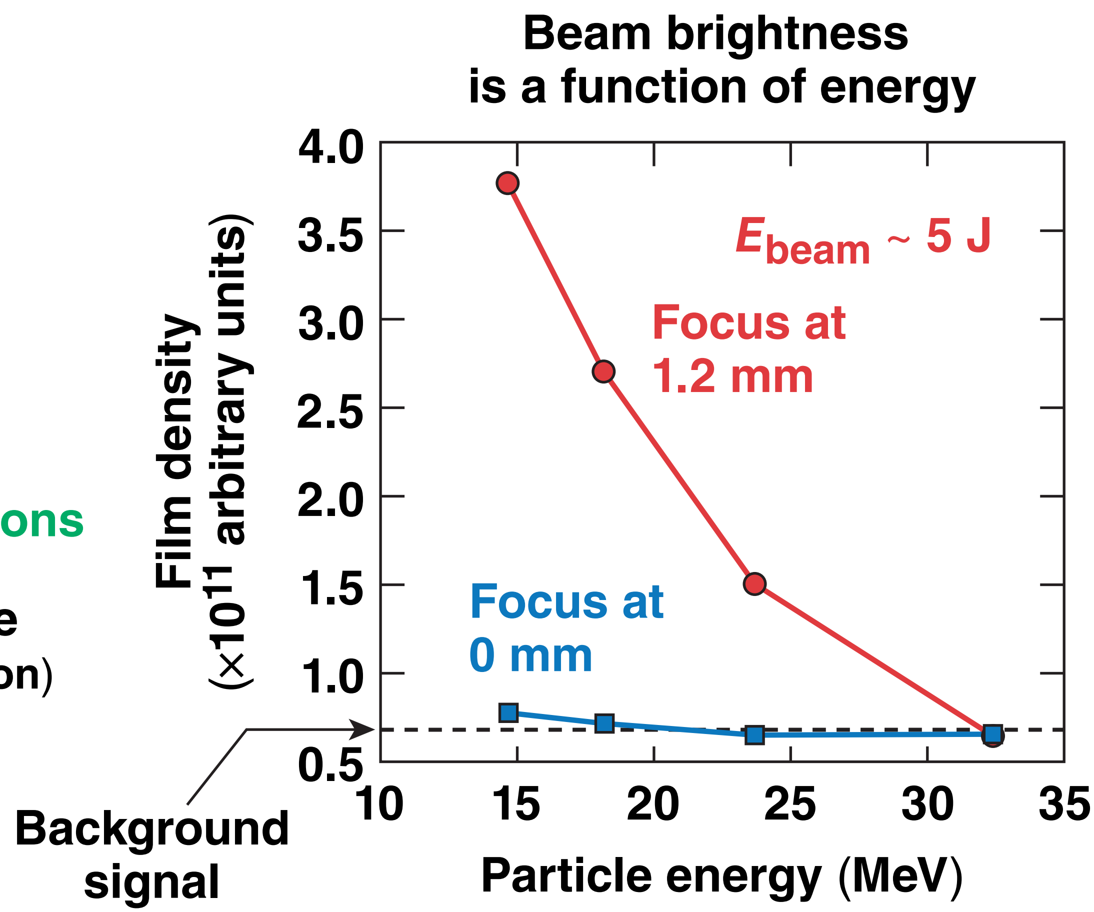
This feature was only observed for the 5×10^{18} cm^{-3} focus position.

Transmitted proton beam image

- Filamented beam structure of accelerated protons
- Beam divergence is a function of energy

The channeling beam produces a sheath field on the CH foil rear side, creating a proton beam in the forward direction in excess of 30 MeV





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Summary/Conclusions

Fast-ignition–relevant channeling experiments on OMEGA EP have been conducted using a 1-kJ, 10-ps pulse incident on a large preformed plasma

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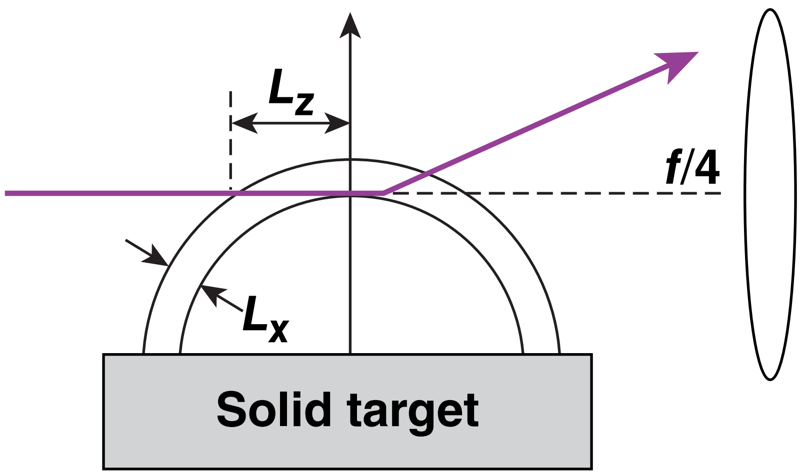
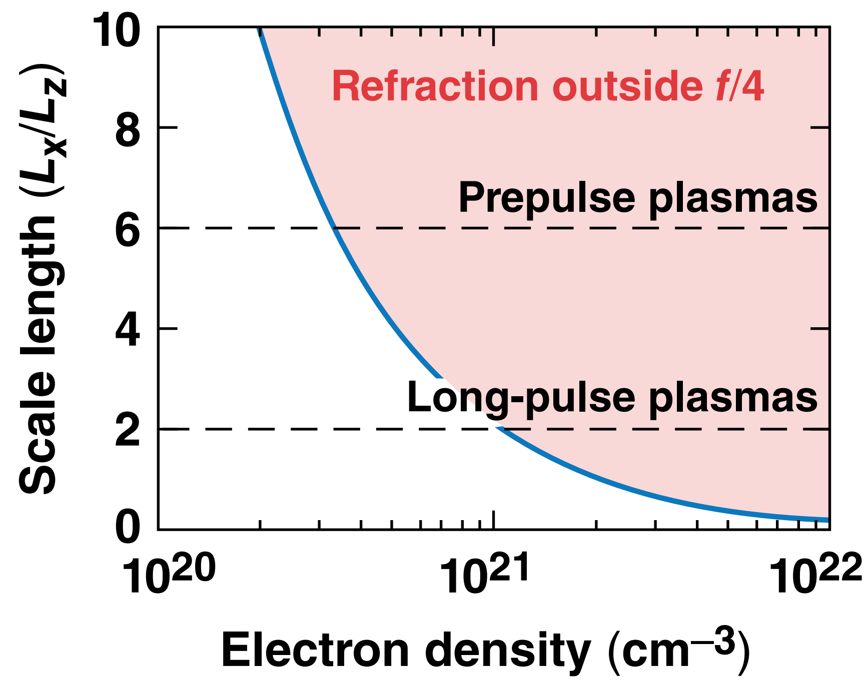
Future experiments will take advantage of the optical probe beam being developed for OMEGA EP

The optical collection system will provide access to high-density laser-produced plasmas

An *f*/4 system can measure

- long-pulse plasmas ($L_x/L_z \sim 2$): $n_e = 10^{21}$ cm^{-3}
- prepulse plasmas ($L_x/L_z \sim 6$): $n_e = 4 \times 10^{20}$ cm^{-3}





An *f*/4 system will provide access to highly refractive plasmas.

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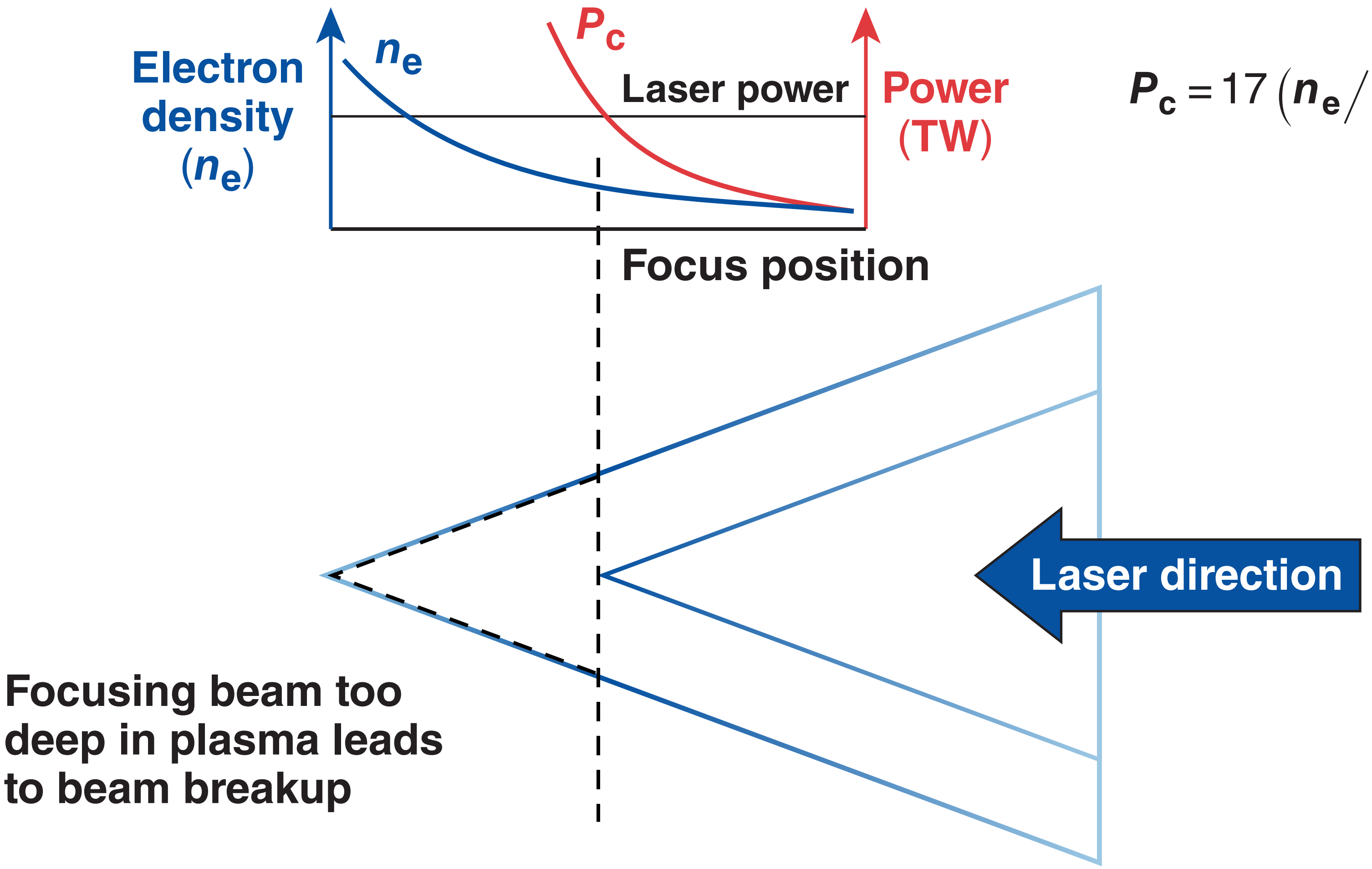
The focusing position of the short-pulse laser beam shows sensitivity to the electron density onto which it is focused



$$P_c = 17\left(n_e/n_c\right)\,\text{GW}$$

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