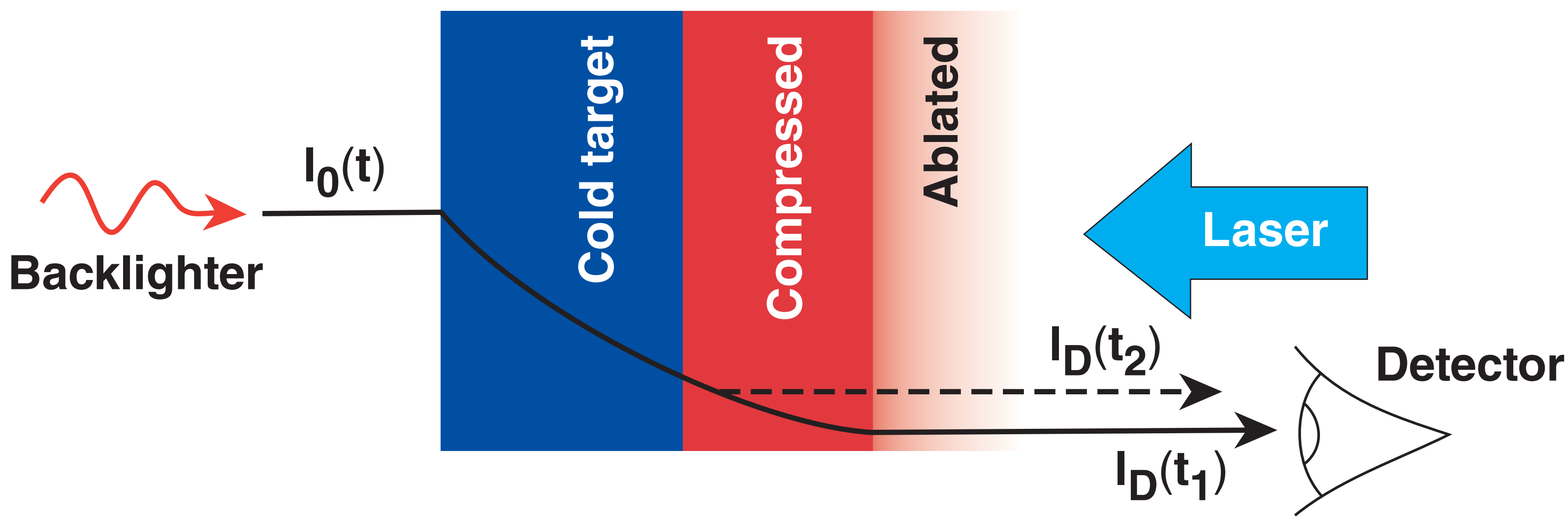
Mass Ablation Rate and Self-Emission Measurements in Planar ICF Experiments



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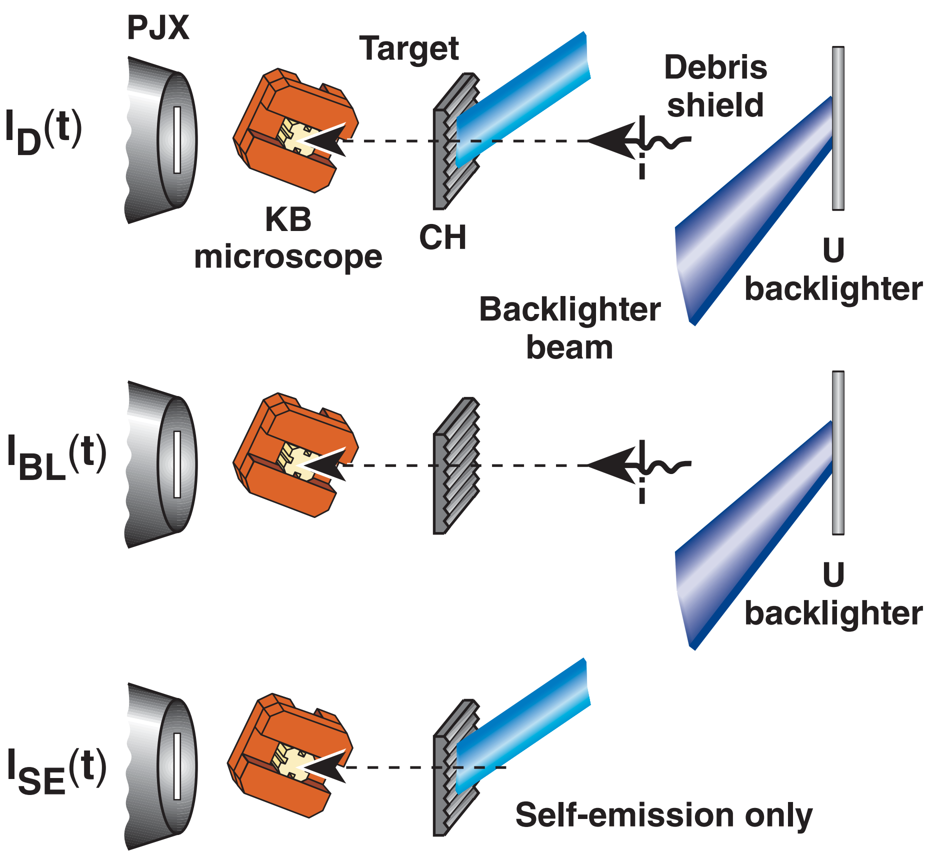
Summary

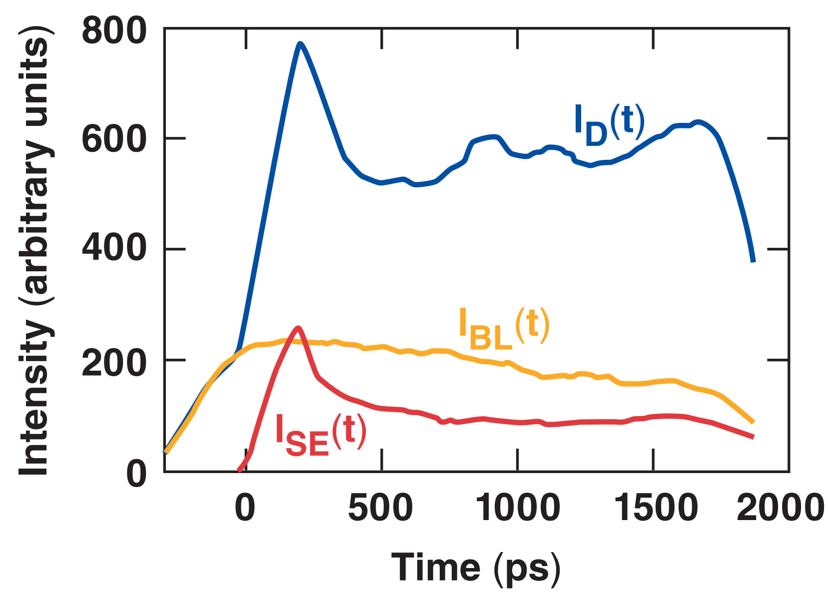
The mass ablation rate can be determined from the changing optical depth of an ablating foil

UR LLE

- For direct-drive ICF, the x-ray mass absorption coefficient does not vary appreciably between the different regions of the target.
- The rate of change in the observed optical depth is proportional to the mass ablation rate.
- Values of the mass ablation rate, determined from existing experiments, are consistent with results from 1-D numerical simulations.

The observed optical depth depends on the level of self-emission and backlighter temporal shape





- Spatially-averaged streak records obtained with the KB-PJX* show the level of self-emission within the experimental spectral window.

*O. Gotchev *et al.*, Rev. Sci. Instrum. 74, 5065 (2003).

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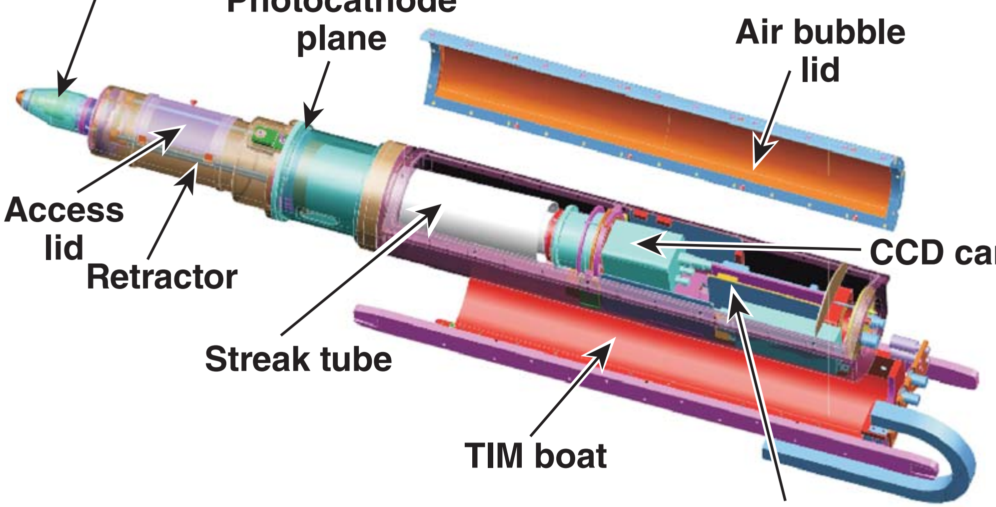
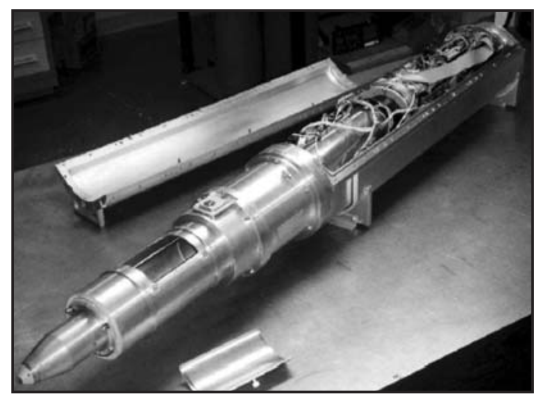
The target optical-depth evolution was recorded with the KB-PJX, a TIM-mountable streaked imager

- The PJX is a self-contained, high dynamic range streak tube with a spatial resolution of $<18\ \mu m$ and a temporal resolution of <20 ps.



Working energy ~ 1.5 keV

- Kirkpatrick–Baez (KB) microscope with sub 5-μm resolution over a 300 μm FOV and a 2.1° incidence angle.
- Its flexible mechanical design accepts a variety of mirrors, currently Ir-coated.



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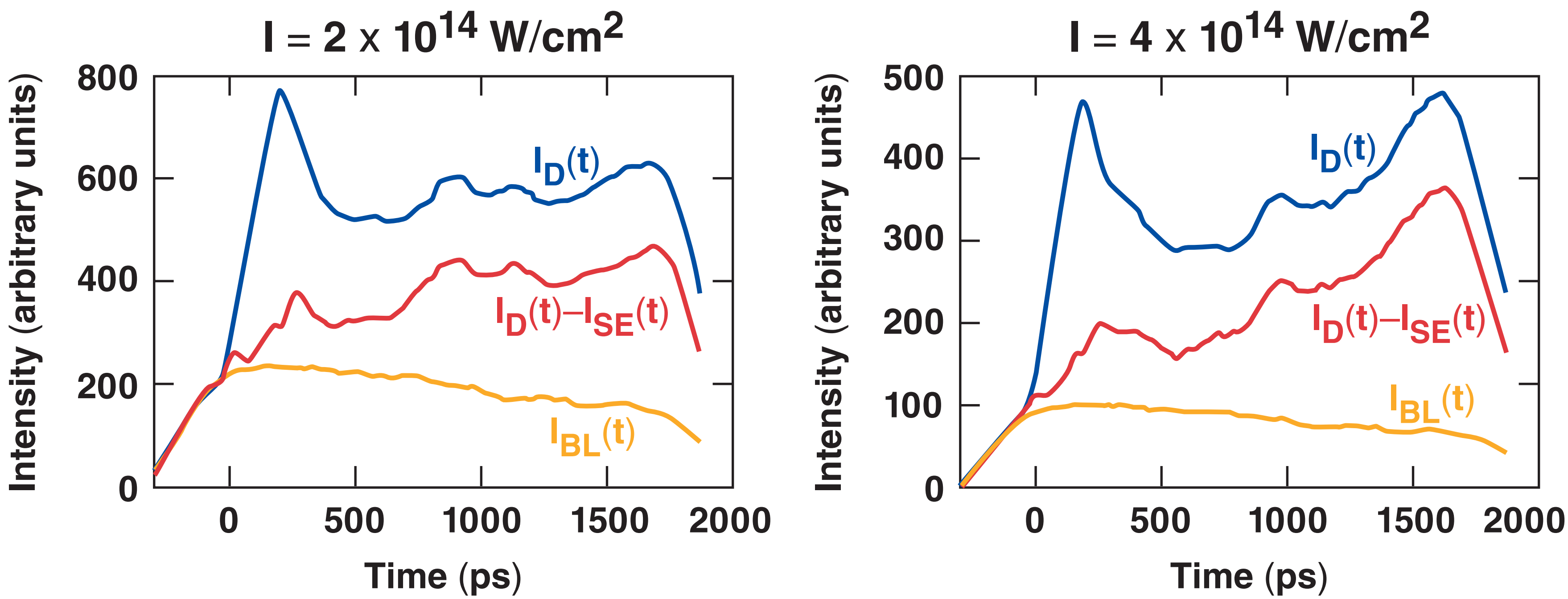
The observed optical depth decreases in ablating targets



- **The difference in the observed intensity for driven targets and the backlighter, attenuated through a cold target, increases in time due to mass ablation.**

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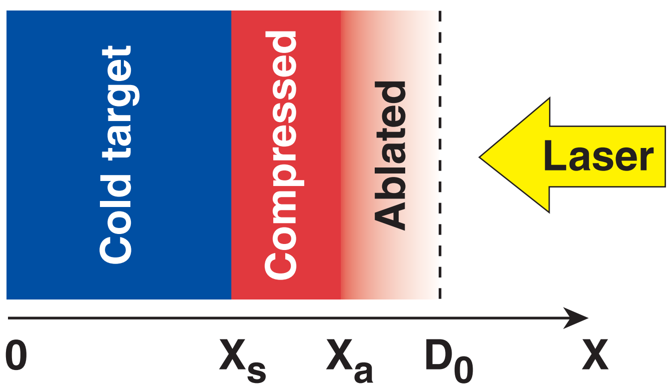
The rate of change in the observed optical depth is proportional to the mass ablation rate



- The blowoff region does not contribute to the total optical depth.
- μ deviates detectably from its cold-target value only in the blowoff plasma.

$$I_D(t) = I_{SE}(t) + I_{BL}^0(t)\, e^{-\left. OD \right|_0^{x_s(t)} - \left. OD \right|_{x_s(t)}^{x_a(t)}}$$

$$\Delta OD = \ell n \left\{ \frac{I_D(t) - I_{SE}(t)}{I_{BL}(t)} \right\} = \mu_0 \int_0^t \dot{m}(t)\, dt'$$

where $I_{BL}(t) = I_{BL}^0(t)\, e^{-\mu_0 \rho_0 d_0}$

$$\dot{m}(t) = \frac{d(\Delta OD)}{\mu_0 dt} = \frac{1}{\mu_0} \frac{d\left[\ell n \frac{I_D(t) - I_{SE}(t)}{I_{BL}(t)}\right]}{dt}$$

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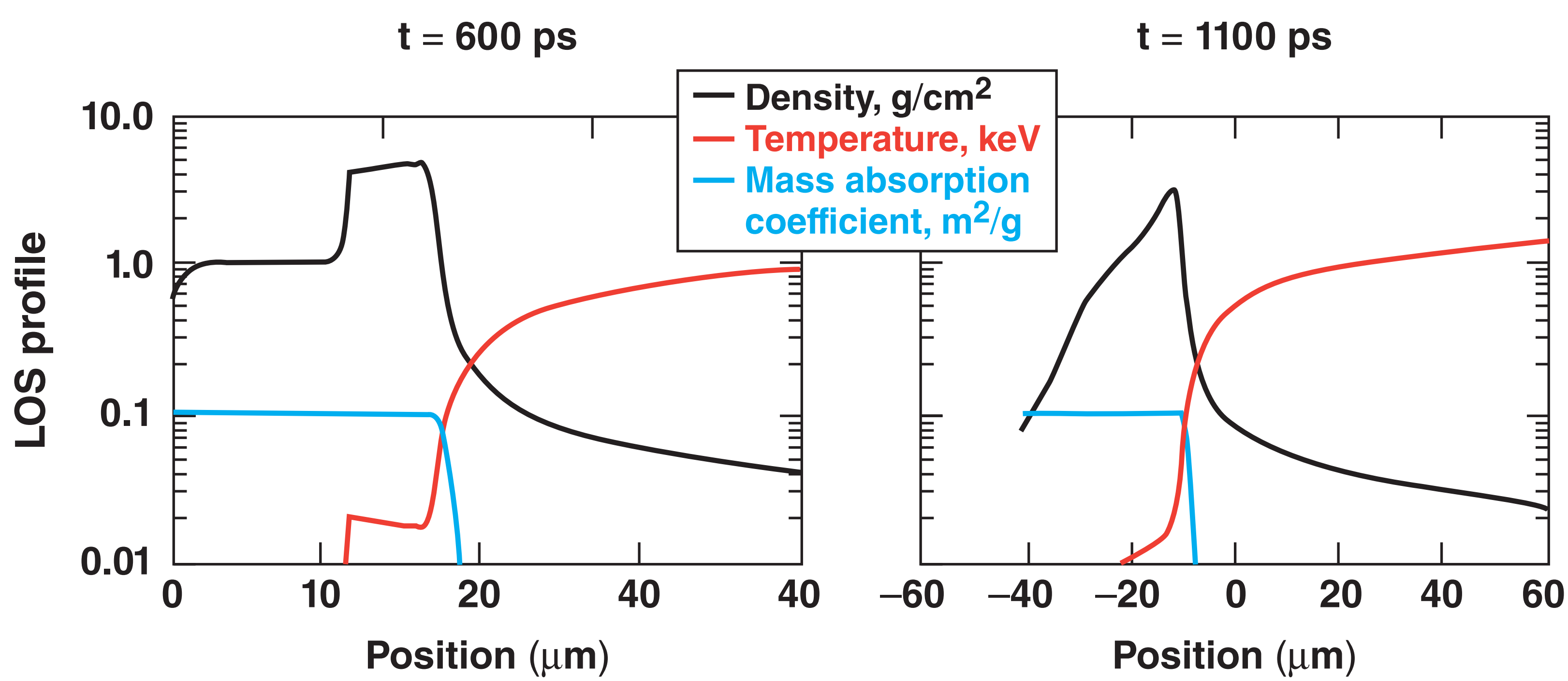
The shock-compressed and unshocked regions have essentially the same mass absorption coefficient



- Simulated density and temperature profiles were used to determine the spectrally averaged mass absorption coefficient* μ throughout the target.

*Obtained from the APL opacity tables. W.F. Heubner *et al*. LANL, Los Alamos, NM, Report LA-6760-M (1977).

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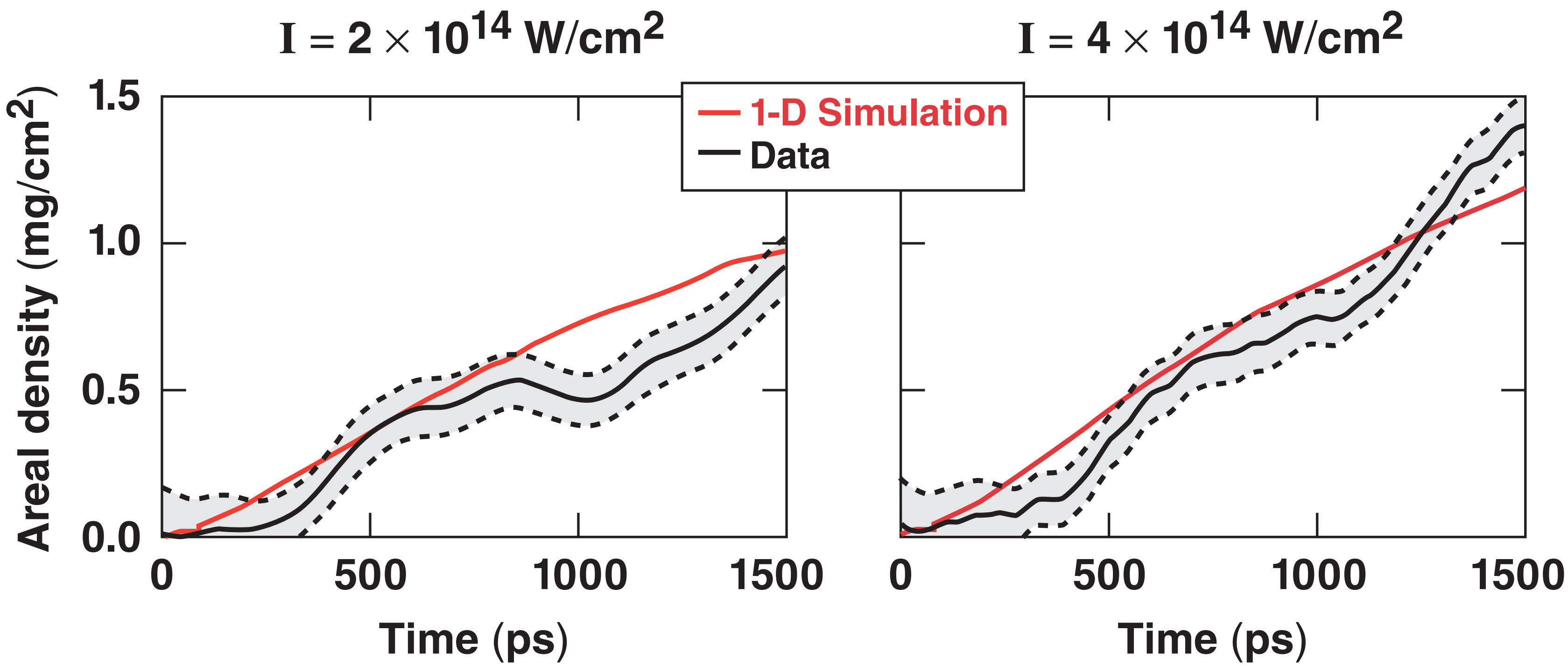
The observed growth of the ablated mass is consistent with 1-D hydrodynamic simulation results



$$\dot{m}_{avg}\,(\text{sim.}) = 0.62\,\frac{\text{mg}}{\text{cm}^2\text{ns}}$$

$$\dot{m}_{avg}\,(\text{exp.}) = 0.54 \pm 0.07\,\frac{\text{mg}}{\text{cm}^2\text{ns}}$$

$$\dot{m}_{avg}\,(\text{sim.}) = 0.76\,\frac{\text{mg}}{\text{cm}^2\text{ns}}$$

$$\dot{m}_{avg}\,(\text{exp.}) = 0.78 \pm 0.06\,\frac{\text{mg}}{\text{cm}^2\text{ns}}$$

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