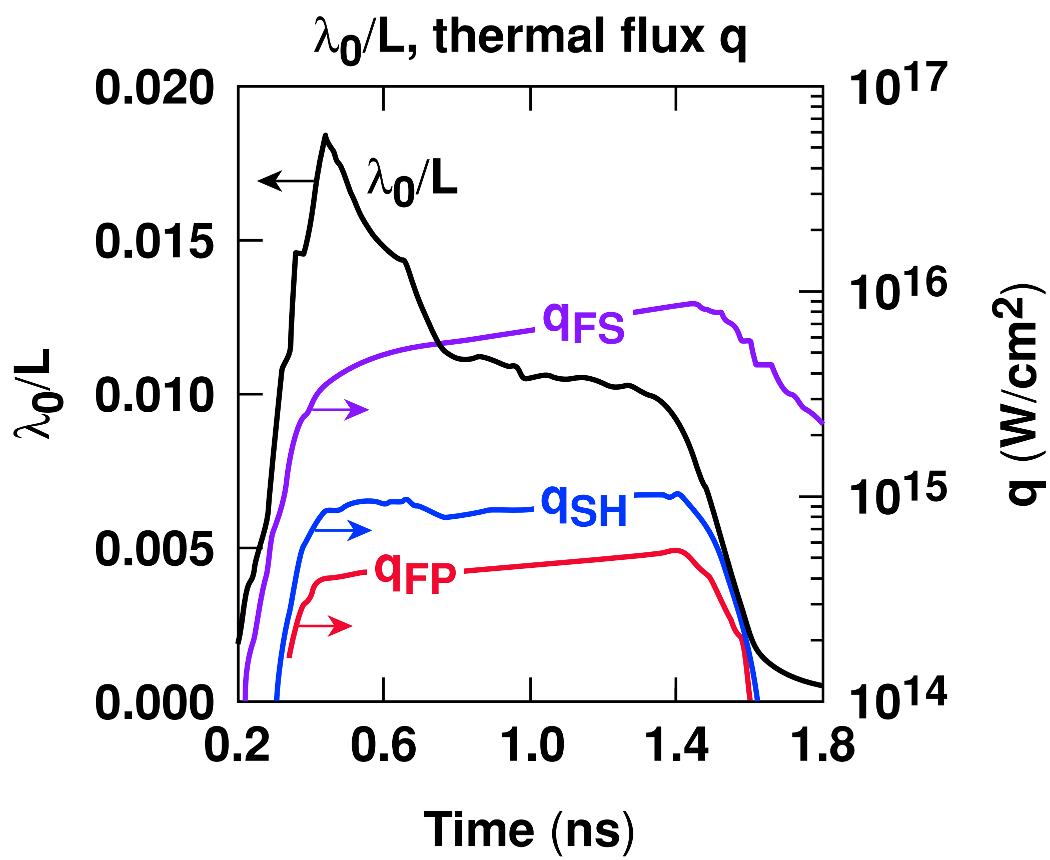
# Fokker–Planck Calculation of ICF Implosions





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Summary

# We have developed a 1-D Fokker–Planck Code and combined it with the 1-D hydrodynamic code *LILAC*

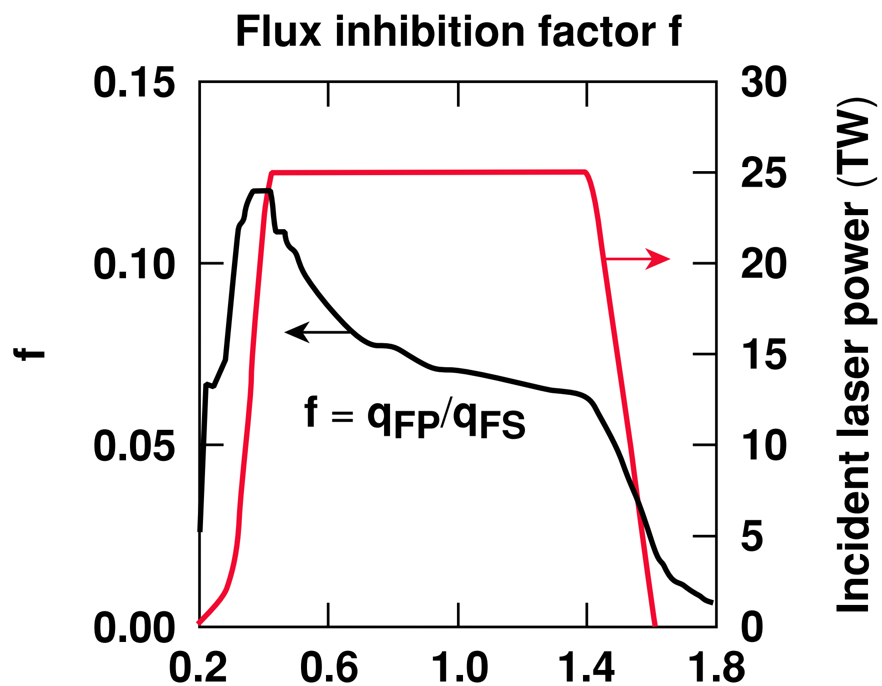
- For CH implosions, comparison of Fokker–Planck (FP) with flux-limited Spitzer–Härm (SH) diffusions shows that
  - the flux inhibition factor is time dependent
  - with FP, the laser absorption is higher than with SH due to a longer density scale length at the critical surface
  - in the acceleration phase, FP gives a density-scale length at the ablation surface 50% longer than SH
  - FP gives good agreement with the experimental bang time.

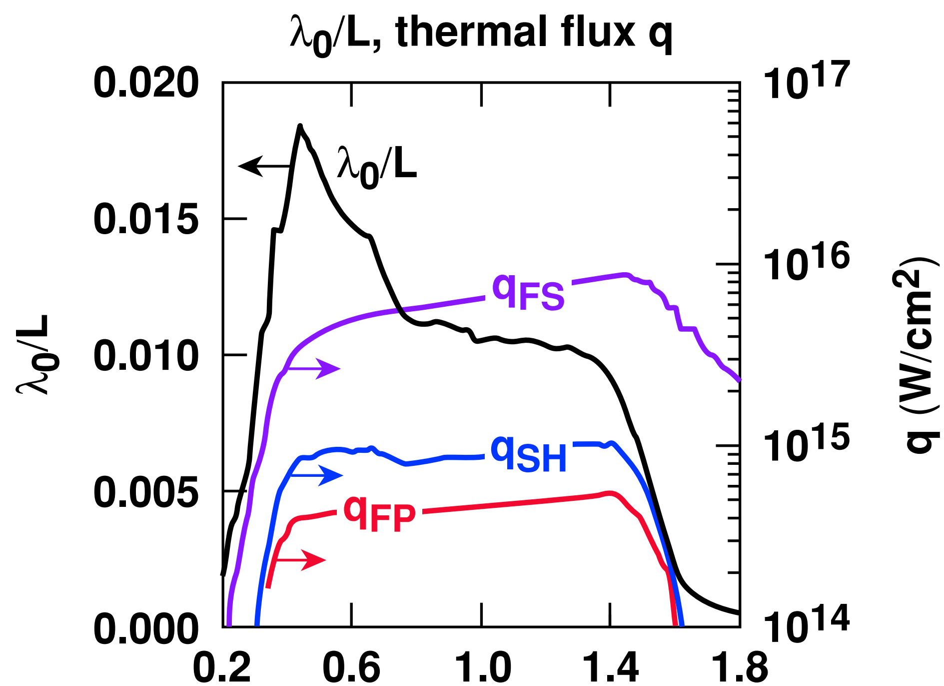
FP Code Equations

# The distribution function is expanded in Legendre modes to second-order

- $f(z, \vec{v}, t) = f_0 + f_1\cos(\theta_z) + f_2\left\{3\cos^2(\theta_z) - 1\right\}/2$
- The Fokker–Planck equations for $f_0$, $f_1$, and $f_2$ are calculated with e-i and e-e collisions.
- For closure, a simplified $f_3$ equation is used.
- The electric field is calculated based on the current free condition.
- $\Delta T_e$ and $\Delta n_e$ are calculated from the hydrodynamics equations without $\nabla \cdot q_e$
- $T_{eff} = \frac{4\pi m_e}{3n_e}\int_0^\infty v^4 f_0 dv$ is computed from FP using $\Delta T_e$ and $\Delta n_e$ as source terms.

# In the FP calculation the flux inhibition factor ($f = q_{FP}/q_{FS}$) is time dependent




- Quantities measured at the critical surface
  - $\lambda_0$: electron mean free path for 90° collision scattering
  - L: electron temperature scale length $L = L_{Te} = T_e \Big/ \frac{\partial T_e}{\partial x}$

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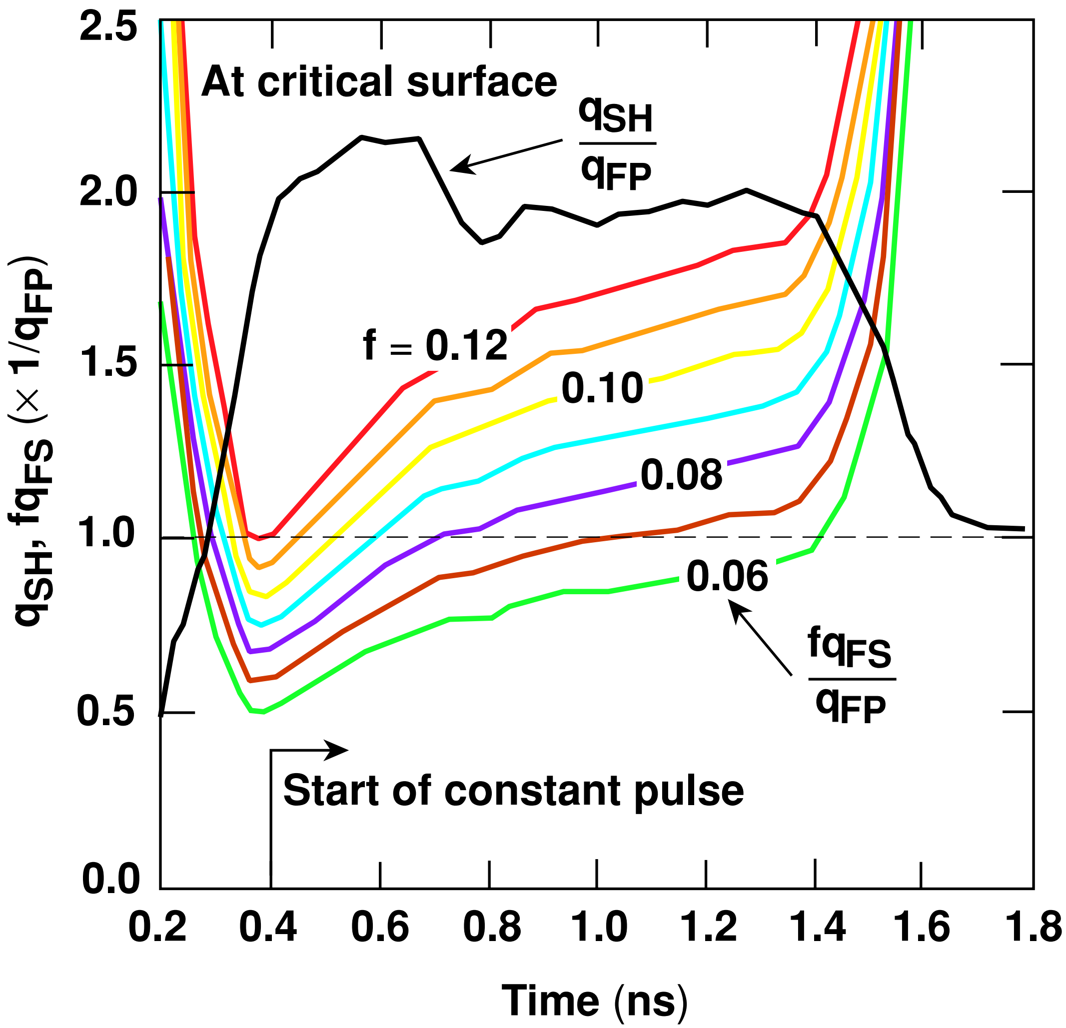
# To match the flux-limited SH flux with FP, the flux limiter should be changed in time




$q_{FP} = \min(fq_{FS}, q_{SH})$

f : flux-inhibition factor

$q_{FS}$: Free-streaming flux

$$q_{FS} = n_e T_e v_{th}$$

$$v_{th} = \left(\frac{T_e}{m_e}\right)^{\frac{1}{2}}$$

$q_{SH}$: Spitzer-Härm flux

**Absorbed laser power-averaged flux limiter**

$$\langle f \rangle = \frac{\int f I_A dt}{\int I_A dt} = 0.075$$

$I_A$: Absorbed laser power

**The inhibition factor is larger early in the pulse.**

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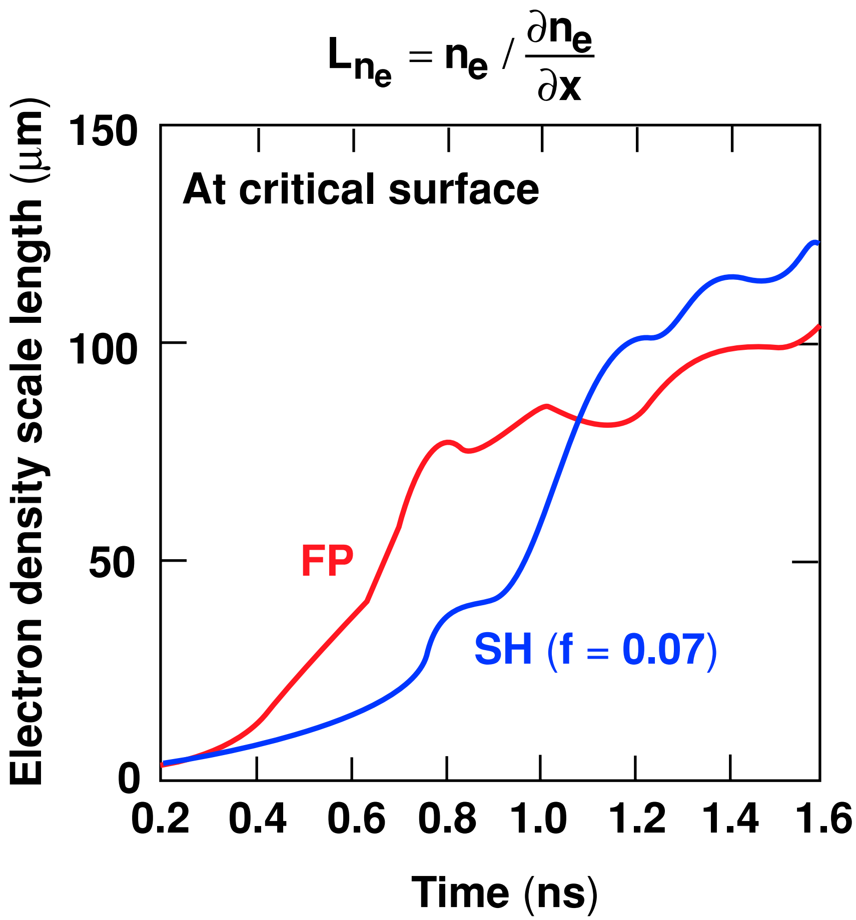
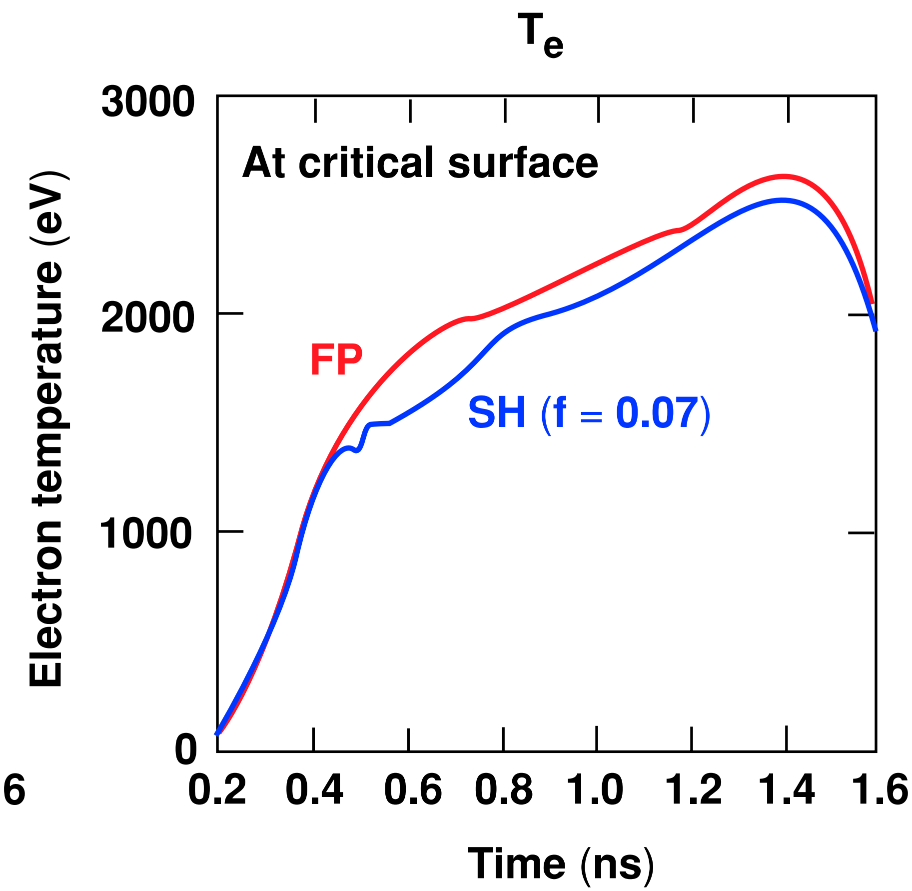
# Early in the pulse, FP gives a large density scale length at the critical surface than SH




**The larger early $L_{ne}$ in the FP case gives rise to a larger absorption fraction than in the SH case.**

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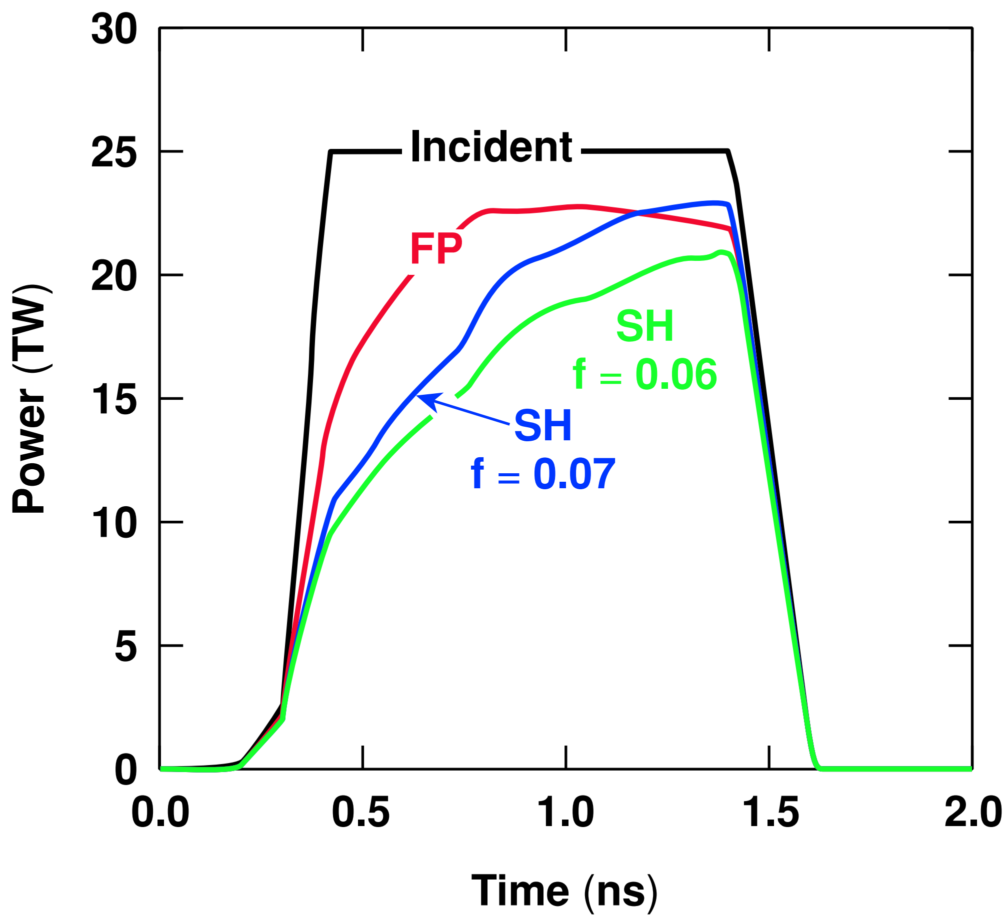
# FP gives a large laser absorption early in the pulse and results in an increase of the total laser absorption fraction




| Total absorption fraction | |
|---|---|
| FP: | 0.83 |
| SH f = 0.07: | 0.76 |
| SH f = 0.06: | 0.68 |

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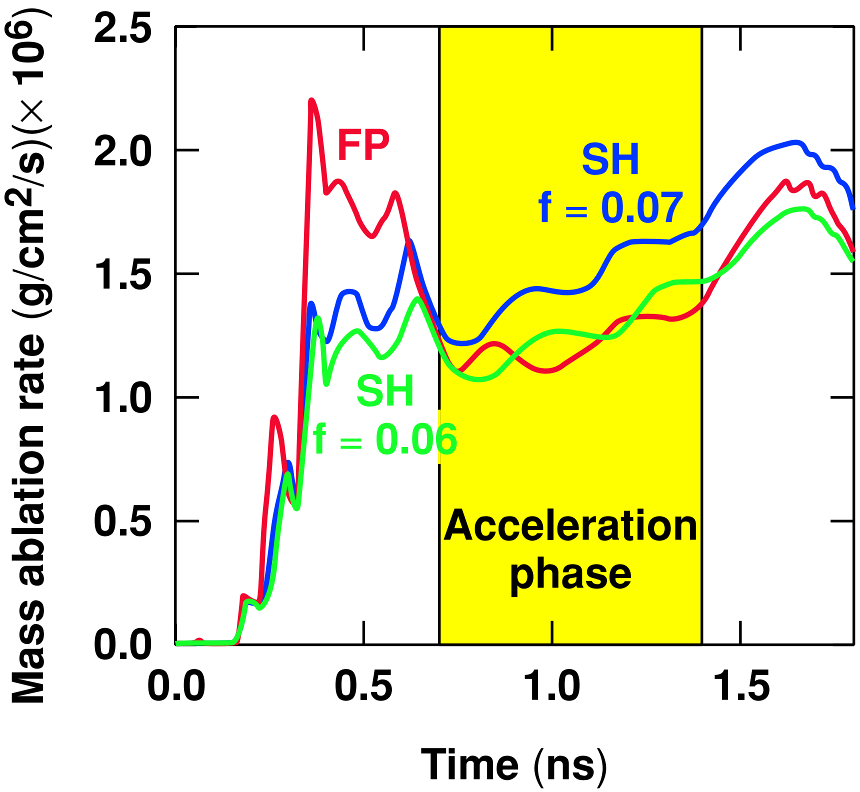
# During the acceleration phase, FP gives a relatively low value for the mass ablation rate




**Time-averaged values over the acceleration phase**

| | FP | SH |
|---|---|---|
| Ablation density $<\rho_a>$ (g/cm$^3$) | 3.06 | 3.77 |
| Ablation velocity $10^5$ $<V_a>$ (cm/s) | 4.01 | 3.99 |
| Minimum density gradient scale length $<L_m>$ ($\mu$m) | 1.31 | 0.83 |

The early large mass ablation rate causes the large scale length in the FP case.

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# For the 1-ns square pulse, both the SH f = 0.07 and FP show good agreement with experimental results

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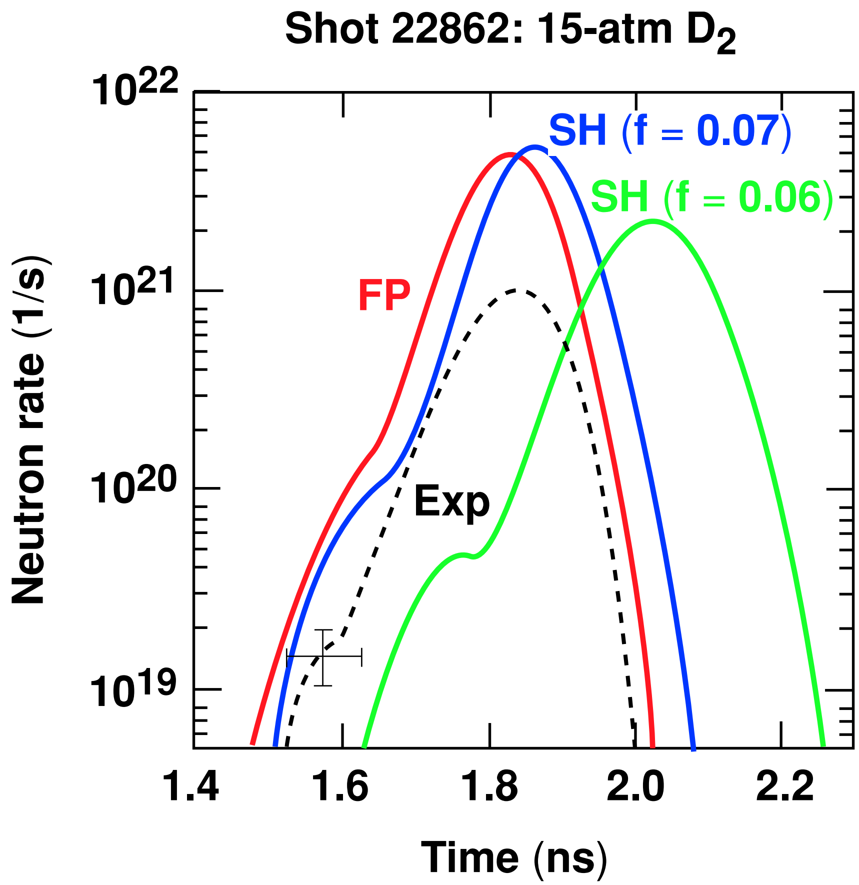
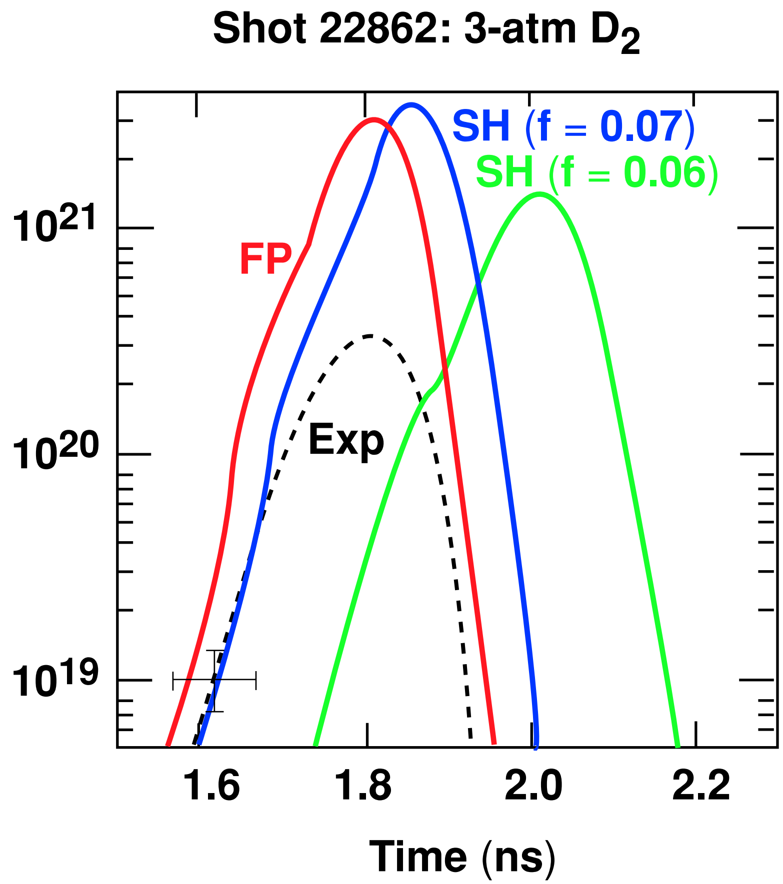
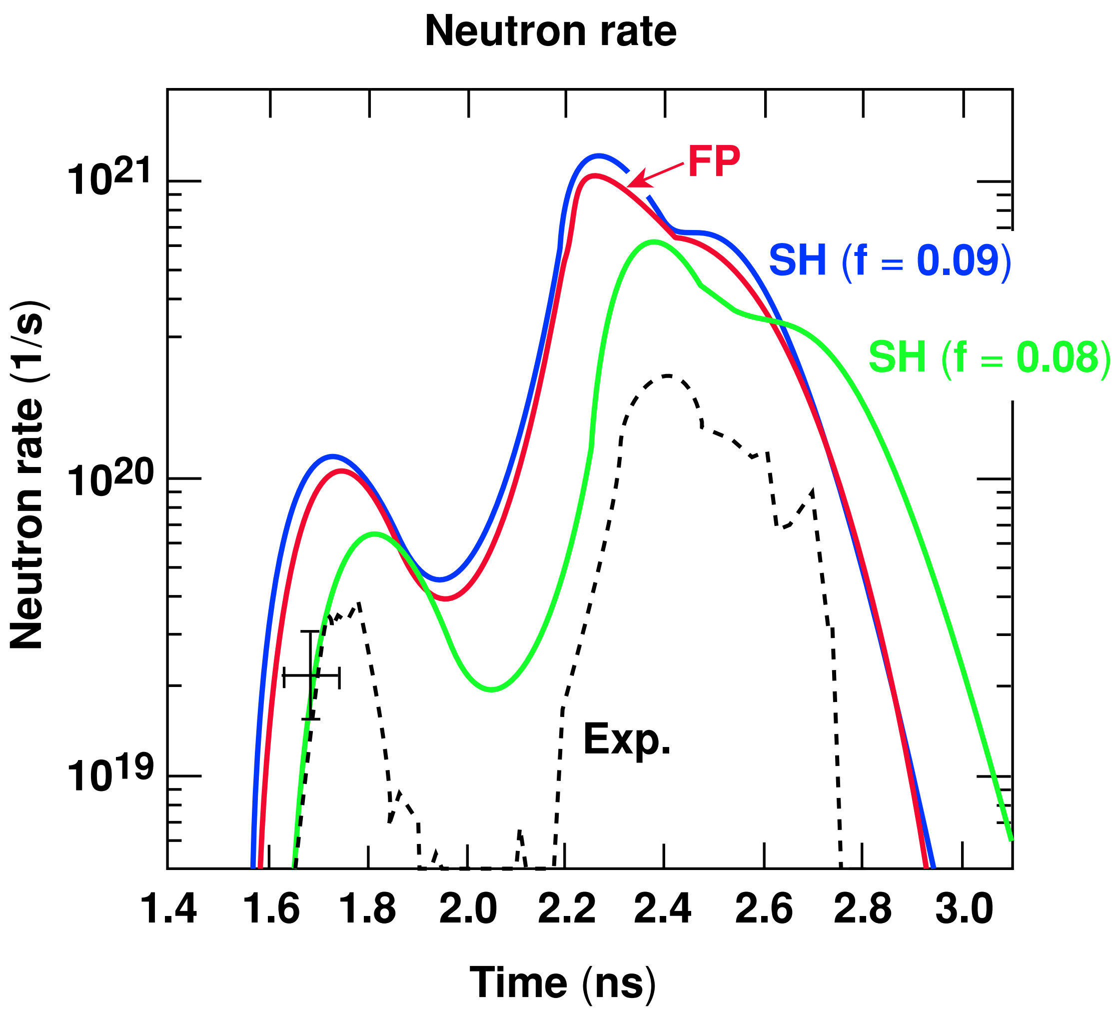



**From FP, ⟨f⟩ = 0.075**

TC5817

# For the 400-ps square pulse, the FP bang time coincides with SH f = 0.09 case, confirming that a larger flux limiter is needed for the short pulse




**Absorbed laser-power-averaged flux limiter**

$$\langle f \rangle = \frac{\int f I_A dt}{\int I_A dt} = 0.087$$

$I_A$: Absorbed laser power

TC5818

Conclusions

# We have developed a 1-D Fokker–Planck code and combined it with the 1-D hydrodynamic code *LILAC*

- For CH implosions, comparison of FP with the flux-limited SH model
  - The flux inhibition factor is time dependent.
  - With FP, the laser absorption is higher than with SH due to a longer density scale length at the critical surface.
  - In the acceleration phase, FP gives a density-scale length at the ablation surface 50% longer than SH.
  - FP gives good agreement with the experimental bang time.
  - Calculations for cryogenic targets with shaped pulses are planned.