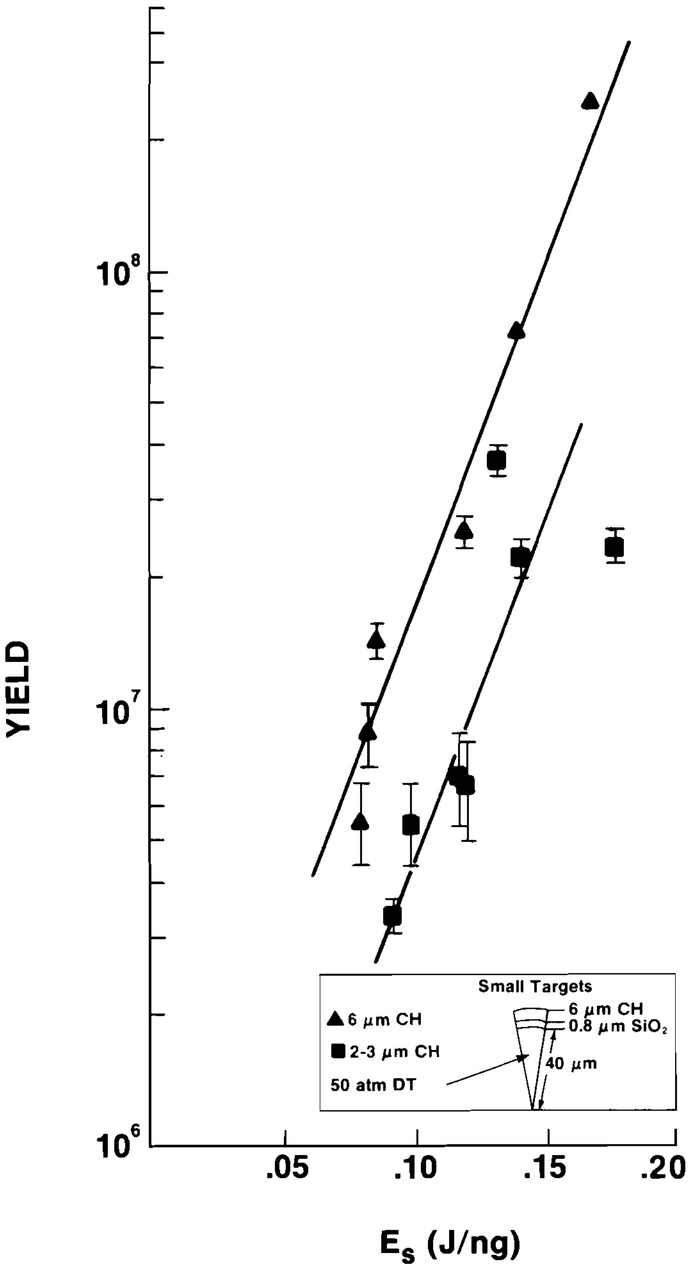

Figure 12 Neutron yield versus specific absorbed energy for the smaller diameter targets of Figure 11. The lines summarize the results for the two coating thicknesses: 6µm CH coatings lead to yields 3-4 times that obtained for 2-3µm CH coatings for the same E_S.

Figure 12 shows the yield versus E_s for the small targets only. For identical E_s, the targets with the thicker 6µm CH coatings have, on the average, 3-4 times the yield of the 2-3 µm CH coated targets. The most important parameter determining the yield is the DT ion temperature T_i. Targets imploded with equal average implosion velocities to the same compression would be expected[6] to reach the same T_i. The yield results alone, then, suggest that these thicker wall targets reach higher compressed DT densities. The x-ray imaging results discussed previously[7] also support an increase in compressed DT density with increasing wall thickness. The higher density increases the yield directly ($Y \sim \rho_{DT}$) and indirectly by the increase in T_i through the extra compressional heating[6,*]. LILAC simulations also give a factor of 3 increase in yield for this wall thickness difference in very good agreement with experiment. It is very encouraging that our implosion symmetry on ZETA is sufficient to demonstrate the increase in yield with wall thickness (at constant E_S) expected theoretically.

2.D High-Density Effects on Thermonuclear Ignition for Inertially Confined Fusion

To obtain net energy production with inertially confined fusion, the DT fuel must undergo thermonuclear ignition. With a sufficiently high fuel ρR (density-radius product), the 3.5 MeV alpha particles produced in the DT reaction deposit their energy within the fuel leading to rapid self-heating (ignition). Values of fuel ρR larger than 0.3 g/cm^2 and fuel plus tamper ρR larger than 1 g/cm^2 have been considered to be required for a thermonuclear burn sufficient for net energy production[8]. The tamper is composed of relatively cold material surrounding the DT fuel and contributes to the yield by prolonging the burn time.

We have found that under some conditions, the minimum required fuel ρR may be reduced. Alpha particles from the DT reaction have been calculated to reflect from a high-Z, Fermi-degenerate shell surrounding the fuel of inertial fusion targets. This leads to a reduction in the minimum fuel ρR needed to sustain a thermonuclear burn, and possibly to a reduction of the minimum input energy required to achieve thermonuclear ignition[9].

The amount of alpha particle reflection from the tamper is determined by competition between energy loss to electrons and Coulomb scattering by ions in the tamper. At the onset of thermonuclear burn, the tamper should ideally be Fermi degenerate for minimum ignition requirements. Since only electrons near the Fermi surface would then contribute to particle slowing down, the energy loss would be less than expected classically, and the relative amount of scattering would be enhanced, increasing the energy deposition in the fuel. This in turn results in a reduction in the minimum fuel ρR needed to sustain a thermonuclear burn.

To find the density needed for reflection, the following test problem was solved. A DT sphere was set at T = 10 keV, $n_e = 5 \times 10^{26}$ cm^3 ($10^4 \times$ liquid density) and $\rho R = 0.3$ g/cm^2. This was surrounded by a gold shell (Z = 79) at 1 keV whose density was varied. To determine how the energy reflection depends on tamper density, the Fokker-Planck equation was solved for the alpha-particle transport.

*A thicker wall target also implies a thicker tamper, which leads to a longer disassembly time and therefore a longer burn time further improving the yield.

The alpha particle scattering from the high Z ions was calculated with standard methods. For energy loss, the electrons, both bound and free, were taken as a semidegenerate electron gas.

Results of this calculation are shown in Figure 13. Plotted is the fraction of all the alpha-particle energy (produced throughout the fuel) which is deposited back into the fuel. The effect of reflection becomes apparent as the electron density in the gold shell exceeds 10^{27} cm^{-3}. At 5×10^{27} electrons/cm^3, energy deposition in the fuel has increased by 25%. The maximum electron density in gold permitted by pressure equilibration with the fuel in this example is about 5×10^{27} cm^{-3} from the Thomas-Fermi equation of state.

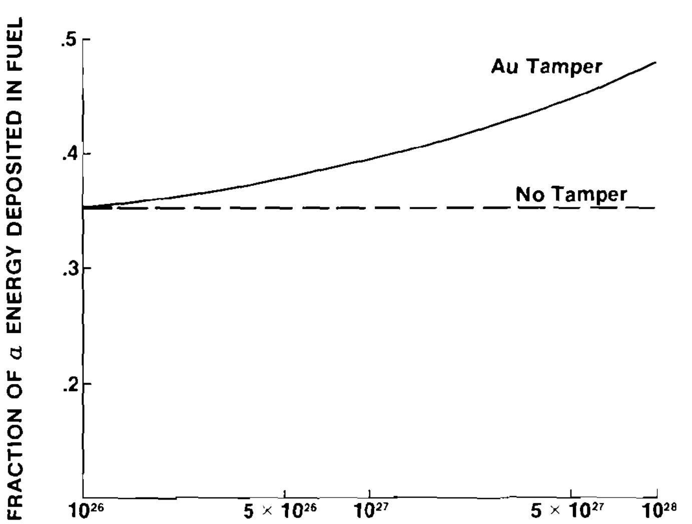

Figure 13 *Fraction of alpha-particle energy deposited in the fuel as a function of density in the gold tamper. (Fuel: $T = 10$ keV, $n_e = 5 \times 10^{26}$ cm^{-3}, $\rho R = 0.3$ g/cm^2. Tamper: $T = 1$ keV.)*

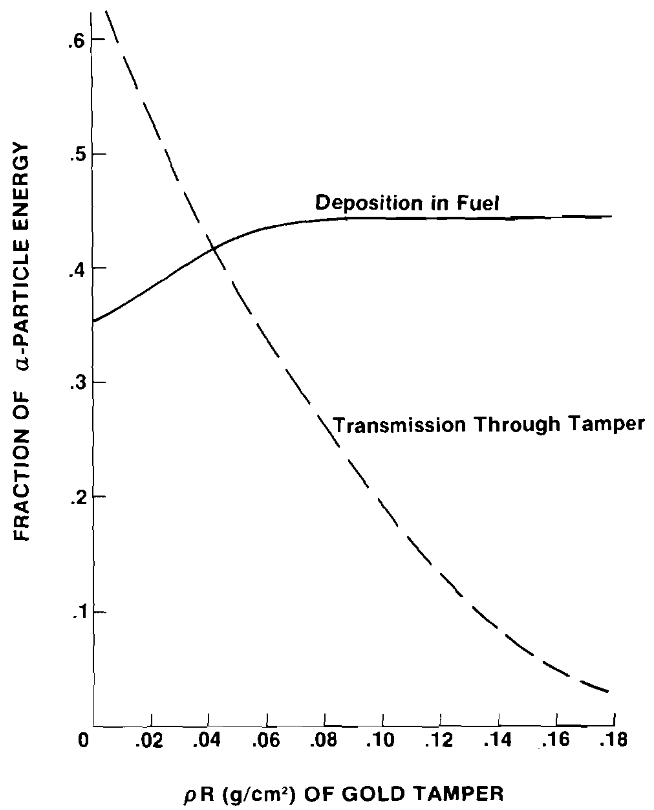

Figure 14 *Fraction of alpha-particle energy deposited in the fuel and transmitted through the tamper as a function of ρR in the tamper. ($T = 1$ keV, $n_e = 5 \times 10^{27}$ cm^{-3}.)*

We may note that the densities required for significant alpha particle reflection are consistent with those originally suggested[10] as optimum for inertial confinement fusion, but higher than more recent estimates of compressed densities for high gain targets[11]. When the compressed density is reduced, the size of the compressed region must increase to maintain the ρR condition, which in turn implies larger targets and more laser energy. Therefore, driver energy requirements would be minimized if the high densities considered here are ultimately obtained.

The size of the gold tamper needed for reflection is shown in Figure 14. For these results, the tamper electron-density was set at 5×10^{27} cm^{-3}, and its ρR was varied. (Fuel conditions remained the same as in Figure 13.) As can be seen, almost all the reflection occurs with a tamper ρR of 0.1 g/cm^2. This is much smaller than the values of ρR ($\sim 1 g/cm^2$) needed for energy breakeven[9]. The fraction of alpha-particle energy transmitted through the tamper is also shown in Figure 14. Such transmission could be important for double-shell target designs which require the thermonuclear burn to propagate from one DT fuel region to another, across a high-Z shell. (The fraction of energy in Figure 14 which was not deposited or transmitted was absorbed by the tamper.) If electron degeneracy had not been considered there would have been essentially no reflection and no transmission; all alpha particles escaping the fuel would have deposited their energy in the tamper.

As a final point, the reduction in ρR needed for thermonuclear ignition is shown in Figure 15. Again, the gold tamper was set with $n_e = 5 \times 10^{27}$ cm^{-3}, but now the ρR of the fuel was changed. The results show that if the bare fuel ignites at $\rho R = 0.3$ g/cm^2, then, for the same fractional energy deposition, it should ignite at $\rho R = 0.22$ g/cm^2 with the gold tamper - a reduction of 25% in ρR. The significance of the 25% reduction obtained for fuel ρR is that it corresponds to almost a 50% reduction in mass of the compressed target. [The mass will vary as $(\rho R)^2$ for fixed ρ since typically most of the mass M is concentrated in the tamper, i.e., $M \sim (\rho R)^2 (\rho_T \Delta R)/\rho^2$ where ρ_T and ΔR are the density and thickness of the tamper.] However, to achieve this reduction, electron densities must reach $\sim 5 \times 10^{27}$ cm^{-3} in the tamper. Since in many target designs, the input energy varies as the compressed mass, alpha-particle reflection could lead to a substantial reduction in the driver energy needed to achieve thermonuclear ignition.

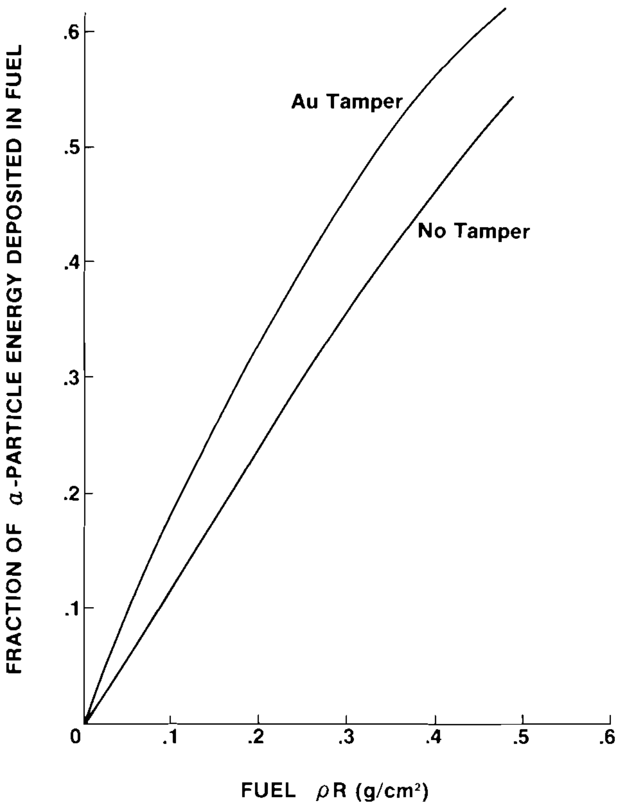

Figure 15 Fraction of alpha-particle energy deposited in the fuel for tamped and untamped pellets. (Tamper conditions $T = 1$ keV, $n_e = 10^{27}$ cm^{-3}.)

The results here were obtained for an idealized situation to demonstrate the possibility of alpha-particle reflection. The exact magnitude of the effect will depend on the particular target design under study.