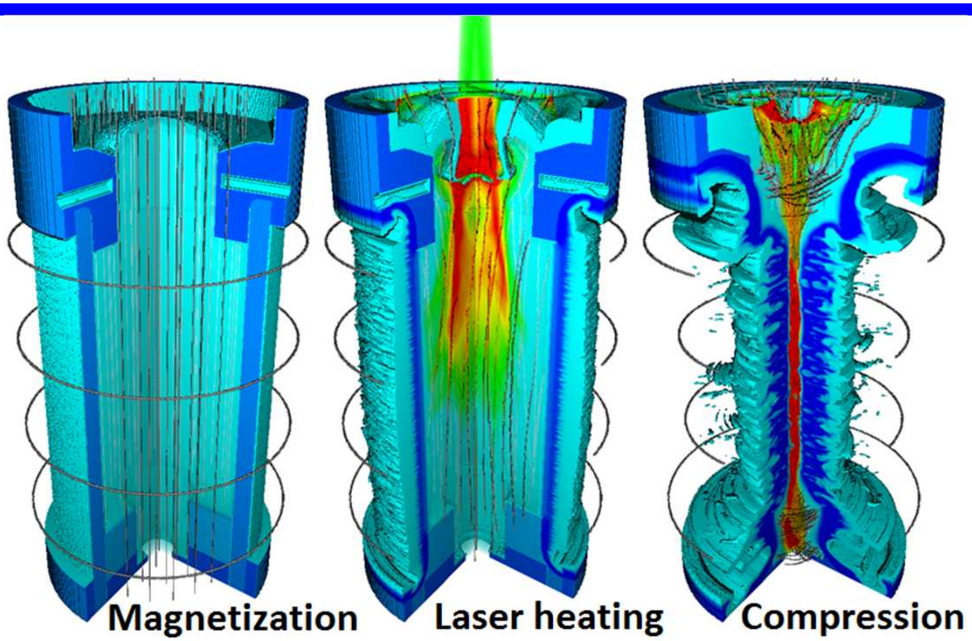
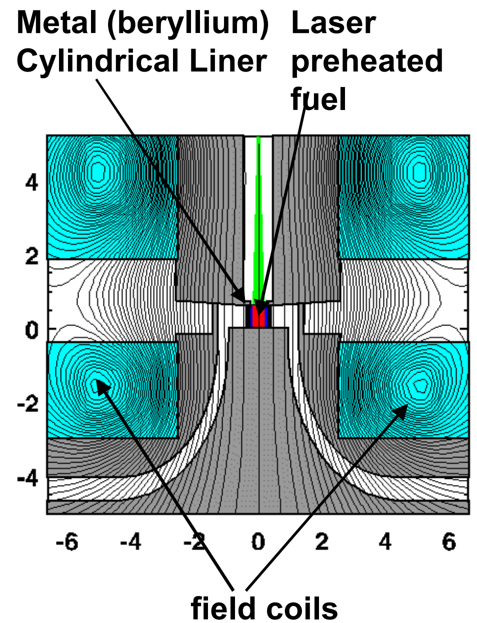
MagLIF scaling on Z and Future Machines





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S. A. Slutz, W.A. Stygar, M.R. Gomez, K.J. Peterson, A. B. Sefkow, D.B. Sinars, R. A. Vesey

Sandia National Laboratories

E. M. Campbell and R. Betti

Laboratory for Laser Energetics, University of Rochester

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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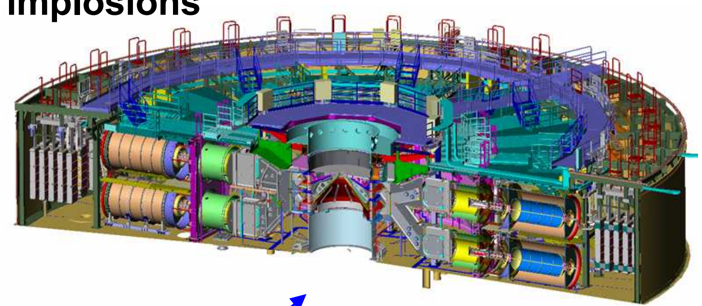
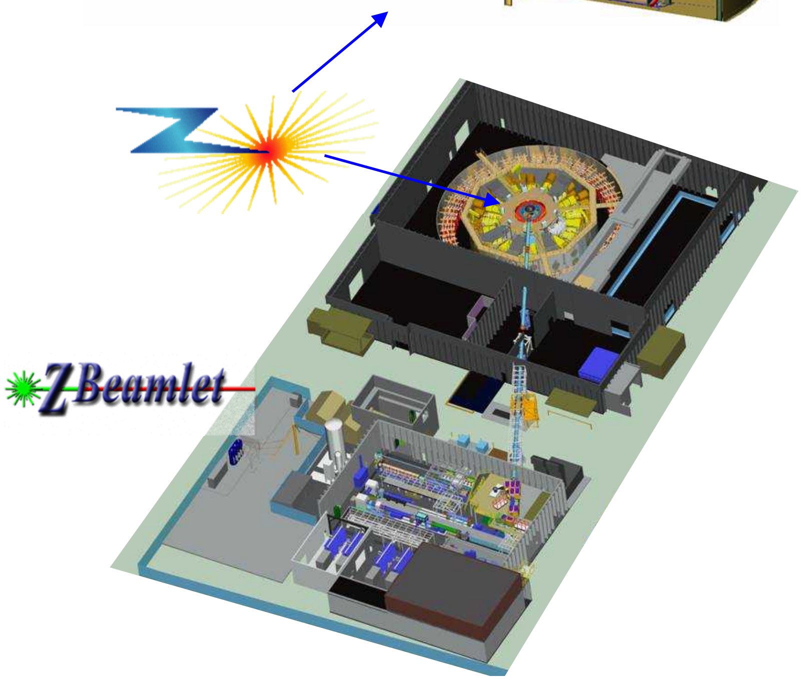
The MagLIF concept[1] is being tested[2] on the Z facility. Higher drive currents could be provided by future machines[3]

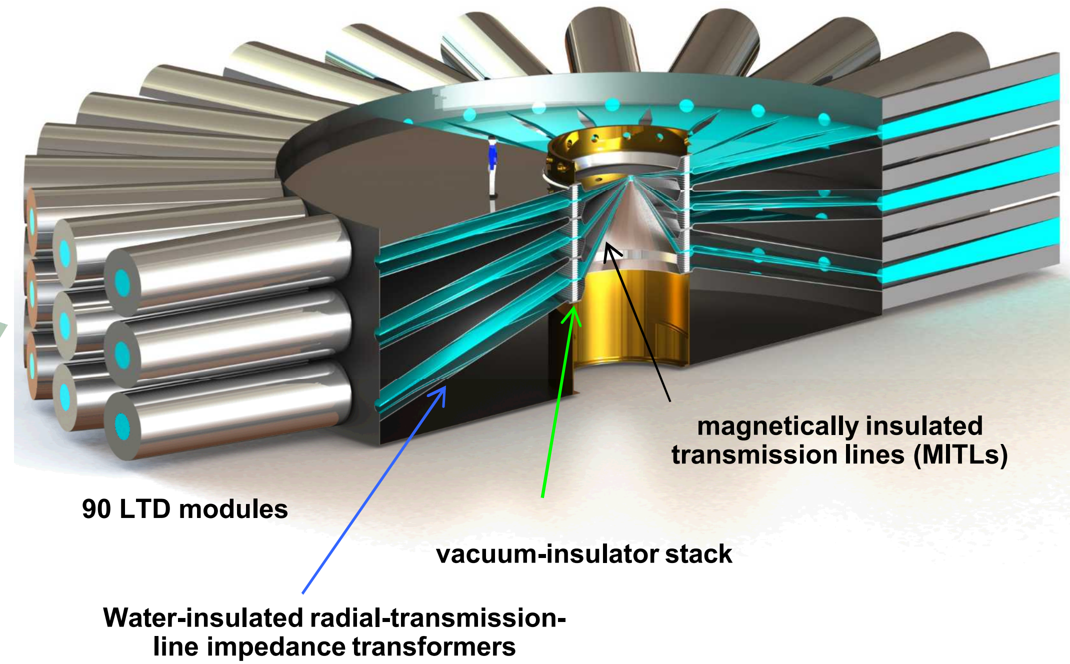
Z can generate high magnetic pressures to drive cylindrical implosions





Z-Beamlet provides fuel preheat

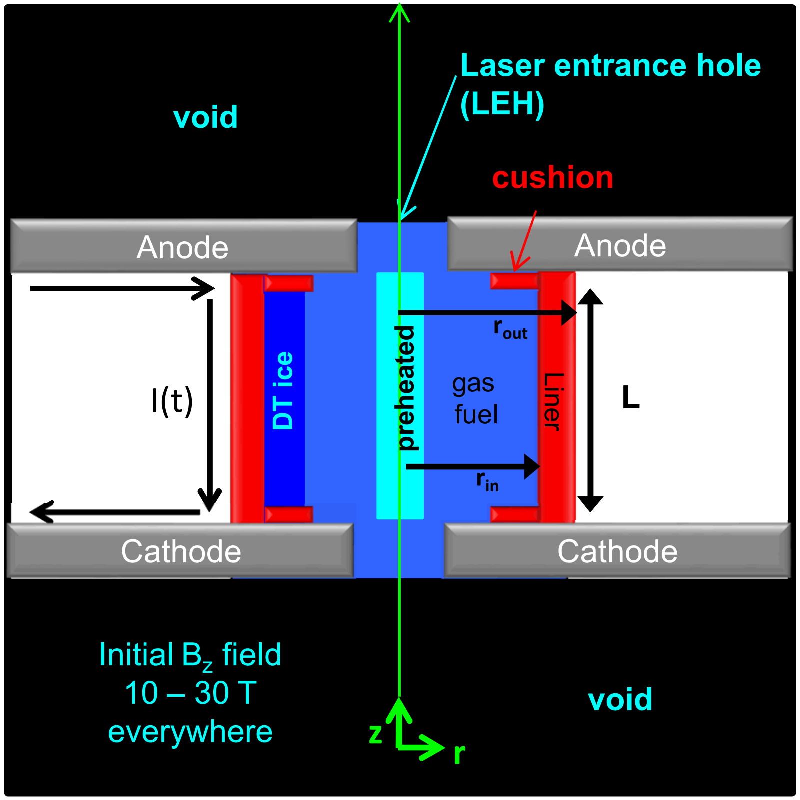
Z 300 employs Linear Transformer Driver (LTD) technology to deliver 48 MA to a MagLIF load, and would fit within the existing Z building.

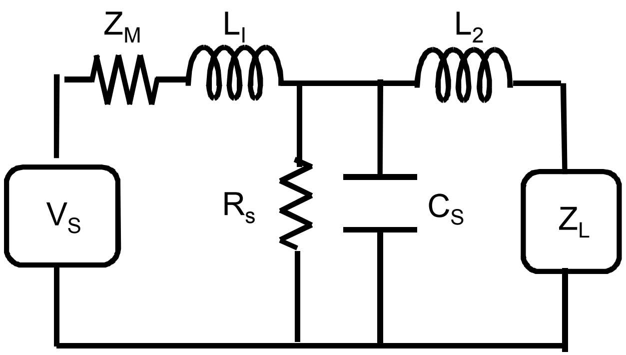


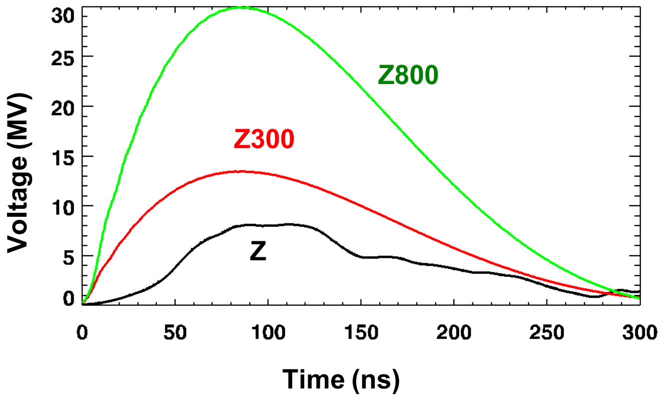
Z800 would deliver 65 MA with the same technology

[1] *Slutz et al. PoP 2010* [2] *Gomez et al. PoP 2014* [3] *Stygar et al Phys. Rev. ST Accel. Beams 2015*

2D Lasnex simulations based on simplified geometry and circuit model

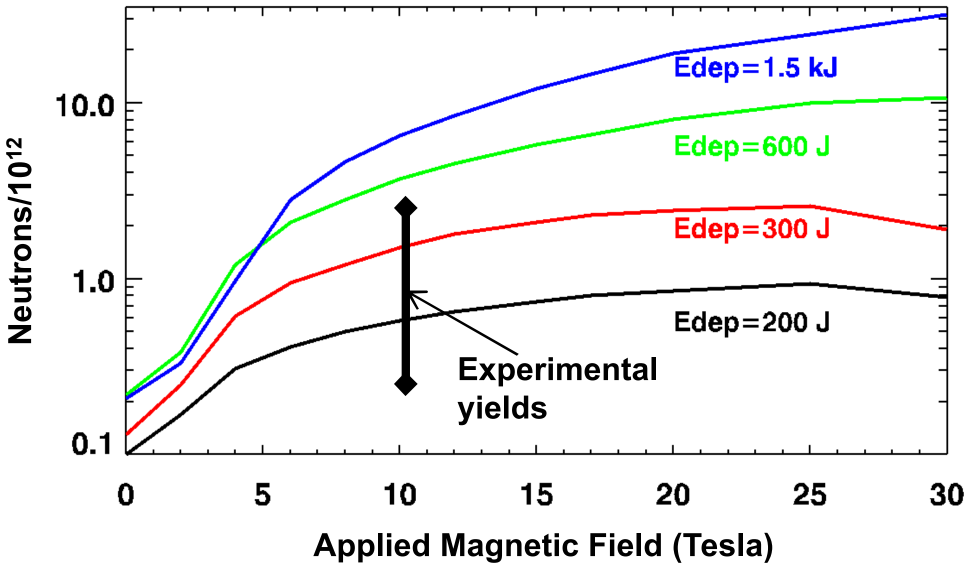






Present experiments on Z at 18 MA do not have optimal values of preheat or applied field according to simulation

2D Lasnex simulations of 1 cm long liners



2D simulations predict yield increases with fuel preheat and applied B

Experiments will be performed to test these predictions

Z Beamlet produces 2 kJ of unsmoothed 0.53 mm light

- **Only ~ 200-400 Joules penetrates foil[1]**

2D simulations indicate that Z300 could drive a MagLIF with a gain greater than unity

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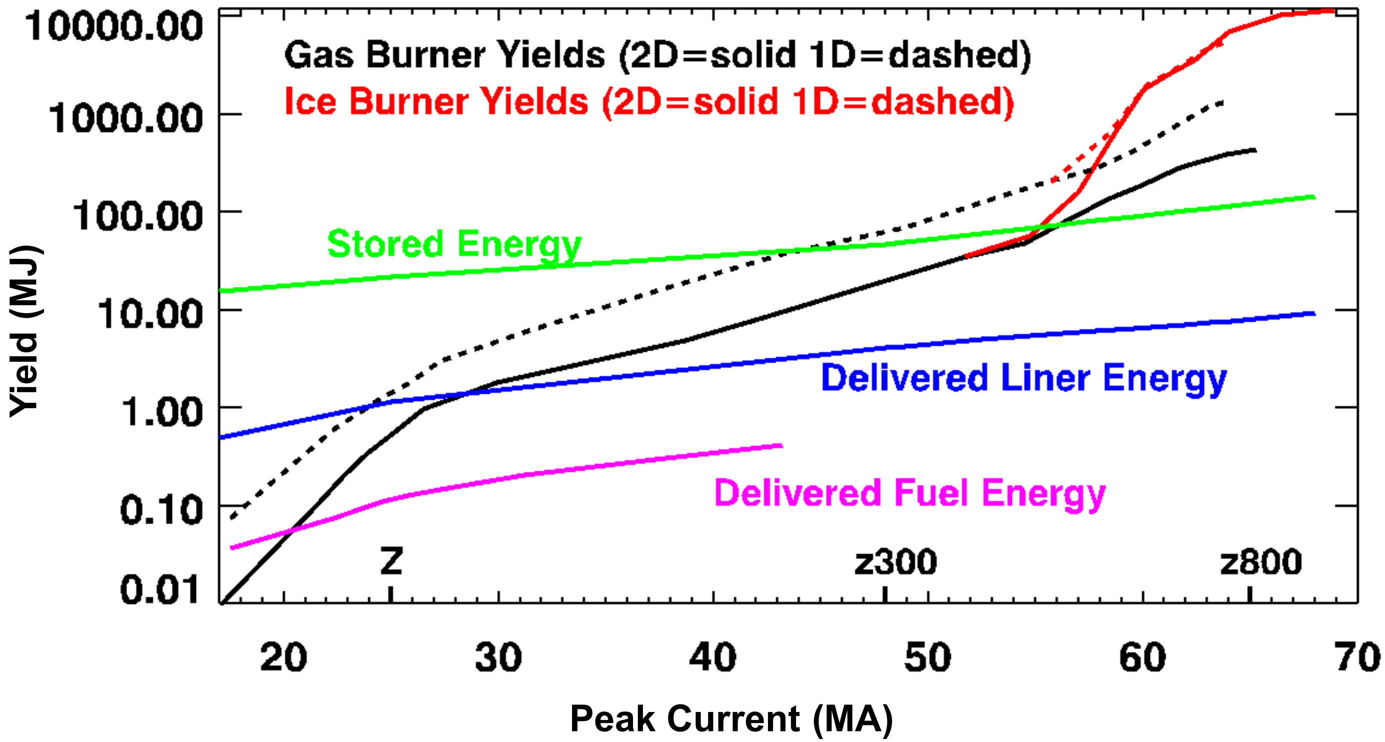
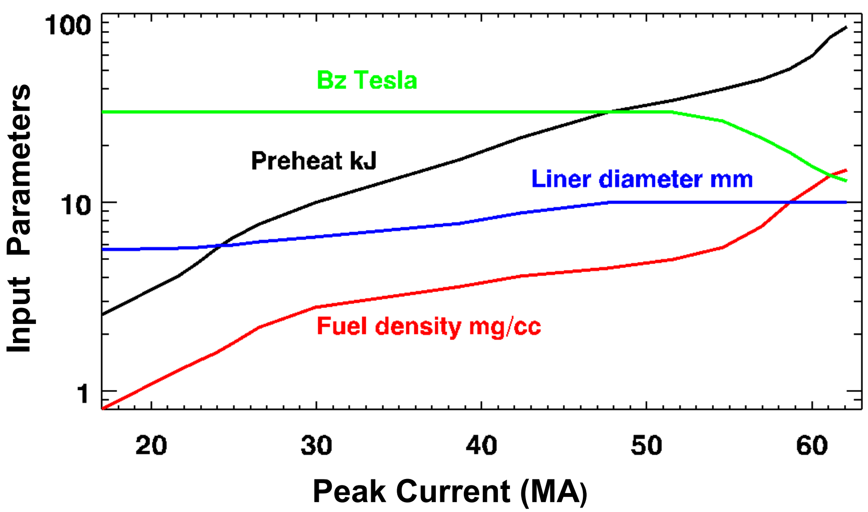
Capsule parameters (radius, fuel density, fuel preheat, and B_z) are optimized at each value of the drive current.

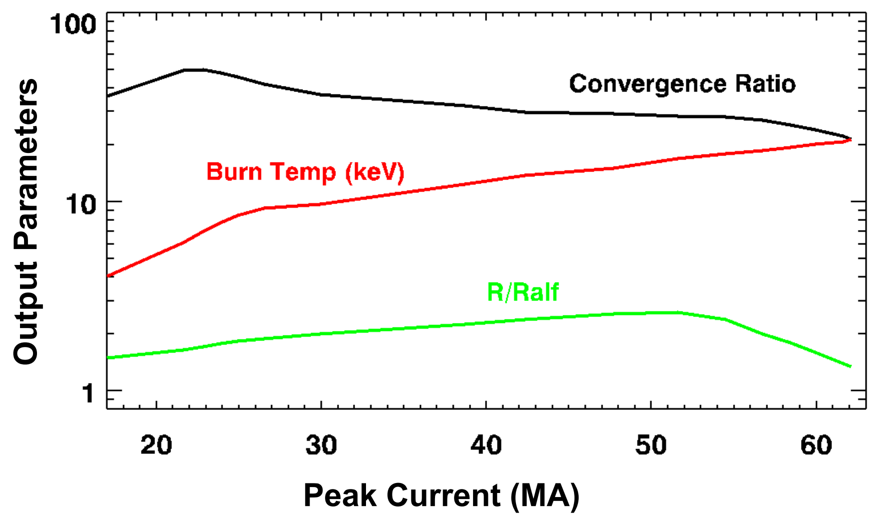


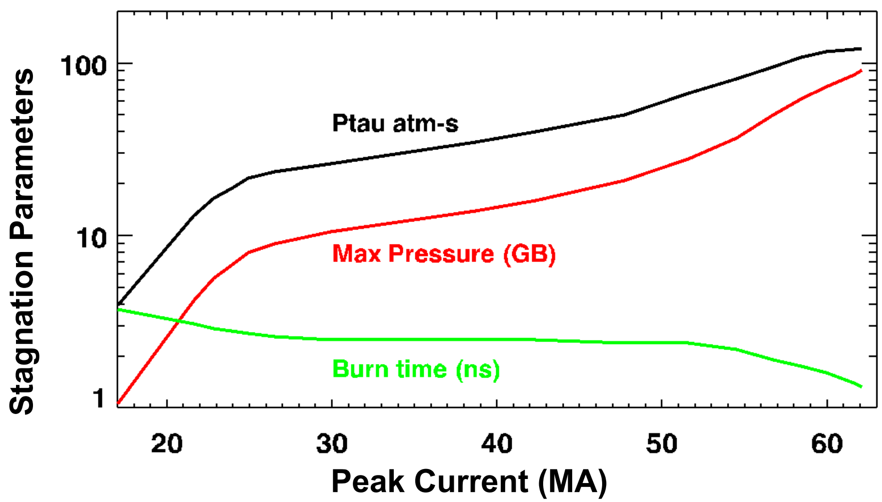
DT ice layers significantly enhance yields for drive currents > 60 MA

Engineering gains of 70 might be possible with Z800 ice burners

2D simulations indicate optimal design parameters and output quantities







Simple analytic theory predicts the laser penetration can be controlled by the beam radius

If laser absorption dominated by inverse Bremsstrahlung

$$C_V \frac{d\theta}{dt} = \frac{dI}{dz} = -kI \qquad k = \frac{\nu_{ei}\omega_p^2}{c\omega_L^2}\left(1-\frac{\omega_p^2}{\omega_L^2}\right)^{-1/2} = \frac{k_0}{\theta^{3/2}} \qquad k_0 \approx 1.23x10^6\left(\rho\lambda_L Z_b\right)^2\left(1-227\rho Z_b\lambda_L^2\right)^{-1/2}$$

$$I = I_0\left(1-\frac{z}{z_f}\right)^{2/3} \qquad z_f = \frac{5}{3}\left(\frac{2}{5k_0}\right)^{2/5}\left(\frac{I_0 t}{2C_V\rho}\right)^{3/5} \qquad R_{laser} = 5.4x10^{-7} E_{laser}^{1/2}\lambda_L^{-.67}\rho^{-1.17}z_f^{-.83}\left(1-227\rho\lambda_L^2\right)^{.17}$$

Hydrodynamics, refraction and particularly Laser Plasma Instabilities (LPI) complicate this simple picture

LPI is unimportant if:

- **the plasma density is much lower than the critical density (n/n_{crit}<<1)**
- **The laser intensity is low ($I_{Laser}<10^{14}$ watts/cm^2)**

Optimum fuel densities are larger on future accelerators

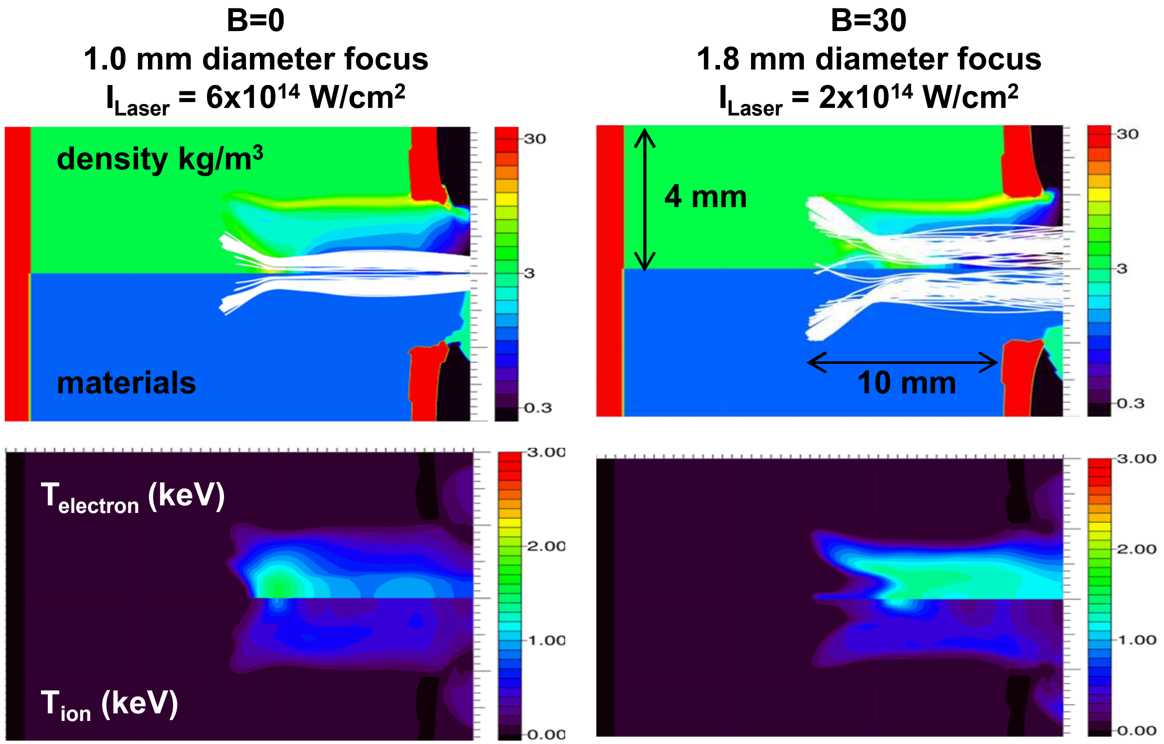
- **Optimal fuel density ~ 5 mg/cc on Z300 (n/n_{crit}~0.13) for 3ω**

Optimum preheat energies are larger on future accelerators

- **Optimum preheat ~ 30 kJ on Z300**
- **Laser pulse can not be too long or gas moves out of the way. Beam intensity may need to be > 10^{14} watt/cm^2**

Laser preheating at Z300 levels could be tested using a quad of NIF

30 kJ 3ω at 5 TW stopped in 1 cm of DT at 4.5 mg/cc



We have presented 1D and 2D simulations of MagLIF on upgraded Z and future machines

Simulations indicate that large yields and gains may be possible on future machines such as Z300

Simulation predictive capability is greatest when the extrapolation is not large

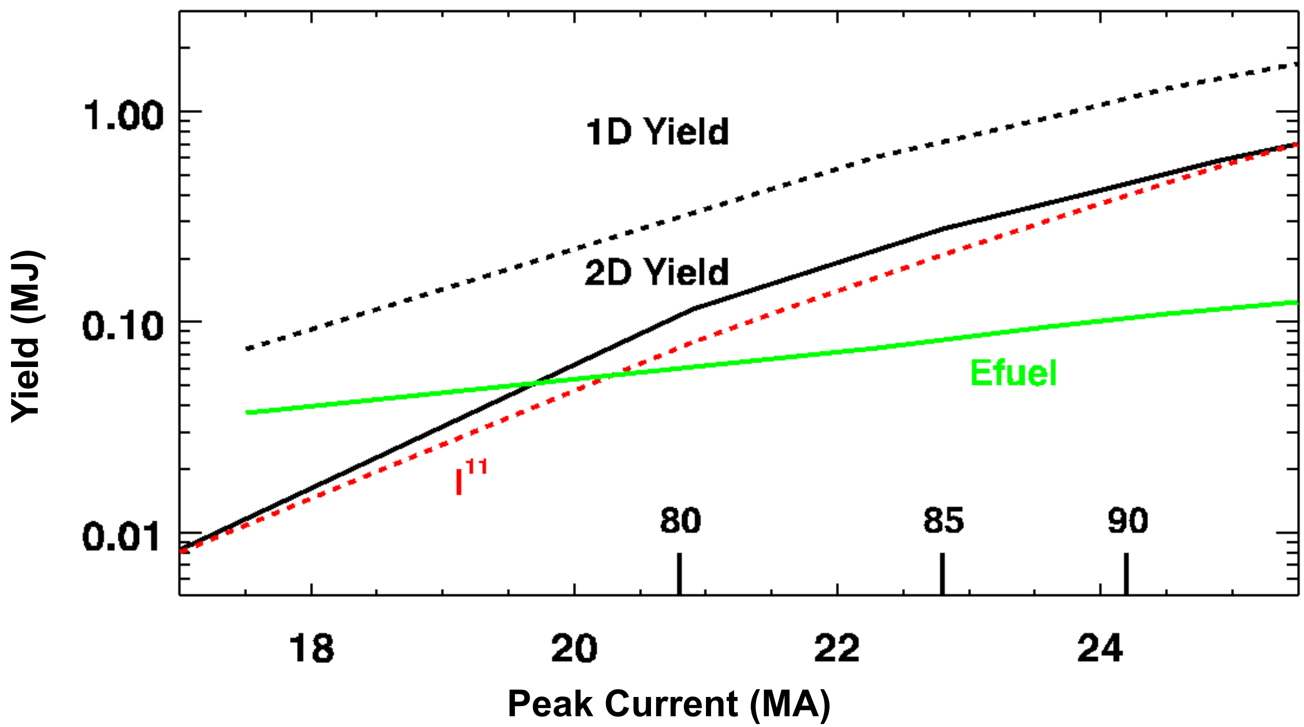
Present experiments have been perform at 18 MA with B=10 Tesla and low preheat ~ 200 joules

- Phase plates have been designed for Z Beamlet to enable larger preheat energies
- 30 Tesla fields are possible with the existing field coil system
- An improved convolute design will be tested with MagLIF to obtain higher drive currents on Z

Full scale laser deposition experiments could be performed using one quad of the NIF to remove uncertainties about laser preheating

Agreement between the simulation scaling presented here and the results of experimental scaling will greatly increase our confidence to predict MagLIF performance on future machines

Simulations indicate that optimized yields are a strong function of current over the range accessible to Z



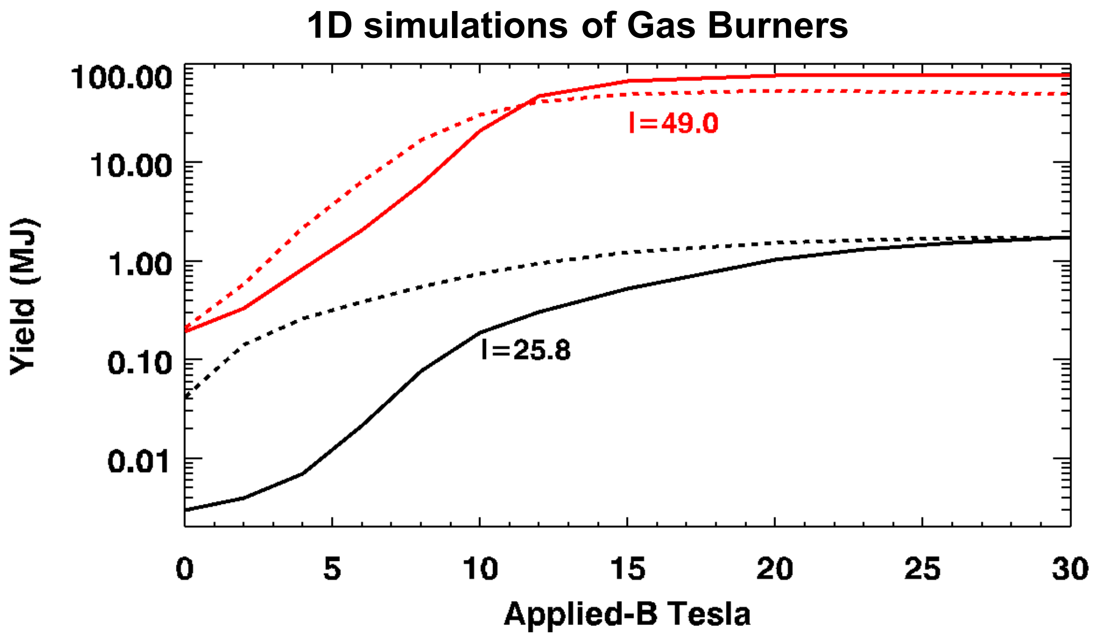
Capsule parameters (radius, fuel density, fuel preheat, and B_z) are optimized at each value of the drive current.

The Nernst effect can be significant

All of the preceding Lasnex simulations have included the Nernst (Ettingshausen) effect

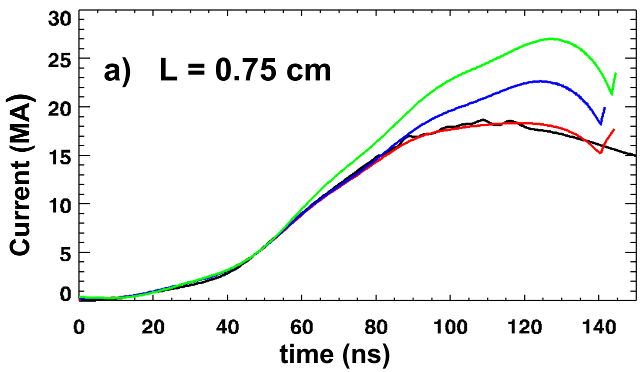
Nernst produces an electric field E_{Nernst} proportional to B x grad(T)

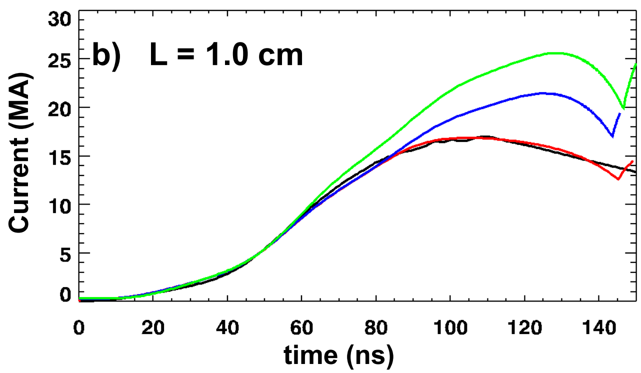
- The magnetic field is advected with a velocity proportional to E_{Nernst}/B
- The magnetic field is reduced in the hot core and increased near the fuel liner interface
- The effect is decreased when $\omega\tau$ is large and is not large for optimal B
- Experiments determining the yield as a function of B will determine the importance of this effect



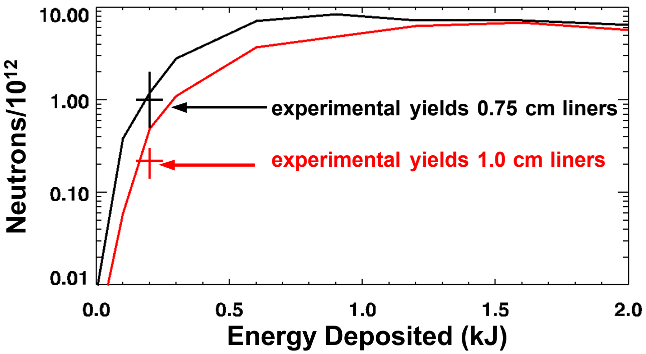
Simulated yields are comparable to experiments results

Black: 80 kV MagLIF experiments results
Red: 80 kV simulated with feed loss
Blue: 80 kV simulated without feed loss
Green: 95 kV simulated without feed loss





2D MagLIF simulations



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[1]M. Geissel et al. 41st EPS Conference on Plasma Physics 26 June 2014, Berlin, Germany