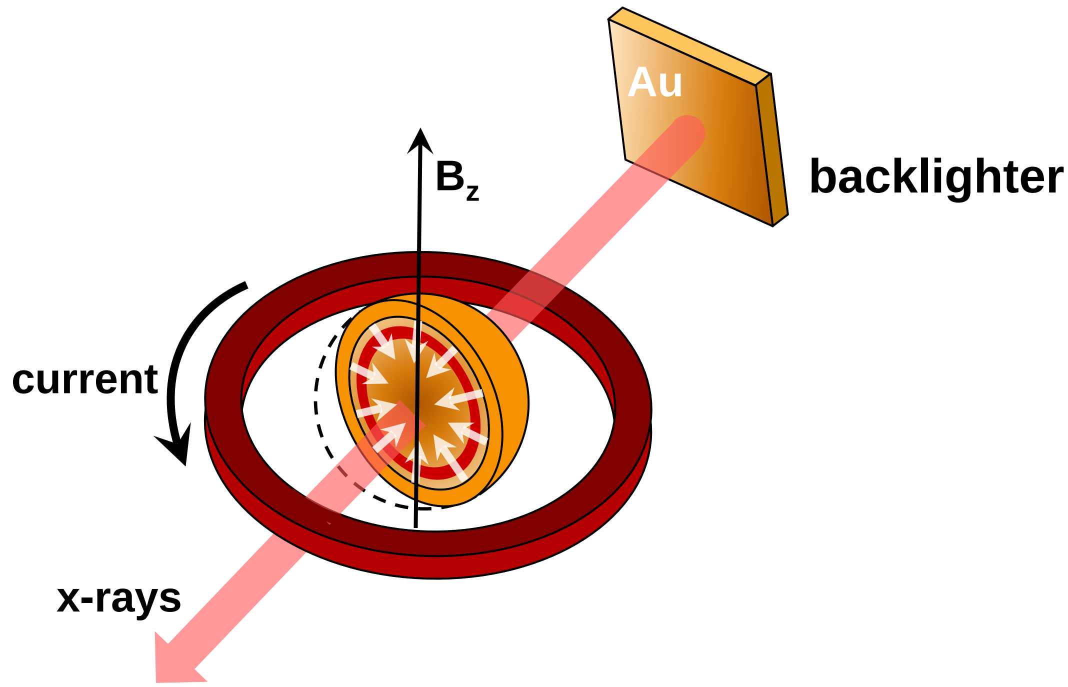
Magnetic Flux Compression Experiments on OMEGA



M. Hohenberger *et al.*
University of Rochester
Fusion Science Center and
Laboratory for Laser Energetics

10th Meeting Fusion Science Center
for Extreme States of Matter
Rochester, NY
7th March 2011

Summary

Laser-Driven flux compression experiments on OMEGA confirm fusion performance enhancement for magnetized hot-spots

FSC

UR LLE

- magnetic field compression has been demonstrated for cylindrical targets with compressed averaged field strengths reaching tens of MG

- Simulations for magnetic field compression in spherical targets predict measurable increase in hot-spot ion temperature and fusion yield

- Ion temperature enhancement of 15% and fusion yield increase of 30% have been observed experimentally in spherical implosions of magnetized ICF targets

Collaborators

P. Chang, G. Fiksel, J. Knauer
and R. Betti

University of Rochester
Fusion Science Center and
Laboratory for Laser Energetics

F. J. Marshall

University of Rochester
Laboratory for Laser Energetics

F. H. Séguin, C. K. Li, M. Manuel,
and R. D. Petrasso

Plasma Science and Fusion Centre
Massachusetts Institute of Technology

The fusion performance of an ICF target can be improved through magnetic field induced heat-flow suppression

FSC

UR LLE

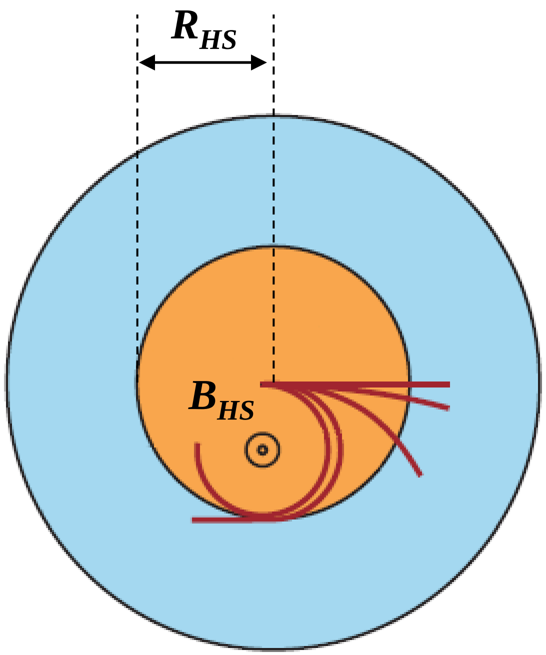
Adding magnetic fields in a compressed ICF target can increase the thermal insulation of the hot spot

- **reduced electron thermal conductivity if**

$$\omega_{ce}\,\tau_e > 1$$

- **enhanced α-particle confinement to within the hotspot if**

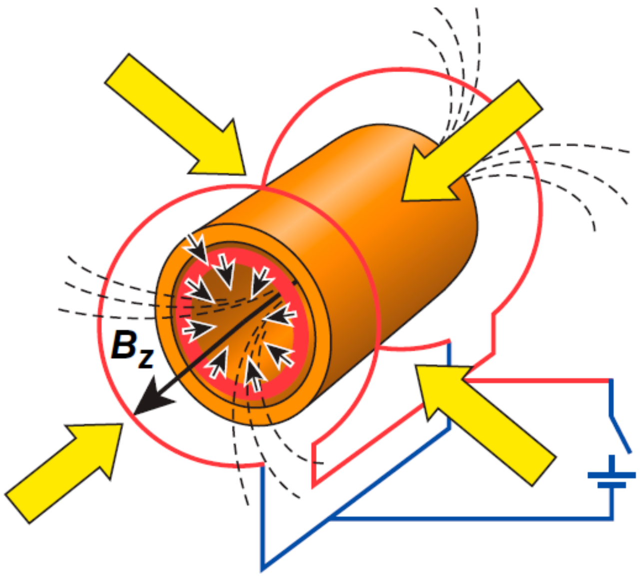
$$r_{L\alpha} / R_{HS} \leq 1$$



NIF 1.5-MJ, polar-drive point design:

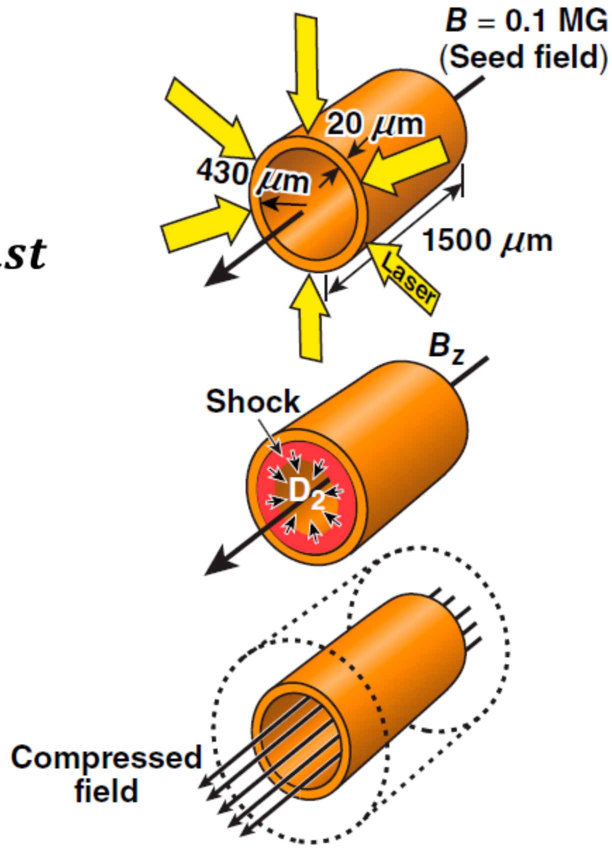
$\omega_{ce}\,\tau_e > 1$	**for B > 10 MG**
$r_{L\alpha} / R_{HS} \geq 1$	**for B > 100 MG**

Laser-Driven Magnetic Flux Compression has previously been demonstrated for cylindrical implosions*



$$\phi = \pi R^2 B \approx const$$

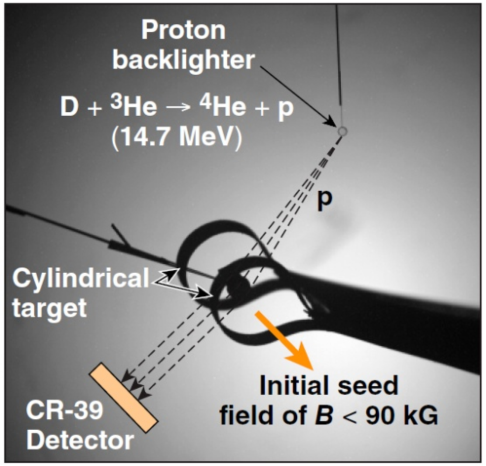
$$\rightarrow B \propto 1/R^2$$

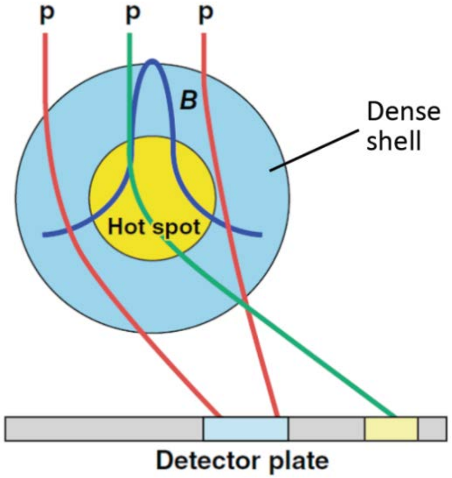


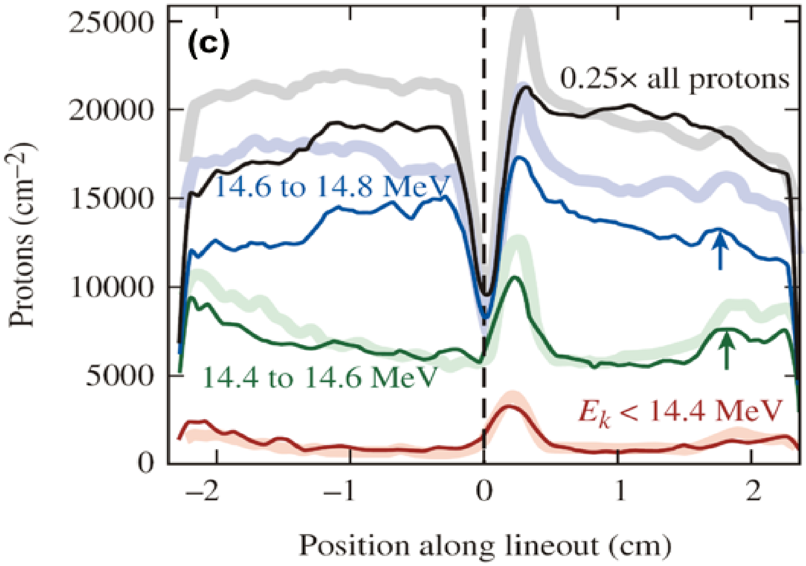
- axial field in cylindrical target is generated using a Helmholtz-like coil
- laser-driven target implosion traps and compresses the magnetic field

*O. V. Gotchev *et al.*, Phys. Rev. Lett. **103**, 215004 (2009)

Using proton deflectometry the hot-spot averaged compressed magnetic field was measured to be 30 MG*



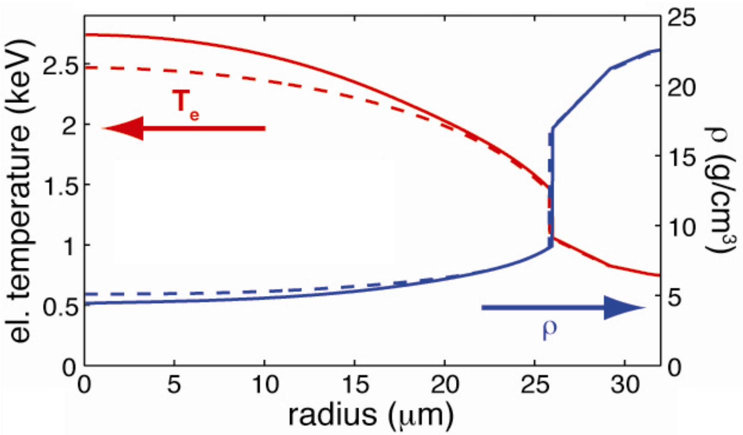


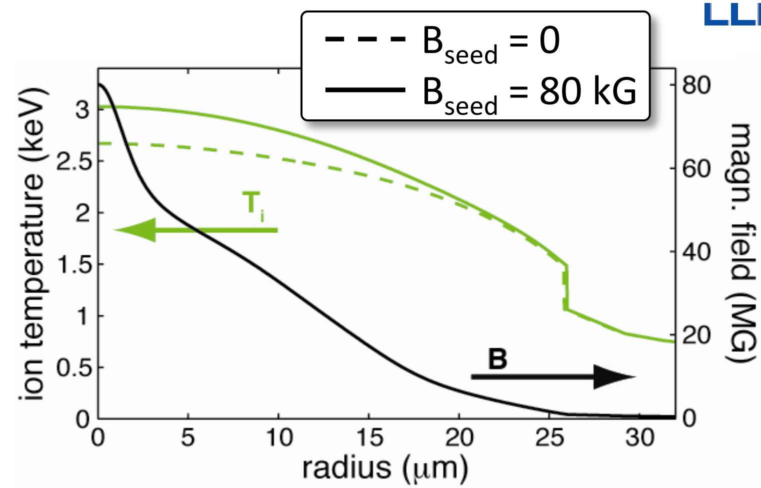


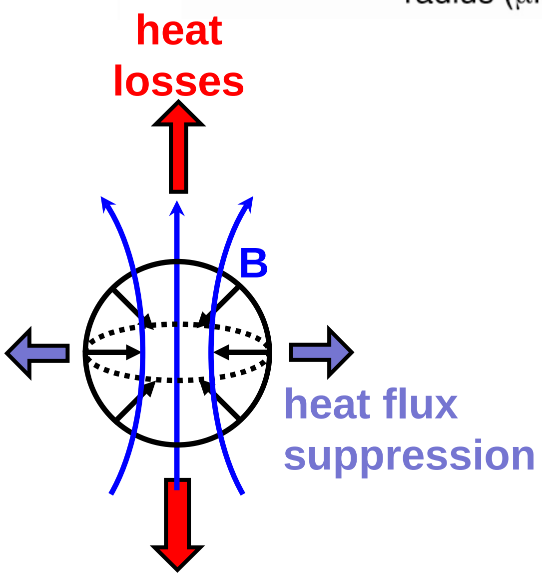
- field topology and density distribution results in two-peak deflection pattern
- as expected, no fusion performance enhancement was observed with cylindrical targets

*J. P. Knauer *et al.*, Phys. Plasmas **17**, 056318 (2010)

1D Simulations predict an 8% ion temperature and 15% neutron yield enhancement in implosions of magnetized spherical targets







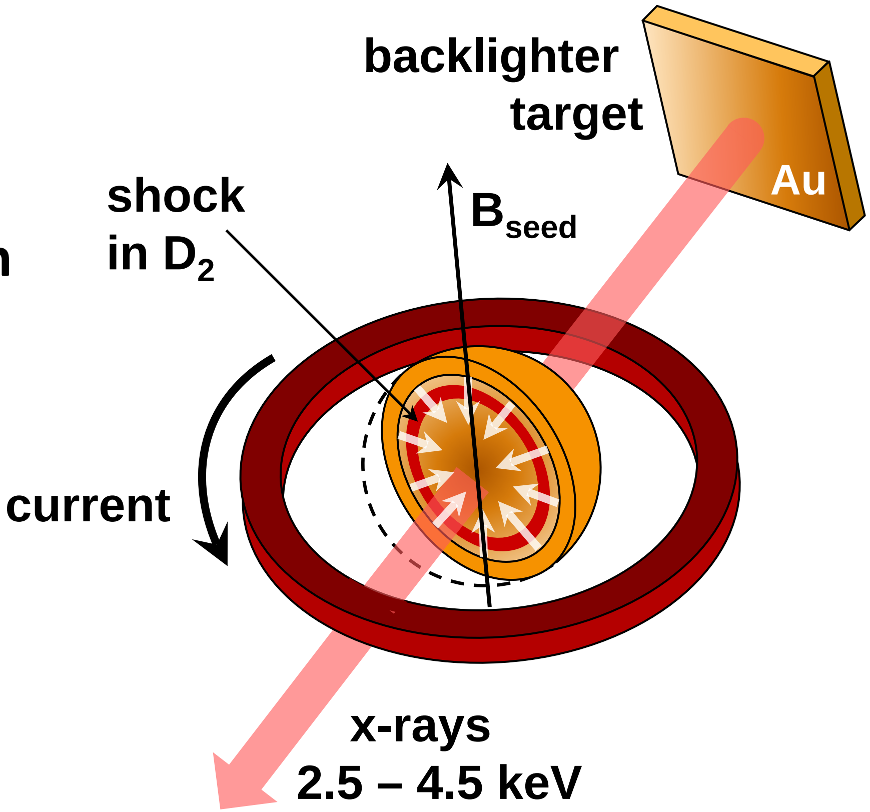
- 1D Lilac-MHD* is used to simulate equatorial plane of a spherical implosion
- heat conductivities calculated based on Braginskii coefficients
- ratio of open field lines to target surface area = 1/2

---

*N. W. Jang *et al.*, Bull. Am. Phys. Soc. **51**, 144 (2006)

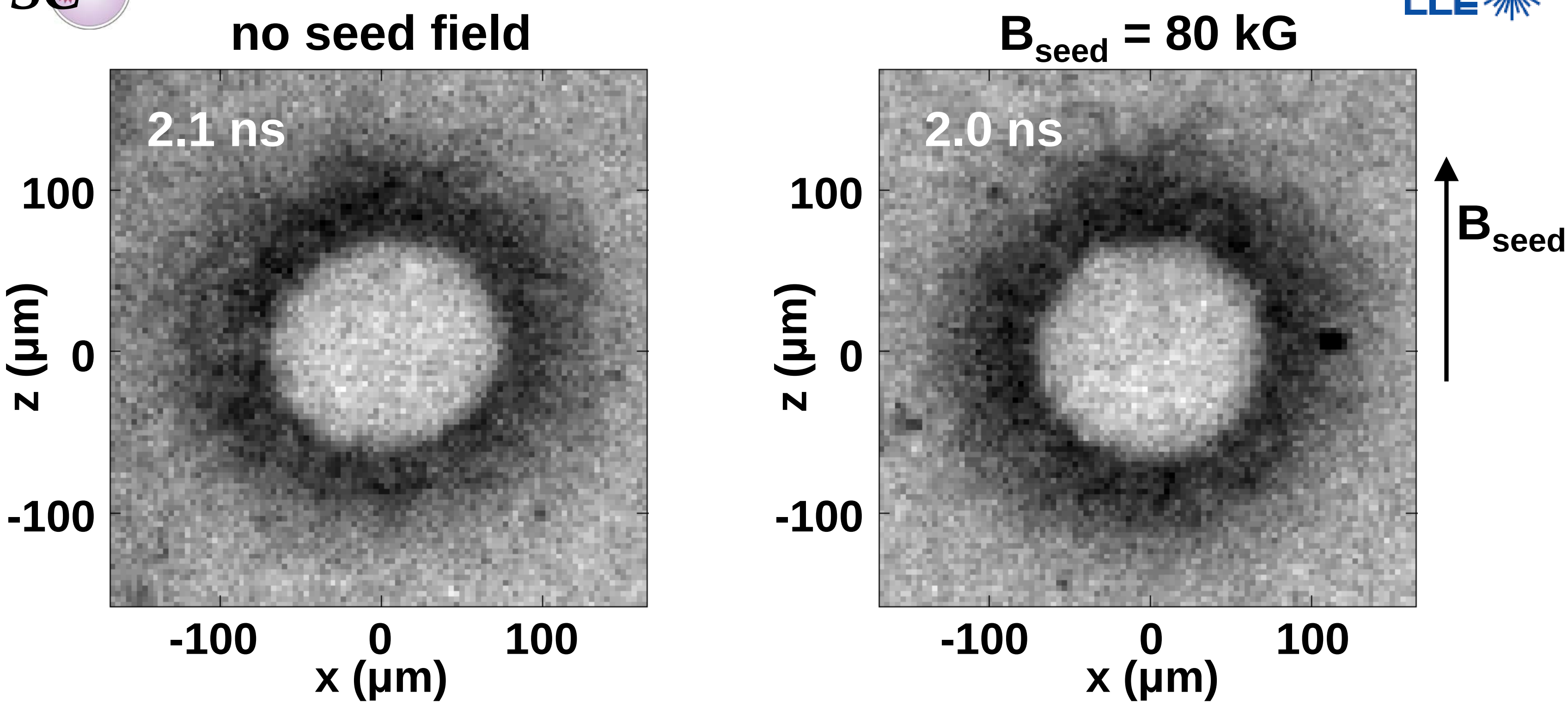
A single-coil setup was used for compression of a spherical target in polar-direct-drive geometry on OMEGA

- Single-coil provides stronger seed-fields, less interference with laser paths
- coil position prevents use of proton deflectometry to assess field strength
- 20 equatorial laser beams are blocked, we use remaining 40 beams in a polar-direct-drive setup*
- implosion uniformity is diagnosed using x-ray radiography



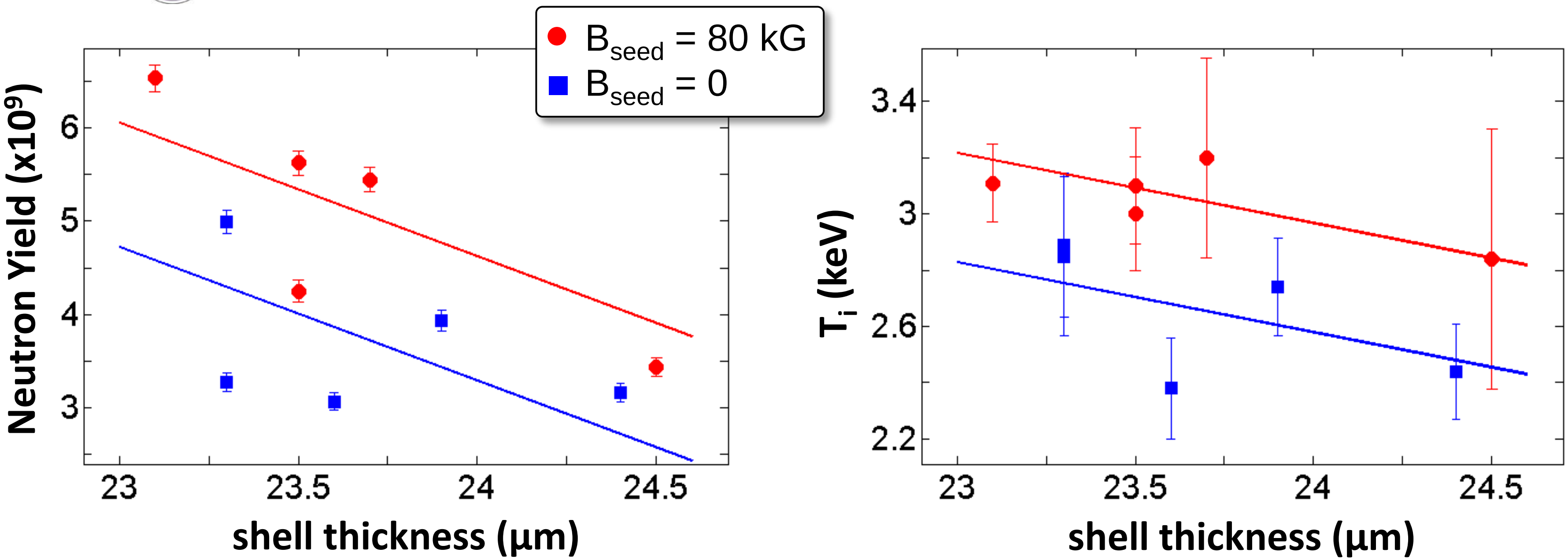
*F. J. Marshall *et al.*, Phys. Rev. Lett. **102**, 185004 (2009)

X-ray backlighter data shows no discernable difference in the implosion uniformity with and without an applied magnetic field



- **Implosion is uniform despite using only 40 beams**
- **MIFEDS coil was present in all measurements**

We observe a 15% ion temperature increase and 30% fusion yield enhancement for magnetized targets

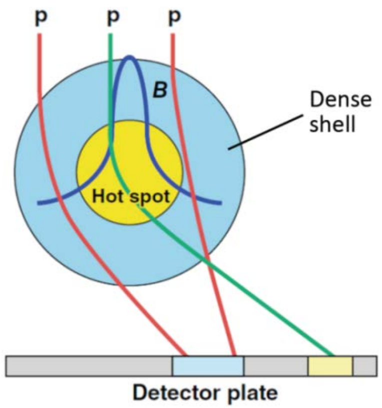


- Fusion performance scales with shell thickness*
- Linear regression fit reveals clear enhancement of magnetized hot spot performance

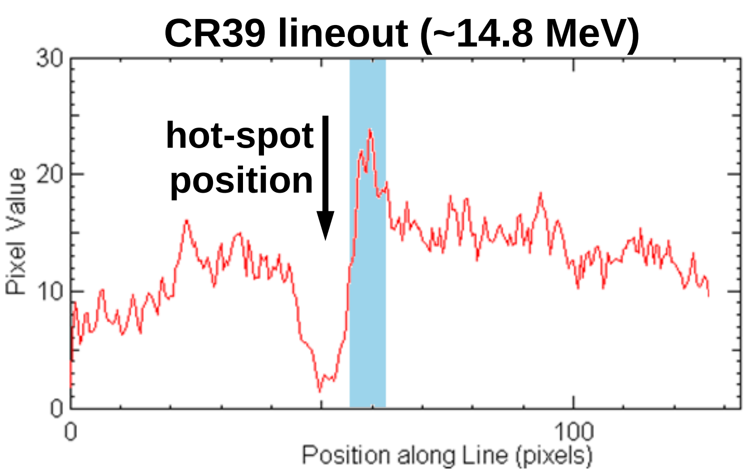
---

*F. J. Marshall *et al.*, Phys. Plasmas **7**, 1006 (2000)

Measuring the compressed magnetic field in spherical geometry has so far been unsuccessful



Deflection

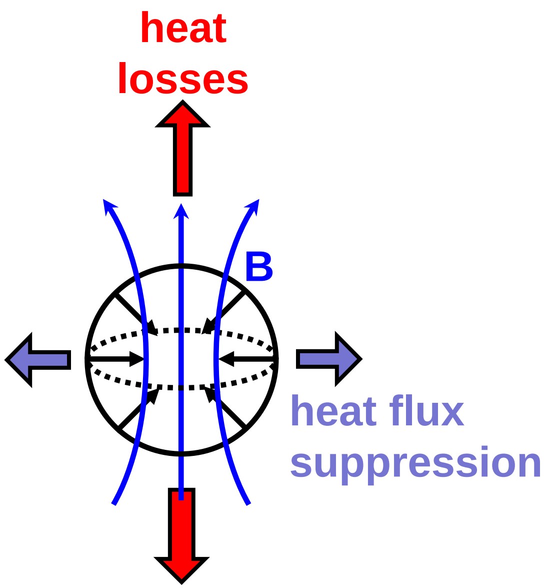


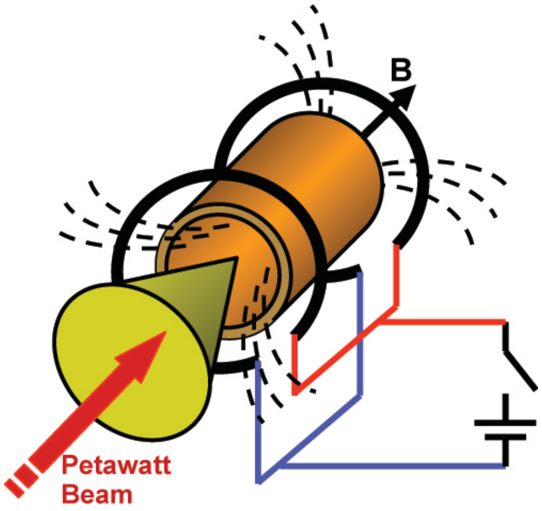
- for cylindrical targets the deflection pattern can be integrated along the cylinder axis to increase signal-to-noise ratio
- spherical deflection pattern is more complicated and interpretation is difficult

- one-sided deflection peak close to the hot-spot position is a signature of field compression

We plan to further investigate magnetic flux compression numerically and experimentally.

- spherical magnetic flux compression is inherently 3D and cannot be fully described with 1D Lilac-MHD
- open field line losses limit the achievable target performance enhancement





- we plan to investigate the applicability of using compressed magnetic fields to guide electrons in a fast-ignition scheme

Laser-Driven flux compression experiments on OMEGA confirm fusion performance enhancement for magnetized hot-spots

- magnetic field compression has been demonstrated for cylindrical targets with compressed averaged field strengths reaching tens of MG

- Simulations for magnetic field compression in spherical targets predict measurable increase in hot-spot ion temperature and fusion yield

- Ion temperature enhancement of 15% and fusion yield increase of 30% have been observed experimentally in spherical implosions of magnetized ICF targets