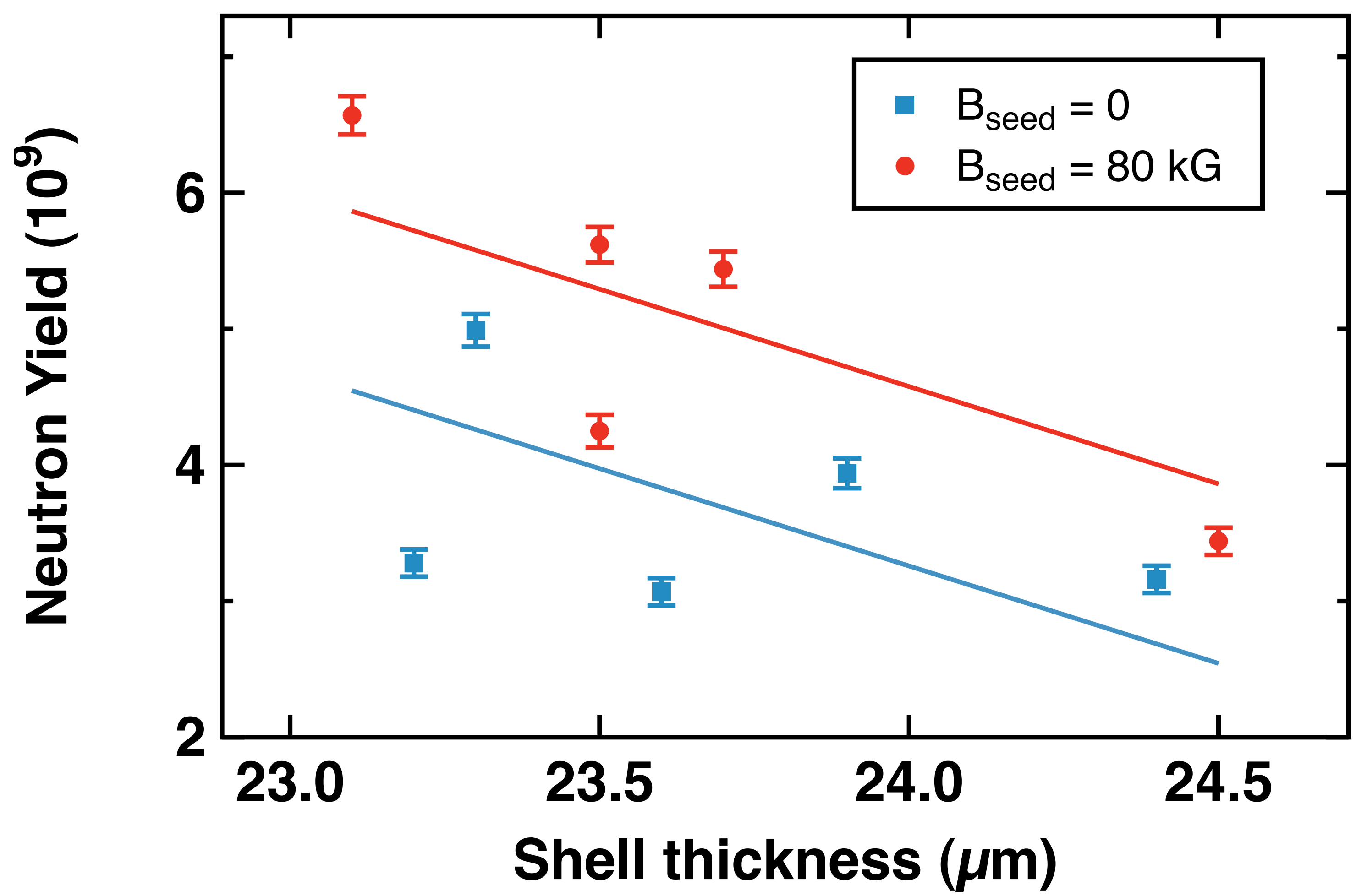
Effect of Magnetic Fields on Neutron Emission From ICF Implosions



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Albuquerque, NM
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Summary

An increase in neutron yield and ion temperature has been observed in magnetized spherical implosions

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- The MIFEDS (magnetized inertial fusion energy delivery system) magnetic field generator has been developed
- Fusion yield increase of 30% and ion temperature enhancement of 15% have been observed
- Laser-driven magnetic field compression to tens of MG has been demonstrated

Collaborators

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Magnetization of plasma electrons inhibits heat-conduction losses

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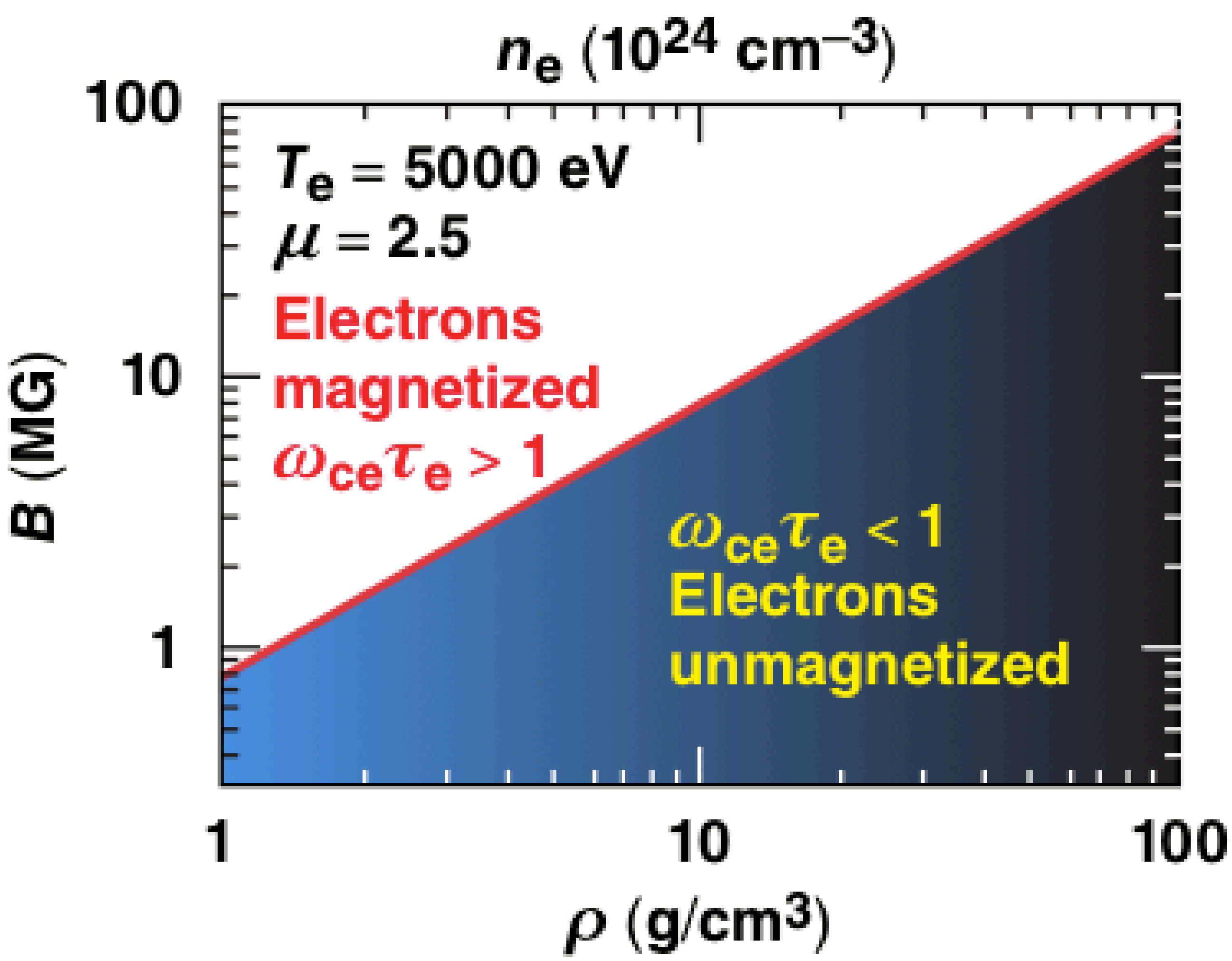
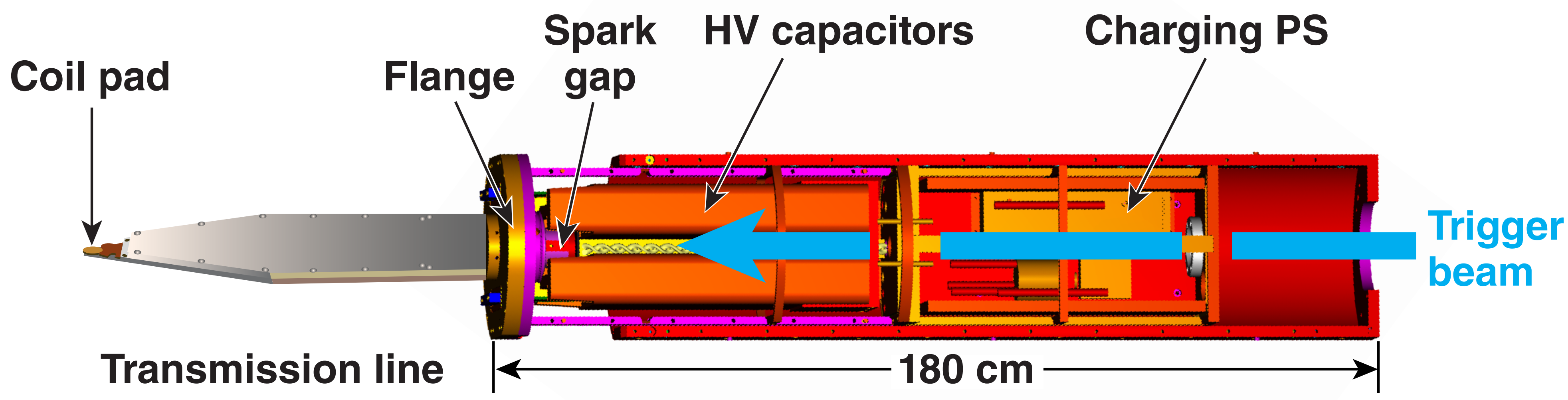
- Tens of megagauss fields are needed to magnetize electrons at typical ICF parameters

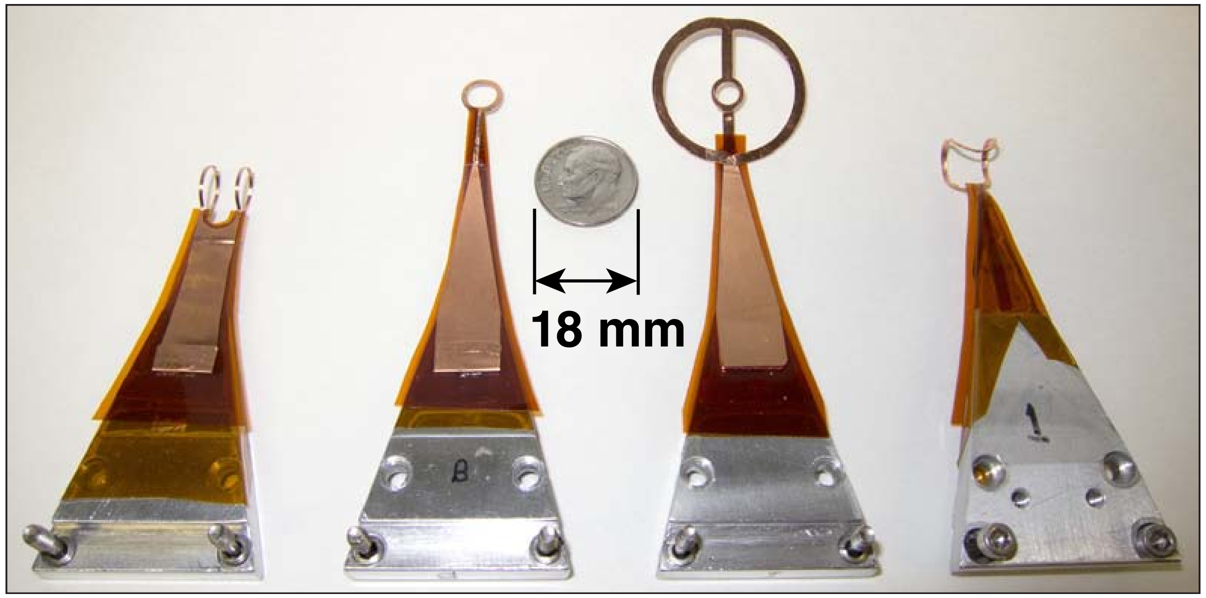


- It can be created by fast compression of a seed field
- Action plan:
  - Create a seed filed of ~ 10 T
  - Compress it ~ 500x
- Hundreds of megagauss fields are needed to magnetize α-particles

The seed B field is created by a compact, self-contained magnetic field generator



- **MIFEDS–Magnetized Inertial Fusion Energy Delivery System**
- **Various coils were tested**
- **Seed fields up to 150 kG can be obtained (depends on the coil size and geometry)**



Helmholtz Single Omega Baseball

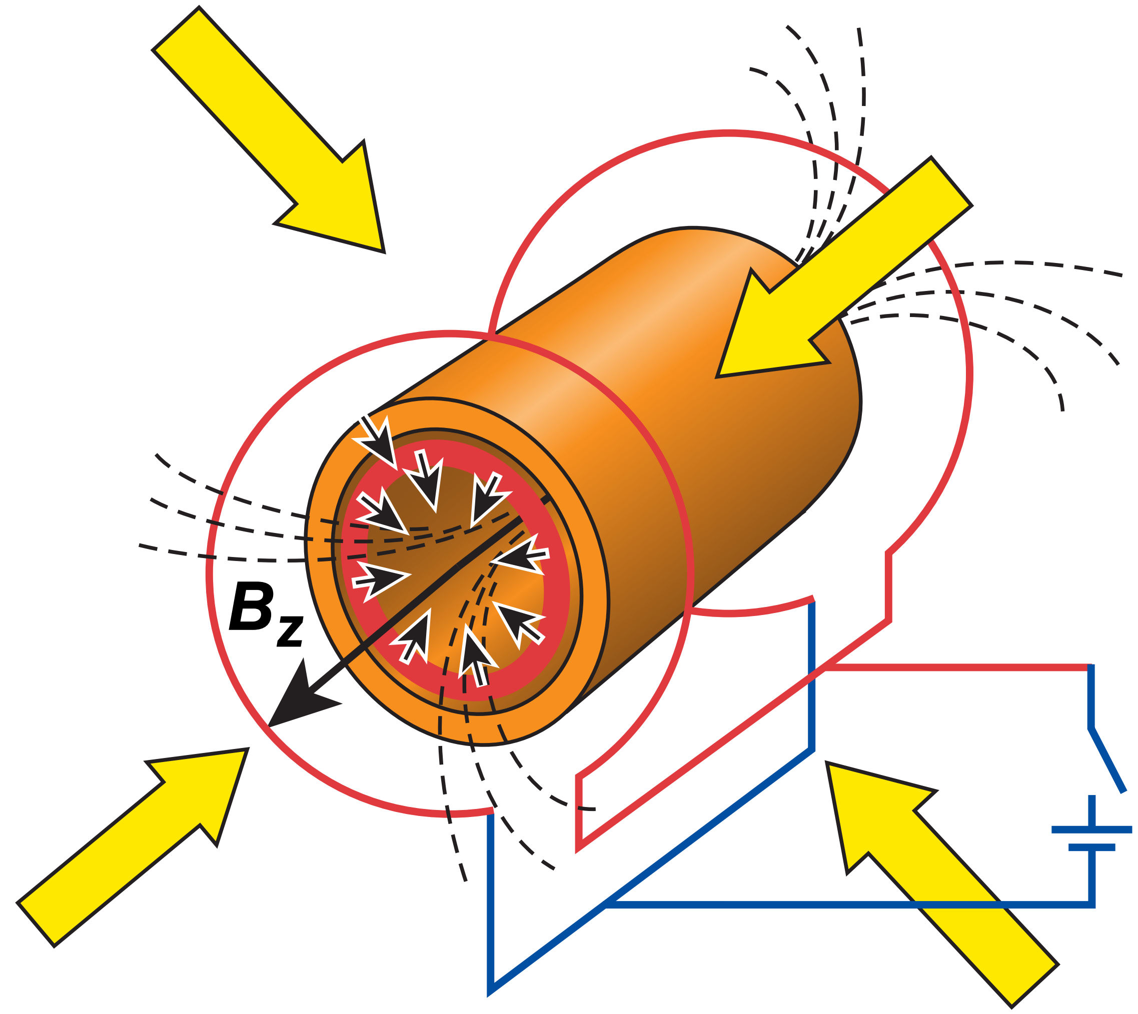
O. V. Gotchev *et al.*, Rev. Sci. Instrum. 80, 043504 (2009).

MIFEDS is installed in an OMEGA Diagnostic Inserter

E19779

MIFEDS has been used for laser compression of magnetic field in cylindrical geometry

- The seed field is generated with a Helmholtz-like coil using the MIFEDS field generator
- Laser-launched shock wave creates a high-conductive plasma that traps the seed magnetic field
- Magnetic field is amplified by target compression



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Spherical Bfield compression is simulated by adding 2-D magnetic diffusion into 1-D hydrodynamic (*LILAC*)

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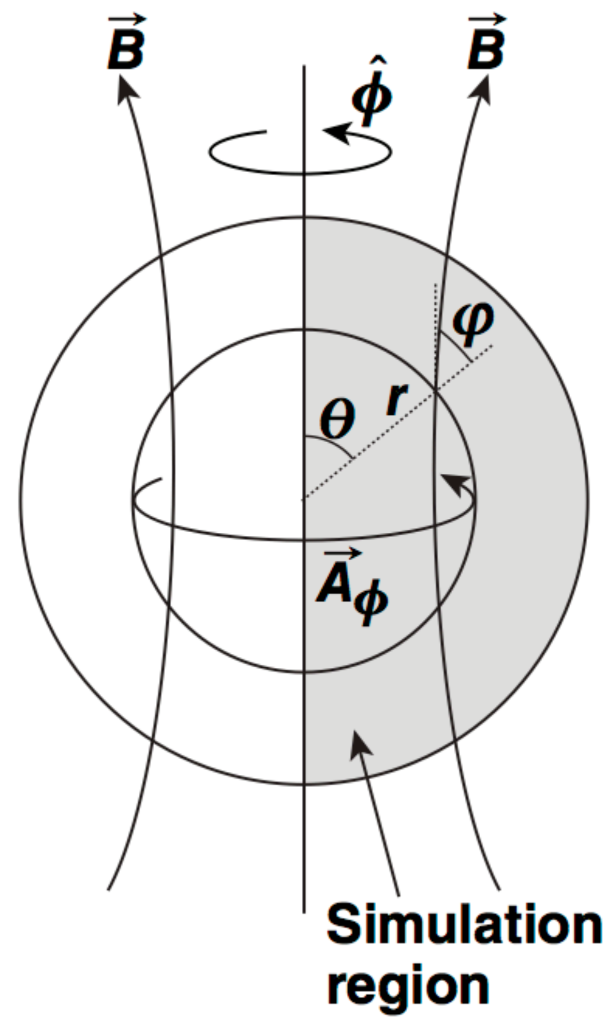

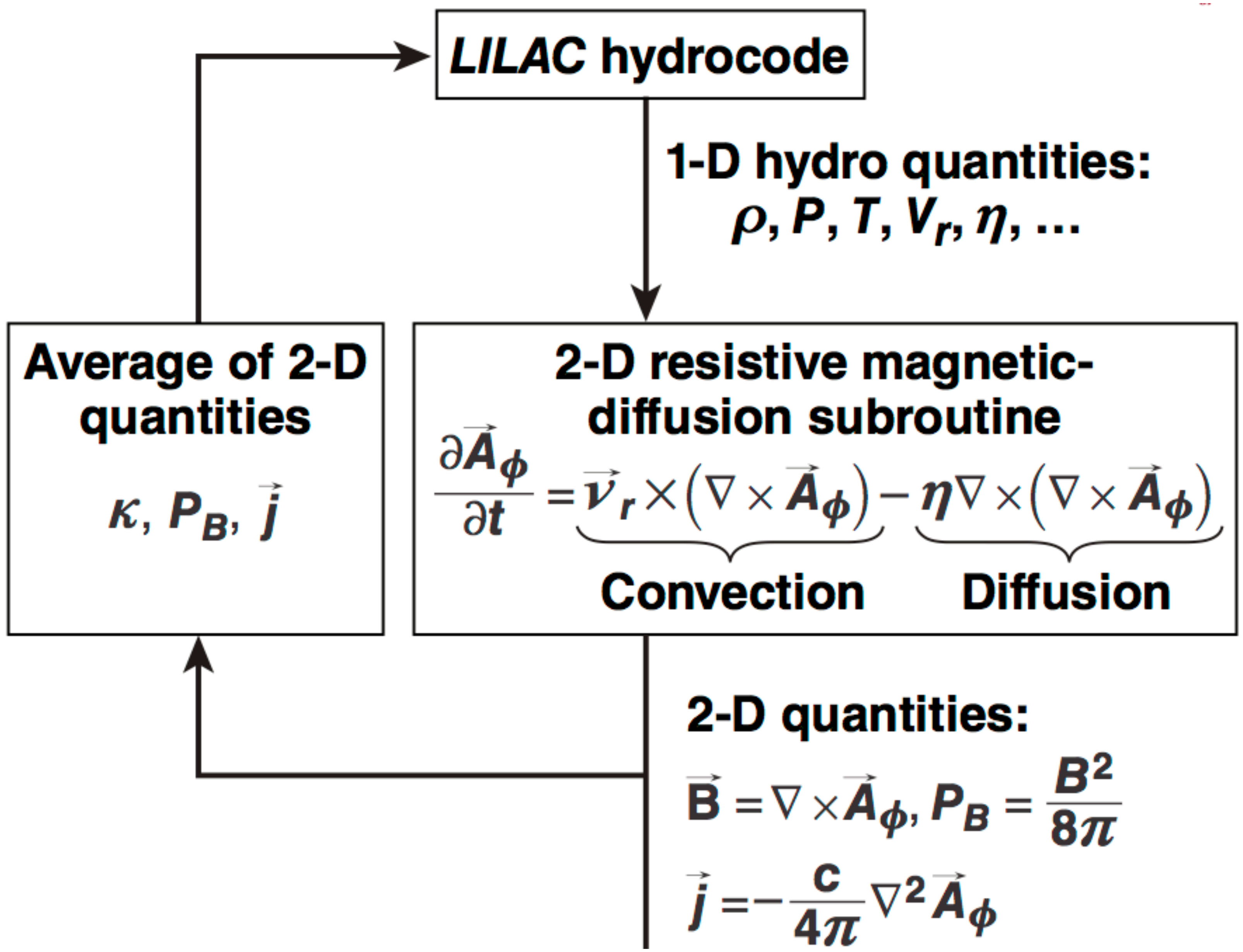

Self-consistent 2-D Hydro–resistive MHD compression (work in progress)

Simulations show that a seed field of 50 kG is compressed to more than 25 MG in the hot spot - 500x amplification

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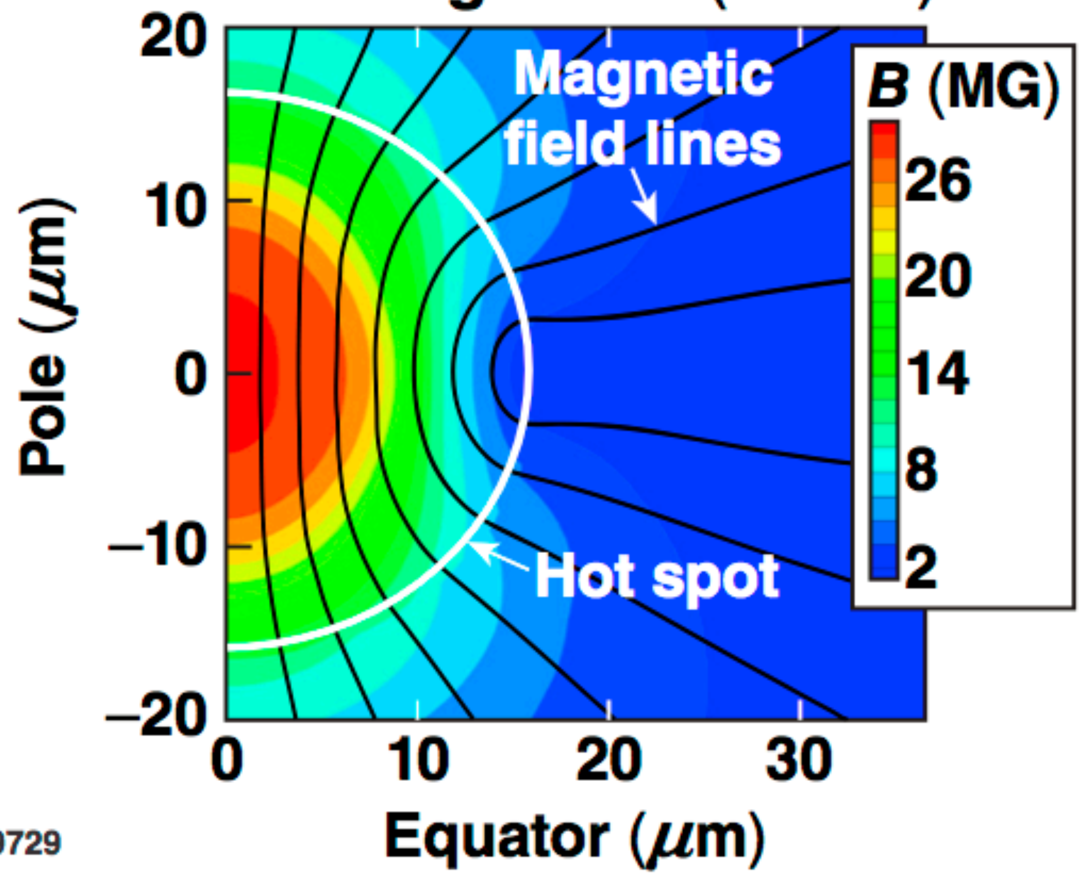
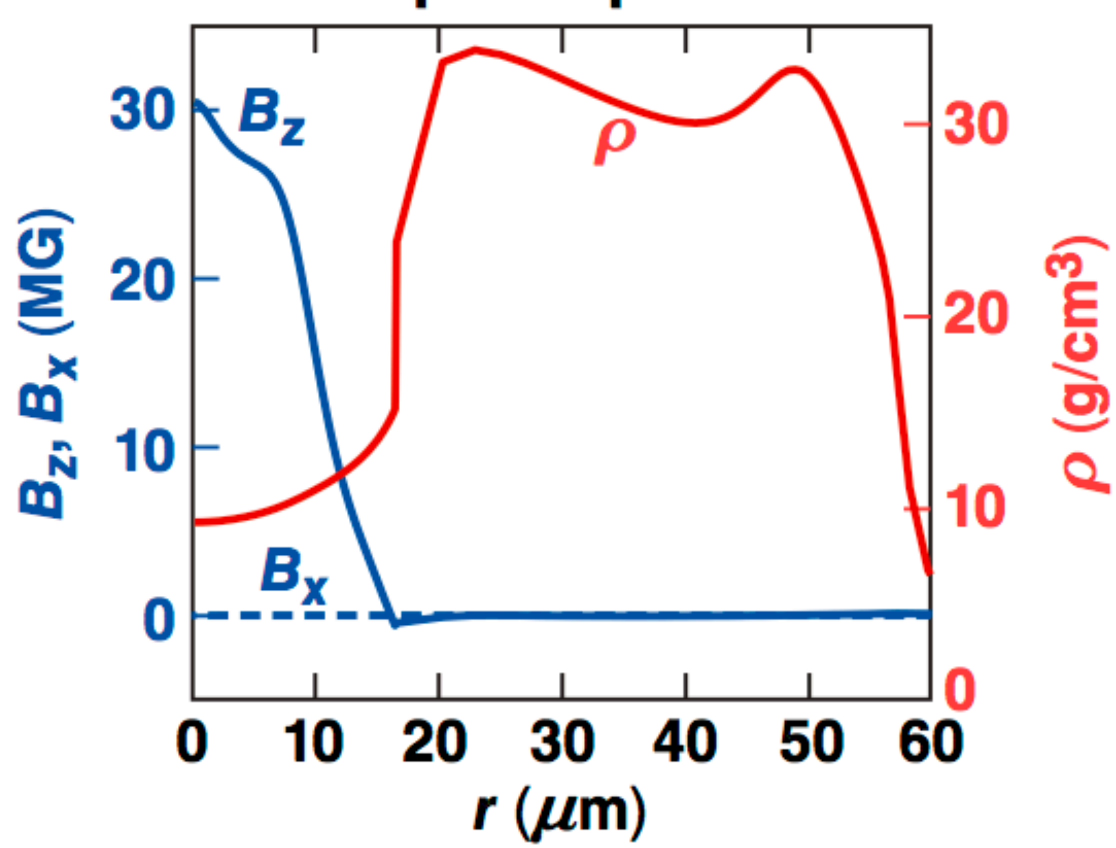
- **Target**
  - radius 460 μm
  - shell 24 μm
  - fill D_2 5 atm
- **Laser**
  - 1 ns square pulse
  - Energy 18 kJ

Field compression 25 MG/50 kG = 500
Target compression $(440/20)^2$ = 480

Simulation results at stagnation (2.1 ns)



Equator plane



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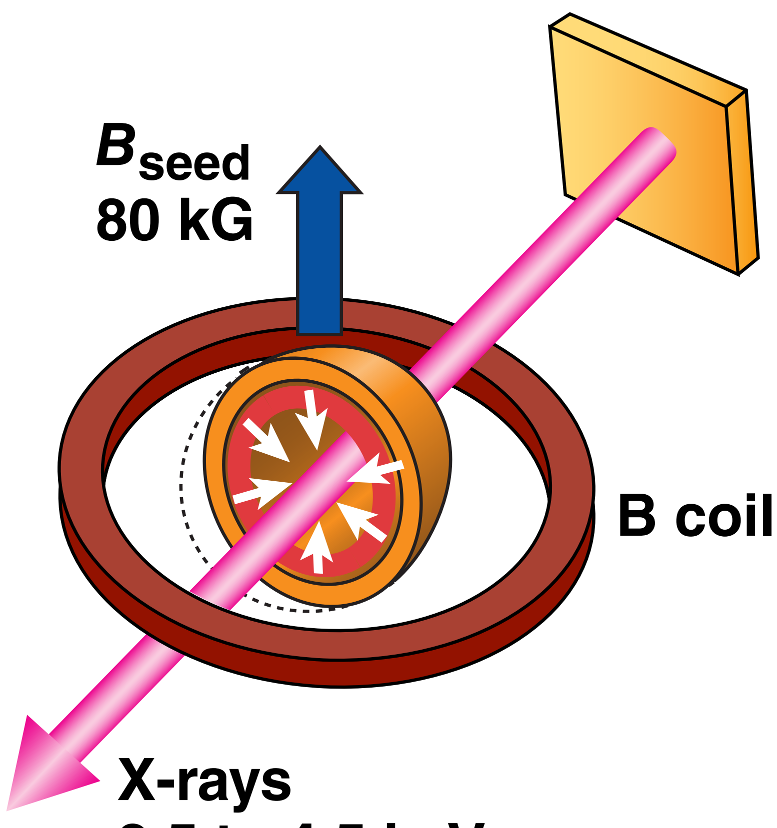
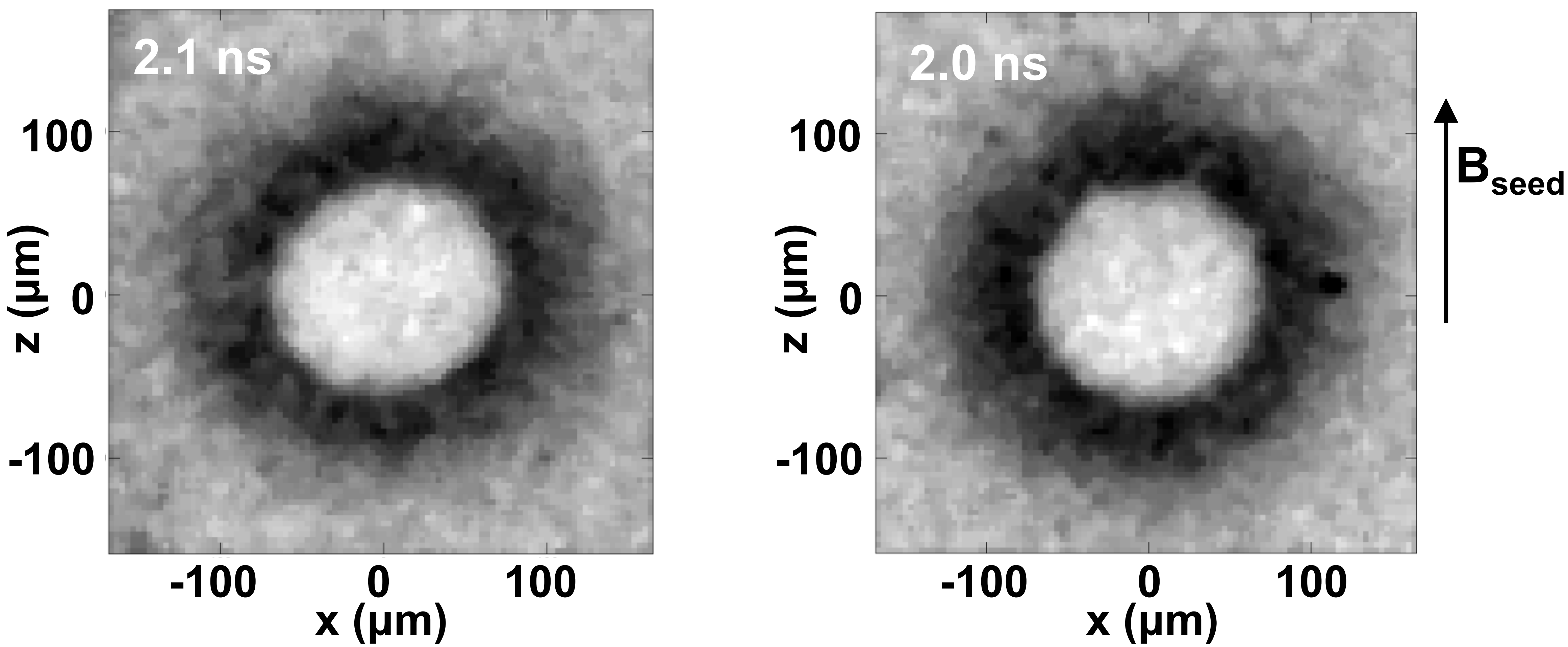
Single-coil B field was used for fusion-enhancement measurements in spherical geometry

- Single-coil provides stronger seed fields (80 kG), less interference with laser beam
- 40 beams (18 kJ/1 ns) were used for compression
- Implosion uniformity is diagnosed using x-ray BL radiography
- nTOF diagnostic was used for T_i and neutron-yield measurements



X-ray backlit images show good implosion uniformity with and without Bfield



We observe a (30±12)% neutron-yield enhancement and (15±4)% ion-temperature increase for magnetized targets

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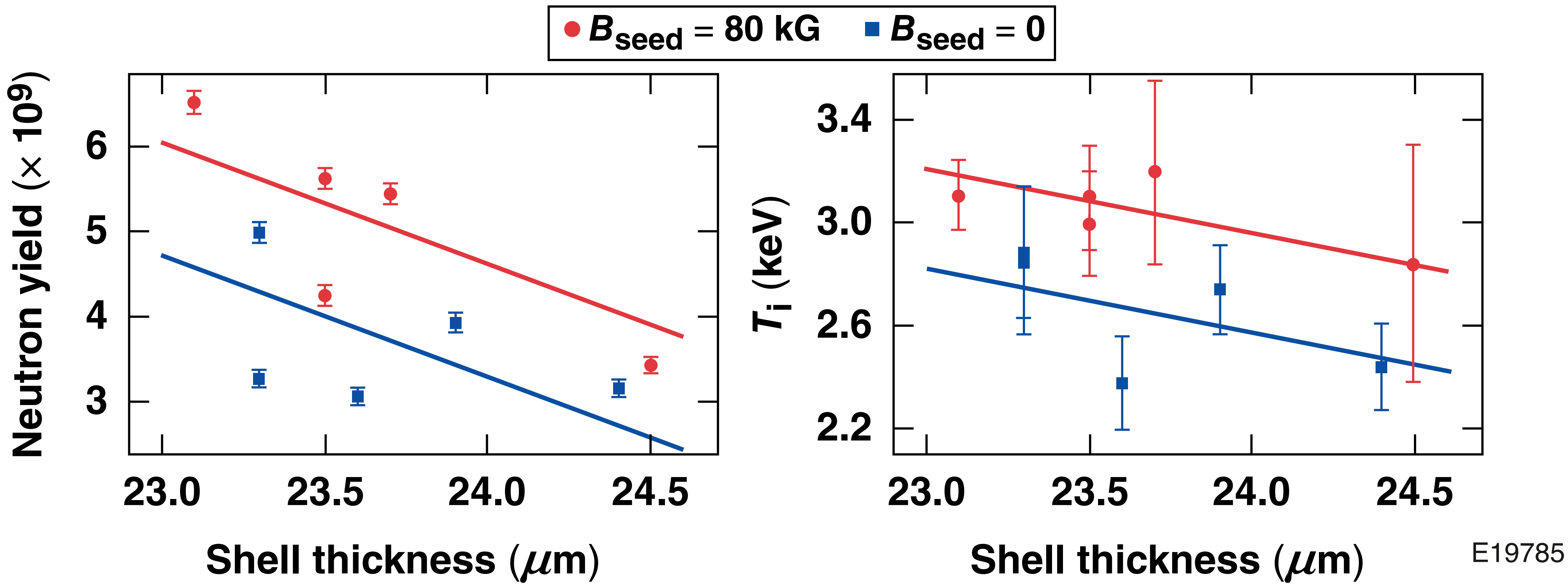


- Diagnostic—nTOF (neutron time-of flight)
- Fusion performance scales with shell thickness

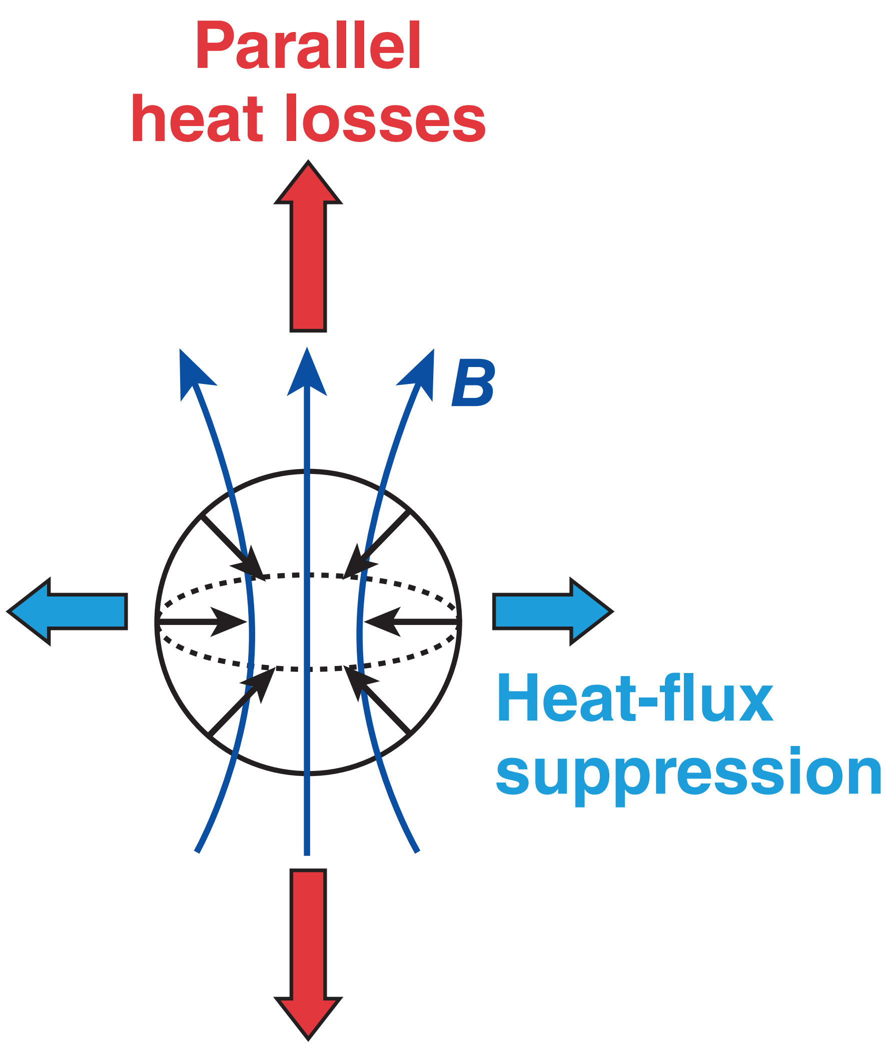
Linear regression fit reveals clear enhancement of magnetized hot-spot performance.

Even the field compression is strong, the fusion enhancement is expected to be limited by the open-field line geometry

- The ratio of open field-lines area to target–surface area ~1/2, so less than 50% of conduction losses is reduced

$$\alpha = \frac{A_{\parallel}}{A_{\parallel} + A_{\perp}}$$

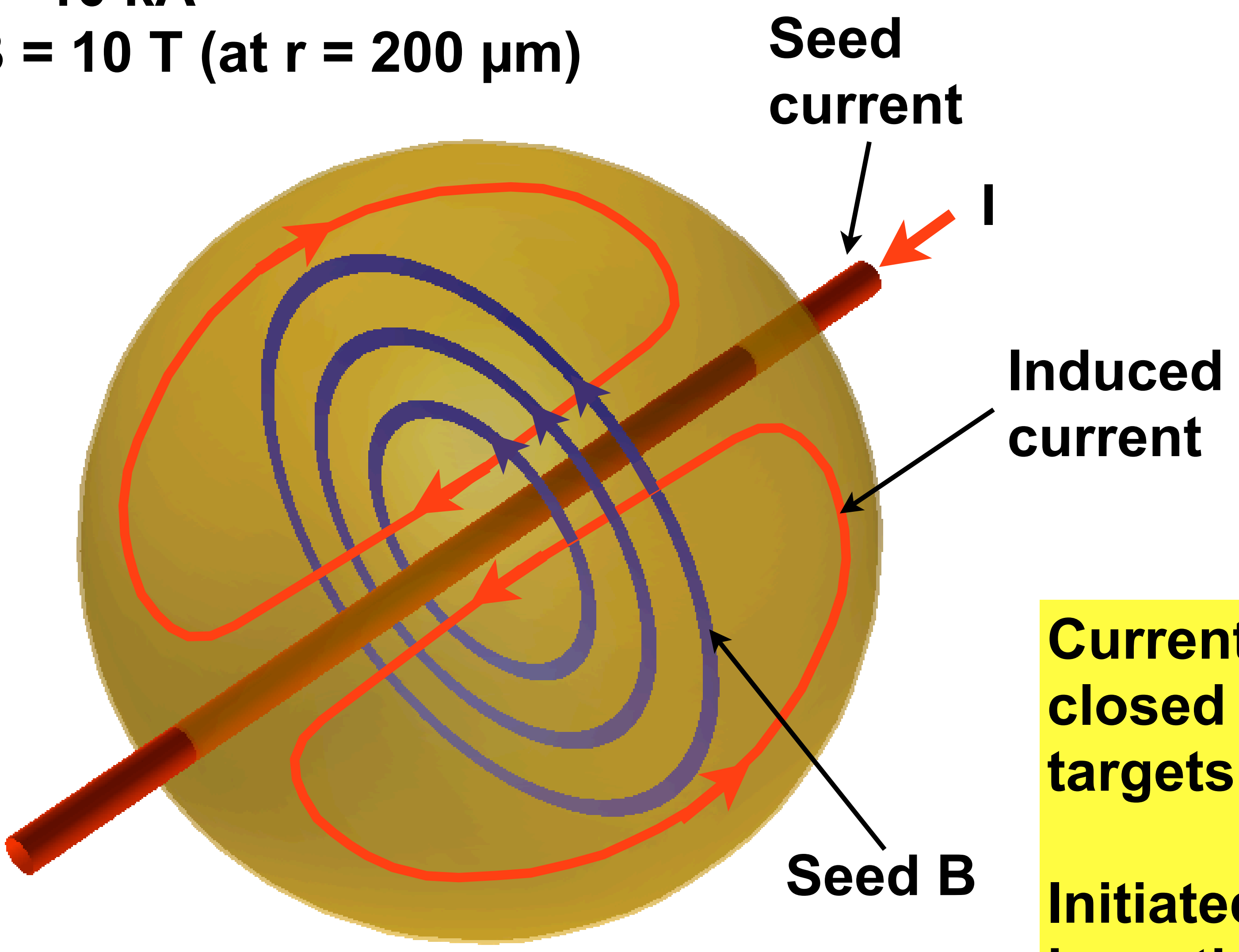
$$k_{eff} = k_{\parallel}\alpha + k_{SP}(1-\alpha)$$



1D *LILAC*	ΔT/T	ΔN/N
Simulation: α = 0.5	8%	15%
Simulation: α = 0 (Full Spitzer reduction)	40%	70%
Simulation: α = 0.25	15%	30%
Measured	15%	30%

Closed magnetic field lines can be created by driving current through the target

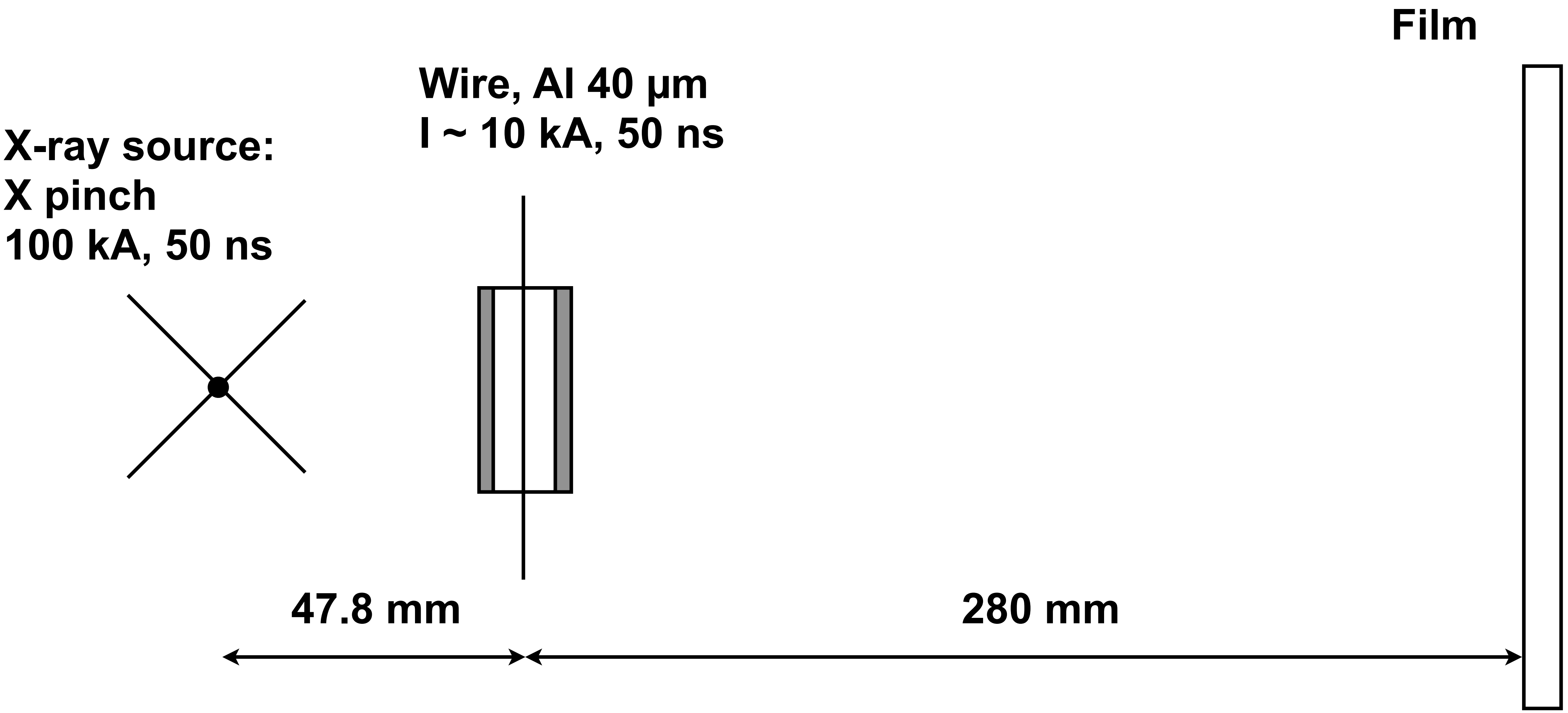
I = 10 kA
B = 10 T (at r = 200 μm)



Current efforts: create closed magnetic surfaces in ICF targets.

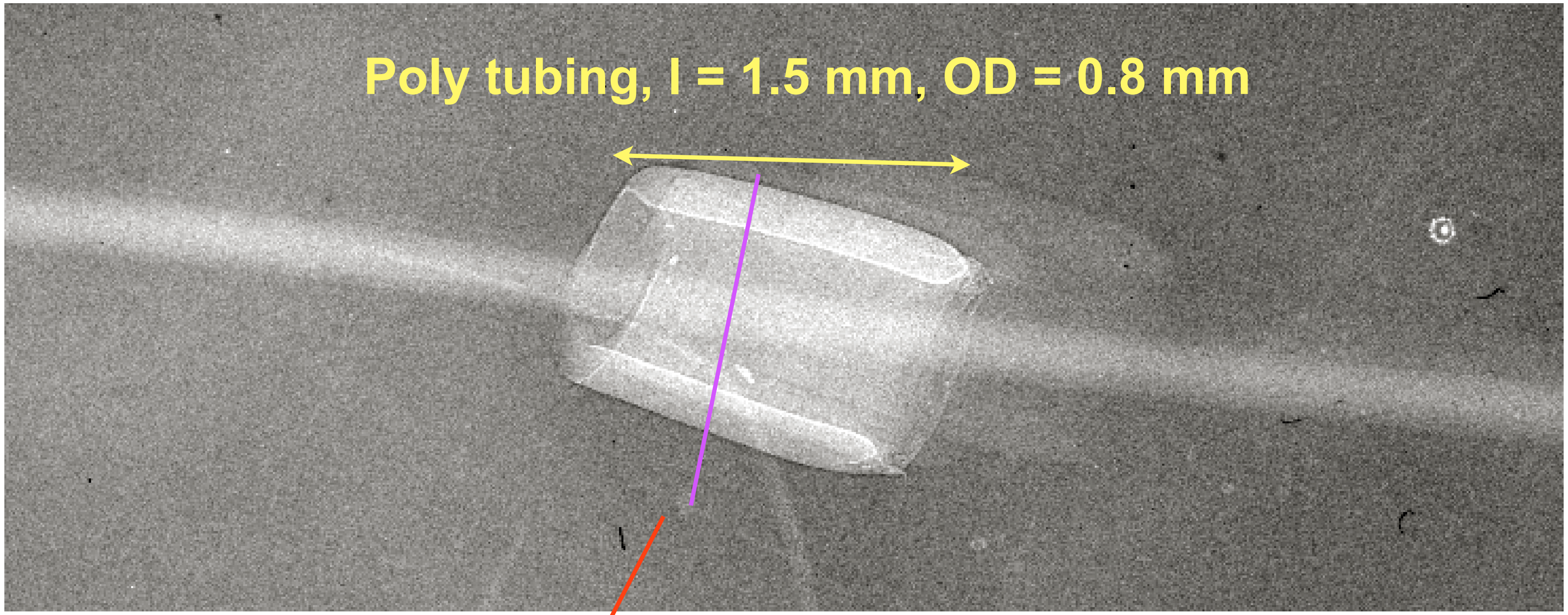
Initiated collaboration with Cornell to investigate thin high-current wires in plastic targets.

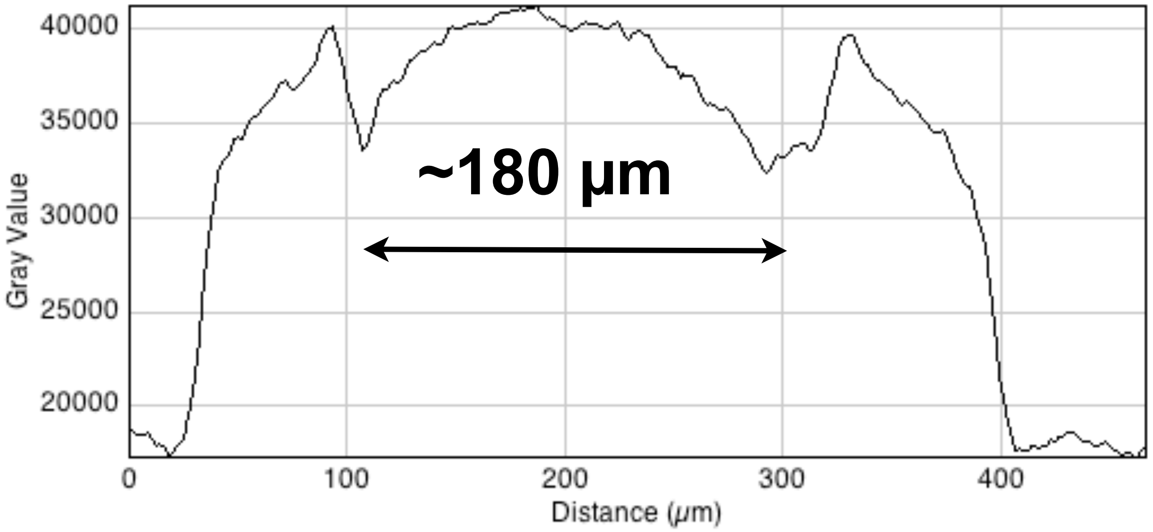
Wire Imaging at Cornell



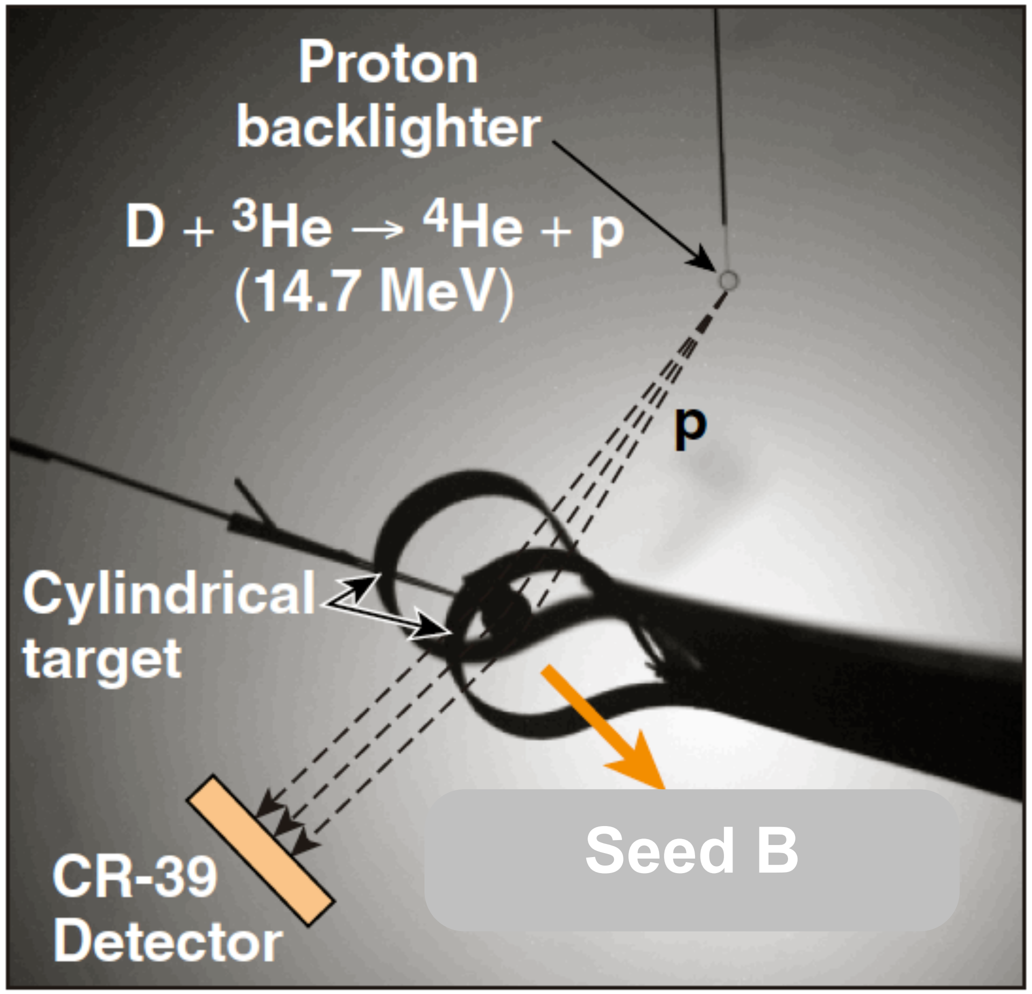
Gennady Fiksel
S. Pikuz
T. Shelkovenko

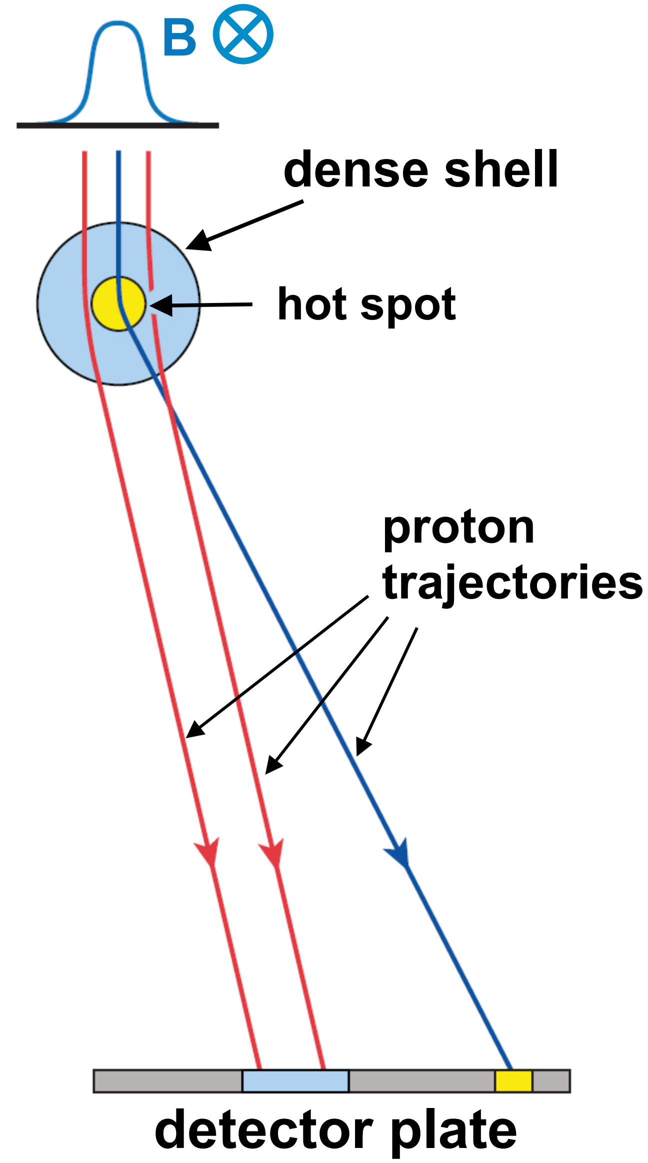
Preliminary result - wire in a short plastic tube - expanded but still intact?





Compressed magnetic fields in cylindrical geometry were inferred using proton deflectometry





Field topology and density distribution causes a characteristic two-peak deflection pattern

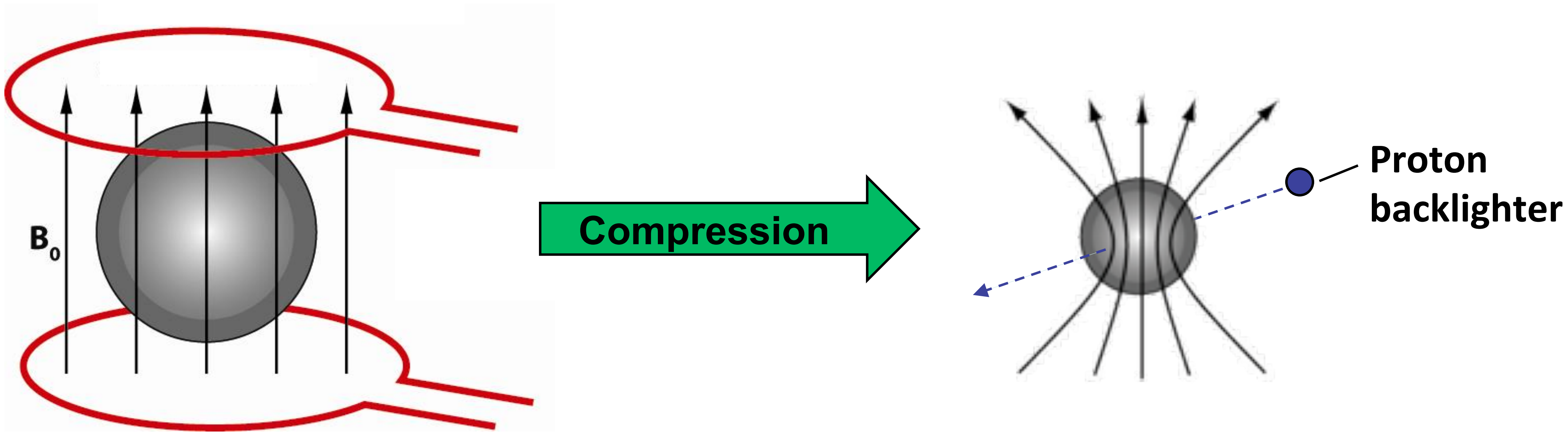
O. V. Gotchev *et al.*, Phys. Rev. Lett. 103, 215004 (2009).

E19780

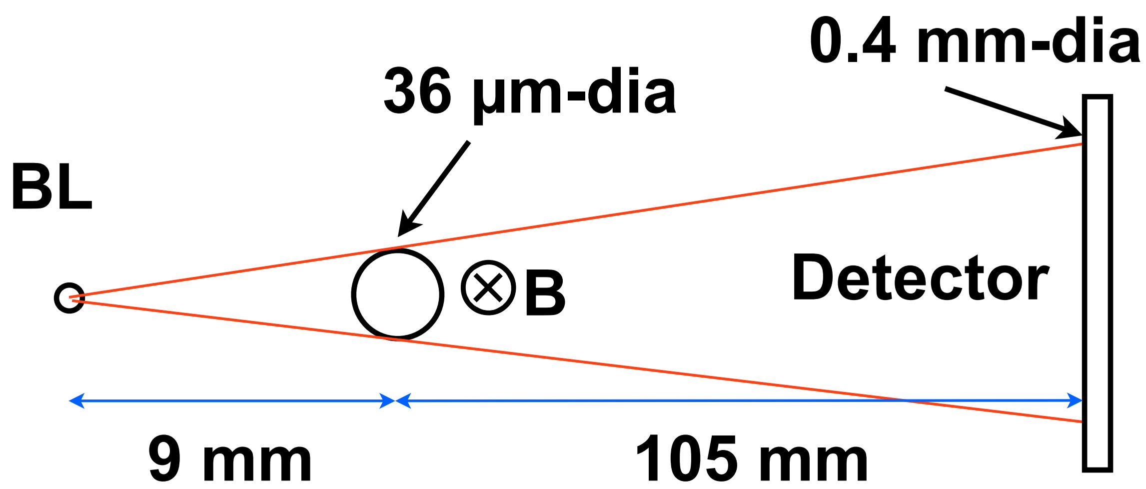
J. P. Knauer *et al.*, Phys. Plasmas 17, 056318 (2010)

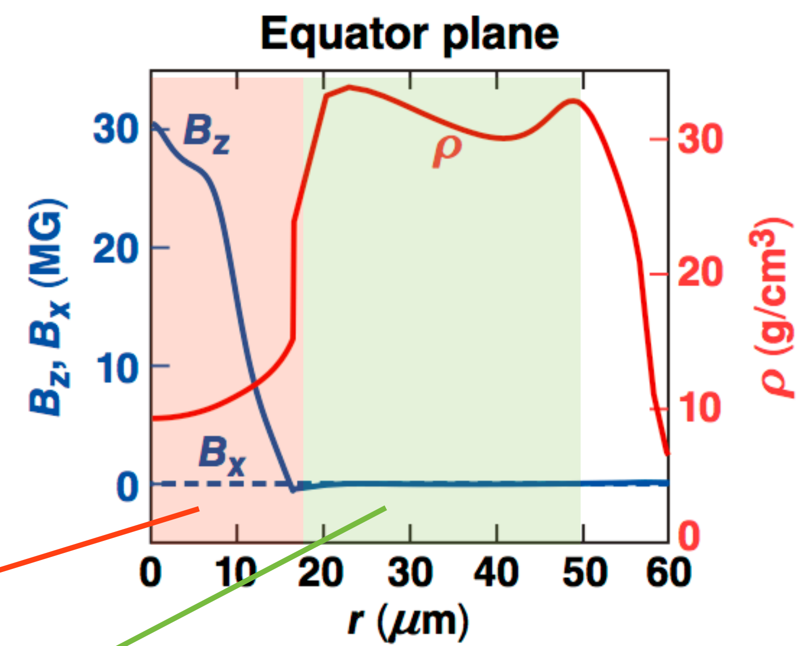
Measuring the compressed field in spherical geometry is challenging

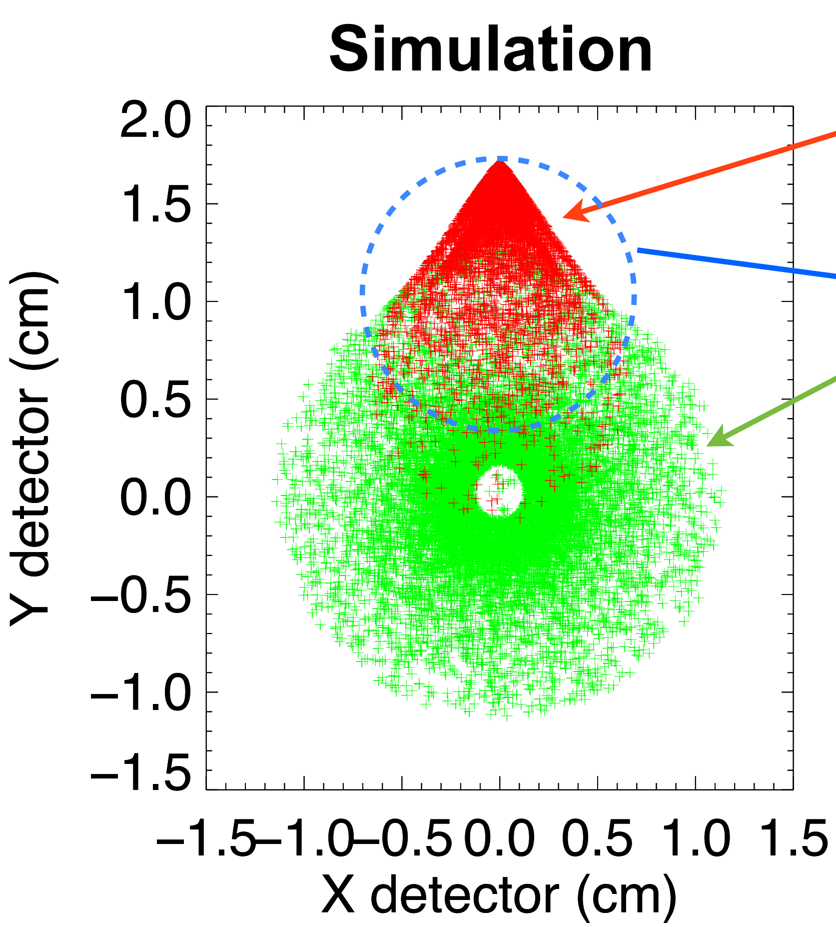
- **Spherical compression of straight field lines results in radial component of the compressed field**
- **Proton deflection pattern becomes more complicated than for the cylindrical case**
- **Small cross section of compressed core results in reduced signal-to-noise**



The density of deflected ions drops by a factor of ~500-1000 due to spreading in Bfield



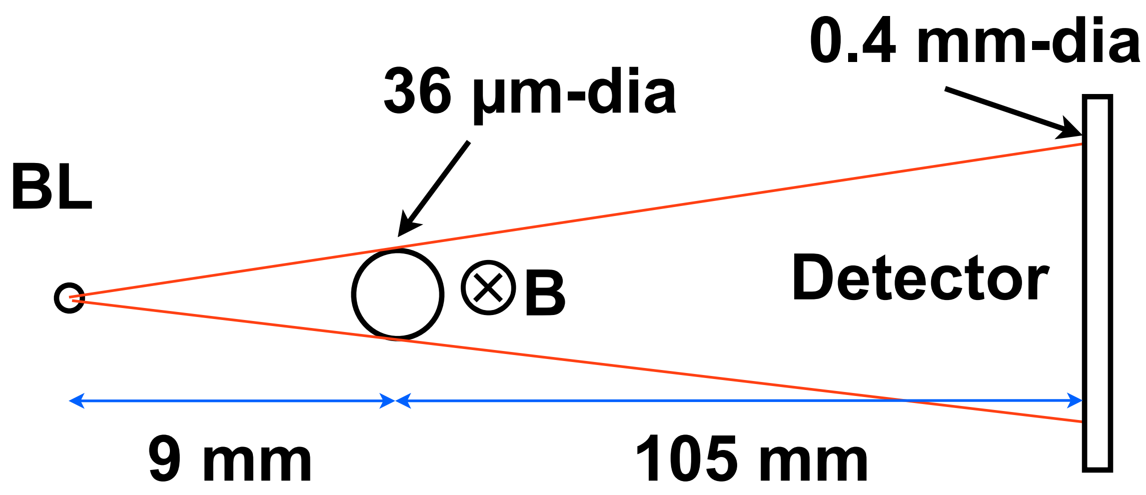


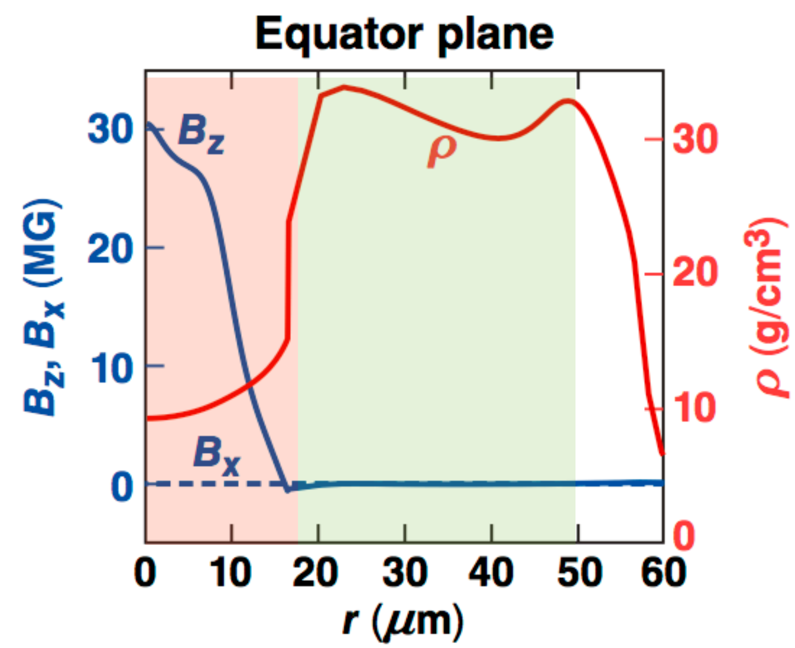


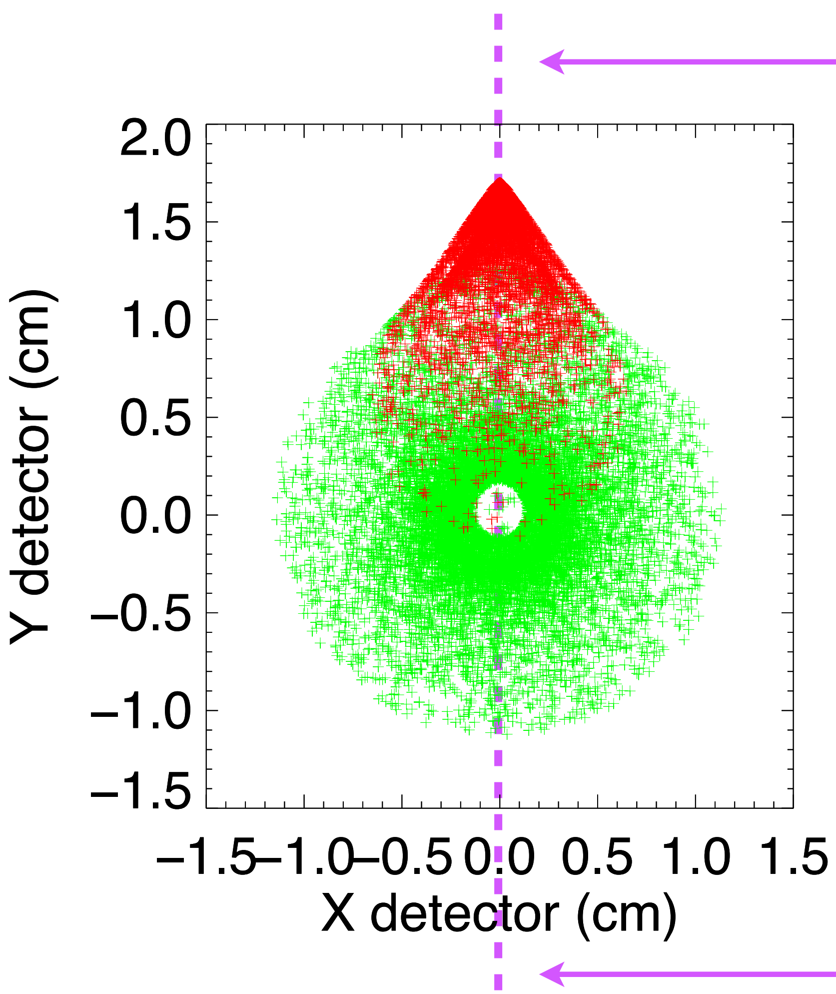
Scattered area ~10 mm-dia

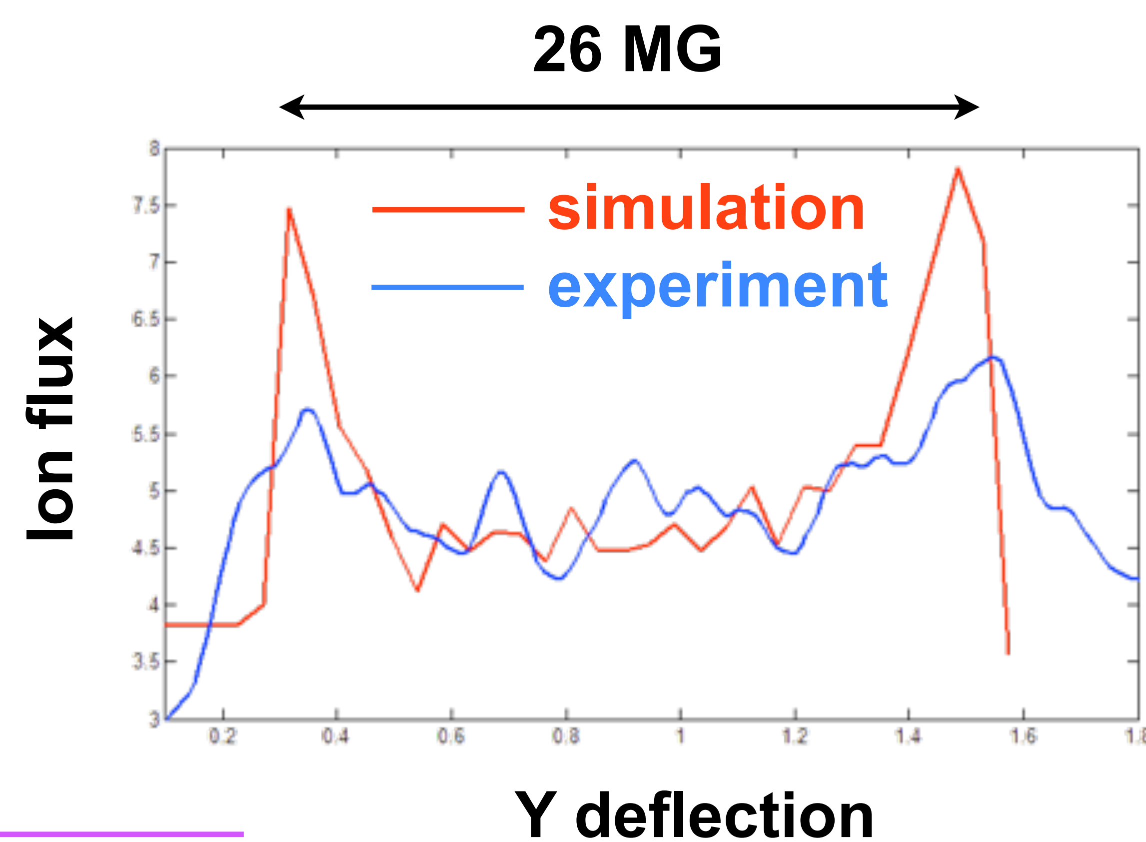
$$\frac{\text{signal}}{\text{background}} \sim \left(\frac{0.4\ \text{mm}}{10\ \text{mm}}\right)^2 \sim \frac{1}{600}$$

Double-peak profiles are observed in simulation and experiment. The inferred B agrees with simulation.









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