Laser-Driven Magnetic Field Generation at the NIF

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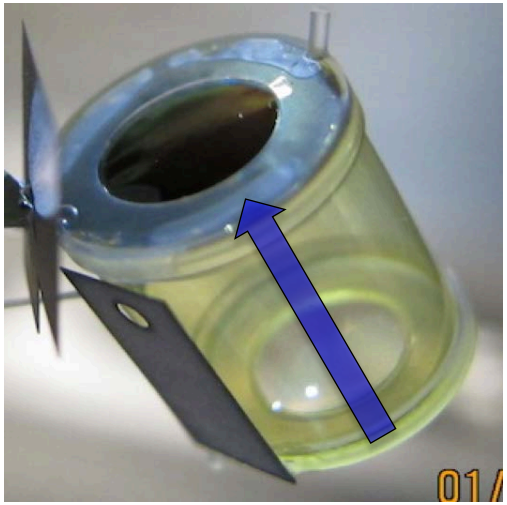
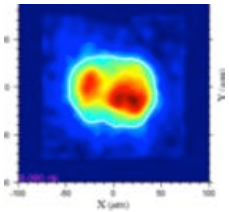
The HED community has great interest in producing 10-100 T B-fields at large facilities

Laser propagation



Relevant for MagLIF laser-absorption

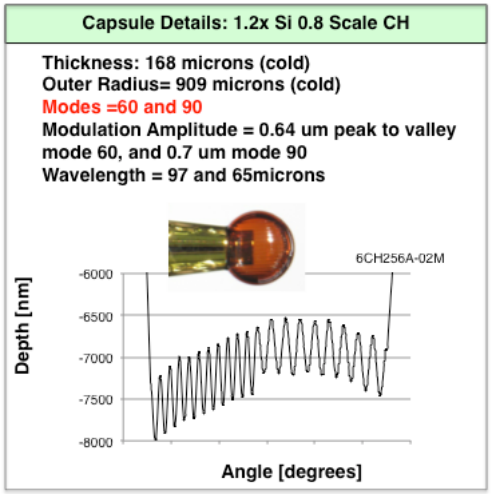
Hot-spot alpha confinement



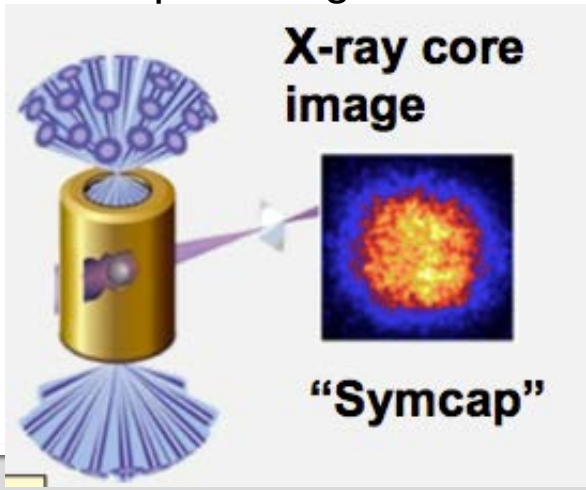
10 ps DT hot spot shape

A 30x convergence increases B from 20 to ~ 10^4 T; sufficient to confine fusion-alphas in a 20 µm hot-spot and facilitate boot-strapping in lower fuel ρR

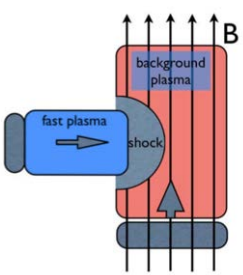
RT growth rate



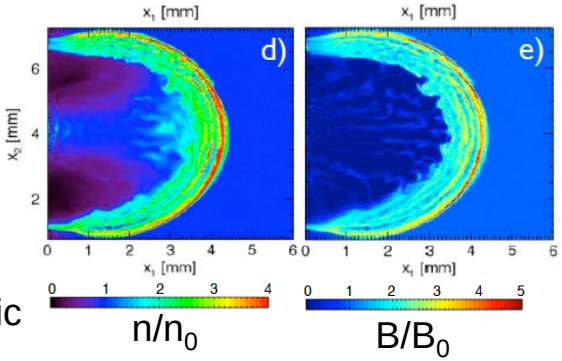
Core shape change with B-field



Collisionless shocks by magnetic reflection from compressed B-field - DS



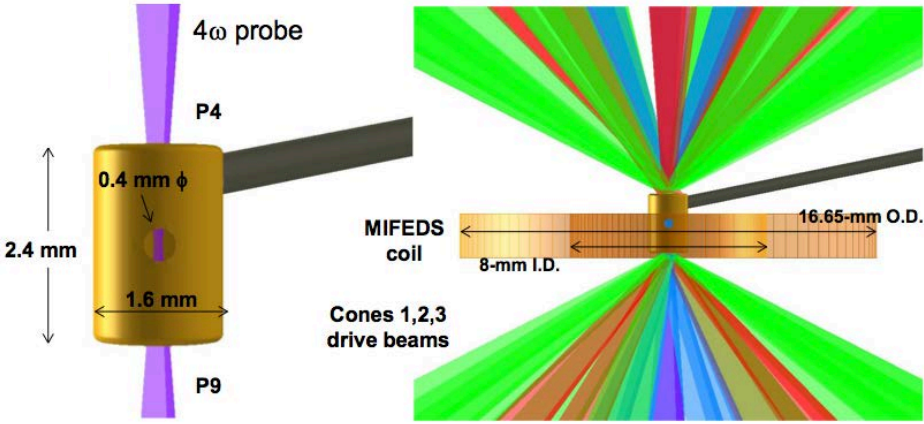
Expt. schematic

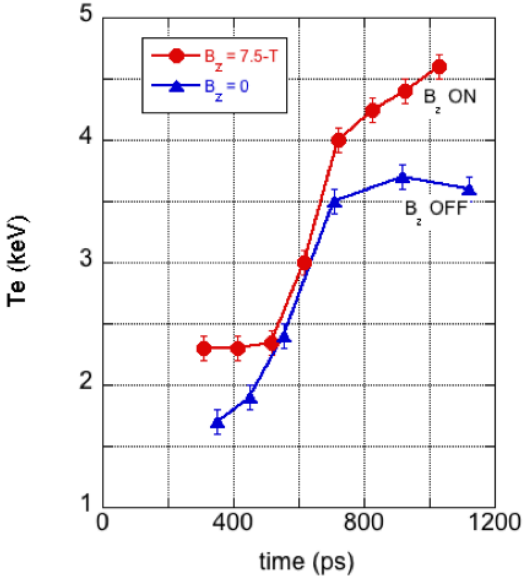


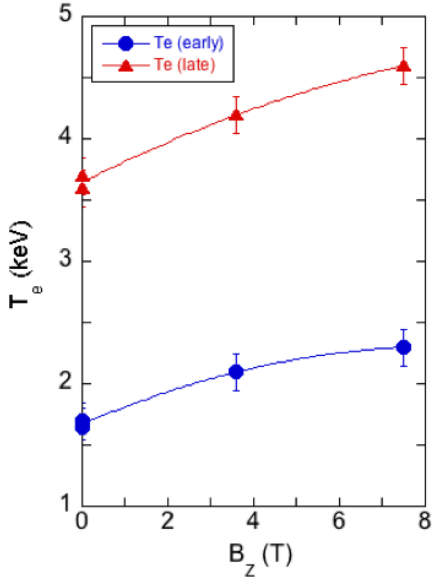
PIC simulation by Fiuza

NIF hosted a workshop in October to explore programmatic and Discovery Science applications

- Dave Montgomery presented work from Omega showing increased plasma temperature with <10 T
- Dave Strozzi showed simulations of NIF-scale targets where 70 T fields achieved the same heating increase, suppressing LPI and allowing the inner beams to better propagate to the wall
- Other ignition schemes (**MagLIF**, polar-direct-drive, shock ignition, **fast ignition**) also benefit adding external B-fields



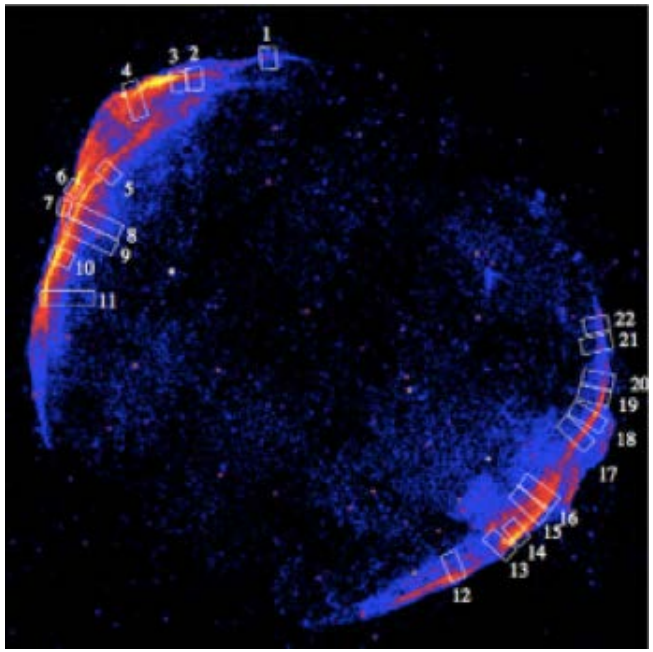




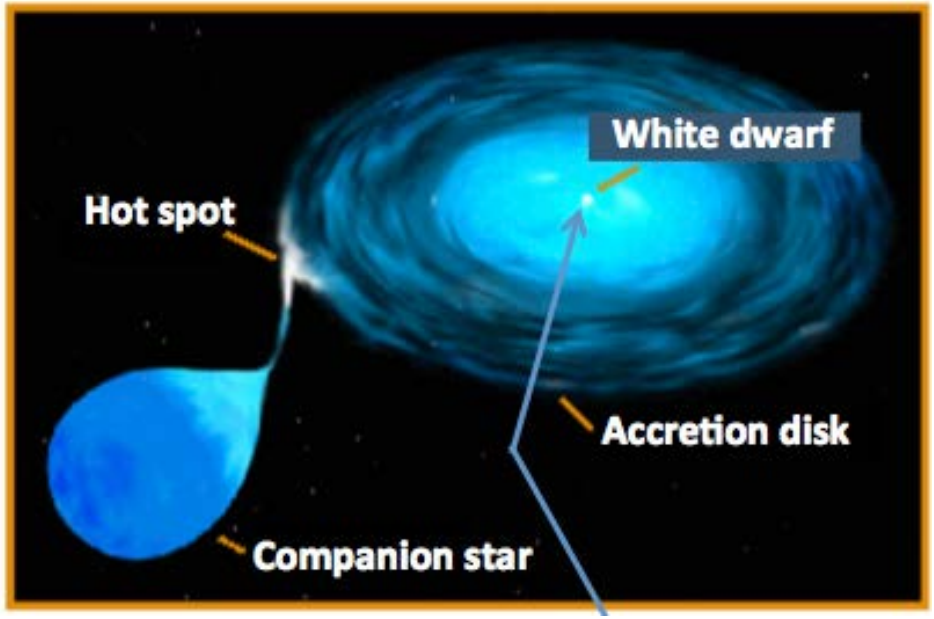
D. Montgomery et al, POP 2015

Many of the Discovery Science talks involving B-fields were focused on laboratory astrophysics

- Collisionless shocks

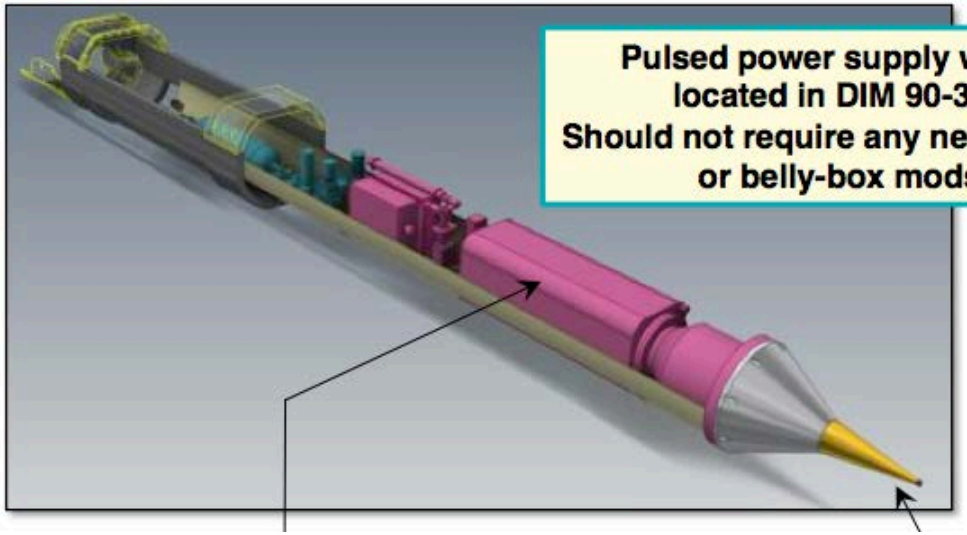


- Accretion discs



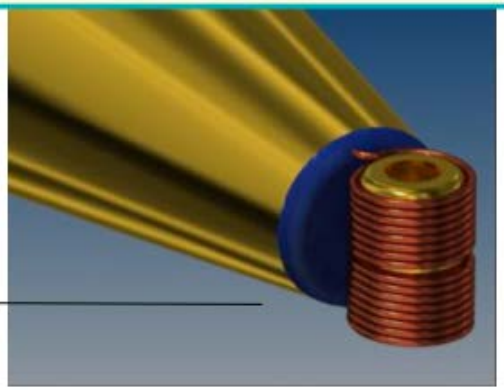
- Shock acceleration
- Pair confinement
- Magnetic reconnection

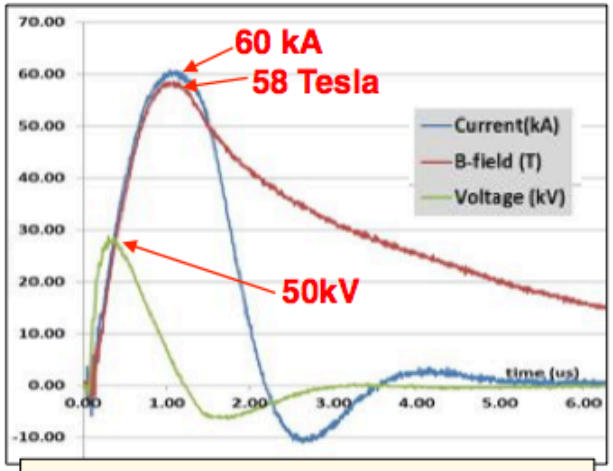
There is a pulsed power B-field system being developed at LLNL



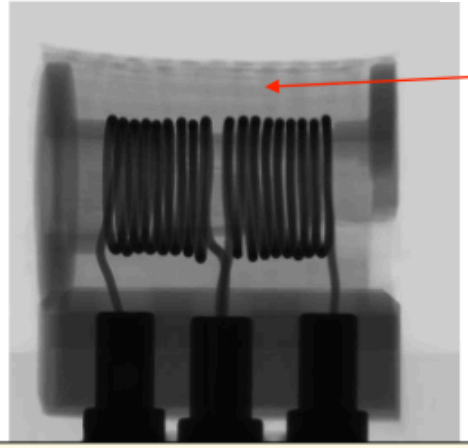
Pulsed power supply will be located in DIM 90-348
Should not require any new utilities or belly-box mods

Room-temp coil hohlraum coil. (50T nominal, 70T max); will have Xylon composite external wrap





Waveforms – latest 58T shot



Coil after a 31T shot

Tensile strength of Xylon composite ~ 5800 MPa.

Tube stress at 50T ~1600MPa.

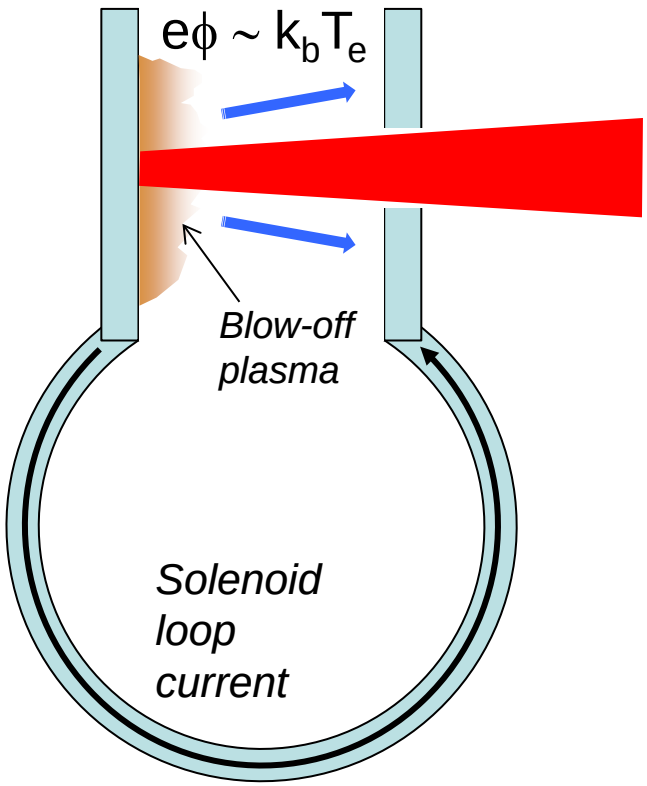
So shouldn't disassemble

(ALE3D suggests no melt at 50T, 70% of melt at 70T but after peak field is reached)

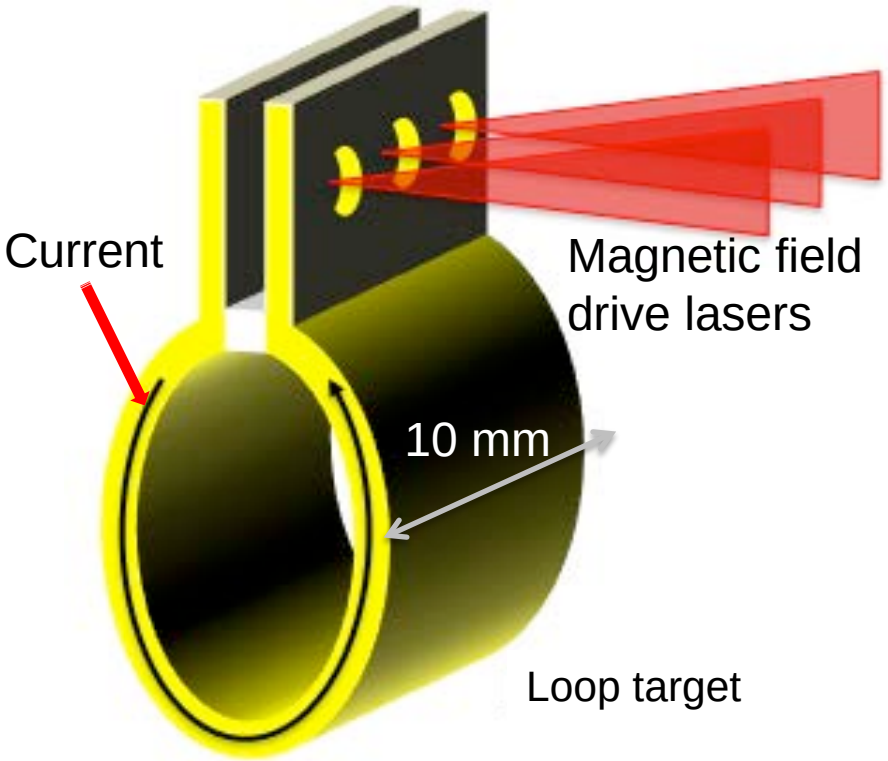
J. Perkins, LDRD

We have been awarded Discovery Science shots to demonstrate laser-driven B-fields at NIF

Laser driven plasma sheath creates voltage source for current

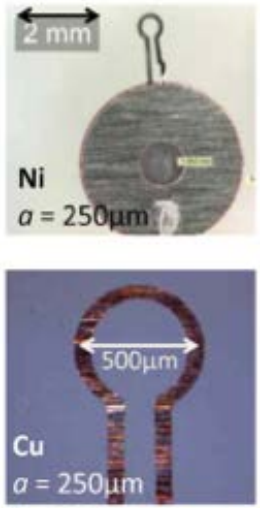


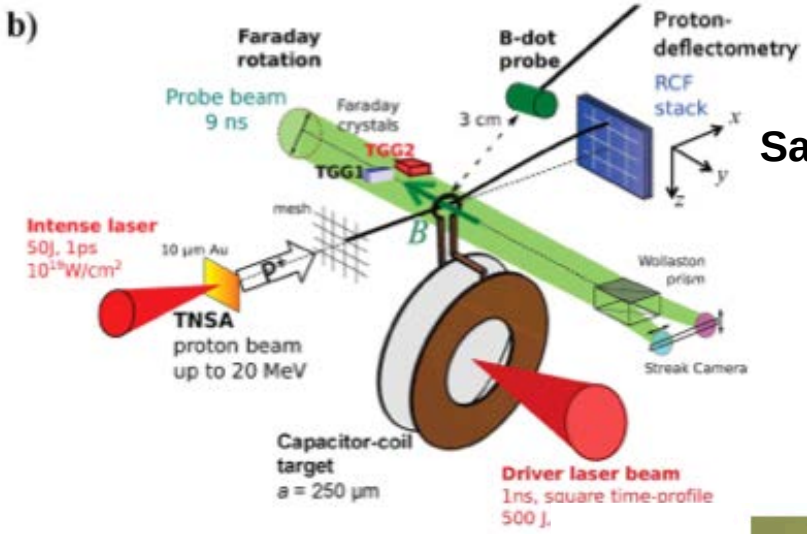
Daido *et al.* Phys. Rev. Lett. **56,** 846 (1986)



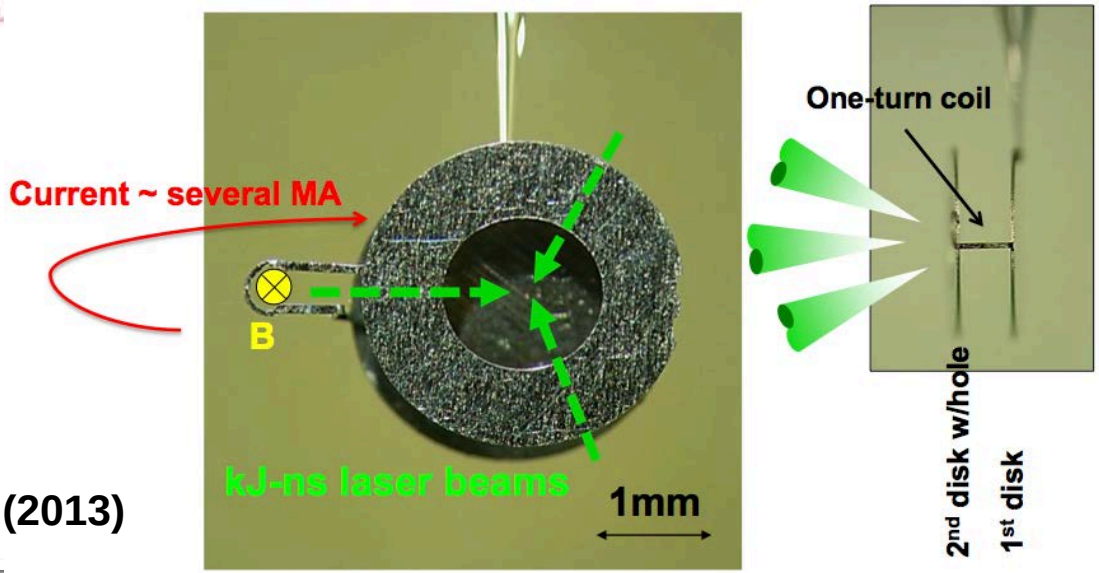
- Alternative to pulsed power
- Fast rise time ($\leq \tau_{laser}$)
- Integrated into the target

A similar scheme is being developed at ILE and at CELIA





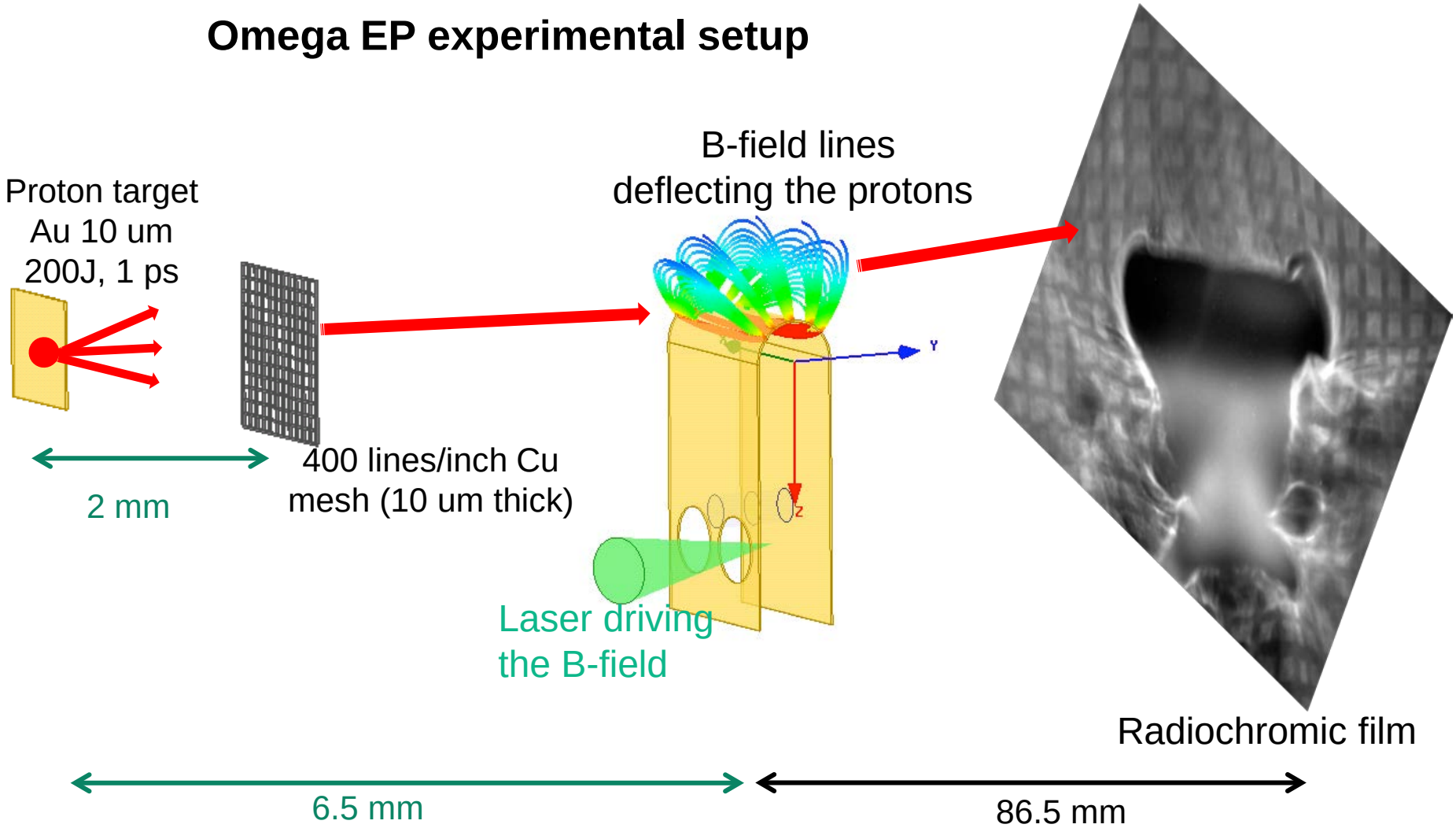
Santos *et al.* New J. Phys. 17, 083051 (2015)



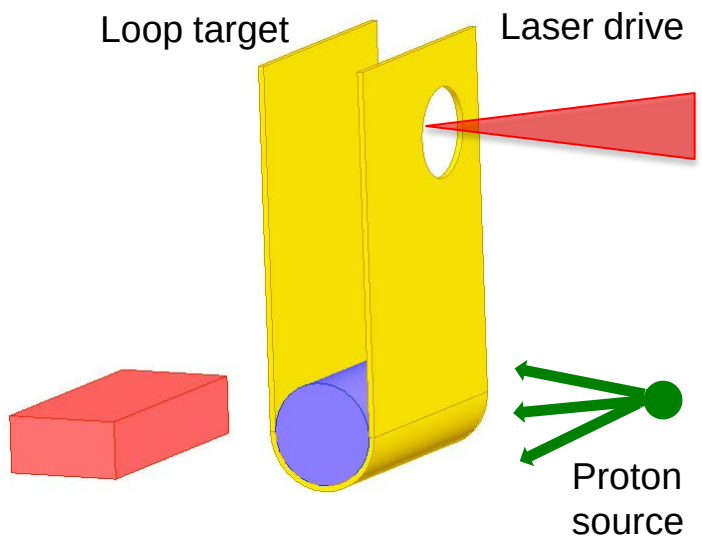
Fujioka et al. Scientific Reports (2013)

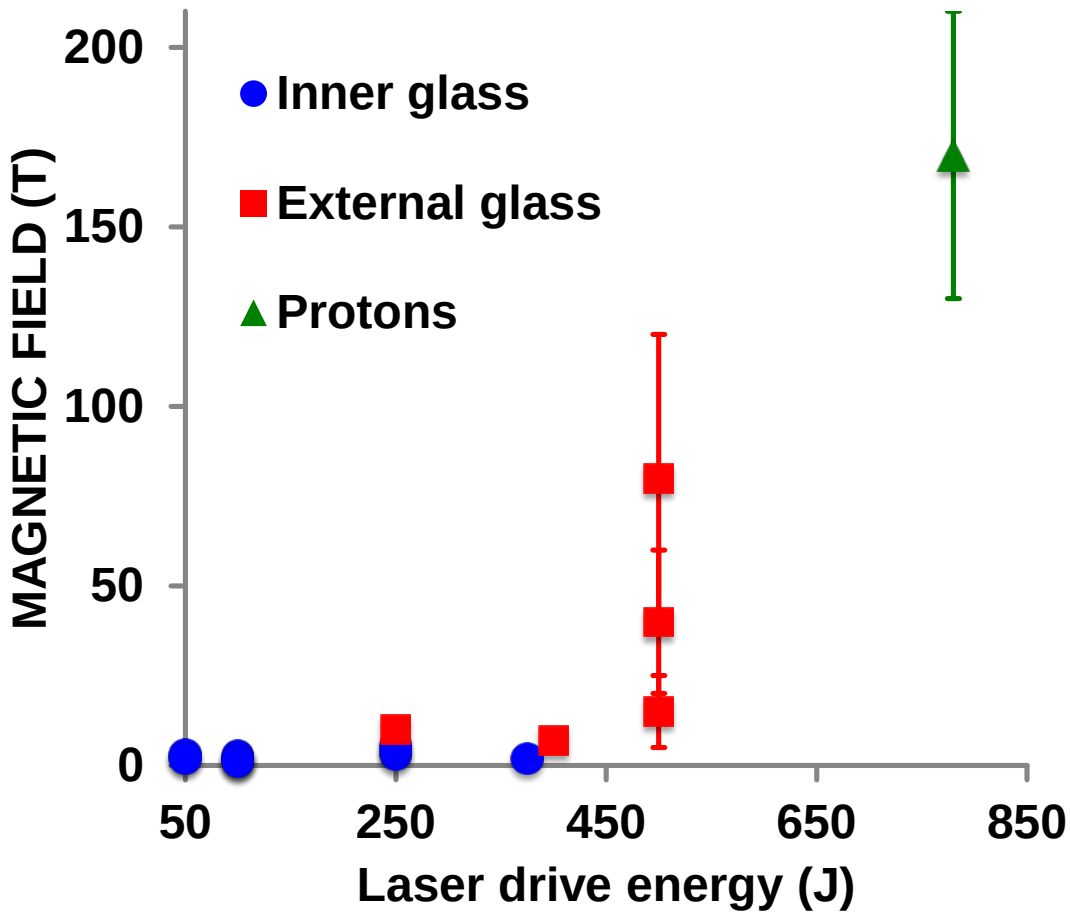
Proton deflectometry at higher laser drive has indicated axial fields of ~170 T at 1.2 TW, 800 J

Omega EP experimental setup



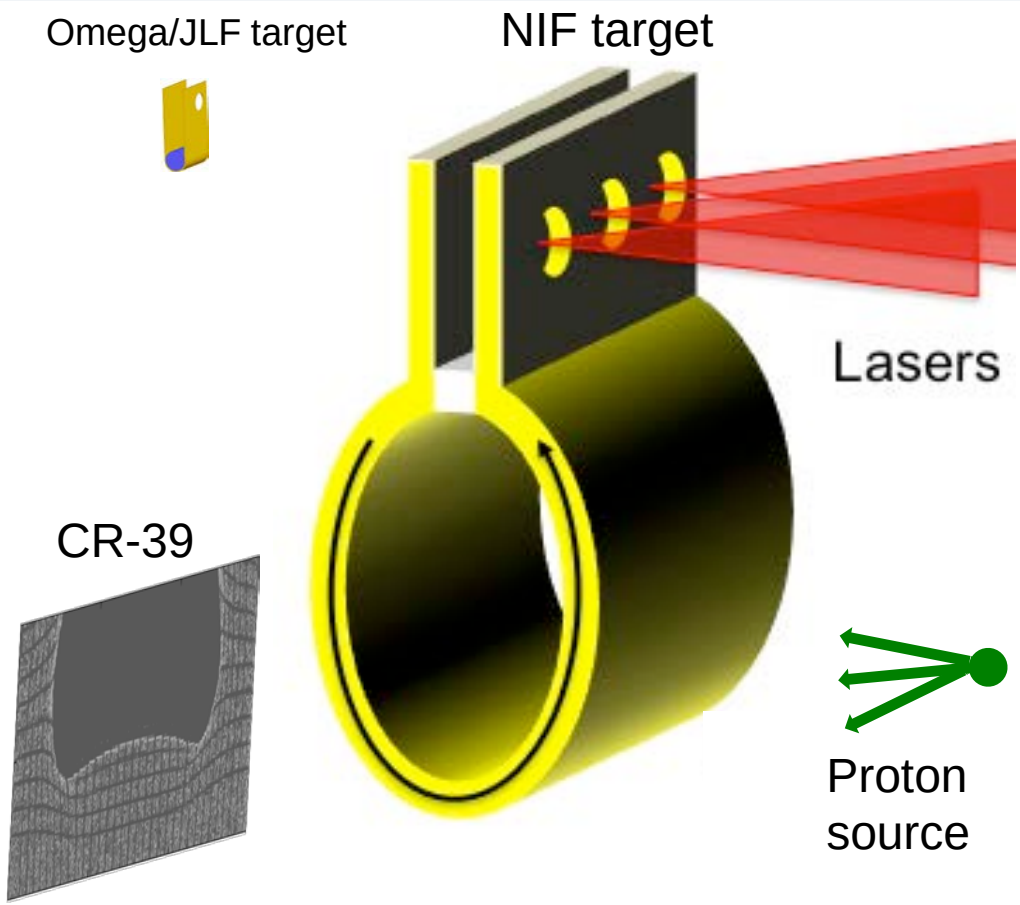
We have scaled the axial field up to 170 T in a ~mm^3 volume at Omega EP

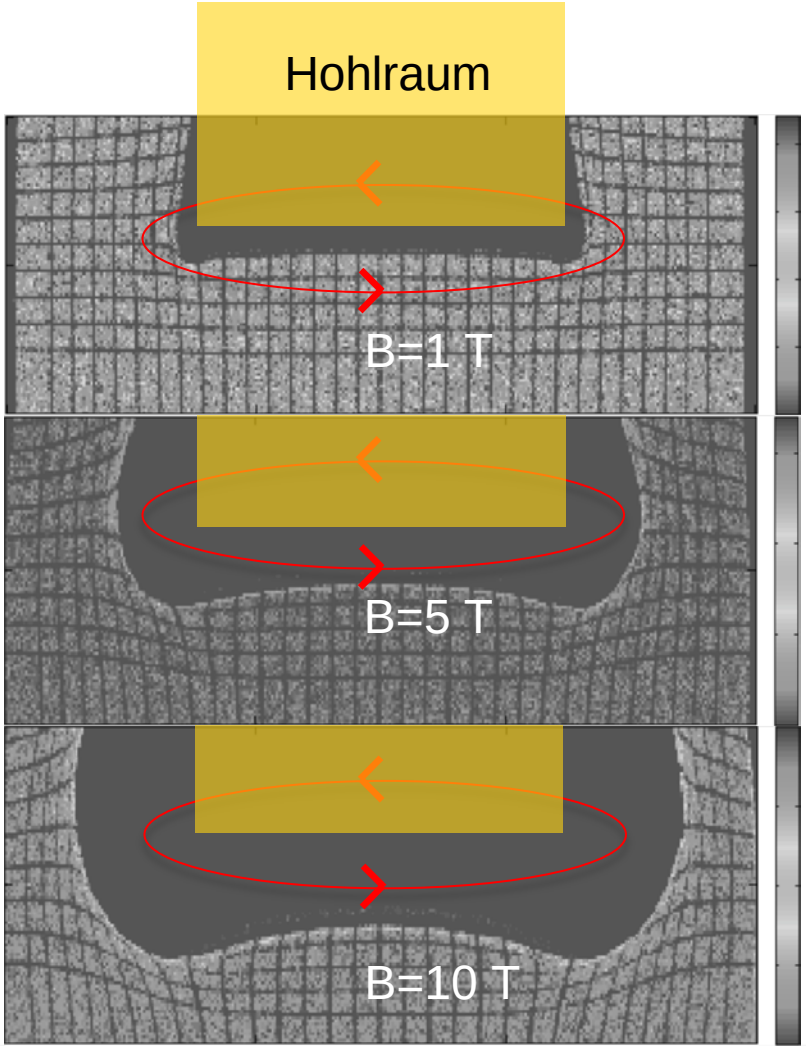




C. Goyon JLF talk tomorrow

The primary diagnostic of the field strength on NIF will be proton deflectometry





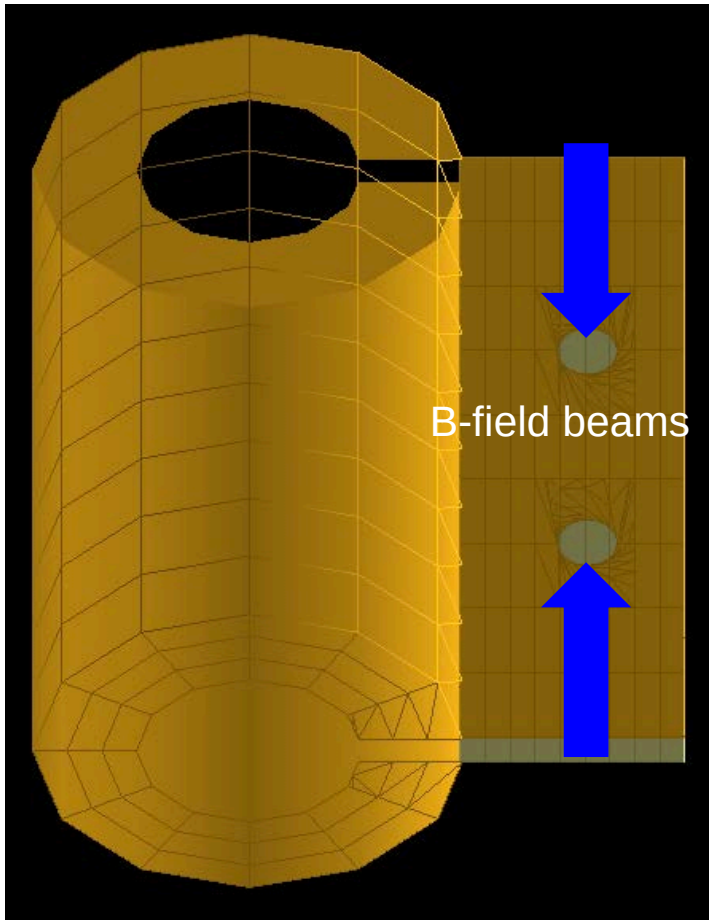
FABS/NBI, SXI, FFLEX, DANTE, GXD's

Thomson scattering, Rogowski coil, Voltage measurement

The laser configuration is similar to a backlighter design

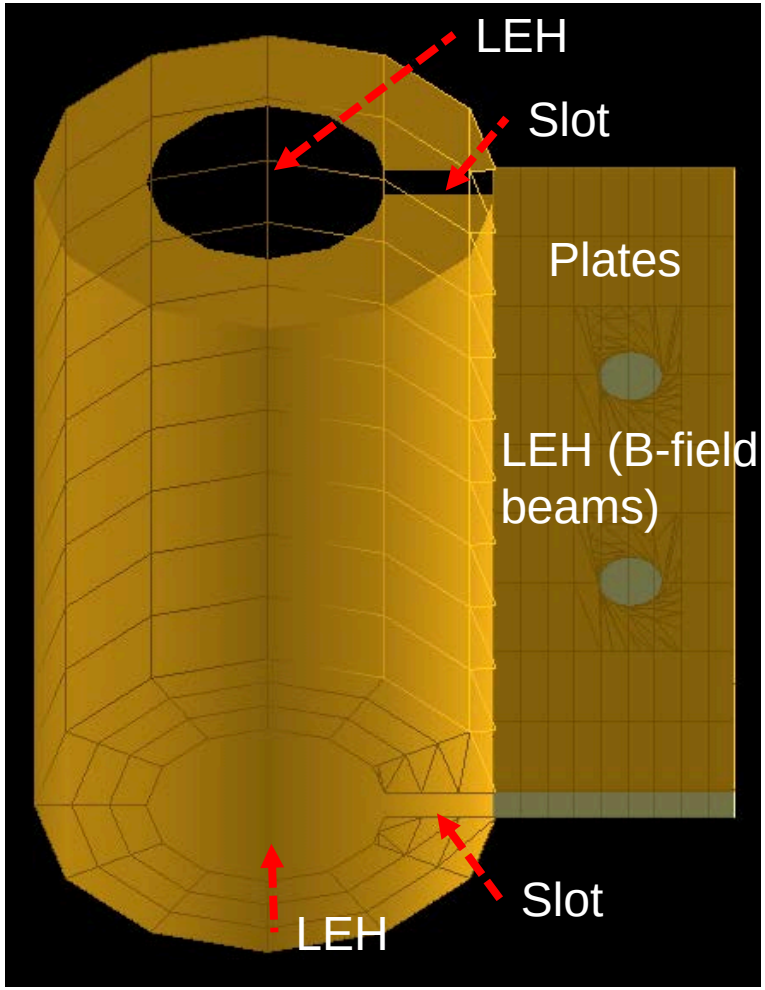
- 1-3 quads are pointed to the magnetic field generation region
- 8 quads illuminate the D3He capsule (not shown)
- Magnetic field beams are requested with maximum energy 10 ns square pulses
- No phase plates for B-field beams

Loop target



The target will be similar to a vacuum hohlraum design with extensions for the magnetic field

- Enables both warm and cryo operation
- Vacuum hohlraums initially, then gas-filled with multiple shot days
- The slotted target with extension is a new target platform
- The slot may need to be filled with an insulating material (uranium oxide)
- The extension plates (~3x10 mm) represent a planar component to the target



Conclusions

- The laser-driven B-field platform is all-optical and provides in-situ fields without occupying a DIM and is readily compatible with cryo-operations
- The laser-driven source will be tested in upcoming gas pipe experiments to measure changes to laser heating and heat transport
- The HED community is very interested in having a magnetic field capability on NIF
- There is a pulsed power source currently under development with plans to be able to field it in a DIM

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