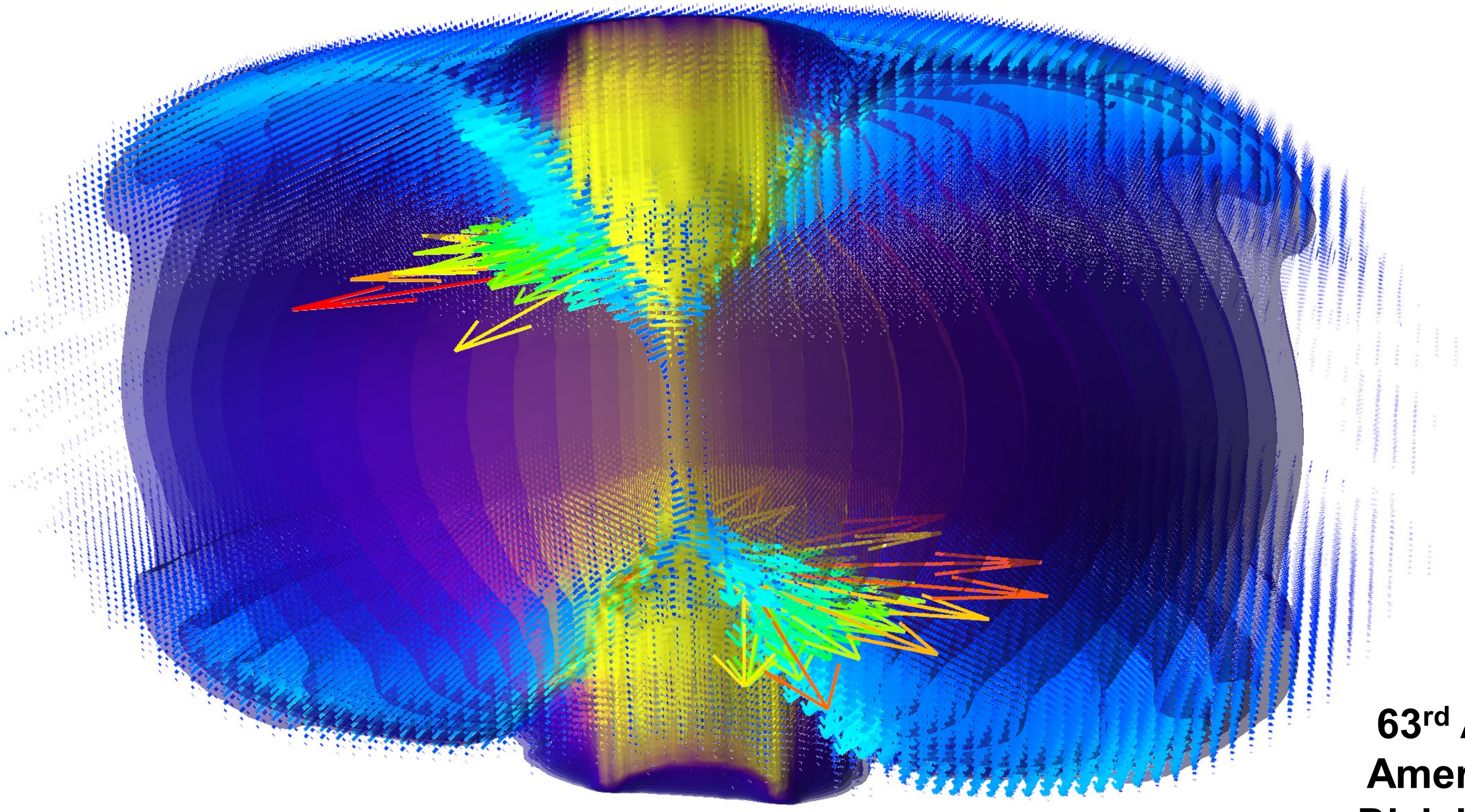
Proton Radiography of Self-Generated Magnetic Fields in Laser-Driven Cylindrical Implosions



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Proton radiography at oblique incidence can measure azimuthal self-generated magnetic fields in cylindrical implosions

- Large magnetic fields can be self-generated in inertial confinement fusion (ICF) and high energy density physics (HEDP) experiments
- The largest fields self-generated in laser produced plasmas are generally azimuthal. Oblique proton radiography can be used to measure these fields
- This technique was applied to several cylindrical implosions on the OMEGA laser facility to measure self-generated magnetic fields in the coronal plasma created by the drive beams
- An open-source charged particle radiography particle tracing algorithm is now available as part of PlasmaPy

Collaborators

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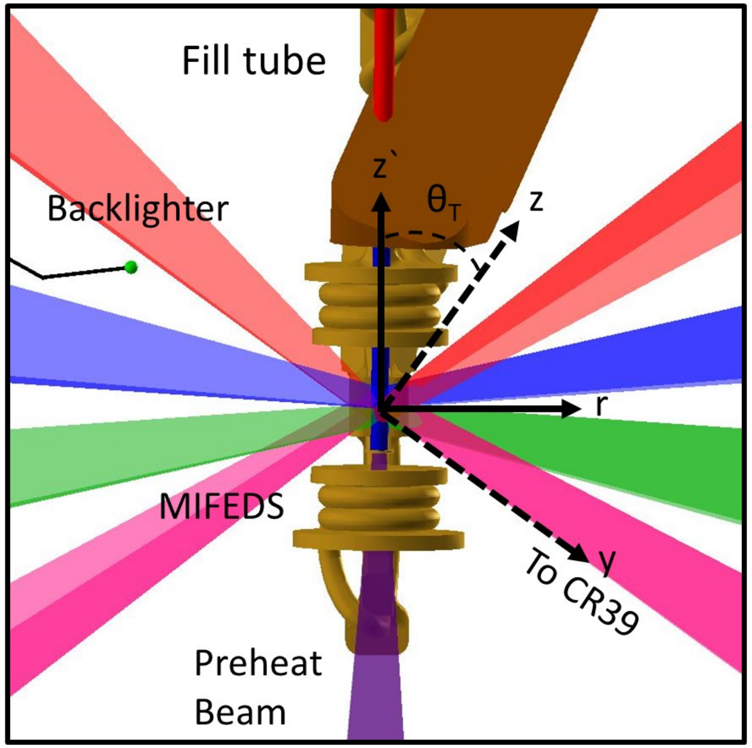
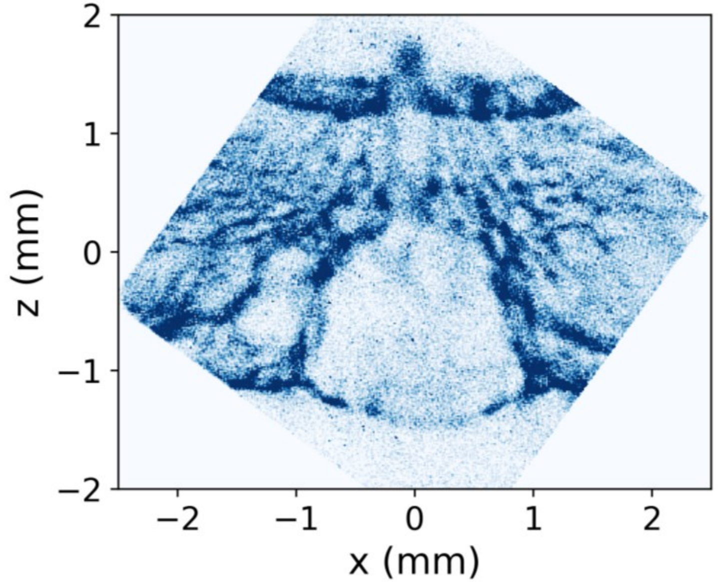
A cylindrical implosion experiment at OMEGA used proton radiography to measure self-generated fields in the coronal plasma



- CH cylinder (20 um thick, 580 um OD).
- Filled with 11 atm D2, preheated with 180 J.
- Imploded with 40 beams (10^{14} W/cm^2).
- Optionally magnetized with a 9 T axial field.

Proton Radiograph



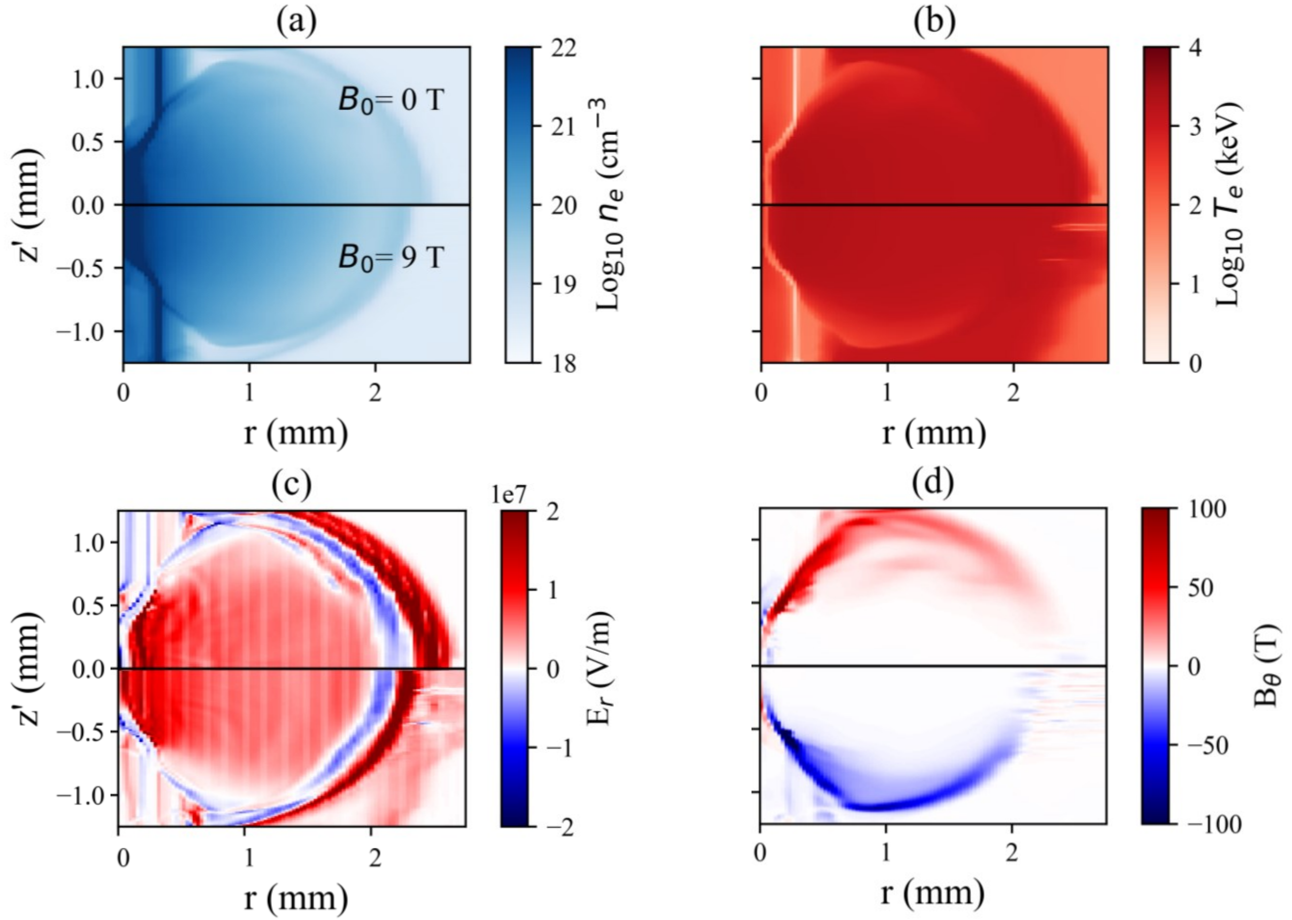
Proton radiography provides a measurement of the line-integrated E&B fields

$$\alpha_x = \frac{e}{2W}\int E_x \cdot dy + \frac{e}{\sqrt{2m_p W}}\int B_z \cdot dy$$

$$\alpha_z = \frac{e}{2W}\int E_z \cdot dy - \frac{e}{\sqrt{2m_p W}}\int B_x \cdot dy$$

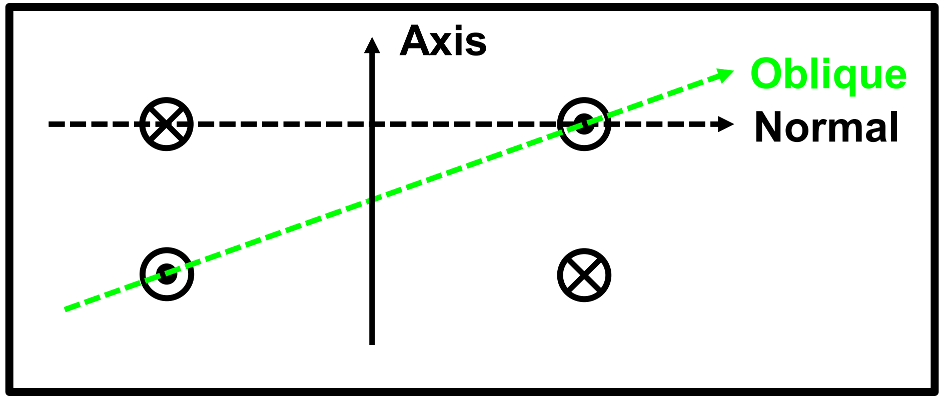
* Davies et al. 2017 PoP

MHD simulations show azimuthal magnetic fields are self-generated in the coronal plasma

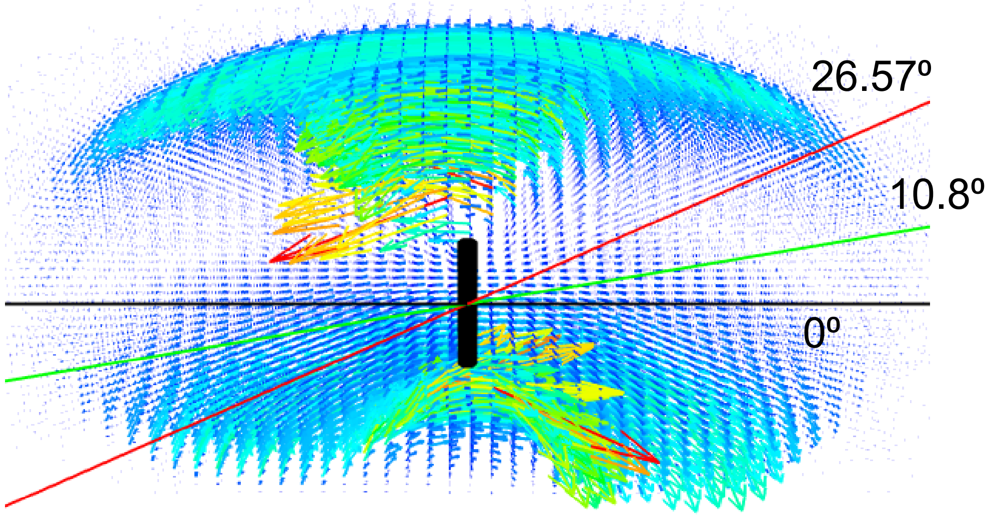


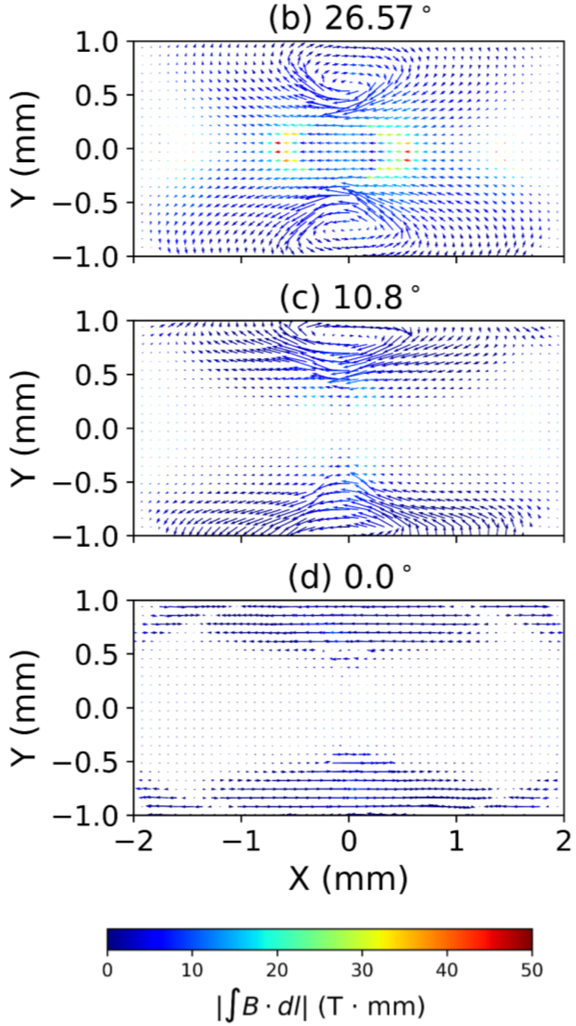
The dominant self-generated magnetic field is azimuthal.

Oblique proton radiography allows the measurement of azimuthal magnetic fields (which cancel out at normal incidence)

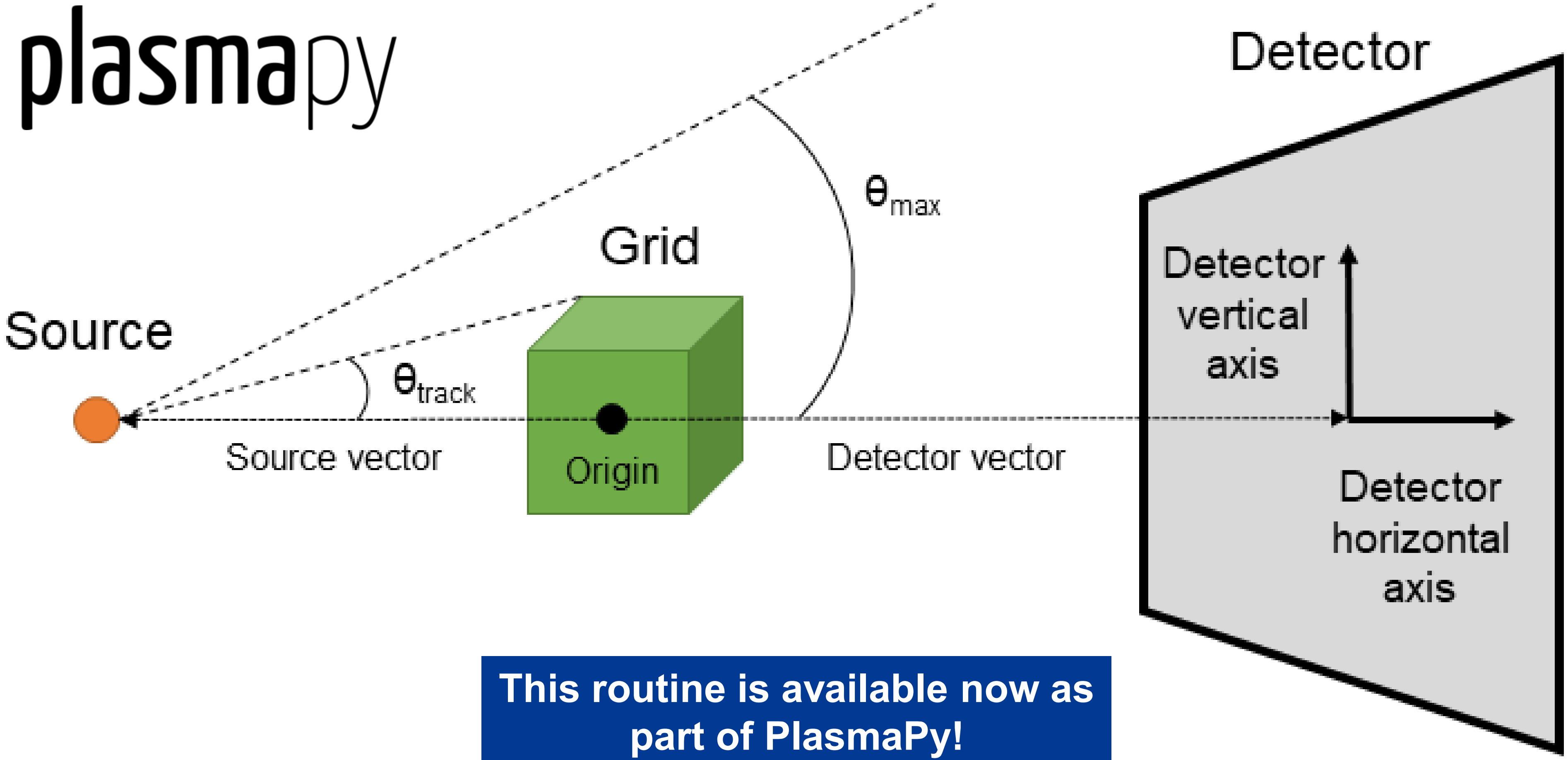


(a)





An open-source particle tracing charged particle radiography code was developed for PlasmaPy to create synthetic radiographs from these simulations

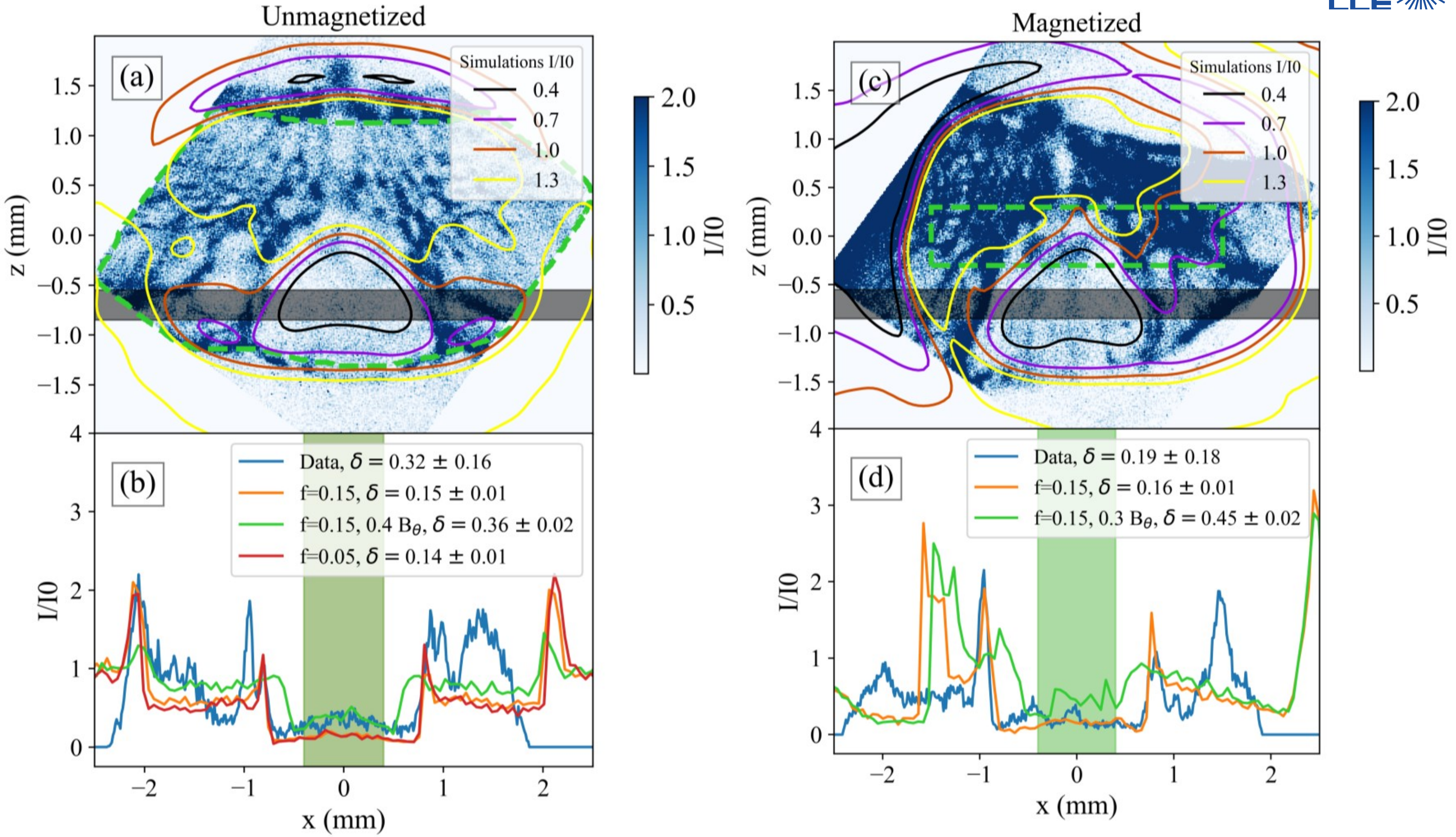


This routine is available now as part of PlasmaPy!

The synthetic radiographs reproduce key features of the experimental radiographs

The unmagnetized radiograph may require a reduced B-field to fit the depth of the cavity.

$$\frac{I}{I_0} \propto \frac{1}{1 + \frac{\partial}{\partial x}\int \vec{B} \times \vec{\mathrm{d}y}},$$



Experimental I_0 has considerable uncertainty in both radiographs.

Summary

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