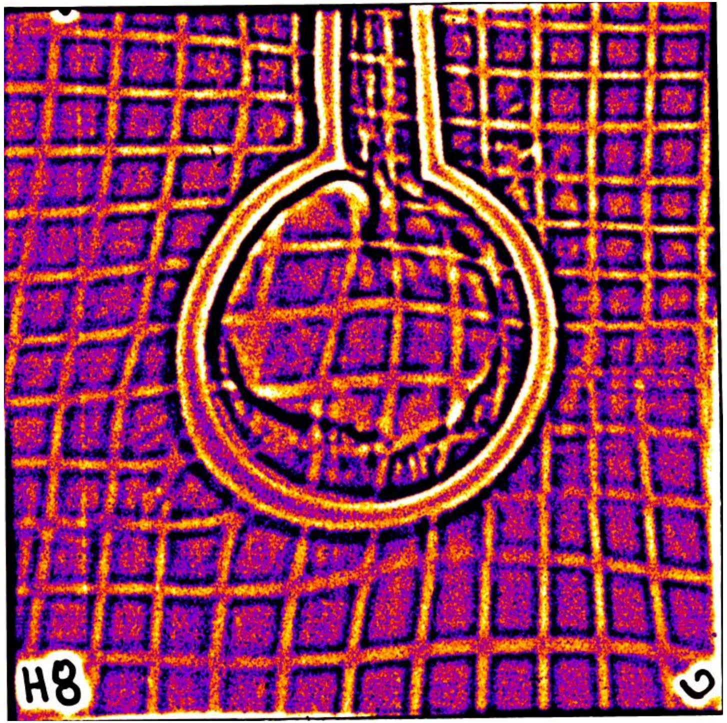
Characterizing Magnetic and Electric Fields from Laser-Driven Coils Using Axial Proton Probing



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Summary

Laser-driven coils can deliver a highly localized magnetic field without using conventional pulsed-power devices

- **Axial proton probing clearly distinguishes magnetic and electric fields**
- **Experiments on OMEGA EP demonstrate the generation of a 60-T field at the center of the coil loop**
- **Axial radiographs can only be reproduced with a combination of electric and magnetic fields**

Collaborators

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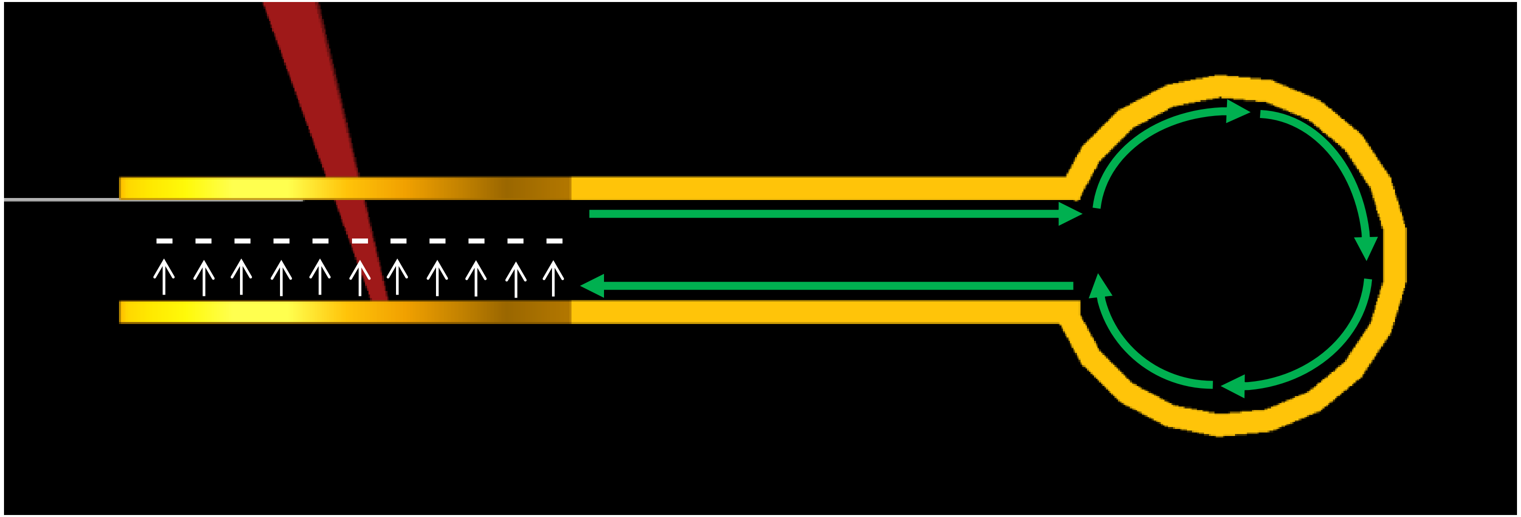
Laser-driven coils rely on a laser to eject electrons from a target, causing a current to be drawn from any connected source

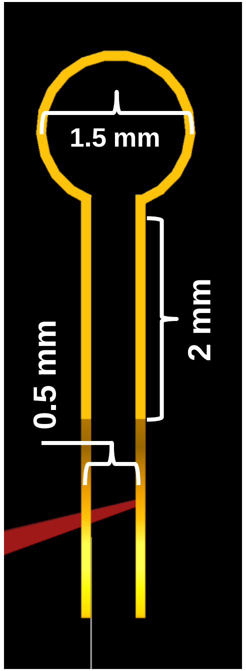


Transverse proton probing of laser-driven coils leaves a lot of room for interpretation

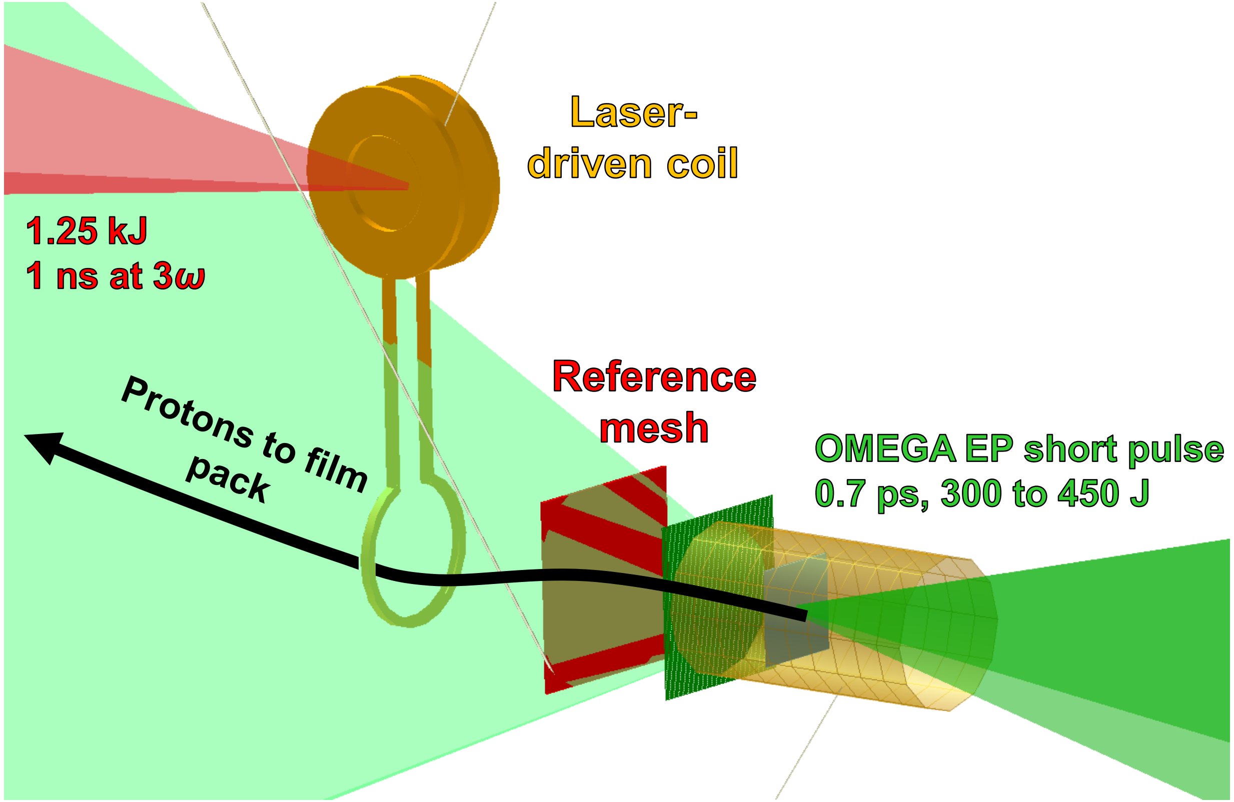
- The primary, axial magnetic field is probed with a transverse proton beam, but so is the radial electric field
- In previous proton-probing experiments the protons were completely expelled from a region around the coils
- The radial component of the magnetic field is also significant and causes rotation of a mesh fiducial, distinguishing it from the radial electric field

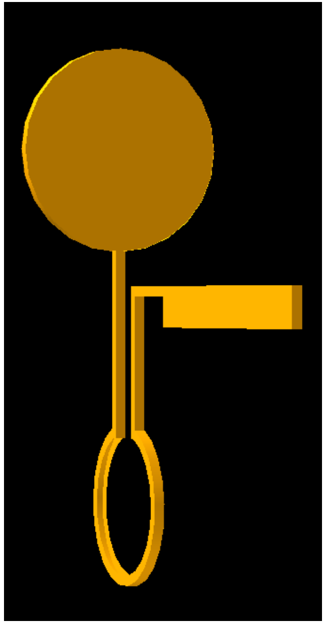
Axial proton probing separates magnetic and electric fields and provides information on plasma conditions inside the coil.

Experimental setup for axial proton probing of double- and single-plate, laser-driven coils on OMEGA EP



Double plate

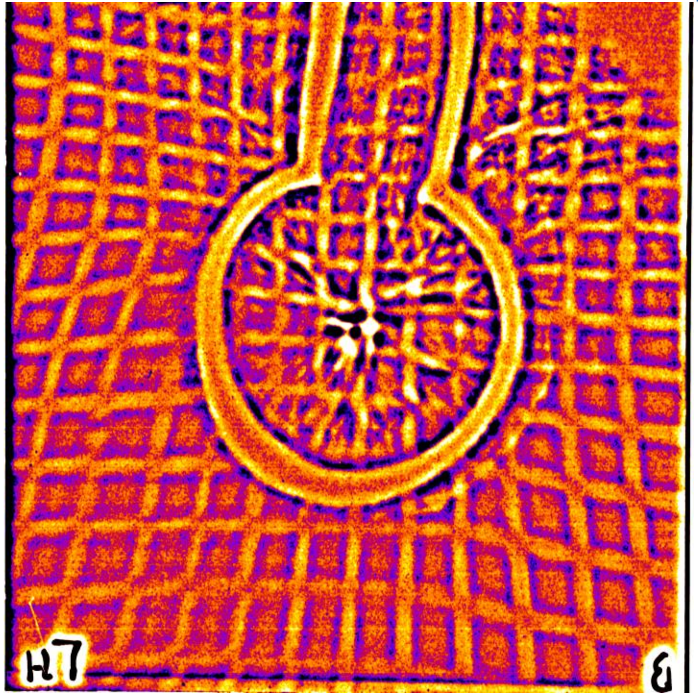




Single plate

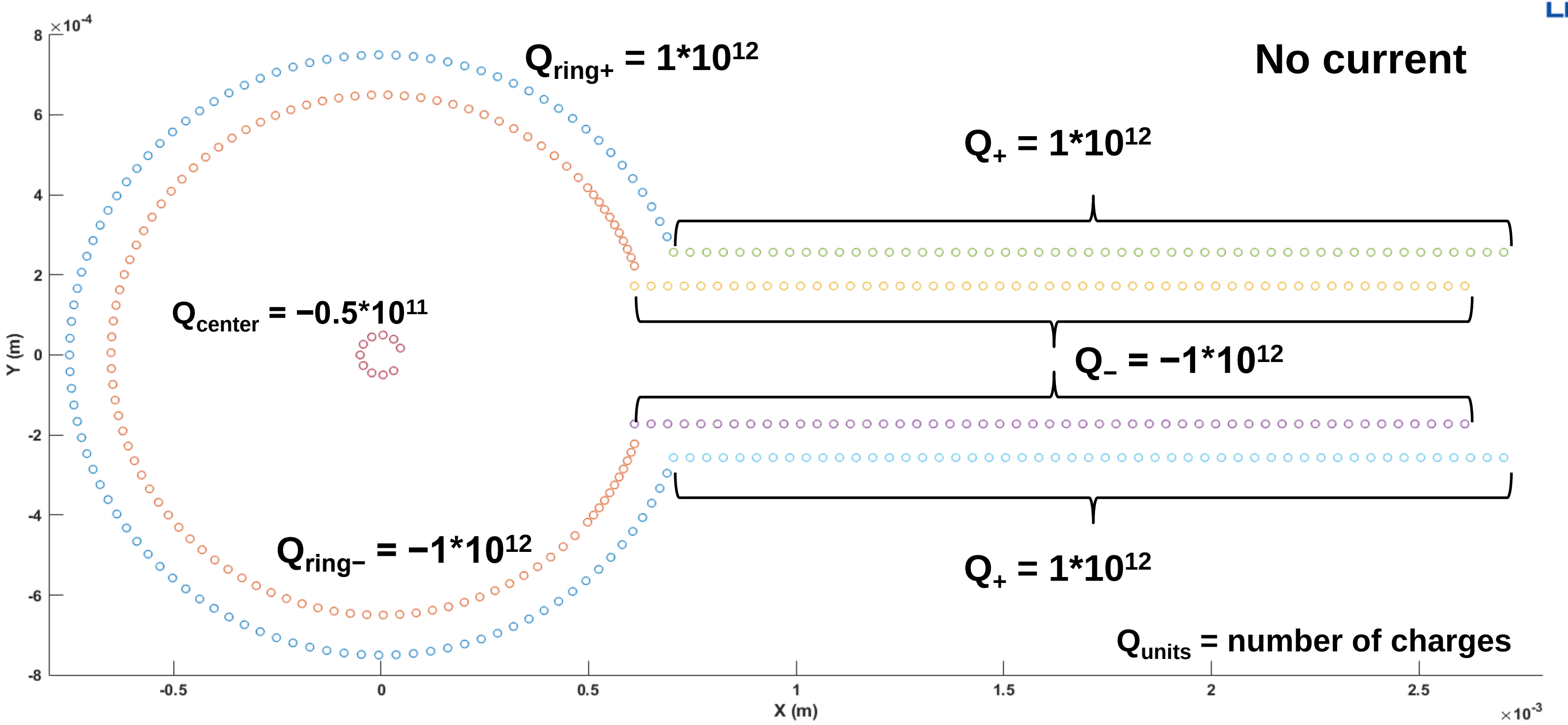
Double-plate shots showed no evidence of a magnetic field at 1 ns

- Charge buildup is clearly seen at the center of the coil
- Deflection is not consistent with a magnetic field
- Plasma appears to have filled the gap between the plates or wires causing a "short circuit"



20-MeV proton probe corresponding to 1.1 ns after the start of the long pulse

Proton tracing with specified current and charge distributions was used to analyze the results

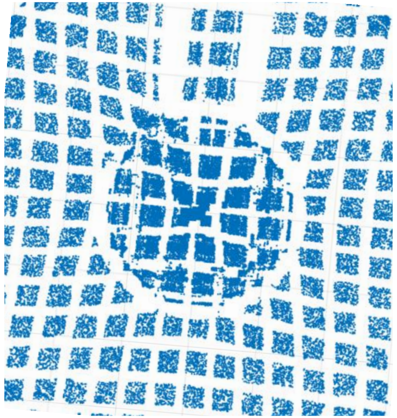


Radiographs in the double-plate case can be duplicated with only charge.

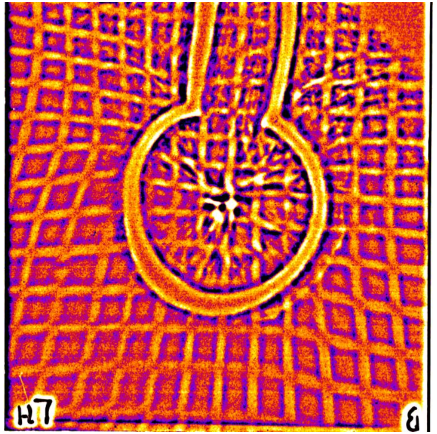
Comparing synthetic and experimental radiographs at two proton energies help separate B and E component contributions

20-MeV protons

Simulated

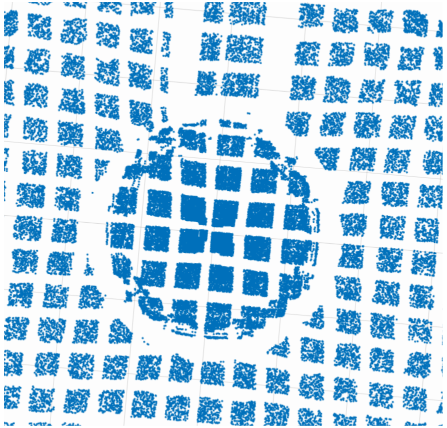


Measurement

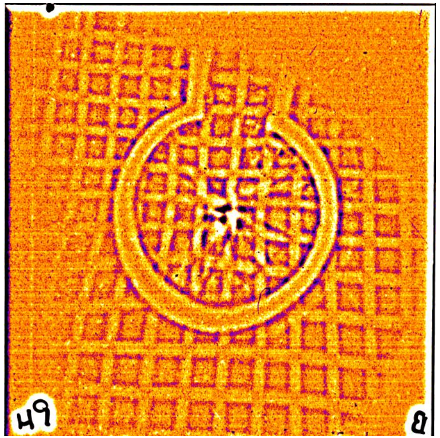


40-MeV protons

Simulated



Measurement



Comparing synthetic and experimental radiographs at two proton energies help separate B and E component contributions

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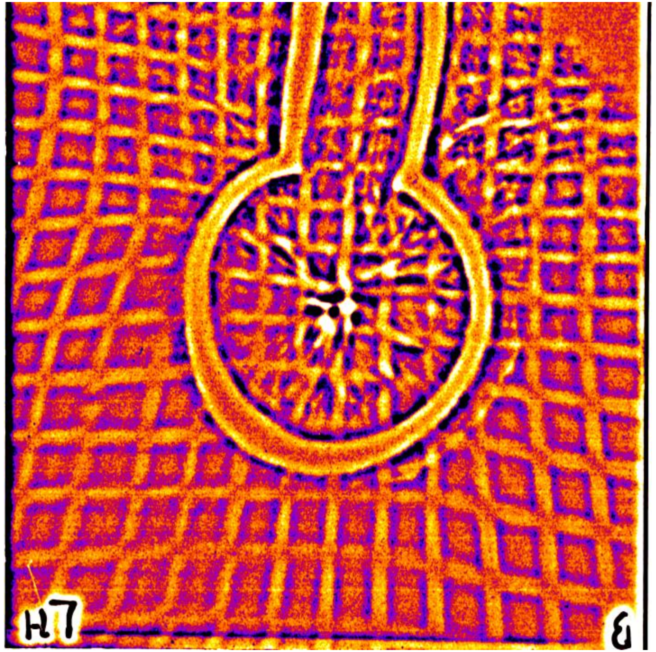
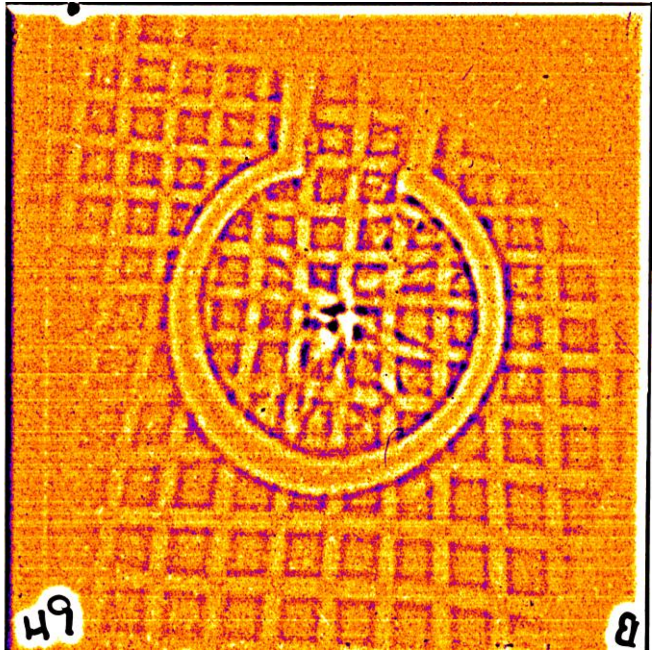
Simulated protons overlaid with measurement

20-MeV protons



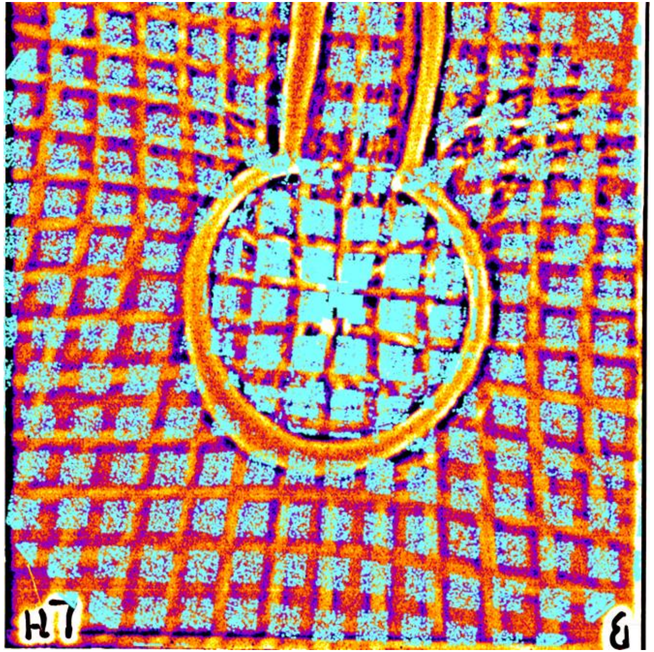
40-MeV protons



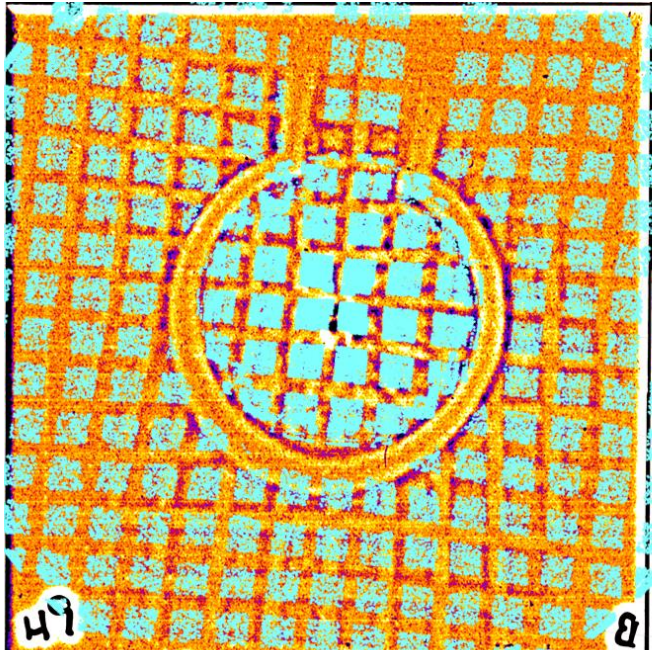
Comparing synthetic and experimental radiographs at two proton energies help separate B and E component contributions

Simulated protons overlaid with measurement

20-MeV protons



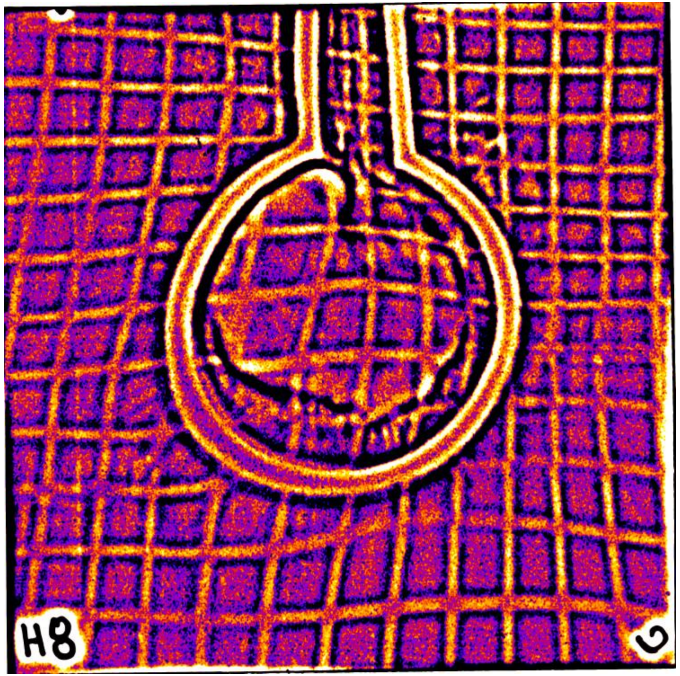
40-MeV protons



Single-plate results indicate an axial magnetic field of ~60 T

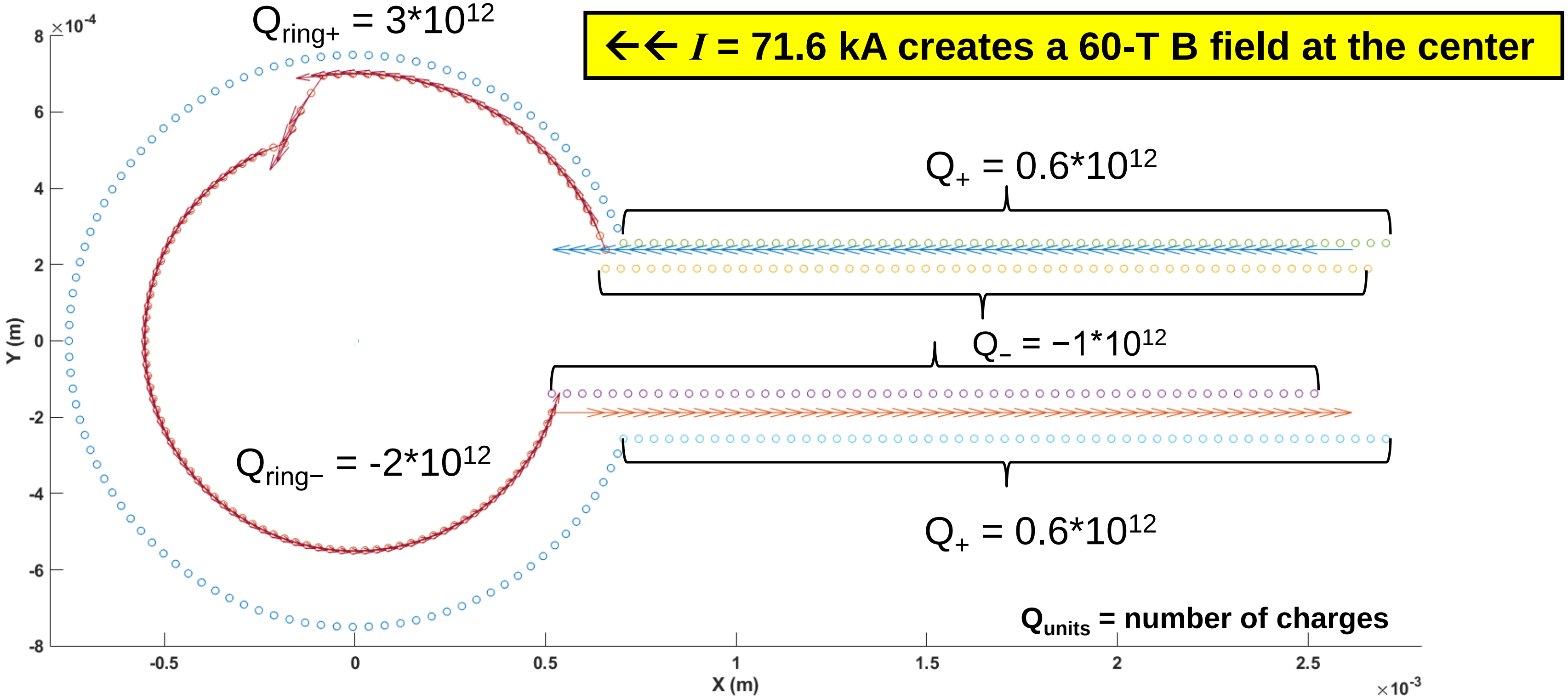
- Distinctly different features are seen with single-plate shots; mesh stretching and twisting instead of focusing

- Mesh twisting near the parallel wires is most likely caused by magnetic fields



20-MeV proton probe corresponding to 1.1 ns after the start of the long pulse

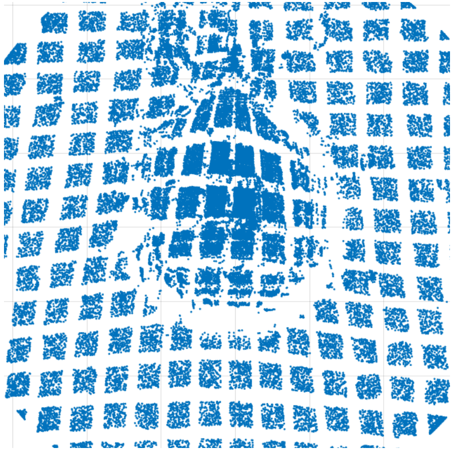
The features can only be duplicated with both current and charge with the current localized at the edge of an electron sheath



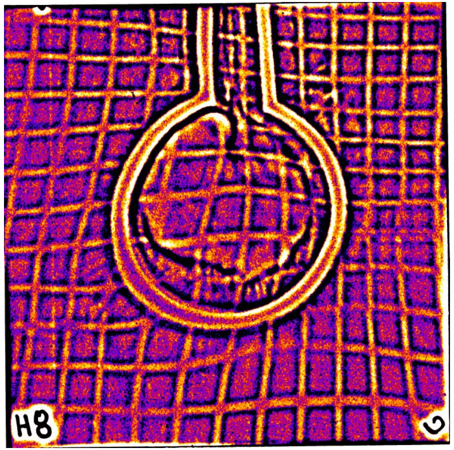
A combination of E and B fields reproduces both 20- and 40-MeV films with only minor discrepancies

20-MeV protons

Simulated



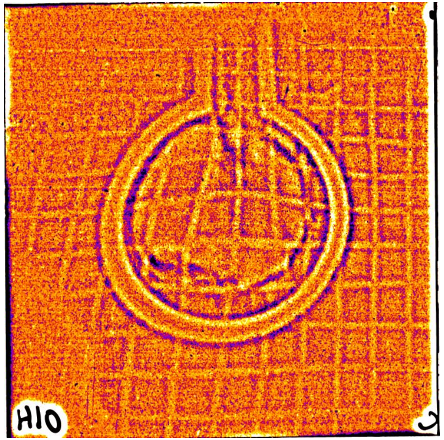
Measurement



40-MeV protons

Simulated

Measurement



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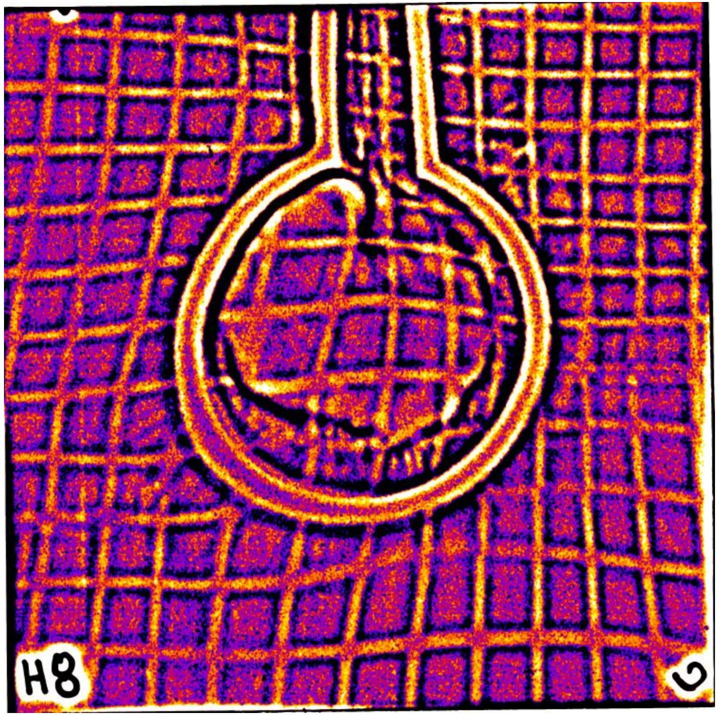
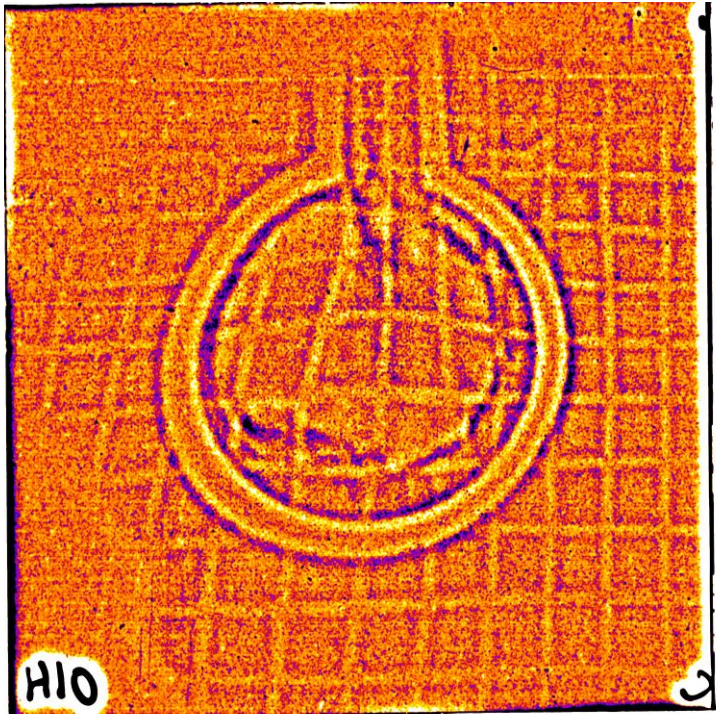
20-MeV protons



40-MeV protons



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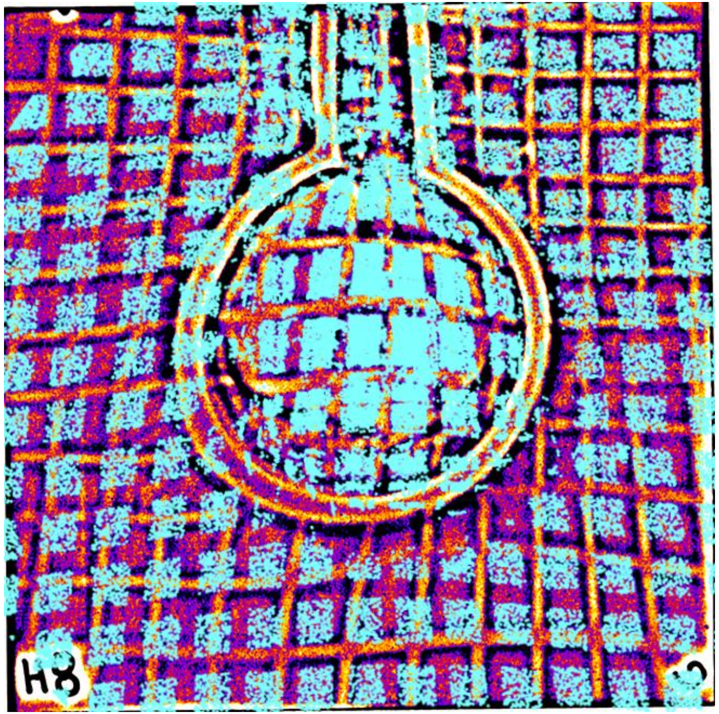
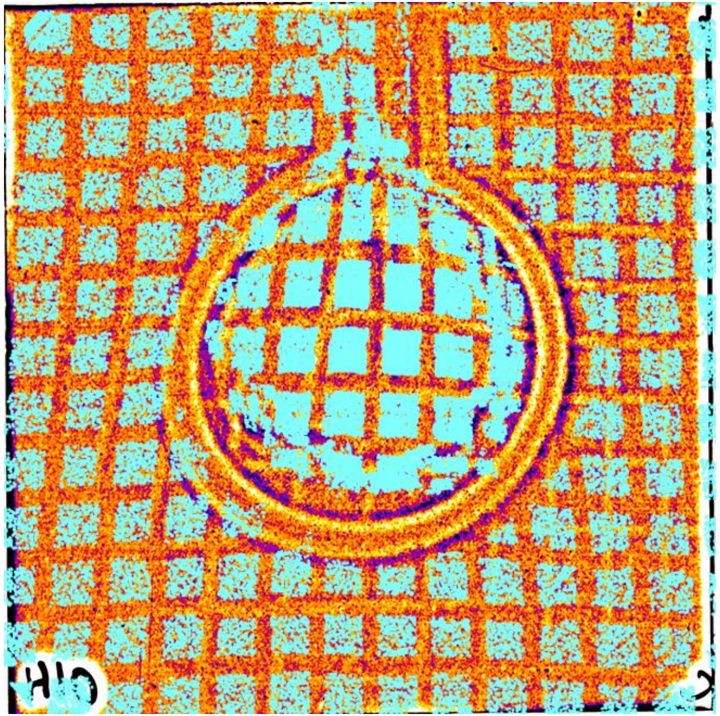


40-MeV protons



Laser-driven coils can deliver a highly localized magnetic field without using conventional pulsed-power devices

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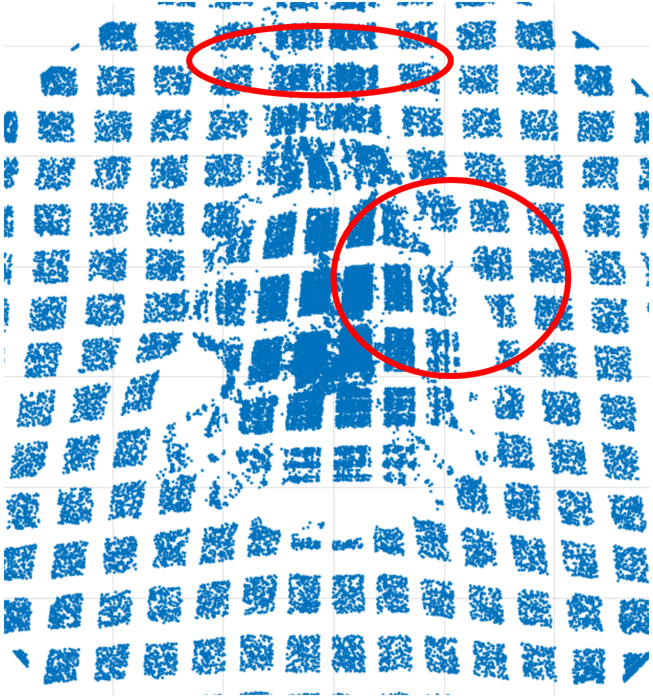
- **Experiments on OMEGA EP demonstrate the generation of a 60-T field at the center of the coil loop**
- **Axial radiographs can only be reproduced with a combination of electric and magnetic fields**

Future experiments will work toward developing ways to model laser-driven coils and quantify mesh displacement.

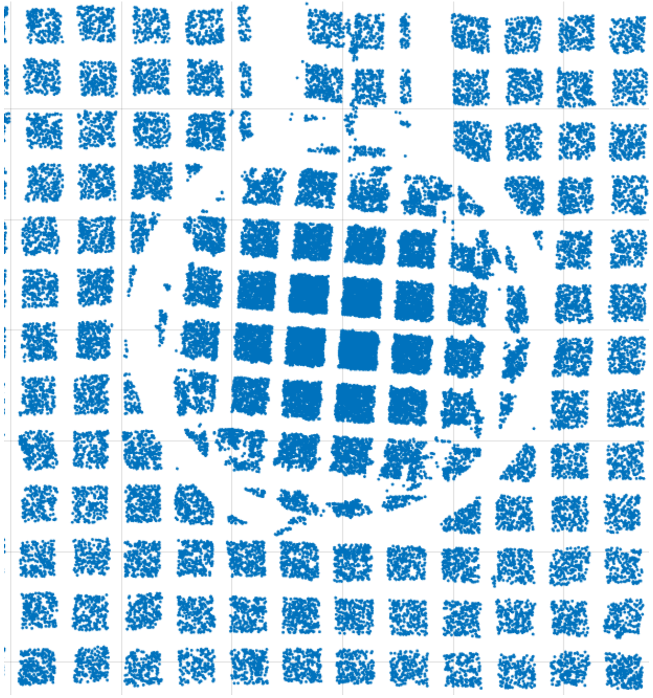
Extra

Axial radiographs can only be reproduced with a combination of electric and magnetic fields

No Current

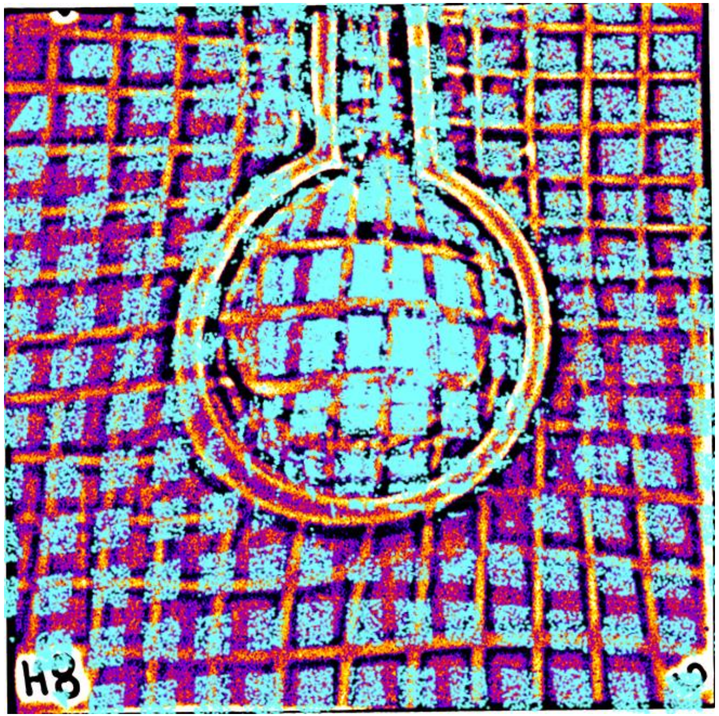


No Charge

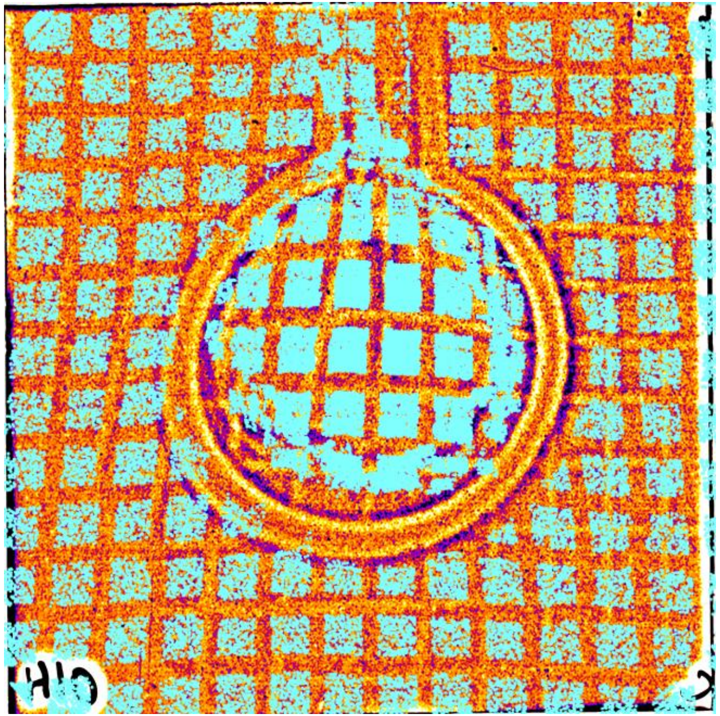


A combination of E and B fields reproduces both the 20 and 40 MeV films with only minor discrepancies

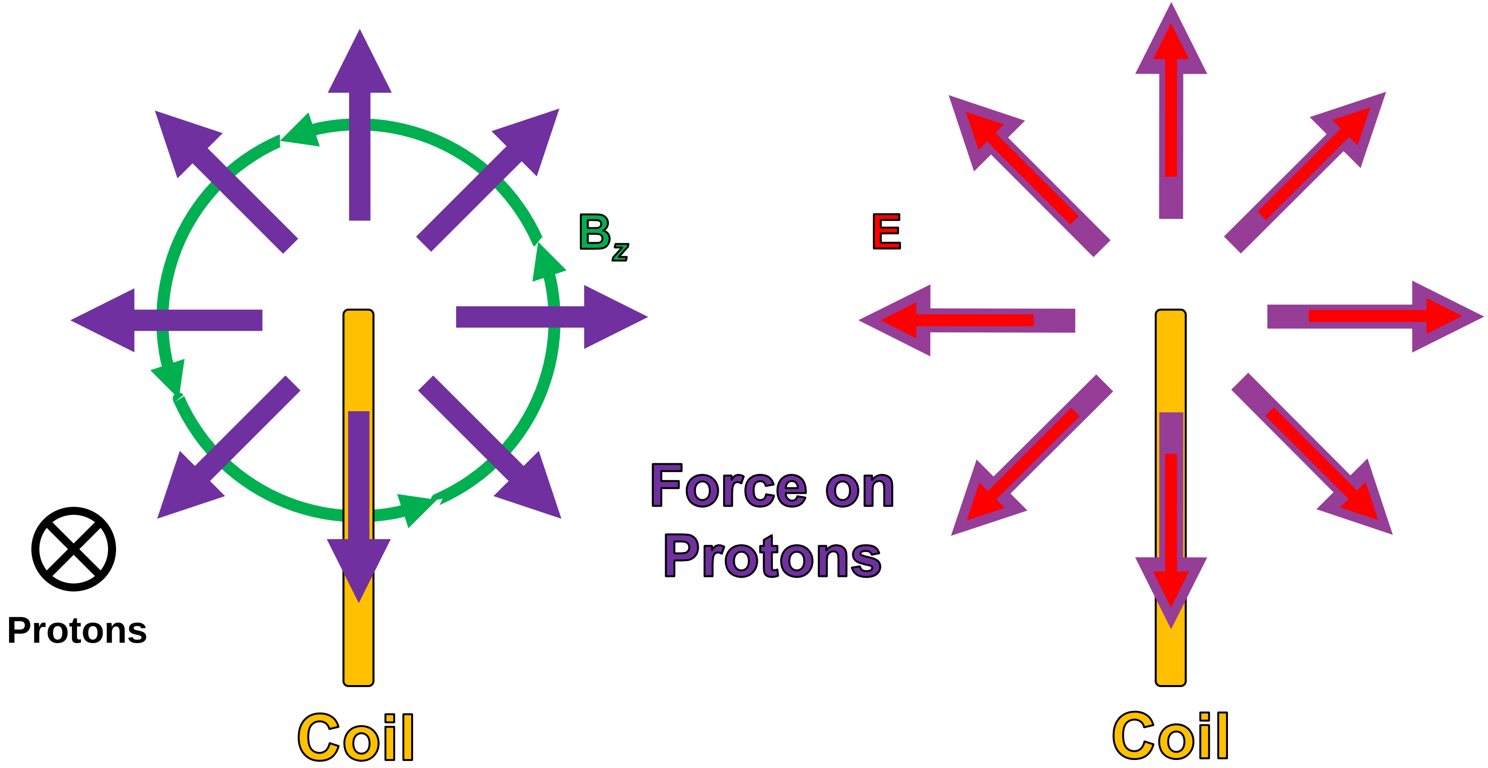
20 MeV Protons



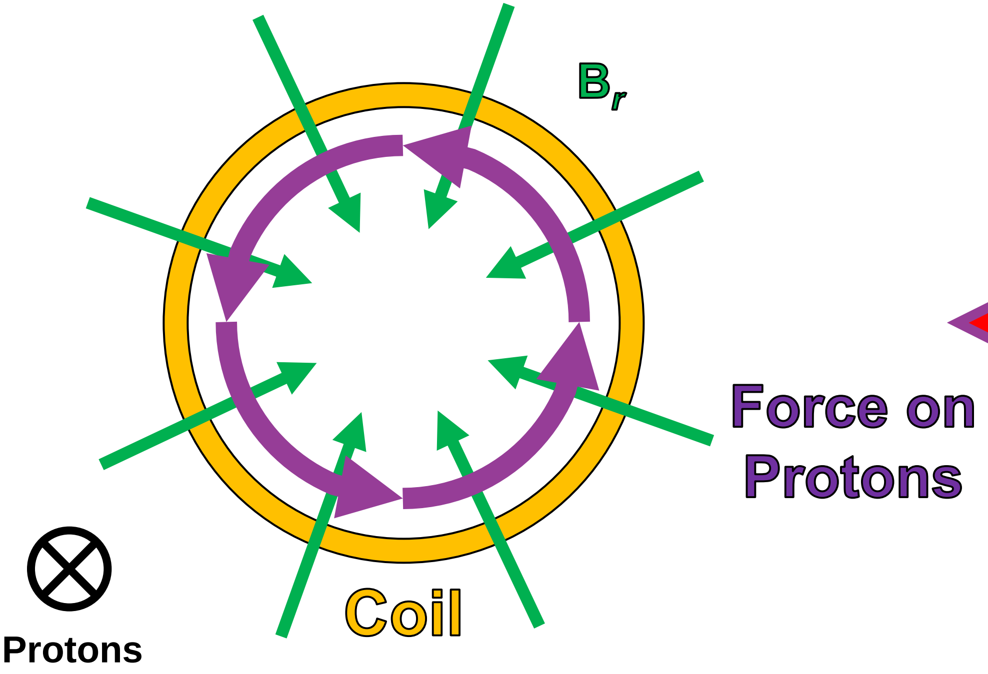
40 MeV Protons

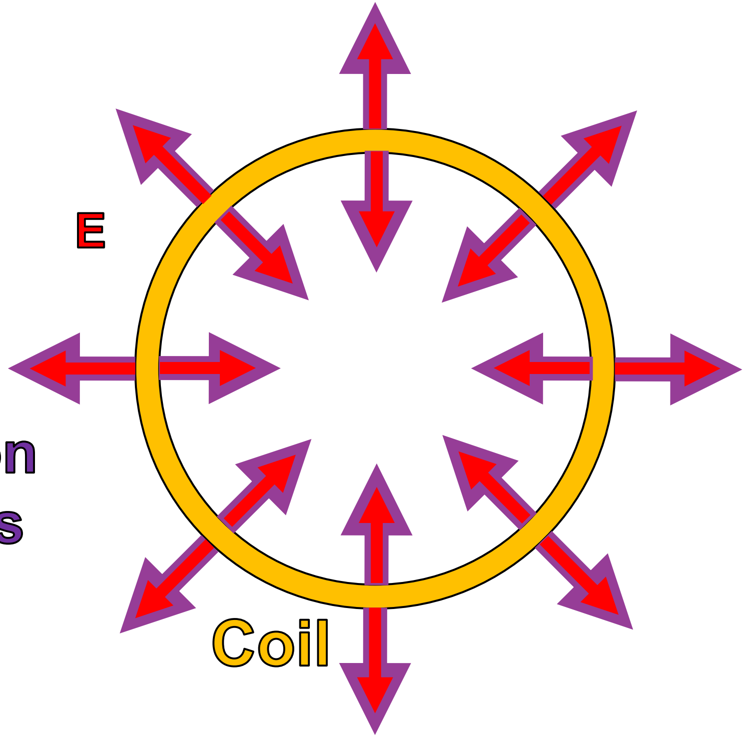


Transverse proton probing has difficulties distinguishing a magnetic field from electric field

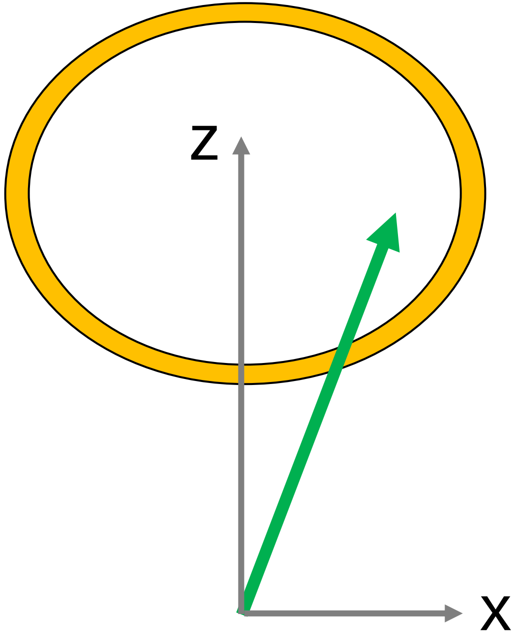


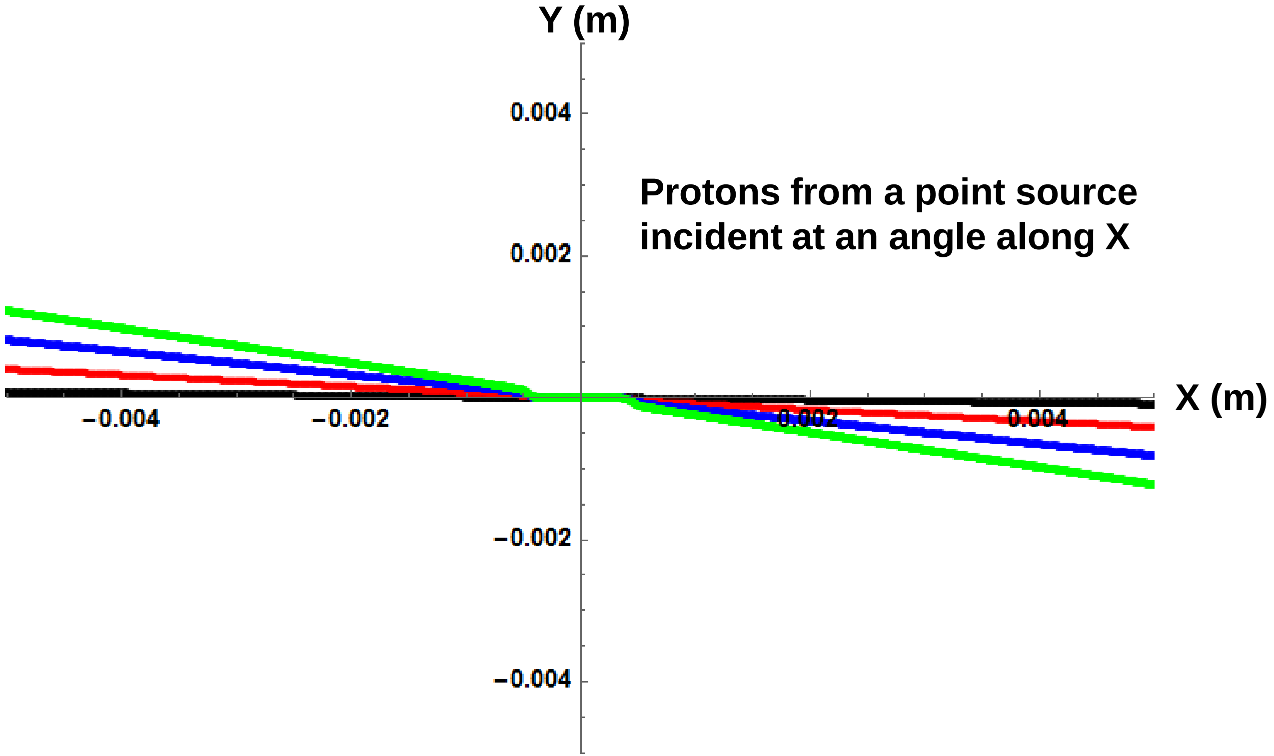
The radial component of a magnetic field rotates axial probing protons; electric field focuses/defocuses protons





Protons initial incidence angle and first deflection breaks symmetry of radial magnetic field





Protons from a point source incident at an angle along X