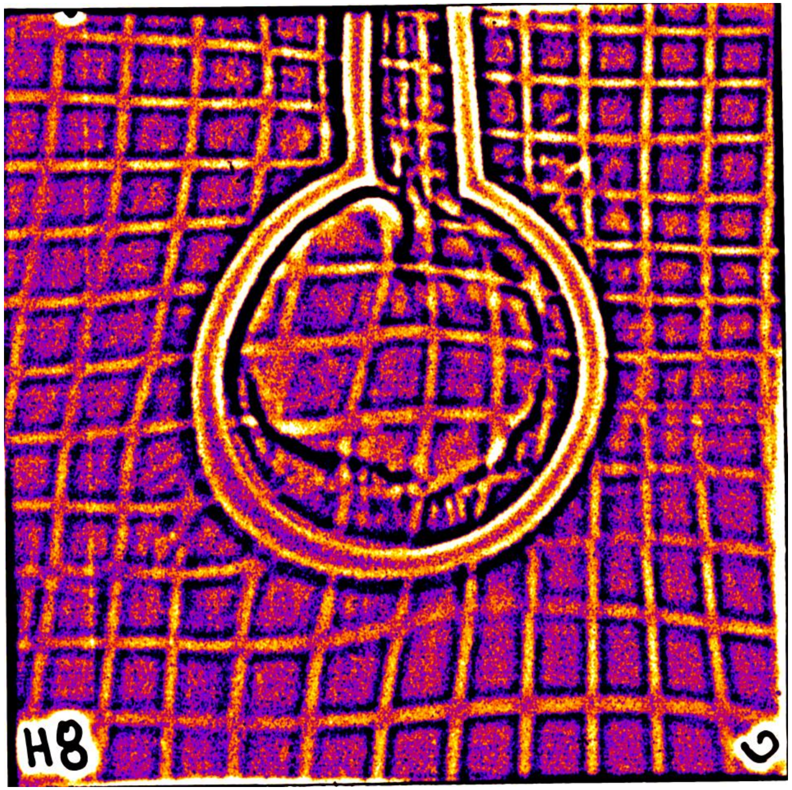
Laser Driven Coils on OMEGA-EP



Jonathan Peebles

April 24th 2018

Meeting on Magnetic Fields in Laser Plasmas

Collaborators

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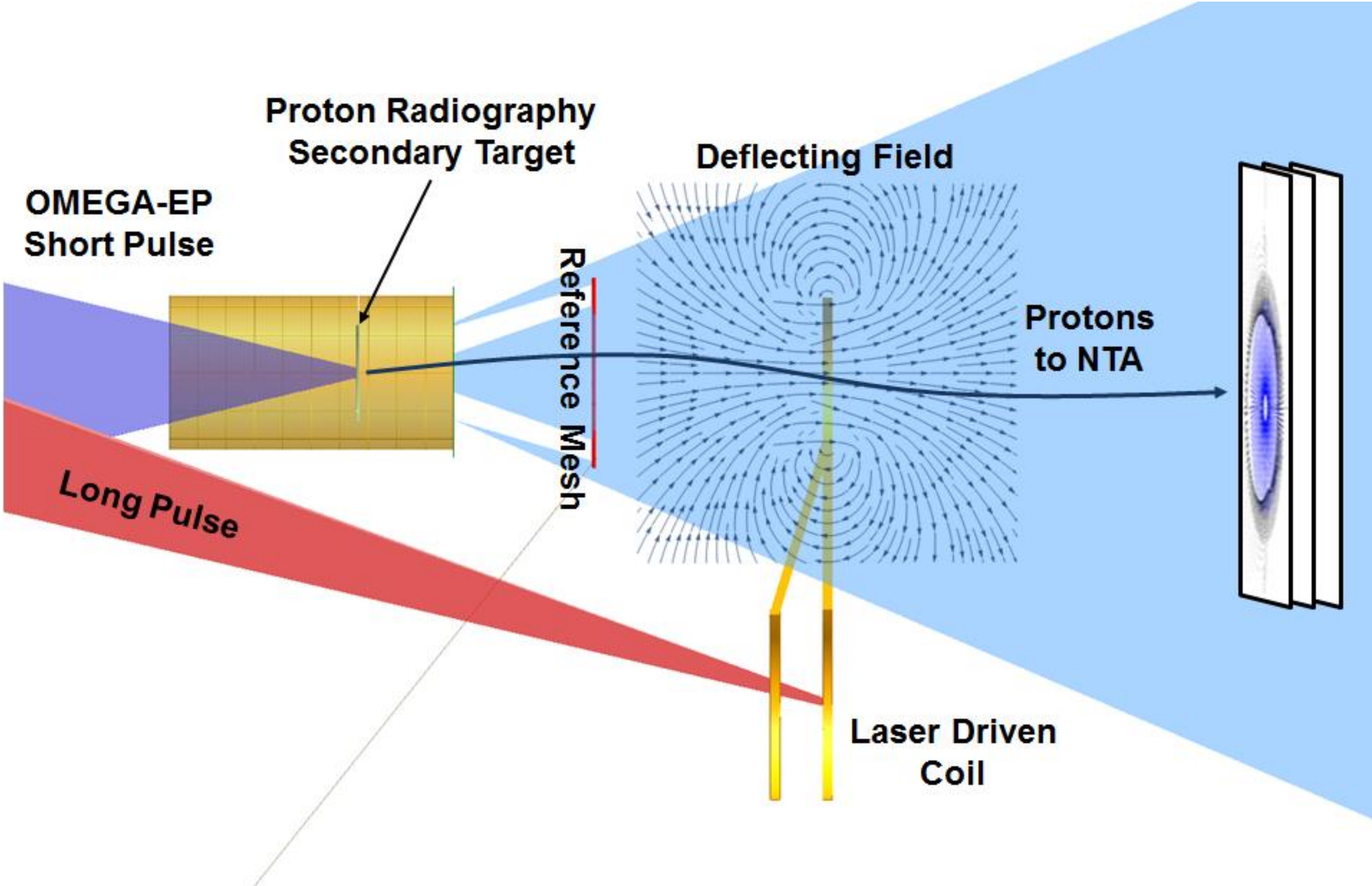
Axial proton probing distinguishes magnetic field from electric field

- **Axial proton probing has never been used to diagnose laser driven coil fields and interactions**
  - **The primary field along the axis for these coils has the greatest impact on protons traveling perpendicular to the axis of the coil**
- **The radial component of the magnetic field is still significant and can cause a rotation effect on the mesh fiducial**
  - **This effect cannot be duplicated by the deflection effects of a strong electric field**

Probing down the axis of the coil separates magnetic and electric field contributions while also providing information of plasma conditions inside the coil

Setup for axial radiography of laser driven coil



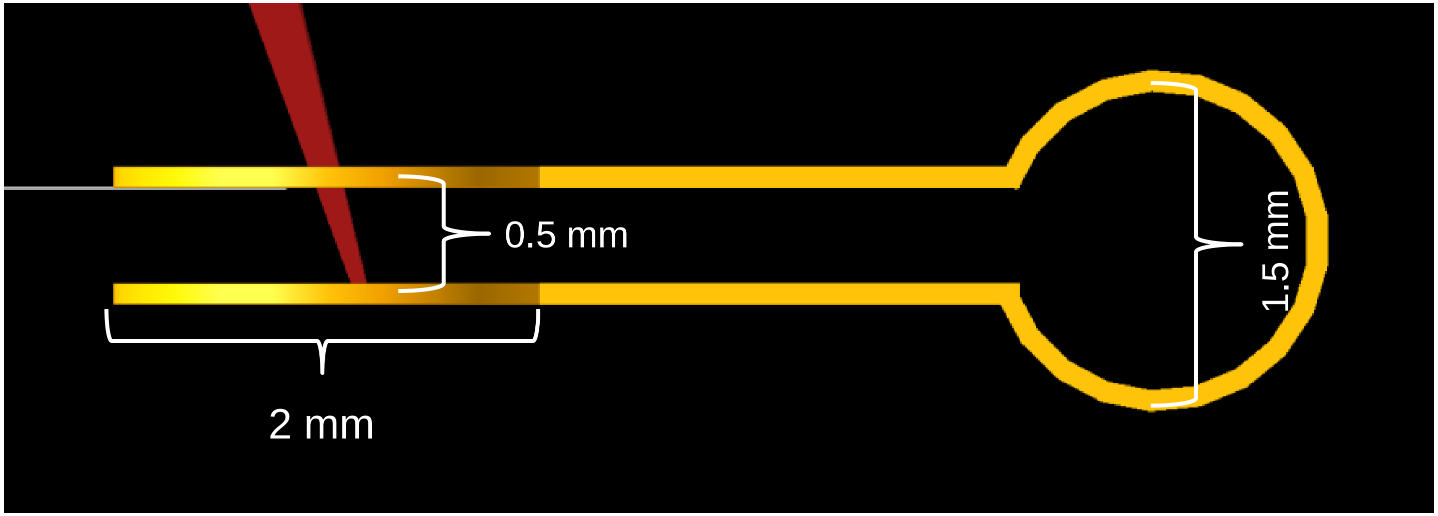
Experiment Parameters

Targets:
750 μm radius Cu foil loop attached via 2 mm wires to 2 mm OD disks

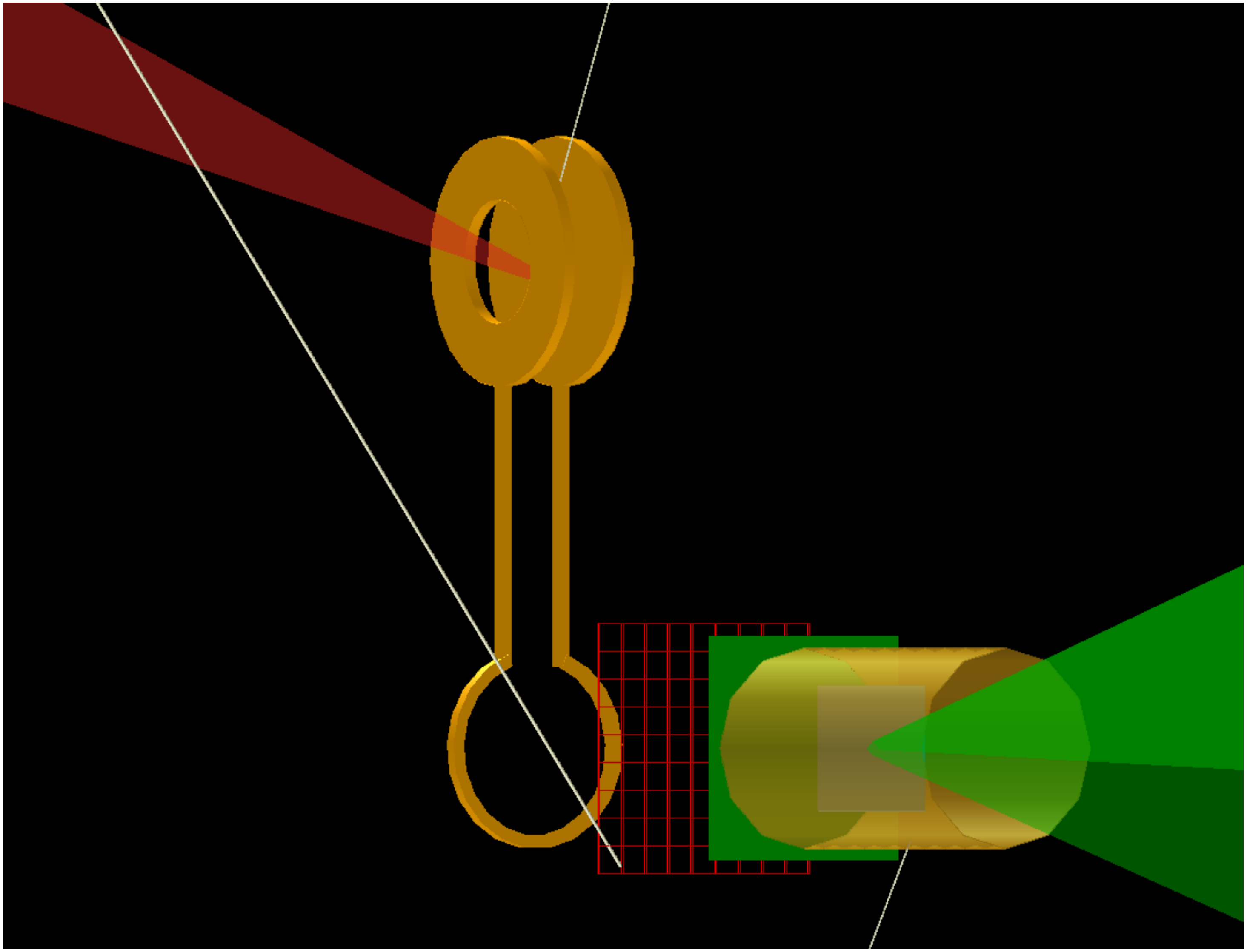
Plates attached in 4 configurations:
- **<u>Standard</u>**
- Reversed current (wires switched)
- Stalk attached to driven disk
- **<u>Single Plate</u>**

Laser:
LDC Driver: EP Long Pulse
1250 J of 3ω light for 1 ns

Proton Probe: EP Short Pulse
Best energy (300-500J),
Best Compression (0.7 ps)

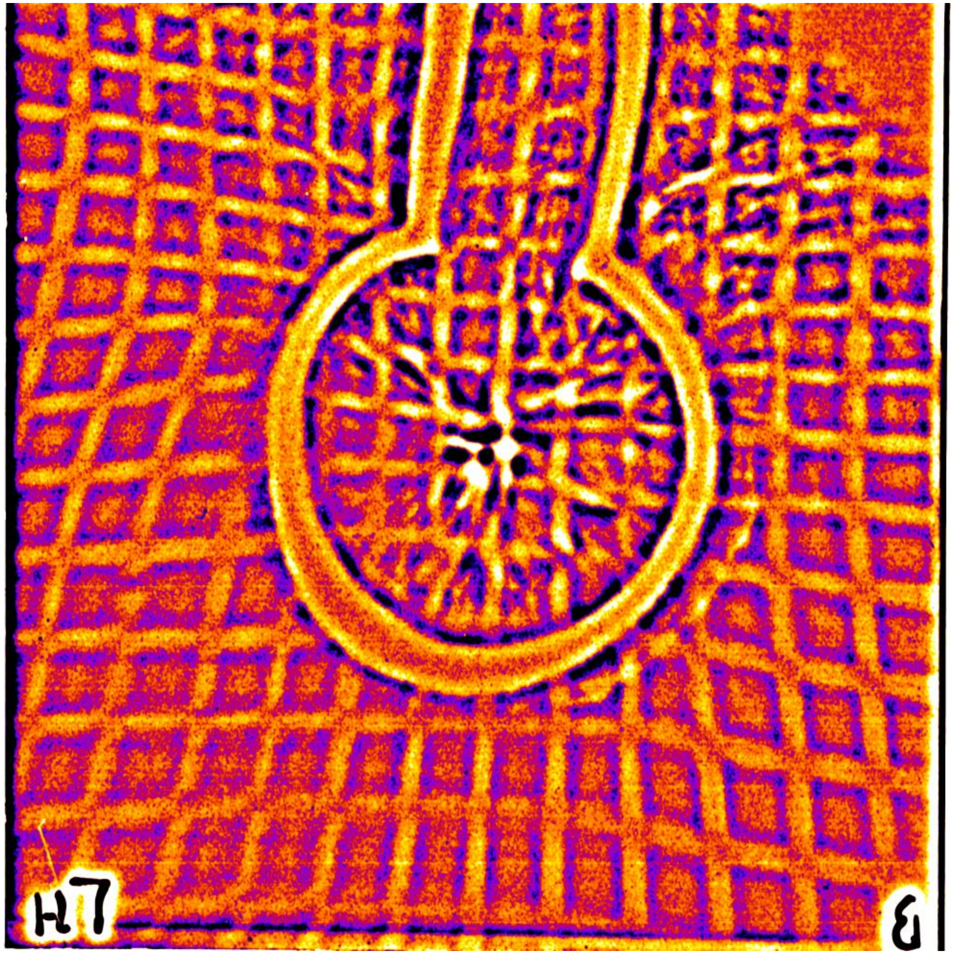


Double plate experimental configuration



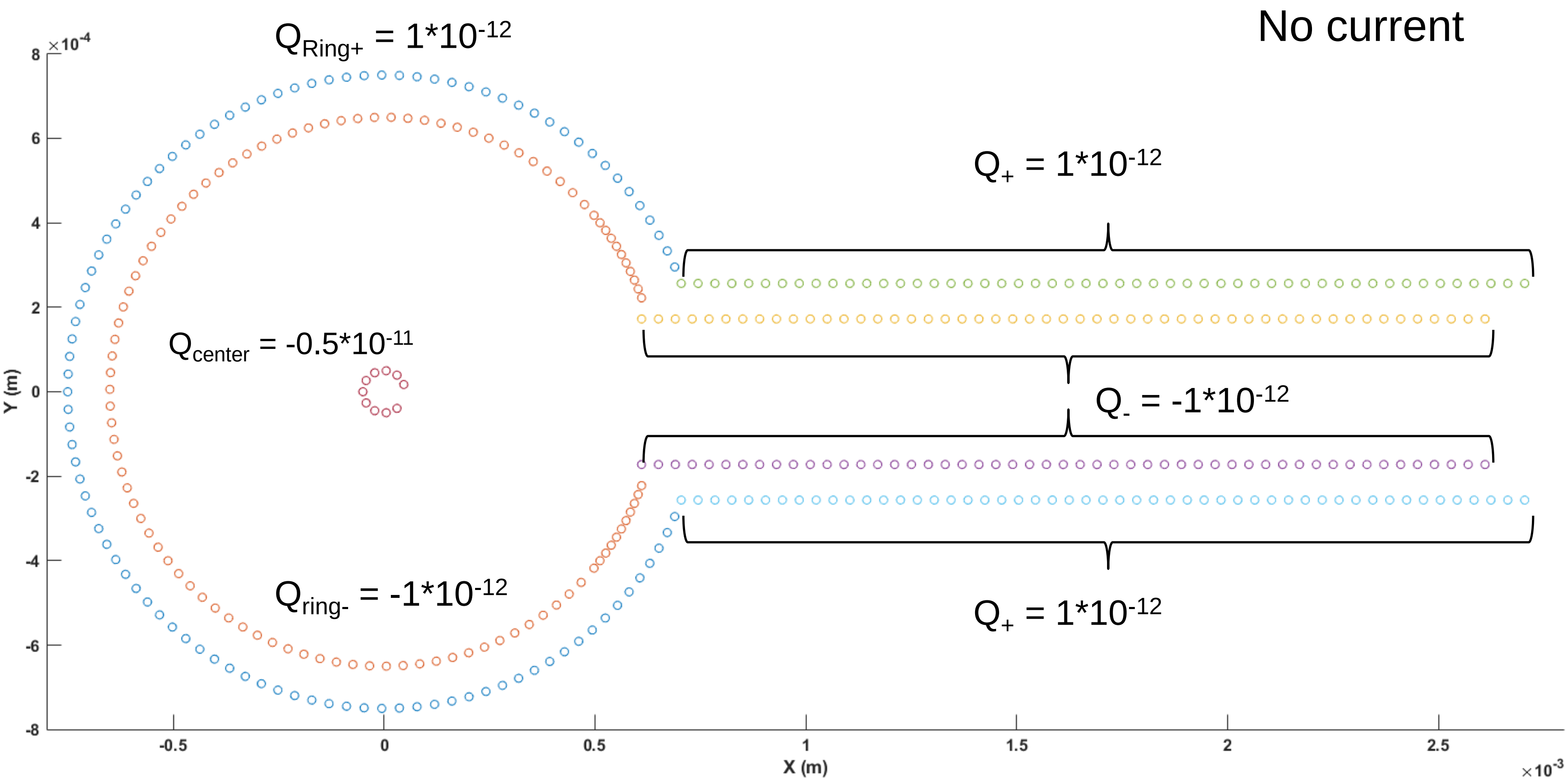
Double plate shots consistently yielded little B field

- **Proton ray tracing explicitly solves for E and B fields on a mesh given a current and charge distribution**
- **RCF images and features in the double plate case can be duplicated with only <u>charge</u> distributions**
- **Charge and low density plasma is clearly seen at the center of the coil**
- **Likely that plasma filled the gap between the plates or wires causing a "short circuit"**



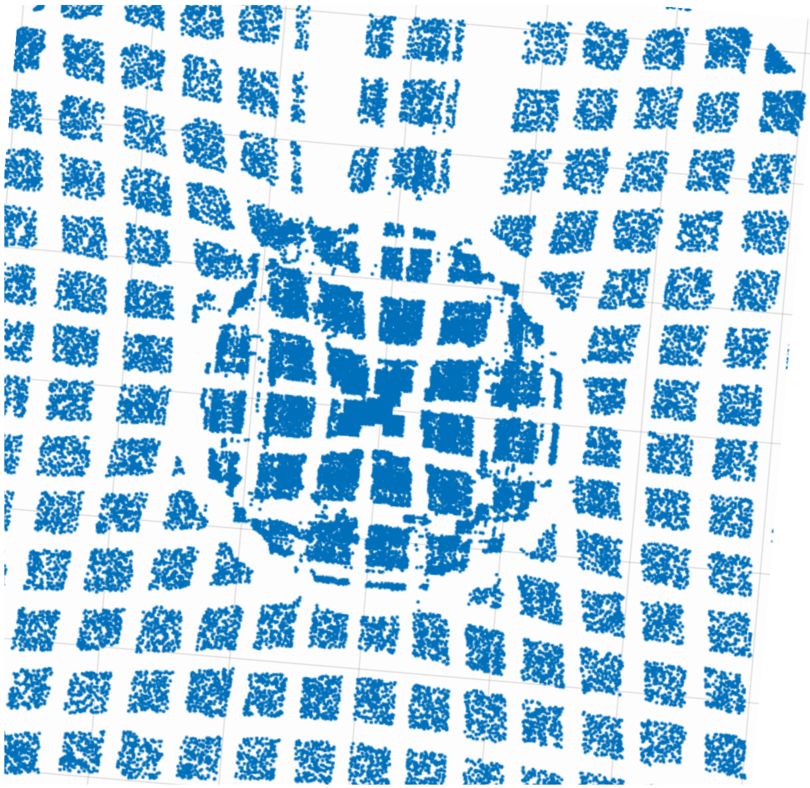
20 MeV proton probe corresponding to 1.1 ns after the start of the long pulse

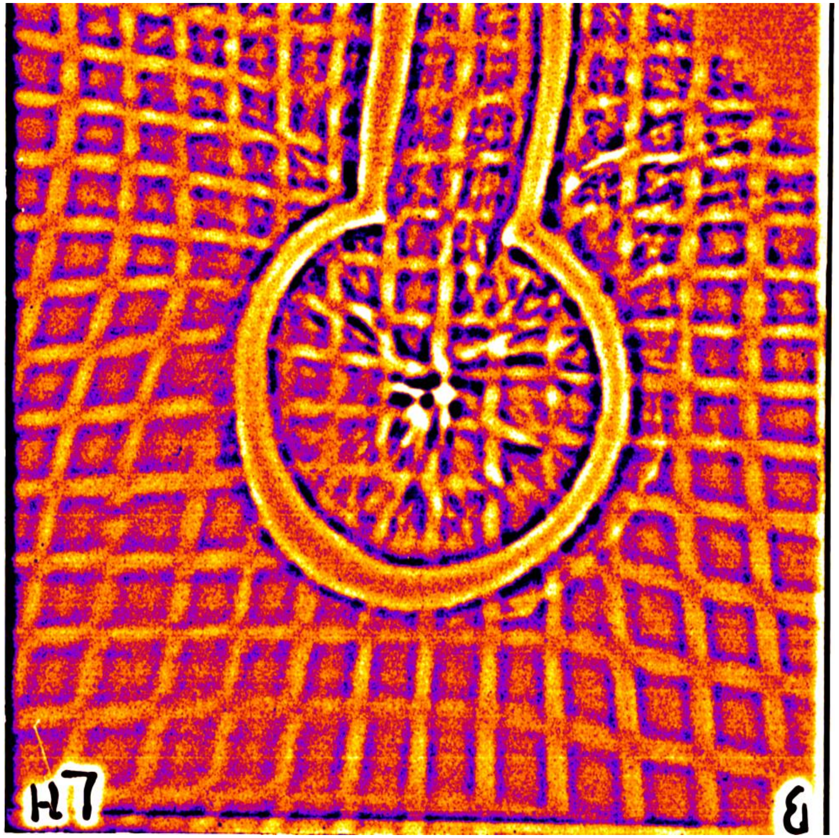
Charge/Current distribution for proton ray tracing



Synthetic vs Experimental Radiographs

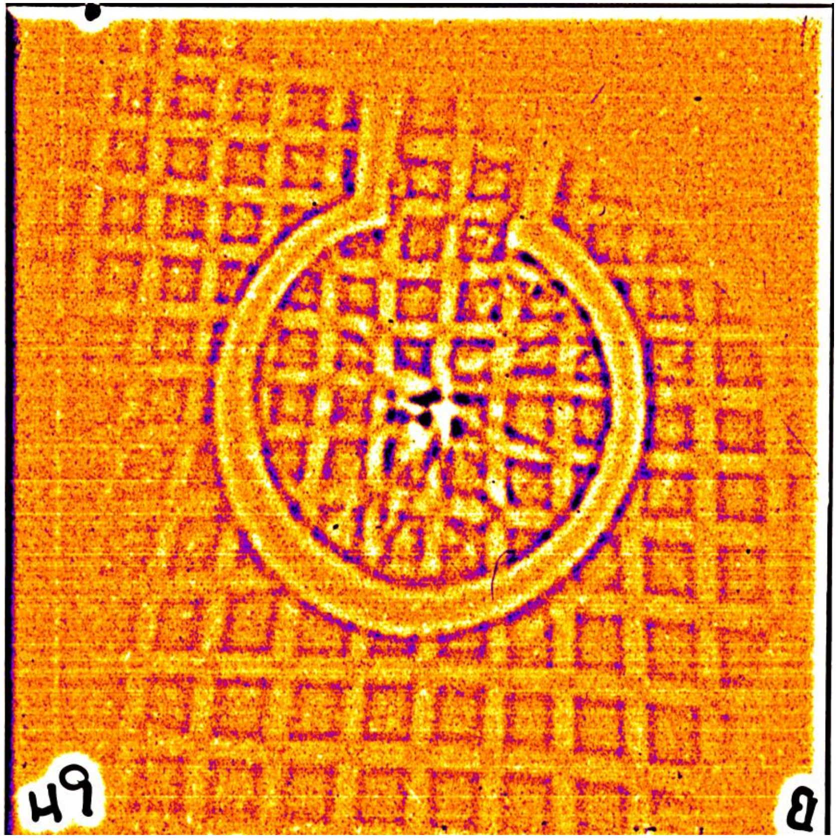
20 MeV Protons





Synthetic vs Experimental Radiographs

40 MeV Protons



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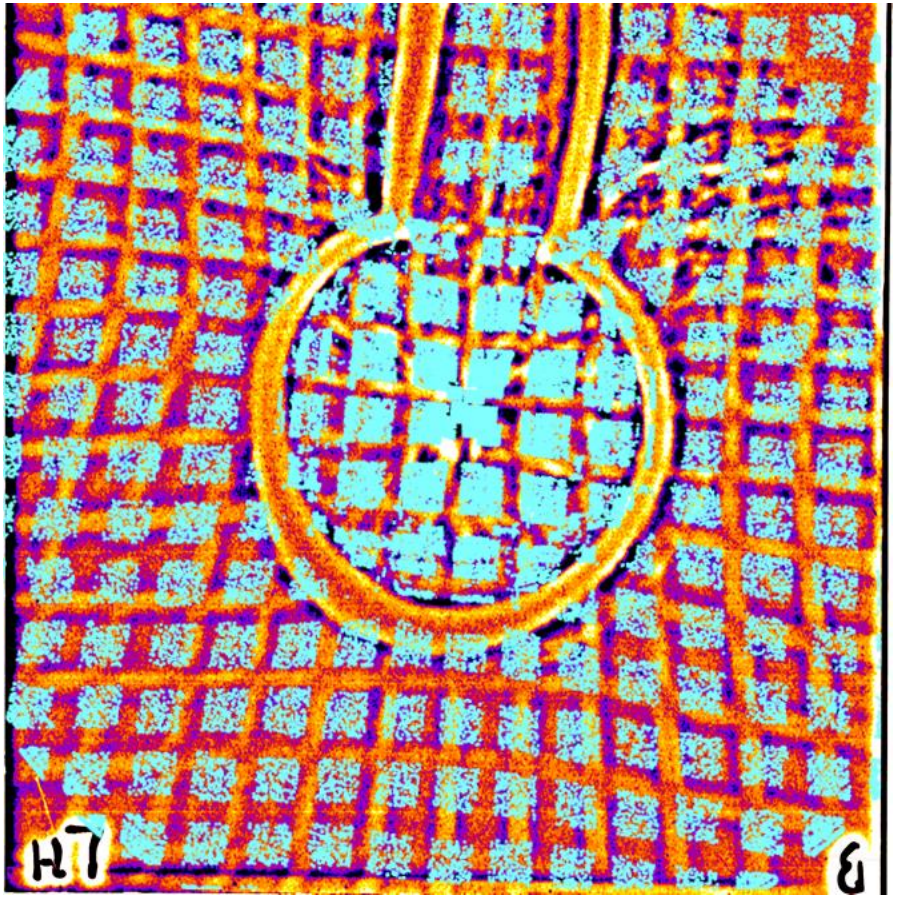
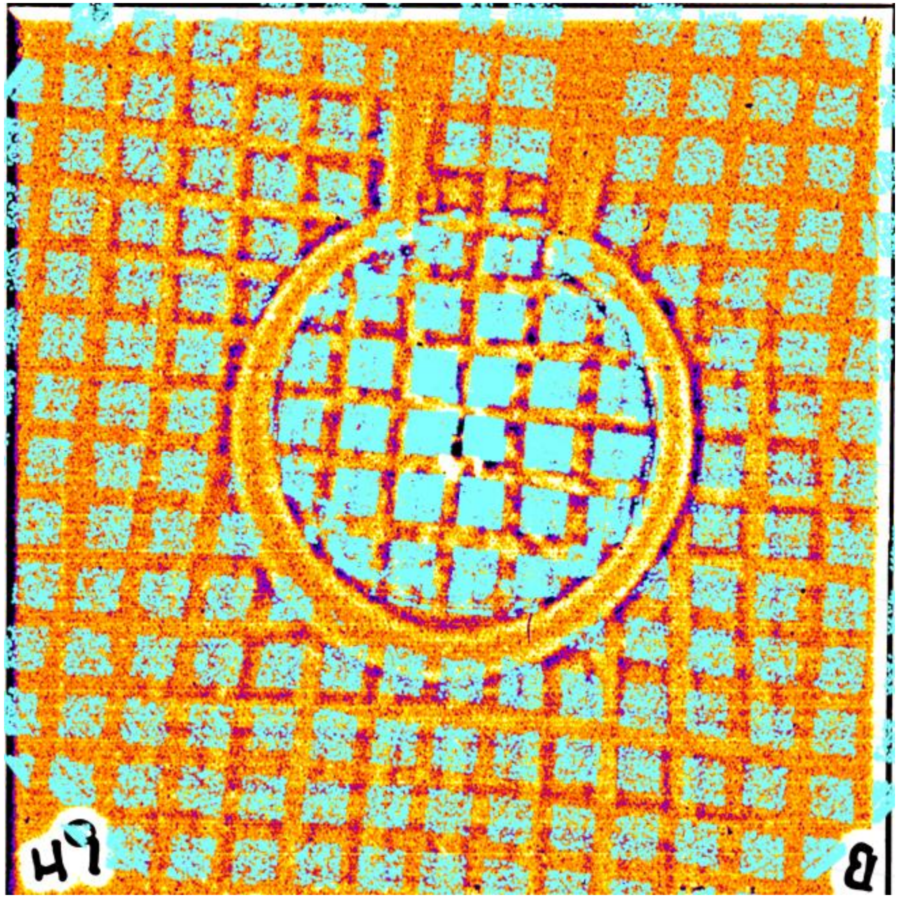
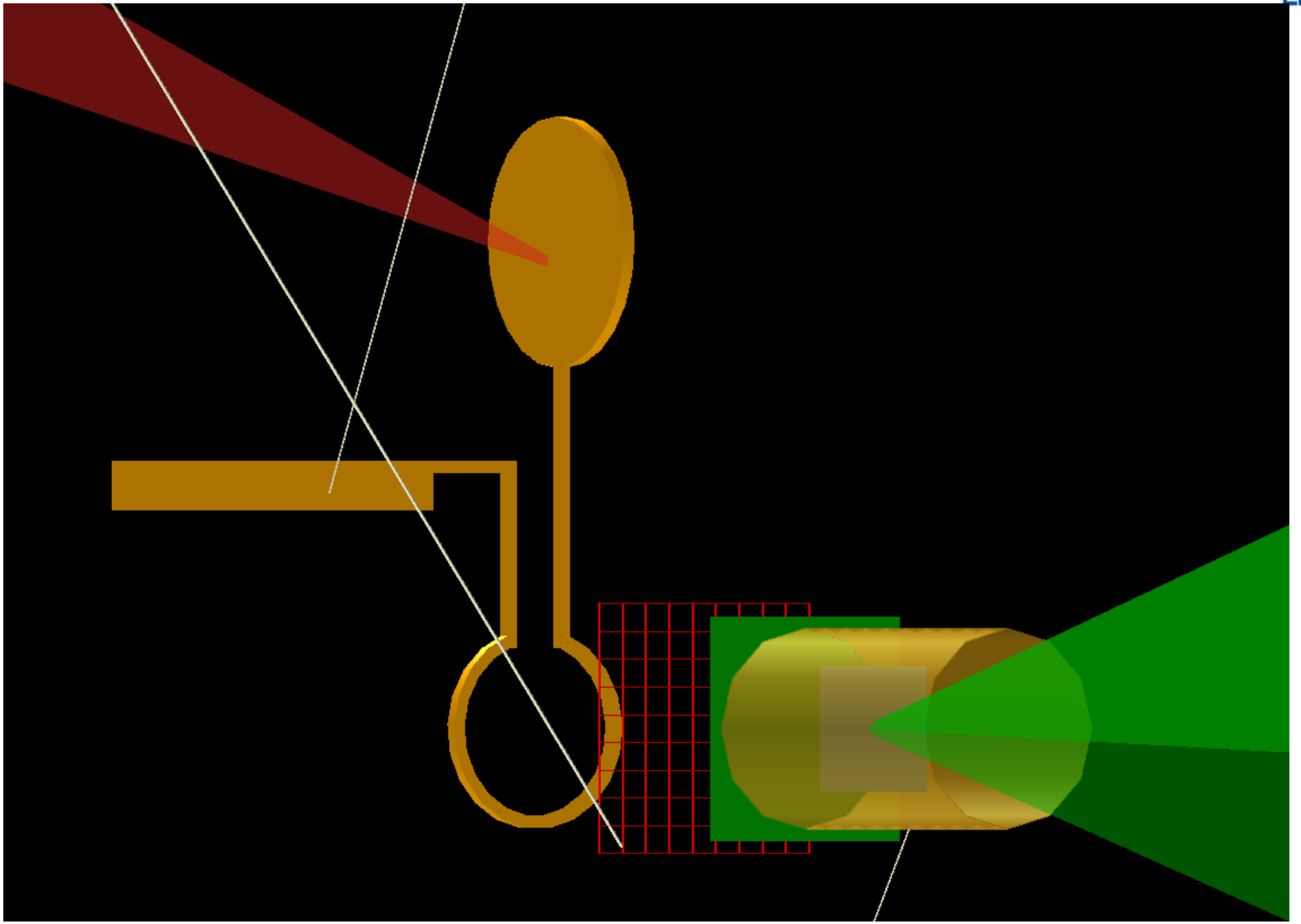
20 MeV Protons



40 MeV Protons

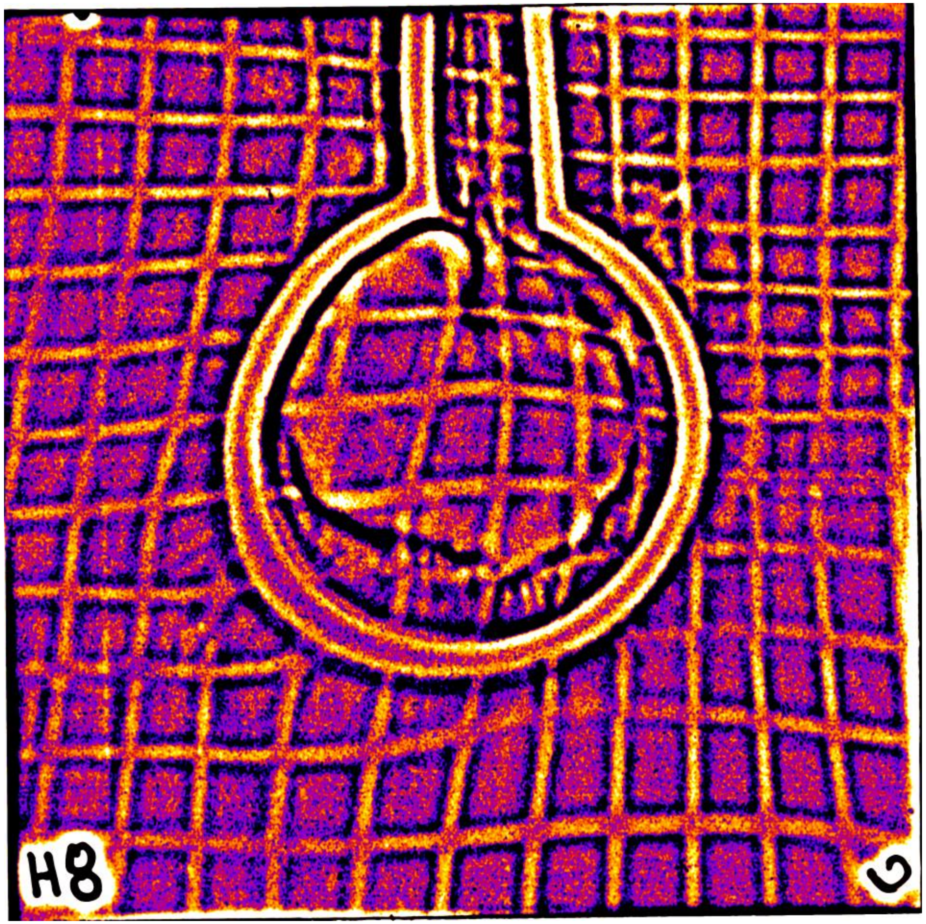


Single plate experimental configuration



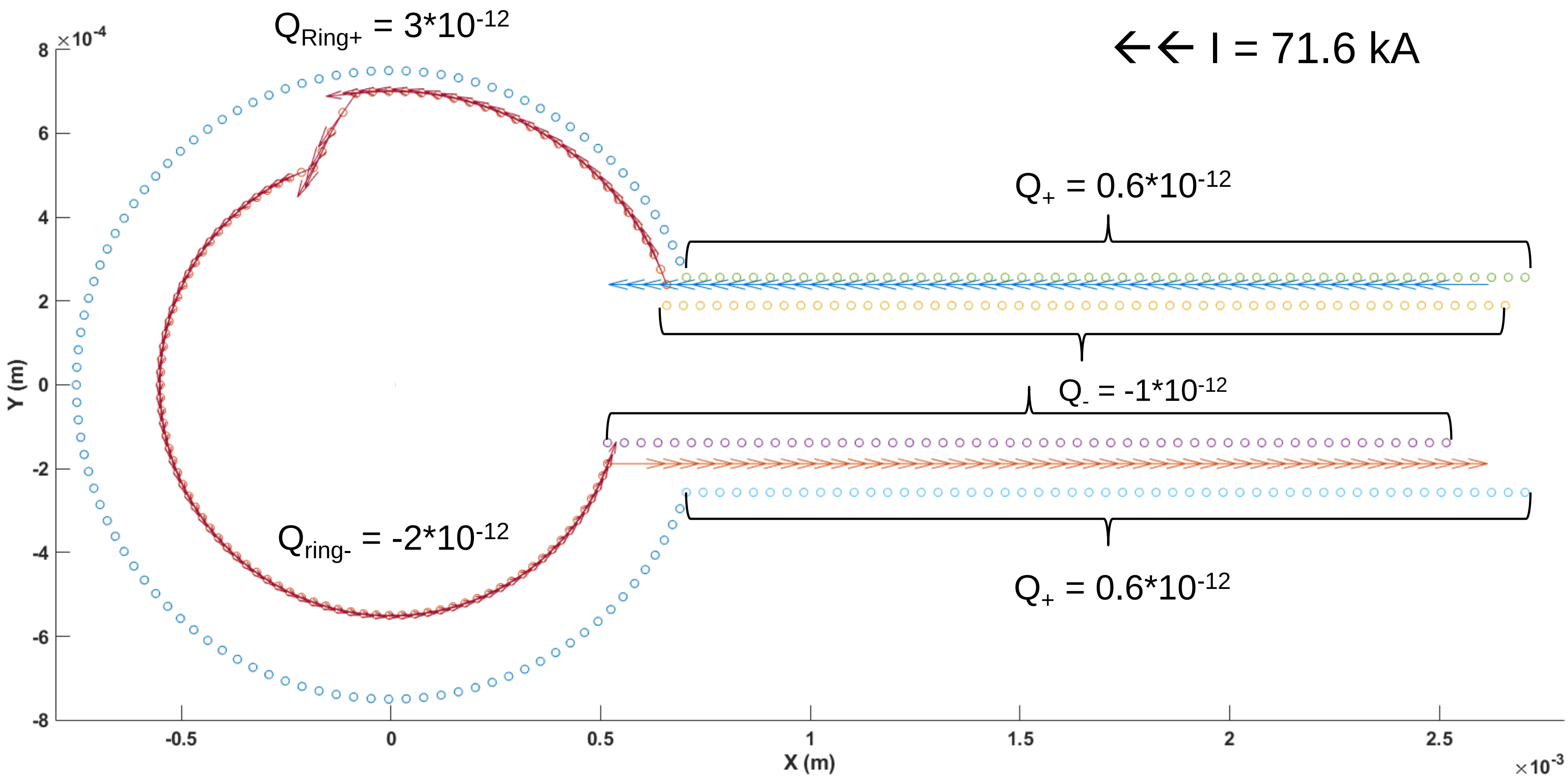
Single plate shot results indicate an axial field of ~ 60 T

- **Distinctly different radiograph features seen with single plate shots, mesh stretching and twisting instead of focusing**
- **RCF features can only be duplicated with <u>both</u> current and charge distributions at specific locations and magnitudes.**
- **Bulging of the grid is caused by a combination of electric fields from coil asymmetry and magnetic field**
- **Mesh twisting near parallel wires is most likely caused by magnetic fields**



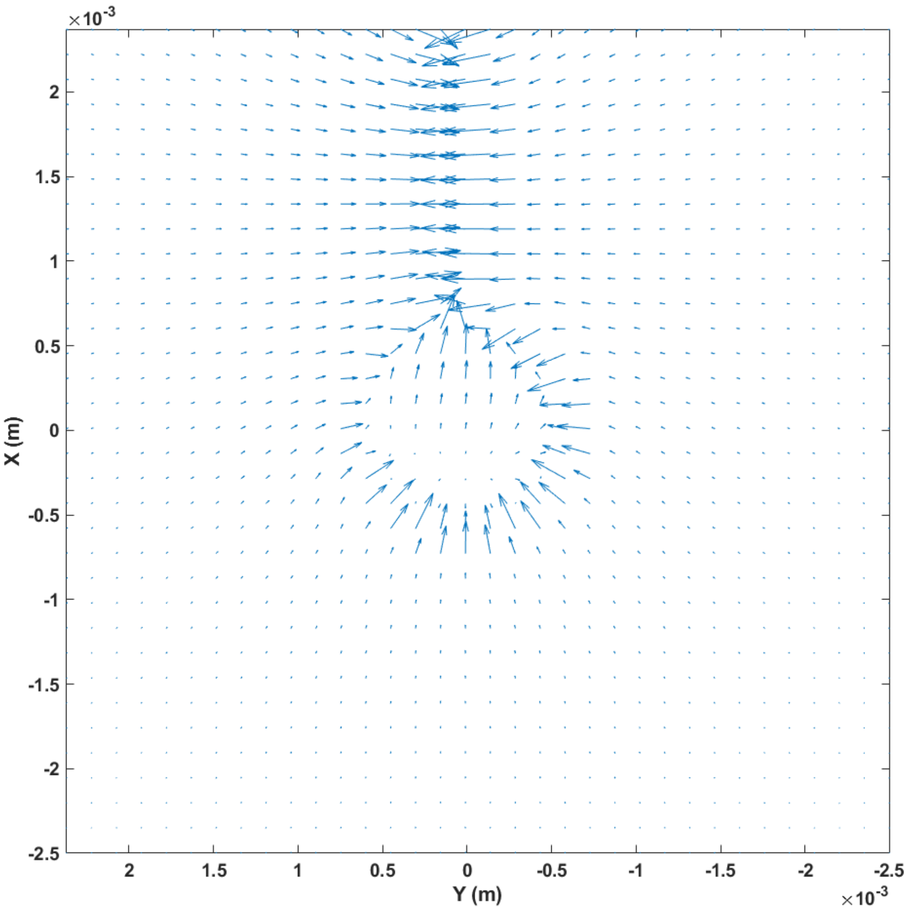
20 MeV proton probe corresponding to 1.1 ns after the start of the long pulse

Charge and current distribution

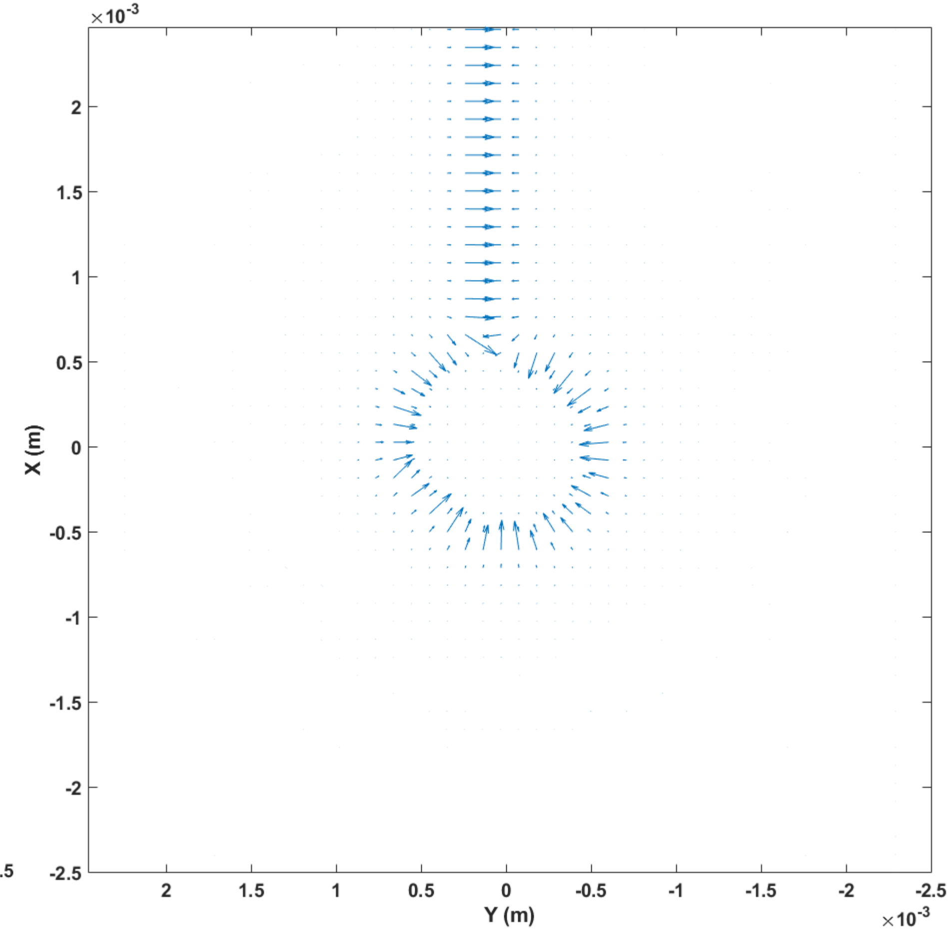


Electric and Magnetic Field Maps

E Field (x and y)



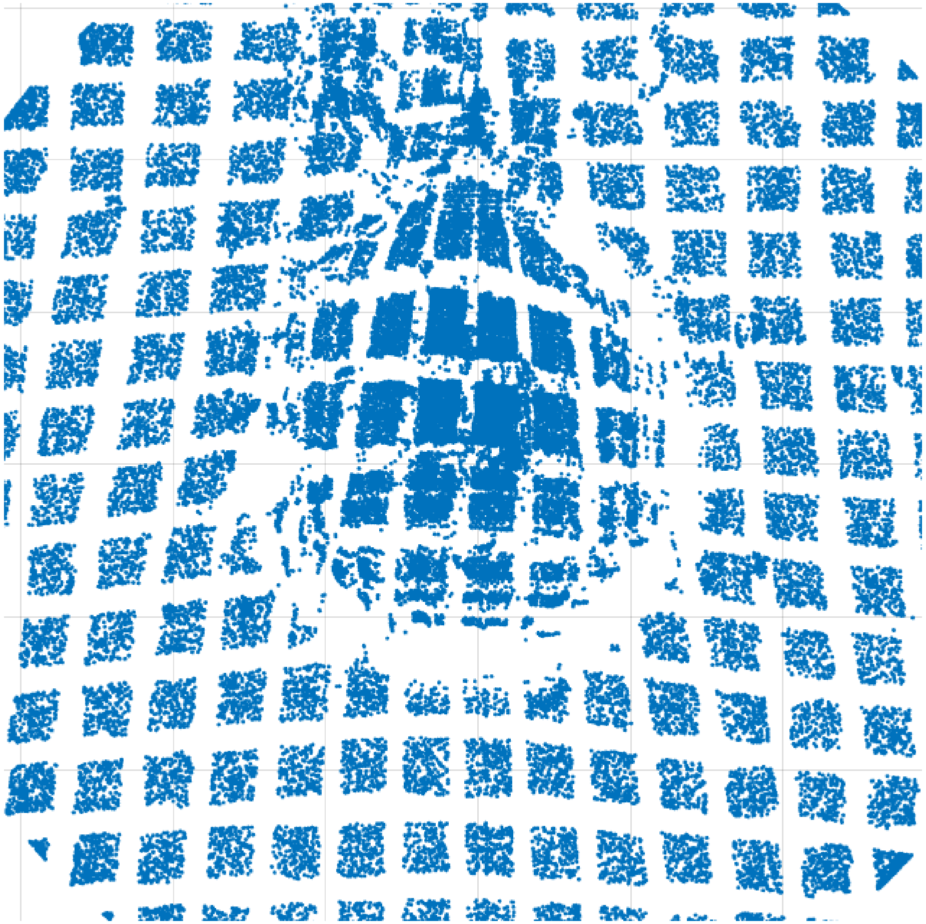
B Field (x and y)

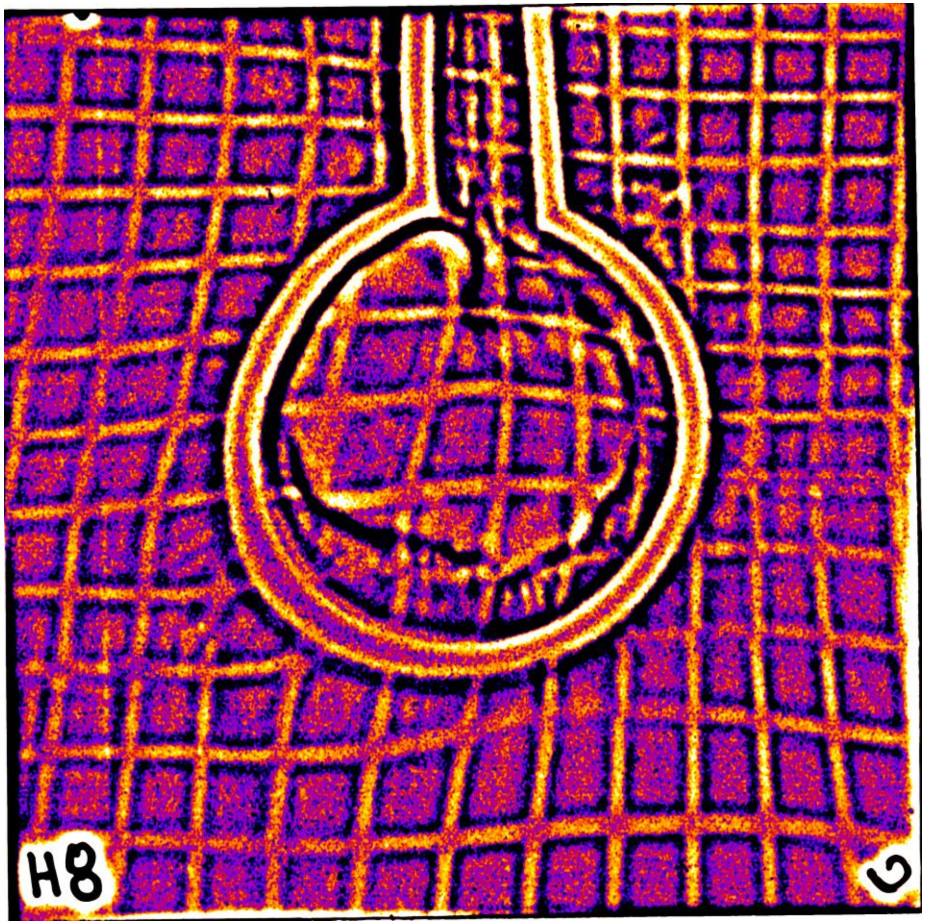


$E_{x,y,z} \sim 10^9$ V/m

Synthetic vs Experimental Radiographs

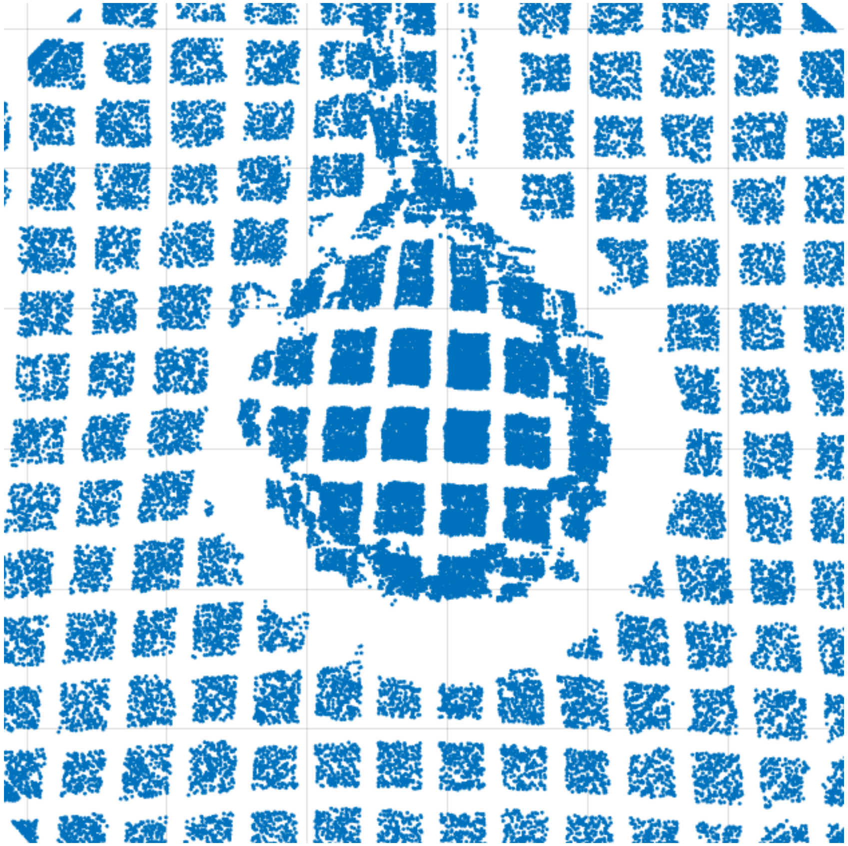
20 MeV Protons

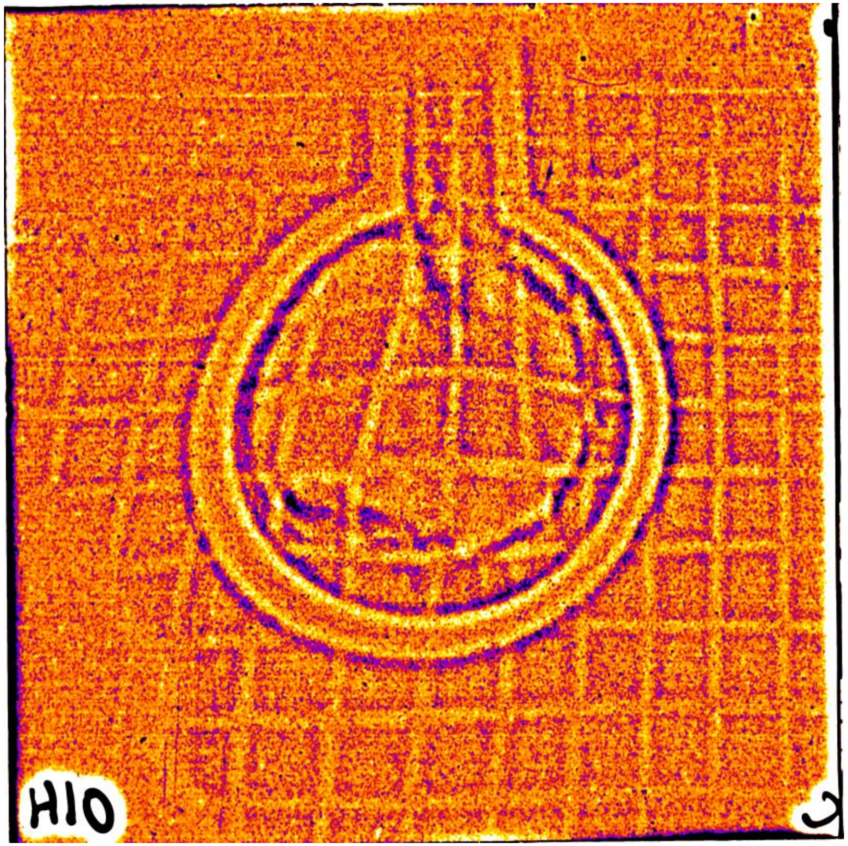




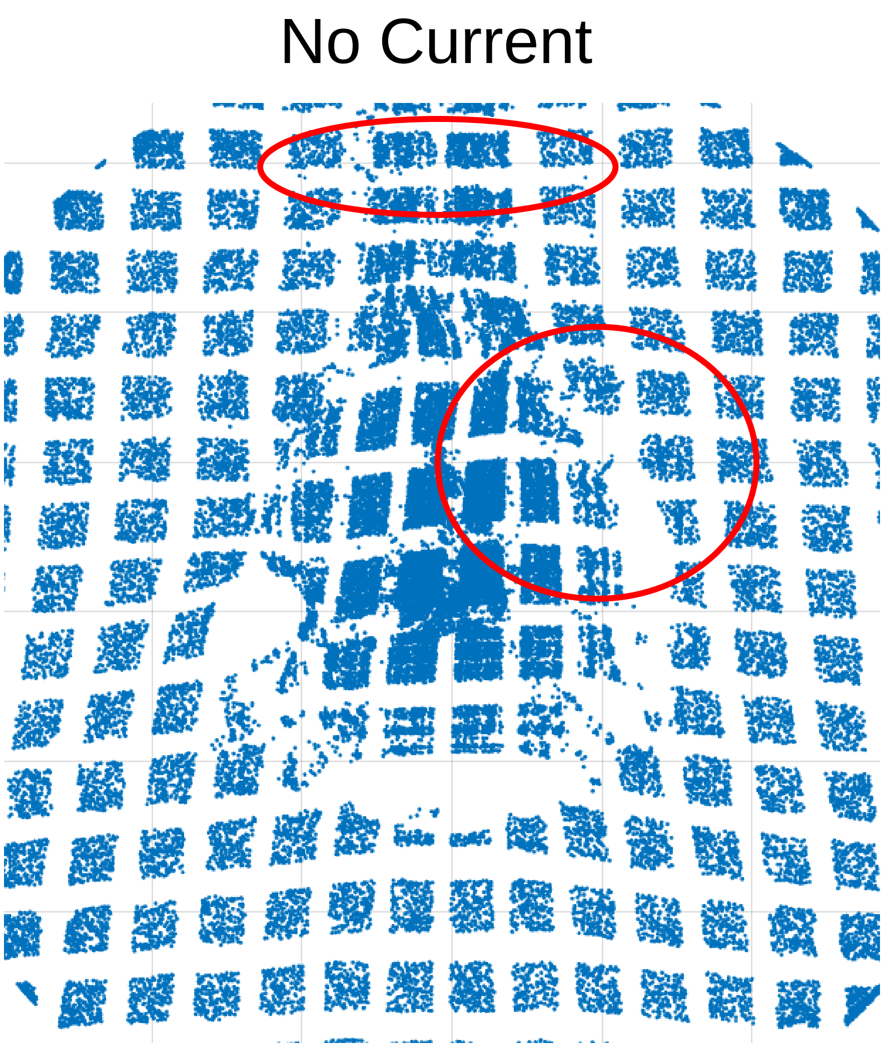
Synthetic vs Experimental Radiographs

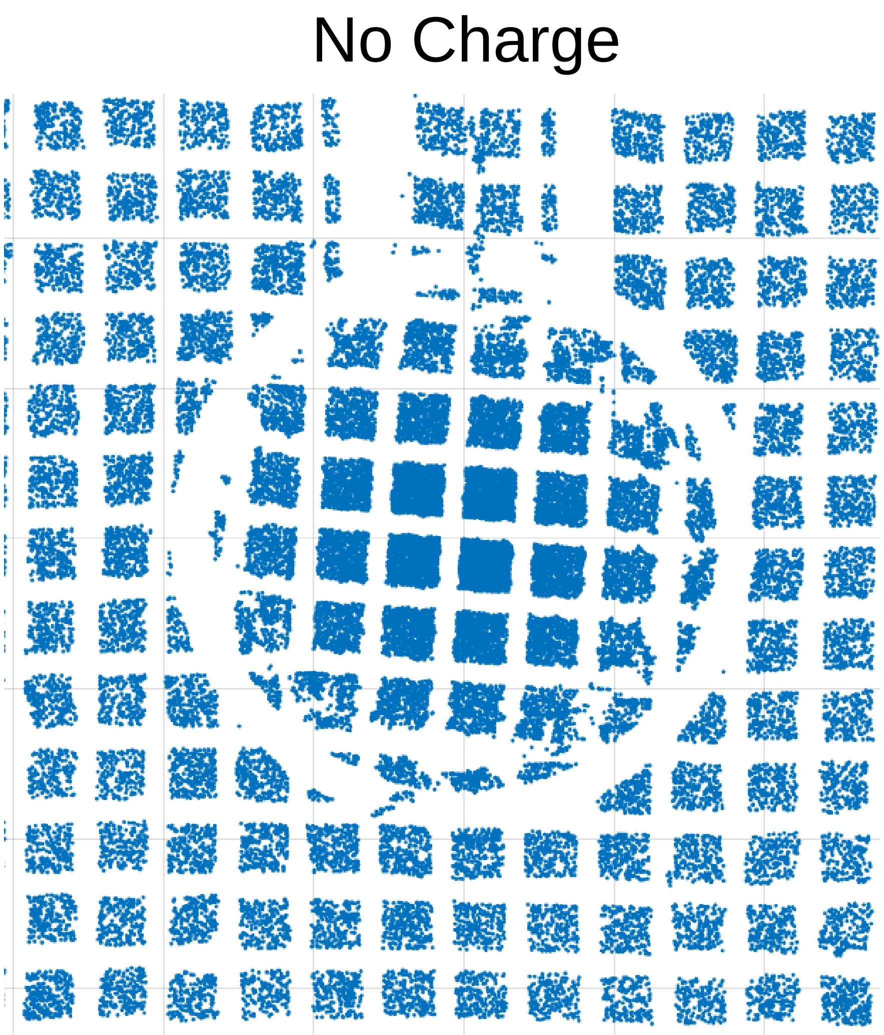
40 MeV Protons





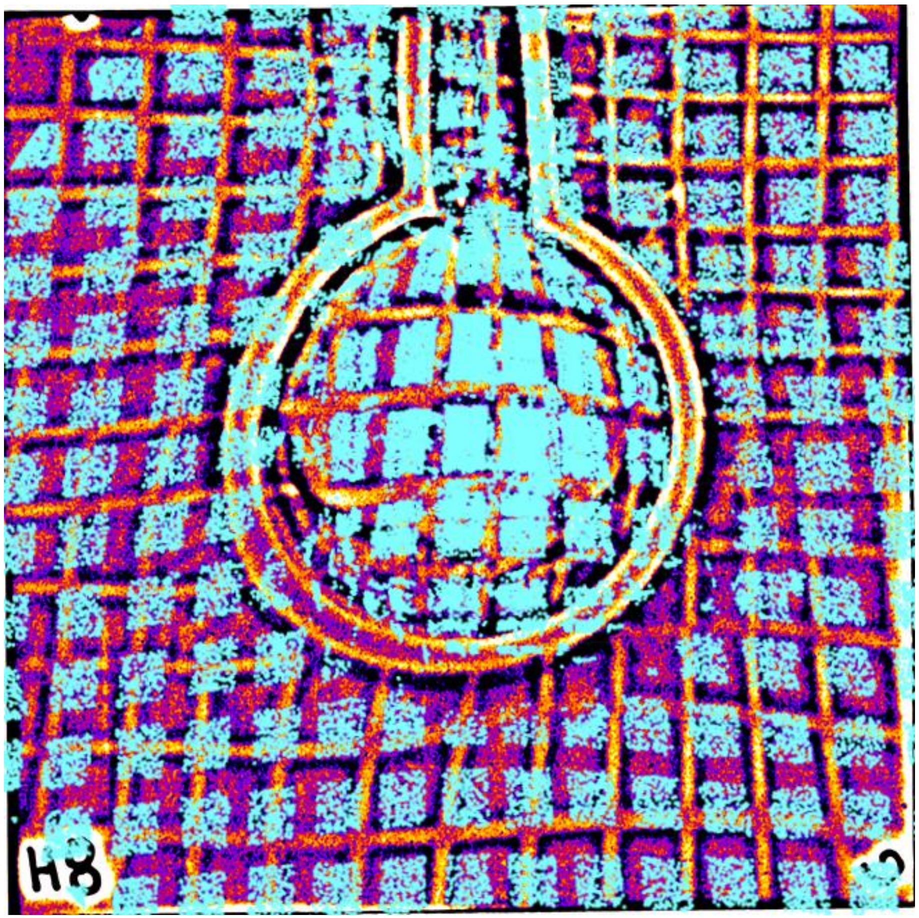
No Charge or No Current



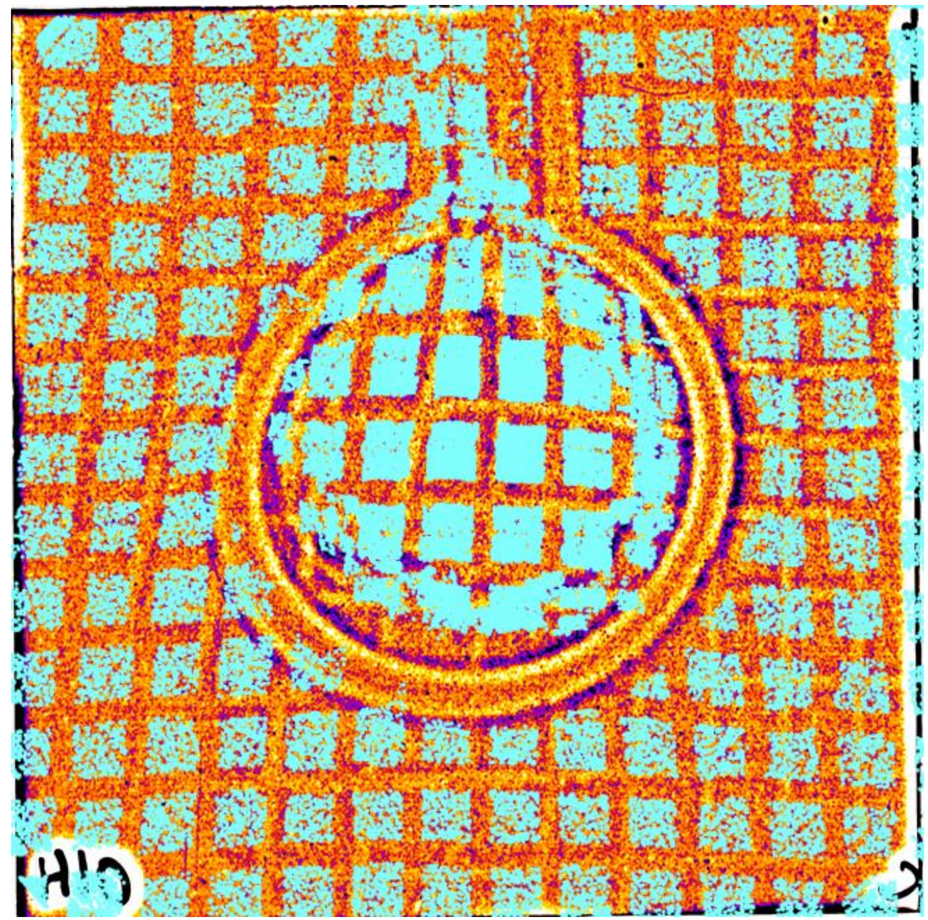


Combination of B and E field reproduce RCF for both 20 and 40 MeV films with some discrepency

20 MeV Protons



40 MeV Protons



Summary and Conclusions

- **Significant magnetic field was measured using axial proton radiography in the single plate target configuration**
- **Double plate type targets saw no field, likely due to plasma filling the gap between plates causing short circuit**
- **Experiment was designed to have a field that could be easily probed (large coil radius, large distance from driving plates. Future experiments can increase this field:**
  - **Use 1ω light rather than 3ω to drive higher temperature electrons**
  - **Smaller loop size, shorter distance from plate, longer/higher intensity driving long pulses or multi-beam driving pulse**
- **Plasma filling the center of the coil and fast B field rise times are a concern for experiments placing targets in the center of the coil**
  - **Conductive targets quickly fail due to induced currents, non-conductive targets will likely be disrupted by plasma blow off**