Flux Ropes and Toroidal Asymmetry in MRX

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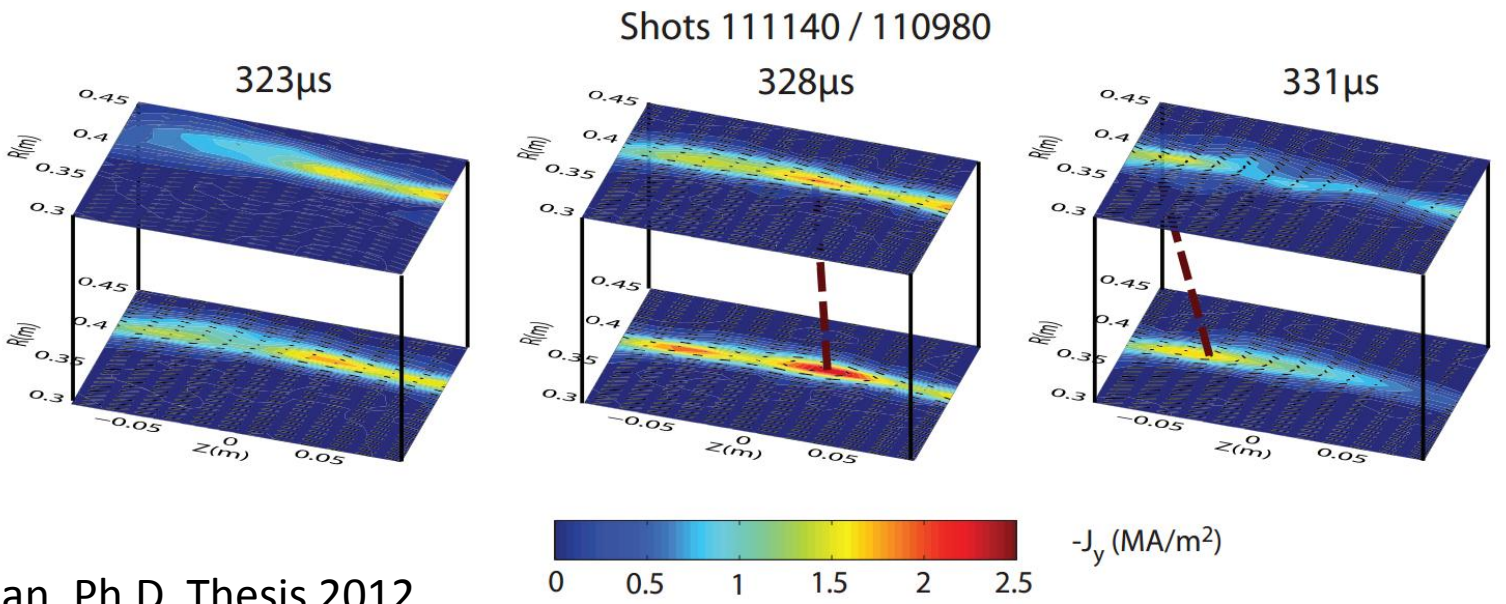
Flux rope dynamics are important to understanding magnetic reconnection

- Numerical simulation have found that the presence of flux ropes can dramatically alter the reconnection process
  - Onset of turbulent reconnection
  - Breakup of current sheet
- Flux ropes have been observed in both spacecraft data and on the sun
  - Outstanding issues
- Small scale flux ropes have been proposed as a mechanism for broadening of the layer width and as a driver for impulsive events

Previous measurements on MRX have inferred the presence of 3D structures

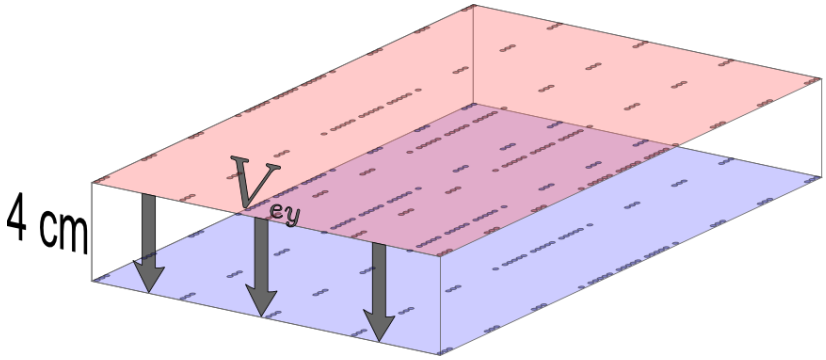
- Two plane profiles were inferred by matching in-plane (r,z) measurements to out-of-plane (r,θ) measurements from different shots
- NO simultaneous 3D measurements
- Previous estimates: L ~ 10 cm, 50° at B_t/B_{sh} = -0.25



S. Dorfman, Ph.D. Thesis 2012

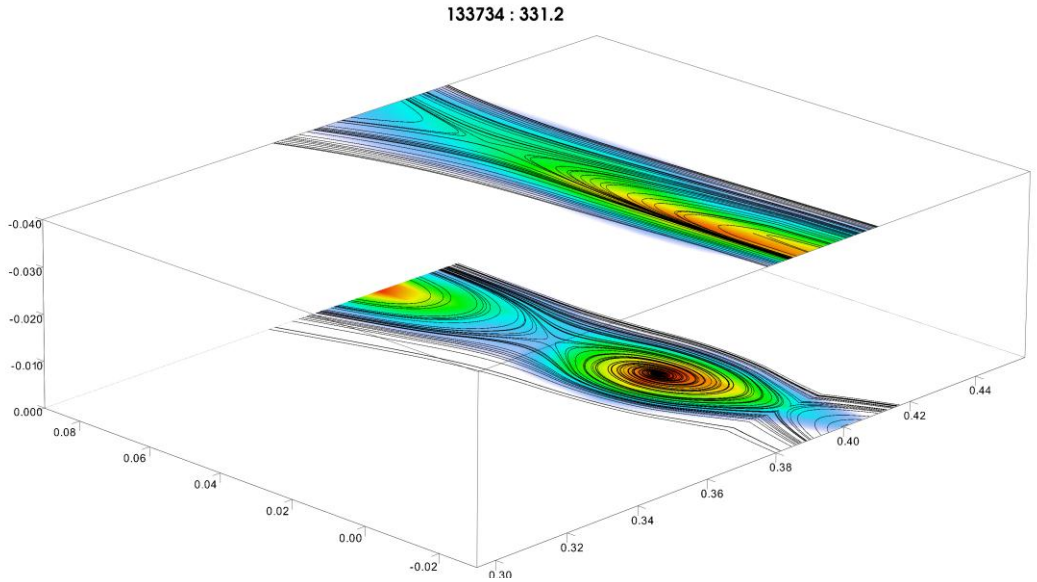
New magnetic probes and hardware allow for simultaneous 3D measurements

- 351 magnetics channels allow coverage of two 12cm x 16cm planes
- New flange allows spacing between planes from 2 to 16cm
- Initial experiments performed with 4cm separation
- SF Jogging coils are used to provide additional drive and increase current

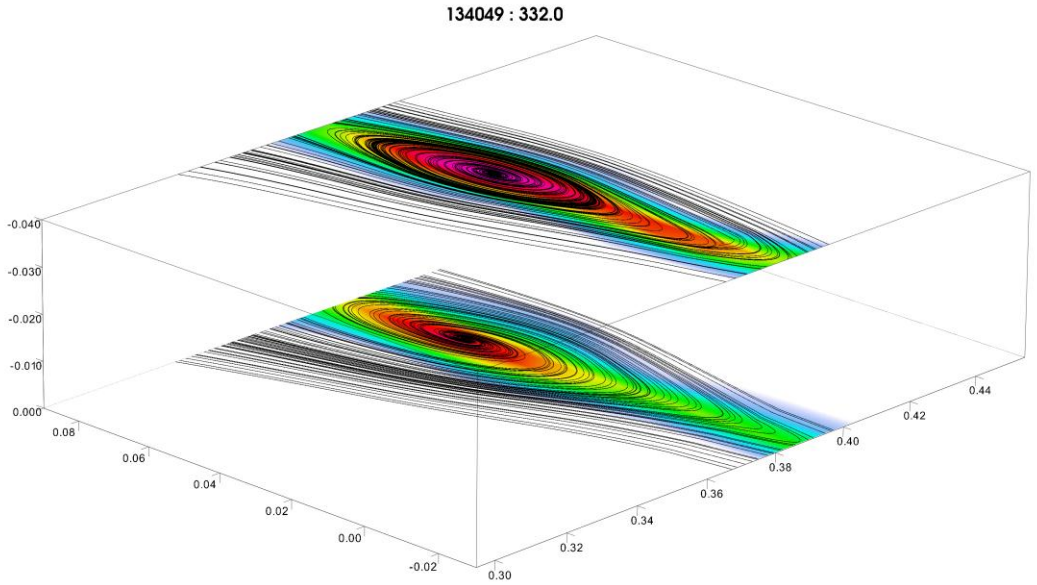


Toroidal asymmetry can be strong

Asymmetric flux rope structure

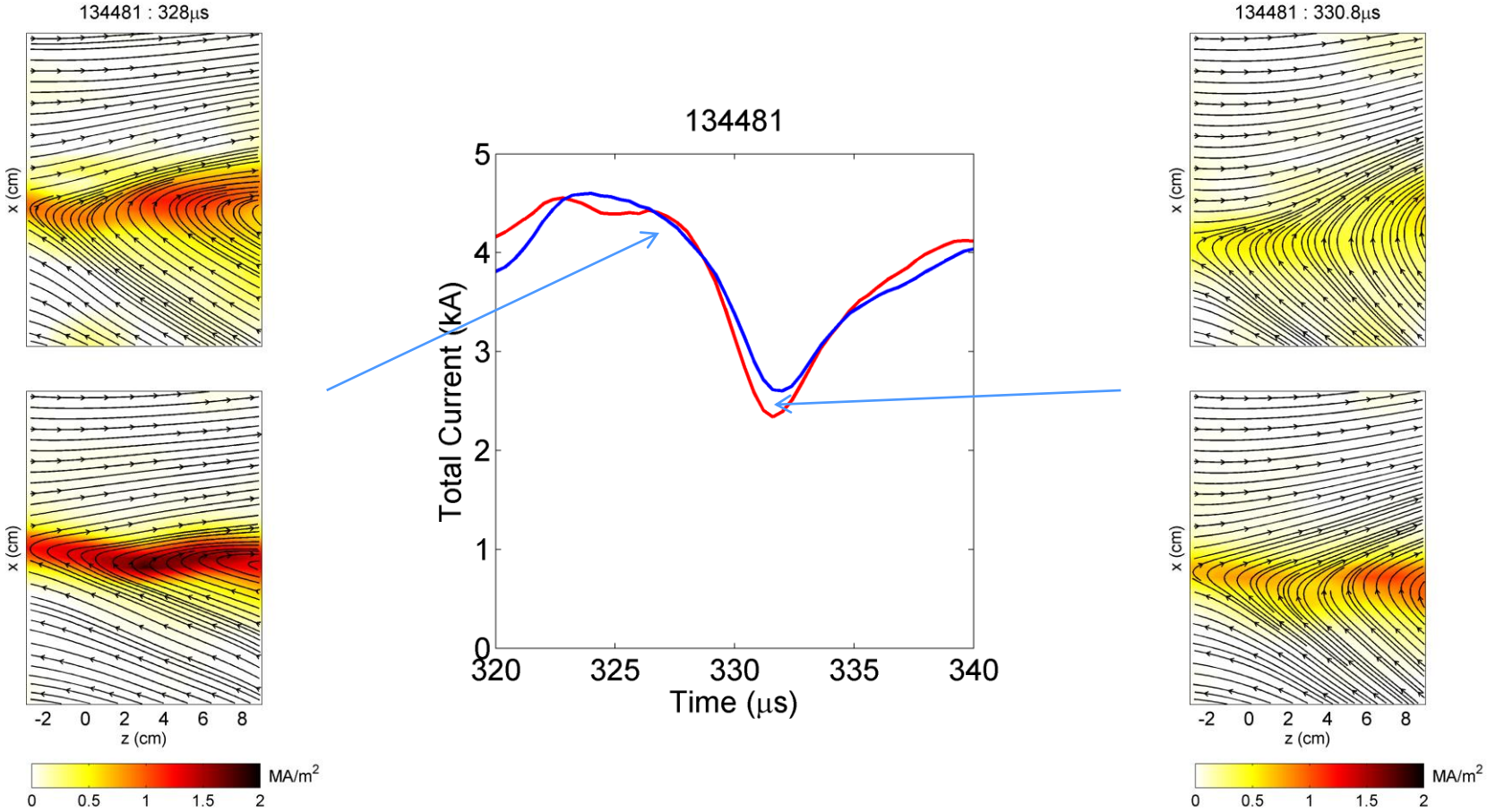


Mostly symmetric structure



Current sheet disruptions are observed

- Despite different parameter regime than previous experiments, disruptions and impulsive events are observed

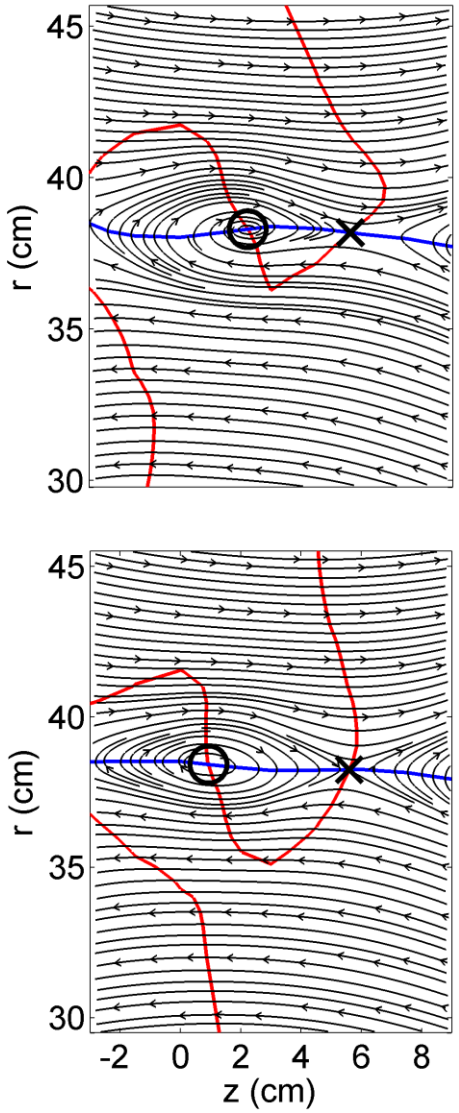


Limited coverage prevents measurement of O-point widths

- 5 axial locations limits width measurements to a small range 6cm < W < 12 cm
  - Width statistics not accessible

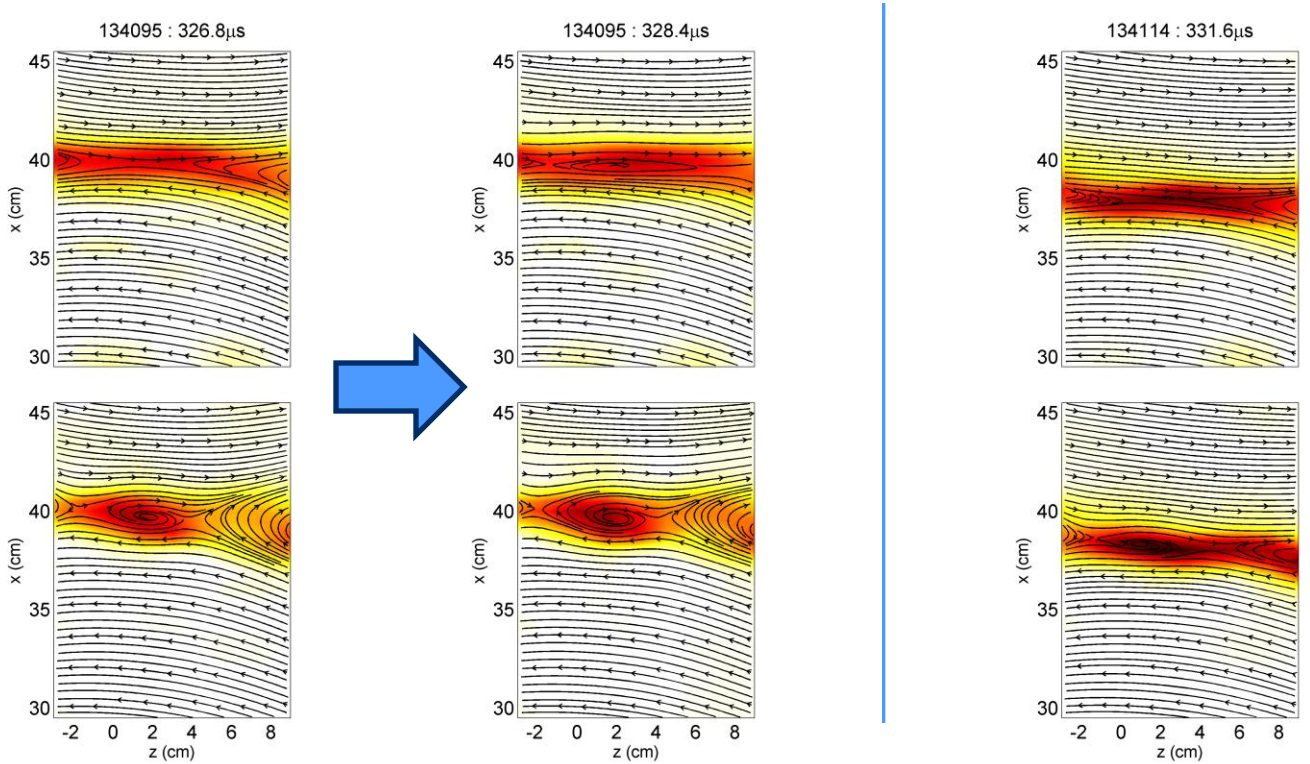
- Local analysis can infer O-point position
  - $\frac{\partial B_r}{\partial z} / \frac{\partial B_z}{\partial r} < 0$: O-point
  - $\frac{\partial B_r}{\partial z} / \frac{\partial B_z}{\partial r} > 0$: X-point

- Position statistics are sufficient to show 3D nature of these structures



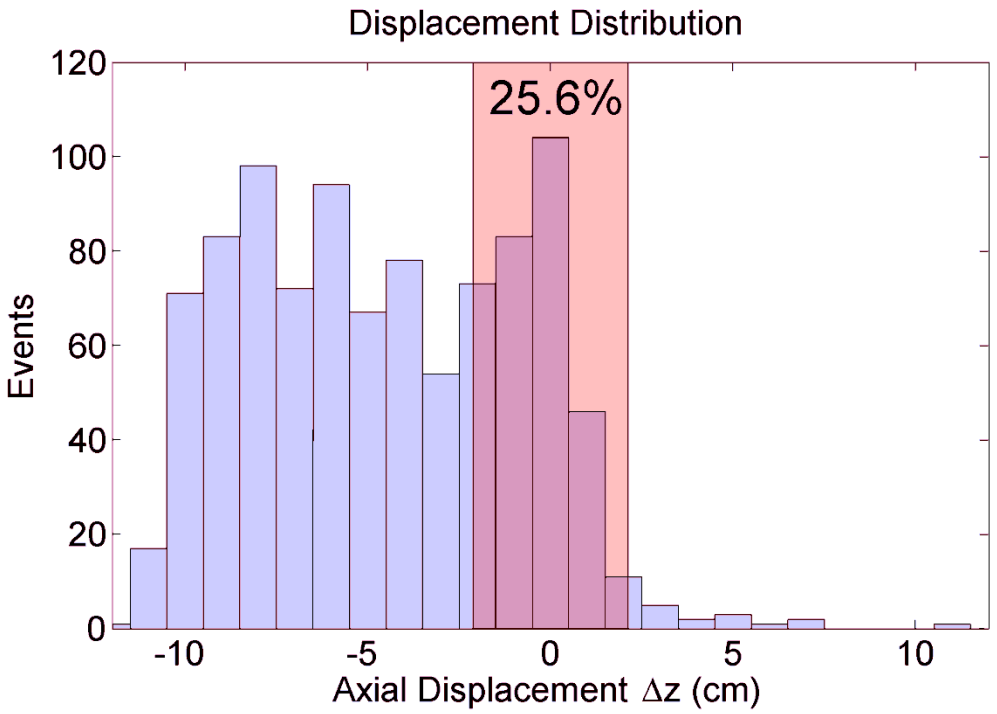
Observed structures are truly 3D

- Often O-points are observed only in a single plane
  - 65% of structures are observed to start in one plane and propagate to the other
  - Occasionally non-propagating single O-points are observed



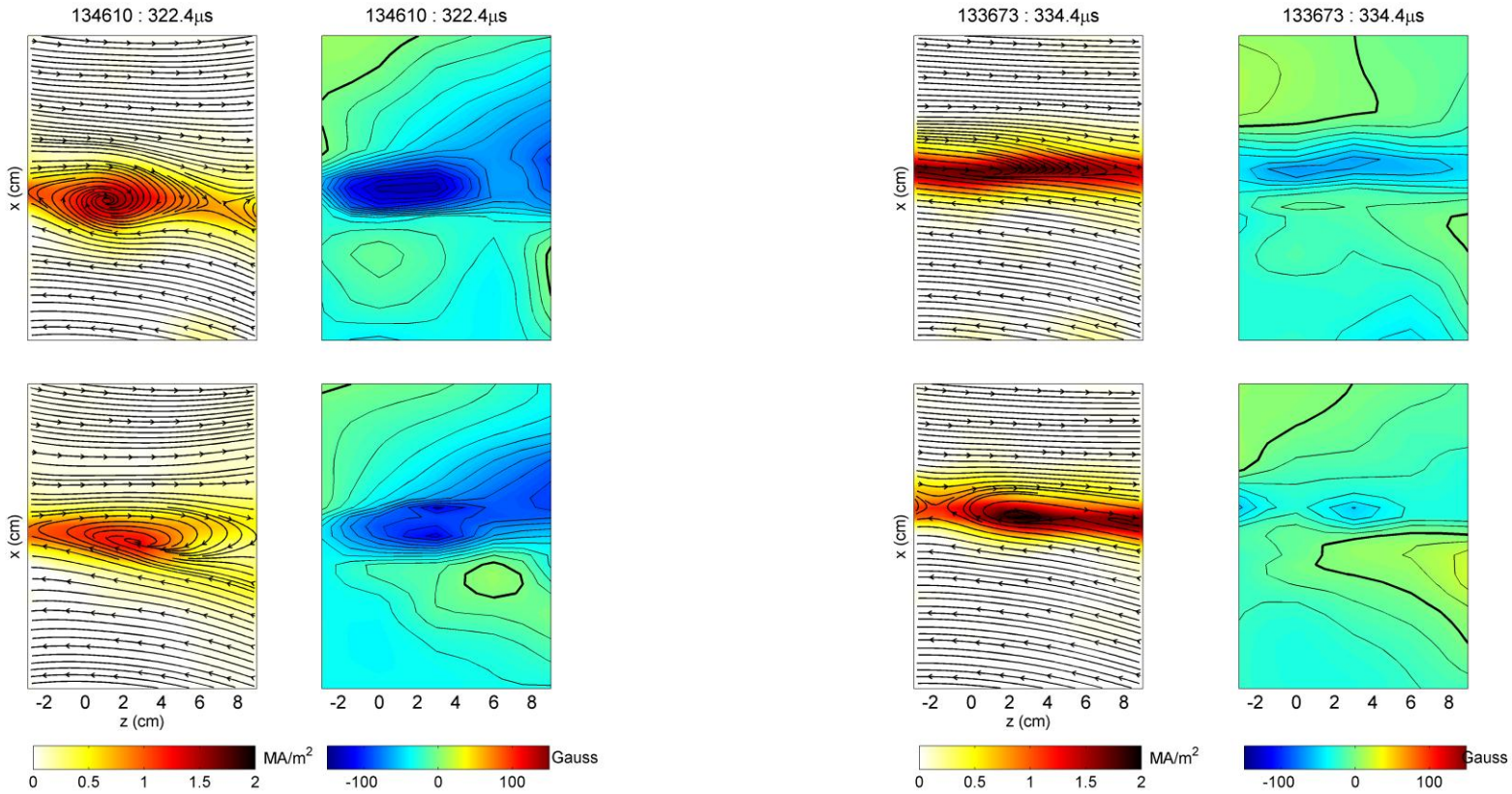
Observed structures are truly 3D

- Only a fraction of structures observed simultaneously in both planes can be explained by 2D magnetic islands



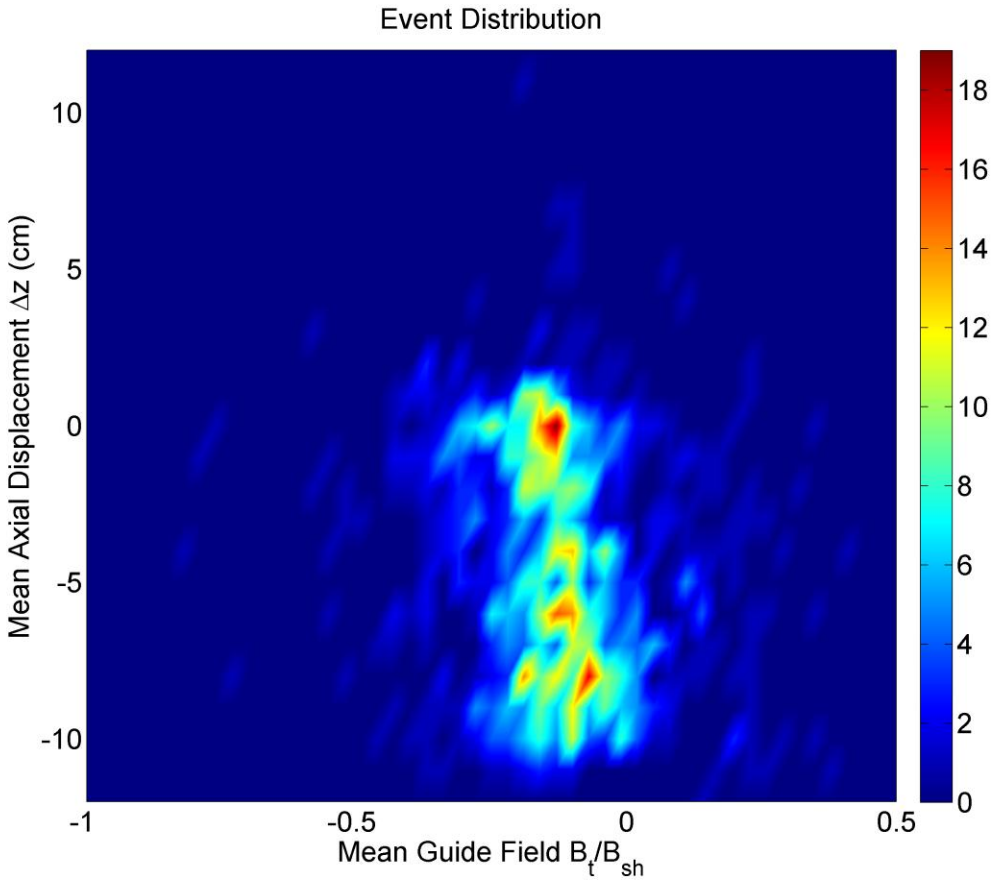
Flux ropes exhibit guide field localization

- Guide field is often localized to a flux rope during formation. Resolution is not good enough to identify an enhancement of guide field as the flux rope evolves.

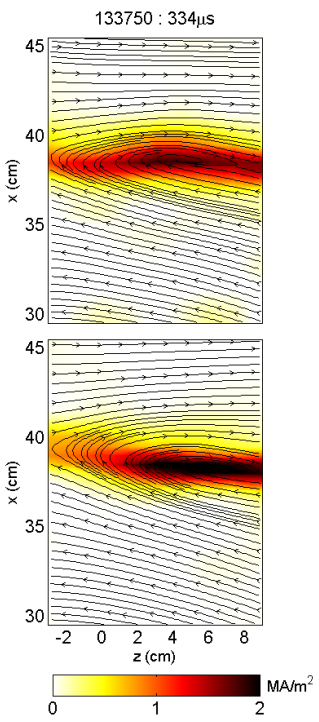


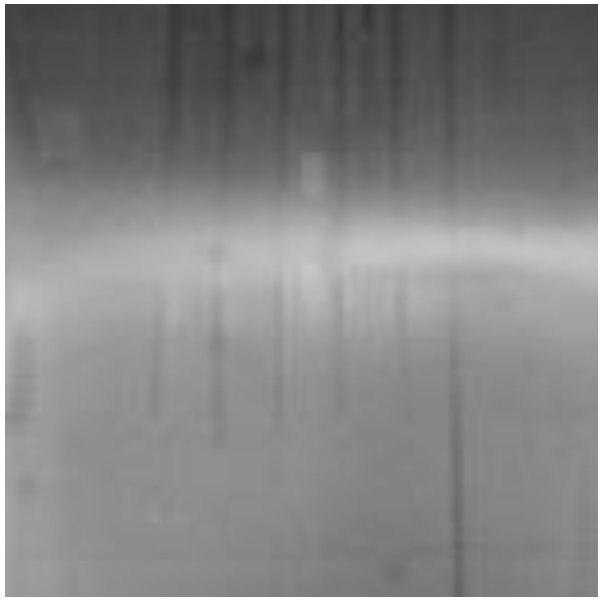
Guide field scaling

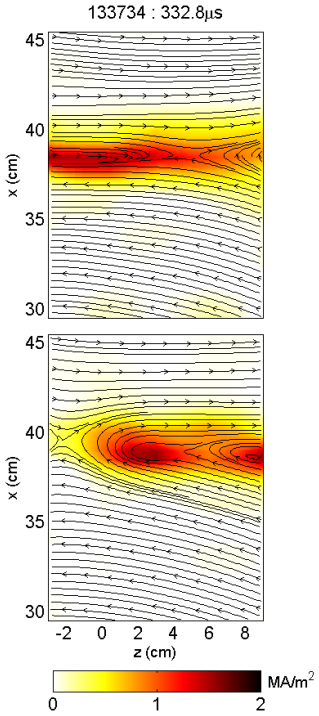
- Flux rope length scale may rapidly increase with guide field
- With significant guide field localization, B_t is underestimated

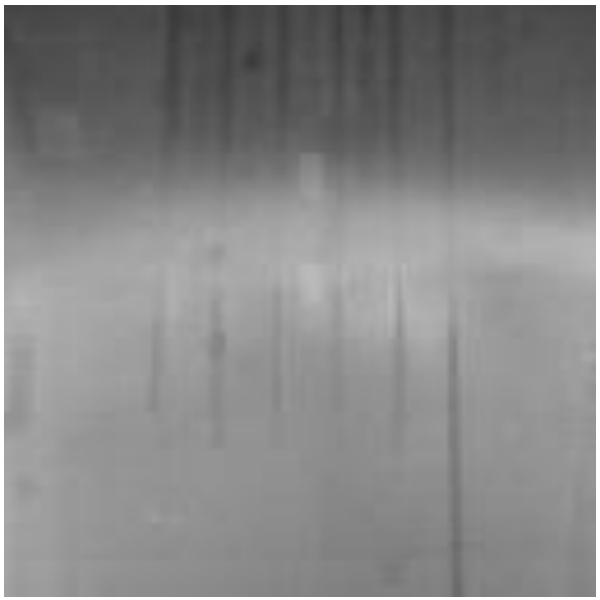


Imaging and phosphor as a flux rope diagnostic









Summary

- Toroidal asymmetry is strong and observed O-points are not magnetic islands, they are flux ropes
- Flux ropes exist at all measureable angles, due to rapid decorrelation as $B_t \rightarrow 0$
- Flux ropes dynamics are important for understanding the evolution of the out-of plane magnetic field

- MRX has the capability to study 3D flux rope dynamics
  - Future experiments can accurately measure widths using high resolution probes and possibly phosphor diagnostics