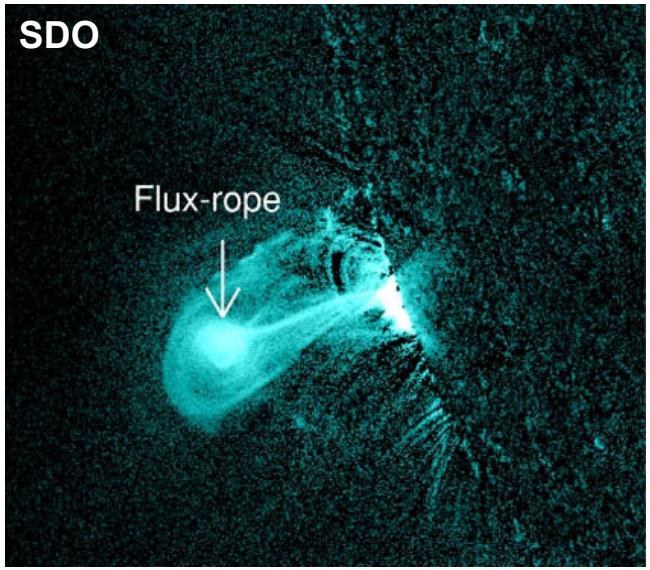
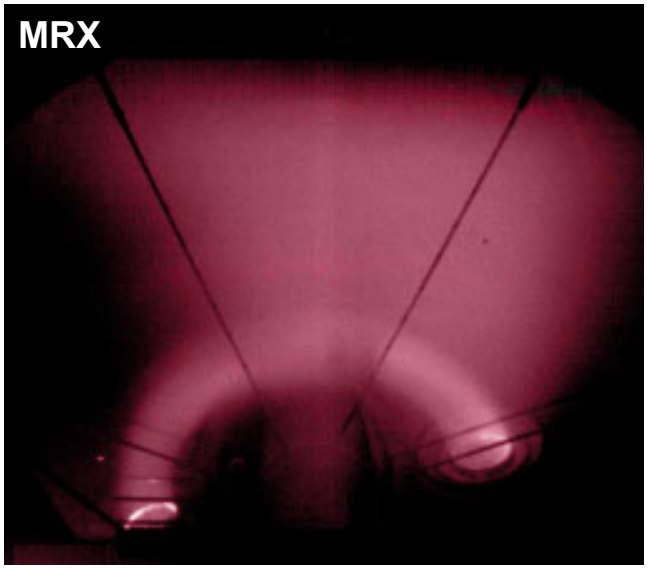
Studying solar-relevant flux rope eruptions in the laboratory



Clayton E. Myers
October 26, 2012



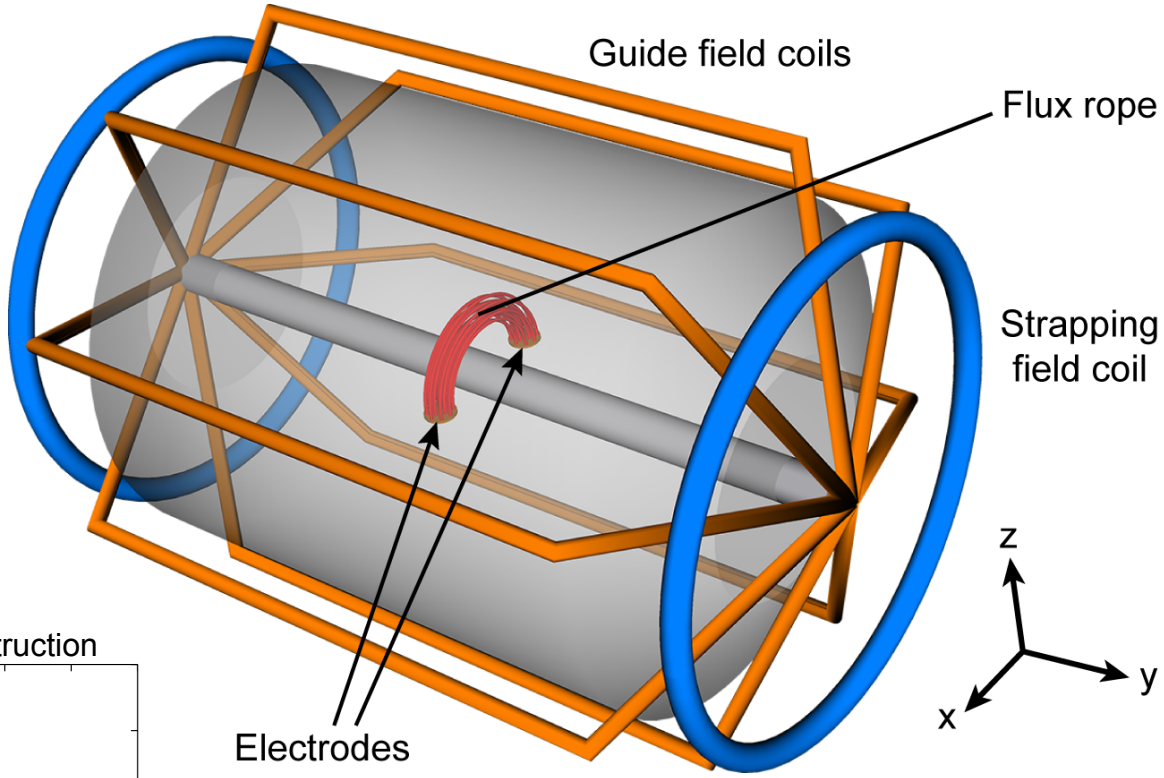
Collaborators: M. Yamada, H. Ji, J. Yoo, E. E. Lawrence, J. Jara-Almonte, T. D. Tharp, R. M. Kulsrud, S. Dorfman, and E. Oz

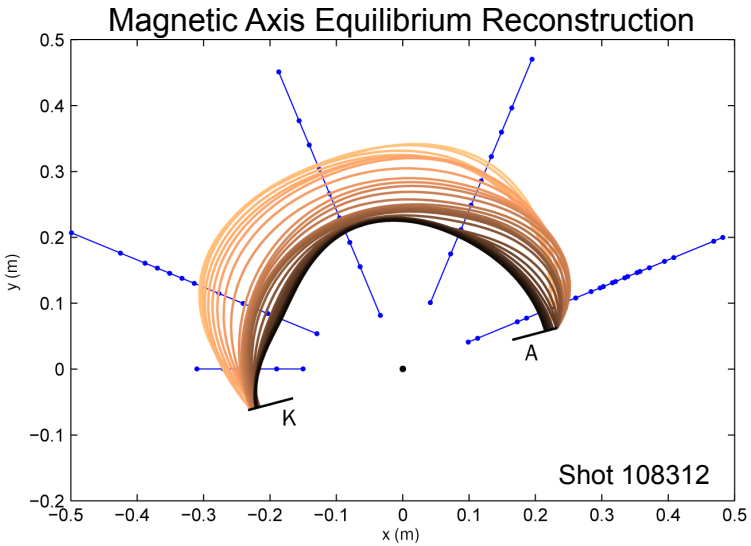
PRINCETON UNIVERSITY

PPPL
PRINCETON PLASMA PHYSICS LABORATORY

Line-tied magnetic flux ropes in MRX

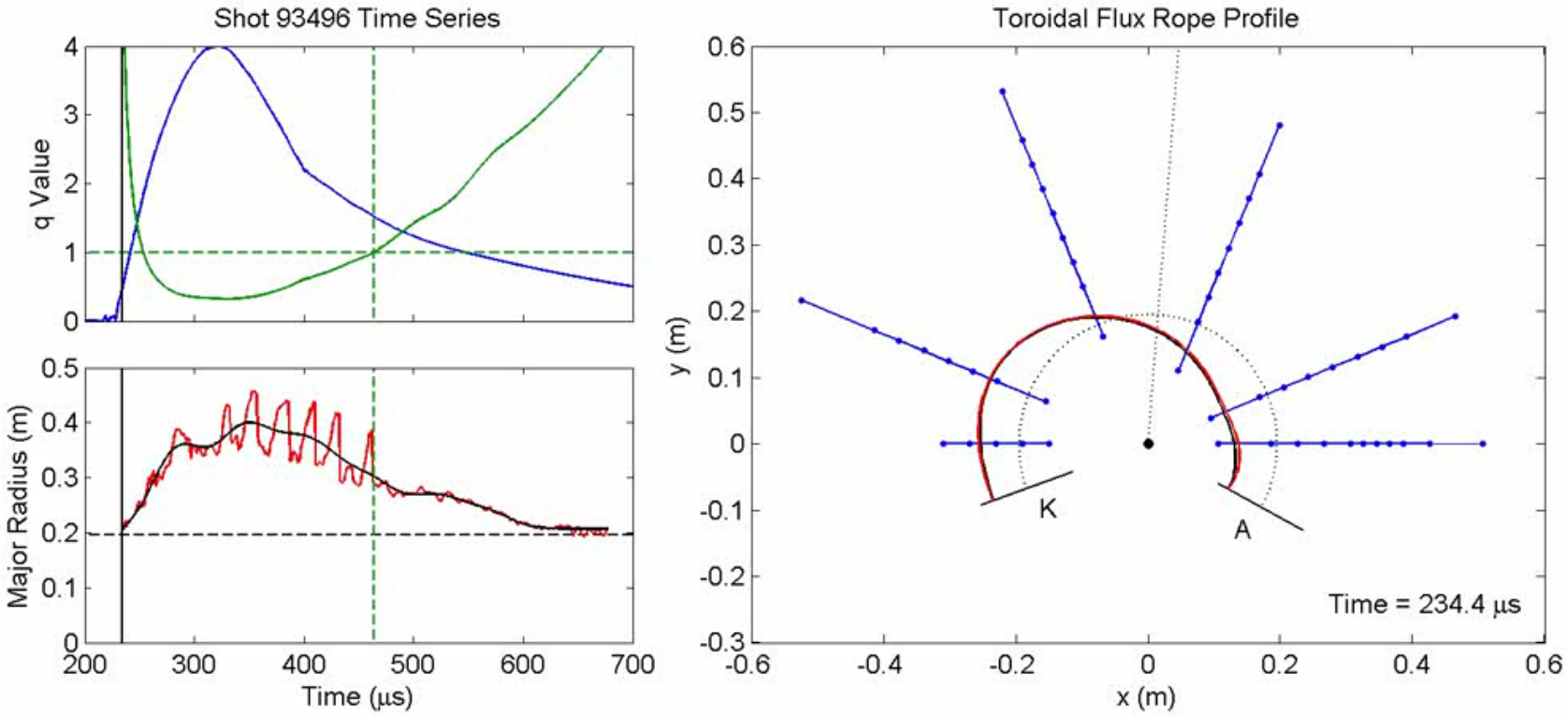
- Fill pressure: 1-100 mTorr
- Gases: H_2, He, CH_4, Ar
- Magnetic field: ~1-2 kG
- Discharge duration: ~700 μs
- Alfvén transit time: ~ 1 μs
- Scale length: ~60 cm
- Peak current: ~25 kA
- Density: ~$10^{13\text{-}14}$ cm^{-3}?
- Temperature: ~10-15 eV?





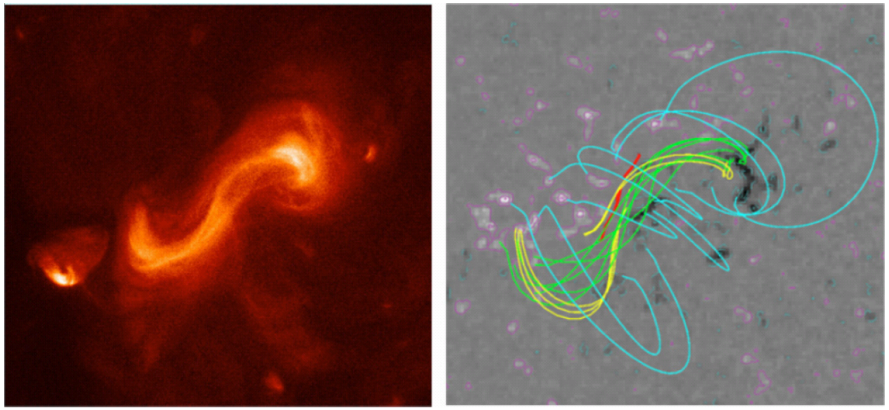
Flux rope formation developed for MRX by E. Oz, *et al.*

A typical MRX flux rope discharge

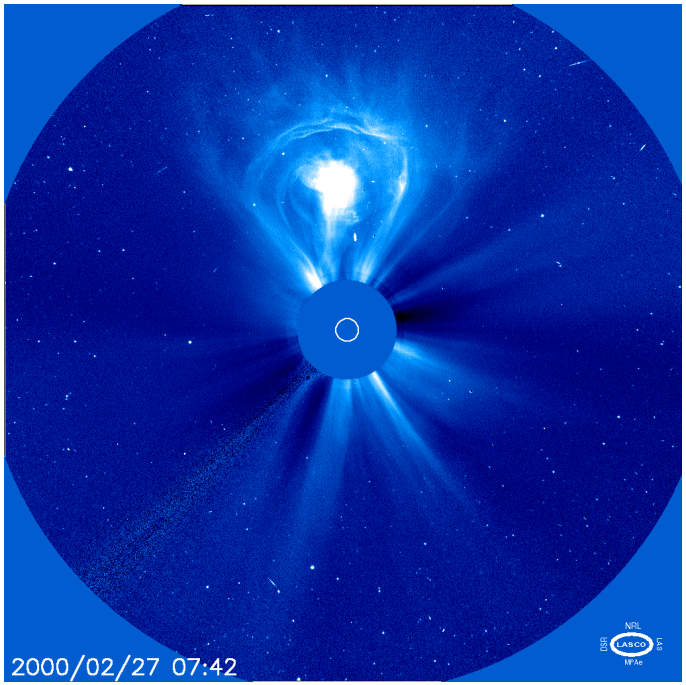


- Quasi-static equilibrium expansion and contraction occurs on timescales that are much longer than the Aflvén time
- The external kink instability grows about this equilibrium when the current in the flux rope is above the kink stability threshold

How can we contribute to understanding solar eruptions?

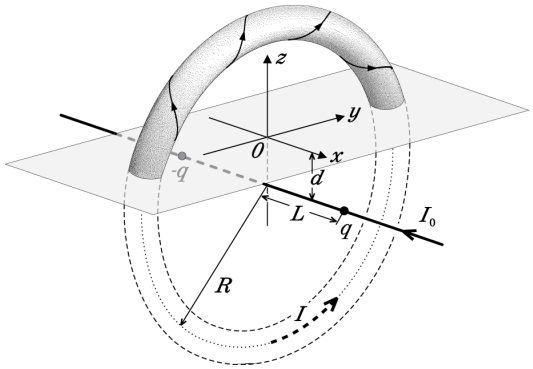


Savcheva et al., *ApJ*, 2012



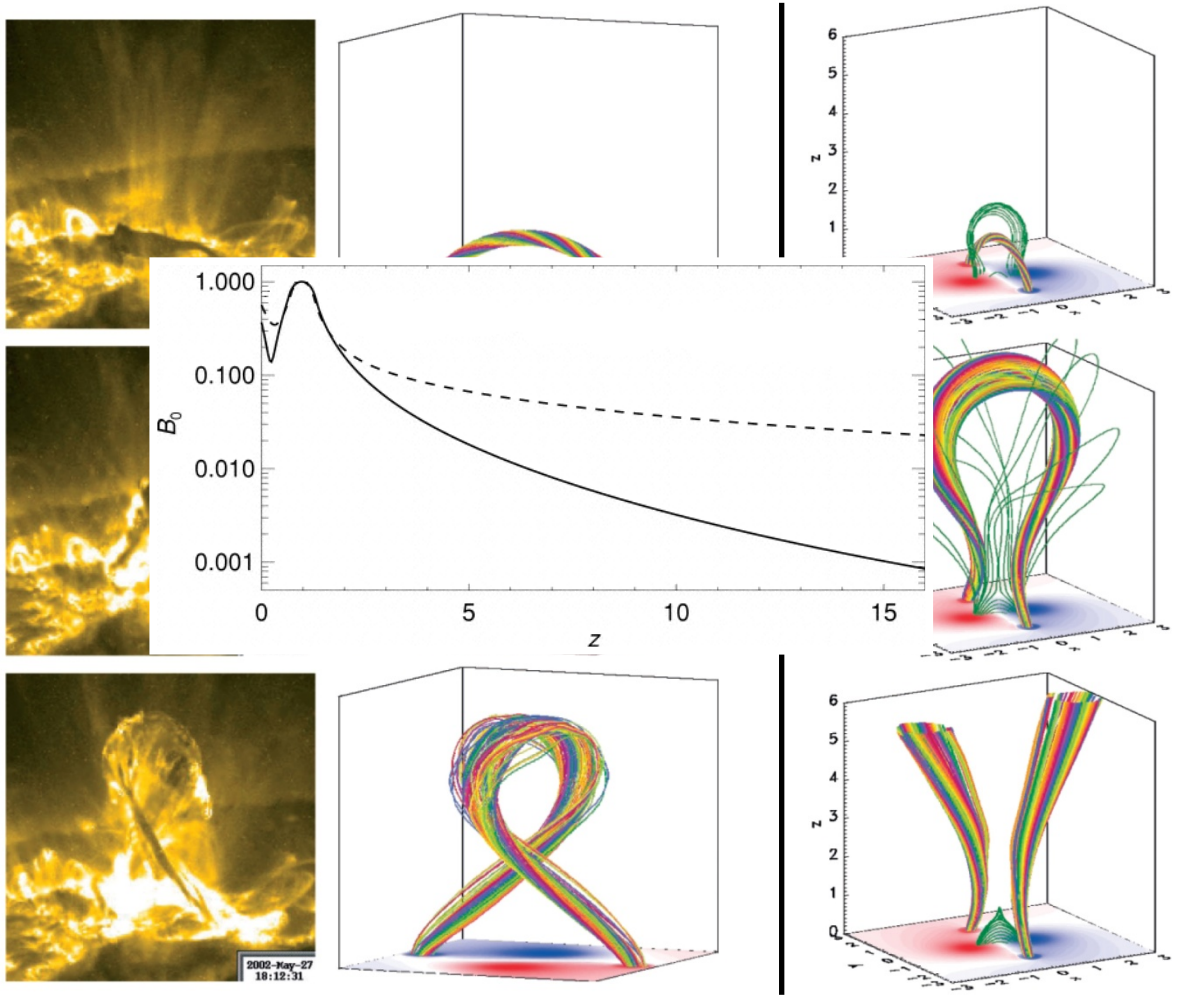
- How do quiescent active regions suddenly transition to a violent eruption?
- We will experimentally “simulate” the topology of a solar active region in the hopes of providing some insight into how flux ropes erupt in the solar corona

Torus instability and/or loss-of-equilibrium



Titov & Démoulin, *A&A*, 1999

- Progressively rising hoop forces slowly drive the flux rope to expand
- Confining fields fall off with altitude above the solar surface
- A point is reached where the restoring forces can no longer counter an outward perturbation to the flux rope



Török & Kliem, *ApJ*, 2005

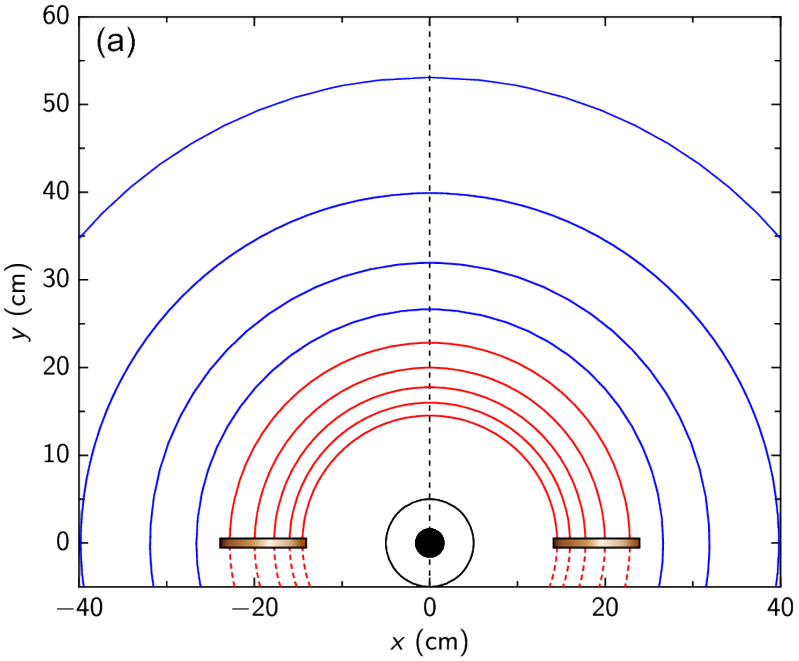
Modifying the MRX potential field configuration

- The relevant parameter for the “torus instability” is the field decay index *n(z)* (see right)
- The present “line current” potential fields in MRX do not exceed a field decay index of *n=1*

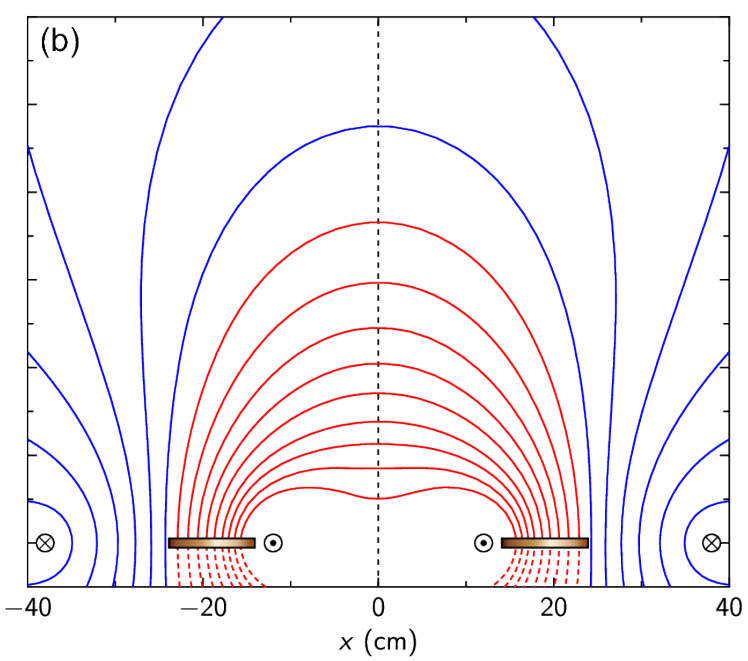
$$B(z) = B_0\left(\frac{z_0}{z}\right)^n$$

$$n(z) = -\left(\frac{z}{B}\right)\frac{dB}{dz}$$

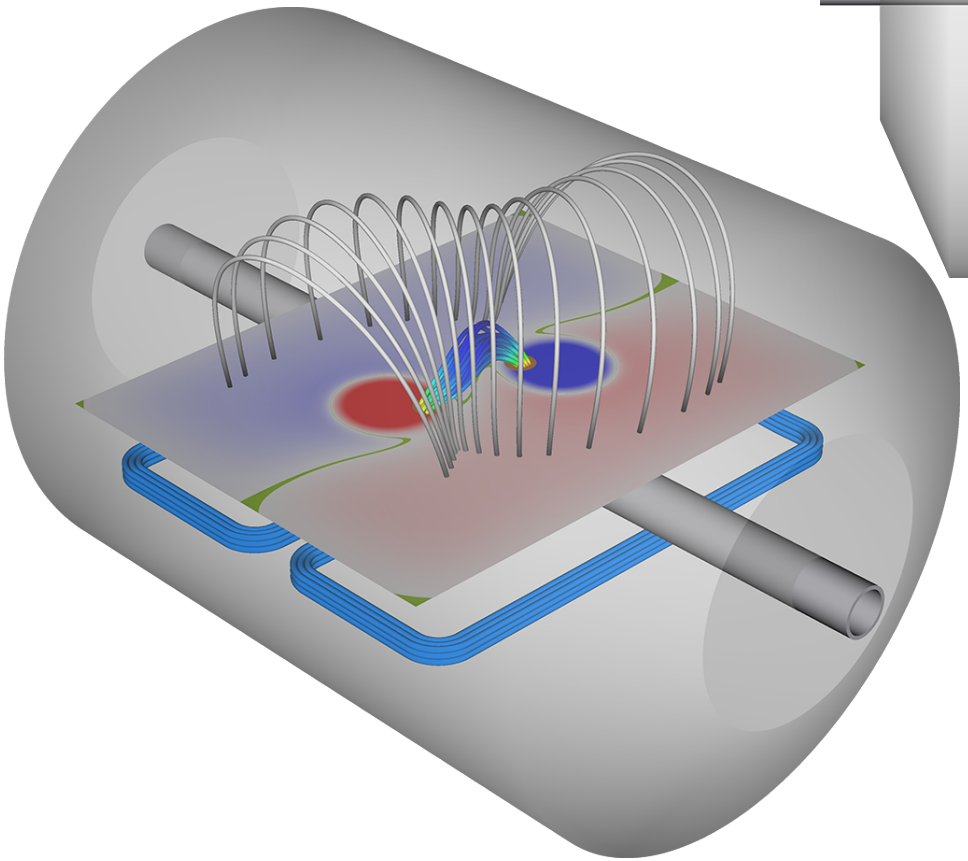
Existing Guide Field (Line Current)

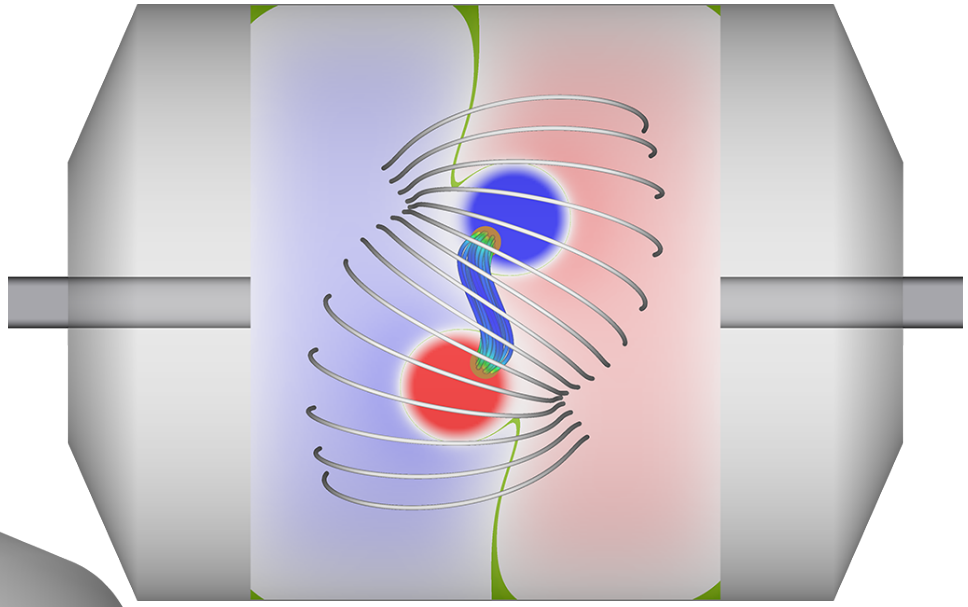


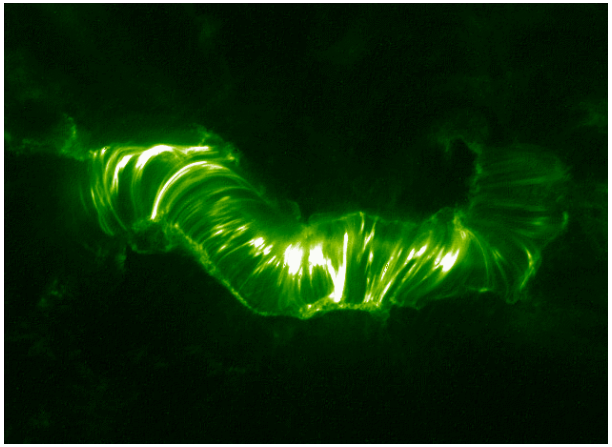
Dipole Coil Guide Field



New active-region-like potential field coils







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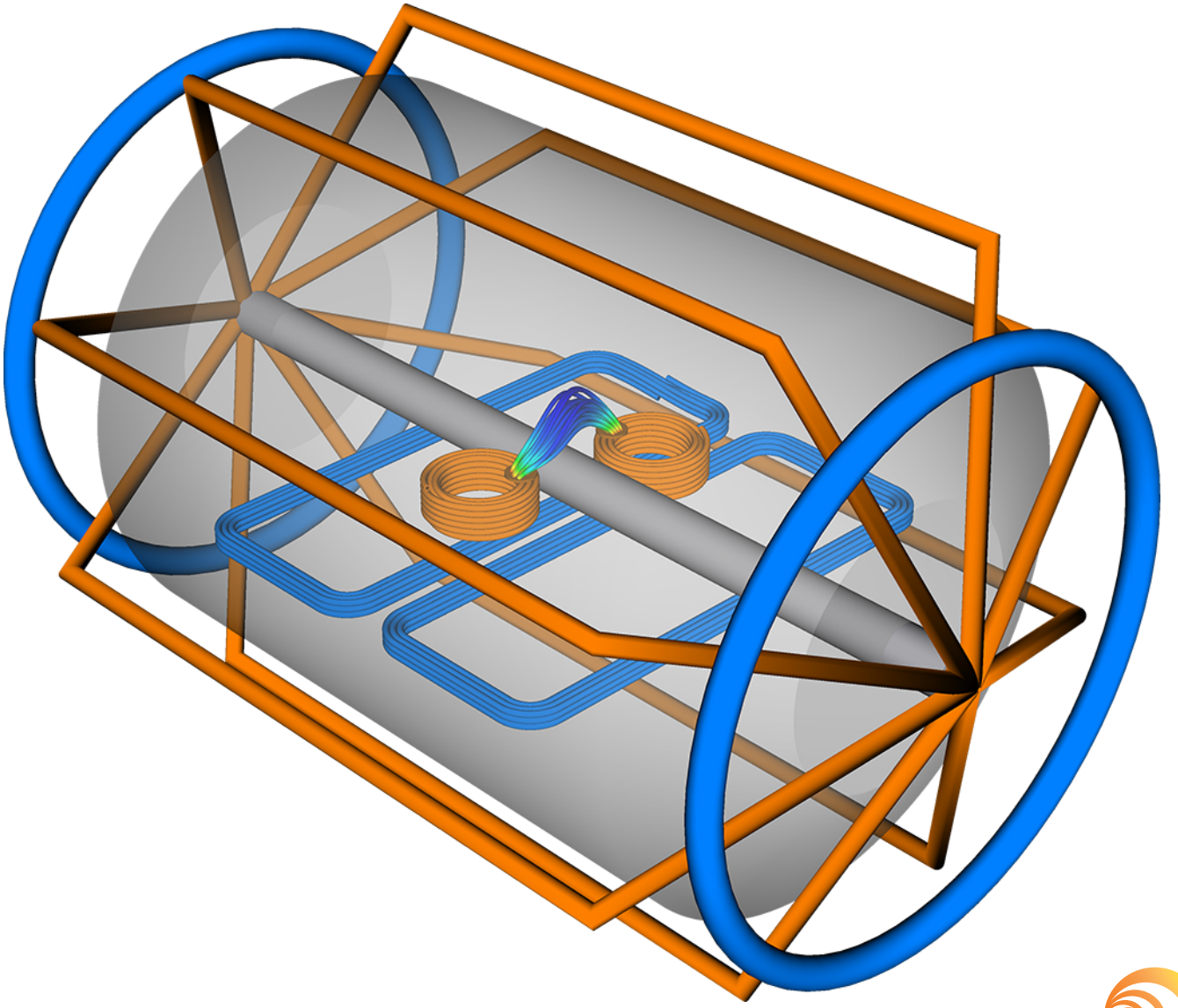
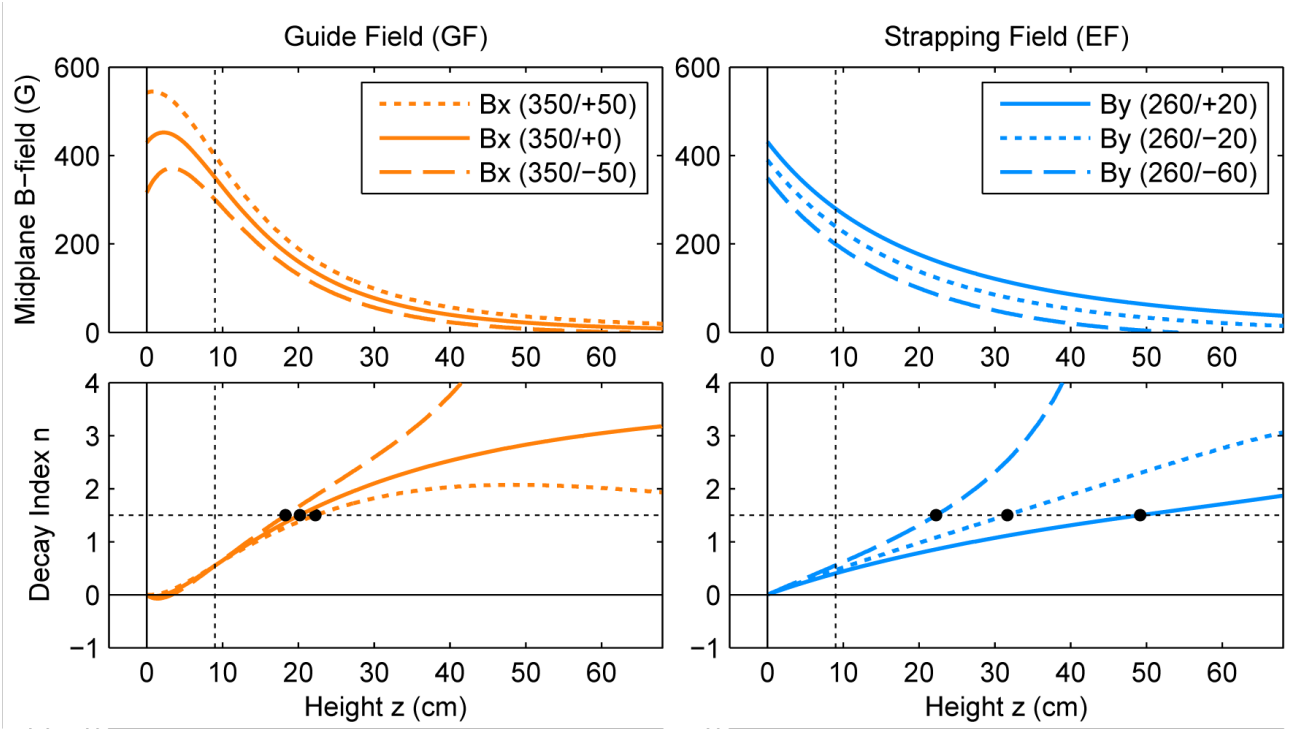


Tuning the field decay index in MRX

- The field decay index profile can be controlled in the new MRX campaign by tuning the currents in the various potential field coils
- We plan to locate and explore the experimental regimes where a loss-of-equilibrium or the torus instability drives a flux rope eruption

$$B(z) = B_0 \left(\frac{z_0}{z} \right)^n$$

$$n(z) = -\left(\frac{z}{B} \right) \frac{dB}{dz}$$



New active-region-like potential field coils