

# Experimental Studies of the Hall Effect in MRX

Y. Ren, M. Yamada, S. P. Gerhardt , A. Kuritsyn,  
H. Ji, R. Kulsrud, M. Inomoto

Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas,  
Princeton Plasma Physics Laboratory

CMSO General Meeting Oct. 5 – Oct. 7, 2005

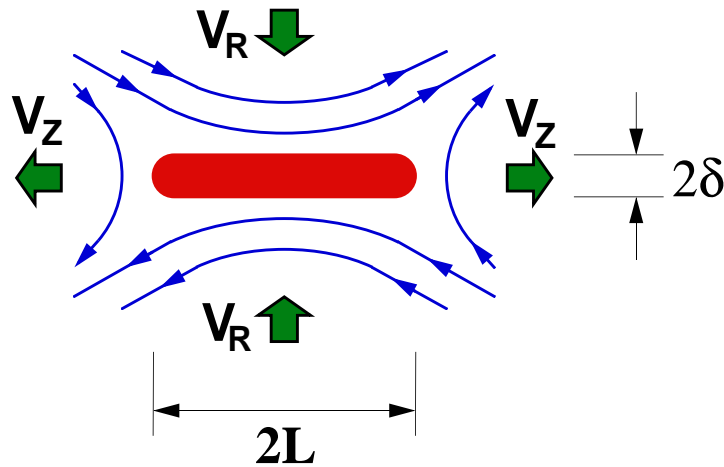
# Outline

---

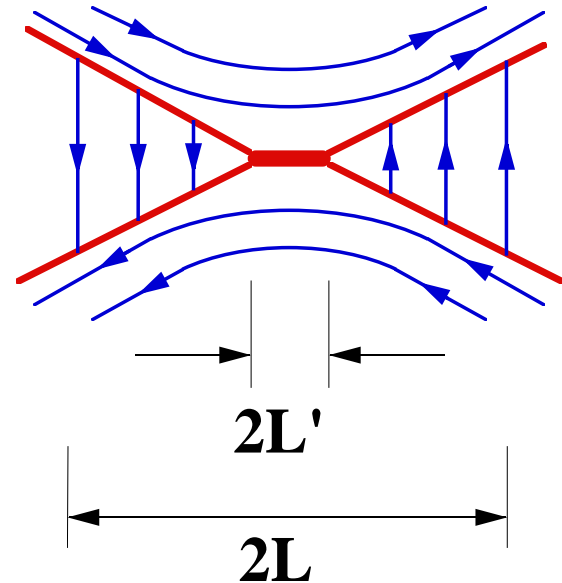
- Quadrupole magnetic field in numerical simulation.
- Experimental verification of the Hall effect during magnetic reconnection in MRX.
- Summary and future work.

# Two Models to Fast Magnetic Reconnection

---

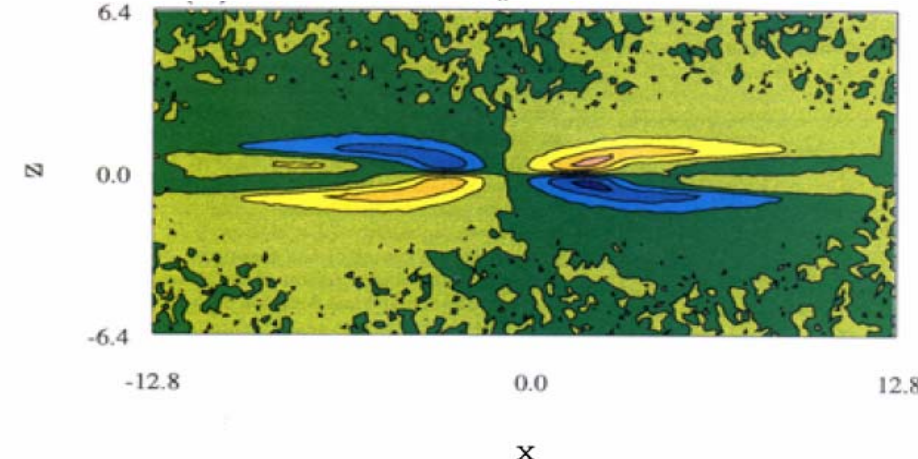
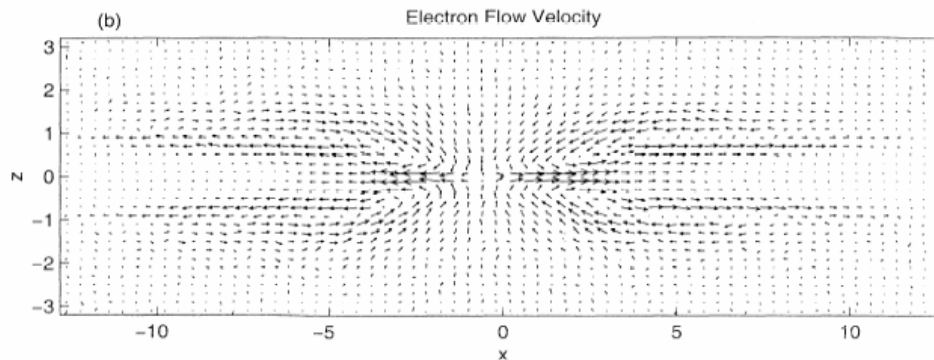
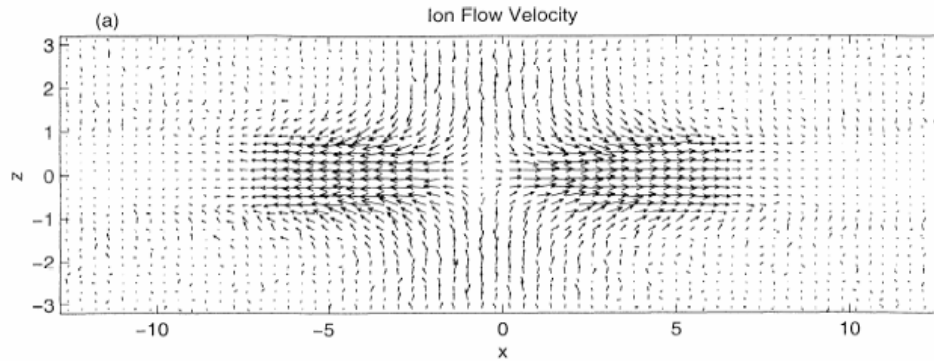


Generalized Sweet-Parker model with anomalous resistivity.

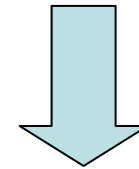


Two-fluid MHD model in which electrons and ions decouple in the diffusion region ( $\sim c/\omega_{pi}$ )

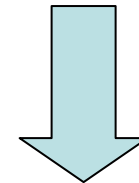
# The Hall Effect During Reconnection Shown in 2D Simulation



Different motions of ions and electrons



In-plane current

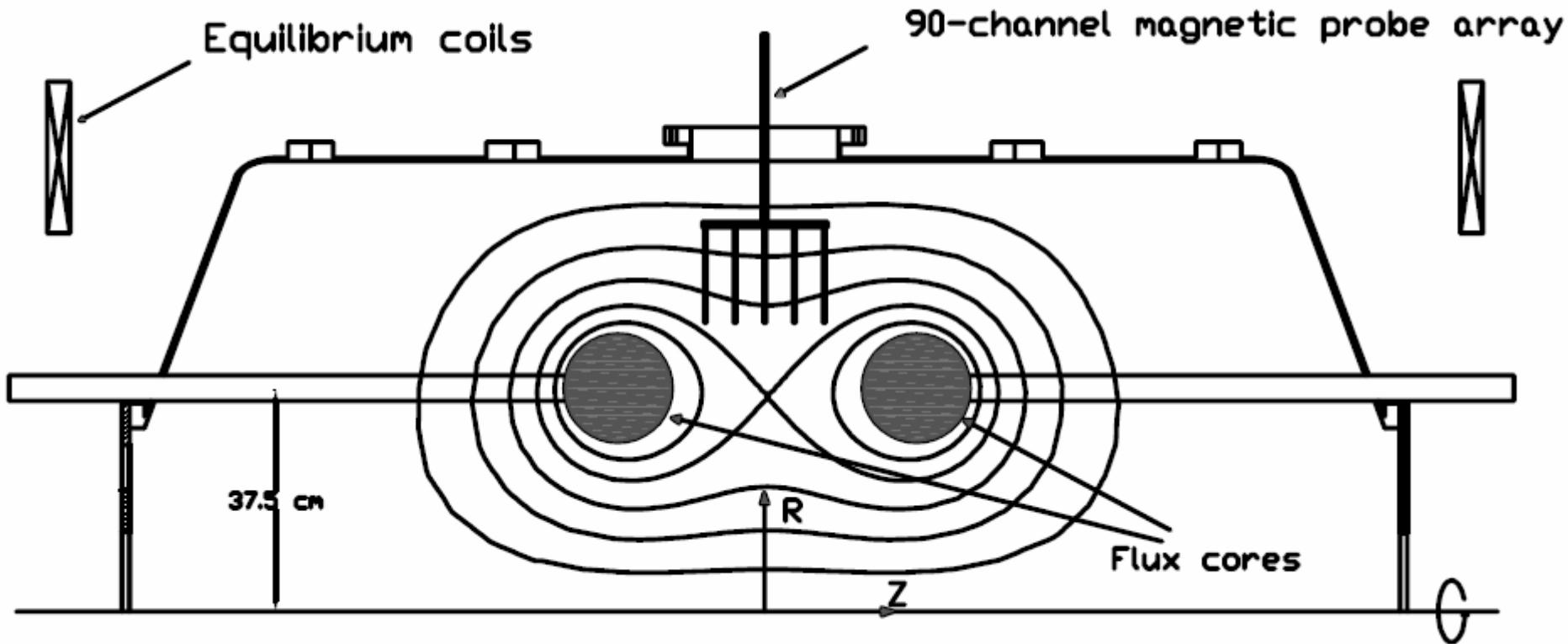


A quadrupole out-of-plane magnetic field

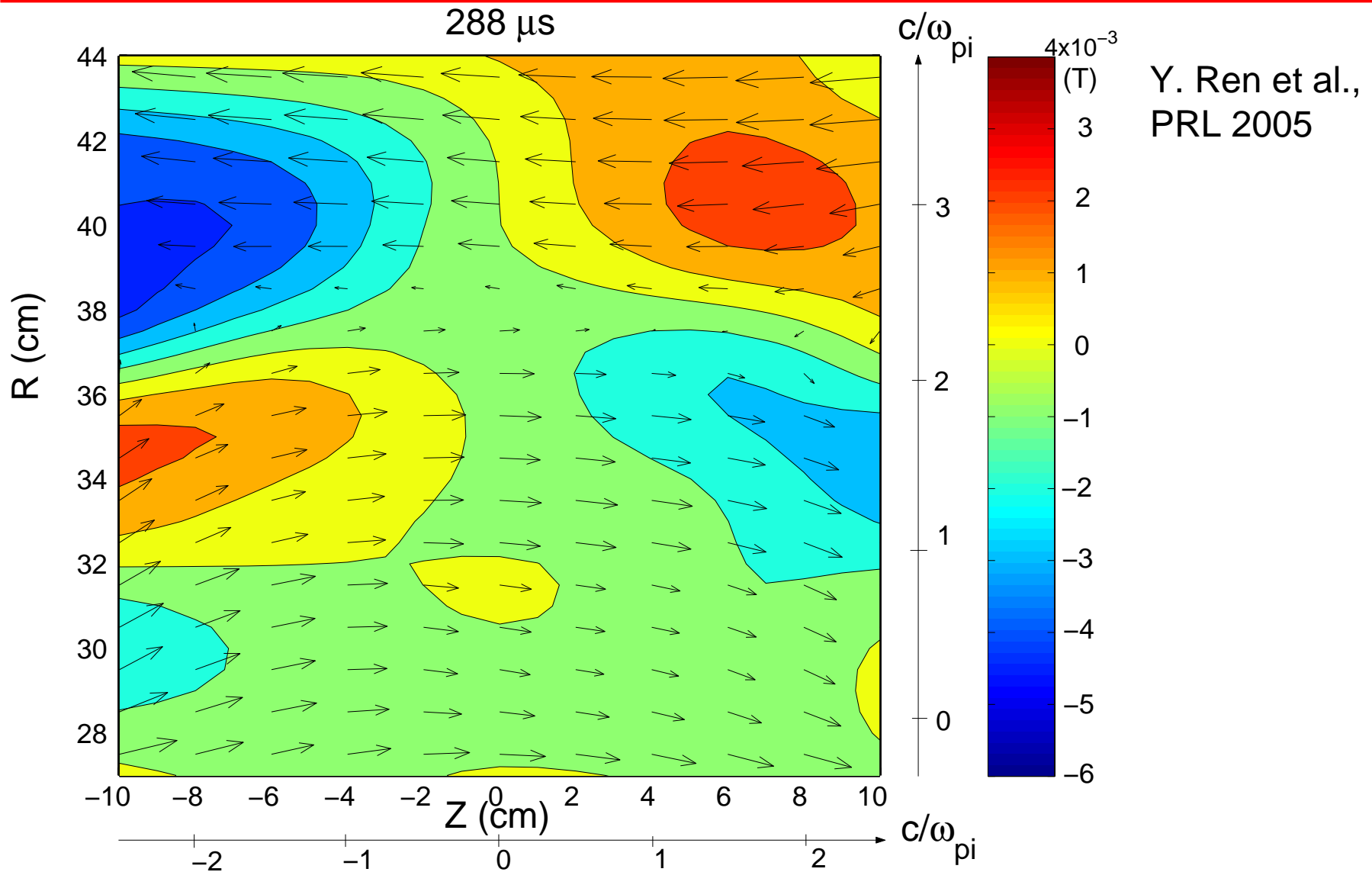
**Can the Hall effect be observed in a laboratory plasma?**

# MRX Upgraded

---

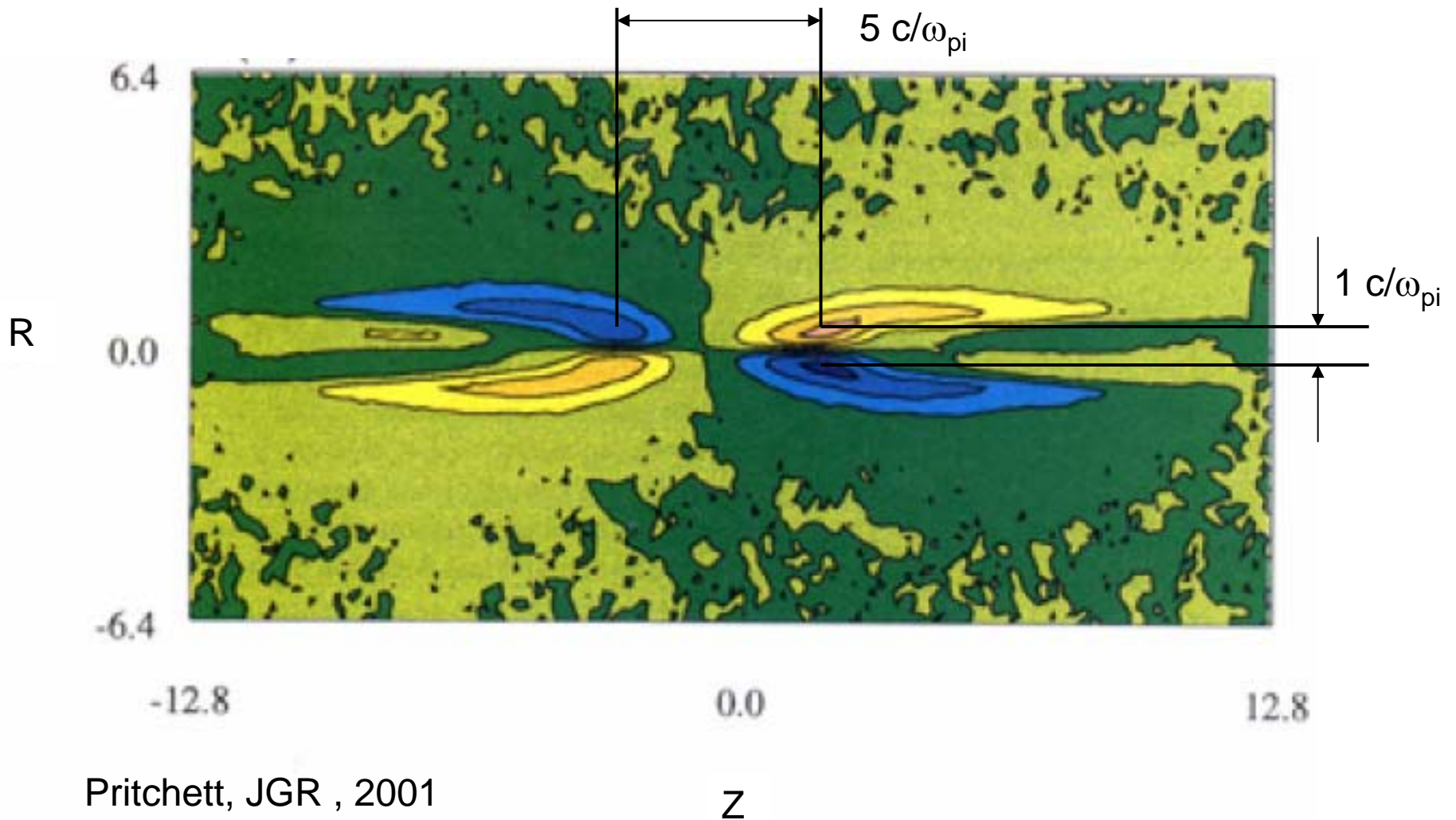


# Quadrupole Magnetic Field is Observed during Magnetic Reconnection



# Experimental Results Agree with Numerical Simulation

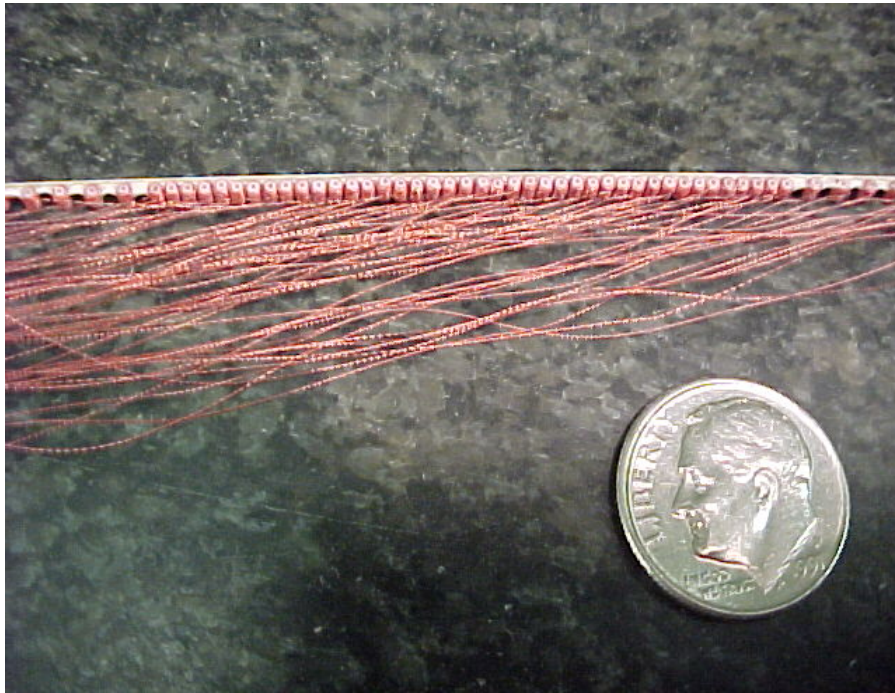
---



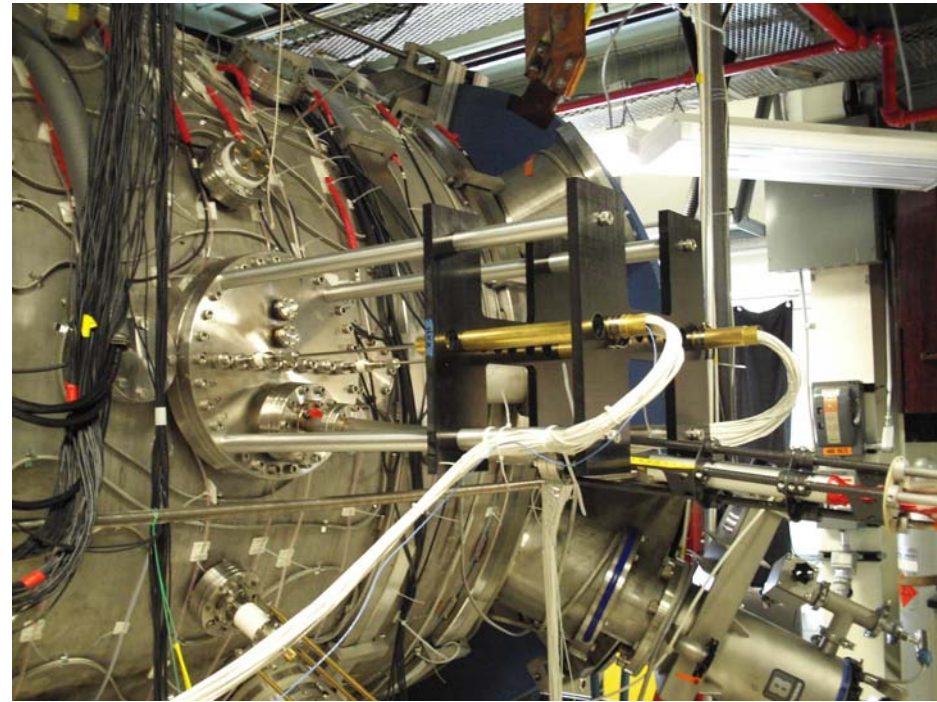
Pritchett, JGR , 2001

# Three Fine Magnetic Probe Arrays are Used to Study the Hall Effect

D. Cylinder and Y. Ren



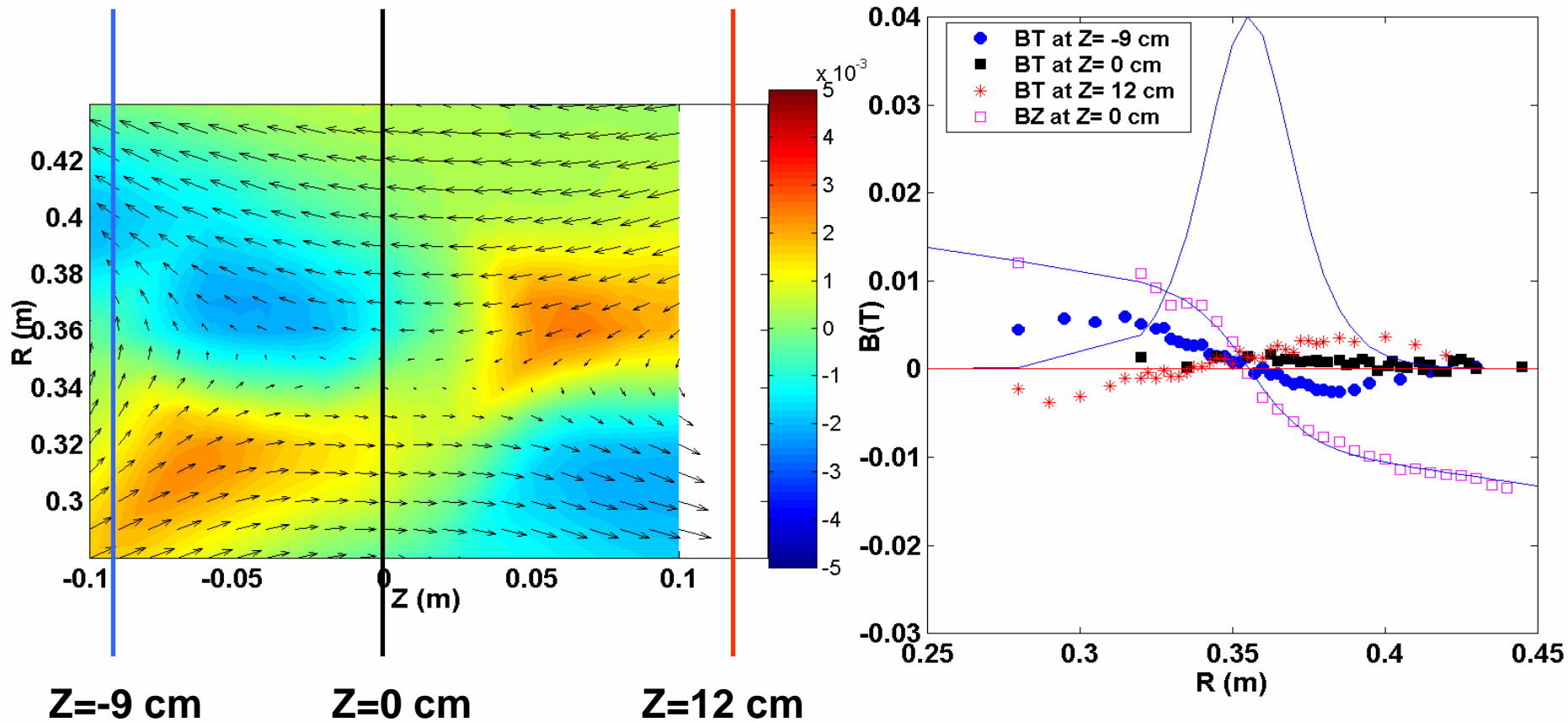
The small coils are glued to an alumina rod.



Three fine magnetic probe arrays with spatial resolution up to 1.25 mm.

# Quadrupole Magnetic Field is Measured with High Spatial Resolution at Three Locations

Shot=47810, Helium, Fill Pressure=6.7mTorr,  $t=320.8 \mu\text{s}$

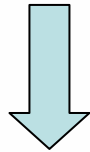


# The Hall Term is Important in Balancing the Reconnection Electric Field

Shot=47810, Helium, Fill Pressure=6.7mTorr, t=320.8  $\mu$ s

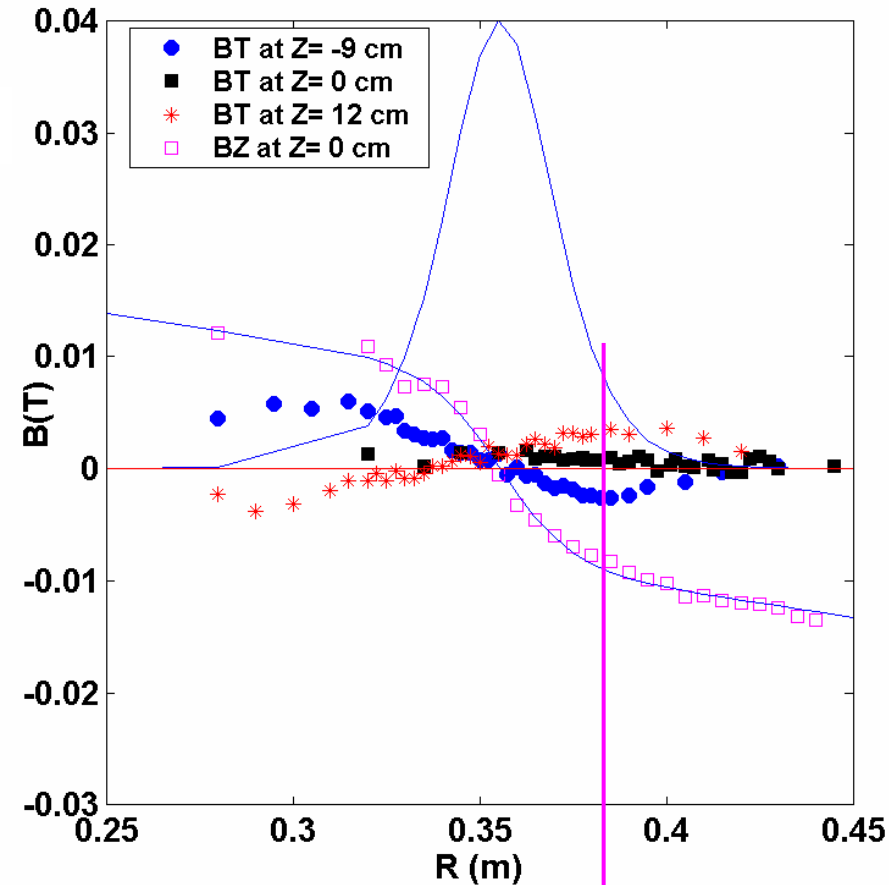
$$\mathbf{E} + \mathbf{V} \times \mathbf{B} = \eta \mathbf{j} + \frac{\mathbf{j} \times \mathbf{B}}{en} - \frac{\nabla \cdot \mathbf{P}_e}{en}$$

$n \sim 2 \times 10^{13} \text{ cm}^{-3}$ ,  $j_r \sim 20 \text{ kA m}^{-2}$ ,  $B_z \sim 100 \text{ G}$



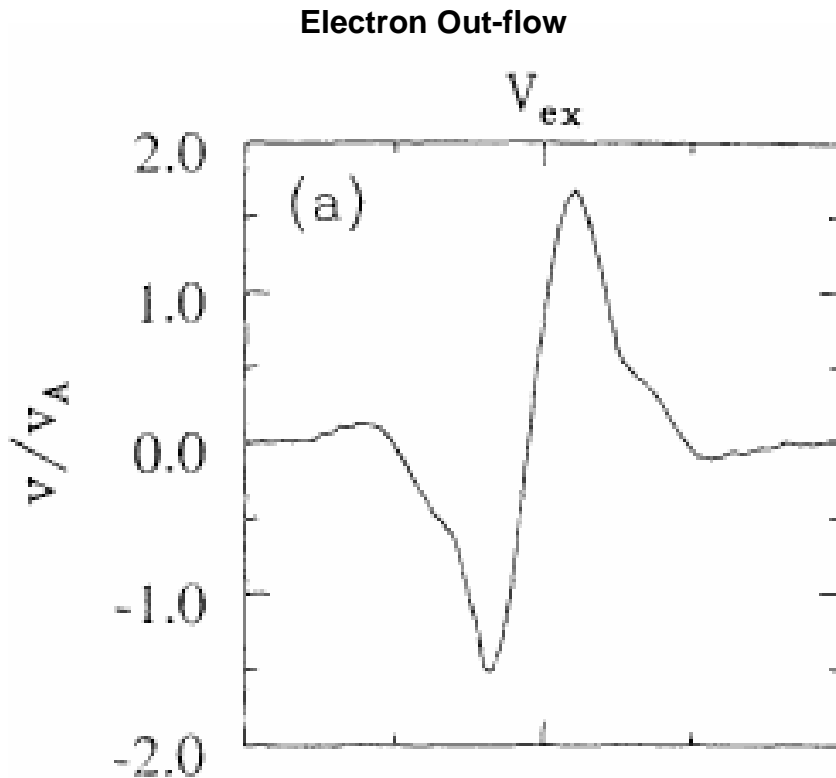
$$\mathbf{j}_r \times \mathbf{B}_z / (en) \sim 60 \text{ V/m}$$

$$\mathbf{E}_t \sim 80 \text{ V/m}$$



# The Electron Out-flow is Alfvénic

Pritchett, JGR , 2001

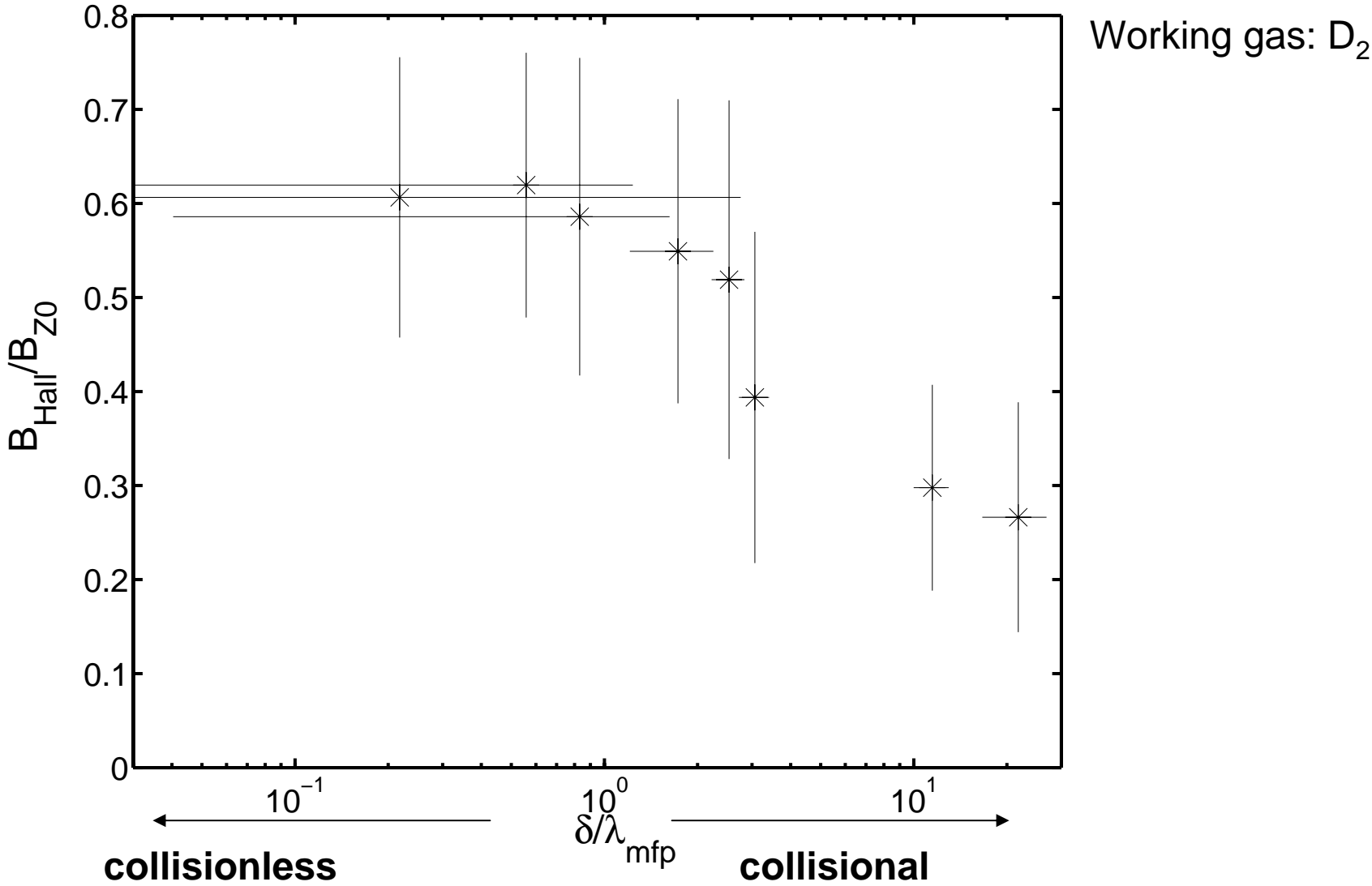


(1)  $V_{xe}/V_A \sim 1.5$  in numerical simulation.

(2)  $j_Z \sim 90 \text{ kA/m}^2$ ,  
 $v_{Ze} = j_Z/(en)$ ,  
 $n \sim 2 \times 10^{13} \text{ cm}^{-3}$ ,  
 $v_{Ze} \sim 28 \text{ km/s}$   
 $v_A \sim 24 \text{ km/s}$

**$V_{ze}/V_A \sim 1.2$  from measurement.**

# The Hall Effect is More Pronounced in Collisionless Region



# Summary and Future Work

---

- The quadrupole magnetic field is observed during magnetic reconnection in MRX.
- Good agreement is found between experiment and simulation.
- The future work
  - Study the relation between the Hall effect and fluctuations.
  - Study the Hall effect and reconnection rate.