Ferromagnetism near three-quarters filling in twisted bilayer graphene

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arXiv: 1901.03520

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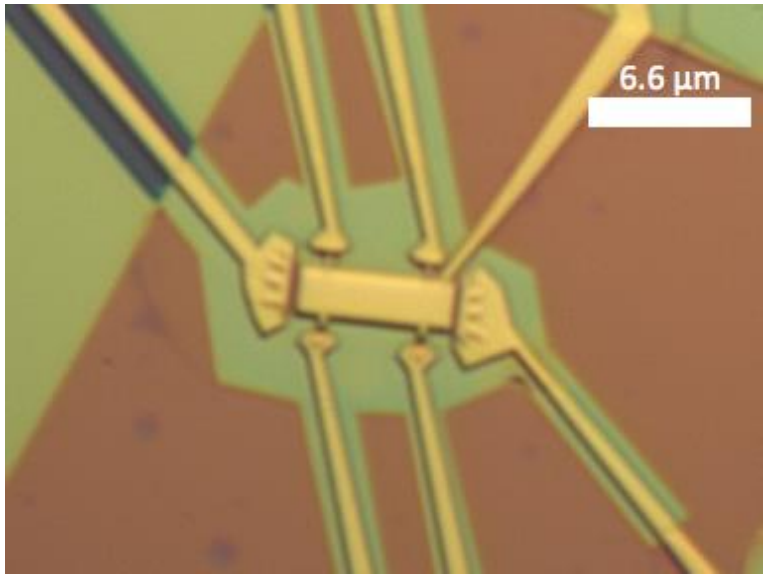
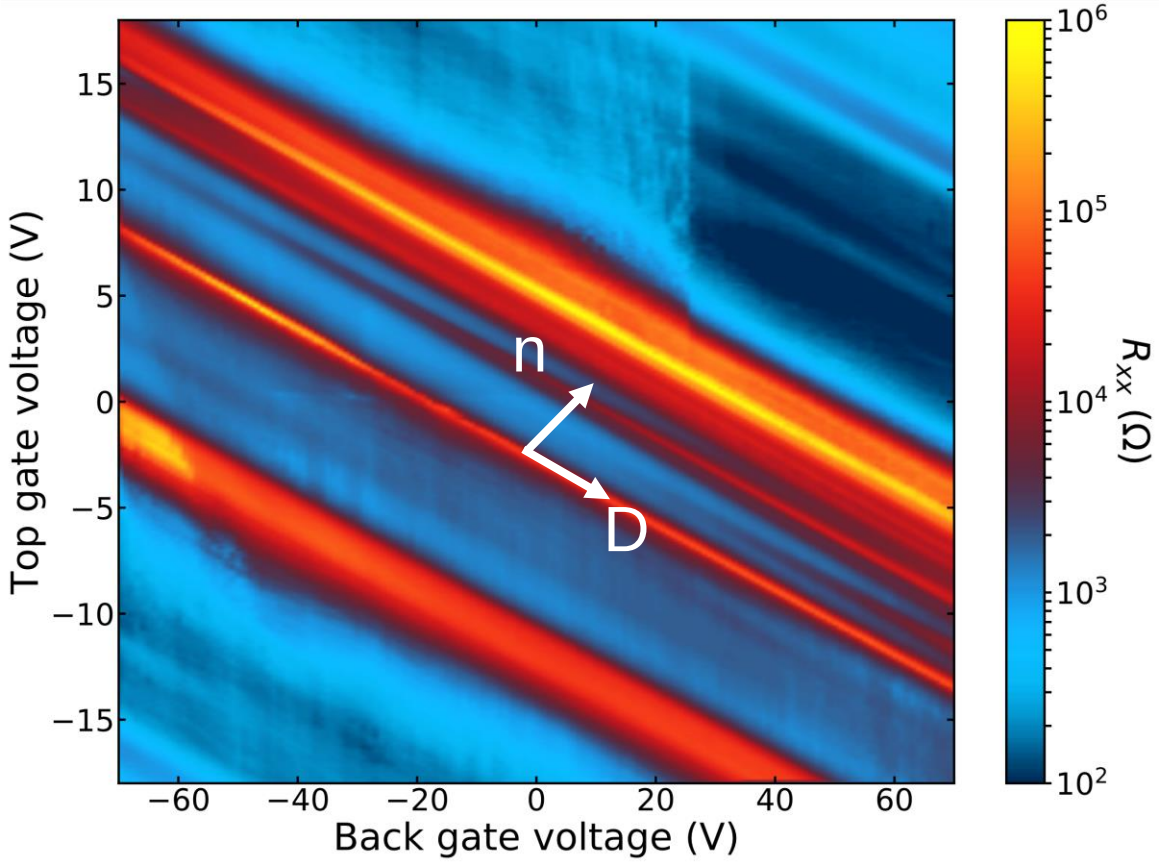
Strong Correlations: Twisted bilayer near magic angle

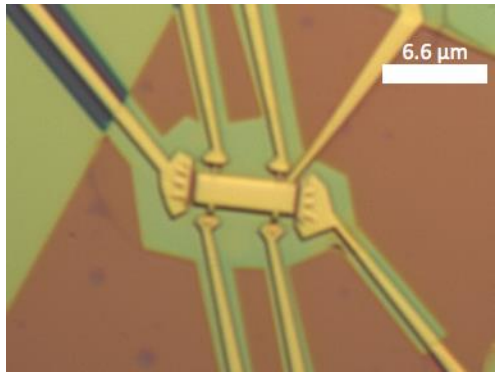




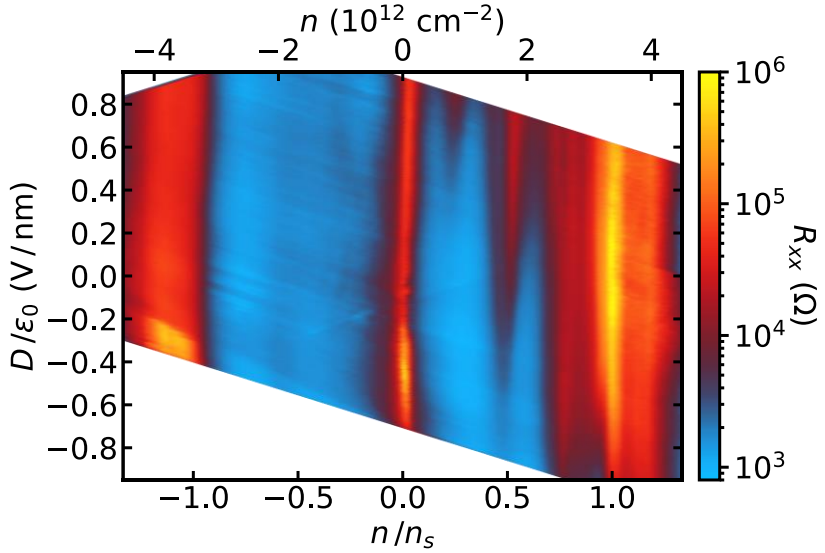
Angle 1.20+/-0.01°. Target 1.17°

Impact of Alignment with hBN

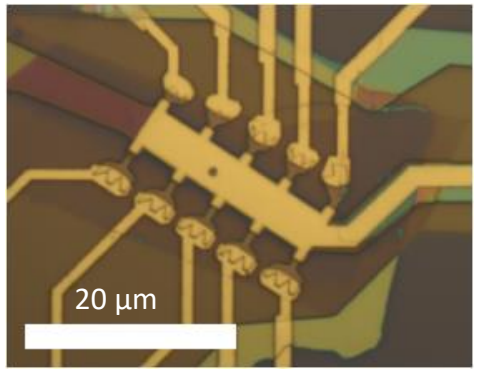
Device 1: ferromagnetic sample
w/ aligned hBN



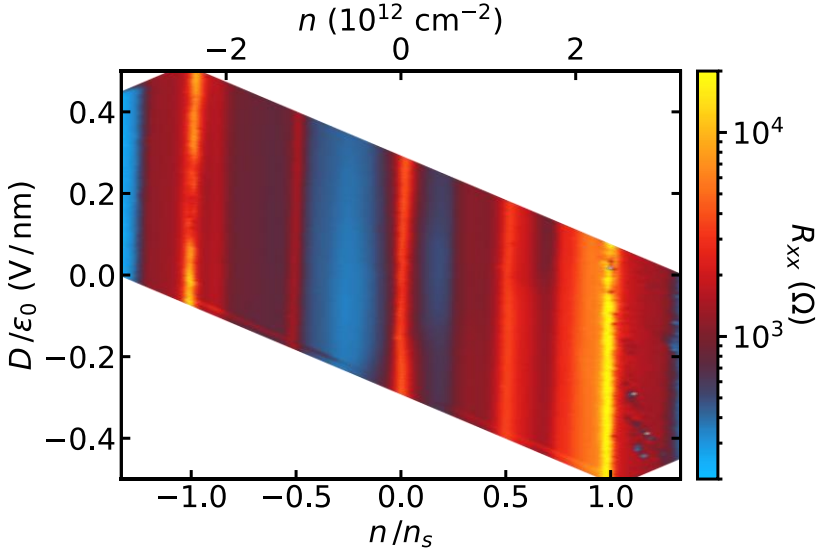
Graphene twist: 1.20 +/- 0.01°
Twist to one hBN: 0.81° +/- 0.02°



Device 2: superconducting sample
w/ misaligned hBN

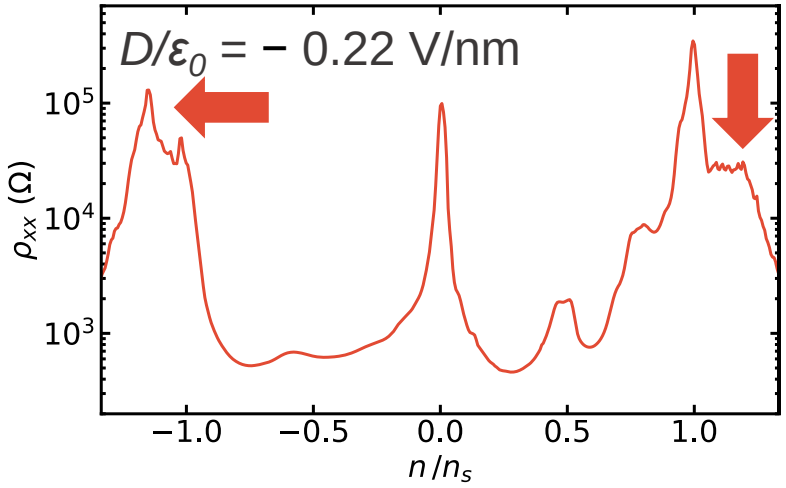


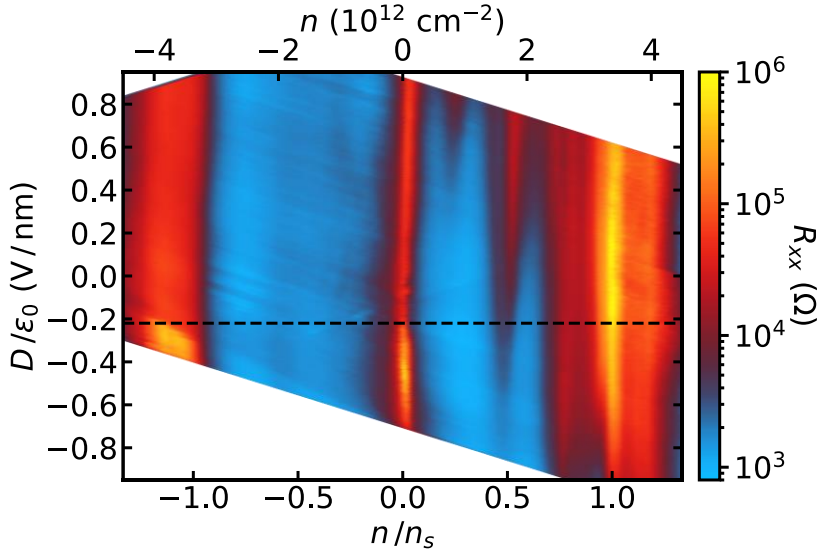
Graphene twist: 1.05 +/- 0.01°
Twist to hBN: large



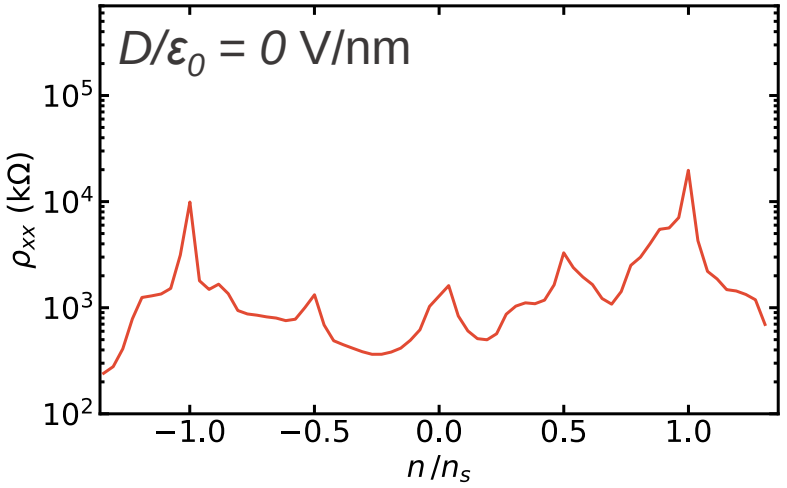
Impact of Alignment with hBN

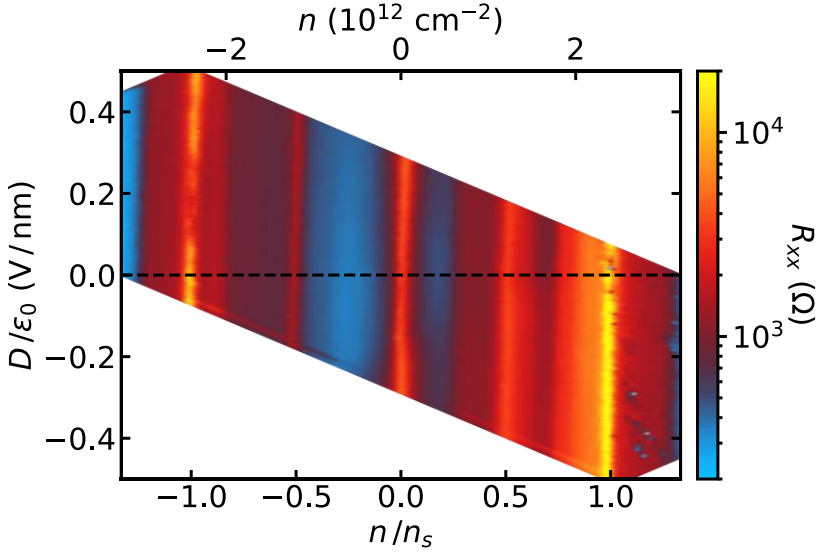
Device 1: ferromagnetic sample
w/ aligned hBN





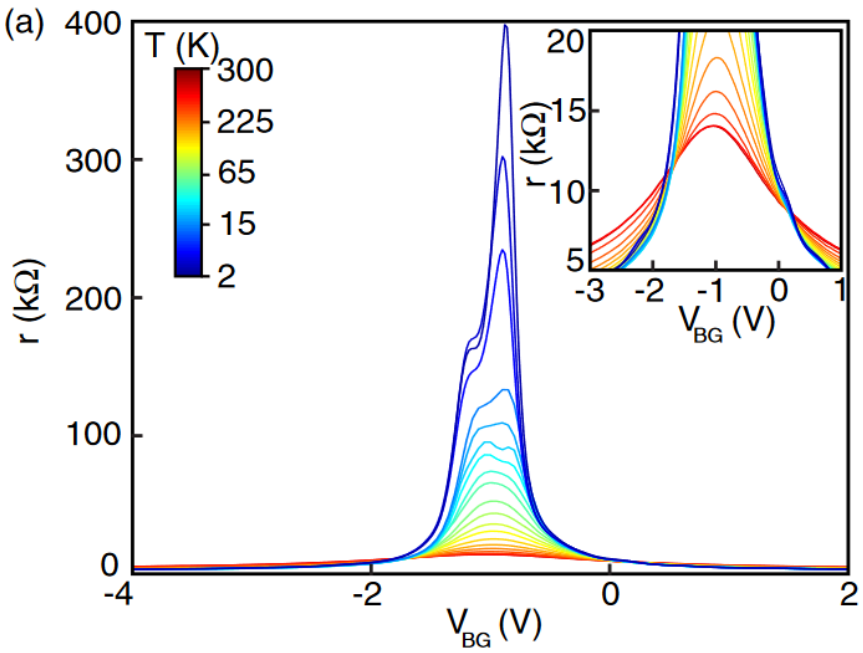
Device 2: superconducting sample
w/ misaligned hBN





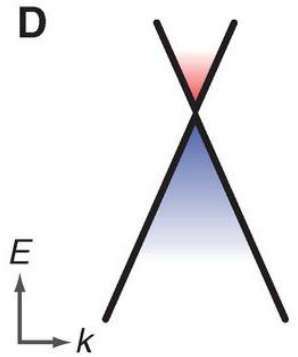
Alignment with hBN

Opens a gap at charge neutrality

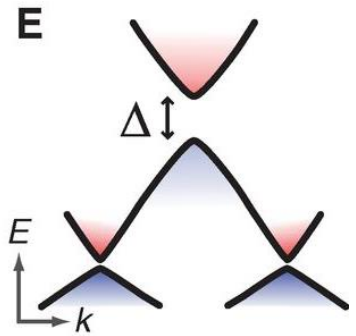


Amet, *PRL* (2013)
Hunt, *Science* (2013)

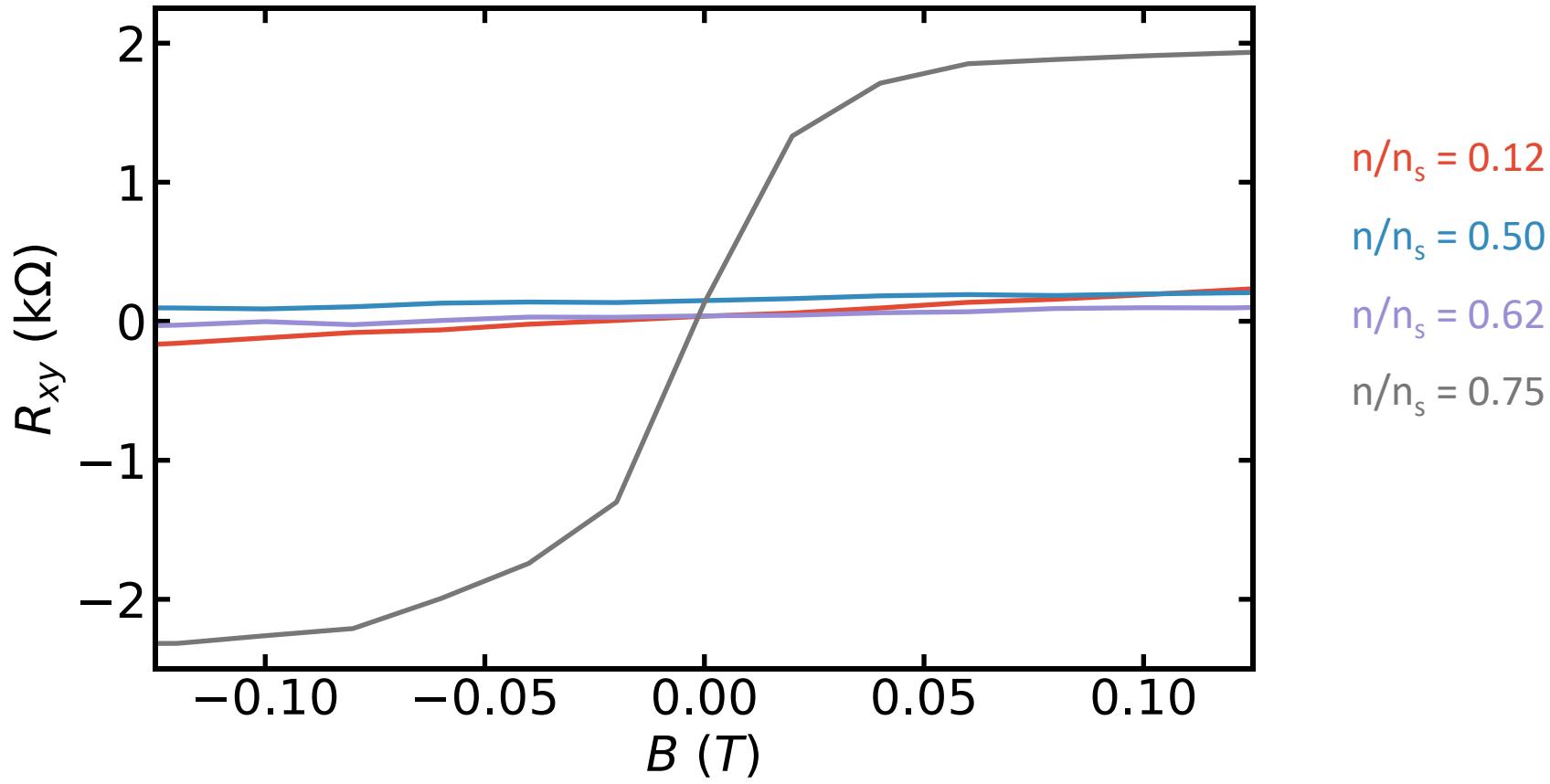
Monolayer graphene



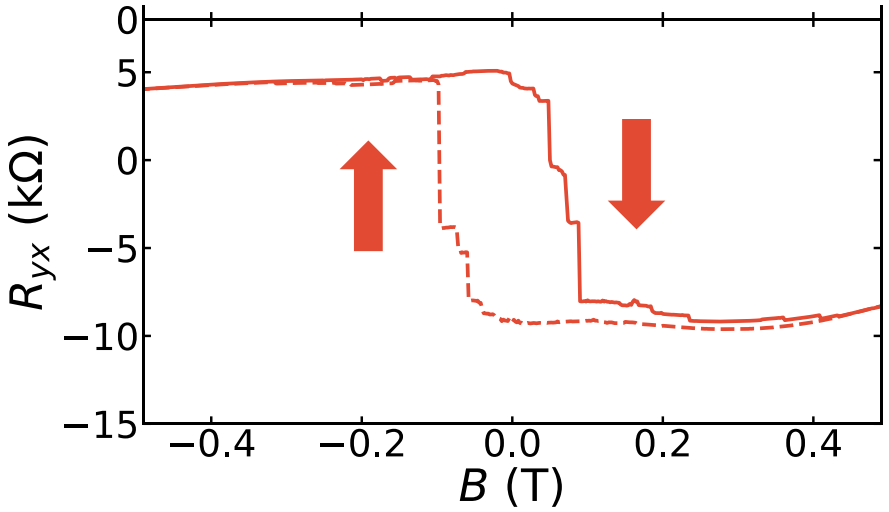
Monolayer graphene + hBN

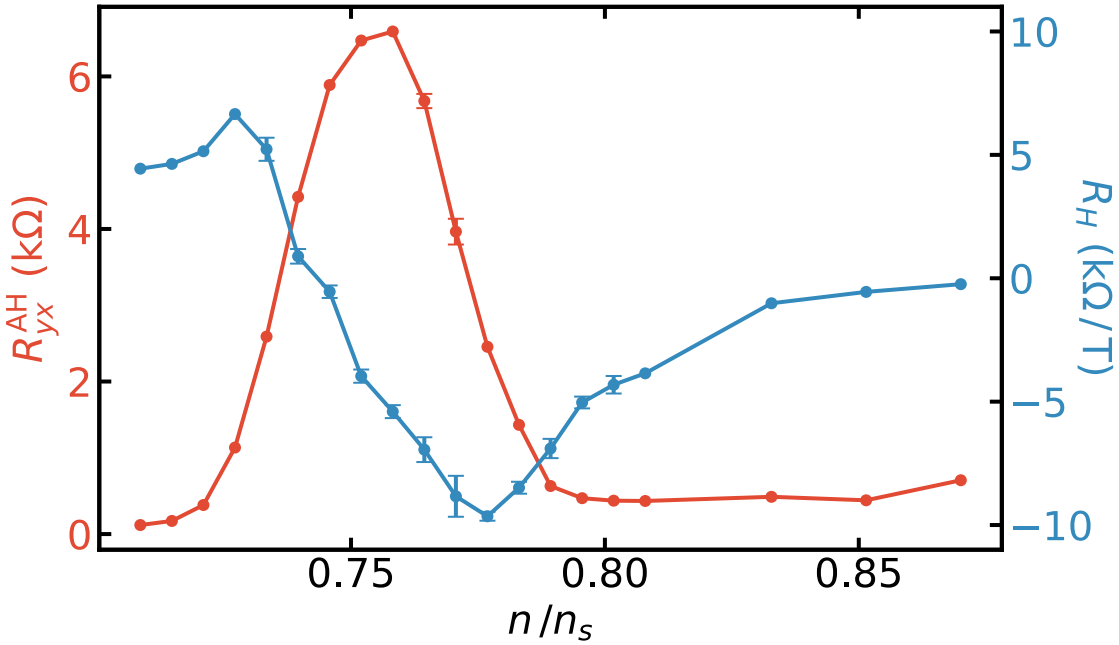


Measuring Hall Slope Density Dependence

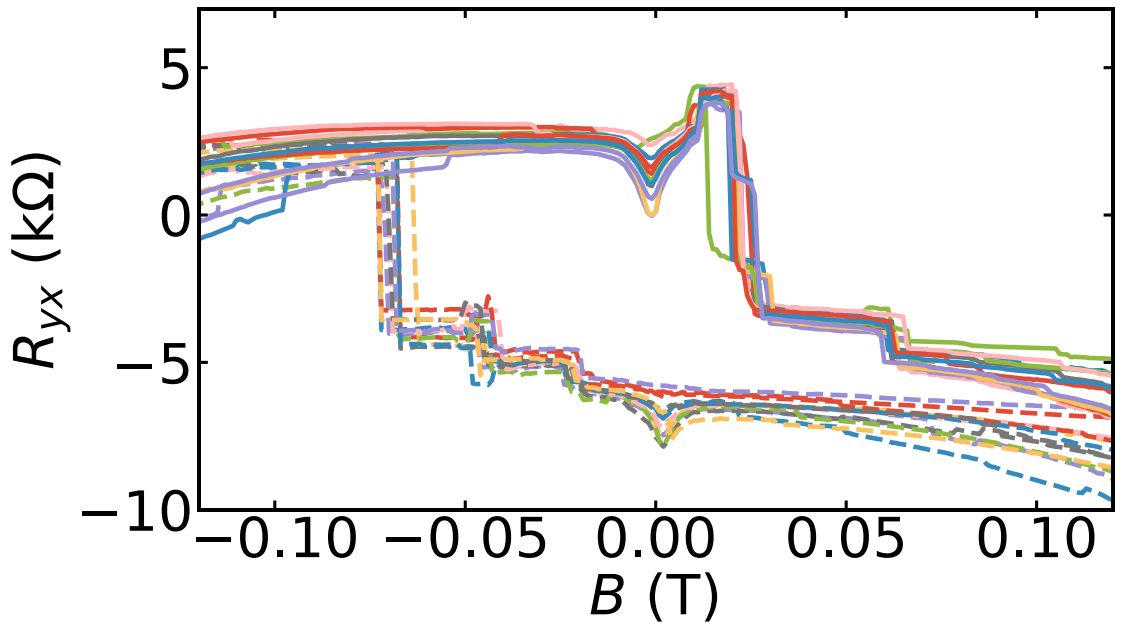


Emergent Ferromagnetism at ¾ Filling

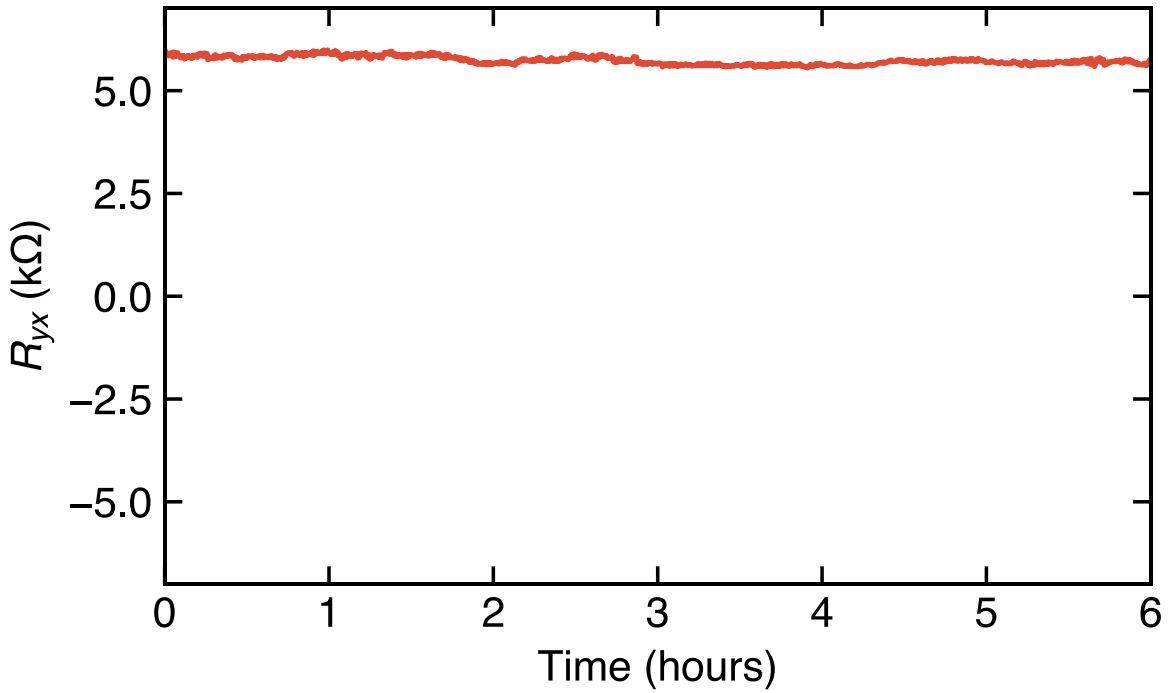


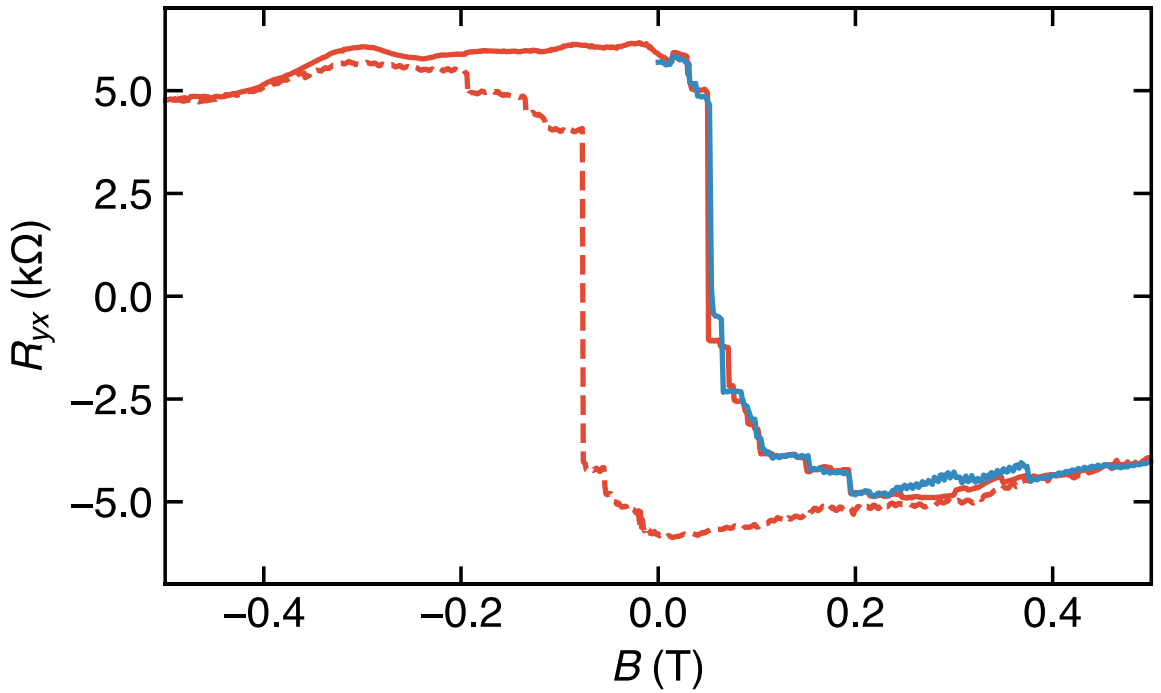


Repeatable Hysteresis Fine Structure in Field

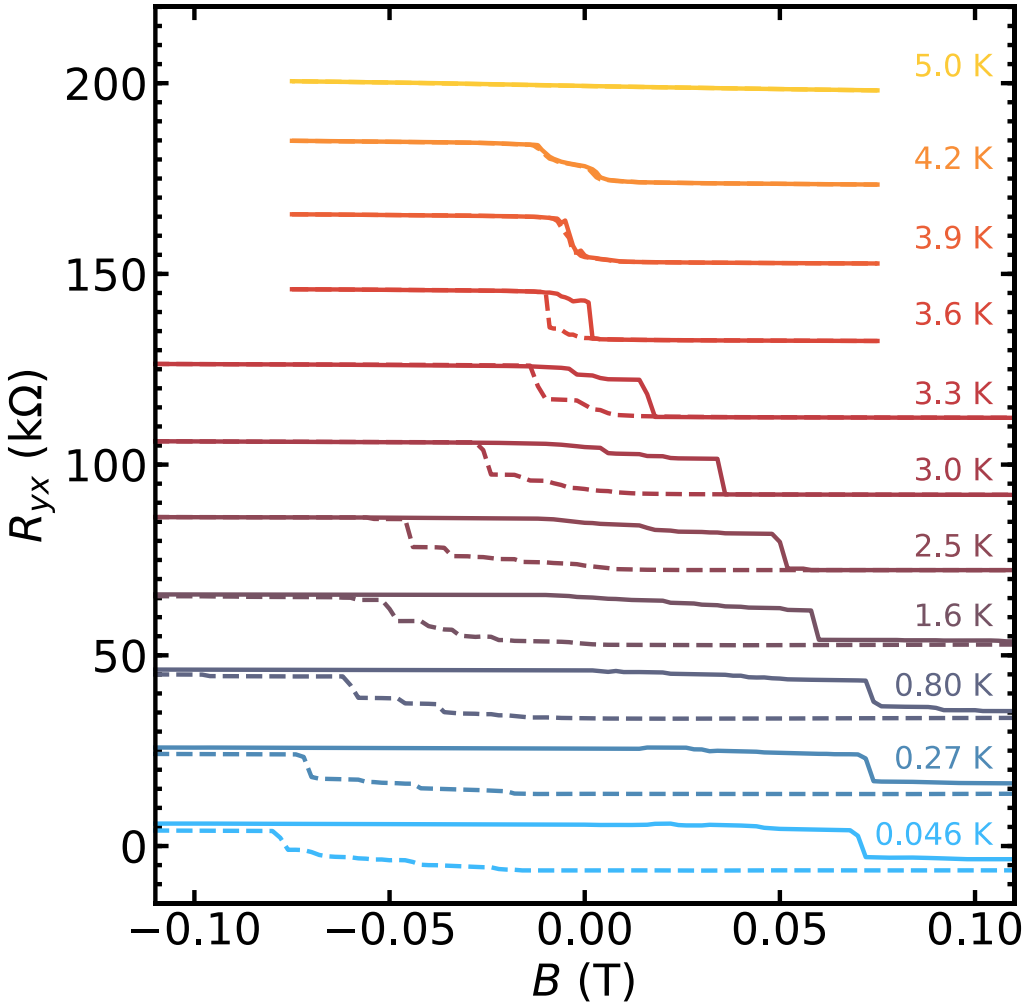


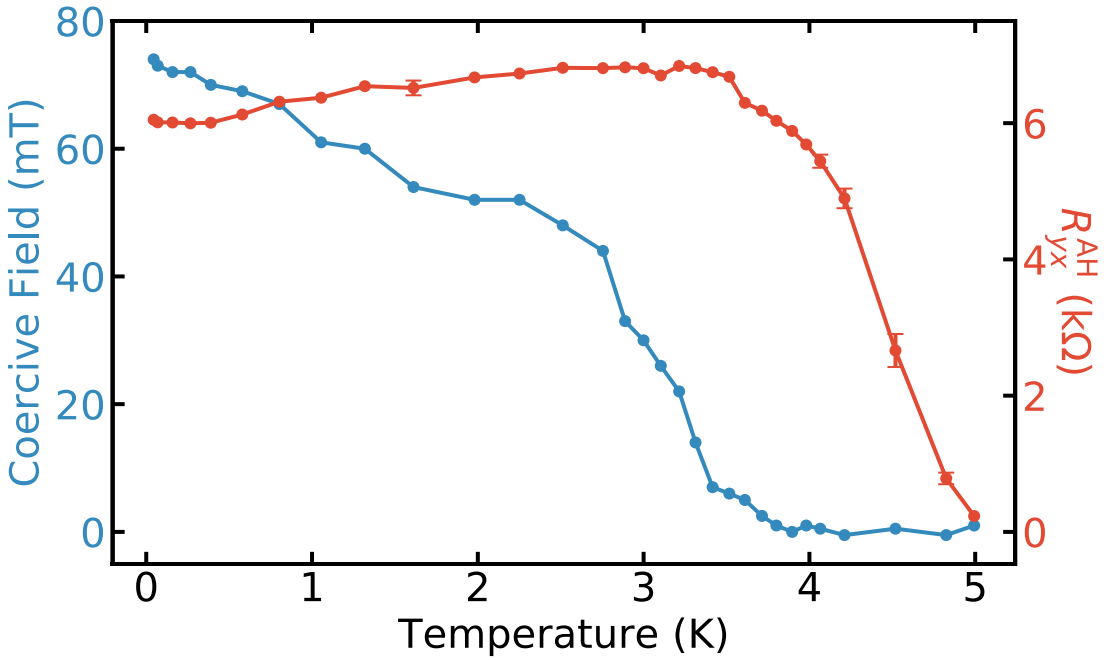
Magnetism is Stable with No Applied Field



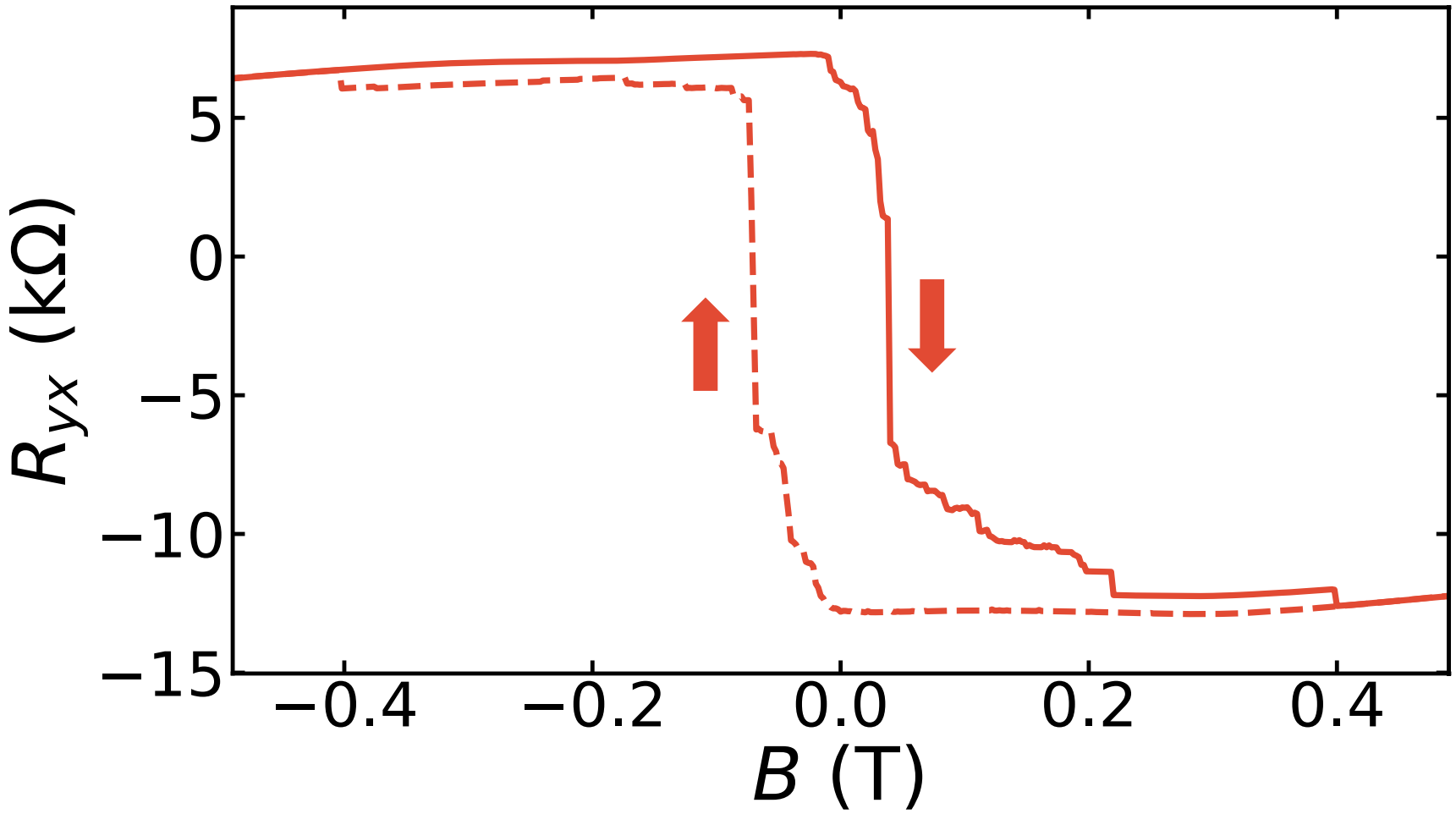


Temperature Dependence of Ferromagnetism at ¾ Filling





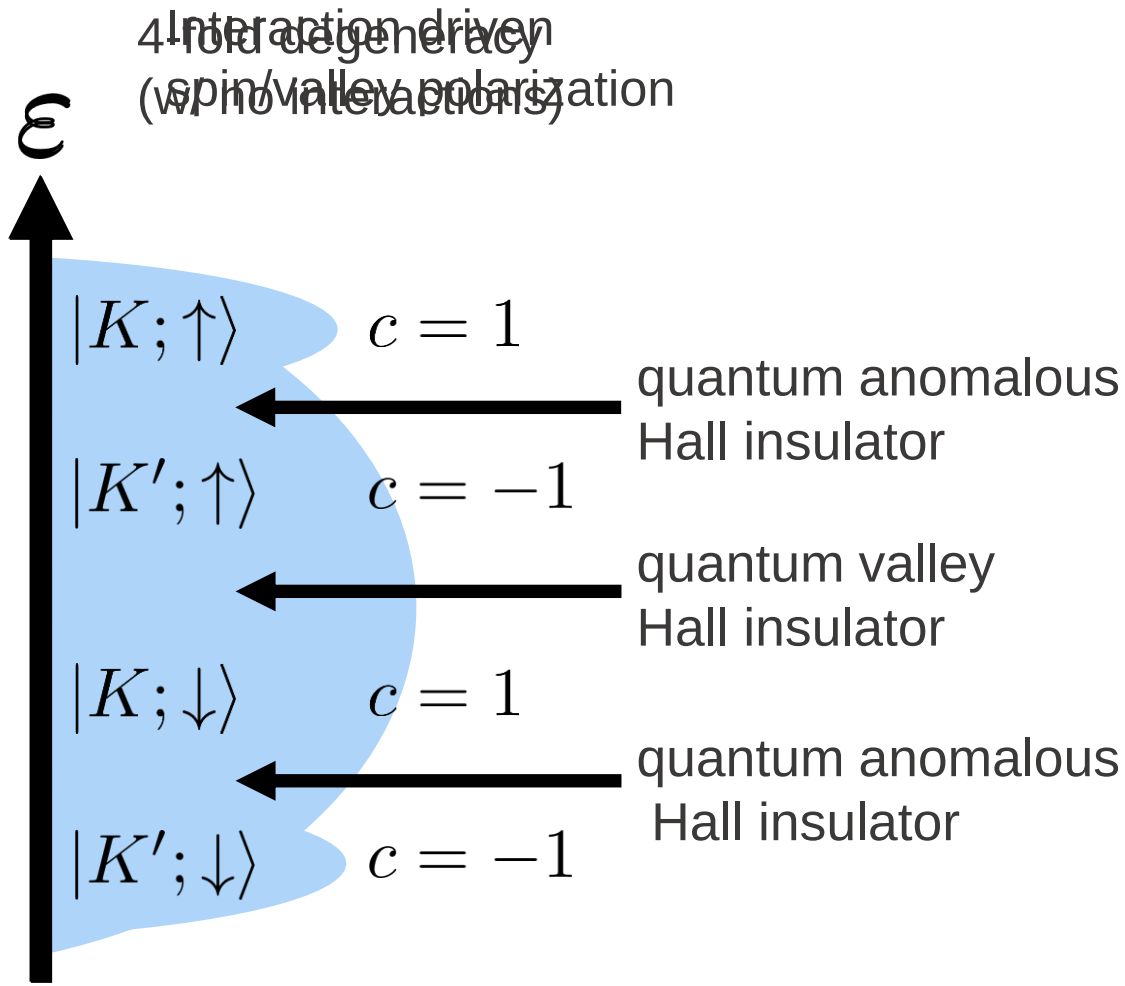
Anomalous Hall Signal Can Be Really Large!



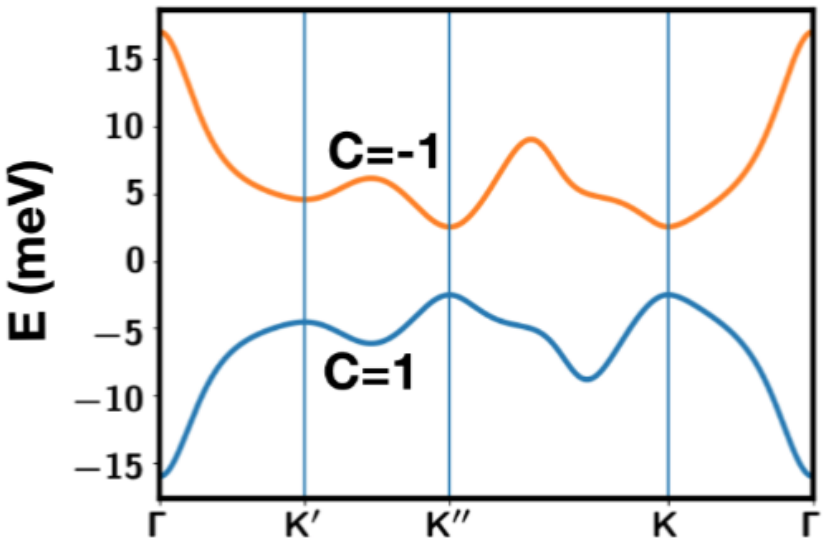
n/n_s=0.775, T=2.1K

Nature of Emergent Ferromagnetism at ¾ Filling?

Simplistic band diagram: what *might* be happening…



Twisted bilayer graphene + hBN

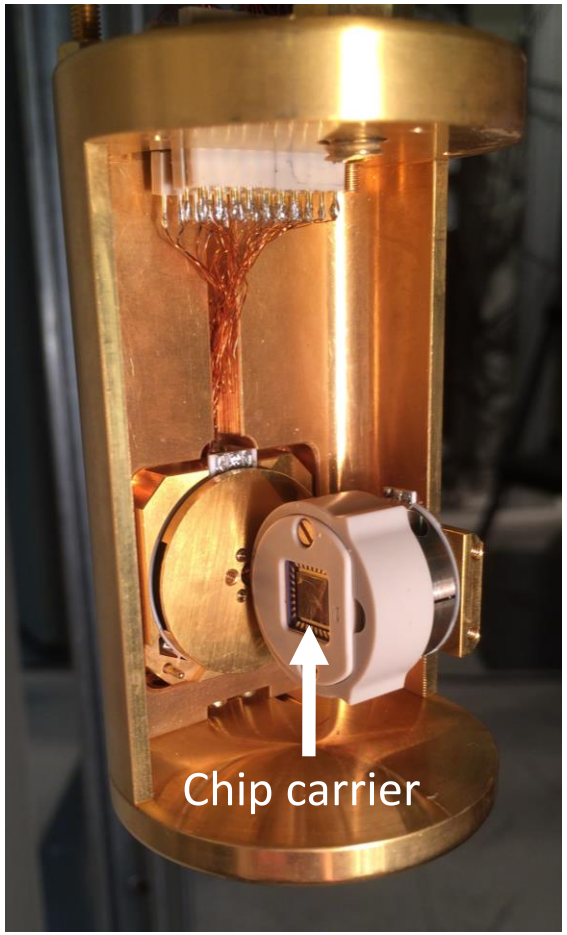


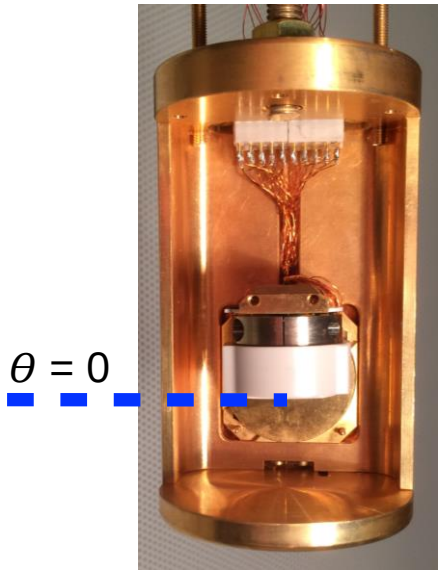
Zhang, *arXiv:1901.08209*
Bultinck, *arXiv:1901.08110*

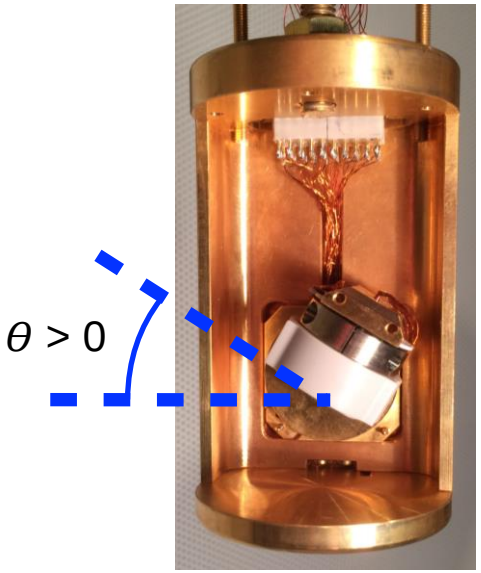
Gap may open spontaneously:
Xie, *arXiv:1812.04213*

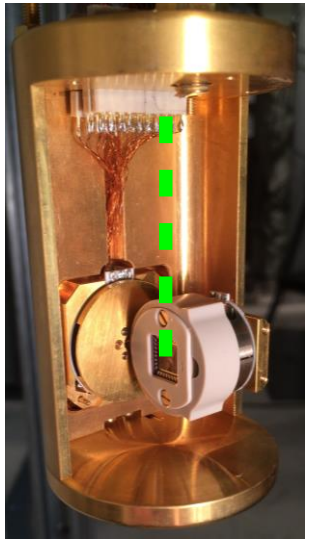
Probing nature of magnetism

Two-axis rotator for tilted field (Attocube)

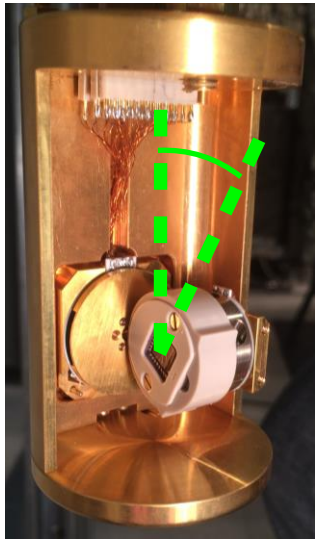






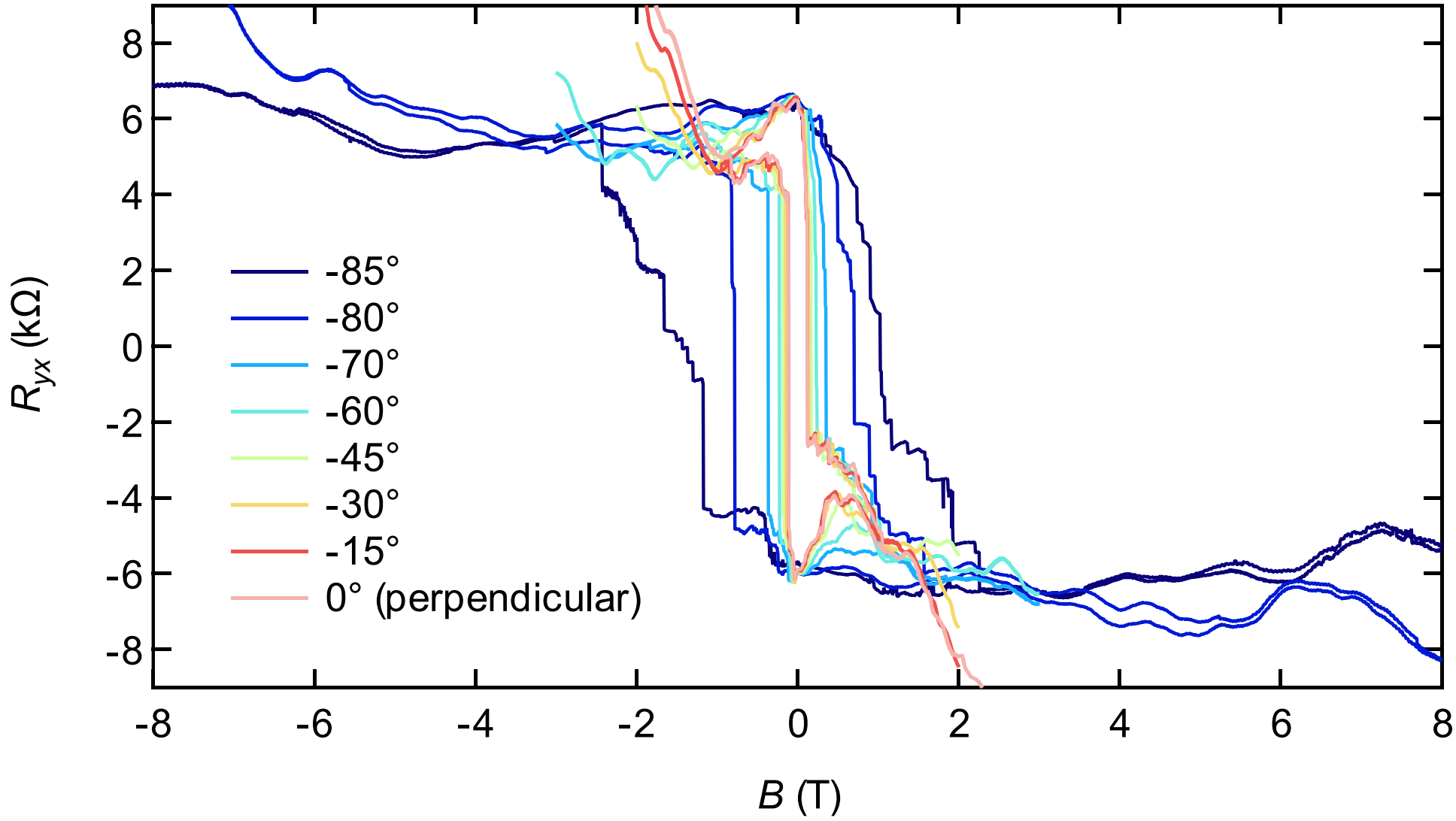


φ = 0



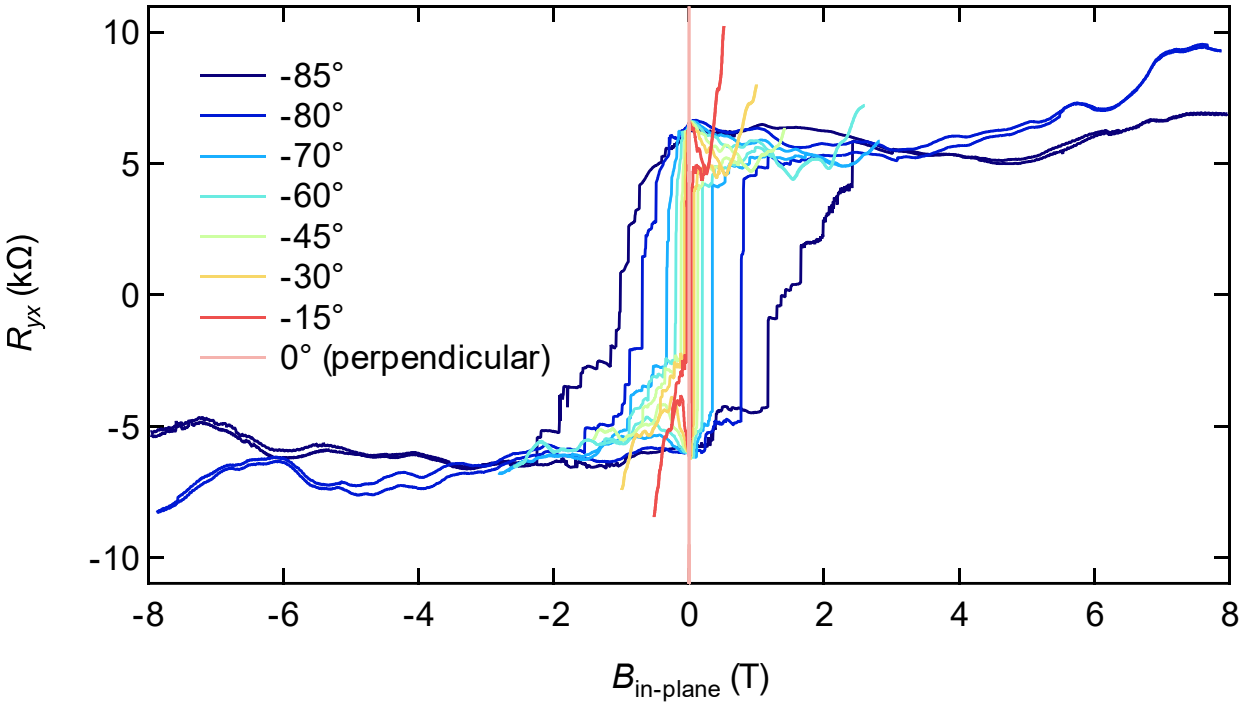
φ > 0

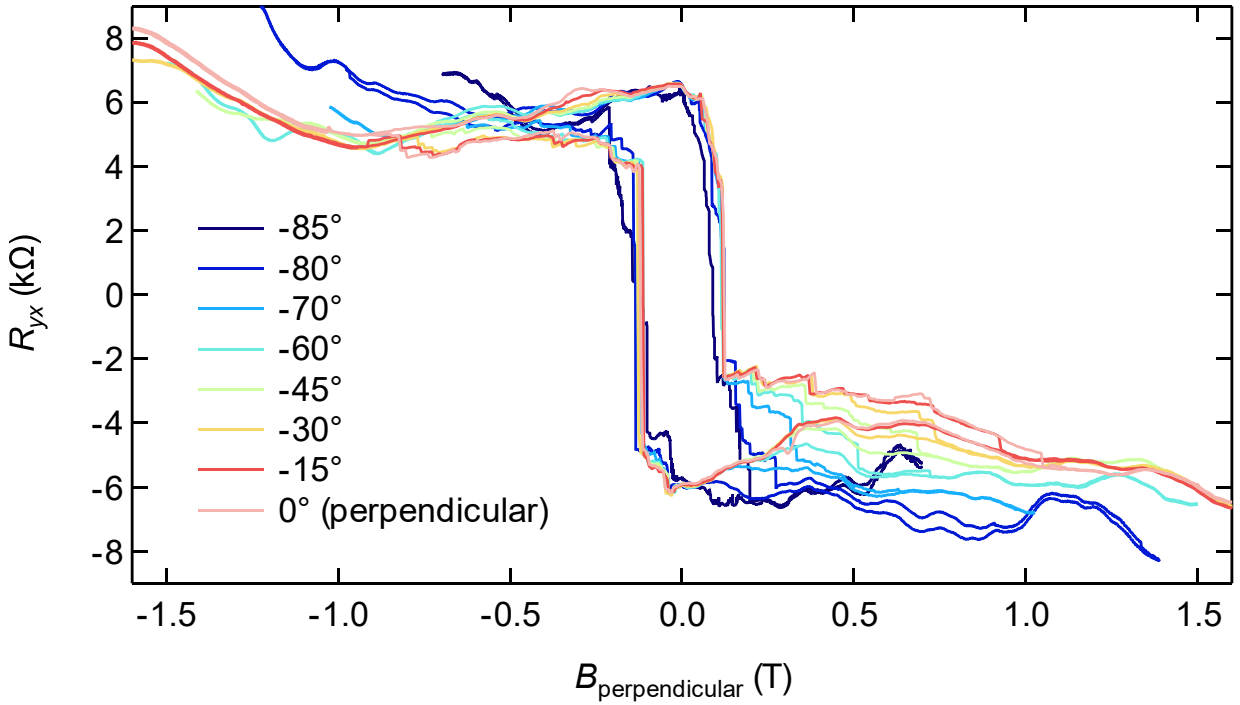
Hysteresis loops in tilted filed



Hysteresis loops in tilted filed

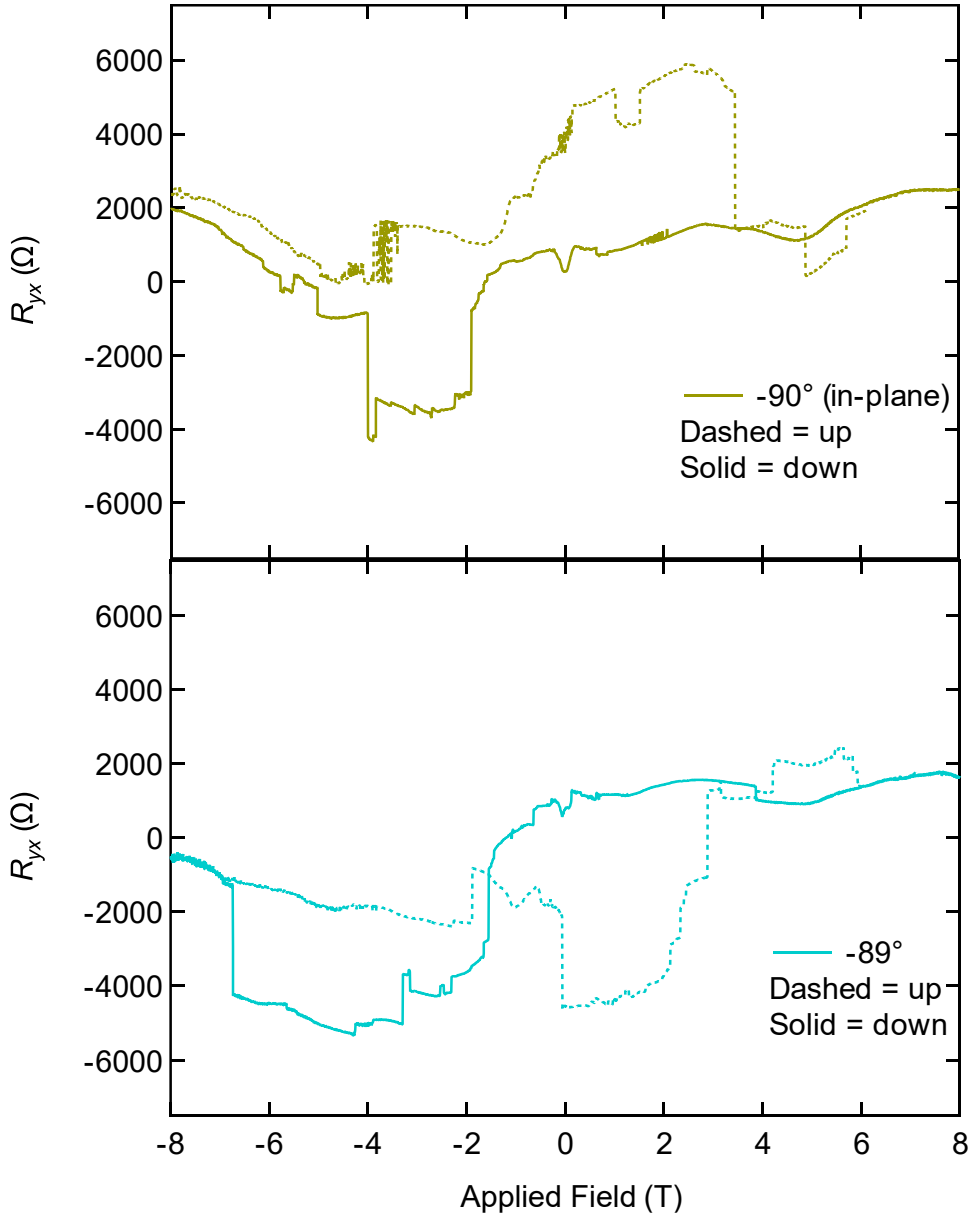
Mostly insensitive to in-plane component

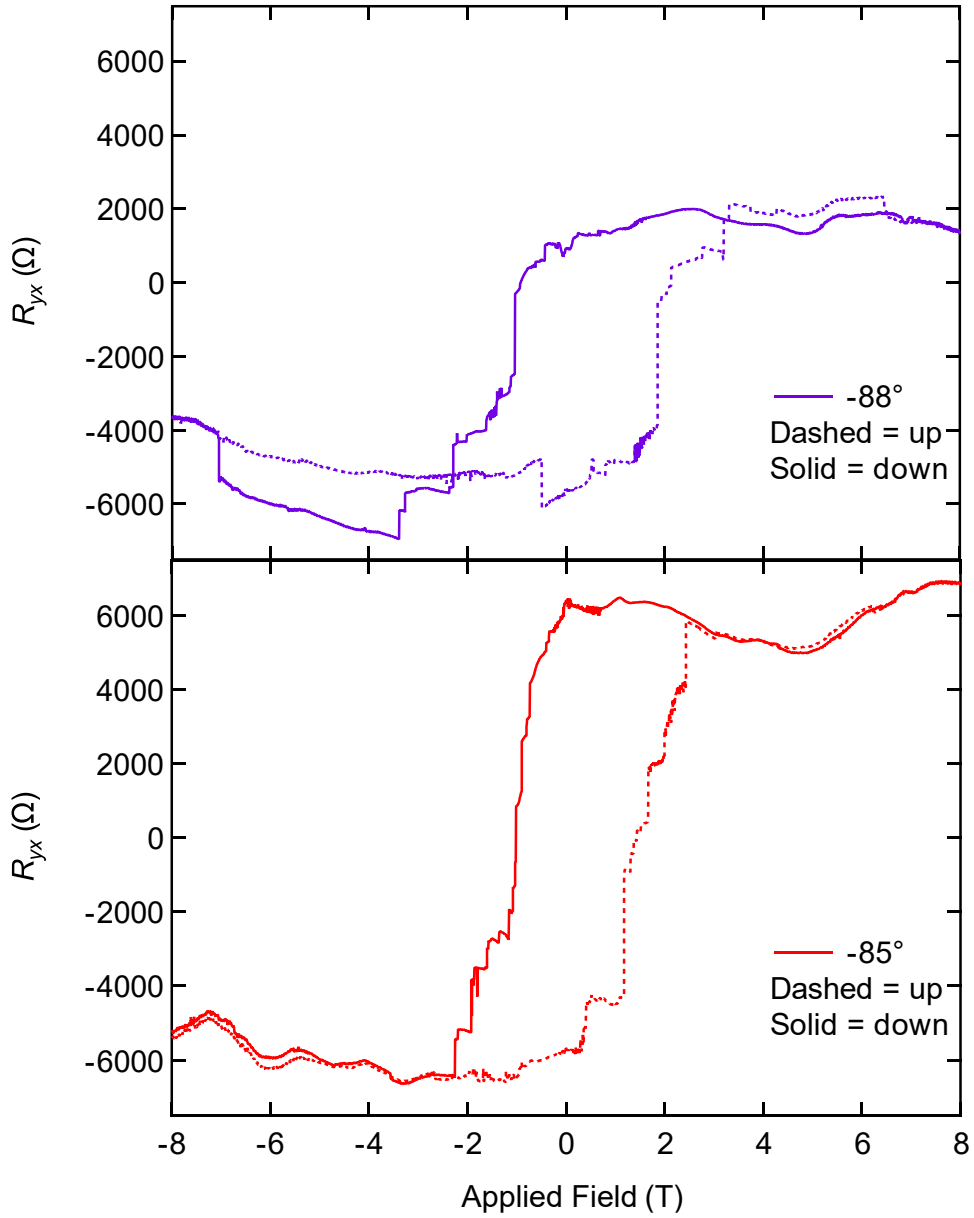




Behavior near in-plane field

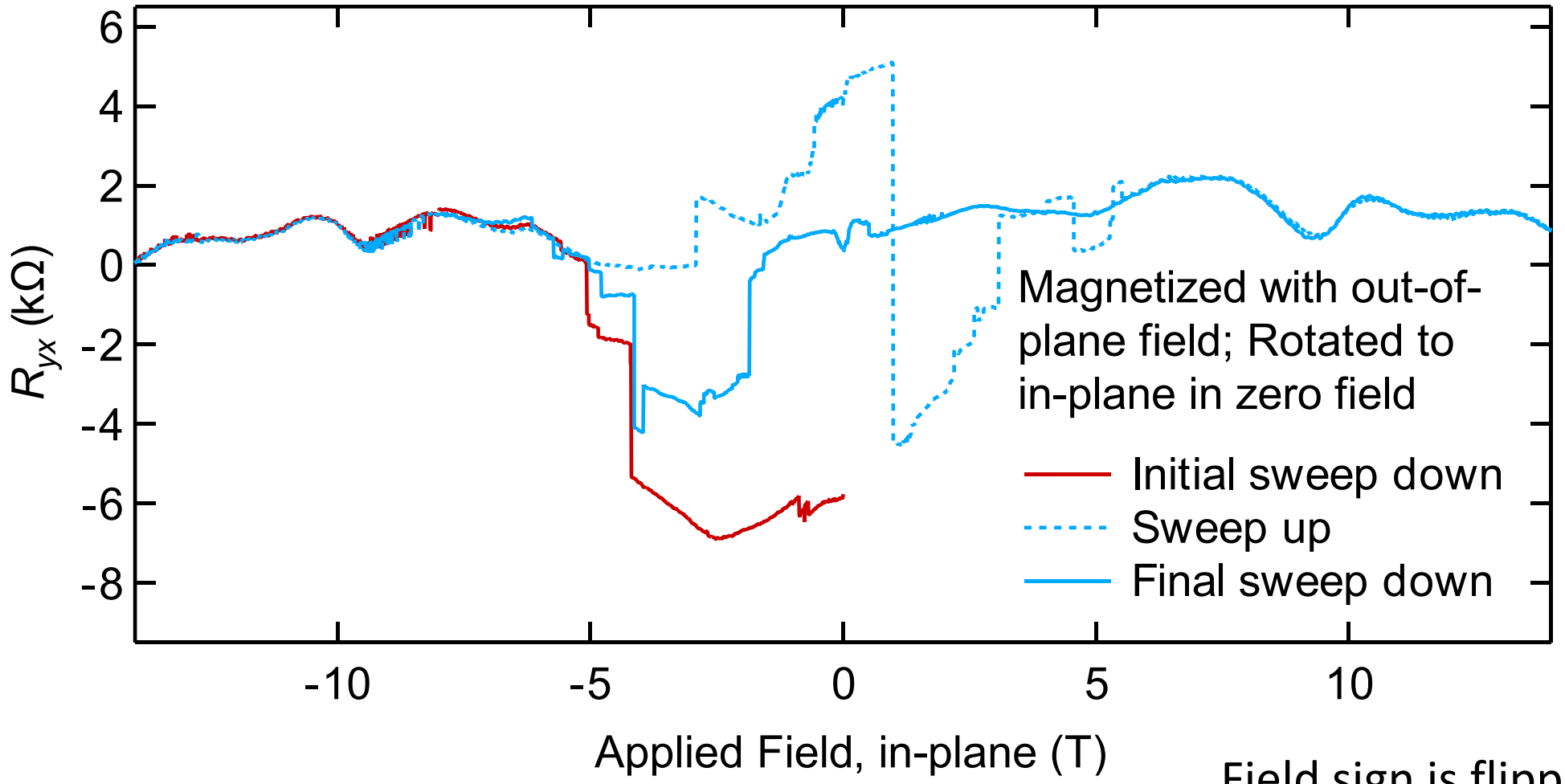
Field is flipped in these plots





Applying in-plane field to a magnetized state

Sufficiently large field appears to erase memory of initial state



TBG becomes ferromagnetic near ¾ filling up to 5 K!

Alignment to hBN may be crucial

At optimal doping
ρ_{xy} = 10.4 kΩ
ρ_{xy}/ρ_{xx} = 1.4

Evidence for edge conduction

Small DC current can flip magnetization

Mainly out of plane field matters

arXiv: 1901.03520