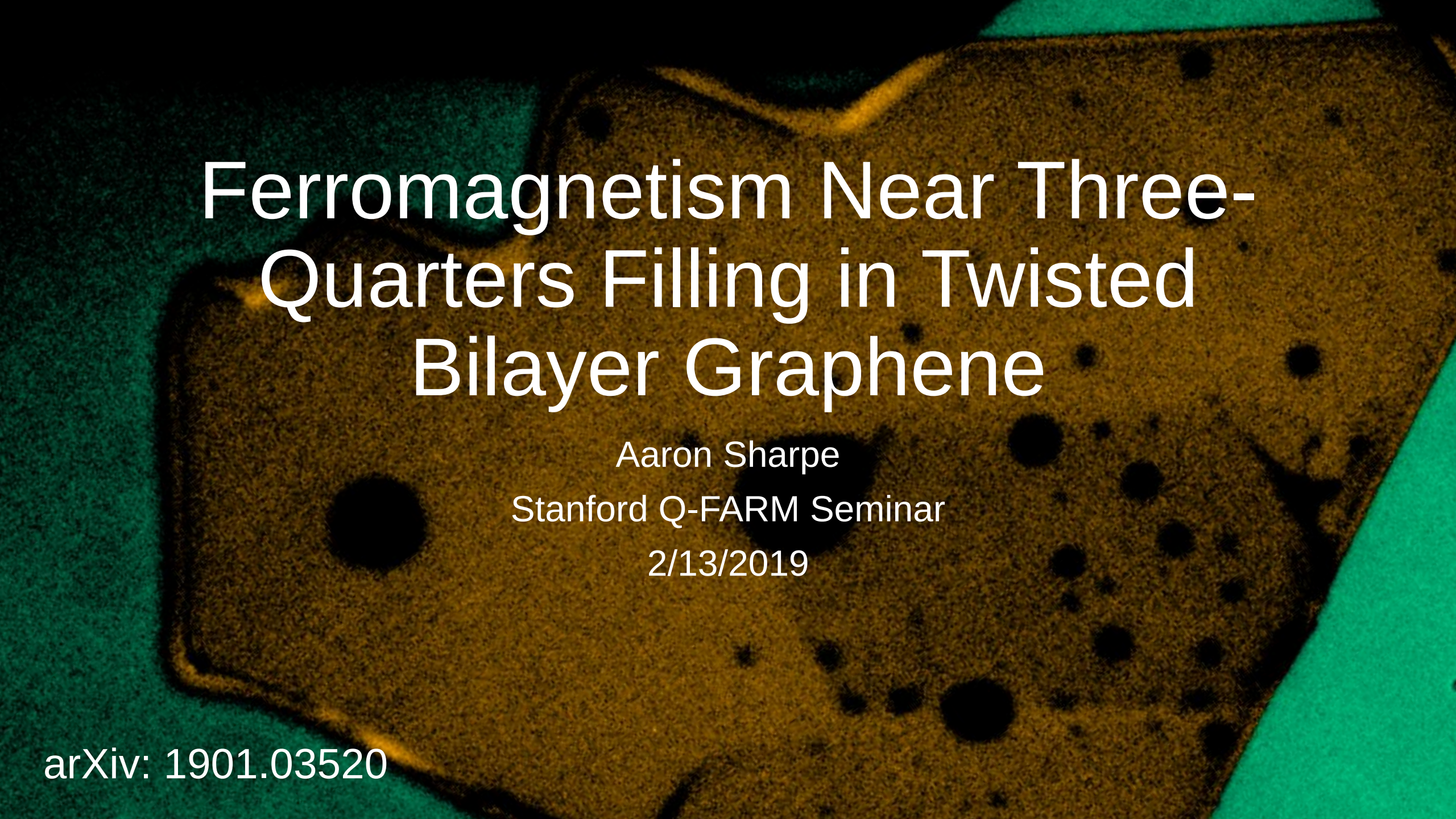




Ferromagnetism Near Three-Quarters Filling in Twisted Bilayer Graphene

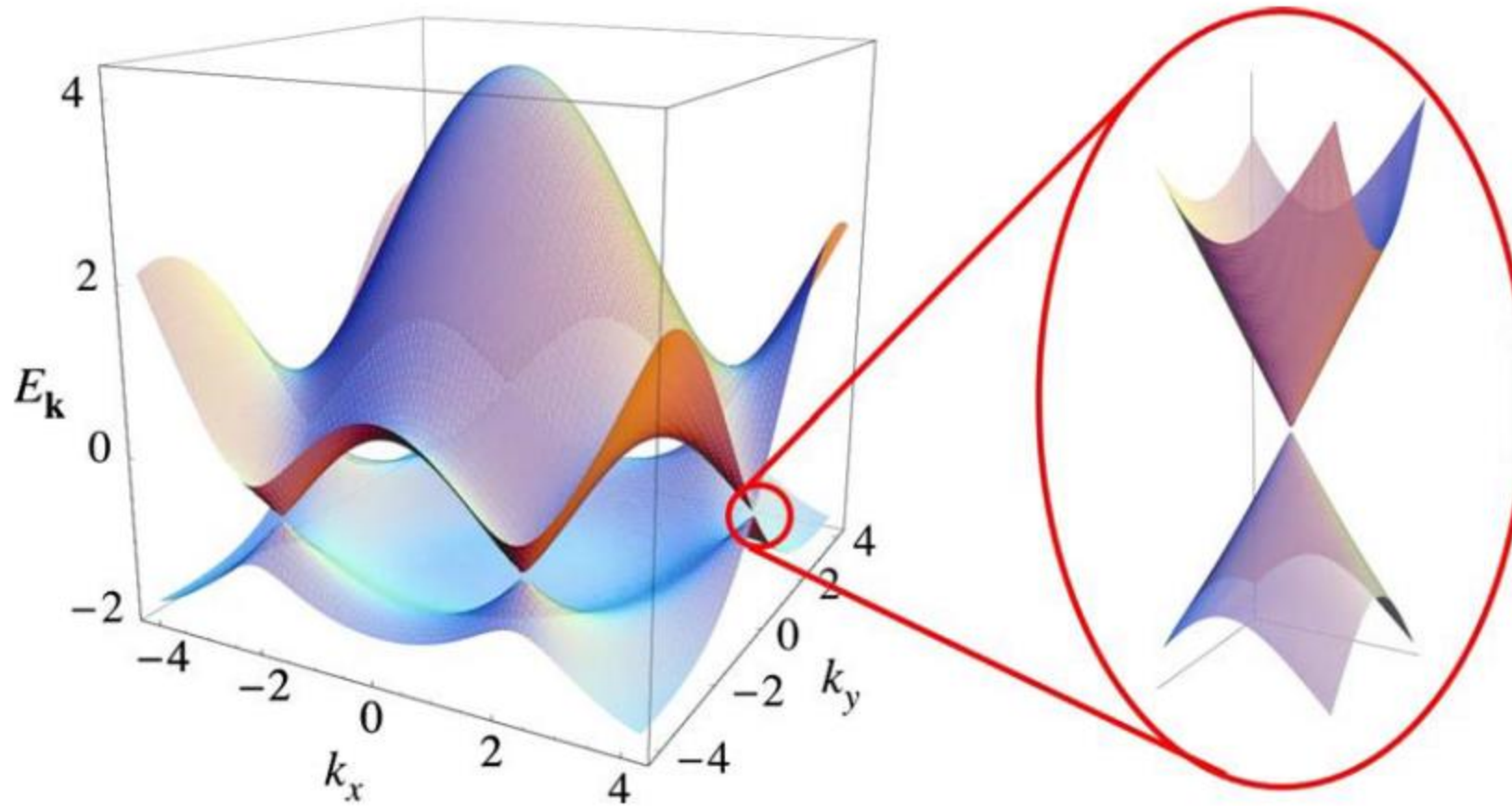
Aaron Sharpe

Stanford Q-FARM Seminar

2/13/2019

arXiv: 1901.03520

Monolayer Graphene



Castro et al., *Rev. Mod. Phys* (2009)

3.5 %

7°

BA

AB

1.7 %

0°

AB

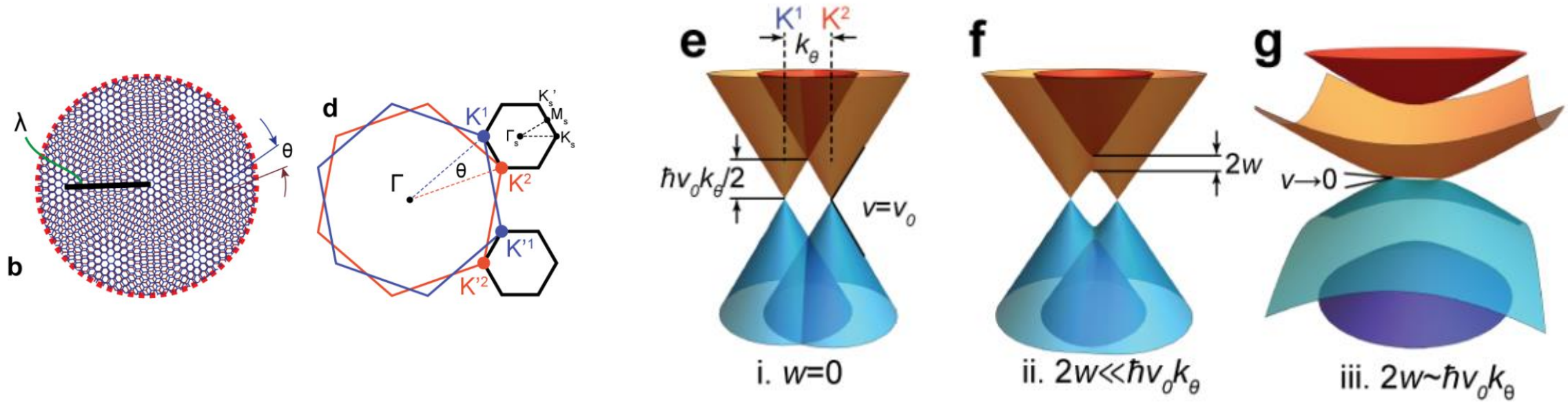
BA

BA

AB

Twisted Bilayer Graphene

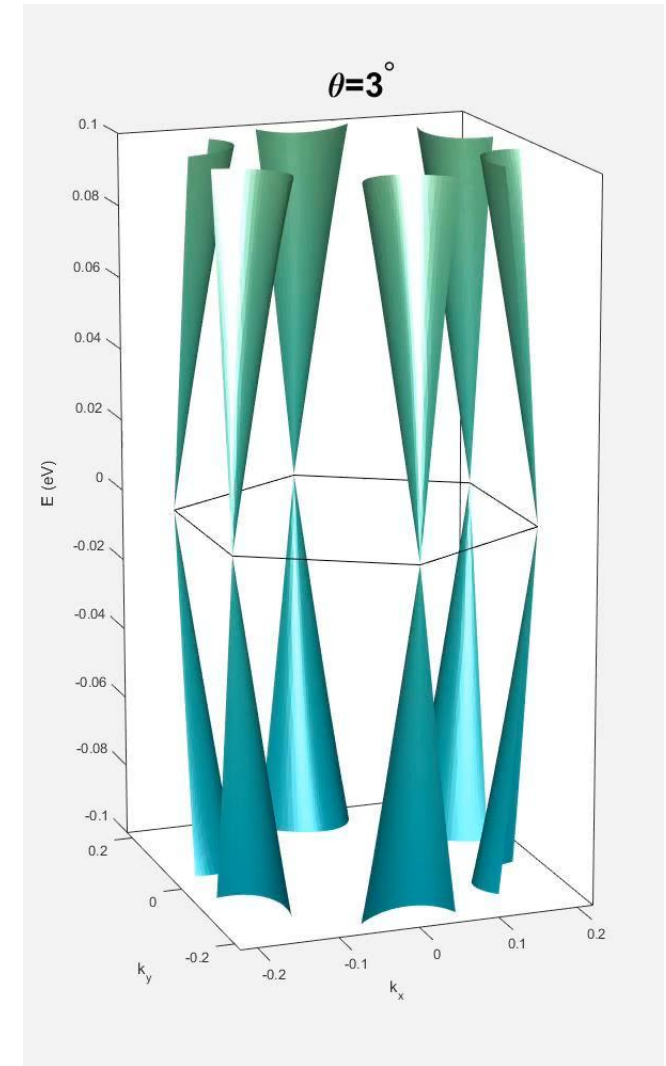
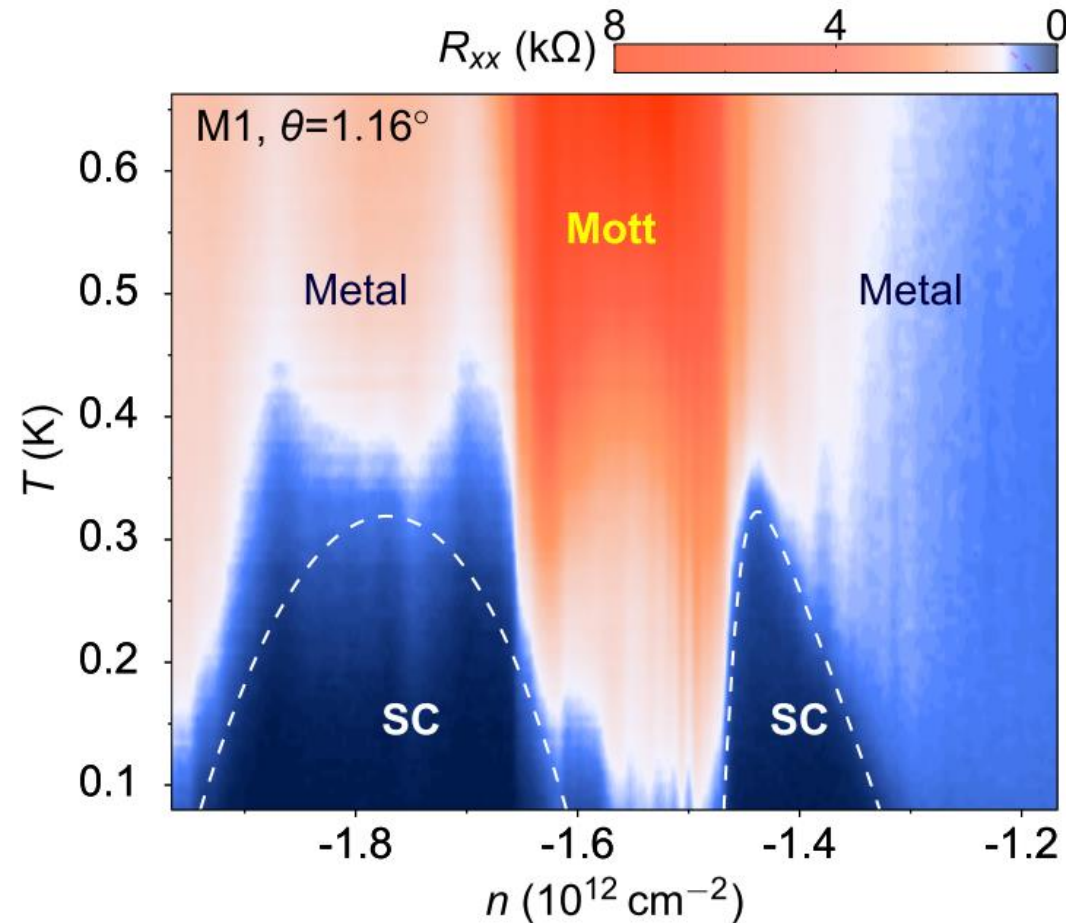
Engineering bandstructure



Cao, *Nature* (2018)

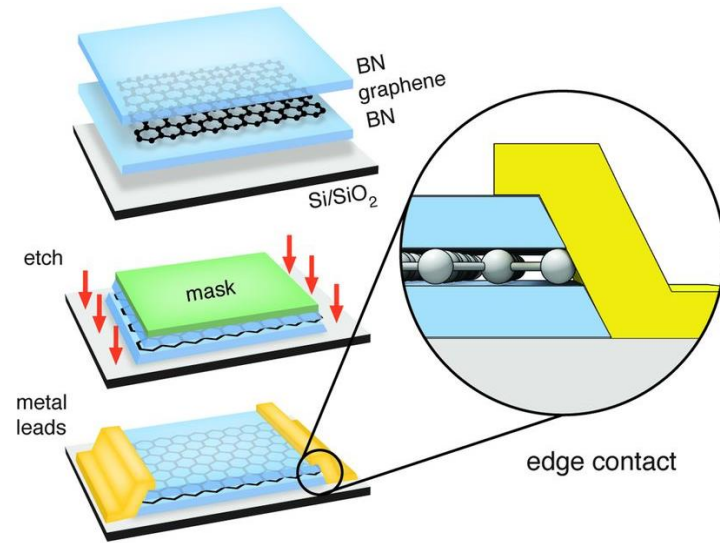
Strong Correlations

Twisted layer graphene and hBN provide unprecedented control of correlations in 2D electron systems

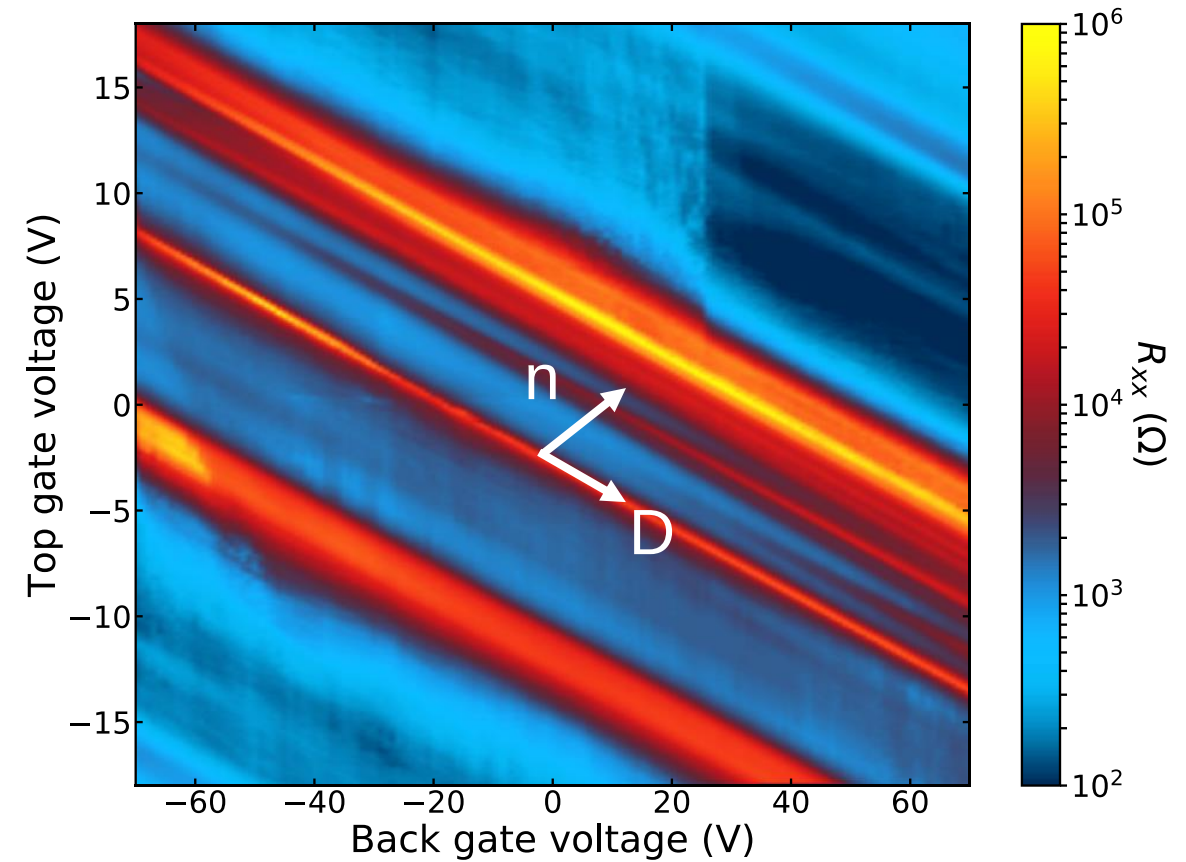
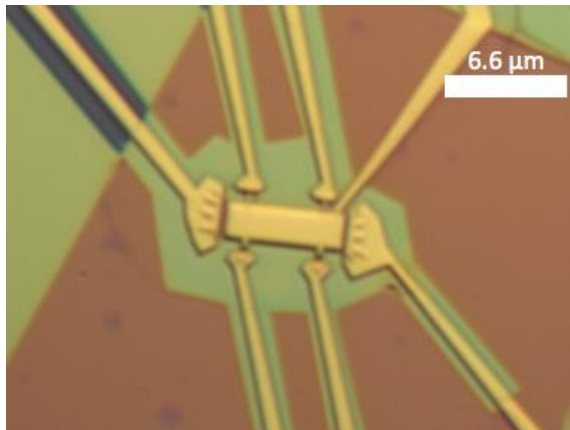


Cao, *Nature* (2018)

Strong Correlations: Twisted Bilayer Near Magic Angle



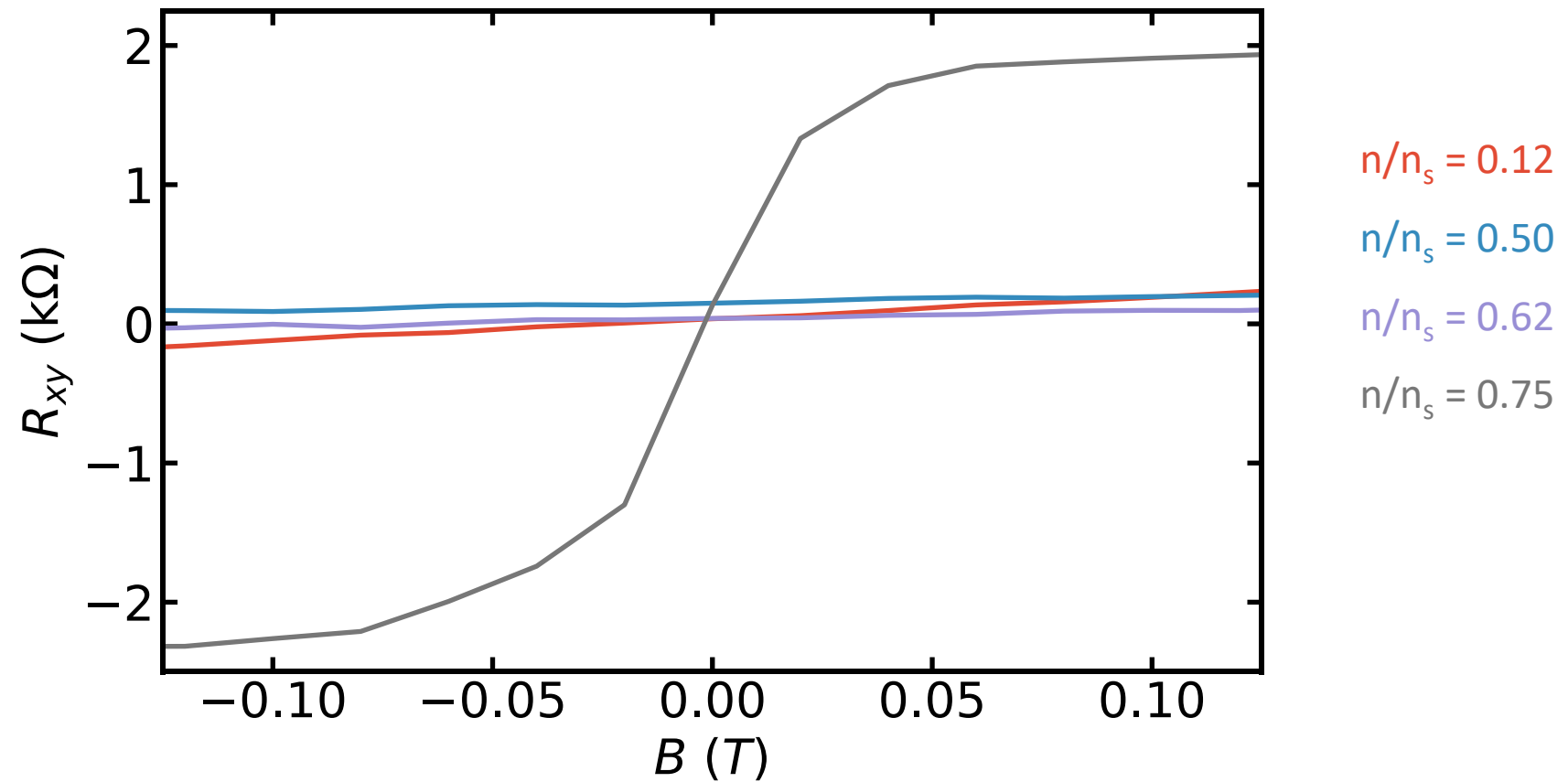
Wang, *Science* (2013)



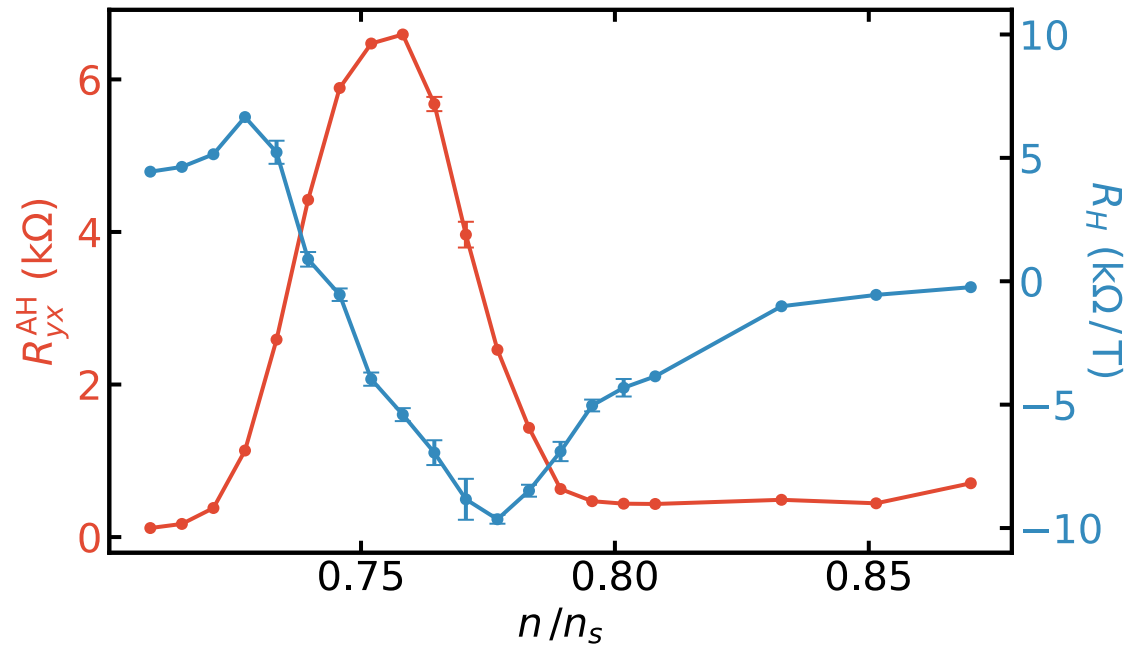
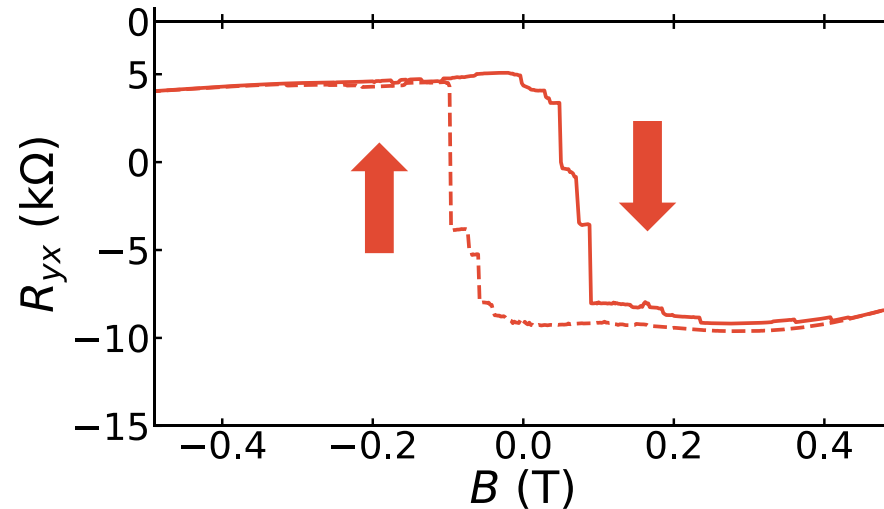
Angle $1.20 \pm 0.01^\circ$. Target 1.17°

Measuring Hall Slope Density Dependence

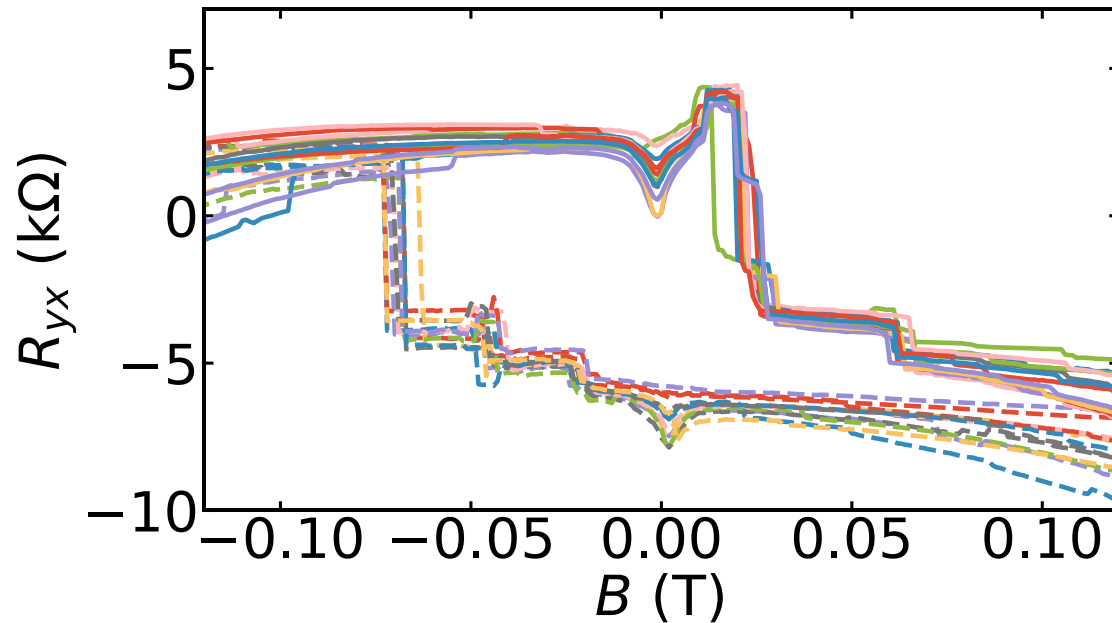
$$R_{yx} = -\frac{1}{ne}B_z + R_{AH}M_z$$



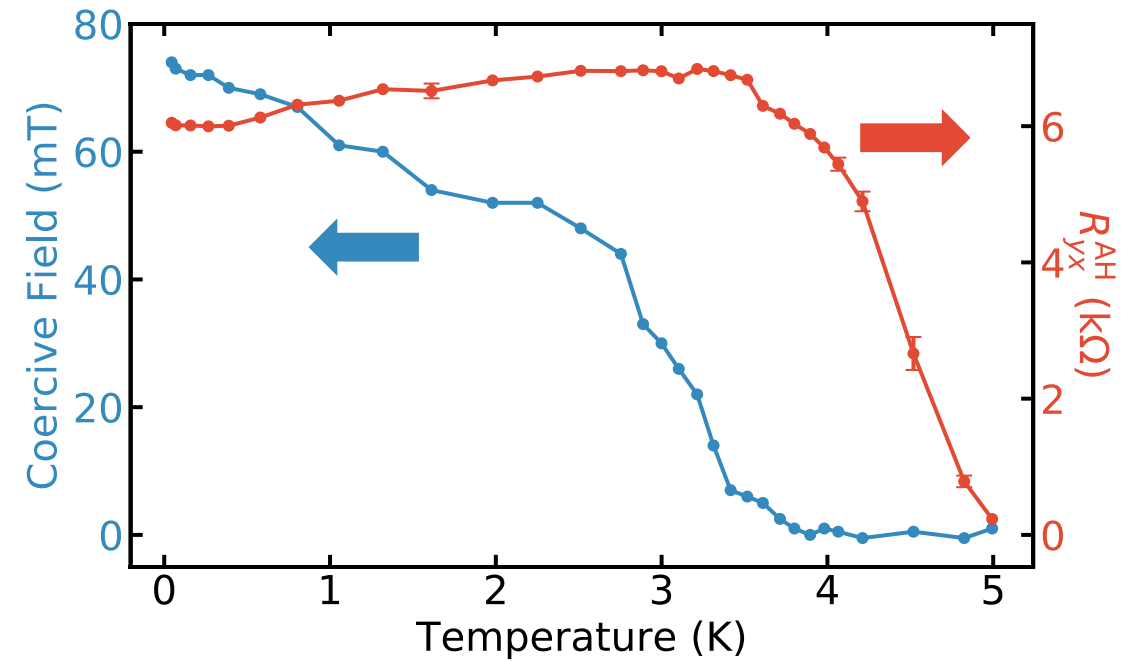
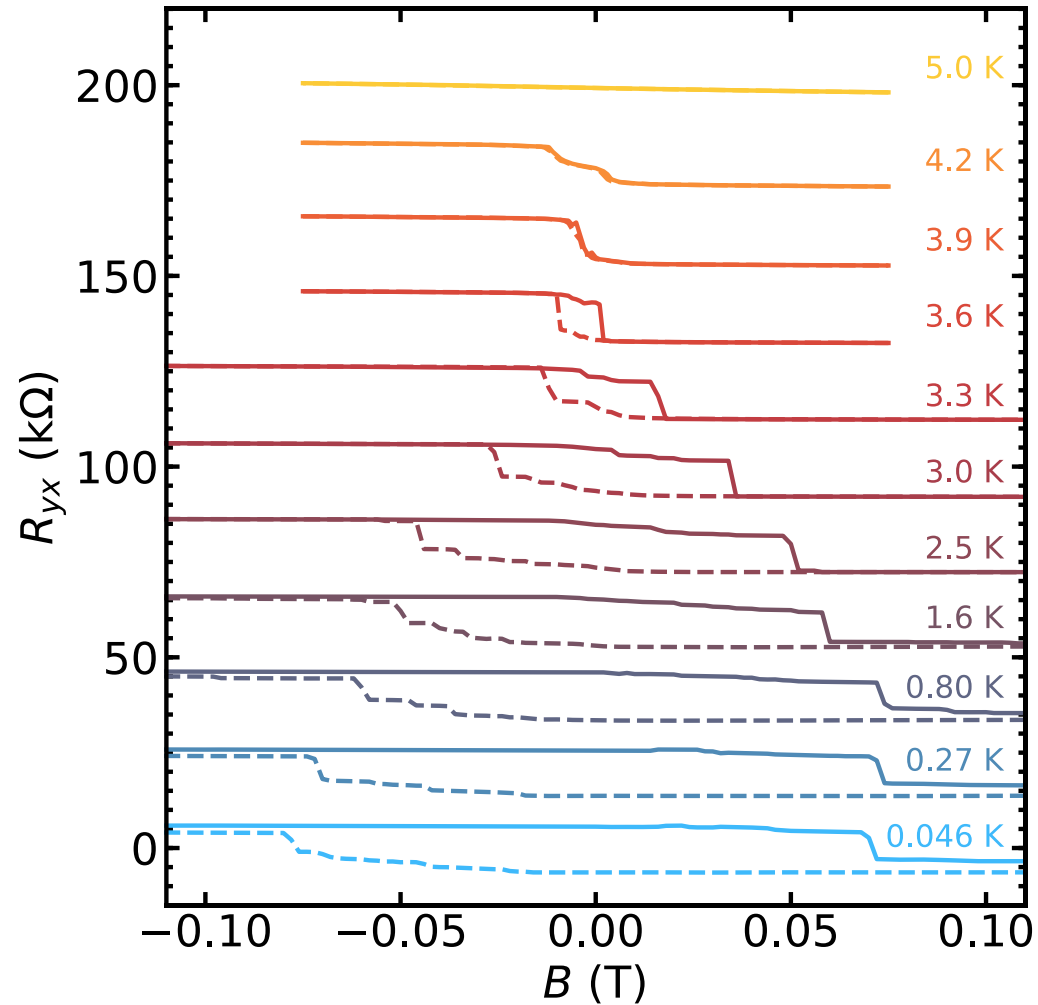
Emergent Ferromagnetism at $\frac{3}{4}$ Filling



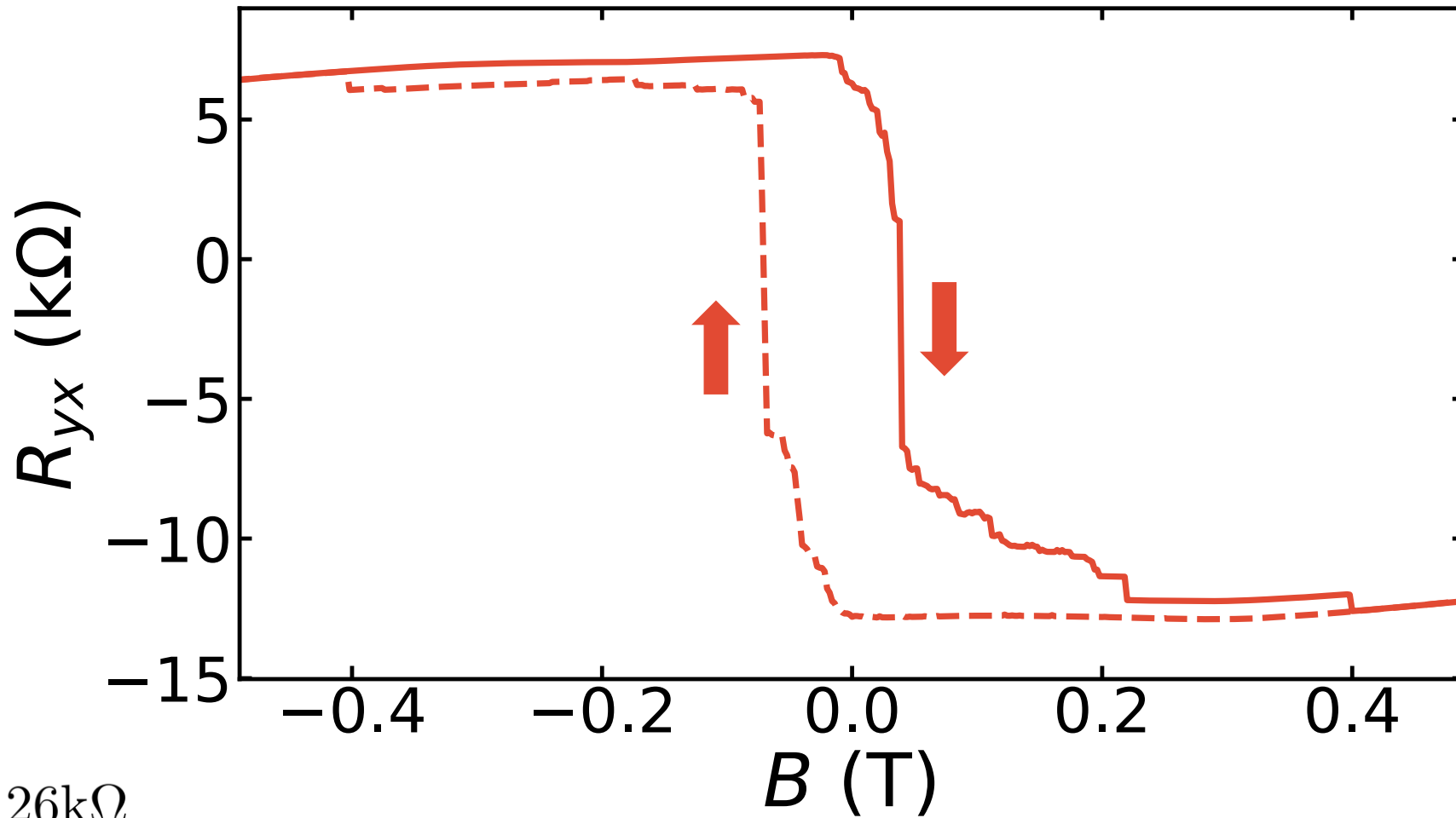
Repeatable Hysteresis Fine Structure in Field



Temperature Dependence of Ferromagnetism at $\frac{3}{4}$ Filling



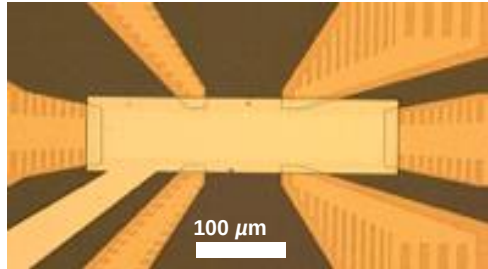
Anomalous Hall Signal Can Be Really Large!



$$h/e^2 \approx 26k\Omega$$

$$n/n_s = 0.775, T = 2.1K$$

Comparison: Quantum Anomalous Hall in $(\text{Cr,Bi,Sb})_2\text{Te}_3$

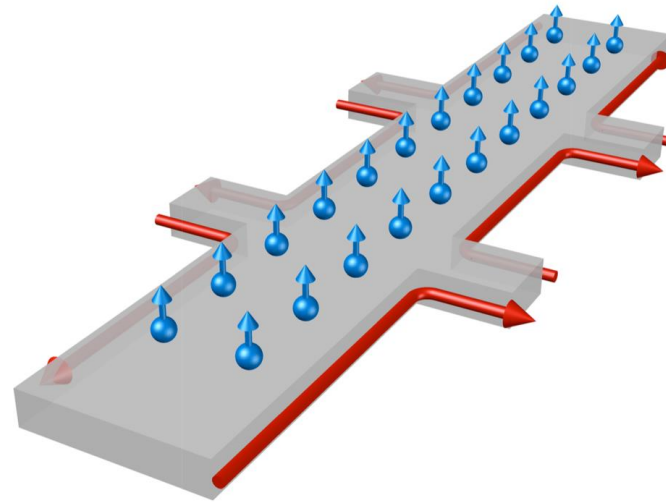


Material & device:

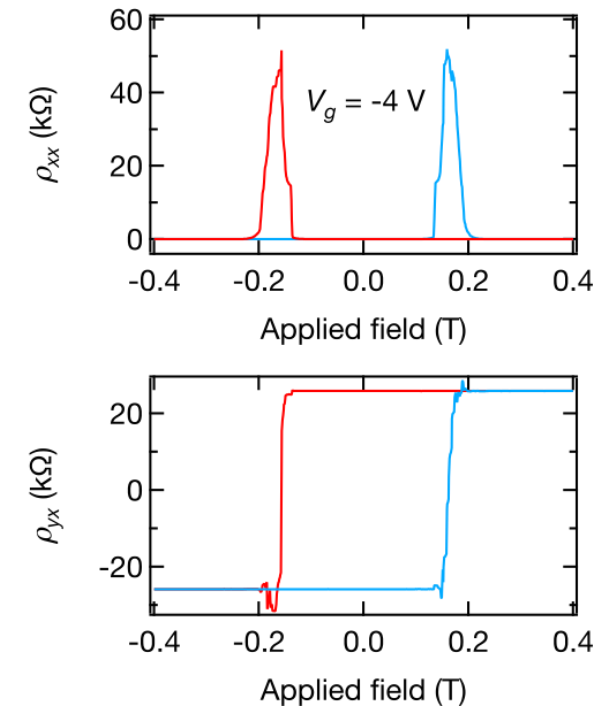
6 QL $\text{Cr}_{0.24}(\text{Bi}_{0.3}\text{Sb}_{0.7})_{1.76}\text{Te}_3$
GaAs substrate
Ti/Au contacts
Top gate

Ideally

$$\rho_{xx} = 0$$
$$\rho_{yx} = h/e^2 \approx 26\text{k}\Omega$$

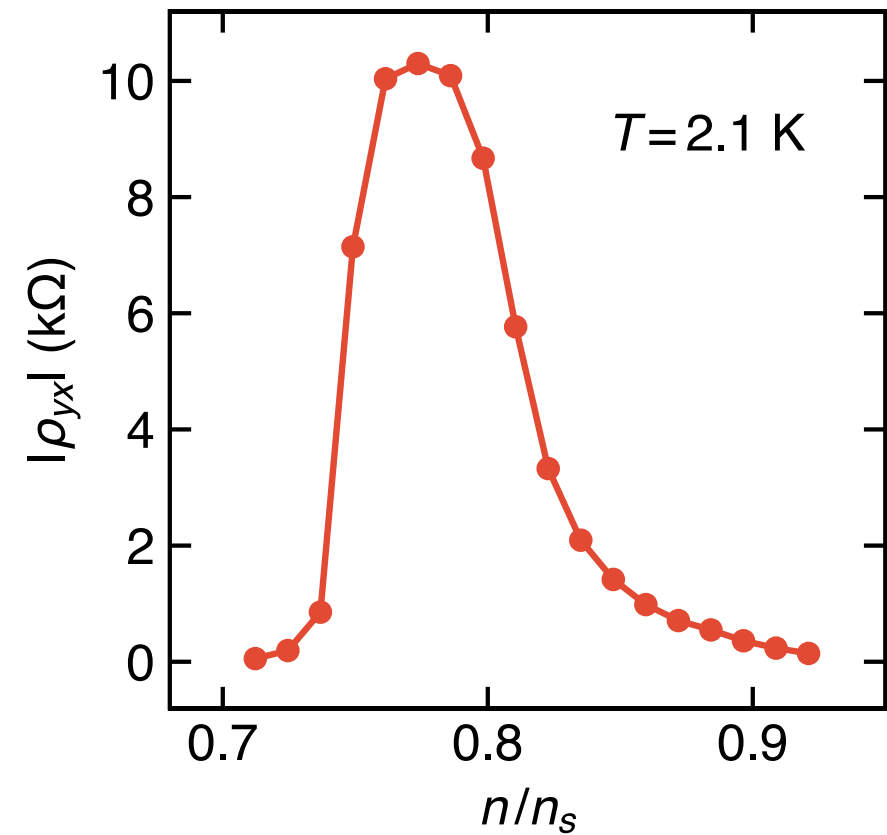
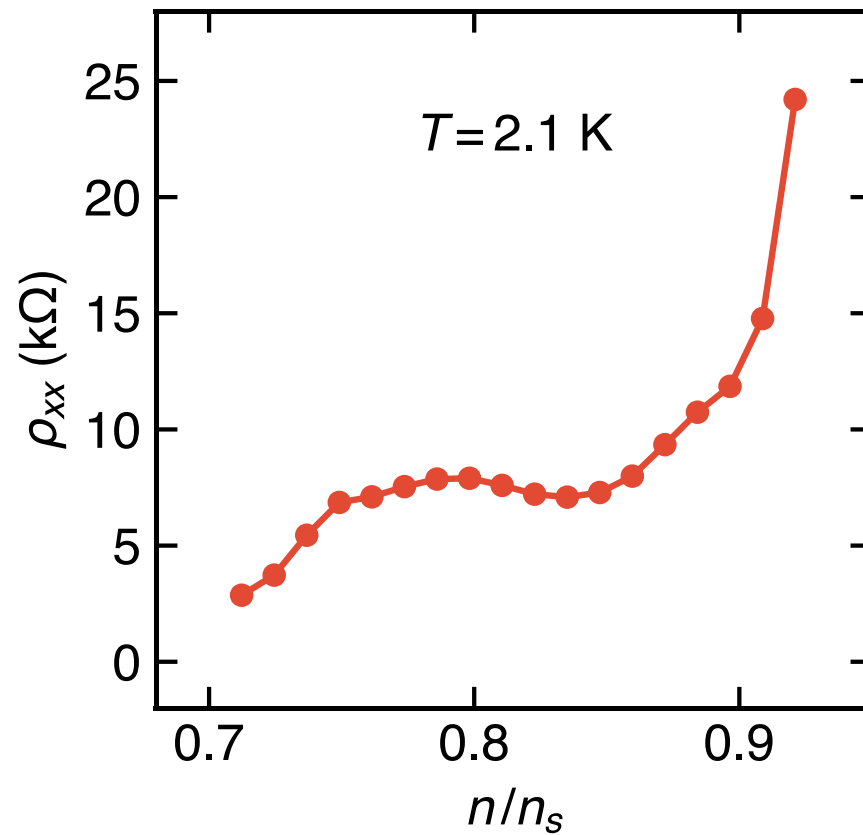


Near optimal gate voltage



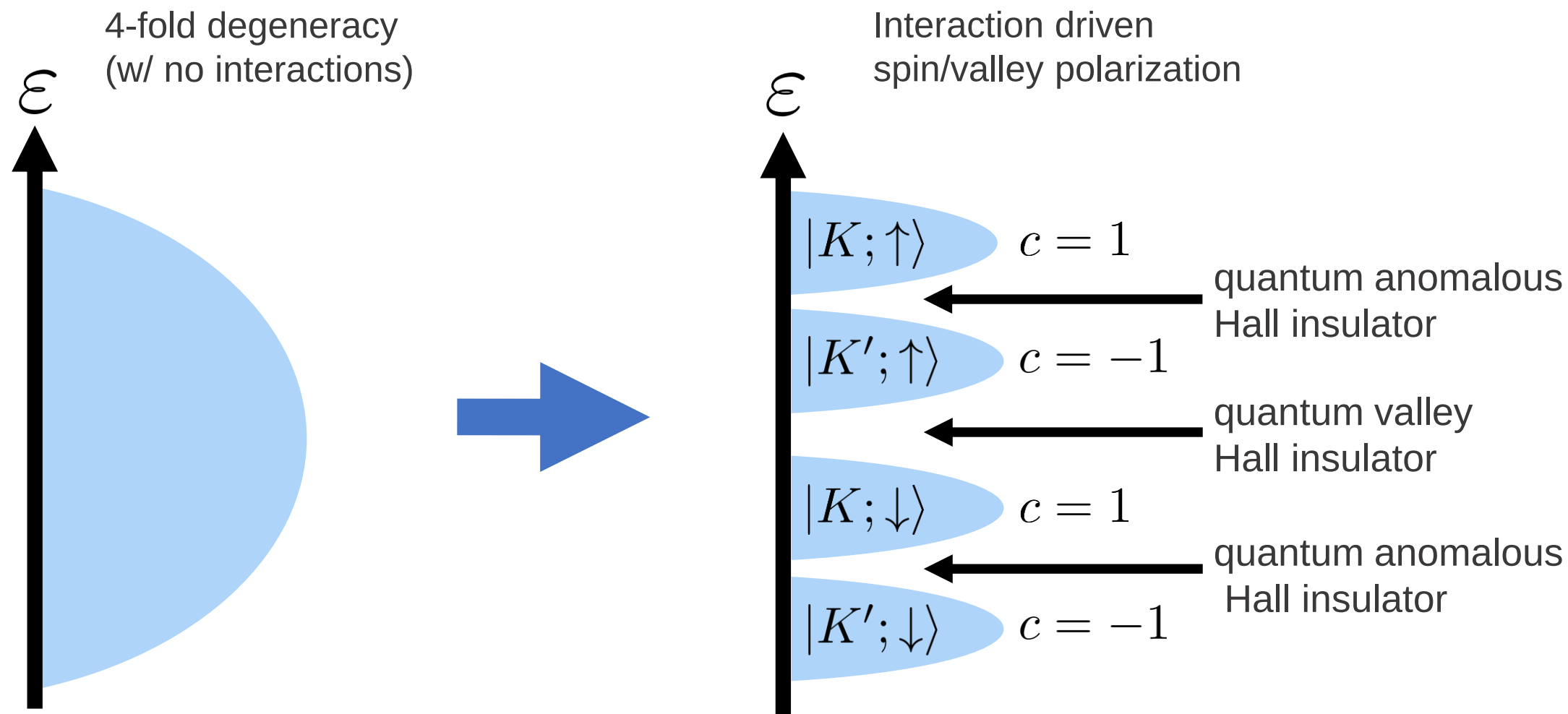
Comparison: Anomalous Hall in TBG

Far from quantization

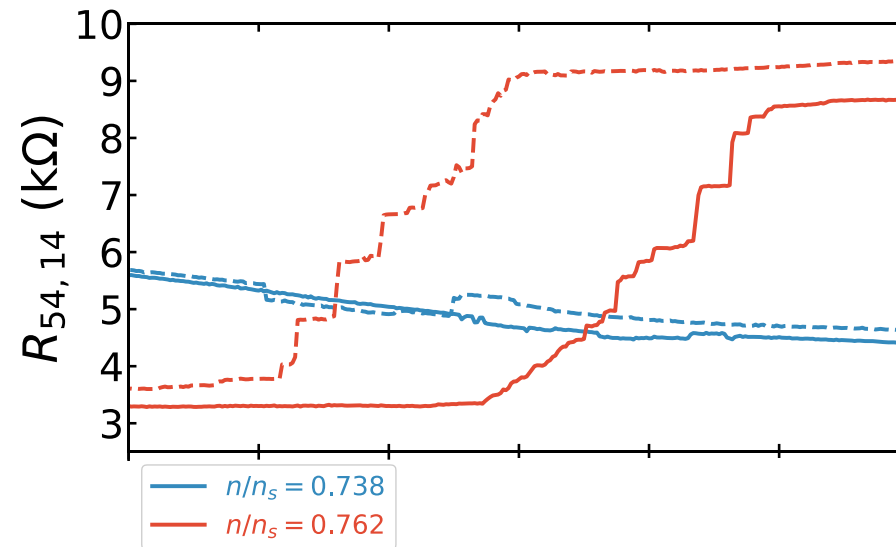
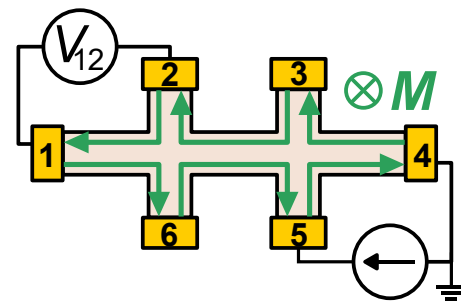
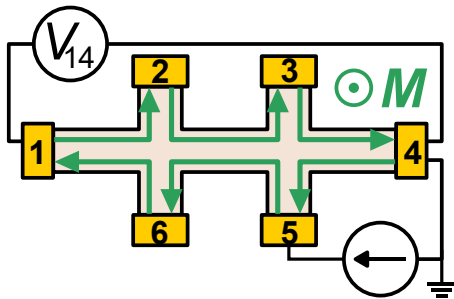


Nature of Emergent Ferromagnetism at $\frac{3}{4}$ Filling?

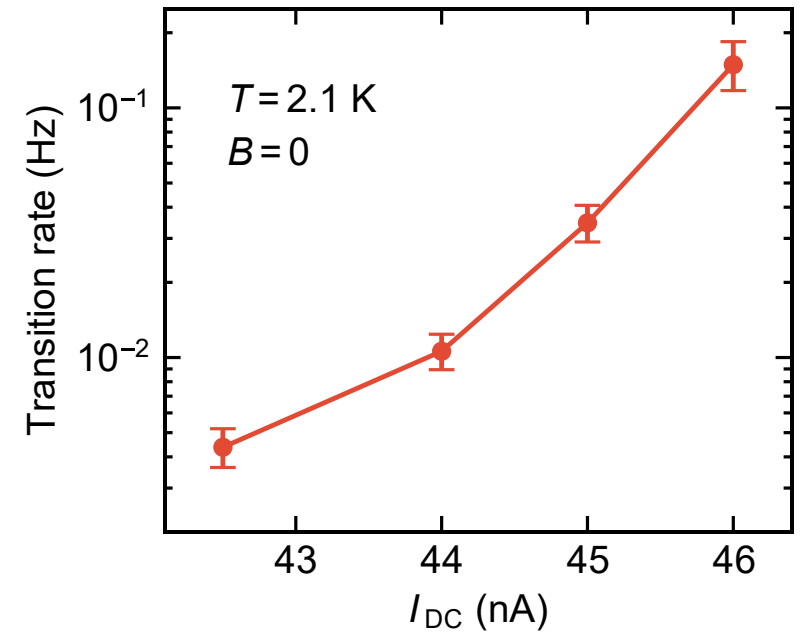
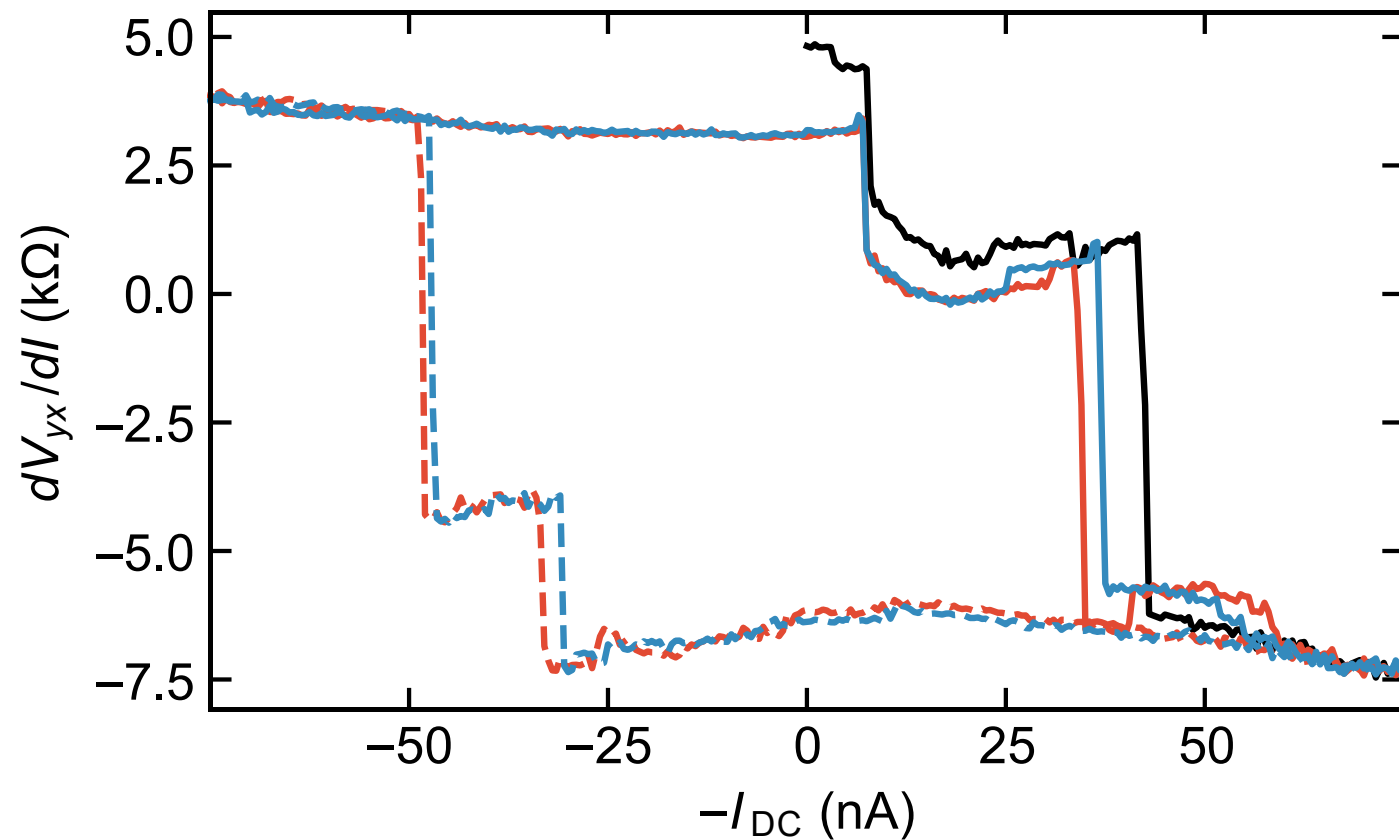
Simplistic band diagram: what *might* be happening...



3- and 4-Terminal Nonlocal Transport at $\frac{3}{4}$ Filling



Repeatable Hysteresis in Current



Acknowledgements

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arXiv: 1901.03520

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Xufeng Kou

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Questions?

