

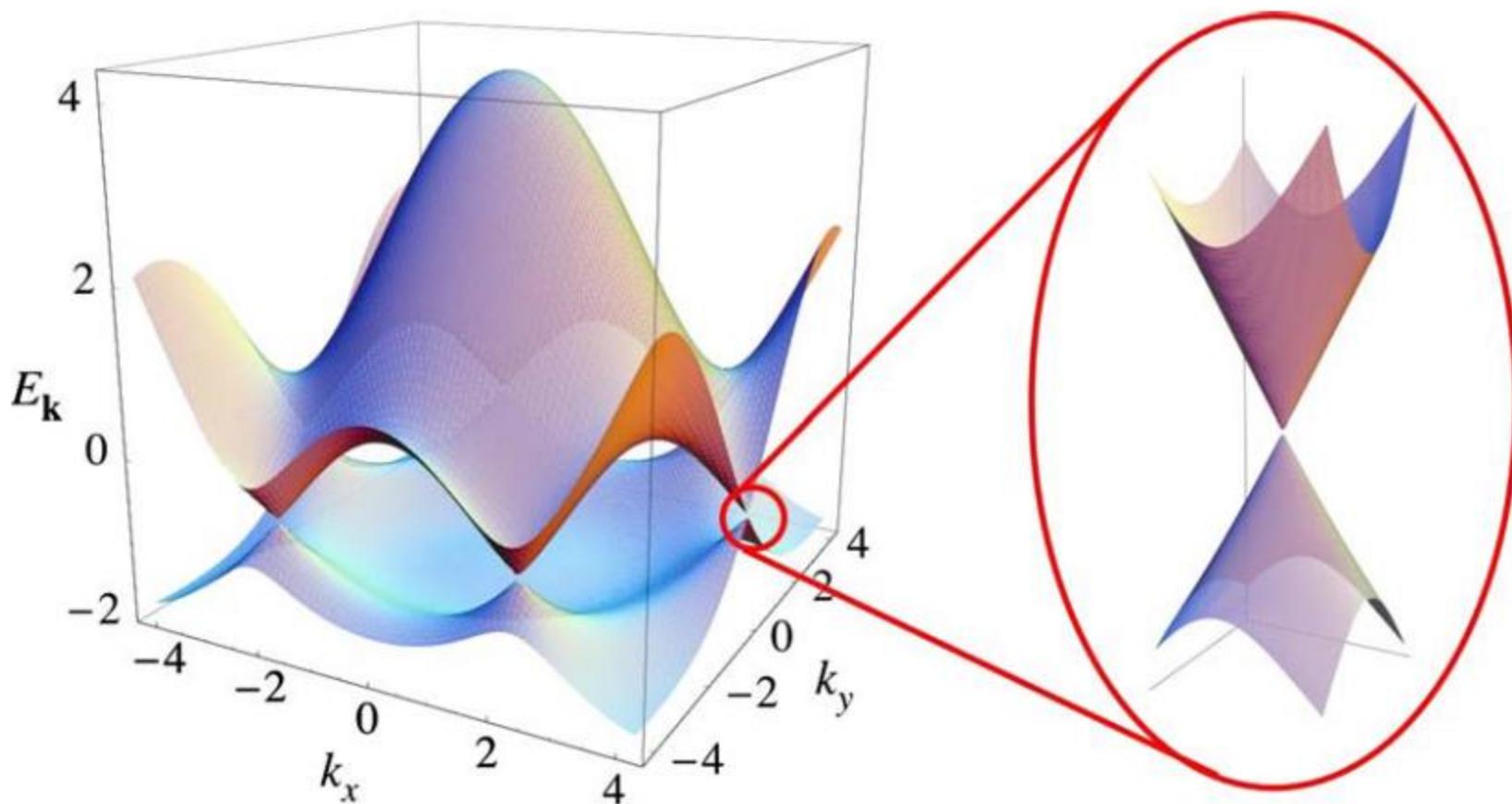
# Ferromagnetism Near Three-Quarters Filling in Twisted Bilayer Graphene

Aaron Sharpe

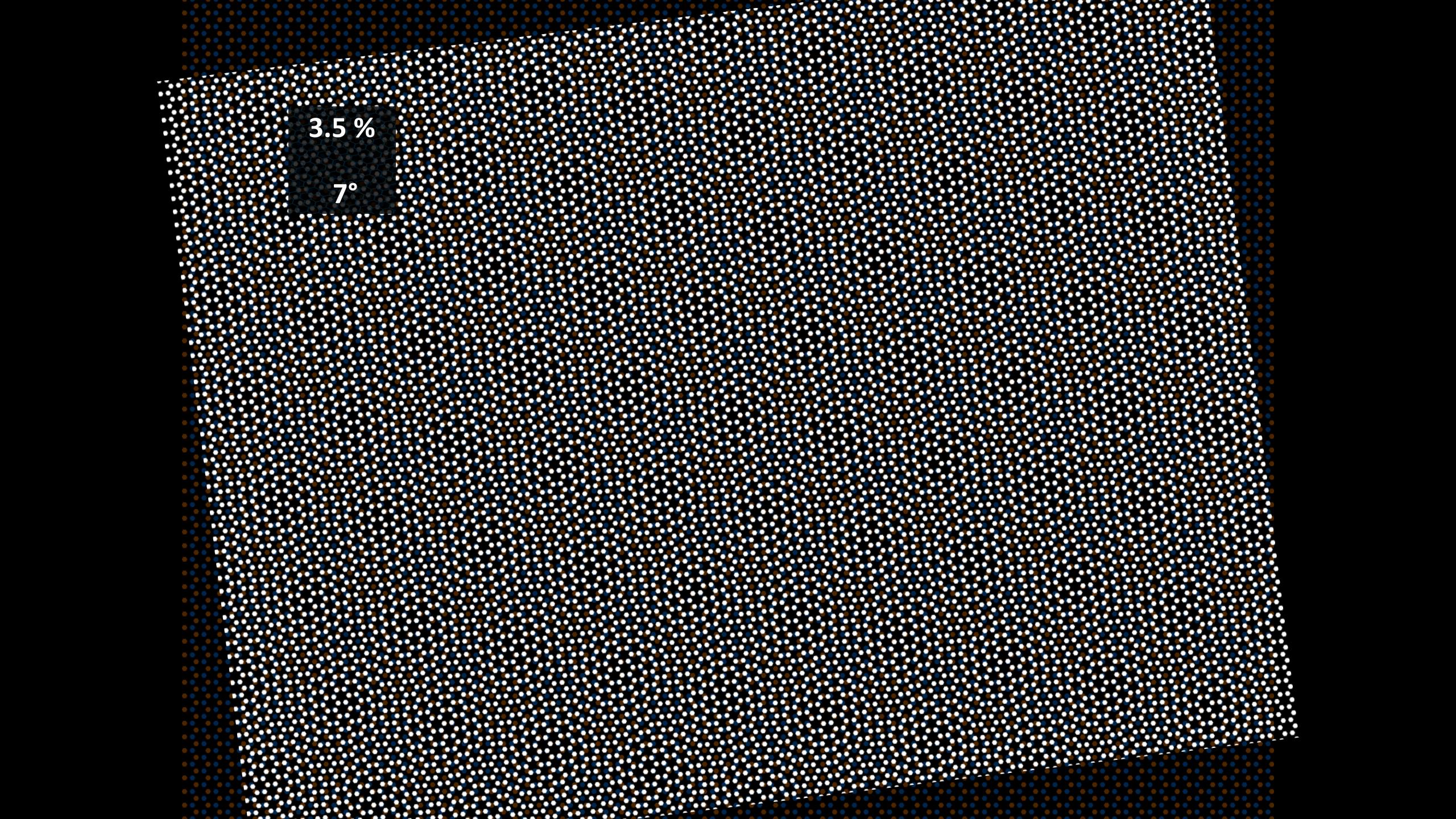
Stanford Q-FARM Seminar

2/13/2019

# Monolayer Graphene



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



3.5 %

7°

BA

AB

1.7 %

0°

AB

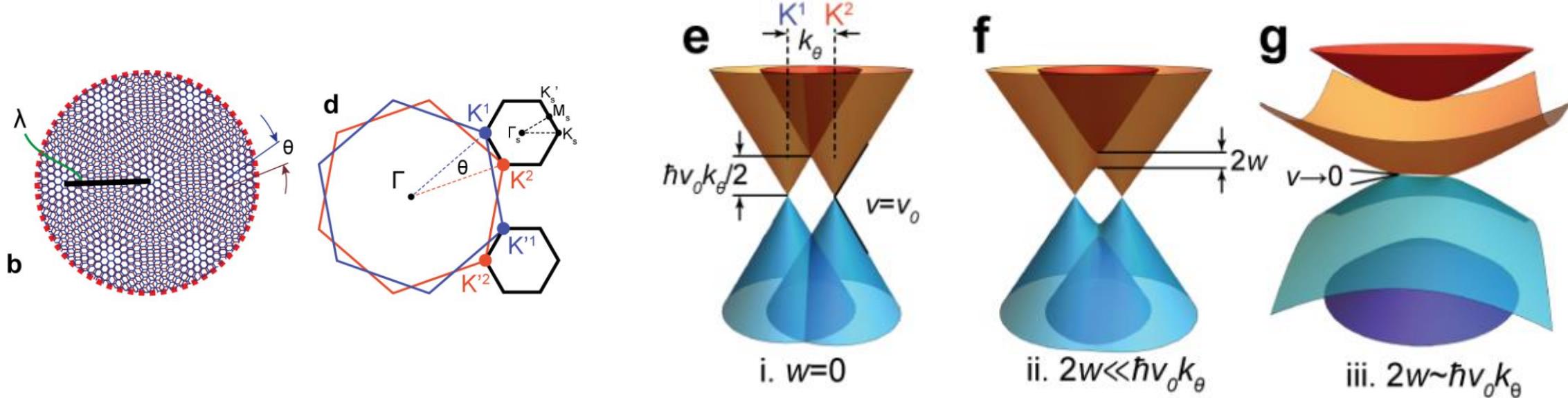
BA

BA

AB

# Twisted Bilayer Graphene

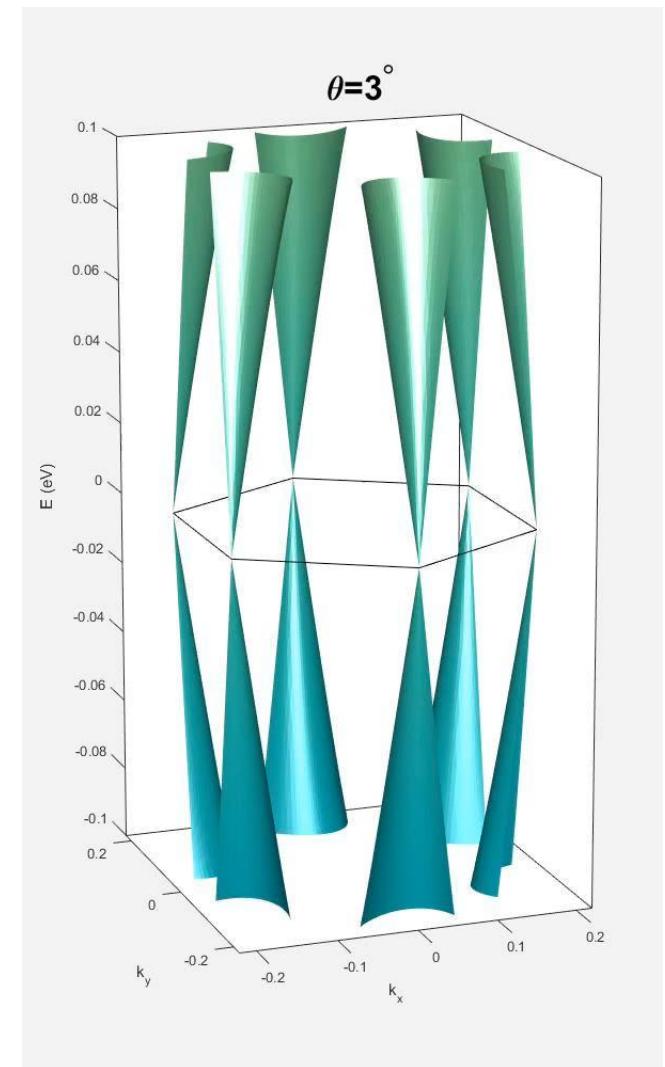
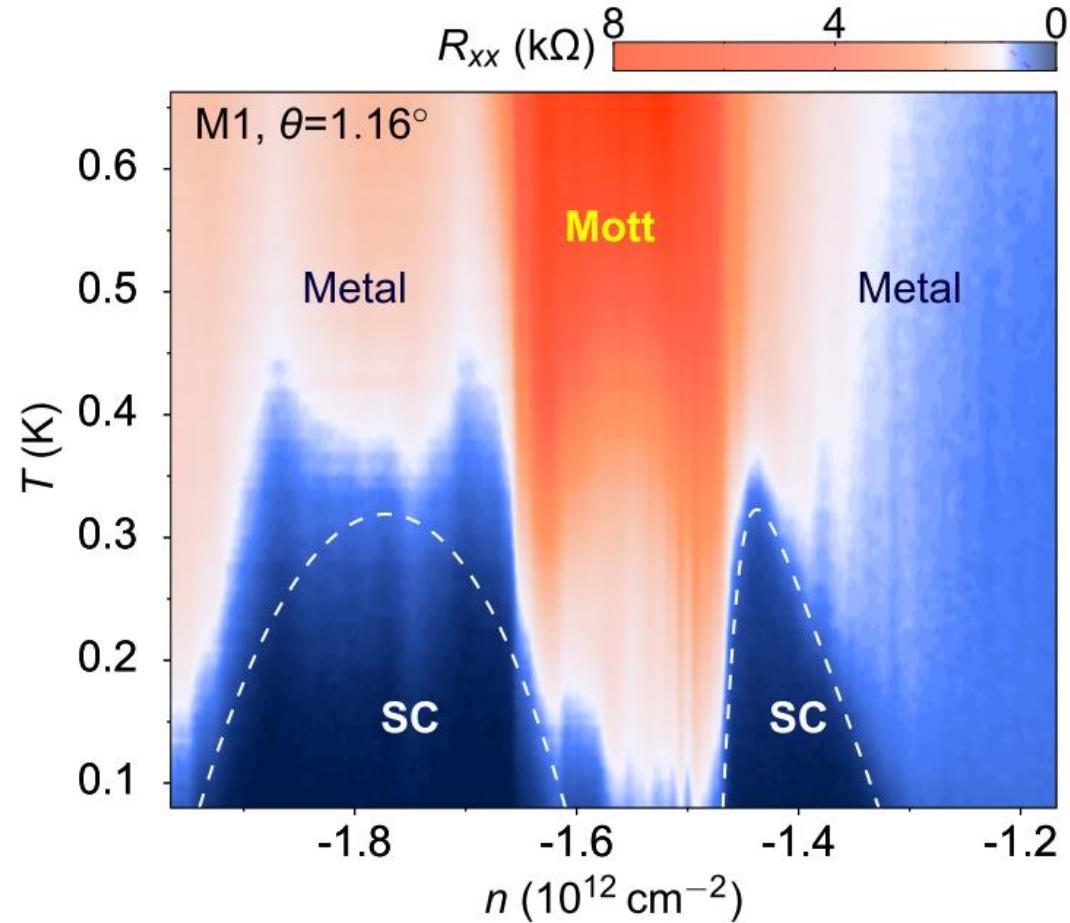
Engineering bandstructure



Cao, *Nature* (2018)

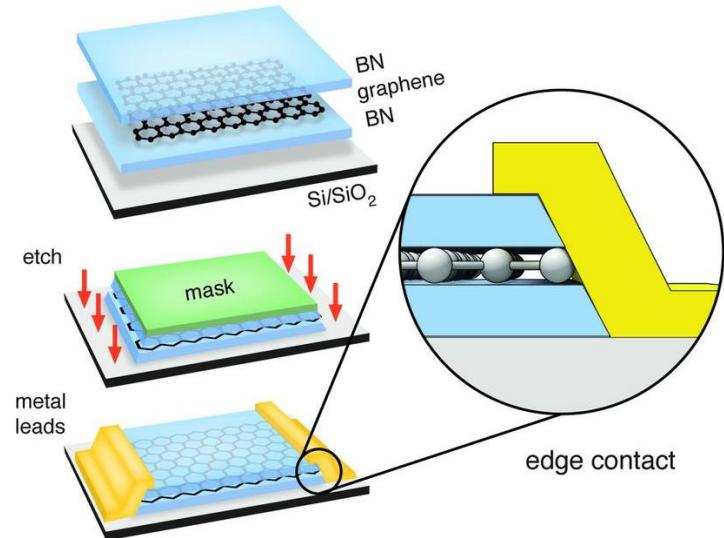
# Strong Correlations

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

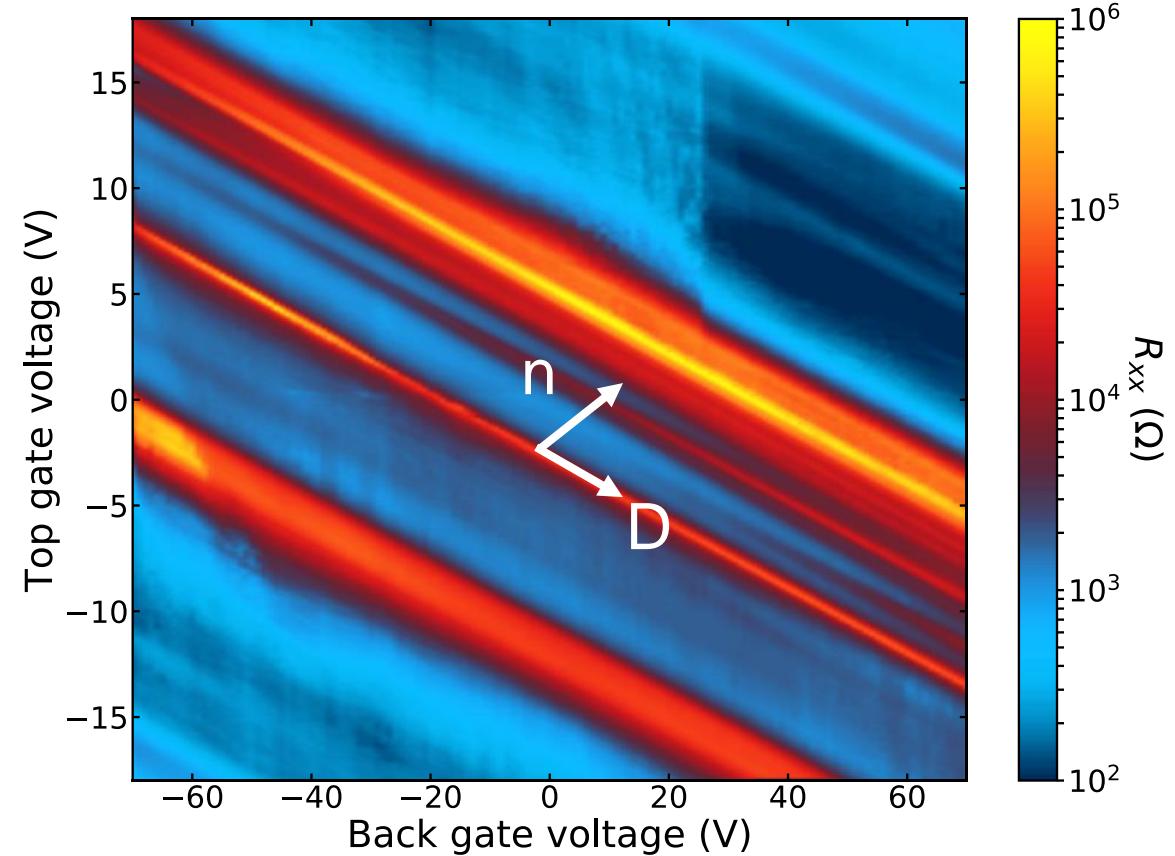


Cao, *Nature* (2018)

# Strong Correlations: Twisted Bilayer Near Magic Angle



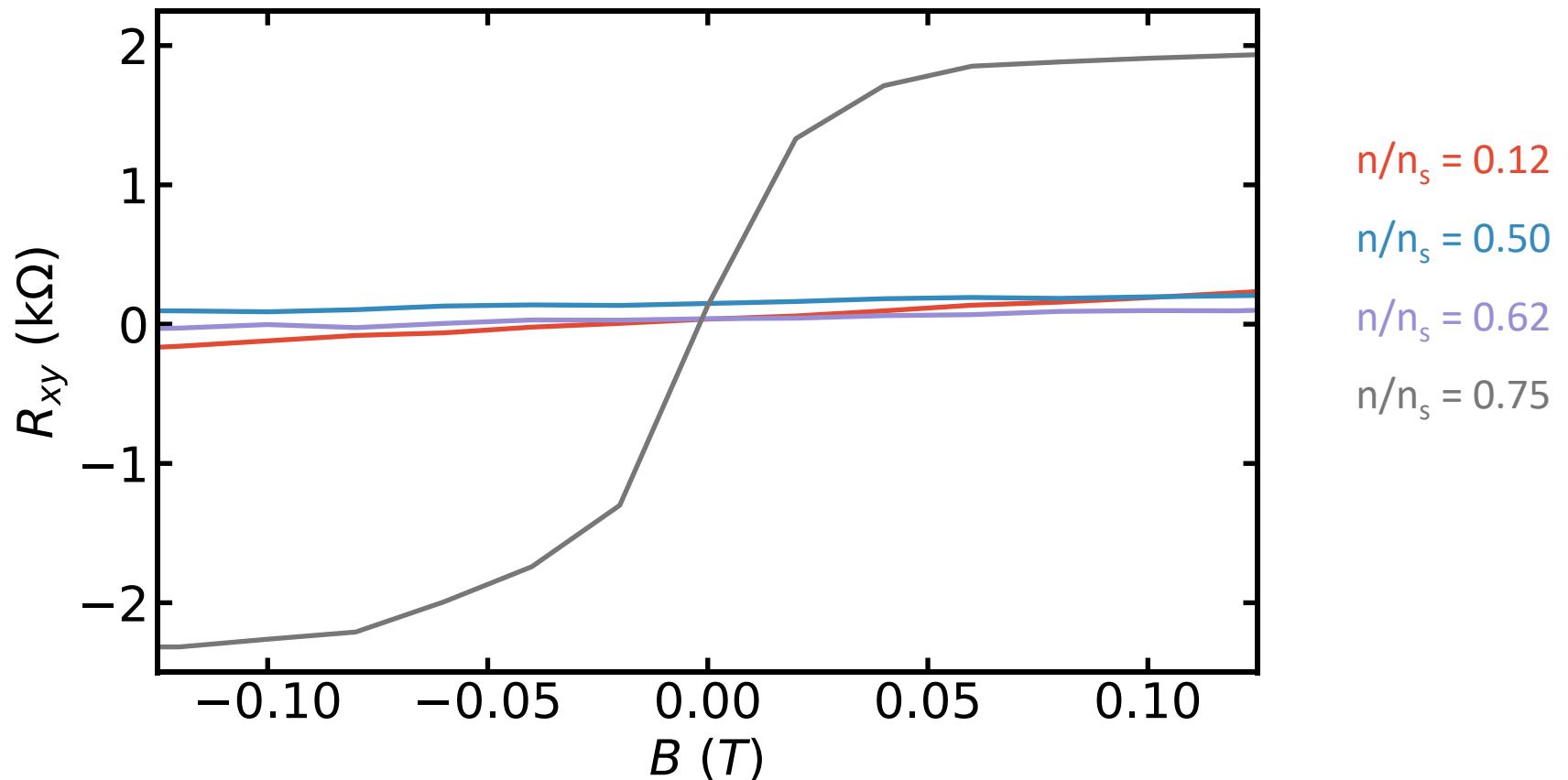
Wang, *Science* (2013)



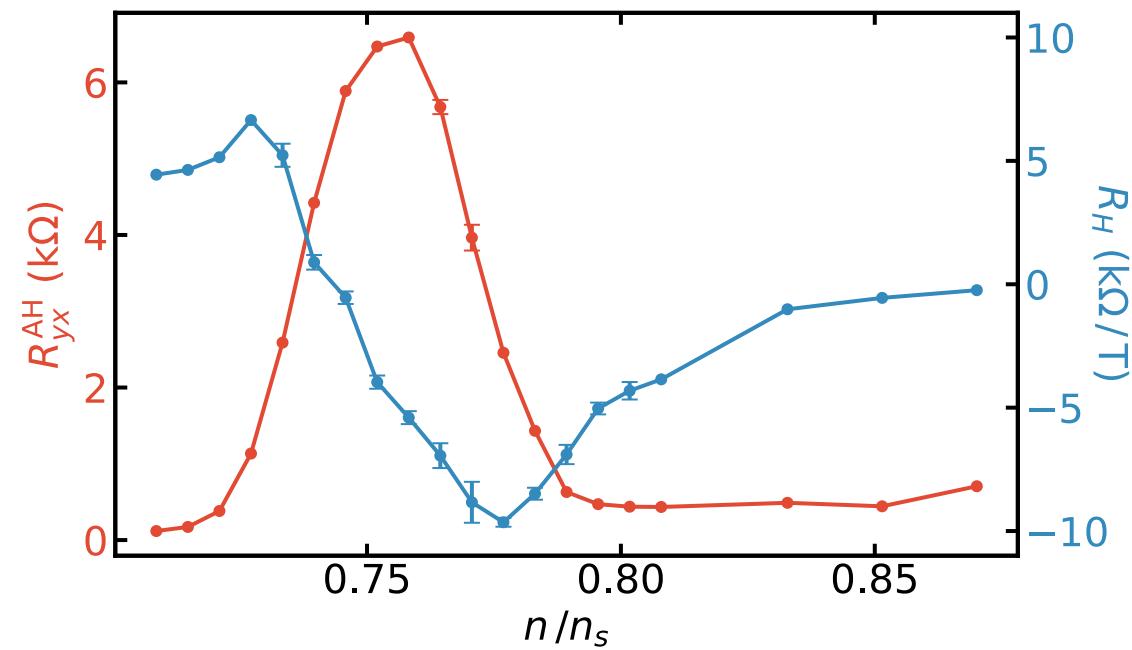
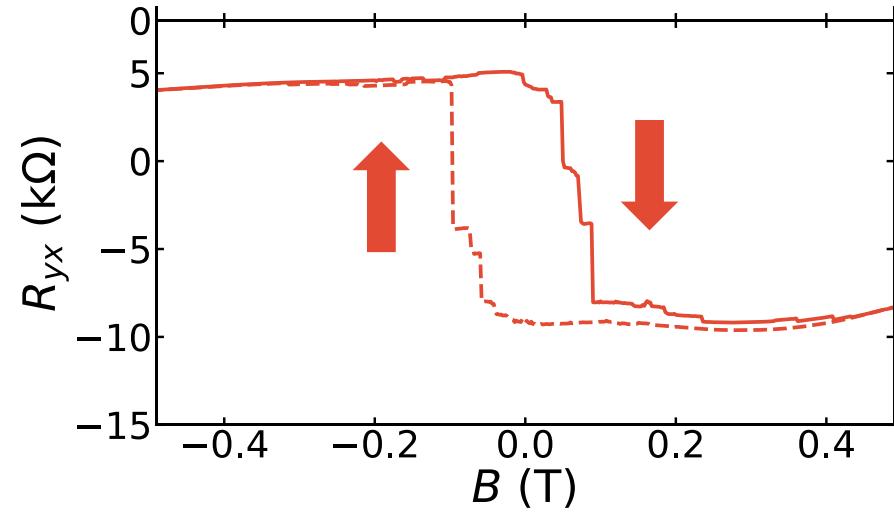
Angle 1.20+/-0.01°. Target 1.17°

# Measuring Hall Slope Density Dependence

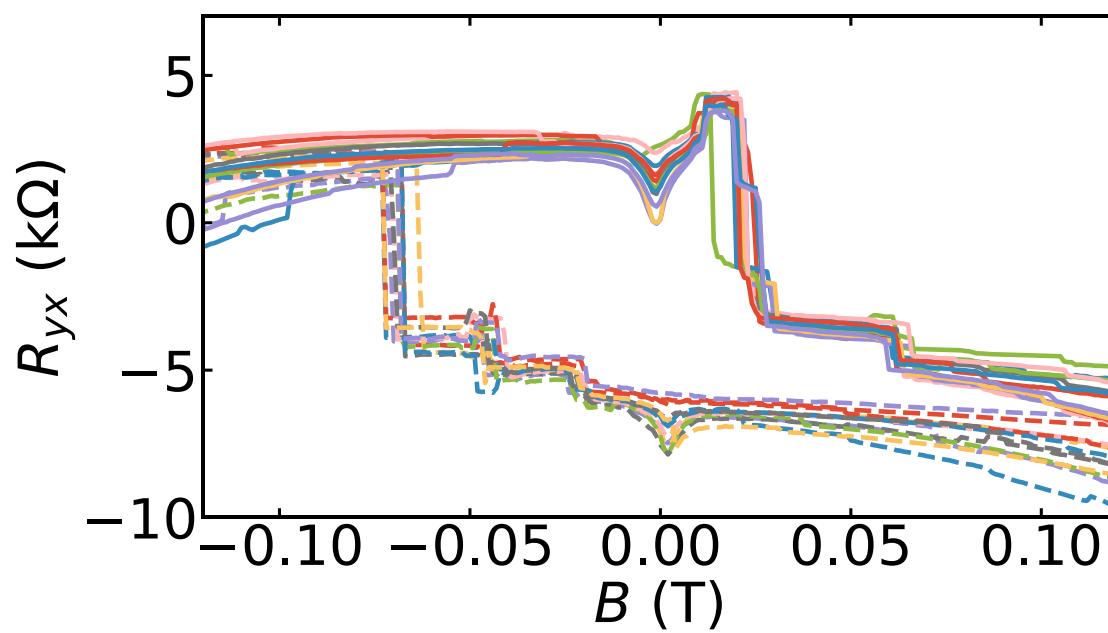
$$R_{yx} = -\frac{1}{ne}B_z + R_{AH}M_z$$



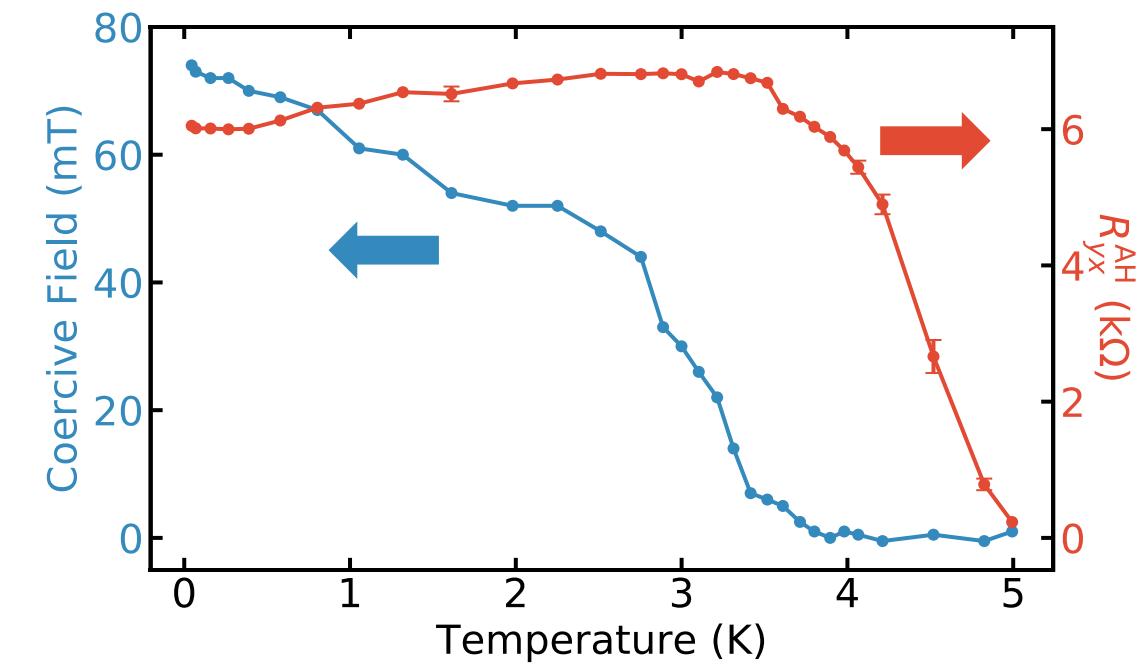
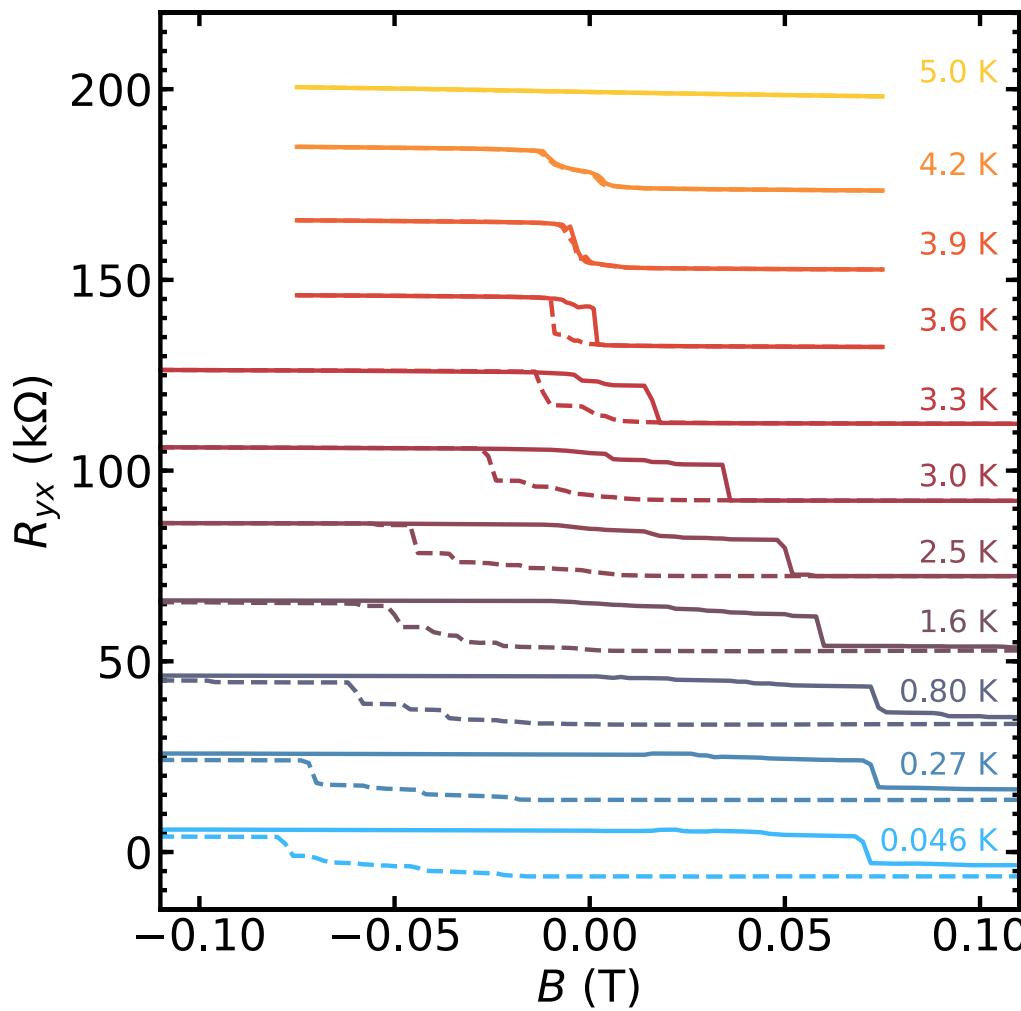
# Emergent Ferromagnetism at $\frac{3}{4}$ Filling



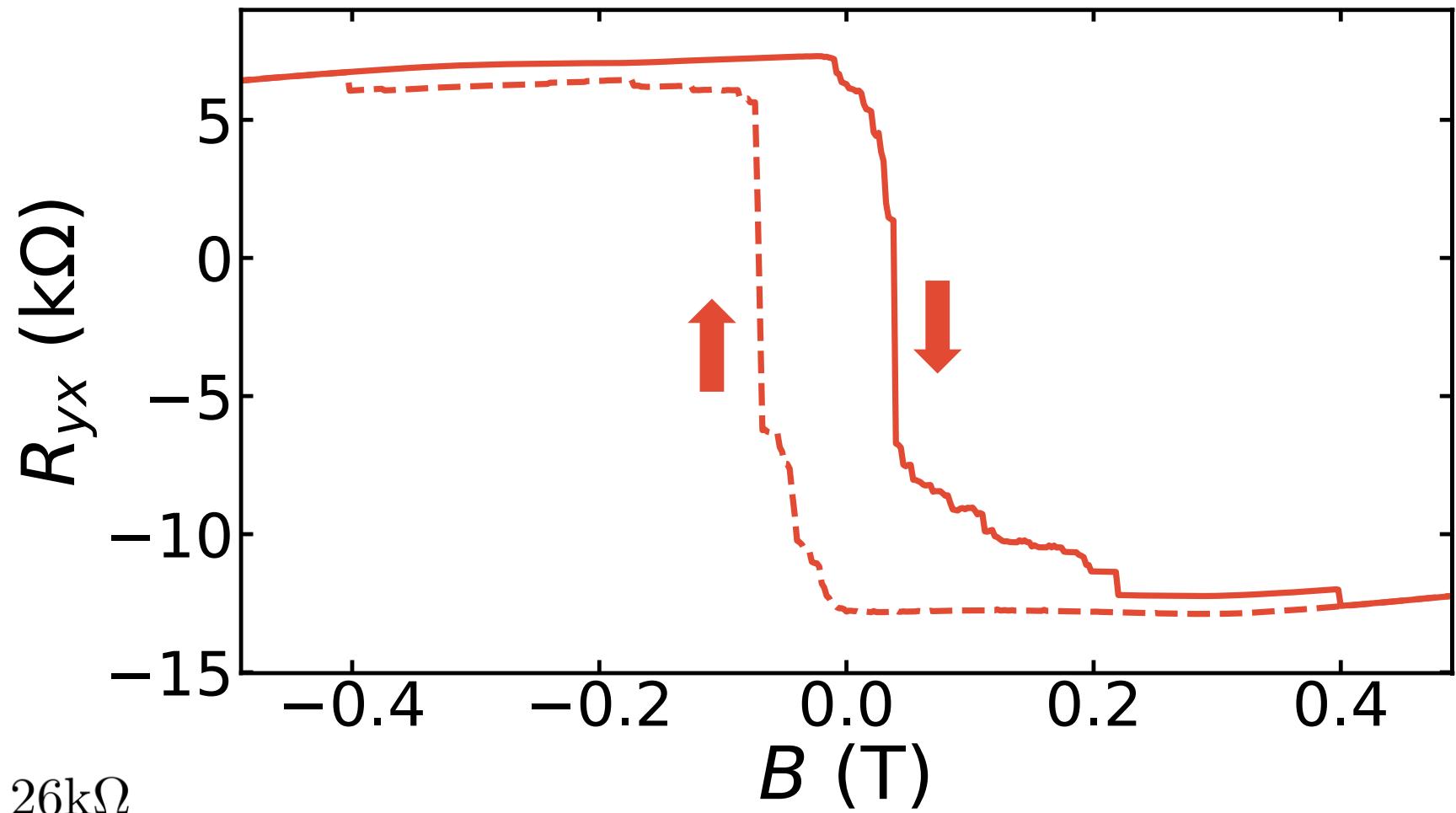
# Repeatable Hysteresis Fine Structure in Field



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



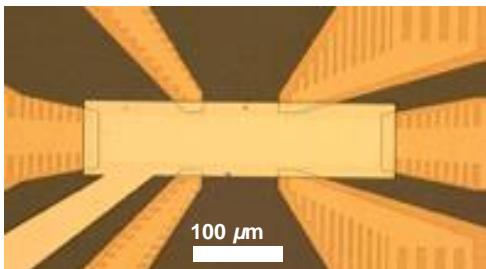
# Anomalous Hall Signal Can Be Really Large!



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

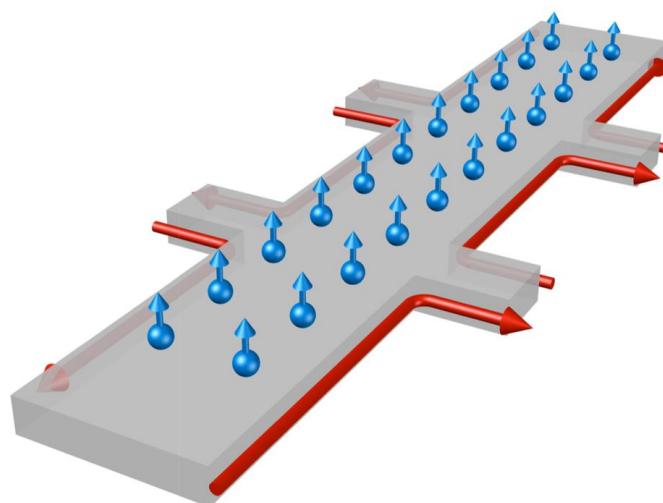
$$n/n_s = 0.775, T = 2.1 \text{ K}$$

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



## Material & device:

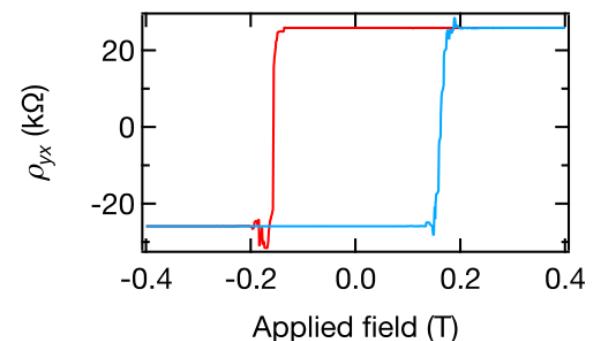
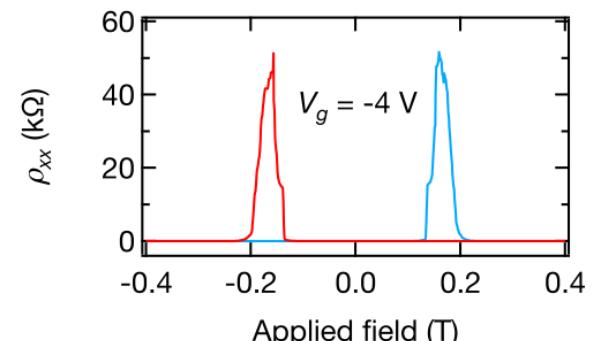
6 QL  $\text{Cr}_{0.24}(\text{Bi}_{0.3}\text{Sb}_{0.7})_{1.76}\text{Te}_3$   
GaAs substrate  
Ti/Au contacts  
Top gate



Ideally

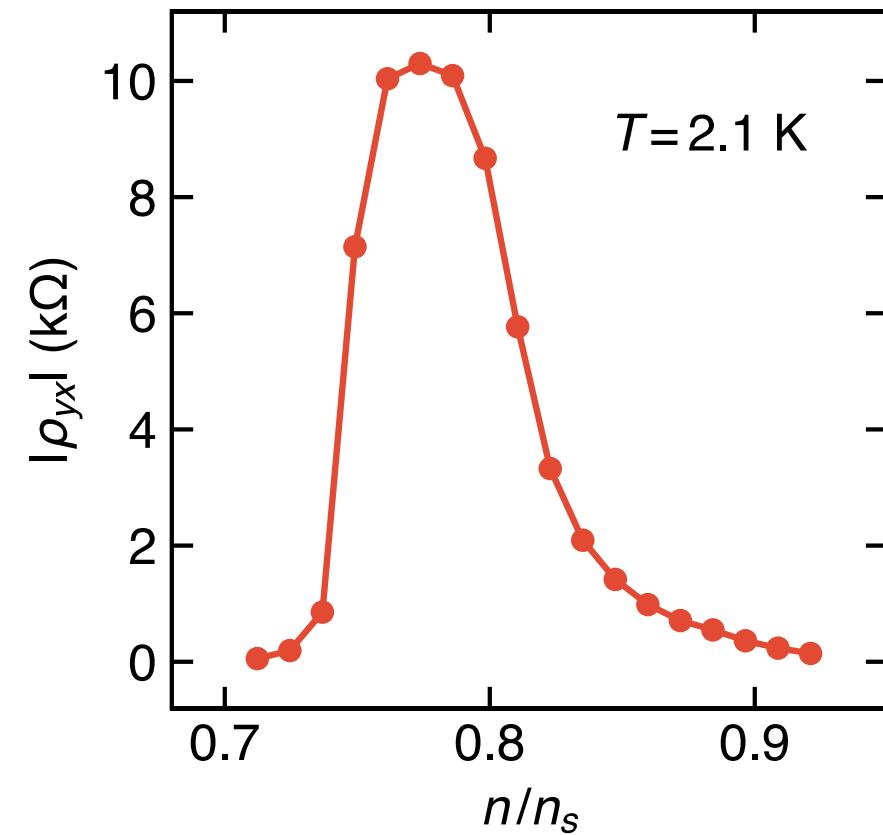
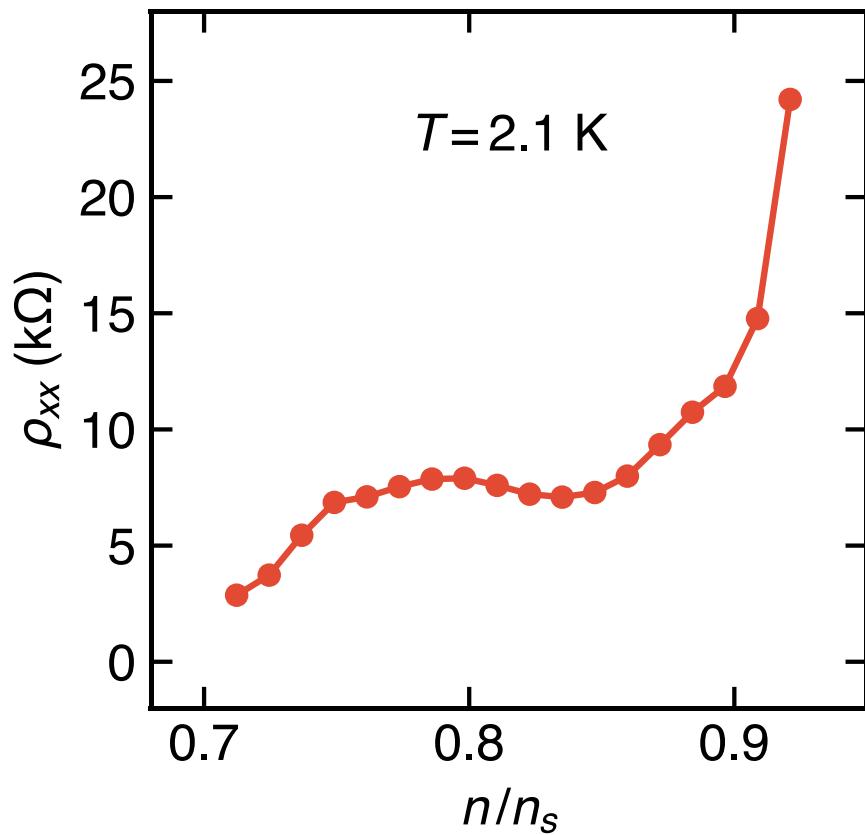
$$\rho_{xx} = 0$$
$$\rho_{yx} = h/e^2 \approx 26\text{k}\Omega$$

Near optimal gate voltage



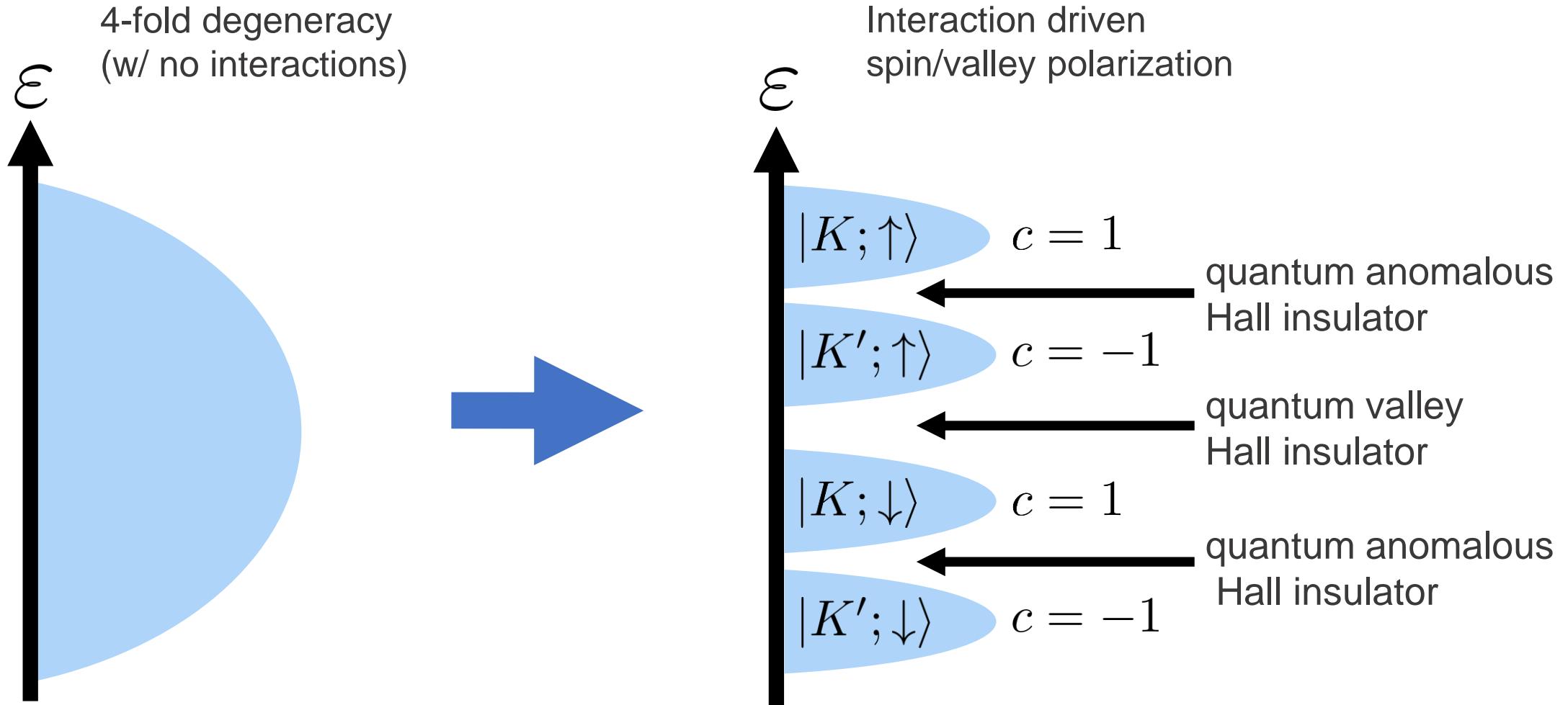
# Comparison: Anomalous Hall in TBG

## Far from quantization

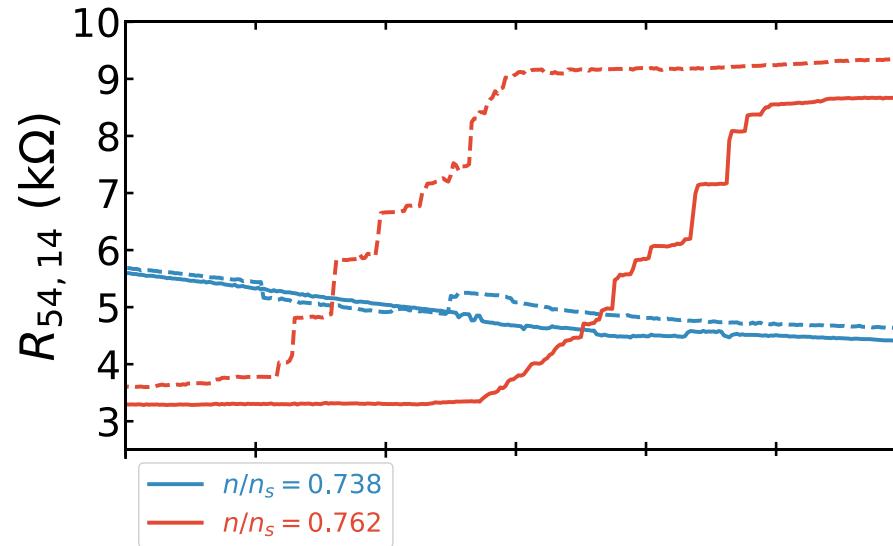
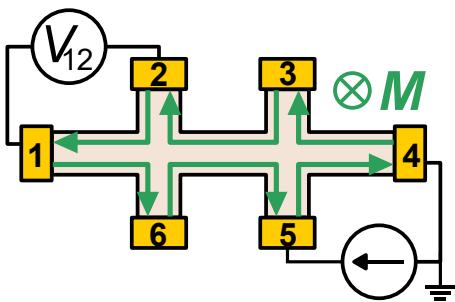
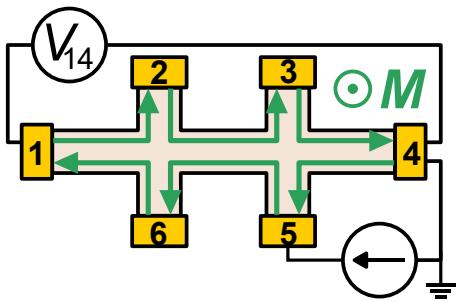


# Nature of Emergent Ferromagnetism at $\frac{3}{4}$ Filling?

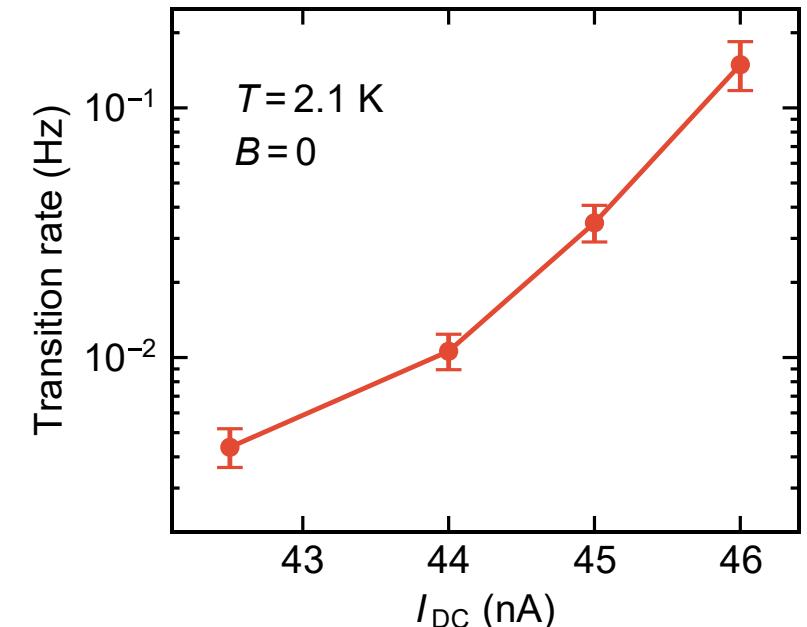
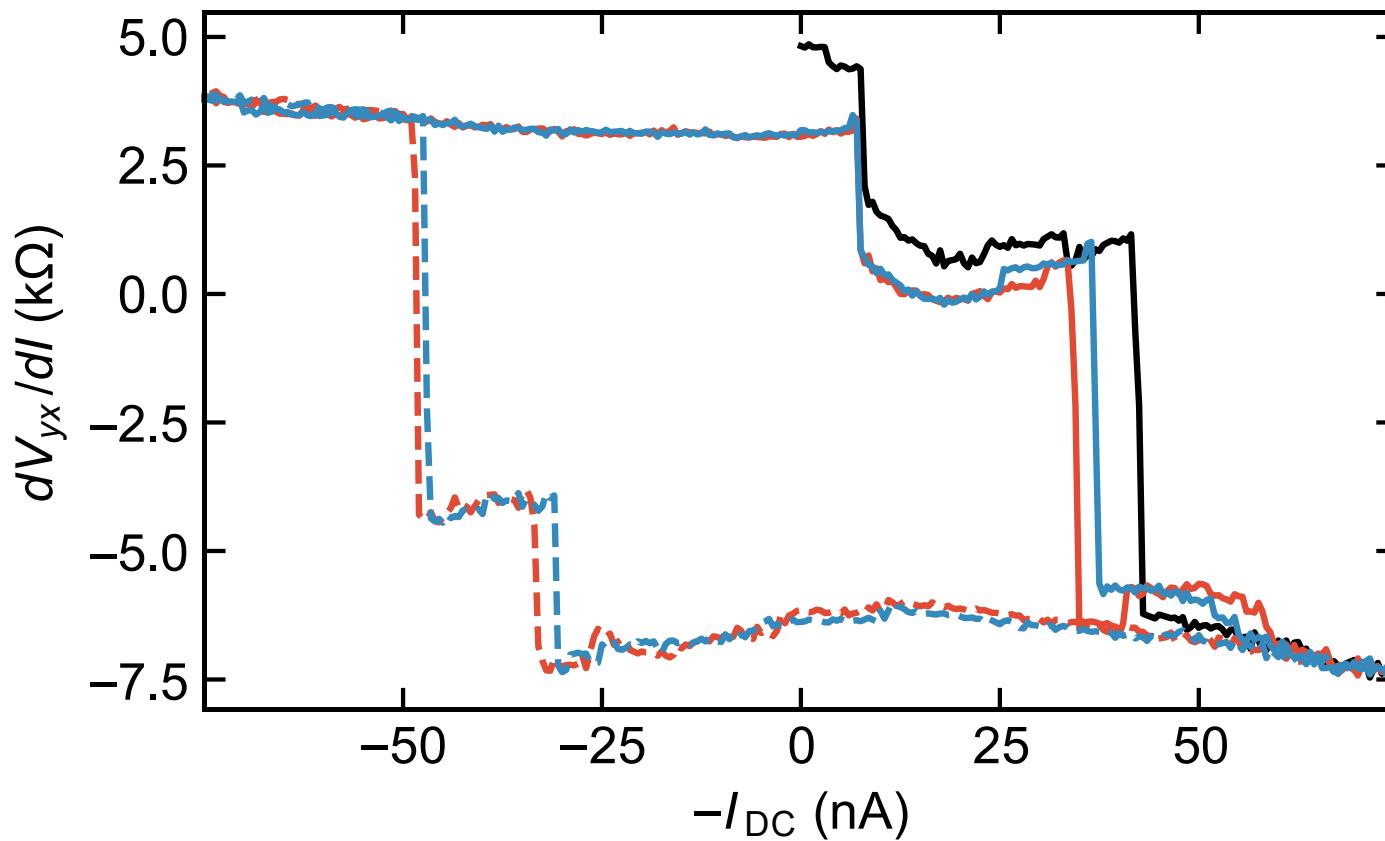
Simplistic band diagram: what *might* be happening...



# 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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# Questions?

