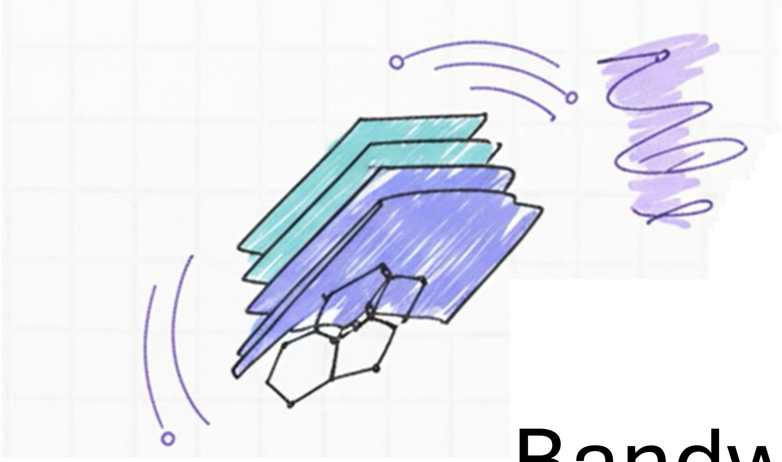
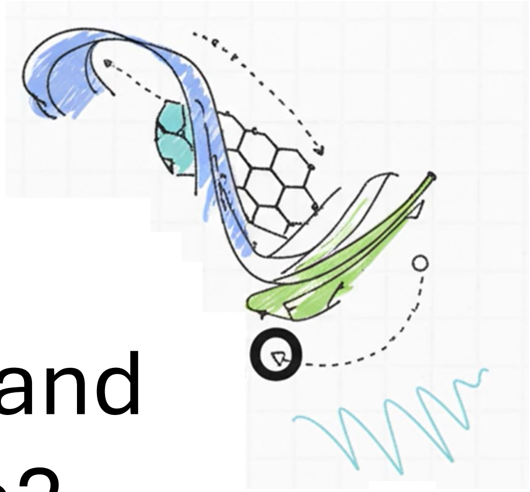
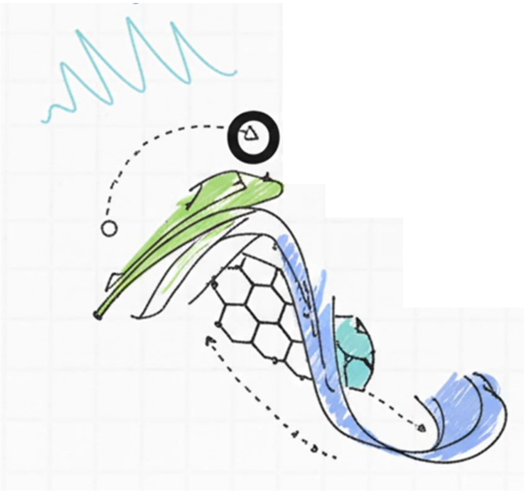


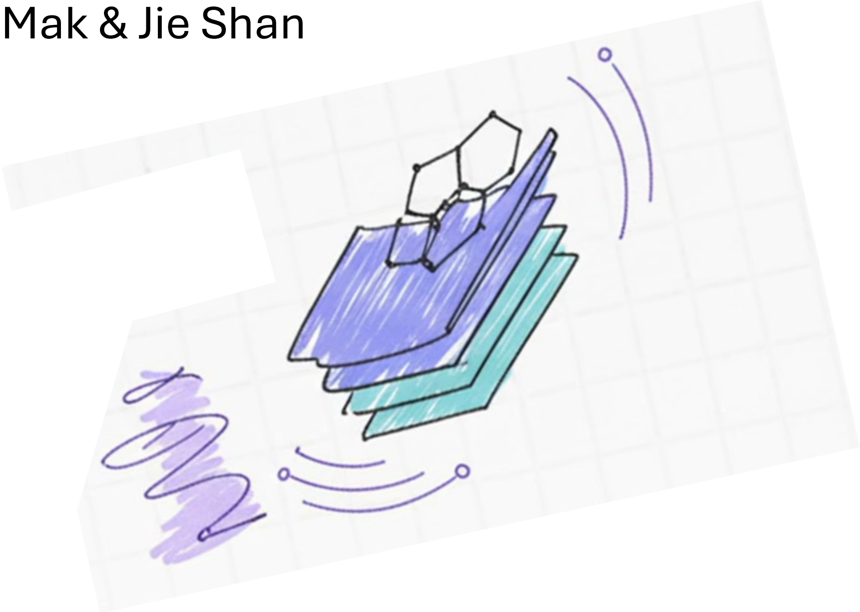


Bandwidth-tuned Mott transition and superconductivity in moiré WSe_2

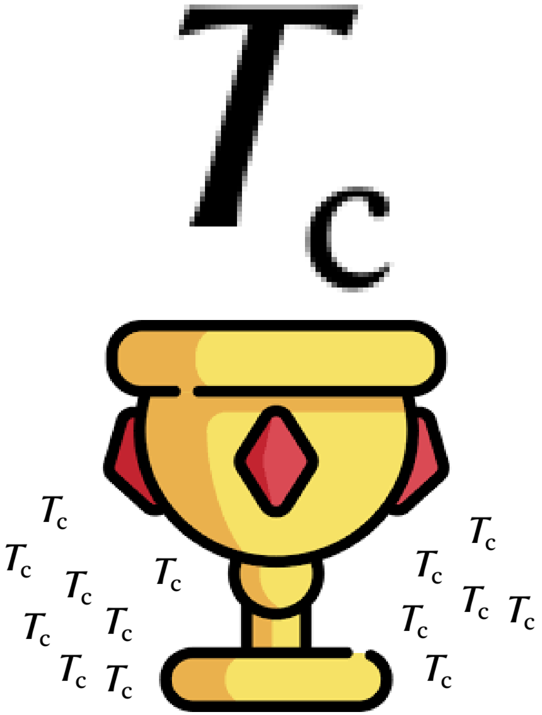
Yiyu Xia, Zhongdong Han, Jiacheng Zhu, Yichi Zhang, Patrick Knüppel, Kenji Watanabe, Takashi Taniguchi, Kin Fai Mak & Jie Shan

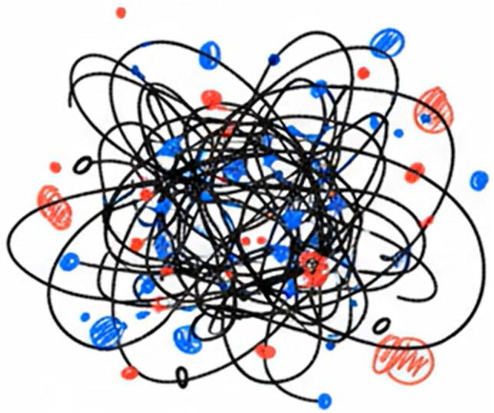
Nature **650**, 585–591 (2026)





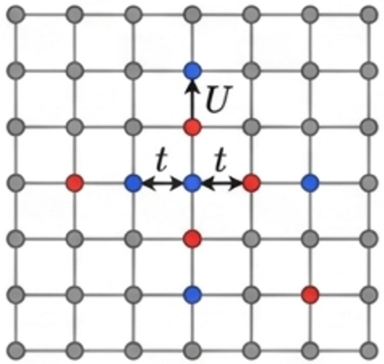
Jibin N Sunil
Journal club /10-04-2026





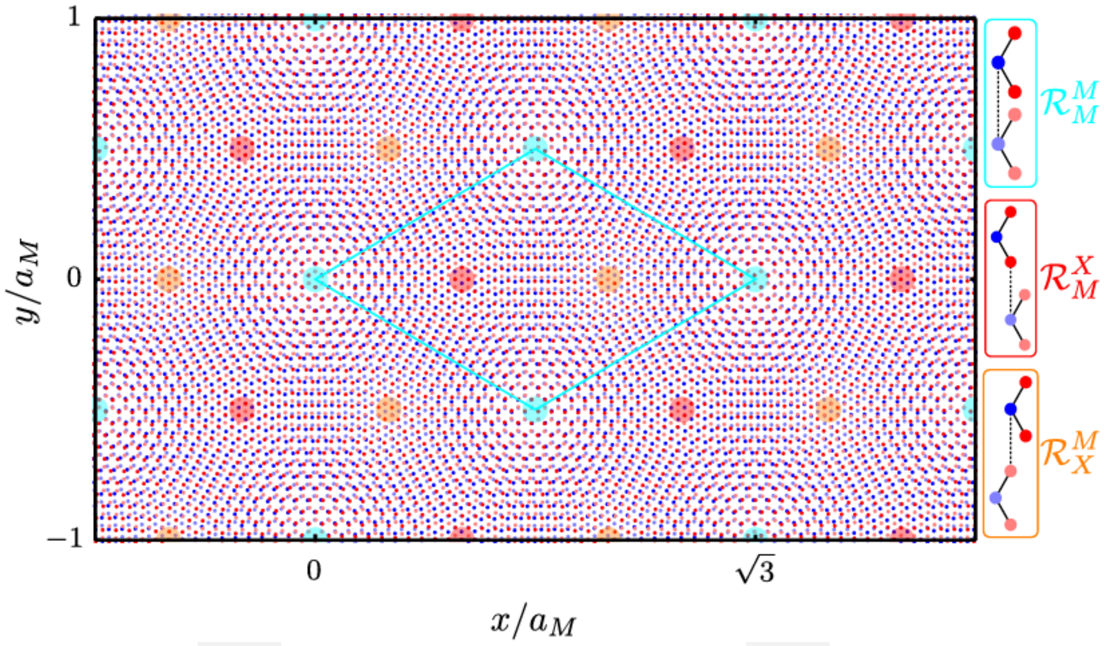
cuprates

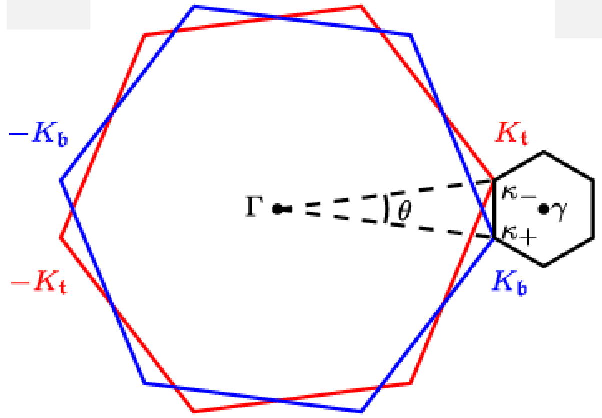
- Generally complex
- Not easily tunable
- Difficult in Modeling



Hubbard Model

- Simple interaction on lattice
- Capture essential physics
- Rich but hard to solve

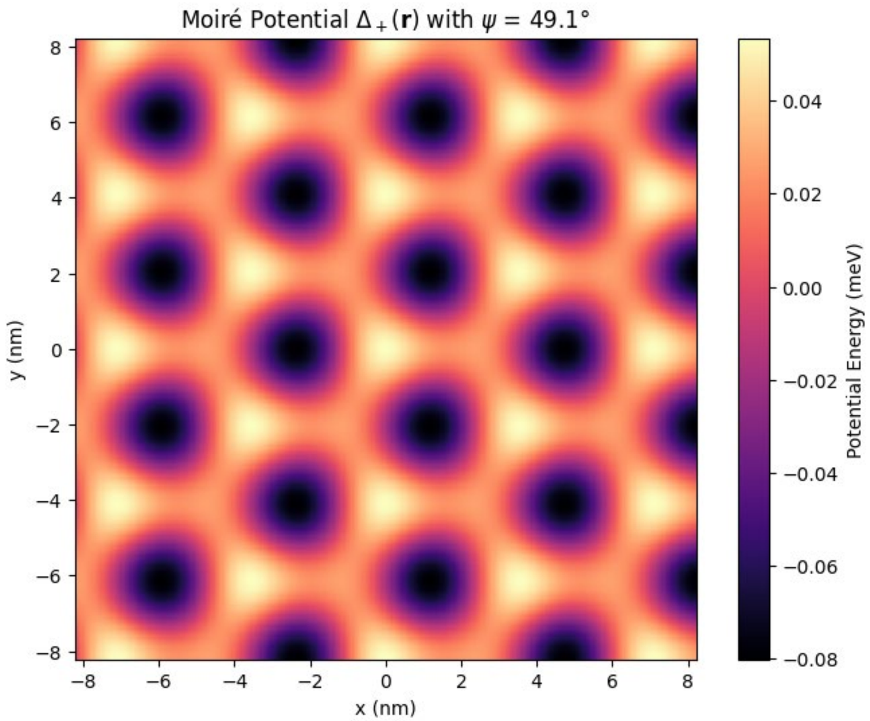


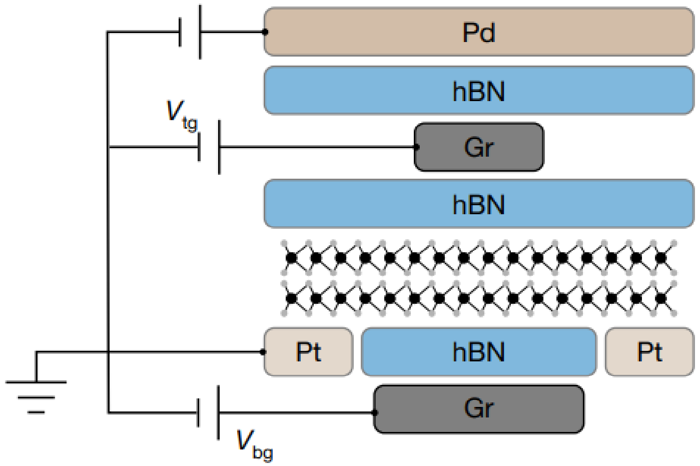


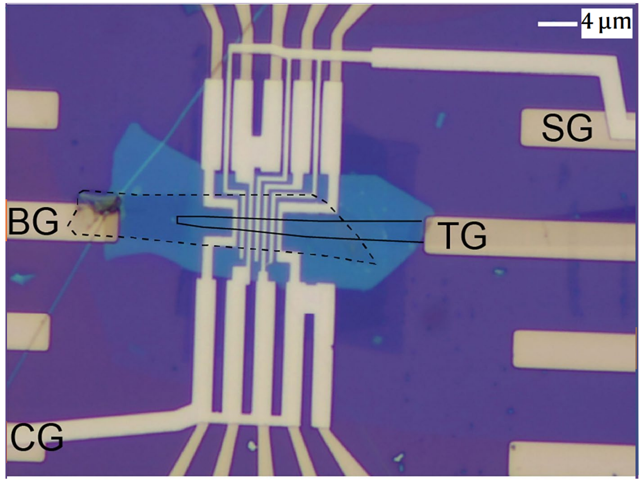
H. Pan et al., Phys. Rev. Research **2**, 033087 (2020)

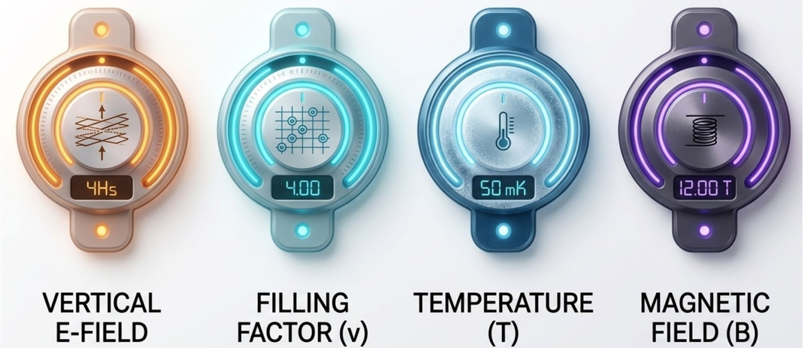
- The twist angle (θ) determines the size of the moiré unit cell.

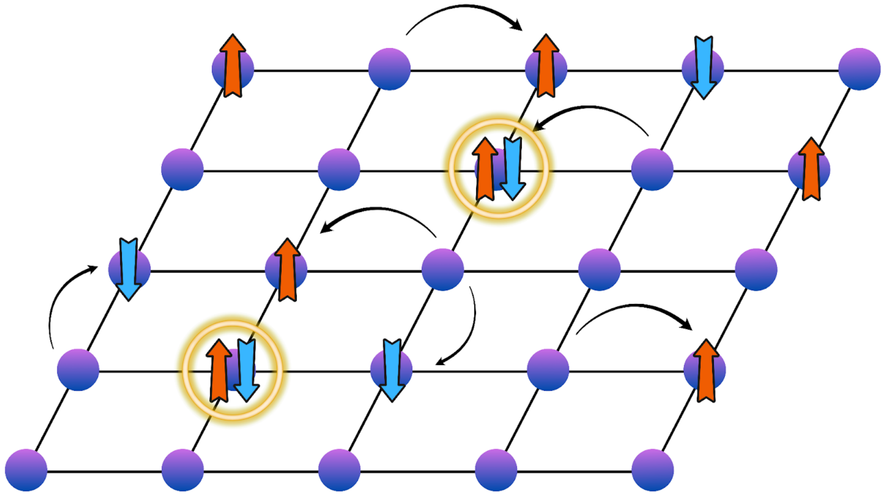
$$\Delta_\pm(\boldsymbol{r}) = 2V \sum_{j=1,3,5} \cos(\boldsymbol{b}_j \cdot \boldsymbol{r} \pm \psi)$$



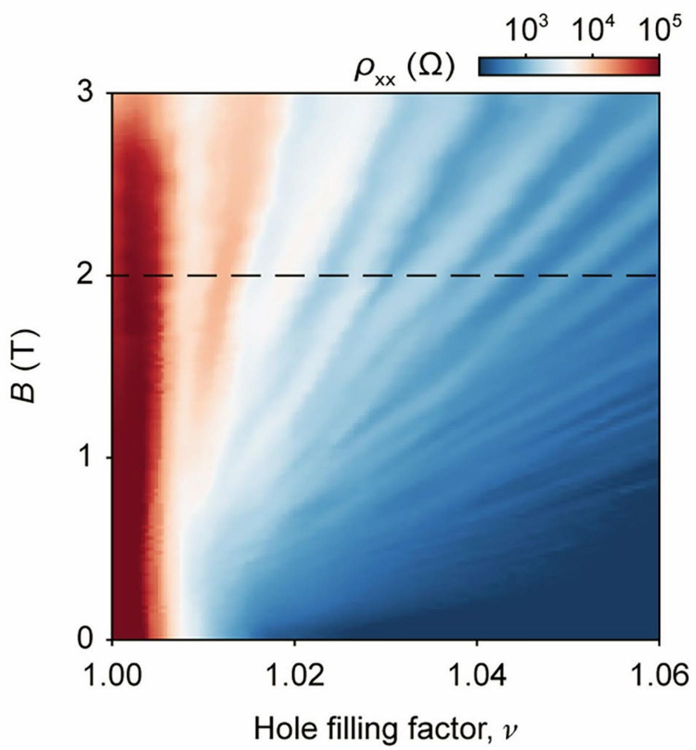

Pd
hBN
V_{tg}
Gr
hBN
Pt
hBN
Pt
Gr
V_{bg}

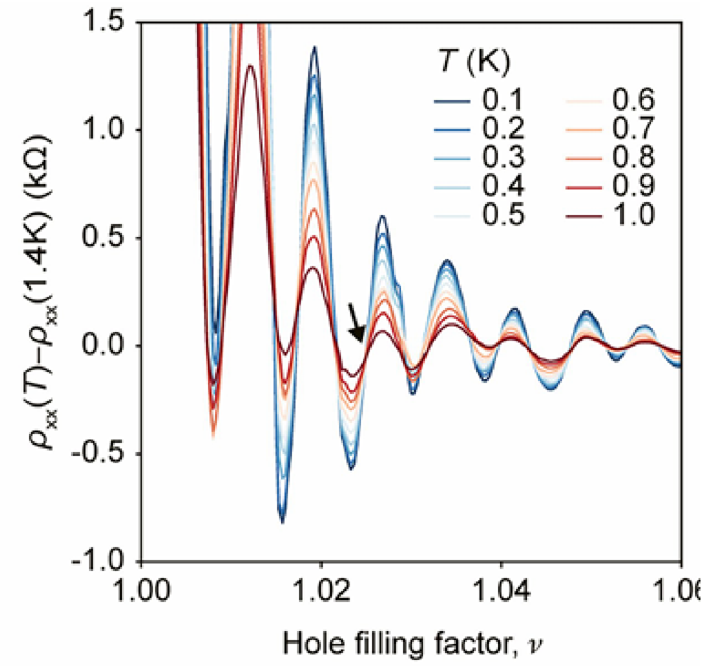

4 µm
SG
BG
TG
CG

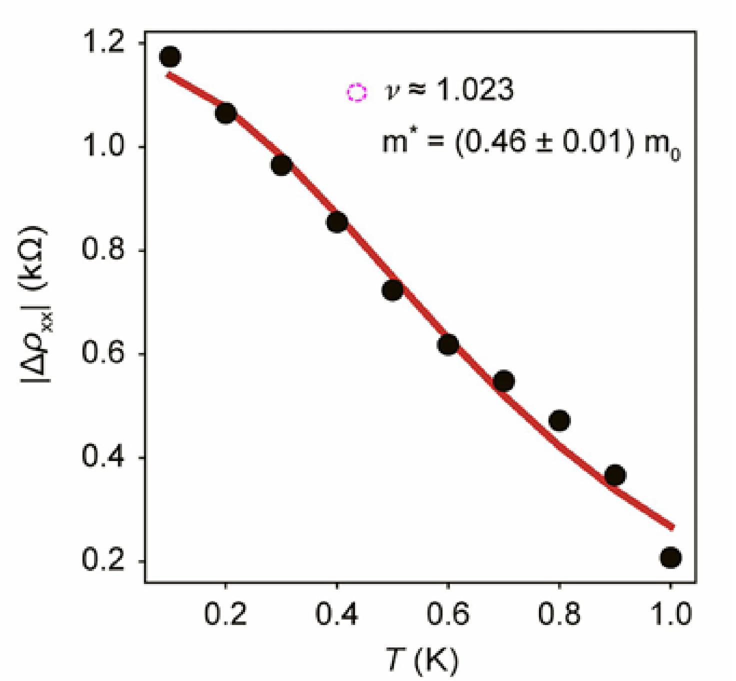

4Hs
4.00
50 mK
12.00 T
VERTICAL E-FIELD
FILLING FACTOR (v)
TEMPERATURE (T)
MAGNETIC FIELD (B)



The moiré density can be calculated with $n_M = \frac{4}{\sqrt{3}a_M^2}$

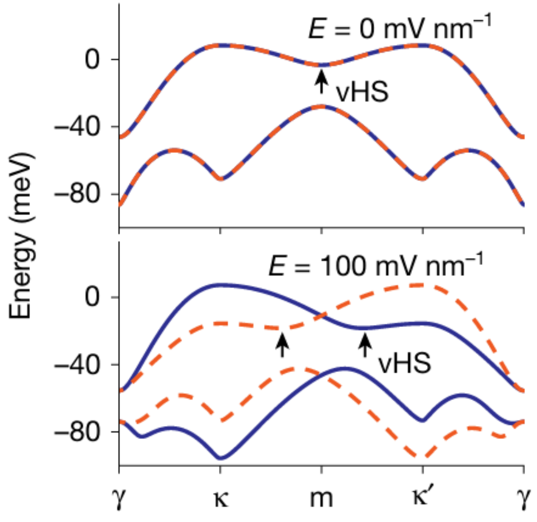




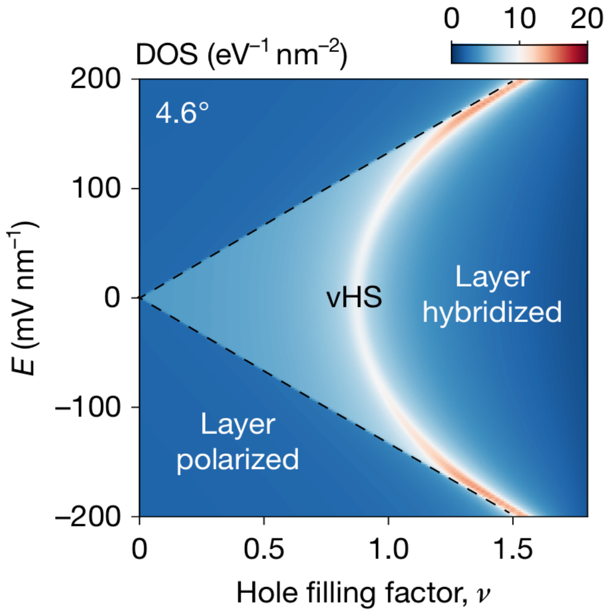


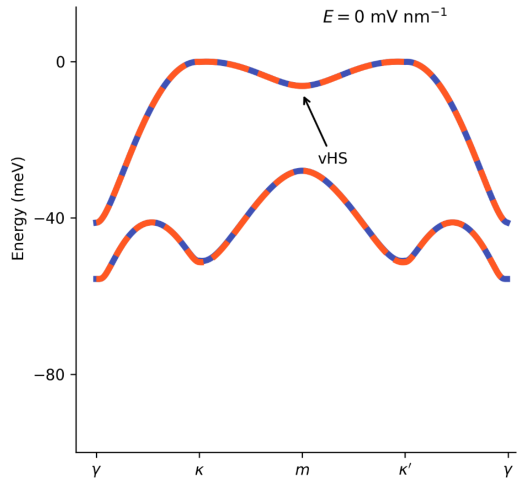
Lifshitz-Kosevich (LK) formula

$$\lambda(T) = \frac{2\pi^2 k_B T m^*}{\hbar e B}$$



Topmost moiré valence bands



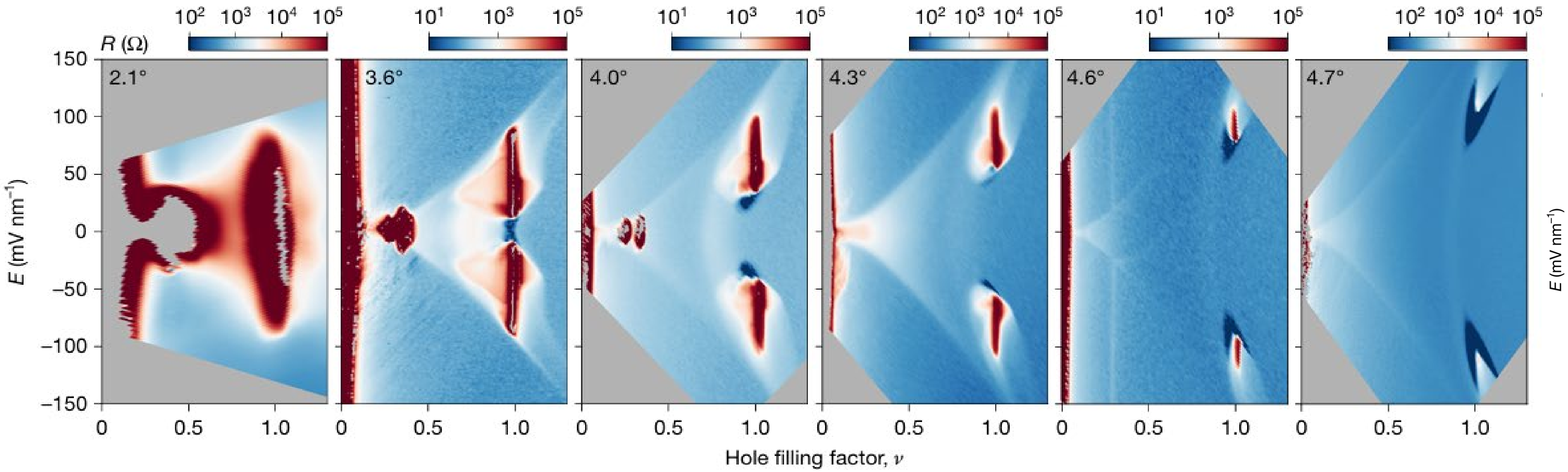


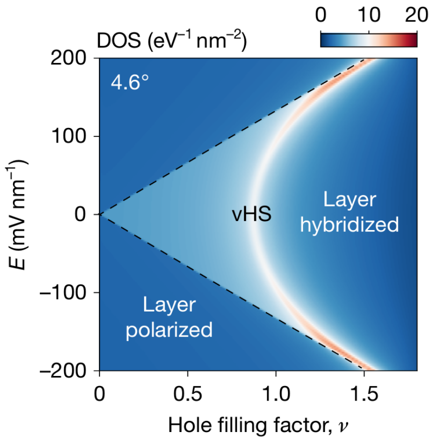
My attempt on recreating the model

$$H_{\uparrow} = \begin{pmatrix} -\frac{\hbar^2(\mathbf{k}-\boldsymbol{\kappa}_+)^2}{2m^*} + \Delta_t(\mathbf{r}) & \Delta_T(\mathbf{r}) \\ \Delta_T^{\dagger}(\mathbf{r}) & -\frac{\hbar^2(\mathbf{k}-\boldsymbol{\kappa}_-)^2}{2m^*} + \Delta_b(\mathbf{r}) \end{pmatrix}.$$

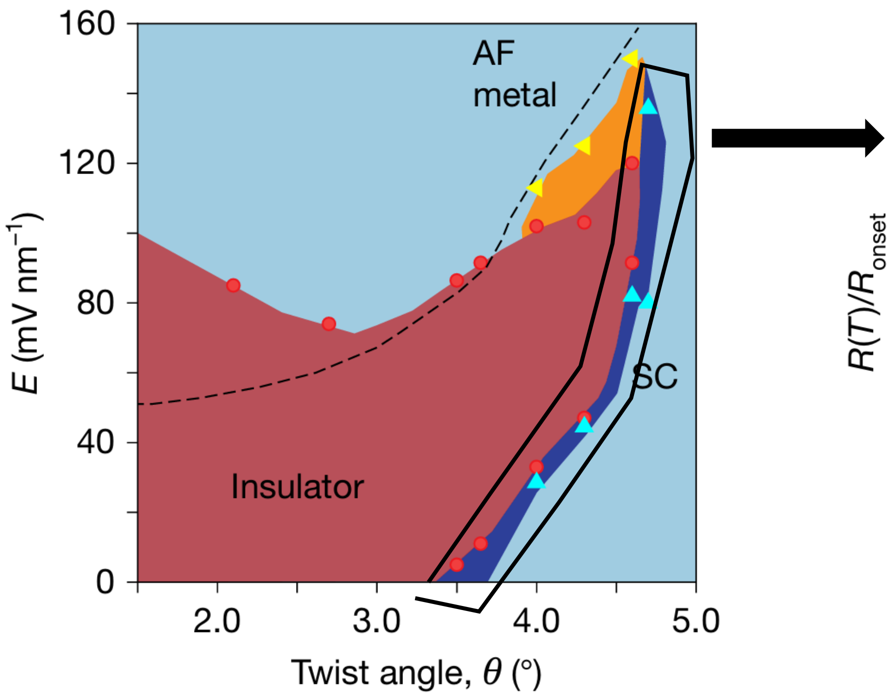
$$\Delta_T(\mathbf{r}) = w(1 + e^{-i\mathbf{g}_2\cdot\mathbf{r}} + e^{-i\mathbf{g}_3\cdot\mathbf{r}})$$

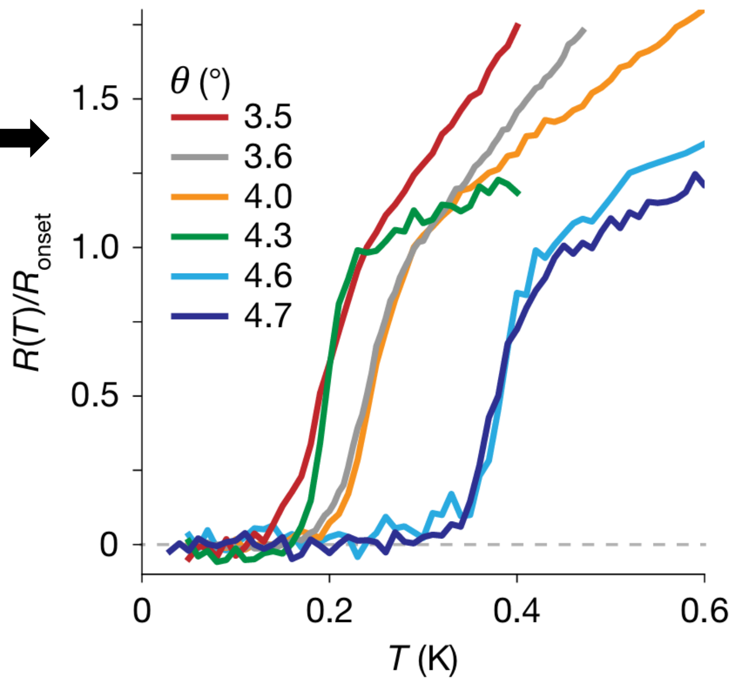
Resistance Measured as a function of Twist angle

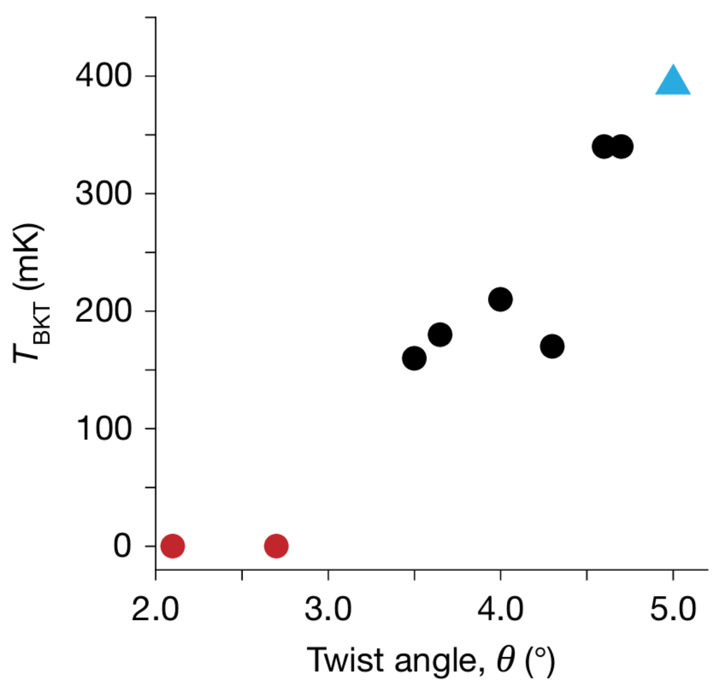




- Qualitatively agree with the DOS map (Insulated states)
- As the twist angle increases, the correlated insulators gradually melt (correlation effects weaken as the moiré period decreases)
- the most robust superconducting state always appears right next to the ‘melting point’ of the v = 1 insulator

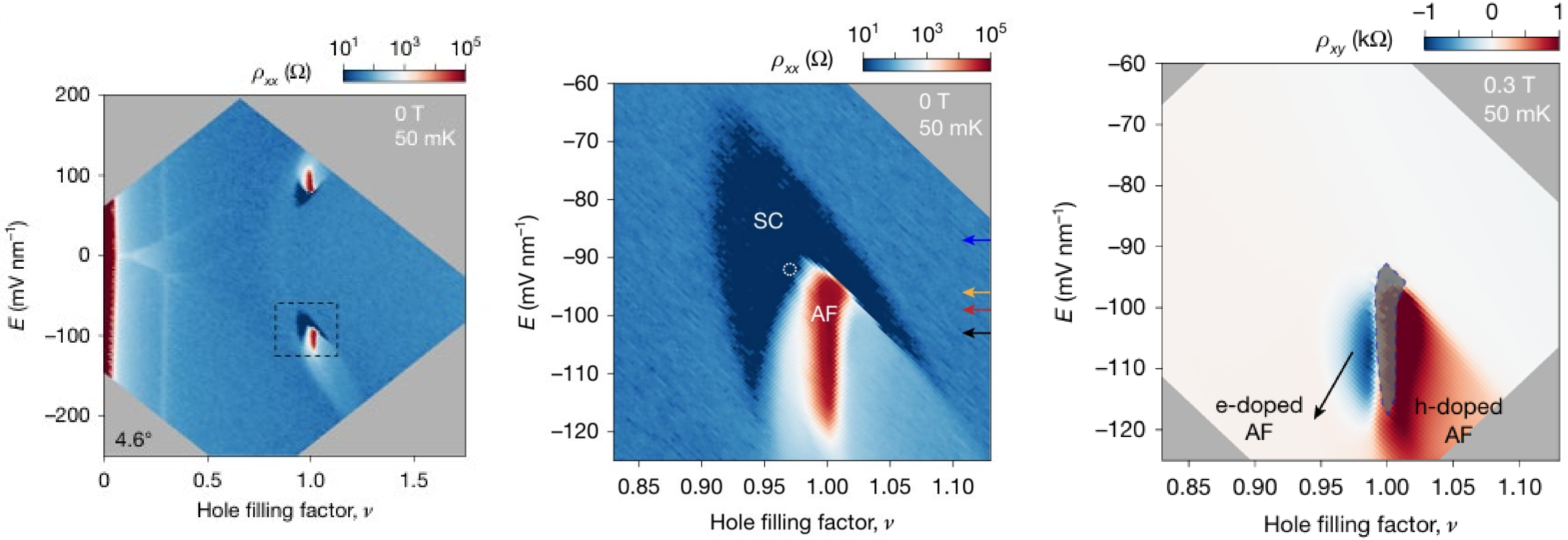


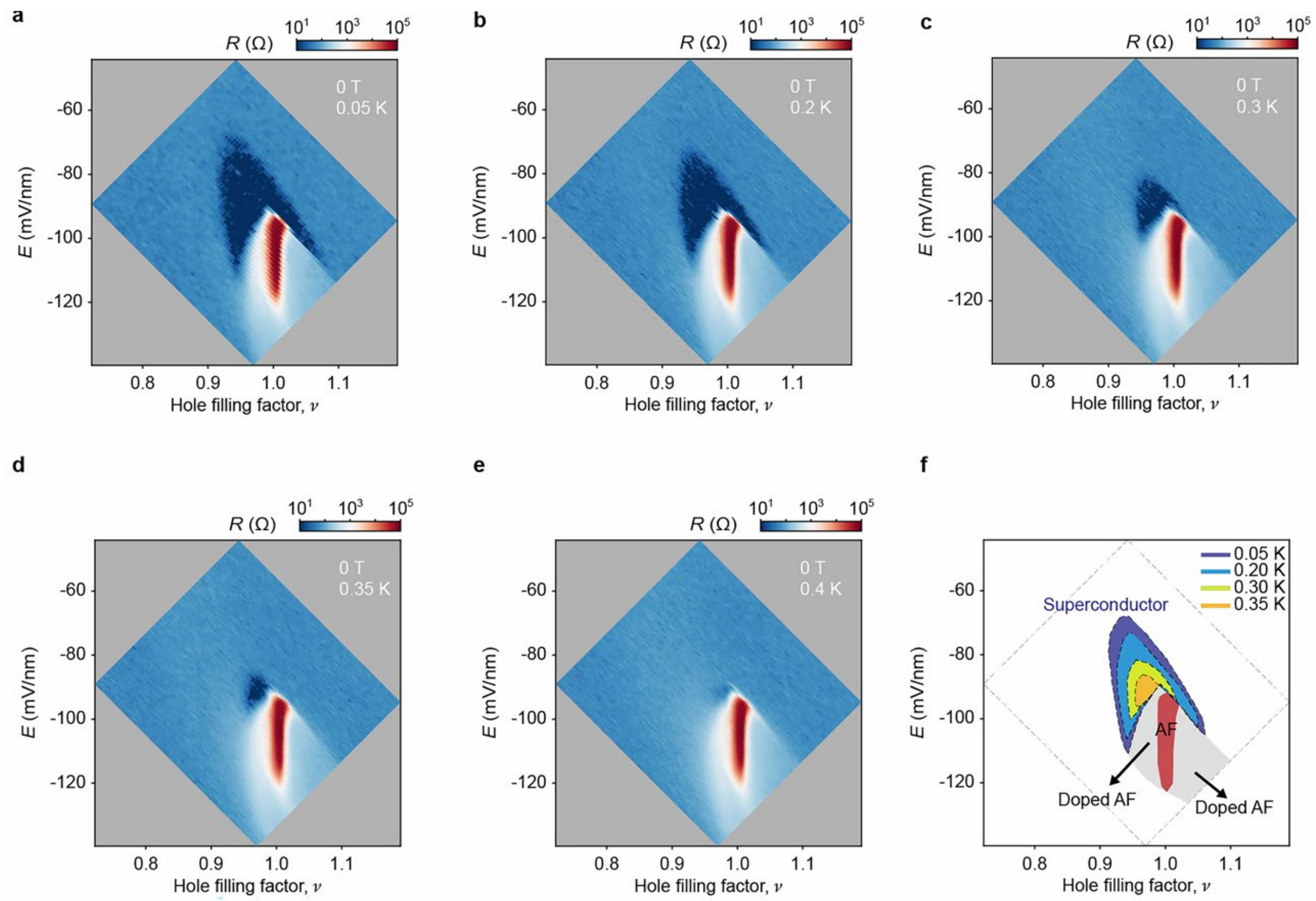


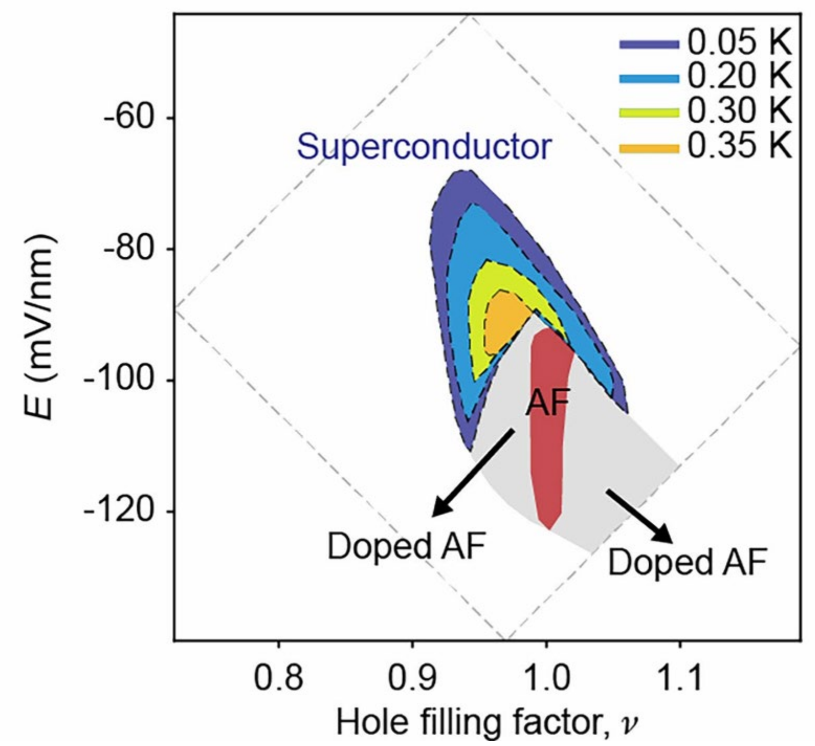


- Phase diagram at hole filling factor = 1
- SC is next to insulating region.
- BKT- temperature increases with twist angle.

Anti ferromagnetic phase

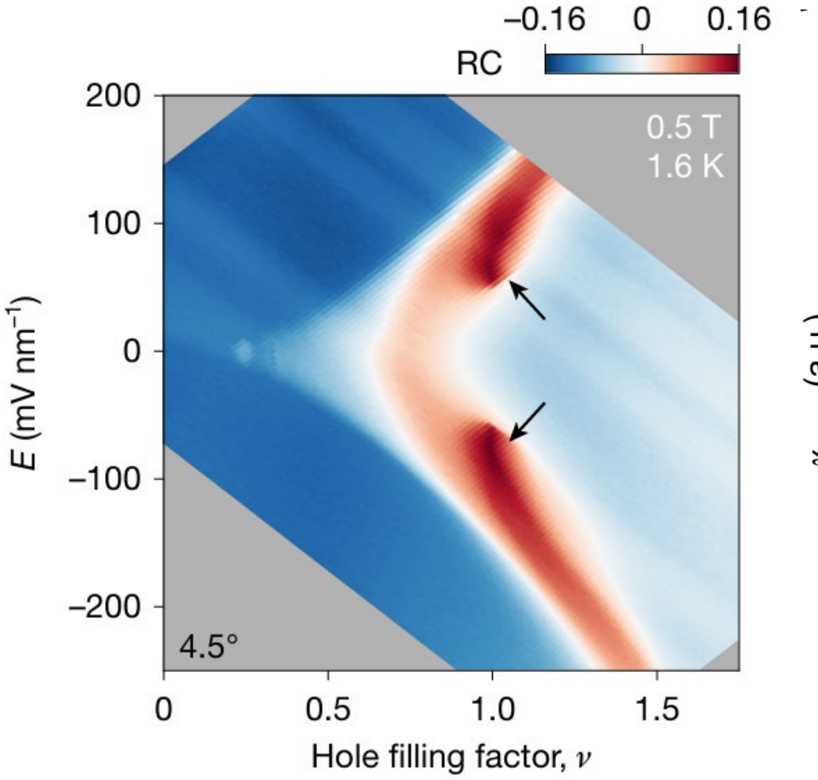


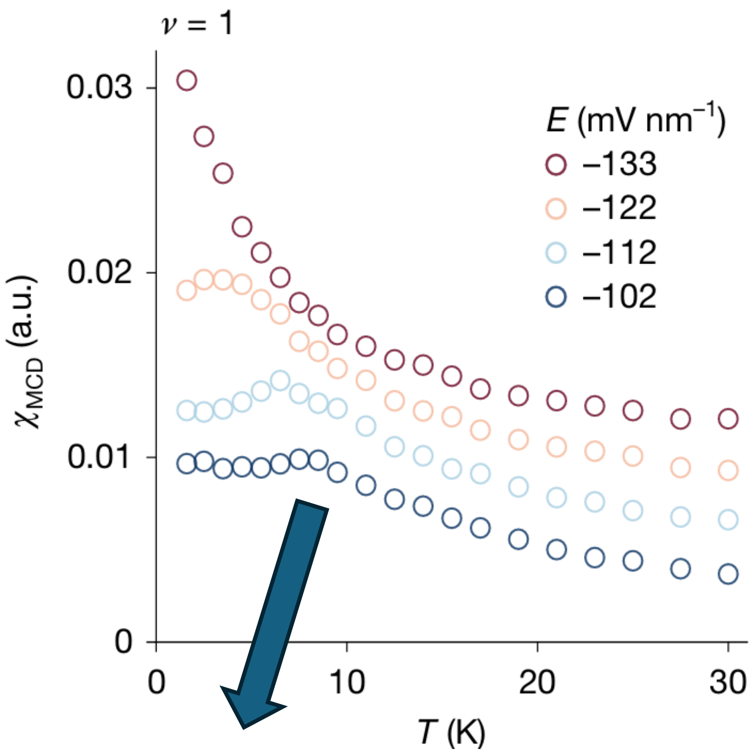


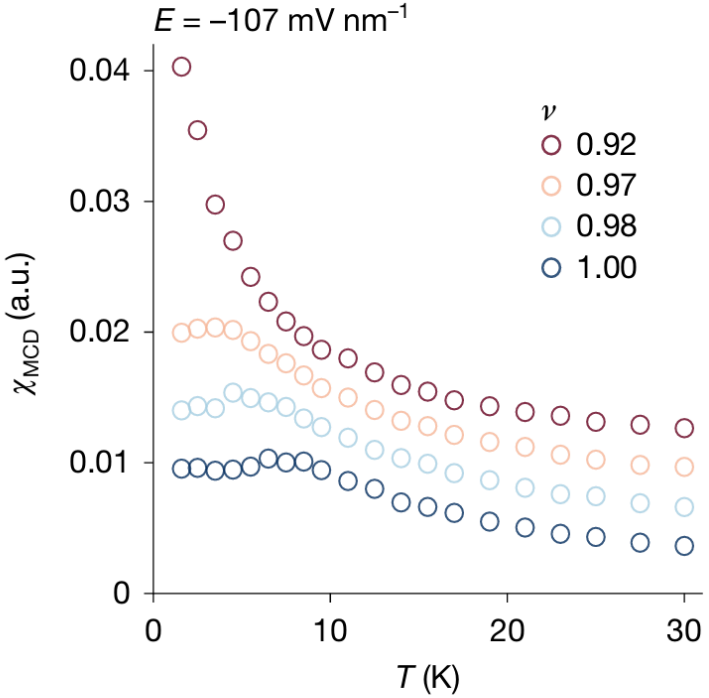


The superconductor is most robust near its boundary with the insulator
0.4 K - Tc

Anti ferromagnetic phase – Confirmation with magnetic circular dichroism







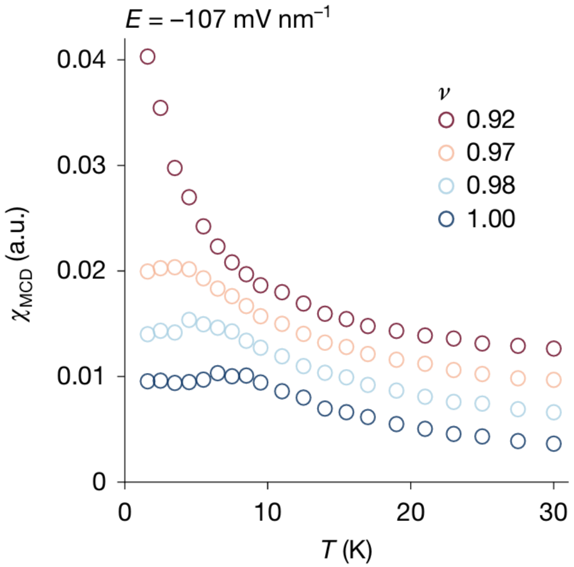
T_N

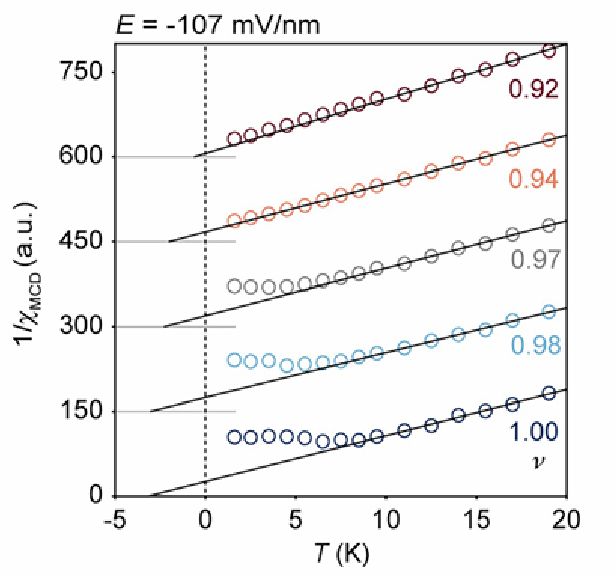
$$MCD = \frac{I_{RCP} - I_{LCP}}{I_{RCP} + I_{LCP}}$$

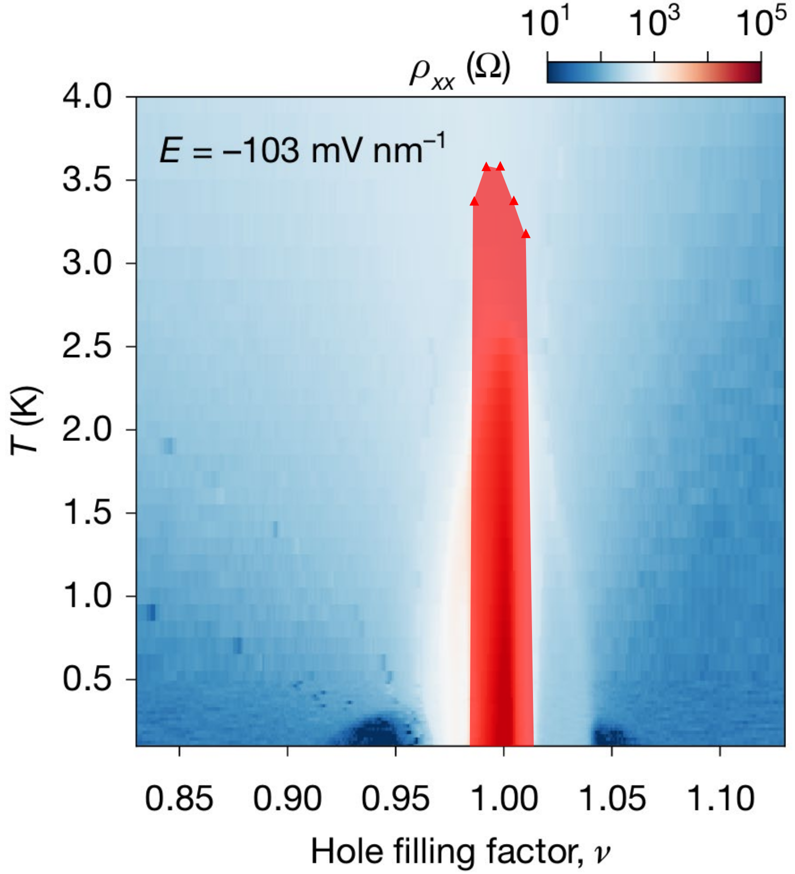
$$\chi \approx \frac{d(MCD)}{dB}$$

2D anisotropic XXZ model predicts this

Anti ferromagnetic phase – Finding T_N





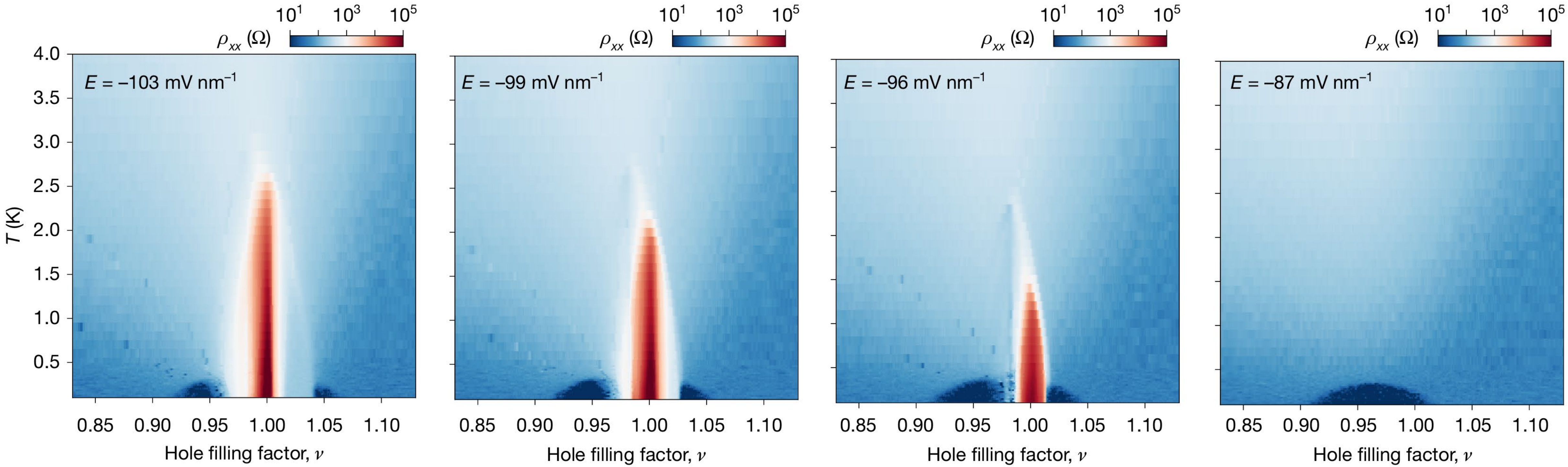


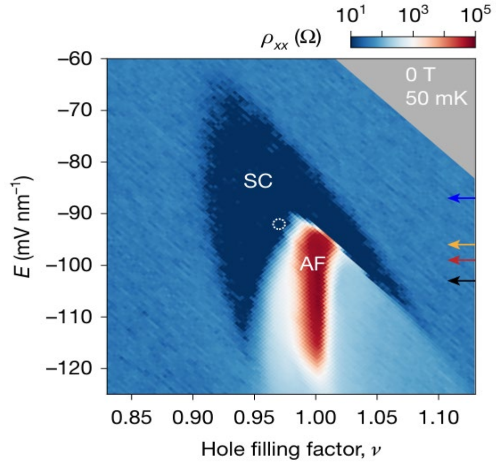
$$\chi = \frac{C}{T - \Theta}$$

$$\frac{1}{\chi} = \frac{1}{C}(T - \Theta)$$

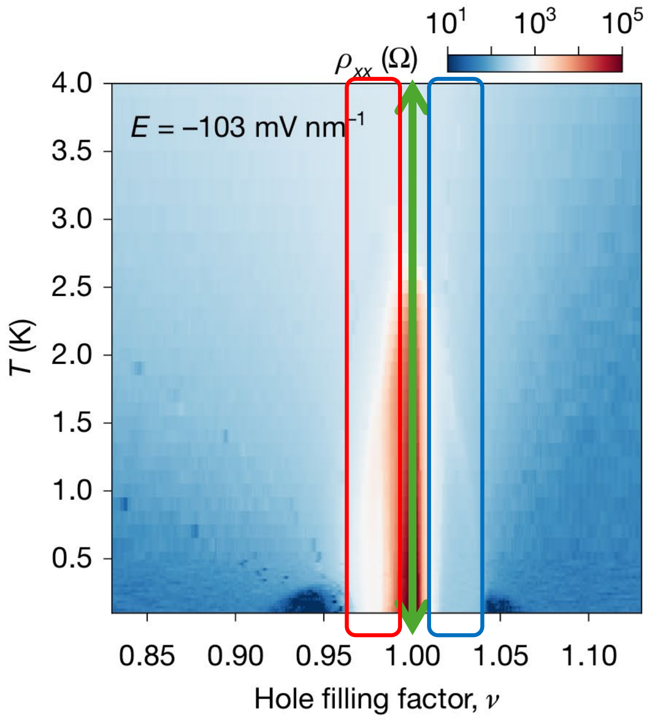
- x- intercept tells how strong the exchange interaction is.
- More negative means strong AF coupling

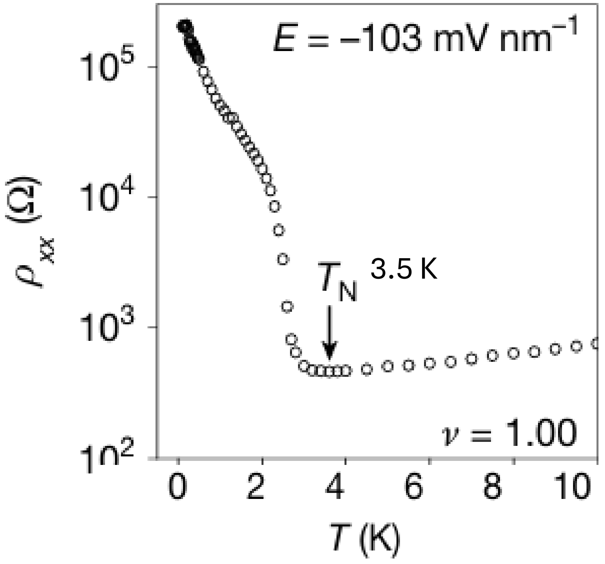
More interesting phases

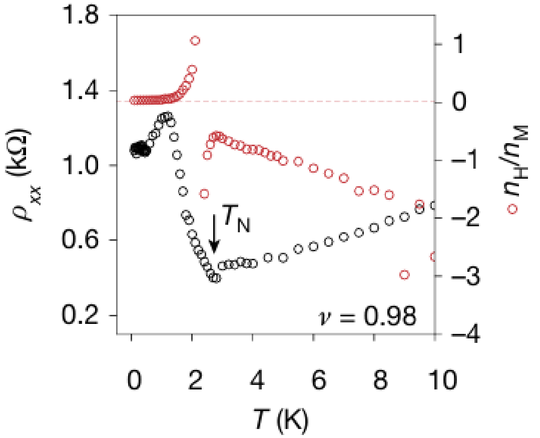




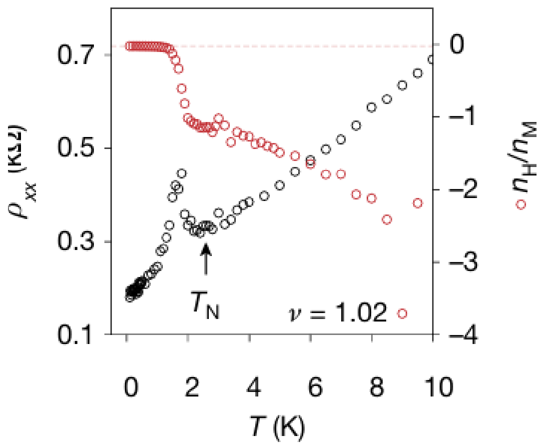
- AF phase melts with Electric filed at a fixed temperature. U/W is tuned by E.
- SC Dome in electron doped region is more robust- vHS is not centered at 1







e- doped



h- doped

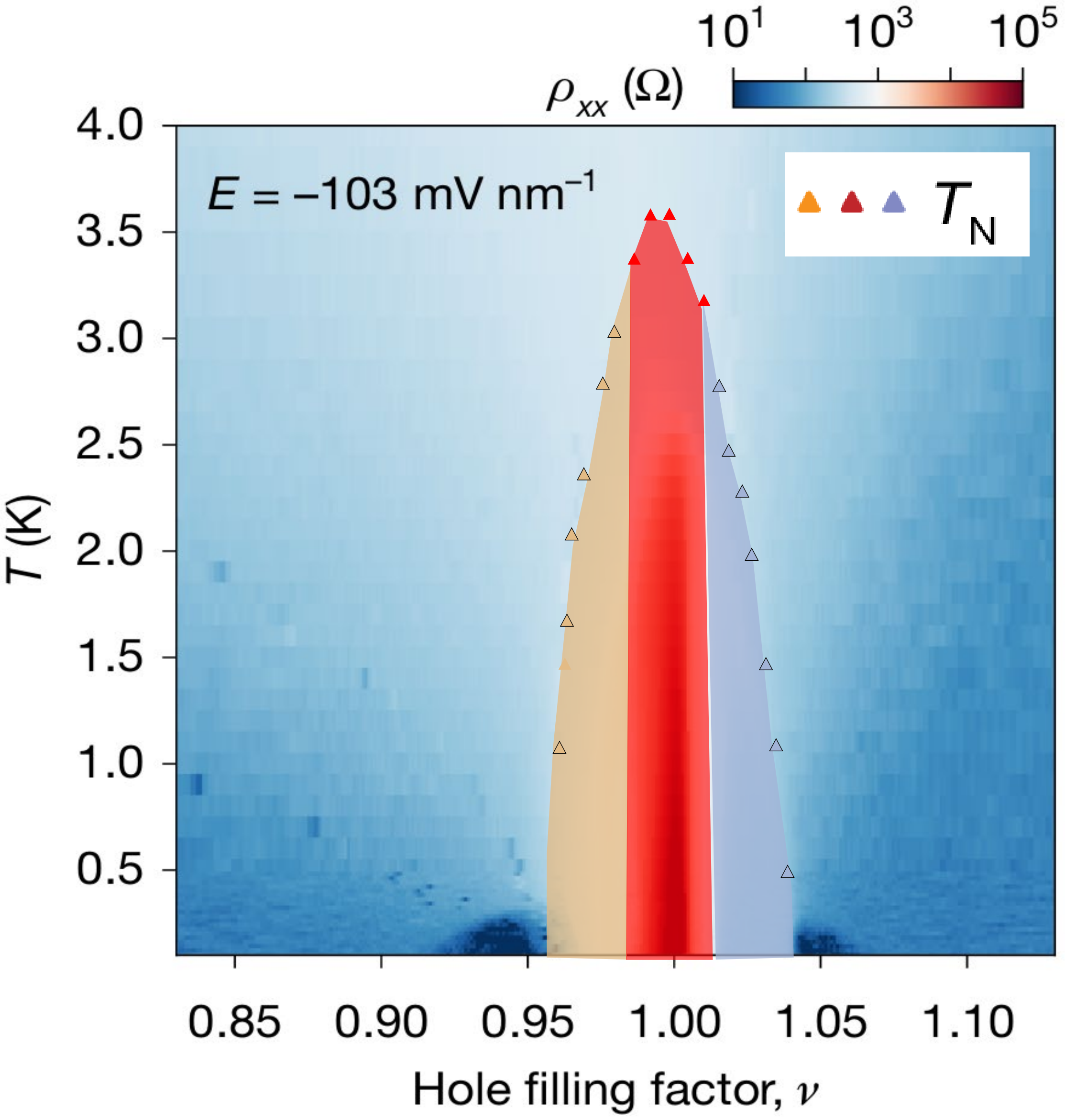
T_N = 3.5 K (ν = 1)

T_N goes down with doping

Above T_N linear behavior -> doped phases are metallic

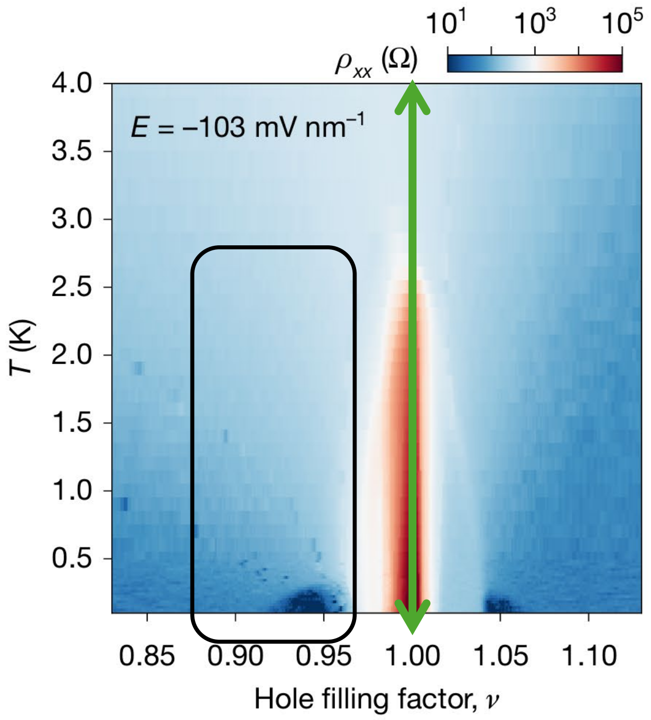
Abrupt jump in the Hall density (n_H) - Fermi surface reconstruction

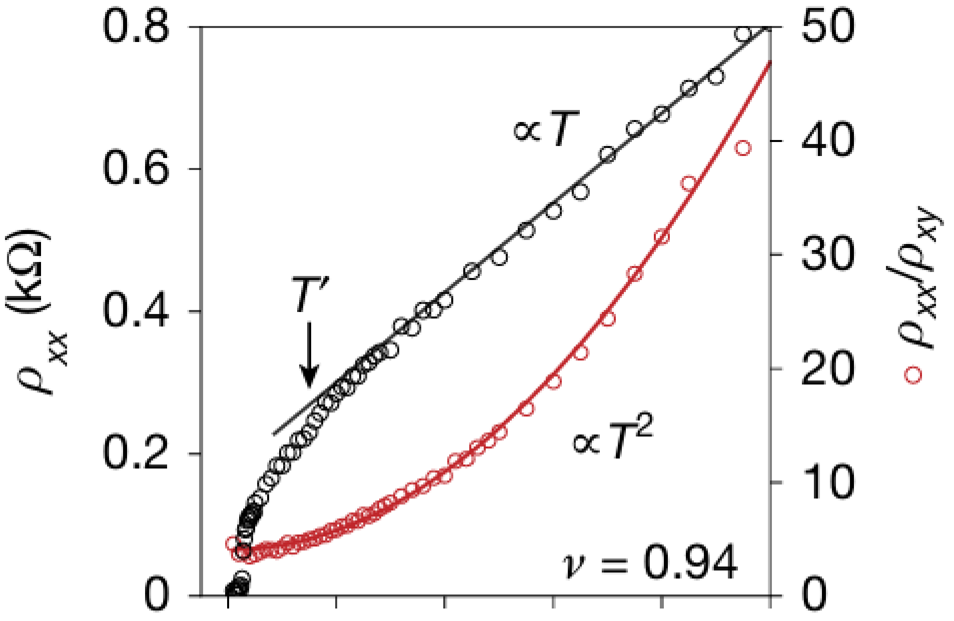
T. R. Chien et al., Phys. Rev. Lett. **67**, 2088,(1991) Strange Metal Phase– in phase diagram

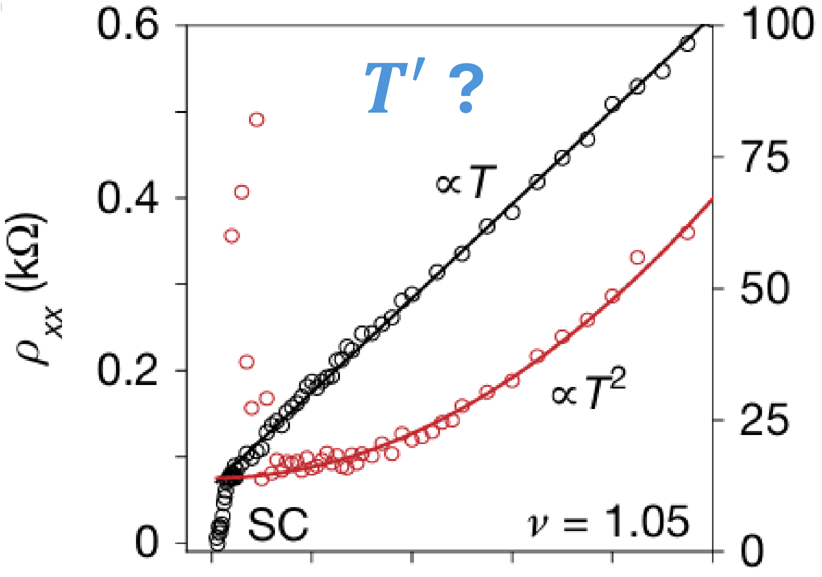


AF Phase

Strange Metal phase



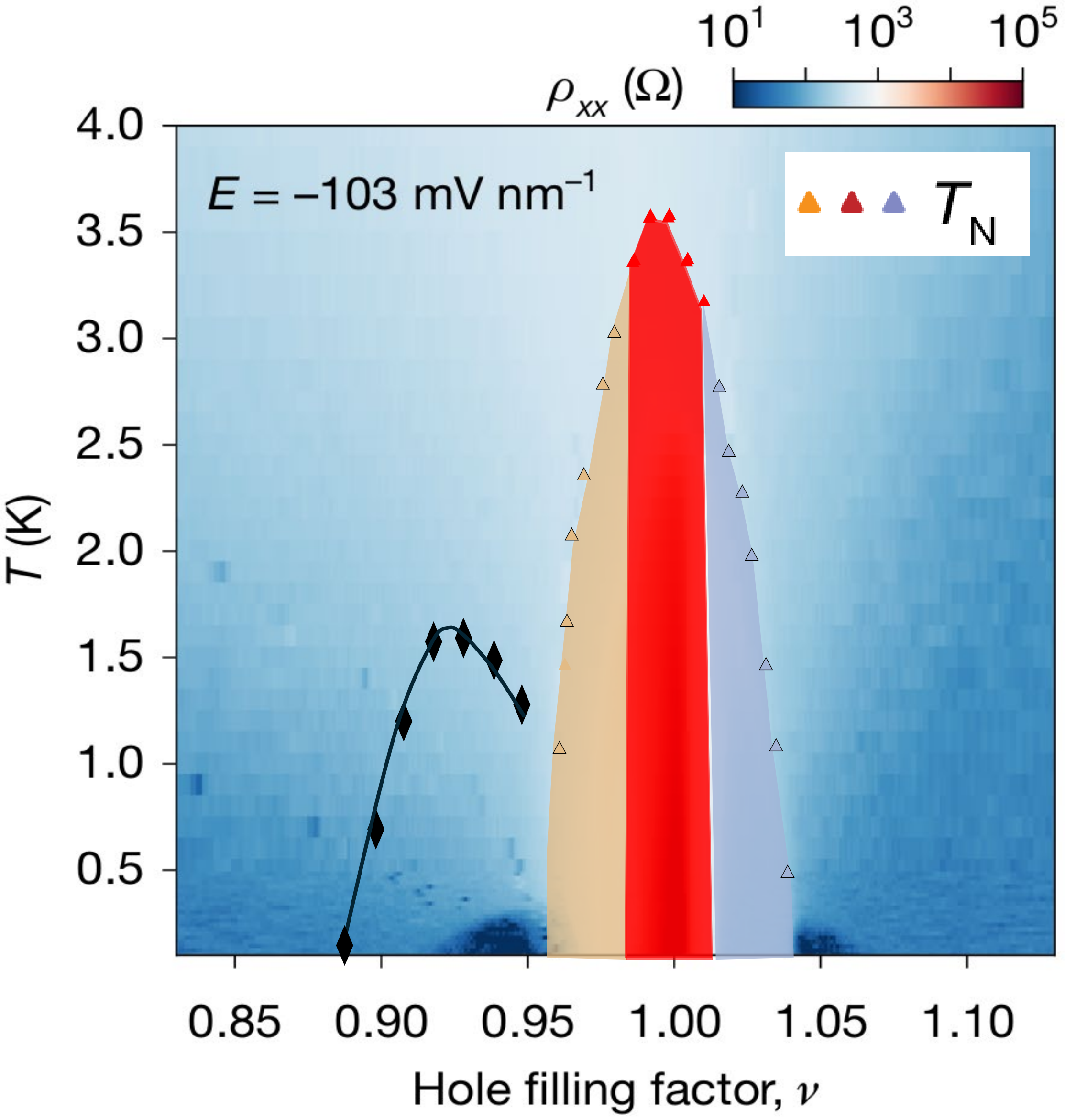




crossover temperature (T') - T above which, ρ_{xx} deviates from the linear dependence by 10%

For e- doped region T' clearly identified. But for h-doped region T' couldn't identify.

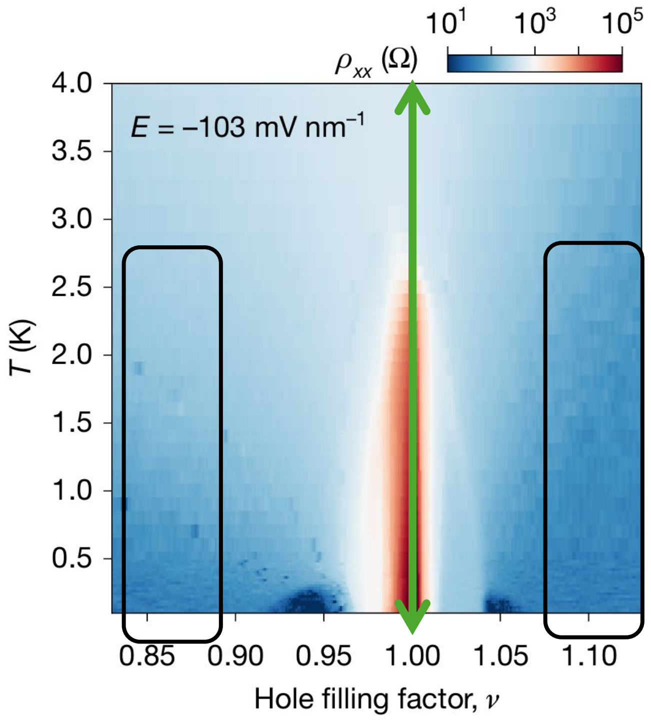
Strange Metal Phase+ – in phase diagram

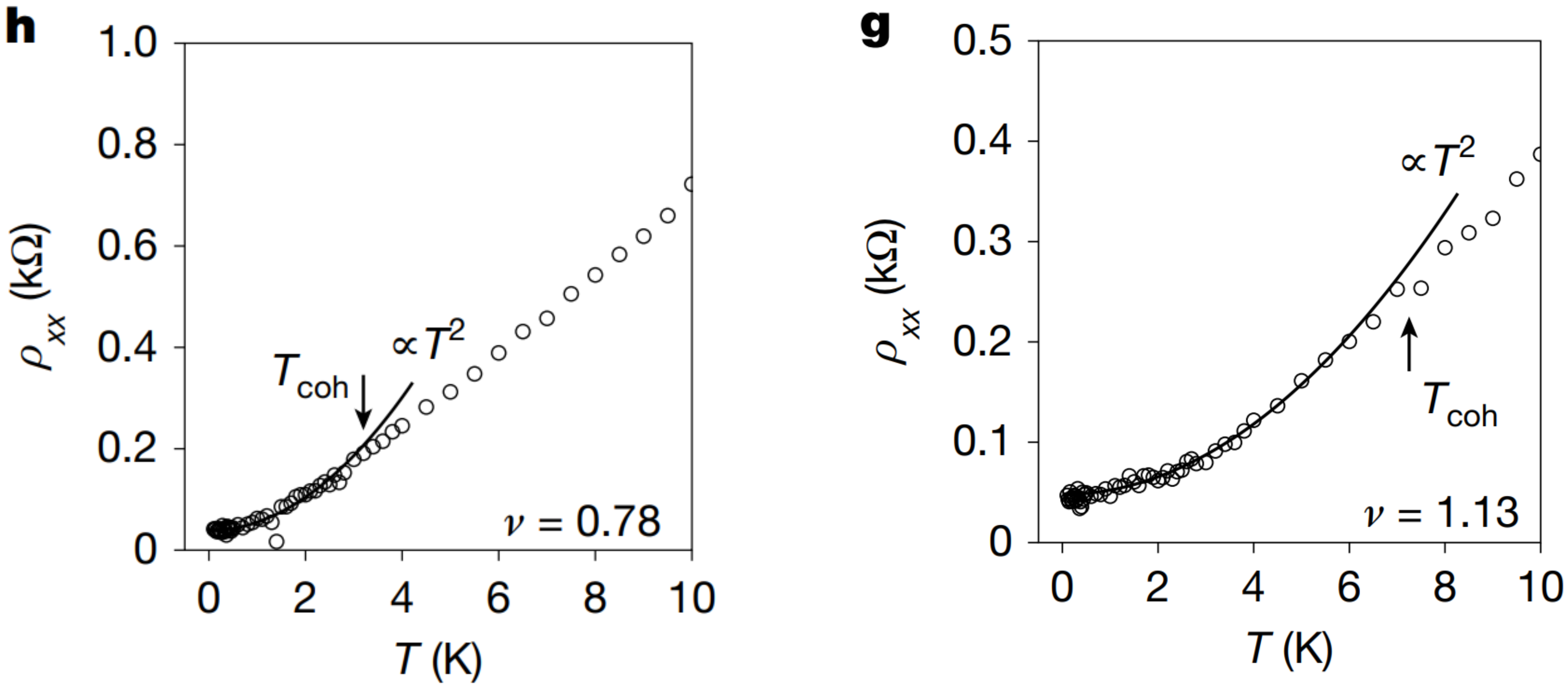


AF Phase

Strange Metal phase

Strange Metal phase+

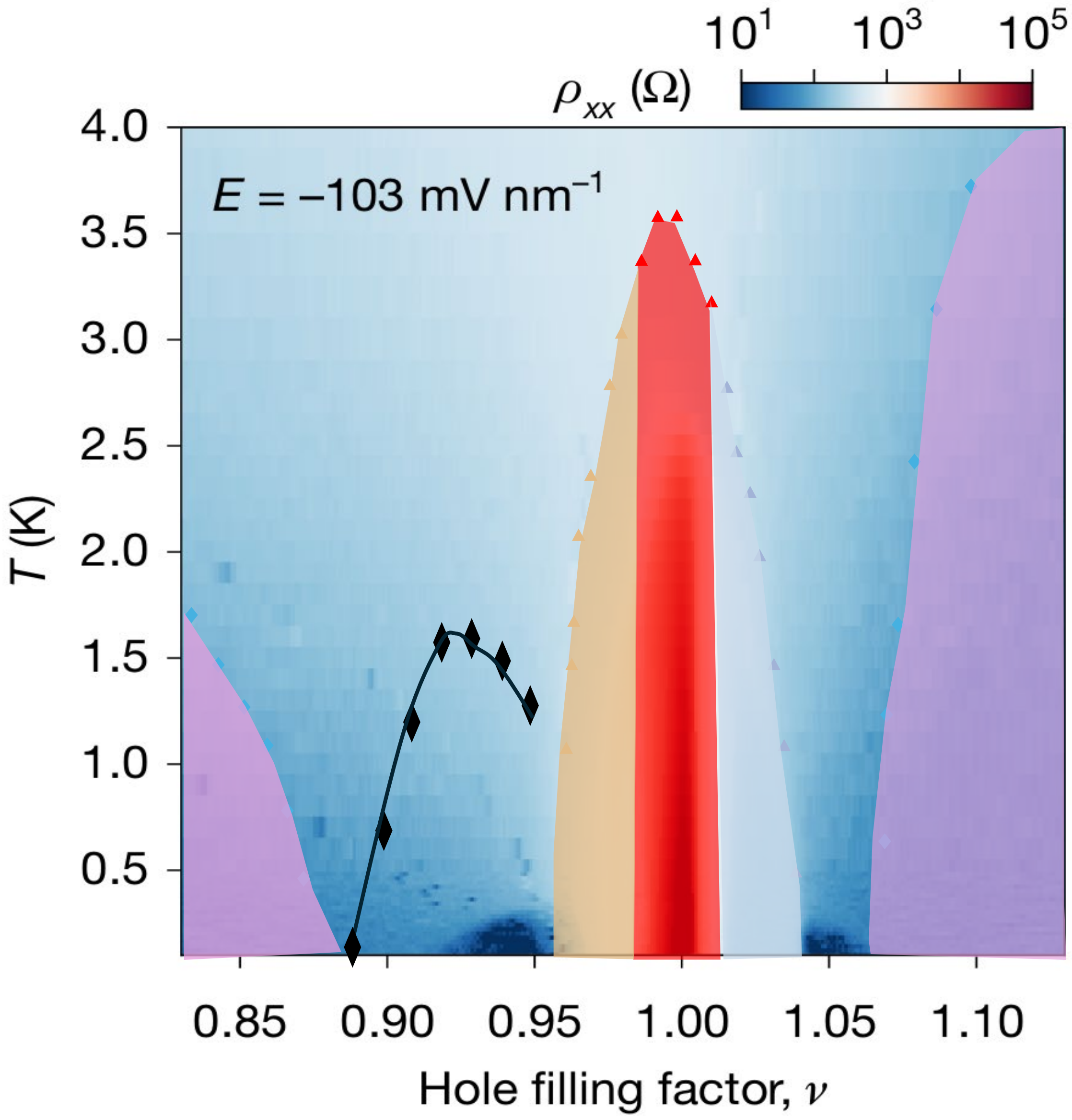




$$\rho_{xx} = \rho_0 + AT^2$$

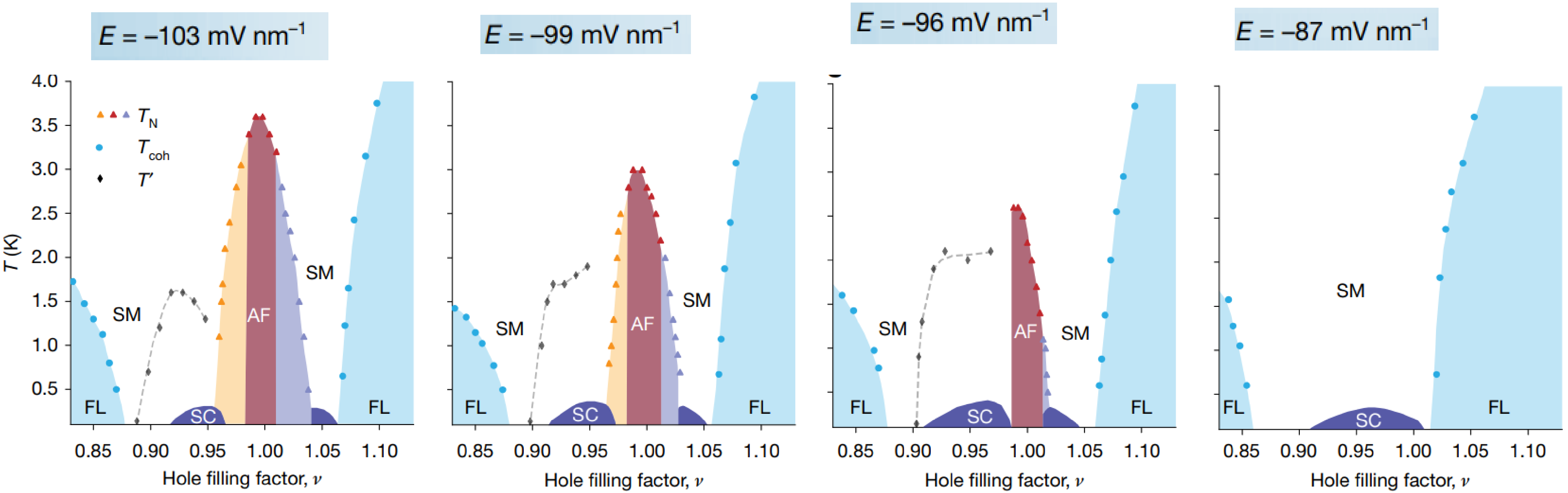
coherence temperature (T_{coh}) - T above which, ρ_{xx} deviates from the linear dependence by 10%

For e- doped region T' clearly identified. But for h-doped region T' couldn't identify.



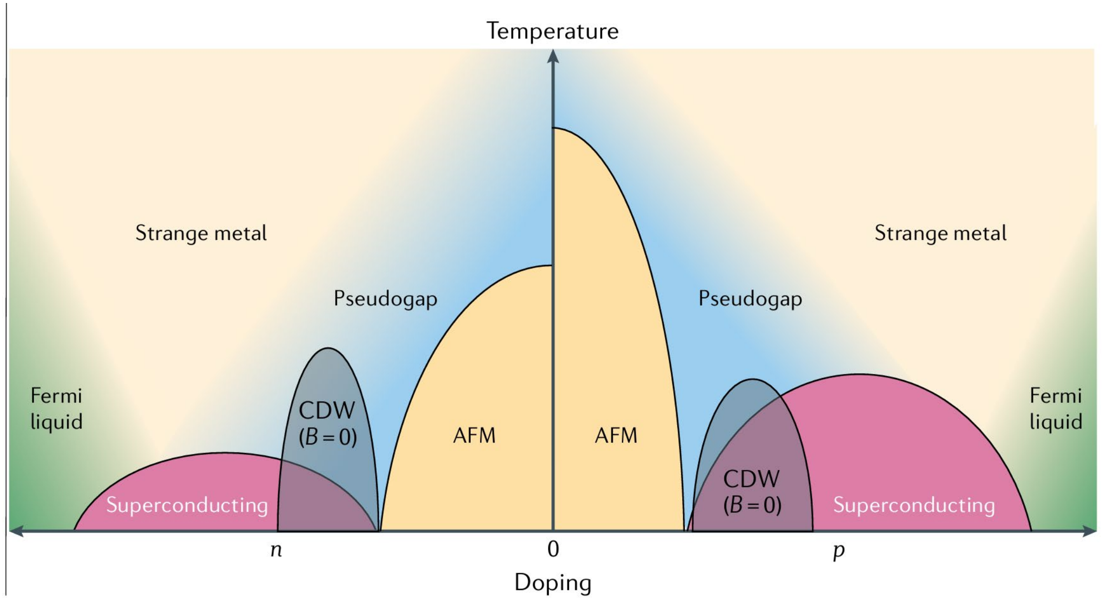
- AF Phase
- Strange Metal phase
- Strange Metal phase+
- Fermi Liquid

Phase diagram for different Electric field



Twisted WSe_2 isn't just a material; it’s a tunable laboratory

This system looks exactly like a "miniature version" of high temperature superconductors.



X. Zhou et al., Nat Rev Phys **3**, 462–465 (2021)

Thankyou