Tuning of Quantum Interference in Top-Gated Graphene

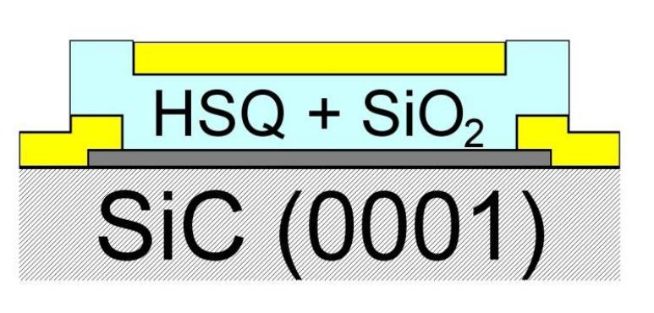
Andrea Iagallo,[1] Shinichi Tanabe,[2] Stefano Roddaro,[1, 3] Makoto Takamura,[2] Hiroki Hibino,[2] Stefan Heun,[1] and Fabio Beltram[1]

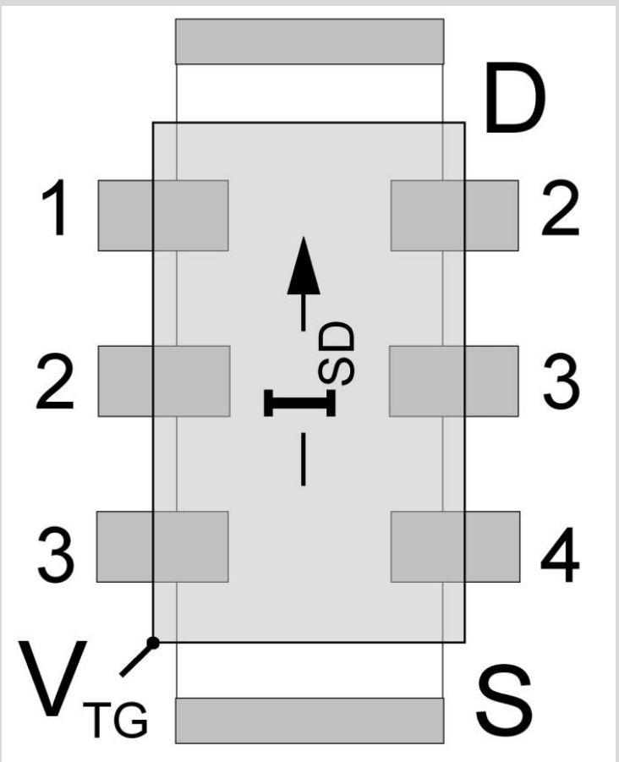
[1]NEST, Istituto Nanoscienze - CNR and Scuola Normale Superiore, Piazza San Silvestro 12, 56127 Pisa, Italy
[2]NTT Basic Research Laboratories, NTT Corporation, 3-1 Morinosato Wakamiya, Atsugi, Kanagawa, Japan
[3]Istituto Officina dei Materiali CNR, Laboratorio TASC, 34149 Trieste, Italy

We report on quantum interference measurements in top-gated Hall bars of graphene epitaxially grown on the Si face of SiC. We perform a systematic study of the quantum corrections to the magnetoresistance due to quantum interference of quasiparticles and electron-electron interaction, by varying the temperature and charge density. We analyze the contribution of the different scattering mechanisms affecting the quantum interference in the $2 \cdot 10^{10}$ - $3.75 \cdot 10^{11}$ cm^{-2} density range and find, besides a transition from Weak Localization to Weak Anti Localization, a signicant infuence of the charge density on the intravalley scattering time. We also observe a modulation of the electron-electron interaction as a function of charge density not accounted for by present theory. Our results stress the role of SiC-based devices as a promising technology for graphene coherent electronics.

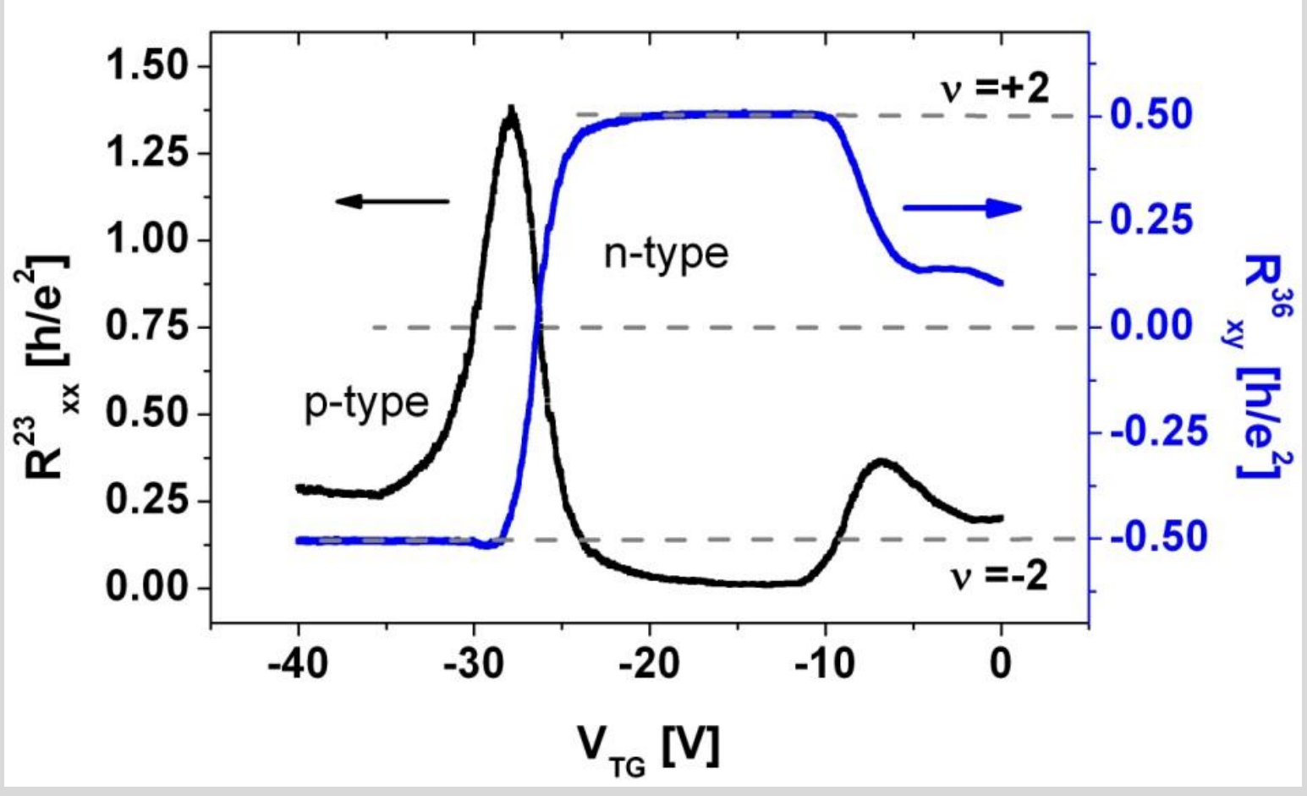
EXPERIMENTAL DETAILS

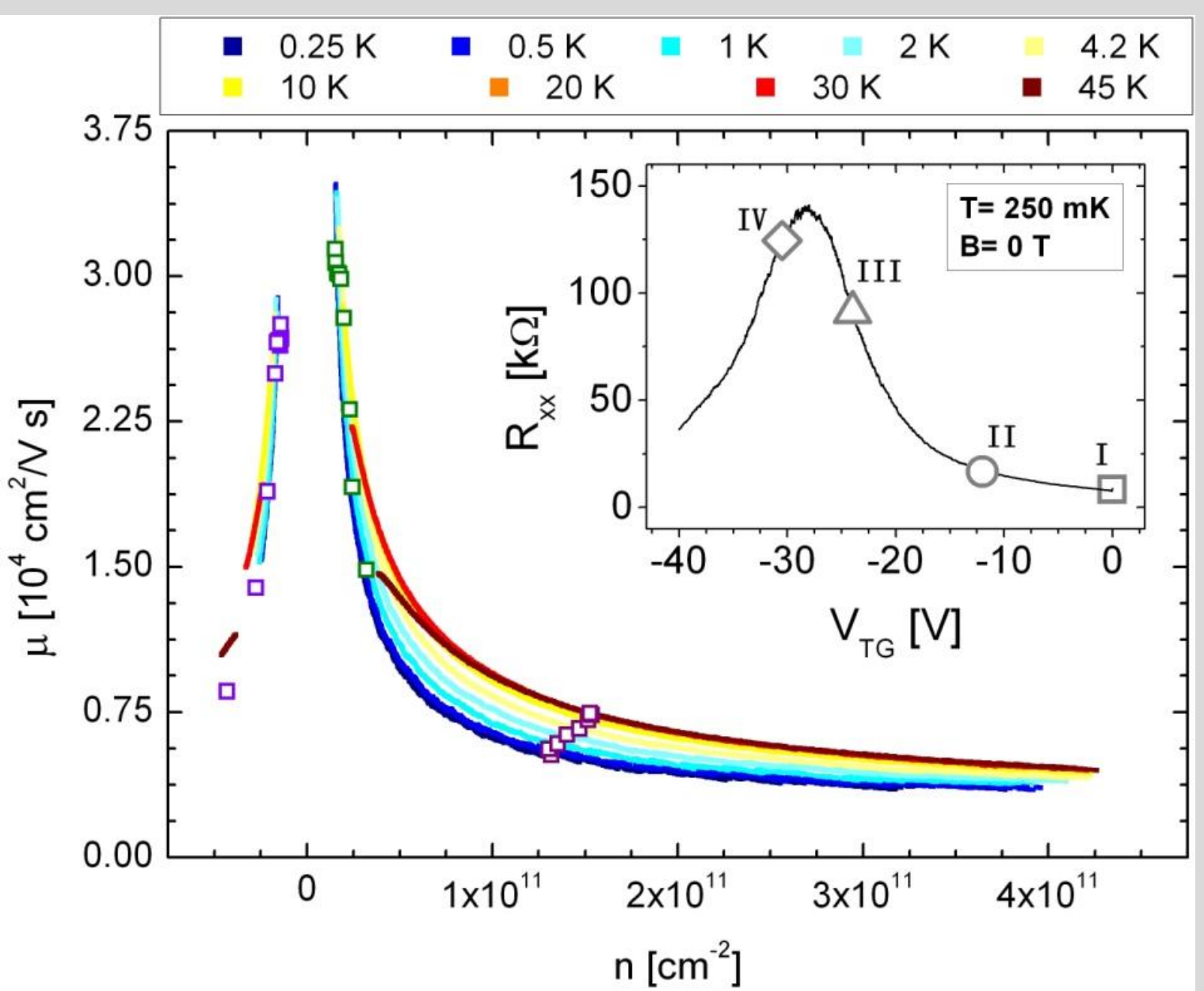
- Hall bar (300 μm x 50 μm)
- Epitaxial graphene layer grown on the Si face of a SiC (0001) wafer.
- The dielectric:
Hydrogen Silsequioxane (140 nm)
+ SiO$_2$ (40 nm).
- Cr/Au (10/180 nm) top gate



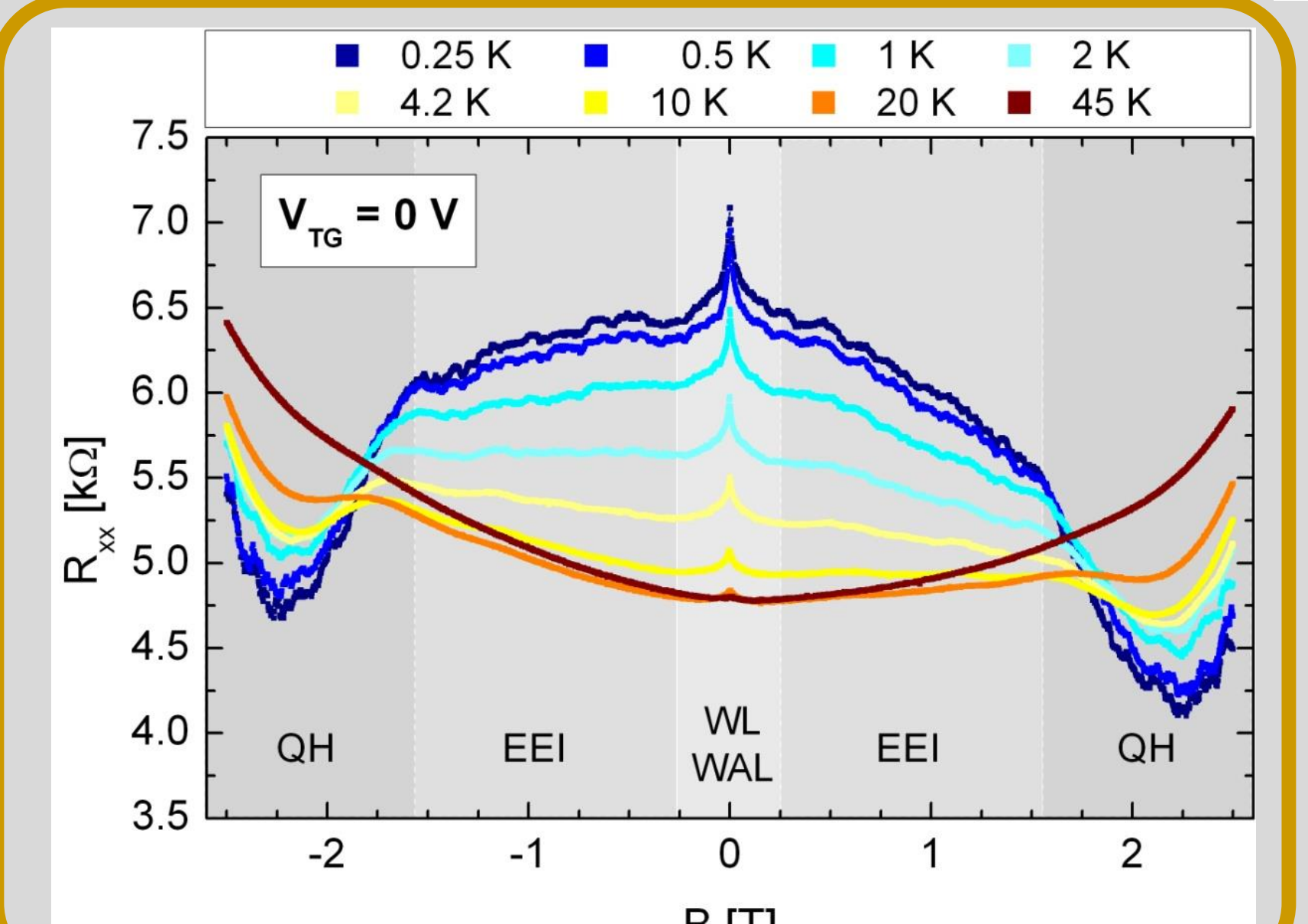


- Half-integer QH effect
⟶ monolayer graphene
- Charge Neutrality Point: $V_{TG} \approx -27$ V





- density-mobility diagram (Ref. [1])
- I ($3.75 \cdot 10^{11}$ cm^{-2}), II ($1{,}43 \cdot 10^{11}$ cm^{-2}),
- III ($2.02 \cdot 10^{10}$ cm^{-2}), IV ($-2.03 \cdot 10^{10}$ cm^{-2})



ELECTRON-ELECTRON INTERACTION

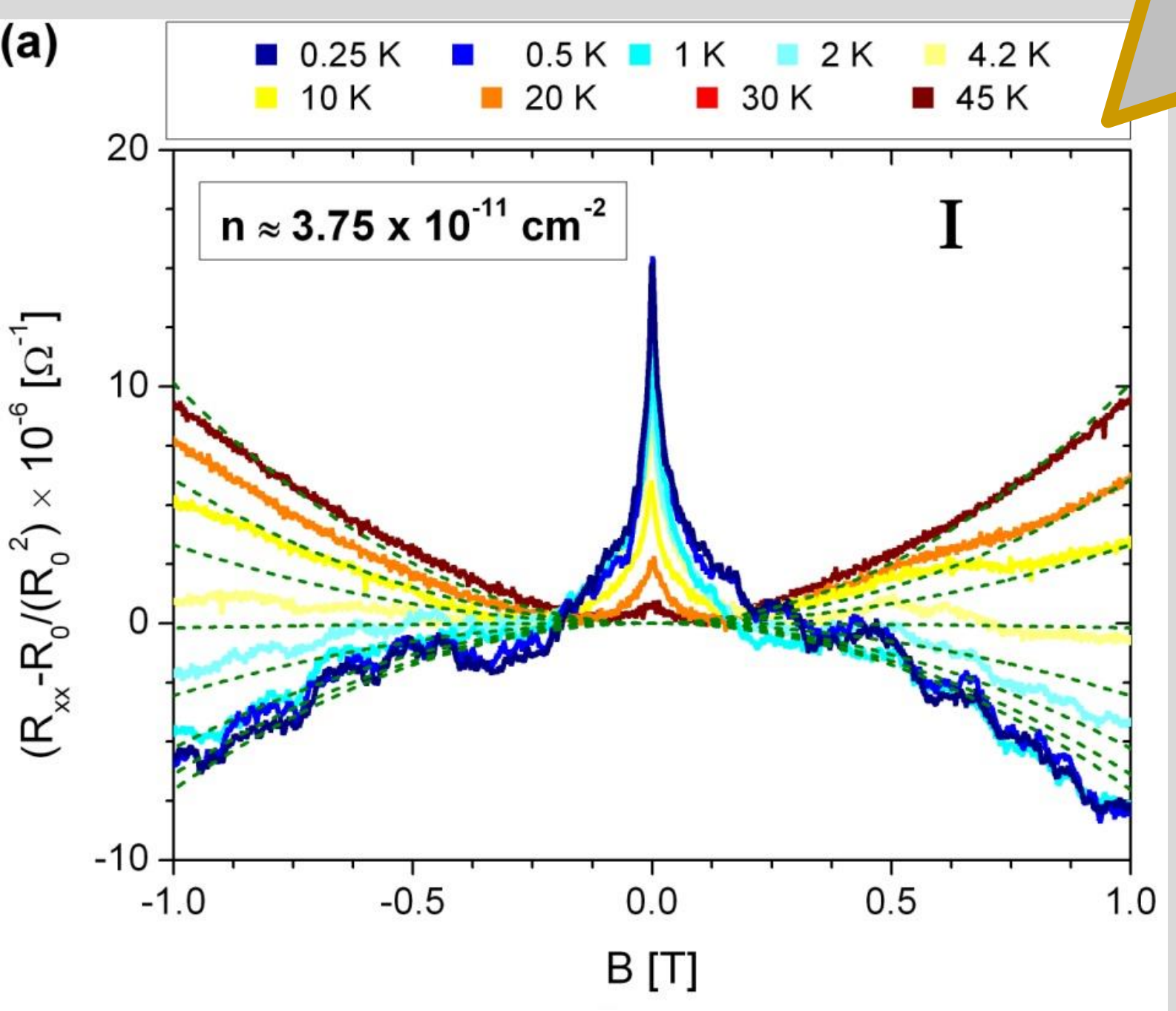
- Aharonov-Altshuler interaction: Coulomb interaction enhanced in diffusive regime by long interaction time [2]:

$$\frac{\delta\rho_{EEI}}{{\rho_0}^2} = (\omega_c^2\tau_{tr}^2 - 1)K_{EEI}\frac{e^2}{\pi h}ln\left(\frac{k_B T\tau_{tr}}{\hbar}\right)$$

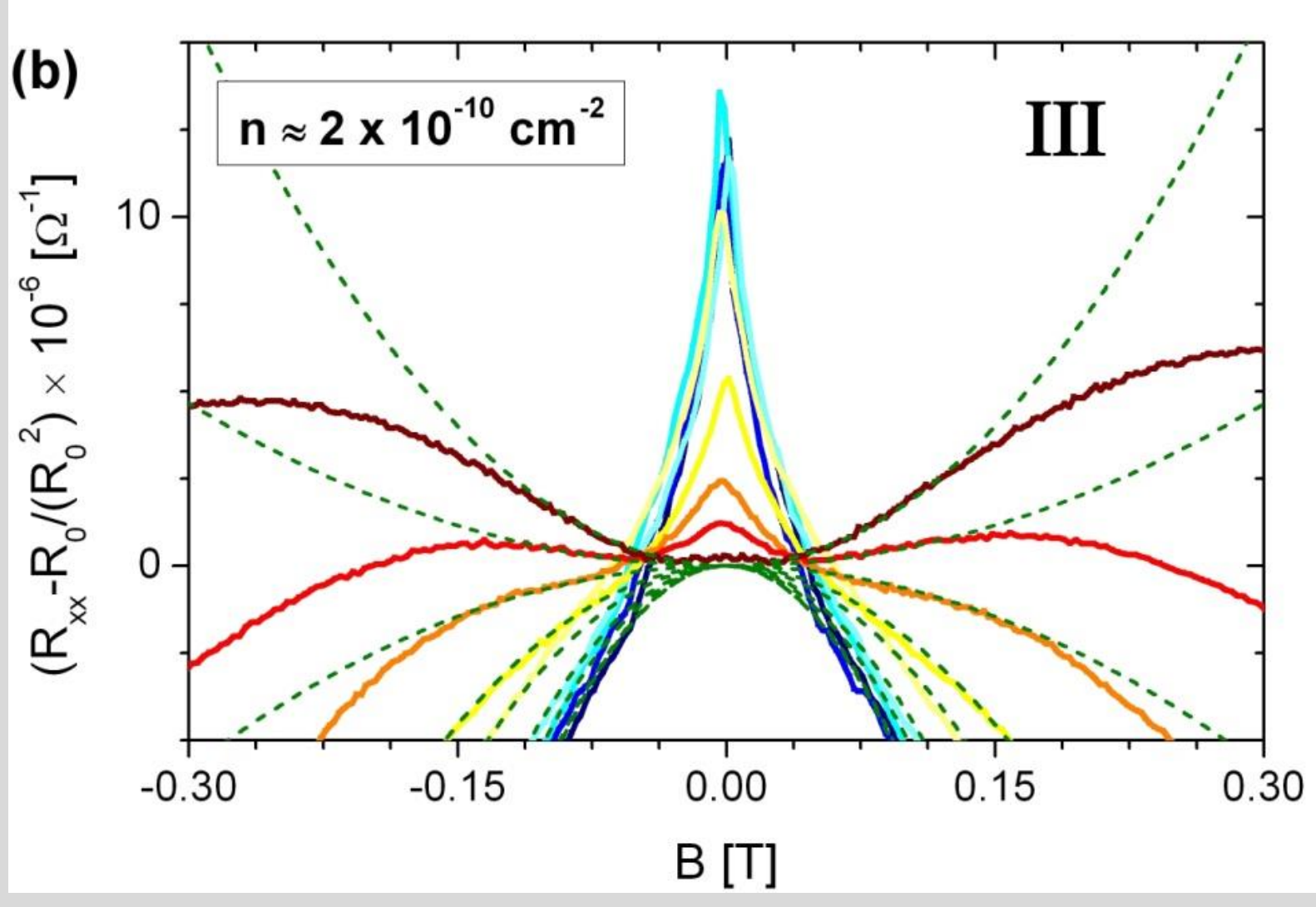
- Parabolic in B: $\omega_c = (v_f e/\hbar\sqrt{\pi n})B$
- momentum relaxation time
$\tau_{tr} \approx 0.01$-0.02 ps
- K_{ee}: *e-e* interaction parameter, depending <u>linearly</u> on the number of channels **c** participating in the interaction.

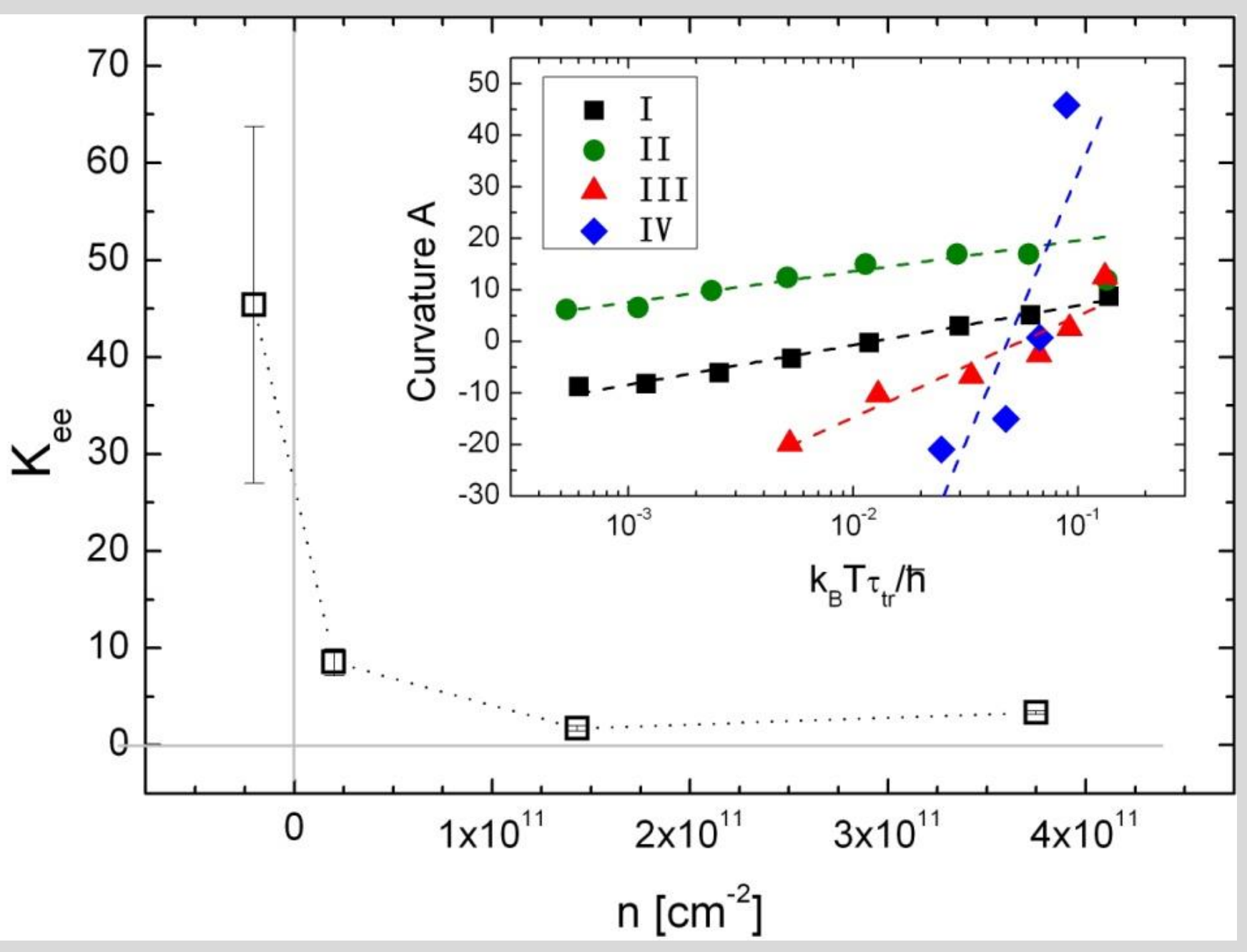
- Data normalized to $(R_{xx}-R_0)/R_0^2$
- Fit to extract $A = K_{ee}\, ln(k_B T\, \tau_{tr}/\hbar)$
- Good fit for all datasets. The B-range depends on T and n, being limited by the onset of QH effect.

(a)



(b)





A ~ K_{ee} ~ **c** (number of channels)
- Constant slope of A (at each density) ⟶ constant **c**

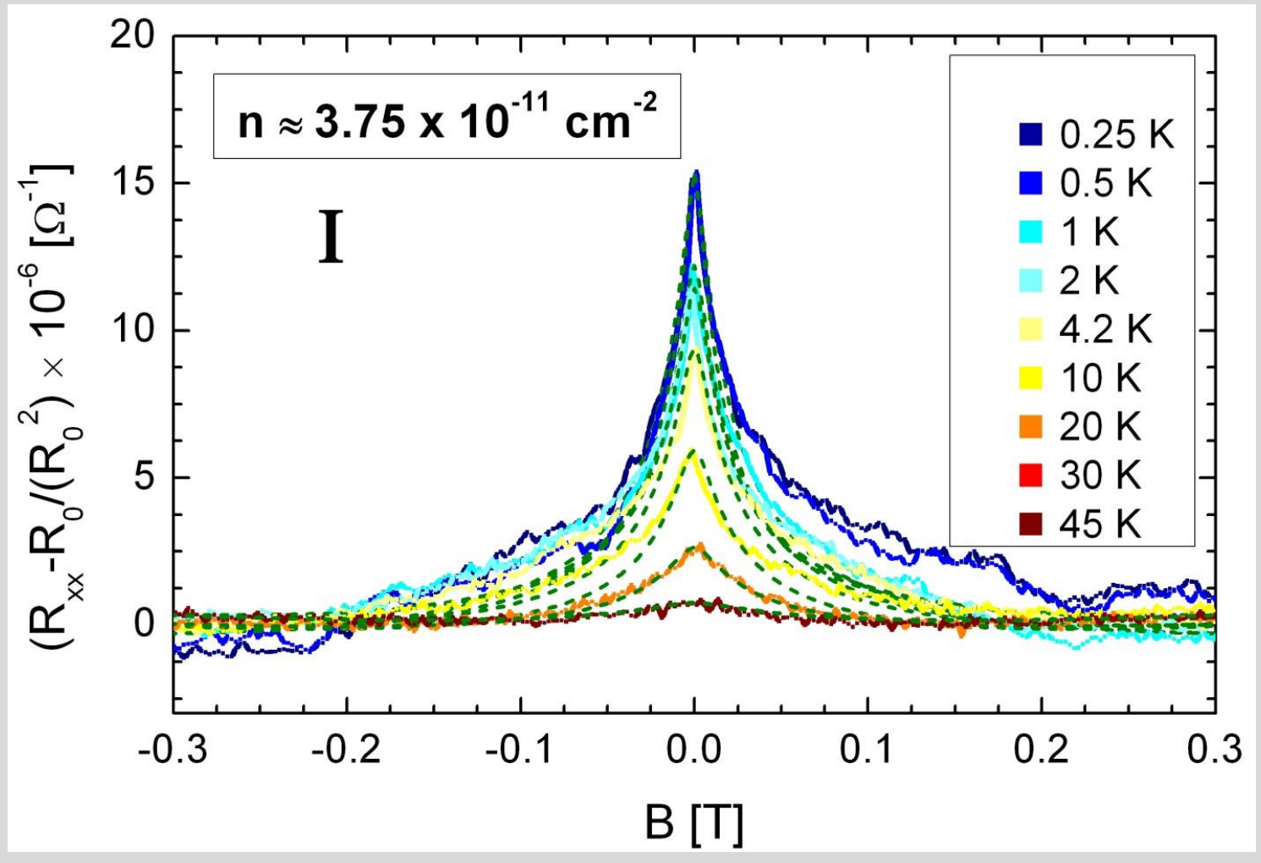
- Variation of channel number **c** with quasiparticle density.

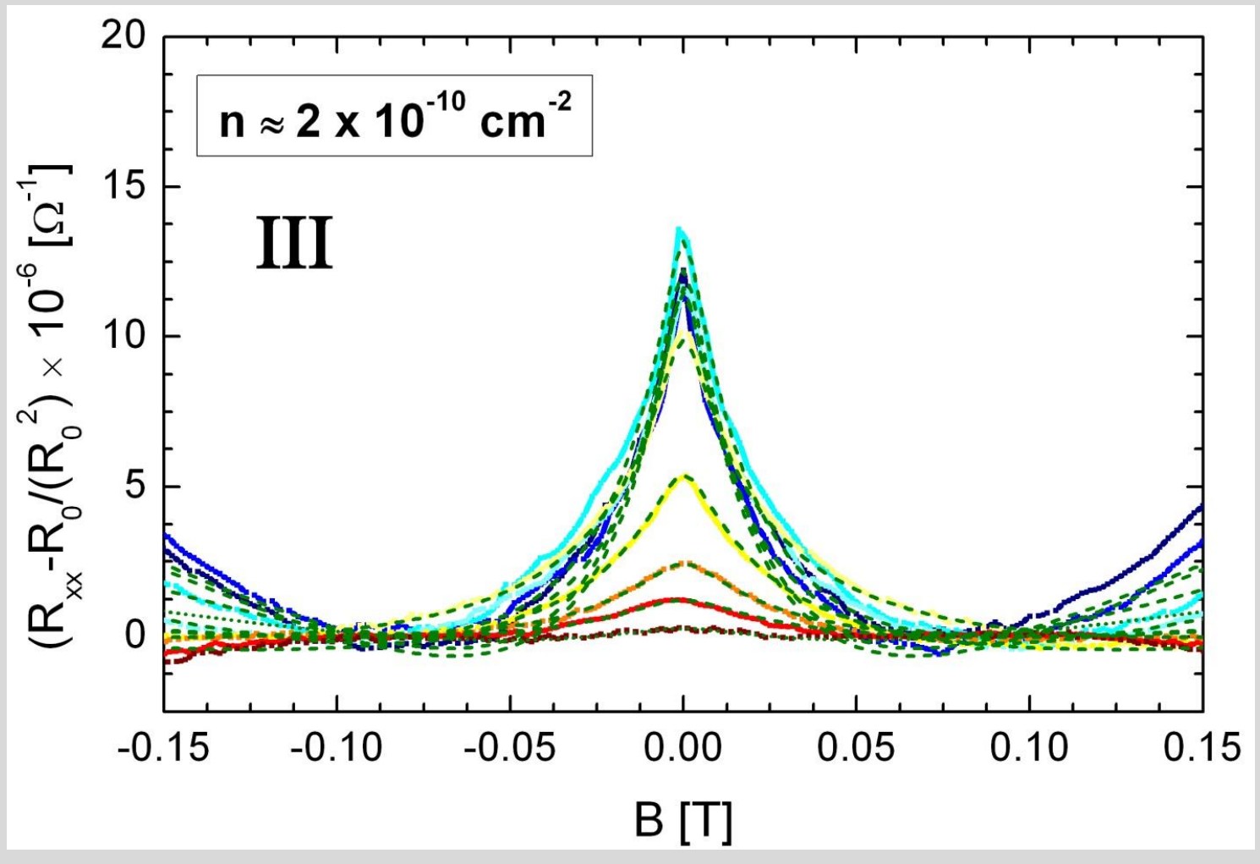
QUANTUM INTERFERENCE

- **Chirality**, due to the peculiar Dirac-like energy diagram, produces destructive interference by adding a Berry phase π, thus Weak Anti Localization (WAL) is expected.
- ***Inter*valley** scattering decreases quasiparticle coherence.
⟶ <u>Suppression of **WL** and **WAL**</u>.
- **Intravalley** scattering preserves coherence, but not chirality.
⟶ <u>Restoration of **WL**.</u>

With definition $B_{\varphi,i,*} = \hbar/(4De\tau_{\varphi,i,*})$, from Ref. [3]

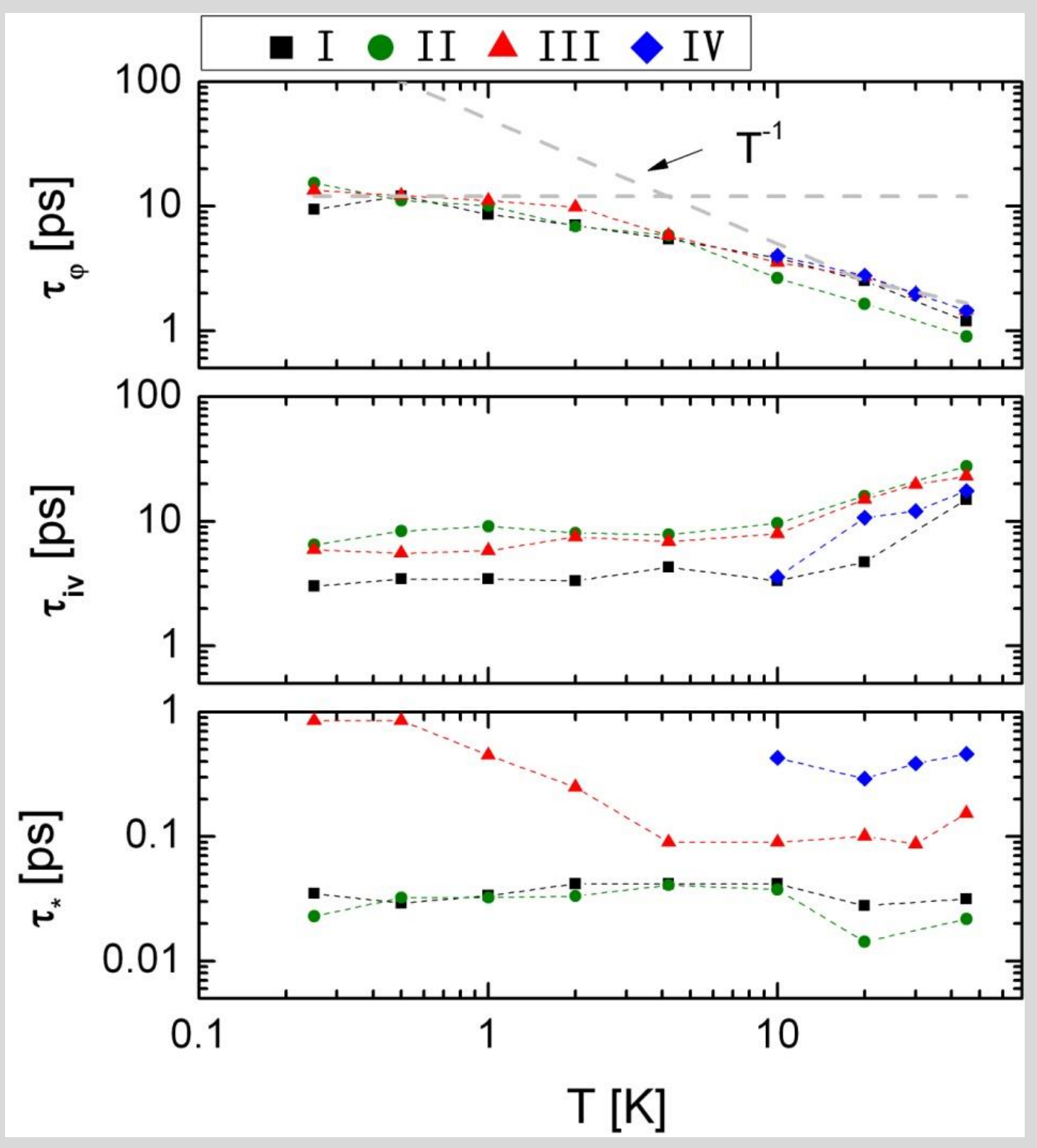
$$\frac{\delta\rho_{WL}}{{\rho_0}^2} = \frac{e^2}{\pi h}\left[F\left(\frac{B}{B_\varphi}\right) - F\left(\frac{B}{B_\varphi + 2B_i}\right) - 2F\left(\frac{B}{B_\varphi + B_i + B_*}\right)\right]$$





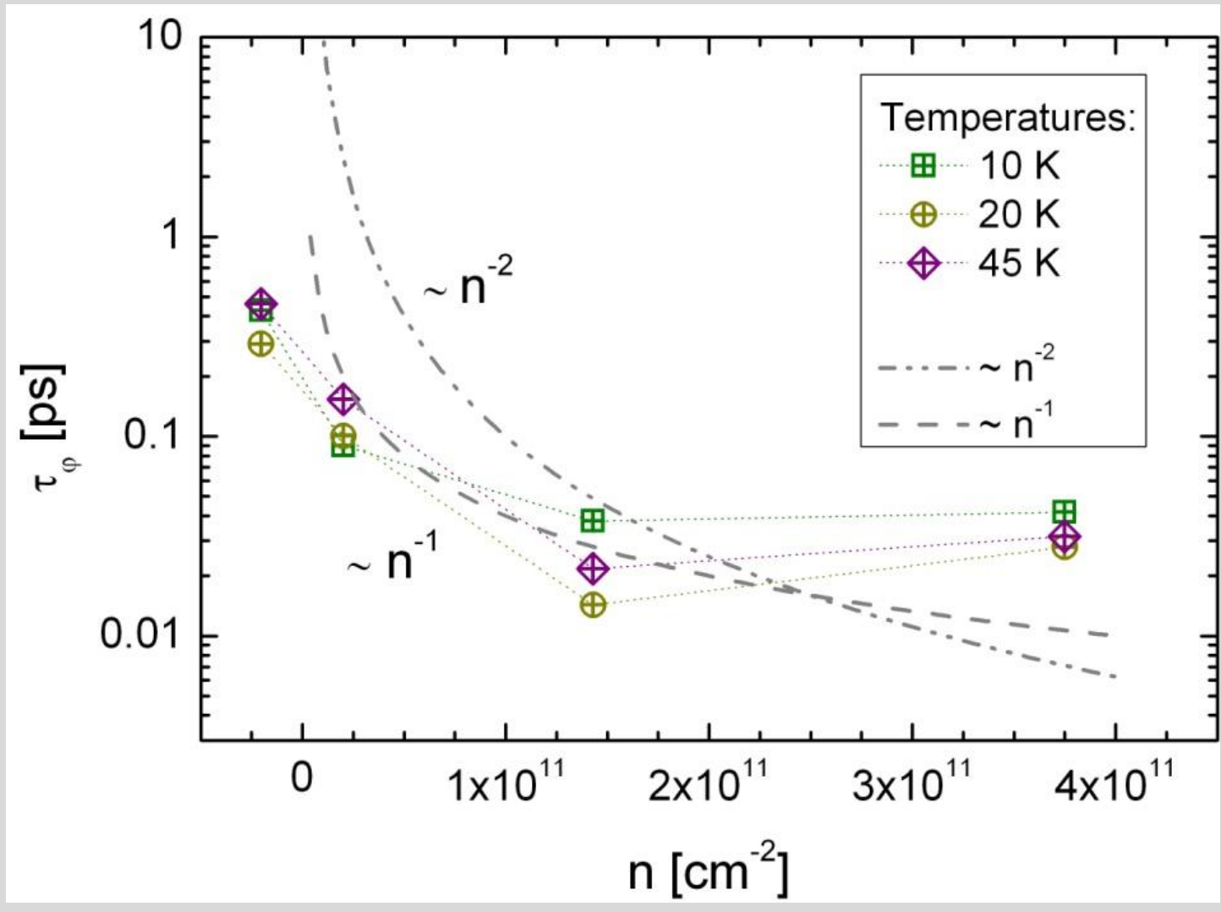
Scattering times:
$\tau_\varphi \approx \tau_{iv} \gg \tau_*$

T behaviour
- τ_φ: T^{-1} (for T>4 K),
saturation (for T<4 K).
- τ_{iv} , τ_* : weak dependence



In epitaxial graphene:
⟶ Coherence is limited by intravalley scattering. Electron-electron is the dominant contribution to dephasing.

n behaviour
- τ_φ: , τ_{iv} weak dependence
- τ_* : decreasing with n. Weaker dependence than the sole warping term $\tau_w \sim n^{-2}$
- we find $\tau_* \sim n^{-1/2}$ (see also Ref. [4])



CONCLUSIONS

- We presented a **systematic** analysis of magnetotransport properties in epitaxial graphene grown on the Si-terminated face of SiC.
- We describe **EEI** in graphene with the current theory for disordered systems, and we find an unexpected dependence of the interaction parameter K_{ee} on carrier density.
- From fits of the **quantum interference** correction, we obtain the scattering times as a function of carrier density. The dephasing and intervalley times are almost constant, while the intravalley scattering time shows a peculiar dependence on density, which is different from the one due to the sole warping term.
- Our results stress the role of **charge density** in determining quantum interference and EEI, and the necessity of further investigation of its impact on the low-field magnetoresistance of graphene devices.

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