COLLABORATIONS

2D holes & 2D electrons in GaAs	Y.Y. Proskuryakov S.S. Safonov L. Li	*University of Exeter*
	M. Pepper M.Y. Simmons E.H. Linfield D.A. Ritchie	*Cavendish Laboratory, Cambridge*
2D electrons in Si	S.S.Safonov S.H.Roshko	*University of Exeter*
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Disorder and Interactions

Total quantum correction to the Drude conductivity:

$$\delta\sigma(T) = \delta\sigma_{WL} + \delta\sigma_{EEI}$$

$\delta\sigma_{WL} < 0$

$\delta\sigma_S < 0$

$\delta\sigma_T$ depends on the interaction constant ***F***

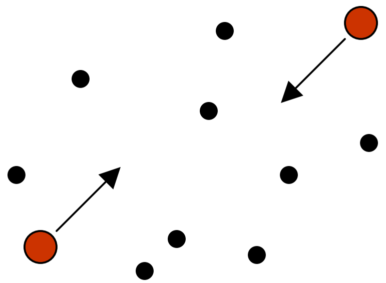
For large $r_s = \frac{U_C}{E_F} \propto \frac{m^*}{n^{1/2}}$ the value of ***F*** is not known.

Electron-electron interactions in the diffusive regime, $k_B T\tau/\hbar < 1$

Altshuler, Aronov; Finkelstein.

Quasi-particle interaction time, $\Delta\tau = \hbar/(k_B T)$,

is larger than the momentum relaxation time, τ : $\Delta\tau > \tau$.



Diffusive motion enhances the interaction strength:

$\tau_{ee}^{-1}(T) \propto T$, instead of $\tau_{ee}^{-1}(T) \propto T^2$.

- *Logarithmic* correction to the conductance:

$$\delta\sigma(T) = \frac{e^2}{2\pi^2\hbar}\left(1 - \frac{3}{4}F\right)\ln T\tau$$

Interactions in 2D systems in the ballistic regime

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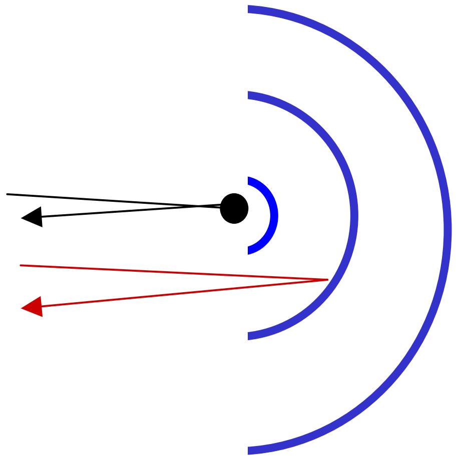
- Diffusive and ballistic regimes: $T\tau < 1$ and $T\tau > 1$.
- Hole-hole interactions in a 2DHG in *GaAs* and 'metallic' $\rho_{xx}(T)$ with $d\rho_{xx}/dT > 0$.
- Electron interactions in a 2DEG in *Si* in the ballistic regime.
- Electron interactions in a 2DEG in *GaAs* in the ballistic regime in the presence of a long-range fluctuation potential.

Interaction corrections to σ_D in the ballistic regime $T\tau > 1$.

Zala, Narozhny, Aleiner (2001)

Physics: Coherent electron scattering by *Friedel oscillation* produced by a ***point scatterer***.



$$\delta\rho(r) \propto \frac{1}{r^2}\exp(i2k_F r)$$

Phase difference is cancelled by the phase of the Friedel oscillation $\Rightarrow$ *interference*.

- Prediction:

$$\delta\sigma(T) = \frac{e^2}{\pi\hbar}\left(1 + \frac{3F_o^\sigma}{1+F_o^\sigma}\right)\cdot T\tau$$

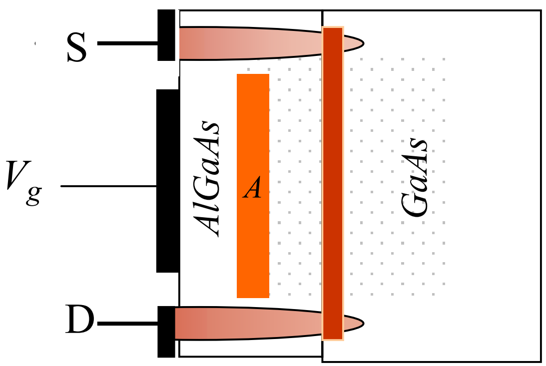
- *linear* correction to the conductance.

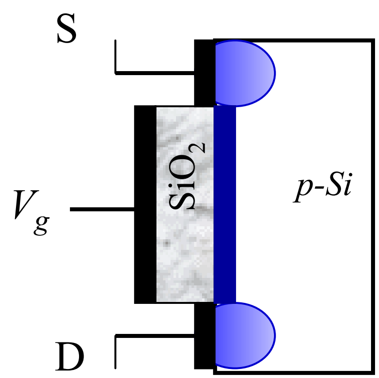
2D structures

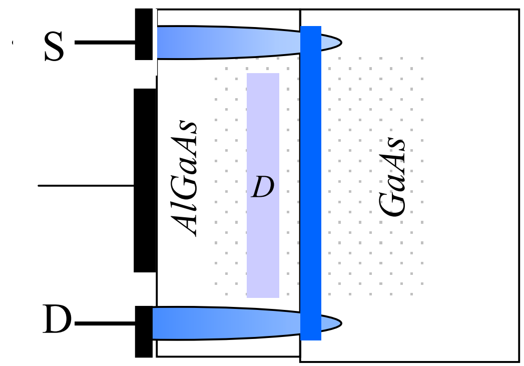
2DHG in GaAs/AlGaAs

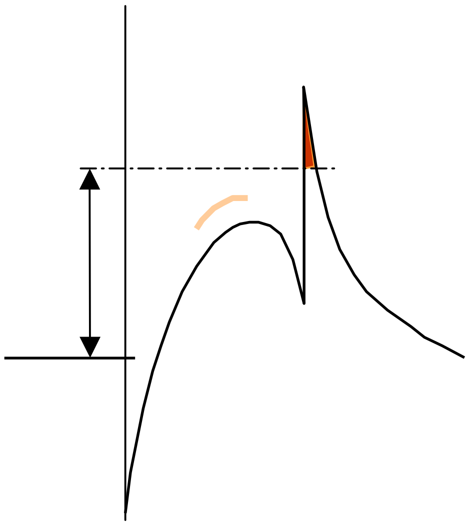
2DEG in Si MOSFET

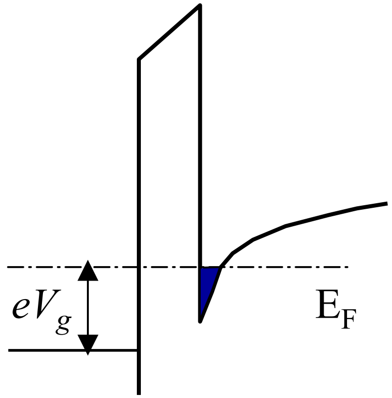
2DEG in GaAs/AlGaAs

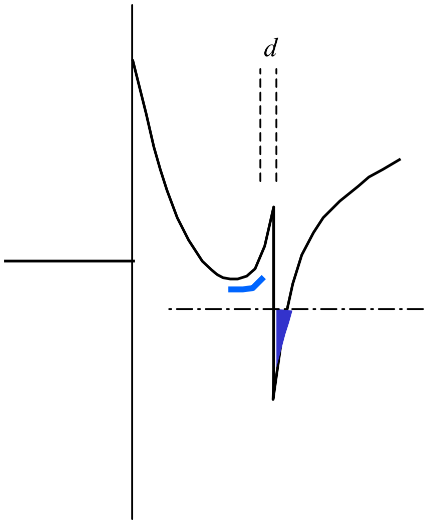










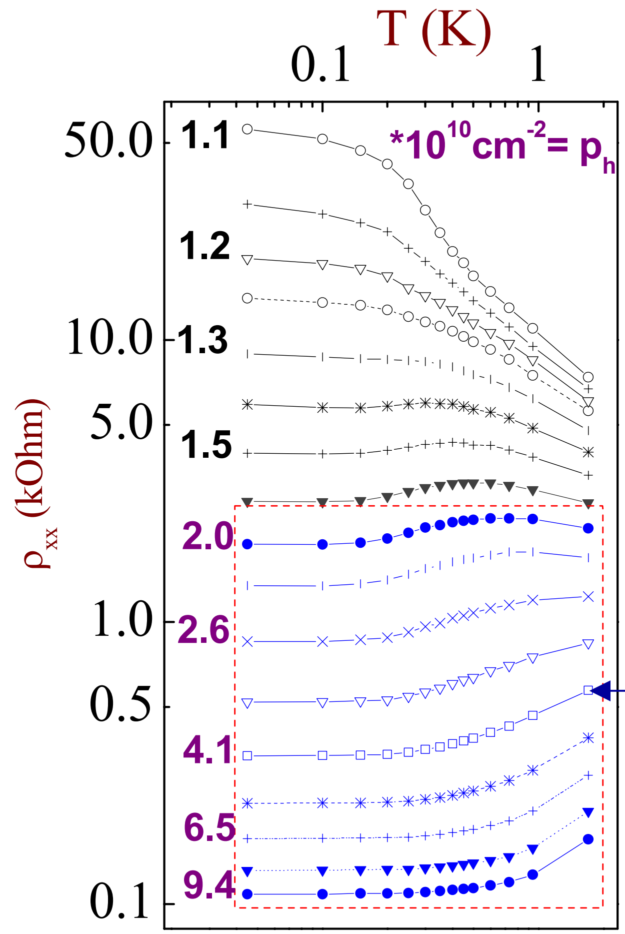


Point-like scatterers
(background impurities)

Point-like scatterers

Long-range potential
(correlation length *d* - *spacer thickness*)

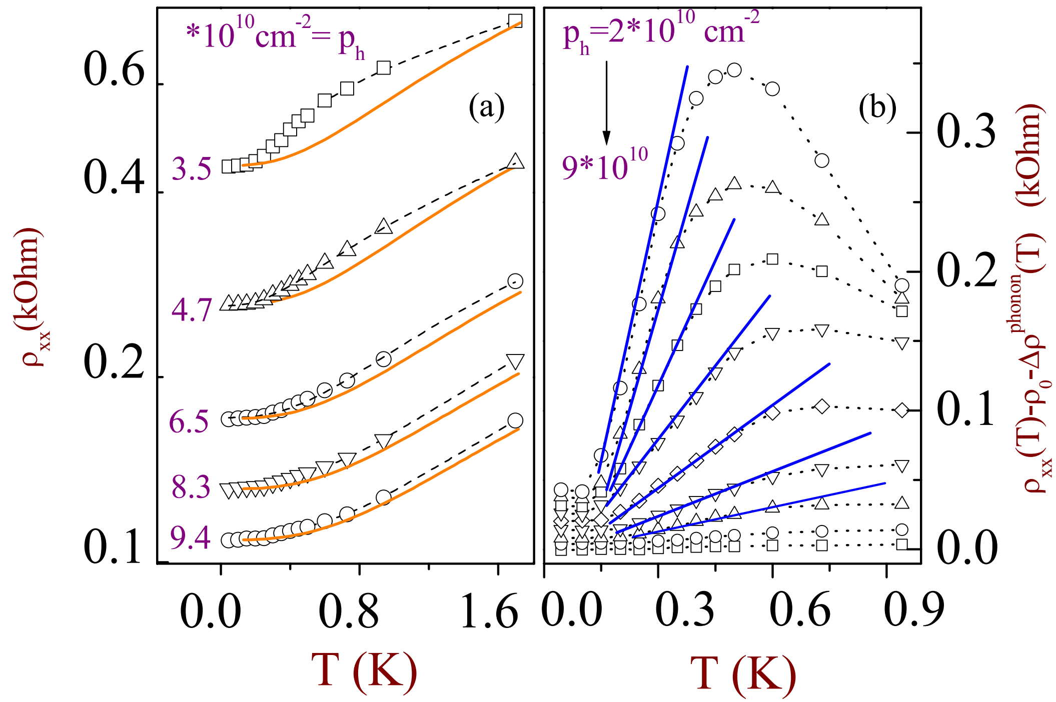
Temperature dependence of resistivity near the crossover.



2DHG in GaAs/AlGaAs

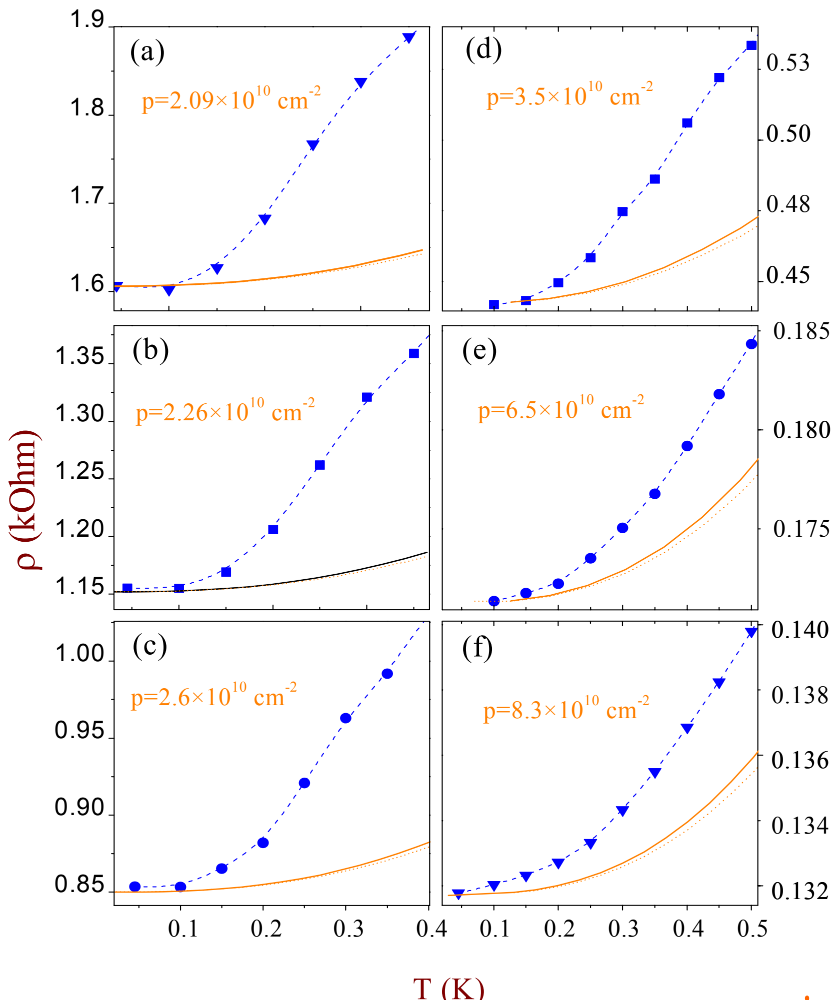
‘metallic’ region

Phonon and impurity scattering in ‘metallic’ R(T)



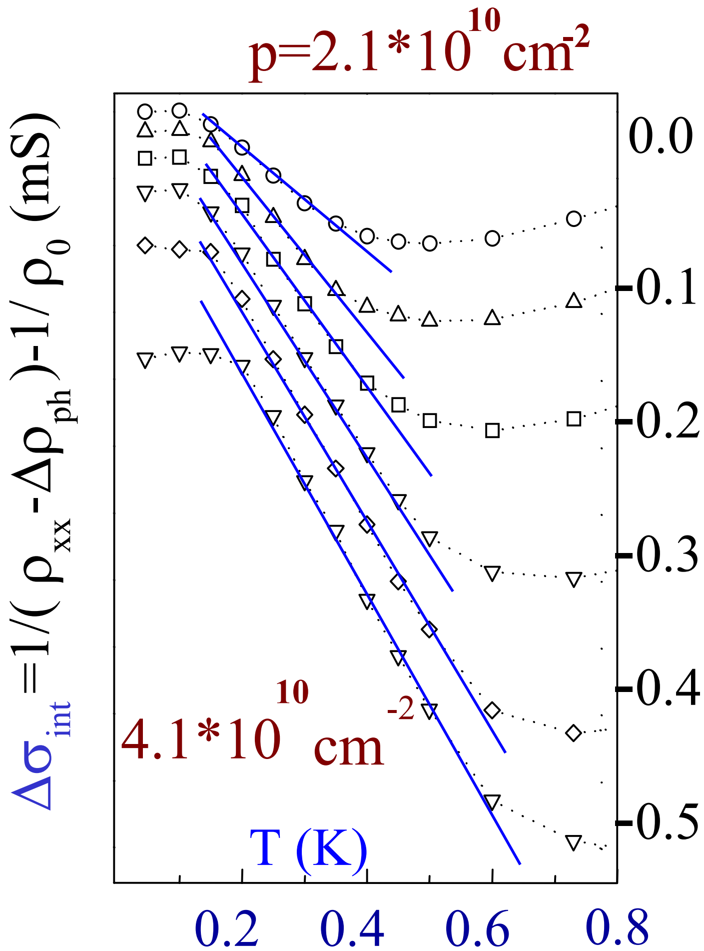
Theory of phonon scattering:
Karpus (1990)

The phonon contribution to $\rho_{xx}(T)$.

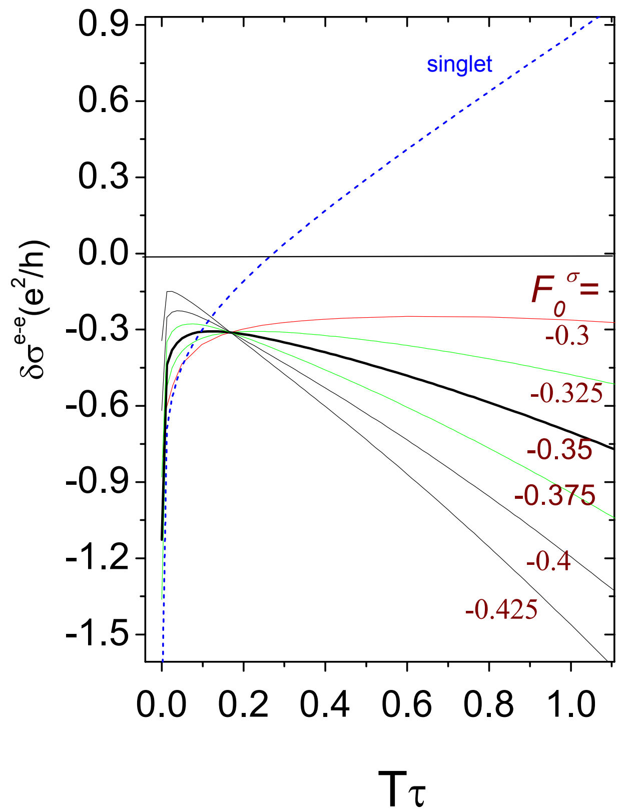


$m^*=(0.38\pm0.2)\ m_o$

Interaction correction in the *ballistic* regime, $k_B T\tau/\hbar > 1$.



Zala, Narozhny, Aleiner (2001)

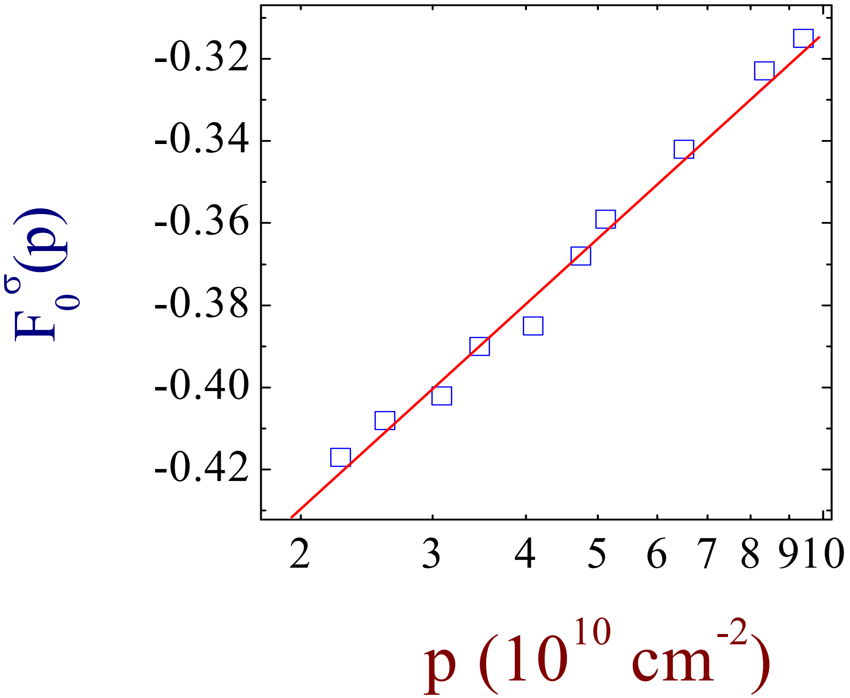


$$\delta\sigma(T) = \frac{e^2}{\pi\hbar}\frac{k_B T\tau}{\hbar}\left(1+\frac{3F_o^\sigma}{1+F_o^\sigma}\right) = \sigma_o\left(1+\frac{3F_o^\sigma}{1+F_o^\sigma}\right)\cdot\frac{k_B T}{E_F}$$

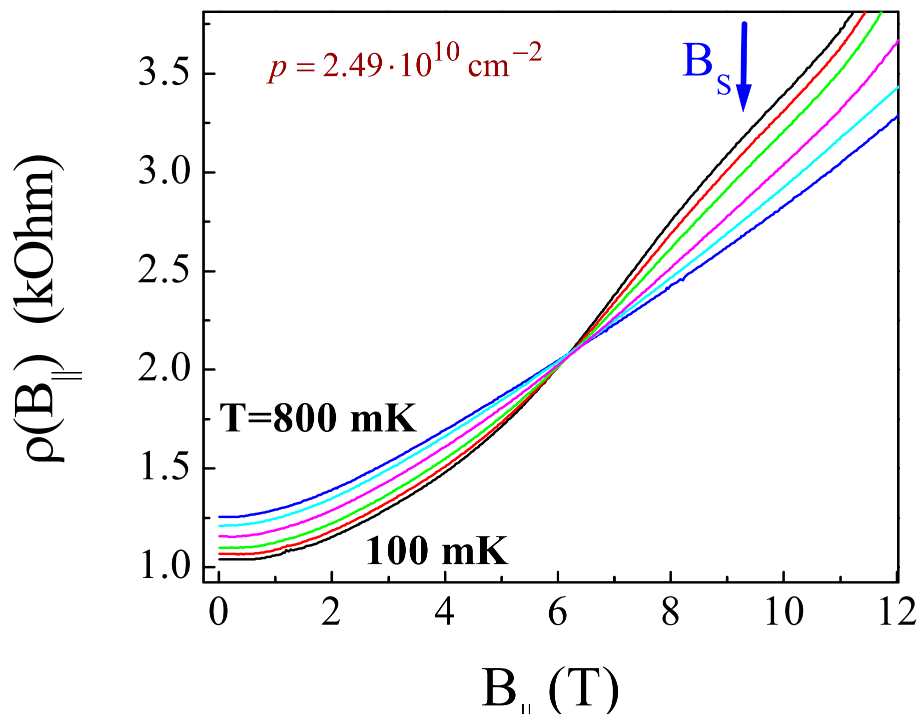
B

singlet ***triplet***

Interaction constant *F* as a function of the hole density



Positive magnetoresistance in parallel field



$d\rho/dT > 0$ $\quad$ $d\rho/dT < 0$

***B**$_s$* is the field of full spin polarisation, $B_s = 2E_F / g^* \mu_B$.

Change in $\delta\sigma(T)$ with B_{par}

$B_{par}=0$

$$\delta\sigma(T) = \sigma_o\left(1+\frac{3F_o^\sigma}{1+F_o^\sigma}\right)\cdot\frac{k_BT}{E_F}$$

< 0

'Metal'

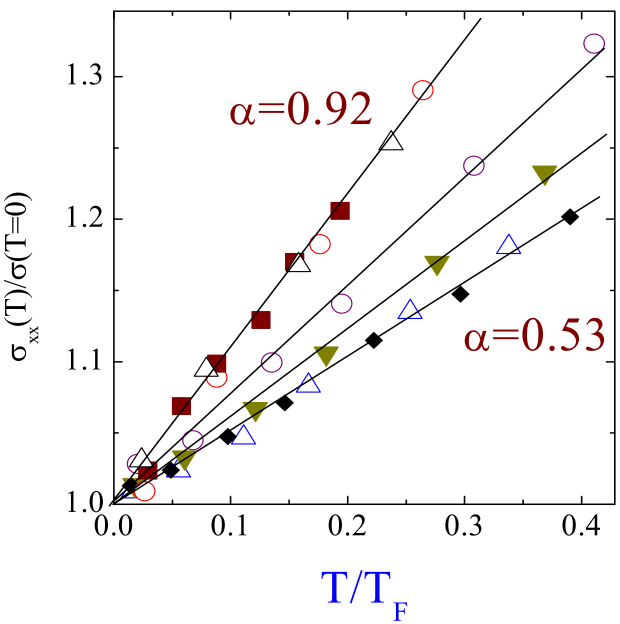
$B_{par}>B_s$

$$\delta\sigma(T) = \sigma_o\cdot\frac{k_BT}{E_F}$$

'Insulator'

$B=B_s$

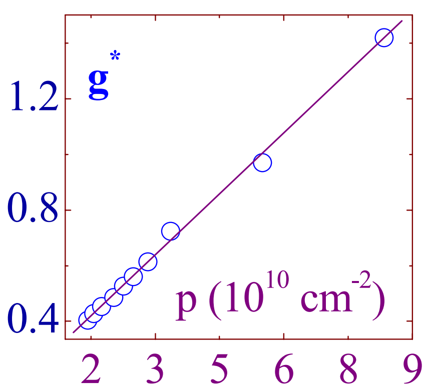
$$\delta\sigma(T) = \alpha\cdot\sigma_o\cdot\frac{k_BT}{E_F}$$

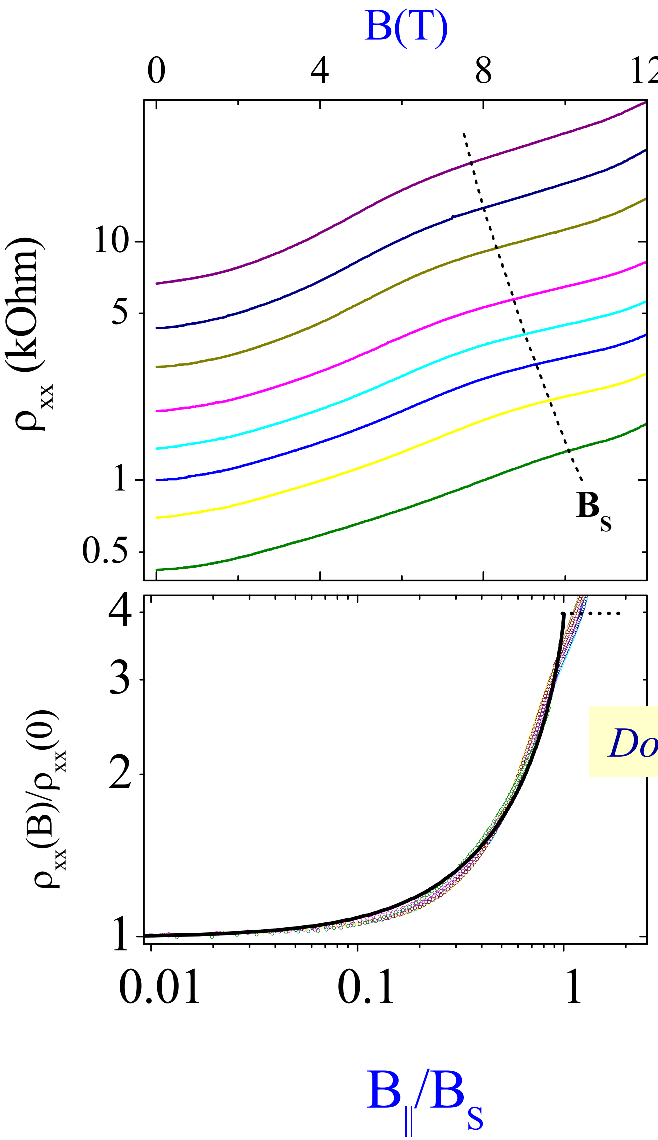


$p = 1.43 - 1.75\cdot 10^{10}$ cm^{-2}

$p = 2.49\cdot 10^{10}$ cm^{-2}

General view on the PMR and the g-factor





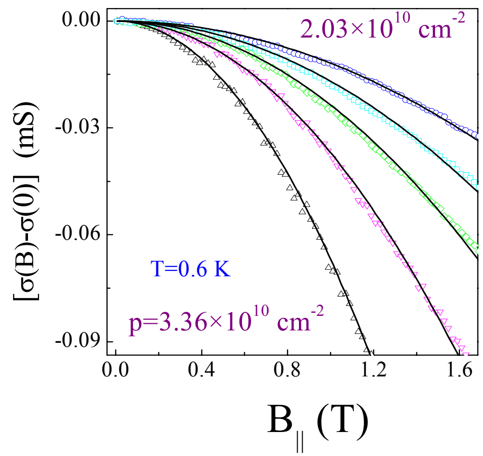
$p = 1.43 \cdot 10^{10} cm^{-2}$

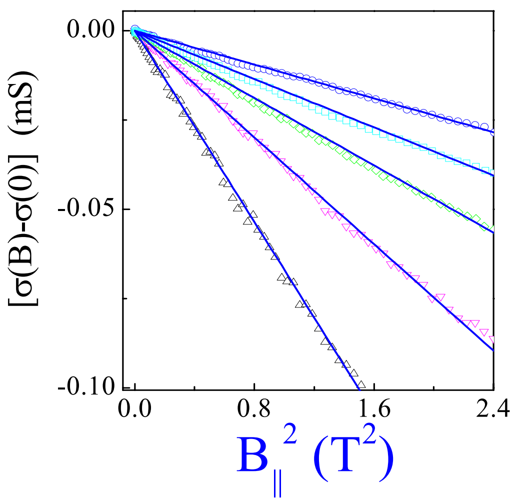
$p = 3.36 \cdot 10^{10} cm^{-2}$

Dolgopolov, Gold (2000)

T=50 mK

Positive magnetoresistance in small parallel field



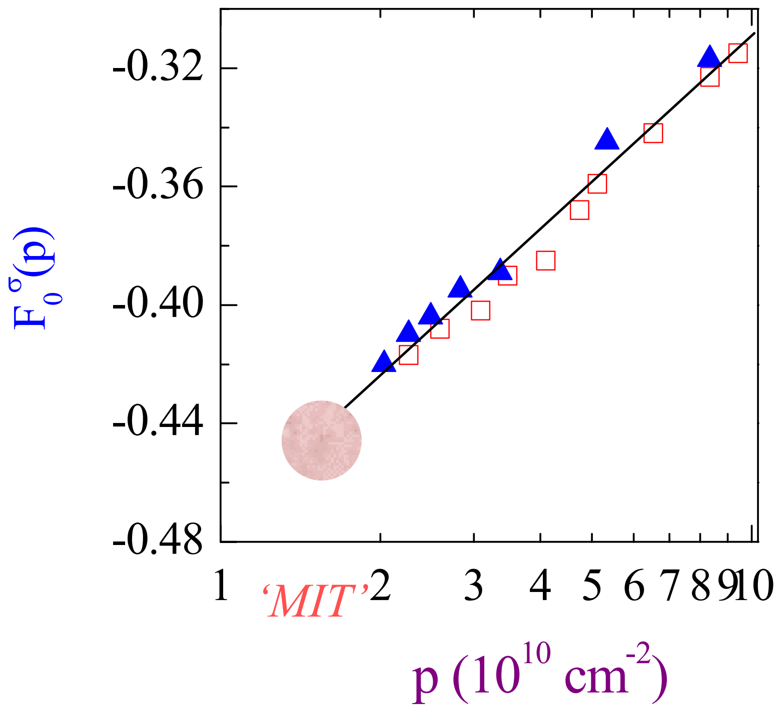


Zala, Narozhny, Aleiner (2001)

$$at \quad \frac{g^* \mu_B B}{2T} < 1 + F_o^\sigma$$

$$\sigma(B) - \sigma(0) \approx \frac{e^2}{\pi\hbar} \frac{2F_o^\sigma}{\left(1+F_o^\sigma\right)} \frac{T\tau}{\hbar} \frac{\left(g^* \mu_B B / 2T\right)^2}{3} f\left(F_o^\sigma\right)$$

Interaction constant in the triplet channel $F_o^\sigma(p)$.



Magnetic susceptibility: $\chi = \dfrac{\chi_o}{1+F_o^\sigma}$

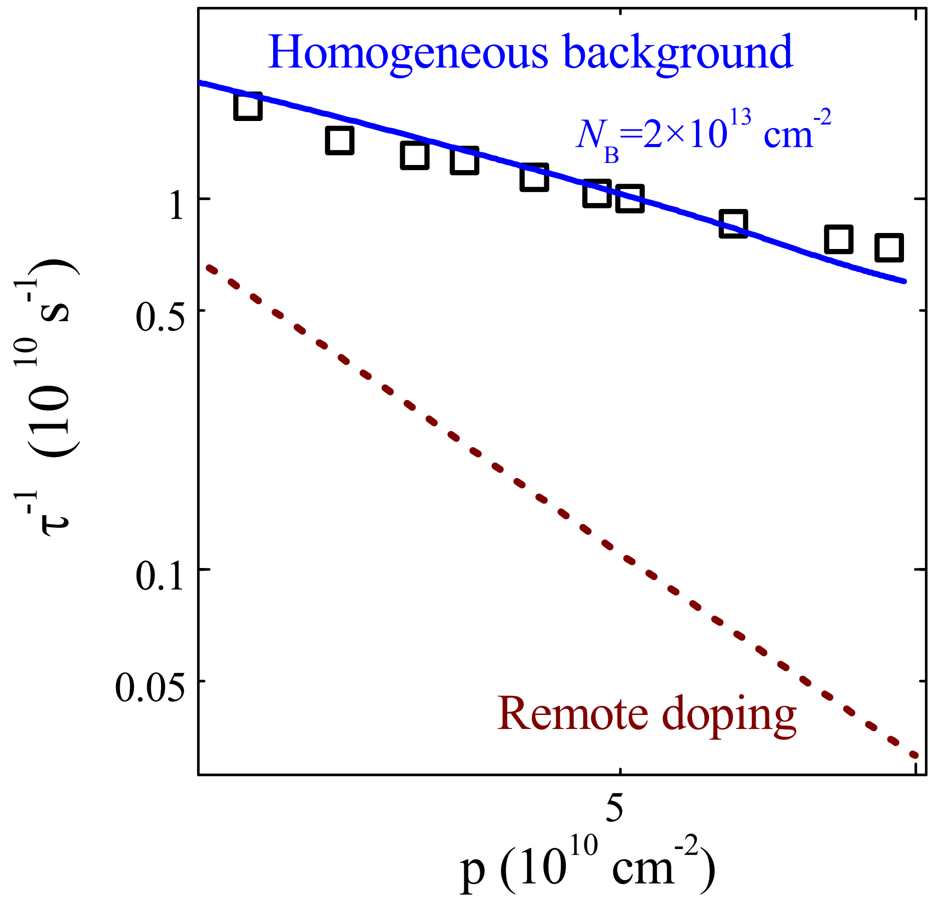
(Stoner instability $F_o^\sigma = -1$)

□ *from* $\sigma(T)$ *at* $B = 0$

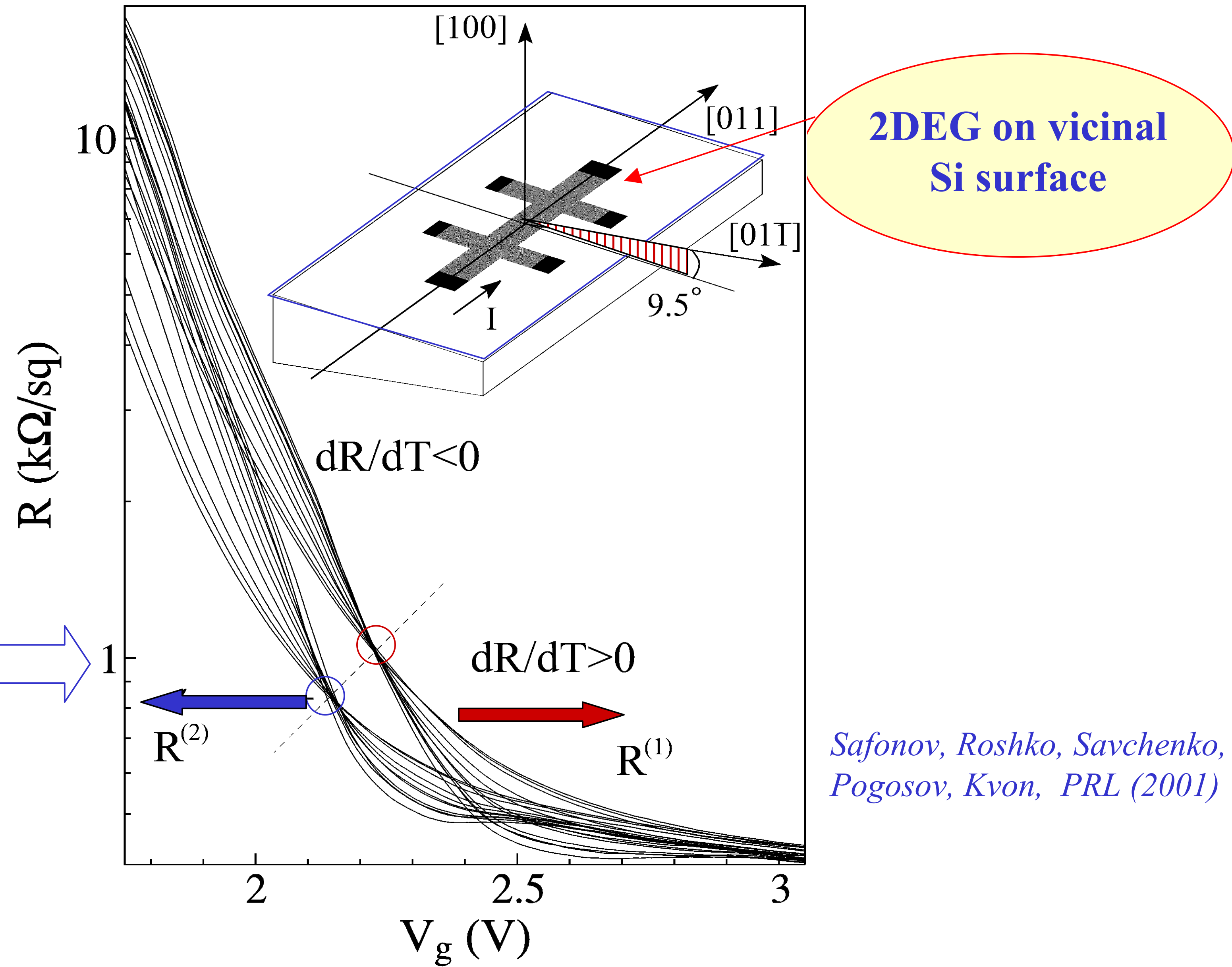
▲ *from* $\sigma(B,T)$ *at* $\dfrac{g^*\mu B}{2T} < 1 + F_o^\sigma$

Proskuryakov, Savchenko, Safonov, Pepper, Simmons, D. A. Ritchie, Phys. Rev. Lett. 89, 076406 (2002)

Short-range scattering in the 2DHG in GaAs



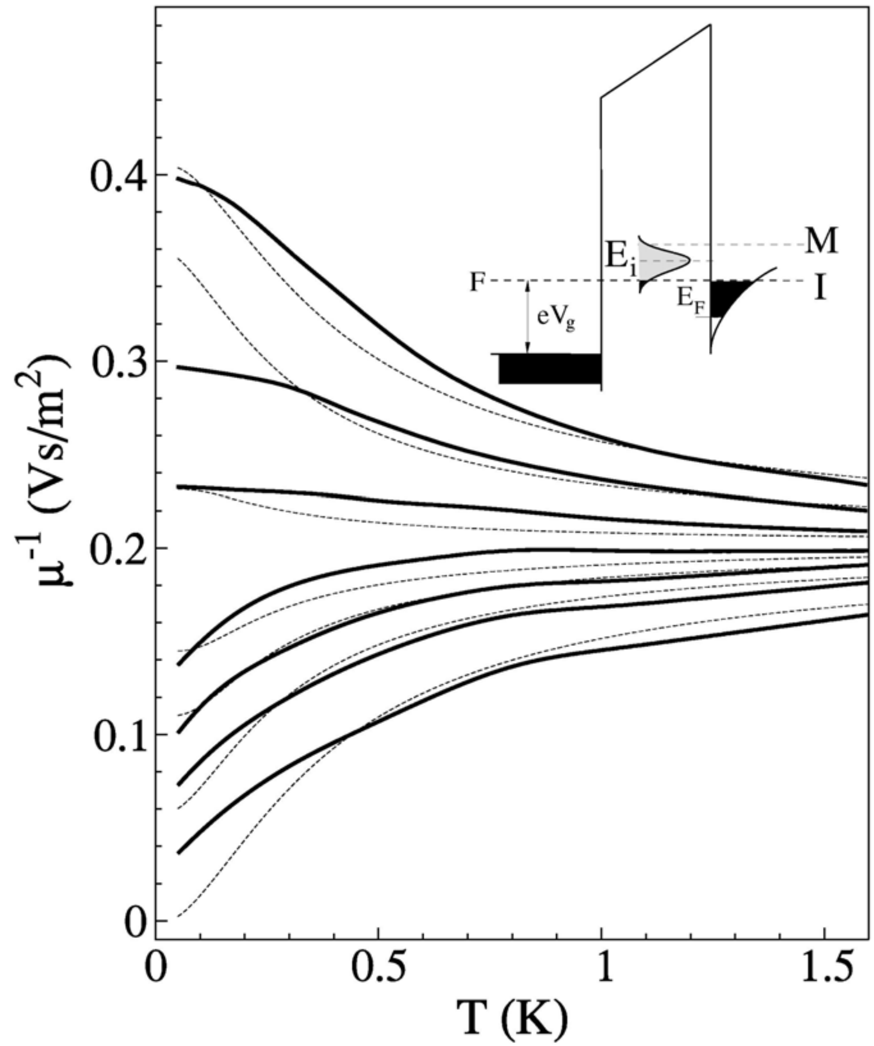
Crossover in the sign of *dR/dT* for different directions of V_g sweep



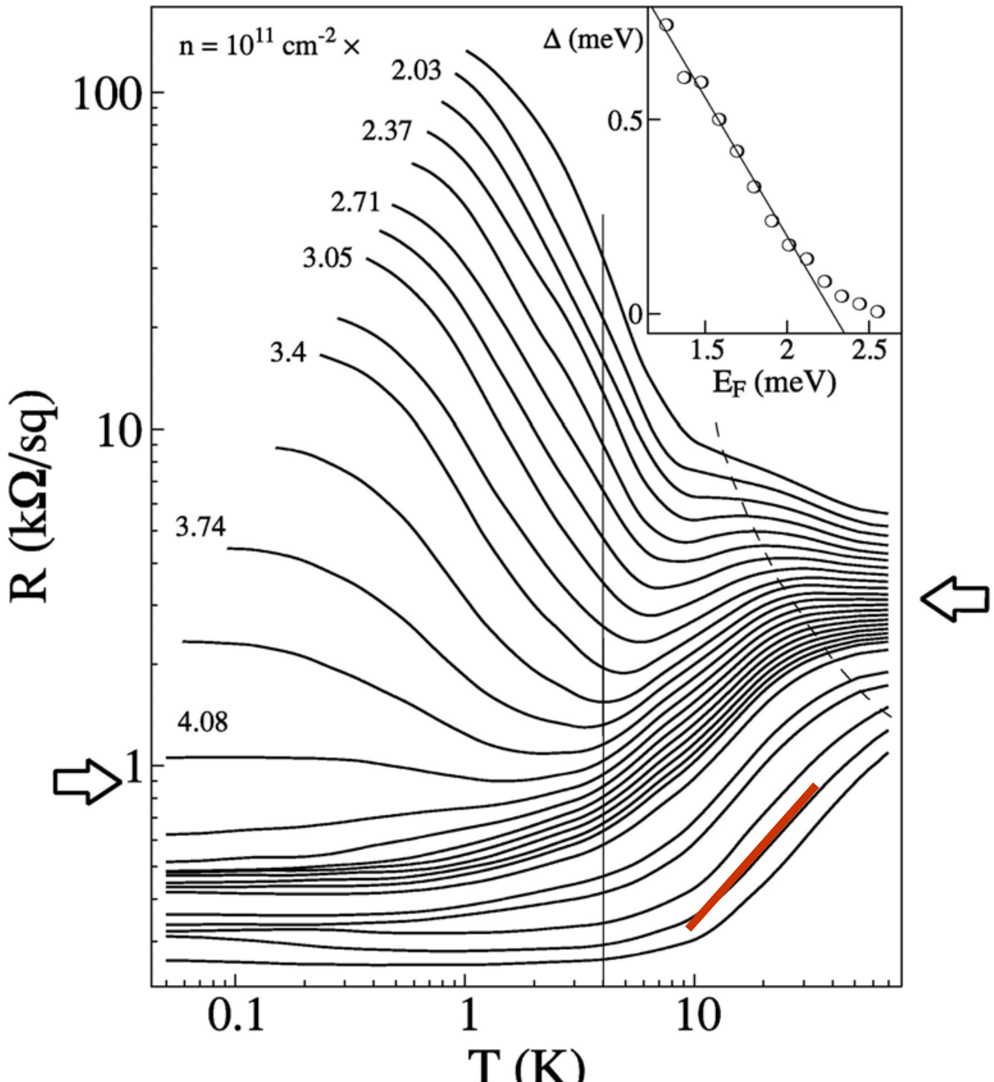
$\frac{1}{25}\left(\frac{h}{e^2}\right)$

Safonov, Roshko, Savchenko, Pogosov, Kvon, PRL (2001)

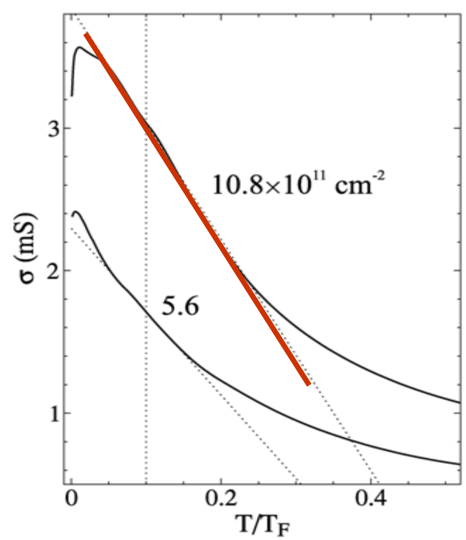
A narrow impurity band in the origin of the 'MIT' in the 2DEG on vicinal Si.



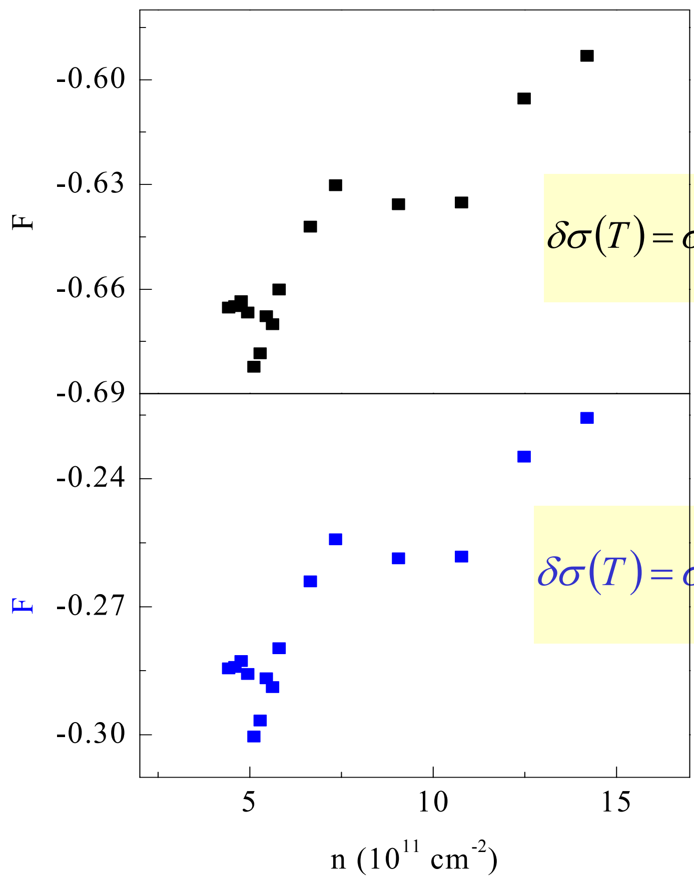
Temperature dependence of resistance of a 2DEG in vicinal Si



2DEG on vicinal Si surface



Interaction constant $F_0^\sigma(n)$ of the 2DEG in vicinal Si

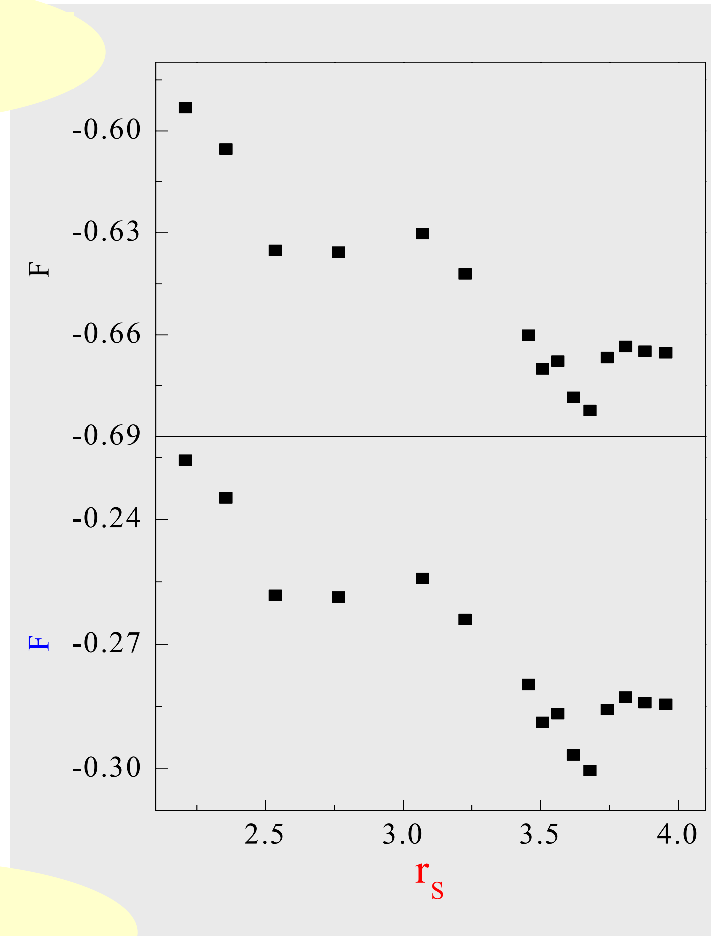


One valley

$$\delta\sigma(T) = \sigma_o\left(1 + \frac{3F_o^\sigma}{1+F_o^\sigma}\right)\cdot\frac{k_BT}{2E_F}$$

$$\delta\sigma(T) = \sigma_o\left(1 + \frac{15F_o^\sigma}{1+F_o^\sigma}\right)\cdot\frac{k_BT}{2E_F}$$

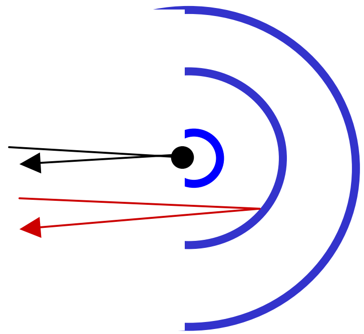
Two valleys



Ballistic regime, $T\tau > 1$, in short- and long-range fluctuation potential

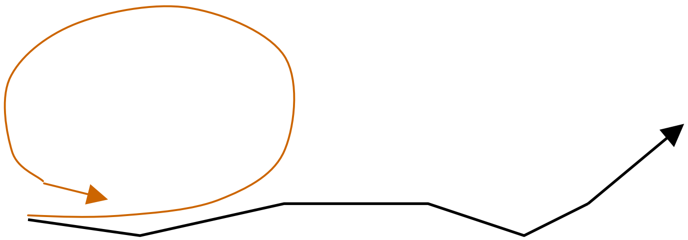
Short-range potential

(essential for *Zala, Narozhny, Aleiner (2001)*)



Long-range potential

(discussed by *Gornyi and Mirlin (2002)*)



- Smooth scattering potential **suppresses** interaction correction (at B=0) .

Measurements of the **interaction correction** by the **parabolic *NMR*** was discussed in relation to the *diffusive* regime:

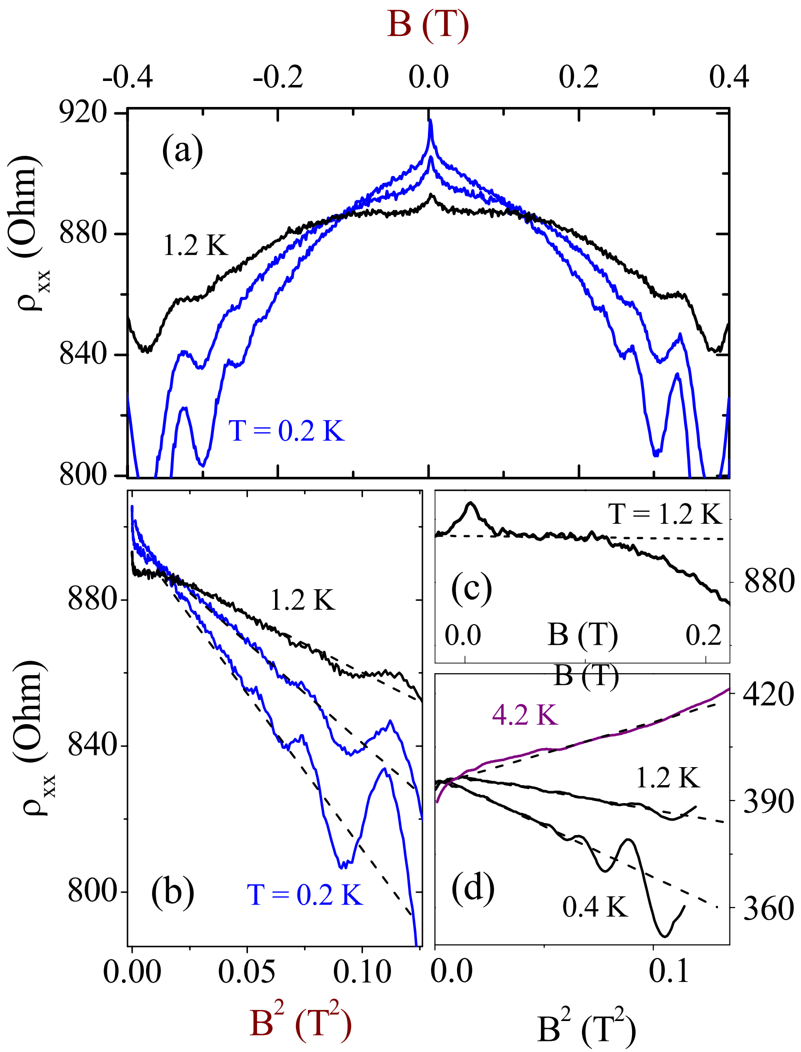
Paalanen, Tsui, Hwang, PRL (1983).

- Strong field, $\omega_c\tau > 1$, **restores** interactions:

$$\rho_{xx} = \frac{1}{\sigma_o} + \frac{1}{\sigma_o^2}(\omega_c\tau)^2 \delta\sigma_{xx}^{ee}(T)$$

Electron interactions in the ballistic regime
in the long-range fluctuation potential

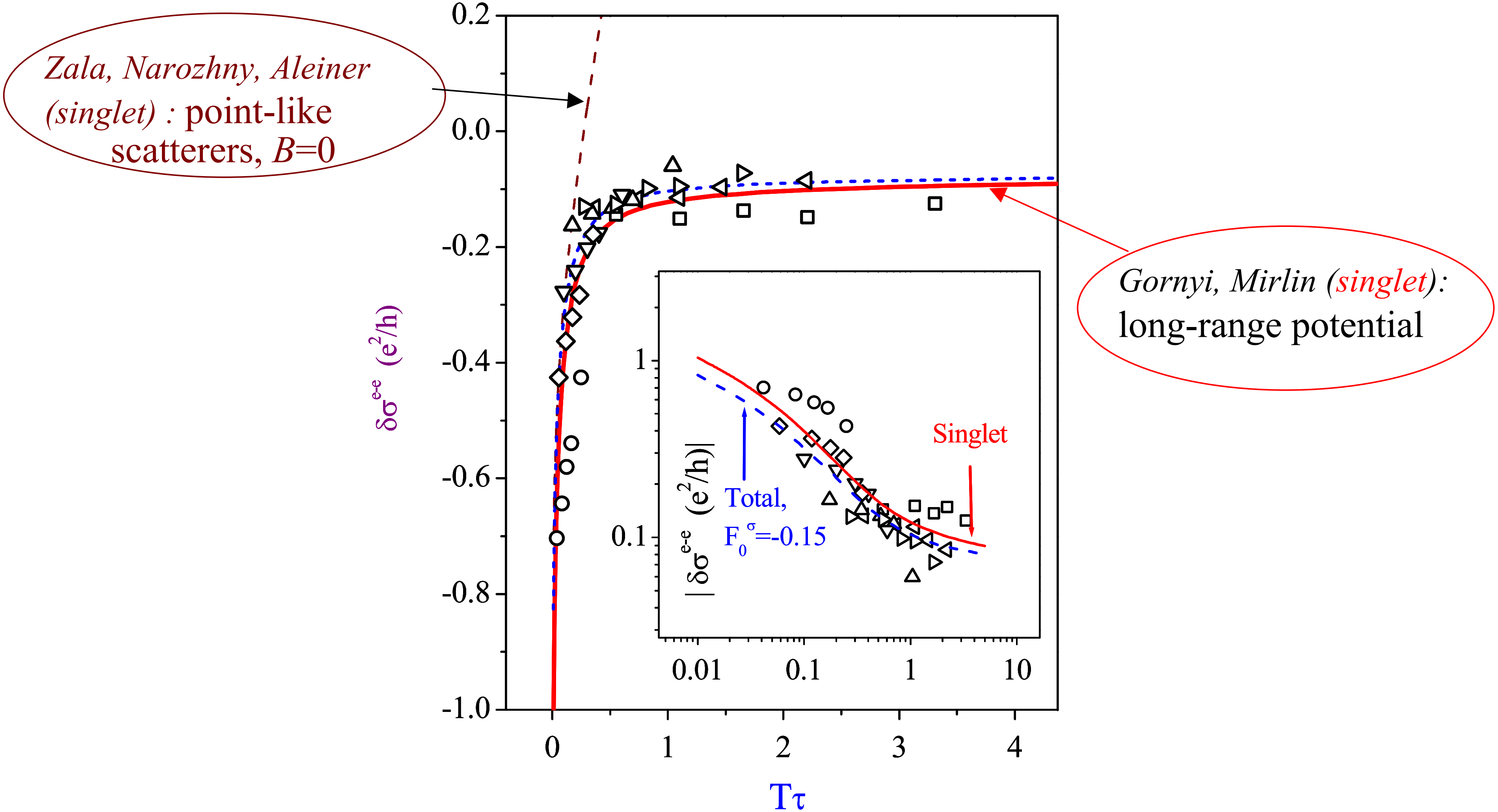
Theory: *Gornyi, Mirlin, PRL (2003)*



Experiment:
Li, Proskuryakov, Savchenko, Linfield, Ritchie, PRL (2003)

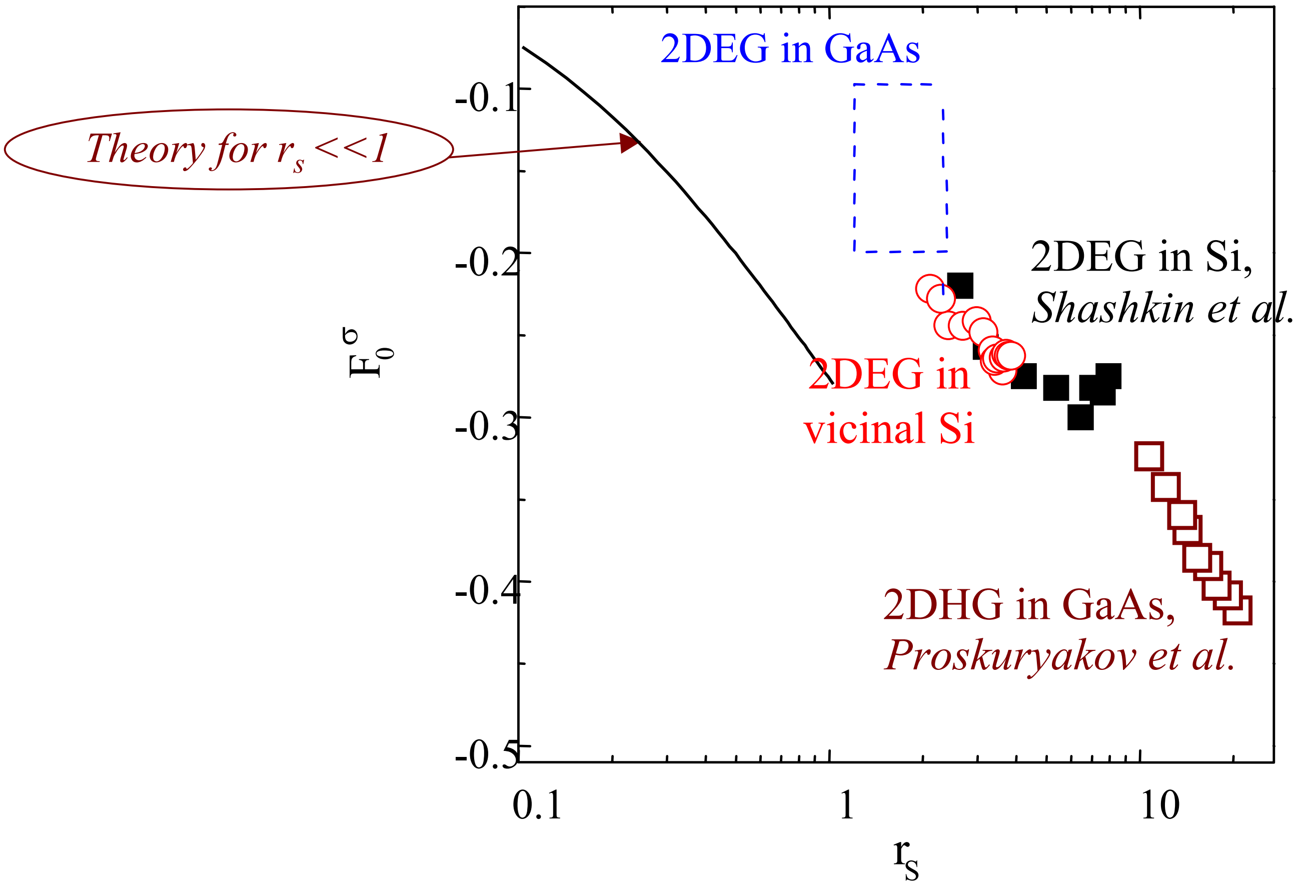
2DEG in GaAs/AlGaAs

Interaction correction $\delta\sigma^{ee}(T)$ in strong magnetic fields



$$\rho_{xx} = \frac{1}{\sigma_o} + \frac{1}{\sigma_o^2}\left(\mu^2 B^2\right)\delta\sigma_{xx}^{ee}(T)$$

Interaction parameter F_o^σ as a function of r_s in different 2D systems



Interaction parameter F_o^σ as a function of r_s in different 2D systems

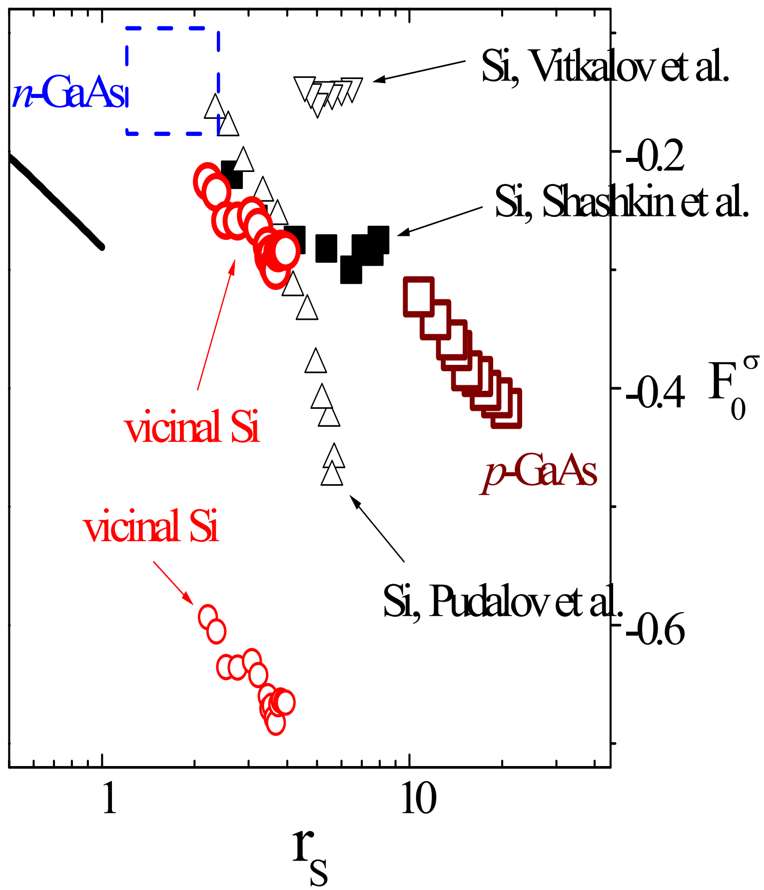


Fig. 1

Conclusions

- Interaction effects in the *ballistic regime* contribute to the 'metallic' $\rho_{xx}(T)$ in the systems
with short-range scatterers:
2DHG in *GaAs/AlGaAs* and 2DEG in *Si*.

- Interaction effects in the *ballistic regime*
depend on the character of the fluctuation potential.
They have different manifestation in the situation of
long-range potential:
as a negative magnetoresistance of
a 2DEG in GaAs/AlGaAs.