Valley polarisation assisted spin polarisation in Si MOSFETs

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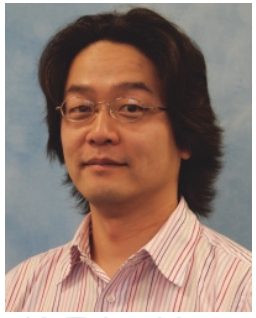
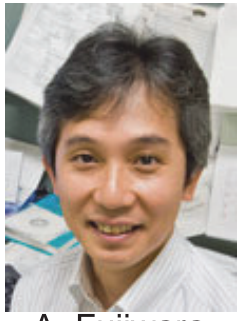
Thanks



K. Takashina

UNIVERSITY OF BATH



A. Fujiwara

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LNCMI

G. Fleury

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X. Waintal

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Agenda

Single particle picture

Previous results

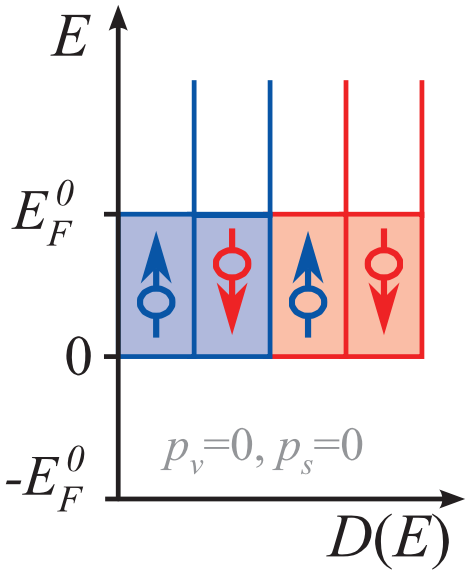
Our samples / results

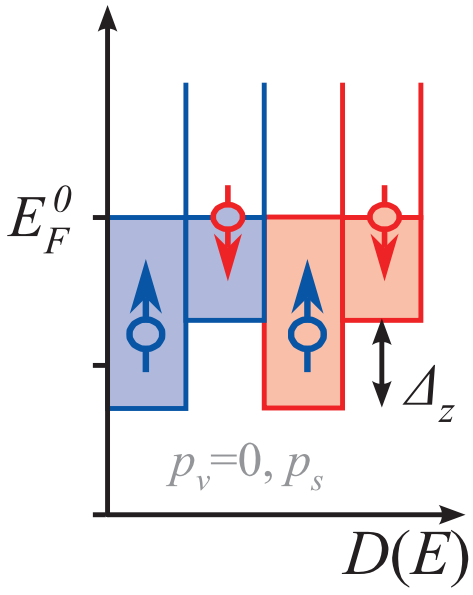
Comparison with Quantum Monte carlo / Discussion

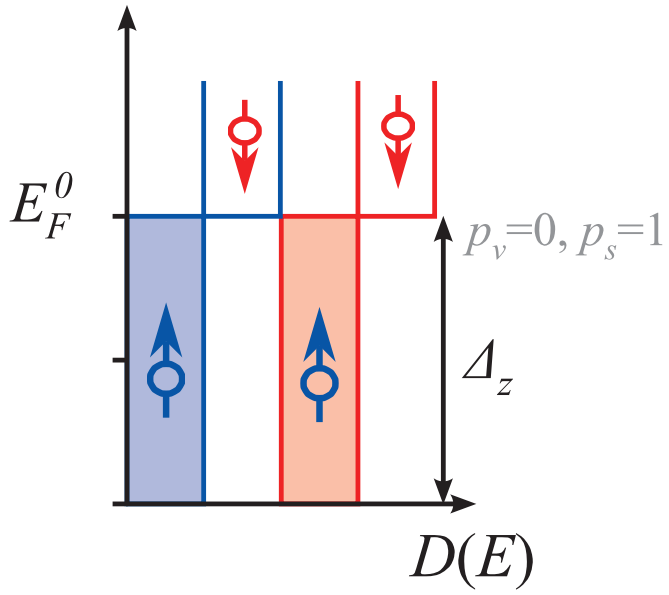
Advertising

Single particle picture

Valley unpolarised 2DEG







Spin up

Spin down

Valley +

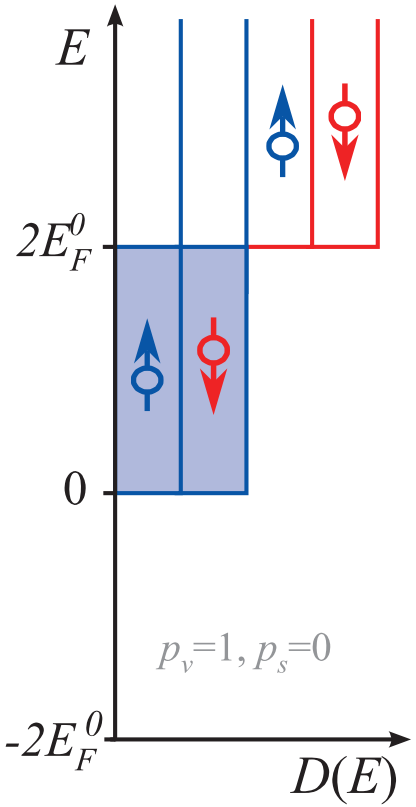
Valley -

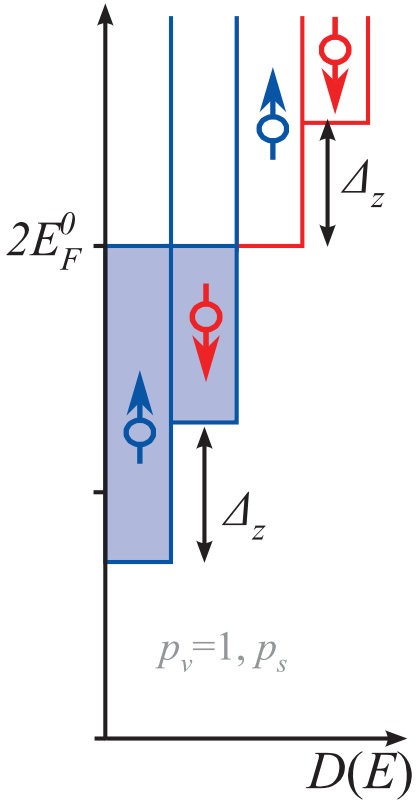
$$\Delta_z = g\mu_B B$$

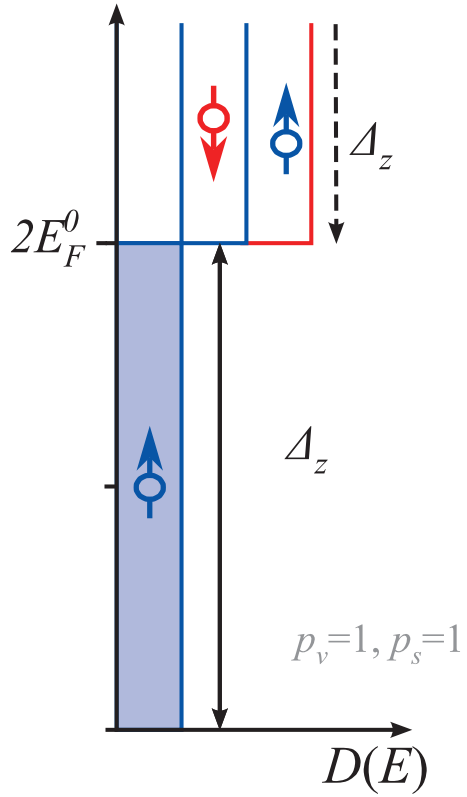
$$p_s = \frac{n\uparrow - n\downarrow}{n\uparrow - n\downarrow}$$

$$B_p = \frac{2E_F^0}{g\mu_B}$$

Single particle picture
Valley polarised 2DEG





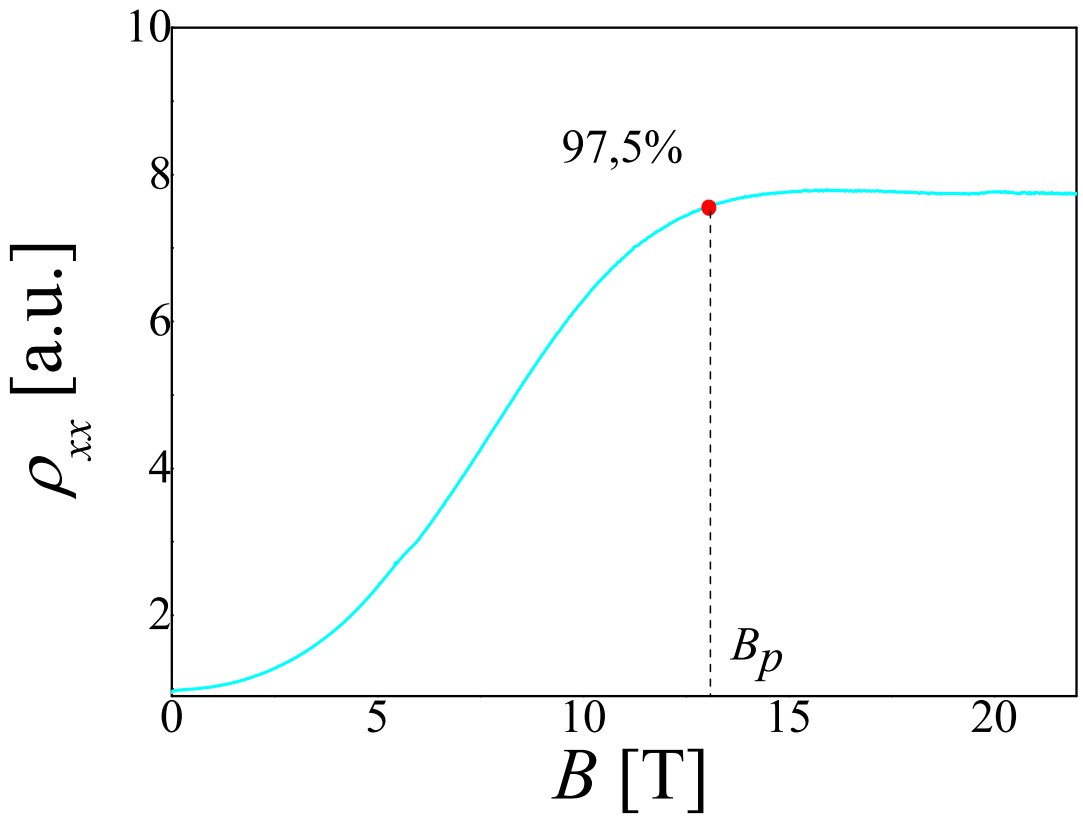


$$B_p = \frac{4E_F^0}{g\mu_B}$$

Determination of B_p

Magnetoresistance in parallel magnetic fields

2DEG (thin)

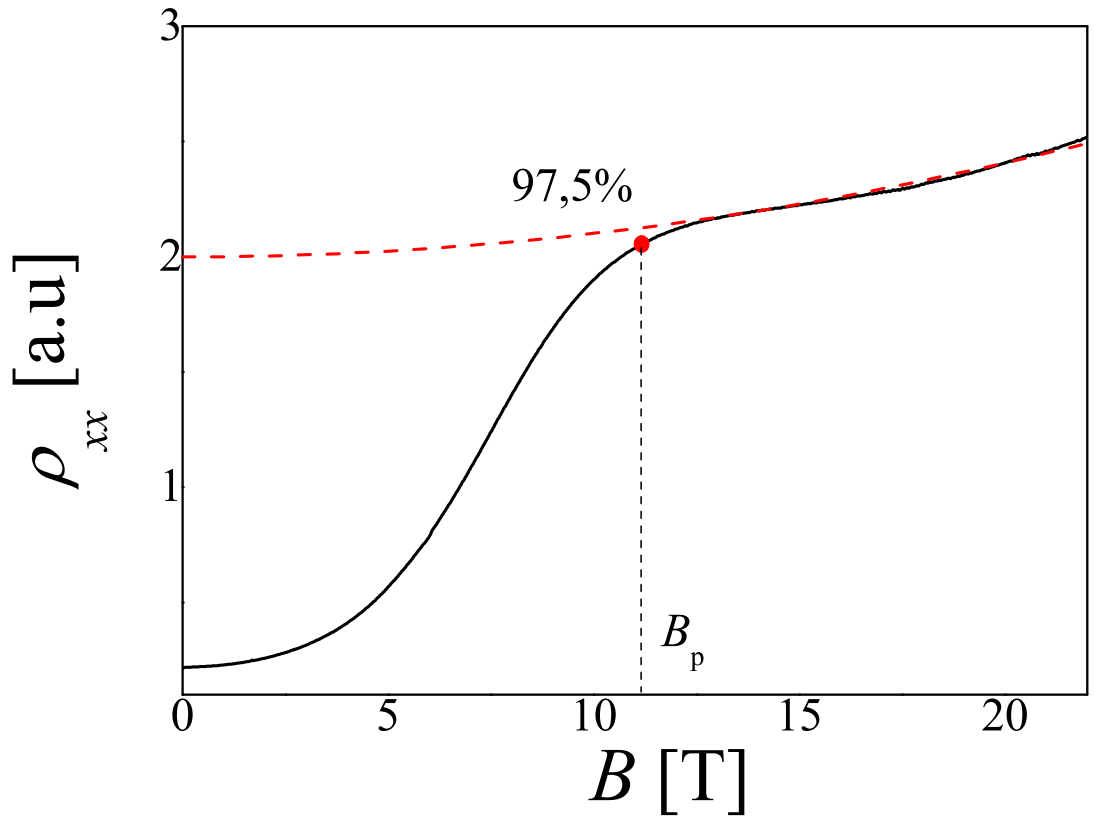


Okamoto *et al.* PRL **32**, 3875 (1999) , Pudalov *et al.* PRL **88**, 076401 (2002)

Determination of B_p

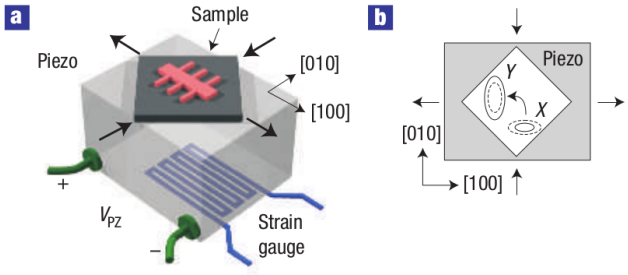
Magnetoresistance in parallel magnetic fields

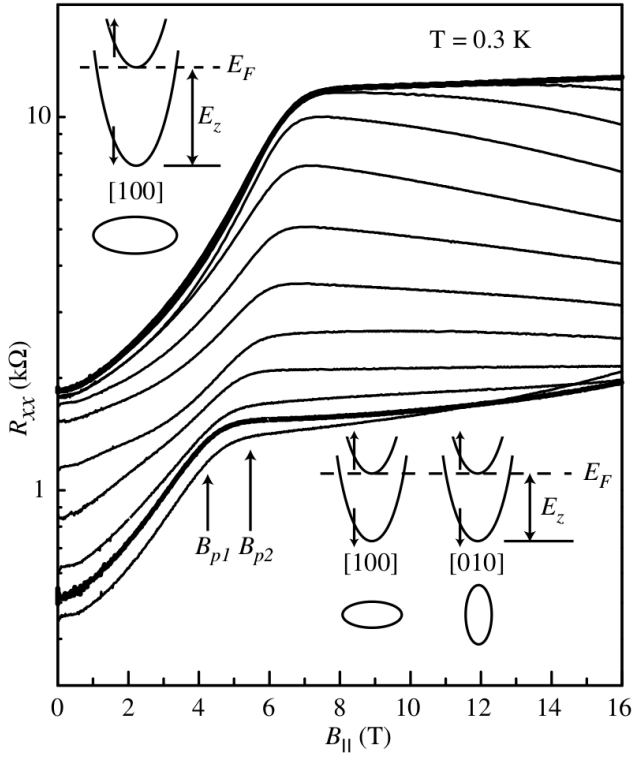
Real 2DEG



Okamoto *et al.* PRL **32**, 3875 (1999) , Pudalov *et al.* PRL **88**, 076401 (2002)

Previous results
AlAs

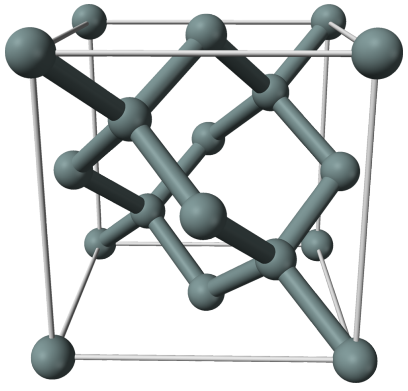




Shayegan *et al.* Phys. Rev. Lett. **92** 246804 (2004); PRB **78**, 161301(R) (2008);
PRB, **81** 235305 (2010)

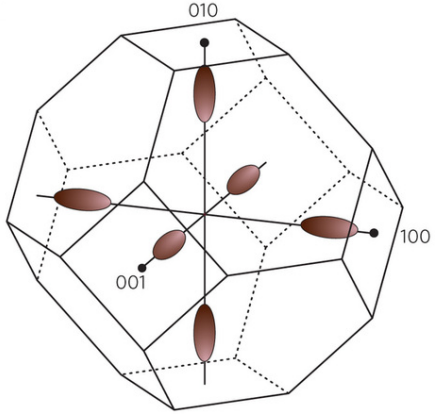
Our samples
Si quantum wells on insulators

Si Crystal



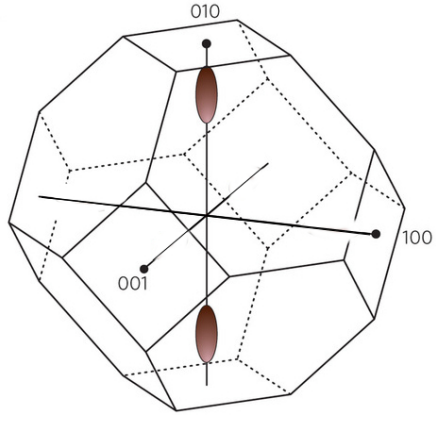
Diamond structure

Bulk



6 valleys

Confined in z direction



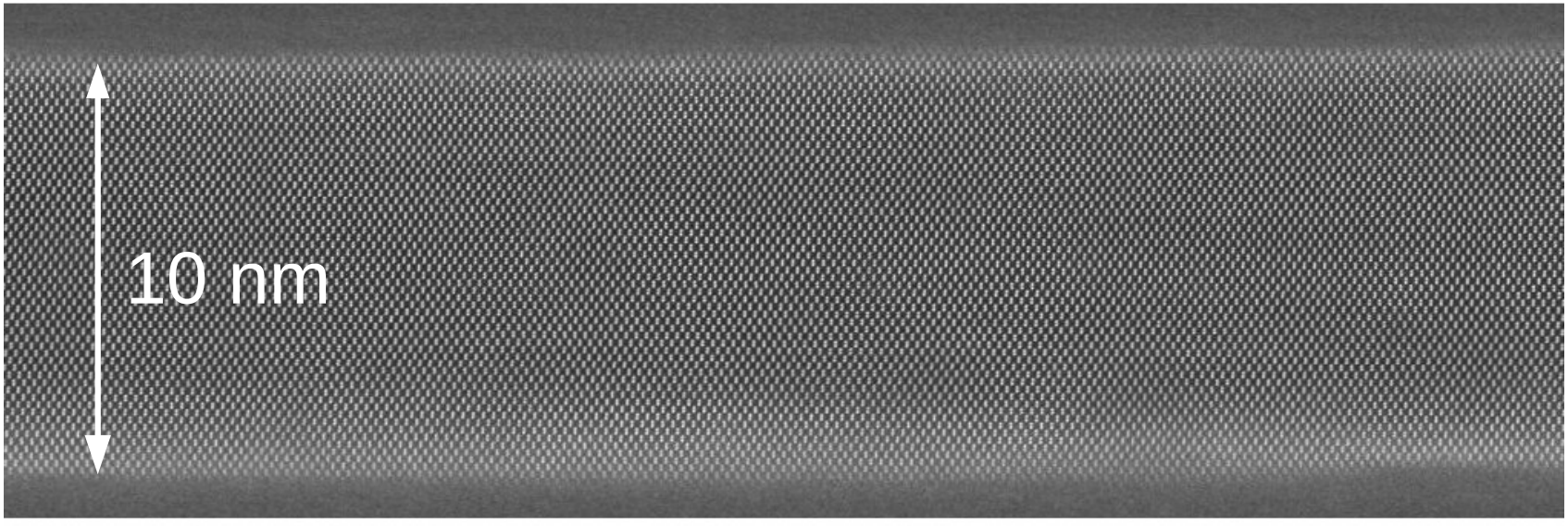
2 valleys

$$m_l = 0.9m_0$$
$$m_t = 0.2m_0$$

Our samples

Si quantum wells on insulators

thermal oxide

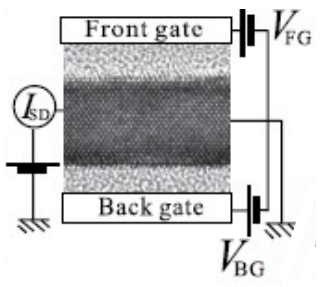


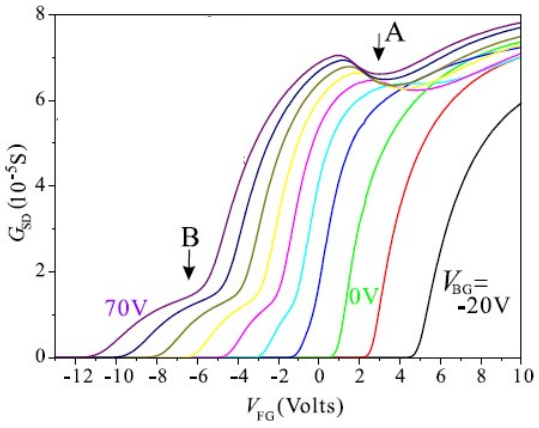
SIMOX oxide

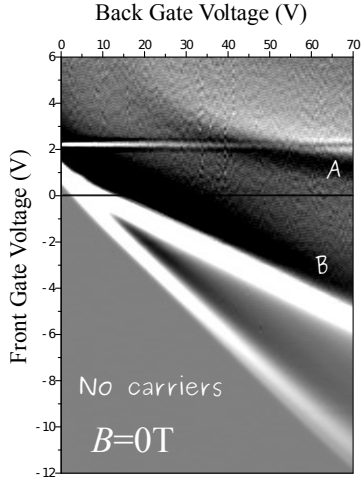
Samples from NTT BRL (Atsugi, Japan)

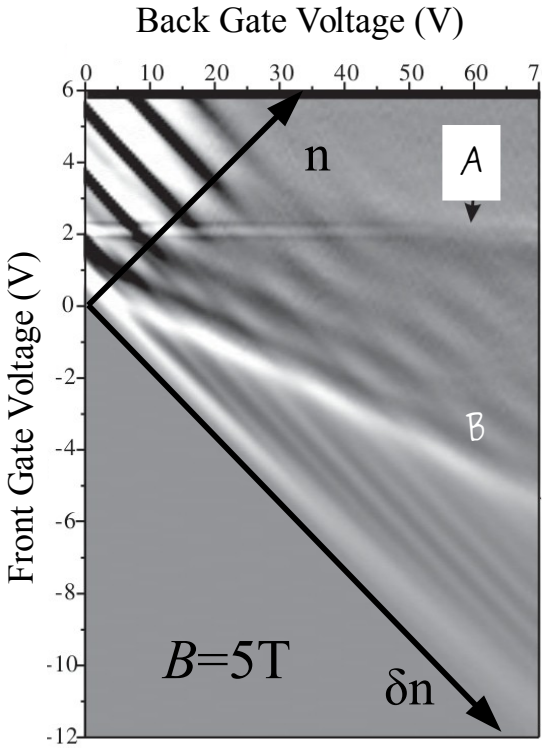
Image by D. Cooper @ Leti

Our samples
Valley polarisation





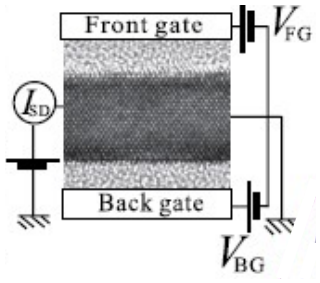


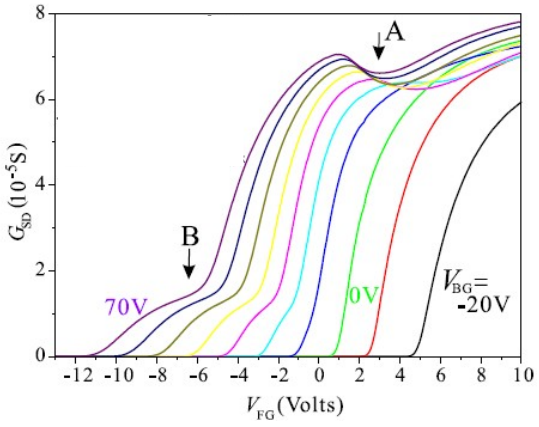


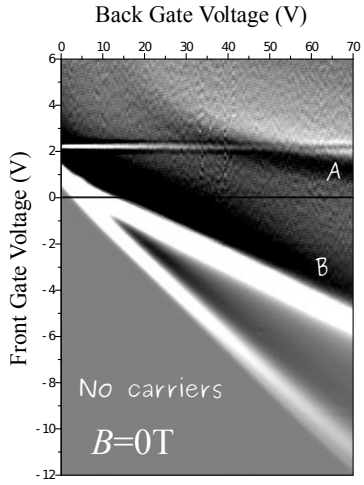
$$n = n_F + n_B \; ; \delta n = n_B - n_F$$

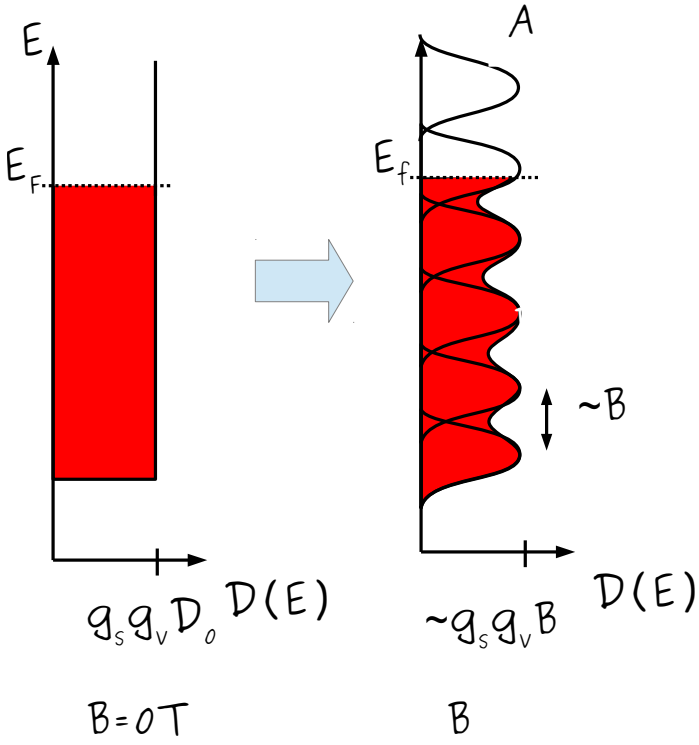
K. Takashina *et al.* PRL (2006)

Our samples
Valley polarisation





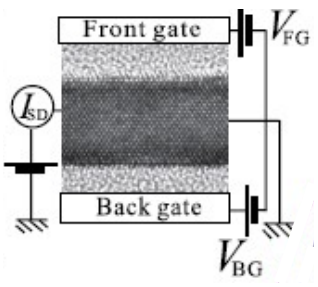


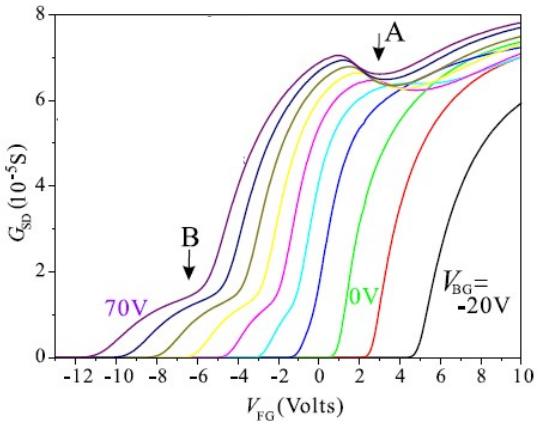


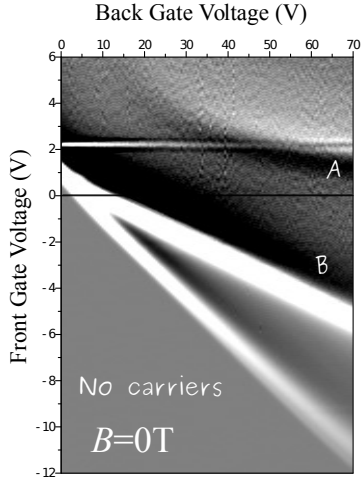
$$G \propto D(E_F)$$

K. Takashina *et al.* PRL (2006)

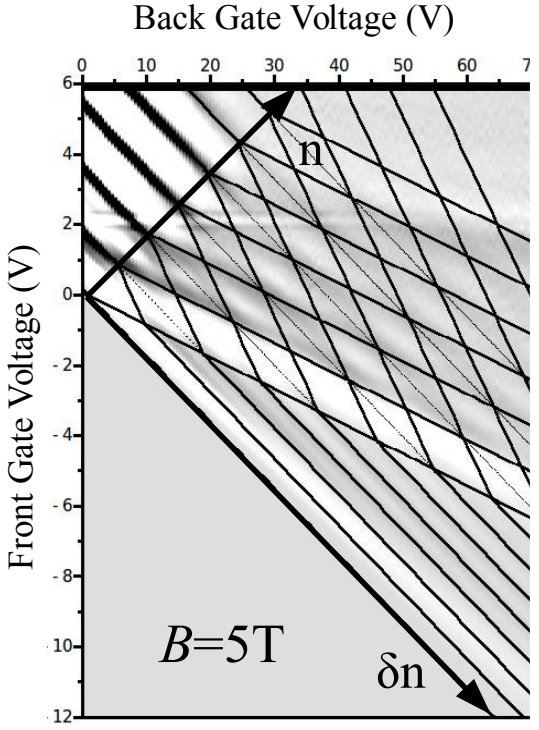
Our samples
Valley polarisation







K. Takashina *et al.* PRL (2006)

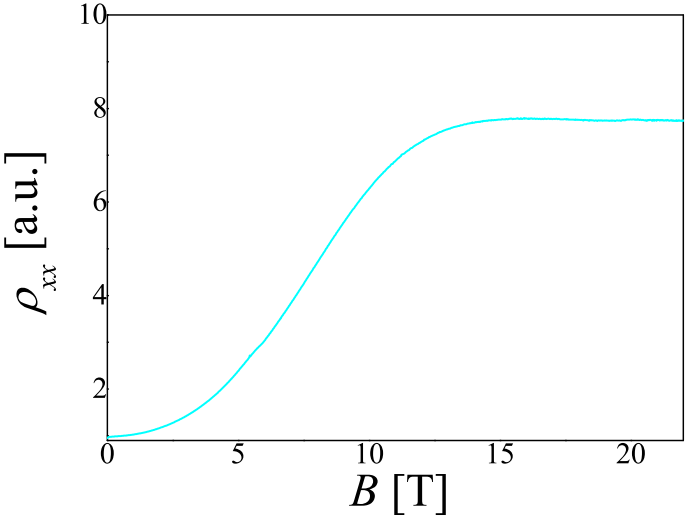


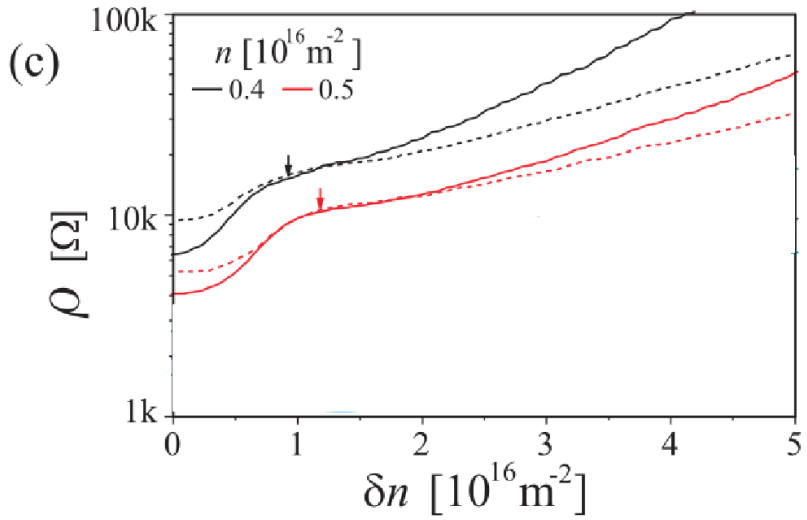
$$n = n_F + n_B \; ; \delta n = n_B - n_F$$

$$\Delta_v = \alpha \delta n$$

$$\alpha = 0.46 \text{ meV}/(10^{15} m^2)$$

Our samples
Valley resistance



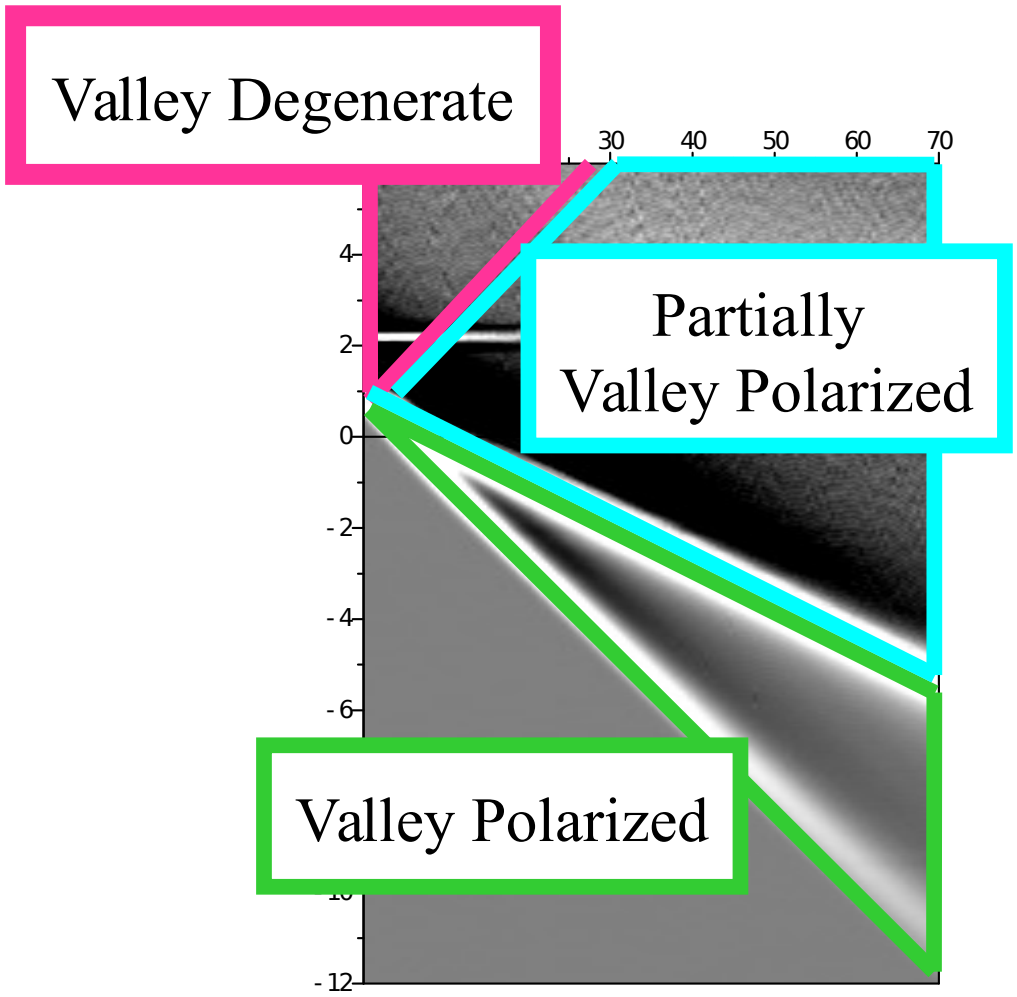


Magnetoresistance

Valleyresistance

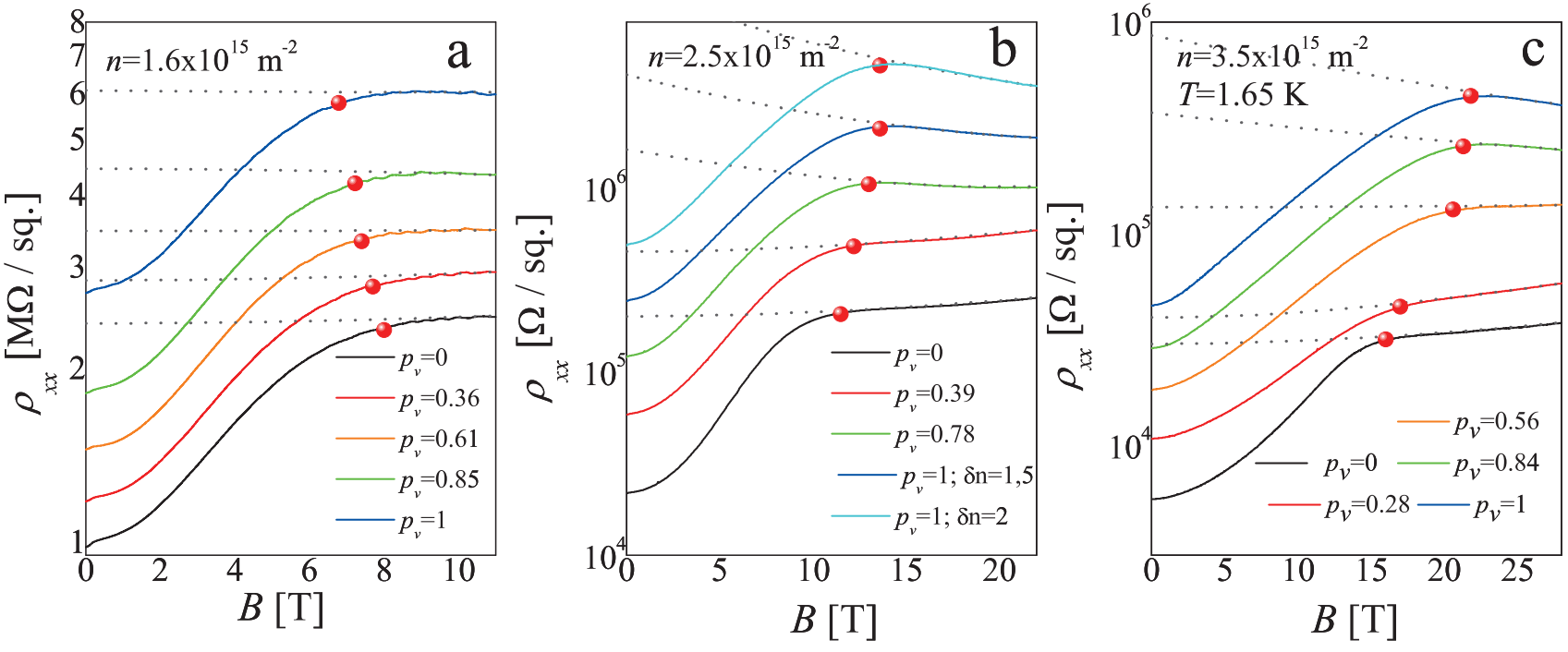
K. Takashina *et al.* PRL (2011),PRB (2013)

Our samples
Summary



Dependence of B_p on valley polarization

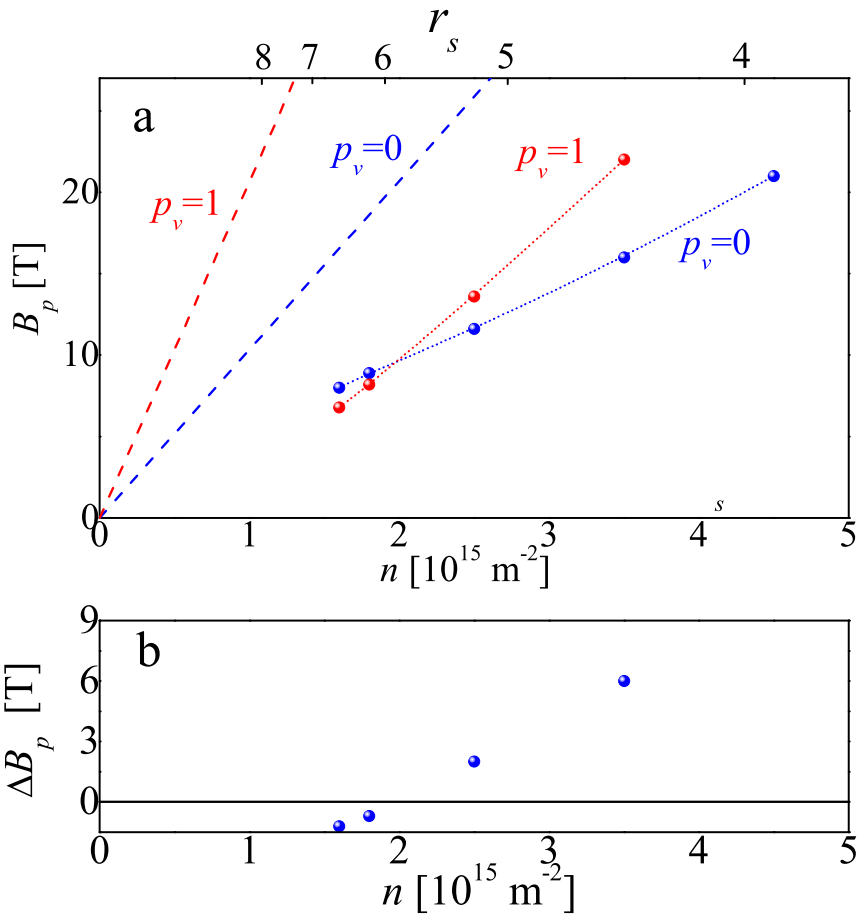
Experiment



Consistent with measurements in AlAs

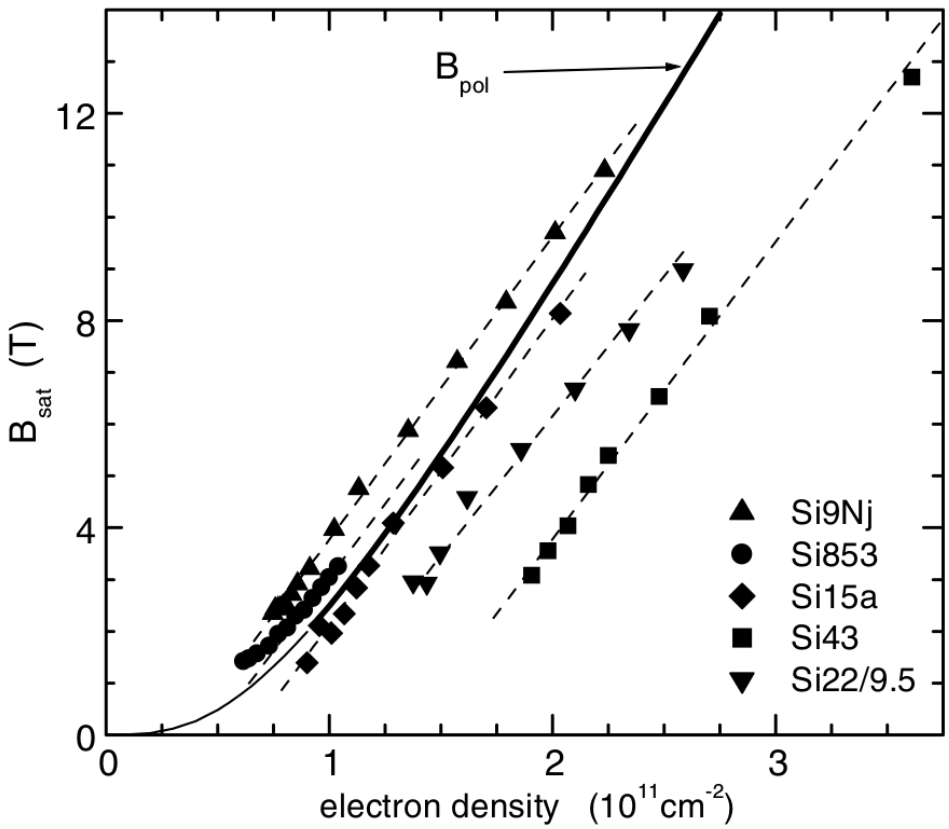
Shayegan *et al.* PRL (2004), PRB (2008), PRB (2010)

Comparison with non-interacting theory



$$r_s = \frac{1}{(\pi n^{-1/2}) a_B}$$

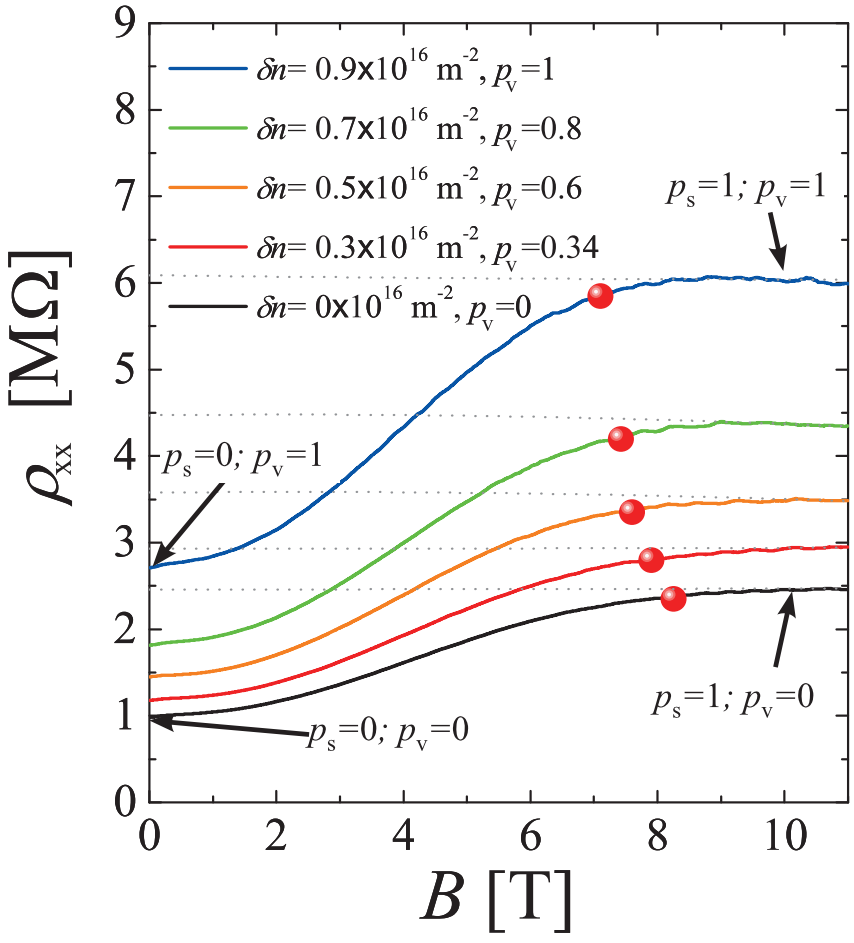
Role of disorder



Pudalov *et al.* PRL **88**, 076401 (2002)

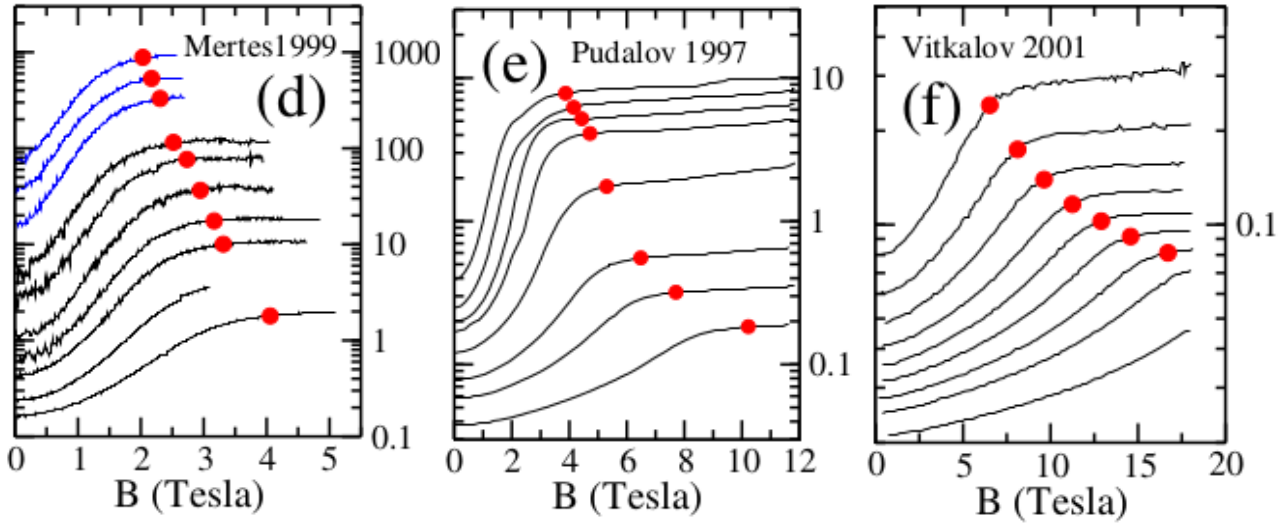
Exclusion of disorder

magnéto- and valley-resistance



Quantum Monte Carlo

Si at $p_v = 0$



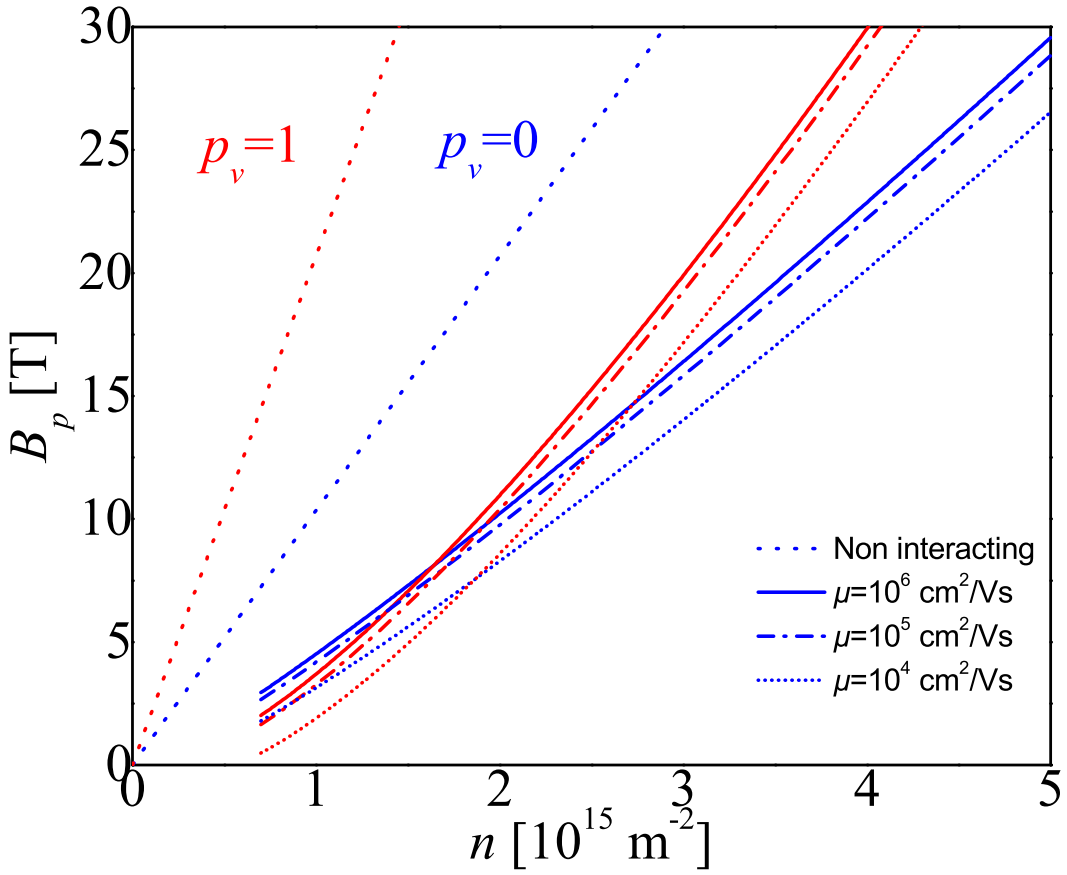
ingredients: interactions and white noise disorder

input : sample mobility at high density

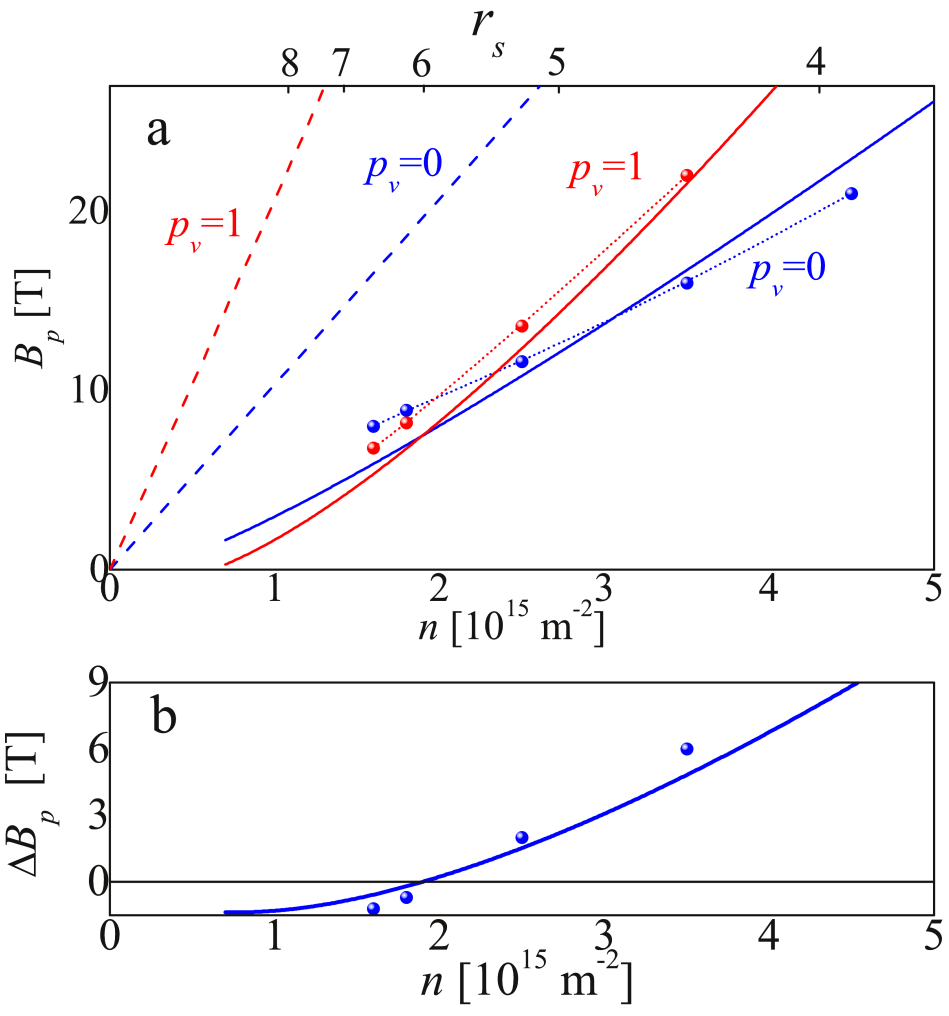
Fleury & Waintal PRB (2010)

Quantum Monte Carlo

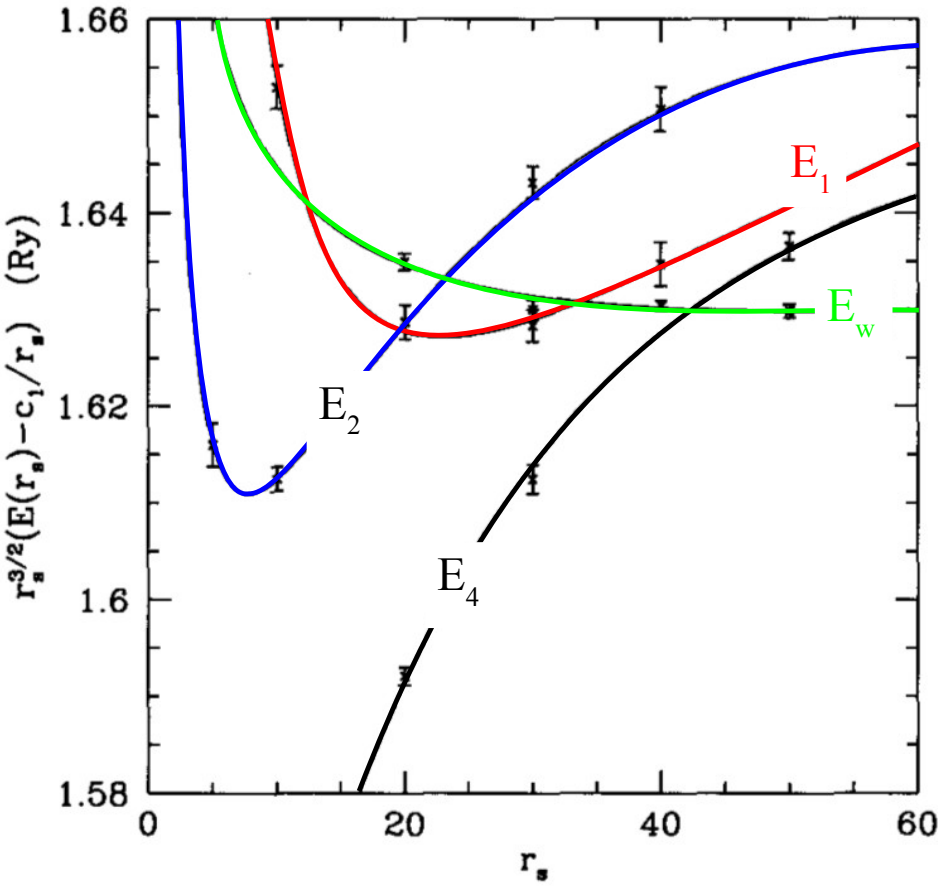
With Valley polarization



Experiment vs QMC



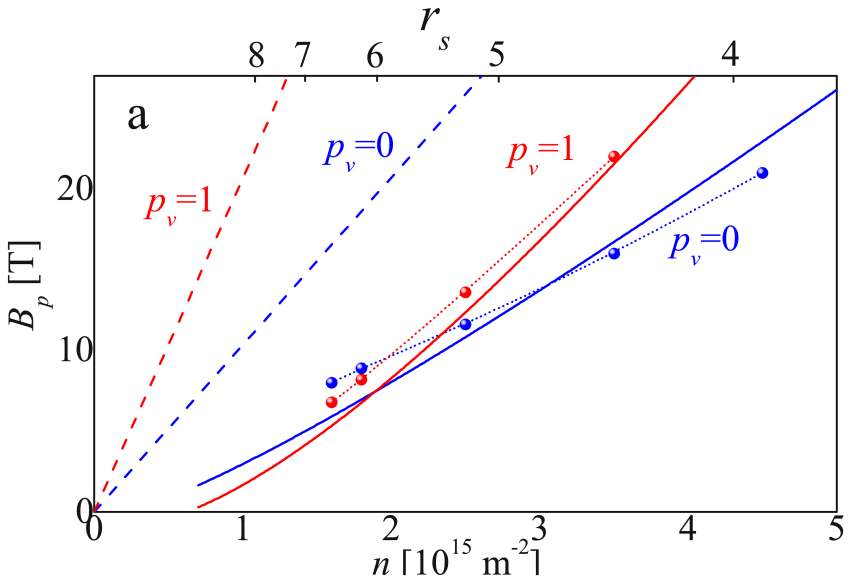
Discussion
QMC with valleys in clean 2DEG



QMC in clean 2DEG by Conti and Senatore EPL (1996)

Discussion
What does our result tell us?

- $p_v = 0$ is more stable vs ferromagnetic instability than $p_v = 1$



- The prediction remains valid in disordered systems

Renard et al. Nature Comm. **6**, 7230 (2015)