UNIVERSITY OF CAMBRIDGE

Non-equilibrium magneto-resistance of Au-Ge

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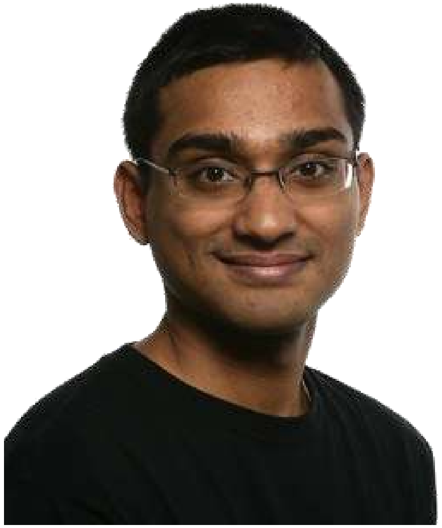
James Dann
Vijay Narayan
Philipp Verpoort

Theory of Condensed Matter & Semiconductor Physics

Collaborators

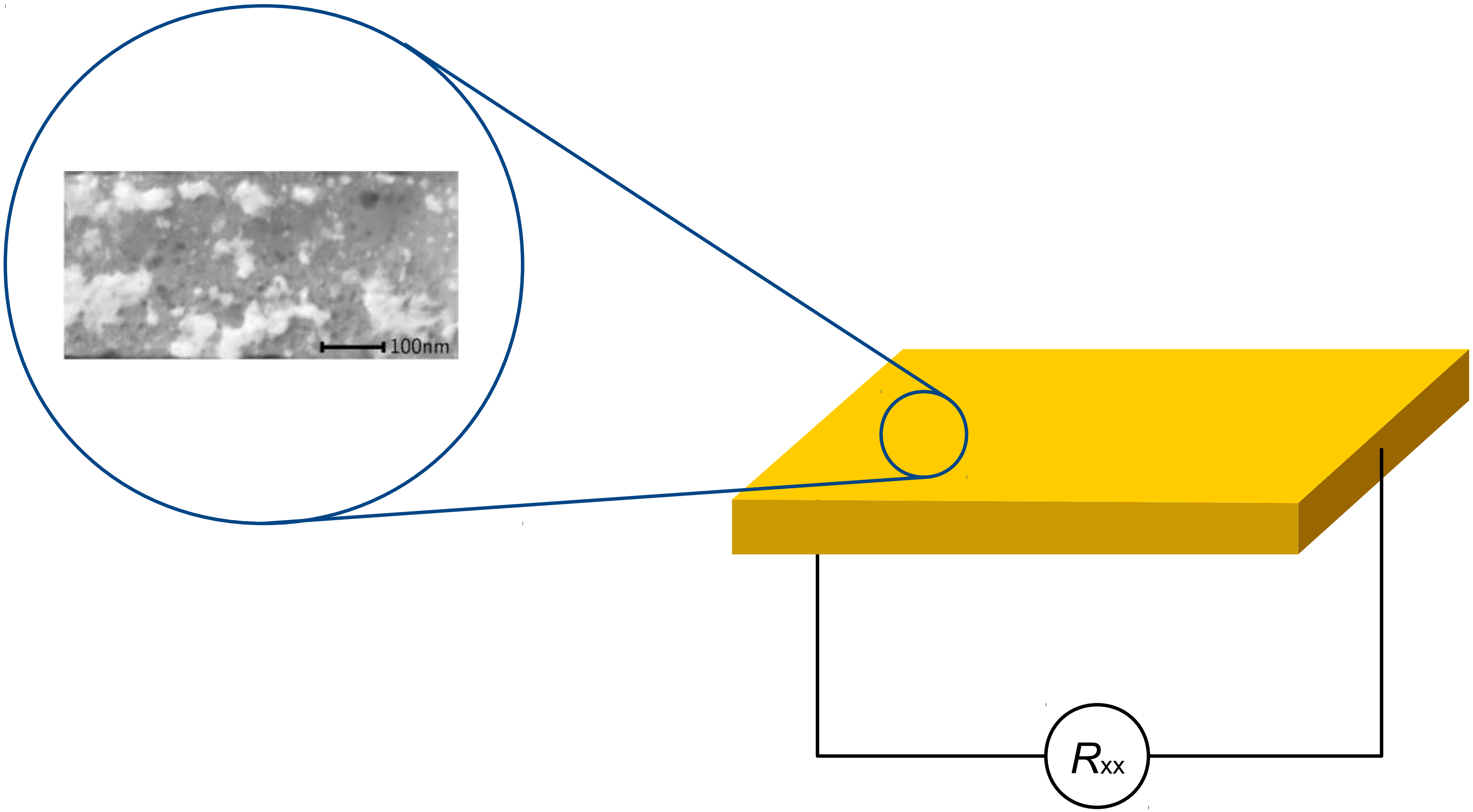
James Dann



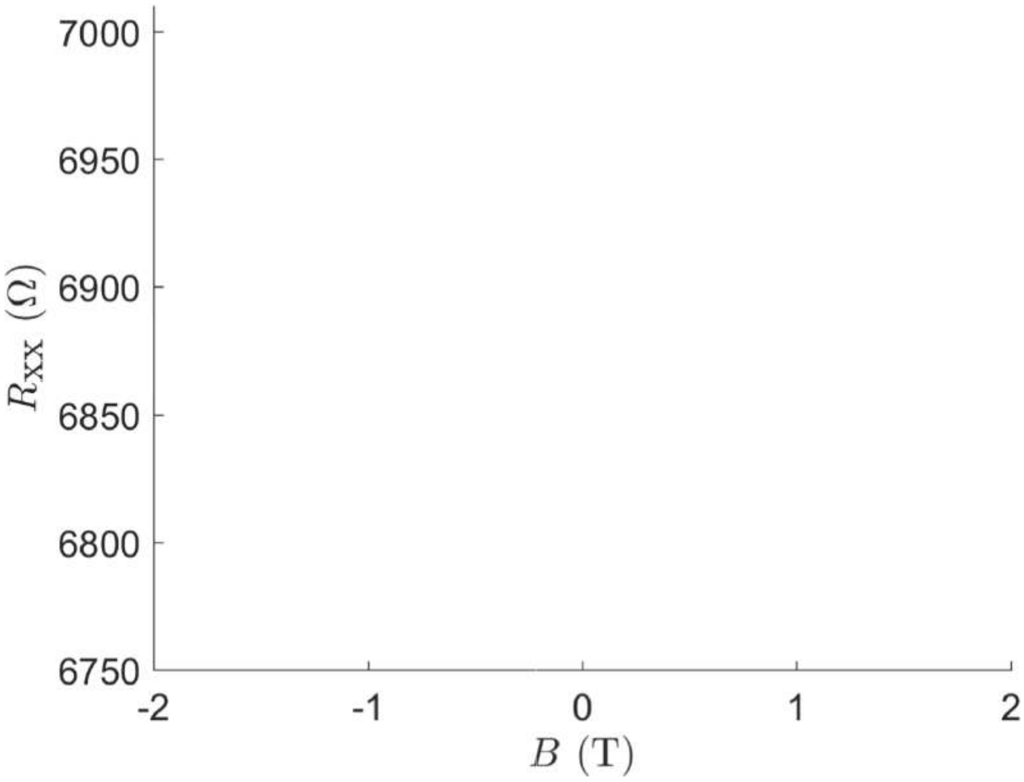
Dr Vijay Narayan

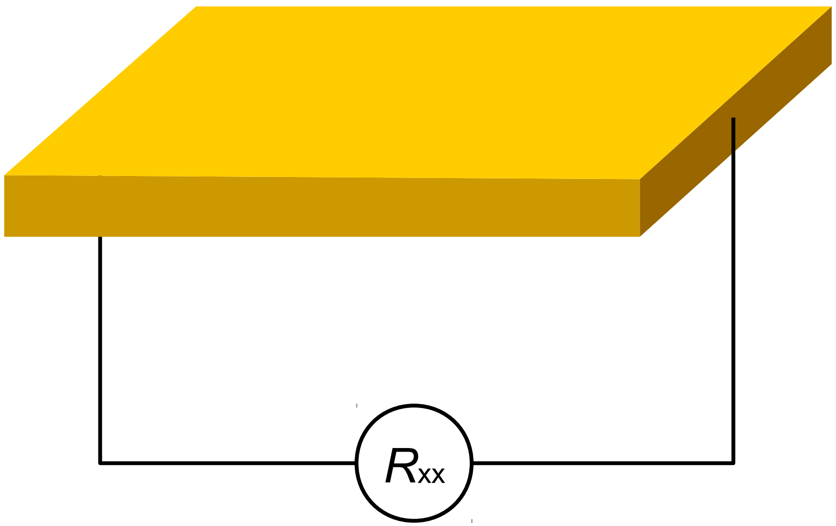
Philipp Verpoort

Setup: $Au_{0.1}Ge_{0.9}$

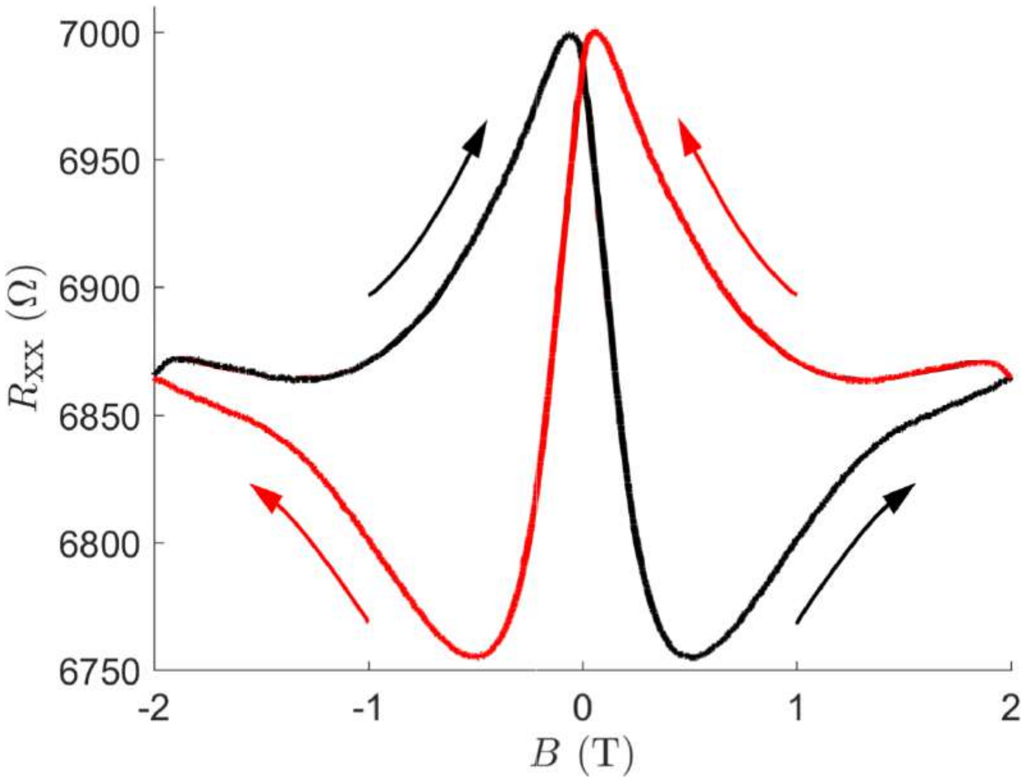


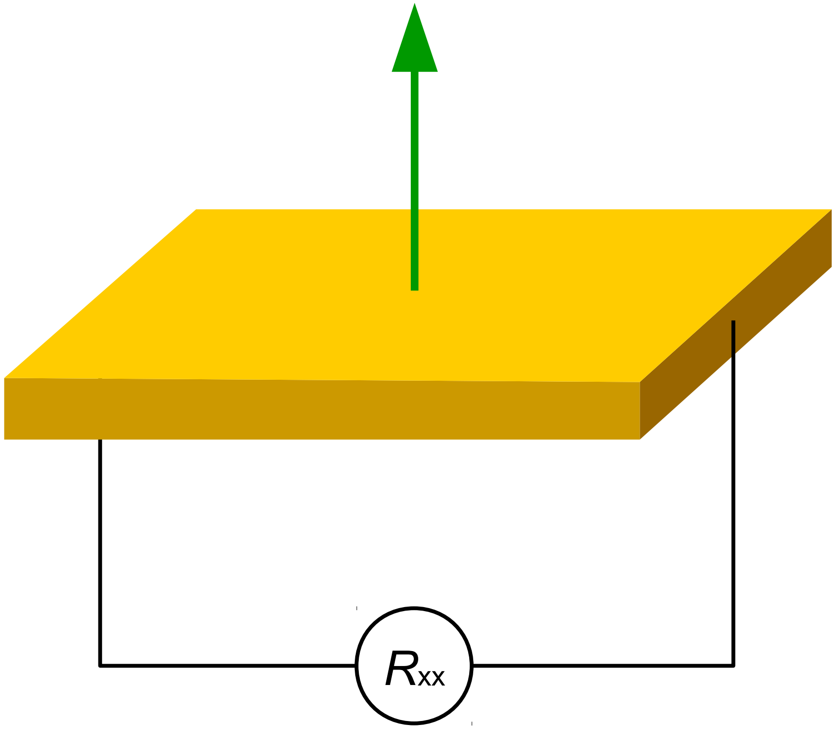
Measure the magnetoresistance of Au-Ge



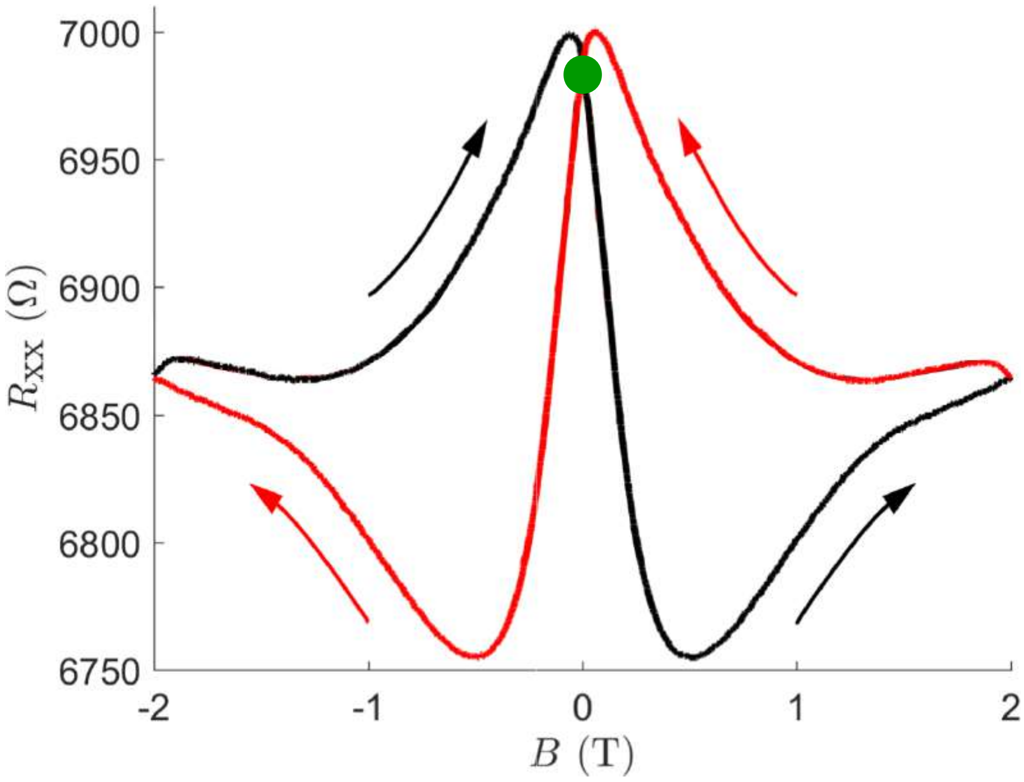


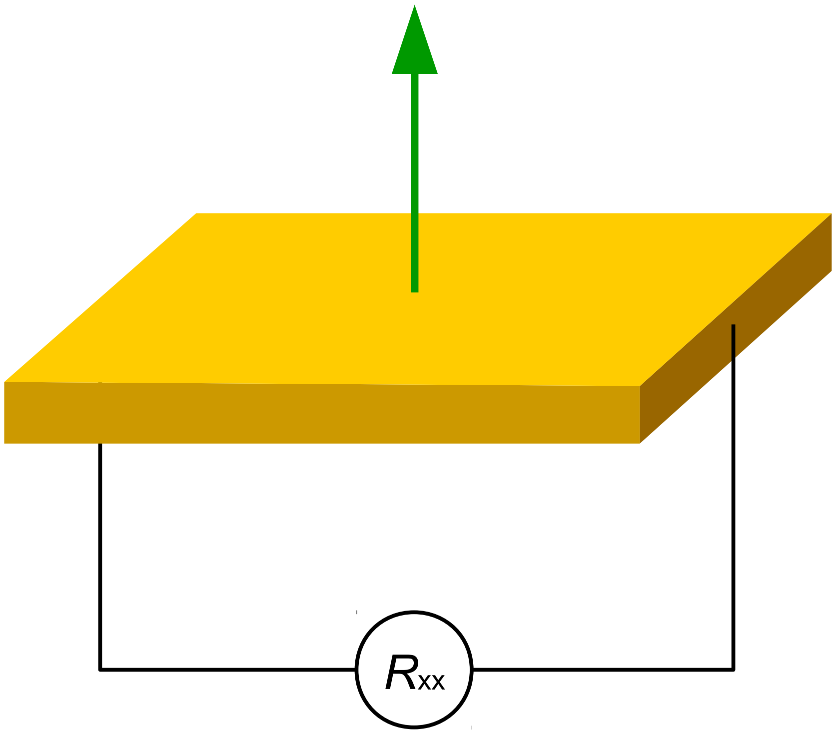
Apply a magnetic field



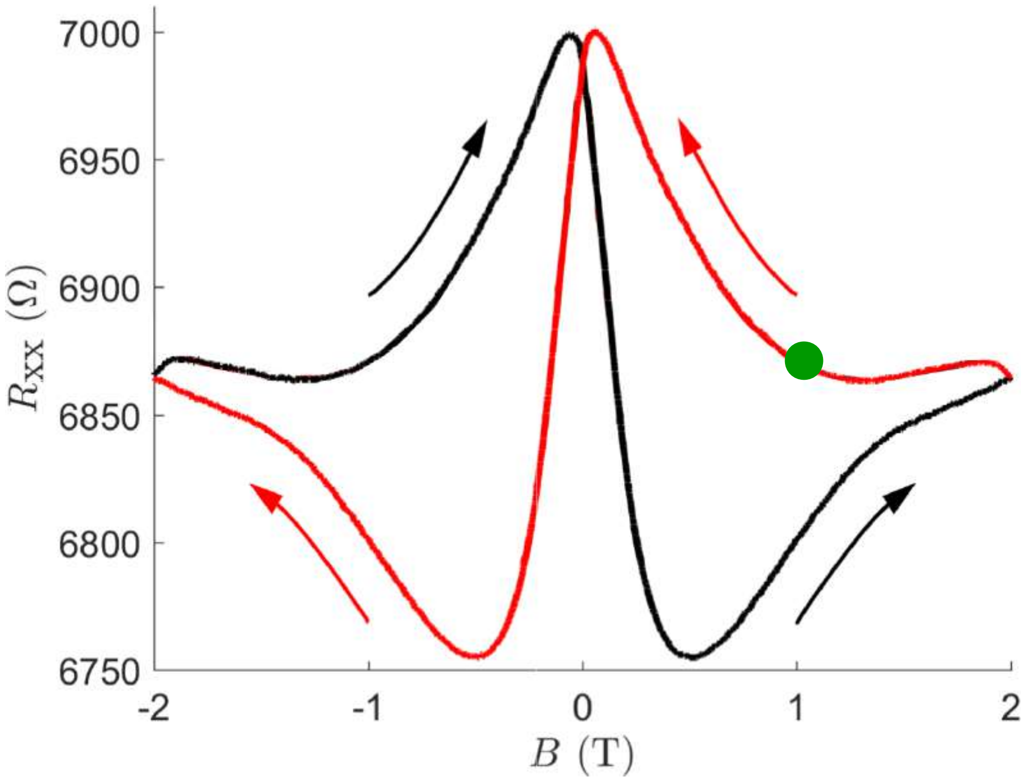


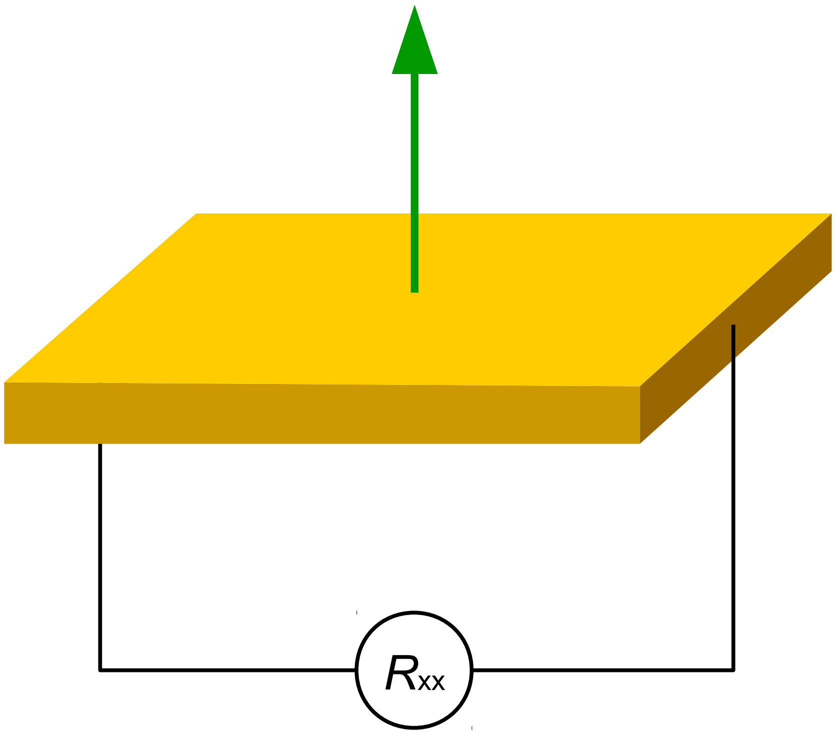
Increase magnetic field



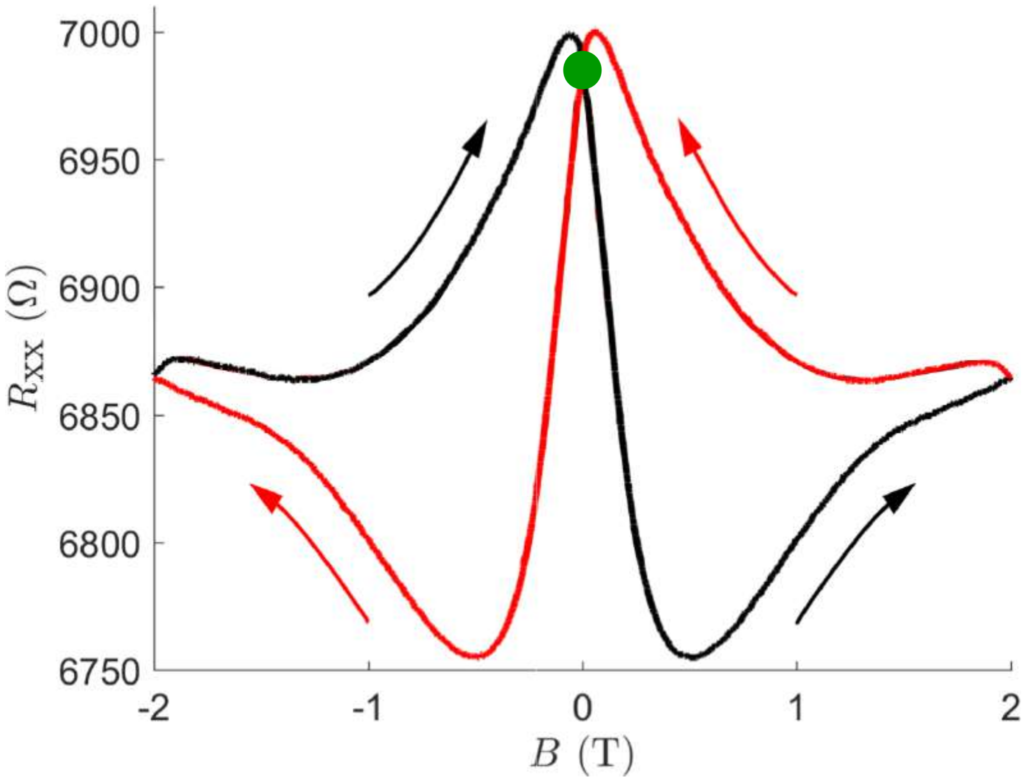


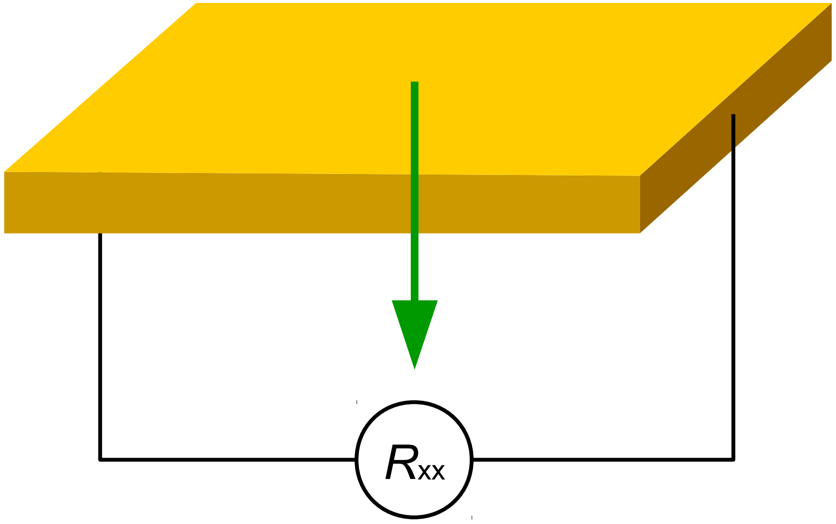
Decrease magnetic field



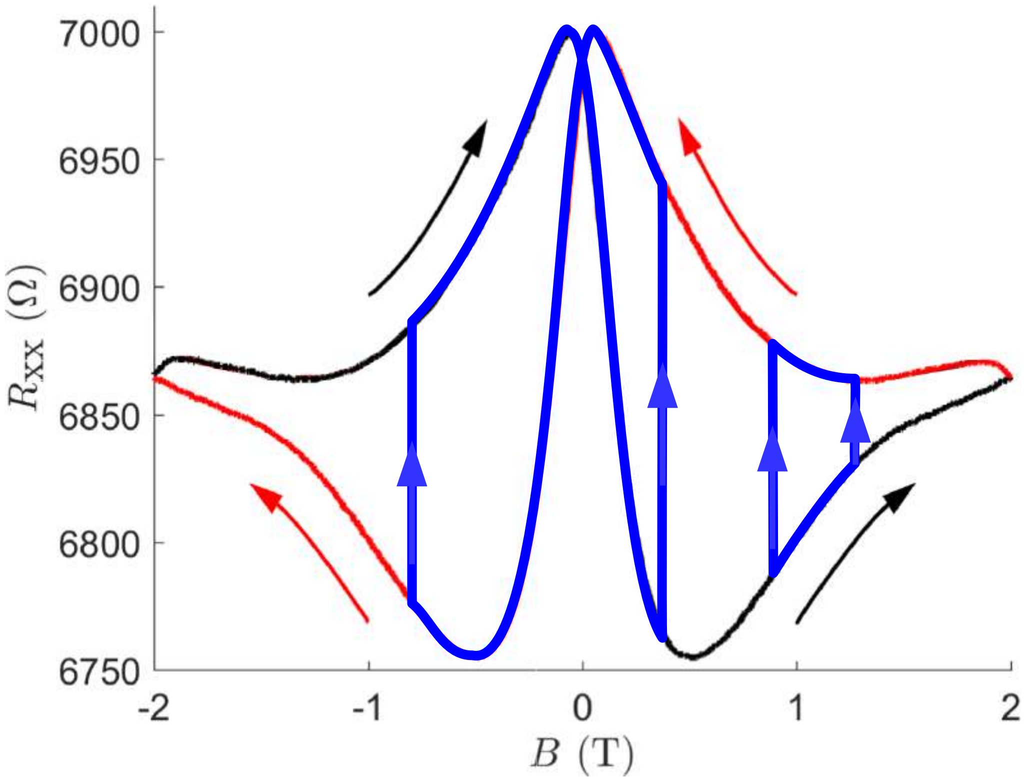


Negative magnetic field

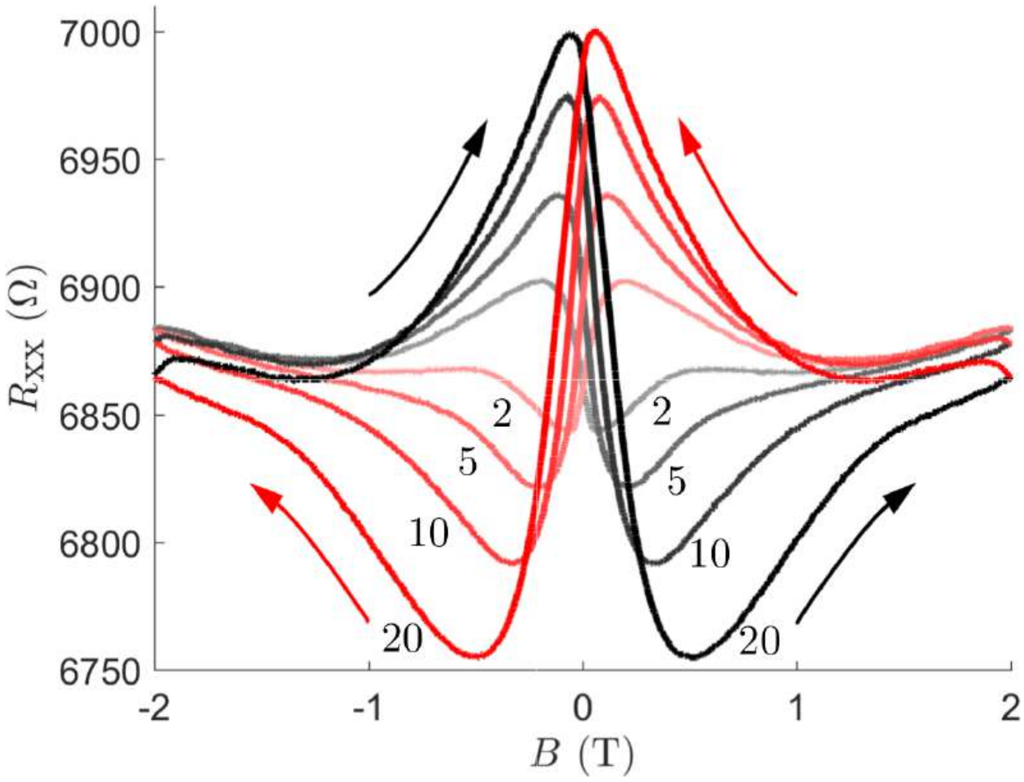




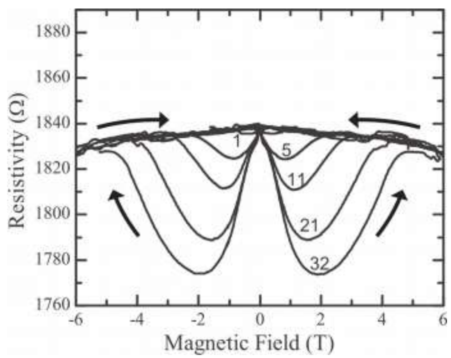
Possible loops



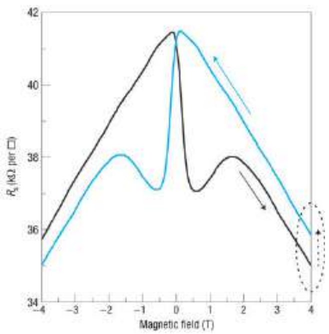
Changing the sweep rate d*B*/d*t*



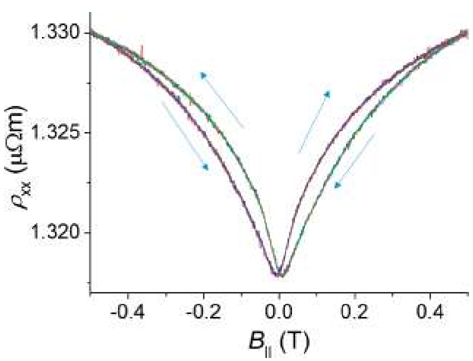
Observation in thin film systems



SmB_6 PRB 92, 115110 (2015)

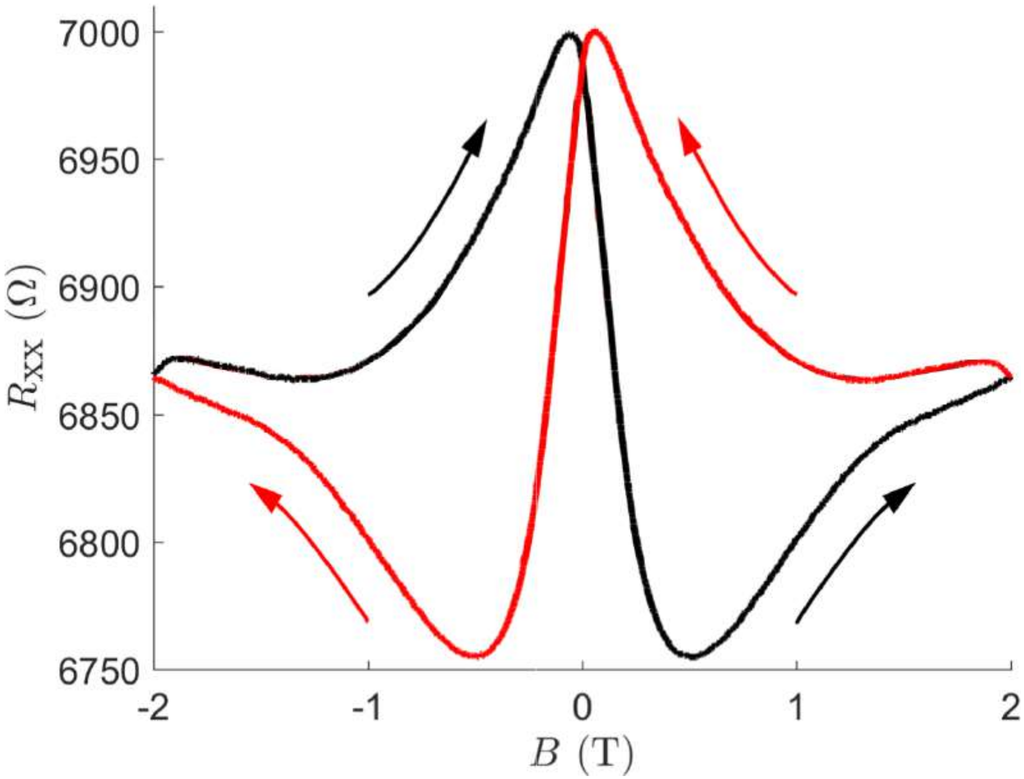


$SrTiO_3$–$LaAlO_3$ Nature Mat. 6, 493 (2007)



GeTe Phys. Status Solidi 10, 253 (2016)

Summary of observations



Magnetoresistance depends on $|B|$ and $B \times dB/dt$

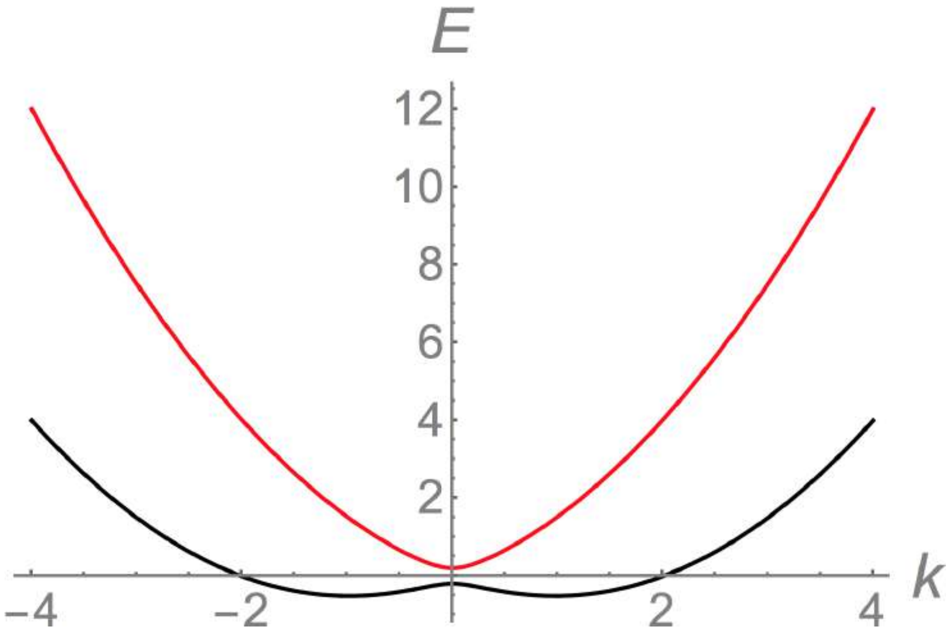
Seen in the bulk and some thin film **spin-orbit** coupled systems

Hamiltonian

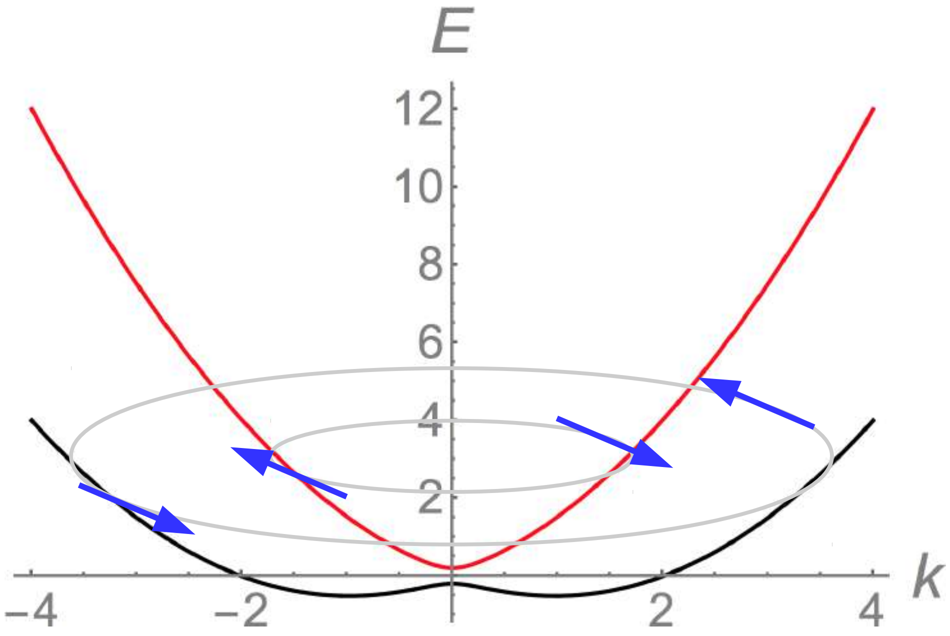
$$\hat{H} = \frac{k^2}{2m} - \gamma \left(k_y \sigma_x - k_x \sigma_y \right)$$

Energy dispersion

$$\hat{H} = \frac{k^2}{2m} - \gamma\left(k_y \sigma_x - k_x \sigma_y\right)$$

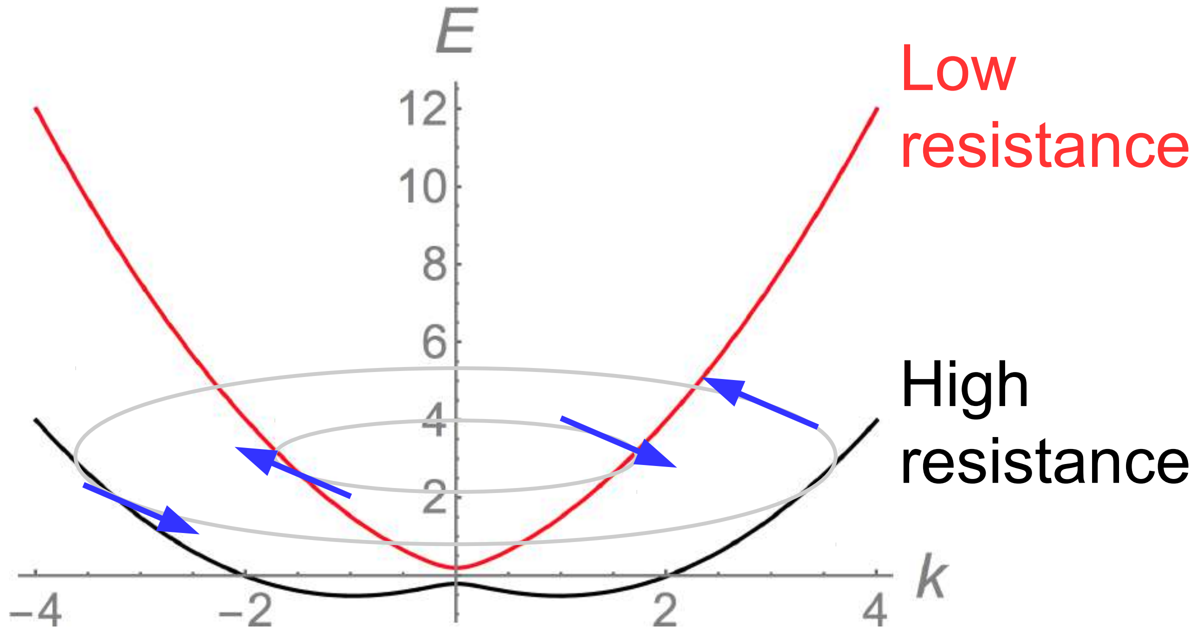


Energy dispersion



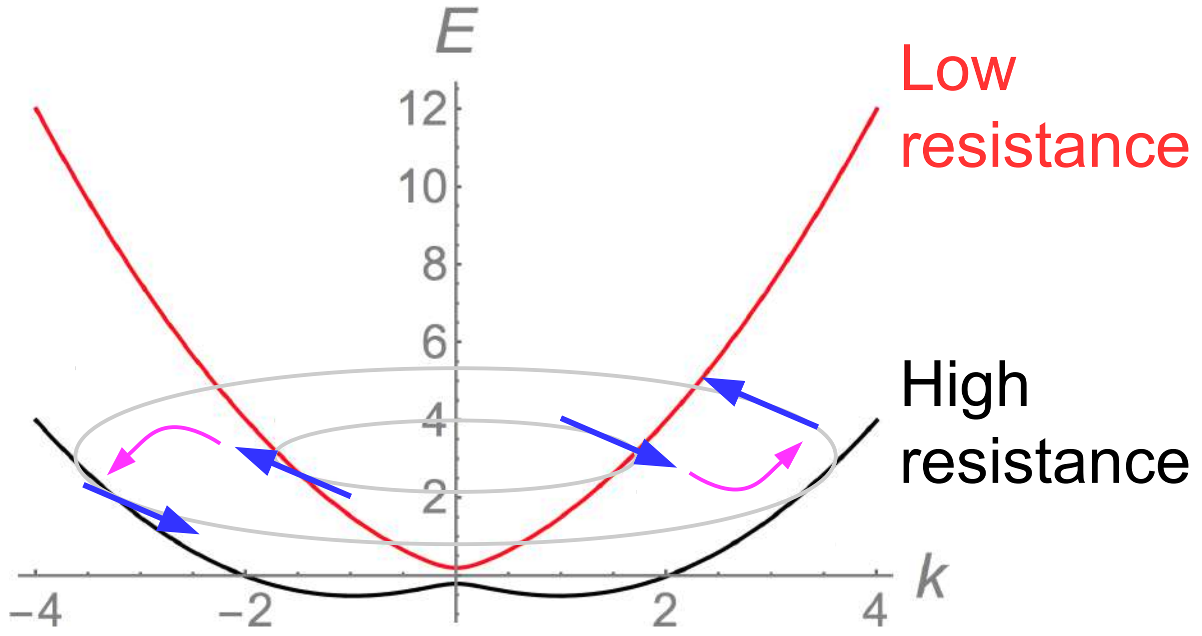
Conductivity of the dispersion

$$e^2\tau\int d^3k\,\frac{\partial E_+}{\partial k}\,\delta(k-k_F)+e^2\tau\int d^3k\,\frac{\partial E_-}{\partial k}\,\delta(k-k_F)$$

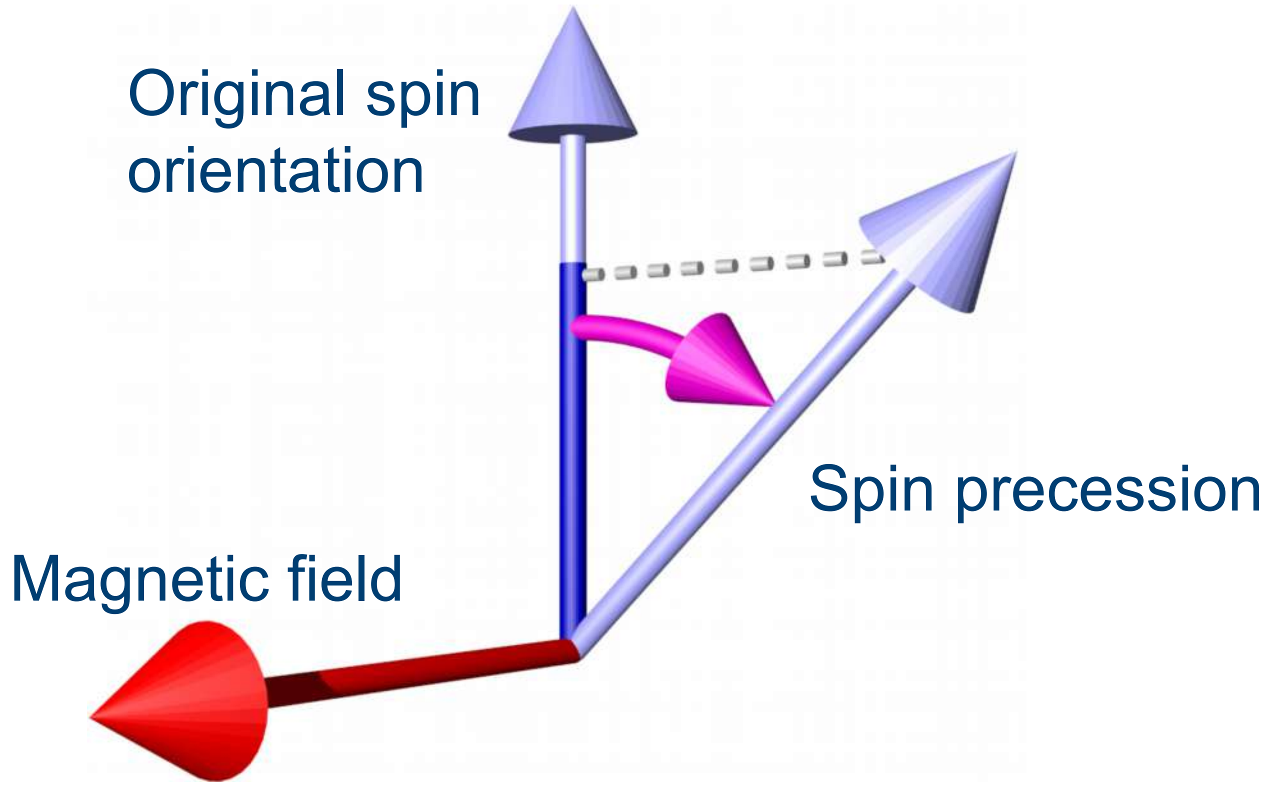


Spin flips would change the conductivity

$$e^2 \tau \int d^3k \frac{\partial E_+}{\partial k} \delta(k - k_F) + e^2 \tau \int d^3k \frac{\partial E_-}{\partial k} \delta(k - k_F)$$

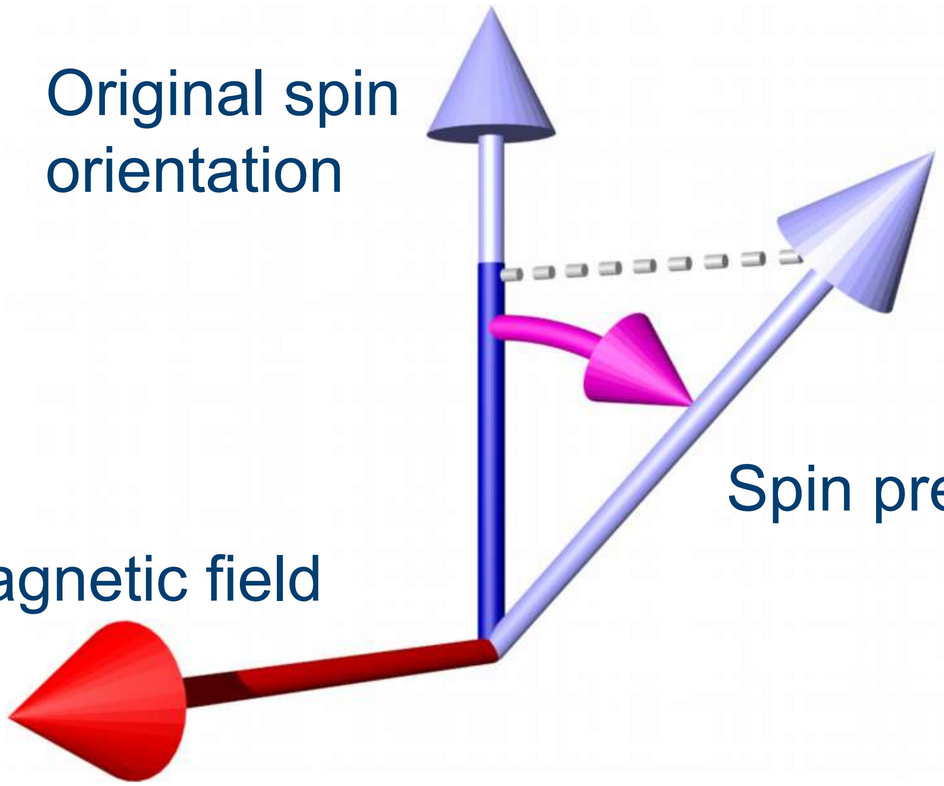


Spin precession



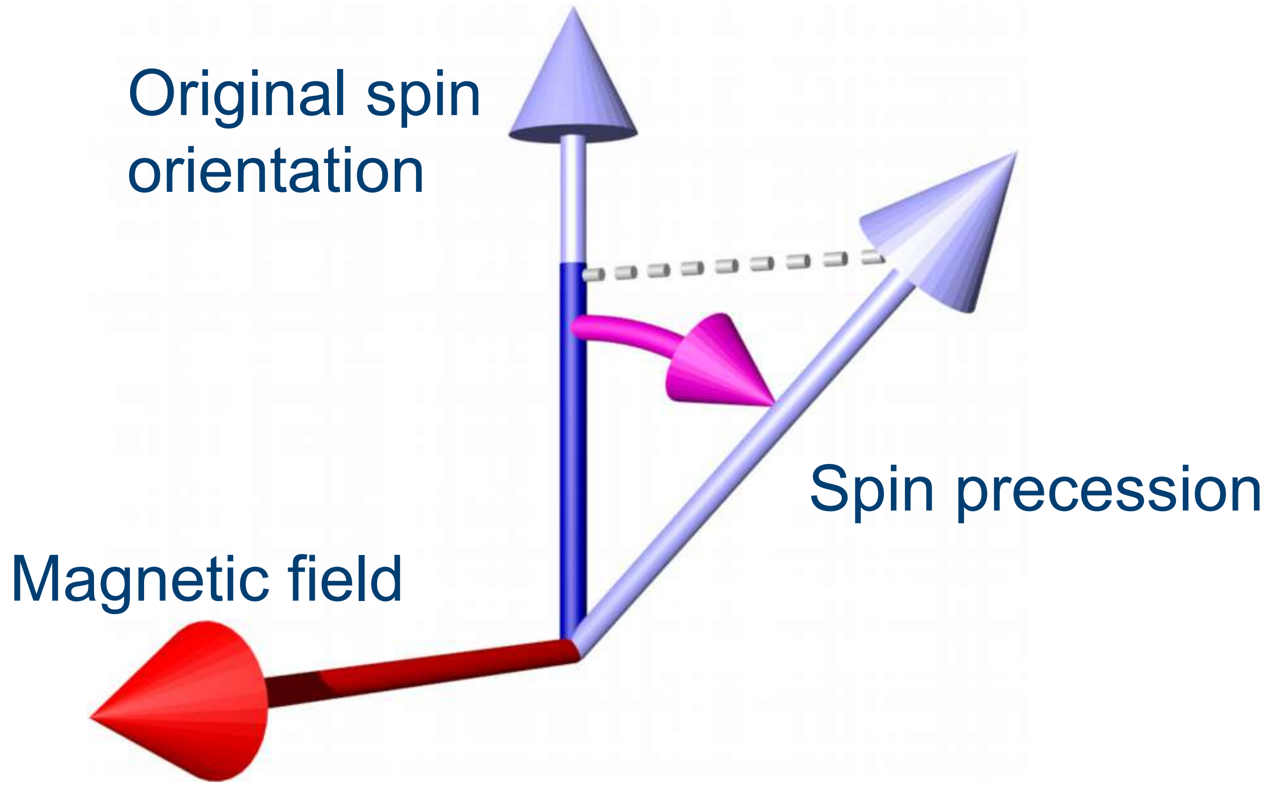
$$\hbar \frac{d\,\boldsymbol{n}}{dt} = \boldsymbol{n} \wedge \left(\boldsymbol{B} + \boldsymbol{\Delta} \right)$$

Spin precession



$$\frac{dn}{dt} = -\frac{B_{\perp}}{\Delta^2}\frac{dB_{\perp}}{dt}$$

Spin precession

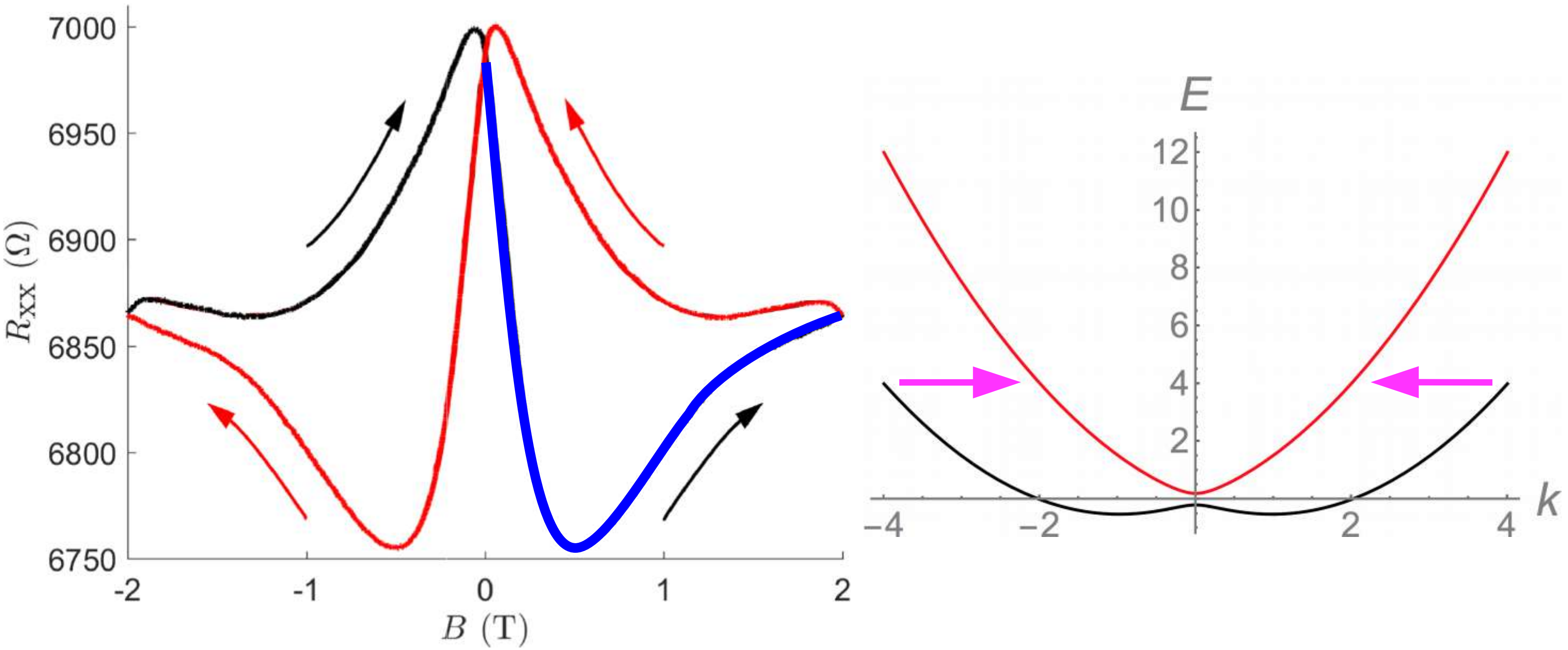


$$\frac{dn}{dt} = -\frac{B_\perp}{\Delta^2}\frac{dB_\perp}{dt}$$

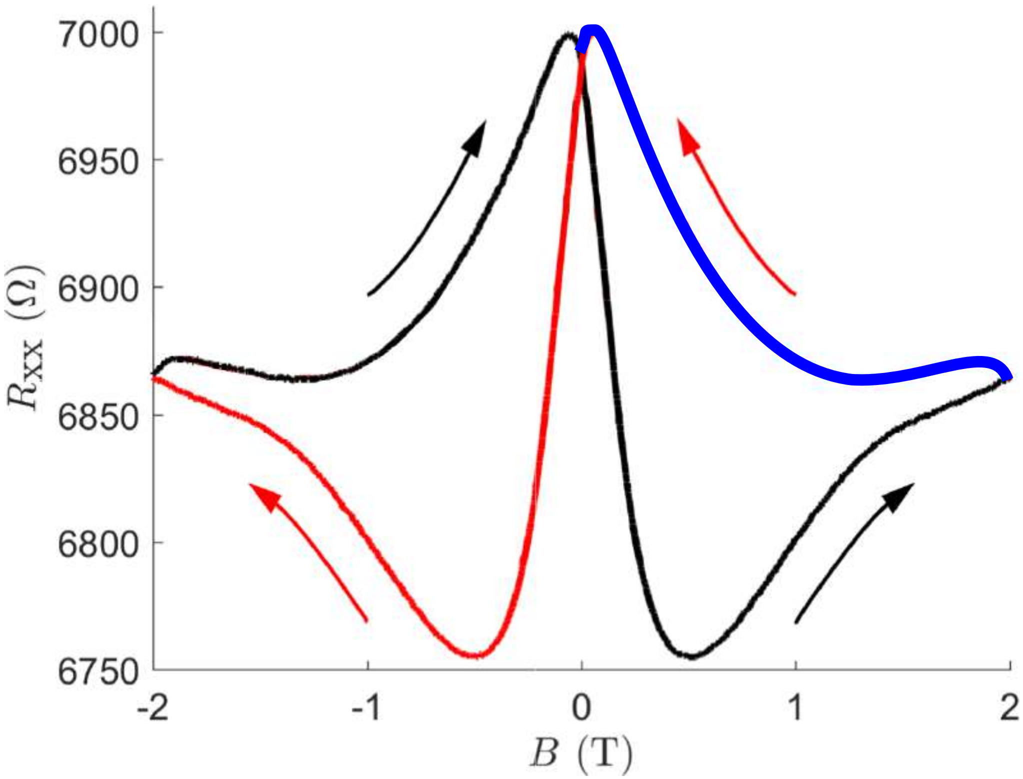
link to result found for Rashba field in PRL 92, 126603 (2004)

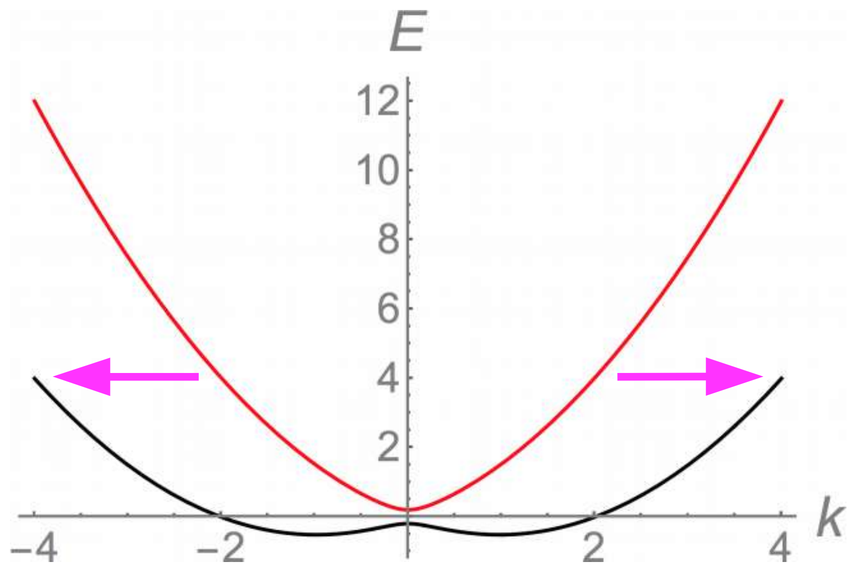
$$\frac{dn}{dt} = \frac{1}{\Delta^2}\frac{d\Delta_\perp}{dt}$$

Positive *B*×d*B*/d*t* raises resistance

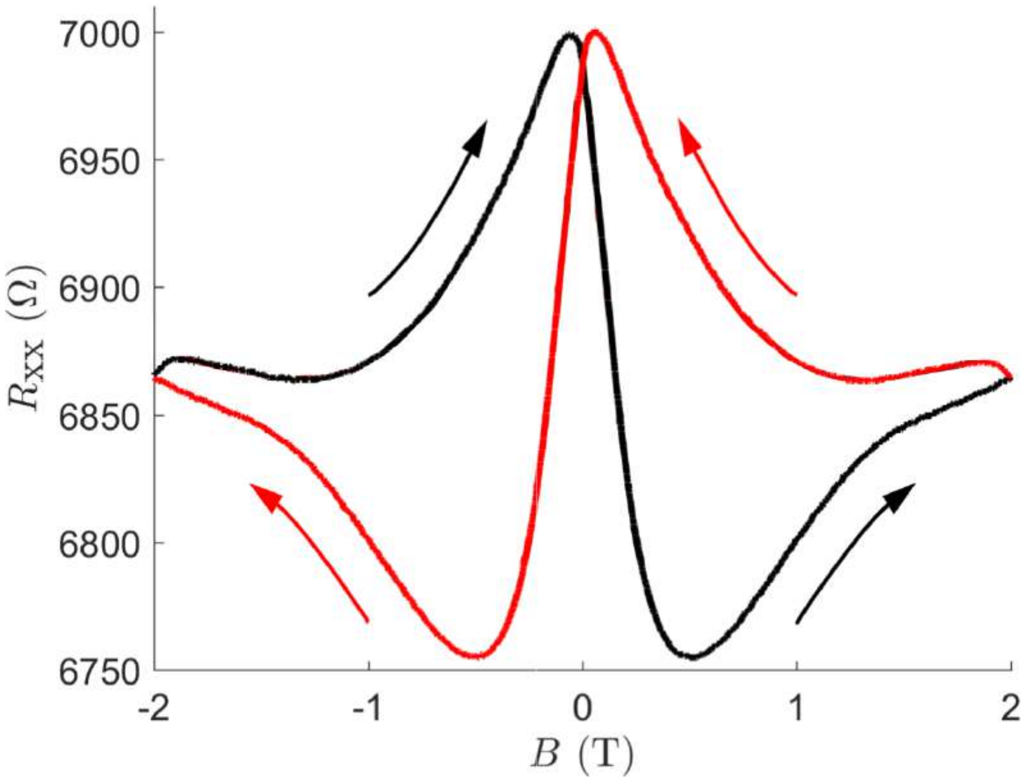


Negative B×dB/dt increases resistance





Magnetohysteresis / magnetocaloric effect?



Switches between branches independent of *B*

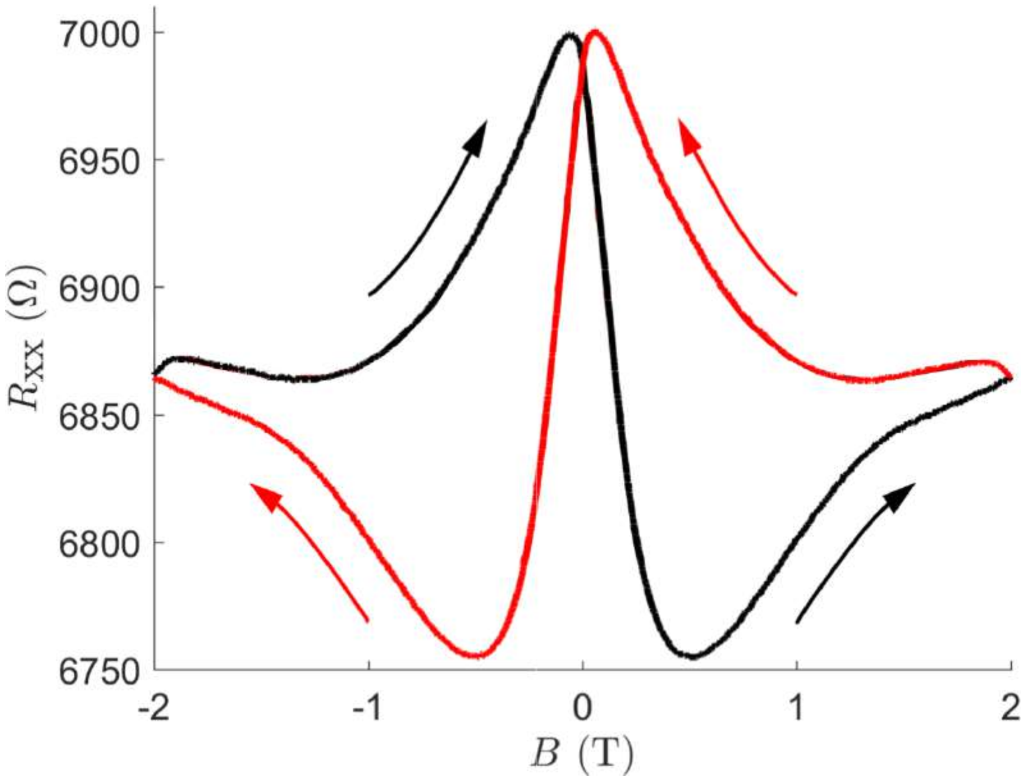
Effect resumes after heating to 5K & cooling back to 0.3K

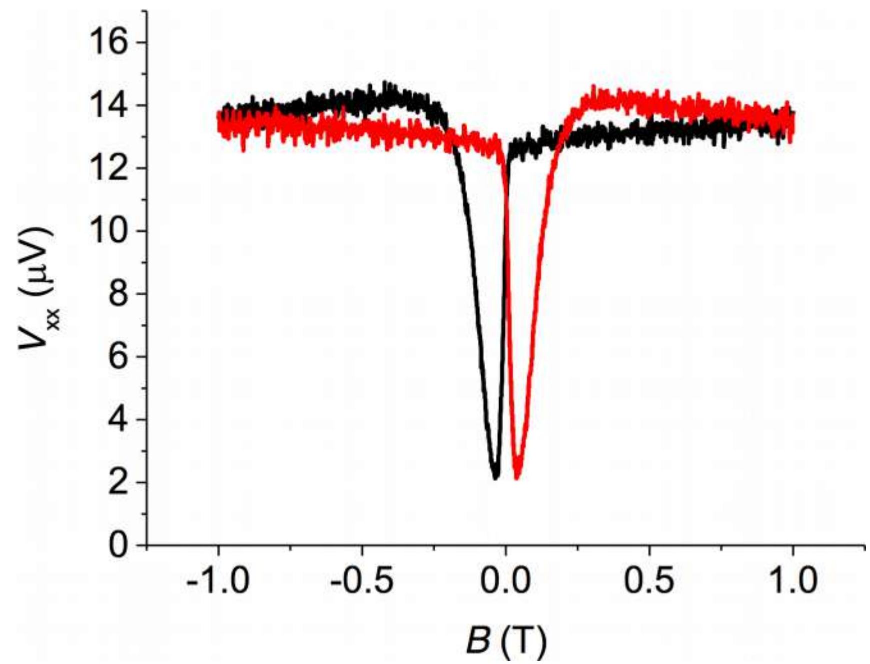
Reversal around at *B*=0

Spin orbit physics: superconductivity in GeTe

Resistance low with large $\frac{dE}{dk}$

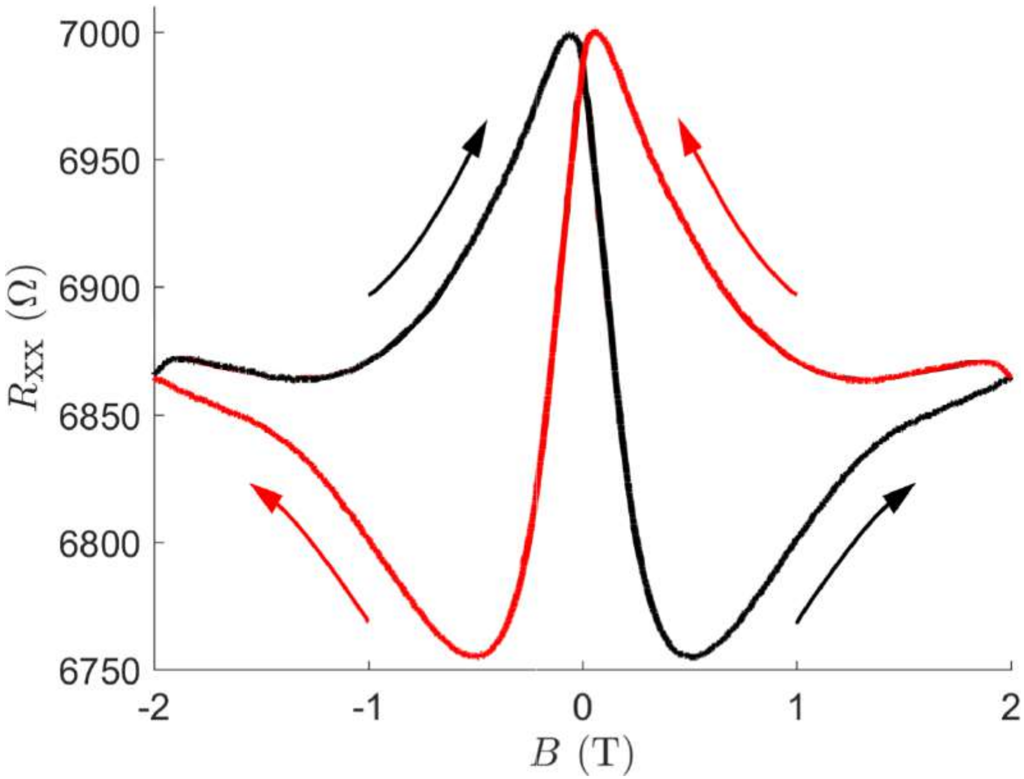
Resistance low with large $\frac{dk}{dE}$





Vijay: Finite field transitory superconducting state in a Rashba superconductor

Summary



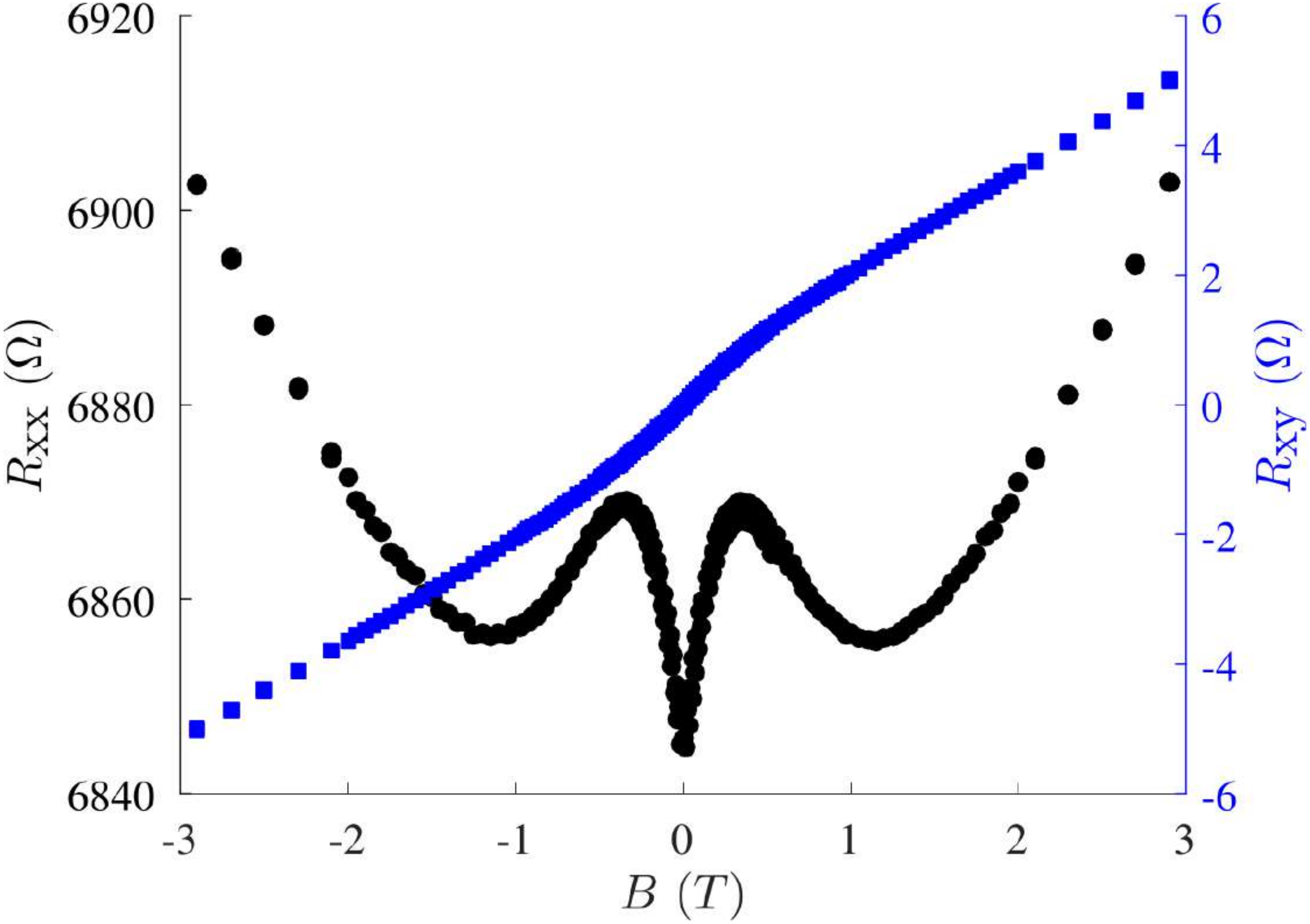
Au-Ge displays a
non-equilibrium
magnetoresistance

Depends on $B \times dB/dt$

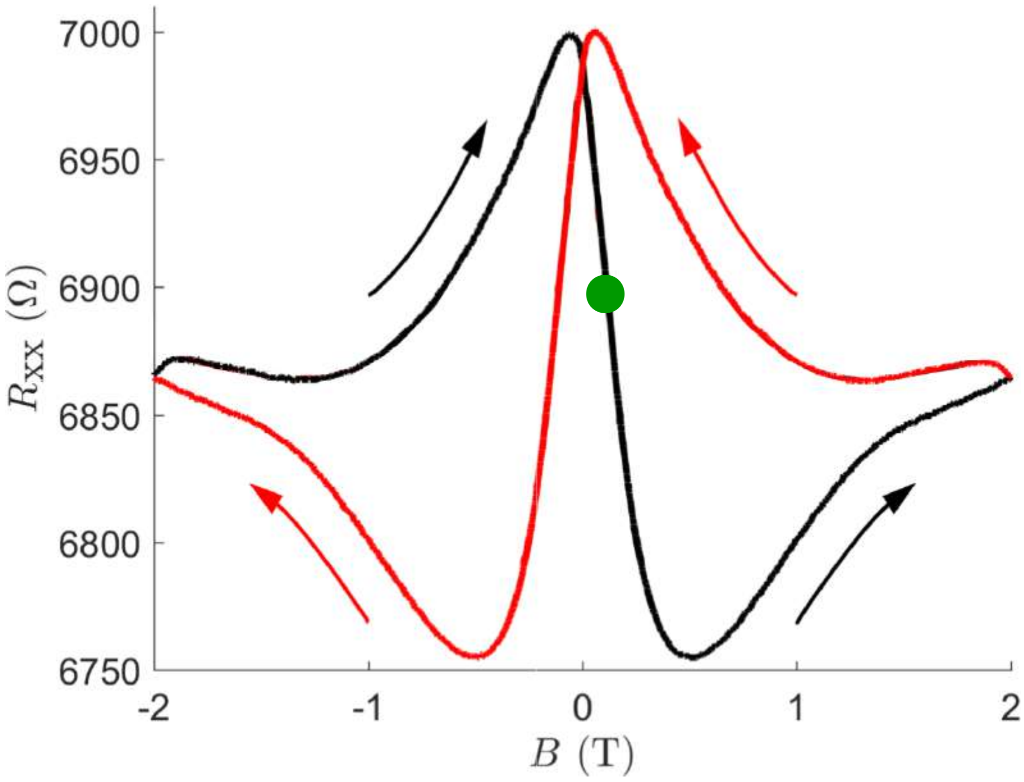
Could be driven by
spin dynamics
in a Rashba field

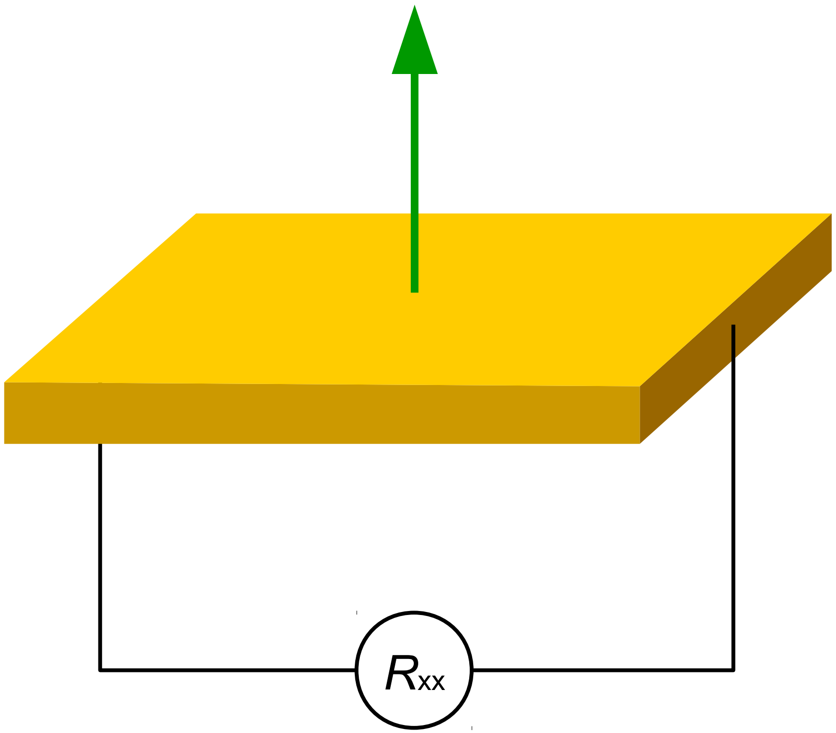
Posters by James Dann and Philipp Verpoort, talk by Vijay Narayan

Quasistatic behavior

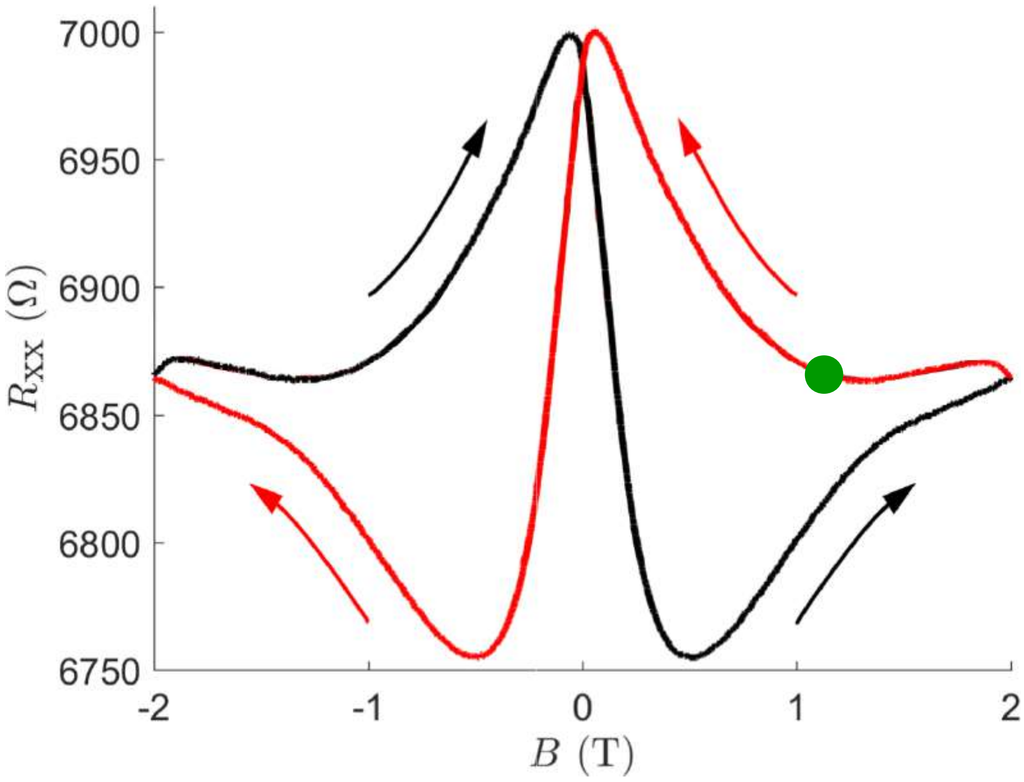


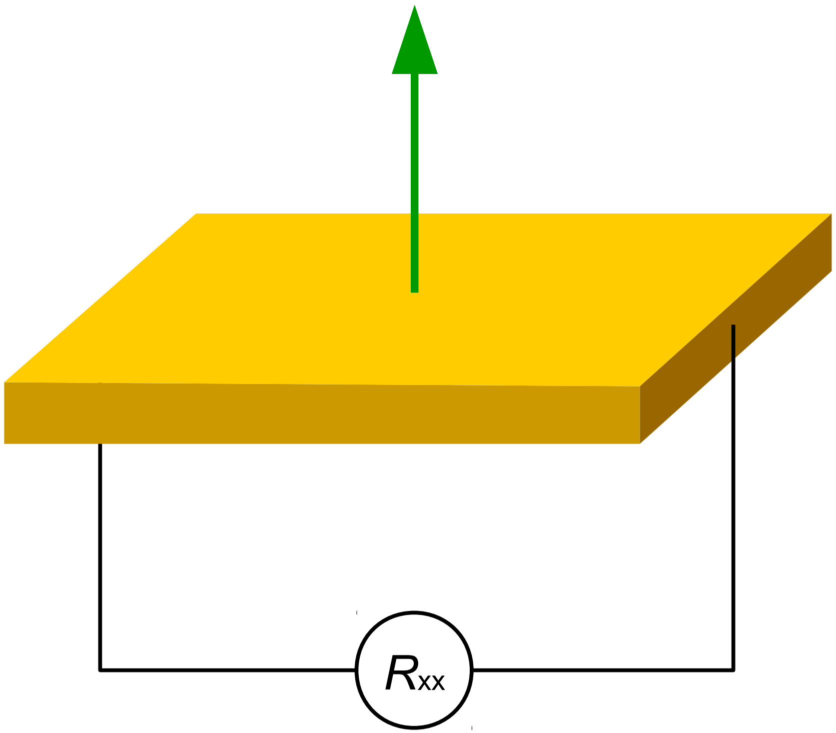
Small increasing magnetic field



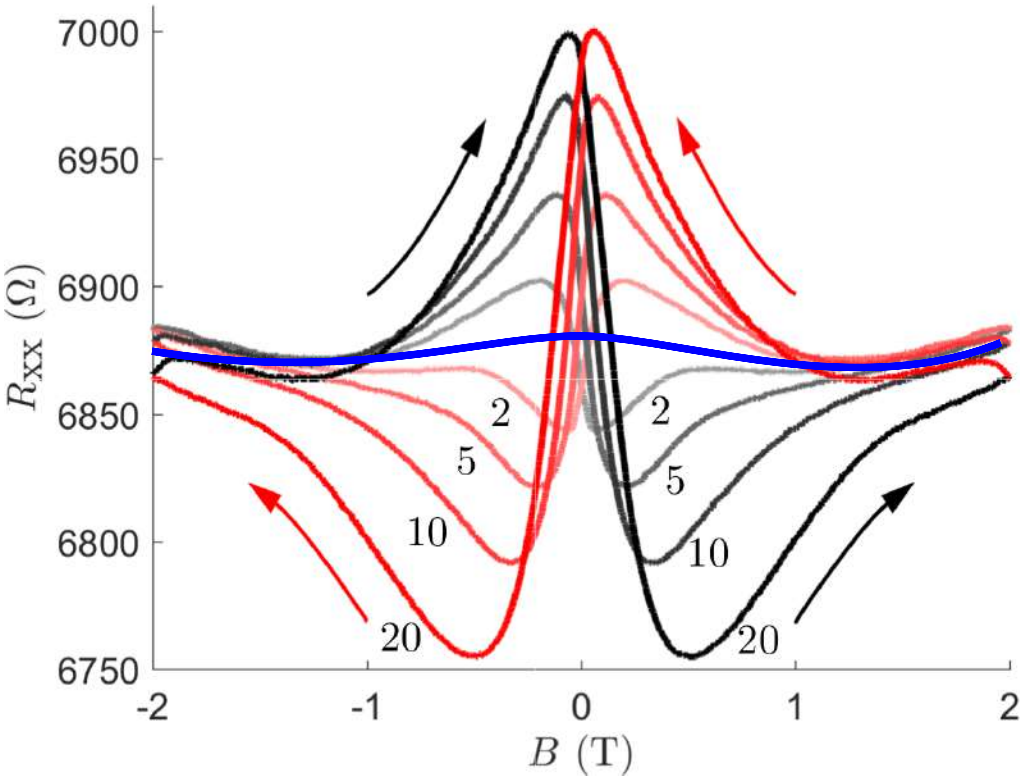


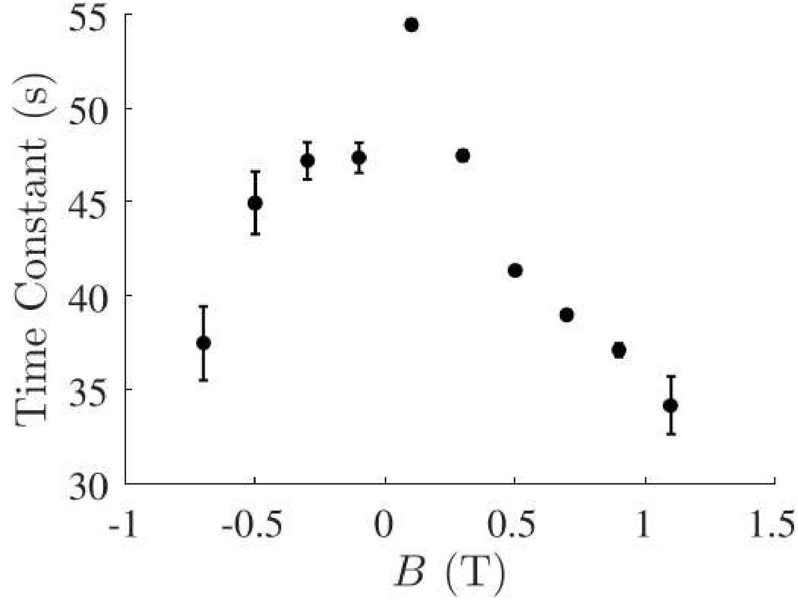
Small decreasing magnetic field



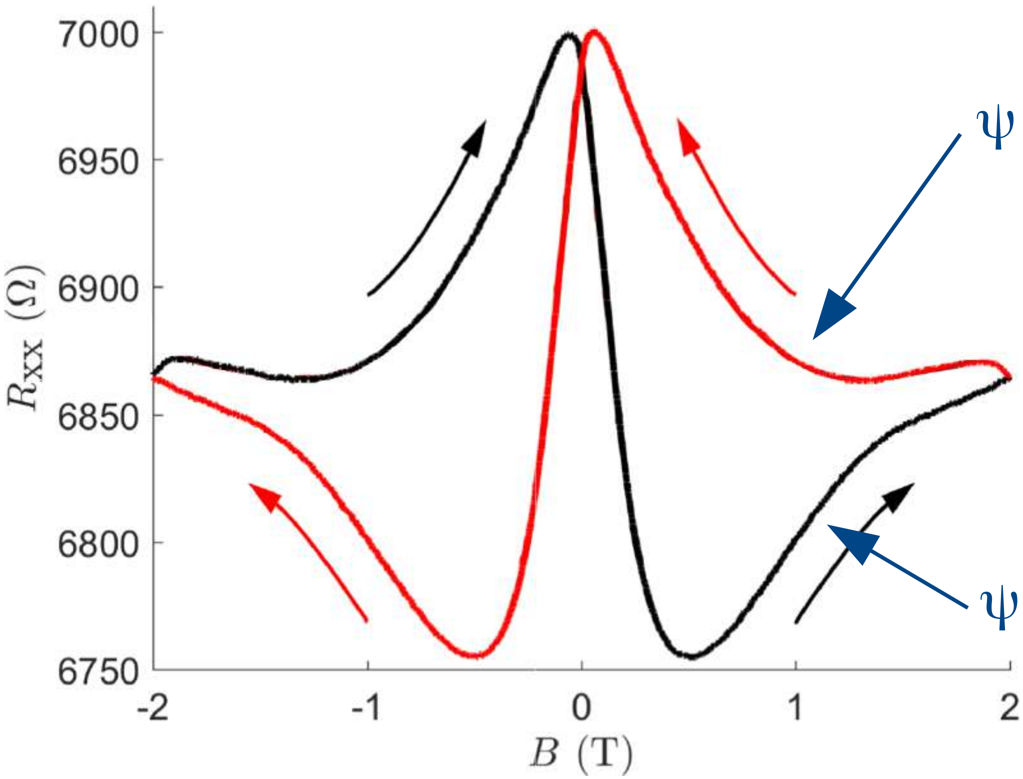


Relaxation time





Spin orbit physics: flipping the sign of *B*



$$\psi=\left(\sqrt{B^2+\gamma^2\left(k_x^2+k_y^2\right)}+B,\ \gamma\left(k_x-\mathrm{i}k_y\right)\right)$$

$$\psi=\left(\sqrt{B^2+\gamma^2\left(k_x^2+k_y^2\right)}-B,\ \gamma\left(k_x-\mathrm{i}k_y\right)\right)$$