Talk by: Karolina Weber
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Strong Interfacial Exchange Field in a Heavy Metal/Ferromagnetic Insulator System Determined by Spin Hall Magnetoresistance

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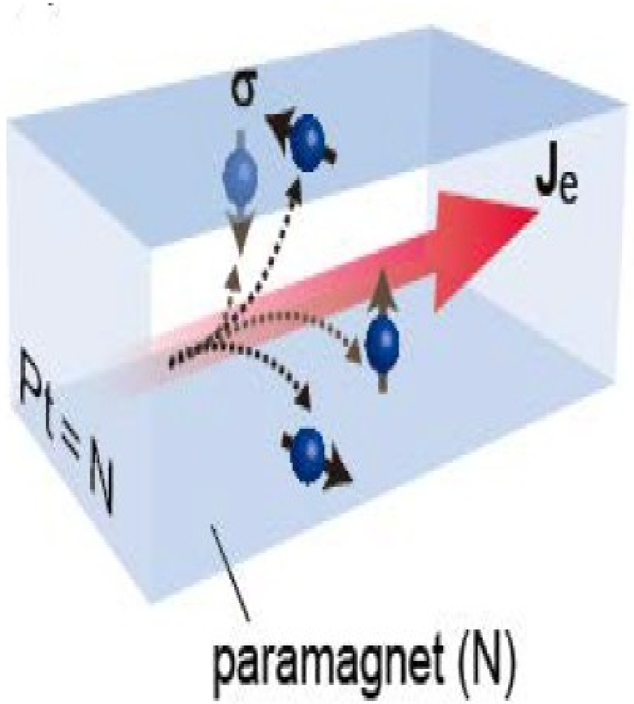
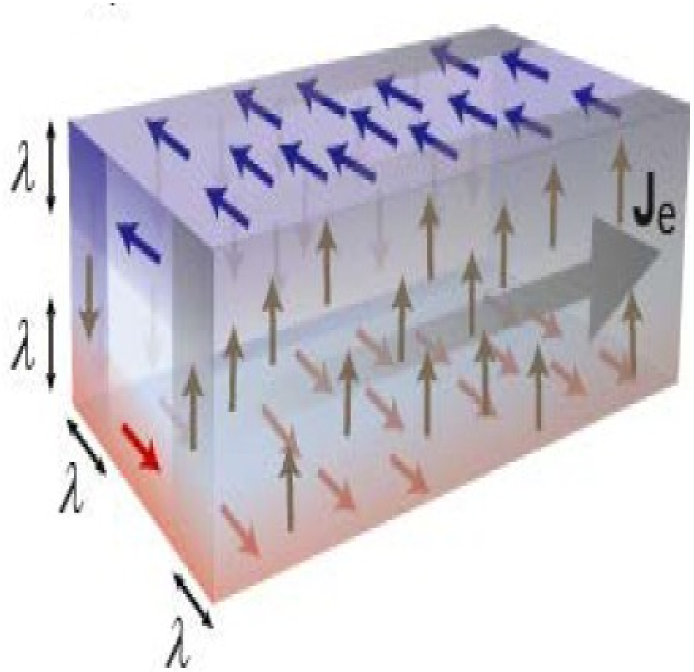
Nano Lett. 20, 6815−6823 (2020)

Outline

- Spin Hall Effect
- Spin Hall Magnetoresistance
- Experiment and Results
- Summary

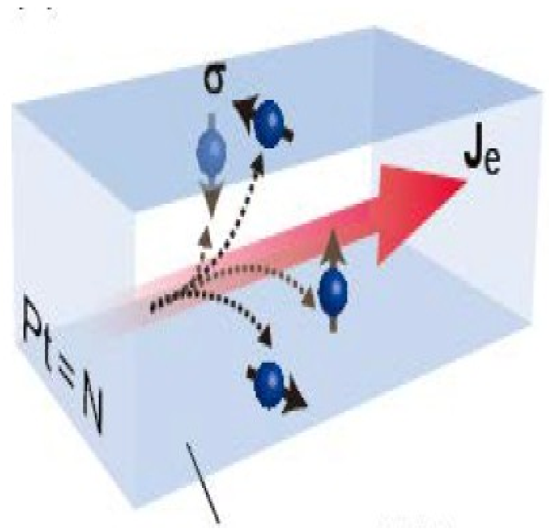
Spin Hall Effect





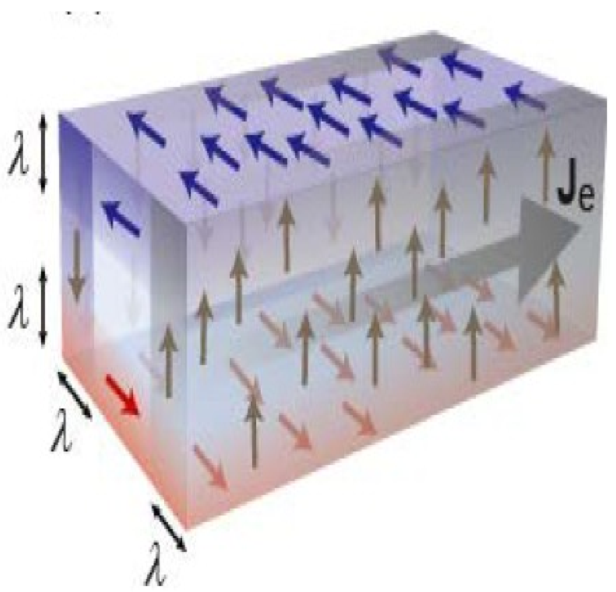
H. Nakayama et al., Phys. Rev. Lett. 110, 206601 (2013)

Spin Hall Effect



- Transport phenomenon
- Analogous to classical Hall effect
- Spin separation instead of charge separation
- Spin accumulation
- No magnetic field needed
- **Only** spin current

  NO CHARGE CURRENT
- Spin Hall Magnetoresistance



Spin Hall Magnetoresistance (SMR)

- SMR = Electrical **resistance** of metal influenced by the direction of an extern magnetic field; due to SHE; in **heterostructure** with magnetic insulator
- Metals in direct contact with insulating magnetically ordered material
- Spin-polarized electrons interact with magnetization of magnetic material

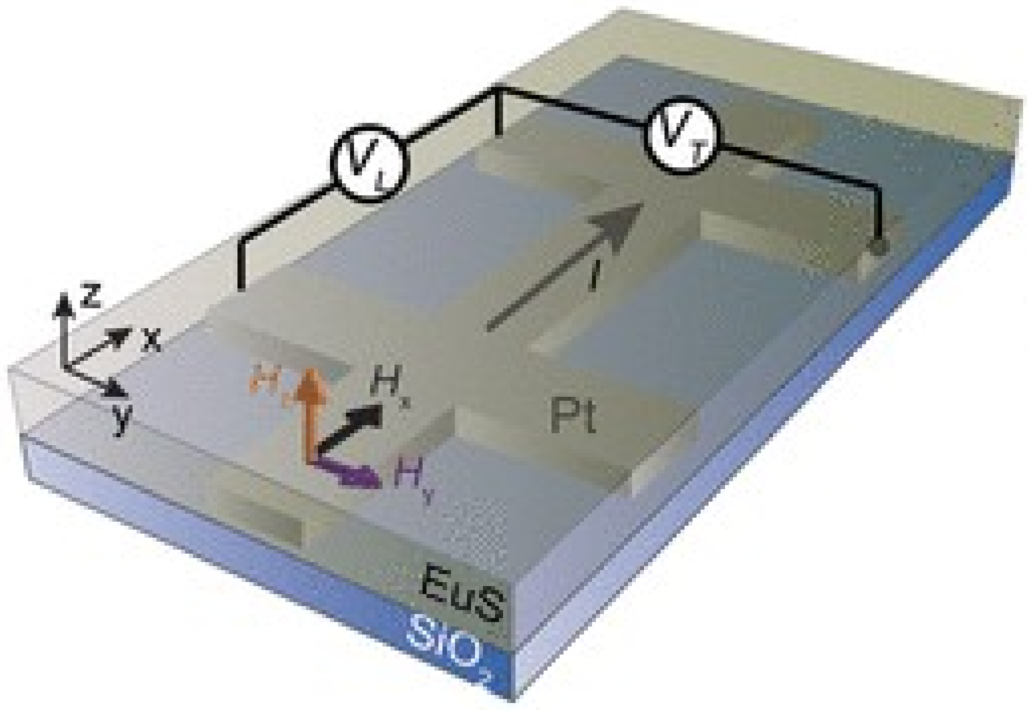
Spin Hall Magnetoresistance (SMR)

- Magnetic field strong enough + perpendicular to spins at surfaces
- Magnetic moments precess

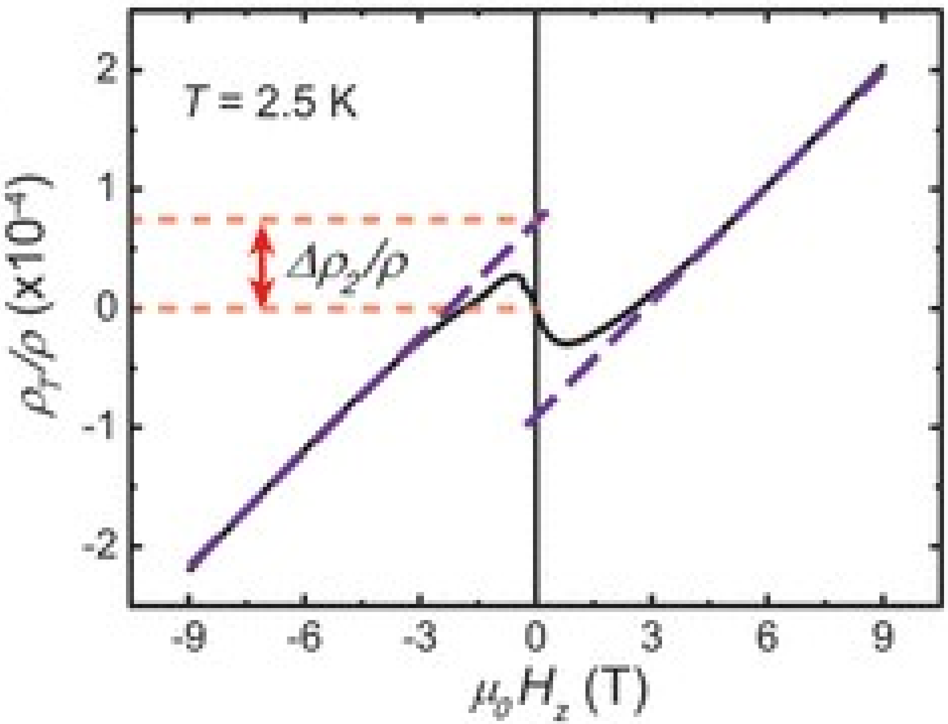
  → **Spin current across interface disappears periodically**
- Magnetic field + combined action of direct and **inverse SHE**

  → change of sample resistance

Experiment



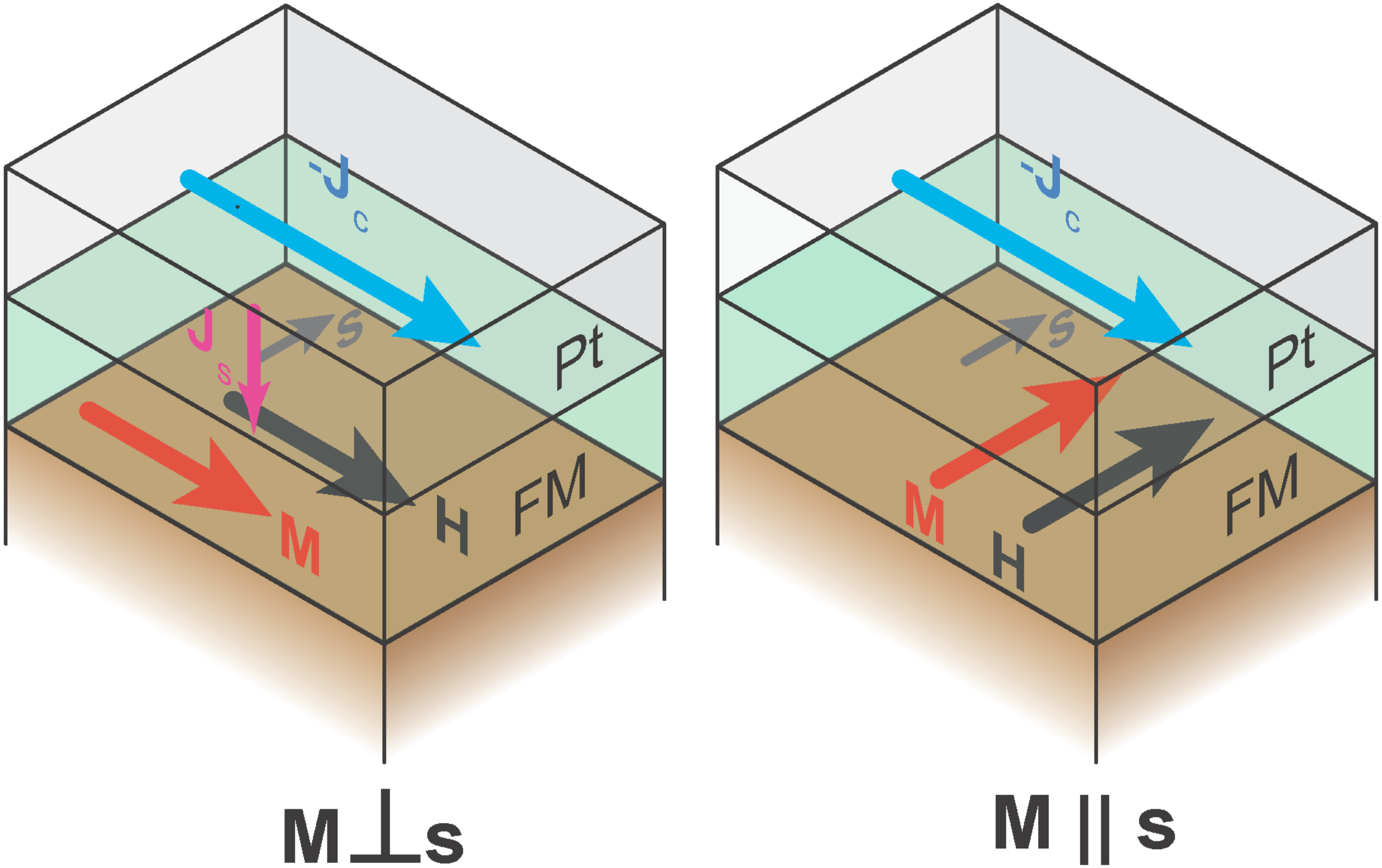
experiment



results

Pt: Heavy Metal
EuS: Ferromagnetic Insulator

Experimental structure



Spin current depends on the relative direction of Magnetization and Spins

Experiment

- SMR measurements in wide range of temperature
- Results fitted with microscopic model
- Obtain temperature dependence of spin conductances out of amplitude of resistivity oscillation

Experiment

- SMR → quantification of interfacial spin conductances
- Temperature dependence of spin conductances

  → field-like torque (G_i)

  → damping-like torque (G_r)

  → spin sink / spin-flip scattering (G_s)
- G_i → interfacial exchange field

Experiment

- Spin current at HM/MI interface:

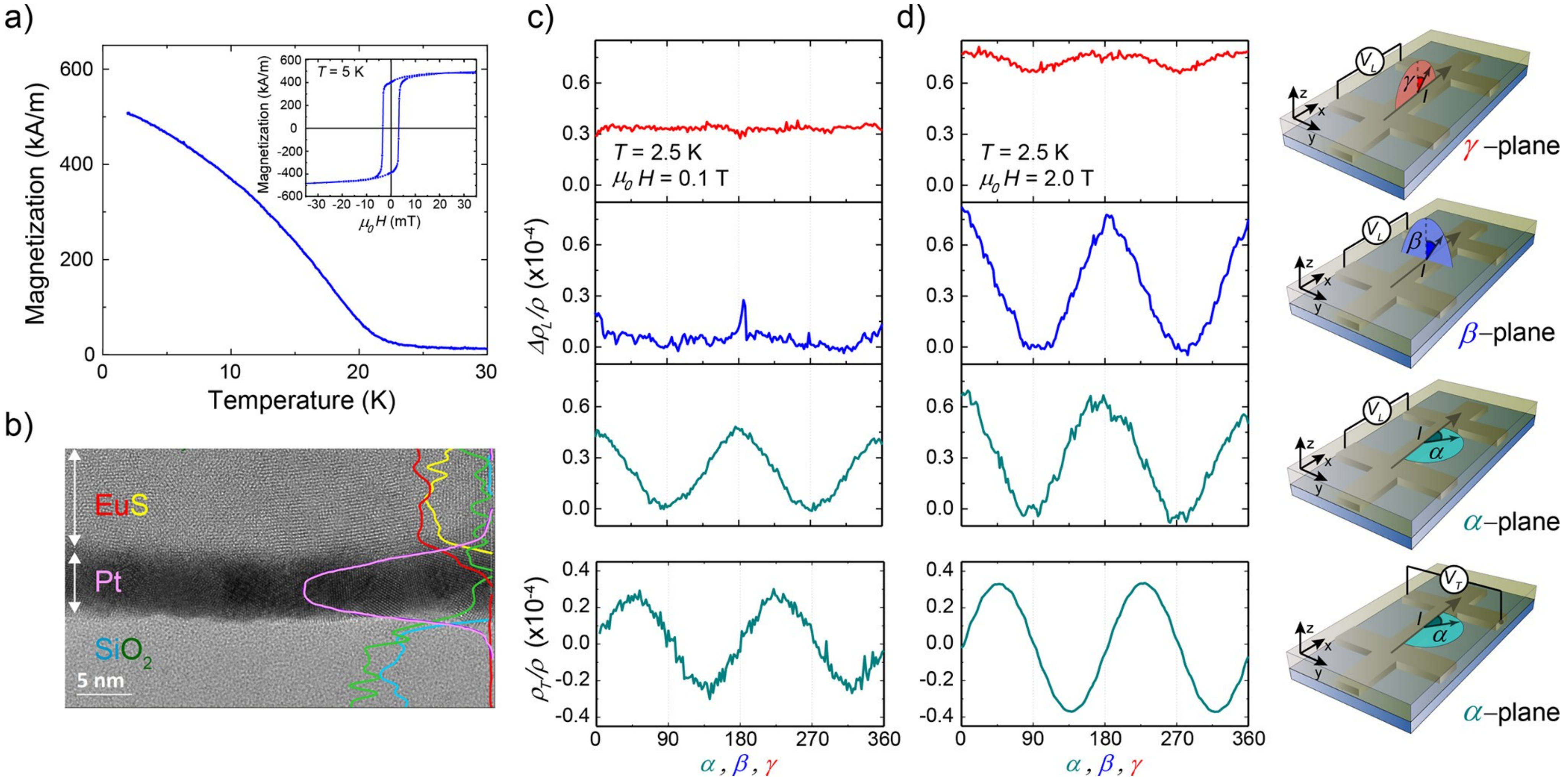
$$-eJ_{s,z} = G_s \boldsymbol{\mu}_s + G_r \boldsymbol{n} \times [\boldsymbol{n} \times \boldsymbol{\mu}_s] + G_i \boldsymbol{n} \times \boldsymbol{\mu}_s$$

→ field-like torque (G_i)

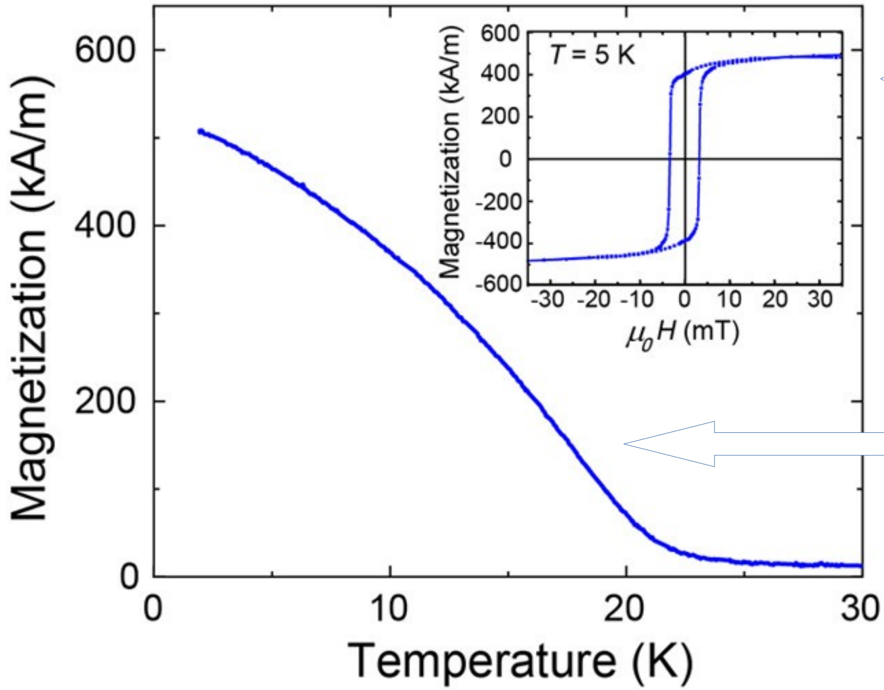
→ damping-like torque (G_r)

→ spin sink(G_s)

Experimental results

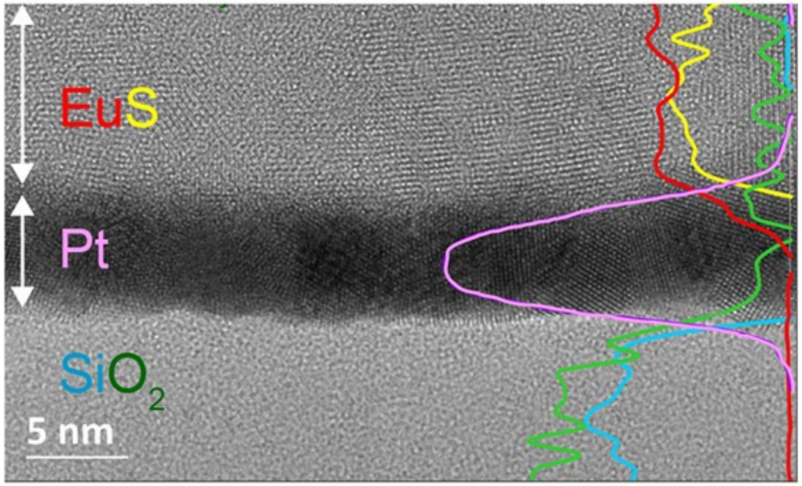


First measurements



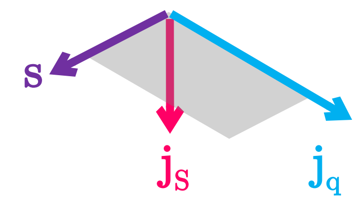
Hysteresis loop

FM behaviour below
Curie-Temperature
~19K

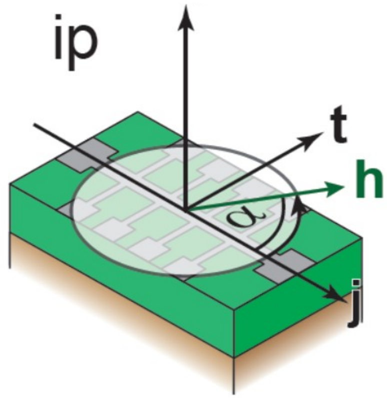


Heterostructure;
high quality of the EuS/Pt
interface

Angle Dependence



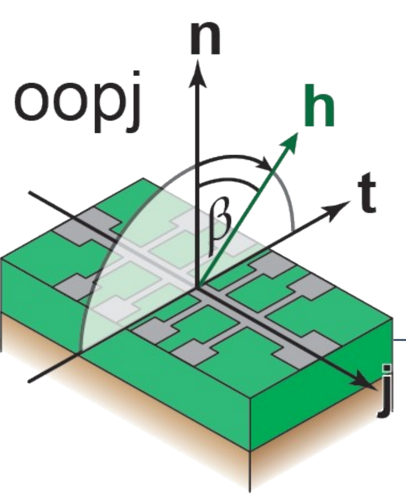
- in plane (ip), angle α

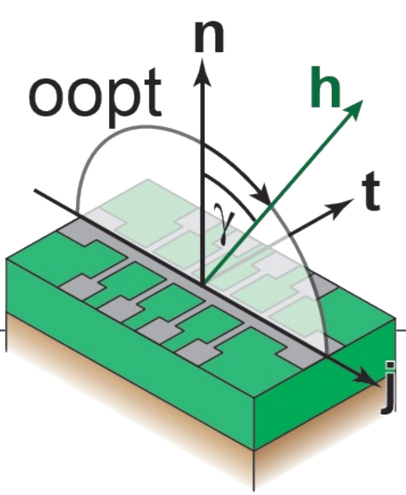


Three Orthogonal Rotation Planes of H

- out of plane perpendicular to **j** (oopj), angle β

- out of plane perpendicular to **t** (oopt), angle γ





M. Althammer et al., Phys. Rev. B 87, 224401 (2013

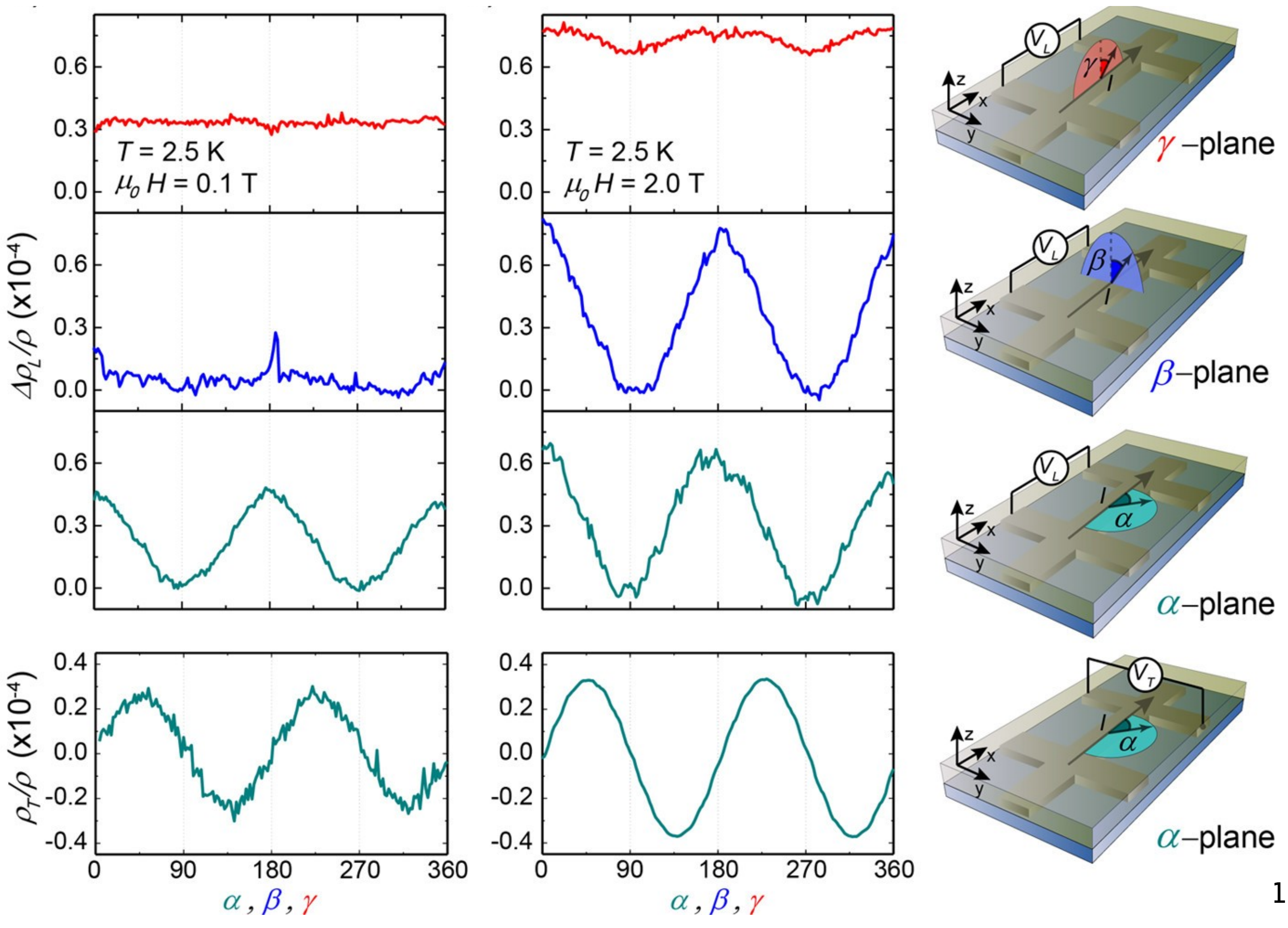
Resistivities

$$\rho_{\mathrm{L}} = \rho + \Delta\rho_0 + \Delta\rho_1(1 - m_y^2)$$

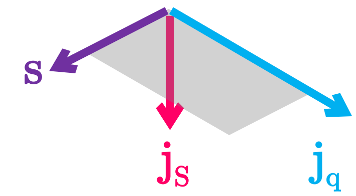
$$\rho_{\mathrm{T}} = \Delta\rho_1 m_x m_y + \Delta\rho_2 m_z$$

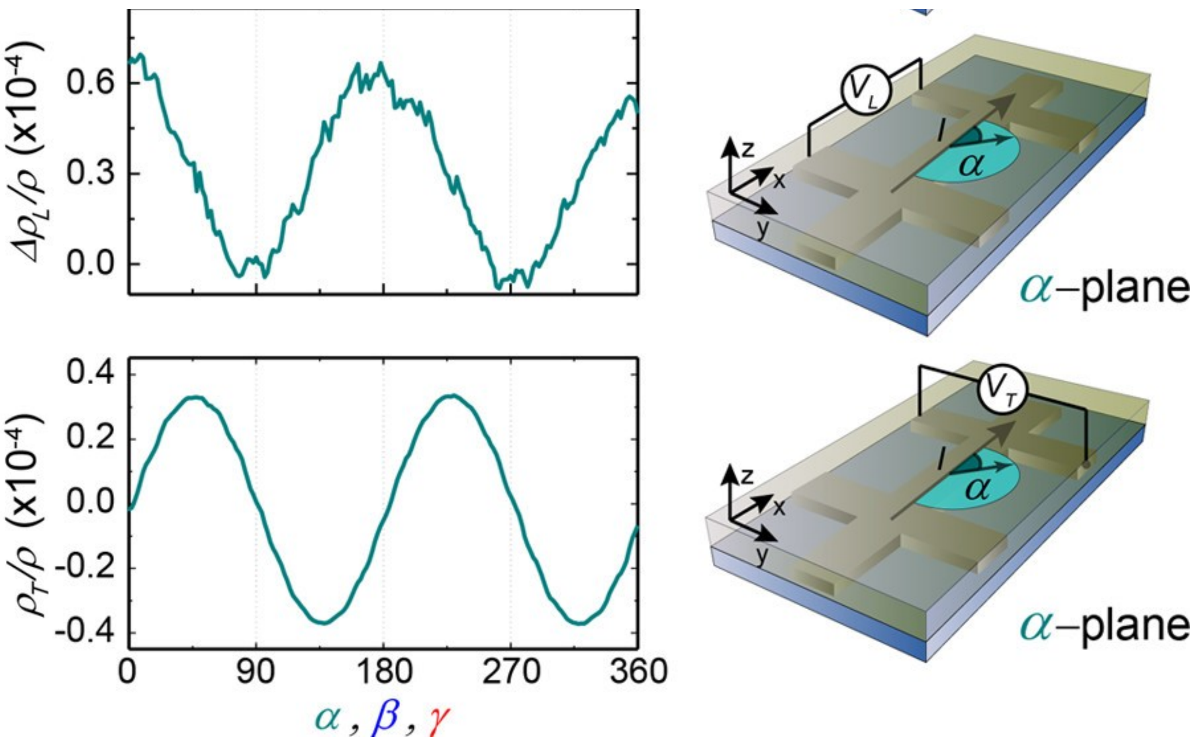
$\Delta\rho_1$ and $\Delta\rho_2$: SMR amplitudes

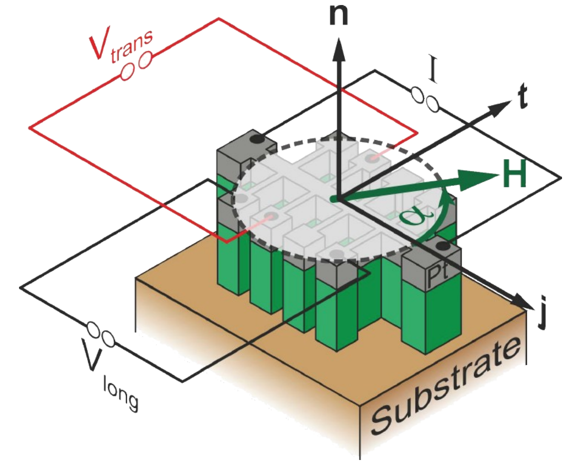
Angle Dependence

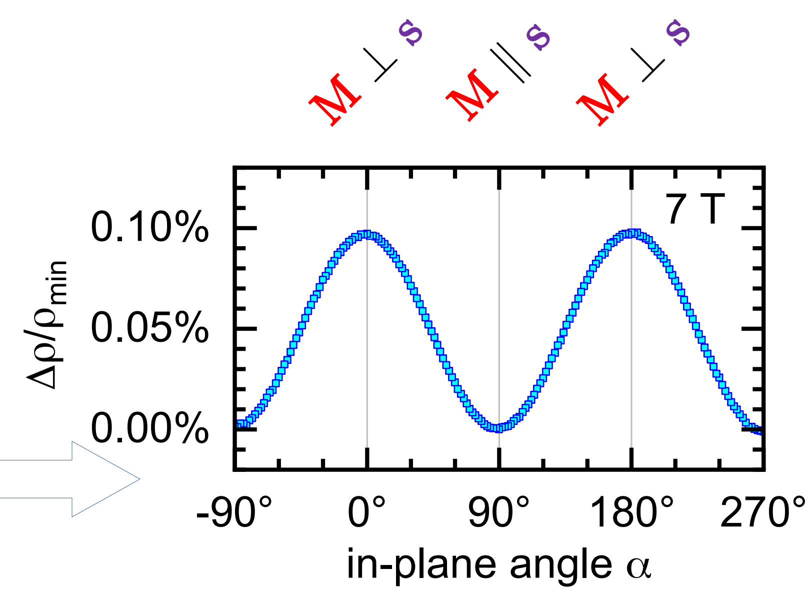


Angle Dependence



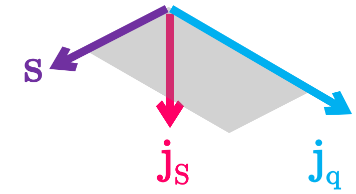


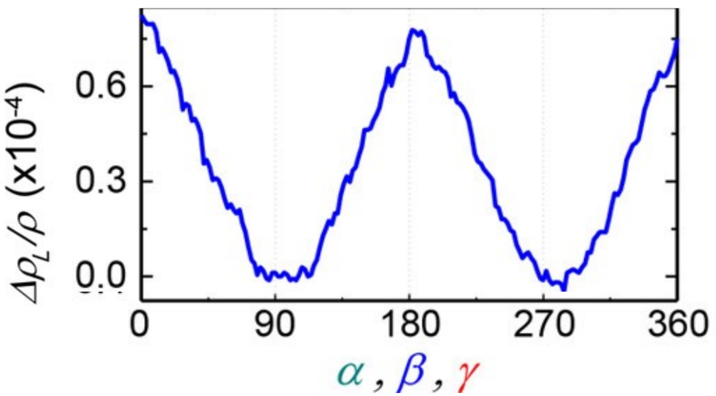


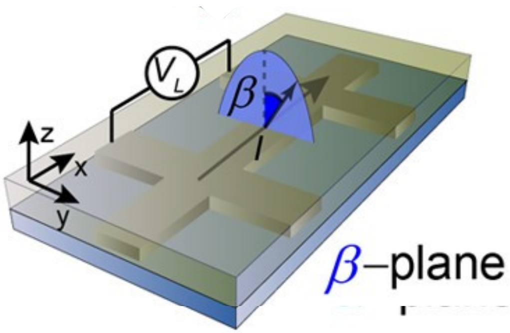


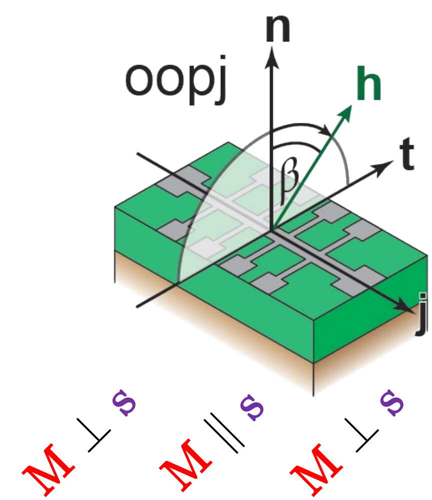
Max when M perpendicular to s;
Min when parallel

Angle Dependence

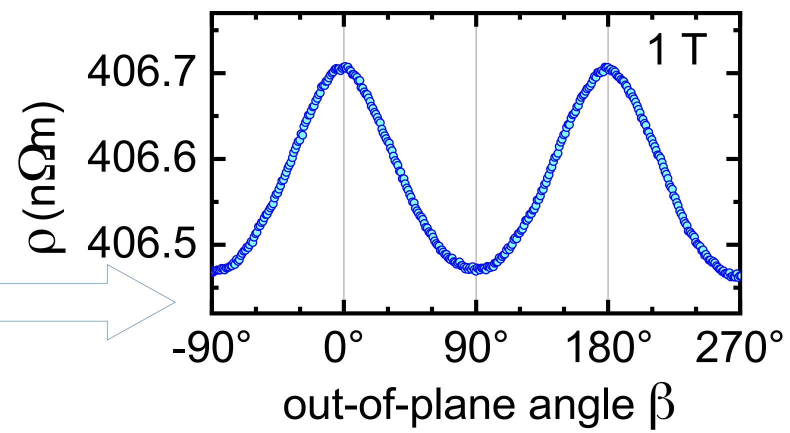




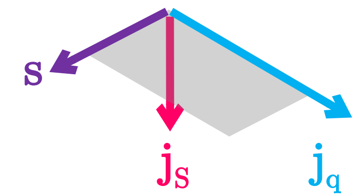


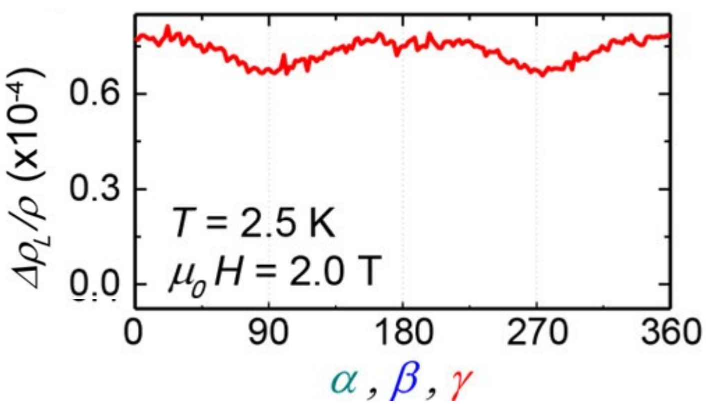


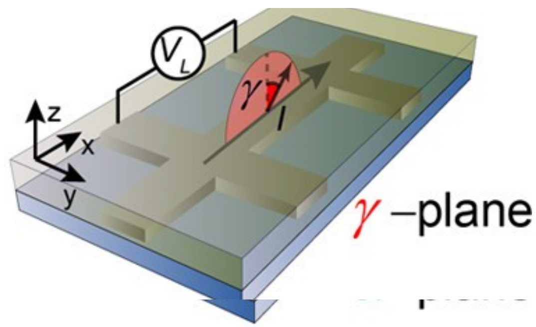
Max when M perpendicular to s;
Min when parallel

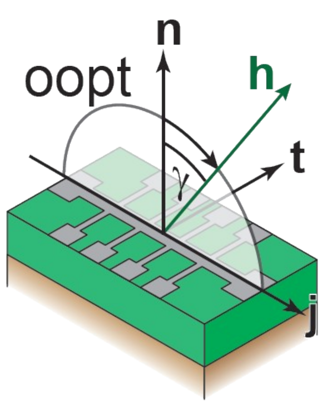


Angle Dependence



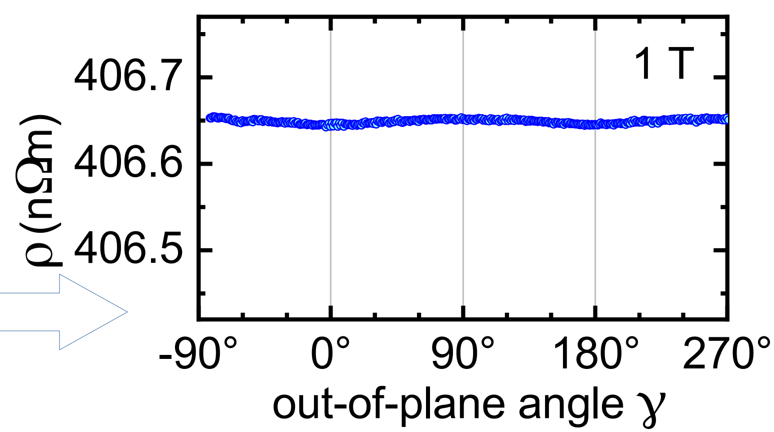




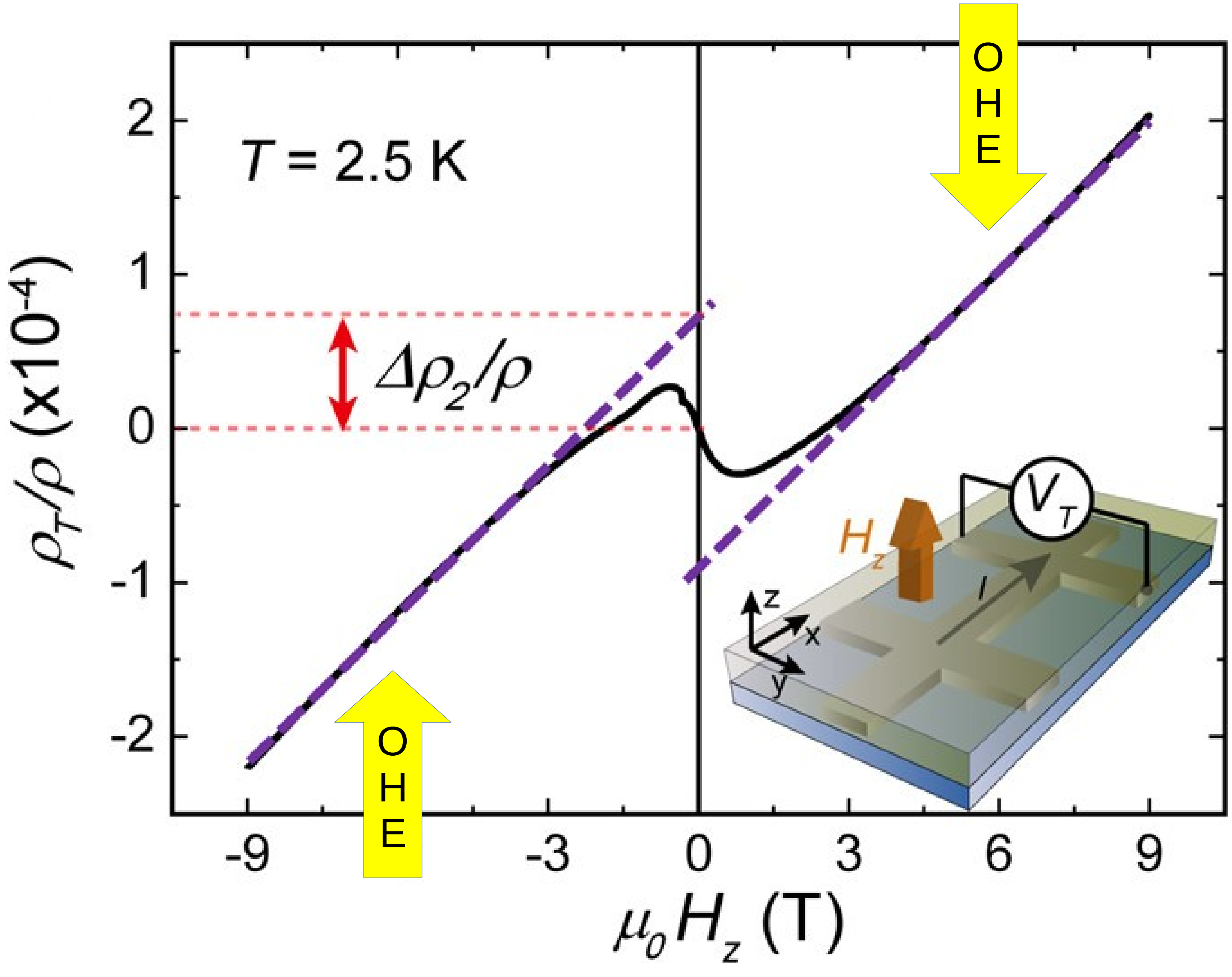


always **M** ⊥ **s**

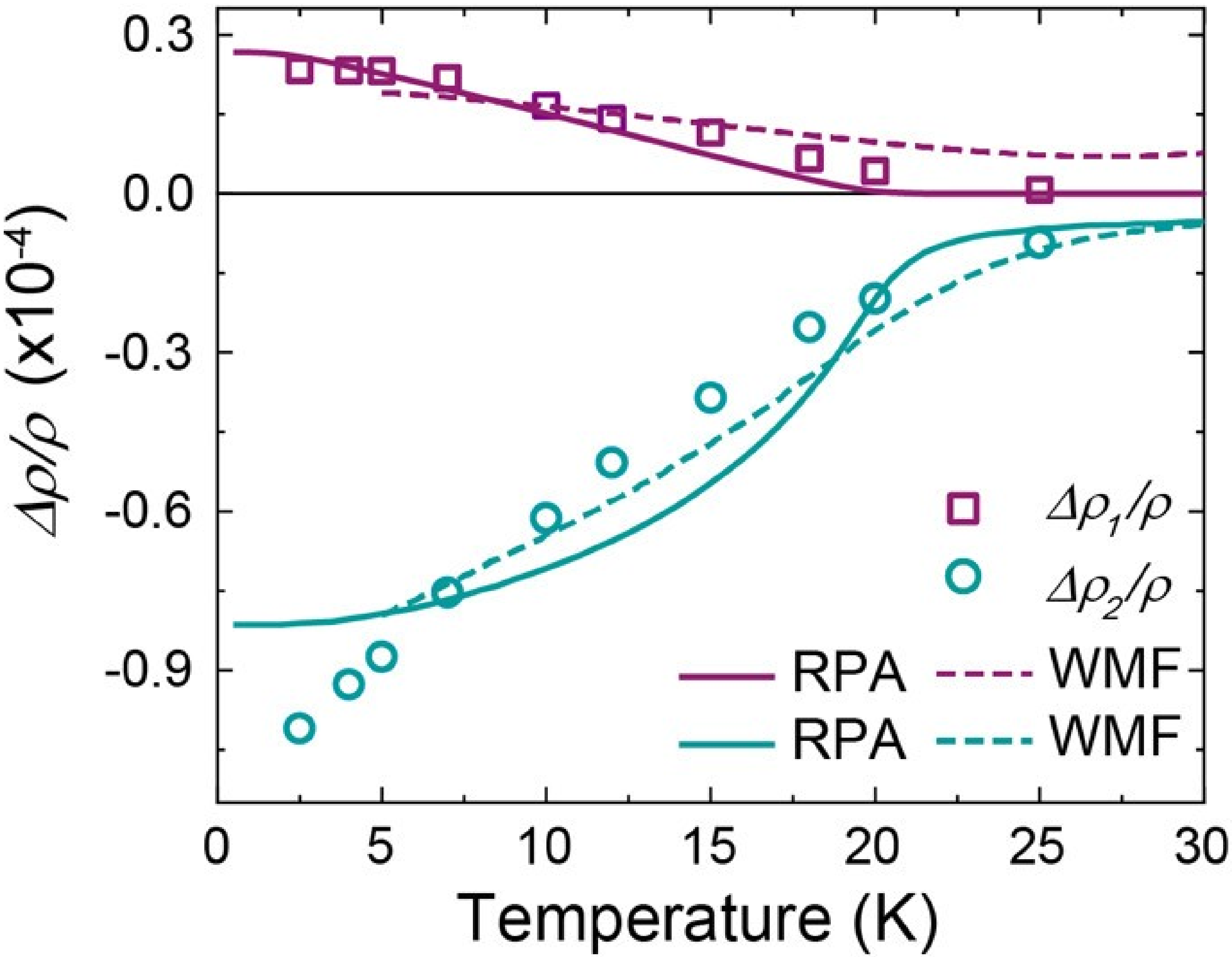
No change in relative direction
→ no change in resistivity



Hall Geometry



Experimental Results



Higher oscillations at lower temperature T (below Curie Temperature)

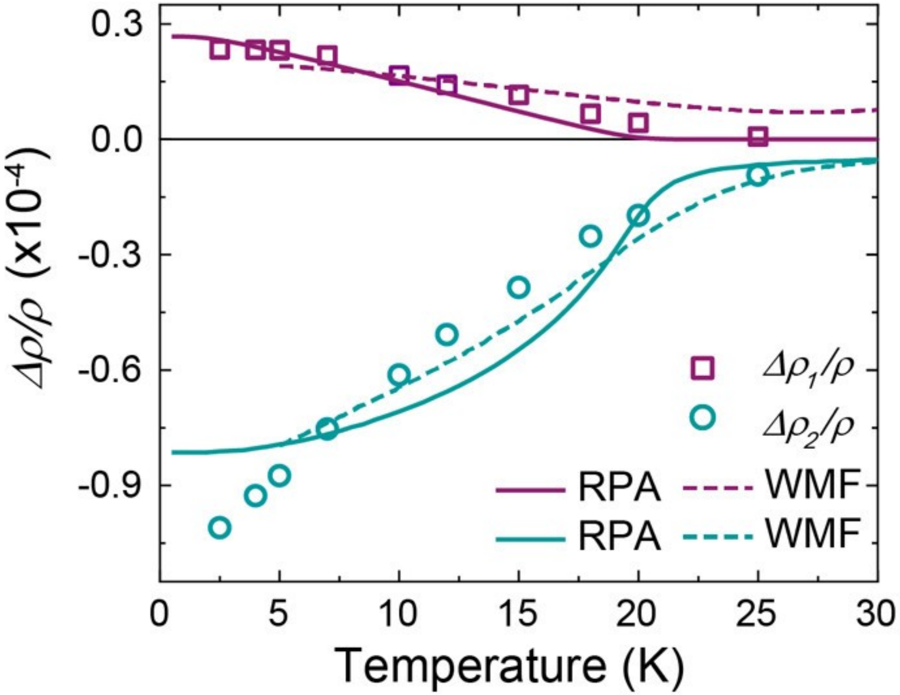
Open dots: experimental data
Solid (dashed) lines: amplitudes obtained with RPA (WMF) model

Experimental Results

- Fit temperature dependence of SMR amplitudes
- 2 approaches

  → Random Phase Approximation (RPA)

  → Weiss Mean Field (WMF)



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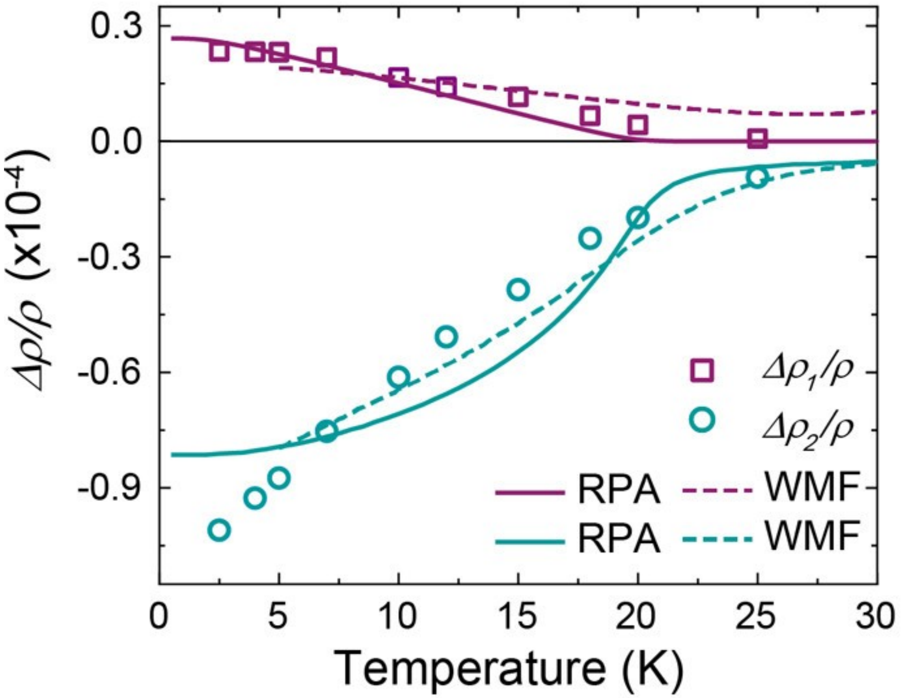
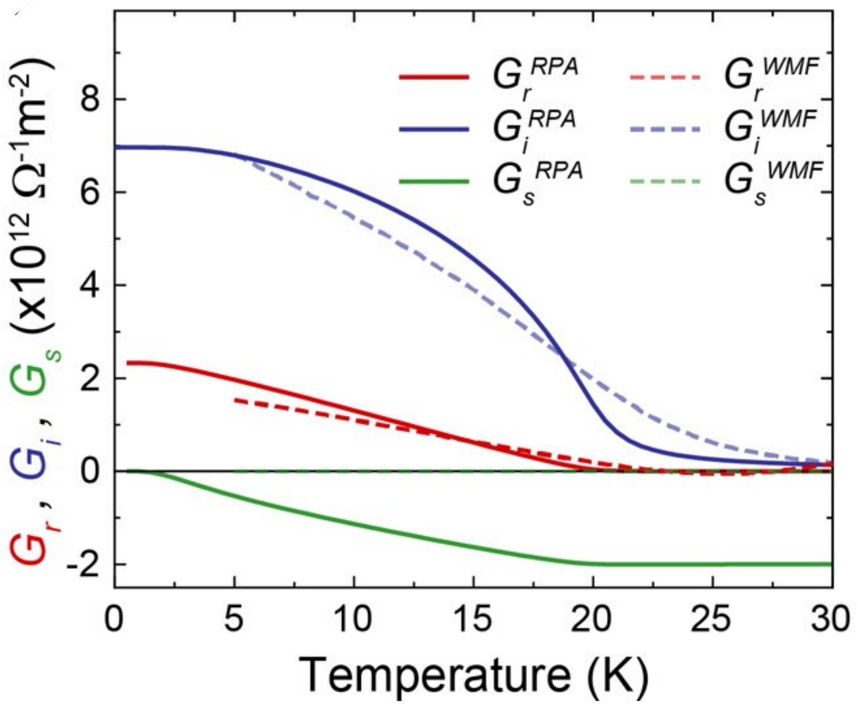


Get to the conductance via the resistivity oscillation amplitude



→ exchange interaction (~3–4 meV)

$G_i > G_r$

SUMMARY:

- Spin transport in a Pt/EuS interface by using SMR
- large G_i
- Temperature dependence of interfacial spin conductances
- Microscopic theory to extract relevant parameters

  → exchange interaction (3-4 meV)
- **SMR measurements offer simple way to quantify effective exchange fields**

Thank you for your attention!

references

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