Projects at SOIS:
Materials for Spintronics Applications

Hugo Dil

Spin-Orbit Interaction Spectroscopy (SOIS)
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Swiss Light Source, Paul Scherrer Institut

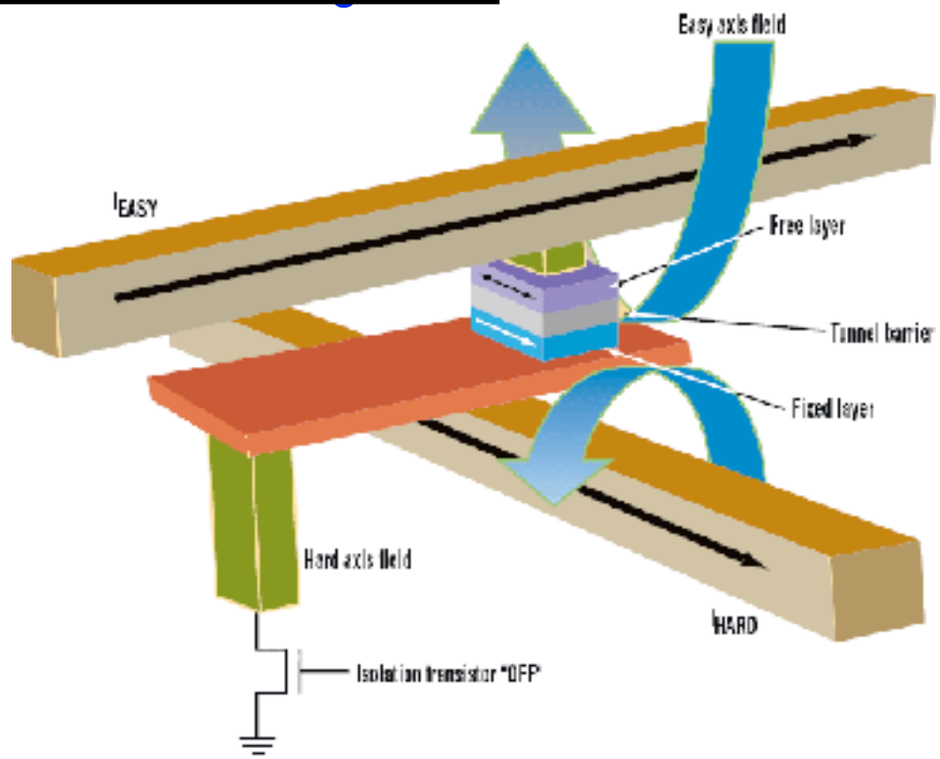
Novel electronics design to use the spin of the electron and not the charge

Main advantage: No movement of charge necessary

- Lower power consumption
- Faster
- Smaller
- Flexibility (not only 0 or 1)
- Spin is quantum state: quantum computing

Common approach based on magnetics

Giant Magneto Resistance (GMR):
Nobel prize 2007
Albert Fert, Peter Grünberg



Taking the magnet out

Physics

Physics **2**, 50 (2009)

Spintronics without magnetism

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The spin-orbit effect is at the heart of efforts to merge spintronics—where information is carried and stored by spin, rather than by charge—with semiconductor technology.

SPG Mitteilungen Nr. 30

Progress in Physics (17)

Spintronics without magnetism?

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Spintronics: magnetics vs. SOI

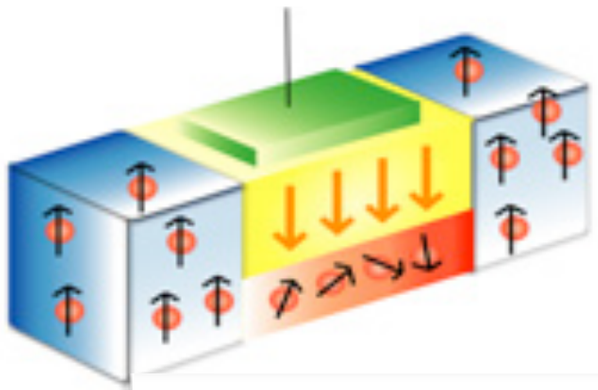
Magnetic fields are non-local and slow

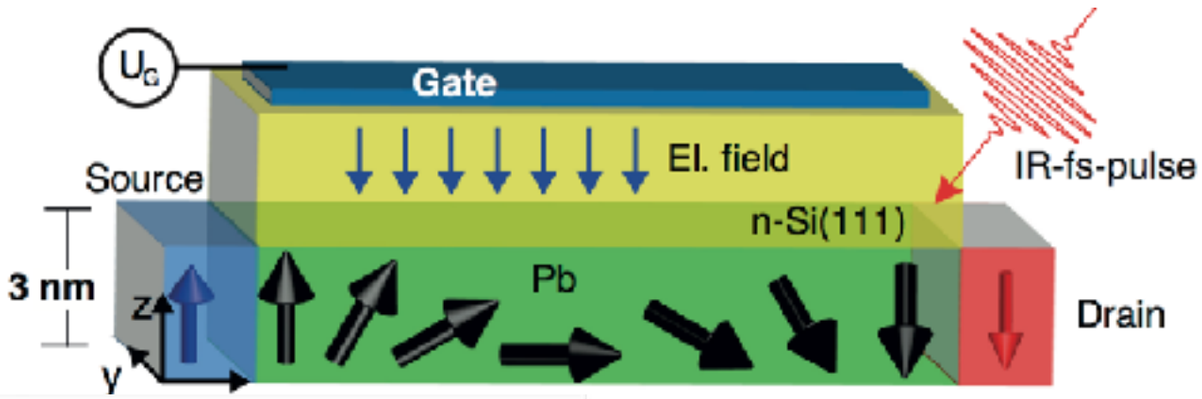
Spin-orbit interaction is local and instantaneous

Magnetics

Spin-orbit interaction

Transistor

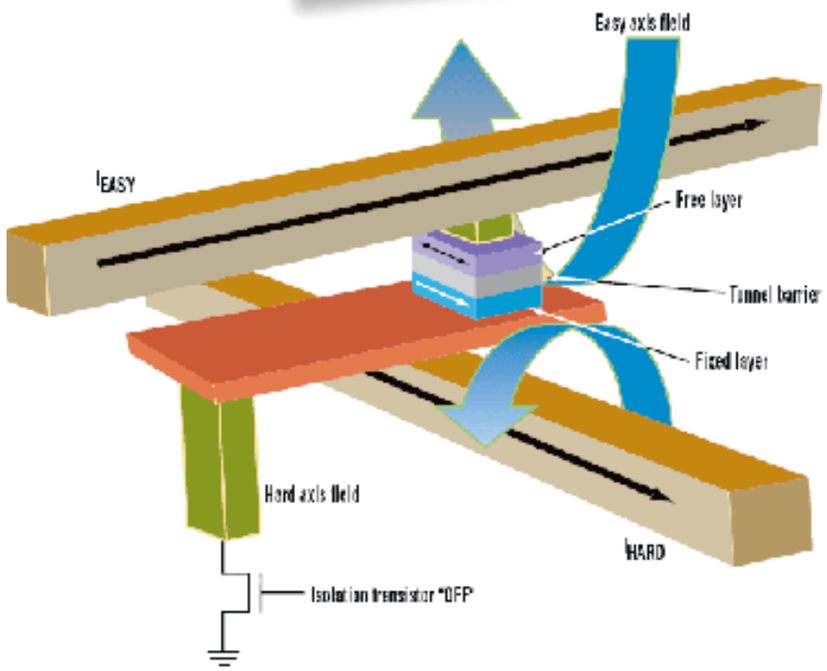


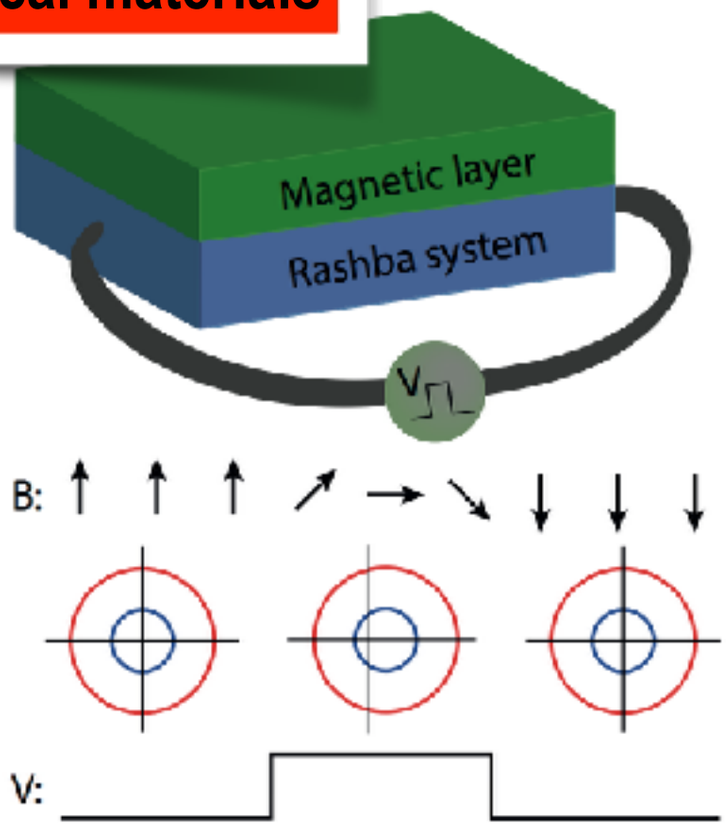


Novel materials needed!
Rashba systems and topological materials

ientific Reports (2013)

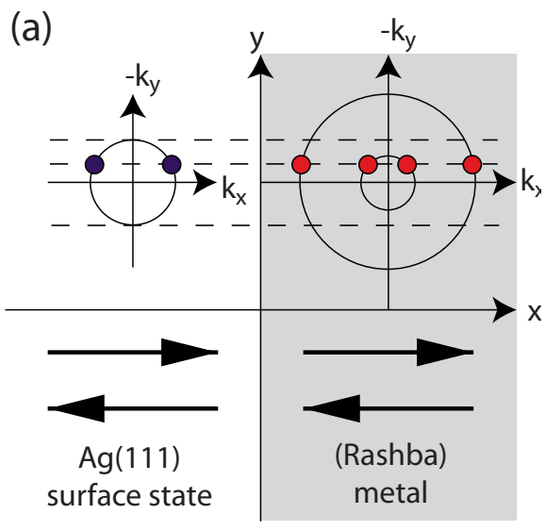
Memory writing

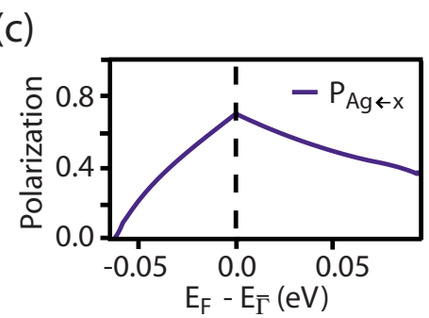




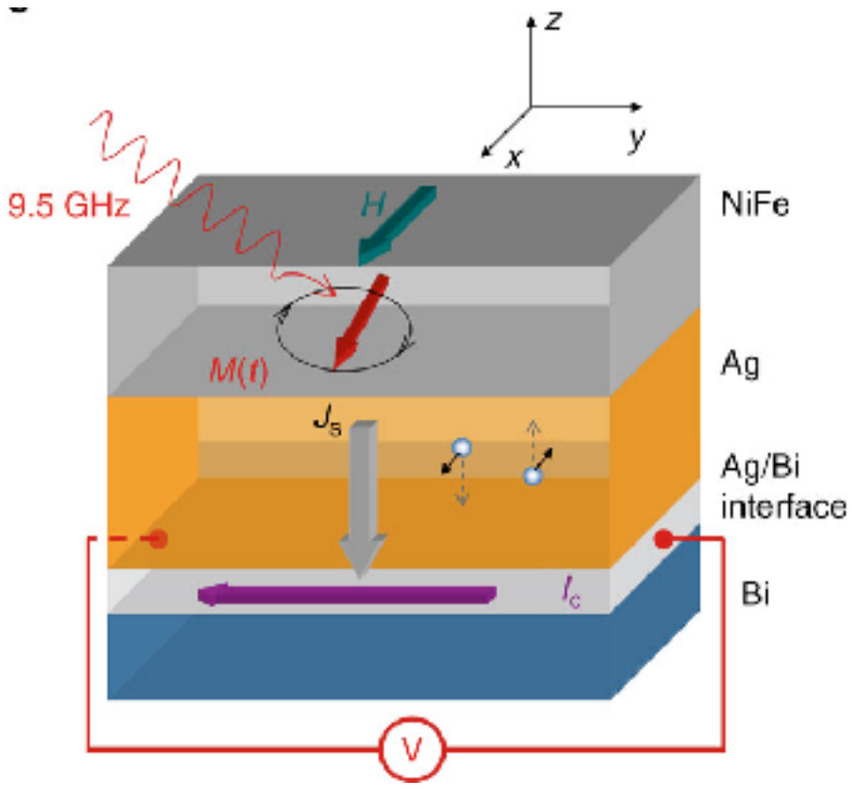
Relevance of the Rashba effect

Spin injection

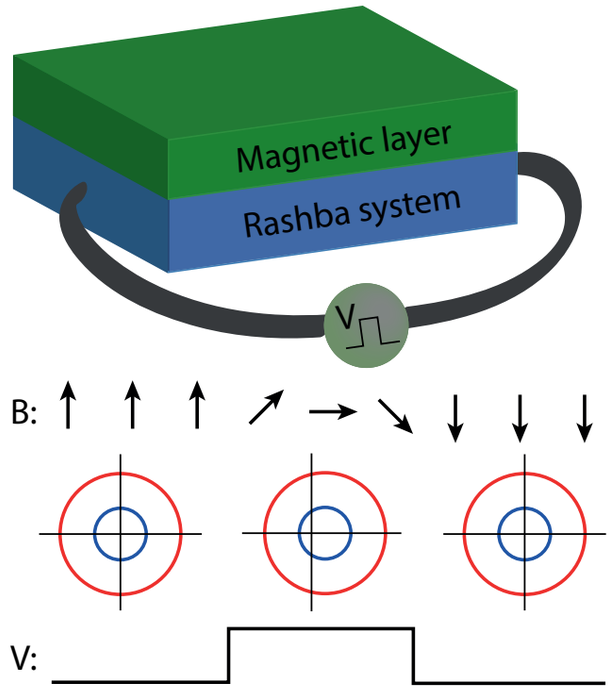




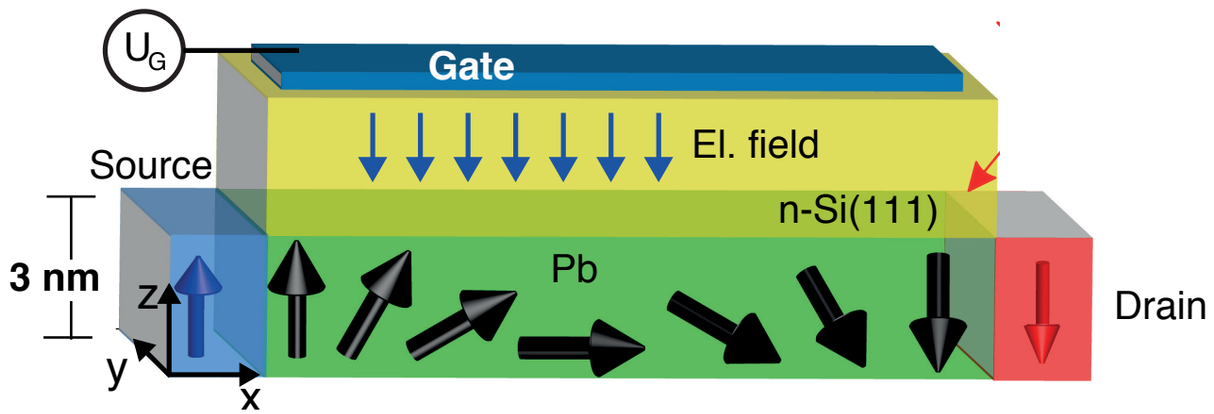
Spin ↔ charge conversion



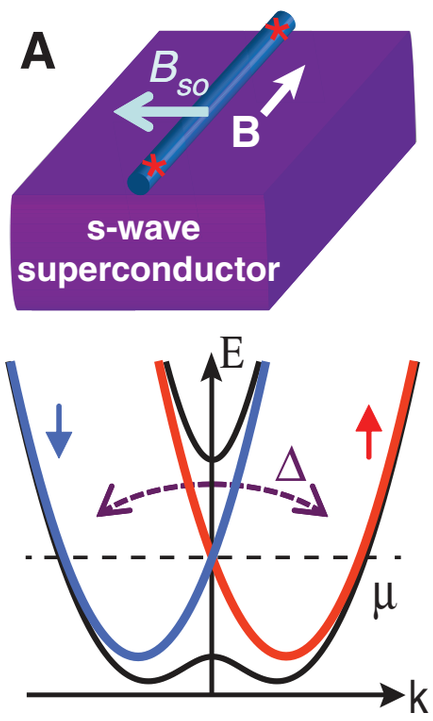
Spin torque: Magnetic writing by small voltage pulse



(b) Spin manipulation



Majorana fermions



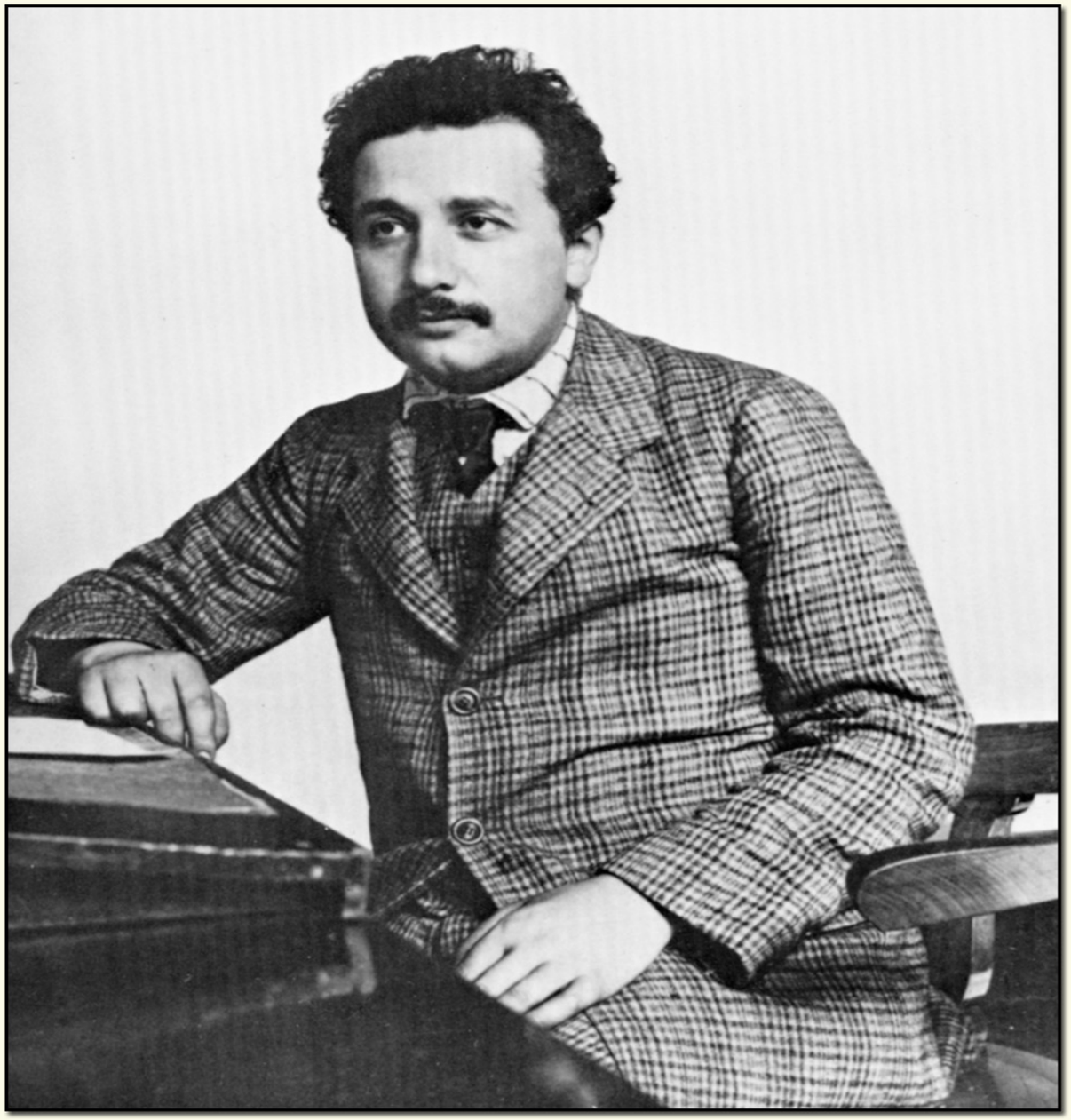
Photoemission spectroscopy

Einstein's Photoelectric Equation

The electron leaves
the body with energy

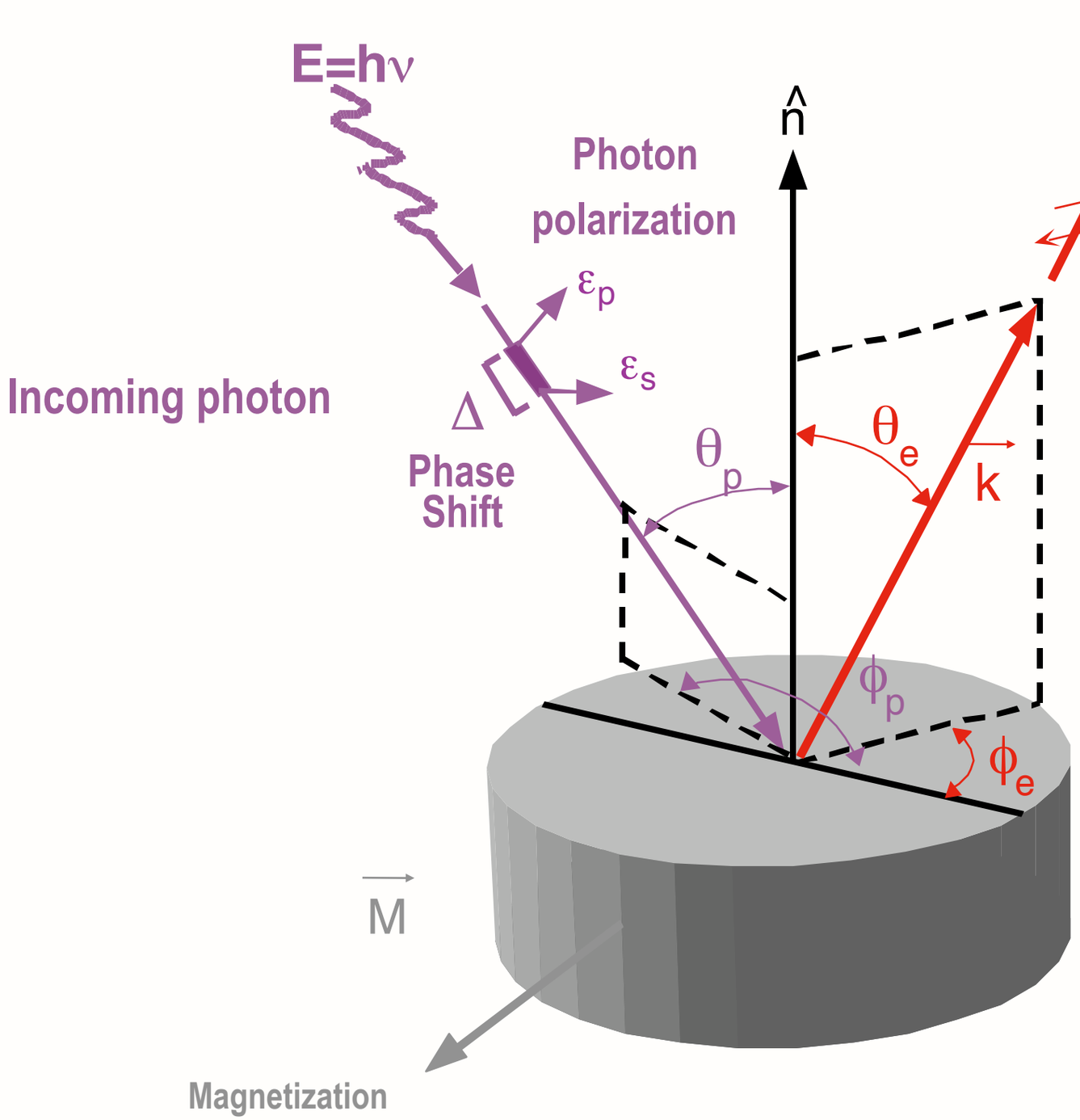
$$\frac{1}{2}mv^2 = hv - \mathrm{P},$$

where h is Planck's constant,
v is the light frequency and
P is the work the electron
has to do in leaving the body.



Albert Einstein, 1905

The photoemission experiment



$$E_k = \frac{h^2k^2}{2m}$$

Measure:

-Kinetic energy

-Emission angle

-Spin

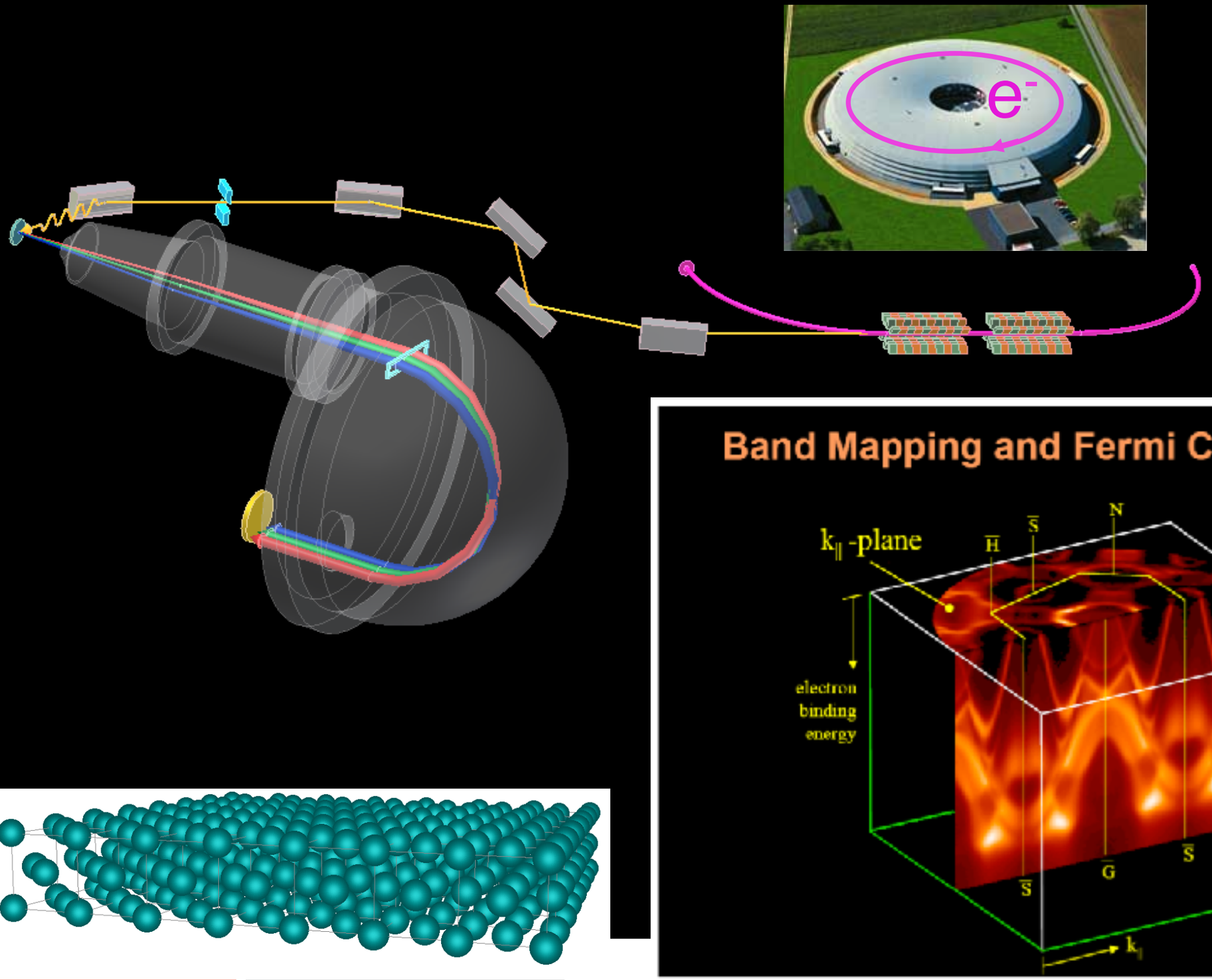
Oriented single crystal

T = 5-300 K

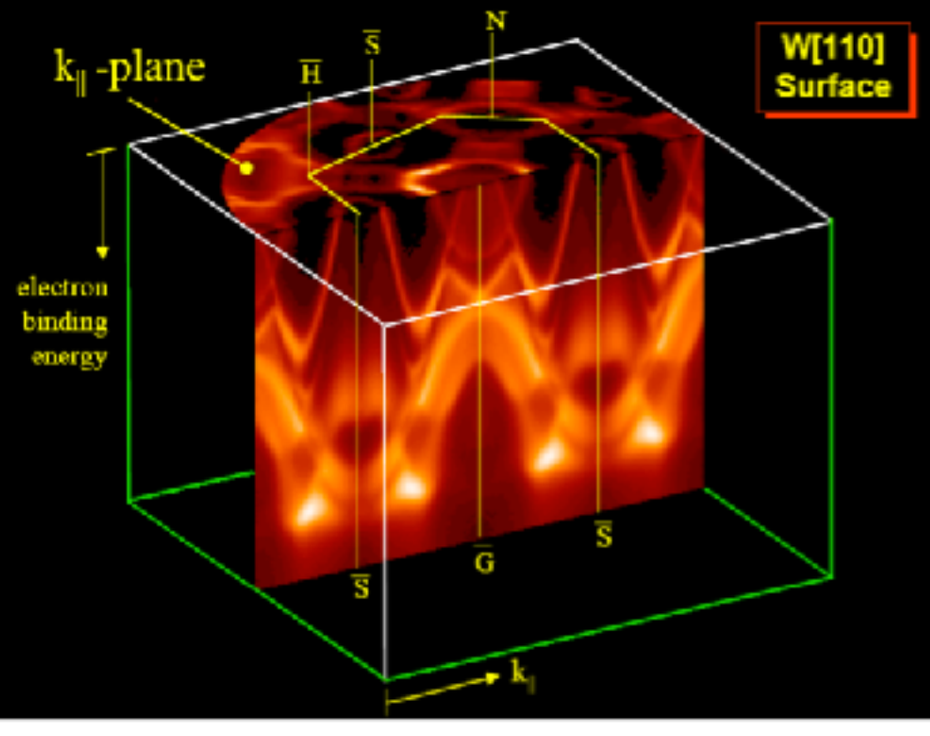
Pressure = 10^{-14} bar (UHV)

Typical ARPES set-up at synchrotron

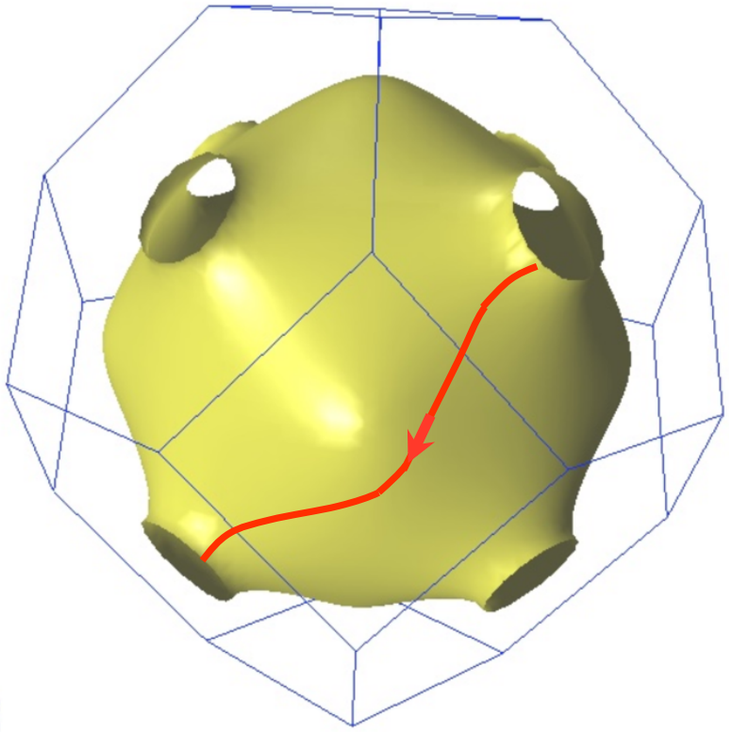
ARPES: angle-resolved photoemission spectroscopy

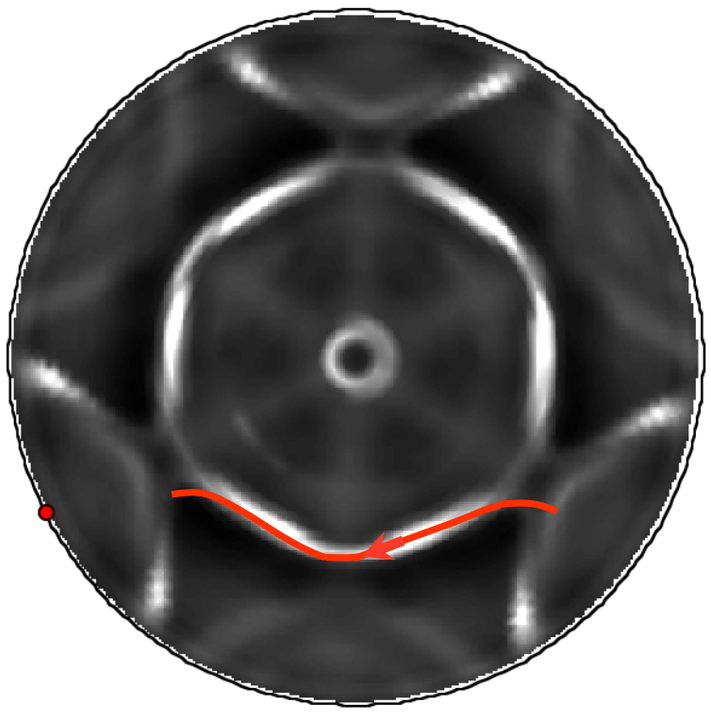


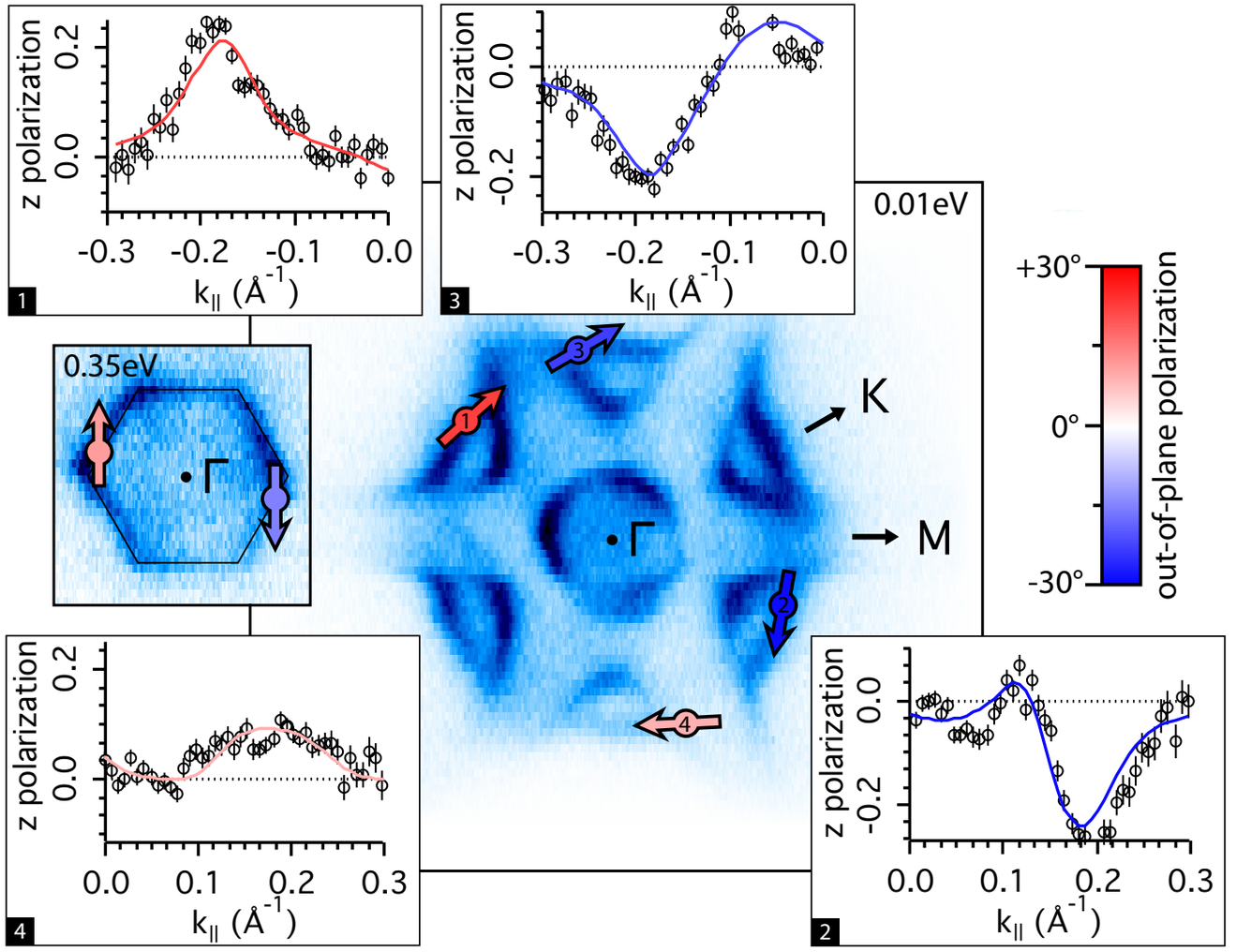
Band Mapping and Fermi Contours



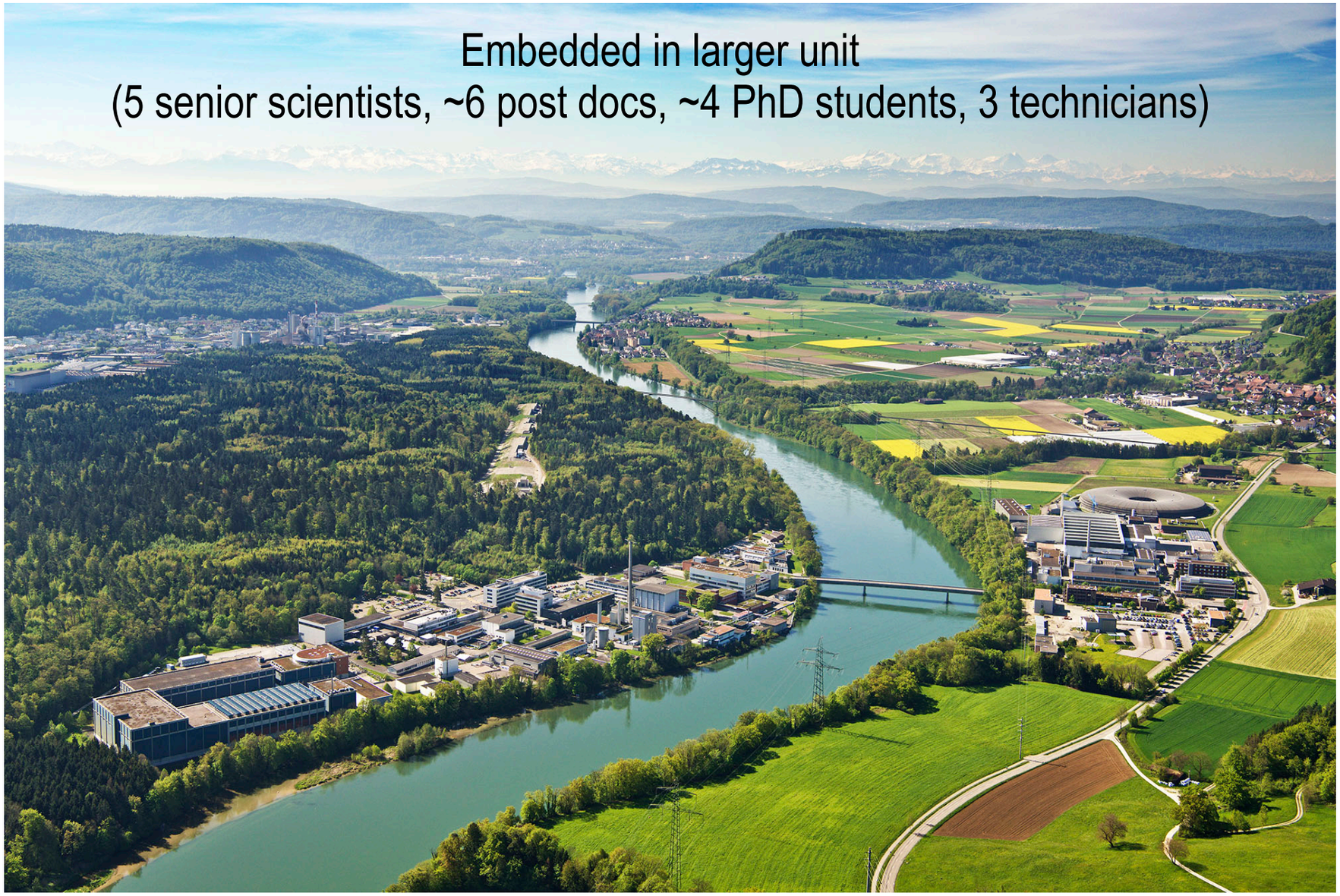
Watching how electrons move and spin







Swiss Light Source group



Embedded in larger unit
(5 senior scientists, ~6 post docs, ~4 PhD students, 3 technicians)

2 beamlines

4 end stations:

-Spin-resolved ARPES (COPHEE)

-High-resolution ARPES

-Soft X-ray ARPES

-Resonant inelastic X-ray scattering

Many other collaborations and possibilities

Typical Master projects:

-Study (spin-resolved) electronic structure of novel spintronic materials

-Study change of electronic/spin structure under *operando* conditions

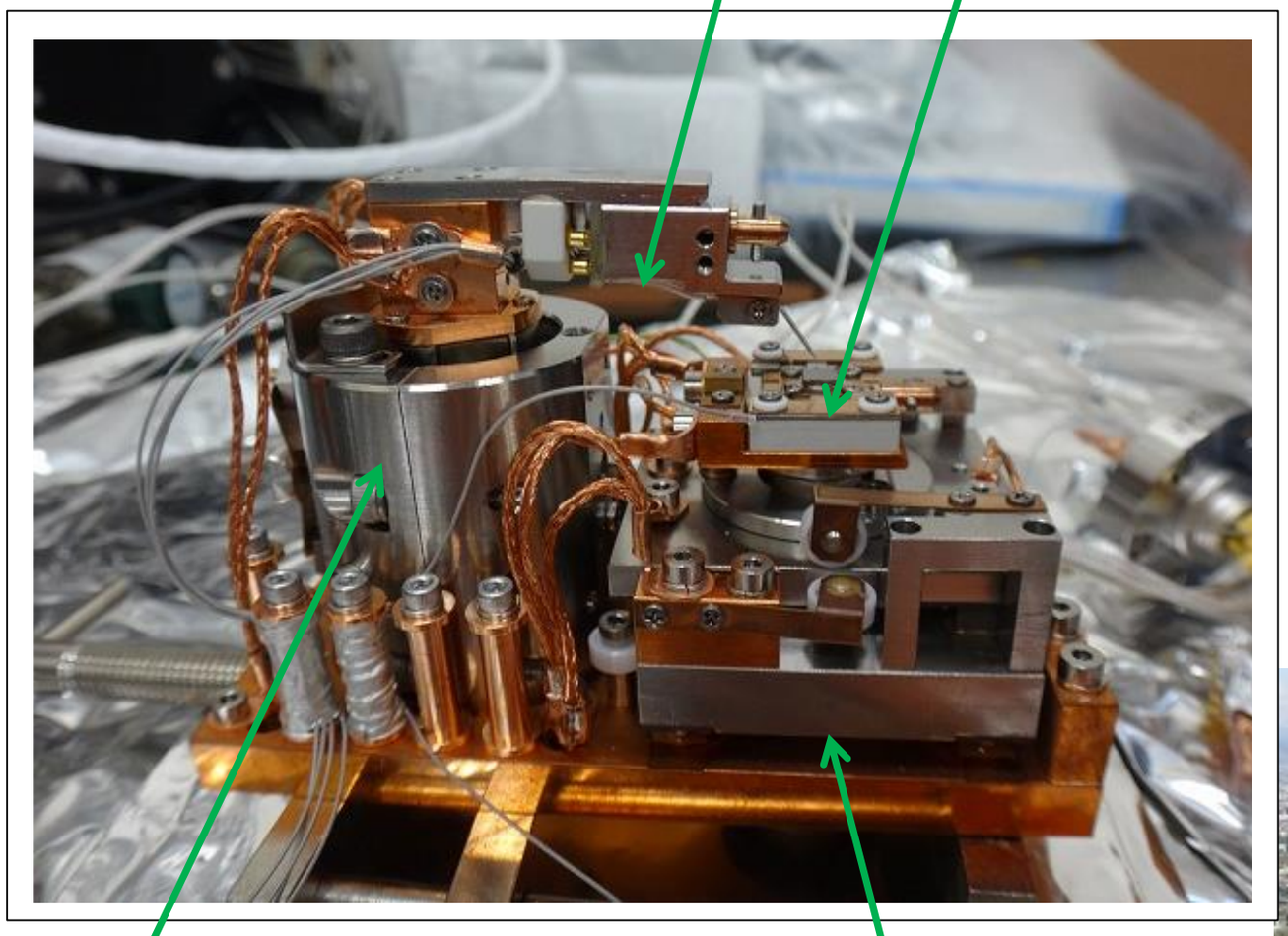
-Develop and test new measurement possibilities (sample environment)

Eating pudding

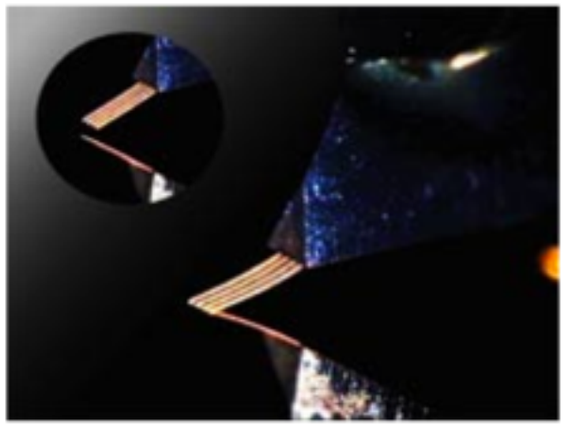
The proof of the pudding is in the eating

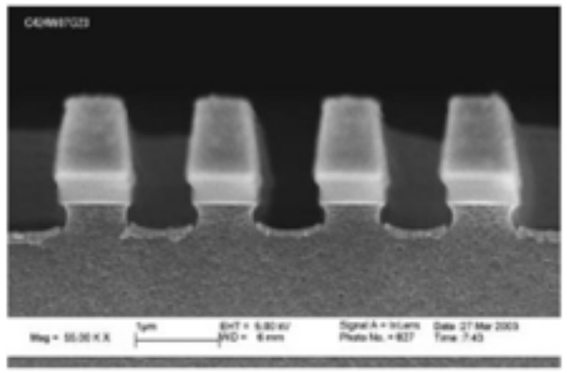
In-situ transport measurements

Unit side view



Micro 4 point probe (M4PP)





Master projects:

-Setting and testing up novel M4PP equipment

-Combined M4PP and ARPES experiments