IMAGING JRA

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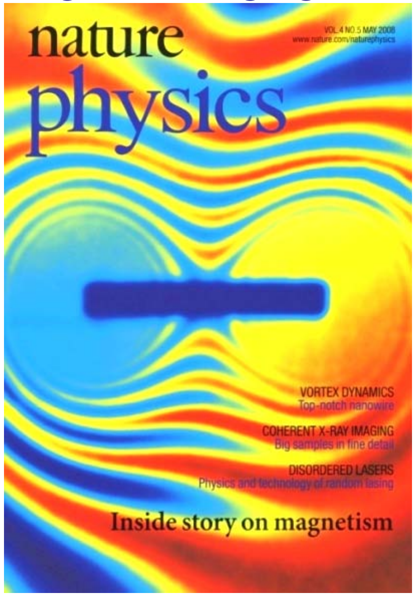
Zsoltan Kiss (MTA EK)
Robert Dalgliesh (ISIS)

Objectives

Neutron imaging gained recently a high importance in material sciences and fundamental research

Magnetic imaging

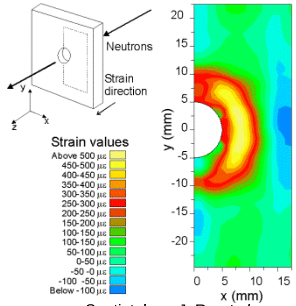


Nature Physics **4** (2008)

Materials science

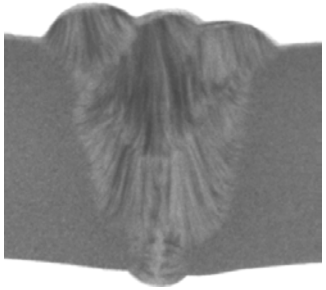
Materials Today **13** (2010)

TOF - imaging



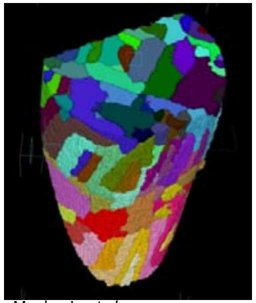
Santisteban, J. R., *et al.*,
Appl Phys a-Mater (2002) **74**

Diffraction - imaging



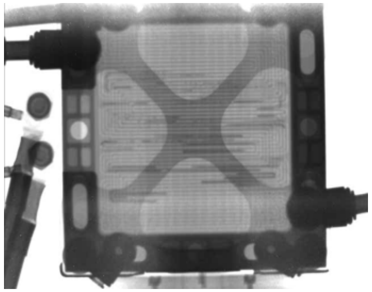
Lehmann, E. H., *et al.*,
NIMA(2009) **603**

Dark-field imaging



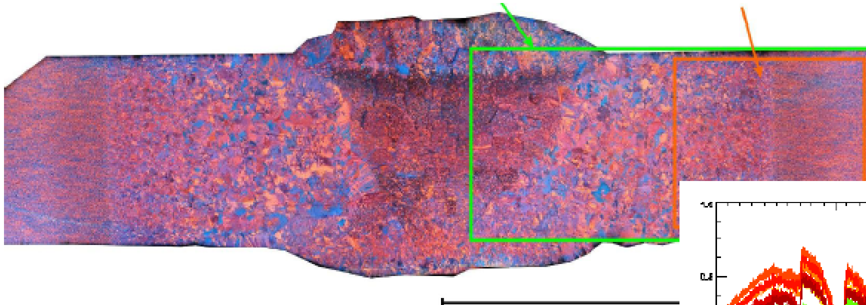
Manke, I., *et al.*,
Nature Communications (2010) **1**

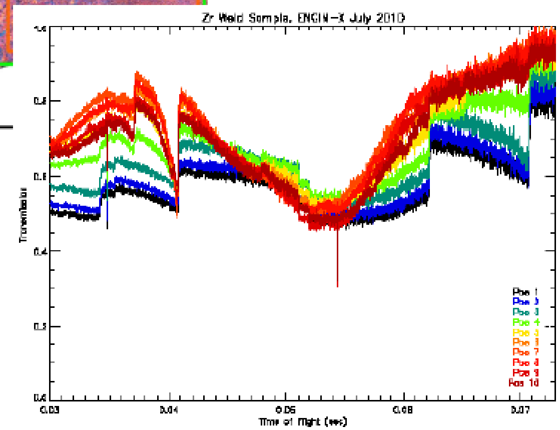
Engeneering

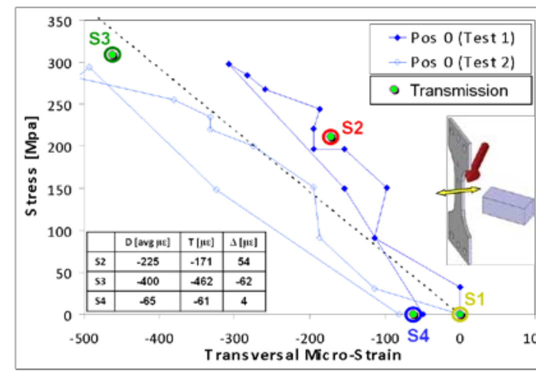


Kardjilov, N., *et al.*,
Materials Today (2011) **14**

New contrasts – Bragg-edge maping



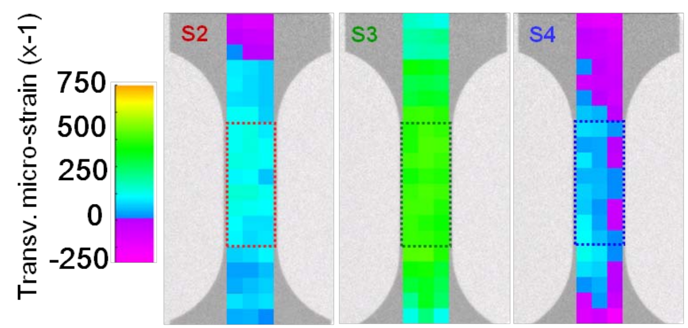




Zr-alloy weld: different grain structures result in large differences in transmission spectrum

A. Tremsin et al, presented at WCNR-9

Residual stress



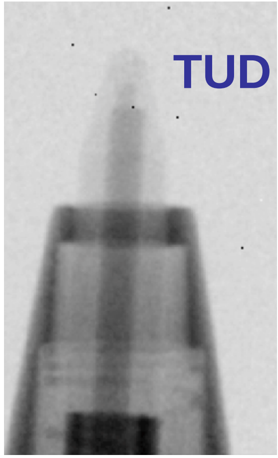
R. Woracek et al, JAP 109 (2011)

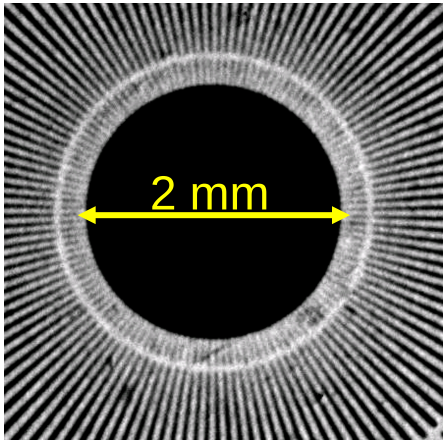
Task 3 (HZB, TUM, PSI)

High-resolution neutron imaging

- Different high-resolution imaging projects at different centers.
- The limits of the imaging detectors are still not achieved.
- There is need to adapt high-resolution detectors to the new methods.
- The desired resolution of below **10 µm** is in the order of features detected by scattering methods.

PSI





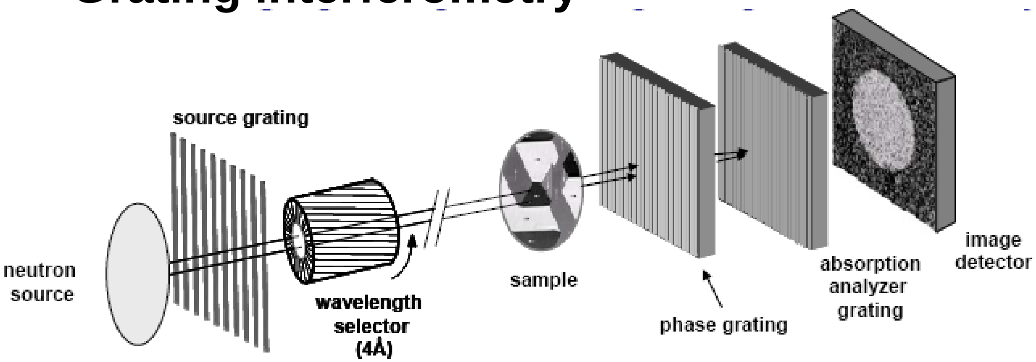
HZB

TUM

Task 2 (HZB, TUM, PSI, TUD, NPI)

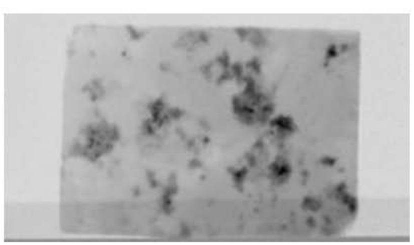
Overlapping between imaging and scattering

Grating interferometry



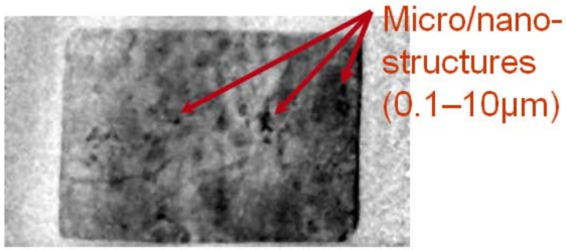
C. Grünzweig et al, Rev. Sci. Instr. 79 (2008)

Attenuation



4 cm

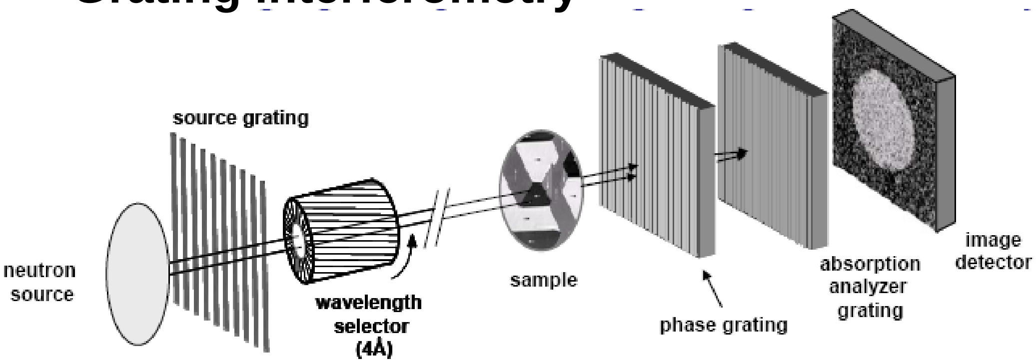
(U)SANS/dark-field



Task 1 (PSI, HZB, TUM)

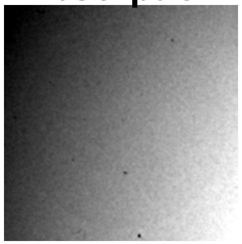
Overlapping between imaging and scattering

Grating interferometry

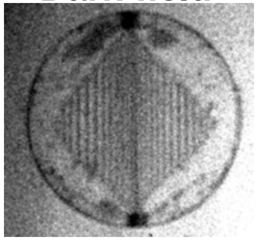


C. Grünzweig et al, Rev. Sci. Instr. 79 (2008)

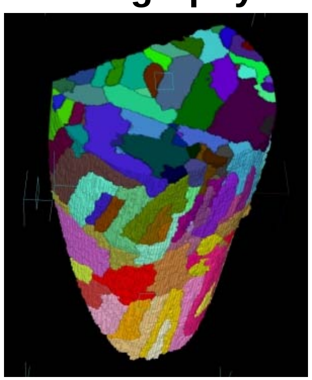
Absorption



Dark-field



Tomography



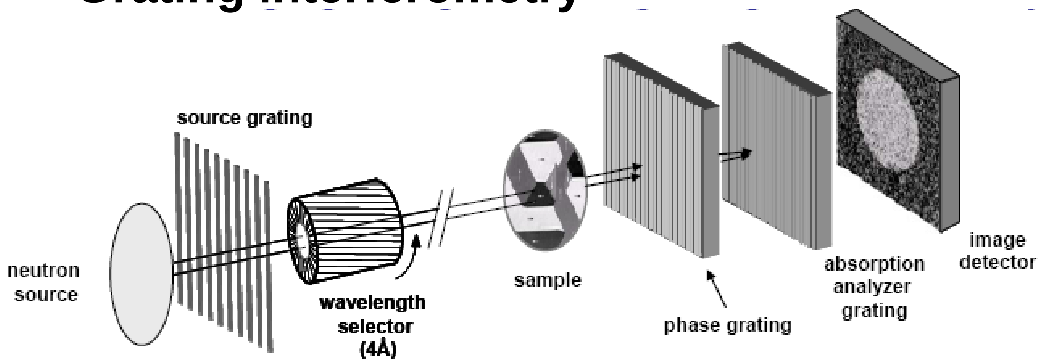
C. Grünzweig et al, PRL (2008)

I. Manke et al, Nat. Comm. (2010)

Task 6 (PSI, HZB, TUM)

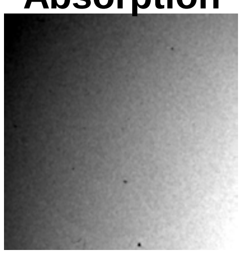
Overlapping between imaging and scattering

Grating interferometry

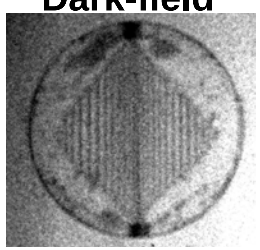


C. Grünzweig et al, Rev. Sci. Instr. 79 (2008)

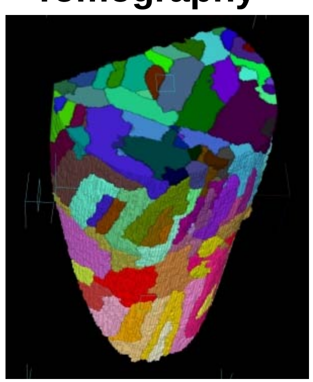
Absorption



Dark-field



Tomography



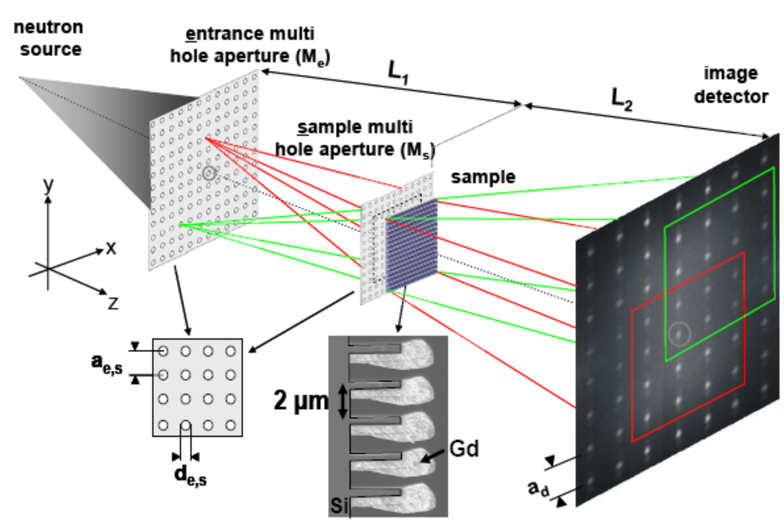
C. Grünzweig et al, PRL (2008)

I. Manke et al, Nat. Comm. (2010)

Task 6 (PSI, HZB, TUM)

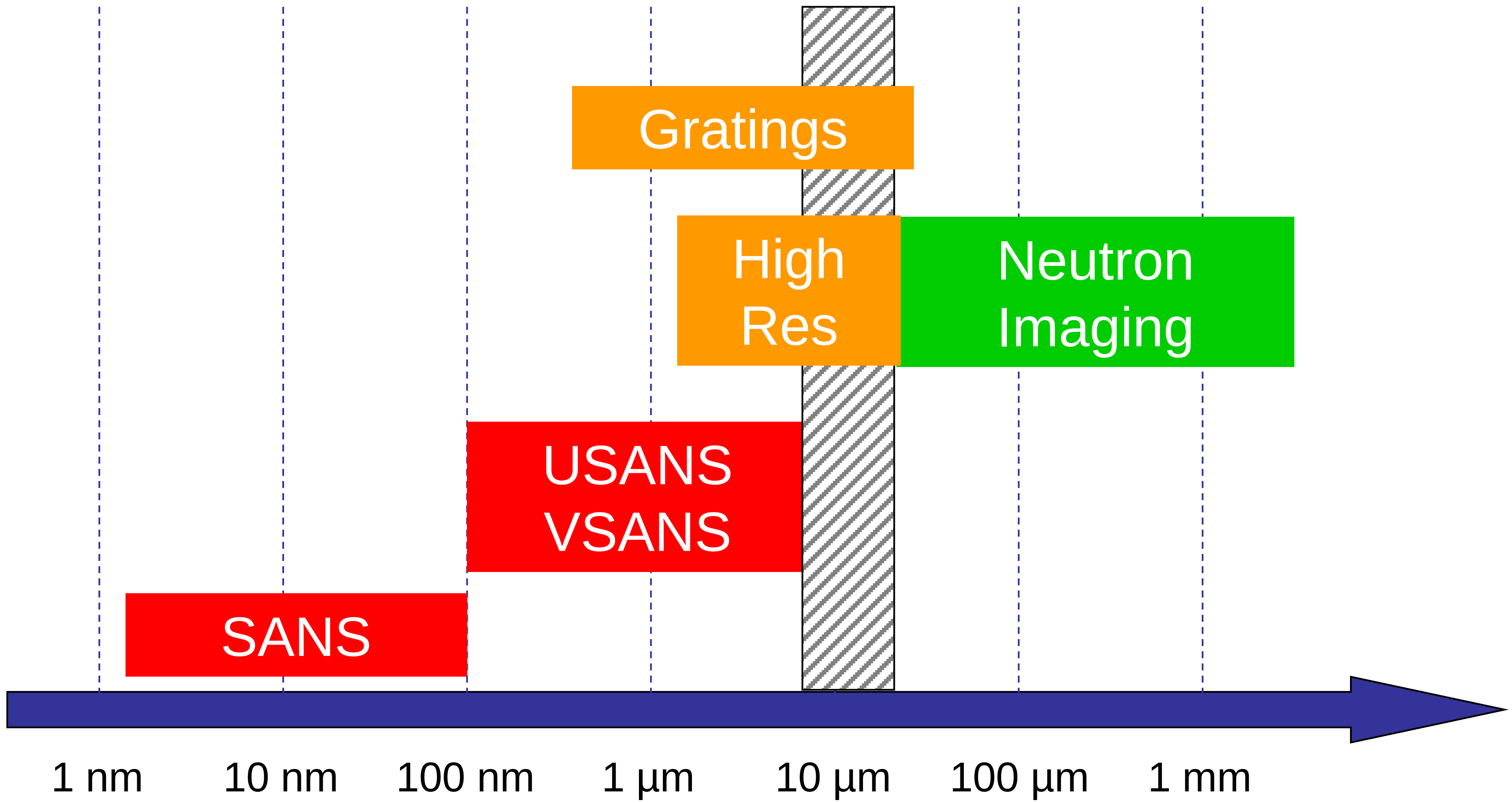
MSANS

structural and magnetic features between 1 µm and 30 µm.



VSANS (HZB), TPA (LLB)

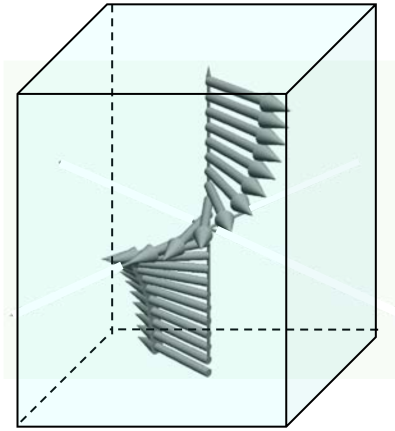
Overlapping between imaging and scattering



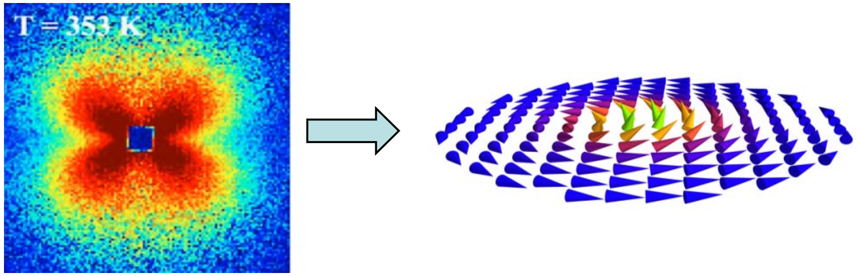
Outline

- Development of imaging techniques of magnetic micro- and nanostructures.
- 3 routes adapted to different characteristic length-scales:
  - Reciprocal Space (1-100nm)
  - Precession space (100nm – 1µm)
  - Direct space (1µm – 10µm)

- « Precessional spectroscopy »
  - In-depth measurements
  - Measurements « almost » in the real space



- SANS 3D : vectorial small angle scattering
  - Volume measurements
  - Measurement in the reciprocal space



- Informations not accessible by other existing techniques

Vector polarization analysis in SANS

Spin configurations within nanoparticles are typically complex: surface anisotropy leads to non-uniform magnetization distribution.

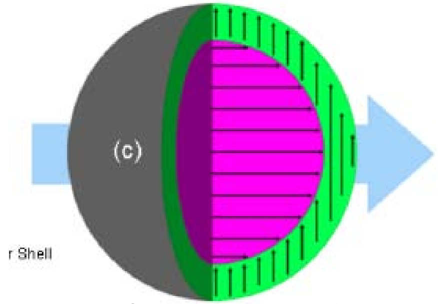


Figure from K. Krycka et al., PRL 104 207203 (2010).

The unambiguous determination of the magnetic field vector **B (**both its direction and magnitude) requires to determine the full polarization tensor:

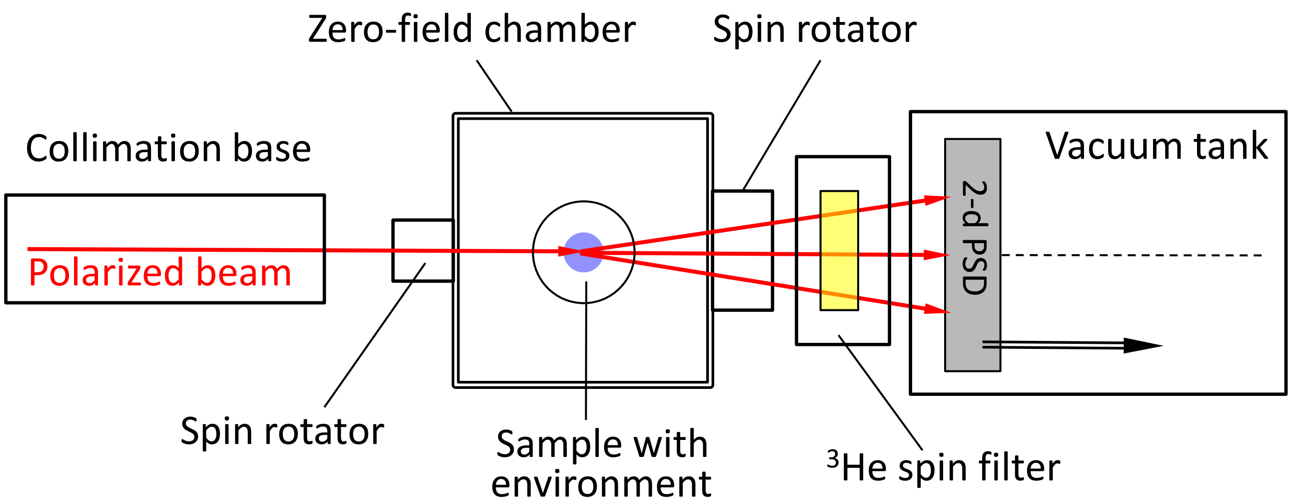
$$P_{ij} = \begin{pmatrix} P_{xx} & P_{xy} & P_{xz} \\ P_{yx} & P_{yy} & P_{yz} \\ P_{zx} & P_{zy} & P_{zz} \end{pmatrix}$$

i = x,y,z - orthogonal components of the incoming polarization vector $\mathbf{P_0}$;

j = x,y,z - orthogonal components of the outgoing polarization vector **P**

We will use this approach in combination with the polarized SANS, so that the Q-dependence of **B** will provide the information about the magnetic field distribution inside micro- and nanoparticles.

SANS with vector (3-d) polarization analysis:

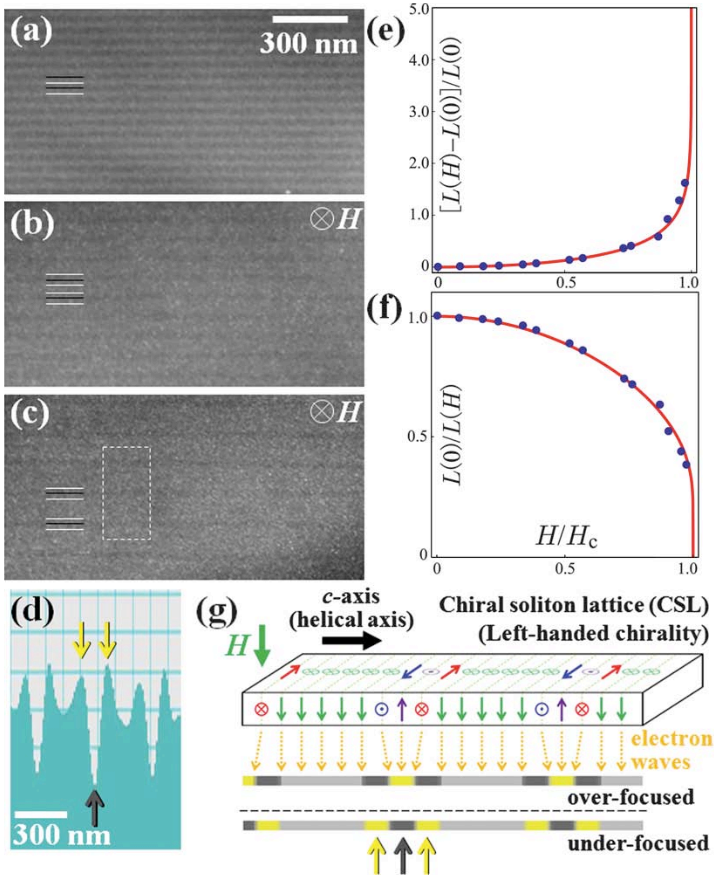


Nanoparticles:
5 to 100nm
Q= (0.006 - 0.15)Å^{-1}

- Design a new μ-metal magnetic shielding and spin rotators, optimized by FEM simulations (magnetic field maps) and VITESS simulations of the neutron spin behaviour in such polarimeter.
- Design of spin rotators with reduced intrinsic SANS.
- Prototype the polarimeter, neutron tests.
- Neutron measurements with real samples at polarized SANS diffractometers at the JCNS.
- Development of VITESS modules for these samples and comparison of experimental results with simulations.

Task 4 (CEA, JCNS, TUD)

Magnetic nanostructures

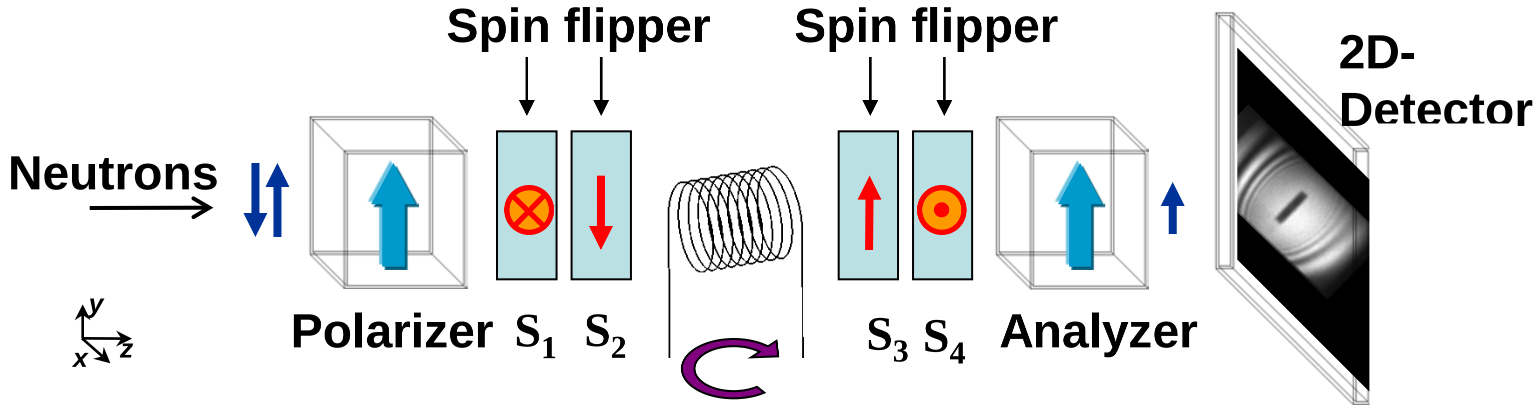


Develop the tools to get magnetization distribution in the bulk
Complementarity to TEM

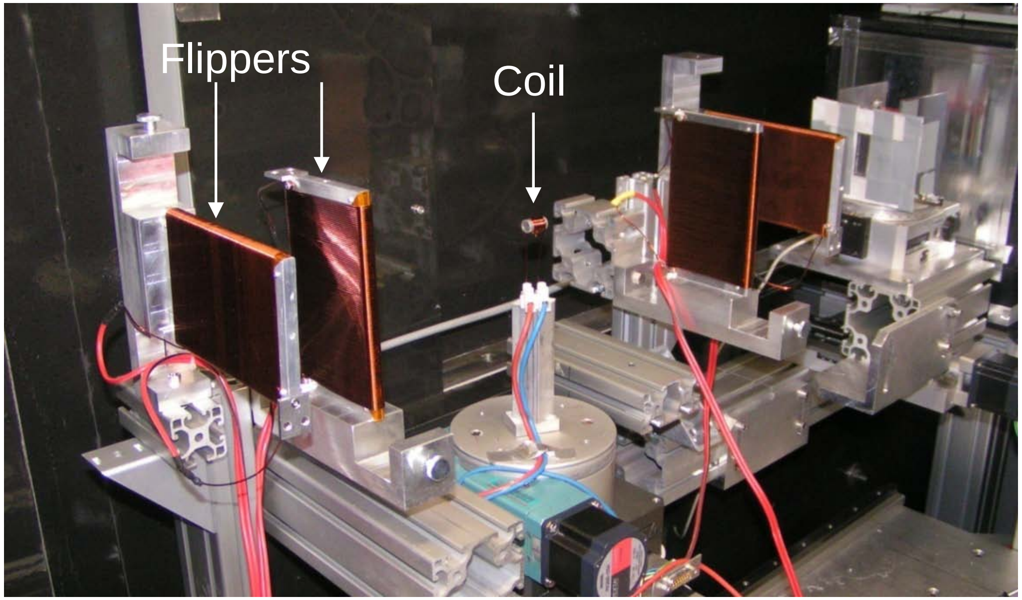
Making neutrons a indispensable tool for spintronic applications

Chiral Magnetic Soliton Lattice on a Chiral Helimagnet
Togawa et al. PRL 108 (2012)

Task 4 (CEA, JCNS, TUD)



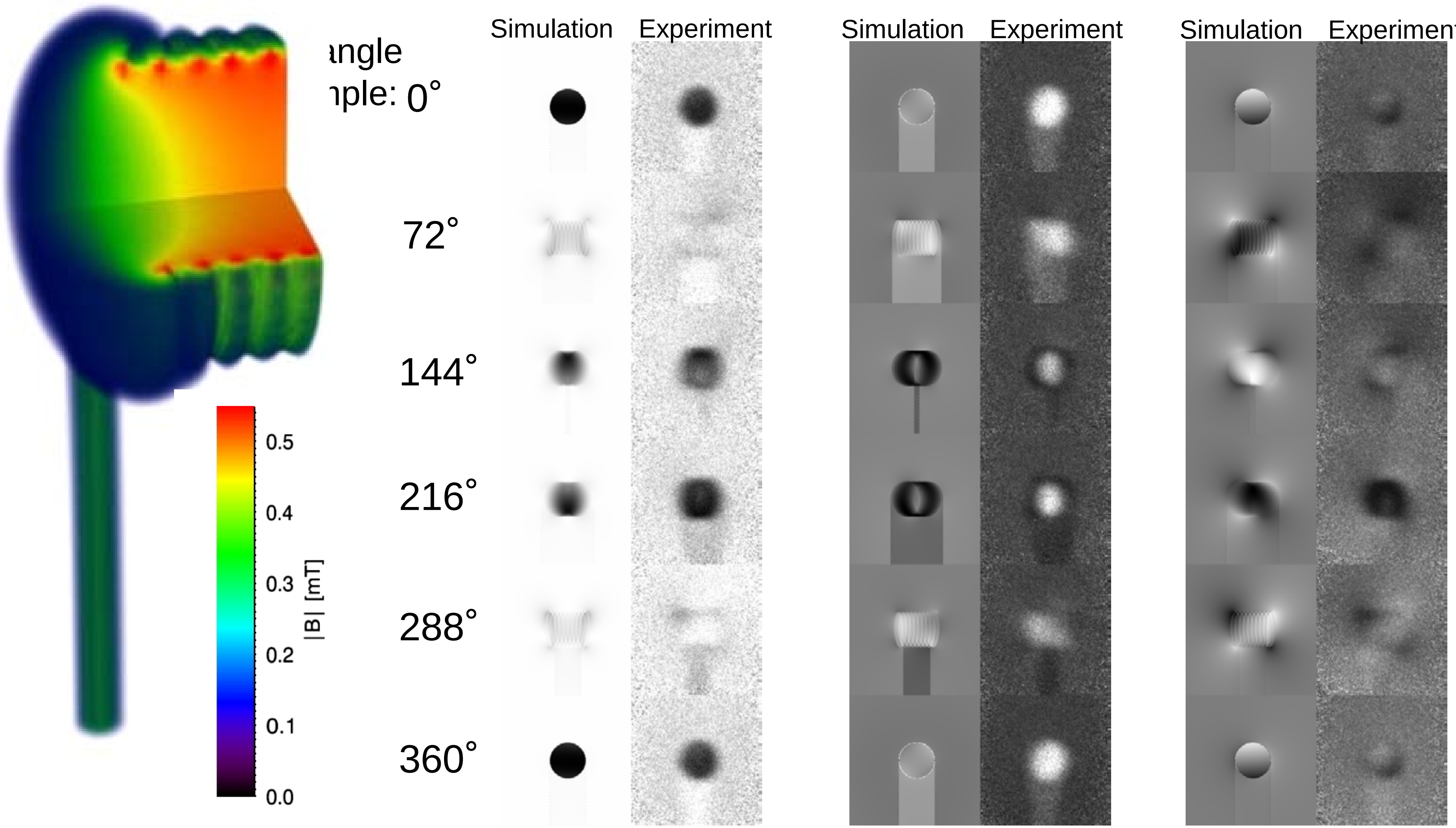
9.5 loops
I = 1.5 A
101 Projections
9+1 Tomographies



Task 6 (HZB, PSI, TUM)

in component: X Y Z

ıngle
ıple: 0°

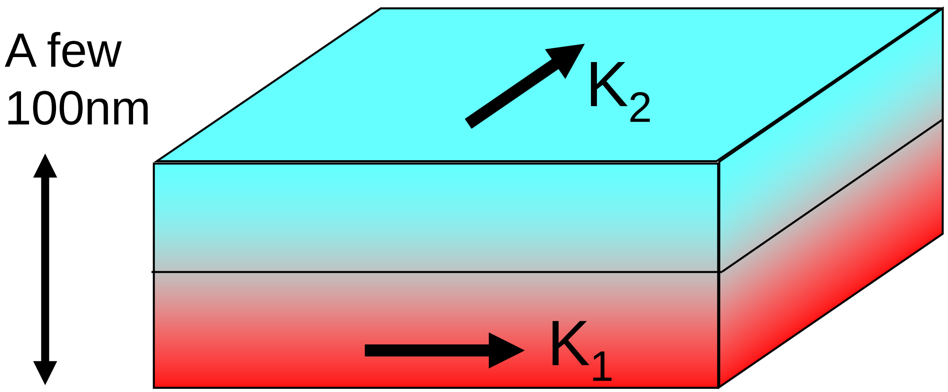


Task 6 (HZB, PSI, TUM)

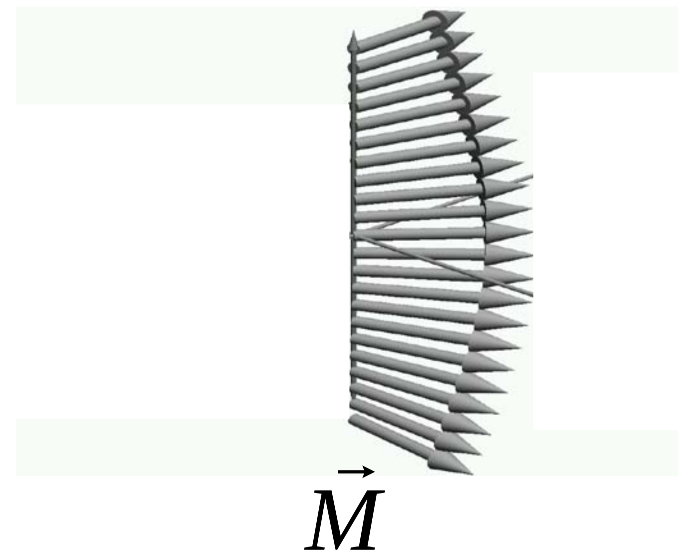
M. Strobl et al, Phys. B (2009)
M. Strobl, NIMA 604 (2009)

Measure of magnetization profiles in thick films

- Problem : Determine the magnetic anisotropy within the thickness of a magnetic film
  - *Important for the Hyper-Frequency properties for ex.*



Materials with different anisotropies

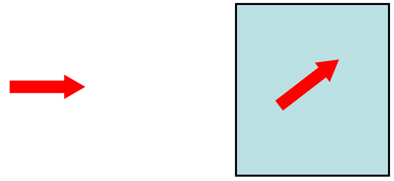


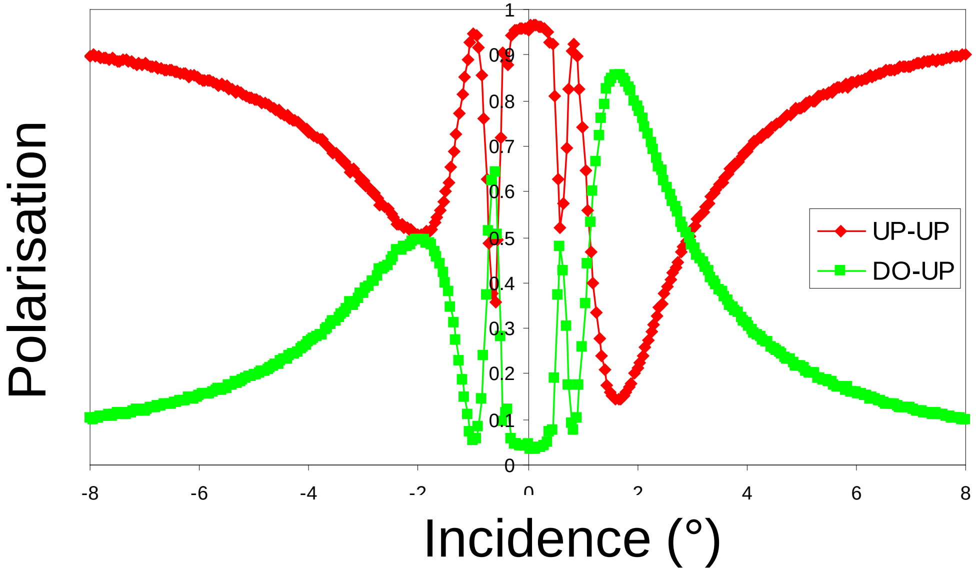
Creation of a planar Bloch wall

Task 5 (CEA, ISIS)

Precession spectroscopy

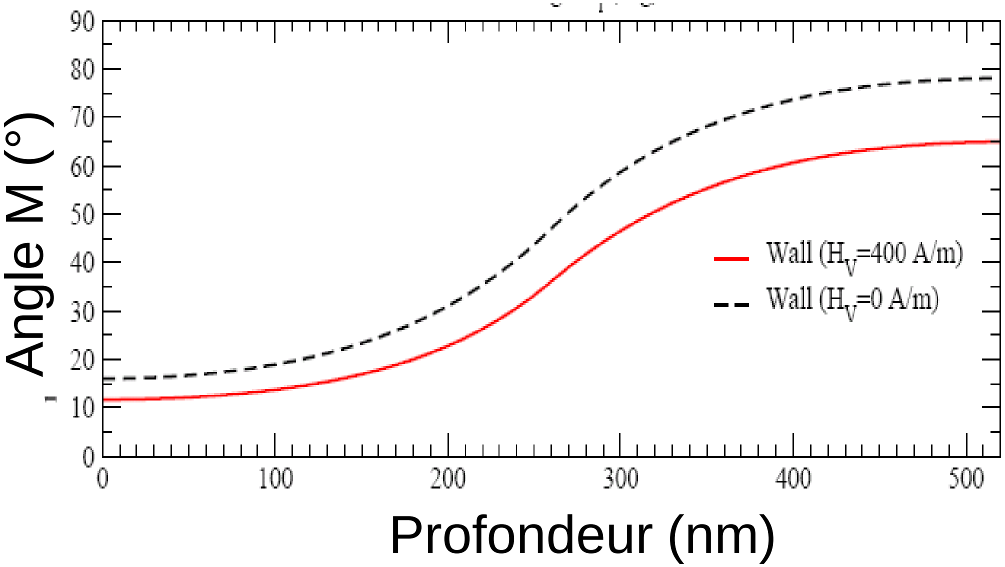
Neutron precession spectra



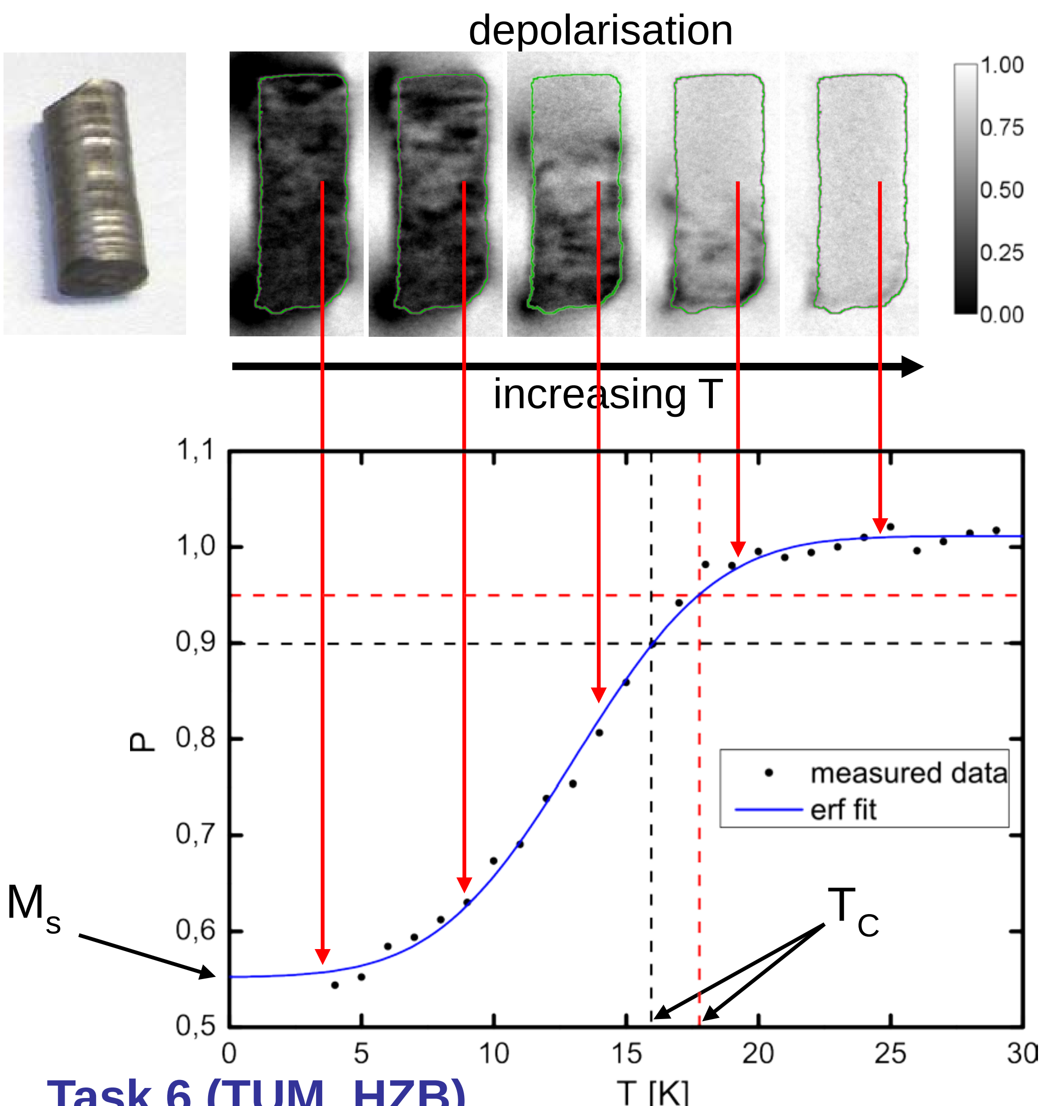


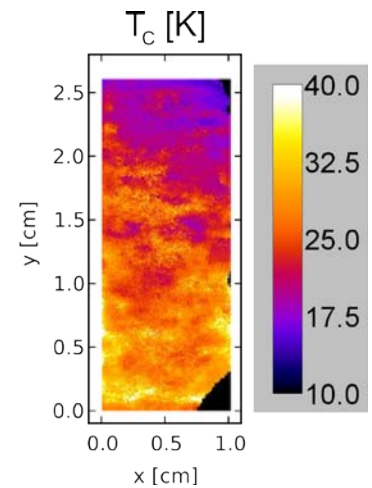
<u>analytical</u> reconstruction of the magnetic profile

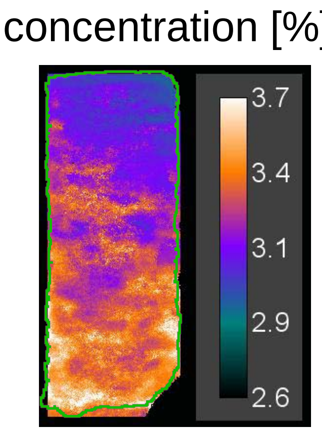
$\vec{M}(z)$



Task 5 (CEA, ISIS)





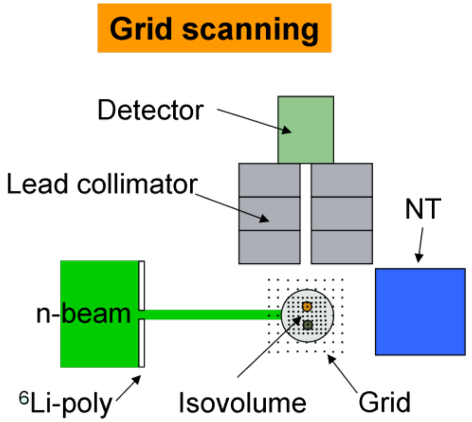


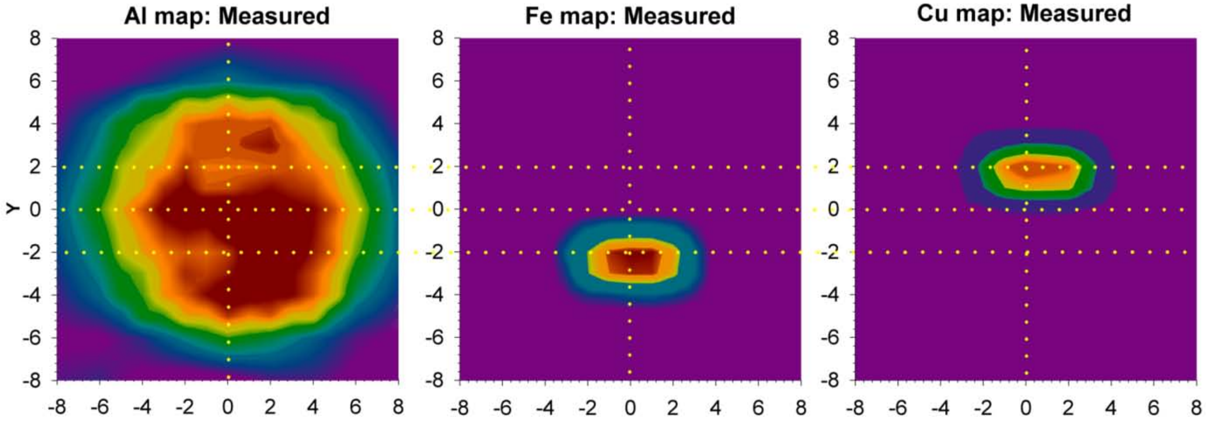
Requirements:
- high spatial resolution
- polarization analysis
- small samples
- sample environment

Task 6 (TUM, HZB)

M. Schulz, PhD Thesis, TUM

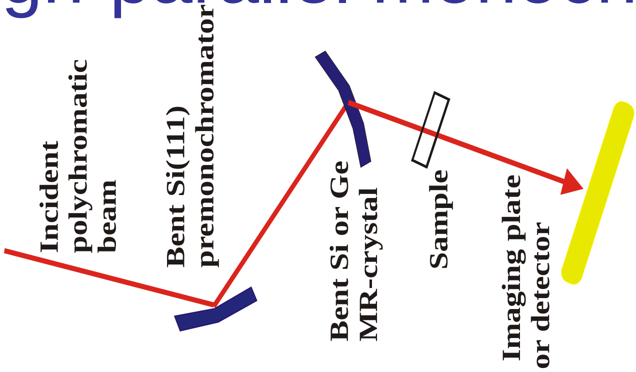
Prompt Gamma Activation Imaging (PGAI)

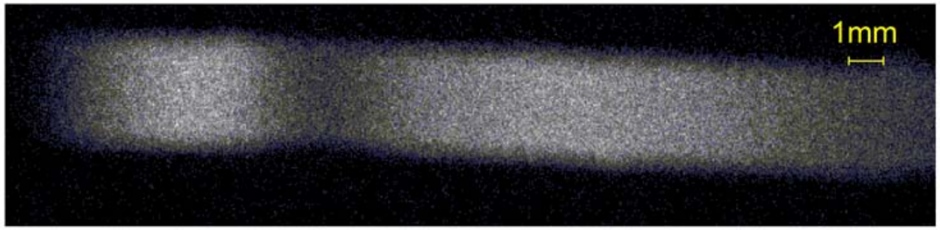




MTA EK

High-parallel monochromatic beam





Task 6

NPI

NPI

The JRA Imaging combines neutron experimental techniques in the direct and the reciprocal space in order to resolve structural and magnetic features on different length scales.