Polarized Neutrons JRA

Alexander Ioffe

Jülich Centre for Neutron Science - Outstation Garching
IFF, Forschungszentrum Jülich, Germany

JRA presentations
General Assembly
Villigen, CH
2009, March 31

Polarized Neutrons JRA

Partners:

LLB	CEA-LLB Sacley
TUW	Technical University - Atominstitut Wien
TUD	Technical University Delft
TUM	Technical University München – FRM II
DTU	Denmark Technical University
PNPI	St.Petersburg Nuclear Physics Institute
FZJ	Forschungszentrum Jülich - JCNS

Observers: ISIS, SNS, ANSTO, ILL, HZB, RWTH Aachen, Hinchu University Taiwan, J-PARC, JAERI, …

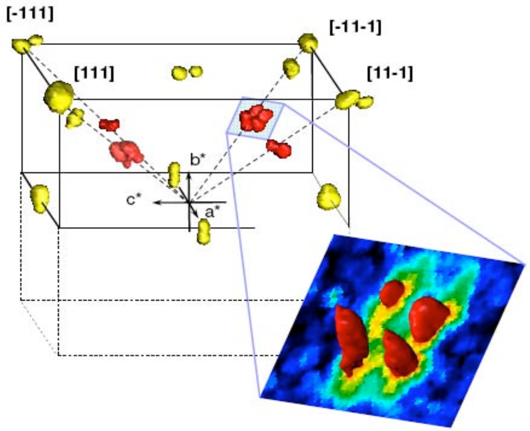
Objectives

- 1. To develop and to make commonly available the wide-angle polarization analysis for neutron diffraction/spectroscopy.

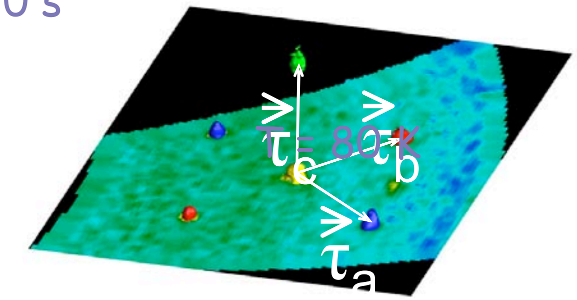
The wide-angle polarization analysis for neutron diffraction and spectroscopy

Large solid angle detectors require <u>large solid angle neutron polarimetry</u> - simultaneous data acquisition over a wide Q-range (IN5, IN6, TOF-TOF, ISIS spectrometers)

BiFe03 crystal:
V= 0.08 mm^3



Eu film: thickness - 75 nm
Image frame: 60 s



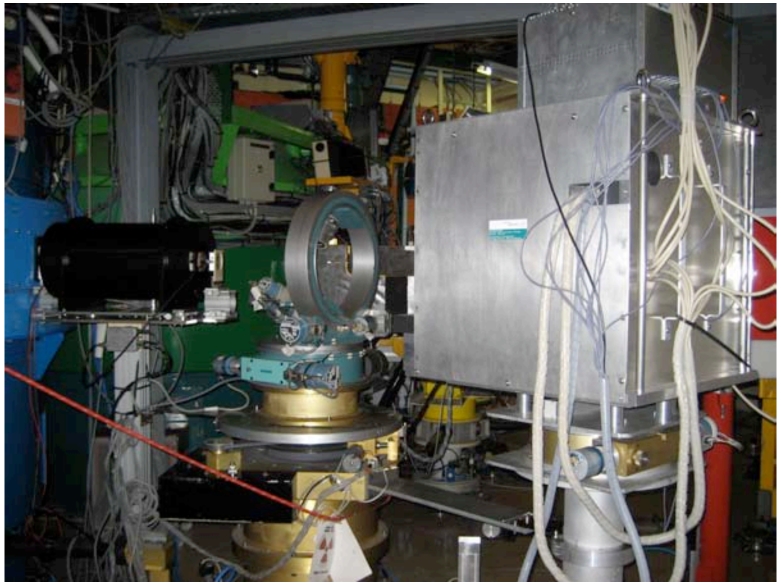
- an enormous gain in the efficiency of neutron polarimetric experiments
- new horizons for detailed understanding of the mechanisms involved in:
  - mutiferroic compounds,
  - photo induced magnets
  - molecular magnets,
  - magnetic nanostructures,
  - spin electronics
  - new superconductors

- the forefront of condensed matter research!

LLB, FZJ, DTU, PNPI

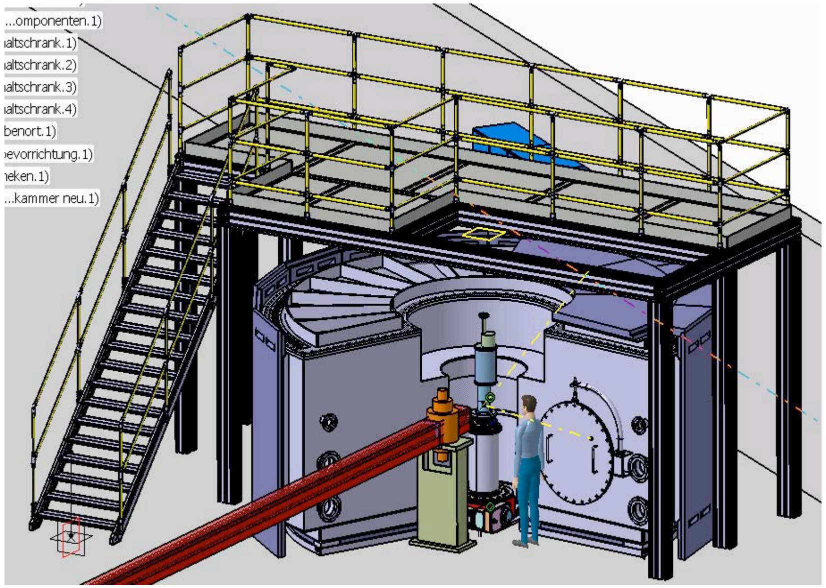
The wide-angle polarization analysis for neutron diffraction and spectroscopy

LLB: Super-6T2 diffractometer with a wide-angle analyzer:



Angular coverage ~20x20°: supermirror radial polarizing bender or He3 spin filter?

JCNS thermal neutron spectrometer TOPAS (E<150meV):



Angular coverage ~40x240°: No choice, only 3He!

The wide-angle polarization analysis for neutron diffraction and spectroscopy

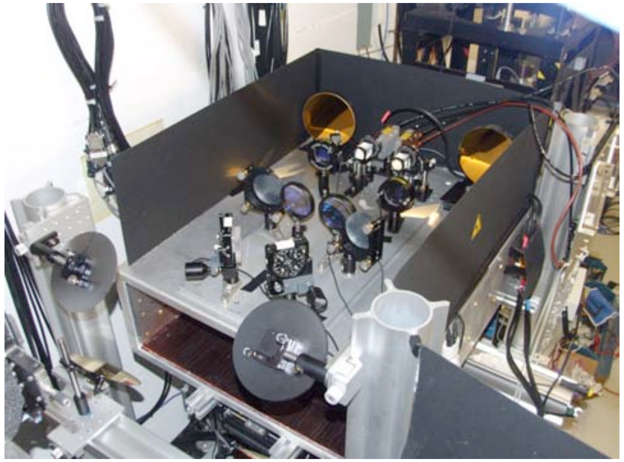
Neutron spin filters in a closed vicinity of magnets:

A bad environment for the polarized ^{3}He because of the induced magnetic field inhomogeneities (result in the lower life time)

Solutions:

- adaptive magnetic systems for field corrections
- on-beam optical pumping to compensate for quicker relaxation

A possible prototype: in-situ system built at ILL and tested at ISIS under NMI3 FP6 collaboration.



Objectives

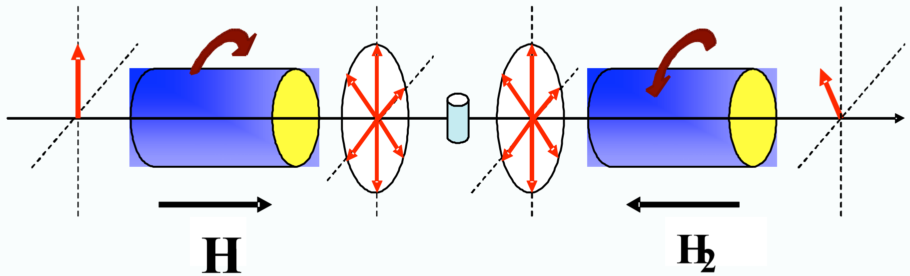
- 1. To develop and to make commonly available the wide-angle polarization analysis for neutron diffraction/spectroscopy.

- 2. To extend possibilities of methods of Larmor labelling towards higher energy and momentum resolution.

Larmor labeling: towards higher energy and momentum resolution.

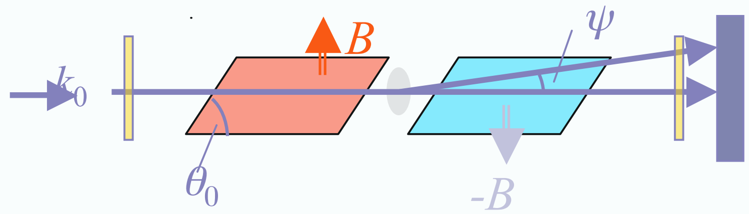
The Larmor labelling of individual neutrons allows the development of “unusual” neutron scattering techniques.

Larmor clocks: go forward before and go back after the sample.



$$\Delta\varphi = \omega_L L \frac{\Delta v_n}{v_n} \propto \Delta E$$

Direct measurements of ΔE



$$\Delta\varphi = \omega_L \frac{L\cot(\theta_0)}{v_n}\psi$$

Direct measurements of ψ

An extremely high energy (momentum) resolution that is not possible in conventional neutron spectroscopy (diffraction) because of intolerable intensity losses, become achievable.

Larmor labeling: towards higher energy and momentum resolution.

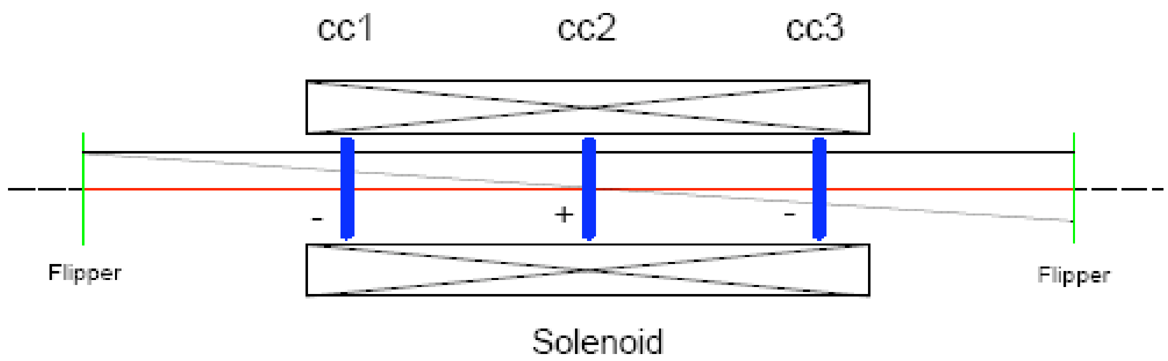
However, to achieve such high resolution one should equalize the magnetic field integral in the precession area up to 10^{-6} .

⇒ correction elements

Example:

A very high resolution NSE instruments –

the achievable neutron spin-echo time beyond 1 μs.



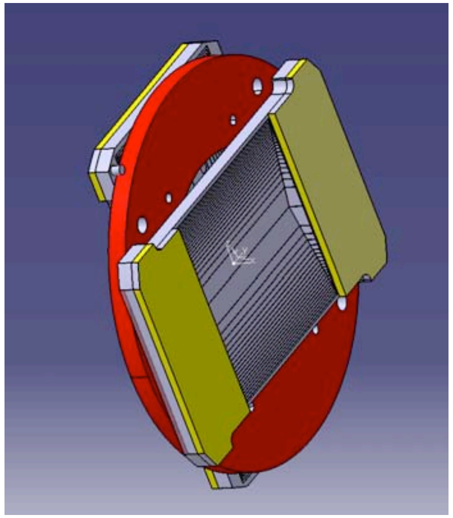
FZJ, TUD

Correction elements

“Phythargoras coils”

$$\Delta J = A\,x^2 + A\,y^2 = A\,r^2$$

(B. Farago, G. Kali, FP6 NMI3)

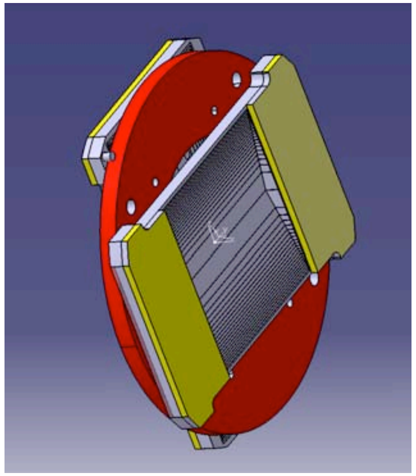


used at IN15 (ILL) and J-NSE (JCNS)

Requirements to correction elements:

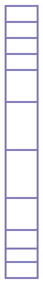
1. High accuracy of correction (10^{-3})
2. Good neutron transmission/low scattering
3. Large effect=high current density

Correction elements



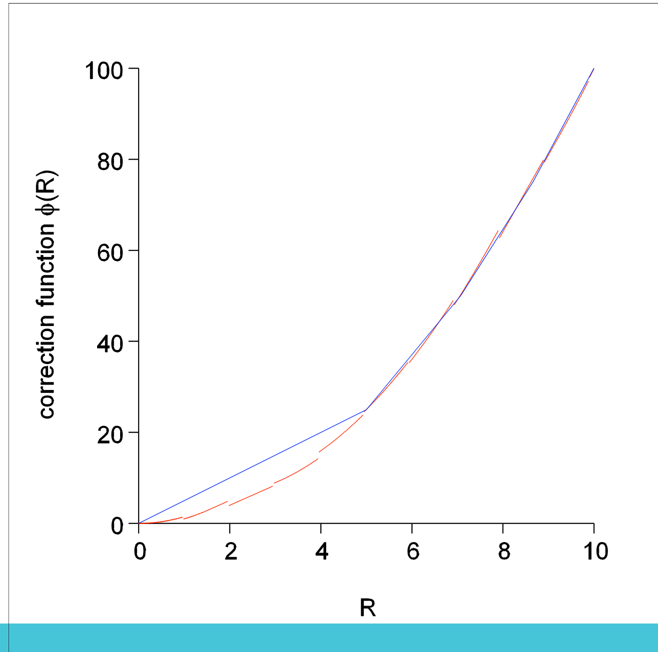
<u>Development tasks:</u>

- better approach to true r^2
- better transmission
- larger area (effect ~ n * l)



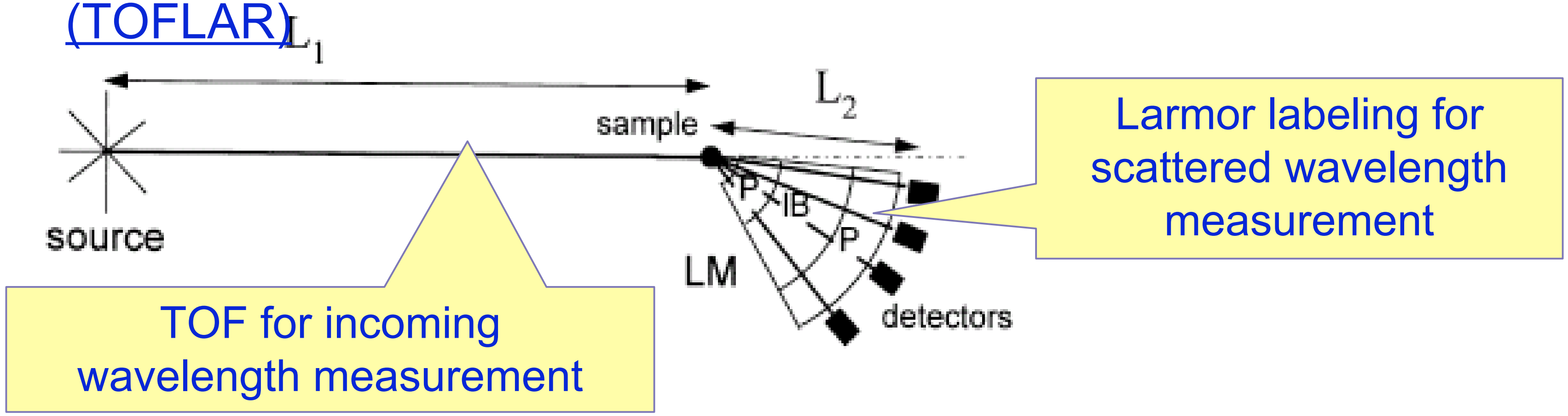
shaping of zones and control of gap effects

Wedge shape → ideal x^2



Larmor labeling for inelastic neutron scattering

Combination of time-of-flight and Larmor beam modulation (TOFLAR)



No monochromatization of neither incoming nor scattered beam: the incoming wavelength is calculated from the TOF and Larmor results

- a very significant flux gain
- large Q, ω range
- very flexible energy resolution

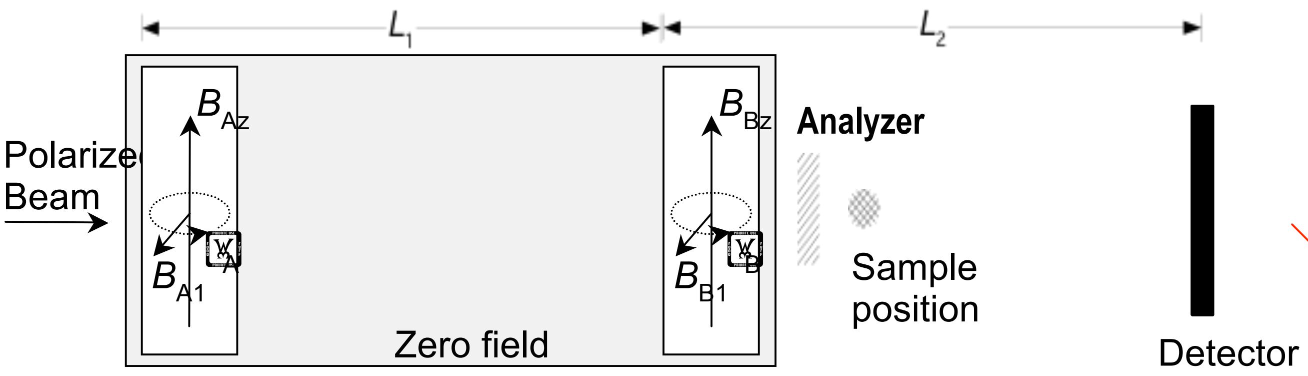
Combination with Mieze will be also investigated

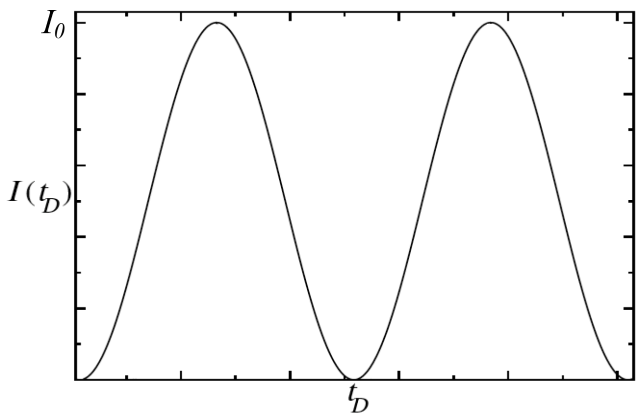
TUD, FZJ

Larmor labeling for quasielastic neutron scattering

MIEZE technique: two RF flippers operating at different frequencies; the polarization analyser <u>before</u> the sample

NSE type measurements in magnetic fields and complicated sample environments.



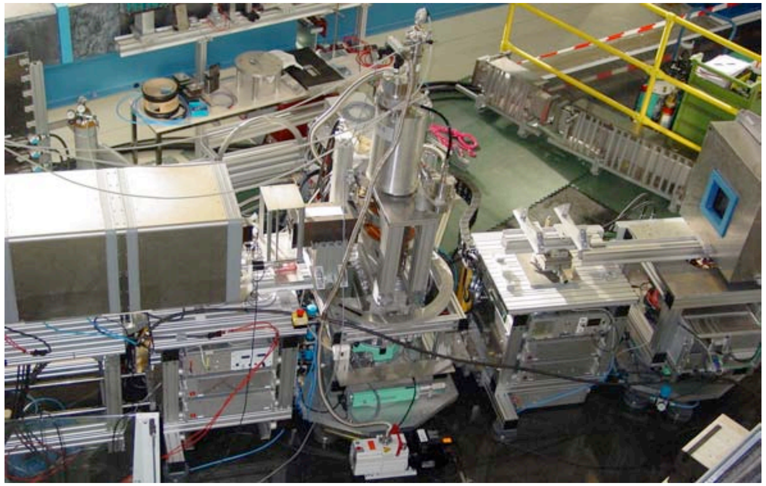


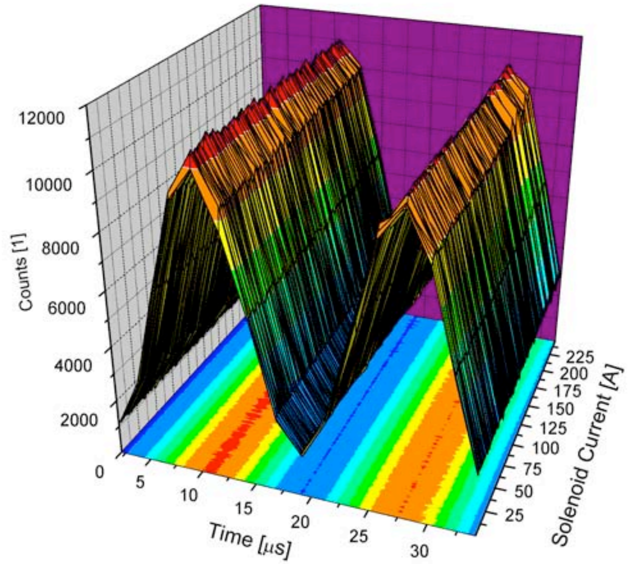
At focusing point $$\frac{L_1}{L_2 - D/2} + 1 = \frac{\omega_B}{\omega_A}$$

intensity oscillates with frequency (ω_A-ω_B)

SANS and reflectometry with MIEZE

Simultaneous operation of a magnetic sample environment and a spin-echo method without signal loss.





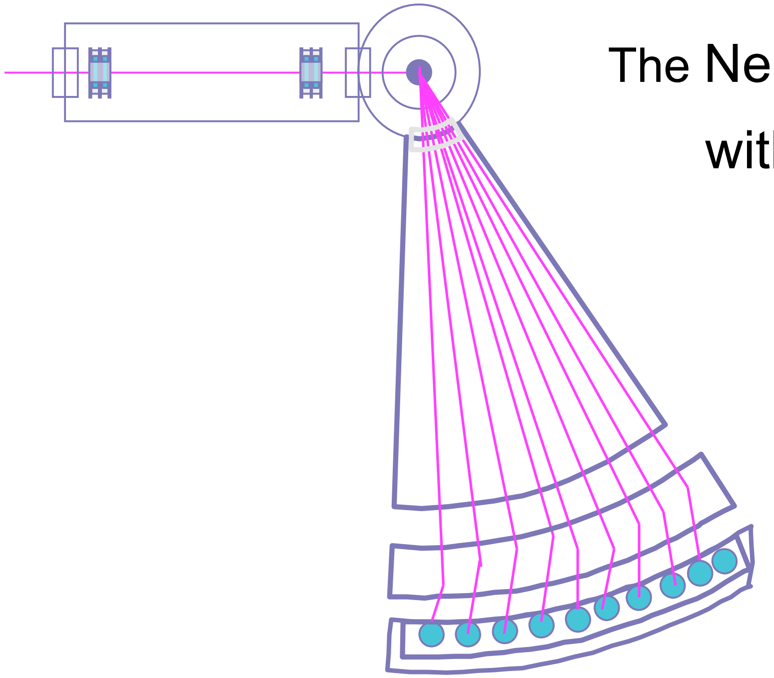
⇒ NSE type measurements in magnetic fields and complicated sample environments.

We will combine the MIEZE principle with the SANS and reflectometry:

⇒ inelastic and spatially resolved inelastic measurements at very small momentum transfer.

FZJ, TUD, TUM

Wide-angle neutron resonance spin-echo

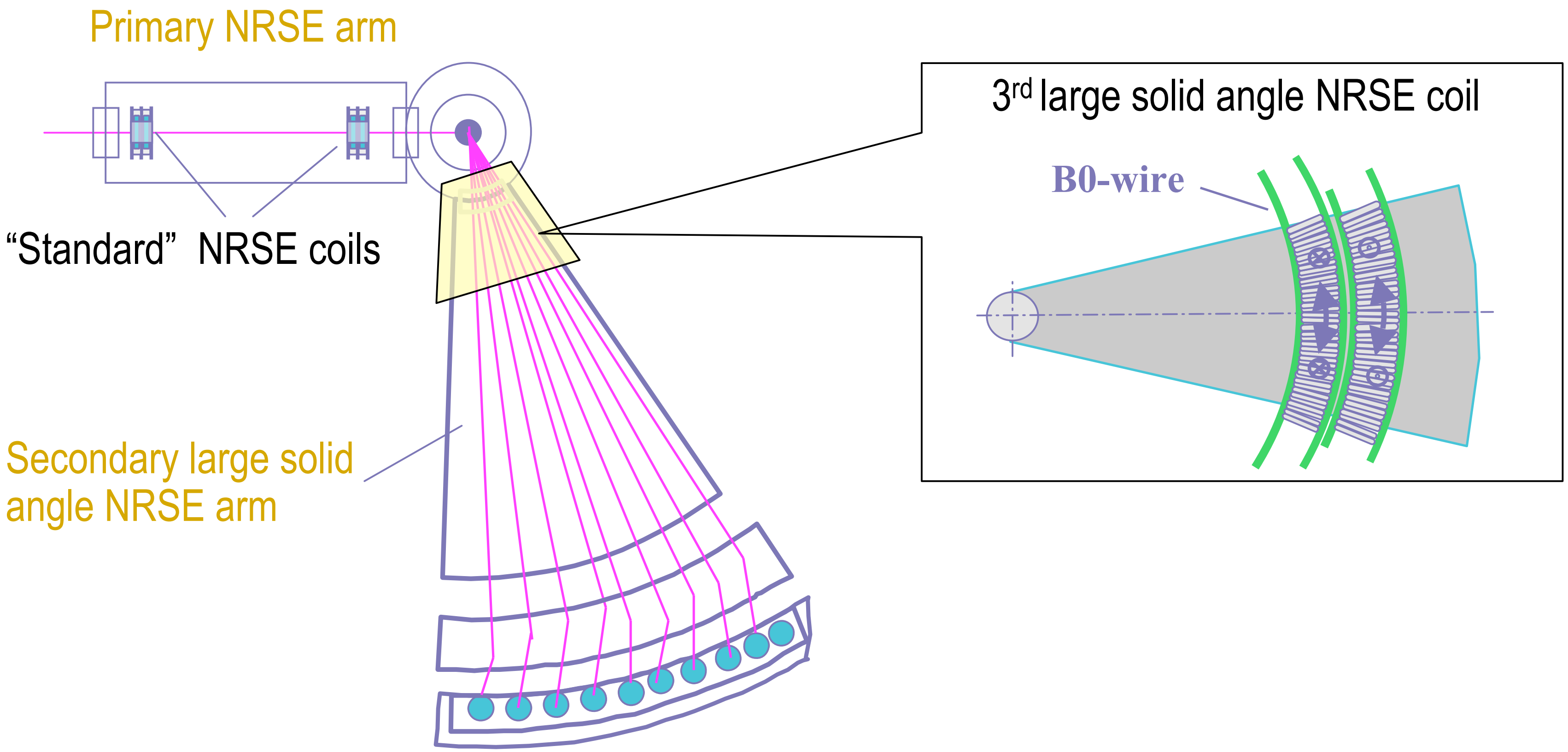


The Neutron Resonance Spin Echo (NRSE) technique
with a multi-detector secondary spectrometer.

We will develop large solid angle NRSE coils allowing for the parallel data acquisition in a wide Q-range and thus resulting in a tremendous gain in the data acquisition rate.

TUM, LLB, DTU

Wide-angle neutron resonance spin-echo



Two alternatives for the 4*th* flipper:

- NRSE: new compact NRSE coils, fixed next to each other
- MIEZE II-principle: without 4th NRSE coil ⇒only short conical shielding needed

Developments of new polarized neutron techniques

- **Ultra-Small-Angle Polarized Neutron Scattering (USANSPOL)**

- **Development of an ultra-flexible neutron magnetic resonator**

  Drabkin-type neutron magnetic resonator allowing for an almost instantaneous variation of key parameters, as incident and final neutron energy, spectral width of incoming beam, energy resolution, etc. by purely electronic means.

- **Polarized neutron technique for measurements of three/many point correlation functions**

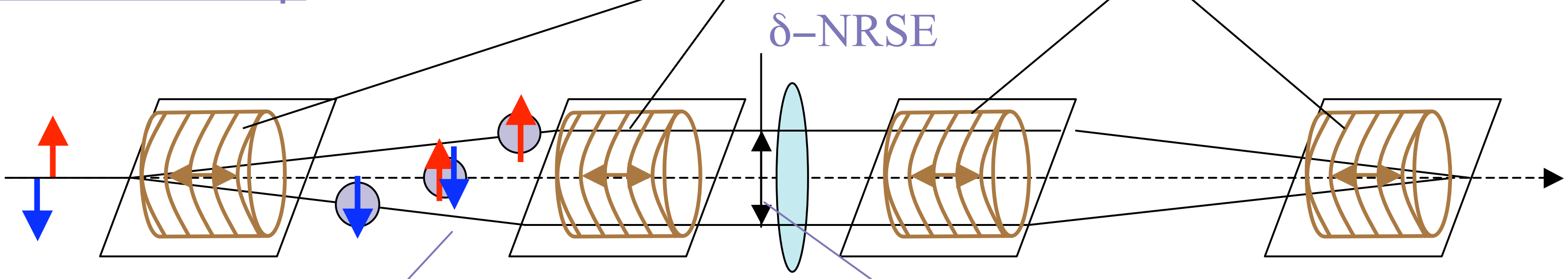
  Development of the principle of the method for measurements of the three-point correlation function (CF).

ATI, FZJ, TUD, PNPI

Measurements of three/many point correlation functions

RF coils with the spin-flip probabilities of ½ split neutron wave in four parts

SESANS setup



These four neutron waves produce phase shifts corresponding to three different distances

Indeed, these neutron waves probe the sample simultaneously on three length scales.

Objectives

- **1. To develop and to make commonly available the wide-angle polarization analysis for neutron diffraction/spectroscopy.**

- **2. To extend possibilities of methods of Larmor labelling towards higher energy and momentum resolution.**

- **3. To broad the user base of polarized neutron scattering by an extensive education and training program.**

  We will continue the proven to be successful practice of the organization schools and workshops on polarized neutron scattering