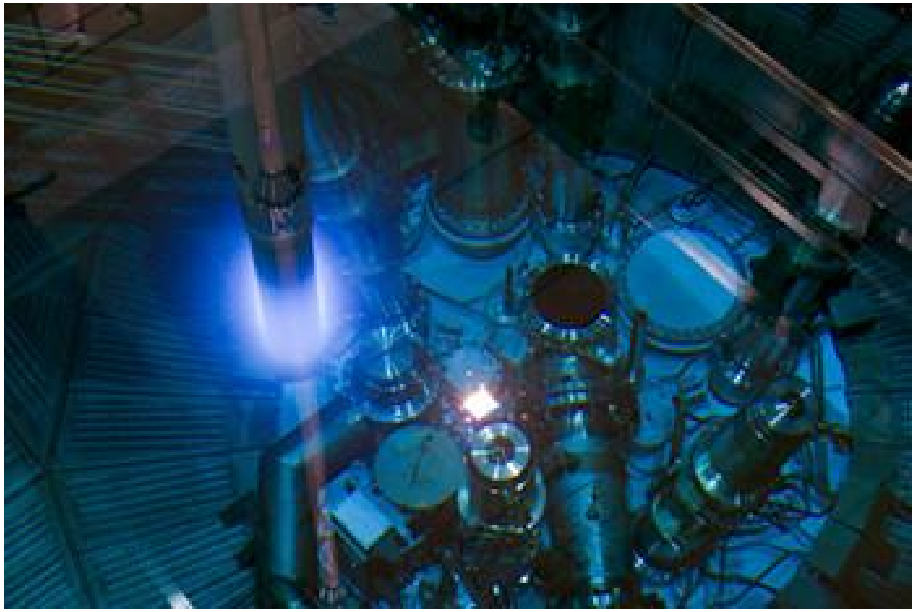
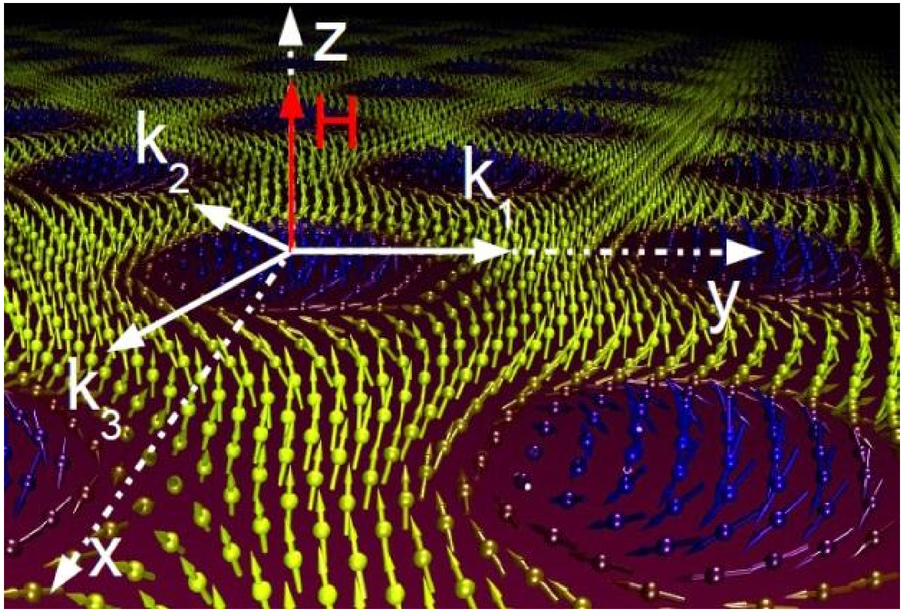
FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

MLZ
Heinz Maier-Leibnitz Zentrum

Physics with Neutrons I, WS 2015/2016





Lecture 3, 2.11.2015

MLZ is a cooperation between:

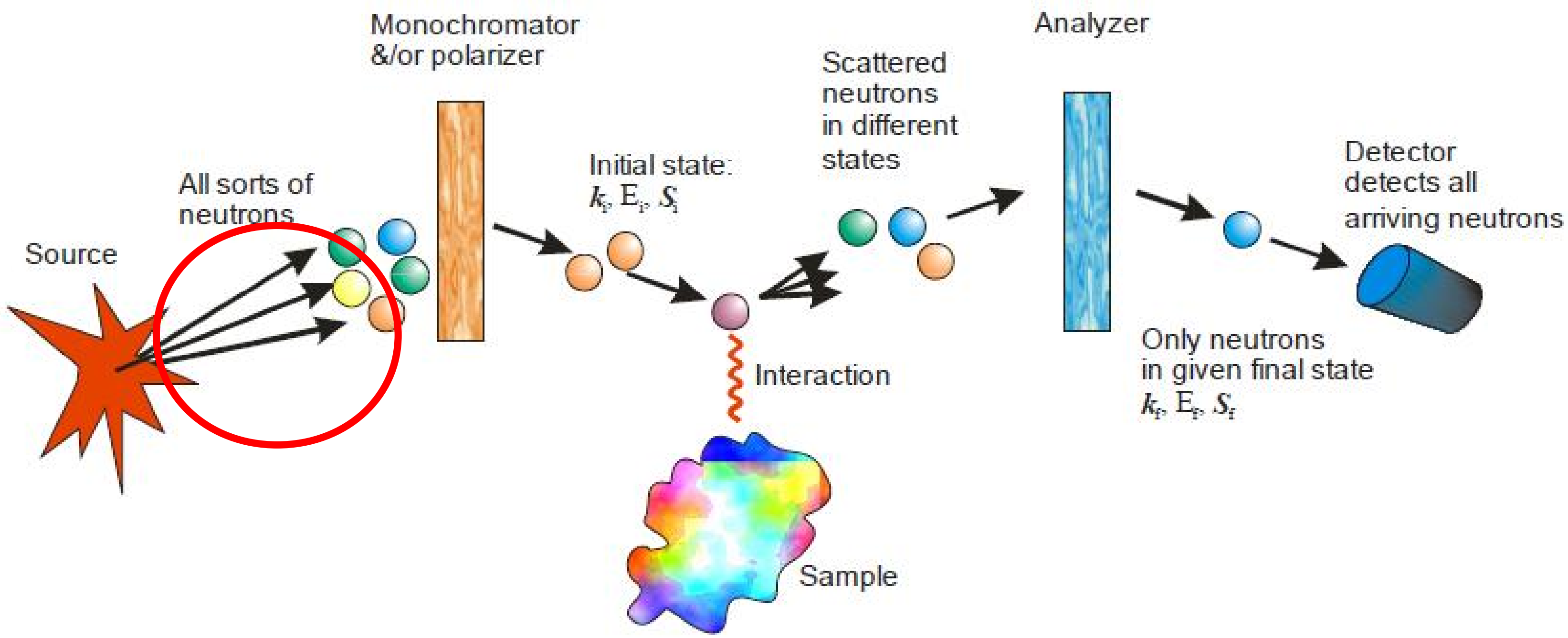
JÜLICH FORSCHUNGSZENTRUM

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

TUM
Technische Universität München

Essence of a neutron scattering experiment (again)

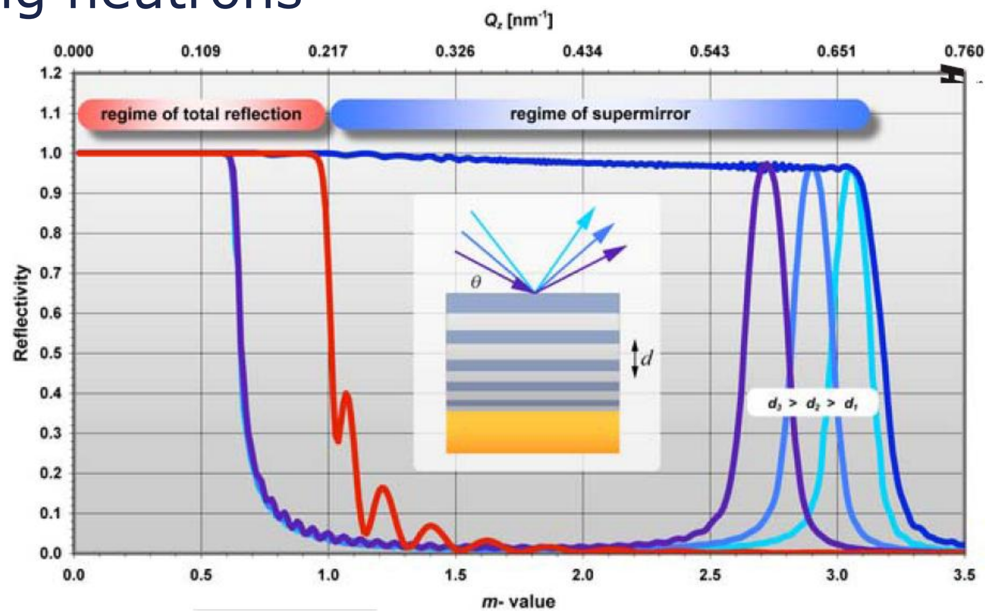
Fundamental principle of a neutron scattering experiment



⇒ Transporting the neutrons

2.6. Overview on neutron instrumentation – elements of neutron instruments

Transporting neutrons



Regime of total reflection: $\Theta_c = \lambda \sqrt{\frac{\rho b}{\pi}}$

Regime of supermirror: $Q = \frac{4\pi}{\lambda} \sin(\Theta)$

Material constant, for ^{58}Ni $\Theta_c[°] = \lambda + 0.1[Å]$

➡ QM-reflection at potential step

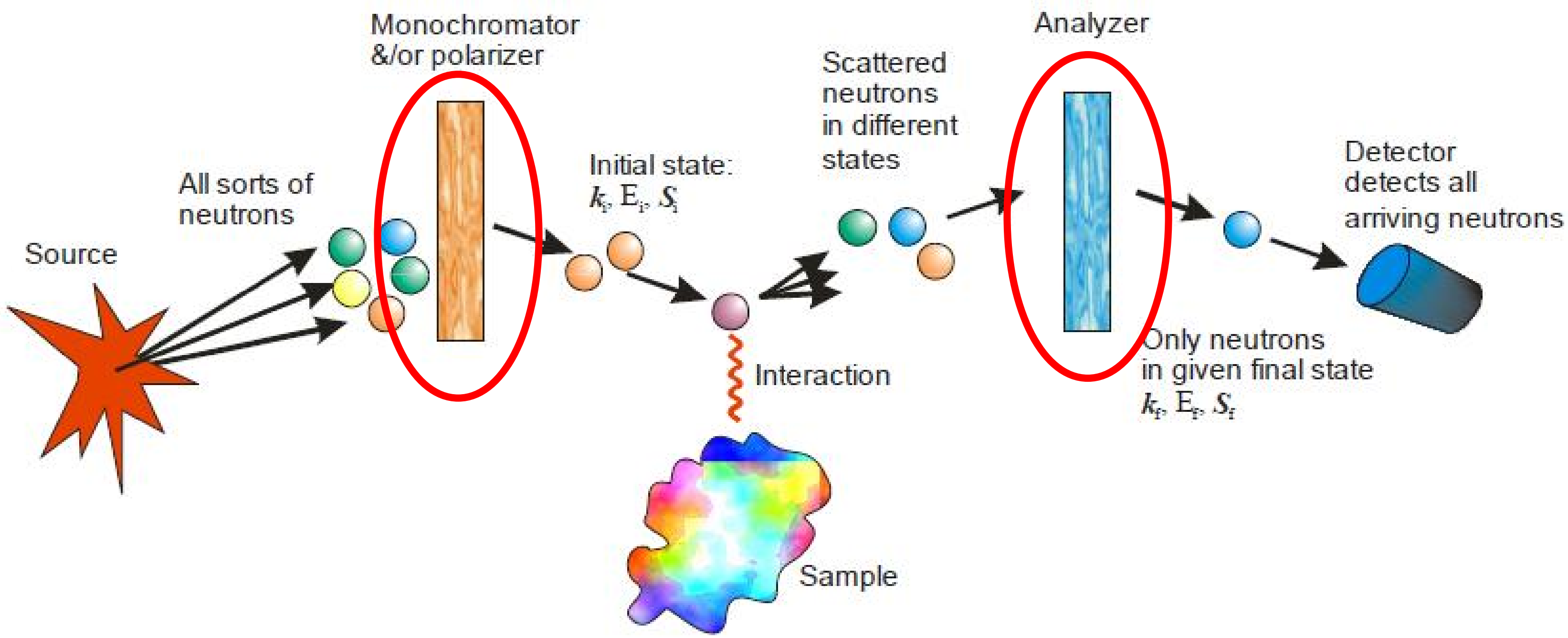
➡ Bragg reflection at 1-D artificial lattice (Ni/Ti)multilayer

Important for transport and focusing of neutron beams: ➡ Theorem of Liouville: Conservation of phase space

Neutron mirrors can have polarizing properties!

Essence of a neutron scattering experiment (again)

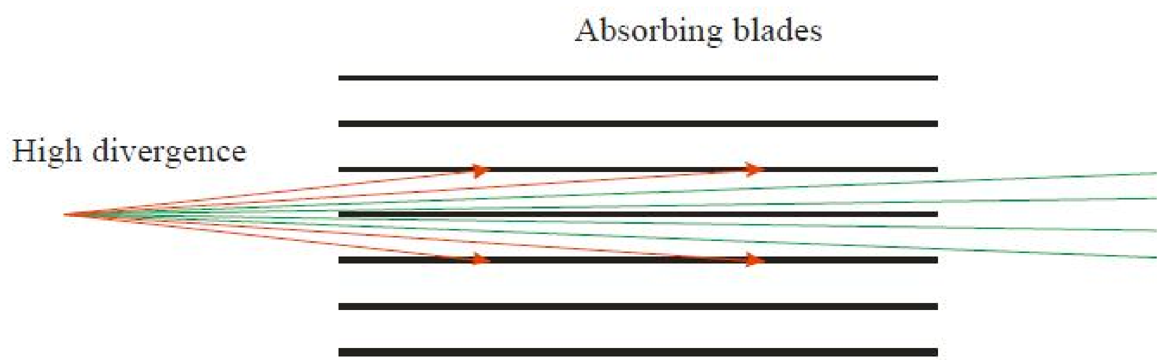
Fundamental principle of a neutron scattering experiment

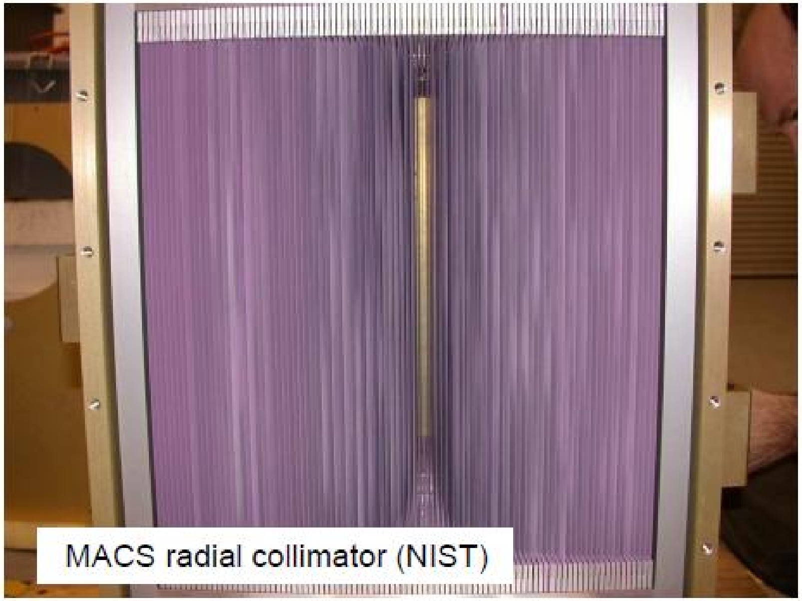


Defining the initial state of the neutron

2.6. Overview on neutron instrumentation – elements of neutron instruments

Defining the initial state of the neutron: Direction of $\boldsymbol{k}_i$

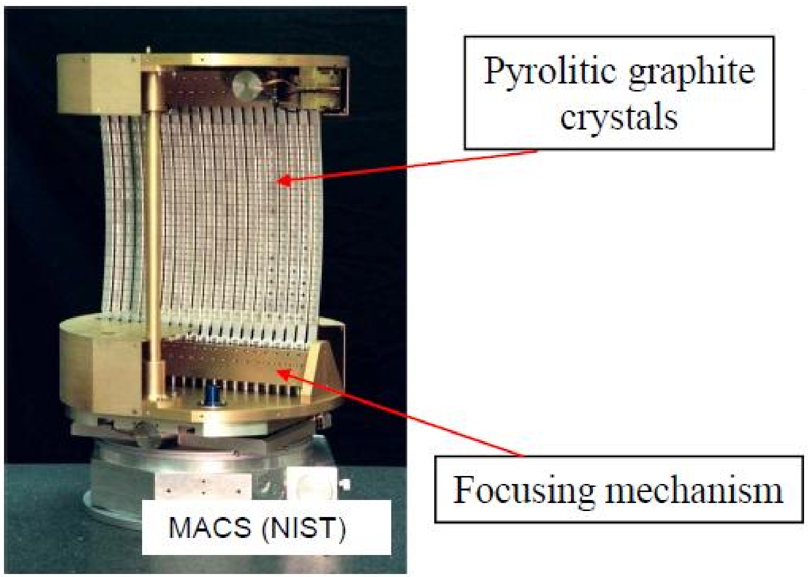




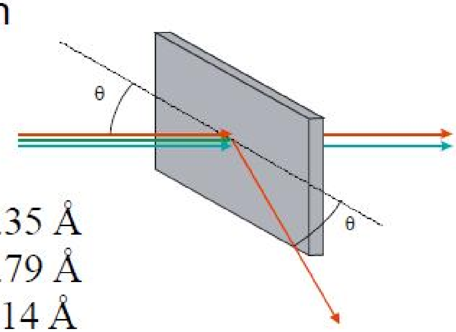
2.6. Overview on neutron instrumentation – elements of neutron instruments

Defining the initial state of the neutron: Wavelength/Energy

Single x-tal monochromator



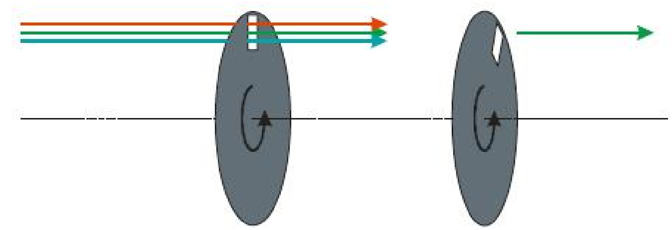
- Bragg reflection



PG(002) d=3.35 Å
Be d=1.79 Å
Si (111) d=3.14 Å
Mica (002) d=9.98Å

$$\lambda = 2d \sin\theta$$

Disc chopper systems

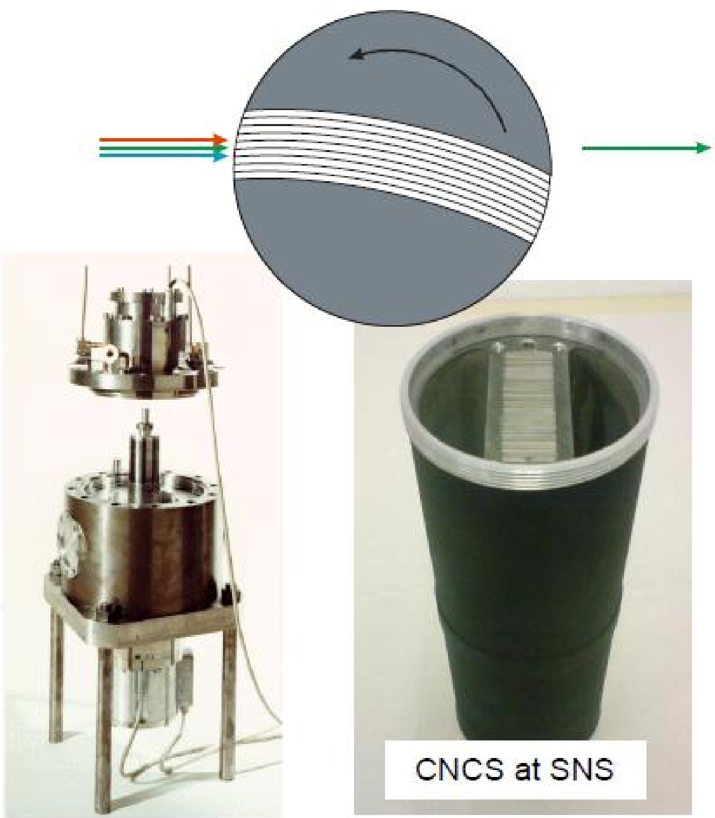


- Chopper advantages:
  - very flexible (resolution, line shape)
  - very efficient at pulsed sources
  - required for TOF experiments
  - can use Doppler effect
- Chopper drawbacks
  - wastes a lot of neutrons on cont. source
  - can not be used to polarize beam
  - does not angle the beam

2.6. Overview on neutron instrumentation – elements of neutron instruments

Defining the initial state of the neutron: Wavelength/Energy

Fermi Chopper – spinning collimator

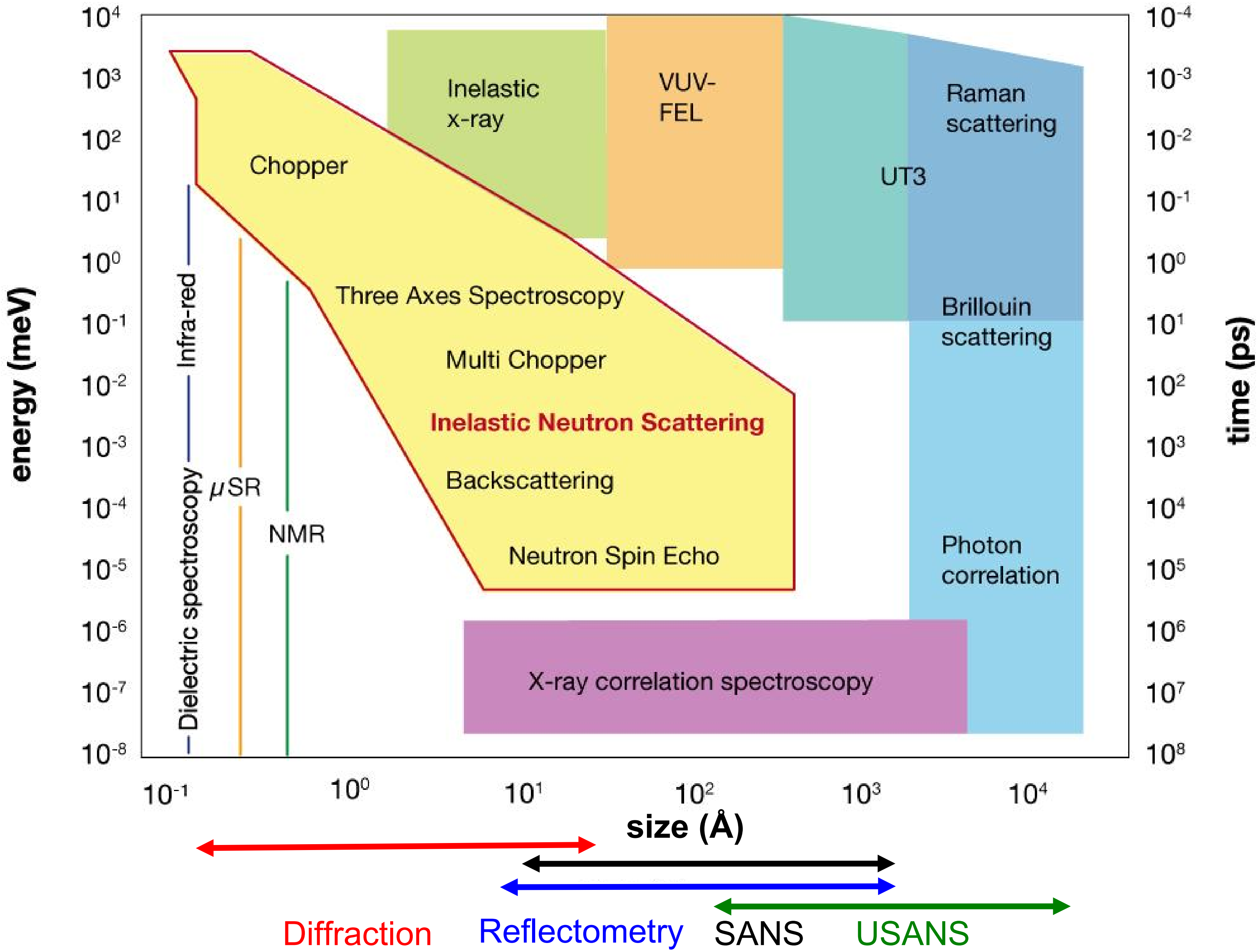


Rotating soller collimator
Used to shape neutron pulses
Pulsed beam with fixed wavelength spread

Mechanical velocity selector

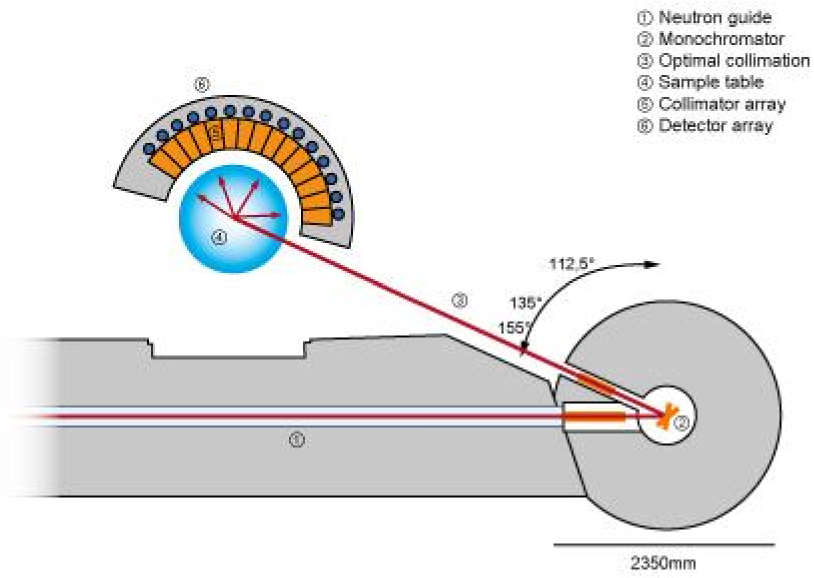
CRP lamellae coated with neutron absorber
High speed rotaion (approx. 27000rpm)
Wavelength adjusted by rotation speed
Continuous beam with fixed wavelength spread

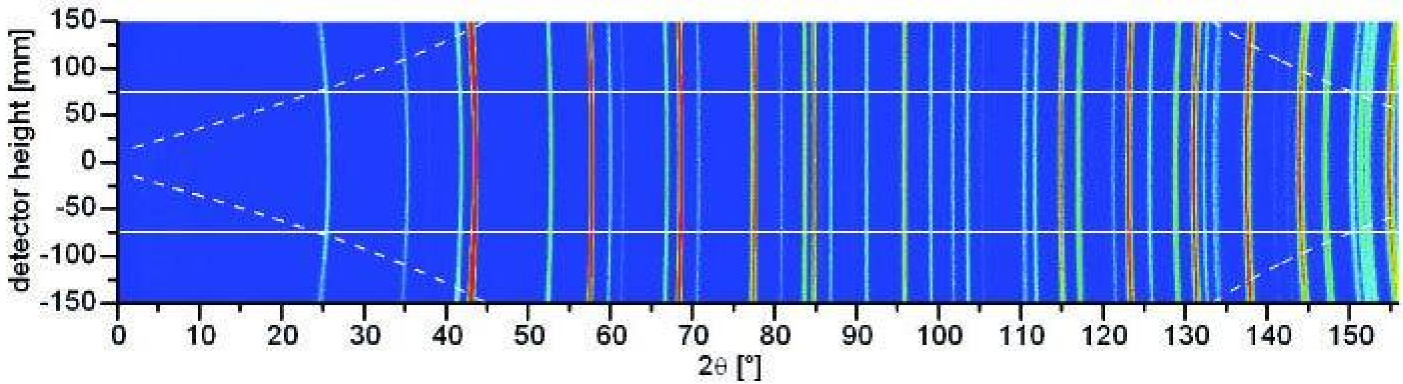
2.6. Overview on neutron instrumentation (Diffraction – elastic scattering)



2.6. Overview on neutron instrumentation (elastic scattering)

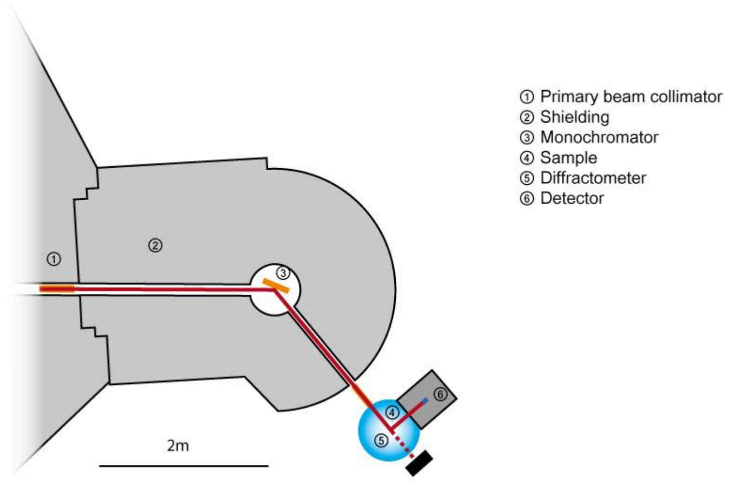
Powder diffraction (SPODI @ MLZ)

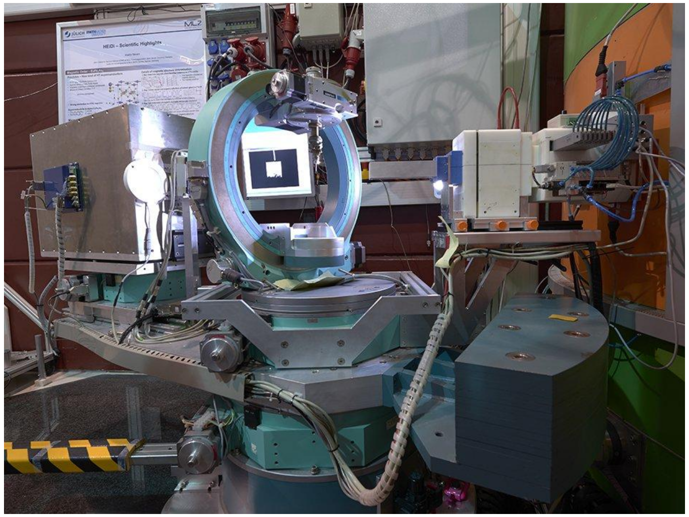




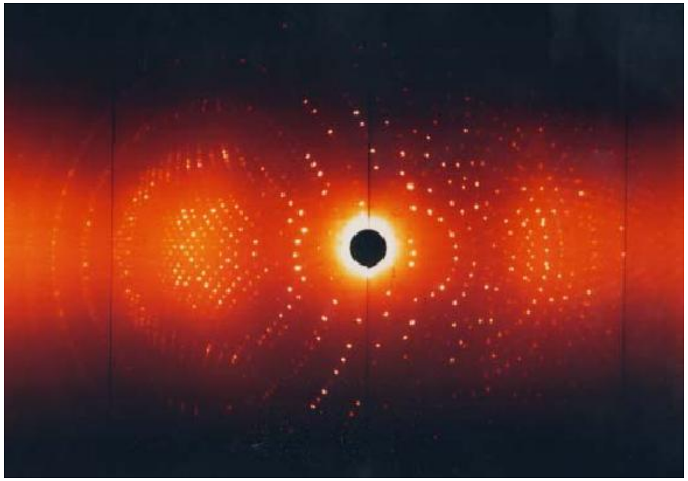
2.6. Overview on neutron instrumentation (elastic scattering)

Single X-tal diffraction (HEIDI @ MLZ)

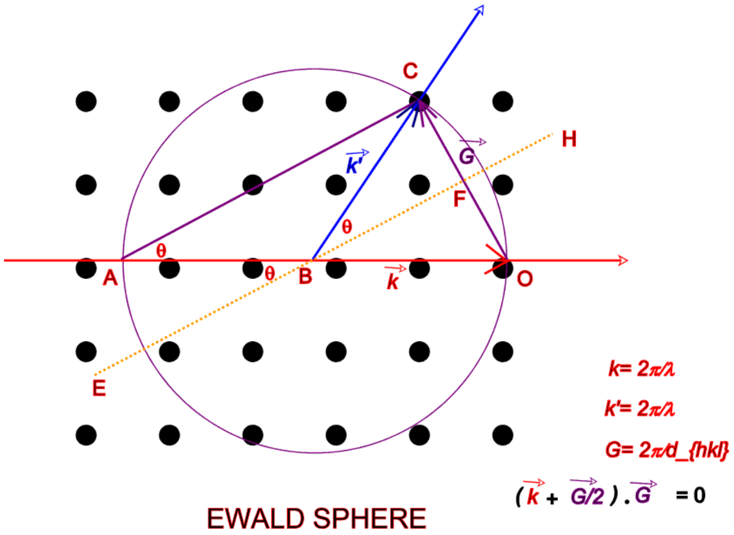




Laue method:

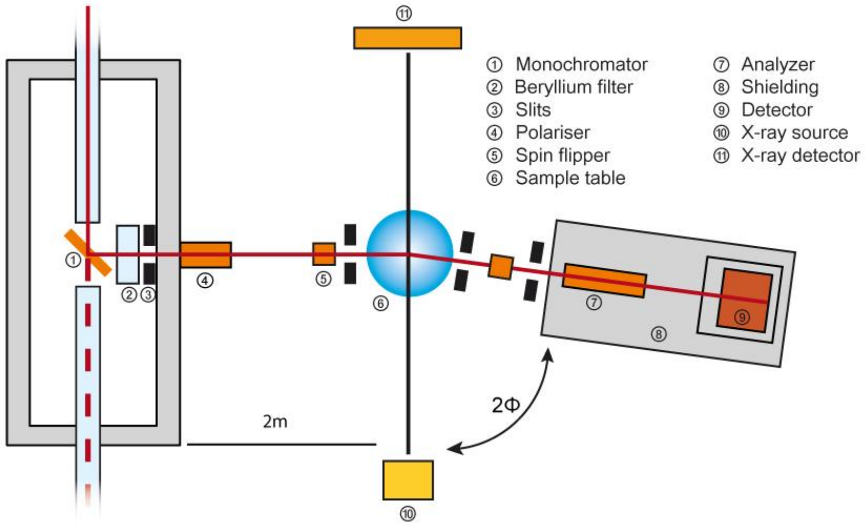


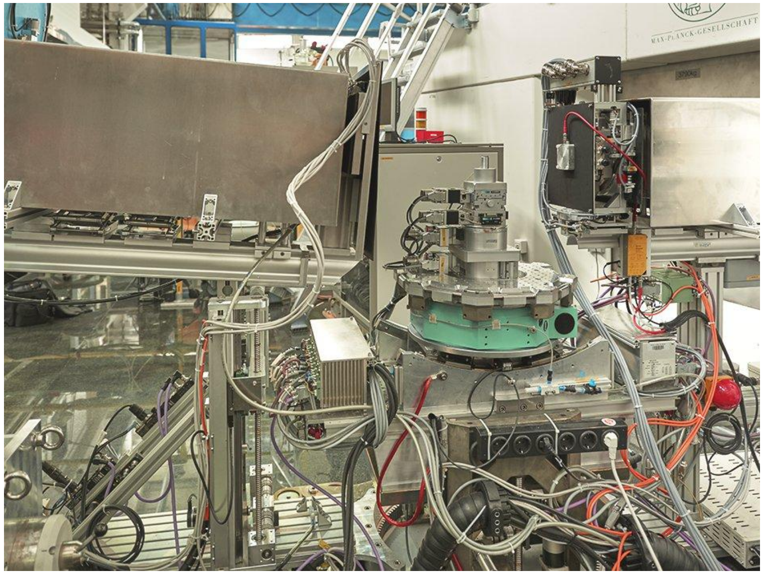
Θ/2Θ scans

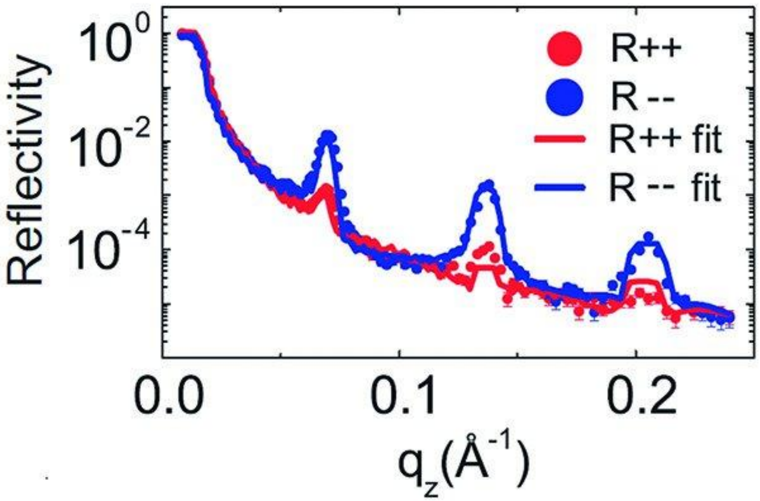


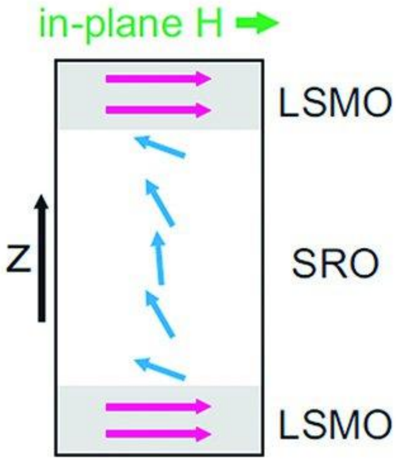
2.6. Overview on neutron instrumentation (elastic scattering)

Reflectometry (NREX @ MLZ)



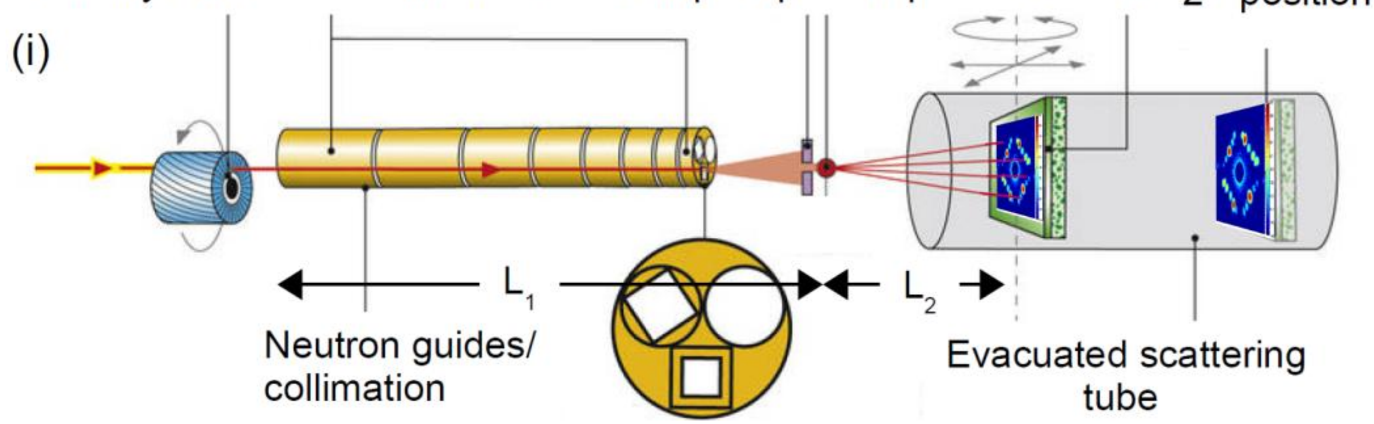


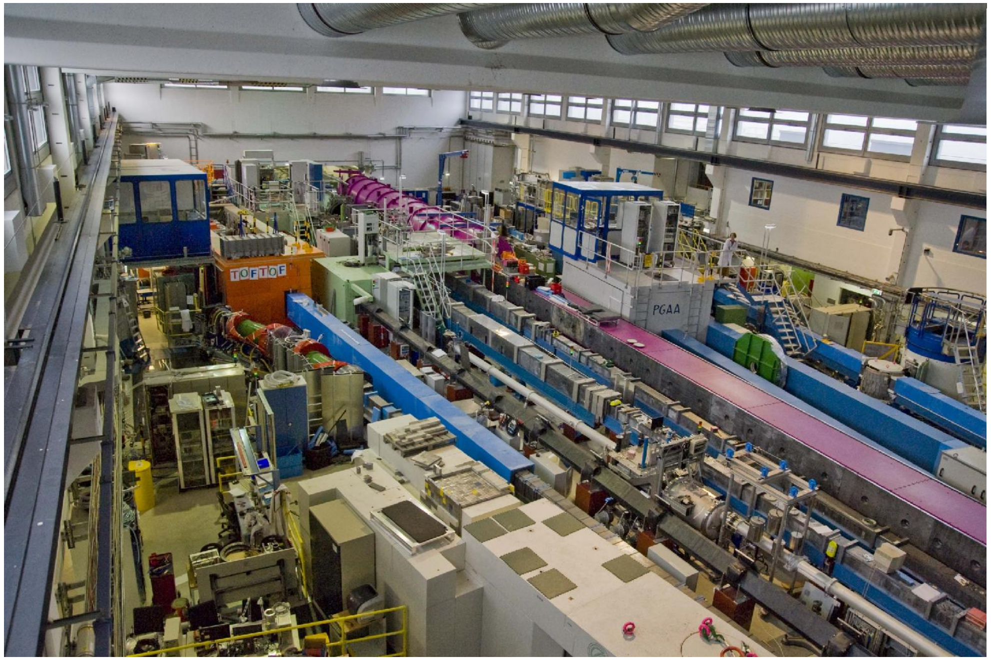


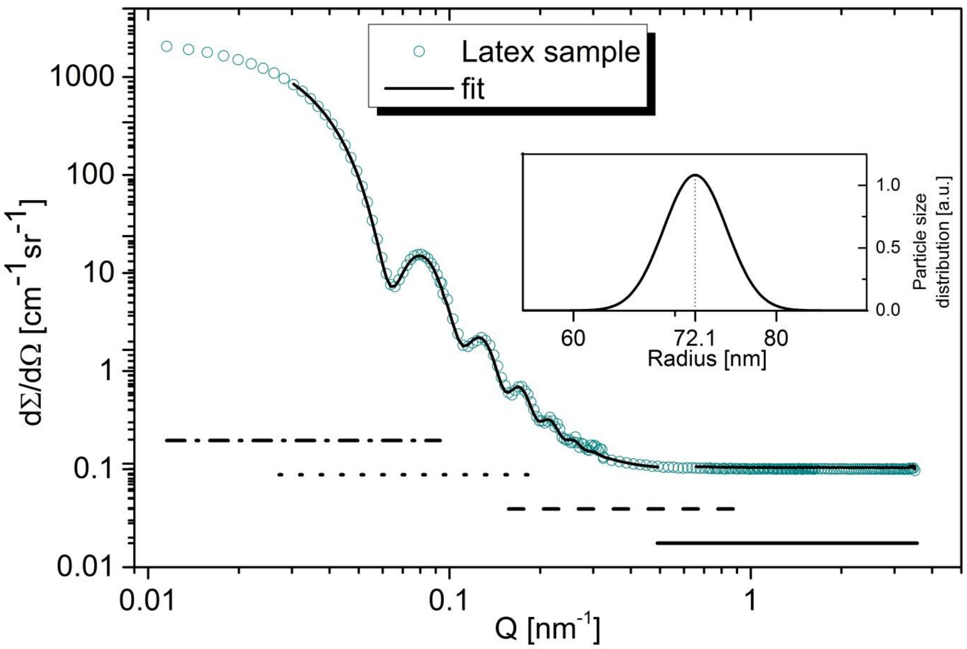


2.6. Overview on neutron instrumentation (elastic scattering)

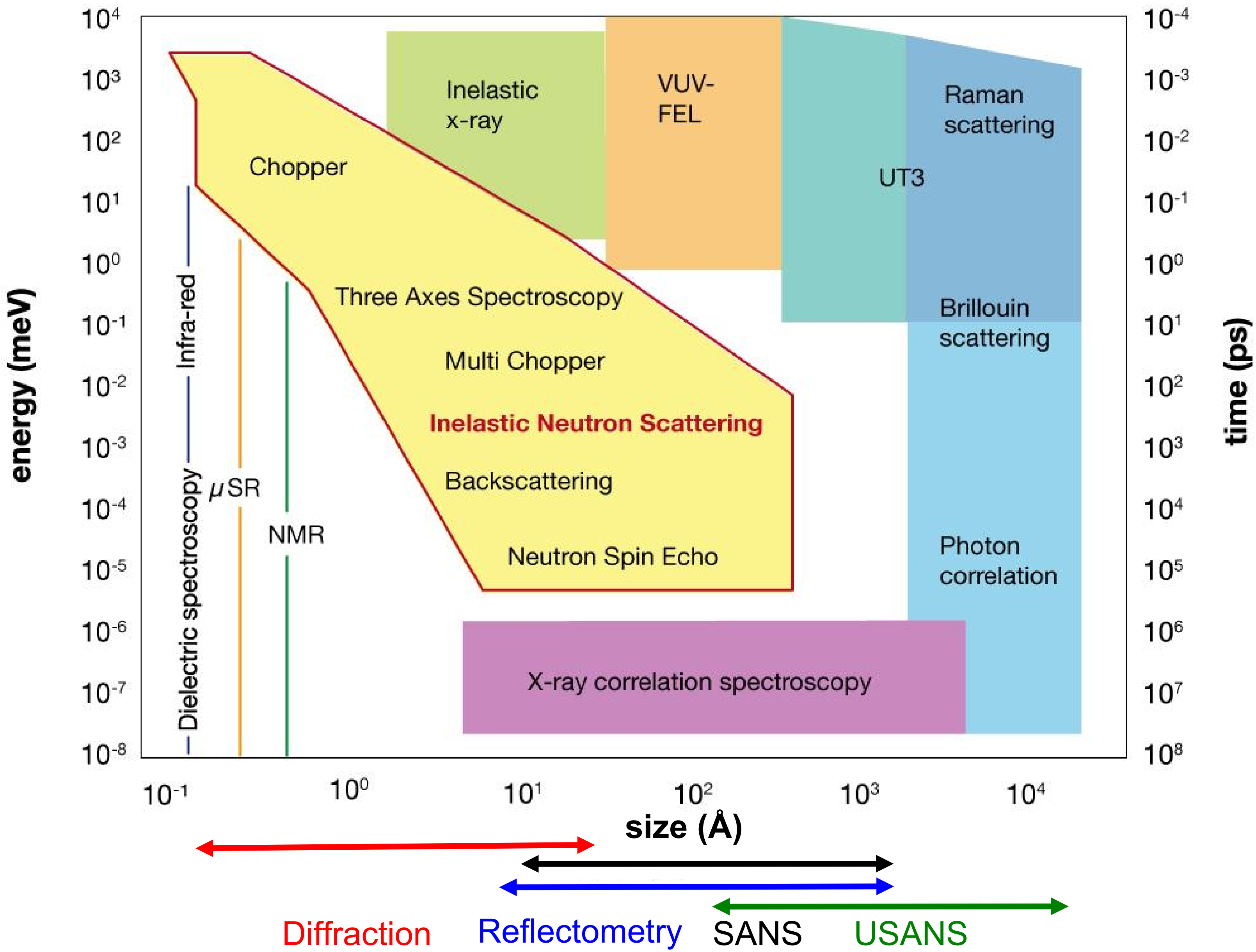
Small angle neutron scattering (SANS-1@ MLZ)





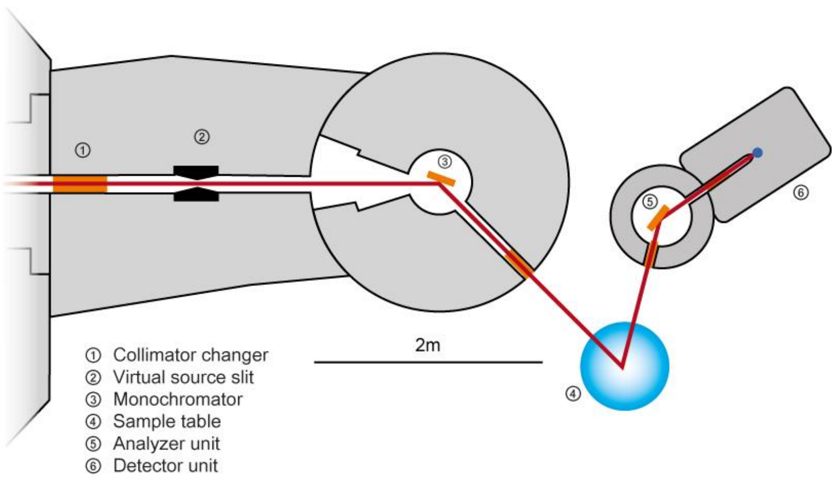


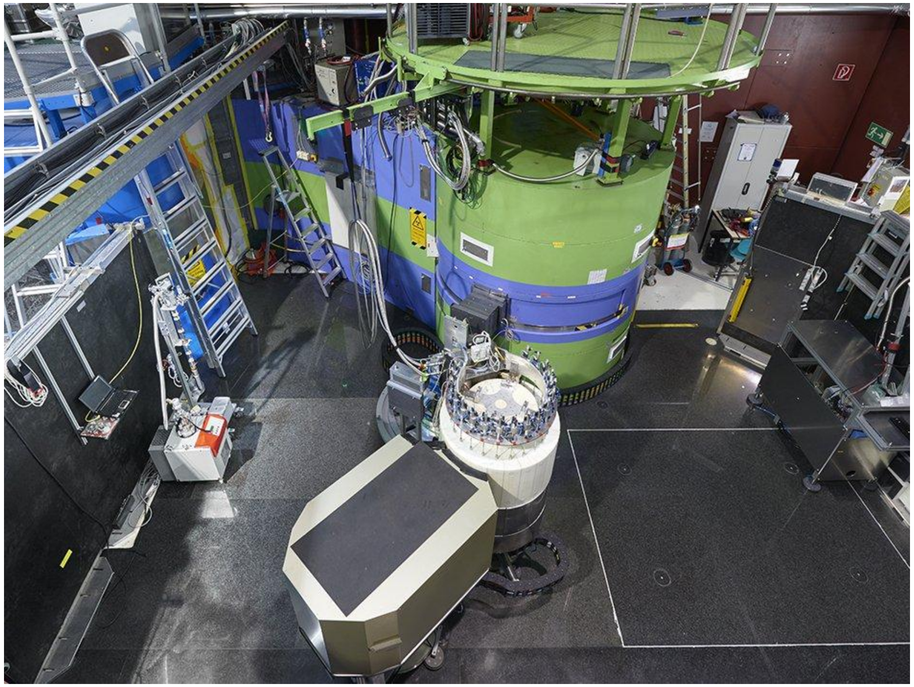
2.6. Overview on neutron instrumentation (Spectroscopy, inelastic)



2.6. Overview on neutron instrumentation (inelastic scattering)

(cold) Triple axis spectroscopy (PANDA/PUMA @ MLZ)





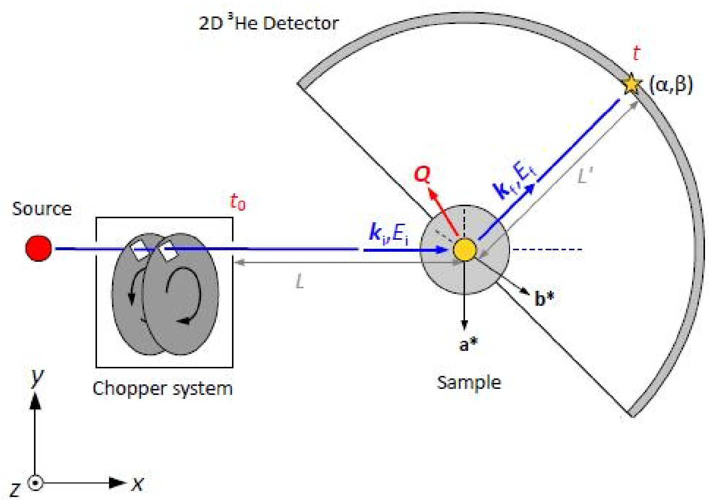
„Working horse" for phonons/magnons in magnetism/superconductivity
Clean data at a fixed point in momentum/energy space
Slow, wasting a lot of neutrons
Using cold neutrons

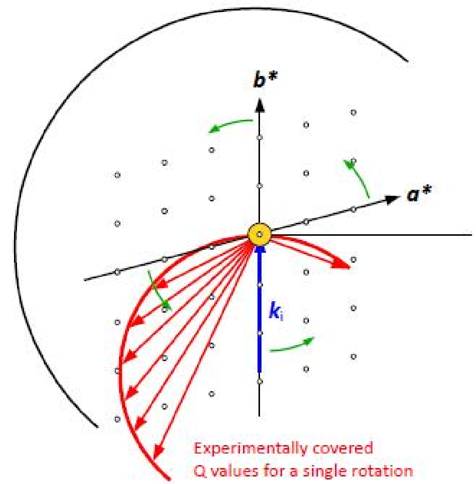
Cold TAS (PANDA)
Best energy resolution: 20μeV
Energy transfer <20meV
Momentum transfer <6Å^{-1}

Thermal TAS (PUMA)
Best energy resolution: 600μeV
Energy transfer <100meV
Momentum transfer <12Å^{-1}

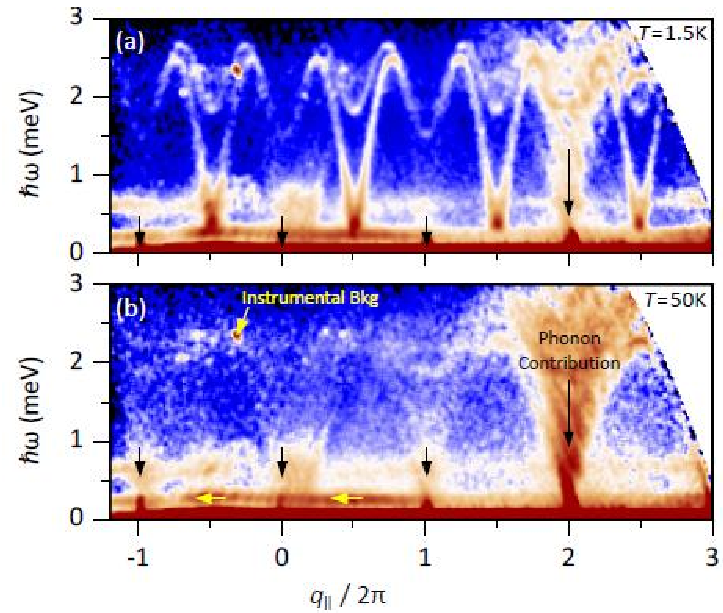
2.6. Overview on neutron instrumentation (inelastic scattering)

Time-of-flight (TOF) (LET @ ISIS)



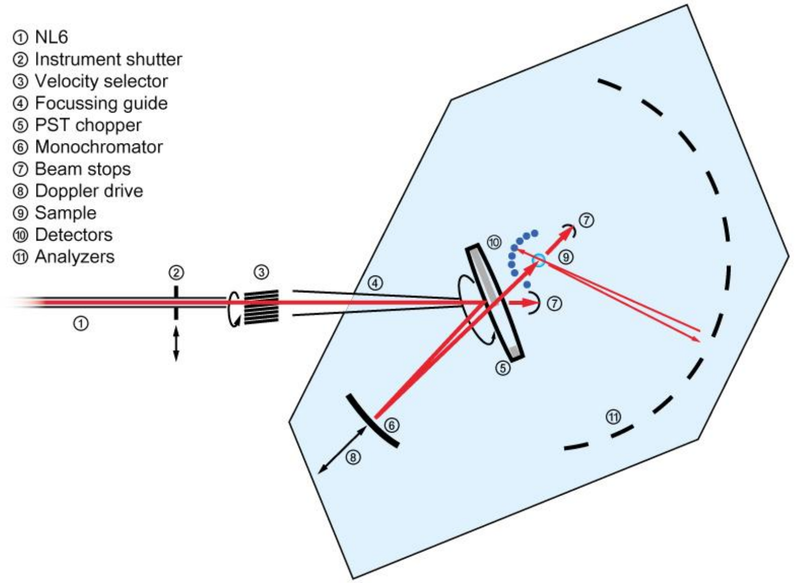


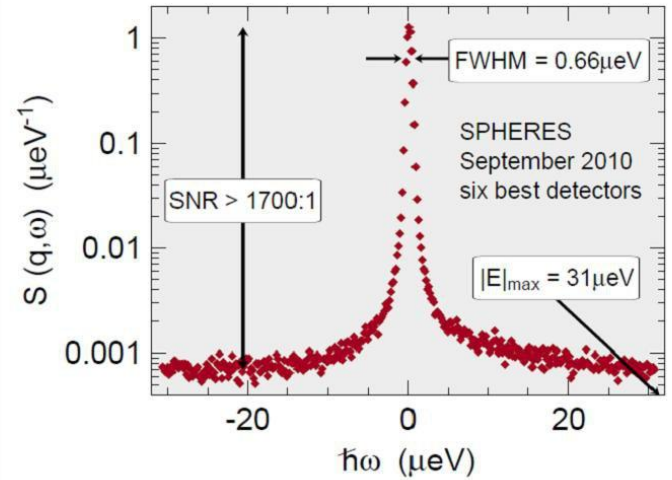
Perfect for diffuse excitations (low D magnetism, melts...)
Covers a large region of momentum/energy space simultaneously
Data treatment tricky
Fast measurements
Perfectly suited for pulsed neutron sources



2.6. Overview on neutron instrumentation (inelastic scattering)

Backscattering spectrometers (SPHERES @ MLZ)



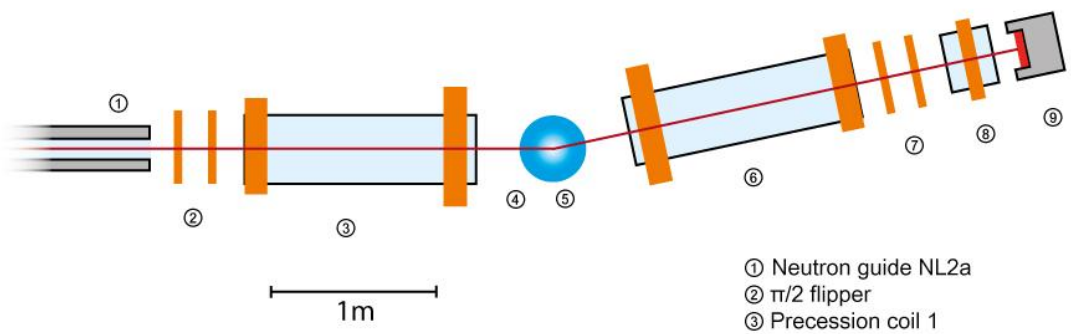


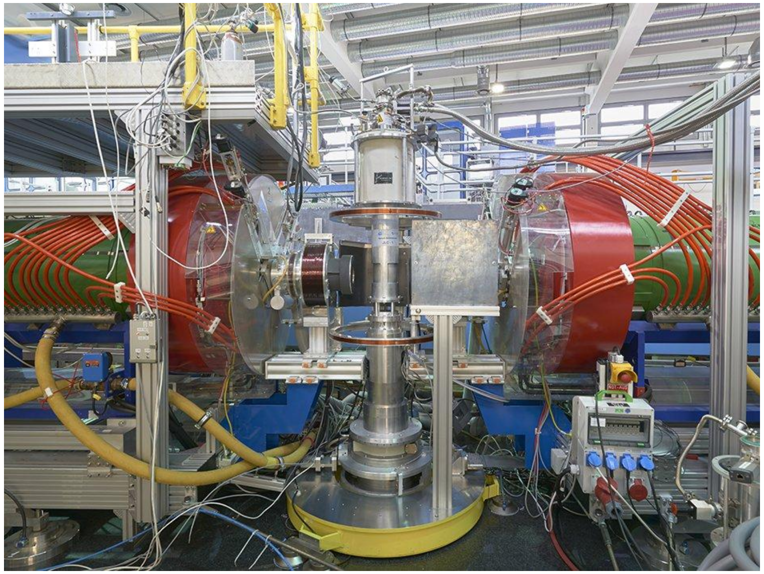
Backscattering for highest energy resolution
Nuclear and molecular dynamic on Ghz scale
(quasielastic scattering of water)

Best energy resolution: 0.62μeV
Energy transfer <31μeV
Momentum transfer $0.2<\boldsymbol{Q}<1.8$ Å^{-1}

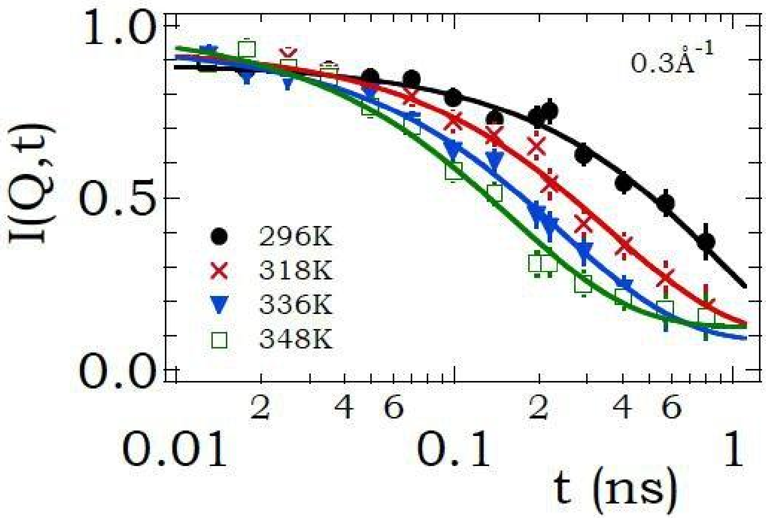
2.6. Overview on neutron instrumentation (inelastic scattering)

Spin echo (JNSE @ MLZ)



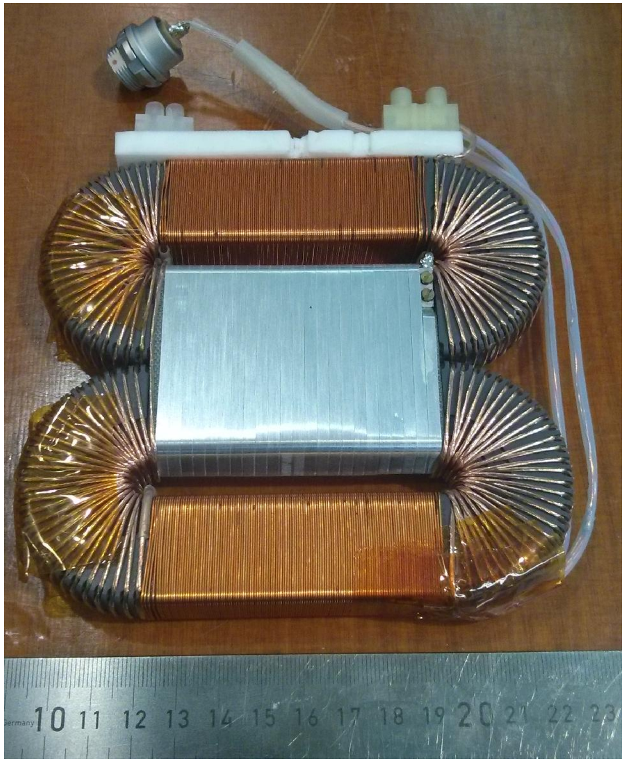


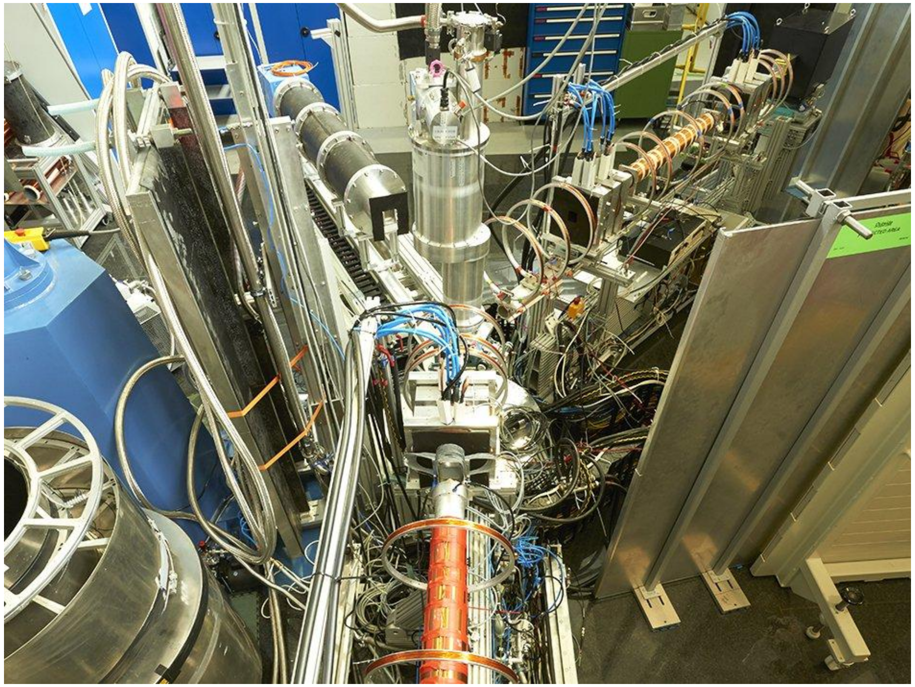
- Neutron Spin Echo
- Decoupling of wavelength spread and energy resolution
- Use the Larmor precession of neutrons in magnetic field as a sort of „clock“ to encode the energy
- Slow dynamics of soft matter /biological samples
- Cosinus Fourier transform S(***Q***,***τ***) of S(***Q***,***ω***)
- 2ps<***τ***< 350ns
- Momentum transfer ***Q***<1.5Å^{-1}



2.6. Overview on neutron instrumentation (inelastic scattering)

Resonance spin echo (RESEDA @ MLZ)





Neutron Spin Echo:
Static precession field.

↔

Neutron Resonance Spin Echo:
Two sychronized rotating HF fields
separated by a zero field region!

Zero field is cheaper as compared to super-precise static fields