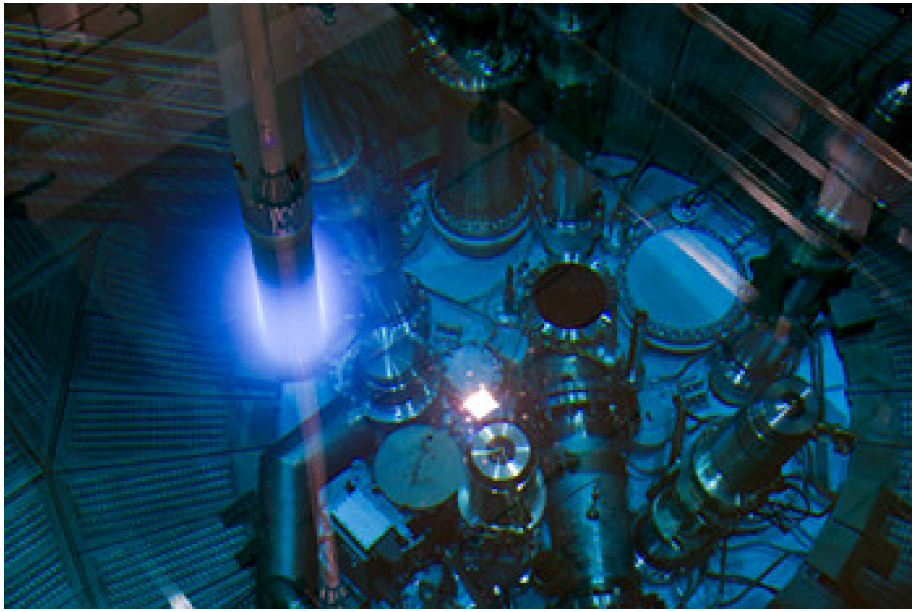
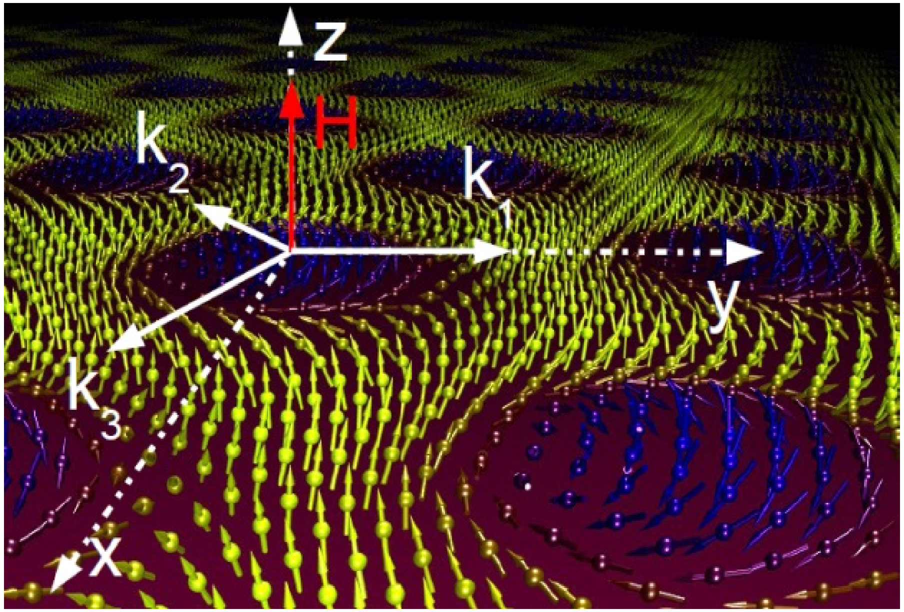
FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

MLZ
Heinz Maier-Leibnitz Zentrum

Physics with Neutrons I, WS 2015/2016





Lecture 1, 19.10.2015

Organization

Lecture: Monday 8:30 – 10:00, PH127
Sebastian Mühlbauer (MLZ/FRM II)
Sebastian.muehlbauer@frm2.tum.de
Tel:089/289 10784

Tuturials: Friday 8:30 – 10:00, 2224 (E21)
(first tutorial 23.10.2015)
Lukas Karge
Lukas.karge@frm2.tum.de
Tel:089/289 11774

http://wiki.mlz-garching.de/n-lecture:index

Suggestion: Seminar Methoden und Experimente in der Neutronenstreuung (PH-E21-1), Wednesday 9:00-10:30, PH2224

What is MLZ?

MLZ is a cooperation

JÜLICH FORSCHUNGSZENTRUM

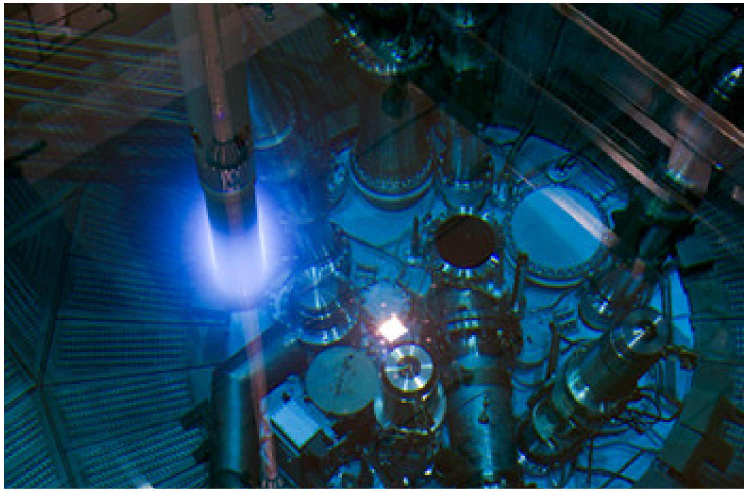
Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Technische Universität München

One of the world leading neutron sources

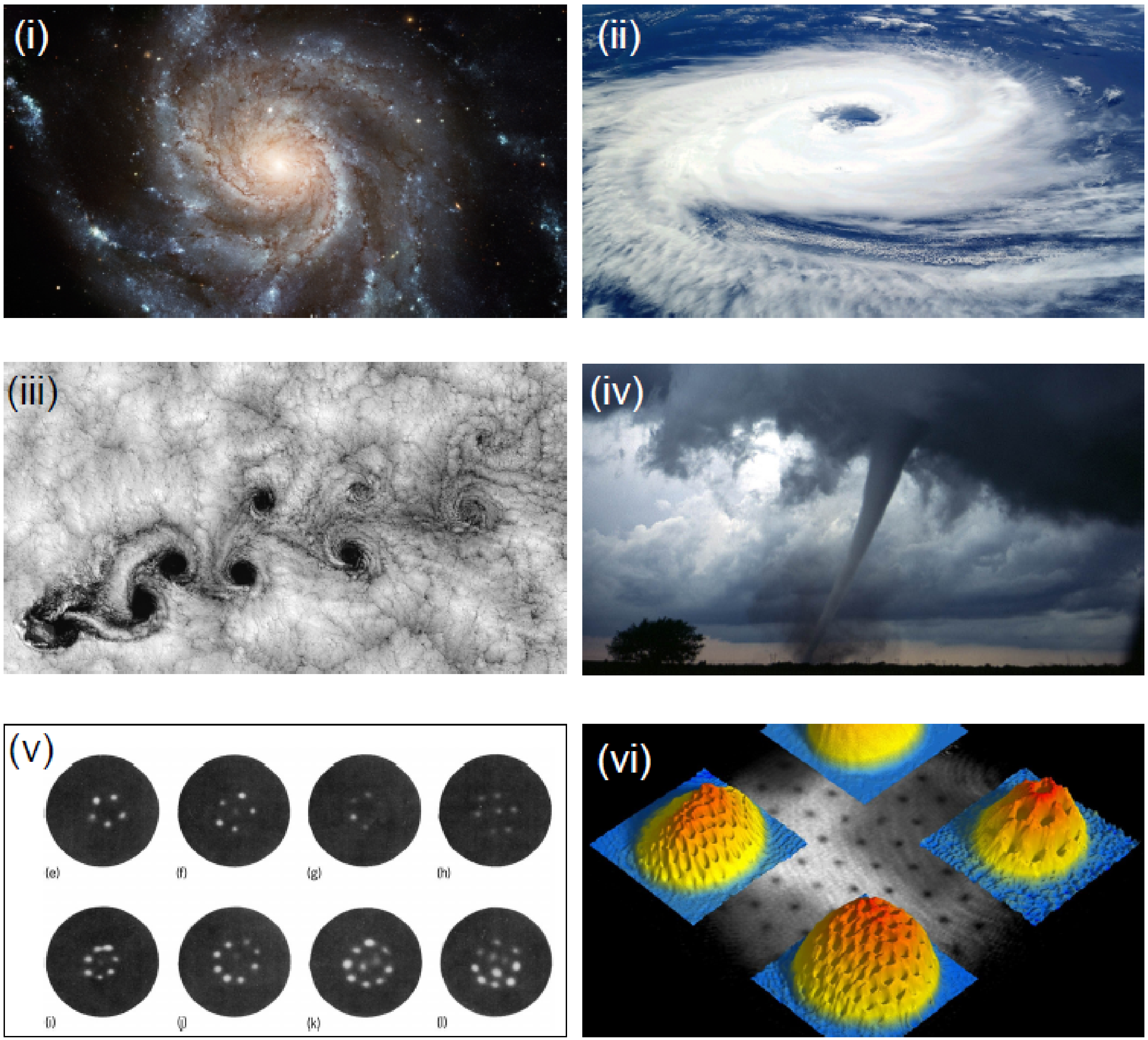
Neutron guide hall

Cherenkov light from the fuel element



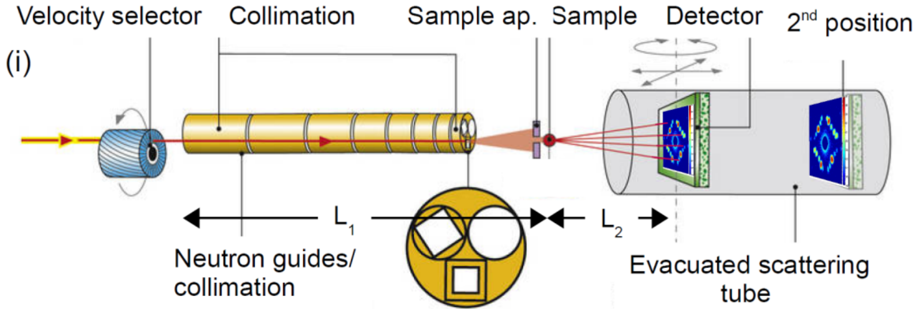
Experimental hall

Vortex Matter(s)

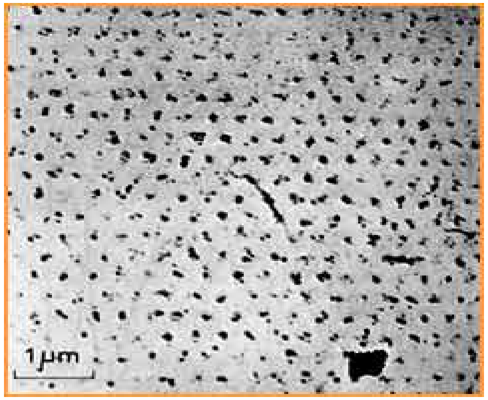


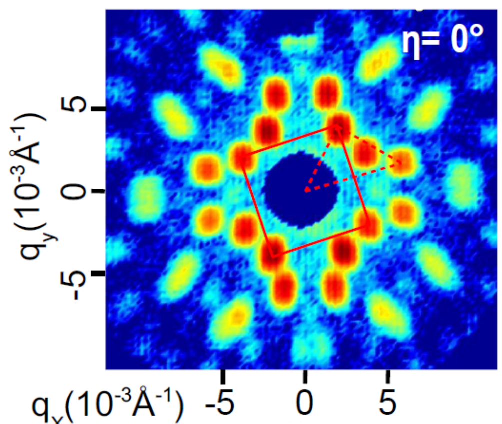
Vortex Matter(s)

Small angle neutron scattering (SANS-1 @MLZ

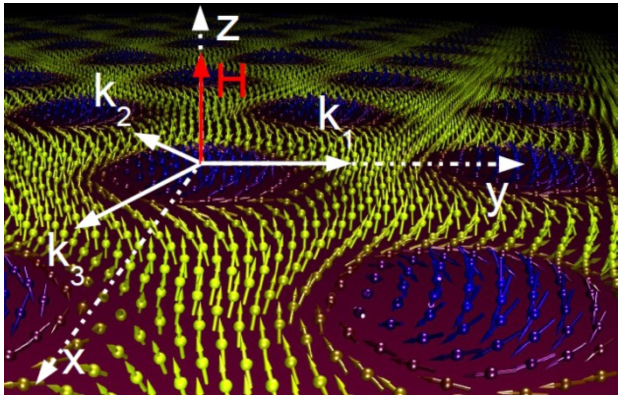


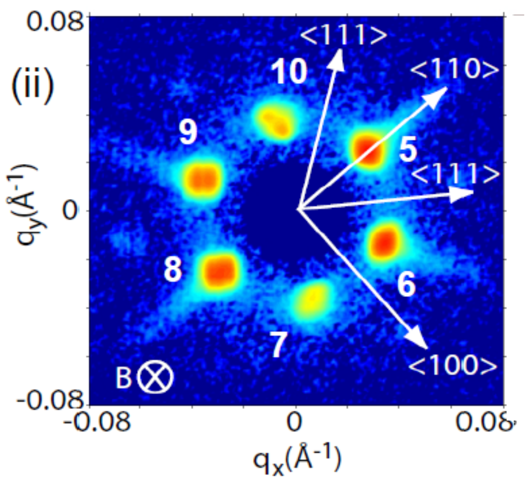
Properties of superconducting vortices



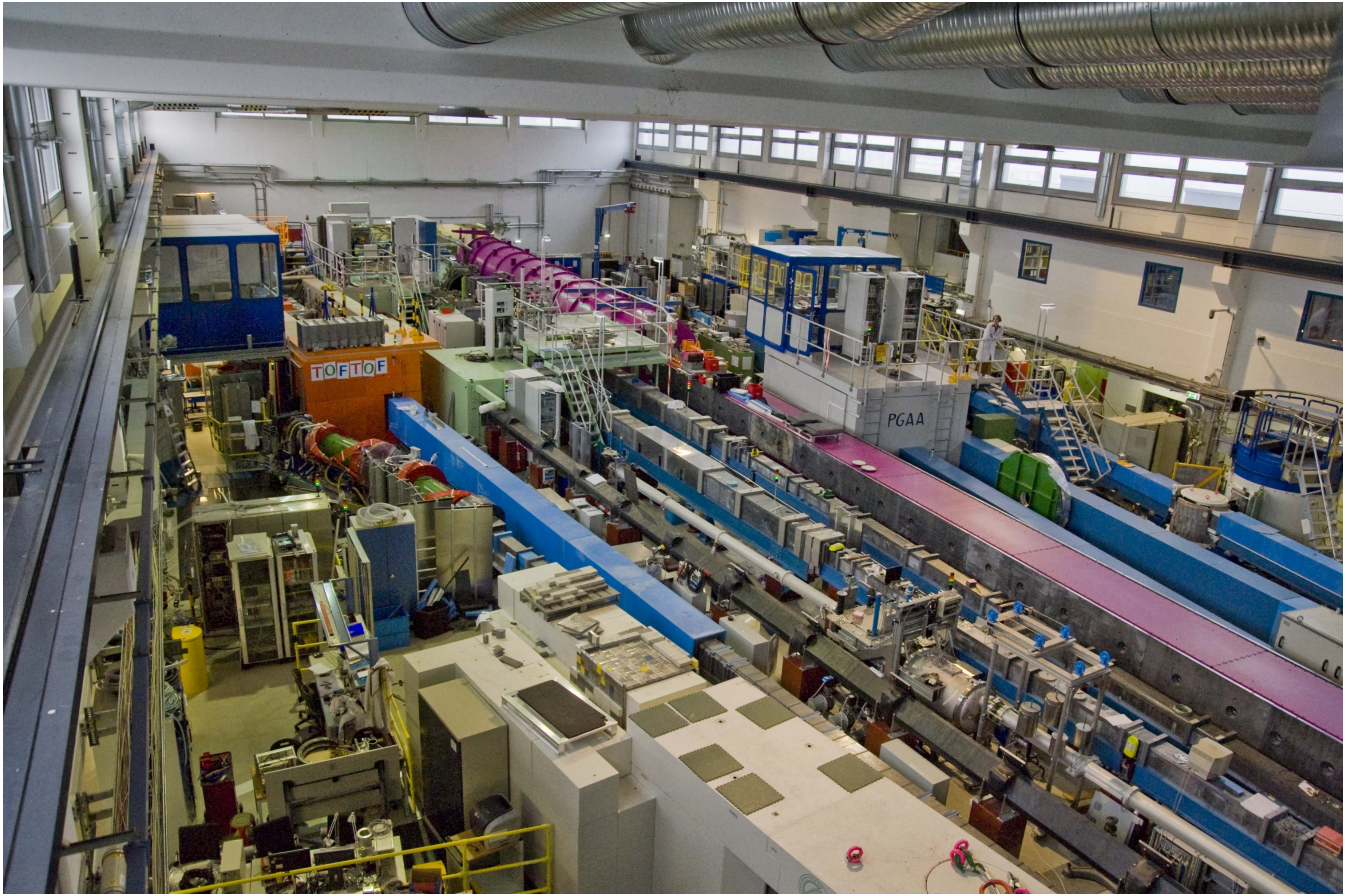


Skyrmion lattices in chiral magnets (MnSi & Co.)





SANS-1



Shedule of the lecture

Lecture 1: 19.10.2015

1. Organizational Stuff
2. Introduction into neutron scattering
2.1. Essence of a neutron scattering experiment
2.2. Basic properties of neutrons

Lecture 2: 26.10.2015

2.3. Overview on neutron sources
2.4. Neutron moderation
2.5. Detecting neutrons
2.6. Overview on neutron instrumentation part I: Powder diffraction, single X-tal diffraction, reflectometry & SANS

Lecture 3: 2.11.2015

2.7. Overview on neutron instrumentation part II: Triple axis spectroscopy, time-of-flight(TOF), backscattering and NRSE

Lecture 4: 9.11.2015

3. Basic neutron scattering theory
3.1. Definition of a scattering cross-section
3.2. Fermis Golden rule

Lecture 5: 16.11.2015

3.3. Coherent and incoherent scattering
3.4. Isotope and spin incoherence

Shedule of the lecture

Lecture 6: 23.11.2015

4. Elastic neutron scattering on crystals
4.1. Bragg scattering from a single crystal
4.2. Types of crystal lattices
4.3. Ewald sphere construction & reciprocal space

Lecture 7: 30.11.2015

4.4. Structure factors
4.5. Miller indices

Lecture 8: 7.12.2015

4.6. Application of elastic neutron scattering on crystals: Powder diffraction
4.7. Application of elastic neutron scattering on crystals: Single crystal diffraction
4.8. Application of elastic neutron scattering on crystals: Protein crystallography

Lecture 9: 14.12.2015

4.9. Thermal motion, Debye Waller factor with Einstein and Debye approximation

Lecture 10: 21.12.2015

5. Inelastic neutron scattering
5.1. Lattice dynamics and phonons

⇨ After the lecture: Visit to FRM II

Shedule of the lecture

Lecture 11: 11.1.2016

5.2. Cross-section for phonon emission and absorption
5.3. Techniques for inelastic scattering: TAS and TOF

Lecture 12: 18.1.2016

6. Correlation functions of neutron scattering

Lecture 13: 25.1.2016

7. Neutron scattering on liquids

Lecture 14: 1.2.2016

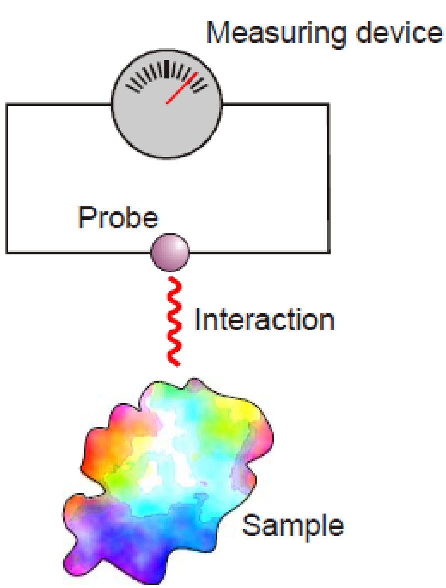
8. Neutron optics

Literature

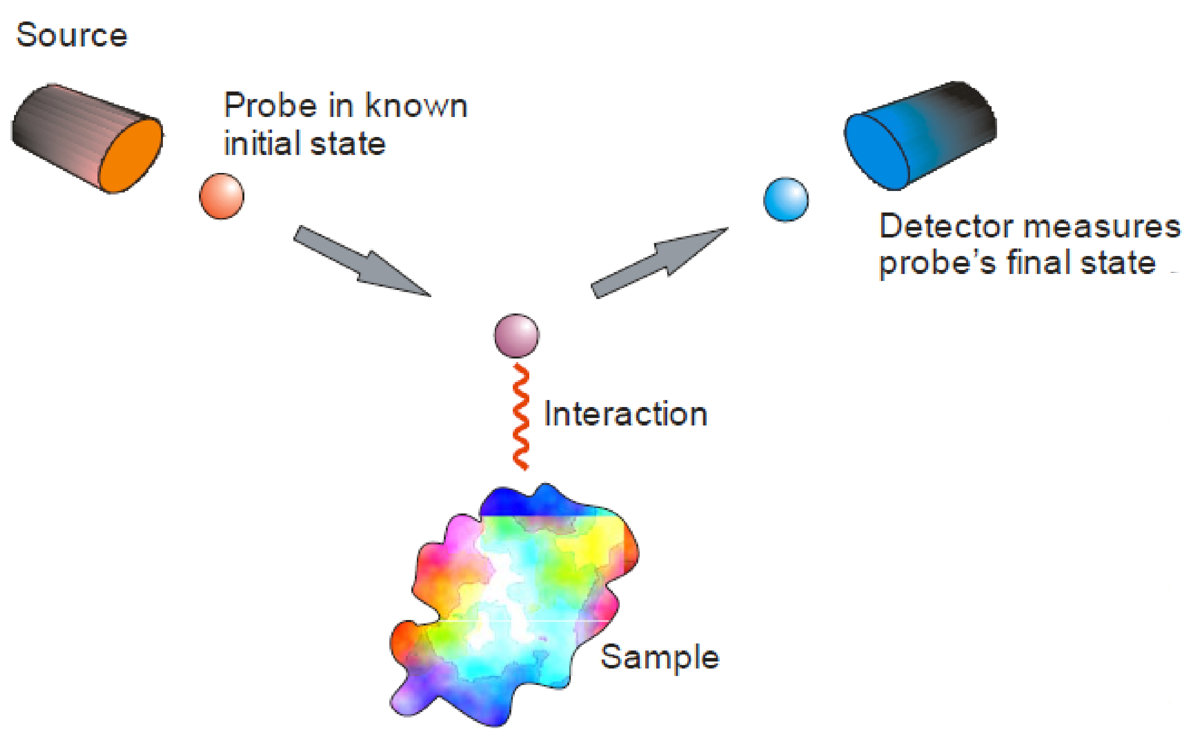
- A. Furrer, J. Mesot, T. Strässle: Neutron Scattering in Condensed Matter Physics, World Scientific, London (2009).
- G. L. Squires: Introduction to the Theory of Thermal Neutron Scattering, Dover Publications, N. Y. (1966).
- S. W. Lovesey, Theory of Neutron Scattering from Condensed Matter I, II, Oxford Science Publ., Oxford (1984).
- A. Furrer: Frontiers in Neutron Scattering, World Scientific, London (1999).
- G. E. Bacon: Neutron Diffraction, Oxford (1962).
- P. A. Egelstaff: Thermal Neutron Scattering, Acad. Press, London (1965)
- L. Dobrzynski, K. Blinowski: Neutrons and Solid State Physics, Ellis Horwood Series in Physikcs and its Applications (1994)

2.1. Essence of a neutron scattering experiment

Sensor measurement

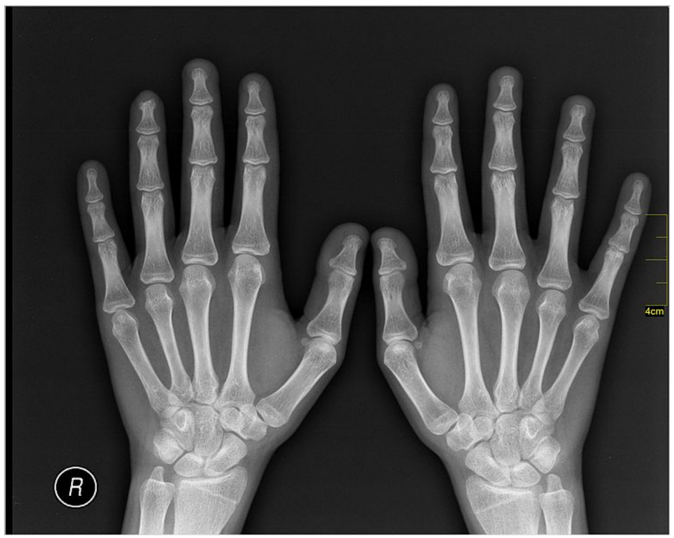


Scattering measurement

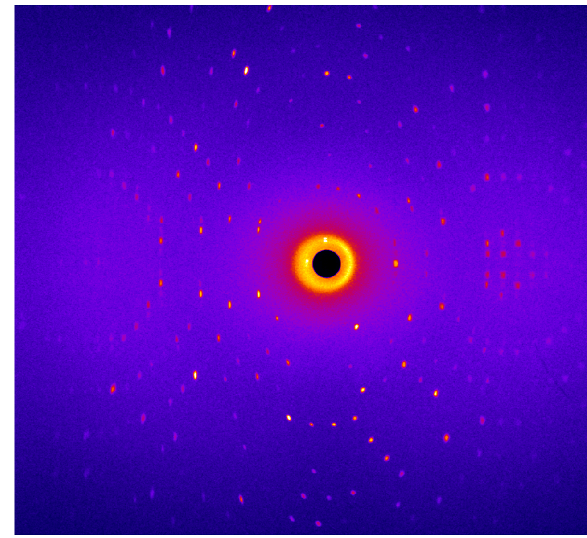


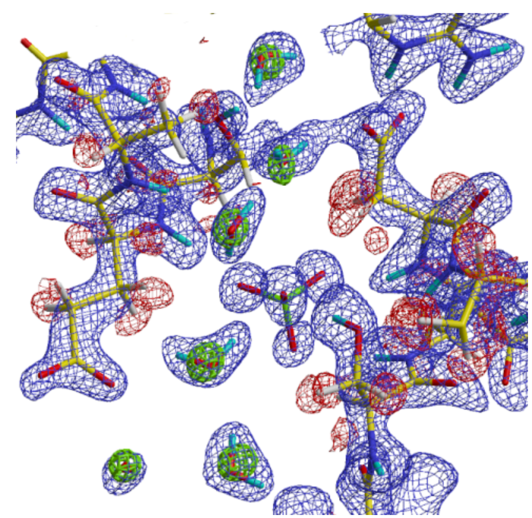
2.1. Essence of a neutron scattering experiment

Particle scattering measurement
$\lambda \ll A$



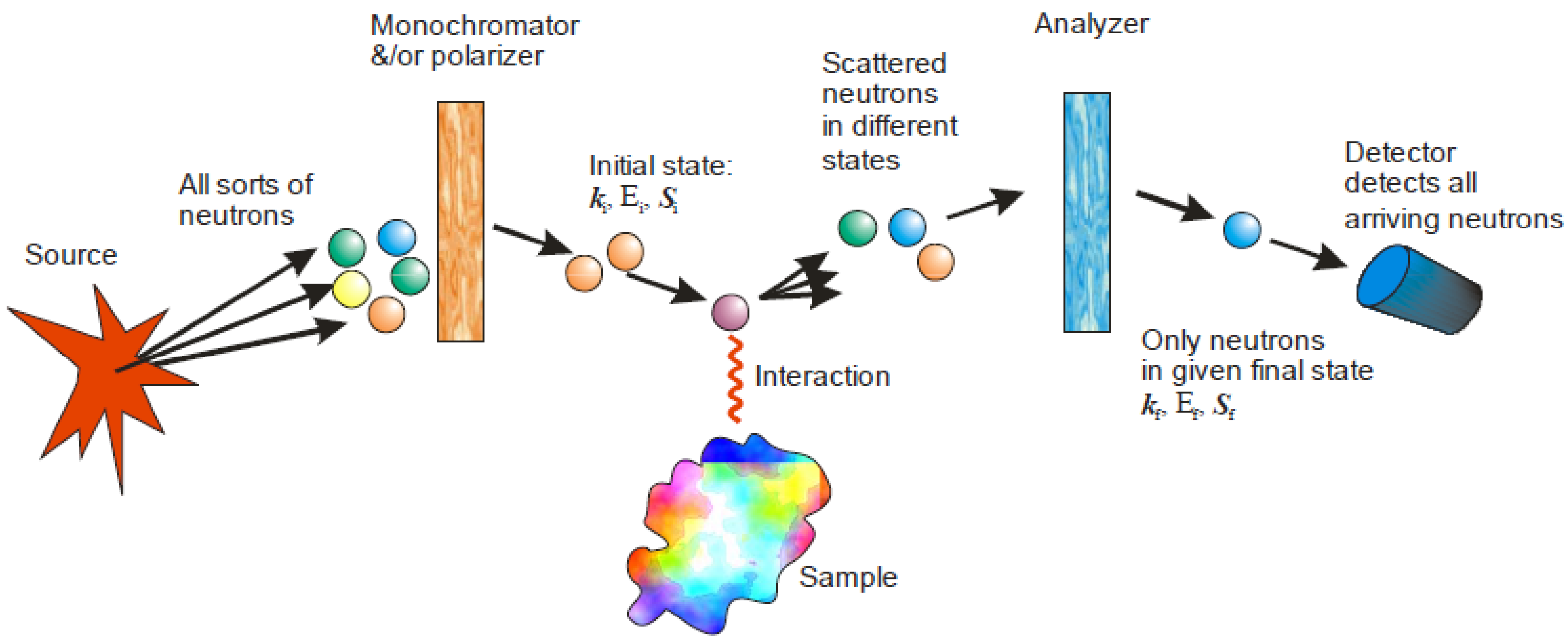
Wave scattering measurement
$\lambda \sim A$





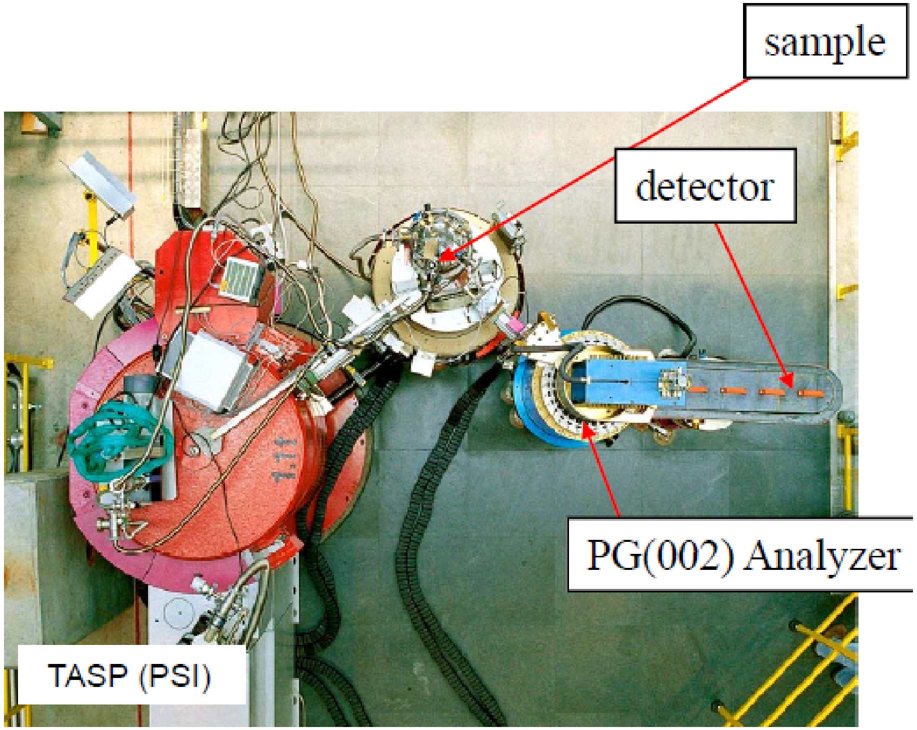
2.1. Essence of a neutron scattering experiment

Fundamental principle of a neutron scattering experiment



2.1. Essence of a neutron scattering experiment

Example: Triple axis spectrometer



2.2. Basic properties of neutrons

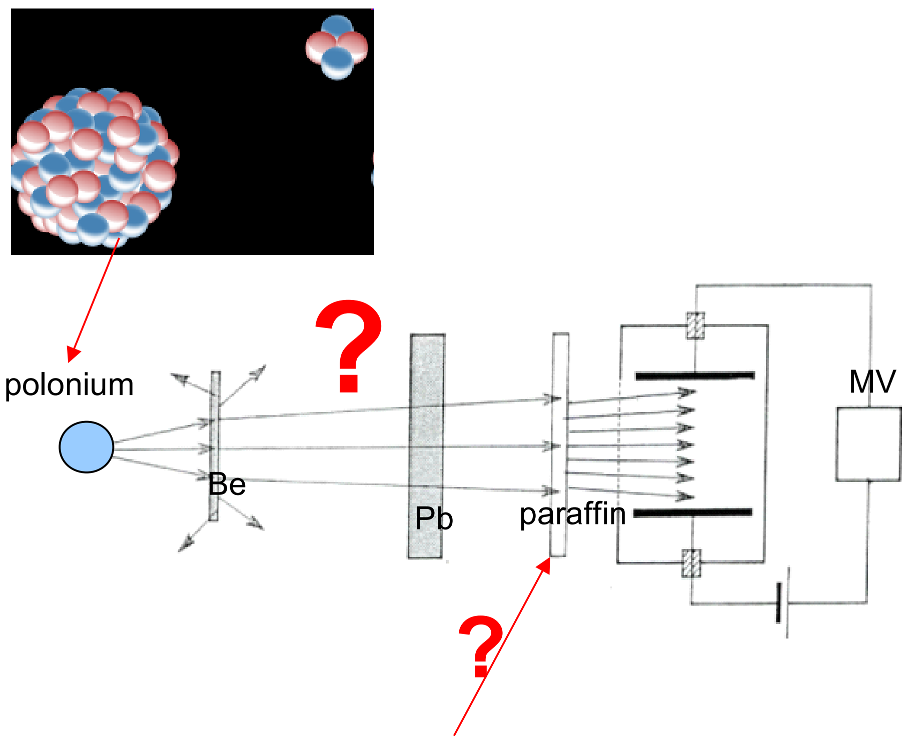
How was the neutron „invented“?

How are neutrons generated?

What are the basic properties?

2.2. Basic properties of neutrons - How was the neutron „invented"?

Bothe, Becker 1930
Curie, Joliot

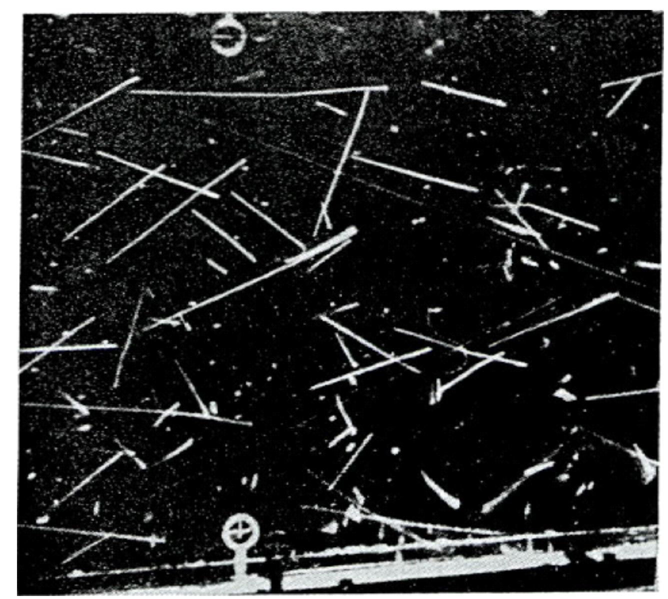


Generation of proton beams in a layer of paraffin by γ-rays from Be.

W. Bothe und H. Becker, Z. Phys. **66**, 289 (1930).

Chadwick 1932:

Be emits neutrons!

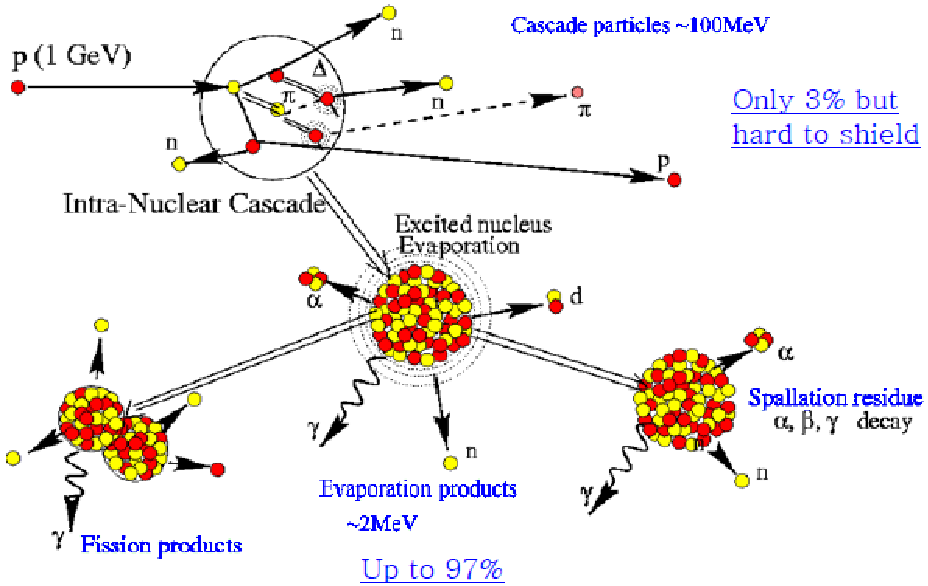


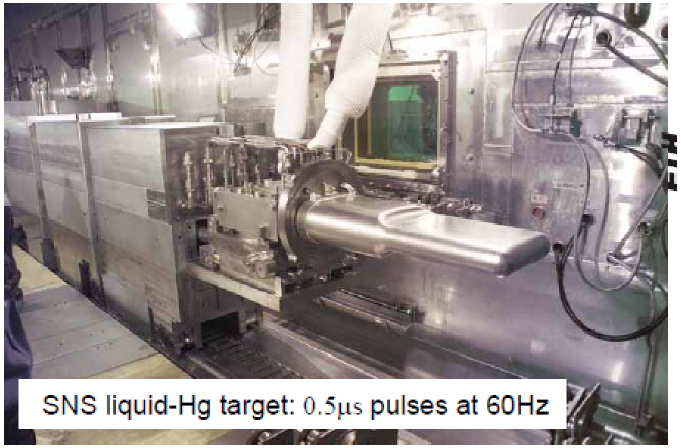
Proton beams in a cloud chamber generated by neutron irradiation

J. Chadwick, Nature **129**, 312 (1932).

2.2. Basic properties of neutrons - How are neutrons generated?

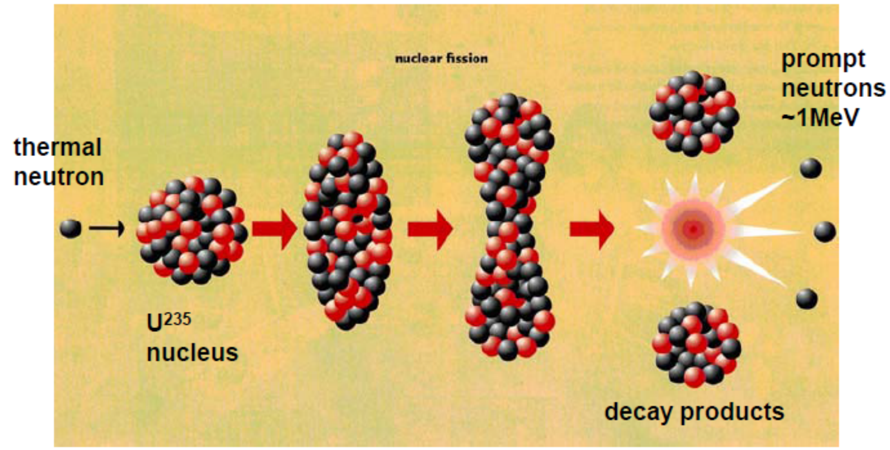
Spallation source - Pulsed (mostly)

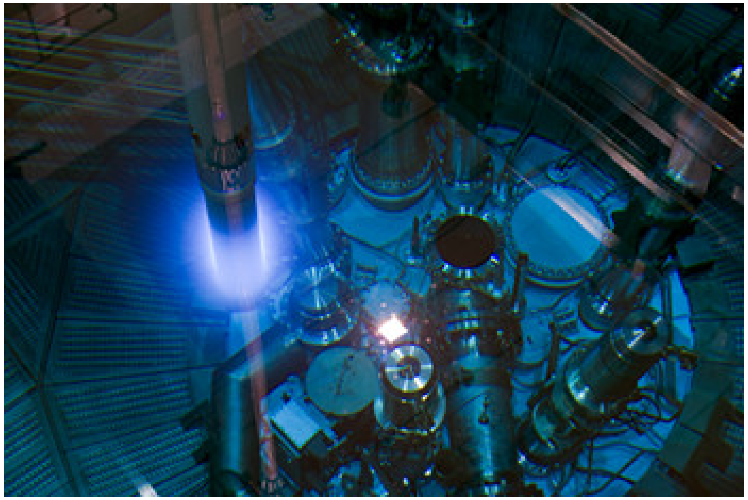




Reactor source – continuous

Thermal fission of U^{235} ⇨ 2.5 neutrons





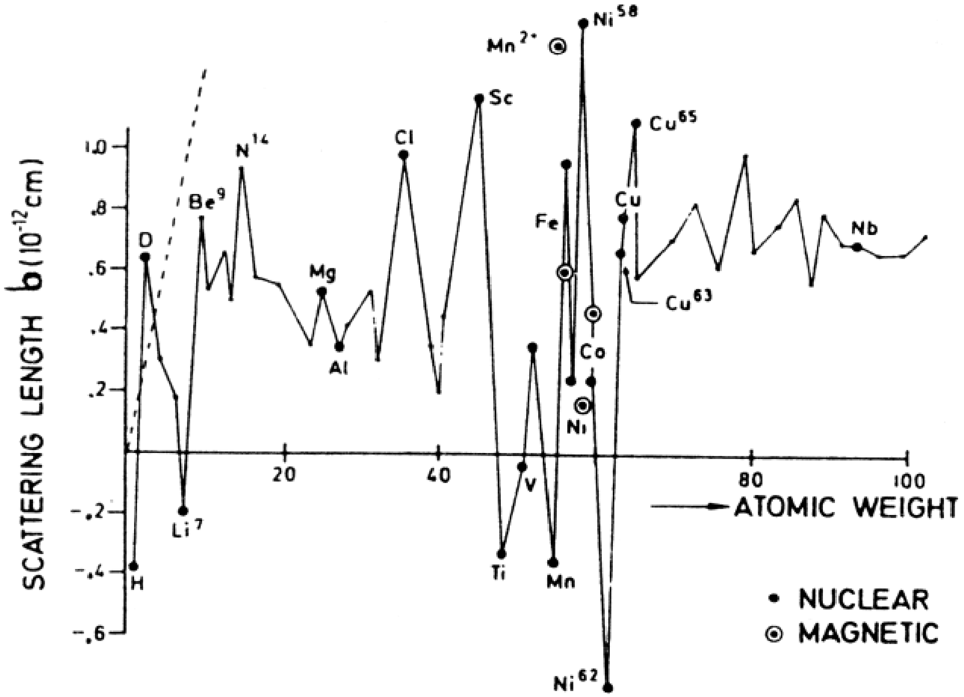
2.2. Basic properties of neutrons – What are the basic properties?

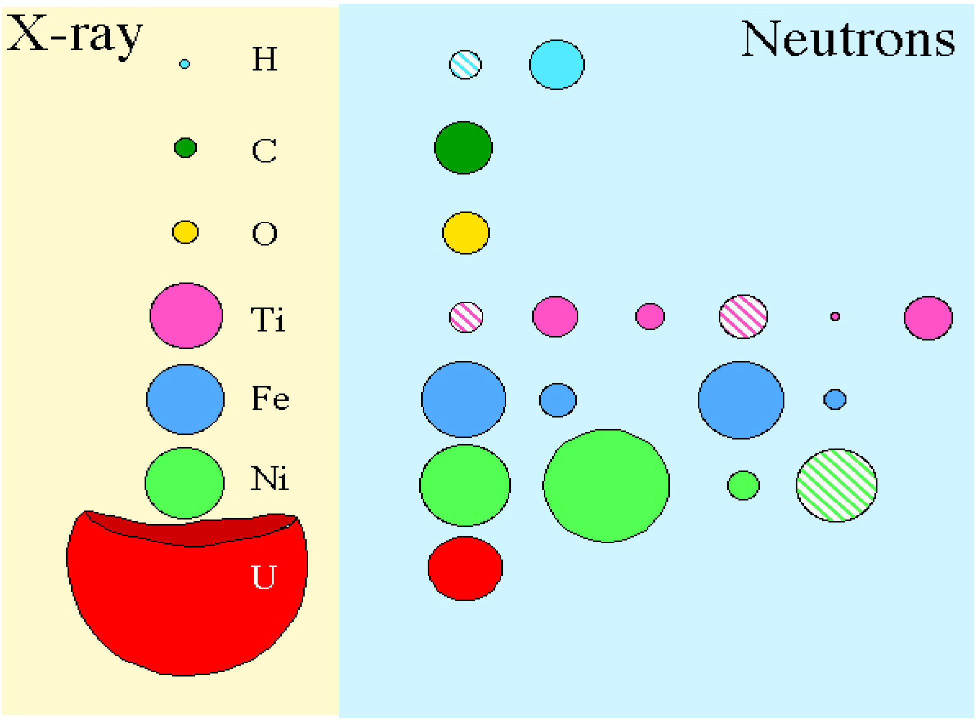
Table 1.2: Properties of the Neutron.

Physical quantity	Quantity	Dimension
Mass	$1.675 \cdot 10^{-27}$	kg
Charge	0	C
Spin	$1/2$	$\hbar$
magn. dipol moment	$\mu_n = -1.913\,\mu_K$	$\mu_K = \frac{e\hbar}{2M_p c}$
nuclear magneton		$1\,\mu_K = 0.505 \cdot 10^{-23}$ erg/G
		$1\,\mu_K = 3.15 \cdot 10^{-14}$ MeV/T
life time (free neutron)	886	s
kinetic energy	$E = \frac{1}{2}mv^2$	meV

2.2. Basic properties of neutrons – Wavelength and interactions

Interaction with matter





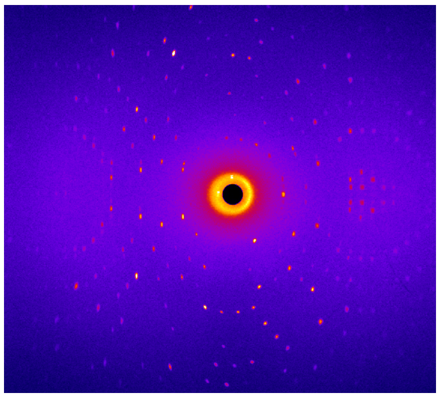
2.2. Basic properties of neutrons – Wavelength and interactions

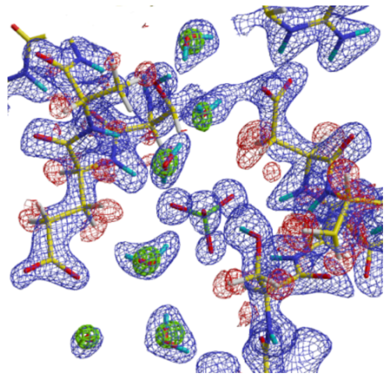
Energy range (eV)	Wavelength (Å)	Classification	Velocity (m/s)	
$0 - 5 \cdot 10^{-3}$	≥ 5	cold	≤ 1000	slow
$5 \cdot 10^{-3} - 10^{-1}$	$1 < \lambda < 5$	thermal	$1000 < v < 4000$	neutrons
$10^{-1} - 1$	$0.3 < \lambda < 1$	epithermal	$4000 < v < 10^4$	
$1 - 10^2$		resonance-		
$10^2 - 10^5$		intermediate		fast
$10^5 - 10^7$	$\lambda < 0.1$	fast	$v > 10^4$	neutrons
$10^7 - 10^{10}$		ultra fast		
$10^{10} - \infty$		relativistic		

Why Neutrons ?!

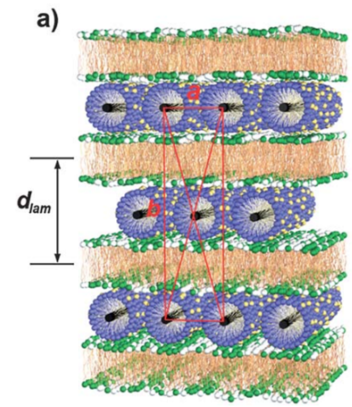
Versatile tool for condensed matter physics

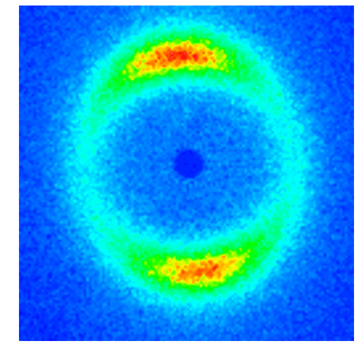
Crystallography



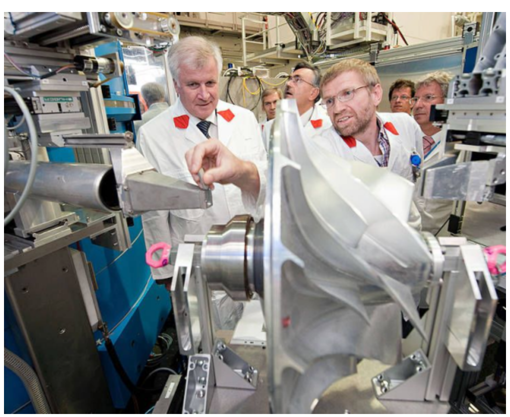


Soft Matter





Materials



Magnetism & SCES