Neutrons in Science

in Germany

Jülich Centre for Neutron Science

FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

MLZ
Heinz Maier-Leibnitz Zentrum

HZB Helmholtz
Zentrum Berlin

Helmholtz-Zentrum
Geesthacht
Zentrum für Material- und Küstenforschung


Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung
GEMS
German Engineering Materials Science Centre
JÜLICH
FORSCHUNGSZENTRUM
JCNS
Jülich Centre for Neutron Science
HZB
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German Engineering Materials Science Centre
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A common introduction by

Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (HZB) ● Heinz Maier-Leibnitz Zentrum (MLZ) ●

Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II) ● Jülich Centre for Neutron Science (JCNS) ●

German Engineering Materials Science Centre (GEMS)

Neutrons in Science in Germany

A growing community of scientists uses neutrons in physics and chemistry, materials sciences, engineering, cultural heritage, biology or earth sciences. Neutrons are applied to probe the microscopic structure and processes in complex matter. Topics ranging from catalysts to magnetism and from protein dynamics to superconductivity are explored. While the neutron wavelength or energy, respectively, is well suited to study atomic structures and motions in matter, the magnetic moment of the neutron interacts accordingly with magnetic moments of the atoms. The different interaction of the neutron with various isotopes of the same chemical element allows marking selected atoms or molecules by isotope replacement to study their specific behaviour. Neutrons penetrate thick materials easily offering unique possibilities for material testing and the development of sophisticated sample environments. By activating materials, neutrons can be applied in non-destructive chemical analysis, medical diagnosis, and therapy.

It was Heinz Maier-Leibnitz, who built the first German neutron research reactor in Garching in 1956 and thus started the successful tradition of neutron science in Germany. The FRM ("Atomic Egg") was soon followed by further research reactors in Berlin, Geesthacht, Karlsruhe, and Jülich in 1962. In today's Germany, the big and active community of researchers finds a well developed infrastructure at highest scientific level. There are two first class research facilities with an extensive suite of state-of-the-art instruments: the research reactor BER II of the Hahn-Meitner-Institut in Berlin since 1973, upgraded in 1989 (successor of the research reactor BER I) and the research reactor FRM II of the Technische Universität München in Garching since 2004 (successor of the "Atomic Egg" FRM).

Dr. K. Habicht
Facility Speaker HZB
Helmholtz-Zentrum
Berlin GmbH

The Helmholtz-Zentrum Berlin für Materialien und Energie (HZB)

operates the BER II facility until 2020. In one experimental hall and two neutron guide halls, a suite of 23 scientific instruments and test beam lines are operated by HZB or in collaboration with German university partners. A broad variety of supplement equipment like high field magnets, furnaces, pressure cells, and laboratory facilities support the neutron experiments. With the synchrotron source BESSY II, the HZB also offers complementary infrastructure and experiments to neutron as well as synchrotron users. In the combination of strong magnetic fields and low temperatures, HZB has a stunning tradition. The high field magnet project at HZB demonstrates this special expertise. The project will allow worldwide unique experiments at continuous magnetic fields up to 26 T.

The Heinz Maier-Leibnitz Zentrum (MLZ)

opens up the scientific use of the FRM II since January 1st, 2011, based on the cooperation contract between the Technische Universität München and the neutron centres of the Helmholtz Association at Geesthacht, Jülich and Berlin. The four partners plus the Max Planck Society as their associated partner and about 20 institutes from German universities form an effective team to provide an outstanding service for scientific users. The cooperation is funded by the BMBF and the Bavarian State Ministry of Sciences, Research and the Arts as well as the partners themselves.

Prof. Dr. W. Petry
Scientific Director MLZ
Technische Universität
München

The Jülich Centre for Neutron Science (JCNS)

is a qualitatively new structure founded as response to the permanent shutdown of the Jülich research reactor FRJ-2 in Mai 2006. JCNS operates instruments at the national and international leading neutron sources FRM II, ILL, and SNS under a common scientific objective. That way, JCNS provides external users with access to world class instruments at the neutron source best suited for their respective experiments. JCNS also provides a frame for the neutron method and instrument development activities of Forschungszentrum Jülich and for its in-house research in condensed matter and key technologies.

The Helmholtz-Zentrum Geesthacht (HZG)

has a long tradition in offering neutron scattering instrumentation to the international user community with a focus on engineering materials science. After closure of the research reactor FRG-1, the German Engineering Materials Science Centre (GEMS) was founded at HZG providing access to dedicated neutron and synchrotron instruments for materials research. The outstation of GEMS at the FRM II in Garching makes access to state of the art instruments at the most powerful German neutron source available.

Access to the facilities is free of charge for scientific use and each year nearly 2000 experiments are performed at FRM II and BER II by scientists from Germany and abroad. The neutron research centres are active partners of the European “Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy” (NMI3) supported by the European Commission to grant and support free access to the European neutron facilities.

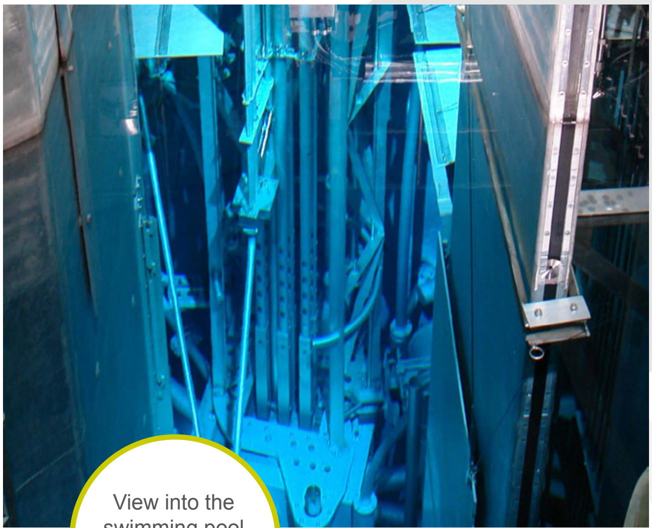
In addition, Germany is a founding partner of the Institut Laue-Langevin in Grenoble (France), and participates with instrumentation at many other international neutron research centres as the Swiss SINQ source, LLB in Saclay (France), ISIS (UK), JINR in Dubna (Russia), the Chinese research reactor CARR, and the spallation neutron source SNS at Oak Ridge (USA). Germany is also a major partner in the development and construction of the upcoming European spallation neutron source ESS in Lund (Sweden) - the next generation European source for neutrons in science. All these activities provide and maintain a strong and competitive scientific basis for neutrons in science in Germany. Represented by the German Komitee Forschung mit Neutronen (KFN) the scientific community, universities, research centres, and funding organisations like the German Bundesministerium für Bildung und Forschung (BMBF) do jointly develop an attractive and efficient scientific infrastructure for science with neutrons in Germany.

Prof. Dr. T. Brückel
Scientific Director MLZ
Forschungszentrum
Jülich GmbH

Prof. Dr. A. Schreyer
Scientific Director GEMS
Helmholtz-Zentrum
Geesthacht GmbH

BER II Source

The neutron facility BER II operated by the Helmholtz-Zentrum Berlin (HZB) is one of the two German facilities for neutron scattering research and one of the best and most widely used neutron sources in Europe. BER II is open to the international community of all kinds of disciplines. It offers access to a great variety of new or upgraded neutron scattering instruments, suited for research in many fields of science. A large range of sample environment equipment is available to carry out experiments under extreme sample conditions.



View into the swimming pool type reactor BER II.

Delivering Neutrons

The research reactor BER II is a light water cooled and moderated swimming pool type reactor to be operated at 10 MW thermal power. The BER II was converted from a HEU (high enriched uranium) to a LEU (low enriched uranium) core and is now in operation with LEU-core since January 2000. The core configuration operates with 24 fuel elements and uses six additional control elements. The core is surrounded by a beryllium reflector from which nine cylindrical beam tubes deliver thermal neutrons to the Experiment Hall. In addition, there is a conical beam tube with a horizontally inserted cold source. The cold source is operated at temperatures of 25 – 35 K with hypercritical hydrogen in the pressure range of 14 – 17 bar.

BER II at Lise-Meitner-Campus in Berlin-Wansee.

Eight neutron guides deliver cold neutrons from the cold moderator cell to two neutron guide halls adjacent to the experiment hall. Since 2005, a multispectral beam extraction guide (NL4a) faces both moderators and supplies the EXED instrument with a wide spectrum of cold and thermal neutrons. The undisturbed thermal neutron flux density in the beryllium reflector amounts to $1.2 \cdot 10^{14}$ n cm^{-2} s^{-1}. The disturbed thermal neutron flux density was measured at $7 \cdot 10^{13}$ n cm^{-2} s^{-1} in a tangential beam tube and $8.6 \cdot 10^{13}$ n cm^{-2} s^{-1} in a radial beam tube. The capture flux density was measured at the end of a ^{58}Ni coated neutron guide at $1.1 \cdot 10^{9}$ n cm^{-2} s^{-1}.

Operating Instruments for Neutron Scattering

Served with neutrons by the reactor BER II, the HZB offers a complete set of continuously renewed instruments for neutron scattering and imaging with thermal as well as cold neutrons. Unique research opportunities are provided due to a continuously expanded world-leading sample environment for complex neutron experiments under extreme conditions, e.g. at highest magnetic fields and lowest temperatures.

Focussed on providing excellent technical and scientific expertise in neutron scattering techniques and applications to both in-house and external users, HZB scientific units operate state of the art neutron instrumentation at the research reactor BER II. Each department provides specialised expertise in distinct scientific areas.

Neutron and photon scattering investigating the dynamic interplay of quasi-particle and charge transport in novel materials for energy conversion is addressed in the **Department Methods for Characterization of Transport Phenomena in Energy Materials**, using the three axes spectrometer for cold neutrons FLEXX. The department holds specialised expertise in high resolution spectroscopy.

The **Institute for Soft Matter and Functional Materials** deals with the basic understanding and possible applications of colloidal and nanoscopic systems, characterised by neutrons, photons, and dedicated labs for the profit of its users from soft matter, materials, and life sciences. The reflectometers V6 and BioRef, the neutron spectrometer NEAT, the small angle scattering instrument V4, and the new very small angle scattering instrument VSANS are operated.

The development, improvement, and operation of imaging, scattering, and diffraction methods to characterise structure and properties of materials is the focus of the **Institute for Applied Materials**. Deep insights into the structure of materials are provided. The institute operates the cold neutron imaging facility CONRAD.

The **Department of Microstructure and Residual Stress Analysis** aims at the characterisation of structure and properties of materials on different length scales extending from nano- to macroscopic dimensions. Complemented by synchrotron and X-ray laboratory facilities, the residual stress diffractometer E3 is operated.

For structural investigations complementary diffraction methods using neutrons, synchrotron, and conventional X-rays are applied by the **Department of Crystallography** for the non-destructive analysis of the atomic structure from the sample surface to deep within the sample volume. The powder diffractometers E6 and E9 are operated together with the new Fast Acquisition Laue Camera for Neutrons (FALCON).

The **Department of Quantum Phenomena in Novel Materials** investigates magnetism and superconductivity with special emphasis on quantum magnetism and strongly correlated electron systems. A suite of diffractometers (E2, E4, E5) are operated and maintained including the development of the ambitious high field magnet installation at the time-of-flight neutron instrument EXED.

High Field Magnet Facility

At HZB a new unique high field magnet has been installed for unique neutron scattering experiments. With a magnetic field strength of 25 to 30 T being about one million times stronger than the earth’s magnetic field, the installation allows the strongest magnetic field for neutron scattering experiments in the world. The high field magnet was developed in collaboration with the National High Magnetic Field Laboratory, Florida. The installation was finished in the beginning of 2015 and this unique facility is now in operation to serve experiments at the diffractometer EXED.

High field magnet facility in the Neutron Guide Hall II of BER II.

HZB puts special emphasis on providing expert support to scientists with no previous experience in neutron scattering and on service for the special needs of young scientists and students.

Neutron Scattering Instrumentation at HZB

At the neutron facility BER II located at the Lise-Meitner-Campus in Berlin-Wannsee, the Helmholtz-Zentrum Berlin offers a unique suite of neutron scattering instruments for scientific research. Distributed in three experimental halls, the HZB neutron facility BER II is open to the national and international scientific community. Up to 70% of the available beam time at the scheduled instruments is given to external users, 30% to in-house research. A fraction of the beam time for external users (up to 20% of the total beam time of an instrument) can be assigned to long-term collaborating groups from German universities as well as national and international research institutions. All remaining beam time is allocated to short term projects via a peer-reviewed selection process.

Diffraction and Single Crystal Structure Analysis

Magnetic and crystal structures, phase transitions, diffuse scattering, and structural analysis in general can be done at various single crystal and powder diffractometers at BER II. Thermal instruments as the flat-cone single crystal diffractometer **E2**, the two axes diffractometer **E4**, and the fine resolution powder diffractometer **E9** are offered together with the extreme environment time-of-flight diffractometer **EXED** and the new neutron Laue-diffractometer **FALCON**, which will serve the users from 2015 onwards.

The diffractometer **E2** is equipped with a position sensitive detector system covering 80° of 2Θ which can be tilted out of the scattering plane to determine scattering in three dimensions in reciprocal space. In addition it offers the possibility of energy analysis. The two axes instrument **E4** allows magnetic structure determination using magnetic fields up to 17 T.

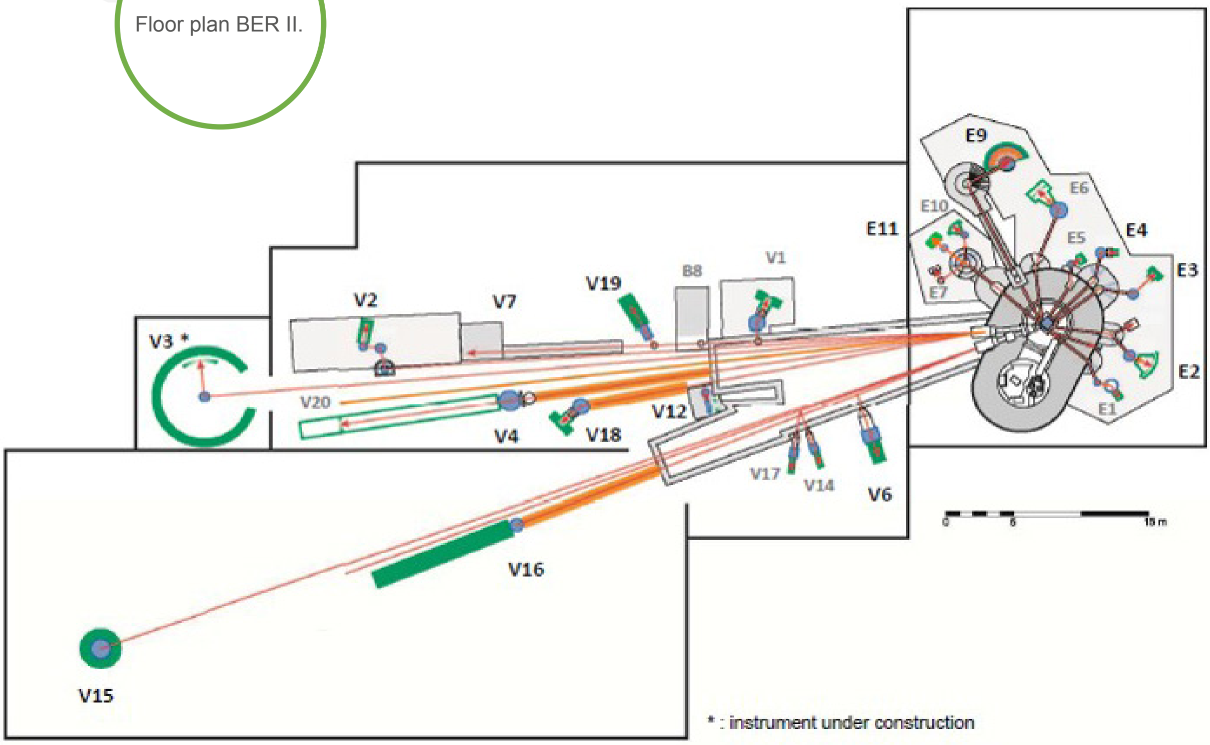
The fine resolution powder diffractometer **E9** (**FIREPOD**) is an angle-dispersive powder diffractometer optimised for a flat resolution function with a minimum width of the reflections at the 2Θ-region with the highest density of reflections.

The powerful new time-of-flight spectrometer **EXED** is capable to host the high field magnet facility at HZB for measurements up to 26 T. It is the flagship instrument for structure analysis at extreme conditions and a unique neutron spectrometer to study quantum phase transitions and highly correlated electron systems.

Stress and strain in mechanical components are investigated on the atomic scale by neutron diffraction. The residual stress analysis and texture diffractometer **E3** is designed for strain and stress analysis for simple geometric samples as well as for industrial applications and heavy tools. A range of equipment for sample positioning and in-situ residual stress analysis is available, such as a closed Eulerian cradle for samples with weights of up to 5 kg, a cradle for heavy samples (up to 50 kg) and a translation table carrying samples up to 300 kg and 1000 mm Ø. The instrument is complement to the synchrotron based diffractometer **EDDI** at BESSY II and intense X-ray lab-sources.

Users at the flat cone instrument E2.

Floor plan BER II.



Spectrometers

Probing the dynamics in hard and soft condensed matter, HZB offers special spectrometers covering all accessable dynamic ranges in neutron spectroscopy.

The cold three axes spectrometer **FLEXX** with NRSE option offers unique opportunities to study low-energy phonon and spin wave dispersion, soft modes, and crystal field excitations. FLEXX also offers the unique possibility to combine three axes spectroscopy with high resolution spin echo spectroscopy. The neutron resonance spin echo technique (NRSE) is based on RF spin flippers replacing the Larmor precession solenoids used in conventional spin echo spectrometers. This instrument is designed for the application of the 'tilted field' phonon focussing technique, which allows to measure linewidths of dispersive excitations with energy resolution in the order of µeV.

The cold neutron chopper spectrometer **NEAT** is best suited to probe dynamic phenomena directly in space and time in the time domain 10^{-13} – 10^{-9} s and on length scale ranging from atomic (0.5 Å) to nanoscale dimensions (up to about 50 nm). The spectrum of application is very broad, including the study of dynamics in biological and soft matter systems, spin dynamics in high-T_c super-conductors and other quantum systems, critical phenomena, glassy behaviour, material transport, and other kinds of functionality. At current, NEAT receives a major upgrade including new guide system, choppers, and detector banks. It will be back in full user operation in 2016.

Small Angle Neutron Scattering and Reflectometry

Determining size and structure in the nanometer range is the power of small angle neutron scattering and reflectometry. Porous structures, alloys, polymers, self-assembled aggregates, fibers, proteins or superconducting flux line lattices are all structures of nanometer dimensions to be probed by these techniques in solid bulk or solution or at interfaces. For such purposes, HZB offers unique opportunities on SANS instruments and reflectometers.

The small angle neutron scattering instrument **V4** covers a Q-range from 10^{-2} to 8.5 nm^{-1} allowing density composition and magnetisation fluctuations in materials to be measured on a length scale from 0.5 nm to 400 nm. Polarised neutrons are also available at the instrument. Using polarised ^{3}He filter cells behind the sample, polarisation analysis is possible simultaneously on the whole 2D detector. Time stamped measurements can be performed using list mode data acquisition. Stroboscopic measurements using a trigger signal allows to probe the dynamic of periodic processes. The currently installed chopper system based on TISANE technique can be used to study dynamics in microsecond range.

Explaining the multi pinhole grid collimation of VSANS.

The second SANS instrument at HZB is dedicated mainly to soft matter research. The very small angle neutron scattering (**VSANS**) time-of-flight spectrometer **V16** covers a Q-range from 10^{-3} to 8.5 nm^{-1}. The instrument works in the time-of-flight mode with ordinary pinhole collimation and in an optional high resolution mode using multi pinhole grid collimation.

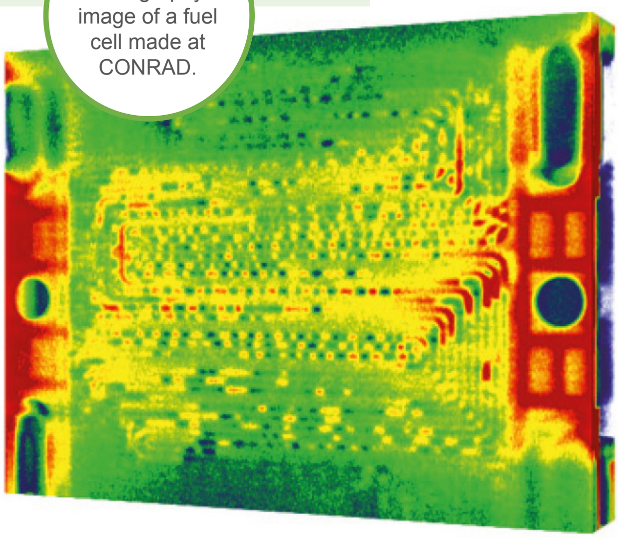
The reflectometer **V6** allows for measuring the neutron optical reflectivities of flat surfaces at grazing angles. Due to a horizontal scattering geometry structural depth profiles can be studied at solid-air, solid-liquid, and free liquid surfaces. With polarised neutrons, magnetic properties and depth profiles near surfaces are reconstructed in a unique way.

The novel BioRef reflectometer **V18** in the Neutron Guide Hall of the BER II reactor at HZB is designed for applications in soft matter science at solid-liquid interfaces especially under dynamic conditions. The time-of-flight reflectometer uses three choppers in order to adapt variable resolutions and wavelength bands to the needs of specific applications. As a unique feature the instrument is equipped with an in-situ infrared (IR) spectrometer operating in its surface sensitive ATR-geometry for simultaneous spectroscopic and structural studies.

Neutron Imaging

Neutron tomography and radiography allows to investigate the macroscopic inner structure or processes of large samples (up to hundreds of cubic centimetres) with a spatial resolution of up to 100 µm. The ability of the neutrons to transmit centimetres of metal easily and to be very sensitive to small amounts of light elements like hydrogen or lithium makes neutron tomography a powerful and unique tool for non-destructive testing. Examples are soot filters, adhesive joints, lubricate films, in-situ, i.e. time resolved visualisation of the water management in operated fuel cells. Applications are also found in the field of archeology and medicine. HZB offers various different instruments for tomography and radiography work.

The cold neutron tomography and radiography (**CONRAD**) beam line V7 at HZB offers the option of high flux measurements for real time imaging time resolved studies and high resolution measurements with spatial resolution up to 100 µm.



Neutron tomography image of a fuel cell made at CONRAD.

The second polarised neutron tomography instrument **PONTO II** is a common project of University Beuth and HZB and dedicated to visualising magnetic structures.

A multiple purpose instrument is the double-crystal diffractometer **V12** for ultra-small angle scattering and special phase contrast tomography applications.

The unique neutron radiography station **B8** allows to irradiate and activate artistic, technical, or geological items (foils, stones etc.) with cold neutrons and to investigate it afterwards with imaging plate technique and/ or gamma spectroscopy. The instrument is used for the investigation of paintings but also usable for other purposes in irradiation.

Sample Environment

The HZB has an outstanding tradition in providing sample environment for extreme conditions. Special emphasis is put on high magnetic fields and low and ultra-low temperatures. A broad range of equipment is available to provide different sample environments for neutron scattering experiments with a wide temperature range from T = 30 mK to 2000 K, with variable magnetic fields up to H = 17 T and with pressure up to p = 10 kbar. The components are mutually compatible and can be used on most of the instruments both in the Experimental and the Neutron Guide Hall. HZB offers magnetic fields up to 26 T at the new high magnetic field facility for neutron research.

Laboratories

For “off beam” preliminary test experiments or additional investigations certain specialised laboratories are available onsite for users:

LaMMB-MagLab

Equipped with four fully operating measurement systems for magnetic fields up to 14.5 T and temperatures down to 260 mK.

DEGAS-GasLab

Offering a suit of modular experimental setups for experiments under controlled gas pressures to serve request from the field of material sciences and soft condensed matter. The dedicated environment for combined gas adsorption and scattering experiments (DEGAS) includes humidity chambers and equipment for in-situ adsorption experiments.

BioLab

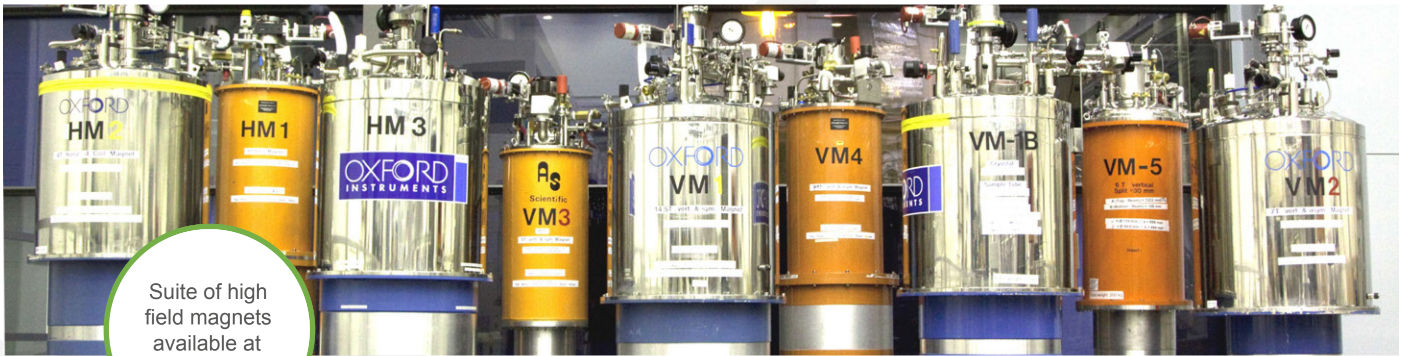
Offering a broad range of laboratory based equipment with a focus on methods in optical spectroscopy.

X-Lab

HZB provides laboratory based X-ray sources for sample characterisation and investigation. At current a reflectometer X2 and an X-ray micro-computer tomography station X3 are offered.

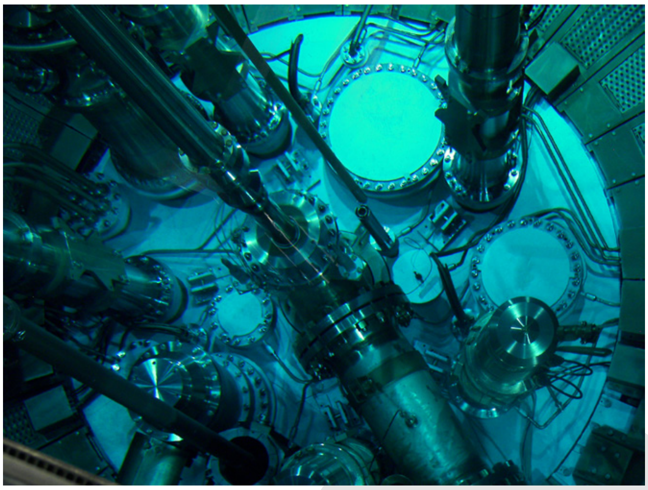
For any further information on our instrumentation, sample environment and user access please refer to

www.helmholtz-berlin.de/user



Suite of high field magnets available at BER II.

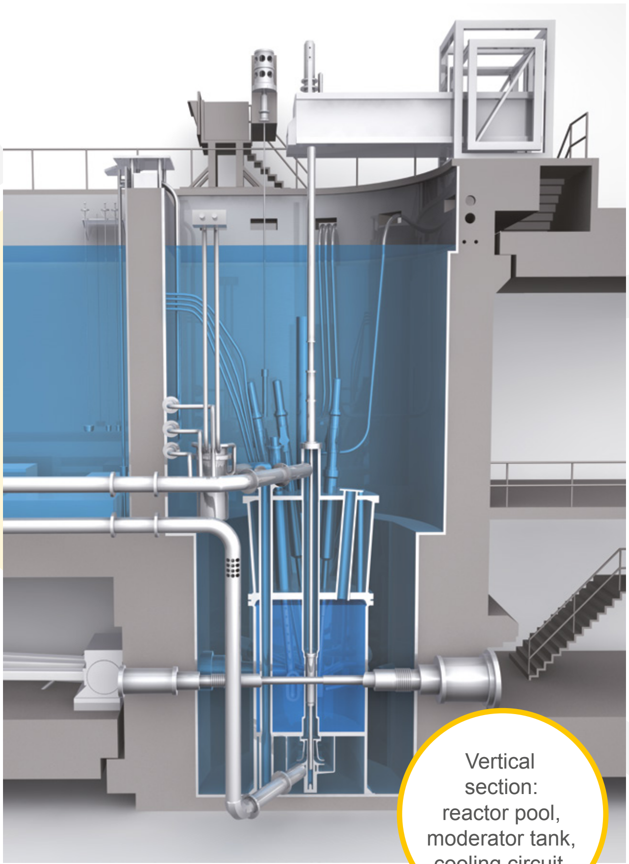
FRM II Source



The research neutron source Heinz Maier-Leibnitz (FRM II) is the most powerful neutron source in Germany and reaches the highest neutron flux ($8 \cdot 10^{14}$ n cm^{-2} s^{-1}) relative to its thermal power (20 MW) throughout the world. It is a beam tube reactor designed for providing neutrons to scientific users from all over the world as well as for medical and industrial applications. The facility is operated as a Corporate Research Center by the Technische Universität München (TUM) in Garching near Munich, Germany. Its first criticality was achieved in March 2004. The experimental facilities are operated by scientific teams from German universities, research institutes of the Helmholtz Association and the Max Planck Society at the neutron source. Today, 26 of these instruments are operational, six are under construction. Furthermore seven irradiation systems for isotope production, silicon doping, and analytical purposes are in service. An irradiation facility for the production of the medical isotope ^{99}Mo is under construction. The FRM II is equipped with cold, thermal, hot, and fast fission neutron sources and covers a broad range of applications, including experiments with positrons. An ultra cold neutron source is under construction. The average neutron flux density in the cold source is about $3 \cdot 10^{14}$ n cm^{-2} s^{-1} at full reactor power, resulting in a cold neutron flux density of $9 \cdot 10^{13}$ n cm^{-2} s^{-1}. The hot source moderates the neutrons upwards from 309 K to 2273 K with a significant gain of flux in the order of one magnitude around 0.6 Å.

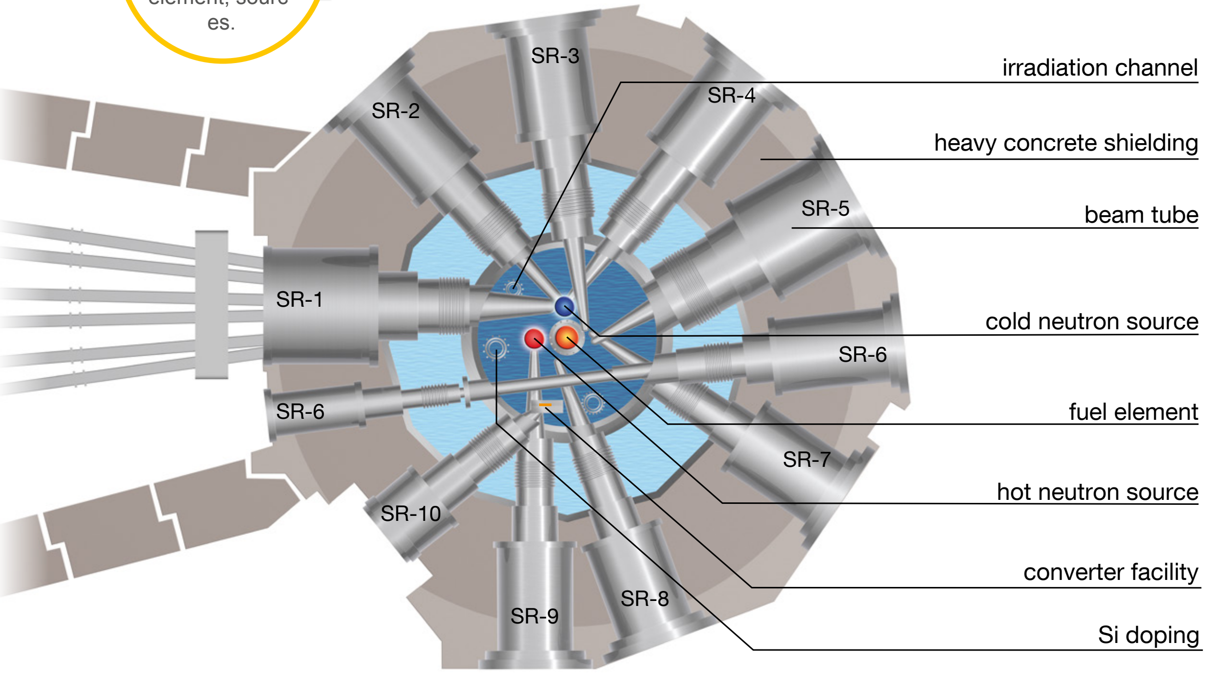
Fuel Element for High Flux

The FRM II was developed for an exclusive purpose: the production of intense neutron beams. Its high performance is based on the concept of a compact core. A single cylindrical fuel element with a diameter of just 24 cm is sufficient for 60 days of reactor operation. The fuel zone measures 70 cm and contains 8 kg of uranium in the form of U_3Si_2. Like other high-performance neutron sources around the world, the FRM II uses highly enriched uranium. This leads to a high neutron flux producing a minimal amount of radioactive waste. The tips of the beam tubes are placed in the region of the maximum neutron flux density. They guide the neutrons to the experiments in the Experimental Hall and Neutron Guide Hall West. In the Experimental Hall a high neutron flux and access to the positron beam lines is provided, whereas the Neutron Guide Hall West is connected to the cold neutron source via six neutron guides. The Neutron Guide Hall East is already connected to the reactor building in order to extend the number of available instruments within the next years.



Vertical section: reactor pool, moderator tank, cooling circuit.

Horizontal section: reactor pool with beam tubes, fuel element, sources.



Irradiation Facilities

The **standard rabbit irradiation system** consists of six independent irradiation channels. The flux densities range from $5 \cdot 10^{12}$ to $7 \cdot 10^{13}$ n cm^{-2} s^{-1}. Sample sizes should be less than 8 cm^3. High dose irradiation, spanning periods from several hours to weeks, is carried out in the **capsule irradiation system**. It is a pool water-driven hydraulic rabbit system exhibiting neutron flux densities of up to $1.3 \cdot 10^{14}$ n cm^{-2} s^{-1}. The rabbit and capsule irradiation systems are used for neutron activation analysis (NAA) to analyse the element composition in a material. Up to 30 or 40 elements can be determined simultaneously down to the ppt and sub-ppt range. Samples sized up to 120 cm^3 can be irradiated in the **mechanical irradiation system**. The neutron flux density is $1.1 \cdot 10^{13}$ n cm^{-2} s^{-1}. The highest possible fluence of all irradiation systems of $1.1 \cdot 10^{21}$ n cm^{-2} s^{-1} can be reached at the **irradiation position inside the control rod**. Silicon ingots are irradiated in an additional **system within the moderator tank**. The doping is achieved by neutron capture and the resulting conversion of individual ^{30}Si atoms into ^{31}P.

Medical Applications and Radioisotopes

As its name indicates, MEDAPP is mostly used for medical applications by directly irradiating tumours for the treatment of patients. In addition, biomedical research on various cell strains is performed using the fast neutrons of the converter facility. Further medical applications use radioisotopes produced at the different irradiation systems and conditioned by radiopharmaceutical companies on-site:

^{177}Lu

which is used for the therapy of neuroendocrine tumours,

^{161}Terbium, ^{166}Holmium

for medical purposes (mainly for tumour therapy),

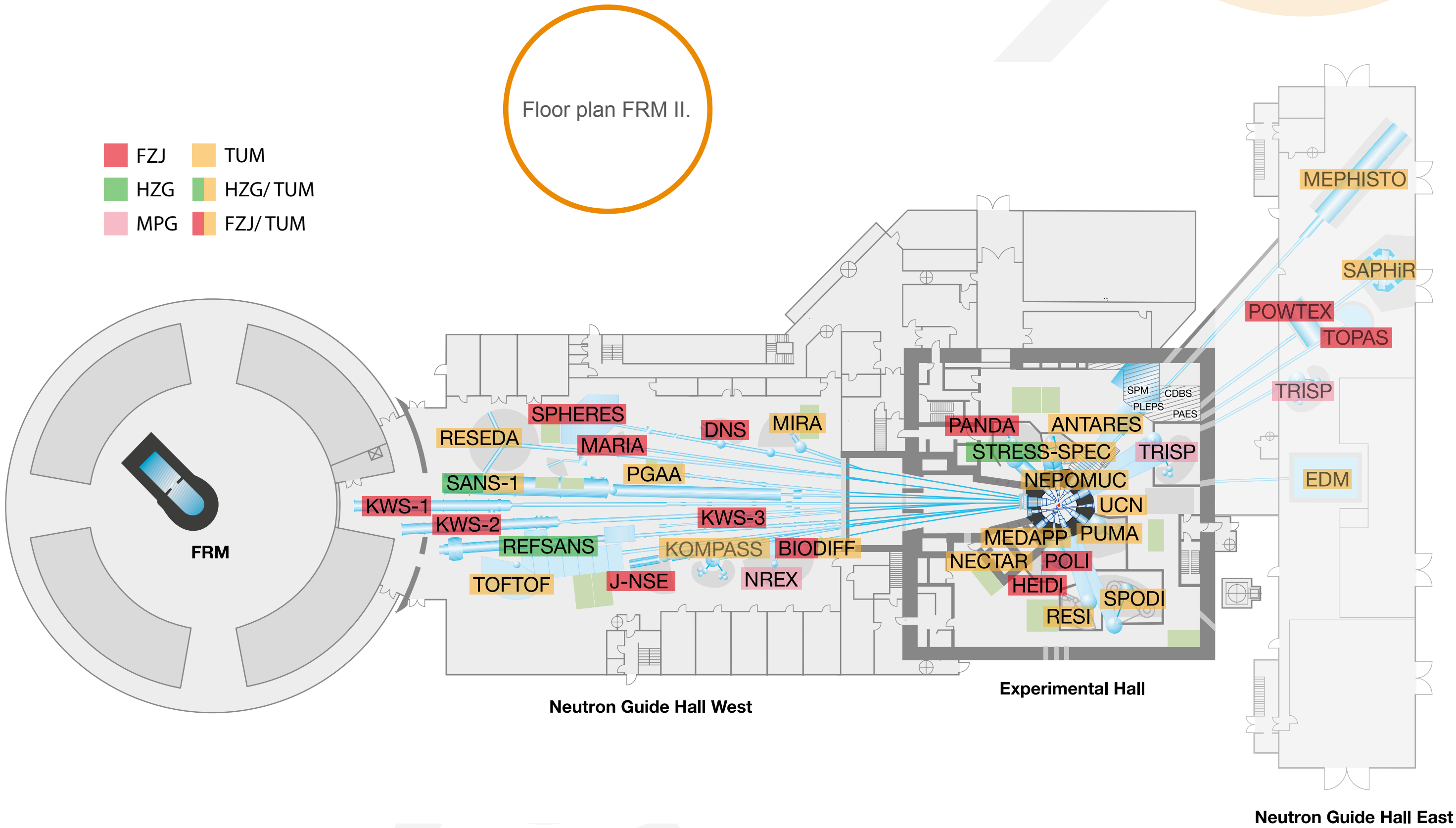
^{60}Co

mainly for industrial purposes,

^{99}Mo production

is planned to start in 2018. Its daughter isotope ^{99m}Tc is used in more than 80% of all nuclear medical diagnoses.

Instrumentation at MLZ

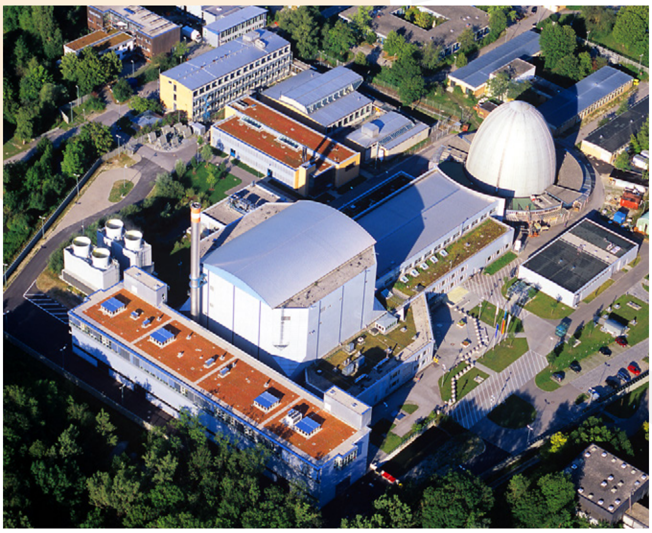


In four cycles per year mounting up to 240 days, neutrons are distributed to the MLZ instruments hosted at the FRM II in Garching. Each instrument is operated by one or two of the MLZ partners Technische Universität München (TUM), Forschungszentrum Jülich (FZJ), and Helmholtz-Zentrum Geesthacht (HZG) or the Max Planck Society (MPG). Together with associated groups from German universities they work continuously on instruments' improvements. As a result a suite of world class instrumentation has evolved over the years and their number will be increased in the future.

In addition, JCNS of Forschungszentrum Jülich also operates one instrument at the Institut Laue-Langevin in Grenoble and another one at the spallation neutron source SNS in Oak Ridge.

The German Engineering Materials Science Centre (GEMS) is a novel concept where the Helmholtz-Zentrum Geesthacht provides a worldwide unique infrastructure for complementary research with neutrons and with photons in the field of engineering materials science. GEMS enables the users to fully exploit the complementarities of the different probes in engineering materials research, e.g. by combining fast in-situ experiments of engineering processes using photons at DESY with neutron measurements on large finished components at MLZ with user support from the same specialised team. Please find all details at

mlz-garching.de



Neutron Guide Hall West.

Experimental Hall.

Diffraction

The instrument **BioDiff** is jointly operated by JCNS and TUM. It is optimised for molecular crystals with a large unit cell. BioDiff is a monochromatic single crystal diffractometer with a Dl/L of 3%. The neutron wavelength can be varied between 2.4 and 5.6 Å. Among the scientific questions addressed are the protonation-state of amino acid residues or to provide information about the orientation of water molecules in the active centre of enzymes.

The single crystal high resolution diffractometer **HEiDi** uses unpolarised neutrons with wavelengths between 1.2 and 0.44 Å from the hot source. The instrument offers a high neutron flux of up to > 10^7 n cm^{-2} s^{-1}, a large accessible Q-range of > 13 $Å^{-1}$ and sample temperatures between about 2.5 and 1300 K. Therefore, HEiDi is a highly performant and versatile tool for detailed structural and magnetic studies on HTSC, multiferroics, ferroelectrics, ionic conductors, mixed crystals, and highly absorbing compounds. HEiDi is a joint project of RWTH Aachen and JCNS.

MIRA is a dual wavelength band instrument with two beam ports. It offers monochromatised long wavelength neutrons ranging from 6 to 15 Å at MIRA-1 or alternatively cold neutrons of wavelength 3.5 to 5.0 Å at MIRA-2. MIRA-1 is predominantely used for polarised and non-polarised neutron reflectometry or small angle neutron diffraction for q-values larger than 0.03 $Å^{-1}$. The main focus of MIRA-2 is single-crystal diffraction of cold polarised and non-polarised neutrons at magnetic compounds with the option to extend to a three axes spectrometer for inelastic neutron experiments.

The diffractometer **POLI** is designed for studies on single crystals using neutron spin polarisation and special sample environments. 3D polarisation analysis using Cryopad, but also polarised or classical diffraction at very low and high temperatures (< 3 K, > 1000 K), high magnetic and electric fields, under pressure, and their combination are typical experiments. Recently moved to its own dedicated beamline, POLI is a joint project between JCNS and RWTH Aachen funded by the BMBF.

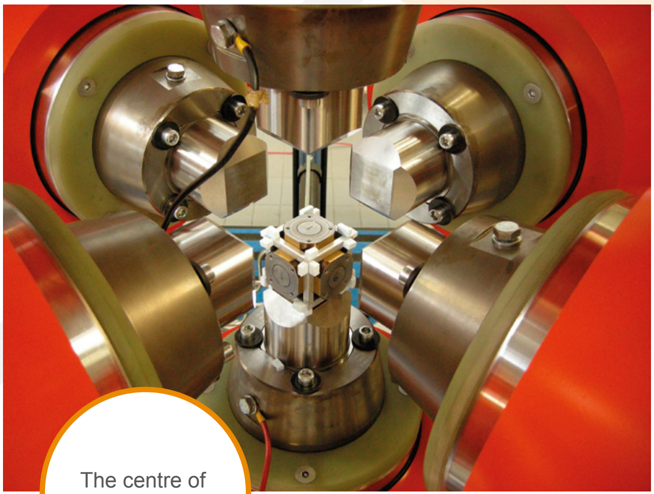
The single crystal diffractometer **RESI** is operated by LMU München. It offers thermal neutrons in the wave length range from 1 to 1.5 Å. The instrument is optimised for measurements of weak diffraction phenomena in a large portion of reciprocal space using an image plate. Typical applications are structure studies on real, i.e. non-perfectly ordered, twinned, incommensurate, and aperiodic crystals, partially crystalline compounds, and diffuse scattering with weak reflections for cells of 1000 to 20000 $Å^3$ and crystal sizes from 5 to 25 mm^3. The sample environment covers a wide range in temperature from 50 mK to 1200 K.

The instrument **SPODI**, operated by TUM and Karlsruhe Institute of Technology (KIT), is a high resolution powder diffractometer using thermal neutrons. It is designed for structure solution and Rietveld analysis on complex systems. Available wavelengths are 2.44 Å, 1.55 Å, and 1.11 Å. The multidetector of SPODI spans an angular range of 160° with 10' Soller collimators in front of each ^{3}He detector tube. Therefore the data collection is performed via stepwise positioning of the detector array to obtain a diffraction pattern of desired step width. Typical applications are: studies on magnetic and crystal structures, phase transitions and structural evolutions including disorder phenomena. In addition to cryostat, furnace, and magnet, also a tensile rig, an electric field cell, and a potentiostat for batteries are available.

Due to the superiority of neutrons concerning strain and texture measurements of large samples, the availability of this technique is essential for GEMS at HZG. **STRESS-SPEC** is jointly operated with TUM. Together with the Technical University of Clausthal, HZG additionally contributes texture competence to the STRESS-SPEC team. The new robotic system can be used simultaneously for automatic sample manipulation and sample change and allows for much faster alignment and positioning of larger samples. Moreover, STRESS-SPEC offers very flexible sample environments for in situ studies such as a tensile rig for both texture and strain investigations.

The six anvil press for high pressure radiography and diffraction **SAPHiR** is under construction by the Bayerisches Geoinstitut. The instrument provides extreme pressure and temperature environments for time-of-flight neutron diffraction and neutron radiography of polycrystalline and liquid samples. The centrepiece is a sixram multianvil press that is placed on a positioning and rotation table for sample adjustment, and surrounded by detectors for neutron diffraction and radiography. The six independently adjustable rams provide a combined pressing force of up to 23.5 MN (2400 tons) that is transferred via a set of smaller second stage anvils to a cubic sample assembly. SAPHiR shares a thermal neutron beamline (wavelength range 1 to 2.4 Å) with the future high-intensity diffractometer POWTEX.

POWTEX will be a pulsed TOF instrument at a continuous neutron source for crystallographic and magnetic structure determination as well as



The centre of SAPHiR.

texture analysis. The newly developed ^{10}B-detector will cover 9 sr and thus yields an accessible Q-range from ~0.5 to ~12.5 Å^{-1} in the thermal wavelength band. The instrument is a joint project between the RWTH Aachen University and JCNS funded by the BMBF.

SANS and Reflectometry

JCNS operates three small angle neutron scattering (SANS) diffractometers. These instruments aim at structures in the Q-range between 10^{-4} and 0.6 Å^{-1}. The corresponding sizes are typical for polymer chains, nano-domains, nano-composites, colloids, proteins, and their small complexes. Especially for soft matter studies the proton-deuteron exchange allows for highlighting every single component. The contrast variation experiment reveals individual structures and relative positions of components.

The instrument **KWS-1** is optimised for magnetic and thin film studies. Neutrons can be polarised before and analyzed after the scattering process by the SEOP ^{3}He neutron spin filter, thus allowing studies of magnetic structures. Furthermore, incoherent background can be subtracted precisely. Thin films are analyzed in the grazing incidence geometry (GISANS) using a hexapod sample positioning system that allows a high precision even with loads of heavy magnets.

The high-intensity/ wide-Q range **KWS-2** is dedicated to structural studies in soft-matter and biophysics: polymer solutions, melts, and films, polymer nanocomposites (clathrates) and aggregates (micelles), colloids, biological molecules and membranes, contrast variation experiments, and kinetics to the sub-second resolution. Within the high-resolution mode with chopper and TOF data acquisition, the instrument resolution is improved by the variation of the wavelength spread from typically 20 to 2.5%. Additionally, neutron lenses and a high-resolution detector permit when combined with the conventional pinhole mode, measurements over a wide Q-range, appropriate for the investigation of hierarchical multi-size structures spanning over a length-scale from 1 nm up to 1 µm. For weakly scattering samples the high intensity mode enables, using lenses and large samples up to 5 cm Ø, an intensity gain factor on the sample of about 11 for the same resolution as in the conventional pinhole mode. Finally, a new detection system based on an array of ^{3}He tubes and a fast electronics (GE Reuter-Stokes Inc.) enables measurements with very high stability at count rates of several MHz with no dead-time.

KWS-3 is a very small angle neutron scattering (VSANS) instrument using the focussing mirror principle. Standard configuration of the instrument with 9.5 m sample-to-detector distance allows performing scattering experiments with a wave vector transfer resolution between $4 \cdot 10^{-5}$ and $3 \cdot 10^{-3}$ Å^{-1}, bridging a gap between Bonse-Hart and pinhole cameras. The second sample position at 1.3 m distance extends the Q-range of the instrument to $2 \cdot 10^{-2}$ Å^{-1} and reaches more than one decade overlap with the classical pinehole SANS instruments. The principle of this instrument is a one-to-one image of an entrance aperture onto a 2D position sensitive detector by neutron reflection from a double focussing toroidal mirror. Thus the length scale that can be analyzed is extended beyond 10 µm for numerous materials from physics, chemistry, materials science, and life science, such as alloys, diluted chemical solutions, and membrane systems.

Looking inside and along KWS-1.

JCNS operates the neutron reflectometer **MARIA** with polarisation analysis. This instrument was designed for the investigation of thin magnetic layered structures down to the monolayer scale and lateral structures but may also be used for the study of “soft” layers at the solid/air and solid/liquid interface. The reflection of polarised neutrons allows to determine individually the density and the modulus and the direction of the magnetisation vector of buried layers. The instrument is optimised for layer thicknesses between 3 and 300 Å and lateral structure sizes from nm to µm sizes. Consequently it is designed for small focussed beam and sample sizes of 1 cm^2 at λ = 4.5 Å (available: 4.5 Å < λ < 40 Å) in a vertical orientation with a maximum incident angle of 180° and outgoing angle ranging from -14° to 100°. MARIA provides polarisation analysis in standard operation, where the beam is polarised by a polarising guide (z-geometry; 4.5 Å < λ < 10 Å) and analyzed by a wide angle ^{3}He-cell. Beside the above described reflectometer mode with good resolution in the horizontal scattering plane, MARIA can be used in the GISANS mode with additional resolution in the vertical direction. The latter mode allows one to measure lateral structures down to the nm scale.

The neutron/ X-ray contrast reflectometer **NREX**, operated by the Max Planck Institute for Solid State Research, is designed for the determination of structural and magnetic properties of surfaces, interfaces, and thin film systems. It is an angle-dispersive fixed-wavelength machine using a horizontal focussing monochromator (beam size down to 5 x 5 mm²). In combination with its spin-polariser/ analyser and flippers (spin leakage < 1%) it is proved to be a powerful tool to investigate magnetic nanostructures. An X-ray reflectometer can be mounted on the sample table orthogonal to the neutron beam and allows for the in-situ characterisation of sensitive soft matter samples and neutron/ X-ray contrast variation experiments. NREX provides specular and off-specular reflectometry as well as grazing incidence small and wide angle diffraction both in polarised and non-polarised modes. A closed cycle cryostat, an electromagnet for fields in all three space-directions and a gas tight chamber for experiments under defined environmental conditions are provided.

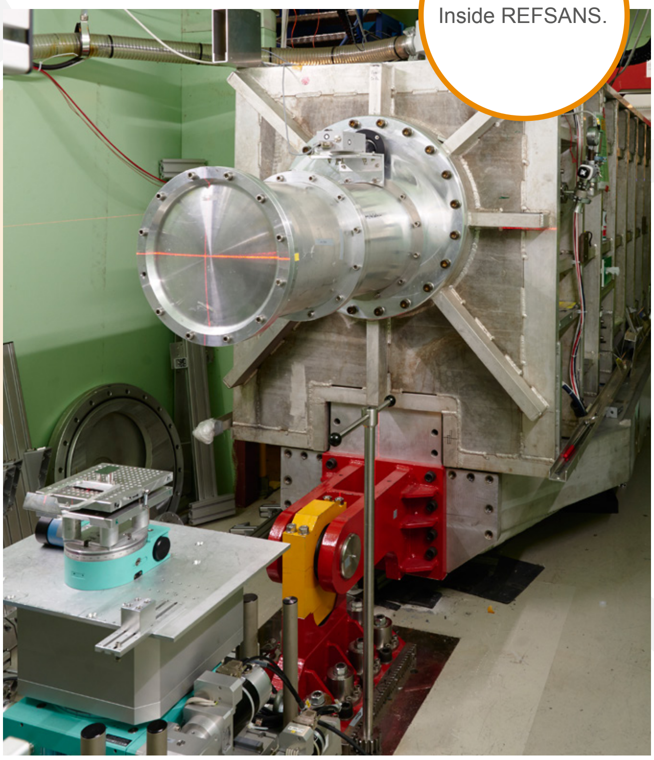
REFSANS, operated by GEMS, is a unique time-of-flight reflectometer for measuring both specular and off-specular reflectivity and grazing incidence small angle neutron scattering (GISANS) from solid samples as well as from the air-liquid interface. The instrument allows for high resolution measurements covering a large range of momentum transfer (up to Q_z = 0.3 $Å^{-1}$ in reflectometry) and ToFGISANS measurements (up to Q_y = 0.05 $Å^{-1}$). REFSANS can accommodate complex and heavy sample environments such as an in-situ sputtering chamber. In 2015, REFSANS has been equipped with neutron polarisers and analysers to allow fully polarised investigations of magnetic structures for reflectometry as well as for GISANS investigations.

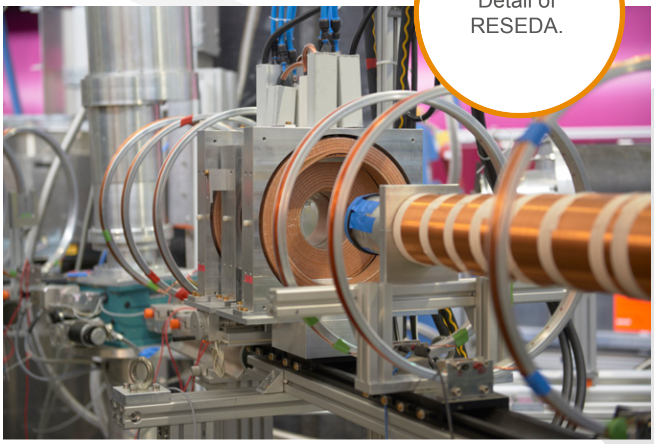
Since 2013, the new small-angle scattering instrument **SANS-1** is fully operational. HZG has designed and built SANS-1 as part of GEMS in cooperation with TUM to be one of the leading SANS instruments in the world. In its recent state of expansion it is equipped with a 1 m x 1 m ^{3}He based position sensitive detector that can handle the very high neutron flux of this instrument. The very flexible collimation systems allow experimental setups both optimised for high flux and high resolution experiments. A wide range of additional experimental equipment is already available. The next step in providing state of the art SANS options is the installation of the TISANE mode and a second velocity selector for very high resolution in 2016.

Spectroscopy

DNS is a versatile diffuse scattering instrument with polarisation analysis operated by JCNS. Compact design, a large double focussing monochromator and a highly efficient supermirror-based polariser provide an impressive polarised neutron flux in the range of 10^7 n/cm²s. The scientific focus lies on the studies of highly frustrated spin systems, strongly correlated electrons, emergent functional materials and soft condensed matter. In the combination with a large array of 1D position sensitive detectors covering the solid angle of about 1.9 sr and a high-frequency disc chopper system, both under development, DNS is expected to become a high count rate cold time-of-flight spectrometer with medium resolution.

Inside REFSANS.





Detail of RESEDA.

The **J-NSE** is a neutron spin echo spectrometer operated by JCNS. Neutron spin is used to encode the tiniest velocity changes during a scattering process. Due to the energy resolution's decoupling from the beam's intensity, that resolution is extremely high. This feature enables to study slow dynamic processes on mesoscopic time range covering 4 orders of magnitude (Fourier time of 2 ps up to 350 ns, currently 200 ns) at length scales from tens to fraction of nm (Q-range from 0.02 to 1.5 $Å^{-1}$). It is not only very well suited for soft matter systems that can be investigated by both coherent and incoherent scattering but also a perfect tool for investigations in the field of magnetism, i.e. spin excitations and material science. With its high signal-to-noise ratio, J-NSE is capable using the GISANS geometry and enabling to measure dynamics in thin films with depth resolution.

The cold three axes spectrometer **PANDA**, operated by JCNS, offers high neutron flux over a large dynamic range keeping the background comparably low. The high flux is achieved by neutron guide elements in the beam tube, a short source to monochromator distance, and the double focussing monochromator and analyzer crystals. Options for high energy and high q-resolution are available. With possible sample environment equipment for high magnetic fields and very low temperatures, PANDA is ideally suited for the studies of magnetism and superconductivity on single crystals. Lattice dynamics and magnetic structures are investigated successfully, too. A polarised neutron setup using both Heusler monochromator and analyzer as well as a sample space Helmholtz-coil set for longitudinal polarisation analysis is available.

The thermal three axes spectrometer **PUMA**, jointly operated by the University Göttingen and TUM, is characterised by a very high neutron flux. PUMA covers an energy transfer up to 100 meV using neutron energies between 5 and 160 meV. An optional multi-analyzer-detector system allows a unique and flexible type of multiplexing. An Eularian cradle is available to access the four dimensional Q-ω-space. Kinetic single shot experiments on short time scales and unique stroboscopic time resolved measurements of both elastic and inelastic signals on time scales down to the micro-second regime are possible. Typical applications are electron-phonon interactions, anharmonic phonons, soft mode phase transitions, magnons, spin waves in anti-ferromagnets, kinematic and dynamic interaction, unconventional superconductors, crystal field measurements.

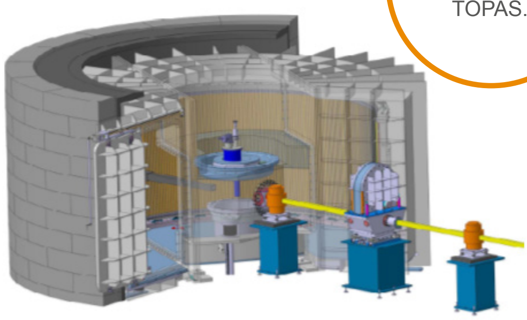
TUM operates **RESEDA**, a high resolution spin echo spectrometer (0.03 – 100 μeV) with an adjustable wavelength (3.5 – 12 Å) using a velocity selector with a high flux of $\Phi \geq 10^6$ n cm^{-2} s^{-1} at 5.3 Å. It offers a large time and scattering vector range for quasi-elastic measurements providing characteristic parameters like relaxation times and amplitudes of dynamic processes in macromolecular and magnetic systems. RESEDA has two independent secondary spectrometer arms. One is dedicated to longitudinal neutron resonance spin echo (LNRSE) comparable to classical NSE applications and the other one to the modulation of intensity with zero effort (MIEZE) method, which enables high-resolution studies of depolarising samples and/ or within depolarising sample environments, e.g. the observation of magnetic fluctuations under an external magnetic field.

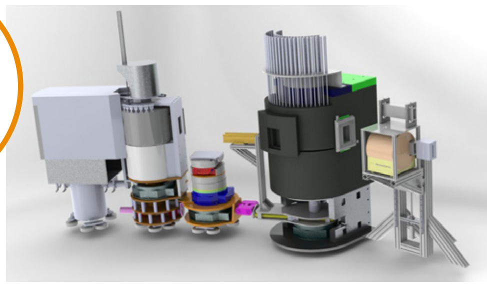
SPHERES is a third-generation backscattering spectrometer with focussing optics and a phase-space transform chopper. It covers an energy range of ±31 μeV with a resolution of about 0.65 μeV and

Q-range between 0.2 and 1.8 $Å^{-1}$. With argon filling of the secondary spectrometer, an unprecedented signal-to-noise ratio of 1700:1 is reached. Most experiments aim at the incoherent scattering: examples are hyperfine splitting, rotational tunneling, hydrogen diffusion, supercooled liquids, and relaxations in polymers and proteins. High count rates enable inelastic temperature scans and kinetic measurements. SPHERES is operated by JCNS.

TOFTOF is a direct geometry multichopper time-of-flight spectrometer using cold neutrons. It is operated by TUM. A seven high speed rotating chopper disc system offers resolutions between 2 µeV and 3 meV for wavelengths between 1.4 and 16 Å. Scattered neutrons are detected by 1000 ^{3}He counting tubes with a time accuracy of up to 50 ns for each neutron. TOFTOF combines high resolution, high neutron flux with an exceptional low background and a well shaped and symmetric resolution function. It is perfectly suited for a large variety of different scientific topics like proton diffusion in hydrogen storage materials, atomic and molecular mobility in liquids, polymer and protein dynamics and molecular magnetism and the dynamics of other magnetic systems. Standard low and high temperature equipment as well as dedicated environments like levitation melting makes the instrument highly flexible to meet the requirements of its users.

The thermal high-resolution neutron spectrometer **TRISP**, operated by the MPI for Solid State Research (Stuttgart), combines three axes and neutron resonance spin echo (NRSE) technique. Using a polarising supermirror guide and a bender or Heusler crystal analyzer it is optimised for studies of intrinsic line widths of elementary excitations (phonons, magnons) with an energy resolution in the µeV region over a broad range of momentum and energy transfers. TRISP also incorporates the Larmor diffraction (LD) technique, which allows to measure lattice spacings with a relative resolution $\Delta d/d = 1.5 \cdot 10^{-6}$. Typical applications cover thermal expansion under pressure and low or high temperatures and distributions of lattice constants (second order stresses). The sample environment includes a dilution cryostat with 8.5 mK base temperature.


Under construction: TOPAS.

Under construction: KOMPASS.


TUM and Universität zu Köln will operate **KOMPASS**, a three axes spectrometer fully designed to work exclusively with polarised neutrons and to provide a zero-field 3D polarisation analysis, complementary to the other TAS at Garching. Typical applications will be investigations of complex as well as weak magnetic structures and dynamics.

The future JCNS TOF-TOF spectrometer **TOPAS** with polarisation analysis will aim at highly correlated electrons in single crystals. The accessible Q-range from 0.1 to 8 $Å^{-1}$ and energy transfer range between 0.5 and 130 meV will be resolved. Polarisation analysis will offer new opportunities particularly for studying magnetic systems and molecular excitations involving hydrogen.

Imaging

The **ANTARES** facility operated by TUM uses a cold neutron beam for tomography and radiography. Based on a pinhole camera principle with a variable collimator, the facility provides a flexible use in high resolution and high flux imaging. ANTARES offers a very versatile setup including different collimations, different beam optics including a double crystal monochromator, beam filters, sample tables, and detection boxes. Gratings for linear phase contrast are available. Typical applications are standard neutron radiography (o-rings in machine parts), computed tomography (geological and biological samples, machine parts), continuous radiography of dynamic processes, stroboscopic imaging (oil distribution in running engines), phase contrast (aluminum foams, magnetix flux lines in superconductors), energy/ wavelength scans (for phase or material identification), magnetic imaging (on ferromagnetic materials), dark field imaging, and X-ray radiography.

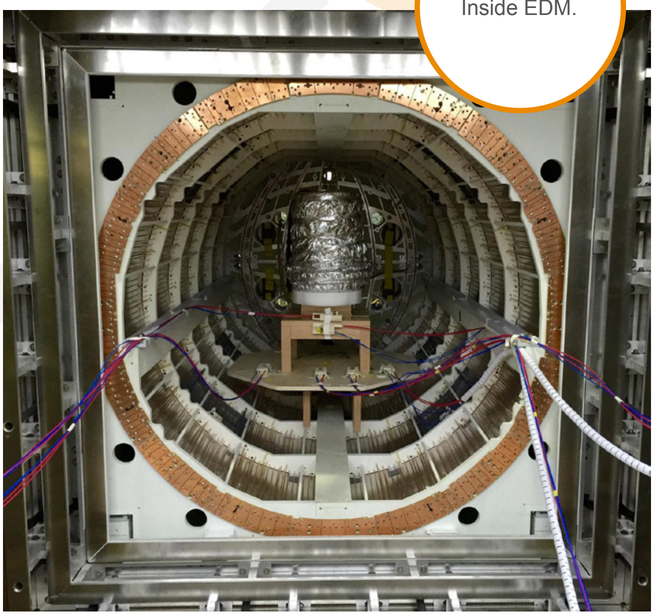
The second radiography and tomography station **NECTAR**, also operated by TUM, uses fission neutrons. Investigations focus on objects with high hydrogen content or massive items, where cold/ thermal neutrons are not suitable. Typical examples are water or oil containing (metallic) objects (e. g. gear boxes), hydrogen storage containers, turbine blades,wooden samples, and cultural heritage objects etc. In addition to the investigation of static objects, time resolved radiography for slow processes like water intrusion in trunks or periodic processes is also possible.

Nuclear and Particle Physics

The experimental area **MEPHISTO** (measurement facility for particle physics with cold neutrons), operated by TUM, is dedicated to long term experiments in the field of nuclear and particle physics. Currently the experimental area moves from the Neutron Guide Hall West to the Neutron Guide Hall East. The solely used neutron guide SR-4b will deliver a white cold spectrum for experiments. A removeable 11% velocity selector at the end of the guide completes the beam line. The MC-simulation for this beam with a dimension of 60 x 10^6 mm^2 propose a mean wavelength 4.5 Å and a gold capture flux of $2 \cdot 10^{10}$ n cm^{-2} s^{-1}. The experimental area is 5 x 25 m^2, diagonal in the Neutron Guide Hall East. It is planned to install the instrument PERC at the MEPHISTO beam line during the first years of operation. This instrument is a precise, bright and intense source of protons and electrons from the neutron decay. The instrument PERC itself is open for external user groups with spectrometers to measure the protons and electrons. Its construction is a collaborative effort of Heidelberg University, University of Vienna and TUM.

PGAA, the prompt gamma activation analysis instrument, is jointly operated by the University of Cologne and TUM. It is based on the spectrometry of prompt and delayed gamma radiation after neutron capture. PGAA is ideal for the determination of light elements (Z < 30) or the matrix composition, and is widely used for hydrogen (water), or boron analysis. The cold neutron beam with the flux up to $6 \cdot 10^{10}$ $cm^{-2}s^{-1}$ can be used for the activation of trace elements (typically Z > 30), too, which can be measured at the new low-background counting facility. Solids, liquid, or gaseous samples of 1 mg – 1g up to 10 cm^3 are being analysed non-destructively from the fields of archeology, geology, medicine, material science, chemical technology, nuclear sciences etc.

In the Neutron Guide Hall East a new facility to search for the electric dipole moment of the neutron (**EDM**) is currently being installed by TUM. The electric dipole moment of the neutron would be a clear sign of new physics beyond known par-



Inside EDM.

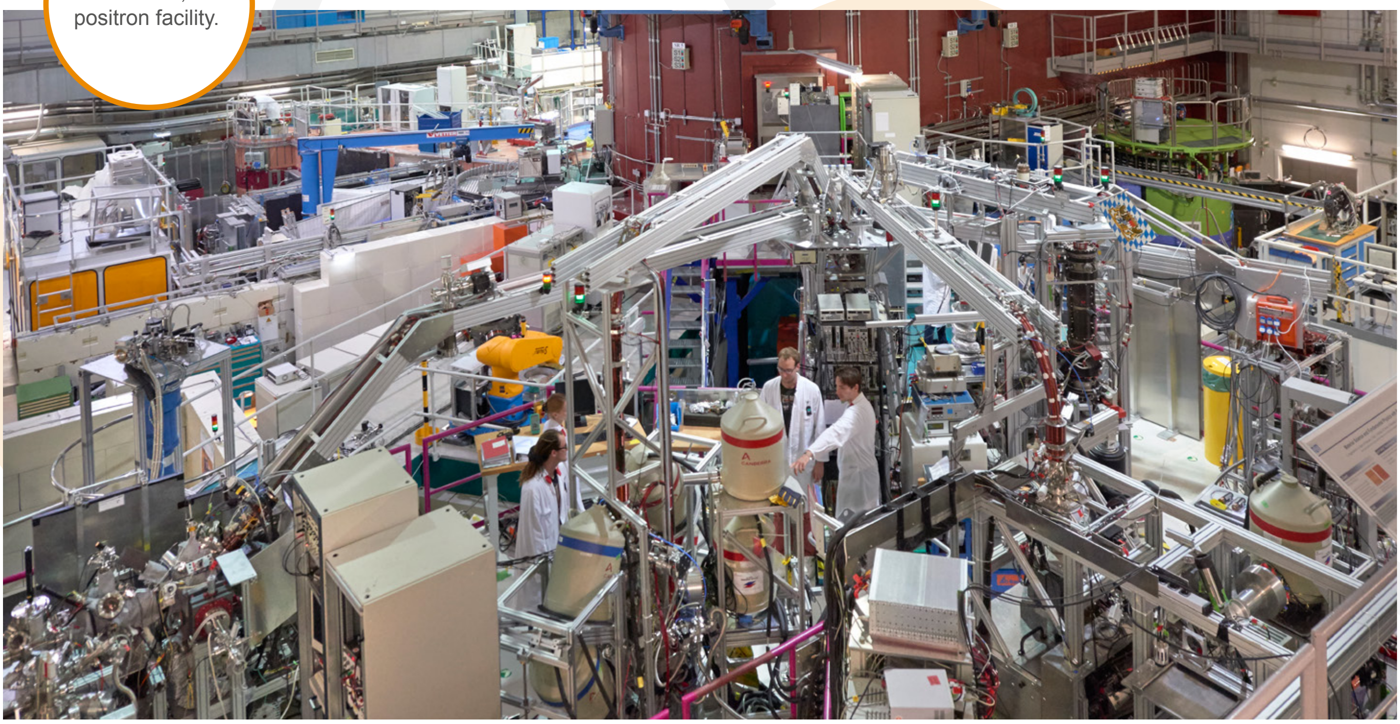
ticle physics applications. This phenomenon is considered one of the most important experiments in fundamental physics and could provide key information on the excess of matter versus antimatter in the Universe. With high measurement precision, this experiment aims to achieve a sensitivity of 10^{-28} ecm for a charge distribution within the neutron. This can be interpreted as a probe of the early Universe, less than 10^{-11} s after the big bang and beyond the reach of accelerators.

TUM, the Maier-Leibnitz Laboratory and the Excellence Cluster Universe are planning a precision experiment on neutron lifetime operating with proton extraction (**PENeLOPE**). Its goal is to determine the neutron lifetime with statistical and systematic errors smaller than 0.1 s using ultra cold neutrons (UCN) trapped by magnetic fields and gravitation. The UCN, coming from the UCN source that is currently under construction, are polarised using a magnetised foil and guided into the storage bottle. Due to gravity, the UCN cannot "jump" out of the trap and the top can be left open to mount a detector to directly register the decay products, protons and electrons, during storage.

Positrons

NEPOMUC provides the most powerful monoenergetic positron beam worldwide. Inside the inclined beam tube SR-11, positrons are generated by pair production in platinum foils using high energy gamma radiation released after neutron capture in cadmium. By variation of its energy, the brightness enhanced beam enables depth dependent studies, and additional lateral scanning allows the three dimensional reconstruction of e.g. defect distributions. NEPOMUC supports various instruments for sophisticated studies with positrons like the coincident Doppler-broadening spectrometer (**CDBS**), the positron annihilation induced Auger electron spectrometer (**PAES**), positron lifetime spectroscopy with the pulsed low energy positron system (**PLEPS**), and the scanning positron microscope (**SPM**). The instruments are jointly operated by TUM (CDBS, PAES) and Universität der Bundeswehr München (PLEPS, SPM). An additional beam port can be used for unique experiments like the production of the positronium negative ion or an electron positron plasma. The positron beam experiments cover a broad range of applications in material science, surface and solid state physics as well as studies for fundamental research.

NEPOMUC, the positron facility.



At the Materials Science Laboratory.

Laboratories

Numerous well equipped laboratories are on-site to support the scientists in preparing and characterising their samples prior to or after the neutron scattering experiments. These laboratories offer a wide range of equipment to prepare and pre-characterise samples. They offer the basic toolset to handle or store the samples under the appropriate conditions, prepare solutions or even perform chemical reactions. For details, please visit

mlz-garching.de/user-labs

JCNS operates the **Biology** and the **Chemistry Laboratory**, both specialised on soft matter samples. GEMS and TUM operate the **Materials Science Laboratory** where complementary analytics to characterise samples are possible. Directly in the Neutron Guide Hall West the **Sample Preparation Laboratory** is located. Even more specific are the transmission electron microscope (**TEM**) and the thin film deposition system molecular beam epitaxy (**MBE**) as well as the **v|tome|x** for X-ray tomography. At MLZ, transmission electron microscopy is used as a complementary technique to support soft matter studies. The MBE system is ready for the fabrication of high-quality thin films intended for the investigation with the neutron reflectometer MARIA or other instruments at the MLZ. The high resolution computer tomography facility v|tome|x is especially interesting for users of ANTARES in order to get more and other insights in their samples.

Detail: standard cryostat.

Sample Environment

A versatile set of sample environment equipment is a key to fully leverage the capabilities of the neutron scattering instruments. A good mix between highly specialised and more standard apparatus which fit to a couple of instruments is the recipe to meet the users' requirements. Its major part is designed and fabricated or assembled in-house by the Sample Environment Group, offering the ability to adapt environments for special requirements. It ranges from temperature equipment down to 50 mK and up to 2200 K. Parameters like magnetic field, pressure or load can be applied to samples under investigation. The equipment is optimised for neutron scattering with a special emphasis on combining different parameters. Details can be found at

mlz-garching.de/se

Detail: HP 400 kN press.

JCNS instruments at ILL and SNS

IN12 at ILL.

IN12 at ILL

IN12 is a three axes spectrometer (TAS) for cold neutrons at the Institut-Laue Langevin in Grenoble, France. It is operated by the Forschungszentrum Jülich in collaboration with the CEA Grenoble as a CRG-B instrument. The available beamtime is shared amongst the collaborating partners and users can apply for beamtime via the respective institutes.

With the recent upgrade, latest modern optical components are employed. A new guide in combination with a virtual source concept and a double focusing monochromator guarantee highest flux. The accessible Q-range lies between 0.1 and 6 $Å^{-1}$ and energy transfers between 0 and more than 20 meV are possible. With its high unpolarised and polarised neutron flux, IN12 allows for demanding experiments and retains its position as one of the best cold three axes spectrometers in the world.

IN12 is ideally suited for elastic or inelastic high resolution investigations at low energy magnetic and lattice excitations mainly in single crystal systems. But also thin films, amorphous materials at the lower Q range, powder samples or even model membranes have been studied in recent time. Typical experiments comprise, e.g., superconductors, pnictide or heavy fermion systems, but also a trend to energy-related materials is found like multiferroic or thermoelectric samples. Users can choose between different sample environments, e.g., high and low temperatures, high pressure, electric and magnetic field up to 15 T, and longitudinal or spherical polarisation analysis with the Cryopad setup.

In the near future also a multi-analyzer multi-detector option (IN12-UFO) will be installed.

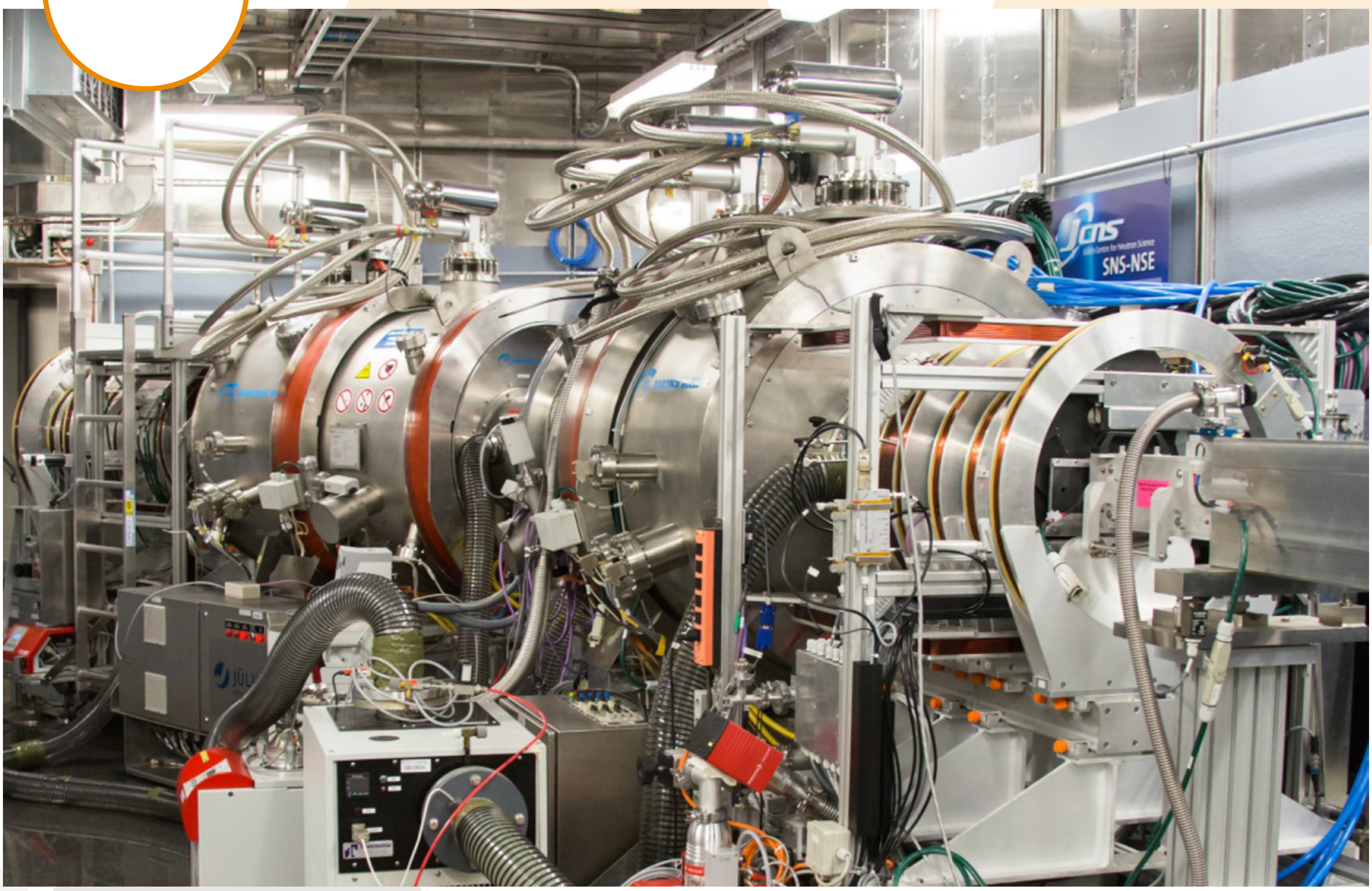
NSE at SNS

The SNS NSE instrument provides ultrahigh resolution spectroscopy with a Fourier time range that covers τ = 1 ps to a nominal 350 ns with a high effective neutron flux, aiming to be the best of its class in both resolution and dynamic range. Researchers use this instrument to investigate soft condensed matter and complex fluids applications in a variety of fields. The design of the NSE spectrometer takes full advantage of recent progress in neutron optics and polarising supermirror microbenders, resulting in considerable gains in polarised neutron flux over a wide wavelength range. For the future, plans are to develop novel field correction elements to extend the maximum achievable Fourier time (i.e., the resolution) up to 1 µs. Using wavelengths of 2 Å < λ < 14 Å, an unprecedented dynamical range of up to $1:10^6$ can be achieved in theory.

Although the NSE spectrometer is designed primarily for soft matter research, its capabilities also make it useful for all fields of modern condensed matter physics, materials science, and biophysics. This instrument is especially suited for analyzing slow dynamical processes and thereby unraveling molecular motions and mobilities at nanoscopic and mesoscopic levels. This feature is highly relevant to soft matter problems in research on the molecular rheology of polymer melts, related phenomena in networks and rubbers, interface fluctuations in complex fluids and polyelectrolytes, and transport in polymeric electrolytes and gel systems. NSE could also aid studies in magnetism.

www.fz-juelich.de/jcns

NSE at SNS.



Access to German Neutron Facilities

The neutron instruments operated at the German neutron sources FRM II and BER II are open to both national and international users. Up to 70% of the available beam time is distributed to external users. Its main portion is foreseen for short term research proposals.

Application for Beam Time

Those proposals for beam time can be submitted electronically at

- **user.frm2.tum.de**
- **fzj.frm2.tum.de**
- **www.helmholtz-berlin.de/user**
- **gems.hzg.de**

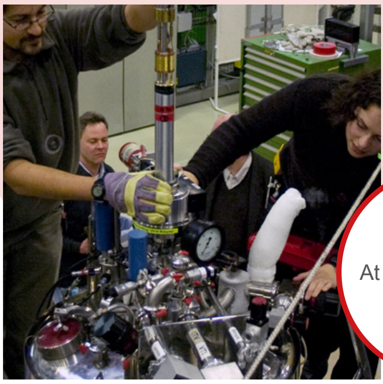
HZB and HZG strongly encourage projects with complementary use of neutrons and synchrotron radiation. For more details on the available methods and stations at the synchrotron facility, please refer directly to the HZB and HZG web pages.

Allocation of Beam Time

MLZ and HZB run scientific selection panels to review all submitted proposals twice a year and advise on priorities and beam time allocation. These well-known international experts base their decision purely on the scientific merit of the proposals.

Urgent scientific research proposals as well as industrial research may apply for director's beam time anytime by contacting directly the individual facilities.

Rapid access is available for special purposes.



At FLEXX (HZB).

Beam Fees

The services of all facilities are free of charge for members of universities and other public institutions. The readiness to publish the scientific results in internationally accepted journals and the proper acknowledgment of the supporting scientist at the used instrument is prerequisite for this charge-free admission. Industrial applicants should contact the individual facilities for information on access.

Financial Support

The facilities offer limited funds to assist with travel and subsistence expenses for users from German universities.

MLZ and HZB are members of a network of European neutron facilities – the "Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy" (NMI3-II). The NMI3-II project is supported by the European Commission through the 7th Framework Programme and is part of the Research Infrastructures action of the Capacities Programme (Contract No: 283883). It brings together 18 partners from twelve countries, including eight research infrastructures. Users from laboratories in EU Member Countries and Associated States can be supported by NMI3 and are eligible for the reimbursement of travel and subsistence expenses when carrying out accepted projects.

nmi3

www.nmi3.eu

At ANTARES (MLZ).

Imprint

Editors
Ina Lommatzsch
Jürgen Neuhaus
(**FRM II**)
Astrid Brandt
Thomas Gutberlet
(**HZB**)
Rainer Bruchhaus
(**JCNS**)
Jean-François Moulin
Martin Müller
(**HZG**)

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User Office Heinz Maier-Leibnitz Zentrum (MLZ)
Lichtenbergstr. 1
D-85747 Garching

+49-(0)89.289.10794
useroffice@mlz-garching.de
mlz-garching.de/user-office

In collaboration with

Helmholtz-Zentrum Berlin für Materialien und Energie GmbH (HZB)

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User Offices

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