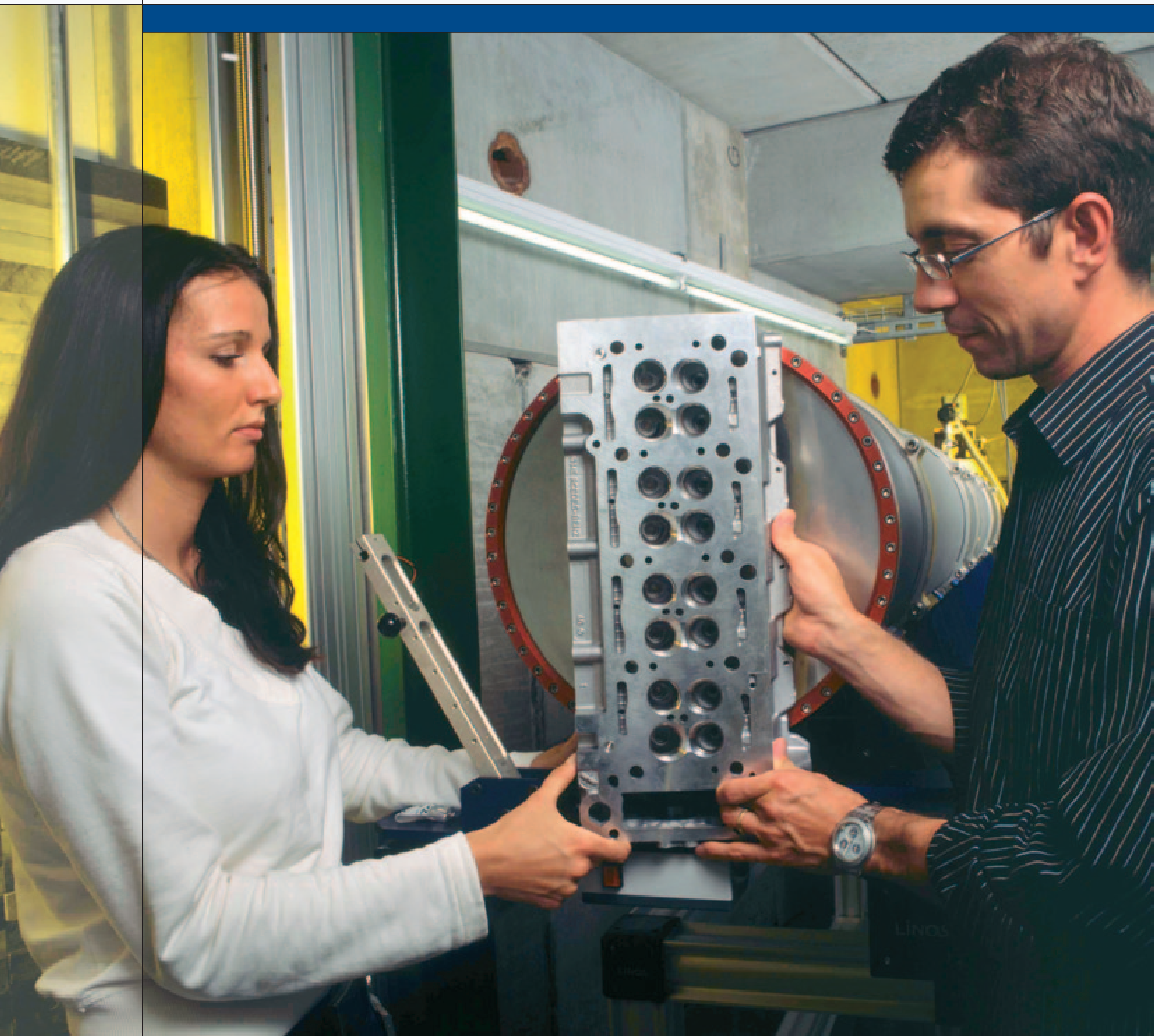
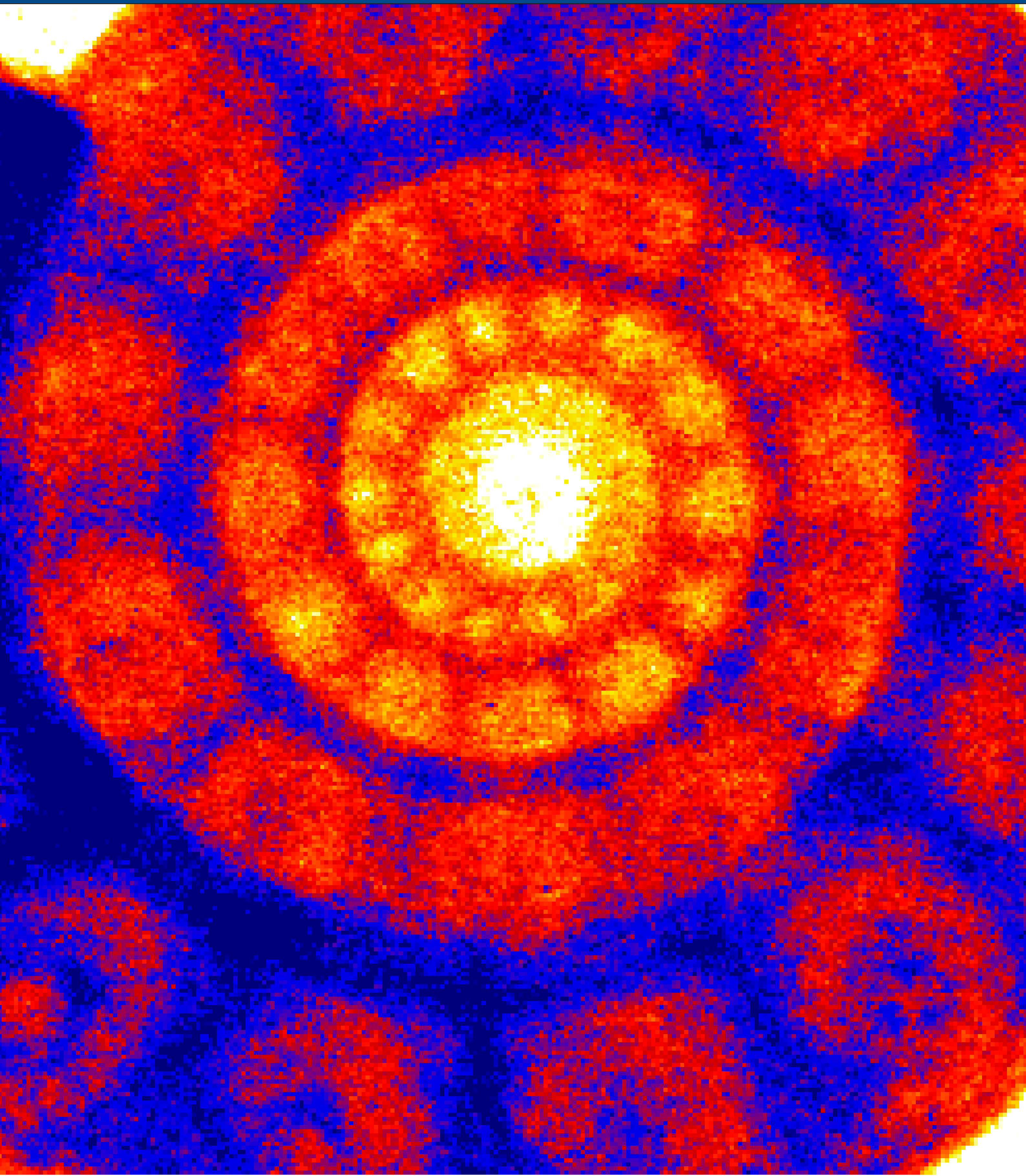
PAUL SCHERRER INSTITUT

Neutron Imaging

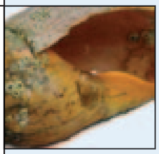
How neutrons create pictures

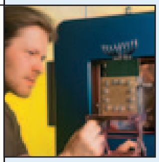


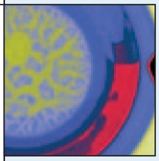


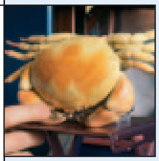
Illuminated by neutrons: the spiral-shaped fossil of a tiny ammonite (diameter 20mm).

Contents



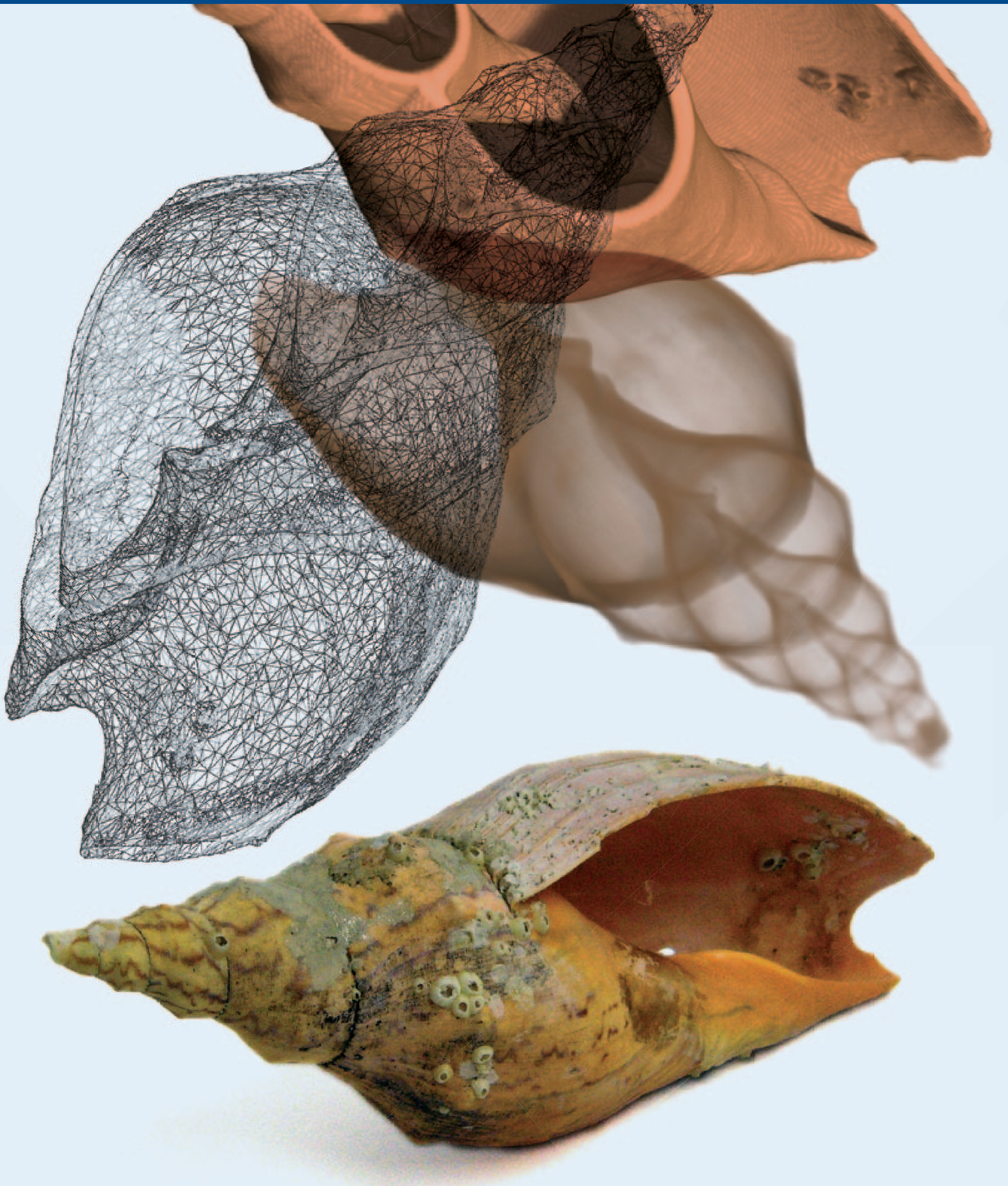






Cover photo: setting up a test object (engine block) at the ICON facility, which is designed for measurements using cold neutrons.

Tomography data can be used to chart the three-dimensional structure of a mussel and create a mathematical model of its surfaces.



A special kind of picture

Neutrons offer a view within

Neutron imaging is a process that produces a special kind of picture. For example, researchers can use this method to look inside a camera without opening it up.

Various methods can be used to see inside objects without destroying them in the process. X-rays are a well-known method often used for medical purposes. Less well known, but no less valid, is a method that uses neutrons (neutron imaging, previously called neutron radiography).

In contrast to X-rays, neutrons are able to penetrate heavy metals such as lead or uranium. Neutron radiation has other advantages: it is the method of choice for delicate organic materials and for water. Whether neutrons or conventional X-rays are the best choice therefore depends on the material to be studied. Neutron imaging represents a valuable complement and alternative to conventional X-ray technology. Thanks to this method, researchers are able to produce images of the insides of objects where other methods fail.

Considerable know-how needed

Nevertheless, neutron imaging does entail a disadvantage: producing neutrons is no easy matter. A large-scale facility and a great deal of expertise are both required in order to produce neutron beams that are intense enough and of high quality. This form of technology is therefore unsuitable for everyday tests. All investigations involving neutrons have to be carried out on site.

At PSI, the large-scale SINQ facility supplies the neutrons required for experiments. SINQ went into service in 1996, replacing the SAPHIR research reactor completed in 1957. SINQ is surrounded by an excellent infrastructure, which makes it possible to study complete processes and structural changes as well as individual samples.

A camera in reality (photo right) and in transparent 3D representation (left). Neutrons can be used to record and depict internal structures.

A fuel cell is installed for investigation in the new ICON neutron radiography facility.

Non-destructive testing

The potential applications of neutron imaging are obvious. We need non-destructive testing methods when investigations must not alter the functional capabilities or external characteristics of an object. Neutron imaging is able to make internal faults or material changes directly visible. The method is used mainly for safety-related objects or for expensive or unique objects. As a result, neutron imaging is often used in air and space travel, in motor manufacture, as well as for investigations of museum pieces.

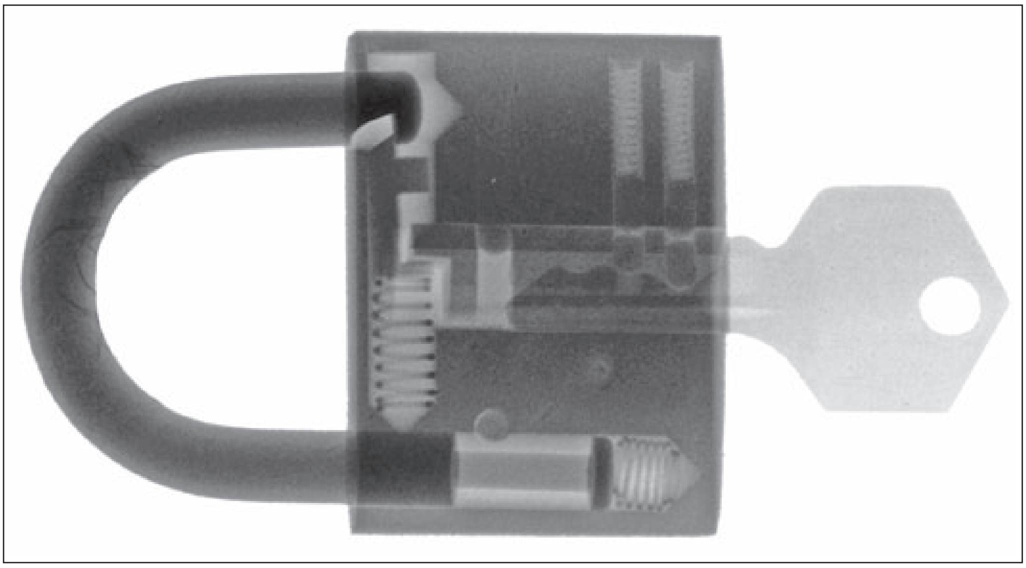
The neutrons that make contact with the object during such tests can penetrate through the layers of material without destroying or damaging them. As shown in the image below, the neutron radiation is weakened to varying degrees, yielding information about the object under consideration. In the best case, attributes such as the quality or internal functionality of the object can be evaluated.

What are neutrons?

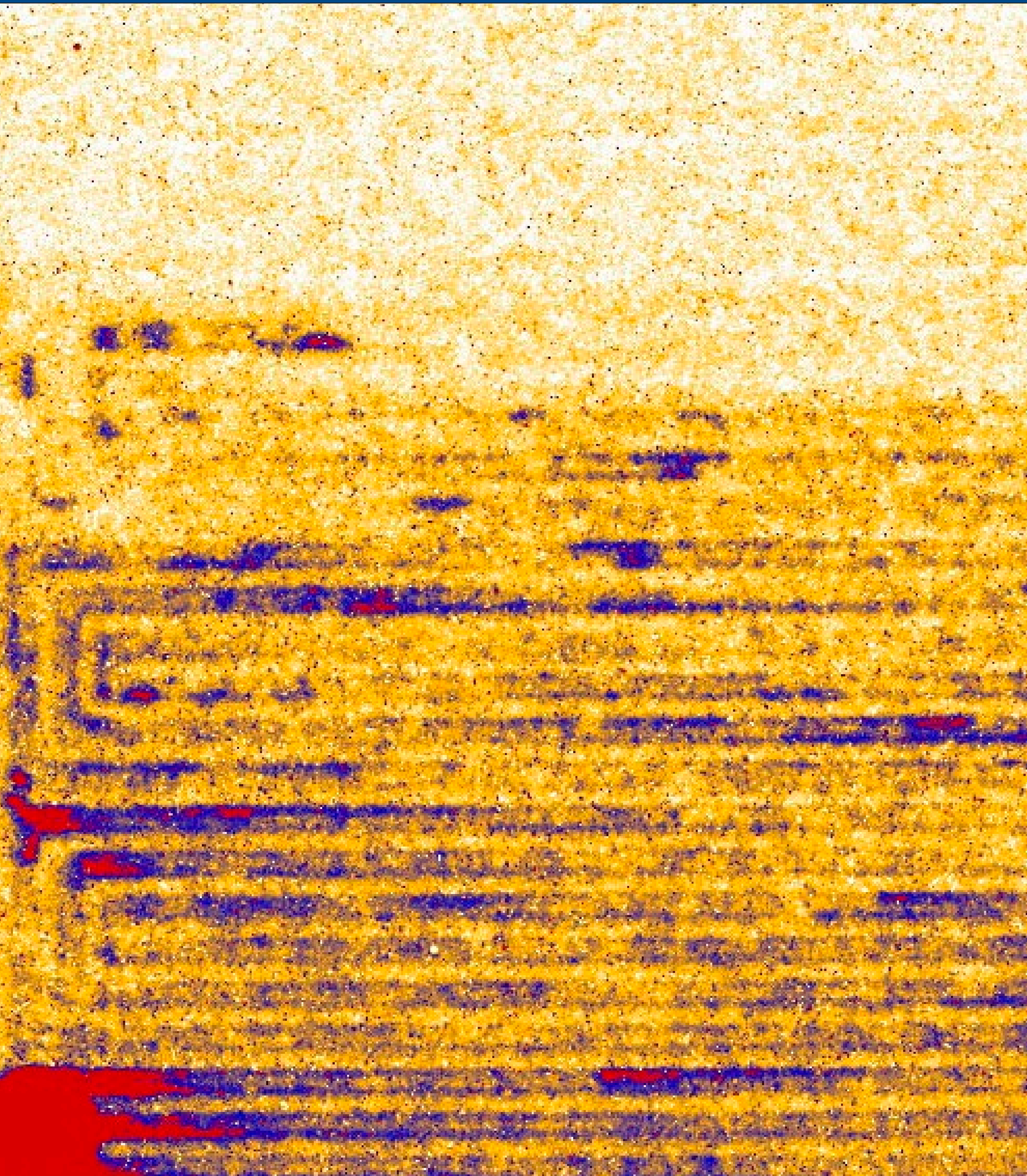
Neutrons are elementary components of matter; all atomic nuclei except for hydrogen are made up of protons and neutrons. Neutrons can only be set free by a nuclear reaction. They can be used as free particles and in the form of guided beams to carry out various types of experiments. Images such as those contained in this brochure have been obtained in this way.

What are imaging processes?

Imaging processes comprise the full range of techniques by which medical, physical and chemical phenomena can be visualised. These include photography, X-ray tomography, positron emission tomography (PET), magnetic resonance tomography (MRT) and neutron imaging.



The full functionality of the various metallic components of the lock can be analysed.



Neutron radiograph of a fuel cell: an excess of water (violet/red areas) affects the supply of oxygen, and therefore performance.

Radiography – the principle

From source to detector

The term “radiography” refers to the creation of images on film or digital data media by the irradiation of objects. The most familiar form of radiography is probably X-ray radiography: this includes X-ray investigations carried out by the dentist, or after breaking a bone, as well as computer tomography (CT), all of which provide images of the inside of the body (radiographs are two-dimensional, while tomograms are three-dimensional).

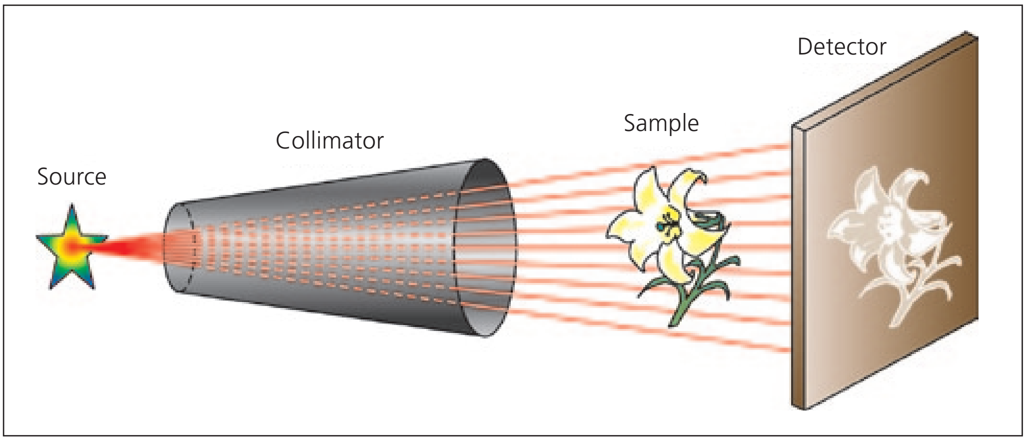
However, X-ray radiography is not just used in medicine; it is also widely used in industrial applications. Ultrasound and magnetic resonance are two other important imaging processes that are used for the non-destructive investigation of materials as well as in medicine.

Neutrons as suppliers of information

Neutron imaging is becoming increasingly established as a method of non-destructive testing – whether as a supplement to X-ray radiography or as the only option under consideration. In principle, neutron imaging works in the same way as X-ray radiography, but with a few important physical differences. These mean that neutron imaging can provide certain information that would be impossible with X-ray radiation.

The principle of a radiography system is illustrated in the graphic below. In addition to a radiation source (X-ray equipment or the SINQ neutron source), neutrons need an evacuated collimator through which the neutrons are propelled before they hit the test object. The detector behind the sample provides a two-dimensional image of the radiation, which will have been weakened to a greater or lesser degree by the sample. Information about the internal characteristics or structures of the sample can be gained in this way without destroying it in the process. If the sample in the radiation field is rotated step by step, special computer reconstruction processes can be used to generate a three-dimensional image known as a tomogram.

The simplified drawing in the graphic below depicts a complicated system in reality (page 19), because the best image quality is produced by the strongest possible source of radiation. Radiation protection requirements must therefore be taken into account, and the facility accommodated in a room that is specially secured and shielded against the type of radiation being used.



The principle of the radiography system: a surface detector fixed behind the sample records the radiation emitted by the source, thus revealing the weakening effect within the sample.

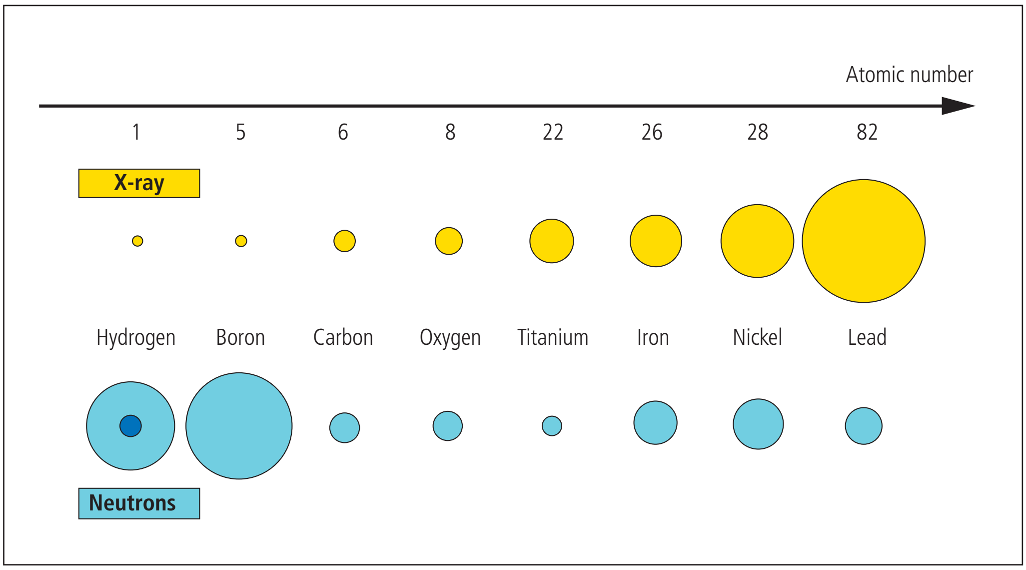
The characteristics of neutrons

- Neutrons are neutral particles, i.e. they are uncharged. Together with the positively-charged protons, they form the nucleus of atoms (except hydrogen).
- A free neutron is unstable. It decays with an average lifespan of 15 minutes into a proton, while emitting an electron and an antineutrino.
- Because neutrons are electrically neutral, they do not react with the electrons that surround the atomic nucleus. As a result, they can penetrate deeply into matter. They react only with atomic nuclei, in a way that varies greatly according to the type of atomic nucleus involved and the energy of the neutron itself. Some atomic nuclei capture neutrons that come near to them or do not have a very high energy. This is called neutron absorption. Materials containing this type of atomic nucleus (e.g. boron, lithium, cadmium and gadolinium) are highly suitable for shielding against and detecting neutrons.

  Other atomic nuclei barely react at all and are more or less transparent to neutrons. Aluminium and lead are important examples of these. Other types of material (mainly substances containing hydrogen) deflect neutrons more or less forcefully from their flight-path. In this case, we speak of the neutron scattering.
- Neutrons can exhibit an extremely wide range of velocities depending on how powerfully they are decelerated after generation. The types known as thermal neutrons and cold neutrons are of very particular interest to PSI researchers, since they are especially well suited to the investigation of materials. Thermal neutrons and cold neutrons differ from each other in their energy or wavelength, and they therefore react distinctively with the atomic nuclei of the sample and the detector. As a result, the contrast in the images will differ, depending on whether the study involved cold or thermal neutrons.

Differences from X-ray radiation

X-ray radiation is a form of electromagnetic radiation, and therefore differs fundamentally from neutron radiation. X-ray radiation reacts with the electrons in the electron shells of the atomic nucleus. For X-ray radiation, the reaction probability therefore increases with the size of the atoms in the sample under investigation, because the larger the atom, the more electrons it possesses. This means that X-ray radiation can not be used to investigate lead containers, since lead is a relatively heavy atom with many electrons. This contrasts to the reaction probability in the case of neutrons, which do not observe such a physical law.

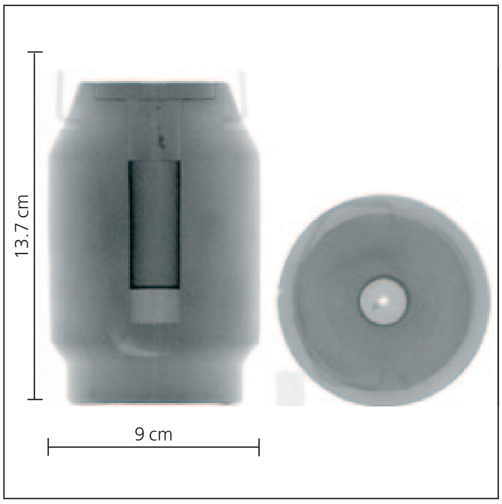


The diagram shows the reaction probability with X-ray or neutron radiation for various materials.

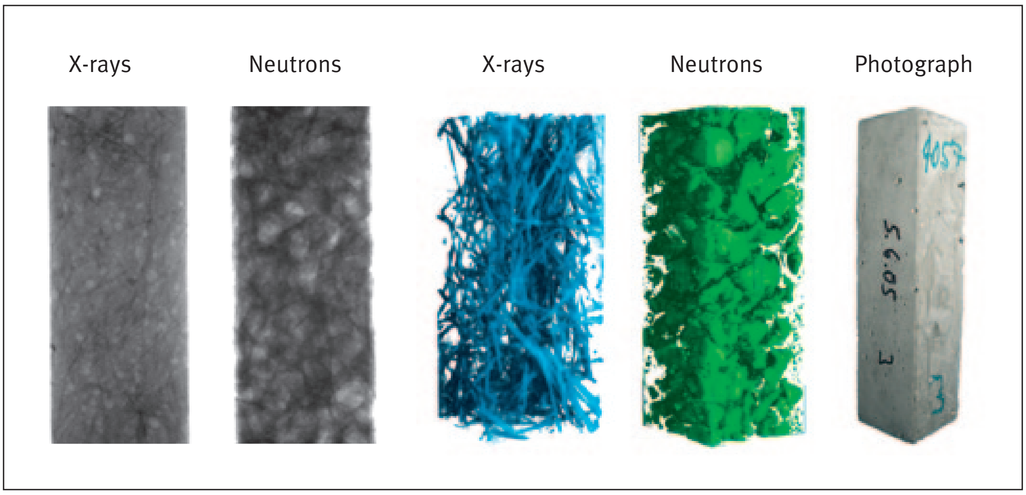
Major difference with lead

The diagram on the bottom left is a graphic representation of the difference in reaction probability for neutron and X-ray radiation; large areas signify high reaction probabilities. The difference is particularly noticeable in the case of lead. While lead is used as a very effective shielding material against X-ray radiation, the reaction probability for neutrons is very low. Lead is practically “transparent” to neutrons, as the image on the right shows. A lead container with contents that were initially unknown was irradiated with neutrons. The recorded image showed that there was an empty plastic beaker inside the lead container, and that the container could therefore be opened without danger. The plastic in the beaker had a much higher hydrogen content than the lead container, and therefore provided much greater contrast.

Neutron and X-ray radiography of the same object often produce complementary information, as can be seen from the illustration below. A sample of reinforced concrete shows the different effects of neutron and X-ray radiation particularly convincingly. The green image shows a tomogram generated by neutrons. It is possible to recognise the hydrogen-containing components of the concrete (sand, gravel, etc.), though nothing can be seen of the reinforcing iron. In the blue image, an X-ray tomogram, on the other hand, the structure of the reinforcing iron is practically all that can be recognised. The two images on the far left are radiographs of the same object. Even though differences are detectable in these images, the tomographic images are better at showing structural differences.



Transparent lead: neutrons can penetrate through a lead container without difficulty and show the empty plastic beaker inside.



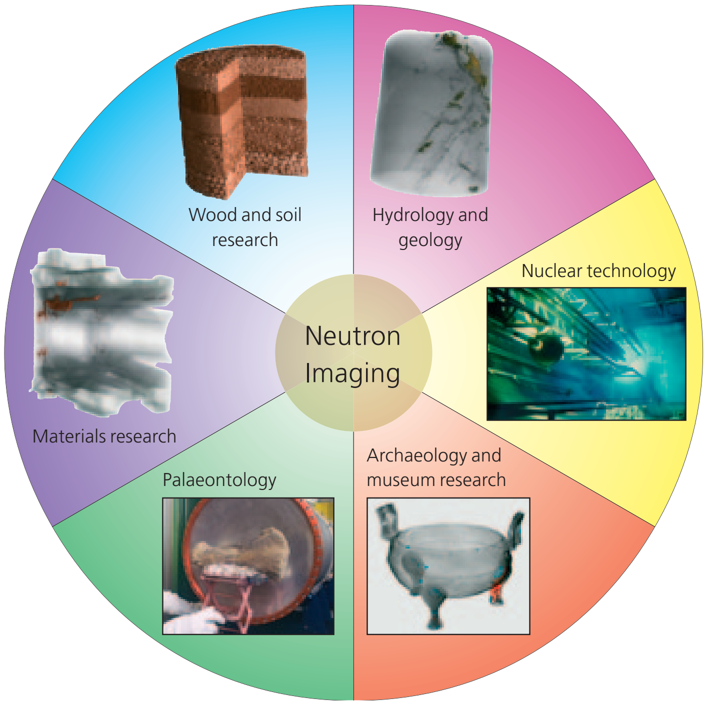
The two images on the left are radiographs of the reinforced concrete sample photographed on the right. The blue and green images are tomograms.

A petrol station filler nozzle is prepared for investigation at the ICON neutron radiography facility. The radiograph is shown on the right.

Fuel cells and bronze sculptures

Applications of neutron imaging

Wide range of scientific and technical applications



Research into wood and soil: e.g. precise analyses of moisture content in wood samples

Hydrology and geology: e.g. analyses of rock formation or geological transport processes

Nuclear technology: e.g. examination of fuel elements and quality control

Archaeology and museum research: e.g. research into bronze and iron objects or paintings

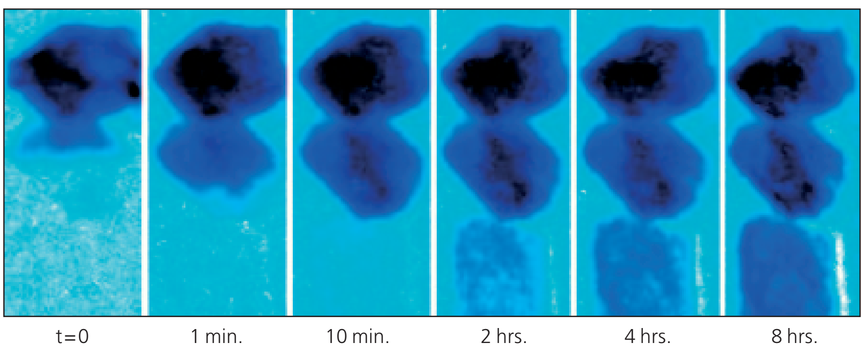
Palaeontology: e.g. examination of fossils

Materials research: e.g. investigations into alloys, welds, etc.

How moisture disperses

The way in which moisture spreads in soil structures, and the conditions under which it spreads, are important and urgent problems that are still not fully understood. The temporal progression of the wetting of grains in soil (agglomeration) can be observed with the help of neutrons, and compared later with models.

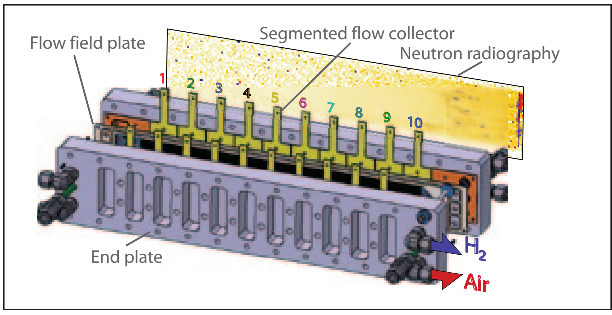
The exchange rate of moisture is determined by the wetting surface: the greater the wetting surface, the faster the water flows from one grain to another.



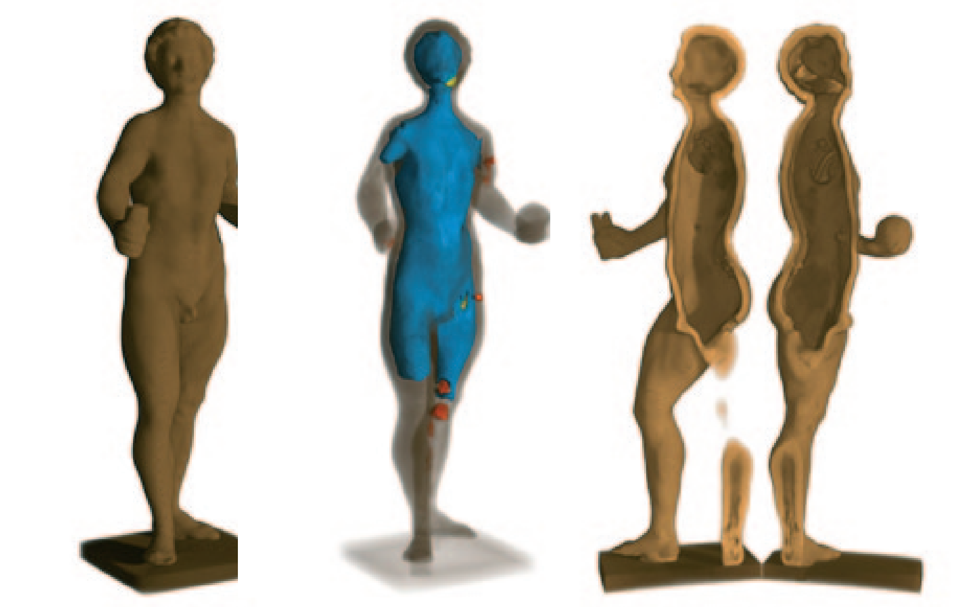
Wetting of soil grains, recorded by neutrons over a period of 8 hours; the moisture alone is illustrated by extracting the soil structure from the images mathematically. The dimension of the grains in these images is about 5mm.

Bronze Renaissance sculptures

A project in collaboration with the Reichsmuseum in Amsterdam carried out the non-destructive analyses of famous bronze statues with the aim of describing the methods of manufacture and any manufacturing faults. Using mathematical tools, virtual sections were produced of the objects on the basis of the tomographic data. At the same time, it was also possible to analyse the hollow internal spaces, the negative of the casting mould, defects and repair sites. Neutrons are particularly effective in this instance, because they penetrate metals well and can provide sensitive evidence regarding organic materials, such as the locations of adhesions, resins or lacquers.



The performance of a PEM fuel cell depends heavily on the moisture content in the membrane. This can be measured inside the external structure with the help of neutrons.



Tomographic views of a sculpture: virtual sections can be taken from any desired position without damaging the object.

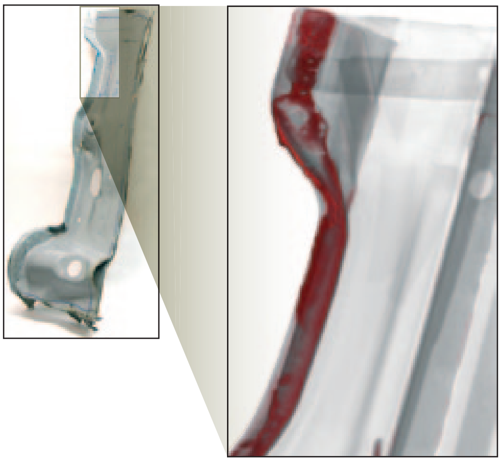
More efficient fuel cells

The transformation of chemical energy into electrical energy occurs much more efficiently in a fuel cell than in combustion processes. Intensive research is being undertaken world-wide in order to understand in detail the processes taking place within the cells and to optimise the characteristics. One important application of fuel cells may be to automobiles.

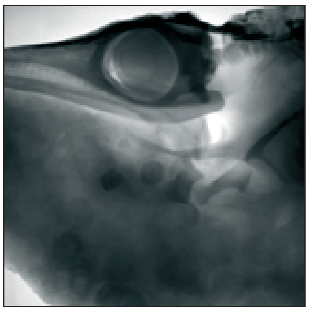
The water produced by the conversion of hydrogen and oxygen plays an important role here. Neutrons can be used to analyse the distribution of water in the fuel cell non-invasively and with good resolution in space and time.

Exposing faulty adhesions

As shown in the following example from the field of motor vehicle manufacture (image below), neutrons can be used to determine the distribution of adhesive material in metal joints extremely precisely. These investigations were carried out using tomographic methods in which the full three-dimensional structure was recorded. As long as the adhesions occur only on even surfaces, radiological investigations are sufficient and significantly



Part of a car body incorporating an adhesive joint: neutron tomography can be used to show the adhesive inside the metal. This makes it possible to see faults.


Fossilised skeleton of an Ichthyosaurus, partially laid open (photo left). View of the area around the eye in the transmission view (centre) and the tomographic view (right). (Source: U Oberli, St. Gallen)

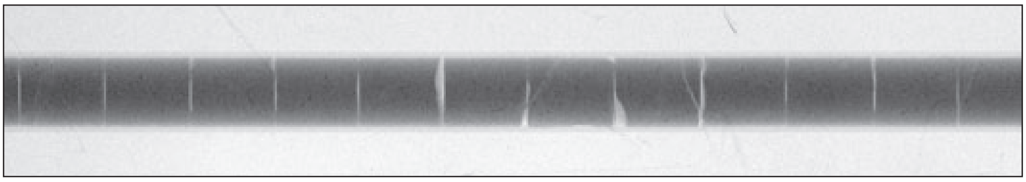
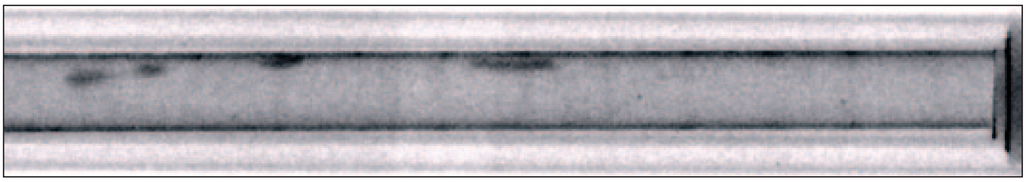
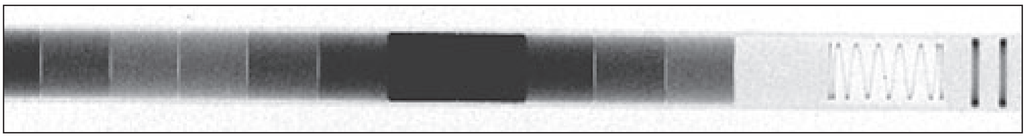
less expensive. This type of investigation is particularly necessary in construction where safety is relevant to ensure that components have been joined together properly.

Palaentological discoveries

Neutron imaging can also be used for the non-destructive testing of very large fossils. The image above shows the partially laid open front section of an Ichthyosaurus. The fossilised bones are separated visually from the sediment in the neutron tomogram of the head area, enabling discoveries to be made about the development of such saurians, or the planning for more advanced preparation.

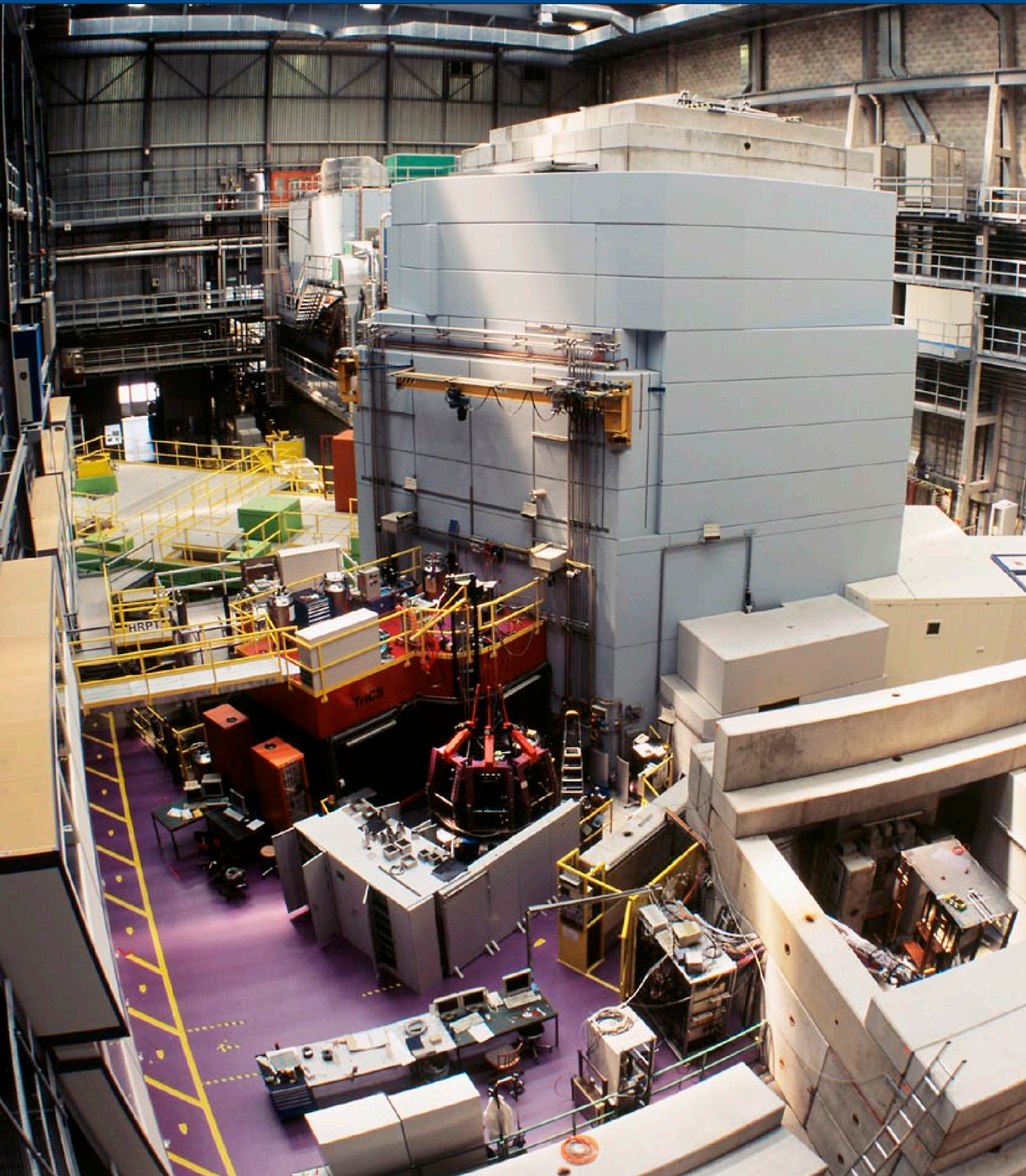
Nuclear fuel investigation

Neutron imaging is particularly suited to the investigation of nuclear fuel for two reasons: neutrons penetrate heavy metals much more easily than X-rays and special neutron detectors can image even strongly radioactive samples. Investigations of the radioactive segments of nuclear power station fuel rods are carried out in collaboration with the PSI hot lab. The NEURAP shield and manipulation structure is used to test the samples. The issues under consideration relate to the structure of fuel pellets following long-term irradiation, for example, or corrosion in the zircaloy tubes that surround the uranium fuel pellets. Uranium enrichment can also be measured exploiting the high degree of sensitivity of thermal neutrons to the U-235 content (images below).

Examination of nuclear power station elements: uranium pellets showing small partial defects (top). Collection of hydride lenses in the zirconium (centre). Pellets of varying enrichment levels in a new fuel element (bottom).

The SINQ spallation neutron source with the target block in the middle where the spallation reactions occur, thereby releasing neutrons.



One source, two options

The highly popular NEUTRA and ICON beam lines

Neutrons can be generated either by a reaction that splits nuclei apart, or by a spallation reaction. At PSI, the SINQ spallation source produces the required neutrons and delivers them to the NEUTRA and ICON facilities, where the experiments are carried out.

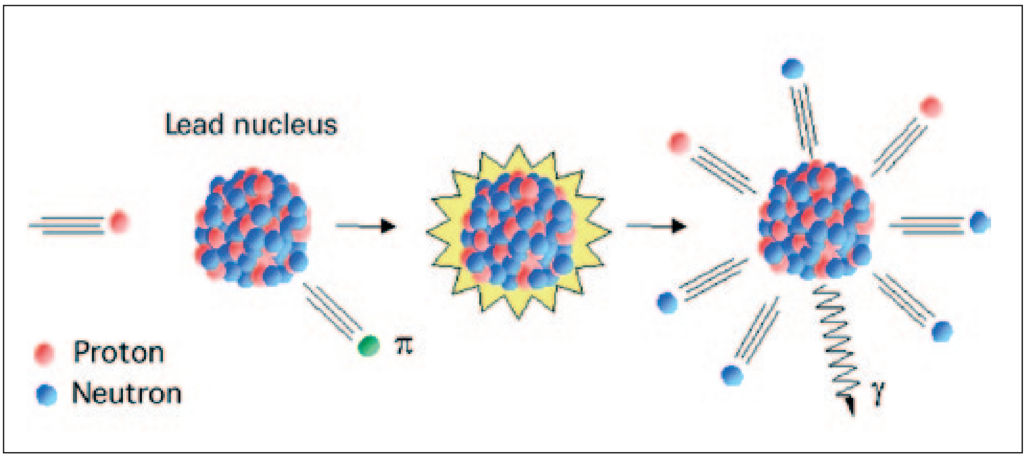
To produce neutrons as free particles, an atomic nucleus must be split apart. The prerequisite nuclear reactions typically elevate the nucleus into an excited state. It then breaks apart, emitting fission fragments, protons, radiation and neutrons.

The two most important options for the generation of neutrons are nuclear fission and spallation. In the first case, a fissile nucleus (e.g. Uranium 235) is struck by a neutron, which breaks it into two fission fragments and releases two to three fast-moving neutrons. A chain reaction, such as would normally take place in a nuclear reactor, exploits these free neutrons. Most of the powerful neutron sources for research purposes world-wide are based on this fission principle.

In contrast, spallation involves the bombardment of massive nuclei with high-energy charged particles from an accelerator. Protons are usually used for this purpose. When they collide with atomic nuclei, they often split them into more than two fragments, which releases even more neutrons than nuclear fission – i.e. about 10 to 15 neutrons, depending on the mass of the target nucleus and the energy of the incoming protons (illustration below).

No fissionable material

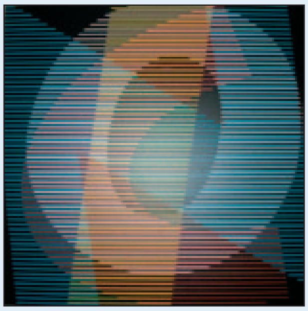
The complete spallation source comprises an accelerator, a proton beam guide, a target station and surrounding shielding (photograph on the left). It may have similar characteristics to a reactor in terms of the neutrons released, but there is no need for any fissile material. However, the primary spallation neutrons are much too fast, i.e. too energetic, which means that they have to be decelerated by collision with atomic nuclei in a moderator. Only when they have reached a velocity of 2200m/s or less, do a large number of them travel through the beam lines to the experiments.



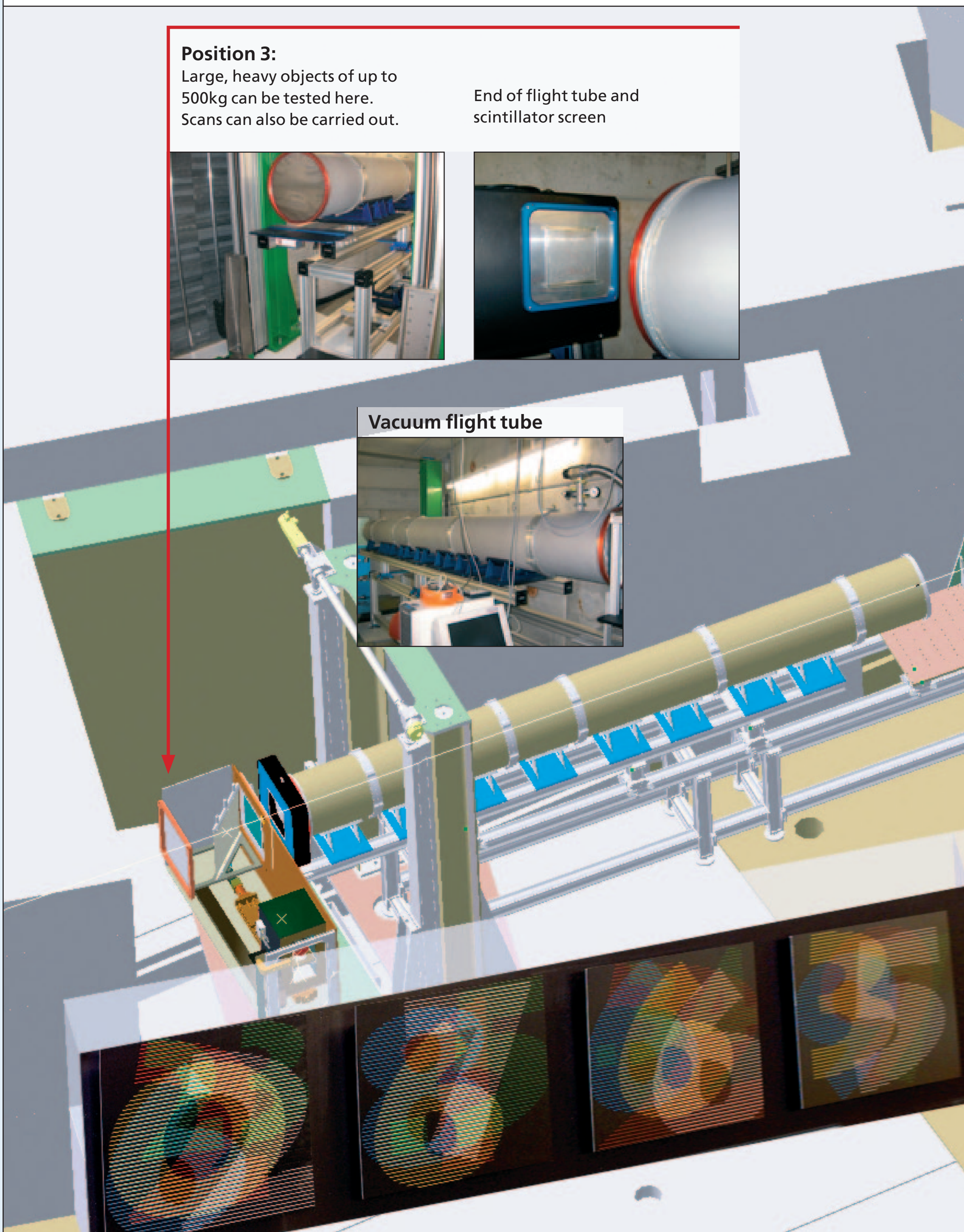
In the spallation process, atomic nuclei with a high mass (e.g. lead) are bombarded with high-energy protons. They then generate nuclear fragments and neutrons, which are decelerated in the SINQ moderator.

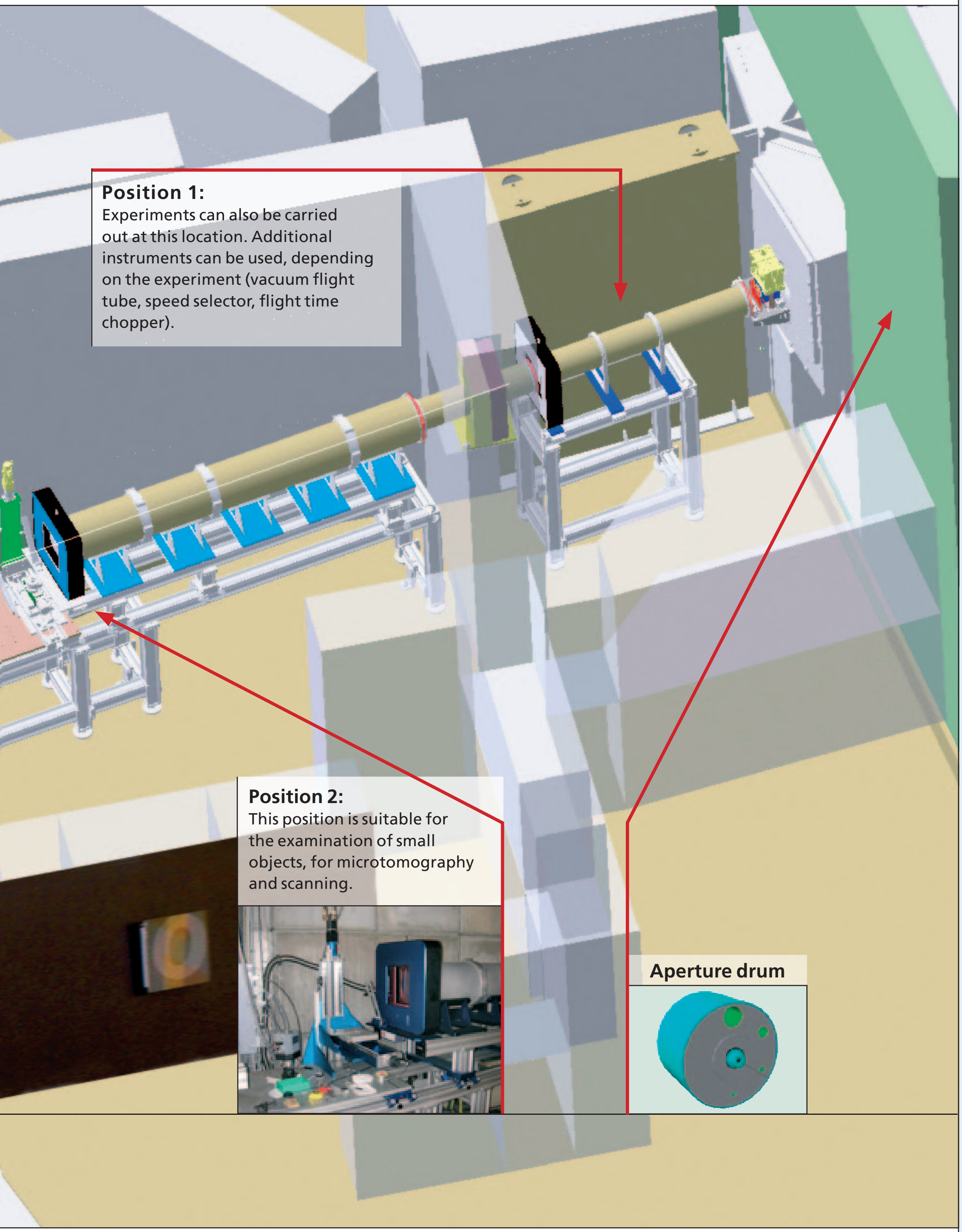
ICON beam line – new opportunities

Researchers from universities and private industry come to PSI to investigate their samples at the ICON and NEUTRA beam lines. Inaugurated in 2005, ICON uses cold neutrons and is particularly suitable for investigations of fuel cells in order to improve their efficiency.



Numbers that tell a story: images made by the scientific artist Jürg Nänni, specially produced for the ICON facility.



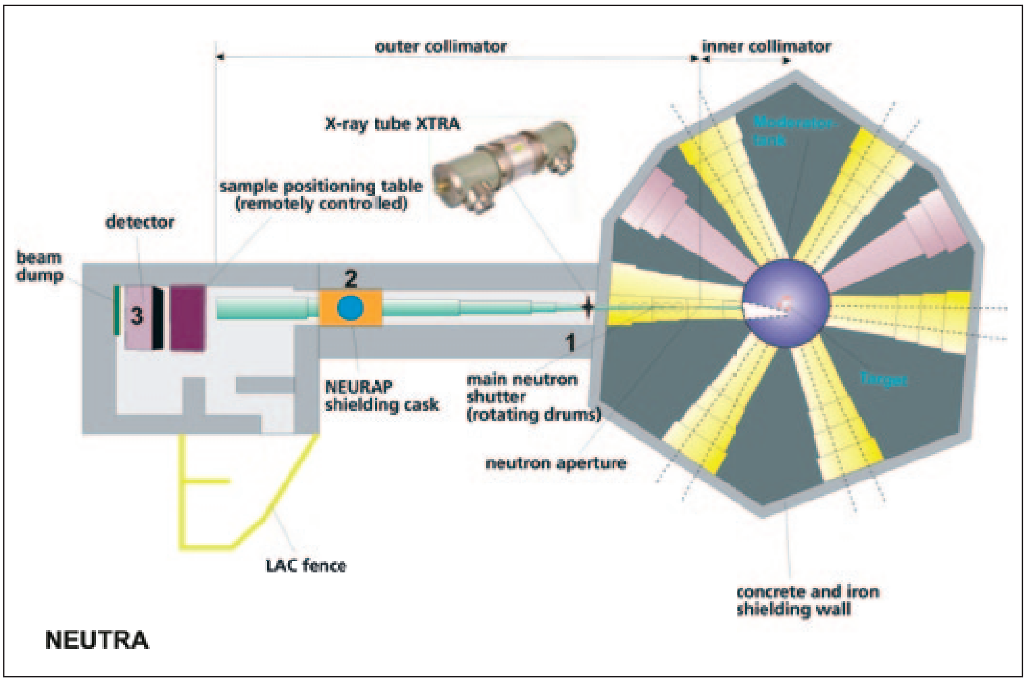

Position 1:
Experiments can also be carried out at this location. Additional instruments can be used, depending on the experiment (vacuum flight tube, speed selector, flight time chopper).
Position 2:
This position is suitable for the examination of small objects, for microtomography and scanning.
Aperture drum

NEUTRA beam line – the classic

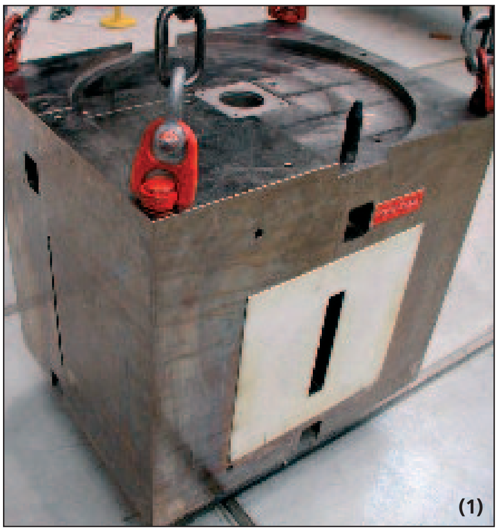
NEUTRA is in demand. The high workload of about 100 studies each year is one of the reasons why the ICON facility was constructed. NEUTRA uses thermal neutrons and consists of a converging inner collimator, which guides the neutrons to the sample, and a fixed neutron aperture with a diameter of 2cm. The collimator expands from a diameter of 15cm at Position 1 to 29cm at Position 2 and to 40cm at the most distant Position 3 (diagram below). This enables samples measuring from a few centimeters to 30cm to be studied.

The special NEURAP construction at Position 2 enables highly radioactive samples to be investigated, because the samples themselves emit so much radiation that they can not be examined with conventional neutron imaging. Irradiation by neutrons using a special detector enables non-destructive investigations to be carried out on heavy metal samples. These samples (e.g. uranium fuel rods from nuclear power stations) must be shielded while they are being transported and positioned by remote control in the radiography beam. NEURAP is therefore constructed of a thick-walled block of iron for shielding, and an exchange flask (illustration on the right).

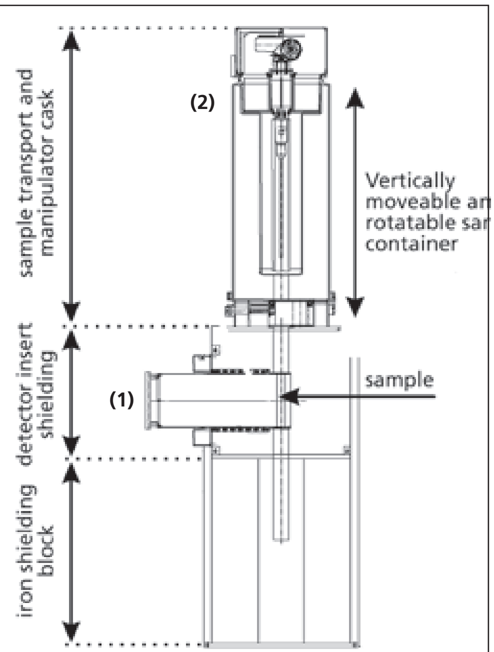
In addition to NEURAP, a further set-up is also available. By using the XTRA X-ray tube at Position 1, the researchers can exploit the varying contrasts provided by X-rays and neutron beams with almost identical recording geometry.



Internal view of NEUTRA (shielding partially removed). Right: graphic representation of NEUTRA.



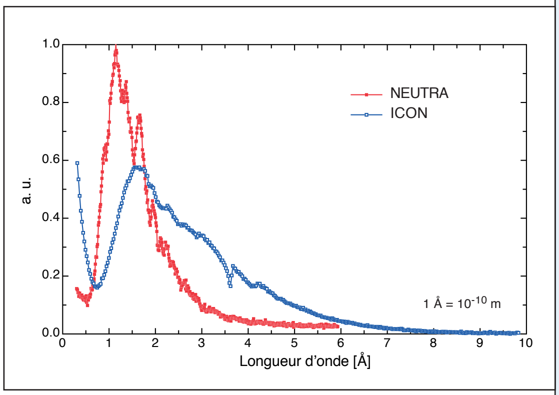
NEURAP structure with shielding block (1) and exchange flask (2), which is also used to manipulate the sample.



NEURAP structure with shielding block (1) and exchange flask (2). NEURAP is used to investigate highly radioactive samples, e.g. fuel rods.

NEUTRA and ICON, complementary and different

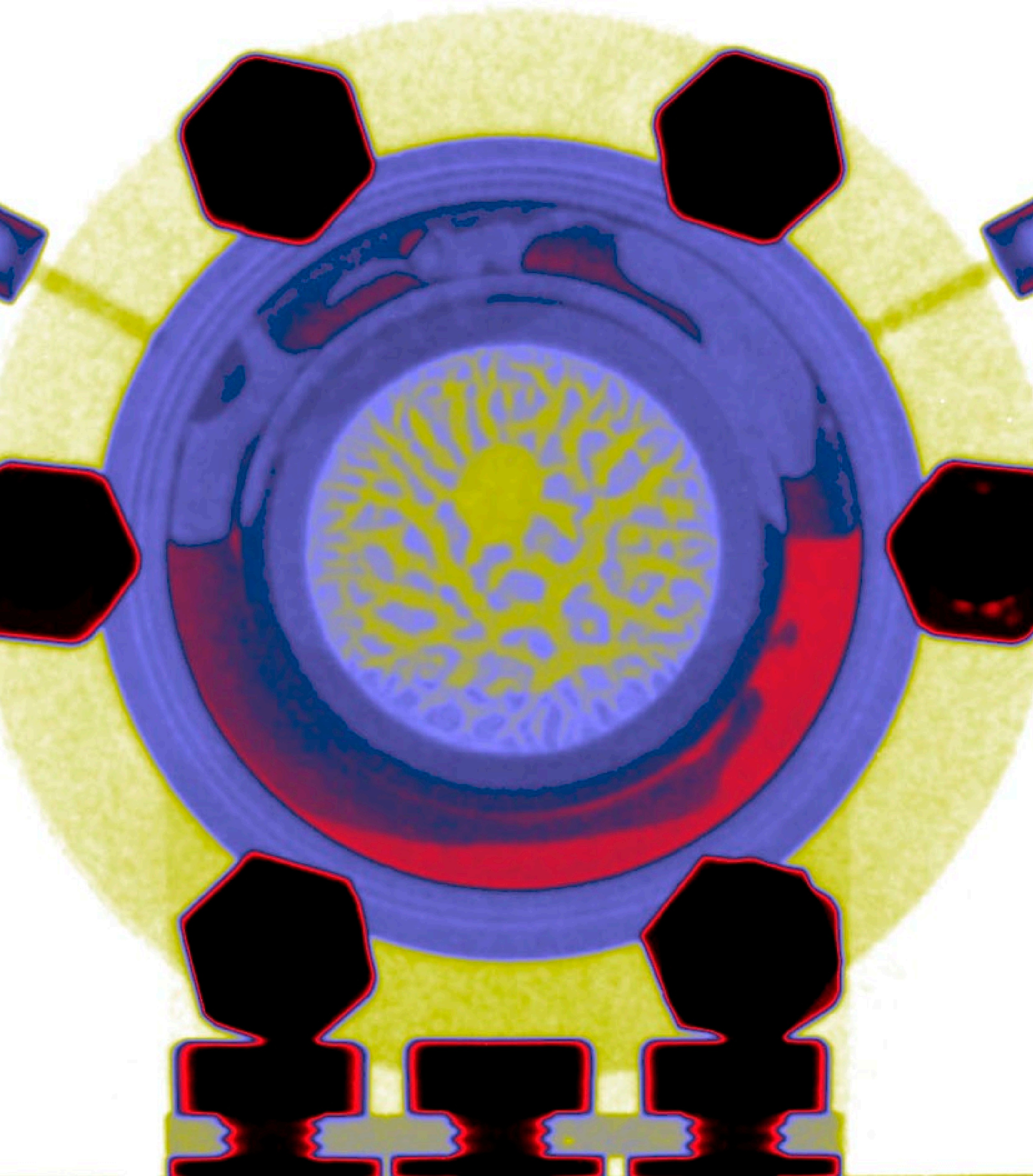
NEUTRA and ICON are beam lines with complementary characteristics: ICON uses cold neutrons, while NEUTRA uses thermal neutrons. This leads to differing wavelength spectra (illustration on the right) for the two facilities, and the resulting images differ therefore in penetration and contrast. For example, cold neutrons are scattered significantly more by thin layers of water, which means that they can be examined with a greater sensitivity. The characteristics specific to each facility are summarised in the table below.



	NEUTRA	ICON
Neutron aperture D	fixed: ø 20 mm	variable: ø 1,0 – 80 mm
Collimation ratio L/D	200, 350, 550	numerous stages: 90 – 10 000
Neutron flux (n/cm²/s/mA) (L = 7,1 m, D = 2 cm)	7,5 10^6	9,2 10^6
Filter for γ and fast neutrons	Bismut	no filter
Tomograpy setup	“large” samples	includes microtomography
Beryllium filter	none	available
Energy selector	none	available
Combination with X-ray	XTRA	no X-ray tube
Setup for highly-active samples	NEURAP	weakly-active samples only

Differences between NEUTRA and ICON facilities.

Visible flow of current: neutron radiograph of a model cell in an electrolyte.



Difficult-to-expose radiation

A wide choice of detectors

Once the neutrons have penetrated the sample, the next challenge is to produce an image of the neutron distribution. Various methods and detectors are available for this purpose. Digital methods are increasingly in use.

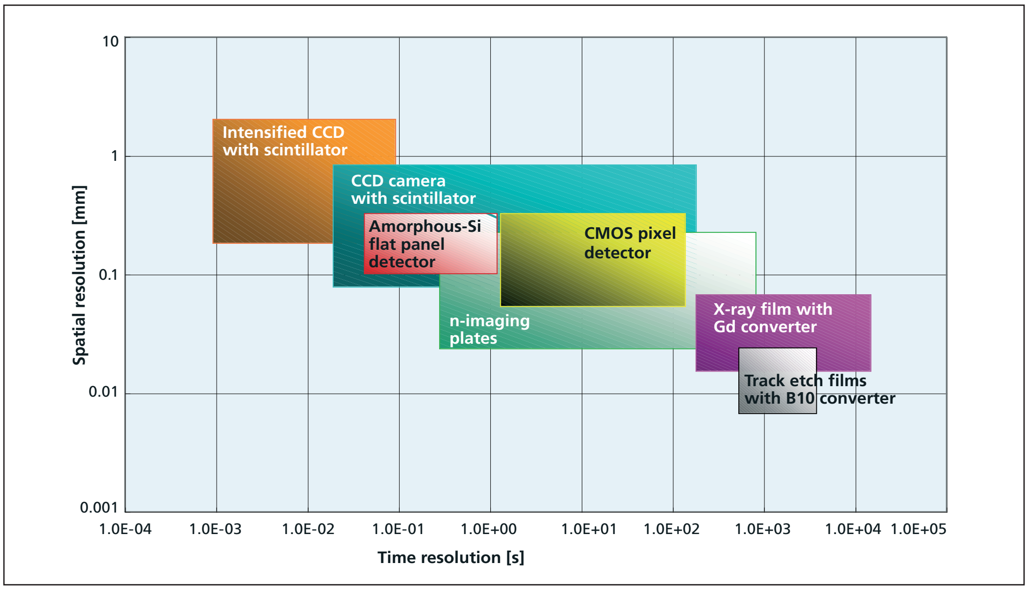
Because neutrons do not carry charge, they do not provide direct ionisation or visible excitation. Nuclear reactions, which either absorb or deflect the incoming neutrons, must take place to prove their existence. Each detection reaction creates ionising radiation.

Occuring at the atomic level, these processes then must be converted to the visible, macroscopic realm so that people can observe them. The resulting signals appear either in the form of light flashes (in scintillator screens), electronic excitations (in video discs) or density (in film).

Although neutron images can be created on X-ray film by using a converter, digital methods have been increasingly used in recent years. The advantages of digital methods are obvious: the image data can be saved, copied, transferred electronically, post-processed and archived. In addition, digital procedures are more sensitive and more efficient than traditional film, implying that radiation times are significantly reduced. Additional stages of analysis, such as filtering, segmentation, referencing and even tomographic reconstruction of volume data, can also be performed on a digital image.

The application governs the method

The many different detectors are distinguished by their resolution in time and space (graphic below). The application usually determines which imaging detector will be used.



Application of the various detector types.

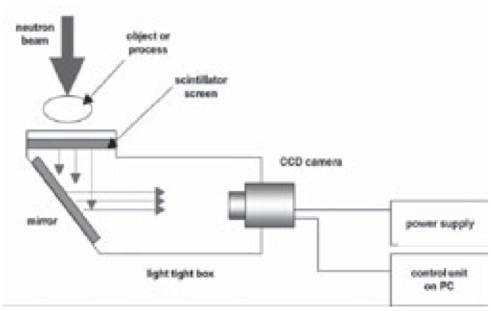
The following detectors are used at PSI:

CCD camera with scintillator

The image produced on the neutron-sensitive scintillator is captured by a light-sensitive, cooled camera and stored digitally. Variable lens systems are used to generate differing fields of vision (between 4 and 40cm). This setup is used mainly for tomography.

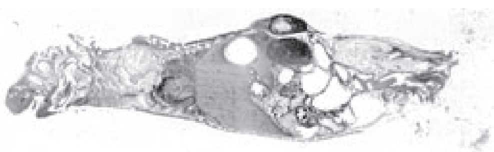
Intensified CCD with scintillator

A series image amplifier can be used to achieve a significantly higher light yield. By setting very narrow time windows, this system can be used to investigate rapidly repetitive processes.



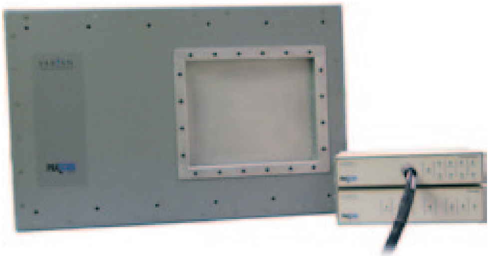
Film methods

Neutron images can be produced with X-ray and trace corrosion films. However, the exposure and developing times are very long.



Amorphous-Si flat panel

The light from the scintillator in direct contact with the restricted gate of the photo diodes is converted into a charging signal, and read out accordingly. High image frequency can be achieved as a result.



Imaging plates

A high-resolution digital image of neutron distribution can be generated by the excitation of electronic states in the sensitive layer followed by read-out using a laser scanner. The imaging plates can be repeatedly used.

CMOS pixel detectors

Each pixel in the detector is equipped with its own amplifier and digitalizer so that any number of detector events can be noiselessly saved. The detector size is limited to a few square centimetres at present.

What is a scintillator?

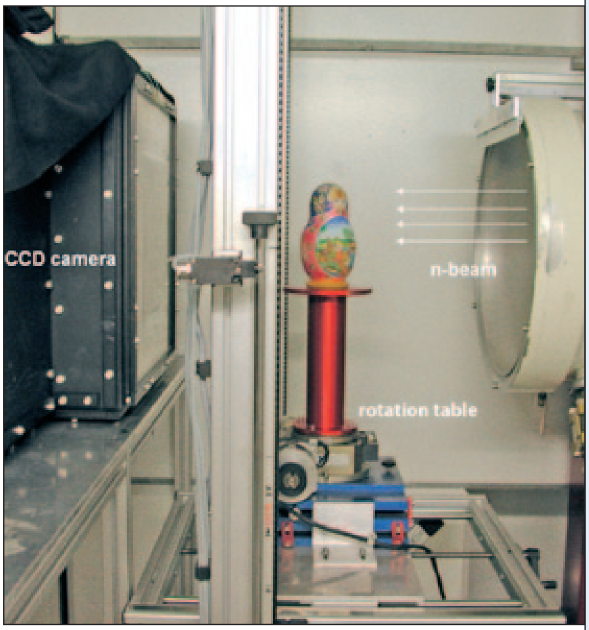
A scintillator is a material that becomes excited when charged particles and γ quanta pass through it and emits the excitation energy in the form of light (usually in the UV or visible range). The amount of light measured can be used to assess the energy deposited (e.g. using a photomultiplier or photodiode). Neutrons can also be detected indirectly via secondary charged particles resulting from nuclear reactions in the material.

From radiography to tomography

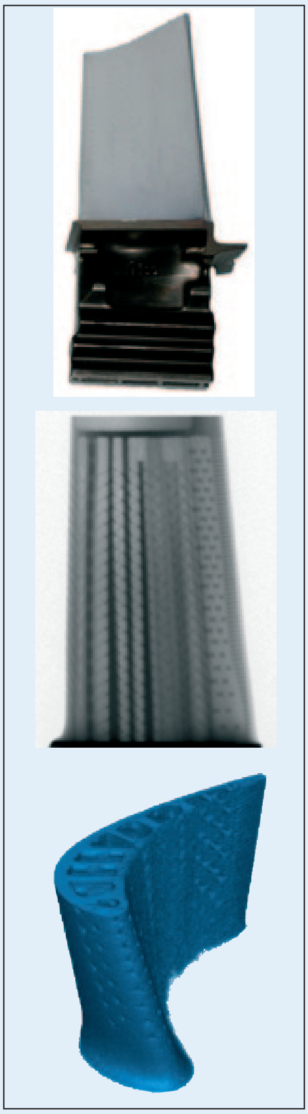
Neutron tomography is an imaging process that can generate three-dimensional image volumes.

This is based on a set of radiographs depicting sections of the object. The process uses the same principle as medical X-ray computer tomography (CT). In a medical CT facility, the X-ray source and detector are turned around a patient, whereas neutron tomography entails an object fixed to a rotation table (photo right) turned in small steps around 360 degrees.

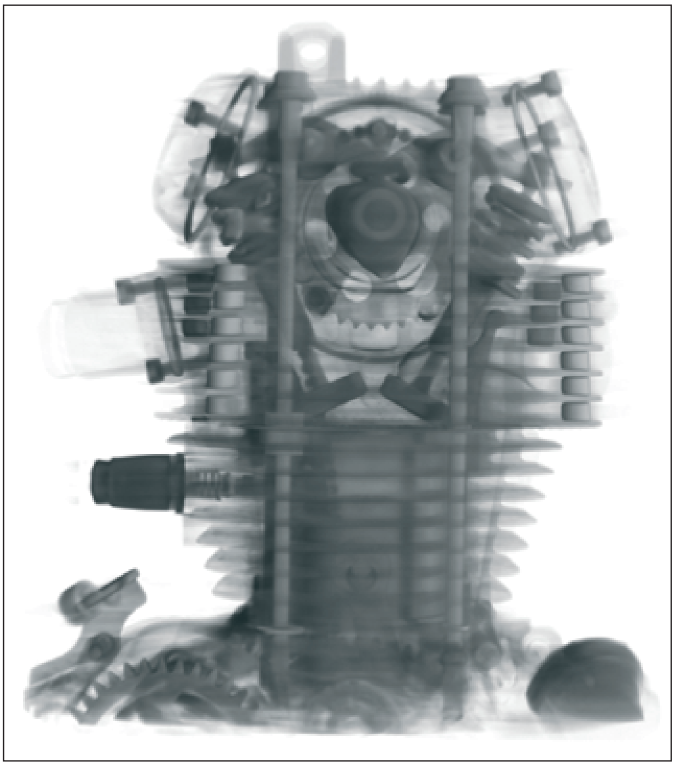
A mathematical technique known as tomographic reconstruction is then used to reconstruct section images at each rotation step from the radiographs. The tomography volume is formed by combining these section images. 3-D visualisation algorithms can then be used to display the required views and sections (images on this page)



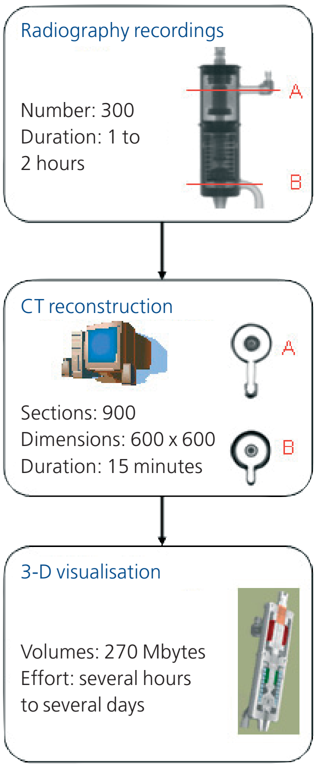
Tomography equipment at the NEUTRA facility.



Turbine blade (top) as neutron transmission radiograph (centre) and neutron tomogram (bottom).



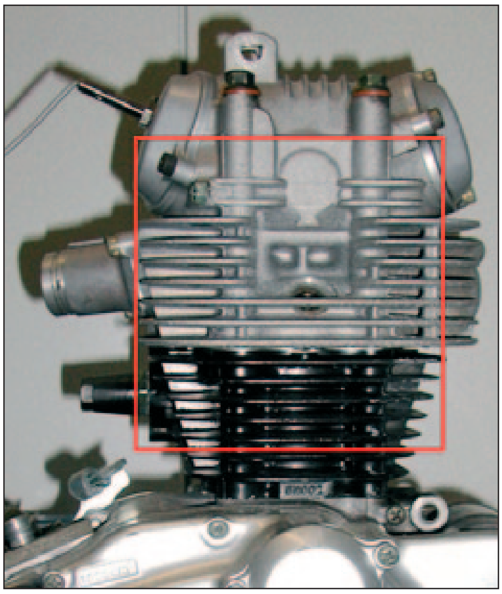
Semi-transparent neutron tomogram of a motorcycle engine (special images on page 26).



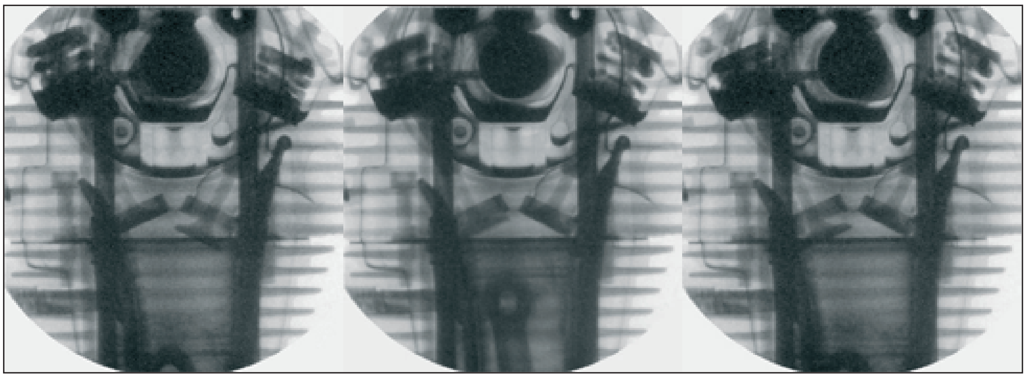
Flow chart for a neutron tomography run.

When radiography tracks time

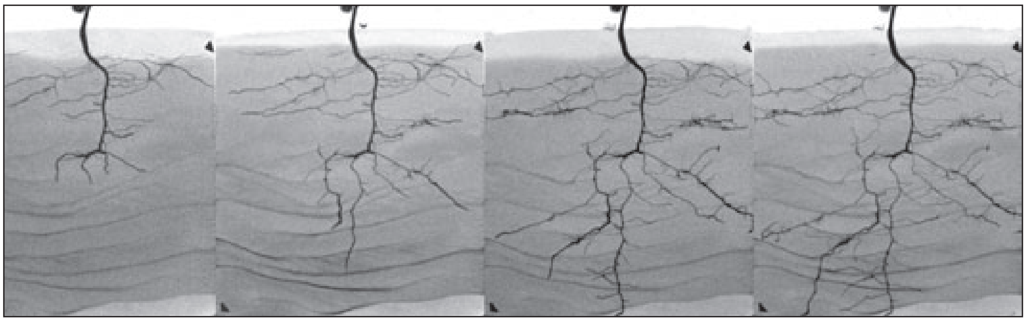
Radiography images can also investigate the progress with time of spatial distributions of materials, e.g. small amounts of substances containing hydrogen inside a sample of rock or soil or metallic objects such as an engine. Thus, the inside of a motorcycle engine can be examined while the engine is running. Time-lapse images with short exposure (illustrated on the right and below) can be used to investigate this type of fast, regular event. Several brief exposures are added together to produce images with good contrast. Flat panel detectors, able to record up to 30 images per second, are suited for acquiring such images. However, the very short exposure times mean that a penalty must be accepted in terms of either the quality of the radiographs or the restriction to materials producing only a high level of contrast.



The motorcycle engine with the detail (red) used for the special images (image series below).



Radiography images of the engine at 1200 rpm, produced with a special camera and an exposure time of 0.1 milliseconds.

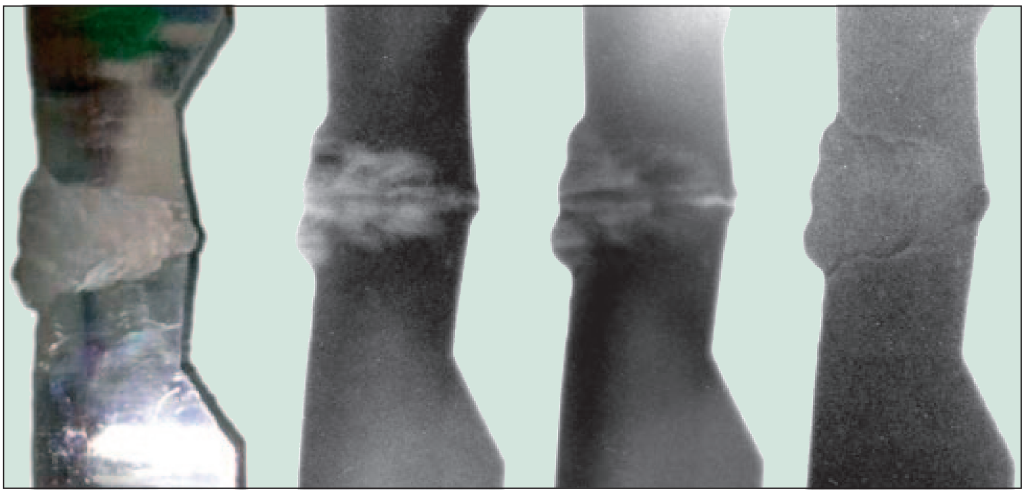


Examination of root growth in a lupin over a period of about four weeks.

Take your pick

The NEUTRA and ICON neutron beams boast a very wide spectrum of wavelengths and energy. It is therefore possible to select for an investigation neutrons with a particular level of energy from the full range supplied by the SINQ spallation source.

Compared to the full spectrum, the selective neutron spectra enables much more precise analyses of material distributions to be undertaken. This phenomenon is illustrated in the image of a thick weld (below), where , depending on the average neutron energy, distinct areas showing different crystalline structures stand out clearly from the homogenous base material.

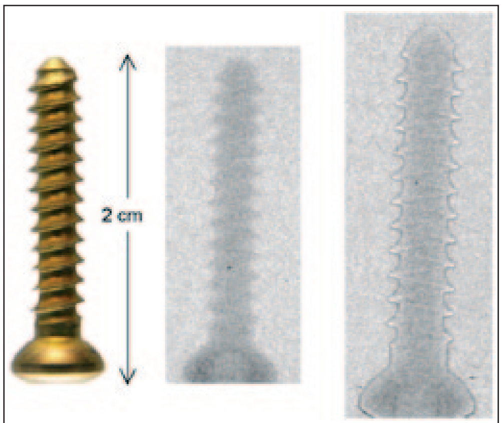


Examination of a weld (photo left) using neutrons with different energies.

Phase contrast reinforces edges and magnifies objects

Neutrons act as waves; they can be deflected by objects and overlay each other (interfere) in the same way as waves in water. Waves passing through an object spread at a different speed than the other waves, and are therefore associated with a different wavelength. The crests of the waves are delayed, a phenomena known as phase shift. This shift leads to phase or image contrast (a difference in brightness), particularly noticeable at the edge of an object forming the boundary with another material (e.g. air).

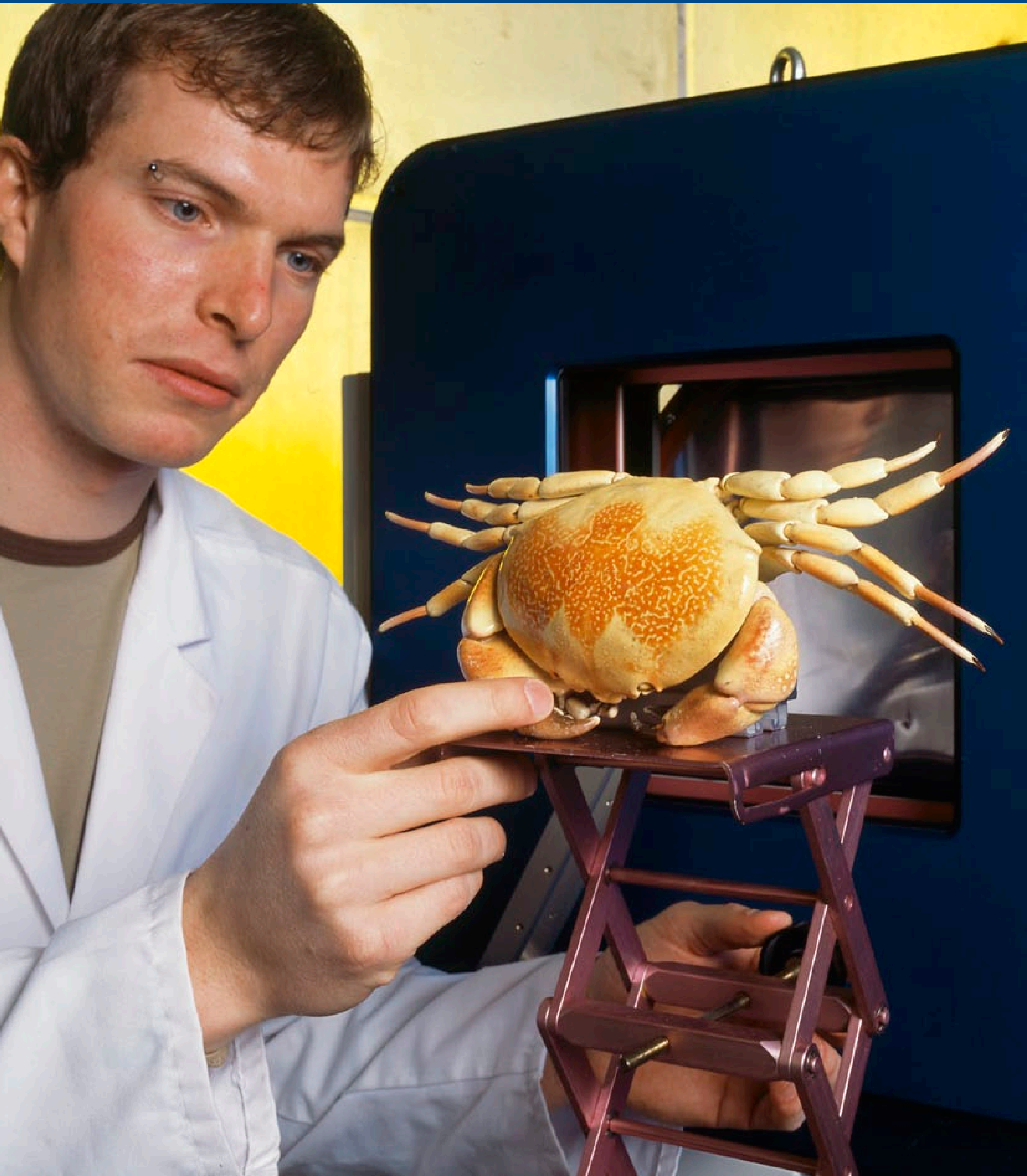
The image on the right shows the advantages of phase contrast radiography. The edges are reinforced and the object magnified in the image, improving the visibility of small objects. Magnification is about 18% in the configuration chosen here. Edge reinforcement takes place not only between material and air, but occurs wherever two materials with different indices of refraction join.



Photography Absorption radiography Phase contrast radiography

Examination of a titanium screw with varying neutron range conditions.

“Neutron Imaging” still sounds exotic to many ears, but this technique provides undreamt of potential.



Refining methods even more

Potential future applications

SINQ, NEUTRA and ICON offer undreamt of possibilities: the examples of neutron imaging illustrated in this brochure introduce only a small selection of the investigations carried out during the past few years. Many groups of researchers from Switzerland and abroad have been able to benefit from the well-established radiography and tomography techniques, as have partners from industry.

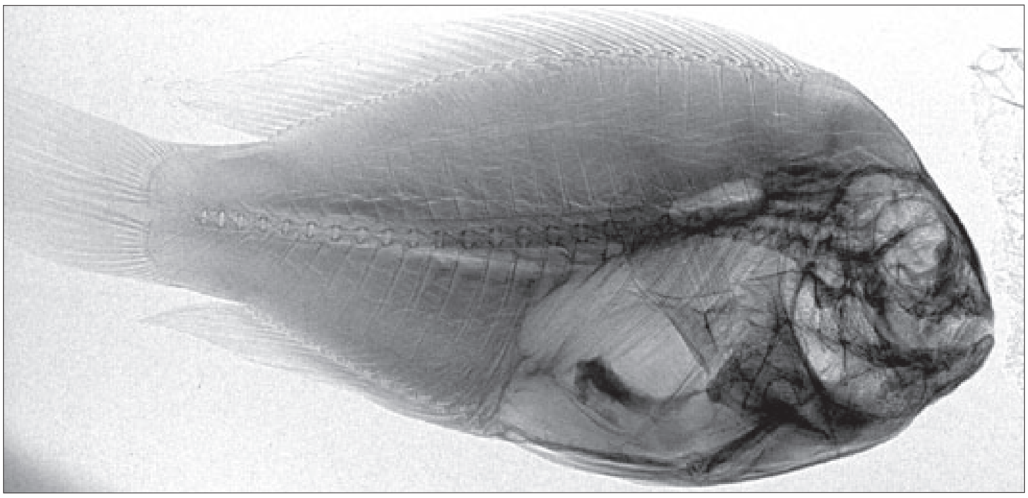
Our aim is to make even greater progress by refining these methods. The imaging processes and analyses must be developed further so that neutron imaging can be used even more widely. The different wavelength spectra of NEUTRA and ICON open up many new possibilities for achieving the best possible conditions with regard to image penetration and contrast.

One of the focuses of our work in the near future is the development of the optimum setup for phase contrast measurements, intended for the widest possible range of object materials and sizes.

Collaboration with the other large-scale facility at PSI, the Swiss Light Source or SLS, is an additional focus of our activities. This is planned to take place in two different ways: An X-ray facility will be integrated in the NEUTRA bunker so that complementary images can be taken under identical experimental conditions with both neutrons and X-rays. In addition, the aim will be to approach the spatial resolution of the SLS microtomography facility, though the goal of 20 micrometres represents a considerable remaining margin.

Increasing the recognition level

Recognition by the public and relevant professional circles is a very significant factor in the judicious and successful application of the neutron imaging method. Unlike X-ray imaging, neutron imaging still sounds exotic to many ears, and is often familiar only to insiders. We therefore hope that this brochure has made a small contribution to the popularisation of this innovative imaging technique.



Phase contrast images of a dried fish of about 6 cm in length.

PSI in brief

The Paul Scherrer Institute (PSI) is a multi-disciplinary research centre for natural sciences and technology. PSI collaborates with national and international universities, other research institutions and industry in the areas of solid-state research and materials sciences, particle physics, life sciences, energy research and environmental research.

PSI concentrates on basic and applied research, particularly in those fields which are the leading edge of scientific knowlegde, but also contribute to the training of the next generation and pave the way to sustainable development of society and economy. The Institute is actively involved in the transfer of new discoveries into industry, and offers, as an international centre of competence, its services to external organisations.

PSI employs 1300 members of staff, making it the largest of the national research institutions – and the only one of its kind within Switzerland. It develops, builds and operates complex large-scale research facilities that impose particularly high requirements in terms of knowledge, experience and professionalism. PSI is one of the world's leading user laboratories for the national and international scientific community.

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PSI, with the SINQ facility in the western area (the building on the left bank of the River Aare).

Foto: Luftwaffe Schweiz

Neutron_e, 09/2008

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