KEY TOPIC

3D VIEWS

The magazine of the Paul Scherrer Institute

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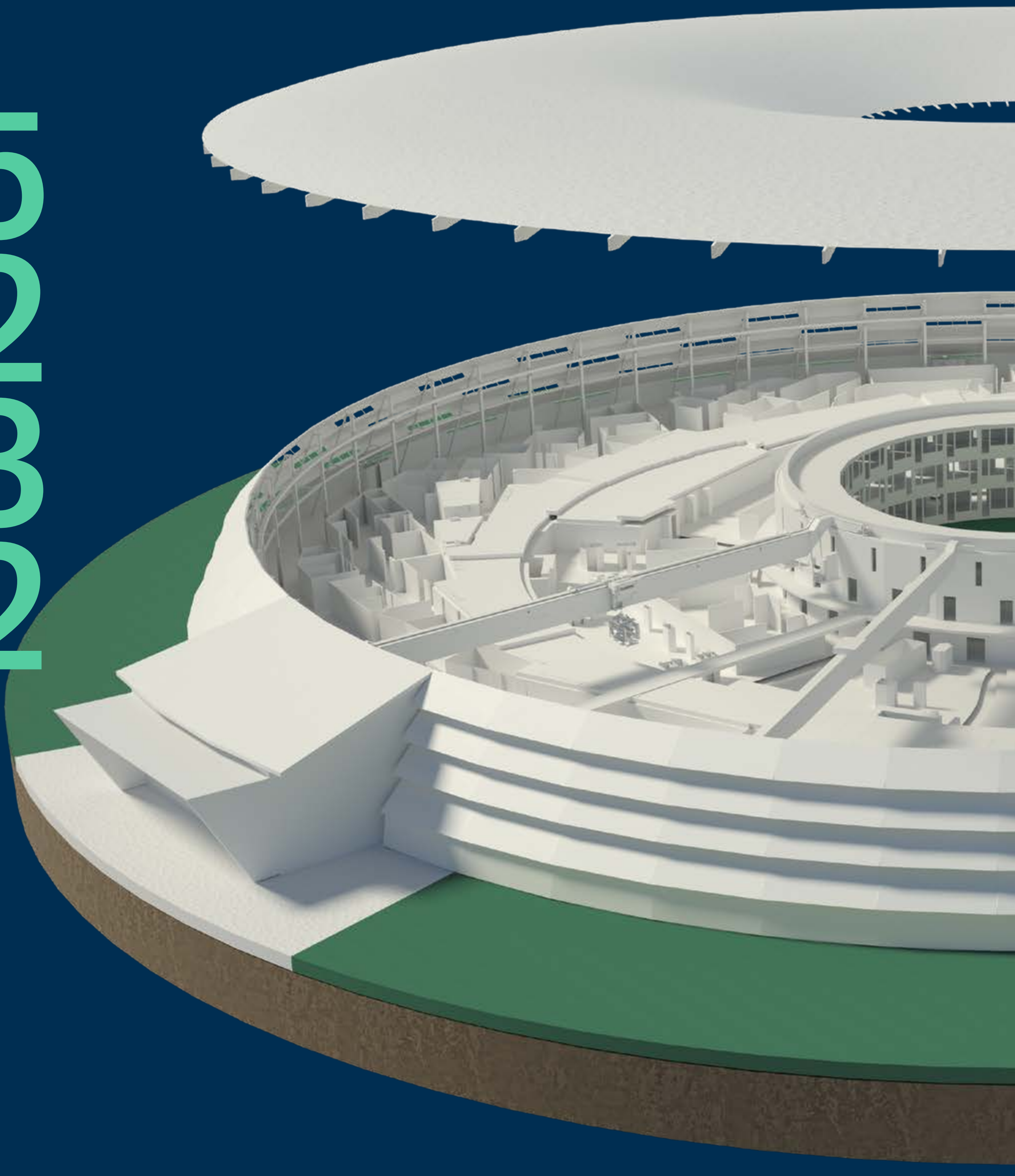

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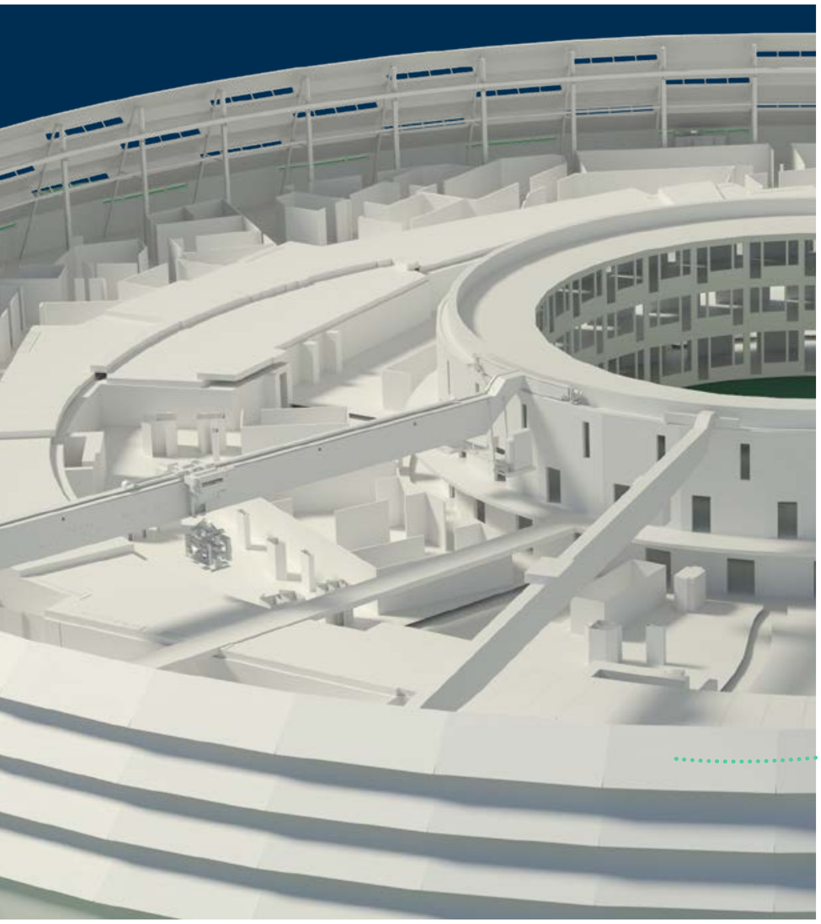

BACKGROUND

3D VIEW

PSI is home to two large research facilities that produce intense X-ray light for high-precision analysis of materials, proteins, and molecular processes: the circular Swiss Light Source SLS and the X-ray free-electron laser SwissFEL, housed in a 740 metre-long building. We describe the machines capable of generating this special X-ray light and how scientists use it for research purposes.

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FUTURE PROJECTS

Upgrades for PSI's large research facilities

The large research facilities at PSI belong to the most advanced in the world and provide a platform for cutting-edge research in Switzerland.
To maintain this international standing, the facilities are continuously equipped with the latest technology and regularly undergo extensive upgrades.

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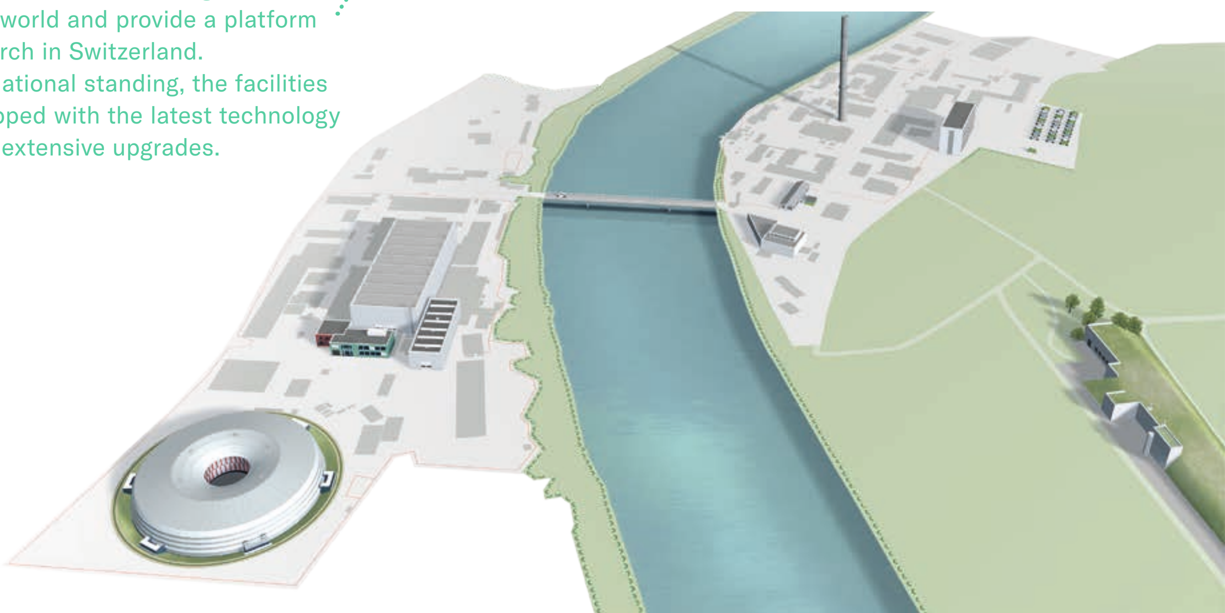

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BACKGROUND

Three facilities that rely on protons

The high-intensity proton accelerator HIPA produces a 1.4 megawatt proton beam, the most powerful in the world. The protons are supplied to three other large research facilities at PSI: CHRISP, the research infrastructure for particle physics; the SμS muon source for research with muons; and the Swiss Spallation Neutron Source SINQ, which generates neutrons for use in experiments.

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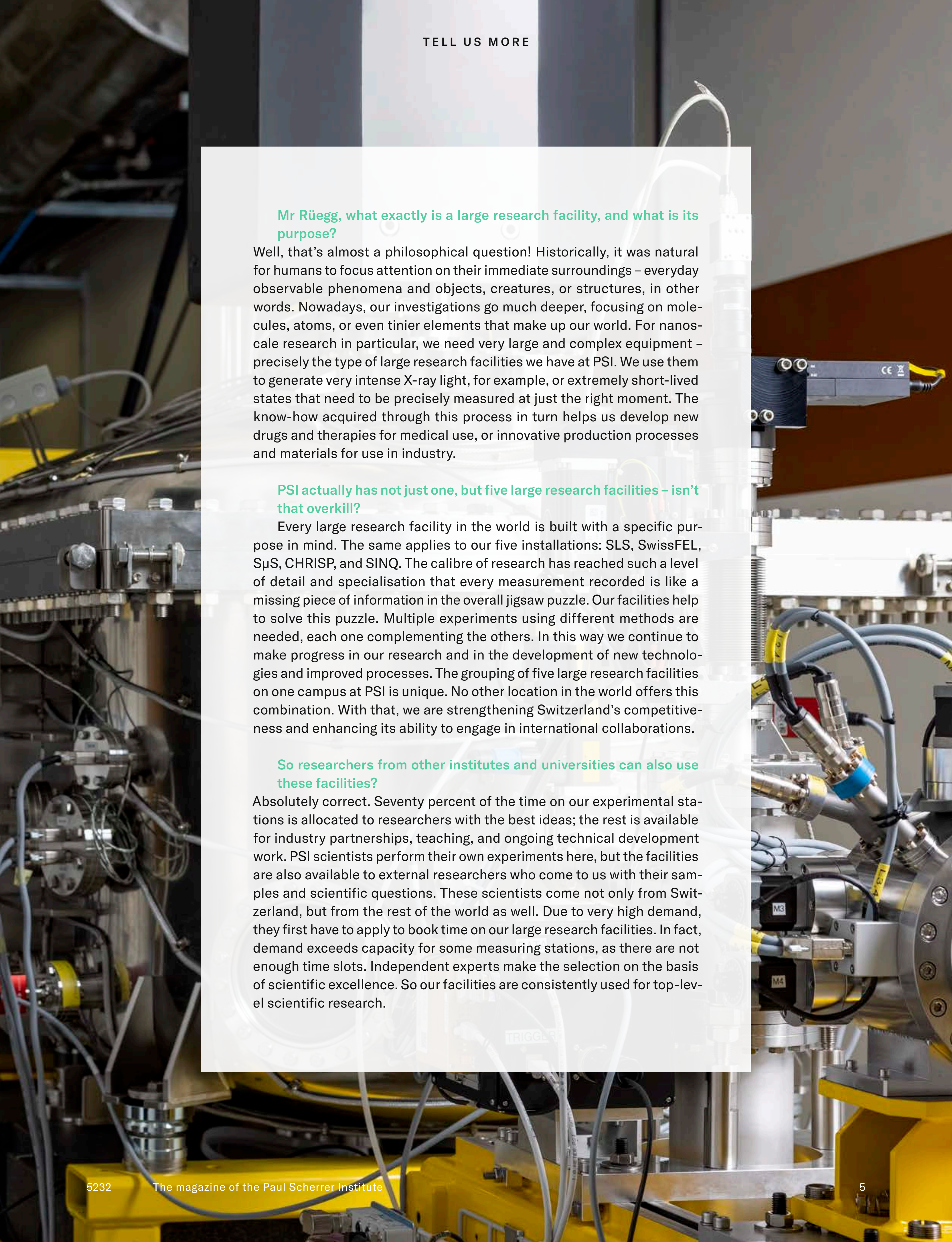
CONTENT

What are you up to, Mr Rüegg?

The Paul Scherrer Institute (PSI) specialises in the construction and operation of large research facilities used for research and development. A total of five such facilities are located on its campus in the canton of Aargau, in the municipal areas of Villigen and Würenlingen. PSI Director Christian Rüegg explains what these installations are used for and why PSI makes them available to scientists from all over the world.



Mr Rüegg, what exactly is a large research facility, and what is its purpose?

Well, that's almost a philosophical question! Historically, it was natural for humans to focus attention on their immediate surroundings – everyday observable phenomena and objects, creatures, or structures, in other words. Nowadays, our investigations go much deeper, focusing on molecules, atoms, or even tinier elements that make up our world. For nanoscale research in particular, we need very large and complex equipment – precisely the type of large research facilities we have at PSI. We use them to generate very intense X-ray light, for example, or extremely short-lived states that need to be precisely measured at just the right moment. The know-how acquired through this process in turn helps us develop new drugs and therapies for medical use, or innovative production processes and materials for use in industry.

PSI actually has not just one, but five large research facilities – isn't that overkill?

Every large research facility in the world is built with a specific purpose in mind. The same applies to our five installations: SLS, SwissFEL, SμS, CHRISP, and SINQ. The calibre of research has reached such a level of detail and specialisation that every measurement recorded is like a missing piece of information in the overall jigsaw puzzle. Our facilities help to solve this puzzle. Multiple experiments using different methods are needed, each one complementing the others. In this way we continue to make progress in our research and in the development of new technologies and improved processes. The grouping of five large research facilities on one campus at PSI is unique. No other location in the world offers this combination. With that, we are strengthening Switzerland's competitiveness and enhancing its ability to engage in international collaborations.

So researchers from other institutes and universities can also use these facilities?

Absolutely correct. Seventy percent of the time on our experimental stations is allocated to researchers with the best ideas; the rest is available for industry partnerships, teaching, and ongoing technical development work. PSI scientists perform their own experiments here, but the facilities are also available to external researchers who come to us with their samples and scientific questions. These scientists come not only from Switzerland, but from the rest of the world as well. Due to very high demand, they first have to apply to book time on our large research facilities. In fact, demand exceeds capacity for some measuring stations, as there are not enough time slots. Independent experts make the selection on the basis of scientific excellence. So our facilities are consistently used for top-level scientific research.

A natural aversion

Oil and water do not mix. Anyone who regularly makes their own salad dressing knows that: No matter how vigorously you stir the oil and vinegar together, the two liquids separate again after a while, and the oil rises to the surface, forming a shiny film.

Vinegar is a watery liquid mainly comprising water molecules, whose formula is H_2O. Some of the molecules (oxygen) carry a negative charge, while the others (hydrogen) are positively charged. These opposite charges mean the individual water molecules mutually attract and try to surround each other, literally shutting out the oil. Fat molecules are said to be "nonpolar" – they have neither a positive nor a negative charge. They simply cannot mix with water. Because the oil is lighter and less dense, it swims on the surface of the water.

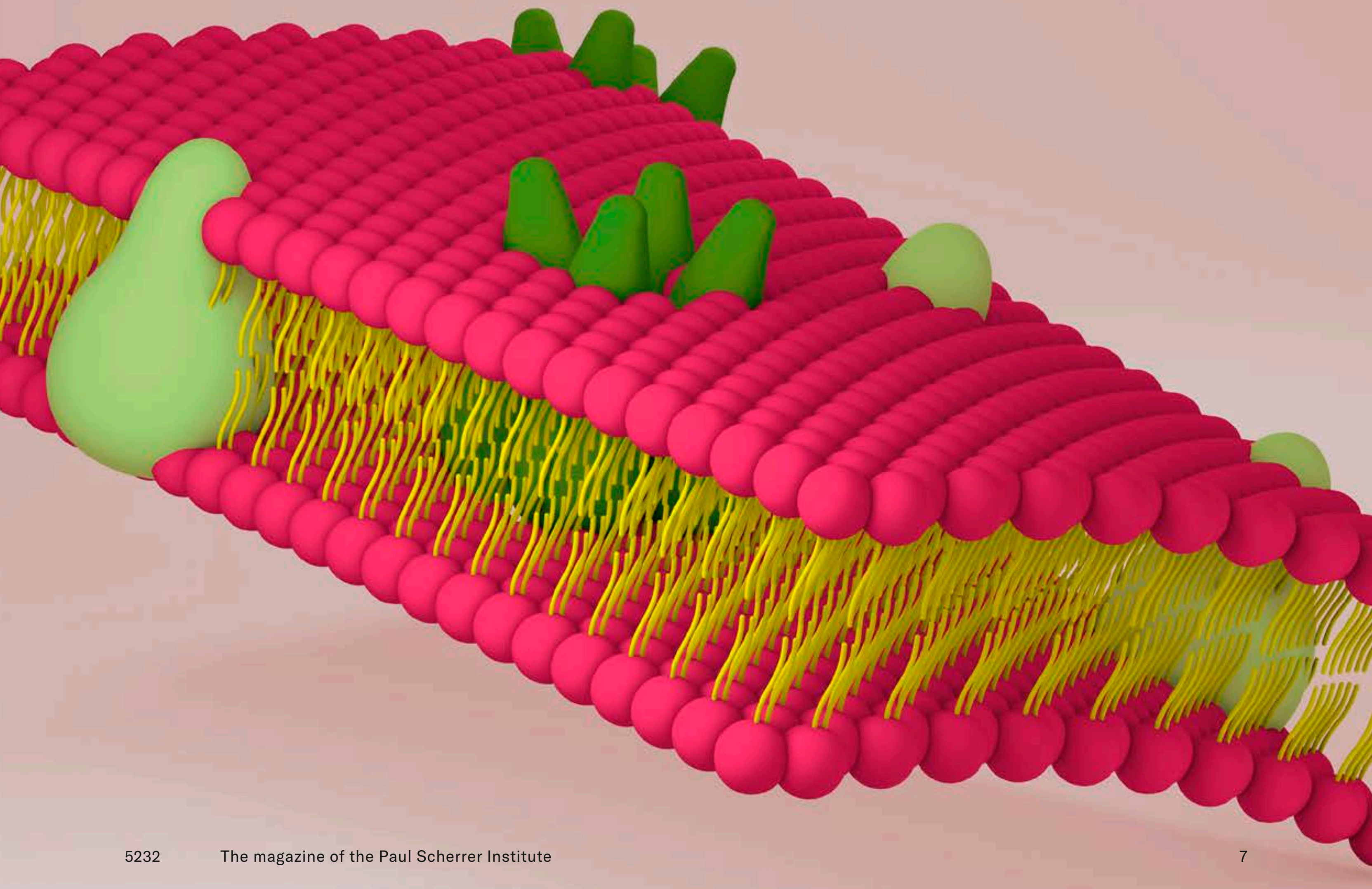
To mix both fluids together requires emulsifiers. These substances have both charged and nonpolar places in their molecular structure. Take soap, for example: It can interact with both water and oil on the molecular level, successfully combining the two. In the case of salad dressing, however, the only solution is to shake vigorously – and not wait too long before serving.

Happily united

Membranes are sophisticated barriers that surround the body's cells. They act as a barrier between living cells and their inanimate environment – without them, no life would be possible. Biological membranes consist of molecules that are attracted both to water and to lipids. They are shaped like a matchstick: The long straight stem is nonpolar and a typical fat constituent, while parts of the small head carry a charge. In the membrane, the molecules arrange themselves so that the water-soluble region faces the membrane surface while the lipid-soluble part faces inwards.

The cell membranes not only act as a protective shell: They also provide the basis for many vital processes. Important cell constituents, such as proteins, are embedded in them. At PSI, scientists investigate these embedded proteins (shaded green in the graphic). Membrane proteins transport substances into the cell's interior, for example, or bind hormones, thus sending messages to the cell. In this way they perform tasks in the body that are essential to human life.

In order to understand proteins and their function, scientists at PSI investigate them directly in their natural environment. They also observe interactions within the membrane, for instance with other embedded proteins. This knowledge helps in the development of drugs, including those used to treat Covid-19.

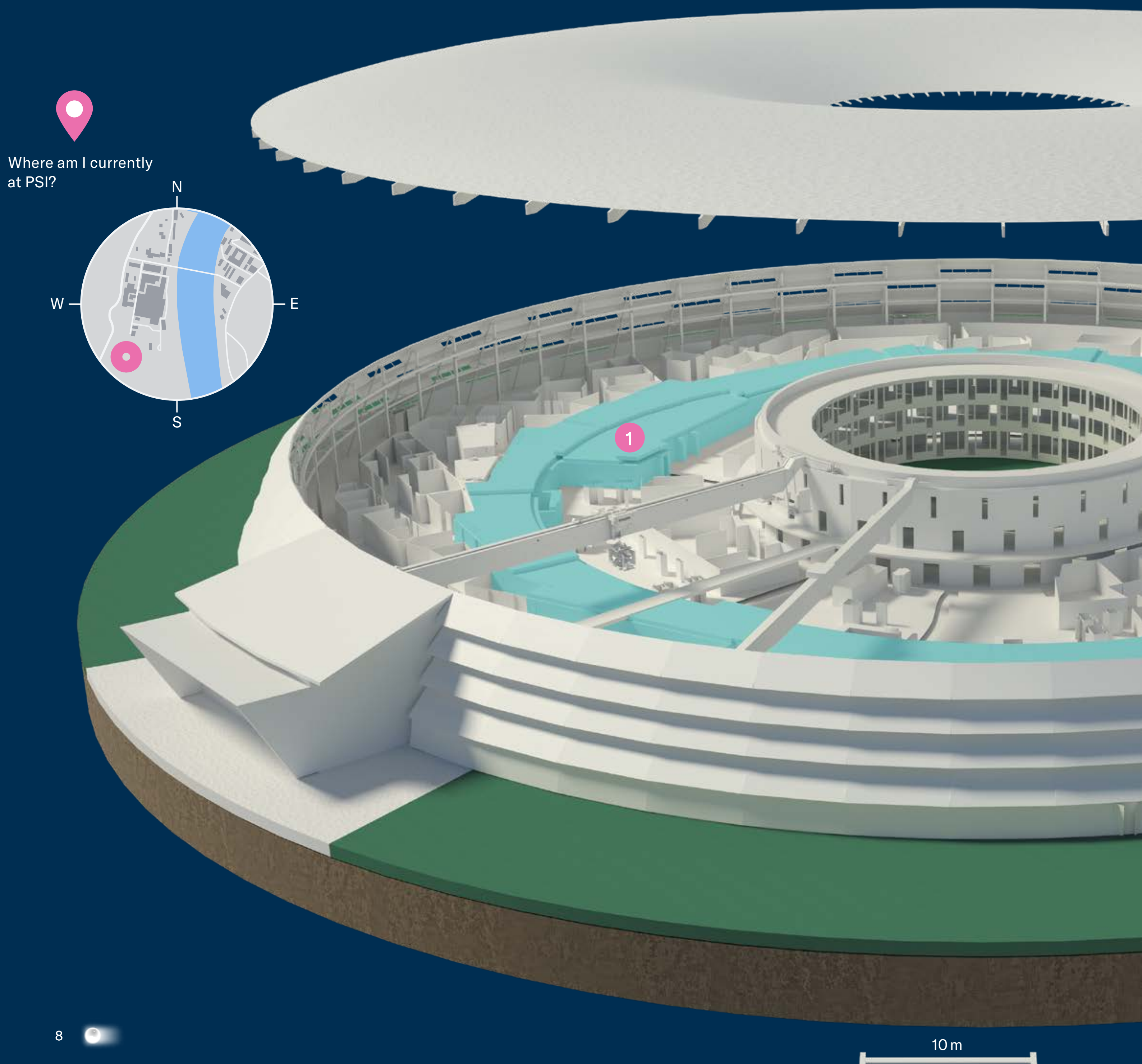


KEY TOPIC

3D views

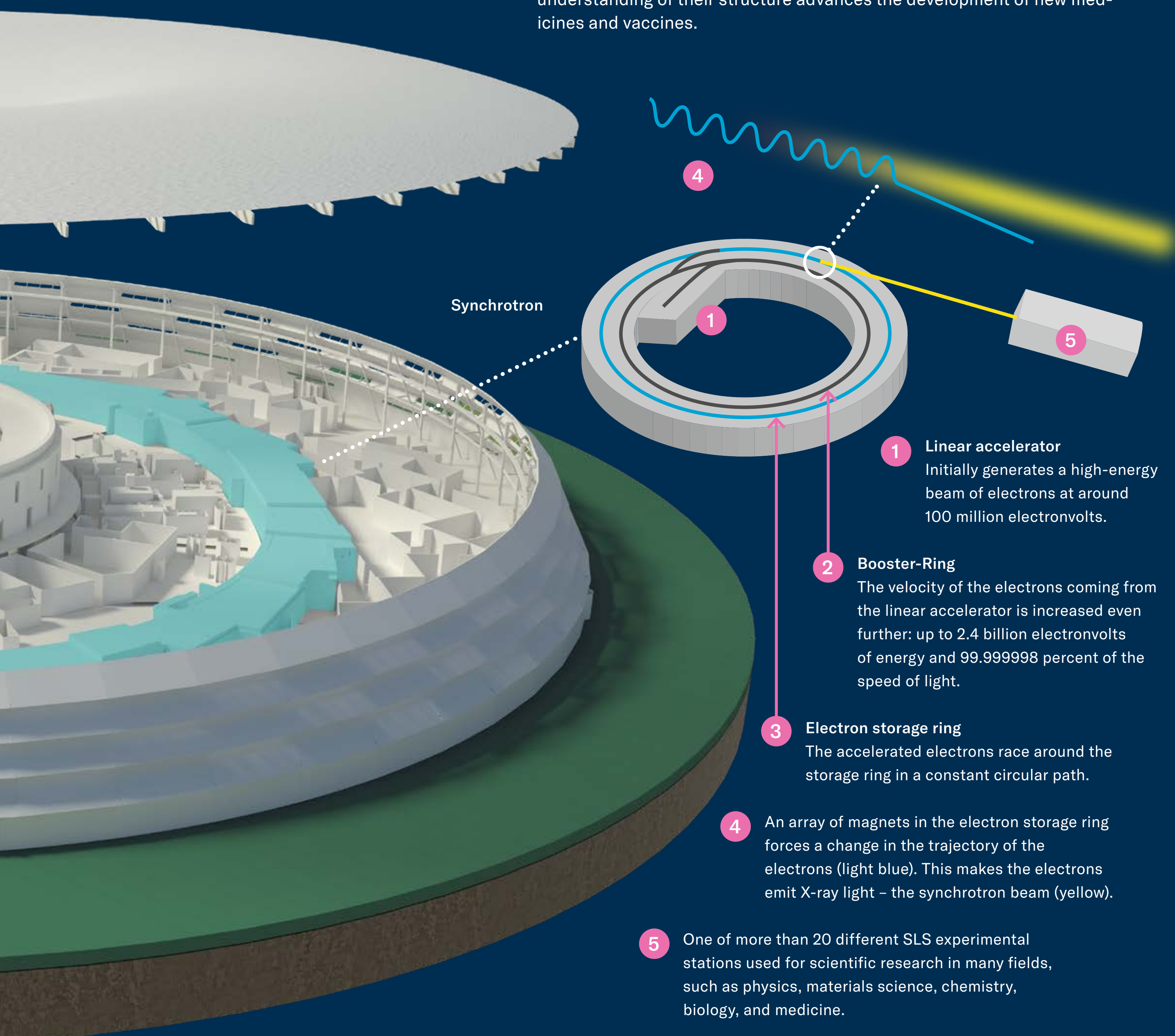
A synchrotron light source, an X-ray free-electron laser, the world's most intense proton source, unique muon and neutron sources – PSI is the only research institute in the world to offer such a combination of different large research facilities on one campus.

Text: Laura Hennemann
3D visualisation: Mahir Dzambegovic



Swiss Light Source SLS

The Swiss Light Source SLS uses accelerated electrons to generate X-ray light. The facility has done important work since its inception in 2001, but now the SLS 2.0 upgrade project (2021-2024) is set to boost the intensity of the synchrotron beam even further. PSI has more than 20 experimental stations where scientists are able to use this extremely bright X-ray light for many different types of experiments: for example, to investigate the electronic or magnetic properties of novel materials that could be useful for the next generation of electronic devices, or for non-destructive 3D imaging with a resolution of just a few nanometres. Other research stations are used to study proteins, the building blocks of life. Deeper understanding of their structure advances the development of new medicines and vaccines.



1 Linear accelerator
Initially generates a high-energy beam of electrons at around 100 million electronvolts.

2 Booster-Ring
The velocity of the electrons coming from the linear accelerator is increased even further: up to 2.4 billion electronvolts of energy and 99.999998 percent of the speed of light.

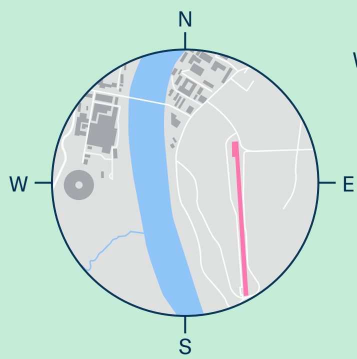
3 Electron storage ring
The accelerated electrons race around the storage ring in a constant circular path.

4 An array of magnets in the electron storage ring forces a change in the trajectory of the electrons (light blue). This makes the electrons emit X-ray light – the synchrotron beam (yellow).

5 One of more than 20 different SLS experimental stations used for scientific research in many fields, such as physics, materials science, chemistry, biology, and medicine.

X-ray free-electron laser SwissFEL

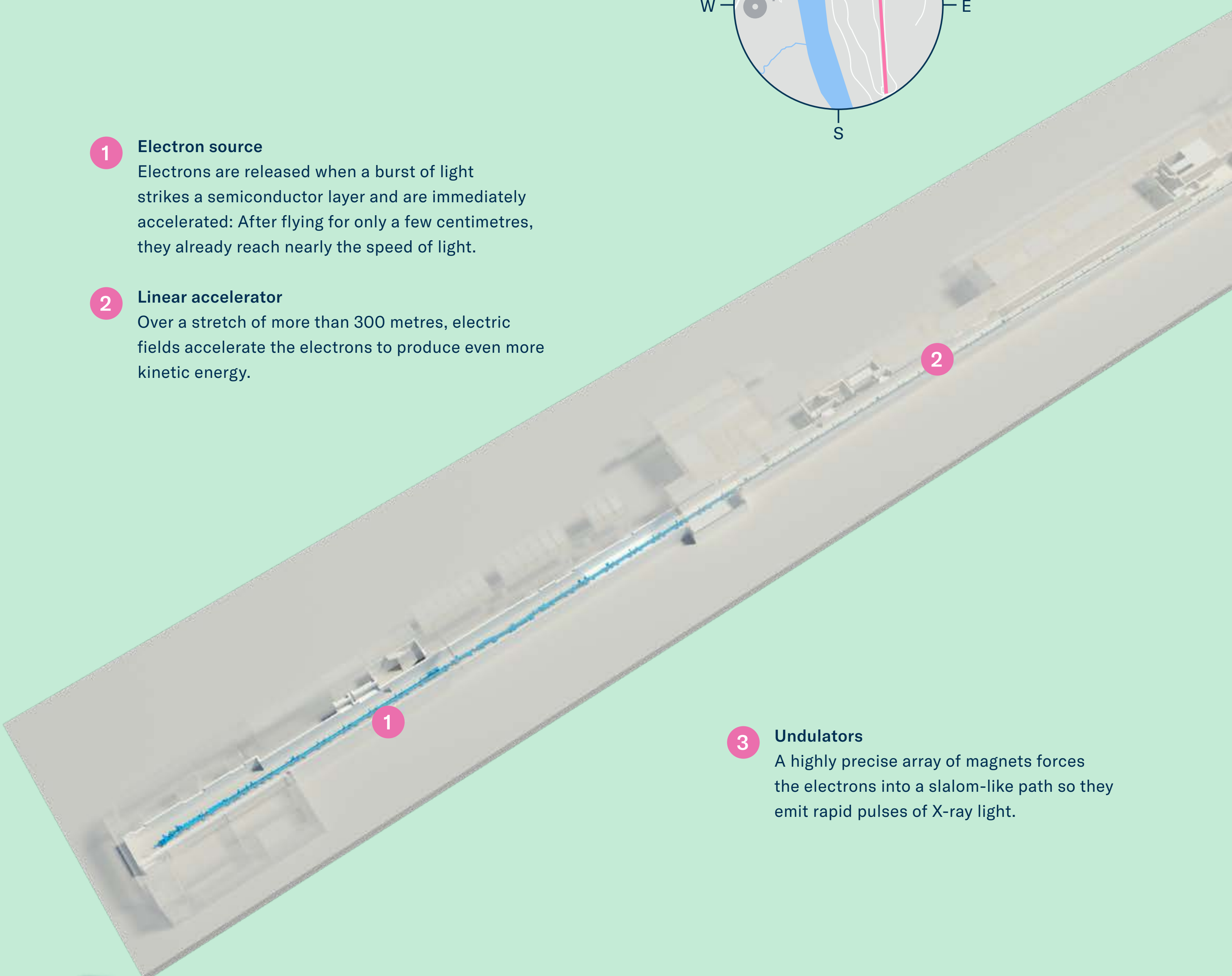
FEL stands for free-electron laser. Like the Swiss Light Source (SLS), SwissFEL produces extremely powerful X-ray light for scientific experiments. It uses electrons to produce this light, as does SLS. The difference is that in the 740-metre-long building housing SwissFEL, the electrons are accelerated along a straight path. In addition, SwissFEL does not produce continuous X-ray light, but rapidly repeating pulses of very intense light. These act like an exceptionally fast stroboscope, so that extremely rapid processes in the material sample can be analysed on the nanometre scale. Thus SwissFEL functions as both a high-resolution microscope and a film studio for ultrafast processes.



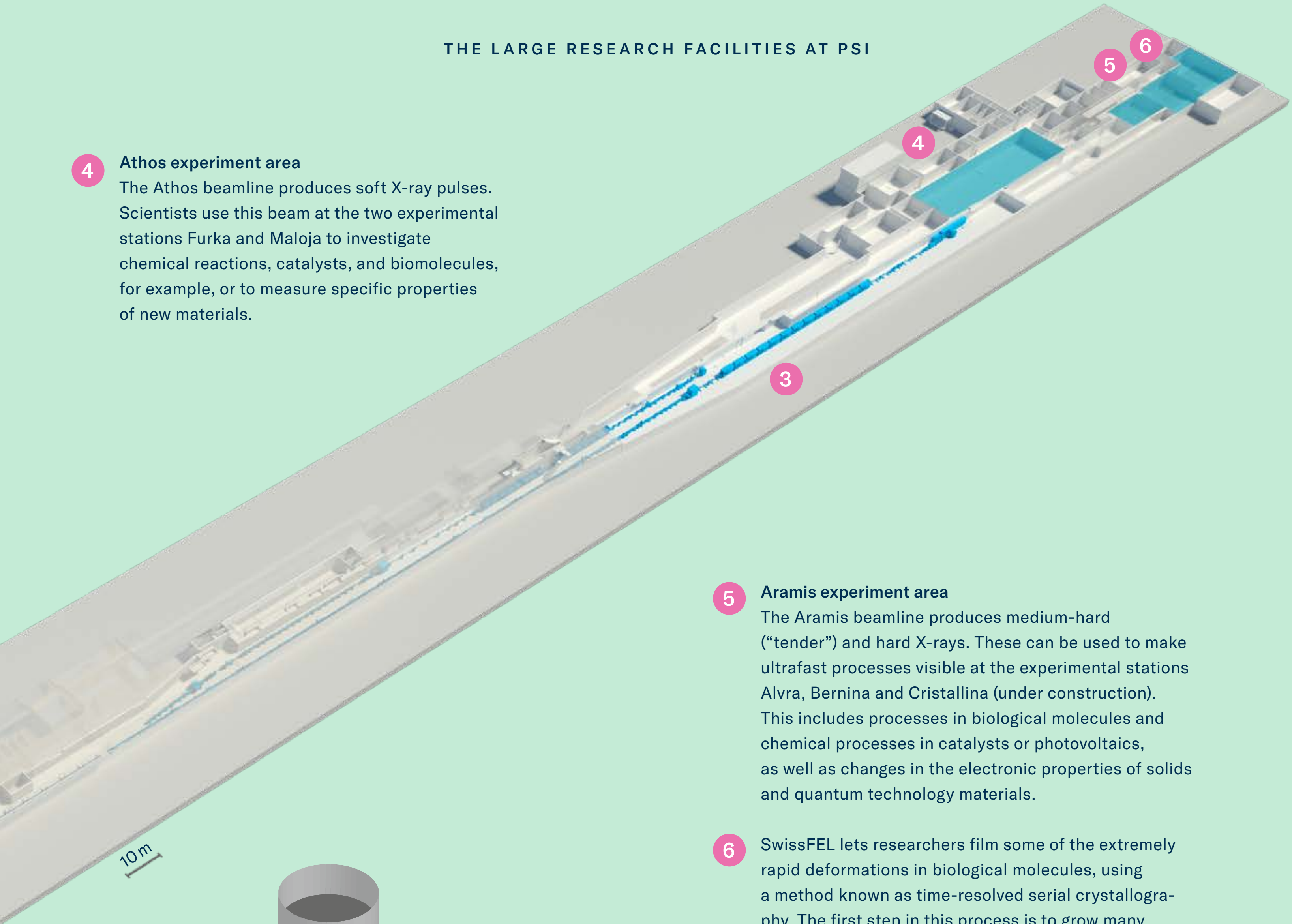
Where am I currently at PSI?

1 Electron source
Electrons are released when a burst of light strikes a semiconductor layer and are immediately accelerated: After flying for only a few centimetres, they already reach nearly the speed of light.

2 Linear accelerator
Over a stretch of more than 300 metres, electric fields accelerate the electrons to produce even more kinetic energy.



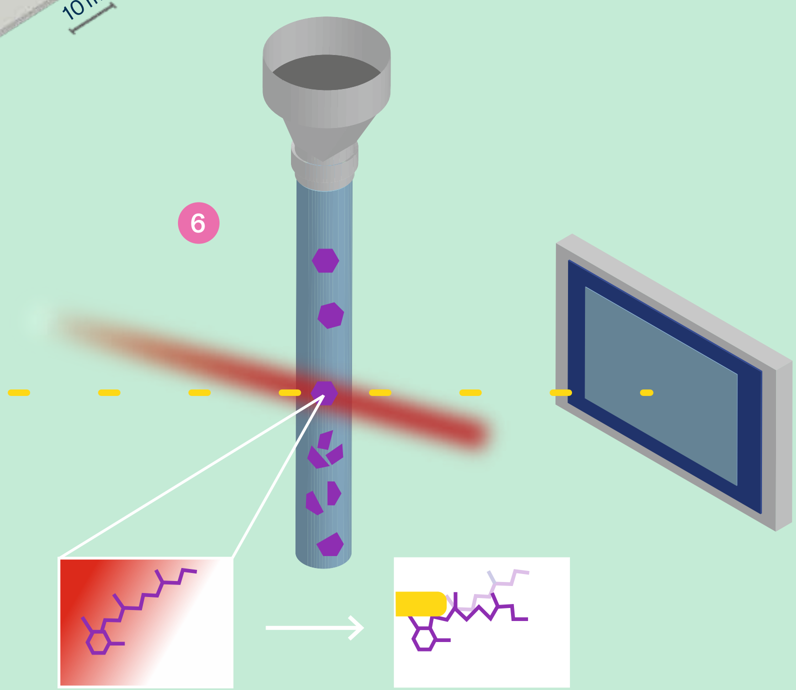
3 Undulators
A highly precise array of magnets forces the electrons into a slalom-like path so they emit rapid pulses of X-ray light.



4 Athos experiment area
The Athos beamline produces soft X-ray pulses. Scientists use this beam at the two experimental stations Furka and Maloja to investigate chemical reactions, catalysts, and biomolecules, for example, or to measure specific properties of new materials.

5 Aramis experiment area
The Aramis beamline produces medium-hard ("tender") and hard X-rays. These can be used to make ultrafast processes visible at the experimental stations Alvra, Bernina and Cristallina (under construction). This includes processes in biological molecules and chemical processes in catalysts or photovoltaics, as well as changes in the electronic properties of solids and quantum technology materials.

6 SwissFEL lets researchers film some of the extremely rapid deformations in biological molecules, using a method known as time-resolved serial crystallography. The first step in this process is to grow many tiny crystals from biological molecules – the proteins. The crystals float in a carrier fluid. This flows through an apparatus in such a way that first a light pulse from a conventional laser (red) and then an X-ray light pulse (yellow) from SwissFEL can hit the crystals. The laser light shifts the protein into a different state: Part of the protein deforms at lightning speed and takes on various intermediate states. These states, some of which are very short-lived, are recorded by the X-ray pulses. Although the measurement process destroys the individual crystal, multiple measurements on new crystals can still be assembled to create a moving picture, as in a flip book.

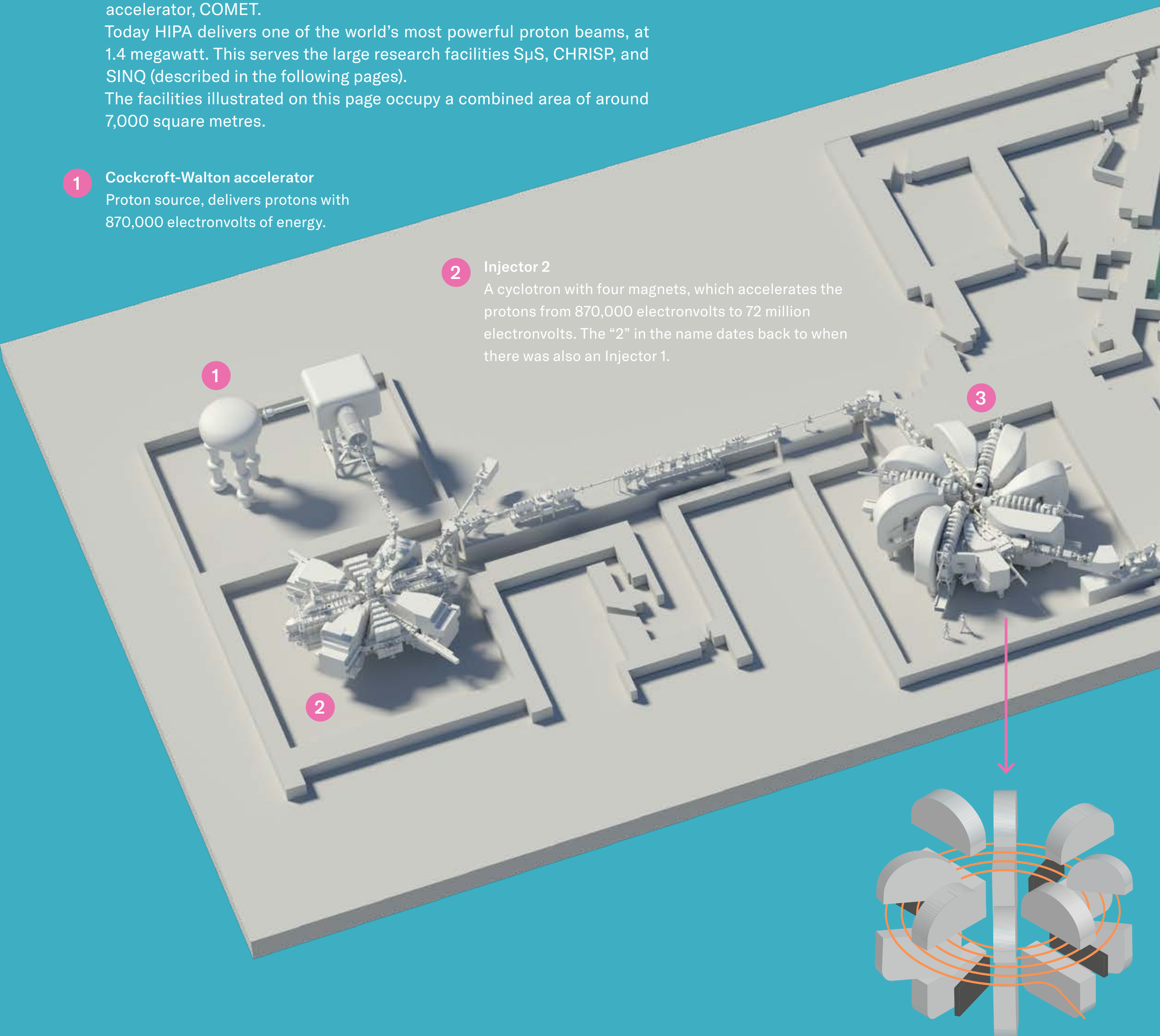


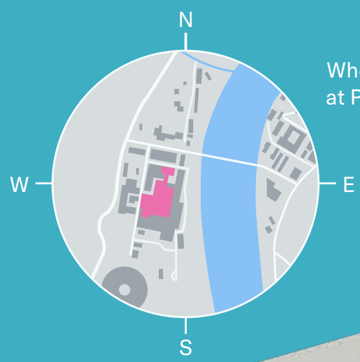
HIPA and the experiment hall – a proton accelerator for three large research facilities

The high-intensity proton accelerator HIPA is a central component for three of PSI's large research facilities. It was originally commissioned back in 1974 – 14 years before the PSI was founded – at one of PSI's two predecessor institutions. Even then, HIPA was used not just for research but also as an accelerator for cancer treatment at the Center for Proton Therapy CPT. In the meantime, however, CPT has acquired its own proton accelerator, COMET.
Today HIPA delivers one of the world's most powerful proton beams, at 1.4 megawatt. This serves the large research facilities SμS, CHRISP, and SINQ (described in the following pages).
The facilities illustrated on this page occupy a combined area of around 7,000 square metres.

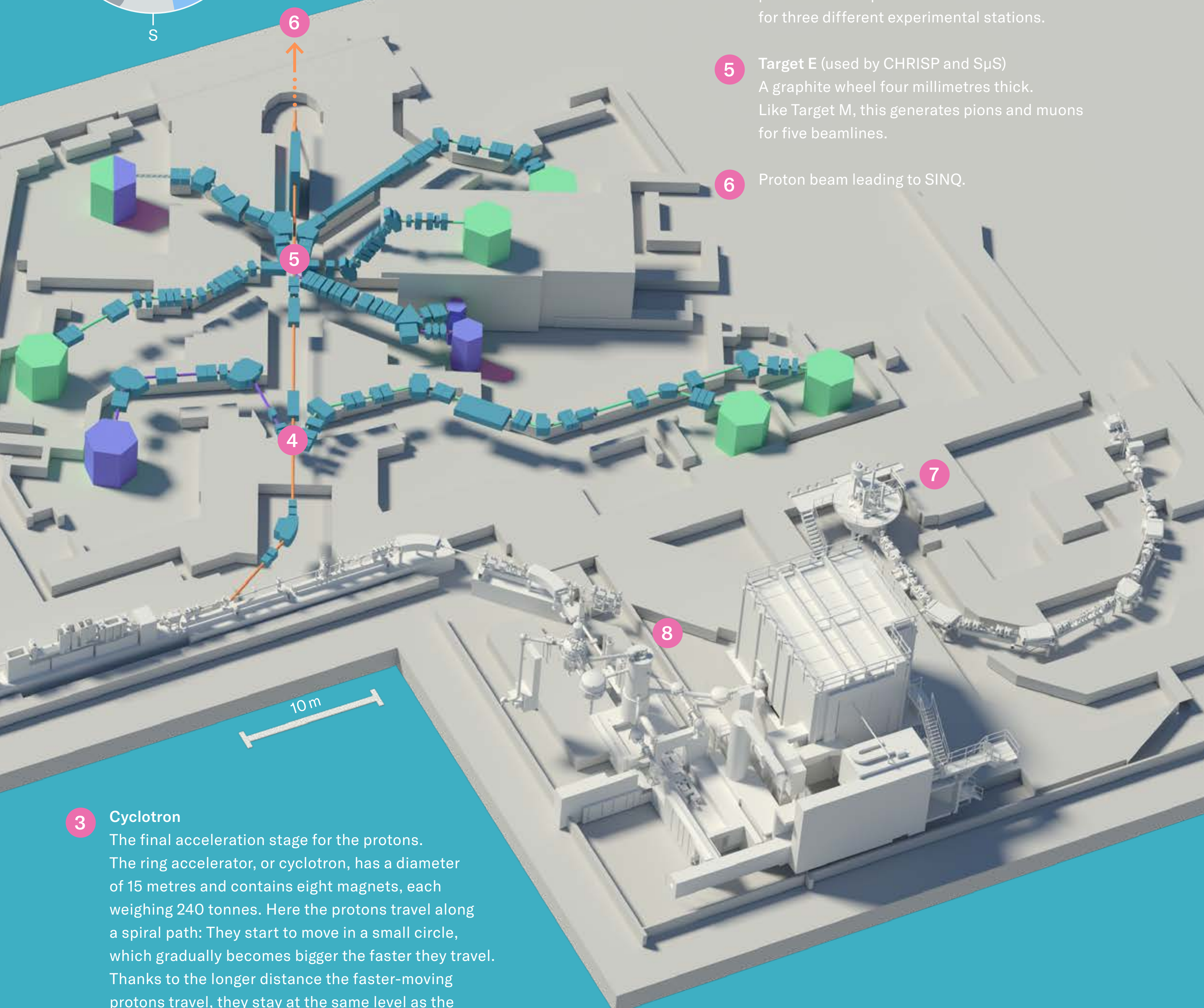
1 **Cockcroft-Walton accelerator**
Proton source, delivers protons with 870,000 electronvolts of energy.

2 **Injector 2**
A cyclotron with four magnets, which accelerates the protons from 870,000 electronvolts to 72 million electronvolts. The "2" in the name dates back to when there was also an Injector 1.





Where am I currently at PSI?



4 **Target M** (used by CHRISP and SμS)
A graphite wheel five millimetres thick. Protons from HIPA are fired at it to produce short-lived particles called pions and muons. These are used for three different experimental stations.

5 **Target E** (used by CHRISP and SμS)
A graphite wheel four millimetres thick. Like Target M, this generates pions and muons for five beamlines.

6 Proton beam leading to SINQ.

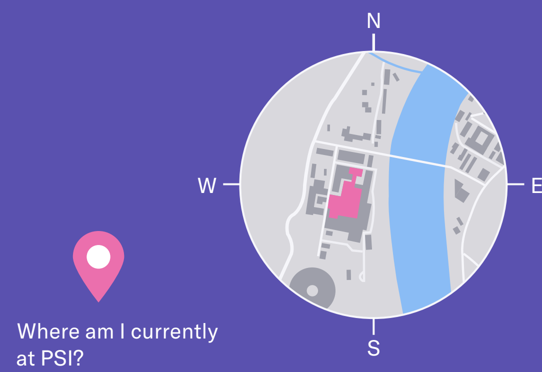
3 **Cyclotron**
The final acceleration stage for the protons. The ring accelerator, or cyclotron, has a diameter of 15 metres and contains eight magnets, each weighing 240 tonnes. Here the protons travel along a spiral path: They start to move in a small circle, which gradually becomes bigger the faster they travel. Thanks to the longer distance the faster-moving protons travel, they stay at the same level as the slower ones. This allows all particles to be repeatedly accelerated at the same pace. After more than 180 circuits, the protons reach their terminal velocity of 79 percent of the speed of light, equivalent to kinetic energy of 590 million electronvolts.

7 **Proton accelerator COMET**
(see next double page)

8 **Ultracold neutron source UCN**
(see next double page)

The Swiss research infrastructure for particle physics CHRISP

The large research facility CHRISP is used for experiments in particle physics: research into the tiny fundamental components of our universe. CHRISP stands for “Swiss research infrastructure for particle physics”. Scientists investigate protons and neutrons, the two types of particles that form the building blocks of atomic nuclei. Here muons make it possible to provide increasingly precise measurements of the proton’s diameter. Another long-term experiment at the ultracold neutron source (UCN) is investigating whether the neutron has a measurable electrical dipole moment. Scientists use these measurements to test fundamental physical theories and constants as precisely as possible.



1 n2EDM experiment
This is a long-term experiment at PSI to search for the neutron electric dipole moment. It uses particles from the ultracold neutron source UCN. This is capable of generating ultracold neutrons – very slow neutrons, in other words – at a rate of nearly one billion per second.

2 Proton irradiation facility PIF
This facility is used to test materials, such as electronic components for space missions. Protons are fired at them to simulate the radiation they would be exposed to from the sun. These experiments are performed at PIF at night and during weekends, because the protons are supplied by COMET. Commissioned in 2007, COMET is mainly used for treating tumours at the Center for Proton Therapy.

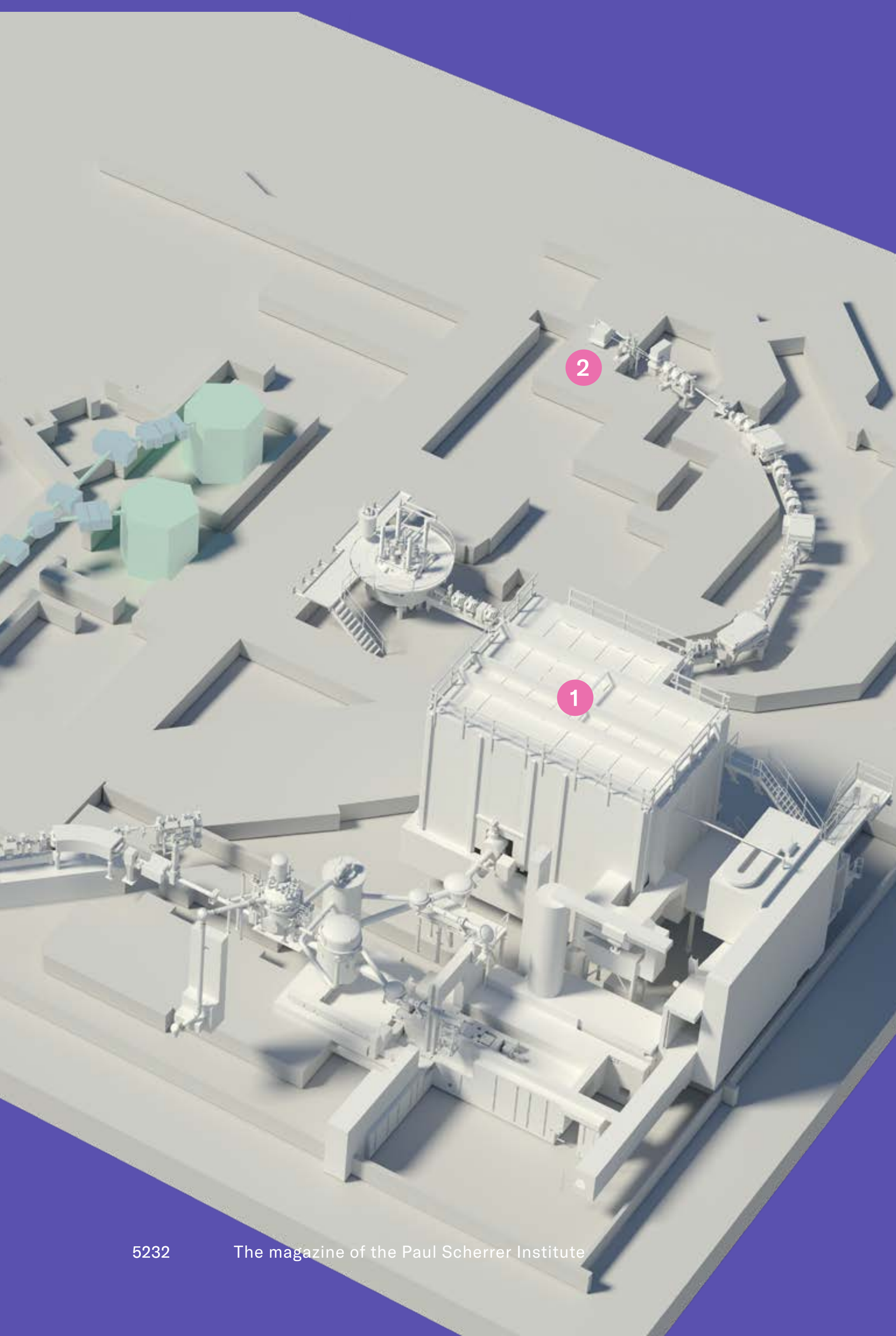
3 **MEG-II-Experiment**
Here researchers are looking for a specific event in which the muon decays into other particles. According to some theoretical models, this is practically unachievable, while others suggest it is possible. The experiment is designed to determine exactly how improbable this decay is. This should in turn help to decide which of the competing physical theories is correct.

4 **Measuring the proton radius with muons**

a Researchers use hydrogen atoms to measure the proton radius. The atomic nucleus of hydrogen consists of just one proton. Scientists fire muons at the hydrogen atoms and can replace the atom's electron with a muon. Because the muon is around two hundred times heavier than the electron, it moves much closer to the atomic nucleus.

b Next, the researchers fire laser pulses at the muonic hydrogen. If the laser beam has the right frequency – known as the resonance frequency – it shifts the muon to a higher kinetic state farther away from the nucleus.

c The resonance frequency recorded allows scientists to calculate the charge radius – in other words, half the diameter – of the proton.



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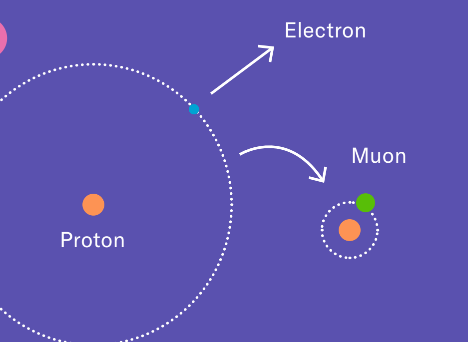

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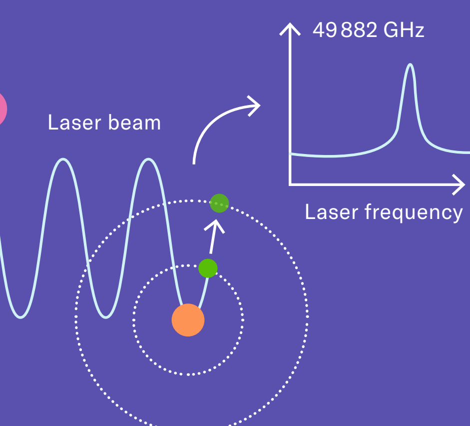

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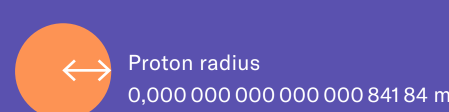
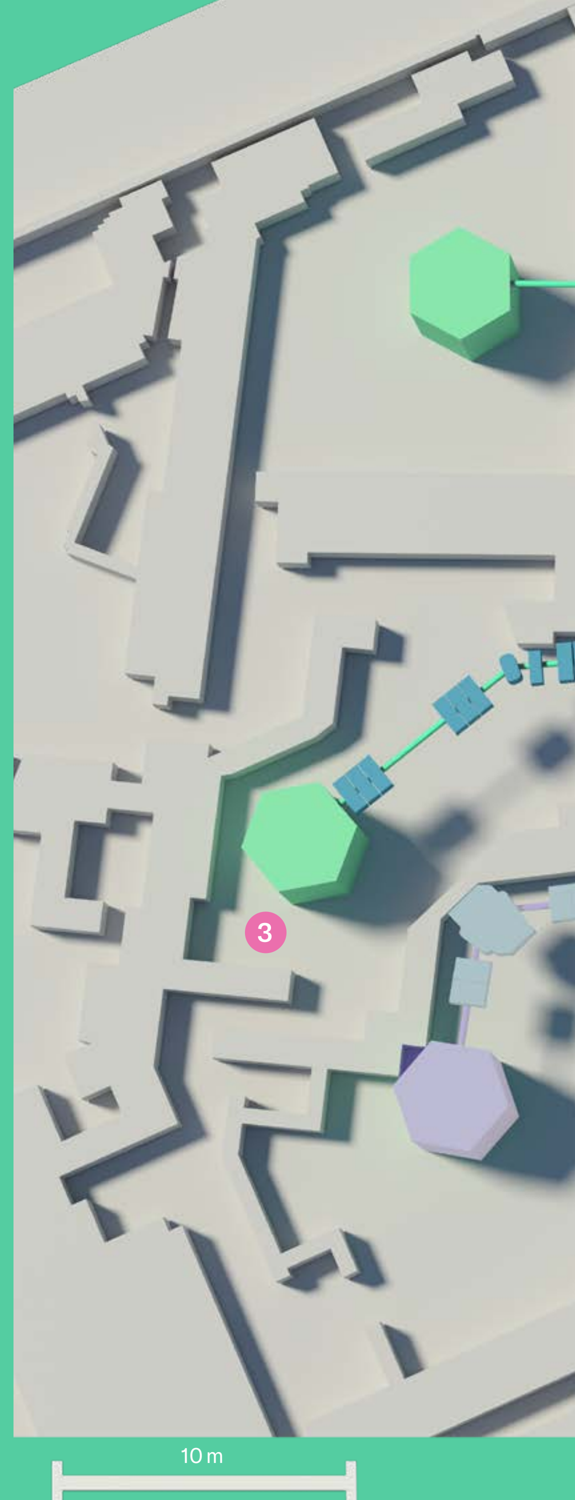


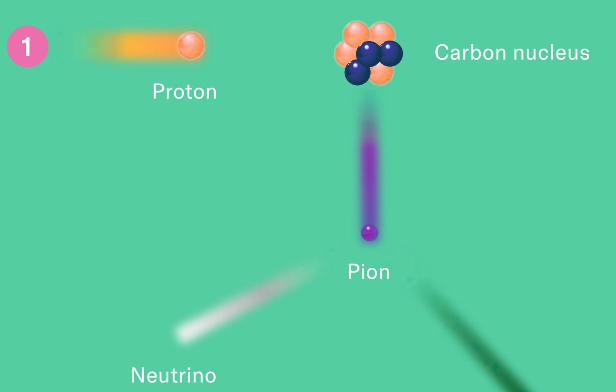
The Swiss muon source SμS

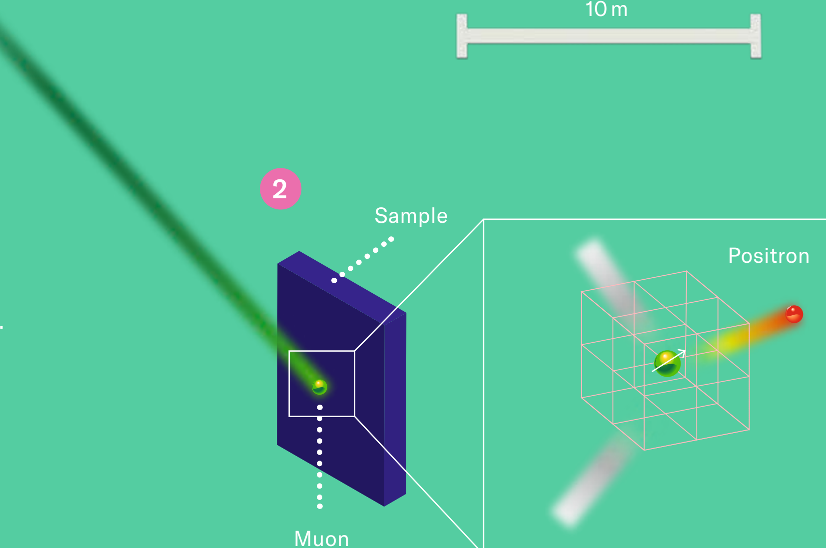
At SμS (pronounced "es-myoo-es") researchers use exotic elementary particles called muons. Muons do not occur in normal atoms, but they do exist as decay products of other particles known as pions.

At SμS, muons are used to analyse samples by means of muon spin spectroscopy. This makes it possible to investigate quantum phenomena, magnetic processes, or very detailed chemical properties of a material, for example. Very precise views into different depths of a sample are also possible. SμS is the most powerful facility of its type in the world, generating 500 billion muons per second.

Many of the local experimental stations have their own unique equipment for exposing samples to a variety of extreme conditions during the measurement process. Some are capable of exerting pressure up to 30,000 bar, while others can create a magnetic field of up to 9.5 tesla. If necessary, samples can be cooled down to minus 273 degrees Celsius or heated to 700 degrees Celsius.







How muons are produced

When an accelerated proton strikes an atomic nucleus in the graphite target, the collision initially generates extremely short-lived particles called pions. A pion then decays into other particles, including a muon. The muon does not exist for long either, but decays within a few millionths of a second into an electron and other particles. Even so, this time frame is still long enough to investigate materials using the muons.

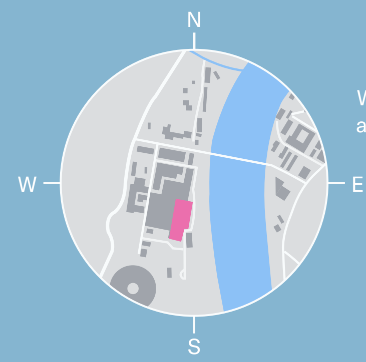
2 Muon spin spectroscopy – muons as "detectives"
When muons are fired at a sample, they immediately search for a place in the atomic lattice. Here they "observe" their immediate environment, especially the local magnetic field. Muons have a property known as spin. This means they react to magnetic fields like tiny magnetic spinning tops. When a muon decays into other particles, these shoot out of the sample in different directions. Positrons, one type of particle arising from this decay, are then recorded by detectors. The direction in which the positrons are emitted gives scientists insight into the information the muons have gathered about the local magnetic field.

3 Experimental station LEM (low-energy muons)
The world's only facility for generating slow muons. These can be used to investigate thin-film structures: samples with layers of material only around 0.00001 millimetres thick.

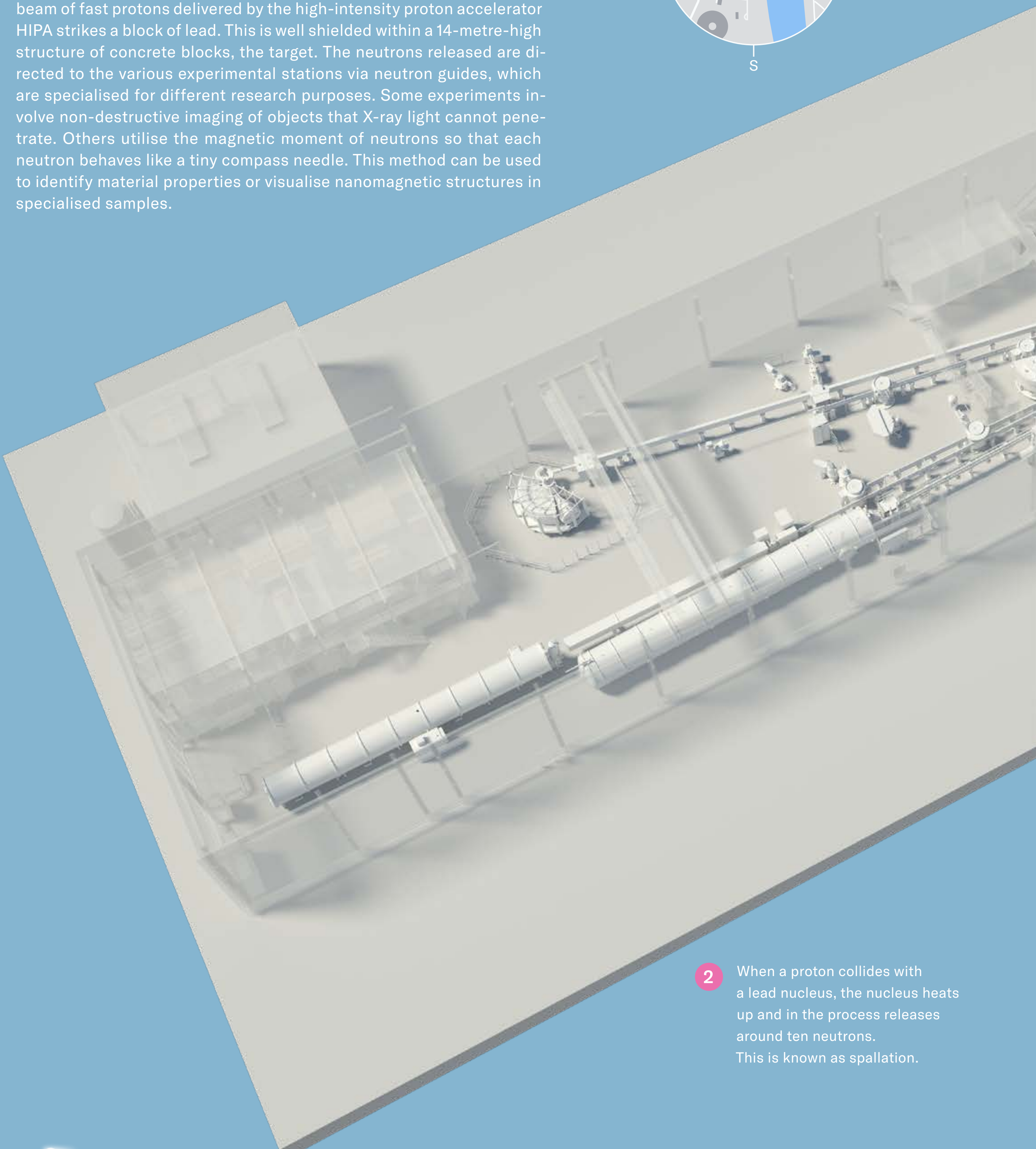
4 Experimental station GPD (general-purpose decay-channel spectrometer)
Nowhere else in the world can muon spin spectroscopy be performed under such high pressure – up to 30,000 bar.

The Swiss Spallation Neutron Source SINQ

The SINQ facility generates around 100 trillion neutrons per square centimetre per second (10^{14} n/cm^2/s). The neutrons are produced when a beam of fast protons delivered by the high-intensity proton accelerator HIPA strikes a block of lead. This is well shielded within a 14-metre-high structure of concrete blocks, the target. The neutrons released are directed to the various experimental stations via neutron guides, which are specialised for different research purposes. Some experiments involve non-destructive imaging of objects that X-ray light cannot penetrate. Others utilise the magnetic moment of neutrons so that each neutron behaves like a tiny compass needle. This method can be used to identify material properties or visualise nanomagnetic structures in specialised samples.



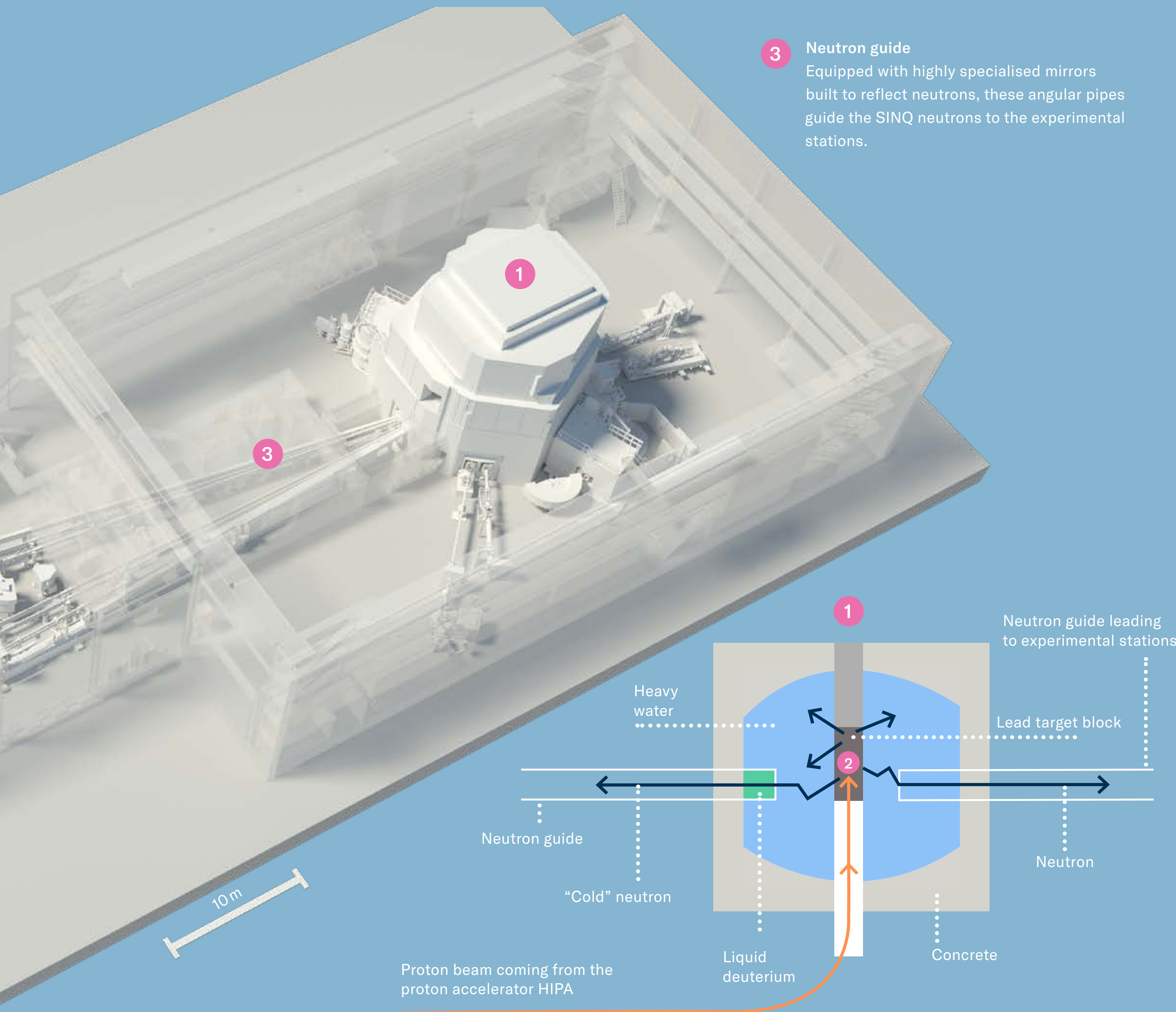
Where am I currently at PSI?



2 When a proton collides with a lead nucleus, the nucleus heats up and in the process releases around ten neutrons.
This is known as spallation.

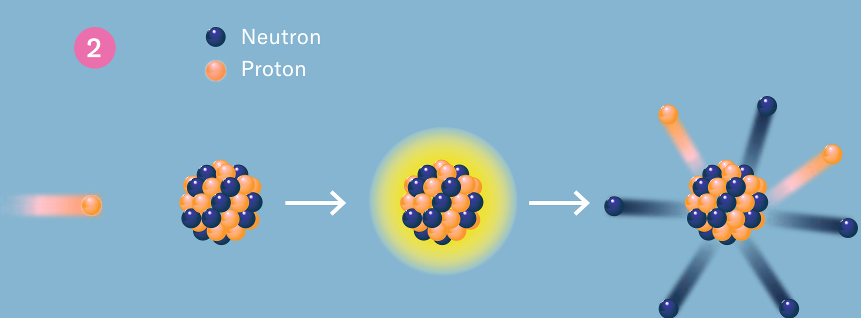
3 Neutron guide

Equipped with highly specialised mirrors built to reflect neutrons, these angular pipes guide the SINQ neutrons to the experimental stations.



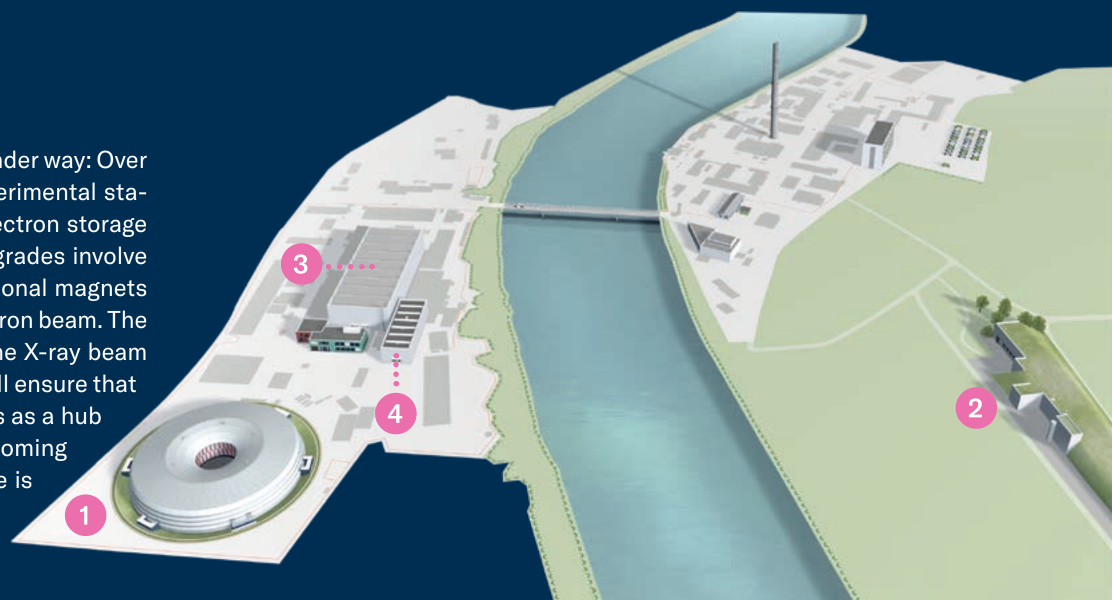
1 In the target block

SINQ produces neutrons when protons from the high-intensity proton accelerator (HIPA, see p. 12–13) collide with a target block made of lead. Neutrons are then ejected at high speed in all directions. A cold source of liquid deuterium held in a 6,000-litre tank slows down or "moderates" the neutrons, which then pass into one of the neutron guides for use in specialised experiments. Neutrons that escape in other directions are blocked by protective layers and ultimately by the concrete cladding surrounding the target block. Some experiments operate with even slower "cold" neutrons. Their speed is further moderated in a 20-litre tank containing heavy water at around minus 250 Celsius.



Upgrades for the large research facilities

The large research facilities at PSI are some of the most advanced in the world and provide a platform for cutting-edge research in Switzerland. To maintain this international standing, the facilities are continuously equipped with the latest technology and regularly undergo comprehensive upgrades.

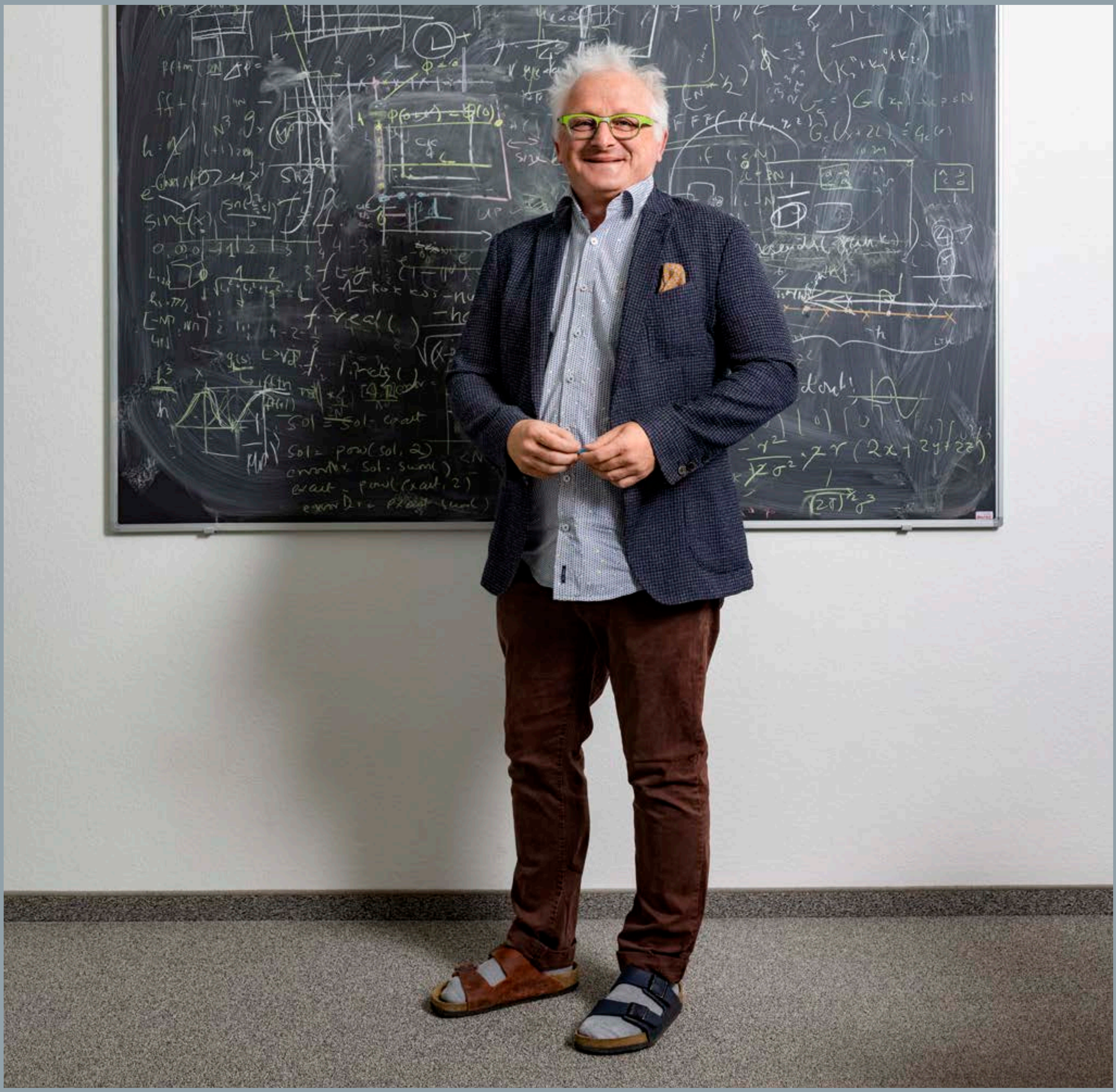


1 **SLS 2.0**
The SLS 2.0 upgrade project is well under way: Over the period 2021 to 2024, certain experimental stations are being revamped and the electron storage ring completely renovated. Other upgrades involve optimising the configuration of additional magnets to provide a much more compact electron beam. The upgrade will improve the quality of the X-ray beam SLS delivers by a factor of 40. This will ensure that SLS maintains its international status as a hub for cutting-edge research over the coming decades. The budget for this upgrade is 129 million Swiss francs.

2 **SwissFEL upgrade**
SwissFEL came into service in 2016, making it the youngest of PSI's large research facilities. So far it has two beamlines: Athos and Aramis, named after two characters in the Alexandre Dumas novel *The Three Musketeers*. Athos has two experimental stations, and a third is currently being added to Aramis. Another two stations are planned. When SwissFEL was first built, provisions were already put in place for a third beamline to be installed after a few years. This is to be called Porthos, after the third musketeer, and will use superconducting components.

3 **IMPACT**
Since it started operating back in 1974, the high-intensity proton accelerator HIPA has been continuously refined, undergoing several upgrades over time. Today's injector cyclotron and many other improvements in the acceleration structure have enabled a continuous increase in the intensity of the proton beam, measured in number of protons per second. Even now, HIPA still holds the world record for beam power and the production of secondary particles. The next project in the pipeline is IMPACT, short for Isotope and Muon Production with Advanced Cyclotron and Target Technology. Due to be rolled out over the period 2025 to 2028, IMPACT consists of two parts: HIMB and TATTOOS. HIMB (High-Intensity Muon Beams) will increase the available muon rates up to one hundred times, which will benefit research into both particle physics and materials science. The purpose of TATTOOS (Targeted Alpha Therapy using Terbium and Other Oncological Solutions) is to produce radionuclides for the simultaneous diagnosis and treatment of cancer.

4 **SINQ guide upgrade**
SINQ came into service in 1996. An upgrade began in the summer of 2020: Three new measuring instruments have been added, along with a new state-of-the-art optical neutron transport system. This has led to the replacement of all the neutron guides. These guides are evacuated glass or metal pipes whose internal surface has an extremely fine metal layer that acts as a type of mirror for neutrons. These pipes guide the neutrons from the source to the various research stations. The upgrade has improved the neutron flux at the various experimental stations by a factor of between two and thirty. The total upgrade cost 17 million Swiss francs.



Modelling and reality

Andreas Adelmann and his team produce results even before an experiment has started: The head of the Laboratory for Scientific Computing and Modelling at PSI translates relevant factors that play a role in planned experiments into mathematical equations. These are solved with the help of a computer program and provide a numerical model for the experiment. The results can be used to predict outcomes in order to optimise experiments, improve scientific instruments, or simulate the effects of phenomena in materials science or bioscience.

Building work is proceeding according to plan – Benno Rechsteiner, CEO of Park Innovaare (left), and overall project manager Daniel Leber check progress during a personal visit to the site.

A neighbour with entrepreneurial spirit

Switzerland Innovation, a nationwide network of technology parks, continues to grow: Park Innovaare, located next to PSI, is flourishing as it pursues its mission to help cutting-edge Swiss research transition to concrete applications and profitable companies.

Text: Brigitte Osterath


Daniel Leber
ERNE

"We are looking at the future cleanroom facility, where researchers will work on particularly sensitive materials," says architect Daniel Leber, entering a massive hall built from reinforced concrete on the Park Innovaare construction site. The hall still looks more like an underground car park, but the project manager goes on to say that with a little imagination, one can easily picture scientists in protective suits tinkering with high-tech materials on the nanoscale. "Cleanroom cubicles will eventually be installed here," he explains. "Specialised filters will purify the air to minimise the amount of particles." This is essential for research and manufacturing processes such as those used for semiconductors or pharmaceuticals.

Leber is an architect with the Swiss construction company ERNE and overall project manager for the innovation campus Park Innovaare being built next to PSI. The expansion has been under construction since November 2019 and should be available by the end of 2023, offering around 23,000 square metres of floor space housing offices, laboratories and workshops.

Daniel Leber is proud to show the progress already made with the four buildings on the innovation campus. He describes the project as "a very inspirational undertaking": "It involves many specialist applications, with a steady stream of structural engineering challenges." The X-ray facility, for example, has reinforced concrete walls 50 centimetres thick. In addition, an overhead crane is needed to install the extremely heavy X-ray machines. A high-tech ventilation system is required for some of the physics laboratories to regulate temperature at a constant 0.1 degrees Celsius. In the clean-room facility, concrete walls are isolated from the walls of adjacent buildings by a special separation layer made of nylon wire mesh. This prevents vibrations passing from one building to the next – critical protection for intricate nanoscale activities.

All aspects covered

Apart from the high-tech installations, all the basic amenities are in place as well, including a restaurant capable of serving up to 200 meals. This will provide a social hub where scientists and innovation pioneers from industry and academia will be able to discuss joint research projects over lunch. "Since its inception in 2015, Park Innovaare has become a meeting place for managers from innovative companies to get together with prominent scientists from PSI and other research institutes and universities," says Benno Rechsteiner, CEO of Park Innovaare. "We bring innovations to market, create new jobs and generate value added for the Canton of Aargau and the whole of Switzerland."

> "We're looking for companies eager to take a genuine technological leap forward."
>
> Benno Rechsteiner, CEO of Park Innovaare

If required, larger industrial companies can even fit out entire floors of the expansion building to suit their individual needs, while small start-ups can rent fully equipped laboratories and offices for immediate use. All tenants can pay to use infrastructures such as cleanrooms, whose construction and maintenance would otherwise be far too costly.

Other facilities are of course available, if needed, on the other side of the street – at PSI itself. "Close proximity to PSI, with its large research facilities and standing in the international scientific community makes Park Innovaare a particularly attractive location," says Rechsteiner. "We're looking for companies eager to take a genuine technological leap forward."

Waiting to move in

17 companies, some of them spin-offs from PSI, are already settled in Park Innovaare. Until the new buildings are ready, current tenants are housed in the deliveryLAB, a two-storey wooden pavilion on the western side, or on the PSI site itself. "We're already excited about moving into the new innovation campus as soon as possible so that we can continue our growth story," says Michael Hennig, CEO and co-founder of leadXpro. The company has rented an entire floor in one of the new buildings.

LeadXpro specialises in the characterisation of membrane proteins – important interfaces and useful target structures for drug discovery. This PSI spin-off uses both the Swiss Light Source SLS and the X-ray free-electron laser SwissFEL to conduct its research. Other tenants in Park Innovaare include the technology transfer centre ANAXAM, which offers companies materials analytics using neutron and synchrotron radiation. Its services range from advice on measurements with tailor-made infrastructures for data analysis, through to the final report.

The close partnership between research and industry not only benefits the spin-offs themselves, but also PSI, as it enables inventions and technological developments to be brought to market sooner. "Close physical proximity allows rapid and straightforward communication – many issues can even be discussed at short notice over lunch," com-

The national network of Switzerland Innovation. The six main innovation parks can also set up satellite sites in other regions. Innovation Park Zurich, for example, also has a branch in central Switzerland and another in Ticino.

Park Innovaare, Villigen

Park Biel / Bienne

Park Basel Area

Park Zürich

Park West EPFL, Lausanne

Park Ost, St. Gallen

ments Jens Rehanek, CEO of Advanced Accelerator Technologies, a joint initiative of PSI and several industry partners. The company commercialises PSI's know-how in the development of accelerator technologies and other scientific installations.

What's the purpose of innovation parks?

"Switzerland leads the way in basic research," says Raphaël Tschanz, Deputy Director of the foundation Switzerland Innovation in Bern, the umbrella organisation for the national network of innovation campuses that includes Park Innovaare. "Unfortunately Switzerland is slipping behind when it comes to translating these research findings into concrete applications and products. There are not enough projects in the technology transfer stage and too little collaboration between industry and universities."

Back in 2012, the Swiss Federal Council decided to address this by creating the legal framework to establish a network of innovation parks. ETH Zurich and EPFL in Lausanne were the two main sites initially, and other sites could then apply to join. In addition to Park Innovaare, Park Biel and Park Basel Area have signed up. This year the Federal Council also gave the green light for a sixth site in Saint Gallen.

"Every site has a thematic focus," explains Tschanz, "in other words, each offers certain specialisations linked to the research competence of the various institutes, universities or companies in the region." The Basel Area, for example, is a leader in biotechnology and biomedicine. The key competences of Park Innovaare include accelerator technologies, advanced materials, human health and energy.

Swiss Romandie: a role model

Tschanz singles out Park Network West EPFL as a prime role model for the more recently established innovation parks. Its sites in Lausanne, Sion, Geneva, Neuchâtel and Fribourg cover all of Swiss Romandie, the French-speaking part of Switzerland. "Private industry has produced consistently high demand in this region," Tschanz notes. "Work has already started in Lausanne 20 years ago to actively encourage partnerships between industry and academic institutions."

The goal is to create a flourishing ecosystem that fosters a truly entrepreneurial spirit. Raphaël Tschanz is confident the new building in Villigen will accelerate this process even further – especially since the PSI will also be a tenant on the innovation campus. "There are only a few places in the world where so much know-how is as highly concentrated as it is at PSI." All types of company stand to benefit from it. ◆

Latest PSI research news

1 The future of data

PSI has officially expanded its own focus areas and established a new research division: Scientific Computing, Theory, and Data. Here researchers will increasingly focus on the development of new computer and data technology and its use in science. The new research division is PSI's sixth, joining the five existing divisions: Biology and Chemistry; Research with Neutrons and Muons; Nuclear Energy and Safety; Energy and Environment; and Photon Science. Computer-aided sciences and the use of high-performance computers such as those at CSCS in Lugano, data sciences, simulations and modelling, and the use of artificial intelligence have all played a role at PSI for a long time. But now they are being assigned an appropriate basis in our organisational structure – and one that is geared towards the future.

The new research division will be more closely networked within the ETH Domain. Several laboratory heads are already EPFL professors, for example. Their dual affiliation will help bring the two institutions closer together.

Further information:
http://psi.ch/en/node/45903

PSI now has 6 research divisions:
The latest – Scientific Computing, Theory, and Data – complements the existing five.

Around 3,6 petabytes (or 3.6 quadrillion bytes) of research data are generated at PSI every year – with a rising trend.

25 petaflops (or 25 quadrillion calculations per second) is the computing power of the supercomputer PIZ Daint at the Swiss National Computing Centre in Lugano, part of ETH Zurich and used by PSI scientists.

2 A Swiss quantum computer

ETH Zurich and the Paul Scherrer Institute PSI have opened a joint research centre, the ETH Zurich - PSI Quantum Computing Hub. Here two competing principles for realising quantum bits are currently being explored: ion traps and superconducting qubits. The mid-term goal is to take at least one of these two concepts and produce a functioning experimental quantum computer on the PSI campus. Although PSI will continue to develop this computer further, it will already be made available for use by researchers: In certain cases it should be able to run complex data processing and simulations much faster than classical computers.

Scientists at PSI and ETH Zurich are already experienced in investigating quantum states and producing qubits. Collaboration between these two prestigious institutions should make it possible for Switzerland to develop advanced expertise in quantum computers from an early stage.

Further information:
http://psi.ch/en/node/44890

3 Cell cytoskeleton as a target for new active agents

Through a unique combination of computer simulations and laboratory experiments, researchers at PSI have discovered new binding sites for active agents – to combat cancer, for example – on a vital protein of the cell cytoskeleton These tubulin proteins give cells their shape, aid in transporting proteins and larger cellular components, and play a crucial role in cell division. Tubulin interacts with numerous other substances in the cell. Many drugs also dock onto tubulin and take effect, for example, by preventing cell division in tumours. In collaboration with the Italian Institute of Technology in Genoa, researchers have identified places where other molecules could dock particularly well onto tubulin. In a subsequent experiment in the laboratory, the researchers sought to verify such sites. Overall, they found 27 binding sites on tubulin, 11 of which had never been described before. These may be suitable for developing new active agents.

Further information:
http://psi.ch/en/node/45064

4 Uniquely sharp X-ray view

Scientists at the Paul Scherrer Institute PSI have succeeded for the first time in looking inside materials using the method of transient grating spectroscopy. This was made possible by ultrafast X-rays at the X-ray free electron laser SwissFEL. The experiment at PSI is a milestone in the ability to observe processes inside matter in unprecedented detail. For the first time, it is possible to look inside materials with atomic resolution as well as with ultrashort exposure times of fractions of femtoseconds (one millionth of a billionth of a second), which even allows atomic processes to be filmed. In addition, the method is element-selective, allowing specific chemical elements in a mixture of substances to be selectively measured. The new method could help advance the miniaturisation of technology, for example, as it can be used to study how heat moves through a semiconductor material or what exactly happens when individual bits on a computer hard drive are magnetised.

Further information:
http://psi.ch/en/node/44815

The power of protons

Every year, hundreds of cancer patients are treated successfully at the PSI Center for Proton Therapy. Proton radiation is less damaging to surrounding tissue and can be used for precise treatment of tumours in particularly sensitive regions of the body – much to the relief of patients and their families.

Text: Sebastian Jutzi

Onwards and upwards

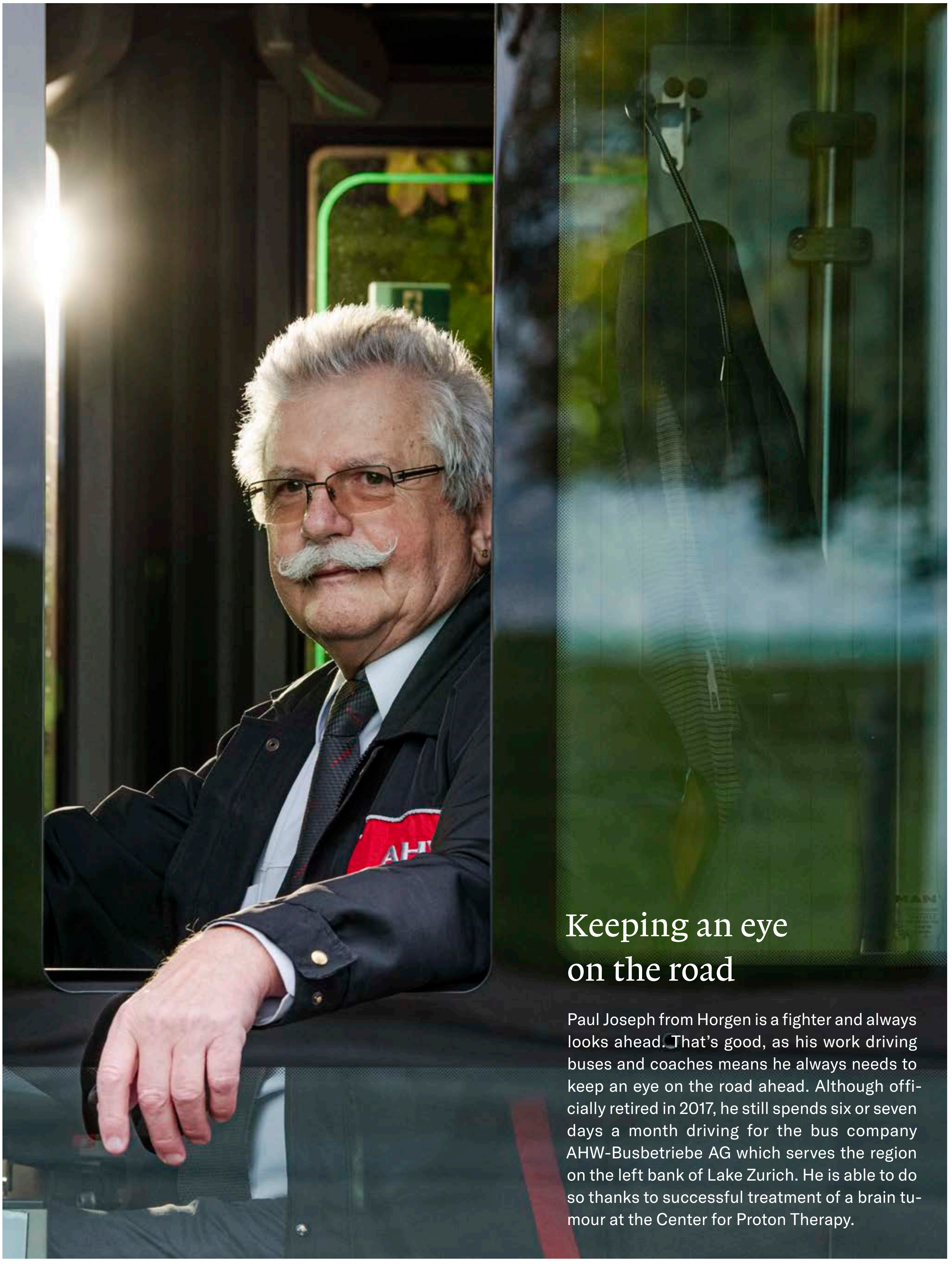
Ute from Malix near Chur was never really keen on sport. In December 2014 a sarcoma was found on her thigh. As the tumour was close to a vital nerve, the tumour tissue could not be entirely removed by surgery. She therefore underwent a six-week course of treatment at the Center for Proton Therapy in April 2015 – and then took up running. Now she takes part in mountain runs and occasionally completes a half-marathon as well.

Flourishing in the garden

Konrad from St. Urban was treated at the Center for Proton Therapy for 42 days following an operation to remove a tumour from his parotid gland. He was reluctant to go ahead with a more radical operation offered as an alternative. At the same time, he switched to a diet high in vegetables. Today this means he is even happier when his garden produces a bumper harvest.

Back on the catwalk

Zoe from Unterägeri was diagnosed with cancer in 2009, just before her ninth birthday: a rare type of tumour in the region of her head. She received treatment at the Center for Proton Therapy from October to November. Today she is delighted to be in remission and go along to photo shoots again – she does modelling work in her free time. This year she wants to pass her vocational qualification (Swiss *Fachmaturität*) and can then decide what subject she wants to study.



Keeping an eye on the road

Paul Joseph from Horgen is a fighter and always looks ahead. That's good, as his work driving buses and coaches means he always needs to keep an eye on the road ahead. Although officially retired in 2017, he still spends six or seven days a month driving for the bus company AHW-Busbetriebe AG which serves the region on the left bank of Lake Zurich. He is able to do so thanks to successful treatment of a brain tumour at the Center for Proton Therapy.

Always on the ball

Lisa from Adlikon is passionate about football. Even the diagnosis of a tumour in the soft tissue of her neck did not bring her down. Seven weeks of treatment at the Center for Proton Therapy in 2013 was a top result– now her team mates can once again count on the school pupil's skills as a goal-scorer.

A balancing act

The appeal of the mountains brought Thomas Mattle back to Switzerland. He completed his PhD at PSI and is now head of Technology and Innovation at Geberit, based in Rapperswil-Jona near Lake Zurich. He believes that being on an equal footing with colleagues is crucial for creating the right atmosphere at work.

Text: Christina Bonanati

Hissing and gurgling sounds fill the laboratories where sanitary technology and bathroom ceramics are developed and tested. Here prototypes of WC cisterns, piping systems, and innovative coatings are tested a hundred thousand times. “The difference in how efficiently toilets flush is incredible,” Thomas Mattle remarks, laughing. He is quite relaxed as he moves through this warren of pipes and gleaming porcelain, stopping for a casual chat with colleagues. Outsiders would probably not even guess that he is actually the boss: Since 2020 Mattle has been head of Technology and Innovation at Geberit International AG, the European market leader in sanitaryware.

It’s not the first time that Mattle’s training and career have taken him to unexpected places. Raised in the canton of St. Gallen, he went to school in Heerbrugg, where he also helped out in the local observatory. Between leaving school and military service he spent four months in Australia, where he not only improved his English, but learned how to build an irrigation system on a cattle farm and at the same time “properly” swear.

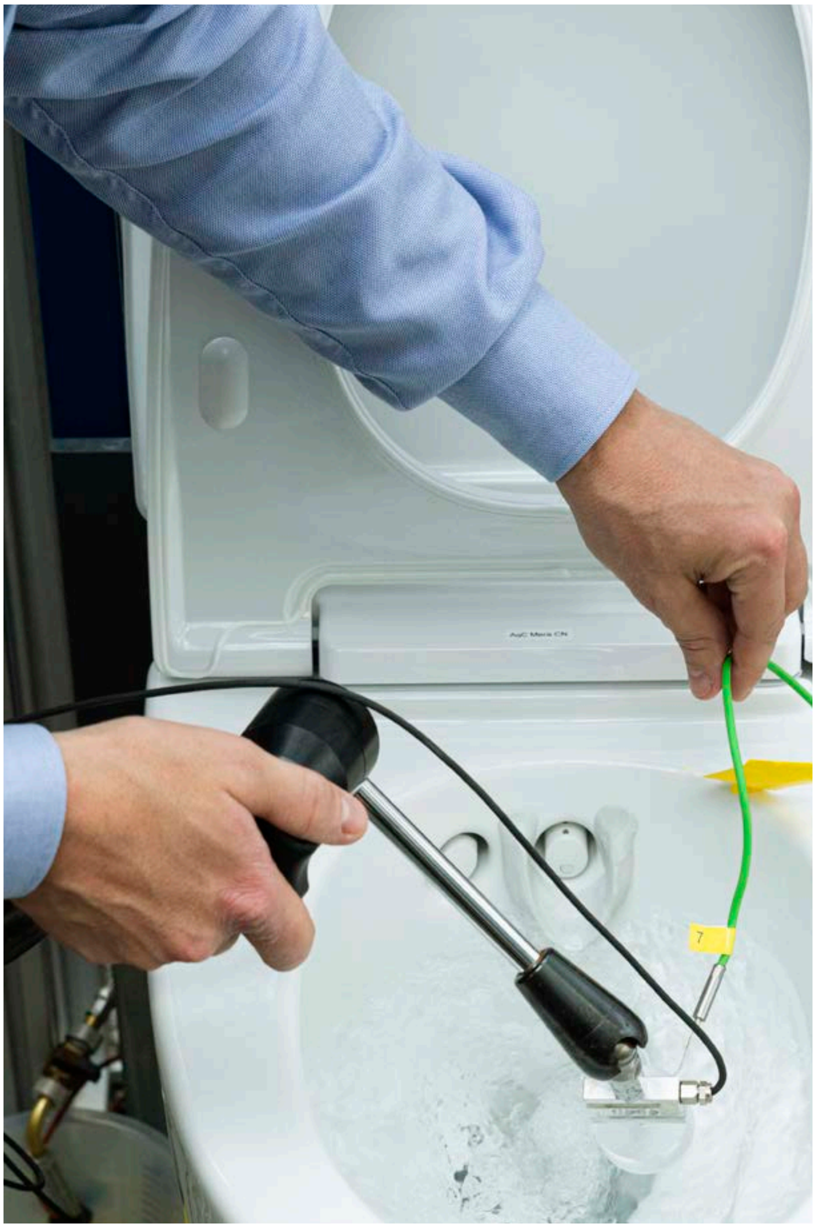
Mattle is convinced that going on to study physics at the University of Zurich was a good decision, especially since back then the laboratories were shared by only fifteen students in each year of study. “We could stroll straight into professors’ offices and they’d know who we were,” he recalls. During his studies he specialised in solid-state physics, and while working as a student assistant he analysed electric detectors for CERN. He spent a year on the Erasmus scheme in Uppsala, Sweden, where he concentrated on his secondary subject, chemistry. He spent a lot of time in the laboratory and also learned Swedish on the side.

The “feelgood factor”

After completing his master’s degree, Mattle applied for the Young Graduate Trainee Programme run by the European Space Agency (ESA). His studies have never have been more exciting than during his year in Noordwijk in the Netherlands, where he worked on batteries for a Mars robot. Even so, he didn’t want to stay there forever: “Holland is flat and the weather is poor,” Mattle explains. “Switzerland is my home – its mountains and sunshine make me feel good.”

His application to study for a PhD at the Paul Scherrer Institute was therefore a very practical decision. From 2009 to 2013 the physicist did research on a process for manufacturing chemical sensors. With the help of a laser focused through lenses, these sensors are printed with tin oxide. This allows the electronic structure – in this case, an active chemical coating – to be applied with a high degree of precision. Originally looking for more product-oriented work, he then unexpectedly became fascinated by a theoretical problem: “While reflecting on why the transfer of the substrate did not work, I chanced upon an exciting book from the 1960s on the supersonic effect and became totally absorbed in the material,” he recalls.

After the intense study required for his PhD thesis, Mattle spent five months travelling through East



“My promotion hasn’t changed much there – my staff members still stroll casually into my office.”

Thomas Mattle, Head of Technology and Innovation, Geberit International AG

Africa. He climbed Kilimanjaro and learned all about the animal world. “If the first boat doesn’t sail for another two days and a storm is approaching, or an elephant destroys the rubbish bin next to your tent, you soon learn to be patient. You also come to recognise your own fears,” he summarises, reflecting on his adventure.

On his return in the summer of 2014, Mattle applied for the job of development engineer at Geberit. He finds working for the global company, which employs around 12,000 people worldwide, particularly interesting due to its practical nature. During his interview for the job, he was also impressed by the open and friendly atmosphere.

In the Technology and Innovation division, experts from a variety of fields support the development and optimisation of Geberit products and manufacturing processes. Mattle joined the company as a development engineer for materials technology, where his main responsibilities were in the areas of adhesives, elastomers, and coatings. “I had no clue about adhesives and had to think my way into work processes in a different way,” he recalls. Fortunately he was able to fall back on his experience as a doctoral student. “If you can’t do something, you read up on it and learn what you need to know.” Before long, Mattle was managing a small technology project that had a successful outcome.

When his immediate boss was promoted eight months later, it soon became clear that Mattle was in line to take over her position as head of the laboratory for materials technology. He also became deputy manager of Geberit’s test laboratory, an accredited test centre for piping systems and sanitary products. “Suddenly my tasks also extended to personnel management and budget responsibility. It was rather overwhelming.” But thanks to great support from his boss at the time and a few management training sessions, he soon mastered this role as well. He says it was “cool” to have produced a new toilet seat after a full year of development work. “I knew that the paint alone involved nine months of work – and now it’s functioning perfectly.”

Taking tips from mountain climbing

Just over a year ago he was promoted again, this time to division head. Thanks to his love of climbing, Mattle says he is quite good at the balancing act of establishing priorities. His team is currently working on speeding up processes in the pipe production facility. When collaborating with start-ups or research institutes, his job includes managing the resources and finances. He is currently working on a joint research project with the University of Zurich, for example, focusing on Legionella bacteria in water and hygiene.

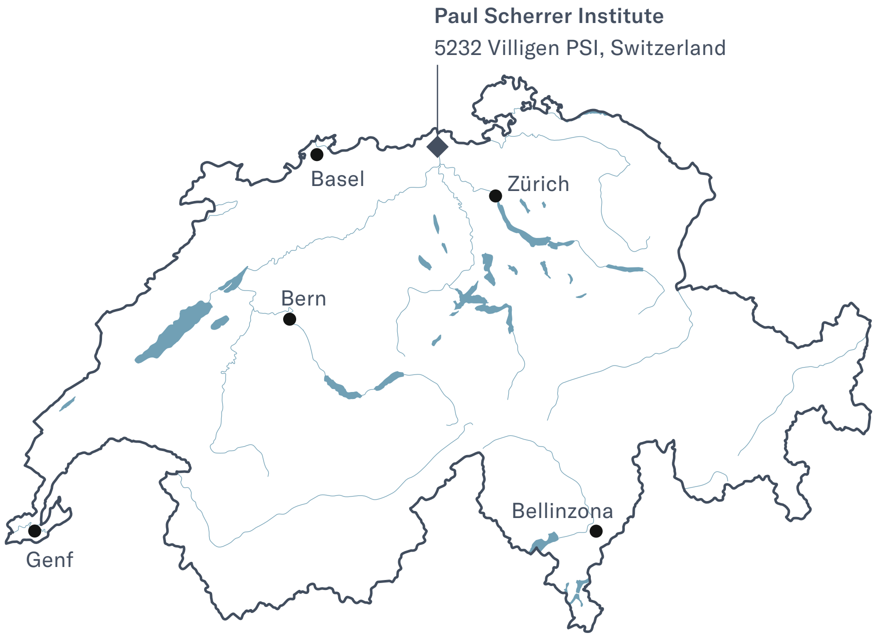
The physicist stresses that he still likes to visit the lab occasionally to soak up information first-hand: “I take the time to talk to people and hear about their progress, and also to listen to any issues or concerns they may have.” As a manager, he is still keen to understand the technology. However, he no longer sees his role as finding solutions himself, but rather in asking his own people the right questions and thus steering them in the right direction towards a solution. He always treats his old lab and office colleagues as his equals. “My promotion hasn’t changed much there – my staff members still stroll casually into my office,” he is glad to report.

Sharing information over coffee and sports

He laments the absence of coffee breaks due to people having to work remotely from home during the pandemic. “A chance encounter by the coffee machine is often an opportunity to share valuable information.” The social bonds created by playing sports together are irreplaceable as well. He points through the window to a sports hall. “You can really get to know people from very different departments and management levels on the badminton court or ski slopes, for example. You become more supportive and are much more likely to call each other now and again.” He is pleased to hear that PSI now has a climbing wall and sports centre as well. He missed that during his time there.

From the Geberit building you can see across Lake Zurich to the mountains. During the summer, Mattle leads two or three climbing tours for the Swiss Alpine Club. He likes to spend his evenings with friends in the climbing hall or dining together. Mattle pats his small paunch and remarks that his new position leaves him very little time for sports – at least for the time being. ◆

From our base in Aargau
we conduct research for Switzerland
as part of a global collaboration.



5

large research facilities that are unique in Switzerland

800

scientific articles a year based on the experiments performed at PSI's large research facilities

5,000

visits every year from scientists from across the globe who perform experiments at our large research facilities

5232 is Switzerland's prime address for experiments on large research facilities. The Paul Scherrer Institute PSI even has its own postcode, a distinction that seems justified for an institute that extends over 342,000 square metres, has its own bridge across the River Aare, and has around 2,100 employees – more people than in most of the surrounding villages.

PSI is situated on both banks of the River Aare in the canton of Aargau, in the municipal areas of Villigen and Würenlingen. Its main areas of research are in the natural sciences and engineering. Funded by the federal government, it belongs to the domain of the Swiss Federal Institute of Technology (ETH Domain), which also includes ETH Zurich, EPFL Lausanne, and the research institutes Eawag (Swiss Federal Institute of Aquatic Science and Technology), Empa (Swiss Federal Laboratories for Materials Science and Technology) and WSL (Swiss Federal Institute for Forest, Snow, and Landscape Research).

Complex large research facilities

Switzerland's federal government has given PSI the mandate to develop, build, and operate large, complex research facilities. These are the only such facilities within Switzerland, and some are the only ones in the world.

Running experiments at our large research facilities enables many scientists from the most diverse disciplines to gain fundamental insights for their work. The construction and operation of these kinds of facilities involve so much time, effort, and cost that comparable meaurement equipment is not available to academic and industrial research groups at their own institutions. That is why we keep our facilities open to all researchers worldwide.

To obtain a time slot to use the experimental stations, however, both Swiss and foreign scientists first have to apply to PSI. Selection committees comprising experts from all over the world assess the scientific quality of these applications and recommend to PSI which candidates should be given measurement time. Even though there are around 40 measuring stations where experiments can be carried out at the same time, there is never enough capacity for all of the proposals submitted – around one-half to two thirds have to be rejected.

Around 1,900 experiments are performed every year at PSI's large research facilities. Time slots are free of charge for all researchers working in academia. In a special process, users from private industry can buy time to carry out proprietary research and use the PSI facilities for their own applied research. For this, PSI offers special research and development services.

PSI operates five large research facilities in total where the internal processes of materials, biomolecules, and technical devices can be explored on the nanometre scale. Here scientists use different beams to “illuminate” the samples they want to investigate in their experiments. The beams available for this range from particles (neutrons or muons) to intense X-ray light from a synchrotron or X-ray laser source. The different types of beams allow a wide variety of material properties to be studied at PSI. The high complexity and cost of the facilities is due to the massive size of the accelerators needed to generate the different beams.

Three main areas of research

However, PSI not only acts as a service provider for researchers, but also carries out an ambitious research programme of its own. The findings produced by PSI scientists help us to understand the world better, and also lay the foundation for developing new types of equipment and medical treatments.

At the same time, our own research is an important prerequisite for the success of our user service programme for the large research facilities. Only researchers personally involved in current scientific developments in the fields external researchers are working in can support them in their investigations and further refine the facilities to ensure they continue to meet the needs of cutting-edge research in the future.

PSI has three main areas of research. In the area of Matter and Materials, scientists study the internal structure of different materials. These results contribute towards a better understanding of processes occurring in nature and provide starting points in the development of new materials for technical and medical applications.

In the Energy and Environment area, activities focus on the development of new technologies to facilitate the creation of a sustainable and secure supply of energy, as well as an uncontaminated environment.

In the Human Health area, researchers search for the causes of illnesses and explore potential treatment methods. Their fundamental research activities also include the elucidation of generic processes in living organisms. In addition to research activities, PSI operates Switzerland’s sole facility for the treatment of specific malignant tumours using protons. This particularly sensitive procedure allows tumours to be destroyed in a targeted manner, leaving the surrounding tissue largely undamaged.

The brains behind the machines

The work at PSI’s large research facilities is challenging. Our researchers, engineers, and professionals are highly specialised experts. It is important for us to foster this expertise. So we want our employees to pass on their knowledge to the next generation, who will then put it to use in a variety of professional positions, not just at PSI. Around a quarter of our staff are therefore apprentices, doctoral students, or postdocs.

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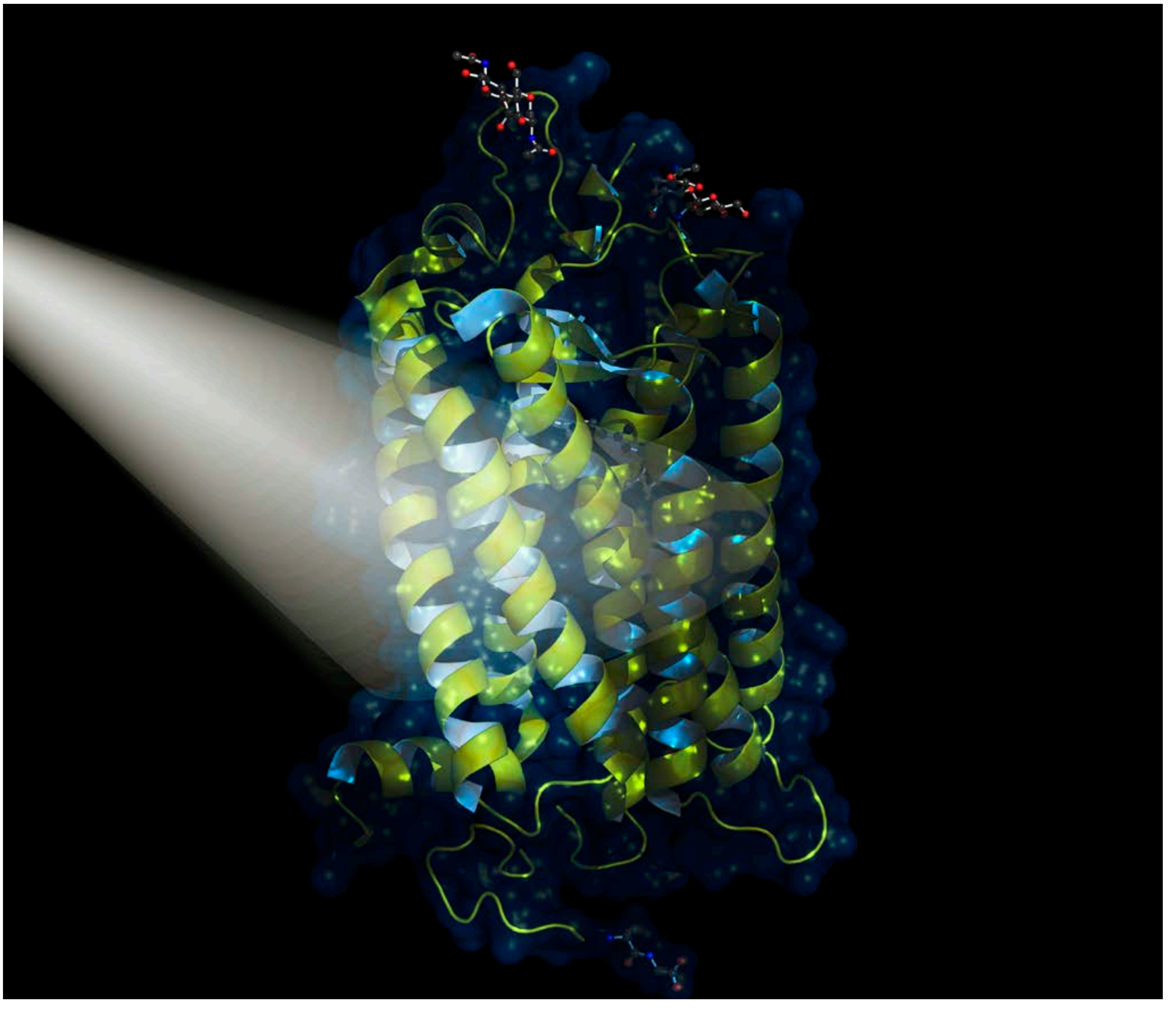
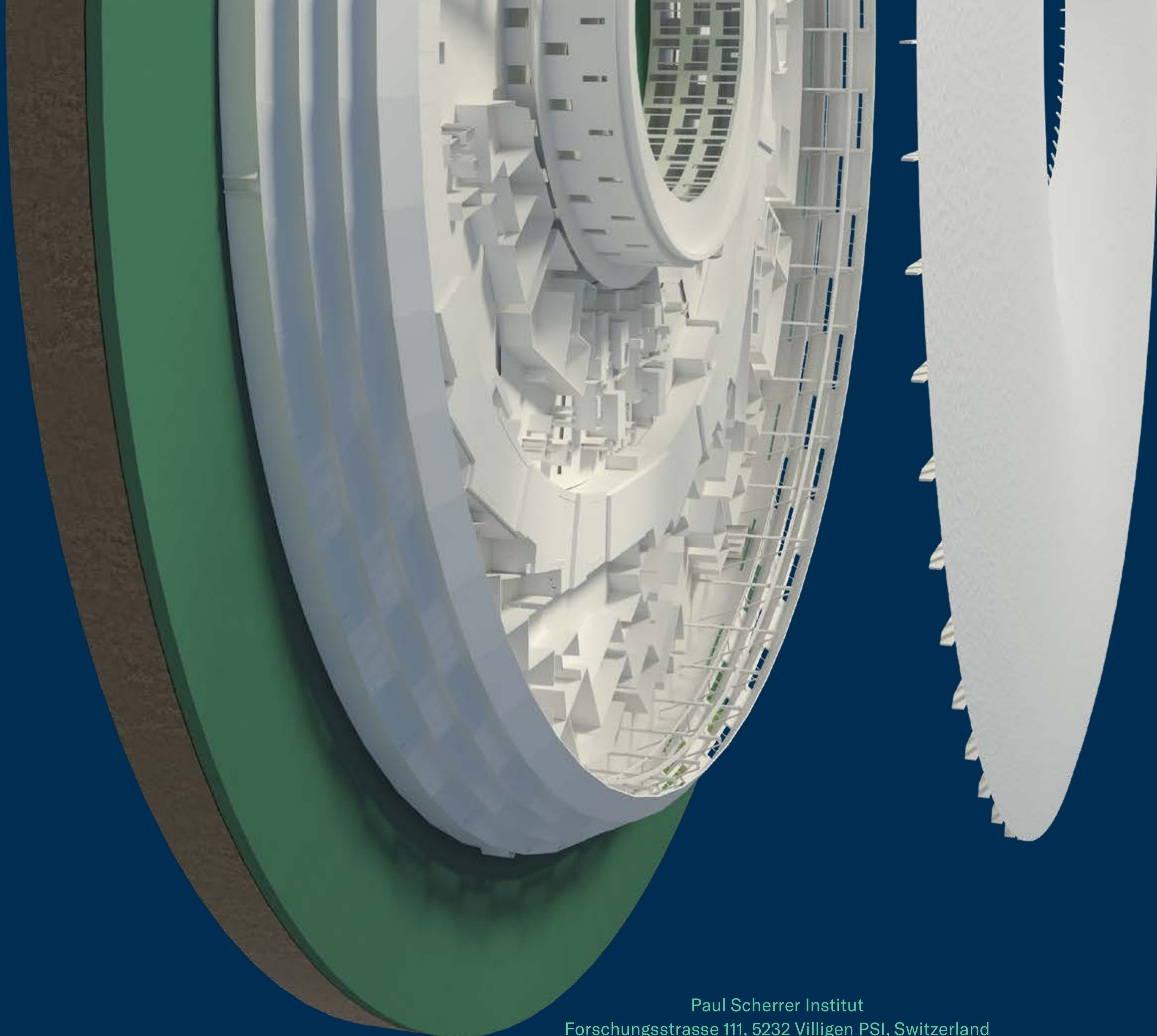


Coming up in the next issue

Without them, it would be impossible for humans and other living creatures to see: light-sensitive proteins in the membranes of our cells. Today our knowledge of these receptors is still cloudy: How do they function exactly? What makes them so efficient? PSI's large research facilities help to shed light on the last big secrets of these extraordinary cell components. The ability to differentiate between light and dark is just one of the amazing skills of these molecular wonders. They also supply the power for ion pumps. Scientists at PSI are currently working as part of an international team to discover how to utilise these proteins to selectively turn protein processes in cells on and off. The long-term goal is to acquire a better understanding of how diseases occur and develop new treatments for them.



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