VATTENHALLEN
SCIENCE CENTER

Shoot protons & tickle electrons

AN INTERACTIVE EXHIBITION ABOUT ESS & MAX IV

Shoot protons and tickle electrons

An interactive exhibition on ESS and MAX IV was inaugurated at Vattenhallen Science Centre in Lund on December 13th, 2012. On a 100 square meter area has been built interactive experimental stations where ping pong balls, iron balls and golf balls represent electrons, protons and neutrons. Visitors can drum loose electrons in the cannon, compete for the best time in the linear accelerator, pushing protons in the spallation experiment and tickle electrons in the storage ring. The exhibition is built to demonstrate and provide visitors with an understanding of the similarities and differences between the two facilities ESS and MAX IV.

EXPERIMENTAL STATIONS

ESS

The PROTON GUN releases protons, which are then accelerated at high speed in a linear accelerator.

Protons are produced using hydrogen. When one removes an electron from a hydrogen atom one is left with a proton. This is done by heating up hydrogen gas with a rapidly fluctuating electrical field, the electrons are thus released from the hydrogen molecules, leaving the protons. The principle is the same as boiling water in a microwave oven, but the frequency is much higher and the effect much stronger.

The protons are accelerated in a 500-meter long LINEAR ACCELERATOR with the help of high frequency electrical fields.

Good acceleration requires the timing of the high frequency electrical fields to be optimal. Magnets positioned down the whole length of the accelerator focus and direct the beam along the right track. After about 40 meters the protons have achieved enough speed for the acceleration to take place with the help of superconducting cavities. These are cooled from the outside with liquid helium to -271 degrees Celsius.

SPALLATION means that neutrons are released when a proton at high speed hits an atom nucleus.

Protons that are accelerated in a linear accelerator are fired at a rotating disc made of Tungsten, where a certain number of Tungsten atoms are hit. Thanks to the high speed of the protons, every proton can release around 30 neutrons.

In the EXPERIMENTAL STATIONS, neutron beams are used by researchers to study their samples.

The sample to be examined is placed in the neutron beam in the instrument. The neutrons penetrate the sample and some of them spread out, bouncing against the atomic nuclei in the material. By measuring the speed and direction of the neutrons when they come out of the test one can, with advanced software, get what is known as a spread pattern. This spread pattern is analysed and gives information on how the atoms are positioned in relation to each other inside the sample, and how they move. This then reveals how the sample appears and functions at a molecular level.

MAX IV

The ELECTRON GUN releases electrons, which are then accelerated at high speed in the linear accelerator.

The electrons can be released by heating. When the electron gun's cathode of barium oxide coated wolfram is warmed to around 1000°C, electrons are released and become free flying. The free flying electrons are accelerated from rest up to virtually the speed of light, by strong electrical fields.

The electrons are accelerated in a LINEAR ACCELERATOR, which is housed in a 300-meter long underground tunnel.

The linear accelerator accelerates the electrons with the help of high frequency electrical fields. Good acceleration requires that the timing of the high frequency electrical fields is optimal. In the linear accelerator the electrons travel at close to the speed of light and their energy increases during their passage through the accelerator.

After the linear accelerator, the electrons travel into the STORAGE RING. They are steered by magnets that bend the electron beam into a circular track.

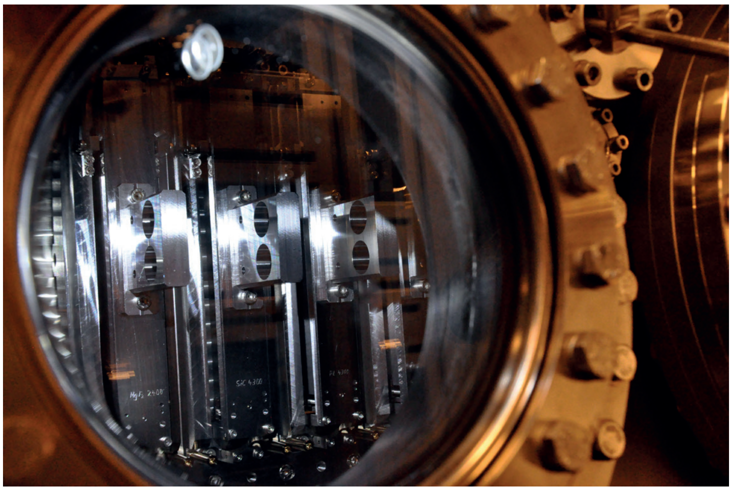
When the electrons travel forward in the storage ring, in the straight stretch before the beam pipe, they pass through a device of magnets called a wiggler. A wiggler is made up of a lengthy series of magnets that cause the passing electrons to swing something like a slalom skier. When the electrons swing they send out an intensive synchrotron light that travels straight forward into the beam pipe. At the end of the beam pipe the light meets the experimentation stations and the researcher's sample. The electrons continue to go round and round in the storage ring.

At MAX IV there will be many different EXPERIMENTAL STATIONS where samples of material are examined in different ways.

A typical way is to light the sample with synchrotron light. The light is shone over the electrons present in the material, creating a spread pattern or what is known as a diffraction pattern. This pattern is processed numerically in a computer to create a picture of the molecules or atoms being examined.

MAX IV continued

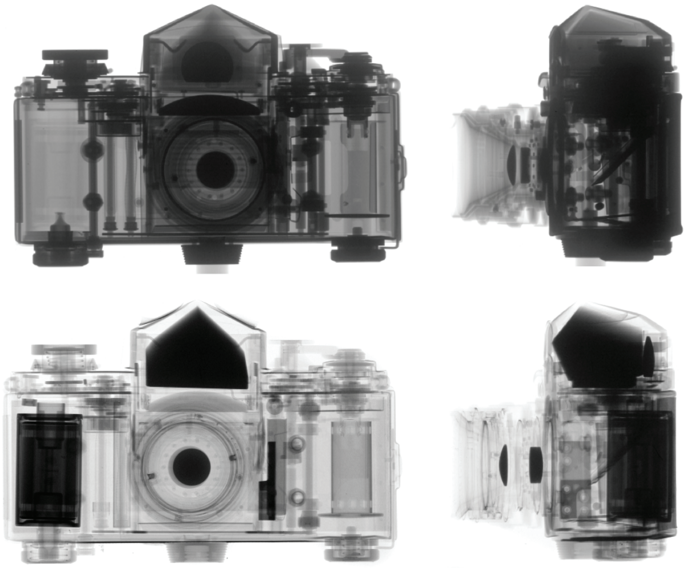
At MAX IV researchers can choose to use light with different wavelengths, from infrared light to x-rays.
Researchers select a particular wavelength to examine their samples. They can do this by filtering away the wavelengths that they don't want. The filter is called a **MONOCHROMATOR** and most commonly comprises mirrors, a grating and a slit. The grating is a surface with a small pattern repeated over it. It can be turned mechanically so that the light with the chosen wavelength passes through the slit.



ESS & MAX IV

SPECTRAL ANALYSIS

A spectrum is a separation of light into different colours, a sort of fingerprint of the substance emitting light.
Each substance gives a unique set of colours. By analysing a spectrum in an unknown gas one can determine what atoms a gas contains. At MAX IV samples are illuminated with **synchrotron light** and the researchers analyse the light from the samples. The emitted light tells which substances the sample contains, for example which iron compounds are found in the 17th century Vasa warship.
At ESS the equivalent method of measurement is called **neutron spectroscopy.** Neutrons with a particular energy are sent into the sample and their energy is measured when they come out. The difference in energy gives information on the material's dynamic condition, for example vibration and rotation.



LIGHT PRODUCES COLOUR

Researchers can analyse the same sample at both ESS and MAX IV.
They can thus supplement the information about their sample. At MAX IV the samples are illuminated by light. Depending on the colour of the light that is used, one gets different information about the sample. In order to study something as small as molecule structures, ultraviolet light or x-rays are used, light with shorter wavelengths than those visible to our eyes. At ESS the samples are struck with neutrons. With the help of these studies, a further picture of the material being examined is obtained.

The painting utilizes particular colours so that aspects of the pattern change when illuminated by light of various wavelengths. Artist: Diane Sandall

The exhibition was built by the exhibition designer Charlott Karlsson, engineer Lars Hedenstjerna and director Monica Almqvist, in dialogue with educators and experts from ESS, MAX IV and the Universities of Lund and Copenhagen. The exhibition was financed by Region Skåne, the Øresund Materials Innovation Community, ESS and MAX IV.

About ESS & MAX IV

Two new world-class research facilities are built on the outskirt Lund. MAX IV was completed and inaugurated in 2016, ESS will be completed 2019th.

Researchers from all over the world comes to use these facilities, which can be compared to two large toolboxes for material research, ESS will produce neutrons and MAX IV synchrotron light. The research is expected to produce completely new results within environment, biotechnology, medicine, chemistry, geology, archaeology, electronics and physics.

Two complementary facilities

At ESS, neutrons are used and at MAX IV light is used. With light and neutrons one can examine different things. The neutrons are uncharged particles and penetrate deep into the material being examined. Researchers can measure the positions of the atomic nuclei in the material and how they move, under examination. Light is used to study the electrons found around the atomic nucleus. If you know where the electrons are and how they behave, you can find out where the atoms are and how they interact with other atoms. This can explain how they build molecules and crystals.

ESS is a European research infrastructure, which is being planned and built by many countries together. At a research minister's meeting in Brussels in May 2009, it was decided that ESS should be built in Lund in Sweden. At ESS neutrons are used to bombard researcher's samples. One gets the neutrons by what is known as spallation, which means that protons accelerate into the atom, which becomes unstable and releases the neutrons.

MAX IV is the world's brightest synchrotron light system and the research facility in Lund was opened in June 2016. Guest researchers from all over the world come to use the light from MAX IV. The light is produced by accelerating electrons and then letting them swing back and forth, as they pass a series of magnets.

To examine materials

Everything that surrounds us is material for example the concrete in houses, the metal in the railway tracks, the chocolate in sweets, the semi-conductors in the computer memory, the protein in the body, the molecules in medicine, the surface of the solar cell, dinosaur fossils in stone. By examining material, we can understand the world around us a little more and using this knowledge, we can try to solve some of what are known as the Global Challenges facing us in areas such as health, environment and energy. These concern such different things as antibiotic-resistant bacteria, environmentally dangerous waste or artificial photosynthesis.

At the same time, basic research is also being conducted within many different research fields. Basic research is driven by man's curiosity and is continuously making surprising new discoveries. These discoveries can give rise to new ideas and possibilities. The Organisation for Economic Co-operation and Development (OECD) has defined basic research like this: "Basic research is about the systematic and methodical search for new knowledge and new ideas without a specific application in mind."

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LUND UNIVERSITY

VATTENHALLEN SCIENCE CENTER

VATTENHALLEN SCIENCE CENTER
Box 118
S- 221 00 Lund
Phone +46 46 222 43 51
www.vattenhallen.lth.se