Institute of Nuclear Research

of the Hungarian Academy of Sciences

Debrecen

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INTRODUCTION

This booklet contains a short introduction to the Institute of Nuclear Research of the Hungarian Academy of Sciences, located in the city of Debrecen, Hungary. To name the Institute, the Hungarian acronym 'Atomki' will also be used. Atomki is devoted to physical research, and its 190-strong staff includes about 100 research workers. Its main activity is basic research in microphysics. Atomki is contributing to the scientific production of the world and is fostering the culture of science at home. In addition to basic research, it is engaged in various applications. Applied research includes, e.g., environmental research, geology, archaeology and medicine (e.g., positron emission tomography). Atomki belongs to the research network of the Hungarian Academy of Sciences (HAS) but it also has a contractual co-partnership with the University of Debrecen, based on a long-standing cooperation in research and education.

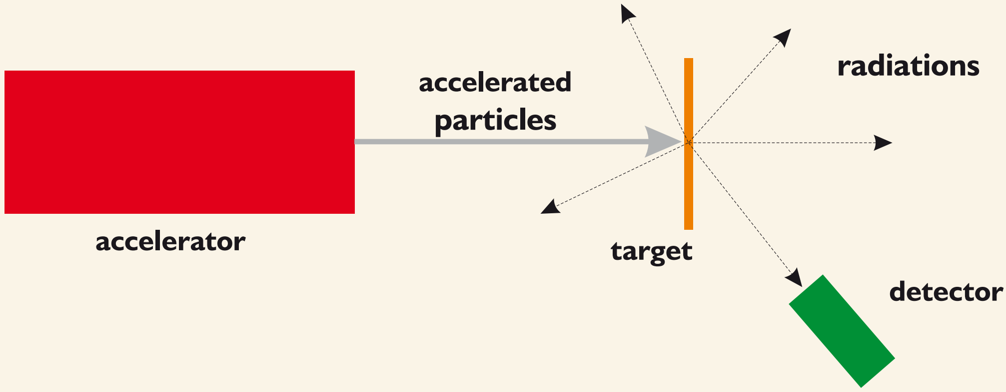
In the following we give a short review of the history, research and organization of Atomki and a pictorial presentation.

This booklet has been written for non-experts as well. The picture captions are formulated in a style comprehensible to laymen, and we immediately start with some explanations. We explain three concepts, which give the key to understanding the activity of a research institute like Atomki: detector, accelerator and target.

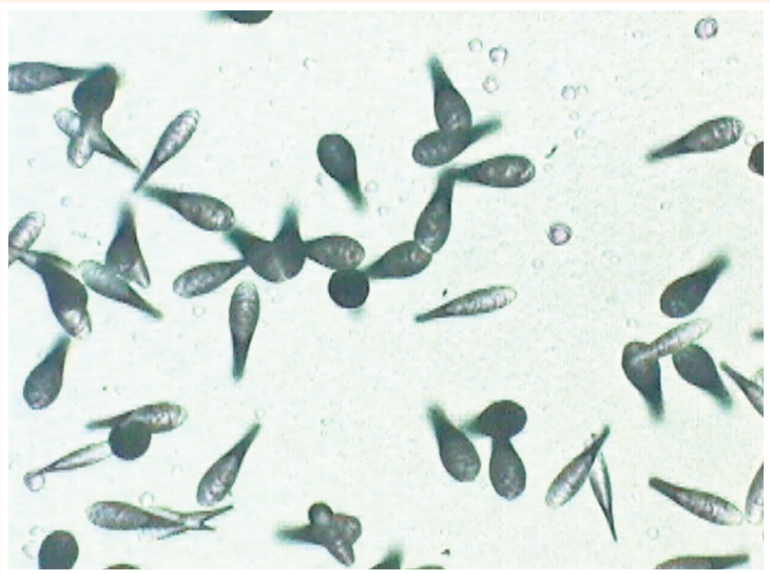
Detectors bridge the gap between the microscopic world and the directly visible objects. The particles of the microscopic world are incredibly small things. Atomic nuclei, e.g., are by 15 orders of magnitude smaller than human dimensions. Let us suppose that we magnify the nucleus of a hydrogen atom, the proton, to the size of a human palm. With such a magnification, our palm would become so large as to cover the solar system. Thus to find a proton on our palm is as hard a task as to find our palm in the solar system. How is it possible to observe things as tiny as a proton? Fortunately, there are phenomena that make it possible. Such a phenomenon is, e.g., radioactivity, which was discovered at the end of the 19th century. Some of the atomic nuclei emit invisible radiation. This radiation, in spite of the fact that it consists of invisibly small flying particles, modifies some objects of everyday dimensions visibly. Such objects are called detectors. The detectors used at the discovery and first study of radioactivity were photographic plates and ionization chambers. The change in the photographic plates produced by the radiation is blackening. The change in the ionization chamber appears as an increase of its conductivity, which can be observed with an electrometer. The use of these early detectors was followed later by the development of many other types. With modern detectors the tiny particles of the radiation can be observed one by one.

In addition to radioactivity, there are many other phenomena and tools that provide information on the microscopic world. If a particle of high velocity impinges on another one, intensive radiation of diverse types may be produced. These radiations can also be detected by detectors. Experiments of these types are usually performed with the use of **accelerator**s. An accelerator (or particle accelerator) is an apparatus to accelerate particles to high velocities. Acceleration is performed via electric fields which act upon electrically charged particles. Accelerators are generally huge and expensive facilities, and they give the distinctive features of a research institute.

Unlike accelerators, **target**s are small, fine things. They contain the other partner of a collision, the particle to be examined. The physical processes we study by the experiments take place in this small piece of matter or very close to it.

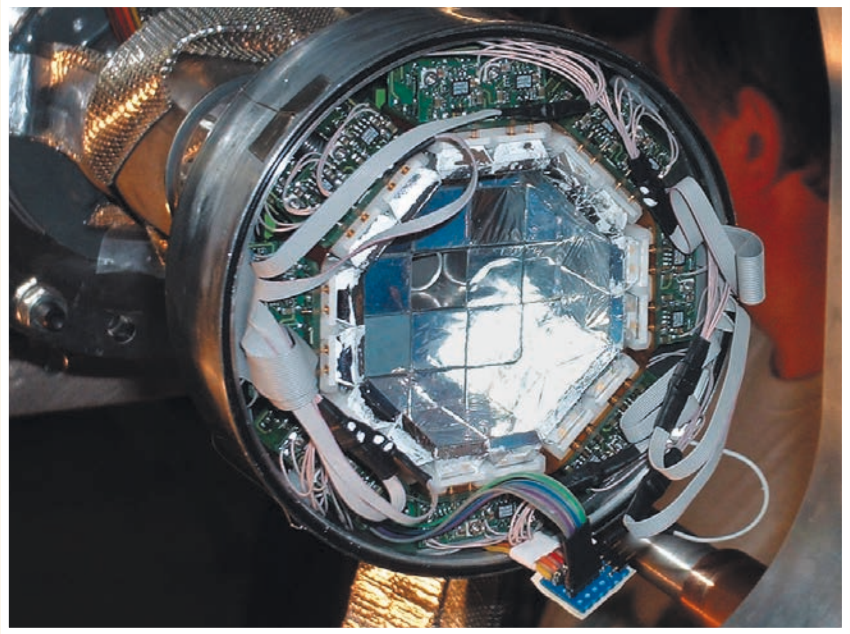


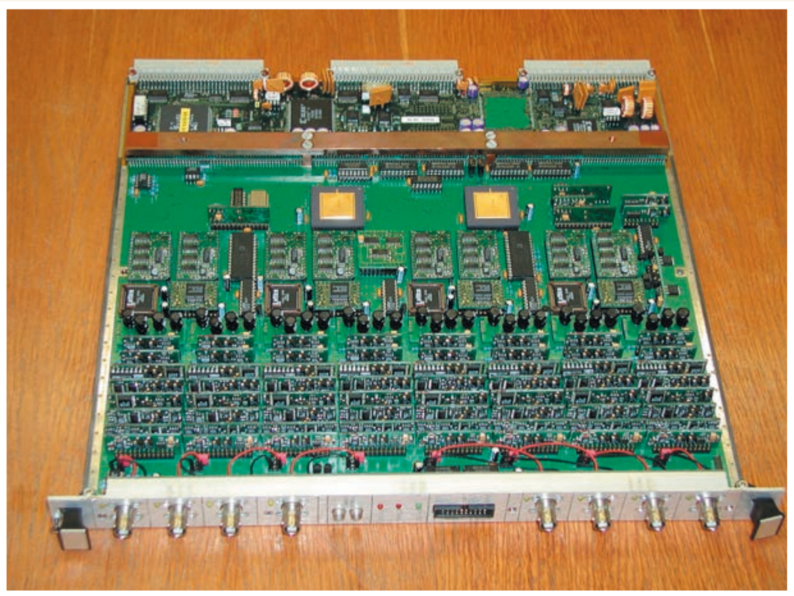
The figure shows the **scheme of a typical microphysics experiment**. High-velocity particles emerging from the accelerator are directed to the target, which contains the atoms or atomic nuclei that play the role of a dartboard. Under the influence of the collision, the constituents of atoms or nuclei – electrons and nucleons (protons, neutrons), respectively – are partly rearranged and fly apart. Detecting these particles, one can determine their properties, and one can learn of the process itself. Most of the devices described in this booklet are elements of this scheme.



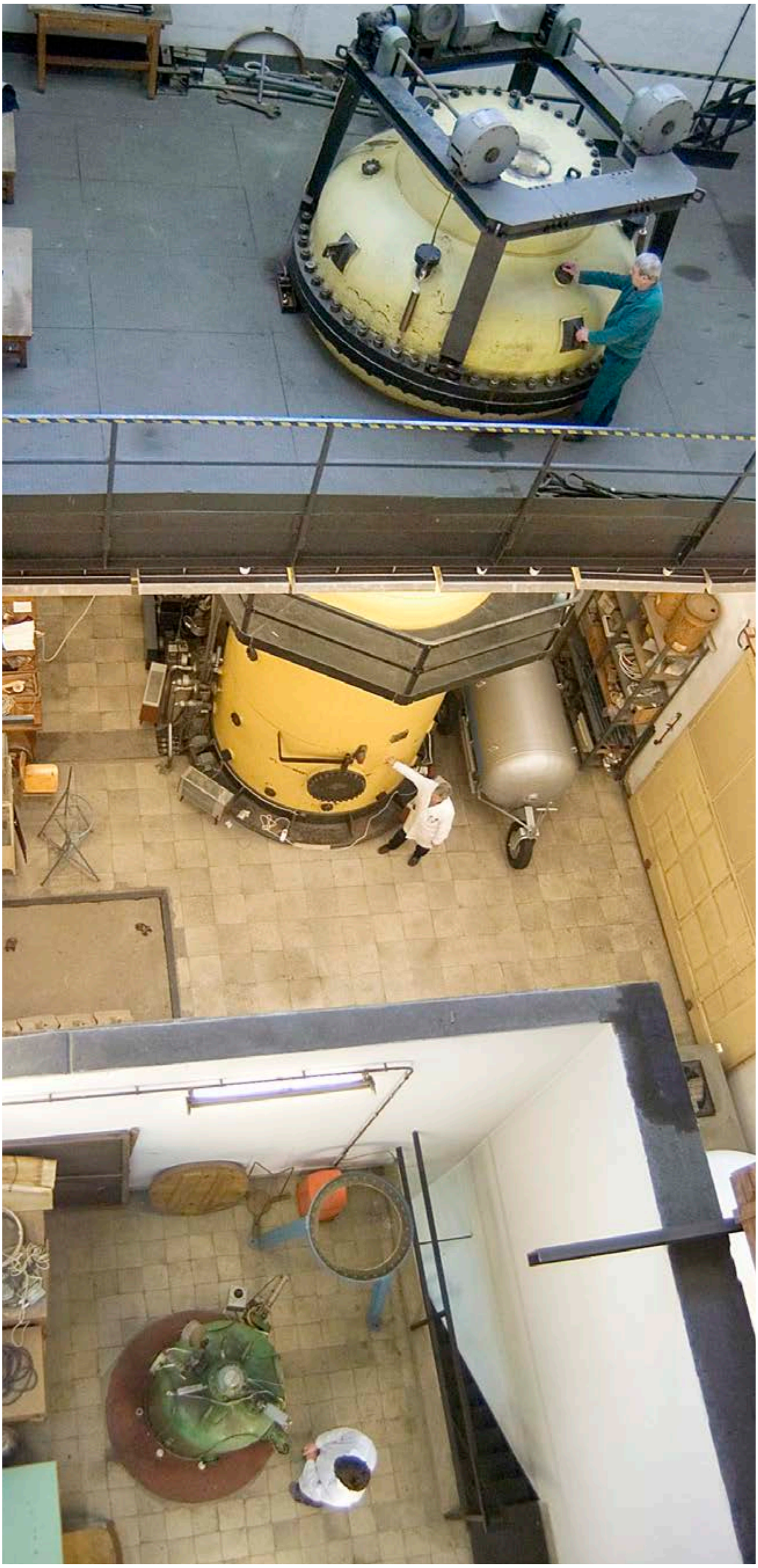
This is a modern detector, which is reminiscent of the photographic plate used in the discovery of radioactivity. In both cases the detector is irradiated first and then a chemical process is used to make the change visible. The optical microscope image shown here is that of a CR-39 type **plastic track detector**, which has been irradiated with alpha particles coming from the radioactive nucleus ^{252}Cf. The tracks of particles were developed by etching in concentrated NaOH. Along the paths of the alpha particles, cone-shaped hollows of lengths of 40 micrometres and of diameters of 10 micrometres appeared, and these 'tracks' can be seen with a microscope. Atomki has achieved remarkable results in developing plastic track detector techniques.

There are detectors of many types that convert the effect of radiation into electric signals, and electric signals can be handled very well with the help of electronic devices. The detector system shown in this picture also consists of such detectors, namely, 56 pieces of CsI(Tl) scintillation crystals of the form of quadratic prisms. They are encapsulated in a lightproof wrapping. During the nuclear physics experiment the detectors and their preamplifiers are used in vacuum. The name of this **detector system** is **Diamant**, and it has been constructed in cooperation with a research group in Bordeaux. In this work the Atomki group has fully mobilized its expertise in detector techniques and nuclear electronics. Diamant is used to determine the energy, type and the moment of impact of light charged particles. The experiments made with this system in the IReS laboratory in Strasbourg were devoted to the search of atomic nuclei of strongly elongated shape.



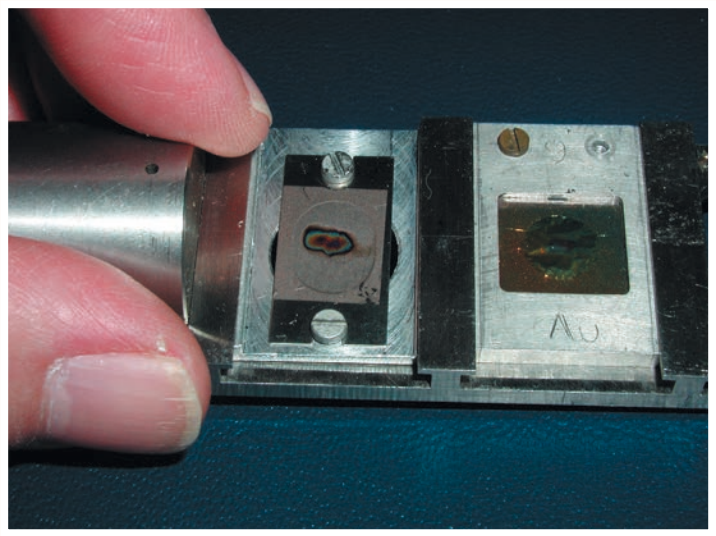


A unit of the electronic signal processor of the detector system Diamant shown in the previous picture. It processes the signals of eight CsI(Tl) detectors simultaneously. The information on an impinging particle is extracted from the shape of the electronic signal. The device has been developed in Atomki.



In Atomki there are **two Van de Graaff accelerators**. They were designed and constructed in Atomki, and they have been working since 1971. The photo shows the tanks that enclose the accelerators. The accelerating voltage of the accelerator contained in the yellow and in the green tank is 5 MV and 1 MV, respectively. The positive electric charge that gives rise to this voltage with respect to the ground is transported by a belt system to the upper part of the machine. At these high voltages discharges may happen, which disturb the operation. The probability of discharges is smaller if the accelerators are kept in the atmosphere of a pressurized mixture of carbon dioxide and nitrogen. That is why the accelerators are kept in tanks.

In the Van de Graaff accelerators of Atomki the acceleration takes place in vertical tubes. At the end of the acceleration process the vertical beam of particles is deflected into horizontal direction by means of an electromagnet. The red block in the picture is the **bending magnet** of the 1 MV accelerator. The deflecting also improves the precision of the energy of the particles. The beam of particles is confined in tubes from which air has been pumped out. Without such tubes, the accelerated particles would get slowed down by collisions with the molecules of the air.



In this picture two **target**s are shown. The one on the left contains uranium nuclei of mass number 235 in the form of uranium oxide. The uranium oxide was evaporated onto a thin carbon foil. This foil is put on a thin metal plate, and this plate is mounted with two screws on the frame of the target holder. The spots on the target arose due to irradiation with accelerated particles. The aim of irradiation was to study the shape of uranium nuclei of mass number 236. The target on the right-hand side is a thin gold foil used in complementary experiments.

BRIEF HISTORY

In the year of preparing this booklet – in 2004 – Atomki celebrates the semicentenary of its foundation. The official date of foundation is 1 July, 1954. The founding director of the institute was Alexander Szalay (1909–1987), a great personality in the physics of Debrecen and Hungary. It was he who started nuclear research in Hungary, and it was under his leadership that Atomki became a research institute known worldwide.
Ernest Rutherford is often called the father of the atomic nucleus because, at the beginning of the 20th century, he discovered that almost the whole mass of matter is concentrated in regions of radii which are ten to one hundred thousand times smaller than atoms. In 1936 Alexander Szalay spent half a year as a postdoctoral fellow in Rutherford's laboratory. This period impressed him decisively. Returning to Hungary, he started nuclear physics research at the University of Debrecen. Compensating for the financial shortage with ideas and enthusiasm, he and his pupils worked remarkably successfully.

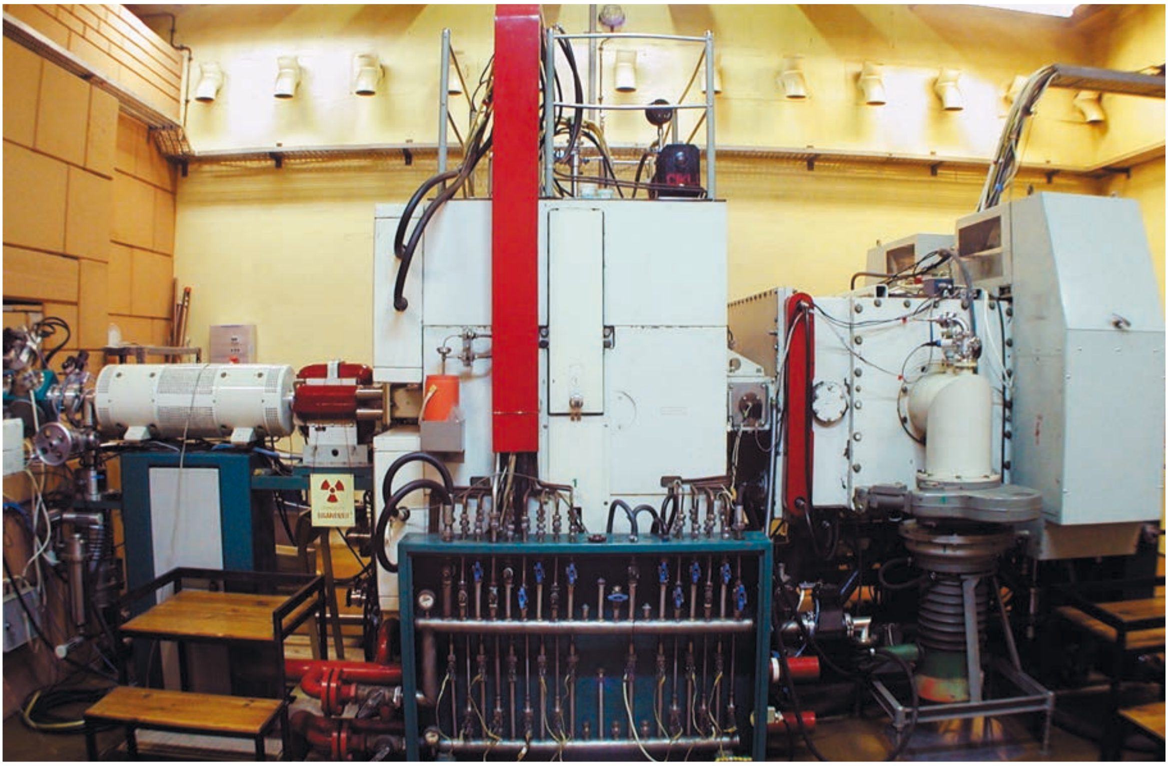
Alexander Szalay (1909–1987), member of the Hungarian Academy of Sciences, the founding director of Atomki

After the war Szalay initiated uranium prospecting in Hungary, and his field work led to the discovery of uranium deposits in the Mecsek mountains. He also gave an explanation of the mechanism of accumulation of uranium. With these results, he established his reputation, which earned him the possibility of founding the Institute.

The Institute started its operation with modest instuments and a staff of 44. The steps of its development has been marked by the installation of its accelerators: a 800-kV Cockcroft–Walton accelerator and a 300-kV neutron generator (1961), 1-MV and 5-MV Van de Graff accelerators (1971), a cyclotron (1985) and an electron cyclotron resonance (ECR) 'ion source' (1996).

In the era of cold-war isolation the institute did not get access to modern instruments available in the West, and was forced to be self-sufficient. This constraint had positive consequences as well. There was an intense activity in developing instruments, especially devices of electronics and vacuum technics, which are indispensable in almost every field of research. Later, as a spin-off, instruments were also produced for sale, home and abroad. For instance, there was a significant export of quadrupole mass spectrometers. At the beginning of the 1990's the export market opened up, and the competition forced serial production to stop. The staff of the institute dropped to less than 200 from its earlier height of 300. But the research capacity did not decrease, and applied research picked up again and has been expanding. The Institute is coping well with the competititive funding of research, and international co-operation has intensified. Atomki is getting similar to the institutes we saw earlier in the `free world'. Hungary became a member of the European Centre for Nuclear Research (CERN, Geneva), and that opened up new possibilities for Atomki. Presently there are about 110 cooperative projects with institutions abroad.

The director of Atomki was Alexander Szalay from 1954 to 1975, Dénes Berényi from 1976 to 1989 and József Pálinkás from 1990 to 1996. Since 1997 the director has been Rezső G. Lovas.



The **cyclotron** shown in the picture is the largest accelerator in Hungary, and it has been operating in Atomki since 1985. It was manufactured by the Efremov Institute, Leningrad (now St. Petersburg). In a cyclotron particles are accelerated not along a straight line, like in a Van de Graaff accelerator, but along approximately circular trajectories in several cycles. For protons the maximum nominal value of the kinetic energy is 20 million electonvolts (20 MeV), which is equal to the energy gain along a straight line caused by a voltage of 20 million volts.

The **control room** of the cyclotron in Atomki

THE PARAMETERS OF THE ACCELERATORS

Cyclotron

Energy stability: 0.3% (0.1% after the analysing magnet)

Ions	Energy	Max. current
H^+	2–20 MeV	50 μA
D^+	1–10 MeV	50 μA
$^3He^{++}$	4–26 MeV	25 μA
$^4He^{++}$	2–20 MeV	25 μA

5-MV-os Van de Graaff accelerator

Nominal voltage: 5 MV

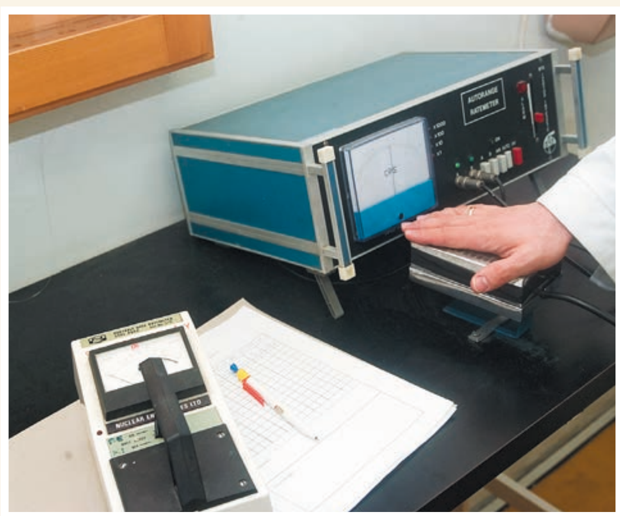
Energy stability: < 1 kV

Ions	Max. current
H^+	10 μA
$^3He^+$, $^4He^+$	20 μA
C^+, N^+, O^+, Ne^+	1–2 μA

1-MV-os Van de Graaff accelerator

Nominal voltage: 1 MV

Ions	Max. current
$^3He^+$, $^4He^+$	5 μA



The radiations emerging in radioactive decay and during the operation of accelerators might harm human organism. There are several measures to minimize the risk. The accelerators and the experimental areas are surrounded by thick concrete walls, which absorb radiation. Automatic locking systems hinder the opening of the concrete doors during operation, so that nobody can approach the area of radiation then. The radiation level is permanently monitored by means of **radiation detectors**. The detectors shown belong to the radiation protection system of the cyclotron.

REVIEW OF RESEARCH FIELDS

Atoms became subjects of scientific discourse in the 19th century, nuclei at the beginning of 20th century, and elementary particles in the middle of 20th century. The corresponding disciplines appeared in Atomki in a different sequence. The institute was founded to do research on nuclei. It emerged two decades later that accelerators are also very useful for clarifying problems in atomic physics (i.e., in the physics of atomic electron shells), and the research started in this field at that time. Another two decades later particle physics also came round in Atomki as a potentiality brought by the Hungarian membership in CERN. In this section we review the research subjects of Atomki in a third sequence: we start with the smallest entities, the particles, next we come to nuclei, which are composed of particles, then we pass to atoms, which contain nuclei, and then conclude with solids, which comprise atoms. This list is not exhaustive, and, furthermore, the activity of the Institute involves some direct practical utilization of the methods and the results. This review is a mere list of titles; otherwise we would exceed the planned size of the booklet. Because of its compactness, the list is useful mainly to experts.

PARTICLE PHYSICS

- Calculation of radiation corrections of quantum chromodynamics
- Theoretical description of the formation of multijets, the most frequent final states of high-energy particle collisions
- Development of devices for the Compact Muon Solenoid detector system planned for the Large
- Hadron Collider at CERN
- Radiation hardness tests of electronic components for particle physics and space research
- Study of possible CPT violation (i.e., whether physical laws are perfectly invariant under a combined transformation of charge conjugation, space reflection and time reversal) at the Antiproton Decelerator of CERN in the framework of ASACUSA collaboration

NUCLEAR PHYSICS

- Study of quantum mechanical systems showing PT symmetry (symmetry under the combined transformation of space reflection and time reversal)
- Interpretation of the binding energy systematics of nuclei on the basis of symmetry considerations
- Clusterization of nucleons in nuclei and the interpretation of related modes of exotic decay
- Description of nuclei close to the nucleon drip lines
- Study of the properties of resonance states and their applications to decaying and weakly bound nuclear states
- Approximate and (in principle) exact description of few-body systems
- Study of elongated nuclear states with length-to-thickness ratio 3:1 (hyperdeformed states)
- Measurements for the difference of the neutron and proton distributions of heavy nuclei and for the symmetry energy of nuclear matter
- Investigation of triaxiality of nuclei in high-spin-state experiments
- Study of shell closure in the nuclei around ^{100}Sn
- Experimental investigation of the nuclear aspects of astrophysical problems
- Study of reactions of the solar neutrino problem in other laboratories using radioactive isotopes produced by the cyclotron of Atomki
- Study of exotic nuclei by means of the radioactive ion beam separator of RIKEN in Japan
- Measurement, systematization and interpretation of nuclear reaction data for the International
- Atomic Energy Agency
- New methods for the production of radioactive isotopes used for PET examinations
- Application of the thin-layer activation method for wear measurements

ATOMIC PHYSICS

- Study of the acceleration mechanism of high-energy electrons emitted in ion–atom collisions
- Investigation of the capture of electrons from the target atom to the energy continuum in the field of ionic, atomic, molecular and positronic projectiles
- Study of electron loss in collisions of molecular and atomic projectiles of similar velocities
- Quantum-mechanical and semiclassical description of atomic collision processes
- Analysis of low-energy photoionization with electron spectrometers installed on X-ray beams of synchrotrons
- Production of carbon plasmas of new types and carbon beams in the electron-cyclotron-resonance (ECR) heavy-ion source
- Investigation of the properties of strongly ionized plasmas by detection of the emitted electromagnetic radiation
- Study of the interaction of highly charged ions and microcapillary surfaces

PHYSICS OF SOLIDS AND SURFACES, MATERIALS SCIENCE AND STATISTICAL PHYSICS

- Examination of the effects of the atomic environment on the Auger transitions and study of electron scattering in solids by means of electron spectroscopy
- Investigation of the properties of magnetic vortex lattices in high-temperature superconductors
- Study of magnetic, diffusion and optical properties of nanostructures
- Study of pattern formation and optimization problems of statistical physics

DETECTION AND SIGNAL PROCESSING TECHNIQUE

- Research and development of nuclear radiation detectors
- Investigation of the mechanisms of the widening of photon spectra of semiconductor detectors
- Search for new methods for analogue and digital processing of signals of nuclear detectors
- Development of electronic devices for medical and pharmaceutical research and for university teaching

ION-BEAM ANALYSIS

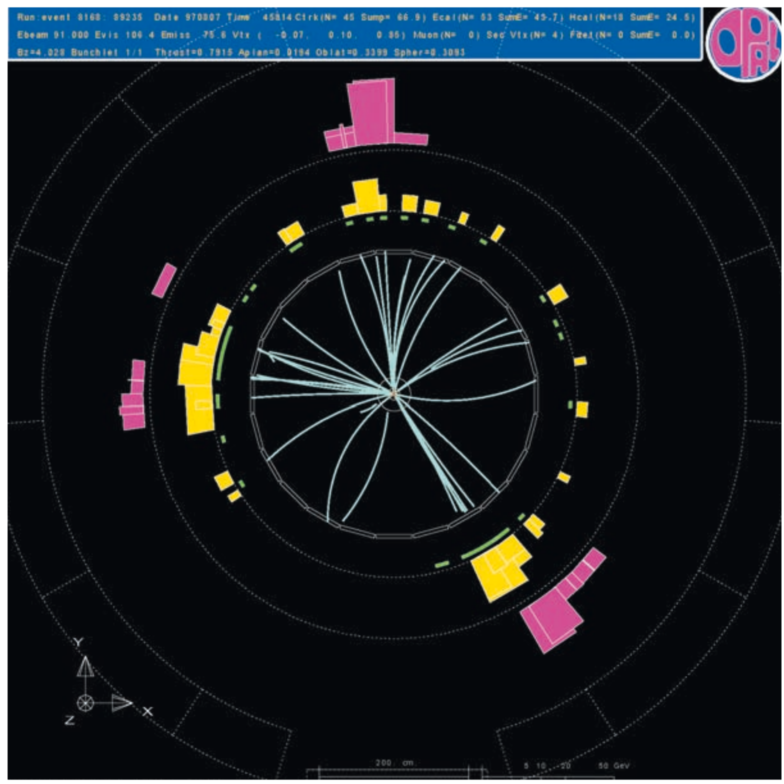
- Research in geology, environmental and materials sciences, biology and archaeology with the methods of ion-beam analysis (proton-induced X-ray emission analysis, Rutherford backscattering, nuclear reaction analysis etc.)
- Proton-beam micromachining of plastics

ENVIRONMENTAL ANALYSIS AND CHRONOLOGY

- Study of the vulnerability of aquifers, of the influence of nuclear facilities on the environment and of climate and vegetation history with mass spectrometry and the radiocarbon method
- Geochronological research with the K/Ar method
- Investigation of the propagation of natural radon in the natural environment and in buildings
- Development of measurement techniques with new, high-sensitivity plastic track detectors and their application in dosimetry

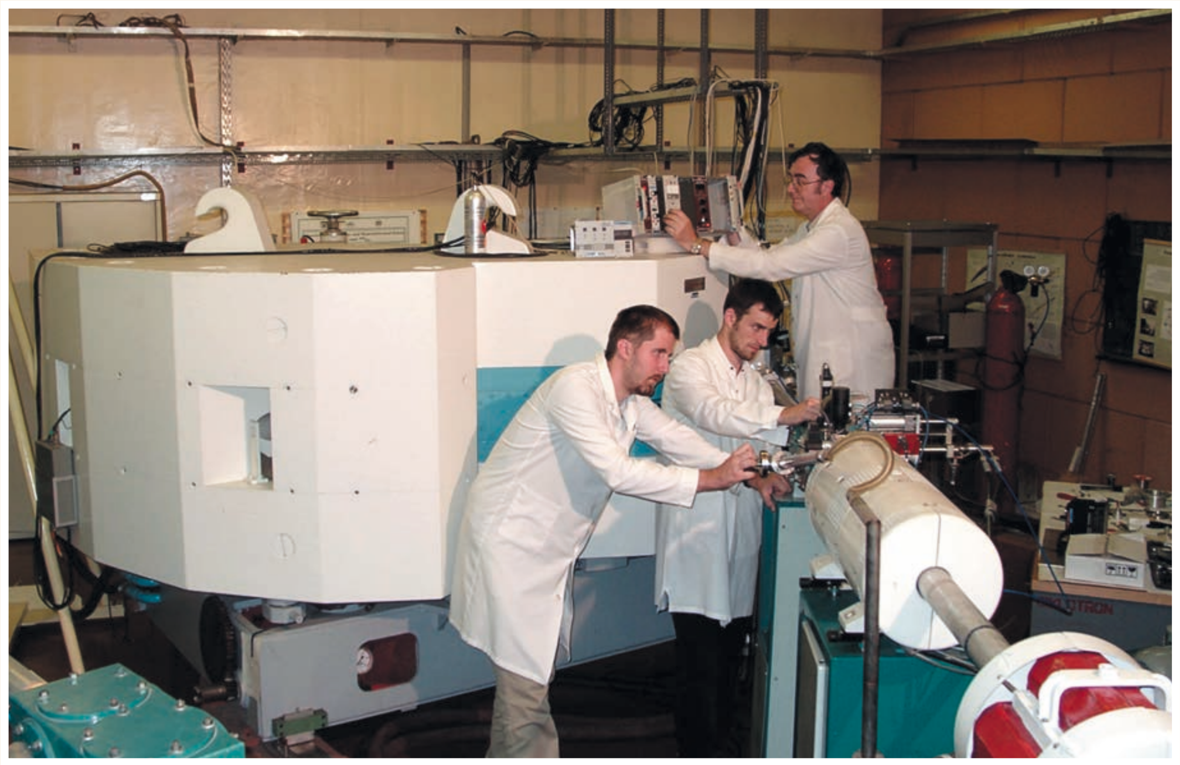
RADIOCHEMISTRY

- Study of the synthesis of pharmaceuticals labelled with on-site produced radioisotopes for single photon (SPECT) and positron emission (PET) tomography

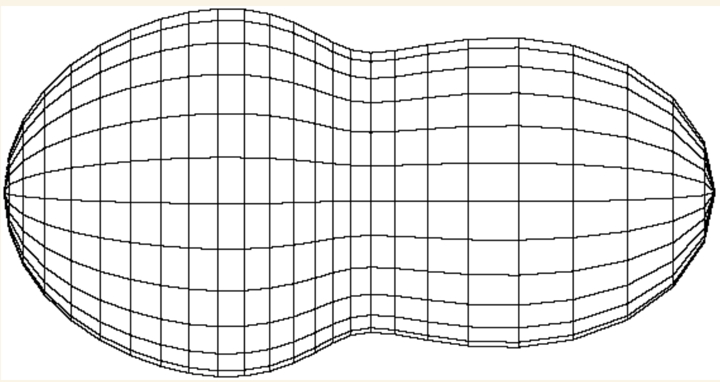


The scientists of Atomki took part in the **experiments** called **OPAL** at **CERN**. They studied many-particle processes following high-energy electron–positron collisions. They examined a huge number of events in order to make reliable statements. The processing of the experimental data is a work for several years. In this picture we see a track-detector image, which shows an event from the direction of the colliding beams. The tracks of charged particles are seen in blue. The diameter of the detector chamber is 5 metres. The tracks are bent by a magnetic field; from the curvatures the particle charges and momenta can be determined. The coloured profiles illustrate some parameters of the particles. The experiments are devised to explore the composition and interactions of the particles. (The nucleons are composite, their constituents are called quarks, and their interaction is described by the famous theory called quantum chromodynamics.)

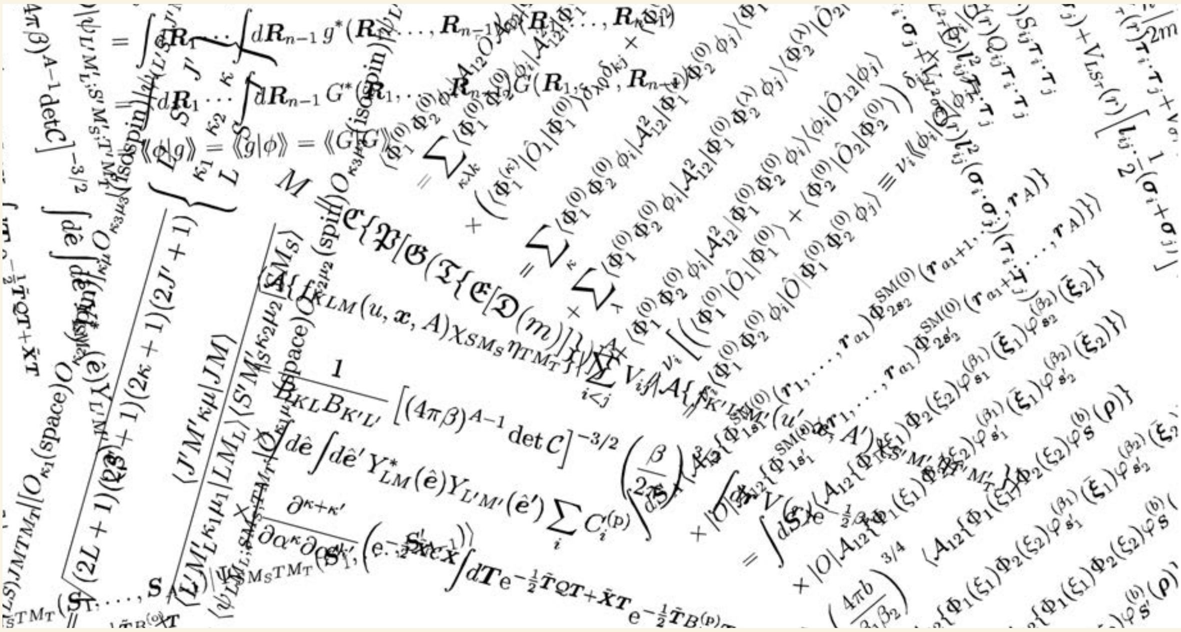
The **Large Hadron Collider at CERN** will be the most powerful instrument ever built to investigate the elementary particles. It will start its operation in 2007. While the accelerator is being constructed, there are several large detector systems under construction. The detector system called Compact Muon Solenoid **(CMS)** is constructed with Atomki participation. The muon detectors of CMS must be positioned very precisely upon installation, and, for such a huge and heavy (12,500 tons) system, that is not an easy job. As a result of instrumental development in Atomki, the positions of the muon detectors will be measured with a precision of 20μm. For this we need 10,000 LED light sources, 700 video cameras and a local network of 50 computers. The construction of this system is in progress. In the photo shown are a few units developed in Debrecen (PC-104 computer, LED light sources, video sensors, diagnostic unit).



A charged particle flying in a magnetic field will be deflected. This effect is used to steer the particle beams of accelerators, as well as to measure the energy of particles emerging from nuclear processes. The **magnetic spectrograph** shown in the picture is a tool for nuclear physics experiments. A target irradiated with a beam from the cyclotron emits charged particles, and the energy of these particles is usually to be determined. The flying particles enter the spectrograph, where they are prompted to travel along a circular orbit by the magnetic field. The radius of the circle depends on the velocity (and thus the energy) of the particle. The particle ends up in a detector, and, from the position of its impact, one can determine the radius of the circle, and hence the energy of the particle.

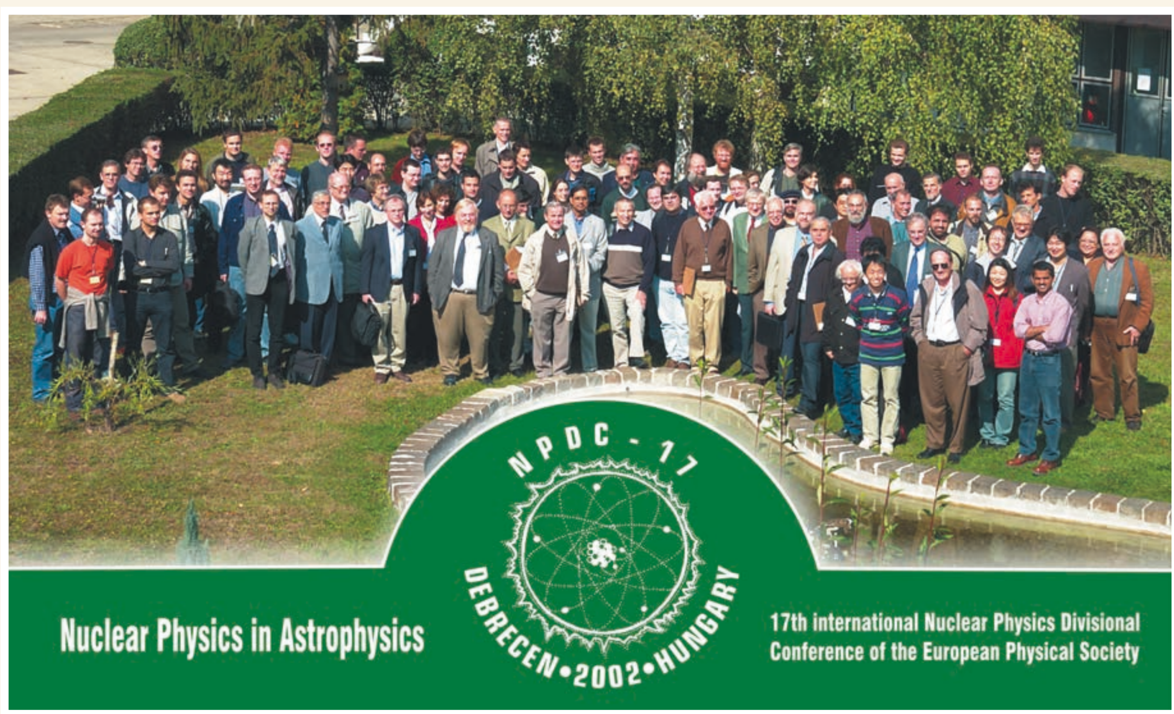


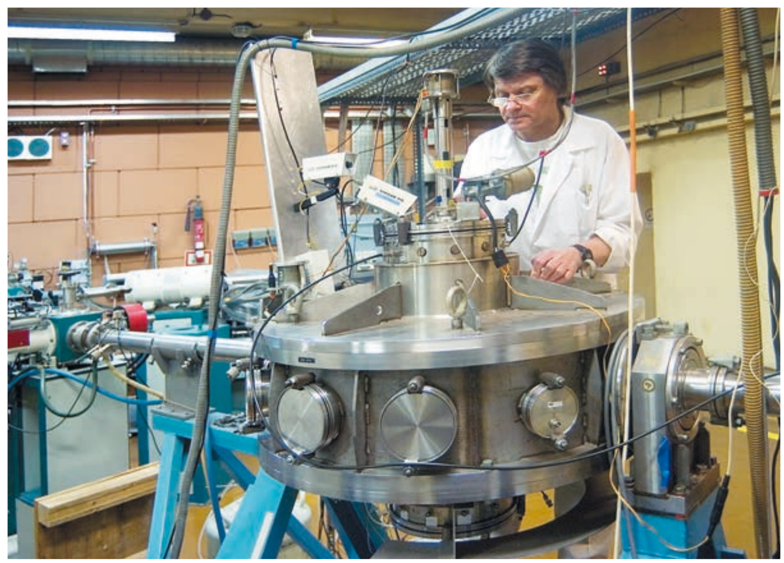
Some experiments with the spectrograph shown in the previous picture were made to study the shape of the nucleus ^{236}U. It was found that the nucleus has states in which it has a strongly elongated shape. This plot shows a nucleus whose length is 3 times as large as its thickness. Such states are called **hyperdeformed states**.



In basic research on physics a **theory** background is of vital importance, and the cultivation of the theory background is nothing but research in theoretical physics. The theory of the microscopic world is written in the language of quantum mechanics. The theoretical physicists of Atomki study the structure and collisions of particles, nuclei, atoms and molecules, with special attention to the symmetries, decay properties and clusterization of the systems.

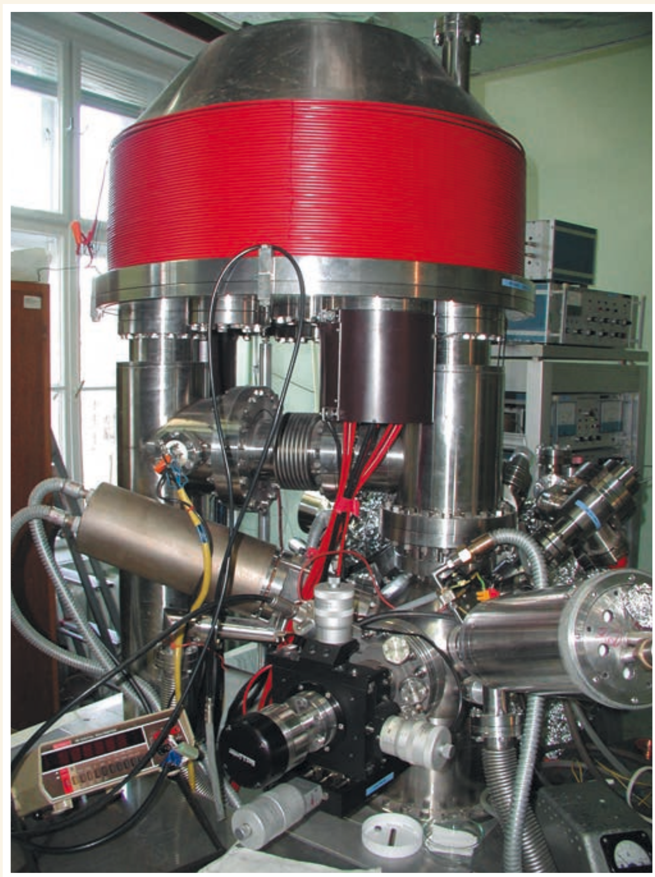
There have been quite a number of international conferences in Atomki. One of the research groups is involved in nuclear physics experiments of interest to astrophysics. They perform experiments both at the accerelators of Atomki and in foreign laboratories. A highly successful conference of this field was held in Atomki in 2002. The photo shows the participants of this **conference**.

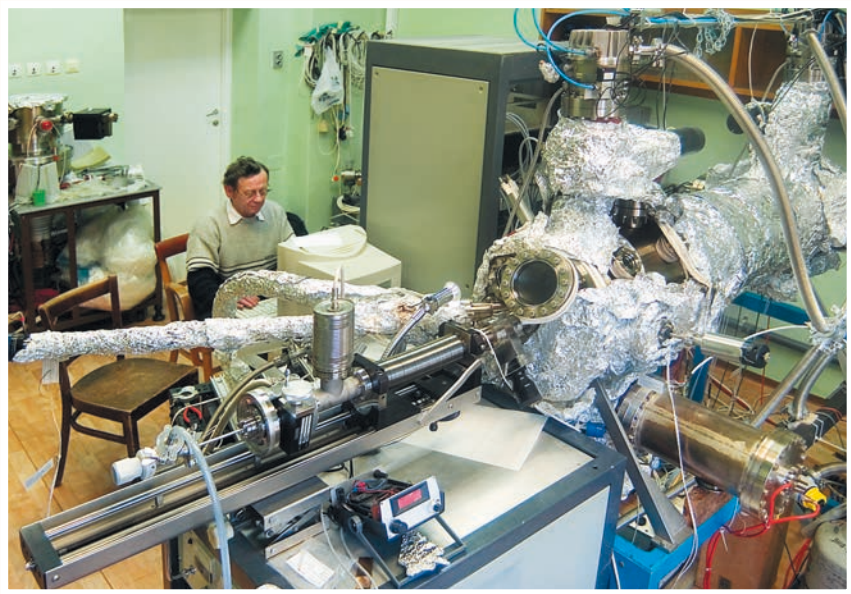




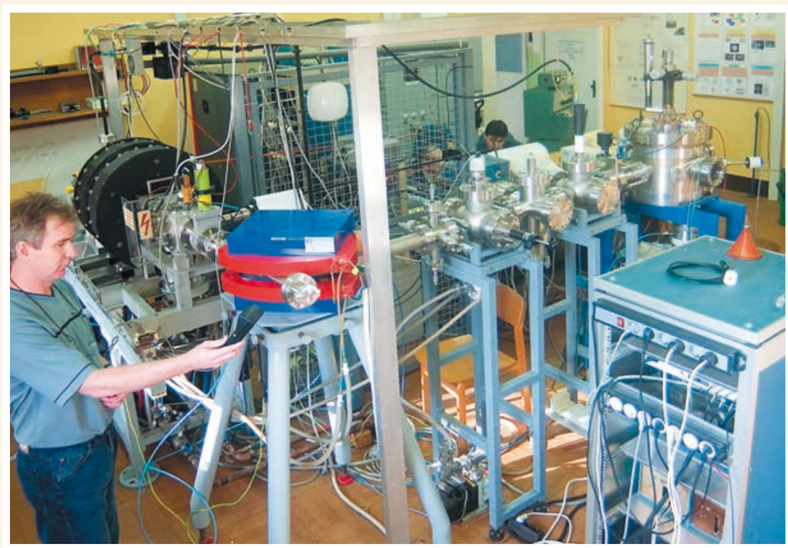
The **vacuum chamber** shown in the picture is installed at one of the beam channels of the cyclotron. In the chamber there are semiconductor detectors, which measure the properties of the particles emerging from the target put in the middle. Some of the reactions studied are replicas of those that take place in stars, and the results are relevant to astrophysics.

If the surface of a solid sample is irradiated with X rays of known energy, and the energy of the photoelectrons kicked out by the radiation is measured precisely, then the difference of the two energies can be used to identify the element and sometimes even its chemical state (e.g., whether it is in elemental form or in oxide). For an element to be detectable, it is enough to be present in the topmost atomic layer, with an abundance of a few per cent. This analytical method can be applied in physical, chemical or materials science research and in state-of-the-art technology. The **electron spectrometer ESA-31** shown in the picture was made in the Institute. The lower part shows the ultravacuum chamber and the X-ray sources for irradiation, and the upper part contains the unit that measures the electron energy.





In low-energy electron spectroscopy the energy and angular distribution of electrons is measured. It provides a broadly applicable method for studying the structure of atoms, molecules and solids. In Atomki there are several home-made devices of this type. The **electron spectrometer ESA-21** shown in the picture is unique in that it can provide the energy and angular distribution data of electrons simultaneously. The aluminium foils covering the spectrometer are to improve the effect of the heating wires underneath. The heating helps to produce good vacuum ('ultravacuum') in the spectrometer.



In our environment the particles of matter are usually combined into electrically neutral structures. If they are to be accelerated, they have to be ionized. That is done in the ion sources of accelerators. The photograph shows the **electron cyclotron resonance** (ECR) **heavy-ion source** constructed in Atomki. This name refers to the process that is used to strip off the electrons from the atoms in this device: they are driven, by microwaves in a strong magnetic field, into resonance-like motion, which tears them off from the atoms. This ion source is able to ionize almost every element and a lot of molecules to an almost arbitrary degree. This is the only such instrument in East Central Europe. The ions produced can be subjected to further acceleration, but presently the device is used as an independent instrument. Highly ionized gases are examined, and atomic physics is studied with low-energy highly stripped ions.

In low-temperature physics it poses a major problem to explore and explain the structure and functioning of **superconductors of the new type**. With the instrument shown in the picture one can measure, at extreme conditions, the electric and magnetic characteristics of samples made of various magnetic and superconducting solids. The cylindrical chamber containing the sample is cooled down. The temperature can be changed from -271°C to room temperature, and the magnetic induction can be set to any value up to 8 tesla.

The beam of accelerated particles can be deflected into any of the 'channels of measurement' defined by straight pipes laid in different angles. Every channel is equipped specifically, for experiments of a particular type. The picture shows the **experimental channels of the 5-MV Van de Graaff accelerator**. The beam is directed to the desired channel by an electromagnet (painted red in the foreground).

There are several methods to determine the elemental composition of a sample by bombarding it by an ion beam of an accelerator. In some studies the subject of the analysis is the composition of individual small grains of a substance. For such a purpose, the diameter of a usual beam (a few mm) is too large. With the **scanning nuclear microprobe** shown in the picture one can produce particle beams with diameters of a few micrometres. It is also possible to scan the target surface with such a 'microbeam', which allows one to get a map of elemental distribution of the sample surface. The microprobe is installed on one of the experimental channels of the 5-MV Van de Graaff accelerator.

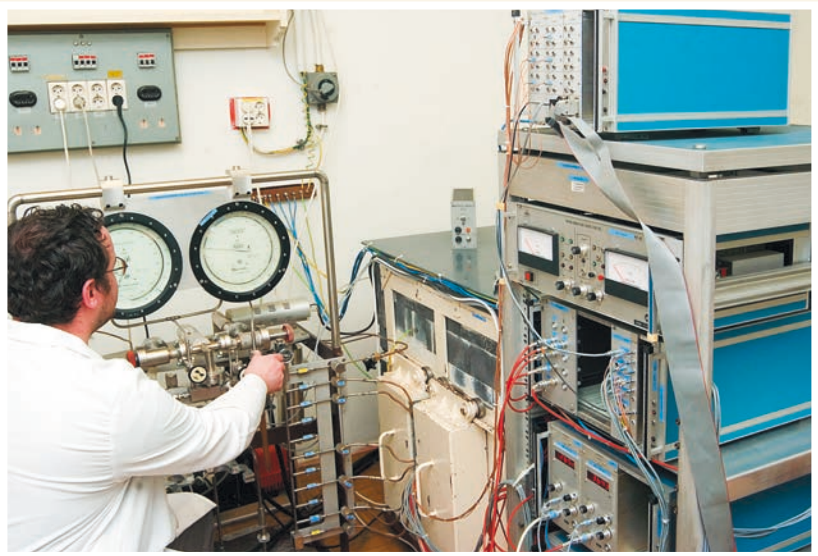
The photo (D. Roddy, © USGS Copyright Free Policy) shows the **Barringer crater** in Arizona. The crater, of diameter of 1.2 km, was created by the impact of a large meteor some 50 thousand years ago. The material of the meteorite originated presumably from an asteroid of our solar system. Scientific investigations of the crater have been going on for a long time, and Atomki has also joined recently. In the process of impact, the substance of the meteorite and the terrestrial rock got heated up, melted and got sprinkled off, from which, upon solidification, small droplets of matter (spherules) froze out. These contain some substance of the meteorite in the form of very small (30 μm) enclosures. Thus information on the composition of spherules may provide cosmological clues. The microprobe shown in the previous picture was used also for such studies.

One of the products of the radioactive decay of natural uranium and thorium is **radon**, which is a chemically inert, but radioactive gas. The bulk of the natural radiation dose that we are subjected to comes from the inhalation of radon emanating from the ground, filtering into buildings and captured there. The scientists of Atomki have developed a method to determine the degree of radon danger for prospective residential buildings. With the instruments shown in the picture, they measure the intensity of radon emanation from the ground, from which they can estimate whether a special 'radon-safe' technology is necessary for the construction there.

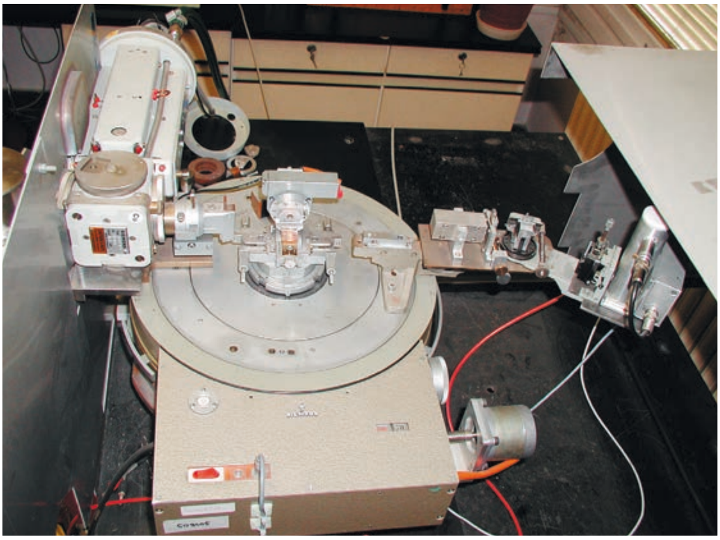
The isotope ratios of the elements in an object may reveal the origin and history of the object. The laboratory of environmental studies is devoted mostly to studying geological and hydrological problems. The **mass spectrometer for isotope-ratio measurements**, shown in the picture, was constructed for such studies. Its computer control is set so as to provide the isotope ratios of the five elements that are most important for environmental studies (S, C, H, O, N). The origin of waters of aquifers and the ratios of external admixtures can be determined, and thus the vulnerability of aquifers and the sources of sulphates and nitrates found in the water are identified. With the measurement of carbon isotope ratios, the adulteration of honey with isosugar can also be discovered.

Tritium (^3H) is an isotope of hydrogen whose nucleus contains two neutrons in addition to the proton. This nucleus is radioactive and, as a result of the decay, it turns into helium (^3He). The tritium content of waters reveals their origin or impurity. The tritium content is inferred from the ^3He concentration, which is measured by a **noble-gas mass spectrometer**, such as that shown in the picture. It is used for nuclear safety studies, for the survey of possible locations of radioactive waste disposal facilities and for geochronological research.

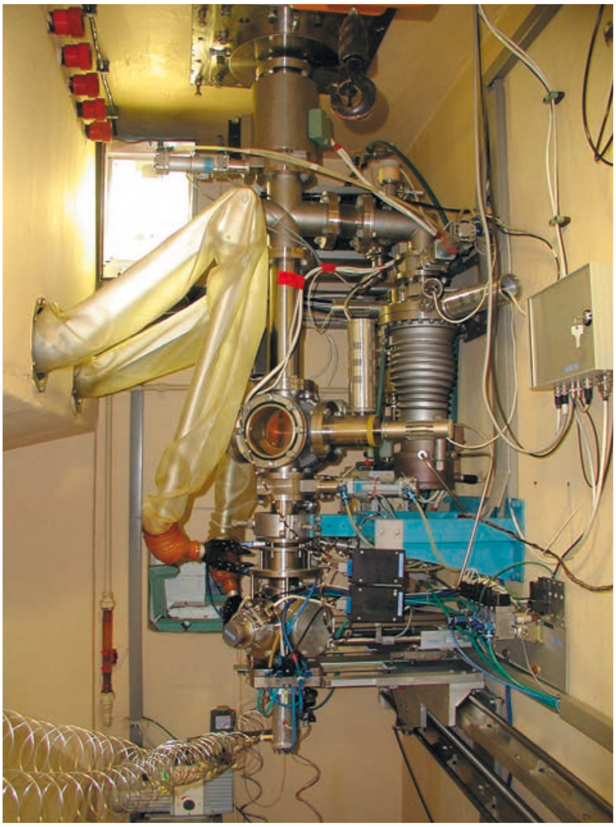
Natural carbon predominantly consists of isotope ^{12}C, whose nucleus contains 12 nucleons: 6 protons and 6 neutrons. In a very small portion, however, it contains the istope ^{14}C (with 8 neutrons) as well. Although that isotope undergoes radioactive decay, it never disappears from the atmosphere as it is being constantly produced by cosmic rays there. Living organisms incorporate ^{14}C, but, at the end of their lives, metabolism stops, and no more ^{14}C nucleus is picked up. The half-life of ^{14}C is 5730 years. If we measure the portion of ^{14}C that remains in an object, e.g., in a bone, we can determine how long time has passed since the creature ceased to live. The **facility for the ^{14}C method** shown in the picture was constructed in the Institute. Atomki has a remarkable record in the dating of archeological finds.



The **potassium–argon dating method** used for the determination of geological ages of rocks is based on the radioactive decay of isotope ^{40}K, which produces ^{40}Ar. The isotopic composition of Ar solved in molten rocks is the same as that of Ar in the atmosphere. In the rock that is cooled down the quantity of ^{40}Ar increases. By measuring the ^{40}Ar excess, one can determine the time elapsed since the solidification, i.e., the 'age' of the rock. In the last half a century the K/Ar method became an indispensable tool in geochronological research. It reveals the time of volcanic activities, the formation of mountains and ore mineralization. In the geochronological laboratory of Atomki the main subject is the study of the Carpathian Basin and the surrounding regions. The instruments shown in the picture are a mass spectrometer for Ar isotopes and a unit for the preparation of samples. Both were constructed in Atomki.



By evaporation one can make very thin (say, nanometre thick) layers of metals, semiconductors or insulators. Structures of such layers are widely used in diverse technologies, so the investigation of their physical properties is of great importance. The **X-ray diffractometer** shown in the picture forms an image of the crystal structure of a sample by the diffraction and reflection of X rays on the crystal lattice. The sample is put into the holder in the middle of the apparatus, and is irradiated by X rays from the source seen on the left. The radiation coming from the sample is detected by the detector on the right. Both the angle of incidence of X rays and the position of the detector are variable.



Accelerators may serve not only the exploration of the laws of nature but practical purposes as well. A most common practical-minded use of the Atomki cyclotron is to produce radioactive materials for medical or industrial applications of the tracer technique. First a properly chosen target is irradiated with a beam of accelerated particles (mostly protons). In the picture an **irradiation chamber** is shown, where the horizontally accelerated particles are injected vertically after being deflected by a magnet. After the irradiation, the radioactive material produced is separated and treated chemically before application.

The substance produced is strongly radioactive, and it could be harmful to the persons handling them. Protection should be applied against radiation danger. The active material must not be approached closely, and the chemical synthesis must be made beneath a protective wall with the use of manipulators. The picture shows the use of **manipulators** viewed from the safe outer side of the wall. The inner parts of the manipulator arms can be seen in the previous picture as well.

The **positron emission tomograph** (PET) of the University of Debrecen is located at the cyclotron laboratory of Atomki. That is the most important consumer of the radioactive isotopes produced on site. In the form of a suitable compound, the radioactive isotope ^{18}F, ^{11}C or ^{15}O is injected into the organism of the patient. With the bloodstream the positron-emitting stuff reaches, e.g., the brain and takes on a distribution characteristic of the cerebral activity. By determining this distribution and its time evolution, one can do tumor diagnostics or other medical examinations. In the PET this measurement is performed via scintillation detectors put around the head of the patient. The scintillators detect the gamma radiation that follows the positron emission. (The positron is the positively charged pair of the electron. When it encounters an electron, the electron–positron pair transforms into two gamma photons, which radiate in opposite directions. The detection of the two photons defines the line of the body, along which the positron has been emitted.)

As part of their cooperation, Atomki and the University of Debrecen run a Department of Environmental Physics jointly in the campus of Atomki. This picture shows a **laboratory class**, with students measuring the properties of alpha and beta rays.

Organization of the Institute

Director: R. G. Lovas, Corresp. Member of the Hung. Acad. of Sci.
Deputy Directors: Á. Z. Kiss, D.Sc.
S. Mészáros, C.Sc.
Finance Officer: Dr. M. Pálinkás

- Secretariat (Scientific Secretaries: Á. Kovách, C.Sc. and Z. Máté, C.Sc.)
- Library (Librarian: Mrs. M. Nagy)
- Accounting (Head: Mrs. J. Sass)
- Basic Services and Maintenance (Head: I. Katona)
- Mechanical Workshop (Head: I. Gál)

Scientific Sections

Division of Nuclear Physics (Head: J. Cseh, D.Sc.)

- Section of Experimental Nuclear Physics (Head: A. Krasznahorkay, D.Sc.)
- Section of Electrostatic Accelerators (Head: Zs. Fülöp, Ph.D.)
  - Nuclear Astrophysics Group
  - Ion Beam Analysis Group
- Section of Theoretical Physics (Head: T. Vertse, D.Sc.)

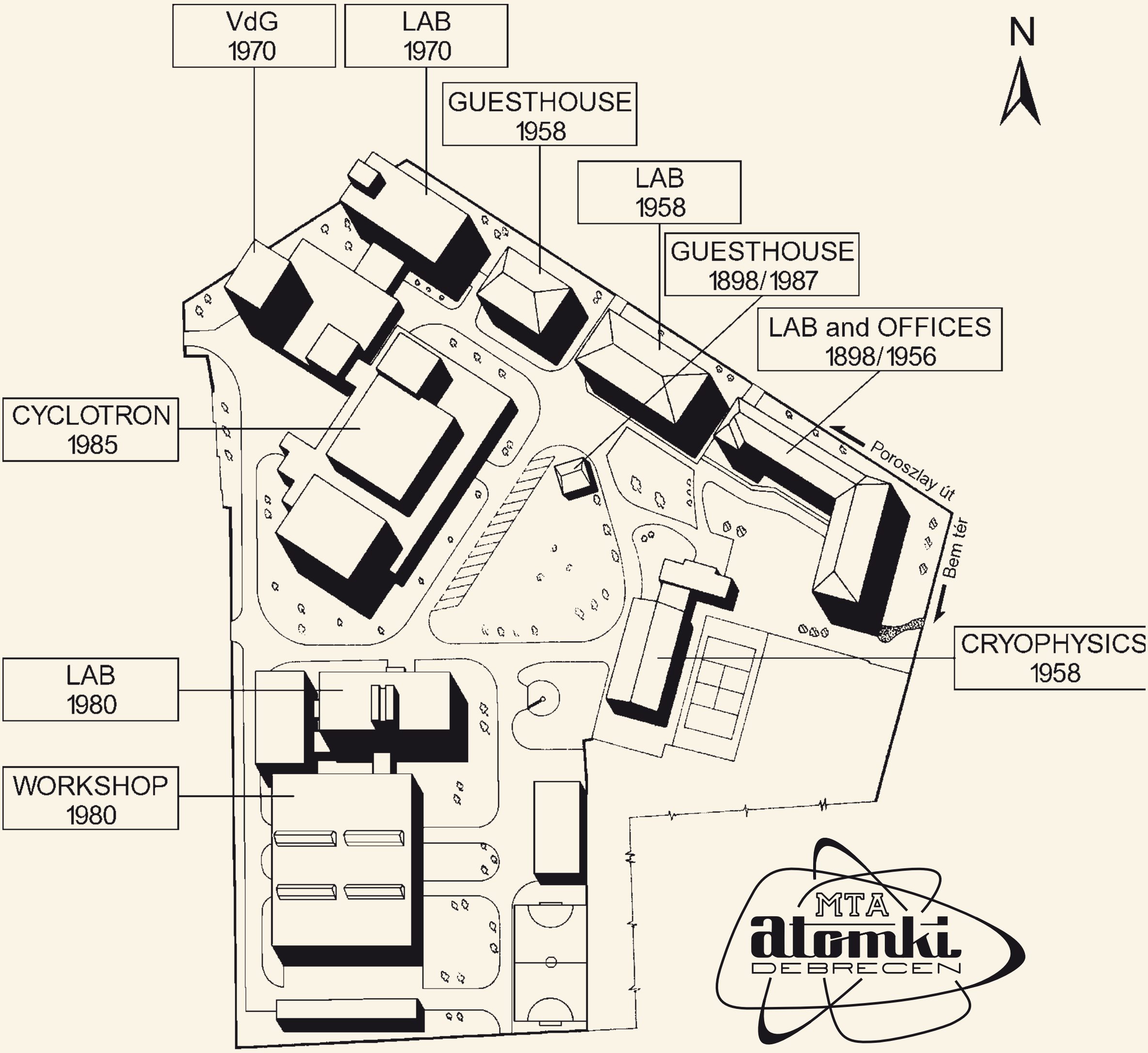
Division of Atomic Physics (Head: Á. Kövér, D.Sc.)

- Section of Atomic Collisions (Head: L. Sarkadi, D.Sc.)
- Section of Electron Spectroscopy (Head: D. Varga, C.Sc.)

- Section of Environmental and Earth Sciences (Head: Á.Z. Kiss, D.Sc.)
  - Laboratory of Environmental Studies
  - Radon Group
  - K/Ar Laboratory
  - Radiation-Protection and Environmental Protection Group
  - Quadrupole Mass Spectrometry Laboratory
- University Department of Environmental Physics (Head: S. Sudár, C.Sc.)
- Cyclotron Section (Head: F. Tárkányi, C.Sc.)
  - Group of Applied Nuclear Physics
  - Laboratory for Radiochemistry
- Section of Electronics (Head: J. Gál, C.Sc.)

National Teachers' Orphanage (1917)
Postcard from the collection of Dr. I. Borbély-Kiss

From left to right: Department of Experimental Physics and Department of Medical Chemistry of the University of Debrecen and the main building of Atomki viewed from Bem Square (2004)



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Szerkesztette: dr. Máté Zoltán, dr. Rajta István

Fotó: Nagy Gábor, dr. Rajta István

Készült a Rexpo Kft. Nyomdájában, 2004-ben