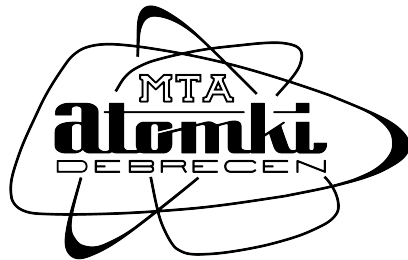


Applied Nuclear Research and Applications in MTA ATOMKI

F. Tárkányi



*Institute of Nuclear Research
of the Hungarian Academy of Sciences
Debrecen, Hungary*

Nuclear applications in ATOMKI

Application fields

- **Cyclotron Applications**
 - Radioisotopes for nuclear medicine
 - Thin Layer Activation
 - Applications of neutrons
 - Nuclear reaction databases for applications
- **Environmental and Earth Sciences**
 - Nuclear Analytics-Earth and Environmental Applications
 - K-Ar Laboratory
 - Radon Group
- **Ion Beam Applications**
 - Analytical applications
 - Micromachining
- **Applied Nuclear Electronics**

**This overview intended to give impression
on the technical background and
on the wide variety of applications.**

Applications are determined by many factors

- Technical background
- Tradition (history, schools)
- Progress of competing methods
- New application fields
- Developments in technology
- Collaborations etc.

Present Status

~10 groups, staff ~50

Main features

- 'Small-scale' equipments
- Wide-ranging collaborations
- Interdisciplinary research
- Final results are frequently at the end-user

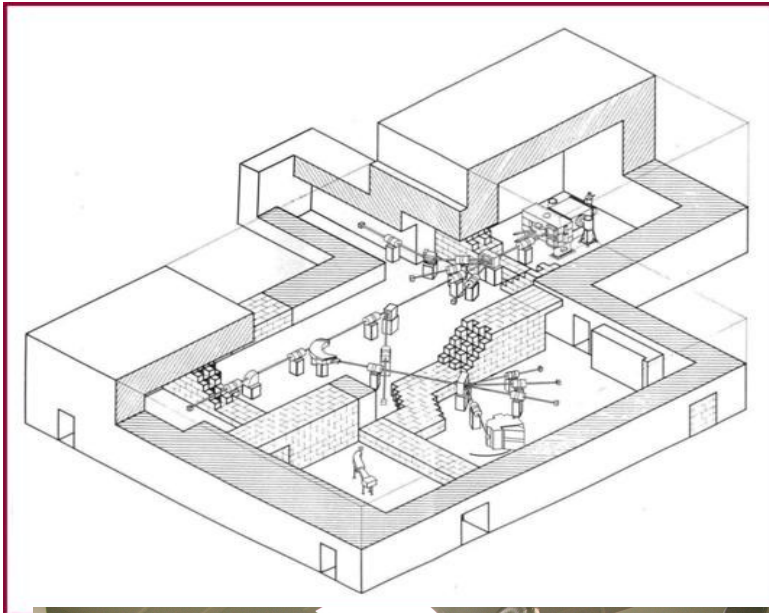
Main methods

- Analytical studies, tracing, radiation damage

Cyclotron Applications

- Radioisotopes for nuclear medicine
- Thin Layer Activation (TLA)
- Application of neutrons
- Nuclear reaction databases for applications

Radioisotopes for nuclear medicine



Radioisotopes for nuclear medicine



The PET scanner in ATOMKI

Molecular Imaging

Pharmapolis Innovative Pharmaceutical Cluster

(for development the pharmaceutical industry, North-East Plain Region, Hungary)

Project companies:

Pharmatom Ltd

Clinical safety pharmaceutical product

IconoPharma Ltd

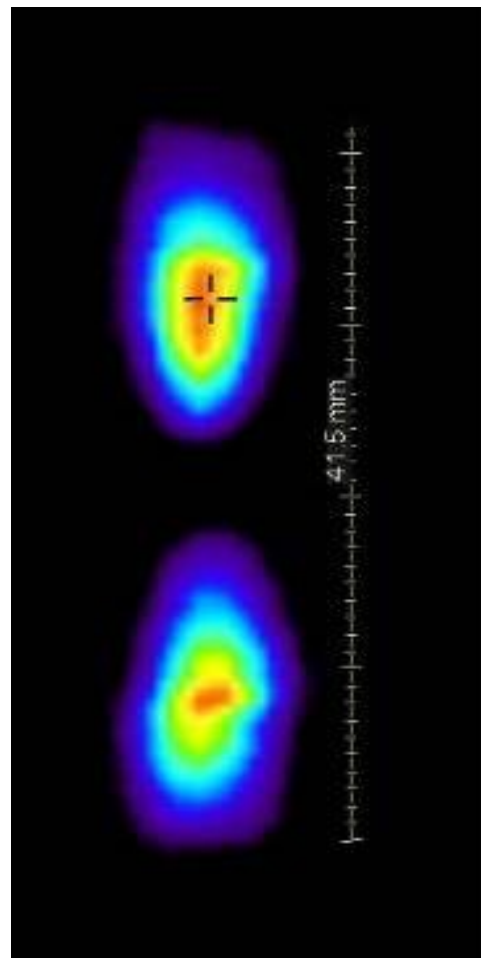
- production of isotopes for radiochemical applications
- production of radiopharmaceuticals
- preclinical trials of radiopharmaceuticals
- clinical trials of radiopharmaceuticals

Other companies.....

Tracing of biological and industrial processes

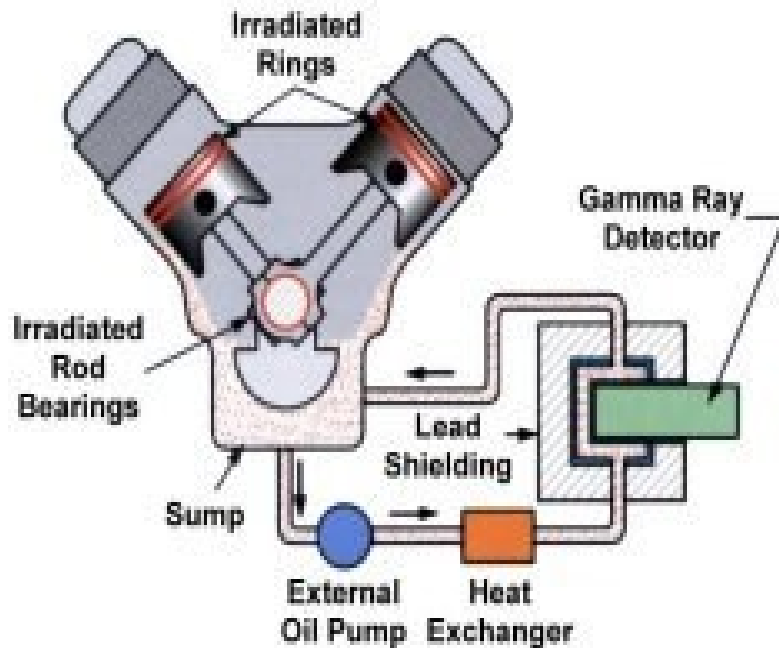


Tracing the sap-flow of plants

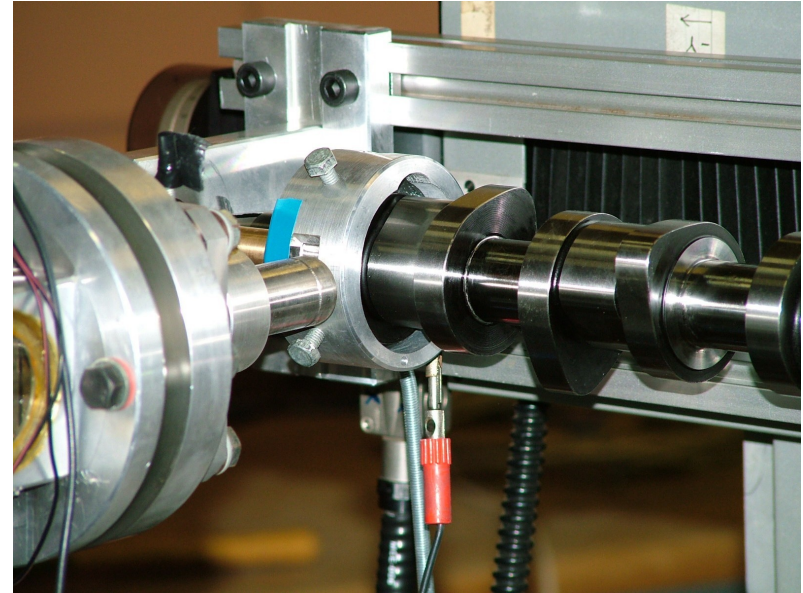


Spatial uniformity of activated cylinders liners using mini-PET

Thin Layer Activation

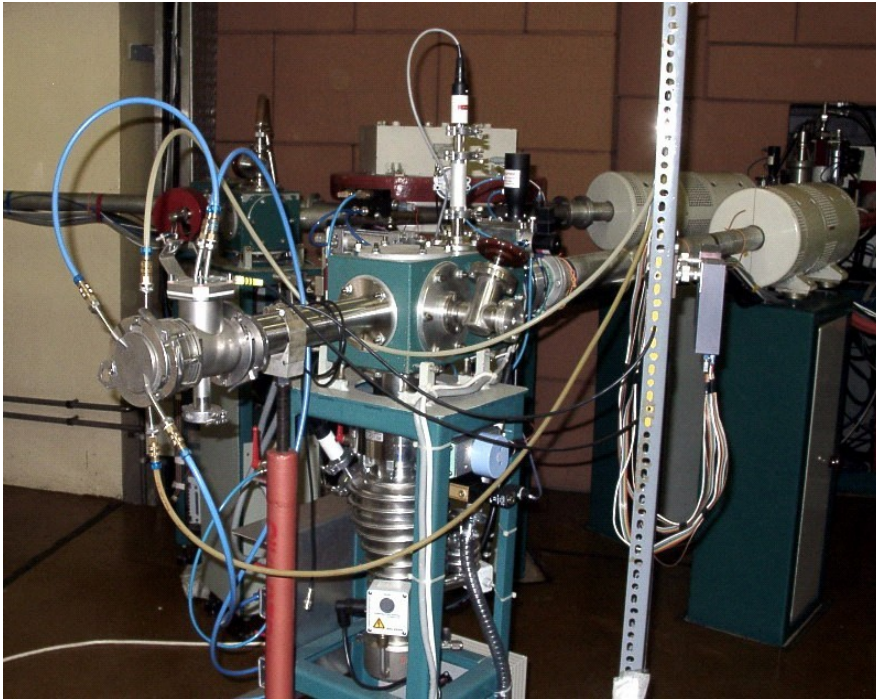


Basic principle of wear measurement

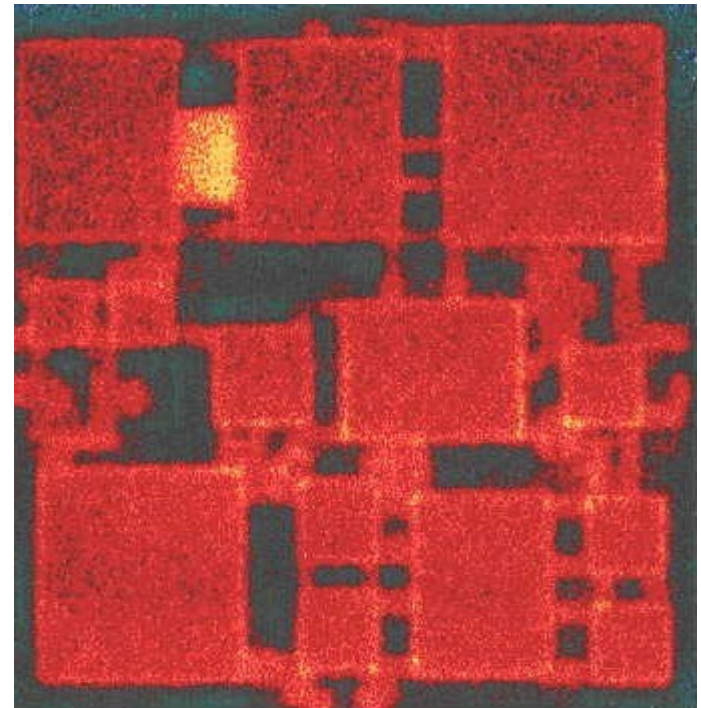


Thin layer activation irradiation of camshaft

Fast neutrons



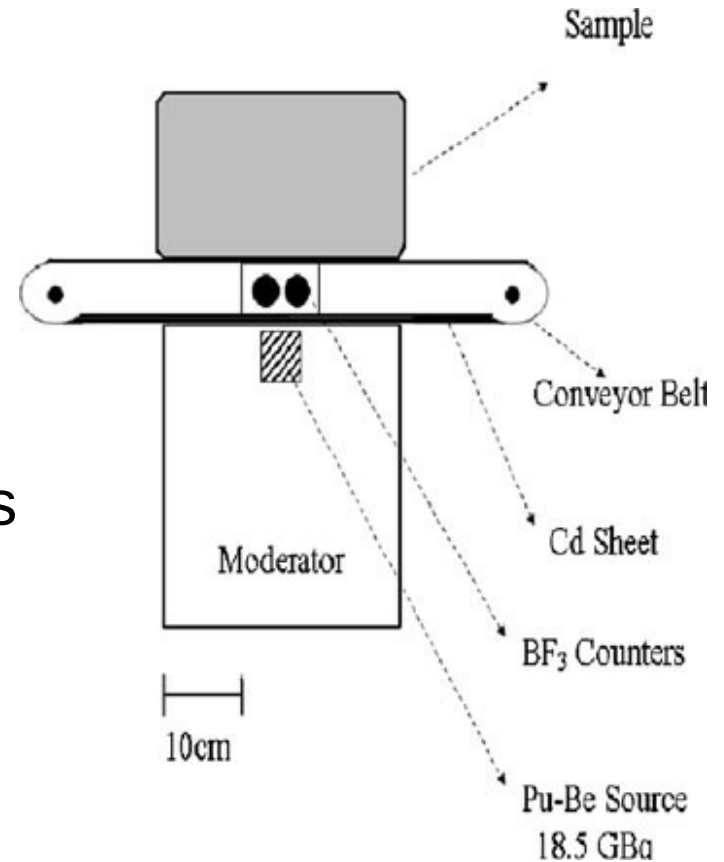
High intensity fast neutron source



Autoradiogram of a multi-chip module after neutron irradiation

Bulk hydrogen analysis

- Thermal neutron reflection and slowing down methods
- H,C,N,O elements
- Landmines, explosives, illicit drugs
- $^9\text{Be}(d,n)$, Pu-Be, ^{252}Cf sources



Nuclear reaction databases for applications

- Development and maintenance of **nuclear technologies rely on** the availability of atomic, molecular and **nuclear data**
- There are also many **nuclear applications** outside the field of fission reactor technology that are of growing economic significance and require substantial data input:
 - accelerator technology**
 - production of radioisotopes for medicine and industry**
 - wear studies with thin layer activation methods**
- Main activity: **charged particle induced activation cross sections**
 - Measurement, compilation, evaluation, dissemination, comparison with theory

Charged particle (CP) induced activation cross sections

- Measurement:
 - p,d,³He and alpha-particle
 - up to 100 MeV
 - around 1000 reactions
- Compilation
 - for EXFOR database and for dedicated evaluations, member of Nuclear Reaction Data Centre Network
- Evaluation
 - CP **beam monitor** reactions
 - Cross sections for **diagnostic radioisotope** production
 - Cross sections for production of **therapeutic radioisotopes**
 - Cross sections for **Thin Layer Activation (TLA)** technique
 - Nuclear Data Libraries for Advanced Systems: **Fusion Devices**

IAEA Medical Portal



International Atomic Energy Agency

Nuclear Data Services

Databases » EXFOR | ENDF | CINDA | IBANDL | Medical | PAAA | NGAtlas | RIPL | FENDL | IRDF-2002

Medical Applications @ Nuclear Data Section

A unified view to medical applications, databases, documents, libraries and ongoing projects

Related links

[Nuclear Data Services HOME](#)

[Dosimetry and Radiation](#)

[Nuclear Data Section](#)

Diagnostic Radioisotope Production

Cross sections for diagnostic radioisotope production and beam monitor reactions

[Gamma Emitters...](#)

[Positron Emitters...](#)

[Monitor Reactions...](#)

[Diagnostic Radioisotope Production web site](#)

Therapeutic Radioisotope Production

Cross sections for production of therapeutic radioisotopes

[Established Nuclides...](#)

[Emerging Nuclides...](#)

[Therapeutic Radioisotope Production web site](#)

MIRD

Tables of nuclear and atomic radiations from nuclear decay and decay schemes

Get (e.g. 99Tc, or 238U)

Provided by Brookhaven
U.S. National Nuclear Data Center

[MIRD web site](#)

Medical Radiotherapy

PHSP - phase-space database for external beam radiotherapy

[Co-60 phsp...](#)

[Photon linac phsp...](#)

[Electron linac phsp...](#)

[PHSP web site](#)

Heavy Charged-Particle Interactions

Compiled and evaluated heavy charged-particle nuclear data for therapeutic applications

[Summary Report CM 2006...](#)

[Summary Report RCM 2007...](#)

[Heavy charged-particle interaction web site](#)

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P.O. Box 100, Wagramer Strasse 5, A-1400 Vienna, Austria

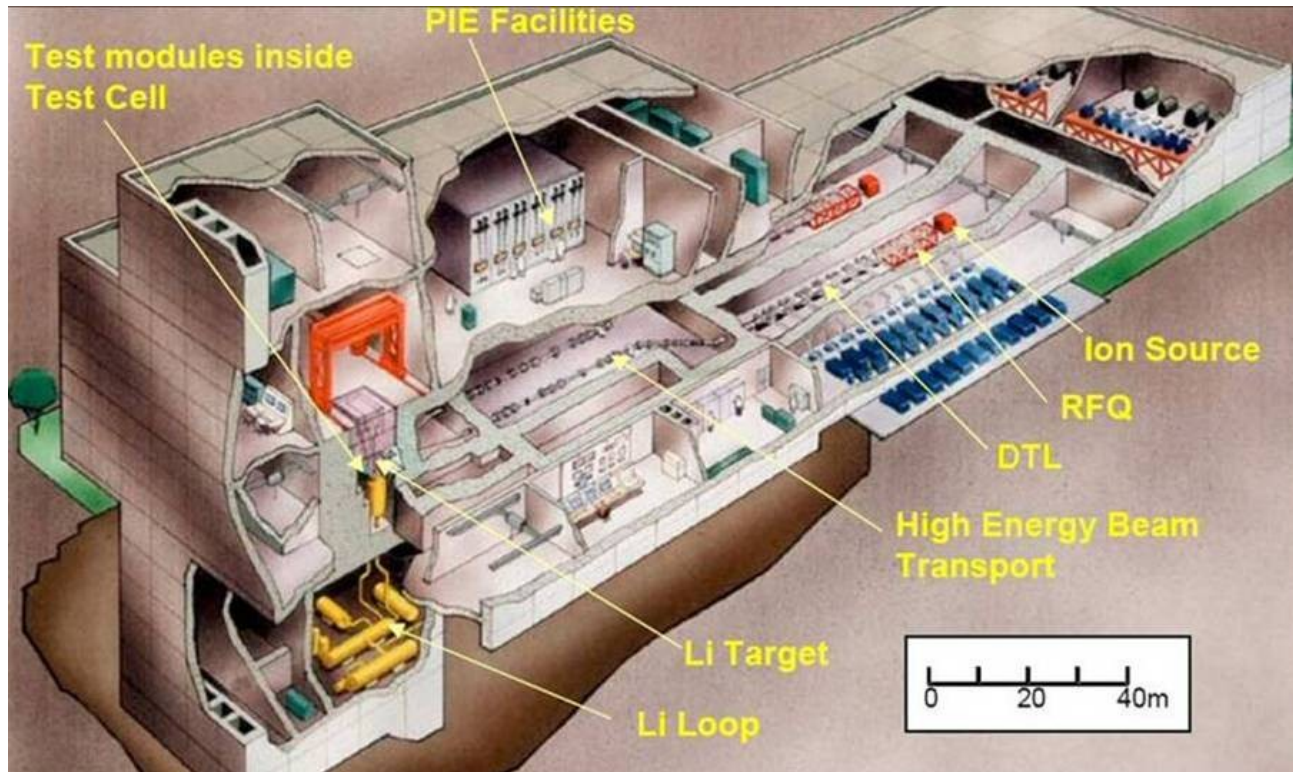
Telephone (+431) 2600-0; Facsimilie (+431) 2600-7; E-mail: online@iaeand.iaea.org. Read our [Disclaimer](#)



CP activation data for IFMIF

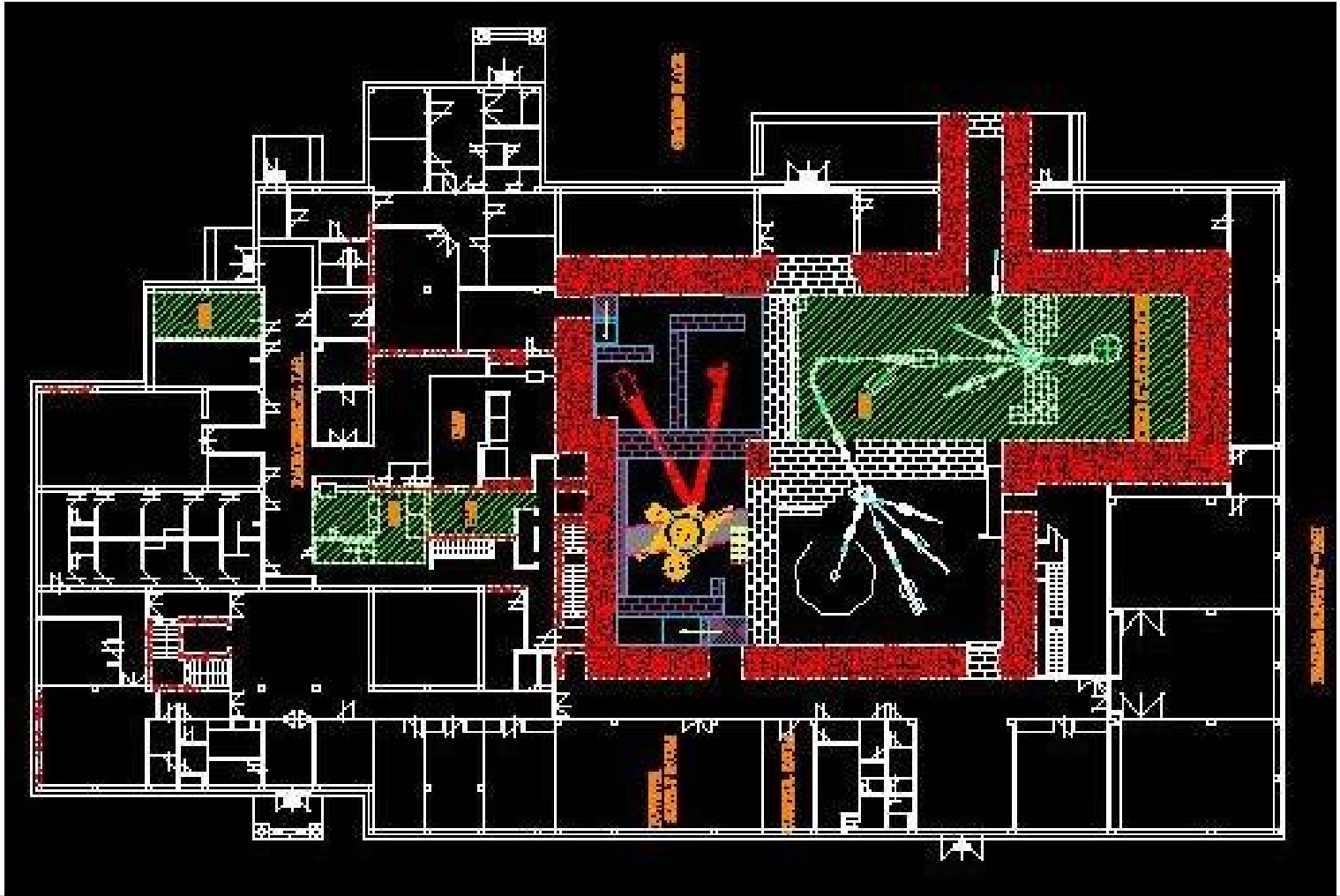
The future IFMIF facility is an irradiation tool, aiming at qualifying advanced materials resistant to extreme conditions, specific to fusion reactors that will succeed to ITER.

<http://irfu.cea.fr/>



In preparation

30 MeV, high intensity cyclotron and upgrade of radiochemistry



Ion Beam Applications in Atomki



Scanning ion microprobe



Basic accelerator: VdG

Two main application areas:

- microanalysis
- micromachining

the youngest beamline on the VdG

Ion Beam Analysis

Atomki
VdG-5

Object slits

Collimator slits

Magnetic
scanning

Quadrupole
lenses

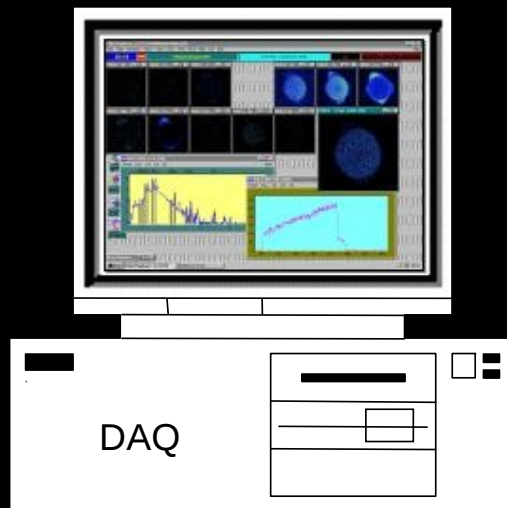
Vacuum
chamber

detector

X-scan

Y-scan

signal



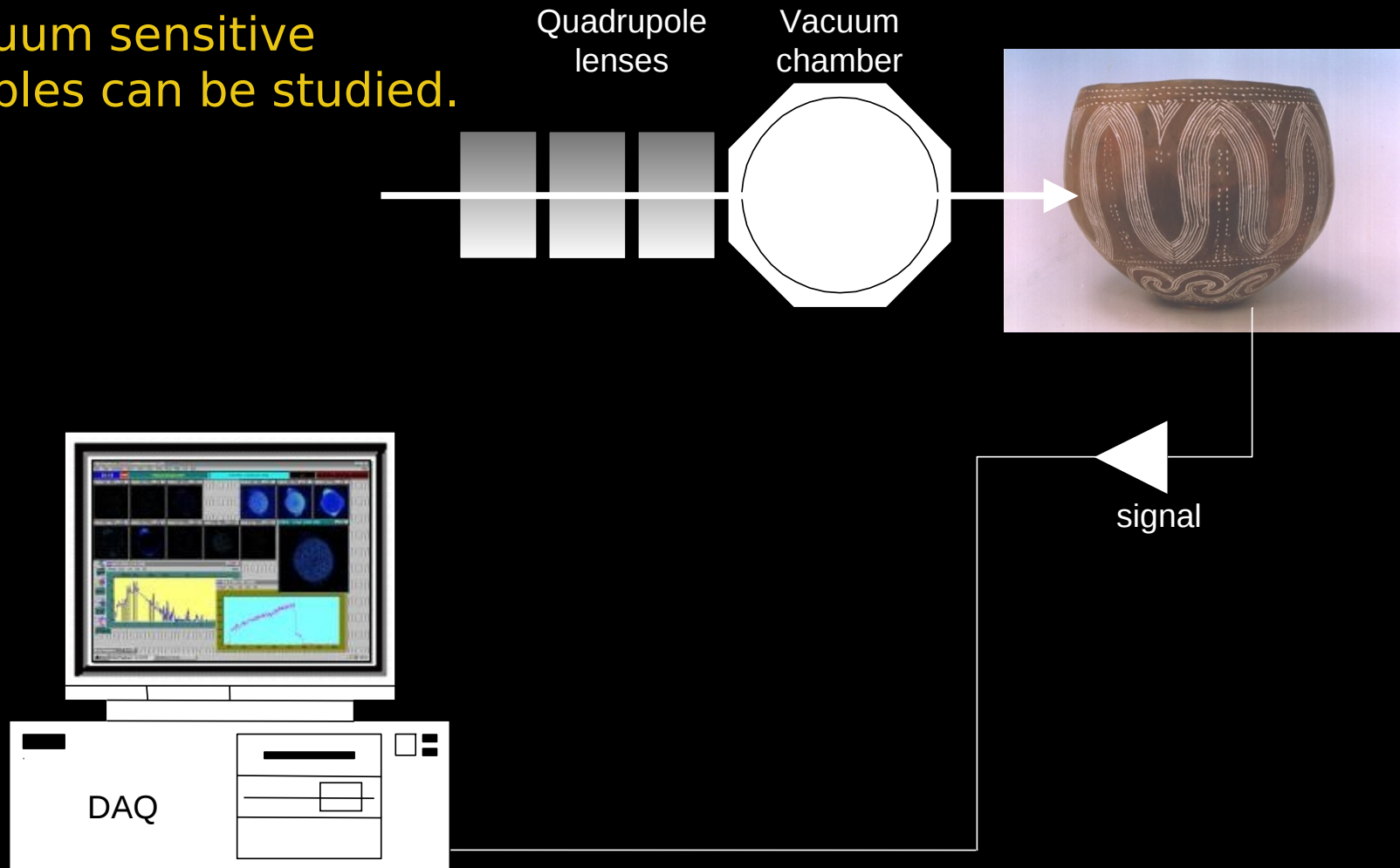
Data acquisition:

- Charge integrator
- PIXE
- RBS
- PIGE
- STIM
- ERDA

External beam

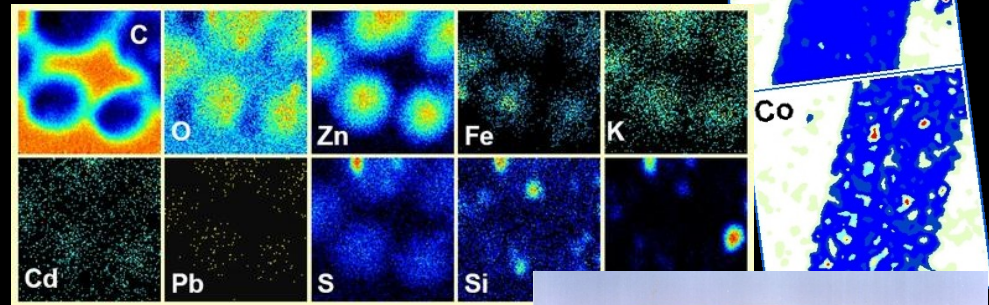
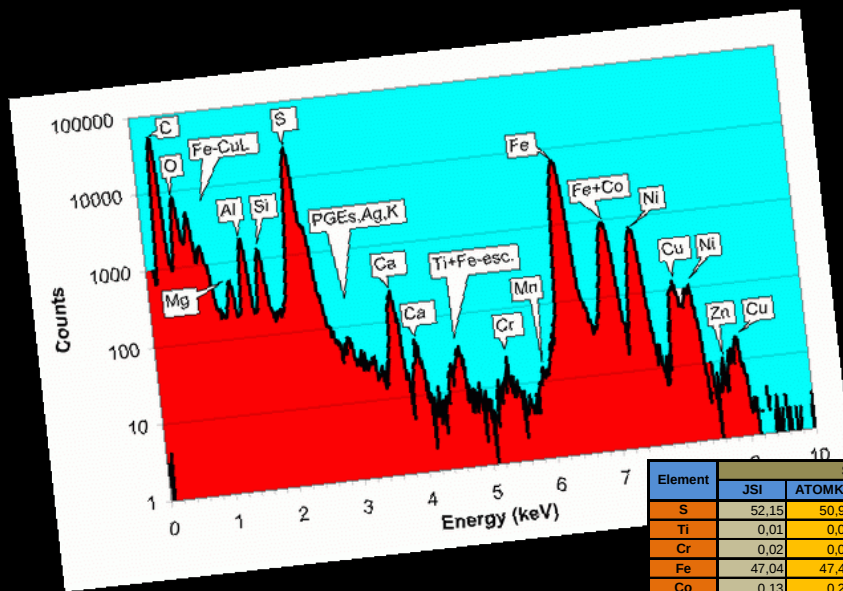
Project currently under progress:

- large
- vacuum sensitive samples can be studied.



Proton Induced X-ray Emission

- Nondestructive elemental analysis
- Elements: C-U, simultaneous detection
- Sensitivity: 10-100 ppm
- Similar to SEM EDX

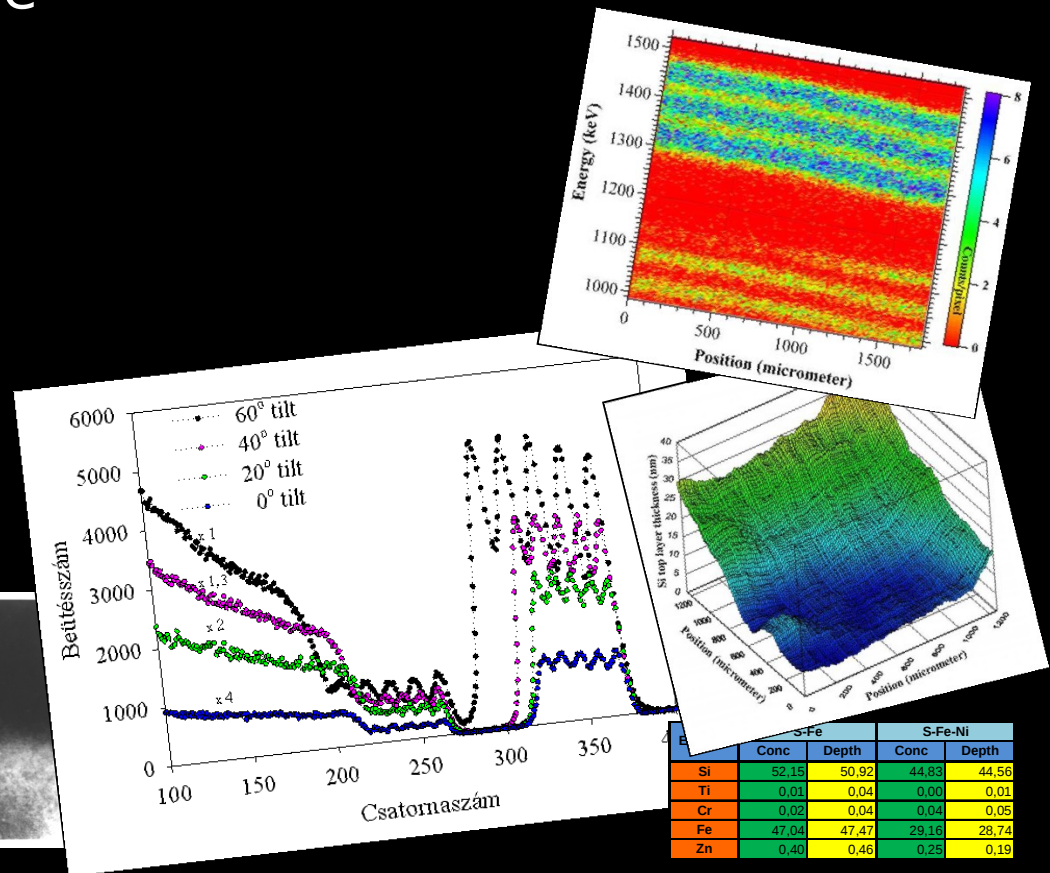
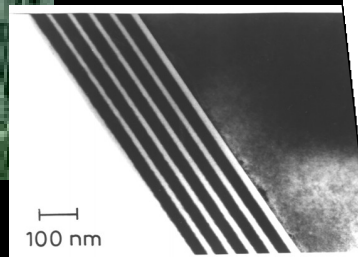
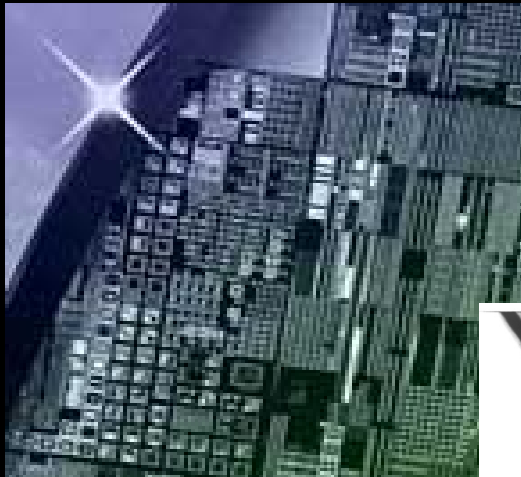


Element	S-Fe				S-Fe-Ni		
	JSI	ATOMKI	EDX1	EDX2	JSI	ATOMKI	EDX
S	52.15	50.92	51.48	49.16	44.83	44.56	46.13
Ti	0.01	0.04			0.00	0.01	
Cr	0.02	0.04			0.04	0.05	
Fe	47.04	47.47	48.52	50.30	29.16	28.74	28.38
Co	0.13	0.27			0.61	0.90	
Ni	0.12	0.49	0.00	0.55	24.89	25.29	25.50
Cu	0.14	0.31			0.21	0.27	
Zn	0.40	0.46			0.25	0.19	



Rutherford Backscattering Spectrometry

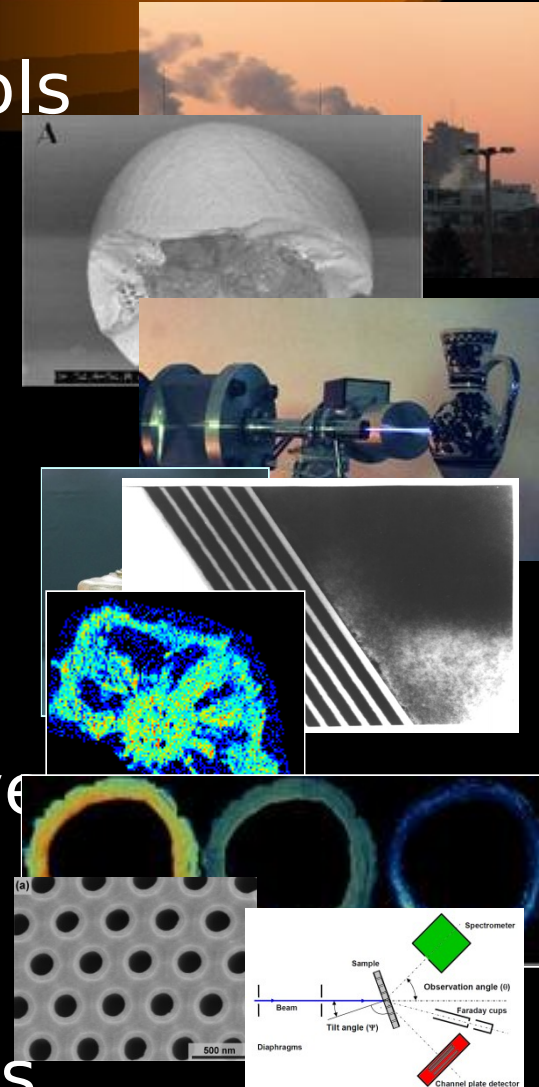
- Nondestructive elemental analysis
- Light elements, simultaneous detection
- Depth profile
- Sensitivity: ppm range



Application areas

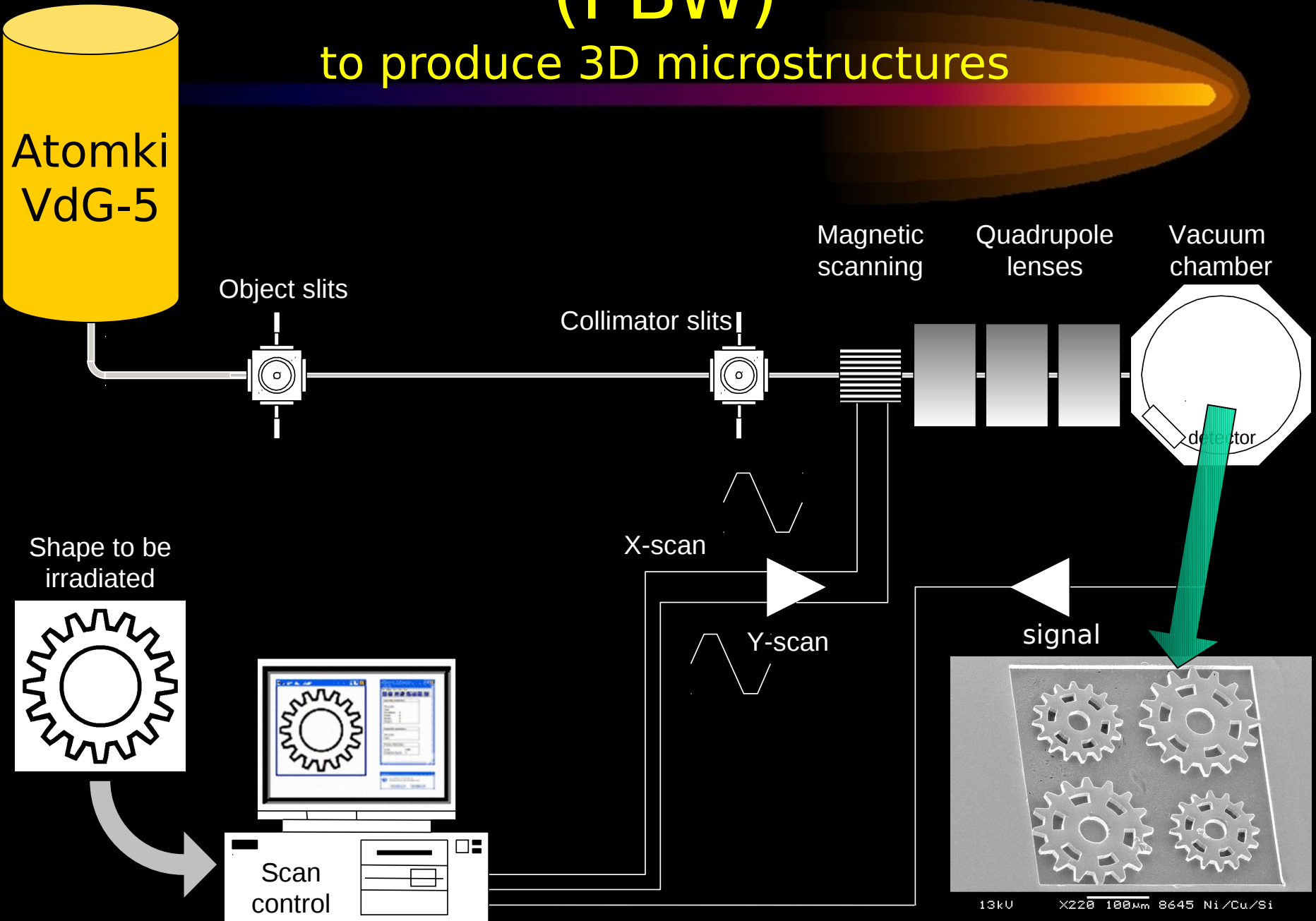
- Environment: atmospheric aerosols
- Geology: meteorites
- Archaeometry: old findings
 - Charisma EU FP7 project
- Materials science: thin layers
- Biology: roots of plants
- Medical: blood vessels, skin, nerves
- Nanocapillaries, atomic physics

These are currently running projects



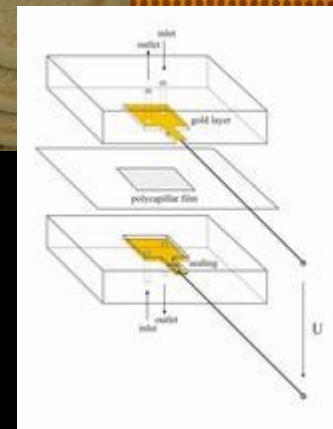
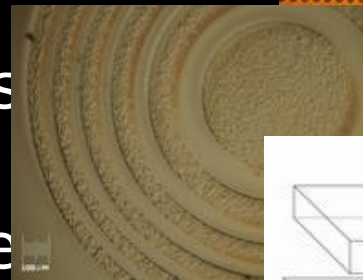
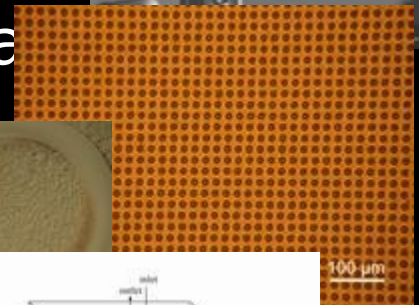
(PBW)

to produce 3D microstructures



Current applications

- Silicon: micro- turbine, pump, membrane
- PMMA: filters for medical & atomphys a
- PDMS: biocompatible polymers
- Microreactors, microelectroche



In preparation



- New accelerator
- Nanobeam development

Laboratory of Environmental Studies

Activities of the Laboratory

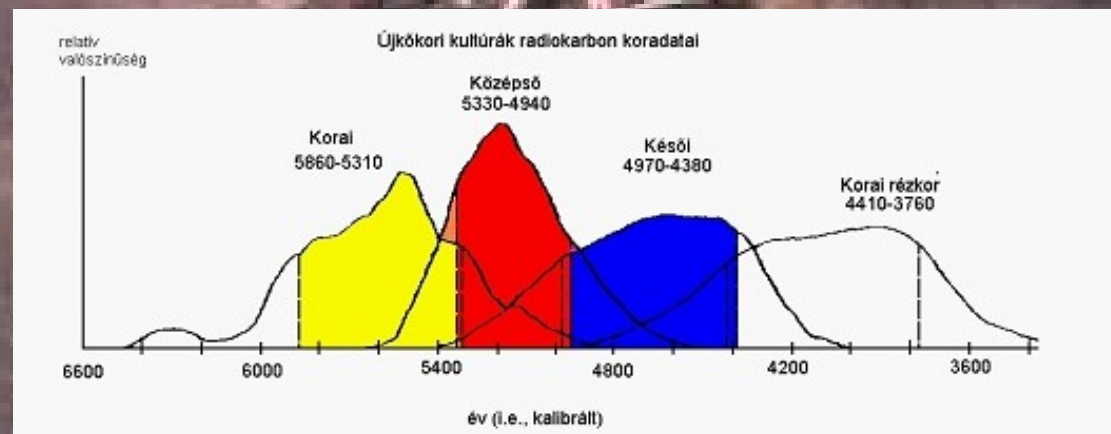
- Interdisciplinary research using physics and physical measurements (stable and radioactive isotopes)
- Research in environmental science (geochemistry, hydrology, archaeology, nuclear industry, etc.)
- Cooperation with research institutes
- Measurement services
- Strong cooperation with an SME (Isotoptech Ltd)



➤ Archaeology (^{14}C)

More than two hundred radiocarbon datings a year

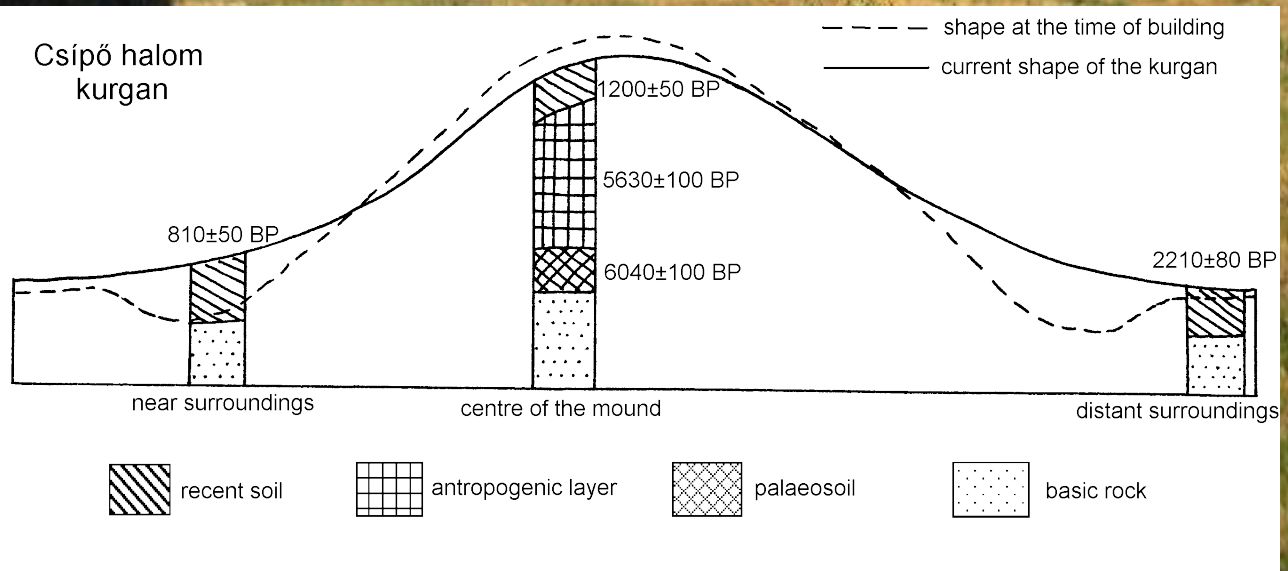
- Bones, coal, teeth, trees, treerings



➤ Palaeobotanic and soil studies (^{14}C , $\delta^{13}\text{C}$)

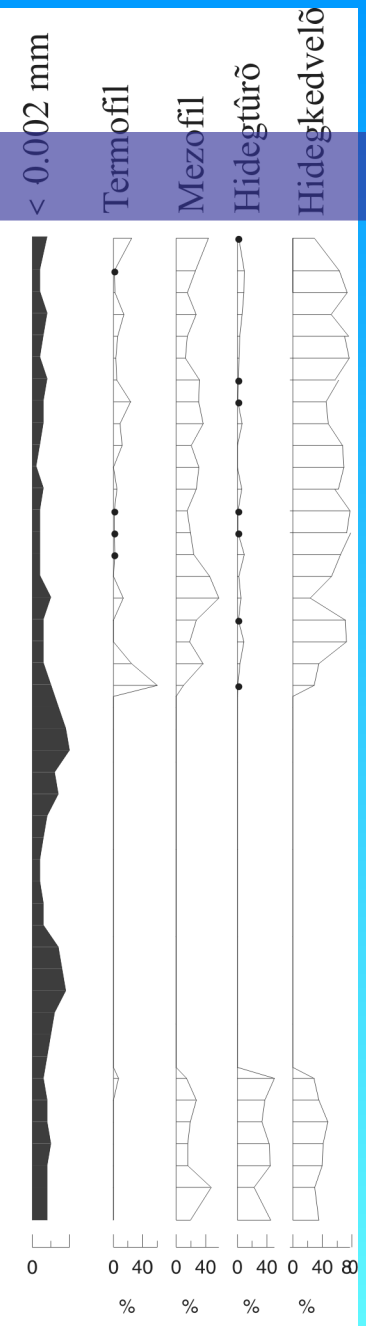
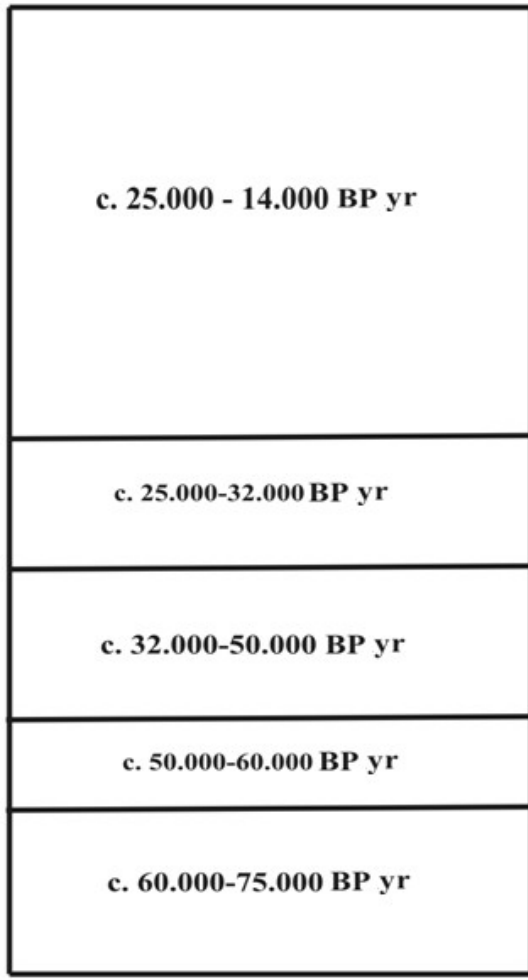
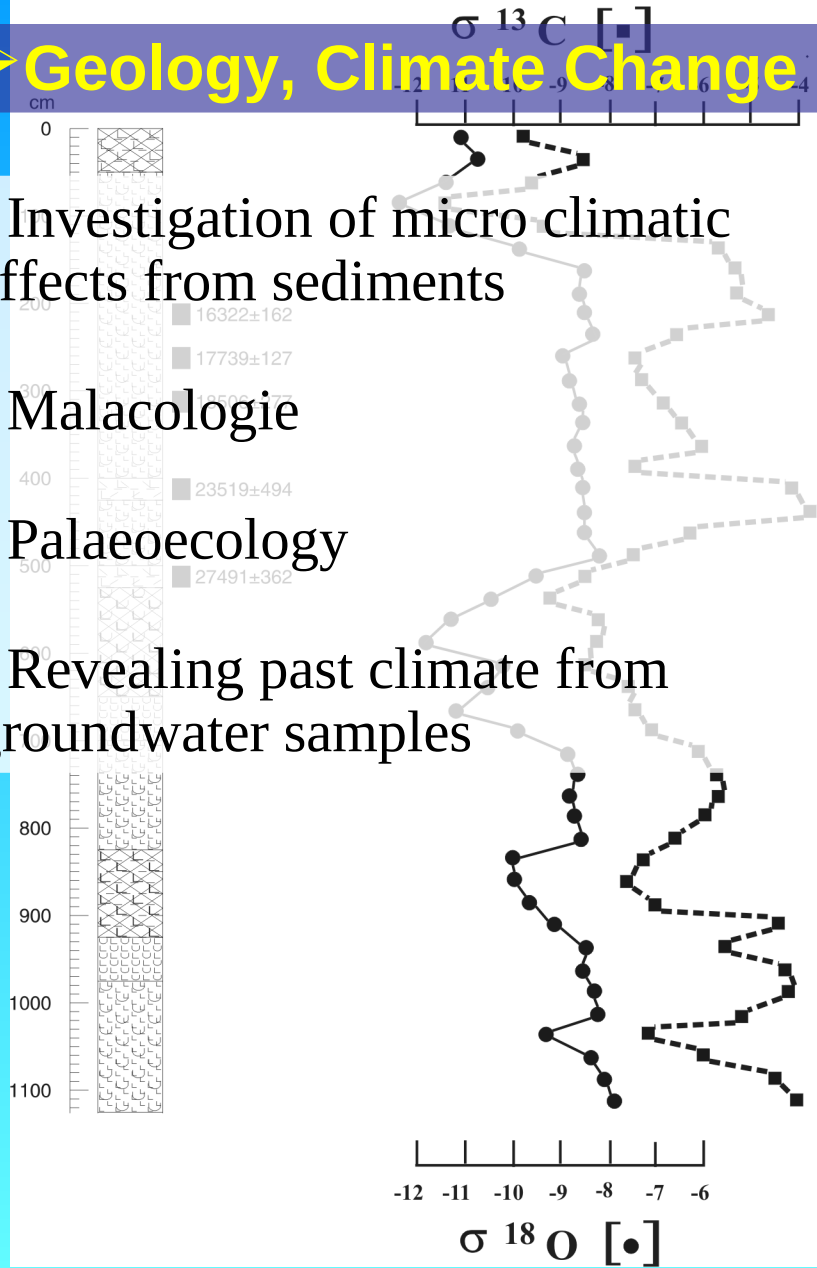
- Examination of kurgans
- Dating of soil-age

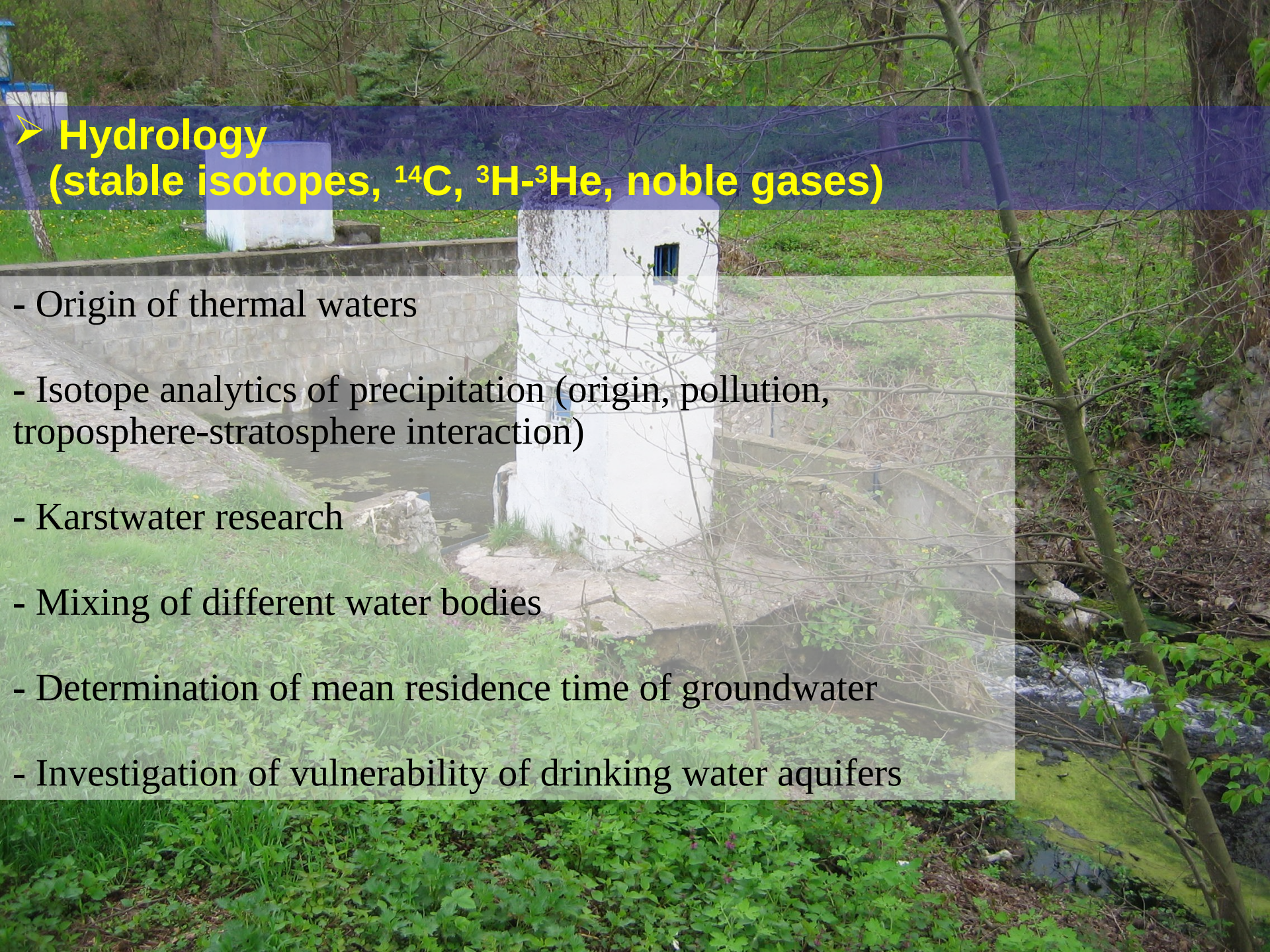
chernozem A horizon
chernozem B horizon
anthropogenic layer
chernozem palaeosoil
parent material (loess)



➤ Geology, Climate Change (^{14}C , stable isotopes)

- Investigation of micro climatic effects from sediments
- Malacologie
- Palaeoecology
- Revealing past climate from groundwater samples



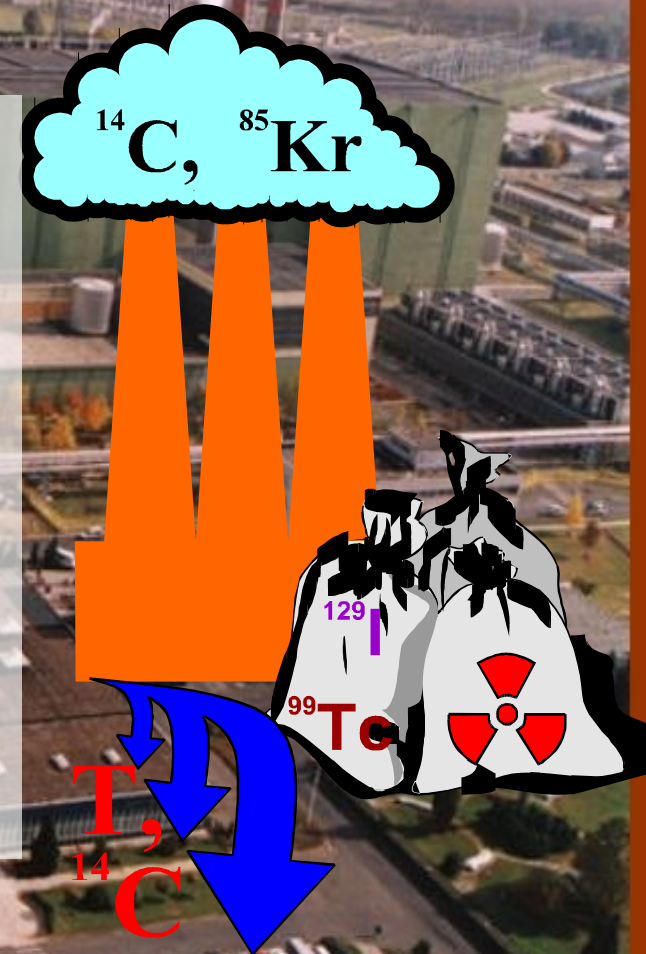
A photograph of a dam and a stream in a forest. The dam is made of concrete blocks and has a small white structure on top. The stream flows through the dam, surrounded by green vegetation and trees. The image is overlaid with a semi-transparent white box containing text.

➤ Hydrology (stable isotopes, ^{14}C , ^3H - ^3He , noble gases)

- Origin of thermal waters
- Isotope analytics of precipitation (origin, pollution, troposphere-stratosphere interaction)
- Karstwater research
- Mixing of different water bodies
- Determination of mean residence time of groundwater
- Investigation of vulnerability of drinking water aquifers

➤ Examination of operational properties of the Hungarian nuclear power plant (^3H , ^{14}C , ^{85}Kr , noble gases, QMS)

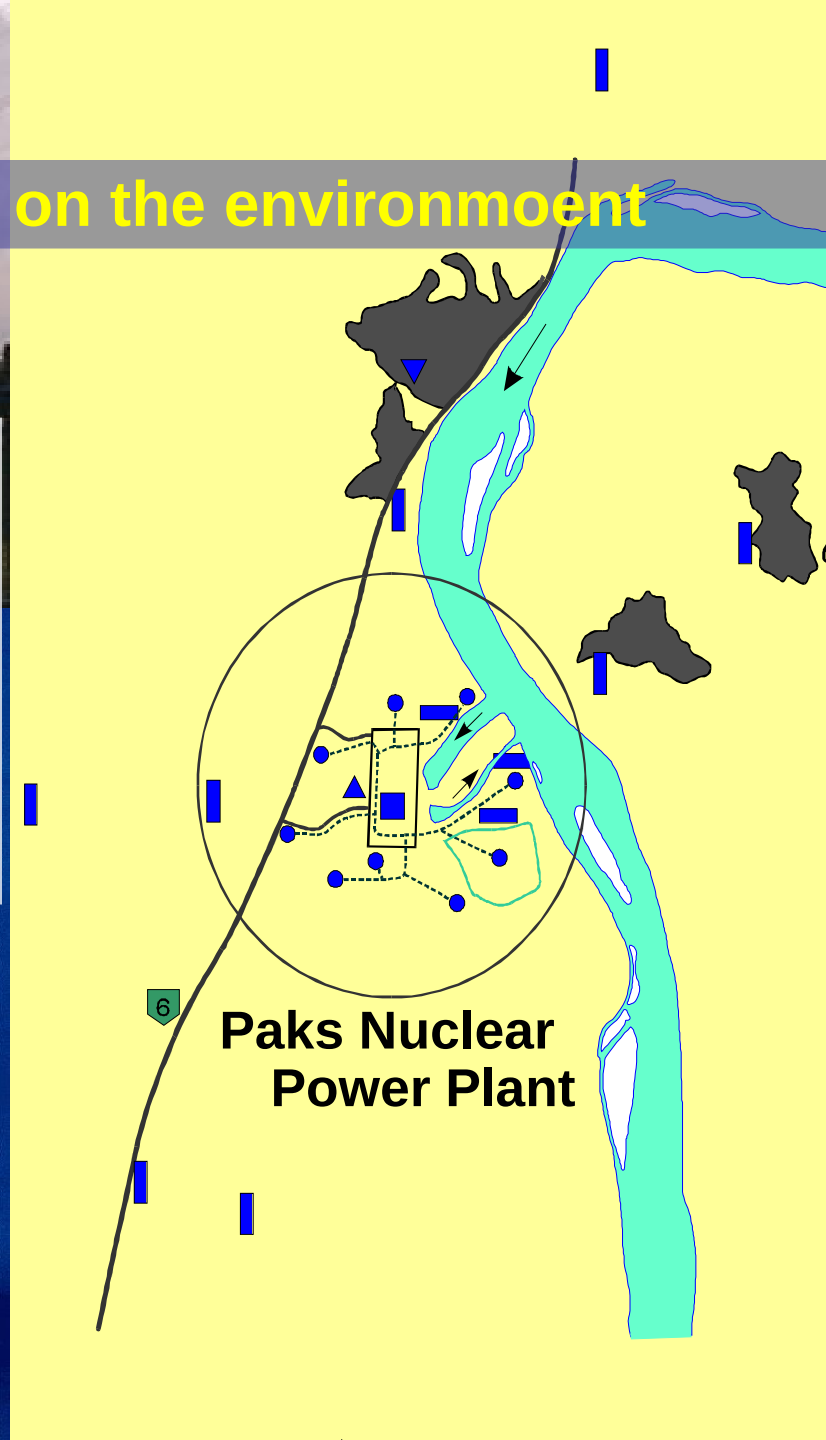
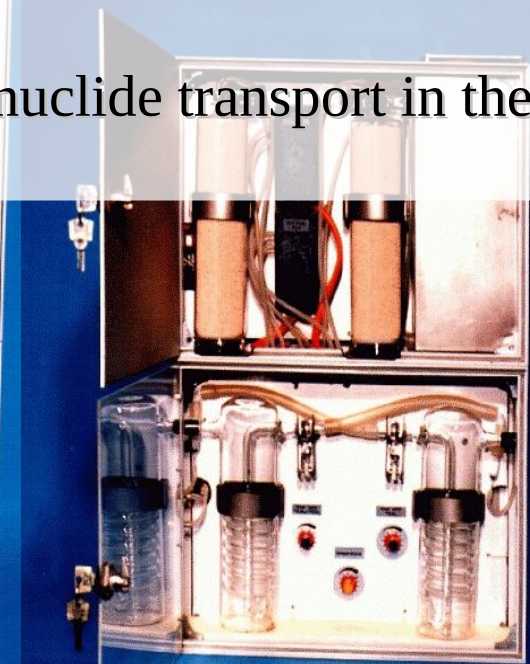
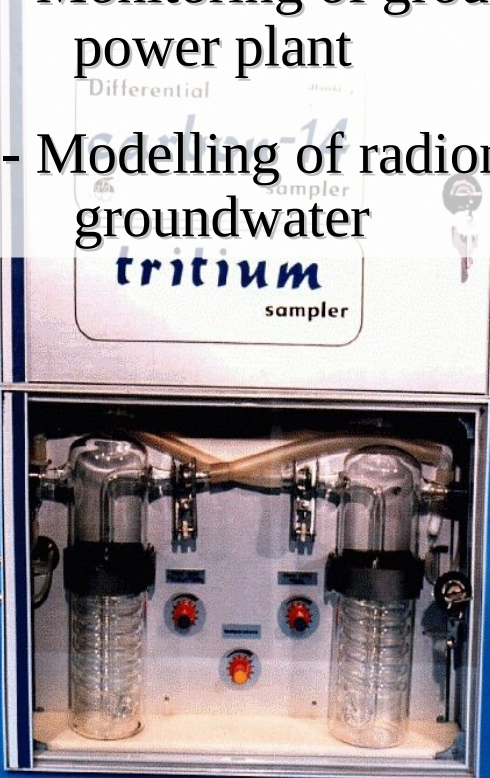
- Searching for leakages of fuel rods by means of Xe and Kr isotopes of fission origin
- Monitoring of ^3H , ^{14}C and ^{85}Kr content of the stack air
- Isotope analytics of hardly measurable isotopes (^{36}Cl , ^{99}Tc , $^{89,90}\text{Sr}$, ^{129}I , ^{94}Nb , ^{125}Sb , ^{79}Se , $^{108\text{m}}\text{Ag}$, ^{107}Pd)





➤ Impact of the nuclear power plant on the environment

- Monitoring of emission of the nuclear power plant to the air
- Monitoring of groundwater around the power plant
- Modelling of radionuclide transport in the groundwater



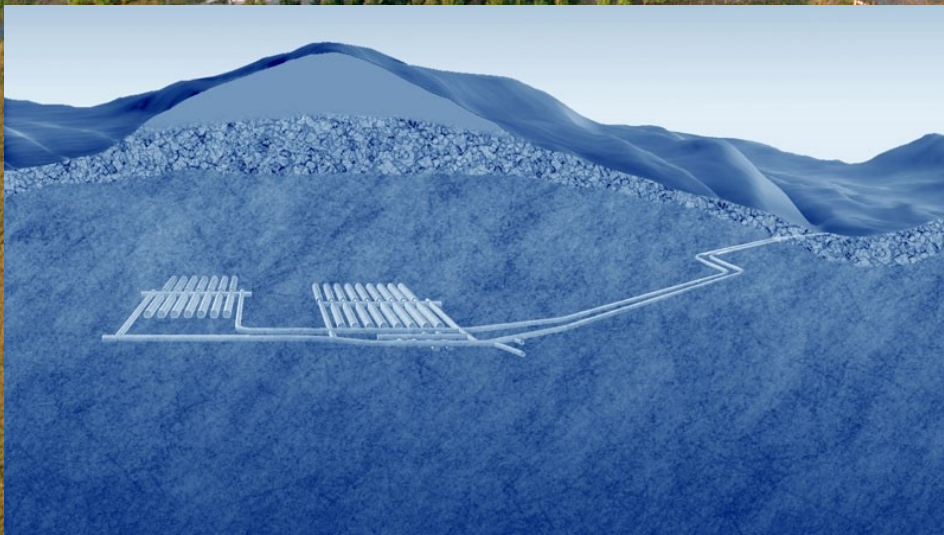
➤ Examination of radioactive waste management

- Gas formation in radioactive waste drums



➤ Safety assessment of radioactive waste disposals

- Monitoring of the environment of the RWDF in Püspökszilágy
- Isotope hydrological and isotope geological examination around the new radioactive waste disposal in Bábaapáti



VG5400



Noble gases

Delta XP



$\delta^{13}\text{C}$

$\delta^{15}\text{N}$

$\delta^{18}\text{O}$

δD

$\delta^{34}\text{S}$

^3H



LSC

^{14}C

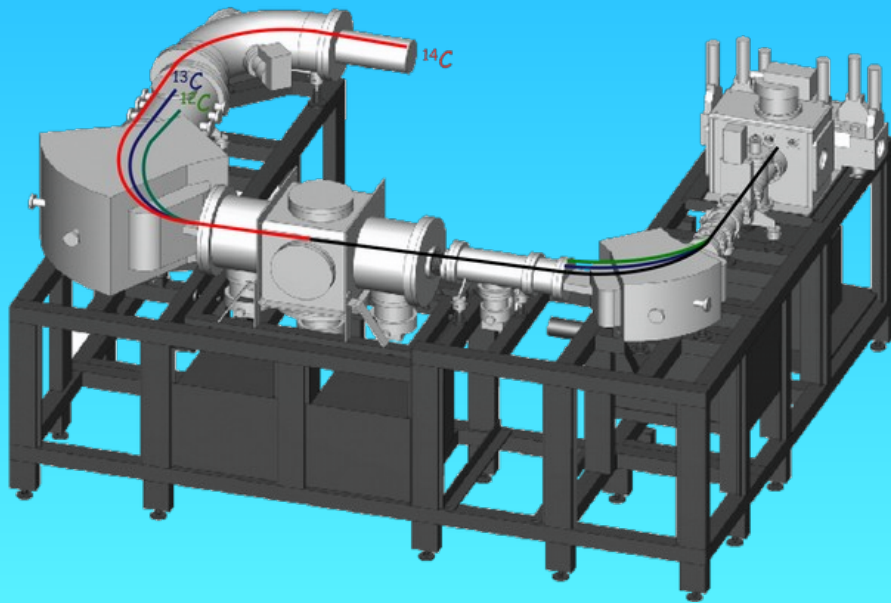


GPC

In 2011:

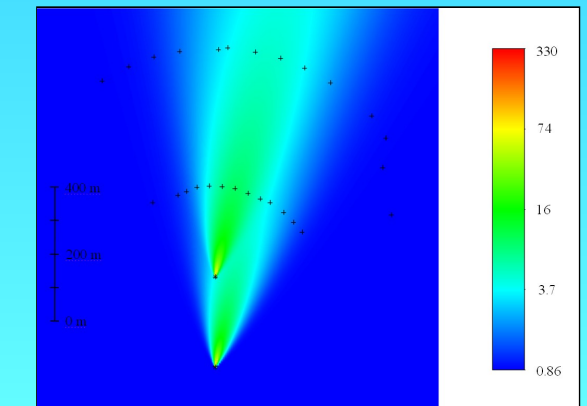
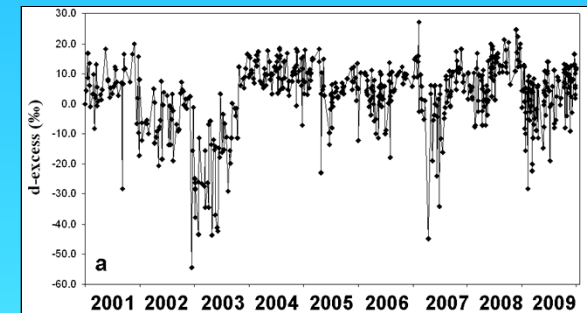
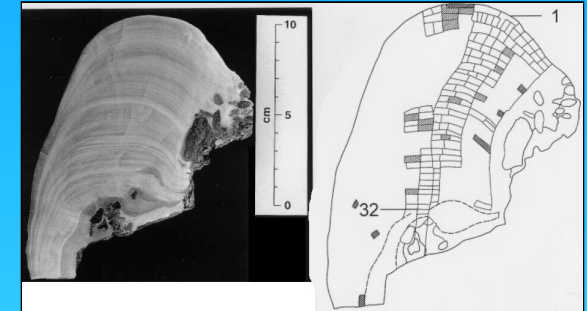
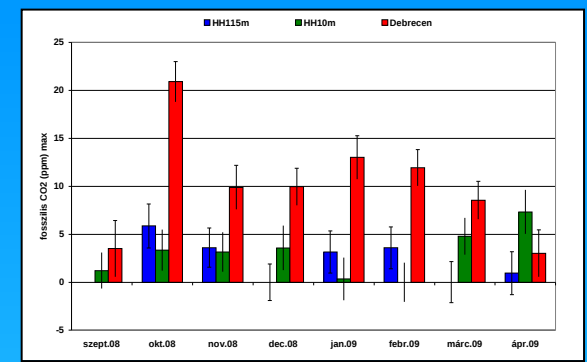
A new accelerator mass spectrometer for ^{14}C has been installed

MICADAS (Mini radioCarbon Dating System) being built in ETH Zürich



Main on-going research fields supervised

- Fossil fuel components of atmospheric CO₂, aerosol and methane (FP7: Integrated Carbon Observation System, ICOS)
- Stable isotopic composition of speleothems
- Noble gas thermometry on fluid inclusions of stalagmites and coral skeletons (FP7-People: Marie Curie Reintegration Grant, NOGAFLUIS)
- Studying the isotopic composition of precipitation with respect to climate and solar cycle
- Impact of nuclear industry on the environment
- Developments in state-of-the-art sampling, preparation and measurement techniques in the field of environmental physics



K-Ar Laboratory

A photograph of a large, layered rock formation, likely a dike or a cliff face, with a pile of rubble in the center. The rock has a distinct vertical, columnar structure. The formation is set against a blue sky with scattered white clouds. The foreground is a grassy field with some small trees and bushes. The text "K-Ar Laboratory" is overlaid in a bold, orange font with a black outline.

Method

- The laboratory works in the field of geochronology by applying the conventional K/Ar and Ar-Ar methods.
- The amount of Ar is measured by mass spectrometry.

The main application fields

- The main fields of research are:
 - Time evolution of magmatic (volcanic and plutonic) processes
 - Dating of ore mineralization
 - Dating of metamorphism and low-grade metamorphism
 - Age determination of tectonic events by using the closure temperature concept
- The studied areas are:
 - mostly the Carpathian Basin and the Balkan Peninsula
 - selected problems are investigated also from the Czech Middle Mountains, Sicily, Sardinia and the Canary Islands.

International cooperation

(120 partner institute from 30 countries)

Country	Partner	Publications	Country	Partner	Publications
United Kingdom	7	17	Vietnam	1	3
Netherlands	2	5	Egypt	3	4
France	4	4	Argentina	1	1
Germany	9	18	Chile	1	1
Switzerland	3	4	Poland	7	15
Austria	3	4	Czech Republic	10	18
Italy	11	24	Slovakia	8	21
Japan	2	6	Ukraine	1	3
New Zealand	1	4	Romania	7	31
Canada	2	2	Bulgaria	5	19
Spain	9	7	Serbia	5	22
Greece	1	6	Croatia	6	8
Russia	4	5	Slovenia	3	4
Georgia	1	1	Bosnia	1	2
Armenia	1	1	Macedonia	2	2

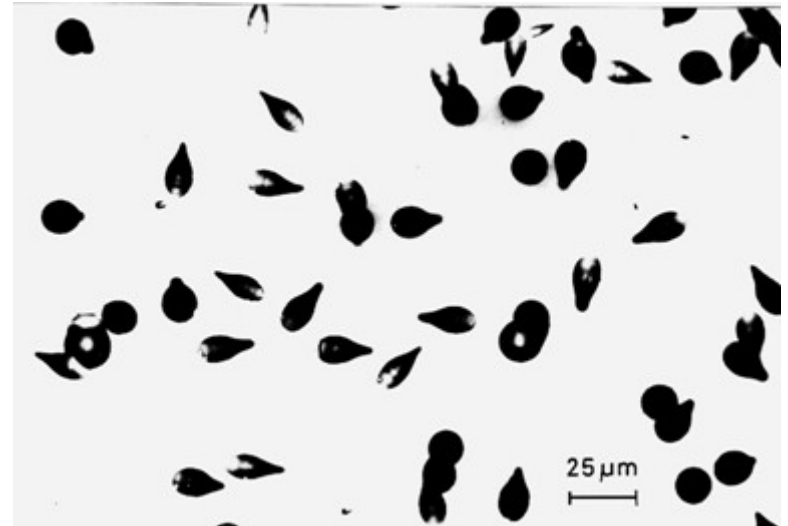
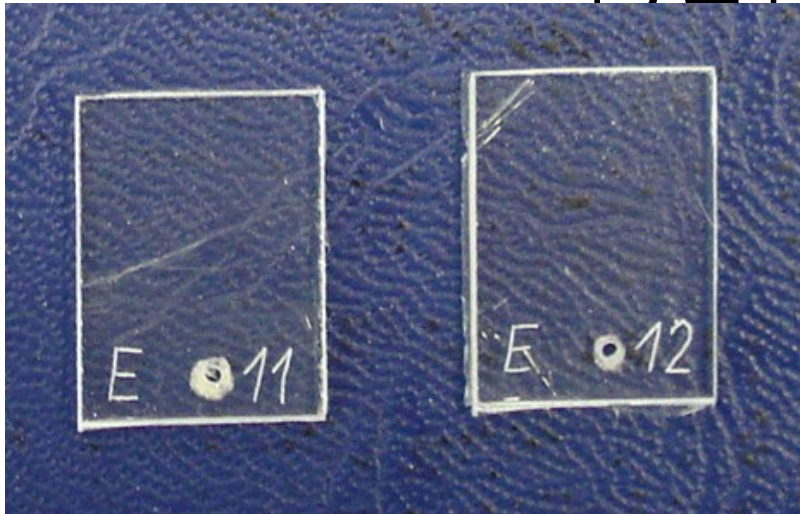
Radon Group

- Etched track detectors, development and applications
- Development of the Radamon etch track radon monitor
- Cosmic ray charged particle measurements on satellites
- Procedure to determine radon potential of building sites
- Radon risk assessment, cost-benefit analysis, action level optimization
- Safety analysis of radioactive waste disposal facility

Etched Track

Detectors

Chemical etching of PADC plastic visualize the tracks of charged particles from cosmic rays and from environmental alpha radioactivity.



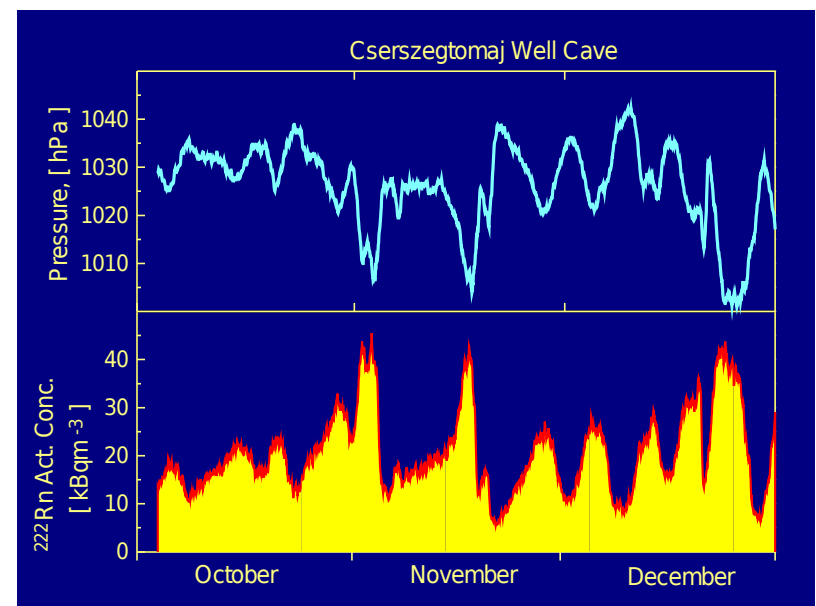
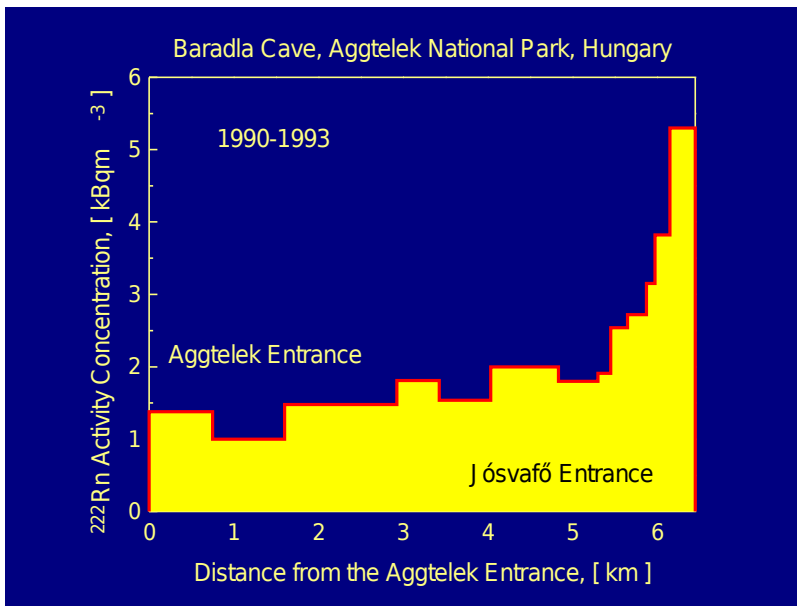
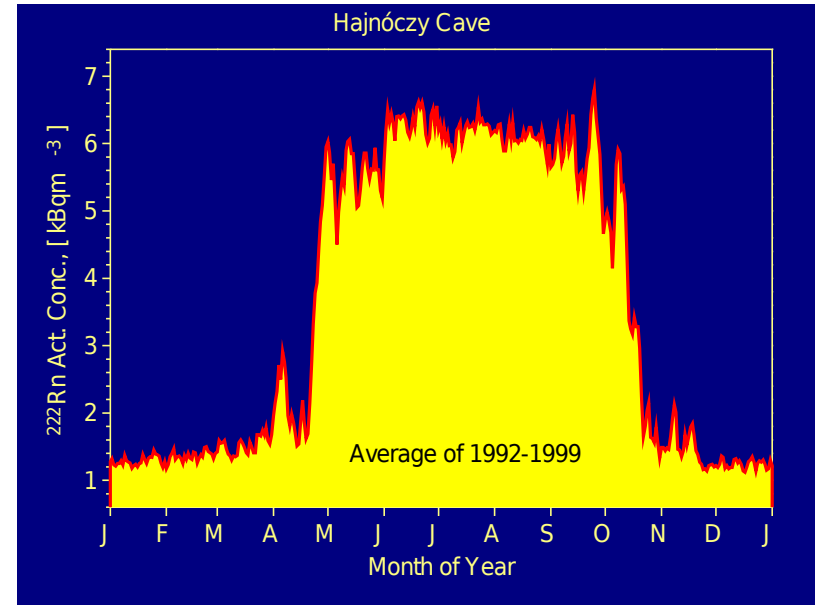
Radon in the Environment

Radon is a radioactive noble gas, originating from rocks. It is known to cause lung cancer among the public. We have developed methods to keep it



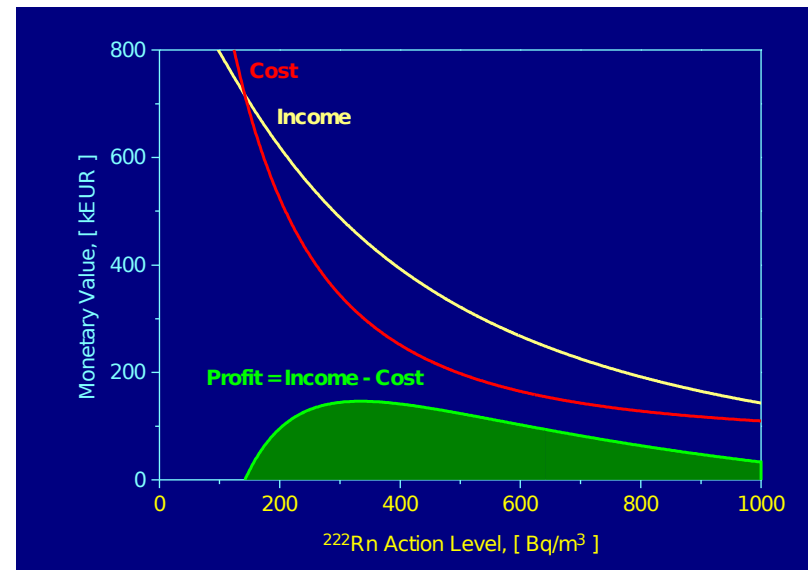
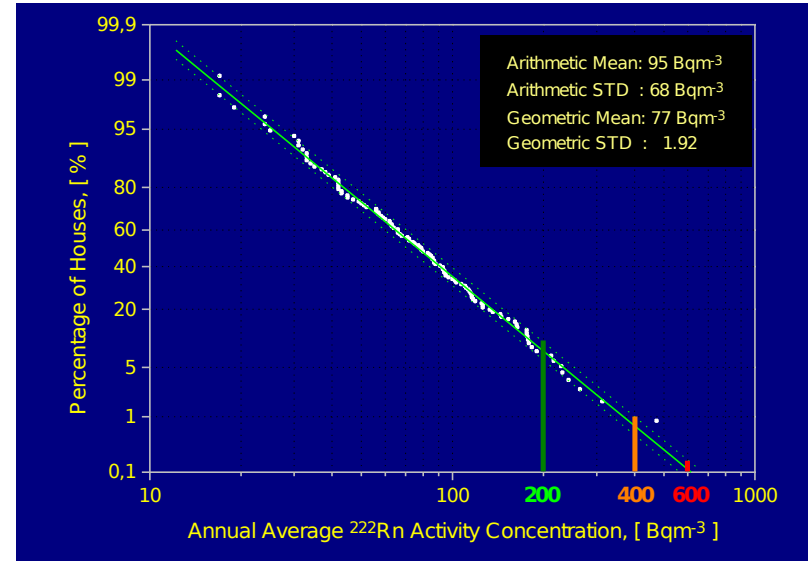
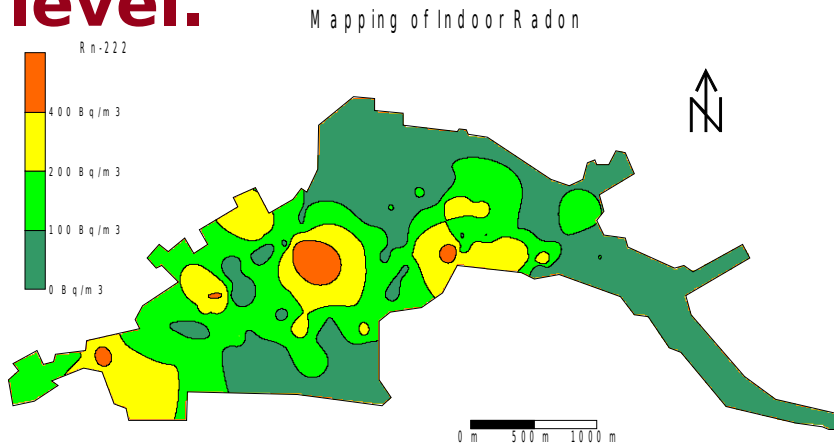
Radon in Caves

Spatial, seasonal and atmospheric pressure induced variations has been shown to be linked to different air circulation patterns in different caves.



Radon in Homes

To protect people against radon in homes we perform representative indoor radon surveys and cost-benefit analysis to optimize radon action level.

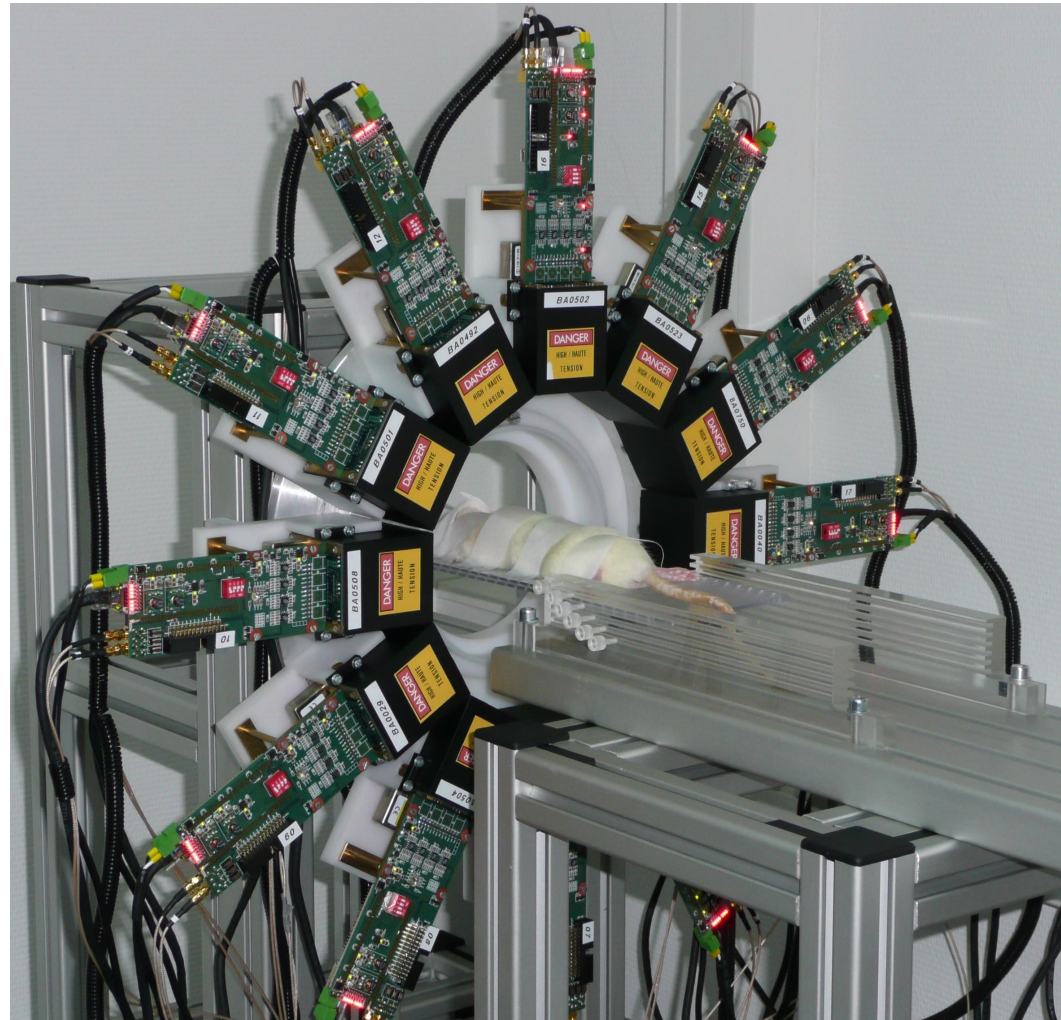


Application related nuclear electronics

- Nuclear Medical Imaging:
 - small animal PET
 - mobile tomographic gamma camera
- Radiation hardness properties of electronic circuits at:
 - satellites
 - accelerators
 - dosimetry systems

Small animal Positron Emission Tomograph: miniPET-II

- In vivo small animal studies
- 12 individual detector modules
- Ring diameter: 206 mm
- Ethernet based data acquisition
- Spatial resolution: ~ 1.3 mm
- Coincidence time resolution: ~ 3 ns
- Collaborators:
 - Institute of Nuclear Research
 - University of Debrecen
 - Budapest University of Technology
 - Mediso Ltd.



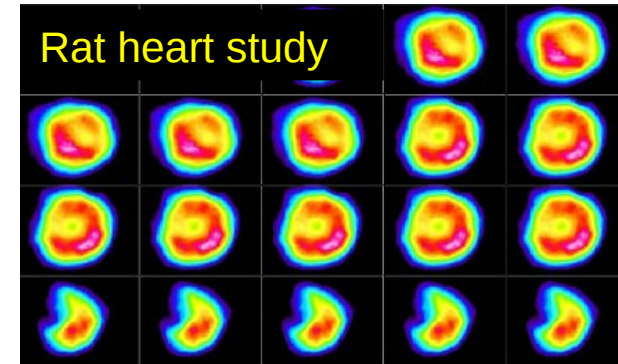
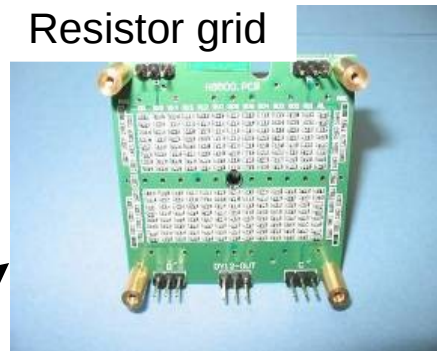
miniPET-II: Detector module



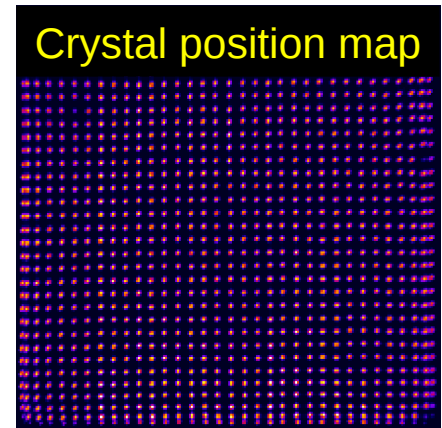
Xilinx Virtex4 FPGA,
digital signal processing (DSP)

High voltage
power supply

Resistor grid



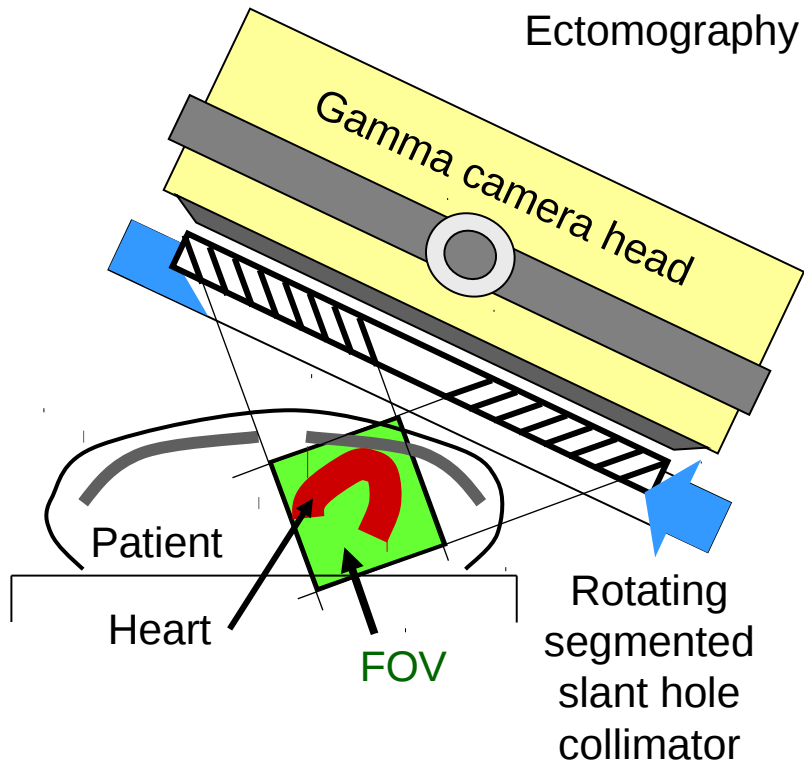
Crystal position map



- 35 x 35 LYSO scintillators
- Crystal size: 1.27x1.27x12 mm
- Active area: 47 x 47 mm²
- Hamamatsu H9500 position sensitive PMT

Cardiotom

Mobile tomographic gamma camera for acute myocardial studies.



In collaboration with Karolinska University Hospital, Karolinska Institute and Royal Institute of Technology, Stockholm, Sweden.

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Thank you for your attention!