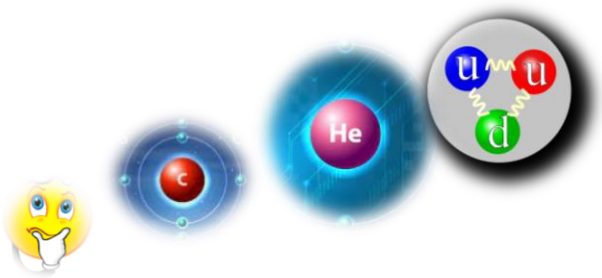
HITRI plus
Heavy Ion Therapy Research Integration

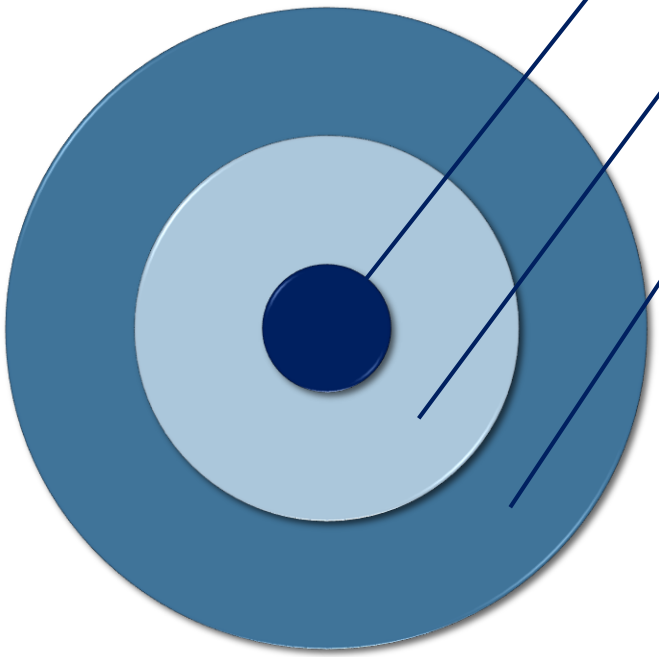
Ion Beam Analysis (IBA) Applications

FEHIMA UGARAK

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

I am going to talk about...





Why am I speaking about the application of ions?

Steps during investigations.

Results and conclusion.

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The goal

*A simple low-energy accelerator set up
*research, education, study of medical radioisotopes production.

Energies: Up to about **10 keV/u** (phase I)

Expansion with RFQ (phase II)
final energy of- **up to 0.5-5 MeV/u**

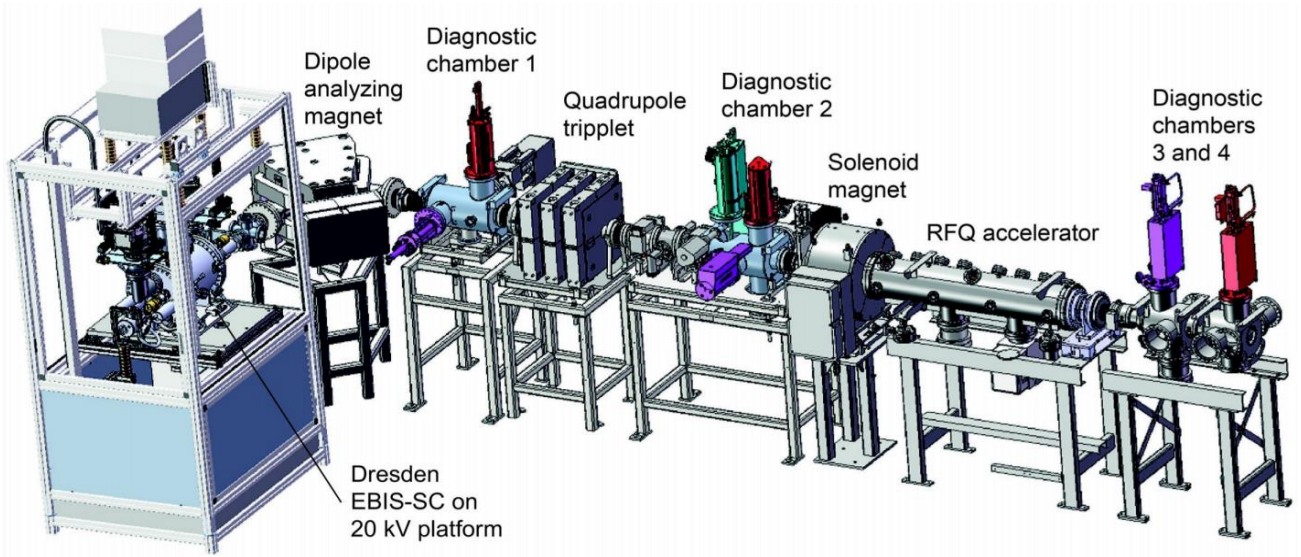
Further studies
What are the potential applications?
What is the optimal final energy?

Nanogan source provides ions (Table 1);
RF power up to 100W; the maximum extracting voltage is 20 kV.

Table 1. Nanogan- an ECR ion source provides:

ion / Q	1	2	4	6	8	9	12	14
H	1000							
He	1000	100						
Ar	300		140	45	20	5		
Xe							10	5
Ta					10		10	5
Au			10	9	8	6		2

Beam intensity for various charge states given in electric μA



[1]RFQ is foreseen for phase 2

Fig. 1. Future test stand

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Ion Beam Analysis

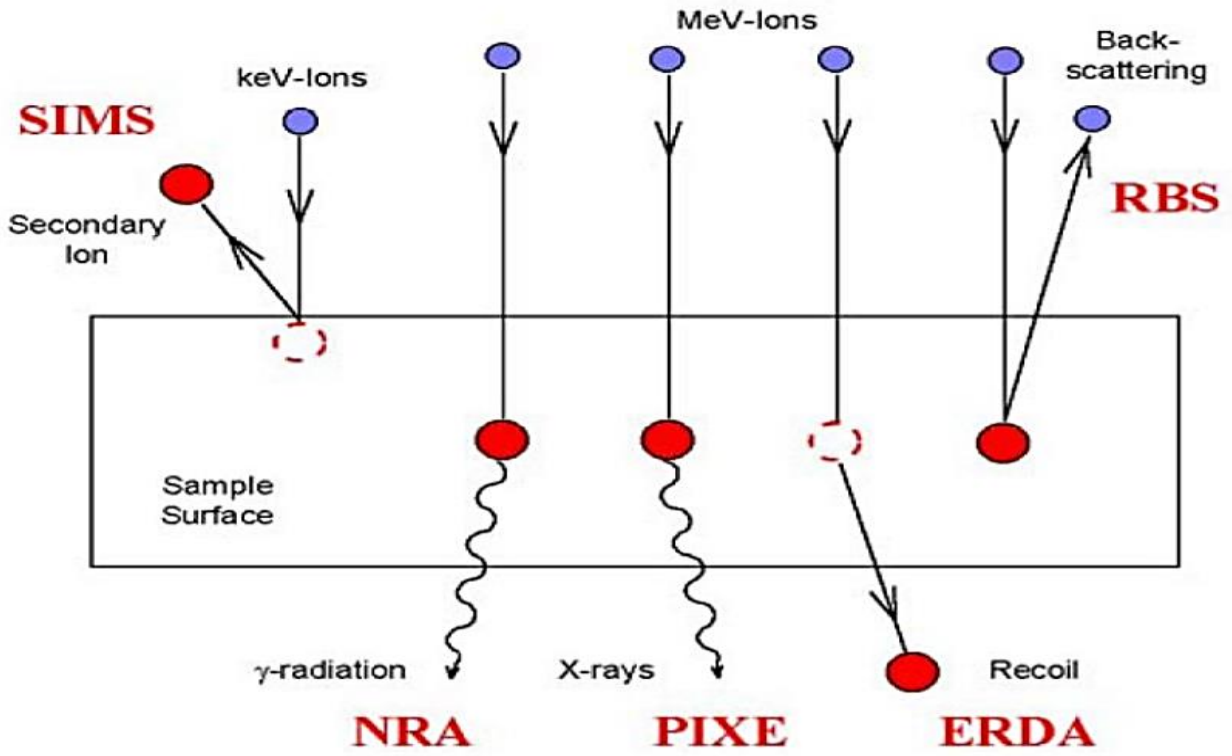

Fig. 2. Energies for IBA techniques

Another IBA technique that exists at keV energies- LEIS (Low Energy Ion Scattering) is not shown in the figure 2.

[1] SIMS- Secondary-Ion Mass Spectrometry
[2] NRA- Nuclear Reaction Analysis
[3] PIXE- Particle Induced X- rays Emission
[4] ERDA- Elastic Recoil Detection Analysis
[5] EBS- Elastic or Nuclear (non Rutherford) Backscattering Spectrometry
[6] RBS- Rutherford Backscattering Spectrometry
[7] LEIS- Low Energy Ion Scattering

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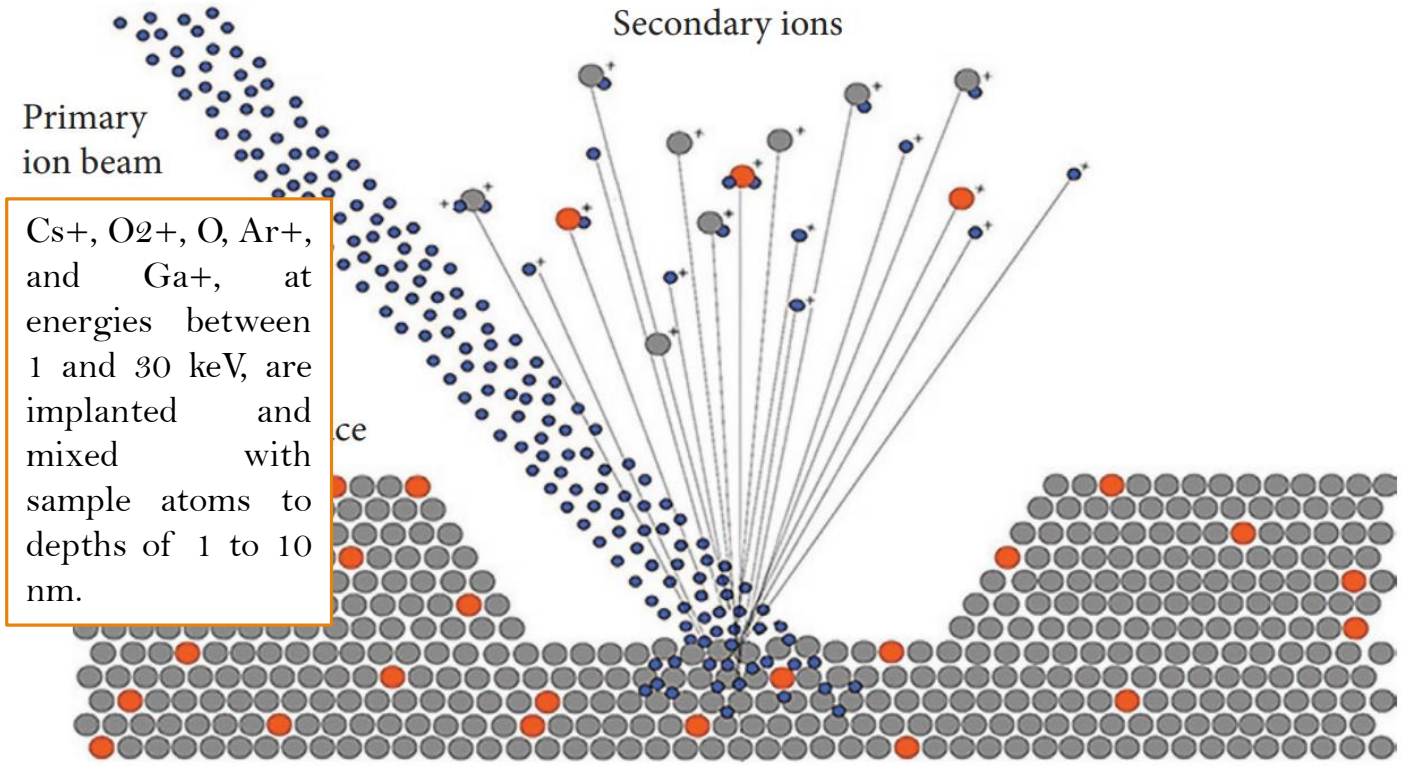
Secondary Ion Mass Spectrometry (SIMS)



Cs+, O2+, O, Ar+, and Ga+, at energies between 1 and 30 keV, are implanted and mixed with sample atoms to depths of 1 to 10 nm.

Fig. 3. Schematic illustration showing the SIMS sputtering and ionization process.

Application in Materials Science.
*provides localized elemental, isotopic and molecular characterization of the sample surface.
*insulators, semiconductors, metals and biological samples.

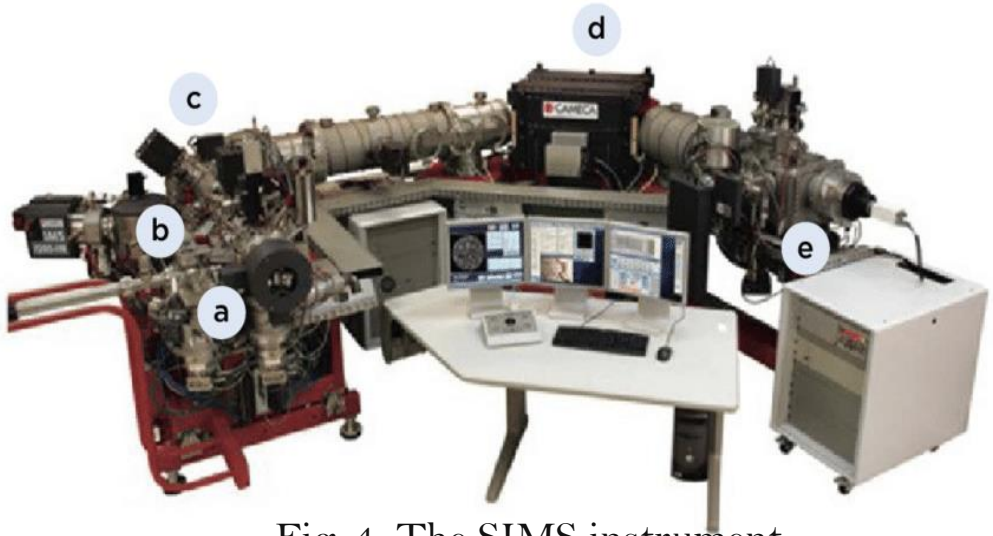


Fig. 4. The SIMS instrument
(a) sample chamber, (b) primary ion source, (c) electrostatic analyser, (d) magnet and (e) detection unit.

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Low Energy Ion Scattering (LEIS)

The elemental composition of the outermost atomic layer of a material, and provides depth profile information about its outer ca. 10 nm.

LEIS is useful for studying:

- the relationships between surface chemistry and surface related phenomena such as wetting, adhesion, contamination, and thin film growth.

Method	Ion beam	Beam energy	Beam current
LEIS	He^+	8 keV	5.6 nA

Typical ion currents range **from 0.1 to 50 nA**.

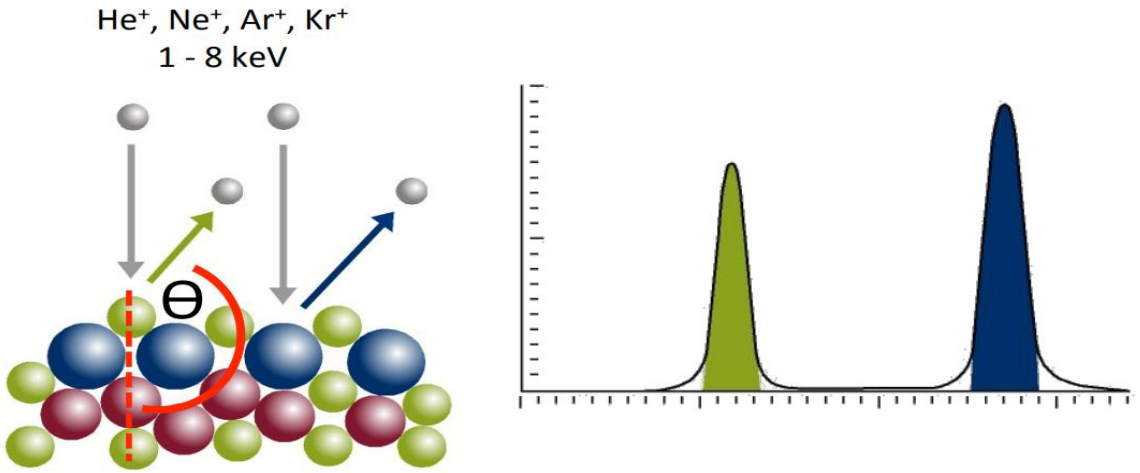

Fig. 5. (Left) Noble gas ion bombardment of a surface with two types of exposed atoms. (Right) LEIS signal corresponding to the surface on the left. Note that there is no LEIS signal from the 'red' atoms.

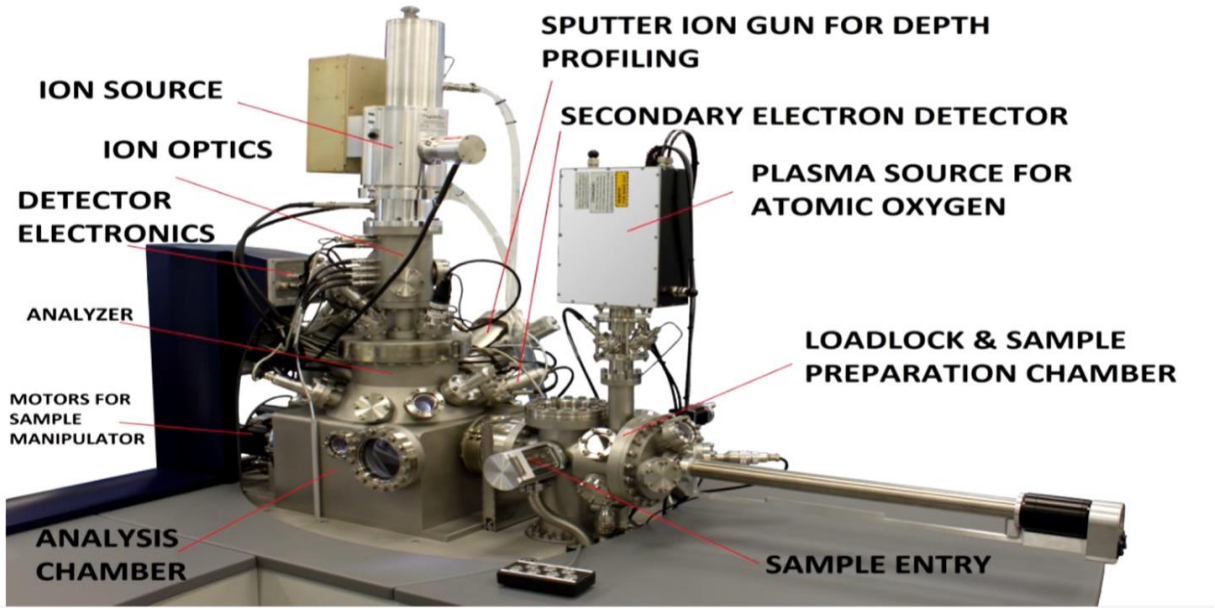

Fig. 6. The real system of components for LEIS

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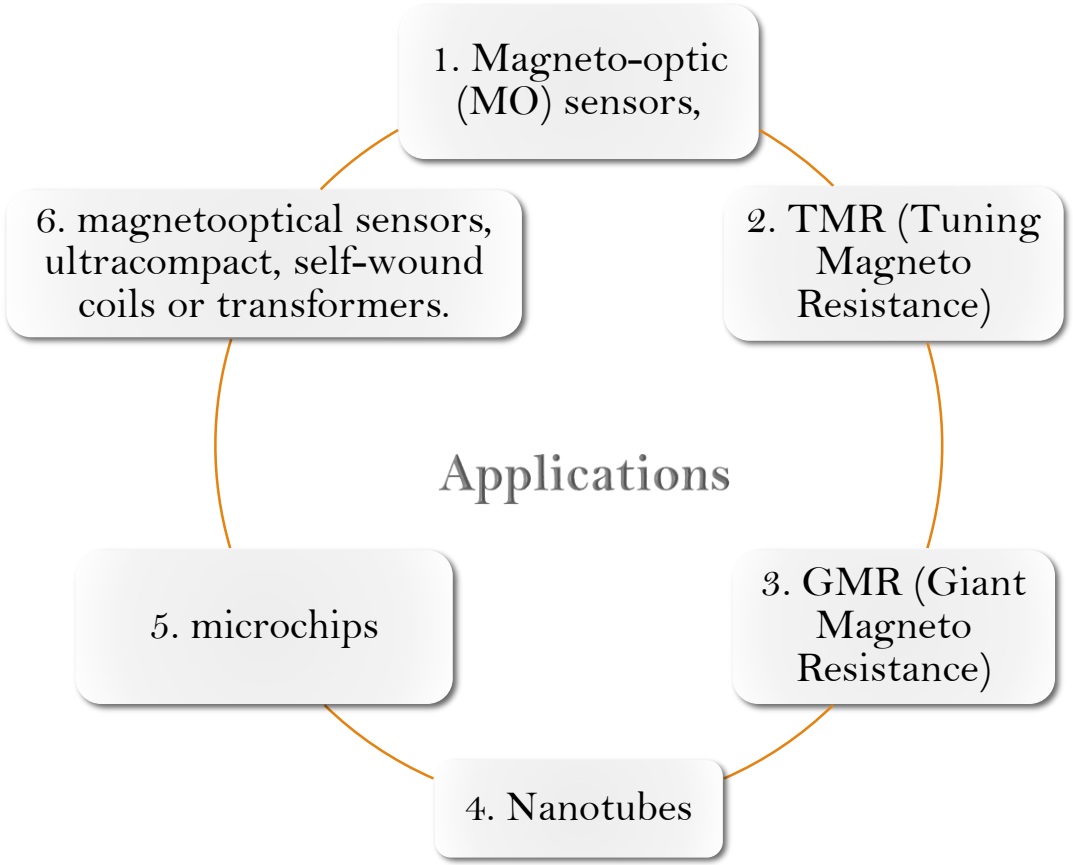
Modification of Magnetizable Multilayer Systems by Ion Implantation

Magnetizable thin films are irradiated with ions- radiation damages in the films, which affects their (magneto-) optical and (magneto-) electrical properties.

The chemical composition of the thin films.

An industrial application.



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Stellar Physics at keV energies

Nuclear fusion reactions

Ideal place to measure cross section of nuclear reaction of astrophysical interest.

Energies needed for nuclear reactions in the Sun are 1.6 keV, and in red giants stars 10 keV.

Emited photons or charged particles.

LUNA project

Ion Source	Ion beams	Current of beams
Radio- frequency	H^+	1 mA
	He^+	(300 – 500) μA

$^3He(^3He,2p)^4He$ & $^2H(p,\gamma)^3He$
$^2H(^3He,p)^4He$

Fig. 7. Inside LUNA

-Ion duoplasmatron source,

-An ion-beam extraction.

- Acceleration system,

- A double-focusing 90° analyzing magnet

Components for the LUNA.

Low Energy Ion Beam Biology Research

Ion Beams of a few tens keVs.

Seeds were bomarded with N ions.

Energy (30-60) keV

Fluences $10^{16}\ \frac{ions}{cm^2}$

For inducing mutation breeding and gene transfer.

- modification of horticultural plants
- a broad spectrum of mutants has been obtained including changes in phenotypes such as the flower color, color intensity, flower shape, petal shape and size

RF- (radiofrequency) driven multicasp plasma source- 30 keV

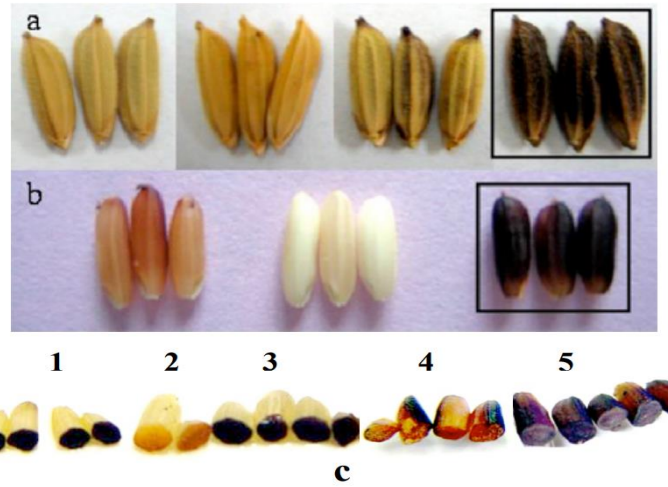

Fig. 8. Ion-beam-induced mutations of purple rice

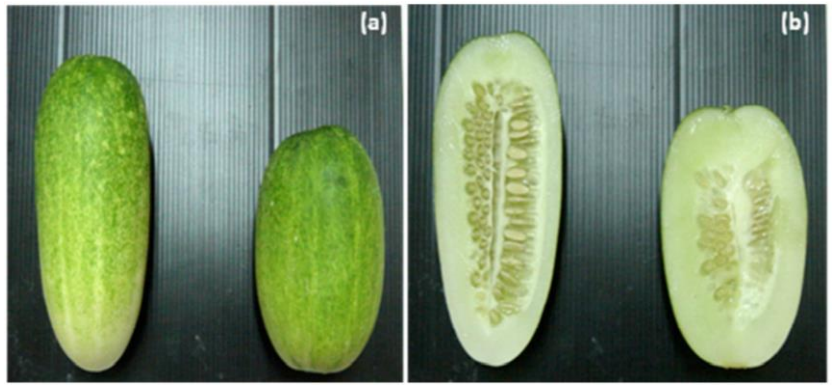

Fig. 11. Effect if ion beam reproductive organ of cucumber
a) and b) control (left) hybrid (right)

Fig. 10. Ion-beam- induced color variation in Gerbera flower petal (original color should be red)

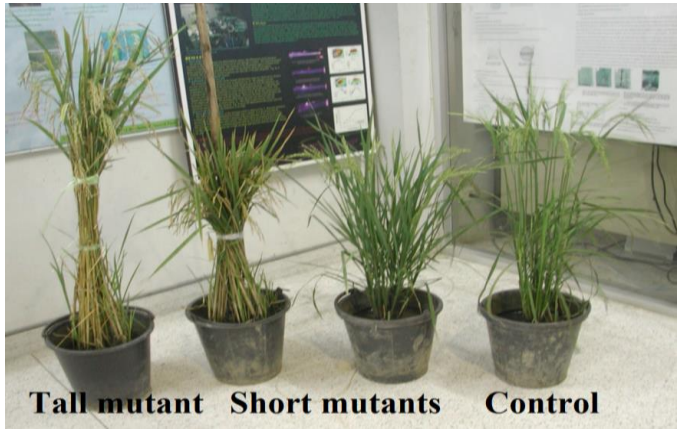

Fig. 9. Ion- beam induced mutants showing the straw stem height change

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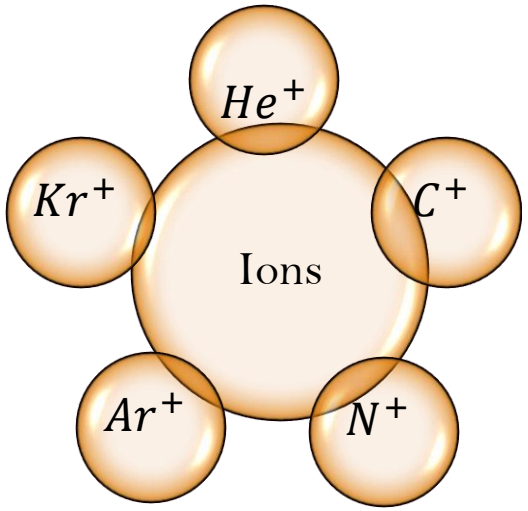
Application of ions on graphene nanomaterials

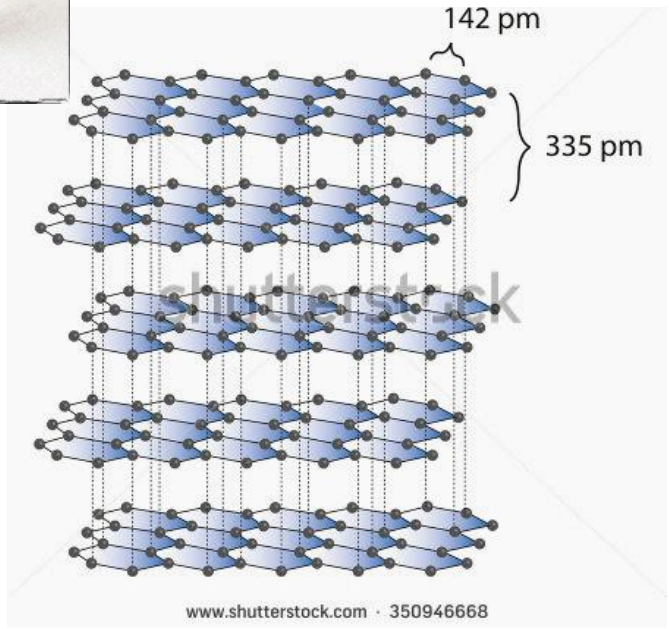
Bombarding graphene materials with accelerated ions controls the types and number of structural defects.



Energy

from 50 eVs

to a few hundred keVs.



The possibility of controlling the types and number of vacancies by choosing a corresponding ion type and its velocity.

Research and practical application of these systems.

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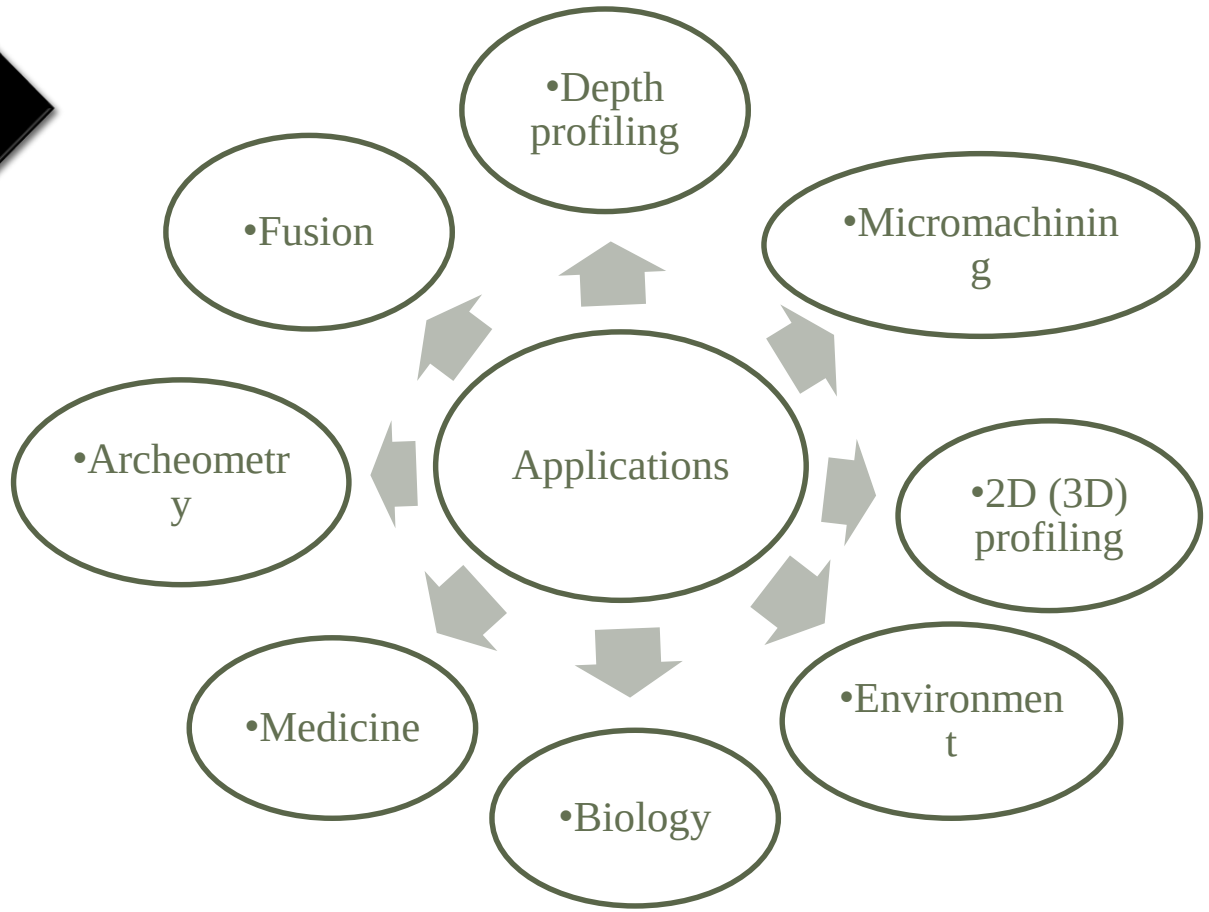
RFQ provides...

MeV energies



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Particle Induced X-rays Emission- PIXE

a)1. Proton/helium ions beam.

2. Ionized atoms try to stabilize by attracting electrons (from outer shells) leading to photon emission – quantum x-rays.

3. Energy of X-ray- identification card of the element.

4. X-ray energy (wavelength)- identification of atom that emitted x-ray!

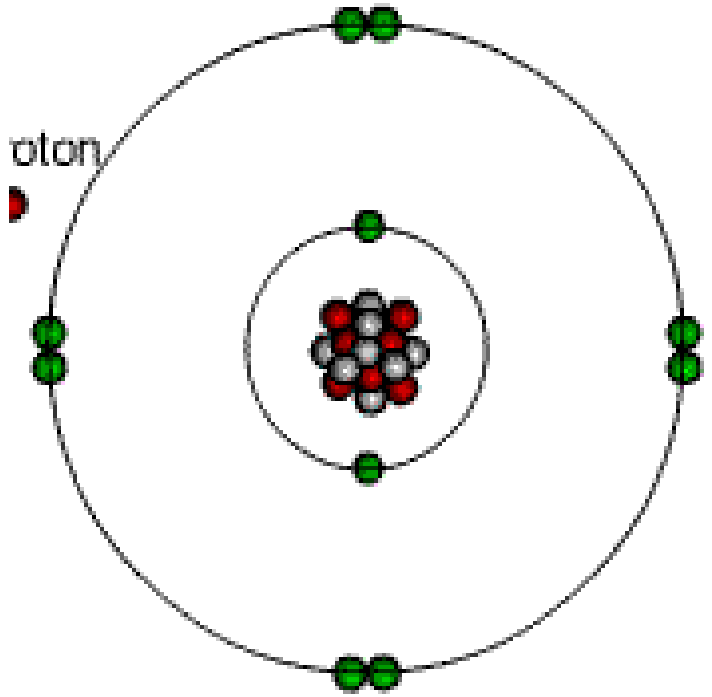

Fig 12. PIXE mechanism

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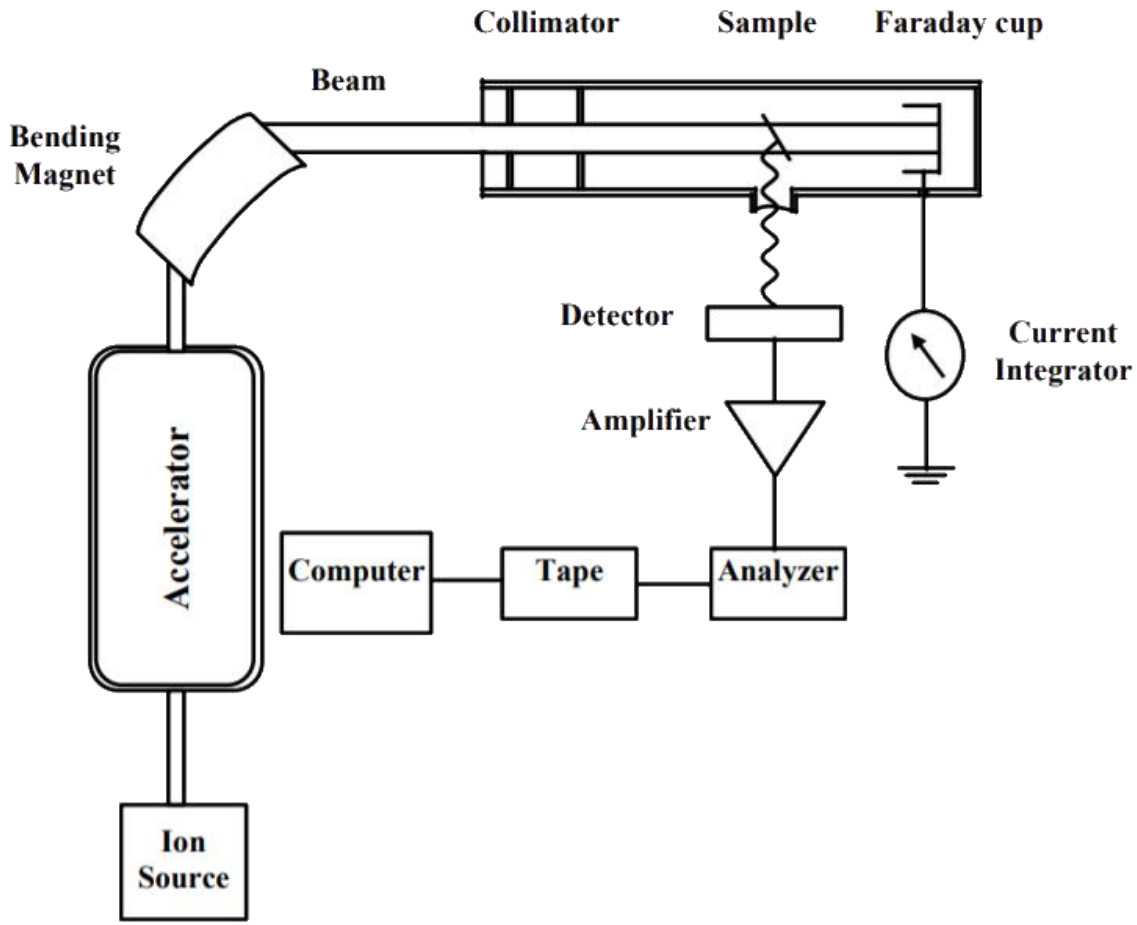

Fig. 13. Typical arrangement for the PIXE technique

The Van de Graaff accelerator

Energies of (2-3) MeV for protons and twice that to doubly charged helium ions.

Several tens of μA current is generated by the accelerator.

*(1-10) nA are currents for the PIXE

*larger currents - pile-up effect

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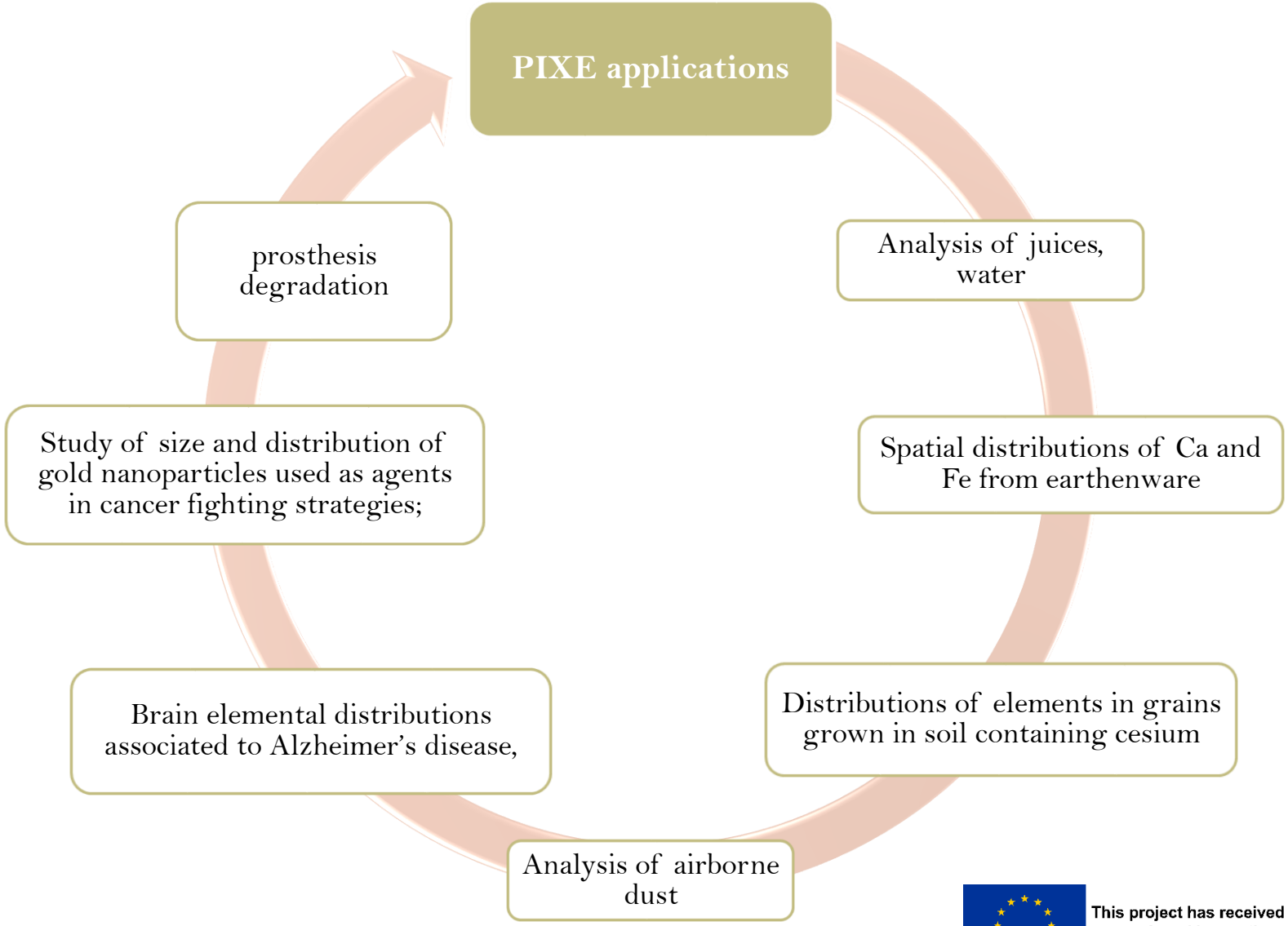

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Interesting application- µPIXE technique

The 2 µm thick tissue slices layered on the object glass

3 MeV proton beam of size 1x1 μm^2 and analytical ion current up to 300 pA

*the optical microscope

*the potential presence of the metallic particles

High amounts of metal elements (Ti, V or Al) in blood- rough estimation of the degree of prosthesis degradation.

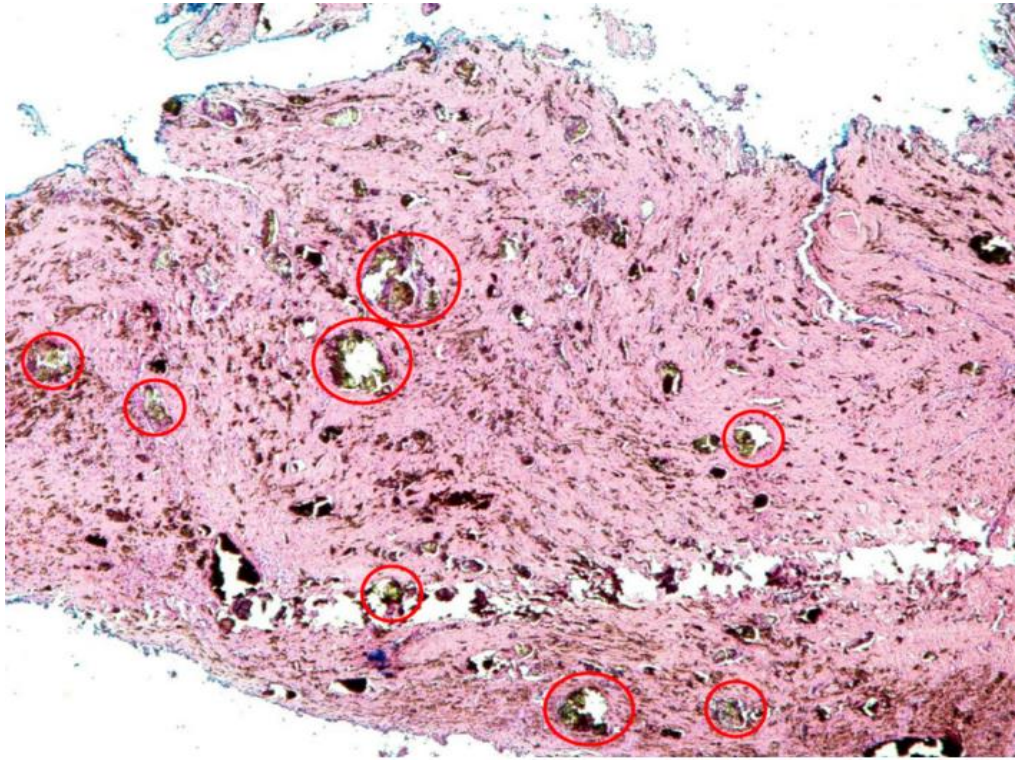

Fig. 14. Corresponds to a microphotograph taken with at 40X from a 2 µm thick slice stained for pathological examination using Hematoxylin and Eosin. The candidates to metallic particle (in yellow-green color) are marked with red circles.

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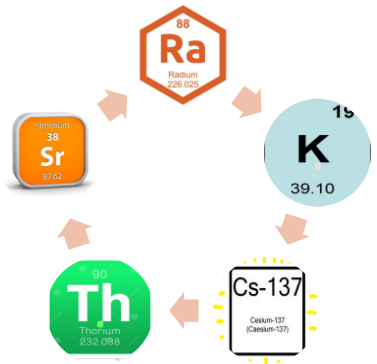
Maybe we can use PIXE...

Determining the presence of radionuclides (natural and artificial origin) in the environment.

The aim is to assess the risk of exposure of the population to ionizing radiation.



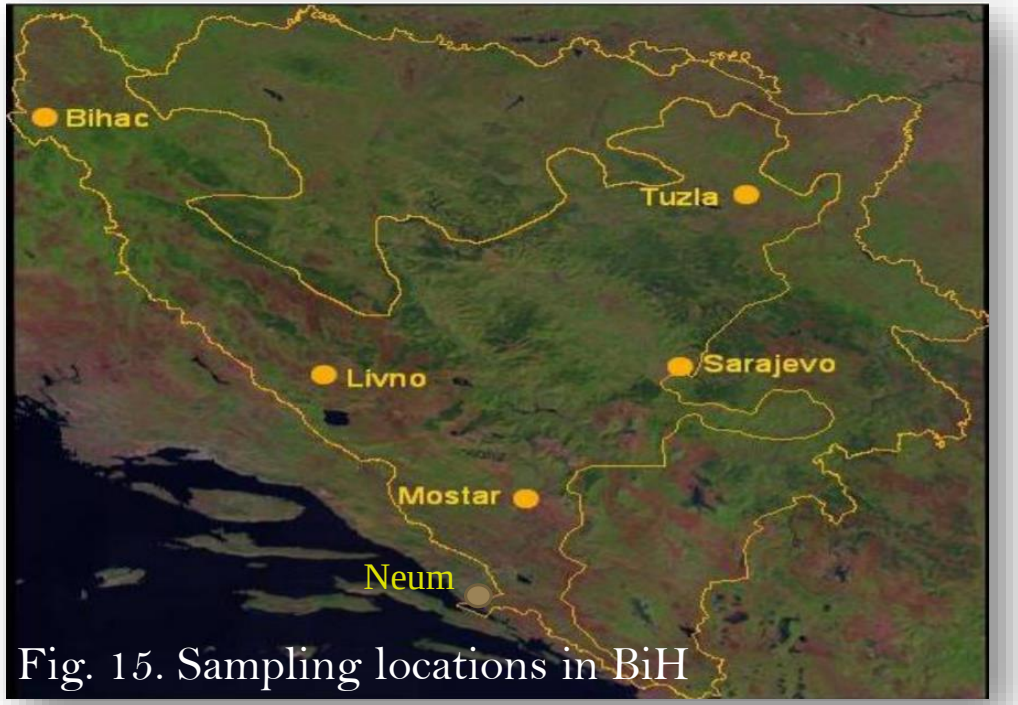


Fig. 15. Sampling locations in BiH

Natural radionuclides in food and water samples that can be detected in B&H are K^{40}, Ra^{226} and Th^{232} and artificial ones Cs^{137} and $Sr^{89/90}$.

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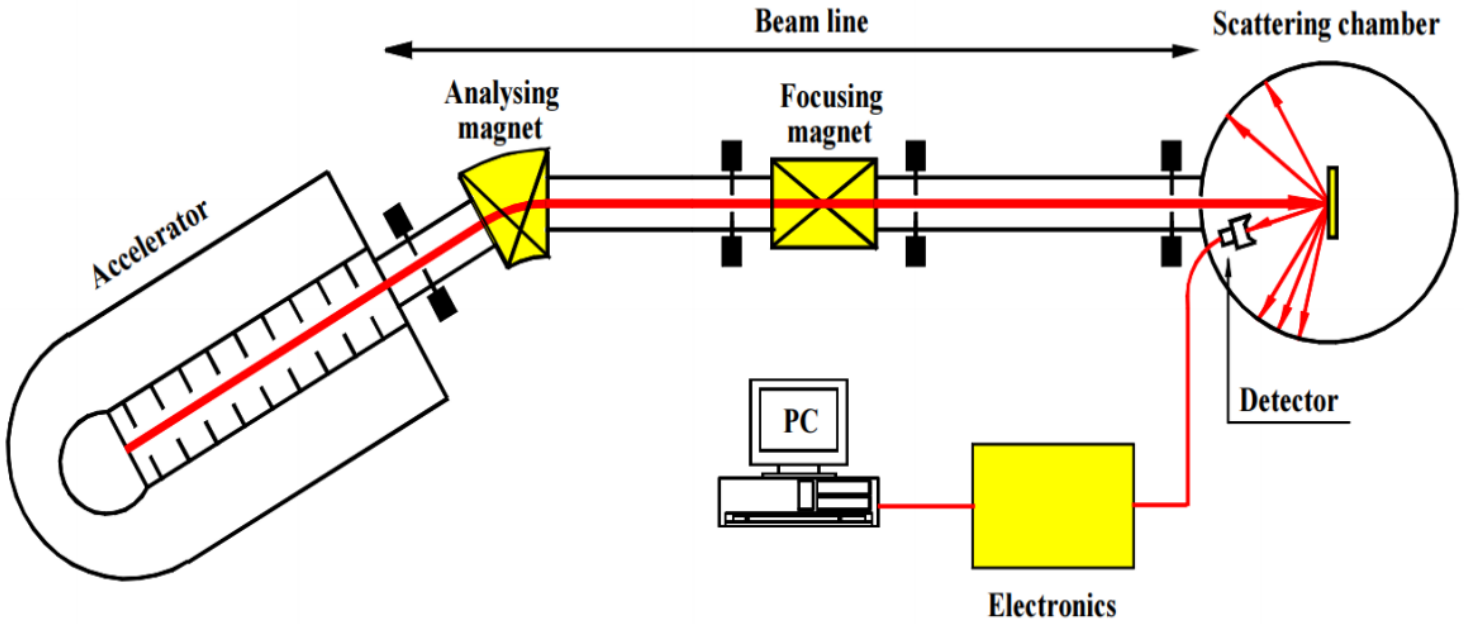
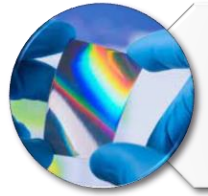
Rutherford Backscattering Spectrometry (RBS)

The RBS method- in a combination with the PIXE method.

Application of the RBS- the composition of material and profile depth of 2 μm for α particles, and up to 20 μm for protons.

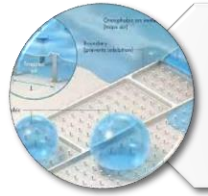


(a) metallurgy



(b) solid-state physics

(c) electrochemistry



(d) surface science

Figure 16. Schematic overview of the RBS set-up

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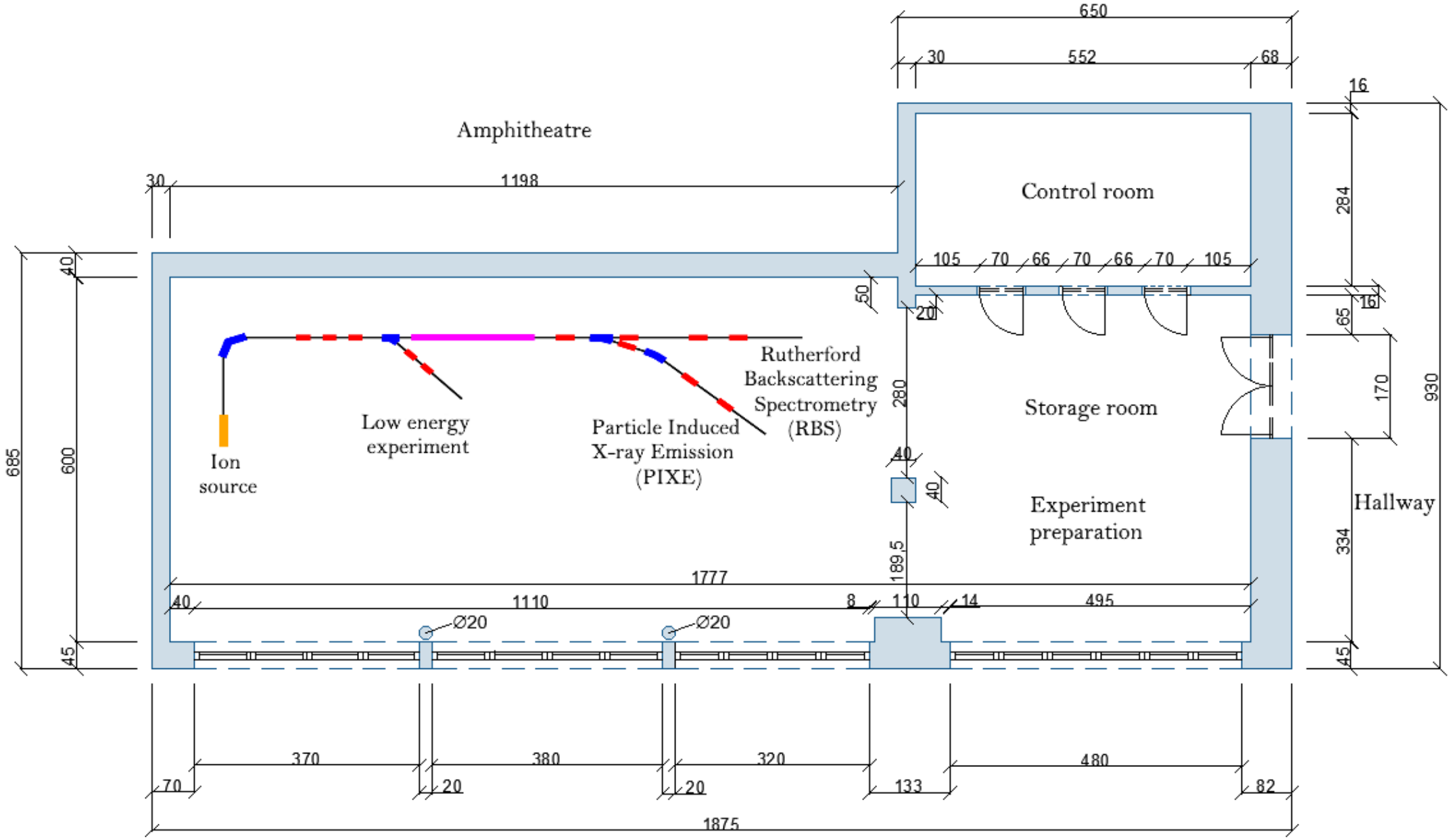
An Auto CAD drawing of a possible setup in a room located in the building of the Faculty of Science in Sarajevo



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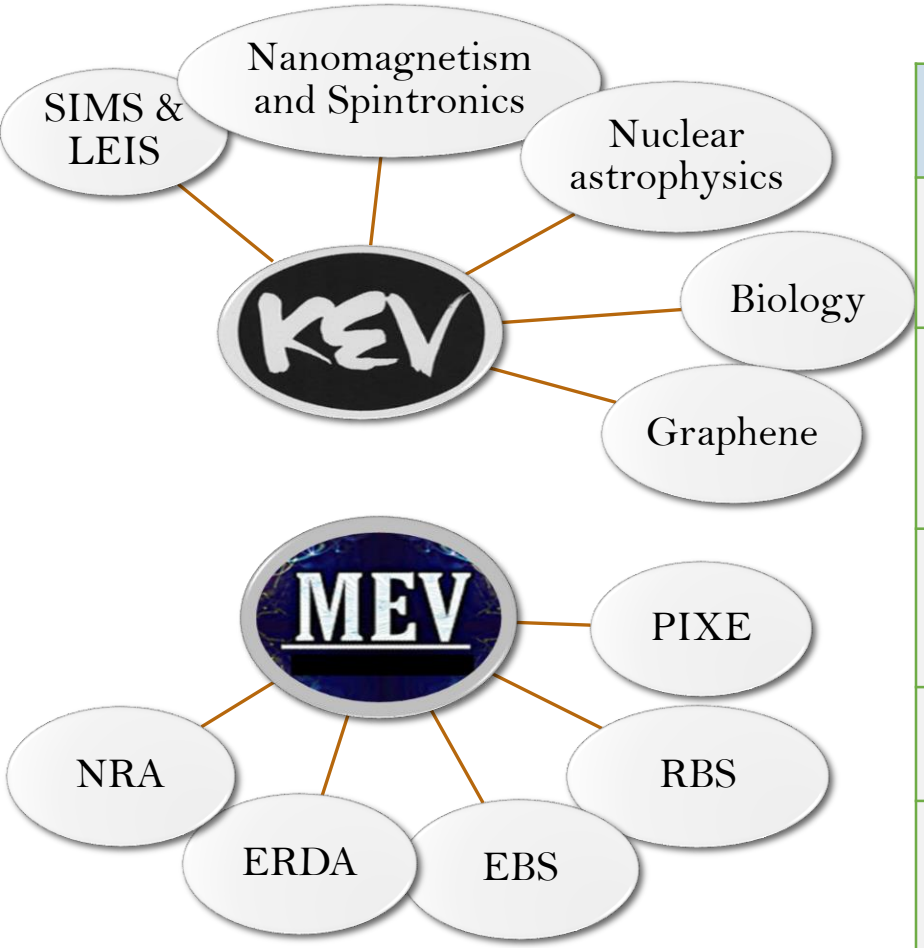
Summary



Application (keV energies)	Viability	Remarks
SIMS, LEIS	rather not	Nanogan source can produce O+, O2+ and Ar+, much weaker beam currents required, other equipment, electrostatic analyzer is expensive.
Ion implantation	possible	Right intensities, additional equipment not very expensive, but low energies limit depth of implantation – requires interest from local scientists.
Graphene nanomaterials	possible	At the Chemistry department exist strong interest in this application.
Stellar physics	rather not	Other equipment (detectors) quite expensive, need strong interests from local physicists.
Biology, Agriculture, Microbiology, and Medical science.	possible	Need interests from local scientists.

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Thank you!

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