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IMPLEMENTATION OF HIGH ENERGY HEAVY ION INDUCED ERDA AT JANNUS SACLAY

P. Trocellier[1], Y. Serruys[1], F. Leprêtre[1], S. Vaubaillon[2,1], T. Loussouarn[1], S. Miro[1], S. Moll[3], H. Lefaix-Jeuland[3] and L. Beck[1]

[1] CEA, DEN, Service de Recherches de Métallurgie Physique, Laboratoire JANNUS,
[2] CEA, INSTN, UEPTN, Laboratoire JANNUS
[3] CEA, DEN, Service de Recherches de Métallurgie Physique, F91191 Gif-sur-Yvette, France

OUTLINE

CONTEXT

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APPLICATION EXAMPLE

COMPARISON NRA/PES/HI-ERDA

CONCLUSIONS

CONTEXT

📖 **Helium is very present in nuclear industry. Indeed, it can be produced either by neutron induced nuclear reaction or by actinide α-decay. Therefore it is of prime interest to study its diffusion under thermal treatment or irradiation damage in model nuclear materials.**

✎ **Three analytical methods can be used:**

- **Deuteron induced NRA for ^{3}He**
- **Non-Rutherford proton scattering for ^{3}He or ^{4}He**
- **High energy elastic recoil detection analysis for ^{3}He or ^{4}He**

EXPERIMENTAL DEVICE

BEFORE **Single beam chamber** **AFTER**

- 4 manual micrometric stages (X, Y, Z, Theta) - 4-axis driven stages
- 1 surface barrier detector (SBD) (manual rotation) - 2 SBD (motorized rotation)

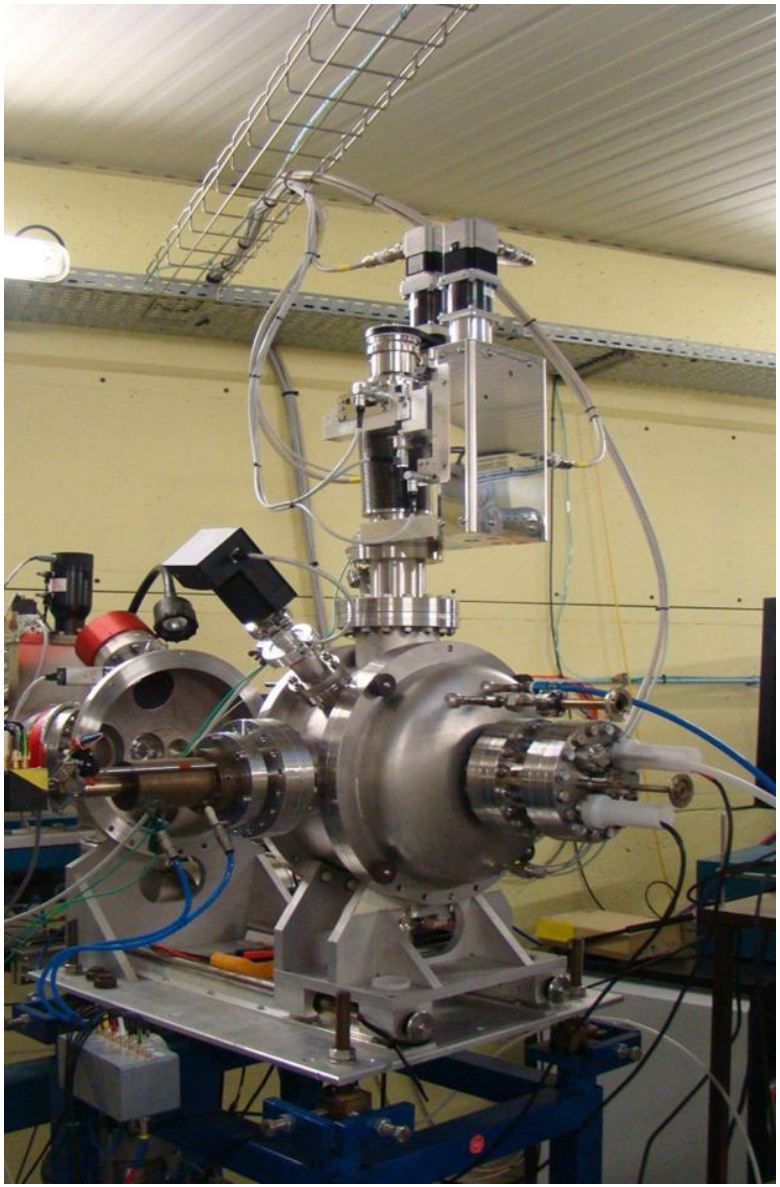
+ 270 V polarized sample holder

- 1 fixed filter holder

beam entrance collimator (polarized ring for electron rejection)

- 1 single ADC - multi-detection (2 ADC)

NEW CONFIGURATION



HYDRA acquisition software (LabView environment)

APPLICATION EXAMPLE

ANALYSIS CONFIGURATION

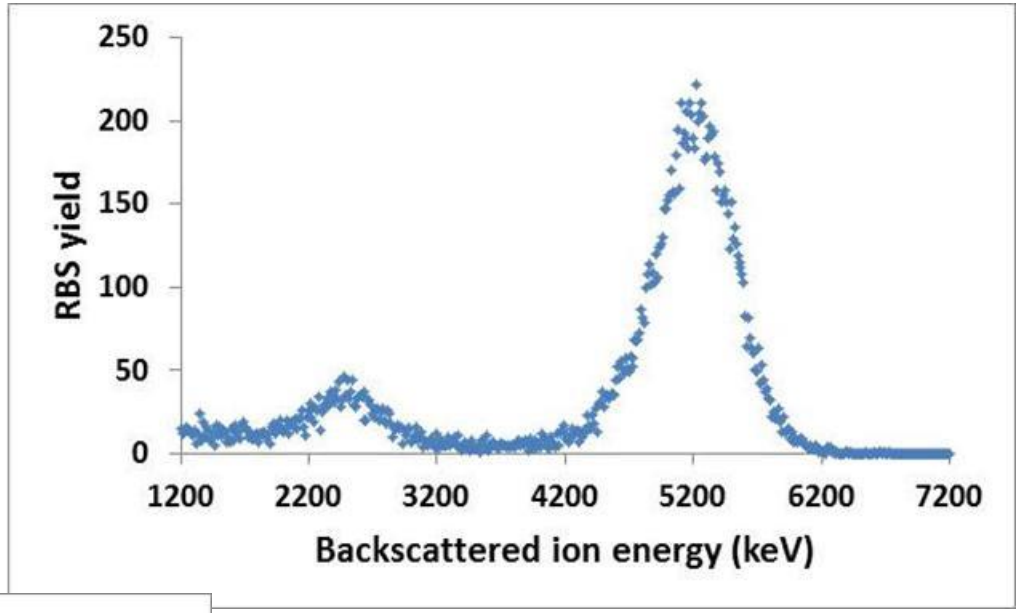
$^{16}O^{5+}$ 15 MeV
incidence angle 75°
recoil angle 30°
9 µm Al

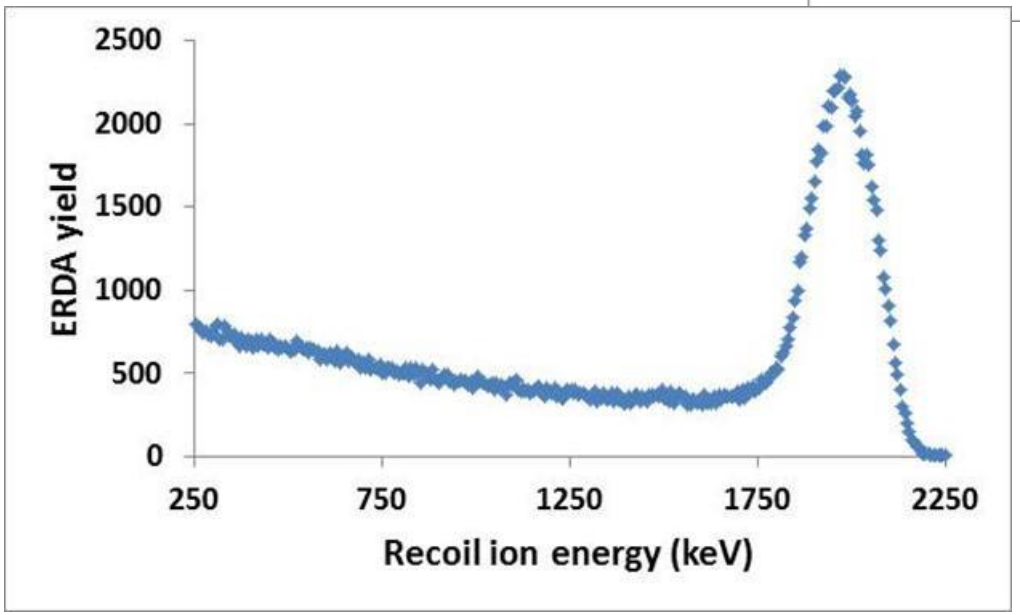
2 standard targets:
0.4 nm Au/Pd coating on Al
40 nm Au coated thick kapton foil

2 pure α-Fe (99.95 %) samples implanted at 60 keV with $^{4}He^{+}$: (theoretical fluences: 5 x 10^{16} and 1 x 10^{17}/cm^{2})

APPLICATION EXAMPLE

TEST ON THE Au/Pd COATING
(energy calibration)



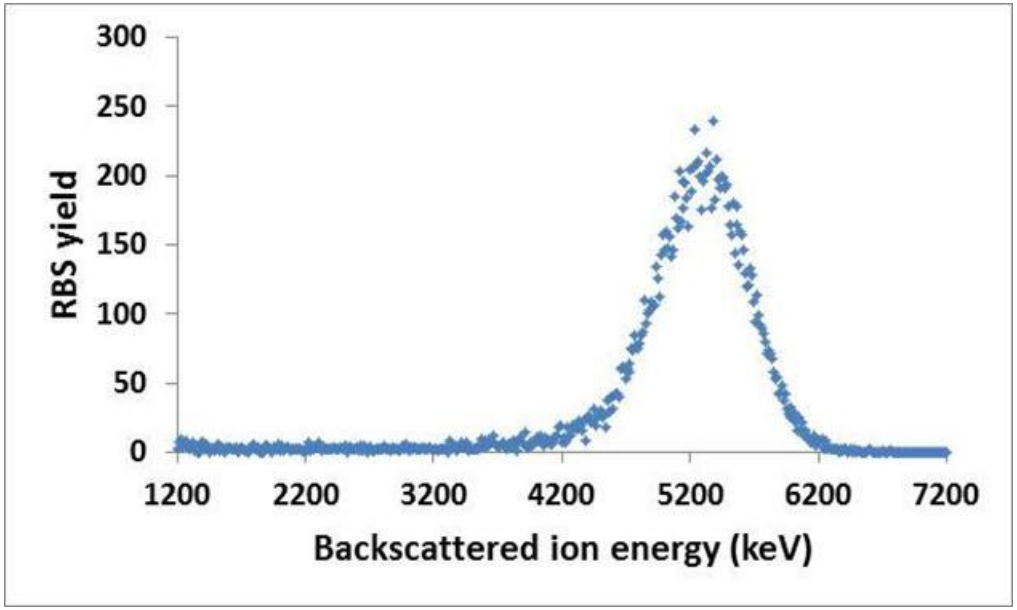


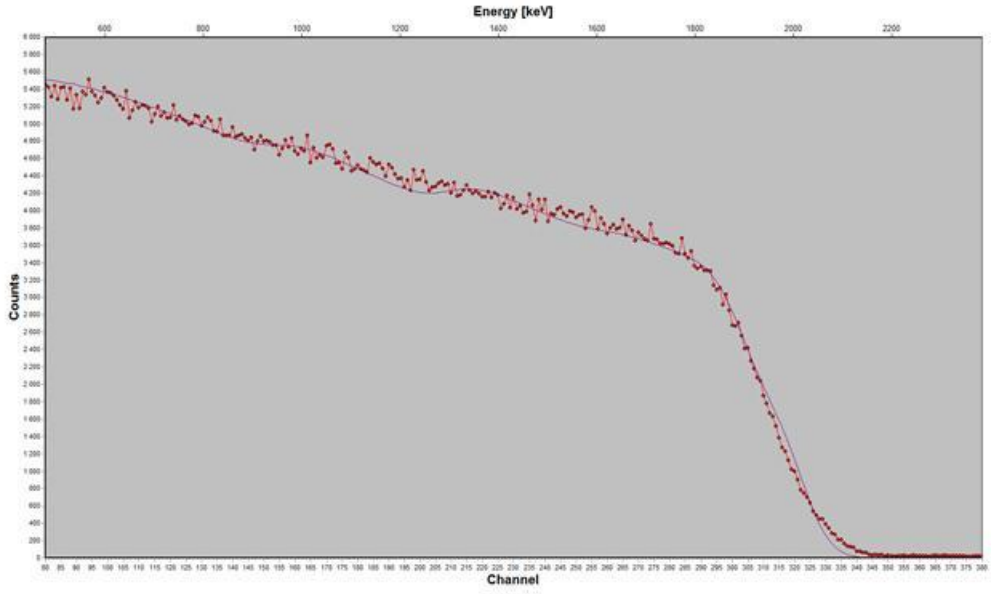
RBS data

HI-ERDA data

APPLICATION EXAMPLE

TEST ON THE THICK KAPTON



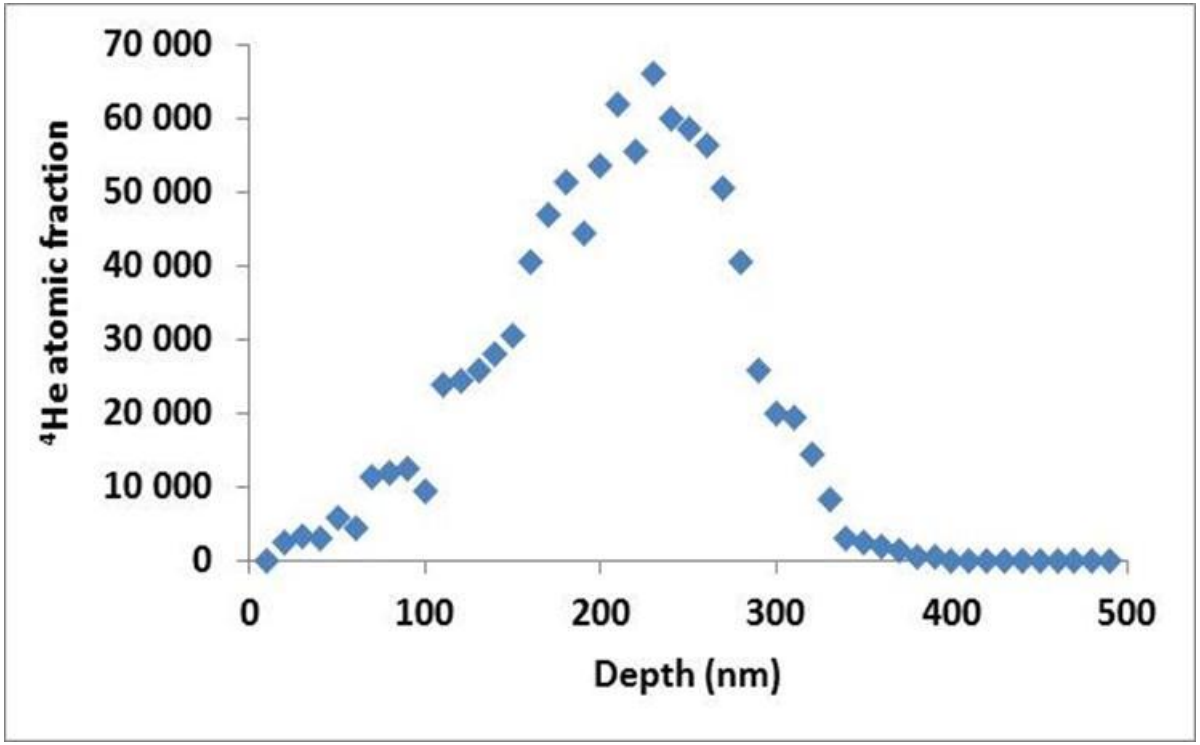


RBS data
(used to monitor the incident ion dose in SIMNRA fitting)

HI-ERDA

APPLICATION EXAMPLE

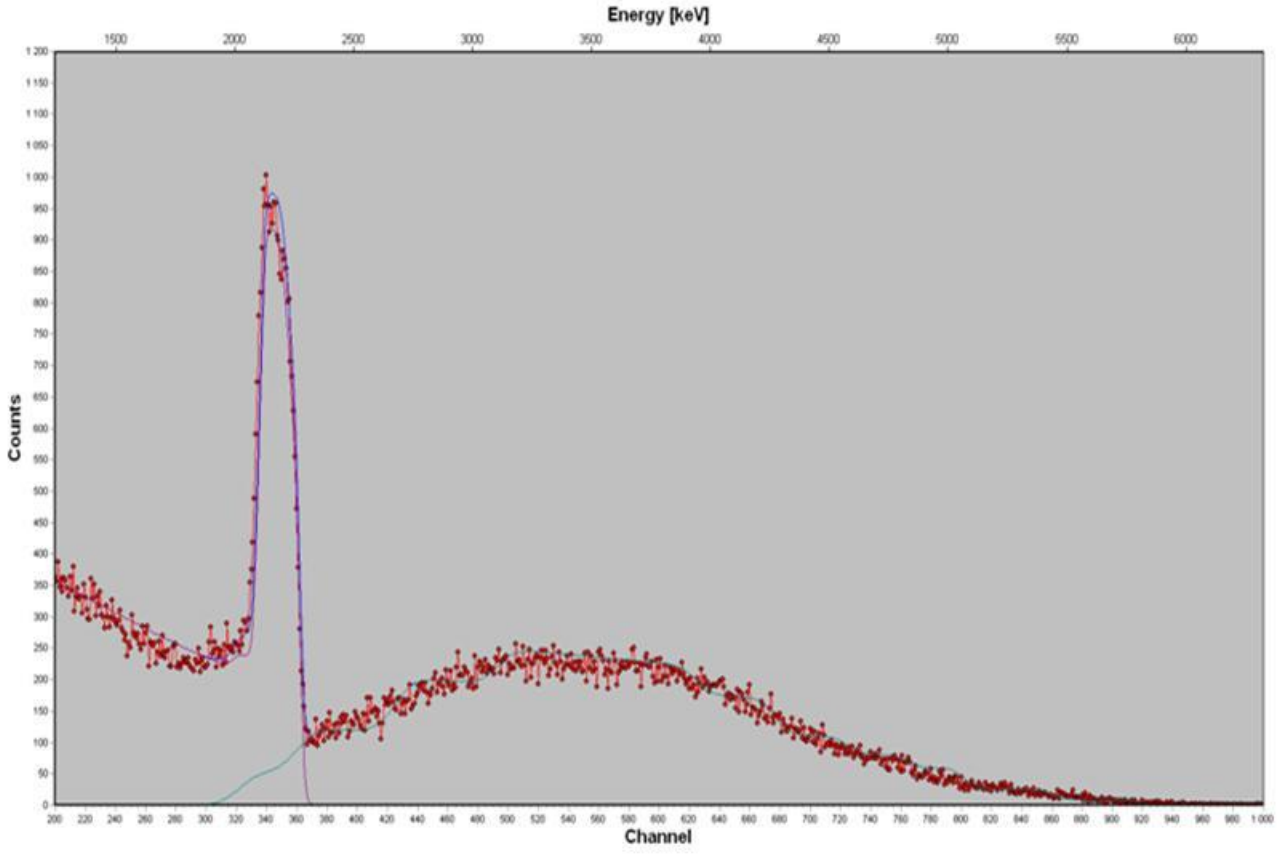
THEORETICAL CALCULATION



Theoretical SRIM depth profile for a 60 keV ^{4}He implantation in pure Fe

APPLICATION EXAMPLE

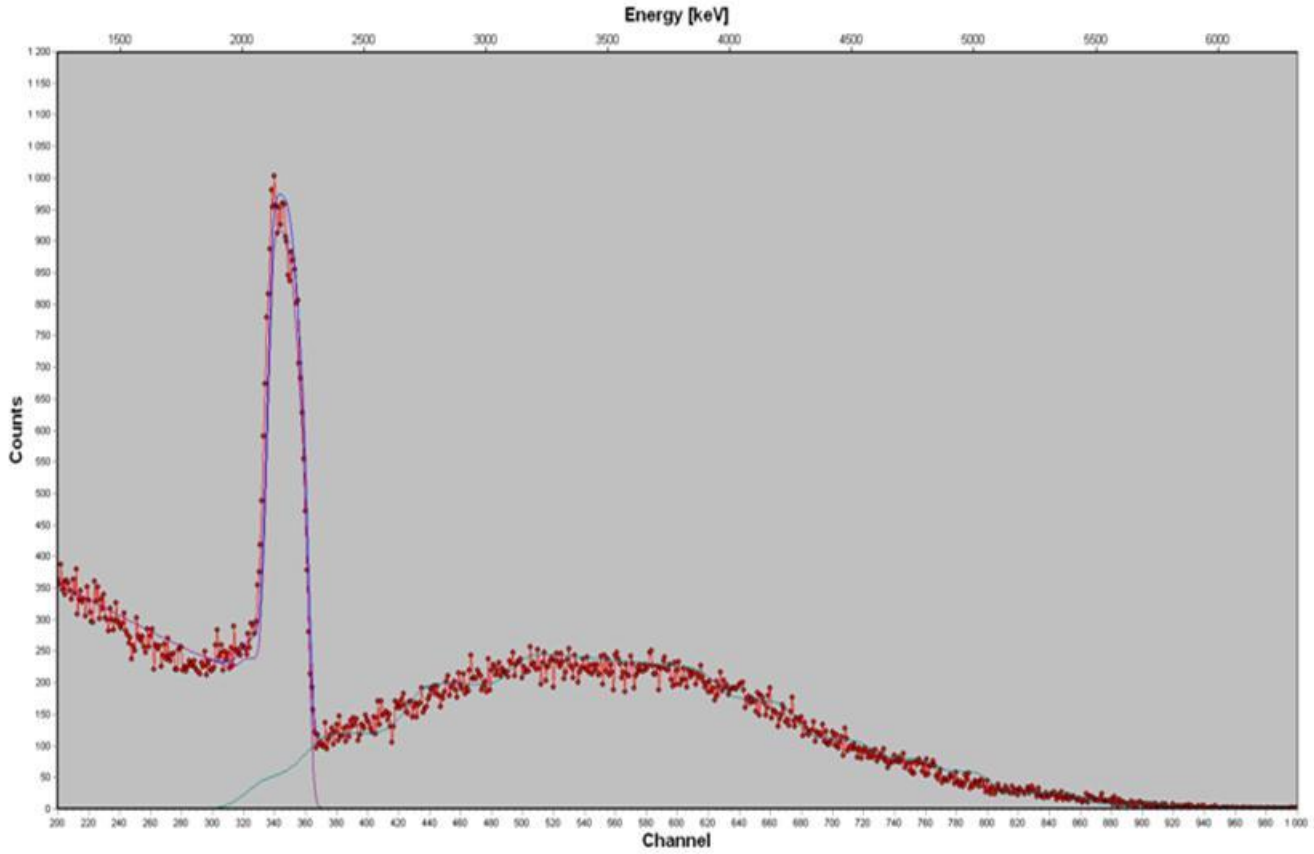
ANALYSIS SAMPLE 1



HI-ERDA spectrum for « 5 x 10^{16} He/cm^2 » implanted sample

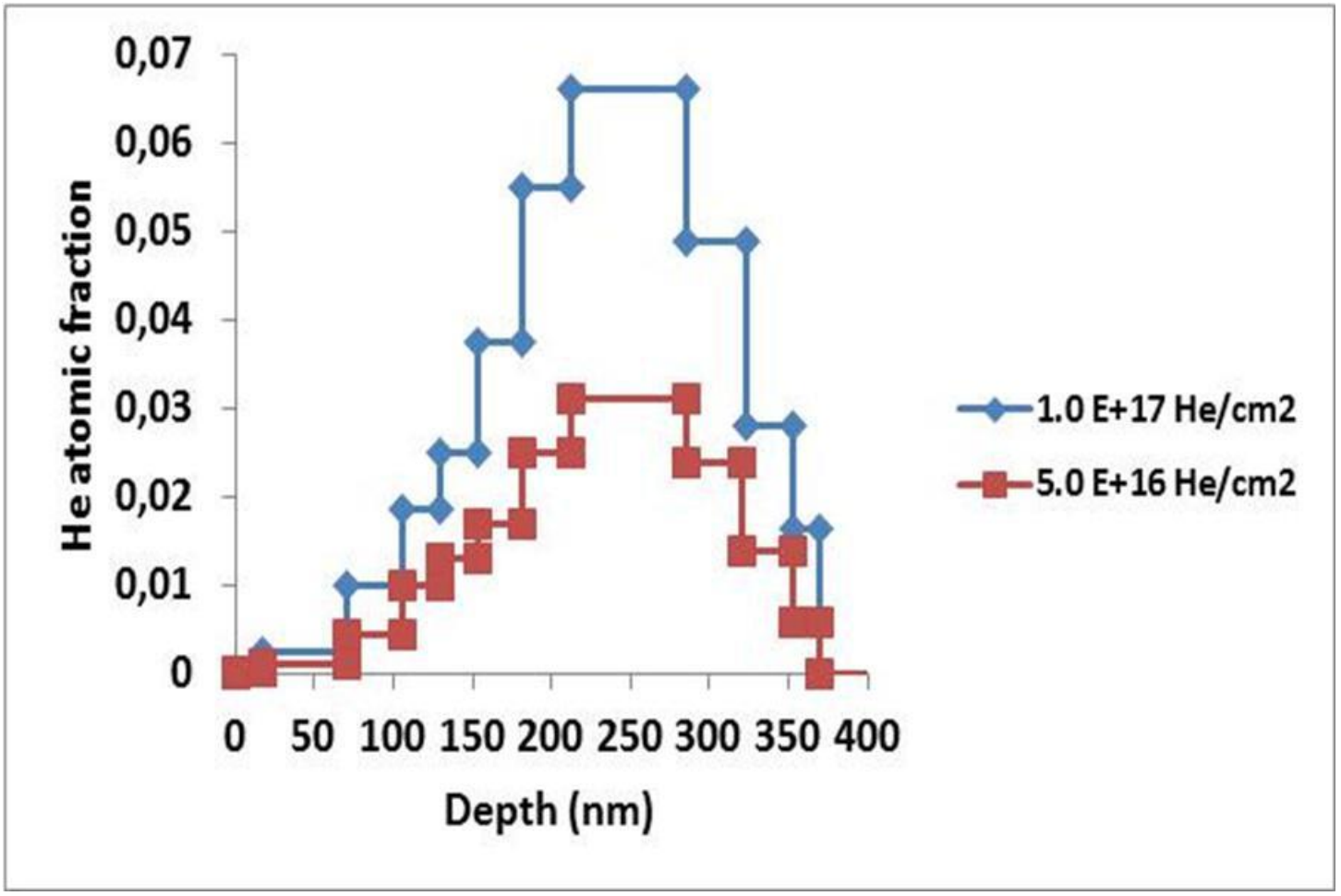
APPLICATION EXAMPLE

ANALYSIS SAMPLE 2



HI-ERDA spectrum for « 1 x 10^{17} He/cm^2 » implanted sample

APPLICATION EXAMPLE



Comparison of the ^{4}He depth profiles (via SIMNRA)

COMPARISON NRA/PES/HI-ERDA

	NRA	PES	HI-ERDA
	$^{3}He(d, p_0)\alpha$	$^{4}He(p, p)^{4}He$	$^{4}He(^{16}O, ^{16}O)^{4}He$
	$E_d \geq 500$ keV	$E_p \geq 2$ MeV	$E_O = 15$ MeV Tilt ~ 75°
Analyzable depth	≤ 10 µm	< 5 µm	≤ 1 µm
Depth resolution	0,1 – 0.2 µm	0.08 µm	0,05 µm
Sensitivity	10^{15} at./cm^2	5 x 10^{16} at./cm^2	10^{16} at./cm^2

CONCLUSIONS

HI-ERDA appears to be a very powerful method to determine ^{4}He depth profile in the near region of solid surfaces. The analyzable depth depends on the capabilities of the accelerator used in terms of mass and maximum energy of the incident ions. At JANNUS, we successfully tested the possibility offered by a 15 MeV $^{16}O^{5+}$ ion beam to measure the implantation profile of ^{4}He in the first 300 nm below the surface of pure iron samples.

The recalculated doses using SIMNRA are $(4.82 \pm 0.50) \times 10^{16}$ /cm^2, and $(1.02 \pm 0.10) \times 10^{17}$/cm^2 respectively.

HI-ERDA seems to be a good complement of deuteron-induced NRA $^{3}He(d, p_0)\alpha$ and proton enhanced scattering $^{4}He(p, p)^{4}He$ to study helium migration in the near surface region of solids.