The latest development of the 1.7 MV tandem accelerator in Beirut

Mohamad Roumié

Accelerator Laboratory

Lebanese Atomic Energy Commission

National Council for Scientific Research

Outlines

- Summary
- IBA Setup & techniques
- IBA applications: case studies
- Perspectives

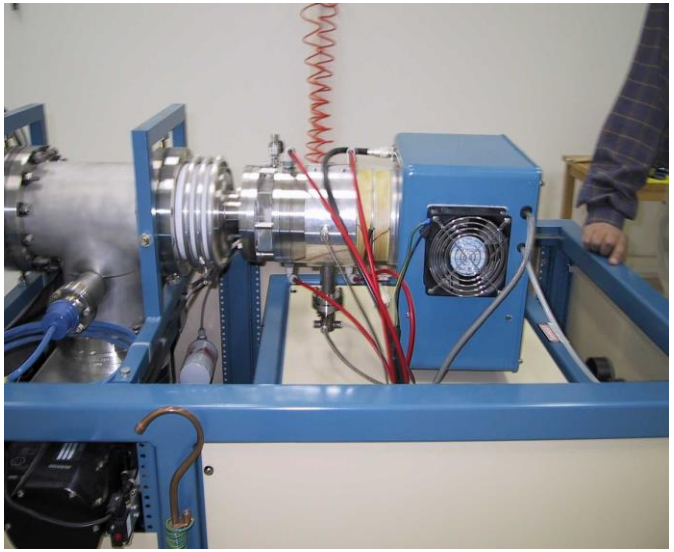
Summary

- Ion beam analysis laboratory based on Pelletron accelerator
- Installation in 1999 within an IAEA TC project
- Performing PIXE, PIGE, RBS/EBS, ERD techniques
- Applications in archeology, environment, pharmaceuticals and materials science
- Large number of samples: coins, soil, sediments, pharmaceutical drugs, aerosol filters and *ceramics*
- Development and upgrading of experimental setup for a better performance and wider applications

Experimental setup & Analytical Techniques

- ✓ 5SDH pelletron tandem accelerator of 1.7 MV from NEC
- ✓ Gupix software package & SIMNRA, **MPAWIN, DppMCA**

- ❖ Alphatross ion source
- ❖ Protons beam:
  0.3-3.4 MeV
  1-200 nA
- ❖ Alpha-particles beam:
  0.5-5.1 MeV
  1-100 nA



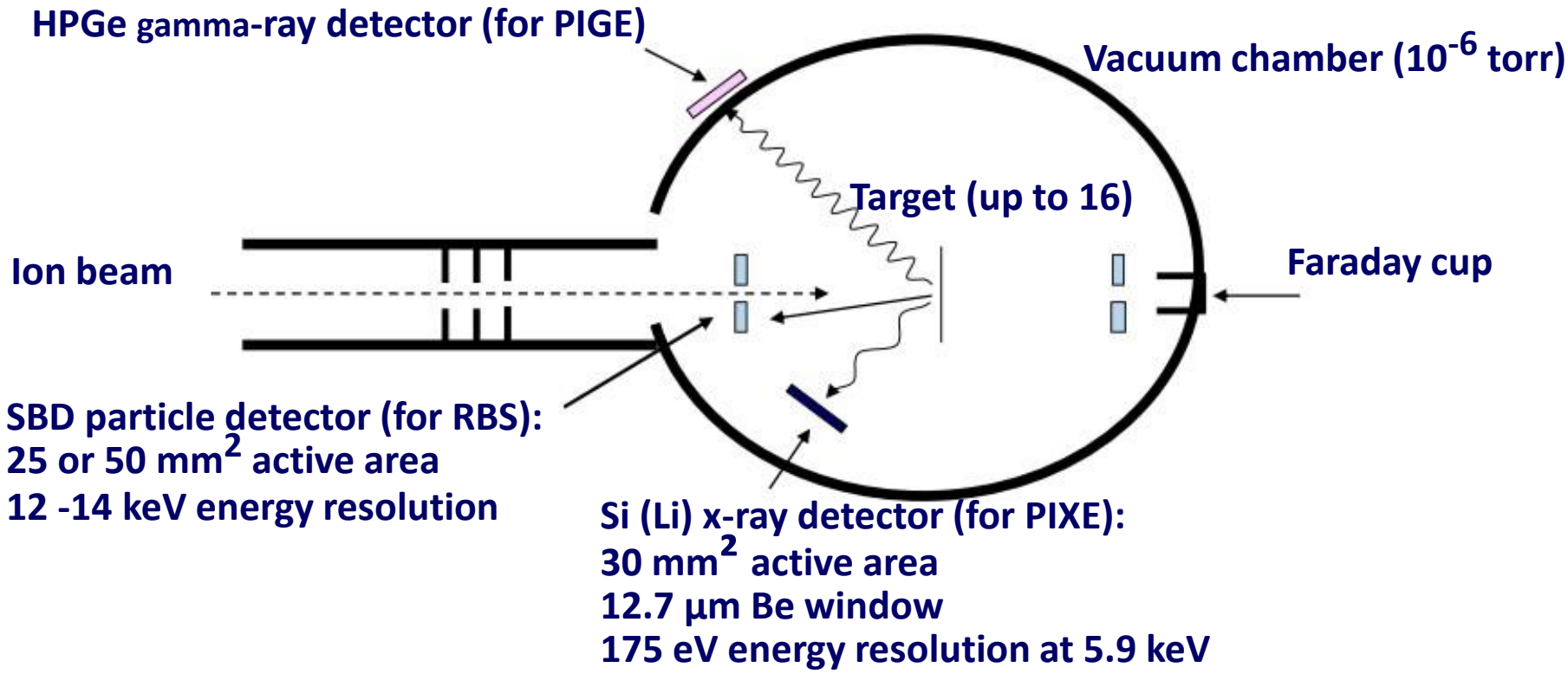
"First Accelerator Based Ion Beam Analysis Facility in Lebanon: Development and Applications",
M. Roumié, & al, *Nuclear Inst. and Methods in Physics Research B* 219-220 (2004) 389.

ION BEAM ANALYSIS TECHNIQUES IBA

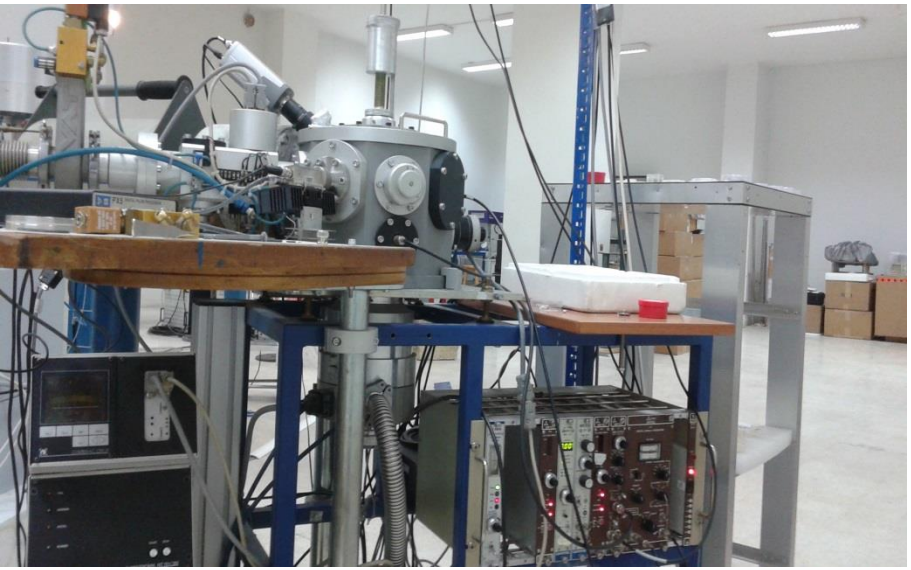
TECHNIQUE	ACRONYM	PARTICLE/RADIATION MEASURED
Particle-Induced X-ray Emission	PIXE	Characteristic x-rays
Rutherford Back-scattering Spectrometry	RBS	Elastically scattered ions in backward angles
Elastic Recoil Detection Analysis	ERDA	Recoiled target nuclei
Nuclear Reaction Analysis	NRA	Prompt product particles or gamma-rays (PIGE)

Often two or more of these techniques are carried out simultaneously in order to obtained complementary information

CONVENTIONAL EXPERIMENTAL SETUP :

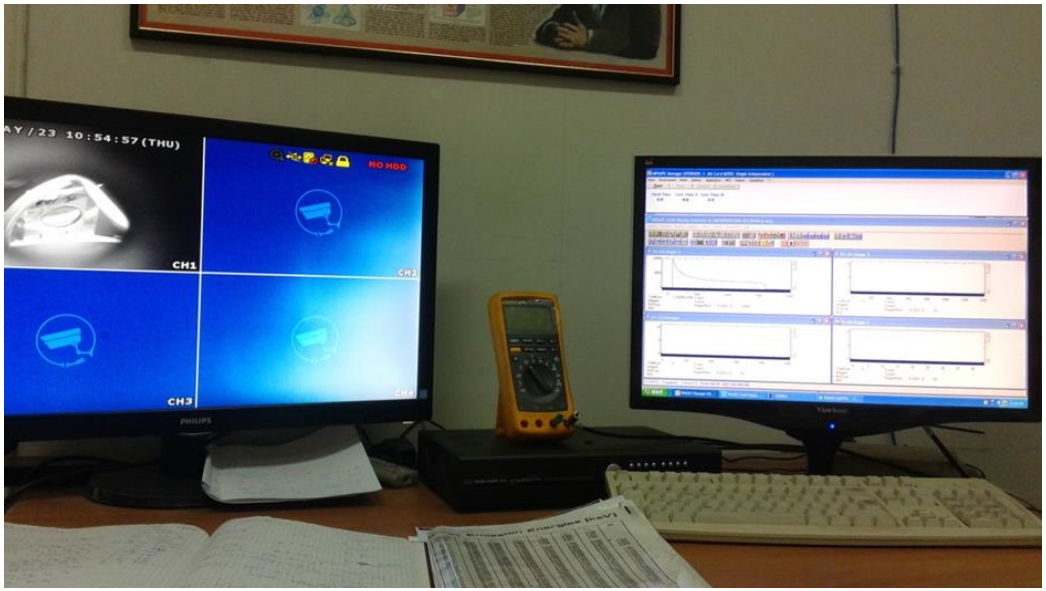


Preamplifier + Amplifier +Current Integrator

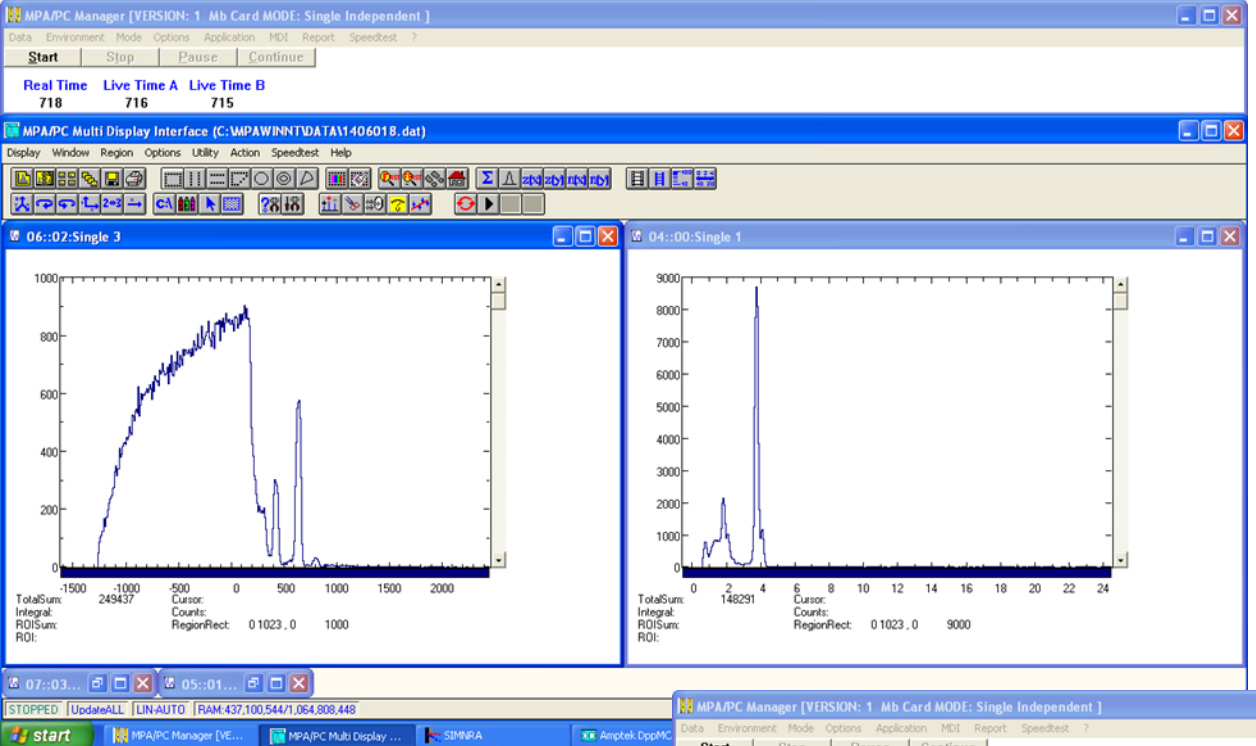


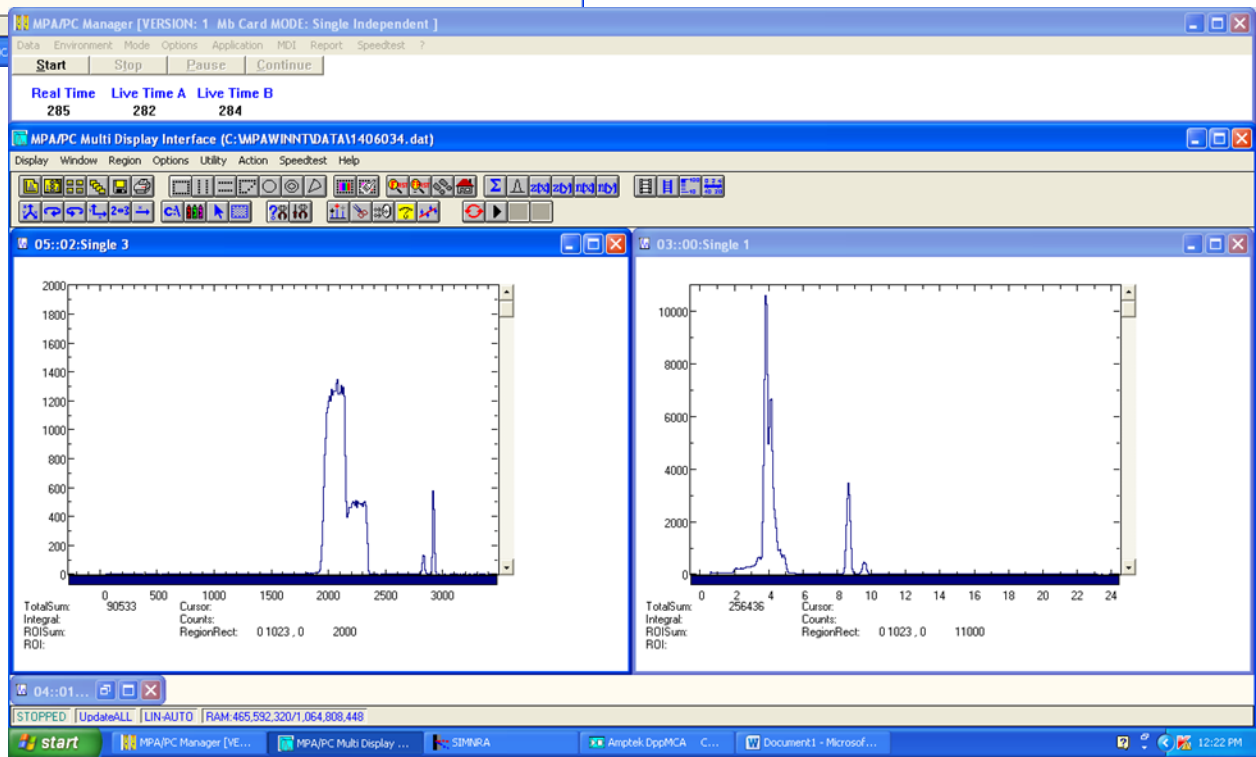
MCA and ADCs (up to 8) and Counter

MPAWIN

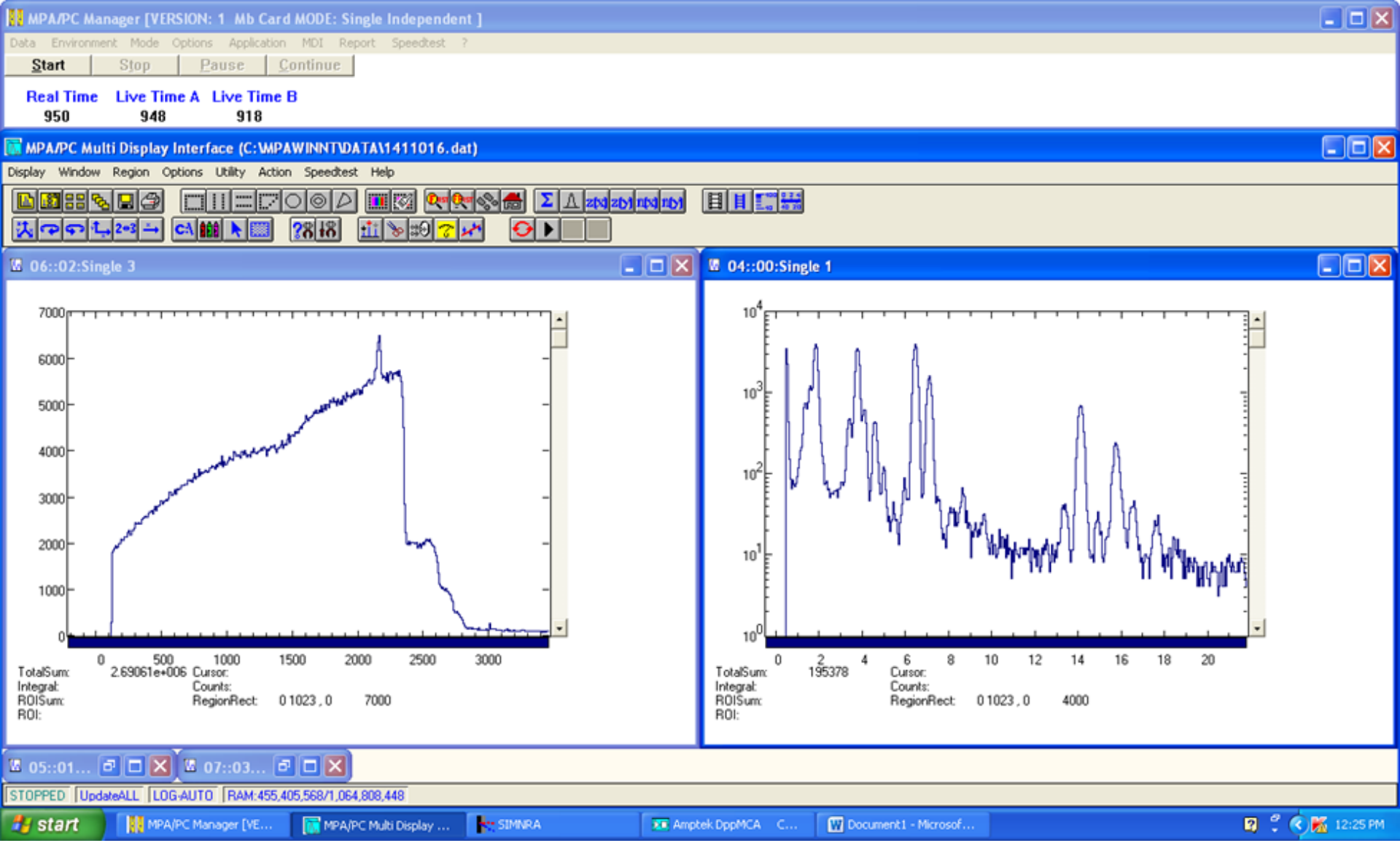


Camera

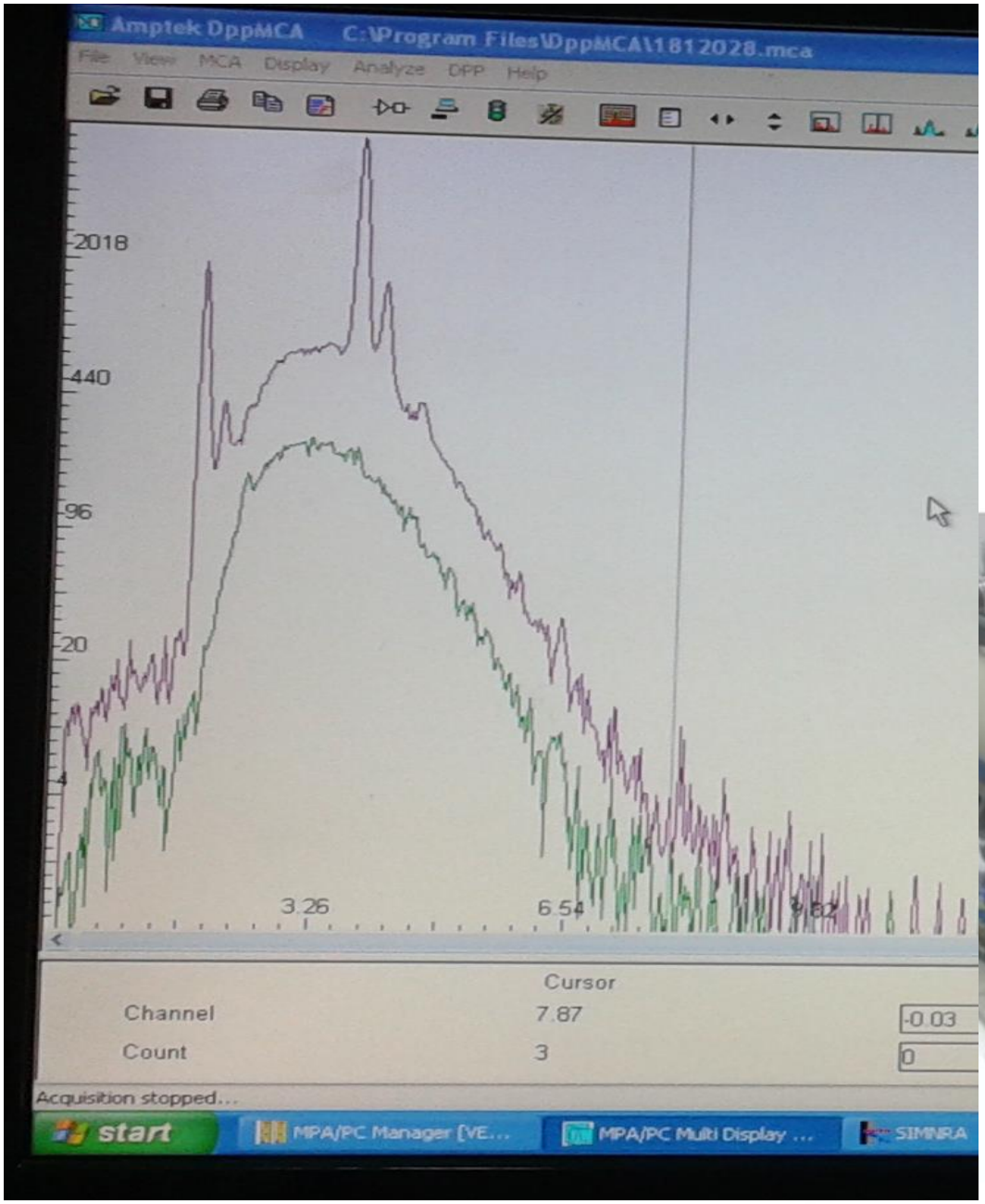




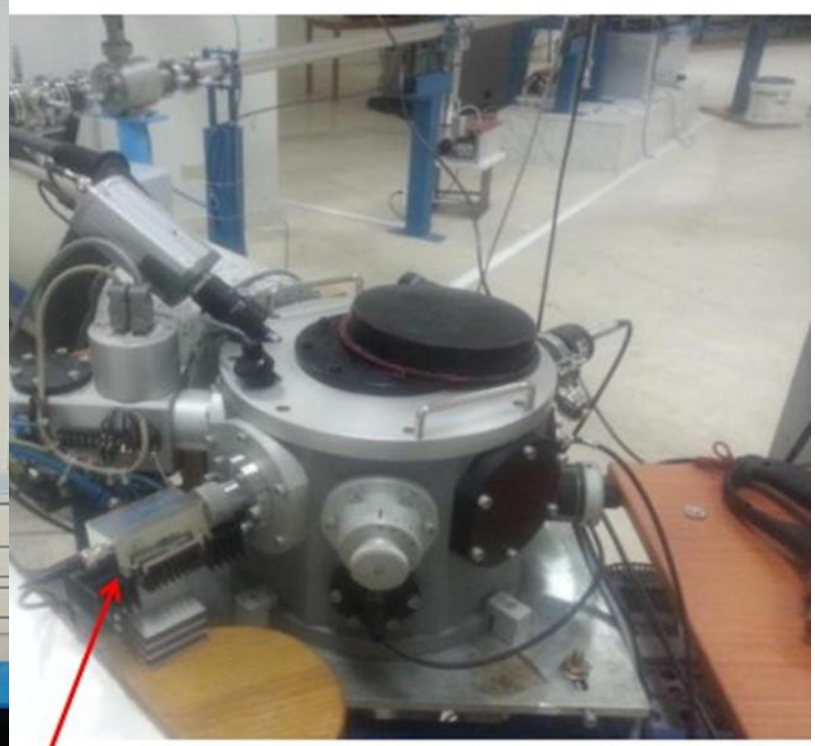
Micromatter Standards



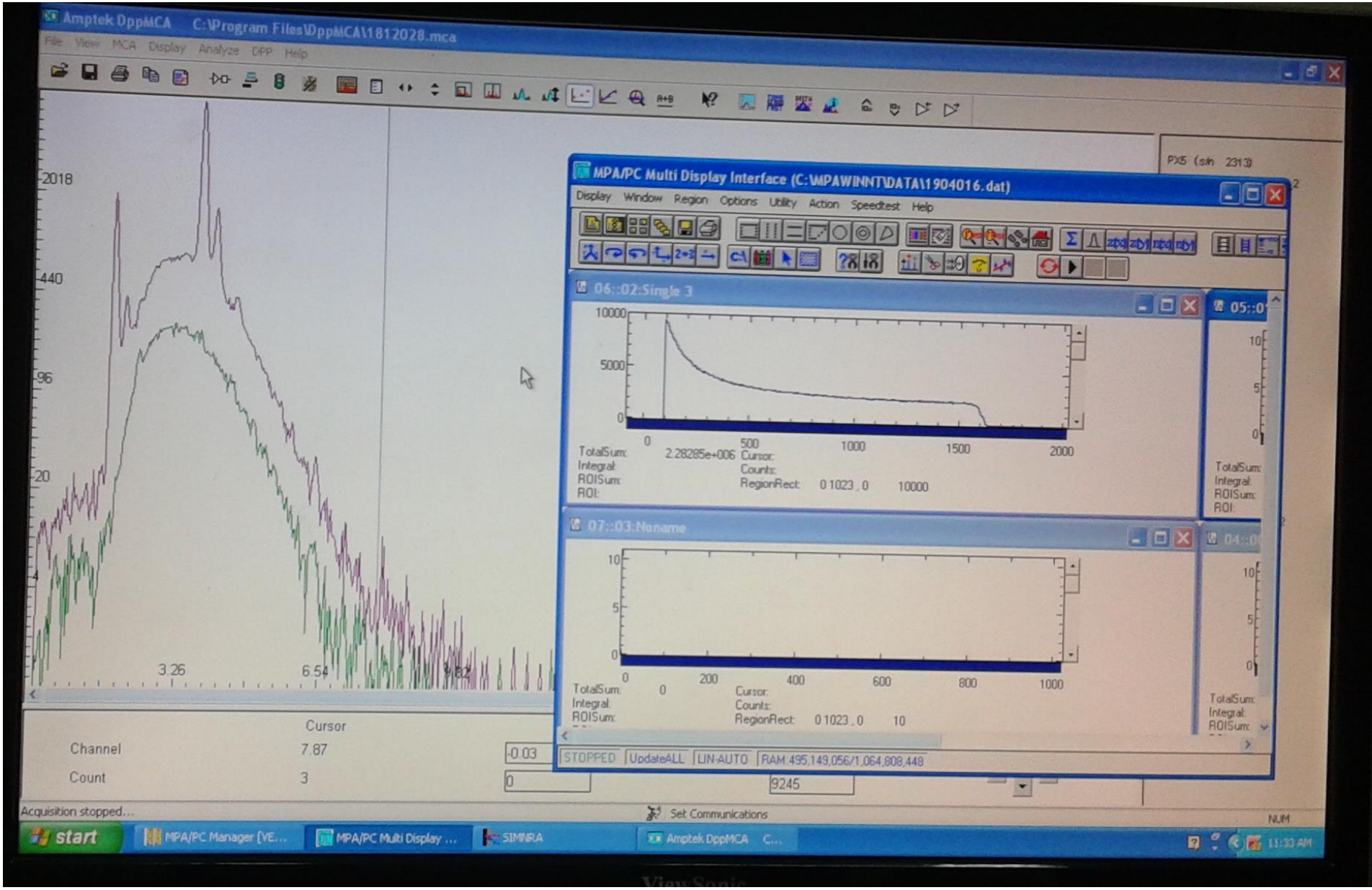
Geostandards



DppMCA



Silicon Drift Detector (130 eV)

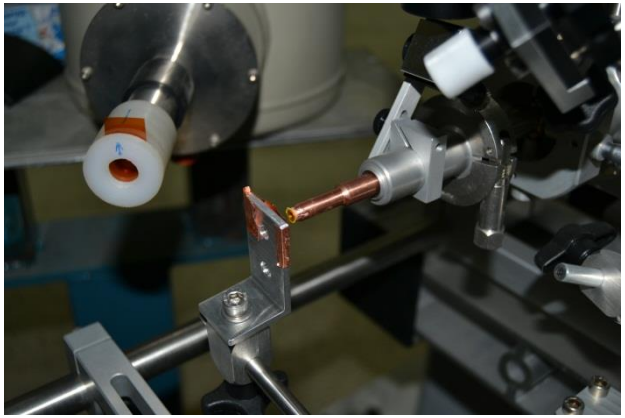


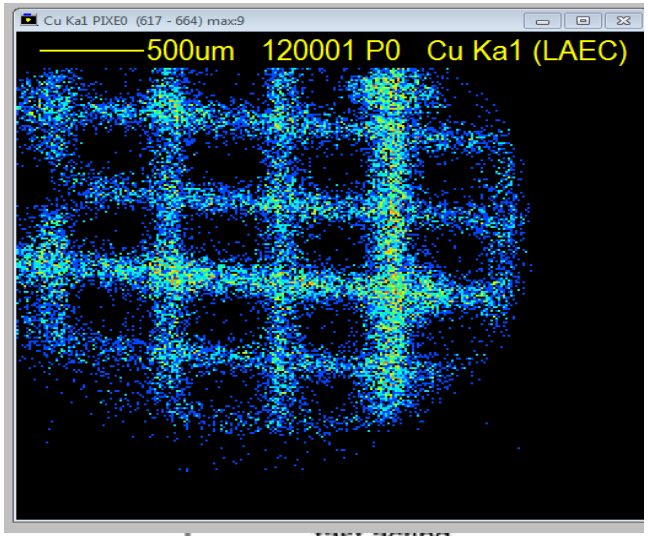
MPAWIN and DppMCA

Technical upgrading of experimental setup

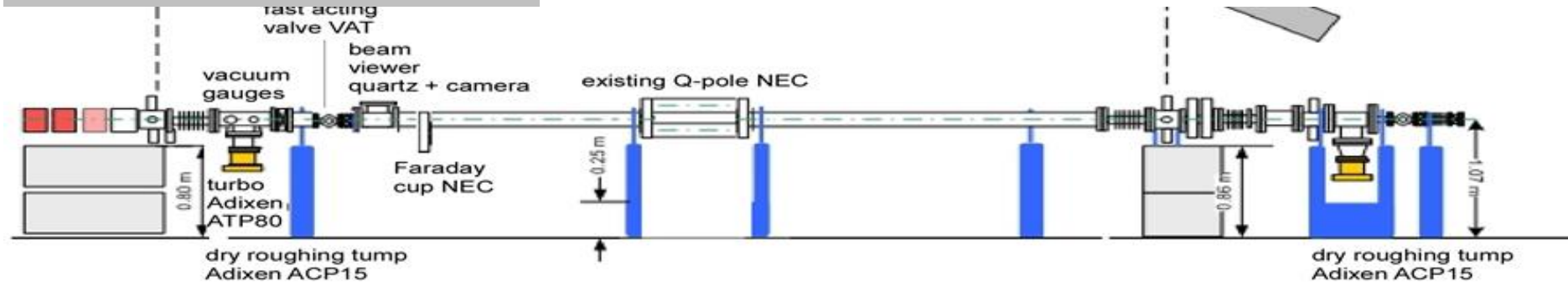
1- IAEA TC project LEB/0/006: "Improving Analytical Capabilities and Technical Performance of the Pelletron Accelerator" (2014-2017)

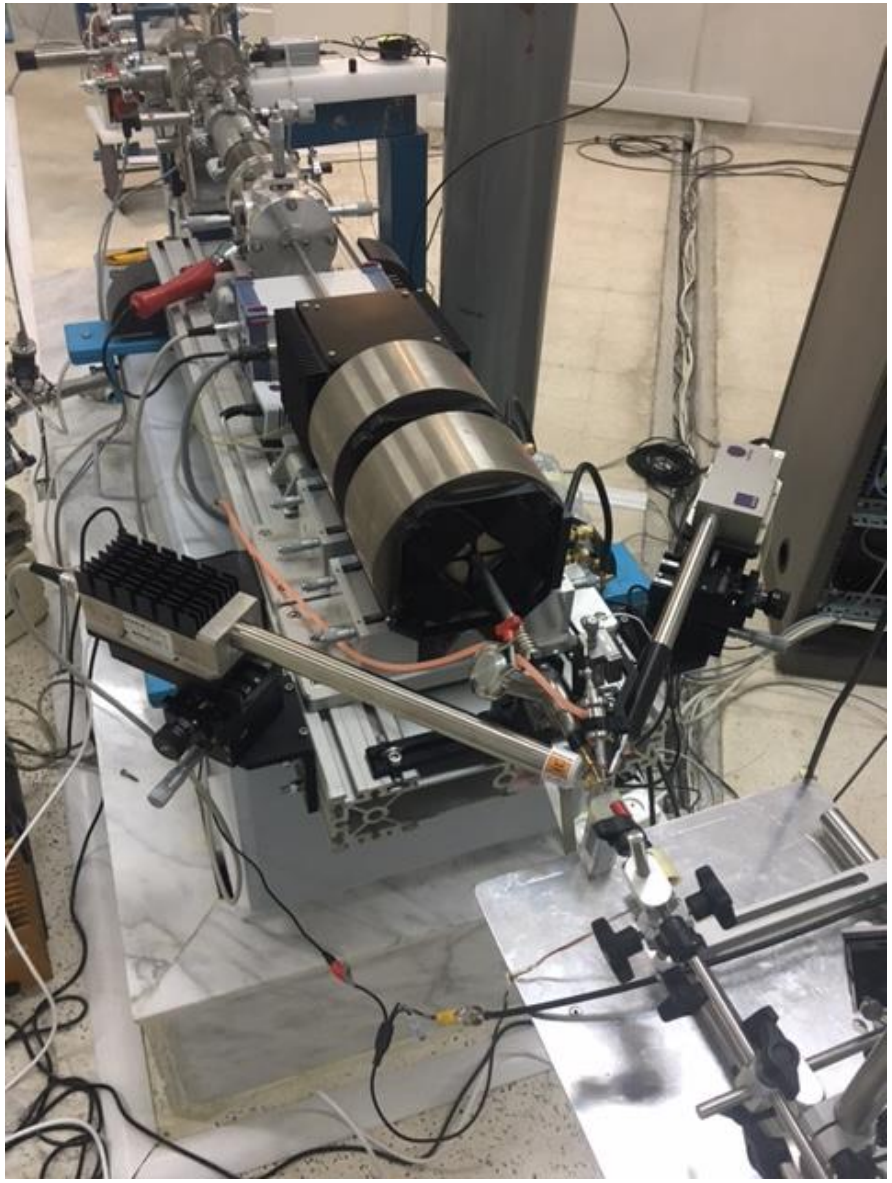
2- IAEA TC project concept LEB/0/008: "Enhancing the Performance and Capacity of the New External Microbeam for the Analysis of Biomedical and Atmospheric Aerosol Samples" (2016-2019)





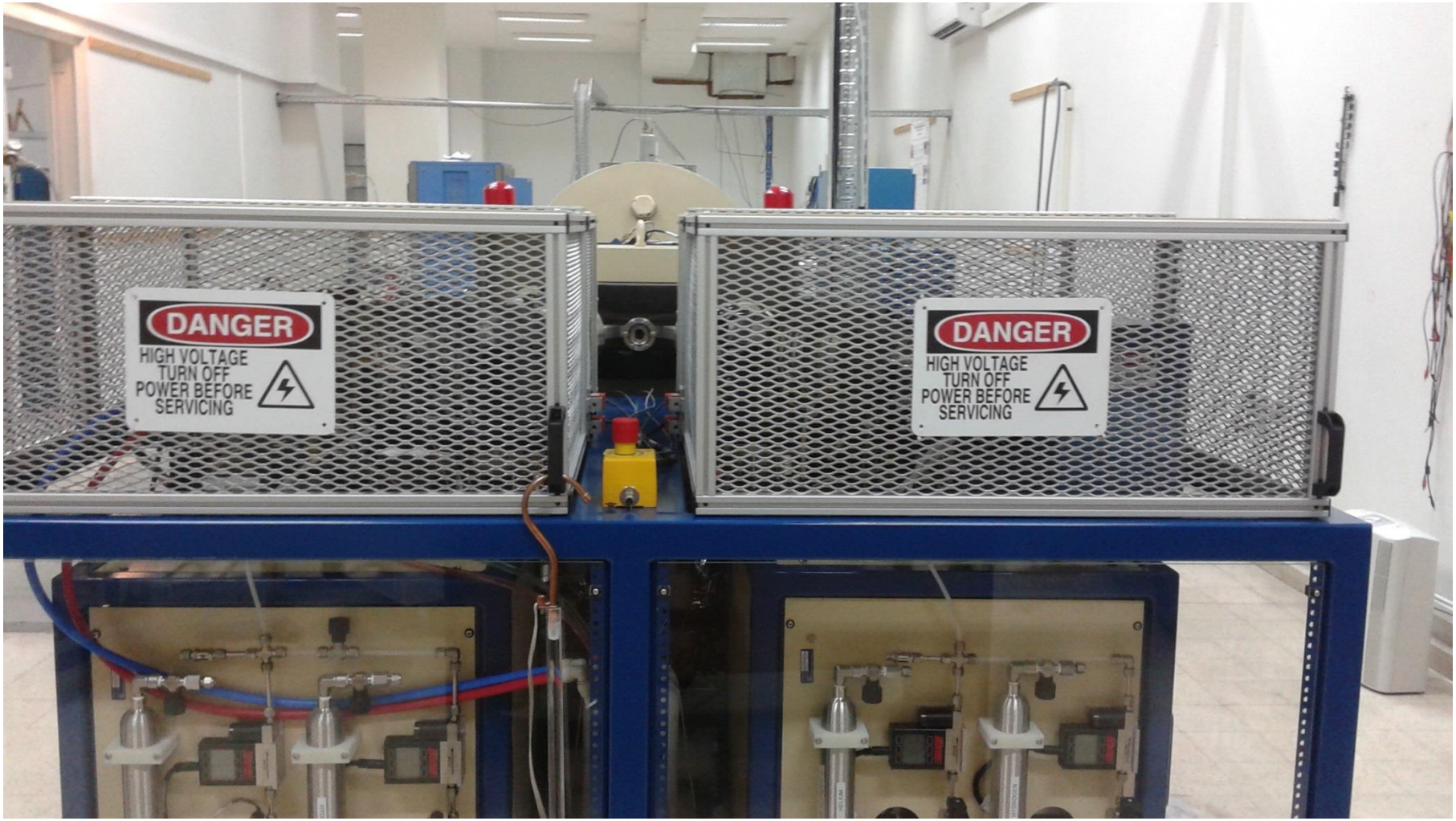
External Micro-Beam





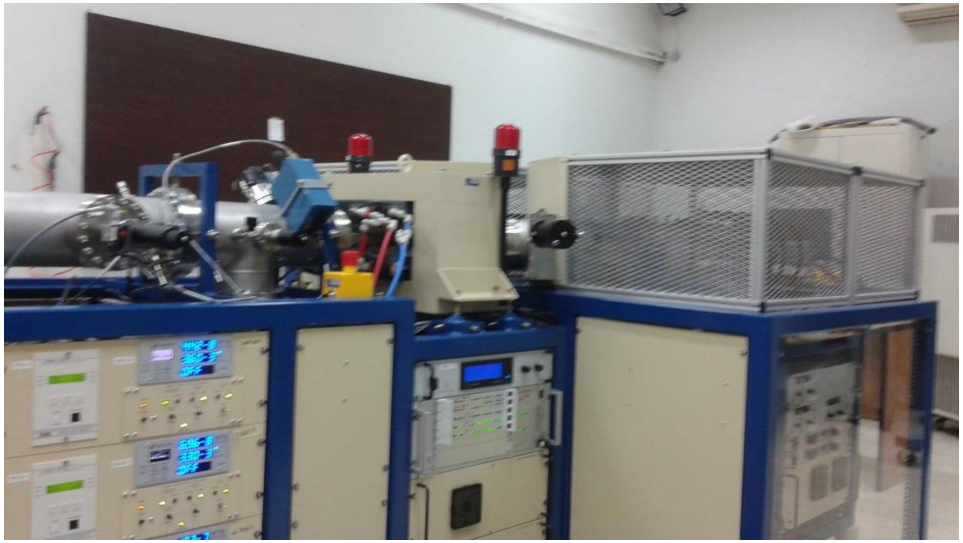
Beryllium

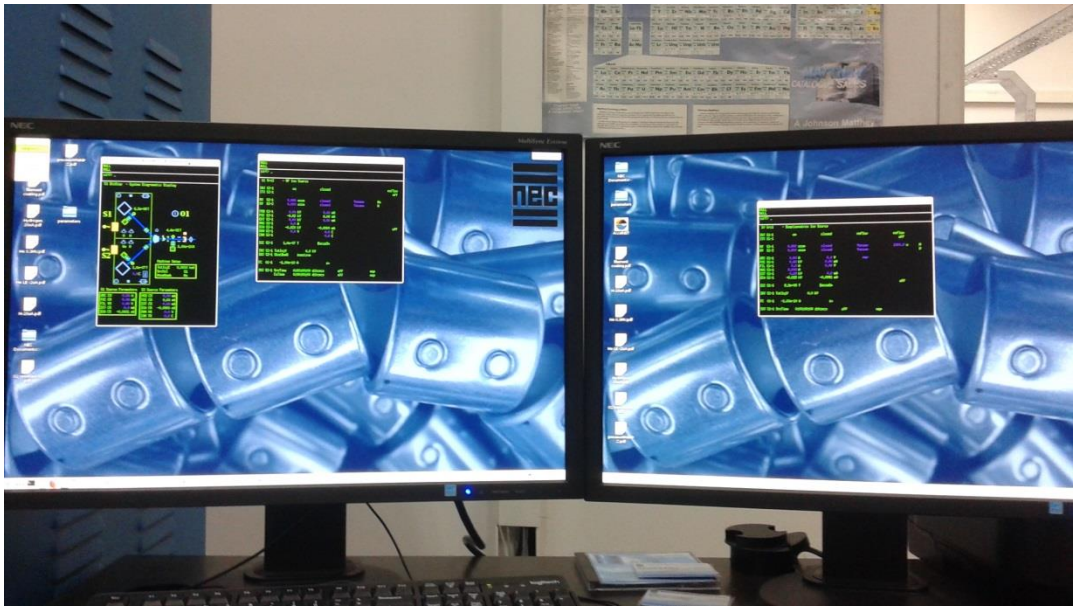
Dual Ion Source



Duoplasmatron
protons (20 µA)

Alphatross RF
alpha (2.4 µA)
protons (4.2 µA)



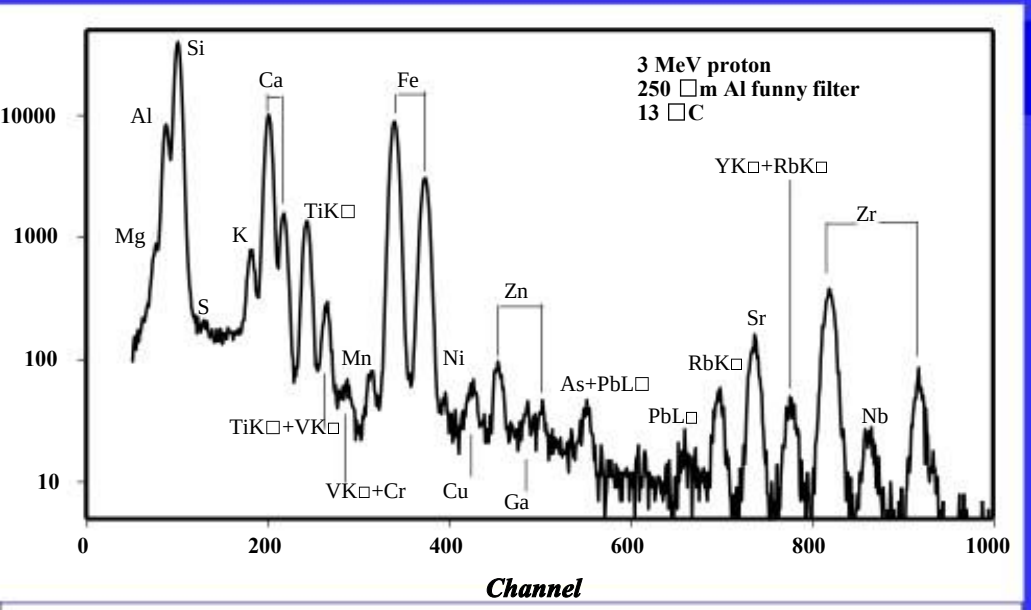

NEC
NEC
nec

IBA Applications: Cultural Heritage

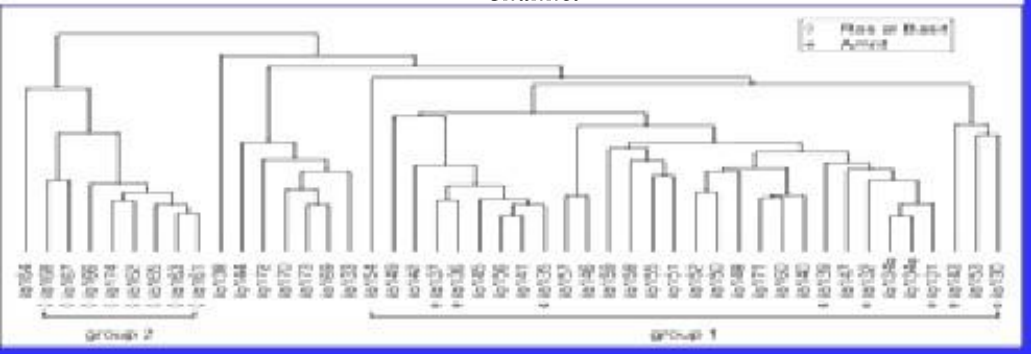
- PIXE is applied to analyze objects relevant to Art and Archeology: pottery, glass, coins, paintings, statues, manuscripts,..
- Answer questions of provenance and authenticity
- Ceramics are most abundant and most studied archeological findings
- PIXE and cluster analysis of excavated potsherds:
  - characterize workshop production
  - attribution and provenance
  - valuable insight into ancient trade connections
- Establish a database of ceramic elemental composition: more than 600 objects

Provenance study of excavated pottery from Beirut using PIXE cluster analysis

Mohamad Roumié, Paul Reynolds, Carol Atallah, Elias Bakraji, Khaled Zahraman, Bilal Nsouli, 17th Int. Conf. on Ion Beam Analysis, *Nuclear Inst. and Methods in Physics Research B* 249 (2006) 612.



A map of the classical sites of Levant



Classification of the studied ceramics, including mostly examples found in Beirut, as well as examples from Ras-al-basit and Amrit (see symbols chart).

Previous joint CNR-CNRS project: Establishment of a Phoenician pottery database on the chemical composition of terracotta using ion beam analysis techniques (IBA) and its importance to the study of artisanal production (pottery and coroplastic) from the Kharayeb archeological site in southern Lebanon

ELSEVIER

Nuclear Inst. and Methods in Physics Research

journal homepage: www.elsevier.com/locate/nimb

PIXE contribution for a database of Phoenician pottery in Lebanon

M. Roumie[a,*], I. Oggiano[b], A. Reslan[a,c], A. Srour[a], Z. El-Morr[a], M. Castiglione[d], M. Ta
M. Korek[c], B. Nsouli[a]

[a] Accelerator Laboratory, Lebanese Atomic Energy Commission, Lebanese CNRS, Beirut, Lebanon
[b] Istituto di Studi sul Mediterraneo Antico, CNR, Rome, Italy
[c] Physics Department, Faculty of Science, Beirut Arab University, Lebanon
[d] Department of Humanistic Studies, University of Calabria, Cosenza, Italy
[e] Department of Physics, Faculty of Art and Sciences, American University of Beirut, Beirut, Lebanon

ARTICLE INFO

Keywords:
PIXE

ABSTRACT

The study the ancient Phoenician cult place of Kharayeb, in the rural hinte
dated to the Iron Age and Hellenistic periods is particularly helpful in evalu

Future: The contribution of ion beam analysis techniques to the study of Phoenician expansion in the Mediterranean through the characterization of potteries from Phoenician settlements

available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/matchar

ELSEVIER

MATERIALS CHARACTERIZATION

PIXE analysis of medieval silver coins

H. Ben Abdelouahed[a,], F. Gharbi[a], M. Roumié[b], S. Baccouche[a], K. Ben Romdhane[c], B. Nsouli[b], A. Trabelsi[a]*

[a] *Centre National des Sciences et Technologies Nucléaires (CNSTN), Pôle technologique, 2020 Sidi Thabet, Tunis, Tunisia*
[b] *IBA Laboratory, Lebanese Atomic Energy Commission, National Council for Scientific Research, 11-8281, Beirut, Lebanon*
[c] *Faculté des lettres et des sciences humaines, Université de Tunis, Tunisia*

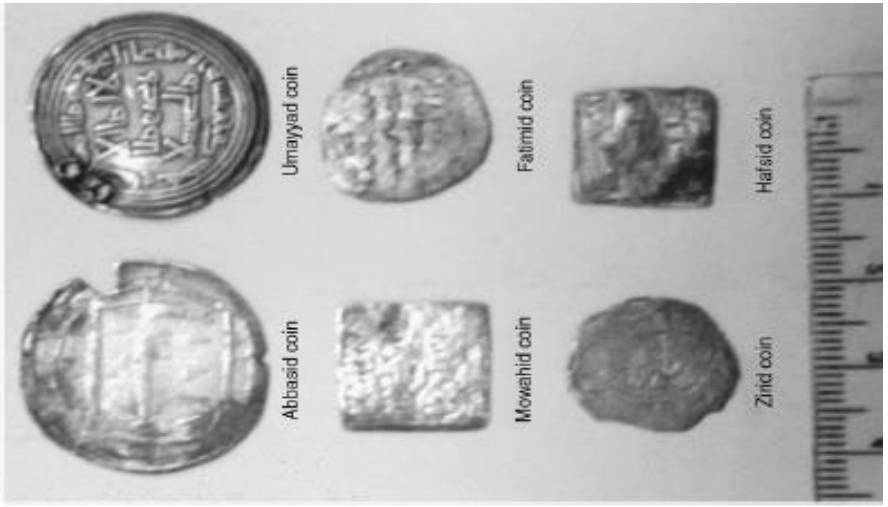
Table 1 – Characteristics of the twenty-eight analyzed silver coins.

Coin ref.	Dynasty	Period (A.D)	Mass (g)	Shape	Dimension (mm)
U1	Umayyad	702–748	2.87	Disc	13<r<14
U2			2.69		
A1	Abbasid	775–833	2.96	Disc	13<r<14
A2			2.83		
F1	Fatimid	909–975	2.25	Disc	7<r<10
F2			1.68		
F3			1.39		
F4			1.16		
F5			1.67		
F6			1.37		
Z1	Zirid	975–1159	1.45	Disc	8<r<9
Z2			1.41		
Z3			1.39		
Z4			1.14		
Z5			1.33		
Z6			1.30		
M1	Mowahid	1159–1230	1.50	Square	14<l<15
M2			1.53		
M3			1.52		
M4			1.53		
M5			1.54		
M6			1.52		
H1	Hafsid	1230–1574	1.45	Square	14<l<15
H2			1.29		
H3			1.52		
H4			1.52		
H5			1.52		
H6			1.34		

ABSTRACT

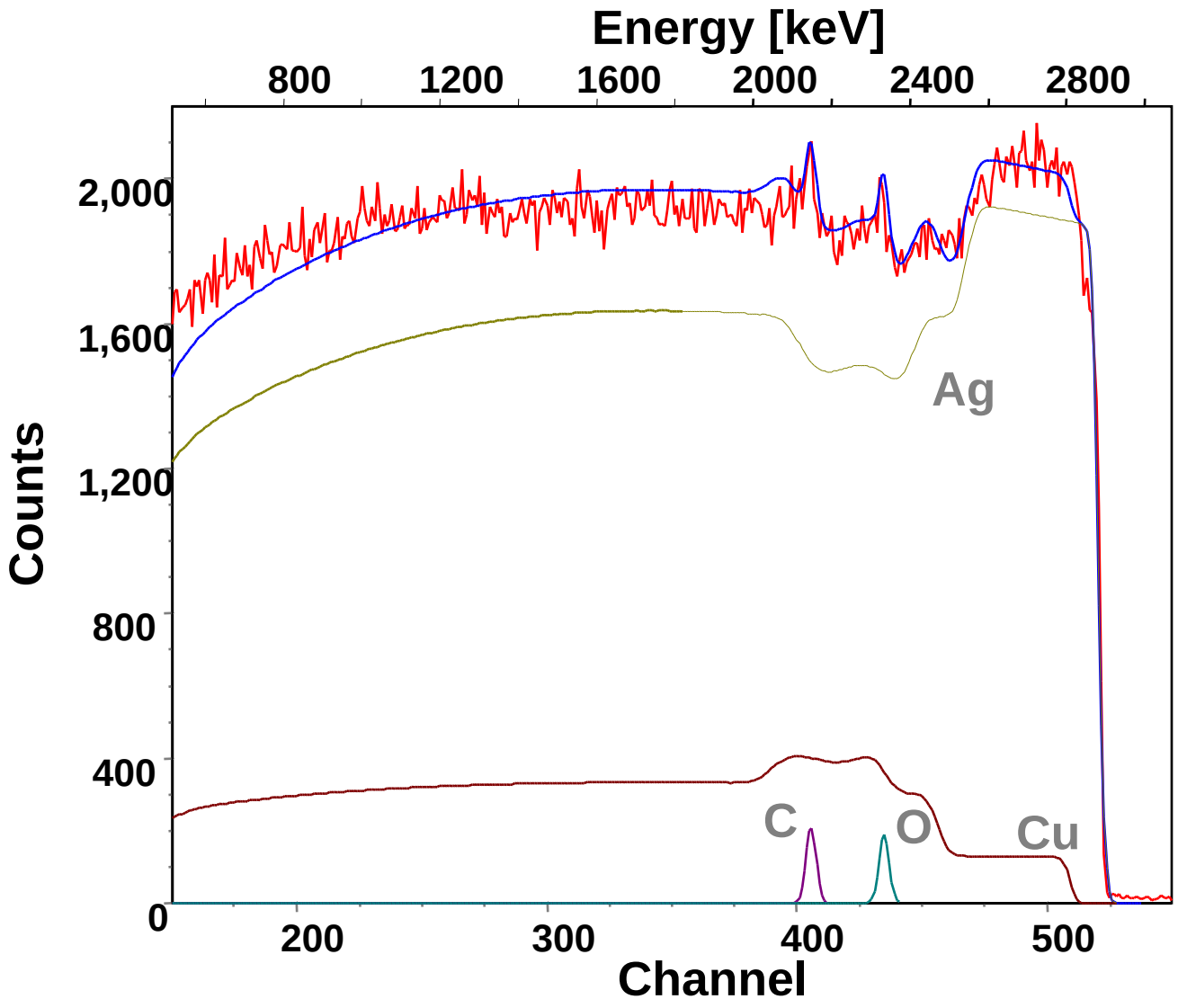
We applied the proton-induced X-ray emission (PIXE) analytical technique to twenty-eight medieval silver coins, selected from the Tunisian treasury. The purpose is to study the fineness evolution from the beginning of the 7th to the 15th centuries AD. Each silver coin was cleaned with a diluted acid solution and then exposed to a 3 MeV proton beam from a 2.7 MV tandem accelerator. To allow the simultaneous detection of light and heavy elements, a funny aluminum filter was positioned in front of the Si(Li) detector entrance which is placed at 135° to the beam direction. The elements Cu, Pb, and Au were observed in the studied coins along with the major component silver. The concentration of Ag, presumably the main constituent of the coins, varies from 55% to 99%. This significant variation in the concentration of the major constituent reveals the economical difficulties encountered by each dynasty. It could be also attributed to differences in the composition of the silver mines used to strike the coins in different locations. That fineness evolution also reflects the poor quality of the control practices during this medieval period. In order to verify the ability of PIXE analytical method to distinguish between apparently similar coins, we applied hierarchical cluster analysis to our results to classify them into different subgroups of similar elemental composition.

© 2009 Elsevier Inc. All rights reserved.



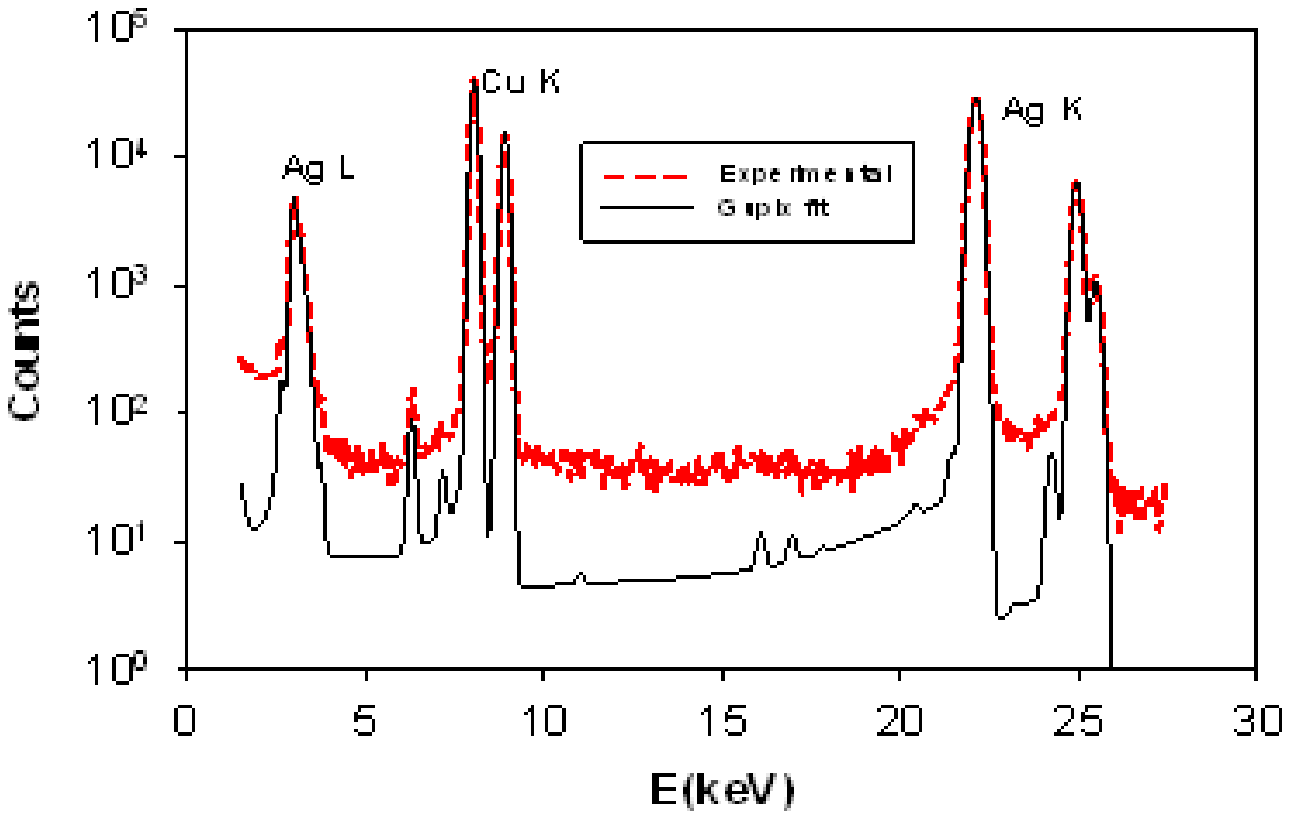
Authenticity determination of Ag-Cu Lebanese coins using combined PIXE and RBS techniques

- Analyzed Coins:
  - Five Lebanese coins of 50 piastres dated from 1952
  - 1-euro & 2-euro (as references)
- Used techniques:
  - PIXE & RBS 3 MeV protons with 250 µm aluminum “funny filter”



RBS spectrum of one of the 50 piastres silver copper coins

Before removing of altered surface layers



PIXE spectrum of one of the 50 piastres silver copper coins

After removing of altered surface layers

Ag: 61.4 ± 0.18 *(60 wt.%)*

Cu: 38.6 ± 0.15 *(40 wt.%)*

Nuclear Instruments and Methods in Physics Research B 268 (2010) 1916–1919

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

Quality control of coins mint using PIXE and RBS analysis

M. Roumie [a,*], B. Nsouli [a], G. Chalhoub [b], M. Hamdan [b]

[a] Ion Beam Analysis Laboratory, Lebanese Atomic Energy Commission, National Council for Scientific Research, Beirut, Lebanon
[b] Banque du Liban, Beirut, Lebanon

ARTICLE INFO

Article history:
Available online 25 February 2010

Keywords:
IBA
PIXE
RBS
Coins
Quality control

ABSTRACT

PIXE and RBS analysis is used to investigate the elemental content of modern Lebanese coins, in order to control their minting quality. The coins of interest were 100, 250 and 500 Lebanese Lira (LL), which are mainly bulky metals with or without coated layer. Using 3 MeV protons, proton induced X-ray emission PIXE identified and quantified elements while Rutherford backscattering spectrometry RBS checked the

powerful tool to inves-
he experimental proto-
-euro and 2-euro.
B.V. All rights reserved.

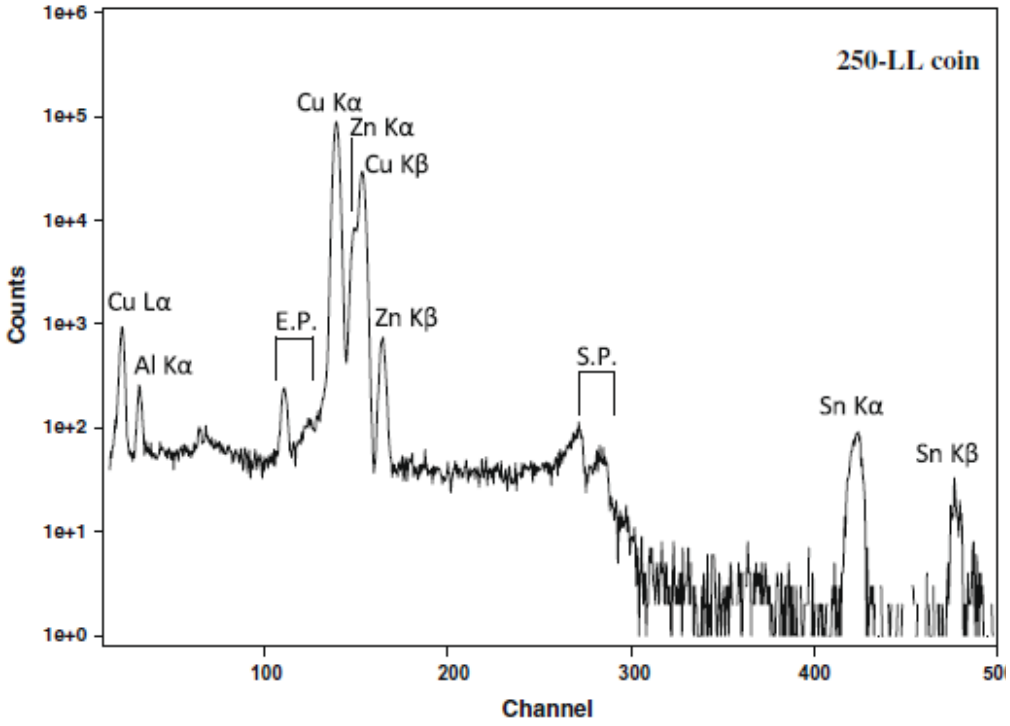


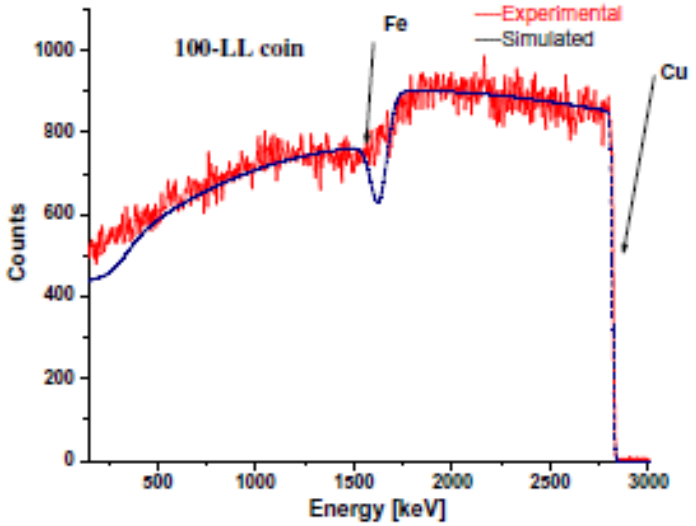
Fig. 3. PIXE spectrum of the 250-LL coin.

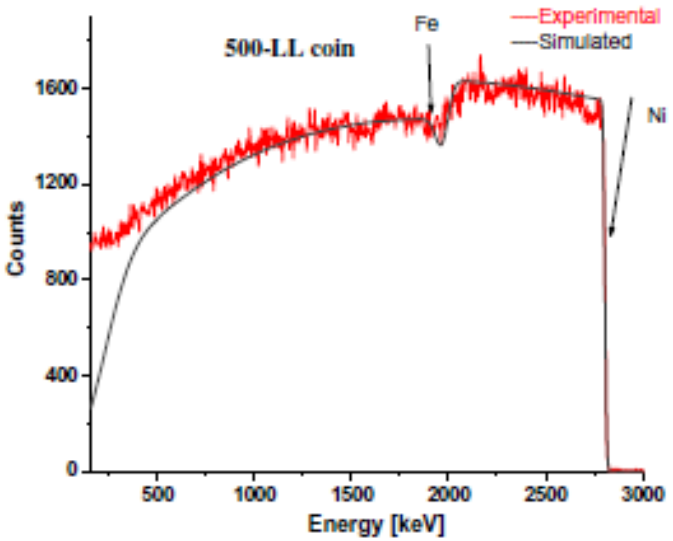
Cu: 89.6%

Zn: 4.8%

Al: 4.6%

Sn: 0.9%





Fe substrate coated with :

- 9 µm Cu (100LL)

- 6.5 µm Ni (500 LL)

Contents lists available at SciVerse ScienceDirect

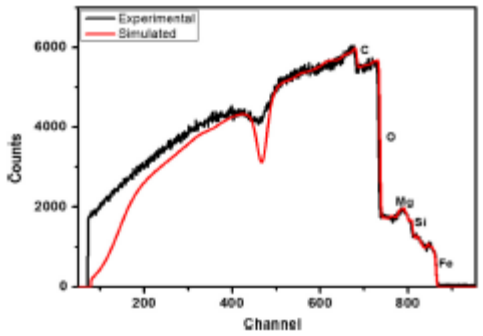
Nuclear Instruments and Methods in Physics Research B

journal homepage: www.elsevier.com/locate/nimb

On the characterization of the "Paris" meteorite using PIXE, RBS and micro-PIXE

M. Noun [a,b], M. Roumie [a,*], T. Calligaro [c], B. Nsouli [a], R. Brunetto [d], D. Baklouti [d], L. d'Hendecourt [d], S. Della-Negra [b]

[a] Accelerator Laboratory, Lebanese Atomic Energy Commission, CNRSL, Beirut, Lebanon
[b] Institut de Physique Nucléaire d'Orsay, UMR 8608, Université Paris Sud, Paris, France
[c] Centre de Recherche et de Restauration des musées de France, CNRS UMR 171, Palais du Louvre, 75001 Paris, France
[d] Institut d'Astrophysique Spatiale, CNRS, UMR 8617, Université Paris-Sud, Bat 121, 91405 Orsay Cedex, France



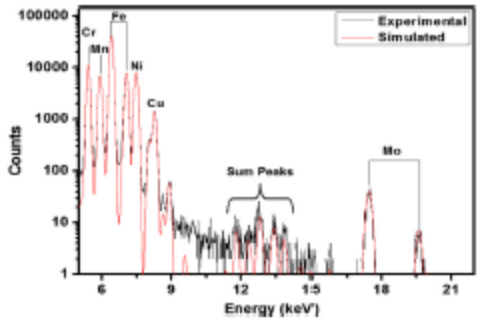


Fig. 5. μ-PIXE spectrum of the point 2 shown on the picture in Fig. 1, where a presence of Mo is noticed.

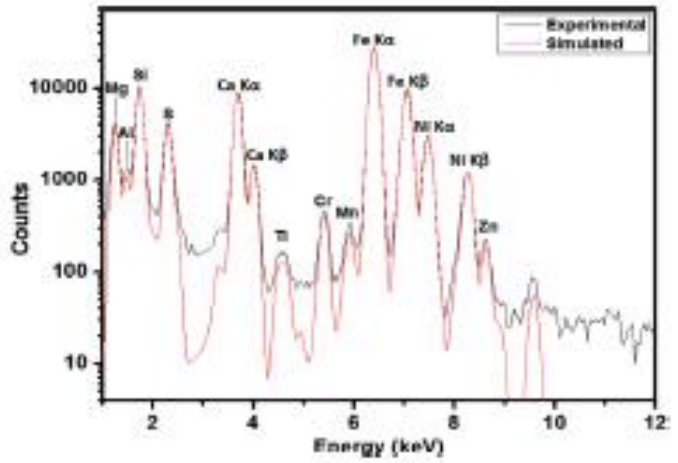


Fig. 2. PIXE spectrum of an average elemental content of "Paris" meteorite at the mm scale.

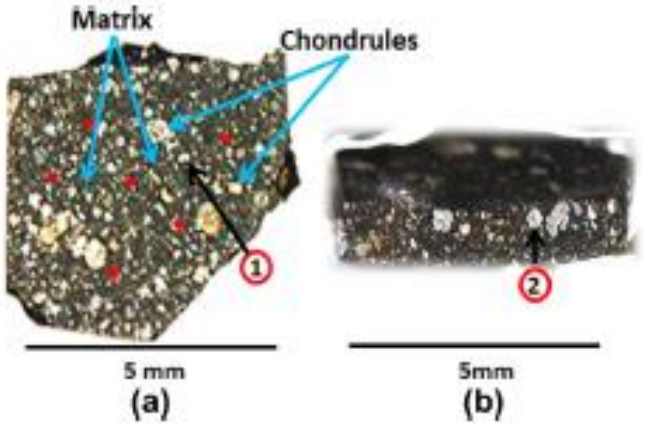


Fig. 1. Pictures of "Paris" meteorite; (a) the meteorite fragment showing the different points analyzed by μ-PIXE, the forsterite crystal was found in the point

Average elemental composition (mg/kg) of "Paris" meteorite, determined by PIXE.

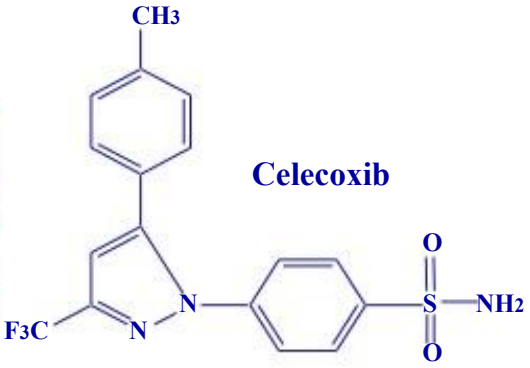
	Concentration (ppm)	Limit of detection (ppm)
Mg	96,443 ± 2008	941
Al	18,652 ± 1254	772
Si	115,962 ± 1489	375
S	38,400 ± 689	279
Ca	64,209 ± 759	163
Ti	906 ± 134	150
Cr	3683 ± 191	154
Mn	1854 ± 209	258
Fe	23,645 ± 1835	241
Ni	12,983 ± 208	86
Zn	297 ± 23	14

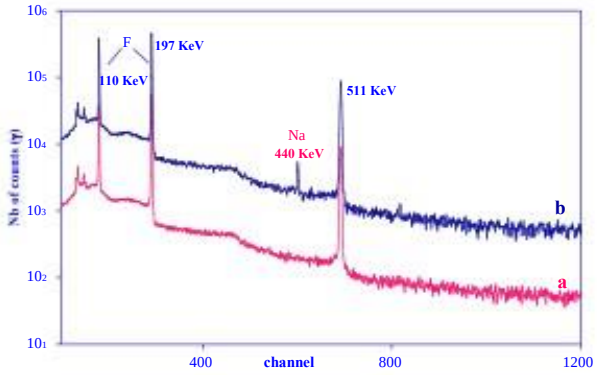
Pharmaceutical Sciences

B. Nsouli, K. Zahraman, A. Bejjani, S. Assi, F. El-Yazbi, M. Roumié

NIM B249 (2006) 692-696

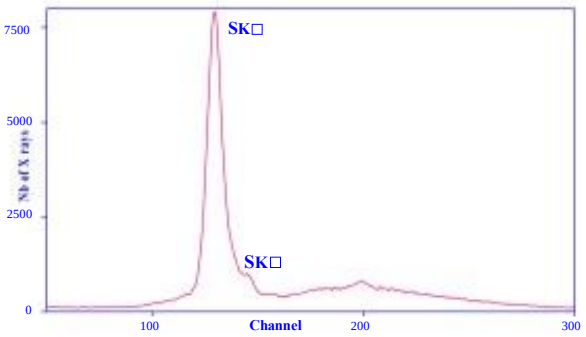
Quality control of commercial drugs using PIXE and PIGE technique





$$m_{AI} = m_{drug} \cdot \frac{I_{samp(F)}}{I_{ref(F)}}$$

$$m_{AI} = m_{drug} \cdot \frac{I_{samp(S)}}{I_{ref(S)}}$$



To assess the ability of PIXE and PIGE technique for rapid and accurate analysis of A.I., containing at least one specific heteroatom in its chemical structure, in solid commercial drug.

IBA Applications: Atmospheric Aerosols

IAEA RAS0078 Project

Evaluate and map air pollutants, mainly PM10 and PM2.5, at local and regional levels (ARASIA region)

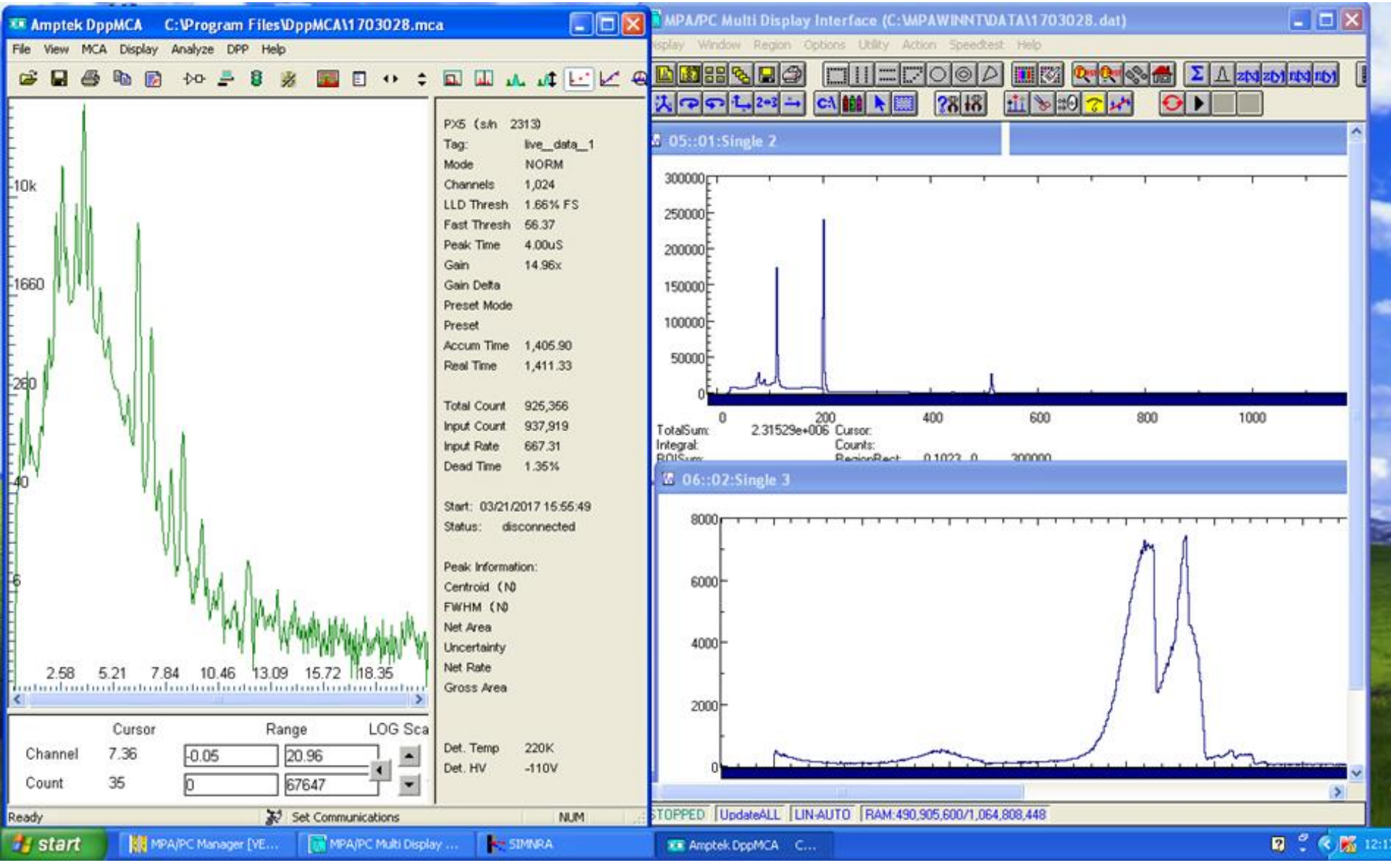
Develop the use of ion beam analysis techniques IBA among ARASIA MSs to investigate aerosol samples

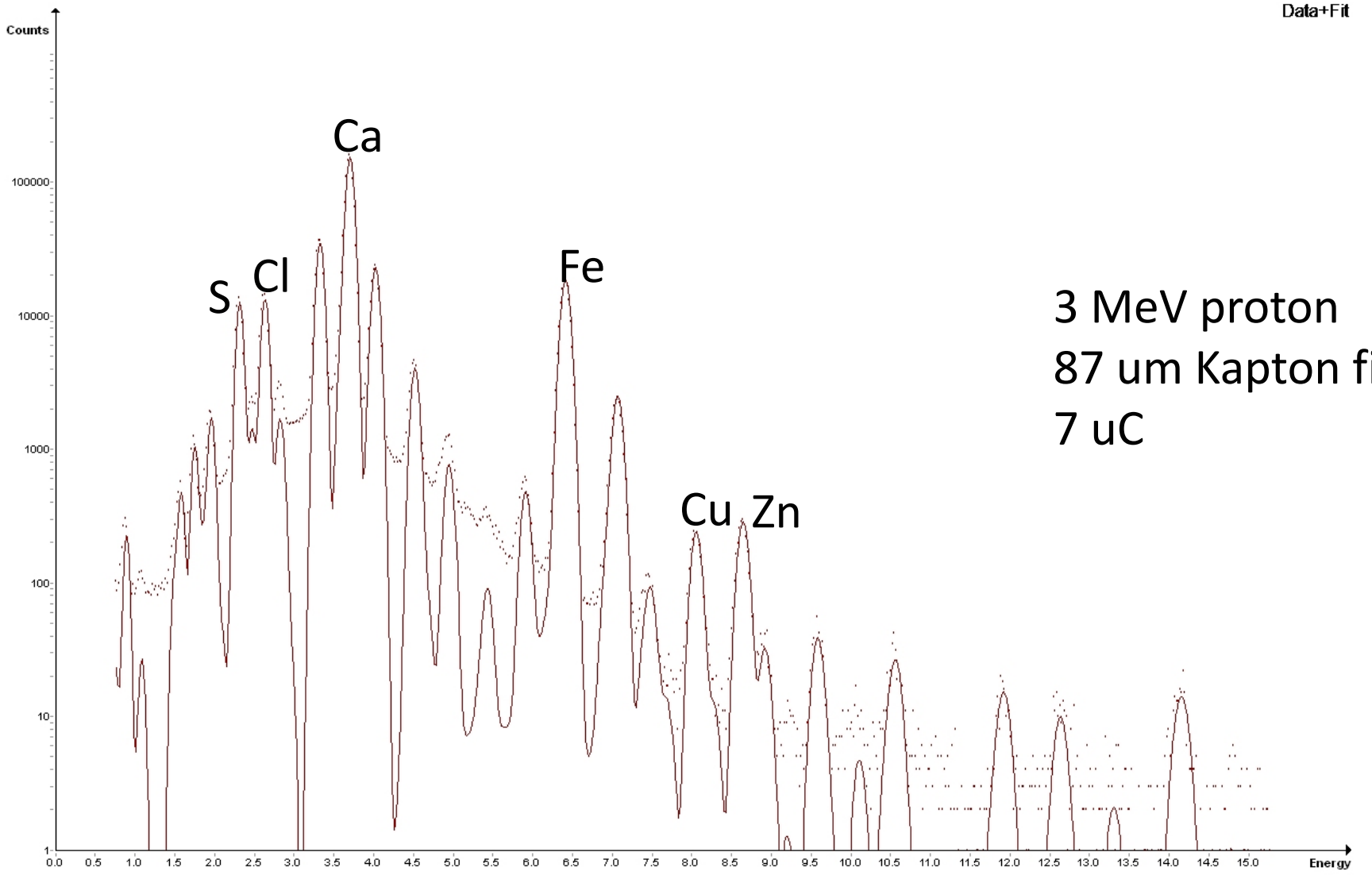
Establish a simultaneous sampling campaign, using similar protocol, filters and samplers

Analysis of samples, interpretation of results, data evaluation, source apportionment, ..

DppMCA; SDD; PIXE

MPAWIN; PIPS; HPGe; EBS, PIGE

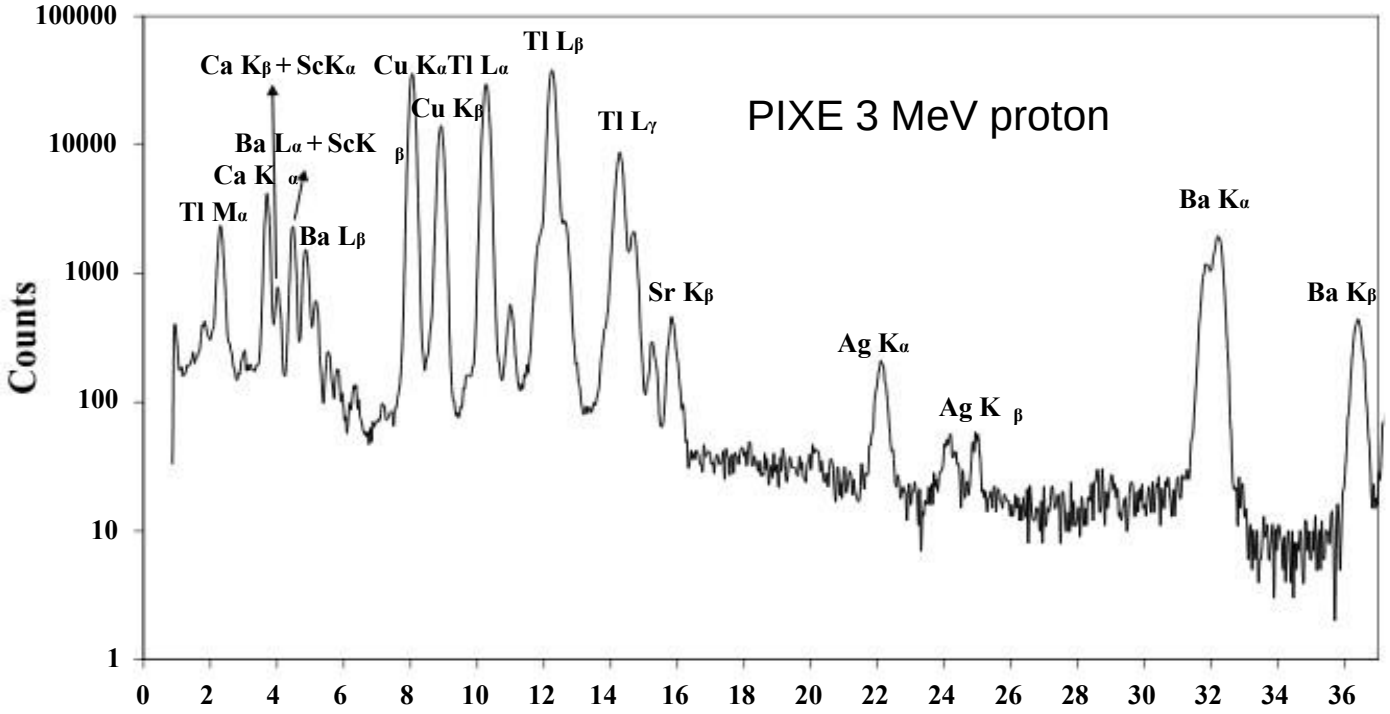




PIXE spectra of filter#LB14 using Amptek SDD

Regional Meeting to Review/Update Procedures and Strategy for Atmospheric Aerosol Sampling and Analyses and Interpretation", Beirut. Lebanon, from 4 to 8 April 2016.

IBA Applications: Materials Science



PIXE and RBS Analysis of Tl-1223 Superconducting Phase Substituted by Scandium

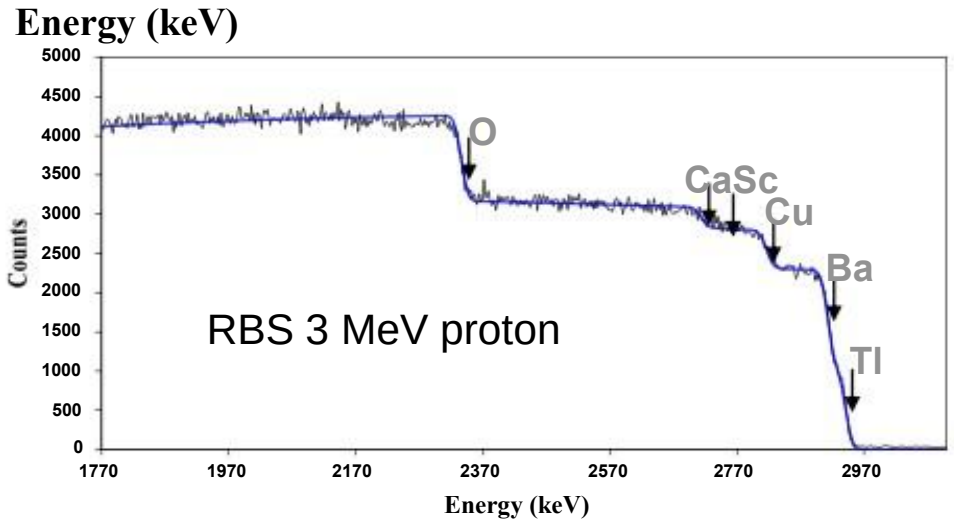
Determination of the elemental stoichiometry of superconducting samples of type

TlBa2Ca2-xScxCu3O9-δ

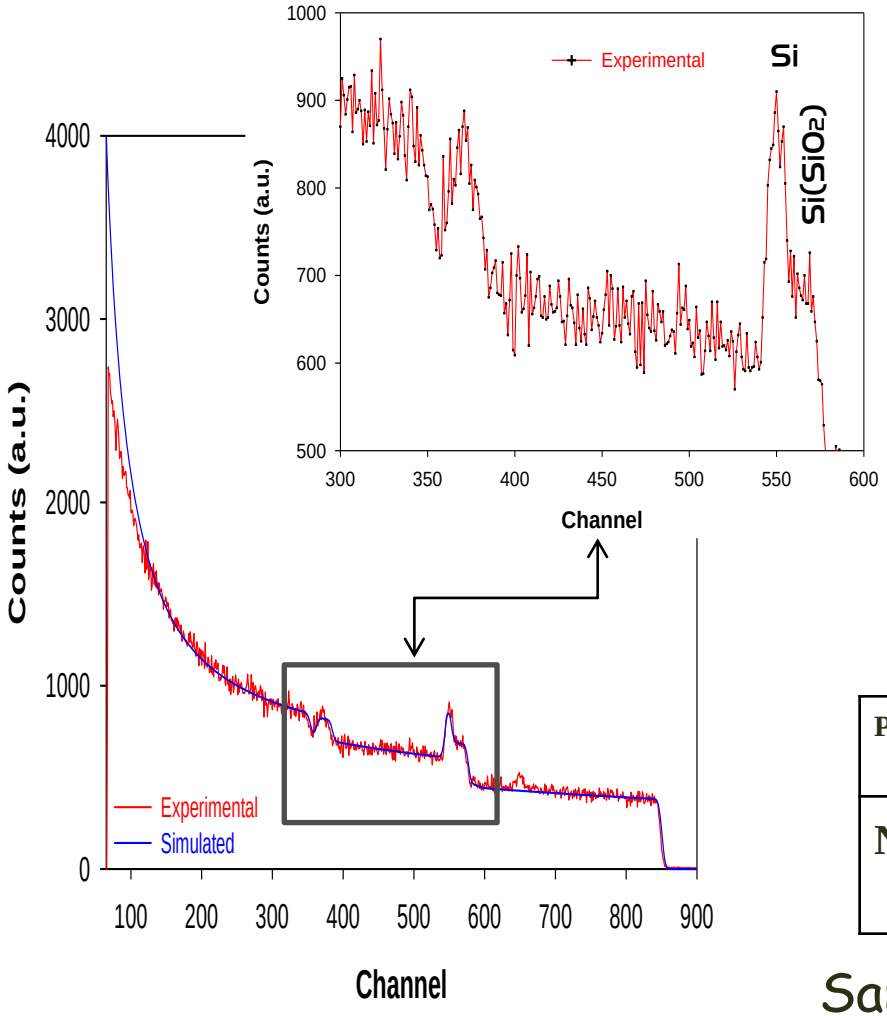
with 0 ≤ x ≤ 0.6, prepared via solid-state reaction technique

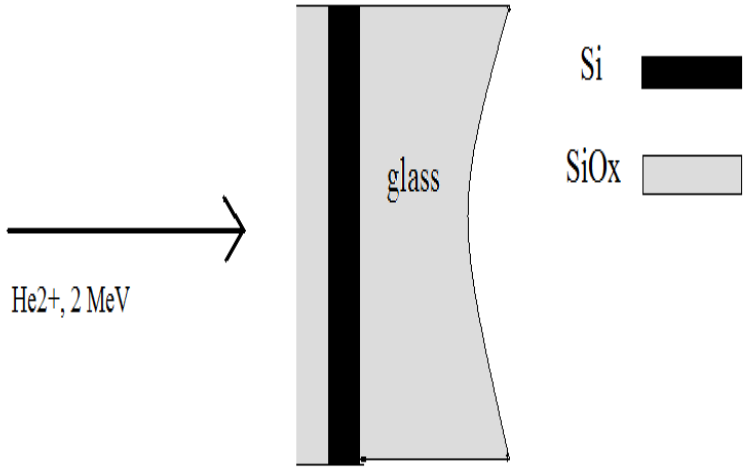
NIM B 266 (2008) 33-139

M. Roumié, R. Awad, I.H. Ibrahim, A. Zein, K. Zahraman, B. Nsouli



Stoichiometry and thickness determination of amorphous multilayers of Si/SiO_2 nano-films using RBS technique



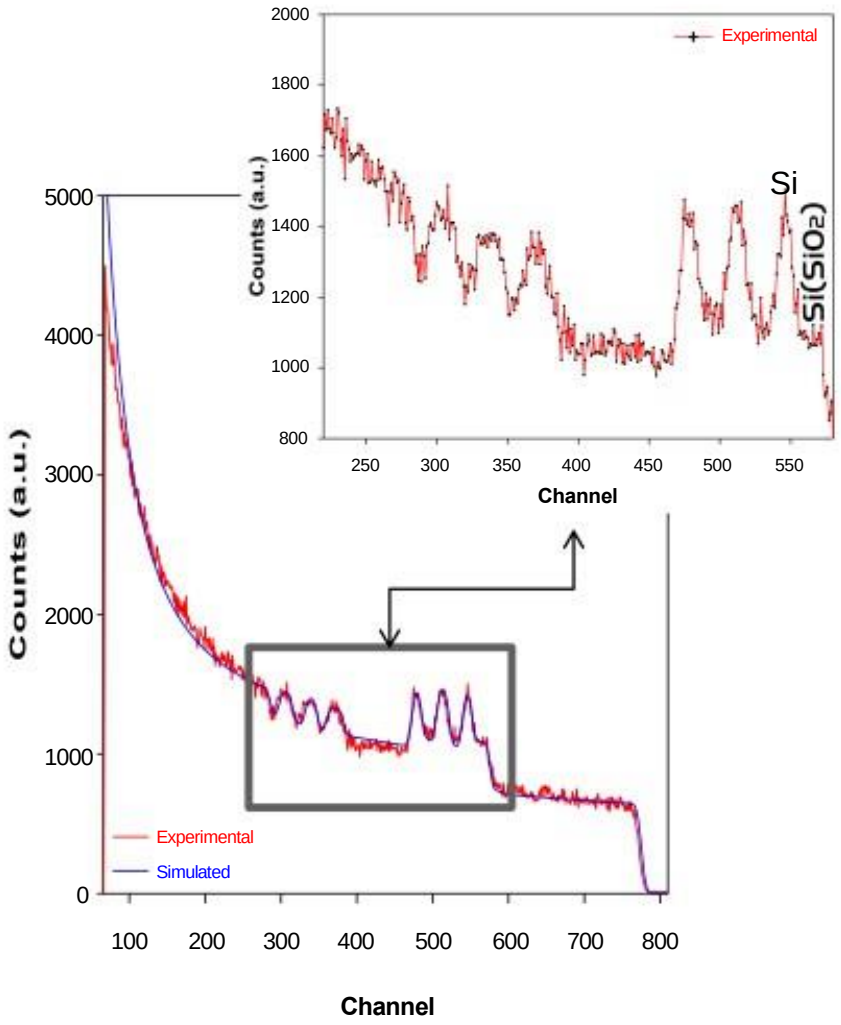


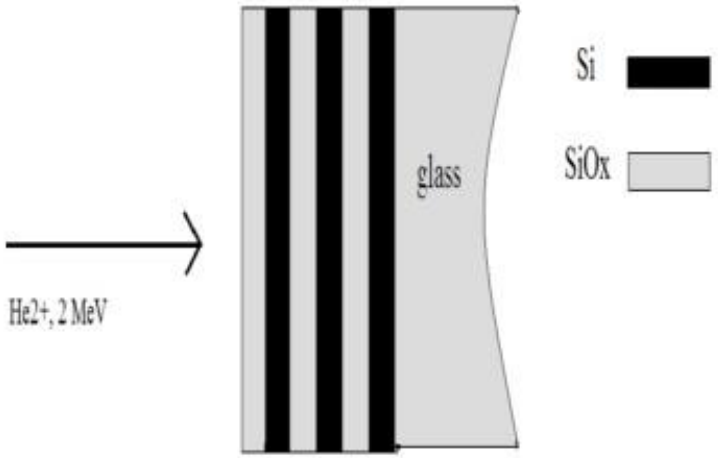
Period	Layer	Thickness (nm)	R
N=1	Si	38.16	
	SiO_x	88.27	1.6

Sample with one period N = 1

Roumie & al., Advanced Materials Research 324 (2011)310-313

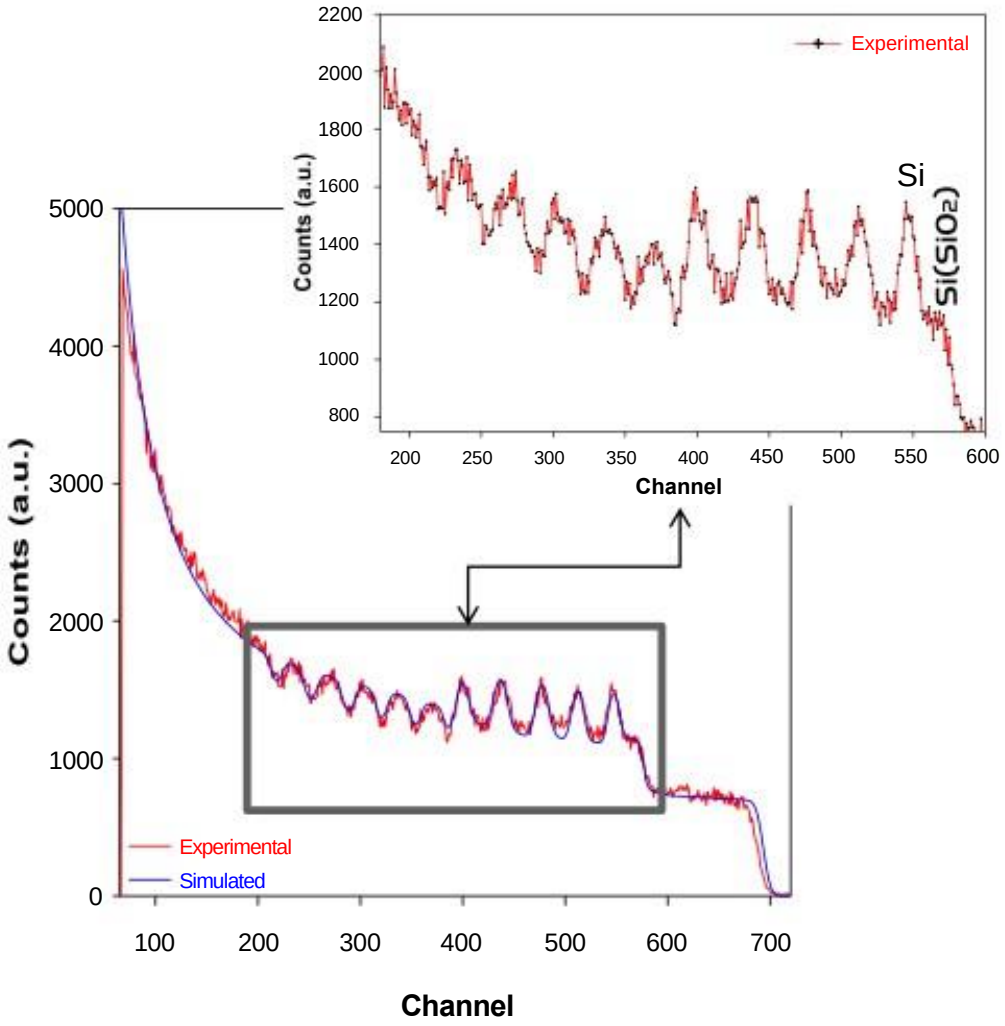
Sample with three periods N = 3



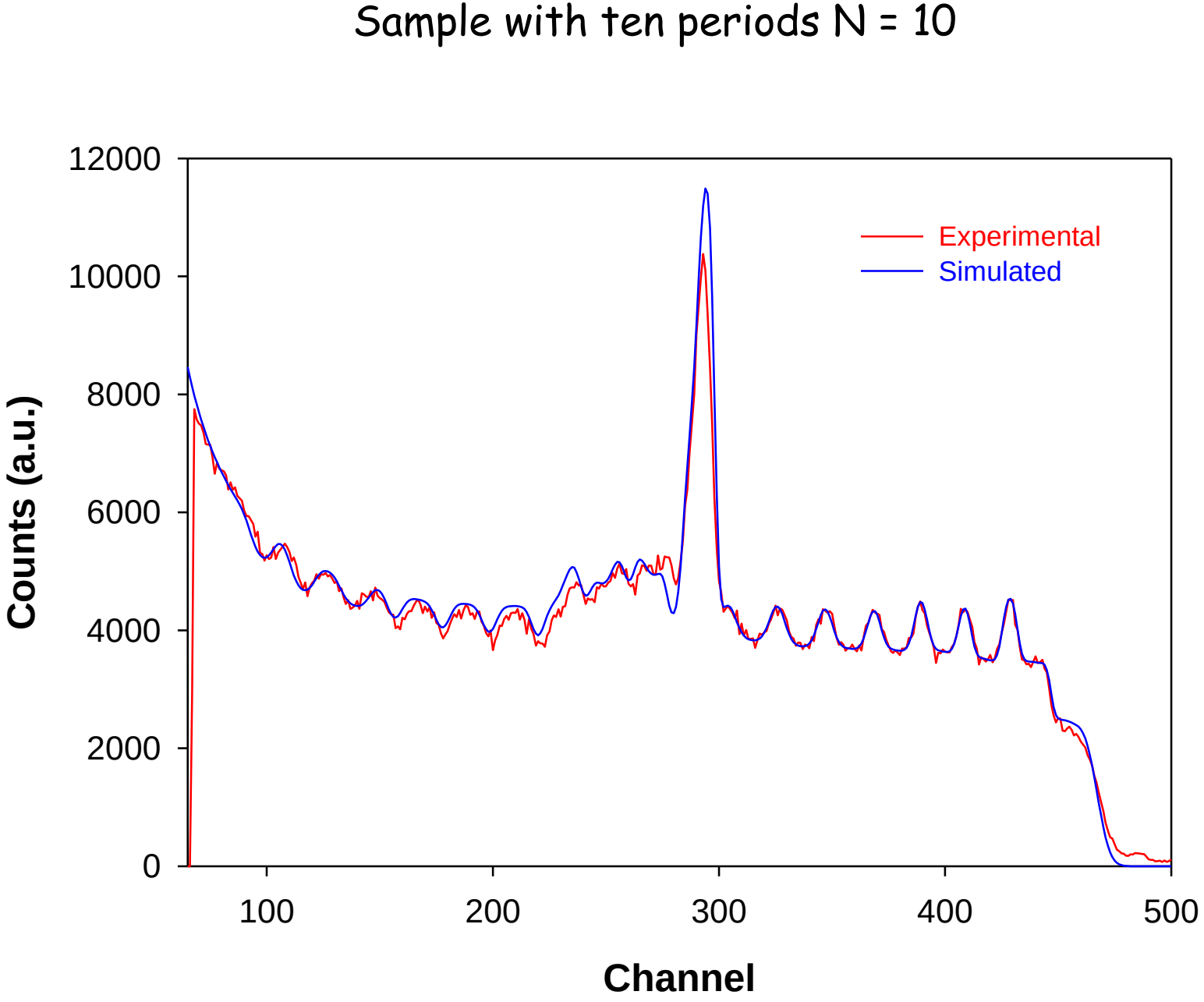


Period	Layer	Thickness (nm)	R
N=3	Si	54.23	
	SiO_x	69.36	2
	Si	76.32	
	SiO_x	63.05	2.3
	Si	60.25	
	SiO_x	84.57	1.6

Sample with five periods N = 5



Period	Layer	Thickness (nm)	R
N=5	Si	46.19	
	SiO_x	81.97	1.7
	Si	60.25	
	SiO_x	88.27	2
	Si	60.25	
	SiO_x	75.66	1.6
	Si	54.23	
	SiO_x	81.97	2
	Si	54.23	
	SiO_x	81.98	1.5


Sample with ten periods N = 10
12000
10000
8000
6000
4000
2000
0
Counts (a.u.)
100
200
300
400
500
Channel
Experimental
Simulated

IAEA TC RAS/1/021 “Harnessing Nuclear Science and Technology for the Preservation and Conservation of Cultural Heritage”

The participants of the group scientific visit with LAEC staff

NEW CRP: Facilitating Experiments with Ion Beam Accelerators (G42008)

New Coordinated Research Project

Sarah Kiehne, IAEA Department of Nuclear Sciences and Applications

JUL
17
2018

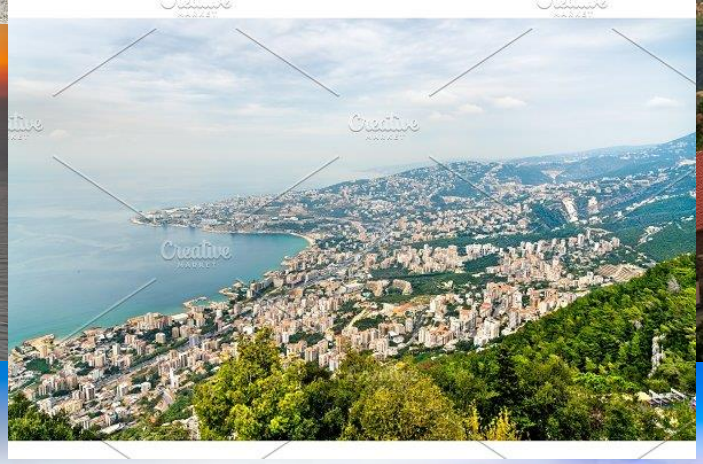
The structure of an ion beam accelerator at a laboratory belonging to the Lebanese Atomic Energy Commission. (Photo: Lebanese Atomic Energy Commission)

Related Resources

- Ion beams
- More background on accelerators
- Accelerators
- Accelerators in science and industry: Focus on the Middle East & Europe
- Coordinated Research Activities
- Development of a Reference Database for Ion Beam Analysis

Perspectives

- Sustainability, maintenance, performance
- Improve DAQ systems (in-air and in-vacuum)
- Full operation of the external micro-beam
- Automated system for applications with large number of samples
- New applications and collaborations
- Centre of excellence in the MENA region

Thank you for your Attention

The prestigious archeological site of
Byblos 7000 years old