Basic and Applied
X-ray Spectrometry at INPP

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Research Activities 2017-2019

Training: 2017-2019

5 MSc theses completed

1 Diploma work completed

Cascade X-ray Emission

X-ray Fundamental Parameters

Basic Research in XRS
Elettra

Resonant Raman Scattering

Improvement/ Development of quantification models/approaches

X-ray Spectrometry Applications
XRF Laboratory
Elettra
AGLAE

Cultural Heritage

Environmental research

Biomedicine

Geochemistry

Advanced Materials

Spin-off

Knowledge Technology Transfer, Services

10 end-users within 2019

Development of XRF Spectrometers for tailored applications

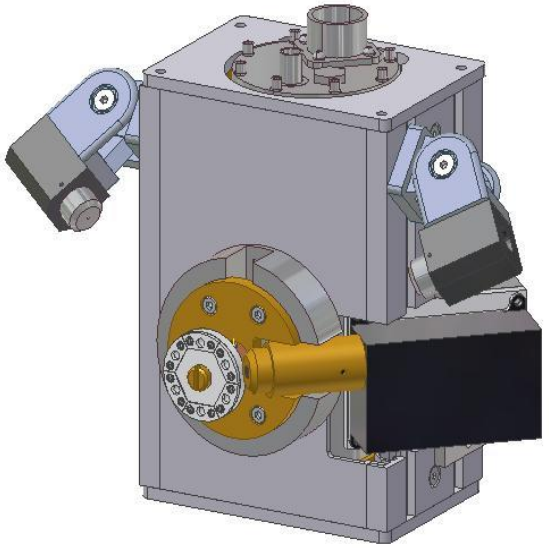
PhD's

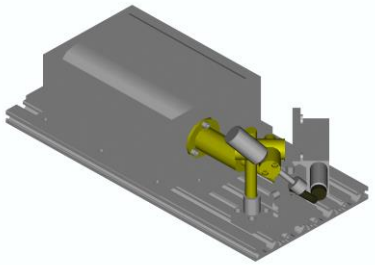
✓ 2003

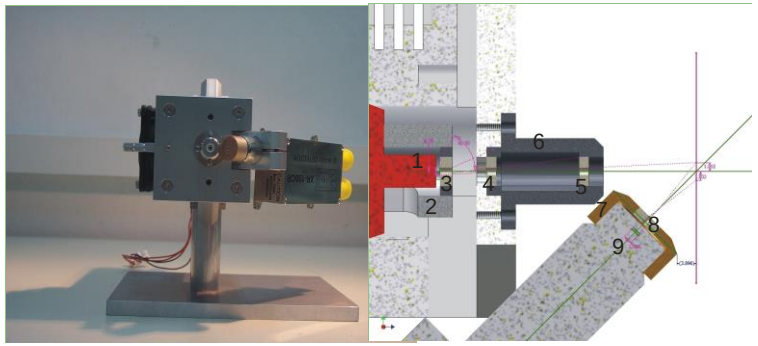
✓ 2010

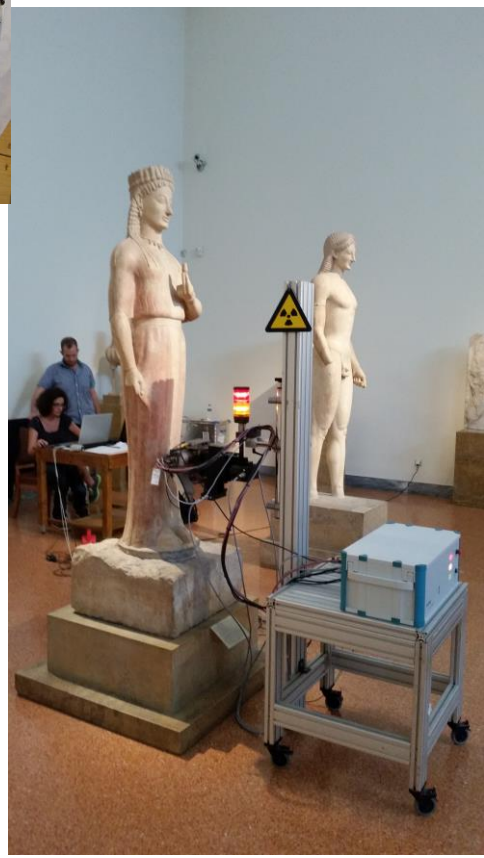
✓ 2016

Infrastructure: Portable XRF spectrometers (μm-mm scale)



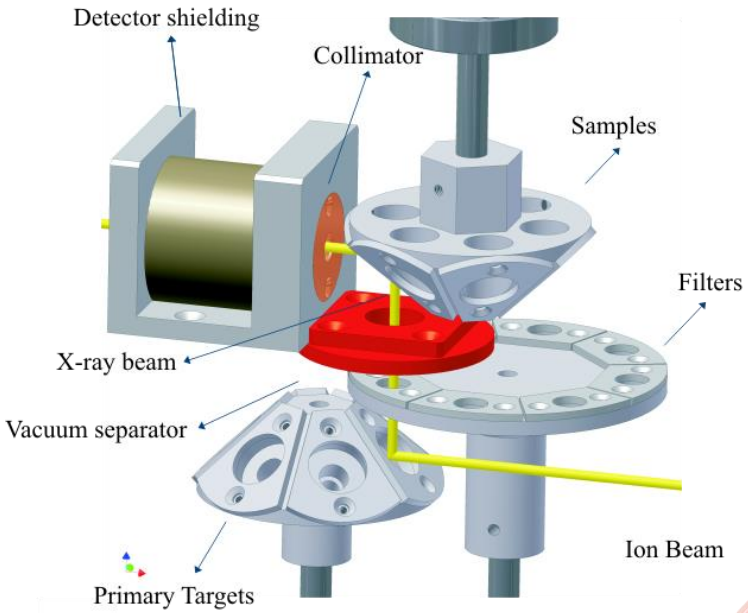


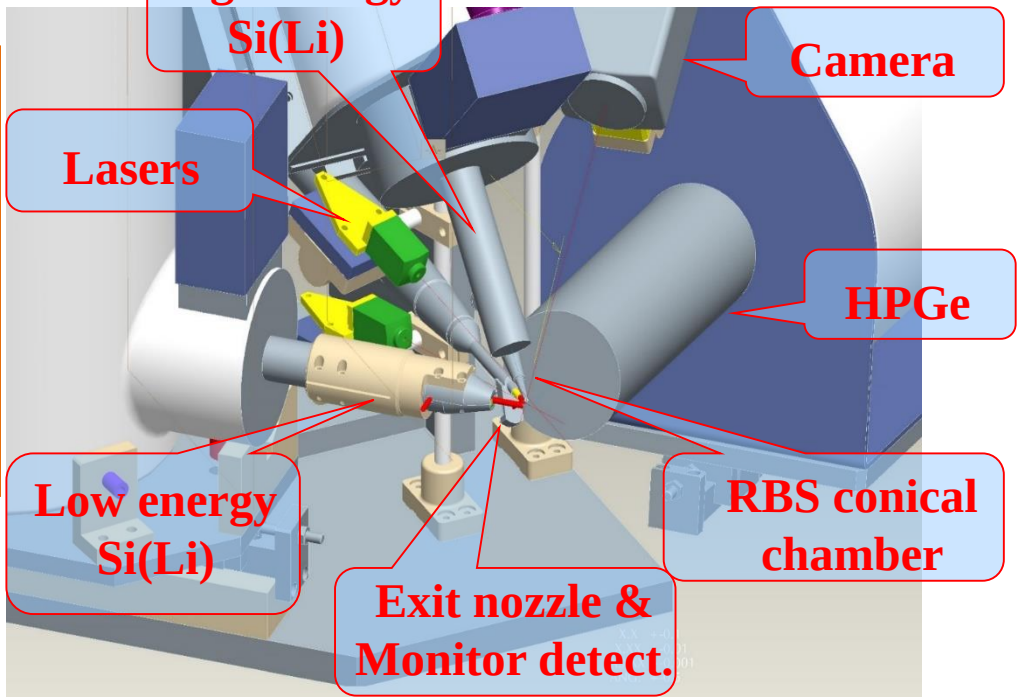


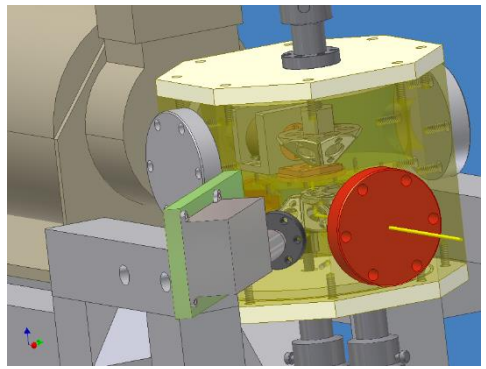


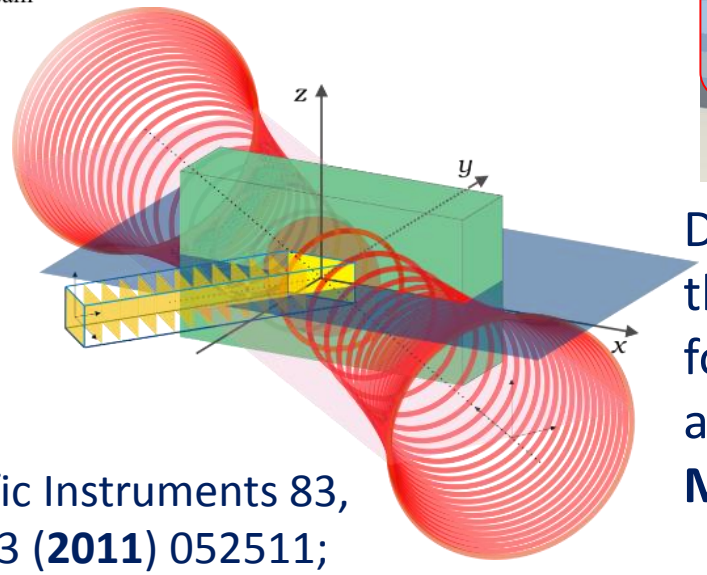
Infrastructure: Proton Induced monochromatic X-ray beams – External Ion Beam Analysis set-up

Sokaras et. *al*. NIM B 269 (**2011**) 519–527







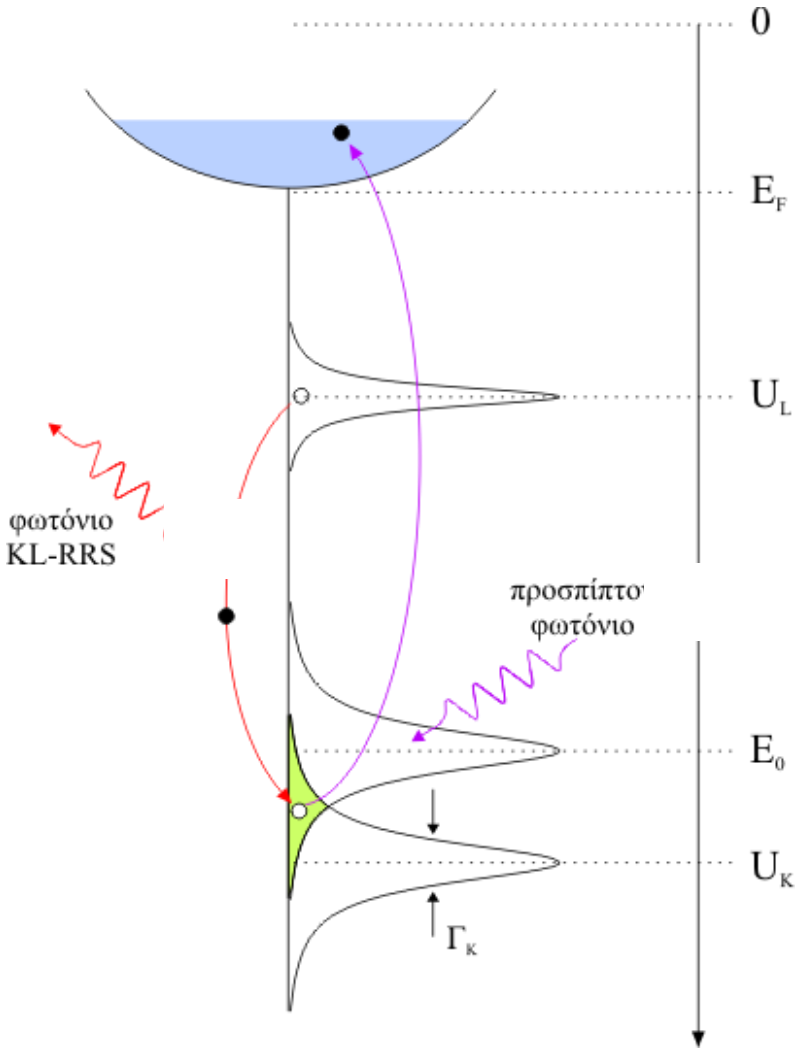


D. Sokaras, et *al*., Review of Scientific Instruments 83, 123102 (**2012**); Physical Review A 83 (**2011**) 052511; A 81 (**2010**) 012703

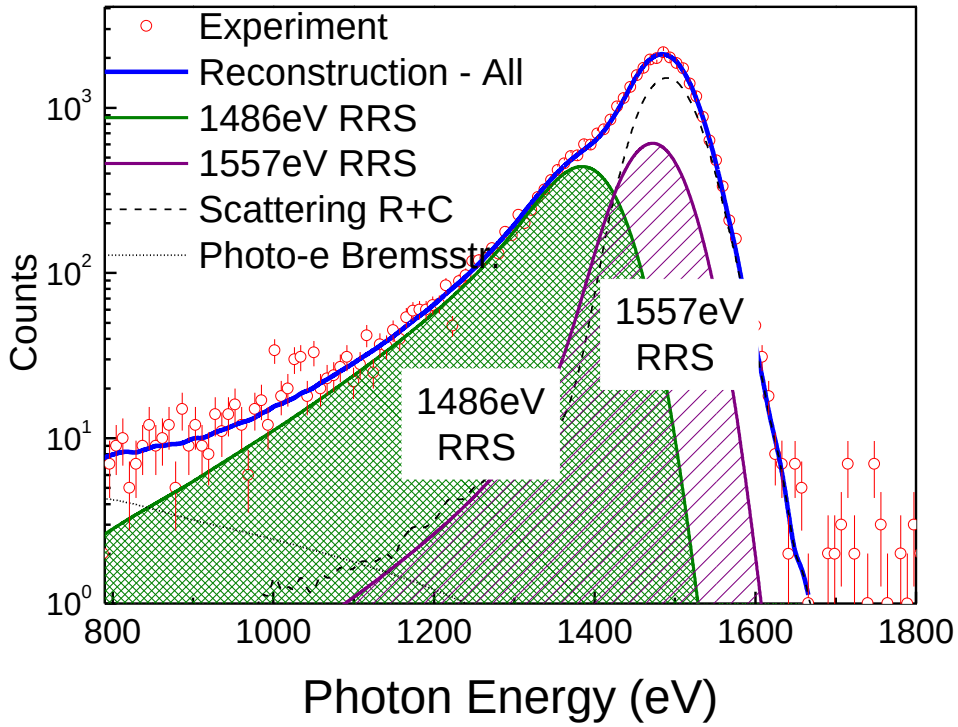
Development of theoretical formulation for quantitative analysis using **confocal Micro-PIXE**

- Karydas et *al.*, JAAS, J. Anal. At. Spectrom 22 (**2007**) 1260
- D. Sokaras, PhD thesis, **2010**; Analytical Chemistry, 81(12), (**2009**) 4946; J. Anal. At. Spectrom., 24 (**2009**) 611

X-ray Resonant Raman Scattering – RRS



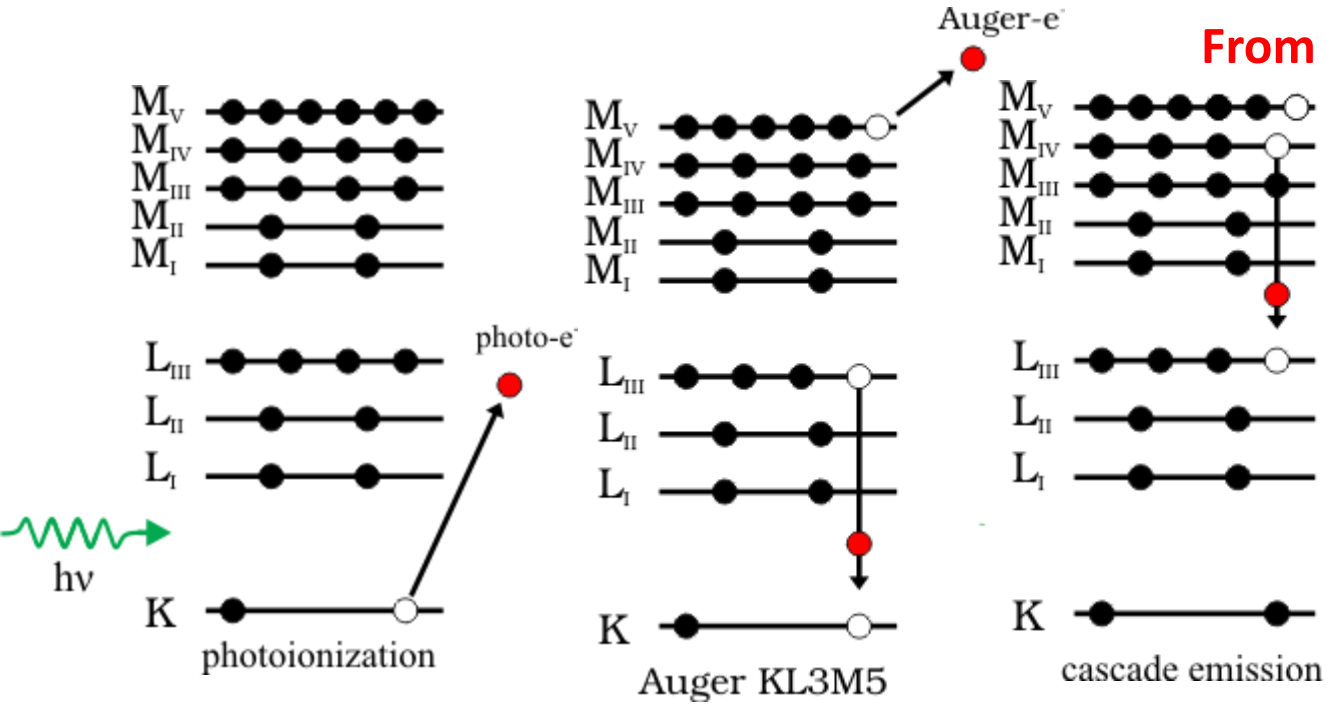
$$H_{int} = -\frac{e}{mc}\mathbf{p}\cdot\mathbf{A} + \frac{e^2}{2mc^2}\mathbf{A}\cdot\mathbf{A}$$



Al (U_K=1559) : 1486 eV (Al-Kα), U_K-E_o=73 eV

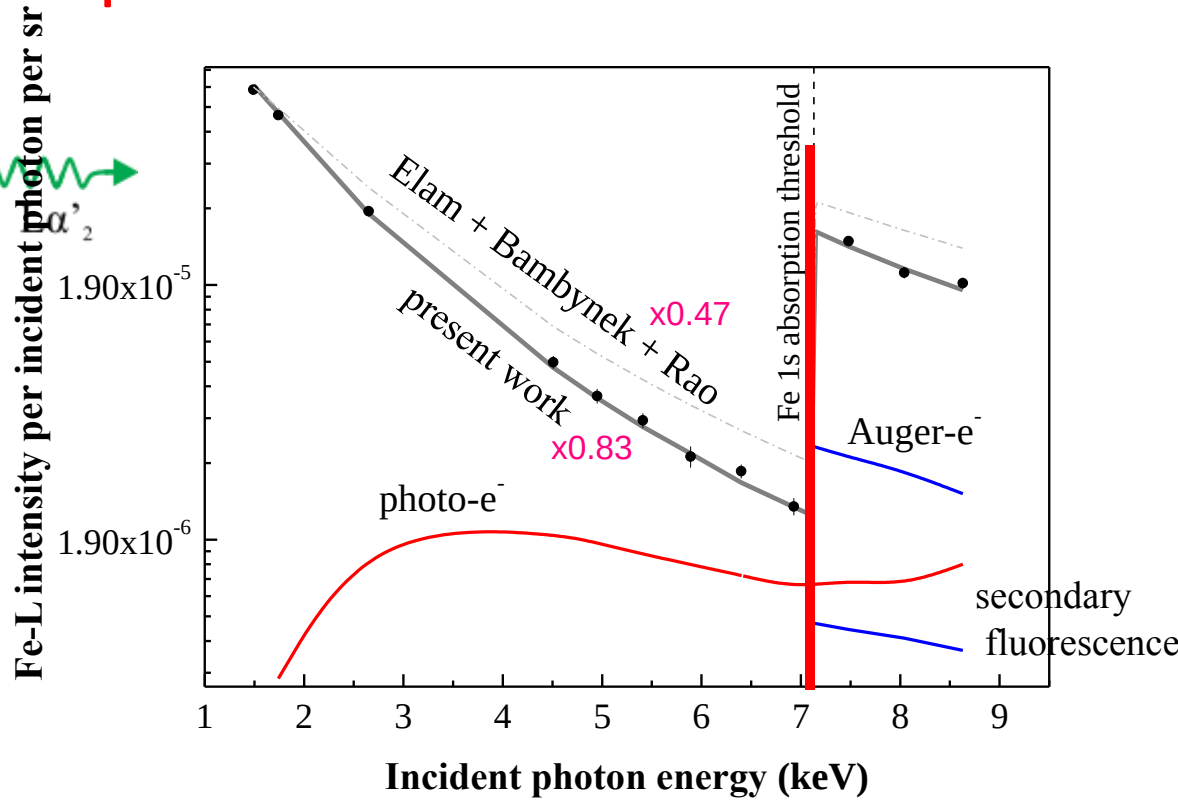
D. Sokaras *et. al, Phys. Rev. A*, 2010, 24, 611

Cascade X-ray emission (KL, LM)



Satellite emission line

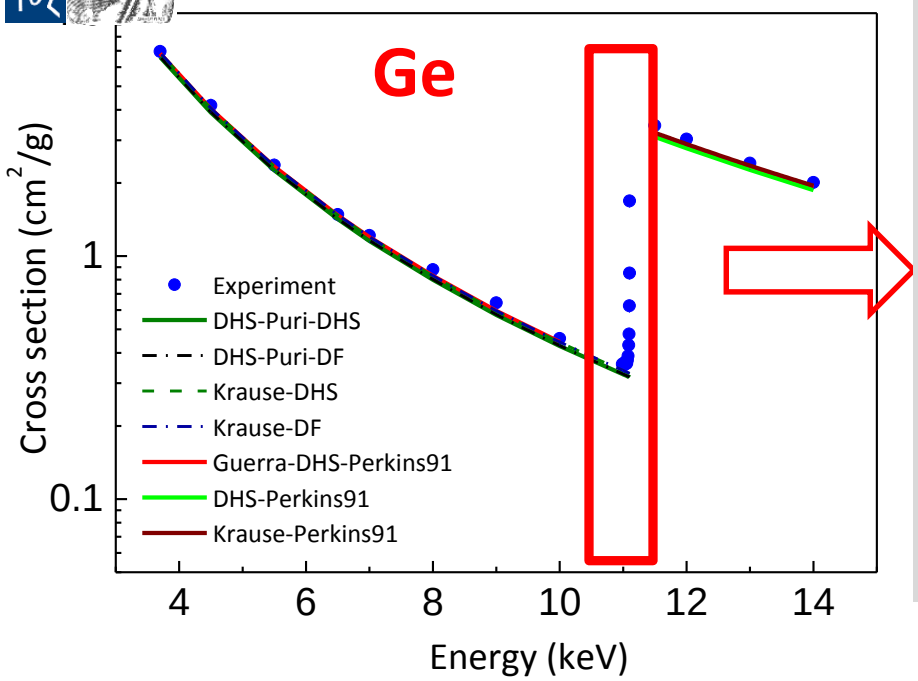
From a multiple ionized atom

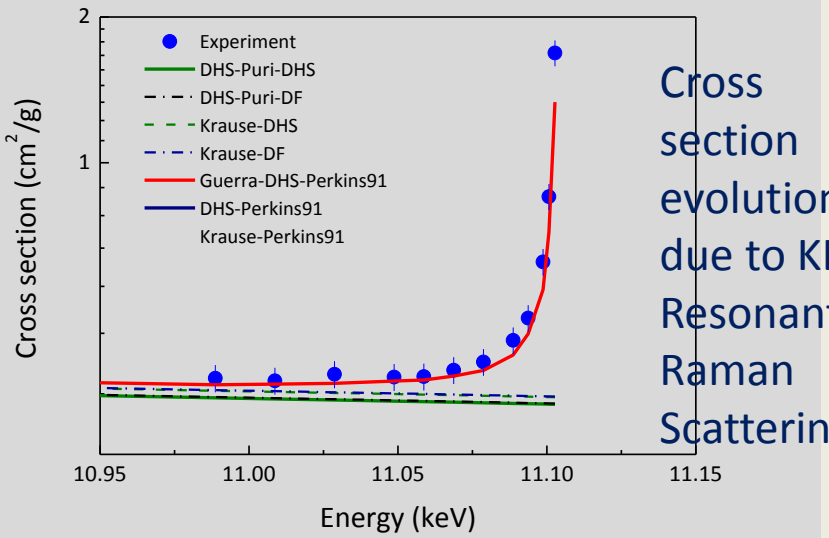


Cascade Emission: X-ray emission due to relaxation of an electronic vacancy created **indirectly** by the relaxation of innermost shell and **not** due to a direct ionization.

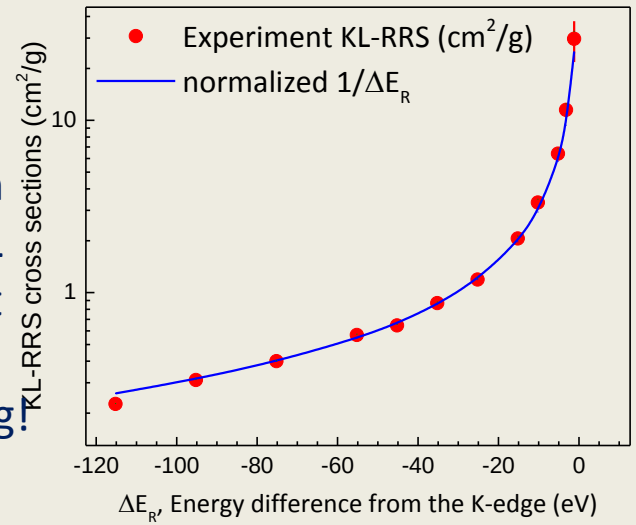
D. Sokaras et al., Physical Review A 83, 052511 (2011)

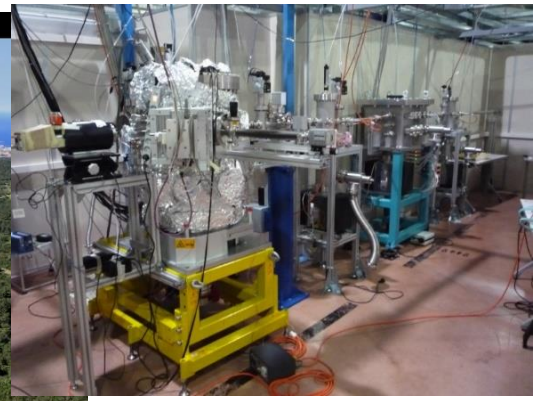
Cascade L X-ray emission in the vicinity of K threshold: Ge





Cross section evolution due to KL Resonant Raman Scattering!





XRF Beamline end-station at Elettra Sincrotrone Trieste, Trieste, Italy

MSc Thesis/PhD Project

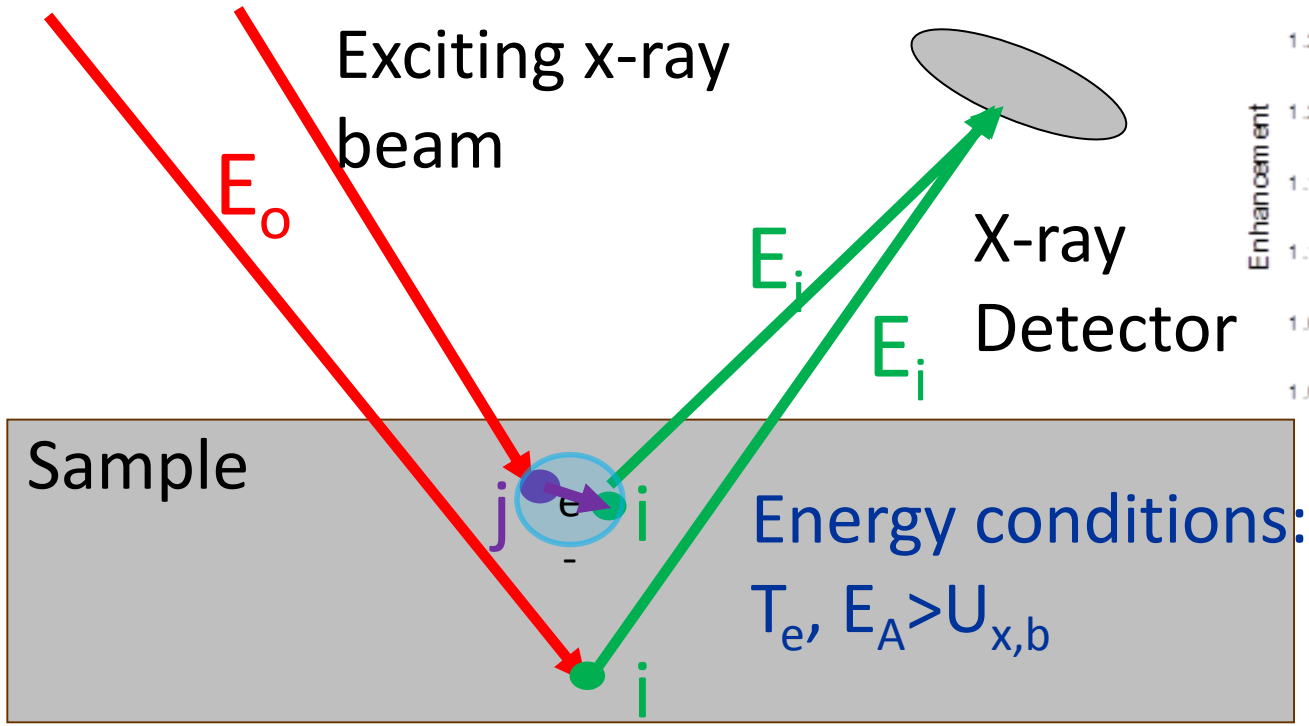
- Cascade KL/KM emission and RRS scattering: Systematic experimental and theoretical studies

✓ Synchrotron experiments @Elettra

✓ *ab-initio* based theoretical calculations

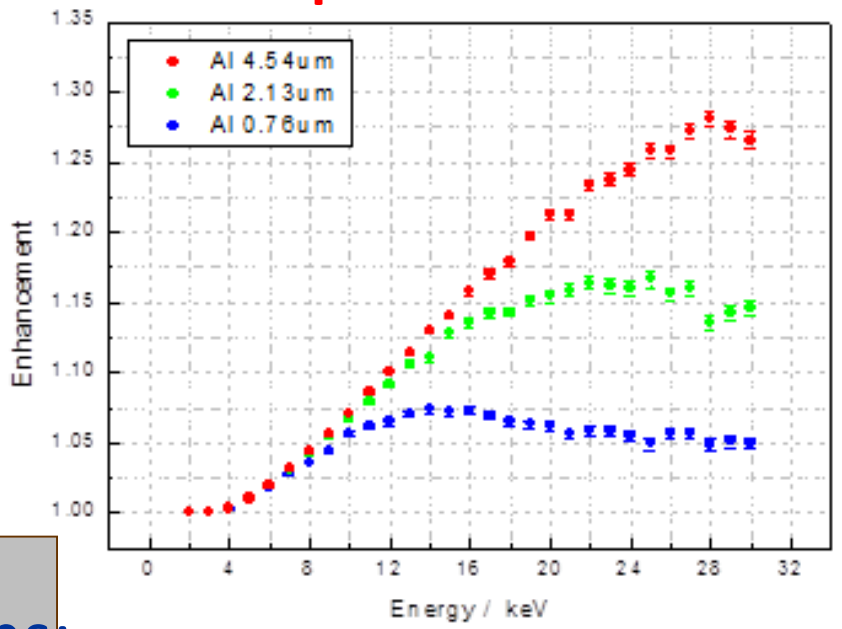
Photo-electron Secondary Fluorescence Enhancement

Electron spectrum: Discrete: Photo-e, Auger
Continuous: Compton



Ejected electrons from the atoms of element *j* can ionize an inner shell of element *i*

MC results, in-house developed

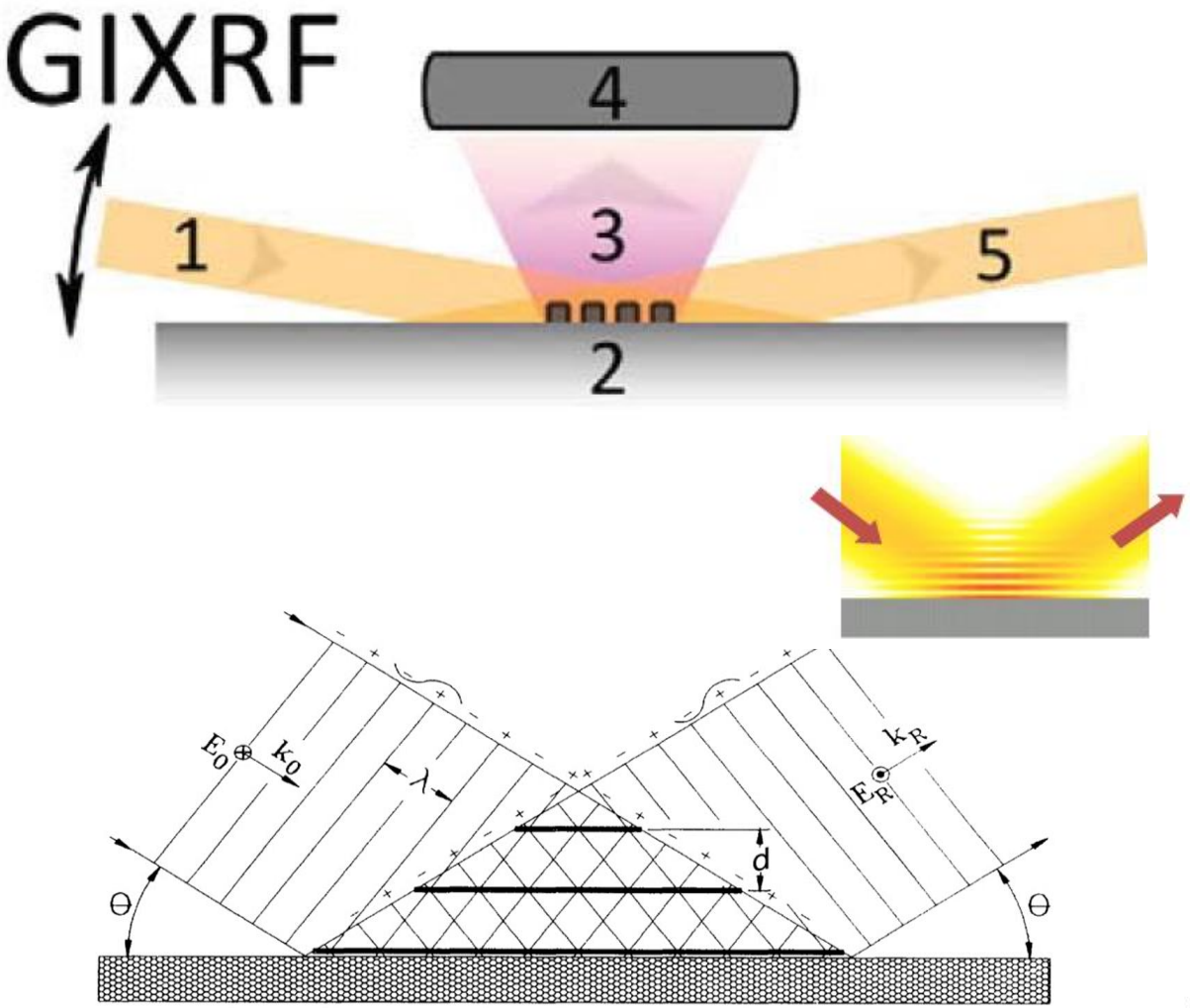


New measurements available for silicon nitride (Si_3N_4) membranes 100, 2000 nm 4-14 keV range

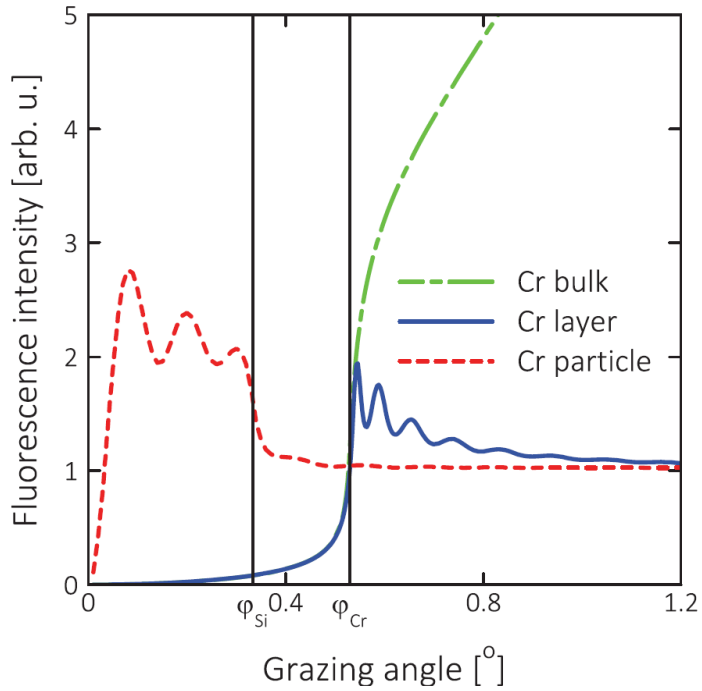
MSc Thesis

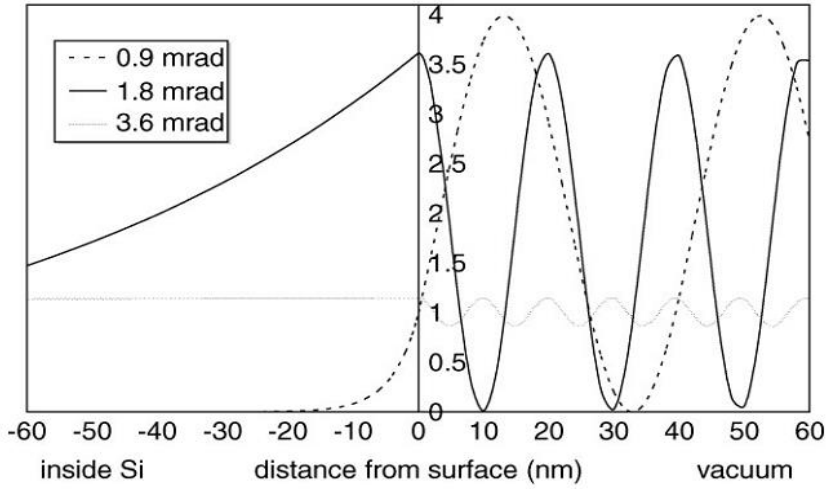
- Data analysis
- GEANT/PENELOPE simulations
- Custom software development

Development of Grazing Incidence XRF applications



Formation of X-ray Standing Wave (XSW) at grazing incident/exit angle

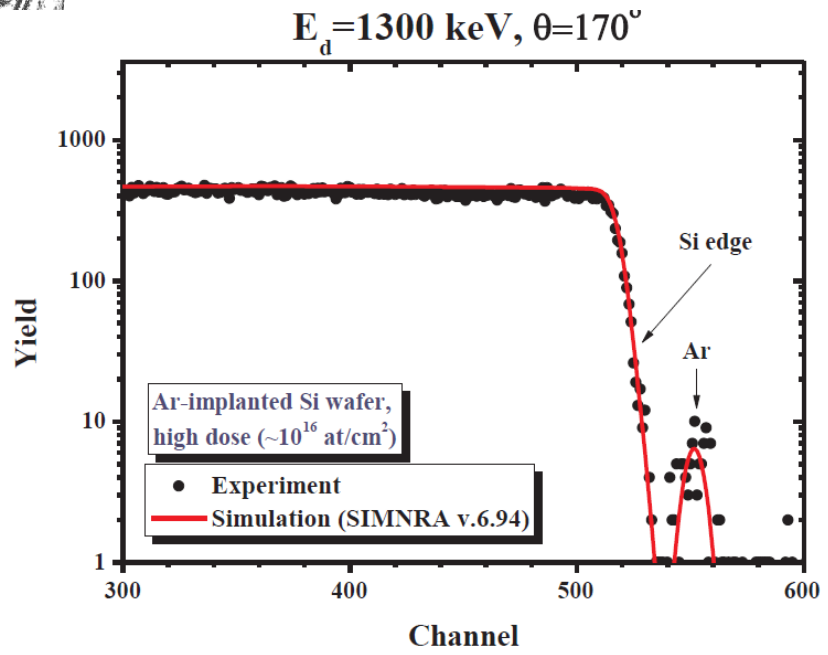


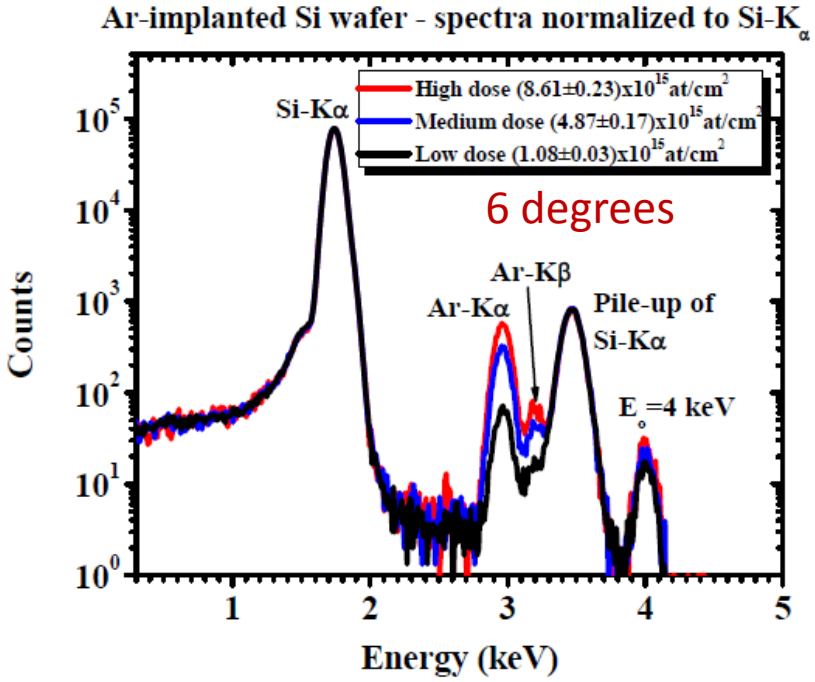


Electric Field Modulations above the surface

Andreas Karydas, ημερίδα ΣΕΜΦΕ, 28/1/2020

Depth distribution of Deep-Implanted ions in Silicon



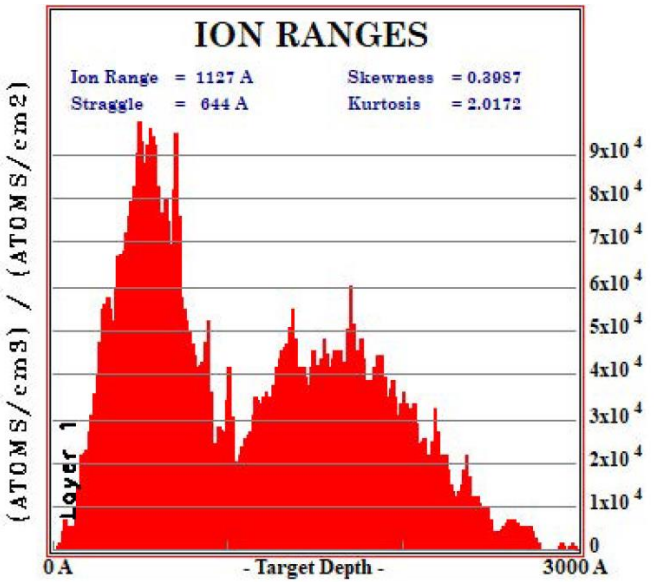


MSc Thesis/PhD Project

- Data analysis and evaluation
- Development of GI-XRF quantification/Software

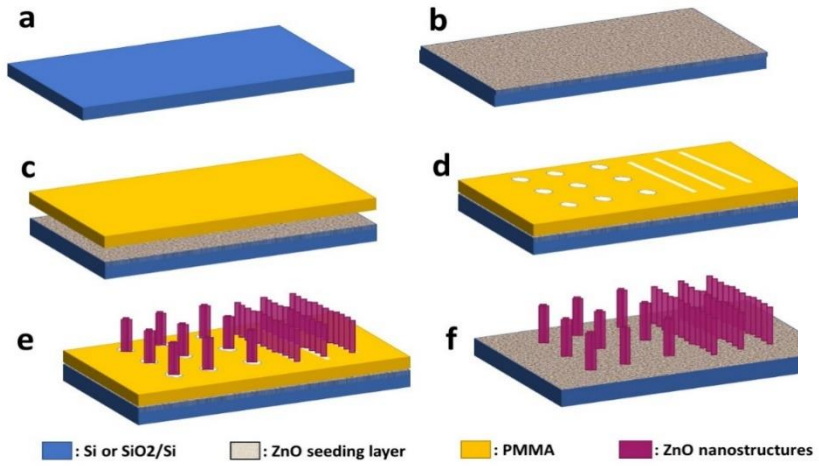
M. Kokkoris, E.G. Androulakaki, M. Czyzycki, M. Erich, A.G. Karydas, (...), V. Paneta, S. Petrović, "**Argon ions deeply implanted in silicon studied by Rutherford/Elastic Backscattering and Grazing Incidence X-ray Fluorescence spectroscopy**", NIM B', 450 (2019) 144–148

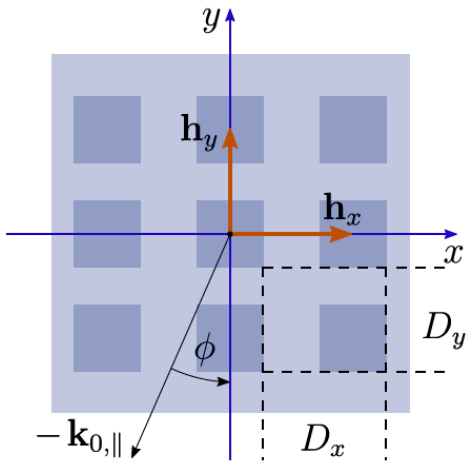
Xe ions sputtering energy: 400/238/84 keV
Fe ions sputtering energy: 180/84/60 keV
Xe/Fe ions, 10^{14}, 10^{15} 10^{15} particles/cm^2

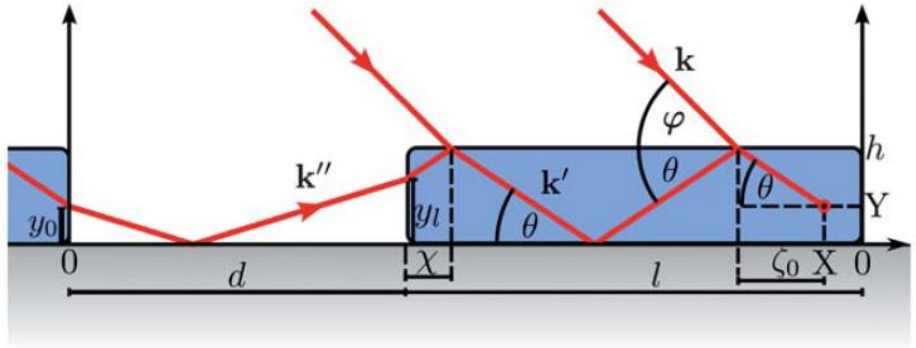


Collaboration with TU of Athens

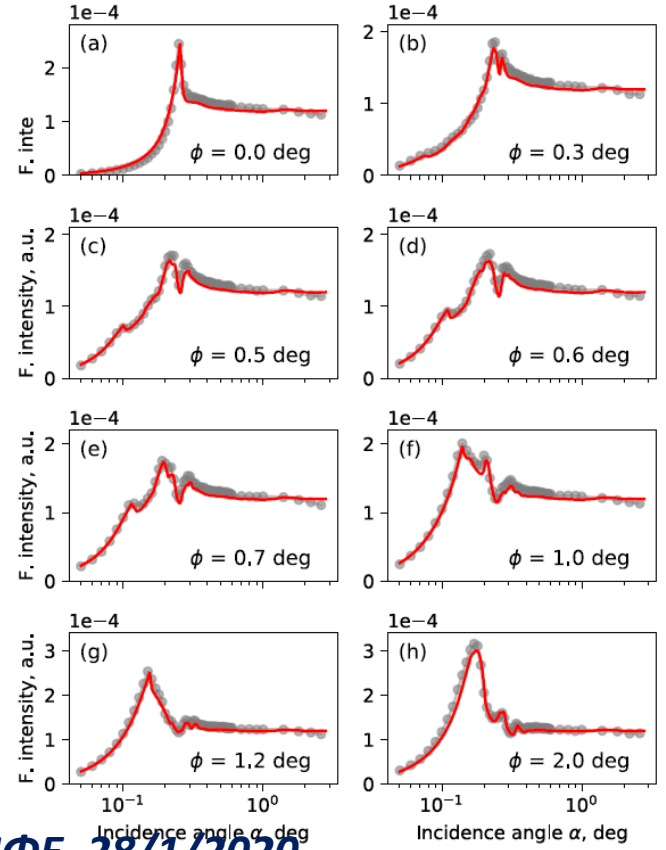
Characterization of 3D nano-structures

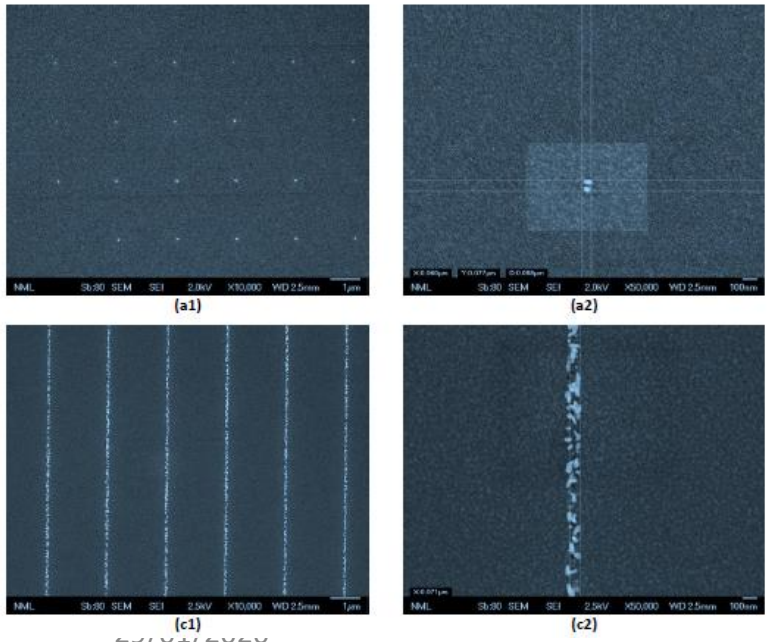






1*μm, 300nm x 300 nm, 24nm*





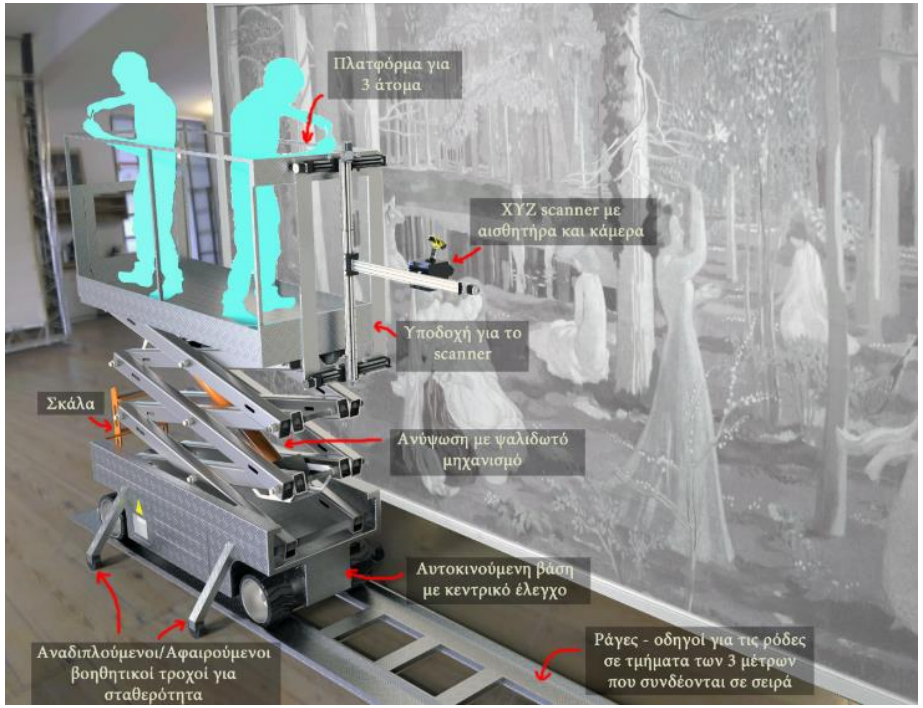
SEM images of periodic arrays of patterns containing ZnO nanorods grown by the two-step HG onto EBL-patterned SiO_2/Si substrates:

dot array/ribbon array;

MSc Thesis/PhD Project

- GI-XRF measurements@EST
- Data analysis and evaluation
- Development of GI-XRF quantification/
- Software

ΠΡοηγμένο σύστημα συλλογής και διαχείρισης αναλυτικΩν δεδομένων για την ανοιχτή προς το κοινό ΤΕκμηρίωση, και συντήρηση ζωγρΑφικών έργων τέχνηΣ μεγάλων διαστάσεων, ΠΡΩΤΕΑΣ, Ερευνώ-Καινοτομώ, 2020-2023



MSc Thesis Project

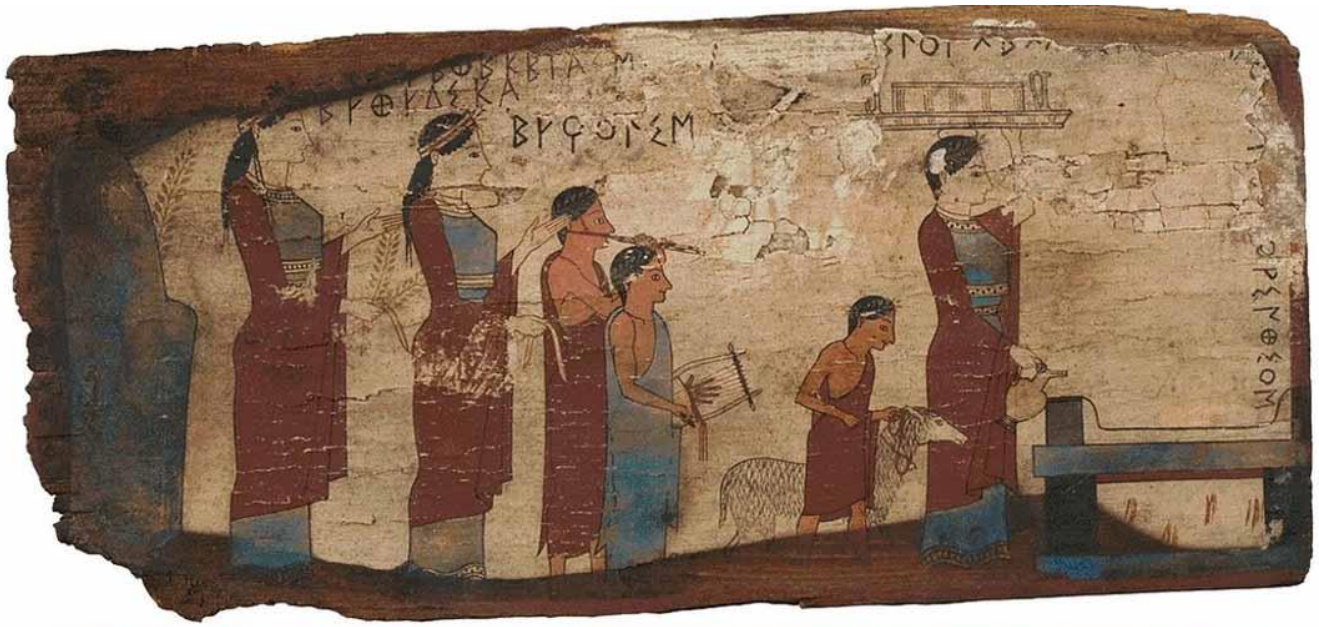
- Development & analytical characterization of a MA-XRF analysis spectrometer probe

Έργο ελαιογραφίας σε ύφασμα του Charles-Louis-Lucien Muller «3η Μαρτίου 1814» (**445 x 845 εκ**)

Αντικείμενο του προτεινόμενου έργου είναι η ανάπτυξη μιας ολοκληρωμένης οργανολογίας και της σχετικής μεθοδολογίας για τη μελέτη και συντήρηση ζωγραφικών έργων μεγάλων διαστάσεων και η πιλοτική εφαρμογή αυτής στο έργο του Muller. Συγκεκριμένα το προτεινόμενο έργο, αποσκοπεί

- στην ανάπτυξη διαγνωστικών μεθοδολογιών και συστημάτων
- στην ανάπτυξη ενός ενιαίου συστήματος διαχείρισης, τεκμηρίωσης και προβολής των αποτελεσμάτων
- στην σχεδίαση και υλοποίηση ενός καινοτόμου συστήματος κίνησης των διαγνωστικών συστημάτων
- στην ανάπτυξη ενός εξειδικευμένου ενοποιημένου λογισμικού για τον έλεγχο και την διαχείριση των συστημάτων
- στην δημιουργία ενός Εργαστηρίου Ανοικτής Θέασης (ΕΑΘ) στους χώρους της ΕΠΜΑΣ

MA-XRF imaging – PITSA Panels



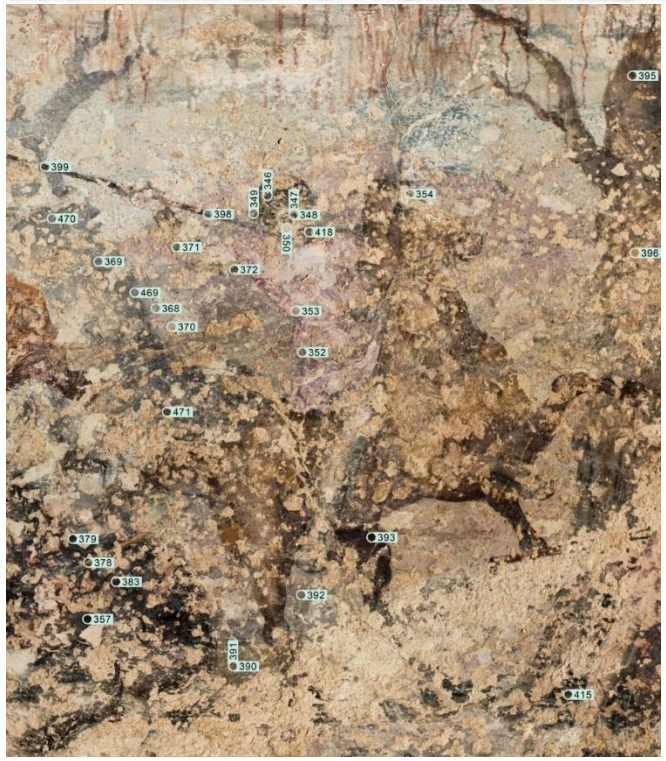
Archaic wooden panels of Pitsa, Earliest painting in Greece

MSc Thesis Project

- Monte Carlo simulations of MA-XRF spectra
- Development of quantification procedures

Hand-Held XRF pigment analysis on Macedonian Funeral monuments

Frieze of the Royal tomb of Philip II, Ancient Aigai



Eurydice Tomb, Vergina, Ancient Aigai

MSc Thesis Project

- Data analysis and evaluation
- Development of HHXRF quantification procedures

Andreas Karydas, ημερίδα ΣΕΜΦΕ, 28/1/2020

Summary

Basic X-ray spectrometry studies (MSc/PhD – Elettra)

- Cascade KL/KM emission and RRS scattering: Systematic experimental and theoretical studies (Synchrotron experiments @Elettra, *ab-intio* based theoretical calculations **(MSc/PhD)**
- Photo electron enhancement in XRF analysis (Data analysis, GEANT/PENELOPE simulations, custom software development) **(MSc)**

Nanomaterials characterization using GI-XRF analysis (MSc/PhD Elettra)

- GI-XRF depth profiling of deep implanted ions (Data analysis and evaluation, Development of GI-XRF quantification/Software)
- GI-XRF characterization of 3D nanostructures (GI-XRF measurements@Elettra, Data analysis and evaluation, Development of GI-XRF quantification/Software)

Cultural Heritage projects (MSc, INPP)

- Development and analytical characterization of a new portable MA-XRF analysis spectrometer probe
- HHXRF analysis of pigments from Macedonia funeral monuments: Data analysis and evaluation, Development of HHXRF quantification procedures
- Pitsa Panels: Monte Carlo simulations of MA-XRF spectra, development of MA-XRF quantification procedures

Σας Ευχαριστώ για την προσοχή σας!!!