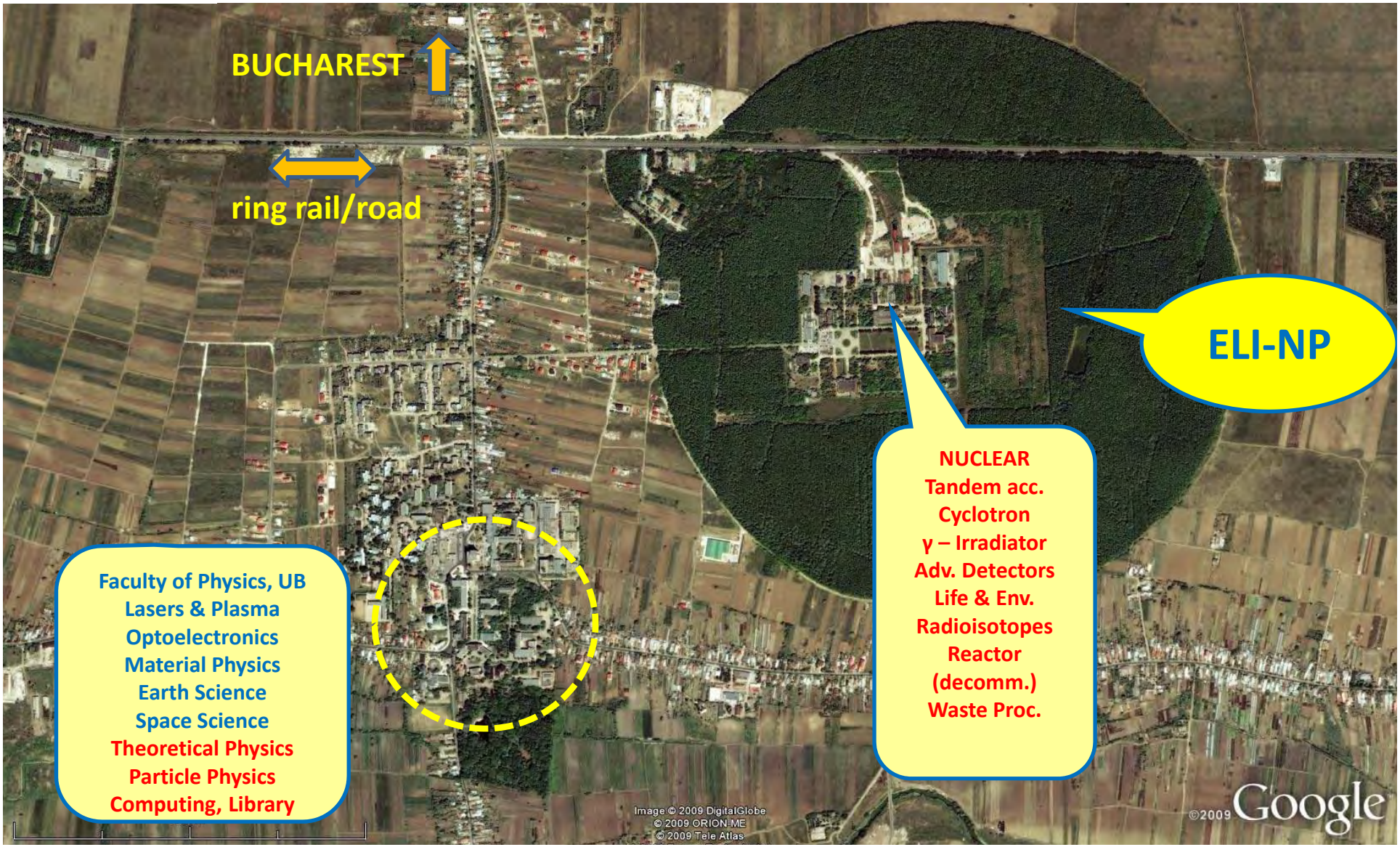
Study and preservation of cultural heritage with atomic and nuclear techniques

at IFIN-HH Bucharest

Livius Trache
for IFIN-HH, Bucharest-Magurele

Gordon Research Conf. New London, May 31st – June 5th, 2015

Bucharest-Magurele Physics Campus
National Physics Institutes




IFIN-HH

Study and preservation of cultural heritage

- Study and preservation of cultural heritage badly needed in Romania, in many countries of the Danube and Balkans; regional cooperation needed
- IFIN-HH Bucharest has the instrumentation, personnel and experience in the application of advanced physical & chemical methods for the study of environment and for the study and preservation of cultural heritage
- IFIN-HH large facilities:
  - tandem accelerator complex (9, 3 and 1 MV)
  - 2 cyclotrons
  - IRASM gamma-rays irradiator
- Cultural heritage studies were done before with "old" infrastructure (9 MV tandem, cyclotron, reactor…)
- Concentrate today on "new" infrastructure:
  - Ion beam analyses at the 3 MV tandetron + at outside facilities
  - ^{14}C dating at the 1 MV tandetron
  - "curing" and preservation with gamma-ray irradiator
  - Variety of analysis equipment
- Use of outside (abroad) facilities possible due to existing collaborations and connections

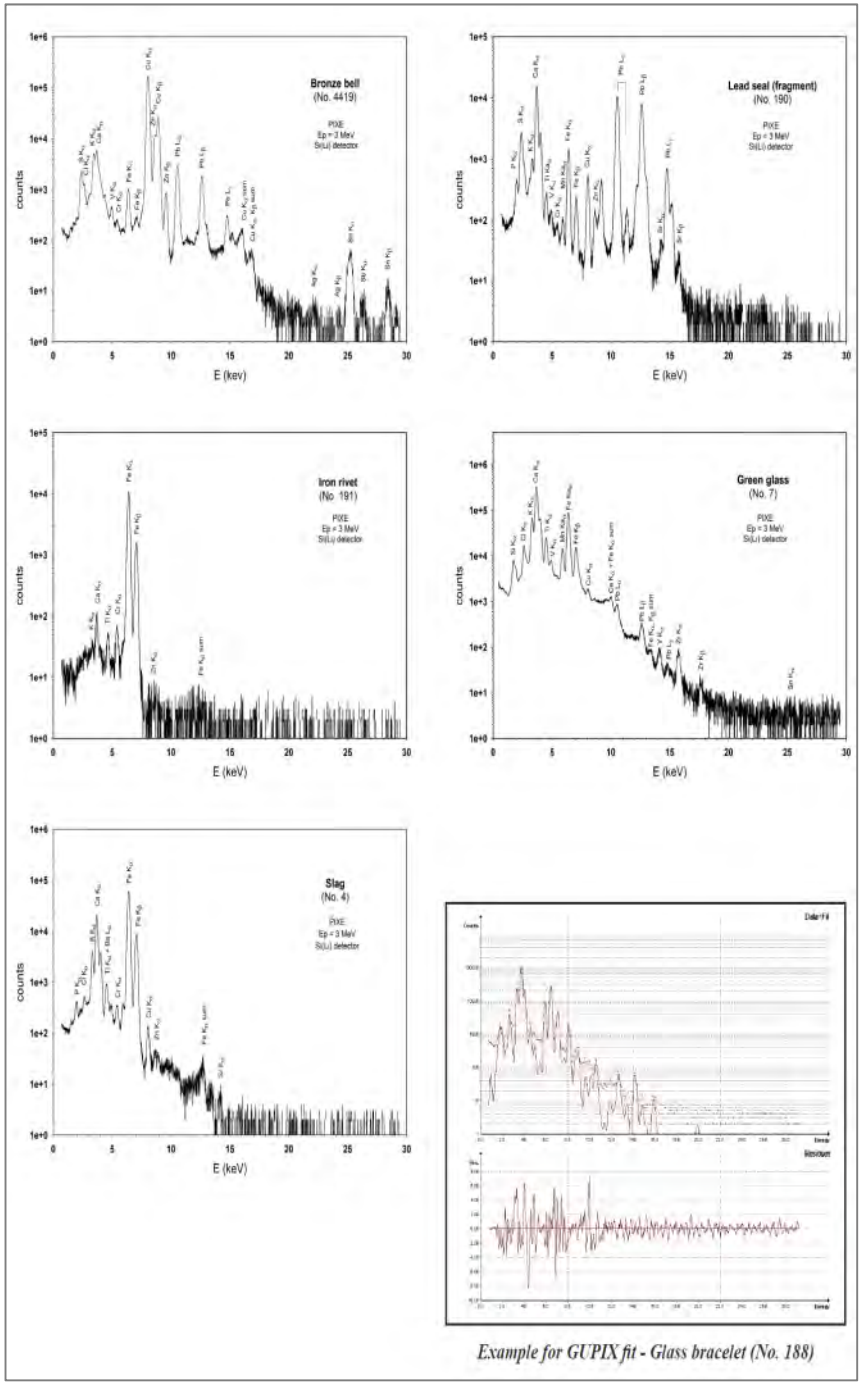
PIXE analysis on Bulgarian artefacts (IX-XI centuries)

Introduction

Proton Induced X-ray Emission (PIXE) analysis has been applied on bronze, lead, iron, and glass artifacts discovered in 2012 from the "Small Wooden Fortification" site of the old medieval capital of Bulgaria, Pliska in IX-XI centuries. The origin and history of archaeological objects can be established based on the presence of specific elements as fingerprint of a given source of raw material and manufacturing procedure. The aim of this paper was to obtain information about the elemental contents of these types of artifacts by PIXE technique (thick targets). Subsequent conclusions concerning the production site and technology, if they are done in Pliska or are imported from other countries, will be drawn by a comparison with previous investigations in Bulgaria [1-3].

Pliska – Trench No 20

Courtesy of Ana Pantelica



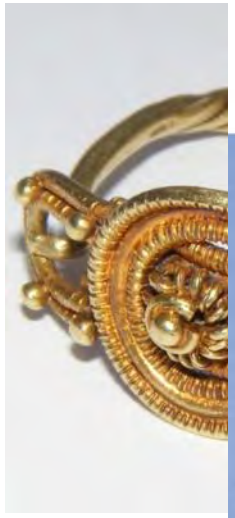
Example for GUPIX fit - Glass bracelet (No. 188)

DFN

JAAS

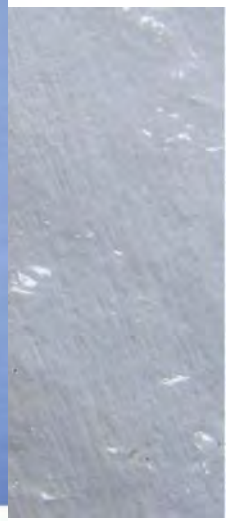
Journal of Analytical Atomic Spectrometry

ology



www.rsc.org/jaas Volume 27 | Number 12 | December 2012 | Pages 1995–2140

Hen and its Chickens



ISSN 0267-9477

RSC Publishing

PAPER
Angela Vasilescu *et al.*
Studies on archaeological gold items found in Romanian territory using X-Ray-based analytical spectrometry

A few stories

Story:

Several hoards containing at least twenty four gold spiral bracelets and few thousands of gold coins (staters) of pseudo-Lysimachus and Koson types (Koson with and without monogram) have been unearthed in the time frame between 1999 and 2001, by organized gangs of illegal treasure hunters, in five different spots in the area of Sarmizegetusa Regia, in the Orastie Mountains, Romania.

Sarmisegetusa Regia – Dacia's center of power & religion;

US Particle Accelerator School

B. Constantinescu, E. Oberlander-Tarnoveanu, R. Bugoi, V. Cojocaru, M. Radtke, *The Sarmizegetusa Bracelets*, Antiquity Journal (London) 84 Issue 326 (2010)1028-1042.

Locally minted gold coins (B.C.)

Dacian Koson without monogram

Dacian Koson with monogram

Compositional studies for identification:

- **Main components of gold alloys (Au-Ag-Cu) which can be used in their authentication**
- **Trace elements might bring significant clues. Trace-elements which can be found in native gold are the Platinum Group Elements (PGE) - Pt, Ir, Os, Ru, Rh, Pd, but also Sn, Sb, Te, Hg, Ti, Zr, As, Bi, Fe.**

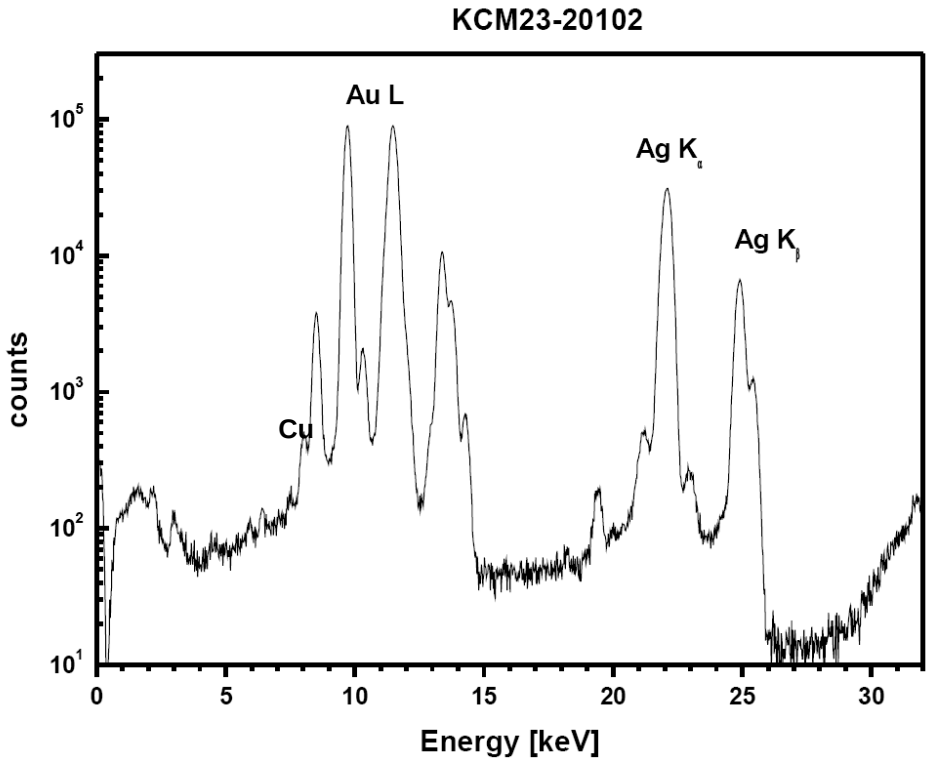
From Antiquity to the Middle Ages, the most important gold source consisted of placer deposits. Alluvial gold is derived from weathered rocks containing vein gold deposits. The overall silver and copper content of the alluvial gold is somewhat lower than the one of the initial vein gold from which it had originated.

Sn from cassiterite is a fingerprint for alluvial gold.

Various methods:

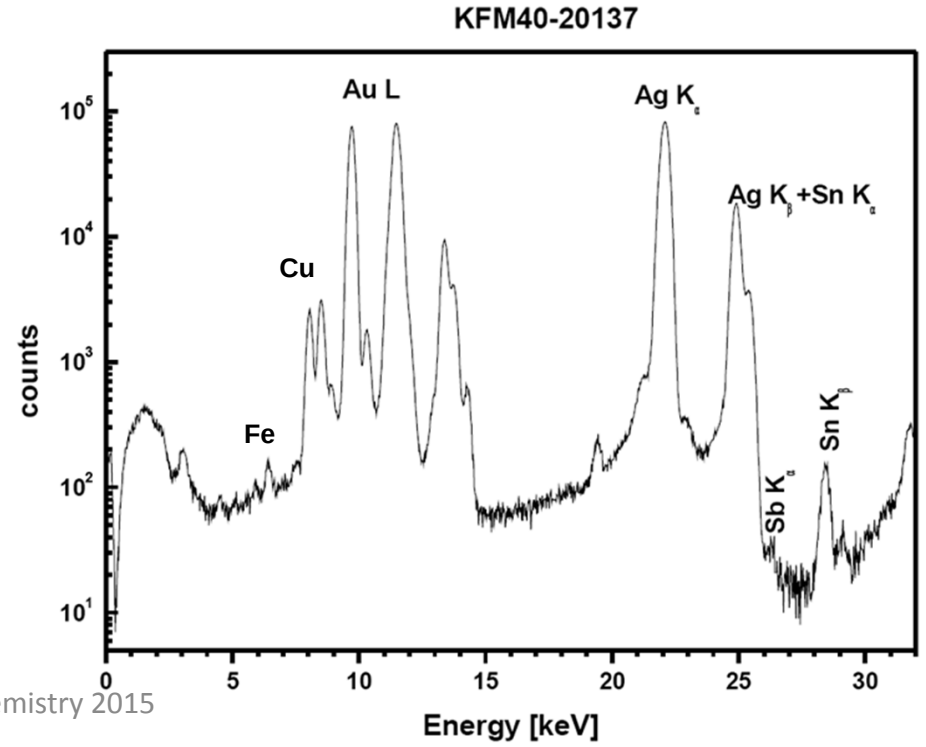
Initial XRF measurements done at home (IFIN-HH)

In early 2011, we obtained the permission of the Romanian authorities to take very small (1-2 mg) samples from the extremities of the bracelets and from 17 Koson and pseudo-Lysimachus staters to analyze them by micro-SR-XRF at BESSY Synchrotron Berlin.



Koson with monogram no.23

Koson without monogram no.40



Two categories of Koson staters:

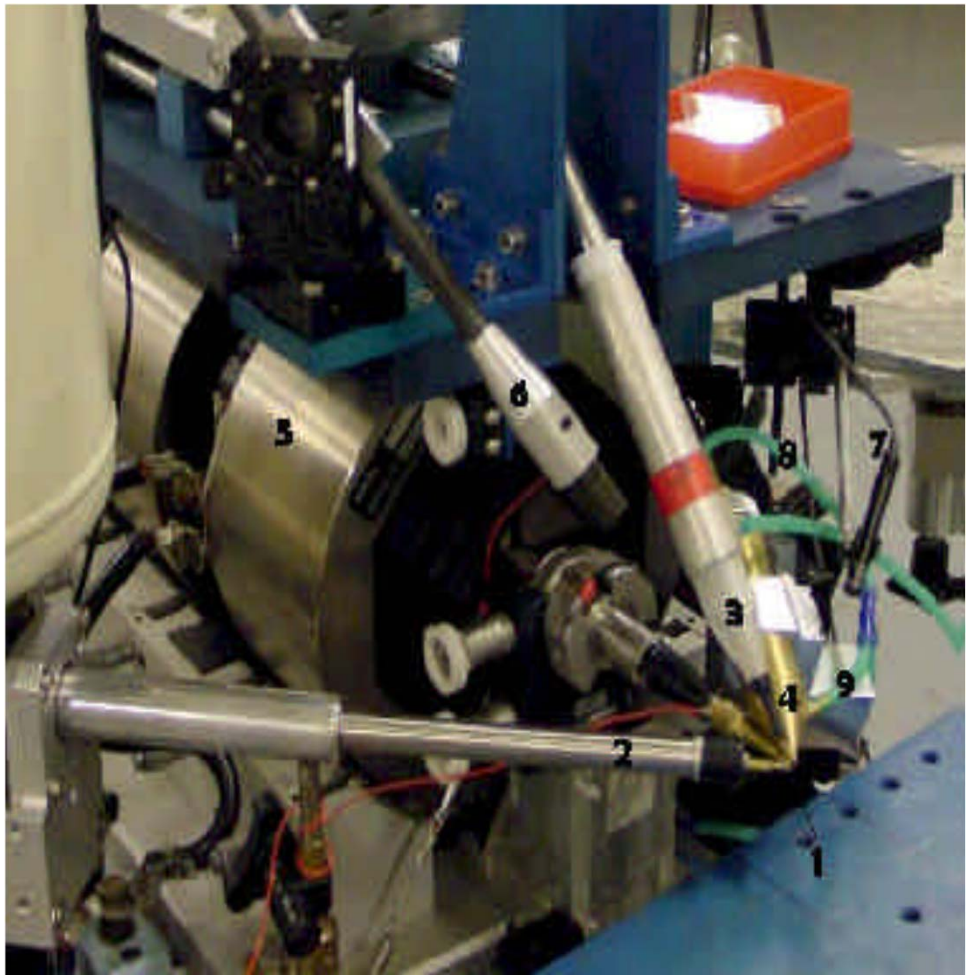
- **The Koson staters with monogram have a high-title (Au: 94.41% - 99.21%) and are rather homogeneous, with a reduced content of copper (0.10% - 0.30%) and tin (0 – 67 ppm).**
- **the Koson staters without monogram have a higher content of silver (8.31% - 15.99%) and copper (0.96% - 2.90%), and a significant presence of tin (149 – 1066 ppm), coupled with an evident inhomogeneity in all metallic elements, but especially in tin, copper and iron.**

A most trustful hypothesis **is that the Koson staters with monogram – the original coins – were minted somewhere in the neighbouring Roman provinces (in the Balkans) from refined, "coined" gold and the Koson staters without monogram are "Barbarian" copies made in Dacia (Transylvania) from native gold using a primitive metallurgy incapable to completely melt the small pieces of alluvial gold.**

The same aspects were revealed after the analyses of similarly small fragments (less than 100 microns in diameter) from 13 Dacian gold bracelets.

Note added in proof: similar conclusion for silver Roman republican denarii (early '80s)

AGLAE accelerator - Centre de Recherche et de Restauration des Musees de France, CNRS - Musee du Louvre



Micro-PIXE at AGLAE accelerator

- **Analysis on geological native gold samples from Transylvania – alluvial and primary (veins) – to demonstrate the provenance of the gold used to produce the Dacian bracelets**
- **3 MeV proton micro-beam (roughly 50 μm diameter) extracted into air**
- **Micro-samples (300-1000 μm diameter)**
- **Identification of trace elements – Sn, Sb, Te, Hg – as fingerprints for Transylvanian gold**

- **An explanation for the relative in-homogeneity of the ingots is that the manufacturers were not using advanced technology: most likely, a mixture of gold nuggets and gold dust was melted together, without being perfectly homogenized.**
- **Traces of Sn were observed in practically all the items. The explanation for this phenomenon is that cassiterite (SnO_2) and gold can simultaneously occur in the same vein or placer deposit.**
- **The presence of Sn and Sb traces and the in-homogeneities demonstrate the bracelets and the coins are authentic Dacian artifacts.**

Publications:

20 Scientific papers in international and national journals as:
Journal of Analytical Atomic Spectrometry, Spectrochimica Acta part B, Applied Physics A, Nuclear Instruments and Methods B, Antiquity, Archeosciences, Studii si Cercetari de Istorie Veche si Arheologie, …

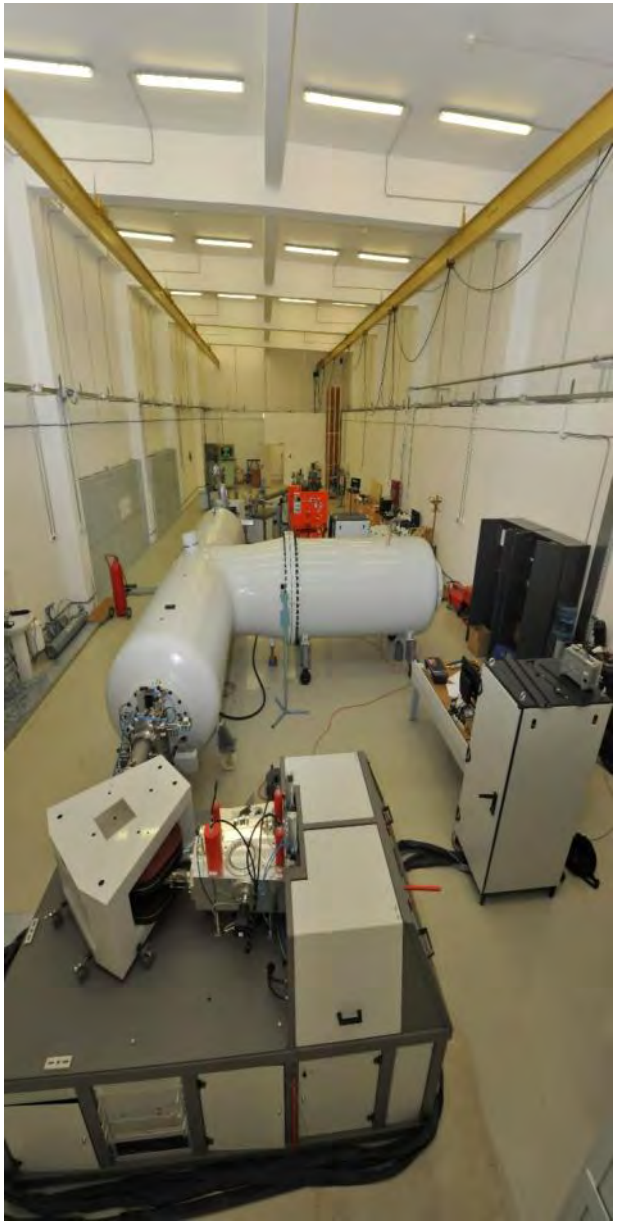
The 3 MV Tandetron Accelerator Dedicated to IBA, ion implantation and nuclear astrophysics

Installed in 2012/2013

- **Beamline dedicated to IBA**
- **Beamline dedicated to ion implantation**
- **Beamline dedicated to nucl astrophys**

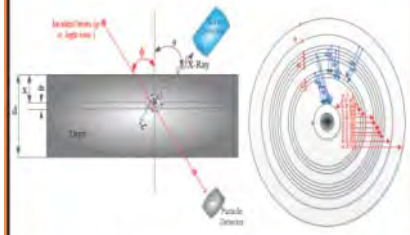
Announced users:
• material scientists – "neighboring" institutes
• archeometrists (PIXE, e.g., on large artefacts)
    •Romania, Bulgaria, Turkey
• enviromentalists
    •Romania, Bulgaria

Bucharest IBA facility – 3 MV Ta



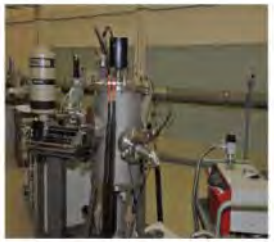
PIXE and μPIXE

IBA end station

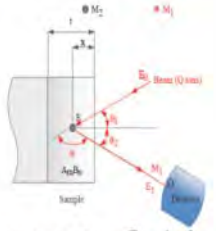


Collision geometry X-Ray Fluorescence

RBS



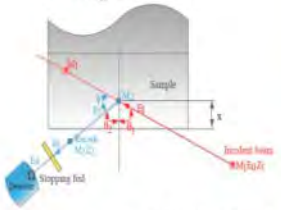
The IBA line



Collision geometry. Good for atoms heavier than the projectile (Z≥11).

ERDA

IBA target chamber



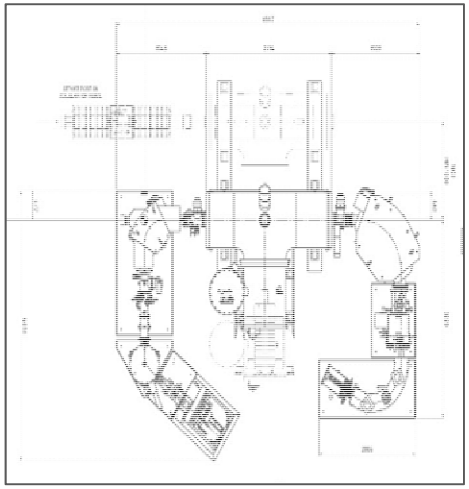
Collision geometry for ERDA. Good for atoms lighter (1≤Z≤9) than the projectile (energy ≈ 1 MeV/aum).

Ion Implatations Line

The ion implantation line together with its end station

The ultra modern equipped ion beam implantation system gives us the opportunity to investigate the effects induced by controlled doping processes on semiconductors and also for treatment of metal components in order to improve the surface durability.

Bucharest AMS System – 1 MV Tandetron®
(AMS = Accelerator Mass Spectrometry)



Isotope ratios measured for:

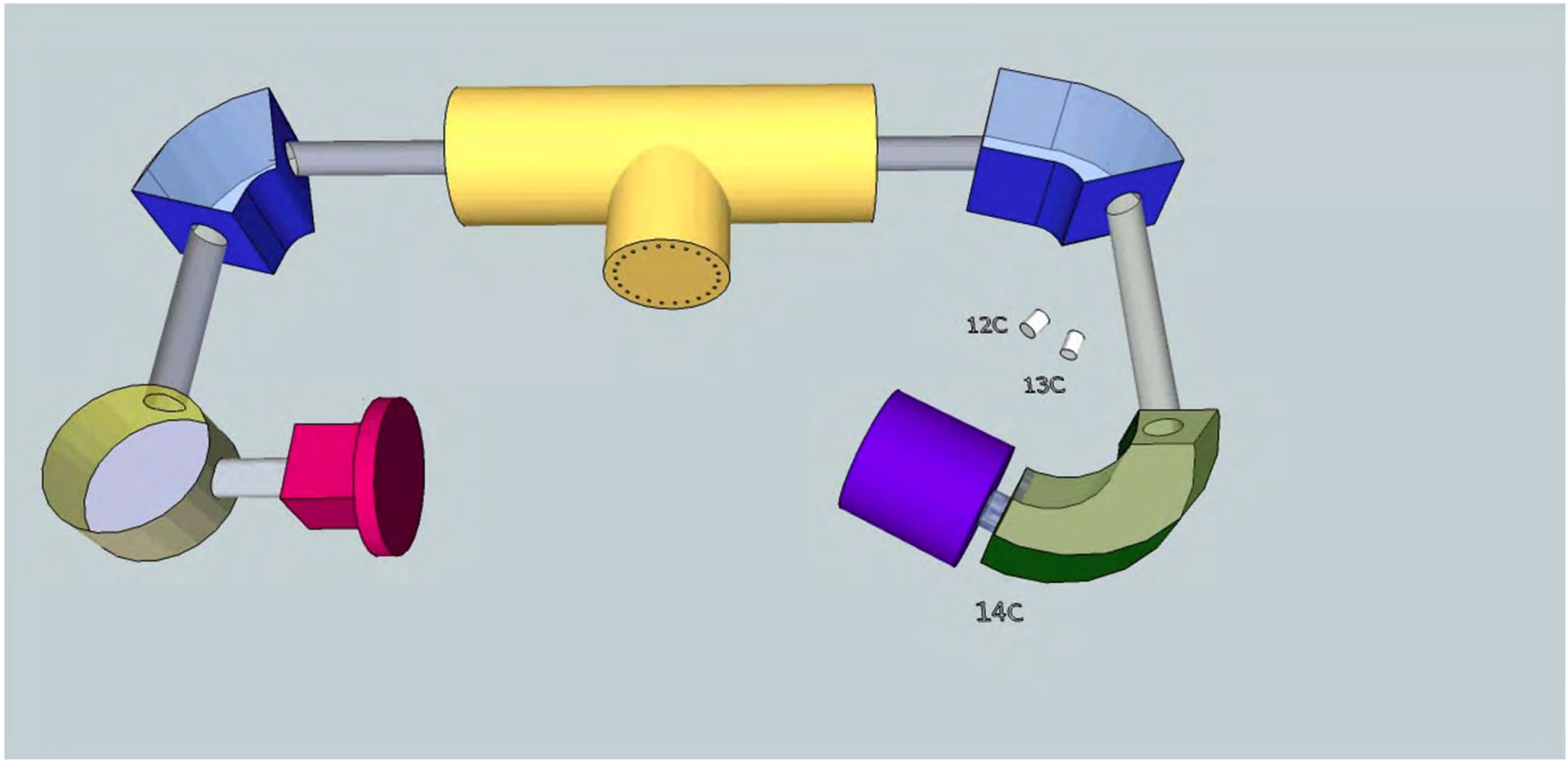
- **Carbon (^{14}C, ^{13}C, ^{12}C)**
- Beryllium (^{10}Be, ^{9}Be)
- Aluminum (^{27}Al, ^{26}Al)
- Iodine (^{129}I, ^{127}I)

Applications in:

- **Cultural heritage studies**
- Environmental studies
- Homeland security
- Energetics
- etc

AMS for C-14 dating

AMS = Accelerator Mass Spectrometry



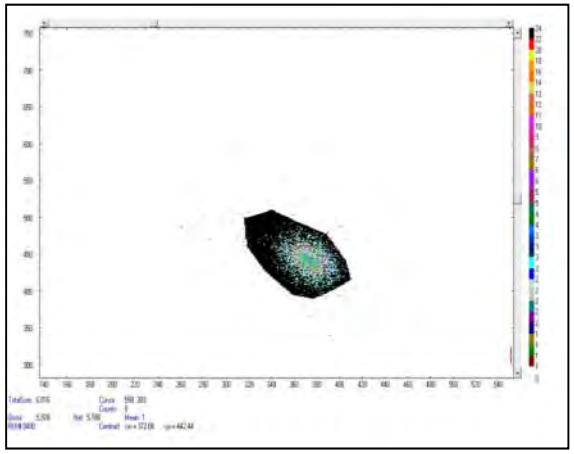
Normal $^{14}C/^{12}C$ ratio: ~10^{-12}; sensitivity 0.5*10^{-15} (cca 60,000 years)

See http://tandem.nipne.ro/~tnd1m/index.html

Sample preparation laboratories & AMS measurements

Types of samples that can be dated via ^{14}C:

- Bones
- Wood
- Seeds
- Corals
- Shells
- Sediments
- Textiles
- Mortars
- Alloys
- Water



^{14}C spectra
C7 Standard (IAEA)
Age: 5645 ± 20 y (BP)
Measurement time: 20 min
$^{14}C/^{12}C$ = 5.6E-13

AGE III - Automated Graphitization System

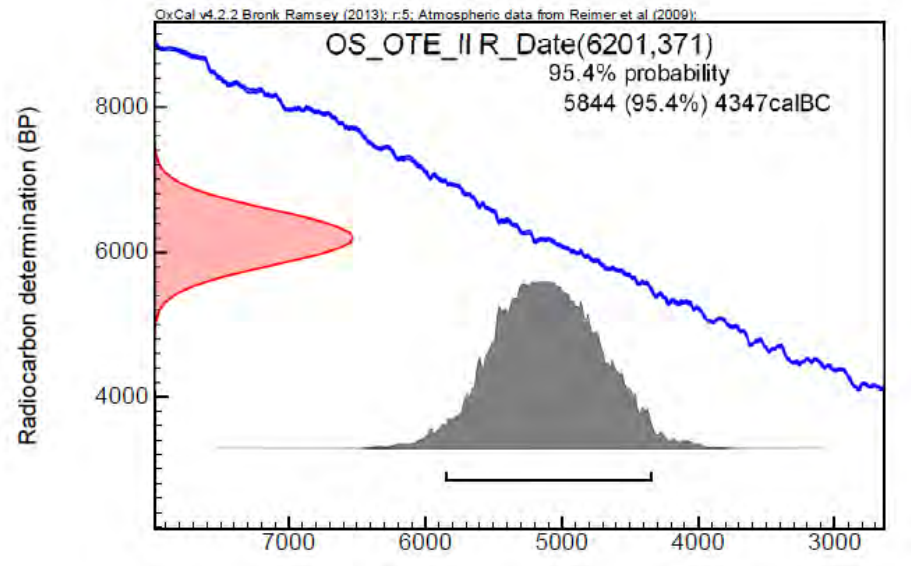
FIRST RESULTS - the estimated age for the first real sample, measured on both AMS and LSC methods

In Brief!

2012

5000 ÷ 4500 BC (archeology)

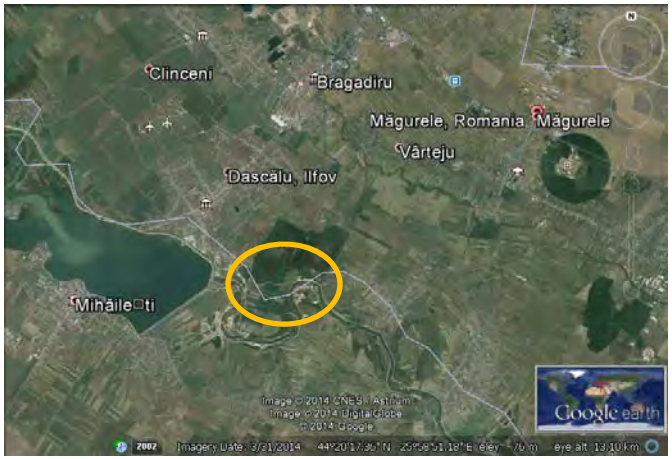
Bone powder (~10 mg) → **Graphite,** Graphitization AGE III → **AMS** 1MV Tandetron Accelerator → **4201±371 BC**



5844 ÷ 4347 calBC with 95.4% probability using the IntCal09 calibration curve from OxCal soft and AMS results.

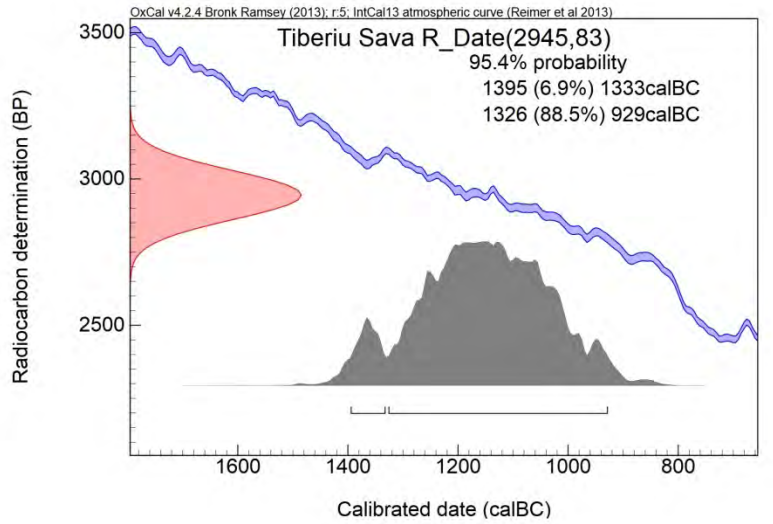
Bone powder (~200 mg) → **CO_2,** Oxidizer 307 → **LSC** Quantulus 1220 → **4302±340 BC**

Dating Ancient Wood from a petrified forest remains on Arges riverside...

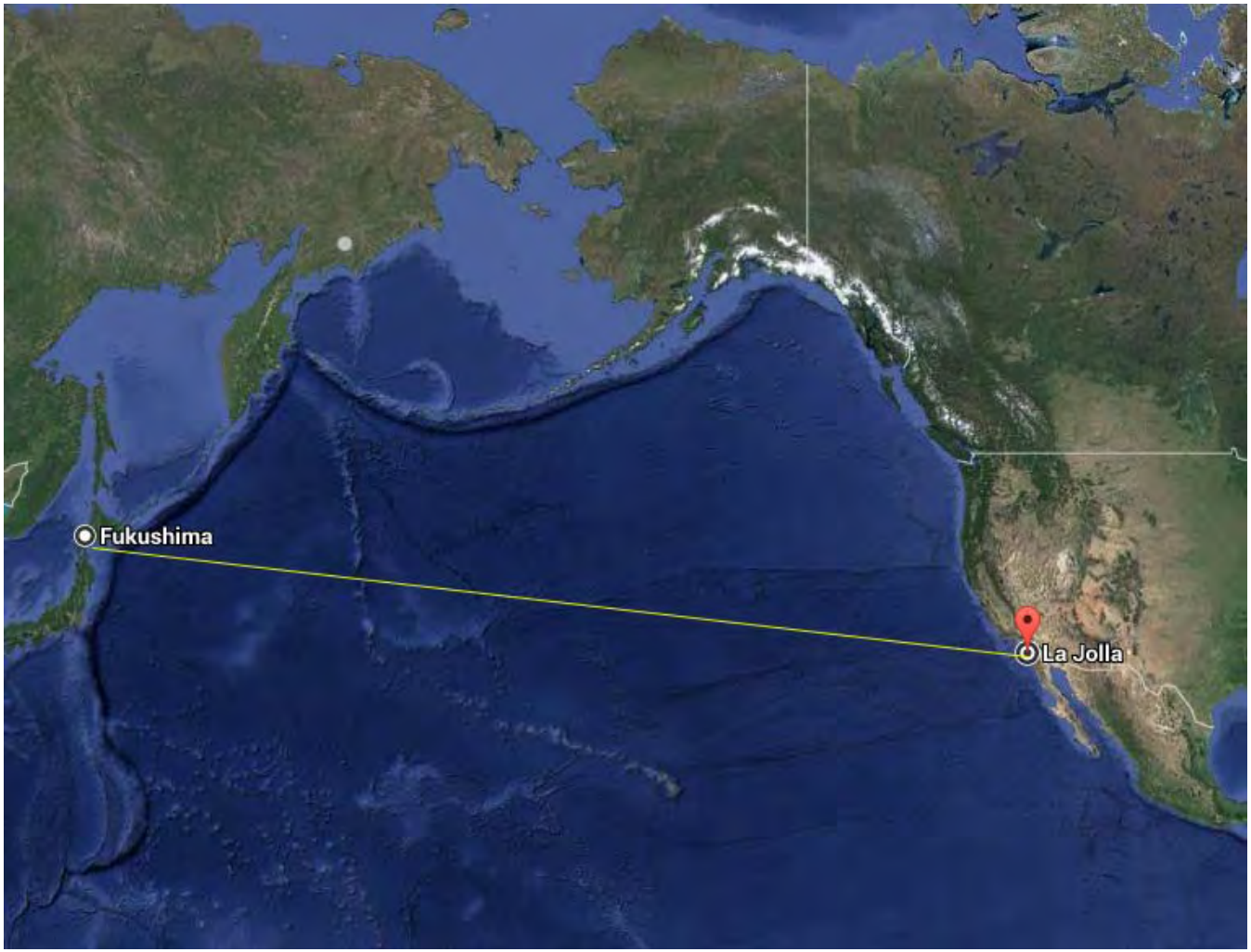


2014

Previous Radiocarbon dating research on discovered remains, at the Universities of Bremen and Kiel, showed that one of the samples existed for 5,300 years ago, and the other two for 3,500 or 1,400 years.

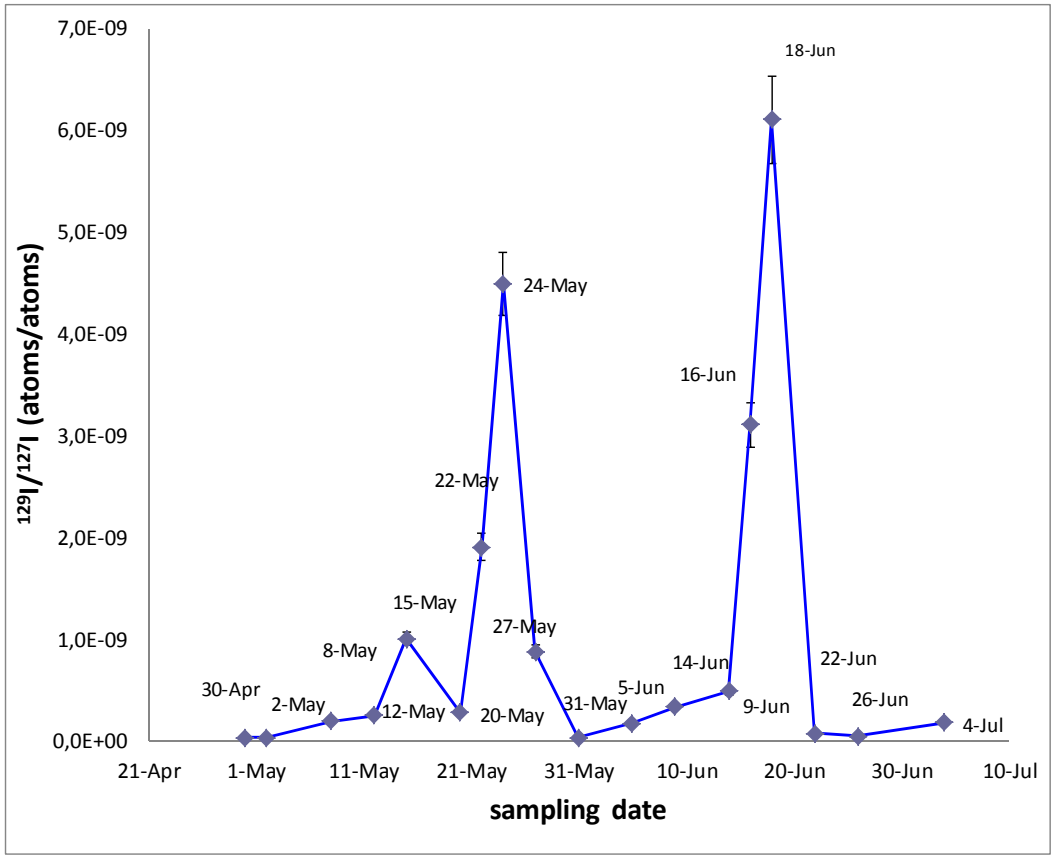


AMS MEASUREMENT OF THE IMPACT OF FUKUSHIMA NUCLEAR RELEASE ON THE WESTERN COAST OF THE USA (LA JOLLA – SAN DIEGO) – ^{129}I circulation



Distance 8792,8 km

2013 Nuclear plume impact on the W coast of USA – ^{129}I



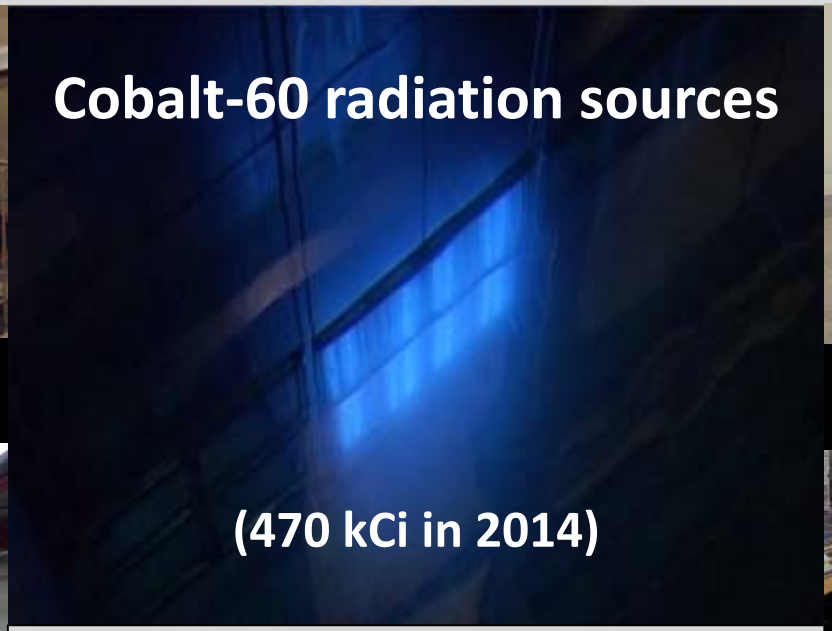
The first release was on 11-12 March 2011 and the second major release on 4th or 5th of April. (24 days)
The measured time difference between the two impact peaks : 24 days
Explosions of the roof of the NPP on day 2
Atmospheric Fall out from Explosions had a total retention time in the atmosphere of ca 1 month.
Speed of the confined nuclear plume: 12 cm/s (in concordance with the Kuroshio current speed)

2013

IRASM MULTIPURPOSE GAMMA IRRADIATION FACILITY

Tote-box conveyor

500 sqm storage



Cobalt-60 radiation sources

(470 kCi in 2014)

Established in year 2000
(IAEA TC Project ROM/8/011)

- Sterilization — MED.DEV
- Bioburden reduction — PHARMA

Research irradiator
(IAEA ROM/8/015)

Materials testing

GAMMA IRRADIATION FOR CULTURAL HERITAGE PREZERVATION

Supported by R&D:

- **Wood** (2004-2007)
- **Polychromed wood** (2009-2011)
- **Paper** (2009-2011)
- **Textiles, Leather and Parchment** (2012-2016)

  Parthership projects financed by ANCS
- **Radiation consolidation of wood** (2013-2016)

  CEA – IFA bilateral cooperation

Papers: 30
Conferences: 83
Books: 3
Patents: 1

IRASM showcase: Furniture

Furniture from Cotroceni Musem, Bucharest

First large scale irradiation experiment (2001)

IRASM showcase : Furniture

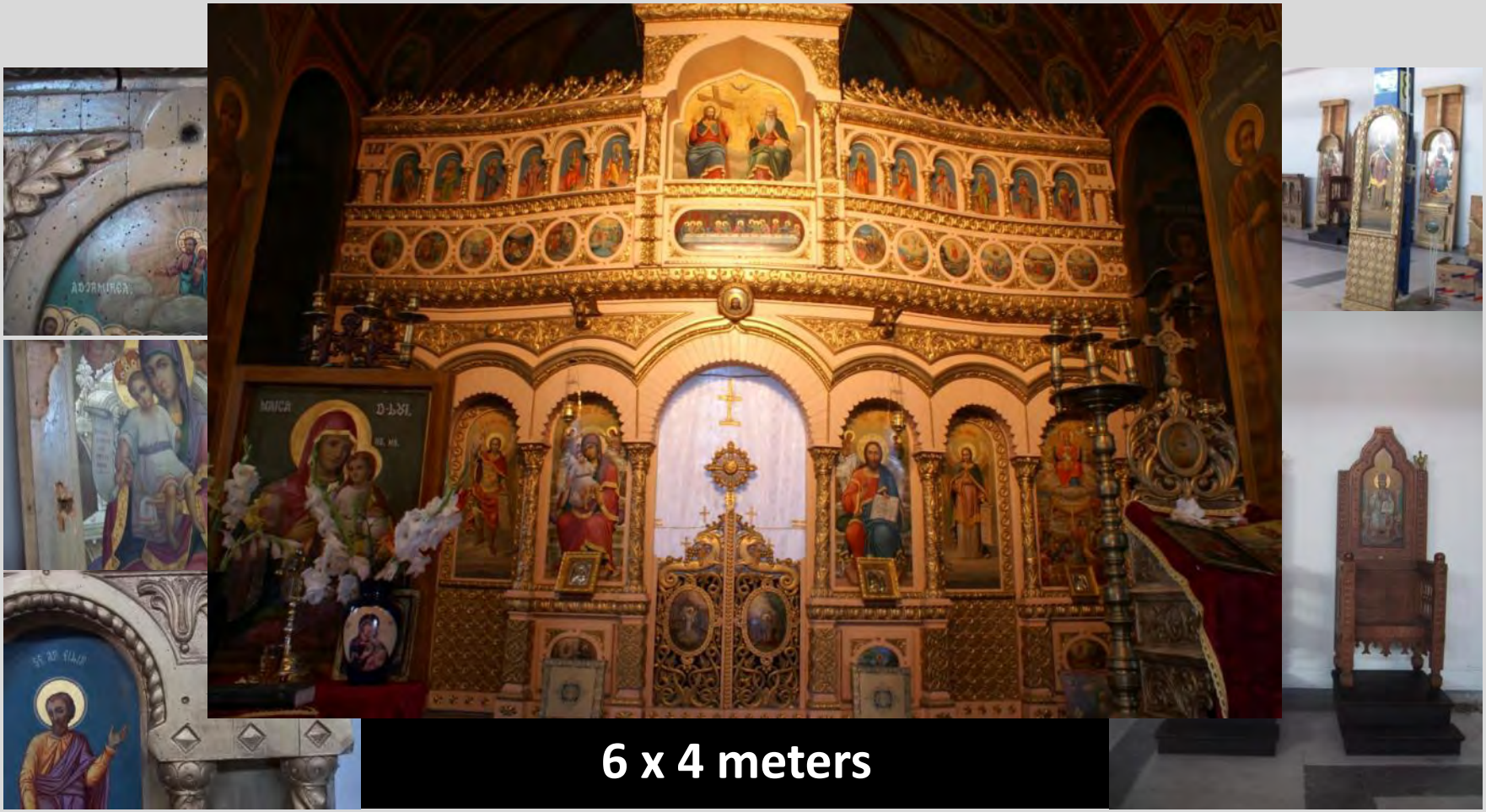
Furniture, flooring, doors, paneling, wallpaper, tools -

Theodor Aman Museum, Bucharest (2010)

IRASM showcase: Iconostasis

Iconostasis – “Izvorul Tamaduirii” Church (2002)

Izvoarele Parish, Prahova county

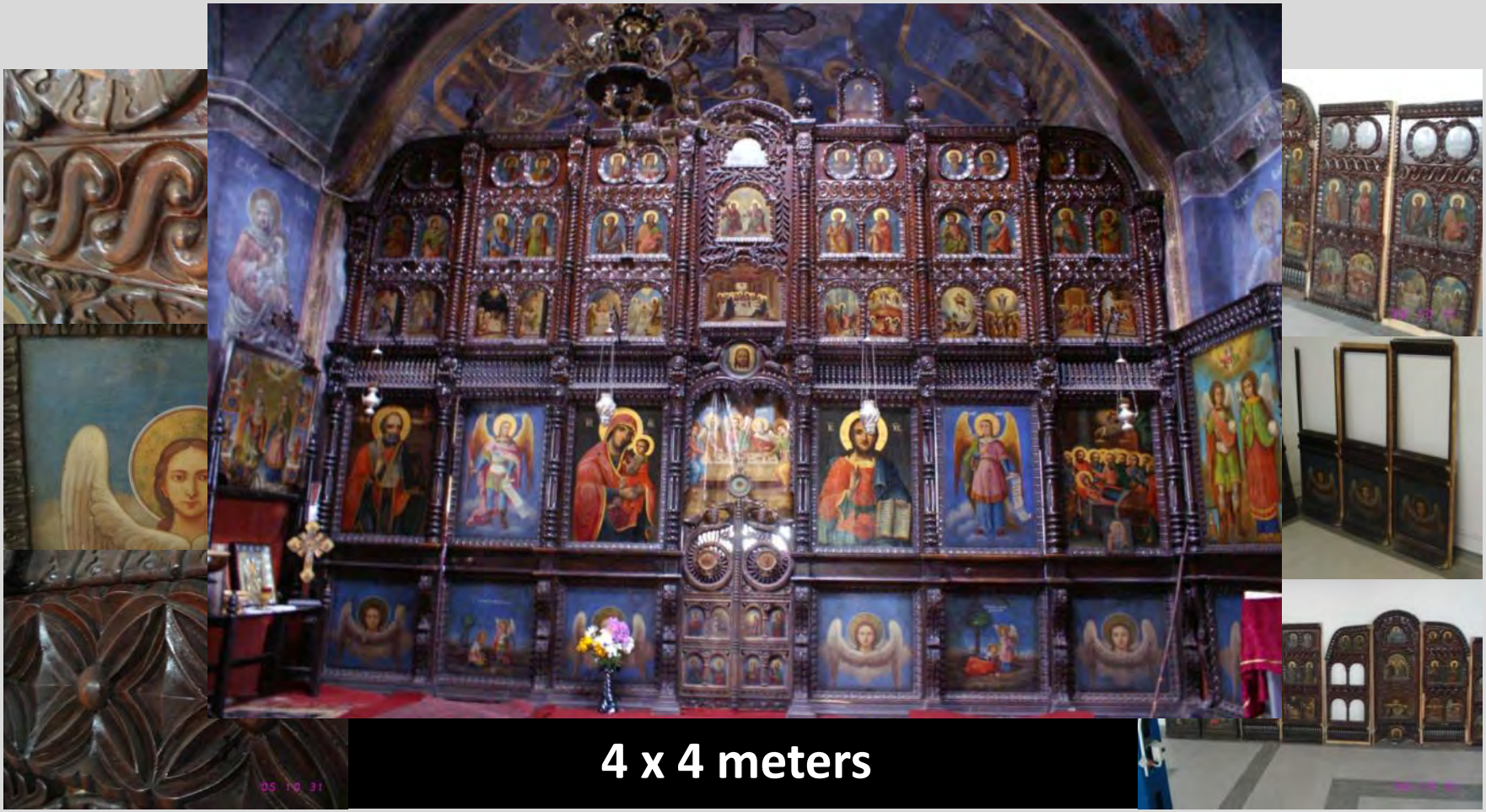


6 x 4 meters

IRASM showcase : Iconostasis

Iconostasis – “Sfintii Voievozi” Church (2005)

Izvoarele Parish, Prahova county



4 x 4 meters

IRASM showcase: Icons

Wooden icons – "Moldova" National Complex
Iasi, Iasi county (2011)





33 icons

IRASM showcase : Icons

Icons from iconostasis – Tismana Monastery (2013)

Tismana, Gorj county

14 icons

IRASM showcase: Wood&Paper

Wooden icons, books, lithography –

Protoieria Braila (2012), Braila county

200 icons

2000 books

IRASM showcase: Wood/Paper/Leather

Old religious books (16–19 century) - private collection

Monica Maria Dascalita / Restaurator, Bucharest 2010

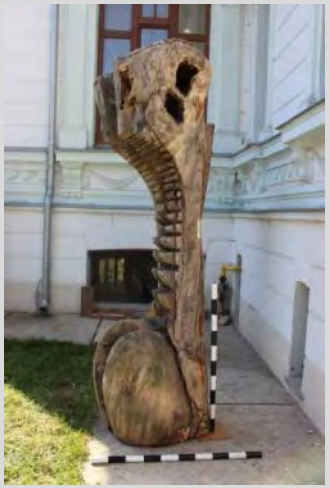
23 books

IRASM showcase : Paper

Archive of Romanian Parliament, Bucharest (2014)

IRASM showcase: Sculpture

"nicapetre" wood sculptures – Braila Museum (2014) Braila, Braila county

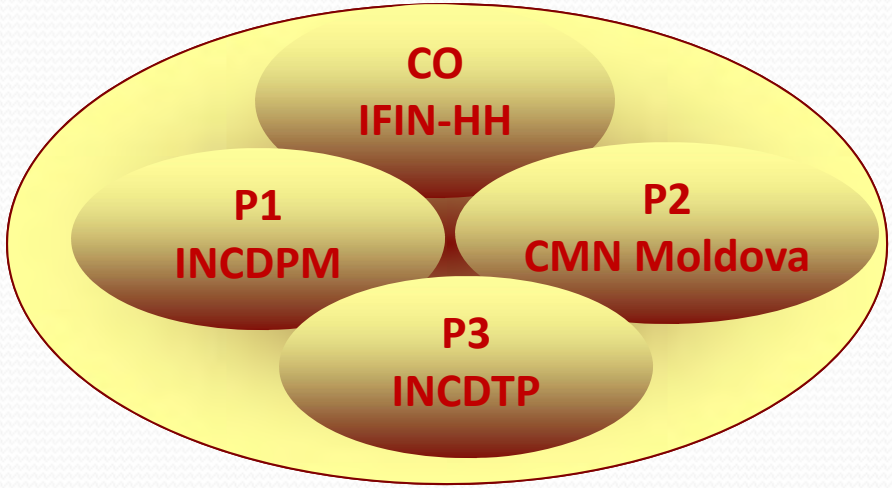







TEXLECONS project
PN2/C2/Partnerships – contract 213 / 2012

- "IMPROVEMENT OF OCCUPATIONAL ENVIRONMENT QUALITY IN CULTURAL HERITAGE DEPOSITS. VALIDATION OF GAMMA RADIATIONS TREATMENT OF TEXTILE AND LEATHER CULTURAL GOODS"

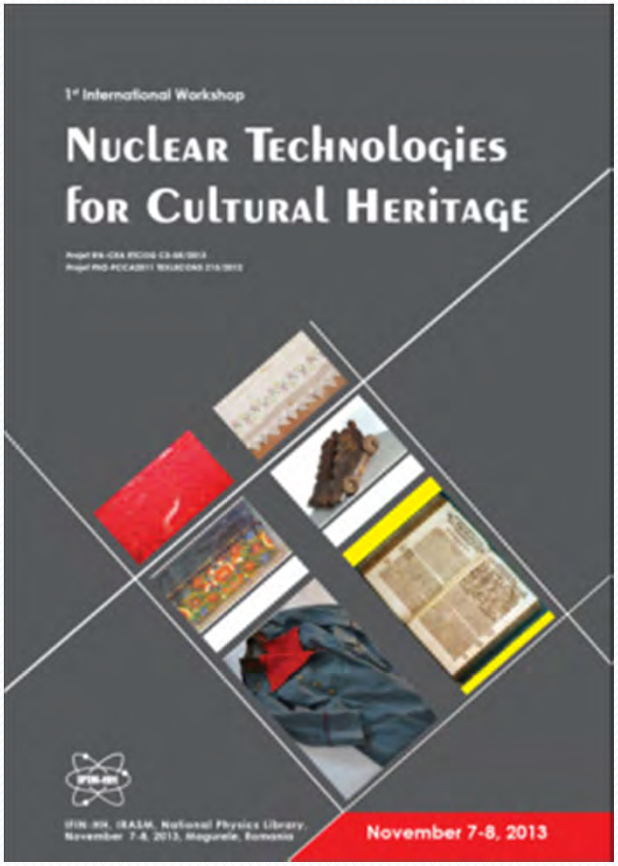


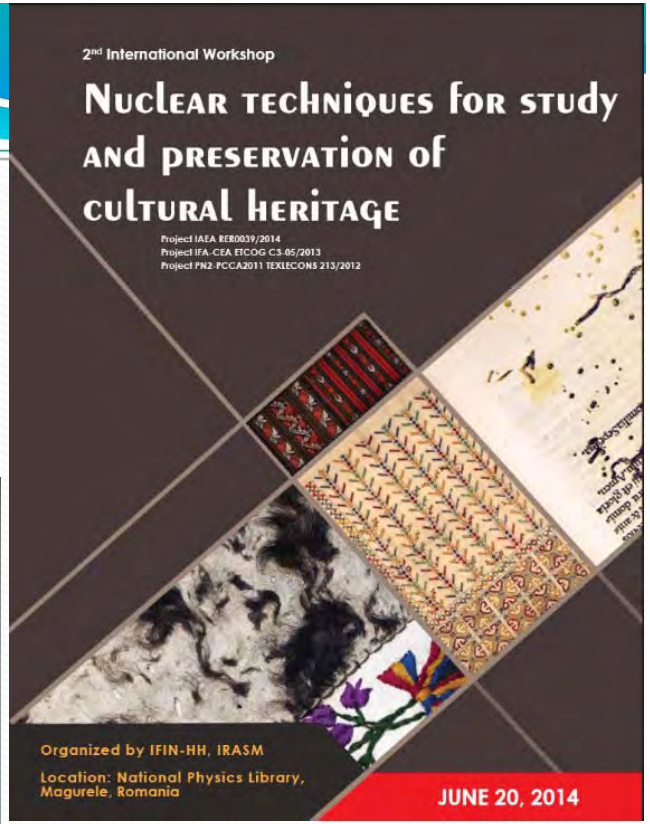
PD project, contr. 27/2010

- **“FOURIER TRANSFORM VIBRATIONAL SPECTROSCOPY USED IN CHARACTERIZATION OF PAINTING PIGMENTS: AN AUTHENTIFICATION CHANCE FOR ROUMANIAN PAINTINGS”**

ETCOG IFA-CEA project C3-05/2013 with ARC-Nucleart, Grenoble

" Education and training in field of cultural heritage conservation by gamma irradiation"






Market Watch, Martie – Aprilie 2015 [Nr. 173]

MARKET WATCH

- Sumarul Articolelor
- Arhiva Revistei
- Abonamente

MW Top Story

Anarhia datelor

Într-un mod oarecum paradoxal, deşi mantra „Informaţia este putere" îşi păstrează valabilitatea, datele tind să ne înece tot mai mult deciziile şi alegerile. Am 130 de programe în grila TV, 20-30 de site-uri web pe care aş vrea să le...

Dictionar

Unified Message Queuing

Revista >> Noiembrie - Decembrie 2013 [Nr.160] >> Cercetare & Invatamant superior

Primul workshop internaţional de tehnici nucleare pentru studiul şi conservarea obiectelor de patrimoniu cultural

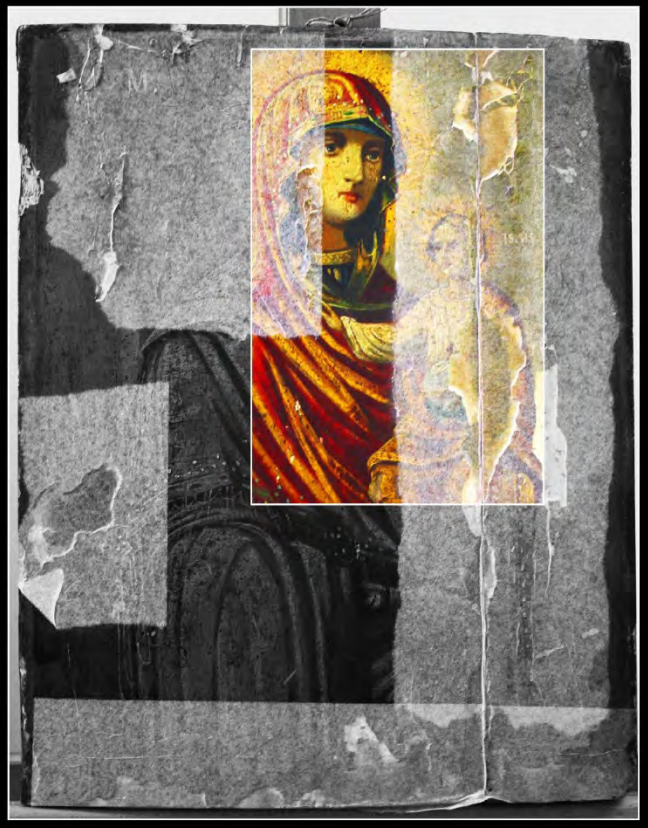
Dr. Ioana Stnculescu, Drd. Valentin Moise - IFIN-HH 02 Decembrie 2013

Primul workshop internaţional „NUCLEAR TECHNIQUES FOR STUDY AND PRESERVATION OF CULTURAL HERITAGE" a avut loc în perioada 7-8 noiembrie şi a fost organizat de către Institutul Naţional de Fizică şi Inginerie Nucleară „Horia Hulubei"(IFIN-HH) în cadrul proiectelor ETCOG (proiect bilateral România-Franţa, finanţat de IFA - Institutul de Fizică Atomică - şi CEA - Commissariat à l'énergie atomique et aux énergies alternatives) şi TEXLECONS (proiect finanţat de Ministerul Educaţiei Naţionale în cadrul programului Parteneriate).

Workshop-ul a avut ca scop prezentarea portofoliului IFIN-HH de tehnici nucleare pentru studiul şi conservarea obiectelor de patrimoniu cultural şi a rezultatelor recent obţinute în cadrul proiectelor ETCOG şi TEXLECONS. La workshop au participat specialişti din institute de cercetare din ţară (IFIN-HH, INCD Textile şi Pielărie, INCD Protecţia Muncii „Alexandru Darabont") şi străinătate (Franţa,Turcia, Iran), precum şi reprezentanţi ai instituţiilor beneficiare sau


L Trache, GRC Nuclear Chemistry 2015


21669



Demonstration of Techniques for Cultural Heritage Protection

IAEA Regional Training Course • Dissemination Workshop

IAEA Technical Cooperation Project RER/8/015

PN2 92083 – ARCON • PN2 92086 – DELCROM

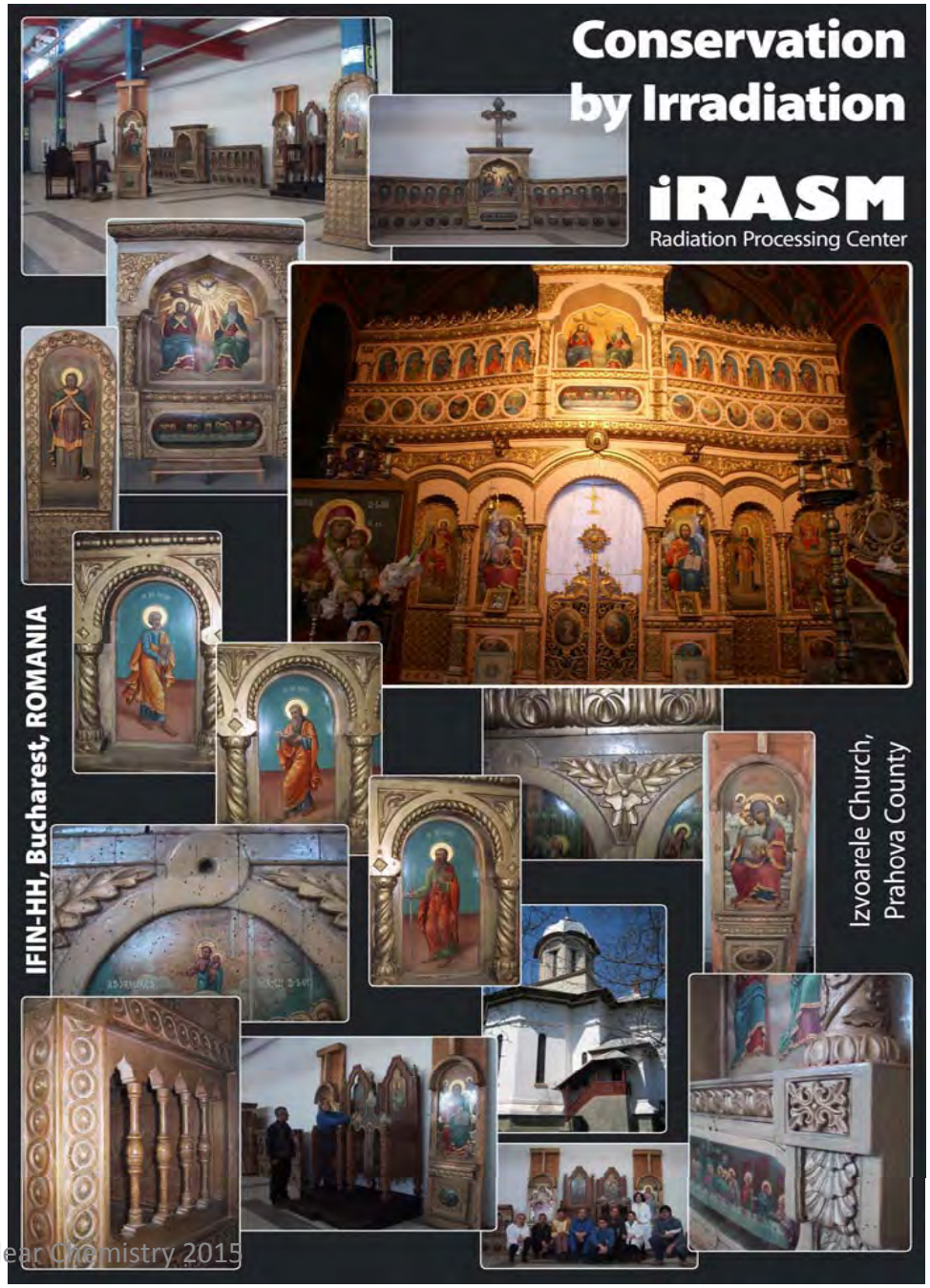
May9-13,2011 • IRASM–IFIN-HH • Bucharest-Magurele • ROMANIA

IAEA Technical Cooperation Project – RER 8015:
Using Nuclear Techniques for the Characterization and Preservation of Cultural Heritage Artefacts in the European Region

IAEA
International Atomic Energy Agency
Atoms For Peace

Nuclear Techniques for Preservation of Cultural Heritage Artefacts


iRASM
Radiation Processing Center
Conservation
by Irradiation
Items from Moldova Museum and National Film Archive
IFIN-HH, Bucharest, ROMANIA


Conservation
by Irradiation
iRASM
Radiation Processing Center
IFIN-HH, Bucharest, ROMANIA
Izvoarele Church,
Prahova County

Networking

Internal co-operation

- Museum of National History of Romania
- National Art Museum
- Municipal Museum Bucharest
- Transylvania National Museum of History, Cluj-Napoca
- Brukenthal National Museum Sibiu
- National Museum Complex Moldova, Iasi
- Braila Museum
- National Museum Complex Astra, Sibiu
- Other county and city musea …

International co-operations

- IEAE: RER 1006, 8015, 0034 (as receiver and donor)
- IRASM – NUCLEART Grenoble (France)
- IRASM – INFN Milan (Italy)
- COST Action IE601 “WoodCultHer”
- Interlaboratories Comparison Test (Microbiological Labs)

Current goals

National Center for Study and Preservation of Cultural Heritage

- How to set up ?!
  - Virtual Center ?!
  - Distributed facility
- How to attract “all interested actors”?!
- How to finance it constantly and consistently?!
  - “Installations of national interest” – the two tandem accelerators and the irradiator will work at no cost for Romanian institutions

Collaborators (authors, actually!)

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- D. Ghita, T. Sava, C. Calinescu, Corina Simion, Oana Gaza, …
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