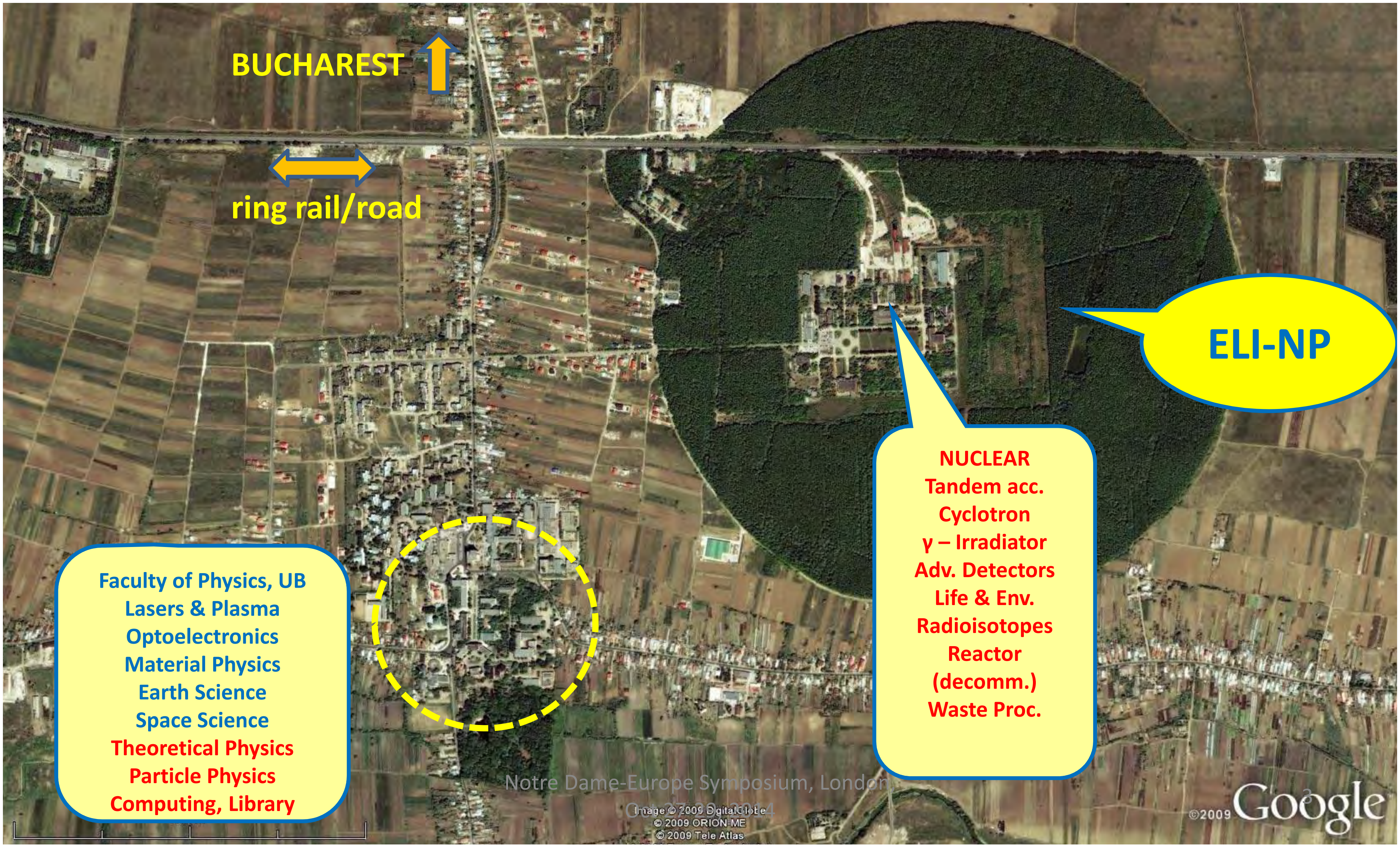
Study and preservation of cultural heritage with atomic and nuclear techniques at IFIN-HH Bucharest

Livius Trache
IFIN-HH, Bucharest-Magurele

Notre Dame-Europe Symposium on Nuclear Science and Society
London, UK, Oct 27-29 2014

Bucharest – Magurele Physics Institutes

Bucharest-Magurele Physics Campus
National Physics Institutes



IFIN-HH in numbers - history and in statistics

Flagship of Romanian research

- From 1949: IFA – Institute of Physics of the Academy (Romanian)
- From 1956: IFA - Institutul de Fizica Atomica (nuclear physics: research reactor, cyclotron)
- From 1977: IFIN – Institutul de Fizica si Inginerie Nucleara (FN tandem, neutron sources, radioisotope center, nuclear medicine, radioactive waste treatment, etc.)
- 2012: "The largest R&D institute in Romania – in terms of assets and personnel, *'Horia Hulubei' National Institute of Physics and Nuclear Engineering* (IFIN-HH) covers almost 10% of the national scientific output." (institutional evaluation, May 2012; international evaluators gave 5.0 out of 5)
- In suburb of Bucharest: Magurele, jud. Ilfov, cca 15 km from centre
- Personnel: ~750
  - 326 researchers: physicists, chemists, biologists, engineers…
  - 174 PhDs
  - 22 PhD advisors
- Budget: cca. 155M RON/year = 35M euro/year
- 12 departments; role of a national nuclear physics lab:
  - Fundamental research in nuclear physics and elementary particles
  - Applications of nuclear and atomic physics: irradiations, analyses …
  - waste treatment and storage, dosimetry of radiations, …
  - Physics of life and environment
  - Grid computing
  - Coordinator of large international collaborations: CERN, FAIR Darmstadt, JINR-Dubna, IN2P3, INFN
  - Training of personnel to work with radiations


IFIN-HH

Study and preservation of cultural heritage

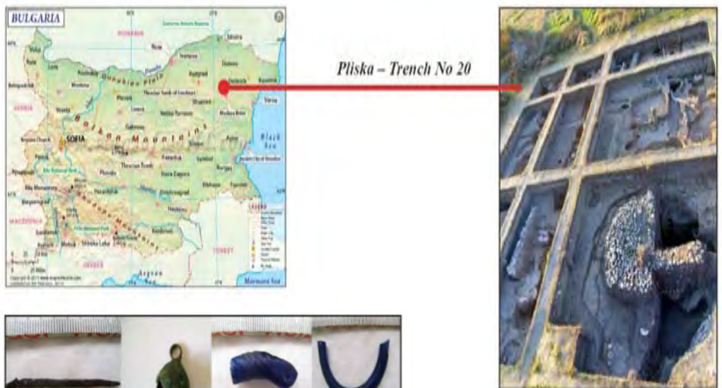
- Environment (specific analyses): radioactive pollutions, heavy metals, new anthropogenic pollutants
- Study and preservation of cultural heritage badly needed in many countries of the Danube and Balkan region; regional cooperation needed
- Transfer of expertise in this area possible, but no solid framework exists
- 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:
  - Large variety of analytical methods: PIXE, RBS, … Raman spectroscopy, etc…
  - Gamma irradiation treatments
  - C-14 dating
  - AMS for geological dating and isotopes tracking

- IFIN-HH large facilities:
  - tandem accelerator complex (9, 3 and 1 MV)
  - 2 cyclotrons
  - Waste processing and storage
  - Reactor (in decommissioning)
  - IRASM 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

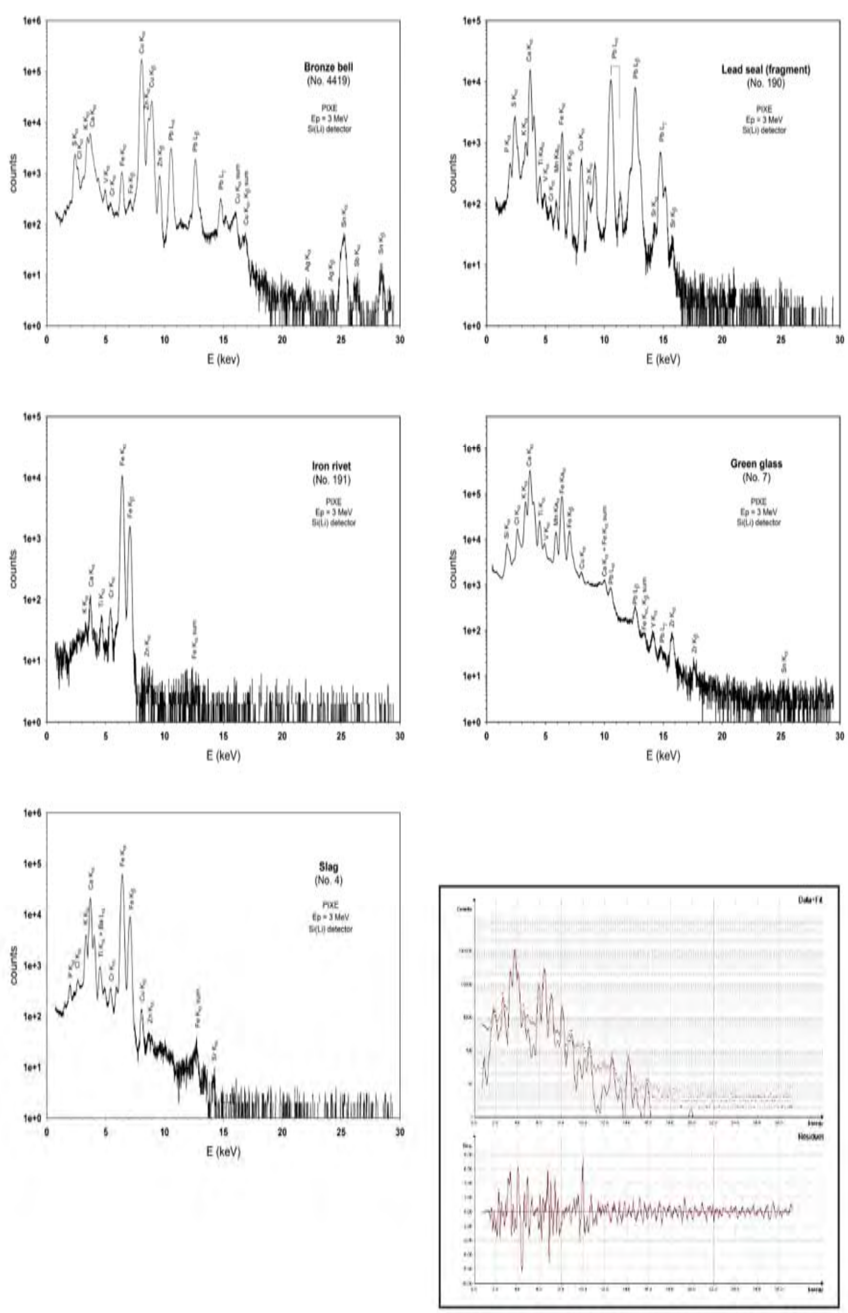
PIXE analysis on Bulgarian artefacts (IX-XI centuries)

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].



Courtesy of A. Pantelica (IFIN-HH)



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

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

Installed in 2012/2013

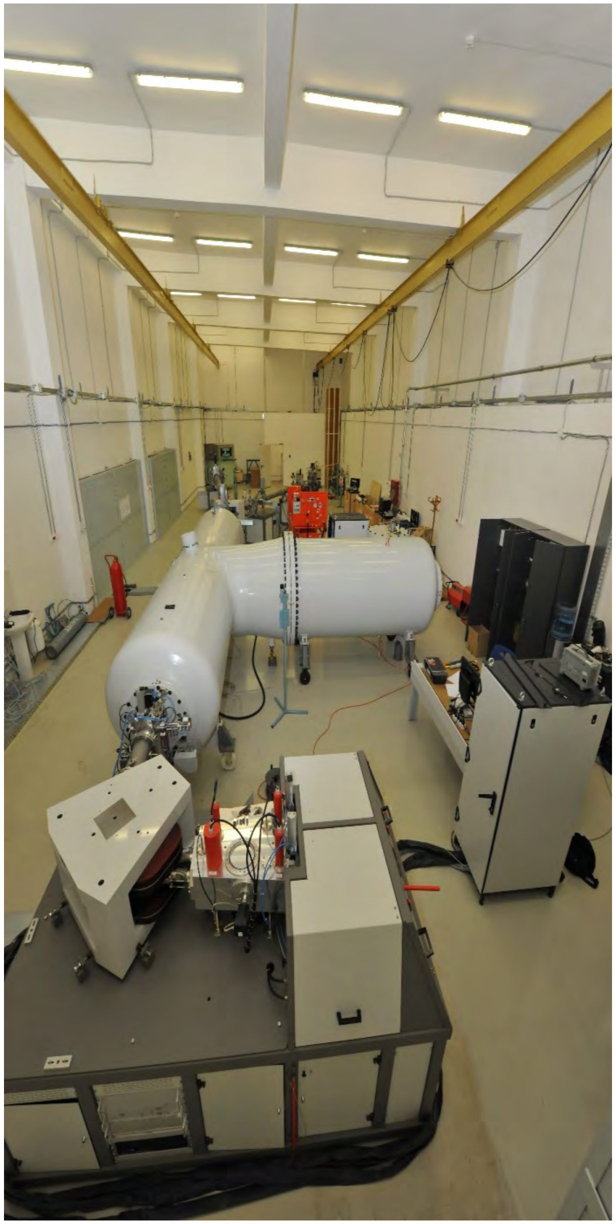
- **Beamline dedicated to IBA**
- **Beamline dedicated to ion implantation**
- **Beamline dedicated to nucl astrophys**

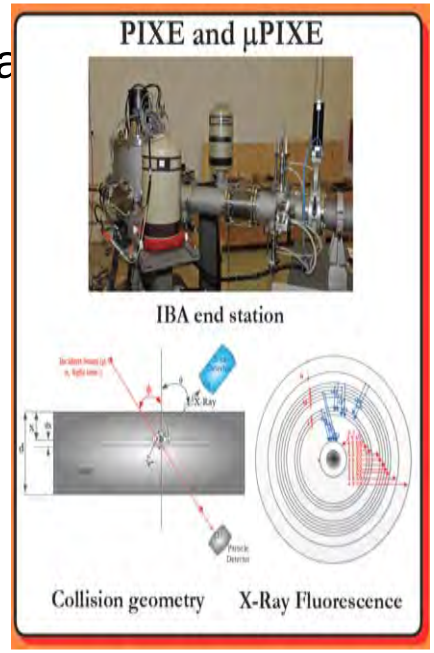
Announced users:

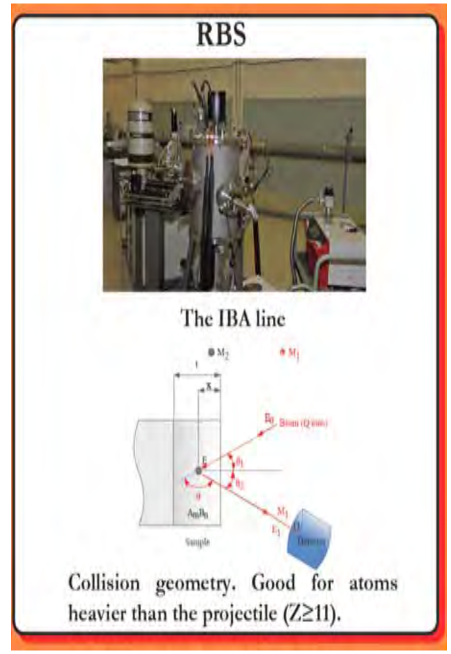
- material scientists – "neighboring" institutes
- archeometrists (PIXE, e.g., on large artefacts)
  - Romania, Bulgaria, Turkey
- enviromentalists
  - Romania, Bulgaria

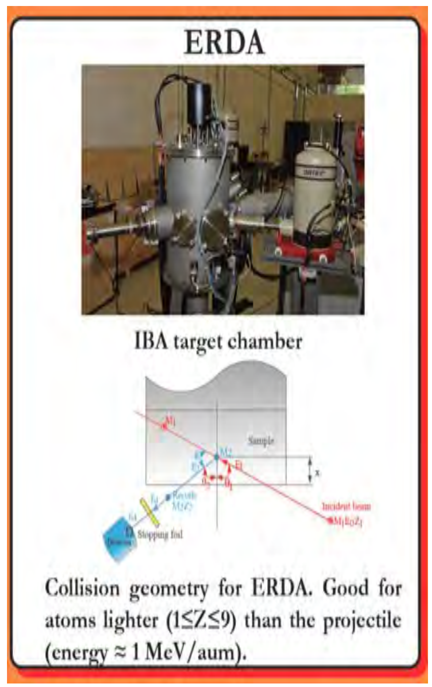
Proposed TNA for nuclear astrophysics in ELAN (European Laboratory Astrophysics network)

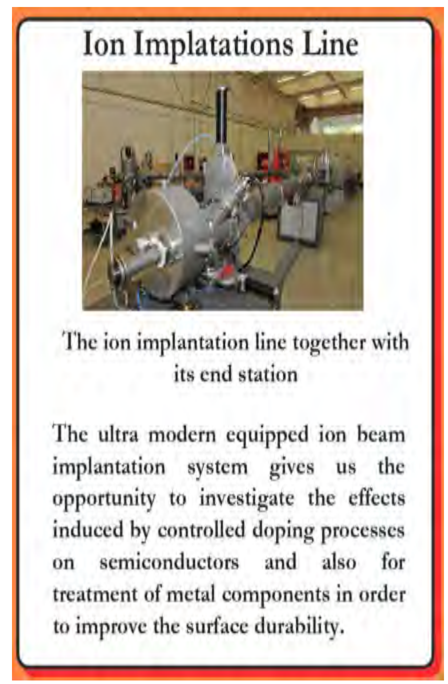
Bucharest IBA facility – 3 MV Ta











DFN logy

JAAS

Journal of Analytical Atomic Spectrometry

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

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

Hen and its Chickens

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;

Sarmizegetusa Regia - The Sacred Zone

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

Pseudo-Lysimachus stater

Locally minted gold coins (B.C.)

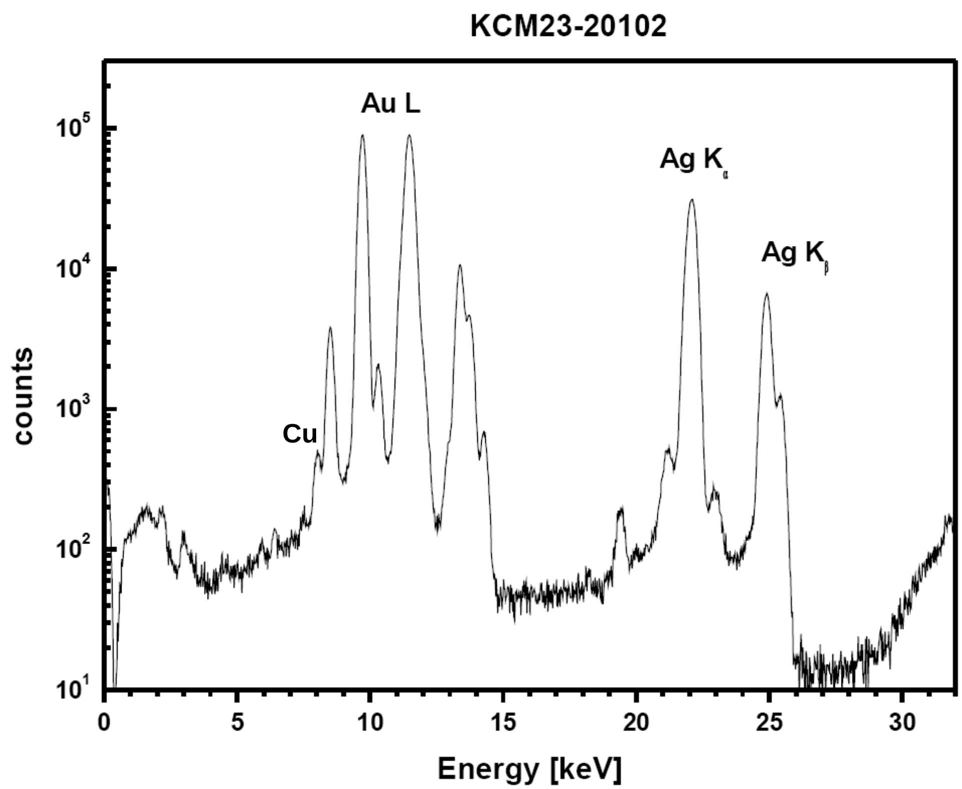
Dacian Koson without monogram

Dacian Koson with monogram

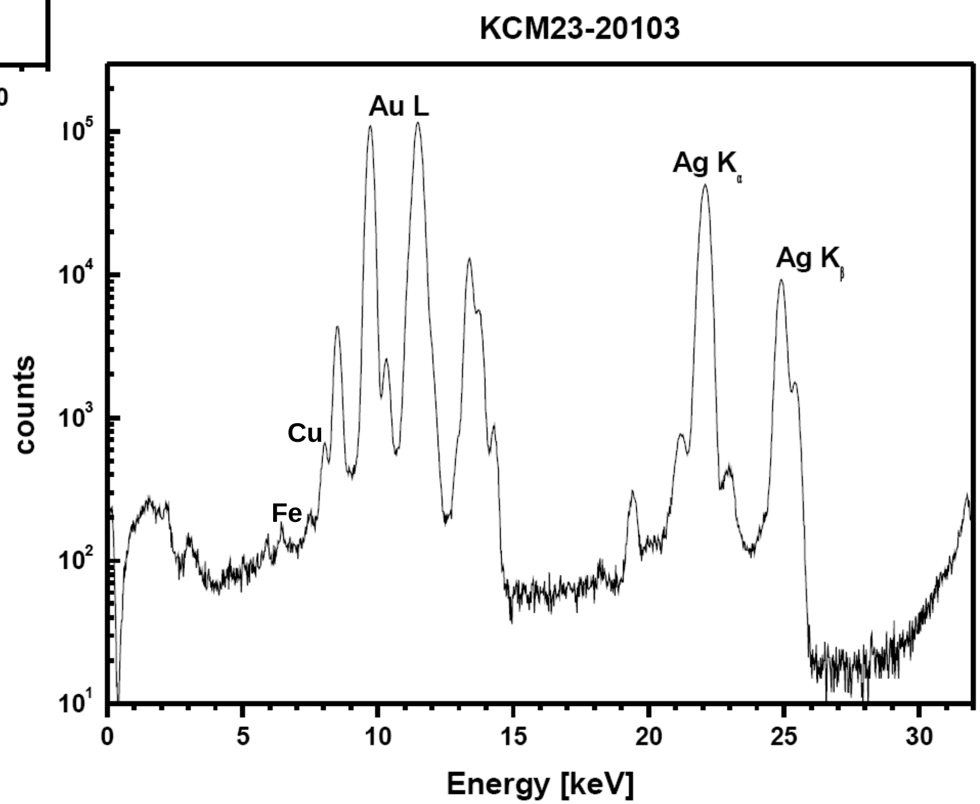
In the compositional studies of archaeological gold artifacts, besides the ratios between the three main components of gold alloys (Au-Ag-Cu) which can be used in their authentication, trace elements might bring significant clues. Trace-elements which can be found in native gold are the Platinum Group 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.

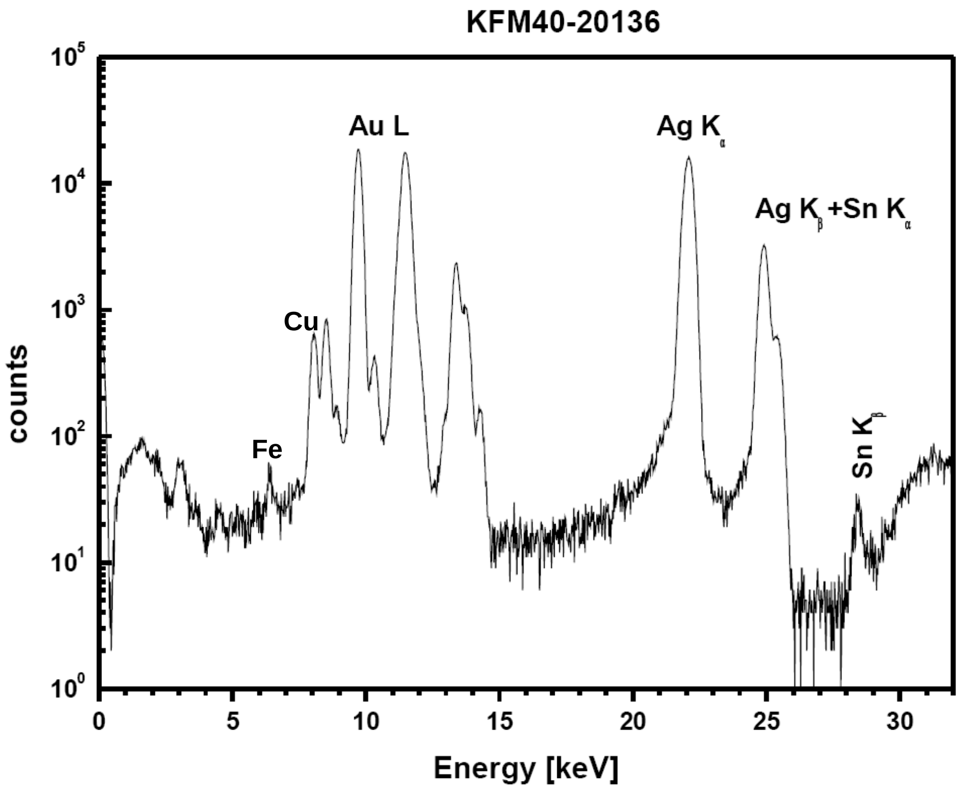
In early 2011, we obtained the permission of the Romanian authorities to take very small (1-2 mg) samples from the extremities of the bracelets and from 17 Koson and pseudo-Lysimachus staters to analyze them by micro-SR-XRF at BESSY Synchrotron Berlin.

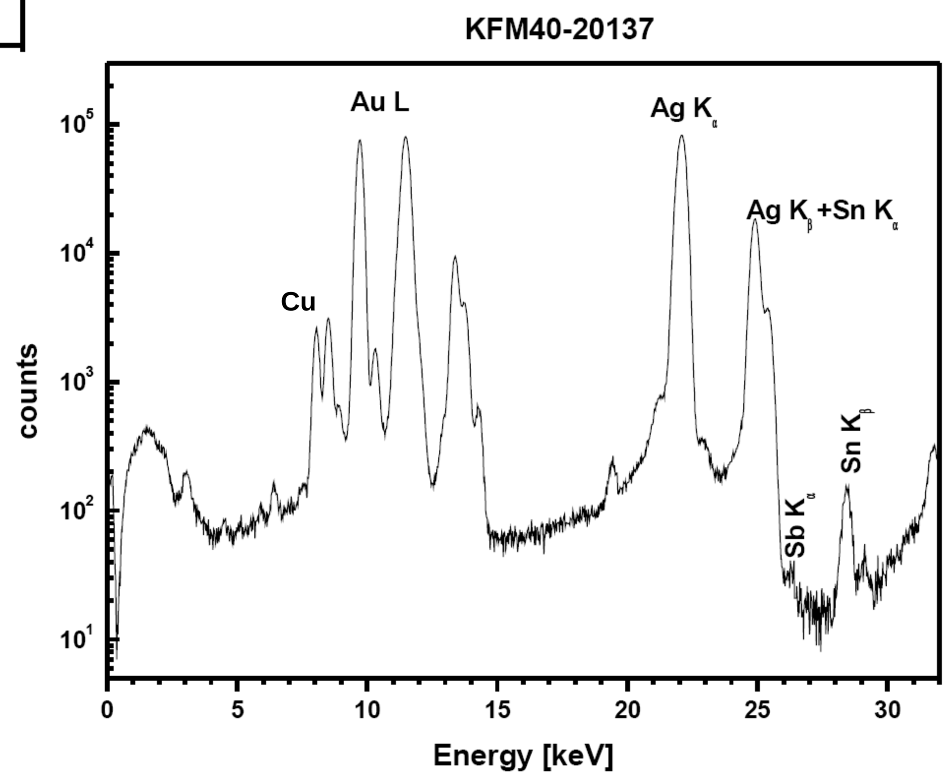


Koson with monogram no.23



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.**

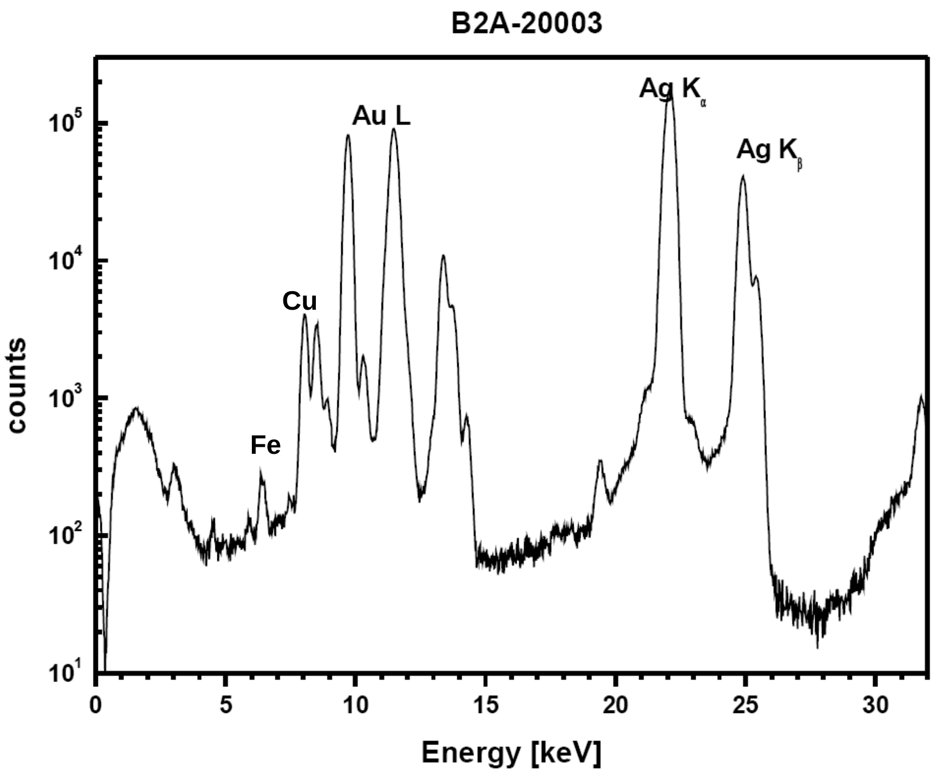
These indicate the use of refined gold (advanced metallurgy) for the Koson staters with monogram and the use of native gold (mainly alluvial) in a primitive metallurgy for the Koson staters without monogram.

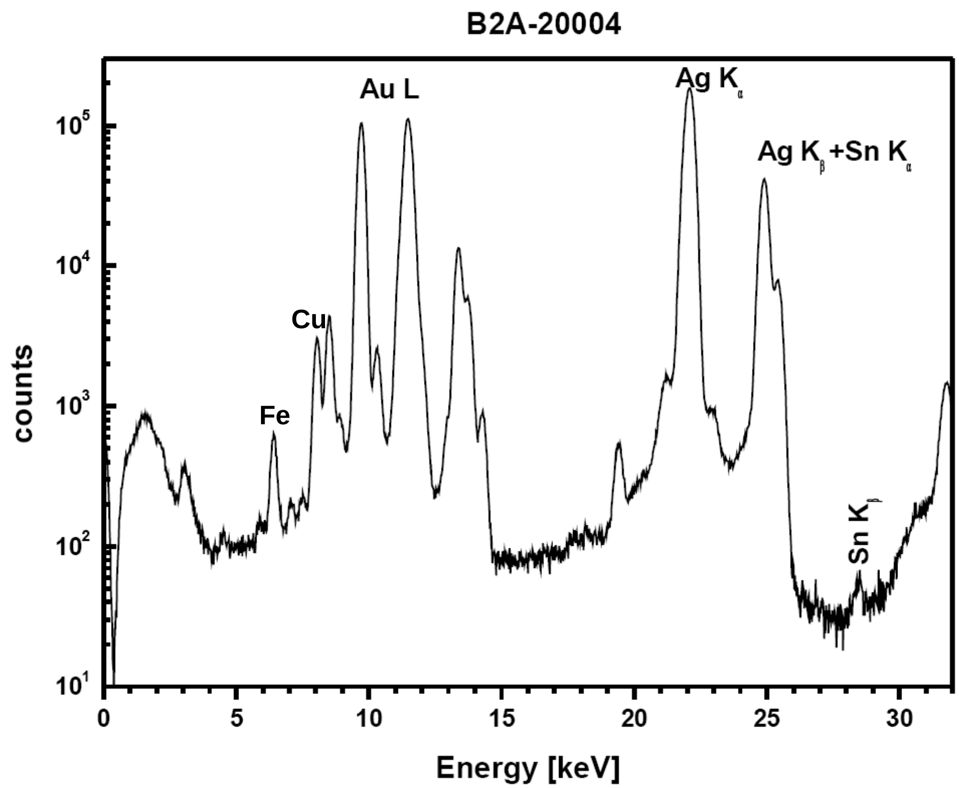
A most trustful hypothesis is that the Koson staters with monogram – the original coins – were minted somewhere in the neighbouring Roman provinces (in the Balkans) from refined, "coined" gold and the Koson staters without monogram are "Barbarian" copies made in Dacia (Transylvania) from native gold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

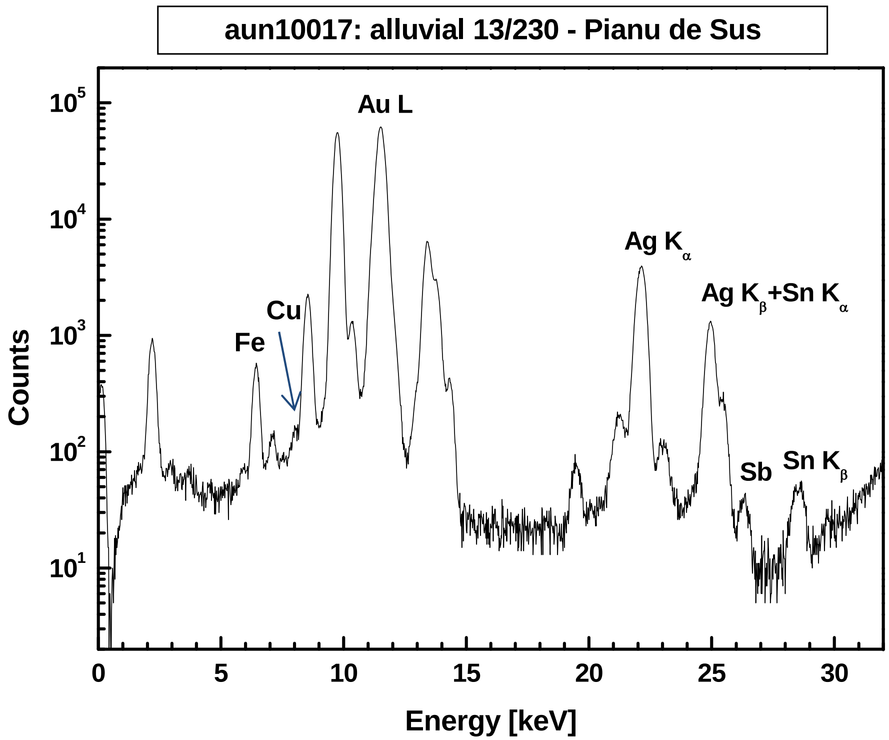
The same aspects were revealed after the analyses of similarly small fragments (less than 100 microns in diameter) from 13 Dacian gold bracelets.

Bogdan Constantinescu, Angela Vasilescu, Daniela Stan, Martin Radtke, Uwe Reinholz, Guenter Buzanich, Daniele Ceccato and Ernest Oberlaender-Tarnoveanu *Studies on archaeological gold items found in Romanian territory using X-Ray-based analytical spectrometry,* Journal of Analytical Atomic Spectrometry, Vol. 27. No. 12, (2012) 2076-2081.

Bracelet 2
Head A – two samples



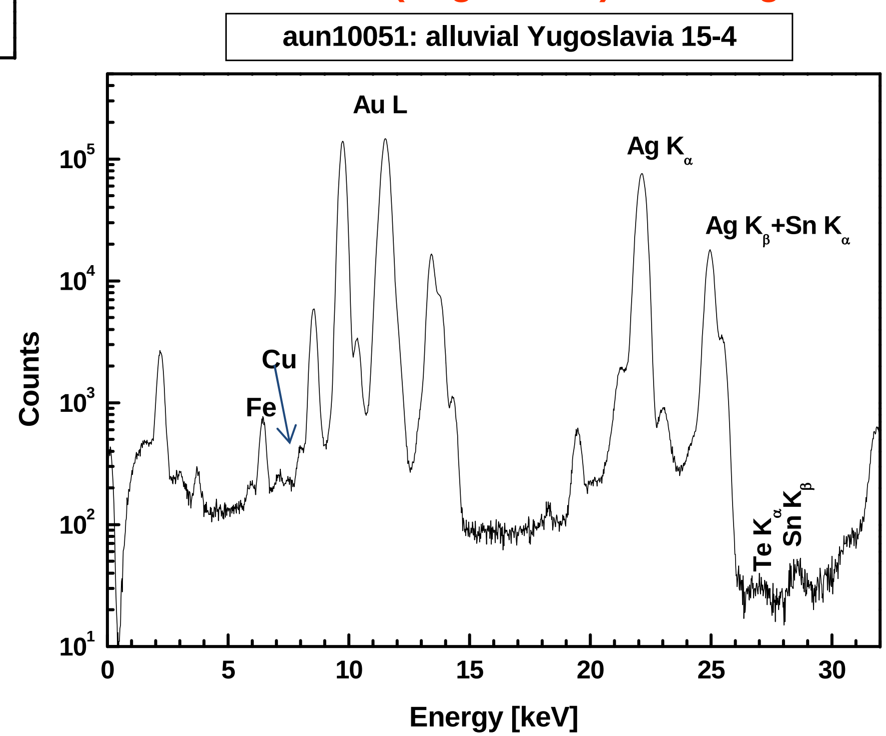




Alluvial gold from the Pianu basin

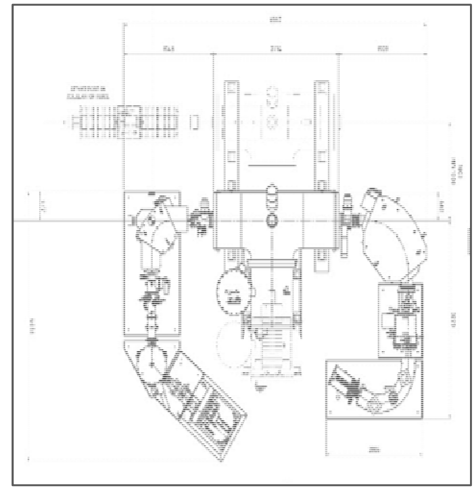
The same inhomogeneous micro-structure was emphasised by micro-SR-XRF for alluvial gold (several small samples, less than 2 mm in diameter). Figures show two point - spectra of a sample from Pianu de Sus (Sn and Sb inclusions) and a sample from a river at the state border between Yugoslavia (now Serbia) and Romania (Sn and Te inclusions).

Serbian (Yugoslavia) alluvial 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.**
- **Both cold working and sintering of gold concentrates are expected to conserve in the final product many mechanical impurities like isolated minerals and inclusions.**
- **Traces of tin 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.**

Bucharest AMS System – 1 MV Tandetron®



Isotope ratios measured for:

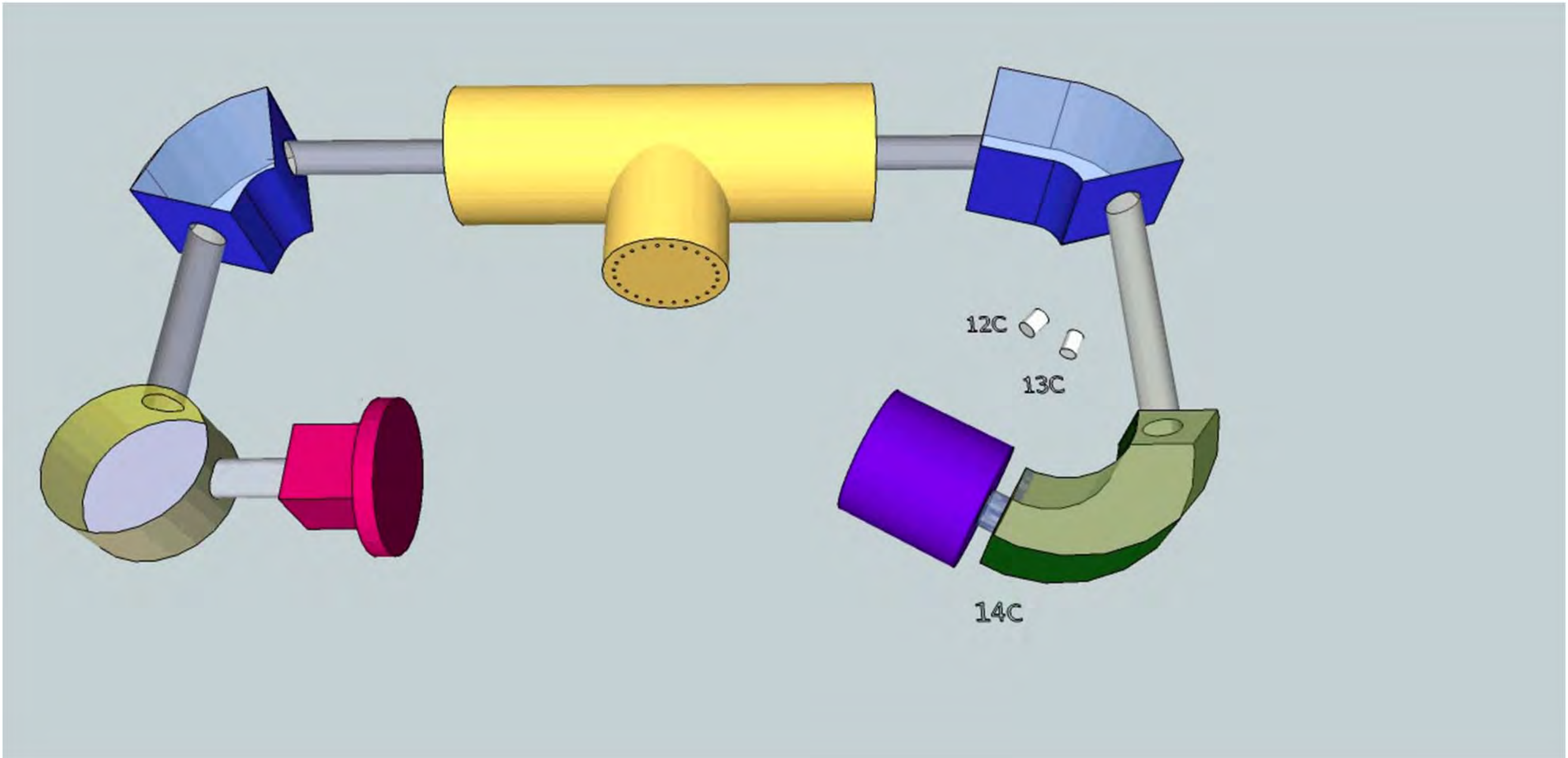
- Carbon (^{14}C, ^{13}C, ^{12}C)
- Beryllium (^{10}Be, ^{9}Be)
- Aluminum (^{27}Al, ^{26}Al)
- Iodine (^{129}I, ^{127}I)

Applications in:

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

AMS for C-14 dating

AMS = Accelerator Mass Spectrometry

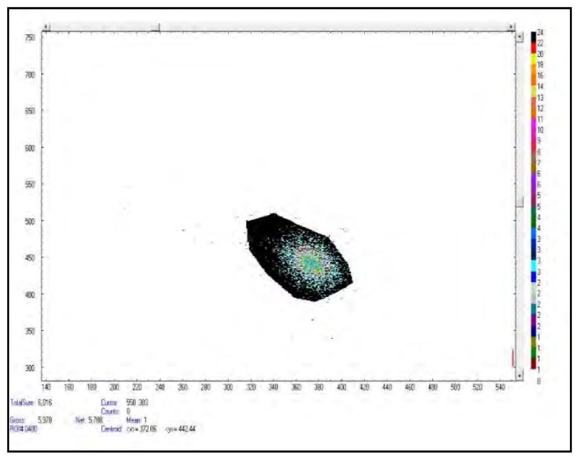


See http://tandem.nipne.ro/~tnd1m/index.html

Sample preparation laboratories & AMS measurements

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

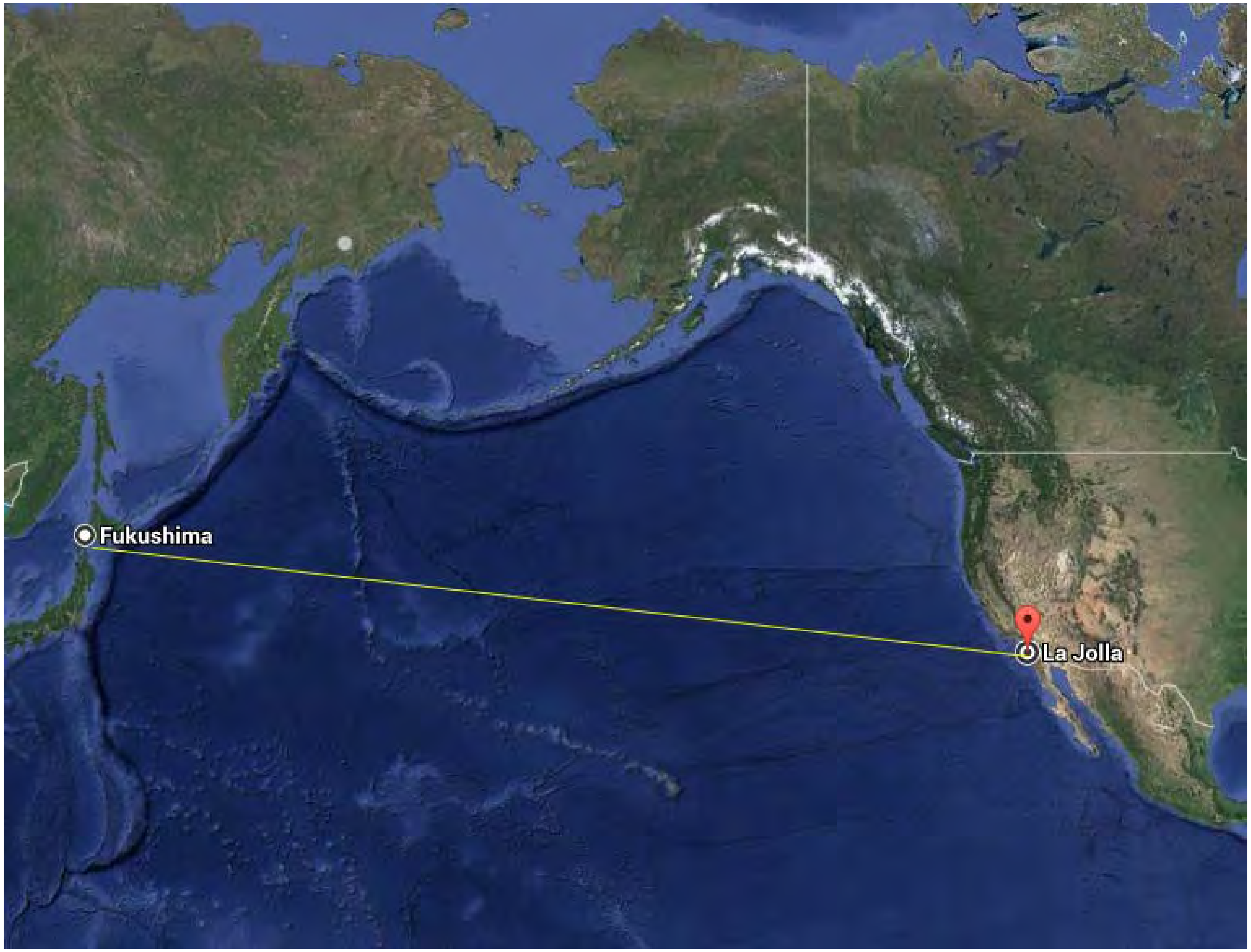
- Bones
- Wood
- Seeds
- Corals
- Shells
- Sedimen
- Textiles
- Mortars
- Alloys
- Water



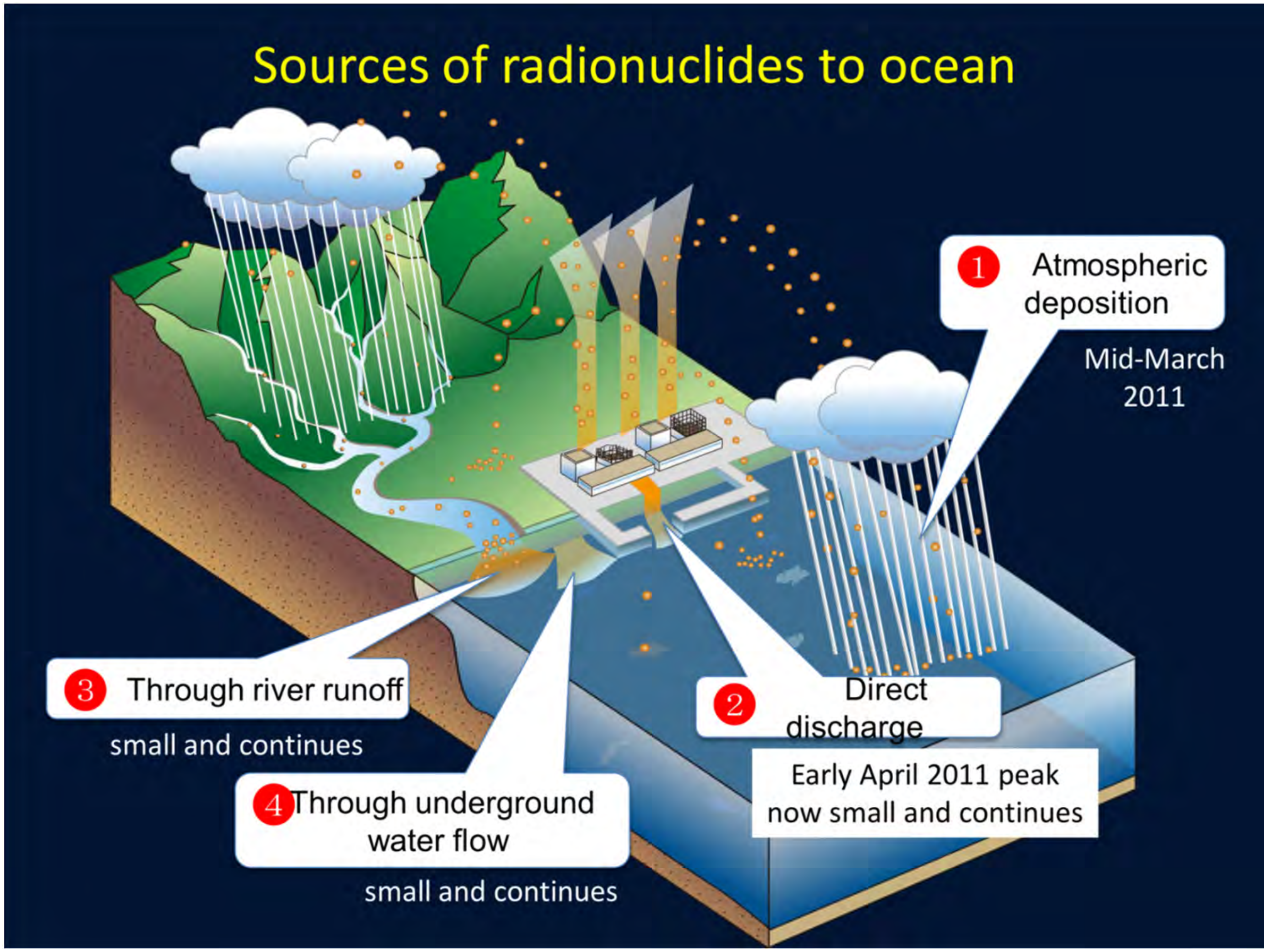
^{14}C spectra
C7 Standard (IAEA)
Age: 5645 ± 20 y (BP)
Measurement time: 20 min
$^{14}C/^{12}C$ = 5.6E-13

AGE III - Automated Graphitization System

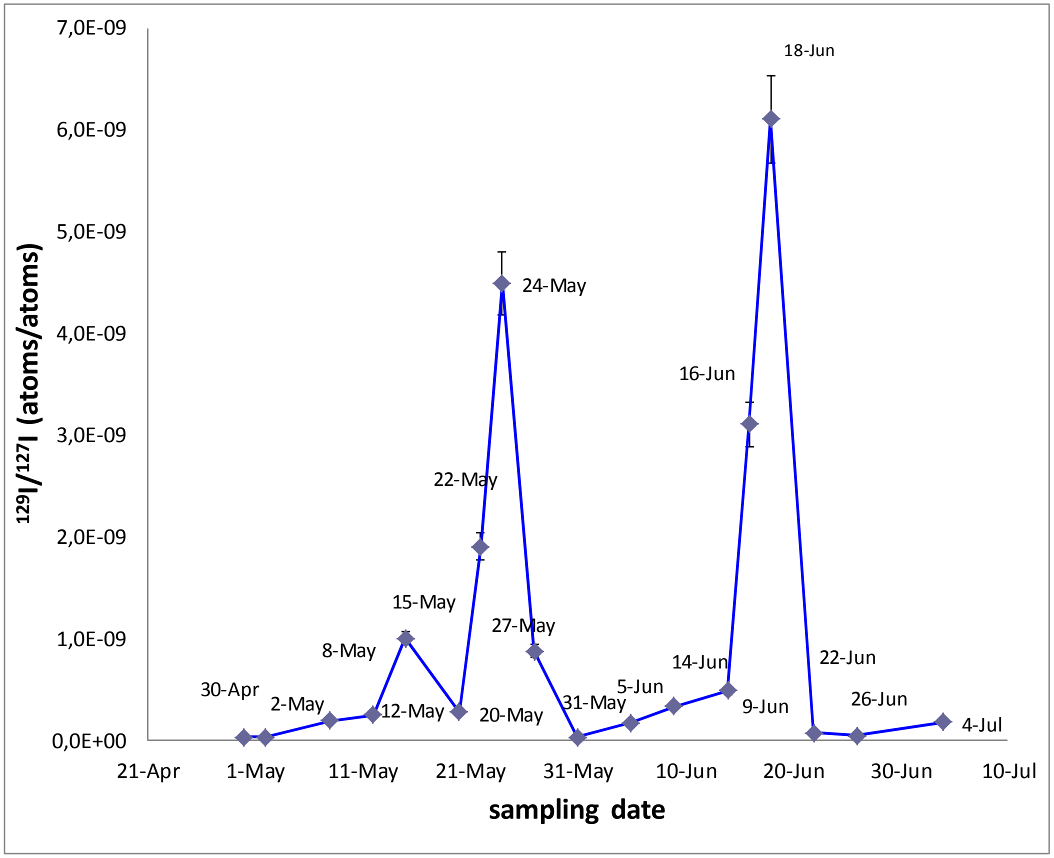
AMS MEASUREMENT OF THE IMPACT OF FUKUSHIMA NUCLEAR RELEASE ON THE WESTERN COAST OF THE USA (LA JOLLA – SAN DIEGO) – ^{129}I circulation



Distance 8792,8 km


Sources of radionuclides to ocean
1 Atmospheric deposition
Mid-March 2011
2 Direct discharge
Early April 2011 peak now small and continues
3 Through river runoff
small and continues
4 Through underground water flow
small and continues

2013 Nuclear plume impact on the W coast of USA

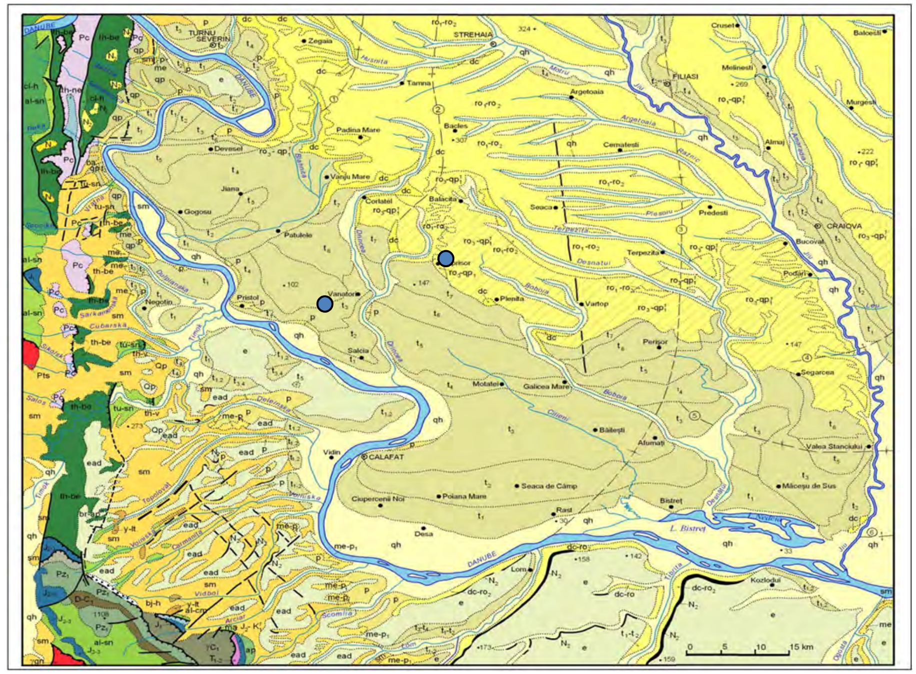


The first release was on 11-12 March and the second major release on 4th or 5th of April. (24 days)
The measured time difference between the two impact peaks : 24 days
Explosions of the roof of the NPP on day 2
Atmospheric Fall out from Explosions had a total retention time in the atmosphere of ca 1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

AMS Dating of the Danube fluvial terraces in the Romanian Plain (Al-Be measurements)

The map of Romanian Plain with the lower Danube River terraces.

Old terrace at Plenita



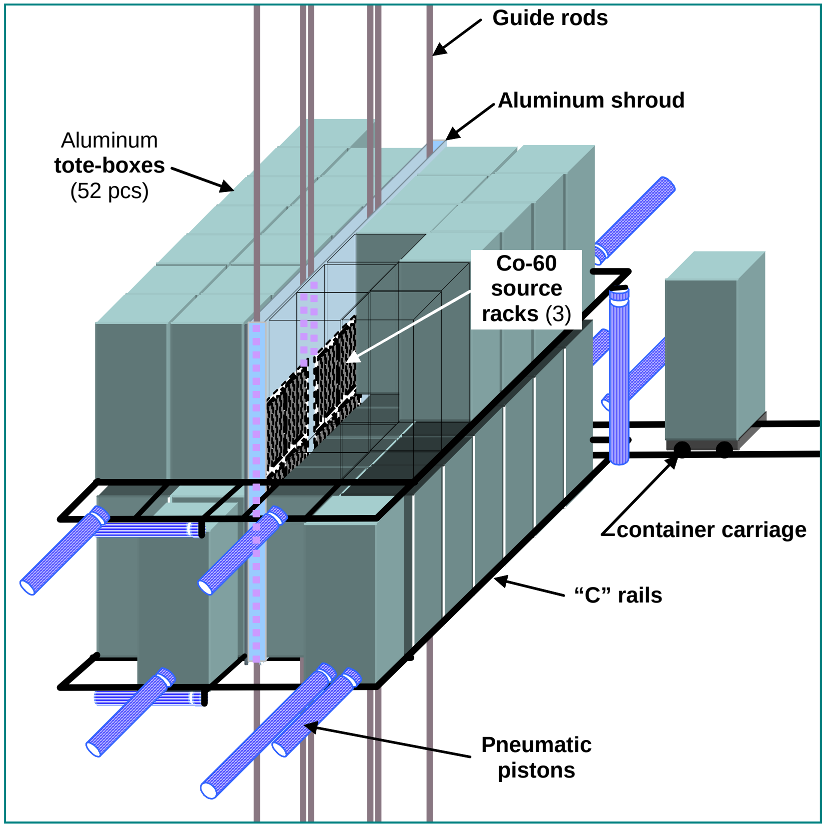
PLENITA TERRACE : 955 ± 100 ka

SALCIA TERRACE : 256 ± 20 ka

IRASM – Radiation Processing Center
IFIN-HH Department

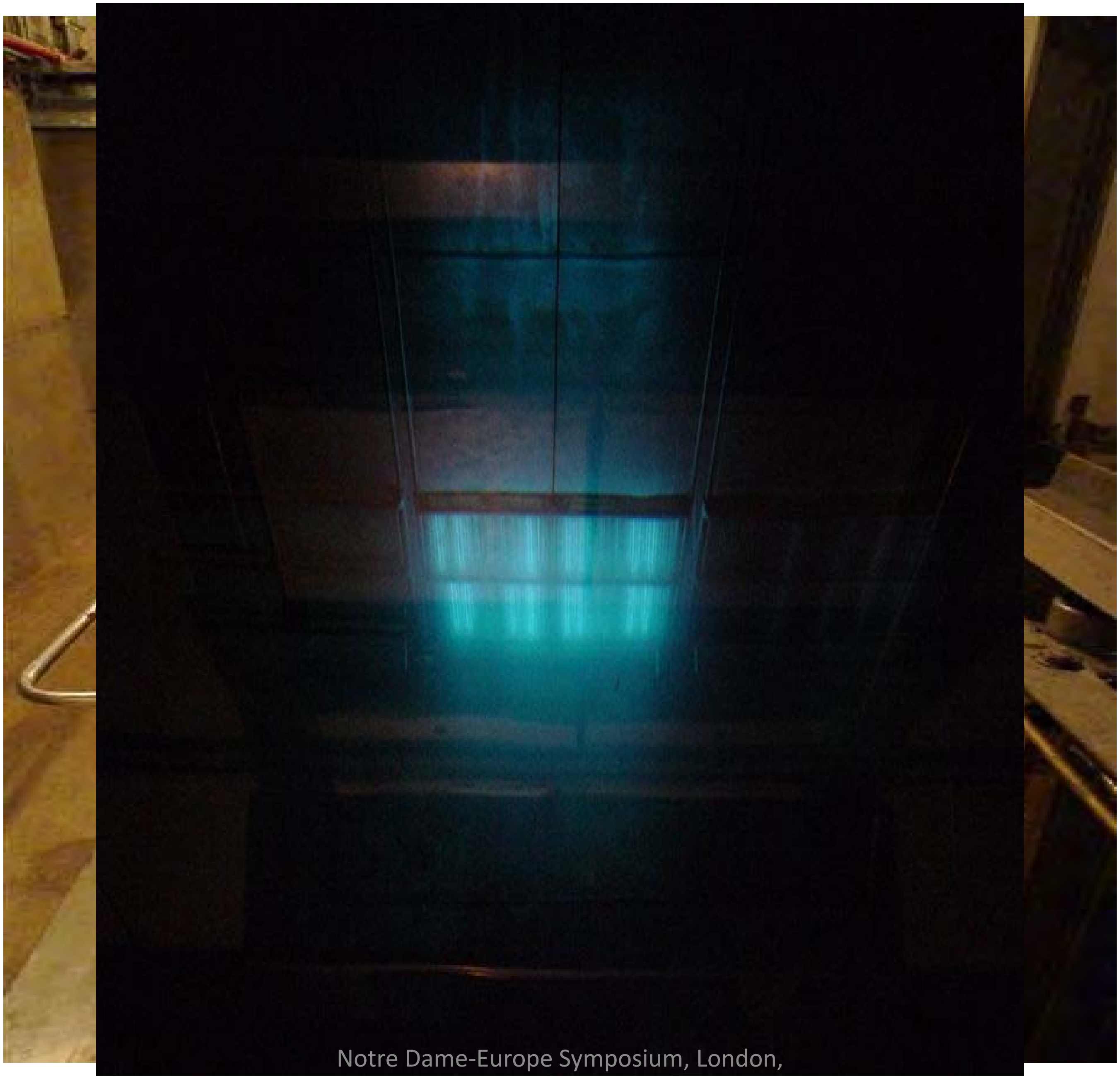
IRASM Irradiator

Multipurpose = wide range of dose (0.1kGy – 10^2kGy), large variety of product size and density



Strong gamma ray source: ^{60}Co
- Technological irradiations
  - Sterilizations
  - Materials research
- Cultural heritage
  - studies & treatments

Radiation sources: Co-60 (CoS-43HH, RSL2089)
Source rack: rectangular (87X95) cm
Rack numbers: 3
Max. source load: 2 MCi
Conveyor: tote-box type; 52
Internal dimensions of totes: (48x 48x 90) cm
Maximum load per tote: 120 kg
Operation modes: Batch, Continuous, Stationary
Installed activity: 400kCi



GC-5000 irradiator

- Cobalt-60, max. 14 kCi
- 5000 cm^3 irradiation volume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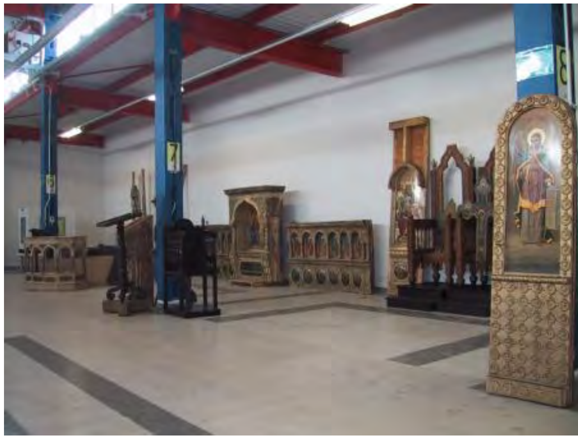
IRASM for Cultural Heritage Preservation



IRASM for Cultural Heritage Preservation

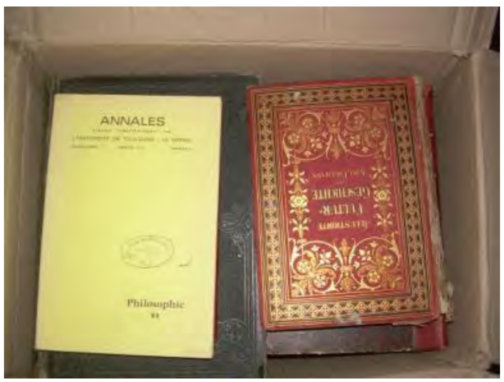
- Accurate irradiations for testing

IRASM for Cultural Heritage Preservation

- Items that can be packed in carton boxes:

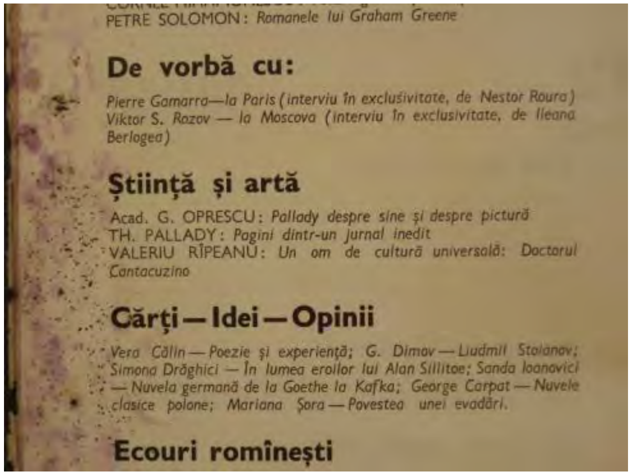
-Usually 46x46x27 cm

-Maximum 46x46x88 cm






IRASM for Cultural Heritage Preservation


PETRE SOLOMON: *Romanele lui Graham Greene*

De vorbă cu:

Pierre Gamarra—la Paris (interviu în exclusivitate, de Nestor Rouro)
Viktor S. Rozov — la Moscova (interviu în exclusivitate, de Ileana Berlogea)

Știință și artă

Acad. G. OPRESCU: *Pallady despre sine și despre pictură*
TH. PALLADY: *Pagini dintr-un jurnal inedit*
VALERIU RÎPEANU: *Un om de cultură universală: Doctorul Cantacuzino*

Cărți—Idei—Opinii

Vera Călin — Poezie și experiență; G. Dimov — Liudmil Stoianov; Simona Drăghici — În lumea eroilor lui Alan Sillitoe; Sanda Ioanovici — Nuvela germană de la Goethe la Kafka; George Carpat — Nuvele clasice polone; Mariana Șora — Povestea unei evadări.

Ecouri romînești


DOCUMENTE
ISTORIA ROMÂNILOR
Volumul XIV
DOCUMENTE GRECESTI
ISTORIA ROMÂNILOR
N. IORGA
PARTEA I
1320-1716

DOCUMENTE
ISTORIA ROMÂNILOR
DOCUMENTE GRECESTI
ISTORIA ROMÂNILOR
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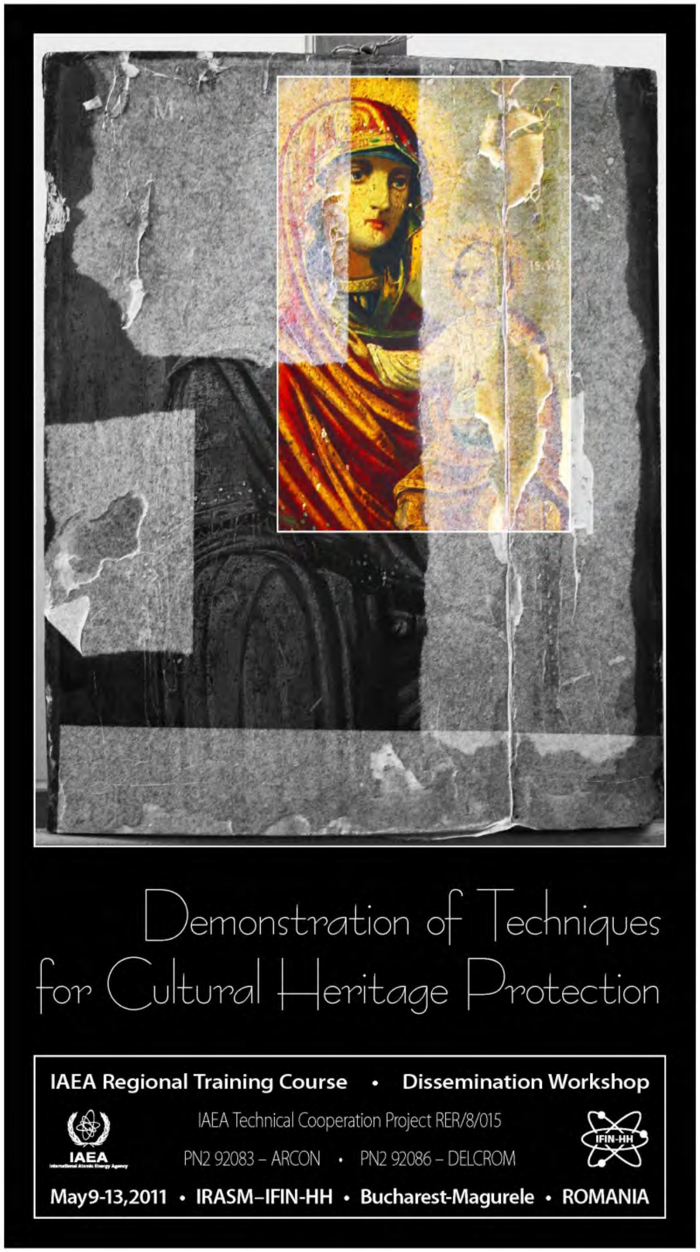
PARTEA I
1320-1716

IRASM for Cultural Heritage Preservation

Thank you for your attention!


6
7
8



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

Frequent circumstances for application

The irradiation conservation is applied especially when one of the following circumstances is present:

- **emergency intervention** (ex: Alan Mason Chesney Medical Archive - USA);
- **intervention on objects with complex structure** (ex: Ramses mummy – treated in NUCLEART);
- **intervention on large objects / assemblies** (ex: Rom. Film Archive, iconostases - Romania);
- **when classical methods can not be applied** (ex: a gas chamber dedicated to CH is not available - Romania);
- **cost/benefit rate have to be low** (ex: icons from parish churches - Romania).
- **Salvage:** reinforcement of objects (wood) thru polimerization

Networking

Internal co-operation

- Museum of National History of Romania
- National Art Museum
- Other musea from Bucharest, Iasi, Sibiu, Galati, Cluj, Braila …
- National Library
- National Pattent Office

International co-operations

- 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 will work for no cost for Romanian institutions

Collaborators (authors, actually!)

- A. Pantelica
- B. Constantinescu, E. Oberlander-Tarnoveanu, Angela Vasilescu, Daniela Stan
- D. Ghita, T. Sava, C. Calinescu, C. Simion, O. Gaza, …
- C. Stan-Sion, M. Enachescu, …
- C. Ponta, V. Moise and the IRASM group