NUCLEAR PHYSICS
FOR CULTURAL HERITAGE

A TOPICAL REVIEW BY

the Nuclear Physics Division of the European Physical Society

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Nuclear Physics Applications in Cultural Heritage

- There has been enormous progress in the use of nuclear physics techniques to study, characterize and preserve cultural heritage objects and artefacts. This expert review, published by the Nuclear Physics Division of the European Physical Society (EPS), seeks to provide the public with a popular and accessible account of the latest developments in this field.

- The contributions from a range of leading specialists explain how applied atomic and nuclear techniques can be used to obtain information that can help us understand the way of life in ancient times and how they can be used to conserve cultural heritage treasures.

- This topical review draws heavily on European work and is extensively illustrated with important discoveries and examples from archaeology, pre-history, history, geography, culture, religion and curation. It outlines key advances in a wide range of cross-disciplinary techniques and has been written with the minimum of technical detail so as to be accessible by as wide a possible audience as possible.

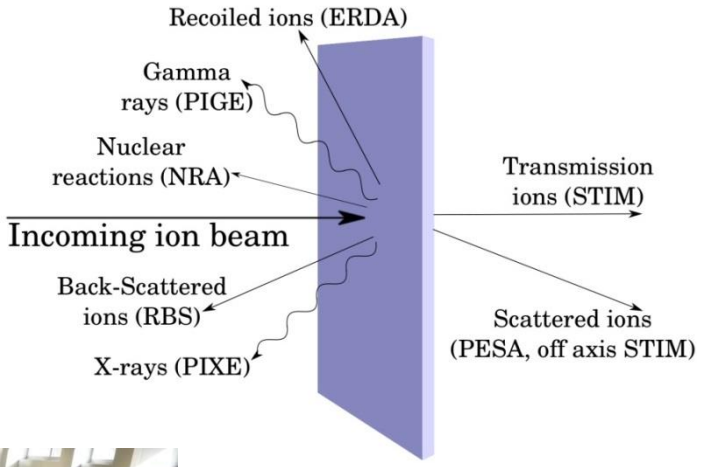
- The large number of groups and laboratories working in the study and preservation of cultural heritage across Europe indicate the enormous effort and importance attached by society to this activity.

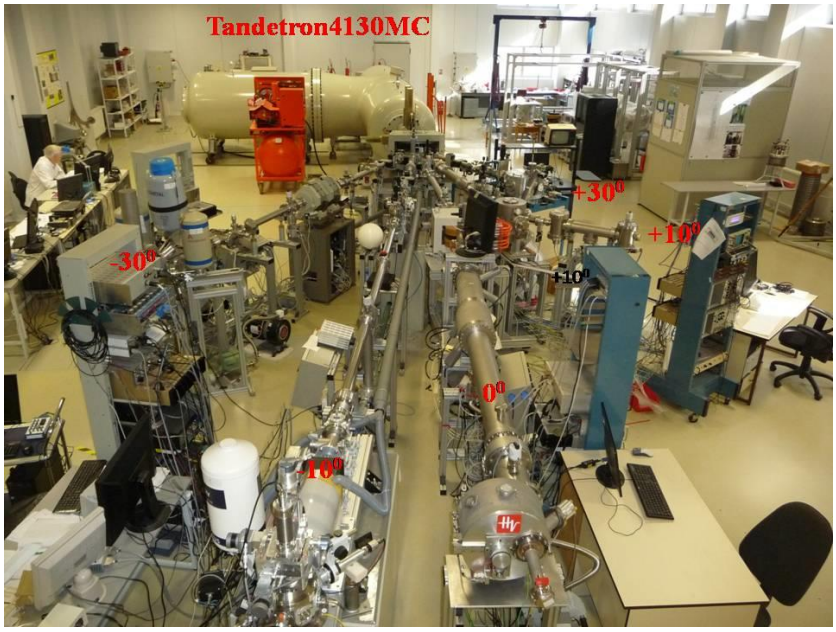
Nuclear Physics as an analytical tool

- Various nuclear radiations (X-rays, γ-rays, electrons, neutrons, ion beams, etc.) are used to analyse the composition of objects, or to preserve them.

- Precious cultural heritage objects remain unaltered after investigation.

- Nuclear analytical techniques are all based on well-known physical processes and the path from measured data to the required information is very straightforward.



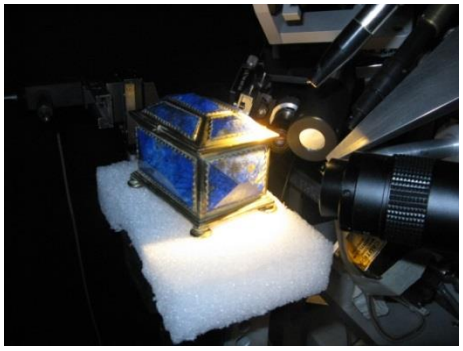


- Low energy ion beams, produced by small accelerators, penetrate matter and interact with atoms to produce X-rays, γ-rays and other particles which provide information about the structure and composition of the object.

- Small accelerators are also used for Atomic Mass Spectrometry (AMS) which is a widely used technique for dating historical artefacts.

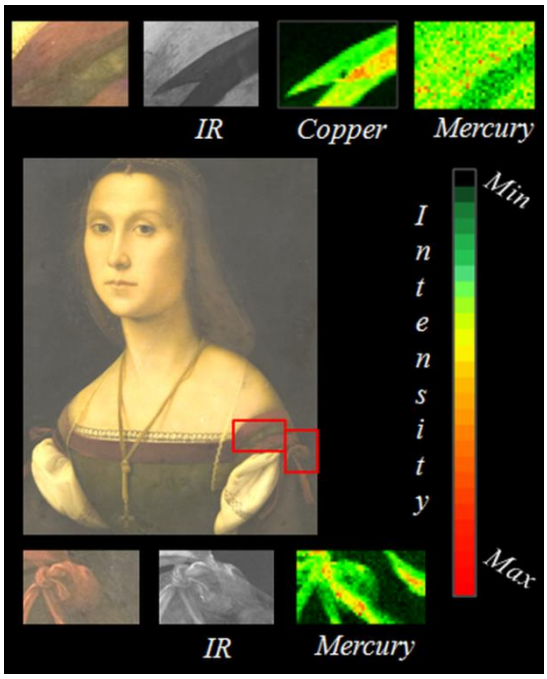
- Neutron beam studies use high flux neutron beams from research reactors. Neutron capture and scattering phenomena provide detailed information about the make-up of objects.

Cultural heritage studies



- The ion microbeam set-up has proven to be versatile and allows many analytical techniques to be in combination. The ion beam is focused onto a spot as small as a few hundred nanometers in diameter. By scanning the beam over the sample surface a 2D distribution of elements can be determined. Varying the ion beam energy may even allow a 3D distribution to be obtained. The results are elemental maps of the investigated artefact. The determination of trace elements often allows information to be deduced regarding the origin of the artefact or its manufacturing process.

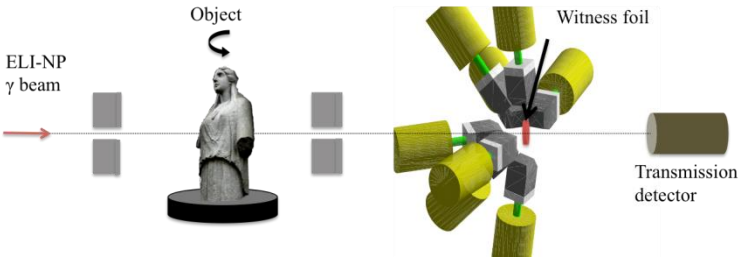
- Neutron beams offer a wide range of possibilities to explore the compositional or structural features of the samples. The low energy and relatively low intensity of guided neutron beams ensure no long-term damage is done to the objects studied and any induced radio-activity generally decays within a few days. Neutron beam tomography is used to map the internal structure and morphology of historical artefacts and teaches us about ancient production technologies.



- Radiocarbon dating provided by AMS has proved to be one of the most useful dating tools for archaeological, environmental and geological studies which all benefit from the ability to date organic materials.

- X-ray fluorescence is a valuable technique used in the elemental identification of cultural heritage objects because it is non-invasive, non-destructive, and highly sensitive. It is a quantitative technique which can, in many cases, be used directly on the surface of the objects to provide information about the chemical composition of inks and paint pigments.

- The European initiative for Extreme Light Infrastructure laboratories in Romania (ELI-NP), will shortly provide tunable energy γ-rays from inverse Compton scattering of laser light on a high-energy electron beam. This will allow Nuclear Resonance Fluorescence studies of isotope-specific trace element distributions to be performed with unprecedented sensitivity. It is planned to use this powerful tool for cultural heritage object studies.



- Preservation often requires high intensities of irradiation. One of the main applications is the sterilisation of an object by γ-rays, a method widely used for medical equipment. The purpose is to kill any bacteria, fungi, or woodworms which would otherwise destroy the object over a period of time.

- The topical review paper is extensively illustrated with a wide range of important discoveries and examples which underline the breadth and importance of this field.

Summary

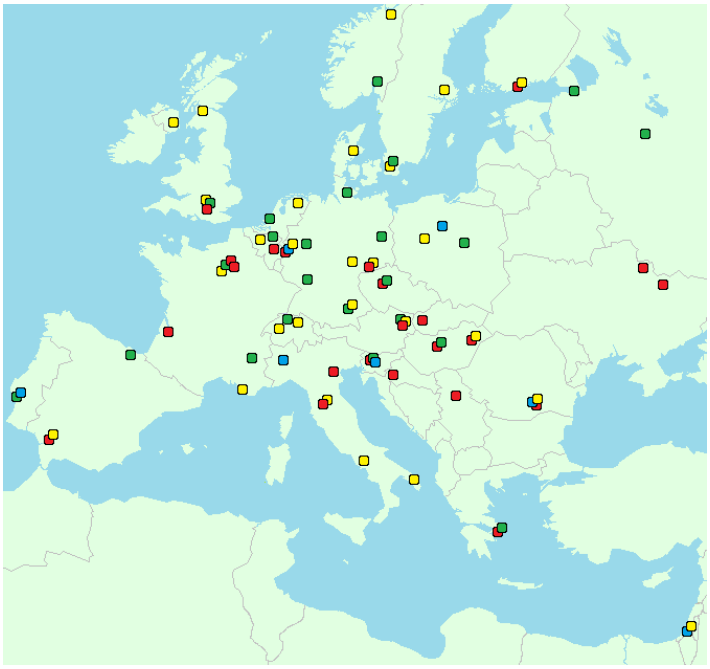
- The application of atomic and nuclear techniques to the study of archaeological objects gives information that can help to test the authenticity and provenance of artefacts and to carry out necessary restorations.

- For this work a multi-disciplinary approach is essential, bringing together physicists, chemists, archaeologists, numismatists, historians, geologists and conservators from different laboratories, institutions and museums.

- This paper, prepared by the EPS Nuclear Physics Division, provides a useful summary for both the public and also the professional community, of just how broad and important the application of the field of nuclear techniques has become in the study of cultural heritage, its characterisation and preservation.

European facilities using nuclear techniques to study cultural heritage

The map below shows the spread of permanent laboratories and centres with facilities used for nuclear physics studies of Cultural Heritage objects across Europe.



- Ion Beam Analysis Facilities in Europe
- European Neutron Sources
- European Accelerator Mass Spectrometry Facilities
- Other European Centres, Facilities and Laboratories

- The large number of groups and laboratories contributing to the study and preservation of cultural heritage across Europe indicate the enormous effort and importance of this activity.

- For more detail the **full paper** can be downloaded from the EPS website:

http://www.edp-open.org/images/stories/books/fulldl/Nuclear-physics-for-cultural-heritage.pdf