Investigation of the elemental composition of Medallion (the 12th - first half of the 13th centuries) by method of neutron resonance capture analysis

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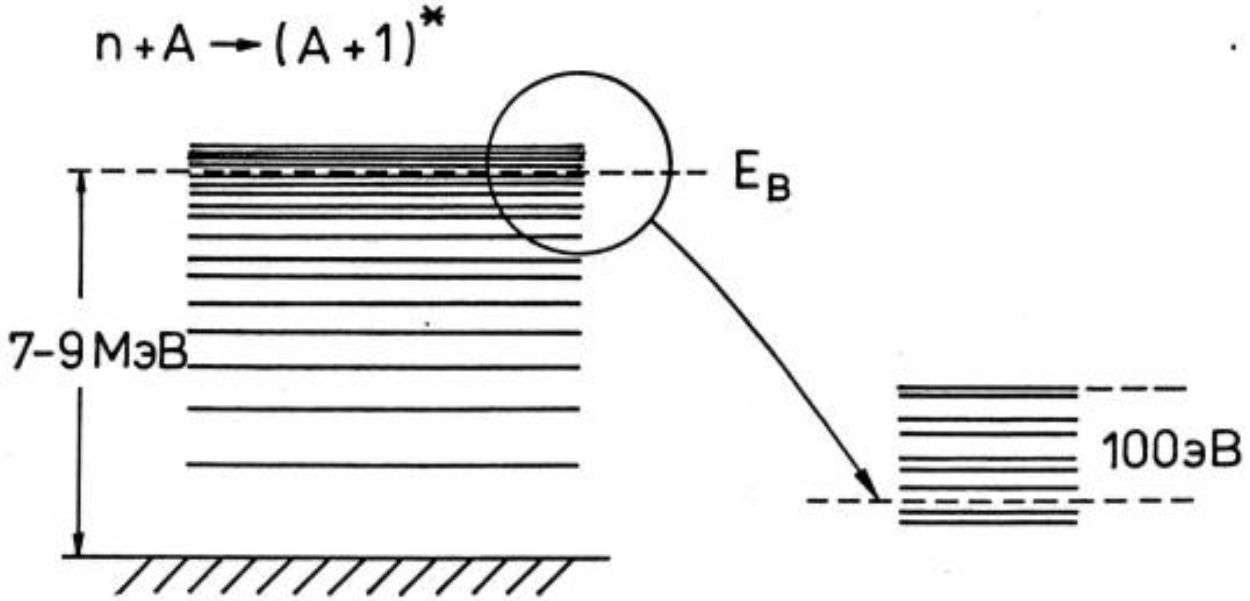
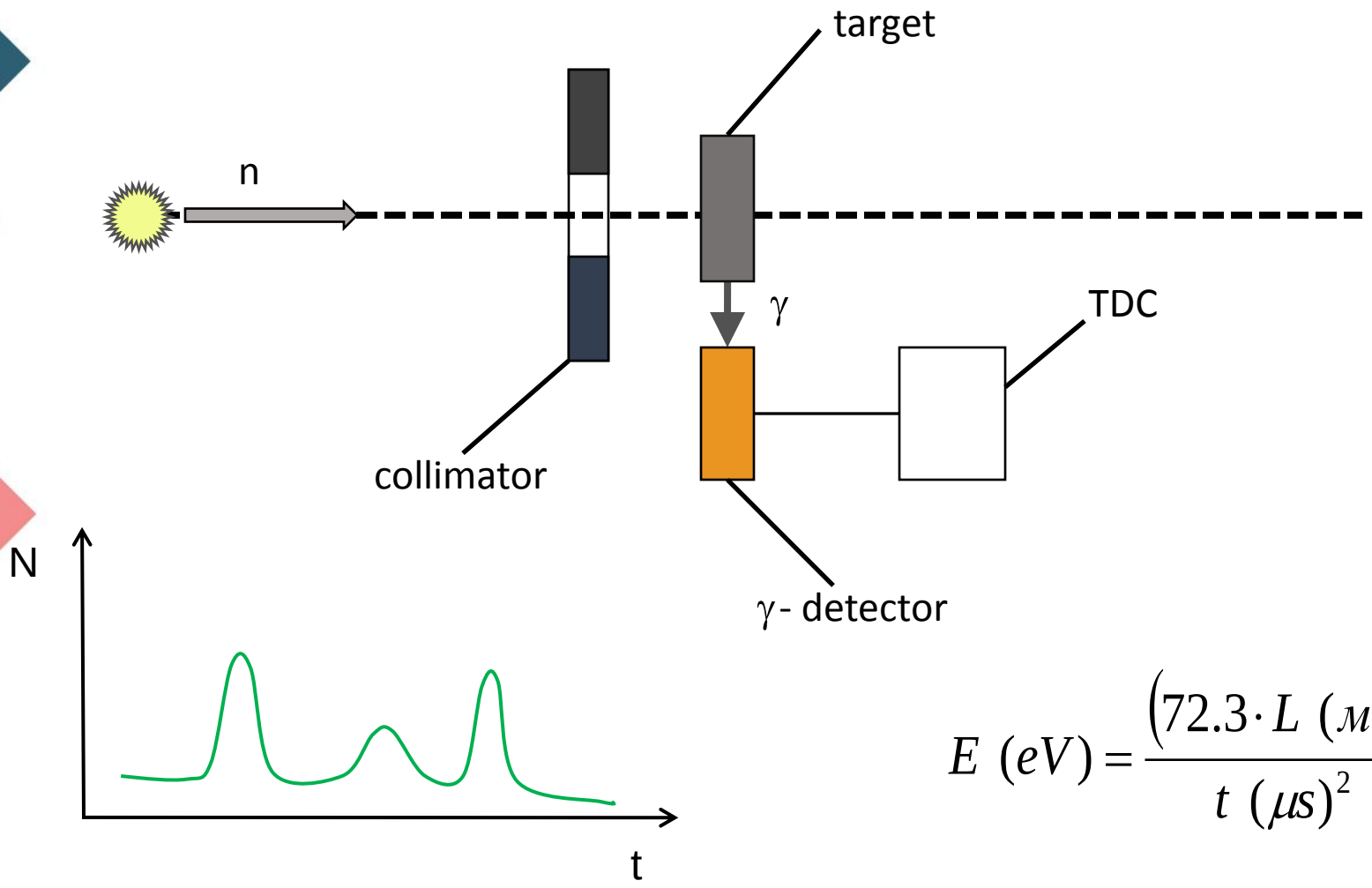
- ***Neutron Resonance Capture Analysis (NRCA)*** can be applied for nondestructive determination of the isotopic composition of samples. The method is based on the registration of neutron resonances and the measurement of the yield of reaction products in the resonances. The resonance energies are known practically for all stable nuclei and the set of energies does not coincide completely for any pair of isotopes. It allows determining the isotope composition.

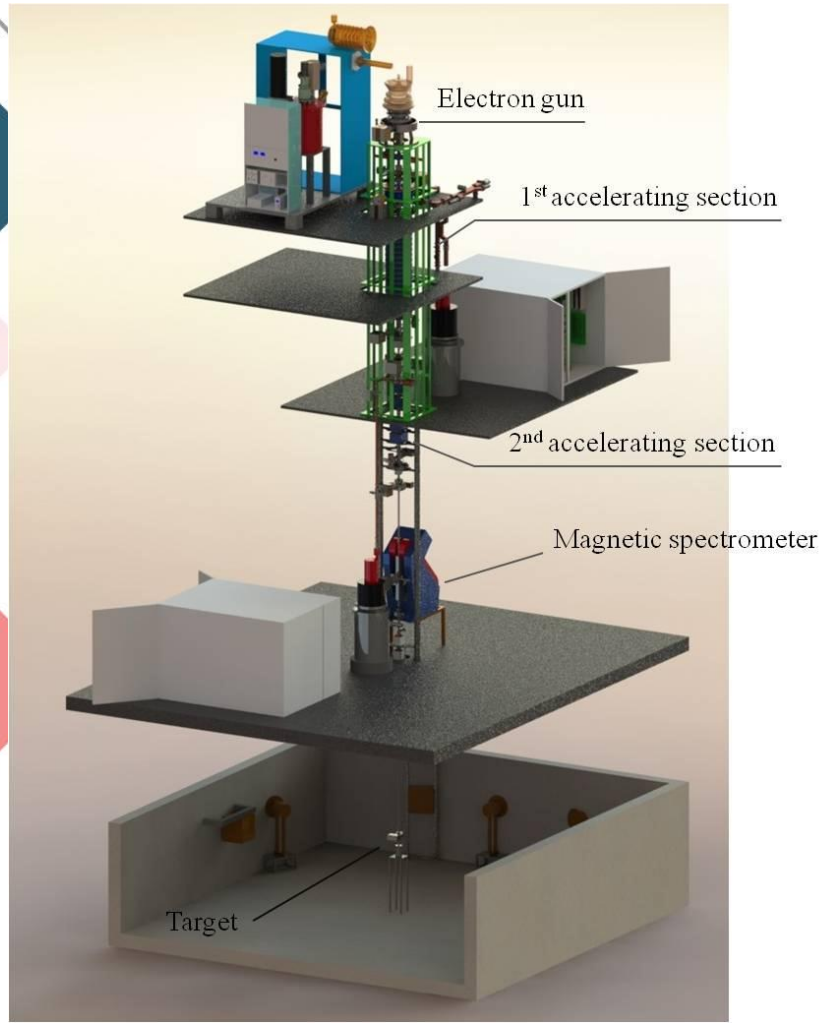


Neutron resonance capture analysis (NRCA) is based on use of the pulsed neutron source and time-of-flight method (TOF)



$$E\ (eV) = \frac{\left(72.3 \cdot L\ (м)\right)^2}{t\ (\mu s)^2}$$

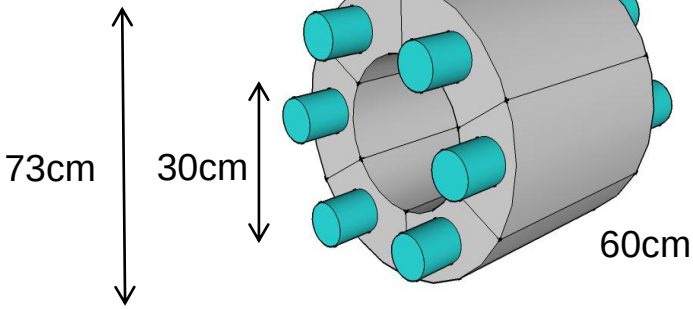
IREN parameters



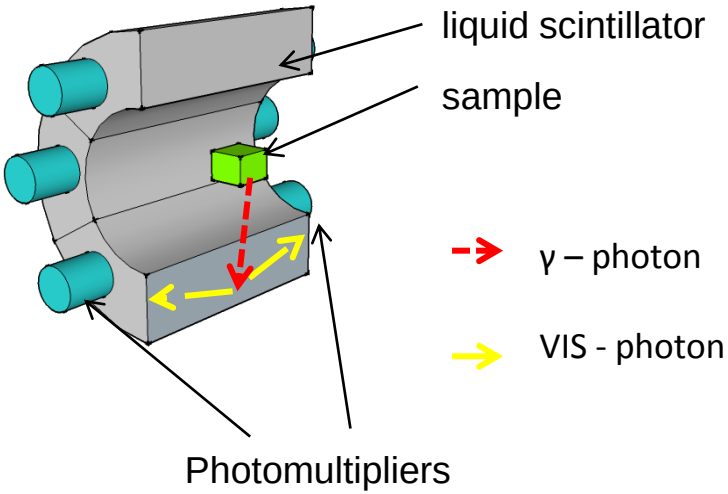
The main part of the IREN facility is a linear electron accelerator. The bunched electron beam generates bremstruhlung in the tungsten target and it produces the neutron pulses via (γ,n)-reaction in the same target.

Peak current, A	3
Repetition rate, Hz	50
Electron pulse duration, ns	100
Electron energy, MeV	60
Neutron intensity, n/s	$4 \cdot 10^{11}$

Experimental setup



6 Liquid scintillator (210 liters)
12 Photomultipliers



Detector contains 6 sections forming together the cylinder with the channel along the neutron beam direction. Diameter of the channel is 300 mm, external diameter of the detector is 730 mm, length 600 mm. Total volume of liquid scintillator is 210 liters. There are photomultipliers in both ends of each section. The signals from two photomultipliers of each section are summarized on output load resistor.

General view of the detector

Then after amplification and shaping they go to the majority coincidence circuit.
The majority coincidence circuit is applied to observe radiative capture of a neutron. Various combinations of coincidence of pulses in different sections are possible.

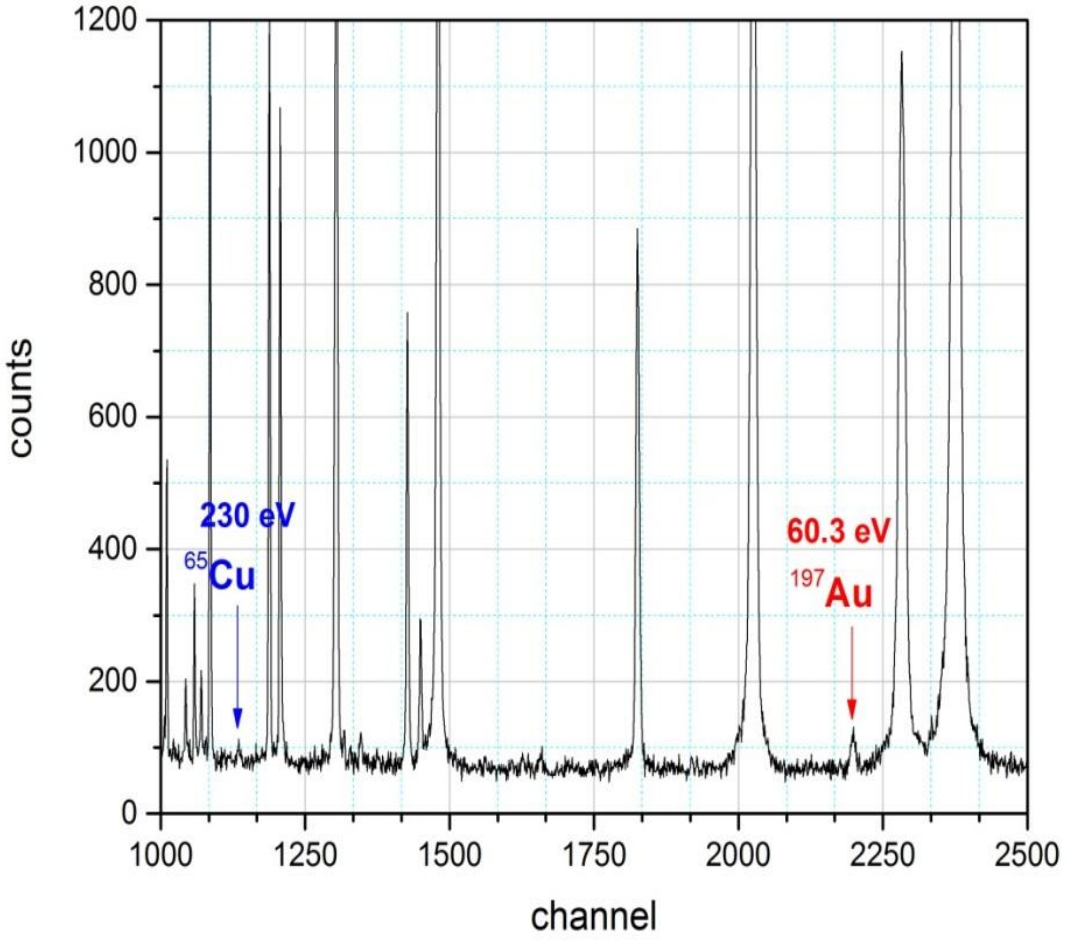
Medallion

We received an application from Institute of Archaeology Russian Academy of Sciences to make the analysis for medallion.

The medallion dates back to the 12th - first half of the 13th centuries (the ancient Russian time). It was found in historical part of Tver city near the Tver Kremlin. Analogues of this medallion are in the expositions of the Moscow Kremlin which consist mostly of silver.

The question is whether the medallion is an original object (mostly silver) or just a copy (mostly copper).

Time-of-flight spectrum from the medallion



Parameters of samples

	Sample	Area, cm^2	Weight, g	Measurement time, h
Standard	Silver	38.46	3.55	7.88
	Copper	162.8	216	6.13
	Gold	31.79	3.049	11.11
Investigated	Medallion	41.53	30.89	41.25

Amount of the element is determined by an intensity of the resonance area

$$\sum N = \Pi(E_0)\varepsilon_\gamma \frac{\Gamma_\gamma}{\Gamma} A$$

$\Pi(E)$ - total neutron number have been falling on the sample during the measurement time per unit of energy

ε_γ - detection efficiency

Γ_γ - radiation width of the resonance

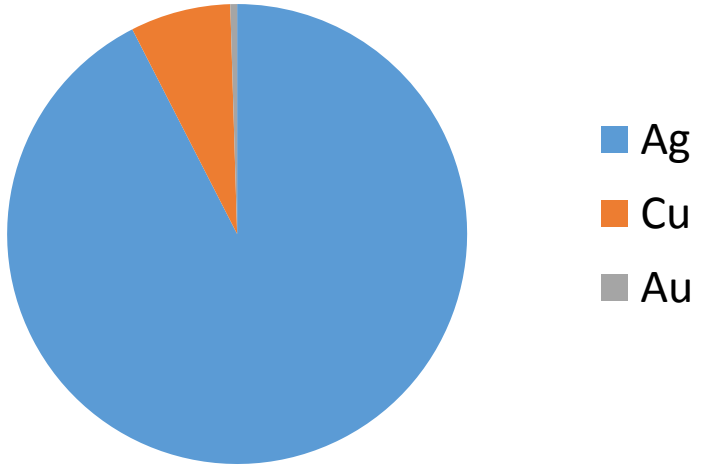
Γ - total width of the resonance

A - resonance area on the transmission curve, $A = \int_{-\infty}^{\infty} [1 - T(E)]dE$

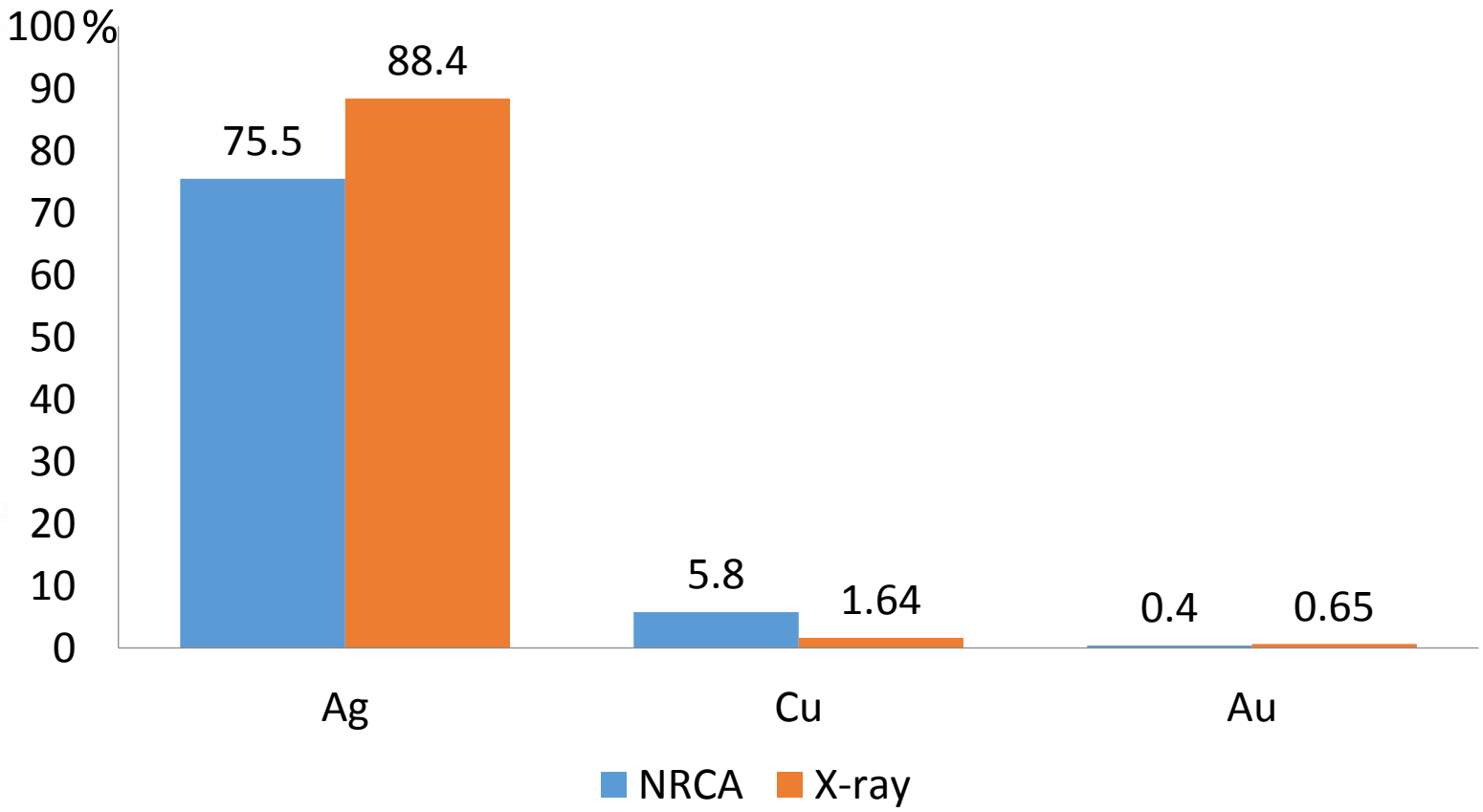
where $T(E)=e^{-n\sigma(E)}$ is defined as function of the resonance parameters and the sample thickness (nuclei/cm^2).

Result for medallion

№	Element	Mass, g
1	Ag	23.32±0.36
2	Cu	1.78±0.83
3	Au	0.12±0.02



Comparison of results of NRCA and X-ray analysis



Conclusion

Analogues of the medallion are in the expositions of the Moscow Kremlin which consist mostly of silver. The medallion was found in not typical place for such kind objects. Therefore it could be good copy but from cheaper materials. Elemental composition information could clarify the issue.

X-ray analysis allows determining elemental composition only on the surface. To determine the origin of archaeological object an investigation of elemental composition needed to be carried out in the "bulk-form“ without destruction. Thanks to analytical tool of NRCA there was found out that the medallion mostly consists of silver and is original object.

NRCA allows not only to identify with high accuracy the elemental and isotopic composition of the sample, but also makes it possible to determine the amounts of elements and isotopes in the sample.
The method is non-destructive, the induced activity of the sample is practically absent. All this makes it promising for research of archaeological artifacts and objects of cultural heritage.

Thanks for your attention !