Joint Institute for Nuclear Research

SCIENCE BRINGING NATIONS TOGETHER

Non-destructive analysis of element and isotope composition by neutron spectroscopy methods

Frank Laboratory of Neutron Physics

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- Theory
- Experimental setup-IREN facility
- Data analysis
- Results

Task

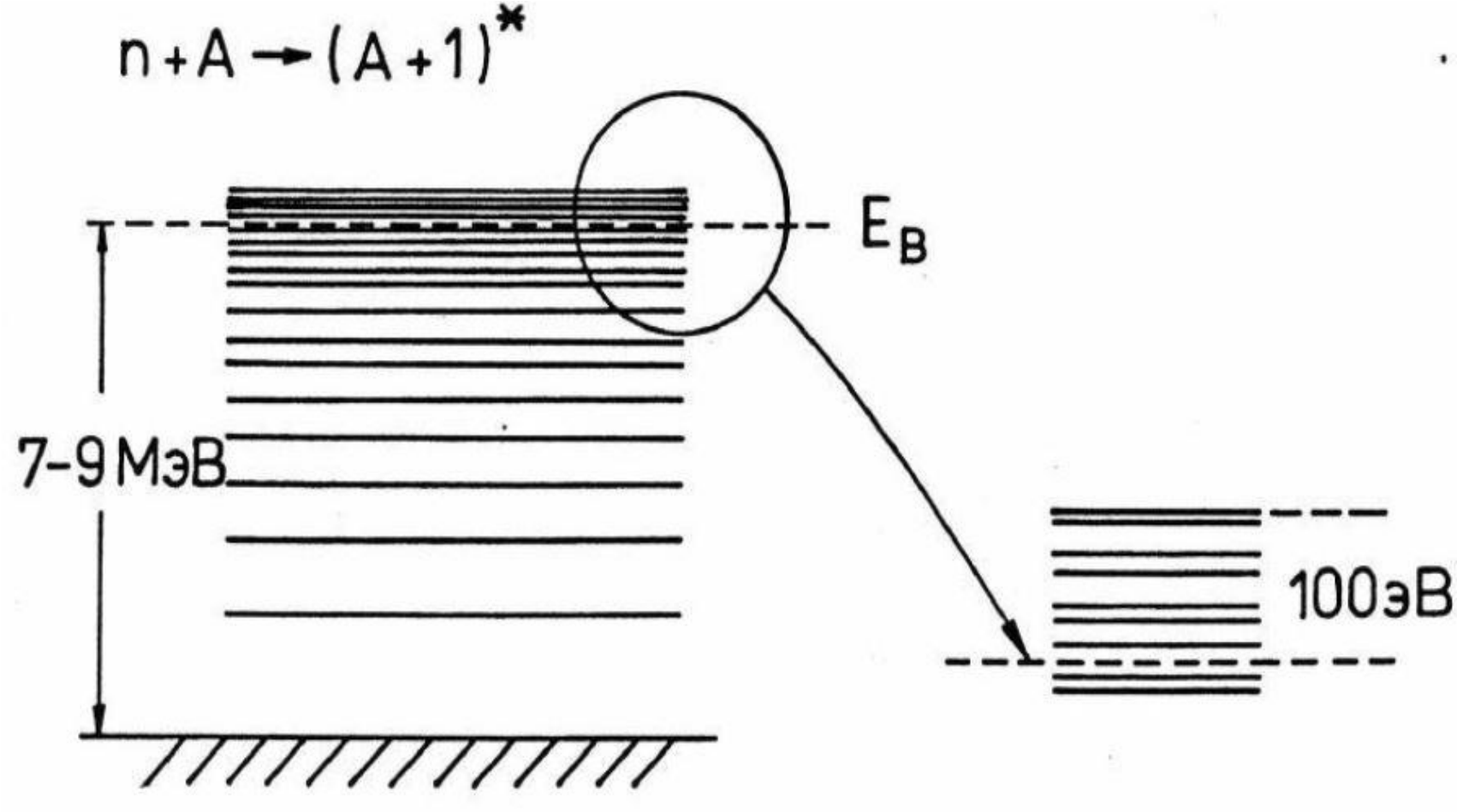
- Determination of isotope and element composition of unknown sample
- Determination of isotop mass

Analysis by neutron spectroscopy

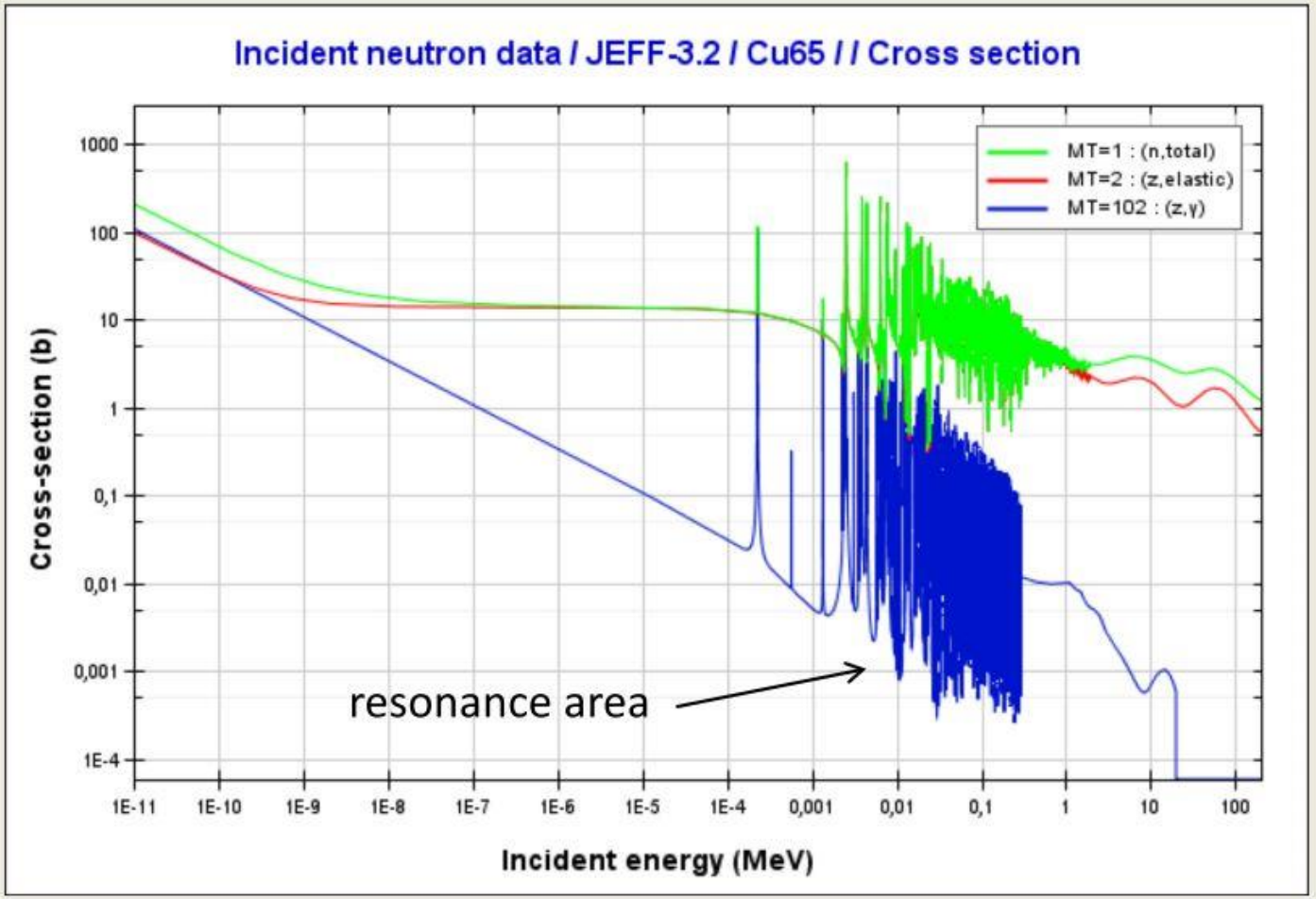
- Neutron spectroscopy is a part of neutron physics studying the energy dependence of effective cross sections of different neutron-nuclei interactions and obtained nuclei excited state characteristics.

- Neutron resonances are characteristic for every isotope and can be used as a “fingerprint” for the identification of elements.

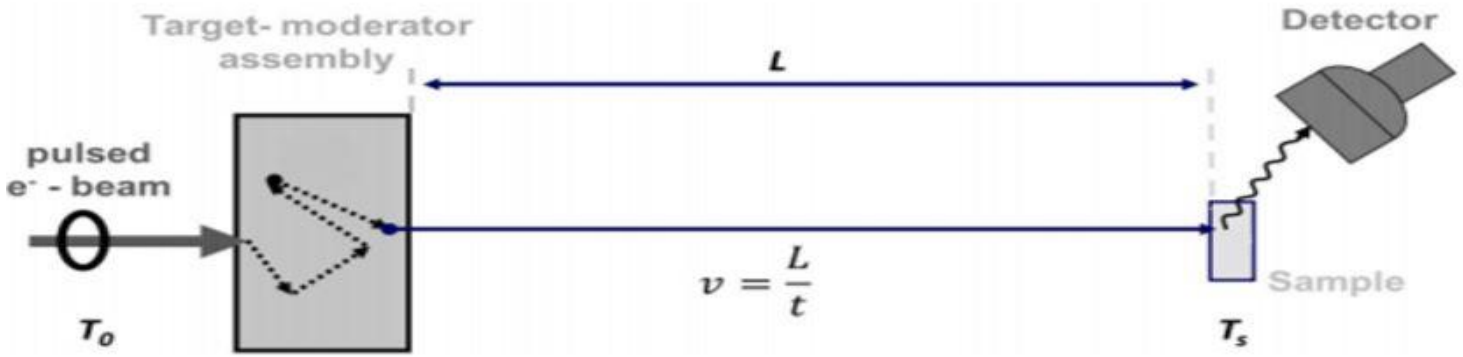
Excitation States



Dependence of Total Cross Section on Neutron Energy

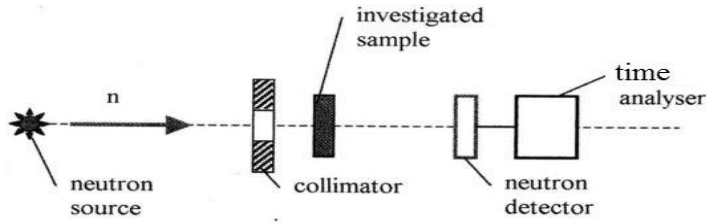


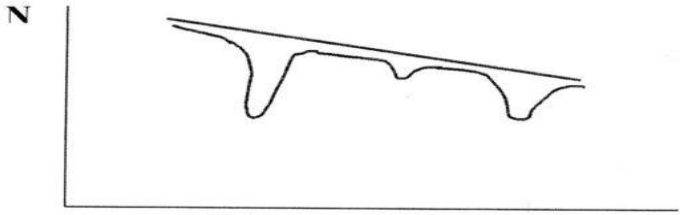
Time of flight method



$$E = \frac{1}{2}\mathrm{mv}^2 = \frac{(72.3\ L)^2}{t^2} = \frac{1.78\ x10^7}{(t - \Delta t)^2}$$

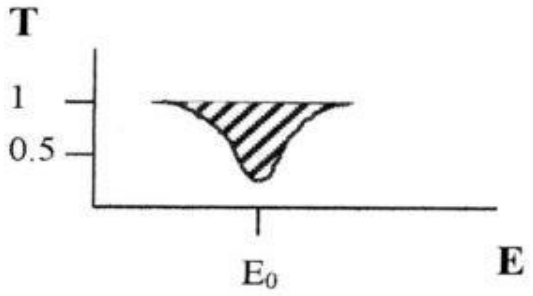
Neutron transmission measurement(Total cross section)





transmission

$$T = \frac{N}{N_0} = e^{-n\sigma_t}$$

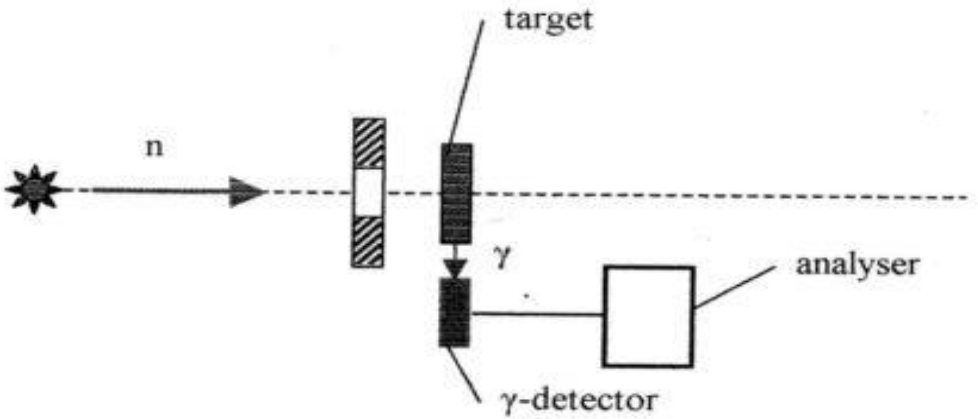


Resonance area on the transmission curve

$$A = \int_{-\infty}^{\infty} [1 - T(E)]dE$$

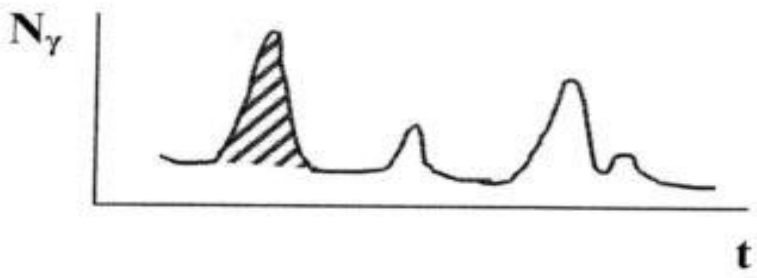
$$A = \frac{\pi n \sigma_0 \Gamma}{2} e^{-\frac{n\sigma_0}{2}} \left[I_0(\frac{n\sigma_0}{2}) + I_1(\frac{n\sigma_0}{2}) \right]$$

Partial cross sections measurement (Neutron capture analysis)



$$\sigma_{tot} = \sigma_s + \sigma_\gamma + \sigma_\alpha + \sigma_f \ldots$$

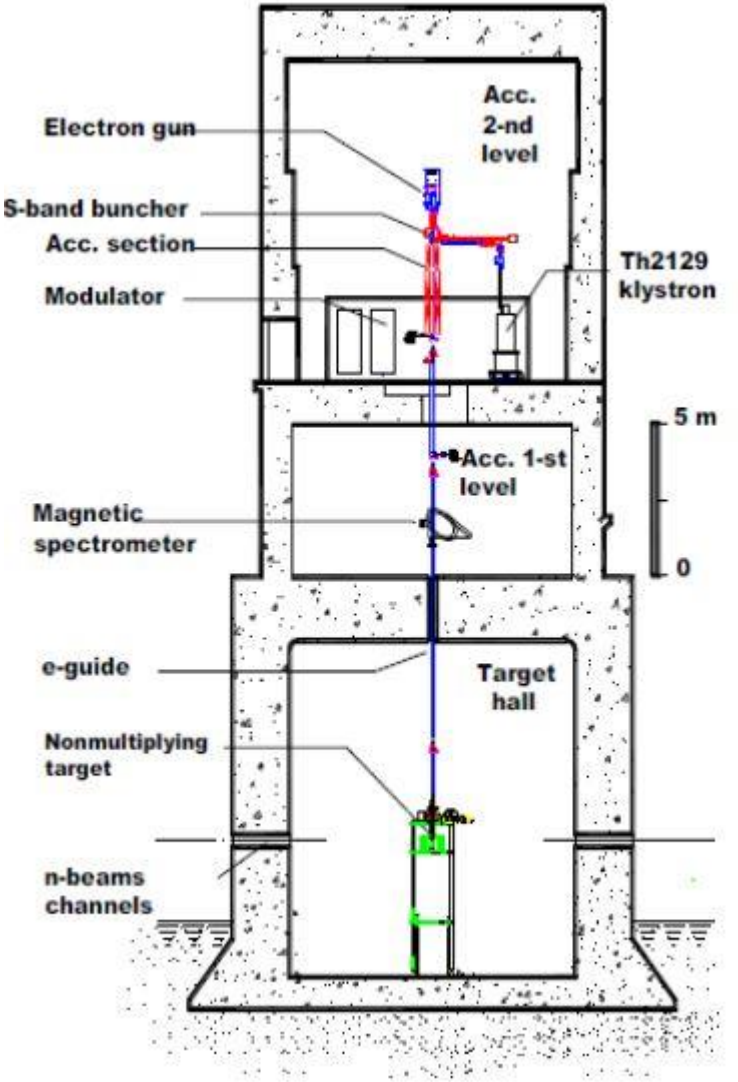
$$\Gamma = \Gamma_n + \Gamma_\gamma + \Gamma_\alpha + \Gamma_f \ldots$$



Eperimental setup–IREN facility

- The investigations are carried out at the Intense REsonance Neutron source(IREN) of FLNP. (Pulsed Neutron Source)

IREN parameters	
Peak current (A)	3
Repetition rate (Hz)	50
Electron pulse duration (ns)	100
Electron energy (MeV)	30
Beam power (kW)	0.4
Multiplication	1
Neutron intensity (n/s)	10^{11}



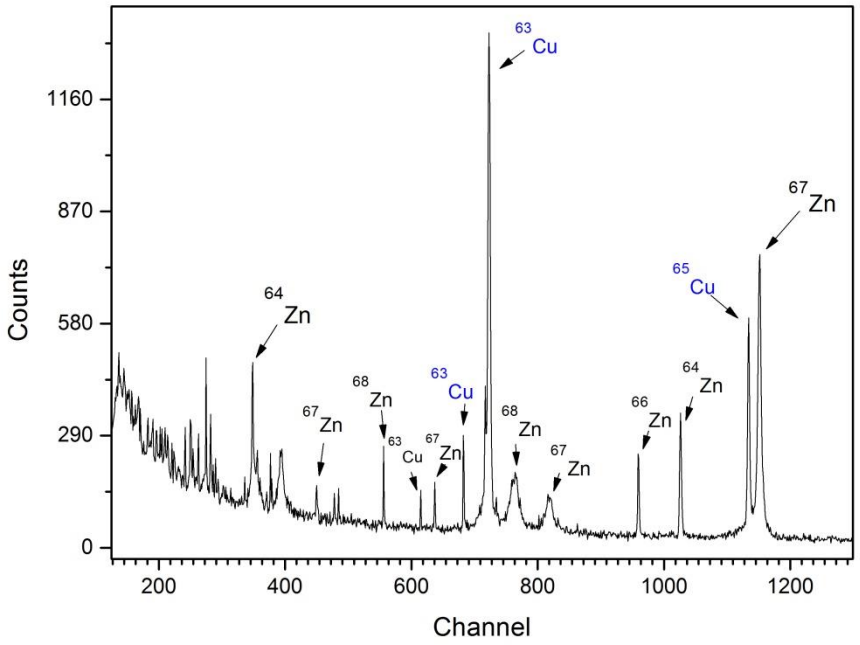
Liquid Scintillator Detector

- Detector contains 6 sections forming together the cylinder with the channel along the neutron beam direction.
- A pair of photomultypliers tubes in both ends of each section.

L=600 mm, D(ext)=730 mm,
D(int)=300 mm

Data Analysis

Channel	E_n(eV)	Isotopes
1152	223.1	^{67}Zn
1134	230	^{65}Cu
1026	281.8	^{64}Zn
959	323.5	^{66}Zn
816	448.2	^{67}Zn
764	514	^{68}Zn
723	579	^{63}Cu
682	650	^{63}Cu
637	750	^{67}Zn
615	807	^{63}Cu
556	983	^{68}Zn
485	1320.8	^{67}Zn
478	1362	^{65}Cu
450	1528	^{67}Zn



Isotope	Mass(g)
^{65}Cu	80.60
^{67}Zn	59.78

Counting out sum on the resonance

$$\sum N_i = \prod (E_0) \varepsilon_\gamma A \frac{\Gamma_\gamma}{\Gamma}$$

$\prod(E_0)$ –total neutron number have been falling on the sample during the measurement time at 1 eV energy interval

$\varepsilon_\gamma - \gamma$–detector efficiency

A–resonance aria on the transmission curve

Γ –total resonance width, equal to half–height peak width

Γ_γ–radiation width

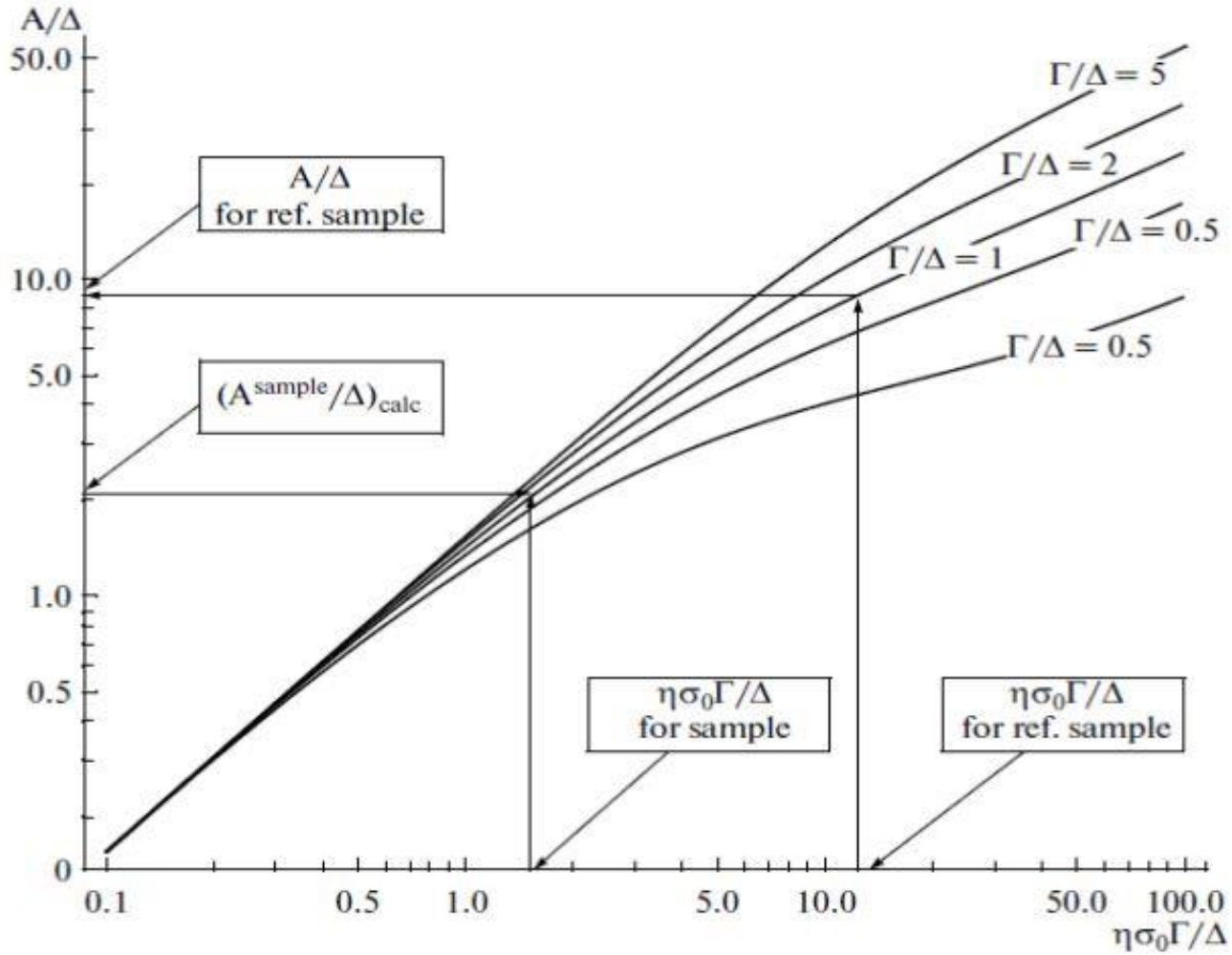


Fig. 2. Value of A as a function of the number of nuclei and the resonance parameters.

Investigated Samples

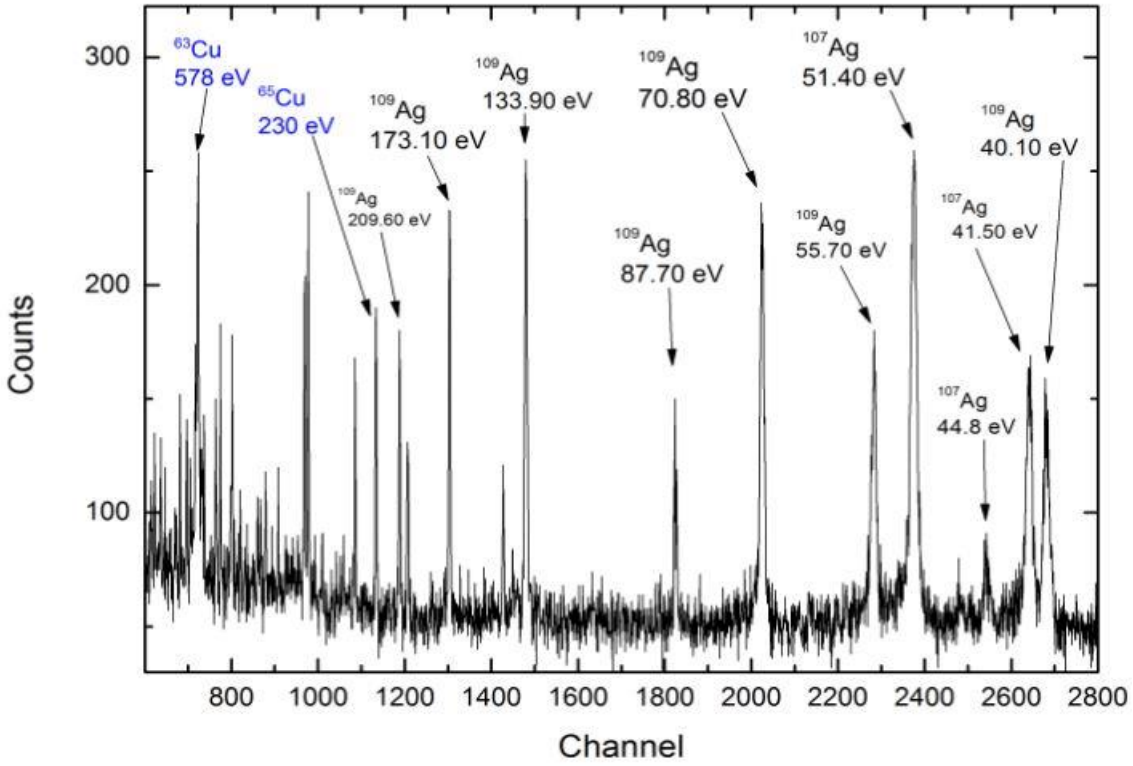
Phanagoria was the largest ancient Greek city on the Taman peninsula, spread over two plateaus along the eastern shore of Cimmerian Bosporus.

The city was a large emporium for all the traffic between the coast of the Maeotian marshes and the countries on the southern side of the Caucasus.

Today the site is located at a short distance to the west of Sennoy in Krasnodar Krai, Russia.

Data Analysis
TOF Method

Channel	E_n(eV)	Isotopes
2680	40.10	^{109}Ag
2641	41.50	^{107}Ag
2377	51.40	^{107}Ag
2283	55.70	^{109}Ag
2024	70.80	^{109}Ag
1821	87.70	^{109}Ag
1480	133.90	^{109}Ag
1190	209.60	^{109}Ag
1131	230	^{65}Cu



Identified isotopes from resonance energies

Results

Isotope	Mass(g)
^{107}Ag	5.41±0.25
^{109}Ag	6.18±0.48
^{109}Ag	6.9±0.47
^{109}Ag	6.01±1.33
^{65}Cu	57.92±6.22

The average mass of silver is 6.12 ± 0.63 g

BRASS { **6 g silver**, **57 g copper**

Thank you for your attention.