Neutron Resonance Spectroscopy

Andrey Smolyakov

Institute for Theoretical and Experimental Physics
Moscow, Russia

Equation-of-State measurements: why NRS?

EOS measurements are of fundamental importance in describing the behaving of materials, especially in Physics of High Energy Density in Matter:

- Extreme conditions
- Rapidly-changing conditions
- Necessity of non-perturbing diagnostics

Neutron Resonance Spectroscopy (NRS) allows to resolve all the difficulties mentioned above and measure material temperature – one of the Equation of State parameters.

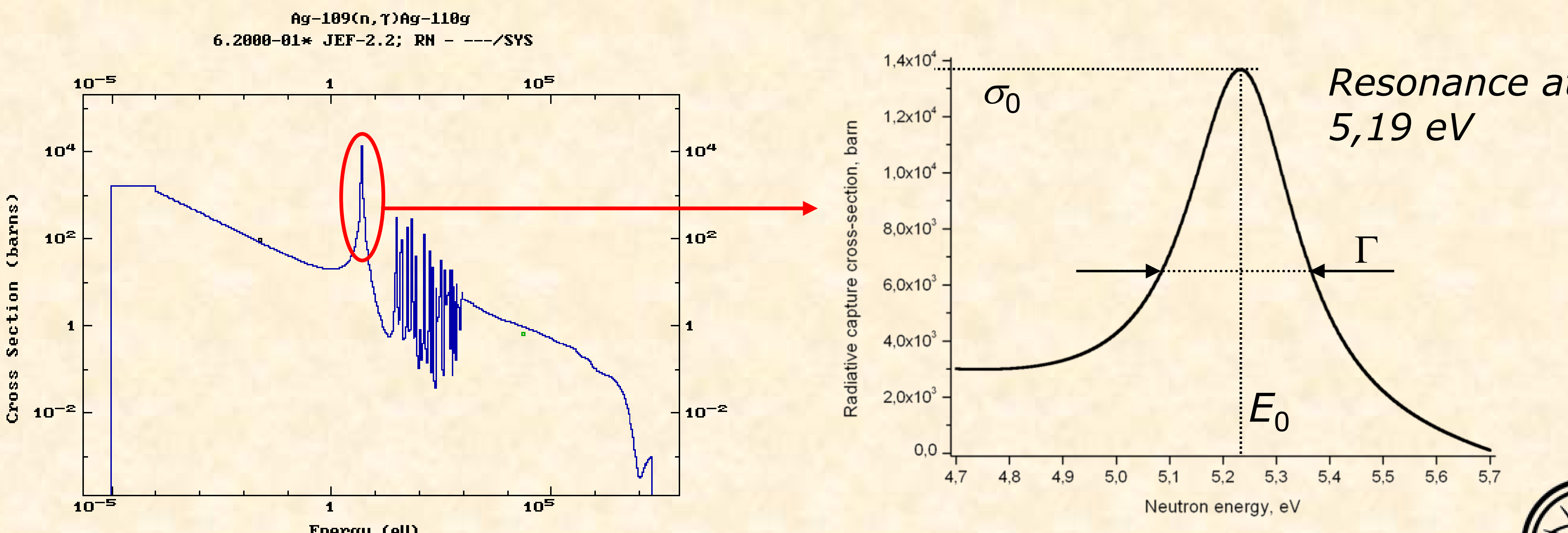
Radiative Capture

Neutrons can be absorbed by nuclei of the matter due to radiative capture process: (*A*,*Z*)+n -> (*A*+1,*Z*)

Shape of the resonance cross-section (Breit-Wigner formula):

$$\sigma_r(E) = \frac{\sigma_0}{4}\frac{\Gamma^2}{(E-E_0)^2+\frac{\Gamma^2}{4}}$$

Ag^{109} neutron capture cross-section:



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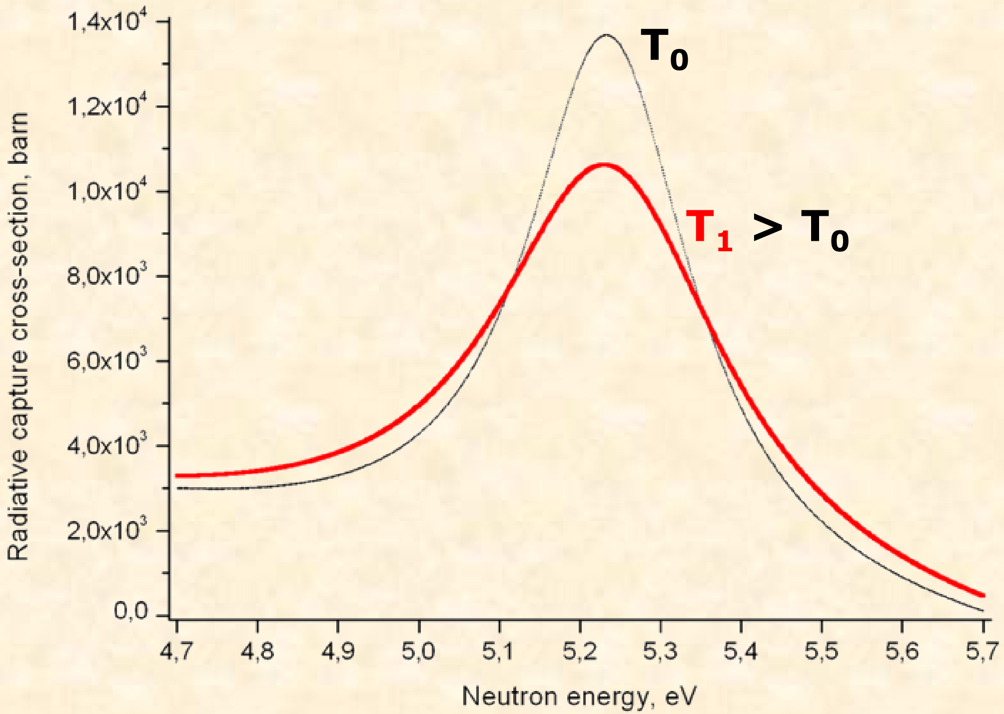
Radiative Capture: Temperature dependence

In general case $\sigma = \sigma(E,T)$:

As material temperature grows, neutron capture resonance broadens and maximum cross-section becomes lower



Resonance cross-section:

$$\sigma(E,T) = \int S(E',T)\,\sigma_r(E-E')\,\mathrm{d}E'$$

Energy-transfer function:

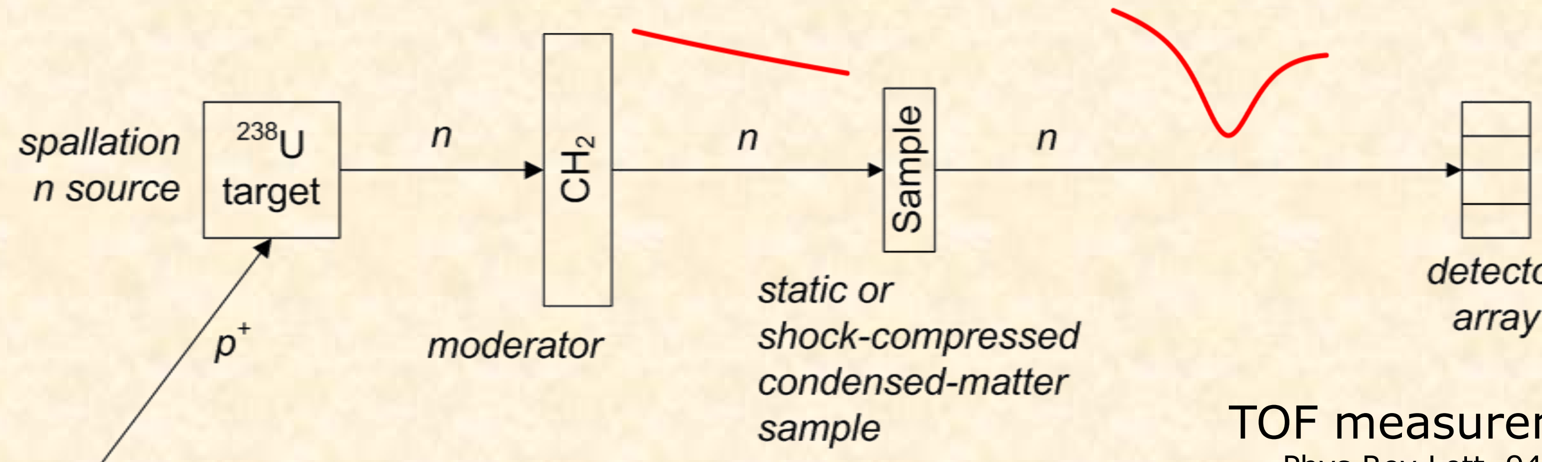
$$S(E',T) = \frac{1}{\Delta\sqrt{\pi}}\exp\left\{-\frac{(E'-E)^2}{\Delta^2}\right\}$$

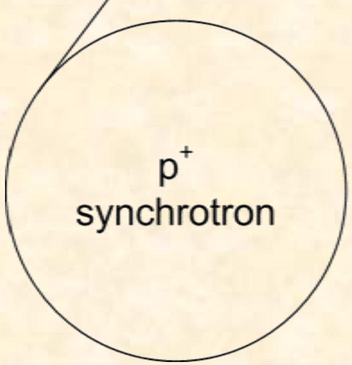
Doppler width ($M >> m$):

$$\Delta = \sqrt{\frac{4mME_0k_\mathrm{B}T}{(M+m)^2}} \approx \sqrt{\frac{4E_0k_\mathrm{B}T}{A}}$$

↑ Simple case of classical solid

Neutron Resonance Spectroscopy





Demonastration experiment (LANL):

- Mo sample with W dopant
- Shock compression with HE
- n pulse duration 125 ns
- Temperature resolution 20 K

TOF measurement at LANL

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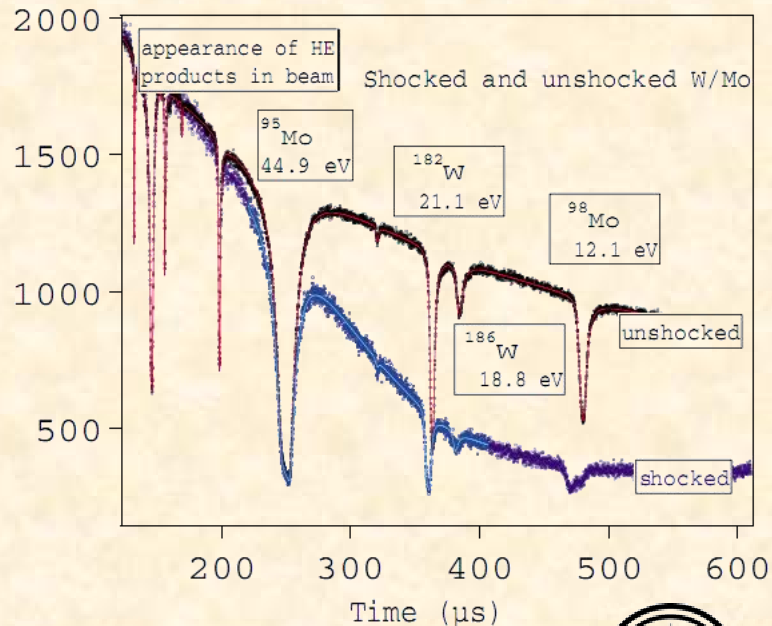


Data from this experiment were used to benchmark FLUKA transport code applicability for simulations of such experiments

Neutron Resonance Spectroscopy at ITEP

The project is supported by Rosatom
(contract N.4e.45.90.10.1055)

NRS setup at U-10 synchrotron, ITEP (design stage)

p^+ beam (4 bunches):

T = 3,0 GeV

$N_p = 2 \times 10^{11}$ protons

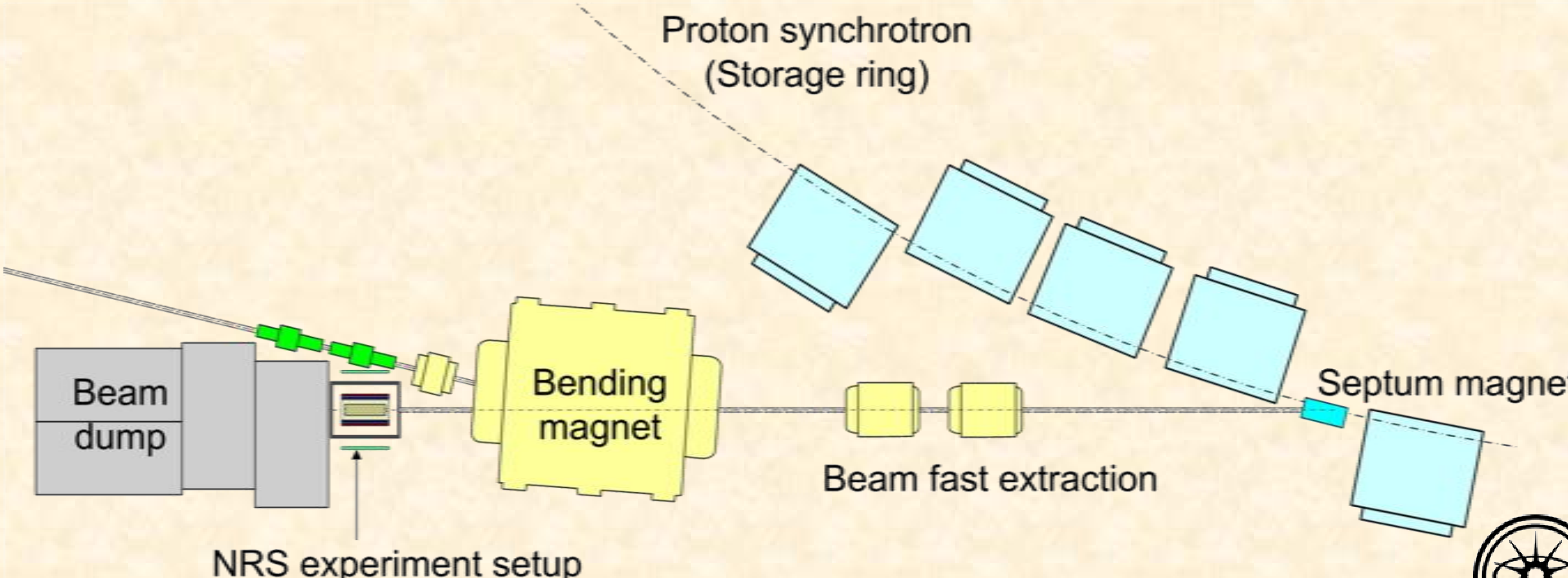
Beam duration 1 μs

Bunch duration < 100 ns

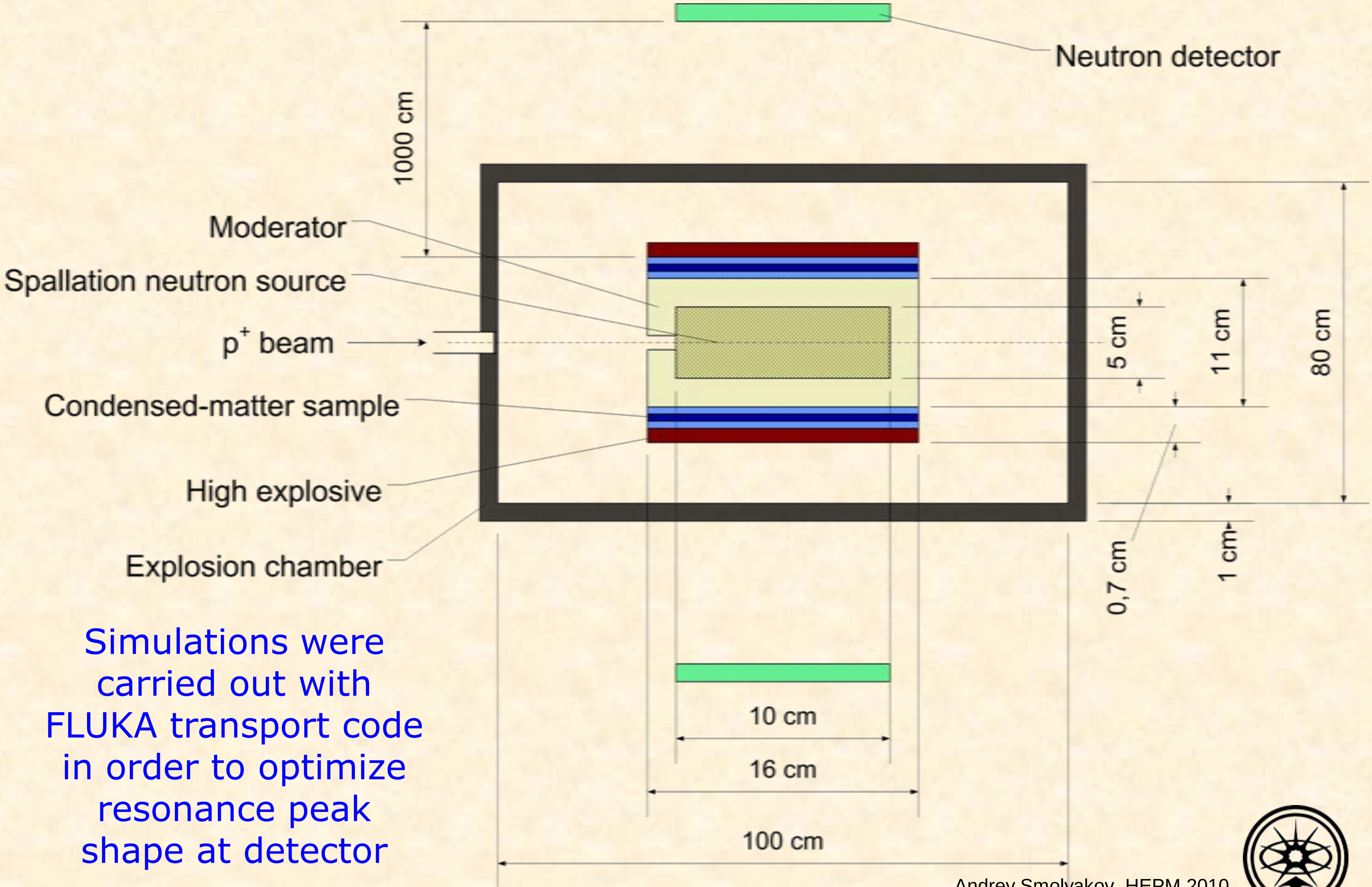
Estimated neutron pulse:

$N_n = 10^{11} \div 10^{12}$ neutrons

Beam duration 1 μs



NRS setup at ITEP. Simulation model

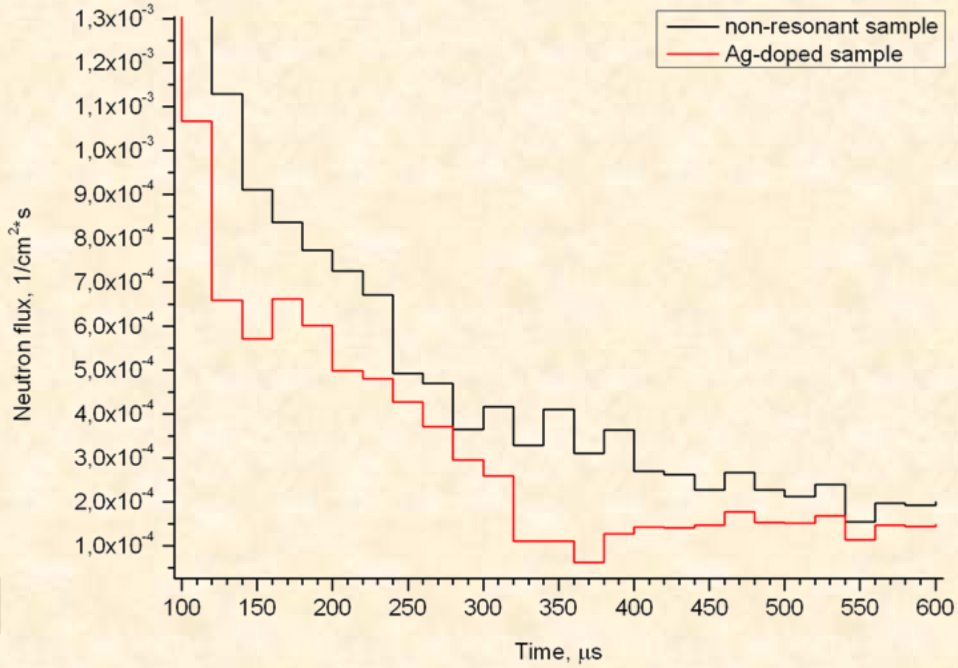


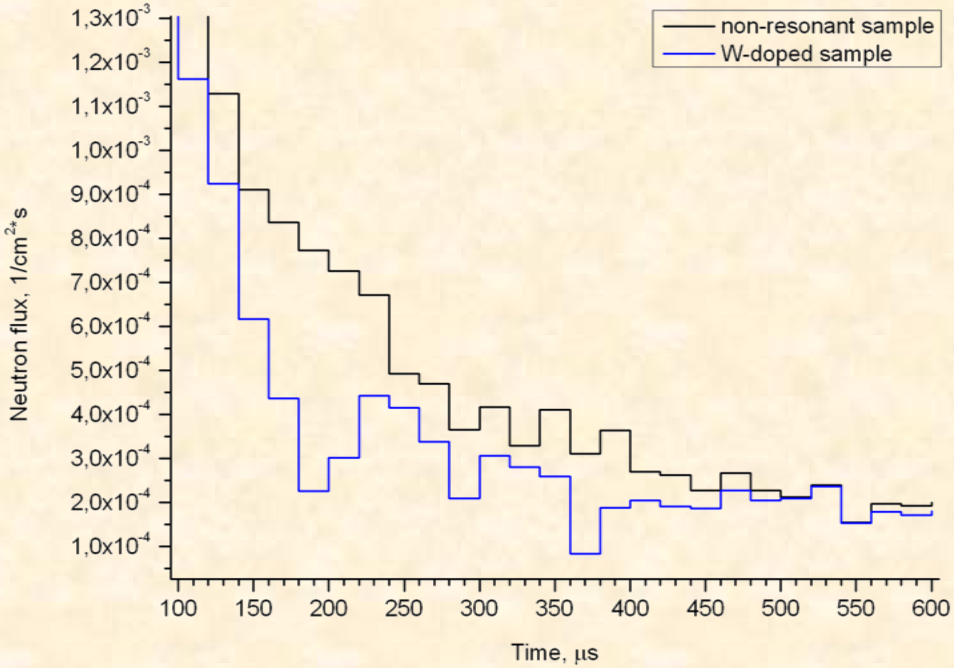
Simulations were carried out with FLUKA transport code in order to optimize resonance peak shape at detector

NRS setup at ITEP. Simulation results

Ag-doped sample:
Well-distinguished resonance peaks at: 5,19 eV and 30,6 eV (Ag^{109})

5,19 eV resonance preferable





W-doped sample:
Well-distinguished resonance peaks at: 4,16 eV and 21,03 eV (W^{182})

21,03 eV resonance preferable


Thank you for your attention!