Problémy při měření neutronových účinných průřezů při vysokých energiích

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20.04.2017

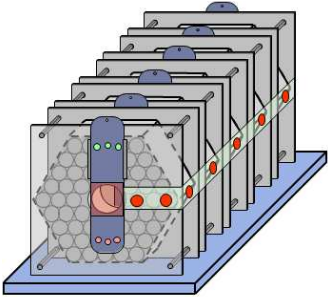
Outline

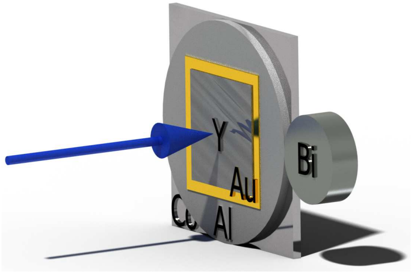
Motivation of measurement

Necessity of fast neutron field monitoring for facilities like

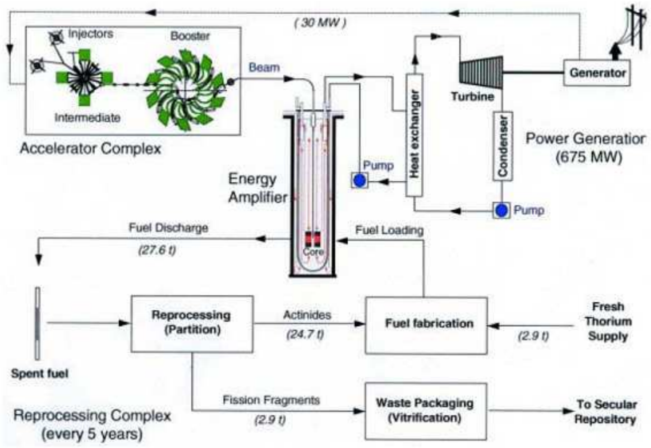
- Accelerator driven systems (ADS)
- Neutron spallation sources
- Future fusion and fast reactors

Improvement of nuclear calculation codes





Principle of ADTS



KLAPISCH, R. Accelerator driven systems: an application of proton accelerators to nuclear power industry. Europhysics News. 2000, 31, 6, s. 26–28.

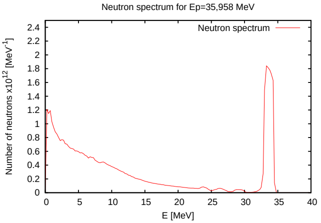
Why yttrium?

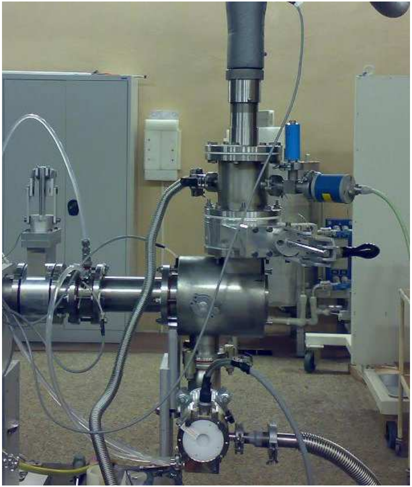
- Products of (n,xn) reactions on yttrium are easily identifiable
- Half-lives of the products have good length for γ-spectrometry
- γ transitions are intensive enough for detection and are well separated from each other

Reaction	E_{thr} [MeV]	$T_{\frac{1}{2}}$	E_γ [keV]	I_γ [%]
^{89}Y(n,2n)^{88}Y	11.6	106.626 d	898.042	93.683
			1836.063	99.24
^{89}Y(n,3n)^{87}Y	21.1	79.8 h	388.531	82.2
			484.805	89.845
^{89}Y(n,3n)^{87m}Y	21.6	13.37 h	380.79	78.055

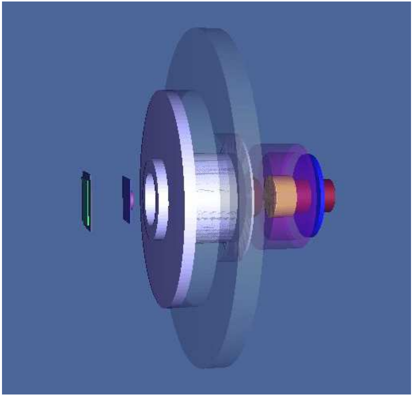
Fast neutron source - NPI CAS

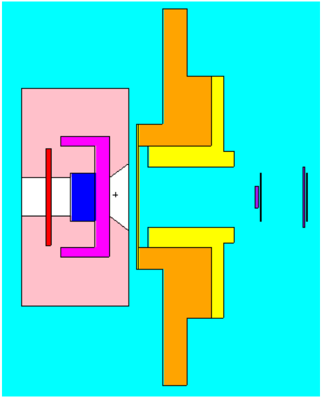
- Source based on reaction ^{7}Li(p,n)^{7}Be
- Neutron energy range 10-37 MeV
- Source intensity $\sim 10^8$ cm^{-2}·s^{-1}
- Neutron spectrum is obtained by an MCNPX simulation





Model of the neutron source with samples





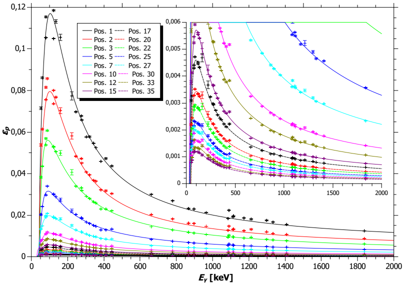
Two yttrium samples for each irradiation, each irradiated with gold foil:

- YN - 25×25×0.64 mm - solid foil, distance 123 mm
- YO - ⌀9×1.5 mm - pill, distance 103 mm

Measurement equipment

HPGe spectrometer GC3018

- Relative efficiency 35%
- Calibration points from 53 to 1836 keV
- Calibrated positions 1, 2, 3, 5, 7, 10, 12, 15, 17,... cm
- Complete shielding



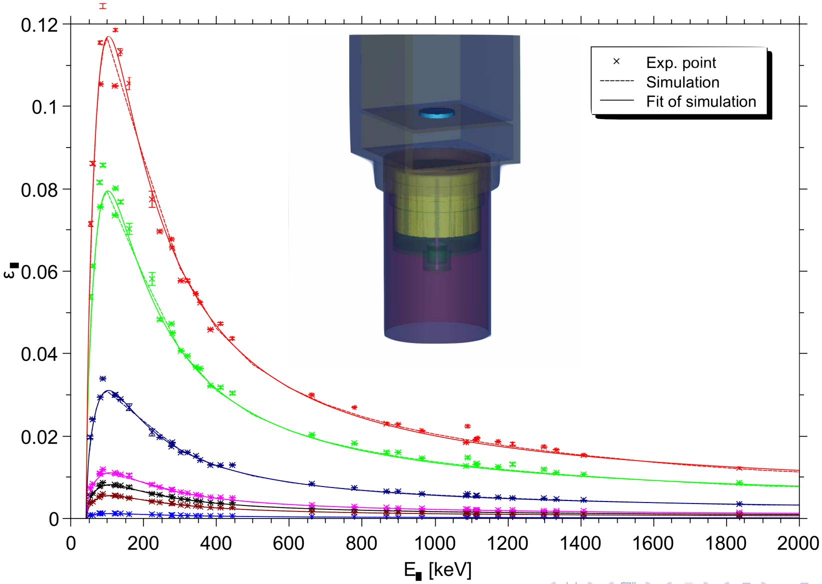
γ-spectroscopic methods

- With accurate knowledge of isotopic composition, it is possible to measure cross-section.
- With known cross-section the number of incident particles is possible to determine.
- Equations for cross-section determination in case of simple decay:

$$N_{yield} = \frac{S_{peak} \cdot C_{abs}(E)}{I_\gamma \cdot \varepsilon_p(E) \cdot COI(E) \cdot C_{area}} \frac{t_{real}}{t_{live}} \frac{e^{\lambda \cdot t_0}}{1 - e^{-\lambda \cdot t_{real}}} \frac{\lambda \cdot t_{irr}}{1 - e^{-\lambda \cdot t_{irr}}},$$

$$\sigma = \frac{N_{yield} \cdot S \cdot A \cdot B_a}{N_n \cdot N_A \cdot m}.$$

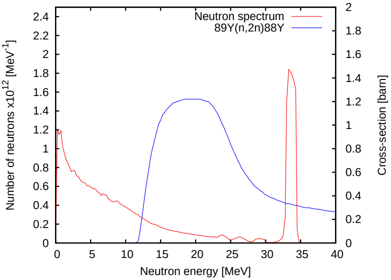
GC3018 simulation

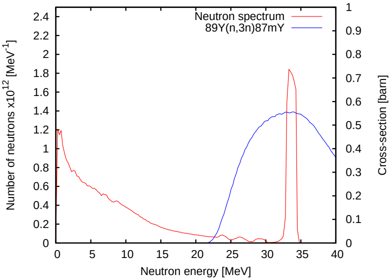


Background subtraction

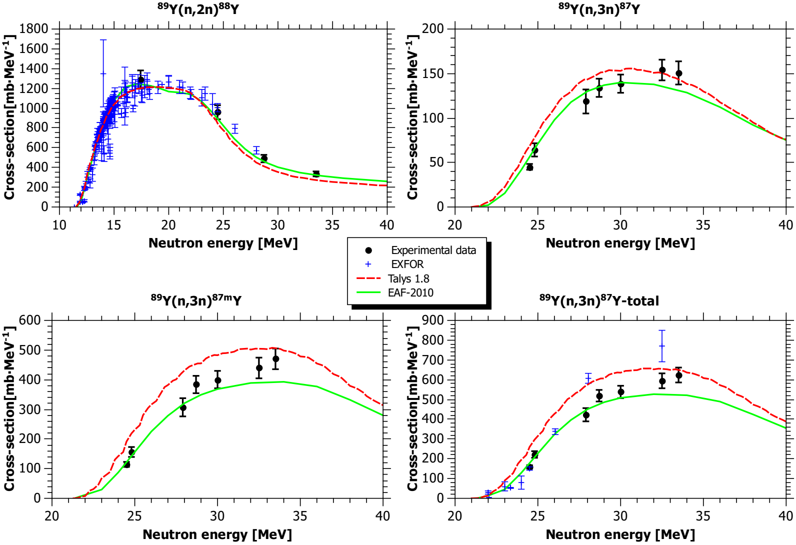
- Neutron source is not monoenergetic
- Neutron background subtraction based on folding of neutron spectrum and cross-section

$$C_{bgr} = \frac{\int\limits_{Peak} \sigma(E) \cdot N(E)\, \mathrm{d}E}{\int\limits_{Spectrum} \sigma(E) \cdot N(E)\, \mathrm{d}E} \longrightarrow C_{bgr} = \frac{\sum\limits_{i \in Peak} \sigma_i \cdot N_i}{\sum\limits_{i} \sigma_i \cdot N_i}$$

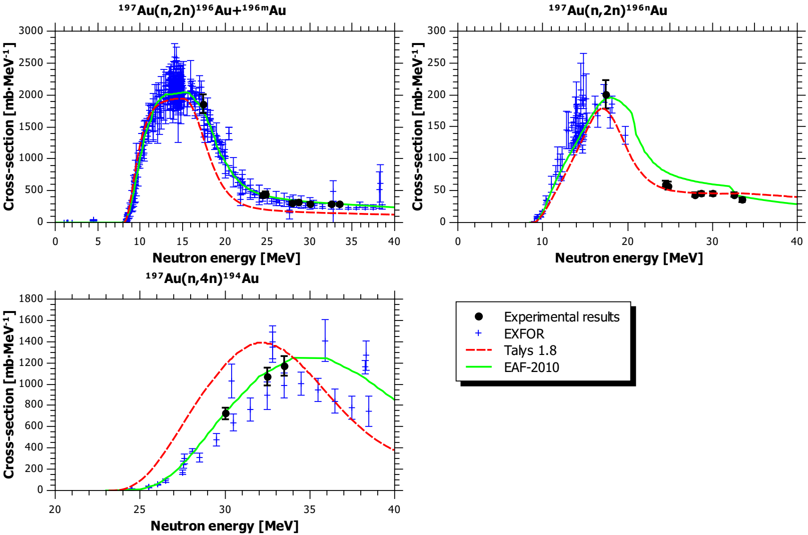




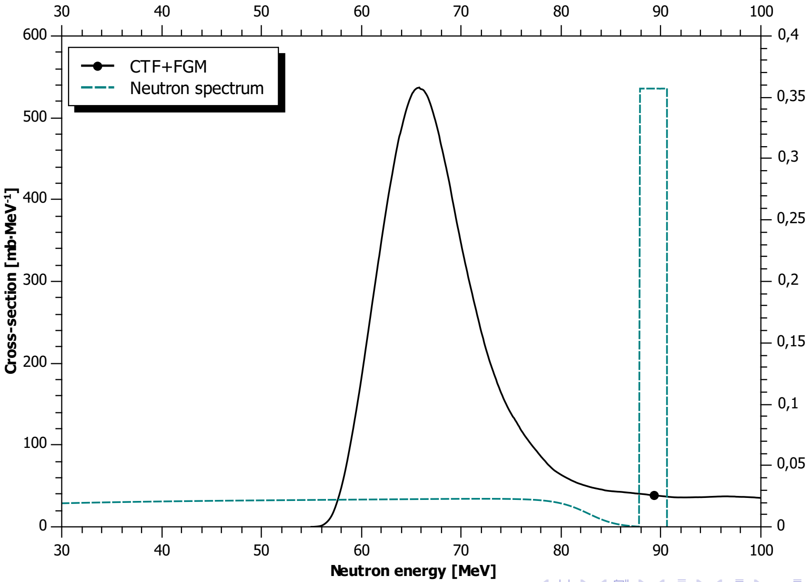
Cross-section of $^{89}Y(n,xn)$ reactions



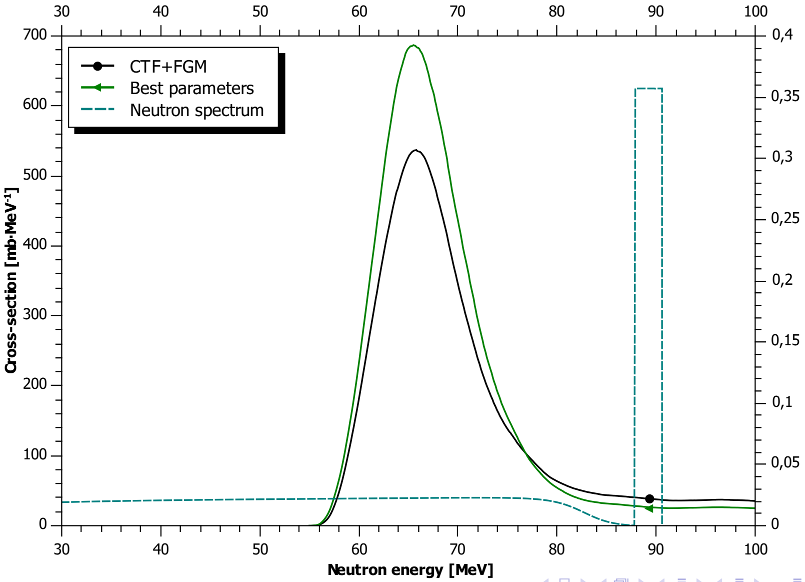
Cross-section of ^{197}Au(n,xn) reactions



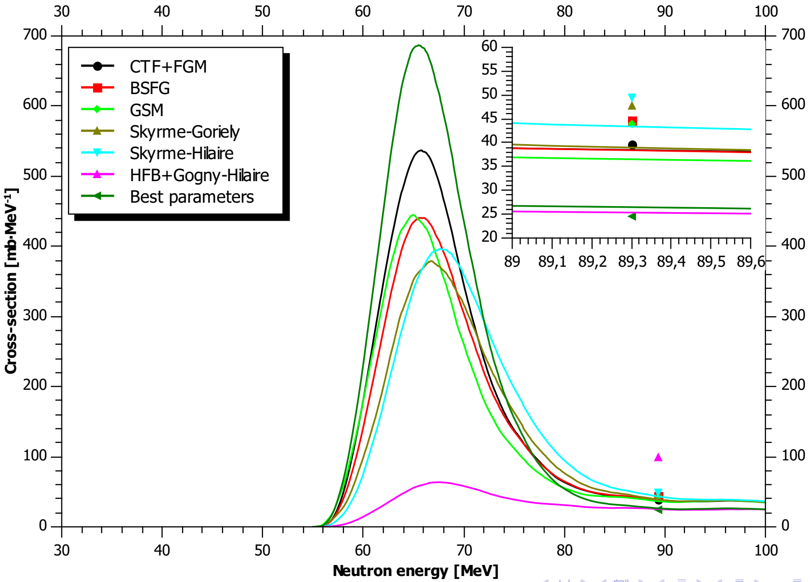
$^{197}Au(n,8n)^{190}Au$ - Likable beginning



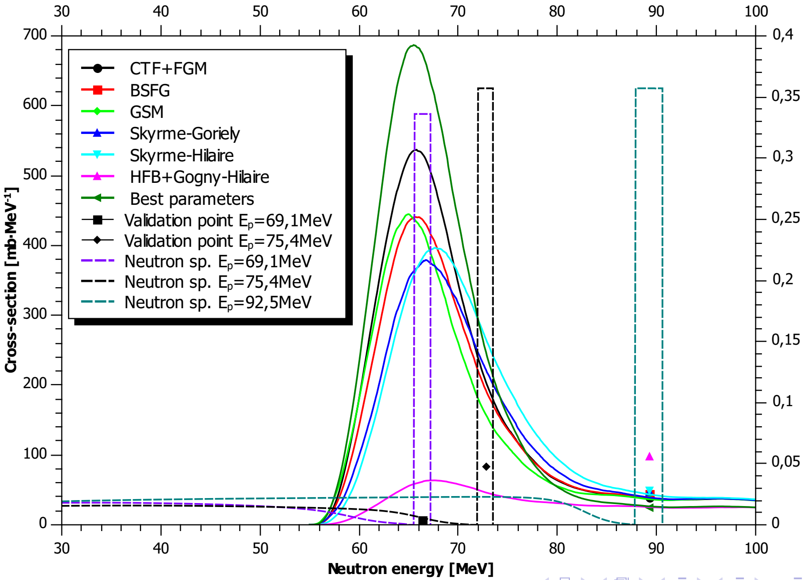
$^{197}Au(n,8n)^{190}Au$ - Rival aproaches



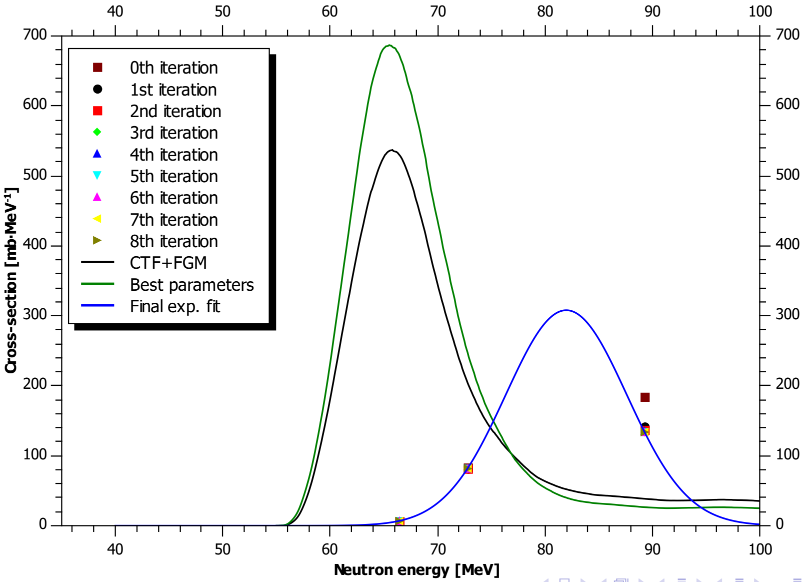
^{197}Au(n,8n)^{190}Au - That's a mess!



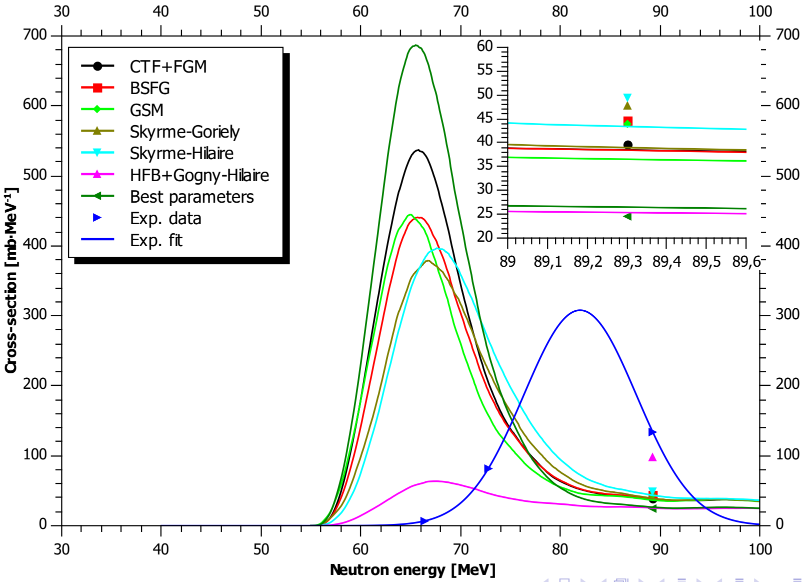
^{197}Au(n,8n)^{190}Au - Bringing order back? Not realy!



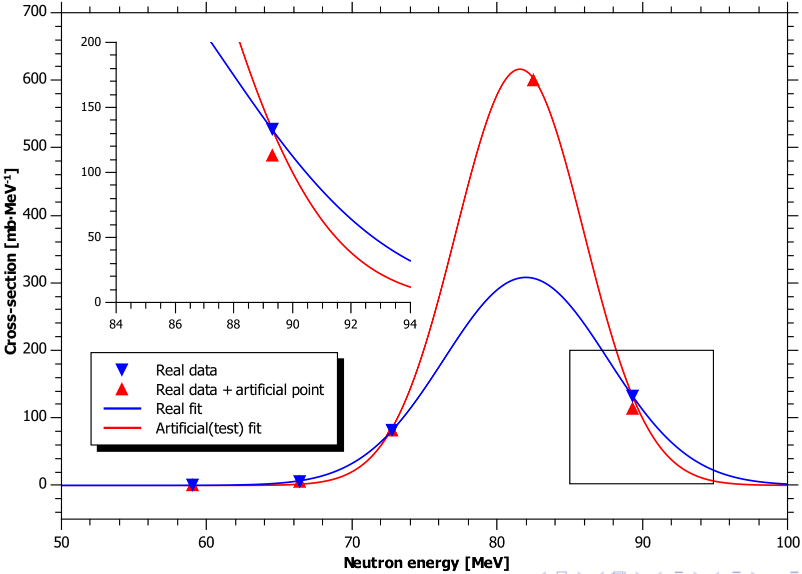
$^{197}Au(n,8n)^{190}Au$ - Excitation function evolution



$^{197}Au(n,8n)^{190}Au$ - Final comparison



$^{197}Au(n,8n)^{190}Au$ - Validation



Conclusion

- Lower degree (n,xn) reactions are described quite well in both ways - experimental data coverage and agreement with calculations.
- It is necessary to test multiple parametrization.
- The data suggest that there is still plenty of work with nuclear models and the nuclear calculation codes.

Thank you for your attention!

The experiments were supported by EU funding programs EFNUDAT, ERINDA and the CANAM program of the NPI CAS.