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ANISOTROPY OF THE FISSION FRAGMENTS FROM NEUTRON-INDUCED FISSION IN INTERMEDIATE ENERGY RANGE 1- 200 MEV

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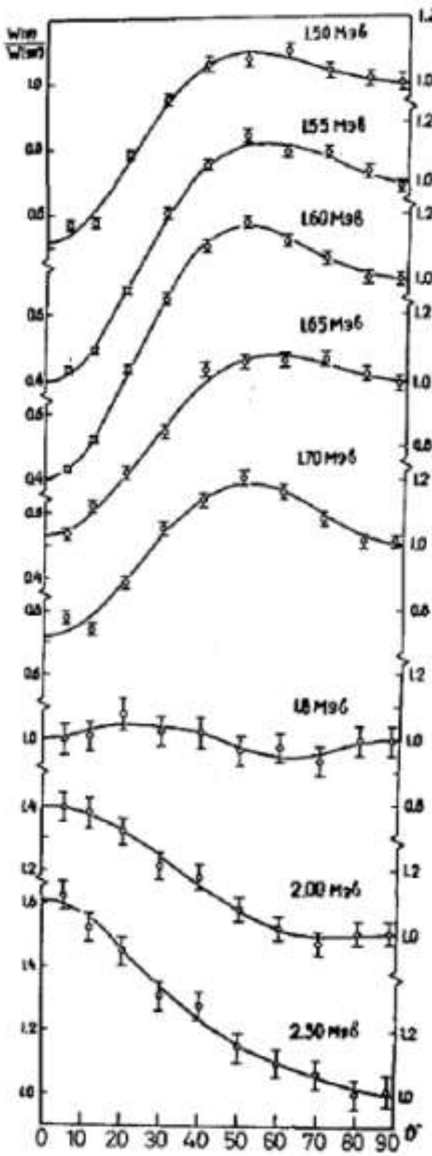
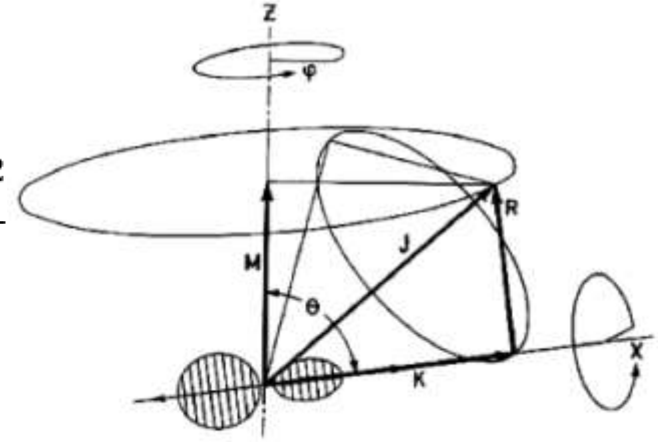
^{232}Th(n,f)
Androsenko et al. (1969)



$$W^J_{M,K}(\theta) = \frac{2J+1}{2}\left|d^J_{M,K}\right|^2$$

$$E_{rot} = \frac{\hbar^2[J(J+1)-K^2]}{2J_\perp} + \frac{\hbar^2 K^2}{2J_\parallel}$$



For low excitation energies we need a proper sum over uniformly distributed *M*, and few available *J*, *K* (fission channels).

$$W(\theta) \sim \sum_{n_{even}} A_n P_n(\cos\theta)$$

At high excitations with many opened fission channels one can use statistical model for the *K* projection distribution – $\rho(K)$:

$$\rho(K) \sim \exp\left(-\frac{E_{rot}}{T}\right) \qquad K_0^2 = \frac{J_{eff} T}{\hbar^2}$$

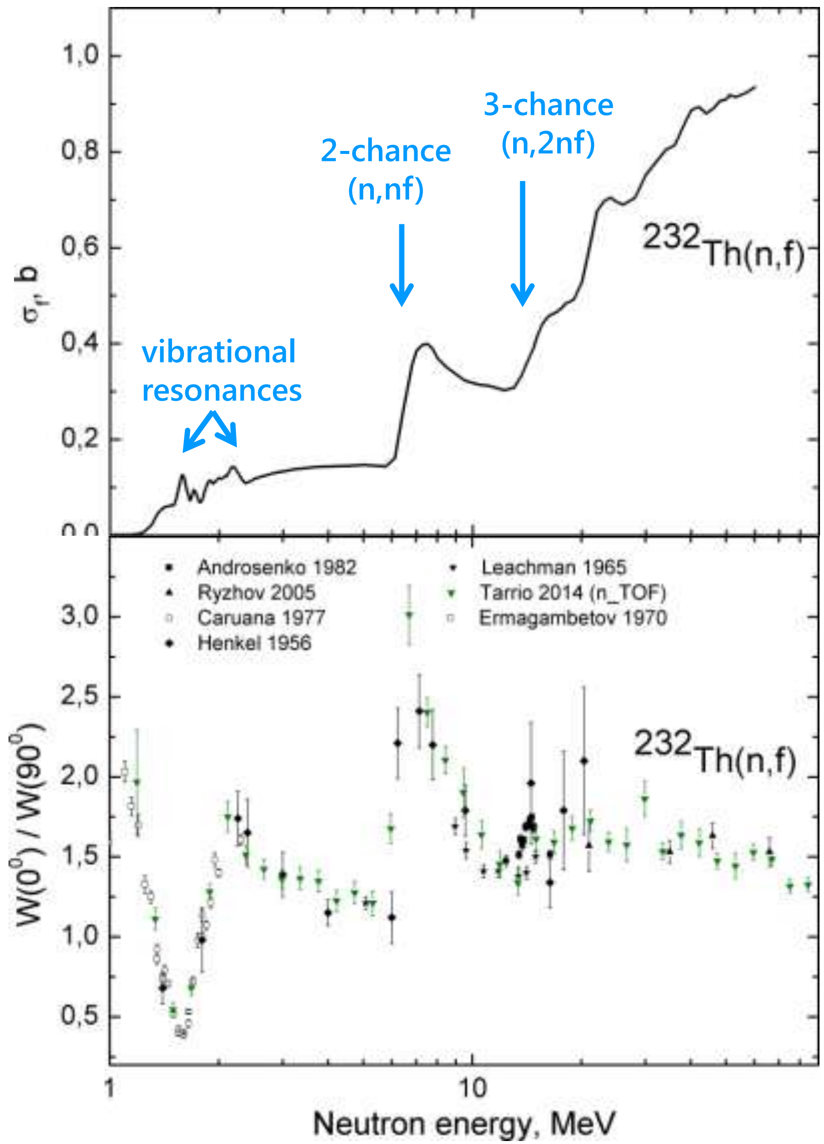
$$J_{eff} = \frac{J_\perp J_\parallel}{J_\perp - J_\parallel} \qquad T = \sqrt{E^*/a_f}$$

$$\rho(K) \sim \exp\left(-\frac{K^2}{2K_0^2}\right)$$

In transition state statistical model:

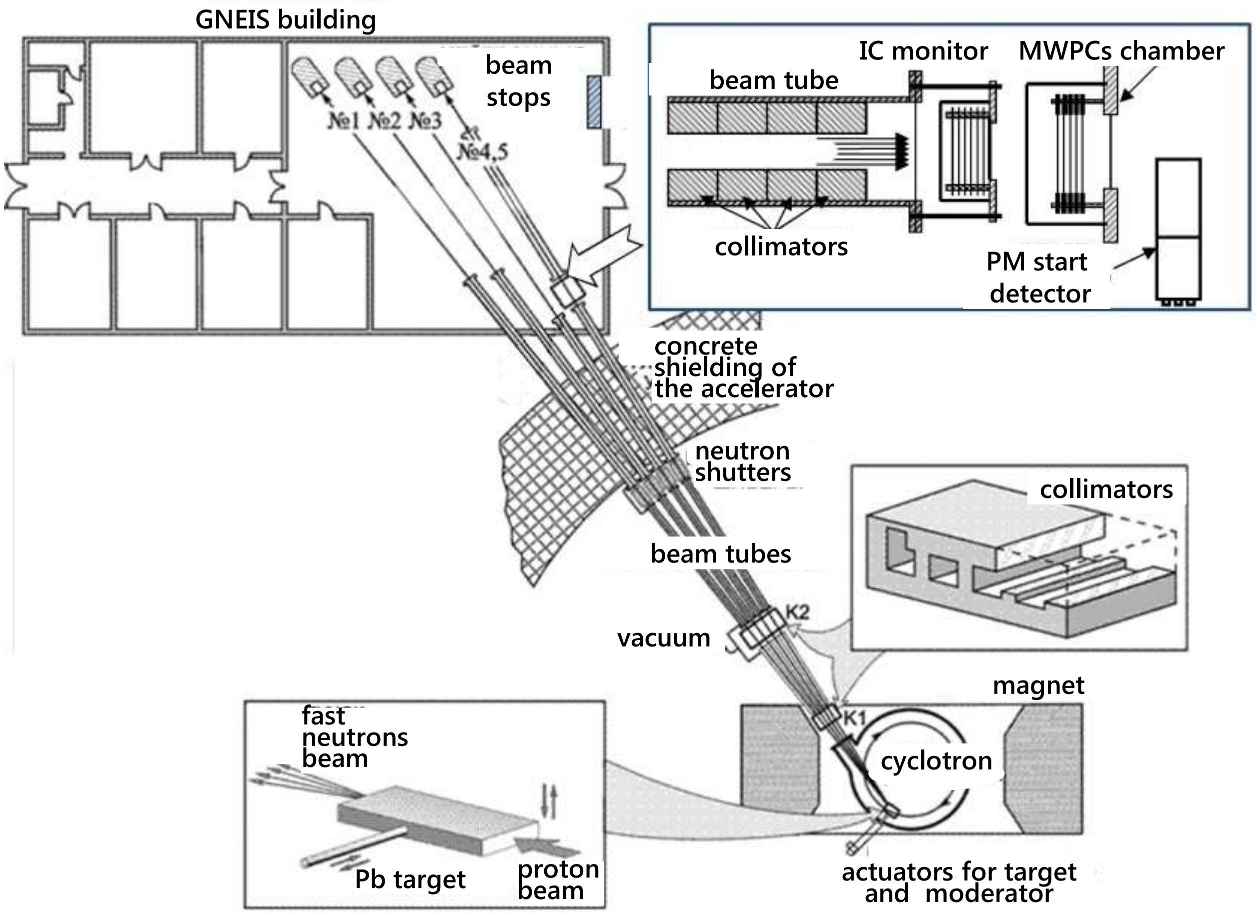
$$W(\theta) \sim 1 + A\cos^2\theta \qquad \frac{W(0^o)}{W(90^o)} = A + 1 \approx \frac{\langle J^2 \rangle}{4K_0^2} + 1$$

Introduction



- The experimental study of angular distributions of fission fragments is a way to determine the properties of transition states of a fissioning nucleus at the saddle point.
- It is important for understanding of the key characteristics and dynamics of the fission process.
- The angular distributions data are also important for precise measurements of the fission cross-sections, since it should be taken into account as efficiency correction for non 4π detectors.

Neutron TOF-spectrometer GNEIS



Main parameters:

$E_p = 1$ GeV; $\Delta t \approx 10$ ns;

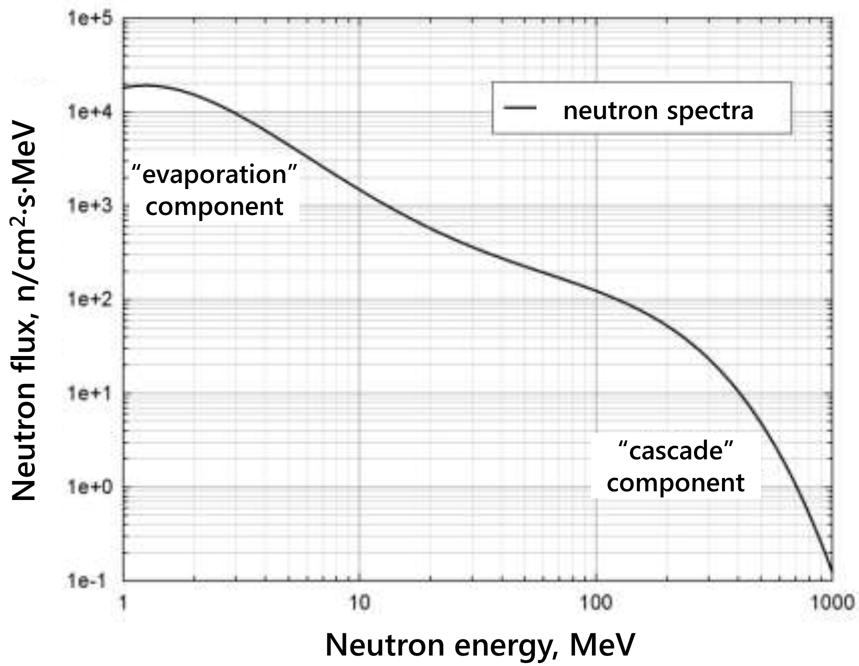
$f \approx 50$ Hz; $\Phi \sim 3 \times 10^{14} \frac{\text{n}}{\text{s}}$;

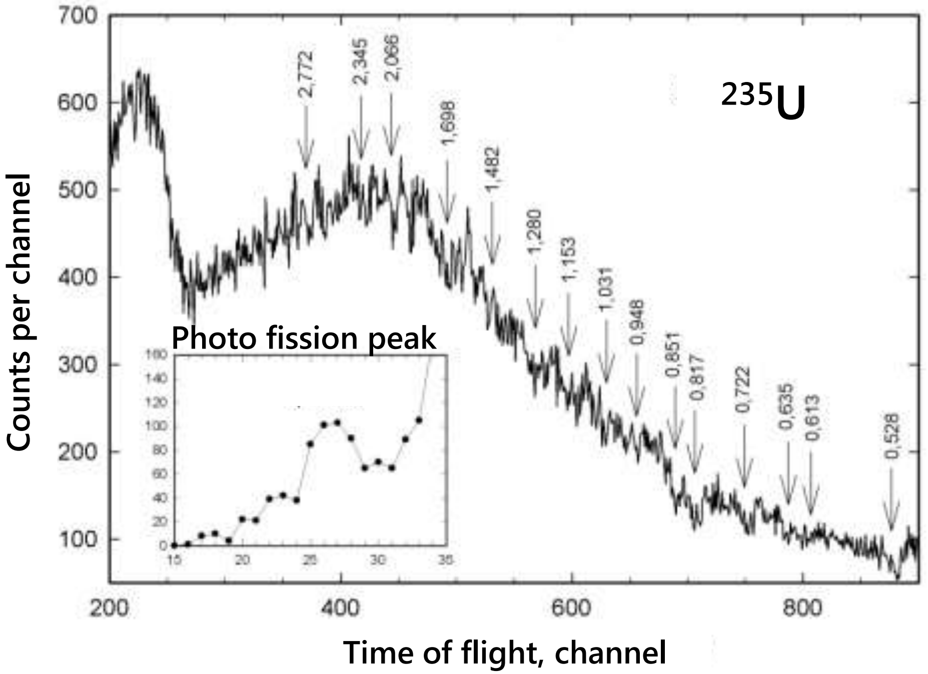
$L = 35.5$ m

$$\frac{\Delta E}{E}(1\ MeV) \approx 1\% \ ; \ \frac{\Delta E}{E}(200\ MeV) \approx 12\%$$

Neutron TOF-spectrometer GNEIS

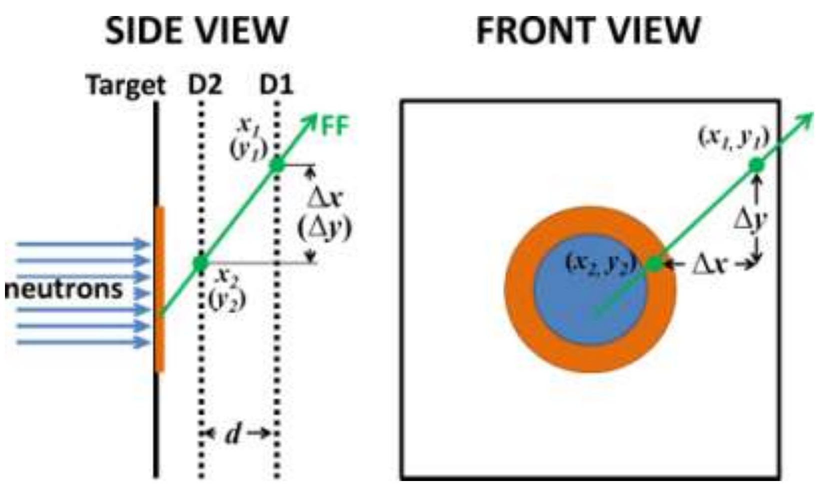
Neutron spectrum of GNEIS,
energy range: from thermal to 1GeV



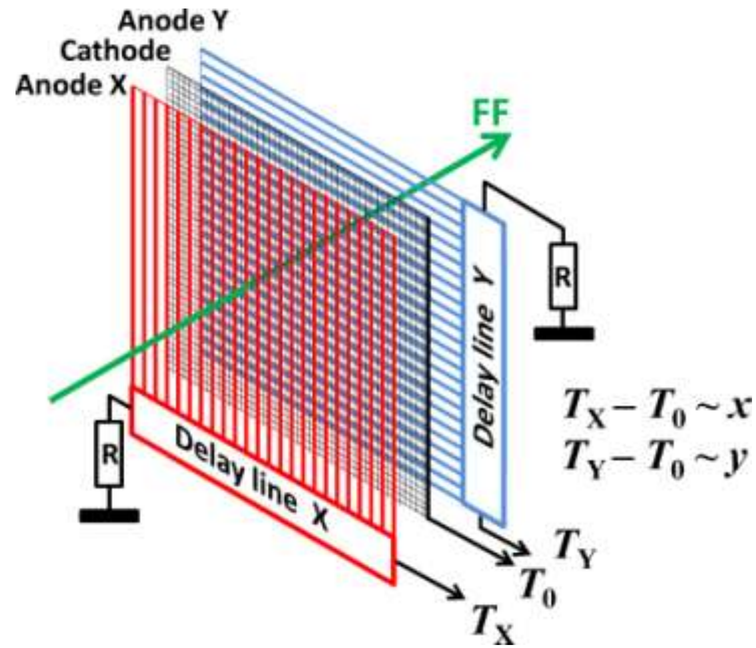


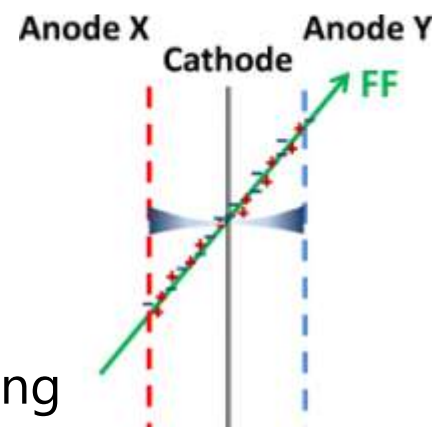
Energy /time-of-flight calibration:
Pb – neutron resonance dips and γ-flash peak

Experimental setup



$$\cos\theta = \sqrt{\frac{(\Delta x)^2 + (\Delta y)^2}{(\Delta x)^2 + (\Delta y)^2 + d^2}}$$





Two position sensitive low pressure multi-wire proportional counters (MWPCs):

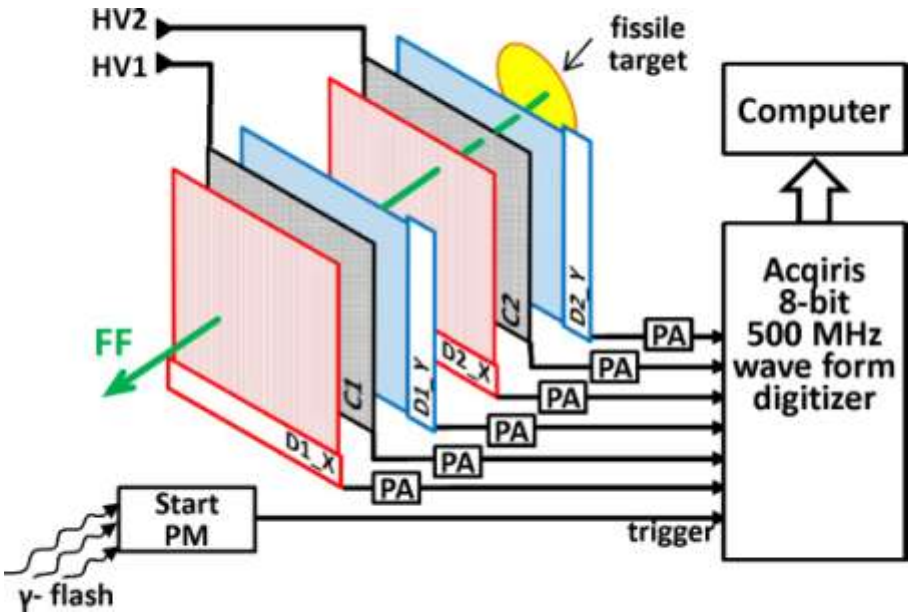
Sizes 140×140 mm;

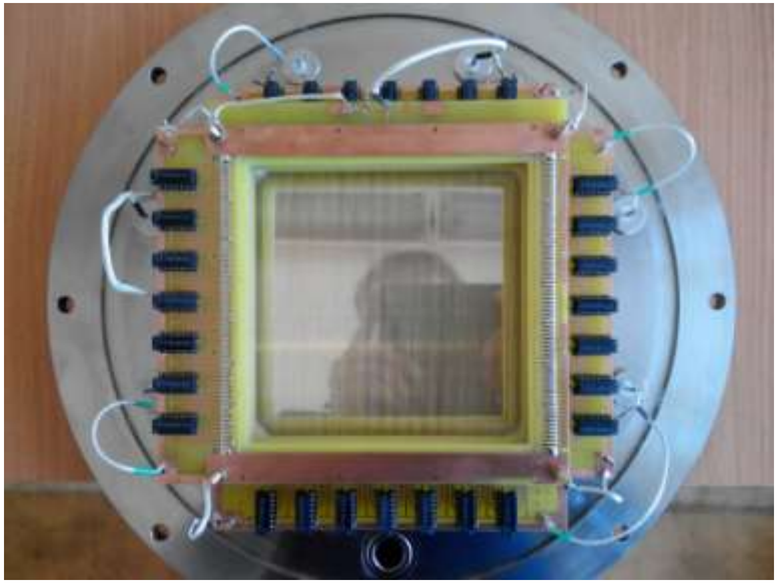
Distances between electrodes planes ~3 mm ;

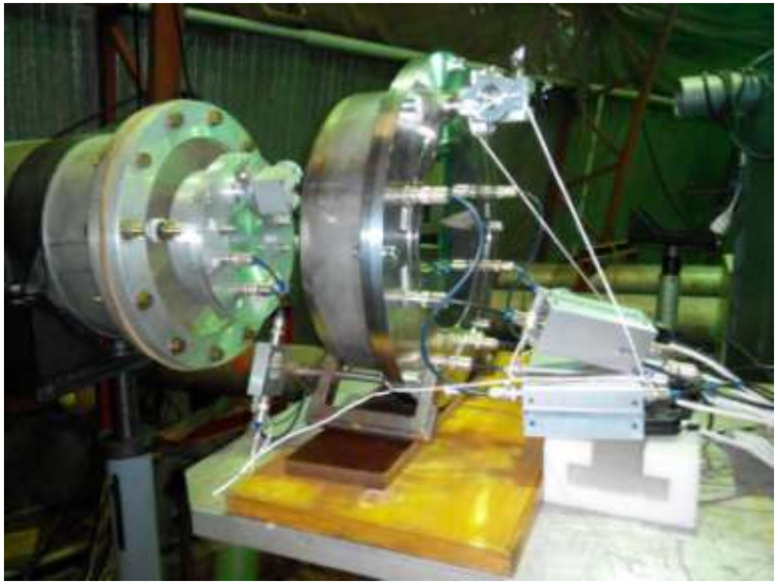
Grids made of 25 µm gold plated tungsten wire, 1 mm spacing

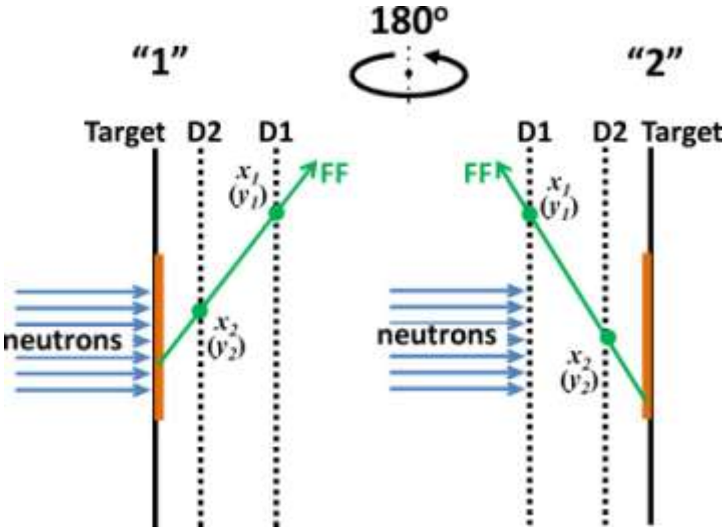
Targets: ~100-150 µg/cm^2 evaporated on 2 µm Mylar foils

Experimental setup



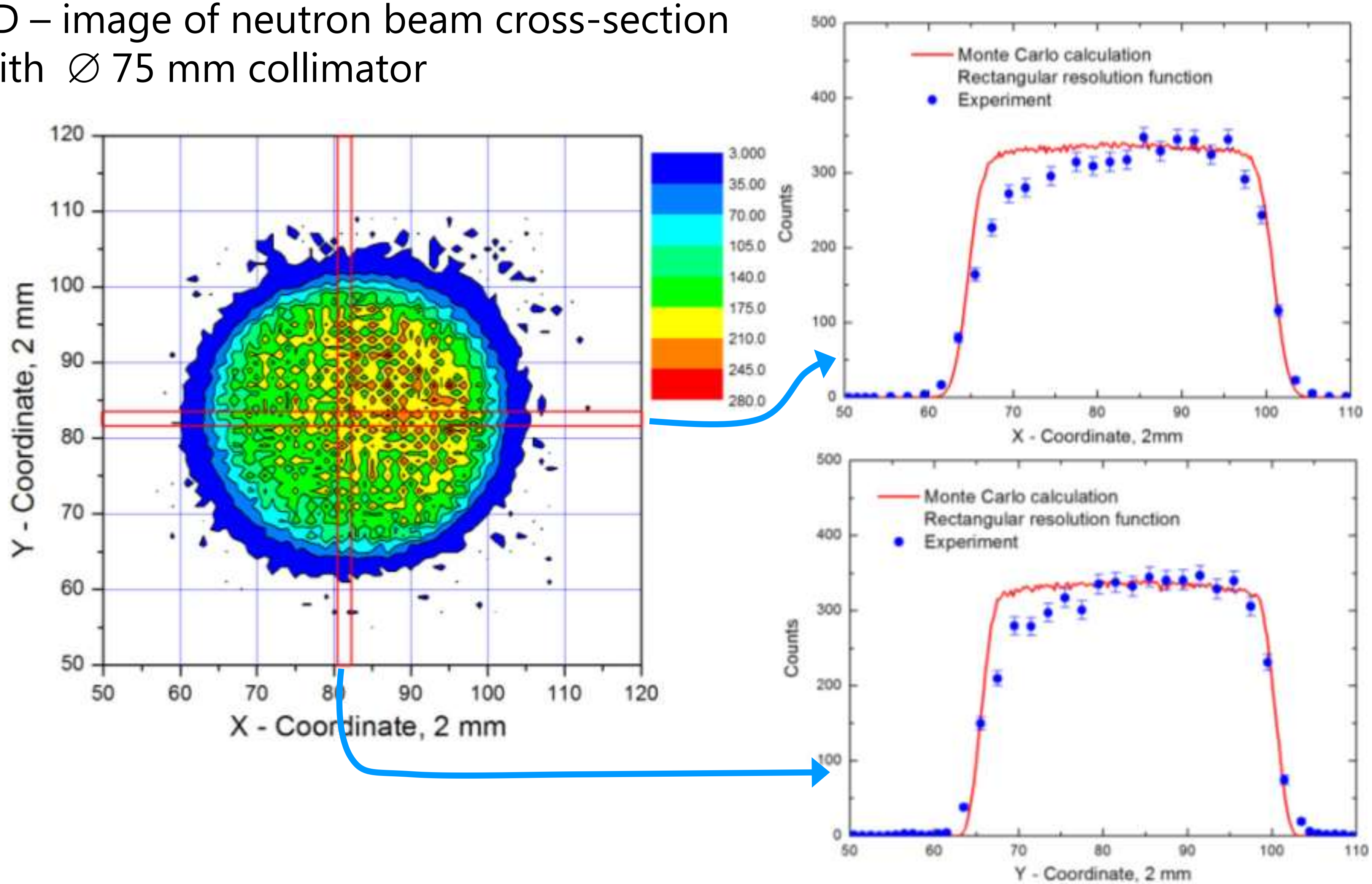






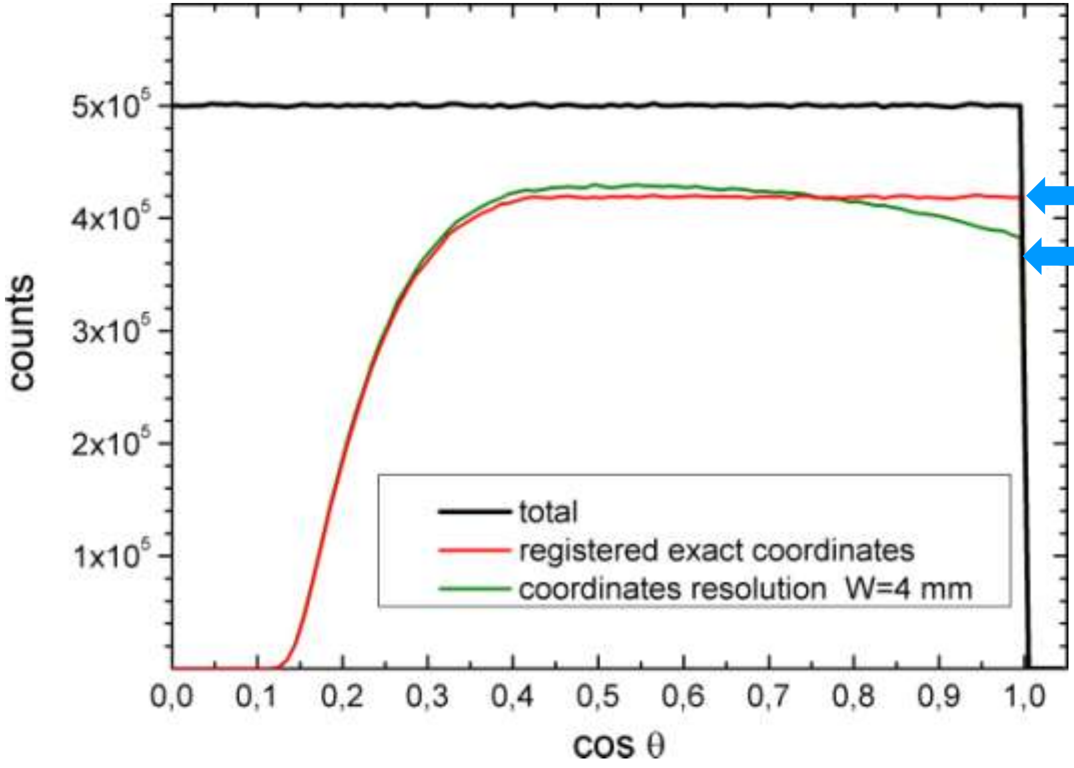
Neutron beam profile

2D – image of neutron beam cross-section with ∅ 75 mm collimator



Cos θ Monte-Carlo simulation with real geometry

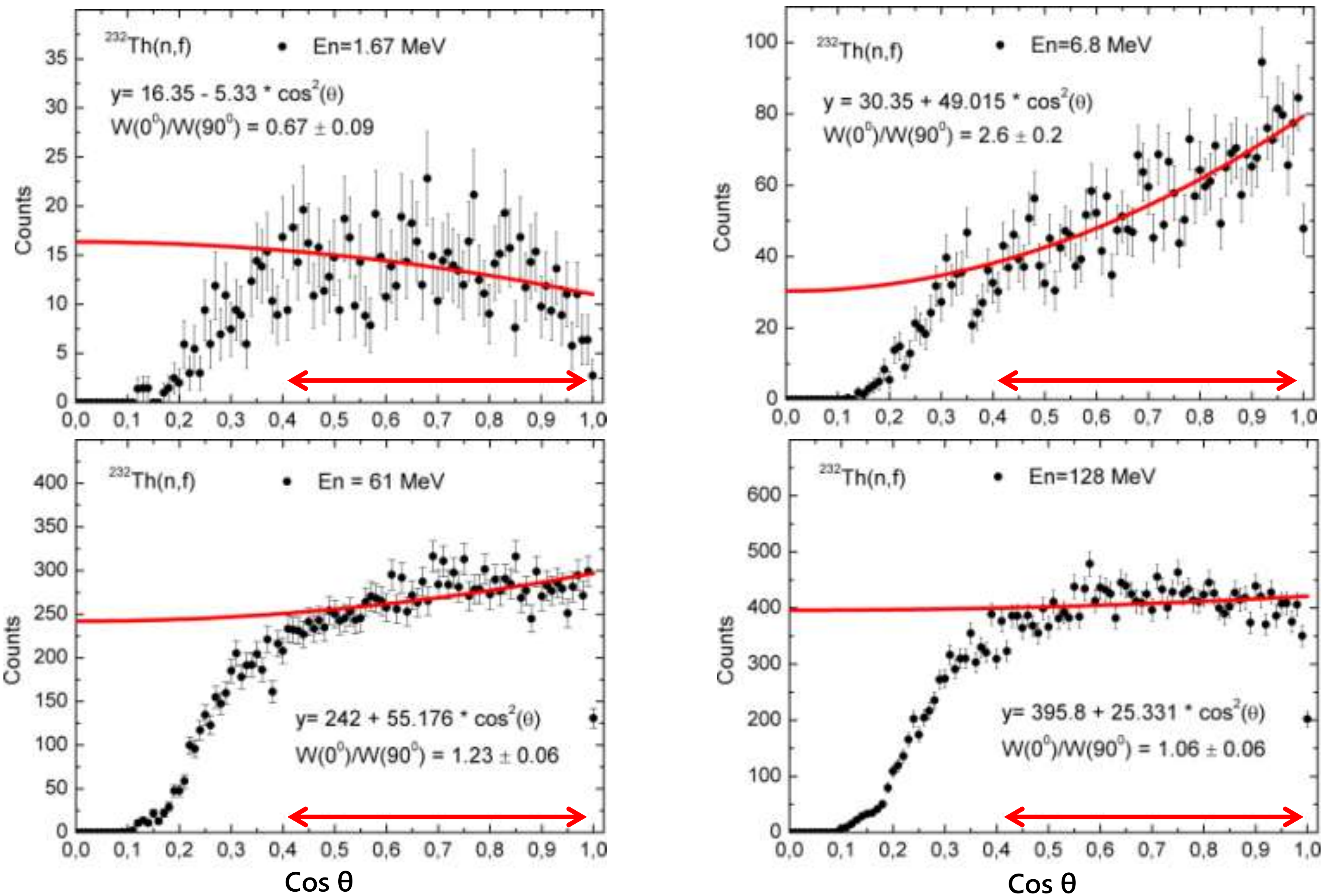
Monte-Carlo simulation with real detectors geometry and wires thickness.
Total efficiency ~62%



Precise coordinates

With real coordinate resolution

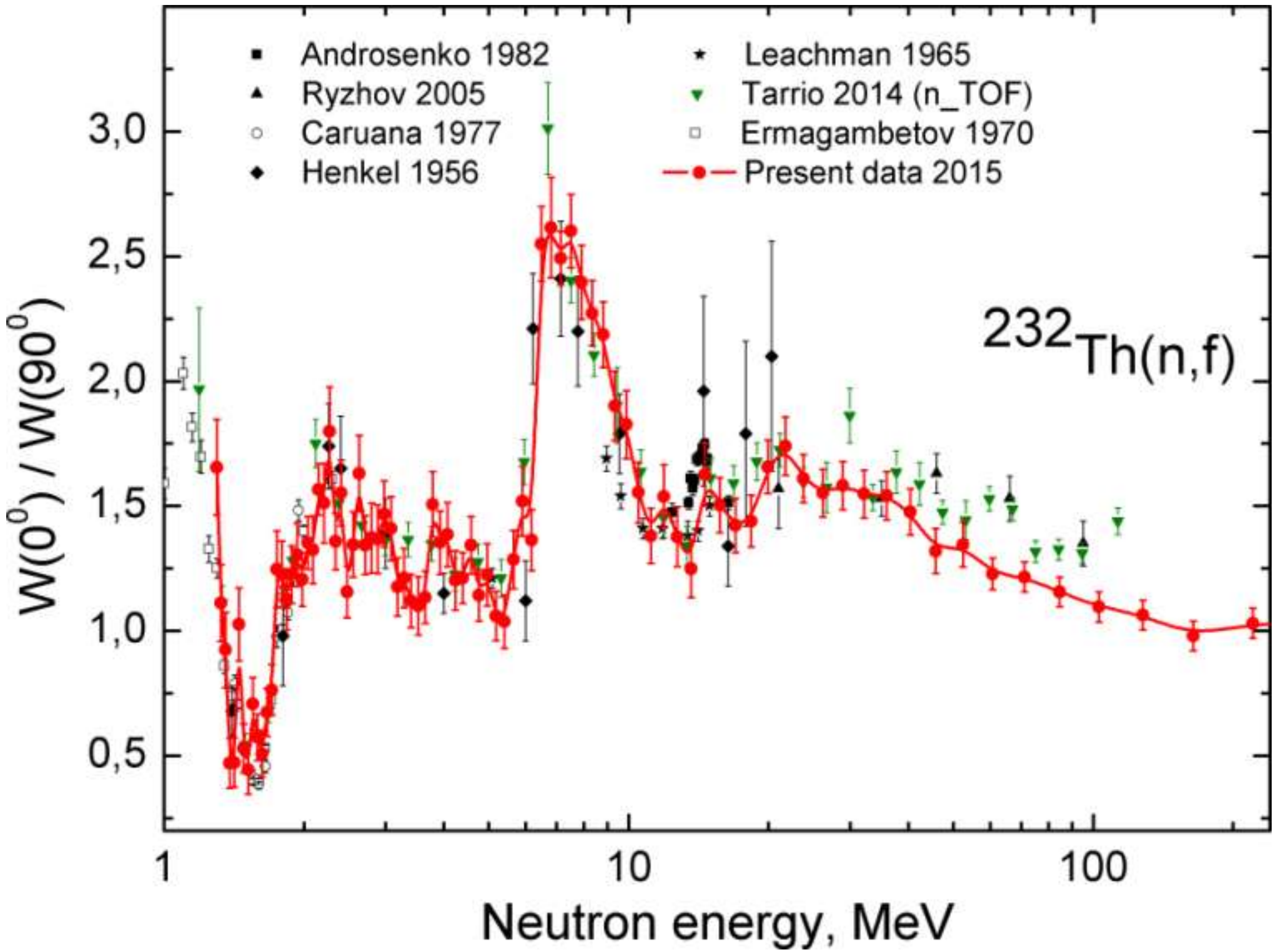
Results (examples of cos θ fits)



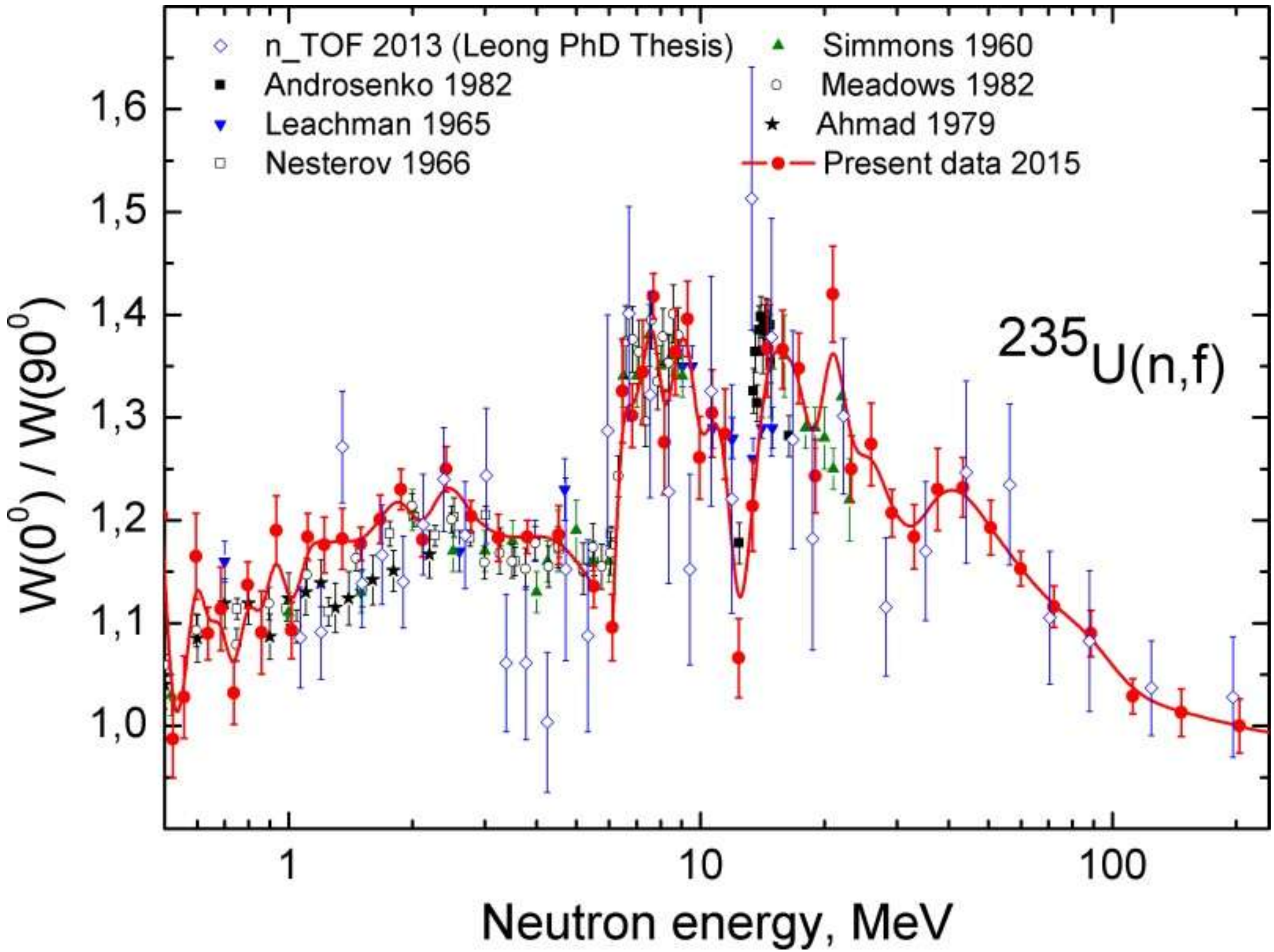
$W(\theta) \sim 1 + A\cos^2\theta$ $\qquad \frac{W(0^o)}{W(90^o)} = A + 1$

Cos θ fitting range was 0.42– 0.98

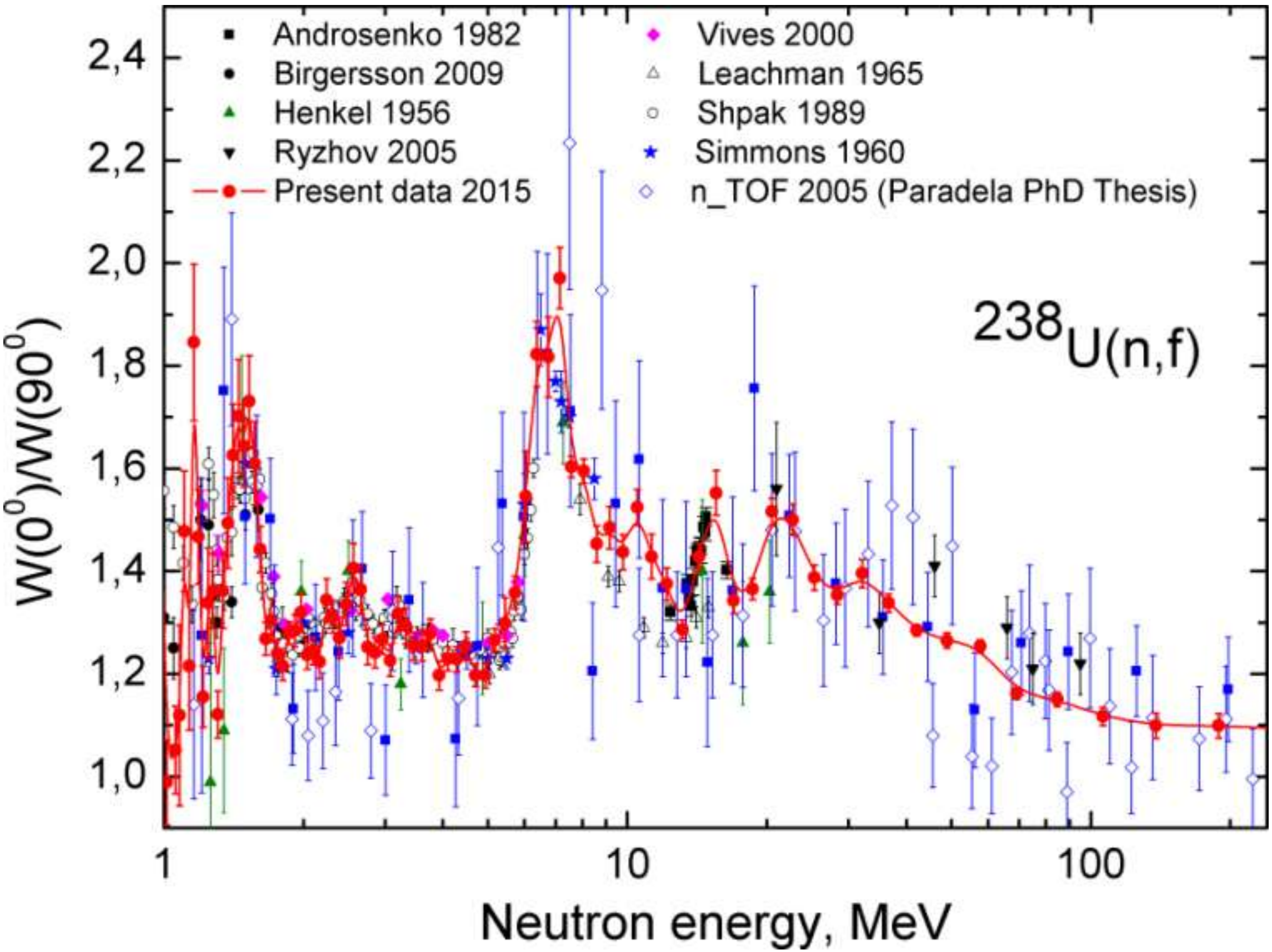
Results (anisotropy in 232Th)



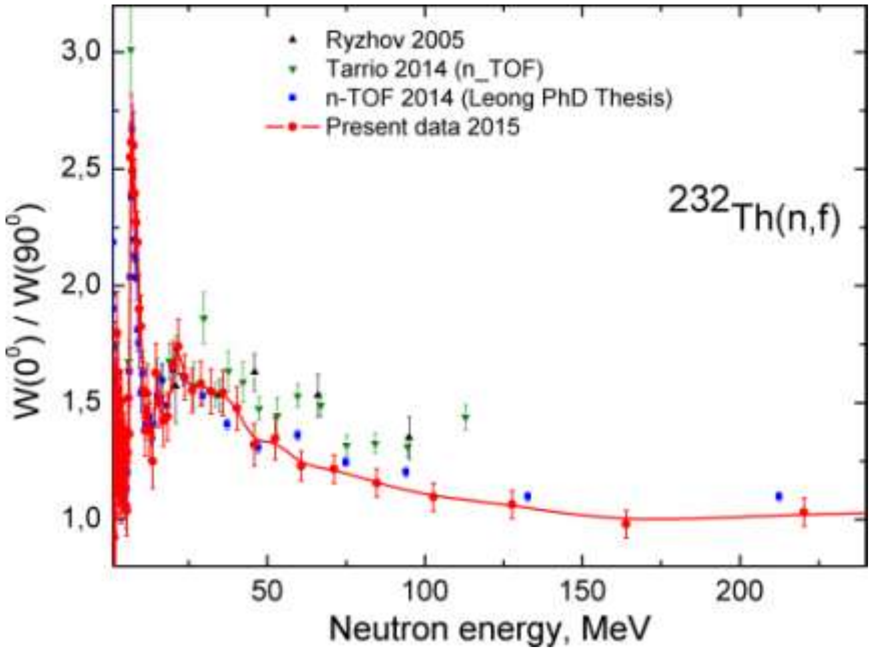
Results (anisotropy in 235U)

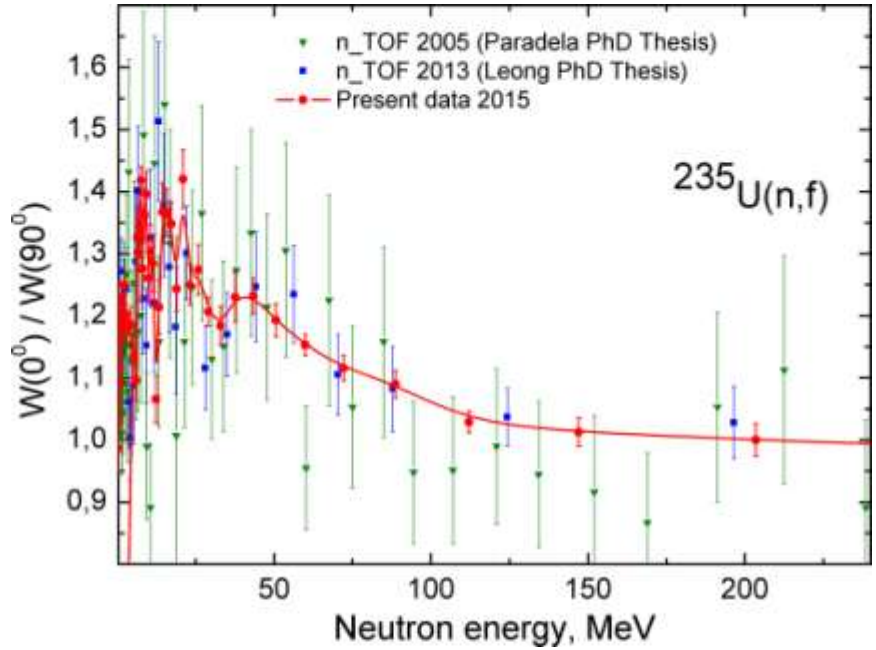


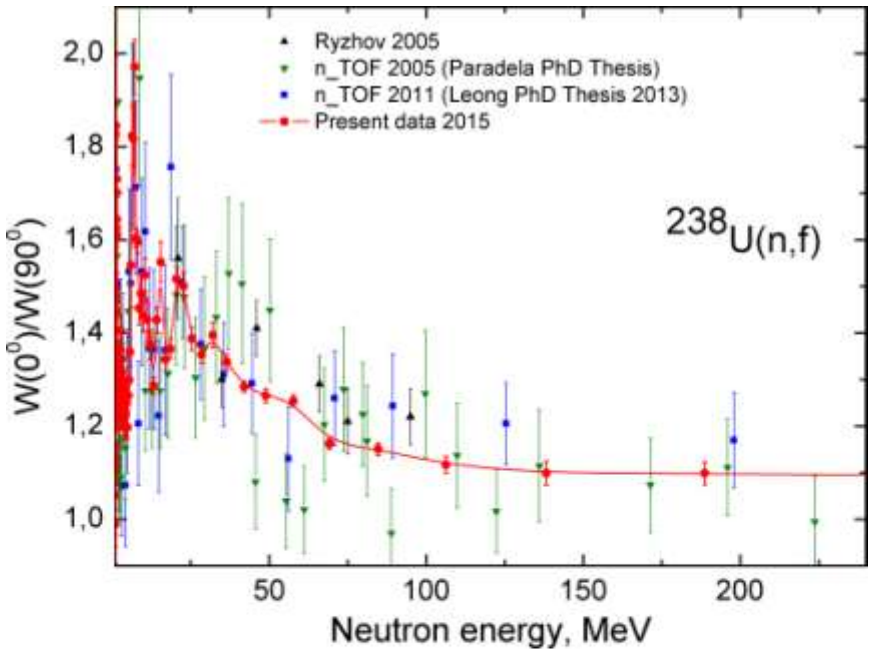
Results (anisotropy in 238U)



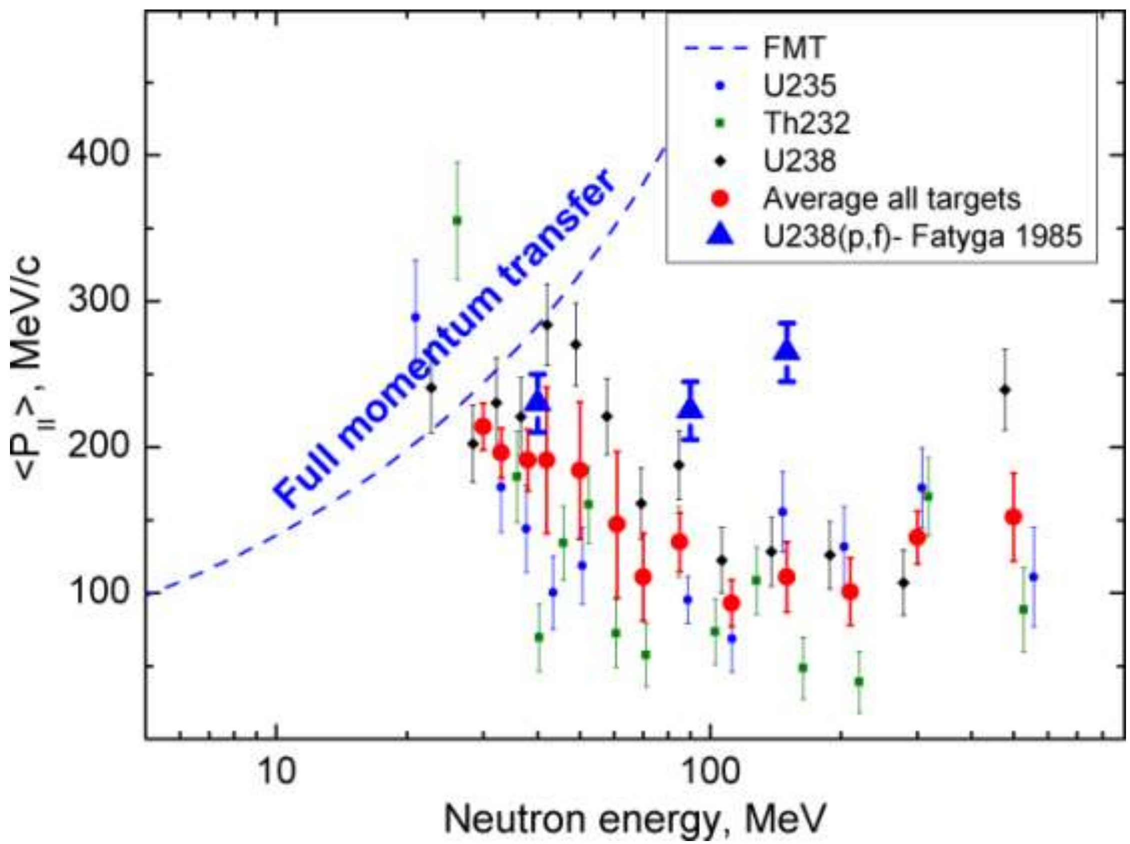
Results (anisotropies in linear scale)







Results (Linear Momentum Transfer)



Conclusion

- Measurements of the fission fragment angular distributions have been done for ^{235}U, ^{238}U and ^{232}Th in intermediate neutron energy range 1-200 MeV using TOF-technique. Low pressure position sensitive multiwire proportional counters (MWPC) were used for fission fragment registration.
- Anisotropy of fission fragments has been obtained from the measured angular distributions with an accuracy comparable with that of previous experiments in energy range 1-15 MeV and improved accuracy at higher energies up to 200 MeV.
- At present the data obtained at the GNEIS for ^{235}U and ^{238}U are the most accurate data.
- The new experimental data on linear momentum transfer obtained from our measurements provide information necessary for improvement of theory of fission at intermediate energies.
- The next stage of the investigation of fission fragment angular distributions at the GNEIS will be the measurements with other isotopes and theoretical analysis of the experimental data.

Thank you for attention

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