On the Signs of ROT-effects in Ternary and Binary Fission of ^{233}U and ^{235}U Nuclei Induced by Cold Polarized Neutrons

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Short history

TRI – effect

- In 1998 large collaboration [1] of Russian and German Institutes have performed an experiment on cold polarized neutrons beam of ILL HFR to measure T-odd angular correlation in ternary fission of ^{233}**U,** which can be described as:

$$W \sim 1 + D_\alpha \cdot \mathbf{p}_\alpha \cdot [\boldsymbol{\sigma}, \mathbf{p}_{LF}], \qquad (1)$$

and it has been found that

$$D_\alpha\ {}^{233}U = -(2.34 \pm 0.07) \cdot 10^{-3}$$

In the next experiment [2] the same measurement have been performed for target of ^{235}**U** and it was found that correlation coefficient has opposite sign:

$$D_\alpha\ {}^{235}U = +(0.76 \pm 0.09) \cdot 10^{-3}$$

The sign of D in the experiment defined relative to the neutron beam polarization vector **σ**, but actually in (1) instead of **σ** should be the polarization vector of the fissionning nucleus "I" which is parallel to σ when I = J+1/2 and antiparallel when I = J-1/2. (J is the spin value of the target nucleus). It must be noticed that the thermal neutron, captured by nucleus, excites both spin states, so in experiments on thermal neutron beam in reality we have measured the small difference of two effects at I(+) = J+1/2 and I(-) = J-1/2.

Short history

ROT - effect

In 2005 the collaboration of PNPI and TU [3] continued detailed investigation of TRI-effect in ternary fission of ^{235}U, and have observed the strange effect - the angular distribution of α-particles was shifted on a small angle when neutron beam polarization was reversed. Authors came to an idea that observed shifting arises due to the rotation of fissionning nucleus at the scission, and it was called the "ROT-effect" (from rotation).

Very soon the same effect was found also for fission of ^{233}U nucleus. It should be emphasized that both ROT-effects shows the same signs. It was interesting to know the relative signs of ROT effects in binary fission of the same nuclei.

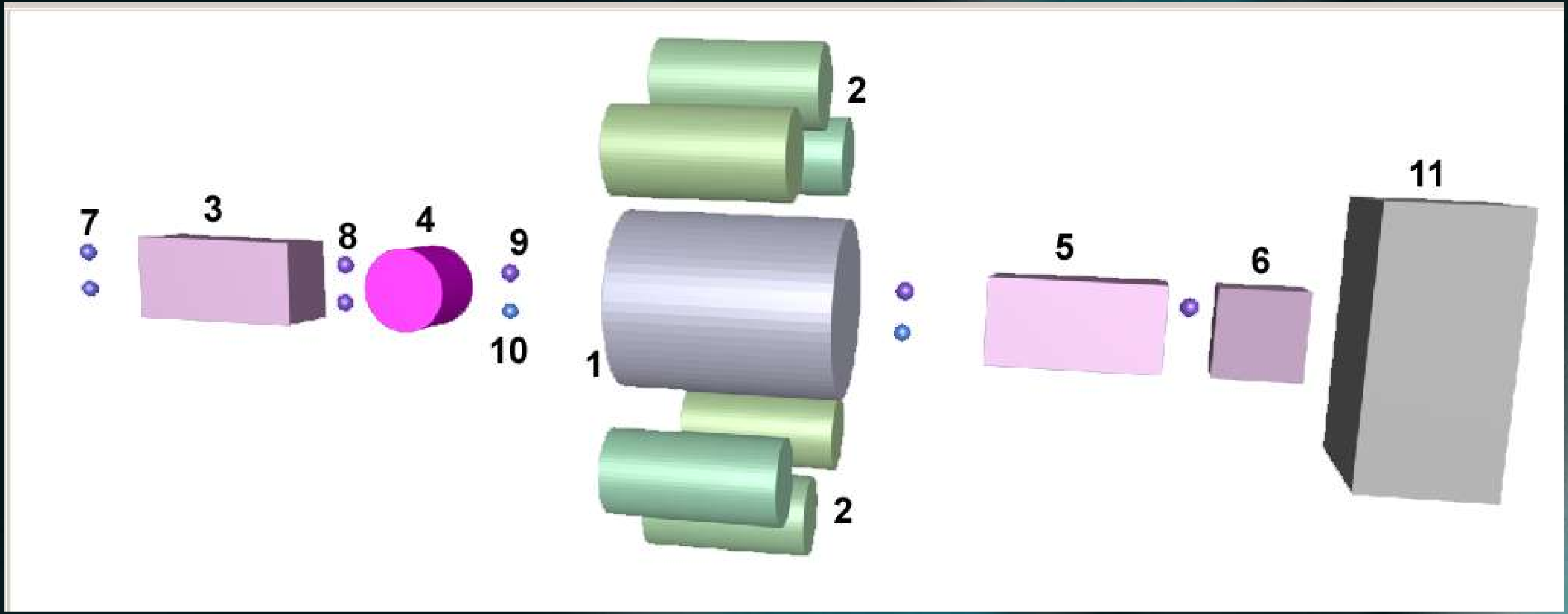
In experiment ROT – asymmetry measured as:

$$R = (N1-N2) / (N1+N2) \sim A \cdot [dN(\theta) / N(\theta)] \cdot \delta\theta$$

Where A is the anisotropy of the detected particles angular distribution, N1, N2 is the coincidence count rates of pulses from detected particle with fission fragment, $N(\theta)$ – angular distribution of detected particles and $\delta\theta$ - small shifting angle.

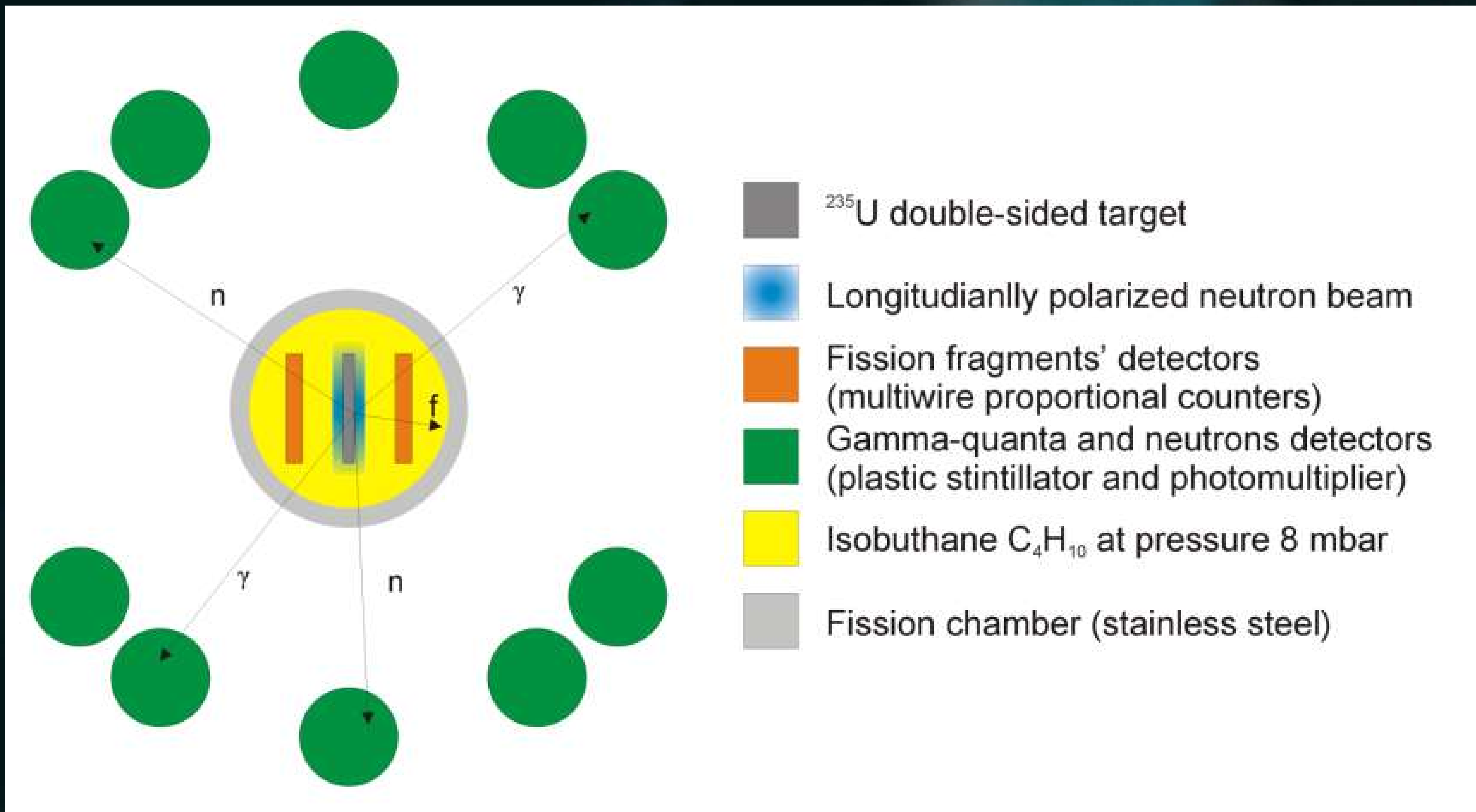
For this reason we have performed the simultaneous measurements of ROT-effects in emission of prompt γ-rays and neutrons for targets of ^{235}U and ^{233}U [4]. Our results (Table 1) are in contradiction with results of PNPI team [3]. All experimental data presented in the Table 2.

View of the experimental setup



1 – fission chamber; 2 – gamma- detectors [NaI(TI) + PM];
3 – polarizer; 4 – spin-flipper; 5 –polarization analyzer; 6 – neutron counter;
7 – neutron beam ; 8 – polarized neutron beam;
9, 10 – neutrons with opposite polarizations after spin-flipper;
11 – beam stop

The cross section view of detectors system



- Table 1. ROT-asymmetry at simultaneously measurements for ^{233}U и ^{235}U nuclei in units 10^{-5}

Prompt fission particles	Angle respect to the fission axis	^{233}U	^{235}U
γ- rays	22.5°	− 2.5±1.7	+ 6.8±2.1
γ- rays	45.0°	− 3.3±1.4	+10.1±1.7
γ- rays	67.5°	− 6.3±2.6	+10.3±3.1
neutrons	22.5°	− 2.9±1.8	+ 5.4±2.1

Table 2. All experimental results for TRI- and ROT-effects

	Particle	Correlation	^{233}U	^{235}U	^{239}Pu	^{241}Pu
1	α TRI in units 10^{-3}	$W \approx 1 + D \cdot \mathbf{P}_\alpha \cdot [\mathbf{J}, \mathbf{P}_{Lf}]$	−3,9 (1) PNPI, TU	+ 1,7(2) PNPI, TU	− 0,23(9) PNPI, TU	+ 1,30(15) PNPI, TU
2	α ROT the angle in degrees		+ 0,021(4) PNPI, TU J=I+1/2	+ 0,215(3) PNPI, TU J=I+1/2	+ 0,020(3) PNPI, TU J=I+1/2	+ 0,047(4) PNPI, TU J=I+1/2
3	γ ROT in units 10^{-5}		**− 6,3(1,6)** ITEP,FRM II	+ 16,6(1,6) ITEP,FRM II		
4	n ROT in units 10^{-5}		**− 4,8(1,6)** ITEP,FRM II	**+21,2(2,5)** ITEP,FRM II		

Conclusion

- Any apparatus asymmetries which could change the sign of ROT-effects for ^{233}U nucleus are excluded in ITEP and PNPI experiments, because such systematic asymmetries should be too large.

- All experimental results for ROT-effect in ternary fission have positive signs, i.e. the ternary fission occurs through the spin state

  $I = J + ½$. I suggest that this preference takes place at saddle, while binary fission takes place at scission point as is generally accepted. Scission take place very fast, so it’s impossible to prepare the configuration which is preferably for ternary fission.

References

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Thanks for your attention

- I would really appreciate for constructive comments

Experimental data

	Particle	Correlation	^{233}^{233}U U ^{233}U	^{235}U
1	α TRI	$W \sim 1+D_\alpha \cdot p_\alpha \cdot [\sigma \times p_{LF}]$	$-(3{,}9 \pm 0{,}1) \cdot 10^{-3}$ ITEP, PNPI, TU	$+(1.7 \pm 0.2) \cdot 10^{-3}$ ITEP, PNPI, TU
2	α ROT		$+(0{,}021 \pm 0.004)°$ **PNPI, TU**	**$+(0{,}215 \pm 0{,}005)°$** **PNPI, TU**
3	γ ROT		**$-(6{,}3 \pm 1{,}6)$** $\cdot 10^{-5}$ **ITEP**	**$+(16{,}6 \pm 1{,}6)$** $\cdot 10^{-5}$ **ITEP**
4	n ROT		**$-(4{,}8 \pm 1{,}6) \cdot 10^{-5}$** **ITEP**	**$+(21{,}2 \pm 2{,}5)$** $\cdot 10^{-5}$ **ITEP**