Simulation of angular distribution of prompt neutrons emitted by fission fragments created during the process of photofission of even-even nucleus by polarized photons via Monte Carlo technique and GEANT4

draft

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Abstract

In this paper we'll describe the procedure which allows one to simulate azimuthal and angular distributions of prompt neutrons using Monte Carlo technique. Only one channel ($K = 0, J = 1^-$) was taken into account [1].

Contents

1 Procedure

For more details see the previous paper. Here we used the following form of the angular distribution function fotr the channel ($K = 0, J = 1^-$) and

$P_\gamma = 0.25$ [1]:

$$W(\theta, \phi) = \frac{3}{2} sin^2(\theta) \cdot (1 - P_\gamma \cdot sin^2(\phi)) \tag{1}$$

The asymmetry was calculated as $A = \frac{N(0^0)-N(90^0)}{N(0^0)+N(90^0)}$. Four cases were considered: (i)vacuum inside the target and vacuum outside the target; (ii) 238U inside the target and vacuum outside the target; (iii) vacuum inside the target and air outside the target; (iv) 238U inside the target and air outside the target. In the case when the material surrounding the target was air, the secondaries produced by the neutrons and by the other particles going out of the 238U target were killed in order to speed up the calculation. Two detectors with 100% efficiency were placed with their centers at $\phi = 90^0$ at a distance of about 197 cm away from the target. The thickness of each of the detectors was 5.1 cm, the width 7.3 cm, and the hight 7.3 cm. The dimensions of the detectors were exactly the same as the dimensions of the scintillation crystalls attached to PMTs used in the previous neutron detection experiments.

2 Geant4 simulation of the asymmetry rate for the case of FF angular distribution function [1] $W(\theta, \phi)$, $P_\gamma = 0.25$ and $(K = 0, J = 1^-)$ channel and 238U target.

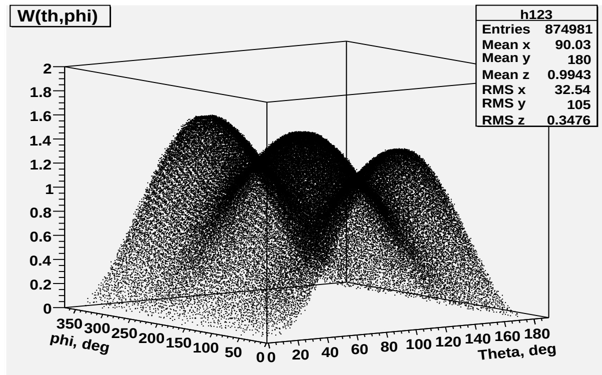
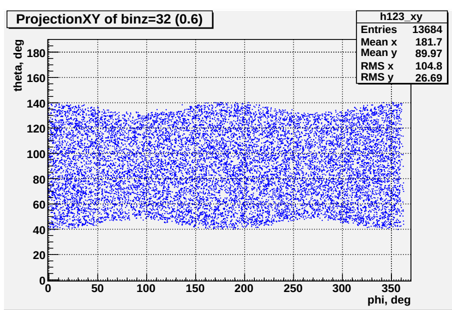
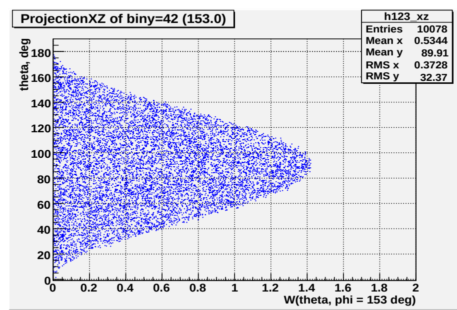


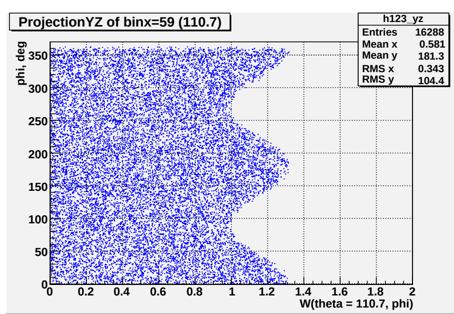
Figure 1: Correlation between angles θ and ϕ of FF emission. Surface shown for the better appearence. Angles were sampled all under the surface.



(a) xy-projection at $W(\theta,\phi) = 0.6$.

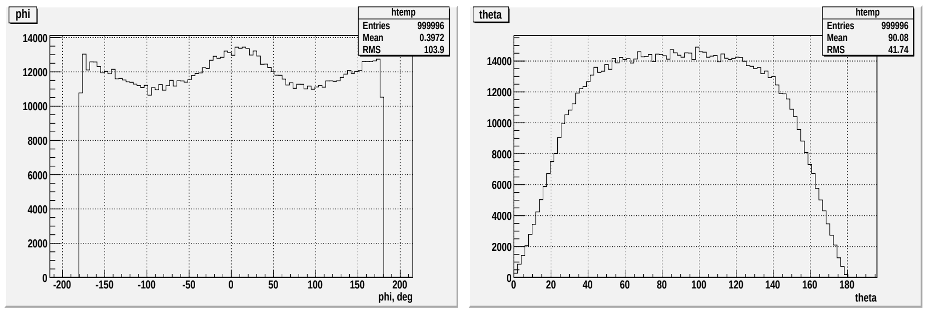


(b) xz-projection at $\phi = 153^0$.



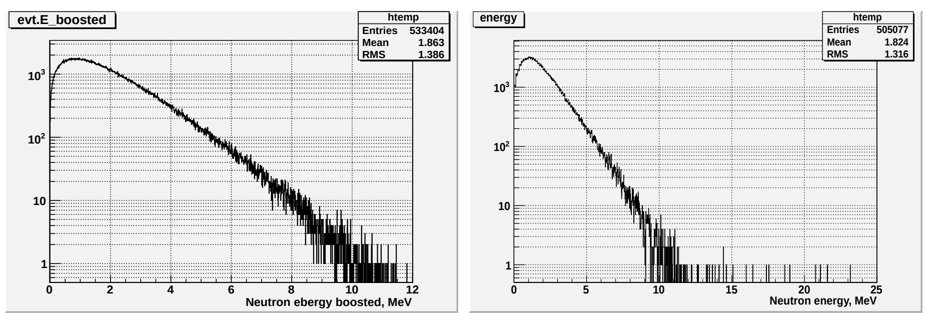
(c) yz-projection at $\theta = 110^0$.

Figure 2: Crossections of the sampled values of FFs angular distribution function. See Figure 1.



(a) ϕ distribution of prompt neutrons. (b) θ distribution of prompt neutrons.

Figure 3: Prompt neutrons angular and azimuthal distributions boosted into LAB frame. G4 generated for $P_\gamma = 0.25$. Initially 10^6 events was sampled.



(a) Energy of neutrons sampled from the given distribution. (b) Energy of neutrons outside of 1 cm 238U sphere. $5 \cdot 10^5$ events were sampled

Figure 4: Neutron energy spectra initial and modified by the target material.

Now let's consider the asymmetries and neutron energy spectra for different cases. In Figure 6(a) and Figure 6(b) it is presented the energy spectra of neutrons detected by the two detectors for the case (238U in/vacuum out).

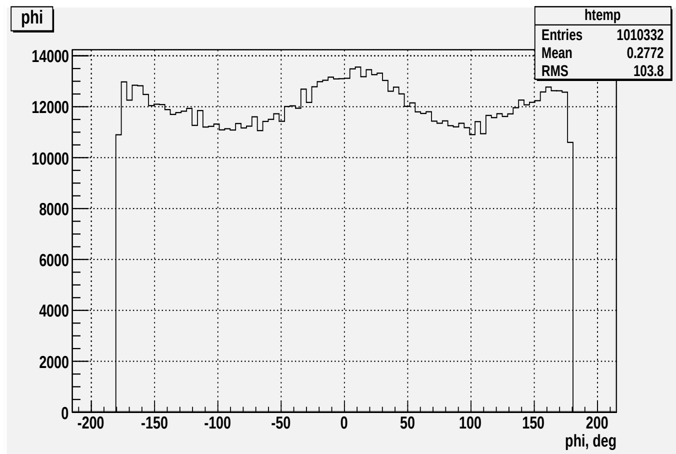
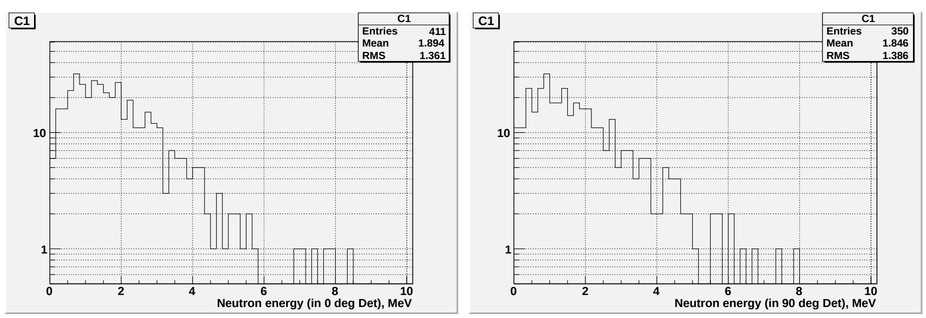


Figure 5: ϕ distribution of prompt neutrons in LAB frame after being distorted by 238U sphere w/ diameter of 1 cm. Initially 10^6 events was sampled.

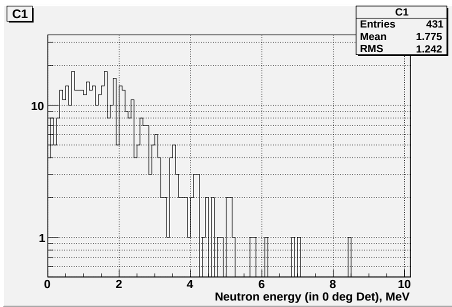


(a) enrgy spectrum of prompt neutrons seen by $\phi = 0^0$ detector.

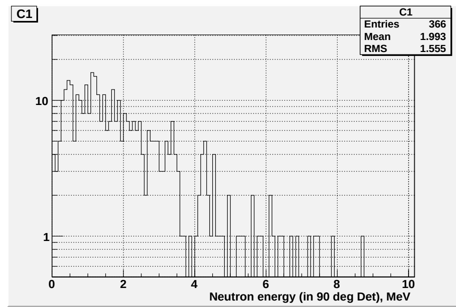
(b) enrgy spectrum of prompt neutrons seen by $\phi = 90^0$ detector.

Figure 6: Energy spectra of the neutrons seen by the detectors. Initially $4 \cdot 10^6$ events was sampled. Obtained in the case (238U in/vacuum out) and $A = 8.02\%$

In Figure 7(a) and Figure 7(b) it is presented the energy spectra of neutrons detected by the two detectors for the case (238U in/air out).



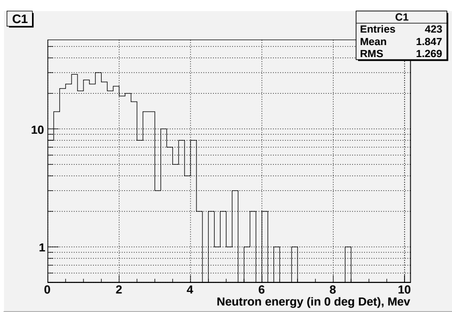
(a) enrgy spectrum of prompt neutrons seen by $\phi = 0^0$ detector.



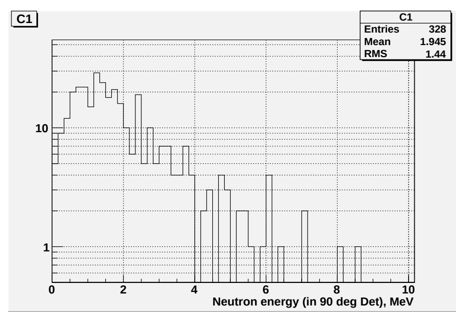
(b) enrgy spectrum of prompt neutrons seen by $\phi = 90^0$ detector.

Figure 7: Energy spectra of the neutrons seen by the detectors. Initially $4 \cdot 10^6$ events was sampled. Obtained in the case (238U in/air out) and $A = 8.15\%$

In Figure 8(a) and Figure 8(b) it is presented the energy spectra of neutrons detected by the two detectors for the case (vacuum in/air out).



(a) enrgy spectrum of prompt neutrons seen by $\phi = 0^0$ detector.



(b) enrgy spectrum of prompt neutrons seen by $\phi = 90^0$ detector.

Figure 8: Energy spectra of the neutrons seen by the detectors. Initially $4 \cdot 10^6$ events was sampled. Obtained in the case (vacuum in/air out) and $A = 12.6\%$

Increased number of initially sampled neutrons $8 \cdot 10^6$ shows that the difference in asymmetries for the cases Vacuum in/Vacuum out and Vacuum in/Air out is

$$A(Vacuumin/Vacuumout) = \frac{790 - 670}{790 + 670} = 8.2\% \quad (2)$$

$$A(Vacuumin/Airout) = \frac{822 - 657}{822 + 657} = 11.2\% \quad (3)$$

The question is how many events will be detected by real scintillators with the efficiency less than 100%?

How can we compare the data simulated and the asymmetry value that we will possibly observe in the experiment?

3 Summary

The azimuthal asymmetry of prompt neutrons in LAB frame was sampled using the angular distribution function of FFs for the case $(K = 0, J = 1^-)$. The results are presented in the table below.

Table 1: The results of the simulation for $4 \cdot 10^6$ events initially sampled.

Target material/Outside material	$A = \frac{N(0^0)-N(90^0)}{N(0^0)+N(90^0)}$, %	remarks
Vacuum/Vacuum	9.3	
Vacuum/Air	12.6	False asymmetry (+3%)?
238U/Vacuum	8.02	
238U/Air	8.15	

Does air introduce additional asymmetry? The air itself gives +3% of asymmetry, however, 238U smears the asymmetry higher than the air and the effect of the air on the asymmetry is not that pronounced?

References

[1] R. Ratzek, W. Wilke, and et al. et al. Photofission with linearly polarized photons. *Z. Phys. A - Atoms and Nuclei*, 308:63–71, 1982.