Simulation of D_2O material effect on the neutron asymmetry obtained in the process of photodisintegration of D_2 using GEANT4

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Abstract

In this paper the result of heavy water effect on the the neutron asymmetry will be described.

Contents

1 Introduction

GEANT4 was used to simulate the effect of the target material on the angular distribution of neutrons generated inside the target. The angular distribution was predefined as $I(\phi) = 1 + 0.3 \cdot cos^2(\phi)$ and the neutron energy spectrum was sampled from the experimental data.

2 Procedure

90% enriched D_2O used in the simulation was composed out of the following elements

$$H - 2 = 10.0705\%; H - 1 = 1.1189\%; O - 16 = 88.8106\%; \quad (1)$$

and its density $1.1056 g/cm^3$. D_2O was shaped into cylinder of 5.5 cm diameter and 18.0 cm hight along the beam line without any shell. Neutron detectors were placed at $\phi = 0^0$ and at $\phi = 90^0$. The experimental setup simulated is plotted in Fig 1.

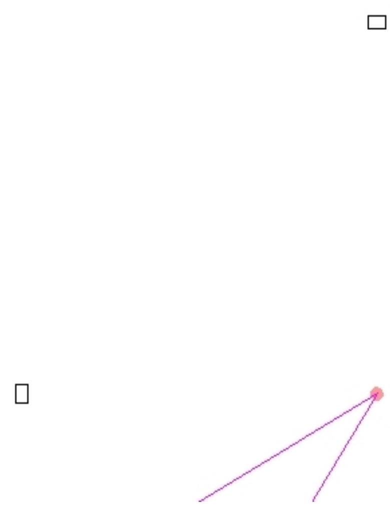

Figure 1: The two neutron detectors and D_2O target. Two neutron trajectories are shown to emerge from the target.

Two kinds of sources were used in the simulation. Neutrons were generated throughout the cylinder volume and, as a second source, point source of neutrons was placed in the center of the target.

The volume source smeared azimuthal asymmetry and was not used. Instead, the point source emitting neutrons with certain azimuthal and energy distribution was implemented.

First, lets consider input parameters for the neutron source. Angular distribution was taken to be $I(\phi) = 1 + 0.3 \cdot cos^2(\phi)$. The plot of the intensity as a function of azimuthal angle is presented in Fig.2.

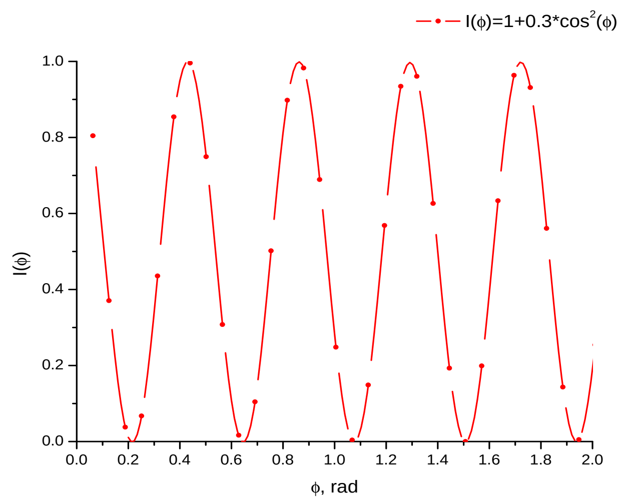

Figure 2: Azimuthal asymmetry $I(\phi)$.

Second, the energy spectrum of neutrons obtained in the experiment on the deuteron photodisintegration by photons with the end-point energy 25 MeV is presented in Fig.3.

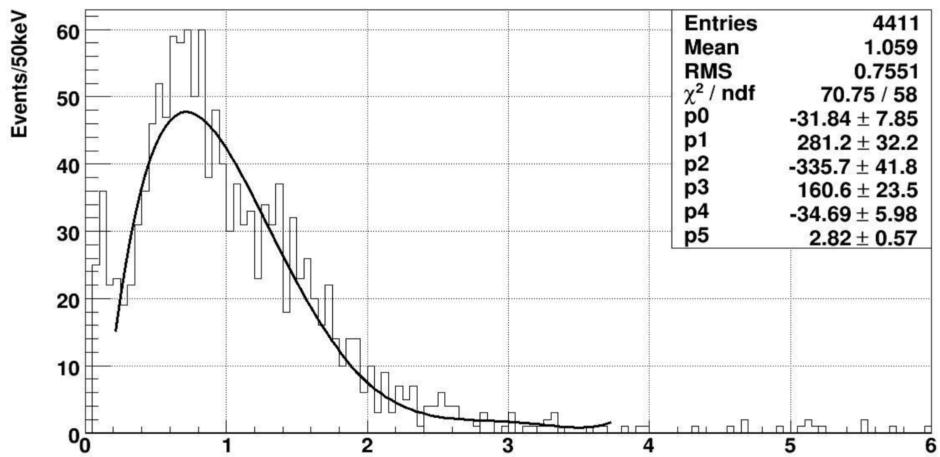

Figure 3: Experimental neutron energy spectrum.

The spectrum which was inserted into GEANT4 and which was used to sample the neutron energy from is presented below in Fig. 4.

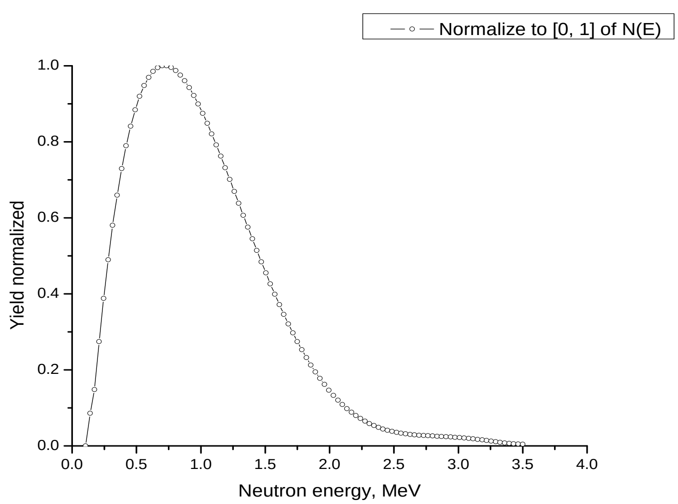

Figure 4: Neutron energy spectrum normalized.

Now let us consider the output parameters obtained for the case when there was no material inside the target, i.e. how good GEANT4 can reproduce input parameters. The azymuthal asymmetry sampled by GEANT4 is presented in Fig. 5

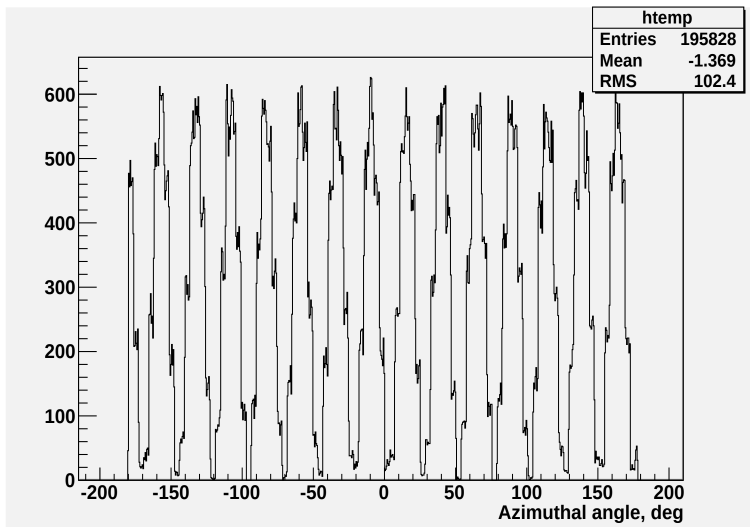

Figure 5: Neutron azymuthal distribution sampled by GEANT4.

The neutron energy distribution sampled by GEANT4 is presented in Fig. 6

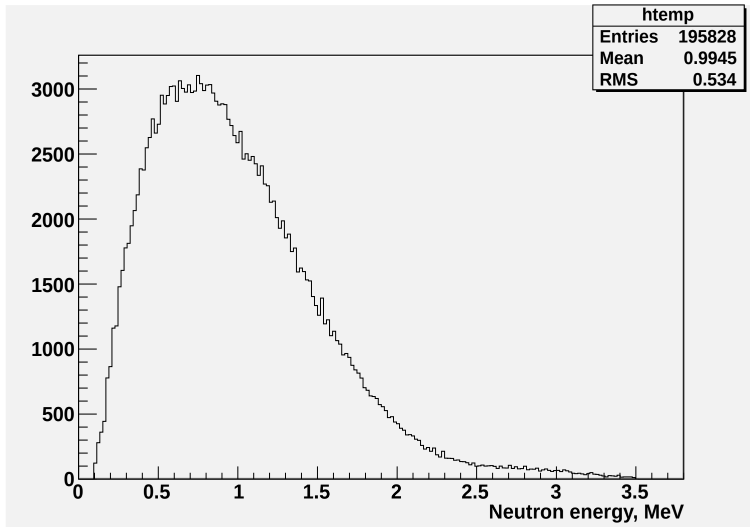

Figure 6: Neutron energy distribution sampled by GEANT4.

After the neutron spectra were detected by each neutron detector, the enrgy cuts were applied to investigate the asymmetry as a function of neutron energy.

3 Results

In order to see the effect of the target material on the azymuthal asymmetry first the simulation was done for an empty target.

The asymmetry is defined as

$$A = \frac{N(90^0) - N(0^0)}{N(90^0) + N(0^0)} \tag{2}$$

So, for the case of empty target it was observed $A(empty) = \frac{172-35}{172+35} = 0.66$. In the case of target filled with D_2O it was observed $A(D_2O) = \frac{178-41}{178+41} = 0.598$. In both cases the total number of events sampled was $5 \cdot 10^5$ and there was no energy cuts implied on the neutron energies.

If the energy cut is applied, the following asymmetries can be obtained. The energy cut is going from high neutron energi to the low ones. The total number of events sampled was $2 \cdot 10^6$.

$A(empty, E_n <= 3.5MeV) = \frac{728-164}{728+164} = 0.632$ - whole energy spectrum.
$A(D_2O, E_n <= 3.5MeV) = \frac{725-161}{725+161} = 0.636$ - whole energy spectrum.
$A(D_2O, E_n <= 3.0MeV) = \frac{721-159}{721+159} = 0.638$
$A(D_2O, E_n <= 2.5MeV) = \frac{716-157}{716+157} = 0.64$
$A(D_2O, E_n <= 2.0MeV) = \frac{691-156}{691+156} = 0.632$
$A(D_2O, E_n <= 1.5MeV) = \frac{625-136}{625+136} = 0.642$
$A(D_2O, E_n <= 1.0MeV) = \frac{437-91}{437+91} = 0.655$
$A(D_2O, E_n <= 0.5MeV) = \frac{131-28}{131+28} = 0.472$

As an example, the neutron energy spectrum seen by the detector placed at 90^0 is shown below in Fig. 7.

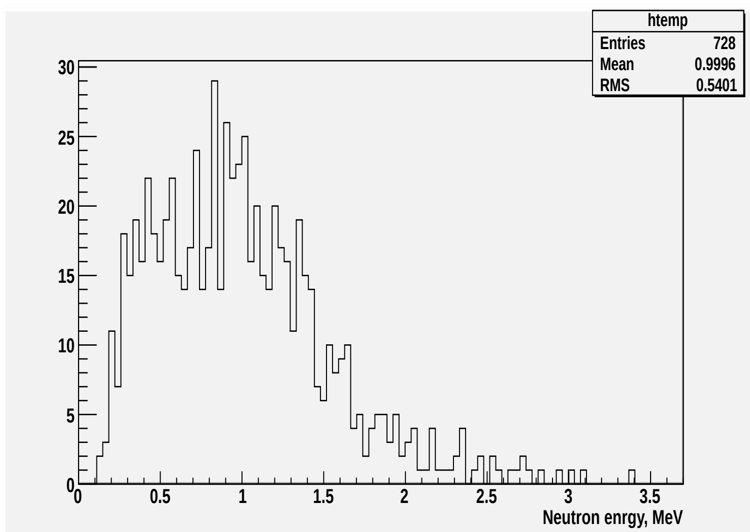

Figure 7: Neutron energy distribution modified by D_2O material.

4 Conclusions

For some reason there was no effect of D_2O target material on the neutron azymuthal asymmetry seen in the simulation described in this paper. Even application of energy cuts didn't improve the results on the asymmetry.