On the technique of the extraction of the neutron detectors effeiciency

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Abstract

In this paper it is proposed the approach on how to extract the efficiency of the neutron detectors used in 2n correlation experiment and the yield of correlated 2n events as a function of the polar angle. This approach is preliminary and needs further discussion.

1 Procedure

1.1 Same pulse data set analysis

Obtaining the efficiency $\varepsilon(\vartheta_{op})$ of the neutron detectors and the neutron yield $Y^{sp}(\vartheta_{op})$ of correlated nn-events as a function of the polar opening angle ϑ_{op} will require the analysis of two diffrent kinds of data sets. First, we will analyze "same pulse" (sp) data for the sequence of HRRL pulses combined into runs of a different duration. The same pulse data will contain the following information:

1. n-n events correlated, both neutrons belong to the same event of fission;
2. n-n events uncorrelated, both neutrons came from different fission events if there were more than one fission per pulse;
3. n-γ uncorrelated, it gives false event in the n-n coincidence spectrum;
4. $\gamma - \gamma$ uncorrelated, it gives false event in the n-n coincidence spectrum.

The combined neutron yield for the same pulse data set can be represented as a sum of the components described above:

$$Y^{sp}(\vartheta_{op}) = Y_{nn}^{corr}(\vartheta_{op}) + Y_{nn}^{uncorr}(\vartheta_{op}) + Y_{\gamma n}^{uncorr}(\vartheta_{op}) + Y_{\gamma\gamma}^{uncorr}(\vartheta_{op}) \qquad (1)$$

Now we should find out the way how to eliminate uncorrelated events to make the $Y^{sp}(\vartheta_{op})$ as a function of the true n-n correlated events $Y_{nn}^{corr}(\vartheta_{op})$ coming from the same fission event.

1.2 Analysis of different pulse data

In this section we will consider the information that can be extracted from the two different HRRL pulses (dp) which belong to the same run. Let's take a look at the data that can be obtained fron the analysis of the two different pulses:

1. n-n events uncorrelated, both neutrons came from different fission events which happend in two different moments of time;
2. n-γ uncorrelated because it happend in two different moments of time;
3. $\gamma - \gamma$ uncorrelated because it happend in two different moments of time.

As can be seen the information that is be obtained from two different pulses will give us the estimate of the background events contaminating true n-n correlation events occured in the same fission event. The total yield of two uncorrelated events in cincidence originating from two different pulses can be represented in the following way:

$$Y^{dp}(\vartheta_{op}) = Y_{nn}^{uncorr}(\vartheta_{dp}) + Y_{\gamma n}^{uncorr}(\vartheta_{dp}) + Y_{\gamma\gamma}^{uncorr}(\vartheta_{dp}) \qquad (2)$$

1.3 Extraction of the pure n-n correlation events

Using the information obtained by following Section 1.1 and Section 1.2 it is possible to extract the uncontaminated n-n correlated distribution as a function of the opening angle:

$$
\begin{aligned}
Y_{nn}^{corr}(\vartheta_{op}) &= Y^{sp}(\vartheta_{op}) - Y^{dp}(\vartheta_{op}) \\
&= [Y_{nn}^{corr}(\vartheta_{op}) + Y_{nn}^{uncorr}(\vartheta_{op}) + Y_{\gamma n}^{uncorr}(\vartheta_{op}) + Y_{\gamma\gamma}^{uncorr}(\vartheta_{op})]^{sp} \\
&\quad - [Y_{nn}^{uncorr}(\vartheta_{op}) + Y_{\gamma n}^{uncorr}(\vartheta_{op}) + Y_{\gamma\gamma}^{uncorr}(\vartheta_{op})]^{dp} \\
&= [Y_{nn}^{corr}(\vartheta_{op})]^{sp}
\end{aligned} \tag{3}
$$

It is possible to calculate the net n-n correlated yield $Y_{nn}^{corr}(\vartheta_{op})$ by using Equation 3, however, the proper normalization procedure of the yields from two different data sets (sp and dp) has to be done.

1.4 Extraction of the efficiency

The extraction of the efficiency of the neutron detectors can be done in the following several steps. First, we will use the experimental data for the yield of single neutrons $Y_n(\vartheta_n)$ as a function of the emission angle ϑ_n to get the information on $Y_{nn}^{uncorr}(\vartheta_{op})$ described in Section 1.2, item 1. We will do that by using GEANT4. It should be possible to sample neutrons according to the experimental $Y_n(\vartheta_n)$ and obtain n-n uncorrelated yield as a function of the opening angle $Y_{nn}^{uncorr}(\vartheta_{op})$. After getting the information on the $Y_{nn}^{uncorr}(\vartheta_{op})$ distribution it will be possible to calculate the shape of the $Y_{nn}^{uncorr}(\vartheta_{op})$ distribution and express it as a different function $D_{nn}^{uncorr}(\vartheta_{op})$. Now it will be possible to represent $Y_{nn}^{uncorr}(\vartheta_{op})$ as a function of $D_{nn}^{uncorr}(\vartheta_{op})$ weighted by the efficiency:

$$
Y_{nn}^{uncorr}(\vartheta_{op}) = \varepsilon_{nn}(\vartheta_{op}) D_{nn}^{uncorr}(\vartheta_{op}) \tag{4}
$$

Since we already know the shapes of $Y_{nn}^{uncorr}(\vartheta_{op})$ and $D_{nn}^{uncorr}(\vartheta_{op})$ we will be able to find the neutron detector efficiency as the ratio:

$$
\varepsilon_{nn}(\vartheta_{op}) = \frac{Y_{nn}^{uncorr}(\vartheta_{op})}{D_{nn}^{uncorr}(\vartheta_{op})} \tag{5}
$$

Since we know from Equation 3 the n-n correlated yield $Y_{nn}^{corr}(\vartheta_{op})$ and the efficiency $\varepsilon_{nn}(\vartheta_{op})$ we will be able to obtain the profile of the n-n correlation $D_{nn}^{corr}(\vartheta_{op})$ as a function of the opening angle:

$$
Y_{nn}^{corr}(\vartheta_{op}) = \varepsilon_{nn}(\vartheta_{op}) D_{nn}^{corr}(\vartheta_{op}) \tag{6}
$$

2 Conclusions

The normalization procedure used in the Equation 3 should be clarified. Further discussion is needed to make sure that the logic behind the presented procedure is well understood and correct.