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Neutron Detection Efficiency in CLAS

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1 Abstract

This note presents neutron detection efficiency studies for the g2 running period (real photon beam with deuterium target). Results for both the electromagnetic calorimeter (EC) and the time–of–flight counters (SC) are presented. The results are compared with previous data [1] (for the EC) and with a Monte Carlo simulation, using GSIM (for EC and SC). The EC neutron efficiency agrees well with previous results which were obtained from a different reaction channel, using electroproduction data.

2 EC Neutron Detection Efficiency from g2 Data

To study the neutron detection efficiency, the reaction $\gamma d \rightarrow pn\pi^+\pi^-$ was used to tag the neutron. To isolate this channel, the data were filtered requiring a π^- and at least two positive particles to be detected in CLAS. The missing mass spectrum for the reaction $\gamma d \rightarrow p\pi^+\pi^- X$ is shown in Fig. 1. The prominent peak at about 0.94 GeV corresponds to the tagged neutron. For these neutrons we can compute missing momentum and direction, using the momenta and directions for the charged particles detected. The two vertical lines in Fig. 1 show the cut applied to separate this reaction from other channels. The neutron detection efficiency can be written as the number of neutrons detected (in the EC or SC) divided by the number of neutrons tagged:

$$\epsilon = \frac{N_{detected}}{N_{expected}} \tag{1}$$

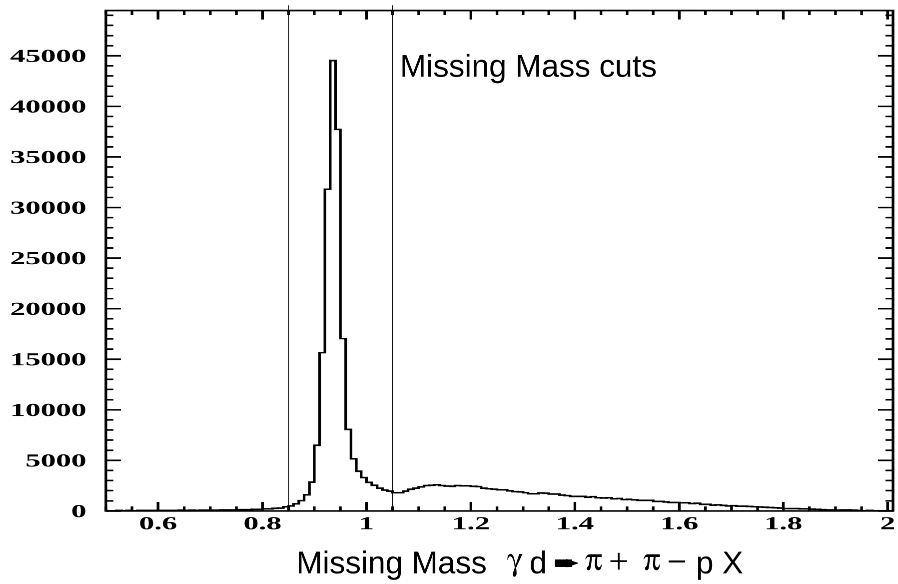

Figure 1:
Missing mass spectrum for the reaction $\gamma d \rightarrow p\pi^+\pi^- X$. The two vertical lines represent the cuts applied to identify the neutron candidates.

In addition to the missing mass cut discussed above, a cut on the six CLAS coils was applied. This cut is similar to the one described in [2]. Fig. 2 shows the effects of this cut on the expected (panel (a)) and measured (panel (b)) neutron angular distributions. The black areas represent the distributions before the cut was applied, the red points represent the same distributions after the cut.

Figure 3(a) shows the momentum distribution of the expected (solid) and observed (dashed) neutrons. The vertical line indicates the momentum cut applied for this analysis (neutron momentum greater than 250 MeV). To ensure that the direction of the detected neutron matches the direction of the expected neutron, cuts were applied on the difference in the θ and ϕ angles for the two neutrons (Fig. 3 panels (b) and (c)).

The results for the neutron detection efficiency of the CLAS electromagnetic calorimeter are shown in Fig. 4, compared with the results given in [1]. The agreement between the two measurements is very good for neutron momenta smaller than about 1.75 GeV. Above this value, the results of the present analysis are not very accurate, with big statistical uncertainties, due to the fact that the highest photon beam energy was around 2.3 GeV. In the high neutron momentum region the charged particles

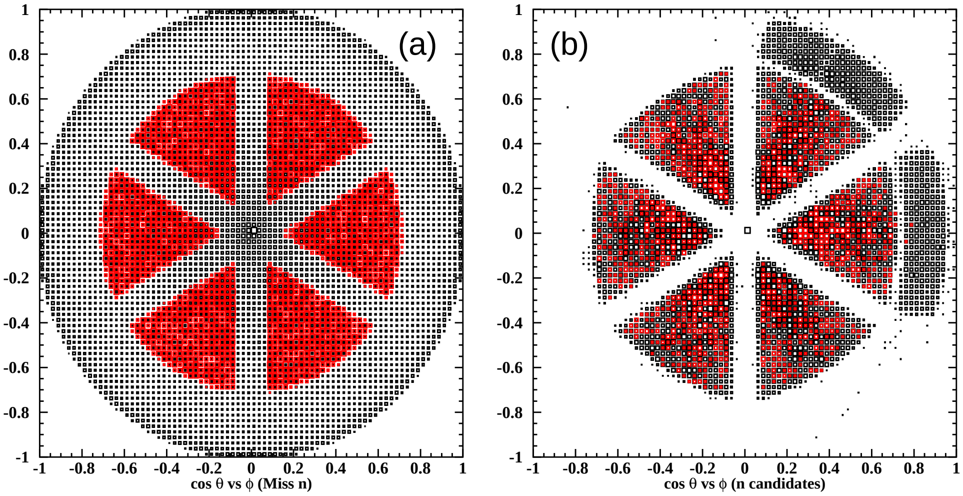

Figure 2:
Theta versus phi distribution for the neutron candidates (a) and the detected neutrons (b). The red points show the distribution after the coil cuts were applied.

detected have low momenta, thus being more affected by acceptance effects, energy loss, decays, etc. This means that some of the events identified as having a neutron in this region might be just background.

Figures 5 and 6 show the θ and ϕ dependence of the neutron efficiency, for two neutron momentum ranges (smaller than 1.25 GeV and greater than 1.25 GeV). The ϕ distribution shows that some sectors have lower efficiency than others, largely due to dead photomultiplier tubes.

Fig. 7 shows the EC neutron momentum resolution as a function of neutron momentum and the bias of the distribution $p_{expected} - p_{measured}$.

3 SC Neutron Detection Efficiency

In a similar way, one can obtain the neutron detection efficiency for the TOF counters in CLAS. The reaction used and the cuts applied in this study are the same as in section 2. The results are presented in Fig. 8 as a function of neutron momentum. The neutron detection efficiency for the SC is about 5%, which is expected for scintillators with these characteristics [3]. The SC neutron efficiency is almost constant for neutron momenta between 0.3 and 2 GeV, range in which the EC detection efficiency increases rapidly.

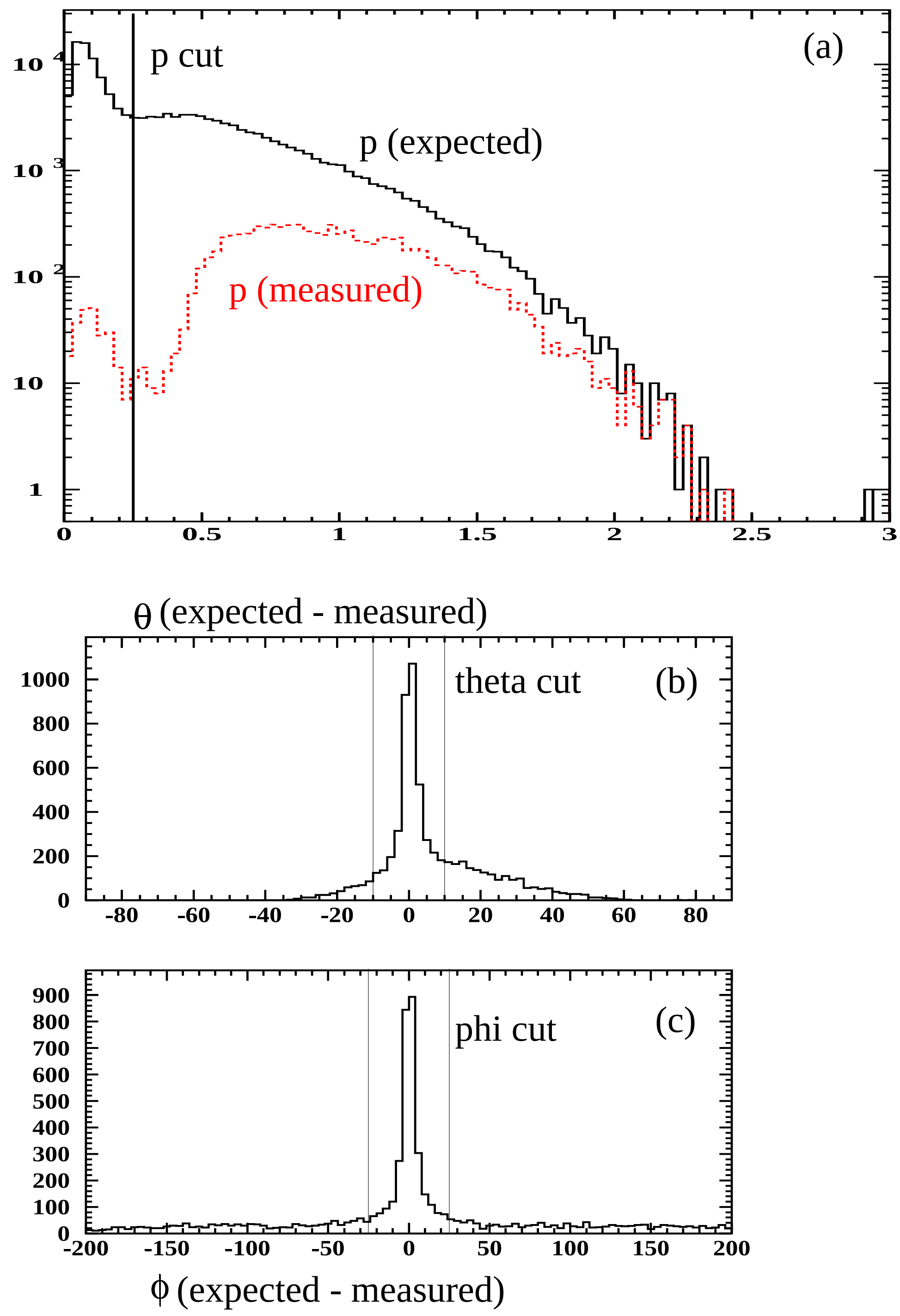

Figure 3:
(a) Momentum distribution for the expected (solid) and observed (dashed) neutrons.
(b) and (c) differences in angles (θ and ϕ) between the expected and detected neutron.

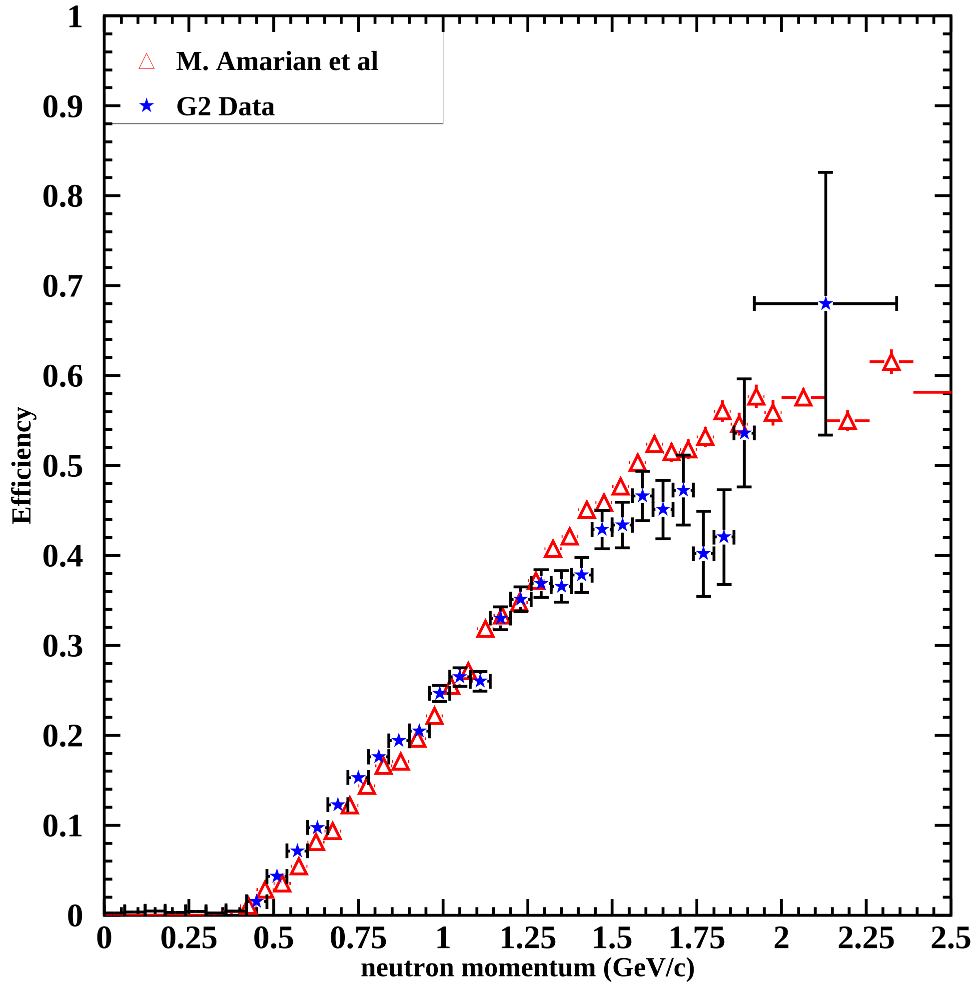

Figure 4:
EC neutron detection efficiency.

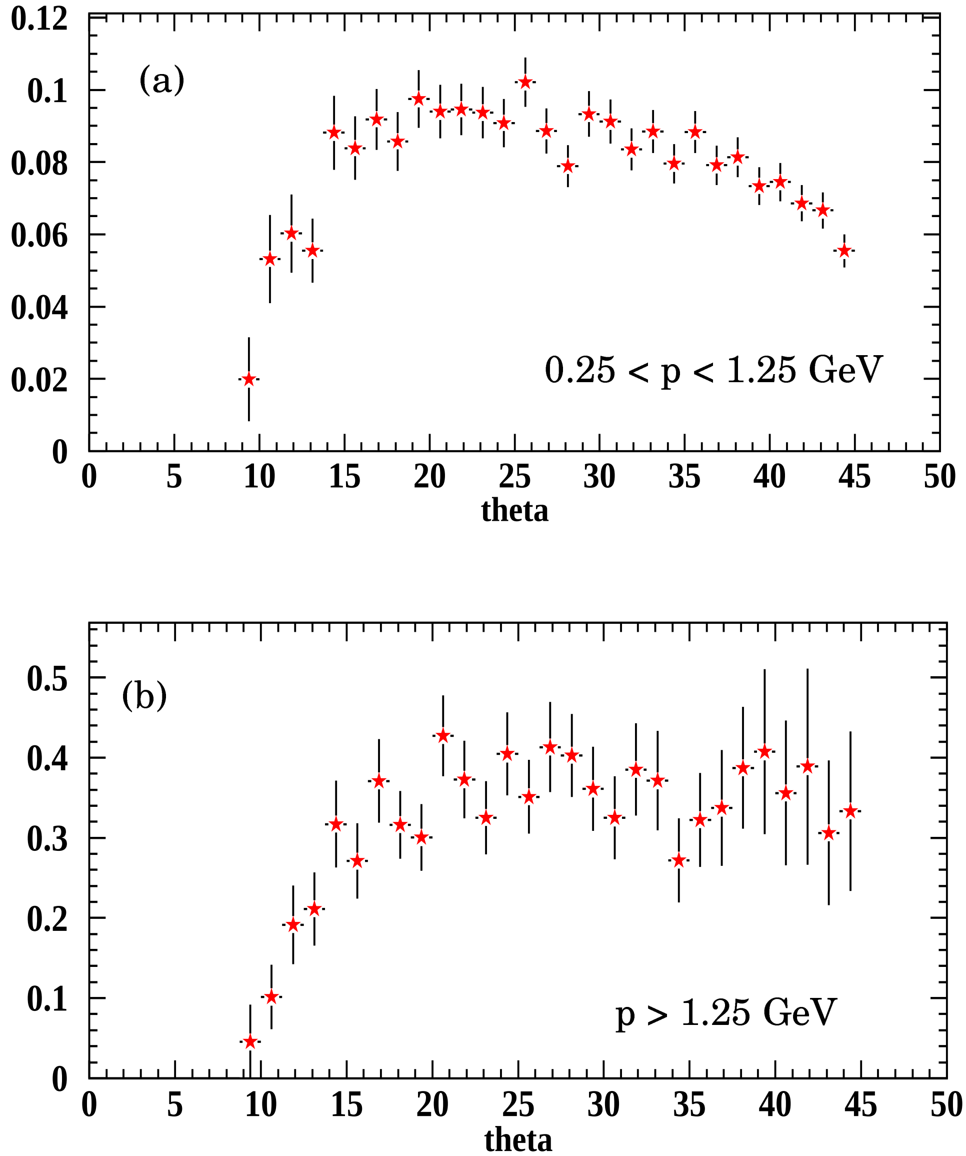

Figure 5:
Theta dependence of the EC neutron detection efficiency.

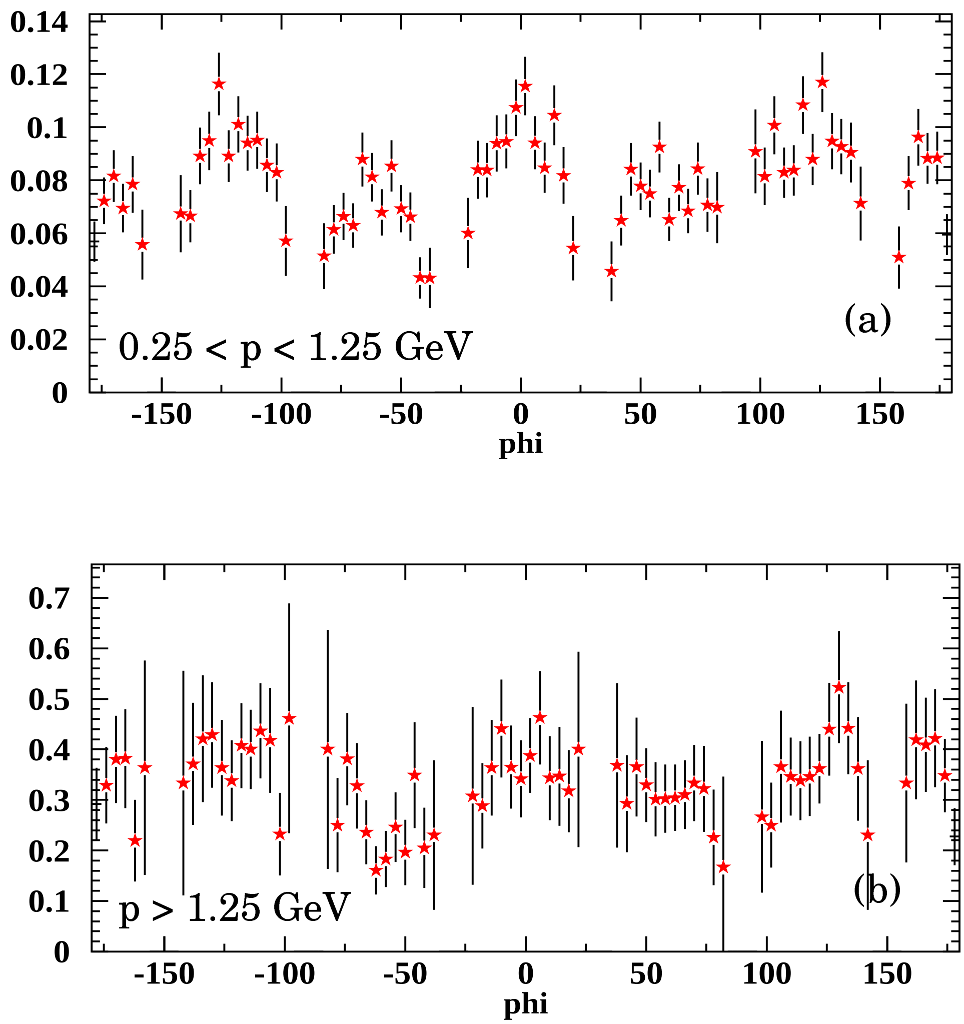

Figure 6:
Phi dependence of the EC neutron detection efficiency.

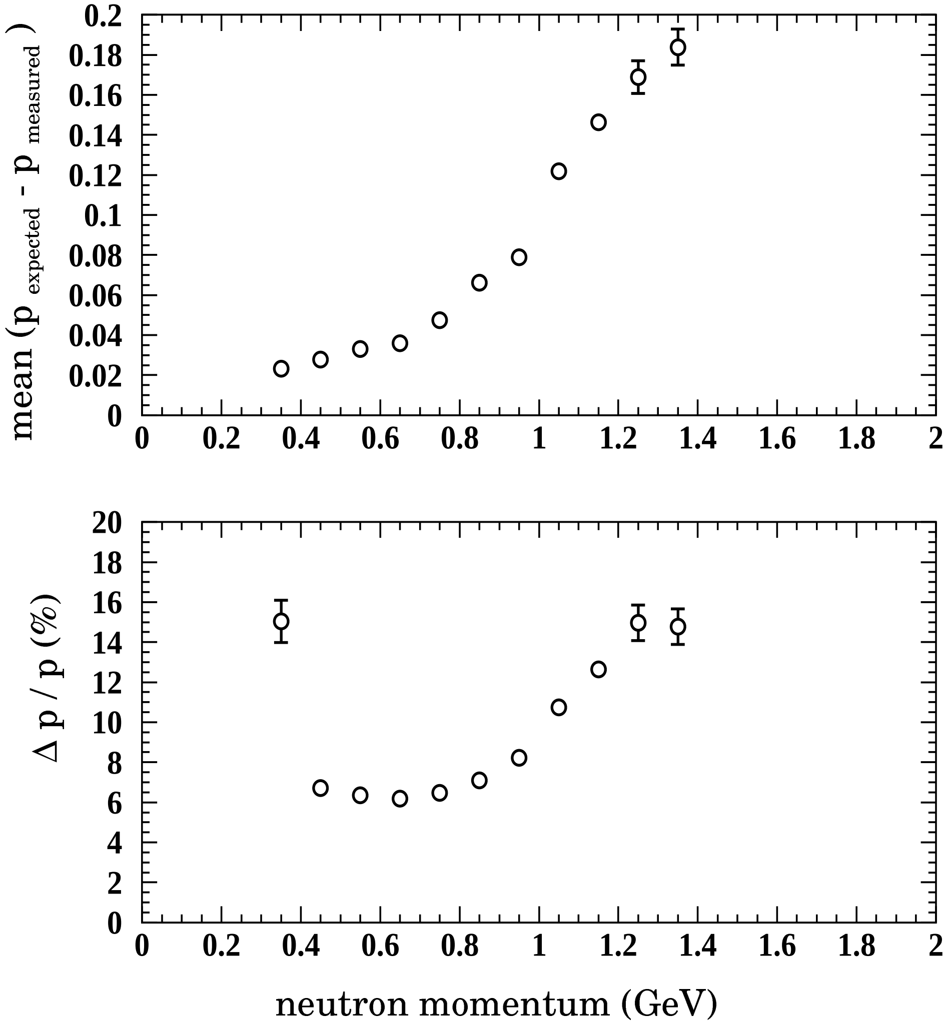

Figure 7:
EC momentum bias (top) and resolution (bottom) as a function of neutron momentum.

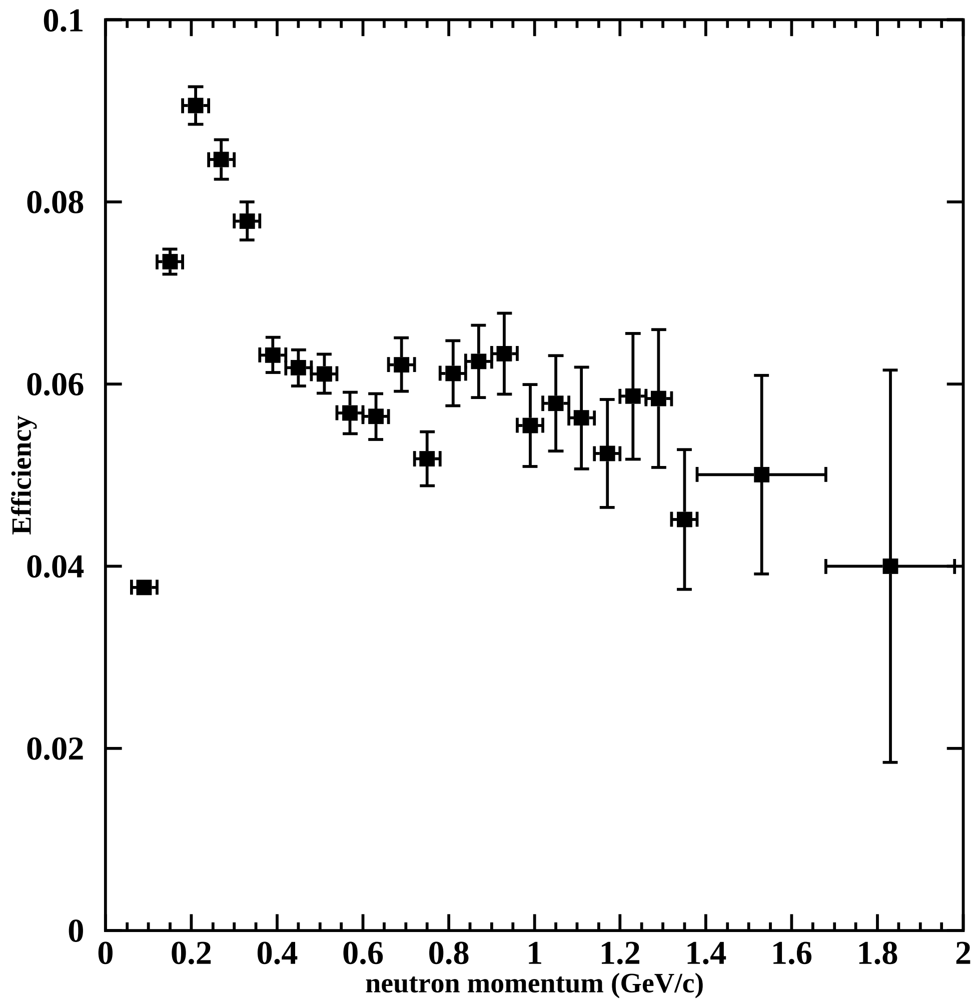

Figure 8:
Momentum dependence of the SC neutron detection efficiency.

4 Comparison with GSIM

For both the electromagnetic calorimeter and the TOF counters, the data were compared with a Monte Carlo simulation using GSIM. Events were generated using the *genbos* [4] event generator, for the reaction $\gamma n \to \pi^+\pi^- n$. The hadronic interactions of the neutrons was simulated using the GHEISHA package in GEANT
citegeant. The simulated events were smeared using the *gpp* [6] package and then analyzed with the same software as the data. Dead photomultiplier tubes in the electromagnetic calorimeter were not taken into account. Results of this comparison are shown in Fig. 9 for the EC (a) and SC (b) detectors.

5 Conclusions

The neutron detection efficiency of the electromagnetic calorimeter in CLAS was tested with photoproduction data on deuterium. The results are found to be compatible with previous studies performed in electroproduction [1]. The results of a GEANT–based Monte Carlo simulation were found to be in reasonable agreement with the detection efficiency extracted from data. More in depth studies, including testing of the neutron interaction cross section in GEANT, should be performed if one is to account for the discrepancies between data and GSIM.

A neutron detection efficiency of around 5% was found for the SC, relatively constant over the range 0.3 to 2 GeV. While not as large as the EC neutron efficiency, this greatly increases the angular coverage for neutron detection in CLAS. This result is also reproduced well by the Monte Carlo simulation.

Good, reliable neutron detection efficiency over a large angular and momentum range adds a new dimension to the multiparticle detection capabilities of CLAS.

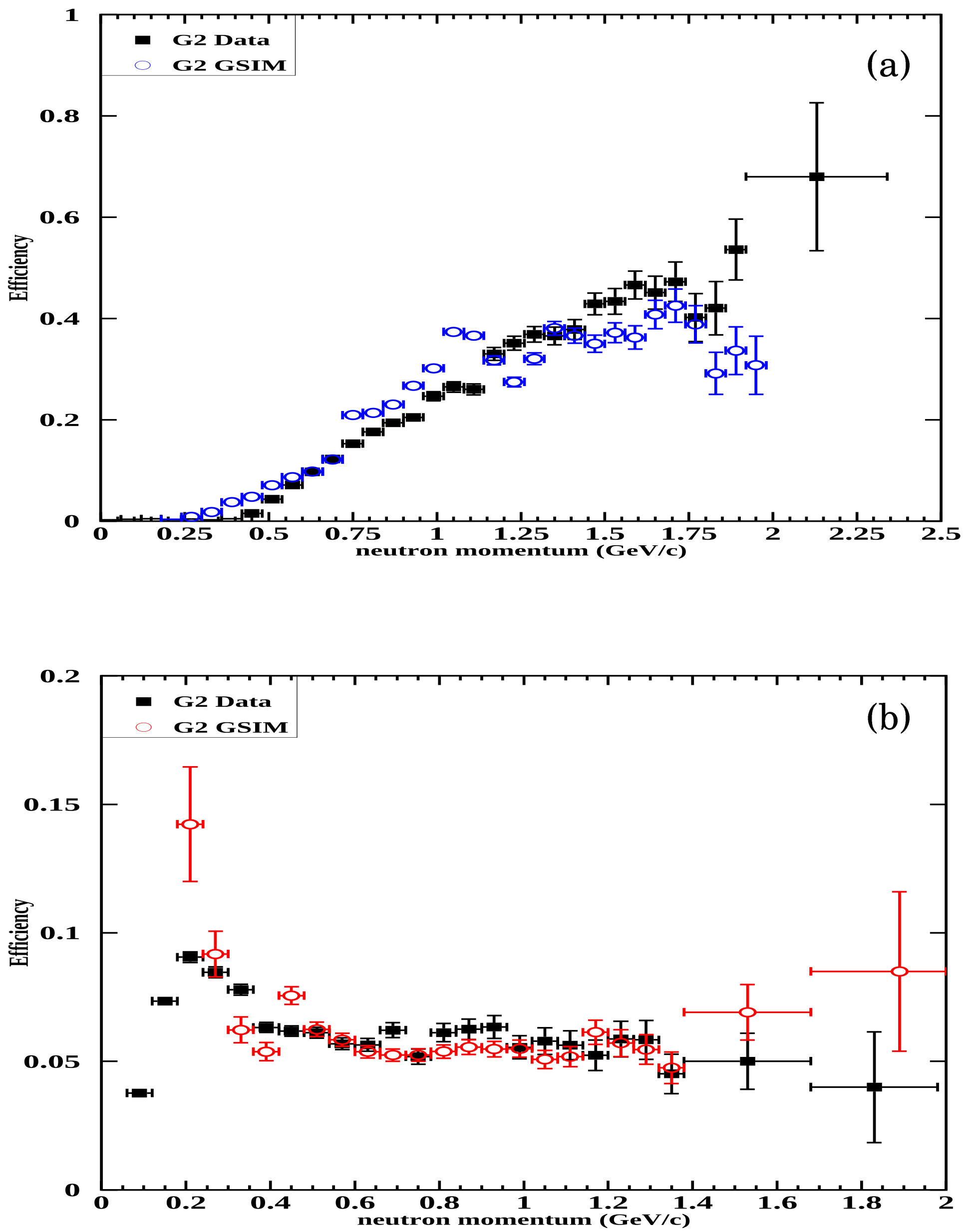

Figure 9:
Comparison of neutron detection efficiency from the data and Monte Carlo, for the EC and SC detectors.

References

[1] M. Amarian et al, *The CLAS Forward Electromagnetic Calorimeter*, February 2000.

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[3] W. Brooks, private communication

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