Simulation study of neutron measurement using NEBULA simulation package for SπRIT project

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Neutron and proton emission is one of many reaction observables that can be used to constrain the density-dependent nuclear symmetry energy[1)], which is important to describe isospin-asymmetric nuclear matter.

In the SπRIT project, we plan to measure the n/p ratio complementary to the t/^{3}He ratio measurement by making use of the TPC and the NEBULA array. In order to investigate the response of the NEBULA array before the actual experiment, we are performing a simulation with the NEBULA simulation package v2.0.5[2)] developed by Nakamura group at Tokyo Institute of Technology on the basis of GEANT4.9.2p02 and ROOT. We are using the Particle and Heavy Ion Transport code System(PHITS)[3)] v2.60 as an event generator to produce collision events with ^{132}Sn projectiles and ^{124}Sn targets. Detailed information on the physics processes used can be found in the link of Ref. 4.

Table 1. Information on generated events

beam energy (AMeV)	neutron events	total events
200	522,665	100,000,000
300	523,058	

In the simulation setup, the NEBULA array is placed 2 m away to the left side of the beam direction so that charged reaction particles having high p_z and beam remnants do not enter the array.

In the distribution of the number of neutrons for each beam energy shown in Fig. 1, lines with "Accepted" in the legend indicate that most of the neutrons generated by the collision are going outside of the acceptance range, and less than 40 neutrons enter the array in our setup.

Figure 2 shows the momentum distribution of neutrons detected by the NEBULA array. The distribution of neutrons with the assumption of 100% detection efficiency(blue) is slightly different from that obtained by taking the time of flight of each neutron's first hit(pink). The difference originates from the exclusion algorithms that excludes some number of scintillator bars near the first detection. This result implies that if we can distinguish the first hit only from the secondary, tertiary, and so on, we can measure most neutrons' momenta with precision. The red line shows the added backgrounds, which should be eliminated to obtain the proper neutron information.

We are building an algorithm to eliminate the background noise, which is about 10 times larger than primary neutron signals as shown in Fig. 2, in order to obtain precise information on as many neutrons as possible. Such information can reveal whether we can distinguish one theoretical model from the others in the actual experiment.

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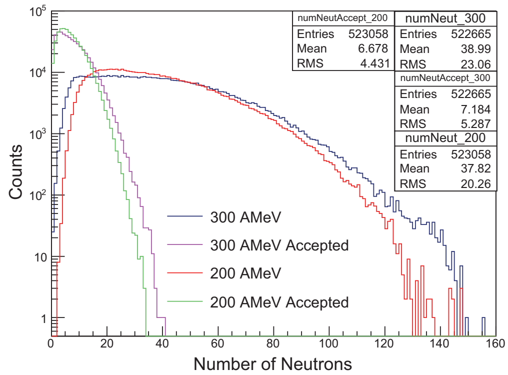

Fig. 1. Number of neutrons in generated events and in accepted the range of the NEBULA array

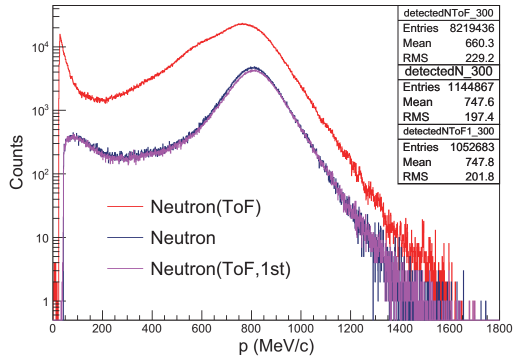

Fig. 2. Momentum distribution of neutrons with beam energy. Blue line is the result with an assumption of 100% detection efficiency of the NEBULA array. Pink line is the result with the time of flight method for the primary reaction. Red line shows the signal plus noise expected in a real experiment without any cut parameter.

References

1) M. A. Famiano *et al.*: Phys. Rev. Lett. **97**, 052701, (2006).
2) NEBULA simulation package: http://be.nucl.ap.titech.ac.jp/~nebula/index.php
3) T. Sato *et al.*: J. Nucl. Sci. Technol. **50:9**, pp. 913-923, (2013).
4) PHITS(Particle and Heavy Ion Transport code System): http://phits.jaea.go.jp/OvMapOfModels.html