Integrated Simulation of Fast Neutron Generation and Detection System in KOMAC

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1. Introduction

Due to a large demand from industrial and scientific area, Korea Multi-Purpose Accelerator Complex (KOMAC) has been providing near-white neutron with 100 MeV proton lineac irradiated to a copper beam dump. It is required to verify a measured data by simulation to provide reliable data to neutron source users. This research presents a comprehensive simulation on the whole process from 100 MeV proton beam irradiation to a scintillation pulse output from 1“ stilbene neutron detector, so that the simulation can be directly compared with the signal output from experimental measurement. The comparison between simulation and experiment can justify the result of each other.

2. Methods and Results

Simulation setup and calculation result evaluation is described in this section. The simulation aims to acquire a rebuilt neutron energy histogram by following the same processes with those of an experimental data previously acquired.

2.1 Simulation Configuration

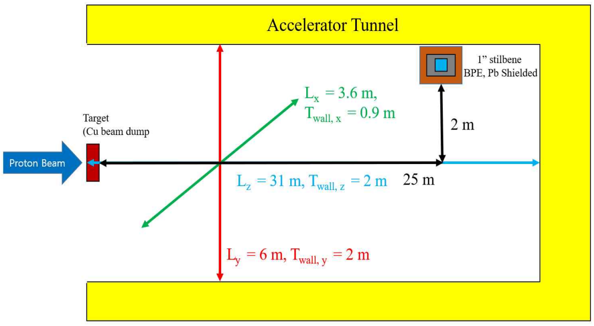

Fig. 1. Top view of geometrical configuration of the measurement setup. X,Y,Z axes are representing height, width, and length of the concrete wall respectively.

Fig. 1 briefly describes configuration of the simulation, which is constructed the same as a setup of measurement previously performed. The tunnel and objects inside the tunnel is implemented, and the concrete wall surrounding the circumstance and 1“ stilbene detector is located at 25 m, 2 m away from beam dump to x axis and y axis respectively. Proton beam is operated at 0.5 kW average power, and the detector is shielded with 5 cm Pb and 10 cm borated polyethylene blocks to minimize signal pileup from low energy neutrons and gamma rays.

2.2 Simulation Process

The simulation involves three processes: neutron generation from Cu target, neutron transport delivered to the 1” stilbene detector, and scintillation light output from the detector. Geant4 Monte-Carlo toolkit is extensively used throughout the simulation, which is the only available Monte-Carlo code that encompasses the whole processes in a single simulation. It allows the simulation can be conducted with minimal simplification and modeling.

QGSP_BIC physics model, recommended in this energy range of hadron process [1-2], is implemented for the simulation with other necessary physics processes. Scintillation pulse is collected by following procedure; neutron is generated from the target by 100 MeV proton, transported to the scintillator volume located approximately 25 m away from the dump, and finally deposits its energy on medium of the scintillator.

Fig. 2(a) shows a graph of scintillation pulses from the simulation, which is processed to rebuild a neutron spectrum histogram collected from the neutron detector. Fig 2(b) is energy histogram collected from the pulse output, which can be directly compared with an experimental neutron histogram.

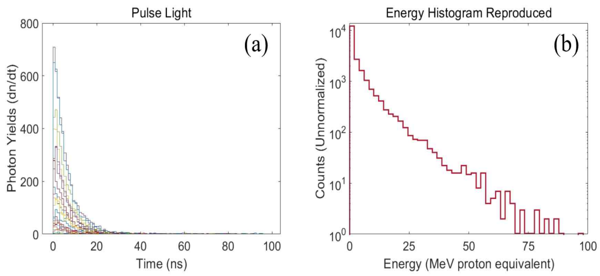

Fig. 2. (a) Sample pulse lights from the simulation. Light properties from stilbene is implemented inside the simulation. (b) Energy histogram reproduced from integrating the pulse signals collected in (a).

This approach features that it follows the same method as the experimental process of neutron detection from a scintillation detector, which enables to take account of light properties of a scintillator such as nonlinear light yield at high energy deposition and intrinsic energy resolution which possibly affects the spectrum shape.

2.3 Result Comparison

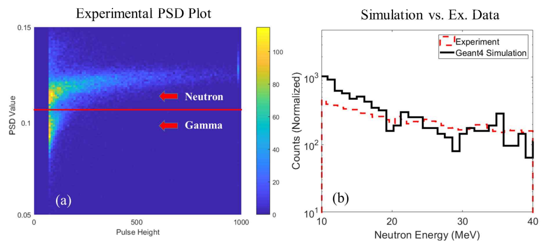

Fig. 3. (a) Measured PSD plot from an experiment of the same configuration, and (b) comparison of the energy histograms between experiment and simulation within the detectable range of experimental setup.

Fig 3(a) is data from an experimental measurement of the same configuration. Pulse light signal is evaluated with pulse shape discrimination (PSD) method, so that the unwanted signal from non-neutronic energy deposition on the scintillator can be identified and excluded. The red line in Fig 3(a) is drawn at PSD value of 0.11 to divide neutron signal from gamma signal. Pulses with more than 0.11 PSD value is considered as a neutron signal and redrawn as a neutron energy histogram.

Fig 3(b) illustrates the comparison between simulation and experimental data. Due to limitation of the experimental measurement setup, the data is only compared from 10 to 40 MeV of neutrons. The result shows rough agreement on the differential histogram shape within the detectable range under a factor of 2. The measured count rate from the scintillation detector is 300 neutron/s at 0.5 kW operation, where the simulated count rate is approximately 366 neutron/s, which is 22% difference between the two.

3. Conclusions

An integrated simulation with Geant4 Monte-Carlo toolkit is conducted to verify the measurement data to observe neutron generating behavior of the KOMAC facility. A single simulation involves consideration on neutron generation from 100 MeV proton beam, neutron transport, and stilbene detector response to the generated neutron spectrum. The result shows a certain degree of agreement with experimental neutron spectrum shape and neutron count rate, which leads to a support of previous calculation result of neutron spectrum and yield studied by Lee [3] and Yoon [4]. Thus, further study on the neutron source can be carried on with this simulation to construct a dedicated fast neutron source which will be designed and installed in KOMAC facility.

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