Simulation of quasi-mono-energetic neutron beam fluence energy distribution at the iThemba LABS time-of-flight facility

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Introduction

Many applications in nuclear physics require detail knowledge of fast neutron beams fluence energy distributions because neutron interactions with matter are energy dependent. For example, in radiotherapy for the treatment of cancer, radiation protection and calibration of detectors used for dose monitoring in space and air-crafts at research facilities such as iThemba LABS. Determining neutron beams fluence energy distributions pose a challenge. In principle, neutron beams fluence energy distributions can either be measured experimentally or calculated using Monte Carlo methods [1].

Monte Carlo codes are useful tools for the design and optimizing the neutron beam delivery system as well as neutron beams fluence energy distributions of the targets at nuclear research facilities such iThemba LABS time-of-flight facility.

In this work the Monte Carlo code MCNPX was used to simulate quasi-mono-energetic neutron beans fluence energy distribution produced at the iThemba LABS time-of-flight facility. Preliminary results obtained will be presented and discussed.

The iThemba LABS neutron beam time-of-flight facility

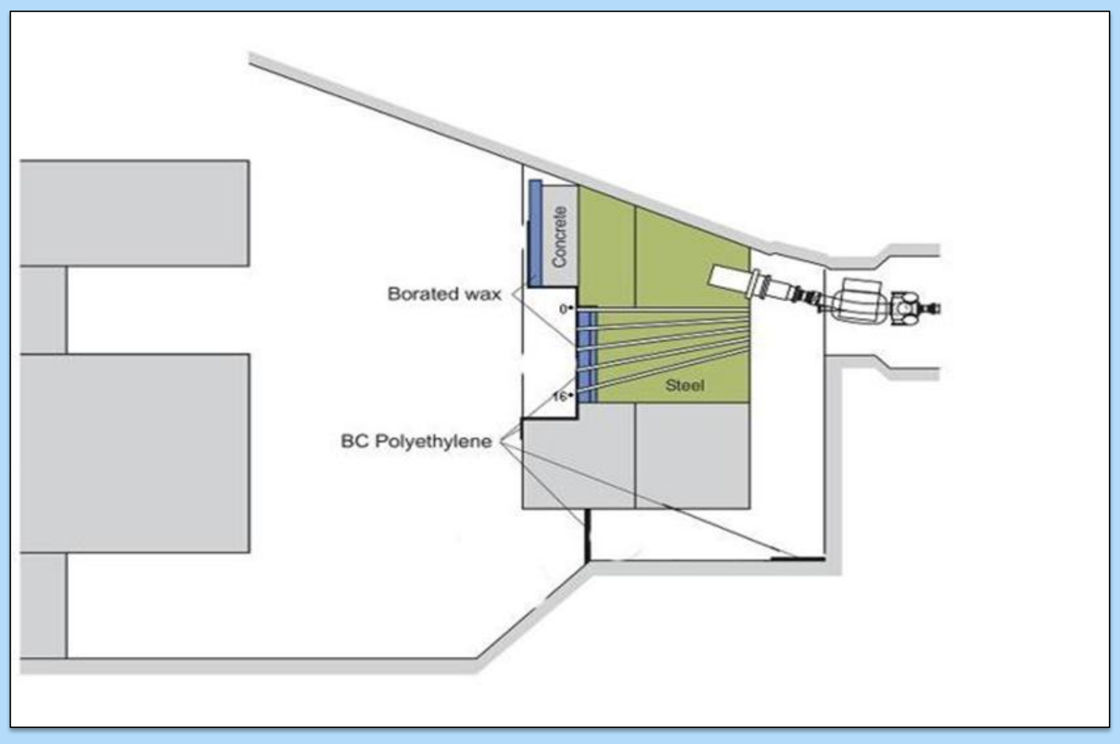

Figure 1: schematic representation of iThemba LABS time-of-flight facility

At iThemba LABS, fast neutrons are produced by bombarding different targets with proton beams of energy up to 200 MeV [2]. Neutrons are produced by reactions like $^{7}Li(p,n)^{7}Be$ and are mostly emitted in forward direction. A 2m thick steel collimator located 2m from target makes possible measurements for neutron emission angles of 0°, 4°, 8°, 12° and 16°. Protons that did not interact with the target and other charged particles are deflected by the cleaning magnet to the beam dump inside the collimator. The carbon blocks of 5 cm × 5 cm inserted at the entrance of the collimator hole absorbs the charged particles that were not deflected by the magnets. The steel collimator is lined by borated wax and Polyethylene that prevents the thermal neutrons from reaching the detector [3].

Monte Carlo Methods

A Monte Carlo method uses a numerical technique that uses random sampling to estimate the solution of a physical or mathematical problem.

MCNPX is a stochastic code developed by Los Alamos National Laboratory (LANL) created with data libraries that contains particle interactions [4]. It simulates every particle's interactions and tracks from its birth until its death or escapes the region of interest [4]. All the particle's interactions with materials are simulated according to probability distributions for energy and direction depending on the particle and material's properties.

Simulation of neutron fluence energy distributions of quasi mono-energetic beams using MCNPX

The simulations carried out in this work used the MCNPX Bertini intranuclear cascade (INC) model [5] and the LA-150 neutron and proton libraries. The geometry of the neutron time-of flight facility was replicated as closely as possible and the composition and the dimensions of materials along the beam were kept intact as far as possible. The detector assembly was modelled as a sphere with a diameter of 5.0 cm and tallying was done on the outside of the sphere using the surface tally card F4.

The simulations were carried out in two stages. First, the proton transport through the beam line onto the target was carried out and the neutrons produced were calculated at a position 1.95m along the 0^0 beam line from the target. The proton beam was modelled as a circular surface source emitting 66.0-MeV protons along the beam axis.

In second stage neutrons produced were transported along the 0^0 beam line in the position 7.71 m in the vault. The neutron source was modelled as a circular surface source (diameter 5.0 cm) with neutrons emitted along the beam axis. Stage 1 and 2 was repeated for 66 MeV protons on beam line at 16^0. Simulation were repeated for 100 MeV proton beam.

Results and Discussion

Dependence of fluence on emission angle

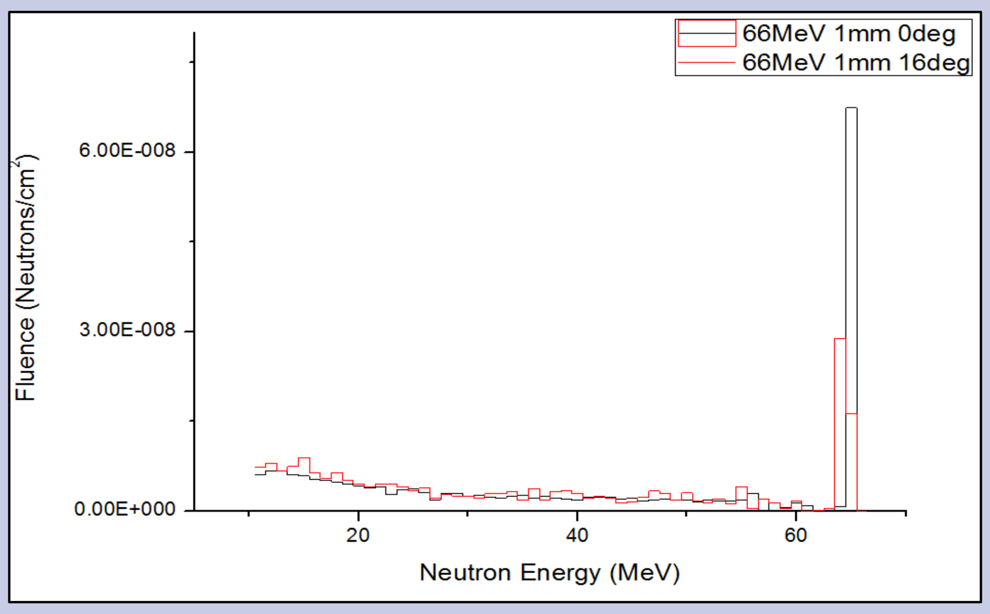

Figure 2: Neutron fluence results calculated from 0^0 and 16^0 collimator holes obtained from interaction of Lithium-7 target with 66 MeV protons.

From the above results it was observed that the peak in the neutron fluence energy distribution decreases with increasing emission angle. Also the peak broadens and shifts towards the lower energy region. Similar results was obtained for 8 mm Li target.

Neutron fluence as a function of the incident proton energy

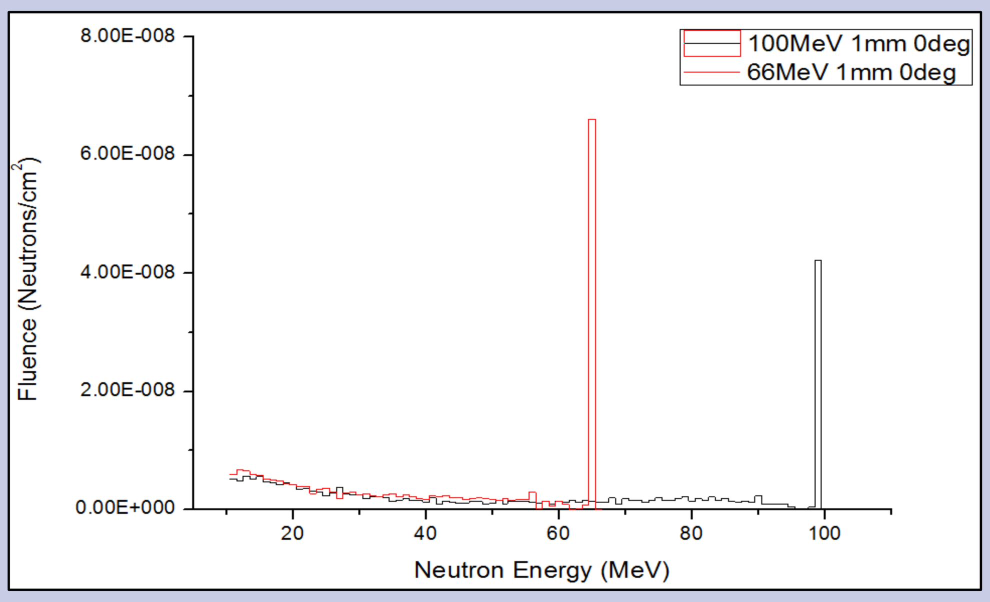

Figure 3: The neutron fluence results from the 66 MeV and 100 MeV on 1 mm and 8 mm Lithium-7 target calculated at 0 degrees collimator.

The fluence spectra follows the expected trend (peaks in spectra) at different proton energies. The spectra shows that mono-energetic neutrons were produced from 1 mm target for both 66 MeV and 100 MeV proton energies.

Dependence of fluence on the target thickness

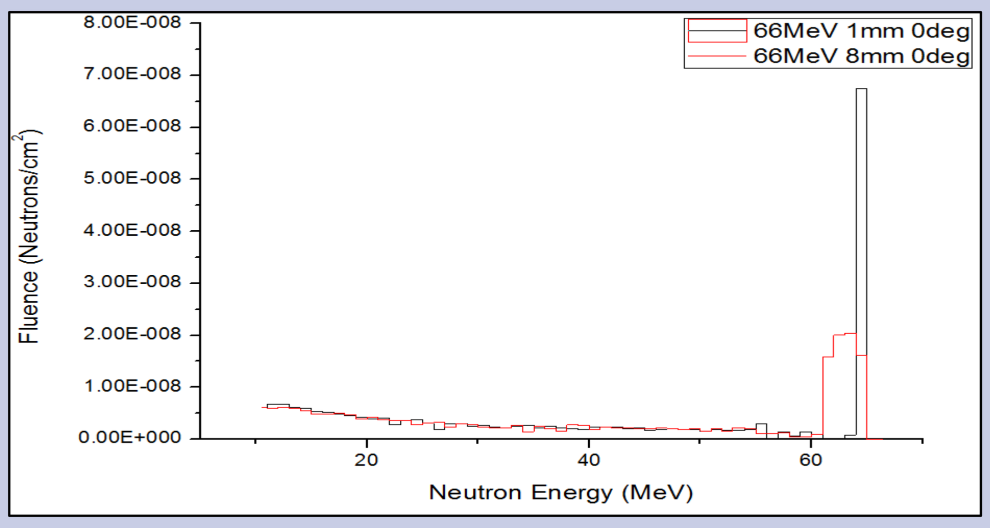

Figure 4: The results calculated from 66 MeV proton energy on 1mm and 8mm Lithium-7 target.

The peak of 8mm target is broader than 1mm target. In a thicker target there is a higher probability for protons interact with the nuclei and thus producing neutrons which covers a large range of energy. The thicker target peak slightly shifts to the lower energy region. This is because the protons loses more energy in 8 mm target than in 1 mm target.

Conclusions

The expected trends were seen in simulated neutron fluence energy distributions as predicted by physics models. The intensity of 16^0 decreases as expected. The peaks appeared at expected energies and the peak broadens as thickness increases. This preliminary results indicates the MCNPX will be reliable to predict the neutron fluence energy distributions.

References

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