Neutron ball background testing

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In the summer of 2018, the configuration of cave 4 was changed to accommodate the AGGIE spectrometer. The concrete wall shielding around the beam dump and the concrete half-wall located right behind the neutron ball were removed, and a new beam dump was designed and installed. Due to the new configuration, the neutron distribution within the cave has changed.

The neutron ball[1] is a neutron detector and is part of the NIMROD multi-detector array. It consists of six segments filled with EJ-335 (pseudocumene and mineral oil) doped with 0.25% wt Gd[2]. In NIMROD experiments, the neutron multiplicity is measured by counting the number of signals within two consecutive 100 μs gates. Understanding the background rate within each gate is essential to accurately measuring the neutron multiplicity.

Initial measurements were taken with a Ne-22 beam @ 19 MeV/nuc on the K150 beam in July (before the cave was reconfigured). Results showed a 1000 counts/sec background without beam with a 10% efficiency. Upon tuning the beam through a blank target frame, the background rate increased to ~2000 counts/sec. Results from a 5.0 mg/cm^2 Sn target showed a rate of 60,000 counts/sec.

In September, the experiment was repeated with the new configuration consisting of a new beam dump and the removal of the half-wall behind the neutron ball. The background rate without beam was still 1000 counts/sec. Initially, when the beam was tuned through the blank target, the beam on background rate was 6000 counts/sec. The Sn target produced a rate of 200,000 counts/sec with 0.3 nA on FC02. When the beam viewer was placed in the beam line, right upstream of the beam dump, it was concluded the dispersion in the x-direction was larger than the target frame at the target position. The beam viewer, located where the half-wall used to be, showed the dispersion in the x-direction was large, however it did not completely cover the viewer. The beam was re-tuned onto the beam dump without a target in the target position. The beam-on background rate was 1500 counts/sec. The beam was also tuned to align the Maryland magnet and two quadrupole magnets (in the cave) and the rate through the blank target frame was 2400 counts/sec and 3000 counts/sec for a Zn target.

The K500 was used to further test the beam dump due to the less dispersive nature of the beam. The background measurement without beam was 8,000 counts/sec at an efficiency of 55% and the beam-on background rate was 10,000 counts/sec with 600 nA on the beam dump. The neutron count was measured in six 100 μs gates. The results are seen in Table I. Each row corresponds to a different attenuation setting with no attenuation corresponding to 600 nA. The neutron gates were triggered using a Si detector. Two measurements were taken for the 1 x 10^{-2} attenuation setting, corresponding to the phase shifter being turned off and on.

Table I. Neutron count in six consecutive 100 μs gates triggered by an event in a Si detector. Results show a large initial neutron rate followed by a large asymptotic drop off. The last column is the difference between the 1st window and the average of the next 5.

Neutron Count							
Attenuation	1st window	2nd window	3rd window	4th window	5th window	6th window	$\Delta x = (x_1-(\overline{x_{2-6}}))$
1×10^{-2}	10.96 ± 0.15	2.35 ± 0.09	2.13 ± 0.08	2.00 ± 0.08	1.91 ± 0.08	2.16 ± 0.10	8.85 ± 0.17
10^{-2} - ps off	11.02 ± 0.11	4.39 ± 0.11	4.36 ± 0.11	4.22 ± 0.11	3.90 ± 0.09	4.18 ± 0.11	6.81 ± 0.14
3×10^{-3}	9.63 ± 0.24	1.77 ± 0.12	1.84 ± 0.16	2.29 ± 0.22	2.00 ± 0.18	1.91 ± 0.19	7.67 ± 0.30
1×10^{-3}	9.02 ± 0.17	2.21 ± 0.17	2.15 ± 0.16	2.20 ± 0.16	2.14 ± 0.16	1.84 ± 0.13	6.91 ± 0.23
3×10^{-4}	8.56 ± 0.24	1.76 ± 0.17	2.14 ± 0.22	1.97 ± 0.27	1.84 ± 0.17	1.82 ± 0.20	6.65 ± 0.32

Beam shielding studies were performed looking at the effect of adding bags of borated polyethylene (“green board”) shavings around the beam pipe right upstream of the beam dump. Table II shows the results in the first two 100 μs gates. The results shown are for no shielding, one layer (3 bags) of green board shavings, 2nd layer around initial layer and a layer upstream, a 2nd layer around the more upstream layer, and a lead brick wall. The lead wall was placed right upstream from the 2nd layer of green board shavings. The results indicate adding layers of green board shavings decreases the neutron rate slightly. The addition of a lead wall did increase the rate in the 1st 100 μs gate, which does not rule out the possibility that the beam is hitting the pipe upstream of the wall. It is believed that the increase in neutron count after the lead brick indicates gamma rays produced from neutron capture is not a large contributor in the neutron ball background rate.

Table II. Results for beam shielding studies. The 1st column consists of the neutron count in the first 100 μs gate and the 2nd column is the neutron count in the 2nd 100 μs gate.

Beam Shielding Effects - Neutron Count		
Beam Shielding	1st window	2nd window
No shielding	8.86 ± 0.13	2.89 ± 0.16
1 layer of green board bags	8.76 ± 0.07	2.63 ± 0.07
2nd layer of bags and 1 layer upstream	8.67 ± 0.12	2.35 ± 0.10
2nd layer of bags upstream	8.48 ± 0.11	2.58 ± 0.12
Lead brick wall upstream of bags	8.80 ± 0.08	2.61 ± 0.09

The neutron ball background rate was characterized for the new cave 4 configuration and beam shielding studies were conducted. The results indicate that the beam dump is successful at thermalizing and capturing neutrons. However, the neutron rates indicate that the beam is hitting the beam pipe, creating a larger background rate than the previous configuration. We are studying how to mitigate these issues.