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Measurements of Photoneutron Spectra from Thick Pb Target Bombarded by 1.2 and 2.0 GeV Electrons

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Abstract

Photoneutron spectra were measured using the TOF method when thick targets were bombarded by high-energy electrons. At the ATF Linac in KEK, 1.2 GeV electrons bombarded a thick Pb target. At the injection Linac of the Pohang Accelerator Laboratory, 2.04 GeV electrons were used. The detector was 5.6 m distant from the target. Several detectors were tested. Neutrons toward 90 degrees from the target were measured up to 150 MeV at the ATF, and 200 MeV at PAL. Calculations of neutron energy spectra were also done using PICA3 and EGS4.

1 Introduction

There are only a few measurements of photoneutron energy spectra from thick targets of high-energy electrons. The highest energy of those experiments was 0.27 GeV [1], and the long flight path, 25-m, was needed in the TOF measurements because of the strong background of electrons and photons.

We started the measurements[2] in Jan. 1996 at the Accelerator Test Facility (ATF) in KEK. The 1 GeV electrons hit 2cm-thick Pb targets. Several detectors were tested. The plastic scintillator with Pb collimator was calibrated using quasi-monoenergetic neutron sources between 5 and 132 MeV. Neutrons toward 90 degrees were measured by the TOF method at the ATF. Because the shielding concrete around the target was not thick enough, the background was large in the measurements. At the Linac of the Pohang Accelerator Laboratory (PAL) in POSTECH, 2.04 GeV electrons were used and the target was placed in well shielded beam dump room. Neutron spectra up to 200 MeV were measured at PAL[3,4].

2 Experiments using 1.2 GeV electrons at the ATF in KEK

At the Linac of the ATF in KEK, the 1-m-thick overhead concrete shields were drilled and a 16cm-diameter collimator was placed. The liquid scintillator, 5"Diam.x5" BC501A, was placed at the exit of the collimator because the neutron detection efficiency of the BC501A detector was well known. But the dead time of the detector was long after the strong pulsed X-rays. Next, 5"-diam.x1" NE102A plastic scintillator was used to reduce the dead time. The situation became better. Because the overhead concrete shield of the ATF is only 1-m thick, additional Pb collimator was needed surrounding the detector, and its shape was not suitable to place in the collimator.

Finally 51mm-diam.x49mm-long PILOT-U (BC418) scintillator was used. It was surrounded by the 40-cm long Pb collimator. The efficiency of the detector without the collimator was calculated by SCINFUL and Cecil's code. The collimator affected the neutron detection efficiency. It was calibrated using quasi-monoenergetic neutron sources, 132, 86.5 and 66 MeV at RRC in RIKEN, 64.7MeV at TIARA in JAERI, 33.0 MeV at CYRIC in Tohoku Univ., and 14.9 MeV at OKTAVIAN in Osaka Univ., 5 MeV at the FNL in Tohoku Univ. It was found the efficiency was not affected by the collimator when the pulse height discrimination level of the detector was high. But the discrimination level was low, 1.1 MeVee, at the ATF, and measured detection efficiency was used.

The experimental setup at the ATF is shown in Fig.1. The detector in Pb collimator was placed on the top of the tower 2.5 m high. The detector was 5.6 m distant from the target. To suppress X-rays, several thicknesses of Pb blocks were placed in the middle point of the flight path between the target and detector. Some neutrons were scattered in these Pb blocks, and these effects were evaluated using LAHET 2.7[6]. The beam frequency was 6 Hz and the pulse width was 0.02 ns, and the rf timing signal was used for the start signal. The TOF spectra were measured using 2 GHz multi-channel scaler. Preliminary results are shown in Fig.2 when 1.2 GeV electrons hit 5x5cm-wide and 2cm-thick Pb target placed in the vacuum chamber in the Linac tunnel. The 15-cm-thick Pb blocks were placed on the flight path. The bar in Fig.2 shows only counting statistical errors. The beam intensity was reduced to minimize the dead time and was approximately 50 pC/pulse. This was far from the normal operation condition of the Linac, and the beam status was not accurately known. Background was estimated from the measurements using 35-cm-thick Fe and 20-cm-thick Pb. Neutrons up to 150 MeV were measured at the ATF.

Calculations of neutron energy spectra were also done. Photon track length in the target was calculated using EGS4. Photo-nuclear cross sections were evaluated using PICA3 code[5]. Transport of secondary neutron and pion etc. was calculated by LAHET 2.7[6]. The calculated results are shown in Fig.2. Though the measured results were not accurate due to large background and uncertainty of the detection efficiency and the beam condition of the Linac, calculated results were smaller than measured ones.

3 Experiments using 2 GeV electrons at PAL

In 1998, the TOF beam line was newly constructed at PAL. The flight path length was the same as that in the ATF, and was 5.6 m. But the overhead shielding concrete was 2.2m thick. So the background was reduced. The experimental setup at PAL[3,4] is shown in Fig.3. The discrimination level of the detector was 4.2 MeVee. The collimator did not affect the detection efficiency and the dead time of the counter after the pulsed X-rays became smaller. The results are shown in Fig.4 when 2.04 GeV electrons hit 5x5cm-wide and 5.5cm-thick (10-radiation-length) Pb targets. The beam frequency was 10 Hz and the pulse width was about 1 ns. The start signal was given from a beam-current monitor. The beam intensity of each pulse was about 500pC, and higher than that at the ATF. So thicker Pb blocks, 15-30 cm, were placed in the middle of the flight path to suppress X-rays. These Pb blocks also reduced neutrons toward the detector, and this effect was evaluated using LAHET 2.7[6]. Even in such a case, the background neutrons and photons were small because the target was well shielded except the flight path.

4 Summary

We started the measurements of photo-neutron spectra toward 90 degrees from thick targets of 1.2 and 2 GeV electrons. Neutrons between 10 and 200 MeV were measured. The experimental setup was smaller compared to the previous one at 0.3 GeV[1].

The neutron spectra were calculated using EGS4/PICA3[5]/LAHET2.7[6]. Calculated ones tend to underestimate the measured ones. More experimental data were needed for different angles and energy range.

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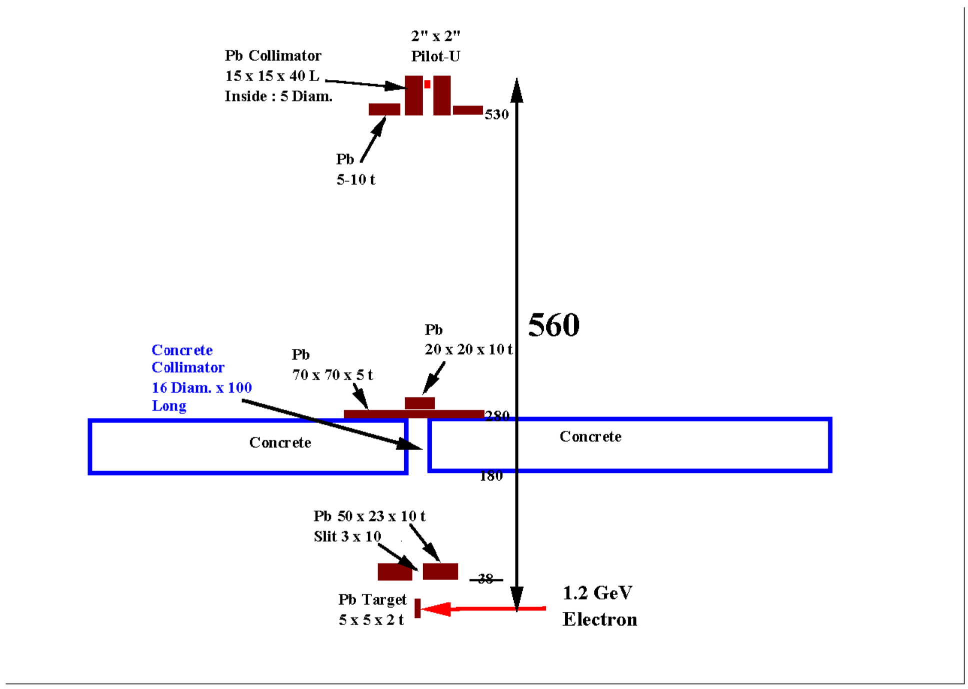

Figure 1: Experimental setup at the ATF when 1.2 GeV electrons irradiated 2-cm-thick Pb target.

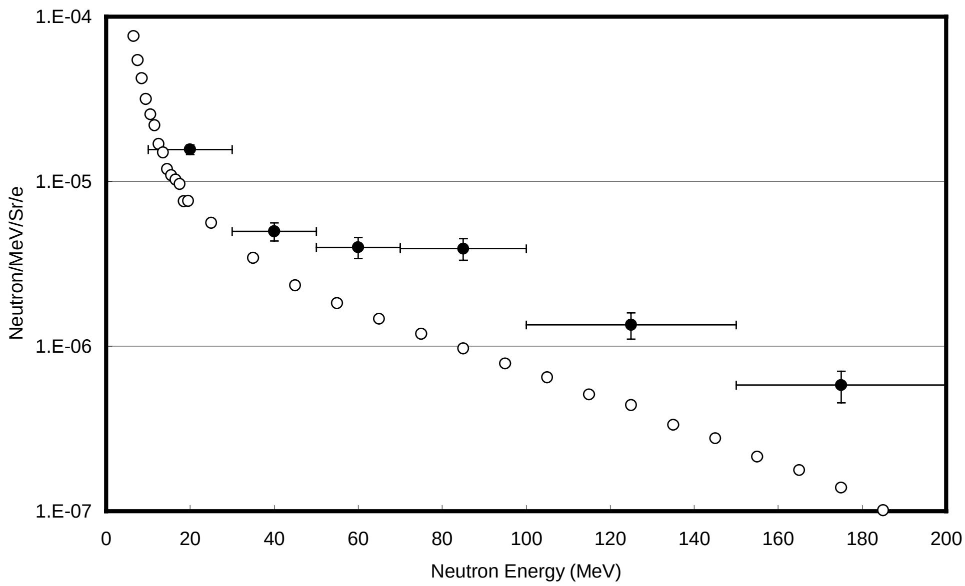

Figure 2: Preliminary results of neutron spectra toward 90 degrees from 2-cm-thick Pb target irradiated by 1.2 GeV electrons. Full circle: Measured at the ATF. Open circle : Calculated using EGS4/PICA3[5]/LAHET2.7[6].

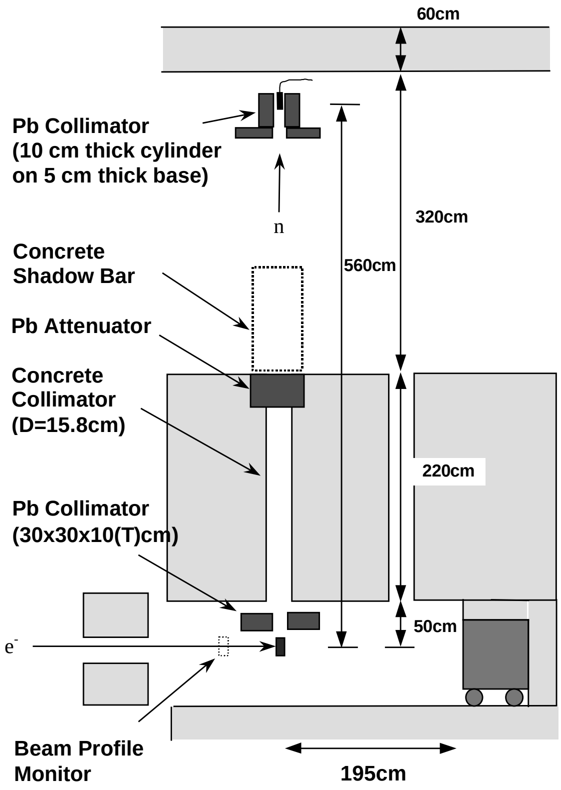

Figure 3: Experimental setup at PAL when 2.04 GeV electrons irradiated Pb targets[3,4].

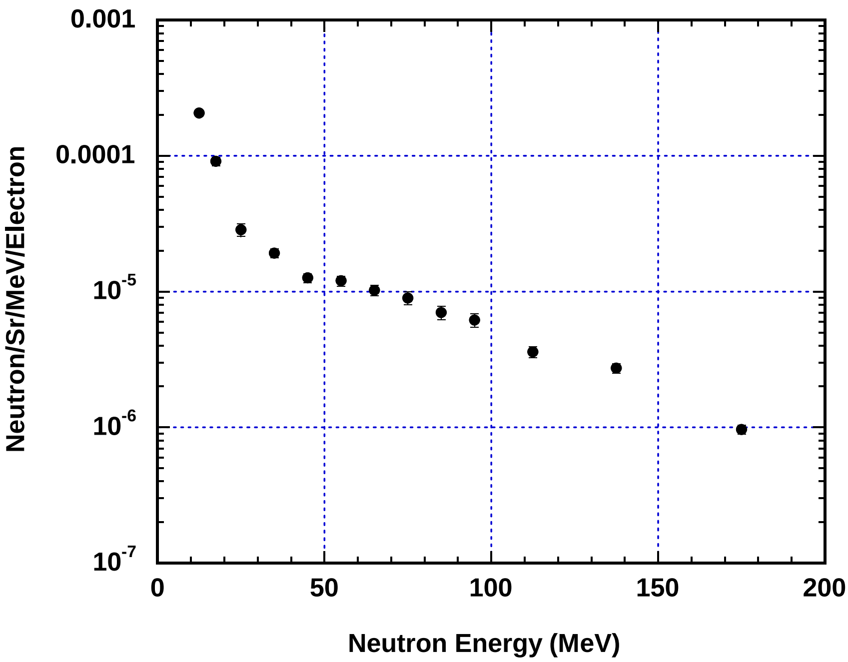

Figure 4: Measured neutron spectra toward 90 degrees from 5.5-cm-thick Pb targets irradiated by 2.04 GeV electrons.