Response of a BaF_2 scintillation detector to quasi-monoenergetic fast neutrons

K. Gunzert-Marx [1], D. Schardt [1], R.S. Simon [1], F. Gutermuth [1], T. Radon [1], V. Dangendorf [2], R. Nolte [2]

[1]GSI Darmstadt, Germany; [2]PTB Braunschweig, Germany

Bariumfluoride scintillation detectors are widely used for the detection of high-energy photons because they offer a high detection efficiency as well as a good energy and time resolution. The response of BaF_2-detectors to fast neutrons has been studied in the past only in neutron fields with broad energy ranges or in mixed fields (neutrons and charged particles) produced in high-energy heavy-ion reactions. In this work we studied for the first time the response of a BaF_2-detector to quasi-monoenergetic neutron beams, using five different energies in the range from 45 to 198 MeV.

The experiments were performed at the neutron beam facilities of the Université Catholique de Louvain (UCL) in Belgium and of the iThemba LABS in South Africa. At both facilities the $^{7}Li(p,n)^{7}Be$-reaction was used to produce beams of quasi-monoenergetic neutrons. The maximum proton energy available was 70 MeV at the UCL-cyclotron and 200 MeV at the iThemba-cyclotron. The proton beam and charged fragments behind the ^{nat}Li-target were deflected by a dipole magnet and the neutron beam was collimated by a thick concrete/iron block. The neutron fluence was measured with a proton recoil telescope [1] relative to the np-reference cross section and transferred via calibrated neutron monitors to the measurement with the BaF_2-detector.

A time-of-flight spectrum obtained in our measurements at iThemba LABS is shown in Fig.1. The neutron field is characterized by a sharp peak corresponding to an energy of 147 MeV and a low-energy tail of slower neutrons. The time resolution (0.46 ns) is obtained from the prompt photon peak. The main neutron peak shows a width of 0.52 ns FWHM.

By defining a gate condition on the peaks in the neutron energy spectra the BaF_2 pulse-height spectra associated with quasi-monoenergetic neutrons were accumulated in the off-line data analysis. An example is shown in Fig.2 together with a Monte-Carlo simulation performed with the particle transport code FLUKA [2].

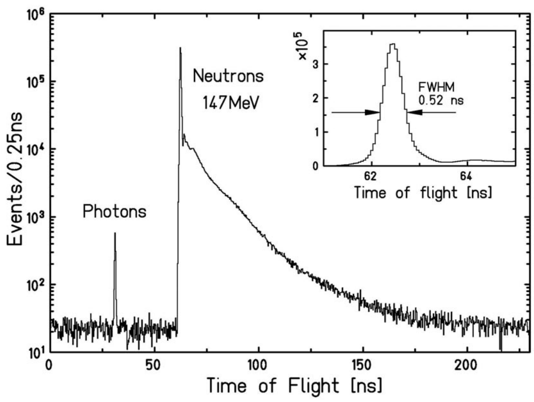

Fig.1. Time-of-flight spectrum measured with a BaF_2-detector in the 147 MeV neutron field at iThemba LABS.

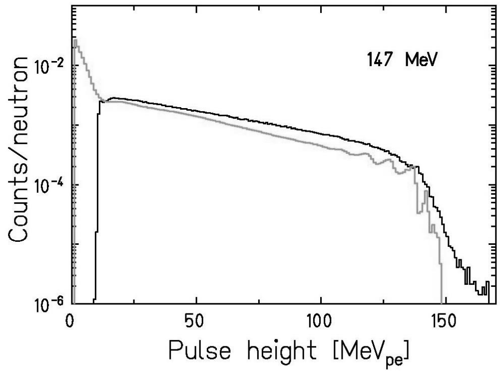

Fig.2. Measured pulse-height spectra (black histogram) of the BaF_2-detector in response to 147 MeV monoenergetic neutrons. Monte-Carlo simulations with the particle transport code FLUKA are shown for comparison (green histogram).

The neutron detection efficiency of the BaF_2-detector is shown in Fig.3 as a function of neutron energy for an electronic threshold of 10 MeV_{pe}. At low neutron energies the efficiency increases rapidly with energy and reaches above 100 MeV a plateau value of about 20%. This value is higher than the efficiency of an NE213 liquid scintillation detector of comparable size and makes the BaF_2-detector attractive for the detection of high-energy neutrons. In recent measurements at GSI it was used for the characterization of the secondary fast-neutron component in therapy irradiations with carbon beams [3].

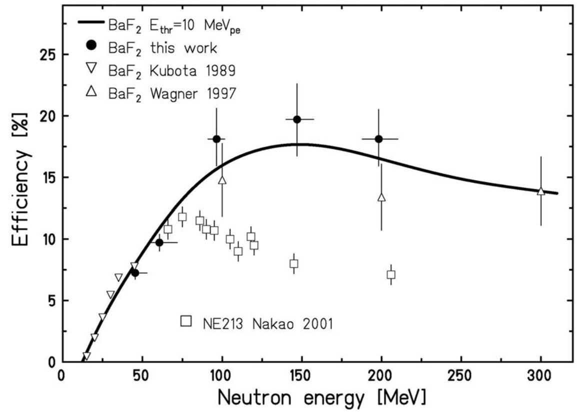

Fig.3. Measured neutron detection efficiency of various BaF_2-detectors and an NE213-detector vs. neutron energy. The solid line represents a manually averaged 'universal' BaF_2 efficiency curve.

References

[1] V. Dangendorf et al. Nucl. Instr. and Meth. A469 (2001) 205.

[2] A. Fasso et al., Monte-Carlo 2000 Conf., Lisbon, Oct.2000.

[3] K. Gunzert-Marx et al., contribution to this report.