Development of Neutron-Time-of-Flight Detectors for the Investigation of Astrophysically Relevant (γ,n) Reactions

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Experimental Setup and Data Acquisition

Neutron detectors are required for future experiments at the new bremsstrahlung facility [1] and the neutron-time-of-flight source [2] at the superconducting electron accelerator ELBE (Electron Linear Accelerator with high Brilliance and low Emit-tance). Three different types of scintillation detectors were investigated for their capability of detecting fast neutrons in an energy range from a few tens of keV up to several MeV [3].

All scintillators were attached to Hamamatsu R2059-01 photomultiplier tubes (PMT). The detector signals were processed by very fast CFDs with a walk of only 400 ps for amplitudes from 1 V down to 10 mV. The data acquisition was assembled by VME electronics using QDCs (CAEN V792) and a Multi-Hit/Multi-Event TDC (CAEN V1190A) to measure correlated energy and time information of ten detectors and to store it in list mode files. The data acquisition was controlled using a Rio3 Power PC running the GSI MBS program.

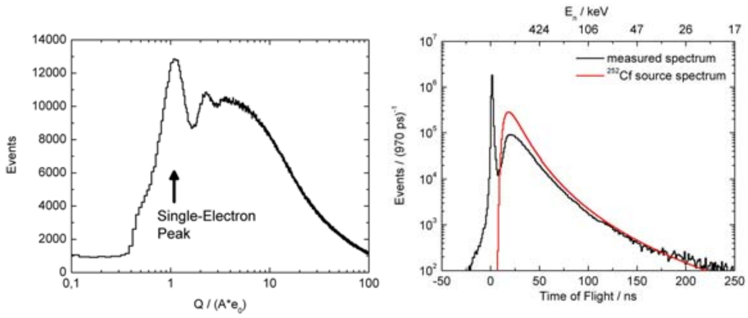
The properties of the detectors (efficiency and time resolution) were determined by means of a ^{252}Cf neutron source.

Material	Dimension / mm $t \times w \times l$ or $\varnothing \times t$	Density of neutron sensitive nuclei	Time resolution (FWHM)	Efficiency at E_n=50 keV
Plastic (EJ-200)	11 x 42 x 125 11 x 42 x 250 11 x 42 x 1000	^{1}H: 5 x 10^{22} cm^{-3}	0.67 ns	90 %
Li-glass (GS20)	46 x 10 46 x 25	^{6}Li: 7 x 10^{21} cm^{-3}	1.0 ns	2 % 5 %
ZnS(Ag) (BC-702)	46 x 6	^{6}Li: 9 x 10^{20} cm^{-3}	2.4 ns	0.6 %

Properties of the different scintillators.

Plastic Scintillators

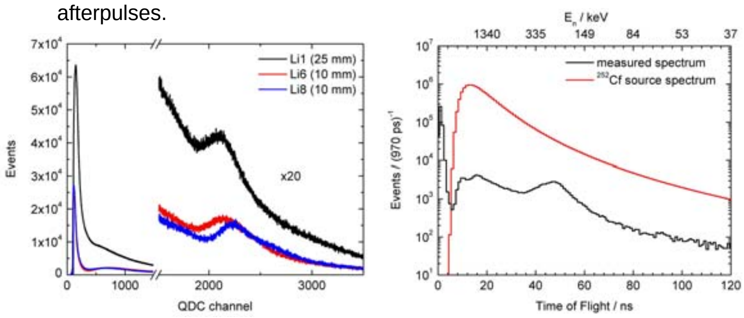
The neutrons are detected via proton recoil. By using two PMTs per scintillator strip, one at each end, a position information of the detection reaction as well as a reduction of the background caused by the dark current of the PMTs are obtained. The neutron detection threshold can be lowered down to a few tens of keV by triggering just below the single-electron peak and requiring a coincidence between the two PMTs.



Left: *QDC spectrum of the plastic scintillator in dependence on the collected charge Q over the amplification A and the electron charge e_0 with the well visible single-electron peak.* *Right:* *Comparison of the measured time-of-flight spectrum of a ^{252}Cf source and the expected source spectrum for the determination of the detection efficiency of the plastic scintillator detector.*

Li-Containing Scintillators

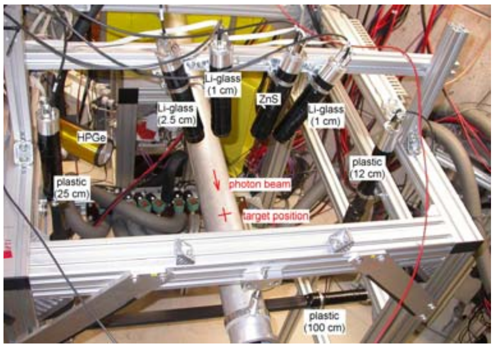
The Li-glass detectors are based on the reaction ^{6}Li$(n,\alpha)t$, which has a positive Q-value of 4.8 MeV. The Q-value can be used to reduce the background of low energy photons as well as events caused by PMT afterpulses.



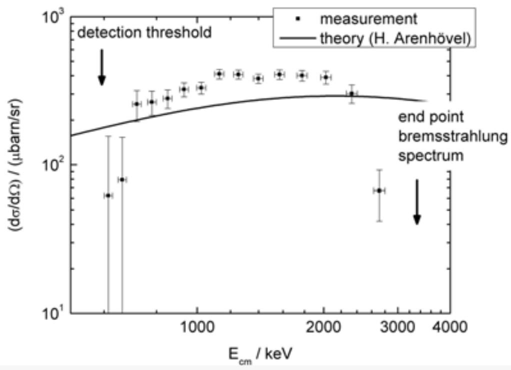
Left: *QDC spectrum of the Li-glass detectors with the "Q-value peak" of the neutron detection reaction.* *Right:* *Comparison of the measured time-of-flight spectrum of a ^{252}Cf source and the expected source spectrum for the determination of the detection efficiency of the Li-glass detector.*

The ZnS detectors use the same detection reaction as the Li-glass detectors but offer the possibility of pulse shape discrimination by means of a long-gate-short-gate QDC measurement to lower the background of photons by 3 orders of magnitude while neutron events stay unaffected.

Test Measurement of the Photodisintegration of the Deuteron, $d(\gamma,n)p$



The different detector types, installed in the set-up for the test measurement of the photodisintegration of the deuteron. Targets of 5 g CD_2 and 5 g CH_2 were irradiated by bremsstrahlung produced by an electron beam of E_{kin}= 5.5 MeV and I = 90 μA. The photon flux of ca 1.5 s^{-1} cm^{-2} eV^{-1} was determined by detecting photons scattered from a 5 g ^{11}B target by means of a HPGe detector.



Measured differential cross section of $d(\gamma,n)p$ in comparison to theoretical calculations of H. Arenhövel [4]. (The error bars do not include the uncertainty of the determination of the photon flux.)

References:

[1] R. Schwengner, R. Beyer et al., NIM A 555 (2005) 211

[2] J. Klug, E. Altstadt et al., Contributed paper to New Trends in Nuclear Physics Applications and Technology, European Physical Society, Pavia, Italy; European Physical Journal A (to be published)

[3] R. Beyer, Diplomarbeit (2005), http://www.db-thueringen.de/servlets/DocumentServlet?id=5298

[4] H. Arenhövel, Johannes Gutenberg-Universität Mainz, Institut für Kern- und Hadronenphysik, private comunication

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