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Institut für Angewandte Kernphysik
Projekt Schneller Brüter

A Facility for the Measurement of Fast Neutron Fission Cross Sections Using an Intense Cyclotron Neutron Source

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ABSTRACT

A facility for the study of fission ratios and fission cross sections in the energy range between 0.5 and 30 MeV is described. For the production of a pulsed neutron beam with a continuous energy spectrum the Karlsruhe isochronous cyclotron is used. The fission fragments are detected by a gas scintillation counter arrangement consisting of nine fission detectors in series. For data acquisition a CDC-3100 on-line computer is used. The principle features and operating characteristics of the facility are described and first results of a measurement on ^{238}U are given.

ZUSAMMENFASSUNG

In diesem Bericht wird eine neu erstellte Flugzeitanordnung zur Bestimmung von Spaltquerschnitten und Spaltquerschnittsverhältnissen im Energiebereich zwischen 0.5 - 30 MeV beschrieben. Einen gepulsten Neutronenstrahl mit kontinuierlichem Energiespektrum liefert das Karlsruher Isochron Zyklotron. Der Nachweis der Spaltprodukte erfolgte am Ende eines 58 m langen Flugwegs mit Hilfe einer Gasszintillator-Anordnung. Diese besteht aus neun hintereinander geschalteten Detektorkammern. Die Datenerfassung geschieht on-line mit Hilfe einer CDC-3100-Rechenanlage. Es werden die charakteristischen Eigenschaften der Meßanordnung beschrieben und erste Ergebnisse einer Messung an ^{238}U gezeigt.

1. INTRODUCTION

Most of the fission ratios and fission cross sections have been measured in the past with monoenergetic neutrons, usually using Van-de-Graaff accelerators and charged particle reactions on light nuclei. However, a systematic study of the energy dependence of these quantities over as wide an energy interval as from several hundred keV to 10 - 15 MeV which is required for fast reactor calculations is very time-consuming. In addition, most of these measurements can cover only part of the total energy region of interest. The use of a pulsed cyclotron neutron source, however, allows such measurement with high resolution over the total energy range in a single experimental run.

This paper describes a facility newly designed for the study of fission ratios and fission cross sections using the Karlsruhe isochronous cyclotron. Some of the principle features and operating characteristics are shown.

2. DESCRIPTION OF THE TIME-OF-FLIGHT FISSION DEVICE

The experimental equipment consists of an improved gas scintillation fission detector arrangement used in conjunction with the Karlsruhe fast neutron time-of-flight facility described in ref. 1. A simplified top-view of the geometric arrangement is shown in Fig. 1. The Karlsruhe isochronous cyclotron is used to provide a pulsed neutron beam with a continuous energy spectrum in the range from about 0.3 to 30 MeV and a burst width of 1 nsec. Neutrons are produced by bombardment of a natural uranium target with 45 MeV deuterons from the internal beam of the cyclotron. With the new deflection bunching system the time-of-flight facility can be operated with a pulse recurrence frequency variable from 0 to 200 kHz. To avoid overlap problems in the fission cross section measurements, a flight path of 58 m and a neutron pulse repetition rate of 100 kHz are chosen.

A. Fission Detector

For the detection of fission fragments an arrangement of nine gas scintillation chambers in series as shown schematically in Fig. 1 is used. In its first form the fission detector arrangement was suggested by E. Pfletschinger and F. Käppeler [2]. The scintillation chambers were made of bronze, 0.4 mm thick. Silver and aluminium were evaporated on the walls as reflector materials. A mixture of 85 % argon and 15 % nitrogen continuously flowing through the detector served as scintillator. Each scintillation chamber [Fig. 3] is separated from its neighbors by a metallized sample to obtain optically decoupled systems and is viewed by one 56 DUVP Valvo photomultiplier tube. A typical pulse height spectrum obtained with a ^{252}Cf source from one of the fission chambers is shown in Fig. 2. Good separation is observed between the α-peak [attenuated by a factor of 50] and the distribution of the fission fragments, so that fission and background events can be well distinguished. For accurate timing each detector was provided with a zero-crossing time mark discriminator [3]. The time resolution of the single chambers was measured using the prompt γ-rays and the corresponding fission events occurring in the fission of ^{252}Cf. The γ-rays were detected with a plastic scintillation counter. An overall time resolution of about 4 ns was measured for all fission chambers. The fission samples used in the first run each consisted of a thin layer of uranium acetate, 70 mm in diameter, [7 samples containing 99,96 % enriched ^{238}U and 1 sample of 99,5 % ^{235}U]. The sample layers were deposited by electro-spraying on 130 μg/cm^2 vyns foils, metallized by 20 μg/cm^2 Al as described by Verdingh and Lauer [4]. The preparation of the fissile samples was performed at the CBNM, Geel/Belgium. This laboratory will also perform an accurate mass determination after the experiments.

B. Data Acquisition

A simplified block diagram of the data acquisition system is shown in Fig. 4. In each chamber of the fission detector fission fragments with a particle energy higher than 15 MeV are detected from both adjacent foils. A 5 nsec coincidence between the pulses from two neighboring fission chambers is registered as a fission event. The corresponding eight time-of-flight spectra are separately accumulated in 2048 channels of a CDC-3100 on-line computer and are sequentially stored on a magnetic disc. The data acquisition system additionally includes a second branch for simultaneously measuring the neutron flux. This is accomplished by two different systems: a neutron double time-of-flight system and a proton counter telescope. Both systems are intended to normalize the fission cross section to the well known n-p scattering cross section. In Fig. 4 the double time-of-flight device is schematically indicated at the right. The time-of-flight spectrum from the scatterer and the pulse height spectrum from the time-to-amplitude converter are recorded simultaneously.

3. EXAMPLES OF OPERATION

A first measurement of the fission cross section of ^{238}U is just now being finished. In this measurement, fission samples with a layer of about 1,2 mg/cm^2 of ^{238}U acetate and ^{235}U acetate were used. Typical time-of-flight spectra for the fission events and the double time-of-flight n-p scattering events are shown in Figs. 5a, b. The data shown in the upper curve result from $\sim$100h of singles counting in the first seven fission chambers. These data which represent the fission yields folded with the neutron spectrum show the well-known steps in the fission cross section of ^{238}U near 25, 15, 7 and 2 MeV. The deviation of the time-of-flight spectrum for the n-p scattering events from a smooth curve is mainly due to the flux depression in the n-p scatterer and the efficiency curve of the neutron detector.
Although relatively thick samples were used, it is intended to determine the fission cross section of ^{238}U relative to ^{235}U as well as relative to the n-p scattering cross section.

Summarizing, it is shown that the cyclotron technique allows the rapid accumulation of fission events with high energy resolution over a wide neutron energy range. Experimental data have been taken from which fission ratios $\sigma_f\,[^{238}U]/\sigma_f\,[^{235}U]$ as well as absolute fission cross sections will be determined.

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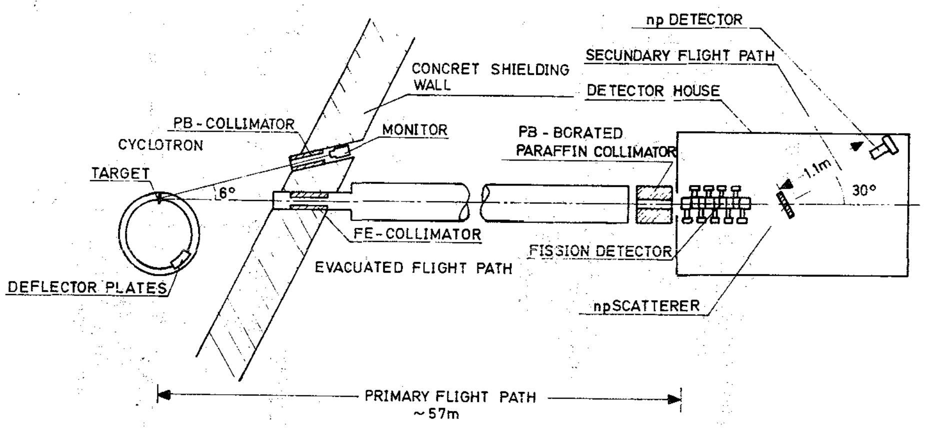

Fig. 1 Geometry of the experimental equipment

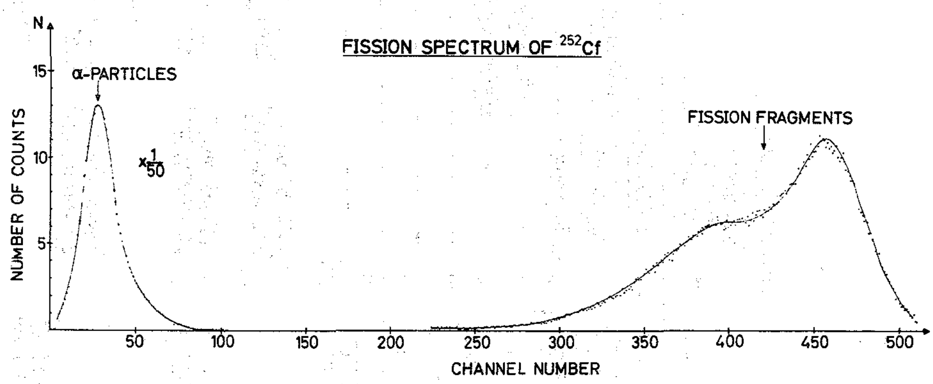

Fig. 2 Pulse height spectrum obtained with a ^{252}Cf source

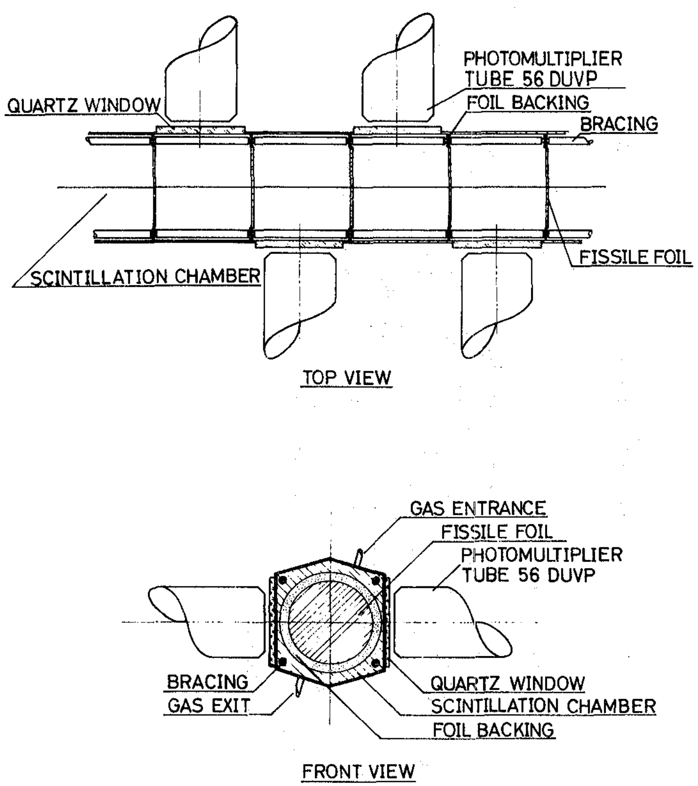

Fig. 3 Simplified drawing of the fission detector

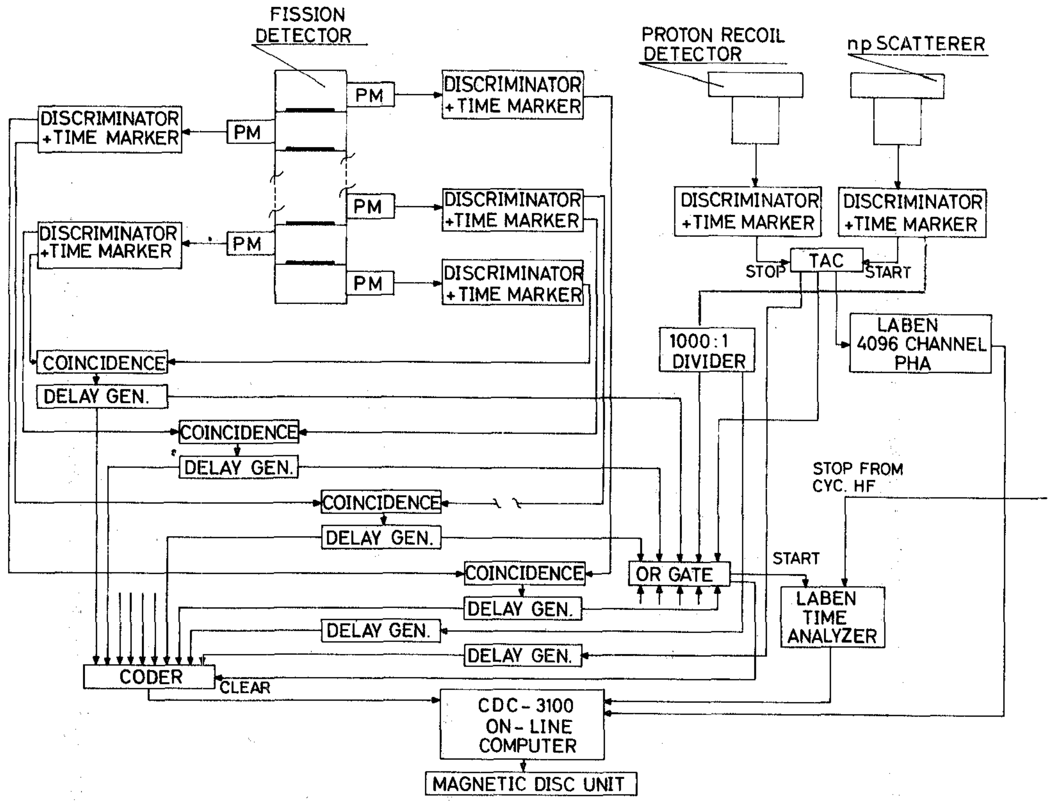

Fig. 4 Block diagram of the data acquisition system

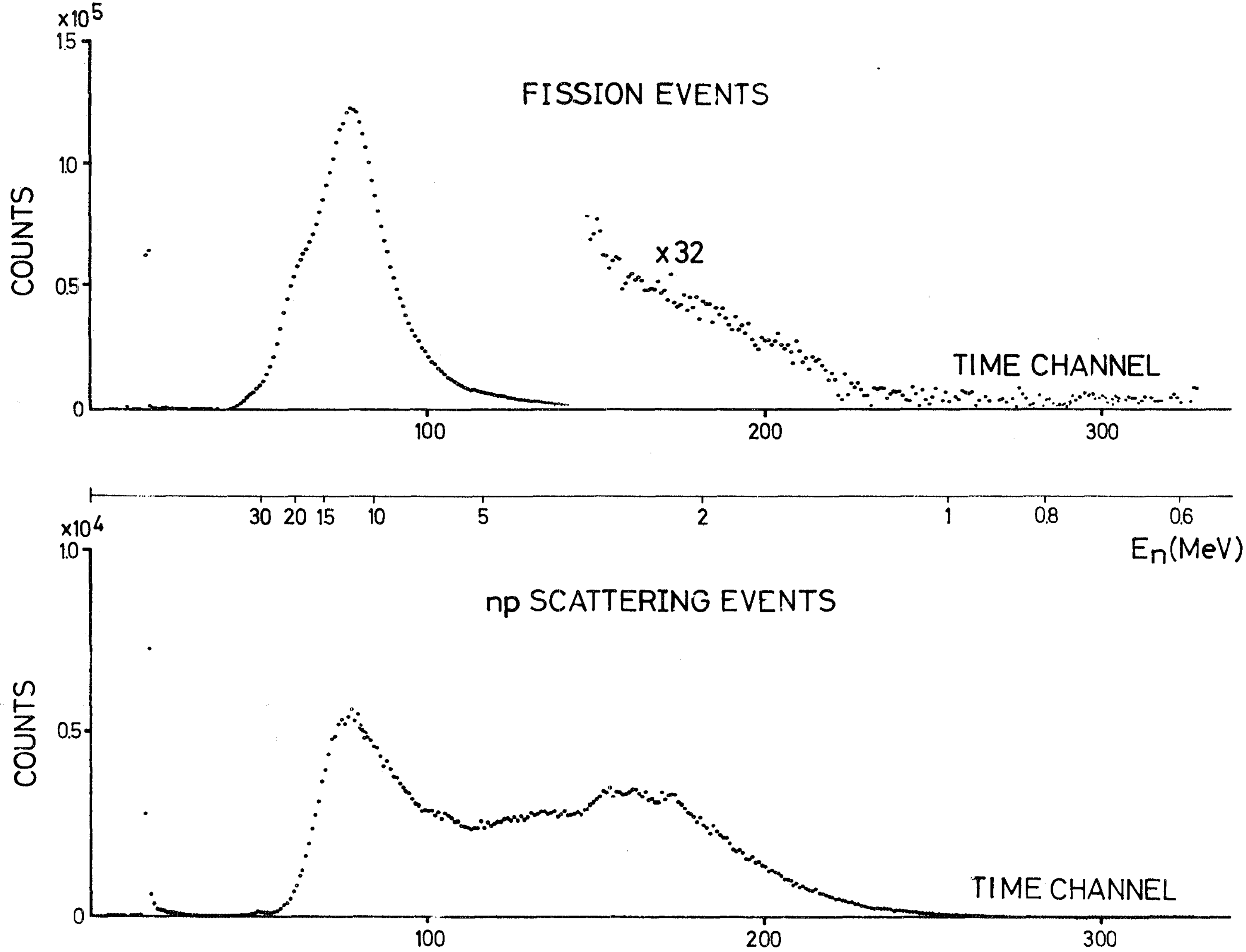

Fig. 5 Time-of-flight spectra obtained with a] fission events, b] n-p scattering events