KERNFORSCHUNGSZENTRUM

KARLSRUHE

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Institut für Angewandte Kernphysik
Projekt Schneller Brüter

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ABSTRACT

The fission cross section of ^{235}U has been measured at two neutron energies using a gas scintillation chamber for registrating the fission events and a telescope-like proton recoil detector for determining the neutron flux. The neutrons were produced via the $^7Li(p,n)^7Be$ reaction at the Karlsruhe 3 MV pulsed Van de Graaff accelerator. The time of flight method served for background discrimination. At 440 ± 25 keV neutron energy the result was σ_f = 1.17 barns ± 3.5 % and at 530 ± 30 keV σ_f = 1.17 barns ± 3.5 %.

ZUSAMMENFASSUNG

Der Spaltquerschnitt von ^{235}U wurde für 2 Neutronenenergien gemessen. Die Spaltereignisse wurden in einem Gasszintillationszähler nachgewiesen und der Neutronenfluß mit einem teleskop-ähnlichen Protonenrückstoßdetektor bestimmt. Als Neutronenquelle wurde am gepulsten 3 MV Van de Graaff-Beschleuniger in Karlsruhe die $^7Li(p,n)^7Be$-Reaktion verwendet. Mit Hilfe der Flugzeitmethode wurde gegen Untergrund diskriminiert. Das Ergebnis war für 440 ± 25 keV σ_f = 1.17 barns ± 3.5 % und für 530 ± 30 keV σ_f = 1.17 barns ± 3.5 %.

A MEASUREMENT OF THE FISSION CROSS SECTION OF ^{235}U AT 440 AND 530 keV NEUTRON ENERGY

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I. INTRODUCTION

The discrepancies in the existing values of the fission cross section of ^{235}U in the neutron energy region between 0.1 and 1 MeV let it appear worthwhile to try a measurement with a novel method, the accuracy of which is expected to be ultimately ± 2.5 % or better. At the present stage, scattering corrections and statistics are not as small as they could be, and the uncertainties are still 3 to 4 %.

The detectors which were used in this experiment were described elsewhere [1,2] in detail. Therefore only the specific features of the experimental technique are given here.

II. EXPERIMENTAL ARRANGEMENT

Fission Detector

The fission detector was a gas scintillation chamber filled with a mixture of 85 % Argon and 15 % Nitrogen at atmospheric pressure. It is shown in Fig. 1 together with a pulse height distribution of the fission fragments. The chamber is viewed by two photomultipliers so that geometry effects are minimized. The efficiency of the detector (the fraction of the pulse-height spectrum above the electronic threshold) was determined to be 0.99 $\pm$ 0.5 %. Not shown in Fig. 1 is a transport chamber into which the fissile sample could be withdrawn. Thus the time-correlated background could be measured with the sample out of the chamber. It was found that the time-dependent background amounted to (4 $\pm$ 0.5) % of the counting rate. The time-independent background due to alpha particles or fission events induced by room-scattered neutrons was about 2.5 %.

Proton Recoil Detector

The proton recoil detector was the same as the one reported at the Helsinki conference [2]. The surface of the solid state detector was metallized with 25 $\mu g/cm^2$ of Gold and the thickness of the insensitive region, measured with a collimated beam of alpha particles impinging under different angles, was about 100 $\mu g/cm^2$ silicon under experimental conditions. This corresponds to an energy loss of 34 keV for 440 keV protons. In Fig. 2 the pulse height distributions of the spectra with covered and uncovered solid state detector are plotted for the two energies.

Samples

The samples were fabricated by CBNM/Euratom in Geel. The fissile layer consists of uranium acetate electrosprayed [3] onto a 0.9 mm thick sheet of stainless steel, 70 mm in diameter and with a polish to better than 1 µm. The thickness of the layer was 92 µg/cm^2 and the diameter 40 mm. From the specific activity and low-geometry alpha counting the total mass of uranium was determined to be 1.161 mg U ± 0.8 %. Only a small correction for the isotopic composition had to be made, because the abundance of ^{235}U was 99.5 ± 0.01 %. An estimation following White [4] shows that an amount of 0.6 % of the fission fragments are absorbed in the fissile layer itself. The absorption correction then becomes 0.994 ± 0.3 %.

The radiator for the proton recoil detector consists of glycerol tristearate $(C_{17}H_{35}COO)_3C_3H_5$, evaporated [5] onto a similar backing of 0.9 mm stainless steel as the fissile layer. By careful weighing with a vacuum balance the total mass of the radiator material was determined to be 1.619 mg ± 0.5 %. The diameter of the layer was 40 mm and the thickness 128 µg/cm^2.

Electronics

Fig. 3 shows a block diagram of the electronics. From the fission events pulse height spectra and time-of-flight spectra were recorded simultaneously. A coincidence requirement between the outputs of the two photomultipliers provides discrimination against multiplier noise. Two spectra of each type were taken because both multichannel analyzers were routed by the same sample changer automatic as the proton recoil detector.

The electronics of the proton recoil detector is the same as described in Ref. [2] except for a new timing unit. This unit improved the time resolution to 12 nsec independent of the pulse height.

Neutron Source

Neutrons were produced with the Karlsruhe 3 MV pulsed Van de Graaff accelerator via the ^{7}Li(p,n)^{7}Be reaction. The pulse width was 1 nsec and the repetition rate $10^6 \frac{1}{sec}$. The neutron energy was determined with a Li-glass detector at a distance of 3.02 m and with a time resolution $< 2 \frac{nsec}{m}$. Normally the ^{7}Li-targets were 40 to 60 keV thick. Ta-backings for the ^{7}Li-targets and a shielding of 2 cm Pb reduced the γ-flash of the accelerator.

III. CORRECTIONS AND UNCERTAINTIES

Besides the corrections mentioned above there are those due to scattered neutrons. For the determination of the influence of scattered neutrons on the measured fission cross section four different detector arrangements were used.

In the first arrangement (geometry I) the detectors were placed back-to-back behind a 450 mm long collimator of paraffin that was coated by cadmium sheet. The scattering correction for this geometry must account for neutrons scattered in the backings of the fissile layer and of the radiators, and in the bronze windows between them. With the calculated correction factor, $K_1 = 0.910 \pm 2.5$ %, the fission cross section at 440 ± 26 keV was found to be $\sigma_f = 1.16$ barn ± 4.5 %.

Another measurement at the same energy was made with the detectors located in symmetric positions with respect to the proton beam axis, without collimator (geometry II). In this geometry, the correction due to scattered neutrons from the backings becomes smaller ($K_2 = 0.982 \pm 0.5$ %), but there is additional scattering from the detector walls. By adding an identical blind fission chamber to the experiment, it was possible to measure the influence of neutrons scattered from the walls. It was found to require an additional correction of $K_3 = 0.92 \pm 1.2$ %. The value determined with this geometry (after application of K_2 and K_3) was $\sigma_f = 1.18$ barns ± 4 %.

A third possibility is to determine the fission cross section from a measurement with the back-to-back arrangement without collimator using the correction K_3 for the scattered neutrons from the detector walls. However, one has to account for the fact that for this arrangement the proton recoil detector is situated closer to the fission chamber than in geometry II. The necessary correction is estimated to be $K_4 = 1.5\ K_3 = 0.88 \pm 3\ \%$. The resulting fission cross section value was $\sigma_f = 1.16$ barns $\pm$ 6 %, again at 440 $\pm$ 25 keV.

The uncertainties, which are given for these three values of σ_f contain all uncertainties listed in Table I, including the statistical uncertainties.

IV. RESULTS AND DISCUSSION

Fission cross sections of ^{235}U have been measured relative to the hydrogen (n,p) cross section at two energies. The result is

440 $\pm$ 25 keV	σ_f = 1.17 barns $\pm$ 3.5 %
530 $\pm$ 30 keV	σ_f = 1.17 barns $\pm$ 3.5 %.

Fig. 4 shows a comparison between these two values and the existing measurements. Agreement is found within the quoted uncertainties between these values and the data of White [4], and Szabo, Marquette, Fort et Leroy [6]. The fission cross sections measured by Allen and Ferguson [7], Diven [8] and Smirenkin [9] are somewhat higher while the data given by Pönitz [10] and - to some extent - those given by Gorlov [11] are lower by about 10 %.

It is planned to increase the accuracy of this experiment in the future by using thinner backings, more samples and longer data acquisition times. The aim is to establish a data set in the energy range between 0.3 and 1.2 MeV with an uncertainty of $\leq$ 2.5 %.

ACKNOWLEDGMENT

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TABLE I

Source of Uncertainty	Uncertainty
Number of Hydrogen Atoms	0.5 %
Number of Uranium Atoms	0.8 %
Efficiency of the Proton Recoil Detector	1.5 %
Efficiency of the Fission Chamber	0.5 %
Absorption in the Fissile Layer	0.3 %
Isotopic Composition of ^{235}U	0.01 %
Correction for (n,γ)-Background	0.5 %
Correction for Equal Flux (For Back-to-Back Position only)	0.3 %

FIGURE CAPTIONS

Fig. 1 The gas scintillation chamber (Top view) and a pulse height distribution of the fission fragments obtained under experimental conditions.

Fig. 2 Pulse height distributions from the proton recoil detector.

Fig. 3 Electronic equipment

Fig. 4 Comparison of the present work (full circles) with other measurements.

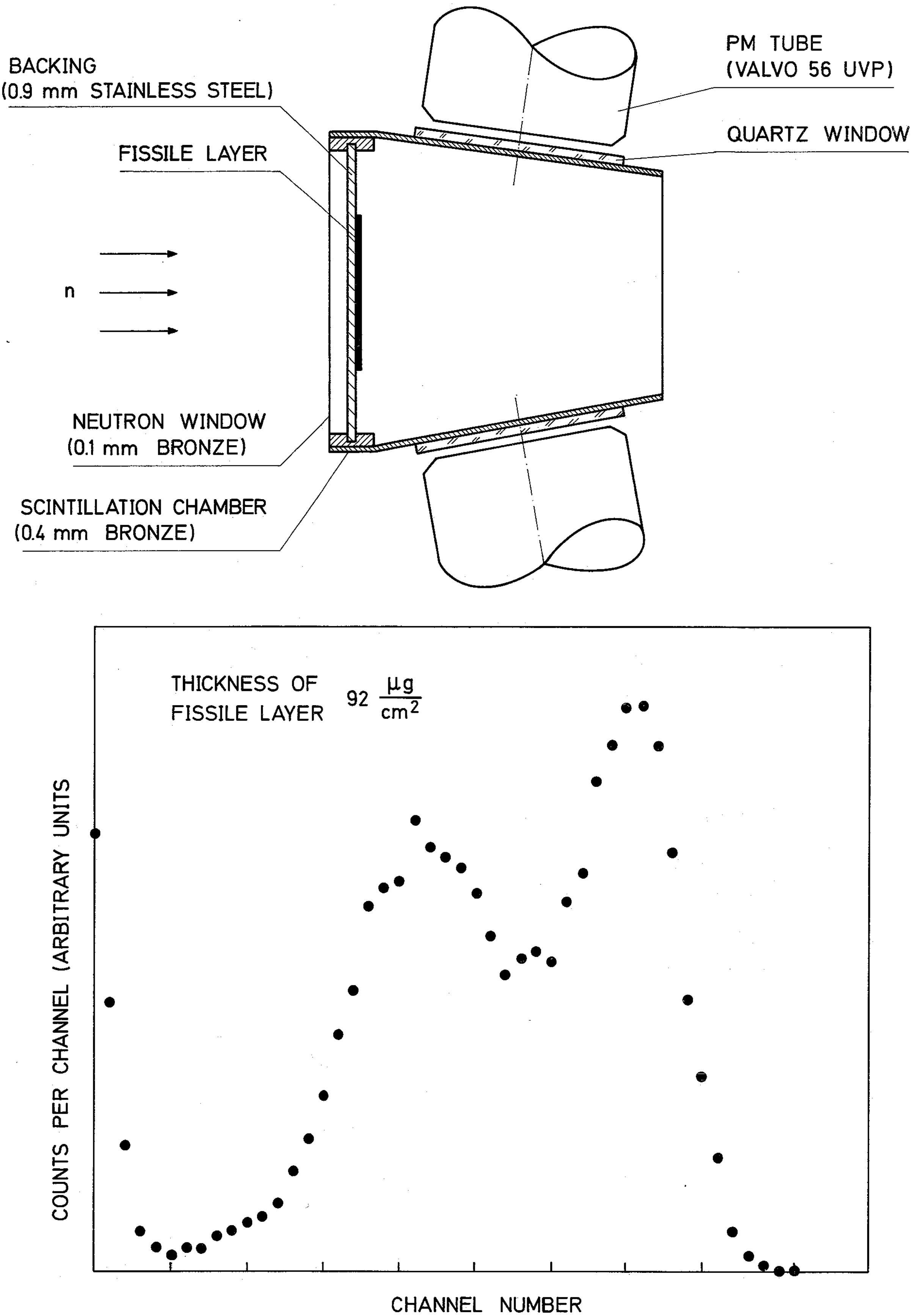

BACKING
(0.9 mm STAINLESS STEEL)
FISSILE LAYER
n
NEUTRON WINDOW
(0.1 mm BRONZE)
SCINTILLATION CHAMBER
(0.4 mm BRONZE)
PM TUBE
(VALVO 56 UVP)
QUARTZ WINDOW
THICKNESS OF FISSILE LAYER 92 $\frac{\mu g}{cm^2}$
COUNTS PER CHANNEL (ARBITRARY UNITS
CHANNEL NUMBER

FIG. 1

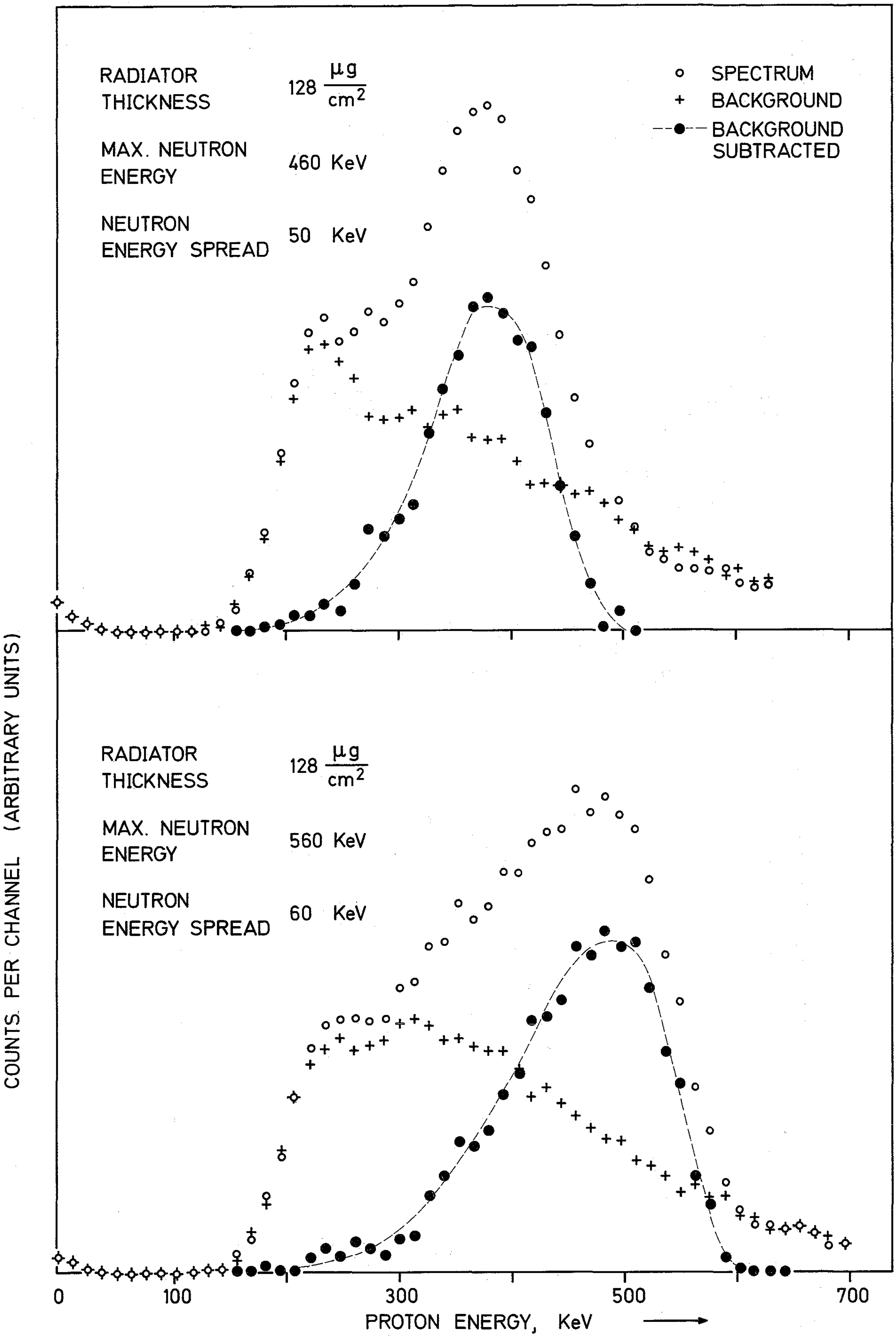

RADIATOR THICKNESS
128 µg/cm2
MAX. NEUTRON ENERGY
460 KeV
NEUTRON ENERGY SPREAD
50 KeV
SPECTRUM
BACKGROUND
BACKGROUND SUBTRACTED
RADIATOR THICKNESS
128 µg/cm2
MAX. NEUTRON ENERGY
560 KeV
NEUTRON ENERGY SPREAD
60 KeV
COUNTS PER CHANNEL (ARBITRARY UNITS)
0
100
300
500
700
PROTON ENERGY, KeV

FIG. 2

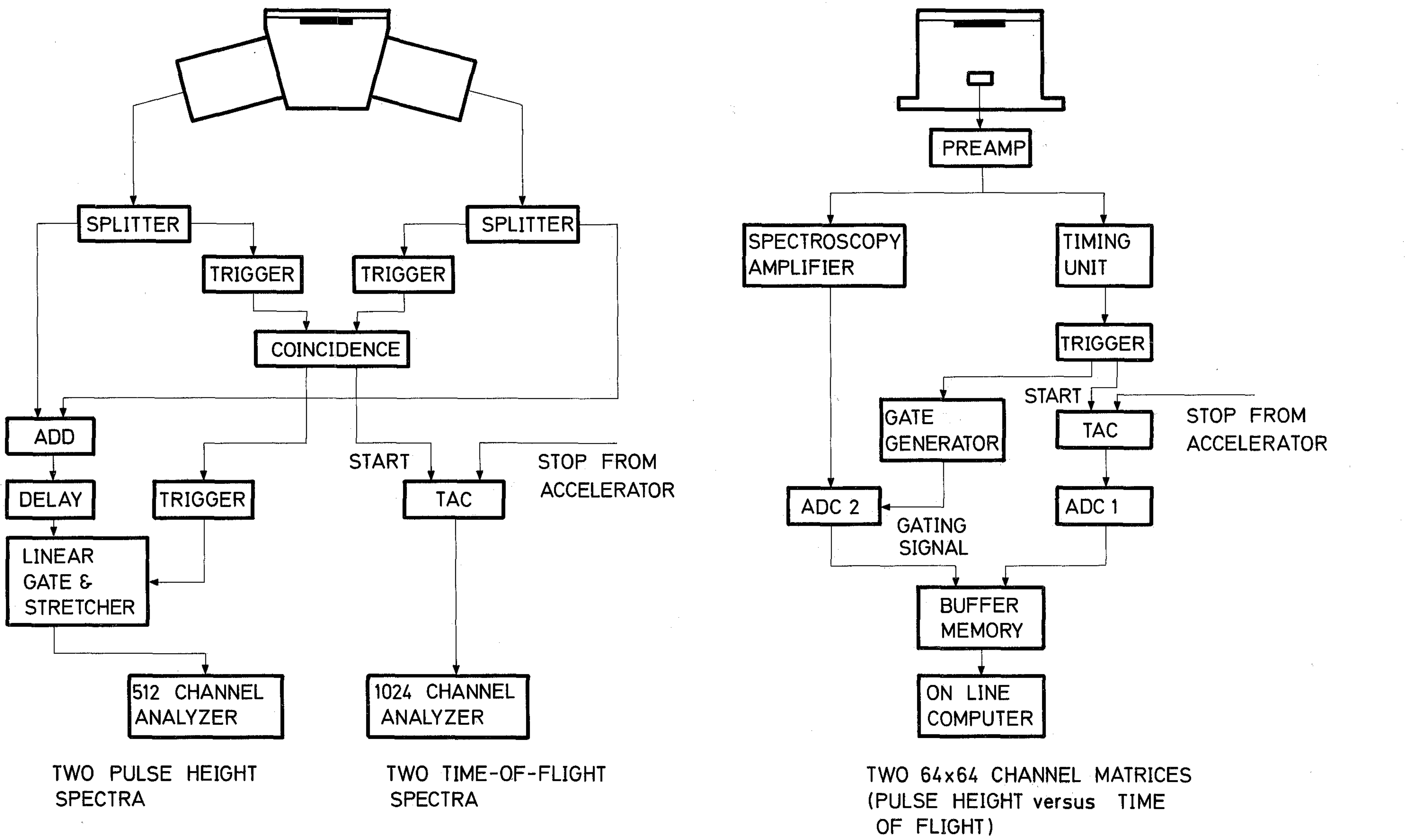
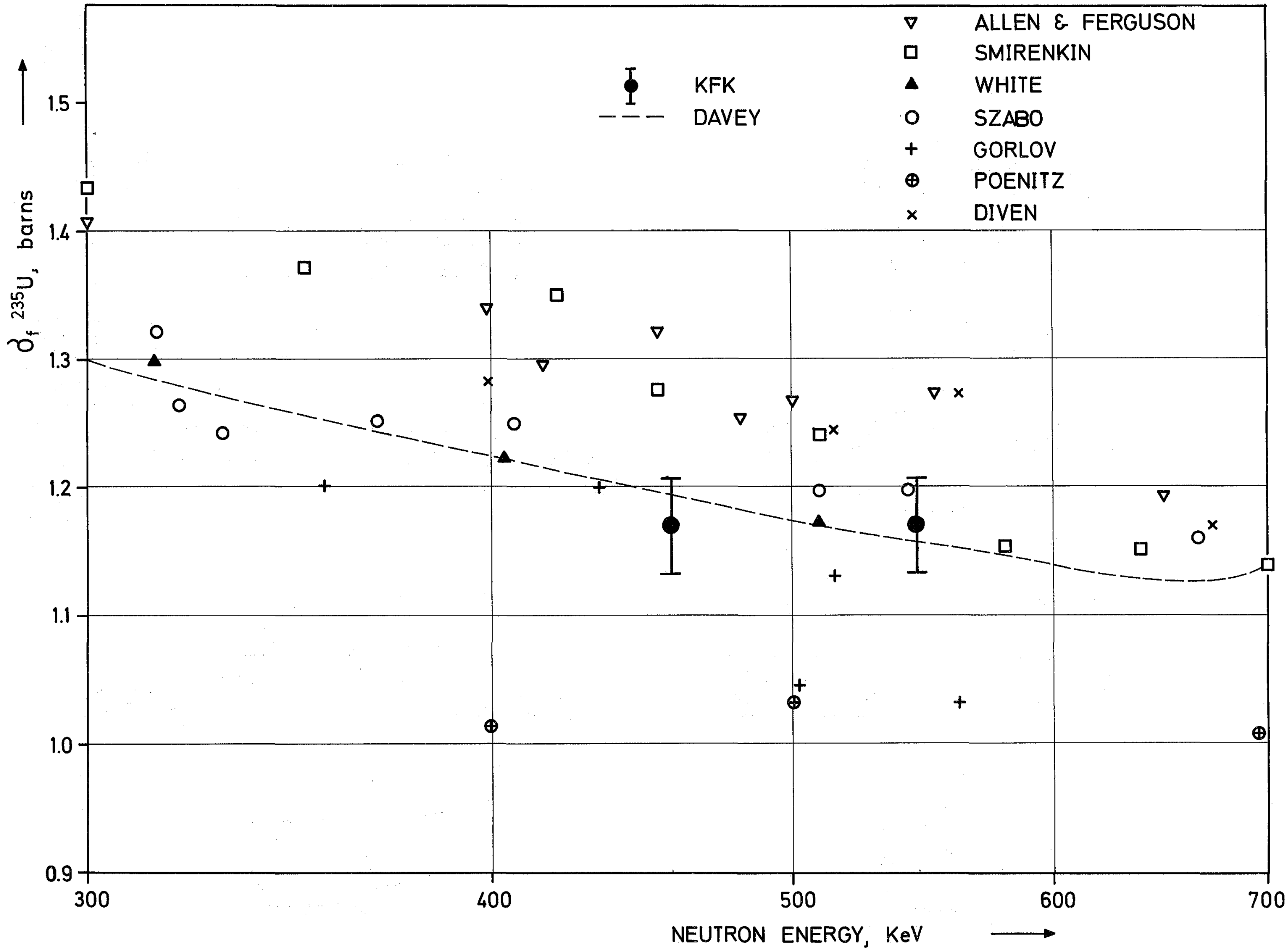

SPLITTER
SPLITTER
TRIGGER
TRIGGER
COINCIDENCE
ADD
DELAY
TRIGGER
START
TAC
STOP FROM ACCELERATOR
LINEAR GATE & STRETCHER
512 CHANNEL ANALYZER
1024 CHANNEL ANALYZER
TWO PULSE HEIGHT SPECTRA
TWO TIME-OF-FLIGHT SPECTRA
PREAMP
SPECTROSCOPY AMPLIFIER
TIMING UNIT
TRIGGER
START
GATE GENERATOR
TAC
STOP FROM ACCELERATOR
ADC 2
GATING SIGNAL
ADC 1
BUFFER MEMORY
ON LINE COMPUTER
TWO 64x64 CHANNEL MATRICES (PULSE HEIGHT versus TIME OF FLIGHT)

FIG. 3



ALLEN & FERGUSON
SMIRENKIN
WHITE
SZABO
GORLOV
POENITZ
DIVEN
KFK
DAVEY
1.5
1.4
1.3
1.2
1.1
1.0
0.9
σ_f ^{235}U, barns
300
400
500
600
700
NEUTRON ENERGY, KeV

FIG. 4