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PROGRESS REPORT TO EANDC
FROM SWITZERLAND

R. W. Meier, Editor

OECD ENEA

April 1965

~~NOT FOR PUBLICATION~~

EUROPEAN-AMERICAN NUCLEAR DATA COMMITTEE

EANDC(OR)40 "L"

Progress Report to EANDC

from Switzerland

April 1965

Edited by R.W. Meier
Swiss Federal Institute for Reactor Research
Würenlingen

Contents

1. Physikalisches Institut der Universität Basel

1.1 Nuclear Temperatures of Highly Excited Nuclei near magic numbers Z = 50 and N = 82

R.Plattner, P. Huber, C. Poppelbaum and R. Wagner.

The measurements on which preliminary data have been reported in the last progress report EANDC (OR) 29 have been terminated and the final results have been published in Helv. Phys. Acta 36, 1059 (1964). The abstract reads as follows:

"For a number of elements, the energy spectra N(E) dE resulting from inelastic scattering of a 14 MeV incident neutron beam have been measured with a time-of-flight spectrometer. The Le Couteur formula was used to infer a nuclear temperature T of the residual nucleus: N (E) dE = const. $E^{5/11}$ exp (-12 E/11 T) dE. The measured elements and their temperatures T in MeV are: Mo (0.90), Ag (0.97), Cd (0.85), Sn (0.83), Sb (0.89), Te (0.96), I (0.89), Ba (1.01), Ce (0.90), Hg (0.98), Pb^{206} (1.11), Pb (1.28), Bi (1.26). From these results the level density coefficients a = E^*_{eff}/T^2 have been calculated, where $E^*_{eff} = E_o - 2\ T + P(Z) + P(N)$ and the P's are CAMERON's valus for the pairing energy. The values of a are compared with the theoretical work of NEWTON and ROSENZWEIG. They show the decrease of the level density near the magic neutron numbers 82 and 126 predicted by NEWTON. No such effect was found near the magic proton number 50."

1.2 Neutron Differential Cross Section of ^{18}O for Neutron Energies between 2.9 and 4.1 MeV.

P. Extermann, E. Baumgartner and P. Huber.

This work is completed and published. The following abstract is taken from Helv. Phys. Acta 37, 505 (1964):

"We have measured the neutron differential cross-sections of ^{18}O detecting the recoils in an ionization chamber. The neutrons produced by the d-d reaction were monitored by a calibrated Hornyak scintillator. Some of the recoil spectra show a superposition of elastic and inelastic scattering due to the (2^+, 1.98 MeV) level of ^{18}O. At 3.4 MeV an inelastic cross-section of 0.9 ± 0.2 b is observed. The nuclear optical model with the parameter of PEREY and BUCK gives a reasonable fit for the 4 MeV data."

1.3 T(d,n) ^{4}He-Reaction with Polarized Deuterons

W. Trächslin, E. Baumgartner, H. Burgisser, P. Huber, G. Michel and H.R. Striebel.

Deuterons from the "Basle Source" [1] having a polarization $\vec{P}$, P_{ij} as indicated in figure 1 were used to bombard a Tritium-Titanium-target. The thickness of the target amounts to ca. 100 keV. Deuteron energies were in the range of 0.15 to 0.57 MeV. The coordinate system used was described by Seiler et al [2]. The counters have been calibrated with neutrons from the reaction with unpolarized deuterons. The anisotropy of the angular distribution of these neutrons has been corrected.
The results in figure 1 show the relative, differential cross sections $(dT/d\Omega)_{rel}$ of the T(d,n) ^{4}He-reaction as a function of the angle ϑ of neutron emission in the centre of mass system.

[1] H. Rudin, H.R. Striebel, E. Baumgartner and P. Huber, Helv. Phys. Acta 34, 58 (1961).

[2] F. Seiler, E. Baumgartner, W. Haeberli, P. Huber and H.R. Striebel, Helv. Phys. Acta 35, 385 (1962)

2. Laboratoire de Recherches Nucléaires, EPUL, Lausanne

Inelastic scattering of 14 MeV neutrons

C. Joseph, G.A. Grin, J.C. Alder and B. Vaucher.

a) The angular distribution of neutrons scattered elastically and inelastically by Carbon (Q = -4,43; -7.6; -9.6 MeV) have been determined by means of the neutron time of flight spectrometer described in the preceeding report. The measurements were carried out with a scattering sample of 2 x 5 x 9 cm separated 20 cm from the neutron source. The neutrons were detected by cylindrical liquid scintillation counters (NE 213) of 2" diameter and 2" hight. The flight path ranged within 1.5 and 2.3 m according to the scattering angle. An iron shadow shield of 30 cm thickness was used to protect the counter from the direct source neutrons. The sensitivity of the counters as a function of neutron energy was measured by means of a hydrogen scatterer in form of an organic scintillator (NE 102).

The differential scattering cross sections were corrected for the finite sample size. The results for the elastic and the first two inelastic groups are shown on figure 2. Graphical integration over the angle leads to the following cross sections

$$\sigma_{el} = 820 \text{ mb} \pm 10\ \%$$

$$\sigma_{4.43\ MeV} = 250 \text{ mb} \pm 10\ \%$$

$$\sigma_{7.6\ MeV} = 55 \text{ mb} \pm 20\ \%$$

The errors include the uncertainties due to detector efficiency as well as those resulting from the sample size corrections. A more precise correction based on a Monte Carlo treatment is under progress. This will allow better corrections for multiscattering processes.

The time of flight spectra clearly demonstrate the inelastic group due to the 9.6 MeV level of ^{12}C. However, it is superimposed on a broad excited state at 10.1 MeV. The separation between these two neutron groups is actually under study.

b) The investigation of the reaction ^{12}C (n,n') at 14.1 MeV has been continued. Measurements are in progress to improve the accuracy of the inelastic scattering cross sections at the levels of 7.6; 9.6 and 10.8 MeV. Further, the broad group of neutrons resulting presumably from the level at 10.1 MeV and/or other reactions resulting in the carbon break-up into 3α -particles is investigated.

This is accomplished with a new experimental method based on the use of an organic scintillator (plastic) as the scatterer and α -detector. The neutrons emitted at different angles are detected in coincidence with the 3α -pulse in the scintillator and their energy is measured by the time of flight from the scintillator to the neutron detector.

c) The investigation of the neutron scattering by nitrogen at 14.1 MeV has been started.

The neutrons scattered by a liquid nitrogen target by an angle of 40° are measured. After corrections for neutrons scattered by the dewar container are subtracted, distinct peaks are observed which are due to inelastic processes resulting from excited states at 2.31 and 3.94 MeV. In a first analysis the following differential cross sections are obtained:

$$\frac{d\sigma}{d\Omega}_{el} = 94 \text{ mb/sterad}$$

$$\frac{d\sigma}{d\Omega}_{2.31\ MeV} = 3{,}7 \text{ mb/sterad}$$

$$\frac{d\sigma}{d\Omega}_{3{,}94\ MeV} = 3{,}7 \text{ mb/sterad}$$

The measurement of the complete angular dependance is in progress.

3. Eidg. Technische Hochschule (ETH), Laboratorium für Kernphysik, Zürich

Neutron Spectra of the Reaction D(n,2n)H at 14 MeV

M. Brüllmann, H. Jung and D. Meier

The break-up of the deuteron by means of 14 MeV neutrons produced with the T(d,n) ^{4}He-reaction is investigated (figure 3). D_2O is used as a scattering sample. The neutron detector consists of a liquid scintillator of the type NE 213 and a 58 AVP photomultiplier tube. Scatterer and neutron detector are separated by 200 cm. The energy of the reaction neutrons is measured by the time of flight technique, where the zero signal is obtained from the associated α-particle in the T(d,n) ^{4}He-reaction.

The main components of the fast-slow coincidence system are the time to pulse height converter (ZPK) and the two fast discriminators (SD). The electronic time resolution of the ZPK is shorter than 5 ps. A fast coincidence circuit (SK) allows to distinguish the sequenve of arrival of the two detector pulses. A factor of two reduction in background is thus achieved. The fast discriminators (SD) cut the background of the pulse spectrum and keep it off the converter. This is particularly important in the α-branch, where very high counting rates occur if measuring times shall be kept reasonably short. Counting rates of 120'000 α/sec have been processed and tests have shown that the neutron time spectrum did not shift at rates up to $2 \cdot 10^6$ α/sec.

In figure 4 a typical example of the neutron spectrum at 30^o scattering angle is given. The resolution of the elastic and the first two inelastic peaks of oxygen is 1.5 ns. This resolution allows the separation of the continuum and the elastic D-line. Figure 5 shows the energy distribution $d^2\sigma/d\Omega\, dE$. compared to results obtained by Messelt [1] and calculations based on Frank and Gammel's [2] theory. Similar measurements have been performed at scattering angles of 15° and 45°. Further data will be obtained in particular at small scattering angles and on the low energy side of the neutron spectrum.

[1] S. Messelt, Nucl. Phys. 48, 512 (1963)

[2] R.M. Frank and J.L. Gammel, Phys. Rev. 93, 464 (1954)

4. Institut de Physique, Université de Neuchâtel

J. Rossel

4.1. Neutron polarization

The polarization of neutrons elastically scattered by deuterons has been measured by left-right asymmetry and time-of-flight methods, the scatterer being a C_6D_6 liquid scintillator. The results are as follows:

$$E_n = 3.8 \text{ MeV} \qquad P_1P_2 = -0.0080 \pm 0.0050$$

$$E_n = 4.6 \text{ MeV} \qquad P_1P_2 = -0.0070 \pm 0.0050$$

The scattering angle was 50° in the laboratory system. P_1 is the polarization of the incident neutrons as produced by the $D(d,n)He^3$ reaction at 50° lab.

A liquid helium scintillation detector and scatterer with improved light efficiency has been built and is being tested with α-rays and neutrons. It will be used as a neutron polarization analyzer if possible for neutron energy as low as 2 to 3 MeV.

4.2. n,γ Angular Correlations and Stripping Reactions

An improved electronic system for n,γ angular correlation measurements has been built. The spin of the first excited level (340 KeV) of ^{21}Na is being remeasured by n,γ angular correlations in the stripping reaction $^{20}Ne(d,n)^{21}Na$. The previously found value of $\frac{5}{2}$ is not definitely established yet.

4.3 Neutron reactions with charged particles

The $^{40}Ca(n,\alpha)^{37}A$ reaction has been studied. The following differential cross sections have been measured:

Θ (CM)	E_n (CM) (MeV)	$\frac{d\sigma}{d\Omega}$ $\frac{mb}{sterad}$
0^o	4,05	12,4 ± 1,4
0^o	5,10	10,2 ± 1,2
0^o	5,85	9,2 ± 1,1
126^o	5,85	5,4 ± 0,6

An improved telescope spectrometer with solid state detector has been built and full angular distributions will be measured for the same reactions and the same range of energies.

4.4 Instrumentation

A 150 kV deuton and proton accelerator with a pulsed high voltage terminal has been constructed and is being tested. It is believed that the length of the beam pulses is of the order of 3 to 5 nanoseconds and that the current in the peak reaches values between 500 μA and 1 mA.

5. Eidg. Institut für Reaktorforschung, Würenlingen

Total Neutron Cross Section of Dysprosium, Lutetium and Iridium between 0.01 eV and 10 eV

J. Brunner

The total neutron cross section of dysprosium and lutetium in the energy range between 0.01 and 10 eV has been measured with the EIR mechanical chopper installation at the reactor DIORIT. A similar measurement has been started on iridium.

A neutron beam is extracted from the centre of the reactor. The chopper behind the transmission sample consists of a K-Monel rotor of 142 mm diameter with 4 slits of 1 mm height. The resolution with 18'000 rpm is 0.5 usec/m including the time analyser channel width.

For the dysprosium measurements samples of metal and oxide were used, for lutetium the oxide only. The purity of the samples was 99.9 % the main impurities being Ho and Y in the dysprosium samples and Yb and Tm in the lutetium samples with negligible influence on the accuracy of the measurements.

Fig. 6 and 7 give the total cross section for dysprosium and lutetium. Consistent results are obtained when using metal or oxide samples as well as for different sample thicknesses. Recent values for lutetium [1] in the lower energy range are considerably higher than our results. Also our dysprosium values deviate from those in BNL 325.

Corrections to the measurements are applied for dead time, oxygen content and time dependent background. The useful range is limited to higher energies by the considerable transmission of the closed rotor or high energy neutrons which contribute mainly to the counter background.

The results of these measurements will be published.

Some new measurements are under way on iridium with the aim of increasing the accuracy of the cross section in the two resonances around 1 eV. The main difficulty at the moment is the preparation of suitably thin samples with accurately known thickness.

[1] Zimmermann et al., Publ. of Inst. En.At. Sao Paolo, Nr. 51 (1962)

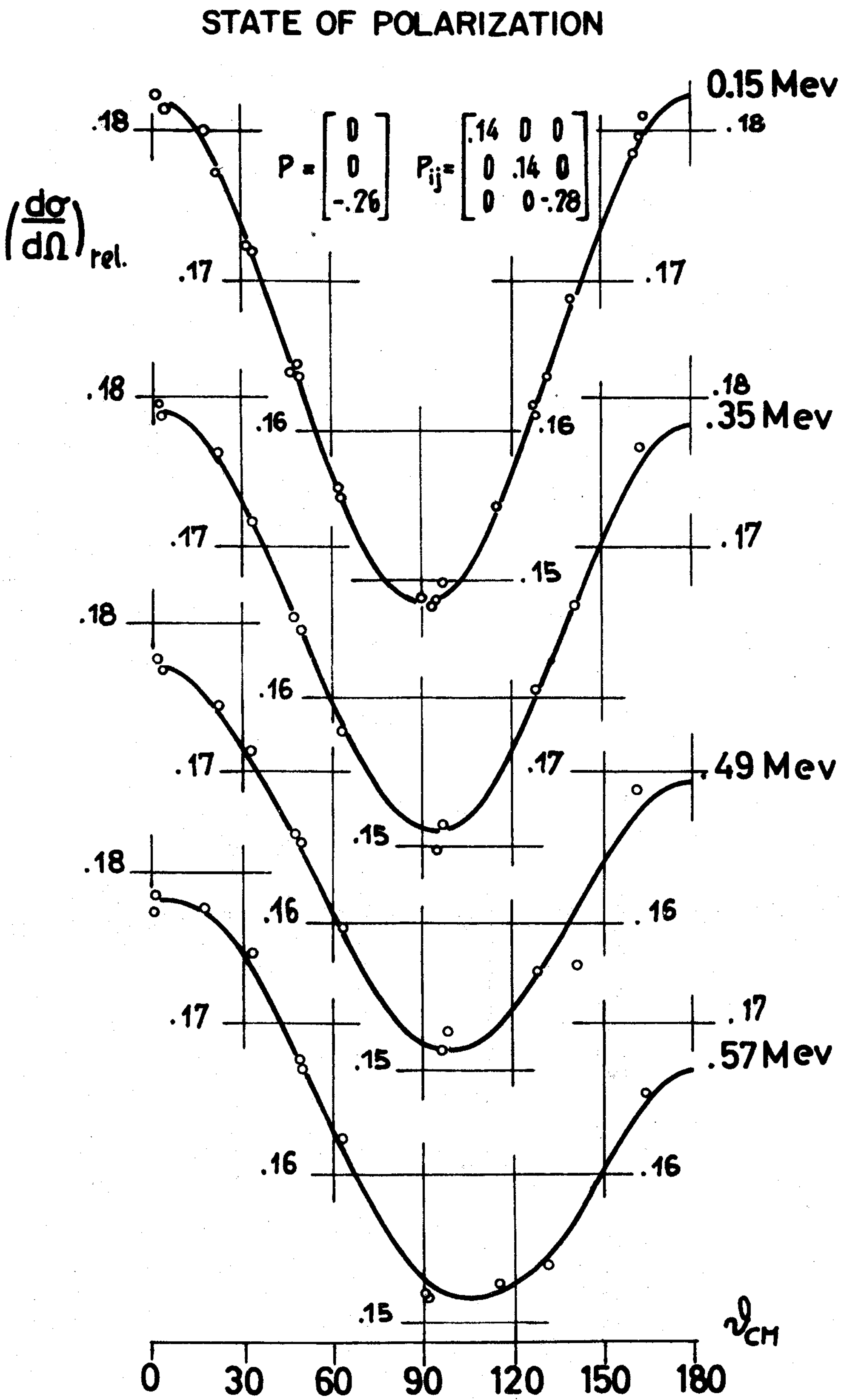


FIG. 1 DIFFERENTIAL CROSS SECTION FOR POLARIZED DEUTERONS AT ENERGIES OF 0.15, 0.35, 0.49 AND 0.57 MeV

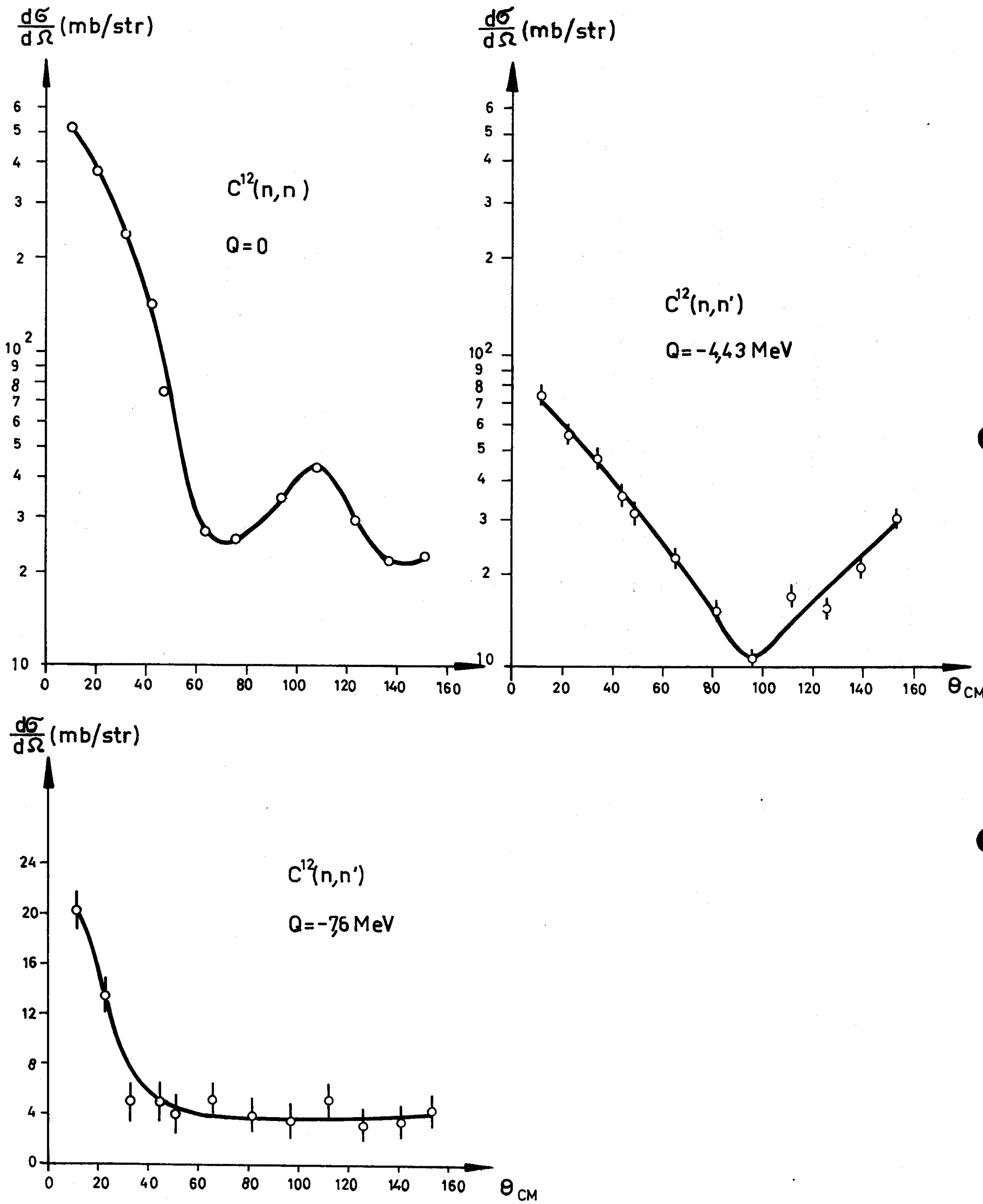


Fig. 2 Scattering cross sections for 14 MeV neutrons on ^{12}C.

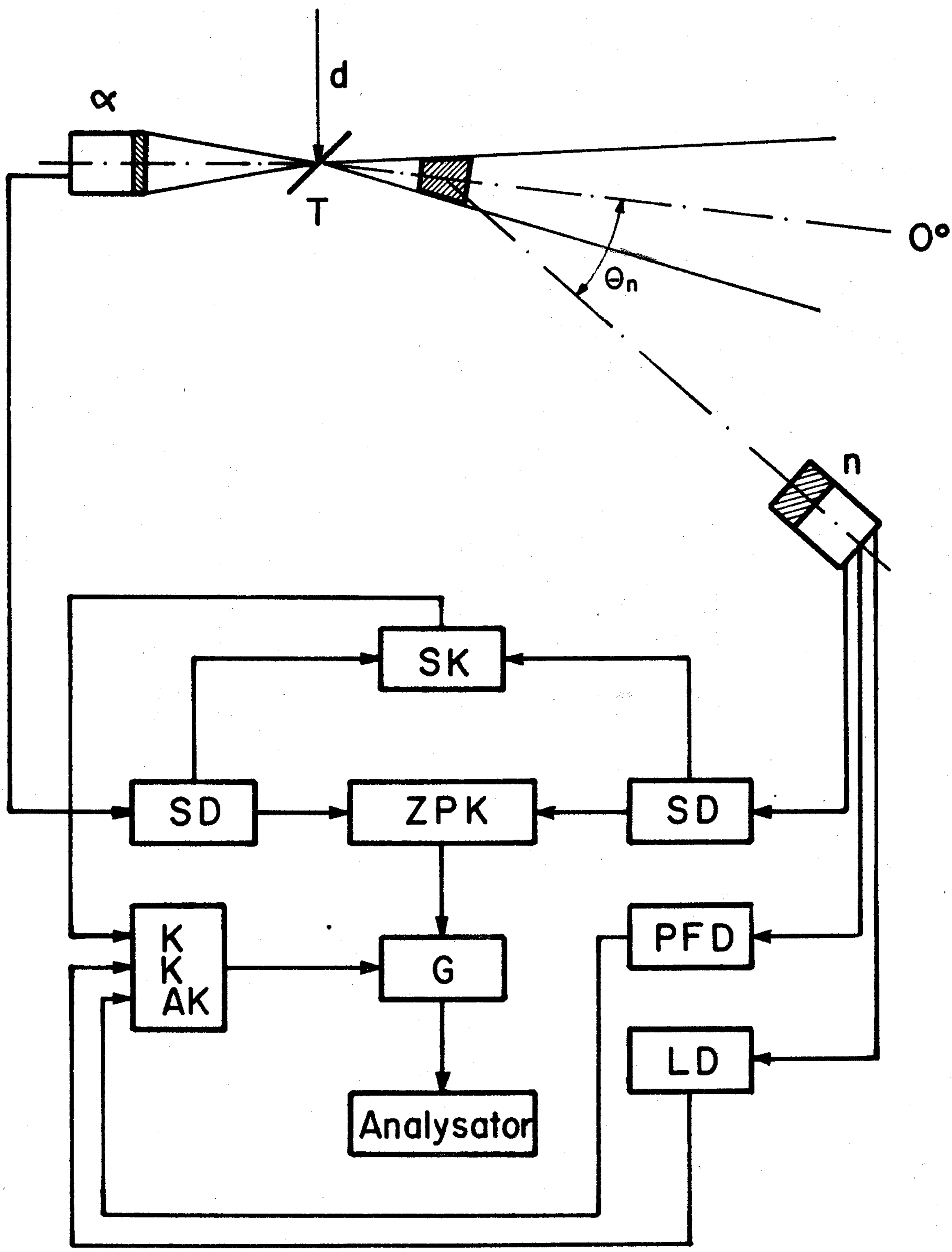
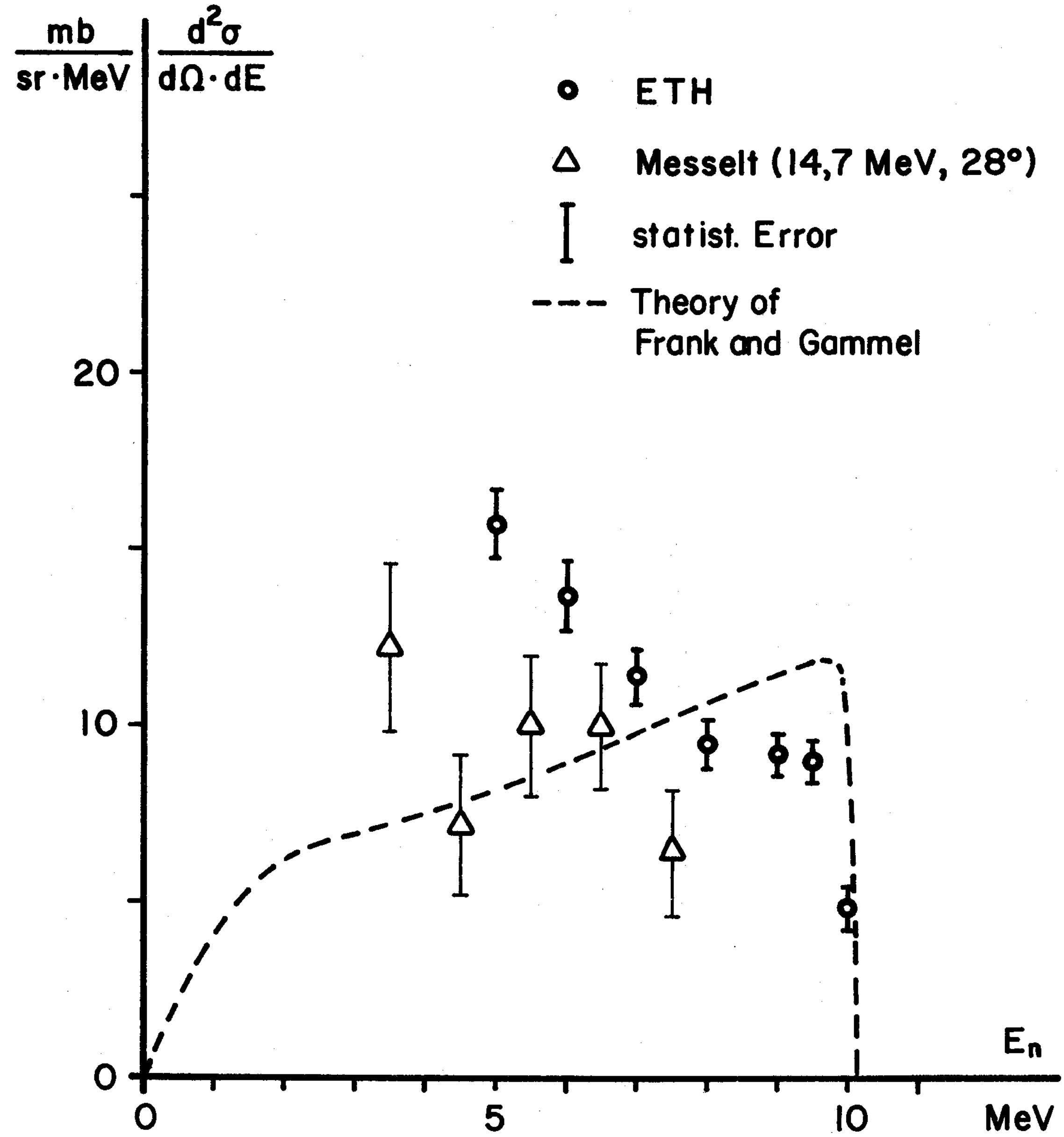


Fig. 3 Block Diagram of Experimental Set-up

Fig. 4 D(n, 2n) H, Energy Distribution at E_n = 14.1 MeV, θ = 30°



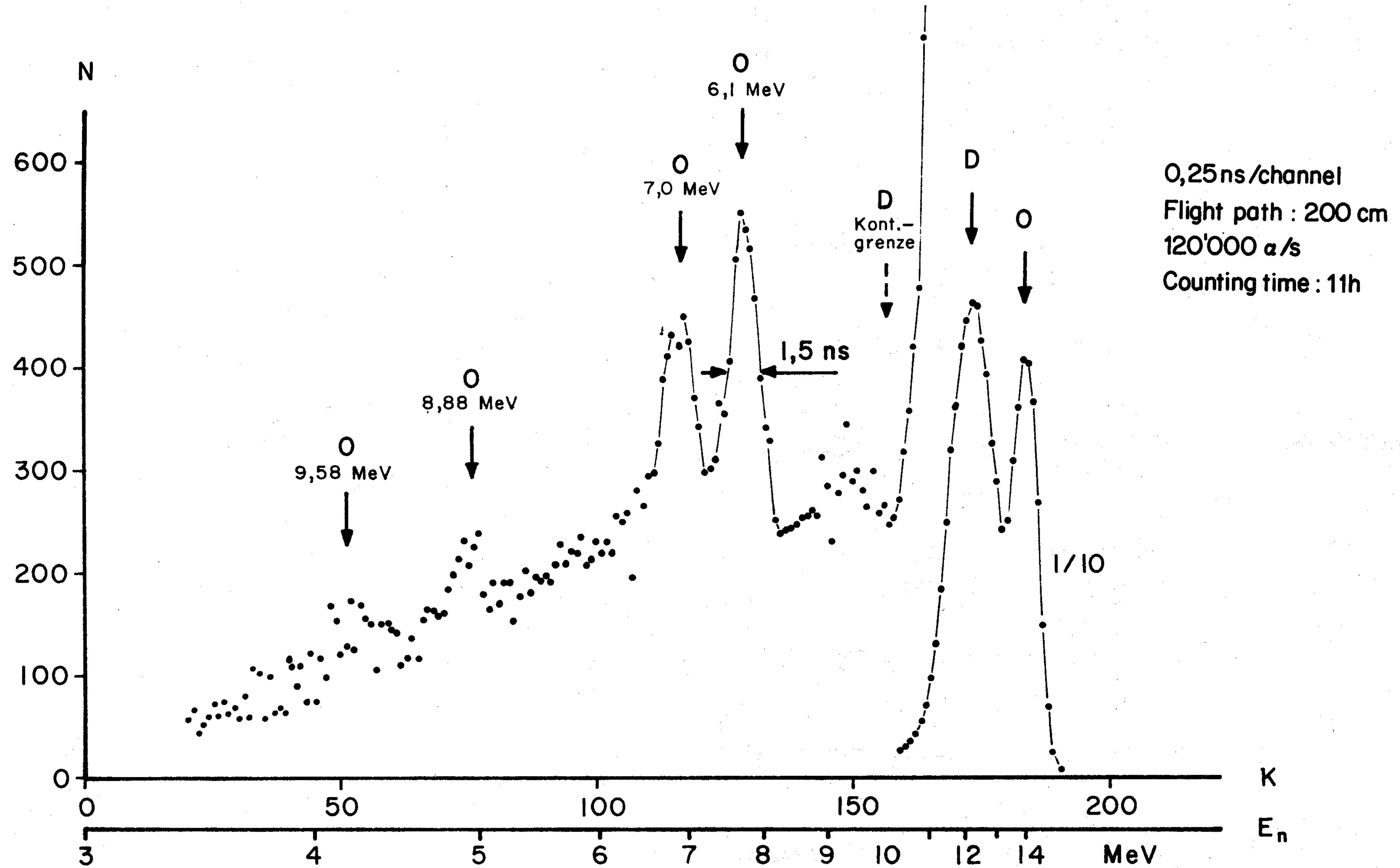


Fig. 5 Spectrum at 30° scattering angle

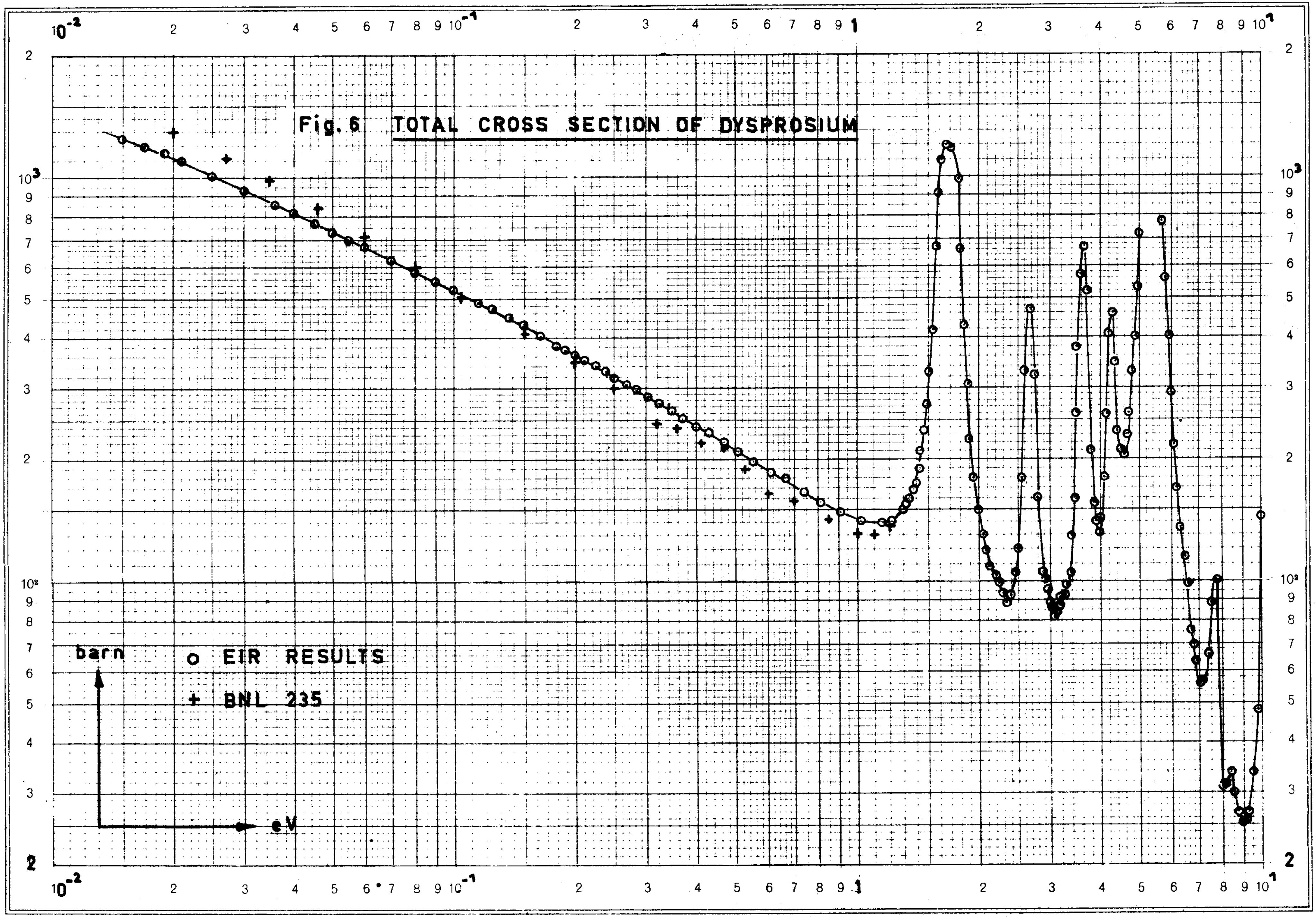


Fig. 6 TOTAL CROSS SECTION OF DYSPROSIUM
o EIR RESULTS
+ BNL 235
barn
eV
10⁻²
10⁻¹
1
10¹
10³
10²
2

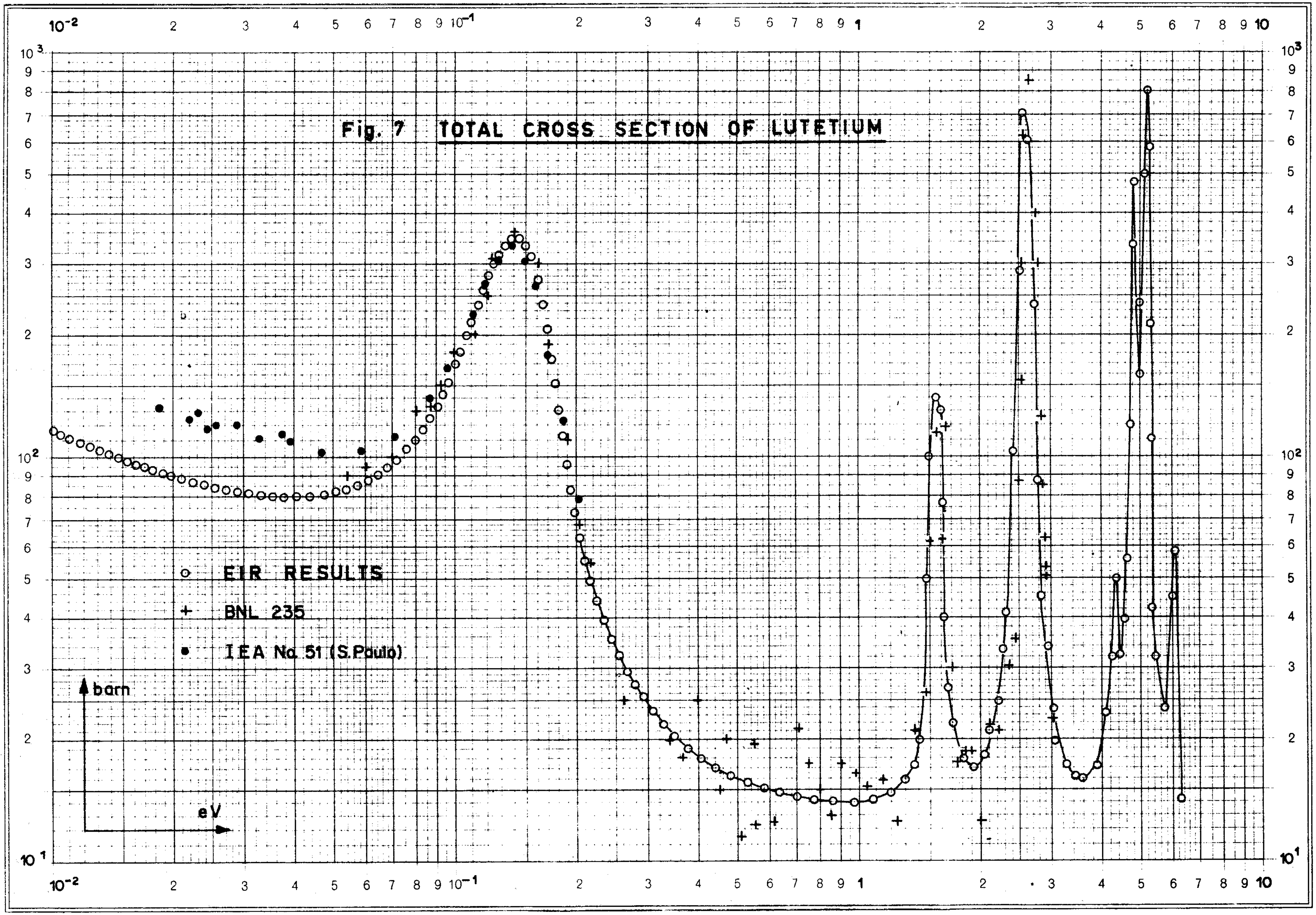


Fig. 7 TOTAL CROSS SECTION OF LUTETIUM
EIR RESULTS
BNL 235
IEA No. 51 (S.Paulo)
barn
eV