

JAERI-M

5 4 1 8

NEUTRON SCATTERING FROM ^{207}Pb

October 1973

Yoshiaki TOMITA, Shigeya TANAKA
and Michio MARUYAMA

日本原子力研究所
Japan Atomic Energy Research Institute

1000
1000

1000 1000 1000 1000 1000 1000

1000 1000

1000 1000 1000 1000

この報告書は、日本原子力研究所が JAERI-M レポートとして、不定期に刊行している研究報告書です。入手、複製などのお問い合わせは、日本原子力研究所技術情報部（茨城県那珂郡東海村）あて、お申しこしください。

JAERI-M reports, issued irregularly, describe the results of research works carried out in JAERI. Inquiries about the availability of reports and their reproduction should be addressed to Division of Technical Information, Japan Atomic Energy Research Institute, Tokai-mura, Naka-gun, Ibaraki-ken, Japan.

JAERI - M 5418

Neutron Scattering from ^{207}Pb

Yoshiaki Tomita, Shigeya Tanaka and Michio Maruyama

Division of Physics, Tokai, JAERI

(Received September 20, 1973)

The elastic and inelastic scattering of neutrons by ^{207}Pb was investigated. Excitation functions were measured in the energy range 1.37-3.56 MeV. No distinct intermediate structure was observed. Angular distributions were measured at five energies between 1.47 and 3.56 MeV. The results were analyzed by the optical model and Moldauer's theory, and values of optical-potential parameters were obtained.

^{207}Pb による中性子の散乱

日本原子力研究所東海研究所物理部

富田芳明, 田中茂也, 丸山倫夫

(1973年9月20日受理)

^{207}Pb と中性子の相互作用をしらべるために, 1.35 ~ 3.56 MeV の中性子エネルギー範囲で, 弾性散乱と非弾性散乱の微分断面積の測定を行なった。励起関数には著しい中間構造はなかった。測定した断面積を光学模型と Moldauer の理論によって解析し, 光学ポテンシャルのパラメーターを求めた。

目 次 な し

1. Introduction

The purpose of this study is first to investigate intermediate structure in the energy dependence of the neutron cross sections of ^{207}Pb , and secondly to obtain optical-potential parameters which reproduce the cross sections. For the first purpose excitation functions for different levels were measured in the energy range 1.37 - 3.56 MeV. For the second purpose angular distributions were measured at five neutron energies between 1.47 and 3.56 MeV. The results were analyzed by the optical model and Moldauer's theory.¹⁾

2. Experimental Procedure

The measurement was carried out with the JAERI 5.5 MV V.d.G. and a pulsed beam time-of-flight spectrometer system. Neutrons were produced by the $T(p,n)$ reaction using a 3 cm long gas target filled with tritium gas at 48 cmHg. The ^{207}Pb scattering sample was 92.4% pure and contained 5.5% ^{208}Pb and 2.2% ^{206}Pb . The sample was cylindrical, 2.54 cm both in diameter and height, and was placed at 8 cm from the centre of the target cell. Energy spreads of the incident neutrons were about 60 keV FWHM, which were produced by the energy loss of the incident proton beam in the tritium gas and the target cell window, and by the finite solid angle subtended by the scatterer at the target. Scattered neutrons were detected in an NE-213 liquid scintillator, 12.5 cm in diameter and 10 cm in depth, placed at 3.11 m or 3.91 m from the scatterer. In order to reduce the background, γ -rays were blocked by a pulse-shape discrimination technique. A typical time spectrum is shown in Fig. 1. Another detector with a small organic scintillator monitored the neutron yield from the gas target. Absolute values of the cross sections were determined by comparison with the $H(n,n)$ cross section, using a cylindrical polyethylene sample 1.0 cm in diameter and 4.0 cm high with an axial hole 0.8 cm in diameter. The measured cross sections were corrected for the effects of flux attenuation and multiple scattering and for the effect of finite solid angle subtended by the scatterer at the target, by the Monte Carlo method. The correction factors for the excitation functions were determined by inter- or extrapolating the factors for the energies where the angular distributions were measured. Since the correction factor for the elastic cross section

depends on the shape of the angular distribution and varies considerably with energy, the absolute values of the excitation function for the elastic scattering may not be very accurate.

3. Experimental Results

Excitation functions measured in the energy range 1.37 - 3.56 MeV with intervals of about 25 keV at a scattering angle of 125° are shown in Fig. 2(a) for the elastic scattering and in Fig. 2(b) for the 1st, 2nd and 3rd excited states. There are seen only small fluctuations and no distinct intermediate structure is present in the excitation functions. Angular distributions measured at neutron energies of 1.47, 2.02, 2.53, 3.04 and 3.56 MeV at thirteen lab angles between 30° and 147° are shown in Fig. 3(a)-(e).

4. Optical Model Analysis

The measured angular distributions were analyzed by the optical model and Moldauer's theory. The potential used was of the following form:

$$-Vf(r; r_0, a) - iWb \frac{d}{dr} f(r; r_s, b) \\ - V_{so} \lambda_\pi^2 (\sigma \cdot \mathcal{L}) \frac{1}{r} \frac{d}{dr} f(r; r_0, a) , \\ f(r; q, d) = \frac{1}{1 + \exp \frac{r - qA^{1/3}}{d}} ,$$

$$\begin{aligned} V_{so} &= 7 \text{ MeV}, \\ r_0 &= r_s = 1.25 \text{ fm}, \\ a &= 0.65 \text{ fm}, \\ b &= 0.48 \text{ fm}. \end{aligned} \quad (1)$$

Energy levels²⁾³⁾ of ^{207}Pb used in the calculation of Moldauer's theory are shown in Fig. 4. In order to fit the elastic angular distribution and the first level cross section, the depth parameters were varied for each incident energy using an automatic search code STAX2⁴⁾. The best fits obtained are shown in Fig. 3(a)-(e) by solid lines and the depth parameters are given in Table 1. The fits to the elastic data are generally

very good, while some of the fits to the inelastic data are not so good. The parameters obtained can be approximately represented by

$$\begin{aligned} V &= 45.8 \text{ MeV}, \\ W &= 1.95 + 0.55E \text{ MeV} \end{aligned} \quad (2)$$

Excitation functions calculated with these parameters are shown in Fig. 2(a) and (b) by solid lines. The calculated values for the inelastic scattering are generally smaller than the measured values. This discrepancy may be in part due to the fact that the energies where the angular distributions were measured are accidentally near the local minimums of the fluctuation of the first level cross section, as can be seen in Fig. 2(b). This discrepancy can be remedied by slightly increasing the depth of the imaginary well without appreciably deteriorating the fits to the elastic angular distributions. Cross sections calculated with the parameters

$$\begin{aligned} V &= 45.8 \text{ MeV}, \\ W &= 2.3 + 0.55E \text{ MeV} \end{aligned} \quad (3)$$

are shown in Fig. 2 and 3 by broken lines. The fits to both angular distributions and excitation functions are fairly good, and the parameters given in (3) can be said to reproduce the average cross sections of ^{207}Pb in the energy range investigated here.

Fits by means of the Hauser-Feshbach⁵⁾ theory were also tried. The resultant parameters are nearly the same for the real well depth and by about 0.5 MeV smaller for the imaginary well depth compared with the values given in Table 1. The quality of fits is always worse than Moldauer's theory. Especially the lower energy data are not well reproduced.

The authors would like to express their appreciation to Messrs Y. Sato and T. Yoshida for assistance in the experiment, and to Dr. K. Harada for reading the manuscript. They are also indebted to EANDC and U.S. AEC for the use of a ^{207}Pb sample in the ORNL pool.

References

- 1) Moldauer P. A. : Phys. Rev. 135, B642 (1964).
- 2) Schmorak M. R. and Auble R. L. : Nuclear Data B5, 207 (1971).
- 3) Saudinos J., Valois G. and Beer O. : Nucl. Sci. Appl. 3, No.2, 22

(1967).

4) Tomita Y. : JAERI 1191 (1970).

5) Hauser W. and Feshbach H. : Phys. Rev. 87, 366 (1952).

TABLE 1
The best-fit potential parameters

E_n (MeV)	V (MeV)	W (MeV)
1.47	45.66	2.76
2.02	45.27	3.32
2.53	45.90	3.12
3.04	46.41	3.42
3.56	45.73	3.98

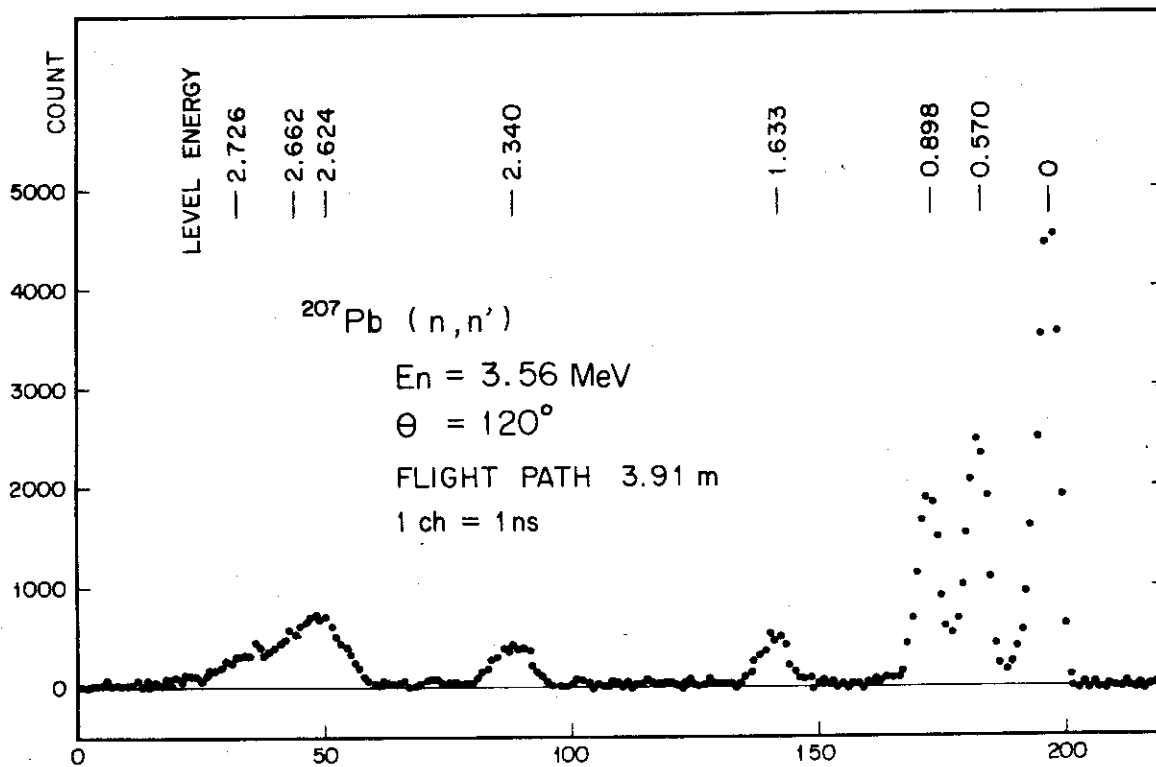


Fig. 1 A typical time spectrum observed at a neutron energy of 3.56 MeV. The background has been subtracted.

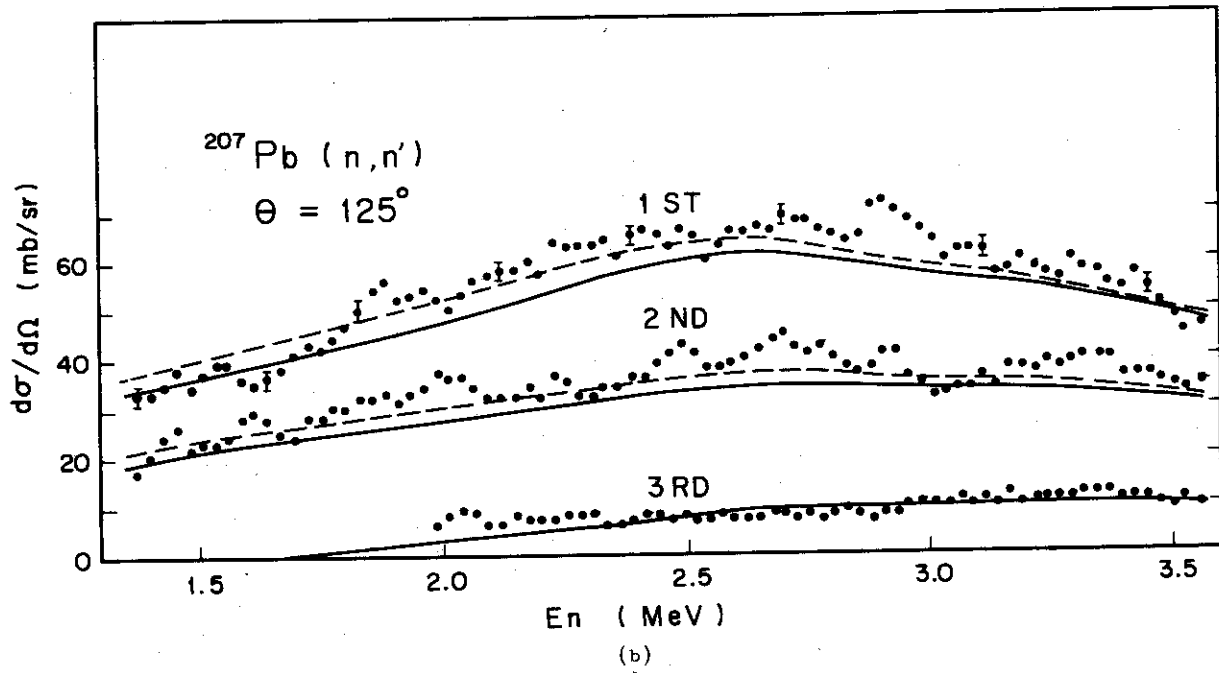
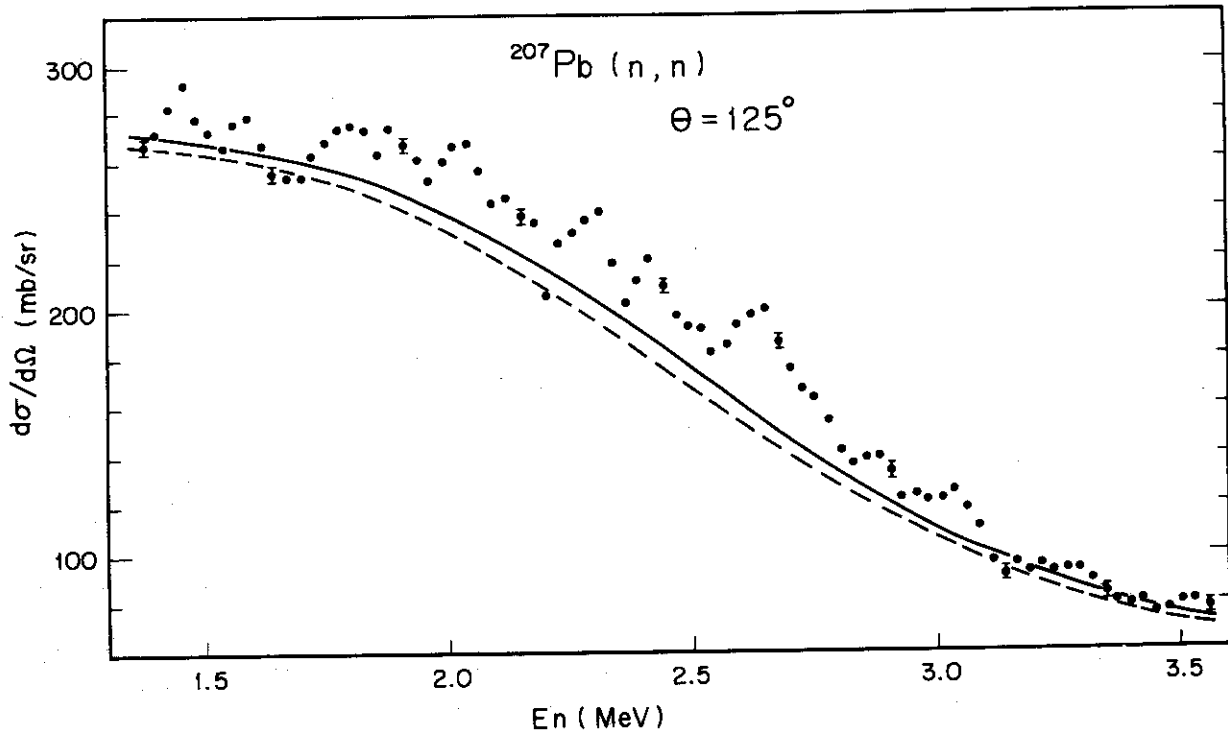


Fig. 2 Excitation functions observed at a scattering angle of 125° .
Solid and broken lines represent the calculations with the
parameters given in (2) and (3), respectively.

(a) elastic scattering

(b) the first, second and third
excited states

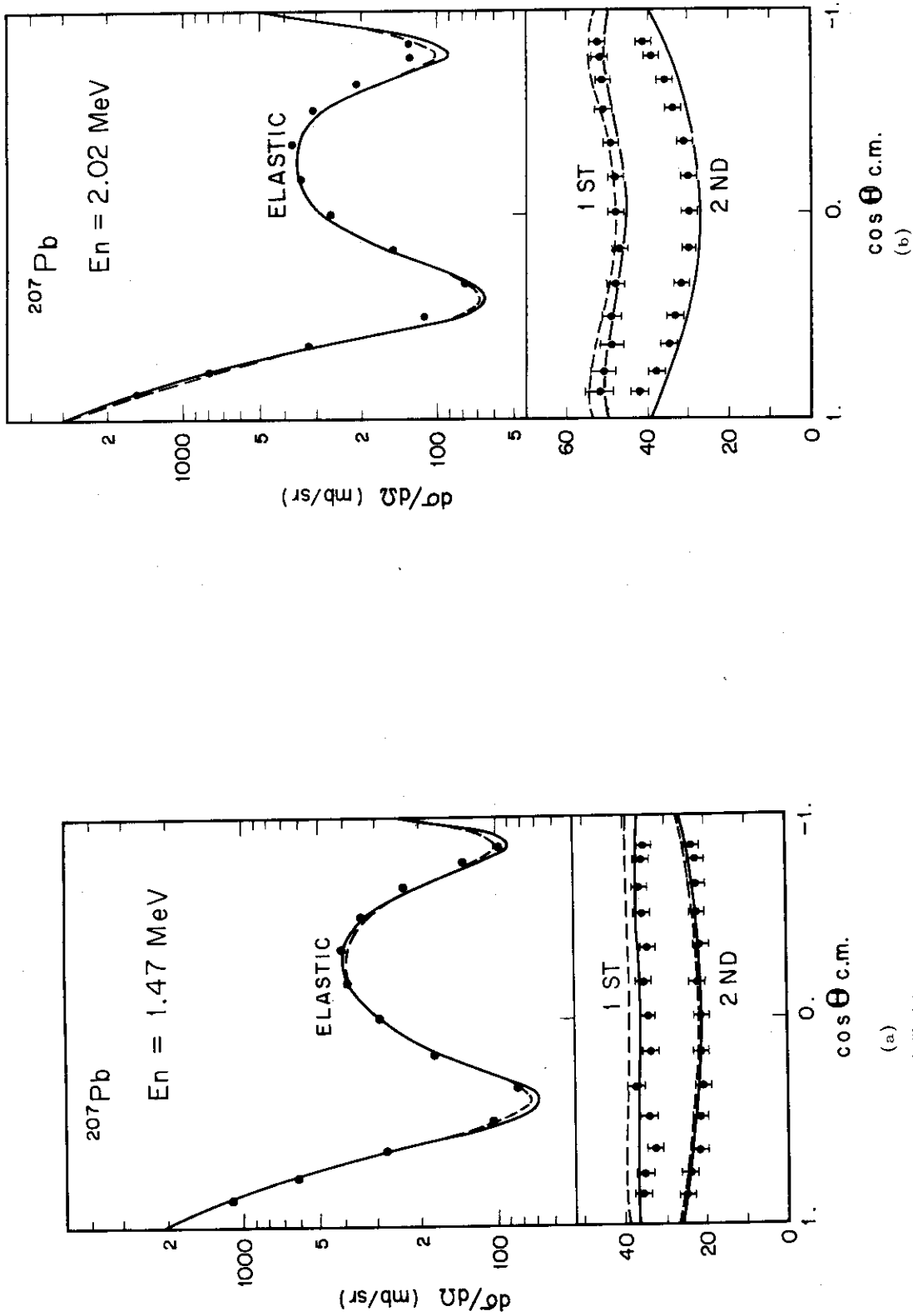


Fig. 3 Angular distributions for elastically and inelastically scattered neutrons. Solid lines are the best-fits of the optical model and Moldauer's theory. Broken lines represent the calculations with the parameters given in (3).

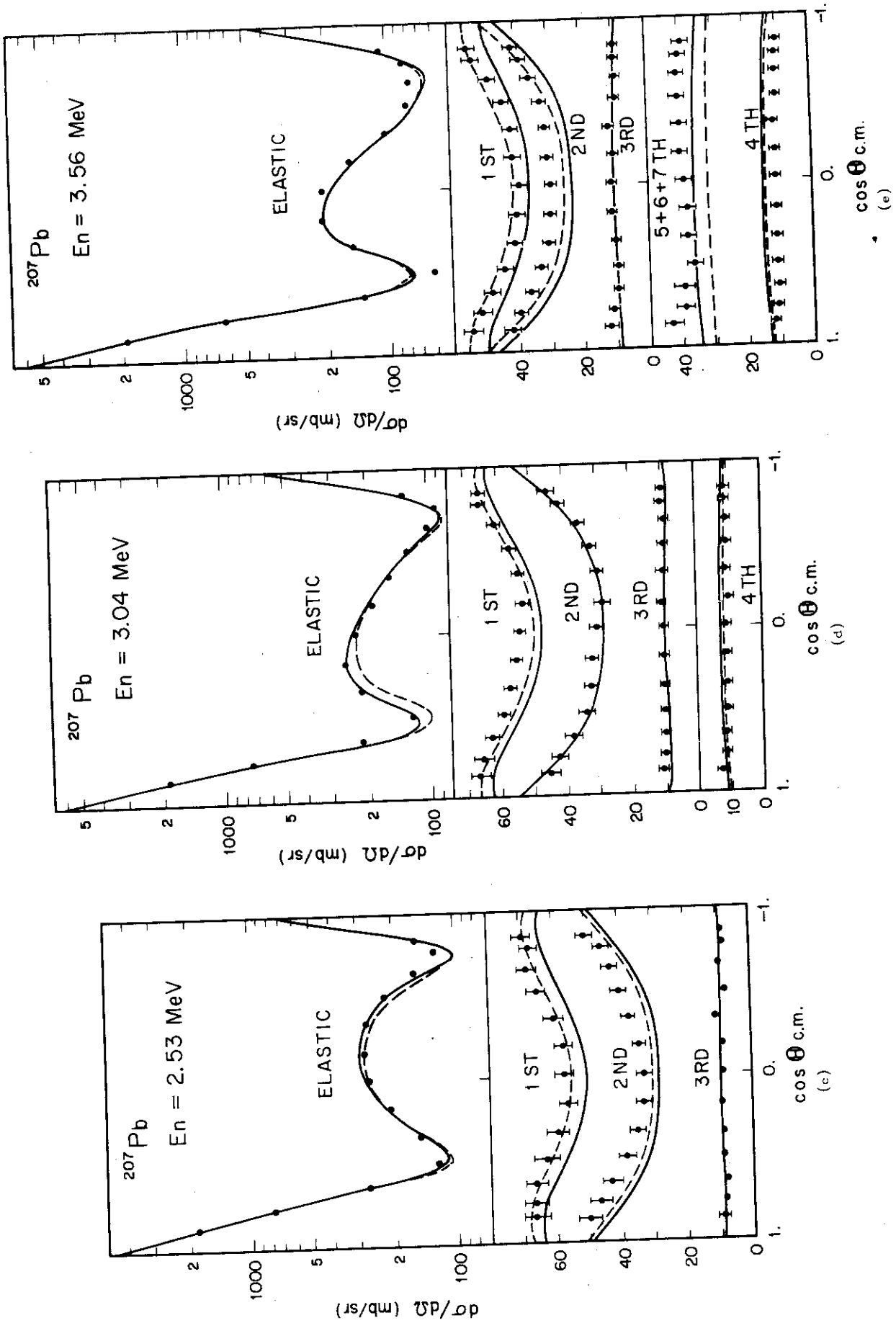


Fig. 3

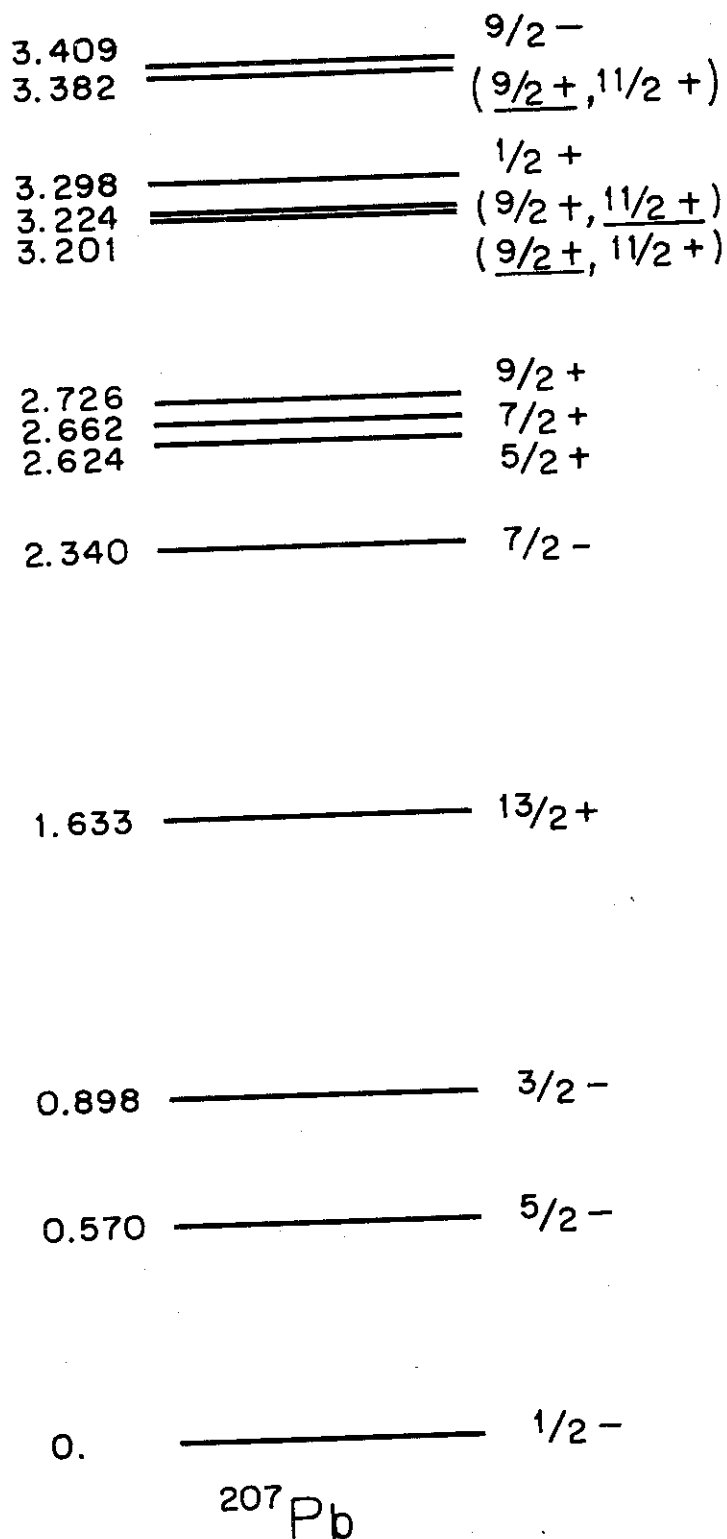


Fig. 4 The level scheme of ^{207}Pb used in the calculation of Moldauer's theory. For levels whose spin and parity are not uniquely assigned, values underlined in the figure were chosen arbitrarily.