Incomplete draft

Survey of the Total Cross Section of Lead below 100 keV

by

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1. INTRODUCTION

The total cross section for lead has been considered on several occasions (ref. 1a, 1b) for its potentialities as a standard for neutron flux determination in low energy experiments. The following citation from ref. 1b (p.11) gives the principal motivation :

"Pb (n,n)

Lead is required as a standard as an alternative to carbon because the lower neutron energy loss on collision is of advantage when using detectors with energy dependent efficiency such as Li glass.

The value of the (n,n) cross section for natural lead is known to about 0.5% accuracy in the energy range below 1 keV.

Natural lead can be used as a standard below 1.68 keV, the limit being set by the lowest resonance level in 204Pb.

With samples of separated 208 Pb, the range can be extended to 78 keV. Cross section data up to 2 keV are at present considered satisfactory."

In this note, the present status of the available cross section data on lead up to about 100 keV is surveyed briefly. The data reviewed here are those on total and capture cross sections not only for natural lead but also for isotopically enriched lead. The details about resonance parameters have not been investigated.

2. AVAILABLE CROSS SECTION DATA

The evaluated data available at March 1968 are listed in CCDN Newsletter 7 [2]. Only one of the 13 files (the UKNDL, file 26) is available at Brookhaven, Livermore or Saclay in computer media, graphical form or tabular form.

The references which have been reviewed for the present purpose are taken mainly from those listed in CINDA 67. The numerical values of relevant data have been supplied by the CCDN at the end of March 1968.

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FIG. 1

In fig. 1, the energy ranges covered by each reference are shown from 0.1 eV to 100 keV. The dashed lines refer to the experiments for which numerical values are not available but where the results are shown in graphical presentation. The solid lines represent the references in which some information about numerical values is given. The thick solid lines and closed point correspond to the references for which numerical data are stored in SCISRS tape. The numbers attached to some of the lines stand for the mass numbers of enriched isotopes of lead used in experiments. For the case marked as BNL-325 ('58), only a graphical presentation is available in BNL-325, second edition (1958) as private communication.

The most important contribution to the total cross section in the energy region reviewed comes from the elastic scattering process. In Fig. 1, the data reported by the ANL group, Ann. Phys. 12 (1961) 135, are not those on the total cross section but on the elastic scattering cross section.

Another reaction contributing to the total cross section is the capture process. The presently available cross section data are shown in Table 1. At thermal energy, the capture occurs mainly in

Table 1

^{207}Pb, and the cross section is assumed to obey the 1/v law in the energy region up to 0.1 eV[3]. As can be seen in Table 1, however, sufficient information is not available in the entire energy range considered here.

3. DISCUSSION

As is seen in Fig. 1, no new information about the total cross section of lead below some 50 keV, except for one datum at 1.44 eV, can be added to BNL-325, second edition (1958). Fig. 2 shows some of

FIG. 2

the experimental results of which numerical information is available, together with a dashed curve given in BNL-325 ('58). A rough estimate shows that the value σ_{total} (^{natural}Pb) = 11.3 barns ± 5 % is a reasonable estimate between 1 eV to 10 keV, although fluctuations can be seen in the data reported in Phys. Rev. 110 (1958) 692.

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Since the capture cross section for natural lead is estimated to be less than 1 % of the total cross section in the energy range shown in Fig. 2, it is not important for the present purpose unless the accuracy in the total cross section is considerably improved. However, the capture process can be more important if enriched samples are used, in particular at the higher energies.

As a conclusion of the present survey, it can be remarked that the quality of existing data does not seem to permit the deduction of a "recommended" cross section curve with sufficient accuracy for the requirements on a standard.

References

1) a) Proceedings of the 8th meeting of the EANDC, Los Alamos, May 1965 (EANDC-47)

b) Report of the IAEA panel on nuclear standards for neutron measurements, Brussels, 8-12 May 1967 (IAE-107, December 1968)

2) CCDN-NW/7 (1968)

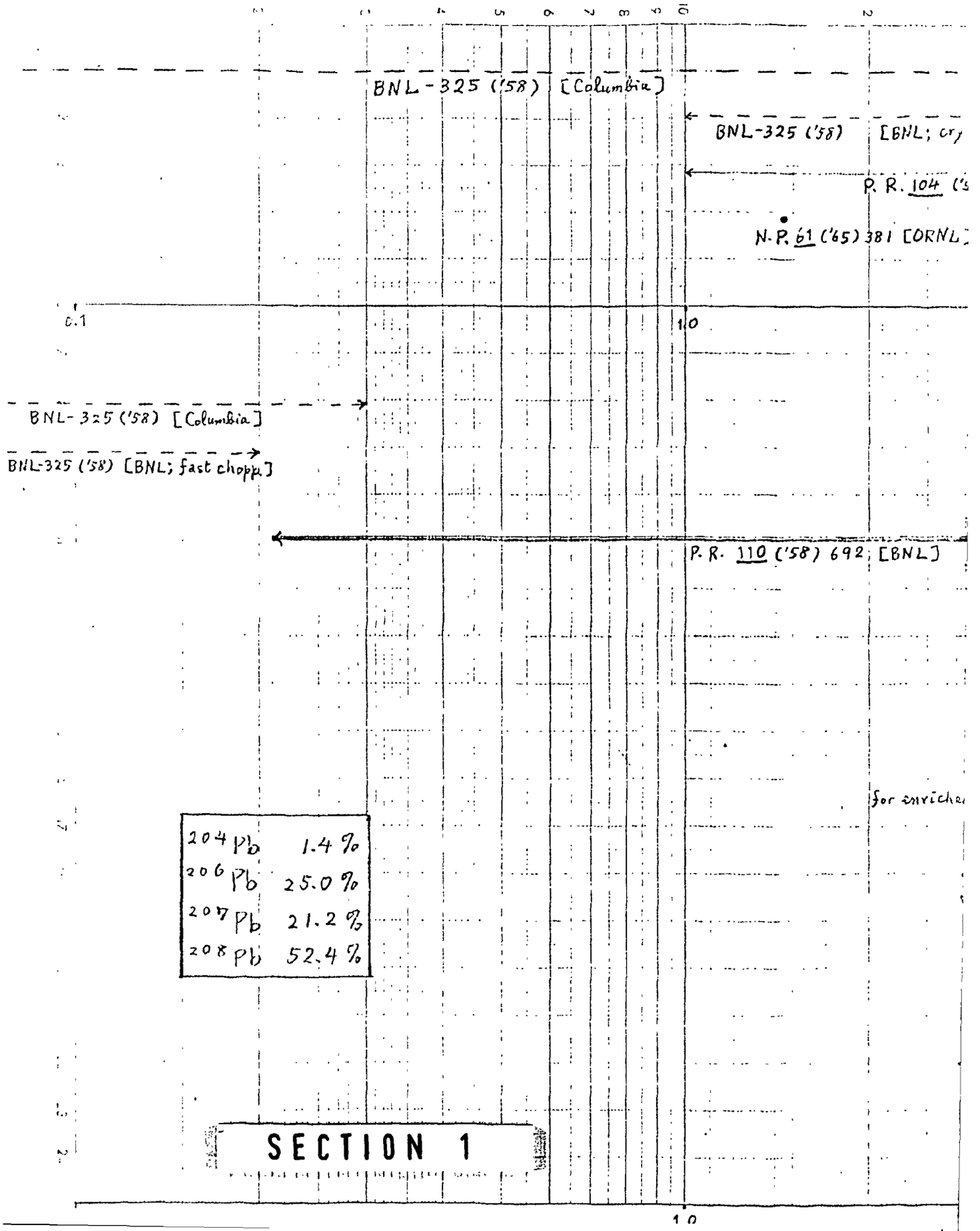
3) AEEW-R 351

Table I. Capture Cross Section Measurements

	Thermal (mb)	keV – Region (<100 keV) (mb)		
		24 keV	30 keV	65 keV
Pb	180 (~'49) Columbia 220 ± 10 ('50) Harwell 160 ± 10 ('50) ANL 190 ± 10 ('51) ORNL (170 ± 2 evaluated by UKAEA)	13 ± 3 ('52) USSR* 3 ± 9 ('60) ORNL 43 ± 7 ('65) USSR* *Same author	3 ± 3 ('63) ORNL	1 ± 2 ('63) ORNL
^{204}Pb	900 ± 650 ('52) ORNL 700 ± 20 ('58) ANL 661 ± 70 ('67) LA	124 ± 25 ('67) USSR		
^{206}Pb	100 ± 100 ('52) ORNL 25 ± 5 ('52) Harwell 31 ± 1 ('62) LA	←	10 to 60 keV in graph ('64) ORNL →	
^{207}Pb	700 ± 70 ('52) ORNL 698 ± 25 ('52) Harwell 709 ± 10 ('62) LA	←	10 to 60 keV in graph ('64) ORNL →	
^{208}Pb	0.45 ± 0.15 ('64) LA no capture ('52) ORNL	6.5 ± 1 ('66) India	← no capture in 10 to 60 keV region ('64) ORNL →	

Maxwellian averaged capture cross sections are listed from 5 to 90 keV for ^{204}Pb, ^{206}Pb and ^{207}Pb. R.M.P. 37 ('65) 166.

Fig. 1 Energy Range of Availa



Available Data on Total Cross Section of Lead

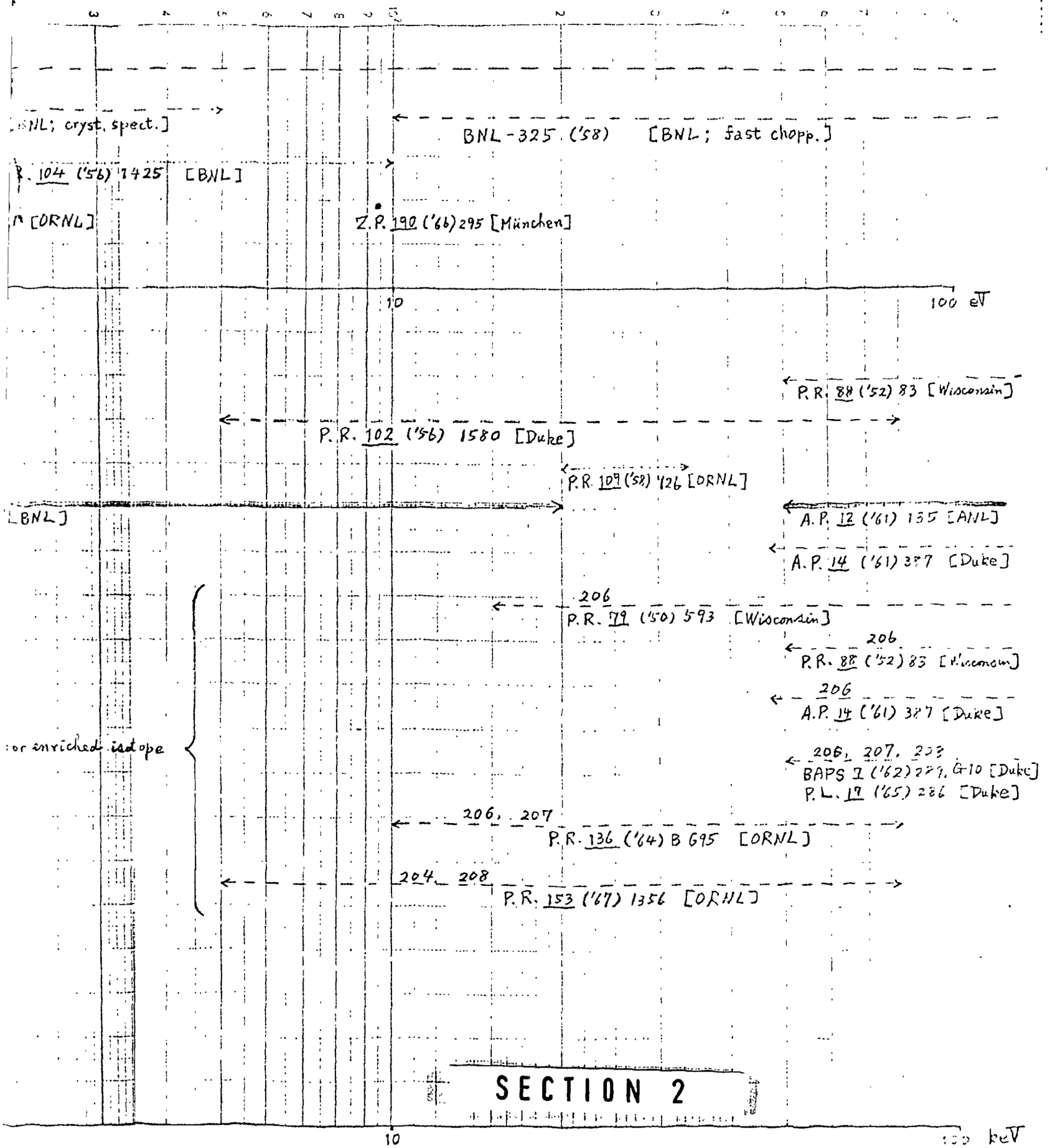
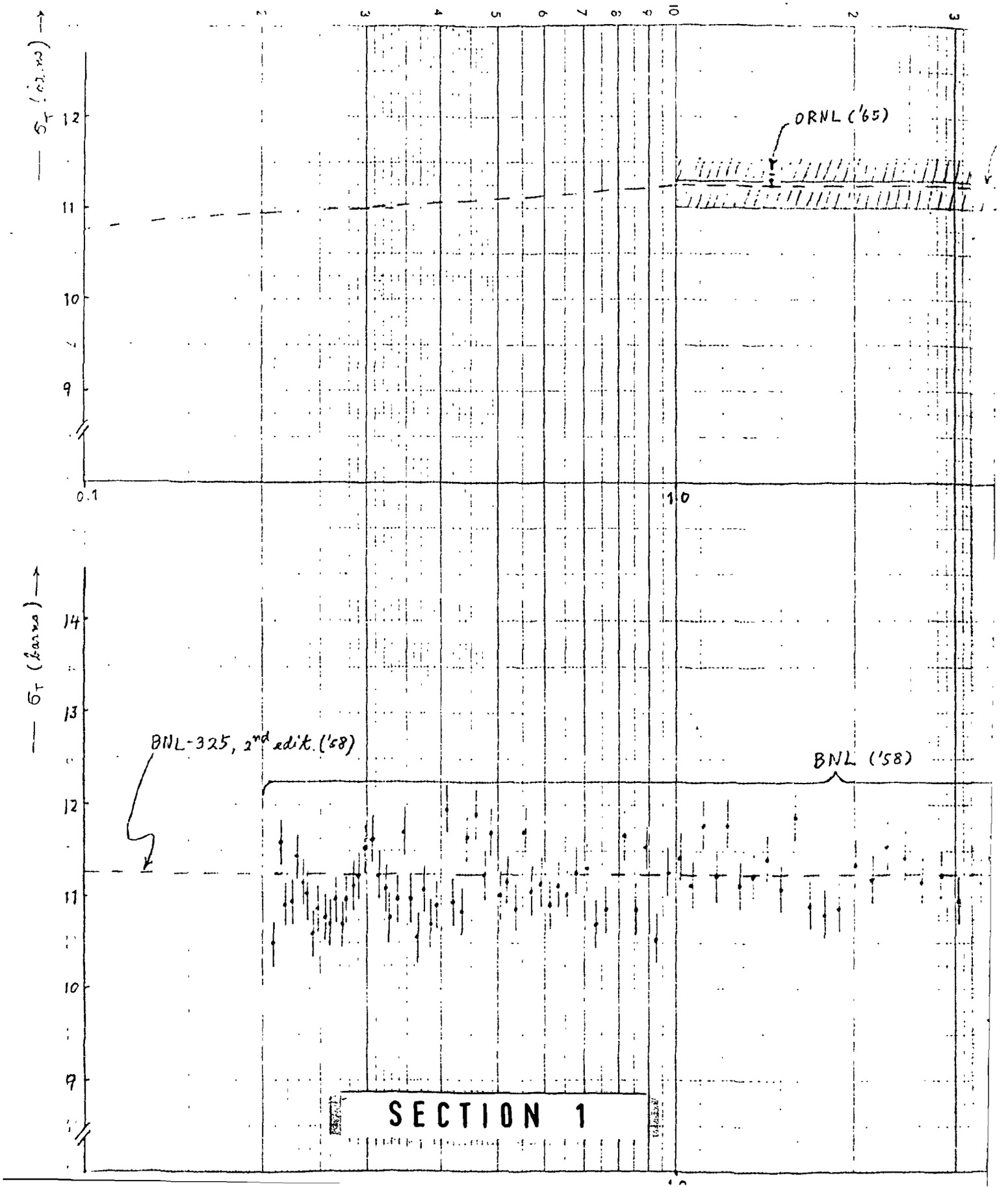
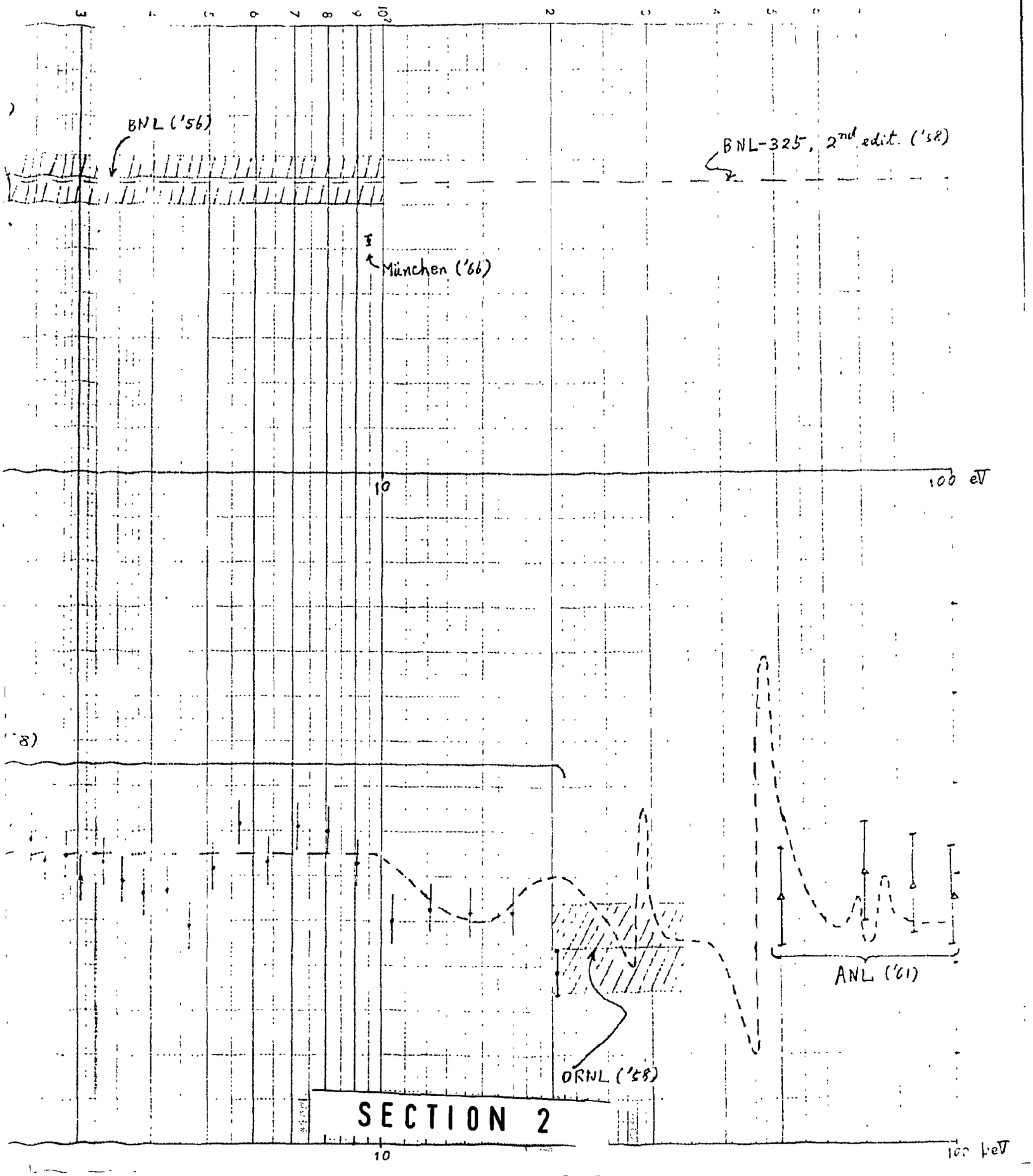


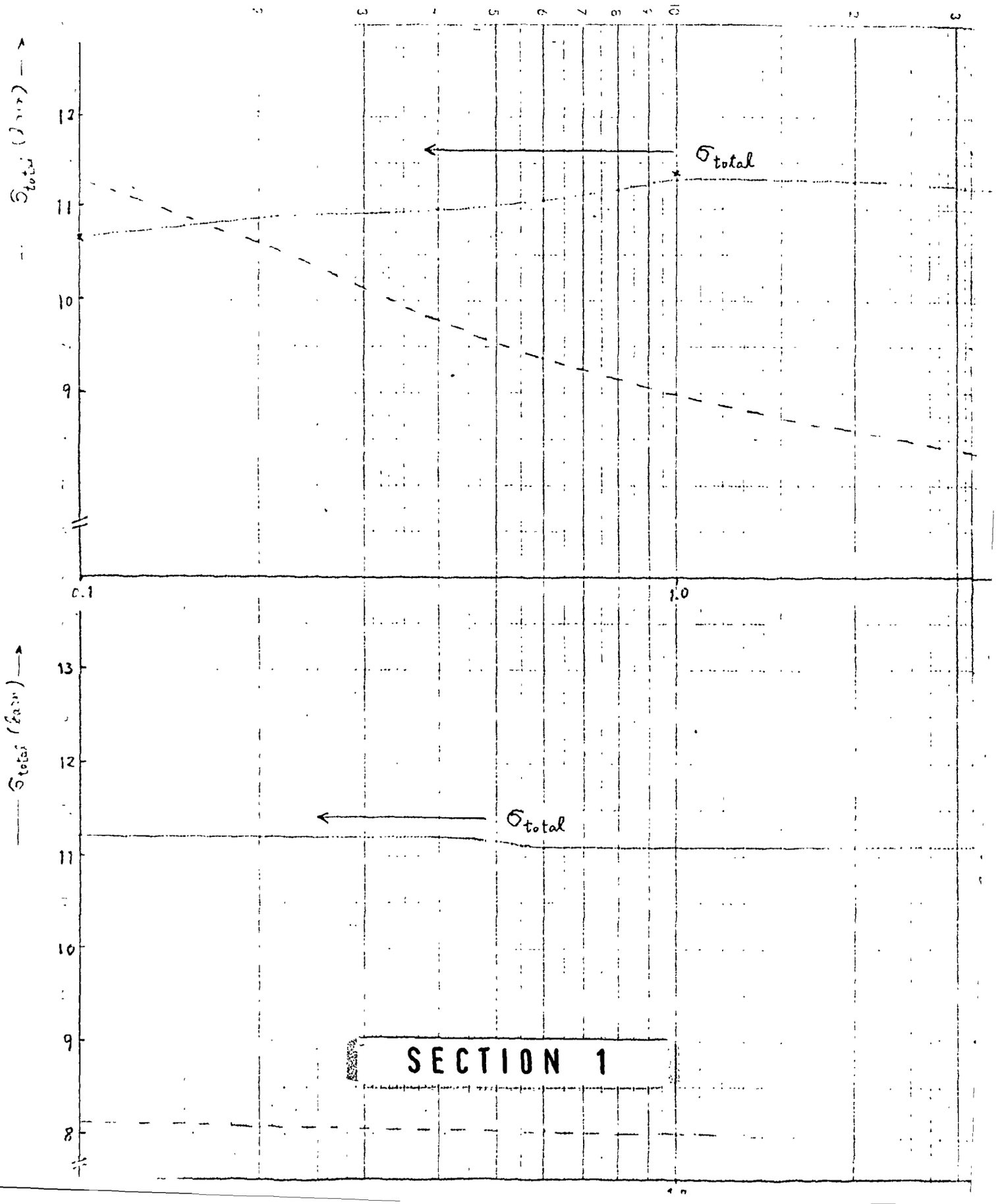
Fig. 2 Total Cross Section



Section of Lead



Total and Capture Cross Sections taken from

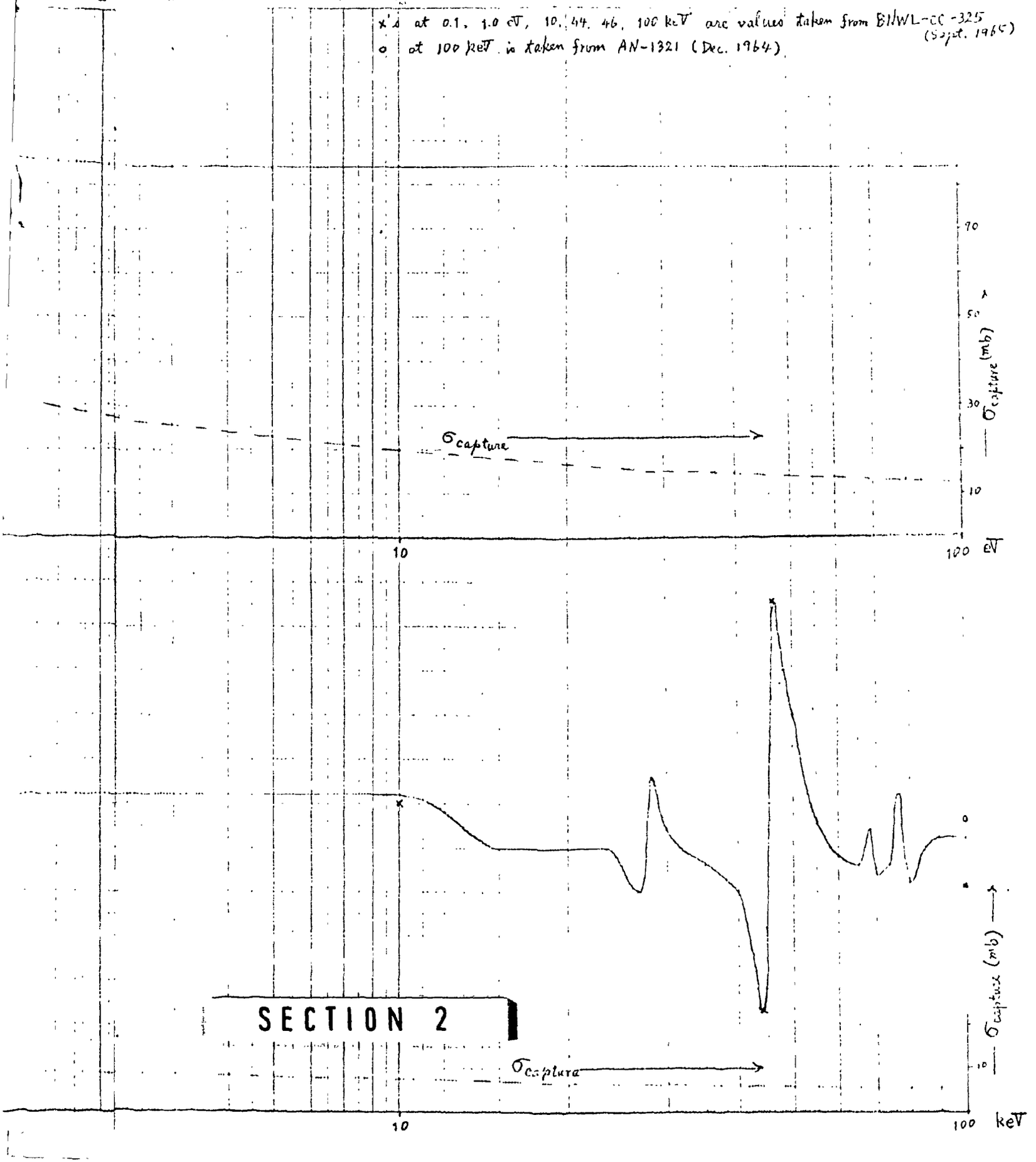


from UK (Aldermaston) File, 1964

[$\sigma_{total} = \sigma_{elastic} + \sigma_{capture}$ in this energy range]

x's at 0.1, 1.0 eV, 10, 44, 46, 100 keV are values taken from BNWL-CC-325 (Sept. 1965)

o at 100 keV is taken from AN-1321 (Dec. 1964)



SECTION 2