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U. Fasoli, D. Toniolo and G. Zago: ELASTIC AND INELASTIC SCATTERING OF PROTONS BY Li^7 IN THE ENERGY INTERVAL 3.0-5.5 MeV. -

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U. Fasoli, D. Toniolo and G. Zago: ELASTIC AND INELASTIC SCATTERING OF PROTONS BY Li^7 IN THE ENERGY INTERVAL 3. 0-5. 5 MeV(x).

ABSTRACT. -

The cross section and the angular distribution of the reactions $Li^7(p,p)Li^7$ and $Li^7(p,p')Li^{7*}$ have been measured in the energy interval between 3. 0 and 5. 5 MeV. The elastic scattering cross section presents a resonance at about 4. 2 MeV attributed to a new Be^8 level at the excitation energy of 20. 9 MeV.

INTRODUCTION. -

The problem of the determination of the level structure of Be^8 has received considerable attention by many experimenters[1]. Recently some new levels have been discovered by Jeronimo et al. [2] and by Cavallaro and al. [3] by bombarding with deuterons and protons respectively the lithium isotopes Li^6 and Li^7.

In the present work we have measured the cross section and the angular distribution for the elastic scattering of protons by Li^7 and for the inelastic scattering leaving Li^7 in its first excited state, at incident proton energy between 3. 0 and 5. 5 MeV.

The cross sections for the above reactions had been first measured by Bashkin and Richards[4] and later by Warters, Fowler and Lauritsen[5] and by Malmberg[6] in different energy intervals, up to a maximum of 3 MeV; they observed several resonances attributed to Be^8 levels with excitation energies between 17. 25 and 19. 8 MeV. In order to compare our results to the results obtained by other authors[4-6], the measurement of the differential cross section for the elastic scattering at the angle of 166° has been extended down to the minimum energy of 1. 2 MeV.

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EXPERIMENTAL METHOD. -

The protons, accelerated with the Van de Graaff accelerator of the University of Padua and analyzed with a magnet whose energy resolution was 0.15%, were focalized on a Li^7 target isotopically enriched to 99.3%, evaporated on a 1000 Å Nickel foil. The target was 30 KeV thick for 1.8 MeV protons and was located in the center of a scattering chamber very similar to that described by Silverstein et al. (7).

The scattered particles were detected by an ORTEC solid state detector wich subtended an angle of 2.2×10^{-3} steradian at the target. The pulses from the detector were analyzed by means of a 512 channel analyzer. The countings were normalized to the same beam charge by a precision integrator of the unscattered beam current, collected by a Faraday cup.

When Li^7 is bombarded by protons with energy between 3.0 and 5.5 MeV, beside the production of gamma rays the following other reactions are possible:

a) $p + Li^7 \longrightarrow p + Li^7$

b) $p' + Li^{7*} - 0.478$ MeV

c) $p'' + Li^{7*} - 4.63$ MeV

d) $t + Li^5 - 4.26$ MeV

e) $\alpha + \alpha + 17.347$ MeV

f) $n + Be^7 - 1.646$ MeV.

The resolution of the counter, which was of about 1%, and the thickness of the target were such as to allow clear separation between the protons elastically and inelastically scattered from Li^7, the tritons and the alfas from reaction d) and e) and the protons scattered from the nickel, oxigen and carbon nuclei present on the target.

The neutrons from reactions f) and the gamma rays gave rise to a continuous background, with a mean value of a few percent of the elastic peak.

The statistical errors were negligible with respect to the errors made in estimating the background.

Corrections for the dead time of the counting chain and for deterioration of the target were negligible and therefore have not been applied.

RESULTS. -

The comparison between the differential cross section obtained in the present work at $\vartheta_{lab} = 166°23'$ and the results obtained by Bashkin and Richards at $\vartheta_{lab} = 164°$, is shown in fig. 1. The agreement is good within the errors of 20% attributed by Bashkin to his results.

Our absolute cross section scale has been evaluated as follows:

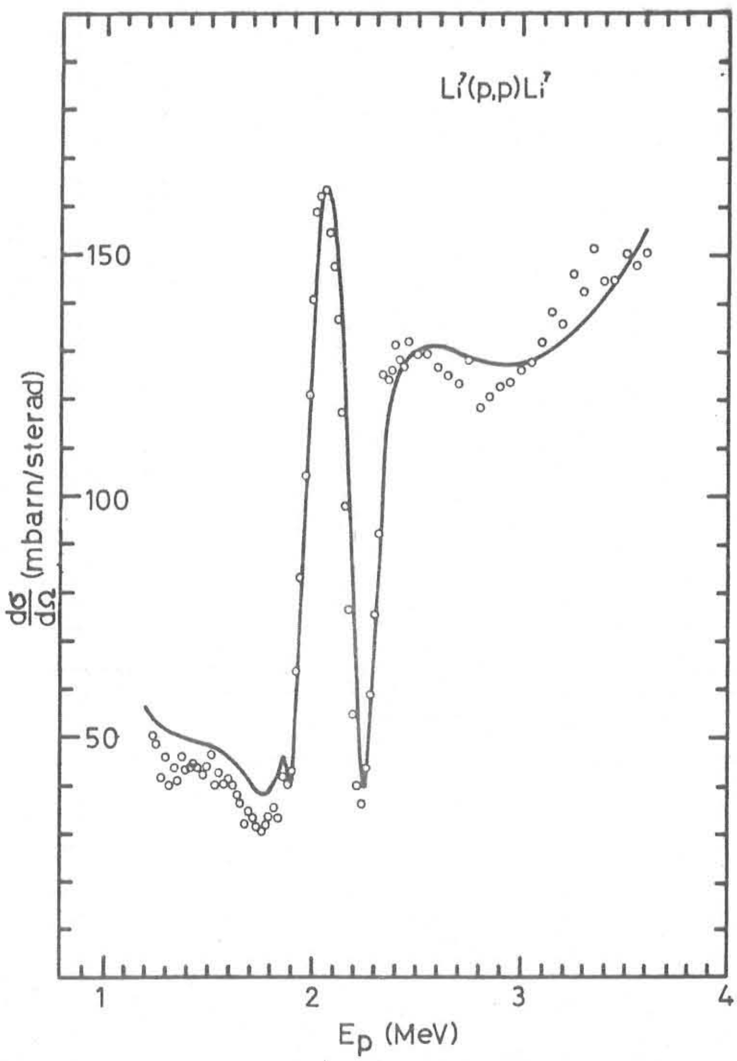

FIG. 1 - Differential cross section for protons elastically scattered from Li^7. The circles are our results for the center of mass scattering angle of $168^o 12'$; the continuous line represents the results obtained by Bashkin and Richards at the laboratory angle of 164^o., transformed in the center of mass system and multiplied by 1. 1.

the Li^7 target has been replaced with a target of natural lithium fluoride where Li^6 and Li^7 are present in the ratio $C_6/C_7 = 7.5/92.5$, and the intensities I_6 and I_7 of the protons elastically scattered by the two nuclei, at $166^o 23'$ and for Ep = 1. 800 MeV, have been contemporarily measured. The absolute differential cross section σ_7 of protons elastically scattered by Li^7, may therefore be calculated, knowing the corresponding cross section σ_6, by the:

$$\sigma_7 = \sigma_6 \frac{I_7 C_6}{I_6 C_7} .$$

The value of σ_6 has been given by Fasoli et al. [8].

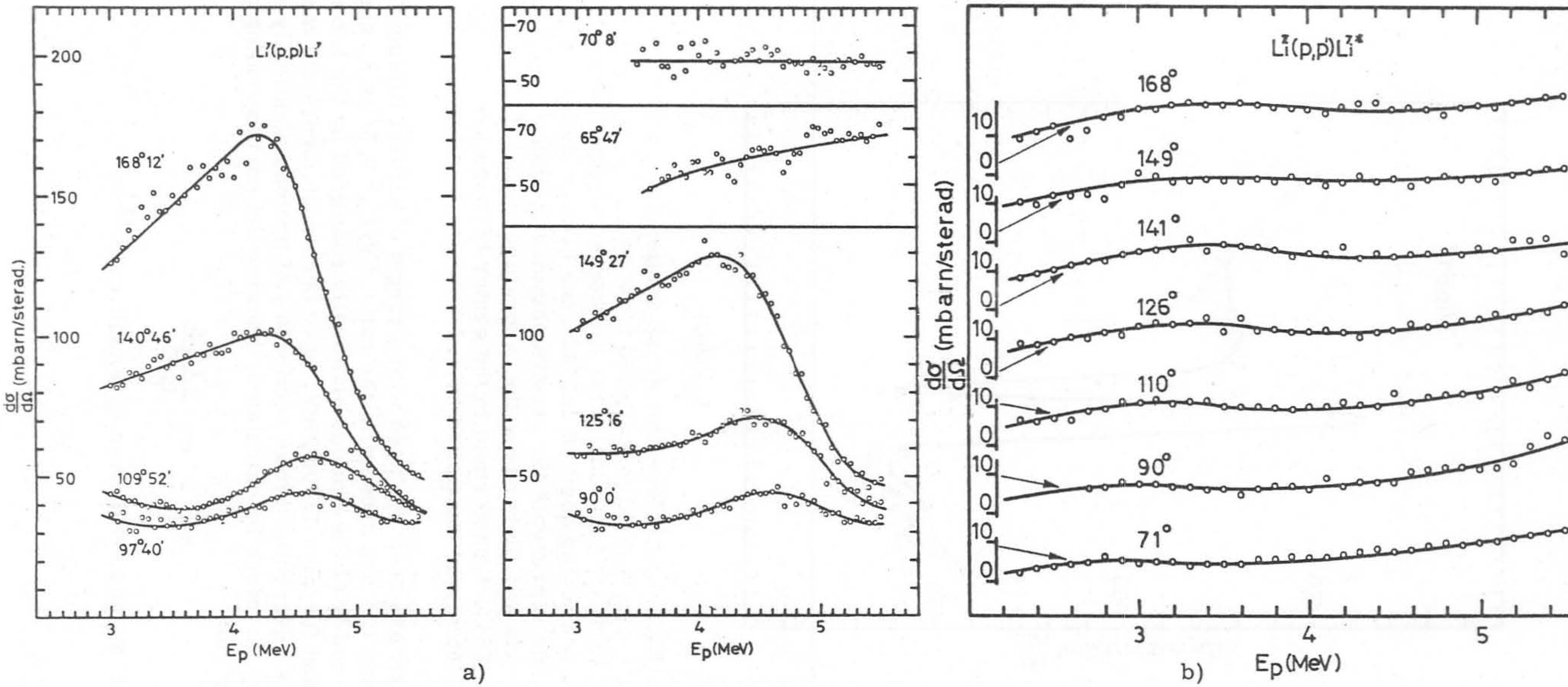

FIG. 2 - Differential cross section of the reactions $Li^7(p,p)Li^7$ and $Li^7(p,p')Li^{7*}$. The cross section and the angles are given in the center of mass reference system. Smooth curves have been drawn through the points.

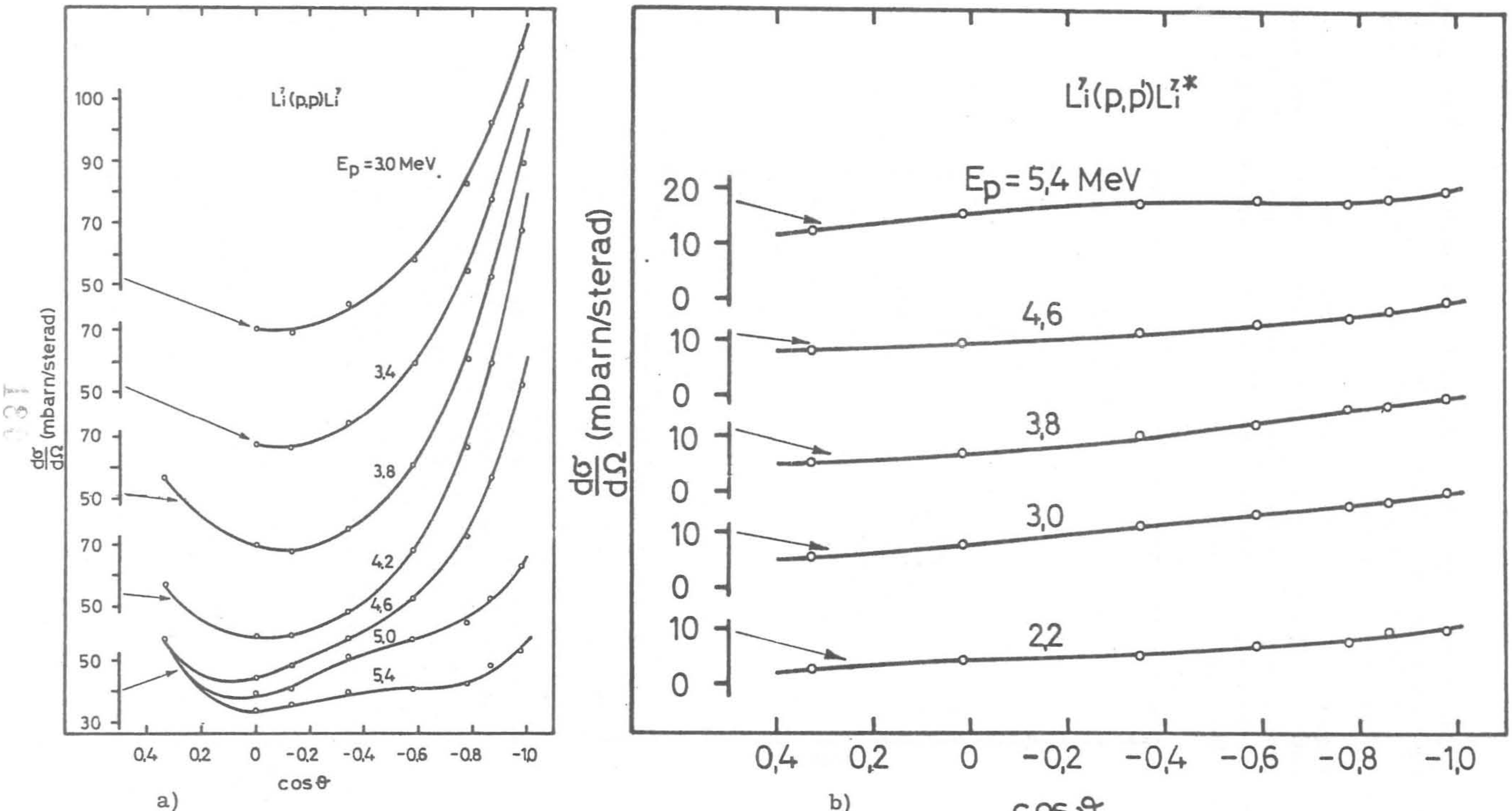

FIG. 3 - Angular distributions of the reactions $Li^7(p,p)Li^7$ and $Li^7(p,p')Li^{7*}$. The circles have been taken from the smooth curves of fig. 2a and 2b. The curves are best fits obtained with fourth degree polynomials.

Figs. 2a and 2b give the differential cross section at different angles for the elastic protons scattered by Li^7 and for the inelastic protons leaving Li^7 in the first excited state. The cross section and the angles are given in the center of mass system.

Figs. 3a and 3b give the angular distribution for the two reactions. It is apparent that the elastic reaction is peaked backwards expecially at the lower energies, the inelastic one shows the same feature. For the former, appreciable contributions of waves with l larger than 1 are present at the higher energies.

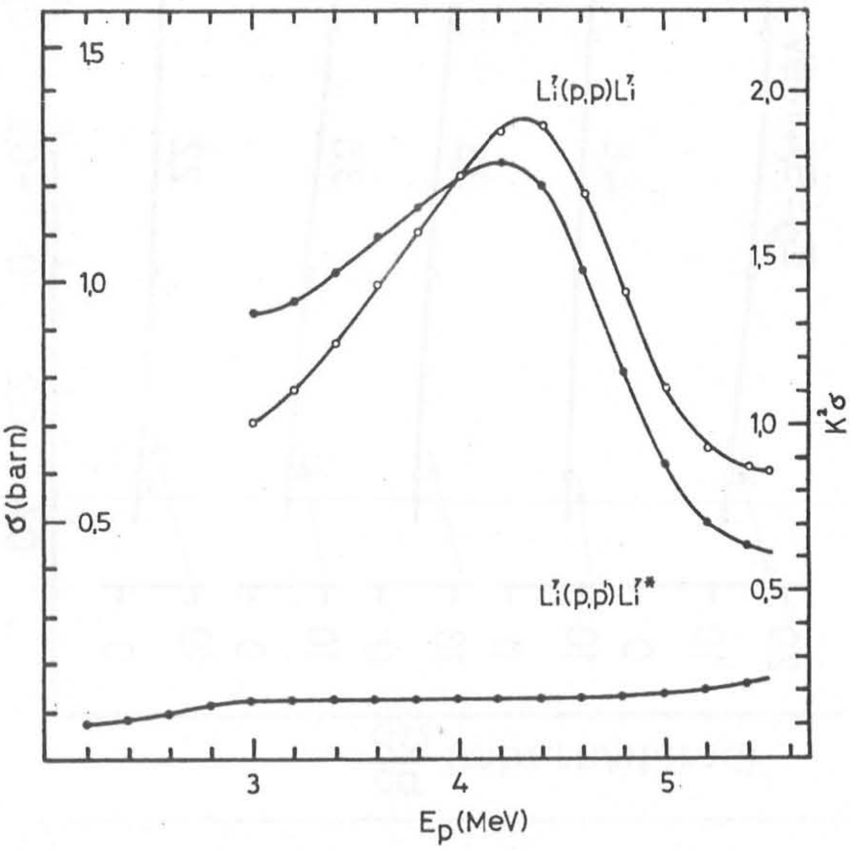

FIG. 4 -- Total cross section σ in the angular interval 70^o-180^o for the reactions $Li^7(p,p)Li^7$ and $Li^7(p,p')Li^{7*}$ (full circles). Open circles give the dimensionless quantity $K^2\sigma$, where K is the wave number of the two particles colliding in the center of mass system of reference. Smooth curves have been drawn through the points.

Fig. 4 shows the total cross section σ for the elastic scattering of protons from Li^7 in the center of mass angular interval (70^o-180^o). In the same figure are given the values of the dimensionless quantity $K^2\sigma$, where K is the wave number of the particles colliding in the center of mass system.

It is evident from fig. 4 that the p-Li^7 elastic cross section presents a resonance at 4.2 MeV of proton energy with a width of about 1 MeV; the corresponding excitation energy of the compound nucleus Be is 20.9 MeV.

DISCUSSION. -

In the explored energy region, of the two inelastic reactions:

$$p + Li^7 \longrightarrow p' + Li^{7*} - 0.478 \text{ MeV}$$
$$p'' + Li^{7*} - 4.63 \text{ MeV},$$

the former has a cross section nearly constant and of the order of 1/10 of the elastic and the latter has a threshold at 5.30 MeV. The threshold for triton emission is 4.86 MeV. So far we have no reason to believe that the maximum at 4.2 MeV be perturbed by competing reactions.

We conclude that the observed resonance of the elastic scattering cross section is due to a level of Be^8 not previously observed, with 20.9 MeV of excitation energy and about 1 MeV width.

Calculations are in progress in order to find the other parameters of the observed level.

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BIBLIOGRAPHY. -

(1) - For a summary of the works done up to 1959 see: F. Ajzenberg-Selove and T. Lauritsen, Nuclear Phys. 11, 1 (1959); and for more recent works see references (2) and (3).
(2) - J. M. Jeronimo, G. S. Mani, F. Picard and A. Sadeghi, Nuclear Phys. 38, 11 (1962).
(3) - S. Cavallaro, R. Potenza and A. Rubbino, Nuclear Phys. 36, 597 (1962).
(4) - S. Bashkin and H. T. Richards, Phys. Rev. 84, 1124 (1951).
(5) - W. D. Warters, W. A. Fowler and C. C. Lauritsen, Phys. Rev. 91, 917 (1953).
(6) - P. R. Malmberg, Phys. Rev. 101, 114 (1956).
(7) - E. A. Silverstein, S. R. Salisbury, G. Hardie and L. D. Oppliger, Phys. Rev. 124, 868 (1961).
(8) - U. Fasoli, E. A. Silverstein, D. Toniolo and G. Zago, INFN/BE-64/1 (1964).