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Abstract

The π^+-H and π^+-D elastic scattering excitation functions for $\theta_\pi = 180°$ were measured between 130 and 280 MeV kinetic energy. The π^+-D results show some evidence for a structure in the vicinity of 250 MeV which could be due to a dibaryon resonance formation.

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In several recent papers, the possible existence of dibaryon resonances appearing as a resonant behavior in p-p scattering (ref.1) and possibly in n-p scattering (ref.2) was reported. The analysis of the C_{LL} spin correlation and of cross section differences between parallel and antiparallel longitudinal ($\Delta\sigma_L$) and transverse ($\Delta\sigma_T$) total cross sections in p-p data yields some evidence for three states at energies of 2.14-2.17 GeV ($^1D_2$), 2.20-2.26 GeV ($^3F_3$) and 2.43-2.50 GeV ($^1G_4$). However, in a theoretical analysis of these nucleon-nucleon anomalies inelastic channels are also present and the assumptions made about inelasticity will introduce uncertainties in the phase shift analysis.

Besides N-N scattering several results which could be due to dibaryon resonances were reported, such as the total cross section (ref.3) or the polarization at 90° (ref.4) in the $\gamma + D \rightarrow p + n$ reaction. In particular, the last experiment leads to an enhancement at 2.38 GeV with a width of 100-200 MeV.

To ascertain these results, the π^+-D elastic scattering excitation function at very backward angles is a specifically well designed experiment. In the energy region of interest, i.e. for pion kinetic energies between 100 and 350 MeV, the forward elastic scattering can be reproduced in terms of πN amplitudes (ref.5) which are dominated by the $\Delta(3,3)$ resonance. In the backward hemisphere for the pion, this single particle contribution to the cross section is reduced due to the large momentum transfer in the reaction which favors a two-nucleon mechanism to share the transferred momentum. Since $\theta_\pi =$ 180° is closest to the nonphysical region where the backward scattering amplitude contains all the exchange singularities, this scattering angle corresponds to the most favorable situation.

Little is known about backward scattering since the experimental data are rather scarce (ref.6-9) and often inconsistent. For this reason, we measured the excitation function at 180° of the π^+-D elastic scattering cross section between 130 and 280 MeV. The experiment was carried out at the Swiss Institute for Nuclear Research (SIN) using the πM1 beam line and pion spectrometer. In addition, the large angle set-up (ref.10) was used. The incident pion beam is momentum analysed and focused on the target located in a semi-circular magnet. The target can be moved continuously between its normal position corresponding to a scattering angle of 135° and the 180° scattering position which is 30 cm further downstream. Good focusing on target in this case is obtained by moving the focal position of the channel downstream by decreasing the current in the last quadrupole doublet of the channel. The backward scattered pions are detected in the high resolution pion spectrometer (ref.11) for which the angle must be selected in order to measure the elastically scattered pions, since the kinematic condition is taken into account by moving the spectrometer angle (ref.10). For π^+-D elastic scattering the spectrometer angle is 123.7°, whereas for π^+-H scattering it is 120.1° for all energies. Since the target is further away from the spectrometer entrance, the normal spectrometer solid angle $\Delta\Omega = 16$ msr is reduced. However, this decrease is independent of the pion energy. In addition, care was taken to have the same focusing conditions on target at each energy. The targets used are liquid C_6D_{12} and C_6H_{12} targets of identical 3 mm thickness with very thin Al windows (30 μm). External kapton windows of 25 μm allow a small air overpressure between the two windows to reduce the deformation of the shape of the Al window due to internal liquid pressure.

Elastic scattering of positive pions on ^{1}H and ^{2}D was measured for θ_π=180° at seven energies between 130 MeV and 280 MeV incident energy. In addition, at T_π=230 MeV, the same cross sections were also measured at θ_π=133°. Fig.1 shows two scattering spectra at θ_π=180° and T_π=180 MeV corresponding to π^+-D and π^+-H scattering taken with π^+-D spectrometer settings. Energy resolution is 900 keV FWHM. Contaminations from carbon and the target windows are clearly observed as well as the inclusive spectrum up to 40 MeV excitation energy of deuterium break-up. Data analysis took into account pion decay and muon contamination. Our results are shown on fig.2 for π^+-H and on fig.3 for π^+-D scattering. Error bars include both statistics and background subtraction. In addition, an overall normalization error of ±15% was added, due mainly to target thickness and acceptance of the pion spectrometer with the large angular facility. The π^+-H and π^+-D elastic cross sections at θ_π=133° and T_π=230 MeV are in accord with previous results (ref.12,13) and new π^+-D results at T_π=256 MeV (ref.14). The π^+-H elastic scattering results at θ_π=180° shown on fig.2 are compared with previous extrapolated results (ref.12,15) where the error bars include the uncertainties arising from extrapolating from $-0.6 < \cos\theta < -0.8$ to $\cos\theta = -1$. Our 180° results are slightly higher than the extrapolated values near the maximum of the $\pi N(3,3)$ resonance, whereas the opposite situation occurs for T_π=255 and 280 MeV. This means that the π^+-H differential cross section is increasing faster than predicted for very backward angles in the region of the maximum of the (3,3) resonance, but decreasing faster for increasing energies. The 180° π^+-D elastic scattering results presented on fig.3 are compared with the 180° data of ref.9 at lower energies and those of ref.7 and 8 for $\theta_\pi \lesssim 164°$ at higher energies. The dashed curve is a calculation by Giraud et al. (ref.5) based on the Faddeev-Lovelace equations with relativistic kinematics used only for the pion (RPK theory). All S and P wave πN channels are included except P_{11} and a parametrization of the $^3S_1$-$^3D_1$ NN channel giving a realistic deuteron wave function is used (ref.16). Compared to the data the general slope is well reproduced. However, there seems to be a deviation for $225 < T_\pi < 300$ MeV reaching a factor of two at 225 MeV. Above 300 MeV, this theory is not well suited. On the same figure, the positions of the three p-p resonances of ref.1 in the π^+-D total center of mass energy are given. The arrows indicate the uncertainties on their energy determination. We observe some experimental structure at T_π=240-260 MeV which is located in the vicinity of the $^3F_3$ resonance.

Kanai et al. carried out a Glauber model calculation (ref.17) with a resonance term including the $^3F_3$ state which shows a significant enhancement of the π^+-D elastic cross section at very backward angles for T_π=230 MeV. In addition, they also include the resonance at 2.5 GeV and find a good agreement with the data of Schroeder et al. (ref.7) at T_π=420 MeV (shown on fig.3), while without this resonance their model yields a cross section too low by an order of magnitude. However, at this stage of the discussion, it should be pointed out that other effects may enhance the backward π^+-D elastic cross section. For example Rinat et al. (ref.18) calculated the π^+-D observables at T_π = 142, 180, 217, 232 and 256 MeV using a fully relativistic three body theory including pion emission and absorbtion. Their θ_π=180° results shown on fig.3 (dot-dashed curve) agree well with the Giraud et al. calculation if absorbtion effects are not taken into account. However the inclusion of the latter produces significant enhancements (crosses on fig.3) although the agreement is satisfactory at T_π=230 MeV only whereas absorbtion effects seem too strong around 200 and at 256 MeV. E.L.Lomon (ref.20) suggested that pion absorbtion effects could be dynamically related to dibaryon resonance formation. Kubodera et al.(ref.19) recently calculated the Faddeev amplitudes mixed with the three T=1 dibaryon resonances but without pion absorbtion. Their result is very sensitive to the mixing of the two allowed pion orbital momenta in the dibaryons and remains always too low by a factor of two if compared to the experimental result at T_π=225 MeV. This could mean that absorbtion effects should be added independently of the dibaryon resonance formation which was done by Rinat et al.(ref.18) at T_π=256 MeV. However when they include both the $^3F_3$ resonance and the pion absorbtion, the π^+-D cross section reaches 0.8 mb/sr which is now too high by a factor of two to three. We propose two explanations:

1) At backward angles the predicted cross sections are very sensitive to the deuteron form factors and depend strongly (see ref.18) on the D-state behavior of the deuteron wave function.

2) As mentioned above, the π^+-H amplitudes used in π^+-D calculations at $\theta_\pi=180°$ should be corrected taking into account our new π^+-H, $\theta_\pi=180°$ measurements which probably will increase the calculated π^+-D cross sections between 100 and 200 MeV and decrease them above 200 MeV.

In conclusion, the π^+-D excitation function at $\theta_\pi=180°$ measured at seven energies between 130 and 280 MeV shows some evidence for a structure in the vicinity of 250 MeV. In this energy region, pion absorbtion or dibaryon resonance formation added in a Faddeev type calculation can produce an enhancement of the backward elastic cross section. The experimental situation should be improved by covering a wider range of energies in the T=1 channel. Furthermore, data in the T=0 channel (π^--D system) would also be useful.

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References

1) I.P.Auer et al., Phys. Lett. 67B (1977) 113 ; 70B (1977) 475 and Phys. Rev. Lett. 41 (1978) 354

2) A.Yokosawa, Argonne National Laboratory Report ANL-HEP-CP-78-52 (unpublished)

3) J.C.Keck and A.V.Tollestrup, Phys. Rev. 101 (1956) 360

4) T.Kamae et al., Phys. Rev. Lett. 38 (1977) 468

5) N.Giraud, Y.Avishai, C.Fayard and G.H.Lamot, Phys. Rev. C19 (1979) 465

6) K.Gabathuler et al., Nucl. Phys. B55 (1973) 397 ; E.G.Pewitt et al., Phys. Rev. 131 (1963) 1826 ; J.Norem, Nucl. Phys. B33 (1971) 512

7) L.S.Schroeder et al., Phys. Rev. Lett. 27 (1971) 1813

8) R.H.Cole, J.C.Mc Carthy, R.C.Minehart and E.A.Wadlinger, Phys. Rev. C17 (1978) 681

9) R.J.Holt et al., Phys. Rev. Lett. 43 (1979) 1229

10) J.P.Egger et al., Nucl. Inst. and Meth. 154 (1978) 437

11) J.P.Albanèse et al., Nucl. Inst. and Meth. 158 (1979) 363

12) J.P.Bussey et al., Nucl. Phys. B58 (1973) 363

13) T.Mizutani and D.Koltun, Ann. of Phys. 109 (1978) 1

14) K.Gabathuler et al., SIN-preprint

15) C.Lovelace et al., πN two body scattering, Lawrence Berkeley Laboratory LBL-63 (1973)

16) G.H.Lamot, 5° session d'études biennale de physique nucléaire, Lycen 79 and private communication, IPN Lyon

17) K.Kanai, A.Minaka, A.Nakamura and H.Sumiyoshi, 8th High Energy Phys. and Nucl. Struct. Conf. (august 79) Vancouver Canada ; 1978 Kyushu preprint 78-HE-13

18) A.S.Rinat, E.Hammel, Y.Starkand and A.W.Thomas, Nucl. Phys. A329 (1979) 285

19) K.Kubodera, M.P.Locher, F.Myhrer and A.W.Thomas, PR-79-006 SIN (Switzerland) June 79

20) E.L.Lomon, Lecture Notes in Physics 82 (1978) 9 (Graz, Austria).

Figure captions

Fig.1. $\pi^+ + D$ (a) and $\pi^+ + H$ (b) scattering spectra measured at an incident pion energy of 180 MeV and a scattering angle of 180°. Since C_6D_{12} and C_6H_{12} targets were used, a small carbon background is visible in the hydrogen spectrum whereas in the deuterium spectrum both carbon and deuteron break-up which starts approximately at channel 240 are clearly seen. The spectra are not normalized to the same number of incident π^+.

Fig.2. $\pi^+ + H$ elastic scattering differential cross sections at a pion scattering angle of 180° versus the kinetic energy in the center of mass system. Our results are compared with data from ref.12 and 15 extrapolated to 180°. The dashed line is a eyeball fit.

Fig.3. $\pi^+ + D$ elastic scattering differential cross sections at a pion scattering angle of 180° versus the kinetic energy in the center of mass system. Our data (●) are compared with the 180° results of ref.9 (▲) at lower energies and extrapolated data of ref.7 (■) and 8 (▼) at higher energies. In addition, the positions of the three p-p resonances of ref.1 are shown. The curves are described in the text.

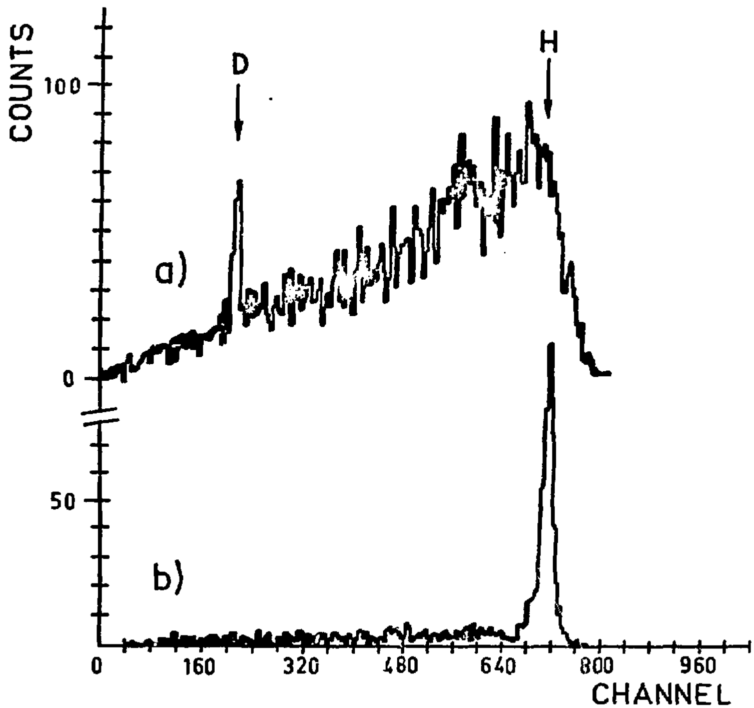


fig 1.

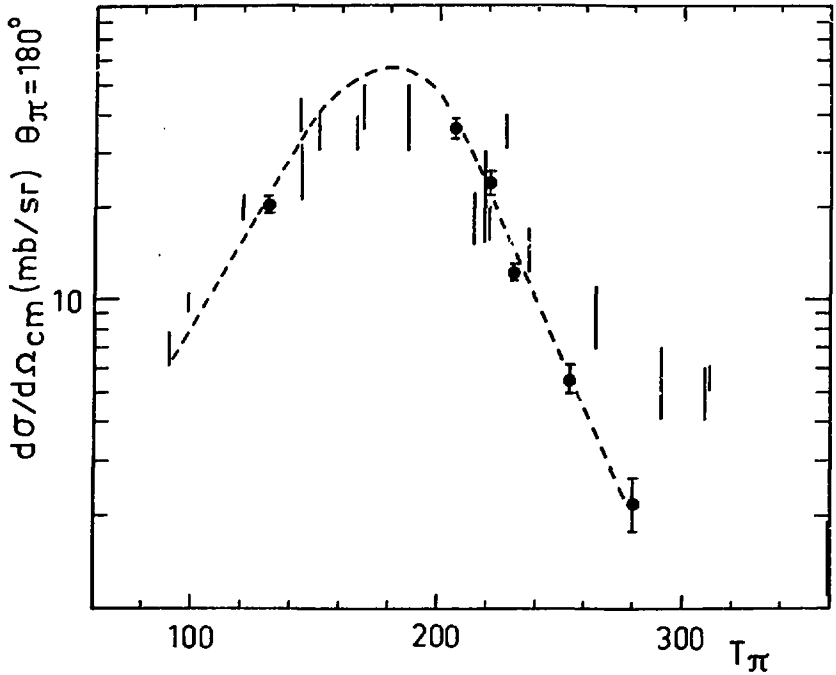
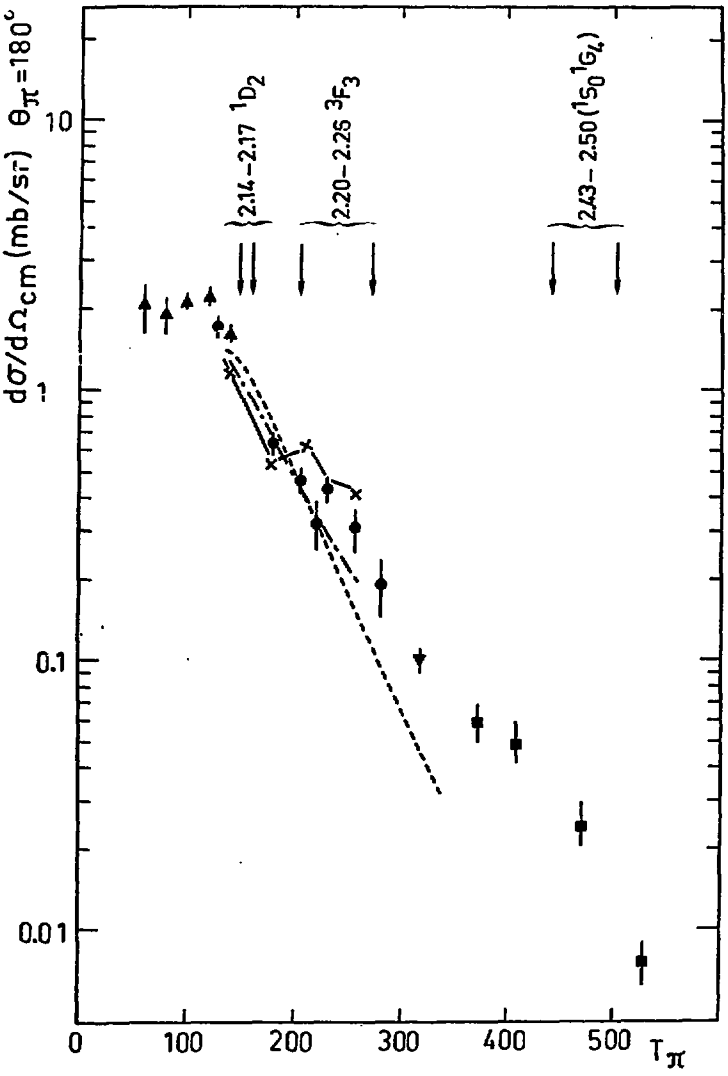


fig 2



dσ/dΩcm (mb/sr) θπ=180°
10
1
0.1
0.01
0
100
200
300
400
500
Tπ
2.14–2.17 1D2
2.20–2.26 3F3
2.43–2.50 (1S0 1G4)

fig 3