$\pi^- p \rightarrow \pi^- p$ DIFFERENTIAL CROSS-SECTION AT 898 MeV/c

F. Bradamante^{*)}, S. Conetti^{*)}, G. Fidecaro^{*)†)}, M. Fidecaro^{†)}, M. Giorgi^{*)},
A. Penzo^{*)}, L. Piemontese^{*)}, F. Sauli^{*)}, P. Schiavon^{*)}

CERN, Geneva, Switzerland

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^{*)} Istituto di Fisica dell'Università, Istituto Nazionale Fisica Nucleare, Trieste, Italy.

^{†)} CERN, Geneva, Switzerland.

The π^-p scattering amplitude has a strong dependence on the incident pion momentum in the range below about 2 GeV/c. When a direct measurement does not exist, the interpolation between two momenta is ambiguous, mainly in the region of high momentum transfer, if it is made via an analysis based on the coefficients of the Legendre polynomials¹⁾. On the other hand, the interpolation on the basis of dispersion relations²⁾ is too model dependent, in particular there is a non-negligible chance of missing resonances³⁾.

To give a quantitative idea of the situation, we report in Fig. 1 the π^-p differential cross-section at 903 MeV/c as evaluated according to the CERN I analysis²⁾. The dashed curve was calculated with the results obtained in the frame of dispersion relations, from the data available at various energies, before the Heidelberg Conference, while the continuous curve is based on the so-called experimental phases. One sees that for some momentum transfers the two evaluations could differ as much as 30%.

As a by-product of an experiment performed at the CERN proton synchrotron to study pion-deuteron elastic scattering⁴⁾, we measured the negative pion-proton elastic differential cross-section at 898 MeV/c, in a range of momentum transfer $0.15 < |t| < 0.61$ (GeV/c)², corresponding to centre of mass angles $43^\circ < \theta_{\text{cm}} < 96^\circ$. Because of the fact that at 900 MeV/c exist only one, bubble chamber, measurement⁵⁾, with poor statistics away from diffraction peak, and that the nearest energy available measurements are at 875 and 925 MeV/c¹⁾, we thought it worth while to report on these data.

The experimental apparatus is sketched in Fig. 2, and is described in detail elsewhere^{4,6}). The method consists in measuring with high accuracy the directions of three of the particles involved in the reaction. For this purpose a system of three magnetostrictive wire spark chambers was used in each branch. The data were recorded on magnetic tape, and then processed by a geometrical and kinematical fit on the CERN CDC 6600 computers. The trigger was given by the coincidence $(C_1 C_{1b} \bar{C}_2)(\bar{C}_3 \bar{C}_6)(C_4 C_5) C_7$, with an additional requirement for the time of flight (TOF) of the recoil to be in the expected range. The C_7 counter, made up of ten stripes 130 cm long, was positioned in such a way that the pulses due to recoil protons with a good approximation arrived at the same time, regardless of the recoil angle. Advantage has been taken of the fact that in elastic scattering the locus of recoil velocities β is a rotation ellipsoid (around the beam direction, with eccentricity $\sqrt{1 + \beta_{c.m.}^2}$) and that in the solid angle of interest we could approximate this surface by a plane.

For beam particles the TOF distribution had a FWHH of 1.3 nsec all along each stripe; the time of propagation of light in the scintillator was measured for each stripe to be (6.5 ± 0.2) nsec/m. A TOF spectrum obtained with C_7 positioned as indicated in Fig. 1 is shown in Fig. 3. The FWHH of the proton distribution is now 3.0 nsec^{*)}. The broad peak on the left of Fig. 3 was contributed mainly by pions and cut away electronically at the trigger stage.

*) This width is the one expected if we take into account the finite dimensions of the target, the beam spread, and the fact that the plane surface is only an approximation to the locus of equal TOF.

Typical figures for the reconstruction accuracy are ± 1 mrad and ± 4 mrad for the directions of the π -tracks and of the proton track, respectively, ± 0.5 mm and ± 1 mm for the vertex coordinate normal and parallel to the beam direction: it follows that the resolution in momentum transfer is $\Delta t/t = \pm 1.5\%$, constant over the whole t -region considered.

The incident pion momentum has been measured (by a range method, by TOF and by magnetic analysis), to be $(898 \pm 0.2\%)$ MeV/c at the centre of the target, the momentum bite accepted was $\pm 0.3\%$, with an intensity of $\sim 6 \times 10^4$ particles/burst.

About 11,000 events which at an early stage of the programme were found to be coplanar within 5° , were fully processed. The kinematical χ^2 -distribution was fitted with the one expected for a 2 C-fit plus a linear background, for bins of momentum transfer of ± 0.02 (GeV/c) 2 .

The background filtered in the $\chi^2 \leq 6$ region goes from 2% at $t = 0.15$ GeV/c 2 to 12% at $t = 0.61$ (GeV/c) 2 .

The data have been corrected for beam contamination measured with a Cerenkov counter to be $(5 \pm 1)\%$ and counting losses estimated to be $(6 \pm 1)\%$.

To get the absolute values of the cross-sections, a measurement was performed with a θ recoil-defining counter in few positions, where the background could easily be evaluated from TOF spectra. The error involved is estimated to be less than $\pm 10\%$.

The results are shown in Table I, and are compared in Fig. 4 with the latest results of the CERN I analysis⁷⁾, which makes use of experimental information available after the Heidelberg Conference. It is interesting to note that while the cross-sections reported here agree nearly equally well

with both the continuous curve of Fig. 1 and the curve of Fig. 4 for $|t| < 0.35(\text{GeV}/c)^2$, they seem to prefer the latest evaluation for $0.35 < |t| < 0.61(\text{GeV}/c)^2$, the level of confidence being 80% against the 40% of the previous one.

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Table 1

$\pi^- p$ elastic differential cross-section at 898 MeV/c absolute normalization error < $\pm 10\%$		
$-t$ (GeV/c) ²	$d\sigma/dt$ mb/(GeV/c) ²	$\Delta d\sigma/dt$ mb/(GeV/c) ²
0.15	24.72	1.05
0.17	19.39	0.69
0.19	17.40	0.62
0.21	15.40	0.55
0.23	13.54	0.52
0.25	11.80	0.46
0.27	10.63	0.43
0.29	10.17	0.43
0.31	9.16	0.36
0.33	8.17	0.36
0.35	6.78	0.44
0.37	7.13	0.50
0.39	6.26	0.76
0.41	6.31	0.77
0.43	5.65	0.69
0.45	4.90	0.61
0.47	4.74	0.60
0.49	3.92	0.52
0.51	3.45	0.47
0.53	2.52	0.37
0.55	2.48	0.36
0.57	1.95	0.31
0.59	1.53	0.26
0.61	2.19	0.34

Figure captions

- Fig. 1 : $\pi^- p \rightarrow \pi^- p$ differential cross-section at 903 MeV/c as evaluated in CERN I analysis (Ref. 2), from dispersion relation (-----) and from experimental (————) phase shifts.
- Fig. 2 : The experimental layout.
- Fig. 3 : TOF spectrum in the recoil counter C₇.
- Fig. 4 : $\frac{d\sigma}{dt}(\pi p \rightarrow \pi p)$ versus $|t|$. The points are from this experiment. The curve was calculated from CERN I "experimental" phase shifts, (post Heidelberg).

Fig.1

SCALE

BEAM

C_{1b}

C₁

C₂

C₄

C₆

C₆

C₃

C₅

C₇

liq. H₂

2.80 m

- C_{1b} ϕ 120 mm, 2 mm thick
- C₁ ϕ 50 mm, 2 mm thick
- C₂ (120x120x10) mm, 18 mm ϕ hole
- C₃ 460x400x10
- C₄ (197x70x5) mm
- C₅ special shape, 10 mm thick
- C₆ (66x70x5) mm + (70x70x5) mm
- C₇ 10x(1300x100x10) mm

Fig. 2

Fig. 3

Fig.4