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MEASUREMENT OF HIGH ENERGY POSITIVE PION-PROTON ELASTIC SCATTERING AT 180°

B. A. Kulakov, M. F. Lykhachev, A. L. Lyubimov, Yu. A. Matulenko, I. A. Savin and V. S. Stavinski

Joint Institute for Nuclear Research, Dubna

(presented by I. Chuvilo)

The differential cross-sections for the elastic scattering of π^+-mesons on protons at 180°, $\frac{d\sigma}{d\Omega}(\pi^+,p)$ were measured. The π^+-meson momenta were found to be 3.14 and 4.6 GeV/c.

The π^+-mesons incident on a liquid hydrogen target 166 cm long were selected by a differential gas Čerenkov counter C_1 and by the scintillation counters S_1 and S_2. The direction of flight of the recoil protons and their velocity were determined by the differential gas Čerenkov counters C_3 and C_4 and by the scintillation counter S_3. The accuracy of the velocity measurements is $\Delta\beta/\beta = 0.0005$. A gas threshold Čerenkov counter C_5 in anti-coincidence with counters C_3, C_4 and S_3 lowered the background counts. The threshold of counter C_5 was adjusted to count only particles faster than the $\pi^+ - p$ elastic scattering recoil protons in the forward direction. The π-mesons emerging from the hydrogen target in the backward direction with a velocity greater than that of π-mesons from inelastic π^+p-collisions were counted by a threshold gas Čerenkov counter C_2.

The solid angle (in the C.M.S.) subtended was 0.002 sterad. The measured values of $\frac{d\sigma}{d\Omega}(\pi^+ p)$ at 180° are 0.92 ± 0.47 mb/sterad, and 0.38 ± 0.24 mb/sterad for π^+ momenta of 3.14 and 4.6 GeV/c, respectively.

Experimental estimates of backward elastic scattering of π^+-mesons with momenta of 2.8 GeV/c [1] and of 7.2 GeV/c [2] were obtained earlier for $(\pi^- p)$ interactions in bubble chamber experiments. But in these experiments the cross-sections were averaged over the backward hemisphere, which could be significantly different from $\frac{d\sigma}{d\Omega}(\pi^+ p)$ at 180°. This difference may be especially significant when comparison is made with theoretical predictions based on a concept of nucleons as manifestations of some Regge trajectories. Gribov [3] has shown that in this case in the angular distribution for backward elastic π^+p scattering at high energies, oscillations have to occur with a maximum at 180°. This backward peak should be narrower than the peak of the diffraction scattering in the forward direction.

The value $\frac{d\sigma}{d\Omega}(\pi^+ p)$ at 180° should also be used for comparison with theoretical predictions of the energy dependence of the backward elastic $\pi^+ p$ scattering. These predictions differ appreciably when different assumptions are used [4, 5, 6].

We are continuing with our measurements of $\frac{d\sigma}{d\Omega}(\pi^+ p)$ at 180° at high energies. In this sense the first estimates obtained are preliminary.

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DISCUSSION

BURHOP: I would like to say something about the question of the form of the cross section at very small scattering angles and its relationship to the optical cross section. Using the method developed by Tzyganov and collaborators in Dubna, Bull and Garbutt have made measurements at 19 GeV. The points below 10 milliradians seem to be going well above the optical point, although of course they are only one standard deviation away. I would point out, however, that Dr. Taylor's work involves an extrapolation from about 10 milliradians down to zero at this energy, whereas with the perpendicular incident method, one gets to very small scattering angles. The 8 GeV data from the Dubna work, our own 19.8 GeV measurements and the 23.5 GeV results from Vienna all have a tendency to be above the optical point, which would require something other than pure imaginary scattering amplitudes.

PERL: How do you correct for inelastic contamination, particularly when slow π's are produced?

CHUVILO: Two Čerenkov counters were used to get the recoil proton in the forward direction. The recoil protons in this case have a momentum greater than the momentum of the particles in the initial beam. In coincidence with these protons we detect the pion which goes in the backward direction. There are low-energy pions in the backward direction from inelastic processes, but if you have an inelastic event, there is no possibility of obtaining in the forward direction a proton with momentum more than the momentum of the initial beam.

COCCONI: When you measure the elastic scattering of proton against proton, looking at the recoil at large angles (essentially 90°) how do you know what comes from hydrogen and what comes from nuclei? I imagine the target was not hydrogen. What target did you use?

CHUVILO: You have seen the example of the distribution of the ranges of protons from the polyethylene target which were detected in the emulsion layers. From this picture you may see that the contribution from the quasi-elastic scattering from nucleon-nucleon interactions and from inelastic processes from nuclei is small. At an angle of 4° the background consists of about 4%.

COCCONI: From what I know of the experiment done here, where only the protons emitted in the forward direction were observed, when you look at carbon, for instance, you have a great deal of elastic scattering from the protons in carbon. So I have the feeling that one has to make a subtraction for instance between polyethylene and carbon, in order to be sure that what we observe is due to hydrogen, because looking only at one particle in the reaction the Fermi motion of the quasi-free particle in the nucleus can have a big contribution.
My second question concerned the fact that there is really an important problem of knowing whether in the forward direction the elastic scattering is purely imaginary, or if there is any real part in it; the question is essentially experimental. It is very delicate because going in the forward direction the errors are bigger, but from what we know it is true that emulsion work always shows a cross-section in the forward direction which is bigger than the one expected from the optical theorem. On the other hand, from work done, for instance, here with hydrogen bubble chambers, this difference does not look so big. Admittedly the angles explored are somewhat bigger. I wonder whether in the plates one is so sure that what is observed is from hydrogen and not from semi-free nucleons in the nuclei, because any contribution from anything spurious, besides hydrogen, would of course increase the cross section and make this agreement between optical theorem and forward amplitude different. It is a very delicate point because we all think that the real part is negligible.

BURHOP: The separation between bound and free protons is astonishingly good in emulsion as one has three criteria to satisfy. One has the range of the recoil, the angle of scattering together with the angle of the recoil and its angle of noncoplanarity in the plane of scatter. You can measure these angles very accurately indeed in emulsion. We have gone very carefully into this question of contamination and we would say that even in our smallest angular interval the contamination from the source you mentioned was less than 2%.

WINZELER: We have measured at 24 GeV by two methods. First with a bubble chamber, and then with emulsions. Vienna and Berne measured this. We have had no indication of any real part in the scattering amplitude with measurements down to a transverse momentum of about 50 MeV/c. May I ask Dr. Chuvilo, what was your lowest transverse momentum measured in $p-p$ scattering?

CHUVILO: It is equal to about 60 MeV/c.

BURHOP: Just a brief comment on Dr. Winzeler's point. I read the preprint from Vienna and I got the impression that there was a correction factor of about 50% at the small angles; the events that we used were actually seen.

WINZELER: It is not very clearly expressed how they obtained the final result. The correction factor was in fact calculated, I think, from the normalization to the bubble chamber results at large angles. The emulsion result at small angles (which cannot be reached by bubble chambers) then indicates that there is no large real part.

MATTHEWS: In calculating the optical point, is it not true that you have to assume both that the amplitude is purely imaginary and that the singlet total cross-section and triplet total are equal, and is there any reason for this second assumption?

TAYLOR: I would like to ask Burhop what was the smallest angle of scattering that they measured.

BURHOP: The smallest angle in our interval is 4 milliradians.

MARQUIT: It is interesting to note that nearly all experiments using emulsion as a detector give forward scattering amplitudes above the optical point. This includes the scattering chamber experiments of Preston *et al.* at 3 GeV, the scattering chamber experiments at 6 GeV and 10 GeV reported here by Chuvilo, as well as the Dubna, Sofia and London perpendicular exposures at 2.8, 6, 8.5 and 19 GeV. The Warsaw group, using a perpendicular exposure at 23 GeV, also obtained indications of a forward scattering amplitude greater than the optical model (the elastic scattering cross-section, partially corrected for scanning loss and with Coulomb scattering subtracted was 12.7 ± 2.6 mb). On the other hand, the experiments with counters and bubble chambers used as detectors tend to give agreement with the optical point. This difference between techniques most certainly warrants very careful study.

FENYVES: I would like to mention simply that some measurements on pion-proton elastic scattering at 7 GeV which have been carried out in Warsaw and in Budapest have shown very good agreement with the calculation of Domokos based on the asymptotics of Regge type.

WINZELER: May I mention that there is a measurement from 1959 or 1960 made by Preston *et al.* on proton-proton elastic scattering using a liquid hydrogen target, and then emulsion as detector but not as target, at 3 GeV. They do not obtain a real part at very small angles, and they conclude that it has to be smaller than 10%.

CHARGE EXCHANGE CROSS SECTION IN $\pi-$p COLLISIONS AT 6 AND 18 GeV/c

G. Bellini, E. Fiorini, A. Orkin-Lecourtois

Ecole Polytechnique, Paris, and Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Milano

(presented by A. Lagarrigue)

The Ecole Polytechnique one-metre heavy liquid bubble chamber was exposed at the CERN PS to 6, 11 and 18 GeV/c π^- beams. 35 000, 10 000 and 30 000 pictures respectively containing approximately 4 pions per picture were taken. The liquid used was a mixture of 86% propane and 14% Freon CF_3Br, by volume. The density of the liquid was 0.55, its radiation length 52 cm.