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EXPERIMENTAL APPARATUS TO STUDY THE INTERACTION OF π^+ MESONS IN ^{4}He

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The experimental apparatus exposed to the positive pion beam of the LEALE Laboratory of Frascati is described. It consists in a diffusion cloud chamber filled with helium at the pressure of 15 atm. Also, the results of the μ^+ and e^+ contamination and energy distribution of the π^+ beam are reported.

1. Introduction

Recently some experiments have been performed to study the $\pi^\pm$ scattering on ^{4}He[1]).

In particular a group of JINR[2]) studies, with a streamer chamber spectrometer[3]), the energy region below 100 MeV with pions of both signs. A comparison between these two charge symmetric processes can yield informations about the electromagnetic structure of the pion[4]).

However it must be noticed that very accurate measurements are requested in order to get reliable results, and the preliminary data of JINR do not yet yet reach this degree of accuracy[2,5]). They seem, by the way, to be closer to Growe's results[6]), obtained by means of counter telescope techniques, than to those of Block et al.[7]), obtained in a liquid helium bubble chamber.

The disagreement between the two sets of data[6,7]) has also been pointed out by Oades and Rasche[8]). On the other hand, the experiments in progress at CERN analyze, with a double achromatic spectrometer[9]), the scattering of only negative pions in the 3–3 π–nucleon resonance energy region.

The preliminary CERN results[1]) show that the general features of (π^-, He^4) scattering drastically differ from those of (π^-, ^{12}C), and that the 150 MeV data

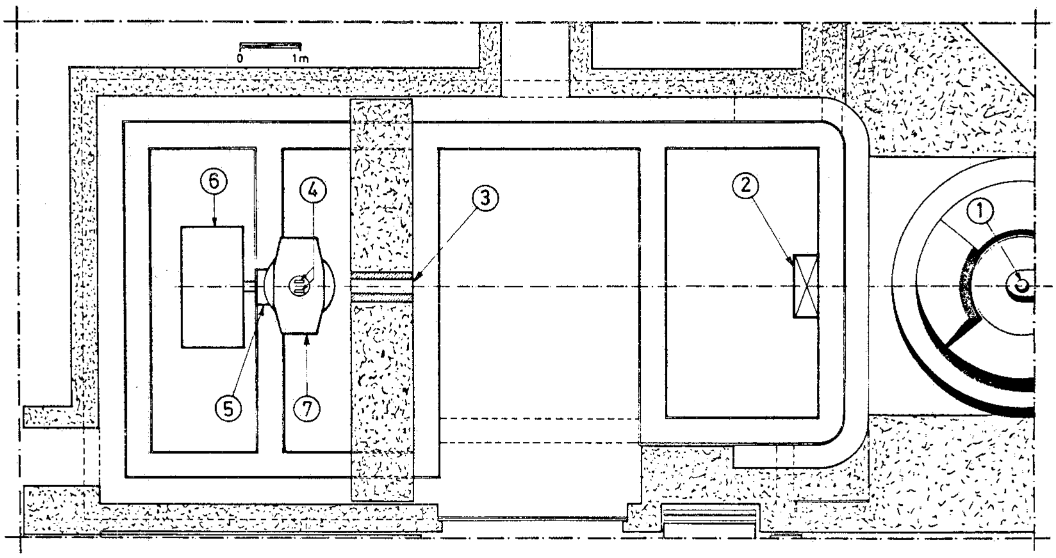

Fig. 1. Layout of the experimental apparatus. (1) – Focus of the bending magnet; (2) – quadrupole lens; (3) – collimator (15 × 2) cm^2; (4) – cameras; (5) – flash unit; (6) – refrigerator; (7) – magnet and diffusion cloud chamber.

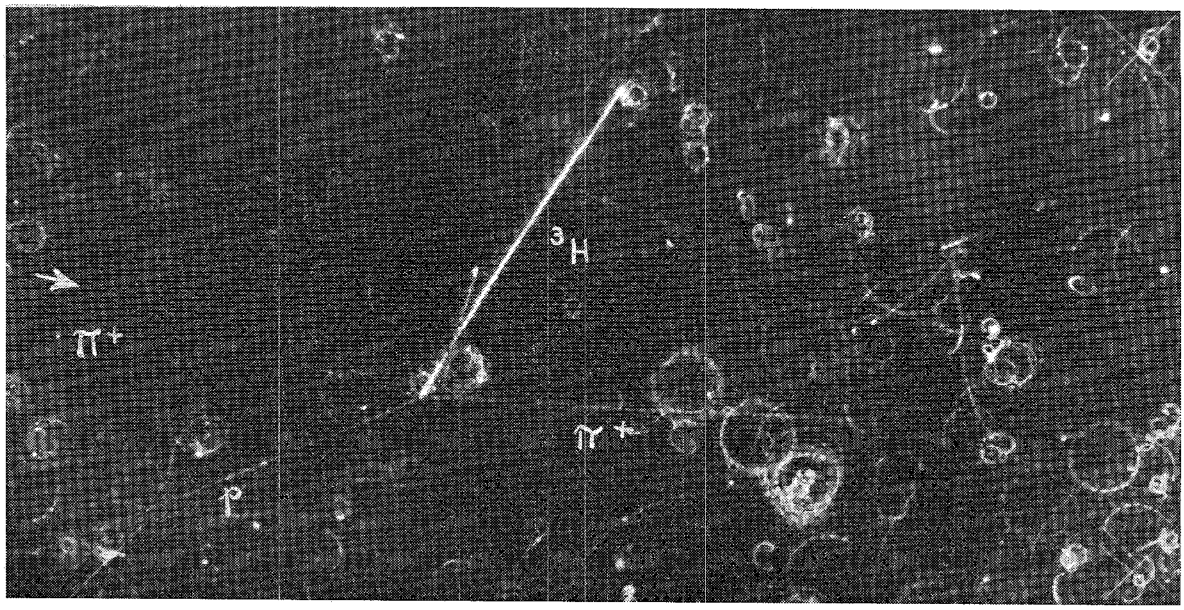

Fig. 2a. $\pi^+ + {}^4He \rightarrow \pi^+ + p + {}^3H$ event.

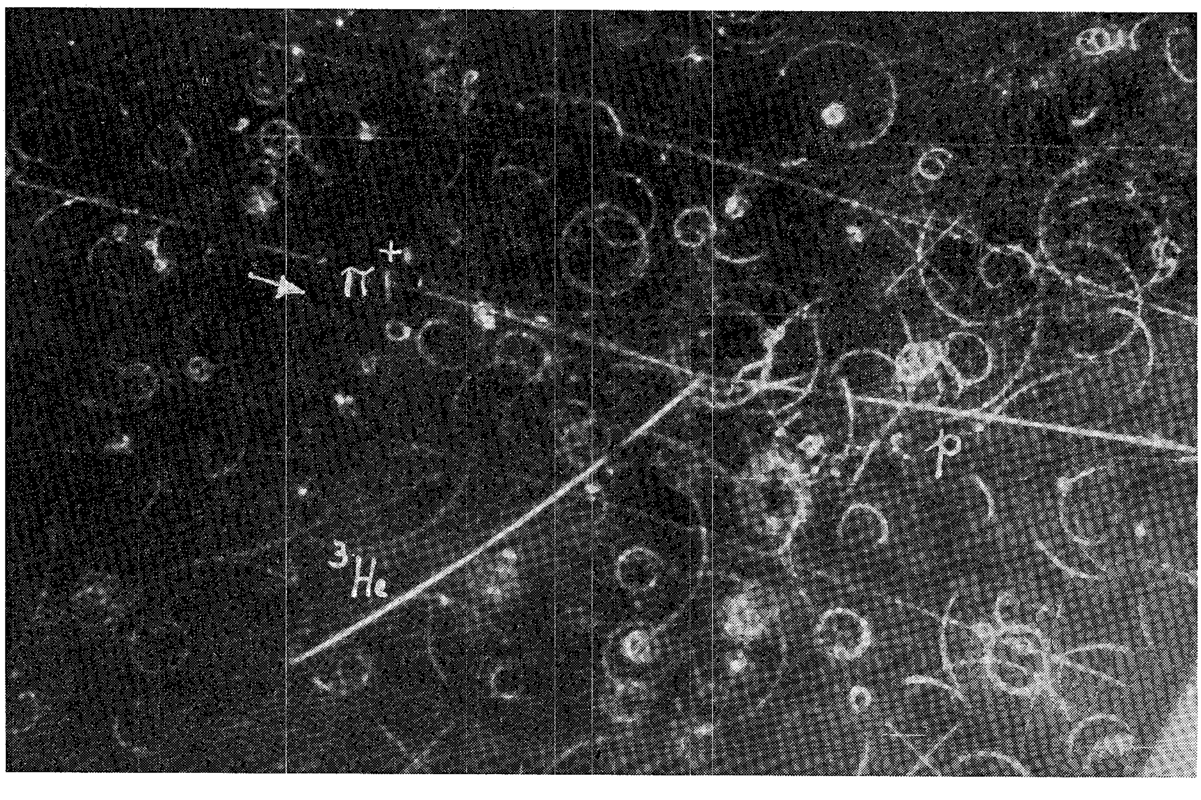

Fig. 2b. $\pi^+ + {}^4He \rightarrow \pi^0 + p + {}^3He$ event.

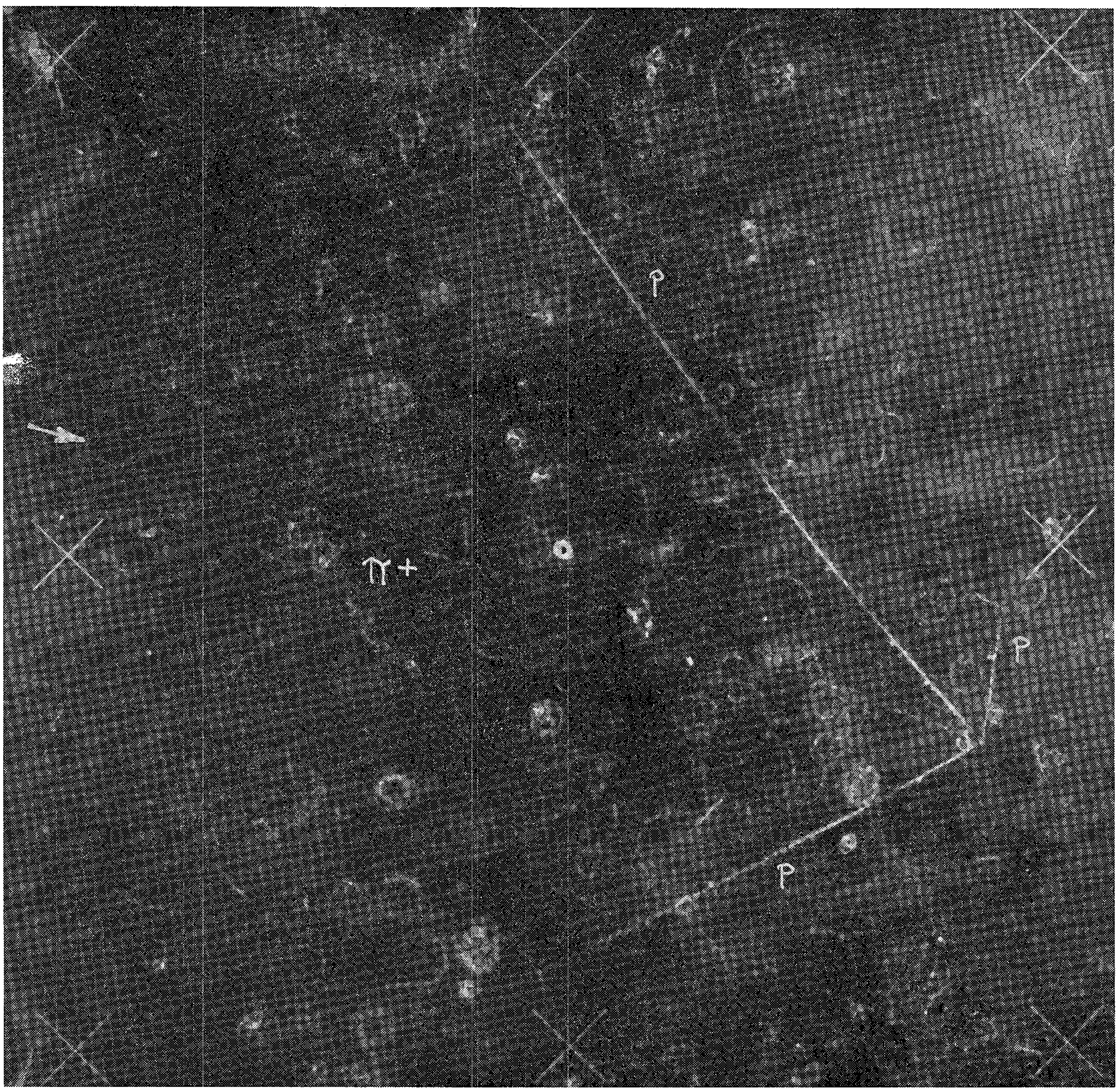

Fig. 2c. $\pi^+ + {}^4He \rightarrow \pi^0 + p + p + p + n$ event.

agree very well with the diffusion cloud chamber results of Budagov et al.[10]).

The diffusion chamber method, as known, allows also to study all the pion absorption processes in ^{4}He[11]) and gives therefore more complete informations on nuclear effects than other experimental techniques.

Therefore we have studied with a diffusion chamber the 150 MeV π^+ absorption cross section on ^{4}He. It could be interesting to compare our 150 MeV results with the π^- data of Budagov at the same energy.

Our diffusion cloud chamber was exposed to the positive pion beam of the Frascati Laboratory. In this paper we describe the experimental apparatus and the results we have obtained for the π^+ beam energy spectrum and contamination.

2. Experimental apparatus

A 38 cm diameter diffusion cloud chamber, filled with helium at 15 atm in a magnetic field of 5 kG, has been exposed to the photoproduced pion beam[12]) of the LEALE Laboratory of Frascati. Fig. 1 shows the outline of the experimental set up. The diffusion cloud chamber is the one we described previously[13]), suitably modified for this experiment. Only one flash unit lights up the sensitive layer but the light of the xenon lamp (Mullard LSD 17) is reflected by the front wall crossed by the incoming pion beam. A 300 μF capacitor, charged to 2 kV, is discharged at the instant of flash. The photographs are taken by two cameras equipped with objectives Summaron (1/3.5; $f = 35$ mm) and Kodak Plus–X pancro film is used. The base of the stereo cameras is 140 mm and the photographs are taken through a glass window 50 mm thick. The distance between the centers of the objectives and the bottom of the chamber is 658.7 mm; the magnifying factor is 0.0576. In order to reduce the pion absorption, in the region crossed by the π beam (2×20 cm^2), the stainless steel wall of the chamber has been made 4 mm thick. The temperature at the bottom of the chamber is -75 °C and the temperature gradient in the sensitive volume is 8 °C cm^{-1}. In these experimental conditions one obtains a sensitive layer about 6 cm high. The pion beam is accepted by an analysing magnet which selects pion's momenta and is focussed by a magnetic quadrupole lens. A rectangular iron collimator (2×15 cm^2 and 1 m long) has been built in the concrete wall which shields the chamber. The magnetic field is homogeneous along the height of the sensitive volume and within $\pm 0.5\%$ along the radius[14]). The distance between the pion source and the diffusion cloud chamber is 14 m. In order to reduce the background in the time interval between two successive photographs and to obtain an average intensity of about ten π^+ per picture, the LINAC operates at a frequency of 150 Hz, but the injector is pulsed only for 0.7 s every 10 s (operating cycle of the experiment). The energy of the electron beam is kept around 370 MeV, with a peak current of 50 mA.

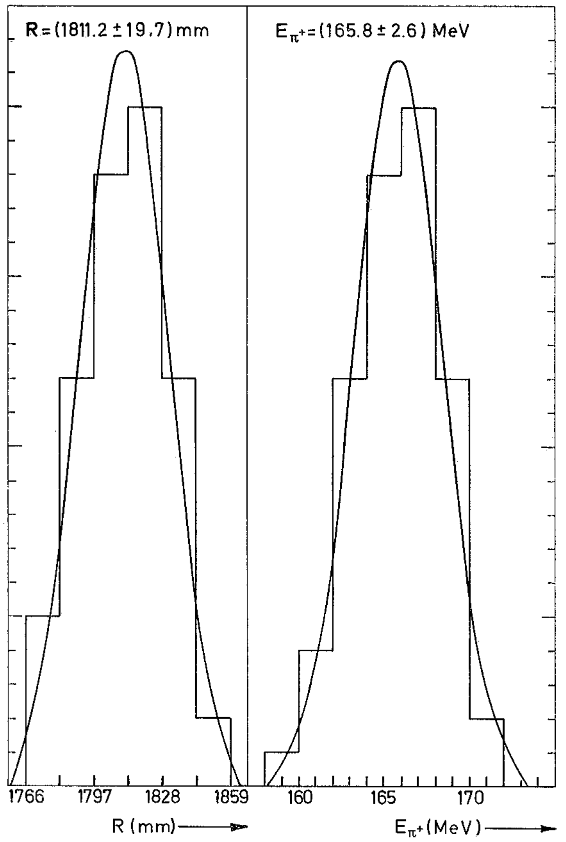

Fig. 3. Left side: distribution of the radii of curvature obtained measuring several times the same pion track; right side: corresponding spread in the pion energies.

3. Results

About 100 000 photographs, with an average number of $8\pi^+$ per picture, have been taken. Figs. 2a, 2b and 2c show typical (π^+, ^{4}He) interactions. Fig. 3 (left side) represents the distribution of the radius of curvature values obtained by measuring several times the same pion track. The track was reconstructed by measuring eight points with a semi-automatic image plane digitizer. Fig. 3 (right side) represents the energy spread corresponding to the spread of the radius of curvature measurements.

In fig. 4 the pion energy distributions for three different energies and alignments of the π^+ beam are given. The full line histograms were deduced taking into account only the central part of the beam (± 5 mm from the middle plane); the dashed line histograms represent the low energy contribution from the edges and side walls of the collimator and of the diffusion chamber window. The sum of each pair of histograms gives the total pion spectrum in the diffusion cloud chamber.

To determine the admixture of μ^+ mesons and positrons in the beam, and also to monitor the energy, range–energy curves in iron were measured using scintillation counters telescope. The average energy of the beam, determined by this method agreed with good accuracy with the central energy accepted by the bending magnet. To measure the beam contamination, a 30 cm lucite Cherenkov counter of the type described in ref. 13 has been also used, in coincidence with the scintillation counters telescope. The results obtained with the two methods were in agreement within the

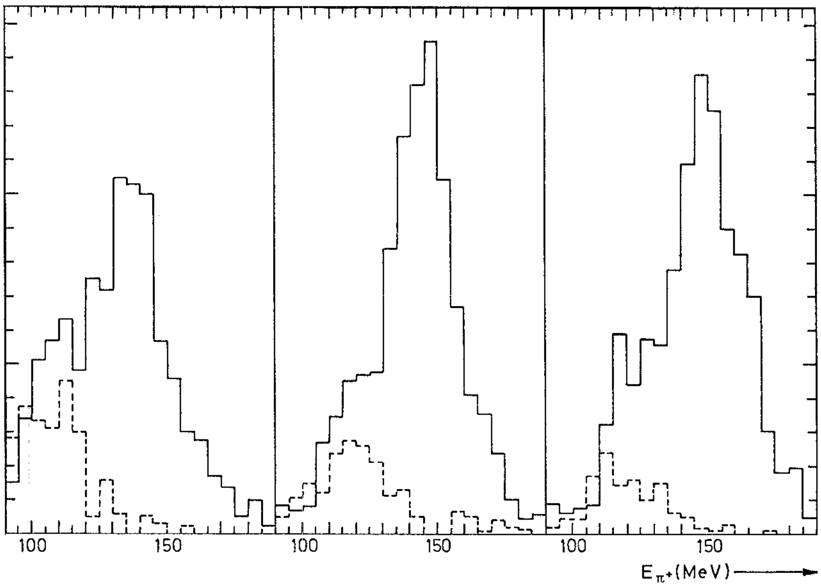

Fig. 4. Pion energy distribution for three different central energies and alignments of the π^+ beam. The full line histograms were deduced taking into account only the central part of the beam (±5 mm from the middle plane); the dashed line histograms represent the low energy contribution from the edges of the collimator and of the diffusion chamber window. The sum of each pair of histograms gives the total pion spectrum in the diffusion cloud chamber.

experimental uncertainties. The total contamination of μ^+ and positrons in the beam amounted to $(12 \pm 2)\%$.

By considering the spectrum of the π^+ entering the chambers and a reasonable need of statistics we can conclude that the films we have obtained allow us to study the π^+ interaction in helium for $E_{\pi^+} = 110 \pm 10\%$ MeV and $E_{\pi^+} = 150 \pm 10\%$ MeV.

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