# MEASUREMENT OF THE CROSS SECTION FOR THE REACTION $\pi^{\pm}+p\rightarrow\pi^0+$(CHARGED PARTICLES) UP TO 1.4 GeV

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*(presented by J. F. Detoeuf)*

## PRINCIPLE OF MEASUREMENT

The purpose of this counter experiment was to measure the variation of the cross section for $\pi^{\pm}+p\rightarrow\pi^{\pm}+p+\pi^0$ as a function of the incident pion kinetic energy between 0.37 GeV and 1.37 GeV.

The reaction is characterized by the emission of a $\pi^0$ accompanied by secondary charged particles. An ideal measurement would consist in counting the coincidences between a $4\pi$ scintillation counter which surrounds a hydrogen target and a second $4\pi$ counter sensitive only to $\gamma$-rays from the $\pi^0$-decay. With a $\gamma$-detector made of sandwiches of Pb plates several millimeters thick and plastic scintillator, one would find that the result is nearly independent of the energy spectrum of the neutral pions.

Neither this " ideal " measurement, nor the actual experiment can distinguish between the reaction given above and those of higher pion multiplicity in which neutral and charged pions are produced simultaneously. The result of the measurement will therefore be a cross section, $\sigma_{\pi^0}^{\mathrm{ch}}$, for the production of $\pi^0$'s accompanied by secondary charged particles. Channels in which $n\pi^0$'s appear intervene with weight " $n$ ".

## EXPERIMENTAL METHOD

A doubly analyzed pion beam with a momentum resolution of $\pm 2$ per cent was used.

The liquid hydrogen target, 30 cm long, was designed in such a way as to present a minimum amount of $\gamma$ converter in any direction. It was essentially a bag of Mylar supported and insulated by styrofoam.

The incident pions were defined by a telescope ($T$). A low pressure gas Čerenkov counter ($T_2$) in anticoincidence eliminated electrons [1]. A final counter ($F$) behind the target was put in anticoincidence with the telescope ($T$). Thus the signal ($T, \overline{F}$) defined the interaction of an incident pion. The target was surrounded (with the exception of gaps for the beam and for supplying the target) by a scintillation detector ($C$) composed of six elements. They were put in coincidence with ($T, \overline{F}$) so that ($T, \overline{F}, C$) defined the interactions which produced charged secondaries.

The $\gamma$'s were counted by means of two independent arrays of five detectors each. The greater part of the interval from $\theta = 10°$ to $\theta = 146°$ was covered by each of the arrays either on the left or on the right side of the target (Fig. 1). The dimensions of the detectors were calculated to be such that they each covered approximately the same solid angle in the

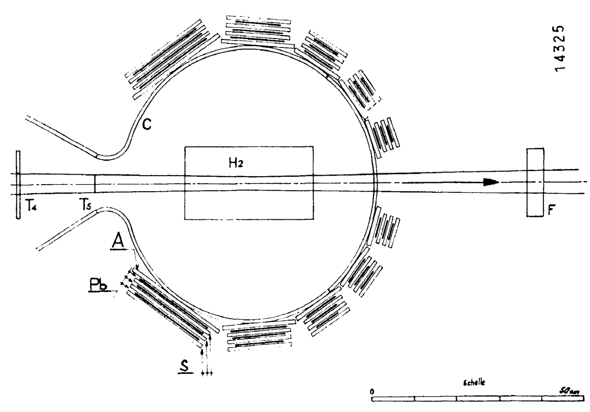


**Fig. 1** Lay-out of the apparatus (see « Experimental Method »)

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$\pi - p$ centre-of-mass system. One array subtended 7.9 per cent of $4\pi$ steradians. A single detector was composed of a scintillator $A_i$ in anti-coincidence followed by a sandwich $S_i$ formed of three plates of 4 mm thick lead and three plates of scintillator. The efficiency for counting a $\gamma$ of energy $E\gamma$ with a potential path length $s$ in the lead converter $\varepsilon(E\gamma, s)$ was calculated from the data given in UCRL 2426 and by Anderson *et al.*[2] for detecting $\gamma$ ray from $\pi^0$ of energy $W_{\pi^0}$. For $\gamma$'s incident normally upon the detector the probability $\bar{\varepsilon}(W_{\pi^0})$ varied from 0.67 to 0.72 for the full range of $W_{\pi^0}$.

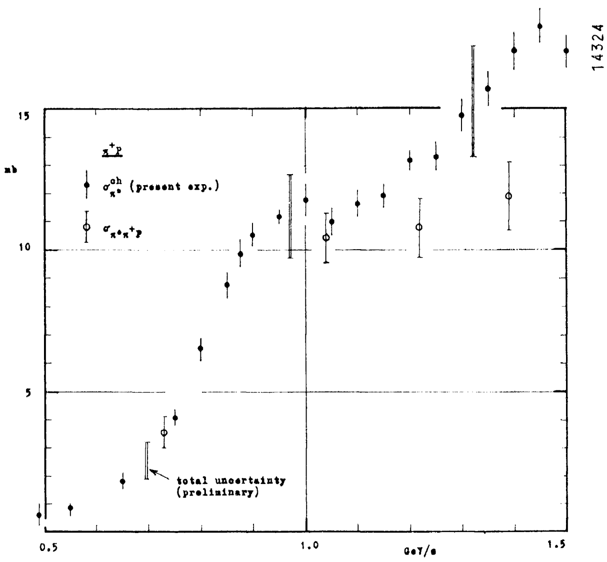
The number of coincidences ($T$, $\bar{F}$, $C$, $\bar{A}_i$, $S_i$) was registered on ten scalers.

At each incident pion energy measurements were made with target full and target empty and, in both cases, with and without lead. Besides this, the lead was replaced by carbon-converters, each thickness (6 mm) calculated so that the probability for detecting the neutron of the reaction $\pi^{\pm}+p\rightarrow\pi^{\pm}+\pi^{+}+n$ would be the same as for lead (2.5 per cent). After subtraction there remained only those counts due to hydrogen and to $\gamma$'s converted in lead.

The calculated probabilities $\bar{\varepsilon}(W_{\pi^0}, s)$ have been checked by a measurement with 0.37 GeV negative pions incident on the same experimental arrangement, except that the $4\pi$ scintillation counter ($C$) was not used. Under these conditions one measures substantially the charge exchange cross section which is known at this energy. Furthermore the calculation is nearly rigorous because here the energy-angle relationship of the particles is unique and the angular distribution has been measured [3]. This measurement gave the result $\sigma\ (\pi^0 n) = 12.4 \pm 1.8$ mb as compared to $\sigma(\pi^0 n) = 13.6 \pm 0.6$ mb given by Caris *et al.*[3]. These authors have used measured efficiencies $\varepsilon(E_\gamma, s)$. Another result, obtained with calculated efficiencies, $\sigma(\pi^0 n) = 12.95 \pm 0.87$, has been given by Brisson *et al.*[4].

## CORRECTIONS AND PRELIMINARY RESULTS

The cross section, as observed, may first be decreased because of the loss of good events (for geometrical reasons, because of internal conversion of the decay-$\gamma$'s, etc.). The total of these losses was of the order of 14 to 17 per cent. Second, an apparent increase may be obtained by any simulation of a good event, for which the most important contribution (about 5 mb) came from $\pi^{-}+p\rightarrow n\pi^{0}+$(neutral) with a neutral particle triggering the counter ($C$) by a secondary effect. This correction was checked at four different energies in runs with, and without, counter ($C$). Other less important corrections included a subtraction of effects due to strange particle production (at high energies) and bremsstrahlung in $\pi - p$ collisions. All the latter corrections, not including " neutral " production, amounted to not more than 2.5 mb at any energy (*).



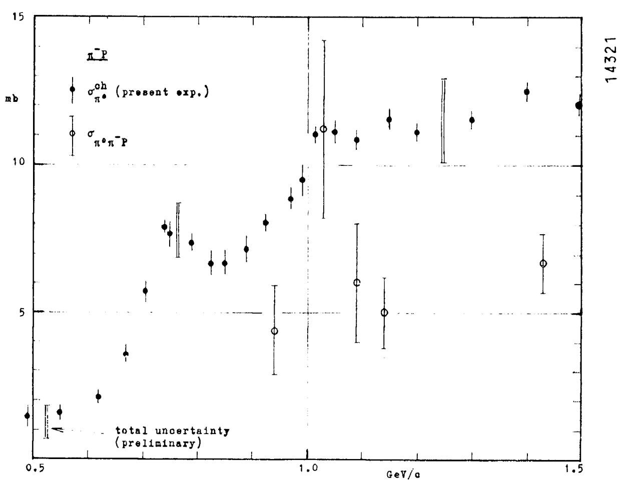




**Fig. 2 and 3** Preliminary results on the cross section $\sigma^{ch}_{\pi^0}$ (see « Principle of Measurements »).
Open circles represent other data on $\pi^{\pm}p\rightarrow\pi^{\pm}\,\pi^{0}p$.

(*) The $\gamma$'s from multipion radiative decays should be subtracted. For neutral multipions, however, such $\gamma$'s were included only if either they were emitted in charged decay modes or if the neutral multipion was produced simultaneously with charged pions. An estimate of the number of multipions produced, based upon the results given by Stonehill *et al.*[5] at 1.26 GeV, shows, for instance, that the reactions $\pi^{+}+p\rightarrow\varrho^{+}+p$ and $\pi^{+}+p\rightarrow\eta^{0}+\pi^{+}+p$, followed by neutral decay of the $\eta$, have cross sections of $<1$ mb at this energy.

Fig. 2 and 3 show the preliminary results for $\pi^+$ and $\pi^-$ respectively. For each measurement the statistical uncertainties are indicated. At several energies the magnitudes of the systematic error are shown as well; since these are slowly varying, the change of the cross section with energy is not seriously affected.

## LIST OF REFERENCES


1. J. Sayag, Compteur Čerenkov à gaz pour électrons, to be published in Journal de Physique et le Radium.
2. H. L. Anderson, W. C. Davidon, M. Glicksman and U. E. Kruse, Phys. Rev., *100*, 279 (1955).
3. J. C. Caris, R. W. Kenney, V. Perez-Mendez and W. A. Perkins, Phys. Rev., *121*, 893 (1961).
4. J. C. Brisson, P. Falk-Vairant, J. P. Merlo, P. Sonderegger, R. Turlay and G. Valladas, Proceedings 1961, Aix-en-Provence Conference on Elementary Particles, Vol. 1, p. 45.
5. D. L. Stonehill and H. L. Kraybill " Pion-pion interactions in $\pi^+-p$ collisions ", Yale University, preprint.


## DISCUSSION

PUPPI: The discrepancy $\sigma$ (charged$+\pi^0$)$-\sigma$ ($\pi^++\pi^-+n$) can perhaps be explained by the process $\pi^++\pi^-+n+(n\pi^0)$ for which a large cross section is found for energies $> 1$ GeV.

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# ON THE THRESHOLD ANOMALIES IN pp-SCATTERING


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As has been shown by Wigner and Baz [1], the energy dependence of the cross section for the elastic scattering of two particles can be of the anomalous character in the vicinity of the threshold for the production of a new particle (*). This anomaly appears as a narrow " cusp " or a " step ". We made an attempt to search for anomalies in the energy dependence of the total cross section of proton scattering near the threshold of the reaction

$$p+p\rightarrow d+\pi^+ \qquad (1)$$

(the threshold energy $E_0 = 288$ MeV) and in the range of higher energies.

## 1. INVESTIGATION OF THE ANOMALY NEAR THE THRESHOLD OF REACTION (1)

The energy dependence of the total cross section of *pp*-scattering $\sigma_t(E)$ near the threshold of reaction (1) is as follows [3]

$$\sigma_t(E) = \sigma_t(E_0)+\tfrac{3}{4}\sigma_s(|E-E_0|)\begin{cases}\cos 2\delta_{1,1}\,, & E\geqq E_0\,,\\ -\sin 2\delta_{1,1}\,, & E\leqq E_0\,.\end{cases} \qquad (2)$$

Here $E$ is the energy of an incident proton, $\sigma_s$ is the cross section of reaction (1) corresponding to meson production in $S$-state [4, 5], $\delta_{1,1}$ is the phase shift of elastic scattering at the threshold point in $^3P_1$-state.

(*) Systematic reviews and references are given in [2, 3].