MSC-0.6/183 15.3.1966

LETTER OF INTENTION

To : Members of the Electronics Experiments Committee

From : D.F. Measday

Re : A measurement of the absolute differential cross-section of the reaction $\pi^+ + d \rightarrow p + p$ at pion energies in the range 50 to 300 MeV

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a) Introduction

A study of either the reaction $\pi^+ + d \rightarrow p + p$, or its inverse, yields the same basic information because the cross-sections are related by detailed balance. We propose to bombard deuterium with pions as this gives us a greater range in the centre of mass energy, but the main purpose of the experiment is to gather information on the inverse reaction.

This study is of both practical and theoretical interest. From the practical point of view, the reaction $p + p \rightarrow \pi^+ + d$ is important for the production of beams of positive pions. In the forward direction, it is the dominant reaction for proton energies up to 700 MeV, and a thorough understanding of it is important in the design of positive pion beams.

In addition a detailed knowledge of the energy dependence and angular distribution of the reaction furnishes a possible means of monitoring neutron beams, since the reaction $n + p \rightarrow \pi^0 + d$ has a cross-section which is exactly half that of the reaction $p + p \rightarrow \pi^+ + d$. This is due to the fact that a pion and a deuteron can only be in a T = 1 state; thus the T = 0 component of the n + p system cannot contribute to this reaction.

Recently several groups have attempted phase-shift analyses of proton-proton scattering in the energy region 600 to 1000 MeV. Knowledge of the π-production reactions is essential for a complete understanding of this problem. In this context it is important to note that the energy spectra of positive pions produced in proton-proton collisions has recently been studied at CERN and Berkeley. It was found that a separation of the three body final state $(p + n + \pi^+)$, from the two body $(d + \pi^+)$ was difficult. An accurate value of the cross-section $p + p \rightarrow \pi^+ + d$ would therefore improve our knowledge of the spectra for the three body final state.

Finally we might mention the recent interest in the absorption of negative pions in nuclei. As this absorption sometimes takes place on a quasi-deuteron in the nucleus[1], it is obviously useful to have a thorough understanding of the reaction of mesons with a real deuteron.

b) Present experimental situation

The present state of our knowledge looks reasonable until one looks at the details and then one discovers quite grave discrepancies.

The total cross-section is known fairly well over a vast range of energies. At a pion energy of 160 MeV there is a peak and the cross-section appears to fall continuously up to the highest energies investigated, 1.8 BeV[2].

The differential cross-section at low energies can be described simply by

$$\frac{d\sigma}{d\theta} = c(A + \cos^2\theta)\text{mb/ster (in c.m.)}$$

Above a pion energy of 360 MeV, it is necessary to include the term $\cos^4\theta$. However Neganov and Parfenov[3] determined the differential cross-section in the energy range 180 to 300 MeV, from only 4 points. We have therefore estimated from the higher energy work of Heinz[4] what value of A he would have obtained if he had determined the cross-section at only the four angles that Neganov and Perfenov measured. We plot in fig. 1 measurements of A in the energy region 50 to 500 MeV for the pion[3-8]. The errors quoted for Heinz represent the errors for the $\cos^2\theta$ approximation, not the experimental errors which are much smaller.

The figure illustrates clearly that there are serious differences between results. If values for A are so widely different one might expect differences between the total cross-section results. Strangely enough the total cross-section of Meshcheryakov and Neganov agree, whilst Cohn is about 10% above Meshcheryakov.

In conclusion we may summarize the goal of the present proposed experiment. We aim to obtain an accurate absolute differential cross-section. This will settle the disagreement on A. We hope also by obtaining the differential cross-section at the small angles ($< 30^\circ$ c.m.) unexplored by Neganov and Parfenov, to observe the transition to the energy region where the $\cos^4\theta$ term becomes important.

c) Experimental method

We intend to use an externally produced π^+ beam; this will help us to reach the highest possible energy. The positive pions produced on a polythene target will be momentum analyzed and transported to the proton hall where a deuterium cryostat will be placed. The incident beam intensity, its composition and spatial distribution will be determined by conventional electronic techniques.

The target will be liquid deuterium, contained in a thin-walled mylar container. The cryostat must have a 270° window so that we can detect protons at all laboratory angles. In table I we give the energy of the proton at three angles (c.m.) for three values of the pion energy.

Table I

E_π (MeV)	Proton energy (MeV)		
	0°	90°	180°
50	121	90	68
150	206	129	82
290	328	178	100

The proton detection will be by a single telescope; two plastic scintillators will be used in anti-coincidence with a perspex Cerenkov counter which is intended to reduce the background due to scattered pions. Following the telescope there will be a total energy counter. A large NaI crystal would be best, but plastic scintillator (about 20 cm diam., 70 cm long) would also do. The scintillator telescope will be used to gate on a pulse height analyzer which will then record the energy of the particle. Since the reaction $\pi^+ + d \rightarrow p + p$ is a two body reaction, protons produced at a particular angle will have a unique energy. We will be able to eliminate the background by utilizing this fact. If the background is still fairly high, we could detect the other proton as well. Since its direction is given by kinematics this will not lead to a loss in counting rate.

We intend to cover the pion energy range 50 to 300 MeV in 50 MeV steps. For the angular resolution we intend to aim for 5°. This will enable us to reach the low angles, so important in the determination of the $\cos^4\theta$ coefficient. Assuming a beam intensity of 10^5 pions/sec, a deuterium target of 1.5 gm/cm^2, and a counter solid angle of 10^{-2} ster., we estimate a count-rate of 1 every 3 sec. For higher pion energies the count-rate will be a little lower; at lower pion energies the count-rate will be higher. 4% statistics will take 30 min, 12 points on an angular distribution will thus take about 8 hours, allowing for angle changes. Six energies will take approximately three days.

Although some counter calibration could be done on parasitic time, a lot of checks will have to be made using prime-time, before data are taken. Subsidiary beam measurements may take one or two days. We estimate that a run of less than one week will be very inefficient. Because of the importance of absolute accuracy in this experiment, it is essential to prove that we can reproduce the data. A second run of one week is therefore necessary. The total estimated time is therefore 40 shifts.

d) The experimental team

The following people have agreed to participate in this experiment, E.G. Michaelis and P. Skarek (CERN), C. Serre (Grenoble) and W. Hirt (E.T.H.).

References

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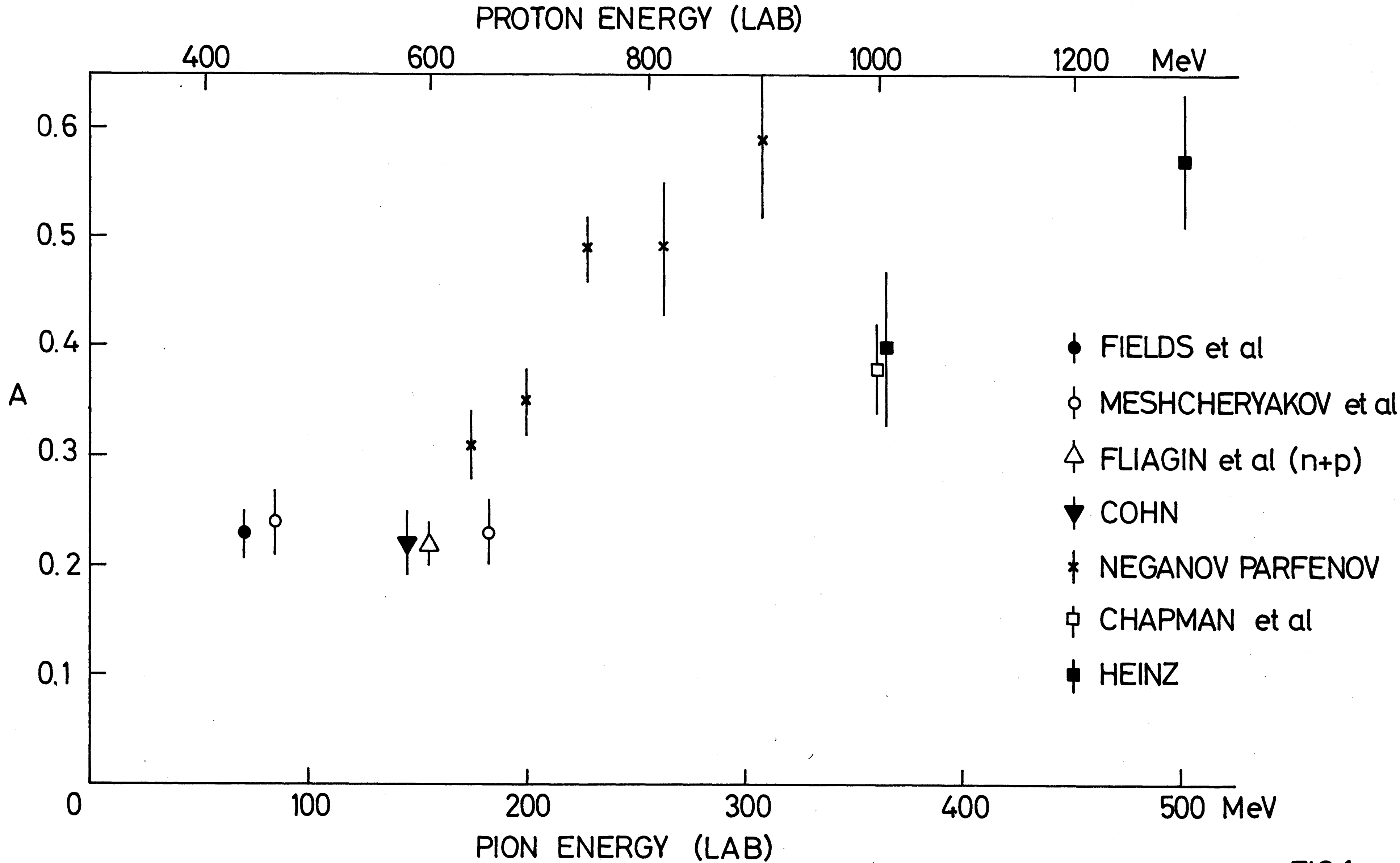
PROTON ENERGY (LAB)
400
600
800
1000
1200
MeV
0.6
0.5
0.4
0.3
0.2
0.1
A
0
100
200
300
400
500 MeV
PION ENERGY (LAB)
FIELDS et al
MESHCHERYAKOV et al
FLIAGIN et al (n+p)
COHN
NEGANOV PARFENOV
CHAPMAN et al
HEINZ

FIG.1