CERN/PSCC/80-85
PSCC/P20
August 22, 1980

PROPOSAL

MEASUREMENT OF $\bar{p}p$ CROSS SECTIONS AT LOW $\bar{p}$ MOMENTA

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1. INTRODUCTION

The LEAR facility will open for the first time the possibility to measure the $\bar{p}p$ cross sections down to very low momenta with high statistical accuracy. In recent experiments[1,2] the integrated and differential elastic, the charge exchange, and the annihilation cross sections have been investigated down to about 400 MeV/c. In the proposed experiment we should like to extend these measurements down to 150 MeV/c. This will bring us close to the region of pure s wave scattering. The scattering and charge exchange cross section give a simple parametrization of the $\bar{p}p$ interaction in terms of scattering lengths. The deduced information, however, will be an average over the two channel spins. Furthermore, the ratio of the real to the imaginary forward scattering amplitude at low momenta can be derived for the first time. This information is of interest when compared to the pp scattering via the dispersion relations.

Though one does not expect great surprises in the behaviour of these cross sections close to the threshold, they are of great importance for planning more detailed experiments.

Last but not least these measurements will offer a further search of high statistical significance for baryonium states close to the threshold. The high statistical accuracy now made possible by LEAR will render this search significant in backward scattering also.

These measurements at low momenta require two essential experimental developments: the design of a thin liquid hydrogen target and the use of a multi wire proportional chamber and plastic detectors in vacuum. Both requirements are consequences of the short range for $\bar{p}$ in matter (1.2 cm for 150 MeV/c $\bar{p}$ in H_2).

2. EXPERIMENTAL SET-UP

The experimental set-up is planned for an investigation of the $\bar{p}$ cross sections between 150 and 500 MeV/c.

The elastic cross sections will be measured by a multi wire proportional chamber, MWPC, and a forward hodoscope, FH, covering an angular range between $-45^{o} \lesssim \Theta_{lab} \lesssim 45^{o}$ (see fig. 1). The measurement of the time of flight between a start detector, SD, and the hodoscope, FH, defines the forward scattered $\bar{p}$ and p, i.e. the backward scattered $\bar{p}$. Forward and backward scattering will be distinguished by the signal which the $\bar{p}$ produces in a forward calorimeter, FC, or a target calorimeter box, TCB, respectively. The whole arrangement is planned symmetrically in order to have a good calibration of the scattering angle for the measurement of $d\sigma/dt$. The spatial extension of the LEAR beam of 1 mm and the resolution of the wire chamber of 2 mm will result in an angular resolution of about 10 mr. This resolution is of the same order as the multiple scattering in an hydrogen target of 2 mm thickness (including 0.1 mm window foils) at the low momenta envisaged.

Due to the large energy loss and straggling of the $\bar{p}$ in matter at low momenta the multi wire proportional chamber, MWPC, and the forward hodoscope, FH, have to be placed in a scattering chamber. This situation is the standard case in low energy nuclear physics experiments and we shall take advantage of our experiences in this domain.

The beam is defined by the start detector, SD, and a small scintillator behind the forward hodoscope. Its rate will be scaled down for data acquisition.

The charge exchange cross section will be defined by the time of flight to the forward calorimeter, FC, of the $\bar{n}$. This calorimeter, which consists of a ring of 18 calorimeter modules, covers an angular range of $-90^{o} \lesssim \Theta_{lab} \lesssim 90^{o}$ and a solid angle of 1.5 sr. The angular distribution of the charge exchange cross section is defined by the modules of the forward calorimeter, FC, in bins of 20^{o} in the cm system.

The distinction between $\bar{p}$ and $\bar{n}$ in the angular range of $-45^{o} \lesssim \Theta_{lab} \lesssim 45^{o}$ will be given by the missing of a signal in the forward hodoscope, FH, and the MWPC. If a charged pion from the $\bar{n}$ annihilation in the forward calorimeter simulates an $\bar{p}$, the geometrical reconstruction by means of the MWPC will suppress these events by a factor of about 50. In the angular range of $45^\circ \leq |\Theta_{lab}| \leq 90^\circ$, where no $\bar{p}$ has to be detected, two scintillators slabs, AC, will be provided.

The integrated annihilation cross section can be determined by the two calorimeter assemblies FC and TCB. They will cover a solid angle of almost 4π since the target calorimeter box will be open only in the region which is covered by the forward calorimeters. These calorimeters are in particular capable of detecting the neutral pions. The pulse height in the calorimeters will allow to distinguish between an annihilation event in the target (single γ's of π^0's) or in the calorimeters.

Most of the experimental techniques (electronics, computer, hodoscopes, etc.) are the same as in our previous measurement[2)] of the same cross sections (without charge exchange) between 400 and 1000 MeV/c. However, the following items will require special developments:

(2.1) Target

A liquid hydrogen target with a thickness of 2 mm has to be built.[5)] Considering the small size of the target a thickness of the target windows between 0.05 and 0.1 mm will be sufficient and therefore no principal difficulties are expected.

(2.2) Multi wire proportional chamber (MWPC)

The MWPC will be adapted from similar chambers for use in low energy heavy ion experiments[3)]. In our case, they will be used with a gas pressure of 1 atm. This requires foils of 50 μm with a supporting wire grid of 2×2 cm^2 width.

(2.3) The forward calorimeter (FC)

The FC will consist of a lead scintillator sandwich of about 20 cm thickness, which is equivalent to about two interaction lengths for the $\bar{n}$ and 20 radiation lengths for the gammas of the π^0. These values will provide a detection efficiency of 90% for the $\bar{n}$ and 100% for the π^0.

(2.4) The target calorimeter box (TCB)

The TCB will serve to detect the pions from the annihilation in the target. It will be of a similar design as the FC, but can be thinner ($\sim$ 3 cm), because only pions shall be detected.

3. EVENT RATES AND BEAM TIME REQUEST

The estimates are given for an intensity of the degraded LEAR beam of 10^5 $\bar{p}$/s. The hydrogen target was assumed to be 2 mm thick. The solid angles have been calculated from the proposed geometry of fig. 1. The cross sections have been extrapolated from measurements at higher momenta[4].

Reaction	$\varepsilon = \Omega/\Omega_{max}$	σ/mb	events/s
$\bar{p}p \to \bar{p}p$	0.27	100	23
$\bar{p}p \to \bar{n}n$	0.27	20	5
$\bar{p}p \to \pi$'s	1.00	250	210

We want to measure the cross sections with a statistical accuracy of 2%. Considering the smallest rate for the charge exchange reaction and requiring 2% accuracy in the average per angular module of FC, one derives a measuring time of 1.4 h per point. Together with the time needed for the change of the momentum we estimate a total time of 2 h per point. This means for a coverage of the momentum region from 150 to 500 MeV/c in steps of 10 MeV/c about three days. In order to eliminate systematic effects, we want to scan the region three times. Consequently a data taking period of two weeks will be required, which includes some margin for down time. For set-up and tuning of the apparatus an additional week is demanded.

This results in the following beamtime request:

set-up and tuning	1 week
data taking	2 weeks

4. ADDITIONAL REQUIREMENTS

The measurements require the change of the beam momentum in small steps ($\sim$ 10 MeV/c). This should be accomplished in the first phase of LEAR, when only a fixed momentum operation is provided by a degrading of the beam. However, this mode of operation requires a specially designed beam line. In particular, an analysis of the beam after the degrader will be unavoidable. We assume that this facility will be provided by CERN.

The experiment will require a space of 3×3 m^2.

The thin liquid hydrogen target will be developed in collaboration with the Cryo Target Group of M. Mazzone at CERN.[5)]

An off-line cross check of the data and data concentration will require 20 hours of CPU time on the IBM computers at CERN. The data analysis will be performed at Heidelberg.

From the EP Electronics Pool we need electronic equipment of a total value of 400 kSF; this equipment is at present being used in our hypernuclear experiment (S166).

REFERENCES

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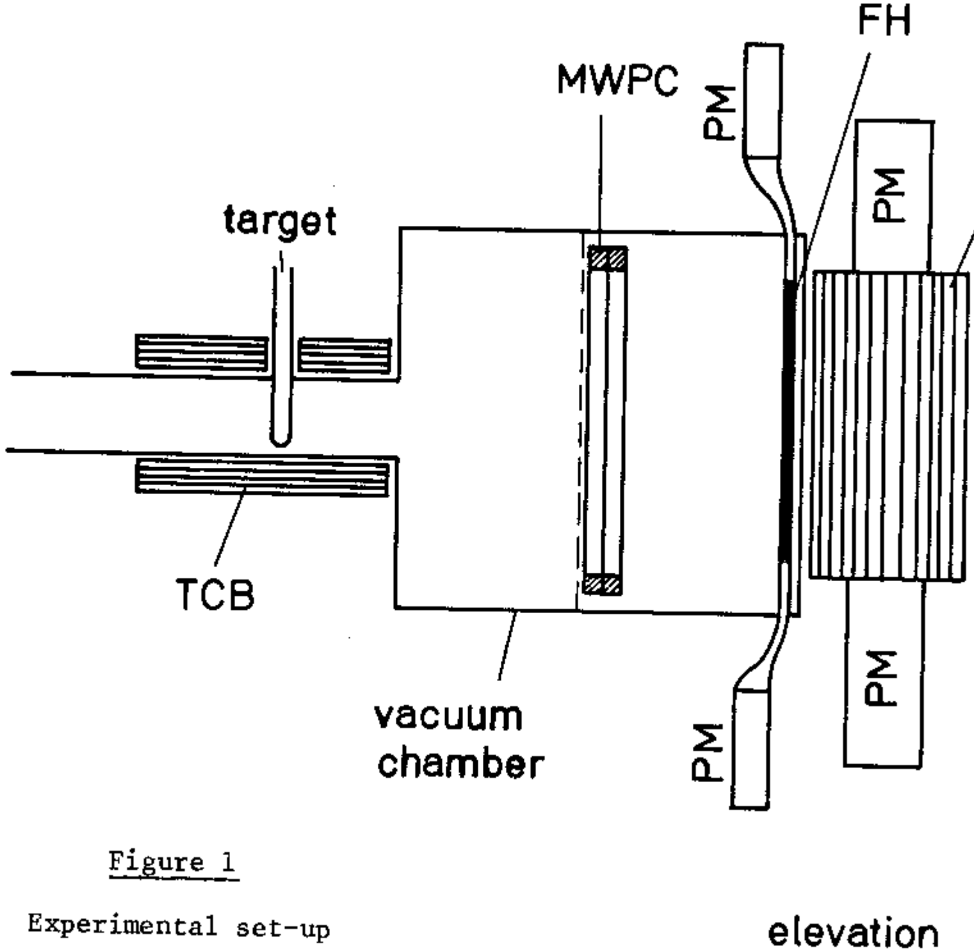
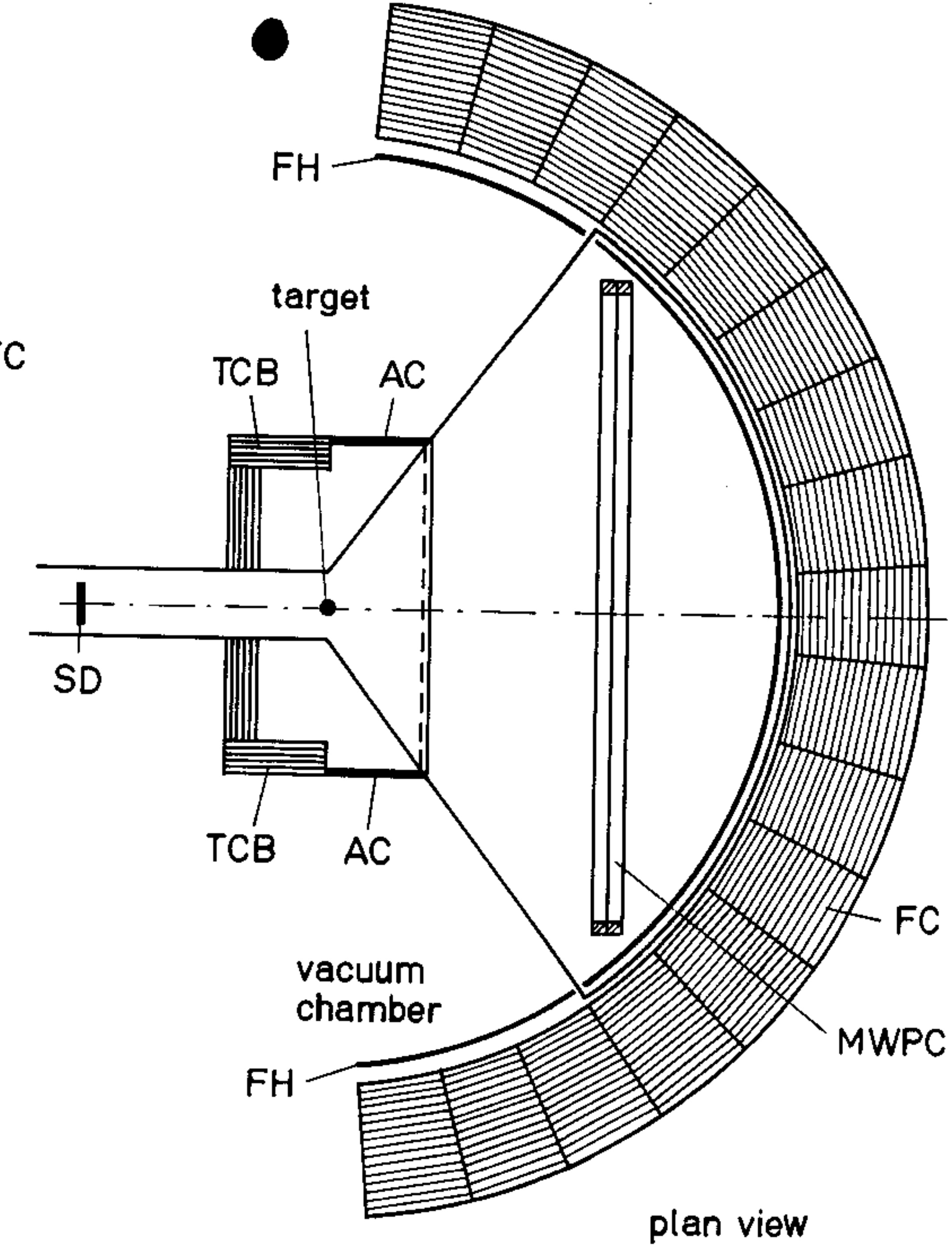
(2) W. Brückner et al., Experiment CERN-S163.

(3) See e.g. U. Lynen et al., Nucl. Instr. Meth. 162 (1979) 657.

(4) CERN-HERA 79-03: Compilation of cross sections III - p and $\bar{p}$ induced reactions.

(5) K. Kilian and L. Mazzone, CERN $\bar{p}$ LEAR Note 87, July 1980.





<u>Figure 1</u>

Experimental set-up

1	SD	$\bar{p}$ defining detector
2	TCB	target calorimeter box
3	AC	scintillator slabs
4	MWPC	multiwire proportional chambers
5	FH	forward hodoscope
6	FC	forward calorimeter
7	PM	photo multiplier