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FIRST OBSERVATION OF ELECTRON PAIR PRODUCTION IN ANTIPROTON-PROTON ANNIHILATION

G. Bassompierre, G. Binder, P. Dalpiaz, P.F. Dalpiaz,
C. Franzinetti, G. Gissinger, S. Jacquey, C. Peroni,
A. Ruzza, M.A. Schneegans and L. Tecchio

Institut des Sciences exactes et appliquées, Mulhouse
Centre national de recherches scientifiques, Strasbourg
Istituto di Fisica Superiore dell'Università e
Istituto Nazionale di Fisica Nucleare, Torino

ABSTRACT

From a preliminary analysis of a partial sample of data of an experiment now in progress at CERN, 29 pairs of electrons with electron energy > 700 MeV have been observed. The electrons produced by stopping antiprotons in a liquid-hydrogen target are detected with optical spark chambers and scintillation counters. Ten of these 29 pairs were found to be collinear; normalizing with respect to hadronic two-body processes $\pi^+\pi^-$ and K^+K^-, a branching ratio

$$BR = \frac{\Gamma(pp \to e^+e^-)}{\Gamma(\bar{p}p \to \text{total})} = (5.1 \pm 2.5) \times 10^{-7}$$

has been obtained.

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1. INTRODUCTION

The proton electromagnetic form factors have been extensively investigated in the space-like region. However, in spite of the great interest of a similar study in the time-like region, only three experiments on this subject have been performed until now.

The reaction

$$\bar{p}p \rightarrow e^+e^- \qquad (1)$$

has been studied in two experiments at the CERN$^{1)}$ and BNL$^{2)}$ laboratories. Upper limits at $q^2 = -6.8$, -6.6, and -5.1 $(\mathrm{GeV}/c)^2$ have been reported.

The inverse process

$$e^+e^- \rightarrow \bar{p}p \qquad (2)$$

has been investigated at Adone$^{3)}$ in Frascati. This experiment gave the first positive result at $q^2 = -4.3$ $(\mathrm{GeV}/c)^2$ on the basis of (25 ± 6) events.

In this paper we present some preliminary results on reaction (1) at rest $[q^2 = -3.5\ (\mathrm{GeV}/c)^2]$. The experiment is now in progress at the CERN Proton Synchrotron (PS). We intend to give the evaluation of the branching ratio:

$$\mathrm{BR} = \Gamma(pp \rightarrow e^+e^-)/\Gamma(\bar{p}p \rightarrow \mathrm{total})$$

at the threshold of the time-like region; this is a necessary step to the determination of the proton electromagnetic form factors at this value of q^2.

2. EXPERIMENTAL APPARATUS

The antiproton beam used in the experiment is the m_{14} of CERN PS. This is a large acceptance beam, for low momentum particles (up to 1 GeV/c) produced in an internal target of the PS and enriched by electrostatic separation.

Extensive studies were made to find the best experimental conditions for a maximum number of antiprotons stopped in the target. The optimal figures of the beam are obtained at 900 MeV/c with the maximum $\Delta p/p = \pm 1.8\%$, where the $\bar{p}$ flux obtained is $6000\ \bar{p}/6 \times 10^{11}$ circulating protons; the $\pi^-/\bar{p}$ ratio is ~ 12 and the image $(8 \times 3)\ \mathrm{cm}^2$.

Figure 1 shows a sketch of the beam telescope. Counters 1 and 2 allow the electronic selection of $\bar{p}$ by time of flight. In this way we eliminate from the trigger the 99.7% of the π contamination.

Counter 2 is followed by 11.5 cm of lead, used as beam moderator. This thickness is optimized to stop a maximum ($\sim$ 10%) of $\bar{p}$ in the 50-cm long, 15 cm diameter hydrogen target. From the thick counter 3 (1 cm) a cut on the pulse height allows a further rejection of pions and of the $\bar{p}$ interacting in the moderator. The $\bar{A}$ anticoincidence reduces the background due to the interaction in the moderator. The thin counter 4 (1 mm) rejects the $\bar{p}$ which have interacted in counter 3. The counter $\bar{Q}$ eliminates the $\bar{p}$ not stopped in the target[*].

Electrons emerging from the target and missing the $\bar{A}$ and $\bar{Q}$ counters are accepted by four blocks of detectors (see Fig. 2) surrounding the target. In each block, thin-foil optical spark chambers (KIN) allow the direction of the electrons to be determined with a precision of ∿ 1°. Counter M ensures that one charged particle enters the region of optical spark chambers, scintillators and absorbers, where the shower develops, starting with chambers (MC), which has thick plates corresponding to a total of 2.2 radiation lengths. Pions and electrons not initiating a shower in the MC chambers are eliminated by discrimination on the pulse height in counter F. In this way we accept ∿ 90% of the electrons and ∿ 15% of the pions. Inside the blocks (SA) of optical spark chambers, absorbers and scintillation counters, the shower develops, and by discrimination on the total pulse height of these counters we can finally obtain an efficiency of ∿ 80% for electrons and ∿ 4% for pions. A further rejection of pions is obtained after examining the photographs of the spark chambers. A total pion contamination of 5×10^{-4} is obtained with an efficiency for electrons of 72%. The method is well explained elsewhere[4]. We can displace each block of detectors in an electron and pion beam in order to check periodically the performance of our apparatus.

3. RESULTS

Scanning a sample of 70,000 events, we found 29 electron pairs with electron energy above 700 MeV. Preliminary analysis shows that 10 events are pairs of collinear electrons, within a precision of about 1°. The remaining 19 pairs, well separated from the sample of collinear events when plotted as a function of the opening angle, are probably produced by $\bar{p}$ in flight and high mass vector mesons from processes of the type

$$\bar{p}p \rightarrow \underbrace{V^0}_{\hookrightarrow e^+e^-} + \pi^0 \ . \tag{3}$$

Results on these reactions will be presented elsewhere.

The hadronic background, which can simulate electron pairs, has been evaluated, scanning for pairs in which one track is clearly a π and the other shows the characteristics of an electron. The contamination of the collinear e^+e^- sample is less than 1%. The contamination of the remaining 19 pairs is about 5%, distributed uniformly over the opening angle spectrum.

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[*] With the precision allowed by our apparatus for the determination of momenta and angles, a $\bar{p}$ is defined "at rest" when its kinetic energy is less than 1 MeV.

We have evaluated the branching ratio

$$BR_{e^+e^-} = \frac{\Gamma(\bar{p}p \to e^+e^-)}{\Gamma(\bar{p}p \to \text{total})} \qquad (4)$$

on the basis of the observed 10 collinear pairs of electrons, normalizing with respect to the rates of annihilation of stopping $\bar{p}$ in $\pi^+\pi^-$ and K^+K^- [5]*). With this method, we eliminate the errors on the evaluation of the fraction of stopping $\bar{p}$, of the solid angle, and of the efficiency of counter M.

We obtain

$$BR_{e^+e^-} = (5.1 \pm 2.5) \times 10^{-7} \; .$$

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*) $BR_{\pi^+\pi^-} = (3.2 \pm 0.3) \times 10^{-3}$

$BR_{K^+K^-} = (1.1 \pm 0.1) \times 10^{-3}$.

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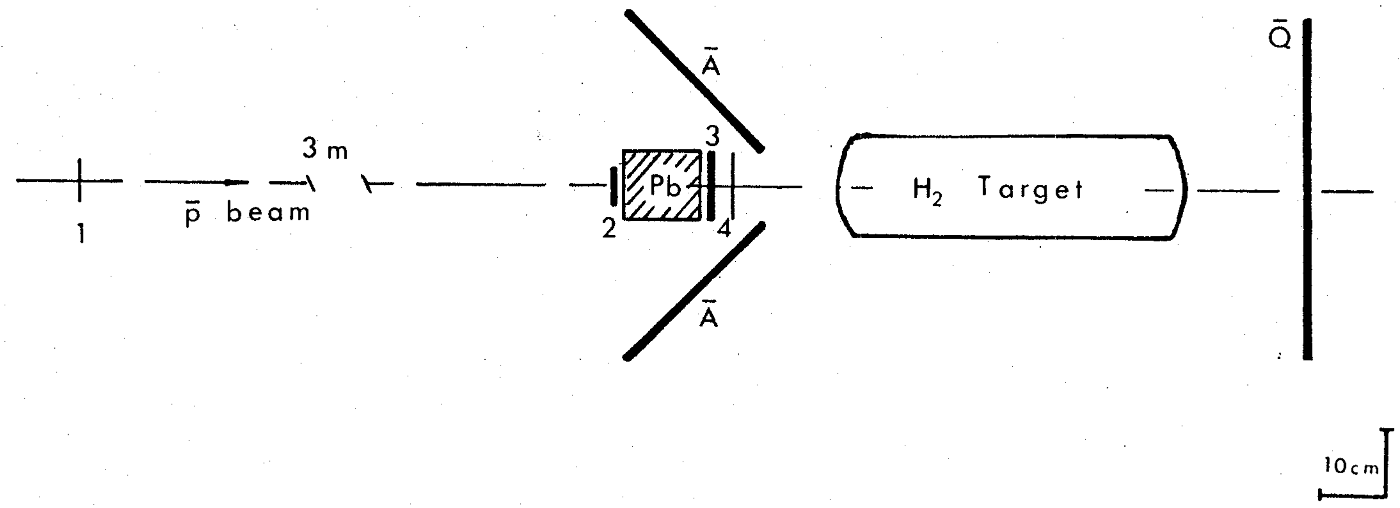

Fig. 1

Figure captions

Fig. 1 :	Sketch of the beam telescope.
Fig. 2 :	Section of the experimental apparatus, in a plane normal to the beam direction. It shows four identical blocks of optical spark chambers, scintillators, and counters. The optical spark chambers of each block are viewed through a cylindrical lens. The detectors are 1 m long along the beam direction line.

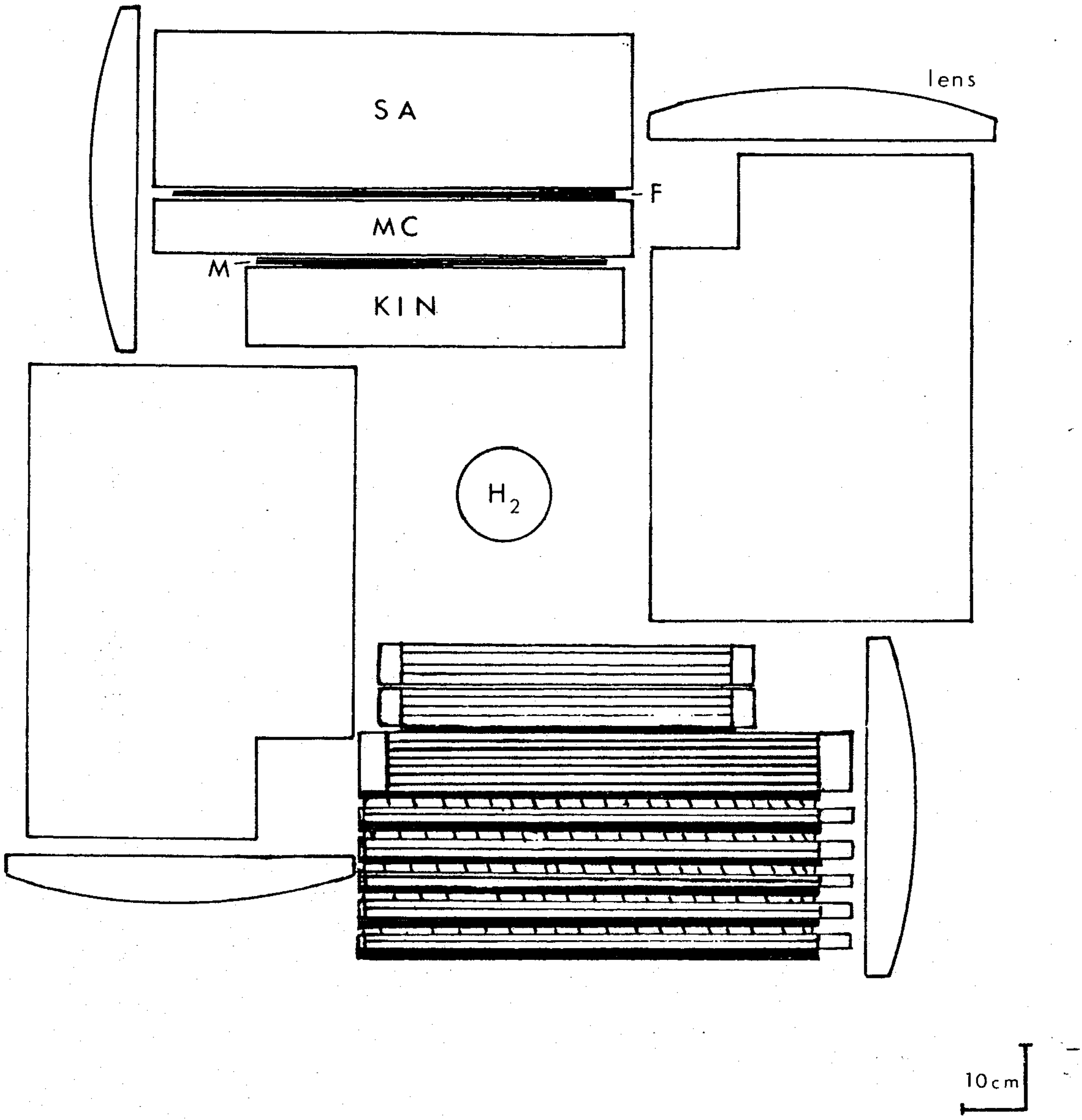

Fig. 2