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$\bar{p}p$ and K^-p Two-Body Cross Sections around 90^o c.m. between 3 and 12 GeV/c

A. de Bellefon, F. Bourgeois, J. Gago,
G. Schuler, P. Sonderegger
CERN, Genève.

C. Aubret, P. Benoit, J.M. Brunet,
P. Billoir, B. Lefièvre, P. Rivet,
G. Tristram, A. Volte
Laboratoire de Physique Corpusculaire
Collège de France - Paris.

M. Bogdanski, D. Perrin, R. Schwarz
Institut de Physique de Neuchâtel.

ABSTRACT

An experiment on two-body reactions around 90^o has been completed recently using the Omega Spectrometer at the CERN SPS and the new RF separated beam.

At 12 GeV/c cross sections for $\bar{p}p$, K^-p elastic scattering are similar to $\pi^-p \to \pi^-p$ and almost 2 orders of magnitude smaller than pp elastic scattering. Two meson annihilation of $\bar{p}p$ is still more than an order of magnitude lower than elastic scattering for $|\cos\theta_{c.m.}| < .6$.

1. INTRODUCTION

We report preliminary results on the reactions

$$\bar{p}p \to \bar{p}p \quad (1)$$

$$\bar{p}p \to K^-K^+ \quad (2)$$

$$\bar{p}p \to \pi^-\pi^+ \quad (3)$$

$$\text{and } K^-p \to K^-p \quad (4)$$

$$\text{and } \pi^-p \to \pi^-p \quad (5)$$

for $-.6 \leq \cos\theta$ c.m $\leq .6$ and at lab momenta between 3 and 12 GeV/c. The experiment was done between May and July 1978 in the Omega Spectrometer at the CERN SPS. The very low cross sections involved could be attained thanks to the new RF separated beam and with the help of a very selective trigger logic. The aims of the experiment were:

(i) to measure the energy dependence of 2-body reactions at fixed large angles, for which definite power laws are predicted [1], and to compare cross sections of crossed reactions (e.g. (2) and (4))

(ii) to scan through the formation region of the η_c (2830) which might show up in reaction(1)

(iii) to look for Ericson fluctuations.

The reactions $\bar{p}p \to \bar{\Lambda}\Lambda$ and $\pi^-p \to K^0\Lambda$ were also recorded, and data were taken at 3.0, 3.1, 3.2, 3.3 (the η_c (2830) region), and 8 and 12 GeV/c. The reaction (5) was recorded at 5 GeV/c, and for part of the time at the above momenta for calibration purposes. We will describe the experiment, as well as the results on reactions (1)-(4) obtained so far, which are based on 1/3 of the data taken in the η_c region and at 12 GeV/c, and correspond to 5 events per nanobarn for $\bar{p}p$ reactions at 12 GeV/c.

2. THE RF SEPARATED BEAM

The new separated beam equipped with superconducting RF cavities yielded, at 12 GeV/c, 600,000 $\bar{p}$ and 200,000 K^- per $1.5\ 10^{12}$ protons of 210 GeV/c incident on the 30cm Be production target, together with 450,000 π^- and e^-. In the η_c region, where virtually no K^- reached Ω, a special separation mode was used: the antiprotons suffered almost no deflection in the cavities, and the pions and electrons were stopped by two collimators which followed the two cavities. The enrichment ratios were 65 for $\bar{p}/\pi^-$ at 12 GeV/c, and 130 for $\bar{p}/e^-$ in the η_c region.

3. THE COPLANARITY TRIGGER

Figure 1 shows the trigger and detector layout. The trigger required an incoming K^- or $\bar{p}$ as defined by three threshold Cerenkov counters, and 2 particles leaving the target at large angles. The coplanar configuration of these figures was selected by a proportional chamber whose cathode plane was subdivided into 57 circular sectors. A decisional logic based on the "hash coding"principle computed the coplanarity within 100 nsec[2]. Several counters outside the main spark chamber detector vetoed events with photons and/or forward anti-neutrons. With a 67cm long hydrogen target, there was one trigger every 50,000 incoming $\bar{p}$'s at 12 GeV/c (1/5,000 at 3 GeV/c).

4. DATA ANALYSIS AND NORMALISATION; SEARCH FOR ANNIHILATION INTO A QUARK PAIR

The data were processed through the Omega pattern recognition and geometry programs, and searched for pairs of tracks of opposite charge, balanced transverse momenta, and originating from a common interaction vertex inside the H_2 target. No pairs of particles of charge $\pm$ 2/3 and a mass up to 2.2 GeV/c^2 were seen at a level of 1 nanobarn. Finally longitudinal momentum balance was imposed, and a 3-C fit of the momentum vectors was performed. Conservation of energy was used to compute M_{sec}, i.e.

- the(common) mass of the secondary particles, for reactions (1)-(3); and
- for K^-p and π^-p elastic scattering, the mass of the positive secondary particle, the mass of the negative one being taken equal to the beam particle's mass.

Figure 2 shows the distributions thus obtained for squared masses M_{sec}^2 for $\bar{p}p$ and K^-p reactions. Reactions(1)and(4)can be unambiguously identified, with very small background, while reactions(2)and(3)can be only tentatively identified at 12 GeV/c at the present status of the data analysis.

The events were then weighted and normalised and the resulting cross sections for $\pi^-p \to \pi^-p$ and $\bar{p}p \to \bar{p}p$ at 3 GeV/c, and for $\pi^-p \to \pi^-p$ at 12 GeV/c were found to agree well with published values at or near these energies[3),4),5)], indicating that the normalisation is good to better than $\pm$ 20%.

5. DATA AROUND $\sqrt{s}$ = 2.83

The momentum of the incoming $\bar{p}$ was measured to ± 0.2%. We have plotted the cross sections for various bands in t against the c.m. energy. We see fluctuations, but in the t range covered by the experiment the cross sections $\frac{d\sigma}{dt}$ are above 10^{-29} cm^2/(GeV/c)^2, and the η_c (2830) would have to decay into $\bar{p}p$ and/or $\bar{\Lambda}\Lambda$ with a probability of the order of 10^{-1} to be seen in this experiment.

6. RESULTS AT 12 GEV/c

Figure 3 shows the preliminary results for $\bar{p}p \to \bar{p}p$ at 12 GeV/c. Published data at 12[6] and 9.7[7] GeV/c are also shown, as well as the cross section for $pp \to pp$ at 12.15 GeV/c[8].

Table 1 summarises our results for reactions(1-5),and quotes for comparison the published data for 5 GeV/c[9].

Cross sections of two-body reactions at large angles[1] are parametrized to first order as

$$\frac{d\sigma}{dt}\ (ab \to cd,\ -t >> 1,\ -u >> 1) = \frac{f(\cos\theta\ \text{c.m.})}{s^n}$$

The exponent n is predicted by the counting rules to be n = 10 for reaction(1),and n = 8 for reactions(2-5). The dependence on cosθ c.m.can be derived from a variety of versions of the Constituent Interchange Model. In particular, the ratios between the cross sections of crossed reactions can be related to the asymptotic values $\alpha(-\infty)$ of the concerned Regge trajectories. The predictions for $d\sigma/dt\ (pp \to pp)/d\sigma/dt\ (\bar{p}p \to \bar{p}p)$ range from 16 to 1024[1c], while our result is of the order of 50, in agreement with the ratio at 5 GeV/c.

Our results for the three elastic scattering reactions do not contradict the above energy dependence with n = 10 for reaction(1)and n = 8 for reactions(4)and(5)(Table 1). An apparent discrepancy in normalisation of 5 GeV/c $\pi^- p \to \pi^- p$ results[3),9)] should be borne in mind.

On the other hand the annihilation reactions do not appear to follow the counting rules. At 5 GeV/c (s = 11.3), the sum of reactions(2)and(3)reach 13% of the cross section for $\bar{p}p$ elastic scattering. If their energy dependence is less steep than $\bar{p}p \to \bar{p}p$ by two powers of s, then their sum should reach 53% of the $\bar{p}p$ elastic scattering cross section at 12 GeV/c.

(s= 24.3). With no annihilation event in the retained region $-.5 \leq \cos\theta \leq .5$ (the 3 events of fig. 2 have $\cos\theta$ = .51, .54 and .62), we find the sum of reactions(2)and(3)to be below 1.5 nbarn at the 95% confidence level i.e. lower than 15% of the cross section found for $\bar{p}p \to \bar{p}p$ in the same interval. The three reactions have been measured simultaneously in the same way and with nearly the same acceptance. Also, the overall normalisation errors cancel mostly out when computing such ratios.

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TABLE 1

Results at 12 GeV/c, and comparison with data at 5 GeV/c[9].
Overall normalisation errors are included.

Reactions	$\bar{p}p \to \bar{p}p$	$\bar{p}p \to K^-K^+$	$\bar{p}p \to \pi^-\pi^+$	$K^-p \to K^-p$	$\pi^-p \to \pi^-p$
12 GeV/c, this experiment					
Events, total	39	total 3 (1KK + 2$\pi\pi$?)		7	10
Events with $\cos\lvert\theta\rvert \leq .5$	23	0	0	5	10
$\int_{-.5}^{.5} \frac{d\sigma}{d\cos\theta} d\cos\theta$, nanobarn	9.9±3.2	<.5 (value for 1 event)	<.5	6 ± 3	12.5±5.
5 GeV/c, ref.[9]					
$\int_{-.5}^{.5} \frac{d\sigma}{d\cos\theta} d\cos\theta$, μbarn	7.2±1.1	.22±.08	.7±.18	2.4±.4	1.23±.2
Exponent n (see text) from comparison of 5 and 12 GeV/c data	9.9±.5	> 9.1	> 10.6	9.6±.9	7.5±.7
Exponent n expected from counting rules	10	8	8	8	8

Fig. 1. - Experimental layout

CC - coplanarity chamber; S6 - counter made up of 6 horizontal slabs used for multiplicity trigger; V6 - circular veto counter; EC - forward particles veto.

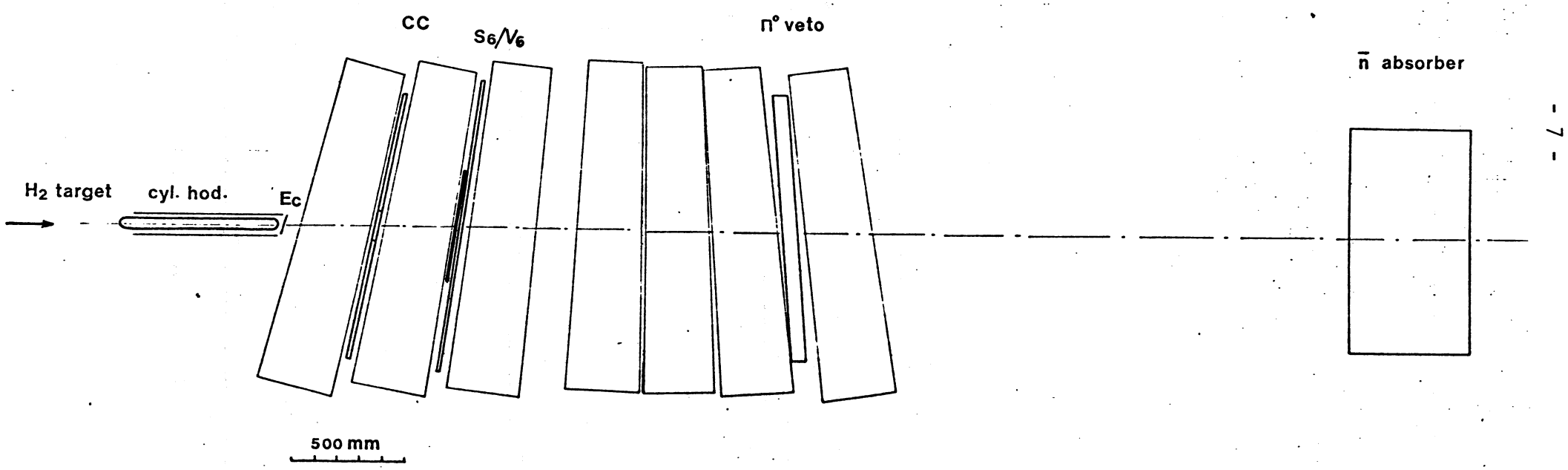

Fig.2: Mass squared as given by the energy conservation constraint, for the secondary particles (a and b) and for the positive secondary particle (c).

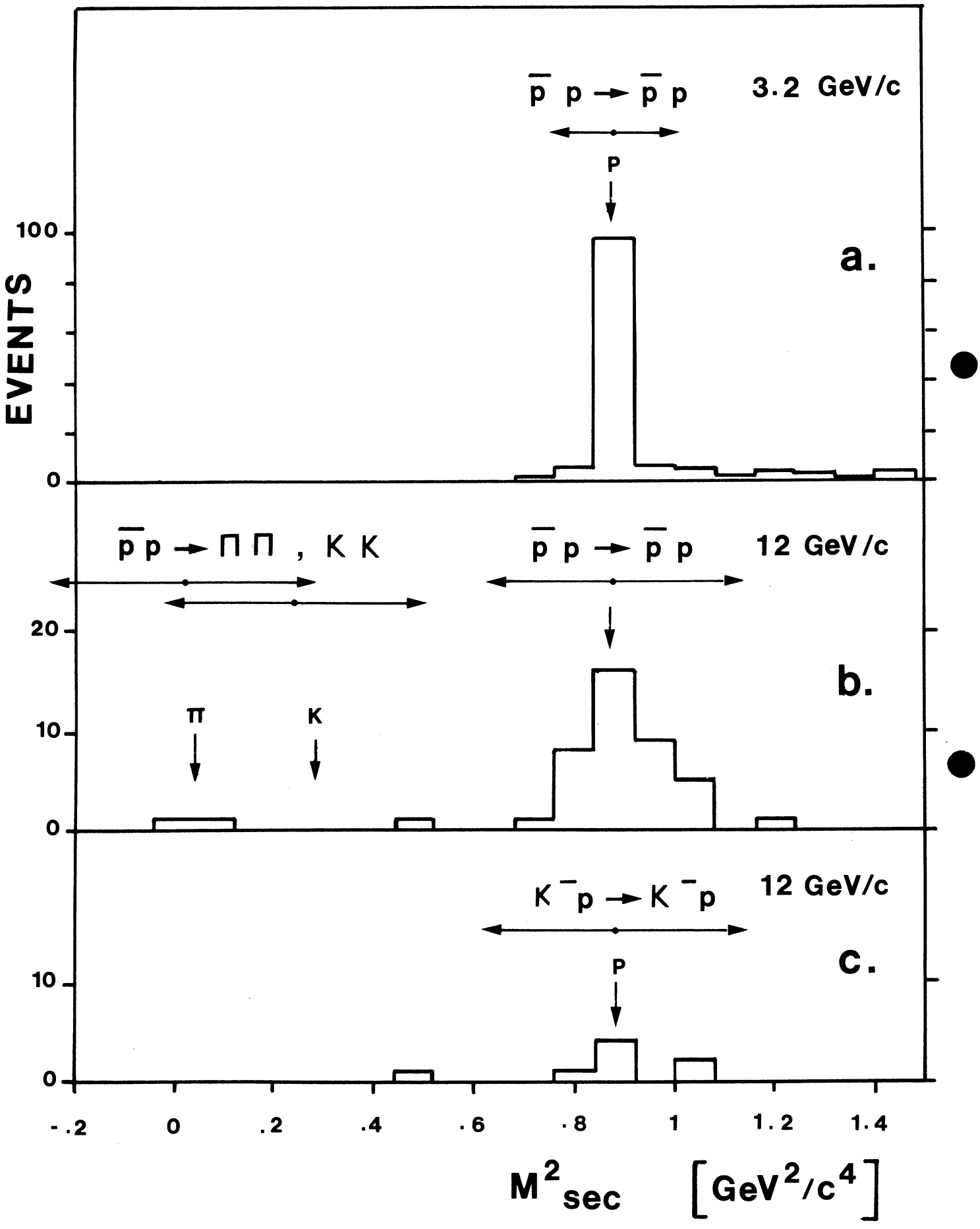

Fig. 3: Differential cross section for $\bar{p}p \to \bar{p}p$ at (or near) 12 GeV/c. Comparison with $pp \to pp$ at large angles.