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OBSERVATION OF PARTON FRAGMENTATION
IN $\bar{p}^{20}\text{Ne}$ REACTIONS AT 607 MeV/C

CERN - COLLABORATION PS-179

BERGEN-BRESCIA-CAGLIARI-DUBNA-
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Abstract

The ratio between the numbers of negative and positive leading pions in \bar{p} ^{20}Ne reactions at 607 MeV/c can only be explained by QCD in terms of parton fragmentation.

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1. Introduction.

In two previous papers [1,2] we showed evidence for leading π^- and K_s^0 in \bar{p} ^4He and \bar{p} ^{20}Ne reactions at 607 MeV/c beam momentum. Spectator-like leading mesons are emitted with high momenta in a direction near the direction of the incident antiproton.

In this paper we study the emission of charged particles with momentum $p > 400$ MeV/c in more detail. We discuss the different mechanisms which can contribute to the emission of these particles in the reaction

(1) $\bar{p} \ ^{20}\text{Ne} \rightarrow \text{anything}$

at 607 MeV/c incident beam momentum. The experimental data have been obtained by an exposure of a self-shunted streamer-chamber to a 607 MeV/c beam of anti-protons from LEAR, CERN. The experimental details have been presented in previous papers [3].

In this experiment the identity of a final state particle is in general not known. A negative particle may be a π^- , a K^- or the \bar{p} . A positive particle may be a π^+ , a K^+ , a p or a d etc. Since the cross section for K^{*+} production is less than about 2% of the total cross section [4], the number of K^+ 's in the final state can be neglected. This is important since only K^- and not K^+ can be leading.

The "forward" hemisphere is defined by $\cos \theta > 0$, and the "backward" hemisphere is defined by $\cos \theta < 0$, where θ is the angle between the momentum vector of a final state charged particle and the momentum vector of the incident antiproton. For particles observed in the forward hemisphere we discuss the ratio

(2)
$$R = \frac{\text{number of negative particles}}{\text{number of positive particles}}$$

2. Processes for Emission of Particles.

We now discuss briefly those fundamental processes which cause emission of particles. Secondary processes like intranuclear cascades are not discussed in this context.

a) Fragmentation of Incident Antiquarks.

If an incident antiproton dissociates to an antibaryon + mesons, the antibaryon may be annihilated by the target nucleus while some meson(s) may proceed in the forward direction, e.g. the well known Deck-effect with (anti)baryon exchange. These reactions are however implicitly taken into account in terms of fragmentation of beam anti-quarks. An antiquark from the incident antiproton may fragment by pickup of a valence or sea quark from the target nucleus. A ^{20}Ne nucleus has equal numbers of u and d valence and sea quarks.

By analogy to well known pickup reactions, e.g. $pd \rightarrow dp$, small momentum transfers and strong forward peaking are expected by antiquark fragmentation. The ratio between the numbers of π^+ , π^- and π^0 produced in this way is [1]

$$\pi^+ / \pi^- / \pi^0 = 1 / 2 / 3.$$

Thus, the ratio R between the number of leading π^- and leading π^+ is expected to be $R(a) = 2$. Contribution of high momentum particles is expected.

b) Fragmentation of Gluon Bremsstrahlung.

When antiquarks are decelerated or stopped by the target matter, gluon bremsstrahlung is expected to be emitted predominantly in the direction of the incident antiproton. Even if the angular distribution of gluon bremsstrahlung is peaked in the forward direction [5], the decay products can be distributed over a wide angular and momentum region. Fragmentation of gluons obviously produce equal number of positive and negative particles, i.e. $R(b) = 1$. Contribution of high momentum particles is expected.

c) Fragmentation of Pair of Sea-Quarks.

A sea quark-antiquark pair originating from the incident antiproton may fragment. This process is kinematically equivalent to fragmentation of gluon bremsstrahlung. Pions produced by fragmentation of the sea-quarks carry some momentum preferentially in the forward direction. We expect $R(c) = 1$. Contribution of high momentum particles is possible.

d) Knock-on $\bar{p}N \rightarrow N\bar{p}$.

The cross section for knock-on emission of a nucleon N in the forward direction is in this context negligible [6]. In terms of exchanges, this process would imply double baryon exchange. If such processes were observed, they would give $R(d) = 0$.

e) Evaporation of an excited target system.

Emission of particles by evaporation is isotropic in the system of the excited nucleus. The nuclear temperature of the excited target nuclei in the reaction (1) defined by the evaporation model was found to be smaller than about 20 MeV [1]. Protons emitted by this mechanism and at the same temperature would have a velocity of emission about 0.2 c, which is a large value as compared to the velocity 0.03c of the $\bar{p}Ne$ system. Contribution mainly of low momentum particles is expected. For evaporation $R(e) = 0$.

f) "Fireballs".

The fireball model [7] is based on the assumption that the incident antiproton is absorbed on one or two nucleons making

a baryon number $B=0$ or 1 "fireball" which propagates through the nuclear matter and decays. While $B=0$ $\bar{p}n$ fireballs give $R > 1$, $B=0$ $\bar{p}p$ fireballs give $R=1$. $B=1$ fireballs give on average $R=1$. Thus, on average $R(f) > 1$. By the decay of a $B=0$ fireball with momentum $p = 607$ MeV/c, the final state particles have an average rapidity $y \approx 0.3$.

3. Discussion of Experimental Results.

Events with two negative particles in the final state due to inelastic scattering of the incident antiproton can have neither an \bar{p} nor a π^- with momentum $p > 400$ in the final state. We therefore discard events with less than two negative particles in the final state.

In Figs.1a and b we show for $p > 400$ MeV/c the distributions of $\cos \theta$ for negative and positive particles, respectively, for $\cos \theta > -0.75$ because of our selection of fiducial volume in the streamer chamber. Therefore, particles with $\cos \theta \approx |1|$ have in general well measured momenta. In the distributions shown in Figs.1, strong enhancements are seen for $\cos \theta > 0.6$, with a strong peaking towards $\cos \theta > 0.95$. These structures are superimposed onto an almost isotropic background. Since excesses in the forward direction are seen for negative and positive particles with high momenta, we infer that the excesses are due to pions. For these excesses, the average longitudinal rapidity is about 0.8, which is so much larger than the rapidity $y = 0.3$ of a $B=0$ fireball that fireballs can not be the reason for the observed forward enhancements.

We summarize the experimentally obtained values of R for three intervals of $\cos \theta$ in Tables 1 and 2 for $p > 400$ MeV/c and $p > 500$ MeV/c, respectively. The statistical errors are negligible. The systematic errors are of the order 5%. N is the number of charged particles in the final state.

Table 1

$\cos \theta$	all events	$N < 9$
0.60-0.80	0.67	0.95
0.80-0.95	0.79	1.14
0.95-1.00	1.08	1.40

The values of R for particles with momenta $p > 400$ MeV/c.

Table 2

$\cos \theta$	all events	$N < 9$
0.60-0.80	0.80	1.09
0.80-0.95	0.92	1.21
0.95-1.00	1.31	1.69

The values of R for particles with momenta $p > 500$ MeV/c.

According to our discussion in Section 2, we expect for the processes a-f the values of R listed in Table 3.

Table 3

Process	a	b	c	d	e	f
R(expected)	2	1	1	0	0	>1

$R > 1$ only for the processes a) fragmentation of valence antiquarks, and f) "fireballs". Since the rapidity of $B = 0$ fireballs is too small to explain the average rapidity of the forward enhancements, only fragmentation of incident antiquarks can give $R > 1$.

For $R \approx 1$, also fragmentation of gluon bremsstrahlung must have given significant contributions. QCD is therefore the only model consistent with our observations.

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Figure Captions

Fig.1.

The distributions of $\cos \theta$ for
a) negative particles,
b) positive particles,
for momenta $p > 400$ MeV/c.

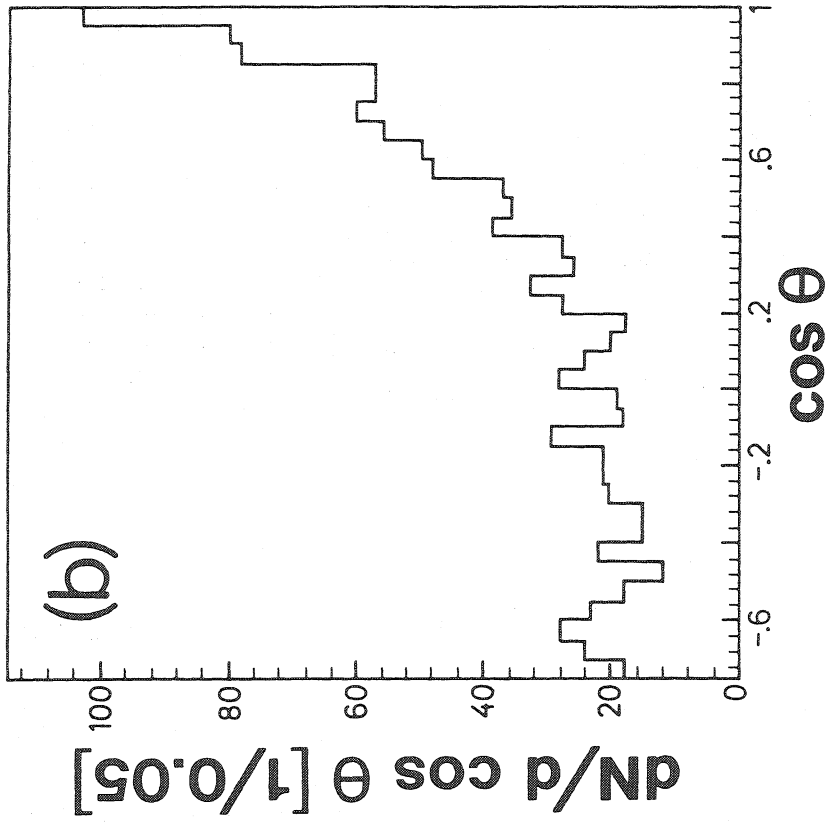
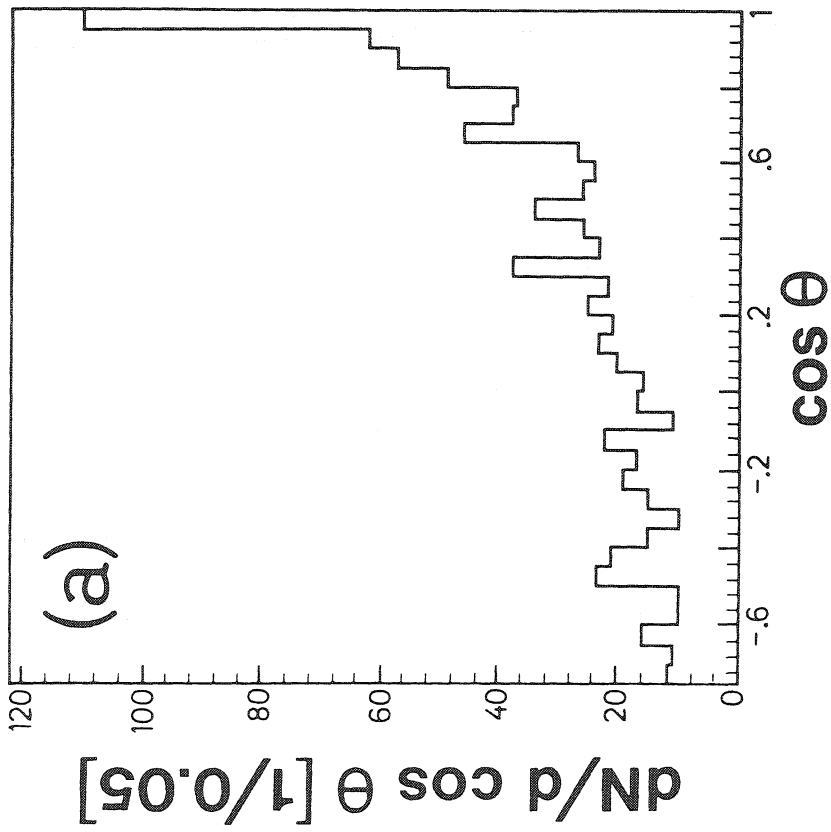


FIG.1

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