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Bergen-Brescia-Dubna-Frascati-Oslo-Pavia-Torino

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Abstract

Two narrow peaks at about 1450 and 1800 MeV/c^2 are seen in the distribution of invariant mass of the assumed six-pion systems in the final states of $\bar{p}$Ne-reactions at 607 MeV/c incident momentum. These systems are emitted also in the backward direction in the laboratory system with momenta near the momentum of the incident antiproton. This observation and the small widths suggest that the peaks are not due to well known baryons or mesons belonging to any Regge-trajecory. The peaks could possibly be due to glueball production.

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1. Introduction.

Based on QCD it is expected that in addition to $q\bar{q}$ and qqq colour singlets, also colour singlets containing only gluons will exist (ref.1). It has been discussed whether the E(1440) first found in antiproton-proton reactions at rest (ref.2) could be a glueball state (ref.3), and if glueballs are possible decay-products of the J/ψ (ref.4).

Some author have discussed glueballs from a theoretical point of view (ref.5). It ought however to be investigated if glueballs may be produced by annihilation of antiprotons in nuclear matter. Could possibly a B=0 "fireball" (ref.6) occasionally be a glueball ?

Antiproton proton collisions are more or less peripheral, and several incident antiquarks may behave as spectators which are dressed as leading pions.
In antiproton nucleus reactions, the three incident antiquarks have a larger probability to be annihilated with the production of three gluons.

Hence, the production of glueballs may be more likely in antiproton nucleus reactions than in antiproton proton reactions. We have therefore searched for glueballs in the reactions

(1) $$\bar{p} + {}^{4}He \rightarrow \pi^- \pi^- \pi^+ \pi^+ + X$$

(2) $$\bar{p} + {}^{4}He \rightarrow \pi^- \pi^- \pi^- \pi^+ \pi^+ \pi^+ + X$$

at 607 MeV/c incident momentum, where we have experimental data obtained by an exposure of a self-shunted streamer - chamber to the antiproton beam of LEAR, CERN, (ref.7). The results suggested glueballs at about 1150 MeV/c^2 with a small width and spin-parity = 0^+ or 2^+ decaying to four pions (ref.8), and at about 1450 and 1800 MeV/c^2 decaying to six pions (ref.9).

In this note we discuss the possibility of glueball production in the reaction

(3) $$\bar{p} + {}^{20}Ne \rightarrow \pi^- \pi^- \pi^- \pi^+ \pi^+ \pi^+ + X$$

at 607 MeV/c incident momentum, according to the diagram shown in Fig.1. These data are obtained in the same LEAR-projekt as the $\bar{p}\,{}^{4}He$ -data. The experimental procedure has been described elsewhere (ref.7).

2. Some General Remarks.

The total sample of events is 12007, and the number of events with at least three negative and four positive particles is 485.

A multiparticle final state of a $\bar{p} + {}^{20}Ne$ – reaction may be due to inelastic scattering or annihilation of the incident antiproton. When three negative particles are seen in the final state, the reaction can not be due to inelastic scattering because of energy conservation. Hence, a negative particle in the final state can not be an antiproton.

Since for annihilation events, K-events / π-events $\approx$ 5/100, we expect about 10 events with charged strange particles. Only the momentum and the charge but not the mass of a final state particle is found by the measurements. Therefore, we discuss our distributions in terms of protons, pions, and kaons, even if the kaons probably can be ignored.

3. Experimental Results.

We show in Fig.2 the distribution of the invariant mass M of the six particle systems assumed to consist of six pions. The distribution has two peaks at about 1450 and 1800 MeV/c^2.

We define two regions of the transverse momentum $P_\perp$

A) $P_\perp <$ 400 MeV/c ,
B) 400 MeV/c $< P_\perp <$ 800 MeV/c ,

and three regions of the longitudinal momentum $P_\parallel$

a) −600 MeV/c $< P_\parallel <$ −300 MeV/c ,
b) −300 MeV/c $< P_\parallel <$ +300 MeV/c ,
c) +300 MeV/c $< P_\parallel <$ +700 MeV/c ,

of the assumed six pion systems. The distributions of the invariant mass of these systems are shown in Fig.3a–f for the six combined regions.

In Fig.3a one prominent peak is seen at about 1450 MeV/c^2 about 14 standard deviations above the background.
In Fig.3f two peaks are seen at about 1450 and 1800 MeV/c^2.
In Fig.3b and c, a shoulder and a possible peak indicate the presence of the 1150 MeV/c^2 peak reported in a previous paper (ref.8). No significant peak is seen in the other regions.

In the regions of longitudinal momentum

d) -600 MeV/c $< P_{\parallel} < -300$ MeV/c,
e) $+400$ MeV/c $< P_{\parallel} < +600$ MeV/c,

with no restriction on the transversal momentum, the peaks at about 1450 and 1800 MeV/c^2 are clearly seen in the distributions shown in Fig.4.

The number of events in the peak regions is about 100, and the number of events with at least two negative particles in the final state is 2995. The ratio between these two figures is 0.033.

The widths of the peaks seen in these data are of the order 150 MeV/c^2. These widths are, however, mainly due to the experimental resolution, and the true widths are therefore very small (refs.8,9), and compatible with almost zero.

Other interesting features in our data have to be investigated with much higher statistics where the identities of the final state particles are found.

We have in some previous reports (refs.8,9) discussed the ambiguity due to the non-identification of the charged particles in this experiment.

The peaks seen in our data may be due to six-particle systems with six pions, or a proton and five pions, or a kaon and five pions, or two kaons and four pions. The masses of the two peaks for the different possibilities are given in Table I.

Table I

	Peak I	Peak II
6π	1450 MeV/c^2	1800 MeV/c^2
$K\,5\pi$	(1800) "	(2150) "
$K\bar{K}\,4\pi$	(2100) "	(2500) "
$p\,5\pi$	2250 "	2600 "

The figures in parenthesis are impossible or very unlikely due to conservation of energy.

4. Discussion.

The peaks at about 1450 and 1800 MeV/c^2 seen in the backward and in the forward directions in the laboratory system do probably have the same origin.

Since the peaks are very narrow, it seems unlikely that they are due to high mass baryon or meson resonances which belong to any Regge-trajectory. Also, since we do not see any production of the low spin Δ(1232), (refs.8,9), it seems unlikely that baryon resonances with much higher spins should be produced in this reaction.

In terms of exchange diagrams, a double baryon exchange is required in order to produce a baryon at the antiproton vertex, which in these terms is not very likely. It has been suggested, however, that B=1 non-resonance "fireballs" (ref.6) may be produced in this way. Double baryon exchange would however not explain the backward production.

If the true peaks are due to meson systems, the baryon peaks may be reflections of the mesons, and vice versa. We have by means of the Monte Carlo program FOWL simulated a baryon resonance and found the reflections in the meson distribution, and vice versa. Our results show that a narrow baryon peak is reflected as a broad meson peak, and that a narrow meson peak is reflected as an even more narrow baryon peak. Furthermore, a two kaon + four pion system with a small width is reflected as a broad six-pion peak, while a narrow six-pion peak is reflected as an even more narrow two kaon + four pion peak (refs.8,9). Thus, the six-particle systems are probably six pion systems.

5. Summary and Conclusion.

The distribution of invariant mass of the assumed six pion systems in the final states of antiproton -^{4}He and antiproton - Ne reactions at 607 MeV/c incident momentum shows two peaks at about 1450 and 1800 MeV/c^2.

For ^{4}He targets these peaks are seen only in the forward direction in the laboratory system. For Ne targets they are also seen in the "backward" direction. The peaks have probably the same origin in He- and Ne-reactions, and in the forward and backward directions.

Because of the anomalous emission, and because the true widths are very small and compatible with zero, these systems are probably not usual baryon or meson resonances. They could possibly be due to the glueball states

$$1^{-+} (\approx 1500 \text{ MeV/c}^2) \quad \text{and} \quad 2^{-+} (\approx 1800 \text{ MeV/c}^2).$$

suggested by Cornwall and Soni (ref.12).

Glueballs must however be assumed to interact very strongly with nuclear matter. Therefore, a possible glueball may have difficulties to escape from a nucleus, unless the nucleus is very small, e.g. the ^{4}He-nucleus. If the nucleus is large, e.g. the Ne-nucleus, the reaction is probably peripheral.

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Figure Captions

Fig.1.
A diagram in terms of antiquark and quark lines for the annihilation of an incident antiproton on a Ne-nucleus target, producing a glueball which decays to six pions.

Fig.2.
The distribution of the invariant mass M of the assumed six-pion systems.

Fig.3.
The distribution of the invariant mass M of the assumed six-pion systems for the regions

a) $0 \text{ MeV/c} < P_{\perp} < 400 \text{ MeV/c}$ and $300 \text{ MeV/c} < P_{\parallel} < 700 \text{ MeV/c}$
b) $0 \text{ MeV/c} < P_{\perp} < 400 \text{ MeV/c}$ and $-300 \text{ MeV/c} < P_{\parallel} < 300 \text{ MeV/c}$
c) $0 \text{ MeV/c} < P_{\perp} < 400 \text{ MeV/c}$ and $-600 \text{ MeV/c} < P_{\parallel} < -300 \text{ MeV/c}$
d) $400 \text{ MeV/c} < P_{\perp} < 800 \text{ MeV/c}$ and $300 \text{ MeV/c} < P_{\parallel} < 700 \text{ MeV/c}$
e) $400 \text{ MeV/c} < P_{\perp} < 800 \text{ MeV/c}$ and $-300 \text{ MeV/c} < P_{\parallel} < 300 \text{ MeV/c}$
f) $400 \text{ MeV/c} < P_{\perp} < 800 \text{ MeV/c}$ and $-600 \text{ MeV/c} < P_{\parallel} < -300 \text{ MeV/c}$

Fig.4.
The distribution of the invariant mass M of the assumed six-pion systems for the regions of longitudinal momentum

a) $-600 \text{ MeV/c} < P_{\parallel} < -300 \text{ MeV/c}$,
b) $400 \text{ MeV/c} < P_{\parallel} < 600 \text{ MeV/c}$.

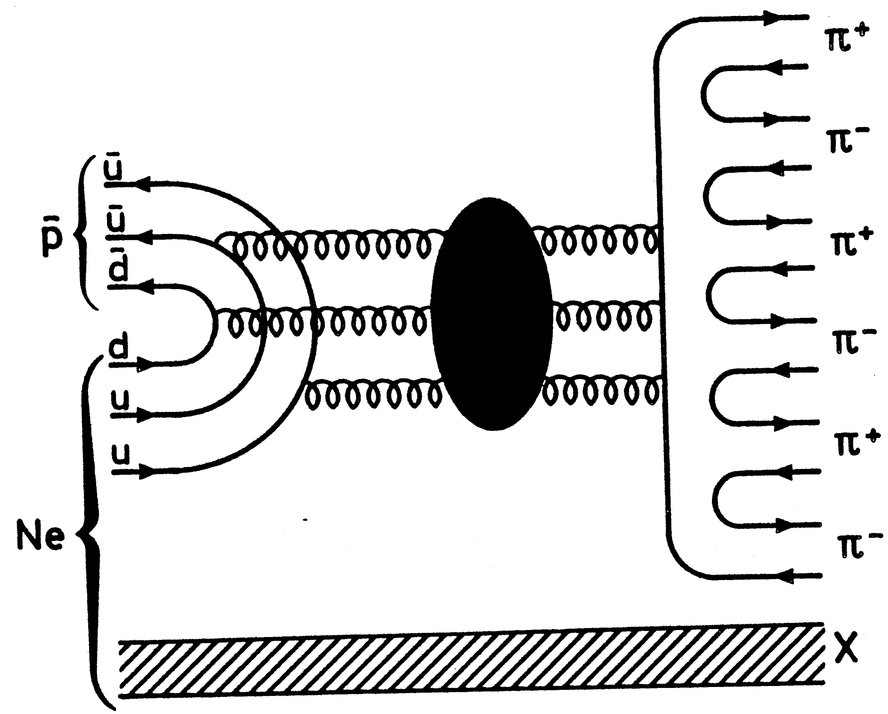

Fig.1

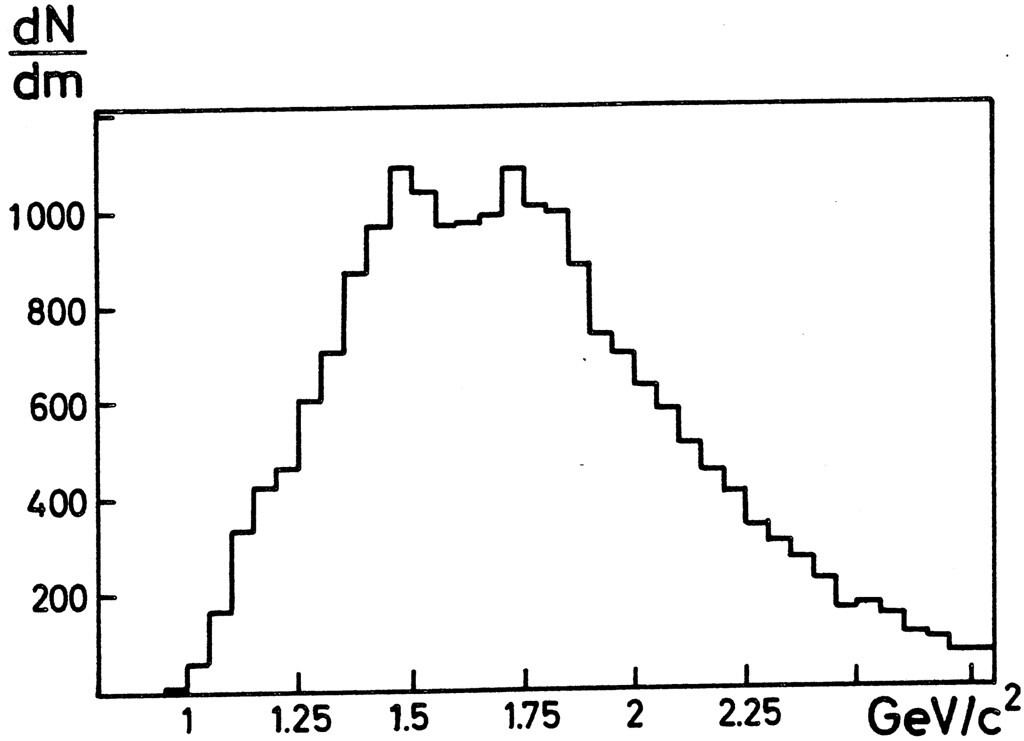

FIG.2

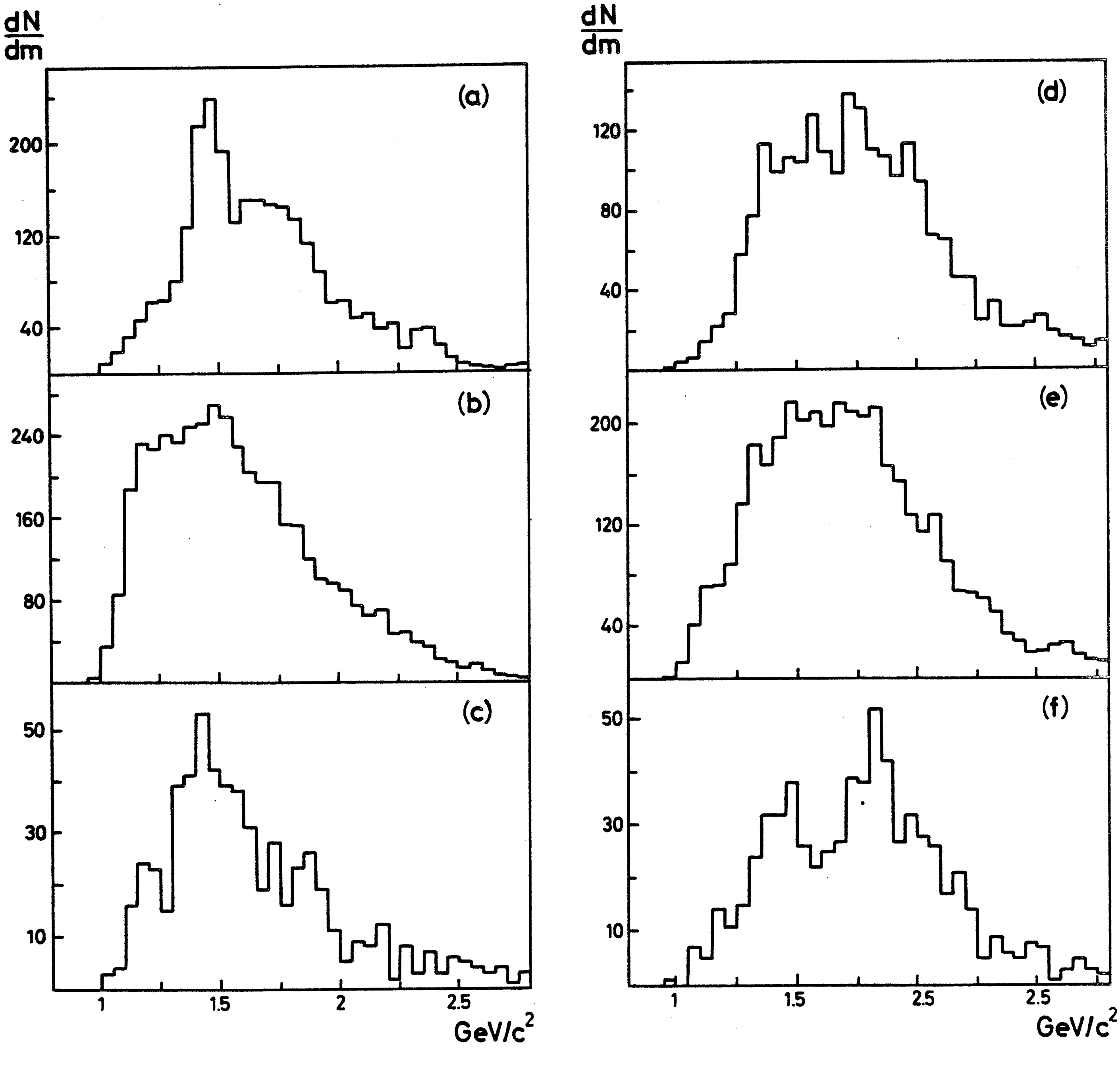
dN/dm
(a)
200
120
40
(b)
240
160
80
(c)
50
30
10
1
1.5
2
2.5
GeV/c²
dN/dm
(d)
120
80
40
(e)
200
120
40
(f)
50
30
10
1
1.5
2.5
2.5
GeV/c²

FIG.3

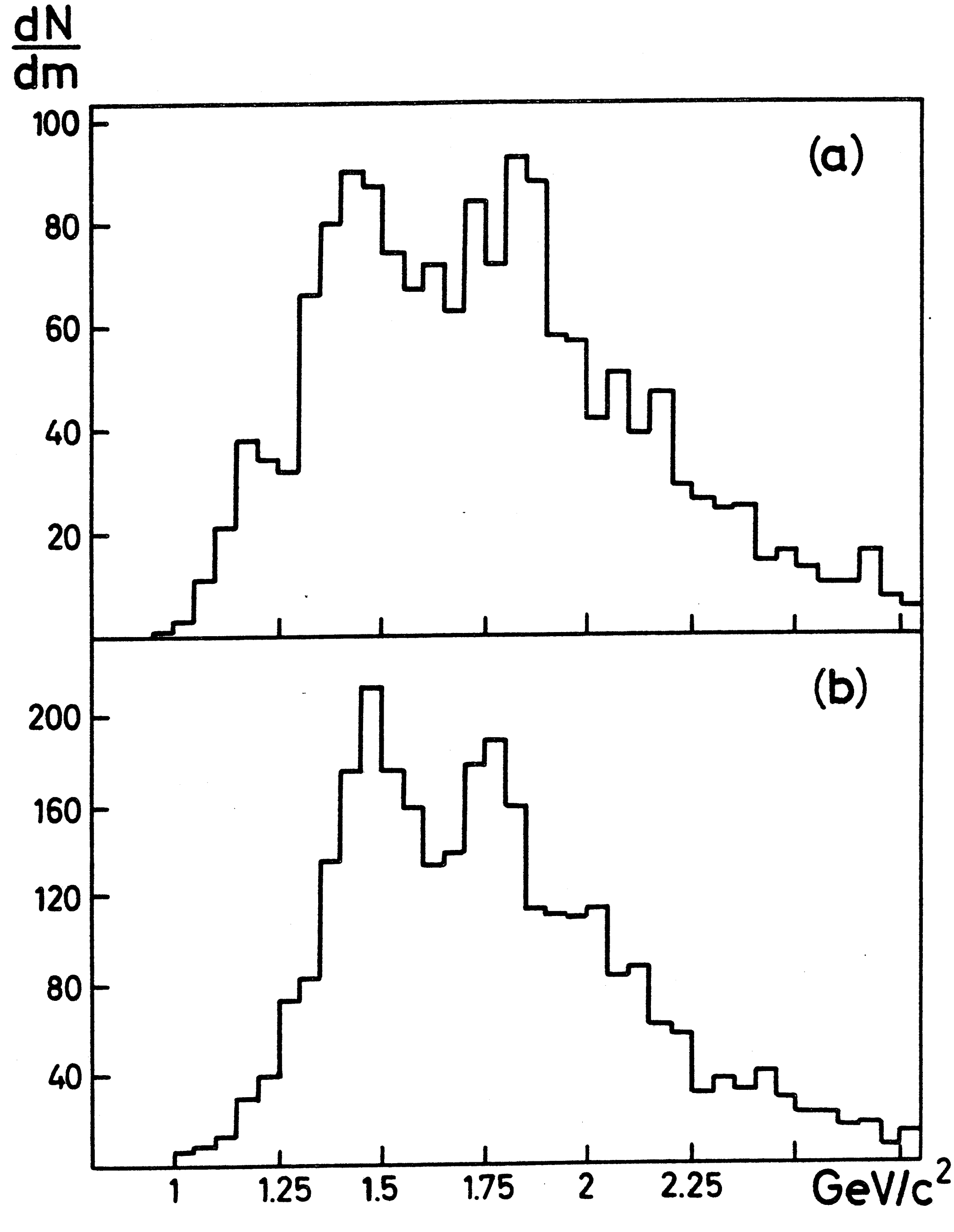

FIG.4

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