UNIVERSITY OF OSLO

NOTE ON POSSIBLE GLUEBALL PRODUCTION IN $\bar{p}\,^{4}He$ REACTIONS AT 0.6 GeV/c INCIDENT MOMENTUM

CERN - PROJECT PS - 179 LEAR

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

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Abstract

The invariant mass distribution of six-particle systems in the final states of $\bar{p}\,^4He$ - reactions at 0.6 GeV/c incident momentum shows two narrow peaks at about 1500 and 1850 MeV/c^2 which may be due to the production of glueballs.

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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). Several authors have discussed glueballs from a theoretical point of view (ref.5).
On the other hand, it ought 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 ? We have searched for glueballs in the reaction

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

at 0.6 GeV/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 (ref.8) suggested a glueball at about 1150 MeV/c^2 with small width and spin-parity = 0^+ or 2^+. The experimental procedure has been described elsewhere (ref.7). In this note we discuss the possibility of glueball production in the reaction

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

seen in the same experiment, according to the diagram shown in Fig.1.

2. Some Experimental Details.

A multiparticle final state of a $\bar{p} + {}^{4}He$ - 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.

The total number of events with at least three negative and four positive particles in the final state is 87. Since for annihilation events, the ratio K-events / π -events $\approx$ 5/100, we expect less than 10 events with strange particles.
Thus, we neglect the presence of the kaons in this context.
Only momentum and charge but not the mass of a final state particle is found by the measurements. Therefore, we discuss our distributions in terms of protons and pions.

3. Experimental Results.

We show in Fig.2a the distribution of invariant mass of the assumed six-pion system. A peak at about 1500 MeV/c^2 and a shoulder at about 1850 MeV/c^2 are seen. The peak is about 5 standard deviations above a handdrawn background. The observed width of the peak is about 100 MeV/c^2.

For the invariant mass M of the assumed six-pion system we define the regions

A) $1450\ MeV/c^2 < M < 1550\ MeV/c^2$,
B) $1800\ MeV/c^2 < M < 1900\ MeV/c^2$.

We show in Figs.3a and b scatter plots of p versus cos θ, where θ is the angle in the labbratory system between the momentum p of the six-pions system and the momentum of the incident antiproton, for the two regions A and B, respectively.

A strong enhancement is seen for cos $\theta > 0.85$ and $p > 400$ MeV/c , i.e. in the direction of the incident antiproton, and for large momenta. Therefore, if these systems are baryons, it implies double baryon exchange to the beam vertex, which is unlikely, unless B=1 "fireballs" are produced (ref.6). This result supports the assumption that the six-particle system is due to the decay of a boson.

In Fig.2b we also show the invariant mass of the assumed six-pion system when cos $\theta > 0.60$. As can be seen, the signal to background ratio has increased in the peak region, and the 1850 MeV/c^2 region now shows a peak. It is also seen that the widths are small.

As an additional test on the possibility of double baryon exchange to the beam vertex with production of some baryon resonances, we show in Fig.4 the invariant mass distribution of the six-particle system when one of the three positive particles is taken to be a proton, for all the three positive particles in the system. Two possible peaks at about 2300 and 2600 MeV/c^2 are seen which may suggest the production of some baryon resonance decaying to a proton and five pions.

4. Discussion.

The experimental resolution in our experiment is found by means of the Monte Carlo program FOWL (ref.9). We generate six-pion states with invariant mass = 1500 MeV/c^2 and zero

width. The momenta of the six pions are distorted in accordance with the uncertainties in our measurements.
We calculate the invariant mass of the six-pion systems with distorted momenta. While the initial distribution has a width = 0, the distribution of the distorted events has a width about 150 MeV/c^2, which is an estimate of the resolution in our experiment. Hence, the widths of the peaks at about 1500 and 1850 MeV/c^2 seen in Fig.2b could be mainly due to the experimental resolution, and the true widths may therefore be very small.

We have by means of the phase space program FOWL Monte Carlo generated the final states $\pi\pi\pi\pi\pi\pi$ T, $\pi\pi\pi\pi\pi\pi$ D N, and $\pi\pi\pi\pi\pi\pi$ N N N, respectively, for antiproton-^{4}He reactions at 0.6 GeV/c incident momentum. (T=Triton, D= Deuteron, and N=Nucleon).
The invariant mass distribution of the 6 π -systems in these three Monte Carlo generated final states are much broader than the widths of the peaks at about 1500 and 1850 MeV/c^2. Hence, the observed peaks are not simple phase space effects.

Because neither the Δ (1232) nor the ρ(770) are seen in our data, these resonances can not be responsible for the observed peaks (ref.8).

A high mass baryon resonance situated on a Regge-trajectory would be expected to have a correspondingly high spin. Since the Δ (1232) is not seen in these data, it seems unlikely that much heavier baryon resonances with much higher spins than the Δ (1232) are produced.
Even if such decay modes have not been observed previously (ref.10), the possible peaks in Fig.4 could be due to previously unknown baryon resonances.

Two meson resonances are possibly seen in the distribution of the assumed six-pion systems, and two baryon resonances are possibly seen in the distribution of the assumed proton + five pion systems. Because we can not find the identity of the final state particles, a proton may by mistake be taken to be a pion. If so, the true peaks could be the baryon peaks, which by wrong identification show two peaks in the distribution of invariant mass of the assumed six pion systems.

In order to investigate this possibility, we have generated $\bar{p}\,^4$He - reactions with three nucleons and six pions in the final state, where a proton and five pions make a baryon resonance at 2300 MeV/c^2 with a width 150 MeV/c^2 by means of the Monte Carlo program FOWL.
We have recalculated the position and width when the proton is replaced by a pion. The six-pion system generated in this way has a position at 1750 MeV/c^2 and a width about 350 MeV/c^2 which is much larger than the true width of the assumed six-pion system.

Hence, the observed widths of the 1500 and 1850 MeV/c^2 peaks are much too small to be reflections of some baryon resonances at 2300 and 2600 MeV/c^2 with widths about 150 MeV/c^2.

If the two peaks were due to two meson resonances situated on Regge-trajectories, then they would also be expected to have much larger widths than the widths of the peaks seen in Fig.2b, when the experimental resolution is taken into account. Therefore, the peaks seen in Fig.2b do not correspond to normal mesons on Regge trajectories (ref.10). We also mention that it is surprising that no ρ(770) is seen, if the 1500 and 1850 MeV/c^2 peaks are normal mesons.

Hence, the six-pion peaks are probably due to boson systems which may not easily be produced in antiproton + proton reactions. Final states where all antiquarks are annihilated are, however, more accessible with nucleus target than with proton target. This is probably the reason why the peaks seen in our experiment have not been seen in any antiproton-proton experiment (ref.10).

If all the three incident antiquarks are annihilated as depicted on the diagram shown in Fig.1, then the three gluons produced may possibly form a glueball with a small width (ref.11). The peaks observed in our experiment could possibly correspond to the two 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).

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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 target ^{4}He-nucleus, producing a glueball which decays to six pions.

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

a) for all entries,
b) for cos θ > 0.6,

where θ is defined in the text.

Fig.3
A scatter plot of p(lab) versus cos θ (lab) for the six-particle systems with mass M in

a) for the region A of M ,
b) for the region B of M ,

where A, B and θ are defined in the text.

Fig.4
The distribution of the invariant mass of the six-particle systems assumed to be systems of one proton and five pions.

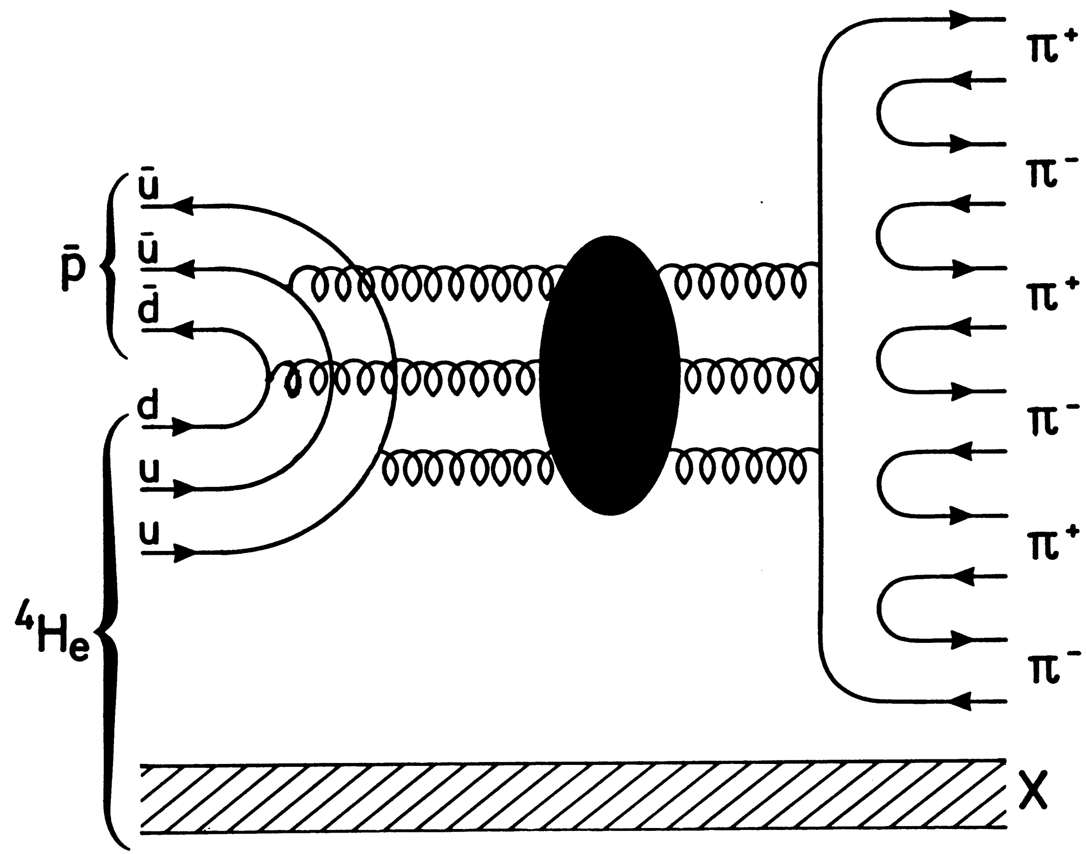

FIG.1

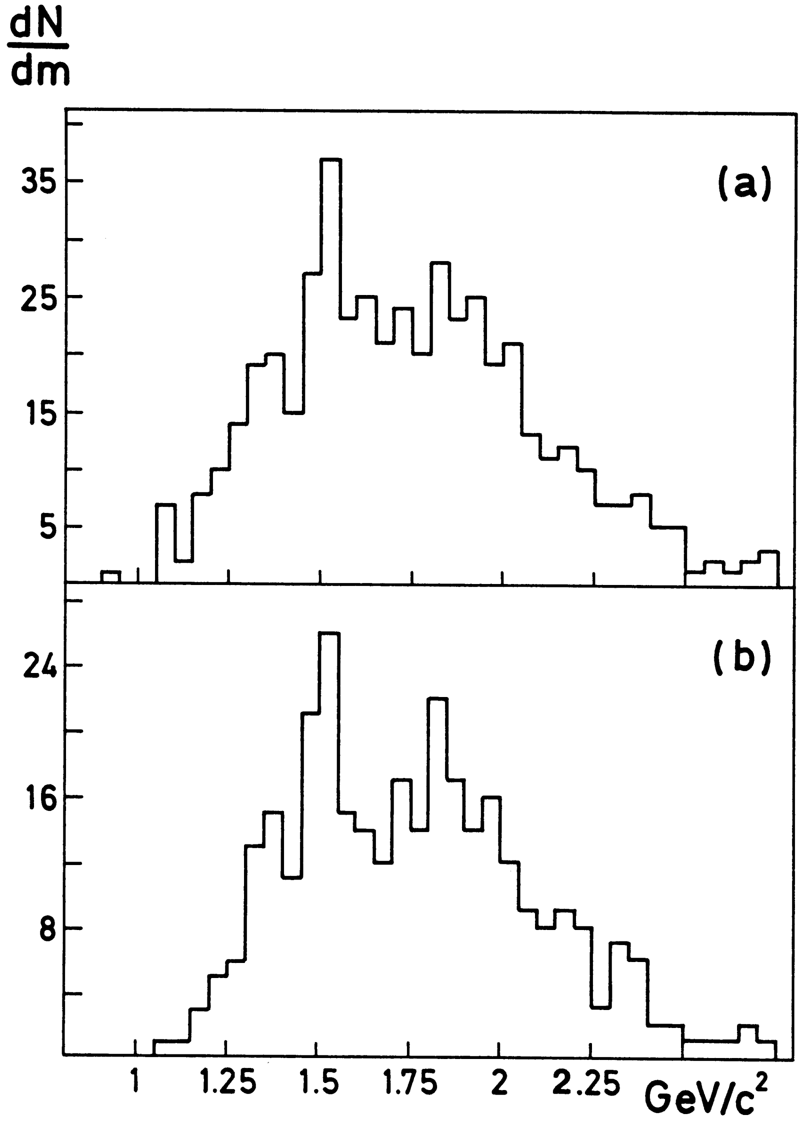

FIG.2

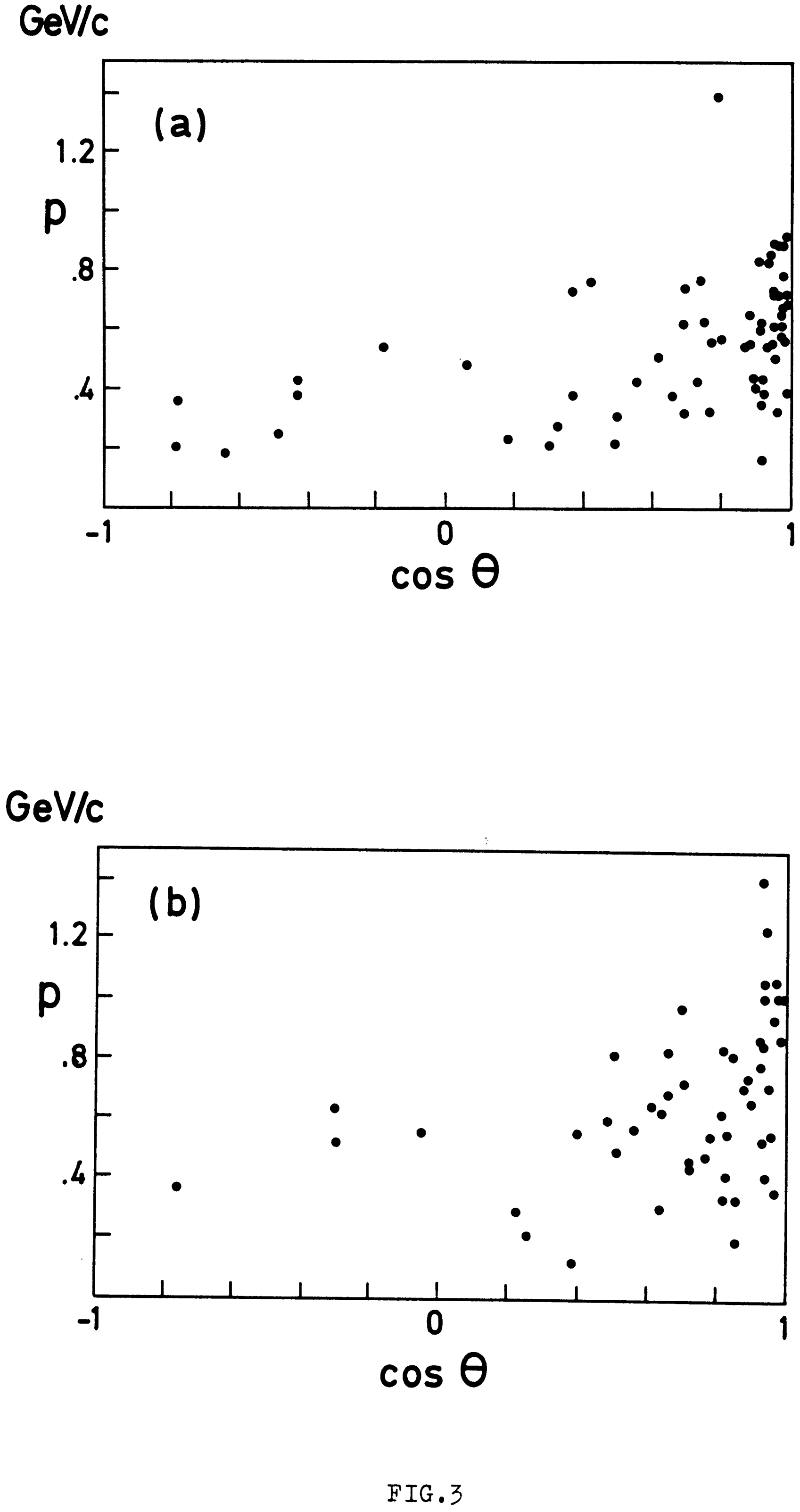

FIG.3

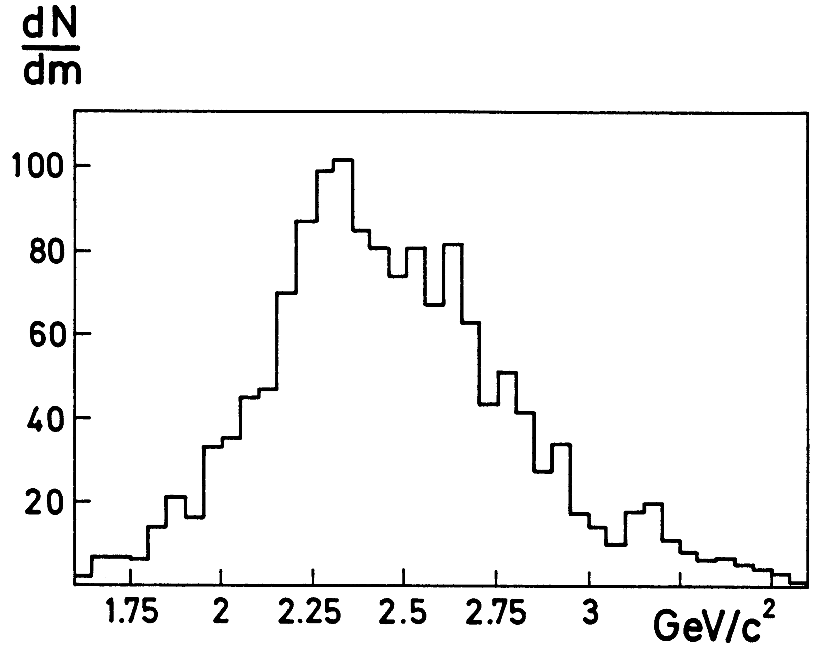

FIG.4

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