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POSSIBLE PRODUCTION OF GLUEBALLS 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

A fairly sharp peak at 1150 MeV/c^2 in the $\pi^-\pi^+\pi^-\pi^+$ - system in the final state of $\bar{p}$ He - reactions at 0.6 GeV/c incident momentum is seen. The four-pion system may have spin = 0 or 2, which are possible spins of a glueball.

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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 (Fritzsch and Gell-Mann, ref.1). Glueballs have however not been observed in elementary particle reactions.

On the other hand, it has not been investigated if glueballs may be produced by annihilation of antiprotons in nuclear matter. Could possibly a B = 0 "fireball" (Cugnon and Vandermeulen, ref.2) occasionally be a glueball ?
Our intention is now to search for glueballs in the reaction

$$\bar{p} + {}^{4}He \rightarrow \pi^{-}_{1} \pi^{-}_{2} \pi^{+}_{1} \pi^{+}_{2} + X \qquad (1)$$

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.
The experimental procedure has been described elsewhere (Balestra et.al.,ref.3).

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 two negative particles are seen in the final state, at least one of them must be a meson. If this meson is a kaon, then the reaction is due to annihilation because of energy conservation. If the meson is a pion, then the reaction is probably due to annihilation.

The total number of events of with at least two negative particles in the final state is 1351.

For annihilation events, the ratio π/K is about 5/100. Hence, charged kaons are not important for the following discussion.

The momentum and the charge but not the mass of a final state particle is found by the measurements. Therefore, we have to discuss our distributions in terms of protons and positive pions.

Also, leading pions (Balestra F. et.al. ref.4) are excluded. A leading pion has direction less than 17 degrees from the direction of the incident antiproton.

3. Angular distribution.

If two two-pion systems which each has a spin = 1, have parallell or antiparallell spins, then the four-pion system could have spin 2 or 0, which are possible spin states of glueballs.

A two-particle system may have an angular momentum = 1 if the plane defined by the momenta of the two particles has some preferred orientation in space. We therefore investigate the relative orientation of two two-particle planes. If at least one of them has undefined or zero angular momentum, no angular correlation between the two planes is expected.

We show in Fig.1 the distribution of $\cos\theta$, where θ is the angle between the vectors

$$\bar{u} = \bar{p}(\pi^-_i) \times \bar{p}(\pi^+_j) \tag{2}$$

$$\bar{v} = \bar{p}(\pi^-_k) \times \bar{p}(\pi^+_l) \tag{3}$$

where $i \neq k$ and $j \neq l$, and $\bar{p}(\pi)$ is the momentum of a pion. The distribution has an enhancement near $\cos\theta = -1$. Therefore, the vectors which are normal to the (i,j)-plane and the (k,l)-plane teno to be anti-parallell for some events. Hence, these events seem to have two two-particle systems with parallell or antiparallell angular momenta >0, If both angular momenta were = 1, then the total angular momentum = 2 or 0. If the particles are all pions, then the total system has a spin = 2 or 0.

We mention that an event may have one "signal" entry but several "background" entries. Thus, the signal to back - ground ratio may be small even if several events may have a genuine signal.

4. Invariant Mass Distributions.

We define these regions in Fig.1

a) $-1.0 < \cos\theta < -0.8$
b) $-0.5 < \cos\theta < +0.5$
c) $+0.8 < \cos\theta < +1.0$.

For the regions a, b, and c, we show in Figs.2a, b, and c, respectively, the invariant mass distributions of the four-particle system, assuming that all particles are pions. While Fig.2b shows a phase space like distribution, Figs.2a

and c have in addition to the phase space like distribution resonance-like peaks at about 1150 MeV. The peaks are thus at the same position for the regions a and c. We add the distributions in Figs.2a and c, and the resultant distribution is shown in Fig.2d. The number of entries above a handdrawn background curve represents an about 9 standard deviations effect.
In order to estimate the width of the 1150 MeV peak, we subtract from the distribution in Fig.2d the distribution in Fig.2b normalized to the interval 950-1050 MeV of Fig.2d. The resultant distribution is shown in Fig.2e.
Obviously, the width of the 1150 MeV peak is about 150 MeV. An additional possible peak is however seen in the region 800-900 MeV. A high statistics experiment is needed to study this peak and the shoulders seen in Fig.2d.

The invariant mass distributions of the two-particle systems assumed to be pions shown in Fig.3a-c have no peak or enhancement corresponding to any known meson resonance.

For the regions a, b, and c, we show in Figs.4a, b, and c, respectively, the invariant mass distribution of the four-particle system, assuming one of the positive particles to be a proton. Significant peaks or enhancements are not seen.

The invariant mass distribution of the two-particle systems assumed to be proton + π^- shown in Fig.5a-c has no significant peak or enhancement.

5. Multiplicities.

The average multiplicities of charged particles in the final states for the events in the groups a, b, and c, are shown in the Table I when the mass m of the four-pion system is

A) $560\ \mathrm{MeV}/c^2 < m$; B) $1100\ \mathrm{MeV}/c^2 < m < 1200\ \mathrm{MeV}/c^2$

Table I

	A	B
a	5.78 ± 0.05 (2.43 ± 0.03)	6.07 ± 0.11 (2.53 ± 0.05)
b	5.45 ± 0.03 (2.32 ± 0.02)	5.86 ± 0.06 (2.50 ± 0.04)
c	5.82 ± 0.05 (2.45 ± 0.03)	6.37 ± 0.10 (2.68 ± 0.06)

(in parenthesis the average number of negative particles).

As can be seen from this table, the multiplicies are significantly larger in the regions a and c than in b, and significantly larger inside the peak-region than for all events.

Hence, some of the events with parallell or antiparallell angular momenta have an on the average larger number of charged particles in the final state than the total average. This is also true for events in the peak-region 1100 - 1200 MeV, which therefore are "special" events.

Vice versa, when events with less than three negative particles are discarded, then the 1150 MeV peak seems more clear, but with less significance.

6. Discussion.

Because neither the P-wave $p + \pi^-$ resonance $\Delta^0(1232)$ nor the P-wave $\pi^+ + \pi^-$ resonance $\rho^0(765)$ are seen in our data, these resonances can not be responsible for the observed angular correlation.

A four-pion system with a spin 0 or 2 and with a small width does not correspond to any known meson resonance (Review of Particle Properties,ref.5). Therefore, the four-pion peak may possibly be a resonance which may not easily be produced in pure elementary particle reactions.

Furthermore, if the observed peak at 1150 MeV corresponded to a meson resonance situated on a Regge-trajectory, a fairly large width would be expected.
Our result is however compatible with a fairly small width. Hence, if the peak does not correspond to a "normal" meson, then it could possibly be due to glueball production by antiproton annihilation in nuclear matter.

One theoretical calculation (Cornwall and Soni, ref.6) fits our 1150 MeV peak very well, namely their gg - state

$$0^{++} \ (\approx 1100 \ \mathrm{MeV/c^2}).$$

References

1) Fritzsch H. and Gell-Mann M., Proc. 16th Int.Conf. on High-Energy Physics,vol.2(Chicago 1972).

2) Cugnon J. and Vandermeulen J.,Phys.RevC36(1987)2726, and references therein.

3) Balestra F. et.al.,Nucl.Phys.A474(1987)651.
Balestra F. et.al, Il Nuovo Cimento 100A(1988)323.

4) Balestra F. et.al., University of Oslo, Inst.of Phys. Report 90-11.

5) Review of Particle Properties, Phys.Lett.B,204(1988) 1-486.

6) Cornwall J.M. and Soni A.,Phys.Lett.120B(1983)431.

Figure Captions

Fig.1
The distribution of cos θ, where the angle θ is the angle between the normals to the two planes described in the text.

Fig.2a-e.
The invariant mass of the four-particle system assuming that all particles are pions, a-e described in the text.

Fig.3a-c
The invariant mass distribution of the assumed $\pi^+\pi^-$ - systems, a-c described in the text.

Fig.4a-c.
The invariant mass of the four-particle system assuming that one positive particle is a proton, two entries per combination, a-c described in the text.

Fig.5a-c
The invariant mass distribution of the assumed $p\bar{\pi}$ - systems, a-c described in the text.

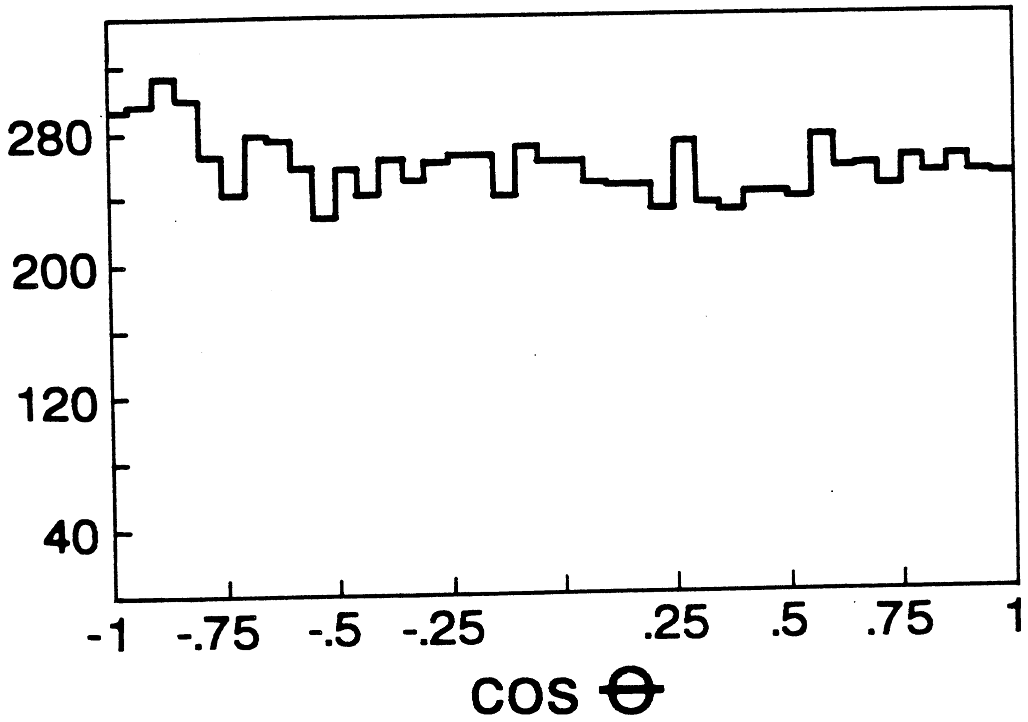
280
200
120
40
-1
-.75
-.5
-.25
.25
.5
.75
1
cos θ

FIG.1

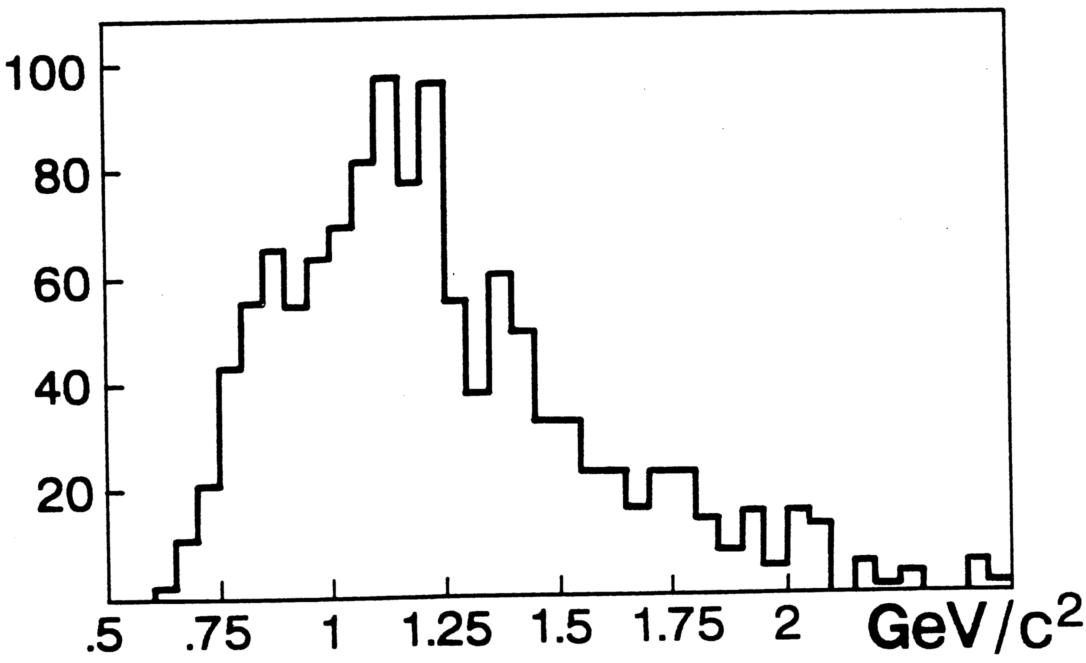
100
80
60
40
20
.5
.75
1
1.25
1.5
1.75
2
GeV/c²

FIG.2a

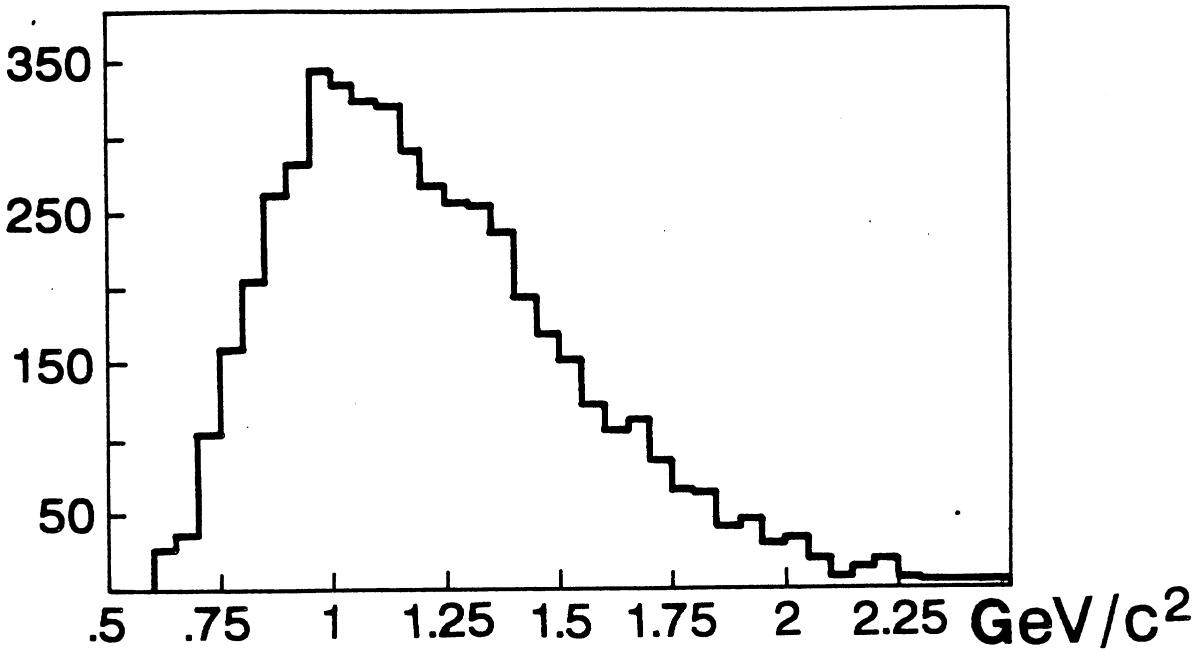
350
250
150
50
.5
.75
1
1.25
1.5
1.75
2
2.25
GeV/c²

FIG.2b

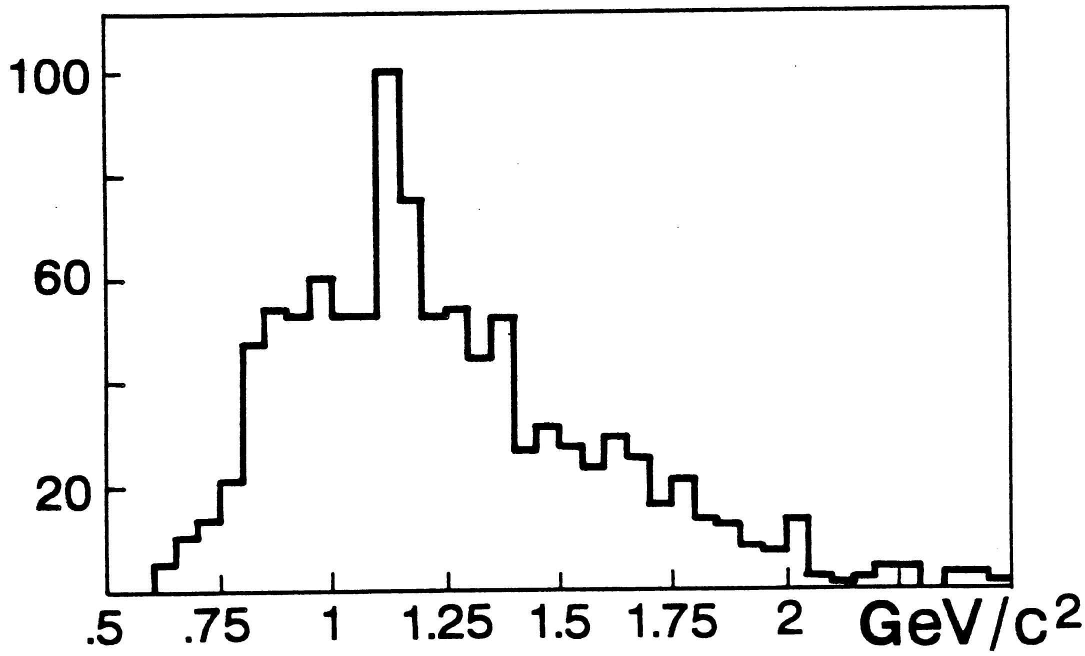
100
60
20
.5
.75
1
1.25
1.5
1.75
2
GeV/c²

FIG.2c

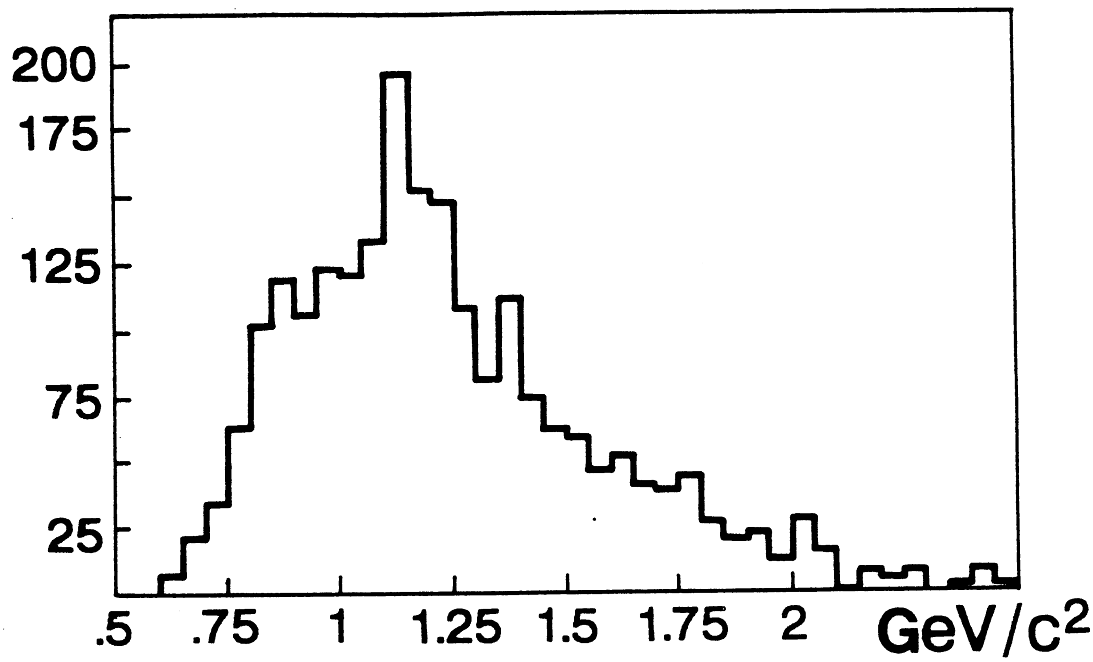
200
175
125
75
25
.5
.75
1
1.25
1.5
1.75
2
GeV/c2

FIG.2d

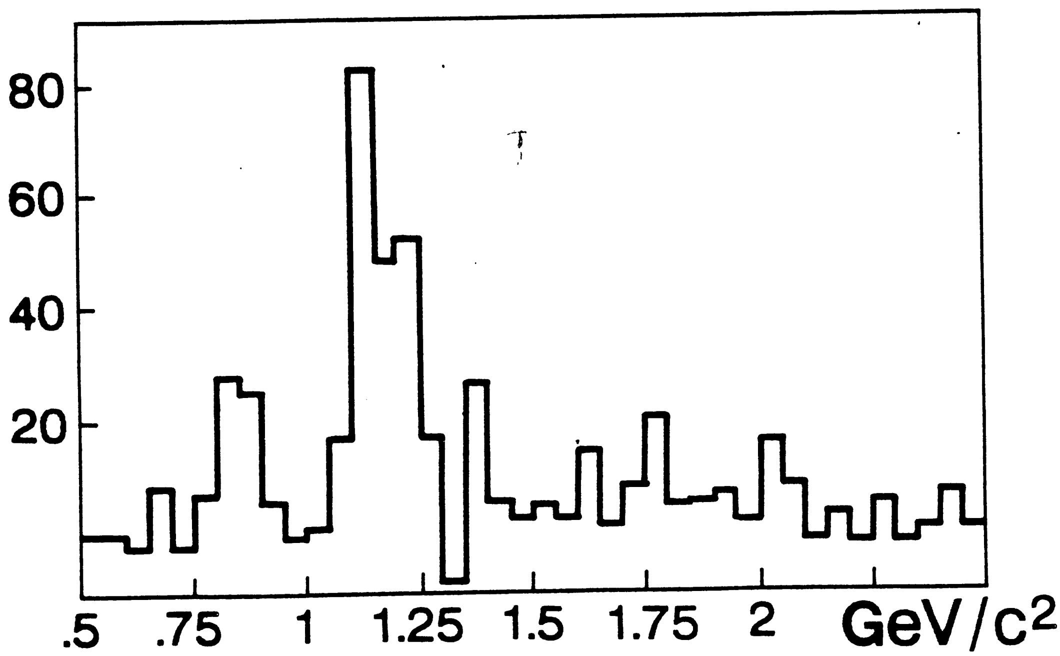
80
60
40
20
.5
.75
1
1.25
1.5
1.75
2
GeV/c2

FIG.2e

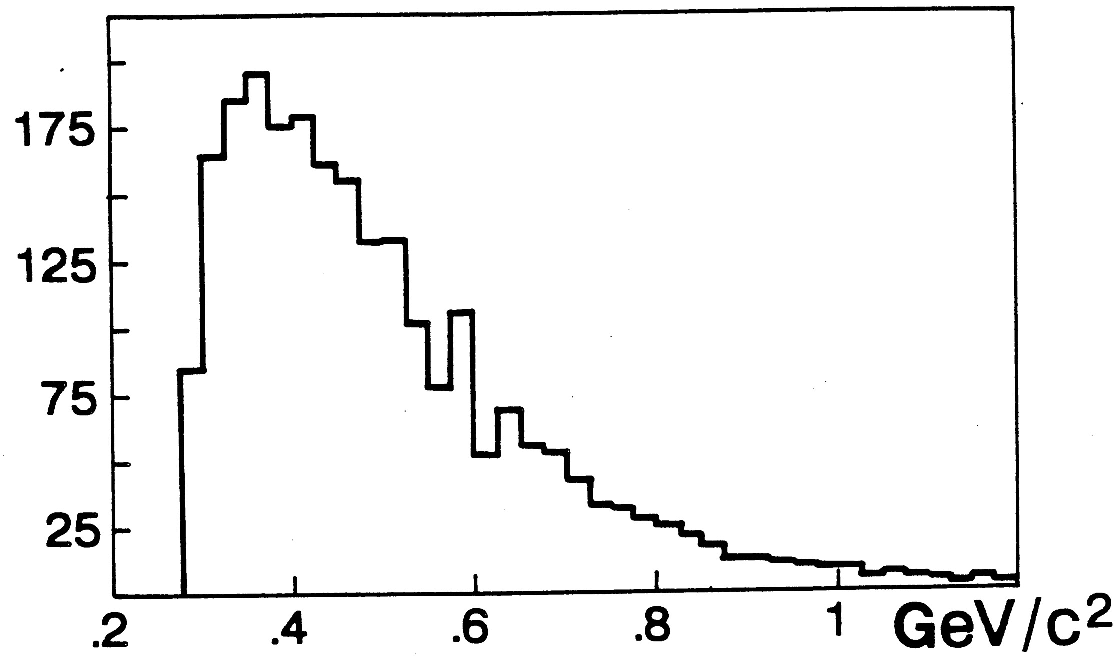

FIG.3a

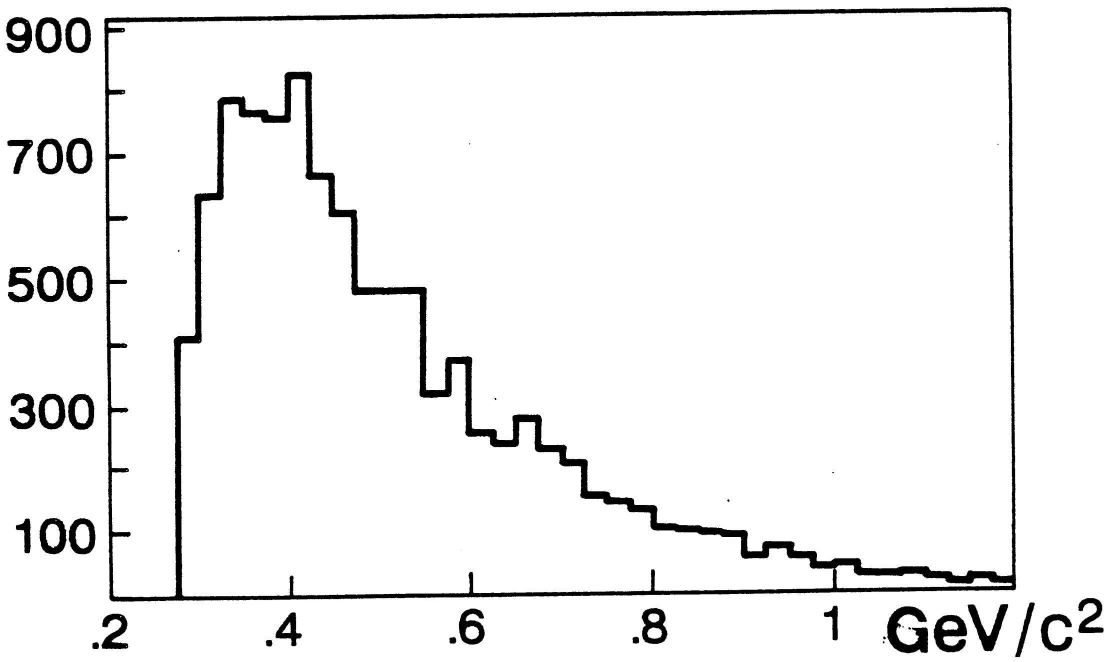

FIG.3b

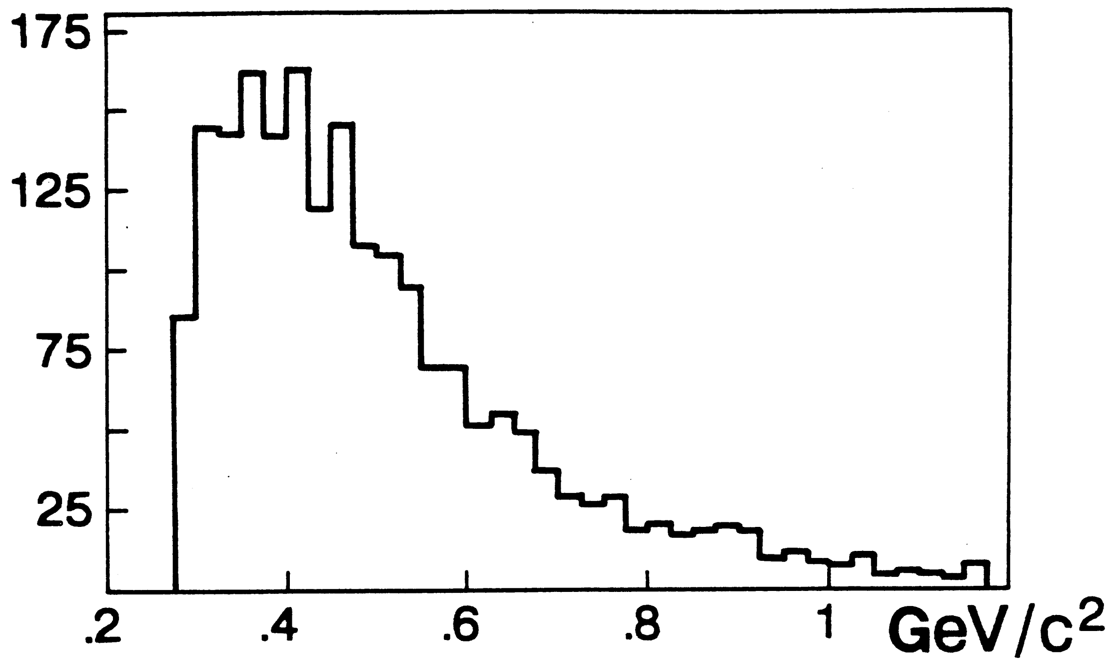

FIG.3c

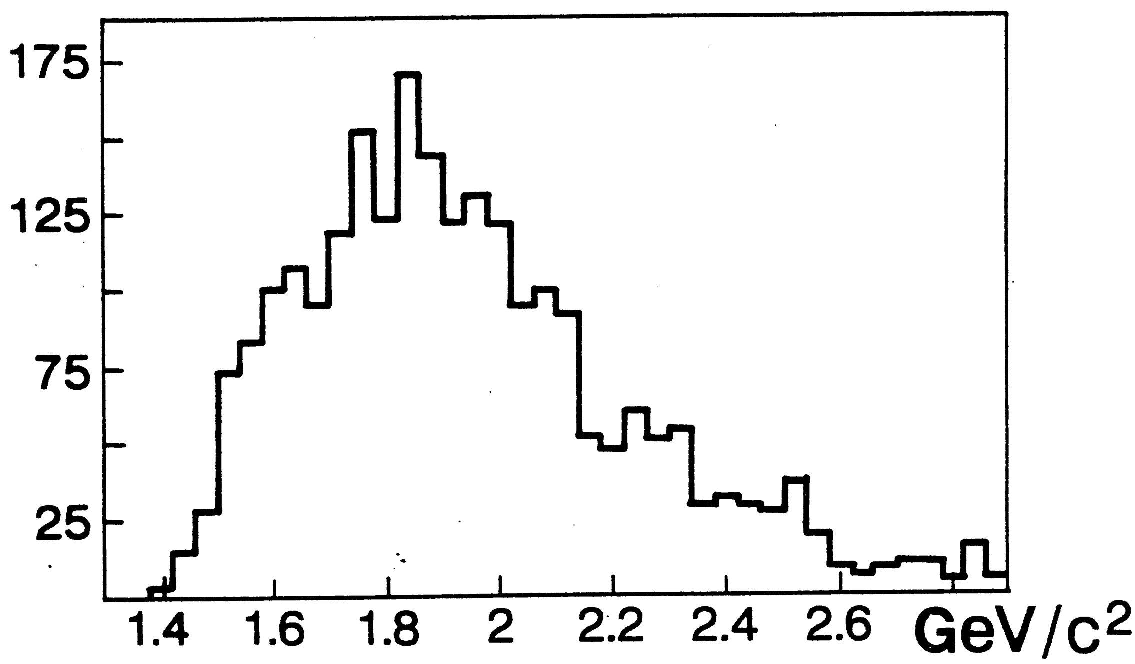

FIG.4a

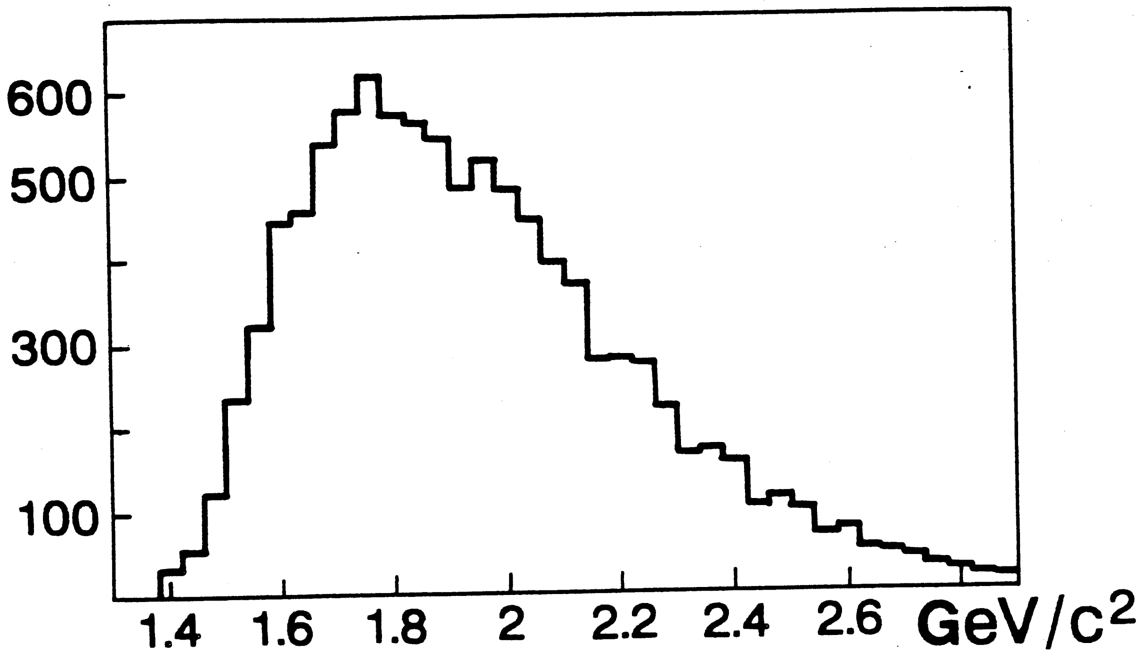
600
500
300
100
1.4
1.6
1.8
2
2.2
2.4
2.6
GeV/c2

FIG.4b

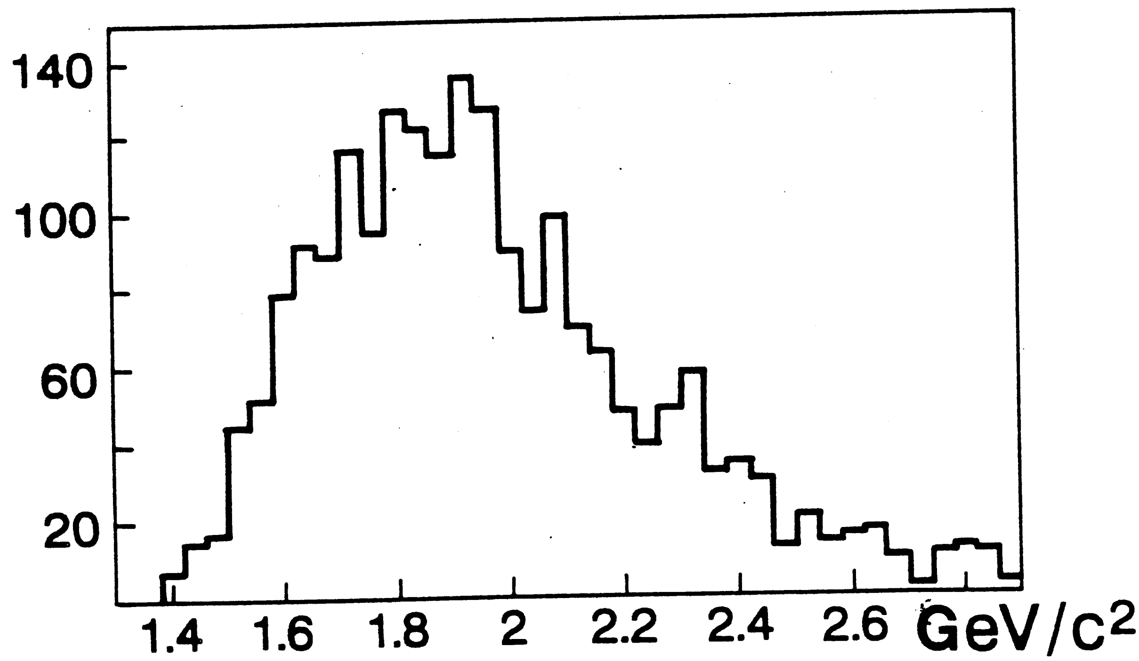
140
100
60
20
1.4
1.6
1.8
2
2.2
2.4
2.6
GeV/c2

FIG.4c

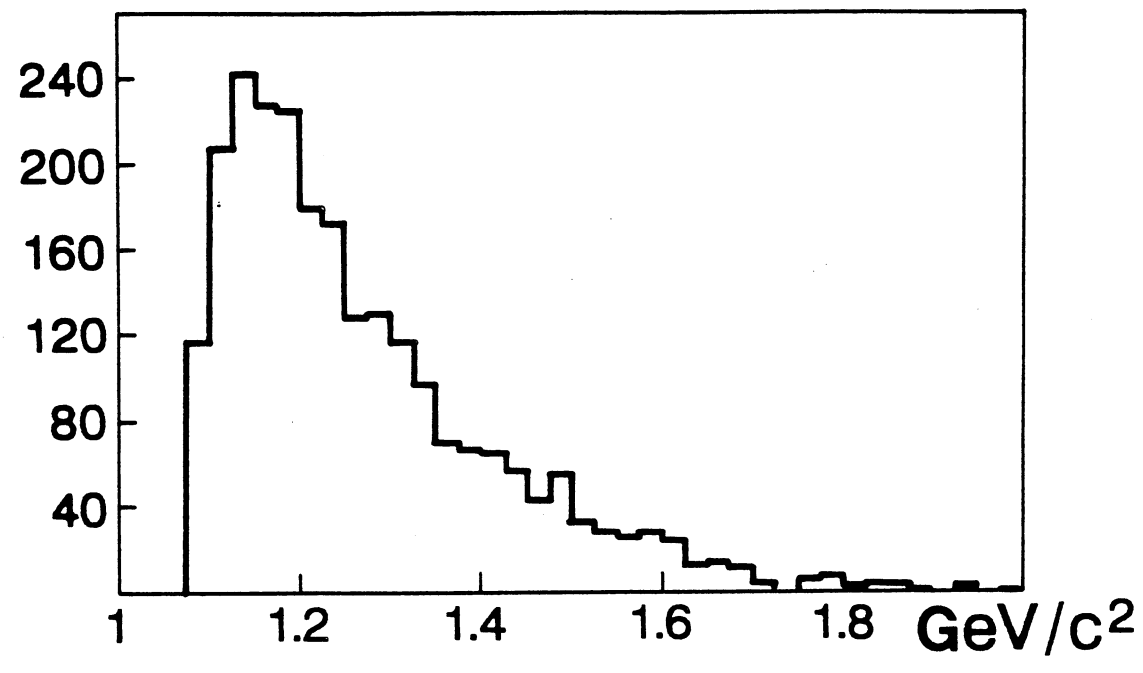
240
200
160
120
80
40
1
1.2
1.4
1.6
1.8
GeV/c2

FIG.5a

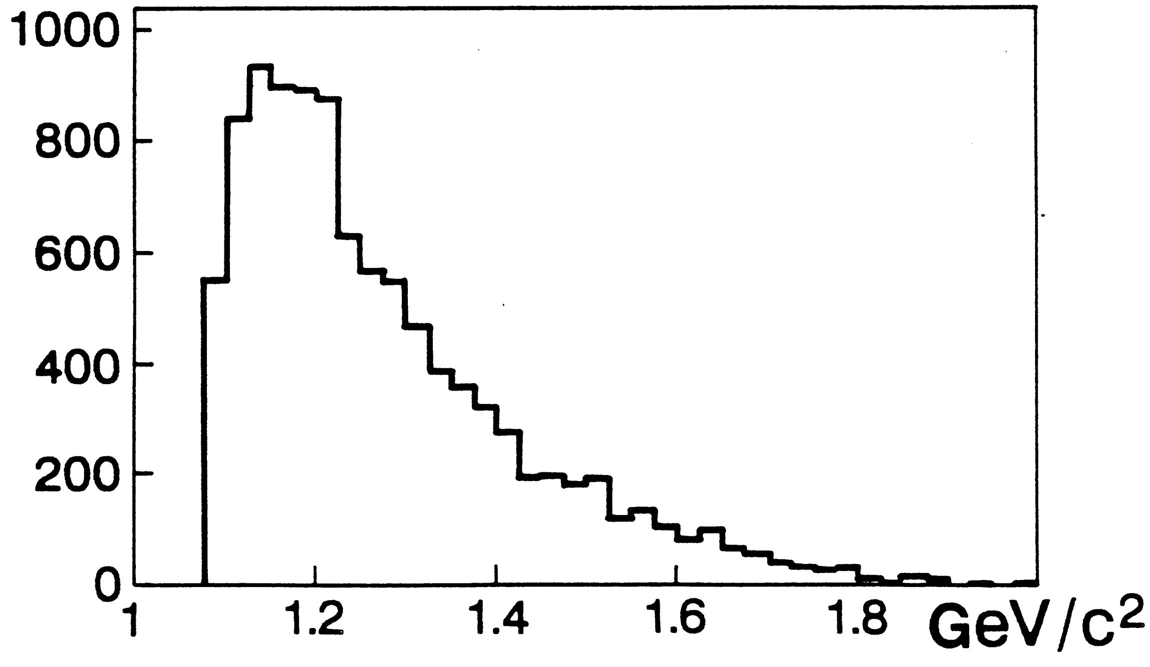
1000
800
600
400
200
0
1
1.2
1.4
1.6
1.8
GeV/c2

FIG.5b

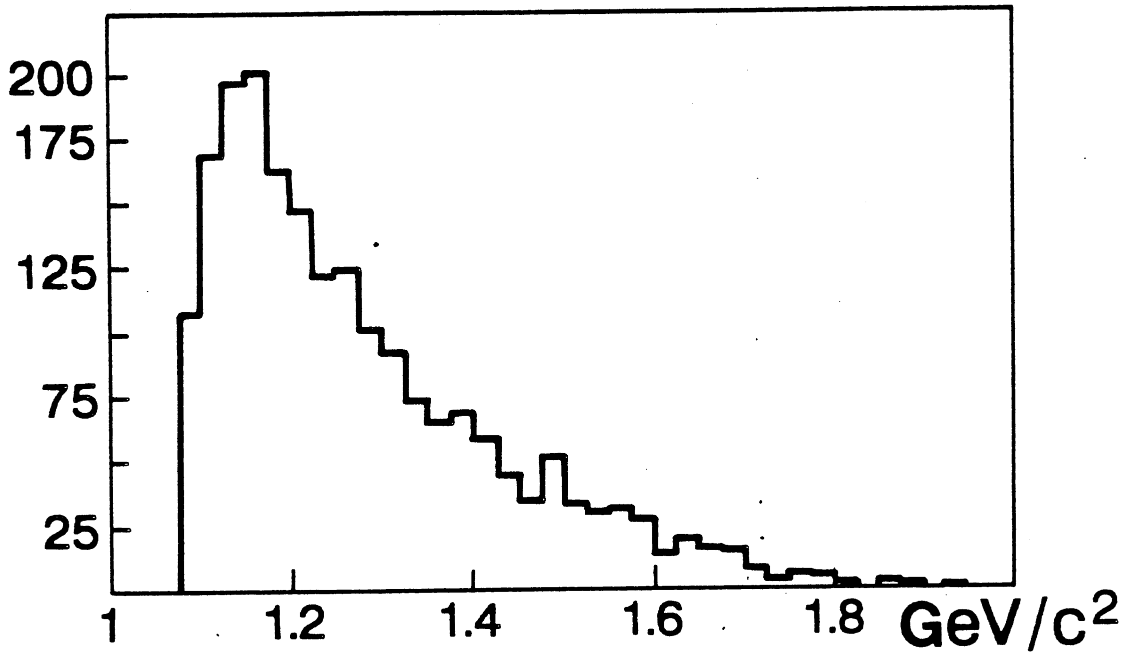

FIG.5c