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B.A.Shahbazian

SEARCH FOR MULTIQUARK RESONANT STATES OF HYPERCHARGE Y > 1

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The results on search for multiquark resonant states of hypercharge Y > 1 are presented below. The pictures from the JINR propane bubble chamber exposed to beams of neutrons of $\langle p_n \rangle$ = 7.0 GeV/c and of negative pions of p_{π^-} = 4.0 GeV/c were used. In the neutron experiment the statistics amounts to 3462 events with one Λ^0-hyperon and Λ^0 and K^0 pairs as well as 1835 events with at least one neutral kaon. In the pion experiment we have 1113 and 493 similar Λ and K events. Besides, in all 57 $\Lambda\Lambda$ pairs and more than 16000 events without V^0-particles have been also collected in both experiments.

Dinucleon systems : pp(I=1, Y=2, B=2, S=0) and np(I=0, Y=2, B=2, S=0)

The invariant mass spectra of the pp systems from $n^{12}C \rightarrow$ ppX and $n^{12}C \rightarrow$ (mp)X interactions for m = 2,3,4,5,6 at $\langle p_n \rangle$ = 7.0 GeV/c are shown in figs. I-5. The diminution of the histogram bins from 5 to 1 MeV/c^2 did not favour the revealing of statistically significant narrow resonance-like enhancements (figs. I-3).

No enhancements have been also observed in the diproton mass spectra made up of events with (i) both protons emitted in the backward hemisphere, (ii) both protons emitted in the forward hemisphere, and (iii) protons emitted in different hemispheres (figs. 2-5). These results have been confirmed in the following experiments shortly reviewed below.

1. The JINR 100cm hydrogen bubble chamber (HBC100) was exposed to a secondary deutron beam with a total momentum of 3.3 GeV/c /I/. The exclusive pp invariant mass spectrum from the dp $\rightarrow$ ppn reaction channel is shown in the upper half of fig. 6. The lower mass peak is due to final states with protons of small relative momenta. These protons both are fast in the laboratory system, where there is also a slow neutron. Thus, the low mass peak is formed of n $\rightarrow$ p charge exchange. On the contrary, the higher mass peak is formed of events with protons of large relative momenta. Therefore this peak is due to elastic pp scattering. The position of its maximum $M_{pp} \sim$ 2300 MeV/c^2 corresponds to the c.m. total energy of the colliding protons.

The lower mass peak in the np invariant mass spectrum (the lower half of fig. 6) is due to events with fast neutrons and protons in the laboratory system (small relative momenta). Thus, these events are due to elastic pp, np scattering and to p $\rightarrow$ n charge exchange events (there is a slow proton in the laboratory system).

The pp invariant mass spectra from the dp $\rightarrow$ ppnπ^0 reaction channels, when the final states contain 1) either only a slow neutron or 2) either a slow neutron or a slow proton in the laboratory system, are shown in the upper and lower parts of fig. 7, respectively.

Thus, from the analysis of figs. 6-7 it follows that in this experiment the pp and np invariant mass spectra do not reveal dinucleon resonances though the momentum per nucleon of the incident deutron is favourable to the resonant excitation of the I=1, J^P=3$^-$, M=2260 MeV/c^2 state claimed in /2/.

2. The HBC100 was exposed to a 5.1 GeV/c monoenergetic neutron beam /3/ . The pp and np invariant mass spectra from the exclusive reaction channels

$$np \longrightarrow pp\pi^+\pi^-\pi^- \quad (1764 \text{ events})$$
$$pp\pi^+\pi^-\pi^-\pi^0 \quad (1149 \text{ events})$$
$$np\pi^+\pi^+\pi^-\pi^- \quad (1249 \text{ events})$$

were studied. No statistically significant resonance-like enhancements were observed.

3. The nn, np and pp invariant mass spectra from the reactions tp$\longrightarrow$ ppnn at 2.5 GeV/c and ^{3}Hep$\longrightarrow$ pppn at 5.0 GeV/c were studied using the ITEP HBC80/4/. No enhancements, which could be ascribed to dinucleon resonance production, were observed.

4. The pp effective mass spectra from the reactions $\pi^- A \longrightarrow (mp)X$, m=2, ..., A=Al, Cu, Pb at p_{π^-} = 3.7 GeV/c were studied using the 1.5m ITEP spark chamber spectrometer /5/ . No indications of the existence of diproton resonances were found.

5. One more experiment devoted to the search for dinucleon resonances has been performed by means of the counter technique in Kharkov /6/. This time the asymmetry coefficient $\Sigma(E_\gamma,\theta)=\frac{\sigma_\perp-\sigma_\parallel}{\sigma_\perp+\sigma_\parallel}$ of the reaction $\gamma d \longrightarrow np$ provocated by a linearly polarized photon beam of E_γ = 80-600 MeV has been measured at c.m.s. proton emission angles of θ = 75°, 90°, 105°, 120°, 135° and 150°. The results of this experiment, the most complete one among those which are analogous and agree with it, are in irreconcilable contradiction with the predictions of several theoretical models. The incorporation in the model of combinations of the presumed dinucleon resonances (I=1, $J^P=3^-$(2260))+(I=0, $J^P=3^+$(2380)) and (I=1, $J^P=3^-$(2260))+(I=0, $J^P=1^+$(2380)) even somewhat increases the discrepancy.

In conclusion of this paragraph let us note that the negative result in the search for dinucleon resonances first obtained at JINR /7-II/ is now confirmed in five experiments performed using different experimental technique.

Three-nucleon systems : 3p(I=3/2, Y=3, B=3, S=0), pnn(I=1/2, Y=3, B=3, S=0) and dp(I=1/2, Y=3, B=3, S=0)

The 3p invariant mass spectra from the reactions $n^{12}C \longrightarrow$ pppX and $n^{12}C \longrightarrow (mp)X$, m=3,4,5,6 at $\langle p_n \rangle$ = 7.0 GeV/c are shown in fig. 8 . No significant enhancements were found. This result first obtained at JINR in 1972 /7-11/ was further confirmed in the experiments described below.

1. The 1.5m ITEP spark chamber spectrometer was exposed to a 3.7 GeV/c π^--meson beam. No 3p resonances were observed in the 3p invariant mass spectrum /5/.

2. The JINR HBC100 was exposed to a ^{4}He beam of a 8.56GeV/c total momentum /I2/. The dp invariant mass spectrum from the exclusive ^{4}Hep$\longrightarrow$ dppn reaction channel is shown in fig. 9 . The maxima at both ends of the dp invariant mass spectrum are due to the kinematics of the reaction and need no hypothesis on the existence of dp resonances. It is quite possible that the lower mass maximum is enhanced because of the final state interactions of deuterons and protons at small relative velocities.

3. The three-nucleon effective mass spectra pnn and dp from tp(at 2.5 GeV/c)and ^{3}Hep(at 5.0 GeV/c) interactions were studied using the pictures from the ITEP HBC80. No resonances in the systems in question were seen /4/ .

Four-nucleon systems : 4p(I=2, Y=4, B=4, S=0), dpp(I=1, Y=4, B=4, S=0), dpn(I=0, Y=4, B=4, S=0), tp(I=0, Y=4, B=4, S=0) and ^{4}He* (I=0, Y=4, B=4, B=4, S=0)

The 4p invariant mass spectra from $n^{12}C \longrightarrow$ 4pX and $n^{12}C \longrightarrow$ (mp)X, m=4,5,6 at $\langle p_n \rangle$ = 7.0 GeV/c are presented in fig. I0

/8-II/ . No significant enhancements were seen. This negative result was confirmed in the following experiments.

1. The dpp and dpn invariant mass spectra from the reaction ^{4}Hep → dppn at 8.56 GeV/c (JINR HBC100) /12/ do not reveal resonance-like enhancements (fig. 18). The broad maxima at the higher mass end of the spectra are due to the kinematical limit of the reaction in question. No enhancements were found as well in the tp effective mass spectrum from the same reaction (fig. II).

2. A special counter experiment /13/ was devoted to the search for highly excited states of the ^{4}He nucleus in the reaction $\pi^- {}^4He \to \pi^- {}^4He^*$ at 5.0 GeV/c. No resonance-like signals were found in the relevant missing mass spectrum.

<u>Systems : 5p(I=5/2, Y=5, B=5, S=0) and 6p(I=3, Y=6, B=6, S=0)</u>

The invariant mass spectra of these systems were investigated at JINR /8-II/ . No resonance-like enhancements were discovered (fig. I2).

<u>Systems : Λpp(I=1, Y=2, B=3, S=-1), Λ3p(I=3/2, Y=3, B=4, S=-1), Λ4p(I=2, Y=4, B=5, S=-1)</u> /8-II/

The invariant mass spectra of the enumerated systems from the reactions $n^{12}C \to \Lambda$ (mp)X and $\pi^{-12}C \to \Lambda$ (mp)X, m=2,3,4,5 at $\langle p_n \rangle$ = 7.0 GeV/c and p_{π^-} = 4.0 GeV/c are shown in fig. I3. No significant enhancements,which could be due to resonances,were found.

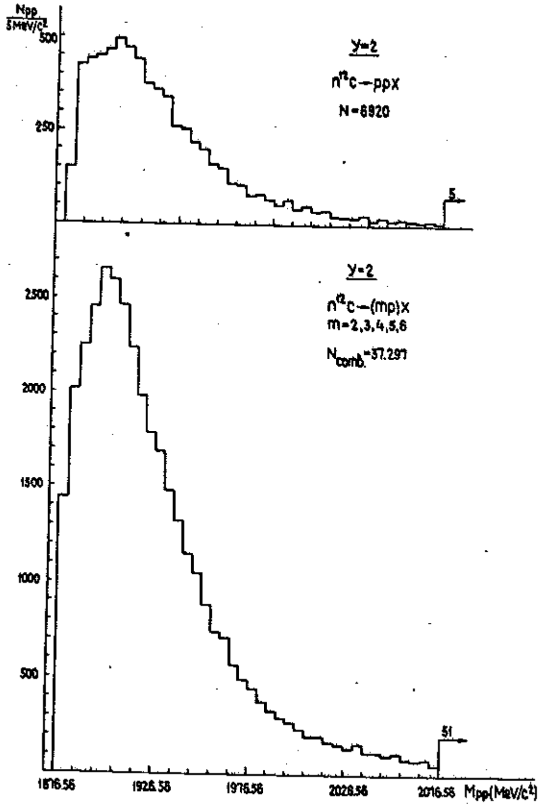
<u>Systems : K^0p(I=1, Y=2, B=1, S=1), ΛK^0p(I=1, Y=2, B=2, S=0), K^0pp(I=3/2, Y=3, B=2, S=1), $K^0$3p(I=2, Y=4, B=3, S=1), $K^0$4p (I=5/2, Y=5, B=4, S=1)</u>

The data on the invariant mass spectra of the systems in question come from $n^{12}C$, np and $\pi^{-12}C$ interactions at $\langle p_n \rangle$ = 7.0 GeV/c and p_{π^-} = 4.0 GeV/c and are presented in fig. I4 /8-II/ . The Kp mass spectra are shown in the left upper corner. The admixture of $\bar{K}^0$p combinations is not excluded. But the exclusion of both K^0p and $\bar{K}^0$p combinations contributed by the $K^0\bar{K}^0$(mp)X final states do not transfigure the spectra. The hatched K^0p invariant mass spectra from the ΛK^0(mp)X final states also do not reveal resonance-like enhancements. No such enhancements are seen either in the ΛK^0p dibaryon or in the $K^0$3p tribaryon invariant mass spectra shown in fig. I4.

Thus, the totality of available experimental results on the search for multiquark resonant systems as well as of the established resonances forces us to formulate the hypercharge selection rule : "The hypercharge of hadronic resonances in weak gravitational fields cannot exceed one : $Y \leqslant 1$." One cannot exclude that this rule is based on a new symmetry principle unknown up to now.

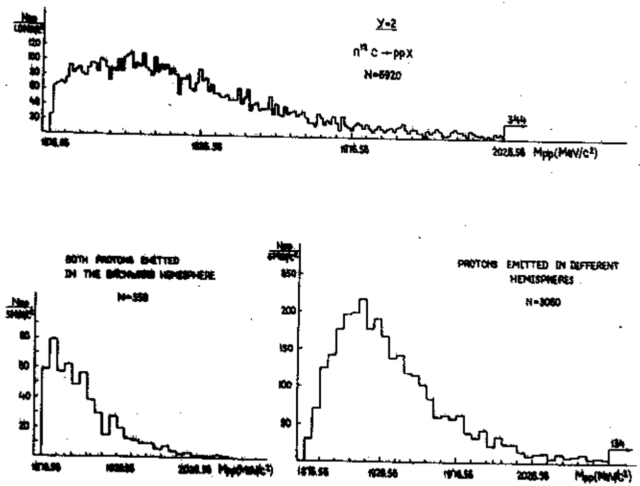
The cumulative effect /I4/ provides, with strong arguments, the existence of quark plasma as one of the permitted states of nuclear matter. The hypercharge selection rule does not contradict this fact. According to this rule, quark plasma is inherent in nuclear matter and is just as confined to its structure unit, the atomic nucleus, as quarks are confined to elementary particles. Thus, it is possible to tear away only quark plasma pieces of hypercharge $Y \leqslant 1$ from the nucleus.

It should be stressed that the sum of all possible flavours : Y = B+S+C+b+... is meant by hypercharge.



Npp / 5MeV/c²
y=2
n¹²C→ppX
N=6920
5
y=2
n¹²C→(mp)X
m=2,3,4,5,6
N_comb.=37.297
51
1876.56
1926.56
1976.56
2026.56
2016.56
Mpp(MeV/c²)

Fig.1



y=2
n¹²C→ppX
N=6920
344
Mpp(MeV/c²)
BOTH PROTONS EMITTED
IN THE BACKWARD HEMISPHERE
PROTONS EMITTED IN DIFFERENT
HEMISPHERES
N=3060
134
Mpp(MeV/c²)

Fig.2

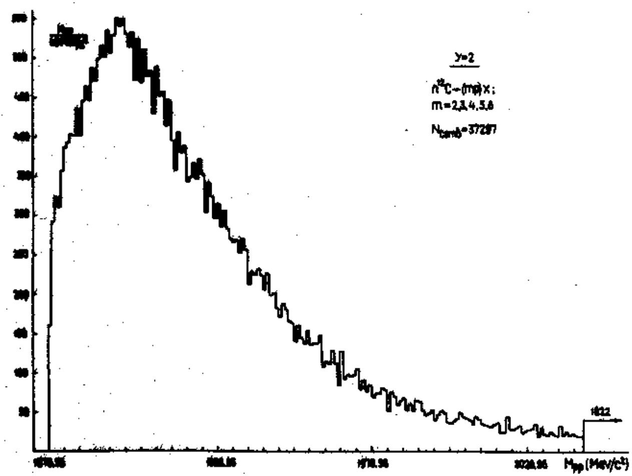

Y=2
$n^{12}C\to(mp)X$;
m=2,3,4,5,6
N_{comb}=37287
M_{pp}(MeV/c^2)

Fig. 3

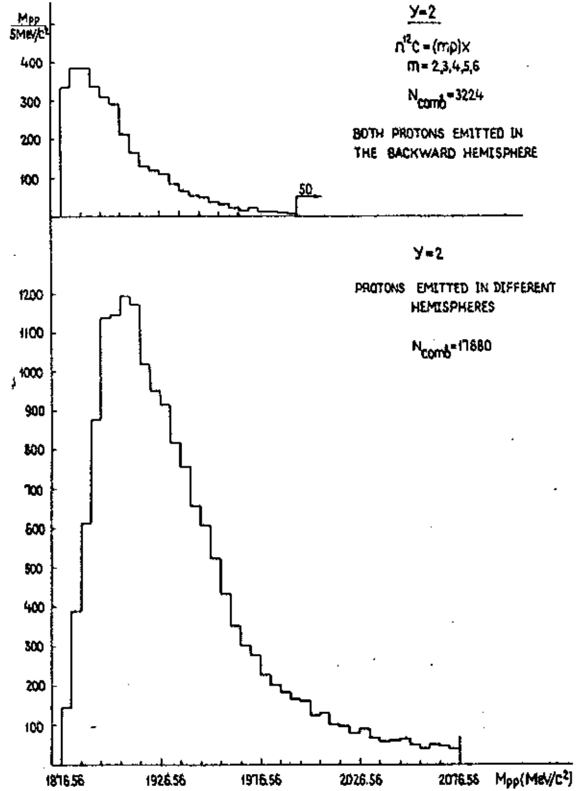
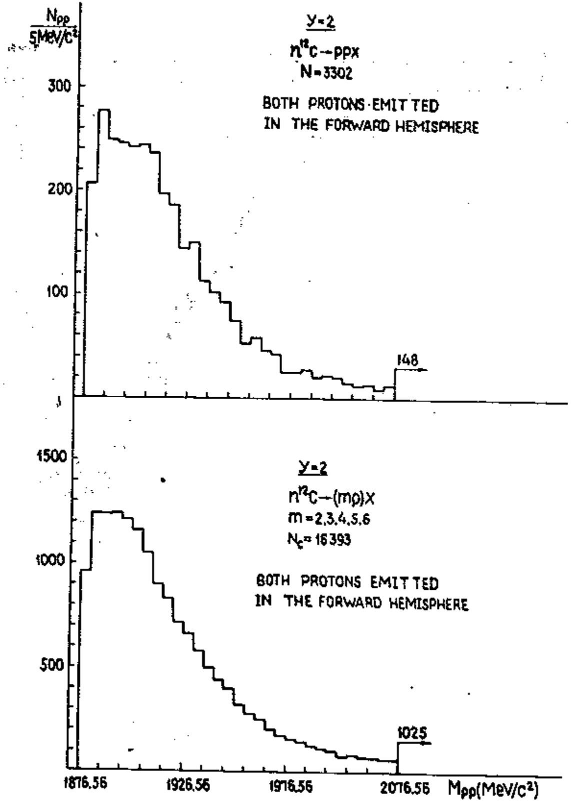
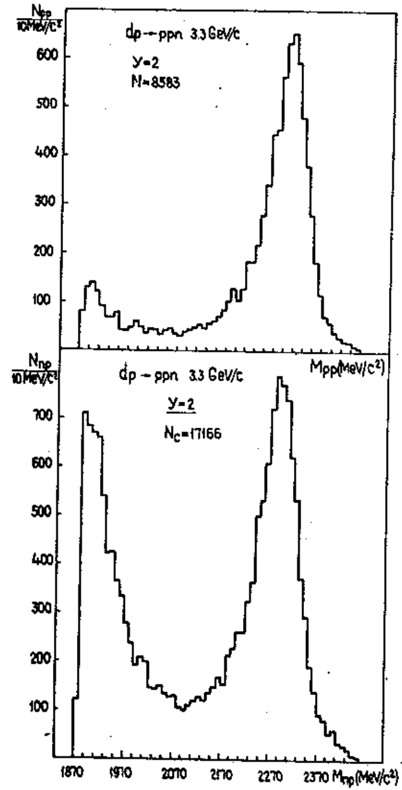

$\frac{M_{pp}}{5MeV/c^2}$
400
300
200
100
Y=2
$n^{12}C\to(mp)X$
m=2,3,4,5,6
N_{comb}=3224
BOTH PROTONS EMITTED IN
THE BACKWARD HEMISPHERE
50
Y=2
PROTONS EMITTED IN DIFFERENT
HEMISPHERES
N_{comb}=17880
1200
1100
1000
900
800
700
600
500
400
300
200
100
1876.56
1926.56
1976.56
2026.56
2076.56
M_{pp}(MeV/c^2)

Fig. 4



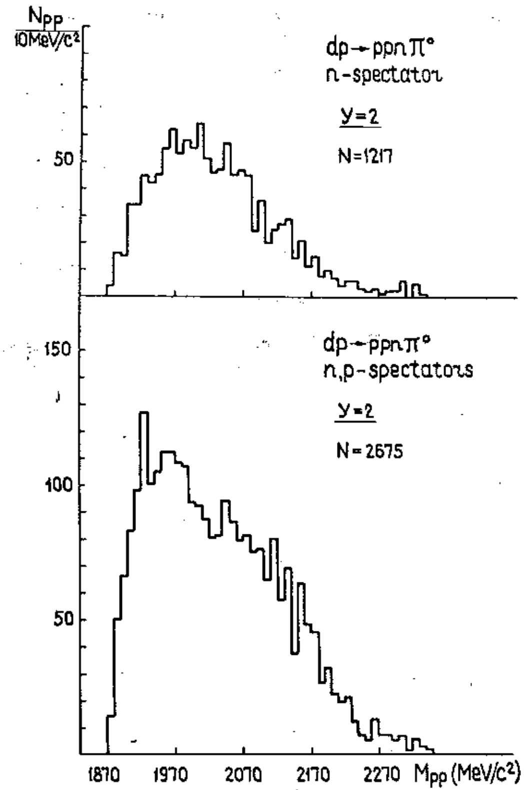
N_{pp} / 5MeV/c²
300
200
100
y=2
$n^{12}C \to ppx$
N=3302
BOTH PROTONS EMITTED
IN THE FORWARD HEMISPHERE
148
1500
1000
500
y=2
$n^{12}C \to (mp)X$
m=2,3,4,5,6
N_c=16393
BOTH PROTONS EMITTED
IN THE FORWARD HEMISPHERE
1025
1876.56
1926.56
1976.56
2076.56
M_{pp}(MeV/c²)

Fig. 5



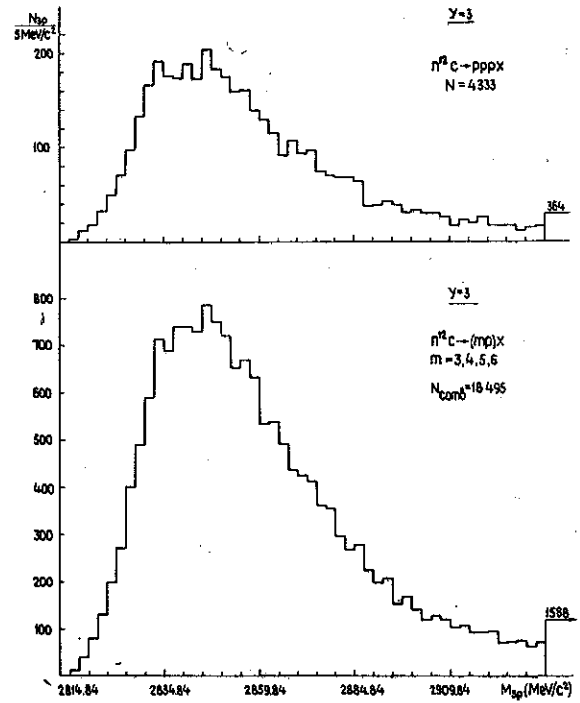
N_{pp} / 10MeV/c²
600
500
400
300
200
100
$dp \to ppn$ 3.3 GeV/c
y=2
N=8583
M_{pp}(MeV/c²)
N_{np} / 10MeV/c²
700
600
500
400
300
200
100
$dp \to ppn$ 3.3 GeV/c
y=2
N_c=17166
1870
1970
2070
2170
2270
2370
M_{np}(MeV/c²)

Fig.6



N_{pp} / 10MeV/c²
dp→ppnπ°
n-spectator
y=2
N=1217
dp→ppnπ°
n,p-spectators
y=2
N=2675
150
100
50
1870
1970
2070
2170
2270
M_{pp} (MeV/c²)

Fig.7



N_{sp} / 5MeV/c²
200
100
y=3
$n^{12}C$→pppx
N=4333
364
800
700
600
500
400
300
200
100
y=3
$n^{12}C$→(mp)x
m=3,4,5,6
N_{comb}=18495
1588
2814.84
2834.84
2859.84
2884.84
2909.84
M_{sp}(MeV/c²)

Fig.8

89

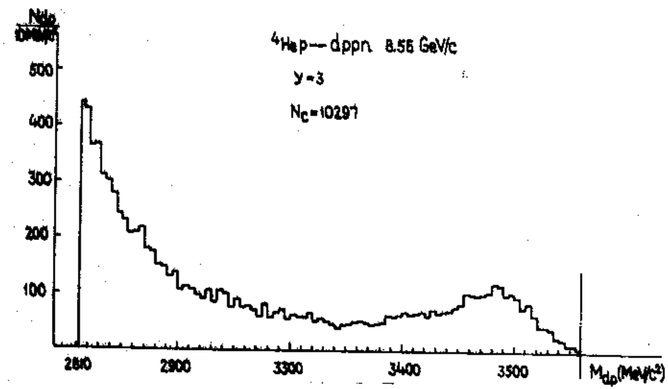


Fig.9

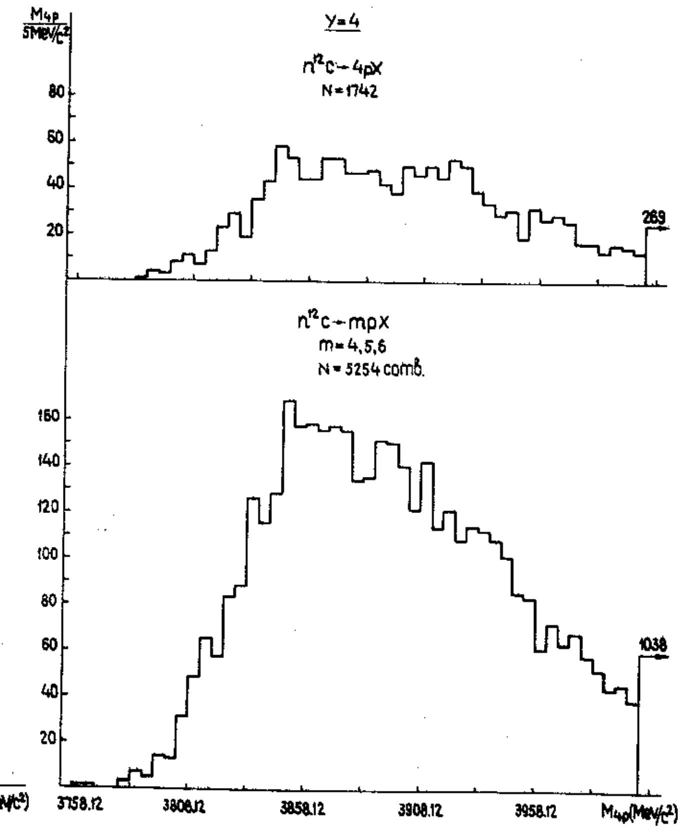


Fig.10

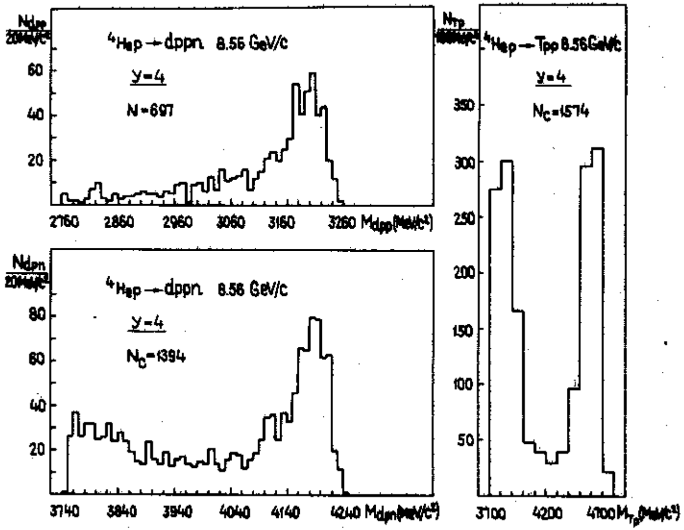


Fig. 11

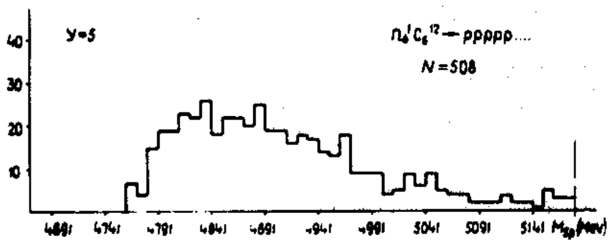


Fig. 12

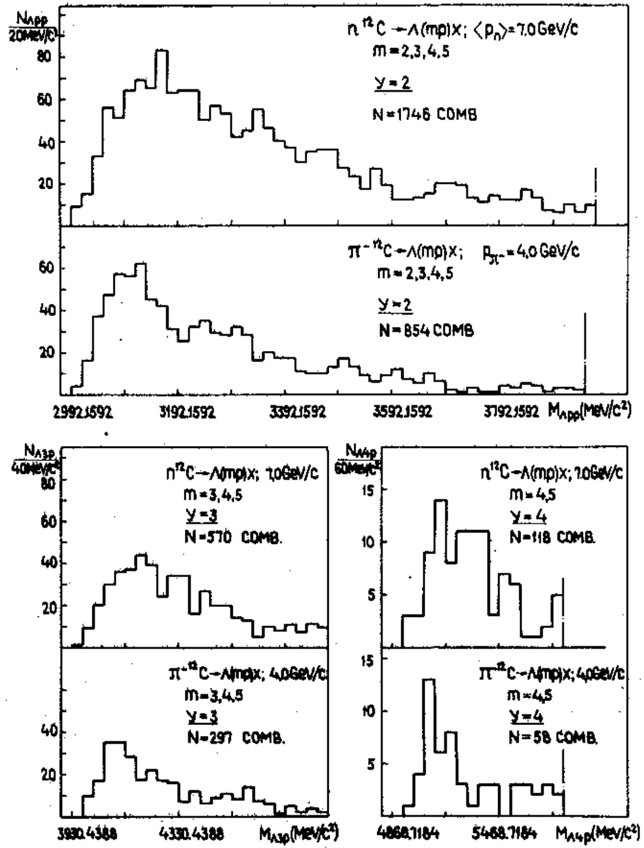


Fig. 13

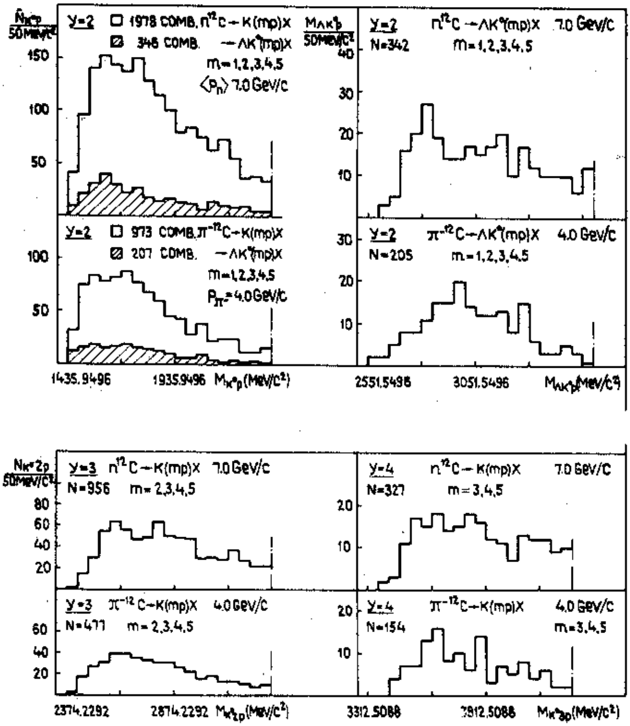


Fig.14

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