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A. F. NILOV

EXOTIC BARYONS FROM LIGHT QUARKS WITH ISOSPIN I=5/2. THEIR STATUS

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EXOTIC BARYONS FROM LIGHT QUARKS WITH ISOSPIN I=5/2.THEIR STATUS: Preprint ITEP 63-95/+

A.F.Nilov - M., 1995 - 24p.

The status of exotic baryons with the isospin I=5/2 consisting of light quarks are presented. The short review of theoretical papers devoted this topic is given. The review of experimental data which have any evidence on existence of exotic baryons from first publication up to now is given. Preliminary data on E 5/2 search in p + Be interactions at 70 GeV/c proton beam are presented. The possibilities of futher searches for exotic baryons in different reactions are discussed.

Fig. - I2, ref. - 48.

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Theoretical status .

The baryon resonances with $I \geq 5/2$, were predicted in first time in 40's in the framework of statistical meson theory [1]. Later the I=J= 1/2, 3/2, 5/2, . . . states arise in bootstrap model [2]. The same set of states occurs in the frameworks where baryons considered as a solitons of effective low energy QCD lagrangian [3].

Multiquark systems arise in bag [4] and string models [5]. But in such models the I = J baryon set doesn't pick out as in previous models. So, in bag model the lowest mass state has S-wave $4q\bar{q}$ baryons with quantum numbers $J^P = 1^-/2$. Here there are no states with isospin I = 5/2 in mass region less than 2 GeV. Multiquark states in bag model can easily decay to white subsystems, corresponding to wellknown hadrons and usually have large widths. But there are schemes, where narrow resonances can exist also [6]. According to some estimates [6,7] such exotic baryons can have masses $M \geq 2$ GeV.

In string models [5] some exotic baryons are predicted in region $M \geq 1.6$ GeV and some of them can have low widths. Exotic baryons arise also in dynamical models as the self-consistent construction of dual amplitudes [7]. There are other approaches [8,9]. For example, the multichannel relativistic Schroedinger equation was applied to meson-baryon interaction in [8]. We are not pretended to get full list of theoretical papers which lead to exotic baryons, but we would like to distinguish model, based on dispersion sum rules for scattering reggeons on particles amplitudes [10,11]. It should be mentioned, that resonances with I = 5/2 and with $M \geq 1.4$ GeV can arise both in the model [10] and in the models [12,13].

The short resume of theoretical models are presented in Table 1.

Experimental status of isobars with isospin 5/2 searches.

The beginning of searches for isobars with I=5/2 started in early 60 's. Matt Roos [14] recorded isobar N^{*++} with M=2.4±0.02 and Γ≅0.12 GeV found in reaction $\pi^+ p \to p\,\pi^+\pi^+\pi^-$ at P_{π^-}=2.59 GeV/c to DPG isobar list. During the ≈10 years (1963-1971) there was an intensive search for such isobars [14-29]. In some papers there are claims on discovery of isobars with M≈1560-1570 MeV [15,16,19] and M≈1627-1672 MeV [21,24,26]. But the next ones didn't confirm such statements [17,20,22,23,25,27-29]. The reactions under search were:

Table 1.
Resume of theoretical models

Reference	Model (theoretical approch)	I , J isospin, spin	M [GeV]	Γ [MeV]
G.Wentzel .Helv. Phys. Asta, 13, 269, 1940. W.Pauli, S. M. Dancoff. Phys. Rev. 62,85, 1942 S.Tomanaga. Progr. of Theor. Phys. 1, 109, 1946	Statistical meson theory	J ≥ I =1/2,3/2,5/2,...		
E. S. Abers et. al. Phys. Rev. 136B, 1382, 1964	Bootstrap	I = J =1/2,3/2,5/2,...	≈1.240(3/2,3/2) ≈1.560(5/2,5/2)	$\Gamma_{mq} \approx \Gamma_{adr}$
E.Witten,Nucl.Phys. B223,433,1983	Solitons of the effective low-energy lagrangian of QCD	I = J =1/2,3/2,5/2,...		
R.L.Jaffe. Phys.Rev.D15,267, 1977;Preprint SLAC-PUB-1774,1976.	Bag model	I = J no pick out	>2. (I = 5/2)	$\Gamma_{mq} \approx \Gamma_{adr}$
M.Imachi et.al. Progr.Theor.Phys.55 ,551,1976;57,517,19 77. G.C.Rossi,G.Venezi ano;Nucl.Phys. B123,507,1977.	String model	I = J no pick out	≥ 1.6	can be narrow
H.Hogaasen et.al. Nucl.Phys. B145, 119, 1978. M.De Crombrudge et.al.Nucl.Phys., B156, 347,1979.	Bag model		> 2. (I = 5/2)	can be narrow
S.Mandelstam: Phys.Rev. D1,1734,1970 R.L.Rosner: Phys.Rev.Lett.21, 950,1968;Phys.Rep. 11C,189,1976	The self-consistent construction of dual amplitudes			

J.Katz,S.Wagner::Phys.Rev. D2, 2070, 1970.	The multichannel relativistic Schroedinger equation was applied to the meson-baryon interaction			
A. A. Grigoryan, A. B. Kaidalov; see ref. [10] A. A. Grigoryan, G.N.Khachatryn Yad.Fiz.44,1075, 1986;Sov.J.Nucl. Phys.44,696,1986	The method of the superconvergent sum rules for the amplitudes of reggeon scattering on particles	I = J = 5/2	≥ 1.4	21 (M=1.42) 37 (M=1.44) 140(M=1.52)
Sh.Ishida et. al. Preprint NUP-A-80-14	Junction string model	I=5/2 $J^P=(1/2)^-$ J^P $(3/2)^-$ $J^P=(1/2)^+, (3/2)^+,$, $(5/2)^+$	1.45-- 1.47 1.55 1.9	
Yu.V.Kulish: Yad.Fiz. 43,179,1986	The hybrid model taking into account mixing of $4q\bar{q}$,Aπ and Δρ states		≥ 1.4	1--100

$$\pi^+ p \to p\,\pi^+\pi^+\pi^- \qquad (1)$$

$$p\,p \to p\,\pi^+\pi^+\pi^- n \qquad (2)$$

$$p\,p \to p\,\pi^+\pi^+\pi^-\pi^- p \qquad (3)$$

$$\pi^- p \to n\,\pi^+\pi^+\pi^-\pi^- \qquad (4)$$

$$\pi^- d \to n\,\pi^-\pi^-\pi^+ p_s \qquad (5)$$

$$\pi^+ d \to p\,\pi^+\pi^+\pi^- n_s \qquad (6)$$

$$k^- d \to n\,\pi^-\pi^-\pi^+ k^0 p_s \qquad (7)$$

$$\pi^+ p \to \pi^-(\mathrm{MM})^{+++} \qquad (8)$$

$$n\,p \to n\,\pi^+\pi^+\pi^-\pi^- p \qquad (9)$$

$$n\,p \to n\,\pi^+\pi^+\pi^-\pi^- p\,\pi^0 \qquad (10)$$

It should be mentioned that all such searches have common features - low energy of bombarding particles (1.1 - 6. GeV/c) and low statistics (100 - 2500 events in individual experiment).

The period from end of 70's till now can be considered as a new stage in searches for isobar with I=5/2. This stage is characterised by attempts to select events with definite mechanism of isobar production (baryon exchange) as it was proposed in [10,30] and remarkable increase of statistics [30 - 40].

This stage started by two searches using bubble chambers methodics. One of them has been done in ITEP [30] another one in JINR (DUBNA) [31]. Now let's follow paper [30]. Here the reaction (4) are considered at P (π^-) = 4.5 GeV/c. Very abundant forward production of $\Delta^-(1232)$ isobar (baryon exchange) was discovered if such cuts on longitudinal momentum were used:

$$P_L(n\,\pi_i^-) \geq P_L(\pi_1^+); P_L(\pi_2^+); P_L(\pi_0^-).$$

The bumps in mass region 1.46 - 1.62, 1.66 - 1.78, 1.9 - 2.06 GeV/c^2 in effective mass distribution $(n\,\pi^-\pi^-)$ system were observed if above cuts are used and events were selected in Δ^- isobar band ($1.10 \leq M\ (n\,\pi_i^-) \leq 1.38$ GeV/c^2) also (fig.1). The values of masses and widths obtained from fit of mass spectrum using sum of background and 3 Breit-Wigner functions are given in Table 2. The value of cross section are 5 ± 3, 5 ± 5 and 22 ± 5 mkbn correspondingly.

In cited paper the indirect proofs were given on existence of $E_{3/2}$ isobar - the presence of $\Delta^{++}(1232)$ isobars going in the beam direction for the reactions (E^{+++} exchange in t-channel) :

Table 2

Reaction	Mass region, Gev/c^2								Refer.
	1.3 - 1.5		1.5 - 1.7		1.7 - 1.9		1.9 - 2.1		
	M, Gev/c^2	Γ, Gev/c^2	M, Gev/c^2	Γ, Gev/c^2	M, Gev/c^2	Γ, Gev/c^2	M,Gev/c^2	Γ, Gev/c^2	
$\pi^+ p \to p \pi^+ \pi^+ \pi^-$			1.56 ± 0.02	0.2 ± 0.02					15
	1.48 ± 0.01	0.08 ± 0.04	1.65 ± 0.02	0.07 ± 0.07					35
	1.491 ± 0.006	0.028±0.008	1.586 ±0.004	0.012 ±0.006					37
			1.680±0.005	0.023 ±0.010					37
$\pi^+ p \to p \pi^+ \pi^+ \pi^- \pi^0$	1.413 ±0.021	0.011 ±0.017	1.567 ±0.019	0.049 ±0.022	1.735 ±0.029	0.099±0.032			34
	1.39 ± 0.01	0.05 ± 0.03	1.63 ± 0.10	0.10 ± 0.05					35
	1.48 ± 0.01	0.05 ± 0.03							35
	1.44	≤0.03							39
$\pi^- p \to n 2 \pi^- 2 \pi^+$			1.522 ±0.03	0.080 ±0.070	1.745 ±0.010	0.003±0.003	1.99 ± 0.02	0.12 ± 0.06	30
					1.75	0.05			32
$\pi^- d \to n 2 \pi^- \pi^+ p_s$			1.64	0.06					24
$k^- d \to n 2 \pi^- \pi^+ k^0 p_s$			1.627	0.03					26
$n p \to p n 2 \pi^- 2 \pi^+$			1.6 - 1.7						21
	1.438	0.023	1.522	≤0.020	1.894	≤0.040			31
$p p \to p 2 \pi^+ \pi^- n$			1.58 ± 0.02	0.200 ±0.020					16
$\pi^+ p \to n 2 \pi^- 4 \pi^+$	1.416 ± 0.006	0.074 ±0.017							40
$p p \to 2 p 2 \pi^+ 2 \pi^-$			1.57	0.14					19
$p Be \to p \pi^+ \pi^+ + X$	1.420 ±0.008	0.064 ±0.038	1.641 ±0.024	0.025 ±0.028					48
$p Be \to p \pi^+ \pi^- \pi^0 + X$	1.435 ±0.010	0.090 ±0.010							48

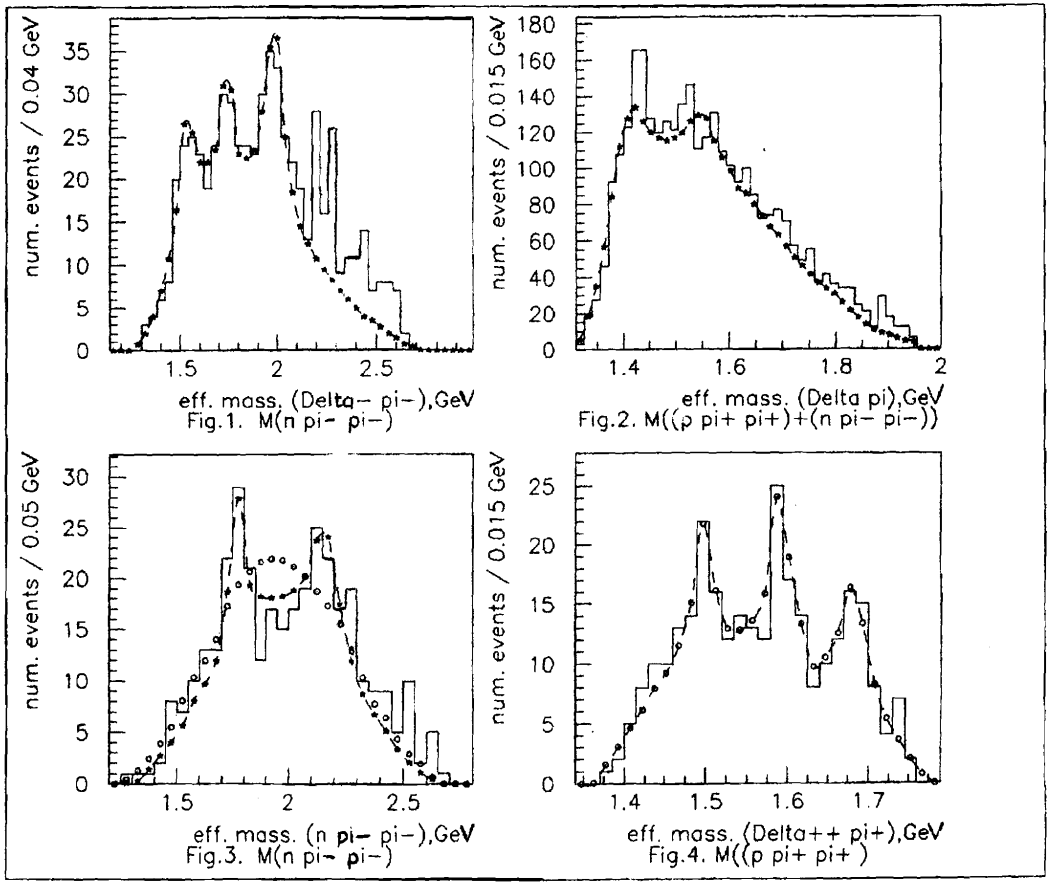


Fig.1. M(n pi- pi-)

Fig.2. M((p pi+ pi+)+(n pi- pi-))

Fig.3. M(n pi- pi-)

Fig.4. M((p pi+ pi+)

$$\pi^- p \to p\,\pi^+\pi^-\pi^-\pi^0 \qquad (11)$$

$$\pi^- p \to p\,\pi^+\pi^-\pi^- \qquad (12)$$

In [31] the search for exotic baryon resonances in the reaction (9) has been done at P(n)=5.10±0.17 GeV/c. Authors claimed presence of 3 excesses of events in ($\Delta\,\pi^-$) -system mass spectrum (fig.2). Bumps exceeded background distribution for 3 - 4 standard deviations. They have low widths. The values of masses and widths are given in Table 2. Possible J^P for resonance with mass 1.522 GeV/c^2 are $1/2^+$, $3/2^-$, $5/2^+$. For more detailed conclusions on J^P, as authors stated, necessary more sufficient increase of statistics. The cross sections of found resonances are 9.9 ± 2.7, 4.8 ± 1.7 and 3.3 ± 0.8 mkbn correspondingly. Authors compared the characteristics of baryon resonances experimentally taken and theoretically predicted of the bag model - B.M. [6], the string junction model SJM [12] and of the superconvergence sum rules model [10]. Such comparison lead to conclusion that the best agreement occur for SJM model (it predicts mass of resonances 1.455,1.550 and 1.900 GeV/c^2).

Next we shall discuss the paper [33] where the search for $p\,\pi^+\pi^+$ - system produced in reaction

$$\bar{p}\,p \to \bar{p}p\,2\pi^+2\pi^- \qquad (13)$$

at 32 GeV/c have been performed. Authors found considerable excess of $p\,\pi^+\pi^+$ combination in the mass region < 1.7 GeV/c^2 and saw narrow peak at M ($p\,\pi^+\pi^+$) ≈ 1.520 GeV/c^2. They explained this bump by interference effects due to π^+ -mesons identity and as a consequence of the abundant Δ(1232)-isobar production both in $p\,\pi_1$ and in $p\,\pi_2$ -systems (kinematics of Dalits plot).

The set of papers devoted to exotic baryons has been done with 2m bubble chamber exposed by π -beams of different sign. So, in [32] the reaction (4) has been investigated at P (π^-)=4.35 GeV/c. The longitudinal momentum space was used to select baryon exchange in the t-channel. They used the following cut $P_L(n)+P_L(\pi_1^-)+P_L(\pi_2^-)>0$. Fig.3 presents ($n\,\pi^-\pi^-$) system mass distribution. Two maxima in 1750 and 2150 MeV regions are observed, they exceed background level on 2.5 and 2 standard deviations accordingly. Parameters of these bumps are given in Table 2. Authors found their cross sections equal to 14.0±2.6 and 12.5±2.5 mkbn correspondingly.

Reactions (1),

$$\pi^+ p \to p\,\pi^+\pi^+\pi^-\pi^0 \qquad (14)$$

$$\pi^+ p \to n\,4\pi^+ 2\,\pi^- \qquad (15)$$

were searched at P (π^+)=4.2 GeV/c.

Fig.4 presents ($p\,\pi^+\pi^+$) system effective mass spectrum for reaction (1) [37]. Three maxima at 1.5, 1.6 and 1.7 GeV/c^2 were observed. Authors used the following cuts:

1. invariant mass of ($p\,\pi_s^+$) system is in Δ^{++}(1232) band (1.15-1.31 GeV/c^2). (indexes "s" and "f"- slow, fast);

2. ($\pi_f^+\pi^-$) system invariant mass is out of ρ^0(770)-band (0.60-0.89 GeV/c^2);

3. square of 4-momentum transferred from target proton to ($p\,\pi_s^+$) system is small by absolute value (<0.5 (GeV/c)^2);

4. ($\pi_s^+\pi^-$) system invariant mass is out ρ and f bands (0.68-0.86 and 1.20-1.32 GeV/c^2, correspondingly);

5. module of π_f^+ - meson momentum in lab. system $|P(\pi_f^+)|$<0.8 GeV/c;

6. module of π^- -meson momentum in lab. system $|P(\pi^-)|$>3.0 GeV/c.

In Table 2 the values of masses and widths, found by fit of spectrum by sum of polynomial background and 3 Breit-Wigner functions, are given. Confidence level ≈ 70% for coincidence of resulting curve with experimental data was obtained. The values of cross sections for E^{+++} baryon production are 6.0±1.5; 3.6±1.0 and 5.7±1.5 mkbn for 1.5, 1.6 and 1.7 GeV/c^2, correspondingly.

Reaction (14) [34] was studied under the following conditions:

1. π^- -meson is emitted to backward hemisphere. π^- - meson angle respect to beam direction >75°;

2. proton momentum P(p)>1.8 GeV/c;

3. ($p\,\pi^+\pi^+\pi^-$) system effective mass is in 1.75-2.75 GeV/c^2 band;

4. one of ($p\,\pi^+$) mass combination is in Δ^{++}(1232)-isobar region 1.15-1.31 GeV/c^2.

Fig.5 presents ($p\,\pi^+\pi^+$) system mass spectrum obtained under such conditions. This spectrum was approximated by background and 3 Breit - Wigner functions. Again the values of masses and widths, found in such fitting, are given in Table 2.

In the reaction (15) [40] resonance peak at ~1.4 GeV/c^2 was observed under cut P(n)>1.3 GeV/c in ($n\pi^-\pi^-$) system mass spectrum (see fig.6,Table 2). Its cross section is σ=8.3±1.5 mkbn.

In another ITEP experiment [35] fulfilled using magnetic spectrometer reactions (1) and (14) were searched at P (π^+)=3.94 GeV/c. To select baryon exchange in such reactions a sample of events with π^- - meson emitted in backward was collected with an additional cut $P_L^*(p) > P_L^*(\pi)$. Fig.7 presents distribution of events of reaction (1) on ($p\pi^+\pi^+$) system mass. In 1.42 - 1.54 and 1.57 - 1.69 GeV/c^2 regions there are bumps above background curve, which authors interpreted as resonance states. To distinguish these states the effective mass spectrum up to M<1.9 GeV/c^2 was described by the method of maximum likelihood using function

$$\varphi = fW(1+\sum_i B_i),$$

where f-geometry efficiency, B_i - Breit-Wigner function, W - function describing background. The curve 1 shown in fig. 7 was used as a background (W). This curve is a sum of a fraction due to OPER mechanism [41] and curve 2. Curve 2 was calculated as a reflection from quasibinary reactions

$$\pi^+ p \to \Delta^{++}(1232)\rho^0(770)$$
$$\pi^+ p \to \Delta^{++}(1232) f^0(1270)$$

and was normalised to number of events collected in this experiment. The curve 1 coincides with phase volume within experimental accuracy. The results of such description are plotted in fig.7 as a smooth curve and are given in table 3.

Table 3

M, GeV/c^2	Γ, GeV/c^2	n^1	n
1.48±0.01	0.08±0.04	9.3	5.1
1.65±0.02	0.07±0.07	5.3	3.9

Here n^1 and n -number of standard deviations for found excesses over the background curve. n^1 is a square root from the number of events under the background curve in the given mass region, n - is a square root from the total number of events in the same mass region. The search for spin - parity of maximum with M=1.48 GeV/c^2 shows that the values $J^P = 5/2^+$ or $3/2^-$ are preferable.

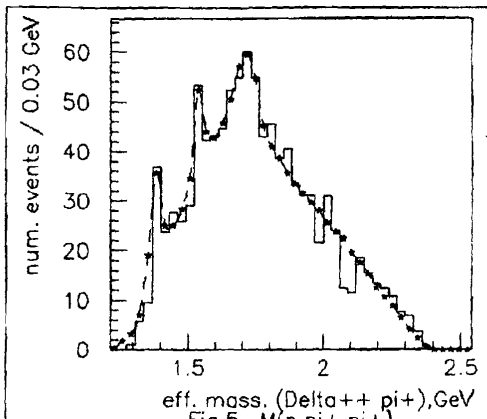


Fig.5. M(p pi+ pi+)

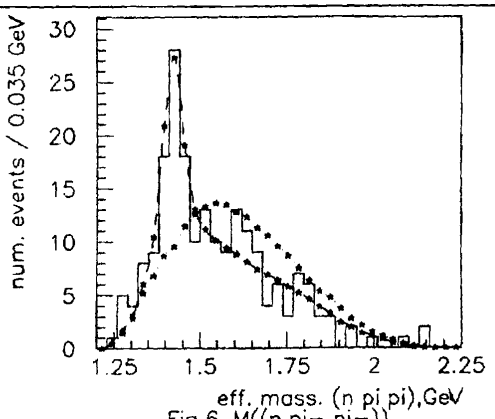
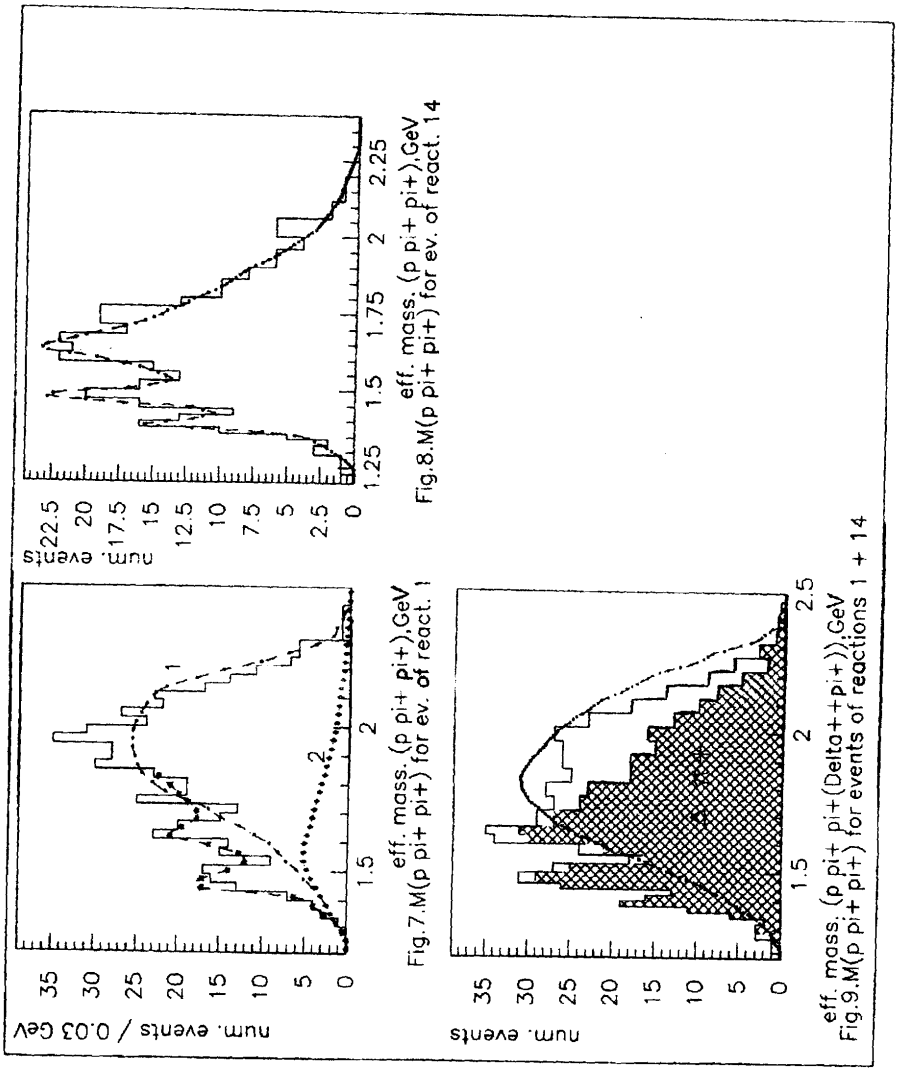


Fig.6. M((n pi− pi−))



2) $P^*(\pi^-)<0$ and $P^*(p\,\pi^+\pi^+)>0$ in peak - 23±9 events.

Now I present preliminary not published data, from my point of view, not contradicted to $E_{5/2}$ baryon production in reaction

$$p\,\mathrm{Be} \rightarrow p\,\pi^+\pi^+ + \mathrm{X} \qquad (17)$$

at P (p)=70 GeV/c. Data were taken using wide-aperture magnetic spectrometer, equipped with MWPC, DC, hodoscopes, two multichannel cherenkov counters for charge particles identification and lead glass electro-magnetic detector. Set-up trigger selected 3 forward charge particles in final state, it allowed additional one charged particle flying aside with momentum less than 2.5 GeV/c. It's possible to conclude that the main contribution to reaction (17) gives the process

$$p\,p \rightarrow p\,\pi^+\pi^+ + \pi^- n \qquad (+\,m\pi^0),$$

where m = 0,1,. . .
because the following reactions:

$$p\,p \rightarrow p\,\pi^+\pi^+ + \pi^-\pi^- p \qquad (+\,m\pi^0)$$

$$p\,n \rightarrow p\,\pi^+\pi^+ + \pi^-\pi^- n \qquad (+\,m\pi^0)$$

$$p\,n \rightarrow p\,\pi^+\pi^+ + \pi^-\pi^-\pi^- p \qquad (+\,m\,\pi^0)$$

strongly suppressed by set-up trigger.

The possible production $E_{5/2}$ baryon can be presented by following Feynman diagrams:

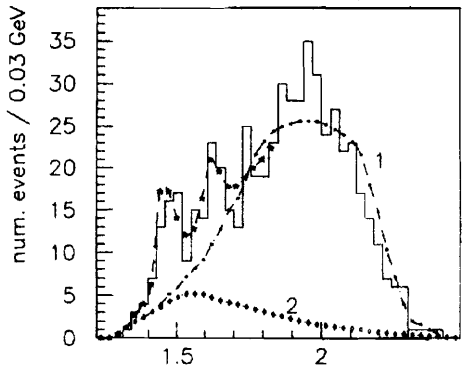


Fig.7.M(p pi+ pi+) for ev. of react. 1

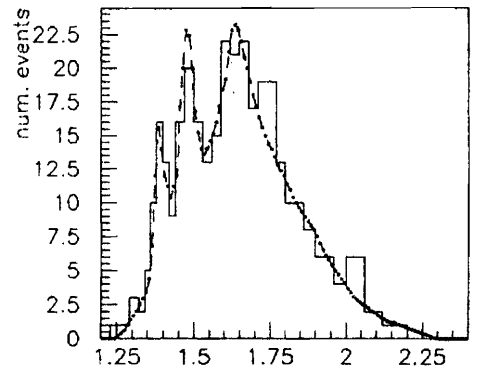


Fig.8.M(p pi+ pi+) for ev. of react. 14

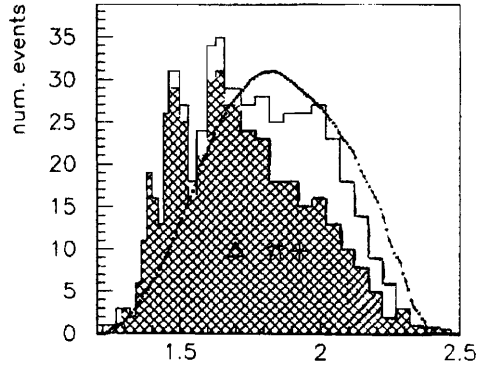


Fig.9.M(p pi+ pi+) for events of reactions 1 + 14

In the same experiment the invariant mass spectrum of ($p\pi^+\pi^+$) system for reaction (14) was investigated. The excesses in 1.34 - 1.42, 1.42 - 1.54 and 1.58 - 1.70 GeV/c^2 intervals were found. The best approximation of experimental distribution was one with sum of phase curve and 3 Breit - Wigner resonance curves. The results of such a description are plotted on fig.8 as a smooth curve and are given in Table 4.

Table 4

M,GeV/c^2	Γ,GeV/c^2	n'	n
1.39±0.01	0.05±0.03	9.2	4.8
1.48±0.01	0.05±0.03	10.4	6.3
1.63±0.01	0.10±0.05	7.9	5.6

The secondary angle distribution analysis has been done in the same manner as for reaction (1). The result was identical to reaction (1) one ($J^P = 5/2^+$ or $3/2^-$), but the set $J^P = 1/2^{+-}$ cannot be excluded.

The summary invariant mass distribution for ($p\pi^+\pi^+$) system from reactions (1) and (14) were plotted in fig.9 [40]. The distribution from its left side up to mass 1.87 GeV/c^2 were described by sum of phase curve and 3 Breit - Wigner functions. The masses and widths of resonances are put in Table 2. Statistical significance for all bumps >5σ. If to try describe histogram in fig.9 by sum of phase volumes curves for reactions (1) and (14), the confidence level will be <0.1% and the excess of events over curve will be in the mass region 1.36 - 1.70 GeV/c^2. Shaded distribution in fig.9 correspond to the case where at least one of ($p\pi^+$) combination belongs to $\Delta^{++}(1232)$-isobar band : 1.13-1.33 GeV/c^2. The authors claimed that because the number of events in the peaks from both histograms does not change, E^{+++} decays mainly through $\Delta^{++}(1232)\pi^+$ channel.

Kvatadze [39] analysed the CERN 81 cm bubble chamber statistics [42]. He searched 5807 events (sensitivity 3 ev/mkbn) of reaction (14) and 7985 events (sensitivity 3.2 ev/mkbn) of reaction

$$\pi^+ p \to p\pi^+\pi^+\pi^- Z^0 \qquad (16)$$

The peak with M≈1.44 GeV/c^2 and Γ≤0.03 GeV/c^2 (36±9 events over background curve for both reactions) has been observed if even one of combination ($p\pi^+$) system belongs to $\Delta^{++}(1232)$ band under next cuts:

1) $M(\pi^+\pi^-) \neq M(\rho^0)$ in peak - 25±8 events;

2) $P^*(\pi^-)<0$ and $P^*(p\pi^+\pi^+)>0$ in peak - 23±9 events.

Now I present preliminary not published data, from my point of view, not contradicted to $E_{5/2}$ baryon production in reaction

$$p\,\mathrm{Be} \rightarrow p\,\pi^+\pi^+ + \mathrm{X} \qquad (17)$$

at P (p)=70 GeV/c. Data were taken using wide-aperture magnetic spectrometer, equipped with MWPC, DC, hodoscopes, two multichannel cherenkov counters for charge particles identification and lead glass electro-magnetic detector. Set-up trigger selected 3 forward charge particles in final state, it allowed additional one charged particle flying aside with momentum less than 2.5 GeV/c. It's possible to conclude that the main contribution to reaction (17) gives the process

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$$p\,n \rightarrow p\,\pi^+\pi^+ + \pi^-\pi^-\pi^- p \qquad (+\,m\,\pi^0)$$

strongly suppressed by set-up trigger.

The possible production $E_{5/2}$ baryon can be presented by following Feynman diagrams:

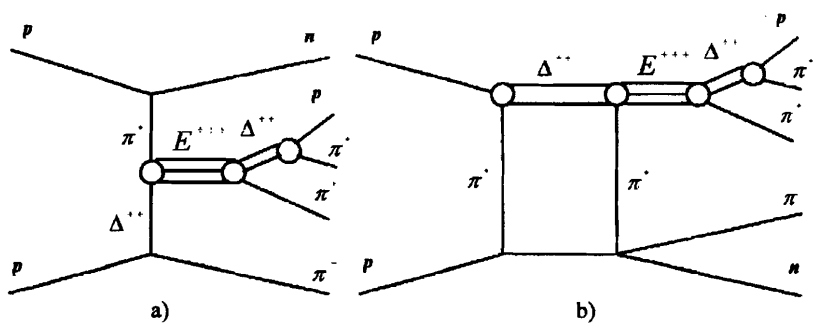

Fig.10

It is clear that Feynman X_f for $E_{5/2}$ produced under diagram fig.10 a) must be less than in fig.10 b) case.

As a result of data handling it was received 915 580 events with three charged particles in final state and 9687 events from them have three positive charge.

We use next cuts:

1) momentum of proton P (p) > 8 GeV/c (identification probability by cherenkov counter for such energetic protons >95%);

2) summary momentum of 3 particles $P\ (p\,\pi^{+}\pi^{+})$< 74 GeV/c

3) event vertex must be inside target.

Such cuts decreased a sample up to 7468 events.

We investigate the behaviour of two and three particle effective masses vs X_f. For it the spectra under search have been plotted for 6 different X_f bands. X_f intervals have been selected in such manner that statistics in each band will be approximately equal to each other. In Table 5 the intervals in X_f and corresponding statistics are given. It should be mentioned that set-up does accept events with X_f=0.3 but in region 0.3<X_f<0.5 its efficiency falls down and statistics is small.

Table 5.

X_f	Number of events
$0.5 < X_f < 0.7$	1270
$0.7 < X_f < 0.8$	1133
$0.8 < X_f < 0.85$	777
$0.85 < X_f < 0.9$	989
$0.9 < X_f < 0.95$	1330
$0.95 < X_f < 1.0$	1606

To separate identical π^{+} mesons we marked them according their momentum π_f^{+} -fast, π_s^{+} -slow one. We plotted effective mass spectra for ($p\ \pi_f^{+}$) and ($p\ \pi_s^{+}$) systems in each X_f interval separately. In each spectrum the abundunces of events in Δ^{++} band are observed but with different intensity. Histograms in each X_f intervals have been described by the function

$$f(x) = A*(x-x_{min})^{B}*\exp(C*x-D*x^{2}) + \frac{F}{(x-M)^{2}+\Gamma^{2}} ,$$

where A,B,C,D - coefficients of background term and F,M and Γ - Breit-Wigner coefficients. The Δ^{++} isobar fraction are 6.5 - 23.7 % in X_f region dependence. The signal/background in

isobar band (1.18 - 1.28 GeV/c^2) better from 2 up to 6 times for ($p\ \pi_f^+$) spectrum relative to ($p\ \pi_s^+$) one.

The investigation of ($\Delta^{++}\pi^+$) system gives of following results.

in ($\Delta^{++}\pi^+$) mass spectrum for range $0.5 < X_f < 0.8$ there are two excesses over smooth background curve (see fig.11). Their fitting parameters are:

$$M_1 = 1.42 \pm 0.14, \Gamma_1 = 0.064 \pm 0.02 \quad \text{and}$$

$$M_2 = 1.64 \pm 0.02, \Gamma_2 = 0.025 \pm 0.016 \text{ GeV/c}^2.$$

The excess of events in region 1.38 - 1.46 GeV/c^2 over background curve exceeds 8 standard deviations (s.d.) and for 1.60 - 1.66 band - about 4 s.d. This result allows us to interpret bumps as a candidates in pentaquark $uuuu\bar{d}$ states.

It should be mentioned that in region $0.95 < X_f < 1.0$ there is also excess of events over background curve, but their Breit-Wigner parameters $M = 1.512 \pm 0.020$ and $\Gamma = 0.092 \pm 0.032$ GeV/c^2 differ from M_1 and Γ_1. The production of last bump possibly connected with another mechanism - with effect of Δ^{++} presence in both ($p\ \pi^+$) combinations (kinematics of Dalitz plot).

But if baryon $E_{3/2}$ exist and are observed in reaction (17), it should be produced in reaction

$$p\,\mathrm{Be} \rightarrow p\,\pi^+\pi_f^-\pi^0 + \mathrm{X} \qquad (18),$$

with isospin projection 3/2. (f index - means fast). The production and decay of exotic baryon in this case can be illustrated by the following Feynman diagram:

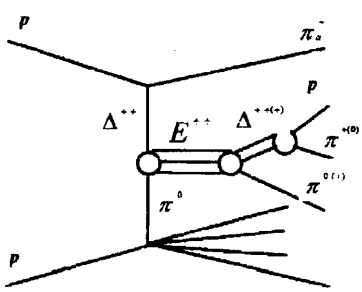

Fig.12

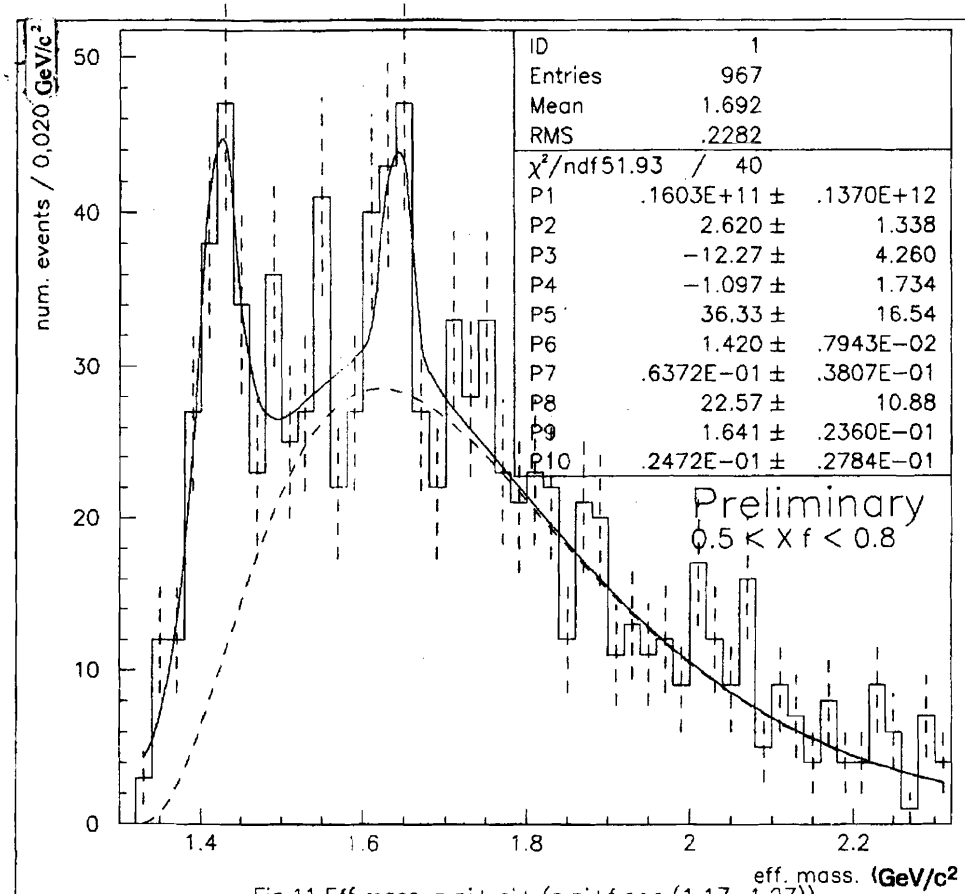

Fig.11.Eff.mass. p pi+ pi+ (p pi+f or s (1.17−1.27))

The data from only one set-up run were used. Out of 888000 events with three charged particles in final state there are 133410 events with 2 positive and 1 negative particles plus γ-spectrometer response. To separate sample corresponding to fig.12 diagram next criteria were used:

a) to improve proton identification - $P(p) \geq 8$ GeV/c ;

b) to select reaction with one π^0 - meson in γ-spectrometer:

$$0.085 \text{ GeV/c}^2 < M(\pi^0) < 0.175 \text{ GeV/c}^2 ;$$

$$66 \text{ GeV/c} < P(p\pi^+\pi^-\pi^0) < 74 \text{ GeV/c}$$

and c) cut for fast π^- - meson (see fig.13).

$$P_L(\pi^-) > P_L(\pi^+) + P_L(\pi^0) + P_L(p) ,$$

L - longitudinal momentum. All cuts fulfilled only for 130 events.

Analysis of $p\pi^+\pi^0(\Delta\pi)$ spectra show that there are no contradiction to production of exotic baryon in 1.4 - 1.5 GeV/c^2 region of mass.

In set of the papers [33,36] were not obseved any proofs on existence of the exotic isobar.

In Table 2 the all data familiar to us on the masses and widths obtained in different reactions have been collected. Analysis of all the data collected in Table 2 gives an opportunity to conclude that there are very serious arguments for exotic baryons with I=5/2 existence. The most probably candidates are ones with M≈1.43,1.55,1.65 and 1.75 GeV/c^2. Mass differences for these candidates have a regular order: ΔM≈100 MeV/c^2. The question is what's the matter - arise.

If I=5/2 exotic baryons exist, according SU(3) symmetry must be 35 plet of baryons [43,44]. In Table 6 the quark contents, quantum numbers and possible decay channels are presented. The decay widths of these resonances can be calculated using dispersion sum rules and it depends on resonance masses very strongly [11](Table 1). In vicinity of threshold of these resonances these states should have small width.

Except $E_{5/2}$ there is now one more candidate in 35 - plet of baryons. This state with M=1956 ± 8 MeV and Γ=27 ± 15 MeV was observed in reaction

$$n + N \rightarrow \Sigma^{*-}(1385)\, k^+ + \cdots \qquad (19)$$

at mean neutron energy $< E_n > \approx 40$ GeV [45]. Because of very narrow width authors [45] interpreted this state as pentaquark baryon candidate with quark content $udds\bar{s}$ and named it - $N_\varphi(1960)$. The SPHINX search [46] showed that N_φ is not produced in diffractive dissociation region. It means that there is no state with proton quantum numbers and if such state exist its it should be 3/2.

Table 6.

Name	Quarks structure	I	Y	S	Decay	Beam
$E_{5/2}$	$uuuu\bar{d}$ $u\to d, \bar{d}\to\bar{u}$	5/2	1	0	$\Delta^{++}\pi^{+}$ $\Delta^{-}\pi^{-}$	
$I_2(S^{*}_{3/2})$	$uuuu\bar{s}$	2	2	1	$\Delta^{++}K^{+}$	
$Y_2(S^{E}_{3/2})$	$uuus\bar{d}$ $ddd\bar{d}s$ $dddd\bar{s}u$	2	0	-1	$\Sigma^{+}\pi^{+}, \Sigma^{*+}\pi^{+}, \Xi^{0}K^{+}\pi^{+}, \Delta^{++}K, \Lambda\pi^{+}\pi^{+},$ $\Delta^{-}K^{0}, \Sigma^{-}\pi^{0}, \Delta^{-}\pi^{+}K^{-}, \Lambda\pi^{0}\pi^{-}$ $\Sigma^{-}\pi^{-}, \Sigma^{*-}\pi^{-}, \Xi^{-}K^{0}\pi^{-}, \Sigma^{0}\pi^{-}\pi^{-}, \ldots$	Σ^{+} Σ^{-} Σ^{-}
$\Xi^{*}_{3/2}$	$ddss\bar{u}$	3/2	-1	-2	$\Sigma^{*-}K^{-}, \Xi^{*-}\pi^{-}, \Xi^{-}\pi^{-}$	Σ^{-}, Ξ^{-}
Ω^{*}_{1}	$dsss\bar{u}$	1	-2	-3	$\Xi^{-}K^{-}, \Omega^{-}\pi^{-}$	Ξ^{-}, Ω
$X^{*}_{1/2}$	$ssss\bar{d}$ $ssss\bar{u}$	1/2	-3	-4	$\Omega^{-}\bar{K}^{0}$ $\Omega^{-}K^{-}$	Ω^{-}
$N^{*}_{3/2}(N_{\varphi}$	$uuus\bar{s}$ $dddd\bar{s}$	3/2	1	0	$\Sigma^{+}K^{+}, \Delta^{++}\varphi, \Delta^{++}\eta, \Delta^{++}\omega \ldots$ $\Sigma^{-}K^{0}, \Delta^{-}\varphi, \Delta^{-}\eta, \Delta^{-}\omega$	Σ^{+} Σ^{-}
Y_1	$uuss\bar{s}$ $ddss\bar{s}$	1	0	-1	$\Xi^{0}K^{+}, \Sigma^{*}\eta, \Sigma^{*+}\varphi, \Delta KKK$ $\Xi^{*-}K^{0}, \Xi^{0}\pi^{-}K^{0}, \Sigma^{*-}\varphi, \Sigma^{0}(\Lambda)\pi^{-}KK,$ $\Delta KKK, \ldots$	Σ^{+} Σ^{-}, Ξ^{-}
$\Xi^{*}_{1/2}$	$sss\bar{s}u$ $sss\bar{s}d$	1/2	-1	-2	$\Omega^{-}K^{+}$ $\Omega^{-}K^{0}, \Xi^{*-}\eta, \Xi^{*-}\omega, \Xi^{*-}\varphi \ldots$	Ξ^{-}, Ω
Ω^{*}_{0}	$ssss\bar{s}$	0	-2	-3	$\Omega^{-}\eta, \Omega^{-}\omega, \ldots$	Ω^{-}

It is possible to estimate masses of SU(3) - 35 - plet members (see Table 7) using as an input masses of $E_{3/2}$ candidates and standard values of masses of constituent *u, d* and *s* quarks. One of such guess for M of N_{φ} equal 1.93 GeV/c^2. Because of crude knowledge of input mass it should be concluded that coincidence of such estimate with experimental value is satisfactory.

Analysis of pole and quarks diagrams, related to members of 35 - plet production shows that in ordinary hadron beams such states should be produced, in general, in many particle reactions at $P_T^2 > 0.3$ (GeV/c)^2 (presence in the t - channel of the baryon exchange, exchange of "heavy" φ, A .... meson trajectories). But the production of exotic baryons can be increased if hyperon beam are used, because their production in this case possible due to π, κ exchange in the t - channel. Up to now there are two hyperon beams: CERN WA89 experiment started; FERMILAB E781 will start next year. There are good perspectives to investigate predictions of different models on 35 - plet members, using hyperon beams. Inclusive production cross sections for several exotic baryons have been calculated in OPER model [11,47] and occurred enough large.

All mentioned before, despite of minor circumstance that the peak in $\Sigma^-\pi^-$ mass distribution are in region of expected values of S_E^{--} mass, give hope to firmly establish S_E^{--} even with not so big statistics, because a large cross section found in OPER model [11,47].

Conclusion.

There are lot of theoretical and experimental works devoted to search for multiquark baryons and particular baryons with I=5/2 discussed here.

Experimental data on this topic is not uniform. In spite of that there are very strong arguments for existence of such baryons it's not possible to make now conclusion about production resonances under search with definite masses and widths. The most probable candidates are ones with masses 1.43, 1.55, 1.65, 1.75 GeV/c^2.

ΔM≈100 MeV/c^2 is puzzle.

The more intensive efforts are needed in this direction using different beams and different final state system (search of 35 - plet members).

Hyperons beams are especially perspective for searches of 35 - plet members.

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Table 7

Name	Massa GeV/c^2			
$E_{5/2}$	1.43	1.55	1.65	1.75
$I_2(S^*_{3/2})$	1.57	1.69	1.79	1.89
$Y_2(S^E_{3/2})$	1.57	1.69	1.79	1.89
$\Xi^*_{3/2}$	1.71	1..83	1.93	2.03
Ω^*_1	1.85	1.97	2.07	2.17
$X^*_{1/2}$	1.99	2.07	2.17	2.27
$N^*_{3/2}(N_\varphi)$	1.71	1.83	1.93	2.06
Y_1	1.85	1.97	2.07	2.17
$\Xi^*_{1/2}$	1.99	2.07	2.17	2.27
Ω^*_0	2.13	2.25	2.35	2.45

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