Figure 2. Two-body weak decay of heavy, stable, neutral dibaryon $H^0 \rightarrow p + \Sigma^0$, $\Sigma^0 \rightarrow \pi^- n$.

Figure 3. Three-body weak decay of heavy, stable, positively charged dibaryon $H^+ \rightarrow p + \pi^+ + \Lambda$, $\Lambda \rightarrow p\pi^-$ (the hypothesis $H^+ n \rightarrow \Sigma^+ \Lambda n$, $\Lambda \rightarrow p\pi^-$).
THE OBSERVATION OF MULTI-QUARK STRANGE METASTABLE AND STABLE STATES

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Abstract

In the metastable state sector the Λ\textsubscript{p}, Λππ and Λpπ resonances found in n+\textsuperscript{12}C-collisions at 7 GeV/c. Preliminary results show that the predicted peaks has been confirmed in p\textsuperscript{12}C collision at 10 GeV/c. In the stable state sector candidates for S=-2 light and heavy dibaryons observed in p+\textsuperscript{12}C collision at 10 GeV/c.

1 Introduction

Quark models with confinement predict the existence of exotic objects as, for instance, glueballs, hybrid states of quarks and gluons as well as multiquark hadrons \cite{1-6}. It is important to stress that the existence of multiquarks is a necessary consequence of modern ideas of non-perturbative QCD vacuum and is a matter of principle to comprehend the characteristics of matter both at microscopic and cosmological levels. New particles or states of matter containing 2-or more strange quarks have inspired a lot of experiments at BNL(AGS), CERN, FNAL, SEBAF, KEK and JINR.

Stable and metastable strange dibaryons were searched a long time ago at LHE JINR, too. A thorough analysis of the merits and demerits of the available detection techniques and data analysis procedures has convinced us that the propane bubble chamber technique is most adequate to the physics problem at the present reconnaissance stage. A reliable identification of dibaryons needs a multivertex kinematic analysis which is in turn is feasible only using 4π-detectors and high precision measurements of the sought objects.

The investigations of multiquark states have been carried out in two directions.

1.1

Multiquark resonance formation via the compression mechanism reduces to the phase transition of normal density super strange hadronic matter revealing itself as multiquark resonances \cite{1-3}.

The problem of experimental examination of multibaryon strange resonances was started at LHE from 1962 up to now. The effective mass spectra of 17 strange multiquark systems were studied for neutron exposure n\textsuperscript{12}C → ΛX at average momentum <p\textsubscript{n}>\textasciitilde7.0 GeV/c, and our group succeeded in finding resonance-like peaks \cite{7-10}(Table 1) only in five of them Λp, Λpπ, ΛΛ, ΛΛp, Λπ\textsuperscript{+}π\textsuperscript{+}. Most significant evidence is included in the Review of Particle Properties.

Up to now, the same group is going on to collect statistics(more 3 time) for strange V\textsuperscript{0} particles on the photographs of the JINR 2m propane bubble chamber exposed to a 10 GeV/c proton beam because it is the necessary to improve a statistical significance of the identified resonance peaks and to search for new strange multiquark resonance states.
Table 1: The effective mass spectra in collisions of 4.0 GeV/c $\pi^-$ and neutrons of a 7.0 GeV/c average momentum with $^{12}$C nuclei, have led to the discovery of the peaks presented below.

| Resonance system | $M$ (MeV/$c^2$) | $\Gamma$ (MeV/$c^2$) | Significance $\sigma$ ($\mu b/^{12}C$) | Bag model predictions |
|------------------|-----------------|----------------------|-----------------------------------|----------------------|
| $\Lambda p$      | 2095.0±2.0      | 7.0±2.0              | 5.70±1.20                         | 55.0±16.0 2110 1^-   |
| $\Lambda p$      | 2181.0±2.0      | 3.2±0.5              | 4.36±1.21                         | 60.0±15.0 2169 1+    |
| $\Lambda p$      | 2223.6±1.8      | 22.0±1.9             | 6.24±1.23                         | 40.0±12.0 2230 0+    |
| $\Lambda p$      | 2263.0±3.0      | 15.6±2.3             | 8.55±1.35                         | 85.3±20.0 2241 2+    |
| $\Lambda p$      | 2356.0±4.0      | 98.6±2.5             | 13.81±1.39                        | 65.0±17.0 2253 1+    |
| $\Lambda p$      | 2129.2±0.3      | 0.7±0.16             | 11.37±1.37                        | 90.0±20.0 2128 1+    |
| $\Lambda p\pi^\pm$ | 2495.2±8.7      | 204.5±5.6            | 12.86±1.68                        | 70.5±15.0 2500 0^-,1^-,2^- |
| $\Lambda\Lambda$ | 2365.3±9.6      | 47.2±15.1            | 4.2±1.40                          | 24.2±7.0 2365 -.,-   |
| $\Lambda\Lambda$ | ≈3568.3         | <60                  | -                                | 16.1±5.2 3570 5/2^-  |
| $\Lambda\pi^+\pi^+$ | 1704.9±0.9      | 18.0±0.5             | 5.3±1.6                           | 19.0±0.6 1710 1/2^-  |
| $\Lambda\pi^+\pi^+$ | 2071.6±4.0      | 172.9±12.4           | 10.3±1.5                          | 88.0±27.0 2120 1/2^-  |
| $\Lambda\pi^+\pi^+$ | 2604.8±4.8      | 85.9±21.5            | 5.2±1.4                           | 31.9±9.0 2615 3/2^-  |

Fig.1(a,b,c) show the preliminary experimental effective-mass spectrum of the $\Lambda\pi$, $\Lambda p$ and $\Lambda p\pi$ produced by pC interaction.

1.2

A simple consideration of symmetry and the properties of color-magnetic interactions argues in favor of increasing binding in three flavor matter-systems containing u,d and s quarks. These objects known as H particles(uuddss). This was first proposed by Jaffe in 1977 using the MIT bag model [3-6]. The possibility that H dibaryon matter may exist in the core of a neutron star was also pointed out. The estimated binding energy of the H particle is model-dependent and ranges from positive (unbound) to negative strong bound states(-650MeV). The heavy isotriplet stable dibaryon H (I=1, J=0+,Y=0,B=2, S=-2) of a 2370 MeV/$c^2$ mass is predicted by the soliton Skirme-like model [1,3].

The search for weak decay channels for stable S=-2,3 dibaryon states is being continued to date. A few events, detected on the photographs of the propane bubble chamber exposed to a 10 GeV/c proton beam, were interpreted as H dibaryons [11-16]. There are two groups of events interpreted as S=-2 stable dibaryons( Table 2):

a) The first group is formed of three neutral, S=-2 stable dibaryons, the masses of which are below $\Lambda\Lambda$ threshold;

b) The second group is formed of neutral and positively charged S=-2 heavy stable dibaryons (Figs.2,3). The masses of all the three dibaryons coincide within the errors are over the $\Lambda\Lambda$, $\Xi N$, $\Lambda\Sigma$ threshold.
Table 2: Mass and weak decay channels for the registration of dibaryons.

| N  | Channel of decay                                                                 | Mass $H$ ($MeV/c^2$) Dibaryon | C.L. of fit % | References                                                                 |
|----|----------------------------------------------------------------------------------|-------------------------------|---------------|---------------------------------------------------------------------------|
| 1  | $H^0 \to \Sigma^- p$                                                            | 2172 ± 15                     | 99            | Z.Phys.C 39, 151(1988).                                                   |
| 2  | $H^0 \to \Sigma^- p, \Sigma^- \to n\pi^-$                                      | 2146 ± 1                      | 30            | JINR RC,                                                                  |
|    | $H^0 \to H^0(2146)\gamma$                                                       | 2203 ± 6                      | 51            | N 1(69)-95-61,1995.                                                      |
| 3  | $H^0 \to \Sigma^- p, \Sigma^- \to n\pi^-$                                      | 2218 ± 12                     | 69            | Phys.Lett B235(1990),208.                                                |
| 4  | $H^0 \to \Sigma^- p, \Sigma^- \to n\pi^-$                                      | 2385 ± 31                     | 34            | Phys.Lett B316(1993),593.                                                |
| 5  | $H^+ \to p\pi^0\Lambda^0, \Lambda^0 \to p\pi^-$                               | 2376 ± 10                     | 87            | Phys.Lett B316(1993),593.                                                |
| 6  | $H^+ \to p\pi^0\Lambda^0, \Lambda^0 \to p\pi^-$                               | 2580 ± 108                    | 86            | Nucl.Phys.75B(1999),63.                                                  |
|    | $H^+ \to p\pi^0\Lambda^0, \Lambda^0 \to p\pi^-$                               | 2410 ± 90                     | 6             |                                                                          |
| 7  | $H^+ \to p\pi^0\Lambda^0, \Lambda^0 \to p\pi^-$                               | 2448 ± 47                     | 73            | JINR Com.(2002)                                                          |
|    | $H^+ \to p\pi^0\Lambda^0, \Lambda^0 \to p\pi^-$                               | 2488 ± 48                     | 72            | E1-2001-265                                                              |

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Figure 2.

a) The effective mass spectrum, showing peaks approximately at 2095, 2181, 2263 MeV/c².
b) The Ann effective mass spectrum, showing peaks approximately at 1704, 2071, 2604 MeV/c².
c) The Ann effective mass spectrum, showing peaks approximately at 2600 MeV/c².