STRANGE MULTIBARYON STATES WITH $\Lambda$ HYPERON SYSTEMS IN pA COLLISION AT 10 GeV/c

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Abstract

Experimental data from the 2m propane bubble chamber have been analyzed for exotic baryon states search. A number of peculiarities were found in the effective mass spectra of: $\Lambda\pi^+$ (from PDG), $\Lambda p$, and $\Lambda pp$ subsystems. A few events detected on the photographs of the propane bubble chamber exposed to a 10 GeV/c proton beam, were interpreted as $S=-2$ $H^0$ light ($< M_{\Lambda\Lambda}$) and heavy $H^{0,+,+}$ dibaryons. New event, detected on the photographs of the propane bubble chamber was interpreted as heavy $H^+(2488)$ dibaryon by two weak decay channels of $K^-pp$ or $\Sigma^+pp\pi^-$.

1 Introduction

Already back in 1977 Jaffe[1], using the bag model in which confined colored quarks and gluons interact as in perturbative QCD, suggested the existence of multi-quark states, glueballs and hybrids, but until now none is established. Very recently, the existence of discrete nuclear bound states of $K_0 p$ has been predicted with phenomenological Kaonic Nuclear Cluster (KNC) model which is based on the experimental information on the $K_0N$ scattering lengths, kaonic hydrogen atom and the $\Lambda^*(1405)$ resonance[2].

A number of peculiarities were found in the effective mass spectrum of $\Lambda\pi^+$ (from PDG), $\Lambda p$ and $\Lambda pp$ subsystems and some above peaks were conformed with results from FOPI, GSI and E471, KEK. A few events detected on the photographs of the propane bubble chamber exposed to a 10 GeV/c proton beam, were interpreted as $S=-2$ $H^0$ light ($< M_{\Lambda\Lambda}$) and heavy $H^{0,+,+}$ dibaryons[4] and were identified by hypothesis in weak decay channels of $\Sigma^-p, \Lambda p\pi^0, \Lambda p\pi^-, \Sigma^+p\pi^-$ and $K^-pp$.

2 Method

The full experimental information of more than 700000 stereo photographs or $10^6$ p+propane inelastic interactions are used to select the events with $V^0$ strange particles. The masses of the observed 8657-events with $\Lambda$ hyperon 4122-events with $K_0^0$ meson are consistent with their PDG values[5]. The experimental total cross sections are equal to 13.3 and 4.6 mb for $\Lambda$ and $K_0^0$ production in the p+C collisions at 10 GeV/c. From published article one can see that the experiment is satisfactorily described by the FRITIOF model. The experimental $\Lambda/\pi^+$ ratio in the pC reaction is approximately two times larger than this ratio from pp reactions or from simulated pC reactions by FRITIOF model at the same energy [6]. The resonance with similar decay properties $\Sigma^{++}(1382) \rightarrow \Lambda\pi^+$ registered as test for this method (Fig. 1a). The decay width is equal to $\Gamma=40$ MeV/$c^2$, $\Delta M/M = 0.7$ in range of $\Sigma^+(1382)$ invariant mass. Just the cross section of $\Sigma^+(1382)$
production (540 simulated events) can estimated by FRITIOF model which is approximately equal to 1 mb for p+C interaction.

3 \( (\Lambda, p) \) spectra

Figure 1b shows the invariant mass of all \( \Lambda p \) combinations(13103) with bin sizes 10 MeV/c² without cuts. There are small enhancements in mass regions of 2100, 2150, 2225 and 2353 MeV/c²(Fig.1b). Their excess above background by the second method is 6.9, 4.9, 3.8 and 2.9 S.D., respectively. There is also a small peak in 2225( 2.2 s.d.) MeV/c² mass region. The peak of 2180 MeV/c² was agreed with the peak from reports of FOPI collaboration. The \( \Lambda p \) effective mass distribution for 2025 combinations with relativistic protons over a momentum of \( P > 1.65 \, \text{GeV/c} \) is shown in Figure 2a. The solid curve is the 6-order polynomial function(\( \chi^2/n.d.f=205/73 \)). Back- grounds for analysis of the experimental data are based on FRITIOF and the polynomial method. There are significant enhancements in mass regions of 2155(2.6 S.D.), 2225(4.7 S.D.), 2280(4.2 S.D.), 2363(3.6 S.D.) and 2650 MeV/c²(3.7 S.D.). These peaks with relativistic protons and with identified protons are conformed.

The \( \Lambda pp \) effective mass distribution for 3401 combinations for identified protons with a momentum of \( P < 0.9 \, \text{GeV/c} \) is shown in Figure 2b. The solid curve is the 6-order polynomial function(\( \chi^2/n.d.f=245/58 \)). The backgrounds for analysis of the experimental data are based on FRITIOF and the polynomial method. There are significant enhancements in mass regions of 3138(6.1 S.D.) and 3320(5.1 S.D.). There are small enhancements in mass regions of 3087(2.2 S.D.), 3199(3.3 S.D.), 3440(3.9 S.D) and 3652 MeV/c²(2.6 S.D.). These peaks in ranges of 3138 and 3199 MeV/c² were agreed with registered peaks from reports of E471 experiment, PS,KEK.

4 New observation for heavy S=-2, \( H^+ \rightarrow K^- pp \) dibaryon

Searches for stable S=-2 dibaryon states are going on[4](Table 1). New candidates for S=-2 \( H^+ \) dibaryon shows in Fig. 2c. The appearance of its first part, 15.8 cm long, with a momentum of \( p_{H^+} = 1.2 \pm 0.12 \, \text{GeV/c} \) and average relative ionization more than \( I/I_0 > 2 \). The second part is due to two stopped protons. The momentum of negative \( K^- \) is equal to 0.56±0.03 GeV/c(\( I/I_0 \approx 1.5 \)). The kinematic threshold does not permit (\( \sqrt{s} = 1.96 \, \text{GeV/c} \)) imitating the reaction with deuteron including fermi motion. The \( H^+ \rightarrow K^- pp \) hypothesis fits the event with \( \chi^2(1V-3C)=2.6 \), C.L. = 28%, and \( M_{H^+}=2482±48 \, \text{MeV/c}² \). There is also possibility for fit by hypothesis with decay channel \( H^+ \rightarrow \Sigma^+ \pi^- p \) which have much less probability than above hypothesis.

5 Conclusion

• The experimental ratio for average multiplicities of \( \Lambda/\pi^+ \) in the pC reaction is approximately two times larger than this ratio from pp reactions or from simulated pC reactions by FRITIOF model at momentum 10 GeV/c[5].
• The invariant mass of $\Lambda\pi^+$ spectra has observed significant enhancement in invariant mass range of 1382 MeV/c² ($\Sigma^{*+}$ from PDG) as a test for this method.
• A number of important peculiarities were observed in $pA \rightarrow \Lambda p X$ reactions in the effective mass spectra for exotic states with decay modes: $\Lambda p$ and $\Lambda p p$.
• A few events were registered by hypothesis of $S=-2$ light $H^0$ and heavy $H^{0:+}$ dibaryons by weak decay channels to $(\Sigma^{−}, p)$, $(\Lambda, p, \pi^0)$, $(\Sigma^+ p \pi^-)$, $(K^−, p, p)$.

![Graphs](image.png)

Figure 1: a) The $\Lambda\pi^+$ spectrum; b) All $\Lambda p$ comb. c) $\Lambda p$ spectrum for identified protons. The dashed histogram is simulated events by FRITIOF.

References

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Table 1: Mass and weak decay channels for the registered dibaryons.

| Channel of decay | Mass $H^0$ (MeV/c²) | C.L. of fit | References |
|------------------|----------------------|------------|------------|
| $H^0 \to \Sigma^- p$ | 2172 ± 15 | 99 | Z.Phys.C 39, 151 (1988). |
| $H^0 \to \Sigma^- p, \Sigma^- \to n\pi$ | 2146 ± 1 | 30 | JINR RC, |
| $H^0 \to H^0(2146)\gamma$ | 2203 ± 6 | 51 | N 1(69)-95-61, 1995. |
| $H^0 \to \Sigma^- p, \Sigma^- \to n\pi$ | 2218 ± 12 | 69 | Phys.Lett B235 (1990), 208. |
| $H^0 \to \Sigma^- p, \Sigma^- \to n\pi$ | 2385 ± 31 | 34 | Phys.Lett B316 (1993), 593. |
| $H^+ \to p\pi^+ \Lambda^0, \Lambda^0 \to p\pi^-$ | 2376 ± 10 | 87 | Phys.Lett B316 (1993), 593. |
| $H^+ \to p\pi^+ \Lambda^0, \Lambda^0 \to p\pi^-$ | 2580 ± 108 | 86 | Nucl.Phys.75B (1999), 63. |
| $H^+ \to p\pi^+ \Lambda^0, \Lambda^0 \to p\pi^-$ | 2410 ± 90 | 6 | E1-2001-265 |
| $H^+ \to p\pi^+ \Lambda^0, \Lambda^0 \to p\pi^-$ | 2448 ± 47 | 73 | JINR Com. (2002) |
| $H^+ \to p\pi^+ \Lambda^0, \Lambda^0 \to p\pi^-$ | 2488 ± 48 | 72 | E1-2001-265 |

Figure 2: a) $\Delta p$ spectrum for relativistic protons; b) $\Lambda pp$ spectrum for identified protons; c) The weak decay for $H^+ \to K^- pp$. The dashed histogram is simulated events by FRITIOF.