Study of narrow baryon resonance decaying into $K^0_s p$ in $pA$-interactions at 70 GeV/c with SVD-2.

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The inclusive reaction $pA \rightarrow pK^0_s + X$ was studied at IHEP accelerator with 70 GeV proton beam using SVD-2 detector. Two different samples of $K^0_s$, statistically independent and belonging to different phase space regions were used in the analyses and a narrow baryon resonance with the mass $M = 1523 \pm 2(\text{stat.}) \pm 3(\text{syst.})$ MeV/c$^2$ was observed in both samples of the data.

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INTRODUCTION

In last three years the observation of a narrow baryon state named $\Theta^+$ predicted by Diakonov, Petrov and Polyakov has been reported by a large number of experiments in the $nK^+$ or $K^0_s p$ decay channels. Several experiments, mostly at high energies, did not confirm the existence of $\Theta^+$. The present situation and complete list of references to positive and null results can be found in the reviews[2, 3, 4]. Here we present a new study of the reaction $pN \rightarrow \Theta^+ + X$, $\Theta^+ \rightarrow pK^0_s K^0_s \rightarrow \pi^+ \pi^-$, with two independent samples of $K^0_s$ used[5].

THE SVD-2 APPARATUS

A detailed description of SVD-2 detector and its trigger system can be found elsewhere[6, 7]. The components of the detector used in current analyses are: the high-precision microstrip vertex detector with active(Si) and passive(C,Pb) nuclear targets; large aperture magnetic spectrometer; multicell threshold Cherenkov counter. For the analyses we use data obtained in the 70 GeV proton beam of IHEP accelerator at intensity $\approx (5 \div 6) \cdot 10^5$ protons/cycle. The total statistics of $5 \cdot 10^7$ inelastic events was collected. The sensitivity of this experiment for inelastic $pN$-interactions taking in account the triggering efficiency was 1.6 nb$^{-1}$.

EVIDENCE FOR A BARYONIC STATE DECAYING TO $K^0_s p$

SVD-2 has performed the searches of $\Theta^+$-baryon in two independent samples of the data selected by the $K^0_s$ decay point.

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For analysis II, the "distant" $K^0_s$ (decay region is 35 – 600 mm, outside the vertex detector) were used.

![Graph](https://example.com/graph.png)
candidates with $p_{\pi} \leq 20$ $MeV/c^2$ were found in the selected events. Proton candidates were selected as positively charged tracks with a number of spectrometer hits more than 12 with a momentum $8$ $GeV/c$. Pions of such energies should leave a hit in the Cherenkov counter, therefore absence of hits in TCC was also required. Effective mass of the $K^0_s p$ system is plotted in Fig.2. An enhancement is seen at the mass $M = 1523.6 \pm 3.1$ $MeV/c^2$ with a $\sigma = 12.9 \pm 2.5$ $MeV/c^2$ with statistical significance of 5.6$\sigma$. It was verified that observed $K^0_s p$-resonance can not be a reflection from other (for example $K^{*\pm}(892)$ or $\Lambda^0$) resonances. The mechanism for producing spurious peak around 1.54 $MeV/c^2$ involving $K^0_s$ and $\Lambda$ decays overlap was also checked. The events were scanned using SVD-2 event display and no "ghost" tracks were found. It is impossible to determine the strangeness of this state in such inclusive reaction, however we did not observe any narrow structure in ($\Lambda\pi^+$) invariant mass spectrum in 1500÷1550 $MeV/c^2$ mass area (Fig.3a). When applying a different cut on $\Lambda$ momentum, $p_{\Lambda} < 6$ $GeV/c$, we observe a structure near 1480 $MeV/c^2$ (Fig.3b). This peak may correspond to the $\Sigma(1480)$, marked as one-star resonance in the PDG review.[6]

THE FURTHER ANALYSIS OF THE RESONANCE PROPERTIES

Our search for $\Theta^+$-particle is an inclusive experiment with a significant background contribution. We have made an attempt to apply a subtraction method to investigate $\theta$ creation region in terms of $X_F$. An effective mass distribution in a peak region was fitted with a sum of background (B) and Gaussian functions. Background was taken as a product of a threshold function and a second degree polinomial, $B(m) = P2(m)(1 - e^{-P2(m - m^0)})$. All the fit parameters were given reasonable seeds but no boundaries, to prove a fit stability. We have chosen a peak region as a gaussian mean $\pm 2$ gaussian $\sigma$. A number of effective background events under the peak, $N_{B \text{peak}}$, was evaluated by integrating background function over the peak region. $X_F$ distributions were plotted separately for a peak and an out-of-peak regions ("wings"); the latter ranged from the threshold to the 1.7 $GeV$ with a peak region cut out, and a result was scaled to a $N_{B \text{peak}}$. Assuming that the background characteristics are uniform, we subtract "wings" distribution from the peak one. Choosing more narrow "wings" does not change the general shape of distribution (a rise at $X_F = 0$) but shows larger fluctuations. These operations were performed over the data from both analyses. Acceptance corrections were taken from the simulations and were specific for each type of analysis. The results are shown at figs.4 and 5. We plot also normalized curves of the predictions made in a Baranov Regge-based model.[9] In this model, overall distribution comes from the sum of quark fragmentation(bell-shaped at $X_F = 0$) and diquark one(seagull-shaped), taken with somewhat arbitrary weights. In [9] the weights are taken as 1:10, as coming from the analysis of non-exotic baryons creation. Our data may indicate some favoring to the quark fragmentation part of the model.

Note that the Analysis II has a specific narrow acceptance in X due to the proton momentum restrictions. We "projected" the $X_F$-result of Analysis I to a second one to check the consistence of our observations. For that, the inverse acceptance correction for Analysis II was ap-
The re-evaluation of the theta creation cross section gives \( \sigma \times BR(\Theta \rightarrow K^0 p) = 6 \pm 3 \text{ mb/nucleon} \) for \( X_F > 0 \). It differs significantly from our previous estimates\[6\]. The main reason is an unusual form of \( X_F \) distribution, assumed flat in our first publications. Taking into account our situation of using inclusive data, and undiscovered yet mechanism of theta particle creation (that means difficulties in acceptance evaluation), we believe that the cross section value is subject to future investigations.

In conclusion, SVD-2 observes in two independent samples a signal in \( pK^0 \) mass distribution with \( M = (1523 \pm 2 \pm 3)\text{MeV}/c^2, \Gamma < 14\text{MeV}/c^2 \), significance of \( \approx 8\sigma, \sigma \times BR(\Theta \rightarrow K^0 p) = 6 \pm 3 \text{ mb/nucleon} \) for \( X_F > 0 \). \( X_F \) peaks at zero with \( < |X_F| > \approx 0.1 \), that agrees qualitatively to a Regge-based model suggested by Baranov\[9\]. While in agreement with evidences of \( \Theta^+ \) observation, there is no direct contradiction to null results in hadron-hadron fixed target collisions, mainly due to different acceptances at \( X_F \approx 0 \).

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