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New data on the $p + N \longrightarrow [\Sigma^0 K^+] + N$ reaction at $E_p = 70$ GeV and the search for exotic baryons

The SPHINX Collaboration (IHEP-ITEP)

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Abstract. New data for the diffractive reaction $p + N \rightarrow [\Sigma^o K^+] + N$ at E_p=70 GeV were obtained with partially upgraded SPHINX setup. The data are in a good agreement with the results of our previous study of this reaction. In the mass spectrum $M(\Sigma^o K^+)$ a structure at the threshold region with a mass ∼1810 MeV and a distinct $X(2000)$ peak with $M = 1989 \pm 6$ MeV and $\Gamma = 91 \pm 20$ MeV are observed. Unusual features of the massive $X(2000)$ state (narrow decay width, anomalously large branching ratio for the decay channel with strange particle emission) make it a serious candidate for cryptoexotic pentaquark baryon with hidden strangeness $|qqqs\bar{s}>$. We also present new results on the narrow threshold structure X(1810) with $M = 1807 \pm 7$ MeV and $\Gamma = 62 \pm 19$ MeV which is produced in the region of very small P_T^2 <0.01 GeV^2. The possibility of the Coulomb production mechanism for X(1810) is discussed.

PACS. 13.85.Fb Inelastic scattering: two particle find state – 25.40.Ve Other reactions above meson production thresholds (energies >400 MeV)

1 Introduction

Extensive studies of the diffractive baryon production and search for cryptoexotic pentaquark baryons with hidden strangeness ($B_\phi = |qqqs\bar{s}>$, here $q = u, d$ quarks) are being carried out by the SPHINX Collaboration at IHEP accelerator with 70 GeV proton beam. This program was described in detail in reviews [1].

The cryptoexotic baryons of $|qqqs\bar{s}>$ type do not have external exotic quantum numbers and their complicated internal valence quark structure can be established only indirectly, by examination of their unusual dynamic properties which are quite different from those for ordinary $|qqq>$ baryons. Examples of such anomalous features are listed below (see [1] for more details):

1. The dominant OZI allowed decay modes of baryons $|qqqs\bar{s}>$ are the ones with strange particles in the final state (for ordinary isobars such decays have branching ratios at the percent level).

2. The cryptoexotic baryons $|qqqs\bar{s}>$ can possess both large masses ($M > 1.8 - 2.0$ GeV) and narrow decay widths ($\Gamma \leq 50 - 100$ MeV). This is due to a complicated internal color structute of these baryons, which leads to a significant quark rearrangement of color clusters in the decay process, and due to a limited phase space for the OZI allowed $B_\phi \rightarrow YK$ decays. At the same time, typical decay widths for the well established $|qqq>$ isobars with similar masses are $\gtrsim 300$ MeV.

As was emphasized in a number of papers [1-6], diffractive production processes with Pomeron exchange offer new tools in searches for the exotic hadrons. Originally, the interest was concentrated on the model of Pomeron with small cryptoexotic ($qq\bar{q}\bar{q}$) component [2,3]. In modern notions Pomeron has a significant multigluon component owing to which exotic hadrons can be produced in gluon-rich diffractive processes.

The Pomeron exchange mechanism in diffractive production reactions can induce coherent processes on the target nucleus. In such processes the nucleus acts as a whole. Coherent processes can be easily identified by studying the transverse momentum spectra of the final state particle systems. They manifest themselves as diffractive peaks with large values of the slope parameters determined by the size of the nucleus: $dN/dP_T^2 \propto exp(-bP_T^2)$, where $b \simeq 10A^{2/3}$ GeV^{-2}. Owing to the difference in the absorption of single-particle and multiparticle objects in nuclei, coherent processes could serve as an effective tool for the separation of resonance against non-resonant multiparticle background (see, e.g. [7;1]).

A study of several proton-induced diffractive production processes $p+N \to [Y^o K^+]+N$, $p+N \to [pK^+K^-]+N$, $p+N \to [pp\bar{p}]+N$, $p+N \to [p\pi^+\pi^-]+N$ and several other reactions, was carried out by the SPHINX Collaboration in a 70 GeV proton beam with a polyethylene target [8-20]. The SPHINX detector used in these measurements includes a wide-apperture magnetic spectometer with scintillator hodoscopes, proportional wire chambers, drift chambers, drift tubes and a multichannel γ-spectrometer made of total absorption lead glass detectors. Charged particles of the final state were identified with RICH spectrometer and two multicell gas threshold Čherenkov counters C_1 and C_2. A detailed description of the apparatus can be found in [8].

As it is seen from dN/dP_T^2 spectra for the above mentioned processes there are strong narrow forward cones in these distributions with the slope $b \geq 40 \div 50$ GeV^{-2} which corresponds to a coherent diffractive production on carbon nuclei. For identification of the coherently produced events, we used transverse momentum cut $P_T^2 < 0.075 \div 0.1$ GeV^2. With this cut non-coherent background in the event sample can be as large as $30 \div 40\%$. It is possible to reduce this background with more stringent P_T^2 cut at the expense of lower signal statistics.

2 Previous data on the coherent diffractive reaction $p + C \to [\Sigma^o K^+] + C$

One of the major results obtained with the SPHINX setup was a study of the $\Sigma^o K^+$ system produced in the diffractive process

$$p + N(A) \to [\Sigma^o K^+] + N(A). \qquad (1)$$
$$\hookrightarrow \Lambda\gamma$$
$$\hookrightarrow p\pi^-$$

Here N is a nucleon (A is a nucleus for coherent reaction). The data for reaction (1) were obtained in two different runs at the SPHINX facility:

a) the former with an old version of this setup ("old run", [8,13,16,17]);

b) the latter with a partially upgraded SPHINX apparatus — with new photon spectrometer, additional drift tubes, new trigger system ("new run", [19-21]). As a result of this upgrade the detection efficiency and purity of Λ and Σ^o events were significantly increased.

The main results of these measurements can be summarized as follows:

1. Old [13, 16-18] and new [19-21] data from the coherent diffractive reaction (1) were obtained under different experimental conditions, with a significantly modified apparatus, with different background and systematics. Nevertheless, the $\Sigma^o K^+$ invarinat mass spectra from the two runs are in a good agreement, which makes them more reliable.

2. The combined mass spectrum $M(\Sigma^o K^+)$ for the coherent reaction (1) from the old and new data (with $P_T^2 < 0.1$ GeV^2) is presented in Fig. 1. This spectrum is dominated by the peak with parameters $M = 1997 \pm 7$ MeV and $\Gamma = 91 \pm 17$ MeV. We will designate this baryonic state as $X(2000)$.

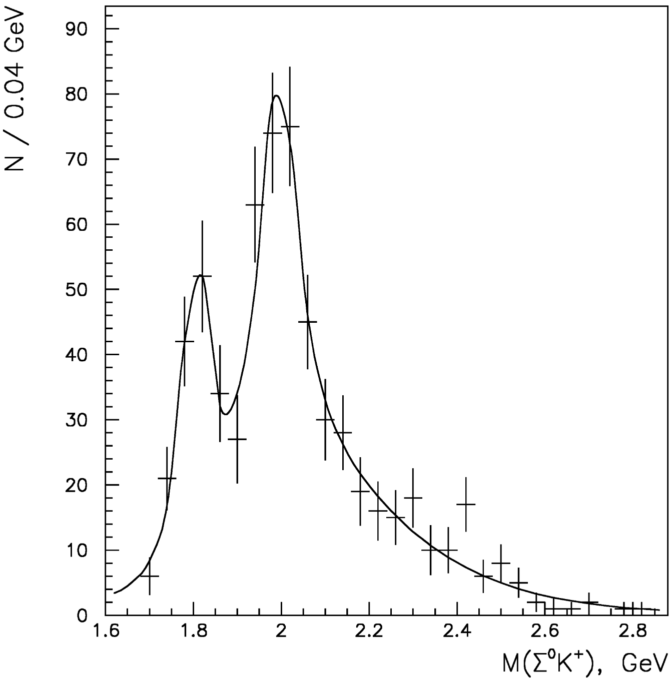

Fig. 1. Combined mass spectrum $M(\Sigma^0 K^+)$ for coherent diffractive reaction (1) in old and new runs at the SPHINX setup ($P_T^2 < 0.1$ GeV^2). The parameters of $X(2000)$ peak in this spectrum are: $M = 1997 \pm 7$ MeV; $\Gamma = 91 \pm 17$ MeV

3. There is also some near threshold structure in this $M(\Sigma^o K^+)$ spectrum in the region of $\sim$ 1800 MeV (see Fig. 1). Such a shape of the $\Sigma^o K^+$ mass spectrum (with an additional structure near the threshold) proves that the X(2000) peak cannot be explained by a non-resonant Deck-type diffractive singularity. Therefore, most likely this peak has a resonant nature.

A strong influence of P_T^2 cut for the production of this X(1810) state was established: this structure is produced only at very small P_T^2 ($\lesssim 0.01 \div 0.02$ GeV^2) — see below.

4. In studying the reactions

$$p + C \to [p\pi^+\pi^-] + C \qquad (2)$$
$$\to [\Delta(1232)^{++}\pi^-] + C \qquad (3)$$

under the same kinematical conditions as with process (1) the search for other decay channels of the X(2000) baryon was performed [16,17]. No peaks in 2 GeV mass range were observed in the mass spectra of $p\pi^+\pi^-$ and $\Delta(1232)^{++}\pi^-$ systems produced in reactions (2) and (3), respectively. Lower limits on the corresponding decay branching ratios were set to be (at the 95% C.L.):

$$R_1 = \frac{BR[X(2000)^+ \to (\Sigma K)^+]}{BR[X(2000)^+ \to (p\pi^+ p^-)]} > 7.8, \qquad (4)$$

$$R_2 = \frac{BR[X(2000)^+ \to (\Sigma^0 K^+)]}{BR[X(2000)^+ \to (p\pi^+\pi^-)]} > 2.6 \qquad (5)$$

$$R_3 = \frac{BR[X(2000)^+ \to (\Sigma K)^+]}{BR[X(2000)^+ \to (\Delta(1232)\pi)^+]} > 0.83 \qquad (6)$$

To obtain these limits the following isotopic relations between the decay amplitudes of a $I = 1/2$ particle were used:

$$BR[X^+_{I=1/2} \to \Sigma^0 K^+] = \frac{1}{3} BR[X^+_{I=1/2} \to (\Sigma K)^+] \qquad (7)$$

$$BR[X^+_{I=1/2} \to \Delta^{++}\pi^-] = \frac{1}{2} BR[X^+_{I=1/2} \to (\Delta\pi)^+] \qquad (8)$$

(the $X(2000)$ state belongs to an isodoublet since it is produced in the diffractive dissociation of a proton)

The ratios $R_1 - R_3$ of the widths of the $X(2000)$ decays into strange and nonstrange particles are much larger than those for ordinary (qqq)-isobars characterized by R at a percent level [16,22].

A narrow width of the $X(2000)$ baryon state as well as anomalously large branching ratios for its decay channels with strange particle emission (large values of $R_1 - R_3$) are the reasons to consider this state as a serious candidate for cryptoexotic baryon with a hidden strangeness $|uuds\bar{s}>$.

3 New analysis of the data with partially upgraded SPHYNX spectrometer

In what follows we present the results of a new analysis of the data obtained in the run with the partially upgraded SPHINX spectrometer where conditions for Λ and Σ^o separation were greatly improved as compared to an old version of this setup. The key element of a new analysis consists in the detailed study of the $\Sigma^o \to \Lambda + \gamma$ decay separation.

The identification of single photons from $\Sigma^o \to \Lambda + \gamma$ decay is a rather complicated problem. The photon spectrum from this decay in the lab frame is soft enough ($E_\gamma \lesssim 6$ GeV). There is a significant background due to the imitation of single photons in the γ spectrometer by the remaining hadron showers, accidentals, etc. To reduce this background a special procedure was developed with stringent criteria for the single photon separation.

The γ spectrometer is used for the detection of one and only one photon from reaction (1) and at the same time as a guard system to suppress the events with additional photon signals ("veto condition"). But this condition must be used with some care: if the veto requirement is too soft, the background under Σ^o peak in $\Lambda\gamma$ spectrum will be significant, but if this requirement is too strong, then it reduces the efficiency of photon detection due to a random veto by very soft accidental signals.

There is also an additional guard system with lead-scintillator sandwich counters which covers the aperture outside the combined magnetic-photon spectrometer of the SPHINX setup [8]. This system helps to separate diffractive exclusive processes and to suppress the background from inelastic processes with $\pi^0 \to \gamma\gamma$ with lost photons.

For the separation of reaction (1) we studied the process

$$p + N(A) \to [\Lambda\gamma K^+] + N(A) \qquad (9)$$

with standard criteria for the identification of $\Lambda \to p\pi^-$ decays and K^+-mesons (see [8,10,13,23]). To separate the single photons in (9) we used one of three possible requirements:

1a) there is one and only one photon with $E_\gamma > 1.5$ GeV in the γ spectrometer (we will designate this condition as "the soft photon cut");

1b) there is one photon with $E_\gamma > 1.5$ GeV and no additional photons with $E_\gamma > 1.0$ GeV ("the intermediate photon cut");

1c) there is one photon with $E_{\gamma_1} > 1.4$ GeV, no additional photons with $E_\gamma > 1.0$ GeV and no more than one photon with $1 > E_{\gamma_2} \gtrsim 0.3$ GeV if $m(\gamma_1\gamma_2) < 100$ MeV; the last condition eliminates the events with $\pi^0 \to \gamma_1\gamma_2$ ("the strong photon cut").

Furthermore, together with one of the requirements 1(a-c), we use additional cuts to isolate reaction (9):

2) the elastic condition $65 < E_\Lambda + E_K + E_\gamma < 75$ GeV;

3) the minimal distance $l > 15$ cm between the vertex of isolated photon shower in the γ spectrometer and the closest hadron track;

4) the rejection of the events with a single photon cluster registered in the high rate lead glass counters arround the beam hole in the γ spectrometer;

5) the reduced $\chi^2 < 5$ for the photon identification of shower.

Conditions 2) and 4) reduced accidentals and inelastic background. Conditions 3) and 5) suppressed the background from hadron showers.

The effective mass spectra for $M(\Lambda\gamma)$ in (9) for soft (1a), itermediate (1b) and strong (1c) photon cuts are presented in Fig. 2. A peak corresponding to $\Sigma^o \to \Lambda\gamma$ decay is clearly seen in all these spectra, allowing for identification of reaction (1). It is evident from this figure that the background under the Σ^o peak is increased for softer photon cuts, but at the same time the efficiency for photon and Σ^o detection is also increased. This background is more important for the region of small $M(\Sigma^o K^+)$ and small P_T^2 in reaction (1). Thus, the study of different kinematical regions of (1) can be made with different photon cuts.

The effective mass spectra $M(\Sigma^o K^+)$ in (1) for all P_T^2 are presented in Fig. 3 (we used the soft photon cut for this figure). The peak of $X(2000)$ baryon state with $M = 1986 \pm 6$ MeV and $\Gamma = 98 \pm 20$ MeV is seen very clearly in these spectra with a good statistical significance. Thus, the reaction

$$p + N \to \underbrace{X(2000)}_{\hookrightarrow \Sigma^o K^+} + N, \qquad (10)$$

is well separated in the SPHINX data. We estimated the cross section for the $X(2000)$ production in (10):

$$\sigma[p + N \to X(2000) + N] \cdot BR[X(2000) \to \Sigma^o K^+] = 95 \pm 20 \text{ nb/nucleon} \qquad (11)$$

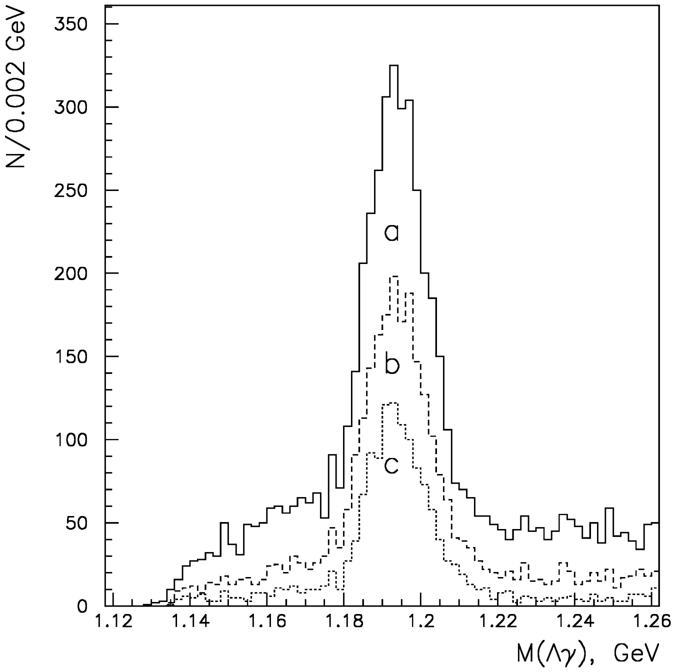

Fig. 2. Selection of the reaction $p + N \rightarrow [\Sigma^0 K^+] + N$ in the study of invariant mass spectra $M(\Lambda\gamma)$ in reaction $p + N \rightarrow [\Lambda\gamma K^+] + N$ with different photon cuts: (a) soft photon cut; (b) intermediate photon cut; (c) strong photon cut (see text)

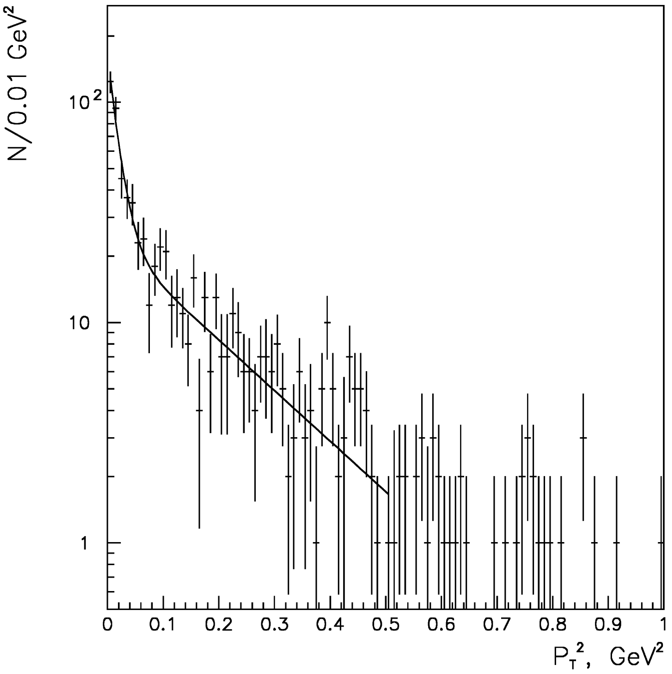

Fig. 4. dN/dP_T^2 distribution for the diffractive production reaction $p + N \rightarrow X(2000) + N$. The distribution is fitted in the form $dN/dP_T^2 = a_1 \cdot exp(-b_1 P_T^2) + a_2 exp(-b_2 P_T^2)$ with parameters $b_1 = 63 \pm 10$ GeV^{-2}; $b_2 = 5.8 \pm 0.6$ GeV^{-2}

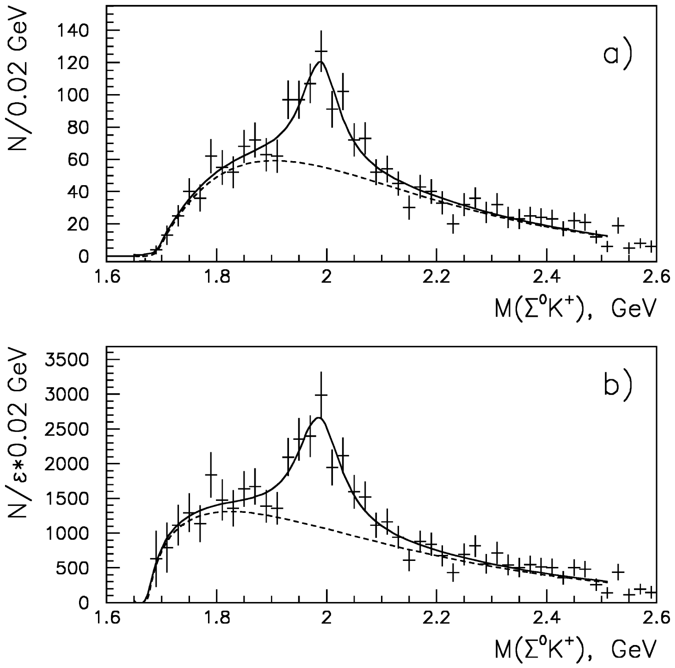

Fig. 3. Invariant mass spectra $M(\Sigma^0 K^+)$ in the diffractive reaction $p + N \rightarrow [\Sigma^0 K^+] + N$ for all P_T^2 (with soft photon cut): a) measured mass spectrum after sideband subtruction of the background under Σ^0 peak in Fig. 2a; b) the same mass spectrum weighted with the efficiency of the setup. Parameters of $X(2000)$ peak are: $M = 1986 \pm 6$ MeV; $\Gamma = 98 \pm 21$ MeV

(with respect to one nucleon under the assumption of $\sigma \propto A^{2/3}$, e.g. for the effective number of nucleons in carbon nucleus equal to 5.24). The parameters of X(2000) peak are not sensitive to different photon cuts, as is seen from Table 1. The dN/dP_T^2 distribution for reaction (10) is shown in Fig. 4. From this distribution the coherent diffractive production reaction on carbon nuclei is identified as a diffraction peak with the slope $b \simeq 63 \pm 10$ GeV^{-2}. The cross section for coherent reaction is determined as

$$\sigma[p + C \rightarrow X(2000)^+ + C]_{\text{Coherent}} \cdot BR[X(2000)^+ \rightarrow \Sigma^0 K^+] = 260 \pm 60 \text{ nb/C nuclei.} \qquad (12)$$

We must bear in mind that it is more convinient to use other relations for the cross sections

$$\sigma[p + N \rightarrow X(2000)^+ + N] \cdot BR[X(2000)^+ \rightarrow (\Sigma K)^+] = 285 \pm 60 \text{ nb/nucleon,} \qquad (13)$$

$$\sigma[p + C \rightarrow X(2000)^+ + C] \cdot BR[X(2000)^+ \rightarrow (\Sigma K)^+] = 780 \pm 180 \text{ nb/nucleus,} \qquad (14)$$

which were obtained from (11) and (12) using branching ratio (7).

The errors in the values of (11)-(14) are statistical only. Additional systematic errors are about ±20% due to uncertainties in the cuts, in the Monte Carlo efficiency calculations and in the absolute normalization.

In the mass spectra $M(\Sigma^o K^+)$ in Fig. 3 there is only a slight indication for $X(1810)$ structure which was observed earlier in the study of coherent reaction (1) — see

Table 1. Data on $M(\Sigma^0 K^+)$ in reaction $p + N \to [\Sigma^0 K^+] + N$, $\Sigma^0 \to \Lambda\gamma$ with different photon cuts (for all P_T^2)

Photon cut		Soft	Intermediate	Strong
N events in $X(2000)$ peak		430 ± 89	301 ± 71	190 ± 47
Correction factor for photon efficiency		1.0	1.4	2.25
Parameters of $X(2000)$				
M (MeV)	weighted spectrum	1986 ± 6	1991 ± 8	1988 ± 6
	measured spectrum	1988 ± 5	1994 ± 7	1990 ± 6
Γ (MeV)	weighted spectrum	98 ± 20	96 ± 26	68 ± 21
	measured spectrum	84 ± 20	94 ± 21	68 ± 20
$\sigma[p + N \to X(2000) + N] \cdot$ $\cdot BR[X(2000) \to \Sigma^0 K^+]$ (nb/nucleon)		100 ± 19	93 ± 25	91 ± 21
	$< M >$ MeV		1989 ± 6	
	$< \Gamma >$ MeV		91 ± 20	
Average values	$< \sigma[p + N \to X(2000) + N] > \cdot$ $\cdot BR[X(2000) \to \Sigma^0 K^+]$ nb/nucleon	95 ± 20 (statist.) ± 20 (system.)		
	$< \sigma[p + C \to X(2000) + C] > \cdot$ $\cdot BR[X2000 \to \Sigma^0 K^+]$ nb/C nucleus	285 ± 60 (statist.) ± 60 (system.)		

Fig. 1 and [19]. This difference is caused by a large background in this region for the events in Fig. 3 (all P_T^2, soft photon cut). To clarify the situation in our new analysis, we investigated also the $M(\Sigma^o K^+)$ mass spectra for coherent reaction (1), e.g. for $P_T^2 < 0.1$ GeV^2 — see Fig. 5. In these mass spectra not only the X(2000) peak is observed, but the X(1810) structure as well (as it was in our previous works).

The yield of the $X(1810)$ as function of P_T^2 is shown in Fig. 6. From this figure it is clear that X(1810) is produced only in a very small P_T^2 region ($P_T^2 < 0.01 - 0.02$ GeV^2). For $P_T^2 < 0.01$ GeV^2 the $M(\Sigma^o K^+)$ mass spectra demonstrate a very sharp X(1810) signal with parameters of the peak

$$X(1810) \to \Sigma^o K^+ \begin{cases} M = & 1807 \pm 7 \text{ MeV} \\ \Gamma = & 62 \pm 19 \text{ MeV} \end{cases} \qquad (15)$$

(see Fig. 7). The cross section for the coherent X(1810) production is

$$\begin{aligned} &\sigma[p + C \to X(1810)^+ + C]|_{P_T^2 < 0.01 \text{ GeV}^2} \\ &\cdot BR[X(1810)^+ \to \Sigma^o K^+] \\ &\qquad = 215 \pm 44 \text{ nb/C nucleus.} \end{aligned} \qquad (16)$$

The additional systematic error for this value is ±30%. It increased as compared to the same errors in (11)-(14) due to the uncertainty in the evaluation of P_T^2 smearing in the region of $P_T^2 < 0.01$ GeV^2, which is more sensitive to the P_T^2 resolution.

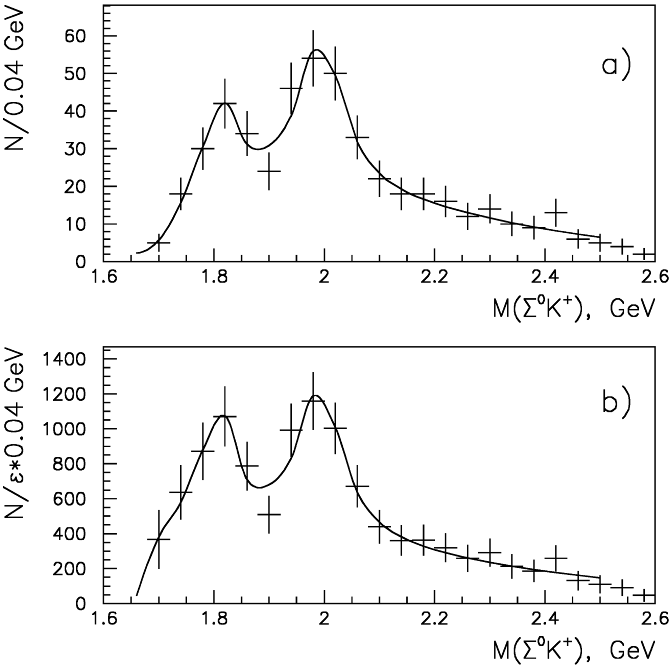

Fig. 5. Invariant mass spectra $M(\Sigma^0 K^+)$ for the coherent diffractive production reaction $p + C \to [\Sigma^0 K^+] + C$ ($P_T^2 <$ 0.1 GeV^2) obtained with the strong photon cut: a) measured mass spectrum; b) the same mass spectrum weighted with the efficiency of the setup

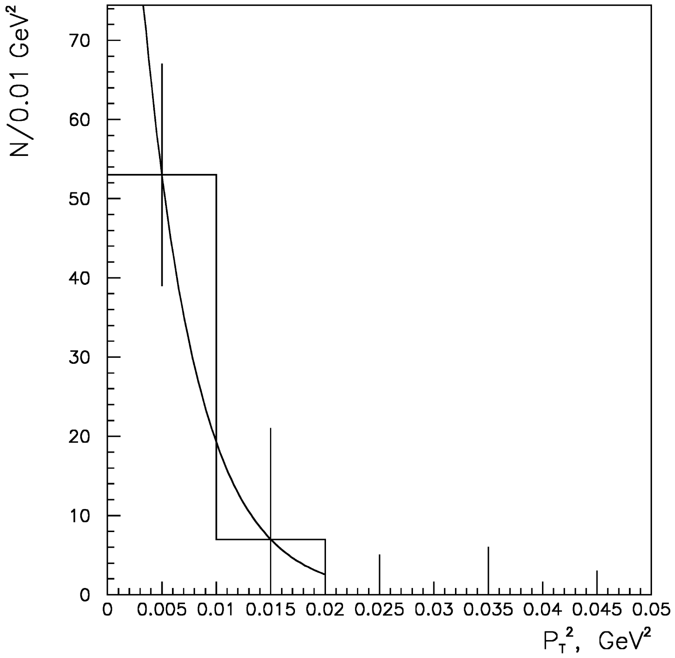

Fig. 6. The P_T^2 dependence for the $X(1810)$ structure production in the coherent reaction $p + C \to X(1810) + C$

We demonstrated also the coherent diffractive X(2000) production in the clearest way by using a "restricted coherent region" $0.02 < P_T^2 < 0.1$ GeV^2 where there is no influence of X(1810) structure (see Fig. 8).

To explain the unusual properties of X(1810) state in a very small P_T^2 region, the hypothesis of the electromagnetic production of this state in the Coulomb field of carbon nucleus was proposed earlier [24]. It is possible to estimate the cross section for the Coulomb X(1810) production

$$\begin{aligned}
&\sigma[p + C \to X(1810)^+ + C]|_{p_T^2 < 0.01\ \mathrm{GeV}^2;\ \mathrm{Coulomb}} \\
&\quad = (2J_X + 1)\{\Gamma[X(1810)^+ \to p + \gamma][\mathrm{MeV}]\} \\
&\qquad \cdot 2.8 \cdot 10^{-30}\ \mathrm{cm}^2/\mathrm{C\ nucleus} \\
&\qquad \geq 5.6 \cdot 10^{-30}\ \mathrm{cm}^2\{\Gamma[X(1810)^+ \to p + \gamma][\mathrm{MeV}]\} \quad (17)
\end{aligned}$$

($J_X \geq 1/2$ is the spin of X(1810)).

Let us compare this Coulomb hypothesis prediction with the experimental value

$$\sigma[p{+}C \to X(1810)^+{+}C]|_{p_T^2<0.01\ \mathrm{GeV}^2} \gtrsim 645\ \mathrm{nb/C\ nucleus}. \quad (18)$$

To obtain (18) we assume in (16) that X(1810) is isodoublet, and then we use from (7) the branching $BR(X \to \Sigma^o K^+) \lesssim 1/3$ (here $\simeq$ means that $BR[X^+ \to (\Sigma K)^+] \simeq 1$, i.e. this decay is dominating).

If the value of radiative width $\Gamma[X(1810) \to p + \gamma]$ is around 0.1-0.3 MeV and the branching $BR[X(1810)^+ \to (\Sigma K)^+]$ is significant, then the experimental data for cross section of the coherent X(1810) production (18) can be in agreement with the Coulomb mechanism prediction (17). It seems that this value of radiative width is quite reasonable. For example, the radiative width for $\Delta(1232)$ isobar is $\Gamma[\Delta(1232)^+ \to p + \gamma] \simeq 0.7$ MeV. The value of radiative width depends on amplitude A of this process and the kinematical factor: $\Gamma = |A|^2 \cdot (P_\gamma)^{2l+1}$ (P_γ is the momentum of photon in the rest frame of the decay baryon and l is the orbital momentum). For $X(1810) \to p+\gamma$ decay the kinematical factor may be by an order of magnitude larger

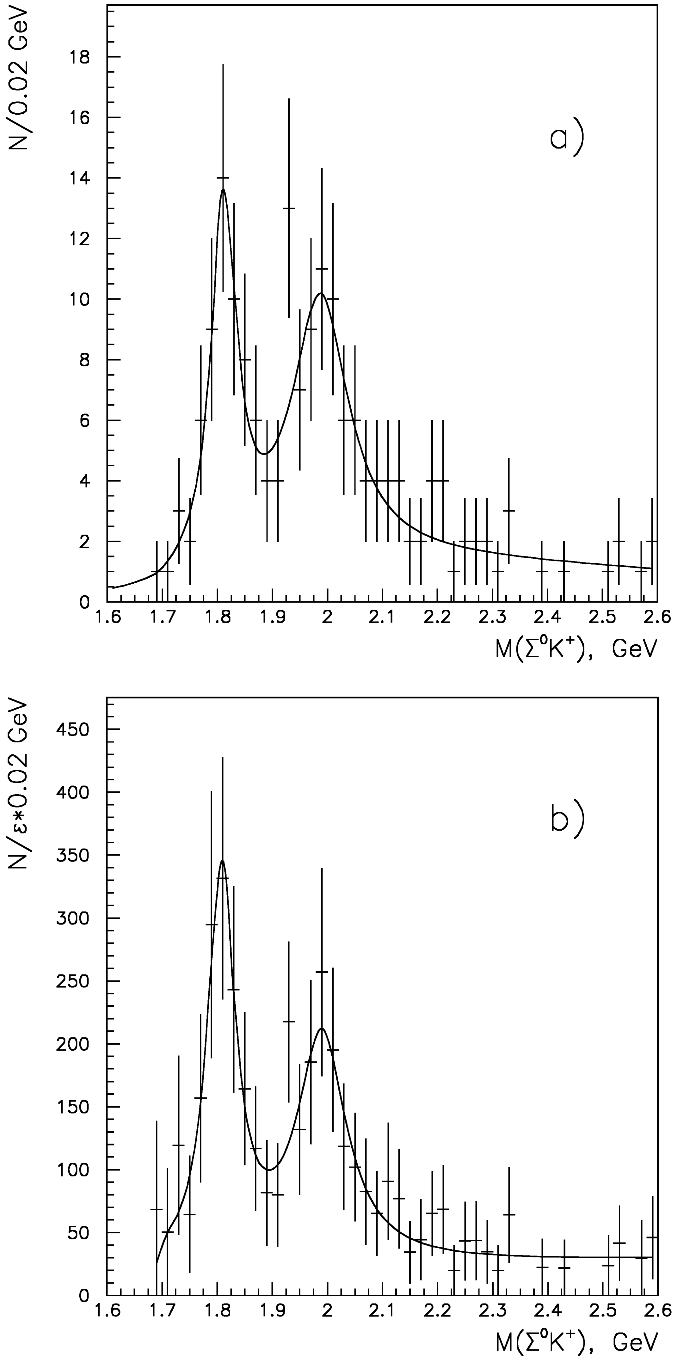

Fig. 7. Invariant mass spectra $M(\Sigma^0 K^+)$ in the coherent diffractive production reaction $p + C \to [\Sigma^0 K^+] + C$ in the region of very small $P_T^2 < 0.01$ GeV^2 (with strong photon cut): a) measured spectrum; b) the same spectrum weighted with the efficiency of the setup. The parameters of $X(1810)$ peak are $M = 1807 \pm 7$ MeV, $\Gamma = 62 \pm 19$ MeV

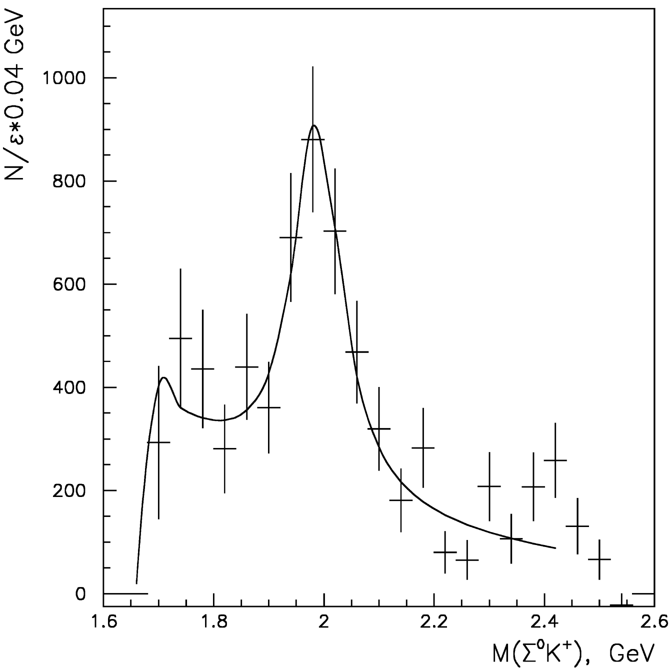

Fig. 8. Weighted invariant mass spectrum $M(\Sigma^0 K^+)$ for the reaction $p + C \to [\Sigma^0 K^+] + C$ in the "restricted coherent region" $0.02 < P_T^2 < 0.1$ GeV^2 (with intermediate photon cut, after sideband subtruction of the background under Σ^0 peak in Fig. 2(b))

than for $\Delta(1232)^+ \to p + \gamma$ because of the large mass of X(1810) baryon. Certainly, the predictions for amplitude A is quite speculative. But if, for example, X(1810) is the state with hidden strangeness $|qqqs\bar{s}>$, then the amplitude A can be not very small due to a possible VDM decay mechanism $(qqqs\bar{s}) \to (qqq) + \phi_{\text{virt}} \to (qqq) + \gamma$. Thus, the experimental data for the coherent production of X(1810) (18) do not seem to be in contradiction with the Coulomb production hypothesis.

The feasibility to separate the Coulomb production processes in the coherent proton reactions at $E_p = 70$ GeV on the carbon target in the measurements with the SPHINX setup has been recently demonstrated in the observation of the Coulomb production of $\Delta(1232)^+$ isobar with $T = 3/2$ in the reaction

$$p + C \to \Delta(1232)^+ + C \tag{19}$$

(see [24]).

4 Reality of X(2000) baryon state

The data on X(2000) baryon state with unusual dynamical properties (large decay branching with strange particle emission, limited decay width) were obtained with a good statistical significance in the different SPHINX runs with widely different experimental conditions and for several kinematical regions of reaction (1). The average values of the mass and width of X(2000) state are

$$X(2000) \to \Sigma^o K^+ \left\{ \begin{array}{l} M = 1989 \pm 6 \text{ MeV} \\ \Gamma = \;\; 91 \pm 20 \text{ MeV} \end{array} \right. \tag{20}$$

Due to its anomalous properties the X(2000) state can be considered as a serious candidate for pentaquark exotic baryon with hidden strangeness: $|X(2000)>=|uuds\bar{s}>$. Recently we have obtained some new additional data to support the reality of X(2000) state.

1. In the experiments with the SPHINX setup we studied the reaction

$$p + N(A) \to [\underset{\hookrightarrow p\pi^o}{\Sigma^+} \quad \underset{\hookrightarrow \pi^+\pi^-}{K^o}] + N(A) \tag{21}$$

In spite of a limited statistics, we observed the X(2000) peak and the indication for X(1810) structure in this reaction which are quite compatible with the data for reaction (1).

2. In the experiment at the SELEX(E781) spectrometer [25] with the Σ^- hyperon beam of the Fermilab Tevatron, the diffractive production reaction

$$\Sigma^- + N \to [\Sigma^- K^+ K^-] + N \tag{22}$$

was studied at the beam momentum $P_{\Sigma^-} \simeq 600$ GeV. In the invariant mass spectrum $M(\Sigma^- K^+)$ for this reaction a peak with parameters $M = 1962 \pm 12$ MeV and $\Gamma = 96 \pm 32$ MeV was observed. The parameters of this structure are very close to the parameters of $X(2000) \to \Sigma^0 K^+$ state which was observed in the experiments at the SPHINX spectrometer. Thus, the real existence of $X(2000)$ baryon seems to be supported by the data from another experiment and in another process.

Preliminary results of studying reactions (21) and (22) were discussed in the talks at the last conferences [26-28] and are now under a detailed investigation.

5 Conclusion

New data for the diffractive production reaction (1) were obtained with the partially upgraded SPHINX detector (with new γ-spectrometer and with better possibilities to detect $\Lambda \to p\pi^-$ and $\Sigma^- \to \Lambda\gamma$ decays). New data are in a good agreement with our previous results on the invariant mass spectrum for the $M(\Sigma^0 K^+)$ system produced in this reaction [13,16,17].

A strong $X(2000)$ peak with $M = 1989 \pm 7$ MeV and $\Gamma = 91 \pm 20$ MeV together with a narrow threshold structure (with $M \sim 1810$ MeV and $\Gamma \sim 60$ MeV) are clearly seen in the $(\Sigma^0 K^+)$ invariant mass spectra. The latter structure is produced at very small transverse momenta, $P_T^2 < 0.01 - 0.02$ GeV^2. Unusual properties of the $X(2000)$ baryon state (narrow decay width, anomalously large branching ratio for the decays with strange particle emission) make this state a serious candidate for a cryptoexotic pentaquark baryon with hidden strangeness

$|qqqs\bar{s}>$. Preliminary data for ΣK states in other reactions (21) and (22) confirm the real existence of $X(2000)$ baryon.

Now the SPHINX spectrometer is totally upgraded and its luminosity and data taking rate were significantly increased. In the recent runs with this upgrated setup we obtained a large statistics that is now under the data analysis. In the near future we expect to increase statistics for the processes discussed above and for some other proton reactions by an order of magnitude.

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