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D1-89-398

SEARCH FOR NARROW BARYONIA WITH NEGATIVE AND POSITIVE STRANGENESS

BIS-2 Collaboration: Dubna - Alma-Ata - Budapest - Bucharest - Moscow - Praque - Sofia - Tbilisi

Submitted to "Zeitshrift fur Physik C"

1989

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The question on the existence of multiquark states is of great significance for the development of strong interaction theory. However, an experimental search for such states has not yet led to convincing results.

A narrow exotic state, a baryonium with negative strangeness decaying into Λ, $\bar{p}$ and pions, has been observed in the WA-62 experiment carried out in a hyperon beam at the CERN SPS [1]. Unlike the experiment in the hyperon beam, the BIS-2 experiment performed in a neutron beam allowed one to search for baryonia with negative and positive strangeness alike [2]. The existence of a narrow baryonium with negative strangeness was confirmed, and indications of the existence of a new baryonium with positive strangeness, and also of doubly charged states of the baryonia were first obtained. The latter gives evidence for a multiquark structure of these states denoted as M_s $(\bar{M})_s$ where s is the sign of strangeness.

New results on a search for and a study of $M_s(\bar{M})_s$ produced in neutron-nucleus and neutron-proton interactions are presented. They are based on larger statistics in comparison with [2]. The experiment was carried out in a neutron beam of the Serpukhov accelerator. The mean momentum of the beam consisting mainly of neutrons was 40 GeV/c. A layout of the main elements of the BIS-2 spectrometer [3] is presented in fig. 1. The magnetic field in the analyzing magnet M directed along the OY axis caused a 0.64 GeV/c change of the transversal momentum of charged particles crossing the field region. The system consisting of multicell threshold gas Cherenkov counters C1 and C2 was used to identify charged hadrons. The counter C1 was filled with air and C2 with freon-12 under atmospheric pressure. The identification system allowed one to identify with some probability charged hadrons in multiparticle events. The trigger conditions required the passage of more than four charged particles.

The thicknesses of the liquid-hydrogen target and the nuclear ones were respectively 2.1 g/cm^2 and $3.4 \cdot A^{2/3}$ g/cm^2, where A is the atomic weight of target nuclei. The nuclear targets interchanged each $(40 \div 50) \cdot 10^3$ recorded events. The results presented here are based on the analysis of $1.9 \cdot 10^7$ neutron-proton and $2.4 \cdot 10^7$ neutron-nucleus interactions.

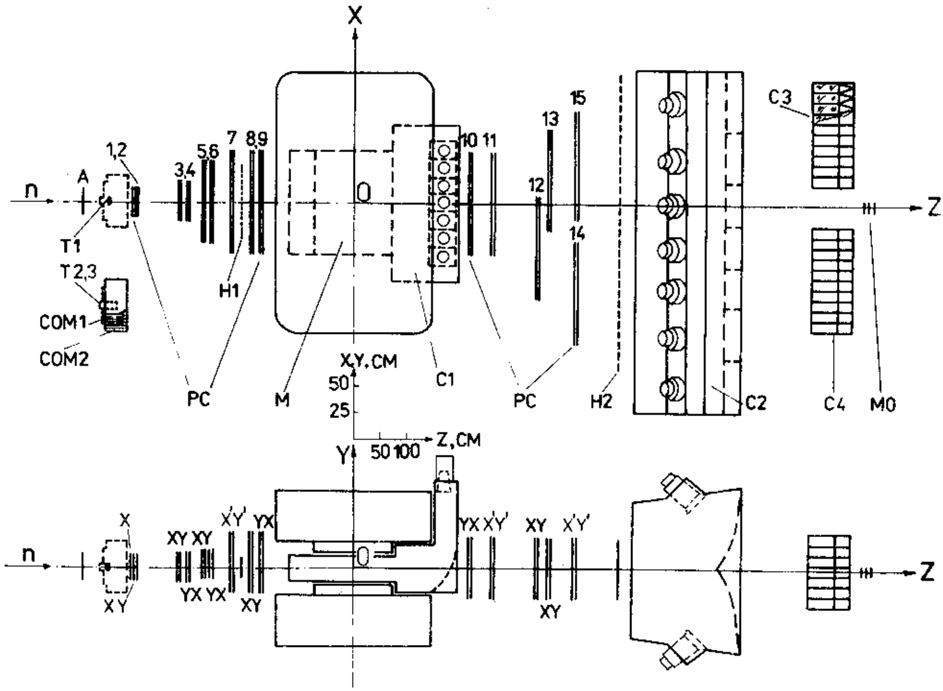

Fig. 1. Layout of the BIS-2 spectrometer. T1/T2,3 - targets, COM1/2 - target surrounding counters, PC 1-15 - two-coordinate proportional chambers. C1/2 - multicell threshold gas Cherenkov counters. C3/4 - glass Cherenkov counters, MO - neutron monitor, M - analyzing magnet.

The narrow baryonium with negative strangeness, M_S, was searched for by its decays into Λ, $\bar{p}$ and pions:

$$\Lambda\bar{p}\pi^+ \ , \qquad (1a)$$

$$\Lambda\bar{p}\pi^+\pi^- , \qquad (1b)$$

$$\Lambda\bar{p}\pi^+\pi^+ \qquad (1c)$$

and

$$\Lambda\bar{p}\pi^- , \qquad (1d)$$

and the baryonium with positive strangeness, $\bar{M}_S$, by its decays into:

$$\bar{\Lambda}p\pi^- , \qquad (2a)$$

$$\bar{\Lambda}p\pi^+\pi^- , \qquad (2b)$$

$\bar{\Lambda}p\pi^-\pi^-$ (2c)
and
$\bar{\Lambda}p\pi^+$. (2d)

$5\cdot10^5$ events with Λ candidates, and $8\cdot10^4$ events with $\bar{\Lambda}$ candidates were selected. Λ and $\bar{\Lambda}$ were identified by their decays respectively into $p\pi^-$ and $\bar{p}\pi^+$ with the topology of neutral Vee. A pair of oppositely charged particles having a minimal distance between their tracks not exceeding a four-fold experimental resolution in this parameter was considered as V^o. The vertex of V^o was required to be behind the liquid-hydrogen target and more than 10 cm downstream the back edge of the nuclear targets. Λ and $\bar{\Lambda}$ were selected according to the invariant masses of V^o in the $(p\pi^-)$ and $(\bar{p}\pi^+)$ systems. Figure 2 shows the distributions of the difference between the effective mass of the $p\pi^-$ $(\bar{p}\pi^+)$ system and the mass of the Λ for the events with more than one extra charged particle.Clear signals near the Λ mass are seen in both spectra. The FWHT of the peak equals ~4.0 MeV/c^2 and ~4.5 MeV/c^2 for Λ and $\bar{\Lambda}$, respectively. These V^o were selected for which the $p\pi^-$ and $\bar{p}\pi^+$ invariant mass was different from the Λ mass by no more than 7 or 10 MeV/c^2, respectively. The background among the selected Λ and $\bar{\Lambda}$ was 15% and 80%, respectively.

The strange baryonia M_S and $\bar{M}_S$ were searched for among the events containing $\Lambda/\bar{\Lambda}$ and more than one charged particle $h^{\pm}$, all produced at the common vertex of interaction. It was required that the tracks of all the particles $\Lambda/\bar{\Lambda}$ and $h^{\pm}$ might have a good "convergence" in the target region, i.e. their r.m.s. distances should be less than a four-fold value of the experimental resolution. This resolution varied from 0.2 to 0.5 cm in runs with different targets. 70613(9253) events containing $\Lambda(\bar{\Lambda})$ and more than one charged particle were selected in accordance with the above criteria. In the events with Λ, one of the negative particles with the largest momentum was assumed to be a $\bar{p}$ candidate and the others to be pions. If the Vee was identified as $\bar{\Lambda}$, then the accompanying positive particle with a maximum momentum was taken as p and the others as pions.

The information obtained from C1/2 was used to reduce the background due to a wrong identification of charged particles in the considered combinations. The identification criteria were chosen to estimate the lower limits of statistical significance of the observation of baryonia. These criteria were not optimal for the signal to byckground ratio, as those used in[2]. To search for the baryonuim with negative strangeness

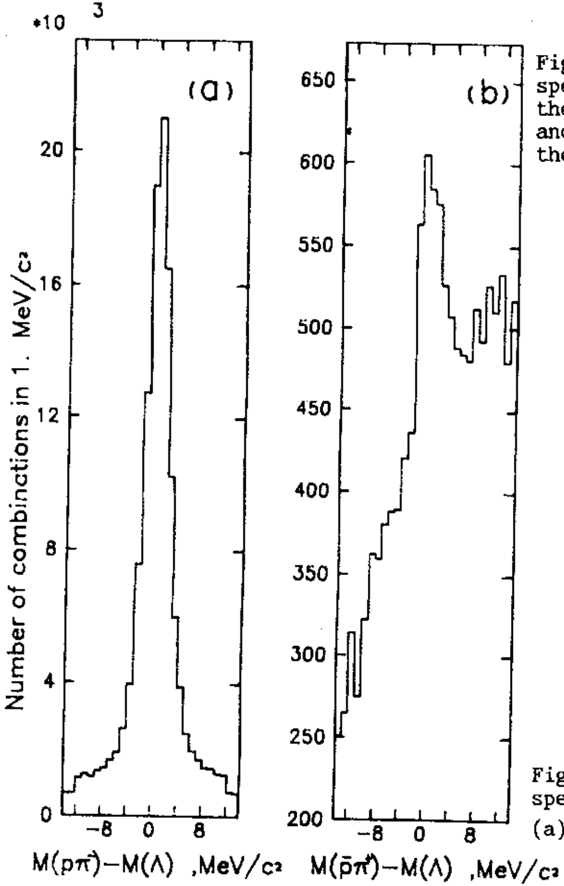

Fig.2.Effective mass spectra of V^0 for the systems $p\pi^-$ (a) and $\bar{p}\pi^+$ (b) near the Λ mass.

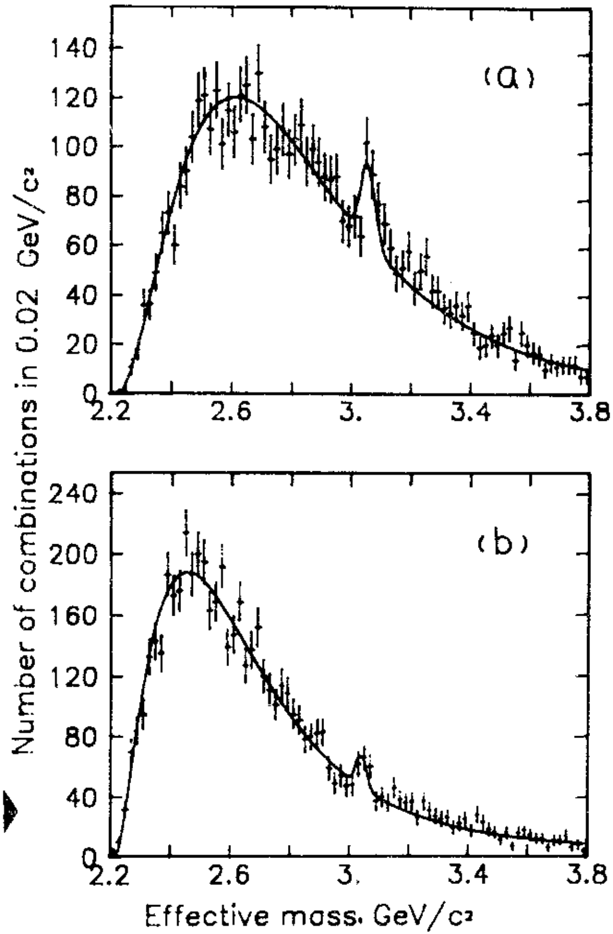

Fig.3.Effective mass spectra of $\Lambda\bar{p}\pi^+$ (a) and $\bar{\Lambda}p\pi^-$ (b).

among the final states (1a-b), $\bar{p}$ should be identified. The momentum of the majority of negative particles, $\bar{p}$ candidates, was smaller than 15 GeV/c. This is below the threshold of Cherenkov radiation for $\bar{p}$ in C1/2. In the selection, not only those combinations were excluded in which $\bar{p}$ candidates were with large probability identified as π^-, but also the ones in which the identification system could not distinguish between $\bar{p}$, π^- or K^-. Approximately 90% of π^- and less than 20% of $\bar{p}$ were lost using these criteria. For particles, $\pi^{\pm}$ candidates, the used criteria allowed one to keep more than 90% of all pions.The number of combinations studied in the final states(1a-d) was decreased almost by a factor of 10 after this analysis. Taking into account the data for $\bar{p}$ production at the Serpukhov energies[5] and the above criteria, approximately 8% of combinations among the remainder contain $\Lambda + \bar{p}$ + pions.

To study the states with positive strangeness (2a-d), such criteria of p and $\pi^{\pm}$ identification were chosen that the fraction of combinations containing $\bar{\Lambda} + p$ + pions among all the selected ones might be the same as the corresponding fraction of combinations containing $\Lambda + \bar{p}$ + pions in the analysis of the states (1a-d). Thus, the criteria of p identification were not so stringent as for $\bar{p}$ identification. Only those combinations were excluded in which p candidates were identified as π^+ with high probability. This allowed one to keep more than 90% of all p. Only geometric and kinematic criteria were used to identify Λ's. As a result of such a selection, the number of combinations in the final states (2a-d) was decreased by a factor of two.

4815 and 5715 combinations entered into the effective mass spectra of the final states (1a) and (2a) (fig.3). 1562 combinations entered into the effective mass spectrum of the sum of the charged final states with negative strangeness (1b and c) (fig.4a) and 4295 combinations into the summarized spectrum of the states with positive strangeness (2b and c) (fig. 4b). 2694 and 4362 combinations entred respectively into the effective mass spectra of the doubly charged final states (1d and 2d) (fig.5a and b). A bin width of 20 MeV/c^2 was chosen to be close to a two-fold value of the experimental mass resolution. The spectra were approximated by smooth functions. Enhancements of different statistical significance were seen in all the spectra. They were fitted by the normal distribution. The obtained parameters of the enhancements are shown in the table. A combinatorial background in the presented spectra is insignificant. So, the ratio of the number of combinations to that of events does not exceed 1.1 within the mass region of these enhancements.

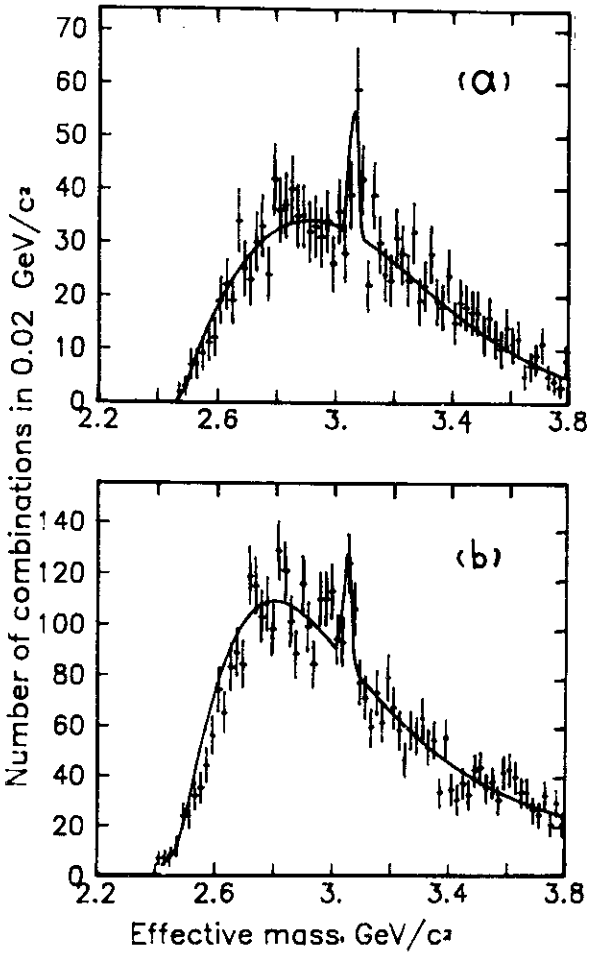

Fig.4. Sum of the effective mass spectra for the final states $\Lambda\,\bar{p}\,\pi^{+}\pi^{\pm}$ (a) and $\bar{\Lambda}\,p\,\pi^{-}\pi^{\mp}$ (b).

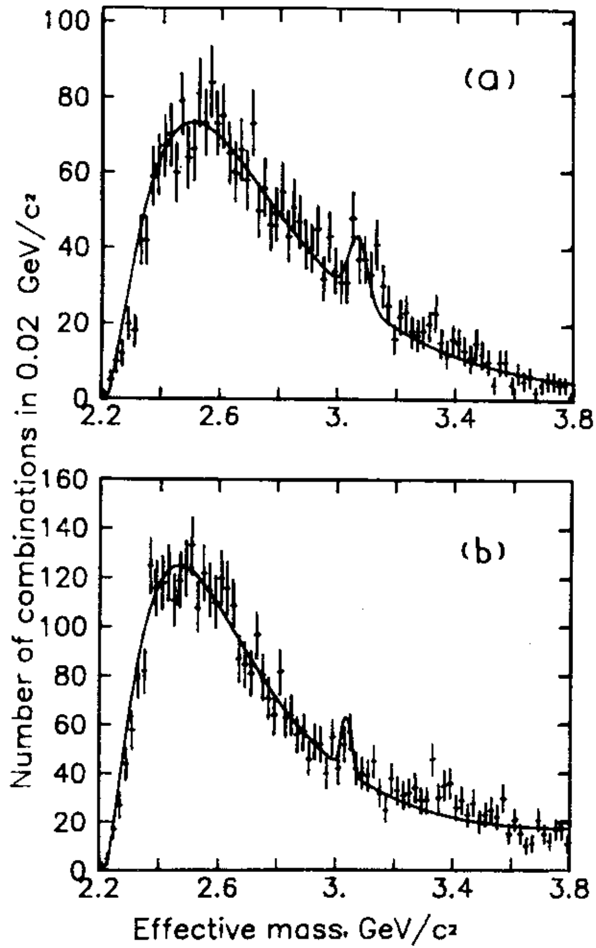

Fig.5. Effective mass spectra $\Lambda\,\bar{p}\,\pi^{-}$ (a) and $\bar{\Lambda}\,p\,\pi^{+}$ (b).

The existence of the enhancements in all the presented spectra of the final states at close masses allows one to suppose that they are due to signals from different charge states

Table

Final state	Mean mass, MeV/c^2	Width, MeV/c^2	Number of comb. in the peaks
$\Lambda\bar{p}\pi^+$	3059±7±20	53±15	92±33
$\bar{\Lambda}p\pi^-$	3042±7±20	38±15	47±24
$\Lambda\bar{p}\pi^+\pi^-$ $\Lambda\bar{p}\pi^+\pi^+$	3062±5±20	28±8	43±17
$\bar{\Lambda}p\pi^+\pi^-$ $\bar{\Lambda}p\pi^-\pi^-$	3046±5±20	29±12	71±36
$\Lambda\bar{p}\pi^-$	3069±9±20	72±22	65±25
$\bar{\Lambda}p\pi^+$	3040±6±20	34±11	41±20

of the two resonances: one with negative and another with positive strangeness. The total spectrum of all the final states with negative strangeness (1a-d) is presented in fig.6a by a solid line. It is obtained by summarizing the distributions presented in figs. 3a, 4a and 5a. A clear peak caused by 150 combinations above a background of 380 is seen in this spectrum near a mass of 3060 GeV/c^2. The sum of the final states with positive strangeness (2a-d) is shown in fig. 6b. A peak caused by 140 combinations above a background of 522 is seen at a mass of 3050 MeV/c^2. Statistical significances of the observed peaks are 7.5 and 6 standard deviations above the background, respectively. This allows one to consider them as physical signals.

Narrowness of the observed enhancements and their presence in the invariant mass spectra of different systems excludes the possibility of their interpretation as kinematic reflections of any resonances. However, the hypothesis of kinematic reflection was checked directly, as $p/\bar{p}$ had not been identified unambiguously. The effective mass spectrum of the sum of

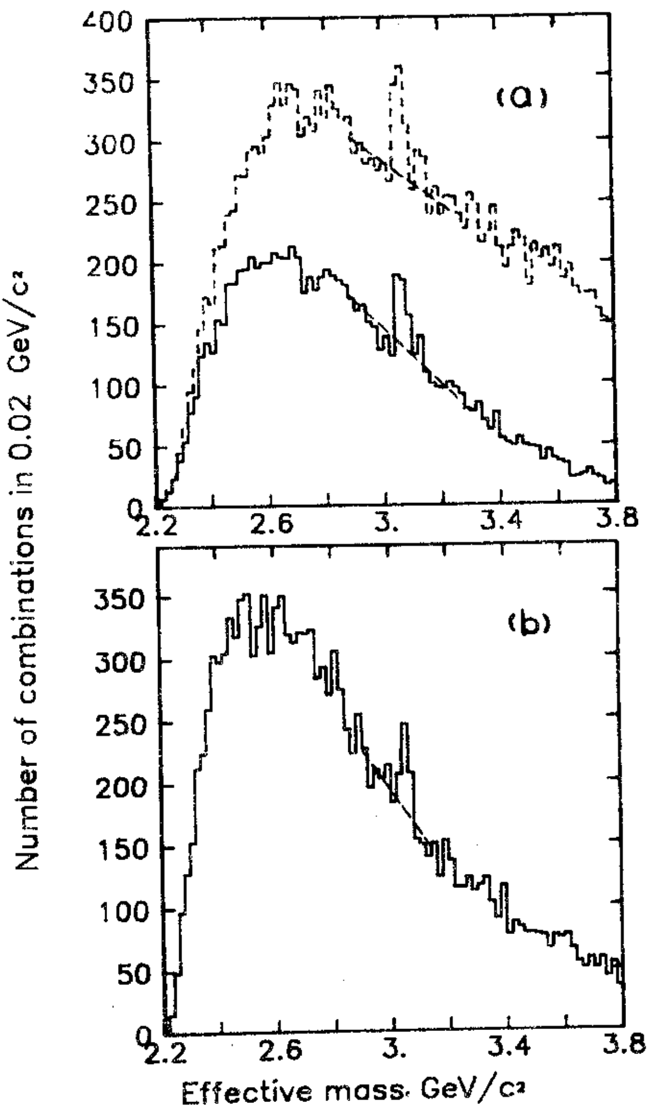

Fig.6. Sum of the final states: a - $\Lambda\bar{p}\pi^{\pm}$ and $\Lambda\bar{p}\pi^{\pm}\pi^{\pm}$ effective mass for soft (dashed line) and stringent (solid line) criteria of charged track identification; b - $\bar{\Lambda}p\pi^{\mp}$ and $\bar{\Lambda}p\pi^{-}\pi^{\mp}$ effective mass.

the final states (1a-d) obtained for such combinations in which completely unidentified h^-'s were also accepted as $\bar{p}$ candidates is presented in fig. 6a by a dashed line. Almost 90% of all $\bar{p}$ and 30% of all π^- remained among negative particles under this selection. Among all the combinations, the fraction of combinations containing $\Lambda + \bar{p}$ + pions should be

≅ 4%. As would be expected, in comparison with the solid-line histogram in fig.6a the background increased appreciably with an insignificant change of the number of combinations in the peak. As another check, the masses of $\pi^{\pm}$ and $K^{\pm}$ were ascribed to the $p/\bar{p}$ candidates. No narrow enhancements were observed in the obtained effective mass spectra. Thus, the hypothesis of enhancements as kinematic reflections of resonances in other systems is excluded.

Statistical significances of the enhancements in each of the considered spectra (figs.3-5) do not allow one to establish unambiguously the existence of signals in all the final states (1a-d) and (2a-d). However, the numbers of combinations responsible for the signals in the total spectra of fig.6 (a and b) coincide, within the errors, whith the sum of the numbers responsible for the enhancements in the three spectra of the final states with negative and positive strangeness (see the table). Differences between the central masses of the enhancements for each of the states (1a-d) and (2a-d) are insignificant. This allows one to suppose that all or the majority of the observed enhancements are physical sighals, i.e. four charge states of M_s and $\bar{M}_s$ are observed.

The geometry of the spectrometer, the Coulomb scattering of charged particles, the spatial resolution of the proportional chambers and their efficiency, and also the efficiency of event reconstruction by the used programs have been taken into account for the Monte-Carlo calculation of the detection efficiencies for the studied processes.The systems under consideration were accepted in the kinematic region:

$$X_F \geq 0.2$$

and

$$P_T \leq 1 \text{ GeV/c}, \qquad (3)$$

where X_F is the Feynmann variable and P_T the transverse momentum of the systems. Because of set-up asymmetry in the XOZ plane, the geomentic acceptance for the final states containing Λ was slighly larger than for those containing $\bar{\Lambda}$. The production cross sections of M_s and $\bar{M}_s$ in the kinematic region (3) times the branching ratios of the observed decay modes were estimated taking into account the calculated efficiences. They coincide within the errors and are of the order of 1 μb per nucleon. The dependence of $A^{2/3}$ on the atomic weight A was used to recalculate the cross sections per nucleon.

CONCLUSION

Narrow enhancements have been observed at almost the same masses in the effective mass spectra of different final states with negative ($\Lambda\bar{p}\pi^{\pm}$, $\Lambda\bar{p}\pi^{+}\pi^{\pm}$) and positive ($\bar{\Lambda}p\pi^{\mp}$, $\bar{\Lambda}p\pi^{-}\pi^{\mp}$) strangeness. They are not kinematic reflections of any resonances in other systems and can be considered as a strong indication of the existence of baryonia with negative and positive strangeness.

These baryonia decay into $\Lambda/\bar{\Lambda}$, $\bar{p}/p$ and pions. Their mean mass is $3053\pm2\pm20$ MeV/c^2 and the width smaller than 35 ± 5 MeV/c^2.

The existence of the enhancements in the spectra of the doubly charget final states $\Lambda\bar{p}\pi^{-}$ and $\bar{\Lambda}p\pi^{+}$ shows that the isotopic spin of the baryonia is $\geq 3/2$.

The authors are greatly indebted to A.M.Baldin, S.S.Gershtein, A.A.Komar, E.I.Maltsev, I.A.Savin, A.N.Sissakian, A.N.Tavkhelidze, N.E.Tyurin and P.A.Cherenkov for their support and permanent interest in the study; to Yu.Klabuhn, E.M.Likhacheva, H.Nowak, H.-E.Rysek, L.V.Sil´vestrov, G.G.Takhtamyshev and K.Hiller for their participation in the experiment.

REFERENCES

1. Borquin M. et al. - Phys. Lett., 1986, B172, p.113;
   Cooper S. - Proceeding of the XXIII International Conference on High Energy Physics, v.1, p.67. Berkeley 1986;
   Siebert H.W. - ibid., v.2, p.1015.
2. Aleev A.N. et al. - JINR Rapid Communications, 19-86, Dubna, 1986, p.16;
   Aleev A.N. et al. - JINR D1-88-368, Dubna, 1988.
3. Eichner G. et al. - JINR,1-80-644, Dubna,1980;
   Maksimov A.N. - JINR, 1-81-574, Dubna, 1981.
4. Voichishin M.A. et al. - JINR, 13-84-161, Dubna, 1984; PTE, 1985, 3, p.49;
   Gus´kov B.N. et al. - JINR, 13-84-373, Dubna, 1984; PTE, 1985, 5, p.71; JINR, P1-86-248, Dubna, 1986.
5. Acherloff K. et al. - Preprint IHEP, 77-86, Serpukhov, 1977.

Received by Publishing Department
on June 14, 1989.