OBSERVATION OF U(3100) IN BIS-2 EXPERIMENTS

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A meson resonance U(3100) with negative strangeness, produced in neutron-nucleus interactions at a mean neutron momentum of ~40 GeV/c, has been observed in experiments performed by means of the BIS-2 spectrometer at the Serpukhov accelerator. Carbon, aluminium and copper were used as nuclear targets. Altogether ~180 decays of four different states of this resonance into $\Lambda^{\circ} + \bar{p} + n \cdot \pi^{\pm}$ and $K^{\circ}_{s} + p + \bar{p} + \pi^{+}$ have been registered. The isotopical spin of the resonanse is equal to 3/2. The resonance production cross section in the region X > 0.2 times the branching ratio of its decay via each observed mode is from 1 to 20 μb per cardon nucleus. The A-dependence of the resonance production cross section is described by the power law A^{α} with $\alpha = 0.6 \pm 0.3$.

The investigation has been performed at the Laboratory of High Energies, JINR.

Наблюдение U(3100) в экспериментах БИС-2

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В экспериментах, проведенных с помощью спектрометра БИС-2, на серпуховском ускорителе наблюден мезонный резонанс с отрицательной странностью U(3100), образованный в нейтрон-ядерных взаимодействиях при среднем импульсе нейтронов ~40 ГэВ/с. В качестве ядерных мишеней использовались углерод, алюминий и медь. Всего зерегистрировано около 180 распадов четырех зарядовых состояний этого резонанса на $\Lambda^{\circ} + \bar{p} + n \cdot \pi^{\pm}$ и на $K^{\circ}_{s} + p + \bar{p} + \pi^{+}$. Изотопический спин резонанса равен 3/2. Произведение сечения рождения резонанса в области X > 0,2 на вероятность его распада по каждому из наблюденных каналов составляет от 1 до 20 мкб на ядро углерода. А-зависимость сечения рождения резонанса описывается степенной функцией A^{α} с показателем $\alpha = 0,6 \pm 0,3$.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

This study was initiated by the results on the observation of a narrow state U(3100) in the experiment [1]

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at the CERN SPS. Our investigation is based on the data
obtained in the experiments devoted to the study of char-
med particles [2] and narrow baryon resonances [3] perfor-
med by means of the BIS-2 spectrometer in a neutral beam
of the Serpukhov accelerator. The neutral beam is mainly
composed of neutrons with a mean momentum of ~40 GeV/c.
A scheme of the BIS-2 spectrometer is shown in fig.1.Se-
condary charged perticles produced in neutron interactions
with carbon,aluminium and copper targets (T) were detec-
ted by the spectrometer.During the experiment the targets
were alternated after each ~$5 \cdot 10^4$ registered neutron-nuc-
leus interactions.Two multicell gas threshold Cherenkov
counters (C1 [4] and C2 [5]) were used for the identificati-
on of charged particles. To trigger the spectrometer, at
least four charged particles passing through it were requi-
red.Altogether $1.2 \cdot 10^7$ neutron-nucleus interactions were
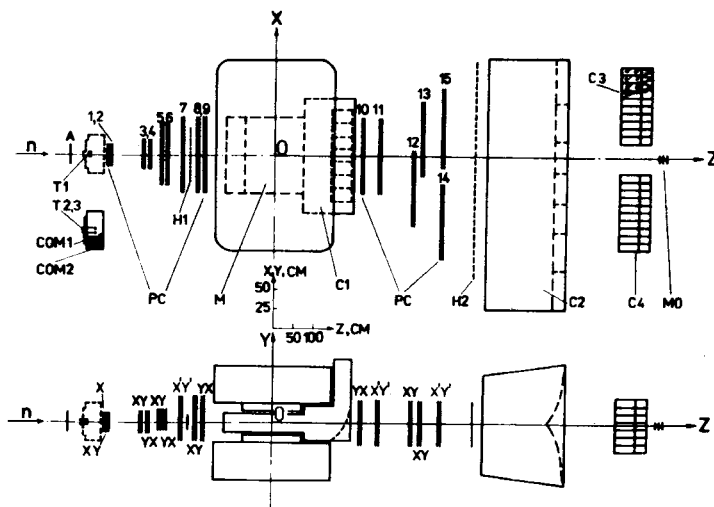accepted during the experiment. A more detailed des-

Fig.1. A schematic view of the JINR BIS-2 spectro-
meter in the 4H channel of the Serpukhov accelera-
tor. n - neutron beam, A - anticoincidence scintil-
lation counter, Ti - hard target, T2 - liquid hyd-
rogen target; COM1 and COM2 - hodoscopes of the
scintillation counters of target surroundings,
PC[1÷14] - two-coordinate proportional wire cham-
bers, C1 and C2 - multichannel threshold gas Cheren-
kov counters, C3 - hodoscope of the full absorption
Cherenkov counters, MO - telescope of the scintil-
lation counters for neutron beam monitoring. M -
SP40A analysing magnet.

cription of the BIS-2 spectrometer and experimental running conditions is presented in [6].

To search for the U(3100), the invariant mass spectra were analysed for the events containing $\Lambda^\circ, \bar{p}$ and charged pions as well as $K_s^\circ, p, \bar{p}$ and charged pions. The Λ° and K_s° were identified among the reconstructed neutral Vee's through their decay into $p\pi^-$ and $\pi^+\pi^-$. The mass resolutions are equal to 4.5 and 6.0 MeV/c^2 FWHM for Λ° and K_s°, respectively. For the Λ° selection the $M(p\pi^-)$ was required to deviate from the Λ° mass by no more than 7 MeV/c^2, and for the K_s° selection the $M(\pi^+\pi^-)$ was required to deviate from the K_s° mass by no more than 10 MeV/c^2. Altogether ~ 8.5·10^4 events with Λ° and ~4.5·10^4 events with K_s° have been selected. For $\bar{p}$ identification the signals from C1 and C2 were analysed. This allowed the π^-/K^- rate to be reduced by a factor of more than three among the $\bar{p}$ candidates.

The invariant mass spectra for the configurations corresponding to the possible decays:

$$U^+ \rightarrow \Lambda^\circ \bar{p} \pi^+ \pi^+, \quad U^\circ \rightarrow \Lambda^\circ \bar{p} \pi^+, \tag{1,2}$$

$$U^\circ \rightarrow \Lambda^\circ \bar{p} \pi^+ \pi^+ \pi^-, \quad U^- \rightarrow \Lambda^\circ \bar{p} \pi^+ \pi^-, \tag{3,4}$$

and

$$U^{--} \rightarrow \Lambda^\circ \bar{p} \pi^- \tag{5}$$

were analysed among the events containing Λ°. The bin was chosen to be equal to 20 MeV/c^2 which approximately corresponds to the experimental mass resolution for the configurations under study. The excesses of events in three bins at ~3060 MeV/c^2 over the background level were observed in all the spectra analysed. A statistical significance of the observed excesses was determined as a result of the spectra approximation by smooth background curves. For the configurations (1-5) they were more than two, five, four, four and three standard deviations over the background curves, respectively. The summarized spectrum, obtained for all (1-5) invariant mass configurations, is presented in fig.2. The peak in a mass region of 3030 – – 3090 MeV/c^2 contains about 130 events over the background level (~270 events). This corresponds to a statistical significance of more than eight standard deviations. The mass scale calibration may have a systematical error of no greater than 40 MeV/c^2. The invariant mass distributions calculated on the assumption that $\bar{p}$ is a kaon or a pion have been analysed for the events from the peak region in each of the considered mass spectra. At each of such
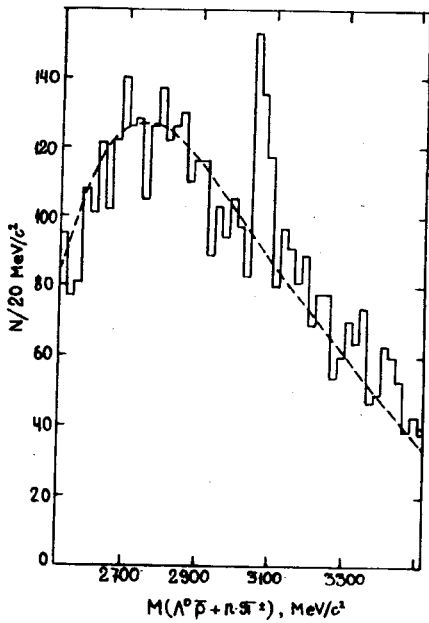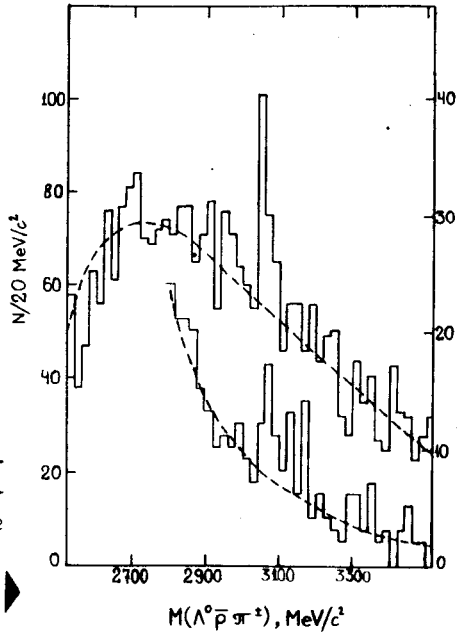
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Fig.2. Invariant mass spectrum for the events containing Λ°, $\bar{p}$ and charged pions.

Fig.3. Invariant mass spectrum of the $\Lambda^\circ \bar{p} \pi^+$ system (upper histogram and left scale of events) and $\Lambda^\circ \bar{p} \pi^-$ system (lower histogram and right scale of events).

assumptions the analysed events form a broad mass spectrum without any peaks. Consequently, the observed peaks in the invariant mass spectra of systems(1-5) are not the kinematical reflections of other resonances caused by $\bar{p}$ misidentification. In the same way the validity of charged pion identification was proved for the events forming the peaks.

About 130 decays of the U(3100) via the modes (1-5) have been observed. The main part (~75 events) is due to the decays via the mode (2). The corresponding invariant mass spectrum is presented in fig.3 (upper histogram). The invariant mass spectrum illustrating the registration of the decay (5) of the double charged U^{--} state is shown in the same figure (lower histogram).

A more detailed analysis of the observed U(3100) state was performed for the registered decays (2). The invariant mass spectrum of the $\bar{p}\pi^+$ subsystem was reconstructed for these events (fig.4). This spectrum is a result of subtraction of the corresponding spectra obtained for the
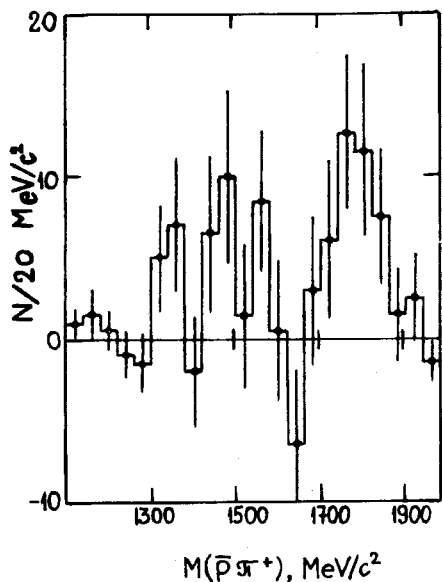
Fig.4. Invariant mass spectrum for the $\bar{p}\pi^+$ subsystem produced in the $U^\circ \to \Lambda^\circ \bar{p}\pi^+$ decays.

events from the peak region and from the peak neighbouring intervals. As is seen from the $M(\bar{p}\pi^+)$ distribution presented in fig.4, a greater part of events is grouped in a mass region of 1700-1800 MeV/c². The shape of the distribution in this region corresponds in mean mass and width to the $\bar{\Delta}(1700)$ parameters [7]. In an analogous $M(\bar{p}\pi^+)$ spectrum, obtained for the events from the intervals abjacent to the peak, such a grouping of events is not observed. Thus, the obtained data are identicative of the two-body decay:

$$U^\circ \to \Lambda^\circ \bar{\Delta}(1700). \tag{6}$$

It has been found that about half the decays (2) accepted are caused by cascade decays through the intermediate resonance state (6).

The invariant mass spectra of the $\Lambda^\circ \bar{p}\pi^+$ system were analysed separately for the events detected in the runs with carbon, aluminium and copper targets. This allowed the measurement of the A-dependence of the U(3100) production cross section. This dependence in the frame of the A^α parametrization (A is the atomic weight of the target nucleus) is characterized by a power value:

$$\alpha = 0.6 \pm 0.3. \tag{7}$$

The invariant mass spectrum of the $K_s^\circ p\bar{p}\pi^+$ system was reconstructed (fig.5) among the events containing K_s°. The mass resolution for such a system is close to the resolution of configurations (1-5). A narrow peak is seen in the "U" mass region as in the above spectra. An excess of 50 events over the background level (~170 events) is seen in a mass region of 3030-3090 MeV/c². The presence of such a peak shows evidence for the observation of the registered decays:
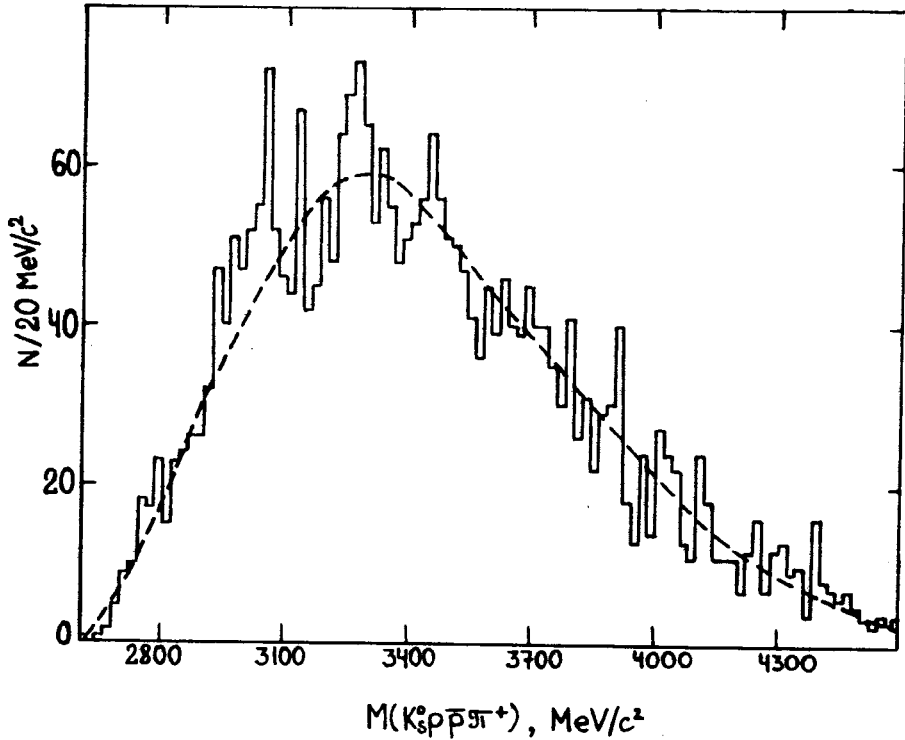
$$U^+ \to \bar{K}^\circ p\bar{p}\pi^+ \tag{8}$$

Fig.5. The $K_s^0 p \bar{p} \pi^+$ *invariant mass spectrum.*

and/or

$$\bar{U}^+ \to K^0 p \bar{p} \pi^+. \tag{9}$$

In conclusion we summarize the results obtained.

1. About 180 events of the narrow resonance with negative strangeness decaying into a baryon, an antibaryon and mesons are registered.The mean mass of the resonance is $(3068 \pm 5 \pm 40)$ MeV/c^2, and its width does not exceed 20 MeV/c^2. The characteristics of the observed resonance correspond to the U(3100) state observed in the experiment[1]. Thus, we have identified the resonance observed with the U(3100) state.

2. In comparison with the U(3100) decays observed in the experiment [1], the new decay modes

$$U^0 \to \Lambda^0 \bar{p} \pi^+ , \quad U^0 \to \Lambda^0 \bar{\Delta}(1700) , \quad U^{--} \to \Lambda^0 \bar{p} \pi^- , \quad U^+ \to \bar{K}^0 p \bar{p} \pi^+$$

and, possibly, the decay of the strangeness conjugated state $\bar{U}^+ \to K^0 p \bar{p} \pi^+$ are detected.

3. The isotopic spin of the resonance is determined to be 3/2. This conclusion is supported by the registration of the decay $U^{--} \to \Lambda^0 \bar{p} \pi^-$.

4. The A-dependence of the cross section of resonance production in neutron-nucleus interactions has been measured. It is characterized by an exponent

$a = 0.6 \pm 0.3$.

5. From the longitudal momentum distribution of resonance events it follows that they are registered in the region $x > 0.2$, where x is the Feynman variable. Their production cross section in this region times the branching ratio of each observed mode is $\sigma \cdot B = 1 \div 20$ μb per carbon nucleus. Such uncertainty of the quoted value is due to the lack of information concerning the resonance production and decay mechanisms. The obtained $\sigma \cdot B$ values are close to those measured in [1]. In the experiment [1] the U(3100) were produced by 135 GeV/c Σ^- on a beryllium target, and because of the S-quark presence in the composition of a primary hadron the $\sigma \cdot B$ value should be greater than in the case of resonance production in a neutron beam. The presented comparison leads to an energetic dependence of the resonance production cross section which decreases with increasing energy.

6. The main properties of the resonance observed are inconsistent with its interpretation as a quark-antiquark state. The totality of the U(3100) states observed should be described under the assumption of their composition of at least four valence quarks.

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