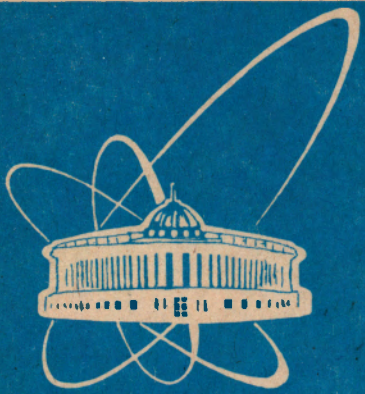

ОБЪЕДИНЕННЫЙ
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OBSERVATION OF A RARE ANNIHILATION CHANNEL DUE TO ANTIPROTONS STOPPING IN NUCLEAR PHOTOEMULSION

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The investigation of interaction processes involving slow antiprotons reveal new possibilities for studying nuclear structure and the dynamics of nuclear reactions with the aid of such processes [1,2].

One such possible line of investigation consists in searching for unusual (or rare) annihilation channels involving antiprotons stopping on nuclei.

Investigation of the secondary charged particle multiplicity in antiproton annihilation on nuclei in nuclear photoemulsion has shown [3] the relative number of one-prong events (involving a sole visible charged particle produced in the annihilation process) to be $(3.5 \pm 0.3)\%$. Most (89%) of the secondary particle tracks in such events are tracks of "s"- and "g"-particles [3] with ranges in the photoemulsion exceeding 3000 μ. Of the 3799 analyzed annihilation events due to antiprotons interacting with nuclei in the photoemulsion, only in 15 one-prong stars were there slow charged "b"-particles detected, forming short black tracks produced by nuclear fragments or by slow hydrogen nuclei. In such a reaction the charge of the primary nucleus will change by, at least, two units, if a positively charged particle is produced in the antiproton absorption, which, in turn, points to participation in the reaction of at least two protons. A similar reaction involving pions is termed pion double charged exchange [4].

The ranges of all secondary "b"-particles in the one-prong events were carefully measured using a microscope with a magnification of 1350x yielding a precision of 0.5 μm. The prong lengths in six events were found to be very close to each other for ranges from 2 μm to 3000 μm, while the remaining secondary particle ranges turned out to be uniformly distributed over the whole interval being studied.

The average range of black prongs in the events singled out was (79.4 ± 5.1) μm. The small spread of the track lengths in one-prong events can be considered to point to antiproton annihilation on nuclei in photoemulsion proceeding via a two-particle channel. It must be noted that in four, out of six, events slow electrons, characteristic of processes on heavy nuclei, were observed at the centres of the stars.

Assuming two-particle antiproton annihilation to take place on a few-nucleon cluster in the surface layer of the nucleus, and the influence of the nucleus on the kinematics of the process to be insignificant, it is possible to calculate the mass of the secondary neutral particle, since the range of the outgoing charged particle and the total reaction energy are known. That there is no noticeable narrowing of "b"-tracks toward the end of the path in the photoemulsion allow the conclusion that the black tracks in the detected events correspond to charges $z \leq 3$. This fact significantly narrows the set of possible few-nucleon clusters relevant to the analysis of two-particle antiproton annihilation channels on nuclei.

The following reaction channels were considered: $\bar{p} + [A] \rightarrow A' + X^{\circ}$, where $[A]$ represents the primary clusters: ^{2}He, ^{3}He, ^{4}He, ^{4}Li, ^{5}Li, ^{7}Li, ^{7}Be, ^{8}Be, and A' represents the respective recoil nuclei: p, d, t, ^{3}He, ^{4}He, ^{6}He, ^{6}Li, ^{7}Li; X° stands for the neutral meson decaying into neutral particles.

The mass of the neutral meson was found to vary between 1872 MeV and 1764 MeV,

depending on the cluster participating in the annihilation. Within this mass range there exists a sole neutral meson, Φ_3° (1850) [5], which decays into $K\bar{K}$ or $K\bar{K}^*$ (892) + charge conjugates, has quantum numbers $0^-(3^{--})$, a mass $M_{\Phi_3^\circ} = 1854 \pm 7$ MeV and a total decay width $\Gamma = 87^{+28}_{-23}$ MeV.

The smallest deviations of the experimental mass of the Φ_3°-meson from the table value were obtained for the annihilation channels on the clusters [^{4}He] and [^{4}Li], i.e. the reactions:

$$\begin{array}{l} \bar{p} + [^4He] \longrightarrow \Phi_3^\circ + t \\ \qquad\qquad\qquad\quad \hookrightarrow K^\circ + \bar{K}^\circ \end{array} \tag{1}$$

or

$$\begin{array}{l} \bar{p} + [^4Li] \longrightarrow \Phi_3^\circ + {}^3He \\ \qquad\qquad\qquad\quad \hookrightarrow K^\circ + \bar{K}^\circ \end{array} \tag{2}$$

In the case of reactions (1) $\Delta M = -8.9$ MeV, and for reaction (2) $\Delta M = -4.6$ MeV.

The production probability of such events per one antiproton stopping on nuclei in the photoemulsion was estimated to be $w_{exp} = (1.58 \pm 0.63) \cdot 10^{-3}$. The probability for an accidental outgoing (4.6 ± 0.2) MeV tritium nucleus to be observed in the annihilation of a slow antiproton on a heavy nucleus in the photoemulsion, calculated using the optical-cascade model of the absorption of stopping antiprotons [3], is $w_{theor} < 5.0 \cdot 10^{-5}$, which is 30 times smaller than the experimental value.

Besides decaying into K°- and $\bar{K}^\circ$-mesons, the Φ_3°-meson can also decay into K°- and $\bar{K}^{*\circ}$ (892) (or into $\bar{K}^\circ$- and $K^{*\circ}$ (892)), i.e.

$$\begin{array}{l} \Phi_3^\circ \longrightarrow K^\circ + \bar{K}^{*\circ}(892) \quad (or\ \bar{K}^\circ + K^{*\circ}(892)) \\ \qquad\qquad\quad \hookrightarrow K^- + \pi^+ \qquad\quad \hookrightarrow K^+ + \pi^- \end{array} \tag{3}$$

or into charged K-mesons via the channels

$$\Phi_3^\circ \rightarrow K^+ + K^- \tag{4}$$

and

$$\begin{array}{l} \Phi_3^\circ \longrightarrow K^+ + \bar{K}^{*-}(892) \quad (or\ \bar{K}^{*+}(892) + K^-) \\ \qquad\qquad\quad \hookrightarrow K^- + \pi^\circ \qquad\quad \hookrightarrow K^+ + \pi^\circ \end{array} \tag{5}$$

In this case an event of antiproton annihilation on a nucleus in the photoemulsion, involving Φ_3°-meson production, will be a three-prong stars with a single black ("b")- and two relativistic ("s") tracks.

An analysis of 3799 annihilation stars yielded 101 such events, six of which had a black "b"-track with a range in the $(59 \div 99)$ μm interval. Measurement of the ranges

of "s"-tracks and of their relative ionization powers revealed that they could all be classified as charged π- or K-mesons produced in the annihilation. Regretfully, it was not possible to measure the kinetic energies of these particles with a good precision, owing to the restricted size of the photoemulsion chamber.

All the selected three-prong antiproton annihilation events were tested for complanarity of the three charged secondaries. It turned out that the deviation of the third prong from the plane did not exceed 24° for all the events. Two events could be classified as representing channel (4), since, given a complanarity of 3° and 8° and a spatial opening angle between the charged mesons of $(170.8 \pm 1.0)°$, they were quite consistent with the kinematical criteria for a Φ_3°-meson of kinetic energy 7.0 MeV decaying into K^+- and K^--mesons.

The mean range of the six black "b"-tracks in the selected three-prong events is $(78.8 \pm 16.4)\mu$m, which is in good agreement with similar measurements for one-prong annihilation stars. Hence, the branching ratio of the annihilation channel for an antiproton, stopping on a nucleus in the photoemulsion, involving an outgoing Φ_3°-meson decaying into pairs of neutral ($K^\circ\bar{K}^\circ$ and $K^\circ\bar{K}^{*\circ}$ ($\bar{K}^\circ K^{*\circ}$)) or charged K- and K^* (892)-mesons, is $W_{\Phi_3^\circ} \geq (3.2 \pm 0.9) \cdot 10^{-3}$.

To be sure not to have any chance coincidences of the ranges of "b"-recoil particles in annihilation events of antiprotons stopping on nuclei in the photoemulsion we have analyzed five-prong events with four relativistic "s"- and one black "b"-prongs. Of the 3799 annihilation stars in the $(40 \div 140)\mu$m interval of "b"-prong ranges no such event was found among the selected events.

Thus, a rare annihilation channel involving antiprotons at rest in photoemulsion and the production of Φ_3°-meson has been observed for the first time. Detailed investigation of the new class of reactions will, most likely, will may be clarify, also, the existence of strange sea quarks in nuclear matter.

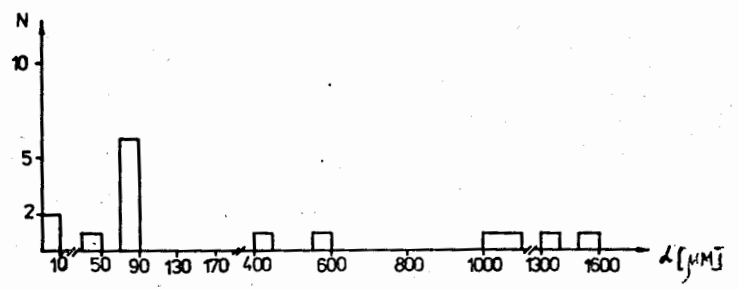

Fig. 1. The range path distribution of "b"-particles in photoemulsion.

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Наблюдение редкого канала аннигиляции остановившихся антипротонов на ядрах в фотоэмульсии

Из анализа 3799 событий аннигиляции остановившихся антипротонов на ядрах в фотоэмульсии было выделено шесть однолучевых звезд, имеющих средний пробег вторичной медленной «b»-частицы $(79{,}4 \pm 5{,}1)$ μm. Малый разброс длин следов в однолучевых событиях указывает на бинарный канал аннигиляций антипротона на нуклонном кластере в поверхностном слое ядра. Кинематический анализ показал, что таким каналом может быть процесс образования $\Phi_3^0(1850)$-мезона при аннигиляции антипротона на тяжелом ядре в фотоэмульсии.

Относительная вероятность образования зарегистрированных событий составляет не менее $(3{,}2 \pm 0{,}9) \cdot 10^{-3}$.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 1996

Batusov Yu.A. et al. E1-96-218

Observation of a Rare Annihilation Channel Due to Antiprotons Stopping in Nuclear Photoemulsion

An analysis of 3799 annihilation events due to antiprotons stopping in nuclear photoemulsion has permitted identification of six one-prong stars with an average range of the secondary slow «b»-particles equal to (79.5 ± 5.1) μm. The small spread of the ranges points to antiproton annihilation on a nucleon cluster in the surface layer of a nucleus proceeding through a binary channel. Kinematical analysis reveals that this channel may involve the production of a Φ_3^0 (1850)-meson in antiproton annihilation on a heavy nucleus in the photoemulsion.

The branching ratio for production of the detected events is, at least, $(3.2 \pm 0.9) \cdot 10^{-3}$.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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