Phys. Lett., 1966, v. 22, N 4, p. 487-489

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ
Дубна

E - 2774

Yu.A.Batusov, S.A.Bunyatov, V.M.Sidorov, V.A.Yarba

HELIUM-8 PRODUCTION IN NEGATIVE PION CAPTURE BY CARBON AND OXYGEN NUCLEI

ЛАБОРАТОРИЯ ЯДЕРНЫХ ПРОБЛЕМ

1966

E - 2774

Yu.A.Batusov, S.A.Bunyatov, V.M.Sidorov, V.A.Yarba

HELIUM-8 PRODUCTION IN NEGATIVE PION CAPTURE BY CARBON AND OXYGEN NUCLEI

Submitted to Physics Letters

For the first time the possibility of He^8 existence was considered by Ya.B.Zeldovich/1/ and V.I.Goldansky/2/ in 1960. Using the data on the energy of neutron pairing the above authors draw a conclusion on a great probability of the existence of the He^8 isotope stable to neutron emission. However, there was no strict experimental evidence on He^8 existence until recently.

All the papers published before 1965 have been considered in the survey/3/. Two publications on He^8 existence appeared in literature in 1966. A.M.Poskanzer et al./4/ have studied the decay schemes of the He^8 nucleus produced by exposing plastic or cotton targets to 2.2 GeV protons. J.Gerny et al./5/ have measured the He^8 mass in the reaction $He^4 + Mg^{26} \rightarrow He^8 + Mg^{22}$. The present paper reports on the direct detection of the production and decay of He^8 nuclei produced in the capture of stopped negative pions by carbon and oxygen nuclei in photoemulsion. The mass of He^8 is determined. The values of the probabilities of He^8 production by various nuclei in photoemulsion are given.

If the He^8 nucleus is stable to nucleon emission, it should decay according to the following schemes:

$$\text{I.}\quad He^8 \xrightarrow{\beta^-} Li^{8*}(0.978;\, 1^+) \xrightarrow{\gamma} Li^8 \xrightarrow{\beta^-} Be^{8*}(2.9;\, 2^+) \rightarrow 2\,He^4$$

$$\text{II.}\quad He^8 \xrightarrow{\beta^-} Li^{8*}(3.22;\, 1^+) \rightarrow Li^7 + n.$$

The first of the two schemes is especially convenient for detecting in photoemulsion, since in this case one is to observe at the end of the He^8 track two electron tracks and two alpha-particle ones going in opposite directions and equally long (a 'hammer' track with two electrons in contrast to the hammer tracks of Li^8 and B^8 which are accompanied by an electron or positron track, respectively).

The present experiment was aimed at searching for He^8 which might be produced in negative pion capture by light nuclei C, 0 and N in photoemulsion. In this case He^8 can be observed in the following reactions:*

1. $\pi^- + 0^{16} \longrightarrow He^8 + B^8$ 2 - prong stars

$$\left.\begin{array}{ll} 2. & \pi^- + C^{12} \longrightarrow He^8 + He^3 + H^1 \\ 3. & \pi^- + N^{14} \longrightarrow He^8 + He^3 + He^3 \\ 4. & \pi^- + 0^{16} \longrightarrow He^8 + Be^7 + H^1 \end{array}\right\} \quad \text{3 - prong stars}$$

---

* Reactions with a larger number of charged particles are not given.

$$\left.\begin{array}{lrl}
5. & \pi^- + C^{12} \longrightarrow & He^8 + H^2 + H^1 + H^1 \\
6. & \longrightarrow & He^8 + H^1 + H^1 + H^1 + n \\
7, & \pi^- + N^{14} \longrightarrow & He^8 + He^4 + H^1 + H^1 \\
8. & \longrightarrow & He^8 + He^3 + H^1 + H^1 + n \\
9. & \longrightarrow & He^8 + He^3 + H^2 + H^1 \\
10. & \pi^- + 0^{16} \longrightarrow & He^8 + Li^6 + H^1 + H^1 \\
11. & \longrightarrow & He^8 + He^4 + He^3 + H^1 \\
12. & \longrightarrow & He^8 + He^3 + He^3 + H^2 \\
13. & \longrightarrow & He^8 + He^3 + He^3 + H^1 + n
\end{array}\right\} \text{4 - prong stars}$$

In the reactions under study the target nuclei fully disintegrate. The energy released in negative pion capture is exactly known. This allows to carry out a strict kinematic analysis of the events observed.

Emulsion stacks 10 x 10 x 2.5 cm^3 large consisting of 600μ NIKFI-BR emulsion layers sensitive to relativistic particles were exposed to the 80 MeV negative pion beam of the Dubna synchrocycloton. Mesons were slowed down in the middle of the stack and the region of pion stops 1 cm wide was scanned with a microscope having magnification 225 X in order to detect hammer tracks*. Then among them search was made for events of two electron tracks (magnification being 1350X) satisfying the following selection criteria:

1. Electrons should be relativistic;
2. The distance from the He^8 track end to the first grain of the electron track should not exceed the trebled average distance between the grains of the electron track. (The relative number of such gaps is 5%).
3. The electron track should be scanned either till the stop in the stack or till it leaves the stack.

By the present time some 7145 hammer tracks have been detected and 3 events with two electrons have been found among them. The kinematic analysis has shown that the three events correspond to the following reactions:

$$\begin{array}{lrl}
1. & \pi^- + C^{12} \longrightarrow & He^8 + He^3 + H^1 \\
2. & \pi^- + C^{12} \longrightarrow & He^8 + H^2 + H^1 + H^1 \\
3. & \pi^- + 0^{16} \longrightarrow & He^8 + He^4 + He^3 + H^1
\end{array}$$

Figs. 1,2 show photomicrographs of two of these events. No events on nitrogen and on Ag, Br nuclei were detected.

In each case the mass of the He^8 atom and the M - A mass excess were measured. The values of M - A turned out to be (30.2 ± 3.1) MeV, (28.5 ± 1.1) MeV and (31.1 ± 1.0) MeV, respectively. The average value of the three measurements is $\overline{M - A} = (29.8 \pm 0.9)$ MeV. The same value measured by 10 counts of the electronics in the reaction $He^4 + Mg^{26} \longrightarrow He^8 + Mg^{24}$ proved to be (31.65 ± 0.12) MeV/5/.

---

* They are, mainly, the tracks of Li^8 which is produced as a result of negative pion capture by light nuclei. The emergence of hammer tracks from heavy nuclei is suppressed by the large Coulomb barrier.

Basing on the detected events one can evaluate the probability of He^8 production in negative pion capture by various nuclei:

$$W_1 = \frac{\pi^- C^{12} \longrightarrow He^8}{\pi^- C^{12} \longrightarrow \text{all channels}} = 2.8.10^{-6}$$

$$W_2 = \frac{\pi^- 0^{16} \longrightarrow He^8}{\pi^- 0^{16} \longrightarrow \text{all channels}} = 2.1.10^{-6}$$

$$W_3 = \frac{\pi^- N^{14} \longrightarrow He^8}{\pi^- N^{14} \longrightarrow \text{all channels}} < 5.10^{-6}$$

$$W_3 = \frac{\pi^- \text{Ag Br} \longrightarrow He^8}{\pi^- \text{Ag Br} \longrightarrow \text{all channels}} =< 0.4.10^{-6}$$

(Here the probabilities are given of the production of He^8 which decays according to scheme 1). As follows from ref./4/, the number of decays going according to this scheme is 88%).

From the fact that there exists a beta-active nucleus of He^8 with such a mass it follows that the coupling energy of the tetraneutron (if any) does not exceed (4.9 ± 0.9) MeV. Otherwise, He^8 would decay into $He^4 + n^4$.

The authors are grateful to Prof. V.P.Dzhelepov for interest and support.

References

1. Ya.B.Zeldovich. J.Exptl. and Theort. Phys., 38 (1960) 1223.
2. V.I.Goldansky. J.Exptl. and Theort.Phys., 38 (1960) 1637.
3. A.I.Baz, V.I.Goldansky, Ya.B.Zeldovich. Uspekhi Phys.Nauk, 85 (1965) 445.
4. A.M.Poskanzer, R.A.Esterlund, R.McPherson. Phys.Rev.Lett.,15 (1965) 1030.
5. J.Cerny, S.W.Cosper, Q.W.Butler, R.H.Pehl, E.S.Goulding, D.A.Landis, C.De'traz. Phys.Rev.Lett., 16 (1966) 469.

Received by Publishing Department
on May 6, 1966.

Table

Event N1

Track number	Range [micron]	Angle [degree]	Energy [mev]	Identification	Reaction, He^8 mass, mass excess
1	44,8±1,1	0	10,9±0,1	He^8	$\boxed{\pi^- C^{12} \rightarrow He^8 + He^3 + H^1}$
2	524±7	219±1,7	33,9±0,3	He^3	$M = (7481,7 \pm 3,1)$ MeV
3	>1320	103±1,5	41,7±3,0	H^1	$M - A = (30,2 \pm 3,1)$ MeV

Event N2

1	7,9±1,0	0	2,7±0,3	He^8	$\boxed{\pi^- C^{12} \rightarrow He^8 + H^2 + H^1 + H^1}$
2	1823±20	136,1±2,4	26,5±0,3	H^2	$M = (7480,0 \pm 1,1)$ MeV
3	1880±27	215,2±2,4	20,1±0,2	H^1	$M - A = (28,5 \pm 1,1)$ MeV
4	4626±80	317,1±2,4	33,6±0,5	H^1	

Event N3

1	18,1 ±1,0	0	5,4±0,3	He^8	$\boxed{\pi^- O^{16} \rightarrow He^8 + He^4 + He^3 + H^1}$
2	5208±75	89,3±1,9	36,0±0,3	H^1	$M = (7482,6 \pm 1,0)$ MeV
3	383 ±4,0	211,4±2,1	32,0±0,5	He^4	$M - A = (31,1 \pm 1,0)$ MeV
4	33,1 ±1,5	320,4±1,8	6,2 ± 0,3	He^3	

$$\bar{M} = (7481,3 \pm 0,9) \text{ MeV}$$

$$\overline{M - A} = (29,8 \pm 0,9) \text{ MeV}$$

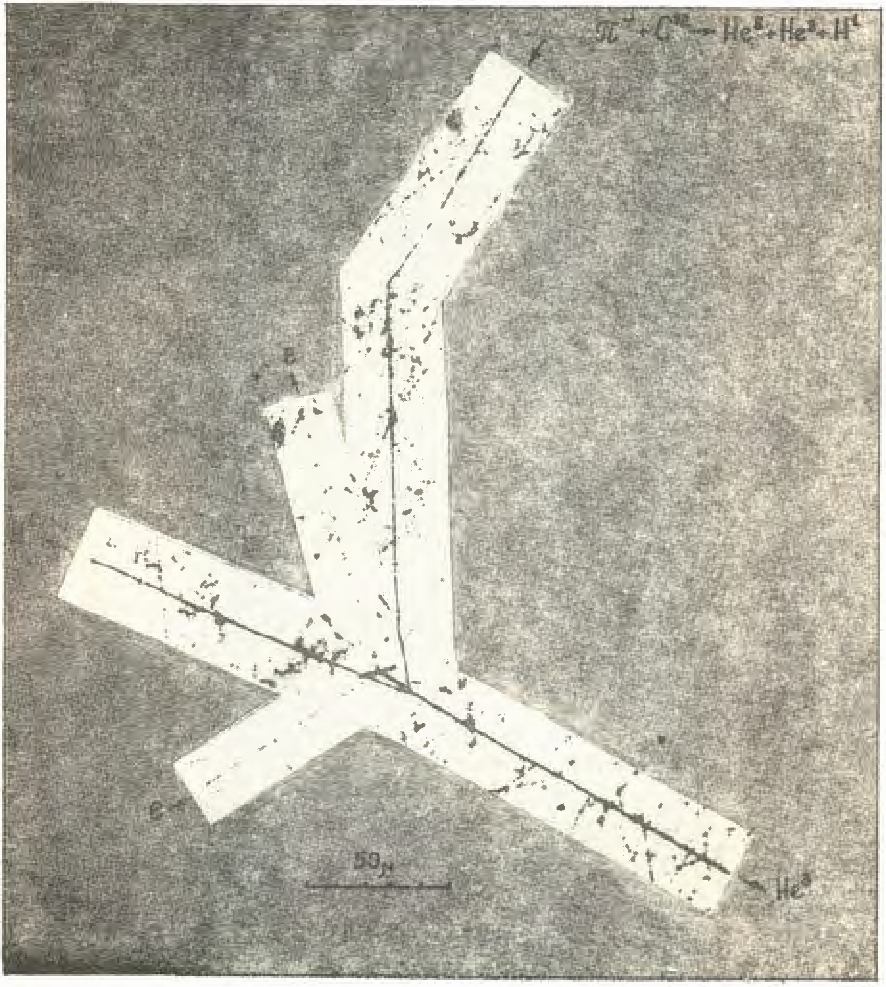
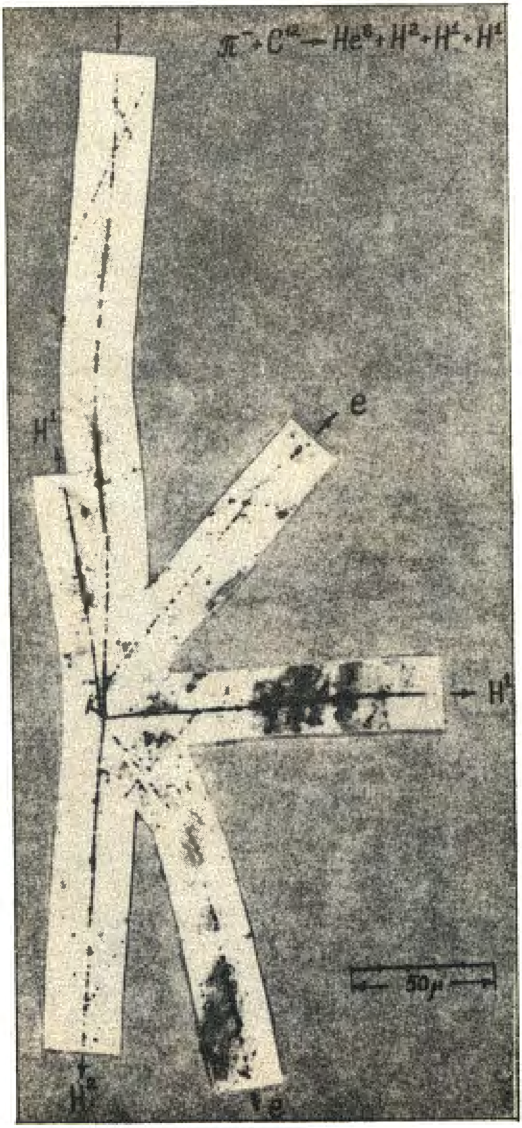


Fig. 1



F i g. 2