ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

ДУБНА

E1 - 10870

B.P.Bannik, I.B.Bobajanov, A.El-Naghy,
A.A.Khushvaktova, R.A.Khoshmukhamedov,
V.A.Leskin, A.Mukhtarov, J.A.Salomov,
G.S.Shabratova, G.Y.Sun-Tsin-Yan, K.D.Tolstov

SEARCH FOR NEW SHORT-LIVED PARTICLES IN π^- - COLLISIONS WITH EMULSION NUCLEI AT 60 GEV/C

1977

E1 - 10870

B.P.Bannik, I.B.Bobajanov,* A.El-Naghy,
A.A.Khushvaktova,* R.A.Khoshmukhamedov,*
V.A.Leskin,* A.Mukhtarov,* J.A.Salomov,
G.S.Shabratova, G.Y.Sun-Tsin-Yan,* K.D.Tolstov

SEARCH FOR NEW SHORT-LIVED PARTICLES IN π^- - COLLISIONS WITH EMULSION NUCLEI AT 60 GEV/C

Submitted to "Письма в ЖЭТФ"

*Physical-Technical Institute, Academy of Sciences, Tajik SSR.

Банник Б.П. и др. **E1 - 10870**

Поиск новых короткоживущих частиц в столкновениях π^--мезонов с энергией 60 ГэВ/с с ядрами фотоэмульсии

При исследовании окрестностей около 10000 звезд от взаимодействий π^--мезонов с энергией 60 ГэВ/с с ядрами фотоэмульсии был найден один случай, который может быть интерпретирован как лептонный распад новой частицы, для ее эффективной массы была получена оценка ~ 2,4 ГэВ, а для времени жизни - ~ 10^{-14} с.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна 1977

Bannik B.P. et al. **E1 - 10870**

Search for New Short-Lived Particles in π^--Collisions with Emulsion Nuclei at 60 GeV/c

At investigation of about 10 000 interactions of 60 GeV/c π^--mesons with emulsion, one event, which can be interpreted as leptonic decay of a new short-lived particle, was detected. The average effective mass of this particle is ~2.4 GeV and its lifetime is ~10^{-14} sec.

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

Preprint of the Joint Institute for Nuclear Research. Dubna 1977

In 1967 one of the authors[1] reported about the possibility of searching for new short-lived particles, with a life-time of $\tau \simeq 10^{-15} \div 10^{-12}$ sec, by means of emulsion technique. In 1971 Niu[2] observed X-particle with a mass of $M \sim 1.5 \div 3.5$ GeV and of $\tau \sim 10^{-14}$ sec. In 1974 new resonances named J or Ψ were discovered[3]. The charm scheme has been regarded, in these years, as the most promising theory for interpretation of both X-particles and J/Ψ ones. Much effort to accumulate examples of new particles has been made by us and other groups using emulsion technique[4-11].

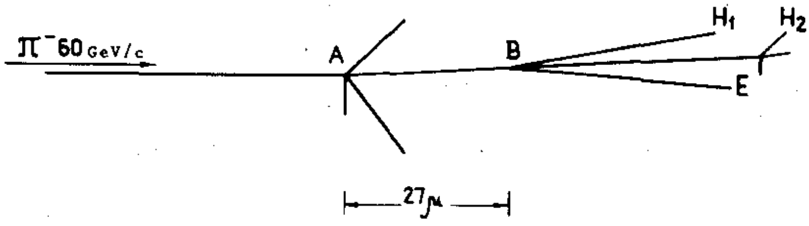
The as yet unknown source of prompt lepton production, in hadron-hadron and hadron-nucleus collisions, provides a further motivation for the present type of experiment. If prompt leptons are produced as decay products of new short-lived particles, then this could be directly observed and confirmed using nuclear emulsion. If they are not seen to be produced via short-lived particles, then this would suggest that they are produced electromagnetically.

In our experiment stacks of Br-2 emulsion were exposed to 60 GeV/c π^--mesons at the IHEP, Serpukhov. The intensity of irradiation was $I \sim 10^5$ particle/cm^2. The following method was chosen for detection: the primary stars were searched for under a small magnification of 7x20, the found stars were registered as points on a special blank of the corresponding squares of the neat coordinate. After area scanning of one strip (~0.3 cm^2) the observer investigated these primary stars under a high magnification of 15x60 for evidence of secondary interactions, decay or any correlated phenomenon, occurring within about a 45° half-angle forward cone and within 100μ of the primary vertex.

Within experimental and statistical errors, the numbers of secondary interactions and decays of known particles in a sample of ~10.000 inelastic interactions are in agreement with calculations. The fundamental signature of generation and subsequent decay of a new particle was the presence of a high energy electron within the decay products. In the following, we present the only event of this type found in our sample.

Topologically, the event represents a secondary star at a distance of 27μ from the primary vertex. The secondary star, at the first glance, consists of five relativistic tracks, coming from one point. A broad series of grains between the primary and the secondary stars indicated that there are more than one track between them.After geometrical measurements and careful analysis (see Appendix) the event has the following features:

The event (6s+1g+1b) is shown schematically in the figure. This star has one short black prong, one grey track and 6 relativistic particle tracks. One of these tracks, AB, is found to give rise to three further relativistic tracks at vertex B after a distance of



27μ. There is no sign of a nuclear recoil track. The space angle of track AB was measured with reference to the incident direction of the primary π^--meson. The space angles of tracks BH_1, BH_2 and BE were measured with reference to track AB. Tracks BH_1, BH_2 and BE were followed until they interacted, left the stack or finished in it. The angular and momentum characteristics are shown in <u>table 1.</u> Track BH_1 is a typical high energy hadron track, it was followed ~15 cm without change in momentum or relative ionization. Track BH_2 was followed ~ 9 cm where it interacted giving rise to a multiprong star. Track BE is a typical high energy electron track, it was followed ~7 cm. The momentum of the particle going along the track BE varies as follows:

$p\beta = 1.2 \pm 0.2$ GeV/c (along 1st 3 cm)
$p\beta = 0.5 \pm 0.1$ GeV/c (along next 2 cm)
$p\beta = 0.2 \pm 0.06$ GeV/c (along next 2 cm)

Then after scattering with an angle of 10° it becomes very slow and strongly scattered in the emulsion. It is to be noted that the relative ionization along the whole length did not change considerably and equals $J = 1.00 \pm 0.05$.

We checked all other tracks from the primary interaction, looking for other electrons, but none was found. Also no associated phenomenon was detected. We also checked the upper and lower emulsion plates near the coordinates of this event for any other electron or correlated phenomenon, but there was none.

A typical electron source, coming from the secondary interaction at point B, is Dalitz pair from π^0 decay into γe^+e^-. This is why, we assumed at first that track BH_1 may be an electron (track BH_2 was excluded since it interacted giving a star), but this possibility is very small because track BH_1 was followed ~15 cm without change in energy (the radiation length in emulsion is ~ 3 cm).

Table 1

Angular and momentum characteristics of the event

Track	Space angle Θ^0	Azimuthal angle	$p\beta$ GeV/c	$p_\perp$ GeV/c	Length L cm	Ionization J^*	
AB	3.3	333			27×10^{-4}		
BH1	1.6	306	2.8 ± 0.3	0.078	15	$0.95\pm.05$	
BH2	6.0	90	4.3 ± 4.0	0.449	9	$1.06\pm.0.6$	interacted
BE	1.9	219	1.2 ± 0.2	0.040	7	$1.00\pm.05$	finished in emulsion

Other sources of background may be summarized as follows:

1. Decay of unstable particles (mainly strange) produced in the secondary interaction (star) and decaying very near to point B($\sim 3\mu$).

2. High energy δ-electron from parent particle (track AB) or from one of the secondary tracks.

3. Formation of asymmetric Dalitz-pair from π°-decay such that one component has energy in the Laboratory system, very small to be observed (~100 KeV).

4. Formation of Dalitz pair such that e^{+} annihilates within a very short distance from the vertex.

5. Formation of Compton electron from the interaction of quanta which come from the decay of π° produced at point B. Quantitative estimations of these sources are given in table 2.

Table 2

Quantitative estimations of backgrounds

No.	Decay Mode	Probability
	$\pi^{\pm} \to e^{\pm}\nu(\tilde{\nu})$	$\sim 3.6 \times 10^{-6}$
	$K^{\pm} \to e^{\pm}\pi^{\circ}\nu(\tilde{\nu})$	$\sim 4.0 \times 10^{-5}$
1	$\Sigma^{+} \to e^{+}\Lambda\nu$	$\sim 7.0 \times 10^{-7}$
	$\Sigma^{+} \to e^{+}n\nu$	$\sim 10^{-7}$
	$\Sigma^{-} \to e^{-}n\tilde{\nu}$	$\sim 10^{-5}$
	$\Xi^{-} \to e^{-}\Lambda\tilde{\nu}$	$\sim 10^{-5}$
2	δ -ray	excluded by kinematics
3	asymmetric Dalitz pair	$\sim 5 \times 10^{-5}$
4	e^{+} annihilation	$\sim 3 \times 10^{-7}$
5	Comptonelectron	$\sim 3 \times 10^{-6}$

As an alternative source, we studied the possibility of leptonic decay of charmed particles. For example, a charmed meson can decay as:

$$M_c \rightarrow e + \nu_e + \text{hadrons}.$$

We have detected two hadrons BH_1, BH_2 and an electron BE, the existence of neutrino is confirmed from the transverse momentum imbalance between tracks BH_1, BH_2 and BE. Assuming that tracks BH_1, BH_2 are pion and kion or vise versa and the neutrino has an isotropic angular distribution, an average effective mass $M \sim 2.4$ GeV was obtained. The corresponding lifetime τ is $\sim 10^{-14}$ sec.

APPENDIX

The primary event consists of one short black prong, one grey track and nine relativistic tracks, five of them are flying as if they are coming from one point B at a distance of 27μ from the primary vertex A. Broad series of grains, nearly 22, between points A and B, indicated that there are two or three tracks coming, in fact, from the primary vertex A (the sensitivity of our emulsion is 30 grain/100 μ). To find the origin of every track, the following were carried out.

1. Three physicists traced every track in the backward direction (towards A and B). They independently decided that at least the first of these five tracks is coming from point A.

2. The X and Y coordinates were measured for a number of points, far from A and B, for every track. Then the linear equation of every track was generated by the least square analysis. The measured positions of A and B were compared with the calculated lines, individually. These results are shown in the following table.

Table

The comparison of experimental and theoretical Y-coordinates of points A, B

Track No.	Point A $\lvert Y_{exp.} - Y_{th} \rvert \pm \Delta Y_{exp}$	Point B $\lvert Y_{exp.} - Y_{th} \rvert \pm \Delta Y_{exp}$
1	0.2 ± 0.2	1.6 ± 0.2
2(BH1)	0.2 ± 0.2	0.0 ± 0.2
3(BH2)	0.9 ± 0.2	0.1 ± 0.2
4(BE7	1.0 ± 0.2	0.2 ± 0.2
5	0.2 ± 0.2	1.2 ± 0.2

From the table, one can see that the first and fifth tracks are consistent with point A not B. The third and fourth tracks are consistent with point B not A., he second track (BH1) is consistent with both A and B. Thus we have the following three possibilities:

1. A three-prong star is formed at the point B no connecting track between A and B, i.e., an inelastic interaction of a neutral particle.

2. The track (BH1) is coming from A and apparently intersects with a "V" tracks (BH2 and BE) at the point B.

3. A relativistic charged particle track (AB) gives rise to three prong star at B.

The first possibility can be neglected due to the existence of a high energy electron (1.2 GeV). The second possibility, relative to the third one, is less probable because the probability of apparent intersection, which cannot be checked experimentally, is small one.

REFERENCES

1. Толстов К.Д. ОИЯИ, 3501, Дубна, 1967, с.32.
2. Niu K.et al.Prog.Theor.Phys., 1971, 46, p.1644.
3. Aubert J.J.et al.Phys.Rev.Lett., 1974, 33, p.1404.
   Augustin J.E.et al.Phys.Rev.Lett., 1974, 33, p.1406.
   Abrams G.S.et al.Phys.Rev.Lett., 1974, 33, p.1453.
4. Hoshino K.et al.Preprint Nagoya University, DPNU-16, Nagoya, 1975.
5. Jain P.L., Girard B. Phys.Rev.Lett., 1975, 34, p.1238.
6. Комар А.А. и др. ЯФ, 1976, 24, с.529.
7. Yock P.C.M.et al.Lett.Nuovo Cim., 1977, 18, p.554.
8. Bozzoli W.et al.Lett.Nuovo Cim., 1977, 19, p.32.

9. Coremans-Bertrand et al.Phys.Lett., 1976, 65B, p.480.
10. Burhop E.H.S. et al. Phys.Lett., 1976, 65B, p.299.
11. Bannik B.P.et al.Proc. of European Conf. on Particle Phys. Budapest, Hungary, 4-9 July, 1977.

Received by Publishing Department
on July 20, 1977.