Search for doubly charged anomalons in p^3He interactions at a ^{3}He-nucleus momentum of 5 GeV/c

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Experimental data were obtained with the help of the 80-cm liquid-hydrogen bubble chamber of the Institute of Theoretical and Experimental Physics. The chamber was exposed to a separated beam of ^{3}He nuclei with a momentum of 5 GeV/c. The statistical base of this study yields no indication of the existence of doubly charged anomalons in p^3He interactions at a proton kinetic energy $T_{\text{pin}} \approx 1$ GeV. How one extremely likely methodological error could result in a simulation of anomalously short mean free paths is demonstrated.

1. Several experiments in the early 1980s revealed indications of the existence of anomalons, i.e., components of nuclear fragments with an anomalously short mean free path (in other words, hypothetical particles with an anomalously large interaction cross section). The number of studies in this direction is fairly large.[1] In most of the studies in which the production of anomalons with a charge $1 < z < 26$ has been observed, the experimental data have been obtained from an analysis of collisions of heavy ions in nuclear emulsions.[2] It has recently been asserted,[3,4] on a large statistical base, that there exists a production of nuclear fragments with $z = 2$ and an anomalously small mean free path (mfp) in p^4He interactions at incident-nucleus momenta of 8.6 and 13.5 GeV/c and also in p^3He interactions at a nuclear momentum of 13.5 GeV/c. Data obtained with the help of the 1-m liquid-hydrogen bubble chamber of the Joint Institute for Nuclear Reserach were analyzed in those experiments. The interest in experiments of this sort has been heightened by attempts to interpret anomalons as particles with a bare color,[5,6] with the associated casting of doubt on the confinement hypothesis.

2. In the present letter we work from data obtained from the 80-cm liquid-hydrogen bubble chamber of the Institute of Theoretical and Experimental Physics, which was exposed to a separated beam of ^{3}He nuclei with a momentum of 5 GeV/c. The experimental procedure is described in detail in our preceding studies (e.g., Ref. 7).

We selected 8258 events of two-prong p^3He interactions with secondary ^{3}He nuclei (we wish to stress that these events were selected from the entire volume of the chamber, from two projections, with a scanning efficiency above 95%). We measured the length of the track corresponding to the secondary nucleus from the primary star to the secondary interaction or to the point at which the nucleus left the chamber. We observed a total of 1096 events with a secondary star and 7162 events with a helium nucleus being emitted from the chamber. We calculated the quantity

$$\lambda(x) = S/n \qquad (1)$$

as a function of the distance (x) between the vertices of the primary and secondary interactions, and we calculated S in Eq. (1):

$$S=(N-n)D+\sum_{i=1}^{n} x_i, \qquad (2)$$

where N is the total number of tracks of secondary nuclei which have traversed a given interval D or which have interacted in it (we first took the interval D to be 2 cm, and then we combined the statistics in the intervals in order to smooth the experimental histogram), n is the number of secondary interactions which fall in the given interval D, and x_i is the length of the segment of the track from the left edge of the interval to the secondary interaction.

The total cross section $\sigma_{\rm tot}$ for p^3He interactions at an incident-nucleus momentum of 5 GeV/c is[7] 125.2 mb; the hydrogen density ρ in the chamber was 0.0612 g/cm^3. Using Avogadro's number N_A, we find the mfp of the primary ^{3}He nuclei, λ_f, from the formula $\lambda_f = 1/N_A\rho\sigma_{\rm tot}$: 219 cm.

3. The statistical reliability of an estimate of the mfp λ_f of a random quantity λ was discussed in Ref. 8.

It was shown there that the value of S for secondary nuclei does not obey a χ^2 distribution and that the mathematical expectation is

$$E(\lambda)=\lambda_f-D/[1-\exp(-D/\lambda_f)]+ND\langle 1/n\rangle,$$
$$\langle 1/n\rangle=\sum_{n=1}^{N}\frac{1}{n}[1-\exp(-ND/\lambda_f)]^{-1}\binom{N}{n}$$
$$\times[1-\exp(-D/\lambda_f)]^n\exp(-(N-n)D/\lambda_f),\quad n=1,2,..N. \qquad (3)$$

Figure 1 shows a plot of function (3) for $\lambda_f = 219$ cm and $D = 2$ cm. We see that for the initial intervals, through which ~5000–7000 tracks pass in our case, an estimate of λ_f by the experimental value of λ is unbiased $[E(\lambda)\approx\lambda_f]$ (the dashed line corresponds to $\lambda_f = 219$ cm).

4. Since the mean free path was large in comparison with the dimensions of the chamber in the experiments, we observed a significant number of events in which a helium nucleus from the beam passed through the entire volume of the chamber and produced a primary star near the boundary of the chamber. The length of the track of the secondary helium nucleus is thus small in this case, and such events would distort the distribution of $\lambda(x)$ as a function of x in the most interesting part of the distribution, at small x. To avoid this distortion, we introduced a new parameter: the potential length $l_{\rm pot}$. We discarded all tracks of secondary helium nuclei which were emitted from the chamber and which had a length smaller than $l_{\rm pot}$. To choose the optimum length of this parameter, we calculated the quantity $\lambda_m = \sum_{i=1}^{N_t} x_i/N_{\rm int}$ where N_t is the total number of secondary tracks taken into consideration, $N_{\rm int}$ is the total number of secondary stars, and x_i is the length of secondary track i. The quantity λ_m thus has the meaning of an average mfp.

Under the assumption that the probability for the production of anomalons is

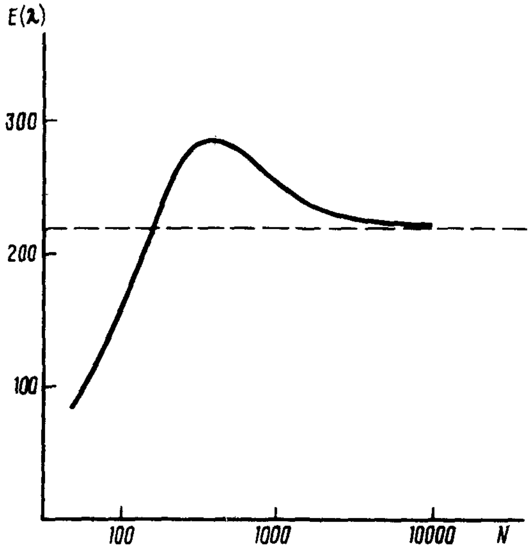

FIG. 1. The mathematical expectation $E(\lambda)$ versus the number of secondary tracks. The dashed line corresponds to a mean free path $\lambda_f = 219$ cm.

small, we chose the potential length in such a way that the relation $\lambda_m \approx \lambda_f$ held. We thus selected a potential length $l_{\rm pot} = 12$ cm. After $l_{\rm pot}$ was introduced, we were left with 6914 events.

The open circles in Fig. 2 are the results of an analysis of our data (each interval contains ~60–200 secondary stars). The straight dashed line in Fig. 2 corresponds to our mfp $\lambda_f = 219$ cm. Within the errors, our points are close to the λ_f line over the entire x interval.

Shown for comparison in Fig. 2, by the filled circles, are data from the Joint Institute for Nuclear Research,[4] which were obtained, as we mentioned above, with the help of a 1-m liquid-hydrogen chamber exposed to a beam of ^{3}He nuclei with a momentum of 13.5 GeV/c (the data of Ref. 4 have been coverted to correspond to our mfp λ_f).

The decrease in λ at small x is clear in Fig. 2.

To reach an understanding of the discrepancy between the two similar experiments, we took up the following methodological problem. We adopted the initial premise that the secondary tracks can be formed not only by ^{3}He nuclei but also by jets of nuclear fragments which are emitted in a cone so narrow that their tracks merge into a single track (e.g., pd or ppn jets). We made a special point of selecting events which were similar in topology to two-prong elastic-interaction events: a short track of a recoil proton and a secondary track produced by a jet of nuclear fragments. The conditions in our chamber and—the most important point—our initial energy ($T_{\rm pin} = 0.978$ GeV) made it possible to work from the "apparent" ionization to distinguish between the tracks of a nucleus and of a jet (in arbitrary units, the ionization of a nuclear track is ~5, and that of a jet track ~3–3.5). We found 130 such events; this sample was included in the overall statistics.[1)] The result is shown by the open

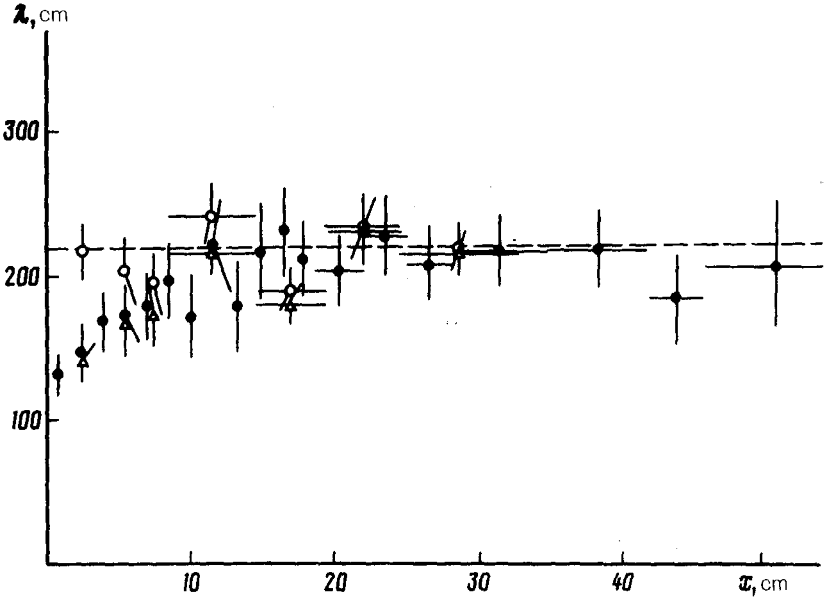

FIG. 2. Plot of λ versus x, where x is the distance betwen the vertices of the primary and secondary interactions. Dashed line—Mean free path $\lambda_f = 219$ cm; open circles—data of present study; filled circles—data of Ref. 4; open triangles—data of present study, including a sample of two-prong events with a topology similar to that of elastic scattering, specifically, a short recoil-proton track and a track formed by a jet of nuclear fragments (see the text proper).

traingles in Fig. 2. We see that the distribution found in this manner is very similar to the distribution of Ref. 4 and simulates anomalously small mfp's at small x. In our opinion, it is a far from trivial matter to distinguish events which contain a genuine ^{3}He nucleus from events which contain a jet of nuclear fragments on the basis of their ionization, because of the large primary energy, $T_{\rm pin} \approx 3.7$ GeV. It is this circumstance that we regard as the primary source of the discrepancy between our experiment and that of Ref. 4.

5. Let us summarize the results of this study. 1) Within our statistical base, there is no indication of the existence of doubly charged anomalons in p^3He interactions at a proton kinetic energy $T_{\rm pin} = 0.978$ GeV. 2) It has been shown that an extremely probable methodological error can result in a simulation of anomalously short mean free paths.

[1)]Twenty-two events with very short secondary tracks (~ 1 cm), which we were not able to unambiguously identify, were included in the overall statistics.

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