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SEARCH FOR ANOMALONS IN 360 GeV/c

π^- p AND pp INTERACTIONS

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ABSTRACT

A study of the length distribution of charged secondary interactions gives no evidence for the existence of charged anomalous in the products of the interactions of 360 GeV/c π^- and protons in hydrogen. Fits to the data yield 95% confidence level upper limits for anomalous production as a function of anomalous mean free path.

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The evidence for and against the existence of anomalons has been reviewed extensively and clearly [1,2,3]. Recently a specialist workshop was devoted to the subject [4]. Briefly, several experiments - mainly low statistics emulsion experiments - have reported the observation of secondary particles with anomalously short mean free path (more than 100 times smaller than conventional hadron mean free paths). These anomalous fragments (anomalons) have been reported exclusively within the domain of nuclear targets and heavy ion beams apart from the recent suggestion of pion-like anomalons [5]. A search in 8 GeV/c deuteron-deuteron data has yielded no evidence for anomalons and the resulting quoted upper limits for anomalon production are quite stringent [3]. A result reporting anomalons in high energy πp interactions which led to a Fermilab proposal [6] has now been withdrawn by the authors.

We have searched for anomalon production in a high-resolution hydrogen bubble chamber exposed to beams of 360 GeV/c π^- and protons. Data come from the CERN charm experiment NA16. This experiment has measured the mean lifetimes of the charm D-mesons [7] and investigated the hadroproduction characteristics of charm [8]. The LExan Bubble Chamber (LEBC) was specially designed for the experiment [9]. The high resolution two-view optics were capable of resolving bubbles with diameter down to $\sim 50 \mu\text{m}$. This is a necessary feature to enable the efficient detection of particles with proper lifetime down to $\sim 10^{-13}$ s. With the typical particle energies obtained in this experiment, detected charm particles have laboratory path lengths of typically a few hundred μm to a few mm. Since the technique has been proven reliable and efficient for the study of particles with short decay lengths (e.g. charm particles) it is naturally suited for the search for particles with short interaction lengths (e.g. anomalons).

For the charm experiment, the bubble chamber was simply the vertex detector with a downstream spectrometer (European Hybrid Spectrometer - EHS) to give secondary particle momentum analysis. For the anomalon search reported here we use only the bubble chamber information.

Data were collected at the CERN SPS with LEBC located in the H2 beam line. In order to increase the data taking efficiency and to allow the photography of bubbles of controlled size, LEBC was equipped with an interaction trigger. This trigger consisted of a set of scintillators

designed to detect an event of any type originating in the body of LEBC. A signal from the trigger initiated the camera flash tube. In this way 350 K good pictures were taken with a 360 GeV/c π^- beam and 500 K good pictures with a 360 GeV/c proton beam. The data sensitivities were 7.3 evt/ μ b and 7.8 evt/ μ b, respectively.

All the film was double scanned and check scanned by a physicist. Any event with any secondary activity (decay or interaction)^(*) was recorded and the projected distance from vertex to vertex was measured in view 1. Decay candidates were digitised and analysed for the charm work reported elsewhere [7,8]. Events with charged secondary interactions are studied in the present work. From a total of 299100 events produced in the hydrogen, 22150 have a detected secondary interaction.

Initially, the π^- and proton data were treated separately. No differences in anomalon content were detected and so, to give a more statistically significant sample, all data are considered as one sample from now on.

Fig. 1 shows the uncorrected projected length distribution for all secondary interaction events. The length given here is the distance in space between production vertex and interaction vertex projected onto the optical plane of view 1. There is clear evidence of short length scanning losses for $L \leq 1$ cm followed by a rapid fall-off for $L \geq 2$ cm. If one interprets this fall-off as due to the presence of anomalons one would quote an anomalon content of $\sim 1\%$ and an anomalon mean free path of ~ 7 cm. In fact, the effect can be readily explained as coming from the finite size of the bubble chamber.

As seen by the optics, LEBC is a 20 cm disc with the beam occupying a central slice 4 cm wide. An event produced at the LEBC entrance has a secondary particle potential length of almost 20 cm. An event produced

(*) It is a unique advantage of hydrogen as target and vertex detector that decays can be distinguished from interactions based on topological information alone. Thus charged decays yield an odd number and charged interactions an even number of secondary charged particles.

far from the entrance point has a much reduced potential length. It is the juxtaposition of all events with potential lengths varying from 20 cm to zero that gives the shape of the distribution in fig. 1. There are more subtle effects too, but these will be mentioned below.

To reduce the effect of the variable potential length, the LEBC picture was divided into five 2 cm slices all of which are located in the first half of the bubble chamber^(*). Figs 2(a)-2(e) show the uncorrected projected length distributions for events originating in these five slices. All distributions exhibit a slow fall-off before the, more catastrophic, end of chamber effect.

In order to understand and reproduce the features of fig. 2 we have used a Monte-Carlo technique. Secondary interactions were generated using the measured multiplicity and momentum distributions for the secondary particles and the total hadronic interaction cross section as a function of momentum. The vertex detector geometry was also included in the Monte-Carlo program. This geometry included not only the finite bubble chamber size in the beam direction but also the sideways limits and the in-focus depth limits imposed by the high-resolution optics. The incoming beam profile was generated to simulate the measured profile.

The Monte-Carlo simulation gives length distributions in excellent agreement with the data. The curves superimposed on the distributions of fig. 2 show the Monte-Carlo predicted fall-off as a function of secondary interaction length. The slightly steeper slope of fig. 2(c) is not significant; it is a fluctuation originating in the finite Monte-Carlo statistics. It is interesting to note that, interpreted as anomalous behaviour, fig. 2 would give an anomalous mean free path of ~ 30 cm. Again this is due to the vertex detector geometry and, to a lesser extent, the variation of interaction cross section with momentum for secondary hadrons.

(*) If one defines the LEBC beam entrance point as $x = 0$ and exit point as $x = 20$ cm, then the five slices are in the x -ranges (1,3 cm), (3, 5 cm), (5, 7 cm), (7, 9 cm) and (9, 11 cm), respectively.

Finally, figs 3(a)-3(e) show the same uncorrected, projected length distributions as before but only for the interactions of secondary particles produced within ± 80 mr of the incoming beam direction. This angular constraint selects the fast secondary particles ($x_F \geq 0.0$) and reduces the effect of the rapid variation of total cross section versus momentum that one has for secondary momenta ≤ 2.5 GeV/c. Again the curves generated by the Monte-Carlo technique are in good agreement with the data. The slightly steeper slope of fig. 3(c) is not significant and comes from the finite Monte-Carlo statistics. Fig. 3 still shows a slow fall-off in the length distribution; here an artificial anomalon mean free path would be ~ 100 cm. Selecting only those secondary interactions with a multiplicity of six or more gave length distributions very similar to those with the 80 mr cut.

In conclusion, we can say that there is no evidence of any anomalous behaviour in our data. All apparently anomalous distributions can be explained in terms of the finite bubble chamber size and the functional form of hadronic interaction cross sections versus hadron momentum. We can, nevertheless, attempt to fit the data to normal hadronic secondary particles plus a small amount of anomalon component with an assumed interaction mean free path (mfp). For all assumed mfp values the best fit is with an anomalon fraction of zero. This can be interpreted as a 95% (2 standard deviation) confidence level upper limit. The results of the fits are given in fig. 4. Anomalons with mfp ≤ 10 cm can be excluded at the 0.1% level; for mfp ≤ 2 cm, the 95% confidence level upper limit is $< 0.01\%$.

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FIGURE CAPTIONS

Fig. 1 Uncorrected length distribution projected onto the optical plane of view 1 for all secondary interactions.

Fig. 2 Uncorrected length distributions projected onto the optical plane of view 1 for secondary interactions whose primary vertices are in the range:

(a) $1 \leq x \leq 3$ cm;

(b) $3 \leq x \leq 5$ cm;

(c) $5 \leq x \leq 7$ cm;

(d) $7 \leq x \leq 9$ cm;

(e) $9 \leq x \leq 11$ cm;

where x is the coordinate in the beam direction. The curves show the predicted behaviour from the Monte-Carlo calculation described in the text.

Fig. 3 Uncorrected length distributions projected onto the optical plane of view 1 for secondary interactions produced within ± 80 mr of the beam direction and whose primary vertices are in the range:

(a) $1 \leq x \leq 3$ cm;

(b) $3 \leq x \leq 5$ cm;

(c) $5 \leq x \leq 7$ cm;

(d) $7 \leq x \leq 9$ cm;

(e) $9 \leq x \leq 11$ cm;

where x is the coordinate in the beam direction. The curves show the Monte-Carlo predictions described in the text.

Fig. 4 Anomalon content (95% confidence level upper limit) plotted against anomalon mean free path. Scanning losses reduce the sensitivity for an anomalon mean free path < 1 cm.

Fig. 1

Fig. 2

Fig. 3

Fig. 4