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A SEARCH FOR SHORT-LIVED ANOMALONS IN PROJECTILE FRAGMENTATION

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Nuclear emulsion studies[1,2] suggest that fragmentation products from relativistic heavy ion collisions have anomalously large reaction cross sections and that these anomalons disappear over the first few centimeters of their track in emulsions. If these "anomalons" exist, their disappearance could be due to either depletion by a very large reaction cross section, or decay with a mean lifetime of about 10^{-11} seconds and with only somewhat enhanced cross section. The counter experiment described here was designed to test the decay model proposed by Barber et al.[2] that explains the emulsion data by assuming that all produced fragments are anomalons with 1.6 times the cross section of normal fragments and that the anomalons have a mean lifetime (τ) of about $1 \cdot 10^{-11}$ s corresponding to a mean decay length ($c\beta\gamma\tau$) of 9 mm. If the disappearance in emulsions is due to decay, one should observe a decreased number of secondary interactions in a low-density target, compared to the number observed in a solid target.

We have conducted an experiment based on this density effect. Figure 1 shows a schematic view of the experiment that was performed by bombarding alternatively a solid (20 mm thick) and a dilute (ten 2-mm slabs each separated by 20 mm) Cu target with a beam of 1.7 GeV/u ^{56}Fe ions at the Berkeley Bevalac. The targets were switched approximately every minute. The produced projectile fragments were detected, within a cone of $\pm 1^{\circ}$ opening angle 5.5 m downstream, in ΔE plastic scintillators having succesive thicknesses of 1, 6, and 38 mm. The existence of short-lived "anomalons" should, because of the greater number of interactions in the solid target before decay than in the dilute one, move yields from the upper part of the energy loss spectrum to the lower part. This change in the shape of the measured ΔE spectra should, when taking the ratio of the yields in the ΔE spectra for solid and dilute targets, show up as a line with negative slope. Some data were recorded using a "start" trigger, where all particles entering the detectors were accepted. It was found that the ratio of the yields of the projectile fragments to the beam particles was the same to 1% in the solid and dilute targets. This alone indicates a negative effect. However, a greatly enhanced set of data was obtained with a "min bias" trigger that rejected events where a beam particle was detected. These "min bias" solid/dilute yields were set equal in the observed region, as determined from the "start" trigger data. The measured pulse height spectra were calibrated using the energy loss of the beam particles in the detectors and then assuming a linear dependence down to zero. This is equivalent to the assumption that ΔE is proportional to Z^2. A linear dependence above $Z = 5$ as observed in some other data was also tried, with no difference in the results to be presented.

Figure 2 shows the ratio of the yields in the ΔE spectra produced by the solid and dilute targets (open circles). The error bars shown are due to statistics only and do not contain the systematic error of 1% due to the normalization. The line is obtained from a least square fit to the data points. A fit to the data for a constant value of the ratio equal to one gave a chi square value of 1.04 per degree of freedom, only slightly greater than the 0.81 value for the line drawn, showing that our data are not significantly different from zero effect. To determine the sensitivity to the various proposed decay scenarios, a Monte Carlo simulation of the experiment was done.

The Monte Carlo calculation proceeded in the following way:

a) All produced fragments within $\pm 1^\circ$ traverse the complete target, which means that the calculation could be treated as a one-dimensional problem.

b) In the calculation it is only the shape of the cross section for production of a fragment with charge Z_F, $\sigma(Z_F)$, that is important and not the absolute value. For $Z_F > 9$ $\sigma(Z_F)$ are constant[3], and for $Z_F < 9$ they vary as Z_F^{-b} taken from ref. 4. The total, $\sum_{Z_F} \sigma(Z_F)$, was normalized to the geometrical cross section of the fragmenting nucleus. The calculational scheme followed only one projectile fragment, but only fragments with $Z_F > 5$ were calculated, for which it is known that the multiplicity is rather small.

c) The percentage of the produced fragments that are anomalons was taken from the different scenarios.[2,5]

d) The cross sections for the normal secondary interactions were taken to be the geometrical cross sections.[3]

e) The anomalon decayed with the mean lifetime determined from the fits to the emulsion data. Furthermore, the anomalon was assumed to decay back to a normal fragment with the same Z as the decaying anomalon. The anomalon was assumed to have an enhanced cross section compared to normal fragments, which was taken from the emulsion data as well.

The calculations were performed for two different scenarios, namely:

a) 100% of the secondary fragments are anomalons with 60% enhanced cross section and a mean lifetime of about $1 \cdot 10^{-11}$ s, corresponding to a mean decay length of 9 mm. This is the "Minnesota" model.[2]

b) 100% of the secondary fragments are anomalons with 35% enhanced cross section and a mean lifetime of about $3 \cdot 10^{-11}$ s, corresponding to a mean decay length of 20 mm. This is a "global" fit to all existing emulsion data taken from ref. 5.

The results of the calculations using these two sets of parameters are shown in Fig. 2. The "Minnesota" parameters are shown as open squares and the "global" parameters as filled squares. As can be seen from the figure neither calculation agrees with the experimental data. The lines are least square fits to the calculated points. A fit to the points of the "global" parameters with a constant ratio equal to one gave a chi square value of 43 per degree of freedom, very much larger than the 1.32 value for the line drawn, indicating that an effect for this model was expected. A way of looking at the significance of the disagreement between the data and the simulation is to calculate the difference in the means of the two sets of points and the standard deviation of the difference. The result of such an analysis is $(2.9 \pm 0.3) \cdot 10^{-2}$. If one adds in the normalization error the difference between the data and the "global" simulation is still three times the expected error in this difference. In both scenarios the reaction mean free path is not much longer than the mean distance for decay. If the disappearance of the short mean-free-path effect is due to decay, then other scenarios with larger enhanced cross sections are excluded.

Our experiment rules out the proposed decay model[2,5] in which the disappearance of the anomalous short mean free path is due to decay. Our data are consistent both with the nonexistence of anomalons and with the disappearance of the short mean free path effect due to reactions. If 100% of the projectile fragments are anomalons, then our data indicate that their mean lifetime must be at least 5 x 10^{-11} s. It would then be desirable to search for them in, for example, a double scattering experiment.

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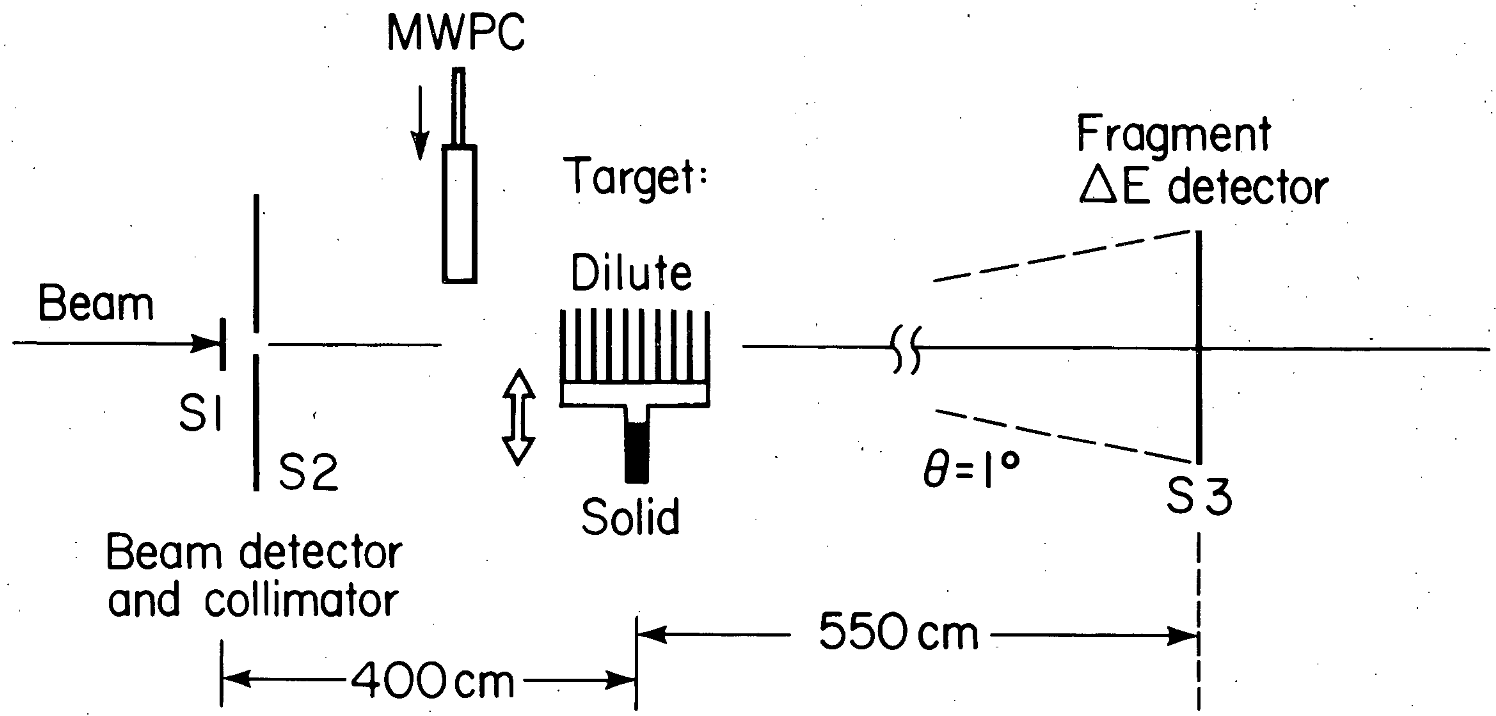
Figure Captions

Fig. 1. Schematic view of the experimental layout, S1 and S2 being the beam-defining scintillators. The multiwire chamber MWPC was used for focusing the beam and then retracted. S3 represents the ΔE detectors.

Fig. 2. The ratio of yields in the ΔE spectra produced by solid/dilute targets. Open circles show the data. The 1-mm plastic detector was used to identify charges larger than 10 while for the lower Z values the 6- and 38-mm plastic detectors were used. Open and filled squares show the Monte Carlo simulations (see text for details).



XBL 831-1137

Fig. 1

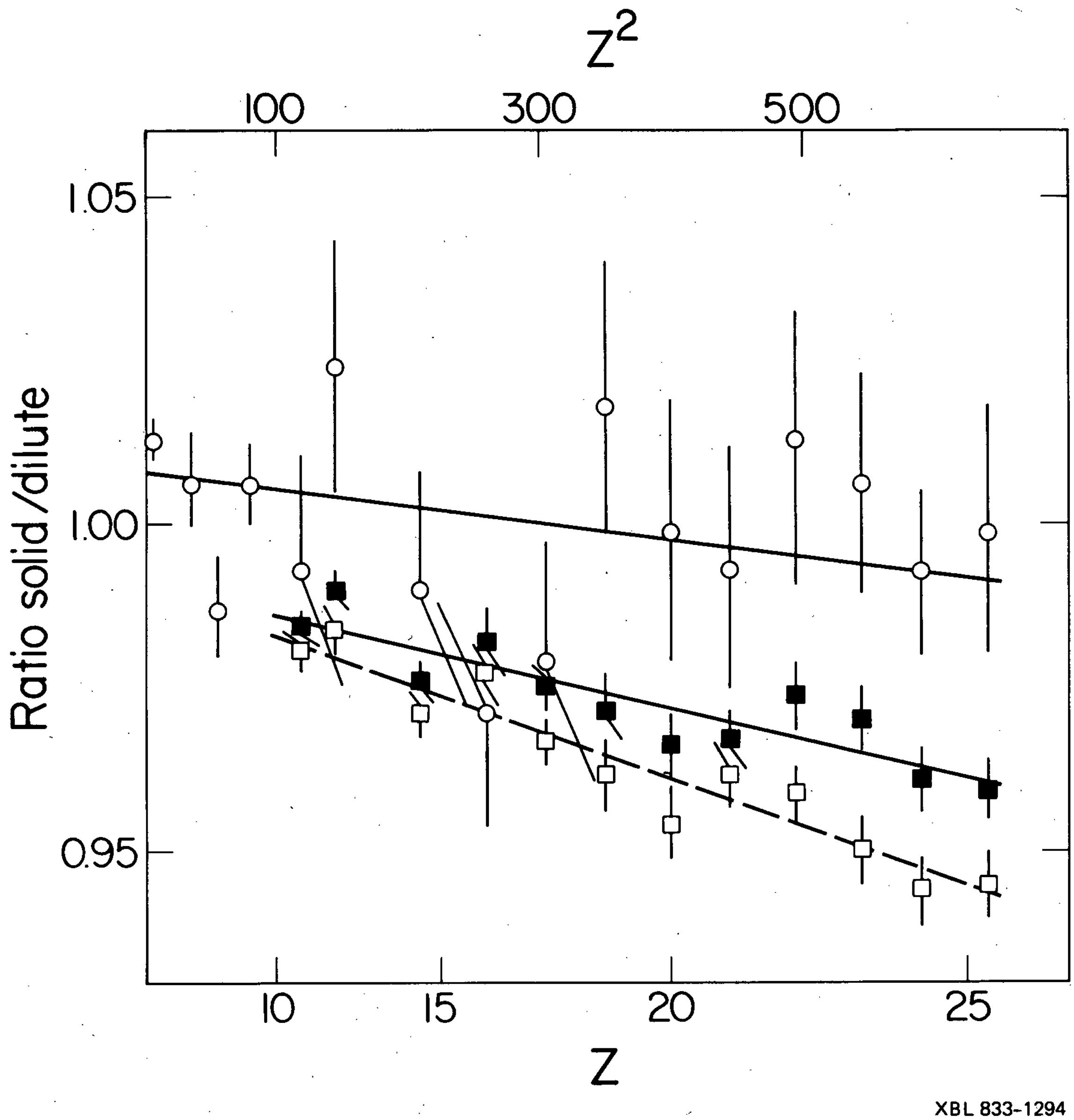

Z2
100
300
500
1.05
1.00
0.95
Ratio solid /dilute
10
15
20
25
Z
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Fig. 2

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