Search for Anomalons Using Plastic Nuclear Track Detectors

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ABSTRACT

We exposed a stack of CR39 track detectors containing Ag foils to a 1.7 GeV/nucleon ^{56}Fe-beam and investigated the anomalous mean free path effect. Neither the whole set of 7517 nor a subset of 2542 interacting fragments produced probably in the Ag target show an effect. By combining the data of this and an earlier experiment we can also exclude an effect for 3219 interacting fragments produced in $\Delta Z=1$ collisions.

INTRODUCTION

The situation of mean-free-path (mfp) measurements for relativistic projectile fragments (PF's) under different experimental conditions is still not clear. The results of emulsion experiments /1-3,11/ showing an anomalously large interaction cross section of PF's within the first few centimeters from their point of emission are contradicted by some other experiments using different techniques like Cherenkov detectors /4,5/, plastic nuclear track detectors /6,7/ or even by experiments using nuclear emulsions /8-10/. There are some indications that the effect is preferentially observed for fragments produced in collisions with heavy target nuclei and for fragments produced in extremely peripheral collisions:

In nuclear emulsion a large number of collisions occurs with silver target nuclei whereas the experiments using Cherenkov or plastic nuclear track detectors provide targets not heavier than oxygen. If anomalons would be produced only in collisions with heavy targets this would explain all the negative results in these experiments.

Furthermore some observations are supporting the idea, that anomalons are produced in extremely peripheral collisions. The most striking hint comes from a bubble chamber experiment /12/, where collision products of a 3.7 GeV/nucleon ^{12}C beam were analyzed. No anomalous behavior was observed for all types of analyzed interaction products except ^{12}C projectiles that had undergone a collision, but did not loose charge. If we follow the hypothesis, that anomalons are produced preferably in peripheral interactions, all experiments having a low sensitivity in detecting these interactions should see a reduced or no effect of anomalous mfp's. Experiments of this type are our first plastic track detector experiment /6/ and the nuclear emulsion experiment of the BCJJL collaboration /9/.

THE EXPERIMENTAL METHOD

We performed a new experiment which meets the requirements of both heavy target and high efficiency for the detection of $\Delta Z=1$ interactions. For this purpose 200µm thick silver foils were stacked between the CR39 foils ($C_{12}H_{18}O_7$) of 600µm thickness. A stack of each 150 silver and plastic foils with a size of 10cm * 8cm was exposed at the Bevalac to a 1.7 GeV/nucleon Fe beam with 10^3 particles per cm^2. The beam nuclei were slowed down in the stack to 0.8 GeV/nucleon. Due to the high sensitivity of the detector material tracks of fragments with charges Z≧7 were recorded.

After etching of the detectors the tracks of all particles were measured using our automatic measuring system /13/. After a calibration the particle charges were determined from the measured areas of the tracks. The reconstruction of particle trajectories through the stack was performed in a similar way as described earlier /7,14/. By measuring the particle tracks on both sides of the detectors it was in principle possible to separate the interactions that took place in the plastic from those that occured in the silver foils. In the following analysis only tracks with a length >4mm containing at least 10 etch cones are included.

RESULTS

The interaction mean free paths $\lambda_Z(x)$ were determined for intervals of distance x from the point of emission of the fragments as described earlier /7/. These $\lambda_Z(x)$ were normalized to a value λ_Z^c which was calculated considering the relative yield of the different isotopes as described in /6/. No statistically significant deviations between the measured interaction mean free paths and the calculated values can be observed. A comparison of the data by a χ^2-test gives a χ^2=46.3 for 37 degrees of freedom.

To improve the statistical significance the normalized interaction mean free paths for all individual fragment charges were compiled to one data set of $\lambda^*(x)$ shown in figure 1. The horizontal bars indicate the intervals of distance from the interaction point. This result based on 7517 interactions of fragments with charges 7≦Z≦25 shows no significant deviation from a constant mean free path.

To investigate a dependence of the result on the mass of the target nucleus we analyzed separately $\lambda^*(x)$ for those fragments produced in collisions with silver target nuclei. Because of some uncertainties of the separation the data set contains only a part of about 70% of fragments produced in silver which however is greater than the equivalent part in experiments with nuclear emulsion. Also this result shown in figure 2 which is based on 2542 interactions gives no indication on a dependence of the mean free path on x.

As described above the experimental data available until now indicate that anomalons may be produced more efficiently in peripheral collisions. Therefore we analyzed separately interactions of fragments produced in ΔZ=1 collisions for this experiment including data of an earlier experiment exposed to an ^{40}Ar beam for which the analysis was extended to Z=16 and Z=17 fragments. From this stack data of tracks longer than 2mm are available. Our efficiency for the detection of a fragmentation with ΔZ=1 decreases from unity to about 84% when the length of the track decreases from 20 to 10 foil layers. The efficiency was measured by artificial shortening of long fragment trajectories contained in our data. This reduced efficiency would equalize a small anomalous mfp effect. We corrected our data based on the measured efficiencies. Figure 3 shows the normalized $\lambda^*(x)$ of fragments produced in ΔZ=1 collisions for which 3219 interactions were observed. No anomalous mfp effect is seen behind the first cm.

Figure 4 shows three curves of confidence in the plane of the parameters α and λ_A, where α is the admixture of the anomalons in the set of PF's and λ_A their mfp. Pairs of the parameters from the region above the curves can be rejected at a confidence level of 95%. One curve results from the fragments produced in $\Delta Z=1$ collisions, another one from those produced in the heavy silver target. Additionally we combined all our data available until now from experiments described in this paper, /6/ and /7/ without any restriction. These experiments with Ar and Fe beams at 1.7 and 1.8 GeV/nucleon, fragments in the range from Z=7 to Z=25 and CR39- or Ag-targets have contributed with altogether 16847 interactions. The resulting curve is drawn in figure 4.

CONCLUSION

In summary we have investigated two hypothesises about the anomalous mfp effect. In our high-statistic experiments using CR39 nuclear track detectors we found no evidence for the existence of anomalons. Neither the use of a heavy silver-target, nor the restriction on the data obtained from the fragments produced in $\Delta Z=1$ collisions are consistent with a strong anomalous mfp effect reported earlier /1-3/. Due to the possibility to measure the mfp at small distances from the interaction point our data provide a higher significance for the rejection of the anomalon-hypothesis than earlier experiments /4/ at interaction lengths below 0.5cm.

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REFERENCES

1. E.M.Friedlander et al., Phys. Rev. Lett. 45, 1084 (1980)
2. P.L.Jain and G.Das, Phys. Rev. Lett. 48, 305 (1982)
3. H.Barber et al., Phys. Rev. Lett. 48, 856 (1982)
4. J.D.Stevenson et al., Phys. Rev. Lett. 52, 515 (1984)
5. T.J.M.Symons et al., Phys. Rev. Lett. 52, 982 (1984)
6. W.Heinrich et al., Phys. Rev. Lett. 52, 1401 (1984)
7. H.Drechsel et al., Phys. Rev. Lett. 54, 30 (1985)
8. R.Holynski et al., Proceedings 18th ICRC, Bangalore Vol.11, paper He 2.2-30, to be publ. in Zeit.f.Phys.
9. S.Beri et al., Phys.Rev.Lett. 54, 771 (1985)
10. G.Baroni et al., Nucl.Phys, A437 (1985) 3,4 p.729 at 7. High Energy Heavy Ion Study GSI/Darmstadt (1984)
11. E.A.Alekseeva et al., Pis'ma Zh.Eksp.Teor.Fiz. 38,no.8,411 (1983)
12. A.P.Gasparian, N.S.Grigalashvili, Zeit.f.Phys.A 320,459 (1985)
13. W.Trakowski et al., Nucl. Instrum. Methods 225, 92 (1984)
14. H.Drechsel et al., Nucl. Instrum. Methods 227,342 (1984)

Fig.1: Normalized interaction mfp as a function of distance x from the point of emission in the composed target CR39+Ag. The dashed line represents the mean value of 0.985±0.012 .

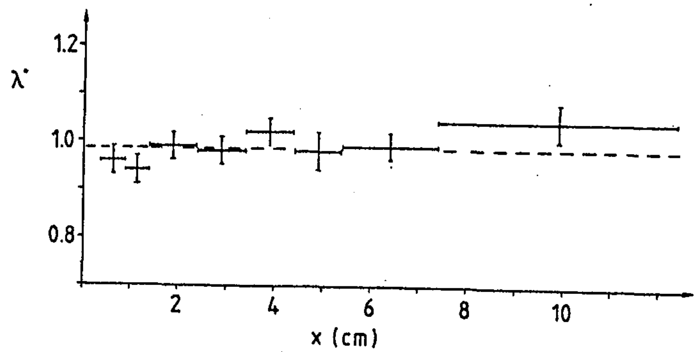

Fig.2: Normalized interaction mfp of fragments produced in the Ag-part of the target as a function of distance x from the point of emission. The mean value is 1.002±0.020 .

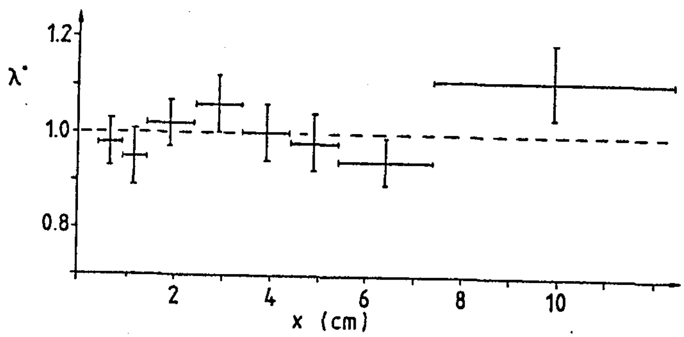

Fig.3: Normalized interaction mfp of fragments produced in ΔZ=1 collisions as a function of distance x from the point of emission. The mean value is 0.986±0.018 .

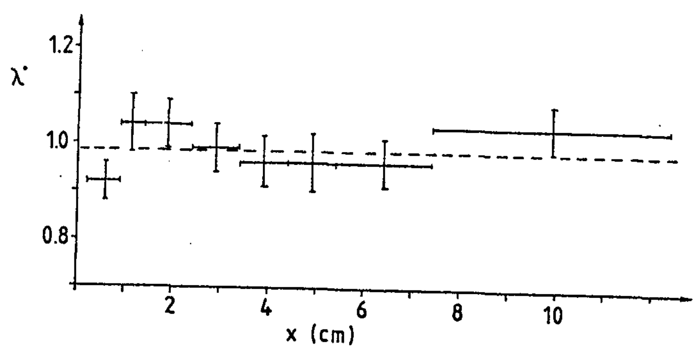

Fig.4: Curves of confidence in the plane of the abundance of anomalons and their assumed mfp obtained from two subsets and a combination of all our data. The regions above the curves are ruled out at a 95%-confidence-level.