FIRST EVIDENCE OF Z=2 ANOMALONS IN PROJECTILE FRAGMENTS IN \(^{24}\text{Mg}\) EMULSION INTERACTION AT 4.5 GeV/c PER NUCLEON

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Abstract

This paper presents evidence of the anomalous interaction mean free path of the relativistic alpha particles emitted from the interaction of \(^{24}\text{Mg}\) with emulsion nuclei at 4.5 GeV/c per nucleon. The tracks were followed systematically through the stack. The preliminary measurements show that the interaction mean free path is anomalously shorter for a few centimeters after their emission. The mean free path has been compared with the mean free path of relativistic alpha particles emitted in \(^{12}\text{C}\) and \(^{22}\text{Ne}\) emulsion interaction at 4.5 GeV/c per nucleon.

Anomalously short interaction mean free paths of projectile fragments from high energy heavy-ion collision has been observed in cosmic ray studies, in bubble chamber experiments as well as in emulsion experiments using high energy heavy-ion beams from accelerator.

Search for anomalous, projectile fragments with short interaction mean free path, in projectile fragments with fixed charge Z=2, using heavy ions of different masses, and energies in emulsion experiments, has yielded controversial results. But status report October, 1984(/1/) shows the presence of "anomalons" in alpha particles emitted from \(^{12}\text{C}\) emulsion interaction at 3.7 GeV/n and also 2 GeV/c. Because of the existing controversy about the reality or lack thereof anomalously short mean free paths of projectile fragments from relativistic heavy ion collisions, independent results using projectiles of different masses at the fixed energy are of immense importance as results are unusual. Hence we present in this paper an investigation on anomalous interaction mean free paths of alpha particles projectile fragments emitted from \(^{24}\text{Mg}\) -emulsion interaction at 4.5 GeV/c per nucleon (3.7 GeV/n).

Our preliminary results, based on detailed observation can be summarized as follows :-

(1) The interaction mean free path is anomalously short for a few centimeters after the point of emission.

(2) The interaction mean free paths, measured at different path lengths from the points of emission are different

(3) The interaction mean free path shows a definite increase in value with increasing path length interval.

(4) The variation of the interaction mean free path with distance from the point of emission is fairly in agreement with the results observed in \(^{22}\text{Ne}\)-emulsion interaction at the same beam energy.
(5) The interaction mean free path of alpha particle projectile fragments emitted in $^{24}$Mg-emulsion interaction at 4.5 GeV/n, is shorter than the interaction mean free path of alpha particle projectile fragments emitted in $^{12}$C -emulsion interaction at 4.5 GeV/c/n, in the path length interval 0-4 cm.

The observations were made in a stack NIKFI-BR-2 nuclear emulsion plates of dimensions 10 cm x 20 cm x 600 cm, with printed grid. The plates were irradiated, tangentially, with 4.5 GeV/c/n, $^{24}$Mg beam, at JINR Dubna, U.S.S.R. 1023 relativistic alpha particles emitted from the primary interactions, with a forward cone of $3^\circ$, were followed, using Litz Ortholux microscopes by along the track method. Identification of alpha particles (Z=2) was carried out by the gap density method and by $\delta$-ray count for the identification of charge. All electron tracks containing two or more grains and apparently originating from the track were counted as $\delta$-rays.

Table 1 summarises the detailed experimental results. The uncertainty in $\lambda$ is $\lambda_{normal} = \frac{19.9}{N}$ cm, which shows the error assigned when testing whether or not, the observed is in agreement with the expected value of the normal alpha beam (primary). The variation of mean free path value ($\lambda$) with the increase in track length interval is shown in fig. 1. The solid line represents the value of the average mean free path of 4.5 GeV/c/n alpha particle beam, $\lambda_{normal} = \lambda_{beam} = 19.9 - 0.6$ cm, as reported by EI-Nadi et al. (/2/). Figure shows the distribution of interaction distances upto 4 cm. We consider the interaction model (/3/) where it is assumed that, in addition to normal nuclei, there is a fraction 'a' of the particle fragments which have a constant mean short free path of and that the remaining fraction 1-a of projectile particle fragments interact normally. By a least square-fit method, we get the best estimates from our data for a = 10% and $\lambda = 1.02$ cm.

The dashed curve in Fig. 1 corresponds to the 10% mixture of anomalous component which interacts with a mean free path of $\lambda = 1.02$ cm.

Fig. II shows results of our experiment (Blobs) plotted on the results of EI-Nadi as published in Ref. (/1/) using $^{22}$Ne projectiles at the same energy. Fig. III shows comparative plotting of variation of mean free path with distance for $^{12}$C fragments (/4/) Z=2 and that of $^{24}$Mg fragments Z=2 at the same energy. In Table II we present a comparative study of the anomalous mean free path of the projectile fragments Z=2 from $^{12}$C and $^{24}$Mg beam at the same incident momentum per nucleon to observe the effect of the mass of the projectile if any. It is interesting to note that there is a significant lowering of average mean free path with the increase in projectile mass number. The relative abundance of anomalous component in case of $^{24}$Mg is also more. It may be mentioned that there is a significant difference between our results and those of Ar-induced (/5/) interaction at 1.8 GeV/n, which however, seem to disfavour the existence of anomalies.

393

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This analysis indicates clearly that the interaction mean free path of the relativistic $^{24}\text{C}_\alpha$ particles emitted from the interaction of 4.5 GeV/c/n $^{24}\text{Mg}$ with emulsion nuclei is anomalously short for the first few centimeters from their emission point. Further work is in progress.

Fig. 1. Plot of interaction mean free path of alpha particles (from $^{24}\text{Mg-Em}$ interaction) with distance from the point of production (D). The dotted curve is the prediction under the assumption of 10% admixture of anomalons with mfp. $= 1.02$ cm

Fig. 2. The mean free path of alpha from projectile fragment from $^{24}\text{Mg}$ (blobs) as a function of D compared with the results from $^{24}\text{Ne}$ at the same incident energy.

Fig. 3. A comparison of the mean free path values of alpha from $^{12}\text{C-Em.}$ and $^{24}\text{Mg-Em.}$ interaction at 4.5 GeV/c/n.
Table 1

<table>
<thead>
<tr>
<th>L(cm)</th>
<th>( \bar{L}(cm) )</th>
<th>Ni</th>
<th>N</th>
<th>Si</th>
<th>(cm)</th>
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<tbody>
<tr>
<td>0-1</td>
<td>0.5</td>
<td>1023</td>
<td>176</td>
<td>955.68</td>
<td>5.43 \pm 1.5</td>
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<tr>
<td>1-2</td>
<td>1.5</td>
<td>840</td>
<td>63</td>
<td>796.32</td>
<td>12.64 \pm 2.6</td>
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<tr>
<td>2-3</td>
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<td>776</td>
<td>52</td>
<td>754.0</td>
<td>14.5 \pm 2.8</td>
</tr>
<tr>
<td>3-4</td>
<td>3.5</td>
<td>724</td>
<td>44</td>
<td>704.44</td>
<td>16.01 \pm 3.0</td>
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Table 2

<table>
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<tr>
<th>Beam</th>
<th>Fragment Charge</th>
<th>Beam Momentum (GeV/c/n)</th>
<th>( \lambda )</th>
<th>a</th>
<th>( \lambda_a ) (cm)</th>
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</thead>
<tbody>
<tr>
<td>( ^{12}_C )</td>
<td>2</td>
<td>4.5</td>
<td>12.05 \pm 1.14</td>
<td>8%</td>
<td>1.9</td>
</tr>
<tr>
<td>( ^{24}_Mg )</td>
<td>2</td>
<td>4.5</td>
<td>9.58 \pm 1.08</td>
<td>10%</td>
<td>1.02</td>
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References