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Multitarget electronic experiment searching for anomalous particle fragments

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We propose an electronic counter experiment for investigating both the existence of anomalous particle fragments and their characteristics. The experiment is based on triggering and isolating the secondary interaction fragments on a solid state multitarget device. This method uses the sensitivity of the anomalous particle fragment effect with respect to absorption experiments and permits us to solve the questions related to the anomalous particle fragment production cross section, their interaction cross section, and their lifetime.

Nowadays, anomalous particle fragments are in fashion despite their ancient first appearance in photographic emulsions exposed to cosmic rays.[1] Recently, the old cosmic ray results have been confirmed by three new emulsion experiments.[2-4] These experiments provide a strong evidence of the presence among the fragments originating in a relativistic ion collision of one component (anomalous particle fragments) whose cross section is anomalously large compared to ordinary nuclei. To explain the experimental evidence we have to accept either excited fragments with a mean life $\simeq 10^{-10}$ s, or a cross section between 2 and 10 times the geometrical one. These hypotheses do not fit into any conventional picture and suggest an exotic model mainly based on color polarization or anomalous quark bags.[5] We notice that no evidence has been found which excludes the existence at the elementary particle level of a similar effect. All that justifies the great interest devoted to clarify both theoretically and experimentally the nature of anomalous particle fragments.

Until now anomalous particle fragments have been studied in emulsions exposed to cosmic rays or ion beams. This technique provides an excellent spatial resolution, but is poor in statistics and does not allow study of the behavior of anomalous particle fragments in vacuum (or air). The emulsion data admit a continuum of possibilities between two extreme hypotheses.

(a) Because no spontaneous decays have been observed in the emulsions, the anomalous component is supposed stable during the time necessary to travel 5–15 cm. Thus, the data are consistent with the presence of $\simeq 6\%$ of produced fragments whose cross section is an order of magnitude greater than the geometrical one.[2]

(b) The anomalous component decays spontaneously with a lifetime of 10^{-10} s (i.e., 3–6 cm) via neutral emission and small kink undetectable in emulsions. In this case the data are consistent with the presence of 100% of anomalous particle fragments in the fragments, with a cross section 2–3 times greater than the geometrical one.[4]

Only the counter technique, using oriented triggers, can provide a great statistics and investigation between hypotheses (a) and (b).

We propose the use of subsequent active targets, whose distances can be varied in order to trigger on the reinteractions of the produced fragments. The method we propose takes advantage of the peculiar feature of anomalous particle fragments and of their enhanced cross section, for improving the sensitivity of the trigger. The presence of anomalous particle fragments among the fragments causes an overproduction of successive interactions. Therefore, triggering on successive interactions of the beam fragments is straightforwardly the best method to find evidence for the existence of anomalous particle fragments and to improve the selectivity of an experiment.

The sensitivity of our method is much greater than inclusive experiments such as the variable density experiment[6] and the absorption experiment,[7] in which the anomalous particle fragment effects have to be picked out in the inclusive flux of the first and secondary interactions. The use of active targets triggerable on interactions could permit to separate a sample of secondary interactions, where the anomalous particle fragments effect is operating. The excess due to the anomalous particle fragment presence is enhanced to fa and $fa(fa+2)$ if the second and the third interactions are selected (f is the anomalous particle fragment fraction of fragment among the ordinary one, and a the enhancement factor of their cross section).

The silicon solid state detector technique seems adequate as active target as well as tracking and charge detectors.[8]

The proposed apparatus (Fig. 1) put in vacuum, is composed of three identical silicon active targets (C_1, C_2, C_3) 2 mm thick, whose relative distances can be varied from 1 to 15 cm.[9] A set of six microstrip chambers (M) 100 μm thick, with a pitch of 20 μm is located after each target. The strips are oriented at 0°, 15°, 90°, 165° and equipped with analogical digital converter read outs in order to get high tracking resolution and charge measurement of the fragments in the fragmentation cones. A comparison of the energy released in C_1 with that expected for the incident ion defines the interaction of the beam in C_1. In order to select on line reinteractions of the emitted fragment on the successive (C_2, C_3) targets and reject reinteractions on the μ-strip telescopes, we require a constant multiplicity in the planes of the same M telescope and a multiplicity step between successive M telescopes. Furthermore, this logic rejects drastically interactions of midrapidity fragments. Disregarding the events in which the incident ion or the

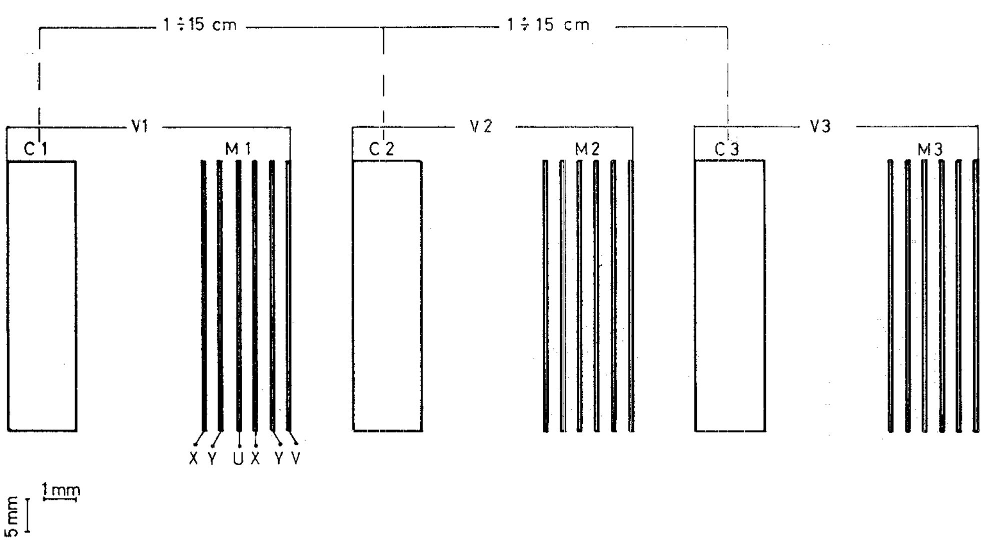

FIG. 1. Sketch of the experimental layout. C_i: silicon solid state targets 2 mm thick; M_i: microstrip chambers 100 μ pitch.

fragment are completely broken up (35%) the apparatus exhibits via Monte Carlo complete simulation a sufficient two track separation with about 15% of double hits on adjacent strips.

In our arrangements one of the triggering conditions is the requirement of the beam interaction on C_1 by looking at the energy loss of the unpinging ion in the active target.

The major part of the midrapidity fragments does not survive the μ-strip chamber (M) and does not reach the following C_2, C_3 targets. The requirement of a constant multiplicity on the six layers of each M telescope drastically reduces on line the events in which these slower fragments interact. In the off-line analysis, the request of a constant energy loss measured in each plane of the microstrip telescope allows us to recognize the midrapidity fragments. Notice that our apparatus is put in vacuum and our procedure does not use absolute predictions but only relative values.

In order to estimate the proper number of events exhibiting successive interactions on the target let us indicate the following: λ_F is the mean free path (MFP) for an ordinary fragment in the target; f is the percentage of produced anomalous particle fragments among the fragments; λ_A is the MFP for anomalous particle fragments in the target; m is the ratio between the percentage of anomalous particle fragments emitted by an anomalous particle fragment interacting and f ($m=1$ means no memory effect[10]); $a=\lambda_F/\lambda_A=\sigma_A/\sigma_F$.

For three successive targets of equal thickness X_T, located at the same relative distances X_R, the interaction probability in each target for ordinary fragments and anomalous particle fragments of a given Z is expressed by

$$P_F=1-\exp(-X_T/\lambda_F),\quad P_A=1-\exp(-aX_T/\lambda_F)\ ,$$

while the respective reinteraction probability on the target are

$$\Delta P_F \simeq 1-\exp(-X_T/2\lambda_F),\quad \Delta P_A=1-\exp(-aX_T/2\lambda_F)\ .$$

If the anomalous particle fragments are not stable over

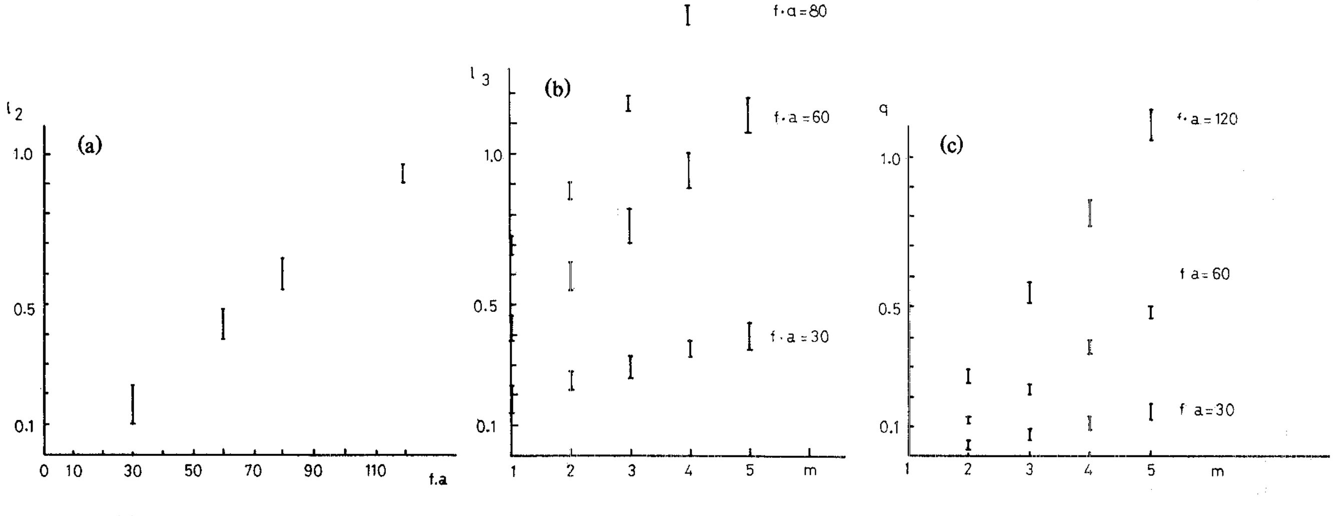

FIG. 2. (a) Expected values of R_2 vs fa. The uncertainties are due to the range of the m values; (b) expected values of R_3 vs m for fixed values of fa. The uncertainties are due to the different f and a choices; (c) expected values of Q parametrized as in (b).

the distances X_P, the decay probability is given by

$$P_D = 1 - \exp(-X_R/\lambda_D) ,$$

where λ_D is the effective decay length, i.e., the lifetime of anomalous particle fragments times the average Lorentz stretching factor.

For a beam of N_0 incident ions, the number of interactions originated by fragments on the second target is given by

$$\begin{aligned} N_2 = N_2^{\text{or}} \{ & (1-f)(1-\Delta P_F) + (1-f)\Delta P_F[(1-f) + fP_D] \\ & + f(1-\Delta P_A)P_D + f\Delta P_A[(1-fm) + fmP_D] \\ & + [(1-f)\Delta P_F f(1-P_D) + f\Delta P_A fm(1-P_D) \\ & + f(1-\Delta P_A)(1-P_D)]a\} , \end{aligned}$$

where N_2^{or} is the number of interactions expected in the ordinary case. Similar formulas can be obtained for the interaction of fragments of second generation on the third target. We calculate the following quantities:

$$R_2 = \left(\frac{N_2}{N_1} - \frac{N_1}{N_0}\right) \Big/ \left(\frac{N_1}{N_0}\right), \quad R_3 = \left(\frac{N_3}{N_2} - \frac{N_1}{N_0}\right) \Big/ \left(\frac{N_1}{N_0}\right) ,$$

$$Q = \left(\frac{N_3}{N_1} - \frac{N_2^?}{N_1^?}\right) \Big/ \frac{N_2^?}{N_1^?} .$$

R_2,R_3 are sensible to the presence of anomalous particle fragments among the fragments by the comparison of the probability of interaction of the incident ions with the probability of interaction of a first or second generation fragments. The quantity Q compares the interaction probability of fragments of second and third generation and is related mainly to the memory effect. In Fig. 2 we report R_2, R_3, and Q in the case $P_D = 0$ as function of different values of fa and m.

The study of the same quantities varying the distances between the target will permit us to distinguish between hypotheses (a) and (b). For example, in Fig. 3 the expected value of the quantity N_3 versus the distance X_R is reported for some of the possibilities between the two extremes (a) and (b).

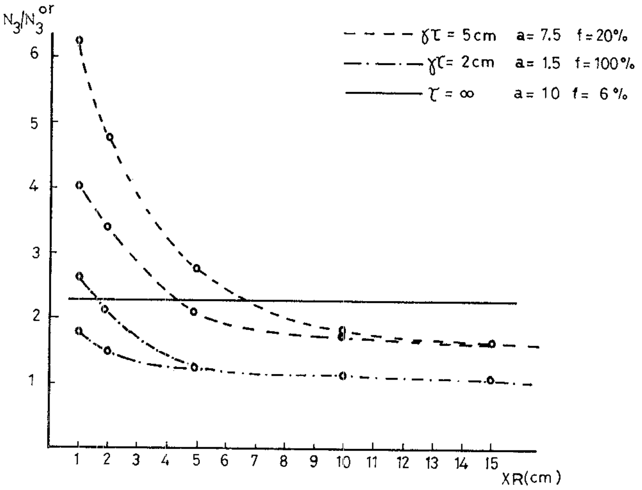

FIG. 3. Value of N_3 normalized to the N_3^{or} expected interactions of third generations in the ordinary case in function of several choices of anomalous particle fragment production parameters.

In conclusion, we have suggested an electronic counter experiment able to study the anomalous particle fragments by taking advantage of their enhanced interaction cross section. The experiment employs a multilayers active target triggering on two and three generation events. The sensitivity of the method is relevantly higher than other proposed experiments.[6] For example, in the case of hypothesis (a), about 50% of the interactions are generated by an anomalous particle fragment instead of the 6% if a nonselected sampling of interactions is considered. In this way a study of the Z distribution of the interacting fragments, on these events, could emphasize favorite Z channels for the anomalous particle fragment production.

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