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HUNTING THE ANOMALONS

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ABSTRACT

The feasibility of a counter experiment searching for anomalons is discussed. The solid state detector technique is proposed for a multilayer active target. The experiment is based on studying two and three-generation events having the aim to untangle the questions related to the anomalon production cross section, to their nuclear interaction cross section and to their lifetime.

1. - INTRODUCTION

Since 1954 multiple nuclear cascades induced by primary cosmic rays have been observed frequently in emulsions(1). To explain the apparent overproduction of multiple interactions it has been supposed the presence, in the fragments originated in the interactions, of one component whose cross-section is anomalously large compared to ordinary nuclei(2). Systematic studies performed by B. Judek(3) confirmed the evidence for an anomalously short mean free path (m. f. p.) of projectile fragments. However, because of limited statistics, these results have not gained a great consideration(4).

Recently, data from interactions of relativistic ^{16}O and ^{56}Fe nuclei on emulsions at Bevalac(5) have confirmed the cosmic rays results about the presence of an anomalous component (anomalons) in the produced projectile fragments. In fact it has been observed that the m. f. p. of the produced nuclear fragments is not constant (Fig. 1).

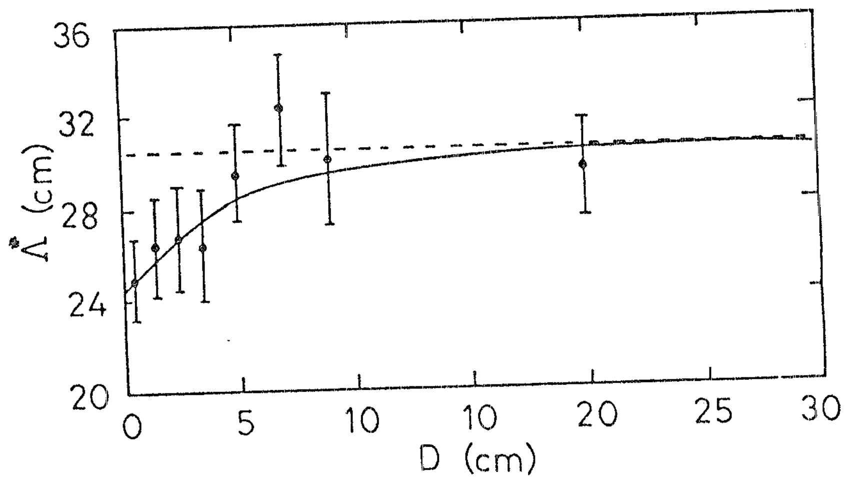

FIG. 1 - The m. f. p. in emulsion depends on the barionic number of the projectile. To use the bulk of informations coming from different Z fragment the parametrization $\Lambda_z = \Lambda^* z^{-b}$ is used. In figure the measured Λ^* is reported for the population of fragments present at different distances (D) from their production point.

In the first centimeters, after the production point, the fragments exhibit a m. f. p. considerably lower than the value measured after 10-15 cm. At these distances from the interaction point the measured m. p. f. reaches a value consistent with that of the primary ion, if the proper Z dependence is taken into account.

Two hypotheses have been proposed to explain the dependence of the m. f. p. on the distance from the production point of the fragments :

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 $\sim$6% of produced fragments whose cross section is an order of magnitude greater than the geometrical one(5).

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

Moreover the correlated analysis of successive generation fragments seems to show a "memory" effect by which a "short" projectile fragment gives origin to a "short" progeny more frequently than a primary ion(7).

From a theoretical point of view, the anomalons, either for their possible mean life of $\sim 10^{-10}$ s or their cross section between 2 and 10 times the geometrical one, are not easily explained. Conventional nuclear physics fails to describe the observed phenomena. Theoretical interpretations have to suppose unconventional mechanisms :

effects of colour polarization of six quark states[8,9], long range nuclear force generated by both extra quarks and unconfined colour fields[10], quasi-molecular nuclear states[11], nuclear density solitons[12], spin and isospin metastable nuclear states[13]. Boguta has suggested a Lagrangian field approach with nucleus and meson fields, in which the repulsive inter-nuclear force becomes a long range force, which allows expanded nuclear configurations[14].

During the last two years, many experimental data have been presented[15-20]. The anomalous component has been observed for fragments with $Z > 3$[15], but contradictory results have been reported for $Z = 2$ fragments[17,18]. The presence of a threshold effect is uncertain[16]. Some preliminary results seem to associate the production of anomalons with specific topologies of the interactions[19].

So far, these investigations have been performed by exposure of emulsions. This technique provides an excellent spatial resolution, but does not allow to distinguish between the above mentioned hypotheses a) and b). In fact it is lacking in oriented triggers and statistics and it does not permit to study the behaviour of anomalons in vacuum (or air).

In this report we made the exercise to design an experiment which could pretend to solve the anomalon puzzle. The inputs for the project were the requirements that the apparatus should be able to:

- trigger on events with a good sensitivity to the presence of anomalons;
- study the behaviour of the anomalons in air in order to distinguish between the hypotheses a) and b);
- verify if there are favoured chains, from the beam ion to a given Z fragment, in the production of anomalons;
- have more information about the possible "memory" effect and about particular topologies in the anomalon production and interactions, if any.

2. - THE EXPERIMENTAL METHOD

The suggested experimental method takes advantages from the peculiar feature of anomalons and from their enhanced cross section. The presence of anomalons among the fragments originates an overproduction of secondary interactions. Therefore triggering on successive interactions of the beam fragments is straightforward the best method to evidenciate the existence of anomalons and to improve the selectivity of an experiment.

The comparation of the rates of secondary interactions is directly correlated with the fraction of anomalous fragments, their cross section and the "memory" effect.

In the frame of the hipothesis a) we have to expect, for example, an excess of three successive interactions of the order of 120% related to the expected value for ordinary ions. Moreover the study of the fragmentation stars in events which exhibit three successive interactions, improves the sample of interactions originated by anomalons (and that of the interaction where anomalons are produced) to 40% of the analyzed one, against the 6% of an unbiased analysis. Only the counter technique, with the use of an oriented trigger, can provide the necessary statistics and permit us to investigate if the anomalons decay spontaneously. We propose to use silicon solid state detectors as active target, as well as, tracking and charge detectors for the emitted fragments.

Solid state detectors have been widely used in the last years. Great technical developments made possible the building of very thin and large area detectors and of a fast associated electronics. Today these detectors are a major instrument in high energy physics(21). The assembly of thin silicon devices as multilayer targets made them well suited for studying weak decaying particles such as D-mesons(22). The use of thin strip electrodes and the possibility of operating these detectors as fine grained proportional chambers, the so called microstrip detectors, can provide a spatial resolution until 10 μm(21).

The experimental apparatus is composed by three identical active targets whose relative distances can be continously varied from $\sim$1 cm to $\sim$15 cm in order to distinguish between the above mentioned hypotheses a) and b). An assembling of microstrip chambers is located after each target to detect the emitted fragments and their charge. This system allows to trigger on events in which one fragment interacts in each target and to study the main properties of anomalons. It could be intended as a vertex coupled to a forward spectrometer to provide a full analysis.

Nowadays ion beam with energy bigger than 1 GeV for nucleon are available at Bevalac and Saturne II. In the near future, relativistic ion beam will be available at CERN.

3. - THE MULTIPLE-TARGET DEVICE

The sketch of the apparatus is given in Fig. 2. It is composed by three similar devices of silicon solid state counters V1, V2, V3 whose relative distances may vary from ~1 cm to ~15 cm. Each set V consists of an active target C and a microstrip

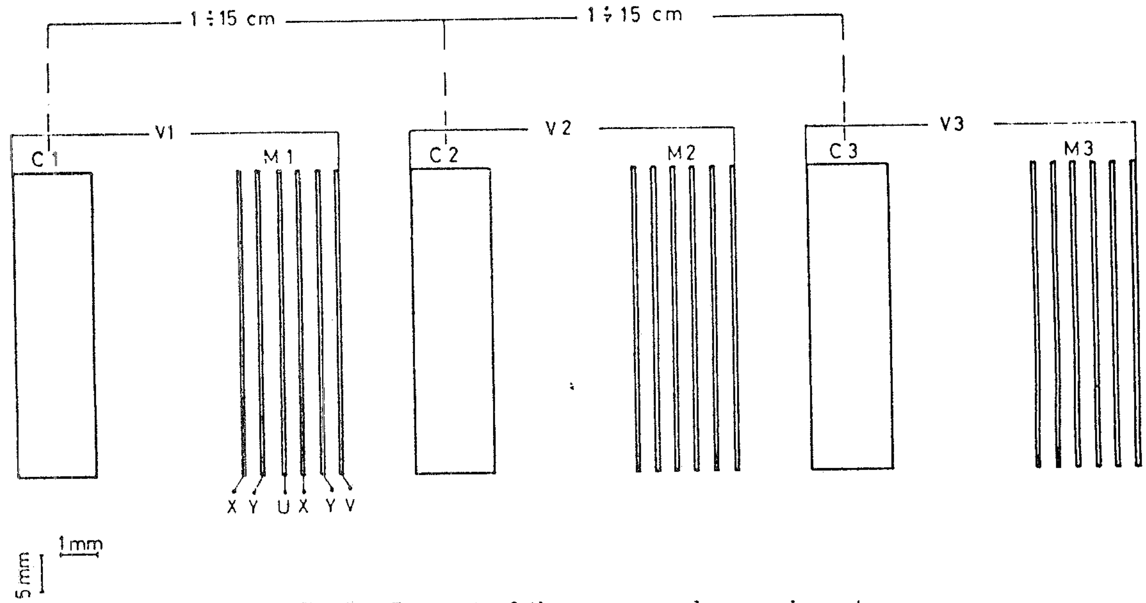

FIG. 2 - Layout of the proposed experiment.

chamber telescope M. The targets C are silicon solid state counters 2 mm thick. The area of the C and M counters is about 4 x 4 cm^2. The ion beam is sent on C1 collimated on a 3 x 3 mm^2 spot. The electrodes of C2 and C3 are shaped in convenient circular areas helping in the reconstruction of the interaction point on the targets. Selected strips of the telescopes M are read in order to cover in each relative dislocation of the targets, a geometrical acceptance of about $\pm$ 50 mrad for all the interactions originated by a progeny of a fragment emitted from C1 in a 100 mrad cone. The strips are equipped with an analogical-digital converter read-out, in order to measure, by the energy loss, the charge of the fragments.

The fast logic acquisition signal includes one of the three following requirements of interactions in the targets:

a - one interaction on C1;

b - one interaction on C1 and on C2;

c - one interaction on C1, on C2 and on C3.

The signal of interaction on C1 is performed comparing the released energy in the active target with the expected energy loss of the incident ion. The same multipli city is required in the first and in the last microstrip detector of each M telescope to avoid the reinteraction of the fragment in these detectors.

Comparing the multiplicity detected in the subsequent M telescopes we can select events in which the fragments interact in C2 or (and) C3.

4. - RATES AND SENSITIVITY IN THE SEARCH FOR ANOMALONS

Let us consider as a specific case an incident beam of Ar of energy > 1 GeV for nucleon.

The cross section of ordinary ion on silicon can be evaluated by the Bradt-Peters form[23]

$$\sigma_b = \pi \; r_o^2 (A_b^{1/3} + A_T^{1/3} - \delta)^2 \qquad (1)$$

where r_o is the radius of the nucleon and δ a screening parameter, A_b and A_T are the barionic numbers of the incident ion and of the target respectively. We obtain for Ar-silicon cross section $\sigma_{Ar} = 1600$ mb which corresponds to an ordinary m. f. p. of about 12 cm.

The triggering conditions will collect a mixed population of events with one, two and three generations of fragments on the target. In the off line analysis three classes of events will be considered:

i) events in which an ion beam interacts on C1 and its fragments don't interact;

ii) events in which an ion beam interacts on C1 and one of its fragments interacts in C2 without any interactions in C3;

iii) events in which an ion interacts on C1, one of its fragments interacts in C2 and one of the fragments of second generation interacts on C3.

The i) and ii) classes of events correspond practically to the events collected by a) and b) triggering conditions respectively. The c) trigger collects events in which one of the fragments generated in C1 interacts in C2 and another interacts in C3 ($\sim$ 50%), as well as, events of three generations pattern (iii) class). To evaluate the rates of the event of these three classes in the ordinary case, and in the hypothesis that a fraction of fragments are anomalons, we need to know the multiplicity and the charge distribution of the generated fragment in each target. Let us indicate the number of interactions generated in the i-target by fragments emitted in the i-1 target, for the total flux No of Ar ions on C_1, as:

$$N_i = No\, K_i \, \Sigma_F \, \sigma_F \; ,$$

$$N_i = No\, K_i \frac{\Sigma_F \sigma_F}{\langle m \rangle_{i-1}} \langle m \rangle_{i-1} = No\, K_i \langle \sigma_F \rangle_{i-1} \langle m \rangle_{i-1}$$

where $\langle m \rangle_{i-1}$ is the average number of heavy fragments emitted in the i-1 target in the acceptance cone, and $\langle \sigma_F \rangle_{i-1}$ is the average cross section of these fragments. We define the weighted number of interactions on the i-target:

$$N_i^A = No\, K_i\, \sigma_{Ar} = N_i\, P_i$$

where

$$P_i = \frac{1}{\langle m \rangle_{i-1}} \frac{\sigma_{Ar}}{\langle \sigma_F \rangle_{i-1}} .$$

Notice that the dependence of σ versus the charge of fragments is known from the formula (1) while $\langle m \rangle_{i-1}$ is experimentally measurable in the apparatus. Practically for each analysis we can use N_i^A instead of N_i. An evaluation of P_1, P_2 can be done taking into account the average topology of the heavy projectile fragments. In the first target disregarding the interactions in which the incident ion is completely destroyed (35%), the remaining events exhibit on average one fragment of mean charge 12 (or several fragments with same total charge) and 2 alphas. Let us consider only the contribution due to the $Z > 2$ fragments: the highest limit value for P_1 is 1.2. Similarly P_2 can be evaluated to be $\simeq 1.8$.

In Table I we report the expected weighted number (N_i^A) of interaction in the ordinary scheme and in the case in which the anomalons are produced following the prescriptions of hypothesis a), for a total flux No of Argon ions beam collected on C_1 of 10^{10} and a loss factor 10 due to the diffractive triggering efficiency and to the off-line

TABLE I

	N_1	N_2^A	N_3^A
Expected rates without anomalons	16×10^6	270×10^3	4.5×10^3
Expected rates with anomalons according to the hypothesis a)	16×10^6	400×10^3	9.6×10^3

reconstruction capability. The realistic case could be an Ar beam of 10^6 extracted ions/burst, collimated at 3×3 mm^2 spot on C1 as 10^5 ions/burst, repetition time of 2.5 s and 70% of running efficiency i.e. ~ 4 days running time.

Namely we expect a 45% excess in second generation events and a 120% excess in third generation events.

Moreover, the use of three successive targets allows us to show up the existence of an anomalous component independently of any predictions in the ordinary scheme and to disentangle the questions related either to the fraction of anomalons present among the fragments, or to their cross section or to the memory effect, if any.

Let us consider the experimental quantities :

$$l_2 = \left[\left(\frac{N_2^A}{N_1} - N_1 \right) \Big/ N_1 \right] ; \qquad l_3 = \left[\left(\frac{N_3^A}{N_2^A} - N_1 \right) \Big/ N_1 \right] ;$$

$$q = \left[\frac{N_3^A}{N_1} - \left(\frac{N_2^A}{N_1} \right)^2 \right] \Big/ \left(\frac{N_2^A}{N_1} \right)^2$$

versus the following parameters :

f = percentage of anomalons produced by an ordinary interactive ion;

a = enhancement factor of the anomalon cross section in respect to the ordinary-one;

m = ratio between the percentage of anomalous fragments emitted by an interacting anomalon and f (m = 1 means no memory effect).

In Figg. 3 and 4 we report l_2 versus f. a, l_3 and q versus m for different values of f·a respectively. The quantity l_2 is sensible to the generation of anomalons by comparing the probability of interaction of the generated fragments with the probability of interaction of the incident beam ions. The memory effect is investigated looking at the l_3 and q terms which compare the interaction probability of fragments of two successive generations. In hypothesis a) we expect $l_2 \sim 0.4$, q = 0 or q = 0.23 in the case of m = 1 or m = 3 respectively.

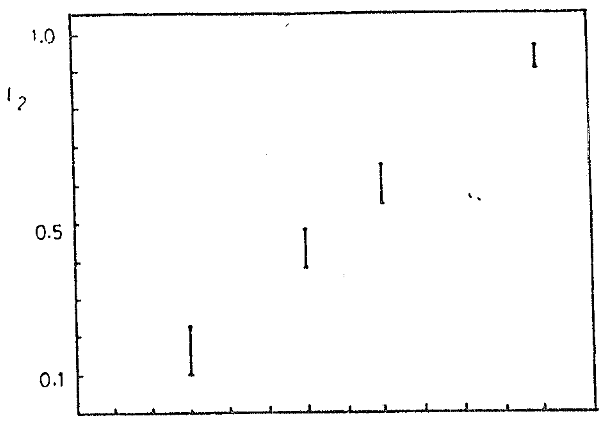

FIG. 3 - Predicted value of l_2 versus f·a. The uncertainties are due to the range of values taken for m (1-5).

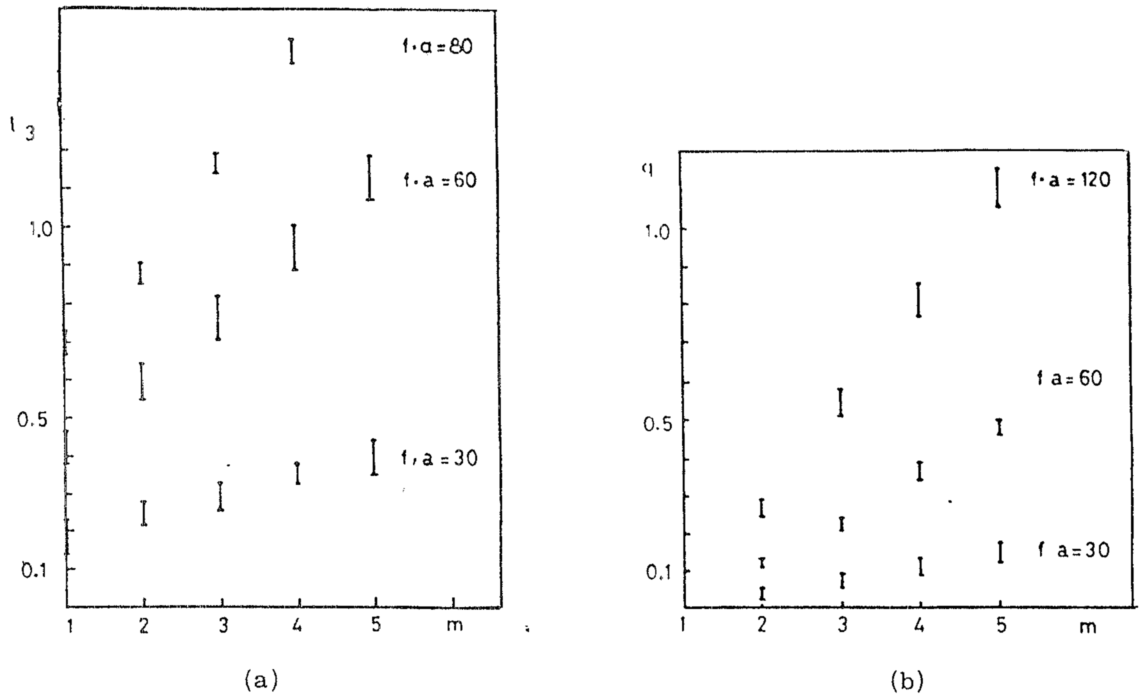

FIG. 4 - Predictions of l_3 (a) and q (b) versus the "memory" parameter m for fixed f·a values.

The study of same quantities varying the distances between the targets C1, C2, C3 will permit us to distinguish between hypotheses a) and b).

5. - CONCLUSIONS

The proposed apparatus seems appropriate to investigate both the existence of anomalons and their behaviour. It provides also a way to study the anomalon production and interaction. In fact, if we consider the event exibiting three generations and we look at the interactions on C2 C3, in the case of hypothesis a), about 50% of the interaction stars are generated by an anomalon instead of the 6% if a non selected 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 anomalon production. The apparatus can also provide the topological configurations of these selected events. Some preliminary data on emulsions seem to indicate a forward-backward asymmetry in the stars originated by anomalons(19), however these results are not conclusive because of poor statistics.

Coupled to a forward spectrometer the described multiple-target device could provide insight into the dinamics of the anomalon interactions.

The momentum distribution of fragments produced by fragmentation of a heavy ion beam, have been investigated in the range of 1-2 GeV/nucleon[24]. The analysis of the selected events, could permit a glimps into the dinamics involved in interactions of an anomalon projectile and the eventual deviations of the fragment momentum distribution from the ordinary one.

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