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S. Bianco, M. Enorini, F.L. Fabbri, A. Zallo and P.G. Rancoita:
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Presented at the "Topical Seminar on Perspectives for Experimental Apparatus of Future High Energy Machines",
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A MULTITARGET SOLID STATE DEVICE STUDYING RELATIVISTIC HEAVY IONS FRAGMENTS

S.Bianco, M.Enorini, F.L.Fabbri, A.Zallo
INFN - Laboratori Nazionali di Frascati, Frascati

and

P.G.Rancoita
INFN - Sezione di Milano, Milano

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ABSTRACT

A multilayer solid state device which is both active target and tracking detector is proposed for an electronic experiment investigating the so-called anomalons and studying their production mechanism, interaction cross-section and lifetime. The experimental method is based on triggering the reinteraction in two targets of heavy fragments, originated in a production target by a relativistic ion beam. This method greatly increases the sensitivity to the anomalon effect when compared to other proposed electronic experiments. Solid state devices seem to provide a resolving technique for the study of these short-lived states among high-multiplicity final systems.

1.- ANOMALONS

Recent emulsion experiments performed at Berkeley with a relativistic ion beam[1] have confirmed some old cosmic rays results[2] which observed an overproduction of multiple interactions originated by produced fragments. These experiments provide an evidence for the presence, among fragments, of a component (the so-called anomalons) whose cross-section appears to be anomalously large if compare to the ordinary one. Such an anomalous behaviour disappears after few centimeters from the interac... point (Fig. 1).

To explain this fact, two hypotheses have been suggested :

a) The anomalons are stable, but they are so strongly interacting that they disappear after a short path. A fraction of 6% of anomalons among the fragments, having a cross-section one order of magnitude larger than the ordinary one is requested to fit the experimental data.

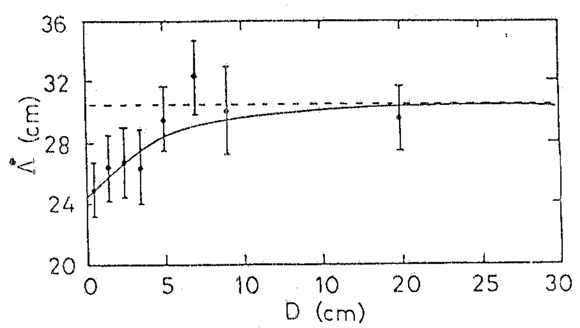

FIG. 1 - The mean free path in emulsion depends on the barionic number of the projectile. To use the bulk of information coming from different Z fragments the parametrization $\Lambda_Z = \Lambda^*.Z^{-b}$ is used. In figure the measured Λ^* is reported for the population of fragments present at different distances (D) from their production point (Ref. (1)).

b) The anomalons are short-lived states with a lifetime $\sim 10^{-10}$ sec and they disappear mainly by decaying to ordinary states. In this case, data are consistent with a 100% of anomalons and a cross-section 2-3 times larger than the geometrical one.

Furthermore the experimental data suggest also the existence of a "memory" effect by which a "short" projectile fragment produces a "short" fragment more frequently than a primary ion(3) as it would occur if a new quantum number is conserved in the interaction.

A mean life in the range of 10^{-10} sec or a cross section much greater than the expected one or a conserved quantum number in the anomalon interaction can hardly fit into conventional theoretical models. Thus, unconventional mechanisms have been considered to approach the solution of this problem: six-quarks states, colour polarization, 'pineuts' (bound states π-n), etc(4). Moreover, some emulsion data seem to show the presence of this effect for Z = 1(5). Amado and Dar(6) noticed also that the antiprotons yields for thick targets were found much smaller than the rates predicted by measurements in thin targets(7), supporting an unknown short-range behaviour at elementary particles level.

2.- THE REINTERACTION METHOD

So far anomalons have been investigated by exposure of emulsions. This technique provides an excellent spatial resolution but it is very poor in statistics and lacking in oriented triggers, and does not allow to clarify the behaviour of anomalons in vacuum. Counting techniques with oriented triggers can provide statistics but, so far, the proposed experiments are based on the absorption method(6,8). Special devices such as thin Cerenkov paddles(9), or radiochemical methods(10) have been proposed, but they are not generally able to recognize each fragment and to track it back to the interaction point.

The method suggested here takes advantage from the peculiar nature of anomalons, i.e. their enhanced cross-section. This originates an overproduction of secondary interactions; therefore triggering on successive interactions of the beam fragments is the best method to show the existence of anomalons and to improve the selectivity of an experiment. If the reinteractions can be selected, the excess due to the anomalons presence is of order of

$$\mathbf{f} \cdot \mathbf{a} \qquad (1)$$

in the second interaction and

$$\mathbf{f} \cdot \mathbf{a} \left(\mathbf{f} \cdot \mathbf{a} + 2 \right) \qquad (2)$$

in the third interaction (**f** is the anomalon fraction of fragment among the ordinary one, and **a** is the enhancement factor of their cross section). The problem is to pick out secondary and tertiary interactions in the inclusive flux of events using a variable geometry apparatus to measure the lifetime of these fast disappeared states.

Moreover, complete spatial reconstruction of these multiple-interactions events is necessary as well as the charge identification of each heavy fragment.

In this paper we show that a technique using solid state counters is adequate as an active target as well as a tracking and charge detector.

3.- THE EXPERIMENTAL APPARATUS

During the last years solid state detectors have been widely used in lifetime measurements of short-lived heavy-flavour mesons[11]. The assembly of thin silicon devices made them well-suited as multilayer targets and changing-multiplicity detectors. The possibility of dividing the electrodes in very narrow strips provides a new fine-grained proportional detector, which is able to identify and reconstruct secondary vertices. Both above features are exploited to the utmost in the proposed detector for the search of the anomalons.

The experimental apparatus, in vacuum environment, is composed by three identical devices of solid state counters V0, V1, V2 whose relative distances can be continously varied from ~1 cm to ~15 cm (Fig. 2).

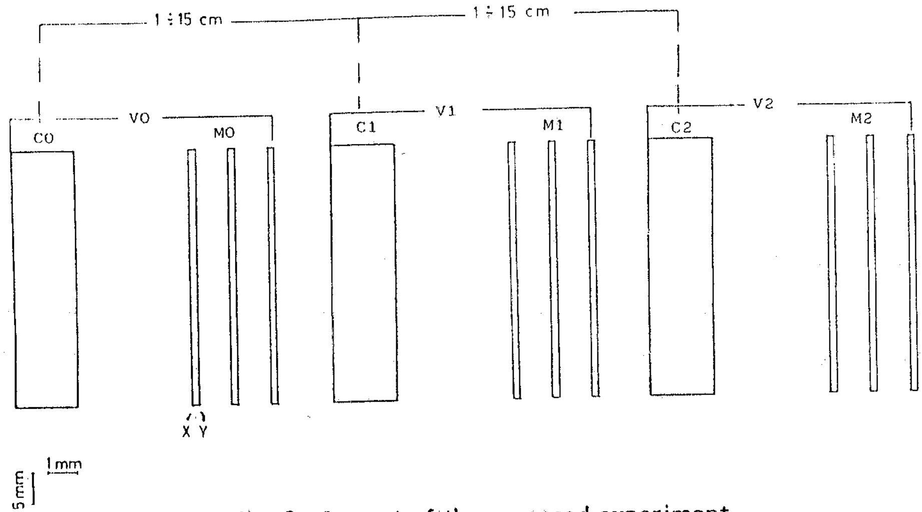

Fig. 2 - Layout of the proposed experiment.

Each set V consists of an active target C and a microstrip chamber telescope M. The area of C and M counters is about 25 cm^2. The targets C are silicon solid state counters and the ion beam is sent on C0 collimated on a 3 x 3 mm^2 spot, while the electrodes of C1 and C2 are shaped in convenient circular areas helping in the reconstruction of the interaction point in the targets. An assembly of microstrips M is located after each target in order to detect the emitted fragments and to measure their charges by the ionization energy loss. Each M telescope is composed by 3 planes 200 μm thick: both faces of each plane have a set of strip-shaped electrodes, with a 20-50 μm pitch, increasing with the distance from the beam axis, and with a relative orientation of 90°. This double readout allows to set a space point information from each microstrip detector. The matching is done by associating similar energy losses detected by perpendicular strips[12,13]. In the M telescopes microstrips are rotated by 120° each. Selected strips of M telescopes are read in order to cover (in each relative dislocation of the target) a geometrical acceptance of about $\pm$ 50 mrad for all the successive interactions generated by a fragment emitted from C0 in a 100 mrad cone. The fast logic acquisition signal includes one of the three following requirements:

a) one interaction in C0;

b) one interaction in C0 and one in C1;

c) one interaction in C0, one in C1 and one in C2.

The primary interaction in C0 is associated to an energy deposited less than the expected energy released by the incident ion. In order to select on-line reinteractions of the emitted fragment in successive targets (C1, C2) and to reject reinteractions on the microstrips telescopes, a constant multiplicity in the planes of the same M telescope and a multiplicity step between successive M telescopes is required.

4.- RATES AND SENSITIVITY

As a specific case, let us consider an ^{40}Ar beam with an energy-per-nucleon > 1 GeV. The ordinary Ar $\rightarrow$ Si cross section is σ_{Ar} = 1600 mb corresponding to an ordinary mean free path $\lambda \sim 12$ cm[14]. The triggering conditions will collect a mixed sample of events with one, two and three generations of fragments in the targets. In the off-line analysis three classes of events are considered:

1) Events in which an ion beam interacts on C0 and its fragments do not interact anymore.

2) Events in which an ion beam interacts on C0, one of its fragments interacts on C1 without any interaction on C2.

3) Events in which an ion beam interact on C0, one of its fragments interacts on C1 and one of the fragments of second generation interacts on C2.

The 1) and 2) samples of events correspond to the events collected by a) and b) triggering conditions. The c) trigger collects events belonging to 3) sample, as well as events in which one of the primary fragments interacts in C1 and another one interacts in C2.

The evaluation of the rates of these three classes in the ordinary case and in the hypothesis that a fraction of fragments consists of anomalons,requires the knowledge of the multiplicity and the charge distribution of the generated fragments in each target.

Let us consider a specific chain

$$Ar(C0) \rightarrow Z1(C1) \rightarrow Z2(C2) \rightarrow \text{anything}.$$

The cross-section of this kind of ions in the ordinary frame can be evaluated using the Bradt-Peters formula[14], or directly measured sending the corresponding ion beam on C0. This allows us to evaluate the expected number of interactions in the successive targets in absence of an anomalous component among the produced fragments.

Let R1, R2 be the ratios between the apparent cross-section in C1, C2 and the ordinary one.

If anomalons are present among the incident Z1 and Z2 fragments the ratios R1, R2 will be greater than 1. Figure 3 shows the dependence of R versus $g \cdot a$, where g is the percentage of the fragments impinging in the targets, whose cross-section is a times larger than the ordinary one. Notice that g differs from the fraction of generated anomalons f (see 1) and 2)) because of reinteractions and multistep channels from the incident ion to the final selected fragment. This difference is within few percents when the targets are thin enough as in the proposed layout. By the way, f can be evaluated studying the trend of g versus the target thickness.

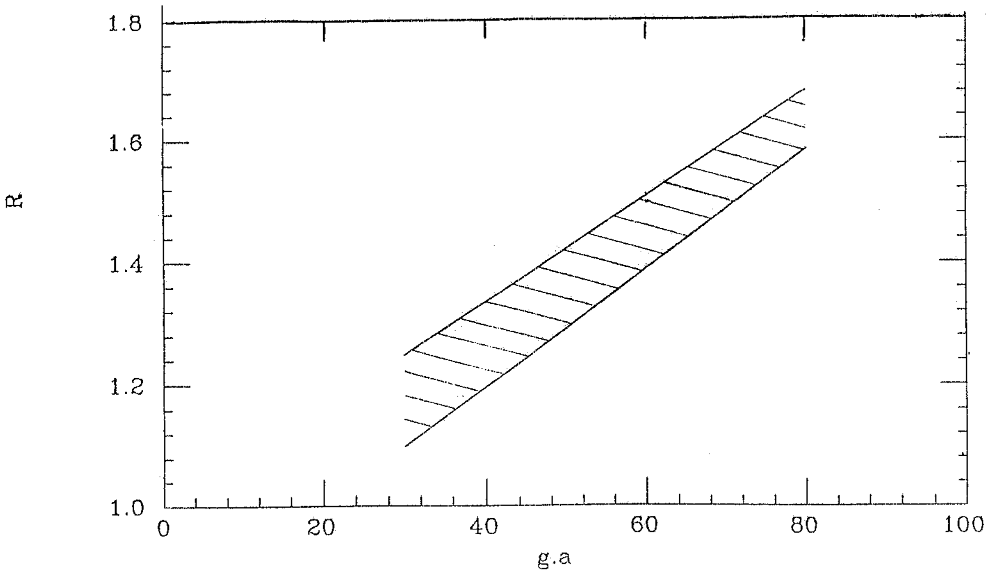

Fig. 3 - Expected values of the quantity R versus the percentage of anomalons g times the anomalous enhancement factor a. The shaded band shows the second order dependence of R from g and a separately.

A dependence of the phenomena from the specific selected channel Zin → Zout as well as the memory effect will originate a difference between the ratios R1, R2.

The existence of a memory effect can be untangled comparing the R2 value with the same quantity obtained when Z1 is not a primary fragment but an ion of the incident beam. In that case, any difference between the two measurements is related to the memory effect.

Some hours of data-taking with fluxes of relativistic heavy ions currently available can provide a dramatic statistics for the measurement of the ratio R1. A satisfactory statistic for R2 is easy to get within about 50 days; this would correspond for the specific chain considered

$$Ar(C0) \rightarrow Mg(C1) \rightarrow O(C2),$$

to $\sim$150 third interactions in C2 in the ordinary case. It is worthwhile noting that the integrated statistic on every Z1 and Z2 is $\sim$100 times larger and it is collected at the same time.

5.- CONCLUSIONS

This paper suggests an electronic counter experiment for the search of anomalons, employing a multilayer active target triggering on two and three successive interactions. The proposed technique based on solid state detectors, seems suitable. By this method a higher sensitivity and statistics than that of other proposed counter experiments are obtained. A study of the Z distribution of the interactions fragments could emphasize favourite Z channels in anomalons production. The apparatus provides the topological configuration of the events and the forward-backward asymmetry in the stars, originated by the interactions of anomalons[15], could be easily demonstrated.

The dynamic involved in the interactions can be investigated when the multiple target device is coupled to a forward spectrometer.

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

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