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(A Proposal to the ISR)

SEARCH FOR HIGH ENERGY MULTIGAMMA EVENTS, POSSIBLE CONSEQUENCE OF MAGNETIC MONOPOLE PAIRS OR OF HIGH Z LEPTONS

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I. INTRODUCTION

Several cosmic-ray experiments involving the exposure of photographic emulsions at high altitudes have shown the existence of high energy multi-gamma-ray events.[1] These events could not be accounted for by conventional electromagnetic showers originating from a single high energy gamma. Rather they appear to be a result of a large number of gammas produced simultaneously from a single interaction. These events remained a mystery for a number of years until recently when Ruderman and Zwanziger[2] put forward a plausible explanation which attributes these high energy multi-gammas as due to the creation and subsequent annihilation process of magnetic monopole pairs. The important point, which has been emphasized by Ruderman and Zwanziger and also by Teller,[3] is that when a pair of monopoles are produced they will rapidly annihilate ($t \sim 10^{-22}$ sec) due to the very strong coulomb attraction and will leave behind remnant photons. The multiplicity of these photons is expected to be large ($\sim 1/\alpha$). Therefore, with energies available at ISR, the production of free monopole pairs would be less probable than the characteristic annihilation processes, either real or virtual. Very recently, T. D. Lee[4] suggested that another possible process which involves the creation of pairs of highly charged leptons ($Z > 10$) can also be responsible for these multigamma events discussed above. In fact, any charged particle with a very strong electromagnetic coupling would yield such events.[4] In the event obtained by deBenedetti, there were 14 gammas with a total energy of > 40 GeV.

The primary objective of the present proposal is to search for high energy multigamma events at the ISR and to study the characteristics and nature of these multigammas in order to gain a better understanding of the origin of such processes. We would also try to ascertain whether or not magnetic monopoles or high Z leptons are responsible for them.

A secondary objective is to simultaneously search for individual monopoles that might be created by the colliding beams.

II. THEORETICAL DISCUSSIONS

A possible mechanism for the production of high multiplicity γ-ray events in proton-proton collisions is the following process:

$$p_1 + p_2 \rightarrow \text{hadrons} + \gamma' \qquad (1)$$

$$\gamma' \rightarrow n\gamma \qquad (1')$$

In Eq. (1), p_1, p_2 are colliding protons and γ' is a time-like virtual photon with momentum q which subsequently decays into $n\gamma$. A possible Feynman diagram for γ' is shown in Fig. 1.

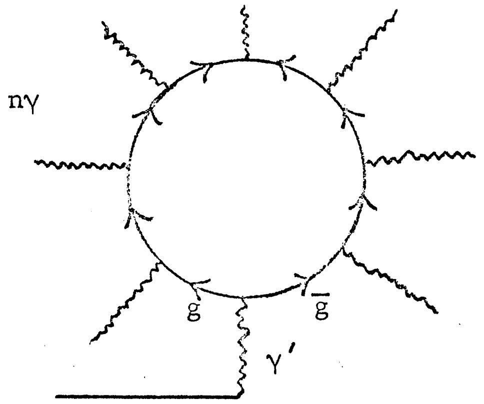

Fig. 1

The particle, g, propagating around the loop in Fig. 1 is presumed to have a very strong interaction with the photon field ($g^2/\hbar c \sim 1/\alpha$) so that the photon multiplicity which is proportional to $g^2/\hbar c$ is large. It is important to note that this effect can be felt even below threshold for g, $\bar{g}$ production. The most obvious candidate for g is the Dirac magnetic monopole which has been shown by Dirac to have a coupling strength of $\frac{1}{\alpha}\frac{n^2}{4}$ where n is an integer. However, as mentioned previously, a highly charged lepton or any particle with a similar very strong electromagnetic interaction will yield a multigamma event.

The expected average energy and angular distribution of the nγ's is derived by assuming that the photons are isotropic and of equal energy in the rest frame of the virtual photon. Transforming to the center of mass of the colliding protons (which is the lab frame for ISR) yields the laboratory energy and angular distribution of the photons for various values of q^2. We will examine large $-q^2$. However, we do not necessarily require $-q^2 \geq 4m^2g$ which is the threshold for g, $\bar{g}$ production since the effect can be felt for $-q^2 < 4m^2g$ and in fact the transition from below threshold to above threshold may only involve a cusp effect in the nγ cross section and would not necessarily imply a significant enhancement of the nγ cross section. The expected energies of the photons will be from a few hundred MeV to a few GeV. These photons will be distributed over a significant part of the available 4π geometry. In particular, at the maximum q^2 they will be distributed isotropically. For lower values of q^2, some collimation about one of the protons is expected with half the photons in a narrow cone ($\tan\theta \sim 1/\gamma\beta$ where β is the velocity of the $q \geq 0$ frame and γ the corresponding Lorentz factor), and the rest in a diffuse cone. It is clear that for large $-q^2$, these cones cover a large solid angle. We would expect these cones are appreciably larger than the cones for pion production. There is no way of reliably estimating the cross section for the process under investigation. The process 1 has been studied theoretically and experimentally, though not at the energies and q^2 values available at ISR.[5-7] For 1′ there is no way of obtaining a reliable estimate because of the large coupling. Therefore, for the purposes of estimation, we will assume that:

$$\frac{d\sigma_{g\bar{g}}}{dq^2}(q^2, E)_{(\text{real, virtual})} \sim K \frac{d\sigma_{\mu^+\mu^-}}{dq^2}(q^2, E) \tag{2}$$

where K is a constant. Equation (2) takes into account the hadronic structure and the constant K is the ratio of the coupling $[(\gamma' \rightarrow g\bar{g})/(\gamma' \rightarrow \mu^+\mu^-)]^2$. If we interpret these couplings as dissociation probabilities as suggested by Goto[8] then the maximum value of K is $1/\alpha$. Therefore, the total cross section for $n\gamma$ production would be $10^{-36}\,\text{cm}^2$ for $-q^2 > 25\,(\text{GeV})^2$. Of course, if we use the elementary coupling for K, then K would be $1/\alpha^2$ and the cross section would be $10^{-34}\,\text{cm}^2$.

III. EXPERIMENTAL PROCEDURE

a) Detection of Multigamma Events

The basic requirement of our detection system is the capability to distinguish between a multigamma event and a conventional high energy electromagnetic shower. The former is characterized by the simultaneous appearance of a large number of energetic showers, while the latter is characterized by single or a small number of showers. Our detection system is designed to observe the development of each shower as well as to measure the energy deposition during its development.

A cross-sectional view of the basic detector unit to be used in this experiment is shown in Fig. 2. Photons incident on the detector cause showers to be developed in the lead glass. The positions and orientations of these showers are established by wire chambers that are positioned at various depths in the detector, and the energy contained in the showers is determined by collecting the light emitted in the lead glass.

The occurrence of multigamma events is established by requiring coincidence between showers located in different portions of the detector. Proper logic is included to allow simultaneous measurement of multigammas above some minimum number (say 10) so as to exclude the photon background from π^o decays. A thin scintillation counter and a wire chamber monitor the number of incident charged particles. The number of events corresponding to simultaneous background photons would be expected to decrease rapidly as the number of simultaneous photons increases. An enhancement at a large number of simultaneous showers (> 10) (Ref. 1) would be a strong indication of the existence of multigamma events.

Particles incident from directions other than that of the interaction region would be rejected by anticounters positioned around the counter assembly.

The background due to π^o mesons is $N = 10^{-26} \times 4 \times 10^{30} = 4 \times 10^4$/sec. Events due to π^o's should have a low multiplicity. Hence, the trigger rate from the π^o production is low and also events produced by π^o's can be eliminated by proper coincidence logic since the time resolution of the basic elements of the detector is extremely short. (The wire chambers have a known time resolution of ~ 10 ns.) Background events due to gas scattering are estimated to be lower than the π^o background and also these photons are of very low energy.

b. Free Monopoles

In the event that free monopoles or high Z particles are produced in the interaction region, they could be detected by the present counter. Both of these particles would deposit an abnormally large amount of energy in the scintillation and Cerenkov counter. Monopoles will be distinguished from high Z particles due to the different ratio of Cerenkov signal to scintillation signal.

IV. EXPECTED EVENT RATES

With the design luminosity of 4×10^{30} $\text{cm}^{-2}\text{sec}^{-1}$, the number of multigamma events per day is:

$$N = L\sigma t = 3.5 \times 10^{35}\ \sigma \tag{3}$$

where σ is the total cross section for multigamma production and t is the time in seconds.

If one assumes a production cross section of 10^{-36} cm^2 and a collection efficiency of 75%, then one can expect to obtain approximately 30 events in 100 days. However, if one assumes a production cross section of 10^{-34} cm^2, then one would expect to obtain 3000 events in the same period.

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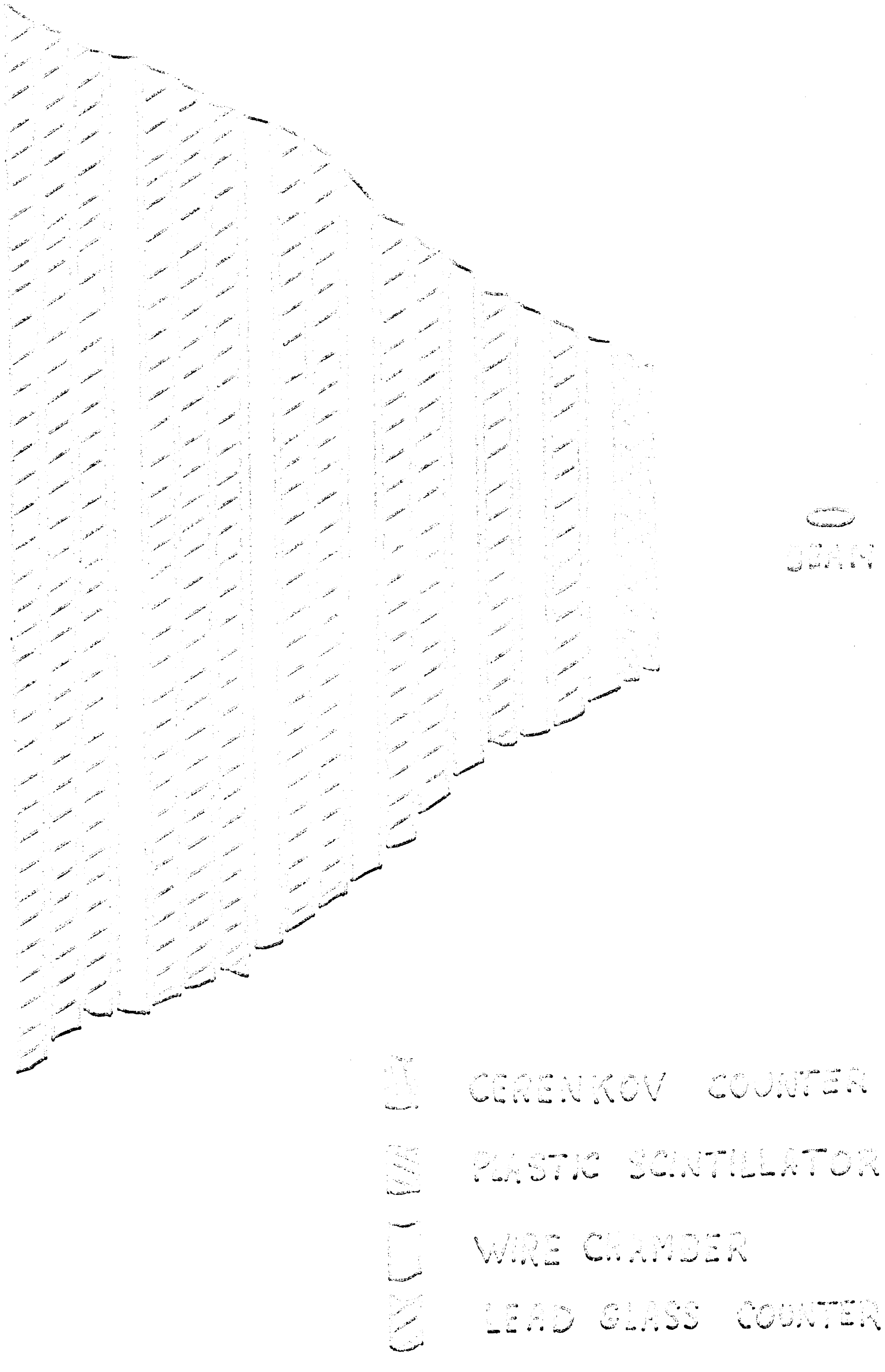

Fig 2 CROSS SECTIONAL VIEW OF BASIC DETECTOR UNIT