LIMITS ON MONOPOLE FLUXES FROM KGF EXPERIMENT

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1. Introduction

The nucleon decay experiment at KGF at a depth of 2.3 Km is eminently suited for the search of GUT monopoles, whose velocities at the present epoch are predicted to be around 10^{-3}C. At this depth the cosmic ray background is at a level 2/day in the detector of size 4m x 6m x 3.7m and one can look for monopoles traversing the detector in all directions, using three methods(1) i.e., i)dE/dx (ionisation), ii)time of flight and iii)catalysis of nucleon decay. The detector is composed of 34 layers of proportional counters arranged in horizontal planes one above the other in an orthogonal matrix. Each of the 1594 counters are instrumented to measure ionisation in the gas (90% Argon + 10% Methane) as well as the time of arrival of particles.

2. Method and Results

(i) dE/dx

The ionisation deposited in each counter is converted to an equivalent number of minimum ionising muons(Neq), whose distribution is approximately Gaussian with $\sigma=0.4/\sqrt{Neq}$ upto Neq≈100 particles. With a threshold of 1/4 I_{min}, the counters are sensitive for monopole velocities > 5×10^{-4}c(whereas the trigger needs a path length > 45 cm corresponding to 7.5×10^{-4}c). In this method we look for uniform ionisation all along the track, a hall mark of monopole signals. To make the search sensitive, only tracks with lengths > 1.5m are considered so that a minimum of 12 sampling points are available for analysis. Moreover, we impose a restriction Neq > 2.5 to avoid closely spaced muons as well as the tail of resolution function of single muons. This corresponds to a lower limit on velocity of 1.3×10^{-3}c.

A total of 1900 events were recorded in a period of 952 days since March 1982. Since none of them have survived the statistical tests on uniformity in ionisation along the track, we set an upper limit on the monopole flux as $F < 2.3/(S\Omega)T = 1.2 \times 10^{-14} cm^{-2} sec^{-1} st^{-1}$ (90% C.L) for the velocity range 1.3×10^{-3}c -- c.

(ii) <u>Time of flight method</u>

The pulses in the proportional counters have a mean rise time of 0.6μsec and consequently the timing resolution achieved is~0.4μsec. The arrival times are measured in a window of 0.5μsec -- 7μsec for all tracks with lengths > 1.5 m but without any restriction on ionisation. These cuts correspond to a sensitive velocity region of 7×10^{-4}c--4×10^{-3}c providing a good overlap with method(1). In a period of 623 days a total of 1200 events were recorded with the timing data. No event has shown the expected progressive delay and hence we obtain the following upper limit of

$$F < 1.7 \times 10^{-14} cm^{-2} sec^{-1} st^{-1} \quad (90\% \text{ C.L}).$$

(iii) <u>Monopole catalysis of nucleon decay</u>

The methods (i) and (ii) are crucially dependent on the monopole ionisation as a function of velocity. If the monopoles catalyse nucleon decay, one can extend this search to low velocities provided the cross section is close to that of strong interactions. One would then record either a chain of decays or isolated decay event depending on the mean free path λ.

(a) Chain decay In this detector a chain of decays can be recorded only if the second decay event occurs within 7μsec of the first one and if the chain length is in the range 0.4m - 4.5m. During a period of 3.6years of operation of the detector, no event was recorded with characteristic chain decay. Fig 1a shows the flux limit as a function of the monopole velocity for 2 representative values of the cross section. For example, with σ = 10mb, the flux $F < 1.8 \times 10^{-14} cm^{-2} sec^{-1} st^{-1}$ for all $\beta > 10^{-3}$, where β is the reduced velocity.

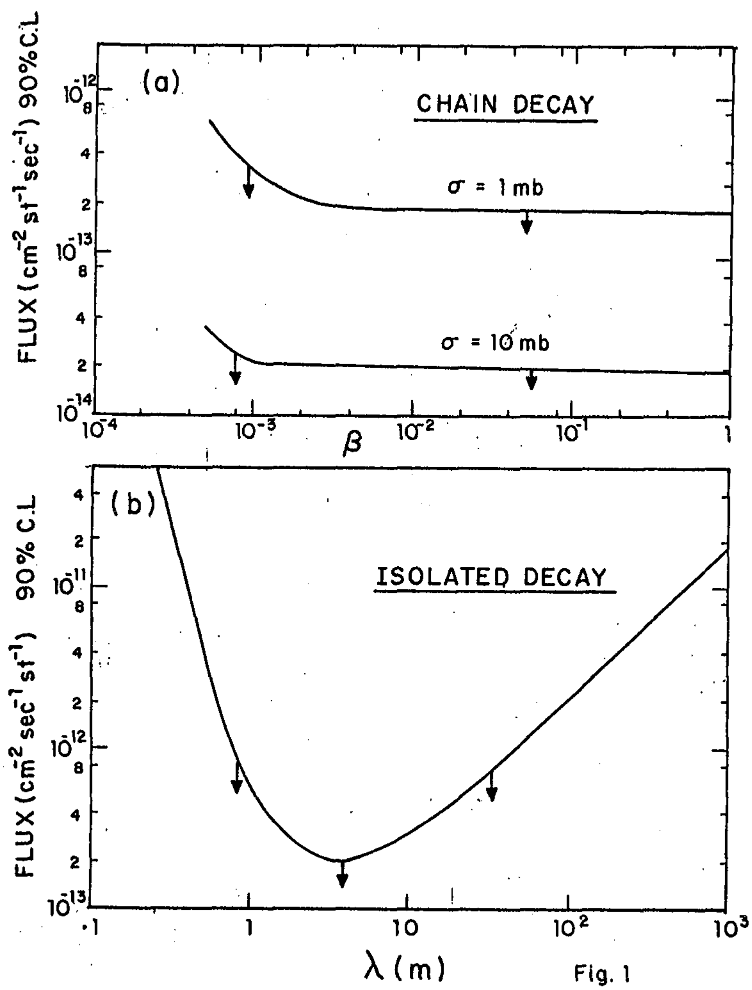

Fig. 1

(b) Isolated decay

If the monopole catalysis results in a momentum imbalance of less than Fermi momentum in iron nucleus it will be indistinguishable from the spontaneous nucleon decay; for larger momentum transfers, it mimics low energy ν-collisions. Thus we consider all the low energy ($\leq$ 1 GeV) confined events as possible candidates for catalysis and set upper limit as shown in Fig 1b without background subtraction.

3. Conclusions

There is no evidence for a monopole signal in the present experiment and the best limit is

$$F < 1.2 \times 10^{-14} cm^{-2} sec^{-1} st^{-1} \quad \text{for } \beta > 10^{-3}.$$

While this is 2 times higher than the Baxan limit, it spans a larger range of velocities and is based on large number of samplings (average number is 25) along the track resulting in an unambiguous search for monopoles.

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