Nuclearite Search with the TL Stack Detector at Ground Level

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Abstract

The TL stack has been develoved as a nuclearite detector. We are planning a nuclearite search experiment at ground level with the TL stacks. Results from a test experiment at Okayama University is reported.

1. Introduction

Witten proposed [8] that quark matter consisting of aggregates of up, down and strange quarks in roughly equal proportions may exist and be stable. This strange quark matter (also called 'strangelets') may have masses ranging from a few GeV to that of a neutron star. De Rújula and Glashow have termed such particles in cosmic rays colliding with Earth, 'nuclearites', and suggested several experimental techniques to detect them [3,4].

A thermoluminescent (TL) sheet stack detector, a sandwich of TL sheets and medical X-ray films, has been develoved as a nuclearite detector [1,6,7]. Using the TL stacks, we have been searching for neclearites at the Gran Sasso underground laboratory since 1996. Though Gran Sasso rock provides us with a very low background environment, it prevents us from detecting neclearites lighter than about 10^{15} GeV/c^2. Hence, we are planning a nuclearite search experiment at Okayama Uiversity, i.e. at ground level.

As a test experiment, 1.4 m^2 of TL stacks had been set at a building of Okayama University. In this paper, analyzed results after 100 days of exposure are reported.

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2. TL Stack Detector

Fig 1. shows the TL stack detector used in the ground level experiment. The TL stack consists of 3 TL sheets and 6 medical X-ray films. The TL stack sensitivity to nuclearites is described in [1,6,7]. Concerning nuclearites lighter than 10^{15} GeV/c^2, we can detect them if their β at ground level is larger than 9×10^{-4}.

Since light nuclearites lose significent energy in the atmosphere, the TL stack acceptance depends on their mass M, β before entering the atmosphere and incoming zenith angle. Fig. 2. shows the calculated acceptance relative to its maximum value as a function of M for $\beta = 10^{-3}$ and 2×10^{-3}.

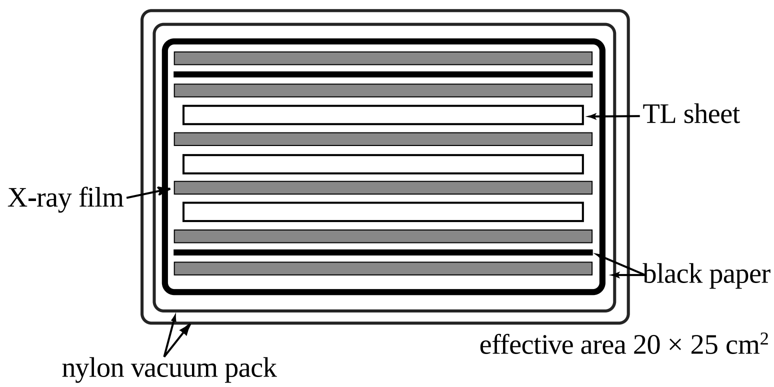

Fig. 1. A schematic diagram of the TL stack. The effective size of one TL stack is 20×25 cm^2.

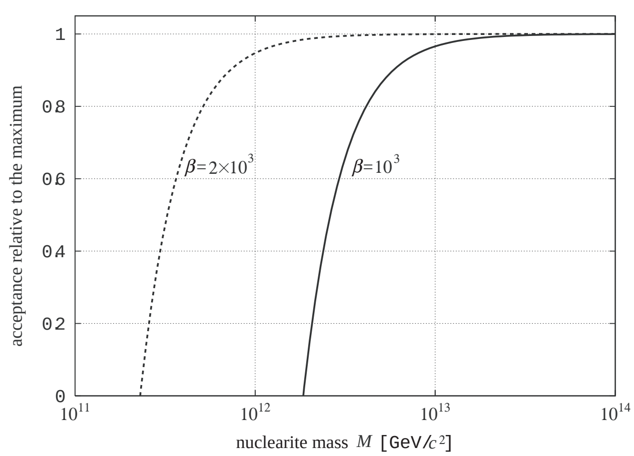

Fig. 2. The TL stack acceptance relative to the maximum as a function of M at ground level.

3. Results

TL stacks of 1.4 m^2 had been set at a building of Okayama University for 100 days (from October 2001 to January 2002). It is found that the average number of background events, visible black marks on the X-ray films due to natural radioisotopes, is small enough for our nuclearite search experiment.

In the analysis of the 1.4 m^2 TL stacks, no penetrating track was found, and we set the 90 % C.L. upper limit for the downward flux of nuclearites as

$$\begin{aligned} F &\leq 2.3/(1.4 \times 10^4 \, [\mathrm{cm}^2] \times \pi \, [\mathrm{sr}] \times 100 \times 24 \times 3600 \, [\mathrm{s}]) \\ &\leq 6.1 \times 10^{-12} \, [\mathrm{cm}^{-2}\mathrm{sr}^{-1}\mathrm{s}^{-1}]. \end{aligned}$$

Fig. 3. shows the limit for the case that β of nuclearites before entering the atmosphere is 10^{-3}. The diagonal line shows the maximum cosmic flux which assumes that all dark matter consists of nuclearites [3,4].

4. Conclusions

To search for nuclearites lighter than 10^{15} GeV/c^2 with the TL stack detector, we have tested a ground level experiment at Okayama University. It is found that background events due to natural radioisotopes are rare enough for nuclearite search experiments. Thus, we are planning to set larger area of TL stacks at the building tested.

The thin dotted curve in fig. 3. shows the flux level that we can explore with 10 m^2 of TL stacks and one year exposure. For comparison, fig. 3. also shows the limit obtained from our underground experiment at Gran Sasso [1] and ground level gravitational-wave detector experiments [2,5]. This figure makes us conclude that our new experiment at ground level will give significant information on the flux of nuclearites.

References

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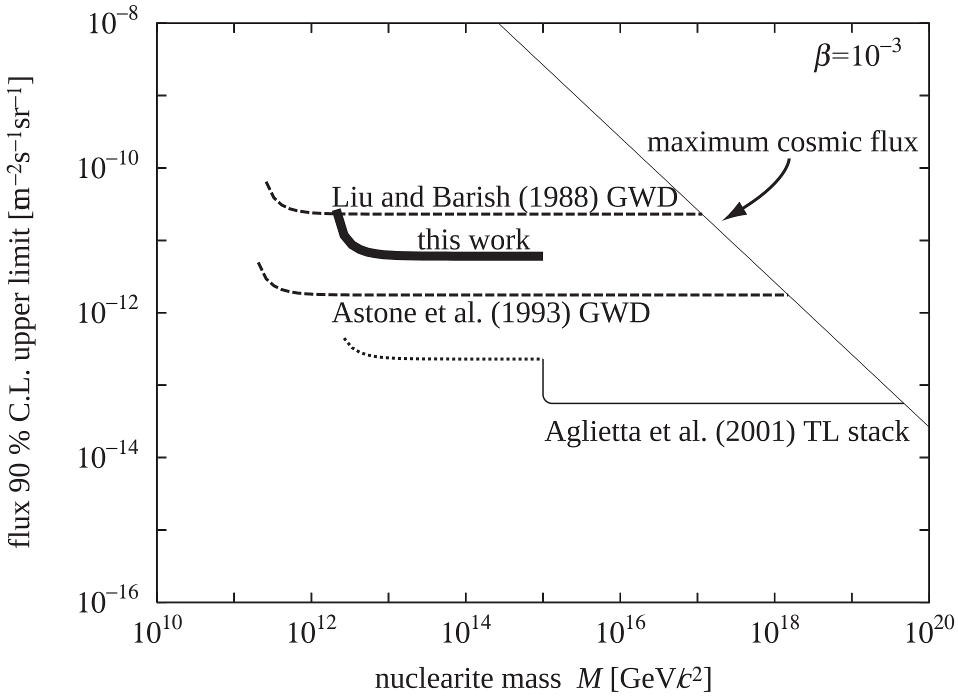

Fig. 3. The 90 % C.L. upper limit for nuclearites of $\beta = 10^{-3}$. The thick full curve shows the limit from this work. The thin dotted curve shows the flux level that we can explore with 10 m^2 of TL stacks and one year exposure. The thin full curve labelled 'Aglietta et al. (2001)' is the limit reported in [1]. Two broken lines are the limits from [2,5] identified by the author and year of publication.