A. E. Chudakov. *Search for heavy magnetic monopoles in an experiment at the Baksan underground scintillation telescope.* As is well-known, attempts of experimental discovery of monopoles—particles with a magnetic charge $q_M = (137/2)e$—have produced no results during the entire fifty years that have elapsed since Dirac had introduced the indicated rule for quantizing the magnetic charge. Since the mass of the monopole in Dirac's theory was not fixed, the search was carried on in the region of mass values at which production of monopole-antimonopole pairs would be possible at accelerator energies or in cosmic rays. Naturally in such processes monopoles would have relativistic velocities, so that their detection would present no difficulty utilizing their tremendous ionizing ability, which exceeds by a factor of 4700 the ionization of the usual relativistic charged particles. On the other hand, relatively light monopoles could be slowed down by the medium, and in this case the ideal method for discovering them would be Alvarez's method which consists of repeatedly passing the suspected sample through a superconducting coil carrying a current and observing the changes in the current. However, both methods indicated above are not the obvious ones in searching for a superheavy monopole predicted by a number of "grand unification models" for electroweak and strong interactions. An impetus for renewed searches was both the appearance of the monopole in the theory, and the necessity of new experimental methods connected with the colossal mass of the predicted particle. We shall base our discussion on the mass most popular at present of 10^{16} GeV, although it should be kept in mind that a signficant further increase in the mass will make the monopole even more difficult to observe. It follows from the mass being assumed that:

1) The monopoles could have arisen only in the first few moments of the "Big Bang."

2) Their motion within the galaxy is controlled by the magnetic field and the characteristic energy is $\gtrsim 10^{11}$ GeV.

3) Accordingly their velocity is $(0.5\text{–}1)\cdot 10^{-2}c$.

4) The earth, the moon and even the sun are practically transparent for these particles.

5) The requirement that the concentration of monopoles should produce no difficulties with respect to the average density of matter in the universe leads to a severe restriction on their flux. For a mass of 10^{16} GeV approximately the same restriction arises from the nondestruction by the monopoles of the magnetic fields of the galaxy. This maximum admissible flux is very small: $10^{-15}\ \mathrm{cm^{-2}\,s^{-1}\,sr^{-1}}$.

6) The low expected velocity of the monopoles and their tremendous penetration power serve as a reliable signature for distinguishing them against a background of ordinary particle in an underground experiment. On the other hand, the ionizing ability of monopoles decreases rapidly at velocities $< 10^{-2}c$ and requires special consideration.

Appropriate calculations lead to the conclusion that a reliable reporting of monopoles in terms of the ionization produced by them (scintillations) in possible at a speed $v \gg 10^{-3}c$. At $v \ll 10^{-3}c$ the use of detectors based on ionization is possible only if the Rubakov effect exists-the monopole inducing proton decay.

For the first time the search for heavy monopoles as slowly moving ionizing particles is an underground experiment with a high aperture ratio was started at the Baksan neutrino observatory of the Institute for Nuclear Research of the Academy of Sciences of the USSR at the beginning of 1981.[1] The Baksan underground scintillation telescope is still the most sensitive installation for such a search. The telescope is situated at a depth of 850 $\mathrm{Gg/cm^2}$, where the intensity of cosmic rays has been suppressed by a factor of 5000. Its dimensions are $16\times 16\times 11\ m^3$ and it consists of eight scintillation layers, each of which contains 400 individual scintillators. The recording scintillation layers are isolated from each other by an absorber of 160 $\mathrm{g/cm^2}$, which is essential for the realization of the method of measuring the time of flight, particularly if the Rubakov effect is present.

The principal requirement in selecting candidates for the event being sought consists of the fact that the particle must cross not fewer than three scintillator layers with a relative delay in the range of 0.1–50 μs. Figure 1 shows a

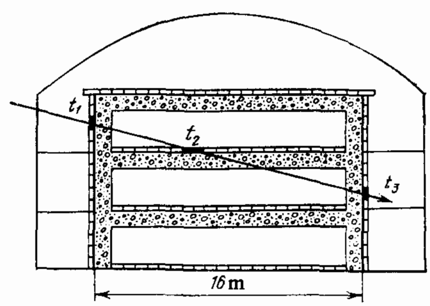

FIG. 1

cross section of the telescope and a typical possible trajectory of a monopole which in the above example is defined by four triggered scintillators (from a total number of ~ 3200). The following measurements are made: 1) time intervals $t_2 - t_1$ and $t_3 - t_2$; 2) pulse amplitudes A_1, A_2, A_3) 3) the pulse widths Δt_2 and Δt_3 (by the oscillograph method). In practice during an observing time of 18,546 h not a single candidate was found for passage of a slow ionizing particle even when only data on the time of flight are utilized. However, information on the pulse shape is extremely important in the case of the appearance of a candidate, particularly if the Rubakov effect is present.

The aperture of the installation in the velocity range $(0.1 - 2)\ 10^{-4}c$ is approximately constant and equal to 1800 m^2 s. This aperture and the observing time determine the upper limit on the monopole flux $< 1.86 \cdot 10^{-15}$ $cm^2\ s^{-1}\ sr^{-1}$ (90% confidence level). For the time being it is the only experimental restriction comparable in magnitude with the maximum flux allowed by astrophysical data.[2]

[1]E. N. Alexeyev et al., Lett. Nuovo Cimento **35**, 413 (1982).
[2]Proc. "Monopole-83", Ann Arbor, Michigan, USA, 1984.

Translated by G. M. Volkoff