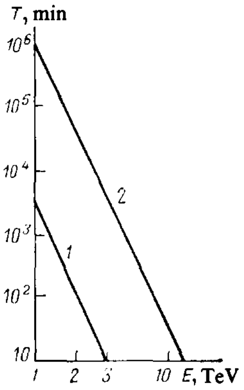

FIG. 1. Time necessary for measuring to within 6% the mass traversed by the beam along the Earth's diameter as a function of the primary particle energy. The detector area on the beam axis is 6000 m^2. 1—pion accelerator, 2—proton accelerator.

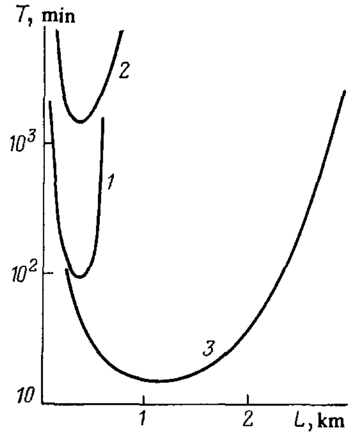

FIG. 2. Time necessary for the detection of a uranium deposit of 1 kg/cm^2 as a function of depth below the surface. 1—accelerator producing 1-TeV pions, 2—accelerator producing 3—TeV protons and $\dot{N}_p = 7.5\cdot10^{12}$ s^{-1}, 3—proton energy of 20 TeV and $\dot{N}_p = 4.3\cdot10^{12}$ s^{-1}.

V. A. Tsarev. *Geophysical applications of neutrino beams.* High-energy neutrino beams in principle offer opportunities for geophysical research.[1] Sources of such beams can take the form of linear accelerators of high-energy pions,[2] which have the following important advantages as compared with circular proton accelerators:[3] (1) better ratio of neutrino to primary particle energies, (2) high pulse repetition frequency (10–100 Hz), ensuring high mean neutrino intensity, (3) smaller angular divergence of the neutrino beam, ensuring higher intensity on the beam axis, (4) high linear density of particles in bunches with the latter being small, and (5) the neutrinos are monochromatic at a given angle to the beam axis, which simplifies the intepretation of measurements.

Comparison of calculations performed for pion and proton accelerators (for equal mean particle intensities) shows that (1)–(3) ensure the flux density of muons accompanying the neutrino beam in matter, and the thermoacoustic signal due to the accelerator pulse are higher by two orders of magnitude for the pion accelerator.[3] This means that measurements such as determinations of the density of the Earth, searches for ore deposits, and oil and gas explorations can be performed much more rapidly with pion accelerators than with analogous proton machines (see Figs. 1 and 2). At the same time, spectral analysis of muons in the case of pion accelerators, which increases the sensitivity of searches for useful deposits and yields their depth and thickness, becomes particularly effective.[4] By virtue of property (4), pion linear accelerators are also particularly suitable in precision geodesic measurements using the neutrino time-of-flight technique.[3]

For a variety of reasons, the rocks in the Earth's lithosphere are usually in a stressed state. Under certain definite conditions, the elastic energy stored in terrestrial rocks can be converted into a seismic signal by a neutrino beam. The strength of this signal may exceed by a few orders of magnitude the thermoacoustic signal due to the neutrino beam itself. This "anomalous" respones may turn out to be important for many practical applications such as exploration for hydrocarbon deposits, studies of stressed zones in the Earth, earthquake forecasting, and so on.[5]

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[1] L. V. Volkova and G. T. Zatsepin, Izv. Akad. Nauk SSSR, Ser. fiz. **38**, 1060 (1974) [Bull. Acad. Sci. USSR Phys. Ser. **38** (5) 151 (1974)]; A. De Rujula *et al.*, Phys. Reports **99**, 342 (1983).

[2] V. E. Balakin and A. N. Skrinskiĭ, Lineĭnye vstrechnye puchki-perspektiva razvitiya (Linear colliding beams-future prospects), MIFI, Moscow, 1984.

[3] V. A. Tsarev and V. A. Chechin, Kr. soobshch. fiz. (FIAN SSSR), 1984; V. A. Saleev, V. A. Tsarev, and V. A. Chechin, Preprint from FIAN SSSR, Moscow, 1985.

[4] V. A. Saleev, V. A. Tsarev, and V. A. Chechin, Kr. soobshch. (FIAN SSSR), 1985.

[5] O. B. Khavroshkin, V. A. Tsarev, V. V. Tsyplakov, and V. A. Chechin, Preprint from FIAN SSSR, Moscow, 1985.

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