THE POSSIBILITY OF REGISTERING PRIMARY COSMIC ELECTRONS BY MEANS OF SYNCHROTRON RADIATION IN THE GEOMAGNETIC FIELD

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Knowledge of the properties of the electronic component of primary cosmic rays is of great importance for the determination of the parameters of the region of containment of galactic cosmic rays and the possible sources of cosmic radiation. This is due to the effective interaction of ultrarelativistic electrons with cosmic electromagnetic fields, which lead to modulation of the energy spectra of the primary cosmic electrons (for details see [1, 2]).

Of particular interest in this respect is the range of high energies of primary cosmic electrons ($E_e \gtrsim 100$ GeV), in which the interaction of the electrons with galactic magnetic fields is most clearly pronounced. However, measurements of the intensity of primary cosmic electrons in this range are made difficult by a number of circumstances, among which the following should be noted:

1) The small fluxes of the primary cosmic electrons. According to [1], the spectrum of the electrons in the energy region $E_e \gtrsim 10$ GeV can be written in the form

$$F(E_e) = 126 E_e^{-2.6} \text{ el/m}^2\text{-sec-sr-GeV}; \quad (1)$$

2) The strong background of nuclear-active particles. At equal particle energy, the electronic component does not exceed one per cent of the total flux of the primary cosmic rays.

For these reasons, the scatter of the results of measurements of the intensity of the primary cosmic electrons is very large. We consider in this paper a possible method of registering primary cosmic electrons of high energy, which makes it possible, in principle, to overcome the indicated experimental difficulties.

This method is based on emission of synchrotron-radiation photons when high-energy electrons move in the geomagnetic field. The average energy of the synchrotron-radiation photons is

$$\langle E_\gamma \rangle = \frac{4}{5\sqrt{3}} \frac{\hbar e H}{mc} \left(\frac{E_e}{mc^2}\right)^2 = 6 E_e^2 \text{ (TeV)keV for H = 0.3 G.} \quad (2)$$

Consequently, electrons with energy on the order of 1000 GeV emit photons with energy on the order of ten keV. Scintillation counters can effectively register the electron and its accompanying photons. The obvious advantage of this method is the clear-cut discrimination of the large-mass nuclear-active particles.

To estimate the feasibility of simultaneously registering an electron and synchrotron-radiation photons, we consider the spatial distribution of the synchrotron-radiation photon. The average range of an electron between the emission of two synchrotron-radiation photons is given by

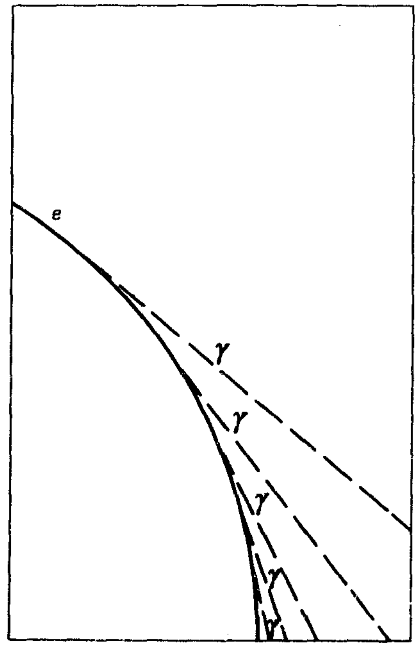
$$\ell = \frac{6}{5\sqrt{3}} \frac{\hbar c}{e^2} \frac{mc^2}{eH} = \frac{1{,}6 \cdot 10^5 \text{ cm}}{H(\text{G})} . \quad (3)$$

When an electron passes through the geomagnetic field, about 10^3 photons are emitted, and this number is independent of the electron energy.

Let us find the distribution of the points where the photon trajectories cross the detector plane. Assuming that the photons are emitted tangent to the electron trajectory, we obtain

$$\mathbf{R}(t) = \frac{ct^2 e}{2E_e}\left\{[\mathbf{n}\times\mathbf{v}]\frac{(\mathbf{H}\mathbf{v})}{(\mathbf{n}\mathbf{v})} - [\mathbf{n}\times\mathbf{H}]\frac{v^2}{(\mathbf{n}\mathbf{v})}\right\}, \qquad (4)$$

where $\vec{R}(t)$ is the radius point of the curve joining the points where the photon trajectories cross the detector plane, $\vec{n}$ the normal to the detector plane, $\vec{v}$ is the electron velocity vector, $\vec{H}$ is the magnetic-field intensity vector at the detector location, and t is the time elapsed between the photon emission and its crossing the detector plane. This expression is valid at high electron energies ($E_e \gtrsim 100$ GeV) for the several dozen photons closest to the electron trajectory. The figure shows qualitatively the distribution of the electrons and synchrotron-radiation photons as they move in the geomagnetic field.



Trajectories of an electron and its accompanying photons in the earth's magnetic field.

Using expression (4), we can estimate the necessary dimensions of the detector and the expected counting rate of the events. The average number of photons crossing the plane of a detector with linear dimensions d is of the order of

$$n = \sqrt{\frac{dE_e}{eH\ell^2}} \,. \qquad (5)$$

Consequently, a detector with linear dimensions on the order of 50 - 100 cm suffices for simultaneous registration of an electron and two or three synchrotron-radiation photons.

The expected counting rate of the events can be determined from (1). Extrapolation of the spectrum (1) into the high-energy region yields a value 4.5 electrons/hour for the number of electrons of energy larger than 100 GeV, incident on 1 m^2 in a solid angle of 1 sr. The exposure of such an instrument on a satellite for a month will result in a statistic on the order of 10^3 events.

[1] R.R. Daniel and S.A. Stephens, Space Sci. Rev. 10, 599 (1970).
[2] S.V. Bulanov, V.A. Dogel', and S.I. Syrovatskii, FIAN Preprints No. 119 and 120 (1971).