Transition-radiation detection of particles

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The angular distribution of transition-radiation photons produced in a foamed-plastic radiator is studied. Some possibilities of detecting particles by their transition radiation are discussed.

The possibilities of using transition radiation to detect ultrahigh energy particles are now being widely discussed[1-11], and from this point of view the streamer chamber method proposed in[4-6] is of definite interest. Among the principal advantages of the streamer chamber must be counted its high spatial resolution and the possibility of determining the number of photons accompanying each particle. These advantages become even more important when several particles arrive simultaneously.

In this paper the angular distribution of transition radiation photons produced in a foamed plastic radiator is examined and some possibilities of detecting superhigh energy particles by their transition radiation are discussed.

It has been shown[6] that one can efficiently separate π mesons and protons with a streamer chamber at particle energies of 2×10^3 GeV and higher by placing a small magnet in the path of the particle between the radiator and the photon detector. We note that in[6] they did not determine the separation efficiency when using the number of photons for discrimination, i.e., when taking events in which the number of photoelectrons exceeds a certain threshold value. The use of photon-number discrimination greatly improves the separation factor while leaving the efficiency for recording the light particle fairly high.

For example, if we attribute distribution a of Fig. 3 in[6] to a K meson, we must assume the energy of the K meson to be 1.3×10^3 GeV. A π meson of that energy would correspond to distribution b. If we use photon-number discrimination and take the threshold as 3.5 photoelectrons, the recording efficiency for π mesons will be 50%, while the K meson will be recorded with an efficiency of 10%, and protons of the same energy with an efficiency of 3%. If we set the discrimination threshold at 4.5 photoelectrons, the efficiency for recording 1.3×10^3 GeV π mesons, K mesons, and protons will be 40, 8, and 1%, respectively. The problem of separating electrons and heavy particles does not arise in this case since the Lorentz factors $\gamma = E/mc^2$ differ considerably.

Let us consider in more detail the use of a streamer chamber with a deflecting magnet to record the transition radiation from ultrahigh energy particles.

Figure 1 is a photograph showing an event in which 3.0 GeV transition radiation photons and electrons were recorded in a streamer chamber, which was 80 cm long and contained neon plus 13% xenon[5]. The electrons were deflected 4 cm from the initial direction by a small magnet. The radiator was 200 cm thick and was mounted 11 m from the chamber. The photograph was taken in the direction of the electron field.

FIG. 1. A typical streamer-chamber record of transition radiation photons and electrons.

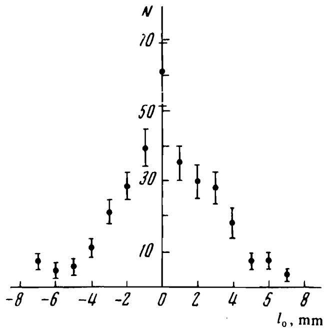

FIG. 2. Distribution of photoelectrons about the particle trajectory; l_0 is the distance of a photoelectron from the trajectory, and N is the number of events.

If the electron had not been deflected in the magnetic field its trajectory would have fallen in the space between the photoelectron tracks at a position that can be calculated from the known angle through which the electron was deflected in the magnetic field. Figure 2 gives the distribution of photoelectron tracks with respect to the distance l_0 from the center of the track to the axial "trajectory" as calculated in this way. The data for this distribution were recorded with the radiator located 5 m from the chamber, so one can obtain the angular distribution of the photons by dividing the abscissas by this distance. The distribution can be regarded as symmetric (within the error limits); this symmetry is evidence that the axial "trajectories" were correctly drawn.

Let us select a region about the maximum of the distribution with a dimension equal to the half-width of the distribution at half maximum, i.e., $l_0 = 2.5$ mm. In the space about the particle trajectory, this region will correspond to a cylinder of radius $R = l_0\sqrt{2}$, which will obviously contain two-thirds of the photoelectrons. Since the magnet does not displace the particle in the direction of the magnetic field, the axis of this cylinder and the trajectories of the particle before entering and after leaving the magnetic field must lie in a single plane. The condition that the particle trajectory and the axis of the photon cylinder be coplanar thus affords the possibility of determining which particle belongs to a given photon cylinder. This opens up a broad prospect for the use of the method under circumstances in which groups of particles strike the detector simultaneously.

We note that the radius of the photon cylinder will be smaller in the case of a heavy particle, since then the multiple scattering in the radiator will be negligible. This is the case for projection onto the direction of the electric field; in another projection the distribution will be broader by the dimension of the streamers.

Actually, it is not difficult to achieve streamer dimensions of 1 cm. For example, by using electron optical converters one can reduce this quantity by a factor of two. The particle-trajectory errors associated with the size of the streamers can be avoided, and the conditions for selecting the photon cylinder accordingly improved, by using two wide-gap spark chambers placed one in front of the magnetic field and one behind it.

Thus, if the radiator is mounted directly in front of the deflecting magnet and the streamer chamber behind it, one can use the condition that the axis of the photon cylinder be coplanar with the particle trajectory before and after the magnetic field to determine with some reliability which track corresponds to a given photon cylinder.

An estimate for the case of a 30 cm magnet gap and a parallel beam of uniformly distributed particles indicates that ~ 15 tracks can be handled without difficulty provided the electric field is parallel to the magnetic field; this number is somewhat larger if the electric and magnetic fields are perpendicular to each other.

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