Title

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The Velocity-Selecting Cerenkov Counter

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A number of varieties of velocity-selecting Cerenkov counters have been described by Dr. John Marshall.[1] We will present a description of a counter different from any described by Marshall in his review article, but of the same type mentioned descriptively by Marshall in another article under the heading "Cylindrical mirror counter without lens".[2] Some tests of this type of counter were carried out by S. J. Lindenbaum and L. C. Yuan.[3]

The counter we describe was developed for the detection of a small fraction of antiprotons in a beam of negative particles originating at the target of the Bevatron.[4] As far as the authors are aware, this represents the first practical use of a velocity-selecting Cerenkov counter in an experimental investigation.

A cross-section view of the counter may be seen in Fig. 1. The Cerenkov radiator is a solid cylinder of suitable optical material with axis horizontal in the counter as shown in Fig. 1. The charged particles are to traverse the radiator parallel to the axis. A particle with specified velocity emits Cerenkov radiation at a specified angle, namely such that $\cos\theta = 1/\beta n$, where θ is the angle of emission of the Cerenkov light with respect to the direction of motion of the particle, β is the velocity of the particle divided by the velocity of light, and n is the optical index of refraction of the optical material of the radiator. Light emitted at a well-defined angle from the horizontal axis of the counter suffers refraction as it leaves the radiator through the flat face at the end and enters air; however, the light direction is still well defined in terms of the particle velocity. Providing the particle giving rise to the Cerenkov radiation is moving parallel to the axis of the instrument (but not necessarily on the axis), and providing the velocity of the particle is that for which the counter dimensions have been chosen, <u>all</u> of the Cerenkov light reaches the cylindrical mirror and is brought to an approximate focus on the axis where an imaginary dotted photomultiplier is shown in Fig. 1. If the particle is either appreciably faster or appreciably slower than the velocity for which the counter has been adjusted the light is intercepted by the blackened baffle.

In practice it is advantageous to have the photomultiplier removed from the axis of the instrument where it would be in the way of the particles being counted (and false counts caused). This is accomplished by using three plane mirrors and three photomultipliers. The three mirrors make an equilateral triangle around the axis of the instrument, and divide the light in thirds. Only one plane mirror and one photomultiplier are shown in Fig. 1, the others being similarly located at 120° intervals about the horizontal axis of the instrument.

In the counter that we have used the radiator is 6.4 cm in diameter and 6.4 cm long and has usually been of fused quartz. Except for rather small aberrations of the cylindrical mirror, the image diameter is the same as the diameter of the radiator providing the velocity is exactly that for which the instrument is adjusted. The given radiator size fits well with the Dumont 5-inch photomultiplier tubes. The whole counter has been built in a large cylindrical can, the ends of which may be slid in and out. Since the radiator is mounted on one end and the photomultipliers mounted on the other end, different angles of light emission and hence different velocities may be selected by sliding the ends in or out.

Since the number of initial photoelectrons in each photomultiplier tube is quite small (estimates vary from 2 to 4), we have required only two out of the three tubes to detect the light from the particle that is to be counted. The output pulses from each photomultiplier have been fed, through 125-ohm cables, to the inputs of three distributed amplifiers, each having a gain of 1000. The amplifier outputs have been introduced into a coincidence circuit of the Garwin variety[5] adjusted to give an output pulse whenever any two out of three signals were present. Connected in this way, the efficiency of the counter for particles of just the right velocity has been found to be 97 percent. Approximately a 75% efficiency would have been attainable if a coincidence of all three phototubes had been required.

Tests of the counter, made with protons rather than with antiprotons, indicate that the efficiency of counting particles drops to 3 percent when the velocity differs by 0.03 c from that for which the counter has been adjusted. The counting efficiency of 3 percent represents a background that does not disappear when the velocity is further removed from the velocity for which the instrument has been adjusted. The background is presumably due to nuclear collisions within the radiator. Such collisions can give rise to particles, particularly mesons, that go in various directions and can cause light to be radiated in any direction. The counter has been tested using scintillation counters in coincidence both before and after the velocity-selecting counter. This is important also in the actual use of the counter, since many of the cases of nuclear collision in the radiator are rejected because the event does not register in the counter behind the velocity-selecting counter.

Beside the limitation just mentioned, we would like to point out the problem of noise pulses in the photomultipliers. Whenever a counter is to operate on only a few photoelectrons, the noise may be a cause for concern, especially since the photomultipliers are then used at very high voltage. In the present application, each tube showed noise pulses at the rate of about 3×10^6 per second, and the coincidence output, when adjusted for a coincidence of two out of three, showed several thousand output pulses per second. There has never been an appreciable number of accidental coincidences from this noise in an actual experimental arrangement because there have always been several scintillation counters also in coincidence in the system, but care must be taken in the choice of amplifiers and coincidence circuits to make sure the circuits are not overloaded by these large pulse rates.

There is one more limitation of the counter that should be mentioned, namely that it is probably not useful for the light particles. The light particles (π mesons or lighter particles), if moving appreciably slower than the velocity of light, are near the end of their range and their velocity is changing quite rapidly. This means that they do not emit much Cerenkov radiation before coming to rest and their velocity is appreciably different in different parts of the radiator.

In closing, we would like to mention the existence of another variety of velocity-selecting Cerenkov counter that has been used very successfully by Dr. V. L. Fitch[6] in counting K mesons. His counter contains a radiator that is similar in dimensions to that used in our counter. It counts only particles within a specified velocity range, but the range over which it counts is usually considerably wider than that of the counter we have first described. In the counter Fitch has used, very slow particles are rejected because they make no Cerenkov radiation in the radiator. Faster particles are counted by their Cerenkov radiation, but for particles that are very fast, the Cerenkov radiation suffers total internal reflection and no count is registered. To absorb the radiation so reflected, the entrance end of the radiator is blackened.

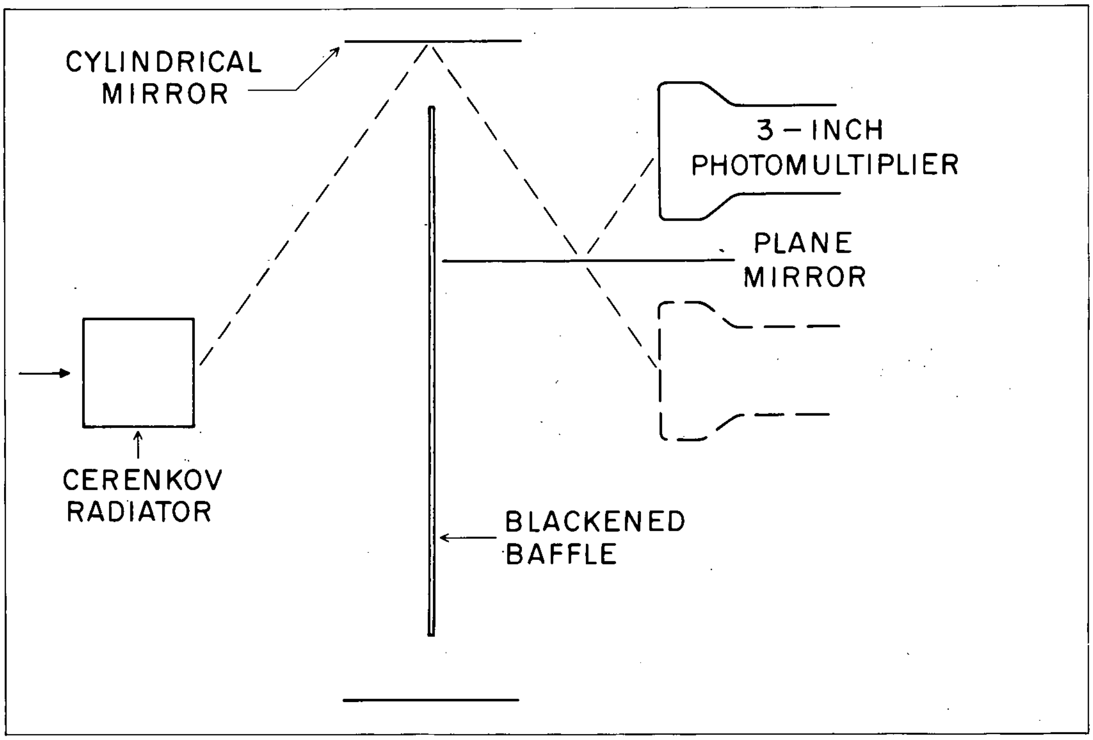
We have tried to indicate the potential usefulness of velocity-selecting Cerenkov counters and at the same time to point out their limitations. We believe they will be quite useful for some problems in the immediate future.

References

1. J. Marshall, Ann. Rev. Nuclear Science, Vol. 4, p. 141 (Annual Reviews, Inc., 1954).
2. John Marshall, Phys. Rev. 86, 685 (1952).
3. S. J. Lindenbaum and L. C. Yuan, private communication.
4. Chamberlain, Segrè, Wiegand, and Ypsilantis, Phys. Rev. 100, 947 (1955).
5. R. L. Garwin, Rev. Sci. Instr. 21, 569 (1950).
6. V. L. Fitch, Bulletin of Amer. Phys. Soc. 1, No. 1, 52 (1956), invited paper.

Caption

Fig. 1. Cross-section view of the velocity-selecting Cerenkov counter.



VELOCITY - SELECTING CERENKOV COUNTER (C2)

Fig. 1