FURTHER ANALYSIS OF A RECENT COSMIC-RAY ANTIPROTON EXPERIMENT

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ABSTRACT

In our recently reported measurement of a cosmic-ray antiproton flux at a few hundred MeV, one of the final background processes to be removed by the data analysis was helium-induced events which satisfied the criteria for topology and timing. These events were identified and removed using the response in the third scintillator S_3. Pulse size information for the top two scintillators S_1 and S_2 was lost during the data-taking. In this paper we report a method of partial retrieval of pulse size information for the scintillator S_2. This is possible because a portion of this signal was subtracted from the Cerenkov response prior to trigger discrimination and data recording, to remove scintillation from the Cerenkov response. The method suffices to separate protons from more highly charged particles. The sample of events identified as antiprotons, for which the method can be applied, indeed have the expected unit charge in scintillator S_2.

1. INTRODUCTION

In our recent low-energy cosmic-ray antiproton experiment (Buffington, Schindler and Pennypacker, 1981) we intended that pulses from five plastic detectors (four scintillators and a Cerenkov counter) be recorded along with the topological spark chamber information. This was accomplished by photographing an oscilloscope trace displaying the pulses (Buffington et al. 1979). Unfortunately, the pulses from the top two scintillators S_1 and S_2 were clipped by inverting transformers, so only timing information for these was retained. One might worry about a background process which could simulate antiprotons by means of a helium or heavier nucleus making the requisite topology in the lead-plate spark chamber, yet somehow giving the required small pulse in scintillator S_3. This background, if it exists, would easily have been detected and removed had the pulses from S_1 and S_2 been properly recorded. In this paper we show that the majority of the antiproton events cannot have been due to such a background process. This is possible because a small portion of the signal from scintillator S_2 was also subtracted from the Cerenkov signal prior to discrimination and display, in order to remove a contribution from scintillation light in the Pilot 425 radiator. No inverting transformer was employed in the subtraction network, so it seemed possible that some of the missing information for scintillator S_2 might be recovered. The oscilloscope record of the pulses for each event preserves enough of the Cerenkov pulse shape to allow a separate determination of the negative-going S_2 contribution, for a substantial fraction of events in which Cerenkov photoelectrons do not occur so early as to obscure the record.

2. THE OSCILLOSCOPE RECORD

The four scintillator pulses and the Cerenkov (with S_2 subtracted) pulse were displayed with a Z-shaped baseline upon the face of a Hewlett-Packard 1744A storage oscilloscope. This instrument was operated in the "variable persistence" mode, which allowed the traces to fade away with a time constant of a few seconds, a time chosen to provide adequate photographic exposure. The flood-gun erasing of the storage screen causes a background illumination strong enough to easily discern the fiducial grid on the face of the oscilloscope. Figures 1a and 1b show a selection of oscilloscope records of typical events with scintillator S_4 not included in the trigger criterion, to permit recording of stopping proton and helium events. Figure 1a shows the full trace of a proton event which is unaccompanied by Cerenkov photoelectrons. Figure 1b shows just the Cerenkov portion of four more events that *do* have Cerenkov photoelectrons, but not so early as to obscure the beginning downward portion of the subtraction from scintillator S_2. Proton and helium events in figure 1 are distinguished by the scintillator S_3 pulse size. One can see from figure 1 that the subtracted S_2 pulse is broader than typical Cerenkov pulses by about a factor of two and usually starts sooner. Presumably this difference in pulse width results from differences between the coupling networks for the two S_2 photomultipliers, and for the twenty four Cerenkov photomultipliers. The estimated traces we have shown in figure 1b for the absence of any Cerenkov photoelectrons (dashed lines) are derived from an average of events in which no narrower, upward going pulses were seen on top of the broad negative subtracted S_2 pulse. For protons, these events are quite common, since there is only about one photoelectron of scintillation contribution and, of course, these stopping events have no actual Cerenkov light since they are well below threshold. For helium, there are few events without Cerenkov photoelectrons, due to the four times larger scintillation contribution. Here, the rear portion of the estimated trace is drawn based on only a few events, although its leading portion is well established.

When a Cerenkov counter photoelectron occurs earlier than where we have marked figure 1a with an arrow, the downward going S_2 pulse is usually obscured, and the lost S_2 information cannot be retrieved. Greater Cerenkov activity is required to ruin a helium event, since the amount of subtracted signal is larger. About 1/3 of the stopping proton events and 1/10 of the helium events have S_2 remaining undetermined for this reason. To quantify the downward going S_2 pulse, we have used the maximum negative slope, in the parallelogram coordinates of figure 1a, achieved by the leading edge of the pulse. The tangent of the angle is read off by laying a ruler parallel to the trace at its point of maximum slope, and determining the number of vertical units corresponding to a single horizontal unit. The baseline, no pulse at all, has a slope of 0.3.

3. RESULTS

Figure 2 shows the results of slope determinations using the above method, for a small sample of known stopping protons and helium, and for all of the antiproton and rejected helium background events for which slopes could be determined. These histograms show that the S_2 pulse distribution as reconstructed by the method above allows a reasonable separation of charge 1 and charge 2 events, and that the sample of antiproton events for the most part exhibits charge 1 in scintillator S_2 as it did in scintillator S_3, the basis of the original separation from the helium-induced background events. The fraction of antiproton events having the initial down-going slope obscured by early Cerenkov photoelectrons (7 out of 17) is about the same as the 1/3 observed for protons. On the other hand, all but five of the nineteen rejected helium background events have the downward going slope obscured, another manifestation of this sample's enhanced activity in the Cerenkov counter, which we have already noted (Buffington, Schindler, and Pennypacker, page 1188). In fact, about half of the helium-induced background events had more than the "six photoelectrons" nominally required for rejection by the trigger criterion, but the photoelectrons were so distributed in time that the threshold was not crossed. This work is supported by Grant NGR-05-002-160 of the National Space and Aeronautics Administration.

REFERENCES

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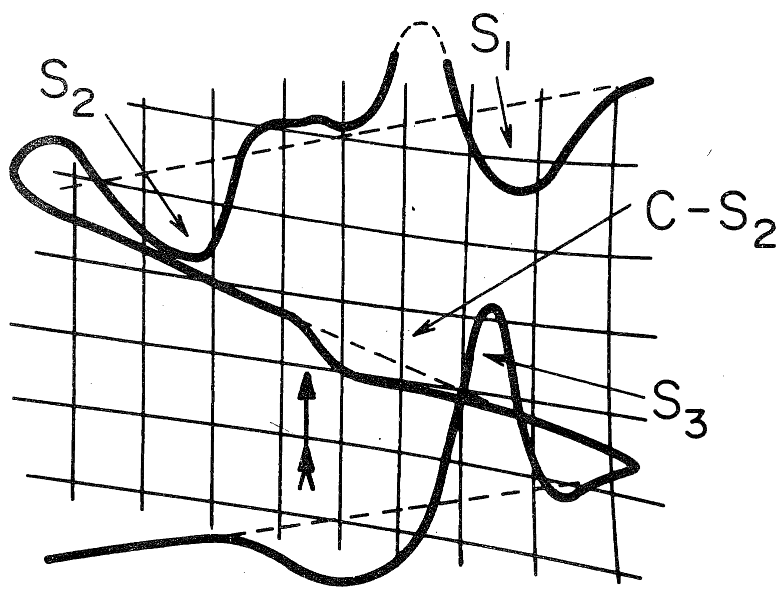

Fig. 1a. Complete oscilloscope record for a stopping proton event, #1663, with no photoelectrons in the Cerenkov counter. Dashed line indicates baseline (no pulses). Horizontal grid spacing is 10 nanoseconds, and time moves from the top of the "Z" to the bottom.

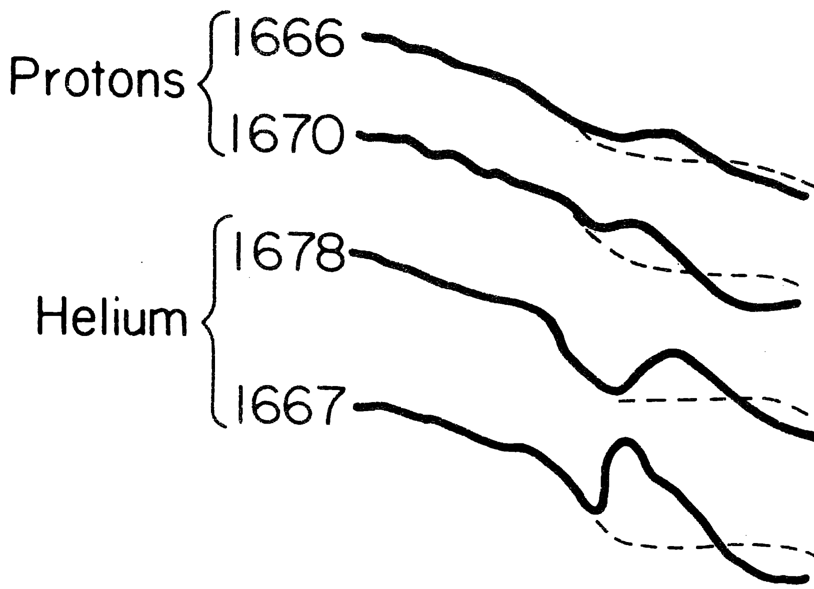

Fig. 1b. Cerenkov portion of the oscilloscope records of two stopping proton and two stopping helium events. Dashed lines indicate the estimated trace had there been *no* Cerenkov photoelectrons for these events.

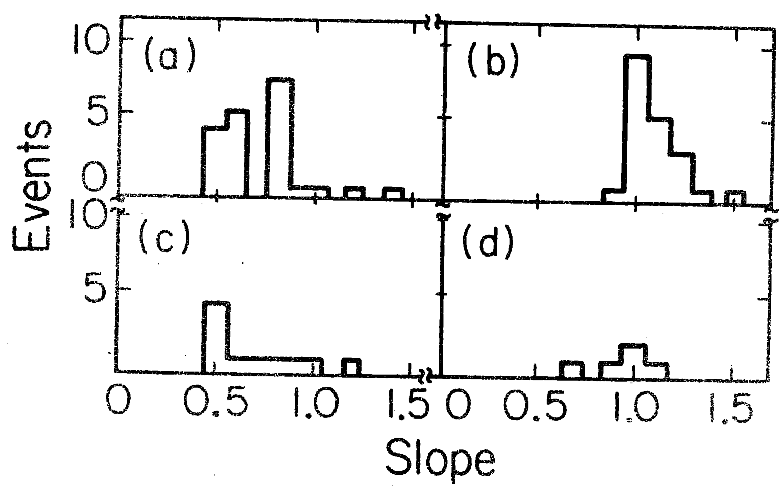

Fig. 2. Histograms of the slope parameter described in the text for four data samples from the experiment. (a) Stopping proton events; (b) Stopping helium events; (c) antiprotons, and (d) rejected helium background.