SLAC-PUB-3298
October 1983
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LARGE AREA SPARK COUNTERS WITH FINE TIME AND POSITION RESOLUTION*

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INTRODUCTION

Spark counters trace their history back over three decades[1] but have been used in only a limited number of experiments.[2] The key properties of these devices include their capability of precision timing (at the sub 100 ps level[3]) and of measuring the position of the charged particle to high accuracy. At SLAC we have undertaken a program to develop these devices for use in high energy physics experiments involving large detectors.[4]

A spark counter of size 1.2 m × 0.1 m has been constructed and has been operating continuously in our test setup for several months. In this talk I will discuss some details of its construction and its properties as a particle detector. We report here on work in progress. The results presented here were analyzed on-line and, no doubt, will be refined considerably in the coming months.

CONSTRUCTION DETAILS

The basic parts of a spark counter (Fig. 1) are two parallel planar electrodes at high voltage separated by gas. At least one electrode is of a highly resistive material, usually glass, with a resistivity around $10^9 \Omega$ cm.[5] The gas is a noble gas, such as argon, with added organic gases to provide quenching of the sparks.[6]

In operation, a charge particle ionizing the gas results, after several decades of gas multiplication, in a spark. The spark can discharge only a limited amount of the surface charge on the electrodes, due to the high resistivity of one of them. Potentially ionizing UV light from the spark is absorbed by the organic gases, so a Geiger mode discharge does not occur.

The signal from the spark is picked up by an arrangement of strip transmission lines and is carried out of the device at both ends of each stripline. The signals are time and pulse

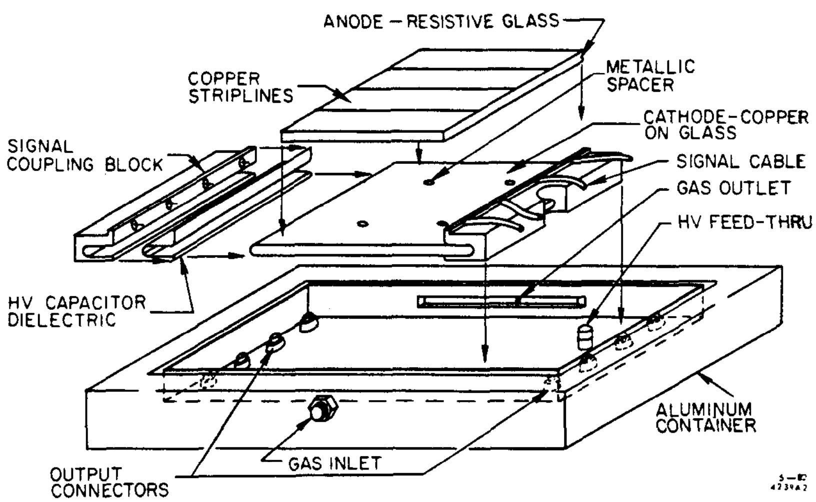

Fig. 1. Exploded view of a spark counter. The 1.2 m counter has eight striplines.

*Work supported in part by the Department of Energy under contract DE-AC03-76SF00515 and by the Japan-US Co-operative Research Project on High Energy Physics under the Japanese Ministry of Education, Science and Culture and the US Department of Energy.

Contributed to the Nuclear Science Symposium, San Francisco, California, October 19-21, 1983.

height analyzed.[4] The mean time of a strip's ends gives the time of the passage of the particle, and the time difference shows where along the stripline the particle passed. Comparing the pulse height in neighboring strips allows one to calculate the transverse position of the particle's trajectory, using a centroid method.

Extending the spark counter from small (9×9 cm^2) devices to large one entailed solving several problems. I mention two of them here.

High Voltage Electrodes

The previously used method for fabricating the copper cathodes — vacuum deposition — was not readily extended to pieces one meter long. In order to make large-area metallic high voltage electrodes, we hit upon the method of glueing sheet copper[7] to a glass substrate with a dry film adhesive.[8] After polishing the copper surface with alumina,[9] we obtained an electrode that compared favorably with the vacuum deposited ones.

Signal Quality

The second problem centered around the extraction of signals from the counters via striplines. It is essential in these devices to obtain well formed pulses out of both ends in order to preserve good resolution. We constructed an electrical model of the PSC, containing a pulser called an Inner Spark Pulser (ISP)[10] and we quickly found problems.

When only one stripline was present the pulse was quite satisfactory. However, when two closely spaced striplines were installed we observed a double pulse at the far end of the stripline (Fig. 2). This was caused by two separate modes of pulse propagation, ~~each~~ with a different velocity. The new mode was one with equal and opposite currents in the two striplines — a kind of differential pair. Excitation of this mode is inevitable. To solve the problem, we were obliged to cause the higher velocity of this mode to match that of the usual mode. This was done by overlaying the striplines with a material[11] whose dielectric constant matched that of the semiconducting glass.

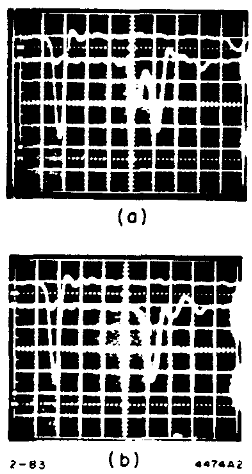

Fig. 2. Oscillographs of the ISP. a) Without dielectric cover. The upper trace shows the pulse after travelling .10 m along the stripline, the lower trace is for 1.1 m travel. b) With dielectric cover. The earlier of the two pulses seen in a) has now merged with the later one. Scale - 2V/div $\times$ 2ns/div.

A cross section of the counter (Fig. 3) shows provisions to solve the latter problem as well as others encountered in the electrical design. These investigations were greatly aided by the uniform, repeatable shape of the ISP pulses.

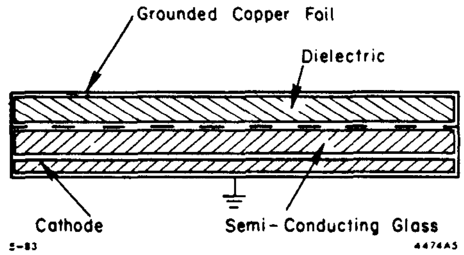

Fig. 3. Cross section of 1.2 m counter, showing arrangement of conductors. The copper foil ground and the dielectric are both necessary to obtain good pulse waveforms.

PROPERTIES AS A PARTICLE DETECTOR

In describing the properties of the working counter, I will comment on the "burning-in" process, the pulse height and efficiency versus applied voltage, the spark development time and time resolution versus voltage, and the position resolution.

Burning In

Afterpulsing is a well known phenomenon in gaseous devices that employ avalanche multiplication. Afterpulses are those pulses which follow shortly after a "first" pulse, and are presumably caused by the first pulse in some way. In our device we can observe such pulses up to 2 μsec after a "first" pulse (Fig. 4). The mean number of afterpulses (per first pulse) is a strong function of applied voltage. We can characterize a counter by the counting rate for first pulses versus voltage. This rate rises sharply above threshold and then reaches a broad plateau. The mean number of afterpulses also follows a characteristic curve, rising to unity at a voltage of about twice the threshold voltage.

In a virgin counter (Fig. 4b), this rate reaches unity at a much lower voltage. If such a counter is operated for progressively longer times, however, the afterpulsing curve gradually shifts to higher voltages. When the total exposure of the counter reaches a value between 2.5 and 10 million sparks per cm^2 no further improvement is seen (Fig. 4f).

This training, or "burning-in," process is not understood at a fundamental level,[12] but has been observed in all counters of this type that we have built. Burning-in the 1.2 m $\times$ .1 m counter occupied about a month's time, using .75 mC of Co^{60}.

Pulse Height and Efficiency

We have measured the pulse height and efficiency of the counter versus voltage, using a drift chamber equipped cosmic ray telescope to define a track in the counter (Fig 5a,b). The variance of the pulse height is $\sim$ 40% of the mean pulse height over the range of our measurements. The mean pulse height itself increases strongly with applied voltage and may be characterized by the third or fourth power of the applied voltage. At the lowest voltages, however, the pulse height does not go to zero, but stays above a certain minimum value.

The efficiency increases with voltage in a predictable way, the highest voltage yielding an efficiency consistent with unity. From the measurements at lower voltage we conclude that the mean total ionization per track is of order 5, in agreement with calculations.[13]

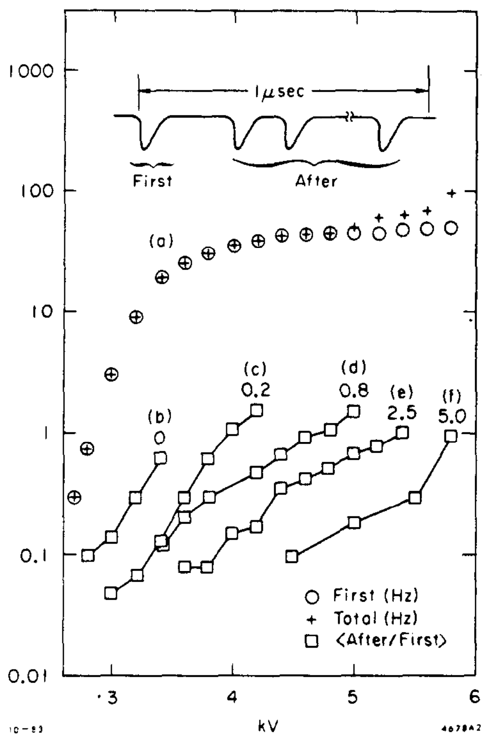

Fig. 4. Burn-in of the 1.2 m counter. Afterpulses are defined to be any pulses that follow a first pulse within 1 μsec. a) Rate of first pulses versus applied voltage. The threshold of this counter is approximately 3100 V. b) – f) Mean number of afterpulses per first pulse versus voltage. The curves correspond to a total pulse count of .17, .25, .75, 2.5, and 5 million/cm^2, respectively.

Development Time and Time Resolution

To measure the spark development time and time resolution as a function of voltage, we employed a smaller counter as a standard. This operated at a fixed voltage of about twice threshold. It's time resolution is inevitably folded in with that of the test counter and seems to be about 100 psec.

The term spark development time means the time between the initial ionization and the spark discharge. It has been measured (Fig. 5c) to vary from ~ 3 nsec to well under 300 psec as the applied voltage was changed from 1.1 times threshold to twice threshold. In all these measurements there exists a systematic offset due to the development time of the standard counter of order 300 psec. The observed dependence of development time on voltage is in good agreement with previous measurements.[13]

The time resolution can be seen to vary in an analogous way. The highest voltage measurements (Fig. 6) seem to be dominated by timing fluctuations unrelated to the 1.2 m test counter.

Position Resolution

The longitudinal and transverse coordinates of a spark are calculated based on the time difference of pulses at the ends of a strip and on the pulse height profile of an event as seen in the strips. Figure 7 shows the difference between the PSC coordinates calculated from the PSC information and from the external tracking device. The longitudinal position resolution,

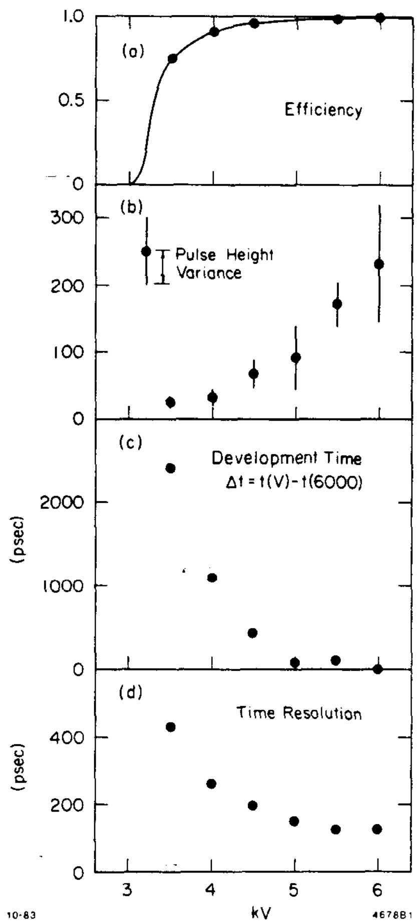

Fig. 5. Characteristics of 1.2 m PSC versus applied voltage. a) Efficiency. The smooth curve follows Ref. 14, assuming a threshold voltage of 3164 V, five ion pairs per charged particle crossing, and Townsend coefficient $\alpha = Ape^{-Bp\delta/V}$, where p is the pressure, V the applied voltage, δ is the electrode spacing, and $B = 79$ V/cm torr. b) Pulse height. The vertical bar in these measurements indicates the variance of the pulse height distribution. c) Development time, defined to zero at 6000 V. d) Time resolution. In c) and d), the curve follows Ref. 13, with allowances made for our gas composition.

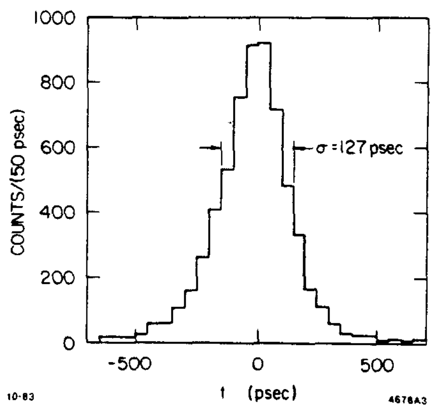

Fig. 6. Distribution of particle flight time. The applied voltage to the 1.2 m PSC was 6000 V.

$\sigma_l = 10$ mm, is five times the value one would expect solely from the time bin of the electronics. We believe pulse height slewing, which is not corrected in these data, to be responsible for the difference. The transverse position resolution, $\sigma_t = 1.0$ mm, is dominated by noise pickup in the cabling to the detector. We expect both position resolutions to be substantially improved by further analysis, taking the mentioned effects into account.

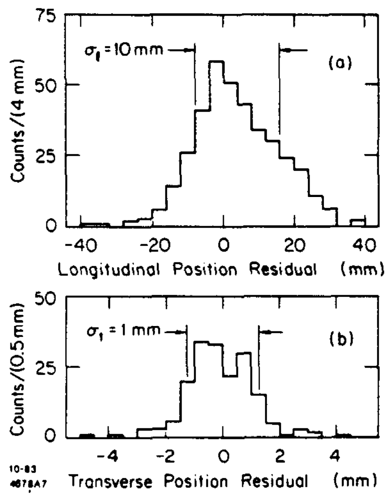

Fig. 7. Residual distribution in the PSC coordinates. a) Longitudinal coordinate derived from the time difference in the strip ends. b) Transverse coordinate calculates as the charge weighted centroid taken over all the strips. The particles were tracked by a drift chamber telescope.

CONCLUSIONS

We have demonstrated the feasibility of building a long (1.2 m) spark counter and have investigated some of its properties. We are now undertaking the construction of counters 3 m long.

ACKNOWLEDGEMENTS

We wish to acknowledge the continuing support of the Research Division of SLAC and the timely help of Doug Michael, Harvard University, in this work.

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3. G. V. Fedotovich *et al.*, *Spark Counter with a Localized Discharge, Proceedings of the International Conference on Instrumentation for Colliding Beam Physics*, SLAC, 1982, p.127.
4. W. B. Atwood *et al.*, *A Test of Planar Spark Counters at the PEP Storage Ring*, Nucl. Instrum. Methods **206**, 99 (1983).
5. Schott S8900 glass, Schott Glass Technologies, Inc., Duryea, PA. The present counter has resistivity 1011Ω cm.
6. The gas used in the present work was at 10 atmospheres pressure and was composed of 2.5% 1,3 butadiene, 10% isobutane, 2.5% ethylene, 5% hydrogen, and balance argon. The electrode spacing was $\delta = .185$ mm.
7. One-ounce electroformed copper foil, Yates Ind., Inc. Beamont, CA.
8. Dry film adhesive, type T100004, Sheldahl, Materials Div., Northfield, MN.
9. 0.3 micron and 0.05 micron Alumina polishing powders.
10. N. Fujiwara *et al.*, *Investigation of Electrical Properties of a 120 cm PSC Using an Inner Spark Pulser*, SLAC-PUB-3063, (1983),to be submitted to Nucl. Instrum. Methods.
11. Stycast© HiK, Emerson & Cuming, Canton, MA, (Dielectrtic constant 10).
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