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PERFORMANCE OF WIRE SPARK CHAMBERS WITH LARGE AREA AND TWO COORDINATE READ-OUT

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Wire spark chambers up to 50×50 cm^2 with a ferrite core storage have been built and tested. The difficulties arising from the large capacity of large area chambers were overcome by limiting the spark current and damping its oscillations. The arrangement of the chamber allows also the high voltage electrodes to be used for the determination of a spark coordinate. Thus with crossed ground and high-voltage-electrode wires one chamber gives two coordinates simultaneously. Efficiencies of 98% and spatial resolutions of approximately ± 0.3 mm have been obtained. Measurements of the sensitive time were also performed.

1. Introduction and principles of operation

Krienen[1]) proposed to substitute the grounded electrode of spark chambers by parallel wires, each of them passing through a ferrite core to ground. The current through the wires touched by a spark flips the cores which store the information reliably for an arbitrary time and may be read out by using conventional computer techniques. The chambers described here have wire electrodes at the grounded and the high voltage side, each connected to a ferrite core storage. If the wires of the two electrodes are crossed by 90° two coordinates of a particle track are determined by one spark chamber instead of two. This results in a simpler experimental set-up, a higher overall efficiency for detecting two coordinates and less material giving rise to scattering.

For large area chambers to be used for an experiment at the Deutsches Elektronen Synchrotron difficulties arise from the increase of the chamber capacity, which essentially determines the spark current and the frequency of its oscillation. In this case the overshoot of the spark current pulse may be large enough to flip back a core, thus destroying its information.

Three possibilities are known to overcome this difficulty: limitation of the spark current, damping its oscillation and increasing the frequency of the oscillations such that they are integrated by the ferrite cores. The cores (Siemens R 495) used here integrate oscillations of more than 20 Mc/s.

A limitation of the spark current is desirable anyway, because it results in a shorter recovery time, fewer spurious sparks and a reduced damage of the electrodes. However, the resistor damping the oscillation must not cause a long rise time of the high voltage pulse, since otherwise it acts like a strong clearing field and reduces the efficiency of detection.

The method used here takes advantage of all three possibilities and is based on suggestions of Neumann[2]) and Fischer[3]). The coupling condenser C charged through a loading resistor R_L and the decay resistor R_D are modified with respect to a conventional spark chamber network (fig. 1a). A spark gap G gives the high voltage pulse, whose decay time is determined by the decay resistor R_D.

The main improvement is achieved by splitting up the spark chamber into many chamber elements, each of them consisting of one wire of the high voltage electrode and a corresponding grounded electrode. These chamber elements in principle are pulsed by a

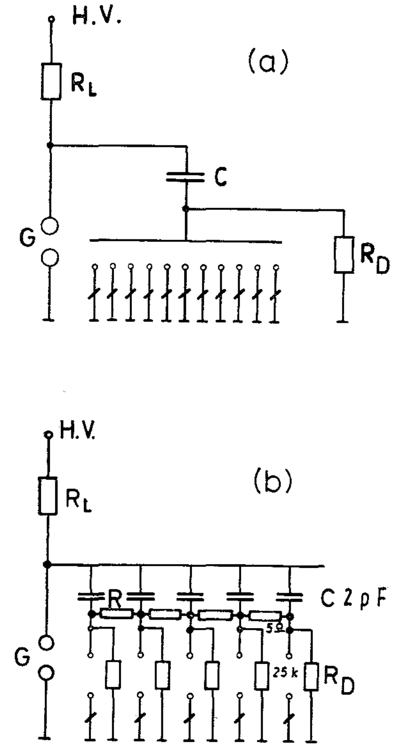

Fig. 1. a. Conventional pulsing network. b. Pulsing network with distributed charge.

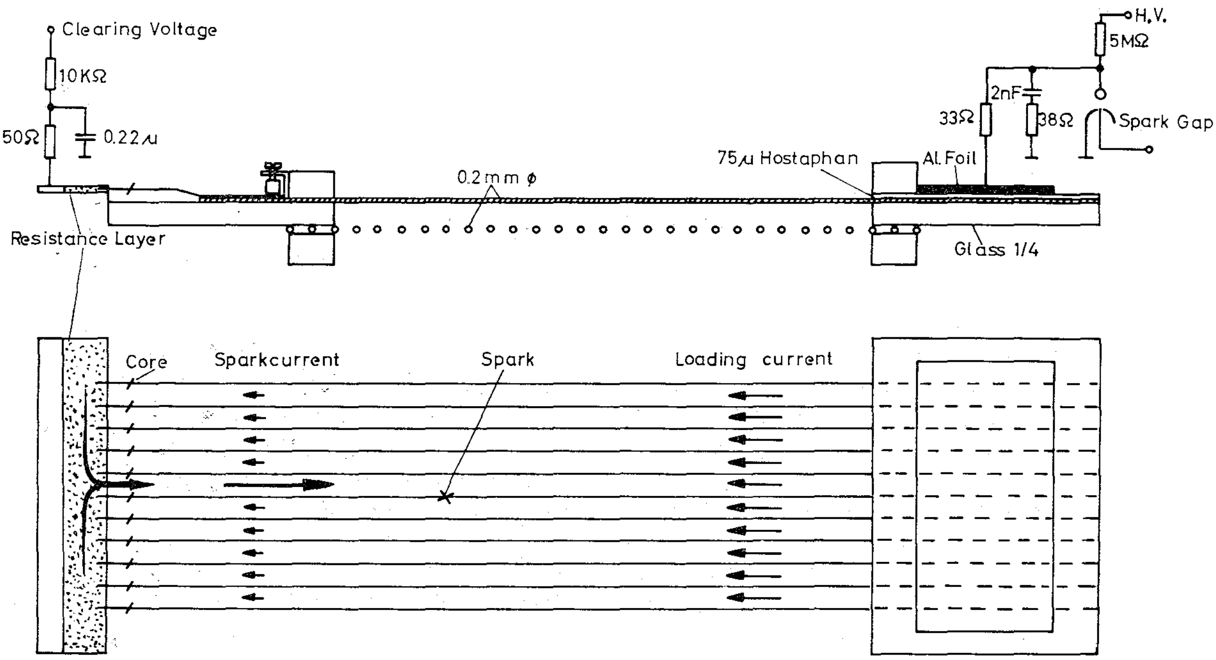

Fig. 2. Design of the spark chamber and distribution of loading and spark currents.

separate coupling condenser and discharged by individual decay resistors. In practice the coupling condensers are realized by placing an aluminium strip on one end of the high voltage wires with a thin Mylar foil between. The decay resistors are provided at the opposite end of the wires by a resistor paste connecting the wires to ground (fig. 1b) and to the neighbouring wires.

This arrangement includes, indeed, all three possibilities mentioned above. The coupling condensers of the chamber elements are chosen so small that the charge stored in them induces no current high enough to flip a core. The flipping is effected by the current flowing from the neighbouring wires to the spark location. The number of wires contributing is adjusted by choosing a proper resistance between the wires.

The wire-to-wire resistance also damps the current without decreasing the rise time of the high voltage pulse. The frequency of the spark current oscillation, determined by the capacity of the small discharge area involved is much higher than the frequency resulting from the entire coupling and chamber capacity. Therefore, the spark current oscillations are sufficiently fast to be integrated by the ferrite cores. In this way it became possible to operate large area wire chambers.

At the same time an additional advantage is achieved. A reliable storage of information on the high voltage electrode, which met considerable difficulties in the past, can be obtained, if the cores are arranged at the wire ends near the resistor paste. Since the wires at the condenser side are not connected, the current from the neighbouring wires flows mainly through the resistor paste to the spark location. This current, however, is just opposite to the current induced by the high voltage pulse (fig. 2). Hence, only the cores of the sparking wires are flipped.

2. Construction of the chamber

The frame of the chamber consists of 6 mm thick glass plates, which are glued together with white (quartz-filled) Araldite. Copper-bronze or aluminium wires of 0.2 mm dia. are wound automatically by means of a specially designed machine into the grooves of two threaded rods attached to an iron frame warranting a distance of 1 mm between the wires. All the wires are then uniformly stretched beyond their yield point. Finally they are glued to the chamber frame with Araldite. For two coordinate chambers the wires of the electrodes have been crossed by an angle of 90°. The wires of the chamber are connected to the core boards[3]) by pressing the printed leads of the core boards on the ends of the wires (fig. 2). In order to prevent edge sparking the wire array is framed on both sides by two wires of 0.5 mm diameter.

The distributed coupling capacity on one end of the high voltage plane is composed of a Hostaphan foil of 75 μm thickness covered by an aluminium strip 4 cm wide (fig. 2). The values of the distributed capacity are given in the equivalent circuit diagram (fig. 1b). The entire coupling capacity is 2.4 nF and the capacity of the chamber itself is 1.1 nF. Both wire planes are grounded by the core boards. The core boards of the high voltage electrode have a resistance layer connecting the wire ends to a printed metal strip, which is grounded or connected to a clearing voltage. The resistance layer consists of a colloid graphite paste "Hydrokollag" mixed with a glue soluble in water to obtain a suitably high resistance. This resistance which is responsible for the decay time of the high voltage pulse is about 50 ohm. The decay time can be adjusted to be longer by an additional series resistor. At the high voltage electrode a drop of oil or Araldite in the hole of each ferrite core insulates the wires fed through it.

The sensitive area of the chamber is 512×512 mm^2. The chamber is filled with a mixture of 90% neon and 10% helium. The covering foils should be water- and gas-tight and of low mass. Here Hostaphan (20 μm) and Hostaphan PE (42 μm) was used. If several chambers are used a helium atmosphere between the individual chambers will reduce the gas contamination. Each spark chamber receives the high voltage pulse from a separate needle spark gap mounted on its frame with short, low inductive connections. These needle spark gaps are fired by a master gap which is triggered electronically. The triggering amplifier required a 2 V input and produces a 4 kV output pulse with a delay shorter than 30 ns and a risetime of 20 ns. The total triggering system including the amplifier and the two gaps have a triggering loss of less than 5×10^{-5} and a total delay less than 60 nsec.

3. Measurements

A collimated electron beam from a ^{90}Sr source with a diameter of 0.5 mm was used to test the chamber. The coincidence signals of two scintillation counters at the back side of the chamber triggered the high voltage pulse.

3.1. Efficiency

Fig. 3 shows the efficiency η as a function of the high voltage applied. At the rise of the curves, where the spark current is low, the efficiency is limited by the magnetic sensitivity of the ferrite cores. Increasing the high voltage, the efficiency of a 0.5×0.5 m^2 chamber approaches an asymptotic value of 98% which is determined by the properties of the spark chamber. Small chambers, built with the same technique, have more than 99% efficiency.

3.2. Spatial resolution

The spatial resolution depends on the average number of wires touched by a spark which is a function of the high voltage pulse. In fig. 3 the dotted curves show the average number N_{av} as a function of the high voltage amplitude and its duration as parameters. This was measured with a wide electron beam.

Naively one would expect that for arbitrary values of N_{av} the best resolution that can be obtained corresponds to $\pm\frac{1}{2}a$ where a is the wire spacing. A more detailed discussion, however, reveals that a better resolution can be obtained if N_{av} is half-integer. This can be understood in the following way. If an odd number of wires is touched the centroid of the spread coincides with the central wire whereas if an even number is fired

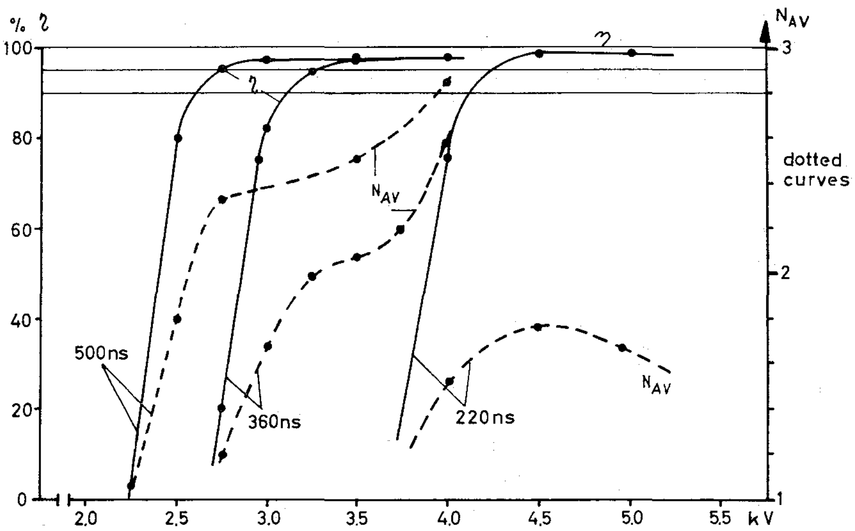

Fig. 3. Particle detection efficiency η and average number N_{av} of wires touched by a spark vs amplitude of the hv pulse for different decay times as parameter.

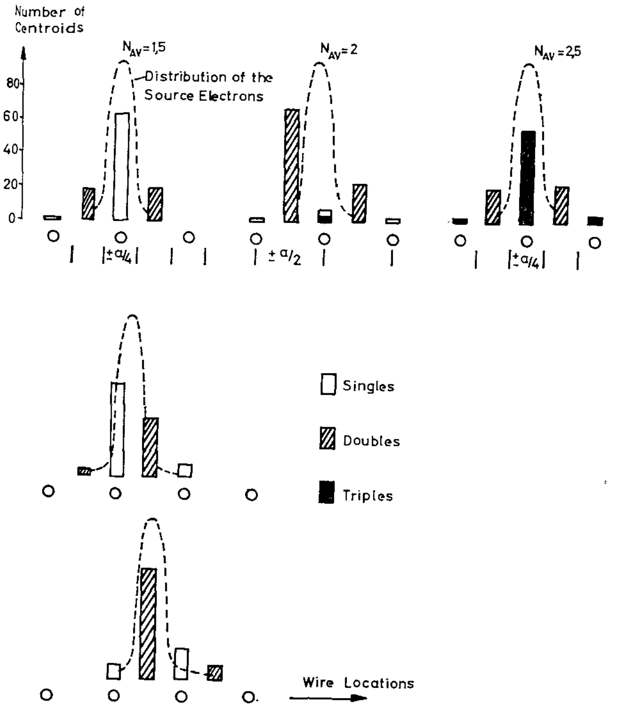

Fig. 4. Typical distributions of spark centroids of singles, doubles and triples as a function of the particle track position (vertical row) and of the average number of touched wires N_{av} (horizontal row).

the centroid falls inbetween two wires. Hence, the smallest distance that can be resolved is $\pm\frac{1}{4}a$. With $N_{av} = 1.5$ a particle passing close to a wire will fire only this one wire whereas a particle passing in the middle between two wires will produce a spark touching two wires. Therefore in this case the distance between the centroid of the spark and the actual particle track will indeed be smaller than $\frac{1}{4}a$. Similar considerations hold for $N_{av} = 2.5$; 3.5 etc. If on the other hand N_{av} is integer, e.g. 2, then every particle will fire two wires and the distance between centroid and particle track is smaller than $\pm\frac{1}{2}a$.

These arguments are only true, however, if the sample of events for $N_{av} = 2$ is composed predominantly of double sparks implying that the contribution of single and triple events is small. Furthermore the good resolution for $N_{av} = 1.5$ can only be obtained if a particle passing a wire closely does not produce double events and conversely a particle track between two wires must not lead to single events.

The existence of this effect giving good resolution for half integer values of N_{av} and only half the resolution for integer values has been demonstrated previously[6]). In order to test in more detail the underlying assumption we have measured the distribution of single, double and triple events with a well collimated electron beam (dia. 0.5 mm) as a function of the beam position with respect to the chamber wires. The results are presented in fig. 4. On the left side the distribution is shown for three source positions and $N_{av} = 1.5$.

It should be noted that this value of N_{av} is only obtained by averaging the distributions for all source positions. As can be seen single events prevail if the electron beam aims at a wire whereas double events predominate if the beam passes between two wires. Since the tails of wrong events can at least partly be attributed to the imperfect collimation of the electron beam the spatial resolution that can in practice be obtained is better than ± 0.3 mm with a wire spacing of 1 mm.

For $N_{av} = 2$ the measurements indicate that indeed the number of single and triple events is negligible and only a resolution of approximately ± 0.6 mm can be achieved. With $N_{av} = 2.5$ a situation similar to that for 1.5 was found. No difference in the spatial resolution and the detection efficiency of the ground and the high voltage-plane was observed. With these two-coordinate-chambers the overall efficiency of an experimental set-up is increased and the scattering material is reduced.

3.3. Sensitive time

The sensitive time was measured by delaying the high voltage pulse after the passage of an ionizing particle. It mainly depends on the clearing voltage applied. Fig. 5 shows the efficiency as a function of the sensitive time with the clearing voltage as parameter. As can be seen sensitive times shorter than 0.75 μsec can be used without decreasing the detection efficiency appreciably.

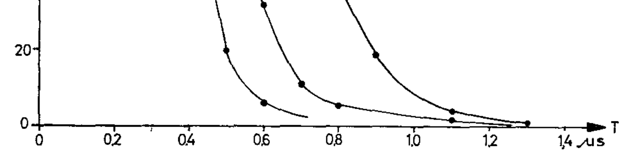

Fig. 5. Particle detecting efficiency vs delay of the hv pulse after particle passage for different cleaning voltages.

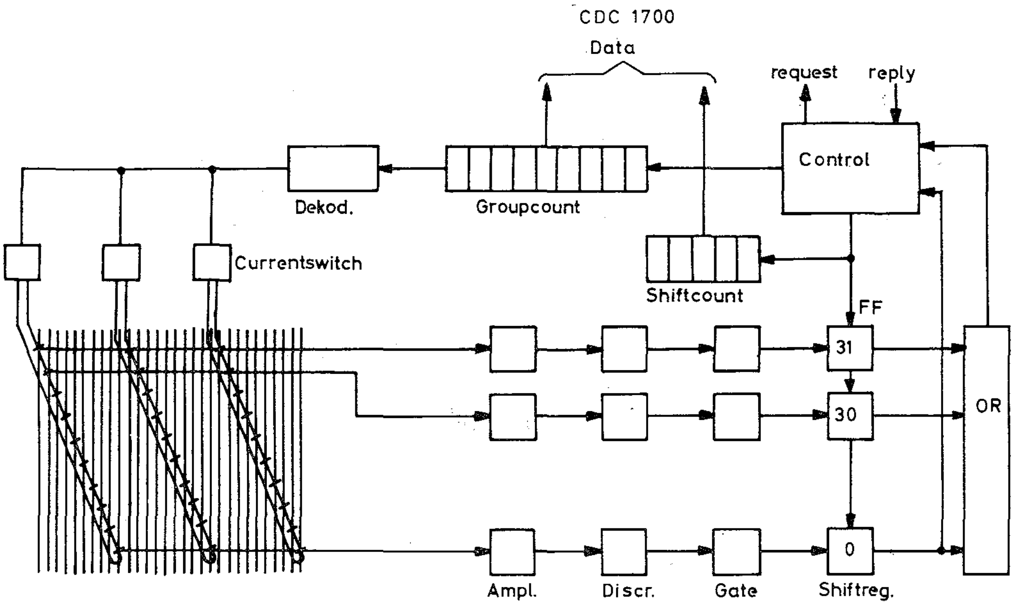

Fig. 6. Block diagram of core read-out-system.

3.4. Multiple tracks and accidental sparking

An additional advantage of the distributed charge conception is the increased detection efficiency for many simultanous tracks. Since only a part of the chamber is discharged by one spark, additional sparks can be detected in other parts of the chamber. However, since this is true not only for genuine events the remaining charge on the wires which is a function of R may favour the occurance of spurious sparks. These are mainly produced by photo-electrons originating from the first spark and can be avoided by keeping the high voltage pulse as low and short as possible without reducing the efficiency. In our case the number of spurious sparks was observed to be less than 2%. By adding an organic vapour to the chamber gas this rate can be further reduced.

3.5. Core read-out

The cores are aligned in core boards containing 4×32 cores each as shown in fig. 6. The core board is connected to the chamber wires by a foil covered with printed copper leads which have the same distance as the chamber wires. These leads are pressed upon the chamber wires. The cores form groups of 32 put on a diagonal drive line. There are 32 sense lines perpendicular to the chamber wires which run through all modules of the system. The core modules are plugged together to fit different sizes of the chambers.

The read-out is performed in a conventional way[4]. Cores are read in groups of 32, the YES's and NO's being transferred in parallel to a 32 bit shift register. If a group contains one or more YES's the corresponding address is generated by means of the shift count, shifting a YES into the ZERO flip-flop of the register. If one group contains no event, the next group is strobed. The number of the group read-out is generated in a scaler. Decoding is performed in two steps. The nine binary stages are decoded in three sets of three to give a 3 out of 24 code on the read busses which select one group driver circuit. The combined contents of the shift and the group counter representing a core number is transferred to a CDC 1700 computer in approximately 2 μs. The read-out of one group takes 1 μs and shifting is done with 4 Mc/s.

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