A SPARK CHAMBER WITH INDUCTIVE LOCATION

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ABSTRACT

In the inductive location method both coordinates of the spark are located by means of signals induced in wire loops around the chamber edges. Spark chambers of this kind have been built and tested. The chambers have electrodes, of size $30 \times 30 \text{ cm}^2$, consisting of a phosphor-bronze mesh and are operated with 70 per cent Ne and 30 per cent He at atmospheric pressure. Calibration was done with a light pulser. The resolution obtained is 0.26 mm (full width at half-maximum). With protons of 300 MeV the efficiency is found to be > 99.3 per cent with a 99 per cent confidence.

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1. INDUCTIVE LOCATION METHOD

The inductive location method makes use of the strong magnetic field produced by the spark current¹⁾. Figure 1 shows a schematic set-up of the chamber. The two electrodes H and E are at one corner connected with the high voltage and the ground by a coaxial cable. Along the electrode edges there are two wire loops S' and S''. For simplicity the loops for the X-coordinate only are shown. In case of a spark there will be a primary current I_p , which induces in both loops voltage signals U'_x and U''_x , respectively according to

$$U = -L \cdot dI_p/dt.$$

$U_x = U'_x + U''_x$ is the total amplitude of the induced voltage signal, the so called secondary pulse, and I_p is the current passing through the spark. The coefficient L of mutual induction depends on the position of the spark. In order to determine L independently of fluctuations in the primary current both U_x and dI_p/dt were measured. The special form of the loops produced an almost linear dependence on the X-coordinate on the one hand and an independence of the Y-coordinate on the other hand. In practice there is a second pair of wire loops around the chamber, measuring the L as a function of the Y-coordinate of the spark in the same way.

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2. CONSTRUCTION

A quadratic frame of plexiglas with a side length of 50 cm and a thickness of 5 mm, was used. Meshes of phosphor-bronze were glued on both sides of this frame. The wire thickness was 0.03 mm, and the transparency 82 per cent. The walls are made of 15 μ plastic film (Trespaphan). The sensitive area of the chamber is 30 $\times$ 30 cm². During the experiments there was a constant flux of gas through the chamber, measured by a flux metre. The gas was Henagal (70 per cent Ne, 30 per cent He).

In order to increase the amplitude of the induced pulse loops of 50 Ω -coaxial cable were used. The centre wire formed the first turn, and its mantle the second. In this way the amplitude of the induced pulse was increased by a factor of 1.8. This coaxial cable was shielded by a grounded metallic cover against distortions caused by the spark. As the calibration depends on the geometry the loops were mechanically well fixed.

3. ELECTRONICAL SET-UP

Figure 2 shows the block diagram of the electronics which fires the spark chamber. The spark chamber is connected by a coaxial cable to a spark gap. The spark gap is also coaxially mounted in a brass pipe. This spark gap was fired in a nitrogen atmosphere of 1.3 atm²⁾. Near by the lead to the spark chamber there is a coil with two turns, which delivers "primary" pulses U_p , which are proportional to dI_p/dt .

As a scintillation counter with a plastic scintillator NE 102 A and a photomultiplier 56 AVP was used. A HV pulse of 4.3 kV and a rise-time of about 20 nsec is created by a trigger which consists of a Marx-bank with avalanche transistors followed by a small thyatron³⁾. The delay between trigger input and firing of the spark chamber was 80 nsec. The HV at the spark chamber was 4.3 kV. The spark chamber is supplied with a clearing voltage at V_c . The block diagram of the read-out system is shown in Fig. 3. The pulses U'_x and U''_x from the two X-loops are added by a pulse transformer with ferrite core. The signal is fed into another transformer via a cable of 100 m length. Figure 4 shows a secondary pulse after the second transformer. The amplitudes of these pulses are 0.5 V for $X = 1$ cm and 1.9 V for $X = 29$ cm. The primary pulse U_p was transmitted in the same way.

4. CALIBRATION METHODS

In order to investigate the effect of the primary pulse height a well-localized spark was fired by an auxiliary discharge⁴⁾. Figure 5 shows two histograms of spark distributions which were obtained by this method. As the accuracy turned out to be limited by the spread of the primary pulses, this error was eliminated by division through U_p . The two histograms illustrate the spark distributions before (full line) and after (dashed line) the division through U_p . The half-widths are in both cases 0.32 mm, but the base of the histogram is smaller in the second case. By using foils for the spark chamber, which are very UV-transparent, it is possible to fire the chamber by a light pulser, if light pulser and chamber are triggered at the same time⁵⁾. For foils, polyolefine foils, e.g. Trespaphan, are used, whereas polyester foils such as Mylar and Hostaphan are unsuitable.

In this way three spark chambers were calibrated individually. Here the light pulser was put in place with an accuracy of ± 0.1 mm; the distance between two adjacent points was 24 mm. At a clearing voltage $V_c = +6$ V the pulse heights U_x , U_y and U_p of each spark event were measured. At these measurements the secondary pulse was also divided through U_p . After this normalization the $L(X)$ and the $L(Y)$, respectively, are obtained.

5. RESULTS OF THE CALIBRATION

The high voltage connection at the spark chamber was chosen as the origin of the coordinates. The calibration curves for the X-direction are illustrated in Fig. 6. The measured values are marked by different symbols for different Y-values ($Y = 78; 150; 222$ mm). A calibration curve is drawn through the points for $Y = 78$ mm only. The curves for the other Y-values show only small differences in position and slope and have the same form. In both directions the calibration curves are nearly linear between $X = 80$ mm ($Y = 80$ mm) and $X = 210$ mm ($Y = 210$ mm). A good fit for all calibration curves was obtained with the polynomial

$$L(\xi) = a + b\xi + c\xi^2$$

where $\xi = X$ or Y . The half-width (full width at half-maximum) of the distribution of the deviations was 0.3 mm.

In order to determine the coordinates of a spark from measured pulse heights, a grid of calibration curves was drawn, which is shown in Fig. 7. The positions where sparks induce the same pulse heights are connected by lines. The solid lines pass through points (X,Y) with the same $L(X)$ -values and the ones, marked with dashed lines through points with the same $L(Y)$ -values.

In order to determine the resolution, the spark chamber was fired at two points one after the other by a light pulser. These two points were 24 mm apart. Figure 8 shows the distribution of the measured values of the induction coefficient $L(Y)$ for two light pulser positions. The full half-width of these histograms is 0.26 mm. It was also tested by means of the same light pulser whether three spark chambers 8 cm apart influence each other. One of the chambers was fired at a fixed point (X,Y), and the resulting pulse height U was recorded. Then the other two chambers were fired in addition. A difference of only ± 0.2 per cent was observed.

6. TEST OF THE SPARK CHAMBERS WITH MEDIUM-ENERGY PARTICLES

Three spark chambers were placed at the Synchro-cyclotron 58 cm apart between two scintillation counters in coincidence. As ionizing particles protons of about 300 MeV were used.

At a gas flux of $> 80 \text{ cm}^3/\text{min}$ the efficiency was for $V_c < 175 \text{ V}$ almost 100 per cent and showed a larger decrease for $V_c > 450 \text{ V}$ only. For $V_c = +6 \text{ V}$ there is an efficiency of > 99.3 per cent with a confidence of 99 per cent for an extended region of the delay. No decrease was seen for an additional delay $< 450 \text{ nsec}$.

The sparks in the three chambers are expected to be on a straight line. Figure 9 shows the distribution of the deviations δ at the middle chamber. The histogram has a full half-width of 0.5 mm. This is fully compatible with the resolution of 0.26 mm (Section 5) as additional effects such as directional scattering of the protons cause also deviations^{6,7)}.

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Figure captions

- Fig. 1 : Schematic drawing of the inductive location set-up. H high voltage plate, E ground plate, U'_x and U''_x voltages induced in the loops S' and S'' , respectively. Similar loops for U'_y and U''_y are not shown.
- Fig. 2 : Block diagram of the trigger equipment. D detector, T trigger, SG spark gap, AE auxiliary electrode, SC spark chamber, V_c clearing voltage. $C_1 = 150$ pF, $C_2 = 3$ nF, $R_1 = 660 \Omega$, $R_2 = 4.8$ M Ω , $R_3 = 420 \Omega$, $R_4 = 1$ k Ω , $R_5 = 22 \Omega$, $R_6 = 7.4$ M Ω .
- Fig. 3 : Block diagram of the read-out system. SC spark chamber, S' , S'' induction loops, T_1 , T_2 transformers with ferrite cores, PS pulse stretcher and amplifier, ADC analog-to-digital converter, S scaler.
- Fig. 4 : Secondary pulse after the second transformer. Vertical scale 0.5 V/cm; horizontal scale 100 nsec/cm.
- Fig. 5 : Spectrum of the secondary pulses obtained by firing the spark chamber by an auxiliary discharge. The solid histogram is for the secondary pulses directly, and the one marked by the dashed line for the secondary pulse after division by the primary pulse height.
- Fig. 6 : Calibration points for the X-coordinate at a constant Y-coordinate. A calibration curve is drawn for $Y = 78$ mm only.
- Fig. 7 : Calibration grid of a spark chamber. Parameters are the two mutual induction coefficients $L(X)$ dashed lines and $L(Y)$ full lines, respectively.
- Fig. 8 : Resolution of the spark chamber by firing with the light pulser at two different positions 24 mm apart. In both cases the half-width is 0.26 mm.
- Fig. 9 : Histogram of the deviations δ between experimental and fitted values as obtained in the experiment with 300 MeV protons.

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