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A LARGE AREA PARALLEL PLATE AVALANCHE COUNTER

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The construction and operation of parallel plate avalanche counters with sensitive areas up to 550 cm^2 is described. With a counter of 50 cm^2 a time resolution of 160 ps (at fwhm) with ^{16}O ions has been obtained.

1. Introduction

Parallel plate avalanche counters (PPAC) are a known instrument for precise timing measurements in nuclear physics since many years[1,2]), but they have rather scarcely been used[3-5]). One reason is that for light particles the ionization is rather low so that solid-state detectors are better suited. In heavy ion physics solid state detectors have some serious disadvantages (e.g. radiation damage) and a new interest in the PPACs has come up[6]). This type of gas counter offers the possibility of building large area detectors with good time resolution when using them in combination with large area position sensitive counters [e.g. multiwire chambers[7,8])]. Furthermore there are no problems with radiation damage and the total thickness of such a counter can be kept rather thin due to the low operating gas pressure. The aim of this work was to develop a large area PPAC with a time resolution of <500 ps for future experiments[9]) at the UNILAC.

2. Principle of operation

A PPAC consists of two thin properly stretched metalized plastic foils mounted parallel to each other. The gap between the foils should be kept as small as possible to achieve a good time resolution. A high voltage is applied between the two planes. The ionizing particles to be detected traverse the counter perpendicular to the planes and produce electron–ion pairs in the counting gas. In the homogeneous strong electric field secondary ionization sets in immediately and an avalanche of the Townsend type will be formed[10]). The number of secondary electrons is given by

$$n(d) = n_0 \, e^{\alpha d}, \qquad (1)$$

with

n_0 : number of primary electrons,
d : drift path,
α : first Towsend coefficient.

α is the mean ionization probability per unit path length and is a function of the reduced field strength E/p [11]):

$$\alpha/p = A \exp\{-B/(E/p)\}.$$

p is the gas pressure, A and B are constants of the specific gas.

At low pressure rather high values can be reached for the reduced field strength ($E/p \sim 500$ V/cm·torr). This gives a gas gain up to 10^4. Primary electrons produced near the cathode contribute most to the signal, as can be seen from eq. (1). The signal has an amplitude of a few mV and consists of two parts[12]):

a) a fast rising component ($t_R \sim 2$ ns) due to the motion of the electrons,
b) an αd times higher, slowly rising component ($t_R \sim 1$ μs) stemming from the positive ions with their much lower drift velocity.

Only the fast component is used for timing measurements, the slow part of the signal is differentiated out in the input network of the preamplifier. Detailed calculations about this pulse shape and the statistics of the electron avalanche can be found in the literature[1,13,14]).

3. Constructional details

Fig. 1 shows one of the PPACs investigated in this work. Two foils of 2.5 μm Hostaphan*, evaporated with a conductive Au-layer (30 μg/cm^2, $R \sim 1$ Ω/cm^2) are glued with epoxy onto the frames of plexiglass. For larger counters frames of epoxy resin have shown to be better suited. The gap between the foils should be very uniform to achieve a good homogeneity of the counter across the surface. This was simply achieved by machined spacers and a very thin homogeneous layer of glue between foil and frame. The attractive electrostatic forces only play a role in counters with surfaces of some hundred cm^2.

If the PPAC is used as a transmission counter, the

* Supplied by Kalle AG, 6202 Wiesbaden, Germany.

foils should be as thin as possible. Foils of FORMVAR or VYNS can be made much thinner than the commercially available Hostaphan foils, but we found it rather difficult to evaporate larger areas ($>20\ cm^2$) with a low-resistive metal layer. It has been possible to produce VYNS foils ($\sim 60\ \mu g/cm^2$) and to metalize them for surfaces up to $\sim 55\ cm^2$. In order to avoid edge effects the edge of the foil which is glued on the frame was not evaporated. The electrodes were contacted using conductive glue. Three types of PPACs were constructed and investigated in more detail:

a) A small one with circular shape (diameter 10 mm) for test purposes. It is used to scan the timing properties across the surface of larger PPACs. Its gap was (normally) 1 mm, tests were also made with a gap of 2 mm.

b) A long counter with a sensitive area of $2 \times 26\ cm^2$. The signal is taken from the 2 cm side. Gap distances of 4, 2 and 1 mm have been used.

c) A large area PPAC with an active surface of $24 \times 23\ cm^2$. In this case the metal layer is divided into five strips, separated by 1 mm. The signals were processed separately for each strip. The gap is 2 mm, a smaller distance between the two foils was not possible due to the strong electrostatic forces.

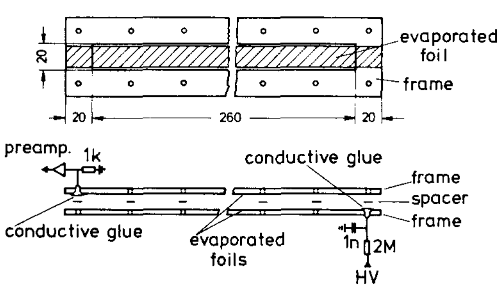

Fig. 1. Schematic view of a parallel plate avalanche counter.

4. The gas

Pure hydrocarbons seem to be best suited for low pressure gas-filled proportional counters[7]). Mixtures of argon + hydrocarbons have also been tested, especially the 'magic gas'[15]), but the observed pulses have a rather poor rise-time ($t_R = 20$–50 ns) and are not suited for the precise timing measurements of a PPAC. The following substances were tested and found to be equally good: Methylal, i-butane, i-butylen, pentane, heptane and mixtures of them. The degree of purity does not seem to be critical; no difference in the performance of a PPAC could be found between using extremely pure i-butane ($>99.95\%$) and a much cheaper quality ($>99.5\%$). Because of its cheapness and easy handling, i-butylen was finally chosen.

It was found that the PPACs work best in the pressure range of 8–15 torr. At lower pressures, the primary ionization gets too low, at higher pressures the foils which keep the pressure have to be considerably thicker.

Usually the PPACs were operated at 10 torr. This corresponds to an energy loss of 3.7 keV for 5.5 MeV α-particles and of 330 keV for 1.4 MeV/amu Xe-particles per mm gas.

When measuring the time resolution between two PPACs, the two counters are sitting in the same gas flow in order to ensure that both counters experience the same pressure. Small changes in the gas pressure have no effect on the timing between these two counters. In addition this simplifies the gas system: no manostat is needed, the gas inlet and outlet is regulated by needle valves.

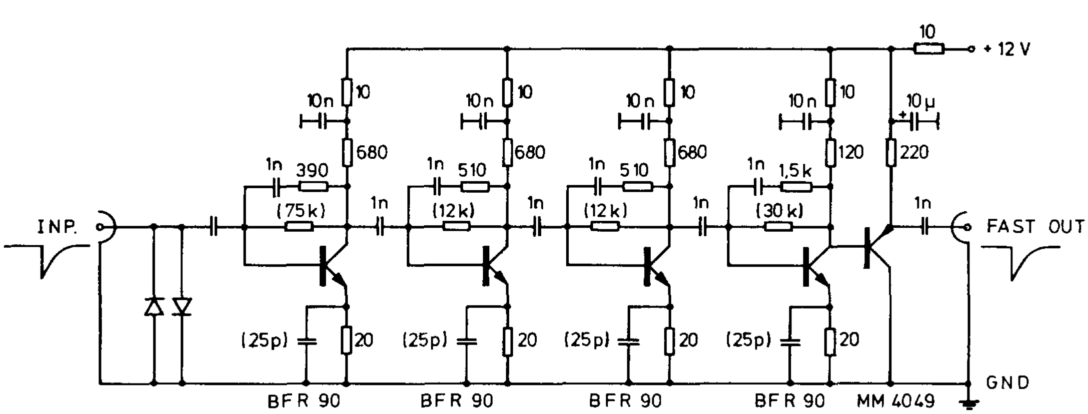

Fig. 2. The amplifier circuit.

5. The preamplifier

The fast, low-noise amplifier used for the PPAC pulses is shown in fig. 2. Its internal rise-time is <1 ns for a gain factor of 150; the input impedance amounts to 120 Ω. The amplifier is built in separate stages, several of which can be cascaded up to amplification factors of ~ 150 (four stages). The noise referred to the input is $<50\ \mu$V, including the two fast diodes at the input stage. When connected to a 50 cm^2 PPAC, a signal-to-noise-ratio of ~ 20 is obtained for α-particles. The distance between detector and preamplifier was kept below ~ 20 cm; if necessary, the circuit was mounted directly on the counter and operated in the gas atmosphere.

6. Results

The performance of the PPACs was investigated with an ^{241}Am α-source and with beams of ^{16}O (1.6 MeV/amu), ^{40}Ar (7 MeV/amu) and ^{132}Xe (1.4 MeV/amu) particles. Fig. 3 shows the signal amplitude (at fixed voltage) of a PPAC versus the primary energy deposited in the counter. The observed linear relation shows that the counter works in the true proportional region and there are no space-charge effects when varying the deposited energy by a factor of 100.

Fig. 4 shows on a log–lin plot the pulse height of a PPAC versus the applied voltage for different particles. When increasing the voltage by ~ 35 V, the amplitude increases by a factor of two.

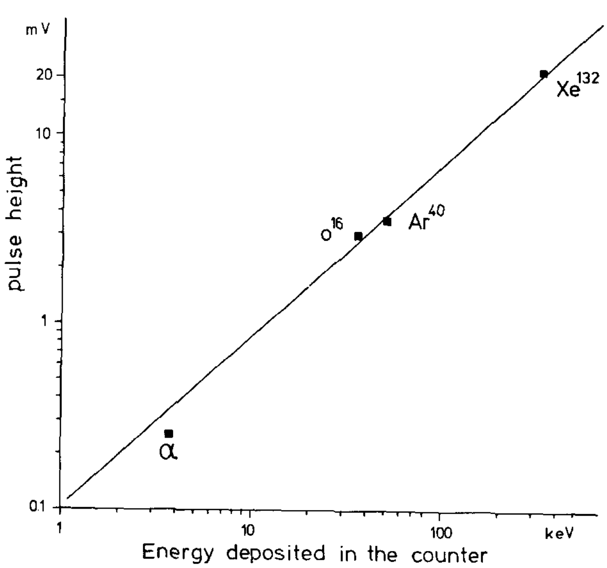

Fig. 3. Pulse height vs energy deposited in a PPAC with a 1 mm gap. The counter was operated in 10 torr i-butylen. The applied voltage was 490 V.

TABLE 1

Time resolution (in ps at fwhm) of PPACs with different geometry. The particle used in the measurement is given in brackets.

Gap (mm) \ Area (cm^2)	1	50	550
4		400 (α) 250 (^{16}O)	
2	320 (α)	320 (α)	350 (α)
1	280 (α) 160 (^{16}O)	280 (α) 160 (^{16}O)	

The time resolution measured with the different types of PPACs is summarized in table 1. The signals were amplified in preamplifiers allready mentioned and then given to constant fraction discriminators (Canberra 1326 D). The quoted resolutions always refer to that of one counter at fwhm. One interesting result is that the performance of PPACs does not depend very much on the size of the counter. The large area PPAC described in section 3(c) has a time resolution of 350 ps, whereas the smaller counters with the same

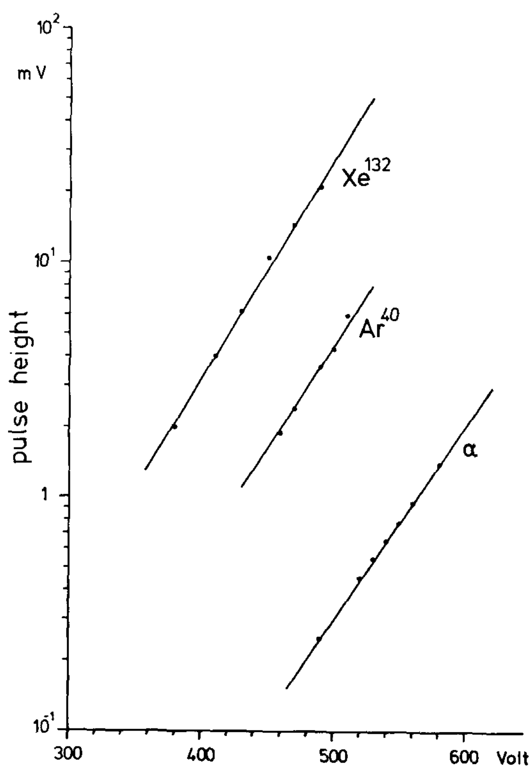

Fig. 4. Pulse height vs applied voltage for different particles. The gap was 1 mm, the counting gas was i-butylen at 10 torr.

gap both show a resolution of 320 ps. These numbers were obtained with α-particles. In the case of large area PPAC a correction has to be made according to the impact point of the particle on the counter. The signal velocity in the counter has been determined by moving an α-source together with a small PPAC (which gives the reference time) across the length of the counter. The resulting shift of the timing signal is shown in fig. 5 and amounts to 1 ns/19 cm. This means that the impact point of the particle on the counter has to be known only very roughly to within 2 cm. Furthermore the time resolution is constant across the length of the counter.

Despite the increasing capacitance a reduction in gap-width results in a better time resolution (cf. table 1).

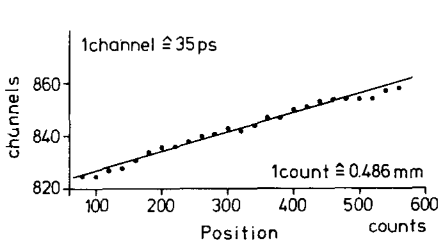

Fig. 5. Shift of the timing signal as a function of the impact point of the particle on the PPAC (2×25 cm^2 surface, gap 1 mm).

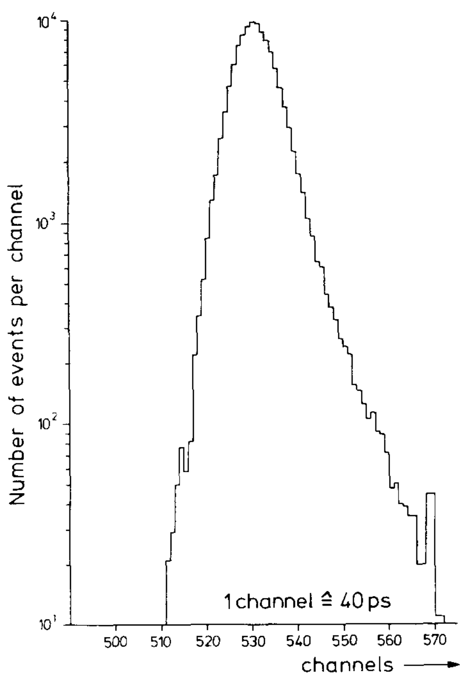

Fig. 6. Coincidence curve (measured with α's) of two PPACs with 0.8 cm^2 and 50 cm^2 surface and a gap of 1 mm.

A coincidence curve between a 1 cm^2 and a 52 cm^2 PPAC (gap 1 mm) is plotted in fig. 6. The curve has a fwhm = 400 ps and has a rather good Gaussian shape. A total of 3.3% of the events are outside three standard deviations.

As already mentioned the primary electrons produced near the cathode contribute most to the signal, and therefore the timing of a PPAC is predominantly given by those primary electrons. Since in the case of heavily ionizing particles the distribution of the primary electron–ion pairs along the particle track is much denser, the time resolution achieved with ^{16}O ions should be better compared to the results observed with α-particles. The time resolution of a 52 cm^2 PPAC with a gap distance of 1 mm is 160 ps, measured with ^{16}O particles (cf. table 1).

It should be pointed out that in the case of α-particles the high-voltage plateau (e.g. the region where the efficiency and the time resolution do not change) amounts to 50 V, which corresponds to an increase in amplitude of nearly a factor 3 (see fig. 4). This shows that the time resolution even for α-particles is not limited by the signal-to-noise ratio.

In an experiment[16]) to study the deep inelastic processes Ar $\rightarrow$ Ni ($E_{\mathrm{Ar}} = 280$ MeV) three PPACs were installed. The scheme of the experimental set-up is shown in fig. 7. The PPAC labelled START had 2×12 cm^2 area and a thickness (including the windows which keep the gas pressure) of 700 μg/cm^2, the other two PPACs T3 and T4 had 2×28 cm^2 sensitive surfaces. The gaps were 1 mm. A coincidence between the counters START and T3 was used as the trigger signal, the coincidence curve had a width at fwhm of 280 ps for the elastic scattered argon particles. Taking

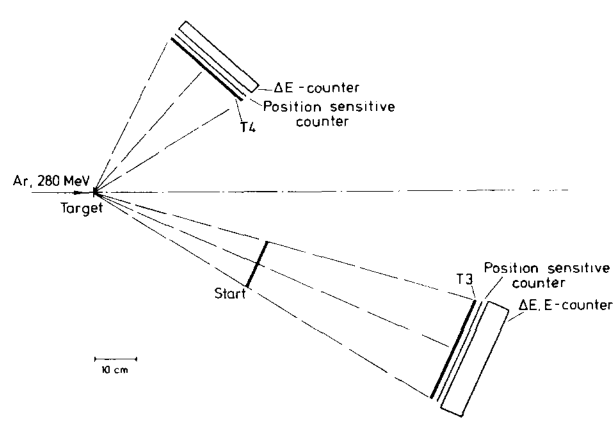

Fig. 7. Scheme of the experimental set-up to measure the deep inelastic process Ar$\rightarrow$Ni. The counters labelled START, T3 and T4 are parallel plate avalanche counters.

into account the time-jitter of 140 ps due to the energy straggling in the target and in the counter START, one gets a time resolution of 170 ps (fwhm) for one counter. This number agrees well with the value obtained in a previous test run.

I like to express my thanks to Prof. R. Bock for his continuous interest in this work. I am indebted to Dr. A. Gobbi for introducing me to the above problem and I thank him and Prof. U. Lynen for many helpful discussions. The foils were prepared and evaporated by Mrs D. Maier; the preamplifier was developed by Mr. H.-J. Beeskow. Their skilful work is greatly appreciated.

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