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# A position sensitive parallel plate avalanche counter for single particle and current readout

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**Abstract**

A parallel plate avalanche counter (PPAC) has been developed to serve as a radioactive beam monitor detector for the REX-ISOLDE project at CERN. The PPAC has a compact design with an active diameter of 4 cm, a low effective thickness of $\sim 1$ mg/cm$^2$, a spatial resolution in the $x$ and $y$ directions of 1.6 mm, an applicability for all heavy ions with $Z \geq 2$, and a large dynamical range in counting rates of up to $10^9$ s$^{-1}$ due to single particle or current readout, respectively. © 2000 Elsevier Science B.V. All rights reserved.

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*Keywords:* Parallel plate avalanche counter; Position-sensitive detector; Radioactive beams

Since 1996 the REX-ISOLDE project at CERN is strongly developing and will deliver various radioactive beams with energies from 0.8 to 2.2 MeV/$u$ for nuclear structure experiments from 2000 onwards. Since the beam typically consists of ions with nuclei far off the valley of stability the beam currents are expected to be rather low compared to stable beams, corresponding to rates from $10^0$ to $10^8$ particles/s. An efficient and spatially sensitive detector is required to monitor the beam at the target area. Moreover, the thickness of the detector should be rather low to prevent the radioactive ions from being stopped and to avoid large-angle straggling. This reduces the background of the other detectors in the target area originating from electrons emitted after β decay of the nuclei in the beam with typically high energies. Heavy ions over the whole range of elements should be registered with high efficiency and at high counting rates [1].

The design of a parallel plate avalanche counter (PPAC; see Figs. 1 and 2) with segmented foils [2] was found to be appropriate to match all these requirements. In order to cover the large dynamical range of possible counting rates the readout of the signals is carried out in two different operating modes: At rates of $< 10^6$ s$^{-1}$ the signals can be read out event by event, whereas at rates of $10^4$–$10^9$ s$^{-1}$ the currents measured on all anode strips are recorded.

The housing of the detector is constructed nearly symmetrically of six parts. All parts are of

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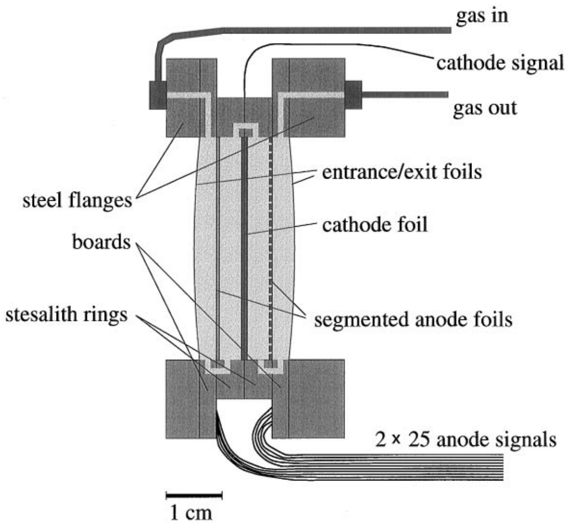


Fig. 1. Schematic view of the parallel plate avalanche counter. The detector consists of a central cathode foil and two segmented anode foils behind and in front of it, respectively. Two additional foils confining the gas volume, the gas supply and the 51 signal wires are indicated.

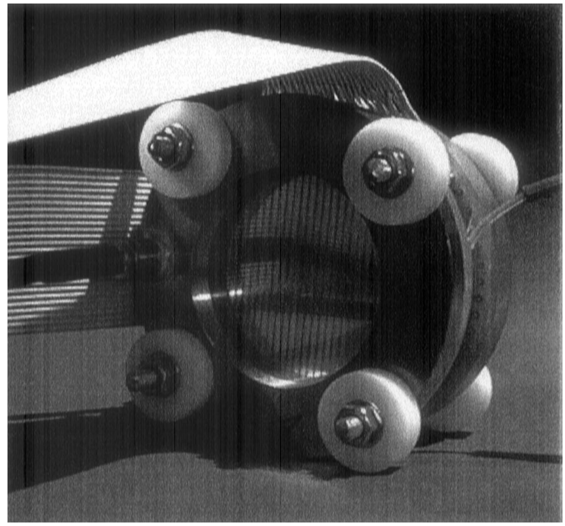

Fig. 2. Photograph taken from the exit side of the PPAC showing the flat cables in light colour and the gas-supply tube in black. On the right-hand side the cable connection of the cathode is visible. Through the exit foil the strip-like structure of one anode foil can be seen. The white rings served for fixing the PPAC in a beam line.

circular shape having an inner diameter of 40 mm:

1. At the entrance and exit sides two steel flanges stabilize the detector and serve as connection to the gas system.
2. Between the two flanges two boards of 3.2 mm thickness are located. They are produced by photo-lithographic means and have a surface structure of 25 copper strips with a pitch of 1.6 mm.
3. Between the boards two rings made of Stesalit of 5 mm thickness serve to fix the distance of the parallel plates and to isolate the voltage applied to the cathode. While the outer diameters of 1 and 2 are 68 mm, it is 54 mm for the Stesalit rings.

The electrodes of the PPAC were fabricated in the following way:

1. The cathode in the center of the detector is a 2 μm mylar foil coated with 100 nm of aluminium on both sides. It is glued to one of the Stesalit rings and is contacted electrically by fixing the foil to the inner wire of a coaxial cable by means of a conductive two-component glue.
2. The two structured anodes are fabricated in several steps: 1.5 μm mylar foils are glued to the side of the etched copper strips of both boards. In the next step aluminium is evaporated onto the foil on each board through a specially designed mask, until strips with a thickness of $\approx 500$ nm of aluminium have grown on the foils. Due to the design and the adjustment of the mask these aluminium strips are completely aligned to the copper strips of the board. Then, all 25 strips on the foils are connected to the strips on the board, using again a conductive two-component glue and the help of an exactly positionable glueing machine. In the last step the end of the strips of the two boards are soldered to flexible flat cables.

The detector is operated with a small but constant gas flow at typical pressures of 4–10 mbar of isobutane. For the investigations shown below a pressure of 5.5 mbar was chosen which corresponds to maximum voltages in the 5 mm gap of the PPAC of 600–700 V. At higher voltages spontaneous discharges may occur. The signals measured by the cathode exhibit pulse heights of about 10 mV for 5 MeV $\alpha$ particles. The rise time of the signals (10–90%) was measured to be approximately 5 ns. These signals are amplified to about of 1 V by means of a fast amplifier with a short integrating-time constant of 4 ns. For the single-particle readout, the 25 signals from the strips are connected to a chain of delay lines with 4 ns delay between neighbouring strips. The signals from the ends of the delay lines show widths around 30 ns which is significantly wider than the cathode signals. They are correspondingly amplified using longer integrating-time constants of 20 ns. The position information is then given by the time difference between the signals from the ends of the delay lines whereas the time sum should be constant (see Fig. 3). Different strips show up as different peaks in this spectrum. Consequently, the spatial resolution of the PPAC is given mainly by the strip pitch of 1.6 mm. Thus, in this mode readout only five timing signals have to be processed in order to get the position information in $x$ and $y$ (four signals from two delay lines) and fast timing information (cathode signal).

In case of high count rates ($\geq 10^6\ s^{-1}$) of particles passing the PPAC the readout can be switched to a current mode: The currents of all $2 \times 25$ anode signals are separately transformed by current-to-frequency converters [1] and fed into scaler modules. These scalers can be read out in fixed time intervals leading to a current profile of the beam (see Fig. 4). This distribution is proportional to the beam distribution and it can be normalized either at low counting rates by switching to the single-particle mode or at very high counting rates by means of a Faraday cup. From such a fixed point the actual beam current has to be extrapolated within a few steps.

In conclusion it can be stated that the PPAC described above meets all of the requirements for REX-ISOLDE: the compact design with an outer diameter of 68 mm, having an active diameter of 40 mm with a spatial resolution corresponding to the strip width of 1.6 mm; an effective thickness below 1.5 $mg/cm^2$ which could even be decreased if necessary for very low-energy beams. The dynamic range reaches down to single $\alpha$ particles and should not be restricted for very heavy ions. A rather unique feature is the possibility to quickly switch the readout of the PPAC from a single-particle mode at counting rates of up to $10^6$ particles/s to a current mode which allows to monitor beams being even some orders of magnitude more intense. With the setups used for the test measurements the time resolution of the PPAC could not be investigated precisely. From the signal shape and the signal-to-noise ratio observed a resolution well below 1 ns is estimated, especially for a beam of heavy ions. Finally – regarding the properties of this PPAC – a variety of applications (besides REX-ISOLDE) is imaginable for such a type of detector.

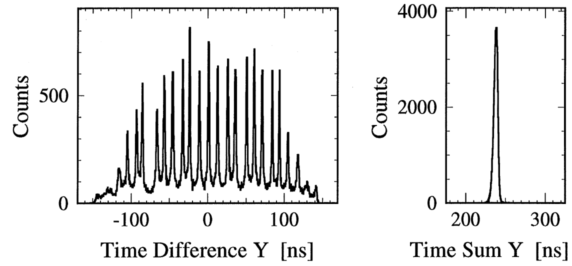


Fig. 3. Time-difference and time-sum spectra using the signals from both ends of one of the delay lines ($y$). The data were taken with $\alpha$ particles from a source impinging on the whole detector area.

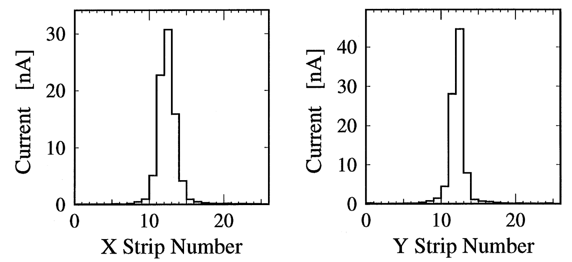


Fig. 4. Current distribution in the PPAC measured with a $^{36}S$ beam at 2 MeV/$u$. This current is proportional to the beam current showing the beam profile in $x$ (left panel) and $y$ direction (right panel).

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## References

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