Multiple hit read-out of microchannel plate detectors with a three-layer delay-line anode

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We have developed a delay-line read-out technique for microchannel plate detectors with an increased acceptance for multiple hit events compared to standard delay-line anodes. This technique allows to unambiguously determine arrival time and position of at least four simultaneously detected particles and/or for an even larger number of particles in a shower as long as any two particles do not arrive at the same time and at the same position within certain limits. We demonstrate and discuss the abilities and limitations of this technique and the relevance for certain experimental tasks.

Detection of single particles or photons with a microchannel plate (MCP) is a well-developed technique. Most demands require determination of position and/or arrival time of quasi-statistically arriving particles, i.e. photons from a celestial object or particles from a laboratory source.

But for some applications there is need to detect a burst of particles, i.e. quasi-simultaneously arriving particles with a smaller time distance than the digital read-out cycle. As the fastest currently achieved electronic read-out cycles for individual particles are typical one microsecond one may define such a multi-hit event as a burst of particles with at least two particles arriving within a few microseconds. An example for such an application is the collision-induced breakup of a molecule into several charged fragments and the projection of the fragments onto a MCP detector.

CCD-based read-out methods provide the position information of simultaneously arriving particles but they can not give precise time information. Pixel-type anodes with independent and parallel read-out chains can provide time and position coordinates, however, the achievable position resolution is limited by the number of channels. Combinations between CCD and pixel read-out suffer from high system complexity and often from low count rate [1].

An alternative approach is the read-out of MCP with the delay-line method. The delay-line method yields very good position resolution. As only fast electronic circuits are used it is possible to operate at a very high rate and thus to handle multi-hit events. However, in the standard two-layer design the multi-hit tolerance of a delay-line anode is still inferior to pixel anodes with truly parallel read-out chains if the relative time distances are of the order of the delay-lines' single path delay (< 100 nsec). As all signals from the detected particles are routed trough the same electronic circuits, the electronic dead time (typically 10 nsec) finally sets a limit to the time distance between two particles of which position and relative arrival time can be determined. The situation is complicated by the fact that different positions of particles on the delay-line are also translated into time distances due the encoding technique.

In order to improve the multi-hit tolerance of the delay-line method we have introduced a novel anode type ("Hexanode") with a third independent layer (see figure 1). Thus we can use information redundancy of the signals obtained on the three layers from each particle hit to increase the phase space (relative position and relative time) where multiple hits can unambiguously by distinguished and the time and position coordinates can be determined. Introducing this third layer means only a small increase in complexity (7 electronic chains instead of 5). However, this pushes the multi-hit ability to the limit of what can be achieved with a non pixel-type anode.

The helical wire delay-line anode that we use for MCP read-out is described by Sobottka et al. [2]. In its standard design two delay-line layers are formed by two helical wire arrays wound around a solid support and oriented perpendicular to each other. The wire arrays are used both for pick-up of the charge cloud from the MCP and for producing the delay that encodes different pick-up positions into different relative signal arriving times at the two ends of each line. Each layer encodes one spatial dimension, so that four (fast) electronic time circuits are required to derive the two-dimensional position. It is of advantage to also record a fifth time signal, from the MCP itself, indicating the arrival of each particle on the MCP. Well-defined potentials on the wires with respect to the MCP exit ensure

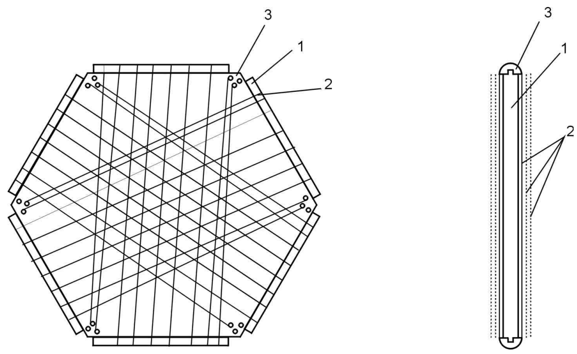
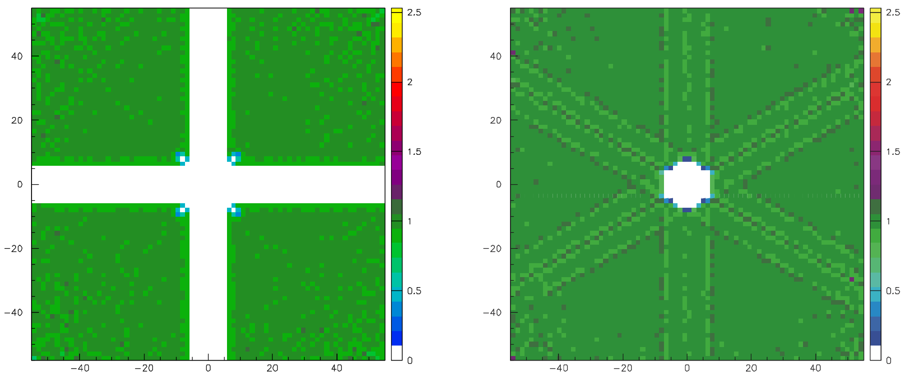


Figure 1: scheme of the Hexanode.
1- metal support, 2 – wire arrays, 3 - ceramic rod

that the charge cloud is equally shared between the two layers and that it is broadened to allow a center-of-gravity position measurement. Thus, the position resolution is not limited by the wire distance but only by the electronic timing precision.

The *Hexanode* is basically a three-layer version of the helical wire anode described above. The shape of the support plane is hexagonal and the layers have a relative angle of 60^o. For the position determination of a particle hit, signals from any two of the layers are sufficient. This redundancy reduces the "blind area" for quasi-simultaneously arriving particles as shown in figure 2. A straightforward algorithm allows reconstruction of all particle hits as long as they do not arrive at the same position *and* at the same time within certain limits (given by the electronic dead time). It is to note that in many physical processes (i.e. Coulomb explosion of molecules) this combination has a vanishing probability anyway.

We found that the additional experimental effort required for using three layers instead of two is indeed minor. With the ongoing development of even faster electronic circuits and flash-ADCs to record the signals from the wires, we expect the electronic dead time to be further reduced in the near future. Then this relatively easy and high precision read-out method will finally be equally suitable for multi-hit applications where so far only rather complicated hybrid detector systems can be used.



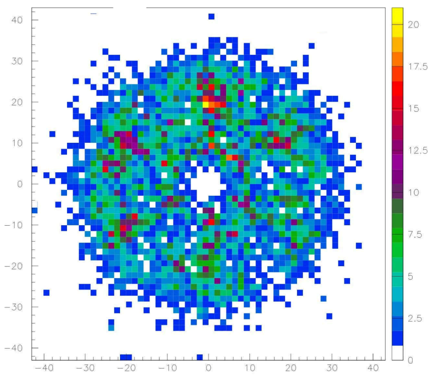
left:

standard (square) delay-line
Dt_{pp} *= 2.5 nsec,* Dt_e *= 10 nsec*

right:

Hexanode
Dt_{pp} *= 0 nsec,* Dt_e *= 10 nsec*

Figure 2: Multi-hit performance of delay-line anodes
Above: displayed are relative positions between two particles (in mm) arriving at a relative time distance Dt_{pp}*. Shown above are Monte Carlo simulations of the acceptance for quasi-simultaneously arriving particles. The standard delay-line is not able to analyse particle pairs with relative positions in the cross-shaped region while the redundancy of the three-layer design reduces the "dead" region to a small disk (i.e. both particles arriving at the same position). As* Dt_{pp} *increases, its diameter becomes smaller and vanishes for* $Dt_{pp} > Dt_e$ *(the electronic dead time).*



Left: data obtained with a Hexanode *from a laboratory particle source:* D_2 *molecules are doubly photoionized, the two electrons are projected onto the MCP by a combined electrostatic and solenoid field [3]. Only electron double hits with* Dt_{pp} *> 4 nsec are displayed. The size of the central hole varies according to the expectation from the simulations.*

References:

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