Efficiency simulation of TPC detectors

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Introduction

The Time Projection Chamber (TPC) are the standard high-resolution position measurement detectors used at the Fragment Separator FRS [1]. As gas detectors, they have the advantage to be very robust and cover a a wide dynamic range simply by HV tuning operation. On the other hand they can work up to $3 \cdot 10^4$ ion/s with an efficiency close to 100%. To improve the ion capability of these detectors, based on conventional delay lines, the use of a single channel digital readout electronics have been assumed. The advantage of the single-strip readout is the reduced time needed to collect the signals from the whole area of the detector. The efficiency at different ion rates for different readouts has been simulated using a Monte-Carlo method.

Simulation and Results

Time Projection Chamber type detectors with GEM foil amplification[2] have been proposed as tracking detectors for slow-extracted beams at the Super-FRS facility[3]. At the focal planes of the main separator of the Super-FRS a beam rate of several MHz is expected. There, ion tacking based on event-by-event analysis is needed for having the required separation and identification in mass and charge of the produced radioactive beams. To simulate the ion rate capability of a Super-FRS tracking detector we have assumed a gas chamber with active size of $38x8cm^2$. The drift velocity of the gas was $5cm/\mu s$, which corresponds to the drift velocity of the P10 gas at normal pressure and temperature at 400 V/cm electric field. The number of ions were generated according to the Poisson distribution around a fixed rate. For the x-coordinate a rectangular distribution over the whole chamber was used. The y-coordinates were generated according to a Gaussian distribution centered in the middle of the chamber with a sigma equal to $1cm$. The results shown here do not consider losses due to noise, delta electrons, recombination etc. The delay line configuration was like described in [1]. By using the delay-line readout we have the possibility to reject the noise because time measurement from delay line(t_L, t_R) and drift times(t_D) are correlated by relation $t_{CS} = t_L + t_R - 2t_D$ [1], where t_{CS} is constant. This method is no longer available in the case of single-strip readout. In other words, whenever two or more signals arrive within the same collection time, the two arrival times are mixed together with their y-coordinates. The collection time (time window) for 8cm drift corresponds to $1.6\mu s$. The results of the simulations are shown in the Fig. 1. The red and black points represents the efficiency curves of the delay line and single-strip readouts, respectively. The

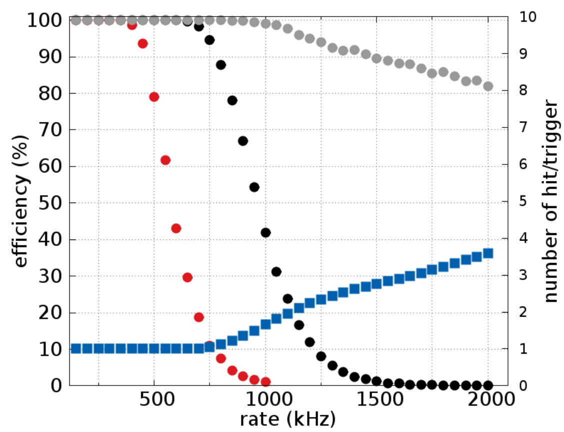

Figure 1: Rate dependence of the simulated efficiency of a TPC detector with P10 gas with different readouts. The red points correspond to the delay-line readout, black points correspond to the single strip readout and blue squares are the average detected particles in the $1.6\mu s$ time window (right y axis). The gray points correspond to the efficiency of a "twin" detector.

results of the simulations show that using a delay line readout the efficiency starts to decrease at beam intensities of 300kHz. Shortening the readout time by single-strip readout, a GEM-TPC design with the assumed gas could stand a rate up to 700kHz. At 700kHz the probability to have 2 or more hits in the same trigger window starts to increase, as shown in Fig. 1 by the blue points. To further increase the efficiency at even higher rates two solutions are possible. Introducing a control sum in the y-coordinate, by using a "twin" design, could further improve the efficiency by a factor of 2, as shown in Fig. 1 by the gray points. Additionally with a faster gas a higher efficiency can be achieved at several MHz.

References

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