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Study of the spatial resolution for binary readout detectors

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Often the binary readout is proposed for high granularity detectors to reduce the generated data volume to be readout at the price of a somewhat reduced spatial resolution compared to an analogue readout. In this contribution we show that the detector geometry could be optimized to offer an equivalent spatial resolution than with an analogue readout.

In our work we have been studying single hit resolutions obtained with a binary readout
using simulations as well as analytical approaches. The resolution has been studied in a generic case, as a function of several parameters: strip pitch, diffusion coefficients, incident track angle, primary electron statistics, etc.

Consequently this study can be useful for detector optimization and may bring new ideas of detector developments.
The speaker will present three different cases : silicon sensor, Micromegas, and GEM-based detector, and shed light on the principle behind.

Summary

In large experiments, comprising hundreds or thousand of detection elements,
it is sometimes more advantageous to use a binary readout electronics than an analogue one. Indeed it is not always feasible to integrate an analog-to-digital converter (ADC) in each channel of the front-end ASIC; the constraints are typically associated with the total area of the integrated circuit and with the power consumption. With a binary readout the cost of an increased number of readout channels would then be balanced by a simpler readout circuitry. In addition the data volume is much smaller with a binary readout.
For many applications one can use the binary readout architecture. In this architecture each channel of the front-end electronics is equipped with an amplitude discriminator which generates 1-bit information in response to each signal above a given threshold. The information delivered by a strip detector is suppressed to the minimum already in the front-end circuit. Binary information can be easily stored in the integrated circuit separately for each channel, which allows one to cope with high rate of particles.
In this contribution, we estimate analytically and by Monte Carlo simulations the spatial resolution with a binary readout for 3 types of detectors: silicon sensor, MICROMEGAS and GEM-based detectors. The spatial resolution is studied as a function of several parameters: strip pitch, diffusion coefficients, detector volume, track incident angle, ionization statistics, etc. Our approach is rather generic which means that in the future these results could be used to optimize the geometry of new detectors.
The simulation parameterizes the primary ionization, the electron drift and diffusion in the detector volume, the gas amplification and the signal induction. The induced signal on each strip is compared to a given threshold and strips above the threshold are combined in a cluster. In the binary case the reconstructed position of the track is the geometrical center of the cluster. In the analogue case, we use the center of gravity method to reconstruct the position.
The analytical model has been developed from the definition of the spatial resolution for a binary readout. From this definition, the formula is split into two terms: one term represents the geometrical effects and the

second one represents the diffusion effects. The geometrical effects result from wide strip pitches compared to a charge distribution that depends on the diffusion, the incident angle, and the threshold. The diffusion effect is almost independent of pitches and incident angles; it can be reduced by arranging a small diffusion coefficient or by increasing the number of ionized electrons.

In this contribution we will present in details our analytical calculation of the spatial resolution for a binary readout. The relative importance of both terms will be discussed for the 3 types of detectors. The results will also be compared with the simulations, for a binary and for an analogue readout.

Primary authors: Prof. DE LENTDECKER, Gilles (Université libre de Bruxelles); Dr YONAMINE, Ryo (Université libre de Bruxelles); Mr MAERSCHALK, Thierry (Université libre de Bruxelles)

Presenter: Dr YONAMINE, Ryo (Université libre de Bruxelles)

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