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On-chip Monitoring of the Performance of Silicon Detectors with Binary Readout

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ABSTRACT

The monitoring of the performance of silicon strip systems with binary read-out is discussed. We propose to instrument a small fraction of the channels with an additional, higher threshold, set at the median of the pulse height spectrum. The ratio of the counting rate at high threshold to the one at low threshold yields the efficiency on-line and without need for tracking.

INTRODUCTION

We are proposing to simplify the readout of silicon detectors by using a binary readout [1], which records only the addresses of strips with pulse height exceeding a fixed threshold value. Thus the pulse height will not be available directly during data taking. We have shown that the pulse height information can be recovered by varying the threshold and measuring the count rate, which is the integral of the pulse height spectrum [2]. Likewise, the noise can be determined from threshold scans without beams [3,4]. During data taking, this method of determining the signal and noise is not usable, because the threshold will be kept constant. We proposed to monitor the performance on-line with a tracking program, and have shown that this can be done in a beam test[5]. In addition, we believe that a direct hard ware monitor of the system performance should be developed. A system with two thresholds would satisfy this need. We have shown before that a concept which employs coincidences of lower thresholds is not practical because of the noise penalty [6]. Here we will investigate the usefulness of a higher threshold

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MONITORING SIGNAL-TO-NOISE: THRESHOLD SCANS

By recording the counting rate as a function of varying threshold, the pulse height spectrum can be extracted. The so-called threshold scan yields the efficiency, which is the integral spectrum of all hits with pulse height exceeding the threshold setting. Its derivative is the pulse height spectrum. Data from a previous beam test at KEK (Ref. [2]) are shown in Fig. 1, with the threshold curve in Fig 1a and the pulse height spectrum in Fig. 1b. An operating threshold of 1fC was established for the binary system.

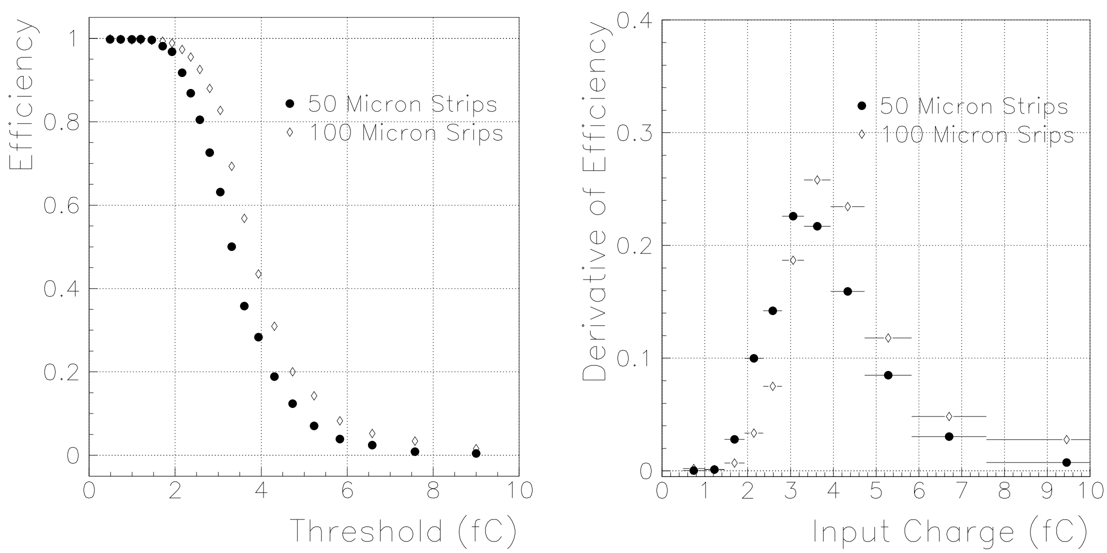

Fig 1: a. Efficiency as a function of threshold, b. Pulse height. (Ref. [2])

Close inspection of the efficiency plot in Fig.1 reveals two different threshold regions. These different regions are emphasized in Fig.2 , which is an efficiency plot from the H8 beam test in 1995.

At the nominal threshold of 1fC, where we want to operate the system, the efficiency is unity, independent of the threshold. Small changes of pulse height will not be detectable. This fact is due to the “head room” of the binary system, which, because of the low noise, is operated at low threshold and thus exhibits good efficiency even at 1.5 times the nominal threshold. The fact that the efficiency is high and insensitive to pulse height changes, means that this threshold region of 1fC is the worst region to monitor the performance, where one wants to be sensitive to small changes in pulse height. This sensitivity to small pulse height variations is present in the region of thresholds of about 3fC, at the median of the pulse height spectrum. Here the slope of the efficiency vs. threshold curve is maximal, and thus small changes in the pulse height due to the degradation of the system will be flagged by large efficiency changes. For example, we estimate from Fig.2 that for a 10% pulse height change, the monitoring efficiency will change by 20%, Again, these efficiency changes at 3fC will not be detectable at the lower threshold.

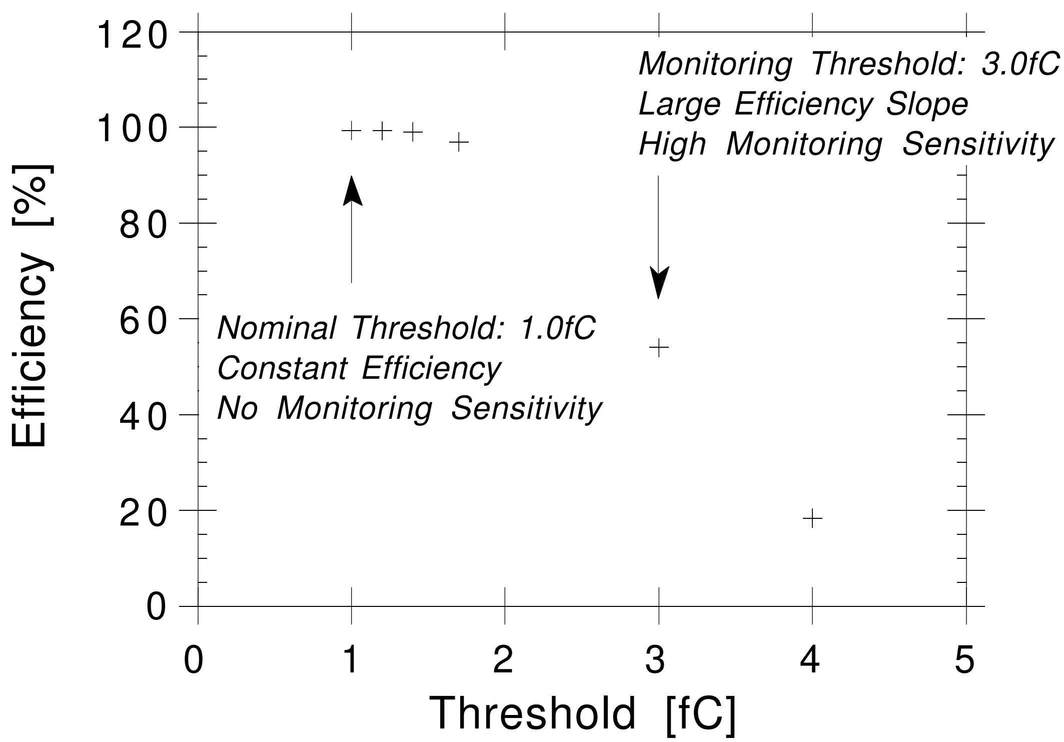

Fig 2: Efficiency as a function of threshold, for an H8 binary module

We propose to use the sensitivity of the higher threshold to small changes in system performance to monitor "on-chip" the performance: two of the 128 channels of a chip are connected to the same strip, One of the two channels will operate with the nominal threshold of 1fC, while the other will be set to a fixed higher threshold, e.g. 3.0fC- in practice, it seems to be more advantageous to reduce the gain in the second channel by the factor 3 and operate the chip with a single common threshold-. While the channel with the normal threshold at 1fC exhibits an efficiency of 100%, the higher threshold will be only 50% efficient, which can be measured on-line by taking the ratio of rates in both. Low noise occupancy assures that even this direct ratio is a good measure of the system performance, but the ratio can be evaluated under more restrictive selections.

The value of the higher threshold is envisioned to be fixed in hard ware and the same on all chips. It should coincide with the median of the pulse height spectrum for maximum sensitivity, but this requirement does not have to be met exactly. From our beam tests [3,5], we are able to determine the correct setting, given a certain admixture of particle crossing angles.

The number of channels sacrificed on the chip for monitoring should be small. We believe that one channel per 128 channel chip is enough, because it will result in 12 monitoring channels per module. In addition, the standard monitoring of the performance of all channels will be done with the help of a tracking program .

CONCLUSIONS

We propose a monitoring system of the binary read-out by connecting the same strip to two amplifier channels, one with the nominal 1fC threshold, the other with a threshold corresponding to the median of the pulse height distribution (about 3fC). The ratio of the counting rate of the two channels is the efficiency at the median which is maximally sensitive to pulse height changes. In order to minimize the impact of this monitoring system, we propose to utilize one of the 128 channels on one chip for the high threshold, which results in 12 monitoring channels per module. For the practical implementation, we suggest to have one threshold per chip, and reduce the gain in the monitoring channel by a factor of 3.

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