An improved detector response simulation for the Silicon Tracking System*

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To achieve realistic simulations the response of the silicon strip sensors should be precisely included in the digitizer, which simulates a complete chain of physical processes caused by a charged particle traversing the detector, from charge creation in silicon to a digital output signal. In the CbmRoot software, the current version of the STS digitizer [1] doesn't include all the processes needed to obtain results with sufficient accuracy. It assumes a uniform energy loss distribution along the incident particle track and accounts for the Lorentz shift and effects of the read-out electronics, as threshold, random noise, charge collection inefficiency, channel dead time. We considered the following improvements to the digitizer: non-uniform energy loss distribution, thermal diffusion, and charge re-distribution over the read-out channels due to interstrip capacitances (the so-called "cross-talk"). There are several possibilities to model each process with a different level of detailing. We suggest the following procedure:

- to divide the incident particle trajectory into thin layers ($3\mu m$); to calculate the deposited energy in each layer according to the Urban method [2];
- to estimate the charge broadening due to thermal diffusion according to the Gaussian low for the charge in each layer [3];
- for each fired strip to calculate the charge sharing due to the cross-talk, to add random noise distributed according to the Gaussian low with $\sigma = ENC$ (Equivalent Noise Charge);
- to convert the charge in each strip from number of electrons to ADC-value; to apply a threshold and other effects of electronics.

We verify the new procedure by choosing tracks with random impact and inclination from $-45°$ to $45°$ (see [4] for more details) and utilizing the Center-Of-Gravity algorithm [5] to reconstruct clusters. From the obtained results we conclude that the most significant effect is the non-uniform energy loss along the incident particle track. Figure 1 shows a comparison between experimental data from the LHCb and our simulation. The experimental data agrees better with the new procedure. The current digitizer predicts most probable amplitude loss for perpendicular tracks to be 0%, whereas the improved version yields 10%. The measured value is yet higher, verifying the advance in development of the digitizer.

Several STS prototype modules based on CBM05 prototype sensors were operated during an in-beam experiment at COSY. Figure 2 shows a comparison between the
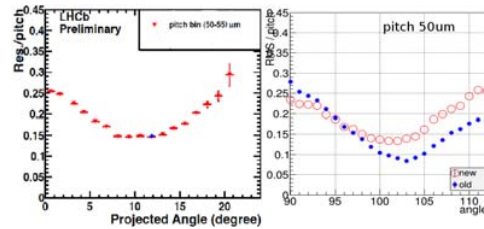
Figure 1: The RMS of the hit position residuals distribution VS track inclination: left panel – the LHCb Vertex Locator ($0°$ – perpendicular tracks) [6]; right panel – our simulation (red circles – the new Digitizer, blue dots – the current version, $90°$ – perpendicular tracks).

simulated data and the data obtained during the experiment, in the external triggering mode at different track inclinations. For perpendicular tracks we adopt a threshold of 9375 electrons and for $20°$ tracks 6250 electrons. As our simulation does not produce noise separately, but only adds random noise to the signal, a slight underestimation of small clusters is acceptable. We can see it for inclined tracks. However we reproduce a general behaviour of the measured cluster size distributions. Eventually, we found several points, where the improved Digitizer agrees better with experiment.
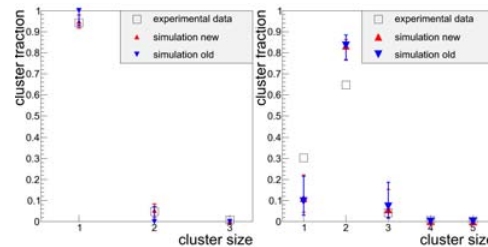

Figure 2: Cluster size distribution for perpendicular tracks (left) and for $20°$ tracks (right). The experimental data – empty squares, the new procedure – red triangles, the current – blue triangles. Error bars show the uncertainty in angle determination.

References

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