Study on electron-pion discrimination with the CBM Transition Radiation Detector

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In the CBM experiment at FAIR, a Transition Radiation Detector (TRD) is foreseen for tracking and electron-pion discrimination. Up to twelve detector layers are considered, each with a thin gas volume in order to have a sufficiently fast readout for the intended high collision rates. In this report, we present a combined simulation study of the dependence of electron-pion discrimination power on the detector thickness and on two methods of combining the signals of the individual layers. The influence of the radiator performance is discussed.

For discriminating electrons from pions in the momentum region of a few GeV/c, a TRD profits from their different energy loss through ionization, but mostly from the additional transition radiation produced by electrons. A complete TRD setup should reduce the number of misidentified pions by a factor of 100 (i.e. a pion efficiency of 1%) while keeping 90% electrons in the sample (electron efficiency of 90%), whereas - because of the statistical nature of both signal contributions - a single detector cannot achieve this unless it has a very thick active volume. For a moderate electron efficiency however, even a detector of around 1 cm thickness rejects more than 90% of the pions. This is demonstrated in Fig.1, showing the results of a stand-alone Monte Carlo simulation with TR production matched to ALICE-TRD sandwich radiator measurements and dE/dx based on Geant 3.21 [1].

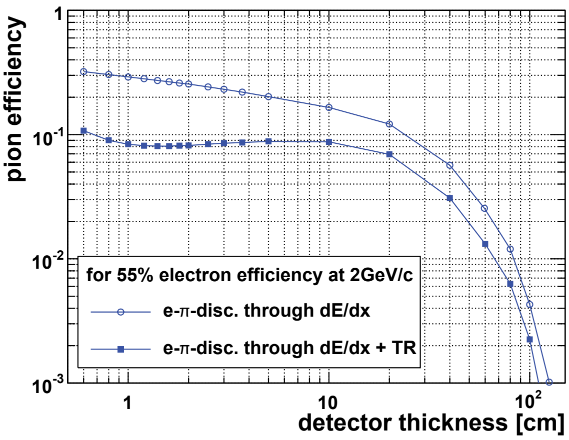

Figure 1: Pion efficiency for a single detector as function of detector thickness for 55% electron efficiency

The performance of multiple detectors depends on the method of combining their signals. For a setup of 12 layers of 1 cm and demanding 90% electron efficiency for the full system, a pion efficiency of 3.4% can be reached by just analyzing the sum of all signals. It is more powerful, however, to decide for each layer between electron and pion and accept electrons with at least k out of n electron-like signals. Figure 2 shows that with this strategy, the lowest pion efficiency can be reached with a single-layer electron efficiency of $p = 64\%$ and demanding at least six electron-like signals. The resulting pion efficiency is 0.2%.

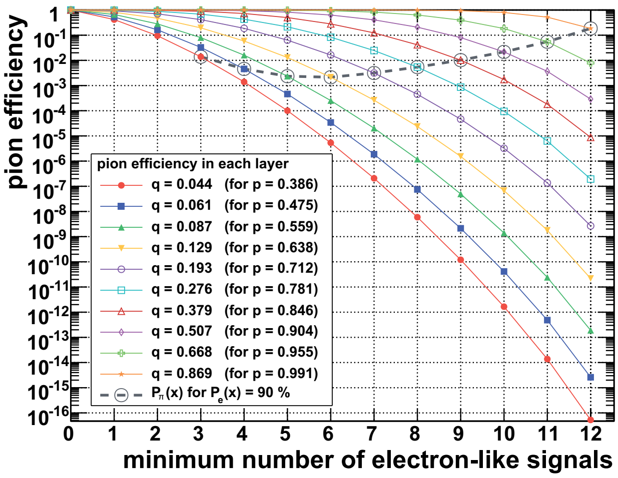

Figure 2: Pion efficiency from 12 detectors of 1 cm thickness as a function of the number of requested electron-like signals in single layers, for different single-layer pion efficiencies q. The dashed line shows values for 90% electron efficiency.

The yield of TR and its spectrum depend on the radiator type and composition. An increase in the photon yield by 20% with respect to the ALICE radiator would e.g. reduce the pion efficiency by a factor of 4 to only 0.05%. Moreover, the energy range of the TR photons is not ideal for absorption in a thin detector. The largest amount of deposited TR energy is reached with an almost 50% softer TR-spectrum (w.r.t. the ALICE radiator), having a mean of 7 keV and also resulting in 0.05% pion efficiency. On the other hand, one finds that a substantial increase of the detector thickness from 1 to 1.6 cm gives a pion efficiency of 0.09%, suggesting that the radiator offers a higher potential for improvements.

References

[1] P. Reichelt, Master Thesis, Goethe-Universität Frankfurt, to be submitted Feb. 2011