Expected data rates of the CBM-MVD at SIS-100 based on realistic beam intensity fluctuations

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The Micro-Vertex Detector (MVD) of the CBM experiment will be located close to the collision point and exposed to very high track densities from heavy-ion collisions at high interaction rates. The design of the MVD requires a detailed knowledge of the detector occupancies and the corresponding data rates, which were simulated in this work.

The first step of the study was to determine typical beam intensities for standard collision systems foreseen at SIS-100, i.e. p+Au collisions at 30 GeV and Au+Au collisions at 10A GeV bombarding energy. Two main constraints on the beam intensity were considered: the hit densities and the radiation dose in the first MVD station placed 5 cm downstream of the target. First, studies demonstrated that a maximal hit density of ~ 17.5 mm^{-2} per readout cycle can be accepted in the MVD [1]. Secondly, simulations of the radiation dose received by the MVD indicated that it could tolerate $\sim 5 \times 10^{13}$ p+Au and $\sim 5 \times 10^{12}$ Au+Au collisions [2], assuming a non-ionizing radiation hardness of 10^{14} $n_{eq}cm^{-2}$. This last value might be in reach for the future sensor at SIS-100, according to measurements performed with MIMOSA-25 featuring a highly resistive epitaxial layer [3].

Simulations of the occupancies in the MVD stations located at 5, 10 and 15 cm from the target were performed using UrQMD + GEANT 3.21, as discussed in [4]. These simulations accounted for the δ electrons knocked out of the target by the Au ions (they could be neglected for p+Au collisions). The geometry of the MVD sensors and stations located at 5 and 10 cm from the target was chosen according to [6]. The third station was extrapolated at 15 cm from the target to satisfy the CBM acceptance. The simulations suggest that in the case of p+Au collisions, the beam intensity is limited by the radiation hardness of the MVD to a mean value of $\sim 10^9$ protons/s. For Au+Au collisions, the beam intensity is limited by the high hit densities caused by the δ electrons to a maximal value of $\sim 2 \times 10^7$ ions/s.

The second step is to estimate the amount of data provided by the MVD sensors during their 30 μs long readout cycle. To account for the beam fluctuations of SIS-100, we assumed a factor of three for the ratio between the maximal and the average beam intensity. This number was motivated by observations made with the HADES beam diagnostics at SIS-18 [5]. We simulated 10^3 readout cycles which contained in average 3×10^4 protons or ~ 200 Au ions passing through the target. The number of nuclear collisions was computed using a Poisson distribution considering a 1% interaction target.

The data volume was estimated based on the data format of MIMOSA-26 [7], since this chip integrates the binary readout and sparsification circuits foreseen for the final sensor of the MVD. The left panel of Fig. 1 shows the data volume per readout cycle in the sensor exposed to the highest track densities. For Au+Au collisions the data flow is dominated by the δ electrons (red curves) and amounts up to ~ 3 kB per readout cycle. Consequently, the memory of the final chip should be increased by a factor of ~ 3 and the output clock frequency by a factor of ~ 7 with respect to MIMOSA-26. The right panel presents the data flow per station for p+Au collisions. As in the absence of hot spots driven by δ electrons, a higher average occupancy can be reached, data flows as high as 7 GB/s for 3 MVD stations are obtained.

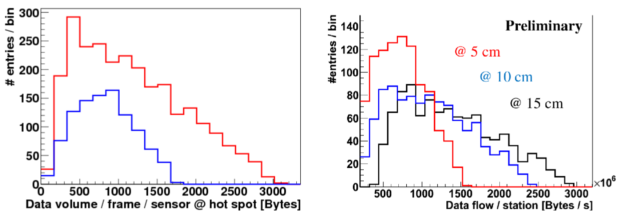

Figure 1: (Left) Data volume per readout cycle in the sensor exposed to the highest track densities, in case of p+Au (blue) and Au+Au collisions (red). (Right) Data flow per station for p+Au collisions.

References

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