Time Based Clustering for Muon Chamber (MuCh) in the CBM experiment at FAIR, Germany

Radha Krishna Garg[1], Vikas Singhal[2],* and Jogender Saini[2],
Chandrasekhar Ghosh[2], [x]Subhasis Chattopadhyay[2]
[1] *Computer Science Engineering, Vellore Institute of Technology, VIT-AP and*
[x] *former* [2] *EHEPAG, VECC, 1/AF Bidhan Nagar, Kolkata-700 064, India*

Introduction

The soon-to-be-realised Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) is engineered to handle data acquisition during nuclear collisions at an exceptional high interaction rate, reaching up to 10 MHz. This state-of-the-art setup incorporates a self-triggered readout system, eliminating the need for conventional hardware triggers. This sophisticated CBM data acquisition system (DAQ) creates a free flow data stream of raw-messages which are further converted via unpackers [1] into 'Digis' - the elemental data units having a timestamp in nano second (ns) order. After unpacking, the pivotal task is formation of clusters and meaningful hits from digitized data 'digis'. For the Muon Chamber (MuCh) system at CBM a cluster and a hit creation algorithm exist, however, it was developed based on the conventional event by event data acquisition approach. This paper highlights the advancements of the MuCh clustering and hit creation process introducing dynamic adaptations to temporal patterns to work with the time-stream data. The advancements discussed in this report are implemented within the `CbmMuchFindHitsGem` class which is used for MuCh subsystem hit reconstruction.

Implementation

The clustering algorithm serves as the linchpin in the conversion of digis into hits, grouping digis to form coherent, meaningful data entities. The available MuCh clustering algorithm provided a foundational framework for organising detector data into clusters. Broadly it processes module wise time sorted digis for a predefined fixed time interval and creates spatial groups on the basis of spatial neighbouring pads and for each local maxima create the hit position based on the weighted charge. It is explained in the MuCh TDR [2]. As it is developed for event by event processing therefore reliably it cannot be used for time based mode (spatially for 10 MHz interaction rate) and it has limitations for handling more complex temporal patterns. Recognising these limitations, we introduced a few conceptual changes to dynamically adapt to the temporal characteristics of the data in the clustering algorithm. A realistic "Cluster Time Slice" is created when the time gap between consecutive digis exceeds the threshold which is twice of the underlying detector time resolution. This ensures that digis occurring after above time interval are grouped separately, maintaining temporal coherence within each cluster.

With the experience of mCBM data analysis, a limit on a maximum time spread of the temporal cluster is also introduced. Earlier, the algorithm was only taking care for clusters within an event therefore a temporal cluster can not be longer than an event. In a free-streaming data taking, due to high interaction rate, event pile-ups increases same pad firing probability. Moreover, at the CBM energies, MuCh will face a moderate detector occupancy, therefore, probability further increases for firing the same pad in a consecutive events. To deal with such situations, a check

*Electronic address: vikas@vecc.gov.in

is introduced that two digis on the same pad cannot be part of a cluster, though, they are temporally far. This refinement overcomes the risk of erroneously grouping digis that belong to distinct incident tracks. Further, temporal 'strict cut' on the separation of two clusters is removed and by comparing the time differences of consecutive digis and then accordingly time slices are adjusted. By this, the algorithm can better capture the nuanced temporal patterns present in the data.

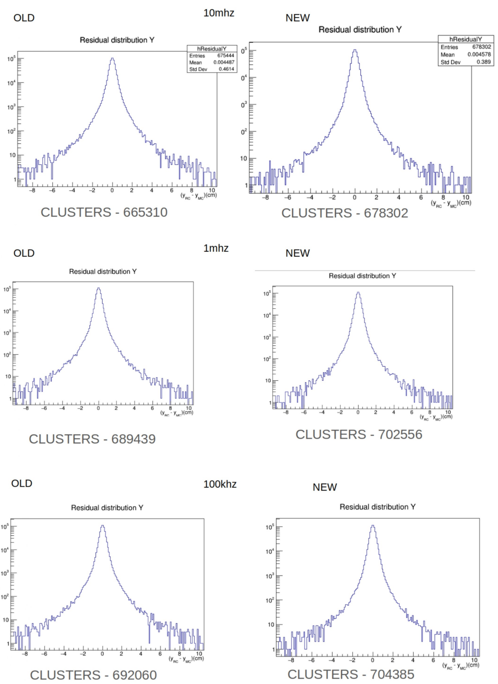

FIG. 1: Residual plots for hit reconstruction, left side using existing algorithm and right side using modified algorithm.

Figure 1 represents a residual plots for Y-coordinate for reconstructed hits across varying interaction rate (10 MHz, 1 MHz, and 100 kHz) in the time based simulation mode for the existing and modified clustering algorithms. The residual plots for X-coordinate are not shown as those are similar. Across all frequency settings, a noticeable increase in cluster count is observed with the modified clustering algorithm compared to the previous version. This rise in cluster count indicates better clustering achieved by the updated algorithm.

Conclusion

To summarise, the updated time-based clustering algorithm improves upon the previous version by dynamically adapting to temporal patterns and maintaining spatial separation capabilities. It enhances in temporal separation leading to increasing number of clusters and hit formation contribute to improved accuracy and fidelity in identifying and analysing hits within the detector system to handle the 10 MHz interaction rate. The algorithmic performance is derived from simulated Monte Carlo (MC) points across multiple interaction rates varying from 10^4 to 10^7 Hz with the time based CBM framework. Further, work is going on to utilise this modified clustering and hit creations process for mCBM data analysis.

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