EVENT BUILDING FROM FREE STREAMING DATA AT THE CBM

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Event building is essential part of the CBM reconstruction chain. Event building is performed in two steps. The first one is an event finding to determine a moment of time when heavy-ion collision had happened. The second one is an event composition, when data corresponding to the found event is collected from several CBM subdetectors. Both event finding and event composition for CBM is described in this paper. General method of event composition for all subdetectors except calorimeters is concluded.

Keywords: Event building, event finding, free-steaming readout, time-based reconstruction

1. Introduction

The CBM will be the first experiment employing a new data treating technique. All data collected from the detector will be transported to computer farm. Physical objects (such as tracks and vertexes) will be reconstructed in the real time and interesting events will be stored for further detailed analysis. A unit of data in this approach is a timeslice – all data collected from all subsystems of the CBM detector in a given period of time. Timeslices contain information from many heavy-ion collisions and may be analyzed independently at different nodes of the computing farm. Information produced by particles, originating from individual heavy-ion collision (event), should be used for physical analysis rather than free streaming data. So dedicated event building procedure from free-streaming data is required. Event building can be performed at different data levels. Sophisticated methods require tracks and vertexes reconstruction and should work for high interaction rate (10 MHz). But development and tuning of such methods require well established time-based reconstruction chain which is absent at the moment. The simplest event building technique works at the level of individual activations of readout electronics channels (digis). This technique is fast and robust, allows usage of standard event-based reconstruction algorithms for free-streaming data, but has limited rate capability. Simplest event building should be used up to 1.5 – 3 MHz heavy-ion collision rate. Each digi, used for the procedure, contains information about activation time, channel number, etc. Event building can be divided in two steps. The first one is an event finding to determine a moment of time when heavy-ion collision had happened. The second one is an event composition, when data, corresponding to the found event, is collected from several subdetectors of CBM setup.

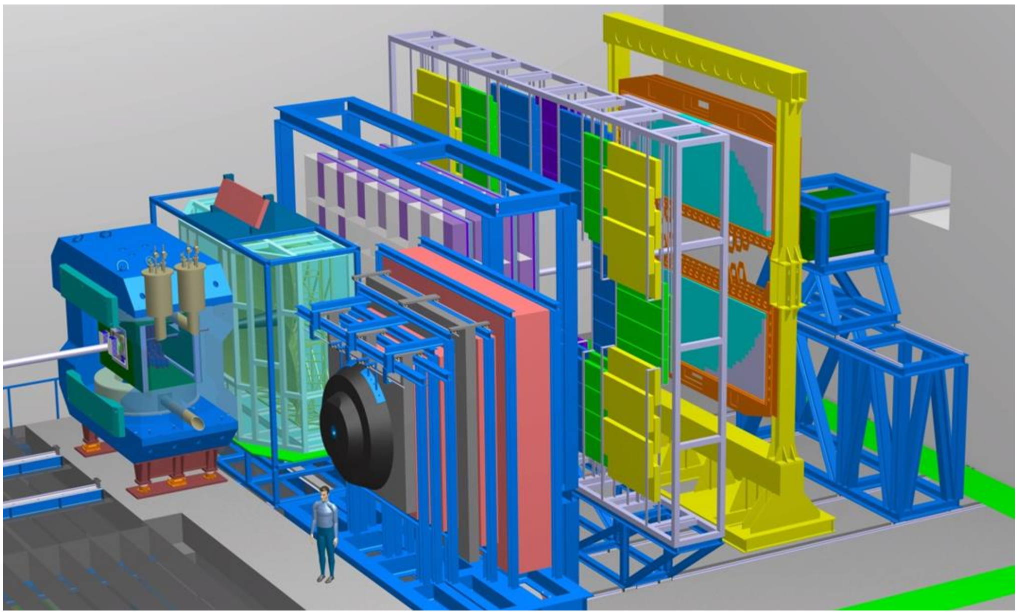

Figure 1. The CBM setup

2. The CBM setup

The scheme of the CBM setup is shown in Figure 1. Beam comes from the left. Target, vertex (MVD) and tracking (STS) detectors located inside the magnet. RICH (Ring image Cherenkov detector) can be replaced with MUCH (muon detector). TRD (transition radiation detector) and time-of-flight (TOF) detector located afterwards and used for particle identification and provide addition tracking information. Finally, there are the electromagnetic calorimeter (ECAL) for photon reconstruction and projectile spectator detector (PSD) near the beam dump.

3. Event finding

Event finding can be performed using data from only one subdetector. The subdetector should be fast, should have good time resolution, adequate acceptance and low noise levels Currently STS and BFTC (forward TOF region) are considered for event finding. This work is focused on using STS for event finding because its modeling procedure is much more detailed and stable than BFTC one.

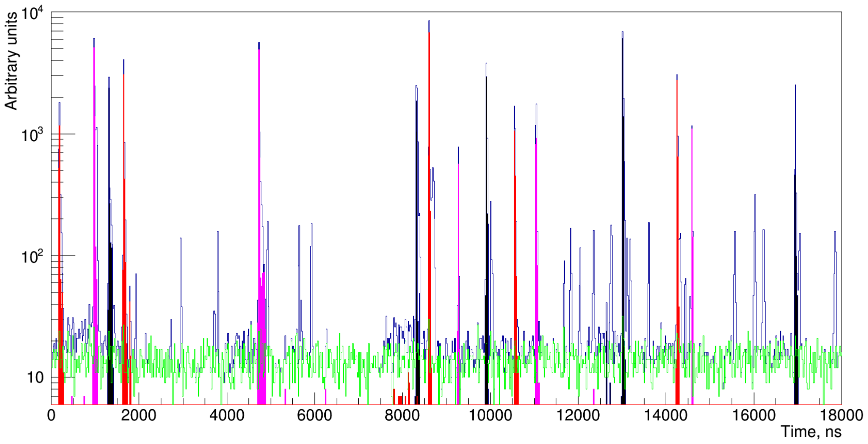

Figure 2. Number of digis from STS detector as a function of time. Blue curve corresponds to all digis coming from the detector, green curve is electronics noise. Colored peaks correspond to particles born in different heavy-ion collisions except for delta-electrons

Typical number of digis, coming from STS detector, as a function of time is shown in Figure 2. Modeled by UrQMD [1] collisions of gold ions at 10 AGeV with 1 MHz interaction rate has been used for the picture. Electronics noise of STS detector has been modeled while no delta electrons, born inside the target due to ion beam, have been simulated. Number of electronics noise and signal digis is comparable in the output of the STS detector at 1 MHz collisions rate. The noise affects the event finding quality. The spectra of the noise and signal digis are shown in Figure 3. Cut ≥2 ADC counts has been used for further studies allowing to keep most of signal digis and cutting almost all the noise out.

In general, event is found if the number of digis in a given time window exceeds a given threshold, which depends on collision system and interaction rate. The event finding efficiency and fraction of correctly found events have been studied as a function of time period used for event finding and number of digis required for event finding. The studies have been performed for minimum bias AuAu collisions 10 AGeV at 1 MHz interaction rate. This colliding system is most difficult for event finding because peripheral collisions should have high probability to be found and, at the same time, algorithm should not produce many fake events due to the clouds of delta electrons, born in the detector after most central collisions. An event has been counted as foundable if it has at least 5 reconstructed long (4 hits or more) tracks in event-by-event approach. An event has been counted as correctly found if it is matched with MC event and more then 98% of its digis is originates from particles from matched MC event. A dead time has been introduced after each found event to suppress production of fake events due to delta electrons, born by particles passing through the material of the detector. The dead time after preliminary optimization has found to be 50 ns. Region of optimal time period and threshold number of digis required to find the event is quite large. The typical event finding efficiency inside the region is 93% and fraction of good events inside the region is about 85%.

The event finding procedure is quite fast (~10 ms per event at one core of Core i7-4970K 4.2 GHz) so found events can reconstructed in parallel using different cores of the computing node to increase the level of parallelism and effective amount of memory to store the time slice.

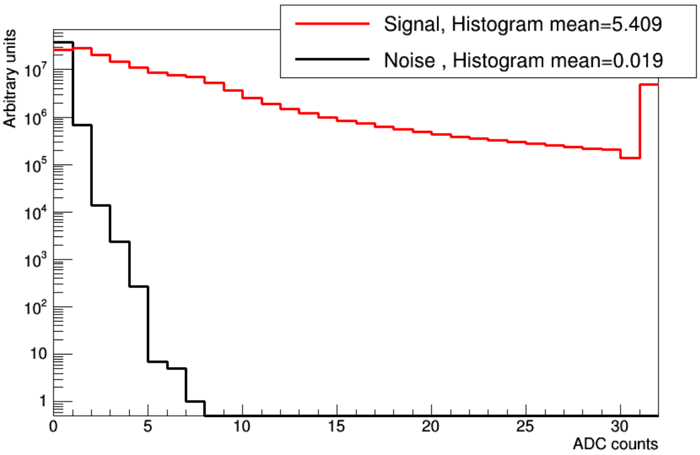

Figure 3. Spectra of signal and noise digis in STS

4. Event composition

Event composition for STS detector is quite easy. The found period of time extended by -5 ns and +15 ns (hereinafter acceptance window). All STS digis (without any cuts) inside the acceptance window are added to the found event.

To describe idea for other detectors let us start with the time-of-flight detector. The time resolution of TOF detector is very good (better than 100 ps) and it can be treated as ideal for event composition. The distance between the target and TOF wall is quite large. Light requires more than 20 ns to travel the distance (for comparison, the acceptance window is 25 – 35 ns in region optimal for event finding). Therefore, in order to add TOF digi into the found event one should subtract from its actuation time a value:

$$l/c,$$

where l is a distance between triggered channel and the target (for example, distance from target to the center of triggered strip) and c is a speed of light. If after the correction (hereinafter l/c correction) digi actuation time falls into the acceptance window, then it is added to the event.

To test the proposed method and estimate its quality, a standard distribution of mass squared versus momentum for all reconstructed particles have been built. The distribution for central gold-gold collisions with energy 10 AGeV and 10 KHz interaction rate is shown in the right plot of Figure 4. The reference distribution, obtained in event-by-event approach, is shown in the left plot of Figure 4. Horizontal regions, corresponding to $\pi^{\pm}$ and K^{+}-mesons and protons, are clearly seen in both plots. The width of these regions is larger in case of free-streaming data, because of the final precision of TOF measurement determined not only by detector resolution (like in event-by-event approach) but also by precision of T0 determination. Moreover, many low momentum reconstructed tracks (especially protons) stays unidentified in case of free-streaming approach, because the extended time window may be insufficient to include digits generated by slow particles. Fine tuning of the acceptance window for the TOF detector may allow to improve the situation and may be the subject of further studies.

MUCH is designed for muon identification and consists of several absorbers interlayered with tracking GEM stations for coordinate measurement. All particles, except muons, are stopped in absorbers and do not produce any signal in tracking planes. The distance between tracking planes and the target differs from 1 to 5 m. It is expected, that STS and MUCH will use the same readout electronics. But the time resolution of MUCH is worse than STS one because of drift effects in GEM planes. MUCH digi is added to the found event is its time after l/c correction lays inside enlarged accepance window. Enlargement by 50 ns in both directions is required to take into account worse time resolution of the MUCH detector. If two enlarged time windows overlap, then digis from the intersection are added to both events which may require careful further analysis.

To estimate applicability of the method, reconstruction of $J/\psi \rightarrow \mu^+\mu^-$ decay for central gold-gold collisions at 10 AGeV and 10 KHz interaction rate has been studied. Simplified CBM geometry, consisting of the STS detector and the starting version of MUCH detector, has been used. UrQMD generator has been used for simulation of heavy-ion collision. Products of the decay $J/\psi \rightarrow \mu^+\mu^-$ have been modeled with Pluto [2]. MUCH readout electronics noises have been taken into account for the free-streaming data. These noises have not been simulated in event-by-event approach. Track reconstruction and particle identification has been performed using standard CBMROOT algorithms. Reconstruction of $J/\psi \rightarrow \mu^+\mu^-$ decay has been done by KFParticle software package. The track has been identified as muon if it has at least 11 hits in MUCH detector. The results for event-by-event and free-streaming reconstruction coincide within the errors.

Generally speaking, described method, namely *l/c* correction to a digi actuation time and enlargement of the time window according to the time resolution of the subdetector, should work for arbitrary subdetector (RICH or TRD, for example) except for calorimeters.

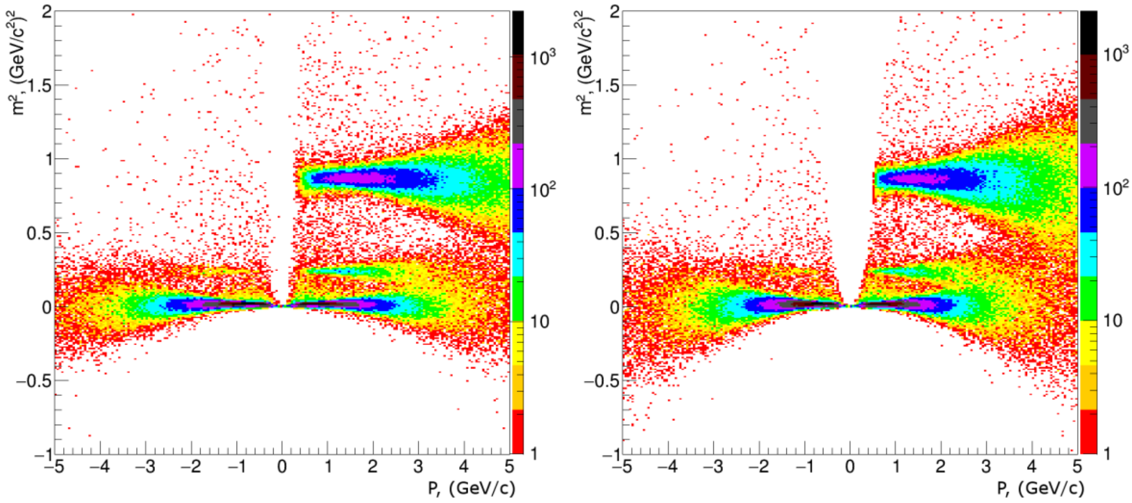

Figure 4. Distributions of squared reconstructed mass vs. momentum for identified tracks. Distribution for event-by-event approach is shown on the left, distribution for time-based approach is shown on right

5. Conclusion

Simple event building method has been described. An event finding efficiency up to 93% has been reached. Fast event finding provides opportunity to increase parallelism of CBM reconstruction algorithms. A general event composition method for all detectors except calorimeters has been developed.

References

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[2] I. Frohlich et al., “Pluto: A Monte Carlo Simulation Tool for Hadronic Physics,” PoS ACAT, 076 (2007) [arXiv:0708.2382 [nucl-ex]].