Optimisation of Selection Cuts for MUCH detector of CBM experiment

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The Compressed Baryonic Matter (CBM) experiment is one of the future research program scheduled at FAIR, Darmstadt Germany. The aim of the planned experiment is to explore the Quantum ChromoDynamics (QCD) phase diagram in the regions of high baryonic densities and moderate temperatures in the beam energy range of 10-45 AGeV. This approach is complementary to the studies of matter at high temperatures and low net baryon densities performed at RHIC and LHC. CBM will also search for the critical point, the first order deconfinement phase transition from the hadronic matter to the partonic matter and the study of equation-of-state of dense baryonic matter. Comprehensive scan of observables, beam energies and collision systems is realised. The observables include: low-mass dilepton pairs, charmonia and open charm, collective flow of rare and bulk particles, correlations and fluctuations etc. Low yield measurements of rare probes, like charmoniun and low mass vector mesons, have to be performed at very high reaction rates$\sim$10 MHz. These conditions demand for fast and radiation hard detectors and associated fast electronics, readout and online event reconstruction. Low material budget is required with in the detector acceptance to avoid multiple scattering which would limit high-precision measurements [1].

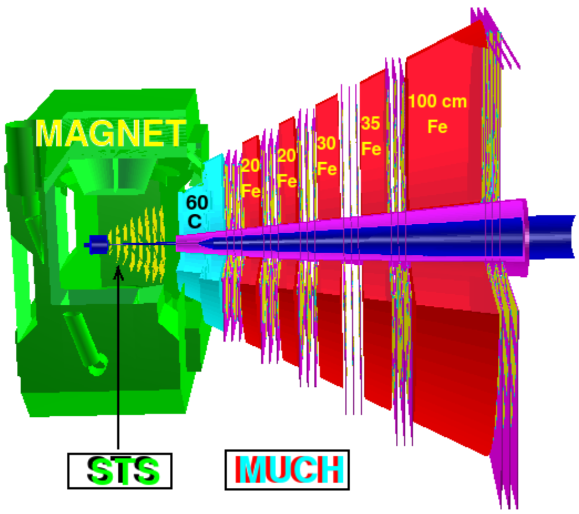


Figure 1: Muon Chamber set-up in CBM experiment for 25 AGeV collision energy

For muon measurements, identification of high and low momentum muons simultaneously i.e. to cover both the regions of low-mass vector mesons(ρ, ω, ϕ) and high mass regions of charmonia (J/ψ) is the challenge for the detector. The novel feature of the proposed muon chambers (MUCH) is that the total absorber is sliced and detector chambers are placed in between absorbers to facilitate momentum dependent track identification. This improves the detection efficiecny of low momentum muons, which would have been otherwise stopped by a single thick absorber. The full design of the muon detector system consists of 6 hadron absorber layers, first made of carbon of thickness 60 cm and rest five iron absorbers of thickness 20, 20, 30, 35, 100 cm respectively as shown in Fig. 2b. The 18 gaseous tracking chambers are located in triplets behind each hadron absorber.

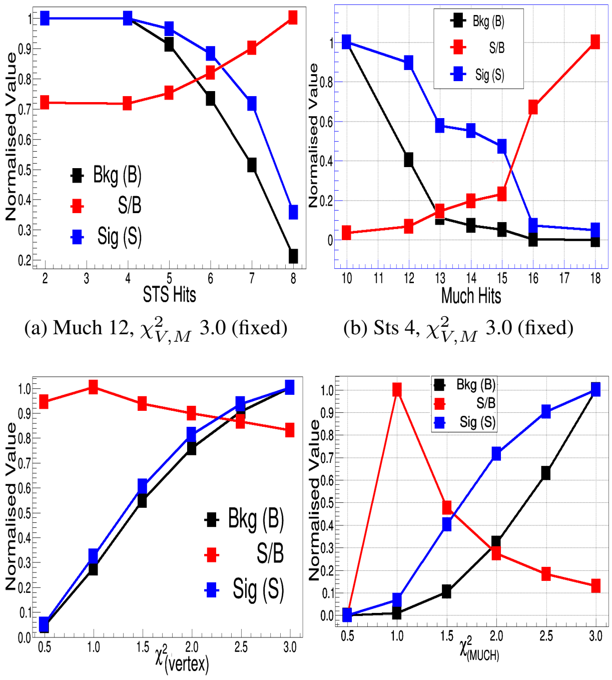
The layout of the MUCH system, i.e. the number, thickness and material of the absorber slices, the number and granularity of the tracking detectors among others has been optimized by simulating the response of the Au+Au collisions at 25 A GeV beam energy using input particles from the UrQMD event generator for background generation. Signal particles like low-mass vector mesons or charmonium are generated using PLUTO event generator. Events from PLUTO and UrQMD are then embedded and transported using the GEANT through the CBM set-up. Primary track finding and reconstruction is carried at STS using cellular automaton method and MUCH detector propagates these tracks through the detector in which track and vertex fitting makes use of a Kalman filter [2].

Selection Cuts

MUCH detector is supposed to detect the muons from the rare probes like charmonium and LMVM. So its very important that it should be placed and used in most effecient way. Most important criteria for muon detection system is to reduce the background and at the same time enhance the signal in best possible way. Once experimental set-up is fixed then one can enhance the signal over background by following ways:

- By collecting More Data: More data means reduction in relative statistical error resulting in clear signal identification.
- By Data (offline selection) Cuts: One can enhance signal significance by using some special criteria that allow one to suppress background by a large factor while leaving the signal events relatively intact. For example, if background charged tracks are mostly pions, one can use electron/pion separation criteria.
- Trigger (online selection cuts): Often one is limited not by a number events that can be produced, but by

the number of events one can record. Then, online selection/cuts (trigger conditions) can be applied to enhance the statistical significance of the signal being looked for. For instance, identification of electrons discussed above can and is often done online.



(a) Much 12, $\chi^2_{V,M}$ 3.0 (fixed) (b) Sts 4, $\chi^2_{V,M}$ 3.0 (fixed)

(c) Much 12, Sts 4, χ^2_M 3.0 (fixed) (d) Much 12, Sts 4, χ^2_V 3.0 (fixed)

Figure 2: Effect on Background (black line), Signal (blue line) and S/B (red line) when Analysis Cut is on: (a) STS Hits, (b) MUCH Hits, (c) $\chi^2(vertex)$, and (d) $\chi^2(Much)$ at 25 AGeV central Au+Au collisions. All curves are normalised to its highest value.

In present work we looked for the optimised selection cuts in our analysis procedure for best signal to background ratio (S/B). Work has been done using GEANT3 simulation with heavy ion collision events given by the UrQMD event generator for radiation background. We used signal input for ω at 25 AGeV Au+Au collisions from the PLUTO event generator with multiplicity taken from HSD and branching ratios from Particle Data Group(PDG) database [2]. We analysed the overall detector performance interms of reconstruction effeciency and background reduction for effecient muon detection which can be quantified interms of a quantity like S/B (signal to bacground ratio). Invariant mass spectra has been calculated from the reconstructed signal muons after embedding them event by event into the UrQMD events.

We have four important parameters that can be exploited in our analysis namely Much Hits, Sts Hits, χ^2_{vertex} and χ^2_{MUCH}. Each parameter has been analysed separatly while keeping others to a loose and fixed value. We plotted the peak background calculated perevent, signal effeciency (%) and their ratio S/B. Fig. 2 shows the results for the same. Each curve in the plot has been normalised to its highest value [which corresponding to S (%), B (per event), S/B are: Fig. (2a) 5.72, 0.000371, 0.0141 Fig. (2b) 6.4, 0.000921, 0.147, Fig. (2c) 5.72, 0.000371, 0.0122, and Fig. (2d) 5.72, 0.000371, 0.0776]. From Fig. 2a its clear that S/B can be improved slighly if cut is on STS hits above 5 where as from Fig. 2b S/B improves if cut is on Much hits above 13. For χ^2_{vertex} cut below 2.0 looks good and for χ^2_{MUCH} from 2.0 to 1.0 is better as far as S/B is concerned. To get overall gain from the combined effect for best S/B one has to compromise for the signal loss upto certain fraction. A combined effect can be seen from the results shown in Fig. 3.

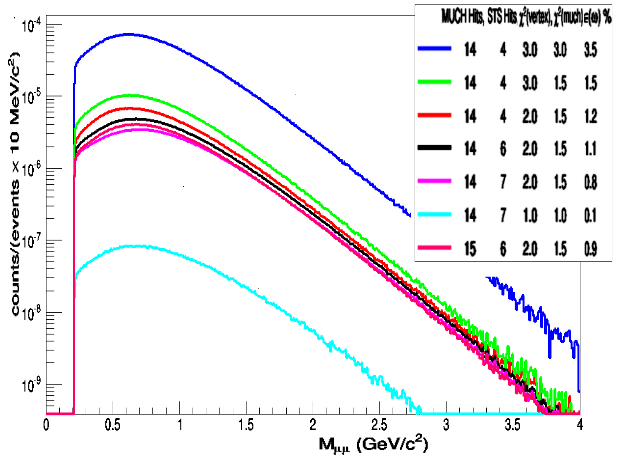


Figure 3: Combined effect of all selection cuts on background as well as Signal.

It can be seen from the figure, to reduce the background, conditions on the quality of the number of hits in STS and MUCH, on the quality of the primary vertex, and on the quality of the tracks in the MUCH are required. From the above results it can be seen that MUCH optimised cut values are "sts hits $\geq$ 6, much hits $\geq$ 14, chi^2 vertex $\leq$ 2.0, chi^2 much $\leq$ 1.5. These cuts are the best compromise between signal effeciency ($\sim$ 1% for ω at 25 AGeV collision energy) and background reduction giving highest and best S/B value with no acceptance loss apart from the one that is due to hadron absorbers.

References

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