# A systematic investigation of di-muon combinatorial background for $\omega$ in the CBM experiment at FAIR

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## Introduction

The focal aim of the Compressed Baryonic Matter (CBM) experiment at FAIR is to explore the QCD phase diagram in the region of high net-baryon densities and moderate temperatures [1]. This experiment is designed to run at unprecedented high interaction rates which would enable precision measurements of rare diagnostic probes which are sensitive to the dense phases of the nuclear fireball. The research program of CBM at SIS100 includes the pioneering measurements of the di-muon ($\mu^+\mu^-$) spectrum with it's full glory in the heavy-ion collisions. Muons being leptons do not respond to strong interactions and thus believed to carry unscathed information about the dense interior of the collision zone. In the multiparticle environment characteristic of relativistic nuclear reactions, the di-muon signals are superimposed on a generally large combinatorial background. Depending on the underlying physics process, the signal could either appear as a narrow peak (eg: resonance decays in muon channel) or might be a continuum (eg: Drell-Yan process, Dalitz decay of vector mesons etc.). When the signal (S) appears as a narrow peak riding over the continuous background (B), it can be extracted by following standard methods of fitting the signal + background distribution with appropriate functions chosen in order to provide a good description of the overall spectrum. This technique however does not work if signal and background have a similar shape like in case of continuum signals. The same is true when resonant signal is small and burried under the background, as is the case at FAIR energies, owing to extremely small multiplicities of the resonance mesons in the di-lepton channel. The only way to overcome the problem is to estimate independently the background distribution and to subtract it from the overall S+B spectrum. In the present article, we demonstrate a method for estimating the combinatorial background and extraction of a di-muon resonance signal ($\omega \rightarrow \mu^+\mu^-$) in 8 AGeV Central Au+Au collisions.

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## Analysis procedure

For this analysis we have used CBM detector setup with Silicon Tracking Stations (STS), MUon CHamber (MUCH), Transition Radiation detector (TRD) and Time of Flight (TOF) detectors [2]. Analysis has been done with the final reconstructed tracks which satisfy some optimized selection cuts specific for identification of muon like candidates viz : the track should have atleast 7 STS hits, 11 MUCH hits, $\chi^2_{STS}$ <2, $\chi^2_{MUCH}$ <1.3 & $\chi^2_{Vertex}$ <2 [2]. A track satisfying these conditions are treated as a muon candidate. Positively and negatively charged muon candidates are stored separately. Signal $\omega$ is generated from PLUTO event generator and background particles are generated from UrQMD. Particle interactions with the detector material has been taken care in GEANT3 transport code.

## Results and discussion

The invariant mass distributions are obtained by pairing different charge combinations muon candidates, like, ++, - - and +- .The combinatorial background is estimated from UrQMD events only, with same event (SE) and mixed event (ME) technique. In SE, pairs are constructed from unlike charge combinations muon candidates from same event. Whereas, in ME, unlike pairs are formed from muon candidates always taken from different events but not from same events. Fig. 1 shows the background distribution calculated from these two methods.

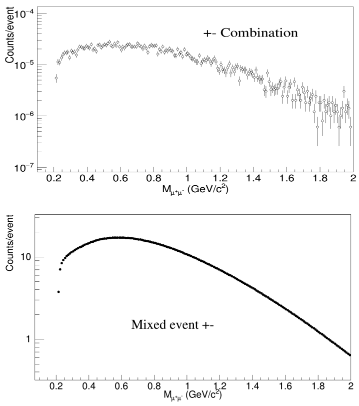


FIG. 1: (top) background distribution from same event. (bottom) mixed event

Combinatorial background in general,refers to uncorrelated pairs of muon candidates not originating from the decay of same mother particle. So one may expect background shape obtained from different methods, to be identical. This has been shown in Fig. 2 by calculation the ratio of SE and ME background distibution. The ratio was found flat over the entire range. Now to estimate signal (S) strength, we reconstruct the invariant mass of $\omega$ decaying to $\mu^+\mu^-$ from embedded events (PLUTO + UrQMD). The signal pairs are weighted by $\omega$ multiplicity in the dimuon channel (19×9×1e-5). To get a realistic dimuon invariant mass spectra, the signal invariant mass distribution was added to background distribution obtained from ME.

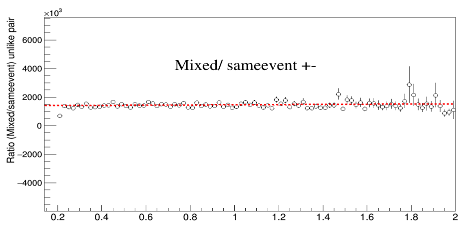


FIG. 2: background ratio of mixed event to same event

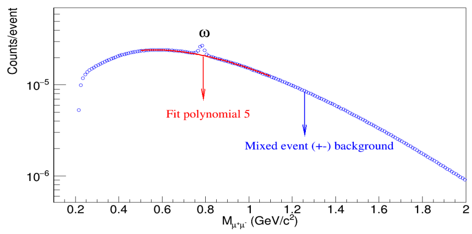


FIG. 3: Mixed event background superimposed with signal $\omega$.

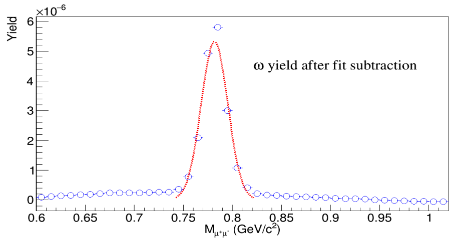


FIG. 4: Signal $\omega$ yield.

As the signal peak over background is very small, so to get a significant yield of signal we need very high statistics for a stable background & ME background has been well suitable for its smooth shape due to large statistics. Here ME background has been scaled to the same lavel as same event. The ME background has been properly fitted with $5^{th}$ order polynomial. The total signal + ME background along with the background fit have been shown in Fig. 3. Finally fit is subtracted from the total S+B spectra to get the signal $\omega$ yield as shown in Fig. 4. We get pair reconstruction efficiency of $\omega$ ~0.97 % which is comparable with the signal efficiency from true dimuons.

## References

[1] Muon Chamber, Technical Design Report.
[2] DAE Symp. on Nucl. Phys. **61**, 808-809 (2016).