Di-muon cocktail reconstruction using machine learning technique in CBM experiment at FAIR

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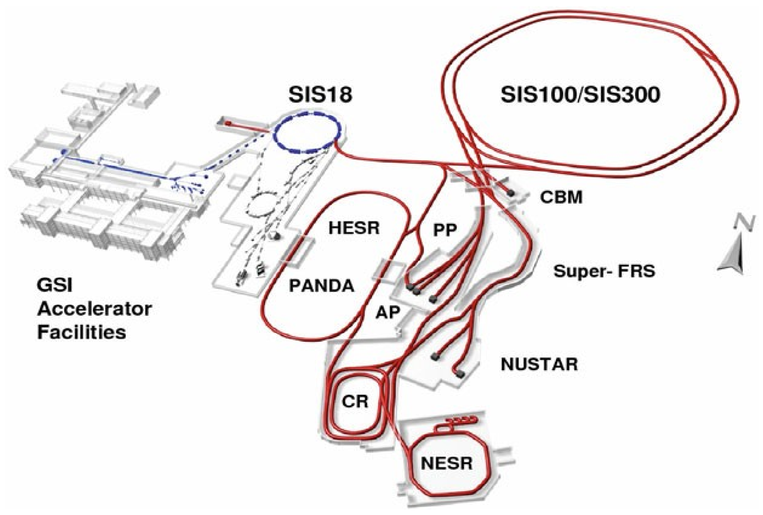
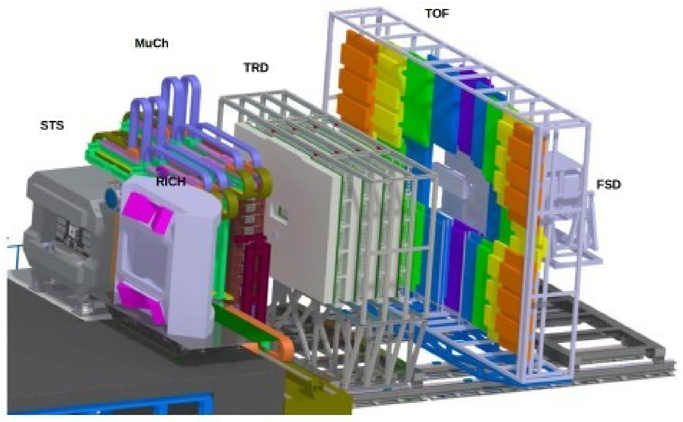
Compressed Baryonic Matter (CBM)



Experiment at GSI-FAIR

- A fixed target experiment in the energy range, 2-35 AGeV for heavy ions.
- Precision measurements of diagnostic probes of strongly interacting matter at extreme net-baryon densities, at SIS 100 energy ranges.
- Main features: High interaction rates, up to ~10 Mhz.
- Lot of new measurements in SIS 100
  energy ranges. Requires very fast and radiation hard detectors, novel DAQ, free streaming electronics.



CBM Experimental Setup

Physics goals :

- Partial Chiral Symmetry Restoration (changes of masses, decay widths of hadrons in medium)
- Thermal approach to collision (T_{preeq}, T_{Chem}, T_{Kin})
- Equation of State,
- Exploring hadron gas ⇒ QGP transition,
- Quarkyonic matter + Critical point searches

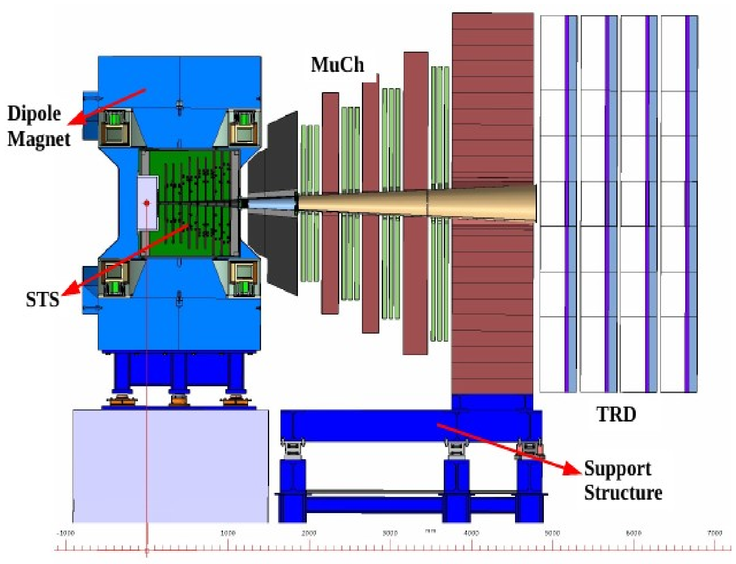
AIM: The properties of strongly interacting matter can be studied by the measurement of rare probes,

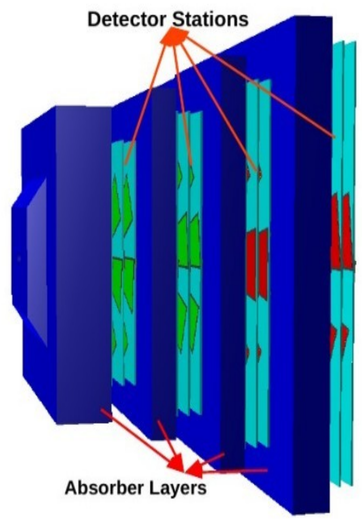
- Low Mass Vector Mesons (ρ , ω , φ)
- Thermal EM radiation
- J/ψ dissociation.

$$\omega(782) \rightarrow \mu^+\mu^-$$
$$\eta(547) \rightarrow \mu^+\mu^-$$
$$\phi(1019) \rightarrow \mu^+\mu^-$$
$$\rho(770) \rightarrow \mu^+\mu^-$$

- The particle multiplicity of the particle like ω, η, ϕ, ρ is quite low.
- The CBM Experiment will exploits the leptonic decay modes of these rare probes.

Muon Chamber (MuCh) System

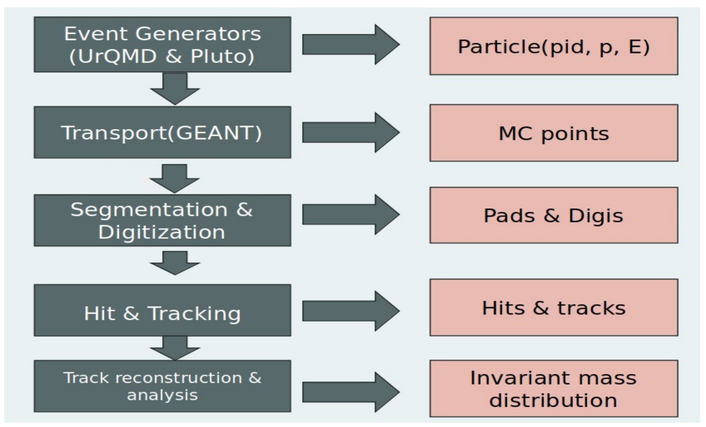




Schematic of CBM-MuCh setup

- Challenge: Identification of low momentum muons in an environment of high particle densities.
- The novel feature of MuCh: Alternate absorbers and detector stations for detection of both Low Mass Vector Mesons(LMVM) and J/ψ.
- There are 4 stations (2 GEM + 2 RPC) and 4 absorbers (3 Fe + 1 C).
- Segmented absorber allow us to reconstruct low momentum muons originating from LMVMs.
- High particle rate (150 kHz/cm^2 for minimum bias collisions) at first two stations → Triple GEM modules.
- As the decayed leptons leave the dense and hot fireball without further interactions, they can provide unscathed information about the fireball
- Dilepton invariant mass can be used to find the temperature and lifetime of the fireball.
- CBM experiment is important as no di-lepton data have been measured in heavy-ion collisions at SIS100 beam energies.

Simulations



Simulation Procedure

→ Muon track candidates selected from the manual cuts & using ML.

Machine Learning

→ To improve the dimuon performance.

→ Signal and background have following variables for training

ML models: Mass, Momentum, $\chi2_{MuCh,}$ $\chi2_{STS,}$ $\chi2_{Vertex,}$ No. of MuCh Hits, No. of STS Hits, No. of TRD Hits, No. of TOF Hits

Models covered using TMVA

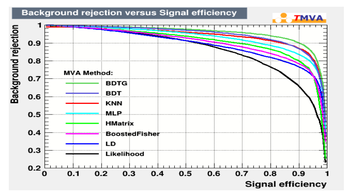
Gradient Boosted decision trees(BDTG)

Multi Layer Preceptron(MLP)

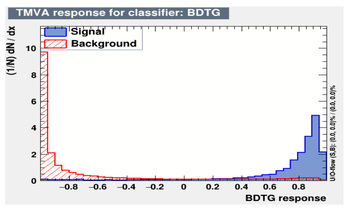
KNN

Hmatrix

→ BDTG model performs better among them.



ROC Curve



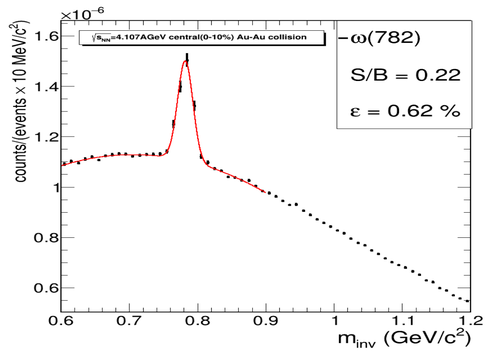
Separability of signal and background

Simulation Results

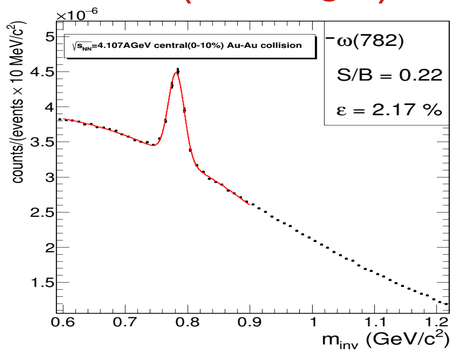
(8 AGeV Au-Au central collisions)

Invariant Mass Spectra of omega meson (ω -> μ⁺ μ⁻)

Manual selection cuts

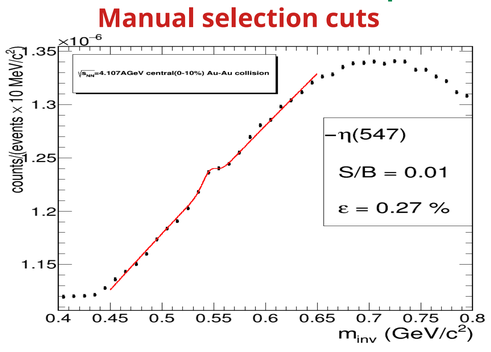


BDTG(Score cut @0.7)

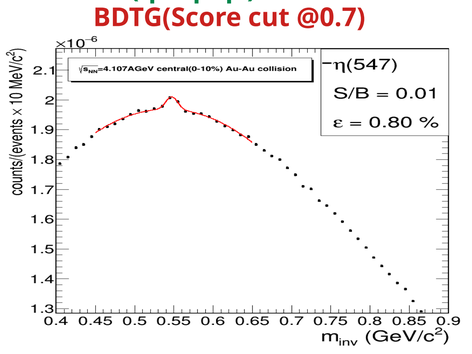


Invariant Mass Spectra of eta meson (η -> μ⁺ μ⁻)

Manual selection cuts

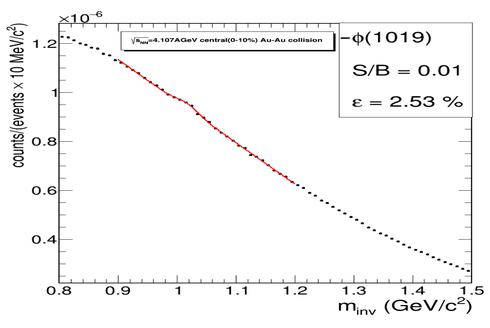


BDTG(Score cut @0.7)

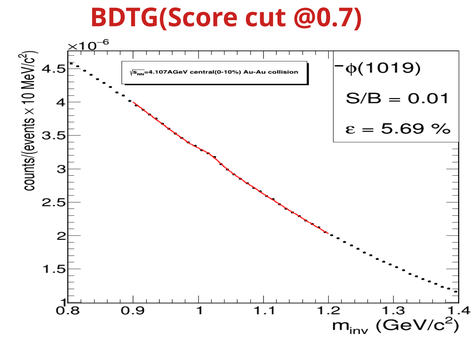


Invariant Mass Spectra of phi meson (ϕ -> μ⁺ μ⁻)

Manual selection cuts

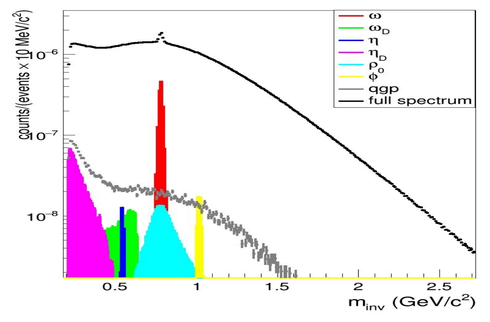


BDTG(Score cut @0.7)

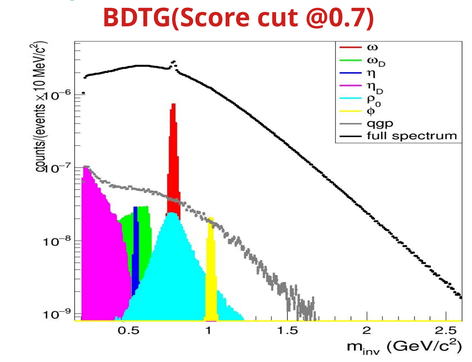


Freeze-out dimuon cocktail spectra

Manual selection cuts



BDTG(Score cut @0.7)



→ For Similar S/B ratio, there is increase in reconstruction efficiency for ω,η φ mesons with the help of ML techniques.

References

1. Chattopadhyay, S., Viyogi, Y. P., Senger, P., Müller, W. F. J. and Schmidt, C. J. (2015), *Technical Design Report for the CBM : Muon Chambers (MuCh).* The CBM Collaboration.

2. TMVA - Toolkit for Multivariate Data Analysis, arXiv:physics/0703039

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