Detection of Low Mass Vector Mesons with Realistic Muon Detector System at 8 AGeV Au+Au Collisions in CBM Experiment at FAIR

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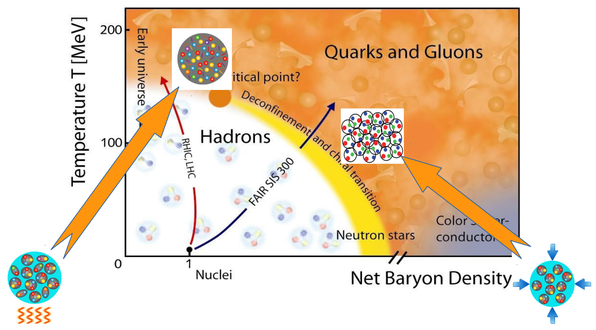
Abstract The Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) in GSI, Germany is a future fixed target experiment which will perform the precision measurement of dilepton pairs in the full mass region (low mass to charmonium) in the energy range 4-40 AGeV. The objective of the MUon CHamber (MUCH)[1] detector in the CBM experiment is to study the di-muon spectra at different mass regions. One of the major experimental challenges of the CBM experiment in the FAIR energy regime is the identification of low momentum muons, originating from the decay of low-mass vector mesons (LMVM), in a very high particle density environment. Till date, no dilepton measurements are available for heavy-ion collisions in the FAIR energy range. We report the performance of the latest CBM MUCH detector, characterized by the detection efficiency and S/B for LMVM.

CBM experiment at FAIR and its physics goal

CBM physics cases and observables

The CBM research program is focused on the following physics cases

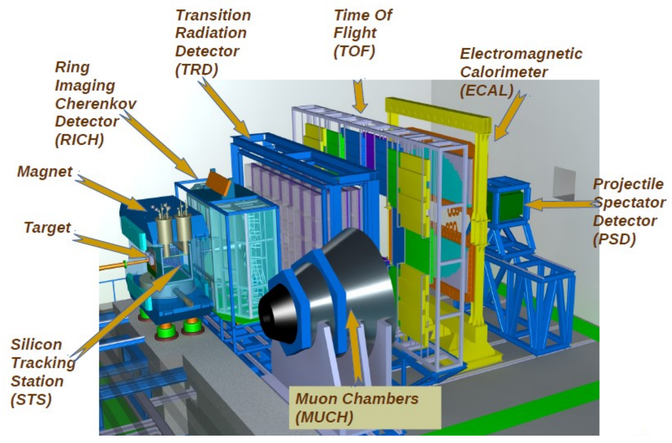
- **The equation-of-state at high ρ_B**
  collective flow of hadrons
- **Indication of Deconfinement phase transition at high ρ_B**
  – Flow of strange (K, Λ, Σ, Ξ, Ω), Charm hadrons (J/ψ, ψ', D0, Ds, D±, Λc) and dileptons
  – Charmonium suppression, J/ψ and ψ
  – Strangeness enhancement
- **QCD Critical End Point (CEP)**
  Event by Event fluctuations of conserved quantities and particle ratios (K/π, ... Ξ/ π, Ω/ π)
- **Onset of chiral symmetry restoration at high ρ_B**
  In-medium modifications of mass and width of hadrons (ρ,ω,ϕ →e+e-(μ+μ-))



At very high temperature:
-- N of baryons ~ N of antibaryons
-- Situation similar to early universe
-- L-QCD finds crossover transition between hadronic matter and Quark-Gluon Plasma
-- Experiments : ALICE, ATLAS, CMS at LHC,STAR, PHENIX at RHIC

At high baryon density:
-- N of baryons<< N of antibaryons
-- Densities like in neutron star cores
-- L-QCD not (yet) applicable
Models predict first order phase transition with mixed phases
-- Experiments: BES at RHIC, NA61 at CERN SPS, CBM at FAIR, NICA at JINR

CBM Experimental Set-up

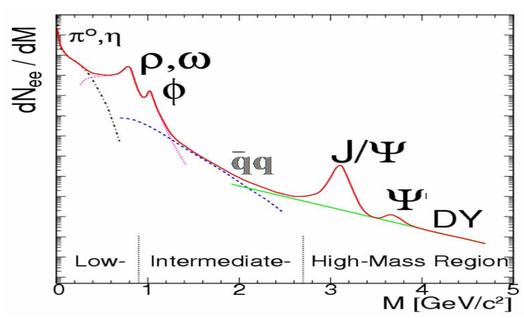


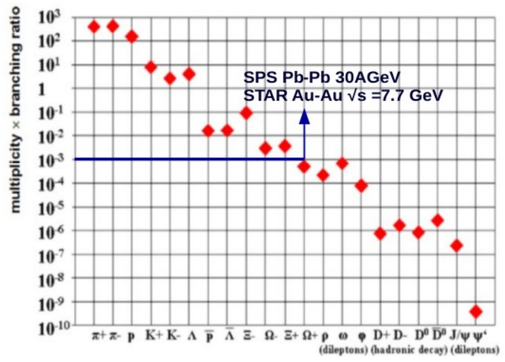
Experimental Challenges

-- 10^5 -10^7 Au+Au reactions/sec
-- Determination of (displaced) vertices ($\sigma \sim 50\ \mu m$)
-- Identification of leptons and hadrons
-- Fast and radiation hard detectors
-- High speed data acquisition and high performance computer farm for online event selection
-- 4D event reconstruction

Challenges of Dimuon Measurement at CBM

Major sources of di-leptons ---

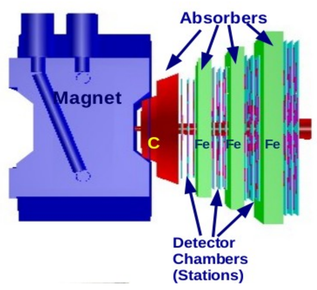


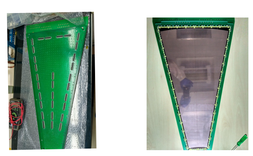


- **No charm data in A-A collisions below 158 A GeV**
- **No di-lepton measurement between 2-40 A GeV.**
- **First time CBM aims to measure precisely multi-strange and particles containing charm quarks which are rarely produced.**
- **Previous experiments at AGS and SPS has overlap with CBM energy but due to low luminosity and detector limitations they could not measure rare particle whose cross-section is very low.**
  – **CBM will collide heavy-ion beams at very high interaction rate (~10 MHz).**
  – **This would help in collecting high statistics data for rarely produced particles (eg. J/ψ, ρ, ω, φ)**

Muon Detector

Muon Chamber



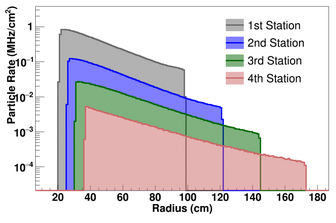


GEM Modules

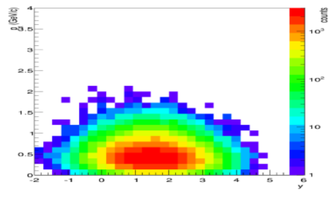
- Muon Chamber is a conical shaped set-up with detector coverage 5.7° to 25° (1.5<η<3.0) to cover most of the forward focused particles.
- Muon chamber starts at a distance 125 cm downstream along the beam line from the target.
- Total absorber is sliced and detectors are placed in between them to facilitate detection of soft momentum tracks (low mass vector mesons).
- 30 cm gap between 2 absorbers and 3 detector chambers are placed in between the absorbers.
- 1st absorber is made of Carbon to reduce the effect of magnetic field and of 60 cm thickness and rest are made of iron of 20+20+30 cm thickness.
- Gas Electron Multiplier (GEM) is used in all detector chambers.

Simulation Studies [2]

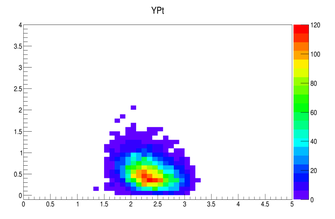
Particle rate



Y-pT acceptance (ρ) [input Pluto]

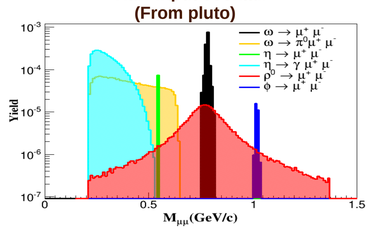


Y-pT acceptance (ρ) [reconstructed]

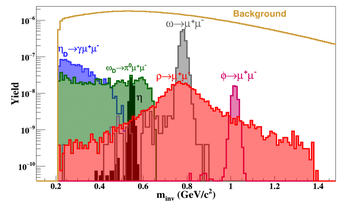


Particle	Eff (%)	S/B
ρ	1.03	0.005
ω	1.01	0.287
φ	1.53	0.005
η	0.56	0.004
η_D	0.23	0.092
ω_D	0.37	0.004

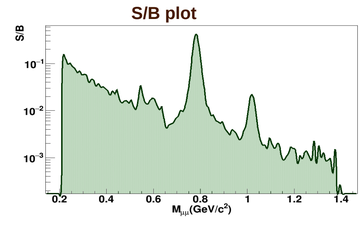
Raw input cocktail (From pluto)



Reconstructed cocktail (After passing through detector)



S/B plot



Summary

Relativistic heavy ion collisions help in exploring phase diagram of strongly interacting matter in the laboratory.

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The CBM experiment at FAIR accelerator facility is aiming at the study of QCD phase diagram at high net baryon density with bulk and rare probes.

Dilepton measurements are an integral part of the physics program of CBM. They are believed to be penetrating probes carrying undistorted information of the dense collision zone.

Till now there is no dilepton data in 240 AGeV, so CBM will make pioneering measurements in this energy region.

Realistic simulations via dimuon channel using optimized muon detector set up establish the feasibility of such measurements.

References

[1] CBM MUCH Technical Design Report
[2] S. Ahmad et al., NIM A 775, 139147 (2015)