# Feasibility Studies of Di-Electron Spectroscopy with CBM at FAIR

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**Abstract**

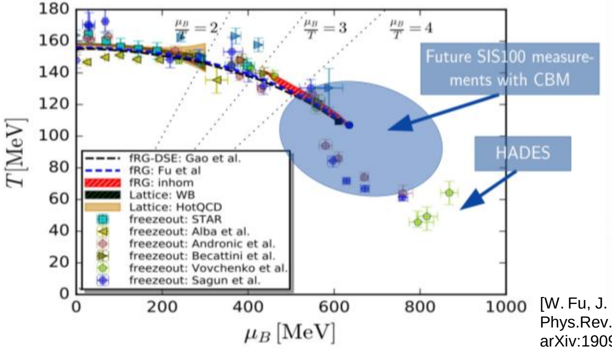
The Compressed Baryonic Matter experiment (CBM) at FAIR is designed to explore the QCD phase diagram at high net baryon densities and moderate temperatures by means of heavy ion collisions with energies from 2-11 A GeV beam energy and interaction rates up to 1-10 MHz, provided by the SIS100 accelerator. Leptons as penetrating probes not taking part in the strong interaction leave the fireball without being modified thus carrying information from the dense baryonic matter. However, di-leptons are rare probes, therefore calling for high efficiency and high purity identification capabilities.

In CBM, electron identification will be performed by a Ring Imaging Cherenkov Detector (RICH), by a Transition Radiation Detector (TRD) and Time-of-Flight Detector (ToF).

In this contribution, feasibility studies of di-electron spectroscopy from low mass vector meson decays will be presented. Special emphasis is put on the experimental challenge to reduce the combinatorial background in order to get a high significance of the extracted di-electron signal.

## Motivation

The high density region of the QCD phase diagram is not yet explored with rare probes. The CBM experiment at the future SIS100 synchrotron at FAIR will investigate this interesting area of the QCD phase diagram.



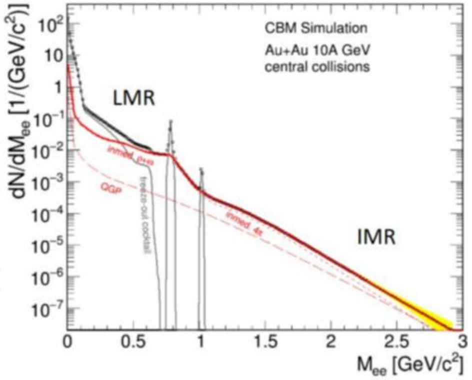

[W. Fu, J. Pawlowski, F. Rennecke, Phys.Rev.D 101 (2020) 5, 054032, arXiv:1909.02991]

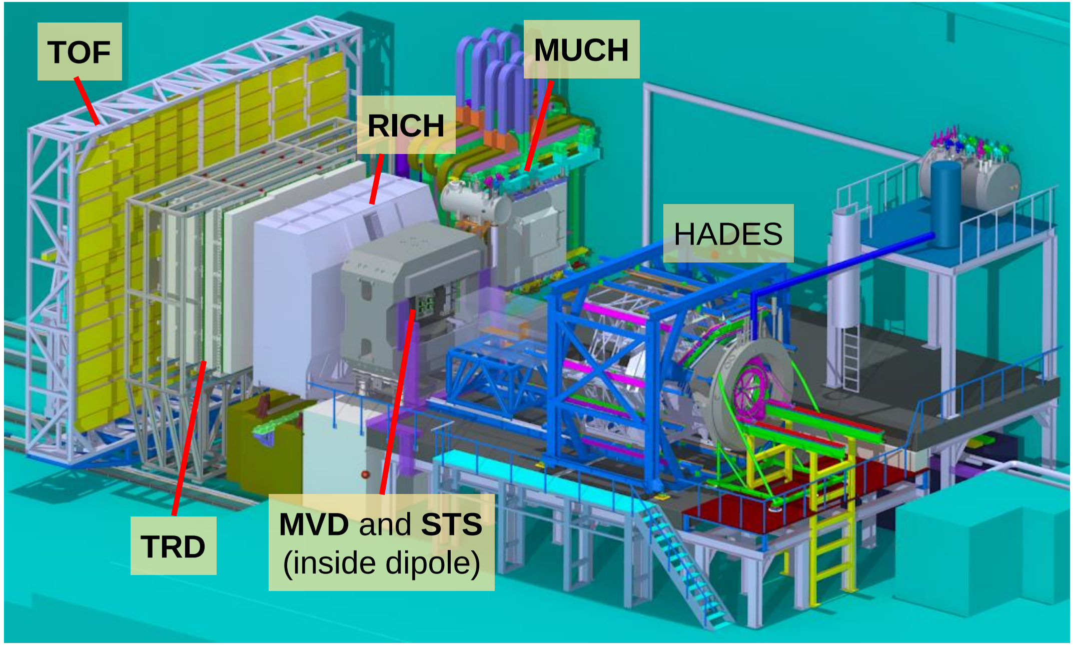
## Di-lepton sources

[Fig. credit: F. Seck]

Di-leptons are produced from vector meson decays but also from QGP radiation. In particular the ρ-meson with its short lifetime (1.3 fm/c) will be modified by the medium and reveal information like the temperature or lifetime of the fireball.

At freeze-out decays of $\pi^0$, η, ω and φ will also contribute to the spectrum.






**CBM Detector**

• CBM: **C**ompressed **B**aryonic **M**atter

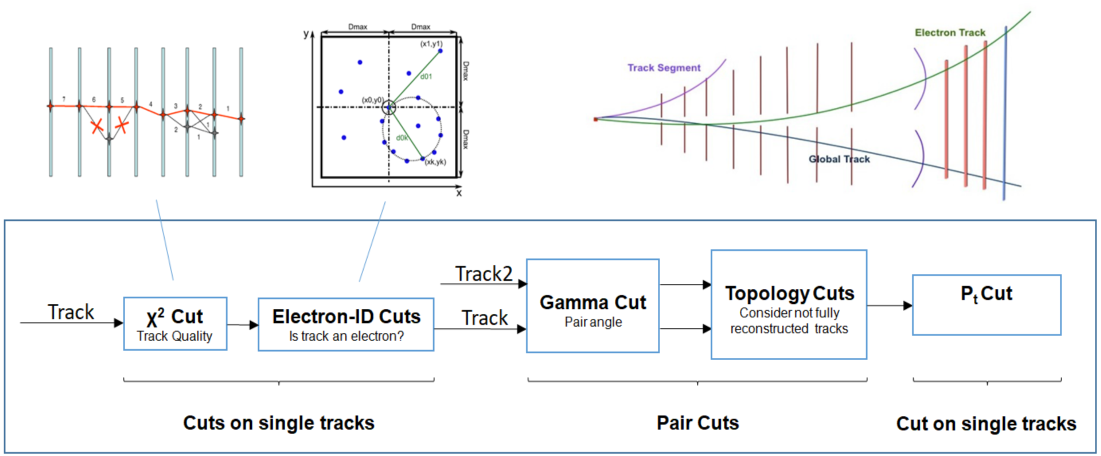
• The CBM detector will explore the phase diagram at high net baryon denisities and moderate temperatures.

• Very rare decay rates of vector mesons into di-electrons ($\approx 10^{-5}$) require very high interaction rates. The CBM detector is designed to process interaction rates up to 10 MHz.

• Electron identification is done by the RICH, TRD and ToF detectors.

• Simulation data:
- central Au+Au collisions at beam energies of 8 AGeV
- UrQMD and PLUTO (for signals)

## Overview of the applied analysis cuts




## Analysis Cuts

Large contributions, mainly from γ conversion, $\pi^0$-Dalitz decay and misidentified charged pions, potentially cause a lot of background. These background tracks have to be sorted out as far as possible. Therefore following analysis cuts on single tracks and track pairs are applied:

### $X^2$ Cut

The $\chi^2$ cut rejects the reconstructed track if its agreement with a fitted track is below a certain threshold.

### Electron-ID Cuts

Based on parameters like ring radius in the RICH, energy loss in the TRD and others, it is decided, partly by means of ANN, to classify this track as an electron track or reject it.

### Gamma Cut

Track pairs are rejected if their invariant mass is below 25 MeV/$c^2$ in order to reduce γ conversions in the sample.

### Topology Cuts

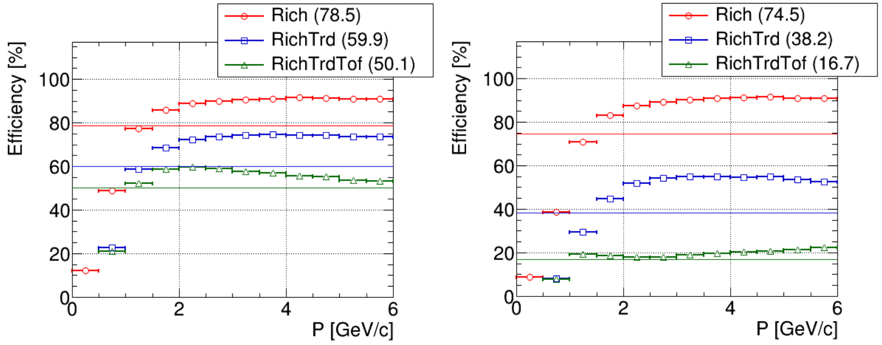
With the topology cuts also track segments are considered that are not reconstructed in all of the corresponding detectors, allow for further rejection of electrons from γ conversion or $\pi^0$-Dalitz decays.

### $P_t$ Cut (optionally)

Rejects tracks with transverse momenta below 0.2 GeV/c.

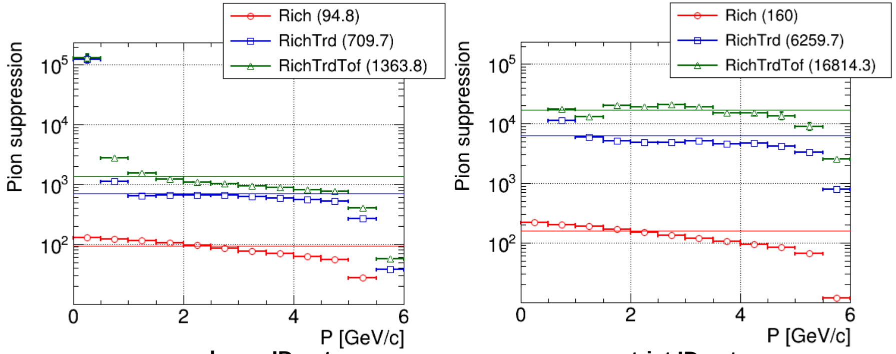
Depending on how strict the ID cuts are set, the output will change. Presented here are the achieved particle identification (PID) efficiency and pion suppression, each for a set of electron ID cuts and for different combinations of included detectors. Here the pion suppression is calculated as the ratio between the number of reconstructed pions divided by the number of pions misidentified as electrons.
On the cost of electron identification efficiency, the pion suppression and electron purity can be improved considerably.

## Particle Identification Efficiency




**more loose ID cuts** | **strict ID cuts**

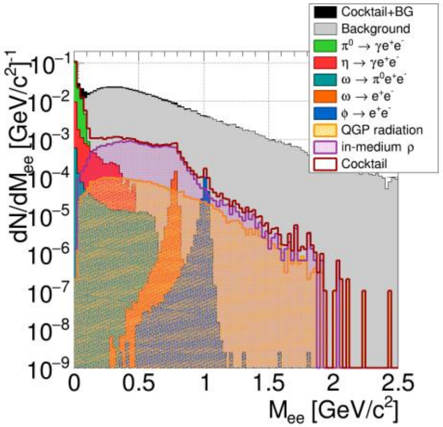
## Pion Suppression



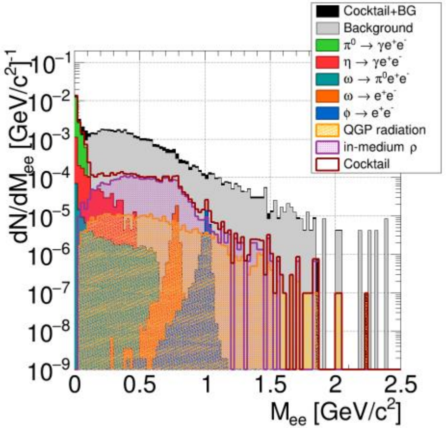

**more loose ID cuts**
(electron purity of 64 %)

**strict ID cuts**
(electron purity of 86 %)

## Invariant Mass

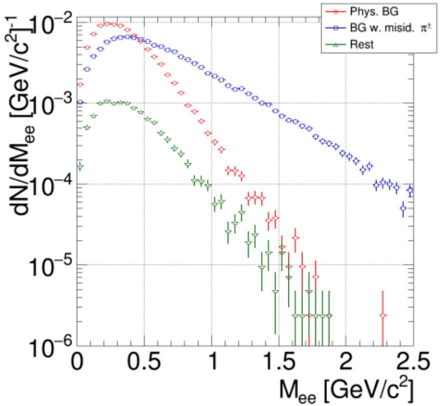



more loose ID cuts

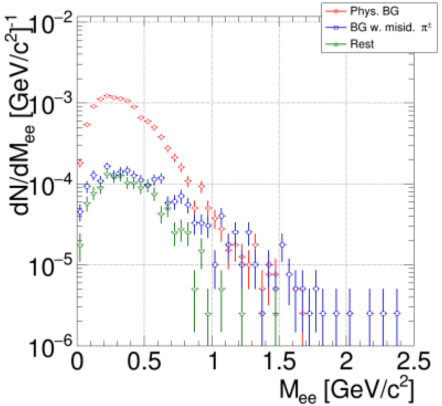



strict ID cuts

## Background




more loose ID cuts




strict ID cuts

## Results

- The contribution to the background is mainly dominated by physical background (i.e. electrons stemming from gamma conversions and $\pi^0$-Dalitz decays) and pairs containing misidentified pions.
- Spectra at high masses can be strongly influenced by misidentified pions; evaluate precision of background subtraction and significance of temperature measurement
- When stricter ID cuts are applied, the total background is suppressed considerably, leading to a higher signal-to-background ratio.

## Summary and Outlook

- Simulation and analysis started to evaluate the significance of temperature measurements in the CBM experiment.
- A procedure to estimate and subtract the combinatorial background and to extract the signal has been implemented. Further studies have to be performed with higher statistics.