PROCEEDINGS OF SCIENCE

Performance studies for the mCBM experiment campaigns in 2022

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With mCBM@SIS18 (short "mCBM") a CBM precursor and demonstrator experiment has been constructed in 2017/18 at the SIS18 facility of GSI/FAIR, taking data within the FAIR phase-0 program since 2019. The primary aim of mCBM is to commission and optimise the CBM triggerless-streaming data acquisition system including data transport to a high performance computer farm, the online track and event reconstruction and event selection algorithms and the online data analysis as well as the controls software packages. mCBM comprises of prototypes and pre-series components of all CBM detector subsystems and their read-out systems. The reconstruction of Λ^0 hyperons will be used as a benchmark observable probing the performance of the CBM hard- and software. Using simulations, various detector configurations have been tested identifying the most suitable geometry for reconstruction of Λ^0 hyperons with the mCBM setup in real data.

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1. Introduction

Λ^0 hyperons are detected in mCBM via their decay into proton and pion. Due to the lack of the magnetic field and particle identification Λ^0s are detected only trough topological cuts on straight tracks under mass assumptions.

Fig. 1, left side sketches one of the mCBM detector configurations evaluated for data taking in 2022, tagged 2022_02. The setup consists of prototypes or pre-series modules of all CBM detector subsystems: Silicon Tracking System (mSTS), Muon Chamber (GEM chamber module), Transition Radiation Detector (TRD1D and TRD2D), Time-of-Flight detector (mTOF). Other configurations with different setups and hence material budgets are tested as well, namely 2022_04 - without two GEM layers, 2022_03 without one GEM layer, 2022_05 without two GEM layers and without TRD2D (two sided prototype).

A simple track finding algorithm is applied based on combining hits in mSTS and mTOF with the additional possibility of adding TRD hits. The scheme of the processing flow is shown in Fig. 1, right side. The algorithm starts with hits in mTOF and construction of Vertex-mTOF lines. Afterwards mSTS layers are scanned for hits (upper branch of the flow diagram). If two hits are found within 3mm from the line a track from the two hits is formed. This track is taken as primary if it's distance from primary vertex (VDCA) is more then 5mm. Since most of the Λ^0 momentum is carried off by the proton these tracks are considered as proton candidates. mSTS hits which are not assigned to proton candidates are used for finding secondary pion candidates. mTOF-mSTS lines are constructed and mSTS is scanned for the second mSTS hit within 3mm. If a hit is found accordingly a pion candidate is created. Both pion and proton candidate tracks can be further approved or rejected by additional matching of TRD hits. The momentum is obtained by measuring velocity via time of flight in mTOF and the assumption that proton and pion candidates have corresponding masses. Hence, a Λ^0 candidate is created in case a pair of pion and proton candidates have their DCA, opening angle (OpAng) and Λ^0 decay position (PathLen) within certain cut ranges which were optimized in this study.

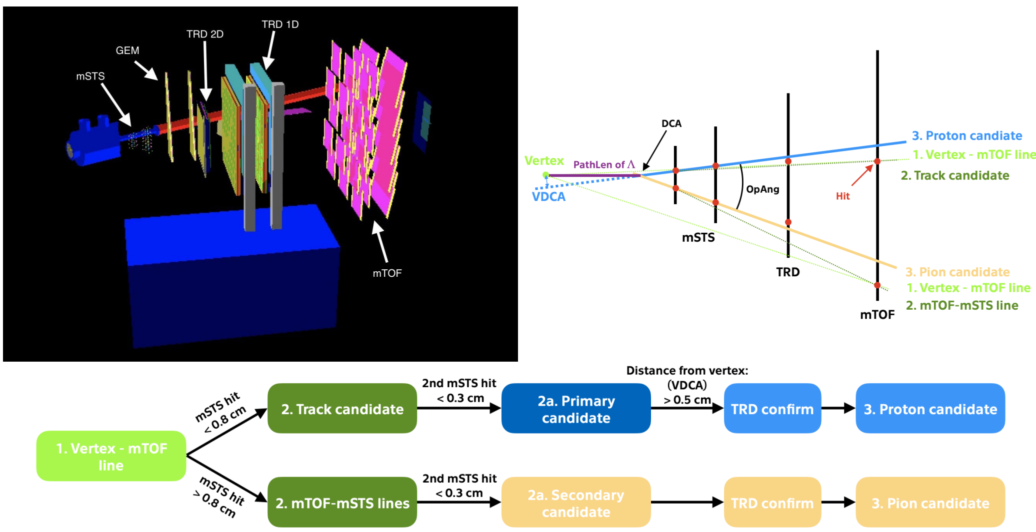

Figure 1: Sketch of the full mCBM geometry 2022_02 (left), Λ^0 finding algorithm (right) and flow diagram of the track finding algorithm (bottom).

2. Results

Nucleus-nucleus collisions were simulated with UrQMD, sampling 100M minimum bias events. Result for Ni+Ni collisions at kinetic beam energy of 1.93 AGeV are shown in Fig. 2. The combinatorial background was obtained using mixed-event technique. As can be seen, even in full (2022_02) geometry Λ^0s are reconstructed with sufficient significance and additional TRD hits are not mandatory. Also, the clear effect of additional material on reconstruction yield is observable. As shown in Fig. 2, the two MUCH stations (GEMs, geometry 03 and 04) reduce the yield significantly while the TRD2D station has only a moderate influence.

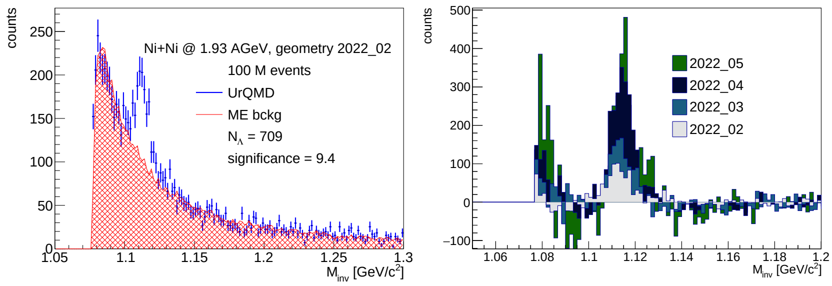

Figure 2: Results for Ni+Ni at 1.93 AGeV in geometry 2022_02 (left) and comparison for different geometries (right).

In Au+Au collisions at 1.24AGeV Λ^0 can not be identified without requirement of additional TRD hits matched to the tracks due to the increased track multiplicity as well as the strongly reduced production probability. In full mCBM geometry (2022_02), the signal is not detectable even when two TRD hits are used, see Fig. 3, most left panel. In setups with smaller material budget, such as 2022_05, the signal can be seen (Fig. 3 middle panel). Moreover, the obtained significance can be further improved when using machine-learning techniques instead of standard cuts, as shown in Fig. 3 right. Specifically boosted decision trees were used with a mixed-event generated background. ML was tested in all geometries however in geometries with higher material budget than 2022_04 the significance is not sufficient to guarantee good statistic of reconstructed Λ^0 at mCBM run 2022.

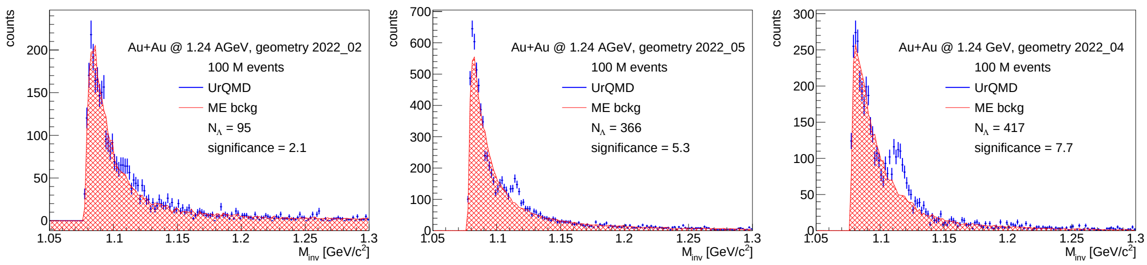

Figure 3: Results for Au+Au collisions at 1.24 AGeV with tracks requiring matching of two TRD hits for three different mCBM geometries with standard cuts and after using machine-learning optimization (right).

3. Conclusions

Simulations of Λ^0 hyperon reconstruction were performed for multiple setups of mCBM detector and collision systems. Significant effects of material budget and particle multiplicity were observed. Efficiency improvements are gained when using intermediate points from TRD detector and optimisation via machine-learning. We are hence expecting to observe a significant Λ^0 signal in the Ni+Ni and Au+Au runs taken in 2022.