Performance studies for the upcoming mCBM experiment campaigns

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Introduction

With mCBM@SIS18 (short "mCBM") a CBM precursor and demonstrator experiment has been constructed 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 Lambda 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 Lambda hyperons with the mCBM setup in real data.

mCBM

Geometry:
- Axis of the mCBM - 25° from the beam pipe
- Acceptance of ± 12°
- 3 m long

Detectors:
- Silicon Tracking System module (mSTS) - 2 layers
- GEM - part of the future Muon Chamber - 2 layers
- Transition Radiation Detector (TRD) - 3 layers
- Time of Flight (mTOF) - MRPC technology

Geometries:
- 2022_02 full geometry
- 2022_03 one GEM
- 2022_04 no GEMs
- 2022_05 no GEMs and only 2 layers of TRD

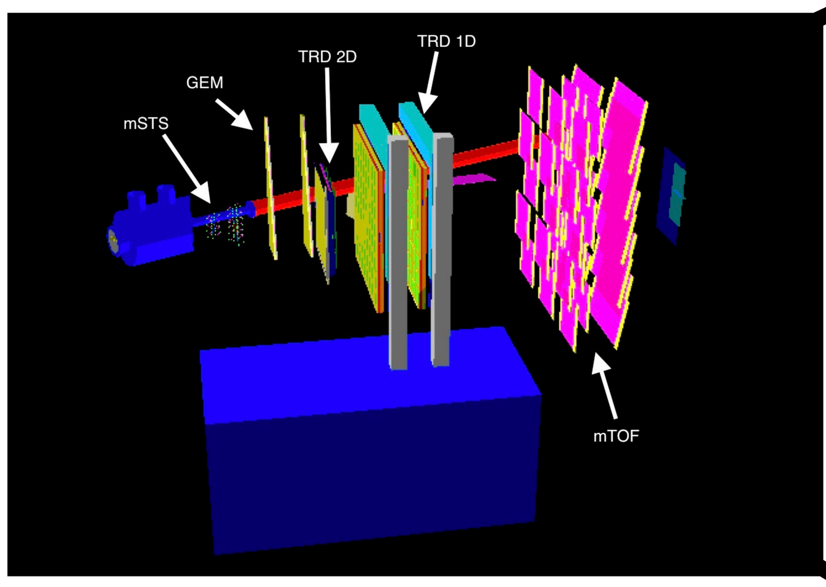

Fig. 1: Layout of the mCBM full geometry 2022_02

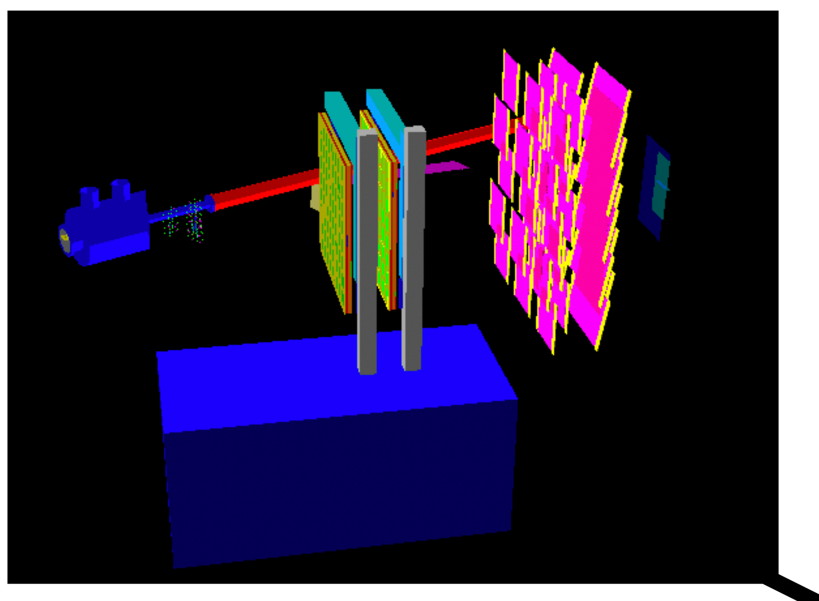
Fig. 2: Layout of the geometry 2022_05

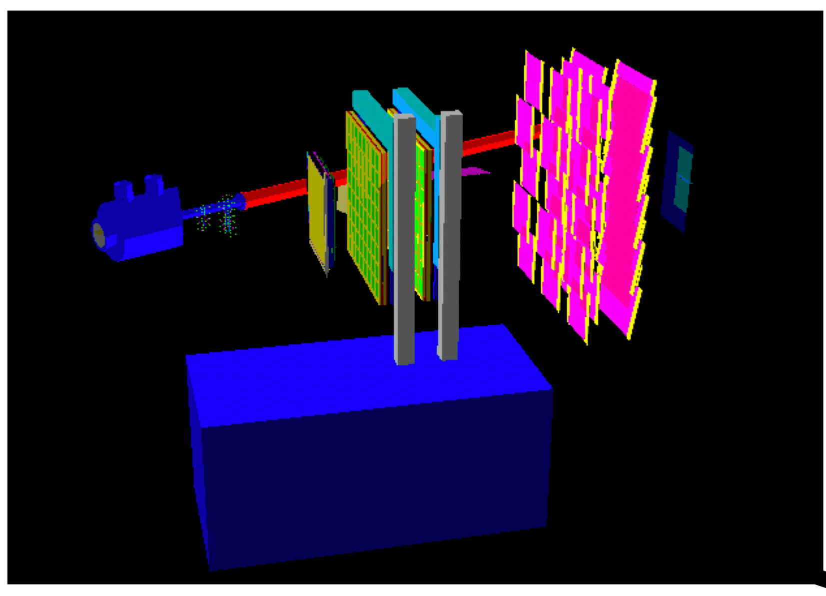
Fig. 3: Layout of the geometry 2022_04

Lambda reconstruction

Effect of different geometries and collisions systems was studied

Lambda reconstruction via $\Lambda \rightarrow p + \pi^-$
No magnetic field - time of flight momentum measurement
No tracking, simple topological selection only
Simulations are event based

Simulations made:
- Thermal produced Lambdas
- uRQMD
  - O+Ni at 2 AGeV
  - Ni+Ni at 1.93 AGeV
  - Au+Au at 1.24 AGeV

Track reconstruction:
- mTOF and mSTS define straight track candidates
- Additional track rejection based on matched TRD hits
- TRD hit:
  - Distance between track and TRD hit < 0.4 cm

Cuts for Lambda reconstruction:
- 0.19 < Opening angle < 0.54
- 5 [cm] < Path length < 20 [cm]
- DCA < 0.1 [cm]

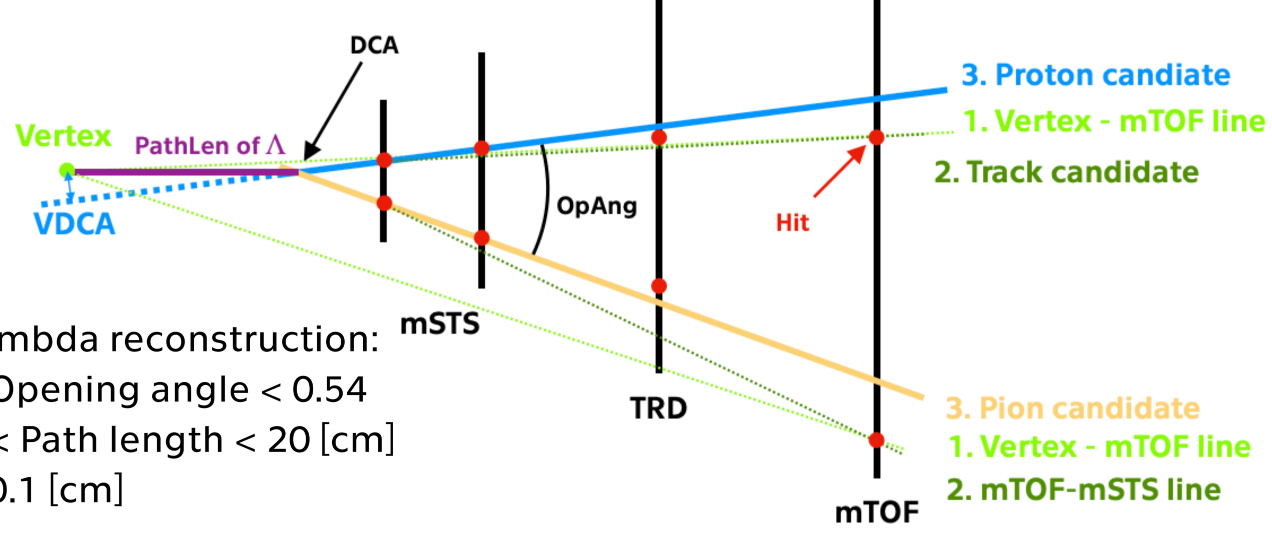

Fig. 4: Sketch of the Lambda reconstruction algorithm

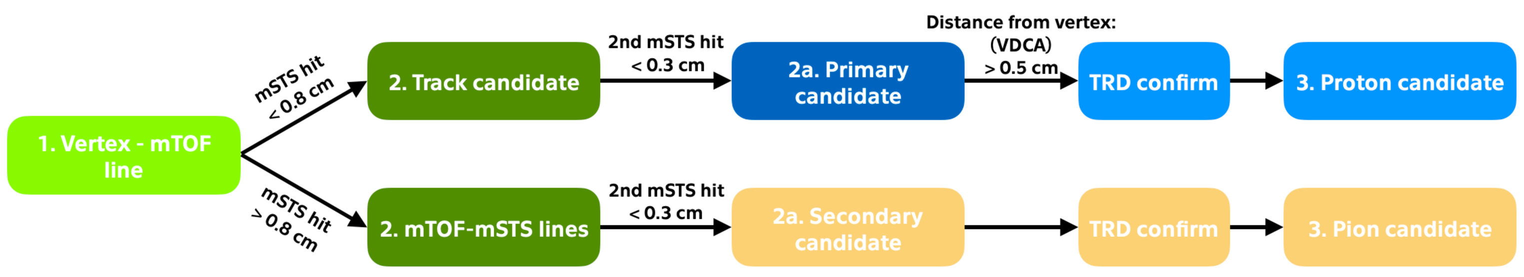

Fig. 5: Flow diagram of the reconstruction of proton and pion candidates

Results Ni+Ni at beam energy 1.93 AGeV

100M zero-bias uRQMD events
Strong signal of Lambda reconstructed
- Manually tuned cuts
- TRD hits not used

Clear effect of additional material on reconstructed yield
- Signal reconstructed for all setups

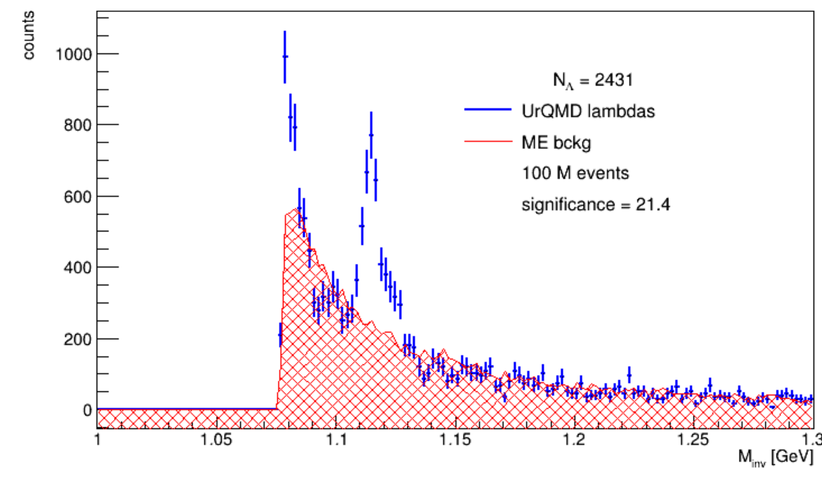

Fig. 6: Standard cuts, geometry 2022_05

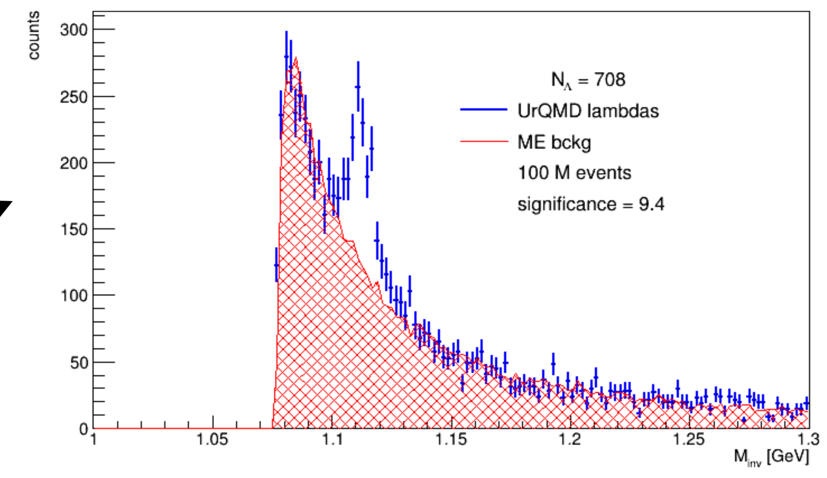

Fig. 7: Standard cuts, geometry 2022_02

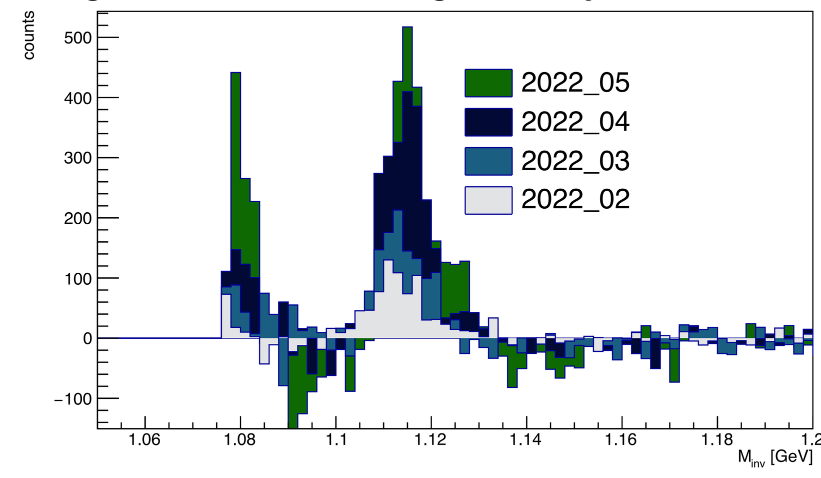

Fig. 8: Comparison of the signal in different geometries

Results Au+Au at beam energy 1.24 AGeV

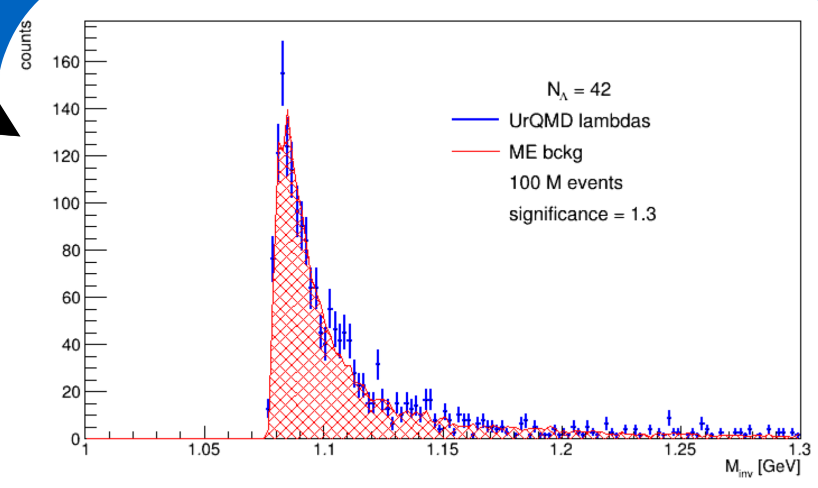

Fig. 9: Two TRD hits, geometry 2022_02

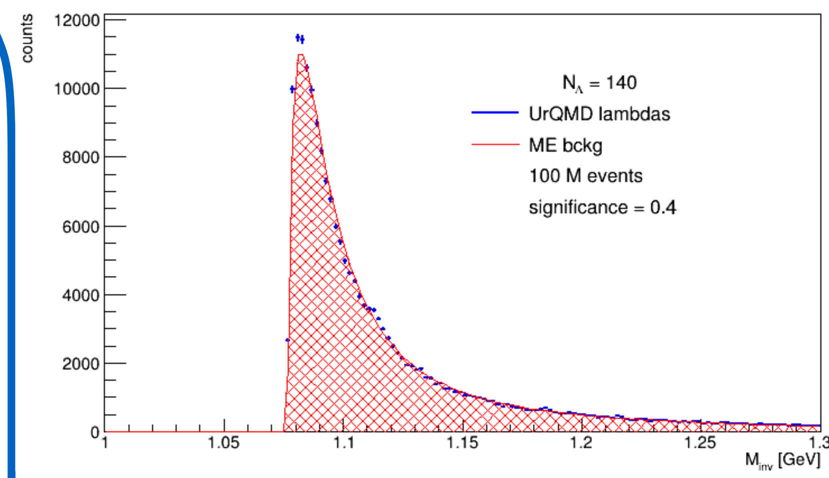

Fig. 10: Standard cuts, geometry 2022_05

Larger background compared with Ni+Ni collisions
With standard cuts no signal
Additional improvement
- Effects of TRD hits
- TMVA (boosted decisions trees)
  - Mix-events background

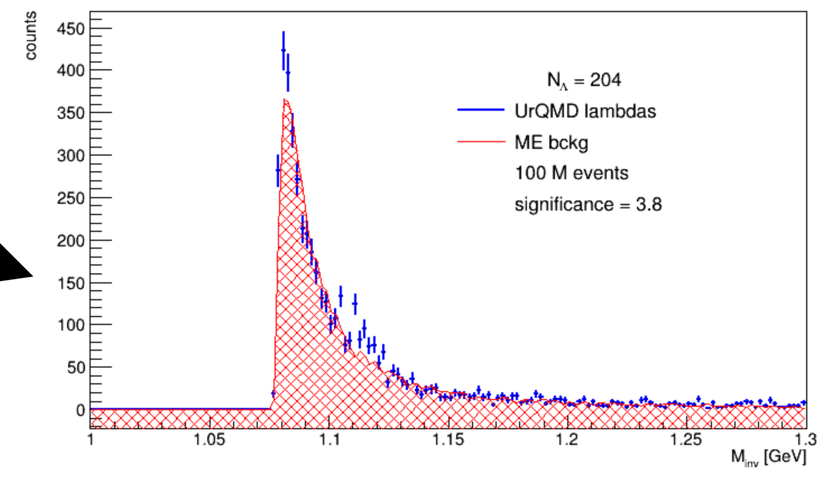

Fig. 11: Two TRD hits, geometry 2022_04

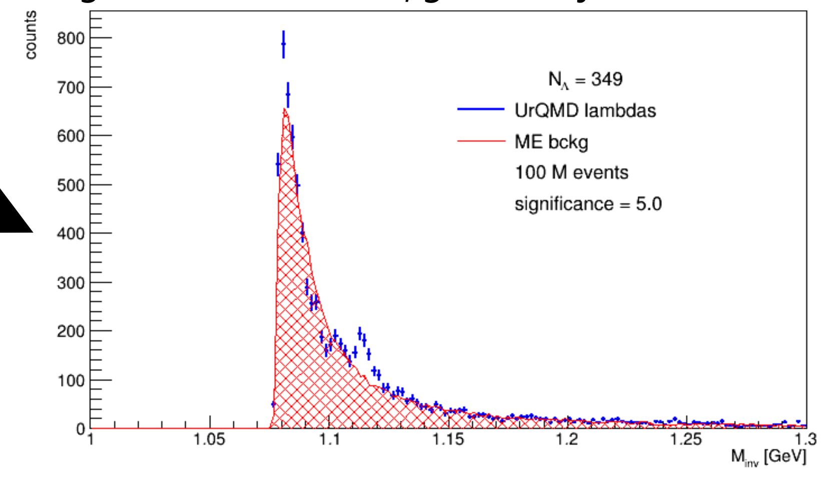

Fig. 12: Two TRD hits, geometry 2022_05

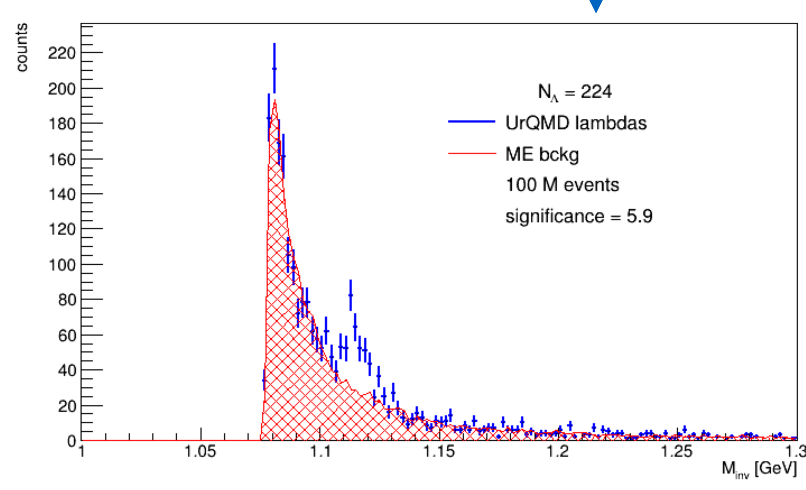

Fig. 13: TMVA + two TRD hits, geometry 2022_05

Conclusions

- Simulation of Lambda reconstruction performed for multiple setups and colliding systems
- Significant effects of material budget and particle multiplicity observed
- Improvements in efficiency gained when using intermediate points from TRD and optimisation via machine-learning
  - L1 tracking will soon be available - further improvement
- We are expecting to observe significant Lambda signal in upcoming mCBM data run
  - Real data statistics will be at least ten times higher compared to MC

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