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The mCBM experiment at SIS18 of GSI/FAIR - a CBM precursor and demonstrator -

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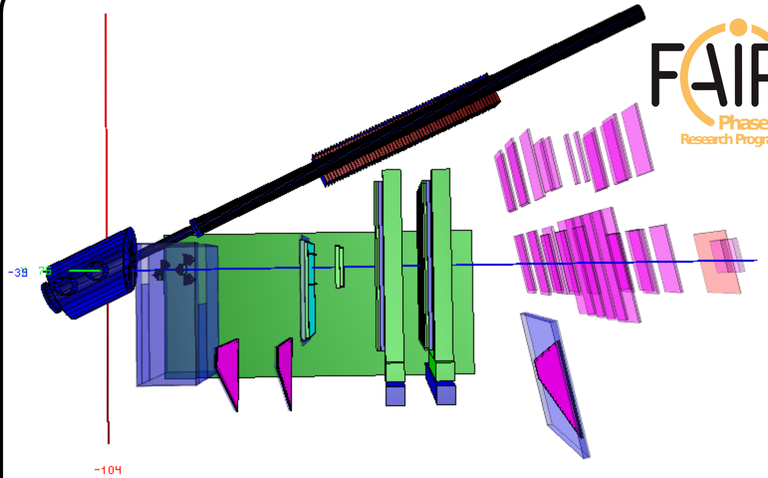
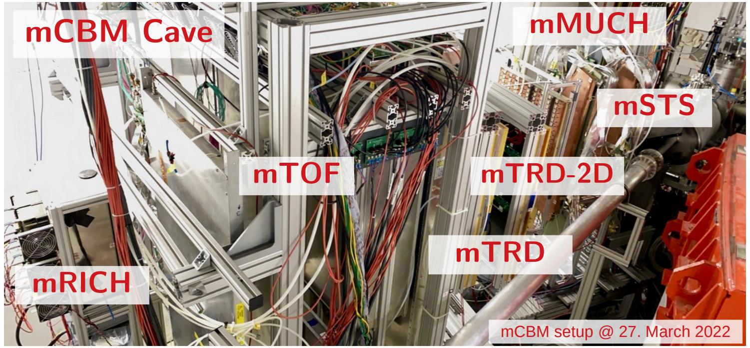
Abstract
The Compressed Baryonic Matter experiment (CBM) at FAIR is designed to measure nucleus-nucleus collisions at an unprecedented interaction rate of up to 10MHz which will allow the study of extremely rare probes with high precision. To achieve this high rate capability, CBM will be equipped with fast and radiation-hard detectors, which are readout via a triggerless-streaming data acquisition system, transporting data with a bandwidth of up to 1 TB/s to a large scale computer farm for event reconstruction and first level event selection. In order to commission and optimize prototypes and pre-series productions of CBM detector systems with their triggerless-streaming read-out chains under realistic experiment conditions, a precursor experiment and demonstrator Named mCBM@SIS18 (short “mCBM") 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 optimize (i) the triggerless-streaming data acquisition system including data transport to a high performance computer farm, (ii) the online track and event reconstruction and event selection algorithms and (iii) the online data analysis as well as the controls software packages. mCBM comprises prototypes and pre-series components of all CBM detector subsystems and their read-out systems. During the mCBM beam campaign ‘21 high-rate tests with nucleus-nucleus collisions for various detector subsystems could be performed, furthermore first runs with the final DAQ / data transport configuration of CBM were taken in O+Ni collisions at 2.0AGeV kinetic bombarding energy, running at approx. 1MHz collision rate. First results of the 2021 campaign will be presented.



Key feature of mCBM

- Located at SIS18 accelerator of GSI/FAIR
  - Participating in FAIR phase-0 program
- Up to 10 MHz collision rate achievable
- Free-streaming readout
- data transport to Green IT cube
- Online event building and selection

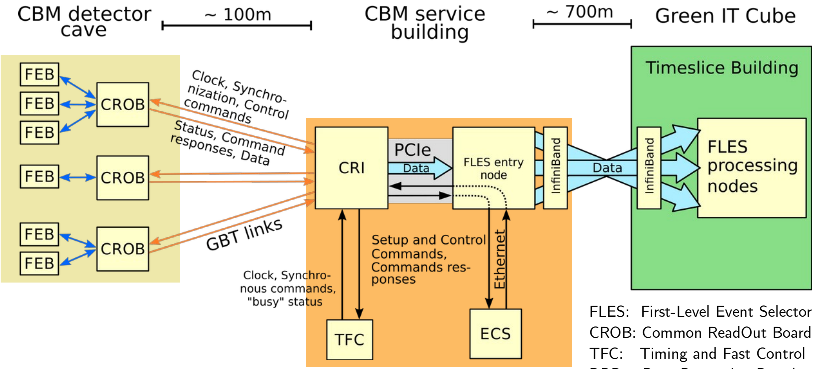


- mCBM (mini-CBM) is a full system test-setup for high-rate nucleus-nucleus collisions at GSI/FAIR
  - CBM prototype detector systems
- Real size prototypes with ***full readout*** concept and detector functionality
- Test free streaming data acquisition and transport
  - How do the detectors behave at high rates?
  - Are there limits in the designs?
- Test synchronicity of detector DAQ
- Online event building and selection

mCBM is of high importance for CBM as high performance hardware and software is needed to achieve high rates
→ Extensive tests are important

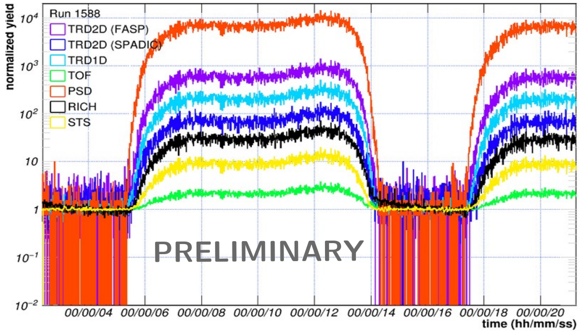
CBM DAQ @ mCBM

- mCBM DAQ relies on common readout interface (CRI) of CBM
  - Dedicated FPGA board that connects the custom front end electronics to the commercial servers of the entry node
- Each subdetector uses several CRI boards for its DAQ
  - Entry nodes already connect to Green IT Cube
- Timeslice building on FLES processing nodes
- Free-streaming mCBM readout chain is already final configuration of future CBM readout



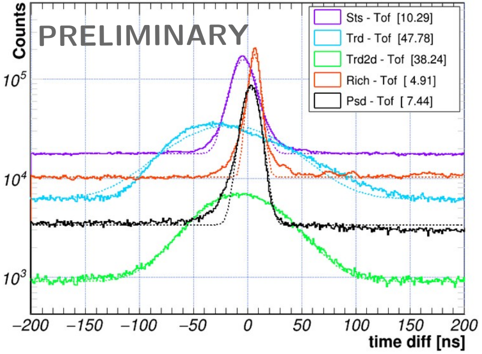
FLES: First-Level Event Selector
CROB: Common ReadOut Board
TFC: Timing and Fast Control
DPB: Data Processing Board
FLIB: FLES Interface Board

mCBM data synchronicity



Time distribution of unpacked data of all sub-detectors reproduces spill structure. Normalized to spill break.

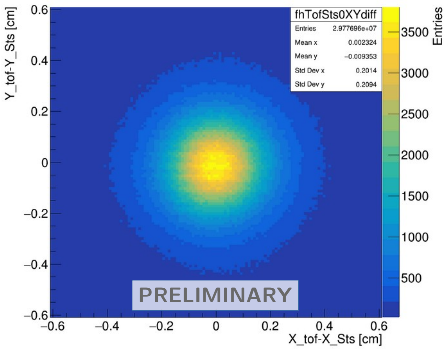
Time difference between unpacked data from all sub-detectors relative to TOF. All detectors are synchronous and stable over time



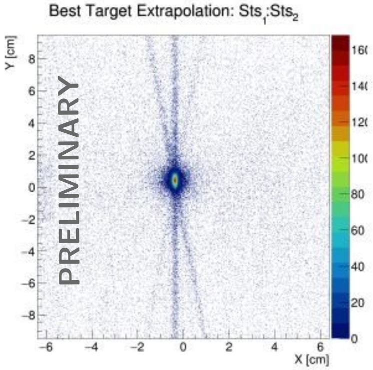
- All sub-detectors are synchronous to mCBM time
- Time precision of up 5 ns could be reached in sub-detectors
- Overall time aligned to TOF by constant offsets.
- All detectors follow the spill shape

Data analysis: data driven mCBM alignment

- Alignment studies between mSTS and mTOF have been done
  - Alignment based on combinations of all modules of both detectors
- Alignment and vertex extrapolation based on mSTS data in different stations
- TOF alignment by residuals of TOF and STS hits
  - Achieved precision in order of 2 mm



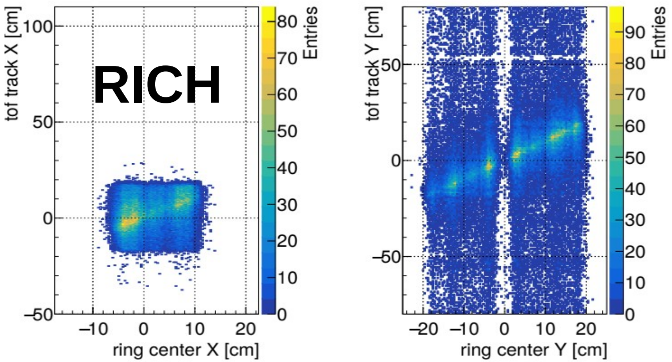
Combination of all residuals from all TOF modules and STS Units. Residuals are from extrapolated TOF and STS hits in X and Y.



Extrapolation of best target position in X and Y by scan of Z-positions from Hist in STS Stations in mCBM.

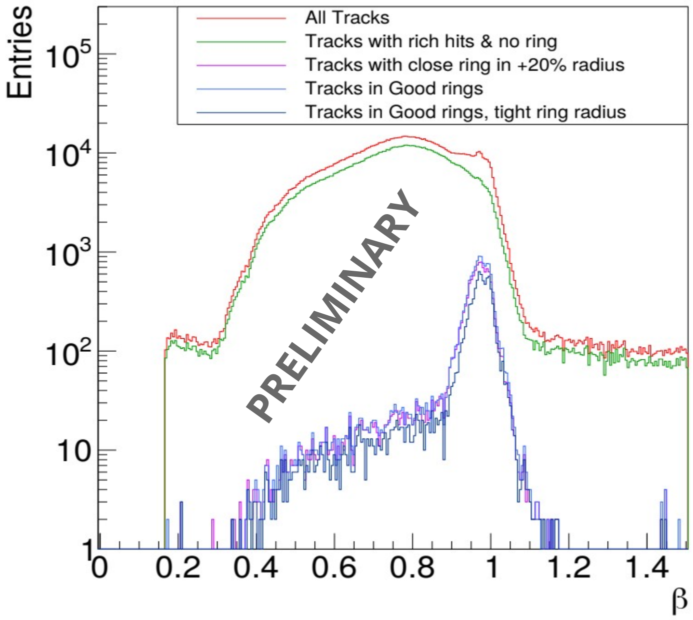
mCBM spatial correlations and beta spectrum

- Spacial correlations are investigated in different sub-detectors
  - Correlations in hits as well as tracks analyzed
- mRICH is a proximity focusing Cherenkov detector with aerogel as radiator
  - Rings are only formed by electrons and pions
- TOF tracks are used to extract beta-spectra of mCBM measurements
- Tracks absolutely calibrated by matching to RICH rings
  - Suppression of protons due to track-ring matching



Spatial correlation between tracks from TOF, extrapolated to the RICH detector plane and centers of reconstructed RICH rings. In X and Y a clear correlation with its center in the origin is seen.

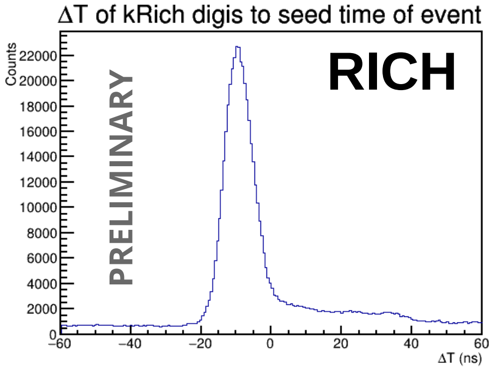
Figures produced by data from ^{208}Pb @ 1.06 AGeV

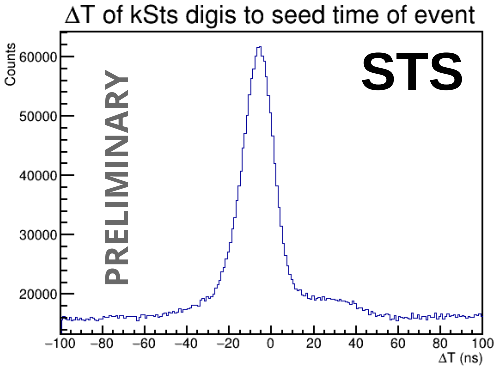


Normalized velocity distribution of tracks formed by 4 hits in the TOF detector. Using the enhancement from electrons and pions at 1 by track-ring matching, the tracks are absolutely calibrated. The comparison to low β range shows the enormous suppression power to protons by the mRICH.

First results on online event building and selection

- Establishing of full readout chain with STS, TRD, TOF and RICH
- Handling of data from data stream
  - Full unpacking of data (digis: unpacked data)
    - Parameter and address assigning to each data point
  - Complete event building with unpacked data
  - Event selection
  - Archiving of events
- Demonstration of the full online data processing chain
- Extraction of time correlation between sub-detectors and seed time of an event from data stream





1st results from March 10, 2022, 3:36 am
Histograms created from streamed data in online histogram server

Result obtained in Fe+Ni@1.71AGeV

Summary

Over the last years, mCBM made a tremendous progress in the test and validation of the free-streaming CBM readout chain. Furthermore, different sub-detector prototypes were tested in a high-rate environment with nucleus-nucleus collision rates of up to 10MHz. The CBM prototype detectors could prove their basic detector functionality and the functionality of their readout chain. Time as well as spatial correlations could be measured and verified the stability of the system. The correlation between sub-detectors was shown on the low level, but also in more advanced data structures as rings and tracks. By the use of the detector features, calibrations on physical measurements could be achieved. Finally, mCBM could show the first results of a full readout chain with online event building and selection under real conditions. Time correlations could be extracted by the full online chain and displayed by an online histogram server. During the 2022 campaign, mCBM will focus on high rate tests and the benchmark measurements of the experiment by Λ-measurements in Ni+Ni at 1.93AGeV.