Performance of the mSTS detector in O+Ni collisions at 2 AGeV with the mCBM setup at SIS18

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The Compressed Baryonic Matter (CBM) experiment is one of the experimental pillars at the FAIR facility. CBM focuses on the search for signals of the phase transition between hadronic and quark-gluon matter, the QCD critical endpoint, new forms of strange-matter, in-medium modifications of hadrons, and the onset of chiral symmetry restoration. The Silicon Tracking System (STS) is the central detector for tracking and momentum measurement. It is designed to measure Au+Au collisions at interaction rates up to 10 MHz. It comprises approximately 900 double-sided silicon micro-strip sensors with 1024 strips per side, arranged in 8 tracking stations. It results in 1.8 million readout channels, having the most demanding bandwidth and density requirements for all CBM detectors. In the context of FAIR phase 0, the mini-CBM project is a small-scale precursor of the full CBM detector, consisting of sub-units of all major CBM systems, which aims to verify CBM's concepts of free-streaming readout electronics, data transport, and online reconstruction. In the 2021 beam campaign at SIS18 (GSI), O+Ni collisions at 2 AGeV were measured with a beam intensity of up to 10^{10} ions per spill. The first results are presented in this work focusing on the mini-STS (mSTS) performance.

FAIR next generation scientists - 7th Edition Workshop (FAIRness2022)
23-27 May 2022
Paralia (Pieria, Greece)

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PoS(FAIRness2022)050

1. Introduction

In the 2021 O+Ni beam campaign at 2 AGeV at SIS18 (GSI), the mini-STS (mSTS) setup consisted of 2 tracking stations built with 11 modules. Prior to the installation in the mCBM cave, an energy calibration was performed to adjust the linearity and dynamic range of the ADC. The measured baseline noise level corresponds to 1000 e ENC for every module, in agreement with the targeted system noise. During the few hours of main data taking, the first tracking station was operated with significantly different thresholds. The achieved mSTS data rates were up to 280 MB/s, corresponding to an average of 70 Mhits/s.

The data from the detectors are free-streamed and recorded in a set of time slices written into a Time Slice Archive (TSA-file). A software trigger condition of 3 mTOF[1] digis[2] was set to accept the event in symmetric time windows $\pm 50\ ns$. Data from all detectors are synchronized by applying an offset and a finer charge-dependent offset to consider the time walk effect. The mSTS detector measures an average time resolution $\sigma = 6.45\ ns$.

2. Results

During reconstruction, clusters are obtained by neighboring strips fired close in time (±20 ns), and hits are built from the correlation of clusters in the p- and n-side within 20 ns. The correlations between hits of the different stations allow us to extract information on the spatial resolution achieved by the mSTS system. X and Y correlations of the hits closest in time are shown in Figures 1(a), 1(b). The correlation is sharper in the X than in the Y direction since the sensor pitch follows the X coordinate while Y is tilted, resulting in a resolution reduced by $1/\tan(7.5^0)$. The standard deviation of the diagonal projection, reported in Table 1, shows remarkable consistency with the simulation values.

Table 1: Standard Deviation for the fitted peaks.

	σ_{XX}[cm]	$\sigma_{YY(0)}$ [cm]	$\sigma_{YY(1)}$ [cm]
Simulation	0.0280(2)	0.0603(6)	0.1063(1)
Data(run 1588)	0.0280(3)	0.0655(7)	0.1099(2)

Using a residual minimization procedure, the best mSTS hit combinations are used to find the vertex position. Figure 1(c) shows the XY distribution of reconstructed vertices, consistent with the target dimensions and a plausible beam spread of about half a centimeter. mSTS hits are also correlated with hits reconstructed in the mTOF detector after a residual minimization procedure [3] has been applied to determine the optimal position of the two detectors relative to each other and the target. Figure 1(d) shows mSTS-mTOF correlations for X coordinate using mSts Unit 1: the width is mainly determined by the larger space resolution of the mTOF detector and the considerable distance between the two systems. All other possible correlations look similar.

An additional external detector allows one to check the performance of each mSTS station individually. Hits in the first mSTS station are correlated with hits in mTOF, the tracklet is

[1]Time of Flight detector

[2]Digi: software object containing the signal information of a fired strip in the detector

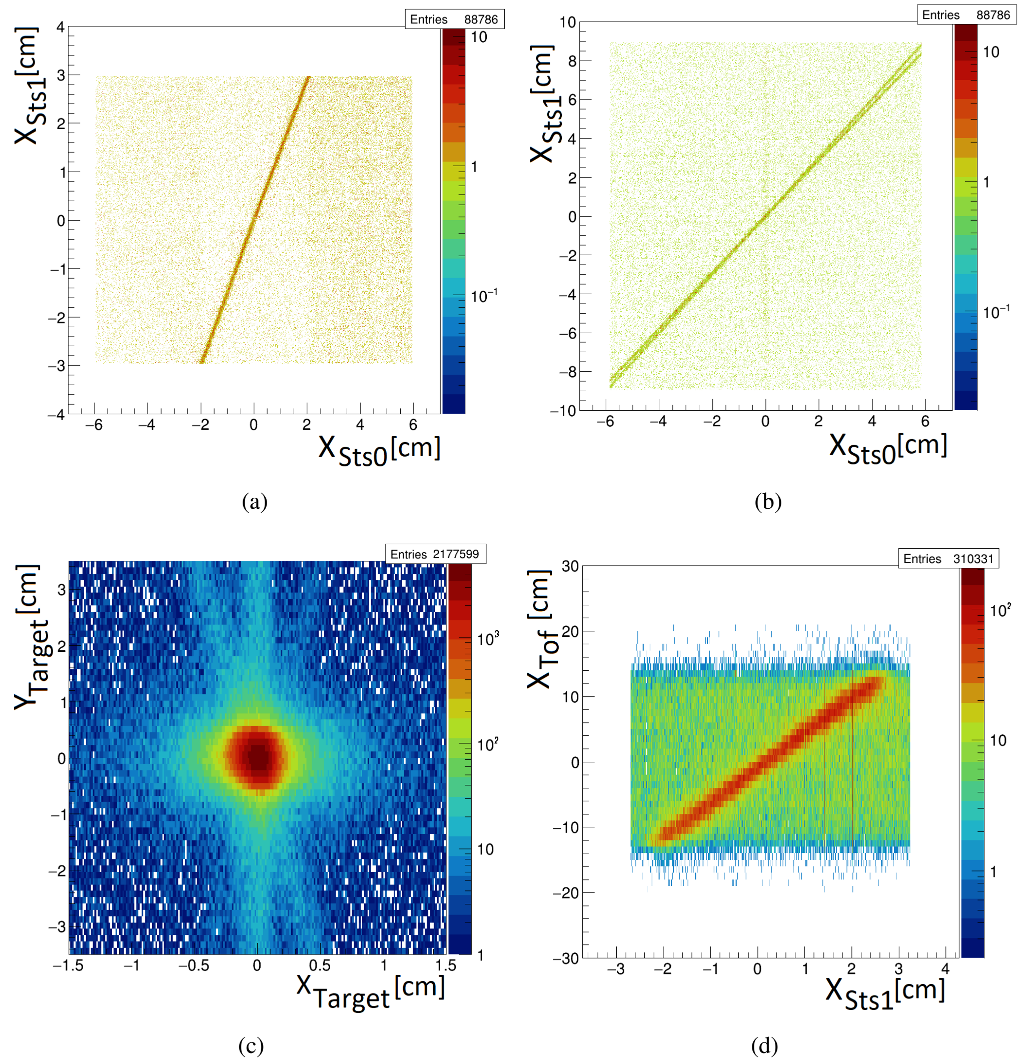

Figure 1: From the left: a) and b) X and Y correlation between hits in the two mSTS stations. c) X-Y distribution of vertex reconstructed from mSTS tracklets. d) X correlation between hits in the first mSTS station and the mTOF.

extrapolated to the plane of the second station, and the position of the expected space point is calculated to check whether it was effectively reconstructed. This can be studied for both mSTS stations. The algorithm has been verified with simulations, where it is possible to check whether the correlated detector hits are generated from the same track. A detailed explanation can be found in [4]. The comparison between expected extrapolated and locally reconstructed hits have been made using areas where the detector is fully operational. It led to an efficiency value of 97.6% for station 1 and 97.4% for station 2. The hit charge is calculated as the average cluster's charge on the p- and n-side. Figure 2 shows the hit reconstruction efficiency as a function of the hit charge. It starts to drop significantly at very high thresholds.

3. Summary & Outlook

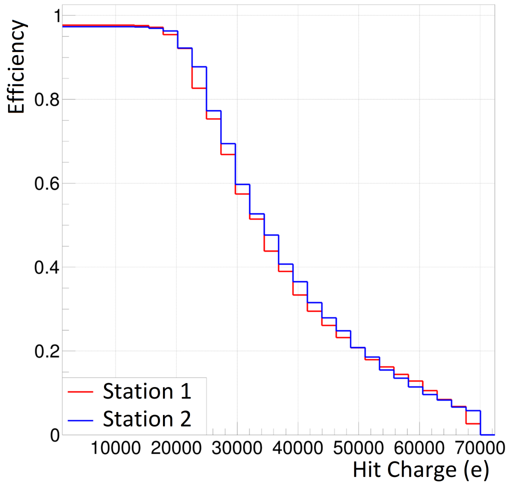

Figure 2: Hit reconstruction efficiency vs. reconstructed hit charge.

For the first time in the beamtime of July 2021, a mSTS setup comprising two tracking stations and many modules was built, assembled, and operated with the most up-to-date components. The targeted STS system noise of around 1000 e ENC was achieved in agreement with theoretical expectations. Reliable operation of the system and stable data taking during the heavy-ion beam test were achieved. Besides a few unconnected channels (typically less than 1%) and two broken ASICs, three detector units were operational. Excellent space and time resolutions, in line with expectations, were demonstrated. The charge distributions of reconstructed hits show a clear separation from the noise. The vertex reconstruction was achieved by using the correlations of mSTS hits. Using the mTOF as an additional external reference, we assessed a satisfactory sizable hit reconstruction efficiency of 97.5%, compatible with the simulation expectation. Further differential studies can shed light on the detector's performance on thresholds and settings.

References

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