ISBN: 978-3-95450-236-3 ISSN: 2673-5350 doi:10.18429/JACoW-IBIC2023-MOP018

BEAM-DIAGNOSTIC AND T0 SYSTEM FOR THE mCBM AND CBM EXPERIMENTS AT GSI AND FAIR

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Abstract

The Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) in Darmstadt requires a highly accurate beam monitoring and time-zero (T0) system. This system needs to meet the requirements of the CBM time-of-flight (ToF) measurement system for both proton and heavy ion beams, while also serving as part of the fast beam abort system. To achieve these goals, a detector based on chemical vapor deposition (CVD) diamond technology has been proposed. In addition, new developments using Low Gain Avalanche Detectors (LGADs) are currently under evaluation. This contribution presents the current development status of the beam detector concept for the CBM experiment.

INTRODUCTION

The CBM experiment [1] is a fixed-target, multi-purpose detector that will be used to explore the QCD phase diagram of nuclear matter at high net-baryon densities and moderate temperatures. The experiment will be located at the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany.

The CBM detector will be able to detect hadrons, photons, electrons, and muons in elementary and heavy-ion collisions over the entire energy range provided by the SIS100 heavy-ion synchrotron, from 3 to 11 A GeV for heavy ions and 29 GeV for protons. The measurements will be performed at event rates from 100 kHz up to 10 MHz using free-streaming readout electronics and fast online event reconstruction.

The BMON system consists of a high-speed time-zero (T0) and halo detector. The detector must meet the requirements of the time-of-flight (ToF) measurement system for both proton and heavy-ion beams. Specifically, it must achieve a time precision better than 50 ps (sigma), maintain stable long-term operation even at high interaction rates of 10^7 particles/s, and have a detection efficiency approaching 100%. A summary of the requirements is provided in Table 1.

THE CBM BEAM MONITORING SYSTEM

The CBM BMON system has been already introduced in [2], it will consist of two detector stations located in front of the CBM target chamber. The T0-station is foreseen to measure the start time of the reaction, while the Halo-station will be used for beam halo monitoring and as a port of a fast beam abort system (BAS). Both detectors will be mounted inside a beam-pipe using commercially available CF 100 vacuum elements, as schematically shown in Fig. 1.

Table 1: Requirements to the CBM BMON System

Max. beam intensity	10^7 particles/s on sensor
Max. read-out rate	5 MHz per channel
Time precision	50 ps
Position resolution	0.5 mm
Beam spot size on sensor	1 cm (2 sigma)
Sensor thickness	70 µm

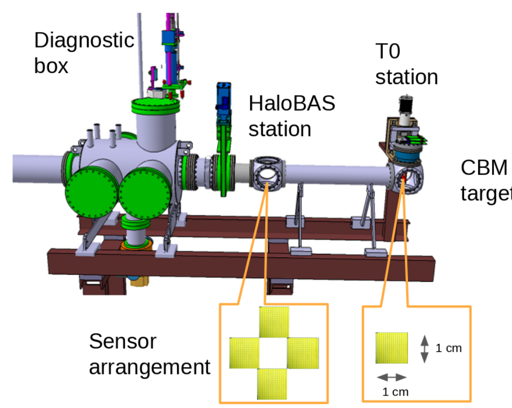

Figure 1: The CBM BMON system consists of two stations for beam halo and T0 measurement. The stations are mounted in standard CF 100 vacuum chambers in front of the CBM target. The T0 station uses a single sensor, while the Halo station uses a mosaic structure of four sensors. The Halo station will also be part of a fast beam abort system (BAS).

The sensor for the T0 station is currently planned to be made using poly-crystal CVD (pcCVD) diamond technology [3]. The sensor will have a thickness of 70 µm and will cover an area of $1 \times 1\ \text{cm}^2$. It will be equipped with a metallization arranged in 16 strips on each side. A detailed description of the sensor and the production and testing of a prototype sensor can be found in [2]. The strip segmentation and orientation, aligned in the x and y-directions, will allow to extract the position information of the beam particles. We are currently also investigating higher segmen-

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tation, i.e. 48x48 strips, for the final CBM T0 sensor. This will increase the rate capability of the sensor.

The halo station is planned to be used as an independent beam monitoring system. The halo detector will consist of a mosaic arrangement of four sensors, each metallized with four strips on both sides. The sensor arrangement is schematically shown in Fig. 1. This arrangement allows to monitor the beam position and its rate during the extraction process. This information will be used to secure sensitive CBM detectors as part of a fast beam-abort system (BAS).

At the moment, we are actively investigating the possibility of using recently developed Low Gain Avalanche Detector (LGAD) technology, especially for proton beams in the CBM experiment. LGAD technology has been shown to be very promising for beam monitoring applications, as it can achieve high time resolution and rate capability [4].

INFLUENCE OF THE T0 DETECTOR ON THE CBM DETECTOR SYSTEM

The influence of the T0 detector on the CBM detector system has been studied using Monte Carlo simulations. The detector was placed at two locations in the simulations: 0.5 m and 2 m in front of the target. A point-like Au beam with an energy of 4 A GeV and a rate of 10^7 ions/s was used. The simulation assumed an Au target with a thickness of 250 µm and 85% of the maximum magnetic field.

In a first study, the widening of the beam due to the diamond material was investigated. The results are shown in Fig. 2. The beam profile is enlarged, but the halo particle rate is not significantly increased. The ratio between the beam spot maximum the beam spot center, at a distance 5 mm from the beam spot maximum, is eight orders of magnitude. This is in agreement with the guidelines of the CBM collaboration.

The additional diamond material in front of the target will also lead to an increased charged particle contamination in the region where the Silicon Tracking System (STS) [5] is located. This is visualized in Fig. 2. However, initial discussions with the CBM STS detector experts suggest that this should not be problematic for its performance.

T0 MANIPULATOR PROTOTYPE

The T0 and halo detectors will be integrated into the CBM beam line in front of the CBM target. The sensors will be mounted inside the vacuum, in standard CF 100 vacuum chambers (see Fig. 3). The feed-through PCBs will be glued into blind flanges.

The T0 detector will be operated for beam intensities of 10^7 particles/s. For higher beam intensities, the T0 detector will need to be removed from the beam axis. We plan to use a step motor in combination with a flexible bellow to allow the remote movement of the sensor from the beam axis. A schematic drawing of a prototype, which is currently being built, is shown in Fig. 3 (right).

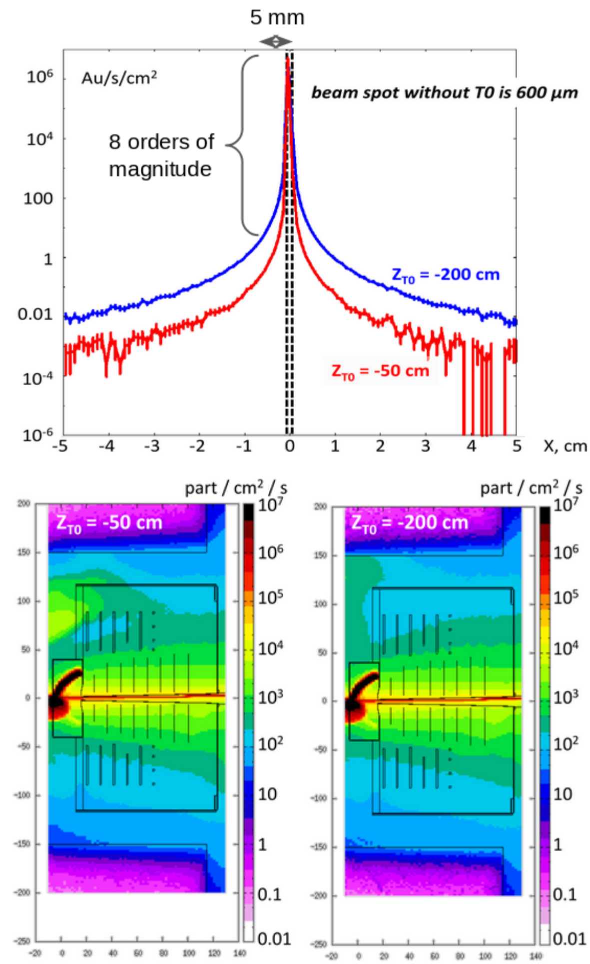

Figure 2: Widening of the beam and charged particle contamination in the STS region for two different T0 positions. **Upper panel:** The widening of the beam due to the diamond material of the T0 detector, which is located 50 cm (red curve) and 200 cm (blue curve) in front of the CBM target. **Lower panel:** The charged particle contamination in the STS region for the two different T0 positions.

SENSOR MOUNT AND FEED-THROUGH PRINTED CIRCUIT BOARD

The T0 sensor will be bonded to a dedicated [6] printed circuit board (PCB) that serves as a sensor holder. A schematic picture of such a PCB is shown in Fig. 4.

To compensate for radiation damage, which will result in a decrease of the signal amplitude, two analog amplification stages are implemented close to the sensor. The sensor PCB will be mounted inside the vacuum chambers. The feed-through PCB (see green part in Fig. 4) will be glued into the flanges of the vacuum chamber.

The T0 detector is designed to operate at beam intensities of up to 10^7 particles/s. Assuming a beam spot diameter of 0.5 cm on the T0 sensor with a metalization of 16 stripes, a rate of 1 MHz per readout channel is expected. The analog signals are discriminated using the PADI ASIC [7] and a

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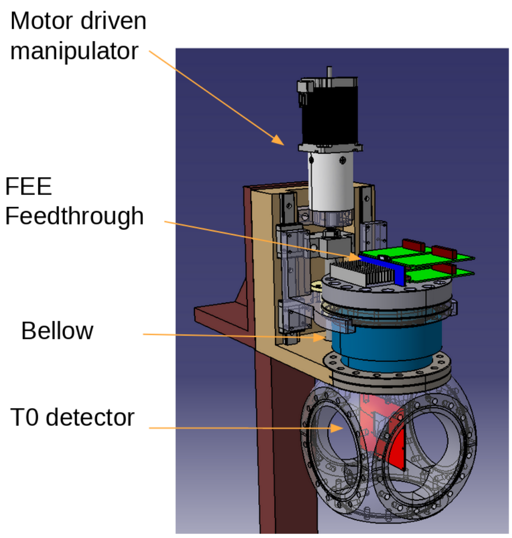

Figure 3: Schematic illustration of the manipulator system for removing the T0 detector from the beam axis.

time-to-digital converter (TDC) is used, the Get4 ASIC [8]. Digital data is then sent to a single Common Readout Interface (CRI) board. A detailed description of the readout system can be found in [2].

SUMMARY AND OUTLOOK

A concept for the CBM BMON detector, consisting of a T0 station and a halo station, has been developed. The T0 station will be used to measure the time of arrival of particles with a precision of 50 ps. It will also be used for beam monitoring purposes and as part of a fast beam abort system.

The system is currently planned to be based on polycrystalline chemical vapor deposition (pcCVD) diamond technology. However, we are also evaluating the recently developed Low Gain Avalanche Detector (LGAD) technology.

The impact of the T0 detector on the performance of the CBM detector system has been studied. It was found that the T0 detector does not negatively influence the performance of the CBM detector system.

A manipulator system has been developed to remove the T0 detector from the beam axis. A demonstrator of the manipulator system is currently in production.

A prototype T0 detector based on pcCVD diamond material has been successfully tested at previous mCBM campaigns. For upcoming campaigns, we plan to further test the T0 detector and evaluate LGAD technology.

ACKNOWLEDGEMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072. We would like to thank TU Darmstadt and GSI Detector Laboratory for the preparation of the diamond sensors.

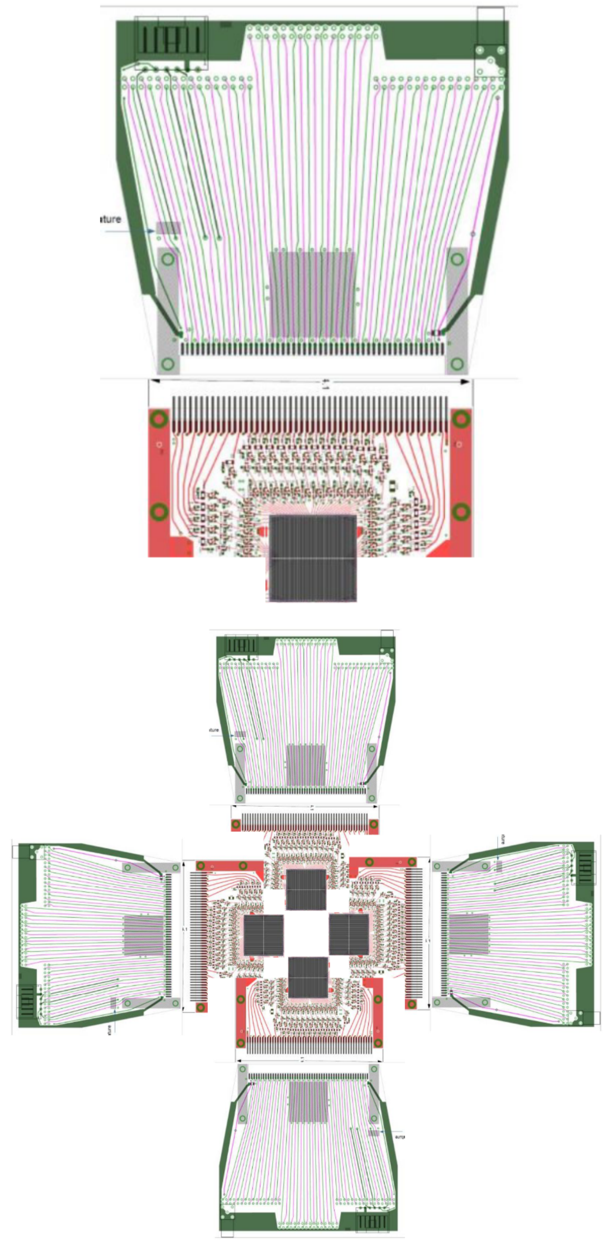

Figure 4: Sensor mount and feed-through PCB. The sensor will be glued into the recess and then bonded to the amplification stage input pads. **Upper panel:** One PCB is needed for the T0 system. **Lower panel:** A mosaic arrangement of four PCBs is used for the halo system.

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