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Document information

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WP2.4: Development and construction of beam monitors, target chamber and beam pipe for the CBM experiment at FAIR

1. CBM Beam pipe

Since February 2023, the Downstream section of the CBM beam pipe has been produced in the Czech Republic after the selection of a contractor in public tendering, tested at the Czech Technical University in Prague at the Faculty of mechanical engineering and delivered to GSI / FAIR in Darmstadt. After the delivery of the downstream beam pipe segments (5 tubes of different lengths) including the connection parts (connecting pieces of beam pipe segments that either include a connector to a vacuum pumping station or they are smooth) to FAIR in May 2023, the preparation for SAT procedure started. First measurements on the beam pipe were performed. Nowadays, the test stand is under further development. Next measurements of the mechanical beam pipe properties are foreseen in early periods of the year 2024.

1.1. Design of the CBM beam pipe

The CBM beam pipe is a vacuum vessel which is a core part of the experimental infrastructure. Inside the CBM beam pipe will be distributed charged particles from the FAIR collider SIS 100 which collide with a target material in front of the CBM detectors.

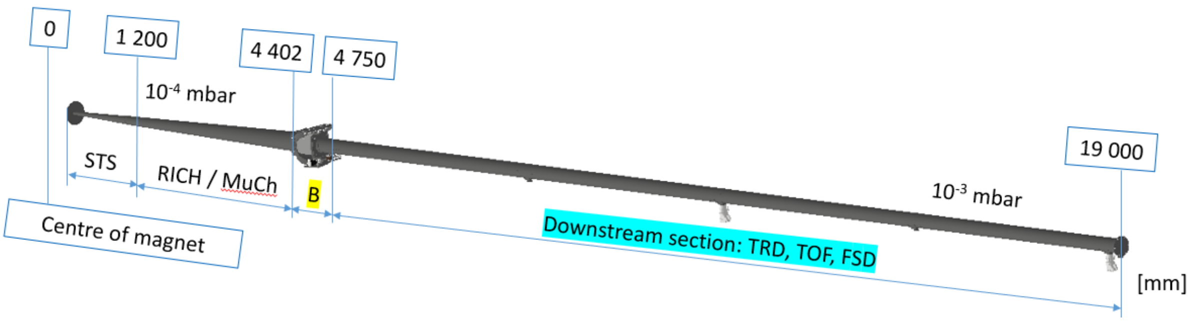

Figure 1: Overview of the beam pipe going through the CBM experiment with highlighted section for the downstream detectors TRD, TOF and FSD

The design of the CBM beam pipe is based on the inclined conical beam pipe which goes through the RICH or MuCH detectors. The geometry of this section is adapted for the beam distribution in a single polarity. For the change of the polarity of the measurement, the RICH MuCH section of the beam pipe must be rotated by 180°. Moreover, the bending of the cylindrical downstream section will be performed by a flexible vacuum component that will connect the RICH MuCH conical beam pipe and the downstream cylindrical beam pipe.

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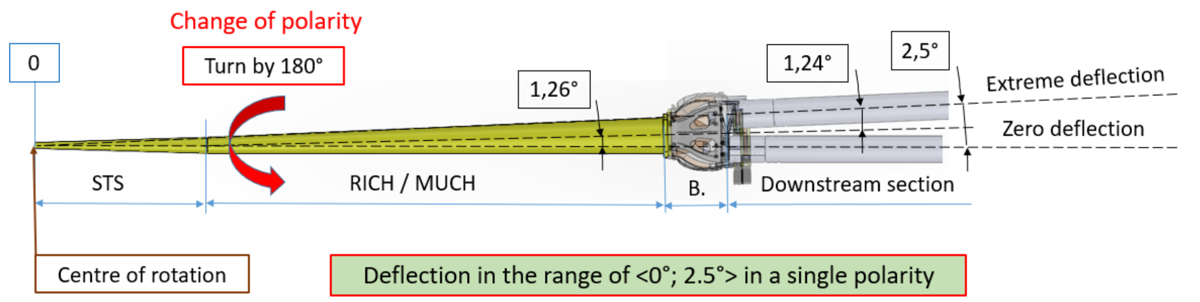

Figure 2: Design oft he CBM beam pipe with bending connector and possibility to change its polarity

1.2. The Downstream section of the CBM beam pipe

The parts of the Downstream beam pipe have been produced. The delivery of the downstream beam pipe to GSI / FAIR was done in May 2023.

The CBM downstream beam pipe is a mechanical vacuum system with inner under pressure. Since all particles have an impact on the results of the experiments performed with the CBM detectors, it is necessary to keep the total amount of the particles within the beam pipe system as low as possible, which is guaranteed by high vacuum inside the beam pipe of 10^{-3} mbar.

The Downstream CBM Beam Pipe is a composite tube with carbon fibre reinforcement and resin matrix. The beam pipe was designed as a self-supporting thin shell. The wall-thickness is 2 mm and the inner diameter 180 mm. Different lengths of its segments allow to change the position of connections to vacuum pumps and measuring equipment along the experimental setup.

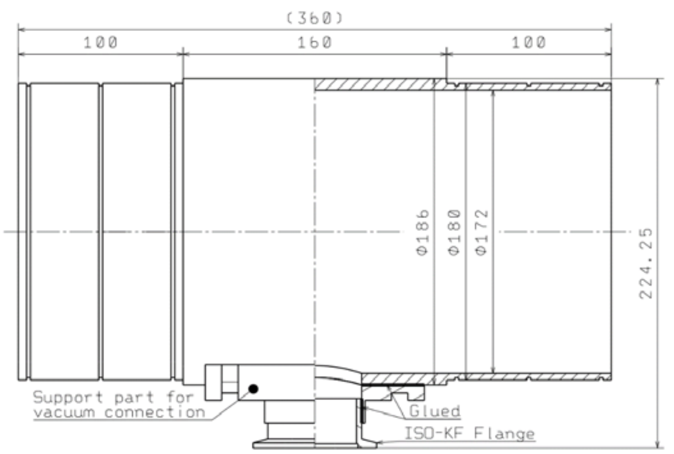

Figure 3: One type of connecting part with the vacuum inlet

The Downstream beam pipe is formed by 5 segments. 3 segments have got a length of 3,35 meters, 1 segment 2,1 meters and the last segment 1,2 meters.

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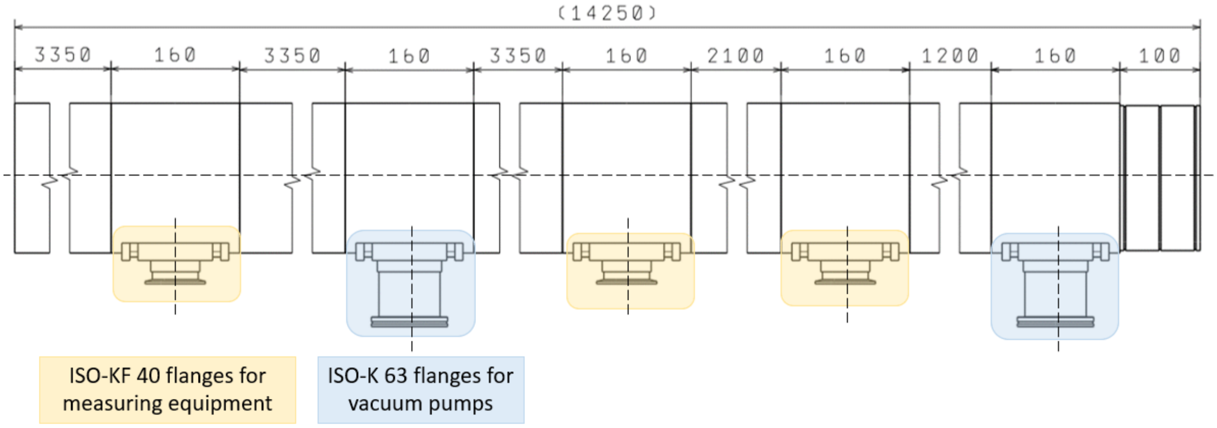

Figure 4: Drawing of the CBM Downstream beam pipe with sections of different lengths and different types of connecting parts

1.3. Experiments with the produced CBM downstream beam pipe

After the production of the Downstream beam pipe, the full setup was tested at CTU in Prague. As a part of the Factory Acceptance Test, the Beam Pipe was assembled and evacuated. The aim was not to reach desired vacuum, but to prove that there are no major leaks within the mechanical vacuum system. Pressure of $3,13*10^{-3}$ mbar achieved after 12 hours of pumping. The test was successful.

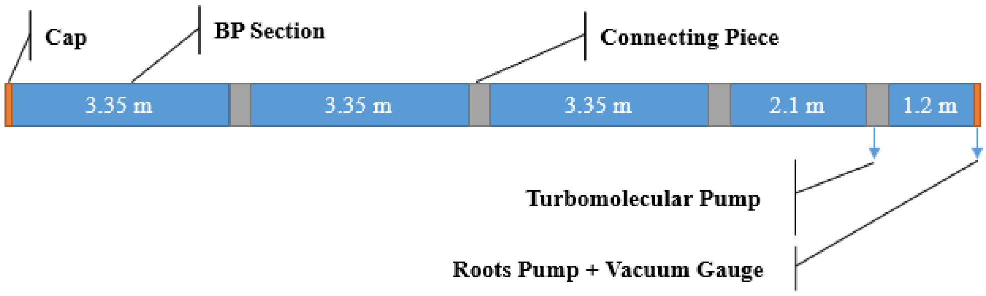

Figure 5: Scheme of the experiment with the beam pipe at CTU

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Figure 6: Assembled CBM Downstream beam pipe at CTU in Prague during measurement

Furthermore, another measurement was performed in order to find out, what is the influence of the friction of the surfaces in the connecting areas formed by the carbon fibre pipe segments and connecting parts sealed by the viton O-rings. Designed O-rings 175x2FPM80 were not used during the test because of issues with assembly. O-rings 165x2 NBR70 were used instead. The NBR O-rings had sufficient gas release parameter for required vacuum. The reduced hardness also provides smoother installation of the beam pipe compared to the FPM O-rings. The bollow depicted diagrams show more different measurements with the beam pipe segment connections and different number of O-rings.

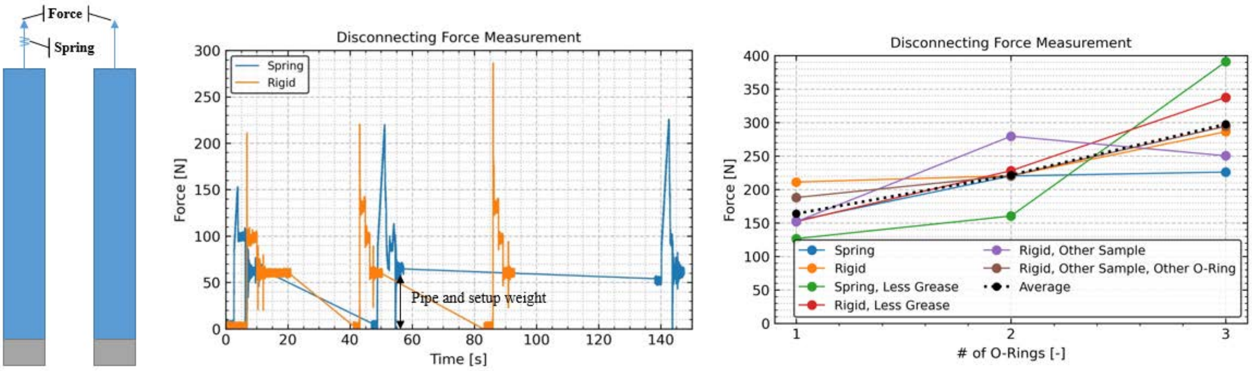

Figure 7: Measurement of disconnecting force of a beam pipe segment and connection part

The next measurement has been already arranged in GSI after the delivery of the Downstream beam pipe to GSI / FAIR. The measurement was a preparation for the upcoming Site Acceptance Test. For the foreseen SAT it was necessary to order new vacuum pumping station. Therefore, the SAT will take place during the next months in the spring 2024.

The test station is presented in the scheme below. It included a vacuum gauge to measure the pressure inside the beam pipe segments. The information about the pressure was transmitted to the Data acquisition station and saved. The pumping station involved a scroll pump and a turbomolecular pump. During the measurement, each delivered segment of the beam pipe was measured separately

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to check the major leaks (possible mechanical damages of the delivered parts). In this first preliminary measurement

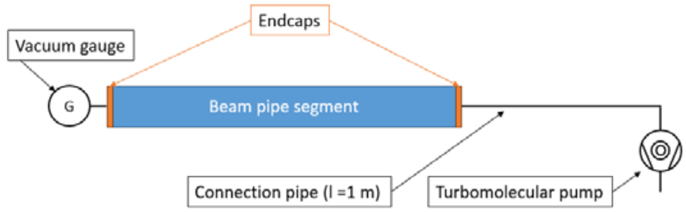

Figure 8: Scheme of measurement of beam pipe segments

Figure 9: Tested beam pipe segment

The results of the first measurement with the beam pipe segments are presented in the figure below. The change of the shape of the curves in the diagram is caused by starting the turbomolecular pump after the pressure in the beam pipe segments reached the value of 10^{-1} mbar. The maximal pumping time for one of the segments was 12 hours. No major leak on any of the segments were found.

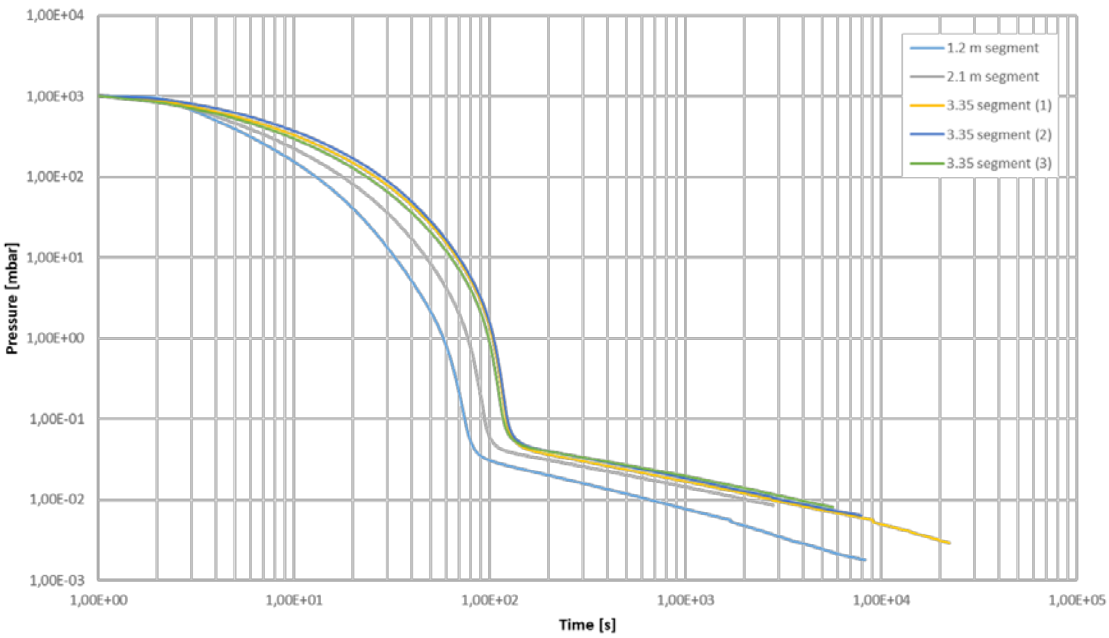

Figure 10: Pressure profiles of beam pipe segments from first measurement

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1.4. CBM beam pipe – conclusion and outline

CBM Downstream beam pipe was successfully delivered to GSI / FAIR in June 2023. Final engineering documentation has been provided to GSI / FAIR (technical drawings. After the first measurements it was approved that no damage of the delivered Downstream beam pipe parts occurred during the transport. In the future, the SAT of the delivered beam pipe will be finished and the design of the bending connector and the beam pipe support structures will be developed.

2. Beam monitors summary

During the funding period, significant progress has been made in developing a cutting-edge beam monitoring and T0 system for the CBM day 1 experiments. The system will be used for T0 measurements with a precision of approximately 50 ps and for beam monitoring purposes, such as beam halo particle measurements. It consists of two detector stations, one for beam monitoring and the other for T0 measurement. Both detector stations will utilize poly-crystal CVD diamond technology. The T0-station sensor, which employs poly-crystal CVD (pcCVD) diamond technology, will cover an area of 1 cm² and is equipped with metallization arranged in 16 strips on both sides. The strip segmentation and orientation are orthogonal, which allows the extraction of position information of the beam particles. The sensors will be mounted on dedicated printed circuit boards, equipped with amplifier and shaping circuits. The detector stations are located in standard vacuum elements that are integrated into the CBM beamline. A Conceptual Design Report has been finalized, outlining the system's architecture, functionalities, and performance targets. Figure 1 shows a schematic illustration of the CBM BMON system and a pcCVD diamond prototype sensor.

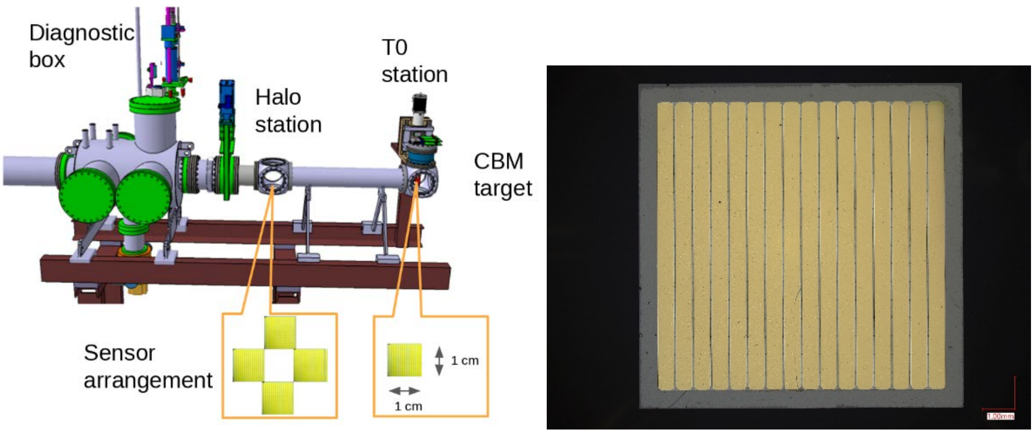

Figure 11: Left: Schematic illustration of the CBM BMON system, located in-front of the CBM target. It consists of two detector stations. For the T0 measurement a single sensor will be used and for the HaloBAS station a mosaic structure of four sensors is foreseen. Right: Close-up photography of the pcCVD diamond based prototype sensor for the T0 measurement. The metallization is arranged in 16 strips (each 300 µm wide) on the front and back side which allows beam profile measurements.

The design of the T0 detector station was completed during the funding period. The detector is equipped with a step motor and a flexible bellow, which allows for remote movement of the sensor

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from the beam axis. Figure 2 provides an illustration of the T0 detector system. Parts have been ordered, and the construction of the first demonstrator prototype is currently underway. In addition, a pcCVD diamond prototype sensor (see Figure 1) has been used to manufacture a T0 demonstrator detector which has been successfully used in the mCBM experiment.

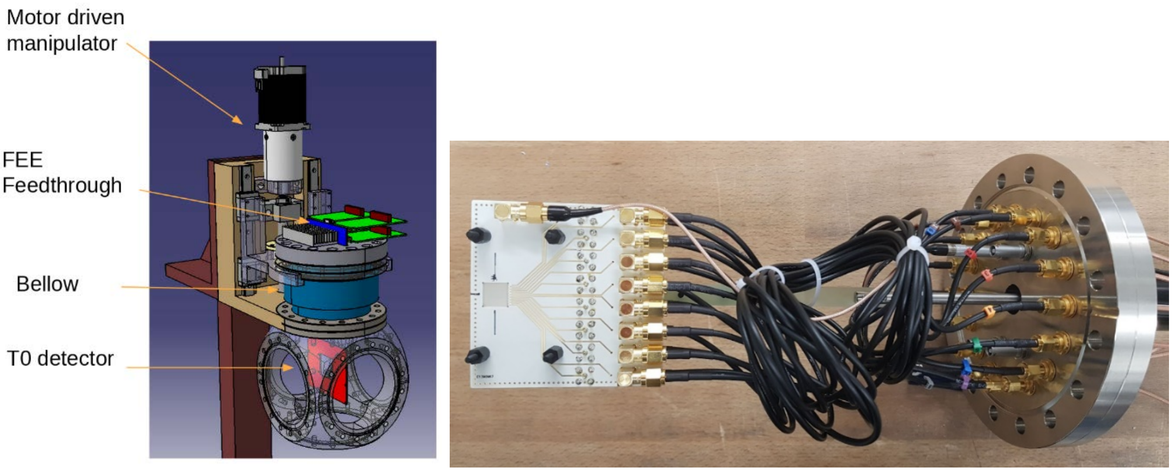

Figure 12: Left: 3D model of the CBM T0 manipulator system. The construction of the first demonstrator is currently underway. Right: T0 demonstrator detector which has been successfully used in mCBM.

The T0 prototype sensor was successfully tested in several mCBM measurement campaigns during the funding period. The sensor has been integrated using a CBM compatible read-out system utilizing the PADI discriminator and the GET4 TDC ASICs. A stable long-term operation could be demonstrated in several beam tests. Figure 3 shows an online measurement of the beam profile and the corresponding spill structure.

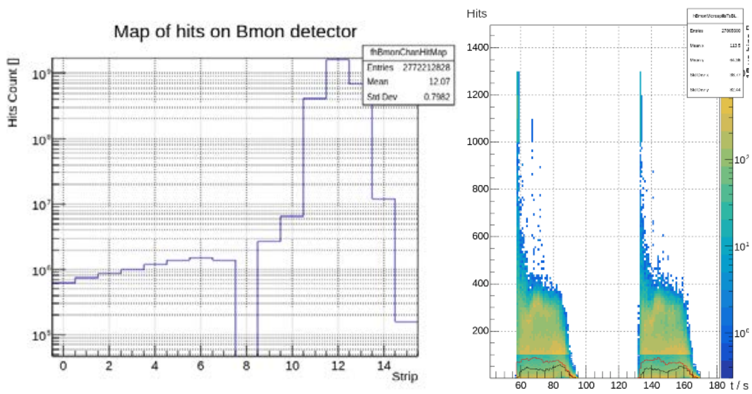

Figure 13: Left: Online beam profile measurement using the T0 detector in mCBM. Right: Corresponding spill structure measurement.

Furthermore, research and development on novel Low Gain Avalanche Detectors (LGADs) has been successfully undertaken at MedAutron and the COSY accelerator facilities. These detectors hold immense potential for enhancing the system's performance in future.

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- NPI CAS Nuclear Physics Institute of the Czech Academy of Sciences (Czech Republic)
- CTU FME Czech Technical University in Prague, Faculty of Mechanical Engineering (Czech Republic)
- CTU FNSPE Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering (Czech Republic)

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[2] SENGER Peter, FRIESE Volfgang, CBM Collaboration: CBM Progress Report 2022 [online], 2. 5. 2023 cit[26. 01. 2023], page 140 – 141, GSI Darmstadt, doi: 10.15120/GSI-2023-00384, available on: https://repository.gsi.de/record/336786

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