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1. Prototype MIMOSIS test system – Purpose and requirements

The deliverable prototype MIMOSIS test system was interpreted as a system demonstrating the capability to operate the state-of-the-art sensor MIMOSIS as developed in WP 7.1 in a real beam environment. As a suited beam telescope for testing MIMOSIS-1 was required within the project, it was decided to realize this system as a beam telescope, which was realized and used routinely during beam tests in 2021 and 2022. To do so, we aimed for a telescope formed from six sensors, which were typically mounted at a distance of 1.5cm. The four outer sensors were projected to serve as reference telescope measuring the track of the impinging particles. The two inner sensors were considered as devices under test (DUT). The basic functionality of the device consists in the reference telescope measuring the track of an impinging particle, which is then interpolated to the position of the DUT. Next, it is checked if the DUT sensed this particle and a detection efficiency can be extracted. Moreover, by comparing the interpolated particle track and the measured particle impact position, one may estimate the spatial resolution of the device. This measurement concept requires and that all six sensors are operated simultaneously, that they are capable of measuring particles and that the data obtained can be received, decoded and interpreted. By successfully operating the telescope, those essential sensor control capabilities are demonstrated. Due to constraints introduced by the Covid19-pandemie and in contrast to the initial plans, the telescope was designed and built under the leadership of the IPHC Strasbourg.

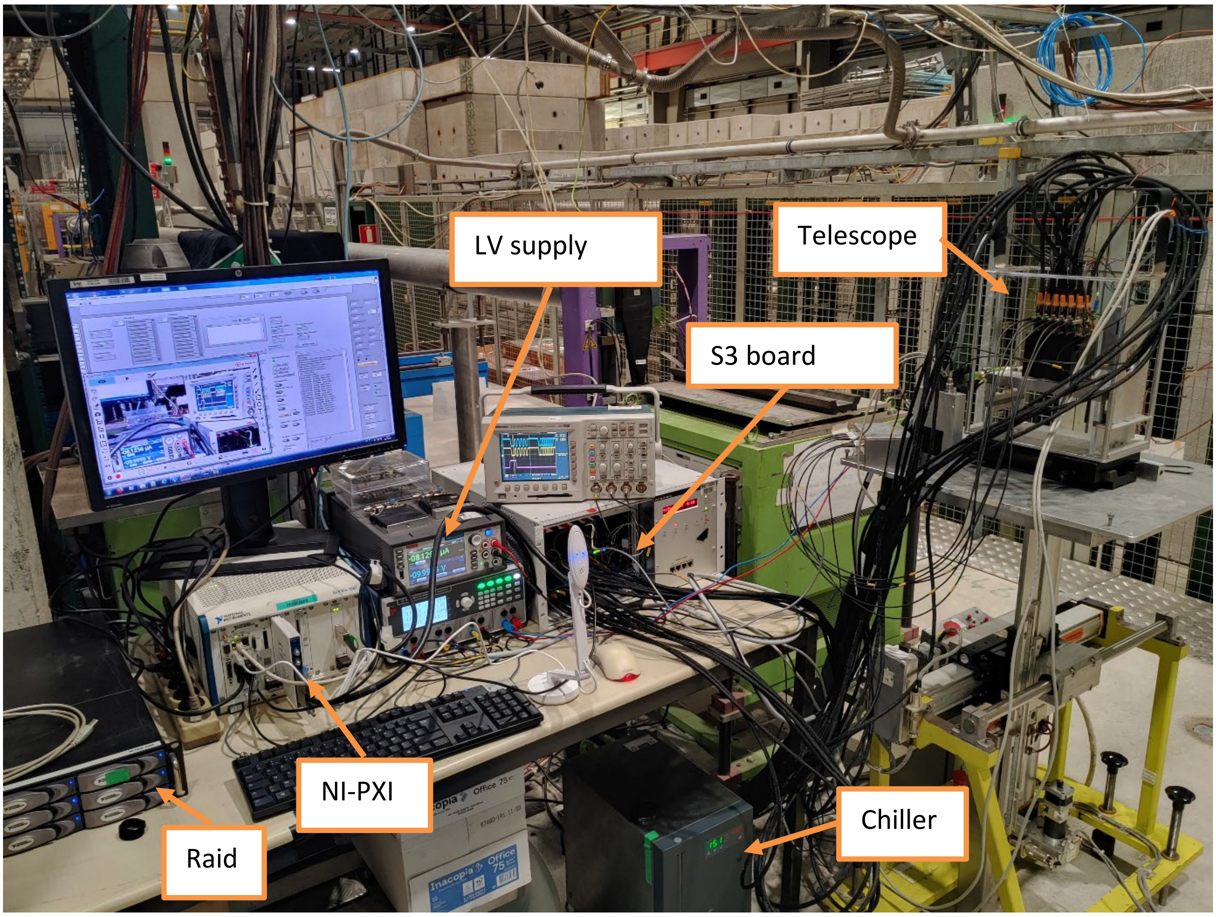

Figure 1: Photo of the telescope and the supporting electronics. The main components of the system are indicated.

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2. Realization of the telescope

The setup of the telescope as used in a CERN beam test is shown in Figure 1. To shield light and to control the temperature, the individual sensors were put into temperature controlled dark chambers. The multiple coulomb scattering along the particle track was minimized by placing 50µm thin sensors on a frame in their related proximity card and to minimize the walls of the dark chambers to few 10µm in the region penetrated by the particles by means of employing untransparent tape. The support structure holding the individual dark chambers were actively liquid cooled by means of a chiller and the typical coolant temperature was set to 15°C. The about 250 mW heat of the sensors was evacuated to this support via the aluminum frames of the dark chambers by means of heat conduction.
The sensors were wire bonded to dedicated proximity cards holding data buffers and voltage regulators. The I2C slow control of the sensors was provided by the S3 (Slow control, Steering Synchro) beam board, a dedicated VME-board developed by the IPHC. This board hosts an Arduino for slow control and clock synthesizer and duplicator IC to generate steering signals. The latter two units generated the fast control signals required to steer and to synchronize sensors of the telescope.
As for the data links, standard HDMI cables were employed as hardware base for the communication between the proximity cards and the control units. The option of MIMOSIS-1 to switch off non-required bandwidth was exploited in the telescope design. As this was considered as way sufficient for all targeted tests, the data was read out via two out of the eight data links of MIMOSIS-1 and forwarded to the NI-PXI control system. Here, it was collected, repacked and forwarded to a RAID server.
No attempt to process and reduce the data was made within the DAQ system of the telescope in order to avoid losing any information on the response of the still experimental sensors. On the other hand, the data link between the NI-PXI system and the data server is too slow to store the full data stream on disc. To overcome this limitation, a throttling mechanism buffering the data of about 5ms (1000 sensor frames of 5µs each) without dead time and hereafter rejecting consecutive frames until the buffer content is transferred to the mass storage, was established and found to provide sufficient data throughput to perform all scheduled tests in an efficient way.

3. Operation experience

The telescope was operated during the full test beam period of MIMOSIS-1, which consisted of seven beam tests carried out at CERN, COSY, CYRCé and DESY. All reference data recorded could be used for analysis and the system availability was essentially 100%, which demonstrates the reliable control of the sensors. A track resolution of 2.5µm for the reference planes was estimated for the high momentum beams available at the CERN-SPS. For the lower beam energies of DESY, an additional multiple coulomb scattering term of about 1.5µm had to be considered. During the beam tests, it was recognized that bunches of sensor frames have to be scanned for tracks as the sensor response shows a non-negligible time walk occasionally shifting hit indications by one frame. This is however a property of the MIMOSIS-sensors and cannot be corrected for at the level of the telescope. Test beams use only a marginal fraction of the bandwidth of the MIMOSIS-sensors, which is therefore filled up with idle words. As no preprocessing is performed, the data volume created by the telescope is rather large and dominated by those idle words. ZIP compression was found as a simple and efficient way to overcome this issue. On the other extreme, high-rate tests performed at the CYRCé accelerator at the IPHC Strasbourg demonstrated the telescope to operate reliably up to the system design limits set by the use of two data links per sensor. At the time of this report, the telescope is located at the IPHC Strasbourg and being upgraded for compatibility with the follow-up sensor MIMOSIS-2.1.

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