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CBM Collaboration STS Note 2018-03
29 August 2018

Report on knowledge exchange for the joint development of components for silicon detectors and for the low energy heavy ion collider NICA

CBM-STS team

GSI, Darmstadt, Germany and JINR-VBLHEP, Dubna, Russia

Editor: Johann M. Heuser, GSI

Abstract

Knowledge exchange towards the development and realization of the silicon tracking detector for the BM@N experiment at Nuclotron has been carried out by GSI and JINR-VBLHEP. We summarize the fields of activities and achievements made.

The work has been done with support from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 654166 (Project CREMLIN) [1]. This note serves as deliverable 2 of the project's work package 3 "Science cooperation with the NICA collider facility in the field of ion beams and heavy ion physics".

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1 The CBM and BM@N silicon tracking system projects: Common physics interests and technical synergies

The FAIR accelerators, in particular the heavy-ion synchrotron SIS-100 in the initial phase, will provide high-intensity beams of ions as heavy as Au at projectile energies up to 10A GeV. At JINR, the Nuclotron will provide beams of heavy ions with energies up to 6A GeV for isospin symmetric nuclei, and 4.65A GeV for Au nuclei. Both facilities are well suited for carrying out complementary physics programmes on the exploration of the phase diagram of strongly interacting matter in the region of high baryon densities. The CBM experiment at FAIR [2] will use the high beam intensities for measurements at collision rates up to 10 MHz. At Nuclotron, the extracted beams for the BM@N experiment [3] are also required to be of such quality that high beam-target interaction rates are achieved which will enable competative high-statistics measurements of physics probes sesitive to the high-density phase of matter.

It is planned in mutual interest by participants from the CBM Collaboration and by JINR to construct, install and operate several CBM experiment STS-type silicon tracking stations as part of the BM@N experiment. The installation of high-resolution silicon tracking stations in the extreme track density region close to the target of the BM@N experiment improves significantly the tracking efficiency, in particular for low-p_t tracks which do not reach the GEM tracking stations at larger distances from the target. A gain of a factor of two or more for reconstructed hyperons has been demonstrated by first simulations. The CBM collaboration in turn will profit greatly from the early-on experience to be gained by commissioning and operating silicon tracking stations similar to those to be installed in the CBM experiment. Moreover, software developments for calibration and alignment of the sensors will be readily applicable to the CBM STS.

A series of meetings has already taken place, reaching from early explorational workgroup meetings to the first “Collaboration meeting of the MPD and BM@N experiments at the NICA Facility” [4] and detailed technical planning workshops organized within the CREMLIN WP3 activity [5, 6].

Figure 1: Participants in the CREMLIN WP3 Workshop: The third Mini-Work Meeting “Making-up a Work Plan for building hybrid DSSD-GEM Tracking System for the BM@N-2”, JINR, Dubna, Russia, 5-6 July 2018.

2 Knowledge exchange on electronics

A vivid interchange on electronics developments has been initiated and practiced through interchange of personnell as well as prototype devices.

The silicon tracking systems for the experiments CBM at FAIR [2] as well as for BM@N at Nuclotron [3] are complex devices comprising not only silicon sensors but also analog micro-fabricated readout cables, high channel densitiy front-end electronics boards with dedicatedly developed readout microchips and finally an FPGA-based data acquisition system for readout of the self triggered data. From signal source to the final receiving computing node the following activities have been pursued:

- Development of micro-fabricated readout cables of ultra low material budget: The precise development of these cable designs is a confluence of technical needs and feasibilities of the interconnect technology, realized both at JINR as well as at GSI. Designs could be finalized after the development of alignment and interconnection jigs for assembly in close collaboration of the cable design team at LTU in Kharkiv and the assembly teams at GSI and JINR. Microcables are seen in Fig. 2 on partly finished STS detector modules prior to the final assembly step.
- Similarly first prototypes of front-end boads have been designed, realized in larger numbers (120 pieces) and distributed to all collaborating teams. These comprise the experiment-dedicated readout ASICs STS-XYTER. The electronics teams of JINR and GSI have mutually visited each other and organized a workshop in Darjeeling (India) [7], where they worked on the characterization and commissioning of the readout ASIC in a team - see the photo on Fig. 3. Through this work first prototype printed circuit boards have been developed and built that successively allowed to take the necessary back-end electronics chain into operation. Here the JINR-Team qualified the firmware code for the FPGA-based readout and fed-back the techical challenges encountered. With this experience at hand, the GSI team then realized firmware modifications and launched the project for reiteration. Indeed, in beamtime preparation, a dedicated workshop was organized on firmware development and finalization in which the engineers from JINR as well as GSI and universities joined to set-up and debug the entire system in a concerted action.
- Software experts from GSI programmed a running and operating readout system which was then employed for further system analysis. JINR software engineers spent a six week period at GSI with the goal to employ the existing readout software for quality assurance tool development for all stages of integration: Chip tests with a pogo-pins interface and using the identical DAQ-SYSTEM, front-end board tests for quality assurance of a final assembled module with readout boards, shown in Fig. 4.

Figure 2: STS detector modules of two variants during assemly. The microcables are visible, attached to read-out ASICs on the right hand side, prior to their installation into front-end read-out boards.

Figure 3: Participants from India and Europe in the Workshop on CBM related ASIC developments at the Darjeeling Campus of the Bose Institute, India.

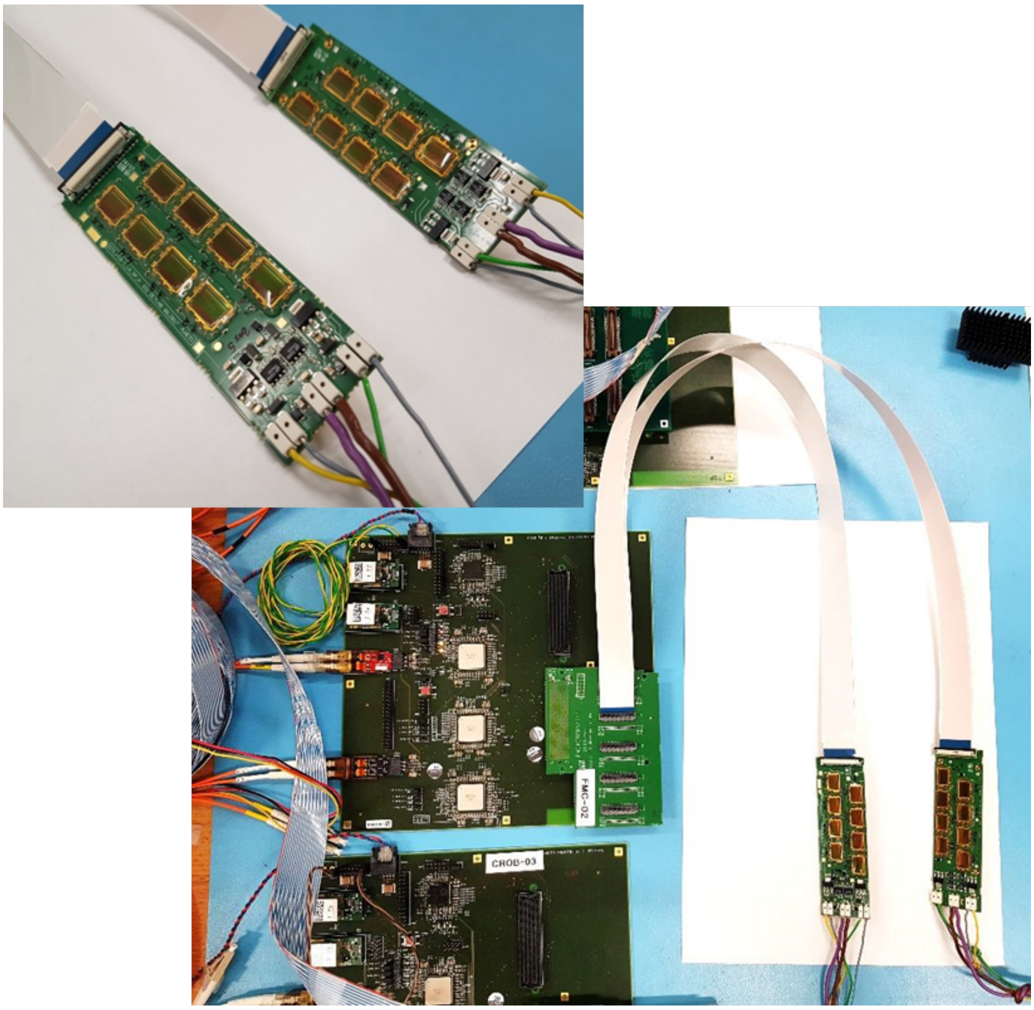

Figure 4: Front-end boards with eight STS-XYTER read-out ASICs have been developed in two geometrical variants. They are read out through data combiner boards based on the GBT chipset developed at CERN. An GBT emulator board with the same functionality will be used for application in BM@N at JINR.

3 Knowledge exchange on silicon sensors

The double-sided silicon microstrip sensors developed for the CBM experiment's tracking system find also application in the BM@N silicon tracking detector. In the course of the final prototyping, knowledge exchange and cooperation between the german and russian CBM participants has been lived.

- Batches of sensors with the second-to-final design iteration, labeled *CBM05*, have been produced in JINR budget to almost the full number required for BM@N. The current sensor design carries the version label *CBM06*. Final prototypes as those shown in Fig. 5 have been realized by GSI in four geometrical variants fitting for CBM. Small production batches have been ordered at two vendors, which are the CiS Forschungszentrum für Mikrosensorik GmbH, Germany, and Hamamatsu Photonics K.K., Japan. Only the three smaller variants are planned for application with BM@N. A small number of the smalles sensors is still to be re-ordered for BM@N to be sufficiently equipped.
- The sensor quality assurance procedure habe been established on both the german and russian sides. Upon delivery, the sensors have been final-inpected by the vendors. However, certain quality parameters have to be re-confirmed on a fractional level, some also fully. Workshops on the topic of electrical and optical sensor quality assurance took place at the University of Tübingen (29 January 2016) and at GSI (12 July 2017). A dedicated protocol and description of the procedure was published as an internal technical note [8]. The readiness of the semi-automated electrical sensor quality inspection on the JINR side has been presented in [9]. Readiness on the GSI side is discussed in the reports [10] and [11].

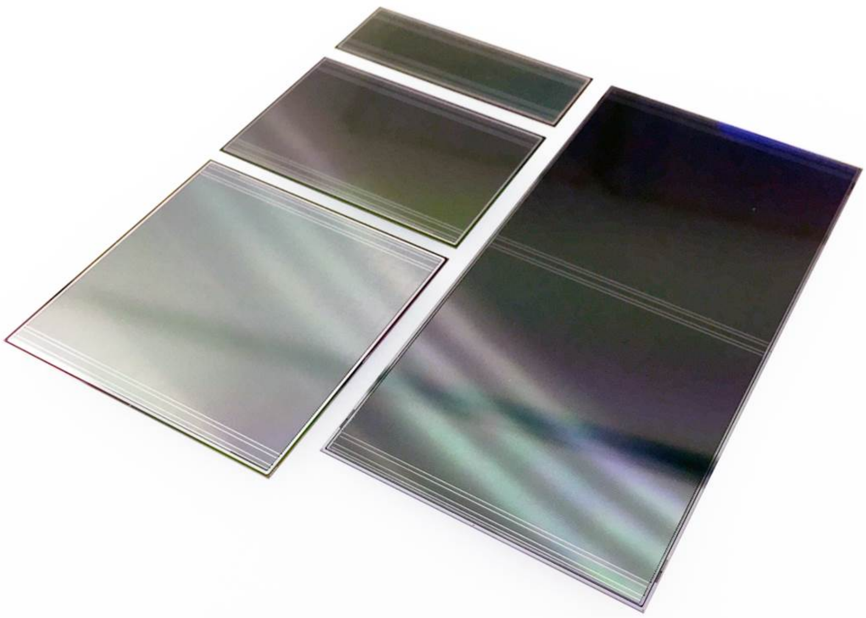

Figure 5: Final prototypes of the double-sided CBM silicon microstrip sensors. The four sensor variants have a common base design segmented into the same number of strips but differ in the length of the strips. On 6.2 cm total width, 1024 strips are placed. The strip lengths are 2.2 cm, 4.2 cm, 6.2 cm and 12.4 cm.

4 Knowledge exchange on modules, ladders and detector system integration

The integration of basic detector components, like front-end electronics boards and sensors, into composite structures that will build up the detector systems has been an extensively practised field of cooperation. In the context of the CBM Silicon Tracking System Project, a weekly Integration Workgroup has been organized, using video conferencing, with participation and contributions from both the german and russian sides.

- Module assembly has been practised in both the cleanroom laboratories established at GSI and JINR-VBLHEP. Tooling has been developed in a complementary way. Equipment for micro-interconnections ("bonding machines") have been set up in both places. The complementarity of module assembly achieved is best illustrated onthe example of the largest module. While the GSI team focused on tooling and exercising the assenbly with the largest 12.4 cm long sensor (Fig. 6), the JINR team explored and solved the technical issies of daisy-chaining two 6.2 long sensors and integrating them into a module of equivalent size (Fig. 6). During that procedure, fine-pitch inter-sensor connecting cables have to be placed on either side between the sensors.

Figure 6: Module assembly exercised at GSI with the longest 12.4 cm sensor variant.

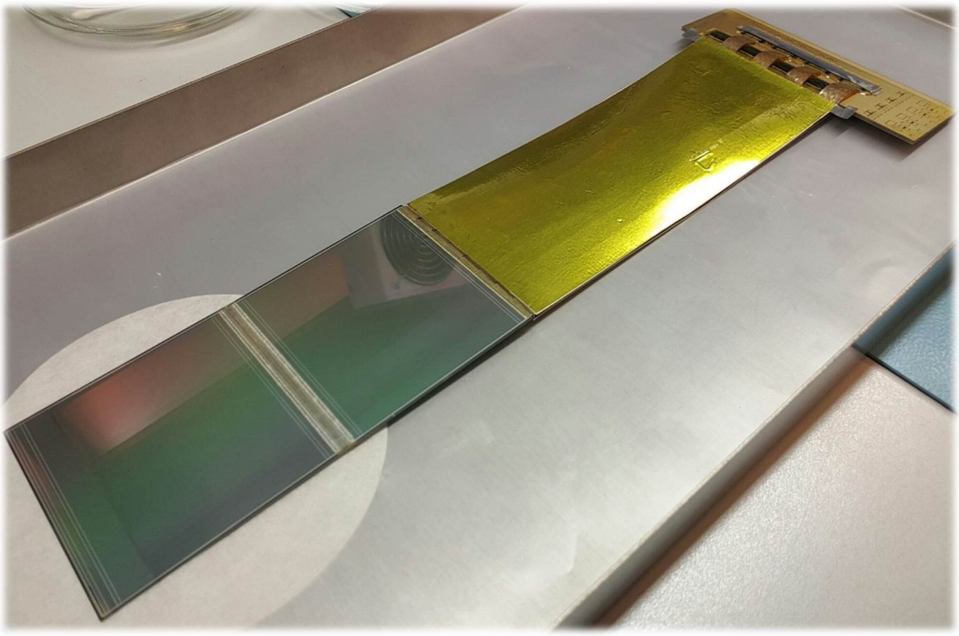

Figure 7: Complementary module assembly exercised at JINR with two 6.2 cm long sensors daisy-chained.

- Ladder assembly has likewhise been addressed commonly. A report on the achievement of prototype ladder assembly is available separately [12].

- The integration of the various component into the physical tracking detector system has been a task of continuous cooperation. Also centered around the weekly STS Integration Workgroup, the different tasks have been addressed. A common CAD design of the detector (Fig. 8) has been achieved and is in the process of being fully detailed. The freezing of design parameters is done step by step to enable progress on the next construction stage. Current issues of include the evaluation of the cooling concept to drain power dissipated by the electronics. A cooling demonstrator is being built for that purpose at the participating University of Tübingen. A technical solution for efficient heat transfer from the front-end electronics boards to the heat sink adapter on the cooling plates is being worked on by the JINR team. A similar work task is to be installed at JINR for the BM@N silicon tracking system.

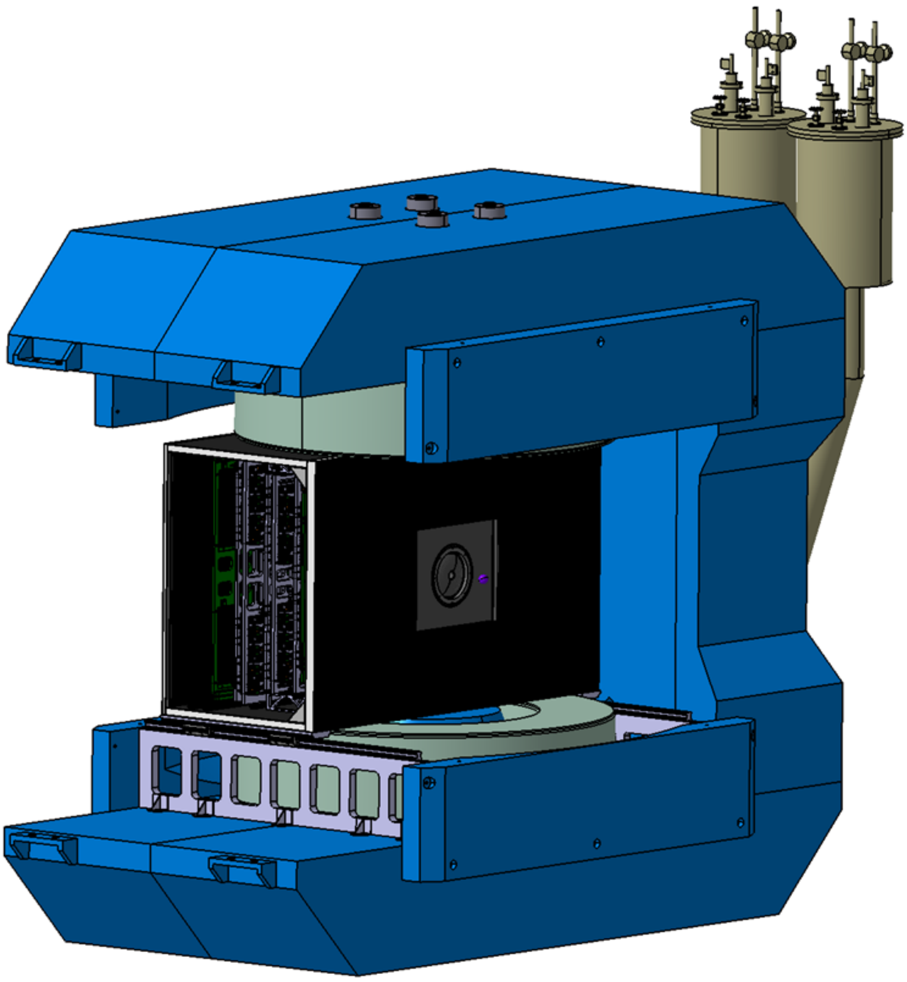

Figure 8: Global design of the CBM-STS in the superconducting dipole magnet.

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