Status of the Compressed Baryonic Matter (CBM) experiment at FAIR*

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The Compressed Baryonic Matter (CBM) experiment will be one of the major scientific pillars of the future Facility for Antiproton and Ion Research (FAIR) in Darmstadt. The goal of the CBM research program is to explore the QCD phase diagram in the region of high net-baryon densities using high-energy nucleus-nucleus collisions. A sketch of the QCD phase diagram is shown in figure 1, highlighting the expected structures at large baryon chemical potentials: a first order-phase transition separating the hadronic phase from quarkyonic matter [2], followed towards larger baryon-chemical potentials by the quark-gluon plasma at high temperatures, and by exotic phases at low temperatures. At small baryon-chemical potentials, theory predicts a smooth crossover between hadronic and partonic matter. According to transport calculations, baryonic densities of about 6 times saturation density can be reached in central collisions between gold nuclei at 10 A GeV, an energy which will be provided by the future SIS100 machine. At these densities, quarkyonic matter is expected to be created. A similar state of matter, a mixture of strange baryons and free quarks, is predicted to exist in the core of neutron stars at densities beyond 4 times saturation density [3].

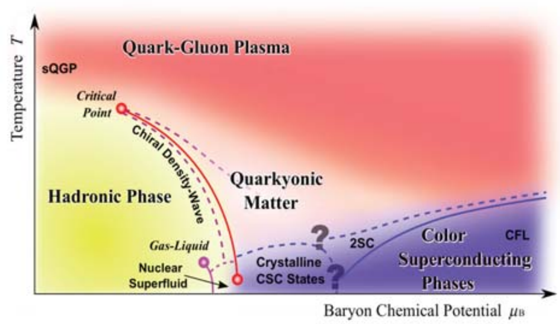

Figure 1: Sketch of the QCD phase diagram [1].

The CBM research program includes the study of the equation-of-state of nuclear matter at neutron star core densities, the search for the chiral phase transition, and for new forms of strongly interacting matter. The CBM detector is designed to measure rare diagnostic probes such as multi-strange hyperons, charmed particles and vector mesons decaying into lepton pairs with unprecedented precision and statistics. In the following, the results of the technical developments in 2013 will be briefly reviewed.

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The superconducting dipole magnet

The design of the CBM SC dipole magnet has been optimized. It has a large aperture (gap height 140 cm, gap width 260 cm) in order to host the Silicon Tracking System. The field integral is 1 Tm. Detailed quench calculations have been performed, and the quench protection system has been designed. The Technical Design Report has been approved in January 2014.

The Micro-Vertex Detector

A refined geometry of the CBM-MVD based on 4 detector stations has been developed. Together with IPHC Strasbourg the 0.18 μm CMOS process has been investigated with respect to radiation hardness and noise. The 2^{nd} generation of MAPS read-out and TRBv3-based data acquisition has been developed. The Analysis of the CERN-SPS test beam data has been concluded, reproducing the intrinsic features of the MAPS chips mounted in the prototype and validating the general concept of the MVD integration.

The Silicon Tracking System

For the CBM Silicon Tracking System (STS) double-sided micro-strip sensors in all required dimensions (6.2×6.2 cm^2, 6.2×4.2 cm^2, 6.2×2.2 cm^2) have been produced in cooperation with CiS, Erfurt, Germany and Hamamatsu, Japan. The front side strips are inclined by 7.5°. In order to interconnect short strips in the sensor corners to a strip in the opposite corner the sensors are equipped either with a second metallization layer, or with pads for an additional micro-cable. The performance of both options will be investigated. Each sensor (2048 strips) will read out via 16 low-mass micro cables (128 wires each) by 16 free-streaming ASICs 125 channels each). A mockup of such a module has been produced, and the tab-bonding of the cables has been successfully tested. Several of these modules consisting of a sensor, the cables and the front-end board carrying 8 ASICs will be mounted on a light-weight carbon ladder. Up to 16 of these ladders will be integrated into a detector station. A mechanical mockup of a half station has been built. A prototype $C0_2$ cooling system has been designed. Several prototype modules comprising single and daisy-chained sensors, read-out cables and a free-streaming read-out-system has been successfully tested in December 2013 with a proton beam at COSY/Research Center Jülich. The STS Technical Design Report submitted to FAIR in December 2012 has been approved in August 2013.

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The Ring Imaging Cherenkov (RICH) detector

The analysis of beam time data from the test campaign in 2012 has been finalized. Important results have been obtained on the performance of the different photon sensors, on the optimal wavelength-shifter coverage, and on the requirements for mirror alignment and gas purity. In the lab new testing devices for single photon scans of photon sensors and the mirror surface have been set up. A larger prototype of the mirror wall is being constructed to perform tests of its stability while minimizing the material budget. The RICH Technical Design Report has been submitted in June 2013, and was approved in January 2014.

The Transition Radiation Detector

The analysis of the test beam established that all full size prototypes (by the groups from Bukarest, Frankfurt and Münster) perform according to the specification in terms of electron-pion separation. Several promising foam-type radiator materials have been identified. The SPADIC 1.0 readout chip has been finalized and tested and can now be commissioned for the upcoming test beams. Also, feature extraction algorithms have been implemented and are ready for tests with real data. The writing of the Technical Design Report is in progress.

The Muon Detection System

The layout of the Muon Chamber system (MuCh) and its performance have been optimized by replacing the first 20 cm thick iron absorber by a 60 cm thick carbon absorber. The mechanical structures supporting the detectors and the absorbers have been designed. A large area (31×31 cm^2) triple-GEM chamber made from single-mask foils has been built by the group in VECC Kolkata and successfully tested in December 2013 with a proton beam at COSY/FZ Jülich. Various prototype hybrid detector systems based on GEM and micromegas technologies have been built and tested at PNPI Gatchina. A full-size prototype Straw-chamber has been built at JINR Dubna. The development of a read-out ASIC has been started at MEPhI in Moscow. The MuCh Technical Design Report has been submitted in December 2013.

The time-of-flight system

The CBM - TOF - wall will mostly be composed of differential impedance matched strip MRPCs that are adjusted to the strongly polar angle dependent particle fluxes by implementing different strip lengths and employing low resistance electrodes where necessary. The low resistance electrodes can be constructed by ceramic, low resistivity glass or for more moderate rate requirements by thin standard glasses. Supermodule designs based on pad - MRPCs for the small polar angles are made available and might offer some advantage in terms of cost and rate capability.The exact layout of the wall is being optimized with the help of a newly created generic geometry description in the CBM simulation framework that also includes a proper description of the passive materials. For the first time a free streaming data processing chain based an the PADI and GET4 ASICs was realized with prototype detectors signals demonstrating the feasibility to achieve system timing resolutions in the order of 80 ps without any noticable dead time. First step are undertaken towards a common software framework capable of handling test beam data and simulations in a consistent way. The TOF Technical Design Report has been submitted in December 2013.

The Projectile Spectator Detector

The layout of the Projectile-Spectator detector (PSD), its distance from the target, and the settings of the magnetic field have been optimized in order to improve the performance in determining the reaction plane and the collision centrality over the full SIS100/300 beam energy range. The PSD Technical Design Report has been submitted in April 2013.

DAQ and First Online Event Selection (FLES)

In order to achieve the required precision, the measurements will be performed at very high reaction rates of 1 to 10 MHz. This requires a novel data read-out and analysis concept based on free streaming front-end electronics and a high-performance computing cluster for online event reconstruction and selection. The development of the full read-out and analysis chain based on detector hits with time stamps is in progress. The FLES system consists of a scalable supercomputer with custom FPGA-based input interface cards and a fast event-building network. It will be largely constructed from standard components, and will be located in the new FAIR data center. The submission of the DAQ/FLES Technical Design Report is planned for 2014.

Status of the Technical Design Reports

Subsystem	Status TDR
Superconducting Dipole Magnet	approved
Micro-Vertex Detector	submission 2014
Silicon Tracking System	approved
Ring Imaging Cherenkov Detector	approved
Time-of-Flight wall	in evaluation
Transition Radiation Detector	submission 2014
Muon Tracking Chambers	in evaluation
Projectile Spectator Detector	in evaluation
Electromagnetic Calorimeter	submission 2014
DAQ/First Level Event Selection	submission 2014

References

[1] K. Fukushima, T. Hatsuda, Rept.Prog.Phys.74(2011)014001

[2] L. McLerran, R. D. Pisarski, Nucl. Phys. A 796(2007)83

[3] M. Orsaria et al, arXiv:1308.1657

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