# Review of the project “Compressed Baryonic Matter Experiment (CBM)”

The description of the CBM project is very detailed and presents complete picture of the physics goals: exploration of the phase diagram of strongly interacting matter using high energy nucleus-nucleus collisions; investigation of highest baryon densities at still moderate temperatures, including the question of deconfinement and chiral phase transitions. The energy range from 10 to 40 GeV/u will be scanned searching for:

* In-medium modifications of hadrons in dense matter.
* Indications of the deconfinement phase transition at high baryon densities.
* The critical point providing direct evidence for a phase boundary.
* Exotic states of matter such as condensates of strange particles.

The research program is focused on the investigation of:

* short-lived light vector mesons (e.g. the ρ-meson) which decay into electron-positron pairs. These penetrating probes carry undistorted information from the dense fireball;
* strange particles, in particular baryons (anti-baryons) containing more than one strange (antistrange) quark, so called multistrange hyperons (Λ, Ξ, Ω);
* mesons containing charm or anti-charm quarks (D, J/Ψ);
* collective flow of all observed particles. event-by-event fluctuations.

The CBM detector is designed to measure multiplicities, phase-space distributions and flow of protons, pions, kaons, hyperons, hadronic resonances, light vector mesons, charmonium and open charm including their correlations and event-by-event fluctuations in heavy ion collisions.

The JINR group made significant contributions to the design of the CBM Superconducting Dipole Magnet, to the development of algorithms and software for data processing and simulation, and to the detector R&D.

The JINR group is responsible for

* The expertise of the design and participation in the maintenance and commissioning of the CBM Superconducting Dipole Magnet.
* The development of the algorithms and software for track and ring reconstruction in different CBM subdetectors as well as for the global track reconstruction.
* Preparation of the physics program for multi-particles dynamics at SIS100 energies.
* The R&D of the straw detectors prototype as an option for two last (3-rd and 4-th) tracking stations for the MuCH detector, R&D of the detectors with SiPM readout.
* Participation in the data taking at mini-CBM, participation in the analysis of the data obtained within FAIR PHASE0 program.
* Participation in the commissioning of the CBM detector.

The group consist of 48 members and contributes 7.9 FTE to the CBM experiment. Such distribution of FTE is related to the specific time of CBM, namely, to its Construction Phase.
 a) Significant part of R&D, software developments and TDRs preparation that required a lot of qualified manpower, is already finished.  Some activity is still needed , for instance, superconducting magnet experize, but this requires less manpower.
 b)  The technicians making contribution into the detector systems are also included in the list as the associated members of CBM.
 c)  Most of LHEP peoples are involved in the NICA project. Synergy  between CBM and HI program at NICA reduces the value of required FTE.
The list of the participants with their FTE will be changed significantly at the end of the CBM Construction Phase within 8-10 FTE in total.

During the previous period (2016 – 2020) the JINR group was very visible within the collaboration. Its members participated in 75 publications, 9 in journals, 46 in CBM Progress Reports, 20 in conference proceedings. They also prepared about 40 talks at CBM collaboration meetings. The group participates also in the management of the CBM experiment, where V.P.Ladygin is deputy spokesperson.

It is important to underline the synergy of the CBM/HADES and MPD/BM@N projects, which is further increased due to the signed in 2018 German-Russian Roadmap for Cooperation in Education, Science, Research and Innovation. It is very positive that the group profits from the DAAD and BMBN-JINR grants for young researchers and from the BMBF grants for detector development (silicon trackers).

The plans of the JINR group are

* 2021: Development of technical documentation and preparation of production of detectors, participation in the magnet expertise, creation of databases, simulation of the detectors and setup, development of a physics program for the CBM project; participation in FAIR Phase 0 experiments at SIS18.
* 2022-2023: Manufacture of detectors, participation in the magnet expertise, development of the reconstruction of events, the elaboration of the physics program of studies on the CBM project; participation in development of the detector prototypes and event reconstruction algorithms; participation in FAIR Phase 0 experiments at SIS18 and Nuclotron.
* 2024-2025: Installation of the magnet and detectors in the CBM/HADES experimental hall, participation in the commissioning of different detector systems and CBM detector as a whole, development of the reconstruction of events, the elaboration of the physics program of studies on the CBM project; preparation of the CBM detector to the data taking.

We have to point out there are two  experiments within CBM project: mini-CBM in 2021-2023 with SIS18 beam and CBM with SIS100 beam starting from 2027.
 a) mini-CBM beam request for 2021 and 2022 is approved by GSI PAC. It includes 15   shifts of any HI beams for the commissioning in 2021 and 15 shifts of Au+Au and Ni+Ni at 1.24 and 1.93 A\*GeV, respectively, in 2022.
 b) According to FAIR Operation Modes plan CBM requires beams of protons, N-14, Ar-40, Ni-63, Ag-107 and Au-197. The energy range for the protons is 5-29 GeV, while for the nuclei is 2-11 A\*GeV. Several targets were discussed and may be required by the physics program: Au+Au, Ag+Ag, Ni+Ni, Ag+KCl, N+C or N+Be data. Runs with proton beam will require at least one light and one heavy targets.

The requested budget is 371 kUSD, where 286 kUSD will be used for equipment, materials and common fund, and 85 kUSD for travel. This is relatively modest amount, compared to the expected BMBN-JINR grant of 500 kUSD. The grant money will be used for equipment, materials and travel expenses.

The authors of the project prepared concise SWOT analysis, where they indicated possible weakness, namely CBM might be late compared to STAR BES-II, NA61 and MPD/BM@N. In such case they plan to focus on the high- statistics measurements of the rare probes like dileptons, hidden and open charm, multi-strange hyperons even at the first stage of the experiment (with a rate up to 500 kHz for Au+Au events).

**The reports of the referees Yu.A.Panebrattsev and V.A.Bednyakov are positive and strongly support the requested extension.** They indicate the outstanding contributions of the JINR group, the expertise of the members, the high scientific value of the project and its complementarity to the other heavy ion experiments, and the political importance of the collaboration with FAIR that brings additional resources to JINR.

**I completely agree with the opinion of both referees and propose to extend the JINR participation in the CBM experiment in 2021-2025**. As referee I would like to thank V.P.Ladygin for his help in clarifying several questions.

Peter Hristov

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