Письма в ЭЧАЯ. 2016. Т. 13, № 5(203). С. 993–999

THE UNIFIED DATABASE FOR THE FIXED TARGET EXPERIMENT BM@N

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The article describes the developed database designed as comprehensive data storage of the fixed target experiment BM@N [1] at the Joint Institute for Nuclear Research (JINR) in Dubna. The structure and purposes of the BM@N facility will be briefly presented. The scheme of the unified database and its parameters will be described in detail. The use of the BM@N database implemented on the PostgreSQL database management system (DBMS) allows one to provide user access to the actual information of the experiment. Also, the interfaces developed for the access to the database will be presented. One was implemented as the set of C++ classes to access the data without SQL statements, the other is Web interface available on the Web page of the BM@N experiment.

PACS: 07.05.-t; 07.05.Bx

THE BM@N FACILITY

Heavy-ion collisions at high energies provide a unique opportunity to study nuclear matter under extreme density and temperature. These conditions are well suited to investigate the compressibility of nuclear matter, in particular, the stiffness of the nuclear equation of state (EOS). Theoretical models, however, suggest different possible scenarios for these modifications, so that new experimental data with high resolution and statistics are needed in order to disentangle different theoretical predictions. The study of hypernuclei is expected to provide new insights into the properties of the hyperon–nucleon and hyperon–hyperon interactions. The research program on heavy-ion collisions at the Nuclotron of the Joint Institute for Nuclear Research includes the following topics: investigation of the reaction dynamics and nuclear EOS, study of the in-medium properties of hadrons, production of (multi)strange hyperons at the threshold, and search for hypernuclei [2].

The BM@N experiment, short from Baryonic Matter at the Nuclotron, is the experiment (Fig. 1) at the extracted Nuclotron beam of the Veksler and Baldin Laboratory of High Energy Physics (VBLHEP JINR) to study collisions of elementary particles and ions with a fixed target with energy up to 4 GeV per nucleon (for Au^{79+}). The BM@N facility is one of the main elements of the first stage of the NICA collider development to study hot and dense matter in heavy-ion collisions.

Figure 2 presents the three-dimensional scheme of the BM@N facility proposed to study the elementary reactions ($p+p$, $p+n$) and cold nuclear matter ($p+A$), the properties of dense

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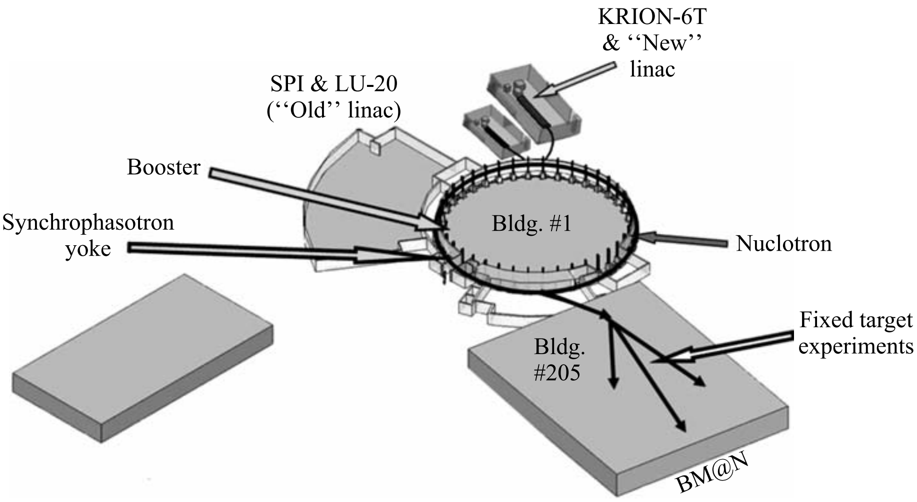

Fig. 1. BM@N experiment at the extracted Nuclotron beam

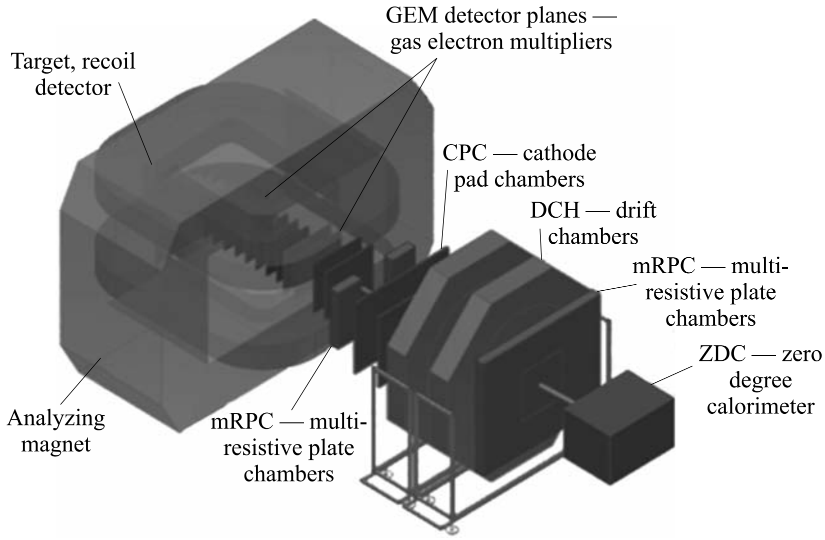

Fig. 2. Three-dimensional scheme of the BM@N facility

baryonic matter in heavy-ion collisions with the fixed target, in-medium effects, hypermatter production, strangeness and hadron femtoscopy. Particle yields, ratios, transverse momentum spectra, rapidity and angular distributions, as well as fluctuations and correlations of hadrons, will be studied as a function of the collision energy and centrality.

In the gold ion collisions with a gold target at these energies, very high multiplicity can be reached. The BM@N facility should identify the particles produced in the collisions with high efficiency and estimates their parameters with high precision for the full study of hot matter, that is why BM@N is constructed as the set of different types of detectors.

BM@N combines high-precision track measurements with the time-of-flight information for particle identification registered by detectors and total energy measurements for event characterization. The beam target is located inside the large-acceptance dipole magnet. The BM@N setup divides detectors for particle identification into "near to magnet" and "far from magnet" to measure particles with low as well as high momentum. Intermediate coordinate detectors fill the distance between the magnet and the "far" detectors to increase the efficiency of particle identification. The TOF (Time-of-Flight) detector is proposed to identify primarily hadrons and light nucleus; Zero Degree Calorimeter (ZDC), to measure centrality of the collisions and the form trigger. The recoil detector, partially covering the backward hemisphere near the target, is planned for the independent analysis of the collision centrality by the measurement of the energy of the target fragments.

PREREQUISITES OF THE DATABASE DEVELOPMENT

The first technical run of the BM@N experiment started on 22 February, 2015, and three experiment runs were conducted during the Nuclotron session with deuteron and carbon beams collided with carbon or copper target at the energy about 3.5 GeV per nucleon. Hundreds of raw data files were obtained and converted to the ROOT [3] format. Multiple parameter data of the BM@N experiment were stored in files of different formats, such as HTML, Excel and text, created manually after experiment runs.

As a result, the following main problems were encountered, which are concerned with the BM@N data storing. The data of the experiment are distributed between many subdivisions, and it is difficult to find necessary absent information for other subdivisions. The required information is stored in a lot of files of different types (binary, HTML, Excel, text). Such data as, for example, detector mapping can be corrected, but users will not know about the changes and will continue to work with old data. The BM@N geometry schemes are hand-drawn and can be varied from run to run.

The main disadvantages of the file storing approach used previously can be noted:

- The usage of multiple files and arbitrary formats, duplication of information in different files lead to data isolation, redundancy and inconsistency.
- Sequential, nonindexed file access and search are not efficient.
- No mechanism exists for relating data between these files.
- It is difficult to access and manipulate the data: one needs some dedicated programs.
- Uncontrolled concurrent access by multiple users also often leads to inconsistencies.

Today the use of databases is a prerequisite for qualitative management and unified access to the data of modern high-energy physics experiments. The unified database designed as central data storage of the BM@N experiment offers solutions to the problems above and provides unified access and data management for all BM@N members, correct multiuser data processing, ensuring the actuality of the information being accessed (run parameters, detector geometries and positions, technical and calibration data, etc.), data consistency and integrity, excluding the multiple duplication and use of outdated data, provides automatic backup of the stored data.

THE UNIFIED DATABASE OF THE EXPERIMENT

First of all, the developed database has merged the existing BM@N databases to simplify access and administration. It merged a simulation database (based on MySQL DBMS) contained information about simulation files generated by different event generators, such as UrQMD and QGSM, and located on the NICA cluster. Also the BM@N geometry database

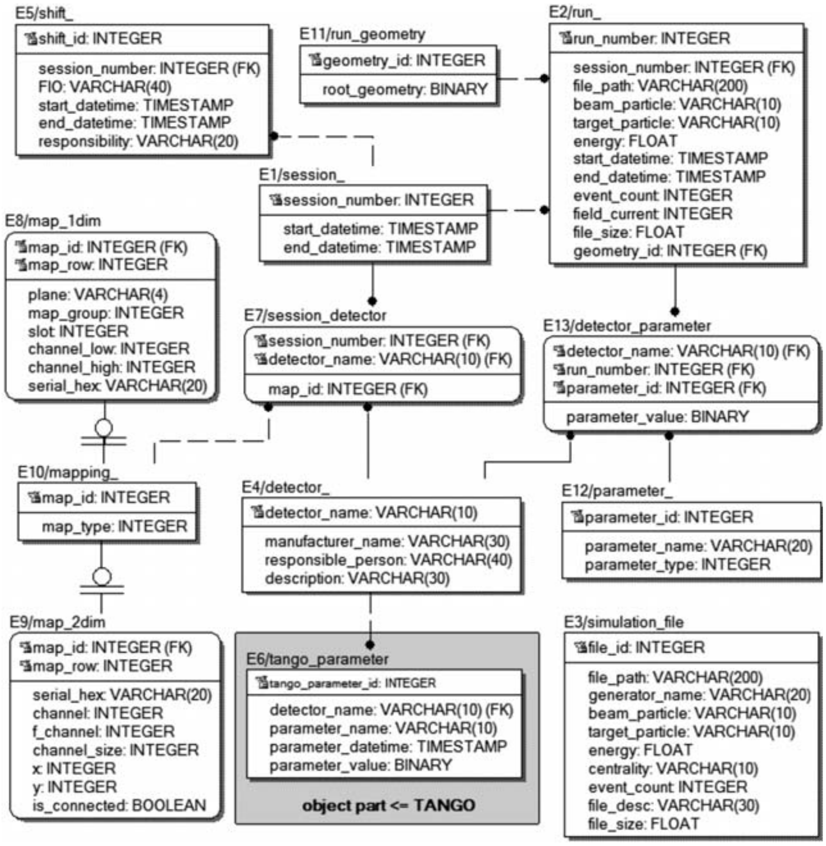

Fig. 3. ER diagram of the unified database

(PostgreSQL) with a set of detector geometries and position data of the BM@N subdetectors was merged.

Entity-relationship diagram of the unified database is shown in Fig. 3. The database contains the following tables: sessions and runs, shifts, detectors and their parameters, detector mappings, the BM@N geometries and simulation files. Tango parameters of slow control system do not correspond to any table of the unified database, but its interface is implemented as C++ object class. Indeed, the database also contains tables to store detector geometries in a more complex way which is originated from the geometry database, but it is not used now.

The data being stored in the BM@N database can be classified into four groups:

1. Configuration data are concerned with the detector running mode, i.e., voltage settings as well as some programmable parameters for front-end electronics.

2. Calibration data describe the calibration and the alignment of different subdetectors. Usually quantities are evaluated by running dedicated offline algorithms.

3. Parameter data present the state of detector subsystems. They comprise a variety of detector settings including the geometry and material definitions.

4. Algorithm data are used to control the way algorithms operate. They include, for example, cuts for selection and production paths of files.

To support the BM@N experiment, the BMNRoot software is developed. The unified database integrates with the BMNRoot software which serves for event simulation, reconstruction, and following physical analysis of particle collisions with the fixed target registered by the BM@N facility. It is implemented in the programming language C++ based on the ROOT and FairRoot [4] environments. The BMNRoot has a runtime parameter manager which writes and initializes parameters from ASCII or ROOT files but it cannot work with a database system. Also, it can be noted that BMNRoot converts the BM@N geometry from *.geo and *.root subdetector files to single ROOT file used to visualize BM@N on the screen and stored in the developed database.

The developed database implemented on the PostgreSQL DBMS provides user access to the actual information of the experiment: run parameters, the BM@N detector geometries changing during the session, experimental data obtained, etc. It avoids the multiple duplication and use of outdated data in different JINR subdivisions. The implemented automatic backup of the unified database ensures that all stored data of the experiment will not be lost due to software or hardware failure.

C++ AND WEB INTERFACE OF THE UNIFIED DATABASE

To process the data of the experiment in the BMNRoot environment, C++ database interface was implemented as a set of C++ class wrappers for all database tables with many specific functions. It allows one to work with the data of the unified database without any SQL statements. The classes correspond to the database tables and manage information about the BM@N sessions (DbSession), shifts (DbShift), runs (DbRun), detectors (DbSessionDetector, DbDetector), mappings (DbMapping, DbMap1dim, DbMap2dim), parameters and their values (DbParameter, DbDetectorParameter), detector geometries (DbRunGeometry), and generated simulation files (DbSimulationFile).

Some additional classes of C++ database interface were developed. DbConnection serves to open and close database connections; DbGenerateClasses, to generate skeletons of the class

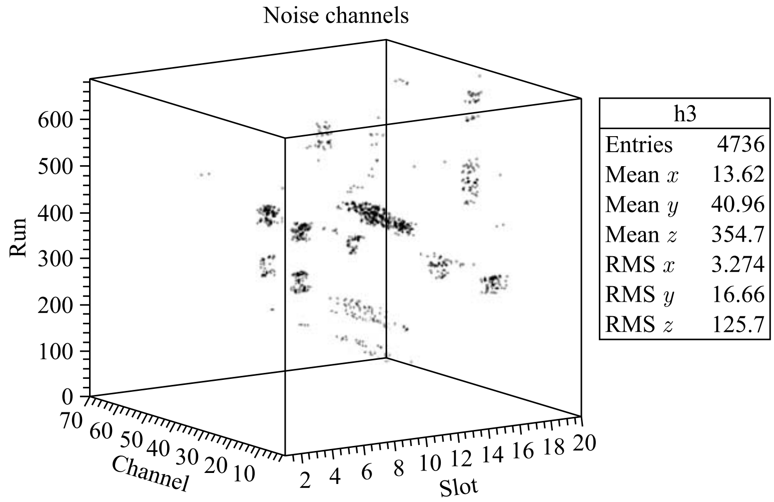

Fig. 4. “Noise channels” parameter

wrappers for all tables of the database; DbParser, to parse existing data of the experiment from HTML, Excel and text files and write it to the unified database; DbGeoConverter, to convert ROOT files with the BM@N geometry to the alternative database view; DbTangoData, to

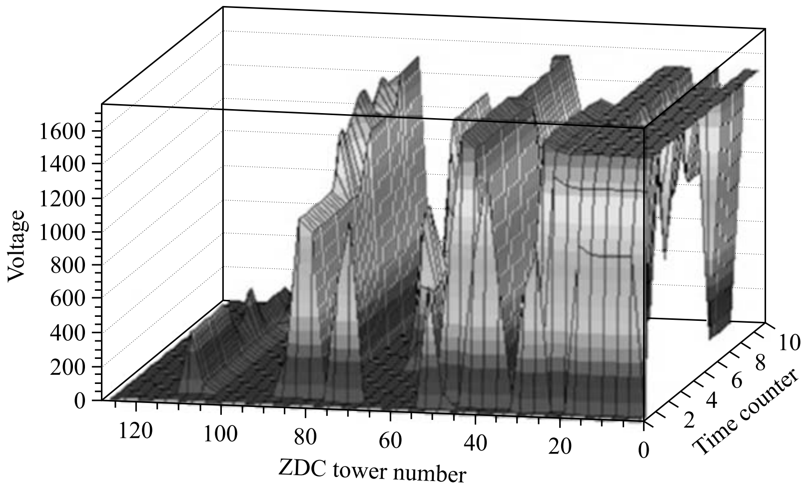

Fig. 5. High voltage of Zero Degree Calorimeter

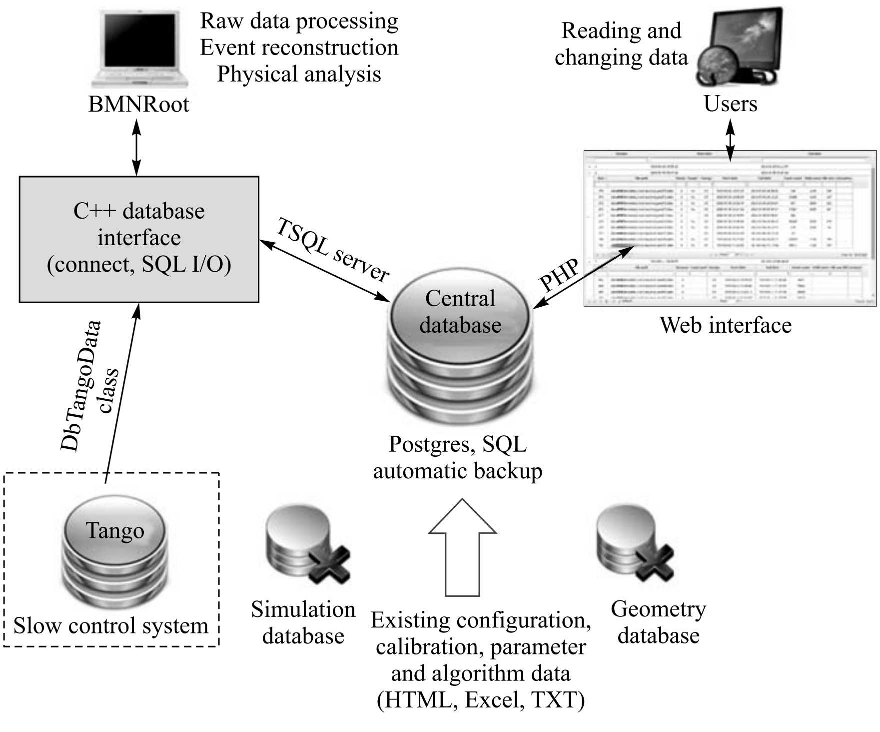

Fig. 6. Common scheme of the unified BM@N database

get data from Tango "slow" control system. Also, the interface includes ROOT macros to execute the tasks presented by the classes above, numerous examples of working with the BM@N database and documentation.

Figure 4 shows the values of "noise channels" parameter obtained from the BM@N database for Drift Chambers and selected runs by the developed interface.

DbTangoData class is used to read hardware data from the Tango control system based on MySQL DBMS. Figure 5 presents an example of using GetTangoParameter function to get the high voltage of ZDC for a selected period of time.

Also, the web interface of the BM@N database was implemented by Ivan Slepov (the member of software group) to simplify reading and managing data of the BM@N experiment over the Web. The common scheme of the unified database is shown in Fig. 6. So, the central BM@N database merged the existing databases and included existing data of the first BM@N runs from multiple files. Users can easily read and change the data of the BM@N experiment by the web interface. The BMNRoot environment uses C++ database interface to get the data for raw data processing, event reconstruction, and physical analysis tasks. Additionally, the BMNRoot has the access to Tango data by the developed class.

CONCLUSIONS

The BM@N database based on Postgres DBMS was developed and deployed on the NICA cluster. It stores configuration, calibration, parameter and algorithm data of the BM@N experiment. The C++ database interface was implemented as a part of the BMNRoot environment and provides the classes and tools to store and access the data without SQL statements. The DbTangoData class was developed to get hardware data from the BM@N slow control system. The Web interface of the BM@N database was implemented to simplify reading and changing the data by users.

The developed database is the central data storage of the BM@N experiment allowing unified access and data management for all BM@N members, correct multiuser data processing, ensuring the actuality, data consistency and integrity of the information, and excluding the multiple duplication. The future version of the unified database will be used for the MPD experiment of the NICA collider.

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