

Event Display for the Fixed Target Experiment BM@N

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Abstract. One of the main problems to be solved in modern high energy physics experiments on particle collisions with a fixed target is the visual representation of the events during the experiment run. The article briefly describes the structure of the BM@N facility at the Nuclotron being under construction at the Joint Institute for Nuclear Research with the aim to study properties of the baryonic matter in collisions of ions with fixed target at energies up to 4 GeV/nucleon (for Au⁷⁹⁺). Aspects concerning the visualization of data and detector details at the modern experiments and possibilities of practical applications are discussed. We present event display system intended to visualize the detector geometries and events of particle collisions with the fixed target, its options and features as well as integration with BMNRoot software. The examples of graphical representation of simulated and reconstructed points and particle tracks with BM@N geometry are given for central collisions of Au⁷⁹⁺ ions with gold target and deuterons with carbon target.

1 Introduction

Heavy ion collisions at high energies provide a unique opportunity to study the nuclear matter under extreme density and temperature. These extreme conditions are well suited to the investigation of the compressibility of the nuclear matter, in particular, the stiffness of the nuclear equation-of-state (EOS). The theoretical models suggest different possible scenarios for these modifications, so that new experimental data with high resolution and statistics are needed in order to disentangle the different theoretical predictions. Moreover, the heavy-ion collisions are a rich source of strangeness, and the coalescence of kaons with lambdas or lambdas with nucleons will produce a vast variety of multi-strange hyperons or light hypernuclei. The study of the hypernuclei is expected to provide new insight 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: 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 hyper-nuclei [2].

The BM@N experiment [1], short from Baryonic Matter at the Nuclotron, presented in figure 1, aims at studying collisions of the elementary particles and ions with a fixed target at energies (laboratory system) up to 4 GeV per nucleon (for Au⁷⁹⁺).

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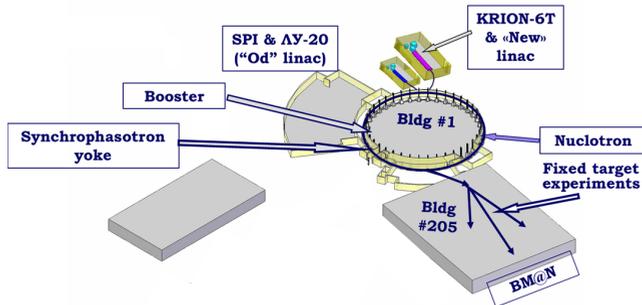


Figure 1. BM@N experiment at extracted Nuclotron beam

The first technical run of the BM@N experiment started on 22 February, 2015. The 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 baryonic matter in heavy ion collisions with 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.

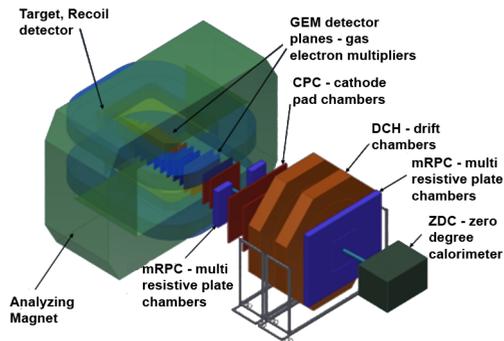


Figure 2. Three-dimensional view of the BM@N facility

In the gold ion collisions with a gold target at these energies, very high multiplicity can be reached, and the BM@N facility should identify the particles produced with high efficiency and estimate their parameters with high precision for the full study of this hot matter. For this purpose 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 BM@N setup divides the detectors for particle identification into “near to magnet” and “far from magnet” to measure particles with low as well as high momenta. The beam target is located inside the large-acceptance dipole magnet with the magnetic field up to 0,35 T for the Y projection. Intermediate coordinate detectors occupy the space between the magnet and the “far” detectors to increase the efficiency of particle identification. The Time-of-Flight detector is proposed to identify primarily hadrons and light nucleus, Zero Degree Calorimeter – to measure centrality of the collisions. The Recoil detector par-

tially covering the backward hemisphere near the target is planned for the independent analysis of collision centrality by measuring the energy of the target fragments.

2 Event Display in High Energy Physics Experiments

Visual representation of the events is an important part of modern high energy physics experiments on particle collisions [3]. Event display system can be used at the design stage of the detectors for model and reconstruction algorithm checking, analysis of algorithms for event data processing by experts; visualization of data reconstruction with better understanding of the detectors and collision event structure by users; for demonstration of running and presentation of results of an experiment. Also event display is required for online visual monitoring of selected events during the experiment run with the aim of visual control and debugging. Visual monitoring of physical processes and data is very important, for example, for visual estimation of the multiplicity of current events which depends on the impact parameters of the particles. The developed system should be able to show immediately both points of particle tracks and the geometry of the detectors registering these particles.

Visualization systems are used in all major high-energy physics experiments such as, for example, CMS, ALICE and ATLAS. The CMS event display is based on the IGUANA visualization framework for graphical representation of the running events. The CMS event display and data quality monitoring system are used to filter the immense amounts of complex event data from the CMS detector and prepare clear and flexible views of the salient features to the shift crews and offline users of the CMS collaboration who process and analyze the data obtained. It provides a visual interpretation of the CMS data on an event-by-event basis and helps in tuning and timing-in the subdetectors [4].

ALICE Event Visualization Environment (AliEVE) is used in the ALICE experiment (Figure 3).

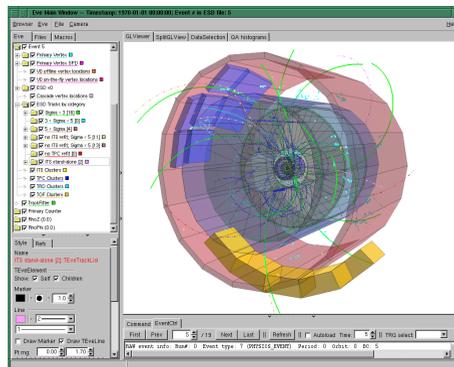


Figure 3. Event display of the ALICE experiment

It is based on the ROOT GUI environment and its graphical classes are working with two- and three-dimensional geometric objects, and OpenGL library. The collaboration group developed their own base classes included in the ROOT environment as a new package EVE to provide graphical representation and management of visualization objects for high energy physics. The AliEVE system is used in the ALICE experiment for event visualization in offline mode and for high-level trigger frameworks at experiment run. It graphically represents clusters, tracks and simplified detector geometry. Event display plays an important role during detector calibration, occupancy and noise-levels estimation in the ALICE experiment [5].

An own event visualization system named Atlantis was developed for the ATLAS experiment. Atlantis is a stand-alone graphical application written in Java based on DALI environment of the ALEPH facility. Atlantis aims to provide easy, fast, error free visual investigation and physical understanding of the complicated events. This visualization system provides a variety of 2D event data-oriented projections with simplified geometry of the ATLAS detector allowing users to understand and visually estimate the parameters of particle collision events as well as to check the correctness of the reconstruction steps and links between objects, e.g., corresponding hits to particle tracks [6].

3 Event Display of the BM@N Experiment

To support the BM@N experiment, the BMNRoot software is developed. The event display package described in this paper is a part of BMNRoot environment which serves for the BM@N event simulation, reconstruction of experimental or simulated data and subsequent physical analysis of the fixed target events registered by the BM@N facility. It is implemented in the programming language C++ and based on ROOT software and FairRoot environment [7] for the FAIR experiment of GSI Institute.

The event visualization in the BMNRoot is realized as follows. The data (types of particles produced, their momenta and other kinematic parameters) obtained by event generators such as UrQMD and QGSM is passed to simulation macro transferring the particles through the detectors by particle transport packages (Geant, Fluka, etc.). The designed detector geometry in a special text format is converted by the macro into a corresponding hierarchy of class instances of the ROOT geometric shapes, transformation matrix and other graphics information that is stored in the ROOT file. So, after the simulation has been completed, the resulting file contains both the Monte-Carlo (MC) data and the BM@N geometry. The next step is the reconstruction of particle data, tracks and other parameters that are written to DST file. The data is stored in ROOT files in a hierarchical tree view.

For graphical representation of the experiment the developed “eventdisplay.C” macro uses both the file with the simulated data together with the BM@N geometry and the DST file with the reconstructed data. The event display is integrated with the BMNRoot software to combine different stages of the event processing with a graphical representation of these events with the aim to evaluate and check the correctness of reconstruction and physical analysis algorithms. In addition, it enables one to take into account adding the subdetectors to the facility structure and changing the current configuration of the BM@N setup.

Modern graphic libraries such as OpenGL usually are applied for the visualization of events. The OpenGL library using the hardware capabilities of GPU allows one to quickly display and update the graphical representation of data on the screen. Thereby, to display detector geometry and events of the BM@N experiment the high-level graphics package EVE of the ROOT environment has been chosen. The EVE classes developed primarily for the creation and management of event objects such as raw data, hits, clusters, points and particle tracks, – allow to select and highlight different elements on the screen, to configure their parameters.

To visualize events of the BM@N experiment new classes were developed for the management of different physical objects and their graphical representation, e.g., hits, simulated and reconstructed points and particle tracks, calorimeter towers. The event display macro provides users with control and graphical representation of detector geometry, MC tracks and their points, as well as reconstructed hits and tracks. It reads detectors’ geometry, simulated and reconstructed event data from the generated ROOT files and displays the objects by the EVE package. All necessary options for graphical representation of the physical objects are included in the macro, set by default, and can be easily changed, so that the user doesn’t need to know the functions and structure of the EVE package.

The event display shows the BM@N geometry and events in different projections and views, and has multiview mode. A user can select the tab with a convenient graphical representation, set light

sources, configure physical objects' parameters, for example, specify a desired color of the object or a background color. The event display offers full interactivity, supporting on-line rotations and picking of objects. Three methods of geometry coloring were released in the visualization system: default by ROOT, hierarchical and pre-selected for detectors. In the case of hierarchical coloring a user can choose colors for the different levels of the BM@N geometry tree. If the pre-selected mode is chosen, a color can be set for each subdetector of the facility.

The figure 4 presents MC tracks (simulated by UrQMD generator) of the central event in collisions of gold ion beam with a gold target at the energy 4 GeV per nucleon. Tracks of different particles are highlighted in different colors for clarity. The EVE package provides a browser (on the left side of the window) to all the displayed objects. The object browser includes both geometry and event information presented in a hierarchical tree. Users can select individually which objects to draw, change object colors and set other visualization settings. In addition, the event display provides quick access to the following settings of event representation:

- selecting an event number displayed on the screen;
- showing all or only primary particles, particles with given PDG codes;
- setting energy range of particles to be displayed;
- changing the background of BM@N views and projections;
- choosing objects to be presented on the screen: simulated hits and tracks, reconstructed points and particle tracks.

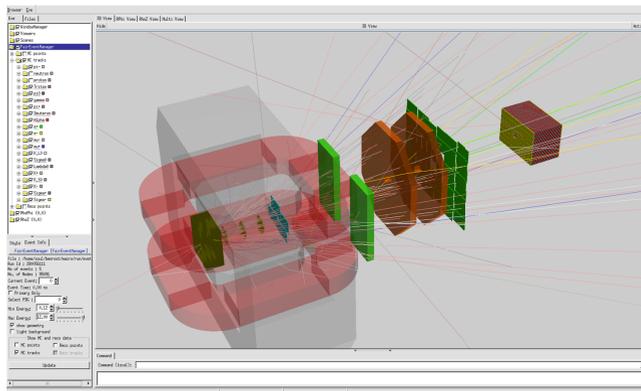


Figure 4. BM@N event visualization of MC tracks in Au – Au collision at 4 GeV/nucleon

Therefore, the event display system allows one to compare the simulated and reconstructed data visually to verify the correctness of developed algorithms. Simulated and reconstructed track points are poorly visible with detector geometry simultaneously displaying on the screen. In order to clearly compare hits and particle tracks the new option was implemented to hide the entire BM@N geometry on the screen. Additionally the option for high transparency of detector geometry was also implemented (figure 5). It sets the different transparency coefficients appropriated for different BM@N subdetectors. Besides it is also appropriate to show only the active detector towers hit by particles and not all track points covered by the Zero Degree Calorimeter.

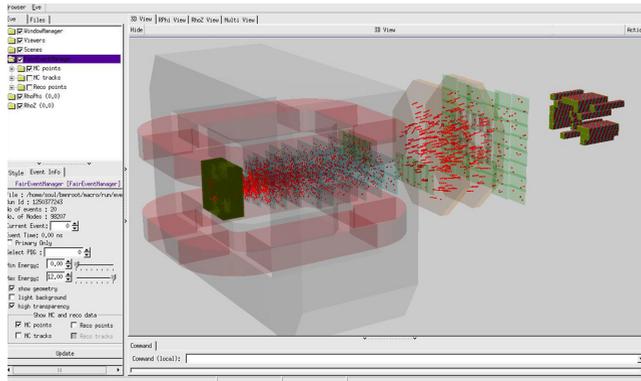


Figure 5. Event display for Au – Au collisions in a high transparency mode

4 Conclusions

An event display system for the BM@N experiment was developed with the purpose to visualize both detector geometry, and simulated and reconstructed events for collisions of particles and ions with the fixed target including hits, clusters, points and particle tracks. The EVE package of the ROOT environment was chosen as visualization tool. New classes and event display macro supporting different views and projections were developed for a graphical representation and management of physical objects in collision events. The visualization system gives an opportunity to visually check the developed algorithms for reconstruction of raw data and for physical analysis of the reconstructed data. With the help of the visualization system some algorithmic errors have been found in the BMNRoot.

Current development of the BM@N visualization system goes in two directions. The first one concerns the visualization of raw experimental data of the first technical run obtained from BM@N subdetectors in special binary formats. The second direction is the online event display development for the BM@N monitoring system.

References

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