SYNERGY IN THE DEVELOPMENT OF FORWARD HADRON CALORIMETERS FOR NA61/SHINE, BM@N, MPD AND CBM EXPERIMENTS*

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The lead/scintillator transverse and longitudinal segmented forward hadron calorimeters will be used in the upgraded BM@N and NA61 experiments and future CBM and MPD experiments to measure centrality and reaction plane orientation in heavy-ion collisions. Common tasks in development of forward hadron calorimeters for these experiments, including development of different approaches of the centrality determination, signals treatment, energy calibration procedure are discussed.

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1. Introduction

At present, there are 2 running fixed target experiments — BM@N at Dubna Nuclotron and NA61/SHINE at CERN SPS which use forward hadron calorimeters with the transverse and longitudinal segmentations assembled of sampling lead/scintillators modules [1, 2]. The same type of calorimeter was developed and constructed for the CBM experiment at FAIR [3]. However, due to the delay of the start of the CBM operation, the opportunity has appeared to use temporarily the modules of the CBM calorimeter for the upgrade of the BM@N and NA61/SHINE calorimeters. Moreover, the same type of modules will be used for the calorimeters at MPD experiment on NICA in Dubna [4]. These calorimeters will be used for centrality and reaction plane orientation measurements in heavy-ion collisions. Taking

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it into account, mutual interest in cooperation of BM@N, NA61/SHINE, CBM and MPD collaborations in development of these calorimeters exists and is discussed in this article.

2. Calorimeters structure at BM@N, NA61/SHINE, CBM and MPD experiments

One of common features of forward hadron calorimeters in all of these experiments is their modular structure with a beam hole in the center. The beam holes in the calorimeters are necessary to protect central modules against high irradiation dose due to high enough heavy-ions beam rates at fixed-target experiments. After the booster commissioning, the BM@N beam rate of gold ions will be about 2×10^6 ions/spill (spill — 2.5 sec.) at beam kinetic energy of $4.5A$ GeV. At the NA61/SHINE, the lead beam rate will be also about 2×10^6 ions/sec during the spill duration of 8 sec. The highest beam rate is expected at the CBM — the gold ions beam intensity will be about 10^8 ions/sec at beam energies up to $11A$ GeV. The photos of already assembled hadron calorimeters for the BM@N and NA61/SHINE experiments are shown in figure 1, upper row, and schematic views of the PSD@CBM and FHCal@MPD, lower row. The inner part of BM@N calorimeter consists of 34 modules with the transverse size of 15×15 cm^2 and outer parts assembled from larger modules of 20×20 cm^2. Initially, 46 large modules were constructed for the hadron calorimeter of the CBM experiment. Before the CBM commissioning 20 CBM, PSD mod-

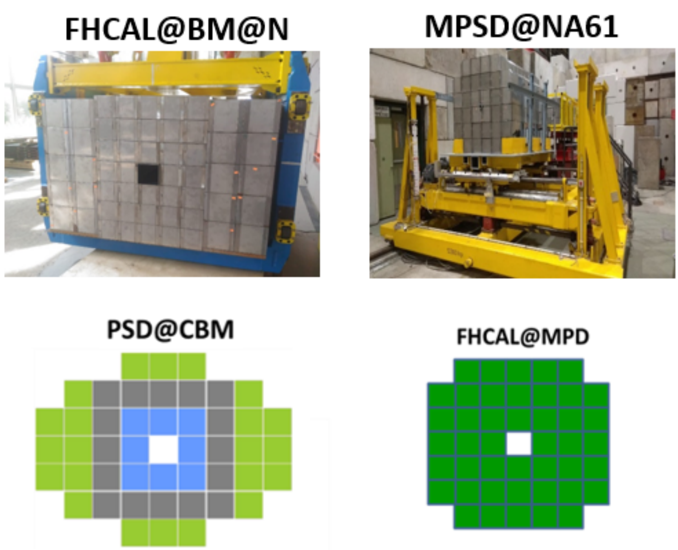

Fig. 1. Photo of assembled FHCal for the BM@N experiment and MPSD for the NA61/SHINE experiment, upper figures. Schematic views of the PSD@CBM and FHCal@MPD, lower figures.

ules are already used for the BM@N FHCal and 12 modules are used for the upgraded MPSD for NA61/SHINE experiment. The MPD will have 2 calorimeters placed on both sides of the interaction point. Each calorimeter consists of 44 modules with transverse sizes of 15×15 cm^2. All modules for the calorimeters for future CBM and MPD experiments are already constructed. The modules of all of these experiments have a similar sampling structure and consist of lead/scintillator layers with a sampling ratio of 4:1 (the thickness of the lead plates and scintillator tiles are 16 mm and 4 mm, respectively). The modules with transverse sizes of 15×15 cm^2 have the longitudinal length corresponding to 4 interaction lengths and the modules with transverse sizes of 20×20 cm^2 — 5.6 interaction lengths. All modules have longitudinal segmentations [3, 4]. Light detection from each of 10 sections in the CBM PSD module and from each of 7 sections in the MPD NICA module is provided with a Hamamatsu S12572-010P MPPC. The light yield measured with minimum ionizing particles is about 40–50 p.e./section for both types of modules. The longitudinal segmentation of modules provides the reduction of measured energy dynamic range in the module and provides the uniformity of light collection along the module.

3. Synergy in the hadron calorimeters development for BM@N, NA61/SHINE, CBM and MPD experiments

3.1. Development of methods for centrality measurements with forward hadron calorimeters

The energy deposition in forward hadron calorimeters with beam hole is a non-monotonic function of the impact parameter and requires the development of special methods to determine the centrality with the use of not only the energy deposition in the forward hadron calorimeters but also other observables. In particular, asymmetry of energy deposition in the calorimeter [1] can be used. At present, the use of an additional quartz hodoscope installed in the beam hole of the calorimeters to measure the sum of fragments Z^2 to extract the centrality classes from correlations of different observables is considered for all of these experiments.

3.2. Development of methods for fit of signals waveform

The fast sampling ADCs will be used for the signals read-out from photodiodes in all of these hadron calorimeters. Digitization of the analog signals in a wide dynamic range with sampling ADC leads to strong fluctuations of the measured charge. Special methods should be developed to select effectively the weak signals on the level of electronic noise. One of the fast methods based on the Prony least squares fit with the fitting function quality assessment criterion has been already proposed recently [5]. This method can be used especially for calibration of calorimeter sections on cosmic muons for the BM@N and CBM experiments where there is no other possibility to calibrate calorimeter sections.

3.3. Energy calibration of calorimeter sections

The procedure of energy calibration of the hadron calorimeter sections in NA61/SHINE is rather straightforward and is done with the beam muons. The calibration of the BM@N, MPD and CBM hadron calorimeters will be performed with cosmic muons because there is no possibility to have muon beams in these experiments. At present, the method of cosmic muons calibration, which uses longitudinal and transverse segmentation of calorimeters is developed. It is required to check this method of energy calibration for calorimeters in mentioned experiments with different trigger possibilities.

3.4. Other mutual interests of collaborations on the forward hadron calorimeters development

Radiation hardness study of MPPCs, which are used in modules near the beam hole, simulation of radiation conditions in different heavy-ion experiments, development of slow control for these calorimeters could be also useful for the cooperation between the collaborations.

4. Conclusion

The similar lead/scintillator transverse and longitudinal segmented forward hadron calorimeters in the upgraded BM@N and NA61 experiments and future CBM and MPD experiments will be used to measure centrality and reaction plane orientation in heavy-ion collisions. Synergy in the development of the methods of centrality and reaction plane determination, signals waveform analysis, methods of energy calibration *etc.* at different experiments are required.

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