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FEASIBILITY TO MEASURE THE PROPERTIES OF φ(1020) MESON IN COLLISIONS OF BISMUTH NUCLEI AT AN ENERGY OF 9.2 GEV IN THE NICA COLLIDER USING THE MPD EXPERIMENTAL SETUP

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Abstract. We report results on a feasibility study of measuring the properties of φ(1020) resonance in collisions of bismuth nuclei at an energy of 9.2 GeV using the MPD detector at the NICA collider. Model calculations of heavy nuclei collisions and the secondary particles – the MPD material interaction have been performed for the $\varphi(1020) \to K^+ + K^-$ decay. The dependencies of the processes' key parameters on the transverse momentum for different intervals of centrality of bismuth nuclei collisions were obtained in the rapidity range from −0.5 to +0.5. The evaluations of the mass resolution, detection efficiency of the MPD detector and the transverse momentum spectra for the **φ(**1020) resonance were made. The sample size of bismuth nuclei collision data that allowed the **φ(**1020) resonance properties to be reconstructed with a sufficiently good accuracy to conduct a study of the φ(1020) meson production was estimated.

Keywords: bismuth nuclei collisions, production, meson, NICA collider, MPD detector

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ВОЗМОЖНОСТИ ИЗМЕРЯТЬ СВОЙСТВА φ(1020)-МЕЗОНА В СТОЛКНОВЕНИЯХ ЯДЕР ВИСМУТА ПРИ ЭНЕРГИИ 9,2 ГЭВ В УСКОРИТЕЛЕ NICA НА ЭКСПЕРИМЕНТАЛЬНОЙ УСТАНОВКЕ MPD

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Аннотация. В статье представлены результаты исследования возможности измерять свойства резонанса φ(1020)-мезона в столкновениях ядер висмута при энергии 9,2 ГэВ с помощью экспериментальной установки (ЭУ) MPD на ускорителе NICA. Выполнены модельные расчеты столкновений тяжелых ядер и взаимодействия образовавшихся частиц с веществом ЭУ MPD для распада $\varphi(1020) \to K^+ + K^-$. Прослежены зависимости ключевых параметров процессов от поперечного импульса для различных интервалов по центральности столкновений ядер висмута в области быстрот от −0,5 до 0,5+. Получены оценки массового разрешения ЭУ MPD, эффективности регистрации в ЭУ MPD и спектров по поперечному импульсу для φ(1020). Проведена оценка объема выборки данных столкновений ядер висмута, позволяющей восстановить свойства φ(1020) с достаточно хорошей точностью для исследования рождения этого мезона.

Ключевые слова: столкновение ядер висмута, рождение, мезон, ускоритель NICA, детектор MPD

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Introduction

Study of hot and dense nuclear matter produced in collisions of relativistic heavy nuclei is one of the priorities in high-energy physics. Such matter is obtained in laboratory conditions in collisions of heavy ions at such accelerator facilities as SPS (CERN, Switzerland) [1], RHIC (BNL, USA) [2] and LHC (CERN, Switzerland) [3]. Commissioning of the FAIR (GSI, Germany) [4] and NICA (Joint Institute for Nuclear Research (JINR), Dubna, Russia) [5] accelerator facilities in the near future will provide an additional opportunity to conduct such studies in the region of high baryon densities and lower temperatures of the phase diagram of strongly interacting matter, compared with the LHC and RHIC accelerators [5]. NICA is the Nuclotron-based Ion Collider facility.

As two relativistic heavy nuclei collide in a small volume comparable to the nuclear overlap region, a considerable amount of energy is released, forming dense and hot matter [6]. The reaction begins with primary nucleon-nucleon collisions, with a pre-equilibrium phase subsequently occurring, when quark-gluon plasma is produced, the nuclear system/matter/ fireball expands and cools, which is followed by a mixed state of quark-gluon plasma with hadronic gas, after which a hadronic phase is formed, and eventually the produced particles leave the collision region.

The characteristics of the nuclear matter forming are studied indirectly by analyzing the properties of the produced particles in the final state, measured by various detector subsystems of the experimental facility. Among all types of produced particles, short-lived resonances play a special role in measuring the properties of dense and hot nuclear matter [7]. Measuring the properties of short-lived hadronic resonances, such as $\rho(770)$, $K^*(892)$, $\varphi(1020)$, $\Sigma(1385)$, $\Lambda(1520)$, and $\Xi(1530)$, is an important part of experimental programs studying collisions of heavy nuclei. These resonances are abundantly produced in collisions of heavy nuclei and can be measured by detector subsystems. Systematic measurement of the properties of resonances with different baryon numbers, strangeness and lifetime allows to understand not only various effects in hot and dense nuclear matter, such as excess yield of strangeness or excess yield of baryons relative to mesons, but also the mechanisms of hadronization at intermediate and large transverse momenta, the dynamics of reactions and processes contributing to the transverse momentum spectra of the particles, as well as the lifetime and density of hadronic gas.

Short-lived resonances are characterized by short lifetimes τ and cover a fairly wide range of τ: from about 1 fm/c for $\rho(770)$ mesons up to about 46 fm/c for $\varphi(1020)$ mesons. Some of these resonances decay within dense and hot nuclear matter. This property of resonances allows them to be used to study the hadronic phase. Daughter particles produced in hadronic gas due to hadronic decays of such resonances can be scattered by the surrounding hadrons and therefore change the initial direction of motion and momentum, eventually leading to loss of the measured signal.

On the other hand, hadrons produced in abundance in hadronic gas can recombine when they form new resonances. As a result, the differential yields and other spectral characteristics of the resonances, such as their mass and width, change. The measured resonance yields are determined by the following characteristics:

yield at the time of chemical freezeout,

hadron lifetimes,

hadronic gas density,

resonance lifetimes,

scattering cross section.

Studies of resonance production at RHIC and LHC [8] in the energy range $\sqrt{S_{NN}} = 7.7-5000$ GeV observed suppression of the resonance yields with lifetimes $\tau < 20$ fm/c in central collisions of heavy nuclei, compared with peripheral collisions of such nuclei and collisions of protons at the same interaction energy. Yield suppression is explained by scattering of daughter particles by surrounding hadrons and dominance of this process over recombination of particles in the hadronic phase. No change in yield was found for longer-lived resonances. The ALICE experiment at LHC allowed to estimate the lifetime of the hadronic phase in collisions of lead nuclei at a center-of-mass energy (per nucleon pair) $\sqrt{S_{NN}} = 5.02$ TeV [6]. For the purpose of this estimation, the ALICE experiment measured the ratio of resonance yields to yields of quasi-stable particles with a similar quark composition, depending on the multiplicity of charged particles in the final state. These ratios were measured in proton collisions and collisions of lead nuclei at the same energy: $\sqrt{S_{NN}} = 5.02$ TeV. The found lifetime of the hadronic phase was about 4–7 fm/c, which is comparable to the lifetime of the $K^*(892)$ meson (equal to about 4 fm/c) and much shorter than the lifetime of the $\varphi(1020)$ meson.

The $\varphi(1020)$ meson is of particular interest among short-lived resonances, with a lifetime of 46.2 fm/c (the longest among short-lived resonances) and a mass of 1020 MeV [9]. Due to the longer lifetime, the production of $\varphi(1020)$ mesons is less affected by the hadronic phase, which allows it to be used in refence measurements for comparison with the production of shorter-lived resonances. The mass of $\varphi(1020)$ meson is comparable to that of a proton with a different quark composition and baryon number.

This feature of the $\varphi(1020)$ meson makes it possible to exclude the dependence on mass in studies of mechanisms behind the formation of particle spectra in the region of small and intermediate transverse momenta. Such studies are carried out by measuring the ratio of the baryon production spectra to the meson production spectra. An excess baryon yield relative to the meson yield in the region of intermediate transverse momenta in central collisions of heavy nuclei (the so-called ‘baryon anomaly’) was detected at RHIC and LHC [10]. The baryon yield in the region of intermediate momenta is suppressed less relative to their yield in proton collisions than the meson yield at the same collision energy.

The baryon anomaly observed at RHIC in collisions of gold nuclei at $\sqrt{S_{NN}}$ = 200 GeV [11] can be described by the recombination model of structural quarks. Baryons consisting of three quarks gain a large increase in transverse momentum compared to mesons consisting of only two quarks, which leads to an excess baryon yield. The yield ratio $p/\varphi(1020)$ in central collisions of lead nuclei at an energy of 2.7 TeV [10], measured at LHC, turned out to lie within the measurement uncertainty, not depending on the transverse momentum p_T in the range $p_T < 4$ GeV/c.

The approximately identical shapes of transverse momentum spectra of mesons and baryons with similar masses in central collisions of heavy nuclei correspond to the predictions of hydrodynamic models where the shape of the spectra is determined by collective radial flow and depends mainly on particle mass, in contrast to recombination models, where the shape of the spectrum is determined by the quark composition of the particle.

Another important feature of the φ(1020) meson is its quark composition. The light vector φ(1020) meson consists of s and $\bar{s}$ quarks and is a particle with hidden strangeness. This structure of the φ(1020) meson makes it possible to study the mechanisms behind the production of strangeness. The excess yield of strange particles in central collisions of relativistic heavy nuclei, compared with their yields in collisions of protons at the same collision energy, is considered a signature of quark-gluon plasma [12]. Excess yields of strange particles (K mesons, Λ, Ξ, Ω baryons, φ(1020), Σ(1385), Λ(1520), Ξ(1530) resonances, etc.) is experimentally observed in collisions of heavy nuclei at energies achieved at AGS, SPS, RHIC and LHC facilities [13]. Experimental observations are in qualitative agreement with the predictions obtained by the models describing the canonical suppression of strangeness yield [14] in colliding systems with small multiplicity, with the exception of the φ(1020) meson. Due to hidden strangeness, the φ(1020) meson is insensitive to canonical suppression and is a key particle for studying the mechanisms responsible for the production of strangeness. Moreover, experiments on production of the φ(1020) meson in collisions of heavy nuclei in the energy range $\sqrt{S_{NN}}$ = 17–5000 GeV revealed that this meson behaves like a particle with open strangeness [13].

Currently, there are no theoretical models reproducing the measurement results for excess yield of particles containing s quarks simultaneously in proton collisions, proton-nucleus collisions and collisions of heavy nuclei characterized by high multiplicity.

Another feature of the φ(1020) meson is the small cross section of its interaction with non-strange hadrons, due to which the φ(1020) meson practically does not react to hadronic effects in the final state [15]. A change in the shape of the φ meson peak in the distribution of its daughter particles over invariant mass may indicate chiral symmetry restoration [16]. The φ(1020) meson peak in the invariant mass distribution typically has a small width and is not overlapped by peaks from decays of other resonances. The dominant decay channel of the φ(1020) meson is the hadronic channel $\varphi(1020) \to K^+K^-$ (the probability of decay is ≈ 49%), but leptonic decay channels are of particular interest.

$$\varphi(1020) \to e^+e^-,\ \varphi(1020) \to \mu^+\mu^-$$

(in both cases, the decay probability is about $3\cdot 10^{-4}$%).

Due to the low decay probability, as well as the high level of combinatorial background, the reconstruction of the properties of φ(1020) mesons in leptonic decay channels is an extremely difficult experimental challenge [17]. Leptons leave the nuclear collision region practically without interacting with nuclear matter, and the properties of the decayed φ(1020) meson are not distorted. Signatures of chiral symmetry restoration can be detected by comparing the measurement results in the hadronic decay channel with the leptonic decay channel, taking into account the resolution of the detectors. The mass of the φ(1020) meson is almost equal to the sum of masses of two kaons. The difference between the mass of the φ(1020) meson and two kaons is only about 32 MeV. Therefore, the yield of φ(1020) mesons reconstructed in the $\varphi(1020) \to K^+K^-$ decay channel is sensitive both to changes in the shape of the φ meson peak in the invariant mass distribution and to changes in the properties of kaons [17].

An accelerator setup with colliding beams is under construction at JINR as part of the NICA (commissioning of the facility is scheduled for 2025). Similar to many modern colliders, NICA will allow for experiments studying both the interactions of colliding beams and collisions of beams with interactions targets. It is expected that the first experiments on colliding beams at NICA will be the interactions of bismuth nuclei with each other and xenon nuclei at energy $\sqrt{S_{NN}}$= 7.0–9.2 GeV. As further adjustments are introduced, the design parameters will be achieved and NICA will be capable of colliding light (p, d, C, etc.) and heavy (Xe, Bi, Au, etc.) nuclei in the energy range $\sqrt{S_{NN}}$ = 4–11 GeV with the maximum luminosity of 10^{27} $cm^{-2}\cdot s^{-1}$ and collision frequency from 50 Hz to 7 kHz. An experiment with a fixed target, BM@N (baryonic matter at Nuclotron), is already underway at NICA to study baryonic matter.

After the commissioning of the storage rings, two more experiments will be launched: the spin physics detector (SPD) to study spin physics in collisions of light nuclei and the multi-purpose detector (MPD) to study the processes in collisions of heavy nuclei [5]. The MPD experiment will be launched together with NICA in 2025. Collisions of heavy nuclei in the energy range of NICA at $\sqrt{S_{NN}}$ = 4–11 GeV correspond to the multiplicity of charged particles in the final state $dN_{ch}/d\eta \approx$ 100–200 at midrapidity [18]. Model calculations based on the UrQMD, PHSD, and AMPT event generators show for collisions of gold nuclei at $\sqrt{S_{NN}}$ = 4–11 GeV with such multiplicity that the resonance properties change significantly under the influence of the late hadronic phase evolving in such collisions [19, 20]. The changes are qualitatively consistent with the results of experiments on resonance production at RHIC and LHC.

Thus, at NICA energies, collisions of heavy nuclei are expected to produce sufficiently dense hadronic gas with a lifetime comparable to the lifetime of the entire collision system. Resonances serve as perfect signatures of hadronization mechanisms in the range of small and intermediate transverse momenta, effect of excess strangeness yield, effect of excess yield of baryons relative to mesons, dynamics of reactions and processes contributing to the transverse momentum spectra of particles, as well as the effects of the late hadronic phase. The study of resonance production is an important component of the physical program at the MPD experiment.

The goal of this study is to determine the feasibility of measuring the properties of the φ(1020) meson using the MPD experimental setup at NICA in collisions of bismuth nuclei at energy $\sqrt{S_{NN}}$= 9.2 GeV in the decay channel $\varphi(1020) \rightarrow K^+K^-$, in the rapidity range $|y| < 0.5$.

The study was carried out based on model calculations of collisions of heavy nuclei and the interaction of the produced particles with matter of the MPD setup.

Experimental setup at the MPD and computational procedure

This facility is a 4π-spectrometer designed to detect and measure the main characteristics of photons, electrons, and hadrons [5]. The MPD will consist of one central and two forward spectrometers. The central spectrometer will consist of a cylindrical superconducting solenoid, a time projection chamber (TPC), a time-of-flight (TOF) detector and an electromagnetic calorimeter (ECal). The TPC, located in a homogeneous magnetic field up to 0.5 T generated by a magnet, will detect charged particle tracks. By measuring the energy losses of charged particles in the drift gas (90%Ar + 10% CH_4 (at atmospheric pressure of +2 mbar)), the TPC detector will also identify charged particle tracks.

The TOF detector will be used for additional identification of particles based on their time of flight. The ECal calorimeter will detect photons and leptons and will also be used to identify particles. The forward spectrometers will consist of Cherenkov fast forward detectors (FFD) and a forward hadron calorimeter (FHCal).

FFD and FHCal detectors are designed to select inelastic collisions of nuclei, determine the collision geometry, including the centrality and plane of reaction, and measure the collision time required for time-of-flight measurements. In the future, an internal tracking system based on silicon ITS detectors will be installed in the central part of the MPD to measure the secondary decay peaks of particles with heavy quarks, and additional forward detectors will be installed in the front. The detector's data acquisition system is designed to collect data at rates up to 6.5 GB/s and with a collision frequency of 7 kHz. The MPD subsystems will have a sufficiently large acceptance. The main subsystems of the central part of the MPD setup cover a pseudorapidity range slightly below 2. The forward detectors cover a fairly wide range of pseudorapidities, from 2 to 5.

Before NICA and MPD are commissioned, the feasibility of measuring the properties of various particles under conditions achievable at NICA accelerator can only be estimated by model calculations. In this work, the UrQMD event generator [21] was used to simulate collisions of bismuth nuclei at $\sqrt{S_{NN}}$ = 9.2 GeV. The hadronic phase is simulated in this event generator.

The interaction of particles produced in simulations of nuclear collisions with the detector matter as well as reconstruction of tracks and other basic characteristics of particles in the MPD were carried out using the MpdRoot software package [5]. The MPDroot software package is the official software for the MPD experiment. This software package, similar to software packages for other experiments on collisions of relativistic nuclei, is based on the GEANT platform for simulating the interactions of elementary particles with matter. The MPDroot software package also contains the most up-to-date configuration of detector subsystems of the MPD setup and their characteristics. The MPDroot software package provides responses from detector subsystems to particles passing through them; the algorithms for reconstructing particle characteristics are identical to those used in analysis of experimental data.

The feasibility of measuring the properties of the φ(1020) meson via the MPD setup was considered for the φ(1020) → K^+K^-decay channel. The algorithms and techniques used were developed for similar studies in collisions of gold (Au + Au) nuclei at energies $\sqrt{S_{NN}}$ = 4.0, 7.7, and 11 GeV [22] and bismuth (Bi + Bi) nuclei at energy $\sqrt{S_{NN}}$ = 9.2 GeV [23].

A more appropriate description of MPD subsystems and more efficient algorithms for reconstructing charged particle tracks were used in model calculations, compared with the studies in [23]. Moreover, the sample of collisions of bismuth nuclei in this work was 10 times larger (50 million collisions). Improved computational methods and expanded sample made it possible not only to more accurately evaluate the properties of the φ(1020) meson in collisions of bismuth nuclei at $\sqrt{S_{NN}}$ = 9.2 GeV, but also to obtain results depending on collision centrality (which is the most crucial) for the first time.

To reconstruct the parameters of the φ(1020) meson, oppositely charged particles identified as kaons were combined into pairs within a single simulated collision of bismuth nuclei. Only collisions with the interaction vertices within 130 cm from the beam crossing were selected from the events reconstructed by the TPC detector.

The collision centrality was determined by the number of charged particle tracks reconstructed by the TPC detector [23]. Centrality is understood as the probability of finding an event in the entire sample of generated events where the number of reconstructed tracks of charged particles would be greater than in a given event with a centrality of *X*%. The centrality was varied in a range from 0 to 100%, where a lower centrality corresponds to events with a larger number of reconstructed tracks in the TPC. The FFD is ineffective for detecting the most peripheral collisions, so collisions of bismuth nuclei with 0–90% centralities were selected for analysis. Charged particles with pseudorapidities below 1 and transverse momenta over 100 MeV were selected as candidates for kaons to increase the reconstruction efficiency of φ(1020) mesons and reduce the background component.

A new, more efficient technique for reconstructing charged particle tracks was used, allowing to reconstruct point from only 10 points measured in TPC (instead of 20), additionally accounting for the type of identified particle in reconstruction of the track. Identification of charged particles in the final state was carried out simultaneously both from the energy losses of charged particles in the drift gas of the TPC and from the time-of-flight measurements of the TOF detector. Only pairs of charged particles with rapidity less than 0.5 were selected. Next, the mass and transverse momentum of the pair were calculated.

Fig. 1 shows examples of reconstructed invariant mass spectra for a pair of oppositely charged kaons (M_{KK}) with the transverse momentum of the pair ranging from 0.4 to 0.6 GeV/*c*.

The reconstructed invariant mass spectrum contains a peak corresponding to the decay channel φ(1020) → K^+K^- and background. The combinatorial component of the background is due to pairing of all charged particles in the event that meet the selection criteria. The combinatorial background was evaluated by mixing events of one type. The daughter particles were taken from different events with similar characteristics, such as the coordinate of the interaction vertex along the beam axis and the multiplicity of secondary particles. Ten events were mixed to reduce statistical uncertainties. The resulting combinatorial background was normalized in such a way that it coincided with the reconstructed invariant mass spectrum of a pair of oppositely charged kaons in the region of large masses, where no correlations are expected. The combinatorial background was subtracted from the spectrum.

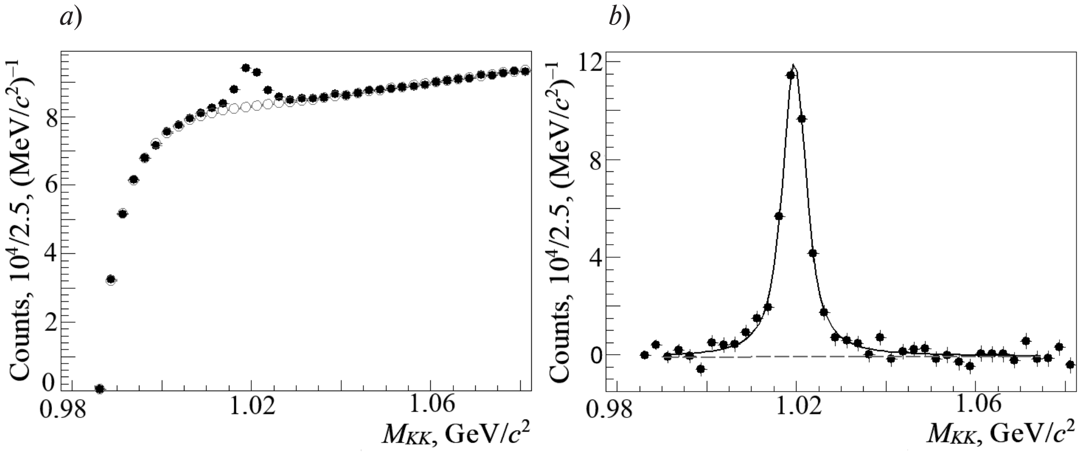

Fig. 1. Invariant mass spectra for pair of oppositely charged kaons (black symbols) in collisions of bismuth (Bi + Bi) nuclei at $\sqrt{S_{NN}}$ = 9.2 GeV before (*a*) and after (*b*) subtraction of the combinatorial background (circles);
Spectra were reconstructed in the transverse momentum ranges $0.4 < p_T{}^{KK} < 0.6$ GeV/c for K^+K^- pair.
Breit–Wigner function convolved with a Gaussian is used to reconstruct the peak (solid line); second-degree polynomial is used for the correlated background (dashed line)

The reconstructed invariant mass spectrum of pairs of oppositely charged M_{KK} after subtraction of the combinatorial background is shown in Fig. 1,*b*. A pronounced peak corresponding to the decay channel φ(1020) → K^+K^- is observed. The yield of φ(1020) mesons in the kaon decay channel was determined by fitting the reconstructed invariant mass spectrum of K^+K^- pairs by a sum of a Breit–Wigner function convolved with a Gaussian (describing the peak) and a second-degree polynomial (describing the correlated residual background). The Breit–Wigner function accounts for the natural shape of the resonance peak, and the Gaussian is necessary to account for the mass resolution of the detector. The mass resolution for peak fitting was given by an estimate. The correlated residual background arises due to jets and wrongly reconstructed decays of heavier hadrons; it is commonly described by a polynomial. A similar set of functions is used by the ALICE experiment at the LHC to measure the resonance yields [3].

The mass resolution of the experimental setup for kaon decay channel φ(1020) → K^+K^- ($\sigma_{M_{KK}}$) was calculated as the distribution width of the difference between the reconstructed mass of the φ(1020) meson and its true value generated by the event generator. The mass resolution was estimated for different transverse momentum ranges. The dependence of mass resolution on transverse momentum of a pair of oppositely charged kaons is shown in Fig. 2. The mass resolution of the experimental setup is 1–2 MeV, which indicates that it is possible to determine the peak shape of the φ(1020) meson with good accuracy and track its variation. The integral of the Breit–Wigner function convolved with the Gaussian was taken as the φ(1020) meson yield. The yields were obtained for different transverse momentum ranges and centrality bins in collisions of bismuth nuclei.

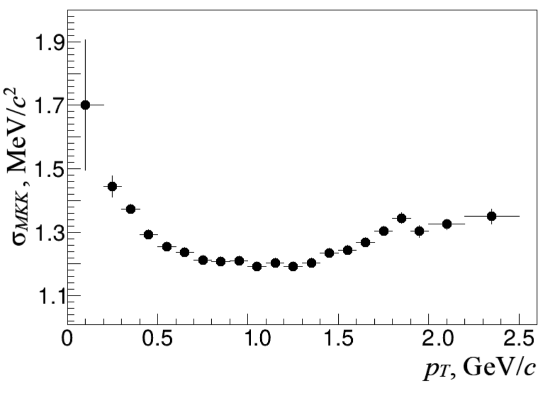

Fig. 2. Dependence of the mass resolution of MPD ($\sigma_{M_{KK}}$) on transverse momentum (p_T) for pair of oppositely charged kaons for decay channel φ(1020) → K^+K^- in (Bi + Bi) collisions at $\sqrt{S_{NN}}$ = 9.2 GeV

The detection efficiency ε for φ(1020) mesons in the decay channel φ(1020) → K^+K^- was calculated as the ratio of the number of reconstructed φ(1020) mesons to their total number generated by the event generator, taking into account the probability of decay in the channel considered. The detection efficiency was calculated depending on the transverse momentum of the pair and the collision centrality (Fig. 3).

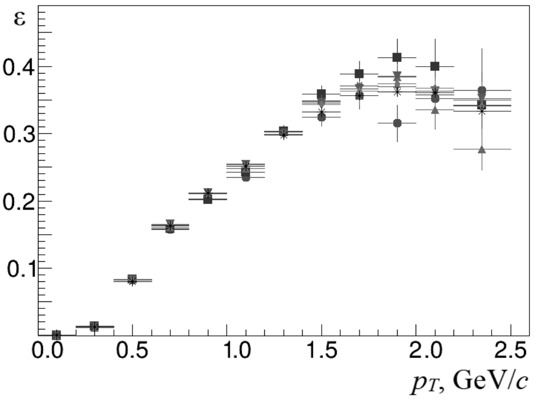

Fig. 3. Dependence of detection efficiency ε for φ(1020) mesons on transverse momentum in decay channel φ(1020) → K^+K^- using MPD for pair of oppositely charged kaons
Efficiency was calculated for (Bi + Bi) collisions at $\sqrt{S_{NN}}$ = 9.2 GeV for 7 centrality bins, %: 0–10 (∗), 10–20 (♦), 20–30 (⋆), 30–40 (▼), 40–50 (▲), 50–60 (■) and 60–90 (•)

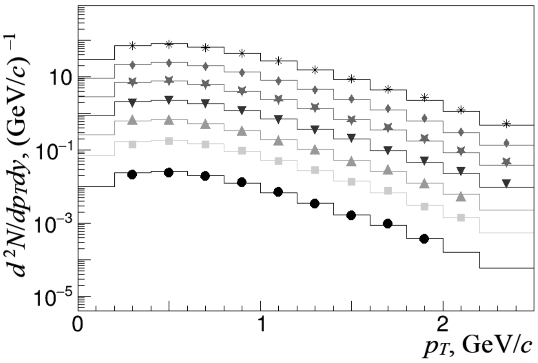

Fig. 4. Reconstructed transverse momentum spectra (symbols) and similar spectra originally generated by the event generator (lines) for the φ(1020) meson in rapidity range $|y|$ < 0.5
These data correspond to the same collisions and energies, for the same centrality bins and notations as in Fig. 3. For clarity, the enlarged spectra are shown in one graph

Evidently, the detection efficiency increases with an increase in transverse momentum of the pair, reaching 35% in the region of transverse momenta above 2 GeV/c. There is a moderate dependence of detection efficiency on collision centrality. Thus, φ(1020) mesons with transverse momenta of more than 0.4 GeV/c can be reconstructed in the decay channel φ(1020) → K^+K^- in the MPD setup in the rapidity range $|y| < 0.5$. The feasibility of reconstructing φ(1020) mesons in the region of intermediate and large transverse momentais limited only by the accumulated sample of experimental data.

Computational results

Similar to other studies on the production of light mesons in collisions of heavy nuclei [24], the differential yield was calculated by the following formula:

$$\frac{d^2N}{dp_T dy} = \frac{N(p_T)}{N_{\text{ev}}\varepsilon(p_T)\Delta p_T \Delta y},$$

where p_T, GeV/c, is the transverse momentum of the φ(1020) meson; y is the rapidity; $N(p_T)$ is the φ(1020) meson yield; $\varepsilon(p_T)$ is the detection efficiency accounting not only for the geometric acceptance of MPD but also the probability of decay in the channel φ(1020) → K^+K^-; N_{ev} is the number of collisions of bismuth nuclei analyzed; Δp_T, GeV/c, is the transverse momentum range within which the φ(1020) meson yield is determined.

The obtained transverse momentum spectra for the φ(1020) meson are shown in Fig. 4. The real transverse momentum spectra of φ(1020) mesons generated by the event generator are also shown for comparison. The spectra were obtained for various centrality bins for collisions of bismuth nuclei at energy $\sqrt{S_{NN}}$ = 9.2 GeV in the rapidity range $|y|$ < 0.5. The spectra appear to be similar, serving to validate the analysis methodology developed in the study.

The estimate of the transverse momentum spectra obtained in this paper makes it possible to estimate the sample size of collisions of bismuth nuclei necessary to measure the properties of the φ(1020) meson in the decay channel considered. A sample of more than 50 million collisions of bismuth nuclei is required to measure the properties of the φ(1020) meson depending on transverse momentum and collision centrality.

Conclusion

The paper considers the feasibility of measuring the properties of the φ(1020) meson in collisions of bismuth nuclei at an energy of 9.2 GeV using the MPD setup at the NICA facility. The study was performed by simulating the φ(1020) → K^+K^- decay, obtaining the dependences of the main process parameters on the transverse momentum for various centrality bins of bismuth nuclei in the rapidity range from -0.5 to 0.5. We found that accumulation of more than 50 million collisions of bismuth nuclei will allow to reconstruct the properties of the φ(1020) meson with sufficiently good accuracy to study the production of the φ(1020) meson in a wide range of transverse momenta from 0.4 to 2.5 GeV/*c*, 10% centrality for central and semi-central collisions of bismuth nuclei and 30% centrality for peripheral ones.

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