The activity report on the project for 2015-2016
High Acceptance Di-Electron Spectrometer (HADES)
(JINR participation)

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Detailed materials on the HADES project can be found at http://www-hades.gsi.de

The High Acceptance Di-Electron Spectrometer at SIS18

HADES is a versatile detector for a precise spectroscopy of e^+e^- pairs (dielectrons) and charged hadrons produced in proton, pion and heavy ion induced reactions in a 1-3.5 GeV kinetic beam energy region. The detector has been set-up at GSI, Darmstadt. The main experimental goal is to investigate properties of dense nuclear matter created in the course of heavy ion collisions and ultimately learn about in-medium hadron properties (like masses, decay widths). The matter created in such collisions differs from the one studied at SPS, RHIC or LHC because it consists mainly of baryons (nucleons and its excited states- baryon resonances) and little mesons and can be compressed up to 3 times nuclear matter density for about 10-12 fm/c. Dielectron pairs originating from in-medium hadron decays and rare strange hadrons (kaons, hyperons) are the main probes measured in the experiment. Since conclusions on in-medium effects rely strongly on the understanding of hadron properties in vacuum and their production mechanism in nucleon-nucleon collisions a complementary program focusing on e^+e^-, kaon and hyperon (Σ, Λ) production in elementary collisions is also in progress.

Collisions of heavy ions allow to probe nuclear matter at high densities and temperatures. These studies have the astrophysical applications, namely, the composition, equation of state- mass-radius relation for compact massive stars (supernova and neutron stars). Dense nuclear matter can be created in elativistic heavy-ion collisions. The baryon density and the temperature of the fireball reached in such collisions depend on the beam energy.The phases of strongly interacting matter are shown schematically in figure 1. The "liquid" phase is realized in atomic nuclei at zero temperature and at saturation density (300 million tons/cm^3). At low densities, the nucleons (i.e. protons and neutrons) behave like a gas. As the temperature and the density are raised, the nucleons are excited into "baryon resonances" which subsequently decay into pions and nucleons.

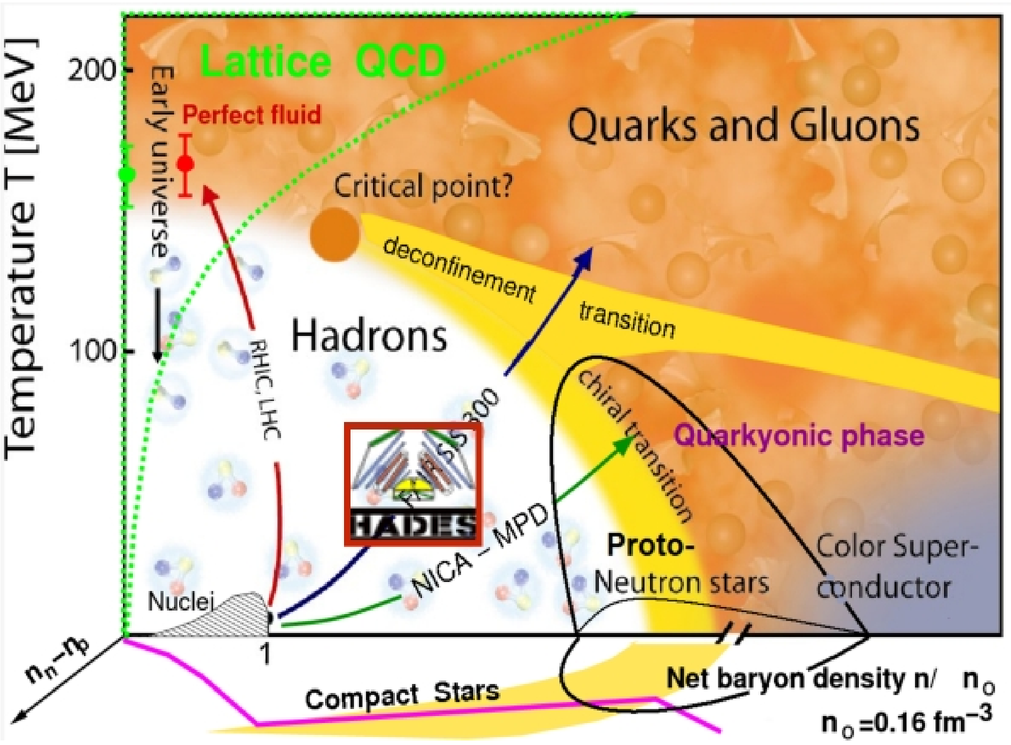

Figure 1: A schematic phase diagram of strongly interacting matter.

This mixture of nucleons, baryonic resonances and mesons is called hadronic matter.In highly compressed cold nuclear matter - as it may exist in the interior of neutron stars - the baryons also lose their identity and dissolve into quarks and gluons. The critical density at which this transition occurs, however, is not known. The same is true for the entire high-density area of the phase diagram. At very high densities and low temperatures, beyond the deconfinement transition, a new phase is expected: the quarks are correlated and form a color superconductor. At the "critical point" the deconfinement/chiral phase transition is predicted to change its character.

The physics motivation for HADES includes the investigation of in-medium modification of light vector mesons as well as the study of dilepton continium in the warm (T<100MeV) and dense(up to $3\rho_0$) hadronic matter at SIS18, GSI. Due to good hadron identification the studies of the strange particles including so-called multistrange hyperons (Λ, Ξ, Ω) and hypernuclei are possible. The HADES strategy is the systematic di-electron and hadron measurements in NN, AA, pA, πN and πA collision.

In future HADES will be a part of the CBM (Compressed Baryonic Matter) experiment at the Facility for Antiproton and Ion Research (FAIR). The CBM experiment will enable researchers to investigate, among other things, processes in supernovae and neutron stars with unprecedented precision. The HADES spectrometer after upgrade will be able to study nuclear reactions in the energy range from 2 to 10 GeV/nucleon.

The HADES detector

The HADES spectrometer is devoted to the 2-nd generation of the di-electron detectors and it is designed to detect these electron-positron pairs heavy ion collisions, which provide information about the properties of the quark-antiquark pairs. The HADES is also able to detect and identify the hadrons what gives the opportunity to study strangeness and multi-pion production. The schematic view of the HADES detector is presented in figure 2.

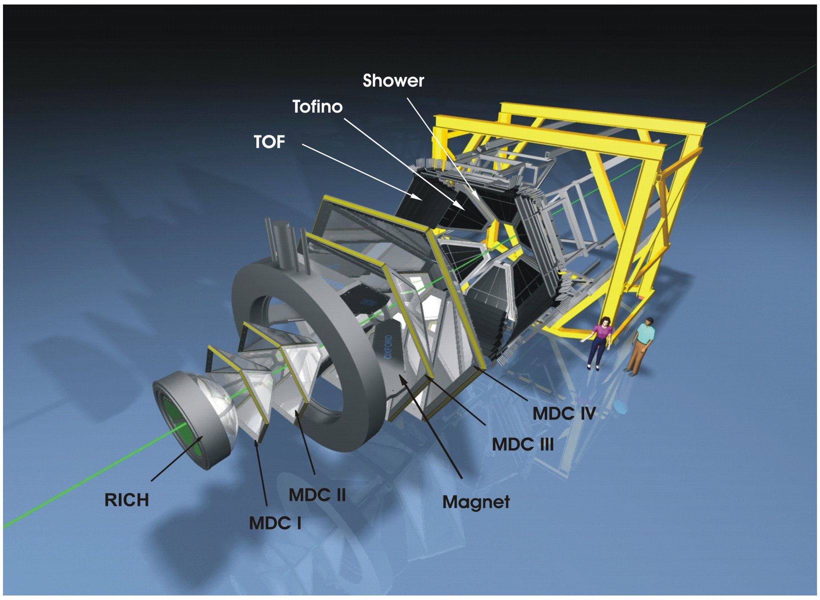

Figure 2: A schematic view of the HADES detector. Magnet is a superconducting toroid, MDC I-IV are the four planes of the multi-drift chambers, RICH is a Ring Imaging Cherenkov detector, Shower is a the pre-shower detector, TOF and TOFINO are the scintillation counters and Resistive Plate Chambers for time-of-flight measurements.

HADES is a large acceptance magnetic spectrometer operating with proton, deuteron and heavy ion beams extracted from the SIS18. It uses directed beam from the synchrotron or optionally secondary pion beams produced in a production target 15 m upstream from the HADES target point. It combines a magnetic spectrometer with detector systems specialized in detecting rare decay products such as electrons and positrons from conversion decays of hadrons. The spectrometer features a sophisticated superconducting toroid, low-mass drift chambers, a ring-imaging Cherenkov detector using a CsI photocathode and a pre-shower detector.The time-of-flight system uses diamond start detectors and scintillator and resistive plate based stop detectors. A tracking system consists of a set of 6 superconducting coils producing a toroidal field and drift chambers and a multiplicity and electron trigger array for additional electron-hadron discrimination and event characterization. A two-stage trigger system enhances events containing electrons. The detector system is characterized by an 85% azimuthal coverage over a polar angle interval from 18 to 85 degree, a single electron efficiency of 50% and a vector meson mass resolution of 2.5%. Identification of pions, kaons and protons is achieved combining time-of-flight and energy loss measurements over a large momentum range. The details of the HADES spectrometer are described elsewhere [1]. In addition the Forward Wall (FW) [2] is used for the measurements of the spectator protons and reaction plane determination. The schematic cut view of the HADES with FW during the experiment with deuteron beam is shown in figure 3.

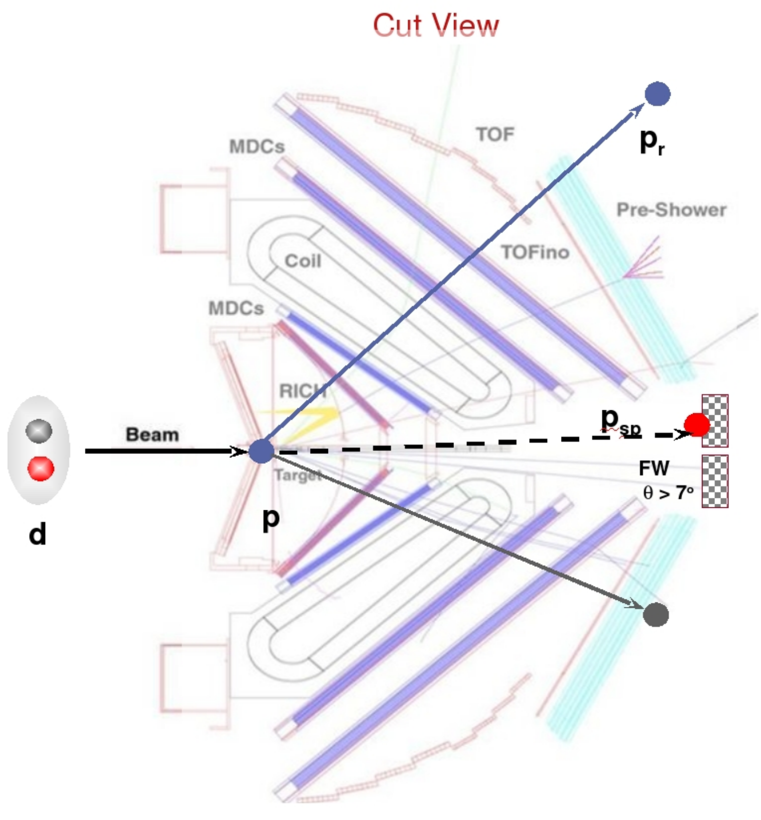

Figure 3: A schematic view of the HADES with FW during the experiment with deuteron beam. Spectator proton is detected by the FW.

JINR contribution in HADES detector

A tracking system of HADES consists of a set of 6 superconducting coils producing a toroidal field and 4 planes of multi-wire drift chambers (MWDCs) [3,4]. The JINR physicists were responsible for the design, production and maintenance of the 2-nd plane of low mass multi-wire drift chambers [5,6]. Each plane contains 6 separate modules with 6 chambers with different wire orientations. The intrinsic space resolution of the 2-nd plane was achieved as 57 μm and 112 μm for the Y and X coordinates, respectively. This plane is used as a reference plane in the tracking procedure. Cathode and field wires are produced from aluminium. The FEE electronics for drift chambers has been developed also at JINR [7]. The picture of the 2-nd MWDC plane installed at HADES detector is shown in figure 4.

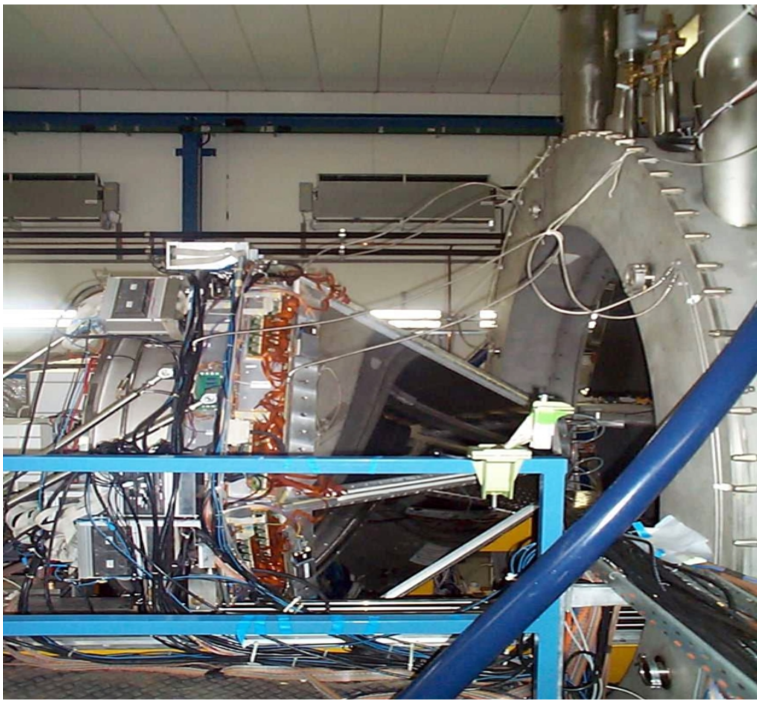

Figure 4: 2-nd MWDC plane installed at HADES spectrometer.

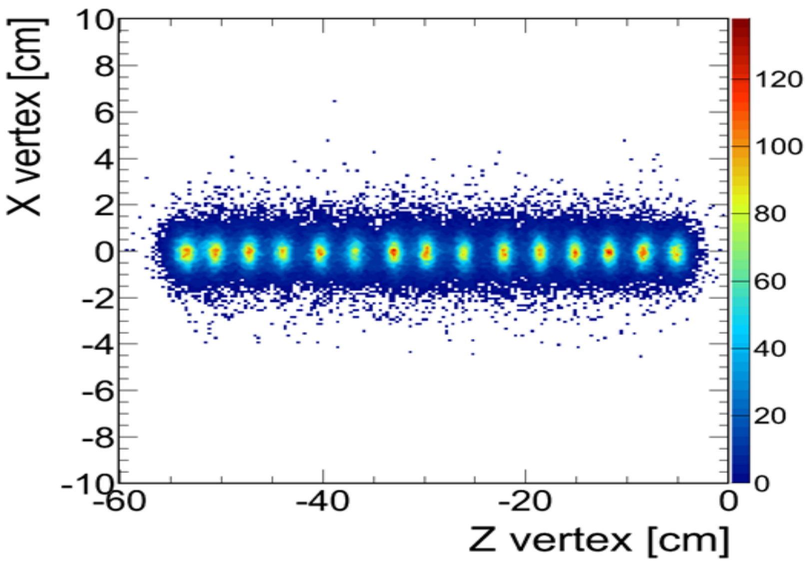

Figure 5: The reconstructed Z position of the segmented Au target (15 segments).

JINR physicists developed tracking software for the momentum and vertex reconstruction [8]. The results on the primary vertex reconstruction for the segmented Au target is shown in figure 5. The results obtained in Au+Au run in 2012. One can see clearly 15 segments with 2 mm in diameter each. JINR participated also in the development of the alignment procedure for HADES [9].

Selected experimental results from HADES (2015-2016 yy)

The main results obtained by HADES in 2015-2016 yy are published in 6 papers in the regular journals [10-15]. These results were reported at the international conferences [16-18]. The major part of the HADES program is the systematic studies of the vector meson production and di-lepton continium in the e+e- mode, but this short period HADES concentrated on the hadronic probes.

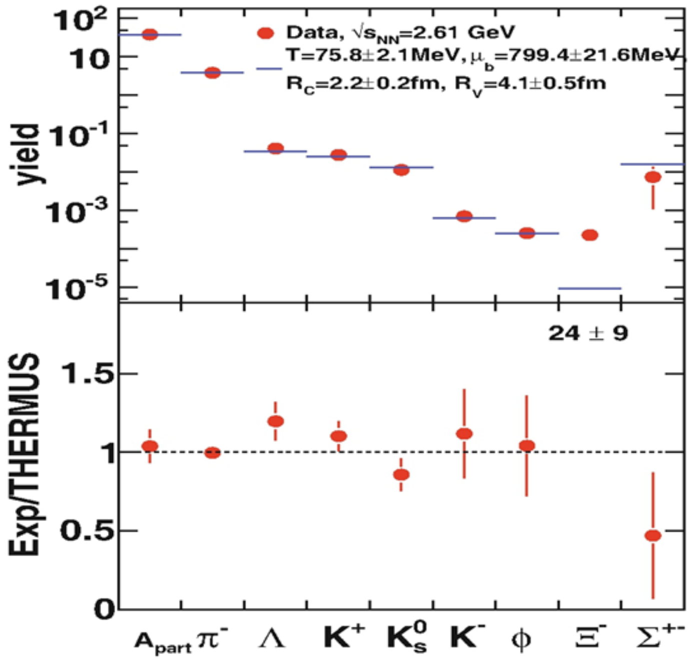

Figure 6: The comparison of the different hadron yields in Ar+KCl collisions at 1.76 AGeV with the THERMUS model [19].

HADES has good hadron identification neccessary for the studies of hadrons including strange weekly decaying particles ($K0^s$, Λ and Ξ). The results on the comparison of the different hadron yields obtained in Ar+KCl collisions at 1.76 AGeV with the THERMUS model [19] are given in figure 6. The freeze-out parameters from a statistical model fit to HADES data in Ar+KCl at 1.76 AGeV and p+Nb at 3.5 GeV collisions have been obtained [14] (see figure 7). The experimental data are in good agreement with the theory except for the Ξ production which excesses the model prediction [19] more than 20 times. The lattest HADES result on the Ξ production in p+Nb interaction at 3.5 GeV [11] confirms also the Ξ yield excess over the different models predictions. It was found that the statistical model is able to describe the p+Nb data as well as the larger system the Ar+KCl data, which questions the often drawn connection between the agreement of statistical models with particle yields in heavy-ion collisions and thermalization [14]. Furthermore, the excess of the Ξ − is already present in cold nuclear matter.

Given the rates of higher-lying N^* resonances predicted by the statistical model fit, it was found feed down of these states a rather implausible explanation for the excess of the $\Xi-$ yield over the model value. The importance of a precise knowledge of the hadron spectrum for interpretation of HIC data is stated. HADES data of central Au+Au collisions will be available soon and might allow to gather further insights into the subjet.

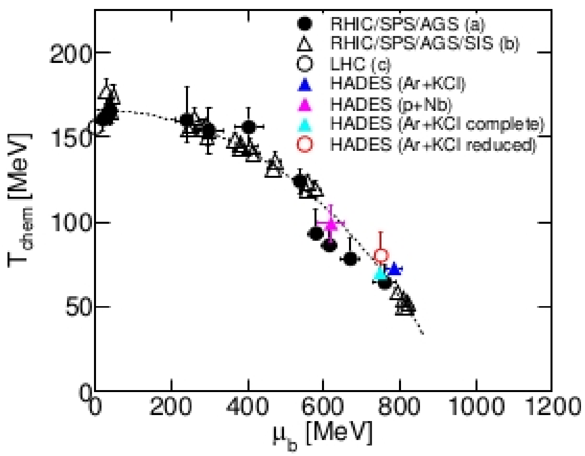

Figure 7: Chemical freeze-out points in the $\mathbf{T_{chem} - \mu_b}$ plane. The black symbols are the world results. The dashed curve correponds to a fixed energy per nucleon of 1 GeV. The dark blue triangle corresponds to HADES Ar+KCl fit, the light blue triangle shows the result obtained for the full sample and open circle to the reduced data sample both.

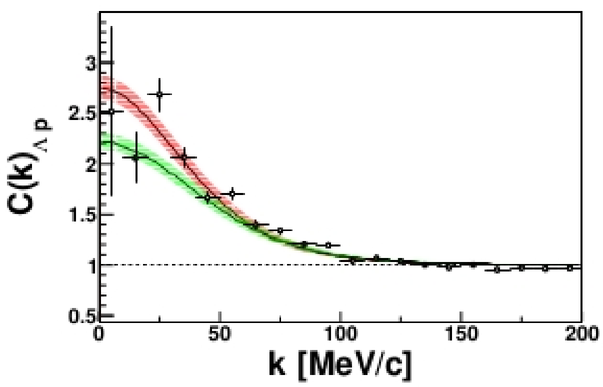

Figure 8: Comparison of the experimental Λp correlation function (open circles with error bars) to the LO (green) and NLO (red) scattering parameter [15]. The error bands in the theory curves correspond to the errors of the Λp source size determination.

The first measurement of Λp and pp correlations via the femtoscopy method in p+Nb reactions at 3.5 GeV has been performed [15]. The pp correlation signal was used as a benchmark to test the possibility of fixing the source size on the basis of UrQMD calculations. This way, the Λp source was estimated. By comparing the experimental correlation function to model calculations, a source size for pp pairs of $r_{0,pp} = 2.02 \pm 0.01(stat) \pm 0.12(sys)$ fm and a slightly smaller value for pΛ of $r_{0,\Lambda p} = 1.62 \pm 0.02(stat) \pm 0.19(sys)$ fm is extracted. The final state interaction strength between pΛ was investigated by comparing the experimental pΛ correlation function to model calculations using scattering parameters from χEFT computations (see figure 8). The statistics was not enough to clearly distinguish between model predictions (an increase by a factor ten would be sufficient) but it was shown that the femtoscopy method is able to provide data which can be investigated with a theoretical framework with the necessary sensitivity to study carefully final state interactions if the size of the particle emitting region is known beforehand. The femtoscopy technique to study interactions between particles can be applied to many colliding systems at very different energies, which can help to improve the understanding of hyperon-nucleon interactions.

The reaction $p(3.5GeV)+p \rightarrow pK^{+}\Lambda$ might contain information about the kaonic cluster "ppK^{-}" via its decay into $p\Lambda$. Due to interference effects in the coherent description of the data, a hypothetical KN N (or, specifically "ppK^{-}") cluster signal must not necessarily show up as a pronounced peak in an invariant mass spectra like $p\Lambda$. Partial wave analysis performed [12] includes a variety of resonant and non-resonant intermediate states and delivers a good description of the obtained data (various angular distributions and two-hadron invariant mass spectra) without a contribution of a KNN cluster. At a confidence level of CLs =95% such a cluster can not contribute more than 2-12% to the total cross section with a $pK^{+}\Lambda$ final state, which translates into a production cross-section between 0.7 μb and 4.2 μb, respectively. The range of the upper limit depends on the assumed cluster mass, width and production process.

The results on the K*(892)+ production in proton-proton collisions at a beam energy of E= 3.5 GeV, which is hitherto the lowest energy at which this mesonic resonance has been observed in nucleon- nucleon reactions, have been obtained [13]. The data are interpreted within a two-channel model that includes the 3-body production of K*(892)+ associated with the Λ- or Σ- hyperon. The relative contributions of both channels were estimated. The total cross section σ(p+p→ K*(892)+ +X) is found to be 9.5±0.9±1.0±0.7 μb, that adds a new data point to the excitation function of the K*(892)+ production in the region of low excess energy. The relative contribution of the channel p+p→ p+Σ+K*(892)+ has been estimated as 0.4±0.2. Within uncertainties of the experimental data, no deviations from a 3-body phase-space population have been identifed in the kinematical distributions of K*, as well as no convincing signal of a spin-alignment has been observed.

JINR group data analysis and interpretation

JINR group is actively involved in the analysis of the experimental data obtained with a deuteron beam at 1.25 AGeV. The two-pion production in nucleon-nucleon (NN) collisions is a rich source of information about the baryon excitation spectrum and the baryon-baryon interactions. In addition to the excitation of a resonance decaying into two pions, which can also be studied in the $\pi N \rightarrow \pi\pi N$ and $\gamma N \rightarrow \pi\pi N$ reactions, the simultaneous excitation of two baryons can be investigated in the NN reactions. By giving access to single and double baryon excitation processes, which both play an important role in the NN dynamics in the few GeV energy range and contribute significantly to meson and dilepton production, the two-pion production appears as a key process towards a better understanding of hadronic processes. In comparison to the one-pion decay mode, it presents a different selectivity with respect to the various resonances. In particular, the excitation of baryonic resonances coupled to the ρ meson can be studied with the two pions in the isospin 1 channel. This is of utmost interest for a better understanding of the dilepton production in nucleon-nucleon reactions, where these couplings manifest clearly, and also in nucleon matter due to the expected modifications of the ρ meson spectral functions. Finally,the comparison of two-pion production in pp and np channels could shed some light on the origin of the surprisingly large isospin dependence of the dilepton emission observed by the HADES experiment [20]. In particular, the ρ production mechanism via ΔΔ final state interaction, which does not contribute in the pp channel, was recently proposed as an explanation for the different dilepton yield measured in pp and pn channels [21]. It is therefore important to check the description of the double Δ process in the two-pion production channels.

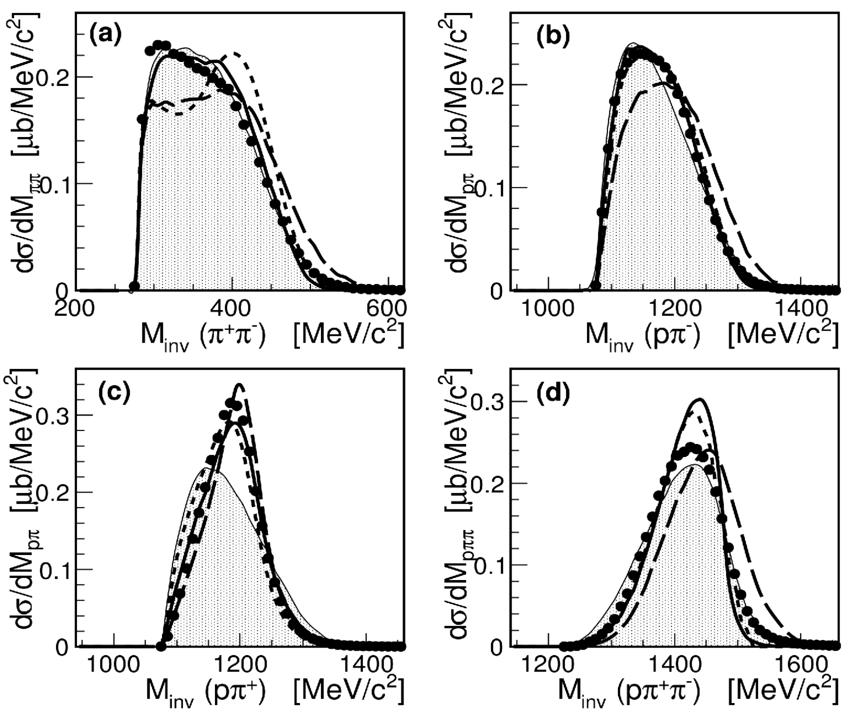

Figure 9: Distributions of the π+ π− (a), pπ− (b), pπ+ (c) and pπ+ π− (d) invariant masses for the np → npπ+ π− reaction at 1.25 GeV. The experimental data are shown by solid symbols. The theoretical predictions within HADES acceptance from different models are given by the solid, dashed and long-dashed curves, respectively. The shaded areas show the phase-space distributions. (See for the expalanations ref.[10]).

The JINR group is analyzing the tagged quasi-free np → npπ+ π− reaction with HADES at a deuteron incident beam energy of 1.25 GeV/nucleon (√s ∼ 2.42 GeV/c for the quasi-free collision) [10]. For the first time, differential distributions for π π production in np collisions have been collected in the region corresponding to the large transverse momenta of the secondary particles. The invariant mass and angular distributions for the np → npπ+ π− reaction are compared with different models. This comparison confirms the dominance of the t-channel with ΔΔ contribution. It also validates the changes previously introduced in the Valencia model to describe two-pion production data in other isospin channels, although some deviations are observed, especially for the π+ π− invariant mass spectrum. The results of the analysis for the mass distributions are presented in figure 9. JINR group developed modified OPER model [22-23] successully applied to describe the differential distributions of the

The extracted total cross section is also in much better agreement with the model taking into accout the dibaryon resonance [21]. HADES new measurement [10] puts useful constraints for the existence of the conjectured dibaryon resonance at mass M∼ 2.38 GeV and with width Γ ∼ 70 MeV. HADES data presented in figure 10 by red circle call for the development of a full model, including in a consistent way the t-channel processes, based on the modified Valencia model [21] and the s-channel processes including the dibaryon with above quoted parameters, which could provide a solid framework for the interpretation of the two-pion production data.

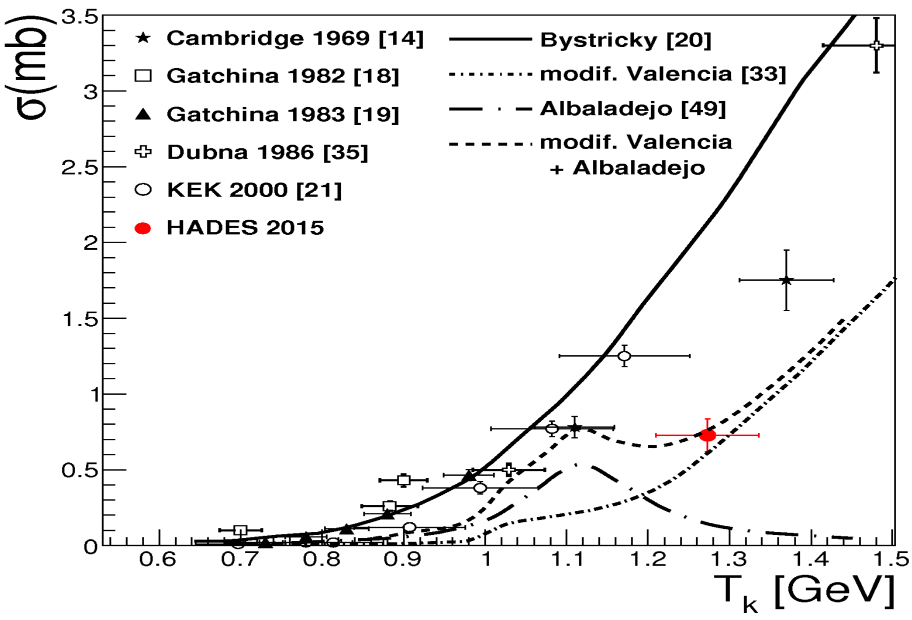

Figure 10: HADES measurement for the quasi-free np → npπ+ π− reaction using a deuterium beam at 1.25 GeV/nucleon (full red dot) compared to world data shown by various symbols. The horizontal error bars indicate the spread of the neutron momentum in the different measurements. The full and short dash- dotted curves display respectively the ”Bistricky parametrization” used for the OPER model [22] normalization and the predictions model [21]. The long dash-dotted curve is the estimate for the contribution of the dibaryon resonance. The dashed curve is the sum of modified Valensia model and dibaryon resonance contributions. See ref.[10] for the details.

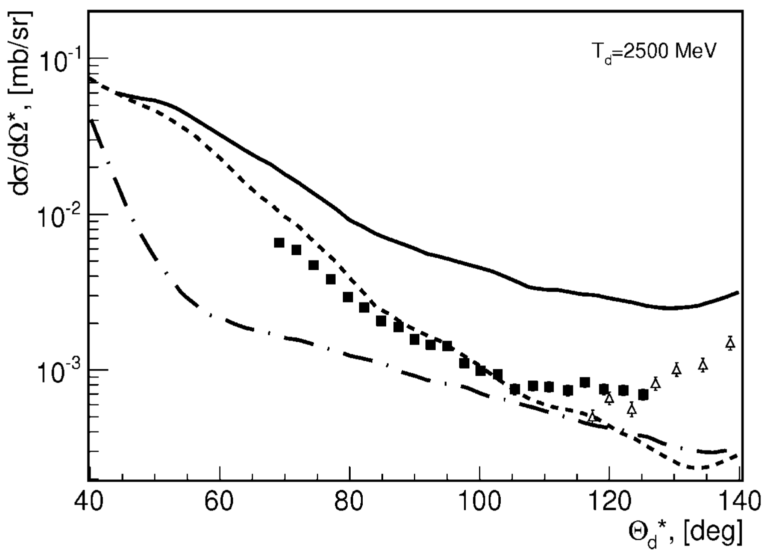

Figure 11: HADES measurement for the dp → dp reaction using a deuterium beam at 2.5 GeV (full squares) compared to world data shown by open symbols.

The JINR group is analyzing the experimental data on dp- elastic scattering obtained using a deuterium beam at 2.5 GeV. The HADES acceptance allows to measure this process at large transverse momenta where the manifestation of the short-range two-nucleon and three-nucleon correlations is possible. The obtained at HADES data between 70 and 130 degrees in the center of mass are in good agreement with the experimental data obtained earlier at backward scattering angles. The theoretical predictions are obtained within the relativistic scattering model taking into account the single and double scattering terms shown by the dot-dashed and solid lines, respectively. One can see, the calculations taking into account the single scattering only and in addition double scattering underestimate and overestimate the HADES data, respectively. Certainly, the additional mechanisms like explicit Δ isobar contribution is required. The results are adopted by the collaboration, the paper prepared for Eur.Phy.J.A is under internal HADES review [24].

JINR group is participating in the data interpretation on the dilepton production in neutron-proton interaction at 1.25 GeV/nucleon [25,26]. Modified OPER [22,23] model is used to estimate the dilepton production from different sources. The calculations within OPER model were performed for multiple pion production in $\pi^- p$- and NN- interactions [27-30] for HADES energy domain.

JINR participation in HADES upgrade

JINR group concentrated on the software development for the analysis of Au+Au data and current HADES upgrade.

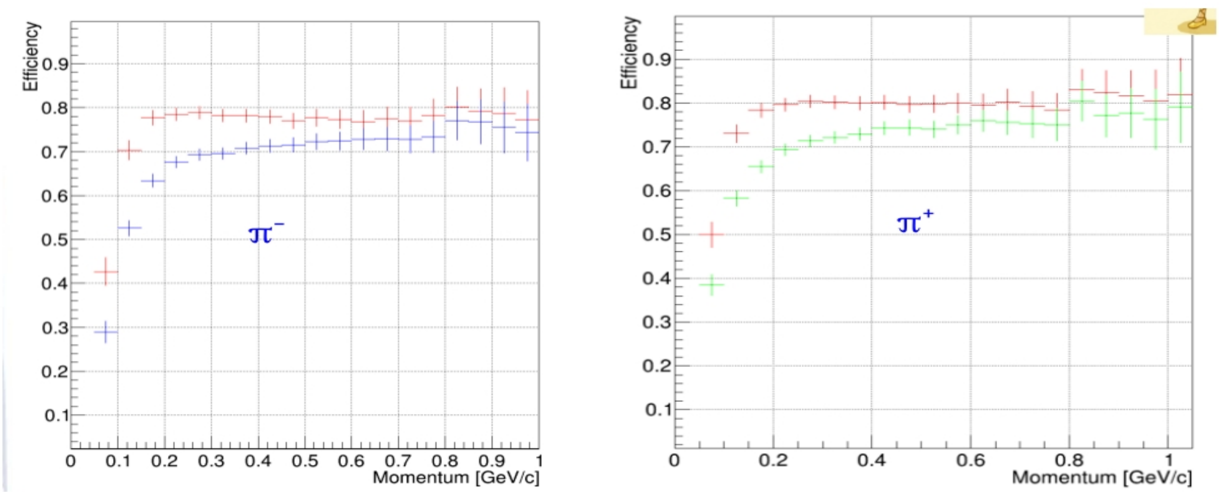

Figure 12: The efficiency reconstruction of the π^- and π^+ from the K_0^s decay for Au+Au events obtained at 1.25 GeV. Red points are obtained for new algorithm [31].

First direction is the participation in further HYDRA2 software [8] development for heavy ion collisions and elementary processes. The efficiency of the secondary vertex reconstruction has been significantly improved by using of new algorithm, which works as following. The wires which were not used in reconstructed primary tracks were combined for two first MDC stations for 2 possible tracks with large opening angle. For each combination the straight line crossed these 4 wires is calculated analytically. The obtained candidates are used in the Off Vertex Track Finder which has been applied for the Au+Au data. The improvement of the efficiency reconstruction (up to 80%) for the π^- and π^+ from the K_0^s decay for Au+Au data are shown in figure 12 [31]. The kinematical fitting procedure for np- interaction data has been improved [32]. This software will be used for the analysis of the experimental data on the $np \rightarrow pp\pi^0\pi^-$ and $np \rightarrow pp\pi^-$ at 1.25 GeV, $pp \rightarrow pp\pi^+\pi^-$ and $pp \rightarrow NN+m\pi$ at 3.5 GeV obtained at HADES.

Second direction is the software implementation for Forward Detector (FD), which will cover the forward angles up to 6.5^0. FD will allow to increase significantly the detection efficiency for the elementary channels, especially, for NN reactions. This detector will contain 8 planes of the straw tubes. The drawing of the Forward Detector with 2 straw stations is presented in figure 13.

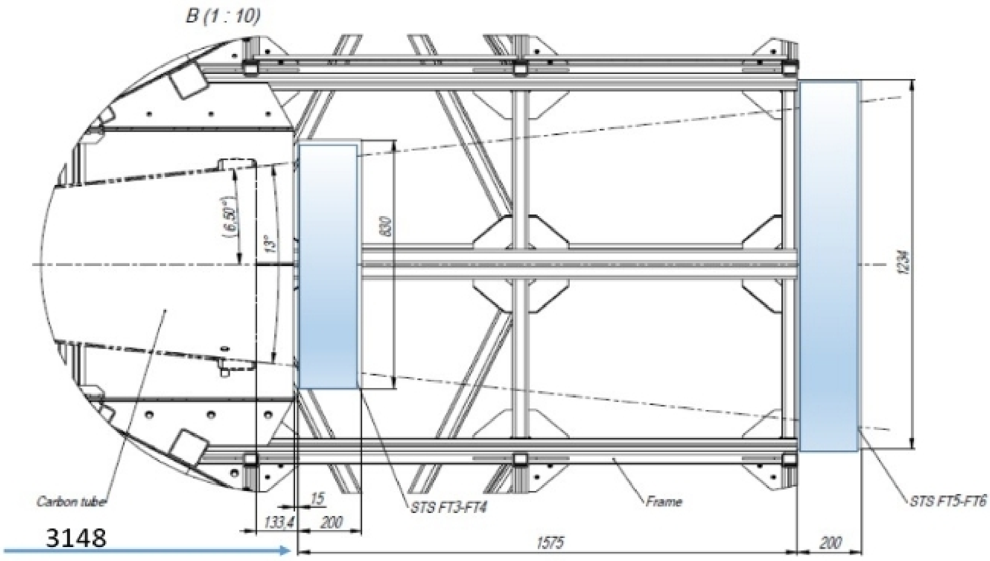

Figure 13: The drawing of the Forward Detector with 2 straw stations.

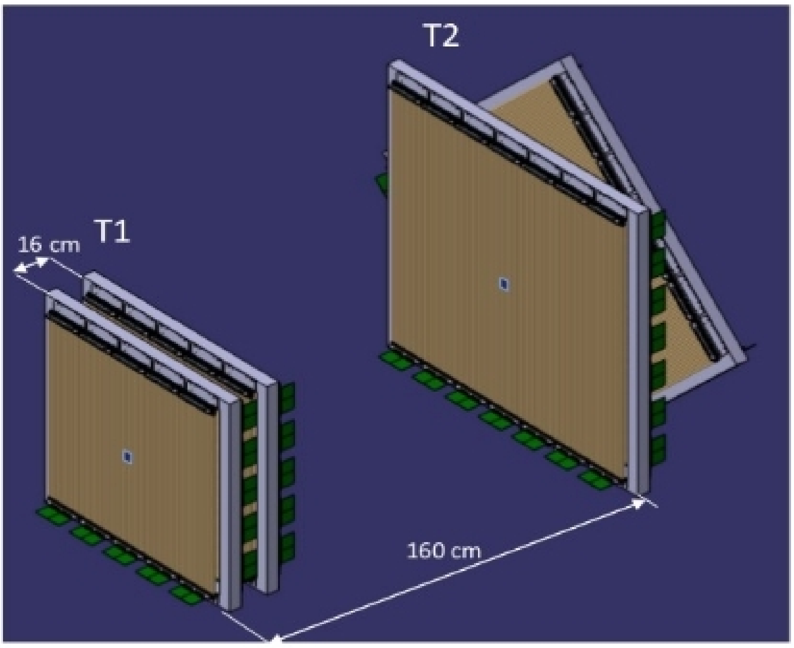

Figure 14: The layout of the straw detectors used for the simulation.

The tracking for FD is based on the «vector finding» algorithm used previously for the CBM MuCH system [33,34]. This software has been implemented into HYDRA2 package. The layout of the straw detectors used for the simulation is presented in figure 14.

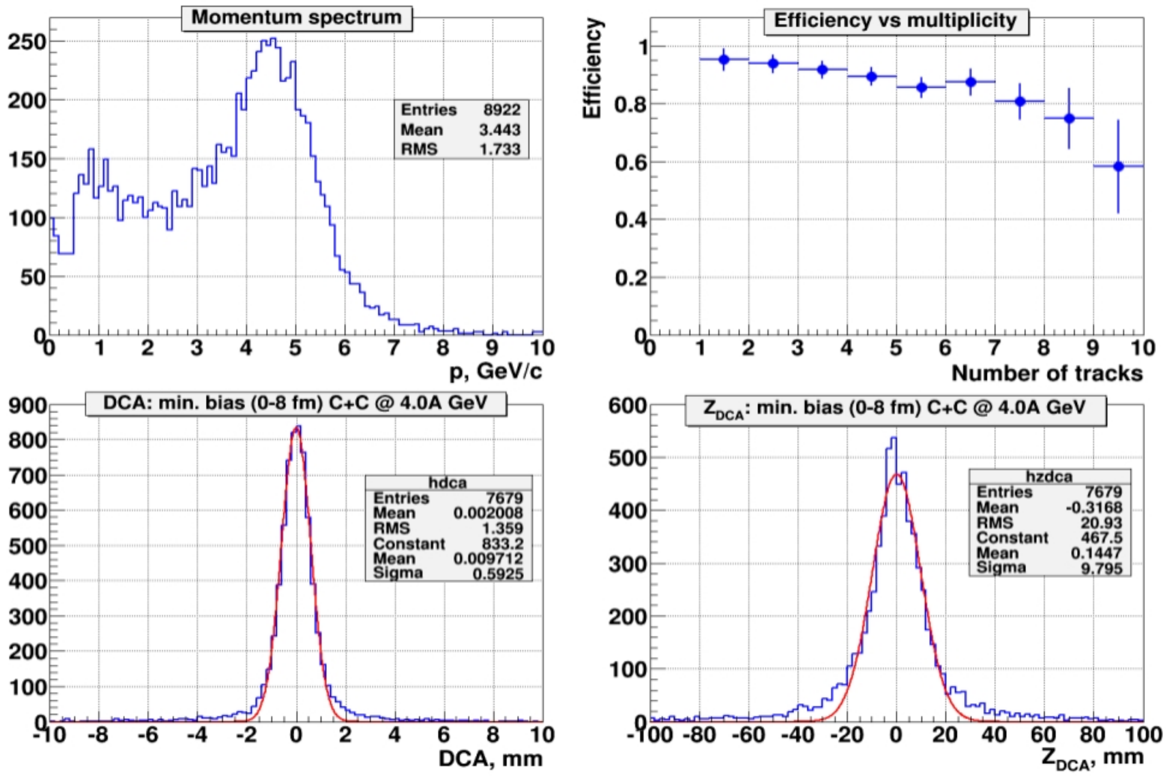

Figure 15: The simulation results for C+C minibias interaction at 4 A·GeV.

The simulation for FD has been performed for C+C minibias interaction at 4 A·GeV. The track reconstruction is based on the «vector finding» algorithm [33-34]. The results of the simulation for the momentum spectrum, efficiency reconstruction, precision of the transverse distance of closest approach (DCA) and in longitudinal direction (Z_{DCA}) are presented in figure 15. The reconstruction efficiency is 90-95% for 1-2 tracks in FD. It decreases as the fuction of the track multiplicity. The precision of the transverse distance of closest approach DCA and primary vertex position in Z direction are found to be 0.6 mm and 10 mm, respectively.

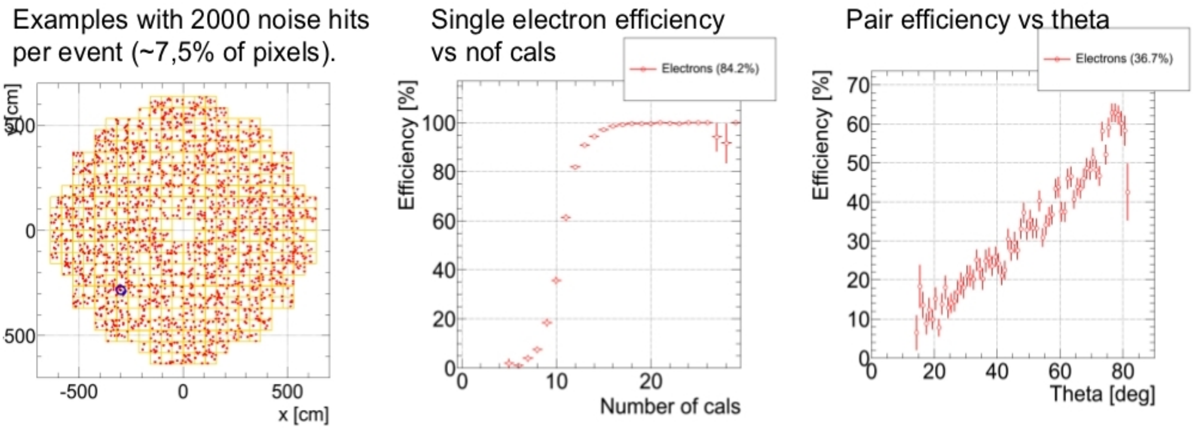

Figure 16: The simulation results for RICH700. Left: the occupancy of the photodetectors for Au+Au centarl event with 2000 noise hits. Middle: the efficiency of the single electron efficiency. Right: the e+e- pair efficiency reconstruction.

The third direction is the development of the software for the ring reconstruction in HADES RICH700. JINR (LIT) participates in the development of the algorithm based on the Hough transform method [35-37]. Simulation and reconstruction software for upgraded HADES RICH were implemented within HYDRA2 framework. The simulation results for RICH700 is shown in figure 16. The occupancy of the photodetectors for Au+Au central event with 2000 noise hits is shown in the left panel. The efficiency of the single electron efficiency as the function of the clusters used for the reconstruction is presented in the middle panel. The e+e- pair efficiency reconstruction is shown in the right panel.

HADES at SIS100 at FAIR

The high-intensity heavy-ion beams of the future FAIR accelerators offer excellent possibilities to produce and to investigate baryonic matter at highest densities in the laboratory. The research program comprises the study of the structure and the equation-of-state of baryonic matter at densities comparable to the ones in the inner core of neutron stars. This includes the search for the phase boundary between hadronic and partonic matter, the critical endpoint, and the search for signatures for the onset of chiral symmetry restoration at high net-baryon densities. HADES at SIS100 will be a part of the Compressed Baryionic Matter experiment. The FAIR accelerators deliver proton beams up to an energy of 90 GeV which permits investigations of elementary processes like charm production in an energy range where no data exist. Nuclear reactions in the energy range from 2 to 10 GeV/nucleon will be studied with an upgrade of the HADES spectrometer, which is currently being operated at the GSI SIS-8 accelerator. The HADES spectrometer will be placed upstream of the CBM setup in one cave (see figure 17).

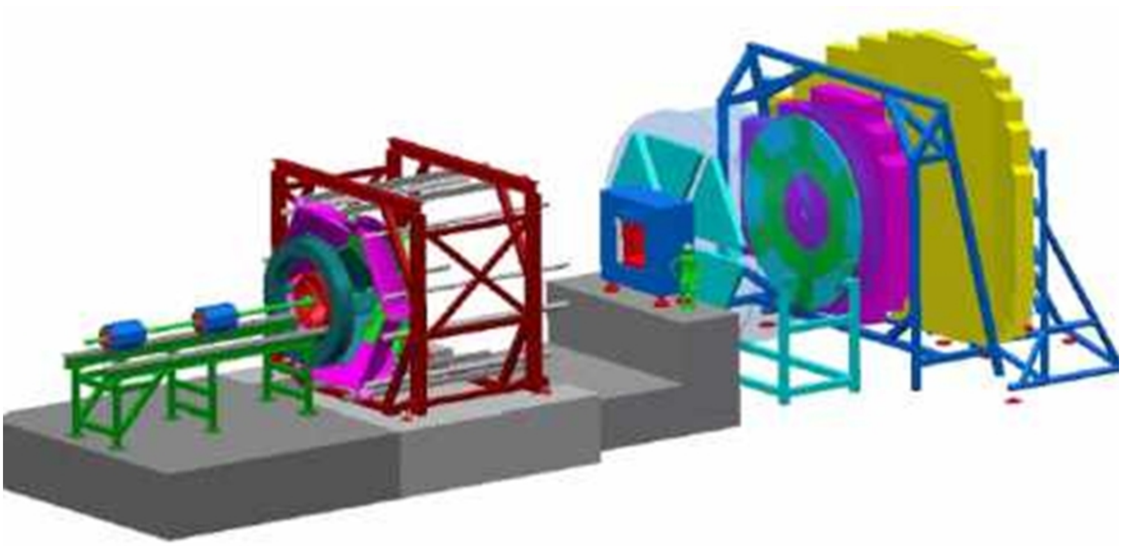

Figure 17: The schematic view of HADES and CBM installed at one cave for the experiments at SIS100.

Due to tracking system based on the use of MWDCs HADES can work only for the Ni+Ni collisions at 14 AGeV. Nowadays the modification of HADES is going on both for the data taking compains in 2017-2018 at SIS18 and for SIS100 in future. The RICH and MWDCs will be upgraded. Electromagnetic Calorimeter wll be put into operation. The JINR physicists are participating in the MWDC upgrade project and in the preparation of the physics program for HADES/CBM at SIS100.

Publications, presentations at the conferences

The main HADES results obtained in 2015-2016 were reported and published in [9-18], [22-23], [25], [30], [32] (6 publications with JINR principal authors).

JINR team presented 11 contributions at the HADES Collaboration Meetings in 2015-2016 [24,26-29,31,33-37] on the data analysis and results interpretation, software development.

JINR team had win the 2-nd LHEP award in 2015y.for the cycle of the papers «Study of the $np \rightarrow np\pi^+\pi^-$ reaction mechanism at 1.0-1.5 GeV».

Plans and request for 2017-2018

The main direction of HADES activity in 2016-2018 is the preparation of the spectrometer for data taking at SIS18 in 2018-2020 yy. Three main options for the experimental program are under consideration: πA run to study strangeness and baryonic resonances production, Ag+Ag at 1.76 AGeV to study di-electron and hadronic observables of the dense matter and p+A (p+p) at 3.5 GeV to study cold matter. The decision will be taken in 2017 depending on the status of SIS18. The JINR group will participate in the preparation and technical support during beam time of the plane 2 of MWDCs, the software support during data taking and DST production.

The second direction is the participation in the data analysis. The JINR group is traditionally involved in the studies of the hadronic probes, especially, in the elementary reactions. The physics includes multi-pion production in different reactions and their azimuthal correlations. Also the theoretical interpretation of HADES data will be continued.

The third direction is the JINR participation in HADES upgrade program and physics simulation for SIS100 at FAIR. JINR team is participating in MWDC upgrade program and software development for FD and RICH700 subprojects.

The activity of JINR group in HADES is performed within MoU between GSI and JINR. It has been supported in 2015-2016 yy. by BMBF-JINR grant (about 25 kEuro/year). The request for 2017-2018 yy. is 25 kEuro/year within BMBF-JINR grant (see Appendix). Note, that the grant is allocated until the end of 2017 yy.

Summary

During 2015-2016 JINR participants of the HADES project concentrated on the data analysis of the multi-pion production in neutron-proton reactions [10] and short-range correlations studies [24], on the obtained experimental data interpretation [22-23,25-30], on the software development [9,31-32] for the current version of the setup for the Au+Au and πA data, as well as for the upgraded version of HADES [33-37]. Total amount of the papers, contributions and talks at the collaboration meetings with JINR participants is 26 [9-18,22-37].

In order to optimize the manpower and money resources «HADES:JINR participation» project will be within the scientific theme 1106 since beginning of 2017.

JINR participants of the HADES project are continuing to work on mainteinance of Multiwire Drift Chambers with assosiated FEE. They will continue to take a part in data taking, data analysis and theoretical interpretation.

Main activity on the HADES project in 2017-2018 are the dollowing:

-the participation in data taking at SIS18 in 2018 (with responsibility for MDC plane 2),

-the participation in data analysis and simulation for hadronic channels in Au+Au, NN, πA and pA collisions at 1.25-3.5 A GeV.

JINR team is participating in the HADES upgrade (software development) and physics program for SIS18 and SIS100. This developed software can be used for MPD at NICA and for BM@N .

HADES heavy ion program at SIS18 started with Au-Au at 1.23 A GeV can have a serious impact on the physics program of BM@N and MPD as well.

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Appendix.

Cost estimation for HADES project (JINR participation)

NN	Name expenses	Total cost (kEuro)*	2017 y.	2018 y .	
	Direct expenses for the project:				
1	Nuclotron, hours.				
3	Computer link				
4	Laboratory design division, hours				
5	JINR workshops, norm-hours				
6	Materials	14	7	7	
7	Equipment	6	3	3	
8	Travelling expenses	30	15	15	
	a) in countries not ruble zone	30	15	15	
	b) In the countries of the ruble zone				
	c) on protocols				
	Total direct expenses	50	25	25	

*- BMBF-JINR grant (allocated for 2015-2017 yy.)