The HADES-at-FAIR project

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After the completion of the experimental program at the SIS18 the HADES setup will migrate to FAIR, where it will deliver high quality data for heavy ion collisions in an unexplored energy range of up to 8 AGeV. In this contribution, we briefly present the physics case, relevant detector characteristics and discuss the recently completed upgrade of HADES.

1. INTRODUCTION

The **H**igh **A**cceptance **D**i-**E**lectron **S**pectrometer (HADES) is a modern multi-purpose detector currently operating at the SIS18 heavy ion synchrotron in the region of kinetic beam energies of up to 2 AGeV for nucleus-nucleus collisions [1]. The main components of the experimental setup are a superconducting magnet, four planes of Multiwire Drift Chambers used for the tracking of charged particles, a Time-of-Flight wall and a hadron blind RICH detector.

At SIS18, HADES has accomplished a number of successful experimental campaigns. Among them are systematic investigations of the di-electron production in light colliding systems at 1–2 AGeV [2, 3] and in nucleon-nucleon reactions [4].

Primarily constructed for the electron-positron pair spectroscopy, HADES is proven to be perfectly suited for hadron measurements, including strangeness production in nucleus-nucleus [6–8] and in proton-proton collisions [9].

The experimental program at SIS18 is not finished — in 2011–2012 HADES will investigate heavy colliding systems: AuAu and AgAg at bombarding energies of 1.25 and 1.65 AGeV, respectively. Measurements of di-electron and hadron production in pion-induced reactions are also foreseen.

2. HADES AT SIS100

In heavy ion collisions at beam energies delivered by the heavy-ion synchrotron SIS100 within the **F**acility for **A**ntiproton and **I**on **R**esearch (FAIR), the nuclear compression is expected to be significantly higher as compared to SIS18. The increase of the beam energy will furthermore cause a transition from the below-threshold to above-threshold production of the light vector mesons (ρ, ω, ϕ). On the basis of thermal models one expects two orders of magnitude higher vector meson yields at SIS100 as compared with SIS18 [10]. Since the key point of the HADES program is the investigation of the vector meson spectral functions at high baryonic densities, these conditions are perfectly suited for the desired goal. Thus, a migration to the SIS100 will be a natural continuation of the HADES experimental program.

The HADES detector ensemble possesses a set of unique features for the measurements at SIS100. It is a running experiment with a well understood performance, which can deliver high quality data shortly after installation in the cave. Moreover, the detector and the analysis software will be further tested and tuned with upcoming heavy ion runs at SIS18.

It is planned that HADES will be installed in a common cave with the CBM experiment, performing measurements at beam energies of up to 8 AGeV. Therefore, it will provide a bridge to higher energies (up to 40 AGeV) to be explored by the CBM experiment.

3. ACCEPTANCE AND OCCUPANCY CONSIDERATIONS

As a first assessment of the HADES performance at SIS100, the detector acceptance and occupancy were studied by Monte-Carlo simulations.

3.1. Di-electron acceptance

In order to understand the acceptance for di-electrons in heavy ion collisions at a kinetic beam energy of 8 AGeV, the pairs originating from the direct e^+e^- decay of ω-mesons using the Monte-Carlo generator PLUTO [11] were studied. Individual leptons were propagated through the HADES acceptance filter and the pairs with laboratory opening angles less than 9 degrees were rejected. Fig. 1 illustrates in transverse momentum versus rapidity coordinates the distributions of di-electrons in the full phase space (upper row) and in the HADES acceptance (lower row). 21% of the di-electrons, coming from ω-mesons produced in CC collisions at 8 AGeV, are in the HADES acceptance. This number has to be compared with 33% for the same system at 2 AGeV. From the distributions shown in Fig. 1 it also follows that the acceptance of HADES with its present geometrical configuration still covers the mid-rapidity region at 8 AGeV. Taking into account the much larger yields of vector mesons anticipated at the higher energy one can expect significantly higher di-electron rates in the corresponding region of invariant masses for 8 AGeV (SIS100) as compared to 2 AGeV (SIS18), compensating by far the slight decrease in acceptance.

3.2. Hadron acceptance

The acceptance of the HADES detector for charged hadrons was studied in a similar way. As an input, hadron events generated with the UrQMD transport code were used. The detector acceptance for the charged hadrons produced in CC collisions at a kinetic beam energy of 8 AGeV is illustrated on Fig. 2. At this energy, 50% of π^+, 52% of π^-, and 15% of protons are inside the HADES acceptance.

Thus, the detector that was originally designed to study symmetric systems at bombarding energies close to 2 AGeV, where the acceptance of light particles is symmetric around midrapidity, provides an adequate acceptance for di-electrons and hadrons also at 8 AGeV.

3.3. Occupancy of the detector

The transition to higher energies will be accompanied by the increase of the charged particle multiplicity in the forward part of the spectrometer. The maximum system size, possible to be studied at SIS100, was evaluated. The performed simulations have shown that the charged particle multiplicity grows by a factor of 14 when going from CC collisions at 2 AGeV to AuAu collisions at 1.5 AGeV. Already in the latter case one expects a 20% double hit probability in the RPC detector (described below) that limits the tracking performance. According to our estimates, the hit occupancy in AuAu collisions at 1.5 AGeV corresponds to the NiNi colliding system at 8 AGeV bombarding energy.

4. THE UPGRADE OF THE APPARATUS

For the measurements at SIS100, HADES will benefit from the upgrade, performed in 2009–2010 with the aim to make the detector capable of measurements with really heavy ions at SIS18. The requirements for the upgrade were that the detector is able to cope with high charged particle multiplicities, typical for central collisions of gold nuclei, and accept a minimum trigger rate of 20 kHz even for heavy ion collisions.

A Forward Wall detector consisting of 280 individual scintillators was installed, extending the HADES acceptance to the region of low polar angles ($0.33° < \theta < 7.17°$). This detector was already used in 2007 for the spectator proton detection in a *dp* experiment [12]. It is essential for the upcoming heavy ion runs at SIS18 and SIS100, since it allows the reconstruction of the reaction plane, necessary, e.g., for the analysis of particle flow.

One of the most important steps in the detector upgrade was the replacement of the low granularity scintillator Time-of-Flight detector TOFino be the high-granularity timing Resistive Plate Chambers (tRPCs) [13]. This detector offers a time resolution better than 100 ps with an efficiency close to 100%. With 1200 individually shielded 4-gap tRPCs, the RPC TOF wall enables HADES to handle multiplicities of up to 200 charged particles per event and it further improves the lepton and charged hadron identification.

Investigations of colliding systems with maximal nucleon numbers aiming at high statistics data samples required also an upgrade of the HADES data acquisition (DAQ) system.

The key component of the newly constructed system is a trigger and readout board (TRB) being a multi-purpose electronic device with on-board DAQ functionality [14].

With the upgraded setup the HADES collaboration aims to collect high statistics data samples that allow to perform multi-differential (as a function of collision centrality, transverse momentum, invariant mass, etc.) studies of di-electron and hadron production.

5. AN ELECTROMAGNETIC CALORIMETER FOR HADES

Currently, another upgrade project is intensively investigated — the extension of the HADES particle identification capabilities by an electromagnetic calorimeter. The proposed calorimeter will open the possibility for the neutral pseudoscalar meson (π^0, η) reconstruction via their decays into two photons. The π^0 multiplicity is a natural choice for the absolute normalization of the measured di-electron spectra. The measurement of the η meson yield is of particular importance, since its Dalitz decay is a significant source of the di-electrons for the invariant masses above 140 MeV/c^2. Whereas at beam energies of 1–2 AGeV the measurements of the η yield in heavy ion collisions were performed by the TAPS collaboration [15], at higher energies, in the SIS100 range, no data on the η production exist.

Another important function of the calorimeter is to improve the lepton-pion separation at high values of the particle momentum ($p > 0.5$ GeV/c). For this purpose, a cut on the ratio of the deposited energy in the calorimeter to the measured momentum in the HADES tracking system will be employed.

We consider to build an electromagnetic calorimeter using lead-glass blocks from the end-cap calorimeter of the former OPAL experiment [16]. In total, ~900 modules will be arranged in six sectors of the HADES setup. The calorimeter will substitute the existing SHOWER detector and will be installed behind the tRPCs.

Dedicated in-beam tests of the lead-glass modules were already performed at CERN (electron and pion beams) and MAMI (γ-beam), confirming the expected energy resolution of $\simeq 5\%/\sqrt{E/\mathrm{GeV}}$ and demonstrating a good potential for the lepton-pion separation.

Recently, a calorimeter simulation software was developed, making use of the GEANT3 program [17] and an external Cherenkov photon transport code [18, 19]. The simulations have shown the feasibility of the π^0 and η reconstruction and the lepton/pion separation in heavy-ion collisions.

6. SUMMARY

In this contribution, plans of the HADES collaboration for the future investigations of relativistic heavy ion collisions at SIS100 were outlined. The newly updated experimental setup is ready to perform investigations of the compressed nuclear matter at FAIR exploiting both lepton and hadron probes.

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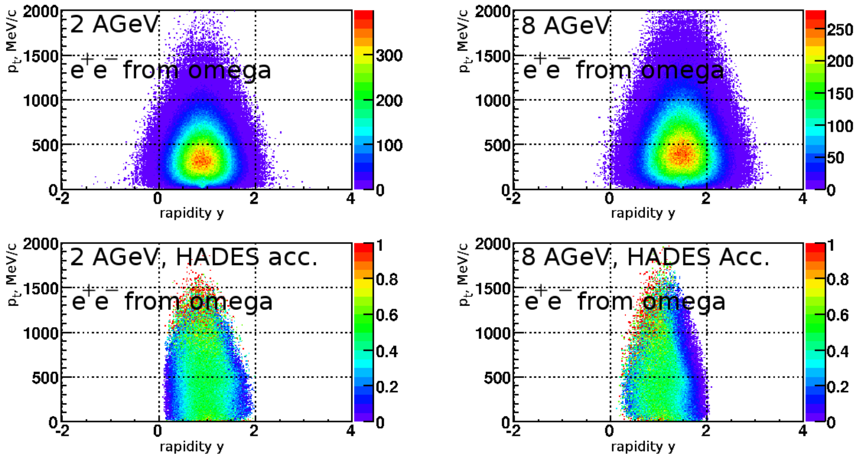

Figure 1. Transverse momentum versus rapidity distributions (upper row) for electron-positron pairs coming from the direct ω decays at beam kinetic energies of 2 AGeV (left column) and 8 AGeV (right column) and the HADES acceptance (lower row)

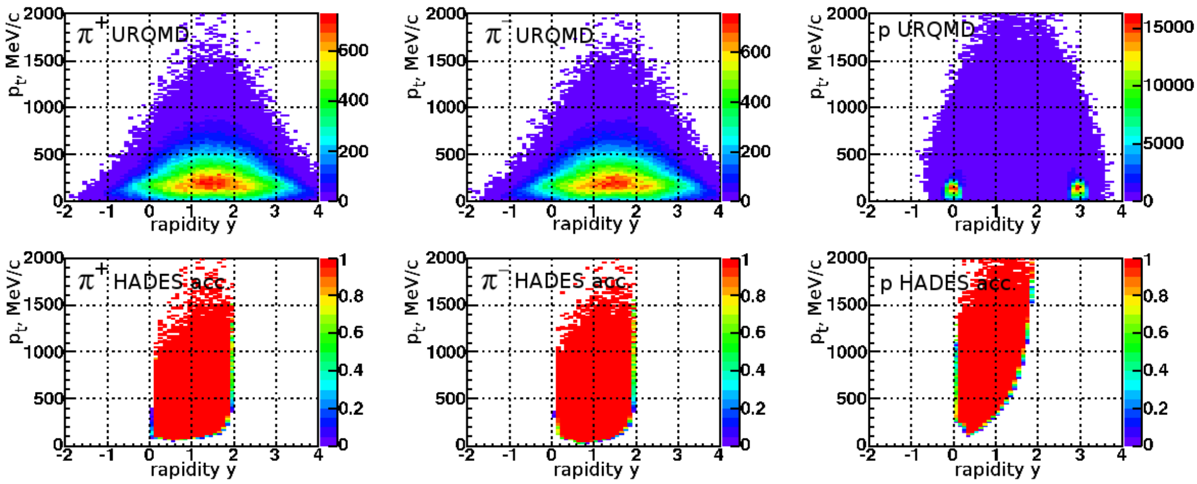

Figure 2. Transverse momentum versus rapidity distributions (upper row) of charged hadrons (left: π^+, middle: π^-, right: protons) produced in CC collisions at a beam kinetic energy of 8 AGeV and the HADES acceptance (lower row)

FIGURE CAPTIONS

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Fig. 2: Transverse momentum versus rapidity distributions (upper row) of charged hadrons (left: π^+, middle: π^-, right: protons) produced in CC collisions at a beam kinetic energy of 8 AGeV and the HADES acceptance (lower row)