EPJ Web of Conferences **291**, 04001 (2024) https://doi.org/10.1051/epjconf/202429104001
MESON 2023

Neutral meson production in Ag+Ag at $\sqrt{s_{NN}}$ = 2.55 GeV

Alexandr Prozorov[1,*] for the HADES collaboration

[1]Nuclear Physics Institute, Hlavni 130, Rez, Czech Republic

Abstract. Relativistic nucleus–nucleus collisions offer a unique possibility for studying nuclear matter under the influence of high temperature and pressure. During the collision a system of interacting nucleons, resonances, and mesons, called hadronic fireball, is created. HADES is a unique experiment capable of simultaneously measuring all three species of pions for this energy regime. Results on neutral pion production in Ag + Ag collisions at $\sqrt{s_{NN}}$ = 2.55 GeV (beam energy 1.58 A GeV) with 14 billion collected events will be presented. A measurement of a directed and elliptic flow, and yields of neutral pions corrected for detector acceptance and efficiency will be shown with respect to transverse momentum and rapidity for certain centrality classes; and further compared with the data, and charged pion data measured in the same experiment. In addition, the obtained results will be confronted with up-to-date model calculations.

1 Introduction and HADES experiment

Conditions similar to the interior of neutron stars can be accessed in heavy-ion collisions with high energy. One of the promising observables of the macrosopic properties of the collision are the virtual photons that carry information from inside of the hot and dense matter, which is formed in the collision zone. Furthermore, they do not interact strongly with the medium and allow one to "look into" the early stages of collision. The yield of neutral pion is important because its e^+e^- decay contributes significantly to the yield of e^+e^- pairs [1]. The time evolution of hadronic matter can be described by the laws of hydrodynamics, assuming that thermalization is achieved in the early stages of heavy-ion collisions and that the interaction between the quarks is strong enough to maintain local thermodynamic equilibrium during subsequent expansion. Radial flow characterizes the collision system in kinetic freeze-out, that is when elastic collisions of the produced particles cease [2]. The HADES setup consists of an ironless six-coil toroidal magnet centered on the beam axis and six identical detector sectors located between the coils. It has the acceptance of nearly complete azimuthal coverage and polar angles that span between $18^\circ \leq \theta \leq 85^\circ$. Each sector is equipped with a central hadron-blind RICH detector, four planes of Mini Drift Chambers, a time-of-flight detectors (Resistive Plate Chamber (RPC) and Time-of-Flight Wall), Electromagnetic Calorimeter (ECAL), and Forward Wall (FWALL). For more references, see [4]. The newly installed Electromagnetic Calorimeter offers a unique possibility for the HADES spectrometer to measure neutral particles. The total area of the HADES calorimeter is approximately 8 m^2 and covers the polar angles between 12° and 45° with almost full azimuthal

*e-mail: alexandr.a.prozorov@gmail.com

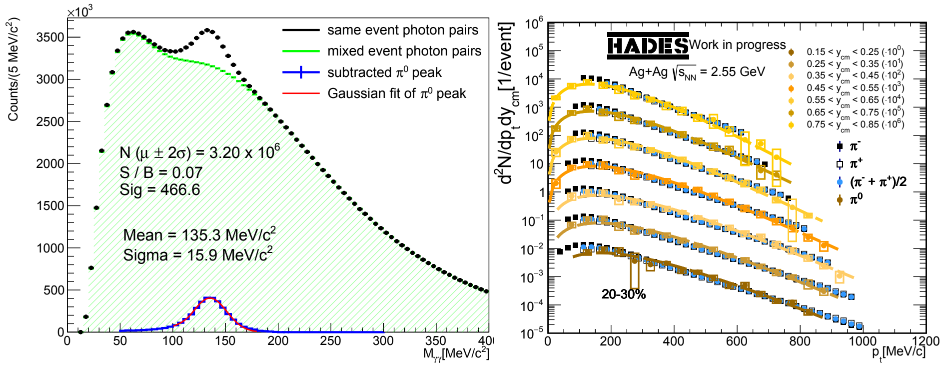

Figure 1: **Left**: Gamma-gamma invariant mass distribution. An example of π^0 yield extraction. The black line represents same-event pairs, green points - mixed-event pairs, the blue points represent the correlated signal, and the red line shows the fit of extracted signal. **Right**: The pion yields in phase space with Boltzmann fits to neutral pions.

coverage. The resolution of the photon and electron energy achieved in the test experiments amounts to $\approx 6\%/\sqrt{E}$. The main element of the HADES ECAL is the modified module of the OPAL end cap electromagnetic calorimeter with CEREN 25 lead glass inside that is used as a Cherenkov radiator.

2 Data analysis and yields

A photon can be reconstructed by demanding a condition of anti-matching with any reconstructed charged track and by the anticoincidence with the RPC detector, which stands in front of ECAL. Only photon candidates with reconstructed energy above 100 MeV are selected. This energy cut removes most of the neutrons, which could also interact hadronically with ECAL. In addition to those cuts, the particle velocity condition $\beta > 0.8$ is applied. The calibration of the ECAL detector was performed in two steps. First, using reconstructed electrons in HADES, one gets a first estimate of the calibration coefficients. Second, by several iterations, these coefficients were slightly modified by requiring the π^0 peak position equal to the known value of 134,98 MeV.

To estimate the combinatorial background, the event mixing method was used which consists of combining photons originating from different events because those particles are not correlated, and hence the correlated signal is absent, and it can be used for the subtraction from one-event photon combinations. These photon combinations must also have the same event topology. An example of π^0 signal extraction is shown in Fig.1. Efficiency and acceptance corrections are then applied, based on GEANT simulations of the HADES setup. The original input from the UrQMD model [3] was processed through GEANT simulations to get response in active material in subdetectors, then it is digitized to get the detector response and analyzed in the same way as experimental data. The phase-space distribution of π^0 yields with Boltzmann fits $\frac{dN}{dp_t} = Cp_t m_t e^{-\frac{m_t}{T}}$ is shown in Fig. 1 along with charged pions and their algebraic average.

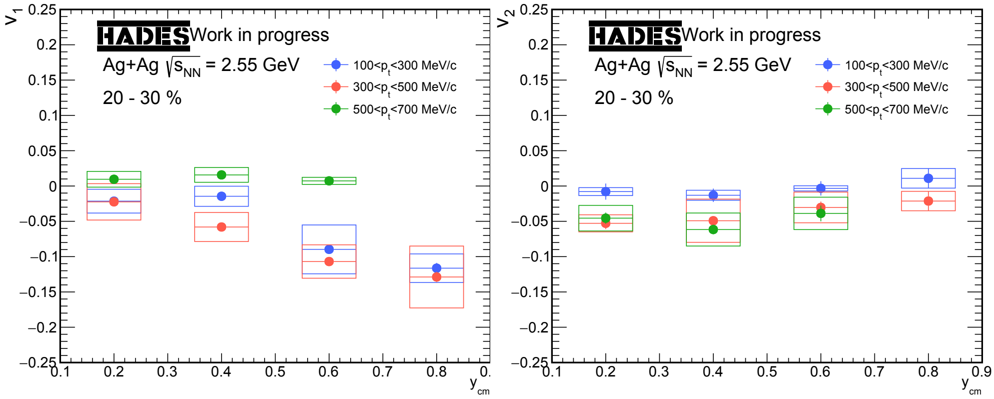

Figure 2: Flow coefficients of π^0 as a function of rapidity for 20-30 % centrality. **Left**: Directed flow. **Right**: Elliptic flow.

3 Flow

To characterize the distribution of the particles, an expansion of the angular distribution of the particles relative to the reaction plane into a Fourier series is used [2].

For the estimation of the reaction plane angle Ψ_{EP} as well as its resolution correction factors, a dedicated detector FWALL was used. The number of extracted neutral pions $dN(p_t, y, C)/\Delta\phi$ in different $\Delta\phi = \phi - \Psi_{EP}$ bins is examined in different phase-space regions in p_t- y and in the centrality class C. This distribution is further fitted with a Fourier decomposition: $\frac{dN(p_t,y,C)}{\Delta\phi} = \frac{N}{2\pi}(1 + 2v_1^{obs}\cos\Delta\phi + 2v_2^{obs}\cos 2\Delta\phi)$. This method is called "standard".

For the systematic uncertainty of the flow coefficients, two more methods were used in addition, that is, the "quarters" method, which involves the distribution of the azimuthal angle in quarters with respect to the event plane, and "tprofile" method, which uses the invariant mass distribution and the decomposition of the flow harmonic n for the observed mean value over all candidates in events. $v_{n,S+B}^{obs}(m_{\gamma\gamma}) = v_{n,S}^{obs}(m_{\gamma\gamma}) + v_{n,B}^{obs}(m_{\gamma\gamma})$ [5].

The standard method was used for the results of directed and elliptic flow, and they are shown in Fig. 2.

The extracted flow coefficients are further compared with various models. In Fig. 3 π^0 flow coefficients from the UrQMD with EoS model are shown. It has a good agreement with the experimental data both for directed and elliptic flows of neutral pions because it was adjusted for the flow of different experimental data in this energy regime and contains some phenomenological parameters. The following observations can be made:

- directed flow depends on a transverse momentum,
- elliptic flow is approximately constant as a function of rapidity and decreases toward higher transverse momentum, and is the same for all pion species
- neutral pion directed flow is stronger in some p_t bins than that of charged pions, which is not the case for UrQMD with EoS.

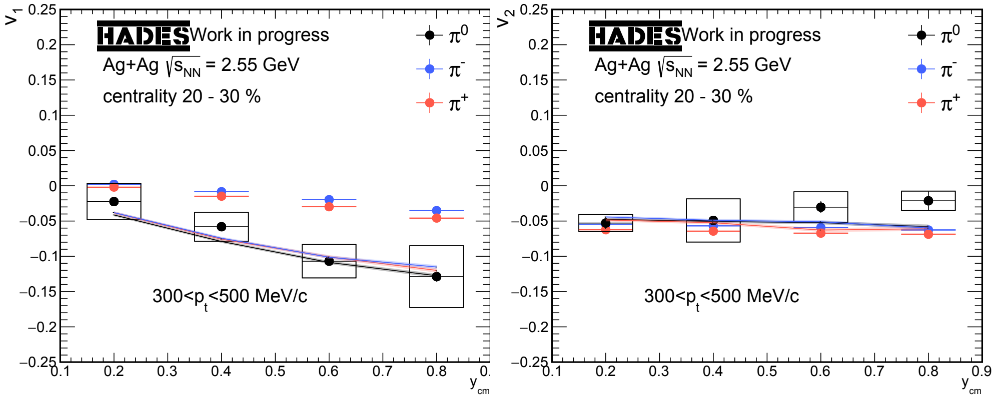

Figure 3: Flow coefficients of all pions species for 20-30 % centrality compared with **UrQMD EOS** model as a function of rapidity. **Left**: Directed flow. **Right**: Elliptic flow.

4 Conclusion

A newly installed electromagnetic calorimeter was successfully used in the experiment Ag+Ag at $\sqrt{s_{NN}}$ = 2.55 GeV. The calibration of ECAL was performed using leptons registered in ECAL and requiring that π^0 peak position was at the known value of 134.98 MeV, and the resulting energy resolution was 6% at 1 GeV. First results on neutral pion yields and flow at such energies in heavy projectile-target collision systems were reported. The comparison with models was performed, a good description by UrQMD EOS was observed. There was found a small disagreement between charged pions flow and neutral pion flow for certain p_t region around 400 MeV.

Acknowledgment

Work supported by: NPI CAS, Rez, Rez (Czech Republic), MSMT LTT17003, MSMT LM2018112, MSMT OP VVV CZ.02.1.01/0.0/0.0/18_046/0016066

References

[1] Tetyana Galatyuk, HADES overview, https://doi.org/10.1016/j.nuclphysa.2014.10.044.

[2] A. M. Poskanzer and S. Voloshin. Methods for analyzing anisotropic flow in relativistic nuclear collisions, Physical Review C 70 (1671). 1998

[3] M. Bleicher, E. Zabrodin, C. Spieles, S.A. Bass, C. Ernst, S. Soff, L. Bravina, M. Belkacem, H. Weber, H. Stocker, W. Greiner: Relativistic Hadron-Hadron Collisions in the Ultra-Relativistic Quantum Molecular Dynamics Model J. Phys. G: Nucl. Part. Phys. 25 (1999) 1859-1896

[4] O. Svoboda et al. Electromagnetic calorimeter for the HADES@FAIR experiment, doi:10.1088/1748-0221/9/05/C05002

[5] N. Borghini and J. Y. Ollitrault. Azimuthally sensitive correlations in nucleus-nucleus collisions. Physical Review C 70 (6). 2004