Studying ρ–N couplings with HADES in pion-induced reactions

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Abstract. The High-Acceptance Di-Electron Spectrometer (HADES) operates at the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt with pion, proton and heavy-ion beams provided by the synchrotron SIS18. In summer 2014, HADES took data using a pion beam on carbon and polyethylene targets. A large part of the data was taken at a pion beam momentum of 0.69 GeV/c in order to explore di-pion and di-electron production in the second resonance region and the sub-threshold coupling of the ρ to baryonic resonances. In this contribution lepton identification will be discussed as well the purity of reconstructed e^+e^-. Finally we will show the preliminary di-electon raw spectra.

1 Introduction

Previous measurements made by the HADES [1] showed an enhancement in di-lepton spectra below the vector meson pole both in proton-nucleus and in nucleus-nucleus collisions [2] in comparison with a cocktail of known hadronic sources. The main interpretation of this effect is based on the strong coupling of the ρ meson to the baryonic resonances (see for example [3]). Exploiting the possibility of GSI to provide a secondary pion beam, HADES has the purpose to study the coupling of the ρ with the baryonic resonances in the second resonance region by means of the reactions $\pi^- p \rightarrow \pi^+\pi^- n$ and $\pi^- p \rightarrow \pi^0\pi^- p$. In addition, the role of the ρ meson in electromagnetic transitions in the time-like region is investigated in the reaction $\pi^- p \rightarrow e^+e^- n$. The validity of the Vector Meson Dominance model will hence be clarified by the combined use of both hadronic and di-electron channels.

2 HADES detector

HADES is placed at GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt. It is a fixed target high interaction rate experiment suitable to take high intensity beams (protons, ions and pions) and it is characterized by a large acceptance (almost full azimuthal angle and between $18 - 85°$ in polar angle). Particle identification is provided by time of flight measurements using TOF and RPC detectors and energy loss measurements in MDCs, that, together with a toroidal magnet, provide also track and momentum reconstruction. In addition, to separate leptons from hadrons, a hadron-blind Ring Imaging CHerenkov detector (RICH) and a pre-shower detector are used. The data analyzed in this work were taken in summer 2014 in π^--PE (polyethylene) and in $\pi^- - C$ collisions at a pion momentum around 0.69 GeV/c [4].

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3 Experimental conditions

SIS18 is able to provide a secondary π^- beam produced in the interaction between a primary beam of N_2 with an intensity of $8x10^{10}$ ions/spill (spill = 4s) and a thick beryllium target. The pions are then transported to HADES by means of a beam line composed of 7 quadrupole and 2 dipole magnets (Fig.1). Since the distribution of produced pions is broad, a system called CERBEROS, composed of two fast silicon detectors, was installed along the beam line to reconstruct the pion momentum with a precision of about 0.3%.

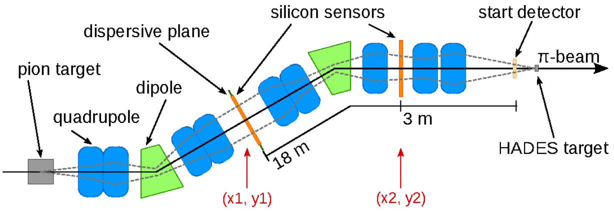

Figure 1. Schematic view of the pion beam line.

4 Lepton identification and purity

4.1 Lepton identification

The measurements of leptons is not an easy task: they are rare probes and they are produced in an environment dominated by pions. Therefore one would like to increase the efficiency of their detection, but at the same time it is necessary to be very cautious to avoid pion contamination. In order to increase the reconstruction efficiency of the di-electron channel an effort was made to analyse these data, characterized by low multiplicity, without information from RICH, relying only on β (=v/c) vs momentum and energy loss information for lepton identification. This was shown to be unsuccessful [5]. Therefore the RICH information was used trying two different approaches: the standard ring finder based on a pattern recognition algorithm to select the good rings [1] and a new approach called backtracking [6], that was developed in order to increase ring identification capabilities taking advantage of tracking information: when a track is found with velocity, momentum and energy loss that correspond to a lepton, it is propagated back to the RICH detector in order to fix the possible ring center on the pad plane. At this point it is therefore possible to be looser in the requirements for a ring. As written in [6], backtracking algorithm succeeded to have similar background rejection and achieves higher efficiency than the standard ring finder.

4.2 Purity determination

Detailed understanding of the purity of the lepton sample is fundamental; for this reason HADES has developed a method to establish purity, when the standard ring finder approach is adopted, using the so-called rotated RICH technique. The RICH detector is rotated (softwarewise) by 60° and then the tracks are matched with the rings. In this way any correlation between tracks and rings is lost and therefore one gets only random matches. Now it is possible to estimate the purity using the angular correlation between the tracks and the ring, i.e. $\Delta\phi \; sin\theta$ as shown in Fig.2. Now the data obtained after applying the rotated RICH technique (and all PID cuts) are considered as the background and the signal is obtained after subtraction of this background from the standard data sample (again after all PID cuts). The purity can be calculated as:

$$Purity = 1 - \frac{rot.\ RICH\ data}{standard\ data}$$

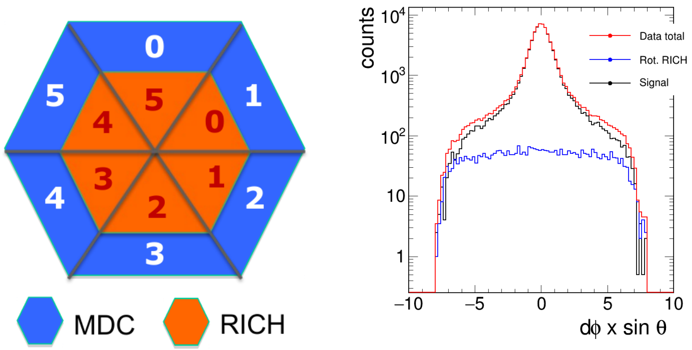

Figure 2. Left, schematic view of the rotation technique. Right, $\Delta\phi$ (difference between ϕ angle of the reconstructed track and ϕ angle of the reconstructed ring) *sinθ*

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Table 1. Purity values.

p[MeV/c]	e^+	e^-
p < 100	99.7 %	99.1 %
100 < p < 200	99.4 %	98.7 %
200 < p < 300	97.7 %	93.7 %
300 < p < 400	97.3 %	89.0 %

This method has to be applied separetely for electrons and positrons in different momentum ranges, since the pion contamination depends on the momentum. In Table 1 the purity values are listed. The purity is very high for positrons in all momentum regions, while for electrons it decreases with increasing of momentum, but stays at a satisfactory level also for the highest momentum region. This trend is due to negative pions originating from elastic and quasi-elastic scattering.

5 Raw spectra

After identifying leptons, they are combined into pairs in order to get the invariant mass spectrum, however, in addition to the signal pairs, also uncorrelated pairs stemming from different production vertices (for example two different π^0 decays) are present in the event sample. Therefore all possible combinations have to be taken into account and then an estimation of the uncorrelated pairs, that form the combinatorial background (CB), is needed. CB is calculated by means of the same event like-sign technique: like-sign pairs (N_{++}, N_{--}) from the same events are formed and then the geometrical average is calculated: $CB = 2\sqrt{N_{++}N_{--}}$. In case one of the two numbers is 0, the arithmetic average is used. Finally to obtain the signal, formed by correlated pairs, the CB is subtracted from the unlike-sign pair sample. An additional cut is applied in order to reduce the CB originating from the conversion of photons from π^0 decay, requesting that the opening angle must be larger than 9°. In Fig. 3 the raw inclusive invariant mass is shown. The number of pairs with invariant mass larger than 140 MeV/c^2 is $\sim$ 1205 for standard ring finder and $\sim$ 3360 for backtracking. So the efficiency is increased by a factor 2.8 with the backtracking method and it will allow multi-differential analysis.

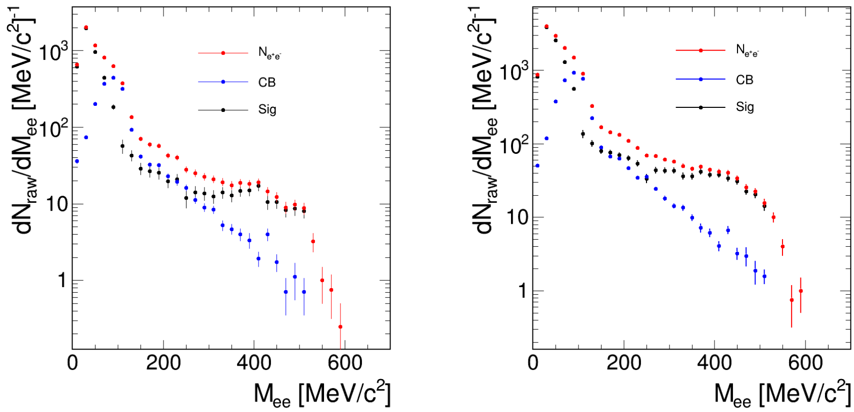

Figure 3. Raw inclusive invariant mass spectra using: left ring finder and right backtracking. Red solid circles show all e^+e^- combinations, blue solid circles show CB estimated using geometrical mean of same-event like-sign pairs, black solid circles show signal Sig = $N_{e^+e^-}$ - CB.

6 Conclusions

The HADES experiment measured for the first time di-electon production in pion-induced reactions in the second resonance region. Lepton identification was discussed and it was shown that the purity is high in all momenta for e^+ and e^-. The new backtracking algorithm increases in a significant way the efficiency of lepton identification in comparison with the standard ring finder. The collected statistics should permit to test different theoretical predictions and, in combination with the two pion production, get information on the role of rho meson in time-like electromagnetic processes.

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