Pion and dielectron production with pion-proton reactions*

HADES Collaboration
[1]www-hades.gsi.de

The combination of the secondary pion beam available at GSI with the universal HADES detector represents a worldwide unique facility to study hadron and dielectron production. The corresponding experimental programme was initiated in summer 2014 by studies of strangeness production off nuclei (see contribution [1]) and dielectron production in π^--p reactions. The main goal of the second experiment was to study inclusive and exclusive (with π^--p$\rightarrow$$e^+e^-$n final state) dielectron production in the energy region of the second resonance ($\sqrt{s}$~1.5 GeV). The studies of exclusive channels allows, for the first time, to measure the Dalitz decay of the D_{13}(1520) resonance D_{13}(1520)$\rightarrow$$e^+e^-$n. This long awaited result is an important step towards for a complete understanding of the ρ meson coupling to baryons, crucial also for the broadening of the ρ meson spectral function in nuclear matter [2]. Furthermore, these measurements of inclusive and exclusive dielectron production provide an important reference for the already measured p-Nb system [3], where a significant excess of e^+e^- yield below the vector meson pole has been attributed to secondary pion-nucleon interactions [4].

In order to separate the resonant from non-resonant contributions in the dielectron channel, final states with hadrons have to be investigated as well. For this purpose the excitation functions of the one pion and the two-pion production around the pole of the D_{13}(1520) resonance have been simultaneously measured. In particular, new data on exclusive π^--p$\rightarrow$$\pi^+\pi^-$n channels are of special importance. These data will be analyzed with the partial wave technique to disentangle the different waves that build up coherently the measured final state and will provide an independent measure of the production amplitude of the ρ meson in its main decay channel. Generally, these data are badly needed to understand the mechanism of two pion decays of various resonances in this energy region. The old bubble-chamber experiments, on which is based all our knowledge about charged pion production, provided only about 240 000 events in the energy interval of $\sqrt{s}$ =1.32-1.93 GeV. The situation is a bit better for the $\pi^0\pi^0$ final state which has been accurately measured by the Crystal Ball collaboration from threshold up to $\sqrt{s}$ 1.525 GeV. Since the ρ meson cannot decay into neutral pions, the new HADES data, which improve the data base by at least two orders of magnitude, will provide a stringent constraint on ρ production at these energies. As already mentioned above, the branching ratios of the resonance decays to ρN are known with bad precision. In the PDG, several resonances important for the in-medium spectral function of the ρ meson, like D_{13}(1520), S_{31}(1620) and the P_{13}(1720), have large branching ratios 20-30%, 7-25% and even larger than 70%, respectively. However, much lower values of these branching ratios are found in some recent PWA analyses. For instance, these branching ratios are respectively 10% ±3%, 12%±9% and 10%±13% in the analysis done by the Bonn-Gatchina group [5]. Lower values for the P_{13}(1720) (lower than 6%) and for the D_{13}(1520) (9%) are found respectively by the KSU [6] and Pittsburg-Argonne [7] groups. With the new precise HADES data on charged pions, the situation can be clarified for the D_{13}(1520) and future HADES experiments with pion beams at higher energies will improve the situation for the higher mass resonances as well.

The experiment was conducted with a primary ^{14}N beam, provided by the SIS18 synchrotron, with an intensity close to the space-charge limit of 0.8-1.0×10^{11} ions/spill. The pions were transported to the HADES target, located 33 m downstream of the production point, by a beam line composed of a lattice of 7 quadrupole and 2 dipole magnets. For pions with a central momentum (p_0) a transmission of about 56% with respect to the entrance solid angle was achieved. The calculated transmission decreases gradually as the π-momenta depart from the central, reaching zero for pion momenta of p_0±6%. The transmission can be represented to first order by a Gaussian distribution with a variance of $\delta p/p_0$=1.5%. The pion intensity distribution at the exit of the pion beam line (last quadrupole) depends on the selected p_0, reaching a maximum of about 10^6 pions/spill at p_0=1.0 GeV/c and decreasing to about half of this value at p≅0.690 GeV/c where our measurements were performed. These intensities are the result of the combined effect of the beam size at production target and of the transmission, mostly driven by the dedicated tuning of the different magnets and the respective apertures defined by the vacuum vessels. For a beam of negative pions, the purity is high and the small contamination by electrons and muons has been estimated to be lower than a few %. Together with their low interaction probability this contamination does not constitute a handicap for the experiment. A dedicated tracking system (CERBEROS) [8], composed of two silicon strip-detectors along the pion chicane and a start detector [9]

* Work supported by INFN-LNS Catania (Italy); LIP Coimbra (Portugal): PTDC/FIS/113339/2009; SIP JUC Cracow (Poland): 2013/10/M/ST2/00042 and NN202198639; GSI Darmstadt (Germany): Helmholtz Alliance HA216/EMMI; TU Darmstadt (Germany): VH-NG-823, Helmholtz Alliance HA216/EMMI; HZDR, Dresden (Germany): 283286, 05P12CRGHE; Goethe-University, Frankfurt (Germany): Helmholtz Alliance HA216/EMMI, HIC for FAIR (LOEWE), GSI F&E, BMBF 06FY9100I; TU München, Garching (Germany): BMBF 06MT7180; JLU Giessen (Germany): BMBF:05P12RGGHM; University Cyprus, Nicosia (Cyprus): UCY/3411-23100; IPN Orsay, Orsay Cedex (France): CNRS/IN2P3; NPI AS CR, Rez, (Czech Republic): MSMT LG 12007, GACR 13-06759S.

DOI:10.15120/GR-2015-1-MU-NQM-HADES-16

right in front of the HADES, has been developed

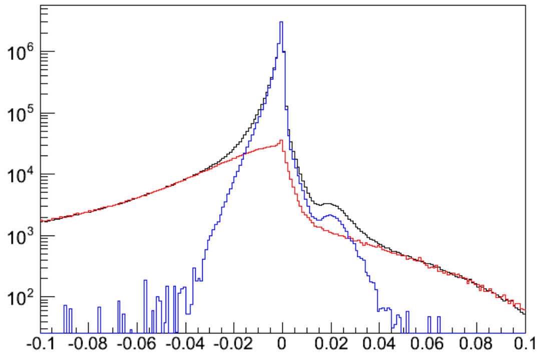

Figure 1: Missing mass squared of the π^--p system obtained after angular conditions to select π-p elastic scattering events. Data obtained at a pion beam momentum p=0.69 GeV/c are shown for the polyethylene (black) and carbon (red) targets. The difference is displayed as a blue curve.

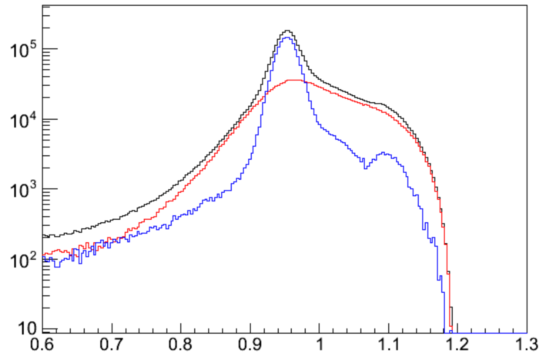

Figure 2: Missing mass of the $\pi^-\pi^+$ system. Data obtained using a pion beam momentum p=0.69 GeV/c are shown for the polyethylene (black) and carbon (red) targets. The difference is displayed as a blue curve.

and successfully used to measure the momentum of each beam particle. From the measured positions of the hit on the two detectors, the pion momentum is reconstructed with a resolution ranging from 0.1% to 0.3% over the acceptance window. This allows for a precise reconstruction of the total center-of-mass energy in pion-nucleon interactions.

Calculations of the pion beam optics have shown that the beam spot at the HADES target position exceeds the diameter of the target (12 mm) and can cause significant background from beam interactions in the narrow RICH beam tube or target holder. In order to reject this background and to also provide start time information a position sensitive detector was placed 30 cm in front of the target. Two types of targets were used for π^--p experiments: polyethylene of 46 mm thickness (containing 4×10^{23} protons and 2×10^{23} carbon) and pure carbon for the background subtraction.

Produced particles where reconstructed by means of the HADES detectors. Fig. 1 shows distribution of the missing mass squared of the π^--p system obtained for the π-p elastic scattering events, selected by angular correlations between identified pion and proton tracks at p_0=690 MeV/c. The black curve shows distributions obtained with the polyethylene target, while the red curve shows the same distribution but resulting from the carbon target. The latter one is normalized to the same yield on the left side of the prominent peak corresponding to the signal from the elastic scattering (blue line), which has been obtained as a difference between the two measured distributions. As one can see, the quasi-elastic peak obtained from the carbon target is much broader. A small peak at 0.0196 $(GeV/c^2)^2$, corresponding to the inelastic channel with one additional pion produced clearly visible in the subtracted distribution, is not observed. The separation between elastic and quasi-elastic scattering is very useful for the subtraction of background originating from the reactions on carbon inside the polyethylene target for other reaction channels. For example, Fig. 2 shows the missing mass distributions of the two charged pion system measured with the polyethylene (black line) and the carbon (red) targets. The latter one was normalized by scaling the number of collected events from the two targets with the factor deduced from the analysis of the elastic events, described above. As one can see in the subtracted distribution (blue line), the signal from the $\pi^-p\rightarrow\pi^+\pi^-n$ final state is clearly visible as a peak around the nominal neutron mass. The background under the peak from the interactions on carbon is on the level of 25-30% only and can be accounted for by the partial wave analysis using the events from the carbon target. Similar distributions have also been obtained for the other beam momenta of p=0.656, 0.748 and 800 MeV/c.

The dielectron analysis is in progress and preliminary results show almost 600 signal pairs with a mass M>140 MeV/c^2 [10]. The ongoing detailed analysis of the dielectron mass and angular distributions in relation with the two pion data will be crucial for the estimation of off-shell ρ meson production.

References

[1] K. Lapidus et al. (HADES Coll.), “Charged kaon production in pion-nucleus reactions at 1.7 GeV/c”.
[2] R. Rapp, J. Wambach, Adv. Nucl. Phys. A 25 (2000).
[3] G. Agakishiev et al. (HADES Coll.), Phys. Lett. B 715 (2012) 304.
[4] J. Weil et al., Eur. Phys. J. A 48 (2012) 111.
[5] A. Anisovich et al., Eur.Phys.J. A48 (2012) 15.
[6] M. Shrestha and D. Manley, Phys.Rev. C86 (2012) 055203.
[7] T. Vrana, S. Dytman, and T. Lee, Phys.Rept. 328, 181 (2000).
[8] J. Wirth et al. (HADES Coll.) this report.
[9] J. Pietraszko et al. (HADES Coll.), this report.
[10] F. Scozzi et al. (HADES Coll.) this report.

DOI:10.15120/GR-2015-1-MU-NQM-HADES-16