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Di-electron production in $d - p$ collisions at E_{kin} =2.5 GeV

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Abstract.
Identification of dielectron pair production in the exclusive npe^+e^- final state from quasi-free $n - p$ interactions using deuterium beams on proton target at kinetic beam energy of 1.25 GeV/u with the HADES spectrometer is presented. Comparison of the dielectron invariant mass distribution to the one measured in the $p - p$ reaction shows a prominent enhancement in the high-mass region.

1 Introduction

The main motivation of this work is to study dielectron production from non-mesonic sources in neutron-proton collisions below the η meson production threshold. According to various microscopic calculation in [1, 2] a dominant process leading to the emission of a virtual photon with a mass larger than the pion mass is bremsstrahlung. The understanding of this process is important for the description of the pair production in heavy ion reactions at these energies and also offers a possibility to study electromagnetic form-factors of nucleon in so called "unphysical" region as described in [3]. Studies of the exclusive channel presented in this work extends former investigations of the inclusive pair production published in [4]. A dedicated experimental run was performed with the High Acceptance Di-Electron Spectrometer (HADES) in [5] placed at the GSI Helmholtzzentrum fur Schwerionenforschung, Germany. Deuteron beams of 10^7 particles/s with kinetic energies of 1.25 GeV/u were incident on a liquid hydrogen target cell with a total length of 5 cm, corresponding to a total thickness of 0.35 g/cm^2. Quasi-free $n-p$ reactions were selected on trigger level by detection of fast spectator protons from the deuterium break-up in a dedicated Forward hodoscope Wall (FW) described in [5]. It was placed 7 m downstream of the target and covered polar angles between 0.3^o and 7^o. Charged particles ($p, \pi^{\pm}, e^{\pm}$) were detected in the spectrometer as described in [6].

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2 Analysis

Electron identification, track reconstruction, and electron pair (unlike- and like-sign) reconstruction were performed as described in detail in [4–6]. The combinatorial background (CB) was estimated as a function of the pair invariant mass using like sign pairs reconstructed in the same event as follows:

$$\frac{dN_{CB}}{dM_{e^+e^-}} = 2 * \sqrt{\frac{dN}{dM_{e^+e^+}} + \frac{dN}{dM_{e^-e^-}}} \tag{1}$$

This method accounts as well for correlated background from a double conversion of photons from π^0 decay in 2 photons or conversion of a photon accompanied by a pair from the π^0 Dalitz decay as for uncorrelated e^+e^- stemming from multi-pion decays. The signal distribution is then obtained as the difference between unlike sign pairs and CB distributions.

In order to normalize the measured yields, $p - p$ elastic scattering from the quasi-free scattering $d + p \rightarrow ppn_{spec}$ were measured during the experimental run. Since the differential cross section of the proton-proton scattering is well known from the EDDA experiment presented in [7], the measured pair yield can be converted to cross sections.

The exclusive npe^+e^- channel was selected by identification of the proton spectator particle in the FW and a proton-, an electron- and a positron-tracks inside inside the HADES spectrometer acceptance. Finally, the neutron was reconstructed using missing mass technique.

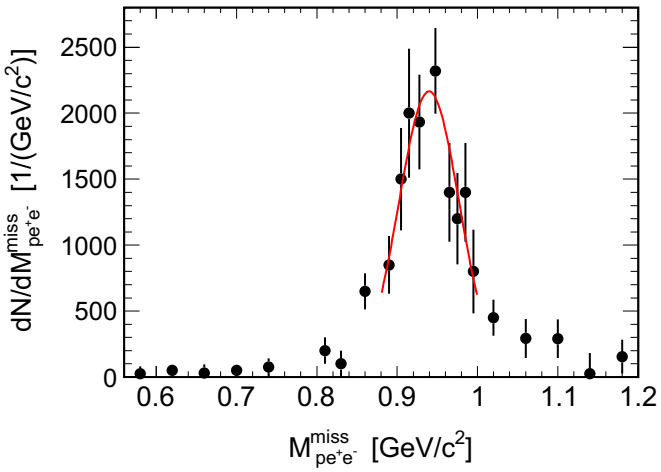

Figure 1. Missing mass distributions for the p, e^+e^- events, with dielectron mass larger than 150 MeV/c^2. The experimental data distribution (black dots) was fitted with a Gaussian distribution (red line).

In Fig. 1 the pe^+e^- missing mass for the dielectron pairs with invariant mass larger than the pion mass and pair opening angle $\alpha > 9^o$ is shown. The obtained distribution shows a clear peak with a mean value of 0.944(3) GeV/c^2 and a sigma of 0.037(4) GeV/c^2 , as expected from simulations. This result shows that the selected events originate dominantly from the $np \rightarrow npe^+e^-$ exclusive process. It is important to stress that the observed width of the distribution is in agreement with the expected combined effect of the experimental resolution and of the momentum smearing of the neutron inside the deuterium.

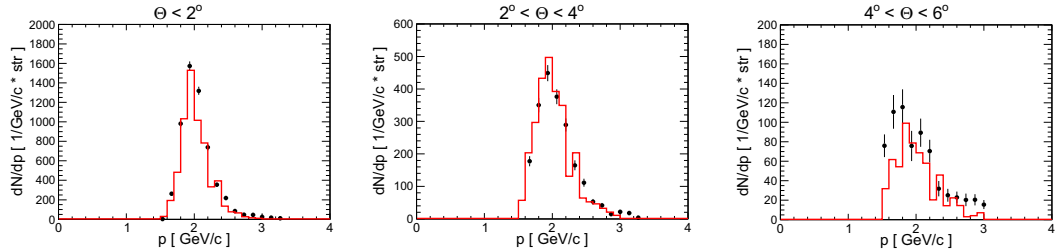

Figure 2. Momentum distributions of the spectator measured by time of flight in FW. Experimental data (black dots) are compared to the simulation (red solid line) for the indicated emission angles and dielectron pairs with $M_{ee} < 0.14$ GeV/c^2. Simulated spectra are scaled to the same global experimental yield.

In Fig. 2 momentum distributions of the proton spectator, determined by the time of flight in FW, for three spectator emission angles and dielectron pairs with $M_{e^+e^-} < 0.14$ GeV/c^2 is presented, where π^0 Dalitz decay is the dominant process. Although, the finite time resolution of the FW (500 ps) dominates the measured width, a broadening of the distributions for larger angles is visible, and is in agreement with the dedicated Monte Carlo simulation performed with the PLUTO event generator described in [8]. The event generator assumes a spectator model with a realistic neutron momentum distribution. For the dielectron production, π^0 Dalitz decay has been simulated, details are described in [9].

Finally in Fig. 3 the distribution of the e^+e^- invariant mass for npe^+e^- events is presented, CB has been subtracted. The signal to CB ratio in the interesting mass region (larger than the pion mass) is better than 10. The distribution is compared to the one measured in the $p-p$ (exclusive $pp \to ppe^+e^-$ reaction) collisions at the same energy, normalized to the same yield in the π^0 region. As one can clearly see, the distribution measured in the $n-p$ reactions has a very different shape, with an apparent excess in the high mass region. The obtained experimental data will be compared to the recent models of Shyam and Model in [2] and Clement and Bashkanov proposed for inclusive data in [10].

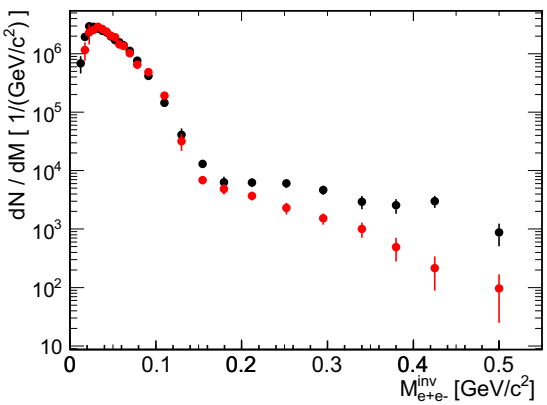

Figure 3. Number of counts as a function of the di- electron invariant mass for the npe^+e^- events measured in quasi-free $n-p$ collisions (black) compared with a similar spectrum obtained for $p-p$ collisions (red).

3 Conclusions

The exclusive pne^+e^- final state in the $d - p$ collisions at beam energy of 1.25 GeV/u has been identified. In particular, it has been demonstrated that the dielectron pairs with a mass larger than the pion mass can be assigned uniquely to the exclusive final state. These pairs show different mass dependence as compared to the one measured in $p - p$ reactions at the same energy. Hence, the measured distributions can be compared to the recent model predictions to identify the underlying process . Furthermore, it was verified that the spectator model applied for $d - p$ reaction describes the shape of the proton spectator momentum distributions for the $M_{ee} < 0.14$ GeV/c^2 very well.

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References

[1] L.P. Kaptari and B.Kampfer. Nucl. Phys. A **764** 338-370 (2006)
[2] U. Mosel, Annu. Rev. Nucle. Part. Sci **41** 29 (1991)
[3] G. Eichmann Acta Phys. Pol. B Proc. Suppl. **7** 597-606 (2014)
[4] G. Agakichiev *et al.*, Phys. Lett. B **690** 118-122 (2010)
[5] G. Agakichiev *et al.*, Eur. Phys. J. A **41** 243 (2009)
[6] K. Lapidus *et al.*, arXiv:0904.1128 [nucl-ex].
[7] M. Altmeier *et al.*, Eur. Phys. J. A **23**, 351-364 (2005)
[8] I. Froelich *et al.*, J. Phys. Conf. Ser. **219**, 032039 (2010)
[9] I. Frohlich *et al.*, Eur. Phys. J. A **45**, 401-411 (2010)
[10] M. Bashkanov, H. Clement, Eur. Phys. J. A **50**, 107 (2014)