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Study of dielectron production in C + C collisions at 1 *A* GeV

HADES Collaboration

G. Agakishiev [h], C. Agodi [a], H. Alvarez-Pol [o], A. Balanda [c,u], R. Bassini [i], G. Bellia [a,q], D. Belver [o], A. Belyaev [f], A. Blanco [b], M. Böhmer [k], A. Bortolotti [i], J.L. Boyard [m], P. Braun-Munzinger [d], P. Cabanelas [o], E. Castro [o], S. Chernenko [f], T. Christ [k], M. Destefanis [h], J. Díaz [p], F. Dohrmann [e], A. Dybczak [c], T. Eberl [k], L. Fabbietti [k], O. Fateev [f], P. Finocchiaro [a], P. Fonte [b,r], J. Friese [k], I. Fröhlich [g], T. Galatyuk [d], J.A. Garzón [o], R. Gernhäuser [k], A. Gil [p], C. Gilardi [h], M. Golubeva [j], D. González-Díaz [d], E. Grosse [e,s], F. Guber [j], M. Heilmann [g], T. Heinz [d], T. Hennino [m], R. Holzmann [d,*], A. Ierusalimov [f], I. Iori [i,t], A. Ivashkin [j], M. Jurkovic [k], B. Kämpfer [e], M. Kajetanowicz [c], K. Kanaki [e], T. Karavicheva [j], D. Kirschner [h], I. Koenig [d], W. Koenig [d], B.W. Kolb [d], R. Kotte [e], A. Kozuch [c,u], A. Krása [n], F. Krizek [n], R. Krücken [k], W. Kühn [h], A. Kugler [n], A. Kurepin [j], J. Lamas-Valverde [o], S. Lang [d], J.S. Lange [h], K. Lapidus [j], L. Lopes [b], L. Maier [k], A. Mangiarotti [b], J. Marín [o], J. Markert [g], V. Metag [h], B. Michalska [c], D. Mishra [h], E. Morinière [m], J. Mousa [l], M. Münch [d], C. Müntz [g], L. Naumann [e], R. Novotny [h], J. Otwinowski [c], Y.C. Pachmayer [g], M. Palka [d], Y. Parpottas [l], V. Pechenov [h], O. Pechenova [h], T. Pérez Cavalcanti [h], J. Pietraszko [d], R. Pleskac [n], V. Pospísil [n], W. Przygoda [c,u], B. Ramstein [m], A. Reshetin [j], M. Roy-Stephan [m], A. Rustamov [d], A. Sadovsky [j], B. Sailer [k], P. Salabura [c], A. Schmah [d], C. Schroeder [d], E. Schwab [d], R.S. Simon [d], Yu.G. Sobolev [n], S. Spataro [h], B. Spruck [h], H. Ströbele [g], J. Stroth [g,d], C. Sturm [g], M. Sudol [d], A. Tarantola [g], K. Teilab [g], P. Tlusty [n], A. Toia [h], M. Traxler [d], R. Trebacz [c], H. Tsertos [l], I. Veretenkin [j], V. Wagner [n], M. Weber [k], H. Wen [h], M. Wisniowski [c], T. Wojcik [c], J. Wüstenfeld [e], S. Yurevich [d], Y. Zanevsky [f], P. Zhou [e], P. Zumbruch [d]

[a] *Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud, 95125 Catania, Italy*
[b] *LIP-Laboratório de Instrumentação e Física Experimental de Partículas, 3004-516 Coimbra, Portugal*
[c] *Smoluchowski Institute of Physics, Jagiellonian University of Cracow, 30-059 Kraków, Poland*
[d] *Gesellschaft für Schwerionenforschung mbH, 64291 Darmstadt, Germany*
[e] *Institut für Strahlenphysik, Forschungszentrum Dresden–Rossendorf, 01314 Dresden, Germany*
[f] *Joint Institute of Nuclear Research, 141980 Dubna, Russia*
[g] *Institut für Kernphysik, Johann Wolfgang Goethe-Universität, 60438 Frankfurt, Germany*
[h] *II.Physikalisches Institut, Justus Liebig Universität Giessen, 35392 Giessen, Germany*
[i] *Istituto Nazionale di Fisica Nucleare, Sezione di Milano, 20133 Milano, Italy*
[j] *Institute for Nuclear Research, Russian Academy of Science, 117312 Moscow, Russia*
[k] *Physik Department E12, Technische Universität München, 85748 München, Germany*
[l] *Department of Physics, University of Cyprus, 1678 Nicosia, Cyprus*
[m] *Institut de Physique Nucléaire (UMR 8608), CNRS/IN2P3 – UniversitT Paris Sud, F-91406 Orsay cedex, France*
[n] *Nuclear Physics Institute, Academy of Sciences of Czech Republic, 25068 Rez, Czech Republic*
[o] *Departamento de Física de Partículas, University of Santiago de Compostela, 15782 Santiago de Compostela, Spain*
[p] *Instituto de Física Corpuscular, Universidad de Valencia-CSIC, 46971 Valencia, Spain*
[q] *Also at Dipartimento di Fisica e Astronomia, Università di Catania, 95125 Catania, Italy*
[r] *Also at ISEC Coimbra, Coimbra, Portugal*
[s] *Also at Technische Universität Dresden, 01062 Dresden, Germany*
[t] *Also at Dipartimento di Fisica, Università di Milano, 20133 Milano, Italy*
[u] *Also at Panstwowa Wyzsza Szkola Zawodowa, 33-300 Nowy Sacz, Poland*

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ABSTRACT

The emission of e^+e^- pairs from C + C collisions at an incident energy of 1 GeV per nucleon has been investigated. The measured production probabilities, spanning from the π^0-Dalitz to the ρ/ω invariant-mass region, display a strong excess above the cocktail of standard hadronic sources. The bombarding-energy dependence of this excess is found to scale like pion production, rather than like eta production. The data are in good agreement with results obtained in the former DLS experiment.

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1. Introduction

An enhanced yield of dileptons with masses below the vector-meson (i.e. ρ^0 and ω meson) pole mass appears to be a general feature of heavy-ion reactions, from bombarding energies as low as 1 *A* GeV, studied by the former DLS experiment [1] at the Bevalac, through the range of SPS energies (40–158 *A* GeV) used by the CERES [2] and NA60 [3] experiments at CERN, up to the highest energies (with $\sqrt{s_{NN}} = 200$ GeV) employed by the PHENIX experiment [4] at the RHIC collider. This enhancement is defined as the excess of the measured pair yield over the summed-up cocktail of dileptons from long-lived sources, namely the decays of π^0, η, and ω mesons. It is hence expected to probe the early phase of the collision and, in particular, the in-medium behavior of short-lived hadronic resonances, as e.g. the ρ and Δ [5–7]. However, while the dilepton enhancement observed at the SPS has been related to modifications of the ρ-meson spectral function in the hadronic medium [8,9], the large pair yields found by DLS in 1 *A* GeV C + C and Ca + Ca collisions remain to be explained satisfactorily [10–13].

The High-Acceptance DiElectron Spectrometer HADES at GSI, Darmstadt, has started a systematic investigation of dilepton production in the SIS/Bevalac energy regime of 1–2 *A* GeV. First results obtained in 2 *A* GeV C + C collisions [14] confirmed indeed the general observation of enhanced emission of e^+e^- pairs with invariant masses of 0.15–0.50 GeV/c^2. In this Letter we report on a measurement of inclusive electron-pair emission from ^{12}C + ^{nat}C collisions at a kinetic beam energy of 1 *A* GeV, i.e. the energy of the DLS experiment. Together with our results obtained at 2 *A* GeV, this allows to discuss the beam-energy dependence of the pair yield. In addition, a direct comparison with the DLS results [1] becomes now possible.

2. Experiment

In the experiment, a ^{12}C beam of 10^6 particles/s was incident on a target of natural carbon with a thickness corresponding to 4.6% of one nuclear interaction length. The configuration of the HADES spectrometer, described in detail in Refs. [15,16], was basically identical to the one used in our former 2 *A* GeV C + C run [14]. To increase the acquired pair statistics, besides a charged-particle multiplicity trigger (LVL1), an online electron identification (LVL2) has been operated as part of the two-level trigger system [14]. All results presented here were obtained from events with a positive LVL2 trigger decision, with a total statistics corresponding to 1.1×10^9 LVL1 triggered events. One major difference to the former run was the presence of up to four planes of tracking drift chambers (two inner and one or two outer), of which, however, only the two inner planes were used in the extraction of the results presented here. This modus operandi was motivated by the goal to simplify any comparison with the results of our 2 *A* GeV run obtained within a low-resolution mode. In the latter the reconstruction of outer track segments is based solely on the position information obtained from the Time-of-Flight and Pre-Shower detectors (see [14] for details). The lepton identification and dilepton-reconstruction were done following the same scheme as used for the 2 *A* GeV data. All this resulted in a momentum and mass resolution, as well as a pair acceptance very similar to those characteristic of the former run, making the comparison of the two data sets unproblematic. As will become apparent below, the achieved mass resolution of $\sigma_{M_{ee}}/M_{ee} = 9\%$ at $M_{ee} = 0.8$ GeV/c^2 is largely sufficient to resolve all spectral features. Results from a high-resolution analysis based on all four drift-chamber planes will, however, be presented in another, forthcoming publication.

In the pair analysis [17], opposite-sign e^+e^-, as well as like-sign e^+e^+ and e^-e^- pairs were formed and subjected to common selection criteria, in particular to an opening-angle cut of $\theta_{ee} > 9°$. From the reconstructed like-sign distributions, e.g. the invariant mass dN^{++}/dM_{ee} and dN^{--}/dM_{ee}, the combinatorial background (CB) of uncorrelated pairs was calculated bin by bin as $N_{CB} = 2\sqrt{N^{++}N^{--}}$. For masses $M_{ee} > 0.2$ GeV/c^2, where statistics is small, the CB was obtained by an event-mixing procedure. Finally, after subtracting the CB, a total of $\simeq 18\,000$ signal pairs ($\simeq 650$ with $M_{ee} > 0.15$ GeV/c^2) were thus reconstructed.

Detector and reconstruction efficiencies $\epsilon_{\pm}(p,\theta,\phi)$ were determined from Monte Carlo simulations by embedding electron and positron tracks into ^{12}C + ^{12}C events generated with the UrQMD transport model [18]. The experimental data were then corrected on a pair-by-pair basis with the weighting factor $1/E_{+-}$, with $E_{+-} = \epsilon_+ \cdot \epsilon_-$. The geometrical pair acceptance of the HADES detector was obtained in analogy to the pair efficiency as the product of two single-electron acceptances $A_{\pm}(p,\theta,\phi)$. The resulting matrices, together with a momentum resolution function, constitute the HADES acceptance filter (for more details see [14]). These acceptance matrices are available from the authors on request.

3. Results on pair production

Fig. 1(a) shows the e^+e^- invariant-mass distribution of the signal pairs after efficiency correction and normalized to the average number of charged pions $N_\pi = \frac{1}{2}(N_{\pi^+} + N_{\pi^-})$, measured as well with HADES and extrapolated to 4π solid angle. In the isospin-symmetric system ^{12}C + ^{12}C, and for small contributions from η and ω decays, N_π is also a good measure of the π^0 yield, i.e. $N_\pi = N_{\pi^0}$. This way of normalizing the pair spectra compensates to first order the bias caused by the implicit centrality selection of our trigger. Indeed, simulations based on UrQMD events show that LVL1 events have an average number of participating nucleons $A_{part} = 8.6$, instead of 6 for true minimum-bias events. The pion multiplicity per number of participating nucleons $M_\pi/A_{part} = 0.061 \pm 0.009$ obtained in our experiment agrees with previous measurements of charged and neutral pions [19,20] within the quoted error of 15%. The latter is dominated by systematic uncertainties in the acceptance and efficiency corrections of the charged-pion analysis, and it represents our overall normalization error. In addition, the uncertainties caused by the lepton-efficiency correction and the CB subtraction add up quadratically to point-to-point systematic errors of 22% on dN^{+-}/dM_{ee}.

* Corresponding author.
E-mail address: r.holzmann@gsi.de (R. Holzmann).