

## The $dp$ -elastic cross section measurement at the deuteron kinetic energy of 2.5 GeV

P. Kurilkin<sup>6,a</sup>, G. Agakishiev<sup>6</sup>, C. Behnke<sup>7</sup>, D. Belver<sup>16</sup>, A. Belyaev<sup>6</sup>, J.C. Berger-Chen<sup>8</sup>, A. Blanco<sup>1</sup>, C. Blume<sup>7</sup>, M. Böhmer<sup>9</sup>, P. Cabanelas<sup>16</sup>, S. Chernenko<sup>6</sup>, C. Drita<sup>10</sup>, A. Dybczak<sup>2</sup>, E. Epple<sup>8</sup>, L. Fabbietti<sup>8</sup>, O. Fateev<sup>6</sup>, P. Fonte<sup>1,a</sup>, J. Friese<sup>9</sup>, I. Fröhlich<sup>7</sup>, T. Galatyuk<sup>4,b</sup>, J. A. Garzón<sup>16</sup>, K. Gill<sup>7</sup>, M. Golubeva<sup>11</sup>, D. González-Díaz<sup>4</sup>, F. Guber<sup>11</sup>, M. Gumberidze<sup>14</sup>, S. Harabasz<sup>4</sup>, T. Hennino<sup>14</sup>, R. Holzmann<sup>3</sup>, P. Huck<sup>9</sup>, C. Höhne<sup>10</sup>, A. Ierusalimov<sup>6</sup>, A. Ivashkin<sup>11</sup>, M. Jurkovic<sup>9</sup>, B. Kämpfer<sup>5,c</sup>, T. Karavicheva<sup>11</sup>, I. Koenig<sup>3</sup>, W. Koenig<sup>3</sup>, B. W. Kolb<sup>3</sup>, G. Korcyl<sup>2</sup>, G. Kornakov<sup>16</sup>, R. Kotte<sup>5</sup>, A. Krása<sup>15</sup>, E. Krebs<sup>7</sup>, F. Krizek<sup>15</sup>, H. Kuc<sup>2,14</sup>, A. Kugler<sup>15</sup>, A. Kurepin<sup>11</sup>, A. Kurilkin<sup>6</sup>, V. Ladygin<sup>6</sup>, R. Lalik<sup>8</sup>, S. Lang<sup>3</sup>, K. Lapidus<sup>8</sup>, A. Lebedev<sup>12</sup>, L. Lopes<sup>1</sup>, M. Lorenz<sup>7</sup>, L. Maier<sup>9</sup>, A. Mangiarotti<sup>1</sup>, J. Markert<sup>7</sup>, V. Metag<sup>10</sup>, J. Michel<sup>7</sup>, C. Müntz<sup>7</sup>, R. Münzer<sup>8</sup>, L. Naumann<sup>5</sup>, M. Palka<sup>2</sup>, Y. Parpottas<sup>13,d</sup>, V. Pechenov<sup>3</sup>, O. Pechenova<sup>7</sup>, J. Pietraszko<sup>7</sup>, W. Przygoda<sup>2</sup>, B. Ramstein<sup>14</sup>, L. Rehnisch<sup>7</sup>, A. Reshetin<sup>11</sup>, A. Rustamov<sup>7</sup>, A. Sadovsky<sup>11</sup>, P. Salabura<sup>2</sup>, T. Scheib<sup>7</sup>, H. Schuldes<sup>7</sup>, J. Siebensohn<sup>8</sup>, Yu.G. Sobolev<sup>15</sup>, S. Spataro<sup>e</sup>, H. Ströbele<sup>7</sup>, J. Stroth<sup>7,3</sup>, P. Strzempek<sup>2</sup>, C. Sturm<sup>3</sup>, O. Svoboda<sup>15</sup>, A. Tarantola<sup>7</sup>, K. Teilab<sup>7</sup>, P. Tlusty<sup>15</sup>, M. Traxler<sup>3</sup>, H. Tsertos<sup>13</sup>, T. Vasiliev<sup>6</sup>, V. Wagner<sup>15</sup>, M. Weber<sup>9</sup>, C. Wendisch<sup>5,c</sup>, J. Wüstenfeld<sup>5</sup>, S. Yurevich<sup>3</sup>, and Y. Zanevsky<sup>6</sup> (HADES Collaboration)

<sup>1</sup>LIP-Laboratório de Instrumentação e Física Experimental de Partículas, 3004-516 Coimbra, Portugal

<sup>2</sup>Smoluchowski Institute of Physics, Jagiellonian University of Cracow, 30-059 Kraków, Poland

<sup>3</sup>GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany

<sup>4</sup>Technische Universität Darmstadt, 64289 Darmstadt, Germany

<sup>5</sup>Institut für Strahlenphysik, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany

<sup>6</sup>Joint Institute of Nuclear Research, 141980 Dubna, Russia

<sup>7</sup>Institut für Kernphysik, Goethe-Universität, 60438 Frankfurt, Germany

<sup>8</sup>Excellence Cluster 'Origin and Structure of the Universe', 85748 Garching, Germany

<sup>9</sup>Physik Department E12, Technische Universität München, 85748 Garching, Germany

<sup>10</sup>II.Physikalisches Institut, Justus Liebig Universität Giessen, 35392 Giessen, Germany

<sup>11</sup>Institute for Nuclear Research, Russian Academy of Science, 117312 Moscow, Russia

<sup>12</sup>Institute of Theoretical and Experimental Physics, 117218 Moscow, Russia

<sup>13</sup>Department of Physics, University of Cyprus, 1678 Nicosia, Cyprus

<sup>14</sup>Institut de Physique Nucléaire (UMR 8608), CNRS/IN2P3 - Université Paris Sud, F-91406 Orsay

<sup>15</sup>Nuclear Physics Institute, Academy of Sciences of Czech Republic, 25068 Rez, Czech Republic  
Cedex, France

<sup>16</sup>LabCAF. Dpto. Física de Partículas, Univ. de Santiago de Compostela, 15706 Santiago de Compostela, Spain

<sup>a</sup>Also at ISEC Coimbra, Coimbra, Portugal

<sup>b</sup>Also at ExtreMe Matter Institute EMMI, 64291 Darmstadt, Germany

<sup>c</sup>Also at Technische Universität Dresden, 01062 Dresden, Germany

<sup>d</sup>Also at Frederick University, 1036 Nicosia, Cyprus

<sup>e</sup>Also at Dipartimento di Fisica Generale and INFN, Università di Torino, 10125 Torino, Italy

**Abstract.** New results on the differential cross section in deuteron-proton elastic scattering are obtained at the deuteron kinetic energy of 2.5 GeV with the HADES spectrometer. The angular range of  $69^\circ - 125^\circ$  in the center of mass system is covered. The obtained results are compared with the relativistic multiple scattering model calculation using the

CD-Bonn deuteron wave function. The data at fixed scattering angles in the c.m. are in qualitative agreement with the constituent counting rules prediction.

## 1 Introduction

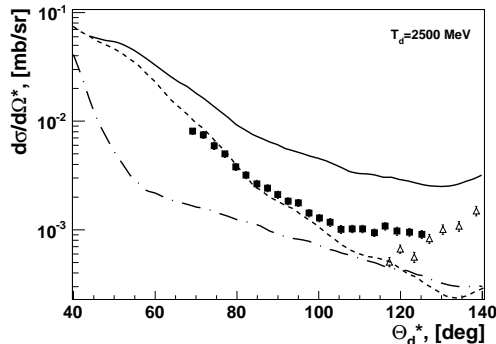
The study of deuteron-proton interaction, in particular at intermediate and high energies, solves the problem of deuteron internal structure and nucleon-nucleon interaction at small distances. Already at the energies of 0.25 GeV the Faddeev calculation cannot reproduce the  $dp$ -elastic cross section data at the large angles in the c.m. [1]. On the other hand, the relativistic multiple scattering model describes well the data on  $dp$ -elastic scattering at 0.88 GeV up to  $110^\circ$  [2]. At high energies and large transverse momenta the constituent counting rules (CCR) [3,4] predict a  $1/s^{n-2}$  dependence of the differential cross section for the binary reaction, where  $n$  is the total number of the fundamental constituents involved in the reaction. A regime corresponding to CCR can occur already at  $T_d = 500$  MeV [5]. In this paper we present new experimental data on the differential cross section for  $dp$ -elastic scattering at a deuteron beam kinetic energy of 2.5 GeV obtained with the HADES spectrometer [6].

## 2 Results and discussion

### 2.1 Experiment

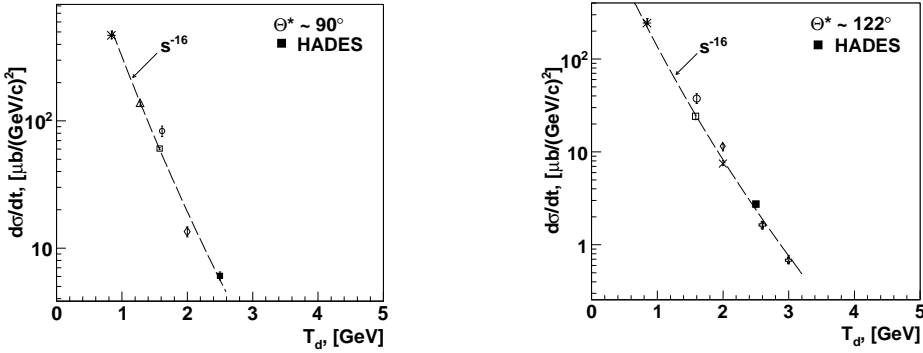
HADES (High Acceptance Di-Electron Spectrometer) is located at GSI, Darmstadt and it is currently operated at the SIS18 synchrotron at beam energies of 1 – 2 GeV/u. It is a magnetic spectrometer which is capable to register  $e + /e -$  particles in a polar angle ranges from  $18^\circ$  up to  $85^\circ$  and has almost full azimuthal coverage. Technical aspects of the detector are described in [6].

In the experiment presented the deuteron beam with a kinetic energy of  $T_d = 2.5$  GeV and an intensity of about  $10^7$  particles/s was directed onto a 5 cm long liquid-hydrogen cell with a total areal thickness of  $0.35g/cm^2$ . In order to investigate the  $np$  interaction using the deuteron beam the HADES setup was upgraded with a Forward Fall(FW) scintillator hodoscope.



**Fig. 1.** The  $dp$ -elastic cross section data compared with the relativistic multiple scattering model calculation at 2.5 GeV. The HADES results are shown by the black squares. World  $pd$ -elastic scattering data at 1.3 GeV/nucleon [9] are presented by the open triangles. The curves are described in the text.

<sup>a</sup> e-mail: pkurilkin@jinr.ru



**Fig. 2.** Differential cross section of  $dp$ -elastic scattering at fixed scattering angle of  $90^\circ$  and  $122^\circ$  in c.m.s The HADES results are presented by the full square. The world data are marked by the open symbols. The curves are the predictions of constituent counting rules.

## 2.2 Results

Fig. 1 shows the result on the angular dependence of the  $dp$ -elastic cross section at  $T_d = 2.5$  GeV compared with the relativistic multiple scattering model calculations [2, 7] using CD-Bonn deuteron wave function [8]. The dashed line corresponds to the calculations taking into account single scattering contributions only. The solid and dash-dotted curves are the results of calculation including the single and double scattering term with and without the principal value part of the three-nucleon free propagator, respectively. The deviations in the description of the angular dependence of the  $dp$ -elastic cross section data and theoretical calculations [2, 7] are observed. The results of the calculation taking into account only the single scattering term underestimate the cross section data, while including the double scattering leads to the experimental data overestimation. World  $pd$ -elastic scattering data at 1.3 GeV/nucleon [9] are presented by the open triangles.

The results on the differential cross section in  $dp$ -elastic scattering obtained at 2.5 GeV and fixed scattering angles in the c.m. are presented in Fig. 2. The HADES data are depicted by the full square. The world data [9–13] are shown by the open symbols and stars. The lines are the result of the fitting of the world data by the function  $\sim s^{-16}$ . The data at fixed scattering angles in the c.m. are in a qualitative agreement with the constituent counting rules prediction.

## Acknowledgements

We thank Dr. N.B. Ladygina for providing us the calculations within the relativistic multiple scattering model and useful discussions.

## References

1. K. Hatanaka *et al.*, Phys. Rev. C **66**, (2002) 044002
2. N.B. Ladygina, Eur. Phys. J, **A42**, (2009) 91
3. S.J. Brodsky, G.R. Farrar, Phys. Rev. Lett. **31**, (1973) 1153
4. V.A. Matveev, R.M. Muradyan and A.N. Tavkhelidze, Lett. Nuovo Cimento **7**, (1973) 719
5. Yu.N. Uzikov, JETP Lett. **81**, (2005) 387
6. G. Agakishiev *et al.*, Eur. Phys. J. **A41**, (2009) 243
7. N.B. Ladygina, Phys. Atom. Nucl. **71**, (2008) 2039
8. R. Machleidt, Phys. Rev. **C63**, (2001) 024001

9. E. Coleman *et al.*, Phys. Rev. Lett. **16**, (1966) 761
10. E. Winkelman *et al.*, Phys. Rev. C **21**, (1980) 2535
11. G. W. Bennet *et al.*, Phys. Rev. Lett. **19**, (1967) 387
12. N. E. Both *et al.*, Phys. Rev. D **4**, (1971) 1261
13. E. Gulmez *et al.*, Phys. Rev. C **5**, (1991) 2067