# STUDY OF THE NN$\eta'$ PRODUCTION WITH COSY-11*

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We describe a new high precision measurement of the production cross section for the $\eta'$ meson in proton–proton collisions $\sigma_{pp\to pp\eta'}$ for five beam momenta at low access energy region $Q$ conducted at the COSY-11 detection system together with an updated results of all other previous measurements of $\sigma_{pp\to pp\eta'}$ at COSY-11.

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## 1. Introduction

Recently, the increased interest in the properties of the $\eta$ and $\eta'$ meson can be observed due to extensive experimental search of the $\eta$ and $\eta'$ bound states performed *e.g.* at COSY [1–6], ELSA [7], GSI [8, 9], JINR [10], JPARC [11, 12], LPI [13], and MAMI [14, 15] as well as intensive theoretical investigations *e.g.* [16–28].

Properties of $\eta'$ in nuclear medium are related with the effects of $\mathrm{U_A}(1)$ anomaly at finite density [17, 19, 20, 29], which is reflected in the large mass of the $\eta'$ meson compared to the masses of the other members of the pseudoscalar meson nonet [30, 31], and with the $\eta$–$\eta'$ mixing [19, 32].

COSY-11 experiment [33, 34] has provided already an important data for these studies [35–38], with the most precise direct measurement of the total width of the $\eta'$ meson $\Gamma_{\eta'}$ [39, 40], and the first rough estimation of the $\eta'$–$N$ interaction from the excitation function of the cross section for the $pp \to pp\eta'$ reaction [41]. Here, we describe an analysis of the data used

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earlier for $\Gamma_{\eta'}$ determination in view of the extraction of the production cross section for the $\eta'$ meson $\sigma_{pp\to pp\eta'}$ in proton–proton collisions and an update of the $\sigma_{pp\to pp\eta'}$ values presented previously [35–37].

## 2. Experiment

In the reported measurement, the $\eta'$ meson was produced in proton–proton collisions reaction and its mass was reconstructed based on the momentum vectors of protons taking part in the $pp \to pp\eta'$ reaction which was measured at five different beam momenta using the COSY-11 detector setup [33, 34] installed at the Cooler Synchrotron COSY [42] in Research Centre Jülich. The schematic view of the COSY-11 detector setup is presented in Fig. 1.

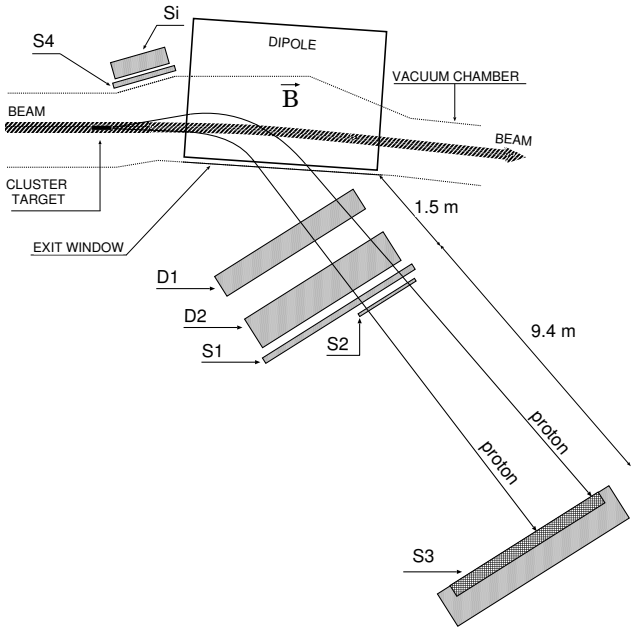


Fig. 1. Schematic view of the COSY-11 detector setup (top view). S1, S2, S3 and S4 denote scintillator detectors, D1 and D2 indicate drift chambers and Si stands for the silicon-pad detector.

The collision of a proton from the beam with a proton cluster target may cause an $\eta'$-meson creation. In that case, all outgoing nucleons have been registered by the COSY-11 detectors, whereas for the $\eta'$-meson identification the missing mass technique was applied. The COSY beam momentum and the dedicated zero degree COSY-11 facility enabled the measurement at an excess energy down the fraction of an MeV above the kinematic threshold

for the $\eta'$-meson production. Modification of the COSY-11 target system allowed to decrease effective beam momentum spread and, therefore, enabled precise determination of the access energy $Q$ with the precision of 0.10 MeV. Good control of the systematic uncertainties was possible due to measurement performed at five different values of $Q$ and monitoring of the beam and target properties [43]. On the other hand, the achieved missing mass resolution in the order of the total width of the $\eta'$ meson itself [40] improved significantly the $\eta'$ production cross section measurement. The number of registered $\eta'$ mesons was obtained from the missing mass spectra for each $Q$ value and corrected for the detector geometrical acceptance and registration efficiency. The luminosity value was determined using comparison of the cross section of $pp \to pp$ reaction determined by the EDDA Collaboration [44] and the number of registered elastically scattered protons.

## 3. Results

Since $\sigma_{pp\to pp\eta'}$ measured at COSY-11 was obtained with the luminosity determination based on the EDDA data available at that time [45], we updated these numbers accordingly to superseded data [44]. COSY-11 measurement at $Q = 16.4$ MeV [38] was already reported with new EDDA data [44], whereas SPESIII [46] and DISTO [47] used different techniques for luminosity determination. The experimental data presented at Fig. 2

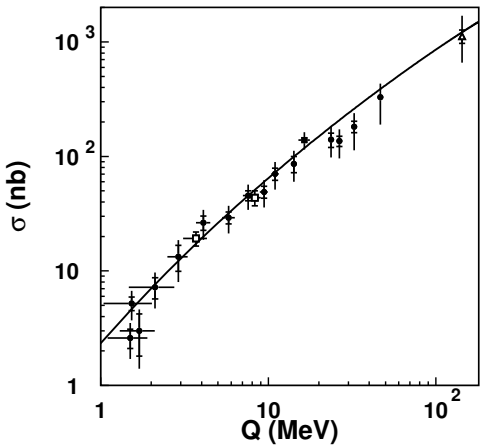


Fig. 2. Total cross section for the $\eta'$-meson production in the proton–proton collision as a function of the access energy $Q$ for the $pp \to pp\eta'$ reaction measured at: COSY-11 (solid circles — updated values of [35–37], solid square — measurement [38] with usage of EDDA 2004 data [44]), SPESIII (open squares) [46] and DISTO (open triangle) [47]. The solid line shows parametrization of the experimental data using formula (1).

are compared to the analytical parametrization derived by Fäldt and Wilkin [48, 49] which takes into account final state interaction of the protons

$$\sigma_{pp\to pp\eta'}(Q) = C\frac{Q^2}{m_p p_{\mathrm{LAB}}}\frac{1}{\left(1+\sqrt{1+\frac{Q}{\epsilon}}\right)^2}, \tag{1}$$

where $Q$ denotes the excess energy, $p_{\mathrm{LAB}}$ beam momentum, $m_p$ proton mass. The parameters $\epsilon = 0.75^{+0.20}_{-0.15}$ MeV and $C = 45^{+10}_{-9}$ mb denote the Coulomb distortion and constant factor, respectively, and have been determined by fitting this formula to the experimental data. Values of $pp \to pp\eta'$ cross sections determined at COSY-11 are gathered in Table I apart from the new measurement reported here, which is still in the final stage of the analysis.

TABLE I

Updated values of production cross sections for the $\eta'$ meson in proton–proton collisions measured at COSY-11 detector [35–38] with statistical and systematic uncertainties, respectively.

| $Q$ [MeV] | | | $\sigma_{pp\to pp\eta'}$ [nb] | | |
|---|---|---|---|---|---|
| 1.5 | ± | 0.4 | 2.6 | ± 0.5 | ± 0.4 |
| 1.53 | ± | 0.49 | 5.2 | ± 0.7 | ± 0.8 |
| 1.7 | ± | 0.4 | 3.0 | ± 1.2 | ± 0.5 |
| 2.11 | ± | 0.64 | 7.2 | ± 1.5 | ± 1.1 |
| 2.9 | ± | 0.4 | 13.3 | ± 3.4 | ± 2.0 |
| 4.1 | ± | 0.4 | 26.4 | ± 3.8 | ± 4.0 |
| 5.80 | ± | 0.50 | 29.2 | ± 3.5 | ± 4.4 |
| 7.57 | ± | 0.51 | 45.5 | ± 4.5 | ± 6.8 |
| 9.42 | ± | 0.53 | 49.0 | ± 5.9 | ± 7.4 |
| 10.98 | ± | 0.56 | 70.5 | ± 8.6 | ± 11 |
| 14.21 | ± | 0.57 | 86 | ± 14 | ± 13 |
| 16.4 | ± | 1.3 | 139 | ± 3 | ± 21 |
| 23.64 | ± | 0.64 | 146 | ± 20 | ± 22 |
| 26.5 | ± | 1.0 | 136 | ± 14 | $^{+22}_{-26}$ |
| 32.5 | ± | 1.0 | 182 | ± 21 | $^{+36}_{-48}$ |
| 46.6 | ± | 1.0 | 329 | ± 18 | $^{+85}_{-122}$ |

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## REFERENCES

[1] P. Moskal, J. Smyrski, *Acta Phys. Pol. B* **41**, 2281 (2010).
[2] M. Skurzok, P. Moskal, W. Krzemien, *Prog. Part. Nucl. Phys.* **67**, 445 (2012).
[3] P. Adlarson *et al.*, *Phys. Rev.* **C87**, 035204 (2013).
[4] A. Budzanowski *et al.*, *Phys. Rev.* **C79**, 012201 (2009).
[5] J. Smyrski *et al.*, *Phys. Lett.* **B649**, 258 (2007).
[6] T. Mersmann *et al.*, *Phys. Rev. Lett.* **98**, 242301 (2007).
[7] M. Nanova *et al.*, *Phys. Lett.* **B727**, 417 (2013).
[8] Y.K. Tanaka *et al.*, *Few Body Syst.* **54**, 1263 (2013).
[9] K. Itahashi *et al.*, *Prog. Theor. Phys.* **128**, 601 (2012).
[10] S.V. Afanasiev, *Phys. Part. Nucl. Lett.* **8**, 1073 (2011).
[11] H. Fujioka, *Acta Phys. Pol. B* **41**, 2261 (2010).
[12] H. Fujioka, K. Itahashi, *Hadron Nucl. Phys.* **09**, 150 (2010).
[13] V.A. Baskov *et al.*, *PoS* **Baldin-ISHEPP-XXI**, 102 (2012).
[14] B. Krusche *et al.*, *J. Phys. Conf. Ser.* **349**, 012003 (2012).
[15] F. Pheron *et al.*, *Phys. Lett.* **B709**, 21 (2012).
[16] C. Wilkin, *Phys. Lett.* **B654**, 92 (2007).
[17] S.D. Bass, A.W. Thomas, *Phys. Lett.* **B634**, 368 (2006).
[18] H. Nagahiro *et al.*, *Phys. Rev.* **C87**, 045201 (2013).
[19] S.D. Bass, A.W. Thomas, *Acta Phys. Pol. B* **45**, 627 (2014), this issue [arXiv:1311.7248 [hep-ph]].
[20] S. Hirenzaki *et al.*, *Acta Phys. Pol.* **B41**, 2211 (2010).
[21] H. Nagahiro, S. Hirenzaki, *Phys. Rev. Lett.* **94**, 232503 (2005).
[22] H. Nagahiro *et al.*, *Phys. Lett.* **B709**, 87 (2012).
[23] E. Friedman, A. Gal, J. Mares, *Phys. Lett.* **B725**, 334 (2013).
[24] A. Cieply *et al.*, arXiv:1312.1547 [nucl-th].
[25] S. Wycech, W. Krzemien, *Acta Phys. Pol. B* **45**, 745 (2014), this issue [arXiv:1401.0747 [nucl-th]].
[26] A.M. Green, S. Wycech, *Phys. Rev.* **C71**, 014001 (2005).
[27] N.G. Kelkar *et al.*, *Rep. Prog. Phys.* **76**, 066301 (2013).
[28] S.D. Bass *et al.*, *Acta Phys. Pol. B* **41**, 2239 (2010).
[29] H. Nagahiro *et al.*, *Phys. Rev.* **C87**, 045201 (2013).
[30] S. Klimt *et al.*, *Nucl. Phys.* **A516**, 429 (1990).

[31] D. Jido *et al.*, *Nucl. Phys.* **A914**, 344 (2013).
[32] H. Nagahiro, M. Takizawa, S. Hirenzaki, *Phys. Rev.* **C74**, 045203 (2006).
[33] S. Brauksiepe *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A376**, 397 (1996).
[34] P. Klaja *et al.*, *AIP Conf. Proc.* **796**, 160 (2005).
[35] P. Moskal *et al.*, *Phys. Rev. Lett.* **80**, 3202 (1998).
[36] P. Moskal *et al.*, *Phys. Lett.* **B474**, 416 (2000).
[37] A. Khoukaz *et al.*, *Eur. Phys. J.* **A20**, 345 (2004).
[38] P. Klaja *et al.*, *Phys. Lett.* **B684**, 11 (2010).
[39] E. Czerwiński, Ph.D. dissertation, Jagiellonian University, 2009, `arXiv:0909.2781 [nucl-ex]`.
[40] E. Czerwiński *et al.*, *Phys. Rev. Lett.* **105**, 122001 (2010).
[41] P. Moskal *et al.*, *Phys. Lett.* **B482**, 356 (2000).
[42] R. Maier *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A390**, 1 (1997).
[43] P. Moskal *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A466**, 448 (2001).
[44] D. Albers *et al.*, *Eur. Phys. J.* **A22**, 125 (2004).
[45] D. Albers *et al.*, *Phys. Rev. Lett.* **78**, 1652 (1997).
[46] F. Hibou *et al.*, *Phys. Lett.* **B438**, 41 (1998).
[47] F. Balestra *et al.*, *Phys. Lett.* **B491**, 29 (2000).
[48] G. Fäldt, C. Wilkin, *Phys. Lett.* **B382**, 209 (1996).
[49] G. Fäldt, C. Wilkin, *Phys. Rev.* **C56**, 2067 (1997).