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 $\sigma_{pp \rightarrow ppp\eta'}$ 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 $\sigma_{pp \rightarrow ppp\eta'}$ 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 $U_A(1)$ 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 $pp \rightarrow ppp\eta'$ 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 $\sigma_{pp \rightarrow pp\eta'}$ in proton–proton collisions and an update of the $\sigma_{pp \rightarrow pp\eta'}$ 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 $pp \rightarrow pp\eta'$ 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.

![Schematic view of the COSY-11 detector setup](image)

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 $pp \rightarrow pp$ reaction determined by the EDDA Collaboration [44] and the number of registered elastically scattered protons.

3. Results

Since $\sigma_{pp\rightarrow pp\eta'}$ 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

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{fig2.png}
\caption{Total cross section for the $\eta'$-meson production in the proton-proton collision as a function of the access energy $Q$ for the $pp \rightarrow pp\eta'$ 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).}
\end{figure}
are compared to the analytical parametrization derived by Fäldt and Wilkin [48, 49] which takes into account final state interaction of the protons

\[ \sigma_{pp \rightarrow pp\eta'}(Q) = C \frac{Q^2}{m_p p_{LAB}} \frac{1}{\left(1 + \sqrt{1 + \frac{Q}{\epsilon}}\right)^2}, \]  

(1)

where \( Q \) denotes the excess energy, \( p_{LAB} \) beam momentum, \( m_p \) proton mass. The parameters \( \epsilon = 0.75^{+0.20}_{-0.15} \text{ MeV} \) and \( C = 45^{+10}_{-9} \text{ mb} \) denote the Coulomb distortion and constant factor, respectively, and have been determined by fitting this formula to the experimental data. Values of \( pp \rightarrow pp\eta' \) 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.

<table>
<thead>
<tr>
<th>( Q \text{ [MeV]} )</th>
<th>( \sigma_{pp \rightarrow pp\eta'} \text{ [nb]} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5 ± 0.4</td>
<td>2.6 ± 0.5 ± 0.4</td>
</tr>
<tr>
<td>1.53 ± 0.49</td>
<td>5.2 ± 0.7 ± 0.8</td>
</tr>
<tr>
<td>1.7 ± 0.4</td>
<td>3.0 ± 1.2 ± 0.5</td>
</tr>
<tr>
<td>2.11 ± 0.64</td>
<td>7.2 ± 1.5 ± 1.1</td>
</tr>
<tr>
<td>2.9 ± 0.4</td>
<td>13.3 ± 3.4 ± 2.0</td>
</tr>
<tr>
<td>4.1 ± 0.4</td>
<td>26.4 ± 3.8 ± 4.0</td>
</tr>
<tr>
<td>5.80 ± 0.50</td>
<td>29.2 ± 3.5 ± 4.4</td>
</tr>
<tr>
<td>7.57 ± 0.51</td>
<td>45.5 ± 4.5 ± 6.8</td>
</tr>
<tr>
<td>9.42 ± 0.53</td>
<td>49.0 ± 5.9 ± 7.4</td>
</tr>
<tr>
<td>10.98 ± 0.56</td>
<td>70.5 ± 8.6 ± 11</td>
</tr>
<tr>
<td>14.21 ± 0.57</td>
<td>86 ± 14 ± 13</td>
</tr>
<tr>
<td>16.4 ± 1.3</td>
<td>139 ± 3 ± 21</td>
</tr>
<tr>
<td>23.64 ± 0.64</td>
<td>146 ± 20 ± 22</td>
</tr>
<tr>
<td>26.5 ± 1.0</td>
<td>136 ± 14 ± 22</td>
</tr>
<tr>
<td>32.5 ± 1.0</td>
<td>182 ± 21 ± 48</td>
</tr>
<tr>
<td>46.6 ± 1.0</td>
<td>329 ± 18 ± 85</td>
</tr>
</tbody>
</table>

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REFERENCES