Near–Threshold η Meson Production in Proton–Proton Collisions

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The role of various meson exchanges as well as influences of final state interaction (FSI) in the η meson production in proton–proton collisions, are still not well known. Existing data on the $pp \to pp\eta$ reaction, originating from measurements at SATURNE using the spectrometers SPES–3 [1] and PINOT [2] and at CELSIUS [3] with the PROMICE/WASA detection system, still leave enough freedom for interpreting the energy dependence of the cross sections. Therefore, the COSY–11 collaboration performed measurements of the $pp \to pp\eta$ reaction close to threshold, where the FSI effects are especially large.

Measurements were performed in a slow ramping mode with the beam momentum varied continuously in the range from 9.6 MeV/c below to 20.4 MeV/c above threshold momentum which is equal to 1981.6 MeV/c. For the data analysis, this range was divided into 2 MeV/c intervals. The number of events corresponding to η production was derived from the missing mass spectra. The beam momentum was determined by shifting the η–meson mass extracted from the missing mass spectra to its value known from the literature. The derived correction to the nominal COSY beam momentum was equal to $\Delta p = -1.88 \pm 0.80$ MeV/c. An extrapolation of the measured $pp \to pp\eta$ counting rate towards the reaction threshold — in analogy to Ref. [4] — results in a correction value of -1.89 ± 0.78 MeV/c which is in very good agreement with the shift in beam energy obtained from the reconstructed η mass. The simultaneous measurement of elastic proton–proton events was used to determine the luminosity and to normalize the η production cross sections.

The values of the total cross sections are shown in Fig. 1 as a function of the excess energy ε. In first order the energy dependence in the threshold region is described by the available phase–space modified by the $pp\eta$ FSI. The FSI can be factorized into pp (f_{pp}) and $p\eta$ ($f_{p\eta}$) factors and the cross section is given by integration over the available phase–space volume ρ_3:

$$\sigma(\varepsilon) \sim \int f_{pp}(q_{pp}) \cdot f_{p\eta}(q_{p_1\eta}) \cdot f_{p\eta}(q_{p_2\eta})\, d\rho_3 \qquad (1)$$

where q_{pp} is the relative momentum of the two protons and $q_{p_1\eta}$ and $q_{p_2\eta}$ are relative momenta of the η meson with respect to the first and second proton, respectively. The enhancement factors for the η–proton FSI were calculated using the effective–range approximation with the complex η–proton scattering length $a_{\eta p} = 0.717 + i0.263$ taken from Ref. [5] and the complex η–proton effective range parameter $r_{\eta p} = -1.50 - i0.24$ from Ref. [6]. The calculations, shown as a solid line in Fig. 1, describe the experimental data very well in the whole range of excess energy. Omission of the η–proton FSI leads to discrepancies with the data as shown by the dashed curve. While the error on the scale of the excess energy depicted in Fig. 1 refers to the uncertainty of the absolute beam momentum, the relative uncertainty of the beam energies is below the symbol size. Within this relative accuracy a calculation neglecting the proton–proton Coulomb interaction (dotted curve) fails to reproduce the energy dependence of the data.

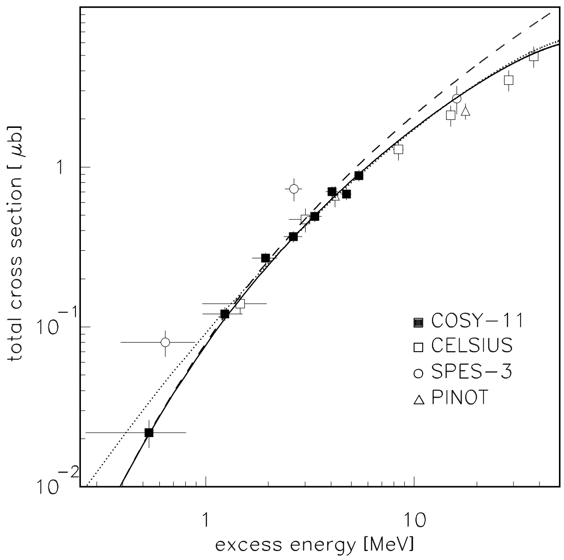

Figure 1: Total cross sections for the reaction $pp \to pp\eta$ near threshold. Curves are described in the text.

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