Production of ϕ-mesons in *pp* collisions close to threshold

M. Hartmann, Y. Maeda and I. Keshelashvili

The $pp \to pp\phi$ reaction has been measured at ANKE for three different c.m. excess energies close to threshold, detecting the K^+K^- decay mode of the ϕ-meson [1]. Figure 1 shows the total cross sections at $\varepsilon = 18.5$, 34.5 and 75.9 MeV together with the data point from DISTO ($\varepsilon = 83$ MeV) [2]. The dashed line is normalized to the ANKE data point at 75.9 MeV and corresponds to the energy dependence following phase-space. The solid line — normalized to all three ANKE data points — takes into account the effect of final-state interaction (FSI) between the two protons in an $^1S_0$ state by the Jost function method. This simple approach describes the ANKE data.

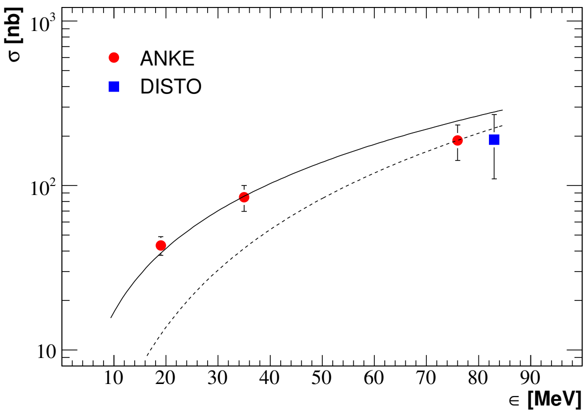

Fig. 1: Total cross section for ϕ production in *pp* collisions as a function of excess energy ε (red dots – ANKE (this work), blue square – DISTO). Error bars include both statistical and systematic uncertainties. The dashed line a shows phase space calculation, fixed at the high energy ANKE result, while the solid line includes proton–proton final state interaction and is normalized to fit best all ANKE data.

The analysis of the differential distributions at ε=18.5 MeV shows a dominant contribution of *s*-wave ϕ-mesons with the proton transition $^3\mathrm{P}_1 \to {}^1\mathrm{S}_0$. Figure 2 shows the differential cross section $d\sigma/d\Omega$ as a function of cosine of the polar K^+ emission angle in the rest frame of the ϕ–meson, relative to the beam direction (left). The data are consistent with a $\sin^2\Theta$ distribution (more details see Ref. [2]), indicated by the solid line. Also the measured polar angle of the ϕ-meson in the overall c.m. system, and the polar angles under which the protons are emitted relative to the beam as well as relative to the ϕ direction, measured in the *pp* reference frame, display no significant deviation from isotropy. On the right side of Fig. 2 the cross section $d\sigma/dp$ is shown in dependence of the proton momentum in the *pp* reference frame. The data points are well described by FSI of the two protons in a $^1\mathrm{S}_0$ state (solid line), whereas the phase space calculation (dashed line) clearly differs.

The Okubo-Zweig-Iizuka (OZI) rule states that processes with disconnected quark lines in the initial and final states are suppressed. Accordingly, the production of ϕ-mesons from initial non-strange states is expected to be substantially suppressed relative to ω-meson production. The cross-section ratio for ϕ- and ω-meson production under similar kinematical conditions should then be in the order of $R_{\mathrm{OZI}} = \sigma_\phi/\sigma_\omega = \tan^2\alpha_V = 4.2 \times 10^{-3}$ [3] where $\alpha_V = 3.7°$ is the deviation from the ideal ϕ-ω mixing angle [4]. Data from πN interactions [5] as well as from mesonic and radiative decays [6, 7, 8] indicate a ϕ-to-ω ratio of $3 \times R_{\mathrm{OZI}}$.

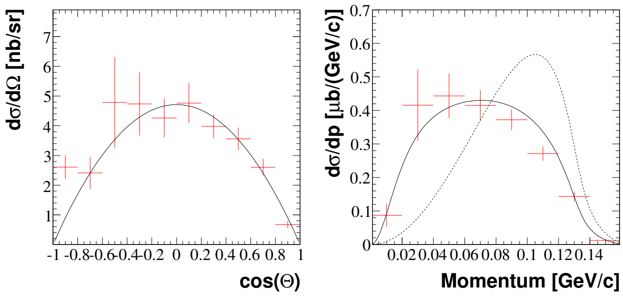

Fig. 2: Differential cross section $d\sigma/d\Omega$ as a function of the cosine of the polar K^+ angle in the reference frame of the ϕ–meson (left) and $d\sigma/dp$ in dependence of the proton momentum in the *pp* reference frame (right) – both for ε=18.5 MeV. Vertical error bars indicate statistical uncertainties. The lines are discussed in the text.

So far, the total ϕ cross section has been measured in *pp* collisions at only two energies in the range ε=2–4 GeV [9, 10]. The ϕ-to-ω ratio at these high energies agrees with the ratios from πN interaction and decay investigations. Using the DISTO result for ε=83 MeV, together with SPESIII [11] and COSY-TOF [12] data on ω-production, the ϕ-to-ω cross-section ratio can be calculated. This ratio is 7 times larger than R_{OZI}. The new ANKE results confirm the enhanced ϕ-to-ω ratio at $\varepsilon \sim 80$ MeV and show, within the existing uncertainties, a similar enhancement at 18.5 MeV and 34.5 excess energy. The weighted mean value for the ϕ-to-ω production ratio in the energy range from 18.5 to 75.9 MeV results in

$$R(\phi/\omega) = (3.3 \pm 0.6) \cdot 10^{-2}$$
$$R(\phi/\omega)/R_{OZI} = 7.9 \pm 1.4\,.$$

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