ϕ-meson production in pp collisions close to threshold

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New data on ϕ-meson production in pp collisions have been obtained at the ANKE facility of COSY-Jülich. These data will provide the energy dependence of the total cross section down to an excess energy of 19 MeV above threshold. In combination with the existing SPES-III and COSY-TOF results on ω-meson production the ϕ/ω production ratio at this low excess energy will be extracted. As an exciting new aspect an enhancement in the invariant ϕp mass spectrum is observed at a mass around 1.965 GeV/c^2.

1. Introduction

The Okubo-Zweig-Iizuka (OZI) rule [1] states that processes with disconnected quark lines in the initial or final state 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 $R_{\rm OZI}=\sigma_\phi/\sigma_\omega=\tan^2\alpha_V=4.2\times10^{-3}$ [2], where $\alpha_V=3.7^\circ$ is the deviation from the ideal $\phi-\omega$ mixing angle [3]. However, one may expect that a certain amount of hidden strangeness in the nucleon would manifest itself in a reaction cross section that significantly exceeds the limit given by the OZI rule. This question has lead to a large experimental activity involving different hadronic reactions. In specific channels in $\bar{p}p$ annihilation [4–6] enhancements of $\mathrm{R}_{\phi/\omega}$ by up to two orders of magnitude have been observed. A systematic analysis of the ϕ to ω cross-section ratio in pp collisions and πN interactions as well as in mesonic and radiative decays have been performed by Sibirtsev and Cassing [7]. Almost all of the existing data give a ϕ to ω ratio of $3\times R_{\rm OZI}$. Only the ratio derived from ϕ-meson production measured at DISTO [8] in pp collision at an excess energy of 83 MeV shows a 7 times larger value than $R_{\rm OZI}$. The final result from ANKE data will provide information on the energy dependence of the ϕ production as well as on the ϕ/ω cross section ratio below the existing DISTO

measurements.

2. Experiment

The reaction $pp \to pp\phi$ at excess energies of ϵ=76 MeV, 35 MeV and 19 MeV has been studied with the ANKE magnet spectrometer [9,10] at COSY-Jülich by detecting the K^+K^- decay mode of the ϕ-meson. The flight times and the momenta of positively and negatively charged particles are determined with scintillation counters and multi-wire chambers. K^+ and K^- mesons as well as one of the forward going protons were detected. The reaction $pp \to pp\phi \to ppK^+K^-$ was selected by a missing mass cut on the non-detected proton. At each energy about 200-300 ϕ-mesons were identified.

First preliminary total cross sections for ϕ production are deduced at ϵ=76 MeV and ϵ=19 MeV. Figure 1 (a,b) shows the efficiency corrected K^+K^- invariant mass distributions.

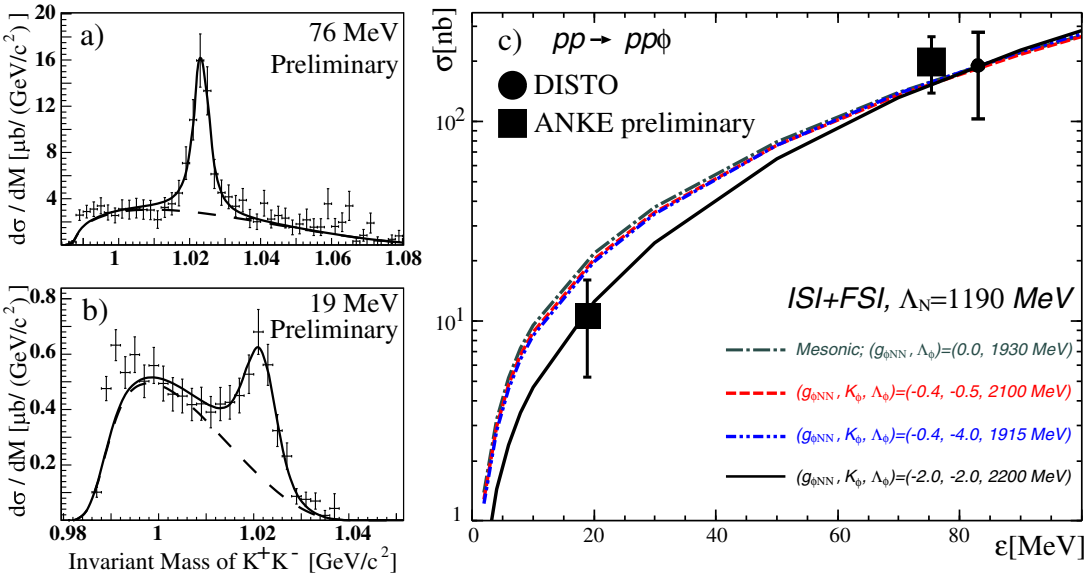

Figure 1. (a) and (b) show the efficiency corrected K^+K^- invariant mass distribution at excess energies of 76 MeV and 19 MeV. The dashed curves are the non-resonant contributions based on four-body phase space. The solid line is the sum of non-resonant contribution and ϕ-meson production including the detector resolution. In (c) the total ϕ cross sections from ANKE are shown together with the DISTO point. The error bars indicate the systematical uncertainties. The lines are predictions from Ref. [11].

The determination of the cross sections has been carried out on the basis of three- ($pp\phi$) and four-body (ppK^+K^- non-resonant) phase space distributions. The ϕ cross section at ϵ=76 MeV (Fig. 1 (c)) is close to the DISTO data point. Figure 1 (c) also shows the ϕ cross section at ϵ=19 MeV. The lines are the theoretical predictions by Tsushima and Nakayama [11] for different model parameters including the unknown ϕNN coupling constant. Within this theoretical framework our preliminary result at ϵ=19 MeV would

suggest a strong ϕNN coupling constant. However, a phase-space calculation normalized to the DISTO result (solid line in Fig. 2 (a)) describes the data as well.

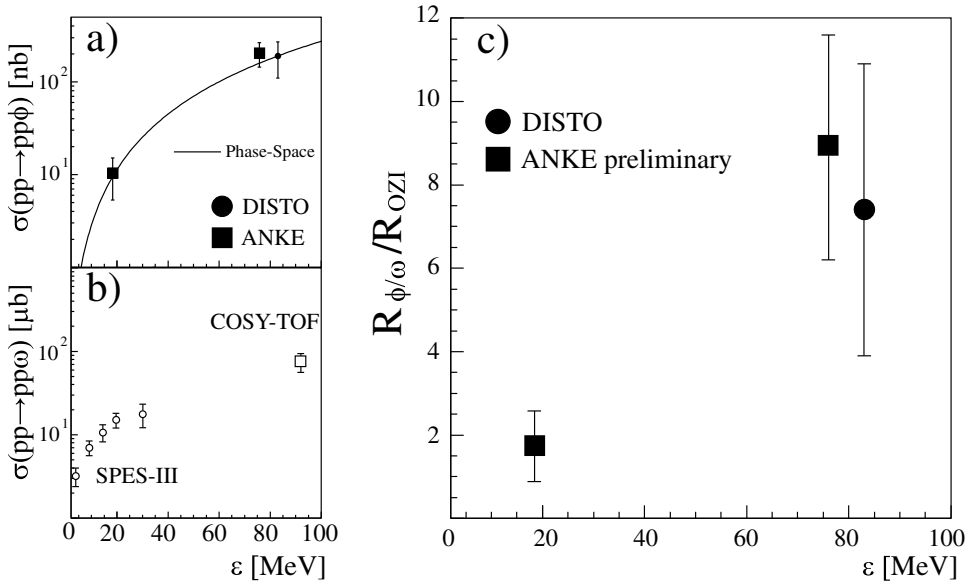

Figure 2. (a) and (b) show the total cross section for the ϕ and ω production in pp collisions, respectively. In (c) the ϕ to ω cross section ratios normalized by $R_{\rm OZI}$ are shown.

In Fig. 2(b) the existing $pp \to pp\omega$ data from SPES-III [12] and COSY-TOF [13] are presented for comparison. The enhanced ϕ to ω ratio at $\epsilon \approx 80$ MeV is confirmed by the ANKE cross section. The ANKE ϕ-to-ω ratio at an excess energy $\epsilon = 19$ MeV is $2 \times R_{\rm OZI}$ and thus significantly smaller than at the DISTO excess energy (Fig. 2 (c)).

3. Structure in the ϕp system

Figure 3 (a) shows the K^+K^-p invariant mass versus the K^+K^- invariant mass at an excess energy of 76 MeV. The spectrum contains less than 5% of background inside the hatched area as deduced from the missing mass of K^+K^-p. At K^+K^-p masses around 1.965 GeV/c^2 a clear enhancement is seen correlated with the ϕ-meson. Figure 3 (b) shows the projection of the K^+K^-p invariant mass spectrum without and with a cut (hatched area in (a)) on the ϕ mass. The pronounced enhancement at low K^+K^-p invariant masses is seen in both spectra. In total the mass region from 1.95 to 1.98 GeV/c^2 contains 107 events, around 80 of them are ϕ-mesons. Outside the ϕ cut the measured K^+K^-p invariant mass distribution is well described by four-body phase space, whereas the observed structure shows a significant deviation from phase space. Two alternative interpretations of this structure, a resonance ϕp state or a final state interaction between ϕ and proton are currently discussed. However, the statistical errors do not allow for any further conclusions. Thus, a new measurement at 76 MeV excess energy has already been scheduled to increase the statistics more than three times [14]. We note that the search of a structure in the ϕp system started in the beginning of the eighties [15,16]. In 1984, the

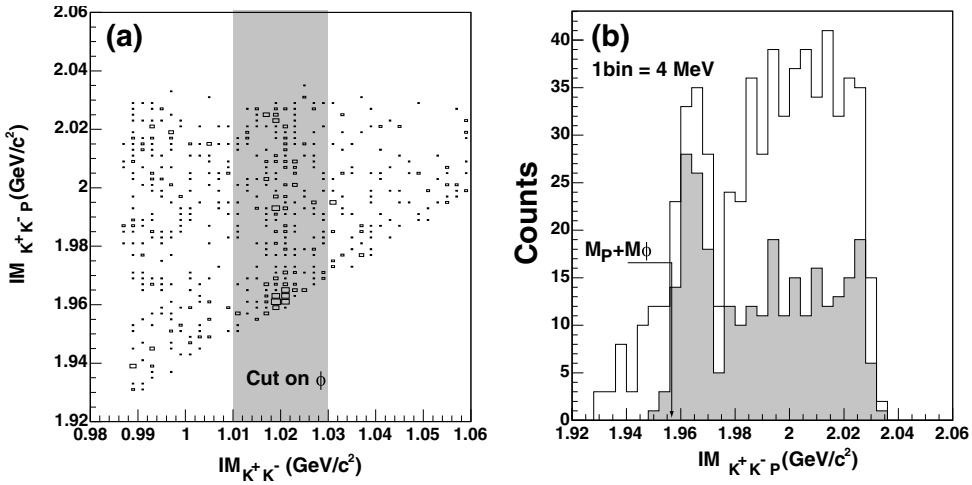

Figure 3. (a) Scatter plot of the invariant K^+K^-p mass versus invariant K^+K^- mass. (b) shows the projection of the invariant K^+K^-p mass spectrum in total and inside ϕ-cut.

reaction $n + C \to \Sigma^- K^+ + X$ was studied at the Serpukhov accelerator using the BIS-2 spectrometer. A narrow resonance with a mass of $1956^{+8}_{-6}\,\mathrm{MeV/c^2}$ and width $29\pm15\,\mathrm{MeV}$ has been observed in the invariant mass distribution of the $(\Sigma^- K^+)$ system [17].

Useful discussions with A.A. Sibirtsev and members of the ANKE Collaboration are gratefully acknowledged. This work has been supported by: BMBF (WTZ-RUS-211-00, 691-01, WTZ-POL-041-01), DFG (436 RUS 113/561, 733), Russian Academy of Sciences (01-04-034, 02-04034, 02-18179a, 02-06518).

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