Close–to–threshold Φ production at COSY–11

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Studies of Φ meson production in nucleon–nucleon collisions are especially motivated by possible violations of the Okubo–Zweig–Iizuka rule [1]. Any significant deviation from the expected suppression of Φ compared to ω production in hadronic interactions might be interpreted as a hint for a strangeness component in the nucleon [2]. Large violations of predictions based on the OZI rule have been found in $p\overline{p}$ annihilation at LEAR (as reviewed in [2]), where it is the spin triplet fraction in the entrance channel which is strongly correlated to the Φ yield as shown in [3]. Similarly, in proton–proton collisions, for close–to–threshold Φ production, the entrance channel must be in a spin triplet $^3P_1$ state.

The exclusive production ratio has been determined in the reaction $pp \to pp\Phi/\omega$ at a beam momentum of 3.67 GeV/c corresponding to excess energies of 82 MeV and 319 MeV to the Φ and ω thresholds, respectively [4]. However, angular distributions indicate already a P–wave component in the pp–system in the final state at this energy. Thus, the influence of the spin triplet entrance channel might be diluted in the presently available data and would be expected to be more prominent in the production closer to threshold.

As a study of feasibility, the reaction $pp \to pp\Phi$ has been measured at the COSY–11 facility at a beam momentum of $p_{beam} = 3.481$ GeV/c, i.e. at an excess energy of 24 MeV with respect to the Φ production threshold [5].

The analysis of experimental data focuses on events with two protons and one K^+ meson identified in the final state. The (squared) invariant mass distribution of a third positively charged ejectile in addition to two identified protons is shown versus the missing mass (squared) of the identified (ppK^+) subsystem in figure 1.

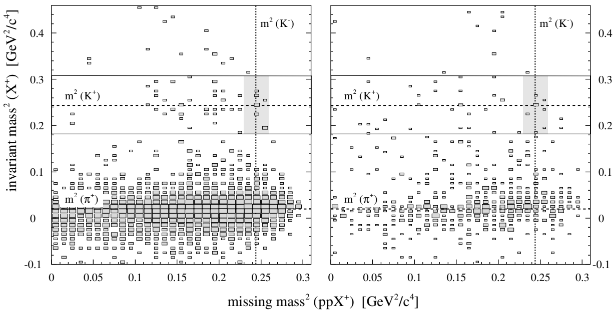

Fig. 1: Invariant mass squared of a third positively charged particle in addition to two identified protons versus missing mass squared with respect to the assumed (ppK^+) subsystem without (left, logarithmic scale) and with (right, linear scale) requiring an additional hit in the K^- scintillator. Solid lines denote the cut on the kaon mass used for the K^+ identification, and the shaded area corresponds to the mass range expected for the ppK^+K^- final state.

On the scale of the invariant mass, positively charged kaons appear rather well separated from the dominant pion signal (fig. 1 left). A group of 39 events with an identified (ppK^+) subsystem stands out close to the K^- mass as expected for a ppK^+K^- final state.

Requiring an additional hit in the dedicated K^- scintillator mounted inside the dipole gap cleans the spectrum especially in the regions of $(pp\pi^+)$ events and lower missing mass values (fig. 1 right, note the change to linear scale). Within the resolutions expected for the kaon invariant mass and for the (ppK^+) missing mass ten events in total remain consistent with a ppK^+K^- final state.

The (ppK^+) missing mass is shown in figure 2 as a function of the (K^+K^-) invariant mass. Without requiring a detected signal of the K^-, a slight enhancement close to the Φ mass is obvious (fig. 2 left). However, the signal disappears when demanding an additional K^- consistent hit (fig. 2 right), although the detection efficiencies for non–resonant K^+K^- production and the reaction $pp \to pp\Phi \to ppK^+K^-$ are comparable (54 % and 46 %, respectively).

The total number of candidates for a ppK^+K^- final state falls short of the estimations based on the available total cross section data [4] and acceptance studies by a factor of two. This, however, might be easily accounted for by the integrated luminosity, which so far has not been determined accurately.

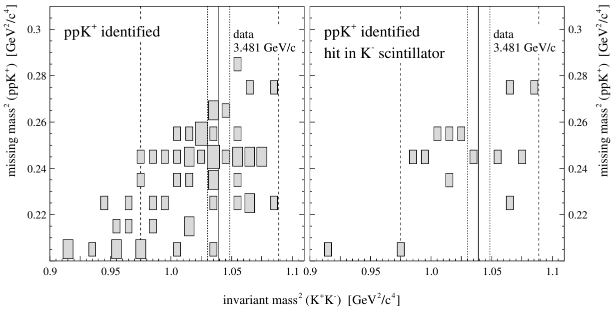

Fig. 2: Missing mass squared with respect to the identified (ppK^+) subsystem versus (K^+K^-) invariant mass squared without (left) and with (right) requiring an additional hit in the dedicated K^- scintillator. Dashed lines mark the kinematical limits of K^+K^- production. The solid line denotes the squared mass of the Φ meson, dotted lines indicate its finite width.

Despite the low statistics, the study of feasibility performed at the COSY–11 facility should allow to determine an upper limit on Φ production in proton–proton scattering at a beam momentum of $p_{beam} = 3.481$ GeV/c and thus on the Φ/ω ratio. The analysis of ω production at the same excess energy is in progress [6].

References:

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