Investigation of the $a_0^+(980)$ Resonance with ANKE

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Abstract

Two experiments on the production of the $a_0^+(980)$-resonance have been performed at the COoler SYnchrotron COSY Jülich. The reactions $pp \to dK^+X$ and $pp \to d\pi^+X$ have been measured simultaneously at beam energies of $T_p = 2.65$ GeV and $T_p = 2.83$ GeV corresponding to excess energies 46 MeV and 103 MeV above the $K^+\overline{K}^0$ threshold. The coincident dK^+ ($d\pi^+$) pairs were detected with the magnetic spectrometer ANKE and events with $m_X = m_{\overline{K}^0}$ (m_η) were identified. For the reaction $pp \to dK^+\overline{K}^0$ a total cross section of about 50 nb has been deduced from the data at $T_p = 2.65$ GeV. The invariant mass distribution of the $K^+\overline{K}^0$ pairs is discussed in terms of $a_0^+(980)$-resonance production.

The nature of the lightest nonet of scalar mesons is a vividly discussed topic in hadronic physics. There are several candidates, one of them being the $a_0(980)$-resonance. Many experiments on scalar mesons have been performed [1] but no unambiguous conclusions could be drawn up to now. Some of the existing theoretical models describe the $a_0(980)$ as a $q\overline{q}$ state (e.g. [2, 3, 4]) and count it as a member of the scalar meson nonet, other models treat it, e.g., as four quark state [5] or a dynamically generated object via strong final state interaction (FSI) [6].

Two experiments on the production of the $a_0^+(980)$ resonance have been performed with ANKE [7] at COSY Jülich and others on the neutral scalars $a_0^0/f_0(980)$ are in preparation [8]. The first experiment was carried out in the beginning of 2001 at a beam energy of $T_p = 2.65$ GeV, the second earlier this year at $T_p = 2.83$ GeV. For both experiments a hydrogen cluster jet target built at Münster University has been used, providing luminosities of $\sim 2\cdot 10^{31}\text{cm}^{-2}\text{s}^{-1}$ for $\sim 3\cdot 10^{10}$ protons stored in COSY.

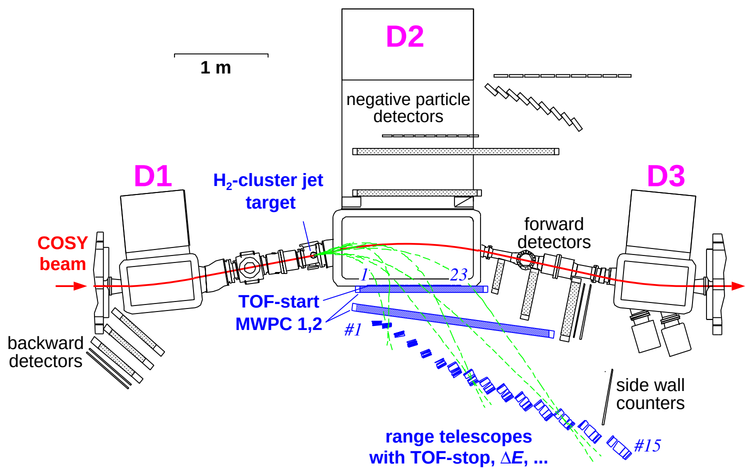

Figure 1: Sketch of the ANKE spectrometer. For the a_0^+ experiments the side and the forward detection systems (SD/FD) and a cluster jet target have been used. The SD comprises 23 TOF start counters, 15 range telescopes, 6 side wall counters and 2 MWPCs for track reconstruction. The FD consists of 2 layers of scintillation counters and 3 MWPCs.

According to the Particle Data Group three decay channels of the $a_0(980)$ have been observed [1]. The decay channel $\pi\eta$ is denoted as dominant, the channels $K\overline{K}$ and 2γ as seen. The $a_0(980)$ experiments at ANKE have the advantage that two decay channels ($\pi\eta$ and $K\overline{K}$) are

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detected simultaneously with a high missing mass resolution. Further goals are the determination of the total production cross section and the investigation of the $d\overline{K}^0$ FSI. In contrast to most of the other experiments the $a_0(980)$ is produced directly, i.e. not via the decay of a higher lying resonance.

ANKE (see Fig.1) allows to detect positively charged ejectiles from hadron induced reactions which are emitted into forward direction. In the discussed measurements kaons and pions were detected with the side detection system (SD). The angular acceptance was $|\vartheta_H| \leq 12°$ horizontally and $|\vartheta_V| \leq 3.5°$ vertically. Kaons were identified in telescopes which offer an excellent kaon to background discrimination [9]. The kaon momentum range covered was $p_K = 390 \ldots 625$ MeV/c. Pions were detected in the side wall counters covering a total momentum range $p_\pi = 620 \ldots 1150$ MeV/c. In this case time-of-flight information has been used for particle identification. The fast deuterons ($p_d \sim 2100$ MeV/c) were detected in the forward detection system (FD) with an angular acceptance of roughly $|\vartheta_H| \leq 10°$ and $|\vartheta_V| \leq 3.0°$ depending on the deuteron momentum.

The procedure to select the events $pp \to dK^+(\pi^+)X$ is as follows: First kaons or pions in the SD are identified by means of TOF and energy loss [9]. The chamber information is used to

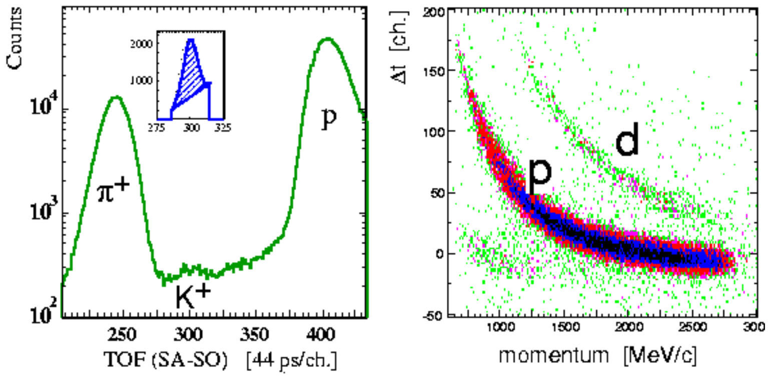

Figure 2: Left side: typical TOF distribution between the TOF start counters and the telescopes after suppression of scattered background. Pions and protons are easily identified, for kaons it is necessary to cut on energy loss (inset: after energy loss cut). Right side: relative TOF of a FD particle and a pion in the side wall counters versus momentum of the FD particle. Most prominent are coincident protons.

suppress scattered background and to determine the momentum. A typical TOF spectrum at this energy after using the MWPC information is shown in Fig. 2, left side. Pions and protons are easily identified, for the kaons it is essential to exploit their energy loss in addition. This yields a strong suppression of the background under the kaon peak (see inset of Fig. 2). The remaining background disappears by requiring for a coincident deuteron hit in the FD.
Deuterons are identified by their TOF relative to the mesons detected in the SD. In Fig. 2 (right) a typical relative TOF of a FD particle and a pion in the side wall counters versus the momentum of the FD particle is shown. Two bands from protons and deuterons are clearly seen. The deuterons are selected by cutting along the upper band.

Finally, the two reaction channels are selected by performing a missing mass analysis. In case of coincident $d\pi^+$ pairs a peak at the mass of the η meson is observed (~ 2300 events in the peak of Fig.3, left side) on a smooth background distribution of multiple pion production. In the missing mass $m(pp,d)$ a shoulder at the mass of the $a_0(980)$ is seen (Fig. 3, right side) reducing to a peak structure with $\Gamma(FWHM) \sim 40$ MeV after background subtraction (using the background events left and right to the η peak).

For coincident dK^+ pairs a narrow structure at the mass of the $\overline{K}^0$ is observed containing about 600 events (see Fig. 4, left side) and reflecting the clean particle identification at ANKE since at this energy the missing particle must be a $\overline{K}^0$ due to strangeness conservation. The distribution $m(pp,d)$ (middle part of Fig. 4) exhibits a narrow peak structure which is limited by the $K\overline{K}$ threshold and the maximal mass accessible for this beam energy. Due to this limited mass interval it is difficult to interpret this structure as resonant production via the a_0. The total cross section for the reaction $pp \to dK^+\overline{K}^0$ at this energy has been determined by normalizing to the known

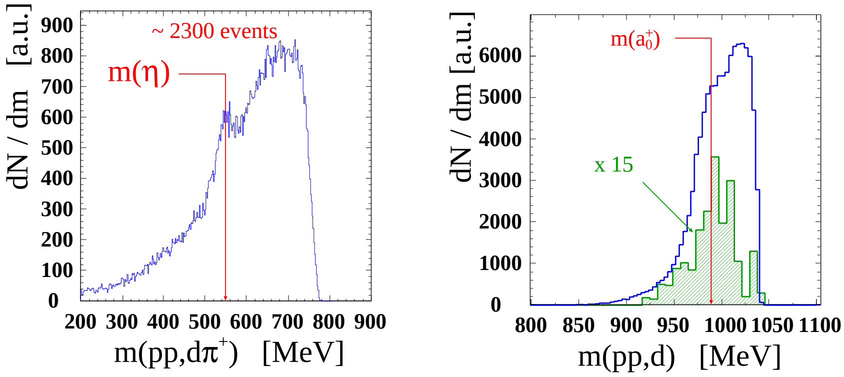

Figure 3: Preliminary missing mass distributions $m(pp, d\pi^+)$ and $m(pp, d)$. About 2300 $d\pi^+\eta$ events are observed on a smooth background distribution $m(pp, d\pi^+)$ stemming from multiple pion production. In the corresponding distribution $m(pp, d)$ a shoulder around the mass of the $a_0(980)$ is seen. After background subtraction a peak structure is left with at width of about $\Gamma(FWHM) \sim 40$ MeV (shaded histogram).

cross section of pp elastic scattering and yields about 50 nb.
The one pion exchange model developed in references [10, 11, 12, 13] predicts that close to threshold the $K\overline{K}$ pairs are mainly produced via the $a_0^+(980)$ resonance (see Fig.5). The model prediction for the total cross section is in good agreement with the experimental data.
It has been suggested by Oset et al. [6] that the missing mass distribution $m(pp, K^+)$ should allow to draw conclusions about the $d\overline{K}^0$ FSI which is expected to be strong. For a possible set of parameters the model distributions with (solid line) and without (dashed line) FSI effects taken into account are shown. We show the non acceptance corrected experimental distribution from ANKE (see Fig. 4, right side). After applying these corrections (which are strong along $m(pp, K^+)$ but rather uniform for $m(pp, d)$) information about the $d\overline{K}^0$ FSI can be extracted from the data. For the determination of the total cross section for the reaction $pp \to dK^+\overline{K}^0$ the acceptance correction has already been applied. The total acceptance only weakly depends on the initial distribution.

During the experiment at the higher beam energy $T_p = 2.83$ GeV coincident dK^+ $(d\pi^+)$

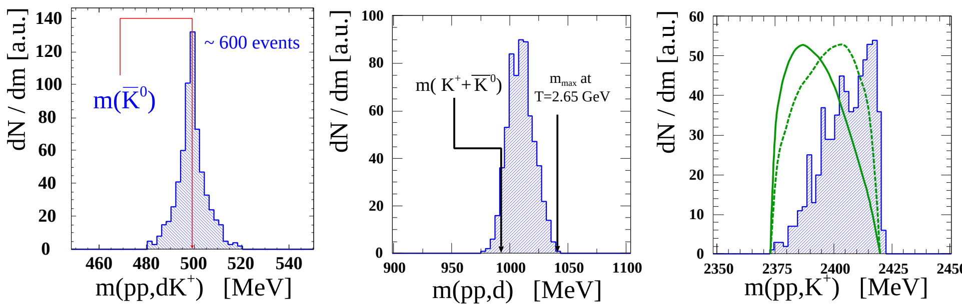

Figure 4: Preliminary missing mass distributions $m(pp, dK^+)$, $m(pp, d)$ and $m(pp, K^+)$. With a missing mass analysis the reaction $pp \to dK^+\overline{K}^0$ is identified yielding about 600 events (left side). In the distribution $m(pp, d)$ a narrow structure is observed limited to the left by the $K\overline{K}$ threshold and to the right by the highest accessible mass for $T_p = 2.65$ GeV. All experimental distributions are not yet corrected for acceptance. According to simulations this will hardly influence the distribution $m(pp, d)$ but is important for the distribution $m(pp, K^+)$. A possible distribution with and without FSI effects taken into account are shown by the solid and dashed line [6], respectively.

events have been collected as well. About 2000 $dK^+\overline{K}^0$ pairs have been identified. The available mass interval $m(pp, d)$ has been extended from 1038 MeV to 1095 MeV. According to the model described in references [10, 11, 12, 13] the contribution of nonresonant $K^+\overline{K}^0$ production rises to a ratio of ~2 for resonant to nonresonant production. This ratio will be extracted from the experimental $m(pp, d)$ distribution and both values can be compared. The analysis of the experimental data is in progress.

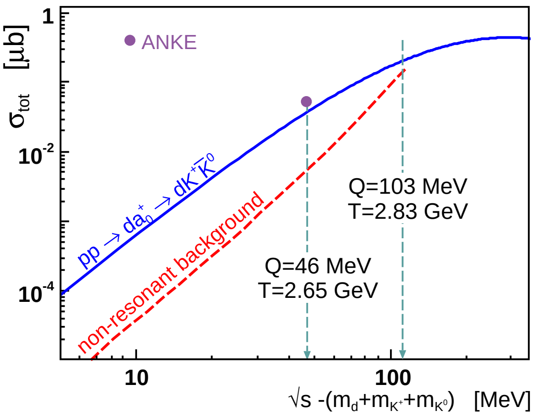

Figure 5: Prediction for the total cross section for $pp \to da_0^+ \to dK^+\overline{K}^0$ and $pp \to dK^+\overline{K}^0$ [13] in comparison with the preliminary experimental total cross section. According to the model at the excess energy of the first measurement at $T_p = 2.65$ GeV resonant $K^+\overline{K}^0$ production via the a_0 prevails.

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