Analysis of diffractive dissociation of exclusive $K^-\pi^+\pi^-$ events in the high energetic hadron beam of the COMPASS-experiment

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In order to study the light-meson spectrum the COMPASS experiment at CERN was taking data with a 190 GeV/c hadron beam hitting a liquid hydrogen target in the years 2008 and 2009. The negative hadron beam contained mainly pions and a small fraction of about 2.5% of kaons. Kaons were identified using CEDAR PID detectors in the beamline. One of the channels of interest are diffractively produced resonances decaying into the $K^-\ \pi^+\ \pi^-$ final state. The presented data selection resulted in 270 000 events from 2008 hadron-beam data. The invariant mass spectra show already the well known resonances like the $K_1(1270)$, $K_1(1400)$ and the $K_2(1770)$. To disentangle all contributing resonances techniques of mass independent partial wave analysis were applied. A short review on the ongoing studies is presented. *Supported by BMBF under the contract 06MZ224.*

1 Introduction

A bound $q\bar{q}$ state in a potential with additional orbital angular momentum between the quarks has several eigenstates whose energy corresponds to the mass of the meson. A coupling of an s or $\bar{s}$ quark with lighter quarks creates isospin $I_3 = 1/2$ states. Those are classified by their total spin-parity J^P. No further eigenvalues like $C(G)$-parity are available as symmetry is broken due to the heavier strange quark.

Resonances decaying into $K^\mp\pi^\pm\pi^\mp$ final states were measured at several experiments [1–3] in the past. Most of them in the late 70s, like WA03 [4] at CERN, often quoted to be the "best" measurement so far in this channel. After 30 years still many unconfirmed resonances [5] as well as open questions about their interpretation exist, giving us the motivation to remeasure those states with the COMPASS high-precision spectrometer.

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2 Measurement

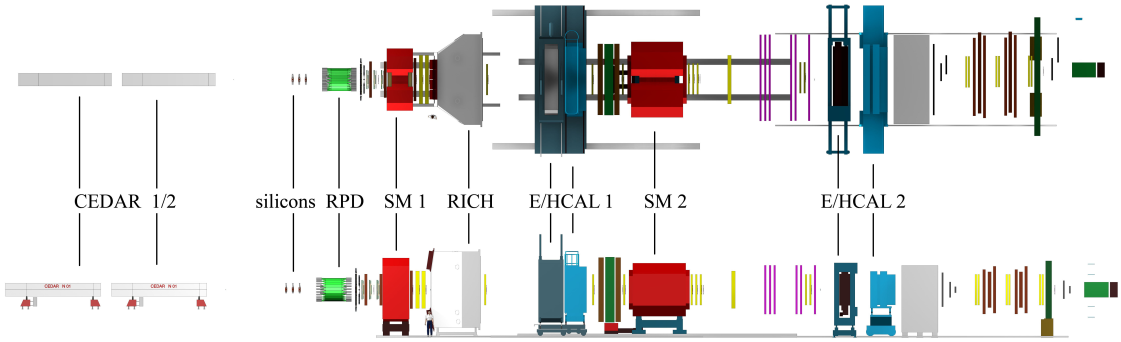

Figure 1: Illustration of the two-stage COMPASS Spectrometer (top/side view). For details see the text.

The production mechanism of choice was single-diffractive dissociation of a projectile on a proton target (see figure 2 left). A beam particle was excited via reggeon (pomeron) exchange to a higher state preserving charge, flavour, energy and G-parity. The target proton stayed intact, only four-momentum was transferred to the proton.

The COMPASS hadron runs in the years 2008 and 2009 were mainly dedicated to the study of meson or baryon excitations. The 60 m long two-stage spectrometer is sketched in figure 1. The negative hadron beam was consisting mainly of pions with a small kaon admixture of about 2.5%. These were tagged by CEDAR detectors 30 m upstream of the target [6]. In single-diffractive processes the target proton scatters elastically. A Recoil Proton Detector (RPD) measured the time of flight of the protons that were kicked out of the 40 cm long liquid hydrogen target using two barrels of scintillator slabs.

Momenta of charged final states were determined by two spectrometer stages, each initialized by a spectrometer magnet (SM), and more then 200 planes of tracking devices along the spectrometer. In addition the first stage featured a ring imaging Cherenkov detector (RICH) for final-state particle identification (PID). Kaons could be separated from pions with momenta up to 50 GeV/c. Neutral particles were identified by their energy deposit in electromagnetic calorimeters (ECAL) in both stages. A more detailed description of the spectrometer is found in [7].

The application of cuts as track multiplicity, charge conservation, planarity of the beam particle, recoil proton and resonance as well as the application of the RICH PID to the negatively charged tracks yielded in about 270 000 final-state events forming the invariant mass distribution in figure 2 (right). As RICH momentum acceptance effects played a bigger role in the smaller phase space of low invariant masses the mass distribution shows an enlarged contribution of higher masses in the K_2 region as compared to previous measurements [4]. The corresponding sub-mass spectra in figure 3 for $K^-\pi^+$ and $\pi^-\pi^+$ track combinations

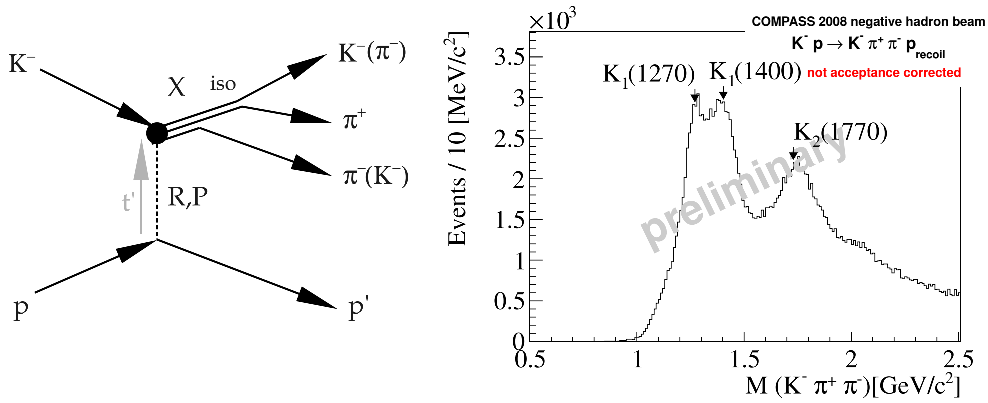

Figure 2: Left: Single diffractive excitation of kaons into $K^-\pi^+\pi^-$ final states via reggeon (pomeron) exchange with a target proton. The dissociation of the intermediate state X is described by a chain of successive two-body decays. Right: The invariant $K^-\pi^+\pi^-$ mass distribution for the 2008 COMPASS data after all cuts.

support the assumption of a decay chain with intermediate isobar states as $K^*(892)$ or $\rho(770)$.

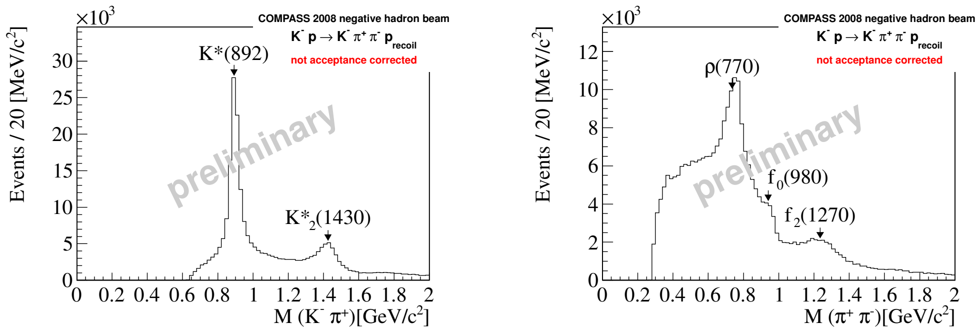

Figure 3: The invariant $K^-\pi^+$ (left) and $\pi^+\pi^-$ (right) mass distributions as contained in the $K^-\pi^+\pi^-$ final state.

3 Partial-wave analysis

The combination of known resonances in the isobar invariant mass spectra in figure 3 and the bachelor particle allows to compose a spin-parity basis for the observed angular distributions. The data sample was divided in invariant $K^-\pi^+\pi^-$ mass bins of $20\,\mathrm{MeV}/c^2$

width. An acceptance-corrected maximum likelihood fit using a spin-density matrix of rank two was performed in each bin. In total 19 partial waves plus a flat wave were found to describe the data set the best. Results were at large parts in good agreement with previous measurements by WA03 [4], but also differences were observed.

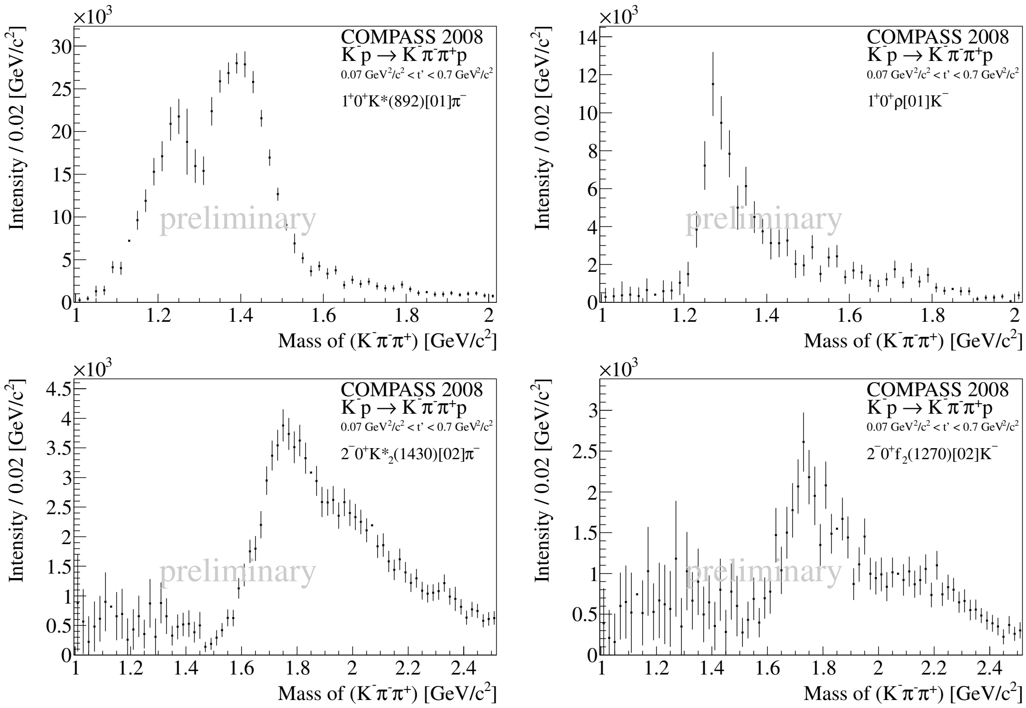

Figure 4: Intensity distributions of the four main partial waves from a mass-independent fit to the COMPASS data. The low-mass region is dominated by $J^P = 1^+$ states coupling to ρK^- and $K^*\pi^-$ channels. The high mass region consists of $J^P = 2^-$ states coupling mainly to $K_2^*\pi^-$ and f_2K^- channels. Both states are believed to be a mixture of spin-singlet and spin-triplet states.

Exemplary four intensities are shown in figure 4. The largest intensities were found in the $J^P = 1^+$ waves coupling mostly to the $K^*\pi^-$ and ρK^- channels. Two peaks were observed particularly in the $K^*\pi^-$ branch. Those are known to be the $K_1(1270)$ and the $K_1(1400)$, the spin singlet and triplet state in the constituent quark model. In contrast to results by WA03 the coupling of the $K_1(1400)$ to the $K^*\pi^-$ states seems to be resulting in a $J^P = 1^+$ spin total with nearly equal intensities for both resonances.

A similar mixing of two spin states is also expected in the $J^P = 2^-$ waves. Indeed broad resonant structures are present in the high-mass region coupling mainly to $K_2^*\pi^-$ and f_2K^- waves. A further decomposition needs a mass-dependent fit as those resonances are strongly overlapping. The mass dependent fit algorithm is work in progress.

Peaks in the $J^P = 2^+$ waves confirm once again the existence of the well known $K_2^*(1430)$

and strong intensities were observed in the low-mass region for $J^P = 0^-$ waves. For a clean identification of a possibly existing $K(1460)$ also here a mass-dependent fit must be applied. These waves are sensitive to Deck-like effects that cannot be separated by a mass-independent fit alone.

4 Conclusion and Outlook

COMPASS data of 2008 contain a clean sample of kaonic resonances decaying into $K^-\pi^+\pi^-$ final states. About 270 000 events were subjected to mass-independent partial-wave analysis showing a composition of $J^P = 0^-, 1^+, 2^+, 2^-$ states that needs further investigation as many resonances in the high-mass region are strongly overlapping. Well-known resonances were observed and the existence of at least one resonance in the $J^P = 0^-$ waves is likely. With the analysis of 2009 data we will probably double the number of events and a prospective mass-dependent partial-wave analysis will give us information about masses and widths of the contained resonances.

Acknowledgments

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