Threshold Measurements of pp $\rightarrow$ ppK$^+$K$^-$ at the COSY–11 Installation

Abstract

With the structure of the $f_0(975)$ and $a_0(980)$ still being discussed, data close to the threshold of the reaction pp $\rightarrow$ ppK$^+$K$^-$ are needed to help interpreting the nature of these scalar mesons. At threshold, proton–proton, proton–kaon and kaon–kaon final state interaction should be observable.

In addition to the standard experimental technique of detecting the baryons in the exit channel, the COSY–11 installation, designed for full geometrical acceptance close to threshold, allows a limited detection of charged kaons, i. e. a complete kinematical determination for all four hadrons is possible. First results obtained during a beam time in October 1995 at this internal experimental facility are presented, an estimate of the counting rate is given.

It is proposed to scan the proton proton interaction in a momentum range defined by the thresholds of K$^+$K$^-$ and K$^0\overline{\mathrm{K}^0}$ production.

Physical Motivation

While low lying pseudoscalar, vector and tensor mesons are described successfully as $q\overline{q}$ states on the basis of the quark model, the situation differs concerning scalar mesons. A study of the reaction pp $\rightarrow$ ppK$^+$K$^-$ is especially motivated by the discussion on the nature of the scalar mesons $f_0(975)$ and $a_0(980)$ (fig. 1):

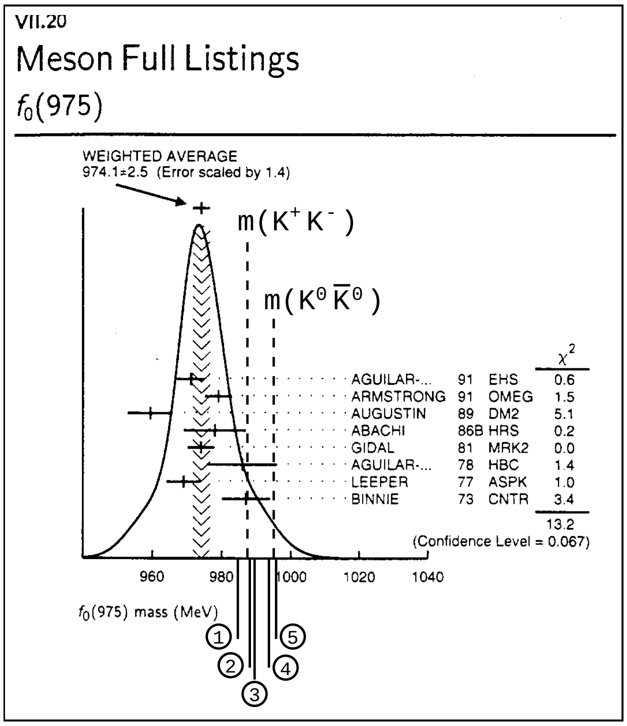

Figure 1: The $f_0(975)$ taken from the PDG [1,2] and proposed scan at the K$^+$K$^-$ and K$^0\overline{\mathrm{K}^0}$ thresholds.

A two–quark two–antiquark state within a nonet derived from colour–hyperfine interactions [3], a conventional $q\overline{q}$ Breit–Wigner nature [4] and a K$\overline{\mathrm{K}}$ molecule structure [5] have been suggested in the case of the $f_0(975)$. At present, existing data on J/Ψ decays into $\Phi\pi\pi$ and ΦKK [6] lead to an interpretation of the f_0 as a $q\overline{q}$ state [7,8]. Results of a recent analysis within the framework of meson exchange models for $\pi\pi$ and $\pi\eta$ interaction also describe these data assuming a K$\overline{\mathrm{K}}$ molecule structure of the f_0 generated dynamically by vector meson exchange [9,10].

Data of high precision and sufficiently large statistics, especially in the threshold region, are needed to help discriminating between these interpretations: The lowest experimental cross section value of the reaction $pp \to ppK^+K^-$ is given at an excess energy of 2.78 GeV [11] ($\sigma\,(pp \to ppK^+K^-)_{\sqrt{s}=3.77\ \mathrm{GeV}} = 34 \pm 12\,\mu$b). In addition, threshold meson production necessarily implies vanishing relative momenta of the reaction products. Consequently, baryon–baryon, baryon–meson and meson–meson final state interaction (FSI) should be clearly visible in the data. Proton–proton and proton–meson FSI have recently been discussed in case of the π^0 and η threshold production (see contribution "Production of η mesons at COSY–11" and [12,13]). In case of K^+K^- production, the possible effects of meson–meson FSI should add to the study of FSI threshold effects the interaction between the simplest hadronic bound states.

Experimental Technique

The basic experimental setup of the internal COSY–11 installation consists of a hydrogen cluster target at the internal COSY target place TP3, installed in front of a regular COSY dipole, which is used to separate reaction products from the circulating beam and to analyze their momenta. The exit windows of a specially developed vacuum chamber, mounted inside the dipole gap, link the COSY vacuum and the detection system, which is operated in normal atmosphere.
Including the knowledge of the magnetic field, the information obtained from two drift chamber systems in combination with a particle identification based on a time–of–flight measurement and the dE/dx–information of two scintillation hodoscopes and a large area scintillation wall allow a complete determination of the four–momentum vectors of both baryons in the exit channel. Apart from positively charged kaons being detected by the drift chamber and scintillation hodoscope system used in case of the outgoing baryons, a detection of negatively charged kaons is provided by a silicon pad detector and an additional scintillation counter mounted inside the dipole gap.
Due to the narrow opening of the dipole gap the geometrical acceptance of the detection system is limited especially in the vertical direction. The geometrical efficiency for detecting two protons and, additionally,

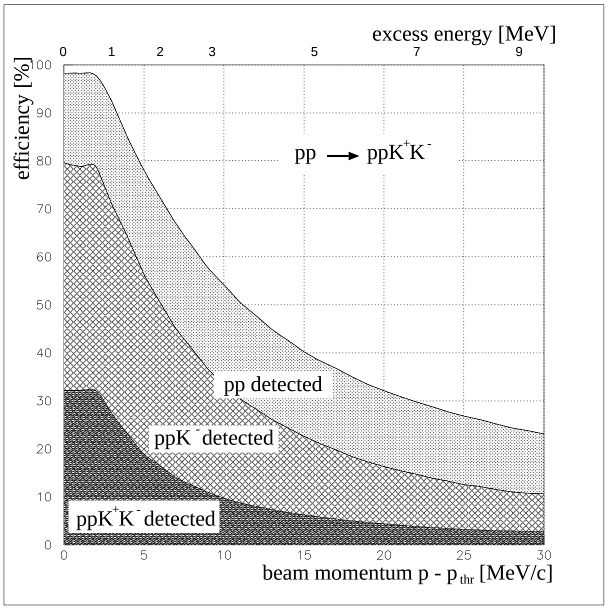

Figure 2: Geometrical efficiency of the COSY–11 detection system for the reaction $pp \to ppK^+K^-$ including the kaon decay probability.

charged kaons, as derived from Monte Carlo calculations is shown in fig. 2 as a function of the beam momentum above threshold ($p_{beam}^{thresh} = 3.3018$ GeV/c) and the excess energy, taking into account the possible kaon decay before detection. For a more detailed coverage of the COSY–11 detection system see [14].

Achievements

In October 1995 first data on the reaction $pp \to ppK^+K^-$ have been taken at the COSY–11 installation with beam momenta of 3.305 GeV/c and 3.308 GeV/c, corresponding to excess energies of 1.0 MeV and 2.0 MeV, respectively, and a total running time of three days each. Using new beam optics (see "Status Report on the COSY–11 Installation" and [14]) an estimated luminosity of $\approx 8 \times 10^{29}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ has been

reached during these measurements. Although the analysis of these data is still in progress, first encouraging signals and an estimate of the counting rate will be presented.
Figure 3 shows a preliminary result of about 10% of the data taken at 3.308 GeV/c. Only events with

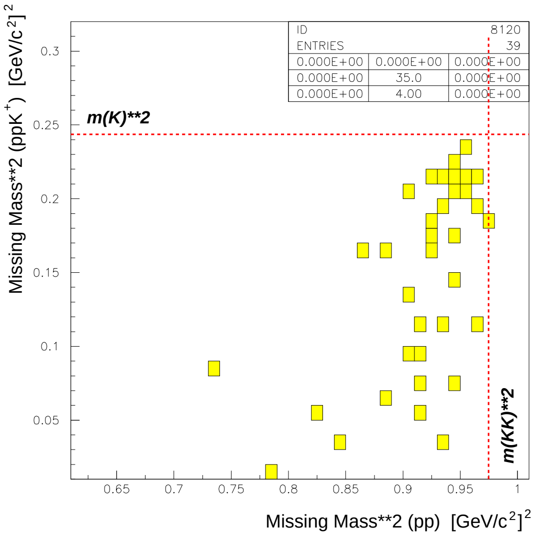

Figure 3: Reconstructed missing mass (squared) in the (ppX^+)–system as a function of the missing mass (squared) in the (pp)–system obtained from three–track events at a beam momentum of 3.308 GeV/c.

three reconstructed tracks crossing the start and stop scintillators S1 and S3 within wide areas limited by Monte Carlo simulations and two tracks each corresponding to an invariant mass close to the proton mass are accepted. Events within an enhancement in the region of the expected squared missing masses of the two subsystems (proton–proton and proton–proton–kaon, respectively) are chosen to be candidates for a (ppK^+K^-) final state. The discrepancy in fig. 3 between the position of the enhancement and the expected

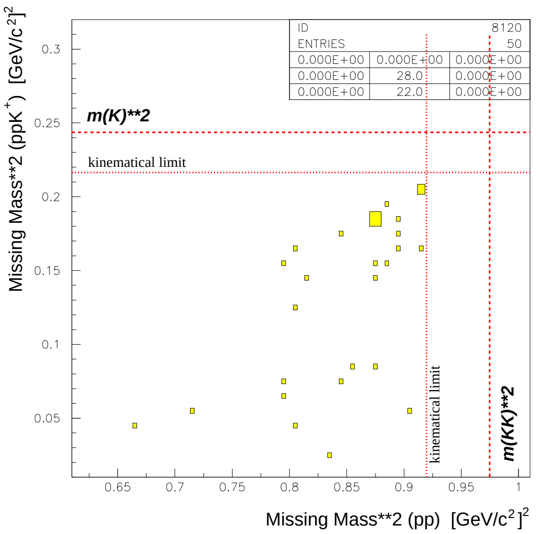

Figure 4: Reconstructed missing mass (squared) in the (ppX^+)–system as a function of the missing mass (squared) in the (pp)–system obtained from three–track events at a beam momentum of 3.212 GeV/c.

position at the squared mass of one and two kaons, respectively, is accounted for by the treatment of the magnetic field by the analysis algorithm. These effects have been studied, and are still under investigation, an improved magnetic field calibration will be implemented in the near future.

Data taken at a beam momentum of 3.212 GeV/c close to the η' threshold and about 90 MeV/c below the K^+K^- threshold were analyzed in the same way and with similar statistics to estimate the experimental background. The lower kinematical limits of the squared missing masses are indicated in fig. 4. Close to these limits, no enhancement comparable with fig. 3 is seen.
The reconstructed tracks from one of the candidates are shown in fig. 5, indicating the corresponding hits in the drift chamber systems D1 and D2 as well as in the scintillation counters S1, S2 and S3.

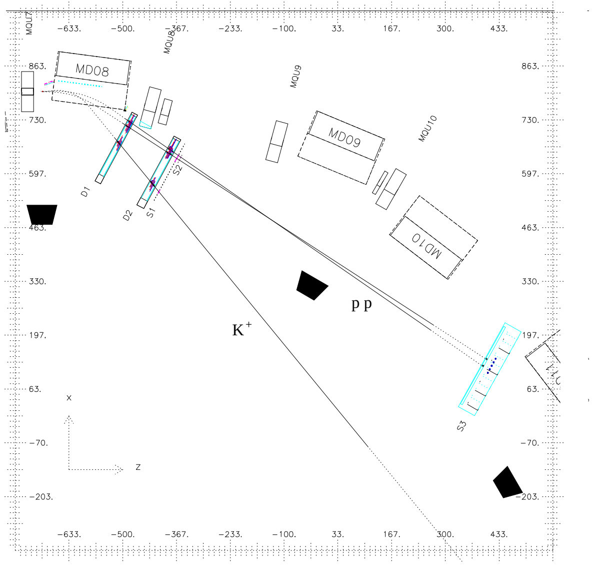

Figure 5: Schematic view of the COSY–11 detection system with reconstructed tracks of two protons and a positively charged kaon.

In comparison of fig. 3 and fig. 4 close to the kinematical limits we estimate preliminarily from the number of (ppK^+K^-) final states out of three–track events a counting rate of $\approx 4\,K^+K^-$ pairs measured per hour, taking into consideration the limited acceptance for the additional detection of positively charged kaons.

Outlook and Beam Request

p_{beam} [GeV/c]	excess energy[a] [MeV]	acceptance[b] [%]	counts[c] [1/day]	required counts	required time [days]	measured[d] time [days]	requested time [days]
3.295	-2.0	-	-	-	3	-	3
3.305	1.0	92.3	130	500	4	4	-
3.308	2.0	72.4	100	500	5	3	2
3.324	7.0	29.8	40	500	12	3	9
3.330	9.0	24.4	35	500	15	3	12
							$\sum = 26$

[a] above K^+K^- threshold
[b] for the detection of two protons
[c] assuming an energy independent cross section
[d] measured in October 1995 and planned for April/May 1996

Table 1: Proposed beam settings for the study of $pp \rightarrow ppK^+K^-$ close to threshold and required beam time.

While the study of three–track events will be continued, the data analysis algorithm for only two–track events, including a possible detection of a negatively charged kaon, should be developed. In addition, as discussed above, the treatment of the magnetic field within the track reconstruction has to be improved.
For the time being, we propose to scan the relevant momentum range in the proton proton interaction at five different energies:

- one beam momentum below the K^+K^- threshold ($p_{beam}^{thresh} = 3.3018$ GeV/c), marked ① in fig. 1,
- two beam momenta above but close to the K^+K^- threshold, at excess energies of 1.0 MeV (②) and 2.0 MeV (③), respectively, corresponding to the momenta already chosen,

- and two beam settings just below (④) and above (⑤) the $K^0\overline{K^0}$ threshold ($p_{beam}^{thresh} = 3.3327$ GeV/c).

Through lack of any experimentally known cross section values, and, in addition, to the best of our knowledge, through lack of any theoretical predictions concerning the K^+K^- production cross section in the proton proton interaction close to threshold, counting rates at higher energies, i. e. close to the $K^0\overline{K^0}$ threshold, can only be estimated from the measured counting rates. Thus, necessary beam times given in table 1 are based on the extracted counting rate at a beam momentum of 3.308 GeV/c, assuming a constant cross section and taking into account changes of the geometrical acceptance of the detection system.

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