# COSY Proposal / Beam Time Request

For Lab. use

| Exp. No.: | Session No. 35 |
|---|---|
| | |

Title of Experiment______________________________________________

Precision measurement of the pp → $ppK^+K^-$ cross section below the φ threshold______________

Collaborators: Institute:

see proposal, ______________________ see proposal__________________________________

and the ANKE collaboration_________

(Continue on separate sheet if necessary)

Spokesperspersons for collaboration: Name: M. Hartmann________________________________


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**Is support from the LSF program of the EC requested?**

Yes No

Date: April 14th , 2008_____


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| Total number of particles and type of beam (p,d,polarization) | Momentum range (MeV/c) | Intensity or internal reaction rate (particles per second) minimum needed | maximum useful |
|---|---|---|---|
| $1\text{-}6\cdot10^{10}$ protons | 3381 | $\geq 1\cdot10^{31}cm^{-2}s^{-1}$ | |
| **Type of target** | **Safety aspects (if any)** | **Earliest date of Installation** | **Total beam time (weeks)** |
| hydrogen cluster-jet target | | September 2008 | 3 |

What equipment, floorspace etc. is expected from Forschungszentrum Jülich/IKP?

## Summary of experiment

The ANKE collaboration has measured the cross sections for pp → ppK+K- at three energies above the ϕ threshold. The differential spectra for the non-ϕ data show clear evidence for the influence of final state interactions in the pp and K-p as well as the K+K- systems and these are reflected in the energy dependence of the total cross section. Such behaviour can be understood within the framework of a factorised final state interaction model.

We would like to continue these studies below the ϕ threshold in order to investigate the effects in greater detail. In order to achieve this, **we request** in total **three weeks** of beam time to measure K+K- production in pp collisions at beam energy 2.57 GeV. This should provide about 1000 ppK+K- events at an excess energy of 25 MeV.

Attach scientific justification and a description of the experiment providing the following information:

**For proposals:**

Total beam time (or number of particles) needed; specification of all necessary resources

**For beam requests:**

Remaining beam time (allocations minus time already taken)

**Scientific justification:**

What are you trying to learn?
What is the relation to theory?
Why is this experiment unique?

**Details of experiment:**

Description of apparatus.
What is the status of the apparatus?
What targets will be used and who will supply them?
What parameters are to be measured and how are they measured?
Estimates of solid angle, counting rate, background, etc., and assumptions used to make these estimates.
Details which determine the time requested.
How will the analysis be performed and where?

**General information:**

Status of data taken in previous studies.
What makes COSY suitable for the experiment?
Other considerations relevant to the review of the proposal by the PAC.

**EC-Support:**

The European Commission supports access of new users from member and associated states to COSY. Travel and subsistence costs can be granted in the frame of the program Access to Large Scale Facilities (LSF).

# Proposal/Beam-time request: Precision measurement of the pp → ppK$^+$K$^-$ cross section below the $\phi$ threshold

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April 14, 2008

**Abstract**

The ANKE collaboration has measured the cross sections for $pp \to ppK^+K^-$ at three energies above the $\phi$ threshold. The differential spectra for the non-$\phi$ data show clear evidence for the influence of final state interactions in the $pp$ and $K^-p$ as well as the $K^+K^-$ systems and these are reflected in the energy dependence of the total cross section. Such behaviour can be understood within the framework of a factorised final state interaction model. We would like to continue these studies below the $\phi$ threshold in order to investigate the effects in greater detail. In order to achieve this, we request in total three weeks of beam time to measure $K^+K^-$ production in $pp$ collisions at beam energy 2.570 GeV. This should provide about 1000 $ppK^+K^-$ events at an excess energy of 25 MeV.

## 1 Physics case

The COSY-11 collaboration made measurements of the $pp \to ppK^+K^-$ cross section at excess energies of $\epsilon_{KK} = 10$ and 28 MeV [1]. These were carried out below the nominal threshold for $\phi$ production, which is at $\epsilon_{KK} = 32.1$ MeV, though the tail of the $\phi$ does extend below this value. In the 28 MeV data they noted a strong tendency for the $K^-$ rather than the $K^+$ to be attracted to the final protons. Specifically, if we define the ratio of the acceptance–corrected distributions in the $Kp$ invariant masses

$$R_{Kp} = \frac{d\sigma/dM(K^-p)}{d\sigma/dM(K^+p)}\,, \tag{1}$$

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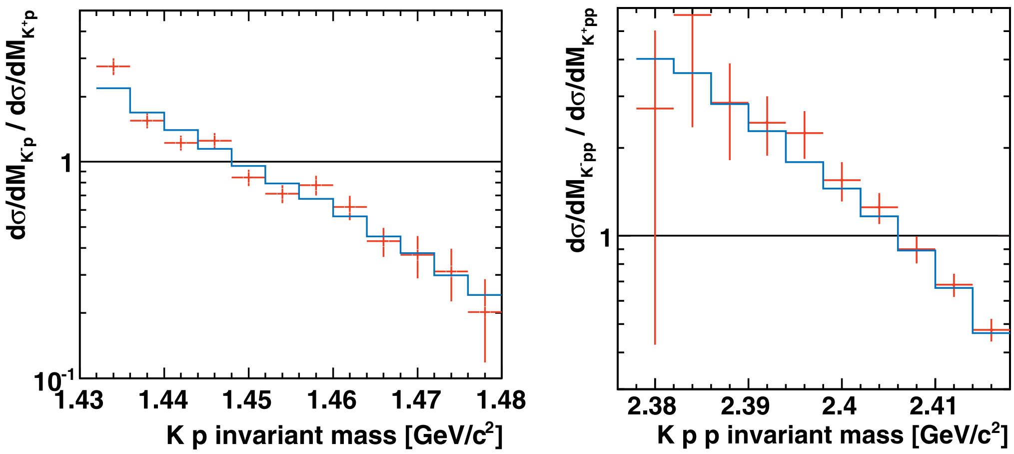
then this showed a very strong preference for low values of $M(Kp)$. The evidence is much less clear for the 10 MeV data, in part because the resolution in $M(Kp)$ is a larger fraction of the 10 MeV/c$^2$ available range but also because of the smaller cross section and the inevitably lower statistics. after taking into account all efficiencies Similar measurements were subsequently carried out using the ANKE spectrometer [2, 3]. In this case the data were taken at excess energies of $\epsilon_{KK} = 51$, 67, and 108 MeV, *i.e.* well above the $\phi$ threshold. The analysis therefore required a very careful study of the $K^+K^-$ invariant mass spectrum in order to separate the $\phi$ from the non-$\phi$ contribution to the differential and total cross sections.

The COSY-11 results on the ratio of the $K^-p$ to $K^+p$ invariant mass distributions were confirmed and extended over a much wider range of masses. It was then found that $R_{Kp}$ varied by about an order of magnitude between the smallest and largest allowed values of $M(Kp)$, as illustrated in Fig. 1a for the $\epsilon_{KK} = 51$ MeV data.




(a) Data in terms of the $K^-p$ and $K^+p$ invariant masses.

(b) Data in terms of the $K^-pp$ and $K^+pp$ invariant masses.

Figure 1: Ratios of the differential cross sections for the $pp \to ppK^+K^-$ reaction at $\epsilon_{KK} = 51$ MeV away from the $\phi$ region. Experimental data (crosses) are compared to a Monte Carlo simulation (histograms).

Equally striking was the behaviour of the three-particle invariant-mass distribution, where the ratio

$$R_{Kpp} = \frac{d\sigma/dM(K^-pp)}{d\sigma/dM(K^+pp)}\,, \tag{2}$$

shown in Fig. 1b, presents the same strong bias towards low masses of the $Kpp$ system.

The magnitude and variation of both the $R_{Kp}$ and $R_{Kpp}$ ratio could be described quantitatively at all three energies by assuming that there were simultaneous final state interactions between the $pp$ and both $K^-p$ pairs of particles.

Within the framework of this simple *ansatz*, the only free parameter is what can be called an effective $K^-p$ scattering length. Once this is has been fixed by the $\epsilon_{KK} = 51\,\text{MeV}$ results, the model describes well the other ANKE data and also those of COSY-11 at 28 MeV.

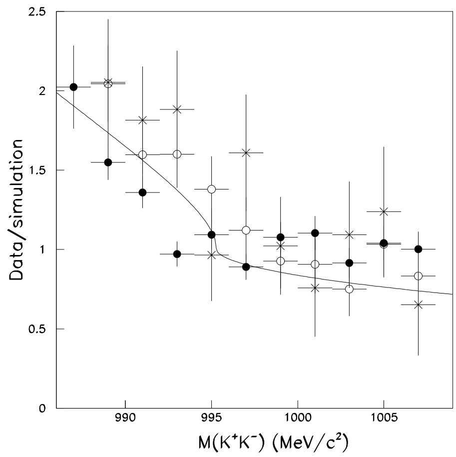



Figure 2: The ratio of the experimental $K^+K^-$ invariant-mass distribution to the Monte Carlo simulation of the $pp \to ppK^+K^-$ reaction. The experimental data were obtained at 2.65 GeV (closed circles), 2.70 GeV (open circles), and 2.83 GeV (crosses). The curve is an illustration of what one would expect to follow from the coupling of the $K^+K^-$ to the $K^0\bar{K}^0$ channels if this were purely in isospin $I = 0$.

The other surprising result from the ANKE data is that the $K^+K^-$ invariant mass distribution for all three beam energies lies above the simulation for $M(K^+K^-) < 995\,\text{MeV/c}^2$. Furthermore, exactly the same effect is seen in the DISTO $pp \to ppK^+K^-$ results [4] and the ANKE data on $pn \to dK^+K^-$ [5]. This is illustrated for the $pp \to ppK^+K^-$ data in Fig. 2 by dividing the experimental values by the simulation. It is tempting to suggest that the anomaly at low invariant masses might be a cusp effect associated with the opening of the $K^0\bar{K}^0$ channel. If, as a simple model, we take the coupling to be purely in isospin $I = 0$ then the curve in the figure shows that effects of this nature are to be expected [6].

The channel coupling might also account for the variation observed in the total cross section, where its value at low excess energy is higher than expected on the basis of phase space modified by the different final state interactions [7]. The structure in this region will therefore be sensitive to the transitions $K^+K^- \rightleftharpoons K^0\bar{K}^0$, which must therefore be very strong. The study of the $pp \to ppK^+K^-$ reaction in greater detail might therefore cast further light on the interaction of the $K^-$ with both protons and with the $K^+$, both of which are subjects of great interest.

In order to pursue this research further, we would like to continue the study of the $pp \to ppK^+K^-$ reaction at ANKE by measuring below the $\phi$ threshold. At an excess energy of $\epsilon_{KK} = 25\,\text{MeV}$ ($T_p = 2.570$ GeV), the contamination from the production of the leading edge of the $\phi$ wing will be minimal. On the other hand, the ranges in the $Kp$ and $Kpp$ invariant masses will still allow the $R_{Kp}$ and $R_{Kpp}$ ratios to be examined in great detail, which would pin down the value of the effective scattering parameter with greater accuracy.

Of potentially greater importance, though, is that we would like to obtain much more precision in the $K^+K^-$ invariant mass spectrum to investigate the structure around the $K^0\bar{K}^0$ threshold. Any deviations in the rest of the spectrum from the simulation could also be an indication of the influence of the scalar $a_0/f_0$ resonances, whose presence might already being felt through the strength of the $K^+K^- \rightleftharpoons K^0\bar{K}^0$ transitions.

The *pp fsi* distribution will also be studied in finer detail, since this will help us to understand better the excitation function and also the strength of the $K^+K^-$ bump.

# 2 Simulation at an excess energy of 25 MeV

In order to estimate the detection rates and optimise the ANKE detector setup, the $pp \to ppK^+K^-$ reaction was simulated using the GEANT4 package [8]. The input distribution was generated at an excess energy of 25 MeV using the model detailed in Ref. [3], which includes the *pp* final state interaction as well as the $K^-p$ with an effective scattering length. The results of the simulation were normalised to a total $pp \to ppK^+K^-$ production cross sections of 4 nb [3]. Using this together with a luminosity of $1.5 \times 10^{31}\text{cm}^{-2}\text{s}^{-1}$, the estimated count rate of the ANKE detector is given by

$$n = L\left(\frac{d\sigma}{d\Omega}\right)\Delta\Omega\ \epsilon_{\text{eff.}} = L \times \sigma_{total} \times \epsilon_{\text{total}}. \tag{3}$$

The estimated total efficiency used above, $\epsilon_{\text{total}} = 1.1\%$, is made up of the following partial efficiencies:

(*i*) The ANKE detector acceptance $\epsilon_{\text{acceptance}} = 4\%$ for the assumed input distribution at 25 MeV;

(*ii*) Considering the COSY duty time between the cycles, the time for regeneration of the hydrogen cluster-jet target, as well as possible down-times of the COSY accelerator, we take $\epsilon_{\text{COSY}} = 70\%$;

(*iii*) The detection efficiency $\epsilon_{\text{detector}} = 50\%$ is given mainly by the overall efficiency of the multi-wire chambers for positively charged (ANKE side and forward systems) and negatively charged particles;

($iv$) The data-taking efficiency of the ANKE data acquisition system $\epsilon_{\mathrm{daq}} = 80\%$.

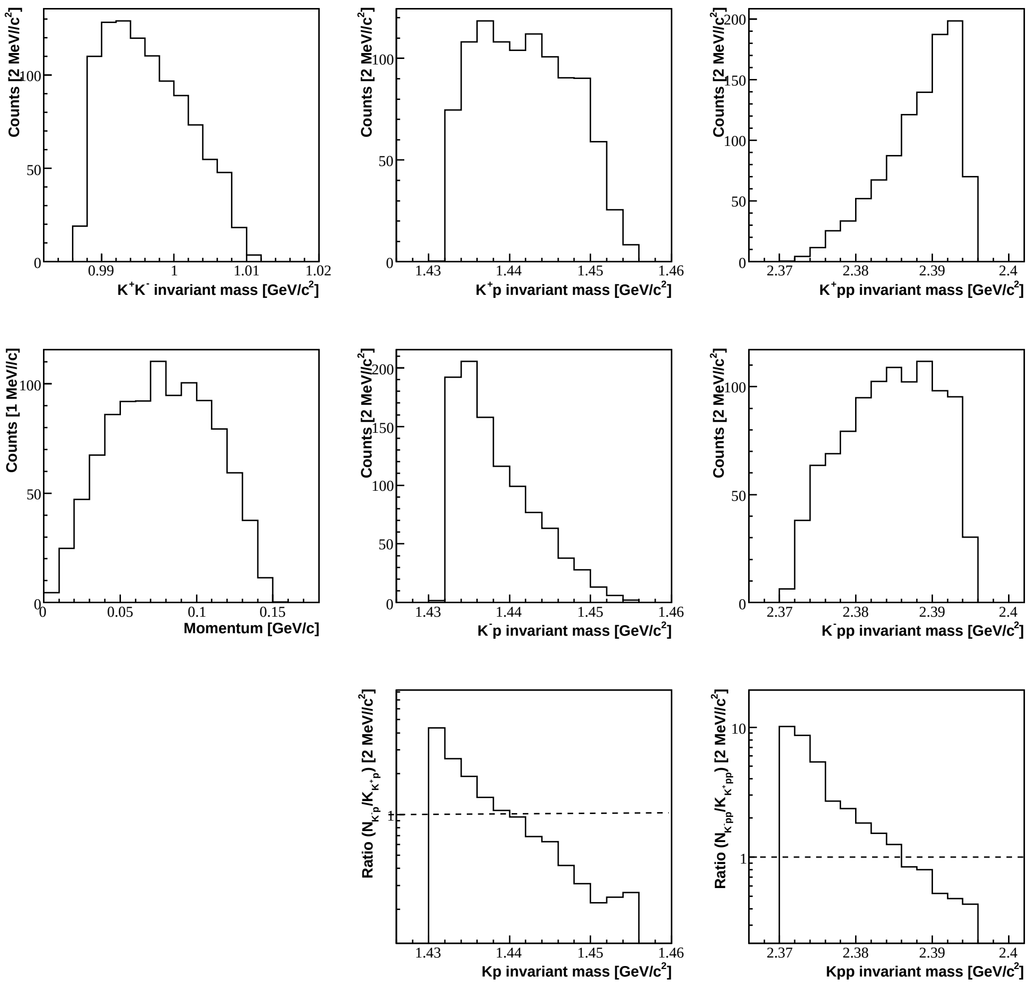



Figure 3: Monte Carlo simulation of the $pp \to ppK^+K^-$ reaction at $T_p = 2.570$ GeV. The input distributions have been generated using four-body phase space moderated by final state interactions in the $pp$ and $K^-p$ systems. No account has been taken of the $K^+K^-$ *fsi* which will influence the low-mass part of the $K^+K^-$ distribution. Although about $10^4$ of the generated events passed through all the selection cuts, these have been scaled down to the $10^3$ events expected to be measured in the experiment.

After taking into account all efficiencies, the number of detected $K^+K^-p$ correlations expected from 18 days of data-taking is about 1000 events. Figure 3 shows the simulated spectra for the $K^+K^-$ invariant mass and the proton-proton relative momentum as well as the $K^{\pm}p$ and $K^{\pm}pp$ invariant mass distributions and the charge ratios. Final state interactions in the $pp$ and $K^-p$ systems have been included but not one between the $K^+$ and $K^-$. About $10^4$ good events were generated but these have been scaled down to the $10^3$ expected in the experiment. The statistical fluctuations will therefore be larger than those shown and be closer to those of Fig. 1.

To bring the ANKE spectrometer into operation for the experiment presented here requires about three additional days in order to complete:
(i) Setup and operation of the ANKE detectors, electronics and readout systems;
(ii) adjustment of individule strobe signals for chamber, TDC, and ADC (QDC) readouts, as well as general trigger conditions and/or correlations;
(iii) calibration of the positive time-of-flight (TOF) trigger electronics for the hardware $K^+$ TOF trigger, setup of several hundred So-Sa counter TOF-windows [9]
(iv) absolute time calibration of all negative and forward STOP counters relative to the in-trigger leading positive STOP counters, calibration of around 600 two-dimensional time spectra using measurements of $\pi^+\pi^-$, $\pi^+p$ and $\pi^+\pi^-p$ particle correlations (calibration runs) [10].

# 3 Beam time request

In total we request three weeks of beam time to measure the $K^+K^-$ production in $pp$ collisions at a beam energy of 2.570 GeV. This energy corresponds to an excess energy of 25.0 MeV above the kaon pair production threshold. During this time we expect to collect about 1000 $K^+K^-p$ correlations.

The ANKE spectrometer is the optimal instrument for this purpose. The measurement would be ready to start from September 2008.

# References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