COSY Beam Request

For Lab. use

Exp. No.:	Session No.
55.2	**23**

Title of Experiment **Study of a_0^+ Mesons with ANKE**

Collaborators:
_______The ANKE collaboration____
__________(see prop. 55.1)_________

(Continue on separate sheet if necessary)

Institute:

Spokesman for collaboration: Name: _M.Büscher______________________________

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Is support from the LSF program of the EC requested?
No

Date: _Oct.-05-2001___________

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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
unpolarized p Int.=$4 \cdot 10^{10}$	≥ 3510	$L \sim 1 \cdot 10^{31}$ cm^{-2}s^{-1}	
Type of target	**Safety aspects (if any)**	**Earliest date of installation**	**Total beam time (weeks)**
H_2, Cluster jet		Febr. 2002	3

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

ANKE spectrometer

Summary of experiment (do not exceed this space):

We apply for the allocation of **three weeks** of beam time (before April 2002) to continue measurements on the near-threshold production of $a_0^+(980)$ resonances in the reaction channel pp $\rightarrow$ da_0^+ ($\rightarrow$ d $K^+K^0/\pi^+\eta$). The relevance of these studies as well as the feasibility to investigate these reaction channels using the ANKE spectrometer was demonstrated in our COSY proposal #55.1. This proposal was approved during the 20th session of the COSY-PAC.

Proposal #55.1 foresees a total beam time of 5 weeks for the study of the a_0^+ resonance. Two out of these 5 weeks were scheduled in Jan./Febr.2001 and first measurements at a beam energy of T=2.65 GeV (p=3.463 GeV/c, Q~45 MeV above the KK threshold) were performed. This beam time is the first exclusive study of a_0 production in pp collisions up to now. The current status of the data analysis can be summarized as follows (see Appendix A for details):

- Very high luminosities of $L \sim 4 \cdot 10^{31}$ cm^{-2} s^{-1} were achieved using a H_2 cluster-jet target.
- The reaction channel pp $\rightarrow$ dK^+K^0 can be selected virtually without any background. Roughly 600 events have been identified up to now which is in line with our cross-section and count-rate estimate from the proposal. The shape of the K^+K^0 mass distribution can be interpreted in terms of $a_0^+(980)$ production.
- The reaction channel pp $\rightarrow$ $d\pi^+\eta$ (via a narrow, Γ~40 MeV, resonance at 980 MeV/c^2) is visible on top of a large background from non-resonant multi-pion production (~3000 events).
- As a by-product, the production of $\Lambda(1116)$, $\Sigma(1189)$, $\Sigma(1385)$, $\Lambda(1405)$ and $\Sigma(1480)$(?) hyperons in pp $\rightarrow$ pK^+Y reactions has been observed.

We now apply for the allocation of the remaining three weeks of beam time at one or two higher beam energies in the range T=2.7...2.75 GeV (p=3.515...3.567 GeV/c). As outlined in Appendix B, these measurements are needed for a clear interpretation of the data in the framework of resonant (via the a_0^+) $K^+K^0/\pi^+\eta$ production. In contrast to the assumption in the original proposal it is not necessary to use the frozen-pellet target for these measurements because:

- The *luminosity* achievable with the cluster target is about *one order of magnitude larger* than anticipated.
- It was previously foreseen to continue the measurements at *lower beam energies* closer to the KK threshold because the maximum energy reachable with COSY was estimated to be T~2.65 GeV. It turned out that the beam energy can be increased above this limit. Thus, for the continuation of our measurements *larger cross sections* are expected.

The higher beam energy will make available a larger mass range for the a_0^+ resonance (Q~60...80 MeV) thus making the interpretation of the data and background subtraction easier, see Appendix B for details. The data will also allow to determine the excitation function for a_0^+ production in pp collisions and the life time (i.e. width) of the a_0^+ meson. It will also be possible to get a clear signal from the $\Sigma(1480)$ from which, in the current data set, only the low mass tail is visible.

For an optimized utilization of the beam time and in order to minimize systematical uncertainties it will be necessary to perform these measurements in one continuous block of beam time. This time should be scheduled early in 2002 since COSY cannot operate at the desired maximum energy during summer time due to cooling problems of the power supplies. Furthermore, we intend to commission and calibrate counters for K^- mesons during this beam time. These counters will be needed in a following measurement (spring 2002, if approved by the PAC) for the study of ϕ-meson production, see the corresponding proposal submitted to this session of the PAC.

Appendix A: Status of the data analysis

In Jan./Febr. 2001 the production of scalar mesons in proton-proton collisions was investigated for the first time at ANKE during a two-weeks beam time. As described in proposal #55.1, deuteron-kaon (deuteron-pion) pairs produced in $pp \to dK^+X(d\pi^+X)$ reactions at a beam energy of $T = 2.65$ GeV were detected. The kaons were identified in dedicated range telescopes which offer an excellent kaon-vs.-background discrimination [1, 2]. This allows to unambiguously identify the events with K^+-mesons in the exit channel. The pions were detected in so-called side-wall counters where only the time-of-flight information can be used for particle identification. The momenta of both, kaons and pions, can be deduced from the information of the two MWPC's positioned at the side of the spectrometer dipole D2 [1, 3]. The coincident fast deuterons ($p_d \sim 2.1$ GeV/c) are detected in the ANKE forward-detection system consisting of scintillation counters for TOF measurements and three MWPC's for momentum reconstruction. In Fig. 1 missing-mass distributions (calculated from the measured momenta of the K^+, π^+ and d) for the $pp \to dK^+X$ and $d\pi^+X$ events are presented.

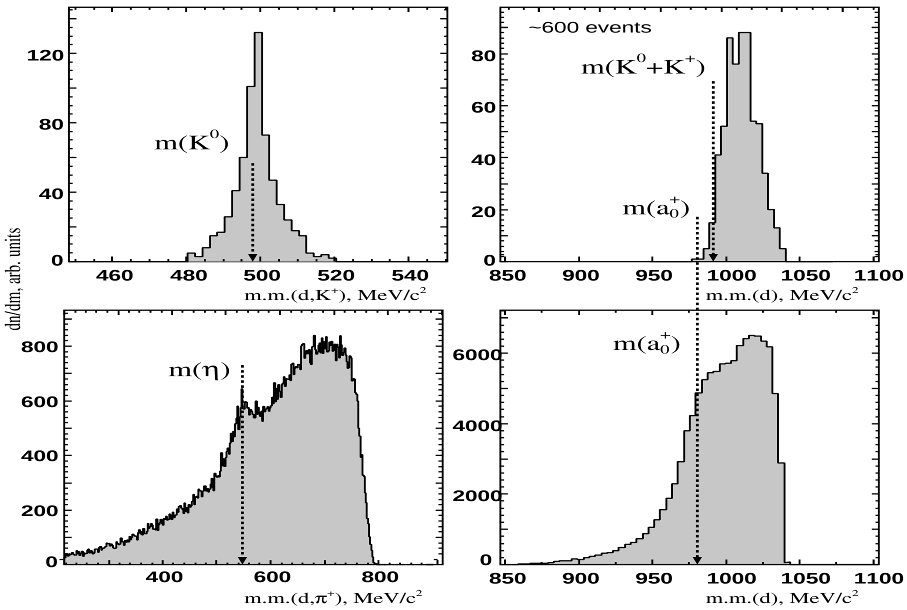

Figure 1: Missing-mass spectra for the reactions $p(2.65\ GeV)p \to dK^+X$ (upper) and $\to d\pi^+X$ (lower). The distributions are not yet corrected for the detection efficiencies. The events shown in the upper (lower) spectra correspond to a measuring time of approx. 5 (3.5) days.

The upper left spectrum of Fig. 1 shows the missing mass of the detected dK^+-pairs. Due to charge and strangeness conservation, at $T = 2.65$ GeV the remaining particle X must be a $\overline{K}^0$. As expected for such $pp \to dK^+\overline{K}^0$ events, the measured dK^+ missing-mass distribution peaks at $m = m_{K^0} = 498$ MeV/c^2. The corresponding mass distribution of the two kaons (i.e. deuteron missing mass) is shown on the upper right spectrum of Fig. 1. Both distributions are free of background from misidentified particles, see also discussion in Appendix B.

At $T_p = 2.65$ GeV the available phase space of the two kaons extends from $m_{\rm min} = m_{K^+} + m_{K^0} = 992$ MeV/c^2 to $m_{\rm max} = 1038$ MeV/c^2 which is small compared to the expected width of the a_0^+, $\Gamma_a \sim 50-100$ MeV/c^2[4], if produced at large energies. Figure 2 shows the predicted a_0^+ mass distributions for the two observed decay channels and $T = 2.65$ GeV. For the calculations a total width of $\Gamma_{a_0^+} = 70$ MeV has been used. The apparently smaller widths in the spectra of Fig. 2 are due to the limited available phase space at $T = 2.65$ GeV and the dominance of P-wave a_0^+-production close to threshold [5].

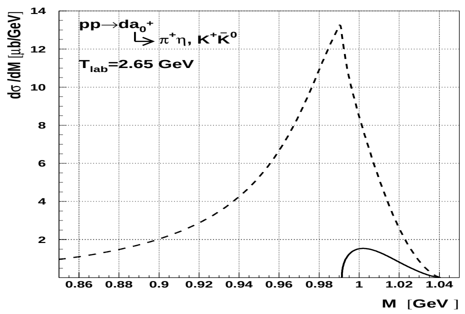

Figure 2: Expected a_0^+ mass distributions for the two main decay channels $a_0^+ \to K^+\overline{K}^0$ (solid line) and $\pi^+\eta$ (dashed). The calculations were performed using the model described in [5].

The main goal of this measurement with ANKE is to extract from the data information about possible resonant $K^+\overline{K}^0(\pi^+\eta)$-production, e.g. via the scalar meson $a_0^+(980)$. This part of the analysis is still in progress and will be based on the analysis of acceptance corrected missing-mass and angular distributions as well as of Dalitz plots. Certainly, the interpretation of the peak in the $K^+\overline{K}^0$-mass spectrum of Fig. 1 will to some extend be model dependent (see e.g. [5, 6] for an overview over different models and their predictions for different mass distributions). At the current stage of the analysis it can already be stated that *i)* there is a good agreement between the measured and predicted [5, 6] $K^+\overline{K}^0$-mass distributions and *ii)* additional data taken at larger beam energies would make the interpretation of the observed peaks easier since a wider mass range of the a_0^+-resonance could be covered. In particular, the mass distribution of (possible) non-resonant $\to K^+\overline{K}^0$ pairs should differ significantly from kaons produced via the $a_0^+(980)$ resonance [5], although it is expected that such background is negligible in our data, see [5, 7] and discussion in Appendix B. Furthermore, the measurement of the a_0^+ excitation function may further help to obtain information about the width of this resonance [8].

The lower spectra of Fig. 1 show the missing-mass distributions for $d\pi^+$ coincidences. In contrast to the background free spectra in case of K^+-production, the expected peak from the missing η-meson sits on a huge background from, e.g., multi-pion production. Nevertheless, a peaking of the deuteron missing mass around 980 MeV/c^2 is clearly visible. The width of this peak, $\Gamma \sim 40$ MeV/c^2 is in good agreement with the prediction from Fig.2. It is expected that from these data the cross section for the reaction $pp \to da_0^+ \to d\pi^+\eta$ can be extracted. As for the case of the $a_0^+ \to K^+\overline{K}^0$ decay, it would clearly be advantageous to obtain data at larger beam energies since background subtraction will be easier.

In summary, the following results can be expected from the data shown above:

- The total cross sections for the reactions $p(2.65\ GeV)p \to da_0^+(980) \to dK^+\overline{K}^0$ and $\to d\pi^+\eta$ can be determined. For the former decay channel theoretical considerations about the strength of non-resonant kaon production will be part of the analysis.
- Missing-mass and angular distributions of the produced $K^+\overline{K}^0$- and $\pi^+\eta$-pairs can be obtained and compared with the predictions from different models. The location and width of the resonance at $m = 980$ MeV/c^2 can be determined.
- The branching ratio of the two main decay channels $a_0^+ \to K^+\overline{K}^0/\pi^+\eta$ can be extracted from the data.
- The $\overline{K}^0 d$ missing-mass distribution will allow to draw conclusions about the $\overline{K}^0 d$ FSI (see, e.g., [6]).

As a "by-product" of the a_0^+ beam time also coincident K^+p events were recorded. Figure 3 shows the missing-mass distributions for these data. Two peaks at $m_Y \sim 1.12$ and ~ 1.20 GeV/c^2 can clearly be seen. The left-hand spectrum in Fig. 3 shows the result of a simulation calculation for the production of $\Lambda(1116)$ and $\Sigma(1193)$-hyperons and the detection of their decay products with ANKE. A cross section ratio of $\sigma_\Lambda/\sigma_\Sigma = 6.6$ yields the best agreement between simulation and data. This cross-section ratio is in good agreement with results from other measurements at comparable energies [9].

The right-hand histogram in Fig. 3 shows the K^+p missing-mass distribution if the coincidence with an additional π^+-meson is demanded. Thus events of the type $pp \to pK^+Y_1(\to \pi^+Y_2)$ can be selected. The remaining distribution shows two peaks around $m_{Y_1} \sim 1.40$ and ~ 1.44 GeV/c^2. According to our simulations the broader peak can be attributed to the production of $\Sigma(1385)$ and $\Lambda(1405)$-hyperons. The best agreement between the simulations and the measured distribution can be achieved for cross-section ratios of $\sigma_\Sigma(1385) = \sigma_\Lambda(1116)/35$ and $\sigma_\Lambda(1405) = \sigma_\Lambda(1116)/55$. The second, narrower, peak may be an indication for the production of $\Sigma(1480)$-hyperons. Since the maximum mass which can be produced at a beam energy of $T_p = 2.65$ GeV is $m_Y \sim 1.48$ GeV/c^2, only the low-mass tail of the distribution can be seen in the data. In order to obtain more information about the $\Sigma(1480)$ further measurements at increased beam energy are needed.

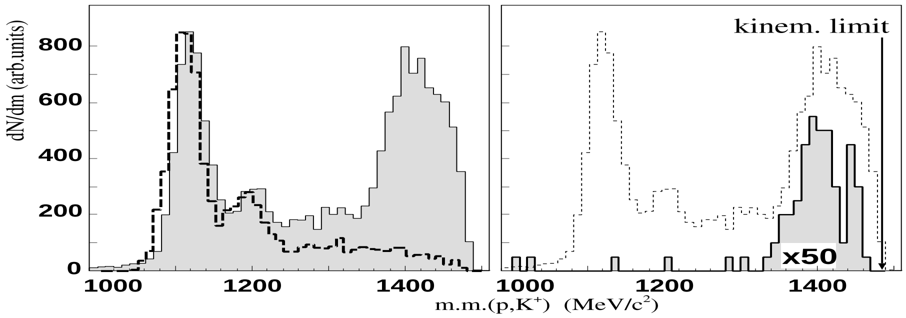

Figure 3: K^+p missing-mass spectra for the reaction $p(2.65\ GeV)p \rightarrow pK^+Y$. The left-hand side shows the measured distribution (shaded) in comparison with a simulation for reactions with $Y = \Lambda(1116), \Sigma(1193)$ scaled by an arbitray factor but with $\sigma_\Lambda/\sigma_\Sigma = 6.6$ (dashed histogram). For the (shaded) histogram on the right-hand side a coincidence with an additional π^+-meson has been demanded. The slight shift between the simulated and measured peak positions is due a preliminary momentum calibration of the spectrometer.

Appendix B: Motivation of further measurements

It has already been indicated in Appendix A that further measurements at one or two higher beam energies in the range $T = 2.7 \ldots 2.75$ GeV would be advantageous. In the following the expected benefits of such measurements are outlined in detail.

The reaction $\mathbf{pp \rightarrow dK^+\overline{K}^0}$: The available phase space for the two kaons at $T = 2.65$ GeV extends only from $m_{\min} = m_{K^+} + m_{K^0} = 992$ MeV/c^2 to $m_{\max} = 1038$ MeV/c^2. A measurement at e.g. $T = 2.7$ (2.75) GeV would increase the upper limit to $m_{\max} \sim 1054$ (1070) MeV/c^2. Therefore, the mass distribution of kaon pairs produced via the a_0^+-resonance could be studied in a wider mass range. Furthermore, possible background from misidentified or non-resonant events can be subtracted more easily which is demonstrated in Fig. 4. The solid histograms in Fig. 4 (upper part) show the reconstructed mass distributions if only very wide gates (on TOF and energy losses) are applied for kaon identification. The expected peak of the $\overline{K}^0$ now sits on a broad background distribution but can still clearly be seen (left spectrum). In the deuteron missing-mass distribution (right) only a background distribution, peaking at ~ 1030 MeV/c^2, is visible. There is no clear indication for a_0^+-production. The dashed histograms (lower spectra) show the same spectra but with narrower gates for particle identification. The amount of background now is reduced to $\sim 10\%$, as indicated by the hatched areas. In particular for the deuteron missing-mass distribution such background can be dangerous since it is not uniformly distributed but peaked at ~ 1030 MeV/c^2, thus distorting the reconstructed a_0^+ mass distribution. It is expected that possible background from events with correcly identified but non-resonant $K^+\overline{K}^0$ pairs follows the same phase-space like distribution as indicated by the hatched area (r.h.s). It is obvious that such non-resonant background can be more easily rejected if the accessible mass range can be extended. The peak-

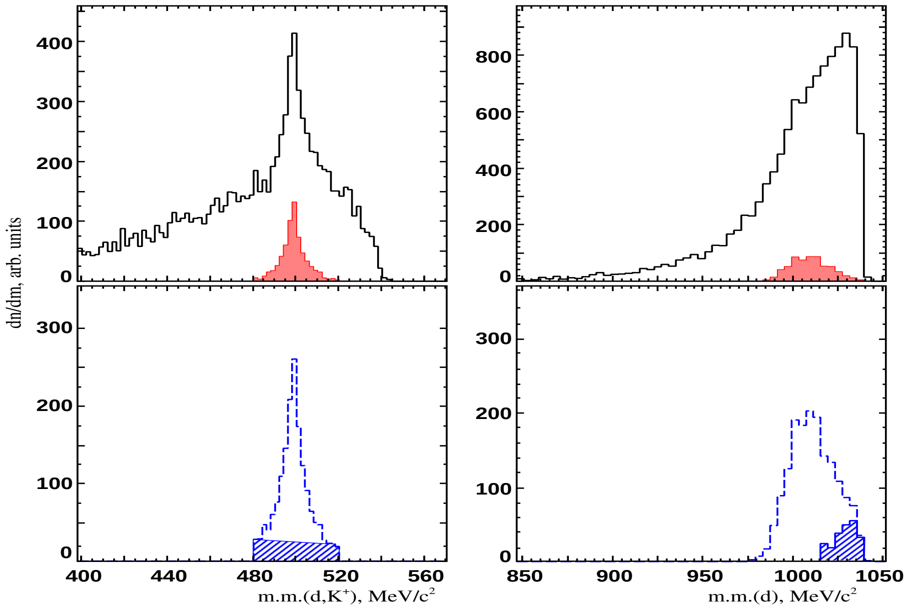

Figure 4: Missing-mass spectra for the reaction $p(2.65\ GeV)p \to dK^+X$ and different cuts for K^+ (and thus $\overline{K}^0$) identification. The hatched areas indicate the background of misidentified K^+-mesons contributing to the dashed histograms (lower spectra), see text for details. For comparison, the shaded histograms in the upper part show the background free missing-mass distributions from Fig. 1.

ing of the background is then expected at higher masses, well separated from the genuine a_0^+ distribution. For comparison, the background free distributions obtained with optimized gates from Fig. 1 (upper) are also shown. These spectra show no indication for any background, in particular no peaking at $m.m.(d) \sim 1030$ MeV/c^2. This can be interpreted such that there is no (or no significant) contribution from non-resonant kaon production in our data.

The reaction pp $\to$ d$\pi^+\eta$: It can be seen from the lower right spectrum of Fig. 1 that the signal from the a_0^+-resonance is located very close to the phase-space limit at $m.m.(d) \sim 1035$ MeV/c^2 and the background peak at $m.m.(d) \sim 1020$ MeV/c^2. This makes the background subtraction and a comparison with predicted mass distributions, c.f. Fig. 2, rather difficult. As for the case of the $a_0^+ \to K^+\overline{K}^0$ decay channel and discussed in Fig. 4, data from measurements at larger beam energies would clearly improve the situation.

The reaction pp $\to$ pK$^+$Y: As already mentioned in Appendix A, a measurement at higher beam energy would also make accessible the heavy $\Sigma(1480)$ hyperon. These data (K^+-p coincidences) will again be obtained as a by-product of the measurements on a_0^+ production. If these new data show that a systematical study of heavy hyperons, $\Sigma(1385)$, $\Lambda(1405)$ and $\Sigma(1480)$, is possible at ANKE, a new proposal will be prepared and presented to one of the future sessions of the PAC.

References

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