1 Abstract

It is proposed to study the production of ω- and Φ-mesons in pp-induced reactions at the COSY-11 facility in an excess energy range of up to 107 MeV. Although the detection efficiency is very low for higher excess energies the coverage of the whole Θ_{CM}-angular range is given. The feasibility for the observation of the ω-production up to high excess energies at COSY-11 can be shown from the analysis of existing data.

As a first step we propose to measure the angular distributions and the total cross sections for the ω-production at excess energies of 25, 50 and 107 MeV. These data should yield informations needed to clarify the role of different reaction mechanisms for ω production. Furthermore at an excess energy of 25 MeV the measurement of the Φ-production is planned in order to study the feasibility at COSY-11.

2 Introduction

This proposal should be considered as an extension of the proposal 45, ' *Production of the ω-Meson at Threshold in the reaction $pp \to pp\omega$ at COSY-11*', presented in November 1996 at the 13. PAC session [1]. Extending the proposal 45 measurements of angular distributions are included now. These data should yield informations needed to clarify the role of different reaction mechanisms for ω production.

The study of vector meson (V) production is very important for a better understanding of the hadronic interactions in the medium energy range. Of specific interest is here the elementary reaction $pp \to pp\ V$. First of all one hopes to obtain information about the nucleon-nucleon-vectormeson vertex functions, in particular the coupling constants. Furthermore due to the large mass of the vector mesons a fairly large momentum transfer is required in the production process and therefore the nucleon-nucleon interaction will be tested at relatively short distances. Finally, the amplitude of the elementary vector-meson production reaction is, of course, needed as input for any more microscopic studies of vector-meson production in light- or heavy-ion collisions.

The coupling of the ϕ meson to the nucleon is expected to be very small. This expectation is due to the phenomenological OZI rule, which says that processes involving disconnected quark lines are forbidden, and the naive quark model, in which the ϕ meson is a (ideally mixed) pure $\bar{s}s$ state whereas the nucleon is build up of just u- and d quarks. In practice the ϕ meson can couple to the nucleon through its small amount of $u\bar{u} + d\bar{d}$ admixture introduced by a deviation from the ideal mixing angle. This deviation is only about 4^o and accordingly, cross section ratios of reactions involving the production of a ϕ and ω meson, respectively are expected to be $R \approx tan^2\ 4^o \approx 4 \cdot 10^{-3}$. Clearly if the nucleon contains also a strangeness component this estimation is no longer valid. Then the ϕ coupling should be stronger and in turn the ϕ/ω production ratio should be larger. Evidently this suggests that ϕ production should be a very sensitve tool to study the strangeness component of the nucleon wave function.

In the past few years cross section ratios of ϕ/ω production were measured in different $\bar{p}p$ induced reactions channels [2]-[5] as well as in $pp \to pp\omega/\phi$ [6] and in $pd \to ^3\mathrm{He}\,\omega/\phi$ reactions [7]. In these experiments deviations from the estimation based on the OZI rule by up to a factor of 25 where observed. From these results a strangeness content of the nucleon of up to 20 % was deduced [8], [9]. However, the theoretical interpretation of the observed deviation from the OZI estimation is still controversial. Other theoretical approaches to the ϕ-production [10]-[15] showed that two-step processes involving $K\bar{K}$ and $\Lambda\bar{\Lambda}$ intermediate states, which are allowed by the OZI rule, lead to a drastic enhancement of the ϕ-production and, as a consequence, agreement with the existing experimental data can be achieved without introducing a strangeness component in the nucleon. In this context ϕ production in nucleon-nucleon collisions is of specific interest. In this reaction one does not expect any significant contributions from competing OZI-allowed two-step mechanisms [16]-[18]. Therefore cross section ratios $\sigma_{pp\to pp\phi}/\sigma_{pp\to pp\omega}$ should provide a clear indication for a possible OZI violation and the amount of hidden strangeness in the nucleon. Very recently first results from a measurment of this ratio were presented by the Disto collaboration [6], indicating an enhancement of about 10 over the OZI expectation. However, this experiment was carried out at a fixed nucleon laboratory energy ($T_{lab} = 2.85$ GeV) and hence effects from the differences in the phase space available for the produced ω's and ϕ's are not well under control. Therefore it is desirable to determine this ratio again, but measuring at the same excess energy of the vector mesons. In this case effects from the phase space should be small and also the influence of the final state interaction should cancel to a large extent.

Recently a theoretical analysis of ω production in proton-proton collisions within a meson exchange model was performed by Nakayama et al. [19]. Subsequently the model was also applied to ϕ production [20]. In this model the basic vector-meson production mechanisms are given by the nucleonic and mesonic currents as depicted in Fig. 1. Various mesonic currents are discussed and the authors conclude that the $\rho\pi$ meson exchange current is by far the most important one. On the other hand, the scarity of ω-production data in the low-energy region (only total cross sections and only three data points are available for excess energies below $Q = 300 MeV$) and uncertainties in the model arising from vertex form factors impede more detailed conclusions. In particular, it is not possible to determine which of the two production mechanisms is really the dominant one.

None-the-less the authors of Ref. [19] observe that the relative magnitude of the contributions from the nucleonic current (fig. 1a) and the meson exchange current (fig. 1b) influences the energy dependence of the $pp \to pp\omega$ cross section. This suggests that a measurement of the production cross section as a function of the incident energy should help to identify the dominant production mechanism. In addition Nakayama et al. [19] demonstrate that the angular distribution of the produced ω mesons is an even more sensitive observable. It provides a unique and clear signature of the magnitude of the two production mechanisms and therefore allows to unambigously disentangle the nucleonic current and the meson exchange current, see Fig. 2.

It is proposed to measure the energy dependence of the angular distribution for the ω-production at COSY-11. The angular distributions will allow to fix the relative contributions of nucleonic and mesonic parts and the energy dependence of these distributions on the other hand could help to constrain the vertex form factors [20].

Therefore such data will yield information needed for an extraction of the coupling constants and the relative importance of different production processes and will increase the accuracy of meson exchange model descriptions.

Besides of being of interest by itself a measurement of the angular distribution of the ω meson will be also very helpful for the study of the reaction $pp \to pp\phi$ by Nakayama et al. [20]. These authors carry out a combined analysis of ω- and ϕ production data

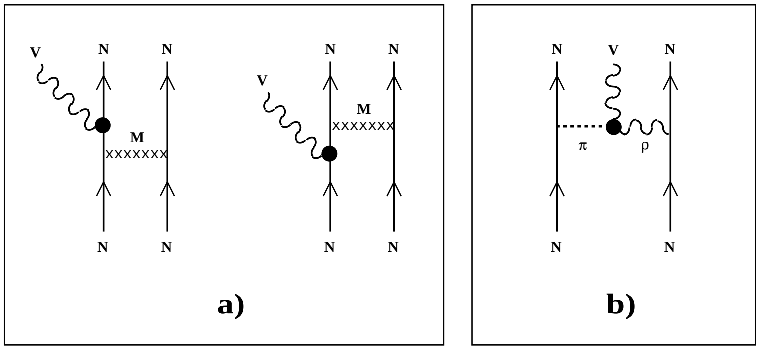

Figure 1: Nucleonic (a) and mesonic (b) exchange currents included in the model of Nakayama et al. with M being π, η, ρ, ω, σ and a_0.

at low energies with the aim of determining the ϕNN coupling constant. The presently available data set (total $pp \to pp\omega$ cross sections at 3 energies and the angular distribution of $pp \to pp\phi$ at one energy) is rather small and therefore does not allow to determine its value very precisely. Thus, any angular distributions for the ω at moderate energies would provide additional and rather stringent constraints for such an analysis and therefore allow to significantly reduce the uncertainty in the extracted ϕNN coupling constant.

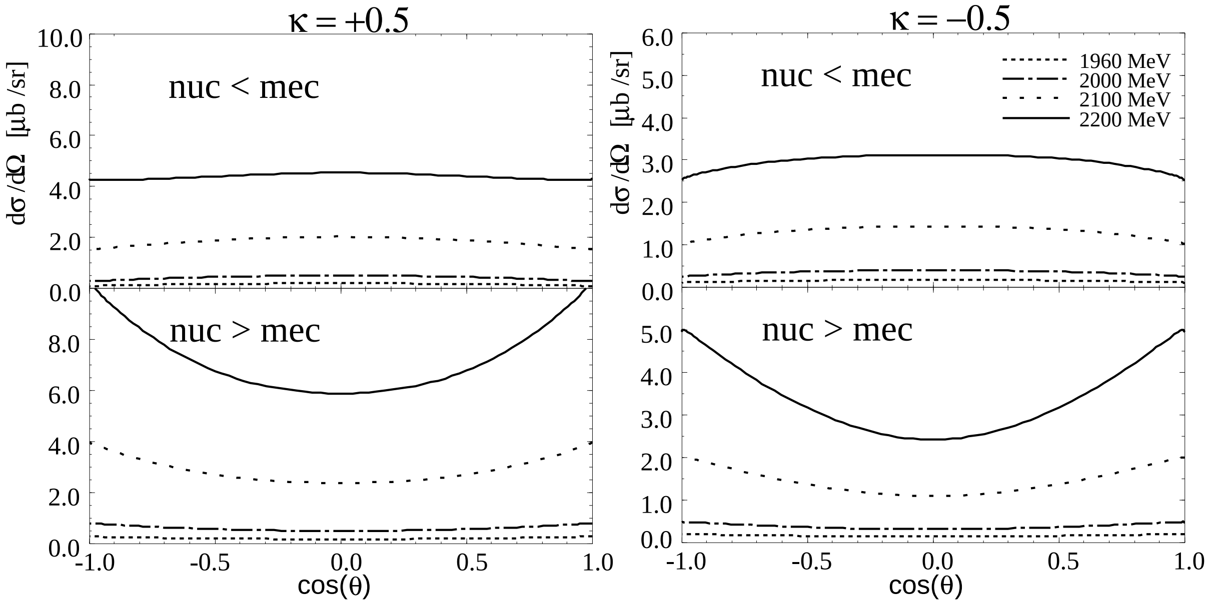

Figure 2: Angular distribution of the ω-production as a function of the beam energy in the excess energy range from 24 - 107 MeV if the nucleonic current is lower than the mesonic current (upper part) and vice versa (lower part). In a) the ratio of the vector coupling constant to the tensor one $\kappa = g_{NNv}/f_{NNv}$ is assumed to be +0.5 and in b) a κ of -0.5 is used. In both cases qualitatively the same behaviour is observed.

3 Vector meson production at COSY-11

The measurement of the vector meson production in the reactions $pp \to pp\omega/\Phi$ is performed via the missing mass technique. The two protons in the exit channel can be detected in the standard COSY-11 setup [22], [1] allowing the determination of the 4 momentum components of positively charged ejectiles from which a calculation of the 4 momentum components of the neutral meson is possible.

The acceptance of the COSY-11 detection system is rather low at higher excess energies needed for these analysis, but due to the large exit window the whole Θ_{CM}-angular range is covered. In fig. 3 the kinematic ellipses of an exit proton for the two body system $(p,\ (p,\omega))$ is shown overlayed with the COSY-11 acceptance region. Protons with momentum components $p_\perp$, $p_{||}$ in the center magnet plane within the shaded regions can be detected at COSY-11.

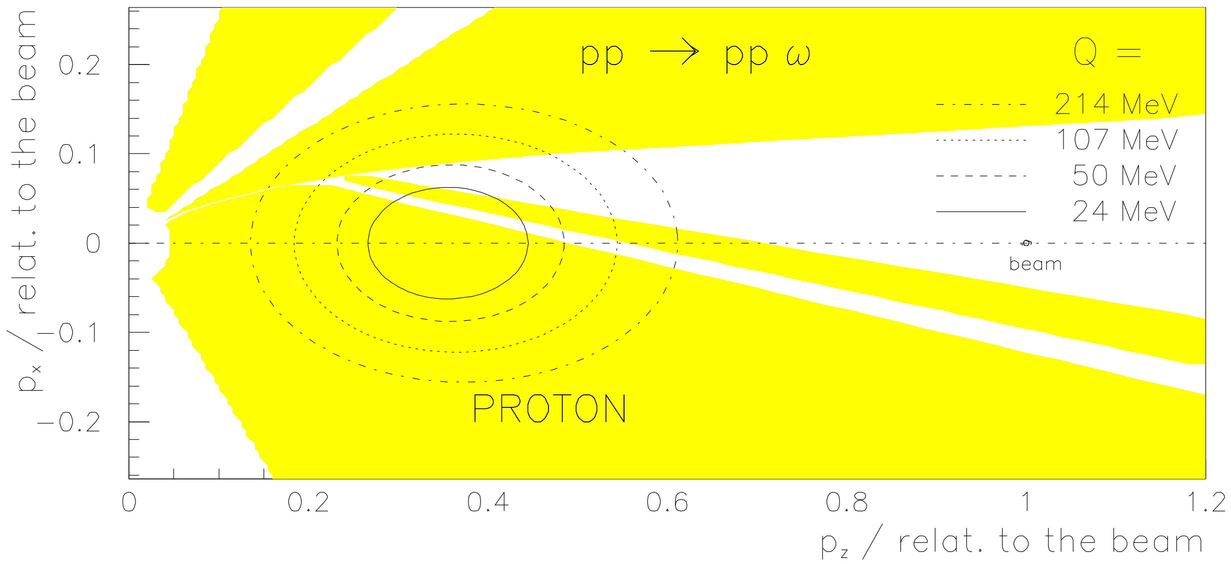

Figure 3: Kinematics of the $pp \to pp\omega$ reaction. The ellipses of an exit proton for the two body system $(p,(p,\omega))$ are shown for different excess energies Q overlayed with the acceptance areas of the COSY-11 detection system.

Up to excess energies of about 200 MeV the whole angular range is covered. In fig. 4 the reconstructed angular distributions of the ω-mesons for Monte Carlo event samples at different excess energies is shown. The modulation of the $\cos(\Theta_{CM})_\omega$-distribution results from the detector acceptance which is in total below 2 % but yields a full coverage of the angular range. For excess energies around 24 MeV positive and negative ϕ-angles can be measured which would allow the extraction of analyzing powers using a polarized beam. With increasing values of Q this option diminishes Similar results are obtained in Monte

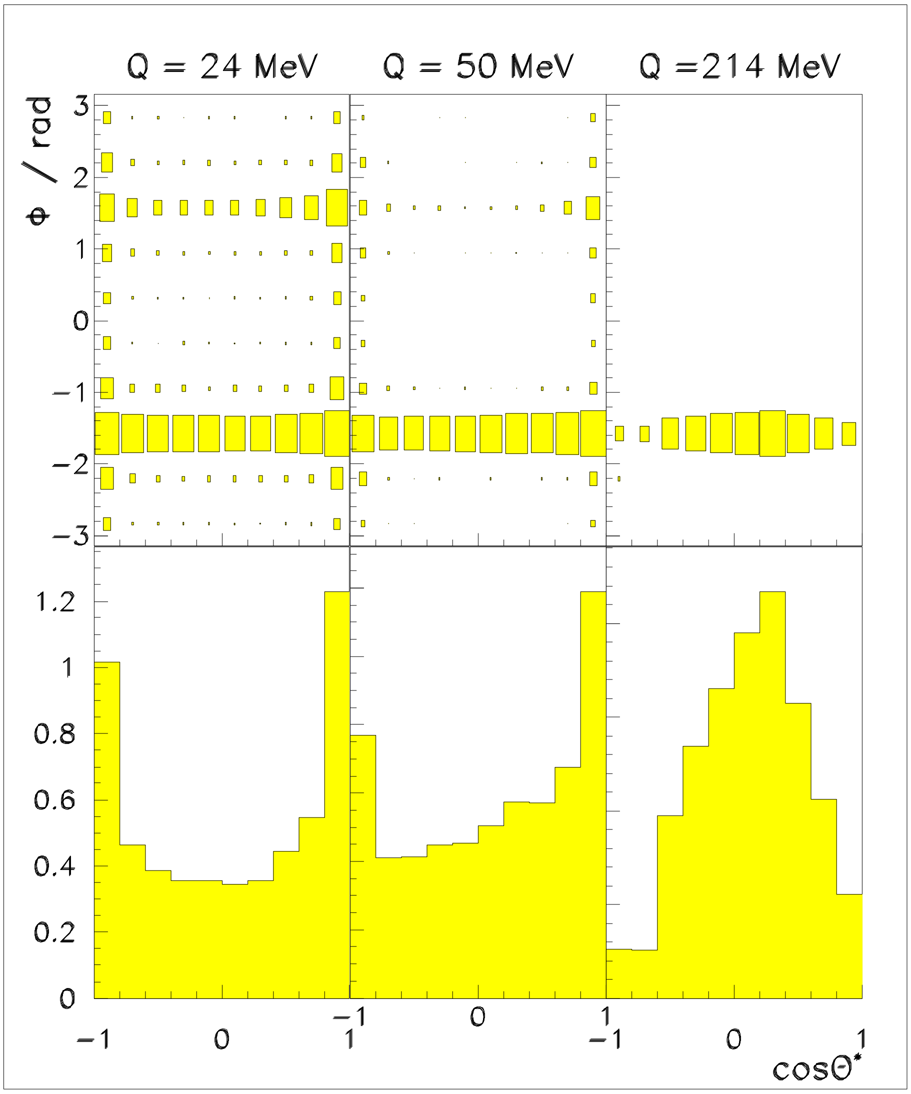

Figure 4: Angular distribution of the ω-mesons which can be measured via the missing mass technique at COSY-11. In the upper part the Φ-angle ($\Phi = 0$ is vertical to the COSY-plane) versus the $\cos(\Theta_{CM})_\omega$ of the produced ω-mesons in the center of mass is shown and in the lower part the $\cos(\Theta_{CM})_\omega$-distribution is given.

Carlo studies of the Φ-meson production.

Using the missing mass technique the detection of the vector mesons is accompanied by an unavoidable background from e.g. multi pion production. To show the feasibility of the ω and Φ measurement at COSY-11 previously obtained results will be discussed in the following. In May 96 a short test run for the ω/Φ-production at excess energies of 24 MeV in each system has been performed. During this run the luminosity was as high as L = $10^{29}\, cm^{-2}s^{-1}$ and the signal/noise ratio (target on/target off) was much worse compared to presently achieved values. A missing mass spectrum of the ω-run is shown in fig. 5, a clear signal of the ω-production is seen.

Concerning the Φ-production the cross section is much lower, which complicates the separation of such events. But with the inclusion of a K^+ detection from the K^+K^- decay branch of the Φ a drastic reduction of the background is achieved on the costs of

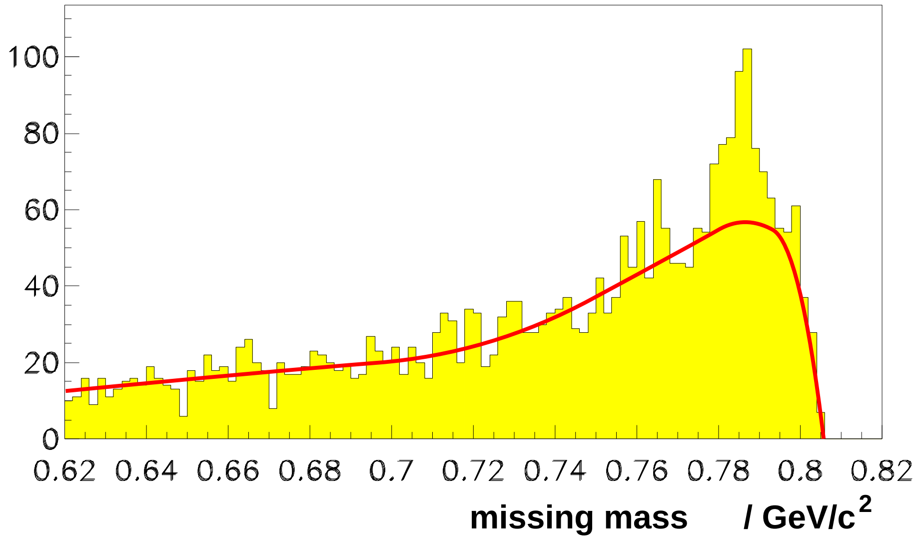

Figure 5: Missing mass spectrum of pp-data for a beam momentum of 2.74 GeV/c corresponding to an excess energy of Q = 24 MeV above the ω-production threshold. The background results from ρ- and multi pion production. A clear ω-peak is observed.

acceptance. In fig. 6 the pp-missing mass spectrum with the condition of an additionally detected K^+ is given for a beam momentum of 3.481 GeV/c, i.e. 24 MeV excess energy for the Φ-production.

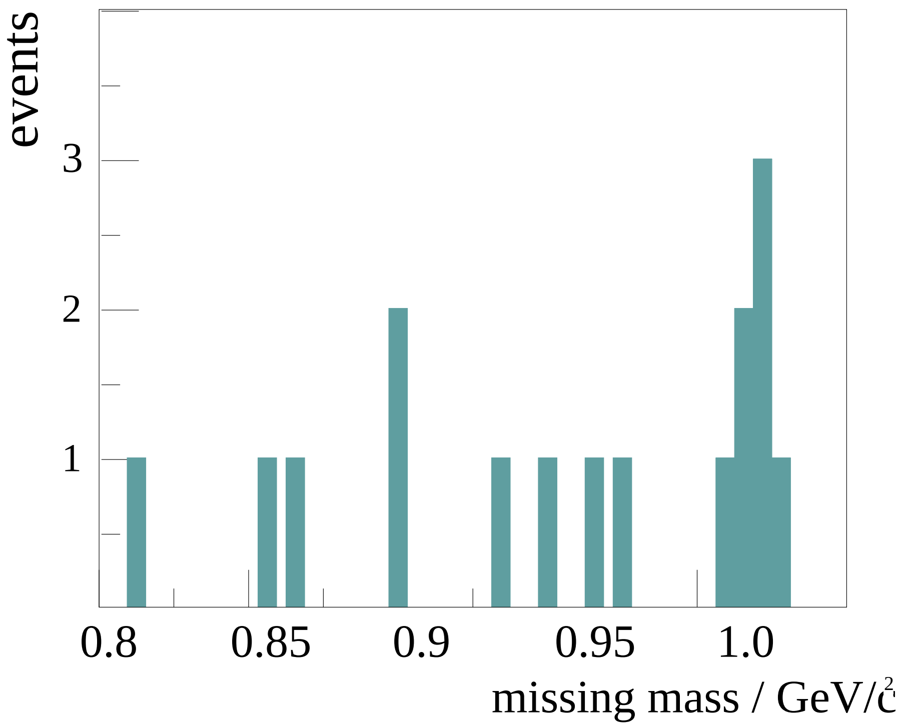

Figure 6: Missing mass spectrum of pp-data for a beam momentum of 3.481 GeV/c corresponding to an excess energy of 24 MeV above the Φ-production threshold. To reduce the background in addition to the two protons, the detection of a K^+ was required.The statistics is very low but at the Φ-mass an indication for an enhancement is seen.

Though the statistics being very low an indication for some Φ-events appears.

For the ω-production further COSY-11 data are available. The preliminary missing mass presentation of data taken at a beam momentum of about 3.3 GeV/c in September 98 for the K^+K^- studies shows a clear ω-peak, see fig. 7.

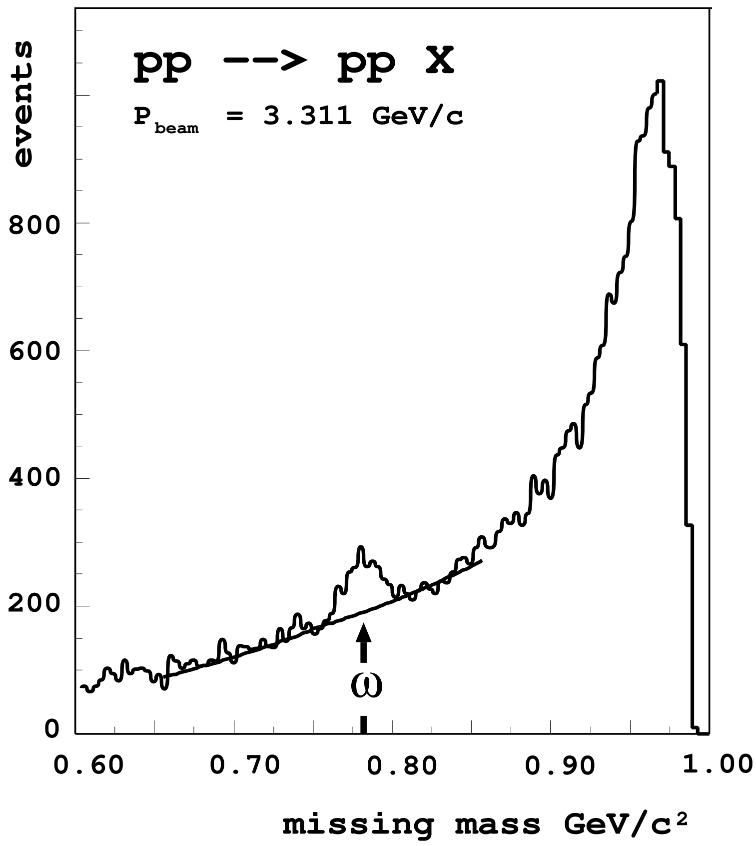

Figure 7: Missing mass spectrum of pp-data for a beam momentum of 3.311 GeV/c corresponding to an excess energy of 214 MeV above the ω-production threshold. In spite of the very low acceptance of the detection system at also here a clear ω-peak is visible.

The data taken during a former test run and in parallel to a different physics program have shown that the detection of ω-mesons at COSY-11 is possible near threshold as well as at much higher excess energies. The detector efficiency at $P_{Beam} = 3.3$ GeV/c (Q=214 MeV) is with 0.06 % much lower than the efficiencies for the planned measurements.

For the Φ-production the separation of Φ-events seems to work but the statistics of the data taken up to now is too low to draw definite conclusions.

4 Beam request

It is proposed to investigate the production of ω- and Φ-mesons at the COSY-11 facility. For both vector mesons the total cross section should be determined, in addition for the ω-meson it is planned to measure the angular distribution at three excess energies within the validity of the meson exchange model: Q = 25 MeV, 50 MeV and 107 MeV.

The measurements will result in the extraction of total and differential cross section data for the ω-production from which the contributions of nucleonic and mesonic currents can be obtained. From the Φ-production data, at least the total cross section will be given and the basis for the planning of further beamtime in this field is prepared. An advantage of the proposed experiment compared to that of [6] is, that we are planning to measure both ϕ and ω production at the same excess energy.

The detection efficiences, expected events and required measurement time are summarized in the following table . The given numbers base on a luminosity of $10^{30}\,cm^{-2}s^{-1}$, a common value for measurements at COSY-11. The cross sections used for the estimations were taken from an extrapolation of the SATURNE data [6]. The range given for the Φ-production results from cross section ratios $\sigma(\Phi X)/\sigma(\omega X)$ in different systems close to threshold.

reaction	Q-value [MeV]	Acceptance [%]	σ [μb]	expected events per day	Beam time [days]
$pp \to pp\,\omega$	25	1.80	2.5	3900	3
$pp \to pp\,\omega$	50	0.55	8.	3800	3
$pp \to pp\,\omega$	107	0.14	40.	4150	3
$pp \to pp\,\Phi$	25	1.79	0.008 - 0.2	12 - 300	5

In total it is asked for two weeks of beamtime.

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