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IMPROVED STUDY OF A POSSIBLE Θ^+ PRODUCTION IN THE $pp \rightarrow pK^0\Sigma^+$ REACTION WITH THE COSY-TOF SPECTROMETER

*W. Schroeder*¹ for the COSY-TOF Collaboration
Physikalisches Institut²
University of Erlangen - Nuremberg
Erlangen, D-91058

Abstract

The $pp \rightarrow pK^0\Sigma^+$ reaction was investigated with the COSY-TOF spectrometer. The main objective was to clarify whether or not a narrow exotic $S = +1$ resonance, the Θ^+ pentaquark, is populated at 1.53 GeV/c² in the pK^0 subsystem. A data sample of much higher statistical significance compared to the previously reported data in this channel [1], has been achieved. The analysis of these data does not confirm the existence of the Θ^+ pentaquark. This is expressed as an upper limit for the cross section $\sigma(pp \rightarrow \Sigma^+\Theta^+) < 0.15 \mu\text{b}$ at the 95% confidence level.

1 Introduction

QCD does not exclude the existence of other color singlet objects, then quark-antiquark pairs or three quark systems. Within a chiral soliton model Diakonov [2] predicted the existence of an anti-decuplet of baryonic states with $J^P = 1/2^+$ consisting of four quarks and one anti-quark. Three members of this anti-decuplet are manifestly exotic, having combinations of strangeness and isospin not allowed for three-quark systems. The lightest of these exotic states is the Θ^+ pentaquark with a quark content of $uudd\bar{s}$ and thus strangeness $S = +1$. In this article the results of an experiment studying the $pp \rightarrow pK^0\Sigma^+$ reaction with the COSY-TOF spectrometer with substantially improved statistical accuracy and extended detection capability are reported.

¹schroeder@physik.uni-erlangen.de

²Erwin-Rommel-Str 1, 91058 Erlangen, Germany

2 Experimental Setup

The external experiment COSY-TOF is a wide angle, non-magnetic spectrometer, which covers, except for small beam holes, the full angular range of the reaction products for the channel $pp \rightarrow pK^0\Sigma^+$. This allows a complete reconstruction of the events, including a precise measurement of the delayed decay of the K_s^0 meson. For detailed information see [3].

3 Analysis

The analysis was carried out with three independent analysis programs, with different algorithms and event selection methods. but with a common calibration of all detector components. A $pK^0\Sigma^+$ event is identified by its topology, that is a prompt track emerging from the target (proton), a delayed decay (K^0) and optionally a kink in a charged track (Σ^+). Due to the different strategies of the analysis the overlap of found event in the different is very small. But in total more than 12.000 independent $pK^0\Sigma^+$ events were reconstructed. The resolution in the invariant mass distribution of the pK^0 subsystem is between $\sigma = 5 - 6$ MeV/ c^2 .

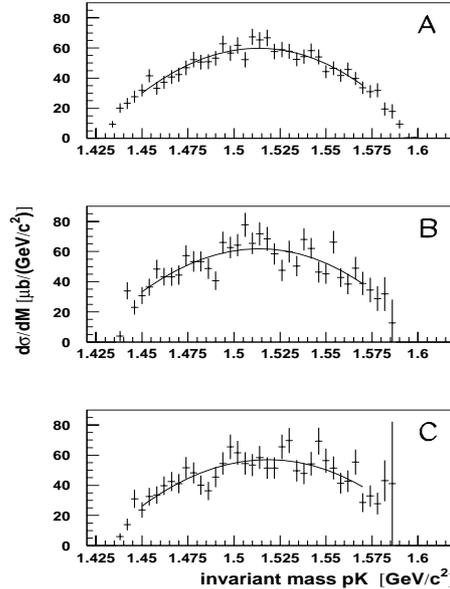


Figure 1: The invariant masses of the pK^0 subsystem for the three analyses together with a 3rd order polynomial parameterization.

4 Results

The pK^0 mass spectra are presented in Fig.1 together with a 3rd order polynomial parameterization in the mass region of $1.45 \text{ GeV}/c^2 < M_{pK^0} < 1.57 \text{ GeV}/c^2$. They were analyzed in order to determine the statistical significance with which a narrow structure might be present. A narrow structure was added to the polynomial described above. The shape of this narrow structure has been taken from Monte Carlo simulations of a resonance with a width negligible compared to the detector resolution. The mass of the resonance was varied in $1 \text{ MeV}/c^2$ steps over the M_{pK^0} range from $1.50 \text{ GeV}/c^2$ - $1.55 \text{ GeV}/c^2$. The strength of the structure for each setting was varied between $-1 \mu\text{b} < \sigma_{\text{tot},X} < +1 \mu\text{b}$. These results are summarized in Fig.2,

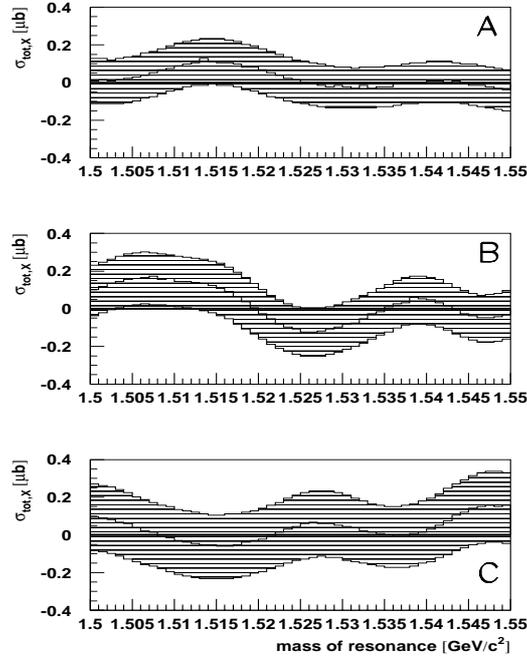


Figure 2: 95% confidence range for the cross section of a narrow resonance as a function of M_{pK^0} for the three analyses. The central lines of each band present the contribution of a hypothetical narrow resonance with the lowest χ^2 value.

where the value of $\sigma_{\text{tot},X}$ corresponding to the minimal value of χ^2 is represented by the central line of the band as a function of M_{pK^0} . The 95% confidence interval for an enhancement or suppression of the measured M_{pK^0}

differential cross section is indicated by the width of the band. The results indicate that over the full M_{pK^0} range investigated here the parameterization assuming $\sigma_{tot,X} = 0 \mu\text{b}$ is consistent with the measured data within the 95% confidence level. In particular, this new, higher statistics data do not contain positive evidence for a narrow structure at $M_{pK^0} = 1.530 \text{ GeV}/c^2$. The fluctuation of the central value of the 95% confidence intervals are not correlated between the different analyses. Based upon the smallest upper limit of the three 95% confidence intervals the maximum cross section for a narrow resonance $\sigma_{tot,X} < 0.15 \mu\text{b}$ has been deduced over the full mass range. Further details of the new measurement are given in Ref [4].

5 Summary

The reaction $pp \rightarrow pK^0\Sigma^+$ was studied in an exclusive measurement at a beam momentum of 3.059 GeV/c with complete phase space coverage. The extracted pK^0 spectra do not show evidence for a narrow resonance in the mass region of 1.50 GeV/c² - 1.55 GeV/c² in any of the three independent analyses. The data are consistent with a cross section of $\sigma_{tot,X} = 0 \mu\text{b}$ and an upper limit of 0.15 μb is derived with a confidence level of 95%. The evidence for a Θ^+ , reported in a first measurement [1], is not confirmed.

Acknowledgments

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References

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