Analysis of $pp \to pK^0\pi^+\Lambda$. Search for the Pentaquark.

M. Nekipelov for the ANKE collaboration

The reaction $pp \to pK^0\pi^+\Lambda$, measured at ANKE at a beam momentum of $p_{\mathrm{p}} = 3.65\,\mathrm{GeV/c}$, allows one to investigate the Kp system, which attracted a lot of attention due to its putative coupling to the pentaquark baryon $\Theta^+(1540)$ [1]. Its current status is reviewed in [2]. There is no theoretical investigation that reconciles both the positive and the negative observations, and it is believed that hadronic experiments at low energies can be crucial to clarify the situation.
The reaction at ANKE has been identified by detecting four particles simultaneously, the π^+ coming from the reaction vertex, the proton from vertex/Θ^+ decay, and the products of the Λ decay: proton and π^-. Besides individual particle identification, the final state is fixed by the missing mass technique. A sizable background remains after cuts on masses are made, and this background is removed by the side band subtraction method.

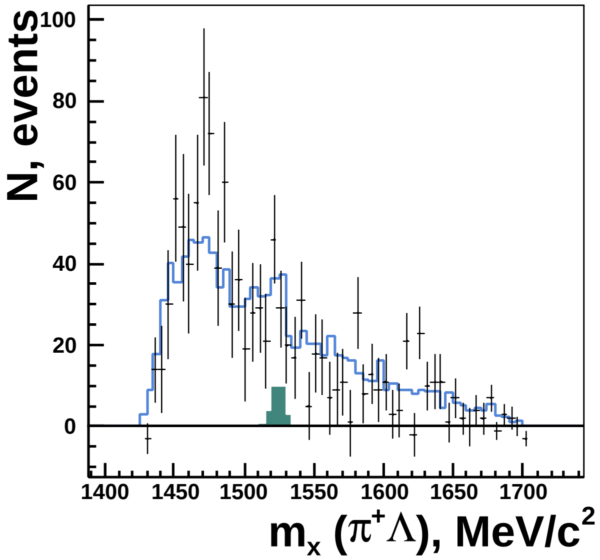

Fig. 1: Missing mass spectrum of $\pi^+\Lambda$ system. The solid line denotes the sum of all the contributions. The black region corresponds to the maximum permissible $\Theta^+(1540)$ signal.

The missing mass distribution $m(\pi^+\Lambda)$, presented in Fig. 1, is the one where the signal from the pentaquark is expected to appear. The solid line includes contribution from non-resonant production as well as contribution from the formation of an intermediate $\Delta^{++}(1232)$, inclusion of which is dictated by other differential distributions. The black area in Fig. 1 corresponds to the possible signal expected from the Θ^+ production. The fit results in a Θ^+ peak area, comparable with the statistical fluctuation of the background. Therefore, only an upper limit for the possible Θ^+ production is deduced:

$$\sigma_{\Theta^+\pi^+\Lambda} < 0.058\,\mu\mathrm{b}.$$

Since the acceptances of both four-body phase-space production and production with an intermediate $\Delta^{++}(1232)$ are very similar, a total cross section for the $pK^0\pi^+\Lambda$ final state can be calculated independent of the decomposition into separate channels. After the normalisation and efficiency corrections, the following total cross section for the $pK^0\pi^+\Lambda$ final state has been deduced:

$$\sigma_{\mathrm{tot}} = 1.41 \pm 0.05 \pm 0.33\,\mu\mathrm{b},$$

where the first error is statistical, while the second is systematic. The systematic uncertainty is mostly coming from the error of $\sigma_{pK^+\Lambda}$ [3], which has been used for the normalisation.
The total cross sections for the non-resonant channel and the channel with the $\Delta^{++}(1232)$ excitation have also been evaluated:

$$\sigma^{\mathrm{non-resonant}}_{pK^0\pi^+\Lambda} = 0.92 \pm 0.16 \pm 0.21\,\mu\mathrm{b},$$
$$\sigma_{\Delta^{++}K^0\Lambda} = 0.49 \pm 0.14 \pm 0.11\,\mu\mathrm{b}.$$

The measured cross section for the $pp \to \Delta^{++}K^0\Lambda$ reaction is significantly lower than a model prediction, $\sigma \approx 6\,\mu\mathrm{b}$ [4]. However, this model overestimates as well the data available at high energies.
It is not possible to directly compare the Θ^+ production cross section obtained at ANKE with the one for $pp \to \Theta^+\Sigma^+$ measured at $p_{\mathrm{p}} = 2.95\,\mathrm{GeV/c}$ by the COSY-TOF collaboration [5] (see also Ref. [6] for the results of an improved study of this channel). Not to mention a difference in beam momentum of $\sim 700\,\mathrm{MeV/c}$, the exit channels are distinct and even the number of particles in the final state differs.
The details of the analysis can be found in Ref. [7].

References:

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