Measurement of $\Lambda(1405)$ in p+p reactions at 3.5 GeV

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The $\Lambda(1405)$ resonance is known to be an exotic state, which can not be understood as a usual 3-quark baryon. In fact, it turns out that the attraction in the $\bar{K}-N$ channel with isospin I=0 is sufficient strong to generate a bound state below the $\bar{K}N$ threshold. This bound state is commonly identified with the $\Lambda(1405)$. Today, theory uses coupled channel calculations, based on the chiral unitary approach, to generate the $\Lambda(1405)$ dynamically as an interference between a $\bar{K}N$ quasi-bound state and a $\pi\Sigma$ resonance [1]. The properties of the $\Lambda(1405)$, especially its line shape, are therefore sensitive to the low energy $\bar{K}N$ dynamics.

As the data base on $\Lambda(1405)$ is rather scarce, we aimed to measure its properties in $p+p$ reactions at 3.5 GeV kinetic beam energy [2, 3]. In these reactions, the $\Lambda(1405)$ is mainly produced together with a proton and a K^+ ($p+p \rightarrow \Lambda(1405)+p+K^+$). We have performed an exclusive analysis of the charged decay channels ($\Lambda(1405) \rightarrow \Sigma^\pm\pi^\mp$). After identifying all final state particles, we were able to reconstruct the Σ^+ and the Σ^- hyperons. By selecting these intermediate state particles, we could finally investigate the missing mass to proton and K^+, where the $\Lambda(1405)$ signal appears. Figure 1 shows the obtained distributions for both decay channels. The experimental data (black points) are corrected for acceptance and efficiency. Compared to the data, are simulations of different reaction channels, contributing to the finally observed spectra. The contribution of $\Sigma(1385)^0$ ($p+p \rightarrow \Sigma(1385)^0+p+K^+$) in the violet histograms could not be determined independently in the analysis, as it shows the same decay channels as $\Lambda(1405)$. Its contribution could, however, be fixed by the neutral channel analysis, presented in [4]. The green histograms show the signals due to $\Lambda(1520)$ production ($p+p \rightarrow \Lambda(1520)+p+K^+$), giving rise to signals above 1500 MeV/c^2. The red, phase space like distributions, are attributed to the non-resonant production of $\Sigma\pi$ pairs (see [3] for details). Finally, the black histograms are simulations of $\Lambda(1405)$. The yields of all the simulations have been fixed by a simultaneous fit to different observables. The incoherent sum of the different contributions is shown in the gray histograms.

The most prominent feature of the obtained spectra is that the mass peak of $\Lambda(1405)$ is clearly located below its nominal mass value of 1400 MeV/c^2. Indeed, also the simulations of $\Lambda(1405)$ assume a Breit-Wigner mass of 1385 MeV/c^2 in order to fit the data reasonably. First theoretical interpretations on this observation have been proposed in [5], where a phenomenological approach is used to describe the $\Lambda(1405)$ as a pure $\bar{K}N$ quasi-bound state, with a binding energy of $\approx$ 30 MeV. The predictions from this model are in fairly well agreement with the measured mass spectra of Figure 1.

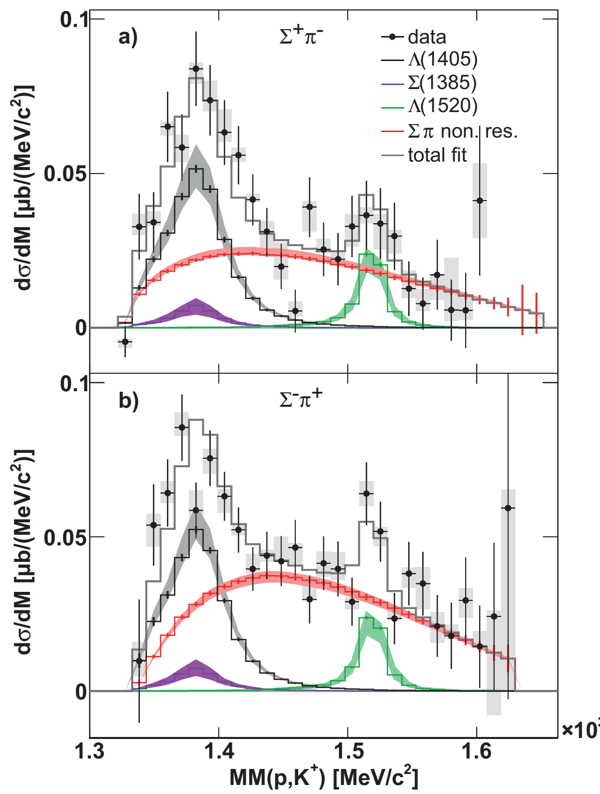

Figure 1: Missing mass to proton and K^+ for the two different decay channels of $\Lambda(1405)$. The histograms show the different contributions to the experimental data. The shaded bands and boxes indicate the extracted systematic errors on the experimental data and on the simulations.

The observed line shape of $\Lambda(1405)$ with its shift below 1400 MeV/c^2 has the potential to reveal further insight into the low energy $\bar{K}N$ dynamics. Therefore, the development of adequate theory models, which are able to handle the complex $p+p$ reaction mechanisms, is requested.

References

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