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Results of analysis of Σˆ+p scattering events in J-PARC E40 experiment: differential cross sections and phase shifts of ˆ3S_1 and ˆ1P_1 states

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Hyperon-proton scattering experiment is one of the most direct methods to study the YN interaction, as in the case of the NN interaction. Although it was experimentally difficult due to short lifetime of hyperons for a long time, we successfully performed novel high-statistics Σp scattering experiment at J-PARC (J-PARC E40 experiment). One of the physics motivations was verification of a strong repulsive force due to Pauli effect in the quark level (quark Pauli effect) in $\Sigma N(I = 3/2)$ system by measuring the differential cross sections of the $\Sigma^+ p$ elastic scattering.

The experiment was performed at the K1.8 beam line in the J-PARC Hadron Experimental Facility by June 2020 for the data collection of the $\Sigma^+ p$ scattering.
Both of production of Σ^+ beam via the $\pi^+ p \to K^+ \Sigma^+$ reaction and the $\Sigma^+ p$ scattering occurred in a liquid hydrogen (LH_2) target. The Σ^+ production reaction was analyzed using the two spectrometers and the momentum of the Σ^+ beam was tagged event by event. The recoil proton from the $\Sigma^+ p$ scattering was measured using CATCH, detector system surrounding the LH_2 target.
The $\Sigma^+ p$ scattering was identified by checking the consistency for the recoil proton between the measured energy and the calculated energy from kinematics. In total, approximately 2400 $\Sigma^+ p$ elastic scattering events were identified in the Σ^+ momentum range of 0.44 to 0.80 GeV/c.

The differential cross sections of the $\Sigma^+ p$ scattering were derived for the three separated-momentum regions. Their uncertainties were typically less than 20% with an angular step of $\Delta \cos\theta_{\rm CM} = 0.1$, and the data quality was drastically improved in comparison with past experiments. The obtained values of differential cross sections are around 2 mb/sr, which are not so large as most theoretical predictions.

Moreover, owing to precise data points and the simple representation of the $\Sigma^+ p$ system with respect to the multiplets of the BB interaction, we could experimentally derive the phase shifts of the $^3S_1$ and $^1P_1$ channels for the first time by performing the phase-shift analysis for the obtained differential cross sections. Especially, the phase shift of the $^3S_1$ channel, wherein a large repulsive core due to the quark Pauli effect was predicted, was evaluated to be $20^\circ < |\delta_{^3S_1}| < 35^\circ$ for the present momentum range. This result suggests that the strength of repulsive force in $\Sigma N(I = 3/2)$ system is moderate.

In this presentation, I will introduce J-PARC E40 experiment and analysis procedures to derive the differential cross sections and phase shifts of the $^3S_1$ and $^1P_1$ states for the $\Sigma^+ p$ elastic scattering.
By comparing our results to theoretical calculations, the nature of the $\Sigma^+ p$ interaction will also be discussed.

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