The $pp \to p\Lambda K^+$ and $pp \to p\Sigma^0 K^+$ reactions

with chiral dynamics

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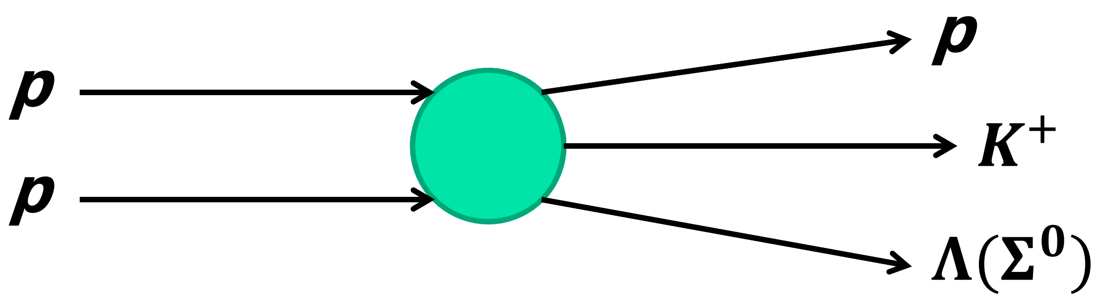
Motivations



- The study of proton-proton scattering is very important and useful.
- The source of information for $p\Lambda$ scattering: scattering length and effective range.

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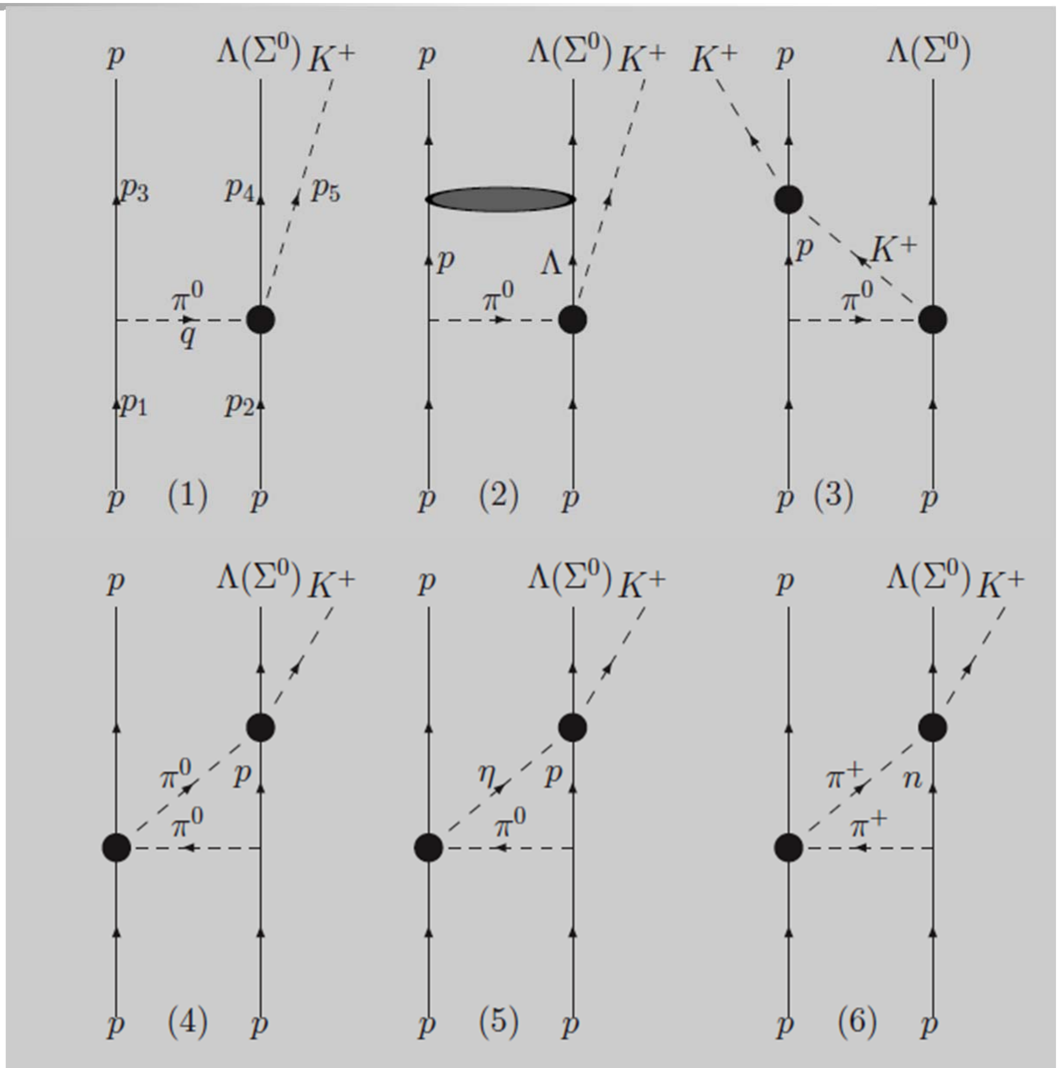
Our dynamics is similar to Casparyan’s papers but we consider in addition the final state interaction of meson and baryon using the chiral unitary theory.

Formalism

- We work at the reaction threshold.
- The processes exchanging π and K mesons give the dominant contributions.
- The final state interactions (FSI) are important.



Formalism

- Elementary Diagrams

$$T_{pp\to p\Lambda K^+} (= T_{\pi NN} G_\pi T_{\pi N\to K\Lambda})$$

- Meson-Baryon Interactions (FSI-1)

$$T_{pp\to p\Lambda K^+} G_{pK^+} T_{pK^+\to pK^+}$$

- Baryon-Baryon Interactions (FSI-2)

$$T_{pp\to p\Lambda K^+} G_{p\Lambda} T_{p\Lambda\to p\Lambda}$$

Inputs

- For strong vertex of πNN and KYN:

  $$f_{\pi NN}\vec{\sigma}\cdot\vec{q} \text{ and } f_{KYN}\vec{\sigma}\cdot\vec{q},$$

  which are related to the **D** and **F** factors.

- Two-body meson-baryon scattering amplitudes such as $T_{\pi^0 p\to K^+\Lambda}$ are obtained using the **chiral unitary theory** (fitted with the experimental data of meson baryon scattering).

Inputs

- For two-body baryon-baryon interactions, we fit the transition $T_{p\Lambda\to p\Lambda}$ using the experimental data of the $p\Lambda \to p\Lambda$ reaction.

$$T_{\Lambda p\to\Lambda p}(\sqrt{s_{p\Lambda}}) = \frac{1}{V^{-1} - G_{\Lambda p}(\sqrt{s_{p\Lambda}})},$$

- For $(p\Lambda)_{I=1}$ and $(p\Lambda)_{I=0}$, we assume they are the same.
- After fitting the potential V and the cut off Λ, and relate them to the scattering length a and effective range r, we obtain

$\bar{a} = -1.75\ fm$, and $\bar{r} = 3.43\ fm$

- We also find it compatible with Hinterberger's results. There is a family of values consistent with the experimental data.

Free Parameters Λ_π/Λ_K

- We add a form factor for the off-shell π and K mesons in the strong vertex

$$F_{\pi NN}(q^2) = \frac{{\Lambda_\pi}^2 - {m_\pi}^2}{{\Lambda_\pi}^2 - q^2}$$

$$F_{KYN}(q^2) = \frac{{\Lambda_K}^2 - {m_K}^2}{{\Lambda_K}^2 - q^2}$$

- When fitting with the experimental data, we have some freedoms.

The $pp \to p\Lambda K^{+}$ reaction

- **Solid line**: with including the $p\Lambda$ interactions
- **Dashed line**: without including the $p\Lambda$ interactions
- $\Lambda_\pi = \Lambda_K = 1300$ MeV

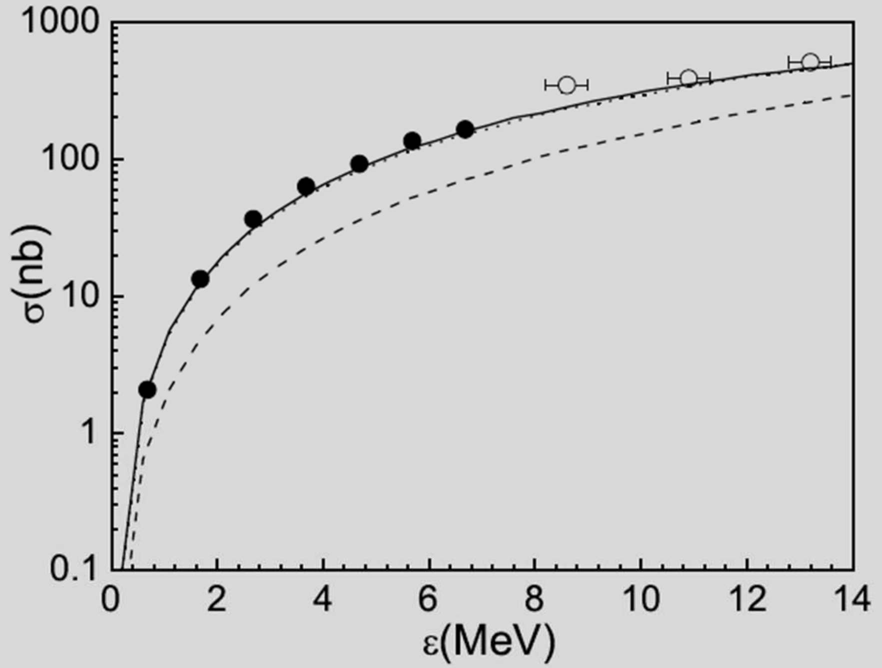


FIG. 5: Total cross section vs excess energy ε for the $pp \to p\Lambda K^{+}$ reaction compared with experimental data from Refs. [26] (filled circles) and [27] (open circles). ~~Solid and~~

The $pp \to p\Sigma^0 K^+$ reaction

- We follow the same procedures and obtain the result for the $pp \to p\Sigma^0 K^+$ reaction (**dashed line**).

- The result is larger than the experimental results, but at the same magnitude.

- The result of the $pp \to p\Sigma^0 K^+$ reaction is much smaller than the result of the $pp \to p\Lambda K^+$ reaction.

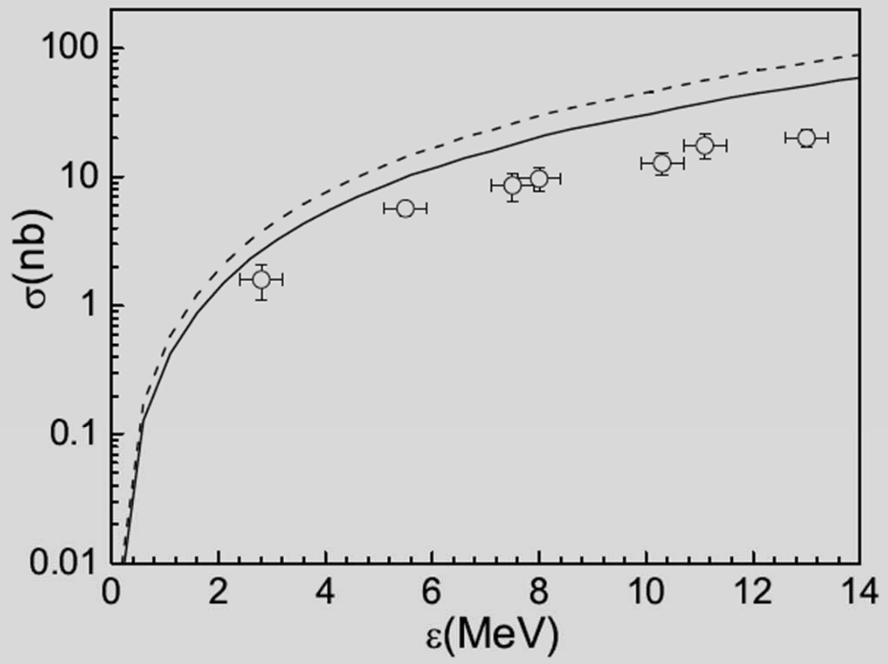


FIG. 6: Total cross section vs excess energy ε for the $pp \to p\Sigma^0 K^+$ reaction compared with experimental data from Ref. [27]. ~~Solid and dashed lines show the results from our~~

The $pp \to p\Sigma^0 K^+$ reaction

- The transition process $pp \to (p\Lambda)K^+ \to (p\Sigma^0)K^+$ is important since $pp \to p\Lambda K^+$ is much larger than $pp \to p\Sigma^0 K^+$.
- The final state interaction $pp \to (p\Sigma^0)K^+ \to (p\Sigma^0)K^+$ may be important, but we do not have enough information of the $p\Sigma^0 \to p\Sigma^0$ reaction.
- The phases among these three processes are unknown but important. Therefore, we do not want to achieve an accurate result, but just a qualitative result in this work.

Invariant Mass Spectra and Dalitz Plot

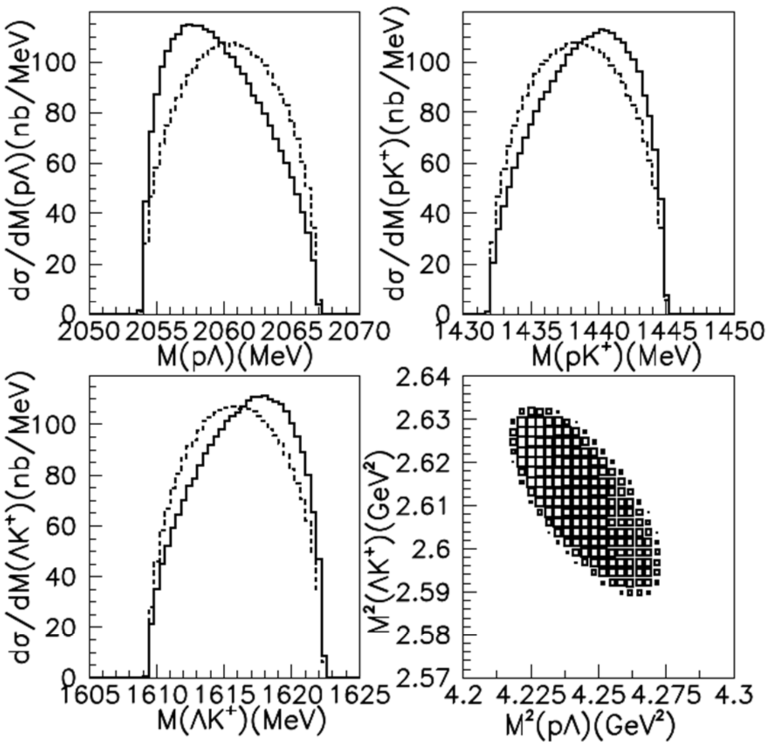


FIG. 7: The invariant mass spectra and the Dalitz Plot for the $pp \to p\Lambda K^+$ at excess energy $\varepsilon = 13$ MeV with the contributions from the full amplitude (solid curve), compared with pure phase space distributions (dashed curve).

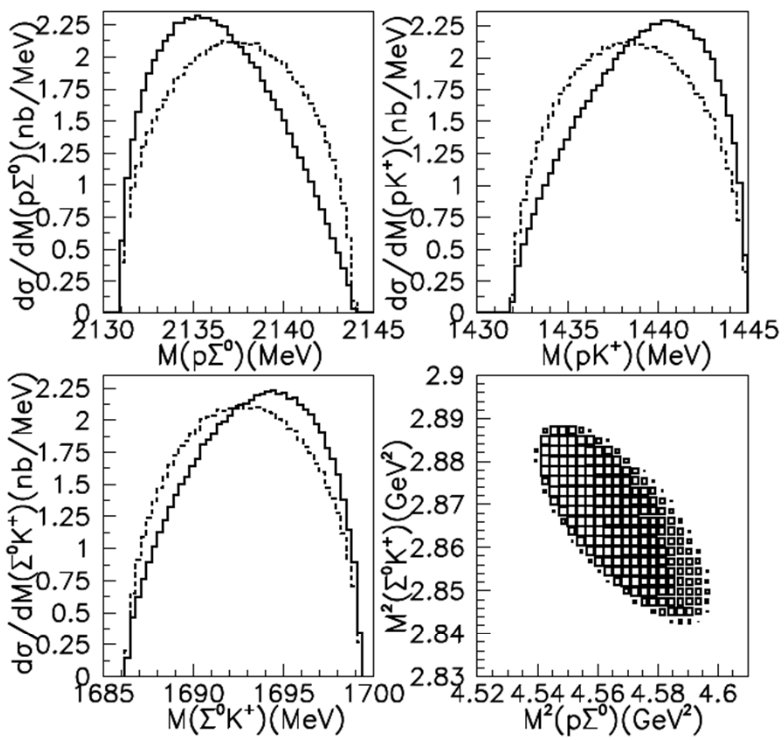


FIG. 8: The invariant mass spectra and the Dalitz Plot for the $pp \to p\Sigma^0 K^+$ at excess energy $\varepsilon = 13$ MeV with the contributions from the full amplitude (solid curve), compared with pure phase space distributions (dashed curve).

Summary

- We have made a theoretical study of the $pp \to p\Lambda K^+$ and $pp \to p\Sigma^0 K^+$ reactions. We have considered the final state interactions of any of the two hadrons.
- The cross section of the $pp \to p\Lambda K^+$ reaction we obtained is consistent with the experimental data.
- The cross section of the $pp \to p\Sigma^0 K^+$ reaction we obtained is much smaller than the one of the $pp \to p\Lambda K^+$ reaction (there is a factor about 20).
- One should consider the transition process $pp \to (p\Lambda)K^+ \to (p\Sigma^0)K^+$ as well as the final state interaction $pp \to (p\Sigma^0)K^+ \to (p\Sigma^0)K^+$ can be important. However, since we do not the their **relative phases**, we can not estimate their contributions.

Thank you very much!