Analysis of (K^-, K^+) Inclusive Spectrum with Semi-Classical Distorted Wave Model

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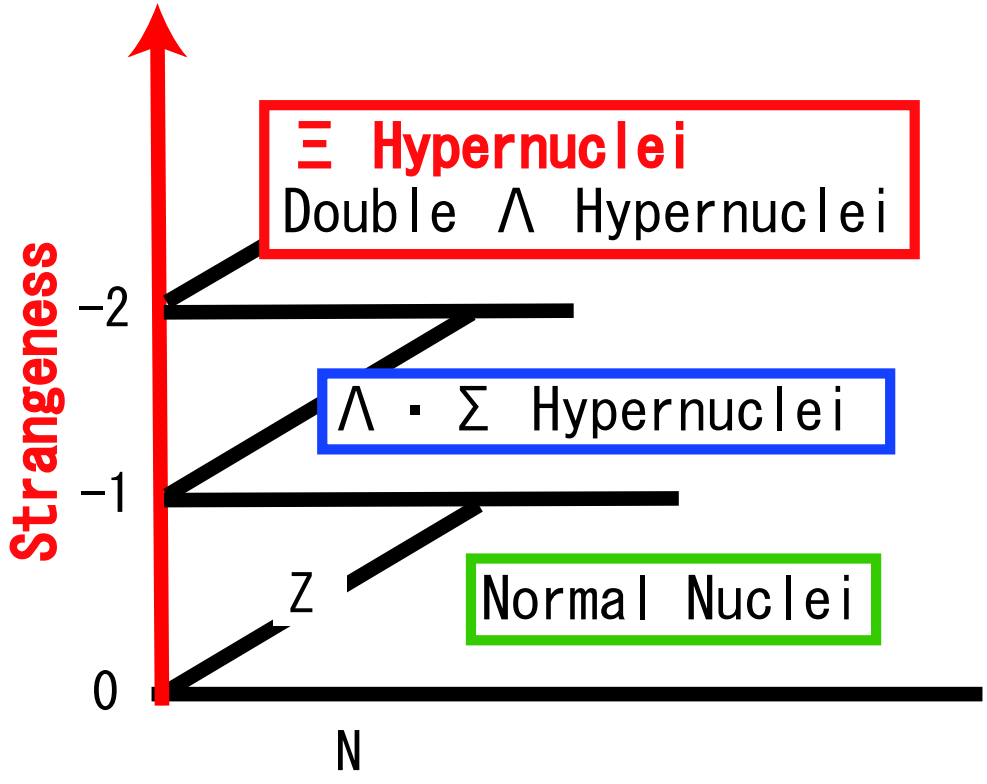
Nuclear Physics at J-PARC (June 1st-2nd, 2007)

Introduction

- **Strangeness Physics:** **Hypernuclear study**
  - **Hyperon-Nucleon interactions**
  - **Hyperon-Hyperon interactions**

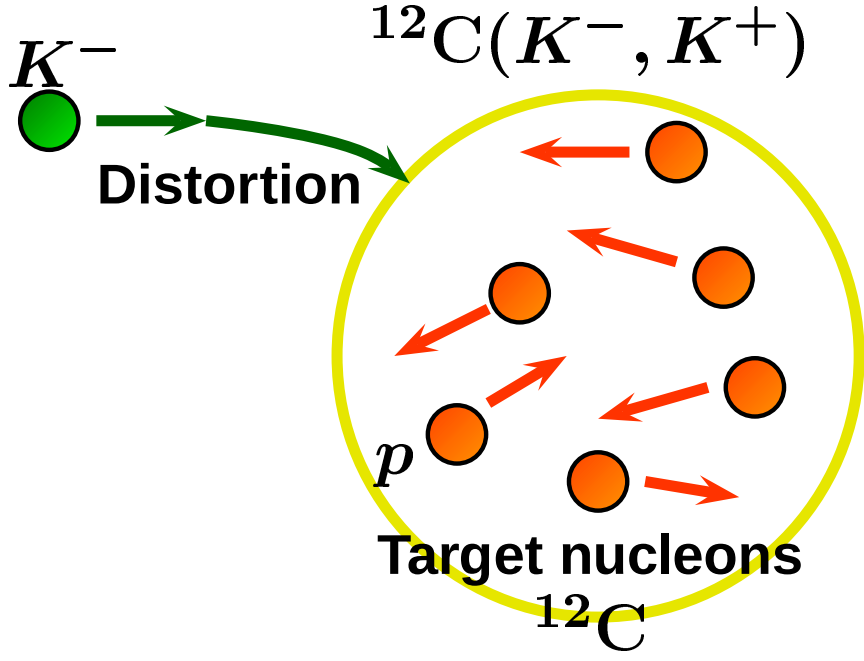


Main target at J-PARC

Previous studies

Double strangeness exchange reaction

- $\Xi(S = -2)$ Hyperon production reaction



Double strangeness exchange reaction

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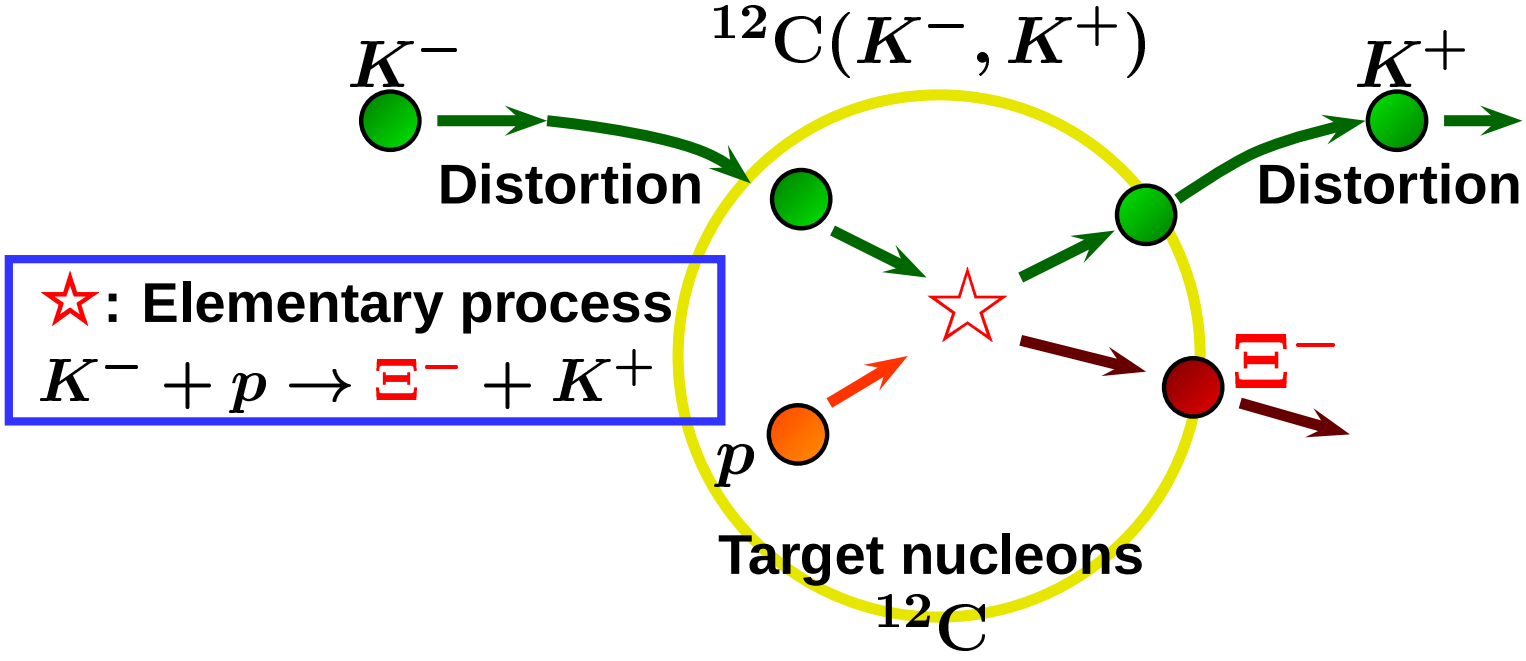

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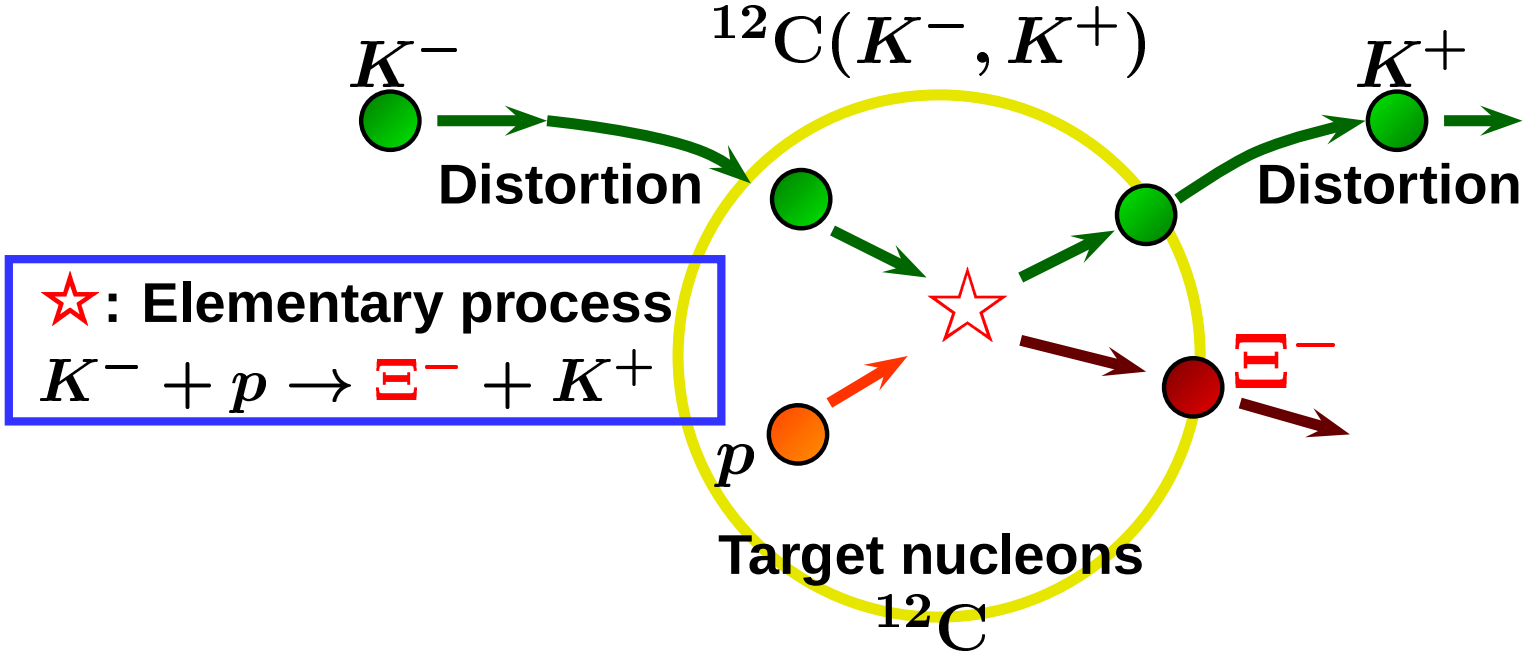
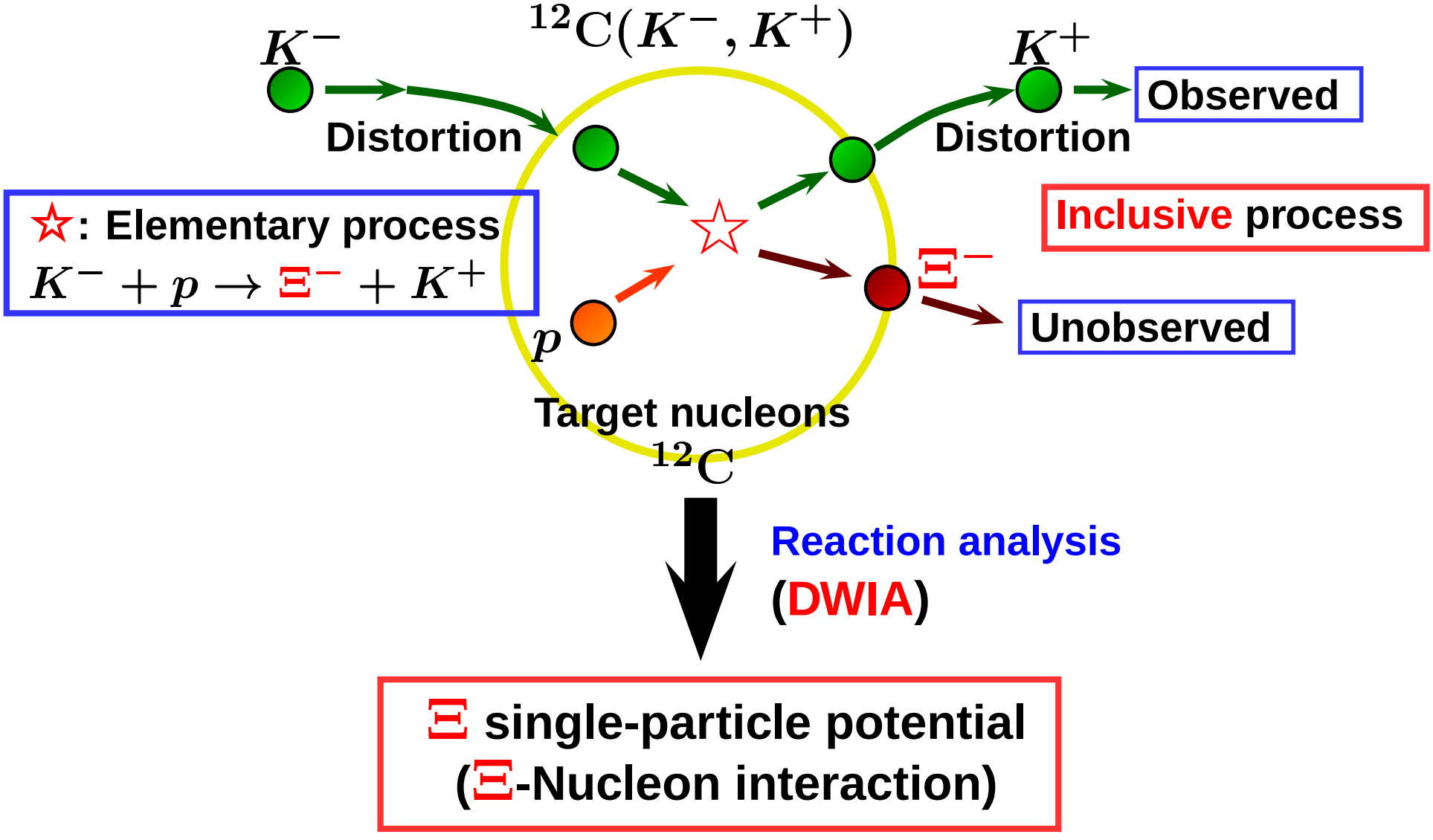


Reaction analysis

Ξ single-particle potential
(Ξ-Nucleon interaction)

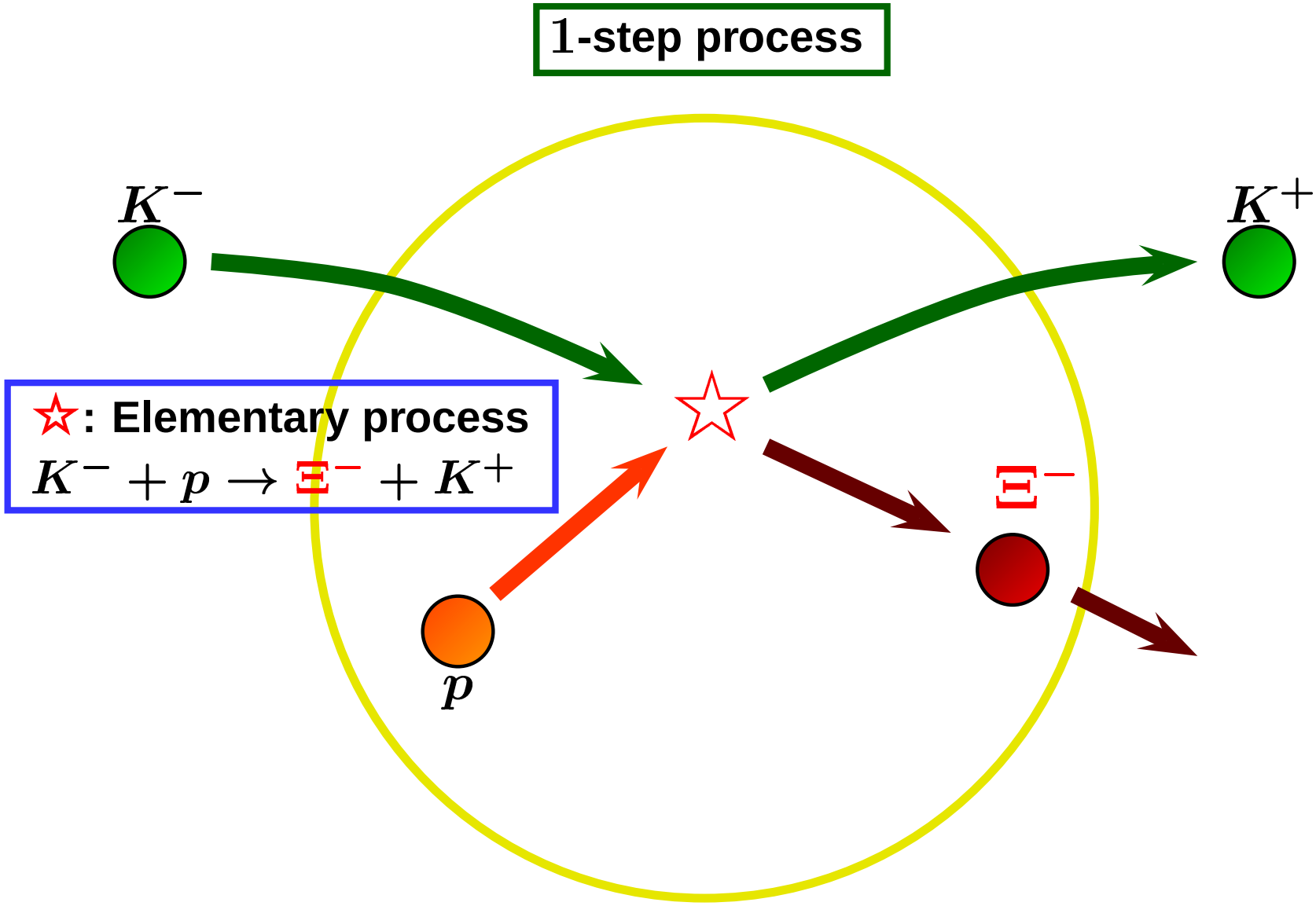
Double strangeness exchange reaction

- $\Xi(S=-2)$ Hyperon production reaction



Multi-step processes

- (K^-, K^+): **Inclusive** process



Multi-step processes

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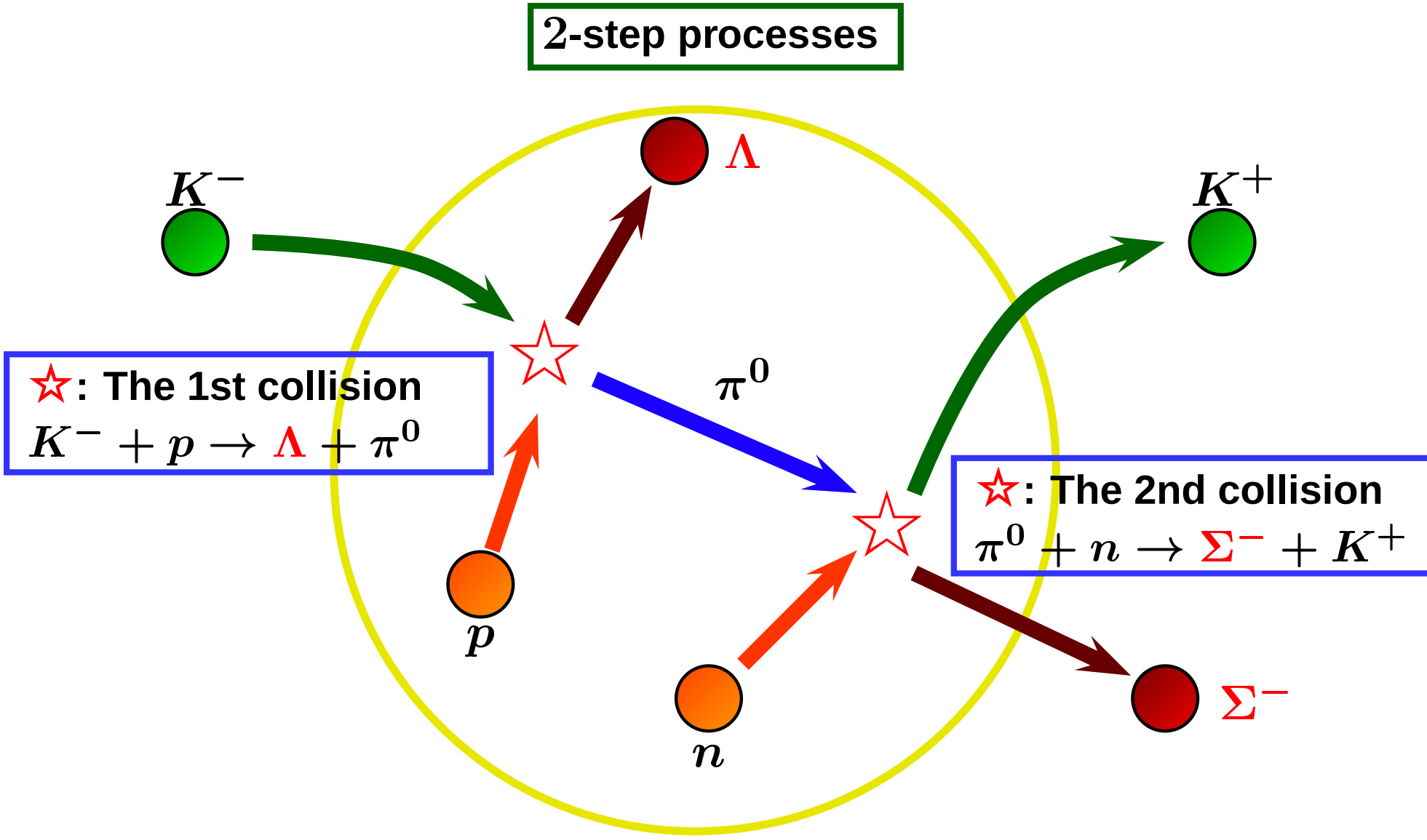
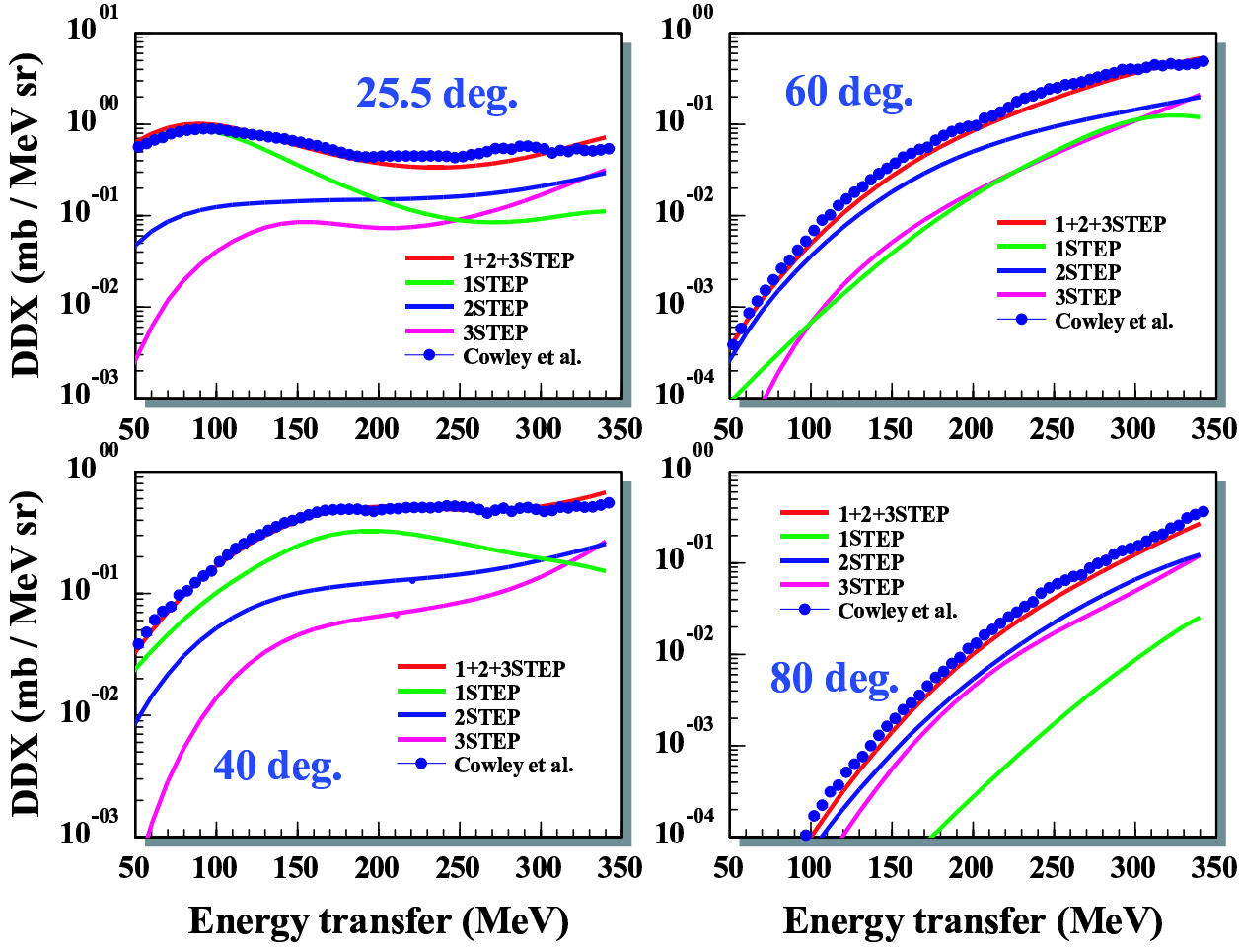


Semi-Classical Distorted Wave model (SCDW)

SCDW is a powerful tool to calculate inclusive cross sections.

- **Double differential cross section (DDX) for $^{40}\mathrm{Ca}(p,p')$ at 392 MeV**



[K. Ogata *et al.*, in preparation.]

Semi-Classical Distorted Wave model (SCDW)

SCDW is a powerful tool to calculate inclusive cross sections.

- **Calculations of multi-step processes**
- **Calculations without any free adjustable parameter**
- **References**
  - **Y. L. Luo and M. Kawai, PLB 235, 211 (1990); PRC 43, 2367 (1991).**
  - **M. Kawai and H. A. Weidenmüller, PRC 45, 1856 (1992).**
  - **Y. Watanabe, R. Kuwata, Sun Weili, M. Higashi, H. Shinohara, M.Kohno, K. Ogata and M. Kawai, PRC 59, 2136 (1999).**
  - **K. Ogata, M. Kawai, Y. Watanabe, Sun Weili and M. Kohno, PRC 60, 054605 (1999).**
  - **Sun Weili, Y. Watanabe, M. Kohno, K. Ogata and M. Kawai, PRC 60, 064605 (1999).**

Cross section formula for 1-step process

Local semi-classical approximation to distorted waves of $K^{\pm}$

$$\chi_c(r+s) \cong \chi_c(r)\, e^{ik_c(r)\cdot s} \ : \text{for small } s$$

Inclusive cross section with SCDW (1-step)

$$\frac{d^2\sigma^{(1)}}{dE_f d\Omega_f} = \int dr \, \frac{k_f/k_f(r)}{k_i/k_i(r)} \left|\chi_f^{(-)}(r)\right|^2 \left|\chi_i^{(+)}(r)\right|^2 \left(\frac{d^2\sigma}{dE_f d\Omega_f}\right)_r \rho(r)$$

$\left(\frac{d^2\sigma}{dE_f d\Omega_f}\right)_r$: **Local average elementary cross section**

[Y. Nara *et al.*, NPA 614, 433 (1997).]

Cross section formula for 2-step processes

Inclusive cross section with SCDW (2-step)

$$\frac{d^2\sigma^{(2)}}{dE_f d\Omega_f} = \int dE_m \int dr_1 \int dr_2 \, \frac{k_f/k_f(r_2)}{k_i/k_i(r_1)} \left|\chi_f^{(-)}(r_2)\right|^2 \left|\chi_i^{(+)}(r_1)\right|^2$$

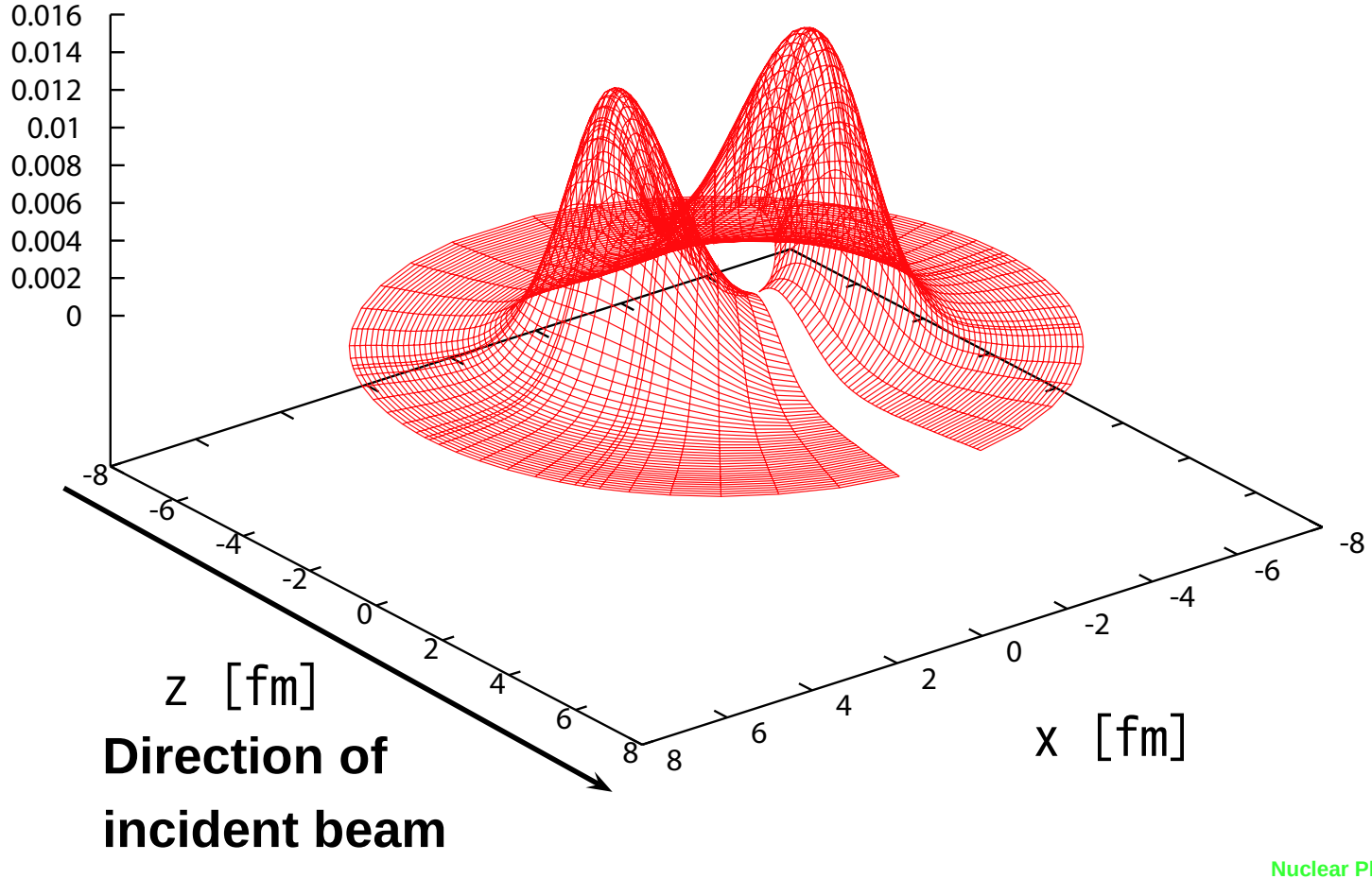
$$\times \left(\frac{d^2\sigma}{dE_f d\Omega_f}\right)_{r_2} \rho(r_2) \frac{\exp(-2\gamma_m |r_2 - r_1|)}{|r_2 - r_1|^2} \left(\frac{d^2\sigma}{dE_m d\Omega_m}\right)_{r_1} \rho(r_1)$$

The 2nd collision **The 1st collision**

Distribution of local cross section

$$\frac{d^2\sigma^{(1)}}{dE_f d\Omega_f} = \int \sigma(r) dr$$

$\sigma(r)$ in the ^{12}C(K^-, K^+) reaction

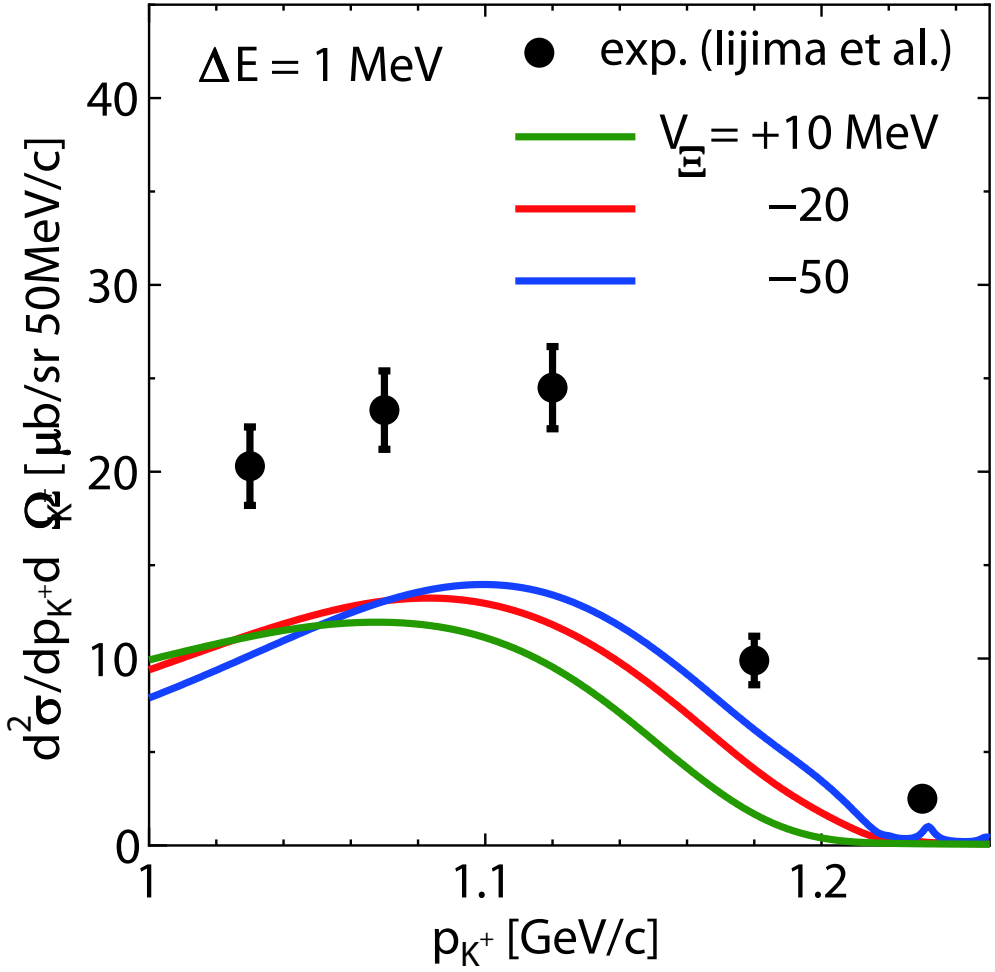


Ξ production reaction analysis

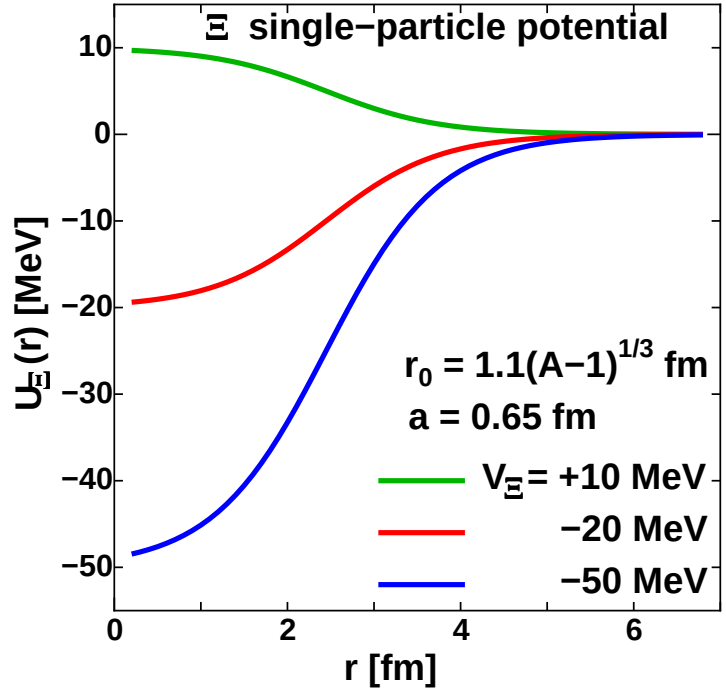
- $^{12}\mathrm{C}(K^-, K^+)$ reaction (at $p_{K^-} = 1.65$ GeV/c)

Exp.: T. Iijima et al., NPA 546, 588 (1992).

K^+ momentum spectrum of 1-step process



Ξ single-particle potential (Woods-Saxon type)



Evaluation of 2-step processes

- $^{12}\mathrm{C}(K^-, K^+)$ reaction (at $p_{K^-} = 1.65$ GeV/c)

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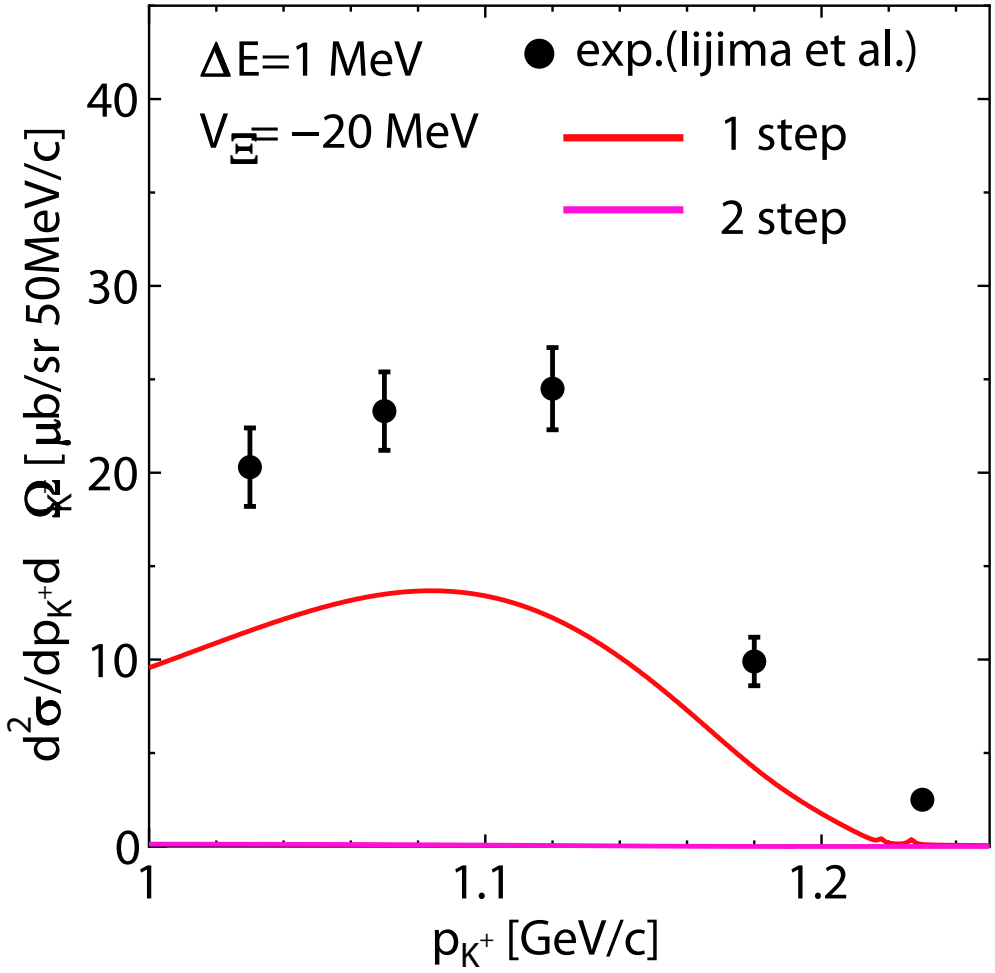
- K^+ momentum spectrum



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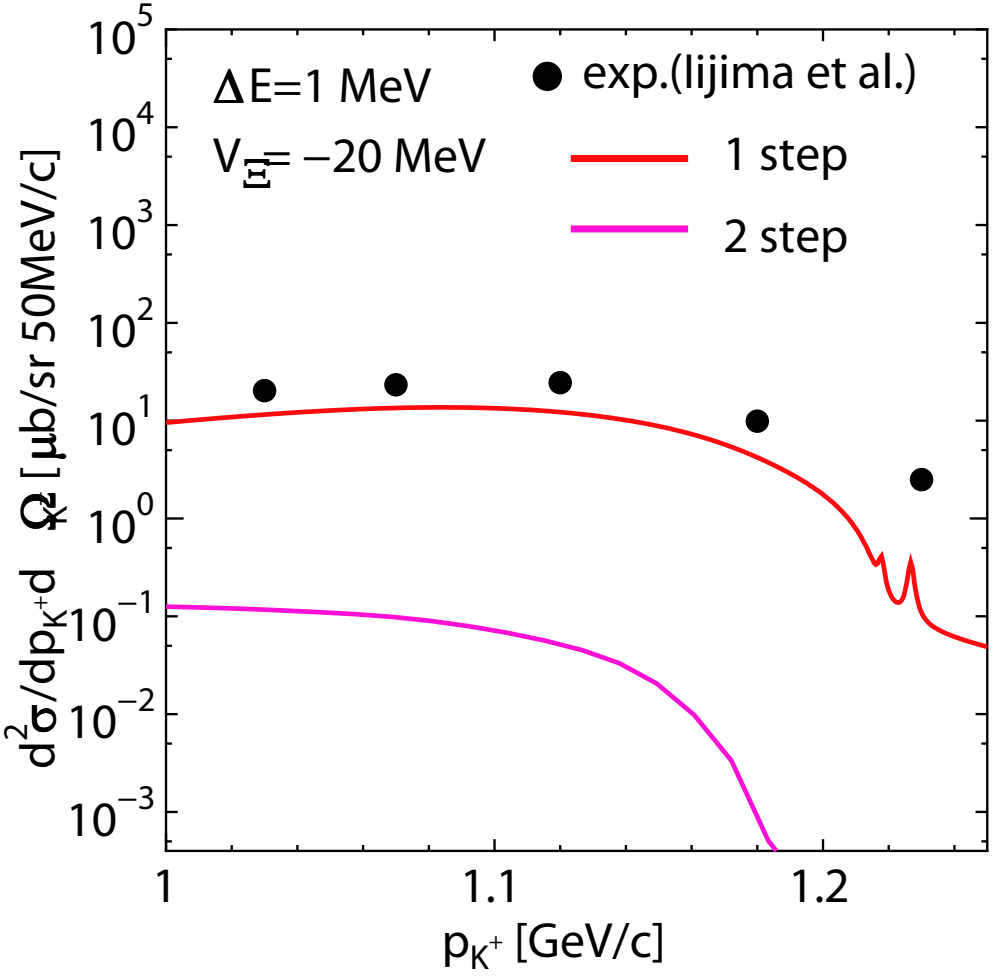
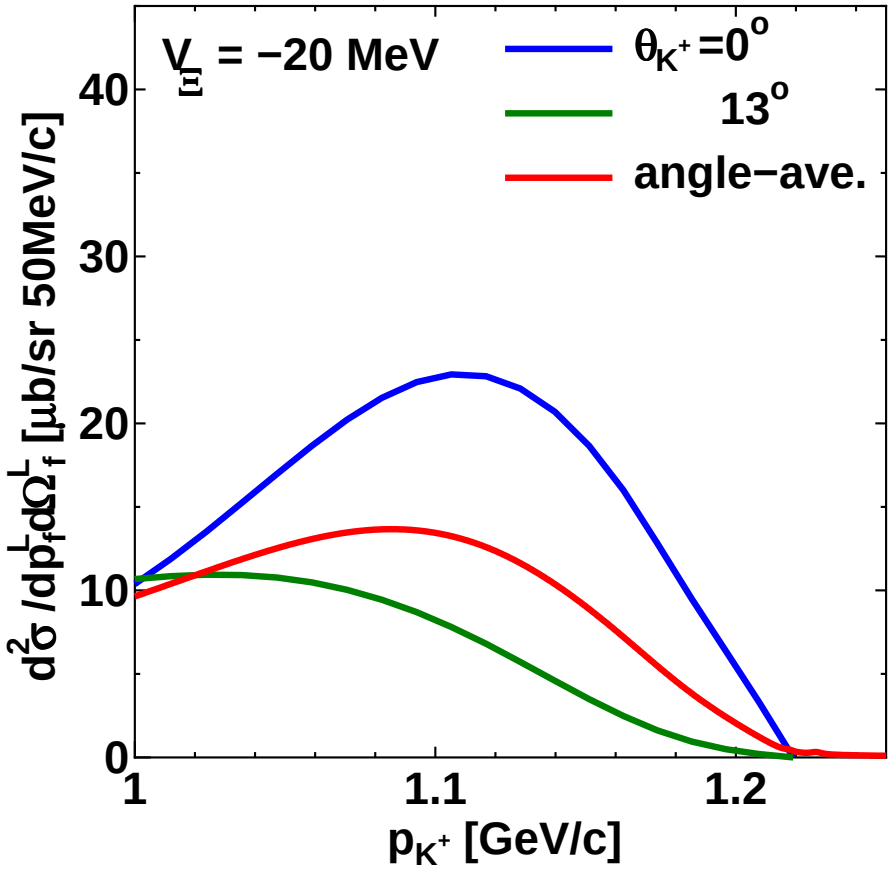


2-step processes is a few percent of 1-step process

Emission angle dependence

- $^{12}\mathrm{C}(K^-, K^+)$ reaction (at $p_{K^-} = 1.65$ GeV/c)
  - K^+ momentum spectrum



SCDW [S. Hashimoto et al., nucl-th/0610126.]

Dependence is very strong.

Summary

- The ^{12}C(K^-, K^+) reaction at $p_{K^-} = 1.65$ GeV/c is analyzed with the Semi-Classical Distorted Wave model, SCDW.
- It is found that the calculated hyperon production cross section depends on the Ξ^- single-particle potential.
- Since the SCDW calculation underestimate the experimental data by 50%, however, we cannot say anything definite about the Ξ^- potential at this stage of analysis.
- The cross section of the 2-step processes in the reaction is a few percents of that of 1-step process. It is cleared that the multi-step processes is not important in the reaction.

Future work

- We should understand the underestimation of the cross section by SCDW calculation.
  - We will improve the SCDW analysis in inclusion of the recoil effect in the reaction
  - We will estimate the ambiguity of the input parameters in the calculation.
- We will analyze the other reactions on the heavy target.