Nuclear Effects in Antineutrino Induced Hyperon Production

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NuWro Wroclaw Neutrino Event Generator

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Introduction

We study the Cabibbo suppressed production of hyperons in the interactions of antineutrinos and nucleons:

$$\bar{\nu}_l + N \rightarrow Y + l^+$$

$$N = p, n \qquad Y = \Lambda, \Sigma^0, \Sigma^-$$

Fewer than 100 events of this type have been observed [1-6], but upcoming experiments such as SBND and DUNE are expected to observe more events [7].

Hyperons are also unique nuclear probes: They are not subjected to Pauli blocking and are therefore free to propagate through the nucleus and rescatter at very low energies.

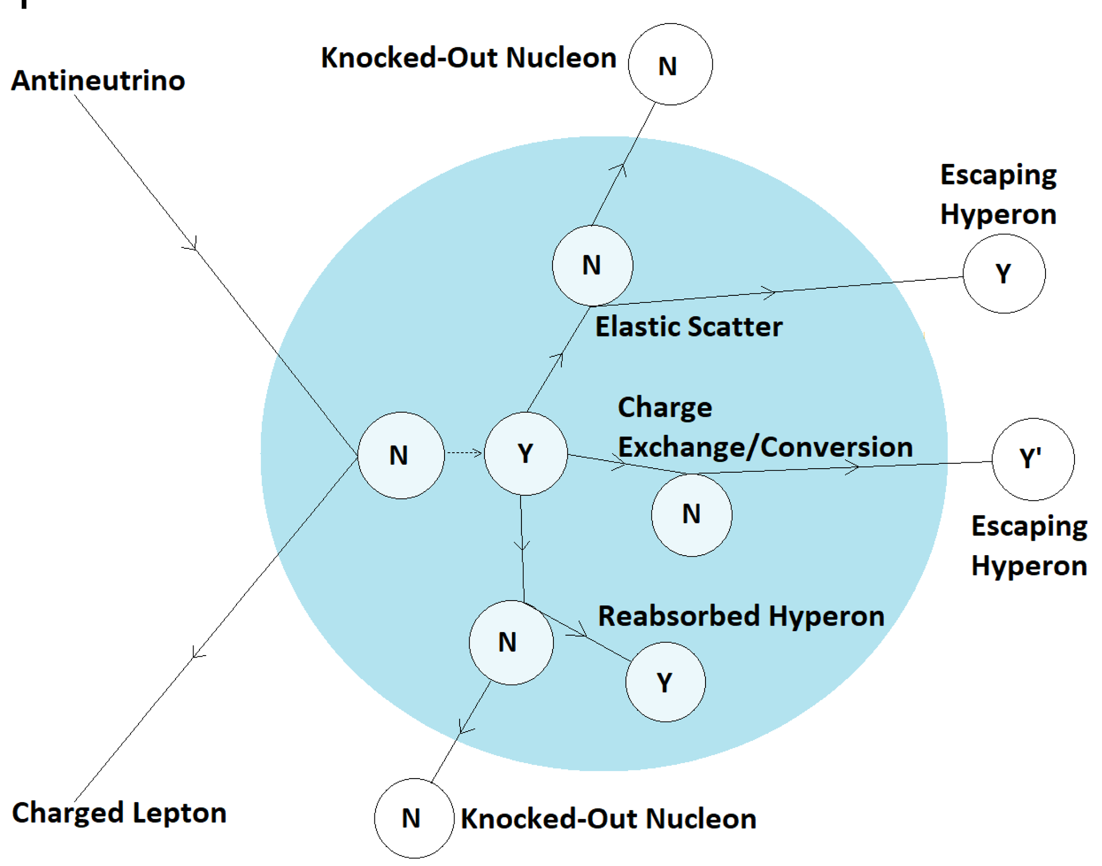
This process was implemented into the NuWro Monte Carlo generator, used here to study its sensitivity to nuclear effects.

Final State Interactions

Most neutrino event generators employ a factorization scheme: The neutrino interacts with a bound nucleon and the resulting particles propagate through the nucleus. The latter process is called **final state interactions (FSI)**.

Several possible outcomes of hyperon final state interactions are illustrated below:

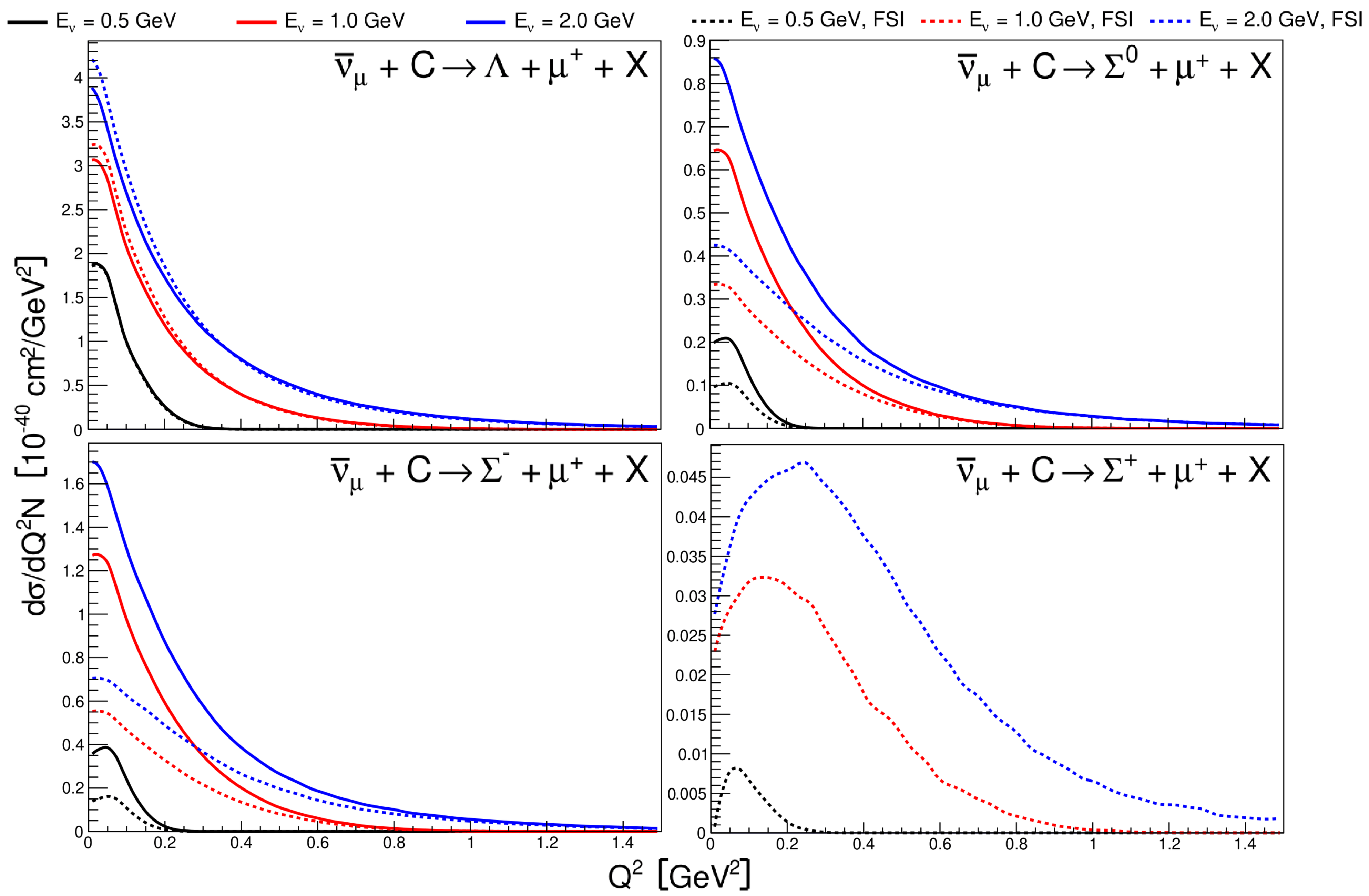
- The hyperon scatters off nucleons producing additional final state particles.
- Changes type via interaction with a nucleon.
- Dissipate its energy until it cannot escape the nuclear potential.



Reinteraction Effects

A comparison of the differential cross sections of the four hyperon production channels for several energies, before and after FSI (solid vs dashed lines) is presented below. Several effects are prominent:

- The Λ production cross section receives a small enhancement from Σ to Λ conversions.
- The Σ channels are suppressed at low Q^2, due to conversions to Λ and reabsorption by the nucleus.
- The Σ^+ baryon is produced exclusively through FSI.

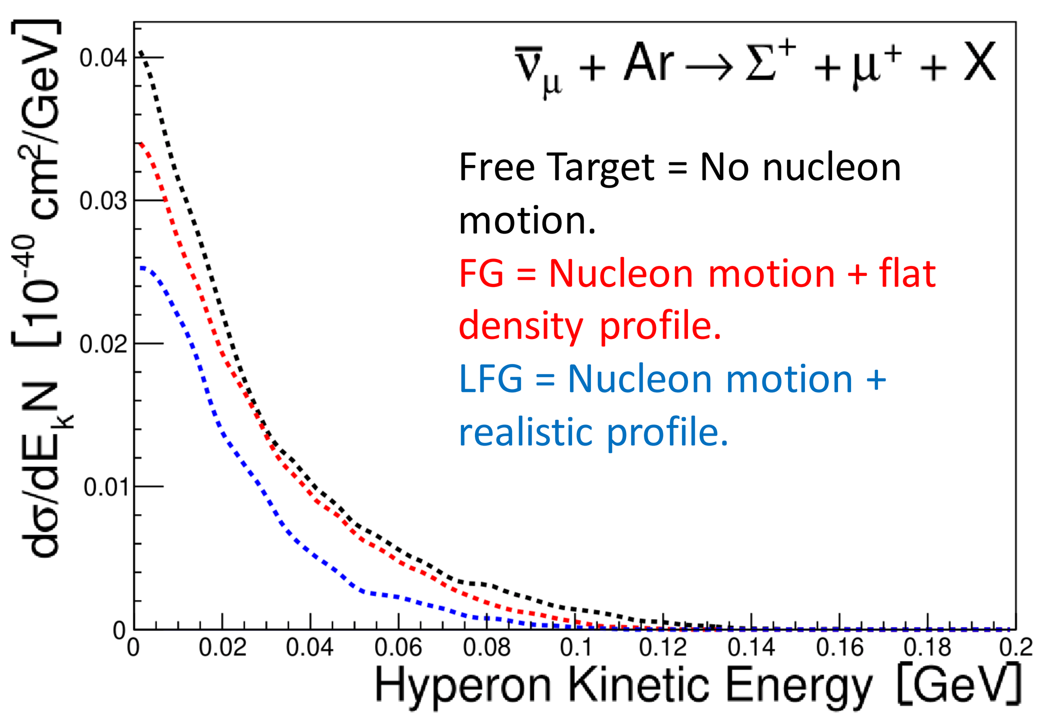


Nuclear Models

Several approaches to modelling the nucleus exist, some of which include nucleon motion.

The differential cross section for Σ^+ production using three nuclear models is shown. This hyperon is produced exclusively through FSI and is sensitive to nucleon motion.

There is a significant change in the distribution when the realistic density profile is introduced.

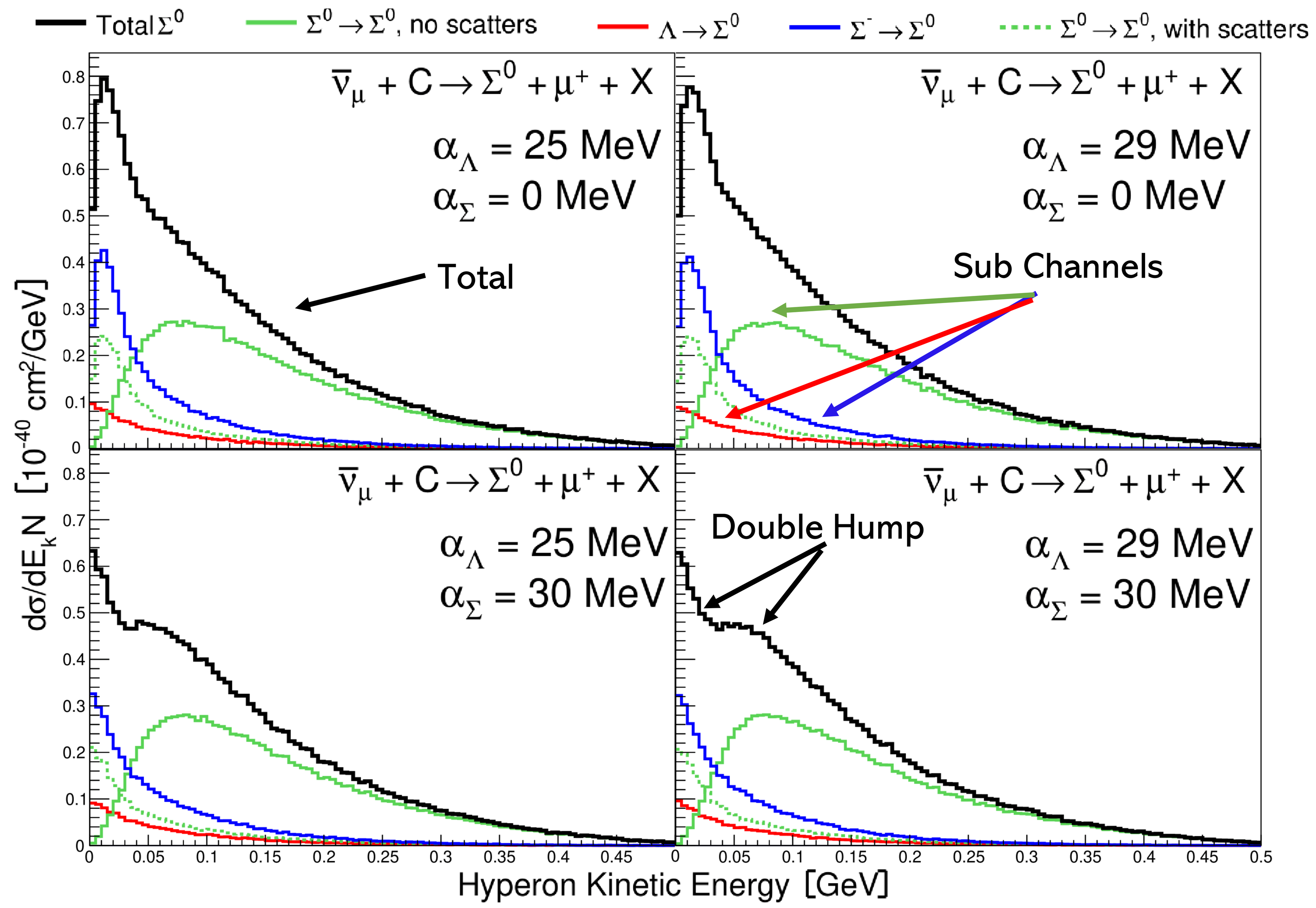


Hyperon Nucleus Potential

The hyperon in the nucleus is subject to the nuclear potential. Here we explore the effects of including a potential proportional to the density of the nucleus:

$$V(r) = -\alpha \frac{\rho(r)}{\rho(0)}$$

The parameter α controls the strength of this potential. We use separate strengths for the Λ and Σ baryons. Other calculations estimate the Λ nucleus potential strength to be in the range of 25-29 MeV [8], while the Σ nucleus potential is far less constrained.



The shape of the hyperon kinetic energy distribution is the result of several sub-channels, including conversions from other types. These contributions are comparable to the no-scatter channel, resulting in a "double hump" structure. Switching the Σ potential on has the effect of translating the $\Sigma^- \rightarrow \Sigma^0$ component to lower kinetic energies, changing the overall distribution significantly.

Summary

Hyperon production is affected by FSI in several ways including conversions between different channels and reabsorption into the nucleus. These effects are significant and should be detectable in future experiments.

This channel is sensitive to the nuclear model and hyperon nucleus potentials.

See Thorpe, Nowak, Sobczyk, Niewczas and Juszczak arXiv:2010.12361 **for further information.**

References

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