Studying Hyperon Production With the NuWro Monte Carlo Generator

Christopher Thorpe

Lancaster University

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c.thorpe@lancaster.ac.uk

What are Hyperons?

- Relatives of the proton and neutron containing strange quarks.
- Produced in interactions between nucleons and antineutrinos:

$$\bar{\nu}_l + p \rightarrow l^+ + \Lambda(uds) \quad (1)$$

$$\bar{\nu}_l + p \rightarrow l^+ + \Sigma^0(uds) \quad (2)$$

$$\bar{\nu}_l + n \rightarrow l^+ + \Sigma^-(dds) \quad (3)$$

- The Σ^+ is generated through final state interactions (FSI).
- Study this process using the NuWro Monte Carlo generator, which includes FSI for hyperons.

Measurement Potential

- Few measurements made by past experiments with very limited statistics.
- Model is poorly constrained at present.
- Upcoming experiments will be able to change this, eg. 12,500 events predicted for SBND [1], likely many more in DUNE.

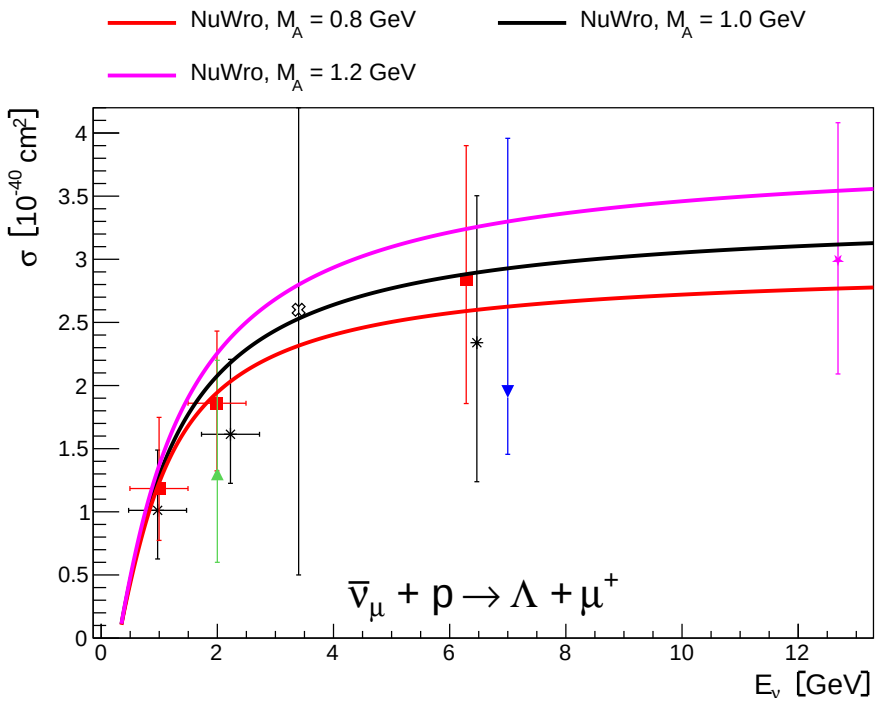


Figure: Total cross section for Λ production from free protons compared with existing data from the Gargamelle [2-4], SKAT [5], BNL [6] and FNAL [7] bubble chambers[1]

[1] Full breakdown of data in backup.

Motivations

- Model is derived using SU(3) quark flavour symmetry to find relations to similar processes[2] - sensitive to violations.

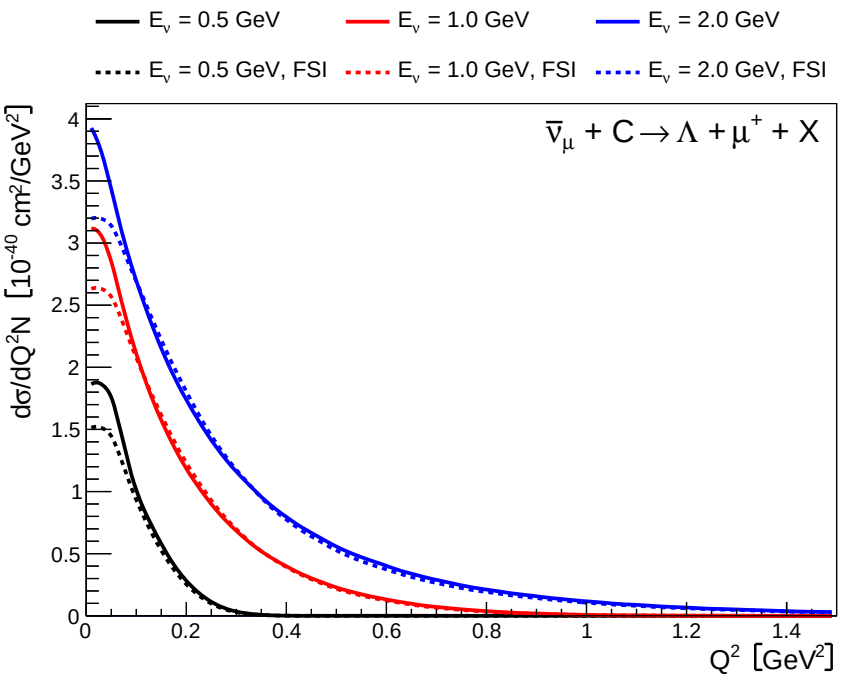
- Nuclear effects:
  - Hyperons are not Pauli blocked, can be produced at low energies inside the nucleus.
  - Hyperons should be subject to a potential generated by the nucleus, affects their appearance inside neutron stars [8].
  - Here we include a potential of the form:

$$V(r) = -30\ \mathrm{MeV}\ \frac{\rho(r)}{\rho(0)} \tag{4}$$

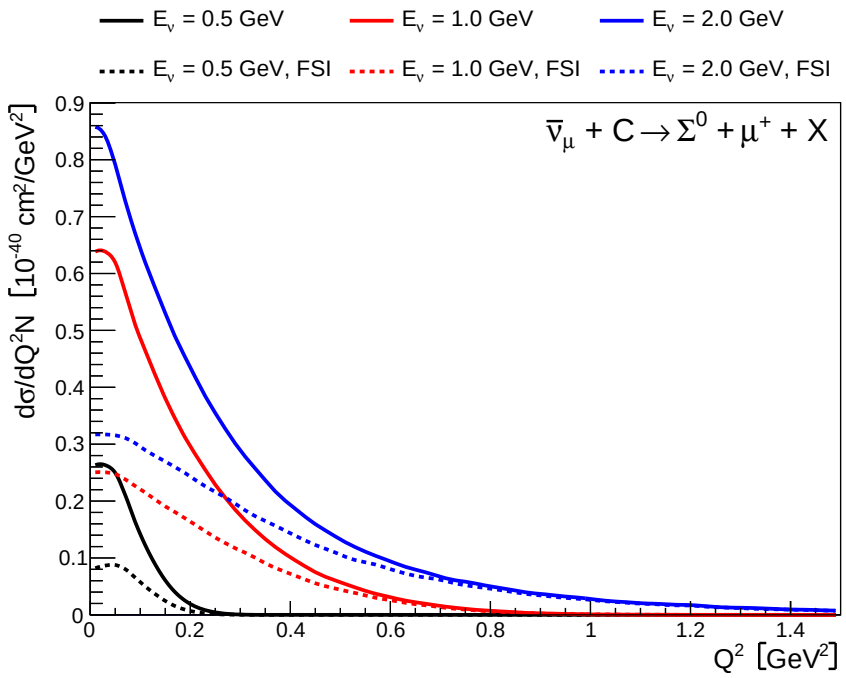
[2] In particular, $\bar{\nu}_l + n \to l^+ + p$

Nuclear Effects

- Study the cross section before and after the application of final state interactions (FSI).
- Prominent FSI effects are the conversion of Σ baryons into Λ and reabsorption of hyperons by nucleus.



(a) Λ production.

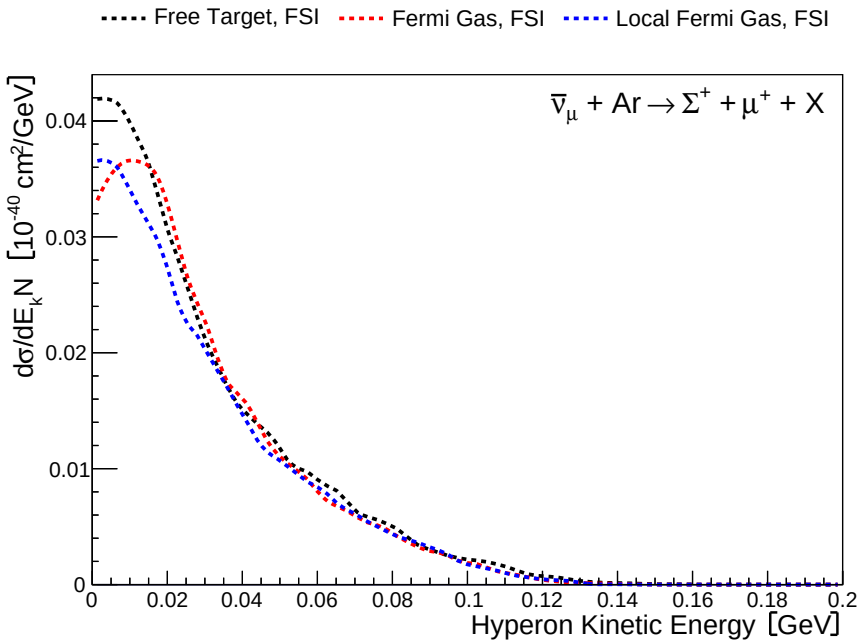


(b) Σ^0 production.

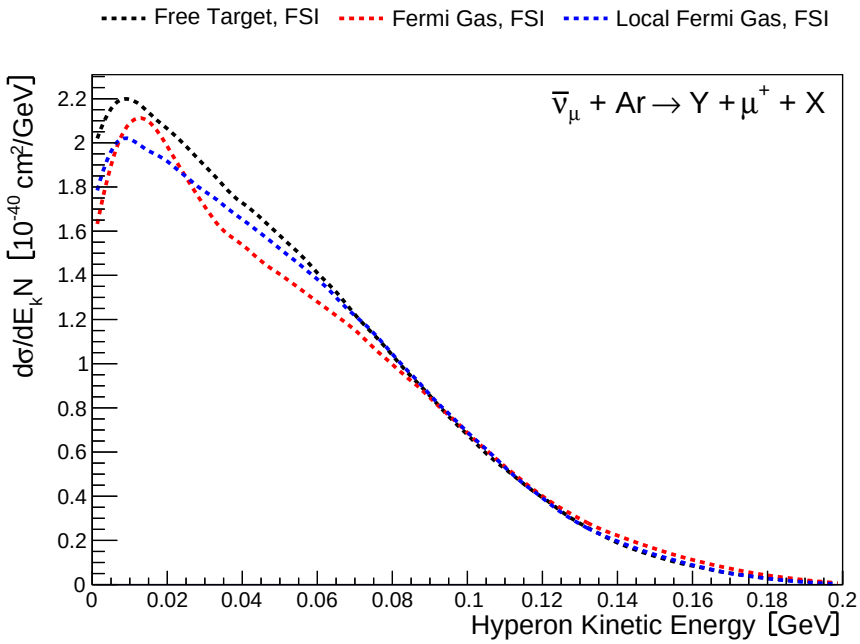
Figure: Differential cross section for production of Λ and Σ^0 from carbon at three neutrino energies.

Σ^+ Production

- Σ^+ produced exclusively as a result of FSI.
- Try out a few different nuclear models: Free target (stationary nucleons), global Fermi gas, local Fermi gas.



(a) Σ^+ production.



(b) Inclusive cross section.

Figure: Differential cross section as a function of the outgoing hyperon kinetic energy. $E_\nu = 1.0$ GeV.

Summary

- Rich phenomenology, very few measurements in existence, but this is expected to change in the near future.
- Lots of nuclear effects to study, predicted to be most prominent for low Q^2 events/slow moving hyperons.
- Conversion of Σs to Λs and reabsorption the most noticeable effects.
- See arXiv:2010.12361 [hep-ph] for more details.

Any questions?

References

[1] D. Brailsford [SBND Collaboration], J. Phys. Conf. Ser. **888** (2017) no.1, 012186

[2] T. Eichten *et al.*, Phys. Lett. **40B**, 593 (1972).

[3] O. Erriquez *et al.*, Nucl. Phys. B **140** (1978) 123.

[4] O. Erriquez *et al.* Phys. Lett. B **70** (1977) 383.

[5] J. Brunner *et al.* [SKAT Collaboration], Z. Phys. C **45** (1990) 551.

[6] G. Fanourakis *et al.*, Phys. Rev. D **21**, 562 (1980)

[7] V. V. Ammosov *et al.*, Z. Phys. C **36**, 377 (1987).

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[9] C. Thorpe, J. Nowak, K. Niewczas, J. T. Sobczyk and C. Juszczak, [arXiv:2010.12361 [hep-ph]].

Backup

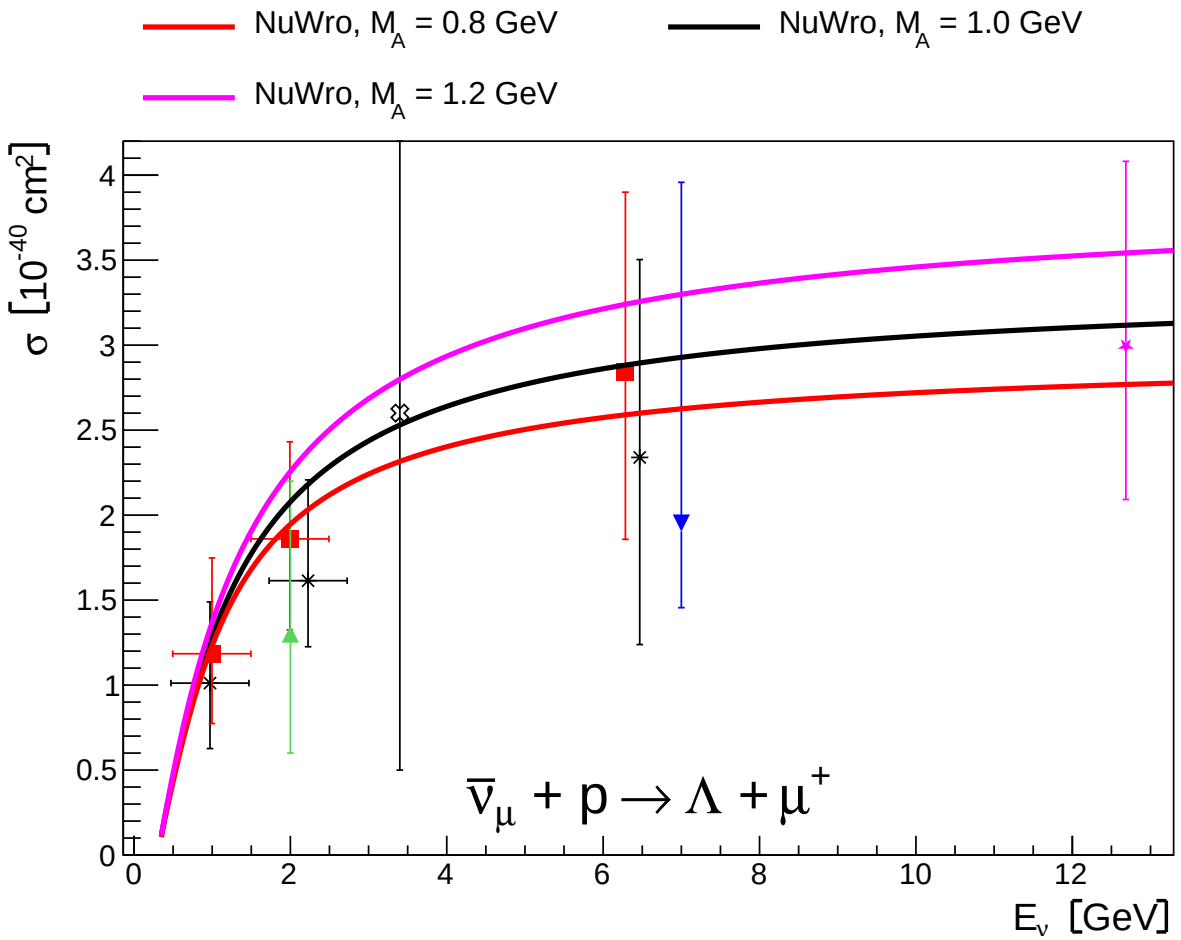

Figure: Total cross section for Λ production from free nucleons. Data is from the bubble chamber experiments: Gargamelle (green triangle [2], red square [3], black X [4]), SKAT(blue triangle [5]), BNL (white cross [6]), FNAL (pink star [7]).