Deep and Shallow Inelastic Scattering

Heather Ray

Department of Physics, University of Florida, Gainesville, Florida 32611, U.S.A.

Abstract. In this session we focused on the higher energy deep and shallow inelastic particle interactions, DIS and SIS. DIS interactions occur when the energy of the incident particle beam is so large that the beam is able to penetrate the nucleons inside of the target nuclei. These interactions occur at the smallest level possible, that of the quark-gluon, or parton, level. SIS interactions occur in an intermediate energy range, just below the energy required for DIS interactions. The DIS cross section formula contains structure functions that describe our understanding of the underlying parton structure of nature. The full description of DIS interactions requires three structure functions: two may be measured in charged lepton or neutrino scattering, but one can only be extracted from neutrino DIS data. There are reasons to expect that the impact of nuclear effects could be different for neutrinos engaging in the DIS interaction, vs those felt by leptons. In fact, fits by the nCTEQ collaboration have found that the neutrino-Fe structure functions appear to differ from those extracted from lepton scattering data [1]. To better understand the global picture of DIS and SIS, we chose a three-pronged attack that examined recent experimental results, data fits, and latest theory predictions. Experimental results from neutrino and lepton scattering, as well as collider experiments, were presented.

Keywords: neutrino interactions, deep inelastic scattering, shallow inelastic scattering
PACS: 13.15.+g, 25.30.Pt

INTRODUCTION

The "deep and shallow interactions" session focused on three primary areas: recent experimental results, fits to the global body of data, and latest theory predictions.

EXPERIMENTAL RESULTS

On the experimental front we have updates from the neutrino sector, lepton scattering, and collider experiments. Latest neutrino results are cross section measurements using the charged-current inclusive samples, or CC-inclusive. The CC-inclusive sample includes both DIS and SIS, and is an important sample to use to develop the particle identification and error handling algorithms necessary for the DIS and SIS analyses. We have CC-inclusive results from three experiments: MiniBooNE [2], MINERνA [3], and T2K [4]. All three experiments are operating with similar beam energies, and thus have similar compositions of event types in their CC-inclusive data sets. These analyses are in various stages of maturity, and use different neutrino generators as the basis for their theoretical predictions. The extracted cross sections and ratios of cross sections agree within a few sigma with the predictions from the NUANCE [5], NEUT [6], and GENIE [7] generators. The final goal for these analyses is to produce these measurements in the least model dependent way, that of a double differential cross section as a function of the reconstructed muon kinematics [8, 9, 10].

The JLab BoNuS[11] experiment is designed to measure the free neutron structure function at large $x_{Bjorken}$, and to measure nuclear effects in deuterium using a method known as spectator tagging. This large $x_{Bjorken}$ region is one that is still not well explored, and where our parton distribution functions are least well known. Filling in this region of phase-space will allow us to separate our up and down quark parton distributions (*i.e.* the valence and non-valence distributions). Results from the initial running of BONUS using the spectator tagging method are preliminary. There are plans to run the experiment with a higher energy beam, providing a probe of the F_2 structure function for neutrons up to a $x_{Bjorken}$ of approximately 0.8 [12].

From the collider front, final structure function data from the H1 [13] and ZEUS [14] experiments have been released. The parameters extracted from these data, and expected from data collected after upgrades to the accelerator complex, will provide tests of our theoretical predictions over four orders of magnitude in Q^2, or four-momentum transfer, in the range of $10^{-4} < x_{Bjorken} < 0.9$. Global parton distribution fits are now starting to use data from the

LHC [15] experiments. We expect many exciting results from these data in the near future [16].

FITS TO DATA AND THEORETICAL MODELING

In this session we also saw the latest results from the CTEQ collaboration [17], who perform global fits to DIS data to extract structure functions, a detailed discussion of the theoretical underpinnings of the GiBUU [18, 19] generator, and the modeling and theory of SIS interactions [19]. The many differences in assumptions and data sets used in the fits were discussed at length. In particular, of great interest was the handling of the transition region between SIS and DIS interactions.

SUMMARY

Presentations in this session covered latest experimental results, as well as fits to the data and theoretical advances. There has been a lot of work put forth on the experimental front, and we expect in the next several years to have a wealth of information coming from: extracted structure functions as a function of nuclear material, ratios of structure functions, SIS inputs, nuclear effects in neutrino vs lepton scattering as a function of the nuclear material, and from the 1 and 2 pion backgrounds in SIS. We have seen that there are a wide variety of fits to the data, but the use of different combinations of data sets and underlying assumptions makes it difficult to reconcile the charged lepton, Drell-Yan, and neutrino data. We have also seen how the various neutrino generators (NEUT, NUANCE, GENIE, and GiBUU) agree/disagree in their predictions. We need to ensure we have the "right" physics modeling included in our generators, but the lack of data for the DIS and SIS interactions makes it difficult to determine what is "right". Future DIS and SIS measurements will aid the development and advancement of these models through comparisons to all models, not just the preferred model for a given experiment.

ACKNOWLEDGMENTS

The author would like to thank the speakers of the session, M. Tzanov, K. Hurtado, A. Weber, E. Christy, E. Rizvi, J. Morfin, and O. Lalakulich, as well as the conference organizers, H. da Motta Filho and J. Morfin.

REFERENCES

1. I. Schienbein *et al.*, Phys. Rev. D**80** (2009) 094004; PRD **77** (2008) 054013
2. http://www-boone.fnal.gov/
3. http://minerva.fnal.gov/
4. http://t2k-experiment.org/
5. D. Casper, arXiv:hep-ph/0208030
6. Y. Hayato, Acta Physica Polonica B**40** (2009)
7. http://www.genie-mc.org/
8. M. Tzanov, in *The 8th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region (NuINT12)*, Rio de Janeiro, 2012.
9. K. Hurtado, in *The 8th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region (NuINT12)*, Rio de Janeiro, 2012.
10. A. Weber, in *The 8th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region (NuINT12)*, Rio de Janeiro, 2012.
11. H. Fenker *et al.*, Nucl. Instrum. Meth. A **592**, 273 (2008)
12. E. Christy, in *The 8th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region (NuINT12)*, Rio de Janeiro, 2012.
13. http://h1.desy.de/
14. http://www-zeus.desy.de/
15. http://lhc.web.cern.ch/lhc/
16. E. Rizvi, in *The 8th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region (NuINT12)*, Rio de Janeiro, 2012.
17. J. Morfin, in *The 8th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region (NuINT12)*, Rio de Janeiro, 2012.

18. http:/gibuu.physik.uni-giessen.de/GiBUU
19. O. Lalakulich, in *The 8th International Workshop on Neutrino-Nucleus Interactions in the Few-GeV Region (NuINT12)*, Rio de Janeiro, 2012.