

Future Needs in Hadronic Production Measurements

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Interactions of energetic particles on target nuclei producing secondary particles are important for fundamental and related Physics research. Current simulation codes rely upon poorly measured results from the past. While current neutrino experiments, both atmospheric and accelerator based, rely upon MIPP and pion production measurements which are poorly known and dominate their errors. The goal for the future upgrade MIPP experiment is to dramatically improve these measurements. It is not only of interest to neutrino experiments, but also for designing hadronic calorimeters for the the International Linear Collider which must achieve unprecedented resolutions for reaching their stated physics goals.

1. Introduction

MIPP upgrade is an experiment studying hadronic flavor particle production at Fermilab that just completed a first data taking run and has plans for future extended Physics. An upgraded version of this experiment is proposed as P960. Collectively these experiments will cover 1 to 120 GeV/c on multiple targets (liquid Hydrogen, Minos targets and various nuclear targets including Uranium) for six beam species (pion, kaon, protons and their antiparticles). This experiment expand upon the older cross section data and brings a variety of new physics goals: improved hadronic flavor production cross sections, studying fundamental scaling law relationships [1] and nuclear target production studies. Figure 1 shows the large uncertainty using current production cross-section data with a simulated neutrino target for the Fermilab MiniBooNE experiment [2]. This and other neutrino production experiments need substantial improvements, since this is what currently limits advances in neutrino physics.

In this modern experiment particle tracking and identification are both paramount, bringing essential information over previous measurements, see figure 2. These new data set and the broad physics analysis planned with preliminary first results on all of these topics are presented in the next section.

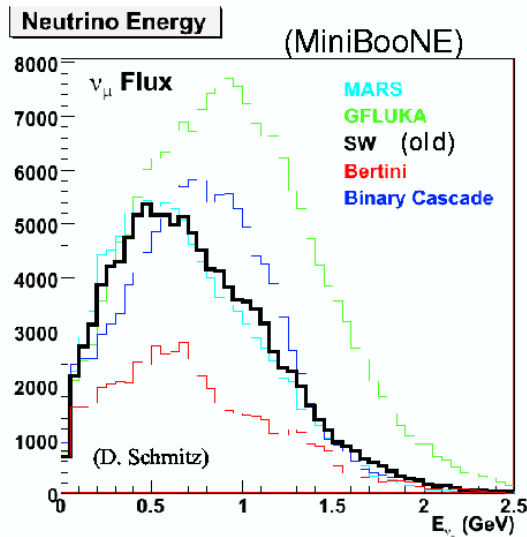
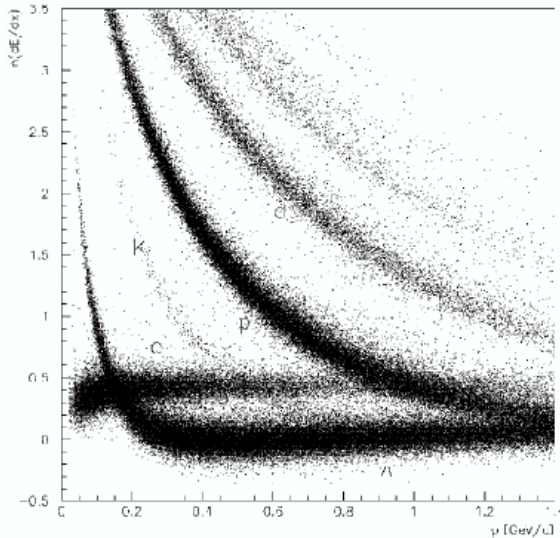


Figure 1. Calculated neutrino fluxes from a simulated MiniBooNE target using various codes and different measurements.



RICH Ring Radius vs. Momentum

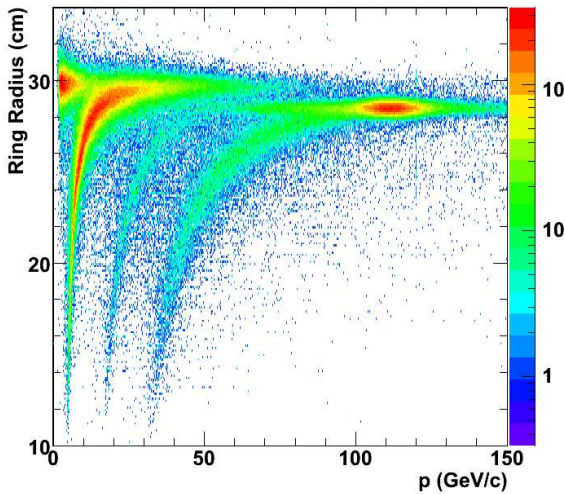


Figure 2. Two examples of the particle identification in these measurements are the TPC using dE/dx on the left (this is the same TPC that is currently in the Fermilab MIPP experiment but using final calibration in the BNL E910 experiment) and on the right is the MIPP RICH detector.

The proposed future run of an upgraded MIPP detector is of importance to future neutrino physics programs worldwide, such as Ice-Cube, NO ν A, Pierre Auger and SuperK/HyperK experiments. By doing a high statistics run including Liquid Nitrogen, for the complete forward production hemisphere with three sigma particle identification, it will permit detailed cross section measurements to refine the Monte-Carlo generators such as Fluka or MARS, which are of major relevance for improved future neutrino detectors. Current SuperK atmospheric neutrinos results are limited to a 20% error [3] from these uncertainties while the Ice-Cube experiment sees a 30 to 40% [4] impact using the current known cross-sections.

2. Recent results

New results were reported recently by the Brookhaven National Laboratory E910 CERNs Harp (PS214) and NA49 experiments. All of these results are for low momentum, and the future needs require higher momentum beam studies.

NuMI Target Studies for the MINOS Experiment with the MIPP data are well advanced with the current MIPP data. Crucial π and K production studies that the MINOS analysis will eventually rely upon will be provided by the MIPP experiment using the spare NuMI composite target. A 120 GeV/c beam of pure protons identical to that which hits the NuMI horn target was run in the MIPP experiment for two months and collected 2 million events. These events using the projectile particle tracking and secondary particle production identification and momentum reconstruction show first results from this analysis in figure 3 [5].

The MIPP experiment is also studying particle production multiplicities and its A dependence, see figure 4, for the first tentative results which are in agreement with [6].

3. Future improved measurements

The Fermilab MIPP experiment proposes to have an upgraded run from 2007 to 2009 with a

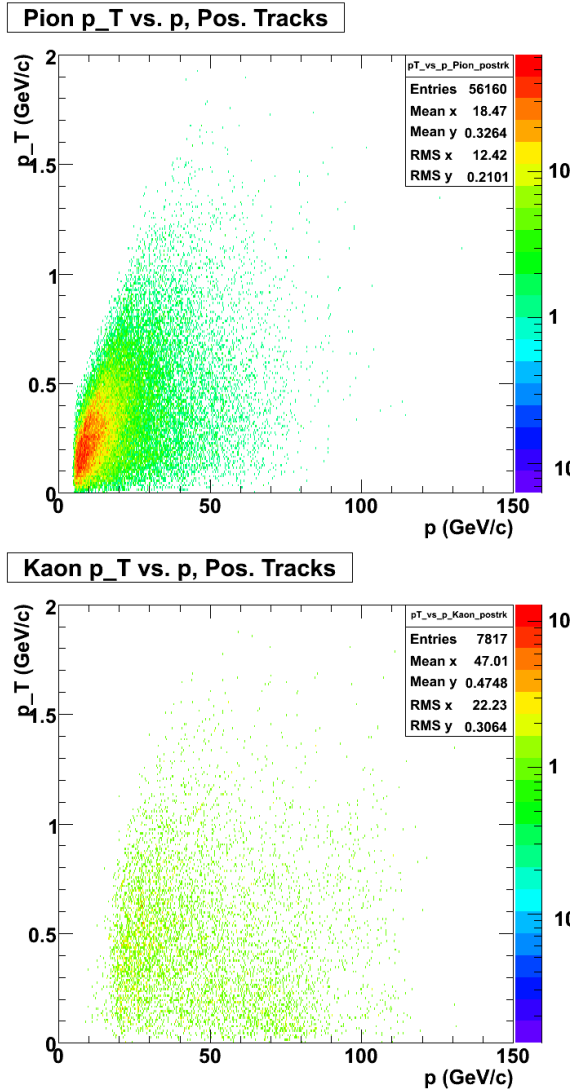


Figure 3. Preliminary study of π (top) and K (bottom) production by 120 GeV/c proton beam on the NuMI target in the MIPP experiment.

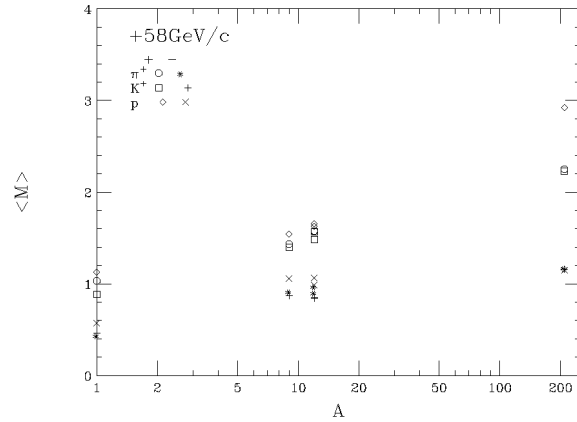


Figure 4. Preliminary MIPP results on the charged particle multiplicity from 0.15 to 1.0 GeV/c particles for beam particles at +58 GeV/c with tagged π , K and protons on nuclear targets from A=1 hydrogen to A=206 Bismuth, the data has been corrected for empty target runs.

faster readout of the TPC so that a 3 kHz rate can be achieved, 4π acceptance by installing a backward hemisphere detector, a new silicon vertex-interaction trigger that can study charm production, an improved calorimeters which is a cooperation with the International Linear Collider and other minor but essential modifications.

An extensive run with a Liquid Nitrogen target with a large data sample so that fine segmentation in angle can be measured for all interaction species, this is explicitly needed for the atmospheric neutrino experiments such as: Ice-Cube and Hyper-K, to improve their neutrino flux from π and K decays. Figure 5 shows the current limitation to the Amanda experiment above 10^4 GeV/c, this comes from the Cosmic Ray uncertainties of atmospheric production of Kaons and pions [7]. Current models are uncertain above 10^5 GeV/c. Members of the Ice-Cube experiment from the Univ. of Wisconsin and Fermilab members of the Pierre Auger Experiment will be joining the MIPP upgraded experiment. By improving the cross-sections at low momentum this

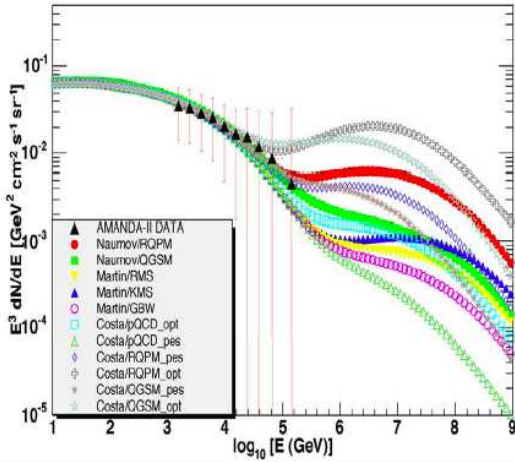


Figure 5. Errors in atmospheric neutrino production based upon current π and K production cross-section on a Nitrogen target.

will assist in the extrapolation to high momentum with improved error bars. We plan to study many different elements for improvements to hadronic shower simulation code for hadronic calorimeter design. These measurements are vital to improving Hadron Calorimetry, which is the most important detector in the ILC. Hadron Calorimetry designs rely upon Monte-Carlo codes where the detector materials are not well known. Furthermore, the response of the ILC test calorimeter to neutrons and its efficiency is essential to the Particle Flow algorithms. By putting the ILC hadron calorimeter in the MIPP beam line they will be able to provide a direct measure of neutron energy and efficiency response with tagged neutrons [8]. It will also provide a unique opportunity for tagged K^0 and \bar{K}^0 physics program.

4. Conclusion

The MIPP experiment with current improvements to the hadronic flavor production studies has greatly helped make improved cross-sections. Future data from the upgraded MIPP experiment

will be a guiding light for both atmospheric and accelerator based neutrino experiments, without which caution would be required before continue neutrino studies with larger and large detectors. Cosmic ray experiments will make use of detailed particle production measurements and hopefully make air-shower experiments the new high-energy frontier for particle physics experiments beyond the LHC. A great improvement in anti-proton interactions and charm production is also planned. Future data and analyzed results are excitingly awaited.

References

REFERENCES

1. R. Raja *et al.*, Phys. Rev. D, v18, p204, 1978.
2. D. Schmitz, Constraining MiniBooNE Neutrino Flux Predictions with the HARP Experiment, APS meeting April 2005.
3. Y. Suzuki for the SuperK collaboration, private communications, March 2006.
4. F. Halzen for the Ice-Cube collaboration, private communications, March 2006.
5. J. Paley (for the MIPP collaboration), Hadronic cross sections for neutrino production in MIPP, APS 2006 poster presentation.
6. F.M. Liu *et al.* Phys. Rev. C69, 054002 (2004).
7. T. Montaruli, Univ. of Wisconsin for the Ice-Cube collaboration, private communications, March 2006.
8. R. Raja *et al.*, Tagged neutrons, anti-neutron and K-long beam in the upgraded MIPP experiment, MIPP note 130, 23 May 2006.