Measurement of the Drell-Yan angular distribution in $p+p$ interaction at 120 GeV/c by SeaQuest experiment at Fermilab

K. Nagai,[*1] Y. Goto,[*2] Y. Miyachi,[*3] K. Nakano,[*2,*4] S. Sawada,[*2,*5] and T.-A. Shibata[*2,*6]
for the E906/SeaQuest Collaboration

The Drell-Yan process, in which a quark in one hadron interacts with an antiquark in another hadron to create a lepton pair through a virtual photon, has been utilized as a method for exploring parton distributions.[1,2] The general expression of the Drell-Yan angular distribution is

$$\frac{d\sigma}{d\Omega} \propto 1+\lambda\cos^2\theta+\mu\sin 2\theta\cos\phi+\frac{1}{2}\nu\sin^2\theta\cos 2\phi, \quad (1)$$

where θ and ϕ represent the polar and azimuthal angles of the positive lepton in the virtual photon rest frame, respectively.

The angular distribution of the naive Drell-Yan process exhibits a $\cos\theta$ modulation but lacks a ϕ modulation, *i.e.*, $(\lambda,\mu,\nu)=(1,0,0)$.[3] A ϕ modulation, observed as a non-zero ν, can emerge when higher-order effects of quantum chromodynamics (QCD) are considered.[4] Comparing experimental results with pQCD predictions, the NA10 experiment, a pion-induced Drell-Yan experiment at 140, 194, and 286 GeV/c, demonstrated excellent agreement with perturbative QCD (pQCD) calculations.[4] However, the ν values measured by the E615 experiment (pion-induced Drell-Yan at 252 GeV/c) and E866 experiment (proton-induced Drell-Yan at 800 GeV/c) deviated significantly from pQCD calculations. Several sources may have led to this discrepancy. One of them is the Boer-Mulders function, a transverse momentum-dependent parton distribution function.[5] Thus far, proton-induced Drell-Yan angular distributions have been measured only by E866. The SeaQuest experiment can be used for further measurements of proton-induced Drell-Yan angular distributions for a more detailed investigation.

The SeaQuest experiment at Fermilab utilizes a proton beam extracted from the Fermilab Main Injector at 120 GeV/c and various fixed targets. In this study, the angular distribution analysis used a liquid hydrogen target. The experimental setup comprised of four tracking stations, consisting of hodoscope arrays and drift chambers or proportional tubes, designed to detect muon pairs. A magnet positioned between the first and second tracking stations was used to determine the muon momenta. A hadron absorber located between the third and fourth tracking stations was employed for muon identification.

The preliminary results of the angular distribution obtained by the SeaQuest experiment are shown in Figs. 1 and 2. Owing to statistical constraints, the λ value is fixed at 1.0, and these preliminary results are extracted for only one p_T bin. The μ value is close to 0.0, as observed in the E866 results. In contrast to the E866 experiment, a significant ν value is observed, compatible with the pion-induced Drell-Yan results.

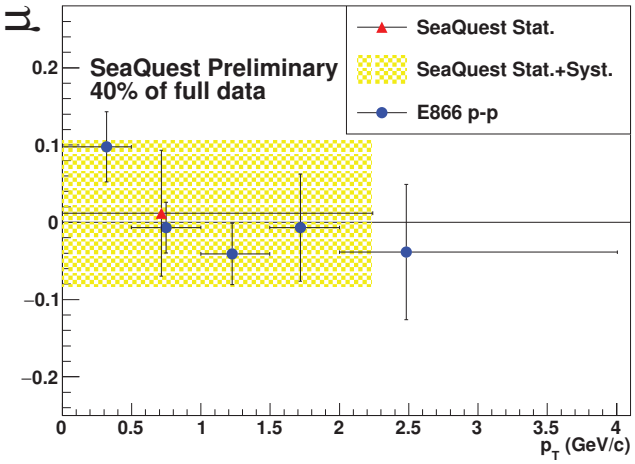

Fig. 1. Preliminary results of μ (red point) plotted with the E866 results (blue points).

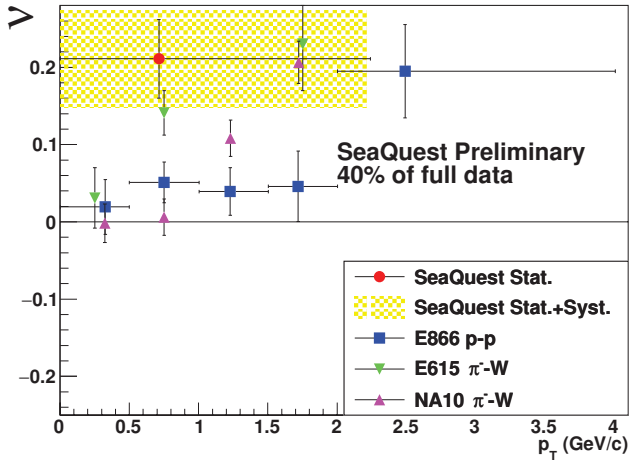

Fig. 2. Preliminary results of ν (red point) plotted with the E866 (blue points), E615 (green points), and NA10 (magenta points) results.

This report focuses on the $p+p$ Drell-Yan angular distribution. However, in our ongoing efforts, we are

*1 Physics Division, Los Alamos National Laboratory
*2 RIKEN Nishina Center
*3 Faculty of Science, Yamagata University
*4 Department of Physics, University of Virginia
*5 Wako Nuclear Science Center (WNSC), IPNS, KEK
*6 College of Science and Technology, Nihon University

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also extracting the angular distribution in $p + d$ interactions.

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