Progress in analysis technique for extracting light-antiquark flavor asymmetry by SeaQuest at Fermilab

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

The amounts of $\bar{d}$ and $\bar{u}$ in a proton were expected to be the same based on the flavor independence of gluon splitting. However, the NMC experiment at CERN showed that the total amount of $\bar{d}$ exceeds that of $\bar{u}$.[1,2] The NA51 experiment at CERN and the E866 experiment at Fermilab measured the Bjorken x dependence of the light-antiquark flavor asymmetry $\bar{d}/\bar{u}$,[3,4] where Bjorken x is the momentum fraction of a parton to a proton. They found that $\bar{d}/\bar{u} > 1.0$ at $x < 0.25$ and $\bar{d}/\bar{u} < 1.0$ at $x \sim 0.3$, although the results at $x \sim 0.3$ is consistent with 1.0 due to the large statistical uncertainty. It is very important to measure $\bar{d}/\bar{u}$ in this unclear region in order to understand the proton structure.

The SeaQuest experiment is a Drell–Yan experiment performed at the Fermi National Accelerator Laboratory (Fermilab) in Illinois, US. The main purpose of this experiment is to measure the light-antiquark flavor asymmetry in a proton in $0.1 < x < 0.45$, which includes the unclear region in the previous experiments.

As shown in Fig. 1, the Drell–Yan process is a reaction in which an antiquark in a hadron and a quark in another hadron annihilate and decay into a lepton pair via a virtual photon: $q + \bar{q} \rightarrow \gamma^* \rightarrow \mu^+ + \mu^-$.[5] The cross section of the proton-proton Drell–Yan process at the leading order is expressed as

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9x_1x_2} \frac{1}{s} \sum_{i=u,d,s,\ldots} e_i^2 \left[q_i(x_1)\bar{q}_i(x_2) + \bar{q}_i(x_1)q_i(x_2)\right], \quad (1)$$

where x is the Bjorken x, the subscripts (1, 2) denote the beam and the target, respectively, and $q(x)$ is the parton distribution function. In the SeaQuest acceptance ($x_1 \gg x_2$), the last term of Eq. (1) vanishes because the PDFs of antiquarks are small enough at the high x region. Therefore, an antiquark of the target proton is always involved in the process and is thus accessible easily.

The SeaQuest experiment measures the muon pairs in the final state of the Drell–Yan process, which is produced with the 120 GeV proton beam provided by the Fermilab Main Injector and the liquid hydrogen and deuterium targets. The details of the SeaQuest spectrometer have been reported in the past.[6] SeaQuest took the physics data from 2013 through 2017. The recorded number of beam protons on targets is 1.4×10^{18}. At this moment, about 40% of the data are being analyzed.

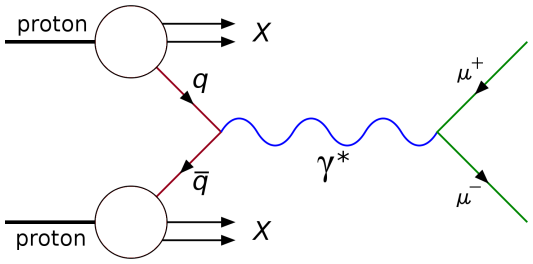

Fig. 1. Diagram of the Drell–Yan process.

The preliminary result of the light-quark flavor asymmetry was reported.[7] The analysis toward the final result is currently in progress.

There are two difficulties that need to be resolved in the current analysis: the estimation of the beam-intensity dependence of the reconstruction efficiency and that of the random background. We are now testing a new method for resolving them based on real data instead of simulation, namely the so-called extrapolation method.

In this method, we evaluate the cross section ratio first as a function of the beam intensity. Here, we do not apply any corrections. Then it is fitted with a function and extrapolated to the zero beam intensity. The extrapolated value is considered to be the "correct" cross section ratio. Through the simulation, we confirmed that the extrapolation method removes the beam-intensity dependence of the reconstruction efficiency correctly. The investigation to confirm whether this method can handle the random background is in progress.

*1 Institute of Physics, Academia Sinica, Taiwan
*2 RIKEN Nishina Center
*3 Department of Physics, Yamagata University
*4 Department of Physics, Tokyo Institute of Technology
*5 Institute of Particle and Nuclear Studies, KEK
*6 College of Science and Technology, Nihon University

References

1) P. Amaudruz *et al.*, Phys. Rev. Lett. **66**, 2712 (1991).
2) M. Arneodo *et al.*, Phys. Rev. D **50**, R1 (1994).
3) A. Baldit *et al.*, Phys. Lett. B **332**, 244 (1994).
4) E. A. Hawker *et al.*, Phys. Rev. Lett. **80**, 3715 (1998).
5) S. D. Drell, T. M. Yan, Phys. Rev. Lett. **25**, 316 (1970).
6) K. Nagai *et al.*, RIKEN Accel. Prog. Rep. **49**, 114 (2016).
7) K. Nakano *et al.*, RIKEN Accel. Prog. Rep. **50**, 118 (2017).