Measurement of anti-quark flavor asymmetry in the proton at SeaQuest

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The distributions of light anti-quarks ($\bar{u}$ and $\bar{d}$) in the proton had been assumed to be flavor symmetric, i.e., $\bar{d}(x) = \bar{u}(x)$, because they should be created via gluon splitting ($g \to q\bar{q}$) with the same probability because of their almost equal mass and flavor independence. However, a large asymmetry has been observed by the NMC, NA51, and E866/NuSea experiments[1]. Various theoretical models are being examined to understand the origin of this flavor asymmetry.[2] The SeaQuest experiment at Fermilab aims to measure the asymmetry $\bar{d}/\bar{u}$ at high x, up to 0.45, to reveal the x dependence of $\bar{d}/\bar{u}$.

SeaQuest utilizes a 120-GeV proton beam from the Fermilab Main Injector ($\sqrt{s} = 15$ GeV). It employs liquid-hydrogen (LH_2) and liquid-deuterium (LD_2) targets to measure the Drell-Yan process in $p+p$ and $p+d$ reactions. In the Drell-Yan process, a quark in one hadron and an anti-quark in the other hadron annihilate into a virtual photon and then decay into a lepton pair: $q + \bar{q} \to \gamma^* \to l^+ + l^-$. At the forward rapidity ($x_F \gg 0$) and under p-n isospin symmetry, the ratio of $p+p$ and $p+d$ cross-sections relates to the anti-quark flavor asymmetry as

$$\frac{\sigma_{p+d}(x_2)}{2\sigma_{p+p}(x_2)} \approx \frac{1}{2}\left(1 + \frac{\bar{d}(x_2)}{\bar{u}(x_2)}\right), \quad (1)$$

where x_2 denotes the Bjorken x of partons in the target-side hadron. Most systematic errors in the measurement cancel out in this ratio.

The SeaQuest spectrometer detects the final-state muon pair of the Drell-Yan process. Details and the recent status of SeaQuest were reported last year.[3] SeaQuest has been acquiring physics data since November 2013 and had recorded 1.1×10^{18} beam protons on targets as of summer 2016. About 50% of the recorded data were analyzed.

The cross-section ratio $\sigma_{pd}/2\sigma_{pp}$ was derived from dimuon yields measured on the LH_2 and LD_2 targets. We selected dimuons with an invariant mass larger than 4.2 GeV, where the Drell-Yan events are dominant. The yields have been corrected for track-reconstruction efficiency and background dimuons. Figure 1 shows a preliminary result for $\sigma_{pd}/2\sigma_{pp}$ measured by SeaQuest. The systematic uncertainty arises from the impurity of the LD_2 target and the inaccuracy of the dimuon-yield corrections.

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The anti-quark flavor asymmetry $\bar{d}/\bar{u}$ was extracted from $\sigma_{pd}/2\sigma_{pp}$. The cross section was computed at the leading order in α_s without nuclear correction for deuterium. Figure 2 shows a preliminary result for $\bar{d}/\bar{u}$ obtained by SeaQuest. It reveals $\bar{d}/\bar{u}$ with the best ever precision at $0.20 < x_2 < 0.58$. The systematic uncertainty includes the uncertainty of the parton distribution function (PDF) used in this extraction (CT10LO[4]). Very interestingly, it suggests $\bar{d}/\bar{u} > 1$ at high x, despite the E866 result.[1] Further analyses are being made to improve the measurement accuracy and investigate the difference with respect to E866.

Physics data are being acquired in fiscal year 2017. We expect to record about 4×10^{17} beam protons on targets. We have upgraded the spectrometer, namely achieving a wider acceptance and a faster DAQ. The statistics with the full dataset will be four times better at high x than the preliminary result.

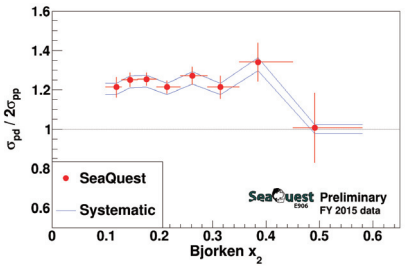

Fig. 1. Ratio of $p+p$ and $p+d$ Drell-Yan cross sections versus Bjorken x of target-side partons (x_2).

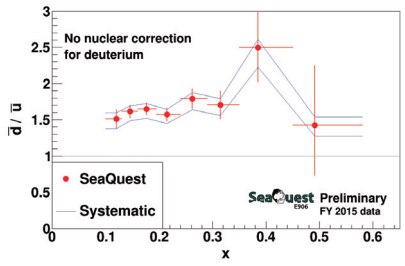

Fig. 2. Anti-quark flavor asymmetry ($\bar{d}/\bar{u}$) versus x.

References

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