Measurement of flavor asymmetry of light-quark sea in the proton with Drell-Yan dimuon production in $p+p$ and $p+d$ collisions at 120 GeV†

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Evidence for a flavor asymmetry between the $\bar{u}$ and $\bar{d}$ quark distributions in the proton has been found in deep-inelastic scattering and Drell-Yan experiments.[1,2] The asymmetry observed in the E866 experiment[3] suggested a drop of the $\bar{d}(x)/\bar{u}(x)$ ratio in the $x > 0.15$ region, where x means the fraction of nucleon momentum carried by partons. Here, we report results from the SeaQuest experiment, with improved statistical precision, for the flavor asymmetry in the large x region up to $x = 0.45$.

The SeaQuest experiment detects $\mu^+\mu^-$ pairs (dimuons) produced in the Drell-Yan process.[4] The differential cross section at leading order is given by:

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9x_1x_2s} \times \sum_{i\in u,d,s,\ldots} e_i^2 \left[q_i^A(x_1)\,\bar{q}_i^B(x_2) + \bar{q}_i^A(x_1)\,q_i^B(x_2)\right], \quad (1)$$

where α is the fine-structure constant, e_i is the charge of a quark with flavor i, and $q_i^{A,B}(x_{1,2})$ are the quark distribution functions in hadrons A and B for quarks carrying a momentum fraction x_1 and x_2, respectively. SeaQuest utilized the 120-GeV proton beam at Fermilab for hadron A and liquid hydrogen and deuterium targets for hadron B. The cross-section ratio of the two targets has a direct sensitivity to $\bar{d}(x)/\bar{u}(x)$ as

$$\frac{\sigma^{pd}}{2\sigma^{pp}} \approx \frac{1}{2}\left[1 + \frac{\bar{d}(x_2)}{\bar{u}(x_2)}\right]. \quad (2)$$

The data that SeaQuest recorded between June 2014 and July 2015 were analyzed.

The result of $\sigma^{pd}/2\sigma^{pp}$ using the "Intensity-Extrapolation" (IE) method was reported in Refs. 5) and 6). We developed another method of extracting $\sigma^{pd}/2\sigma^{pp}$, called "Mass-Fit" (MF) method, in order to confirm that the systematic uncertainty of the IE method has been properly evaluated. The results of $\sigma^{pd}/2\sigma^{pp}$ using the two methods are shown in Fig. 1. They are in excellent agreement.

The ratio of $\bar{d}(x)/\bar{u}(x)$ was derived from $\sigma^{pd}/2\sigma^{pp}$ and reported in Refs. 5) and 6). Using $\bar{d}(x)/\bar{u}(x)$ as input, we can determine the difference, $\bar{d}(x) - \bar{u}(x)$. It provides a direct measure of the contribution from non-perturbative processes, since perturbative processes should cancel out in $\bar{d}(x) - \bar{u}(x)$. Figure 2 shows $\bar{d}(x) - \bar{u}(x)$ at $Q^2 = 25.5$ GeV^2 over the region $0.13 < x < 0.45$. For comparison, experimental data and theoretical calculations are overlaid. The SeaQuest data have better uncertainty than the existing data, and are in good agreement with the two calculations.

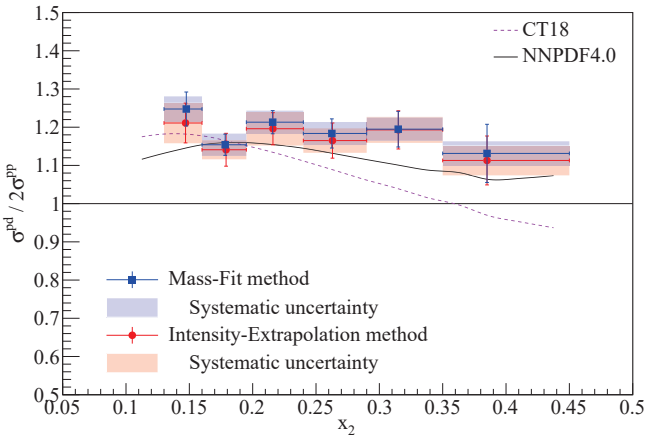

Fig. 1. The cross section ratio versus x_2 obtained with the two extraction methods.

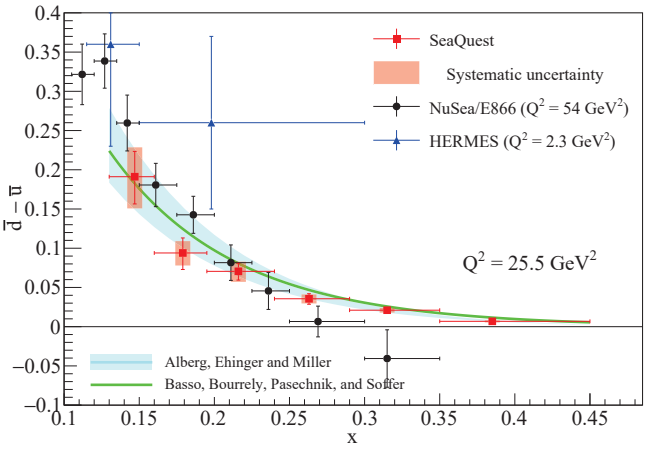

Fig. 2. Result of $\bar{d}(x) - \bar{u}(x)$.

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