$\bar{d}/\bar{u}$ Asymmetry in the Nucleon Sea – Fermilab Experiment E866

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Fermilab experiment E866 is a high-precision measurement of the light antiquark composition of the nucleon via a study of Drell-Yan muon pair production in 800 GeV/c pp and pd collisions. The ratio of the Drell-Yan cross sections in these two reactions as a function of the momentum fraction, x_2, of the participating target parton provides a direct determination of $\bar{d}/\bar{u}$ in the proton as a function of x. E866 took data to determine the cross section ratio $\sigma^{pd}/2\sigma^{pp}$ with three different spectrometer settings, optimized for different effective masses of the Drell-Yan muon pair. The low mass setting provided good coverage from below the J/ψ to about 8 GeV, the intermediate mass setting provided good coverage from about 5.5 GeV to 11 GeV, and the high mass setting provided good coverage from below 7 GeV to 15 GeV. Initially, the collaboration chose to focus on the analysis of the high mass data, since it suffered from fewer systematic problems associated with random backgrounds and rate-dependent reconstruction efficiencies than the other two. The results of that analysis, which served as the basis for E. Hawker's Ph.D. thesis, were described in last year's report and have now been published [1]. It should also be noted that Dr. Hawker was recently awarded the 1999 APS Division of Nuclear Physics Thesis Prize for his work on E866.

Since then, the analysis effort has focused on a detailed understanding of and correction for these systematic effects in all three data sets, with the goal of both improving the statistical precision in our determination of $\bar{d}/\bar{u}$ and reducing its systematic uncertainty. The analysis of all three data sets is now complete, and the results are being prepared for publication. Figure 1 demonstrates the excellent agreement that we obtain for $\sigma^{pd}/2\sigma^{pp}$ from the three independent data sets. These cross section ratios have been combined to determine $\bar{d}/\bar{u}$ over the range $0.015 < x < 0.35$, as shown in Fig. 2. The figure shows $\bar{d}/\bar{u}$ as predicted by two previous state-of-the-art parton distribution functions, MRS(R2) and CTEQ4M. Both provide a very poor description of the data. The figure also shows $\bar{d}/\bar{u}$ as predicted by MRST, the first parton distribution fit that has incorporated our results from the high mass data set as additional constraints. This demonstrates that, while our

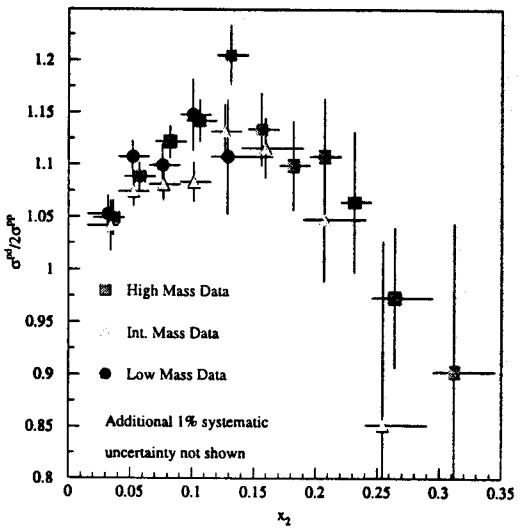

Figure 1: The Drell-Yan cross section ratio versus x of the target parton, for each of the three spectrometer settings.

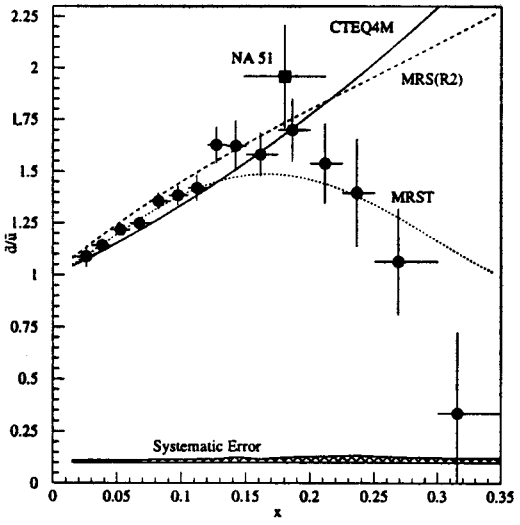

Figure 2: $\bar{d}/\bar{u}$ in the proton as a function of x, from a combined analysis of the measured Drell-Yan cross section ratios in the three mass settings. Also shown are predictions for $\bar{d}/\bar{u}$ from three recent parton distribution function fits.

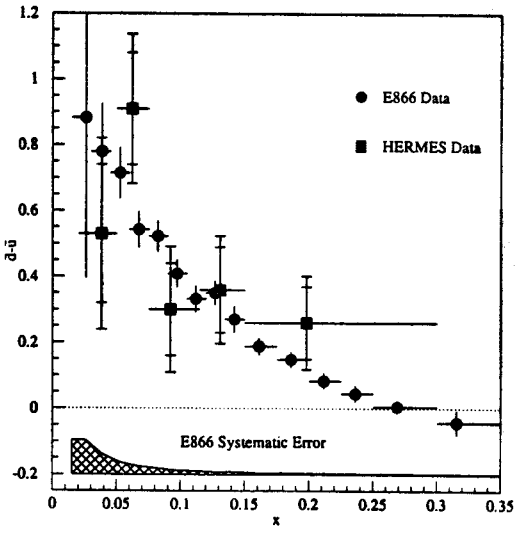

Figure 3: $\bar{d} - \bar{u}$ in the proton as a function of x from E866 is compared to a recent determination by the HERMES collaboration, based on observation of semi-inclusive deep-inelastic scattering.

results are quite different from previous theoretical expectations, they are consistent with the weak constraints that had been placed on $\bar{d}/\bar{u}$ by previous experimental work. Figure 3 shows our results for $\bar{d}-\bar{u}$, together with the results of a recent determination of $\bar{d}-\bar{u}$ from semi-inclusive deep-inelastic scattering by the HERMES collaboration [2]. The figure shows both that the two determinations, which are sensitive to very different systematic errors, are in good agreement, and that the E866 results are far more precise. We find that the integral of $\bar{d} - \bar{u}$ over all x is 0.115 ± 0.012, in agreement with and substantially more precise than the previous determinations by the NMC [3] and HERMES [2] collaborations.

Although the primary focus of the $\sigma^{pd}/2\sigma^{pp}$ measurements was a determination of $\bar{d}/\bar{u}$, the data are sufficiently precise to provide constraints on the gluon distribution in the nucleon as well. For example, while the primary mechanism for Drell-Yan dimuon production at small to moderate p_T is the annihilation of a $q\bar{q}$ pair, producing a virtual photon that decays into the $\mu^+\mu^-$ pair, at large p_T the dominant reaction is believed to be gluon-quark Compton scattering. Figure 4 shows the measured cross section ratio $\sigma^{pd}/2\sigma^{pp}$ as a function of p_T. The substantial drop in the cross section ratio beyond 3 GeV/c is a signature of this changing reaction mechanism.

These new, high-precision results will provide significant constraints on attempts to explain the origin and composition of the nucleon sea. Furthermore, the x dependences of $\bar{d}-\bar{u}$ and $\bar{d}/\bar{u}$, as determined by E866, provide an important measure of the trade-off between perturbative and non-perturbative effects in the generation of the nucleon sea [4].

In addition to the determination of $\bar{d}/\bar{u}$, the Fermilab E866 collaboration has several other

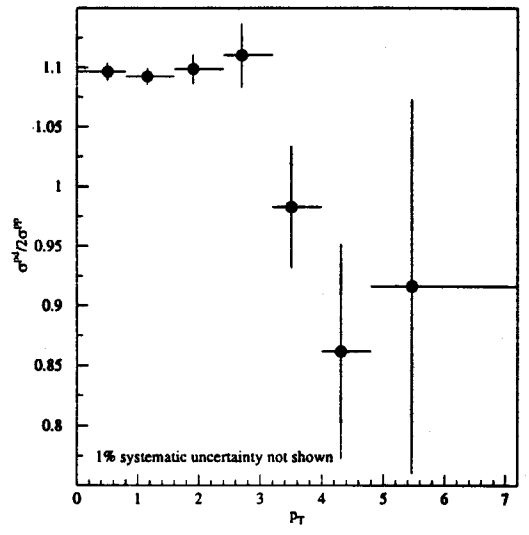

Figure 4: The Drell-Yan cross section ratio versus p_T, from the combined results of the three spectrometer settings.

analysis efforts underway. Three are well advanced and should lead to publications shortly. One, led by collaborators from LANL and Georgia State, is a determination of the nuclear dependence of J/ψ production, especially as functions of x_F and p_T. A second, led by collaborators from New Mexico State, is a determination of the polarization of the J/ψ when produced in 800 GeV/c p-Cu collisions. These two measurements will provide important information regarding the J/ψ production and suppression mechanisms in advance of the use of J/ψ production as a signature for quark-gluon plasma formation at RHIC and the LHC. The third, a study of the nuclear dependence of Drell-Yan dimuon production, is being led by our group at Texas A&M and is described in detail in another contribution to this report.

References

[1] E.A. Hawker *et al.* (FNAL E866/NuSea Collaboration), Phys. Rev. Lett. **80**, 3715 (1998).

[2] K. Ackerstaff *et al.* (HERMES Collaboration), Phys. Rev. Lett. **81**, 5519 (1998).

[3] M. Arneodo *et al.* (New Muon Collaboration), Phys. Rev. D **50**, R1 (1994).

[4] J.-C. Peng *et al.* (FNAL E866/NuSea Collaboration), Phys. Rev. D **58**, 092004 (1998).