CONF-921182--17

ANL-HEP-CP--92-108

DE93 005565

THE GLUON DENSITY

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ABSTRACT

In next-to-leading order quantum chromodynamics, gluon-gluon interactions dominate the production of bottom quarks at hadron collider energies, and gluon-quark interactions control inclusive prompt photon production at large transverse momentum in *pp* collisions at fixed-target energies. Using such data, in conjunction with data from deep inelastic lepton scattering, we determine a new gluon density whose shape differs substantially from that derived from previous fits of data. The new set of parton densities provides a good fit to bottom quark, prompt photon, and deep inelastic data, including the most recent NMC and CCFR results.

We report the results of a new determination of the gluon density, $G(x,\mu)$, from a simultaneous fit[1] to the Fermilab CDF[2] and CERN UA1[2] collider data on bottom quark production, the CERN WA70[3] and Fermilab E706[3] fixed-target prompt photon production data, data from deep inelastic lepton scattering[4], along with data from massive lepton-pair production[5]. In $G(x,\mu)$, μ is the factorization scale. Our analysis is carried out within the context of the factorization assumption and employs next-to-leading order hard scattering cross sections.[6,7] The approximate ranges of x probed by the different experiments are: $0.01 < x < 0.06$ by CDF; $0.03 < x < 0.16$ by UA1; $0.20 < x < 0.65$ by E706; and $0.35 < x < 0.61$ by WA70. The collider bottom quark data and the fixed target prompt photon data therefore provide support for $G(x,\mu)$ in non-overlapping but nearly contiguous ranges of x. We remark that we do not include prompt photon data at collider energies in this work. Such data include important fragmentation contributions and, for experimental reasons, require a photon isolation selection, both of which complicate the analysis.[8]

An unguided simultaneous fit to data from bottom quark production, prompt photon production, and deep inelastic scattering would not be successful since there are many more data points from deep inelastic scattering, with much smaller uncertainties. The strategy adopted was an iterative one: starting with a published set of parton densities[9], we forced the gluon determination by fitting first to the bottom quark and prompt photon cross sections. Then, with that gluon density as a starting distribution, we determined a wholly new set of quark, antiquark, and gluon densities by refitting the prompt photon, the deep inelastic, and the bottom quark cross sections together. The fits were carried out in the $\overline{MS}$ factorization scheme. Evolution of the parton densities was carried out to two-loop level.

A satisfactory fit was obtained to the combined data set. Comparisons with the bottom quark data are presented in Fig. 1. Comparisons with the prompt photon and deep inelastic data sets and a table of the values of χ^2 from the combined fit may be found in Ref. 1. In Fig. 2 we show our new gluon density for two values of the scale μ.

The qualitative features of the curves in Fig. 2 are easy to understand. The magnitude of the CDF data exceeds predictions based on earlier gluon densities, including set B1 by about a factor of 2. Since gluon-gluon scattering dominates, the data require an increase in the normalization of the gluon density by roughly $\sqrt{2}$ in the neighborhood of $x = 0.05$ for values of $\mu \simeq 5$ GeV. The fixed-target prompt photon data support the magnitude of $G(x, \mu)$ for $x \geq 0.2$. In order to satisfy the momentum sum rule, the increase of the gluon density at intermediate values of x must be compensated by a decrease elsewhere, resulting in the depletion observed in Fig. 2. We caution, however, that the CDF bottom quark data with $|y| < 1$ do not place any constraint on the behavior of $G(x, \mu)$ for very small x, i.e., $x < 10^{-3}$, and that QCD evolution rapidly reduces the difference as μ increases.

The normalization of the CDF data at relatively small values of p_T is critical since these data constrain $G(x, \mu)$ at the smallest values of x. Since the data on b

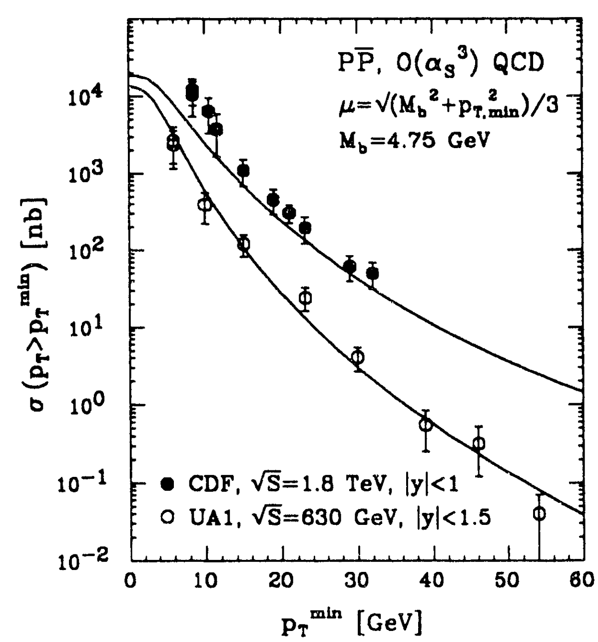

Figure 1. The solid curves show the results of our fit to the CDF and UA1 data. They are obtained from convoluting the $O(\alpha_s^3)$ QCD hard scattering cross section with the new parton densities determined from our combined fit.

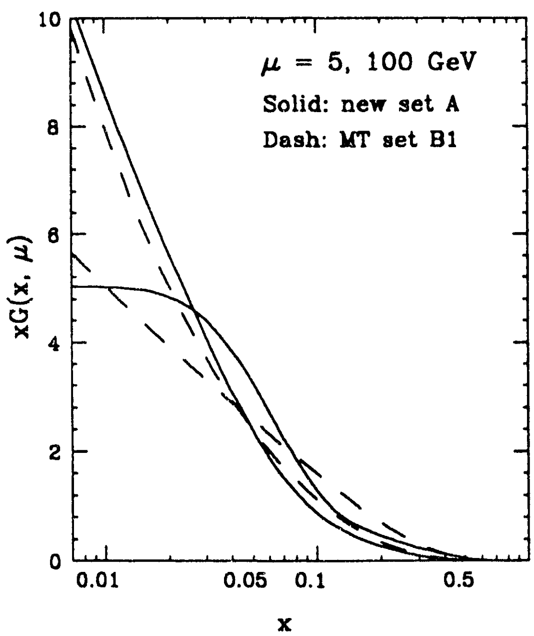

Figure 2. Solid curves show the behavior of our new gluon density as a function of x, for two values of the factorization scale μ. Dashed curves show the behavior of the gluon density from MT set B1.

production at small p_T are determined from measurements of J/ψ production, it is essential to be certain that the production mechanism for J/ψ production is well understood. Contributions to the cross section in order α_s^4 and beyond, including the effects of off-shell initial gluons[10], may provide a partial explanation of the discrepancy between the CDF bottom quark cross section and previous order α_s^3 calculations, and they may help remove the remaining discrepancy between our calculation and the CDF data shown in Fig 1. A more definitive quantitative fit awaits better understanding of these contributions and the greater statistical precision promised from forthcoming runs at the Tevatron. The fortran code for the current version of the parton densities is available upon request(MENG@ANLHEP).

We are grateful to Professor Jianwei Qiu for discussions and collaboration on the prompt photon production work. Work supported in part by the U.S. Department of Energy, Division of High Energy Physics, Contract W-31-109-ENG-38.

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