

*Sudakov resummation effects
for parton distributions*

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Soft gluon resummation

Extending the range of perturbative QCD

- Soft and collinear gluons generate *large logarithms* in QCD cross sections near kinematic thresholds.

$$\text{DIS} \longrightarrow \alpha_s^n \log^{2n-1}(1-x)/(1-x)$$

- Soft and collinear logarithms can be computed to all orders and they *exponentiate* in moment space.

$$\sum_k \alpha_s^k \sum_p^{2k} c_{kp} L^p \rightarrow \exp \left[L g_1(\alpha_s L) + g_2(\alpha_s L) + \alpha_s g_3(\alpha_s L) + \dots \right]$$

- Resummation *extends the range* of perturbation theory

$$\alpha_s L^2 \ll 1 \longleftrightarrow \alpha_s \ll 1$$

- Resummation reaches beyond perturbation theory
finite order \longrightarrow resummation \longrightarrow power corrections

The case of Deep Inelastic Scattering

- *DIS* coefficient functions are known to *NNLL* accuracy

$$C_{\text{res}}(N, Q^2) = \bar{C}_{\text{NLO}}(N, Q^2) + C_\delta(Q^2) \exp [E(N, Q^2)] ,$$

$$E(N, Q^2) = \int_{Q^2/\bar{N}}^{Q^2} \frac{d\mu^2}{\mu^2} [\log(\bar{N}\mu^2/Q^2) A(\alpha_s(\mu^2)) + B(\alpha_s(\mu^2))]$$

→ A, B known to $(N)\text{NNLO}$ → *NNLL* accuracy

- The structure of *power corrections* to the DIS cross section *near threshold* begins to be understood (powers of Λ^2/W^2).
- Ansatz for *nonperturbative* factorization (Korchemsky *et al.*)
 $F_2^N(Q^2) = H(Q^2) J_N(Q^2/N, \mu_F^2) q_N(\mu_F^2) J^{\text{NP}}(N\Lambda^2/Q^2)$.
- Improved perturbative calculations *can be trusted* at large x .



A case for resummed PDF's

Theory

- The boundary between *perturbative* and *nonperturbative* must be *defined*.

Leading Twist \leftrightarrow NLO \leftrightarrow $\overline{\text{MS}}$ do not mix well!

- Resummation provides a gate to nonperturbative corrections.

Define resummed exponent \leftrightarrow define power correction

NOTE: consistency recently checked for F_2 (Korchemski *et al.*)

- QCD *models* for power corrections to structure functions can be *tested* (as done for event shapes).
- Lattice* determinations of PDF's use different, precise definition of *leading twist* ... comparison?



A toy large- x parton fit

G. Corcella, LM, hep-ph/0506278

We consider *NuTeV* data for charged current F_2 and F_3 , and *NMC/BCDMS* data for neutral current F_2 .

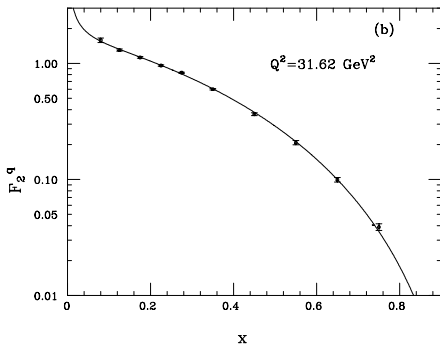
- Data are *parametrized* at different *fixed* values of Q^2
- *Moments* of data can be computed with reasonable uncertainties.

NOTE: resummation takes place in *moment* space \rightarrow natural determination of PDF moments

- *Extract* moments of linear combinations of PDF's, *solve* for valence quarks with *assumptions* on gluon and sea.
- *Fit* x -space functional forms to moments.

Parametrizations of different data sets

Charged current F_2 from NuTeV



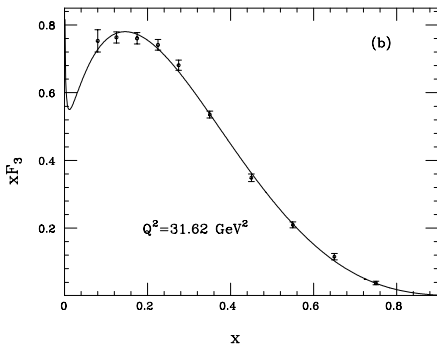
- $F_2^q = x \sum_q |V_{qq}|^2 (q + \bar{q})$
- CTEQ *gluon* subtracted point by point.
- $F_2^q(x) = ax^{-\alpha}(1-x)^\beta(1+bx)$
- $a = 0.240 \pm 0.002$,
 $\alpha = 0.562 \pm 0.020$
 $\beta = 3.211 \pm 0.065$,
 $b = 13.085 \pm 0.767$

Parametrization of charged current F_2 from NuTeV at $Q^2 = 31.62$



Parametrizations of different data sets

Charged current $x F_3$ from NuTeV



- $F_3 = \sum_q |V_{qq}|^2 (q - \bar{q})$
- $x F_3(x) =$
 $cx^{-\rho}(1-x)^\sigma(1+kx)$
- $c = 0.103 \pm 0.012,$
 $\rho = 0.294 \pm 0.034$
 $\sigma = 3.325 \pm 0.089,$
 $k = 42.972 \pm 4.700$

Parametrization of charged current F_3 from NuTeV at $Q^2 = 31.62$



Parametrizations of different data sets

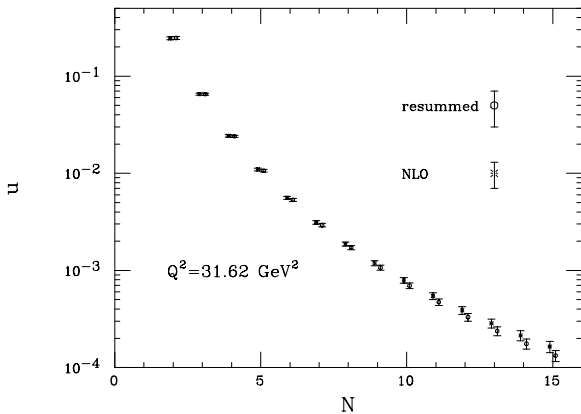
Neutral current F_2 (nonsinglet) from NMC/BCDMS

For $F_2^{(NS)}(x) \sim x(u(x) - d(x))$ we use the *Neural Network* parametrization of the *NNPDF* collaboration.

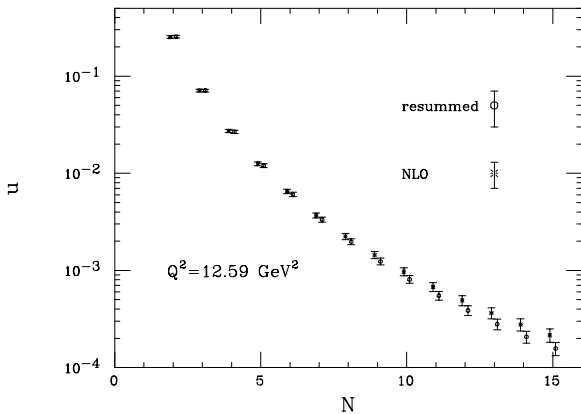
- *NN* provide *unbiased* and *faithful* parametrization of data.
- We make use of the *NNPDF* parametrization for the structure function $F_2^{(NS)}(x)$, constructed with *NMC* and *BCDMS* data
- At $Q^2 = 31.62$, large- x coverage is comparable to *NuTeV*, $x < 0.75$.
- *Moments* and *errors* are computed treating NN set as faithful *Monte Carlo* sample of probability distribution of F_2 .



Moments of u quark distribution



Moments of u quark distribution



Perspective

- *Soft gluon resummations* have become a *standard tool* in perturbative QCD.
 - Extended *applicability* of perturbative calculations.
 - A tool to identify *power corrections*.
- *PDF fits* including resummation effects are *possible*, and would be *necessary* to achieve **5%** precision at large x .
- *More data* can be included in resummed fits.
- A *qualitative analysis* shows **-10%** effects on valence quarks in the range $x \sim 0.5 \rightarrow 0.75$ with a possible *enhancement* at smaller x , for $Q^2 \sim 30 \text{ GeV}^2$.
- A *quantitative analysis* would require including more *data*, in the context of a *global fit*.

