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Gluons in the Proton

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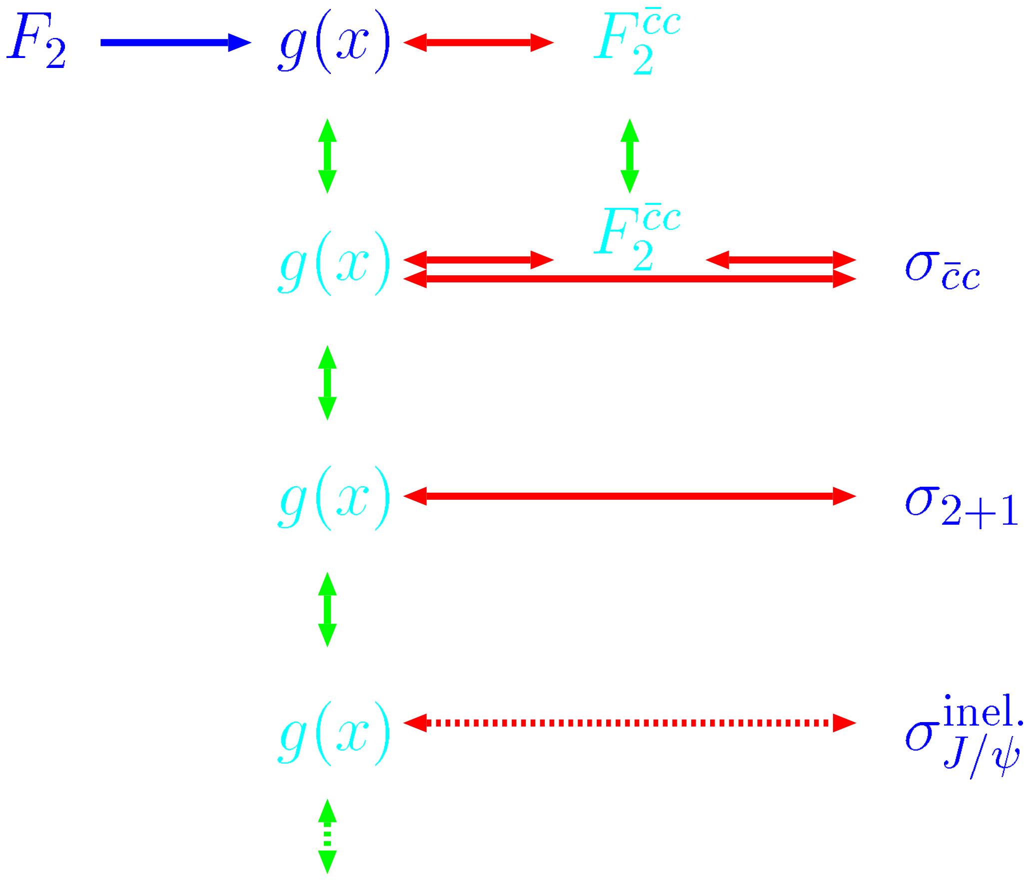
For ZEUS and H1

- Introduction
- Scaling Violations (F_2)
- Charm Production ($F_2^{c\bar{c}}$)
- Jetrates (R_{2+1})
- Conclusions

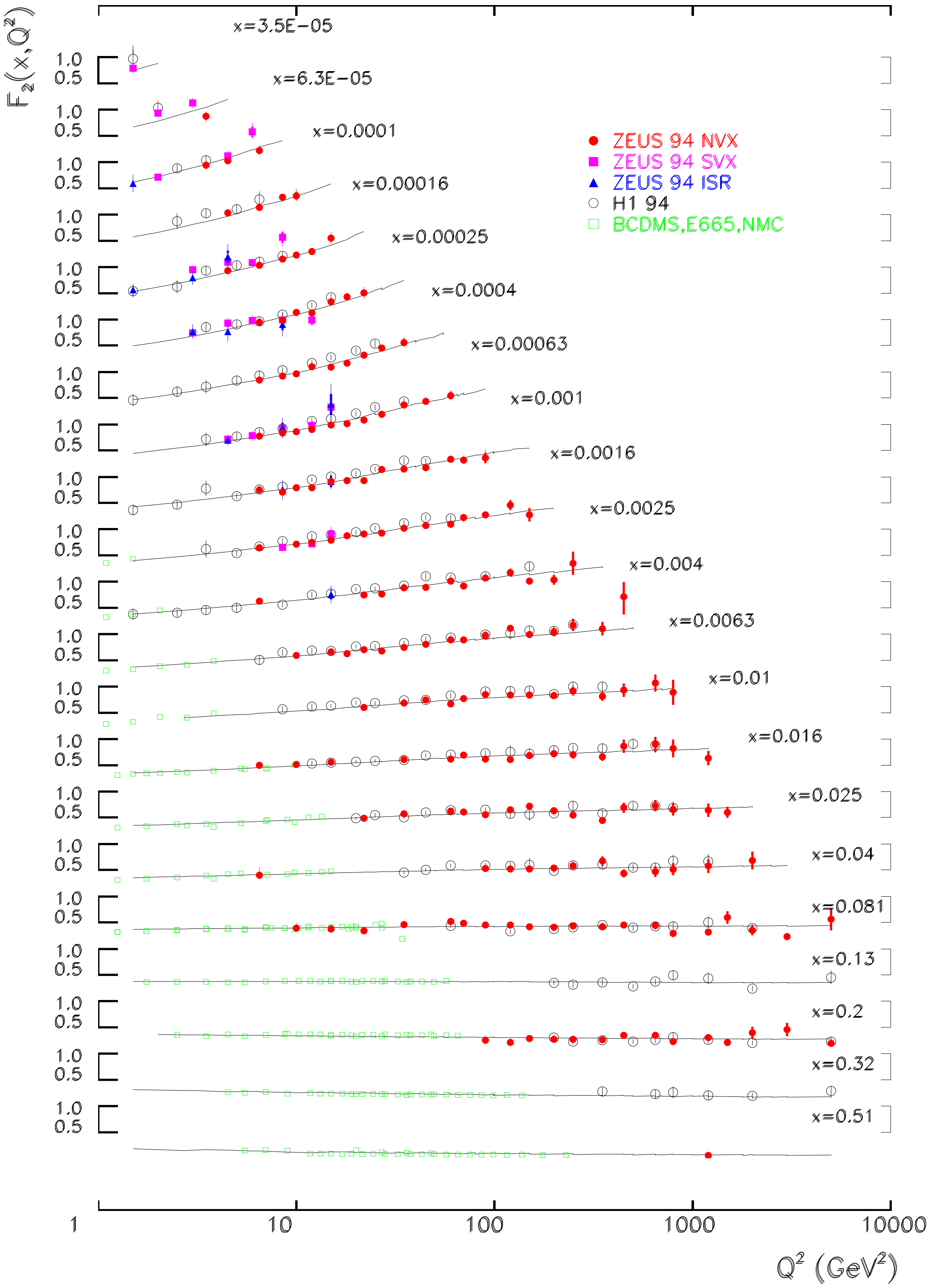
Introduction

- F_2 at HERA: Strong Rise towards Small x, Described by DGLAP, Driven by $xg(x)$.
- Predict Gluon Induced Cross Sections $\leftrightarrow$ Compare with Measurements.



- Test Model Approach:
  - Factorization,
  - Universality of Parton Densities,
  - DGLAP, pQCD

Scaling Violations



$$\text{At low } x \text{ in LO : } \quad \frac{dF_2(x,Q^2)}{d\ln Q^2} \propto \alpha_S(Q^2)\cdot xg(x)$$

Fit Procedure

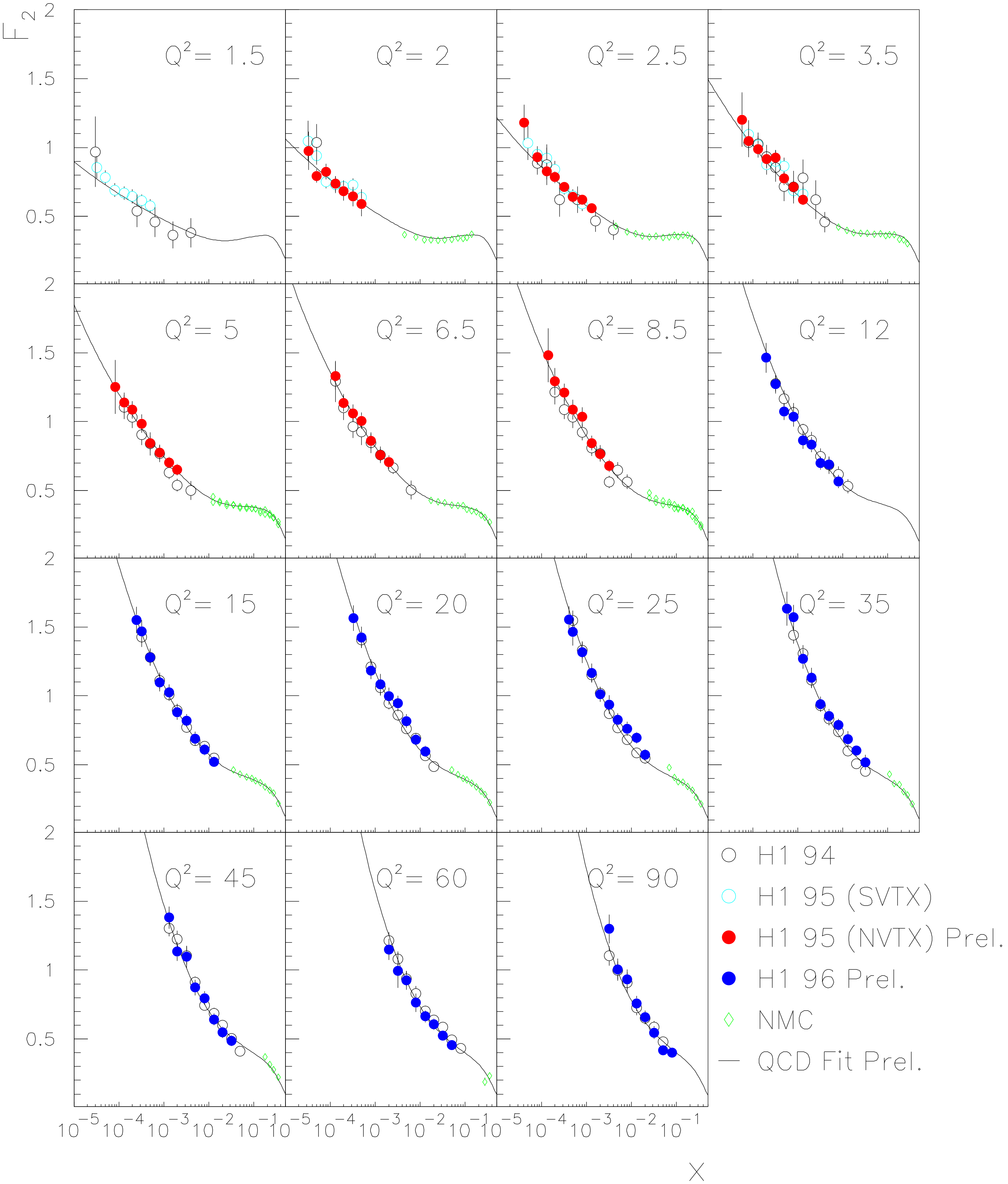
- $F_2 = F_2^{uds} + F_2^c$
- Evolution of 3 Light Flavours in $\overline{MS}$ Scheme.
- F_2^c Calculated in NLO BGF ('Massive Charm') (Riemersma, Laenen et al.).
- Parametrize Parton Distributions at Starting Scale Q_0^2:

$$xf_i(x) = A_i x^{B_i}(1-x)^{C_i}(1 + D_i x + E_i\sqrt{x}).$$

- Constraints: Quark Counting Rules, Momentum Sum Rules (Strange Sea: 20%)

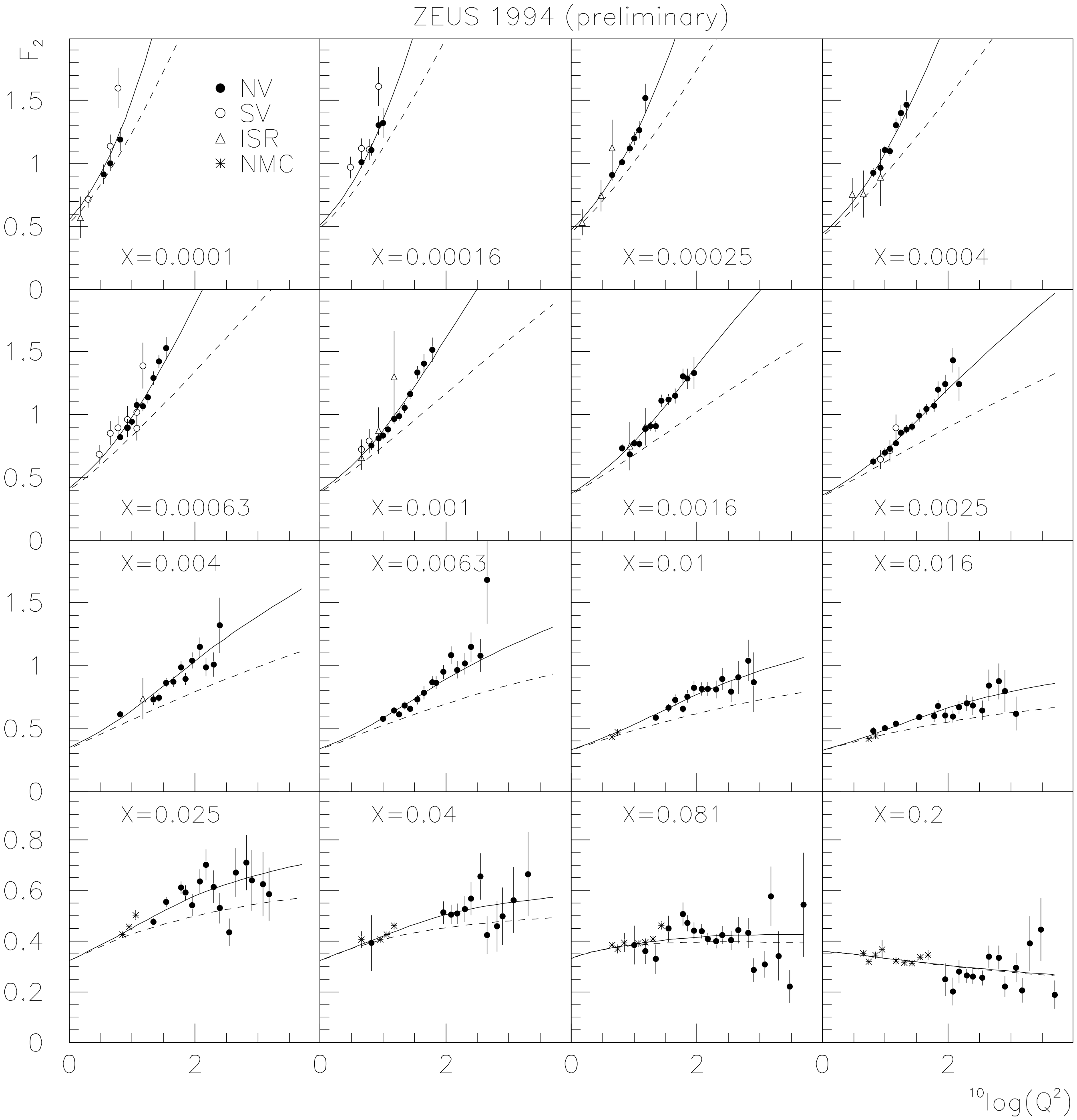
	H1	ZEUS
Data Input	$Q^2 > 1.5$ GeV^2	
Q_0^2	1 GeV^2	7 GeV^2
$\alpha_S(M_Z^2)$	0.118 ± 0.005	0.113 ± 0.005
m_c	1.3 ... 1.8 GeV	1.3 ... 1.5 GeV
$\#[xg(x)]$	3	4
$\#[xq_{NS}(x)]$	5	3
$\#[xq_S(x)]$	5	5

H1 Fit to F_2 Data



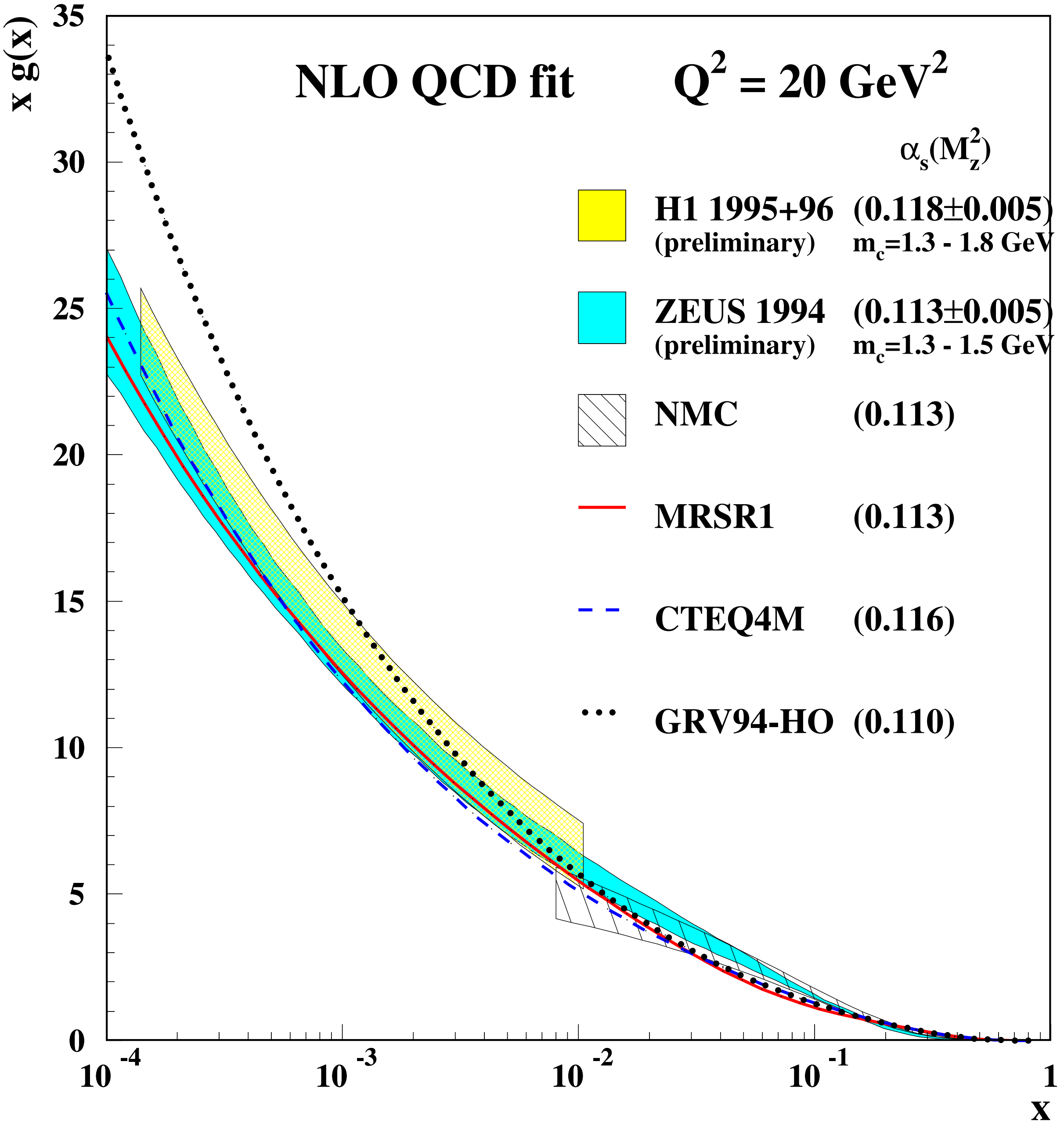
- Fitted Data Sets: H1 (94, 95, 96), BCDMS, NMC (p, d)

ZEUS Fit to F_2 Data



- Fitted Data Sets: ZEUS 94 (NVTX,SVTX,ISR), NMC (p, d)

Gluon from F_2



- Good Agreement between Various Analyses
- Precision $\sim 10\%$.

$\rightarrow$ Precise Cross Section Predictions Possible.

Charm Production

- More Direct Access to the Gluon.
- Recent Theoretical Calculations.

ZEUS and H1 Analyses:

- Identify Scattered Positron,
  Measure x and Q^2:

$$1\ \mathrm{GeV}^2 < Q^2 < 600\ \mathrm{GeV}^2,$$
$$0.01 < y < 0.7.$$

- Tag Charm by Reconstructing D Mesons from Tracks.

$$D^*+ \to D^0 \pi_s^+ (+c.c.)$$
$$D^0 \to K^- \pi^+ (+c.c.)$$

- π_s^+: Slow Pion due to Small Mass Difference between D^*+ and D^0. $\Delta M = 145.4$ MeV.

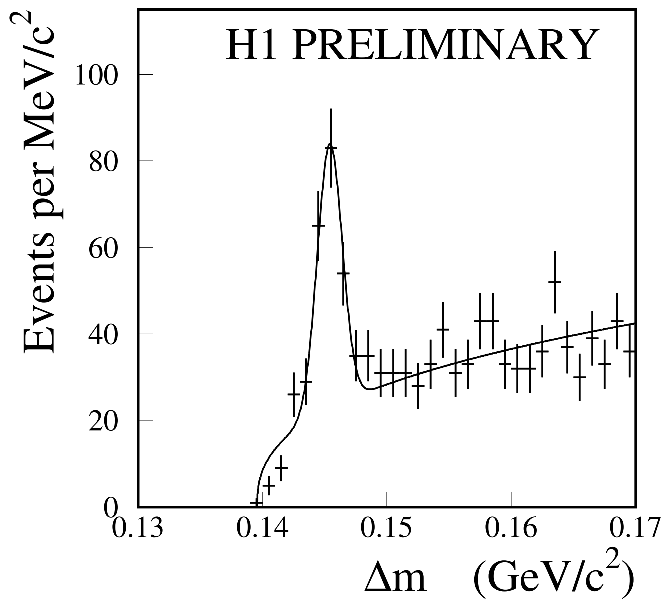
  $\mathrm{BR}(D^* \to D^0 \pi_s) \times \mathrm{BR}(D^0 \to K\pi) = 2.7\%$

- Limited Tracker Acceptance:

$$p_\perp(D) > 1.5\mathrm{GeV}$$
$$|\eta(D)| < 1.5$$

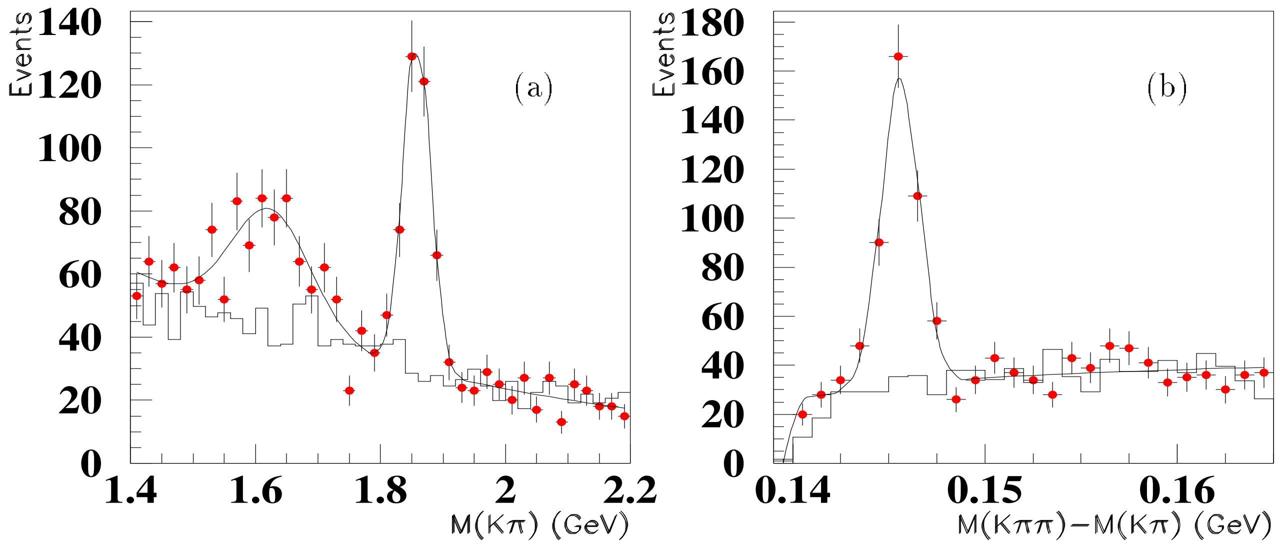
Charm Signals

H1 PRELIMINARY 95



153 ± 17 Events

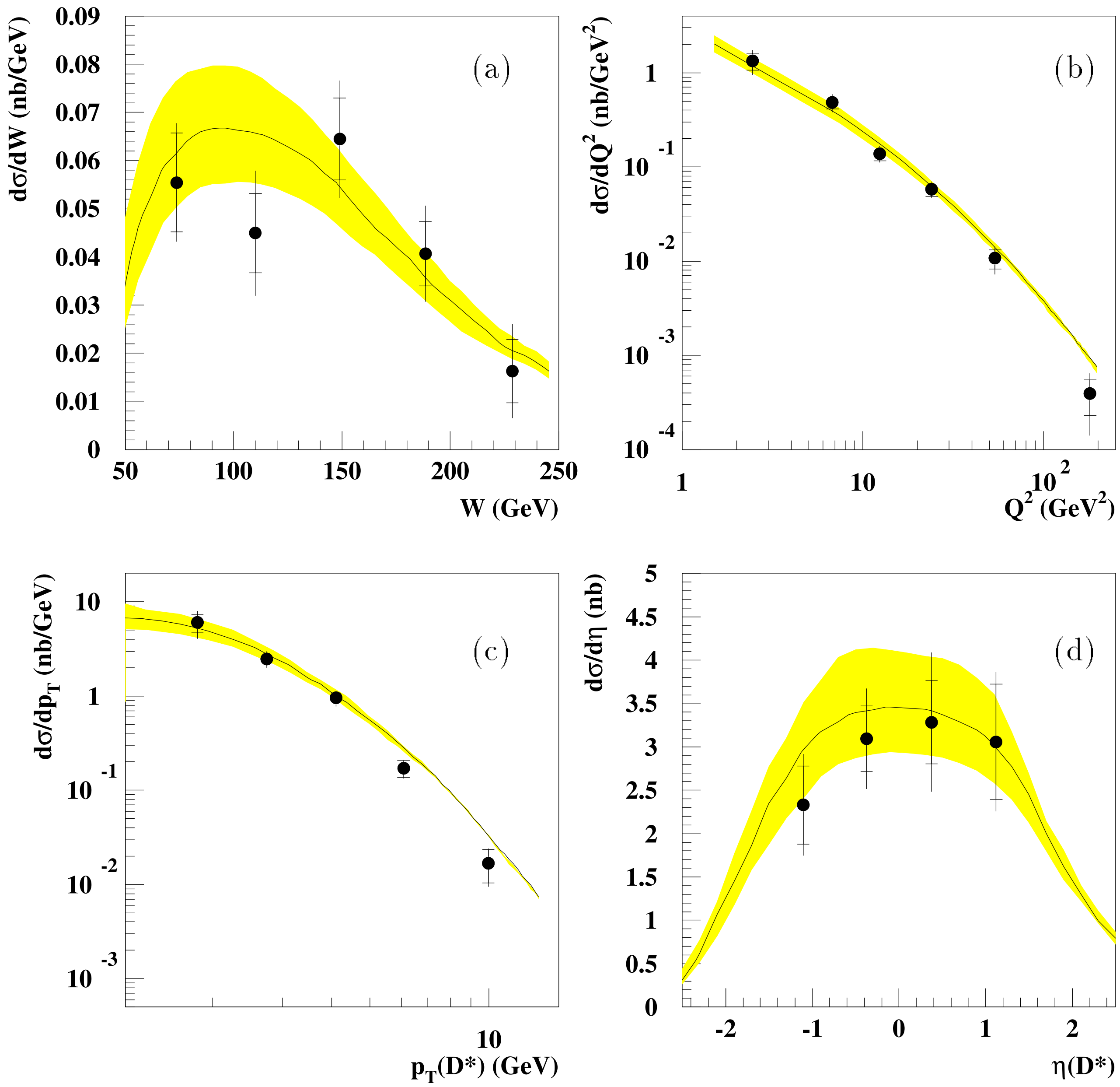
ZEUS PRELIMINARY 95



309 ± 23 Events

Visible Cross Sections

ZEUS 95 (Preliminary)



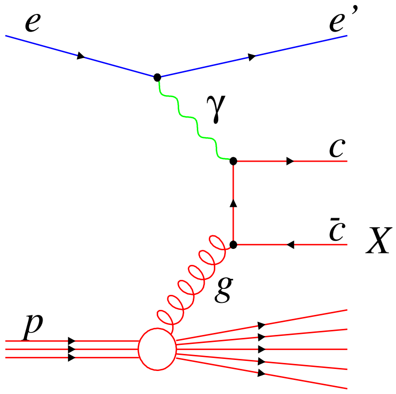
- $3 < Q^2 < 170\ \mathrm{GeV}^2$ $\quad |\eta^{D^{*\pm}}| < 1.5$

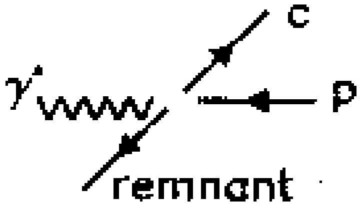
  $80 < W < 210$ GeV $\quad 1.5 < p_T^{D^{*\pm}} < 10$ GeV
- Reasonable Agreement with Expectation Using NLO. Calculations (BGF) with $g(x)$ from F_2, Peterson Fragmentation $p(c \to D^*) = 26\%$
- Bands: Variation of $m_c = 1.3...1.7$ GeV

Charm Production Mechanism

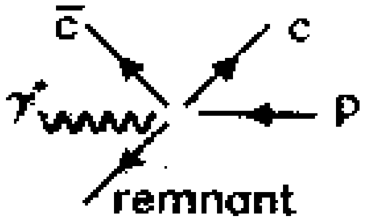
Boson Gluon Fusion (BGF)

or Sea Charm?





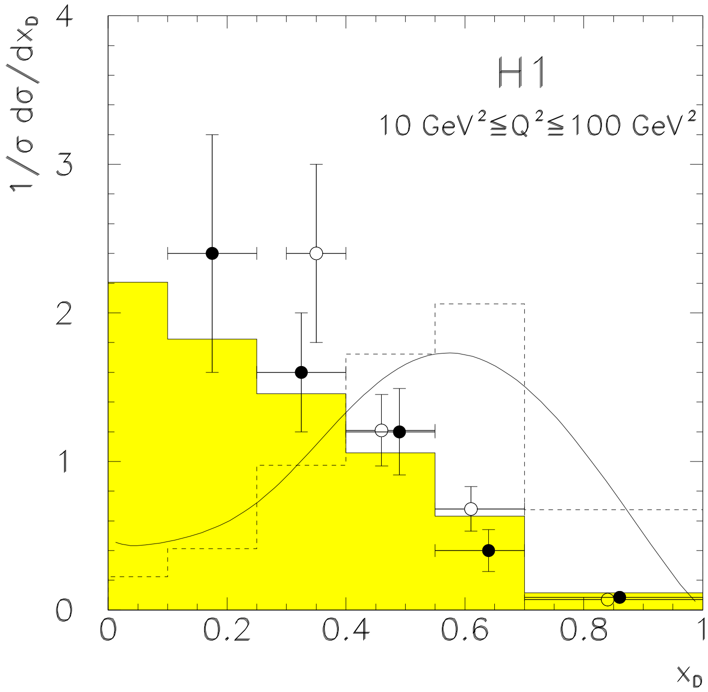
Sea Charm (Massless)



BGF (Massive)

Define:

$$x_D = \frac{|p^*_{D^0}|}{|p^*_p|} = \frac{2|p^*_{D^0}|}{W}$$



Fit → Sea Charm less than 5% at 95% CF
in Present Kin. Regime.

→ Assume Pure BGF for Calculations.

Charm Cross Sections

$$\sigma(ep \to ec\bar{c}X)$$

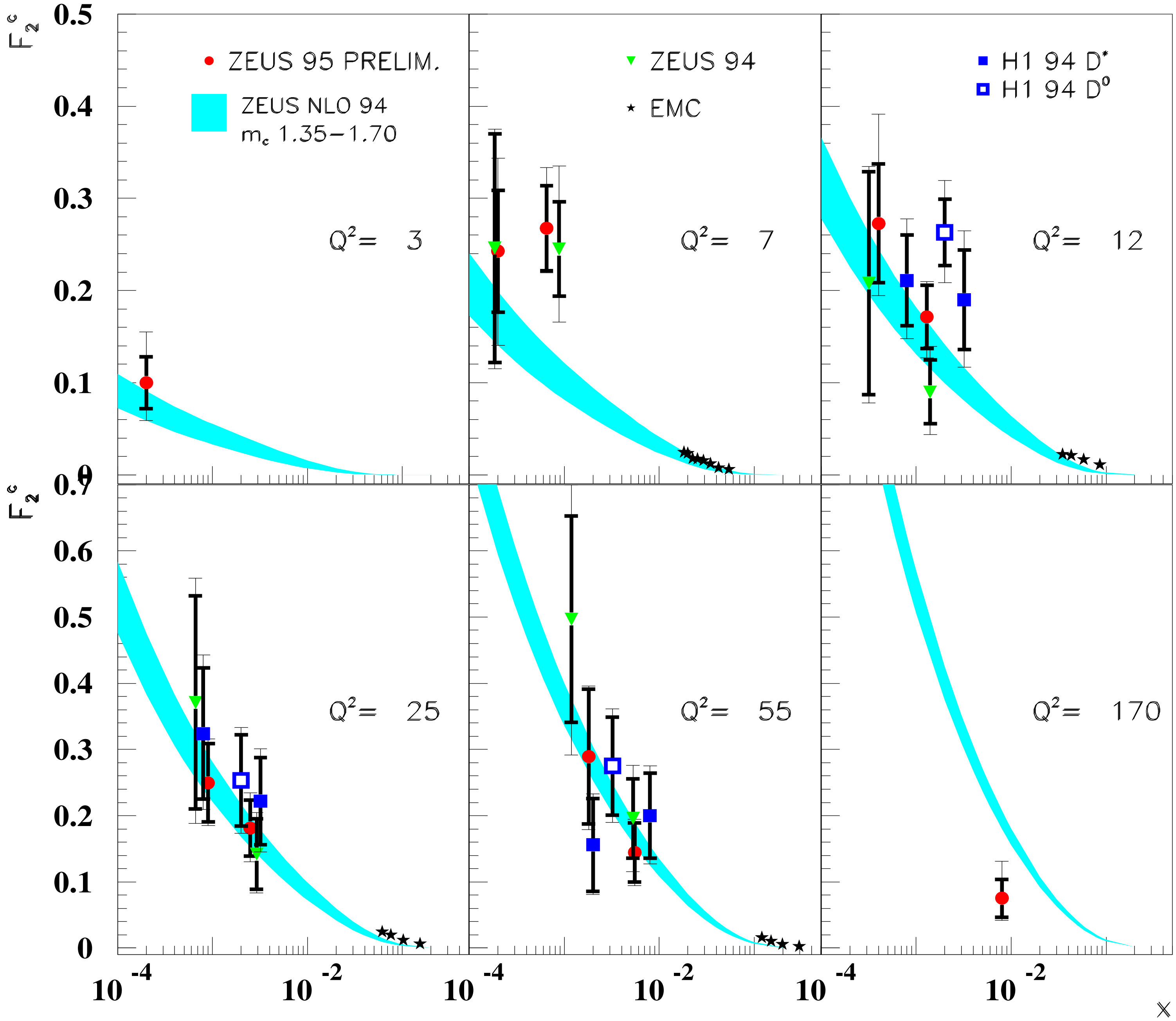
- Extrapolate into Unmeasured Region of p_T and η using NLO Calculations (BGF) with $g(x)$ from F_2.
- $40\% - 50\%$ of total D^* Cross Section Visible.
- LO Calculations Give Similar Results.
- Fragmentation Probability $p(c \to D^*)$ Taken from other Exps. (OPAL, ARGUS, CLEO).

		$10\ \mathrm{GeV}^2 < Q^2 < 100\ \mathrm{GeV}^2$
D^0	H1(94)	$19.5 \pm 2.6^{+2.7+1.6}_{-2.6-1.2}$ nb
$D^*\pm$	H1(94)	$15.1 \pm 1.8^{+2.4}_{-2.0} \pm 1.2$ nb
$D^*\pm$	ZEUS(94)	$12.5 \pm 3.1 \pm 1.8^{+1.5}_{-1.1}$ nb
	LO(with GRV)	12.4 nb
	NLO(with GRV)	11.4 nb

		$5\ \mathrm{GeV}^2 < Q^2 < 10\ \mathrm{GeV}^2$
$D^*\pm$	ZEUS(94)	$13.5 \pm 5.2 \pm 1.8^{+1.6}_{-1.2}$ nb
	NLO (with GRV)	9.4 nb

$F_2^{c\bar{c}}$ from ZEUS and H1

$$\frac{d\sigma^{c\bar{c}}}{dxdQ^2} = \frac{2\pi\alpha^2}{Q^4x}(1+(1-y)^2)F_2^{c\bar{c}}(x,Q^2)$$

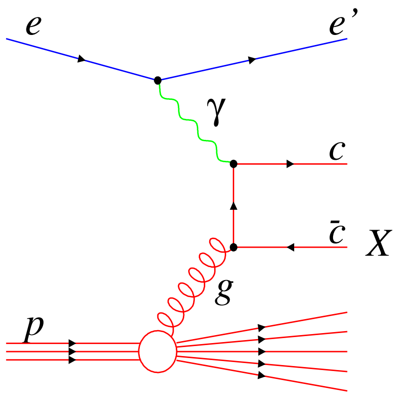


- $F_2^{c\bar{c}}/F_2 \approx 25\%$ at HERA.
- Strong Rise towards small x ($F_2^{c\bar{c}} \propto xg(x) \Leftarrow$ BGF)
- Consistent with NLO Calculations Using $g(x)$ from F_2.

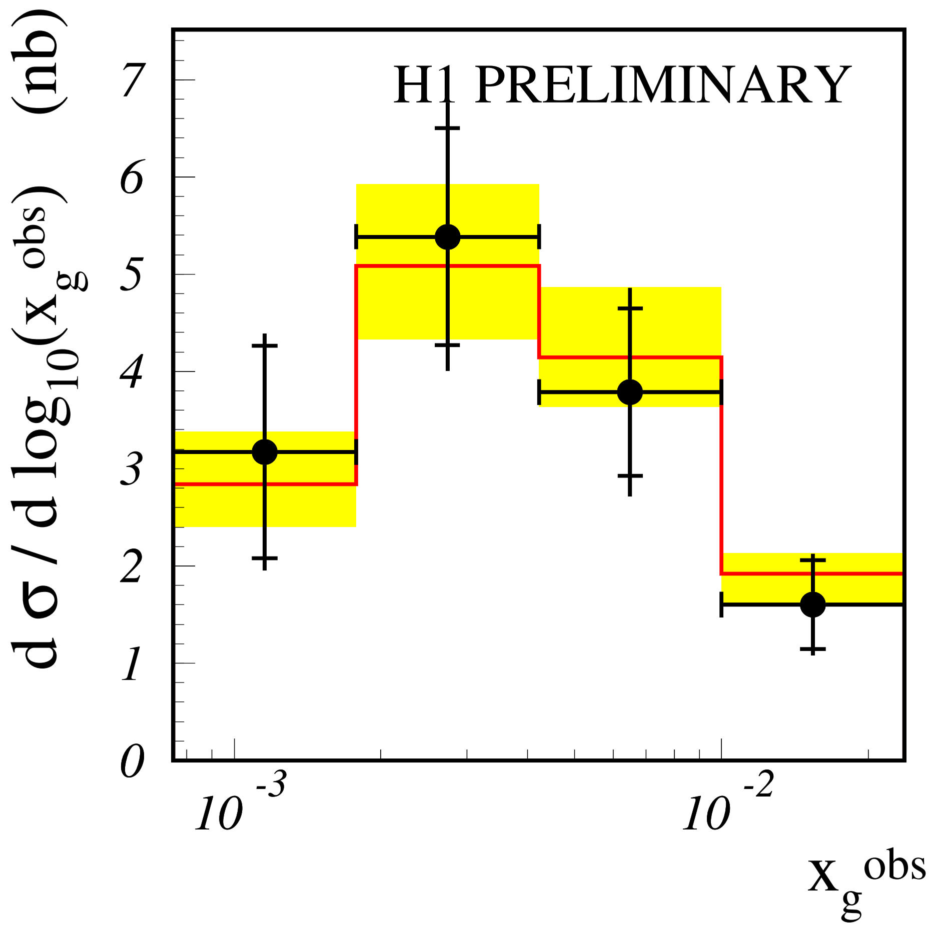
Gluon from Charm

- Direct Measurement: Need x_g

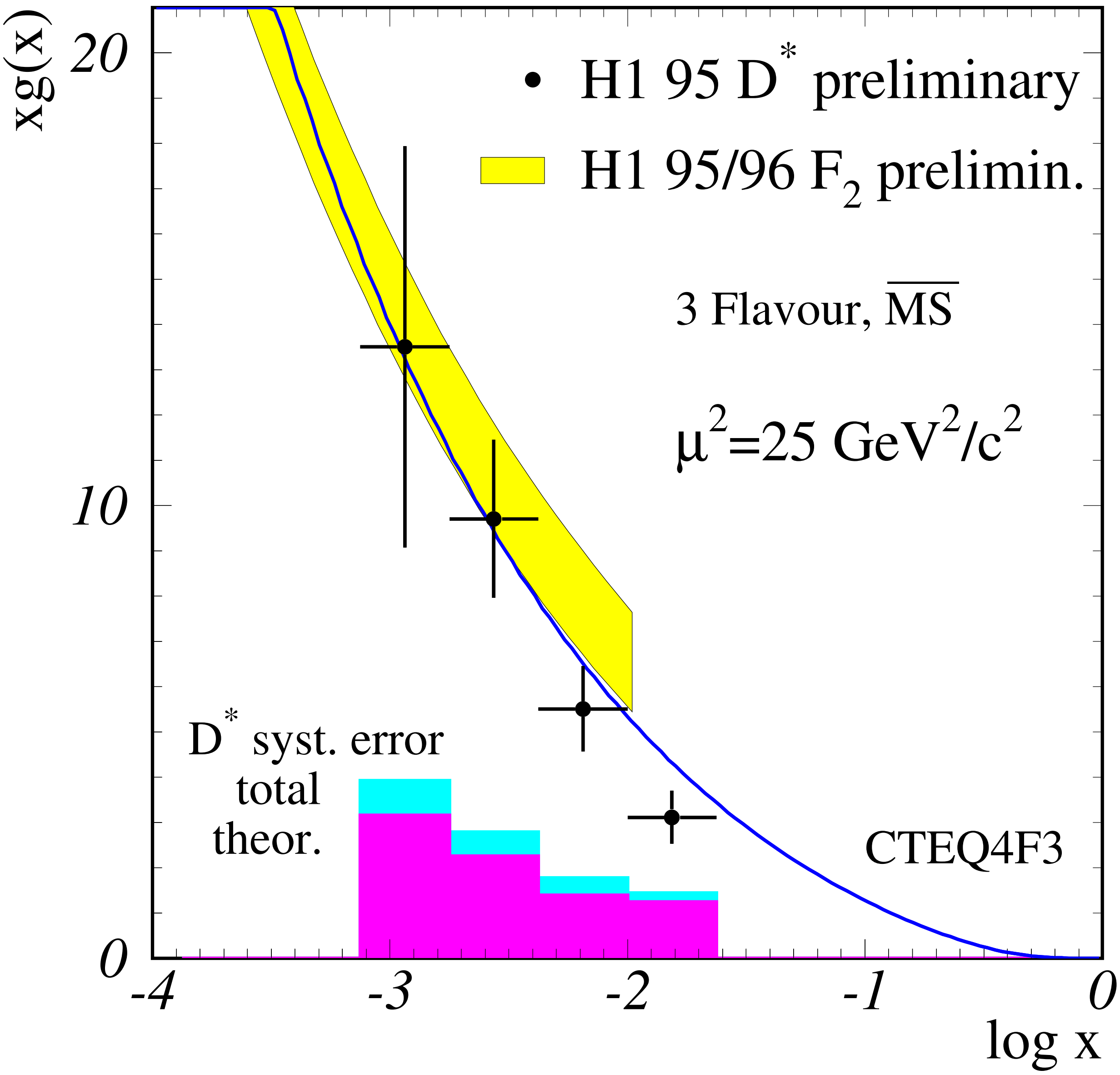
  At LO : $x_g = x \cdot \left(1 + \frac{M^2}{Q^2}\right)$



- At NLO: Gluon Radiation causes 'Smearing'.
- Measure $\sigma^{vis}(x_g^{\mathrm{OBS}})$ from Scattered e and tagged D^*: $x_g \to$ 'observed x_g^{OBS}'.
- Correct $x_g^{\mathrm{OBS}} \to$ true x_g^{OBS} using NLO Calculation with Corresponding Acceptance Cuts.



$xg(x)$ from Charm



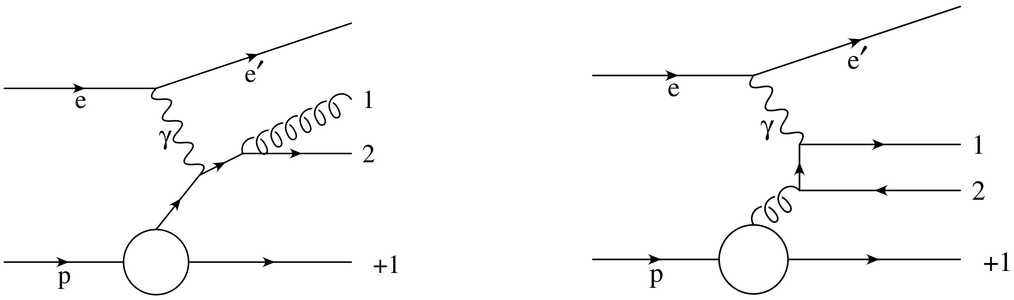
Consistent with $xg(x)$ from Scaling Violations.

- Main Uncertainties Presently (also for $F_2^{c\bar{c}}$):
  - Data: Statistics
  - Theory: Charm Quark Mass Value
- Advantage to $F_2^{c\bar{c}}$: Charm Kinematics Exploited, Bin to Bin Correlations $25 - 50\%$.

Gluons from Jetrates

2+1 – Jet production: Access Gluon at High ξ

$$\frac{d^2\sigma_{2+1}}{dxdQ^2} = \int \frac{d\xi}{\xi} f_{q/p} C^{LO}_{Compton} + f_{g/p} C^{LO}_{BGF}$$

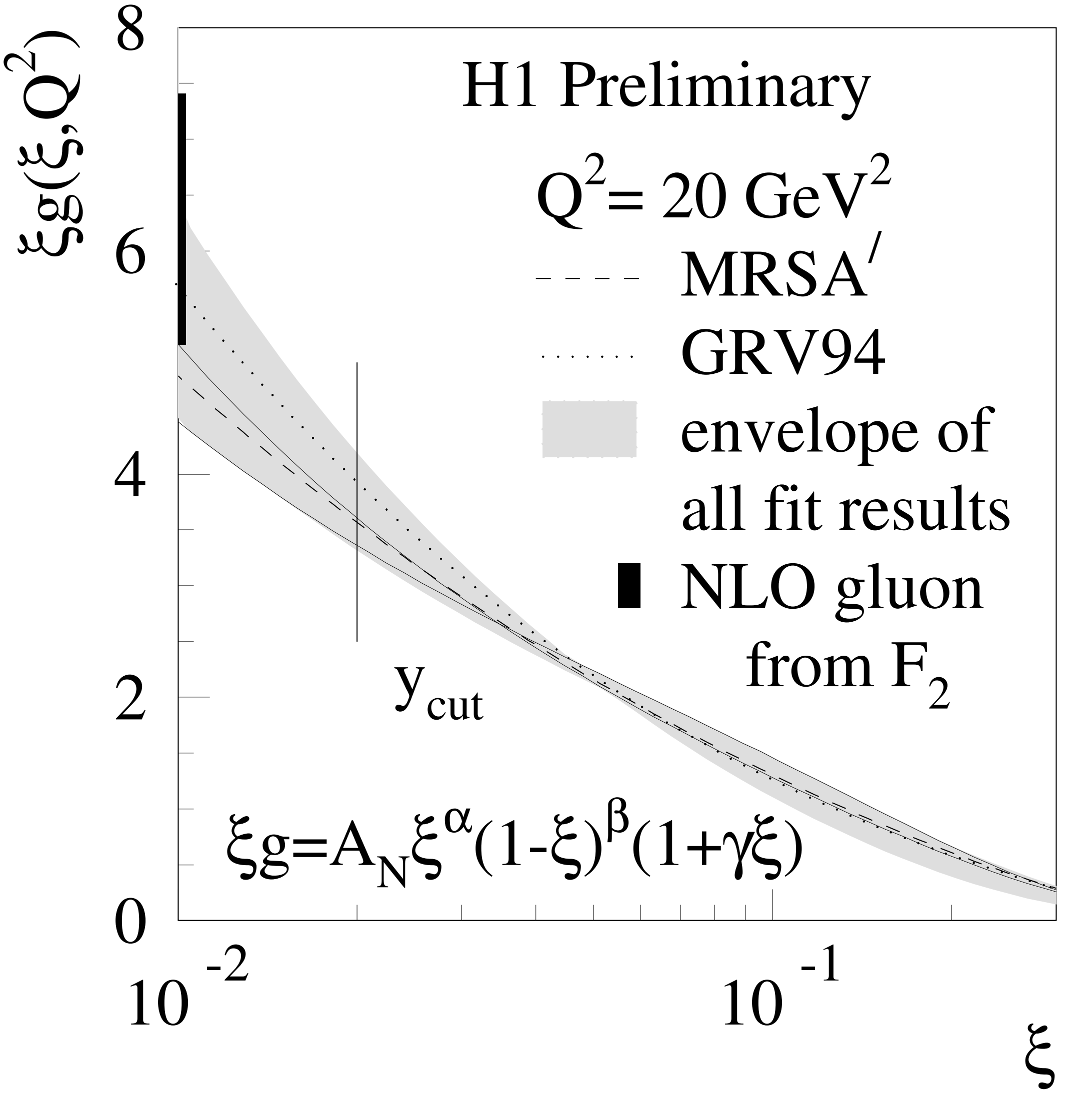


Analysis:

- Calculate σ_{2+1} to NLO Using DISENT.
- Fit $f_{g/p}$ to Match with Measured Cross Section (Mellin Transforms).

Data: H1 94+95 ($40 < Q^2 < 4000$ GeV^2), Jade Algorithm

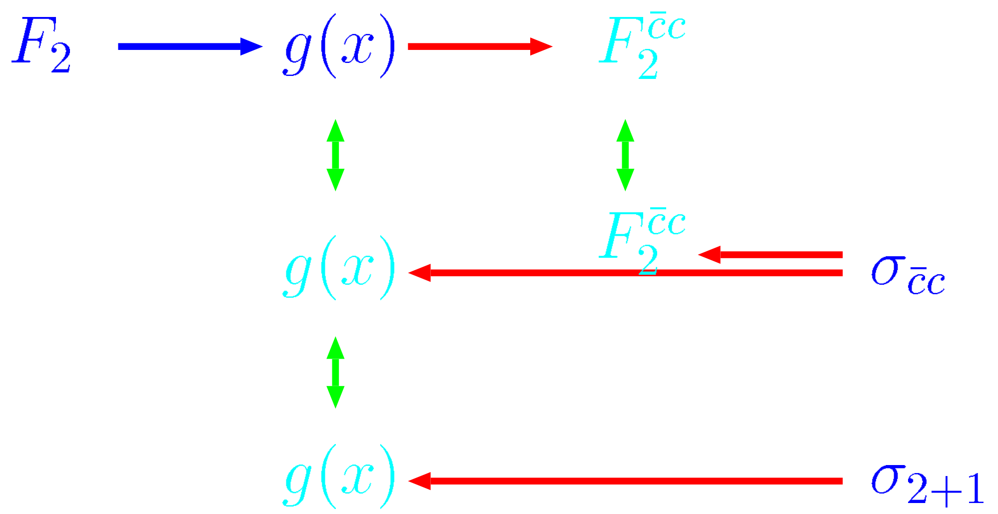
$xg(x)$ from Jetrates



- 1 – Parameter Fit:
  - Quark Densities Fixed (MRSH)
  - Momentum Sum Rules Imposed.
- With this Approach Result Consistent with Standard Parametrizations.
- Full Error Analysis to be Done.

Conclusions

- F_2: Gluon Measured within 10% Using Global QCD Fits by Various Exps. $(10^{-4} \leq x \leq 10^{-2})$.
- Charm Production in DIS: More Direct Sensitivity to Gluon. New Measurements of $F_2^{c\bar{c}}$, $xg(x)$ $(10^{-3} \leq x \leq 5 \cdot 10^{-2})$.
- Results Consistent with NLO Calculations (BGF) Using $xg(x)$ from F_2.



- pQCD, DGLAP, PDF Approach Confirmed.