B Physics @ the Tevatron : working group IV

"Charm fragmentation issues at HERA"

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Intro / motivation

- there is an observed excess of D^* mesons in the forward region at HERA Relative to NLO QCD prediction.

- only known explaination is a "beam-drag" effect

- the same physics may enter in B physics at the Tevatron

- so far, together w/ E. Laenen (NIKHEF) and E. Norrbin (Lund) we plan to study various aspects of this during the workshop

This talk:

- Overview of the NLO calculation used at HERA (for DIS)

- Comparison w/ H1 & ZEUS results

- Beam drag effect

- Close with comments about B physics at Tevatron

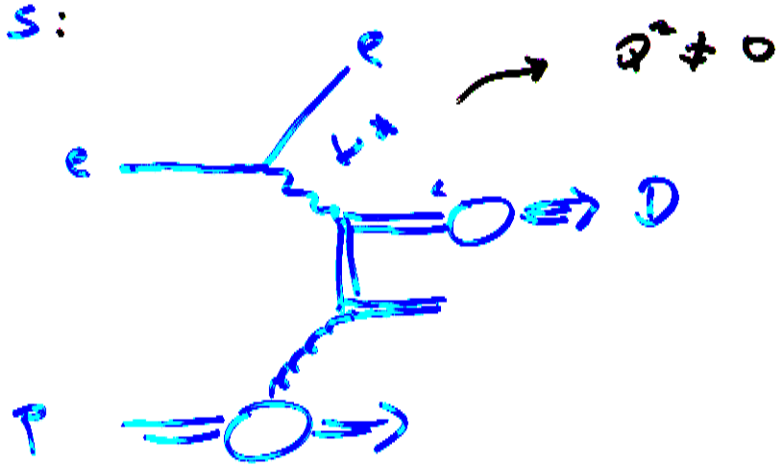
HERA

backward $\quad p \longrightarrow \qquad \longleftarrow e \quad$ forward

820 GeV $\qquad\qquad$ 27 GeV

$$\sqrt{s} \sim 300 \text{ GeV}$$

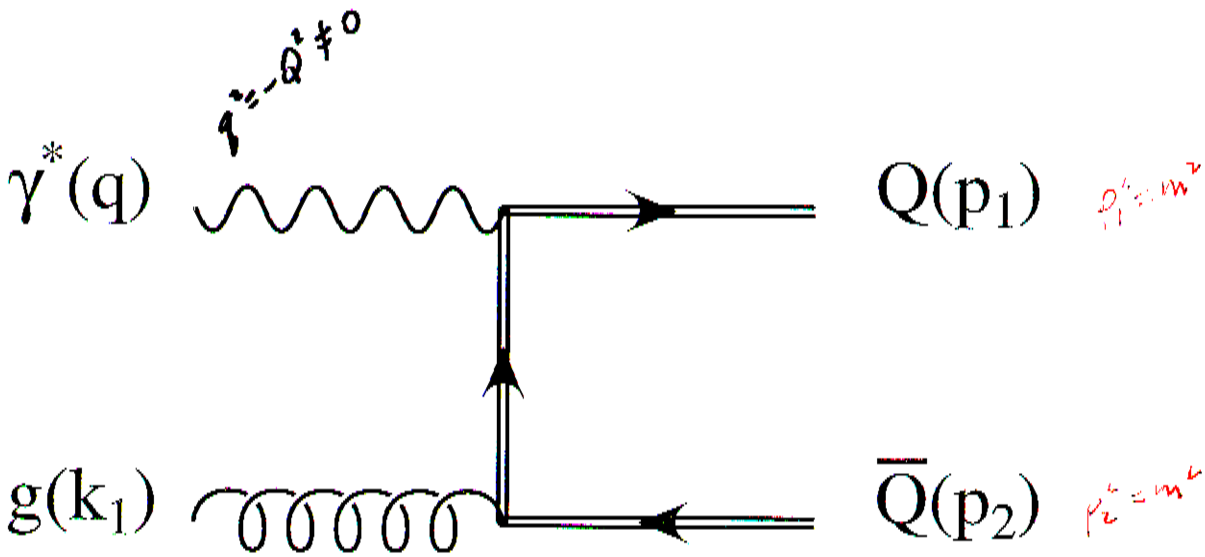
DIS:



Calculation (NLO Fixed order pQCD)

for $Q^2 \sim m_c^2$ leading order is

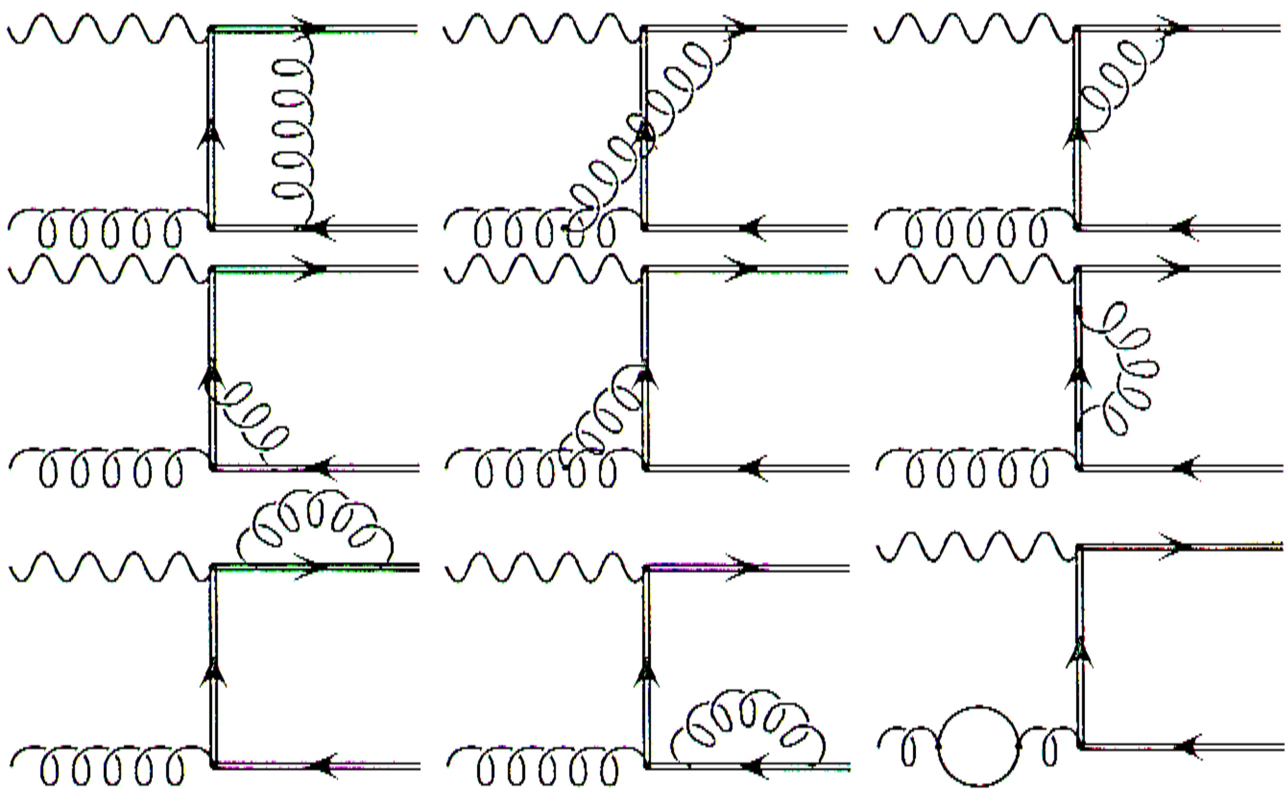
photon-gluon fusion (flavor creation)



- quark masses are kept throughout

Fig 2

Virtual diagrams



- renormalized in CWZ scheme

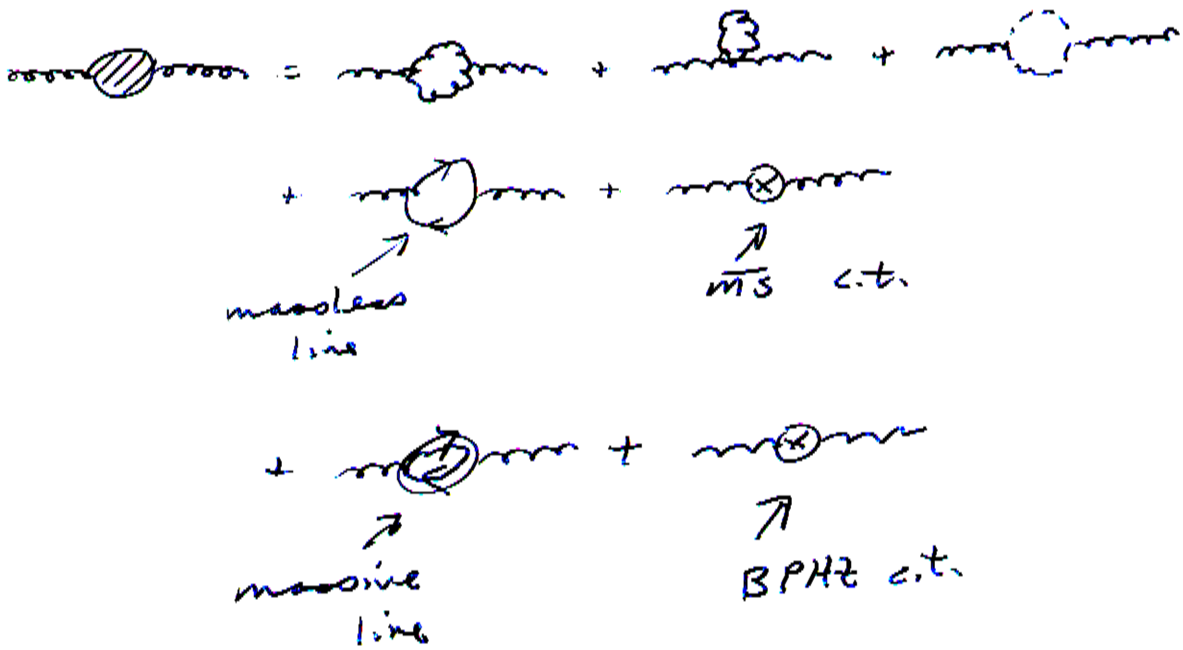
  g and ξ use $\overline{MS}$

  Q use BPHZ

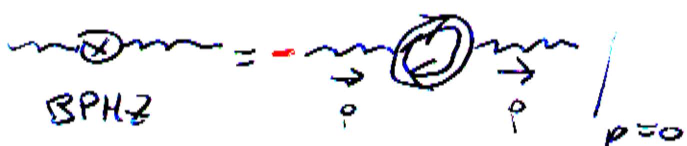
Collins, Wilczek and Zee subtraction scheme

- Use $\overline{MS}$ scheme for graphs containing no quarks as well as for graphs containing quarks with mass less than μ. Use BPHZ* for graphs involving heavy quarks.

- For example, Z_3 follows from



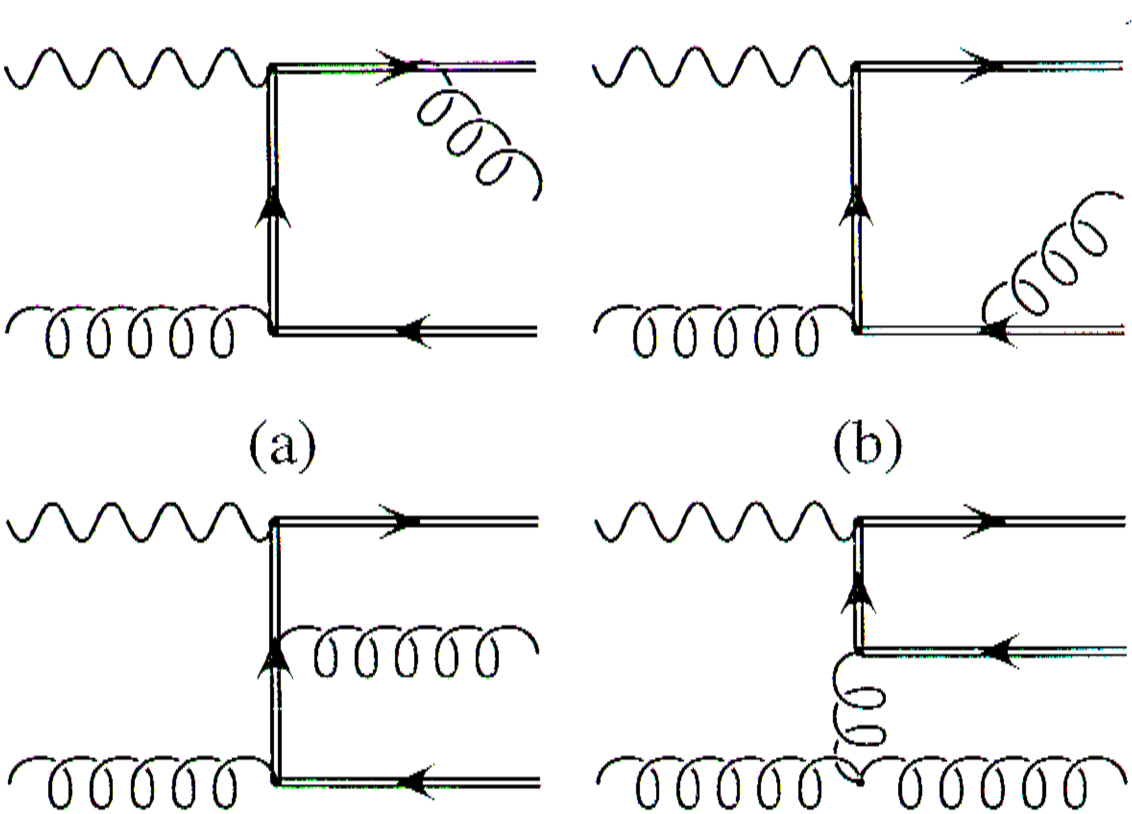
with



- removes a class of potentially large logarithms $\left[\begin{array}{c} \ln\left(\frac{-p^2}{\mu^2}\right) \\ \ln\left(\frac{m^2}{\mu^2}\right) \end{array}\right]$
- $\Rightarrow$ β function $\Rightarrow$ $\alpha_s(\mu)$
- $\Rightarrow$ $n_f = 3$ for charm production

* Bogoliubov – Parasiuk – Hepp – Zimmermann

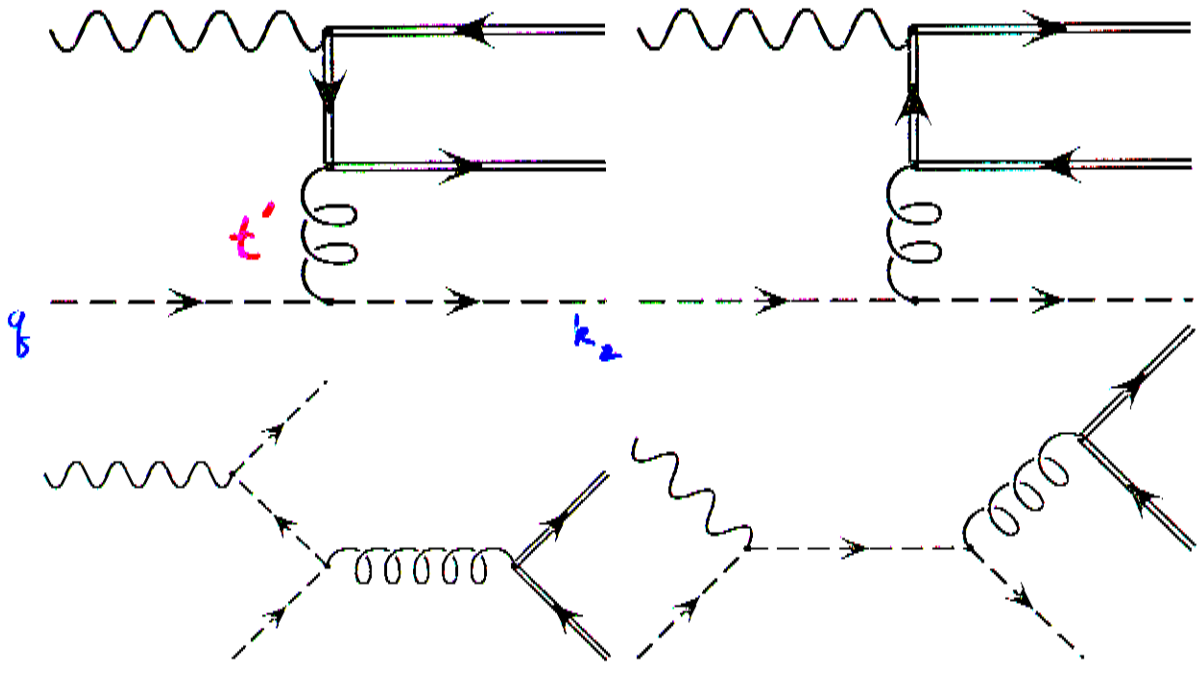
gluon radiation diagrams



(a) (b) (c) (d)

- massive quarks in (a) and (b) regulate would be final state collinear singularities
- (d) contains initial state collinear singularity removed by mass factorization
- soft singularities cancel upon addition of virtual contributions

light quark initiated diagrams



- $t' \propto (1+y)$ w/ y cosine of the angle between $\vec{q}$ & $\vec{k}_2$ in $\gamma^* q$ cms.

- $-1 \leq y \leq 1$
  ↳ collinear singularity

$$e^-(l) + P(p) \to e^-(l') + Q(p_1) + X$$

$$\frac{d^2\sigma}{dy\,dQ^2} = \frac{2\pi\alpha^2}{yQ^4}\left\{\left[1+(1-y)^2\right] F_2^c(x,Q^2,m_c) - y^2 F_L^c(x,Q^2,m_c)\right\}$$

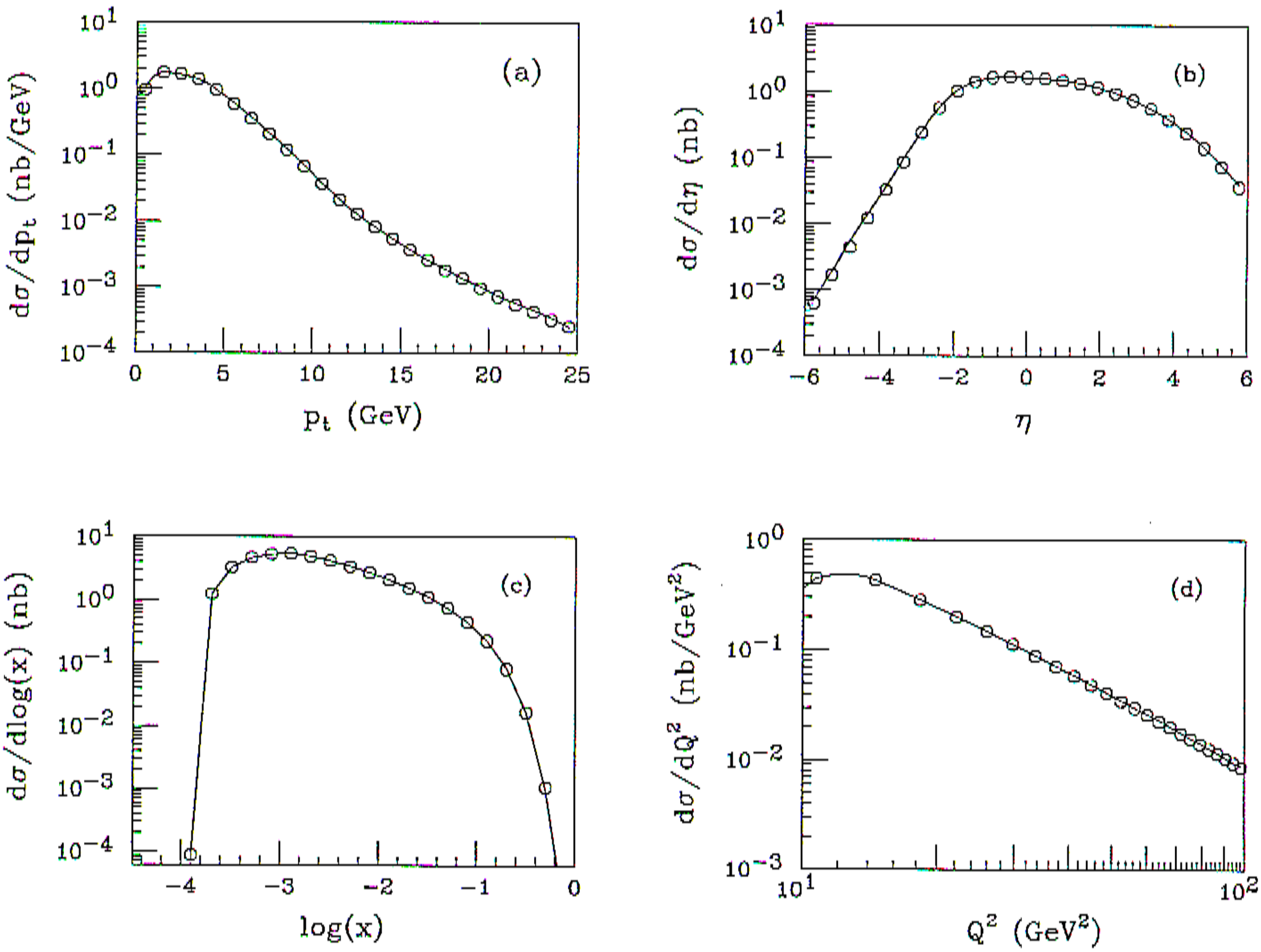
$$\sigma = \int_{4m_c^2/S}^{1} dy \int_{m_c^2 y^2/(1-y)}^{yS-4m_c^2} dQ^2 \left(\frac{d^2\sigma}{dy\,dQ^2}\right)$$

checks:

- NLO scaling functions vs. Riemersma et al ✓
- NLO total σ vs. Riemersma et al ✓
- $Q^2 \to 0$ limit NLO vs. Frixione et al ✓
- LO vs. AROMA Monte Carlo ✓

Important because it's the only calculation of it's type.

LO ME, 2 body PS, boost check

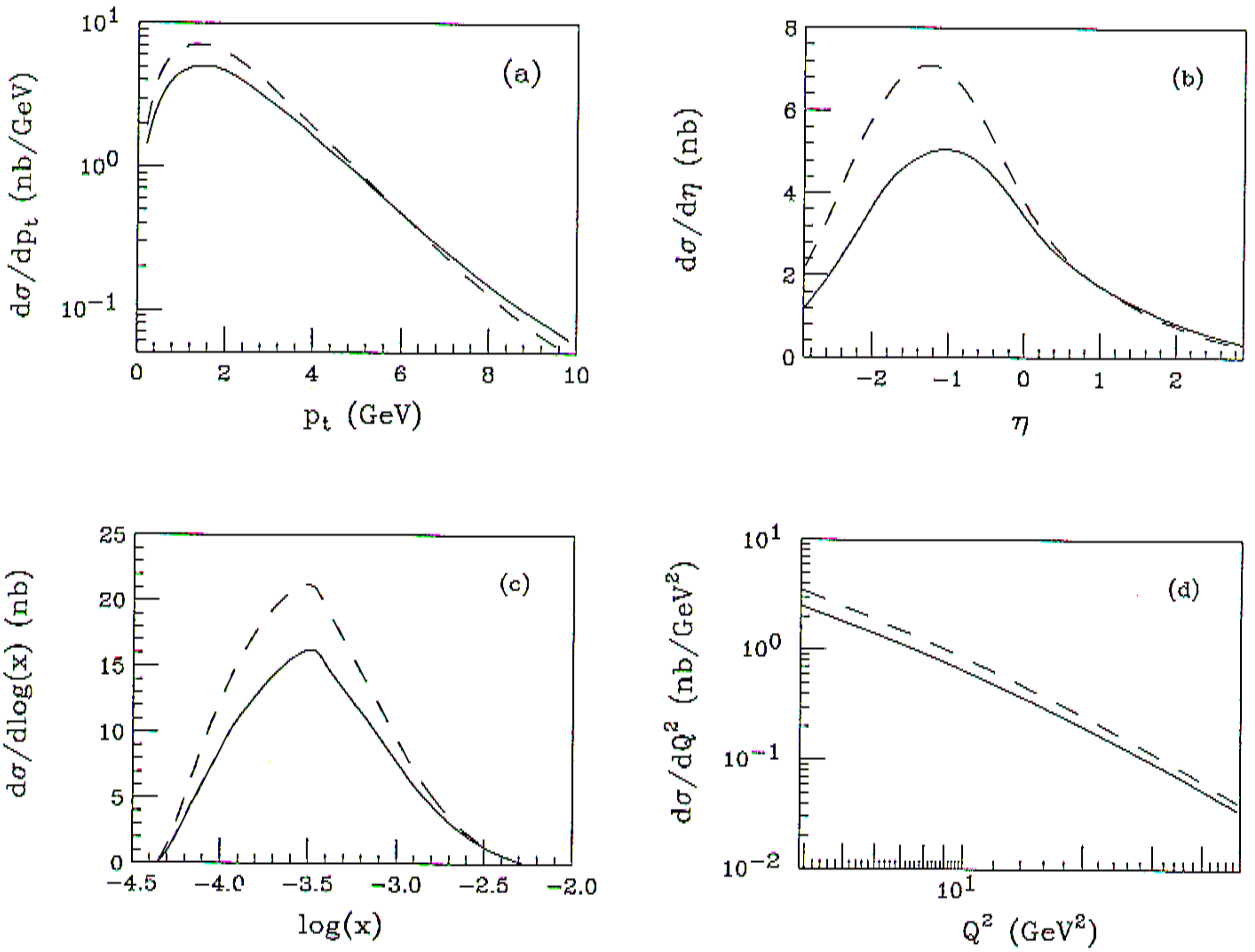


LO vs. AROMA MC

↳ Ingelman, Rathsman and Schuler

(parton level, showing off)

Charm production at HERA



LO vs NLO

D^* cross section

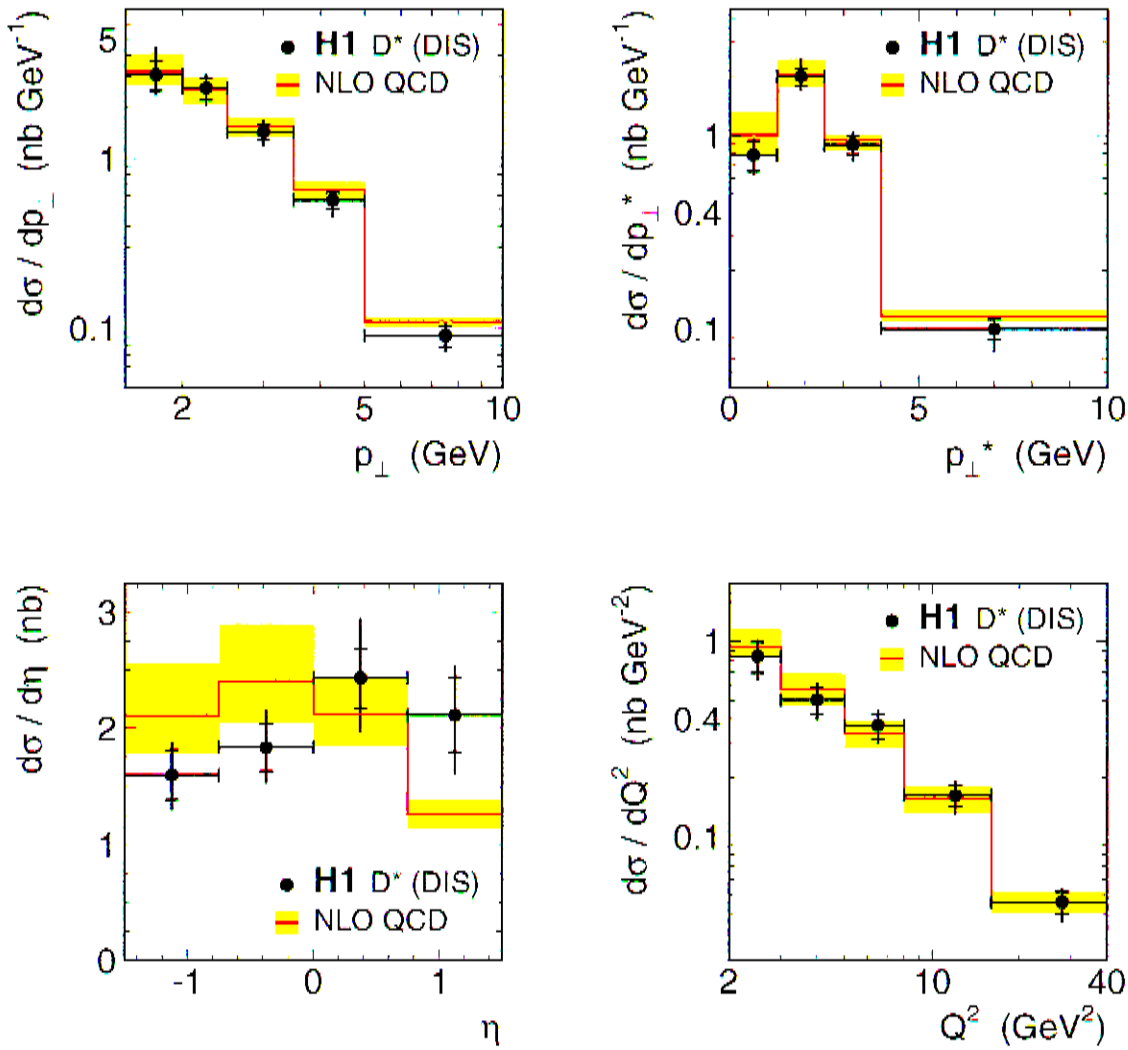
- assume simple fragmentation function of Peterson et al:

$$D(z) = N\left(1 - \frac{1}{z} - \frac{\epsilon}{1-z}\right)^{-2} \; ; \quad \int dz\, D(z) = 1$$

- normalization fixed by $P(c \to D) \simeq 0.26$ (LEP)

- $p_t \sim m_c \Rightarrow$ neglect evolution

- ϵ Nason, Oleari NLO fits

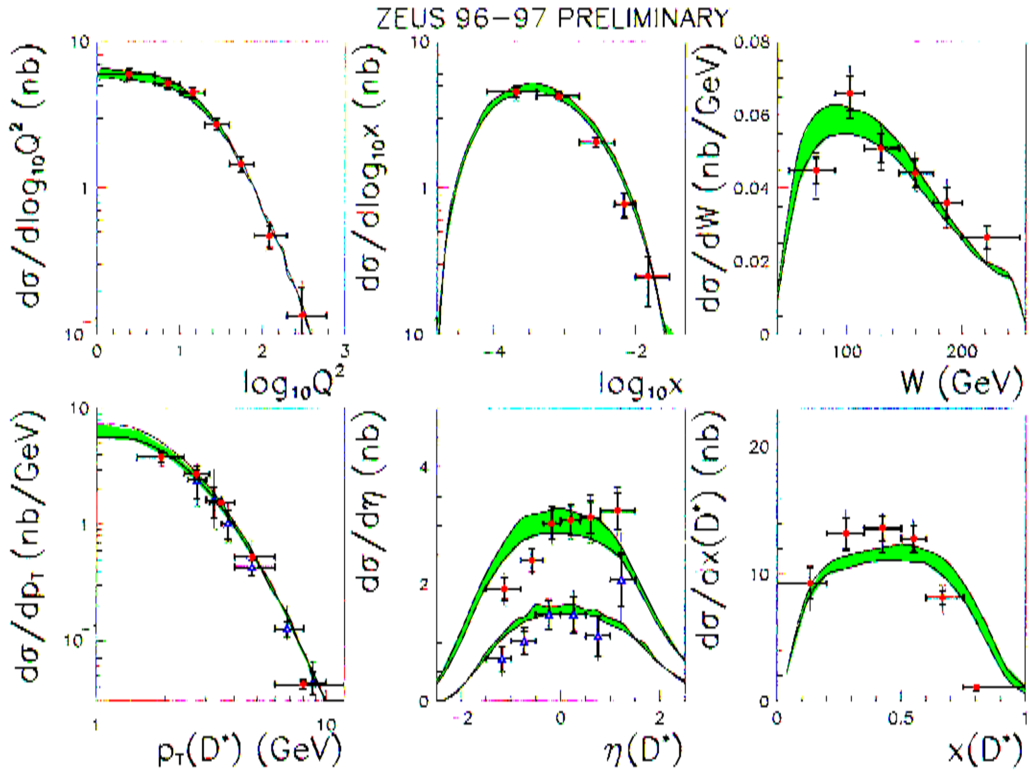


H1 D* (DIS)
NLO QCD
dσ / dp⊥ (nb GeV⁻¹)
p⊥ (GeV)
dσ / dp⊥* (nb GeV⁻¹)
p⊥* (GeV)
dσ / dη (nb)
η
dσ / dQ² (nb GeV⁻²)
Q² (GeV²)

Comparison to NLO QCD.

$\sigma(e^+p \to e^+D^{*\pm}X)_{k\pi} = 8.31 \pm 0.31(stat)^{+0.30}_{-0.50}(sys)\ nb$
HVQDIS $\to 8.44 \pm 0.55(m_c \pm 0.1)\ nb$

$\sigma(e^+p \to e^+D^{*\pm}X)_{k3\pi} = 3.65 \pm 0.36(stat)^{+0.20}_{-0.41}(sys)\ nb$
HVQDIS $\to 4.12 \pm 0.20(m_c \pm 0.1)\ nb$



$W^2 = Q^2\left(\frac{1-x}{x}\right)$

NLO (TFNS) Band:
$\epsilon = 0.035, pdf = ZEUS94, mc = 1.3 - 1.5\ GeV$

$\to$ Agreement in Q^2, x, W, $p_T(D^*)$ and σ_{KIN}
$\to$ $p_T(D^*)$ too low in first bin.
$\to$ η shifted towards the proton remnant.
$\to$ $x(D^*)$ shifted towards lower values.

[I. Redondo, DIS99]

Comments:

Cannot be explained by

PDF set

scale choice

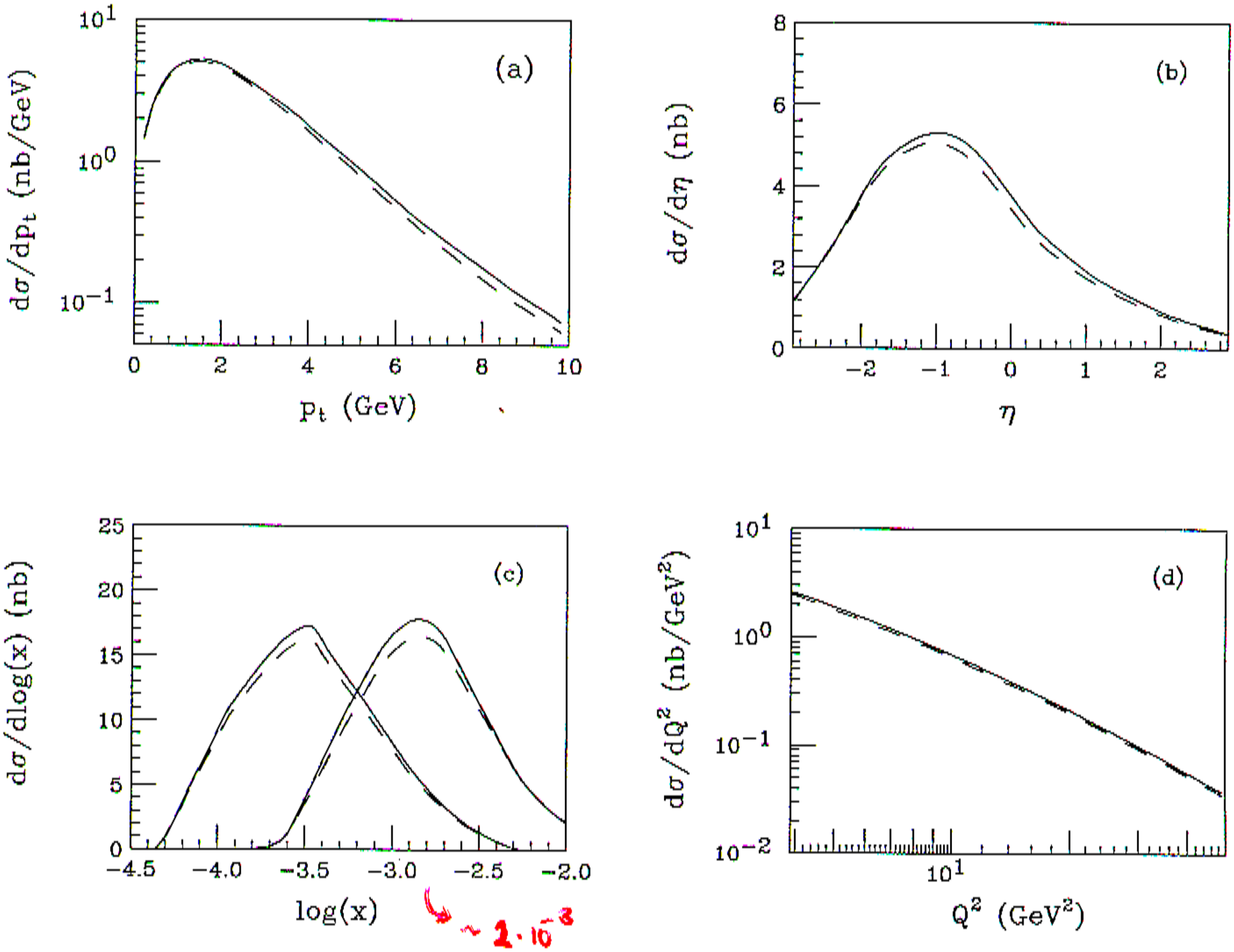
m_c

Peterson ϵ

evolving frag. func.

photon structure

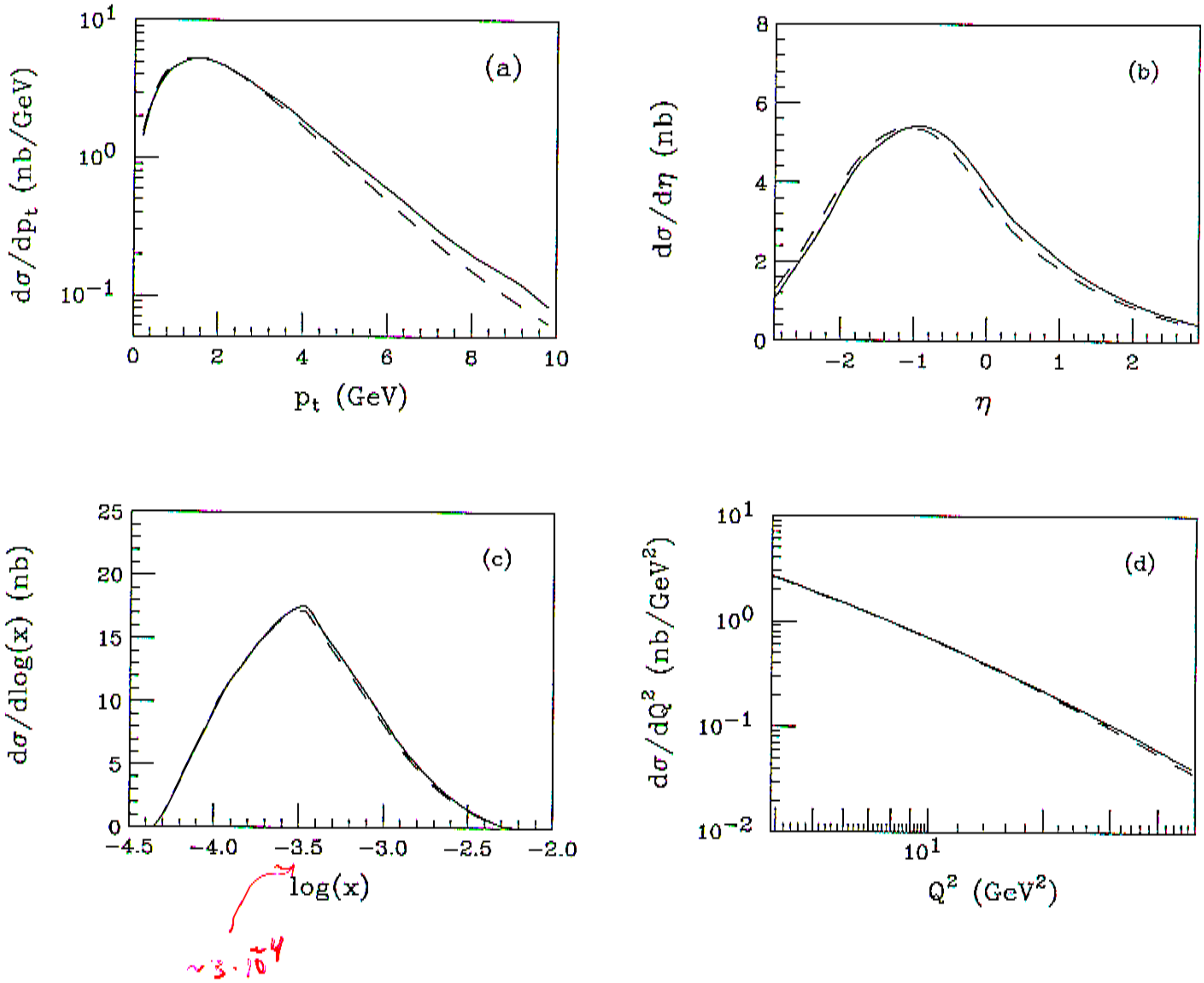
PDF Set dependence



- - - - GRV 94

——— CTEQ4F3

scale dependence

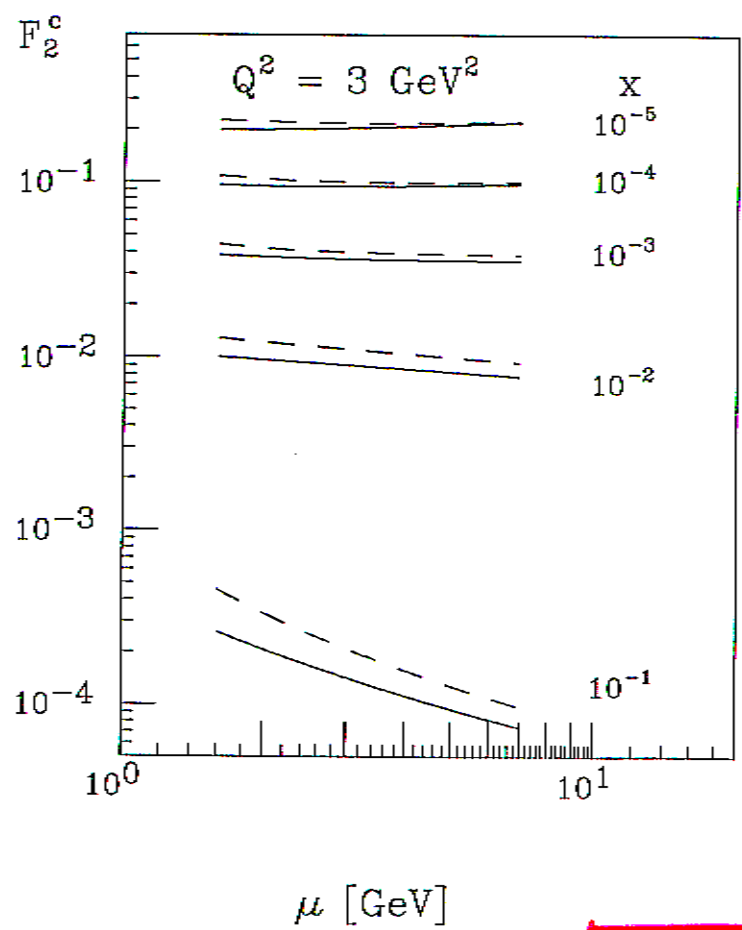


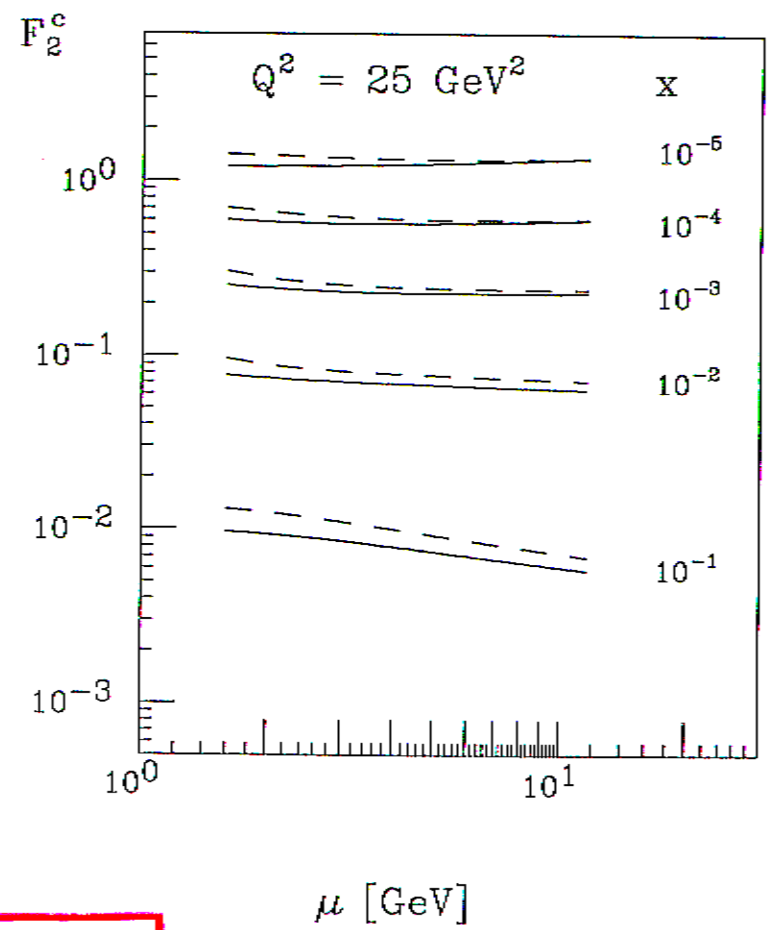
$\mu = 2m_c$ (solid)

$\mu = 2\sqrt{Q^2+4m_c^2}$ (dash)

Scale dependence of structure functions

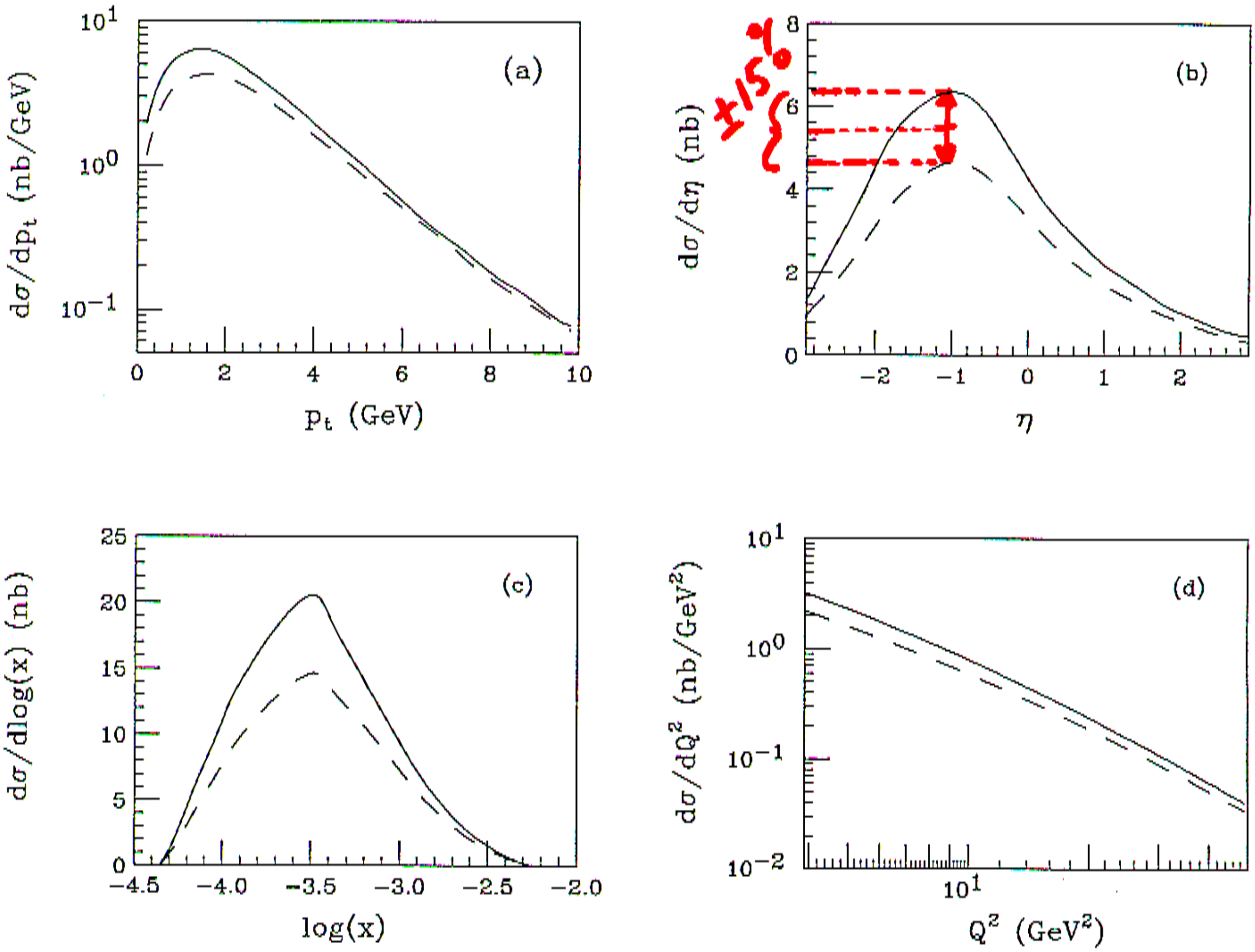
Solid: GRV94, Dash: CTEQ4F3





$\boxed{m_c^2 < \mu^2 < 4(Q^2 + 4m_c^2)}$

mass dependence

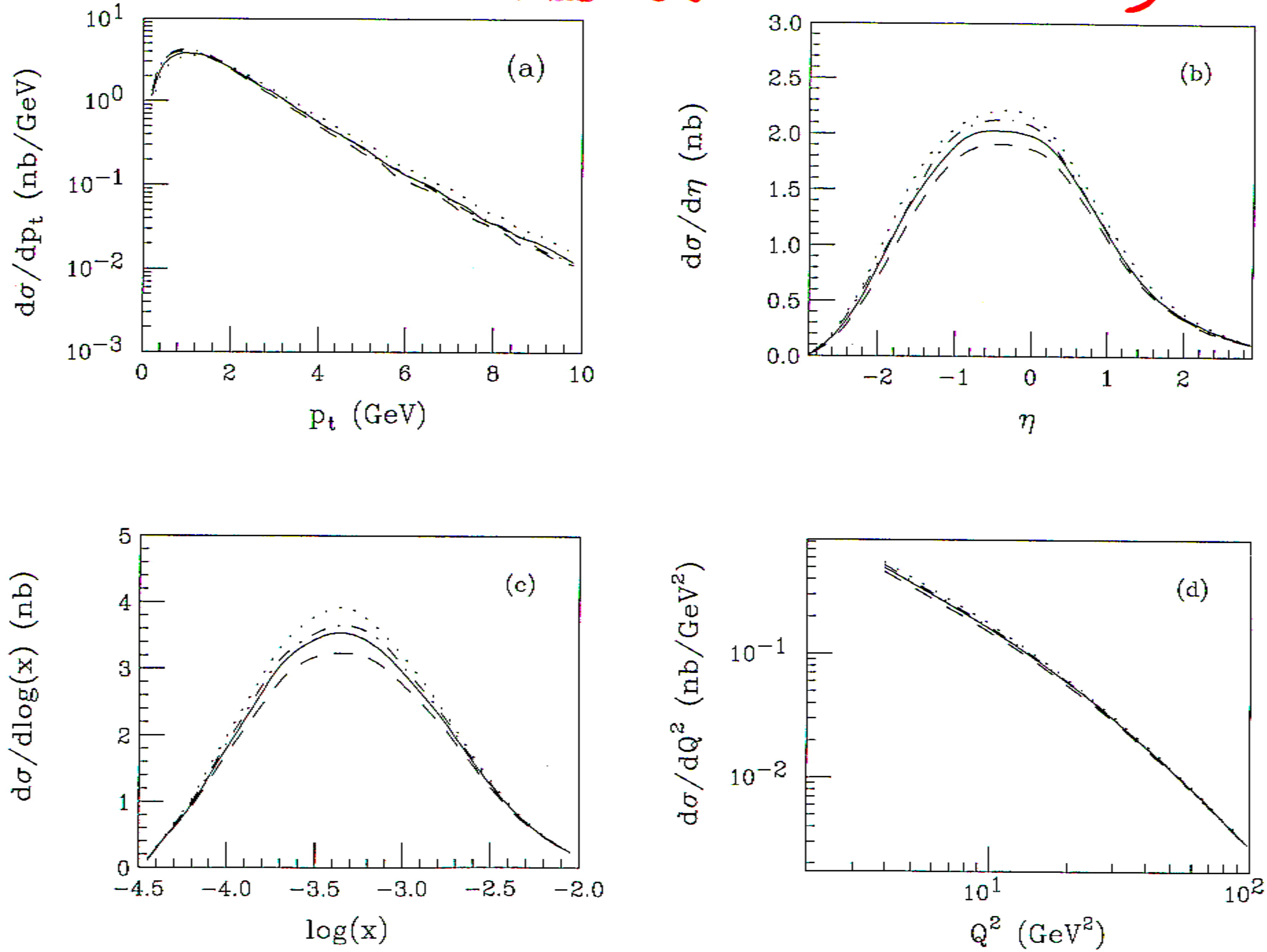


m_c = 1.35 GeV (top)

m_c = 1.65 GeV (bottom)

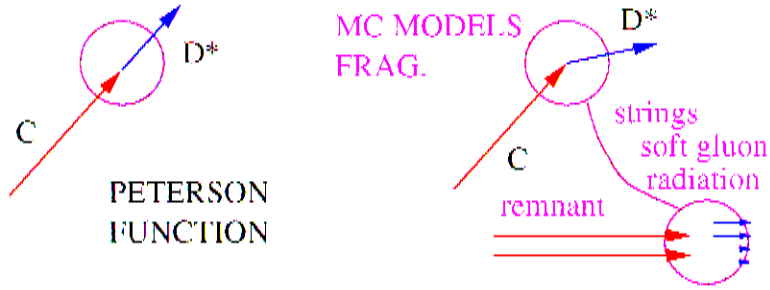
= 1.5 GeV ± 10%

D^* cross sections ($\epsilon = 0.03 \rightarrow 0.09$)

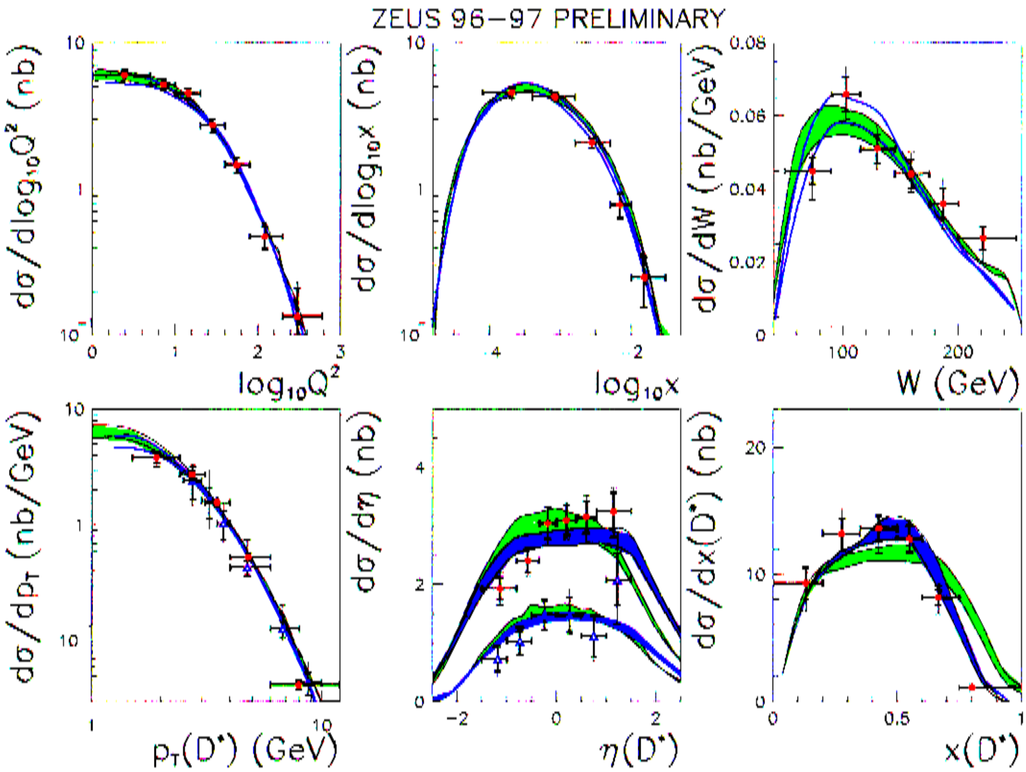


Fragmentation Effects.

- In MC models (HERWIG, JETSET), a shift towards the forward direction is produced during the fragmentation (Beam drag).



⇒ Reweight RAPGAP (JETSET) MC to follow NLO $p_t(c), \eta(c)$ distribution.

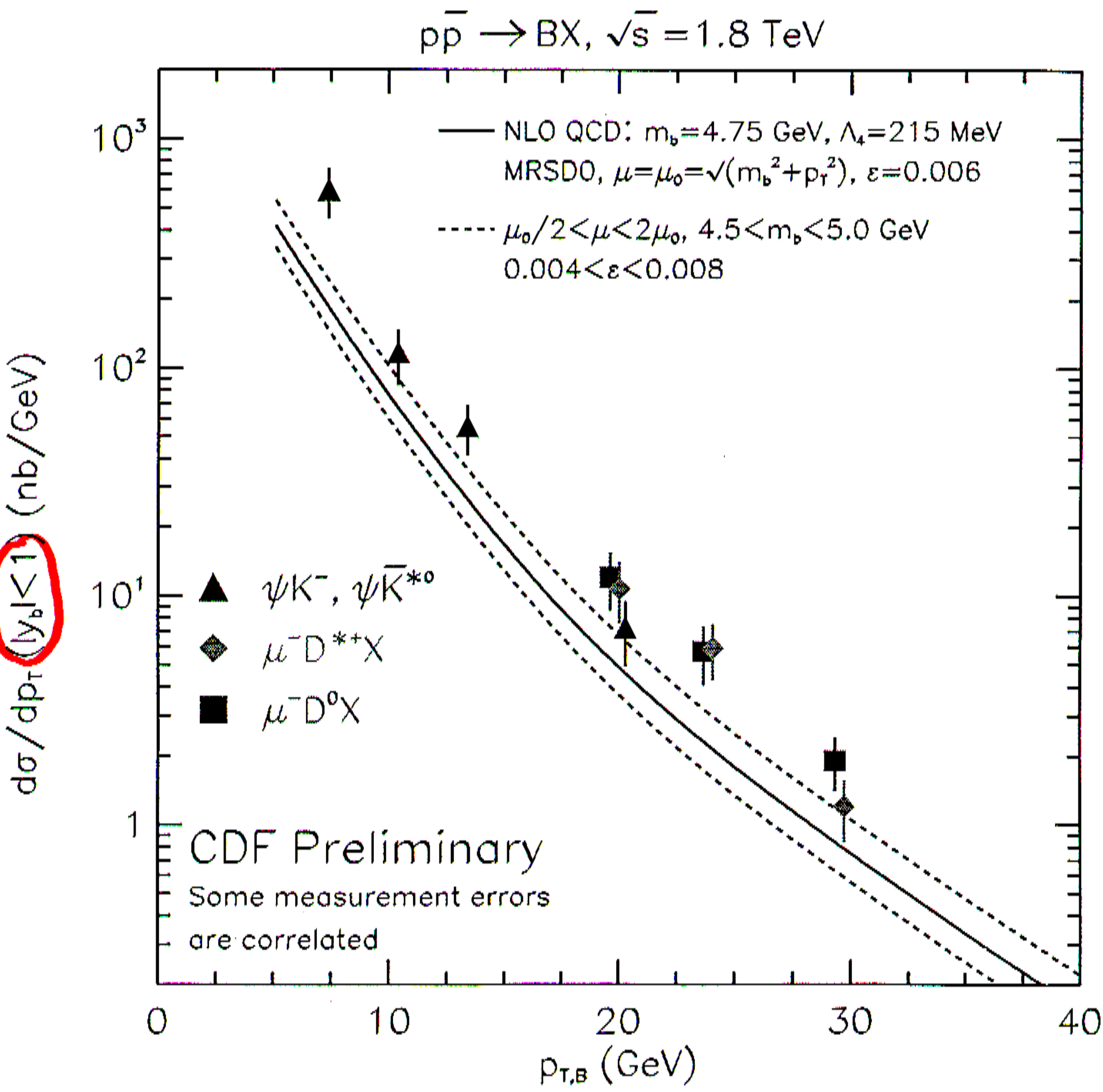


- Better description of the data.

[Norrbin & Sjöstrand : photoproduction case
hep-ph/9905493]

[I. Redondo, DIS99]

Will not help with:



but may contribute to...

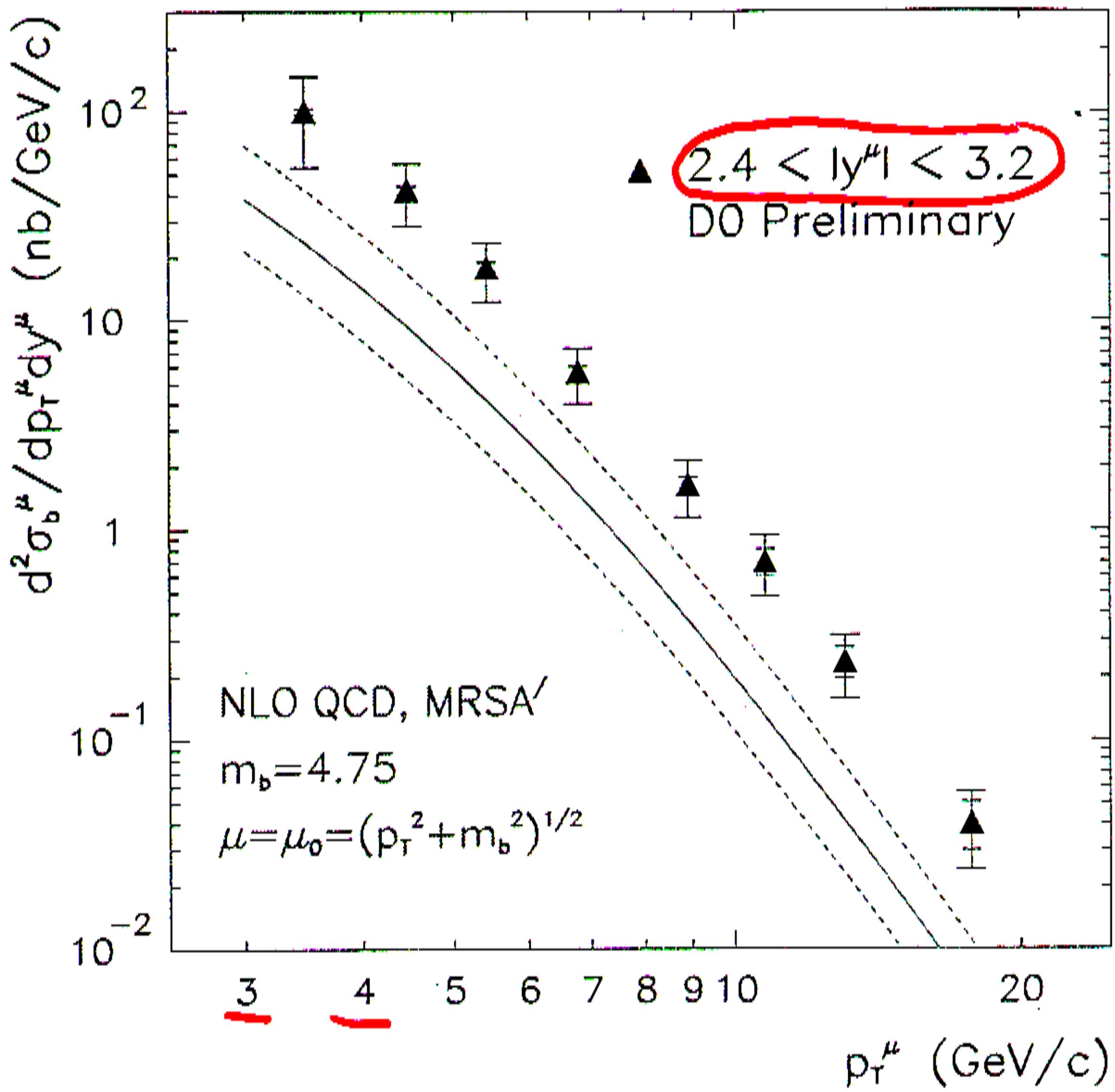


FIG. 6. The measured differential muon cross section from b production as a function of p_T^μ. The Solid curve is the prediction of the NLO QCD model described in the text, with the dashed curves representing the theoretical uncertainties.

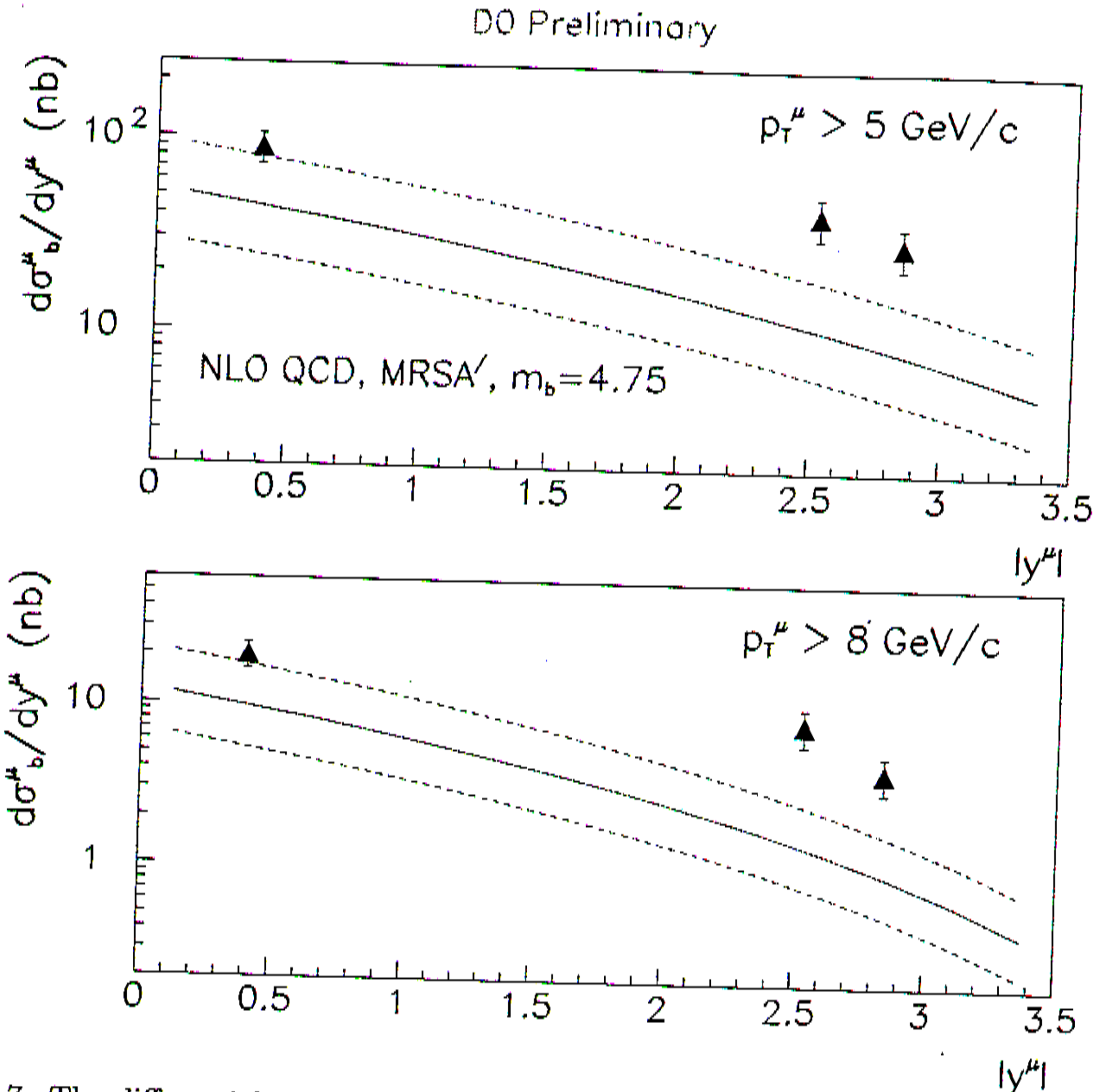


FIG. 7. The differential muon cross sections from b production and decay as a function of y^{μ} for (a) $p_T^{\mu} > 5$ GeV/c, and (b) $p_T^{\mu} > 8$ GeV/c. The Solid curves are the predictions of the NLO QCD model described in the text, with uncertainty bands shown by the dashed lines.

- shape also off
- needs further study

- what about BTeV studies?

Current ideas:

- series of MC studies (Pythia, ...)
- more rig. QCD studies (power suppressed..)