Photoproduction of jets

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3 June 2014

DFG

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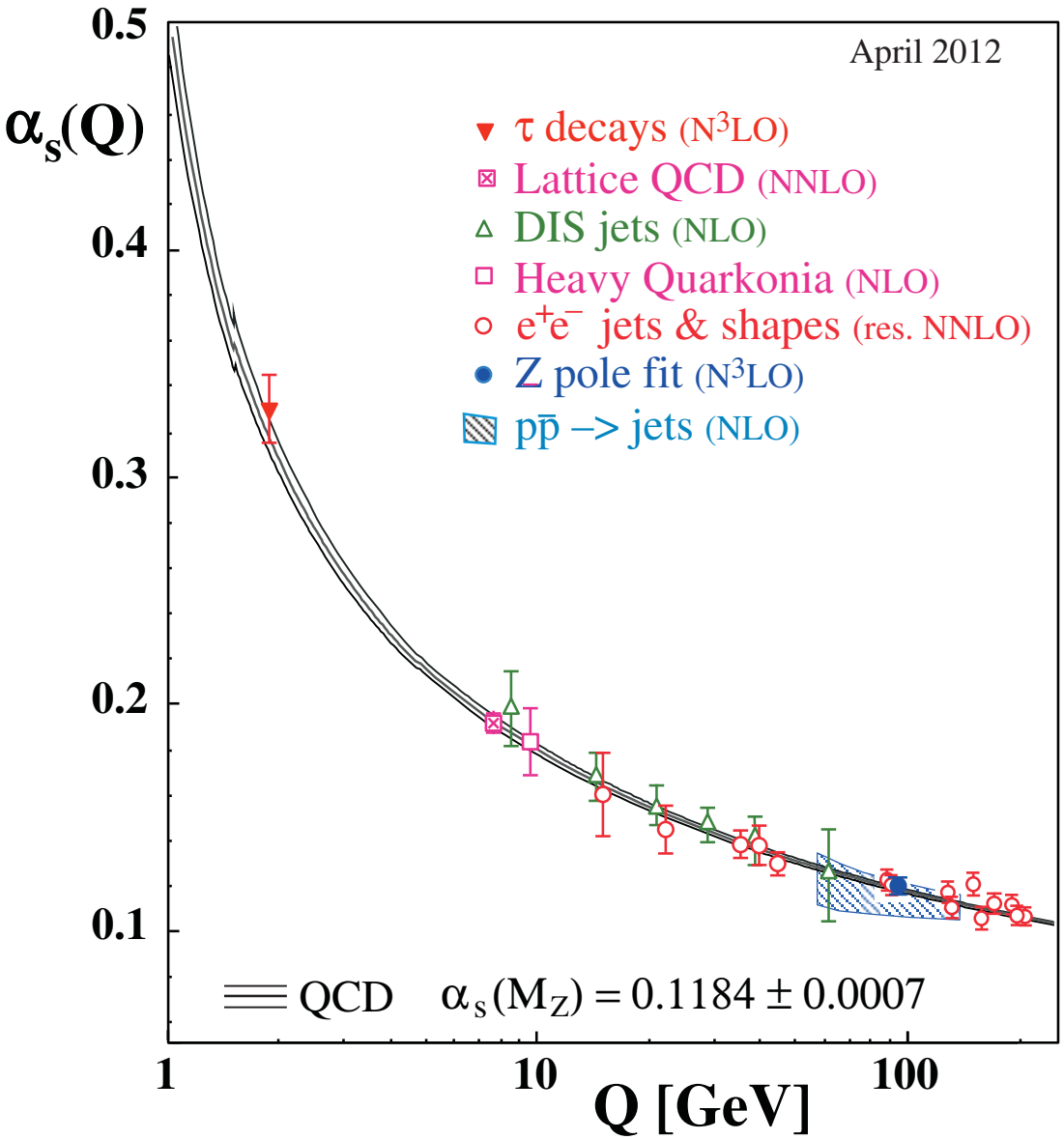
References

- MK
  Theory of hard photoproduction
  Rev. Mod. Phys. 74 (2002) 1221 [hep-ph/0206169]
- MK, G. Kramer, M. Michael
  NNLO contributions to jet photoproduction and determination of α_s
  Phys. Rev. D 89 (2014) 074032 [1310.1724]
- MK, G. Kramer
  Dijet photoproduction of massless charm jets at next-to-leading order of QCD
  Eur. Phys. J. C 71 (2011) 1774 [1104.0095]

Running of the strong coupling

PDG collaboration, Phys. Rev. D 86 (2012) 010001



Jet photoproduction in peripheral heavy-ion collisions

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Equivalent photon spectra

- Elastic scattering
- Inelastic scattering

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Differential $\gamma\gamma$ cross section:

$$\mathrm{d}\sigma = \sum_{a,b} \int \mathrm{d}x_a \, f_{a/\gamma}(x_a, \mu_a) \int \mathrm{d}x_b \, f_{b/\gamma}(x_b, \mu_b) \, \mathrm{d}\sigma_{ab}(\alpha_s, \mu, \mu_a, \mu_b)$$

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Pointlike contribution to photon PDFs ($Q^2 \equiv \mu^2 \equiv \mu_{a,b}^2$):

$$f_{i/\gamma}^{\mathrm{pl.}}(Q^2) = \frac{\alpha}{2\pi} \left[\frac{4\pi}{\alpha_s(Q^2)} a_i + b_i + \mathcal{O}(\alpha_s) \right]$$

Photon structure function

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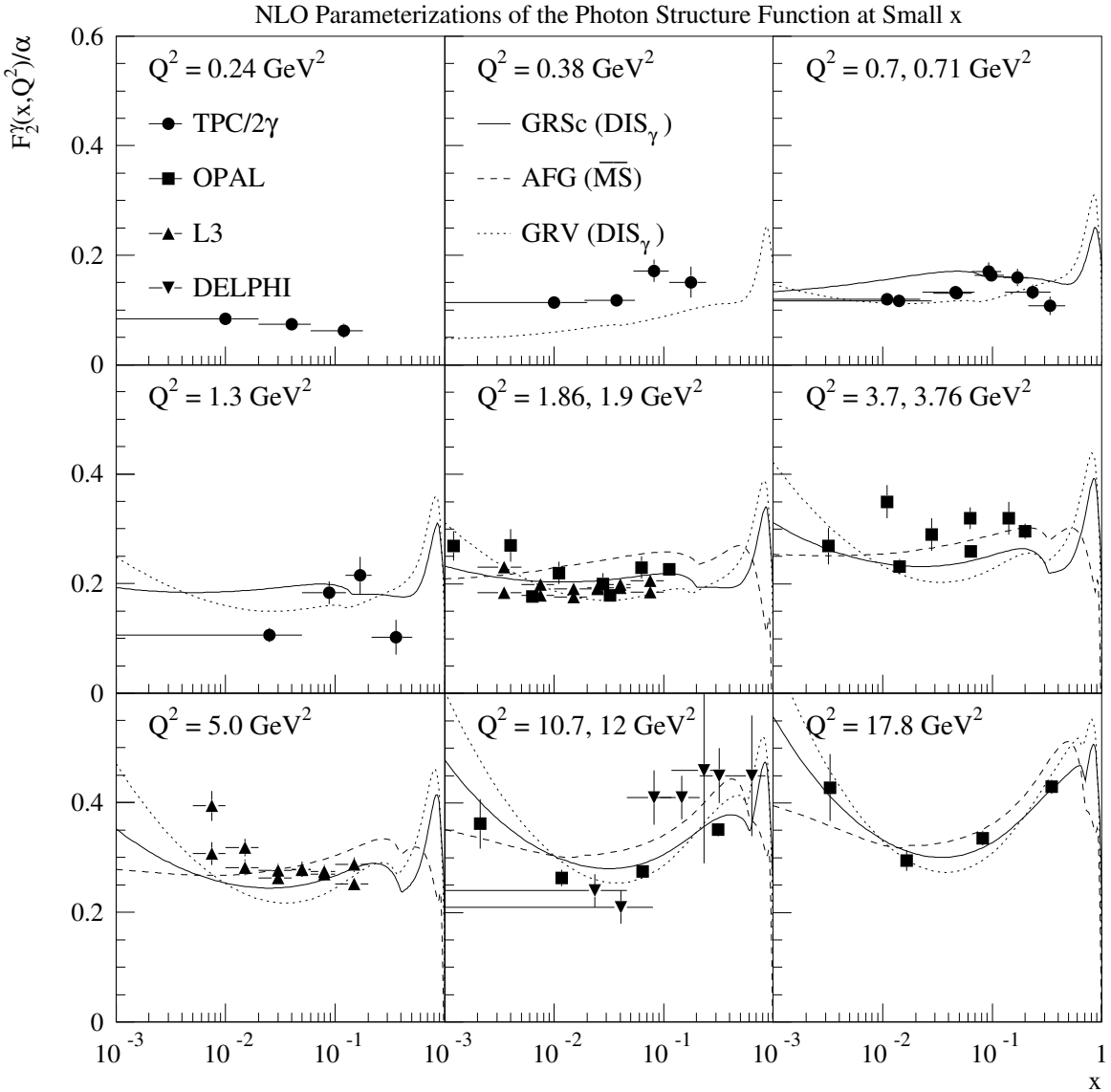

Jets in $\gamma\gamma$ collisions at TRISTAN ($\sqrt{s} = 58$ GeV)

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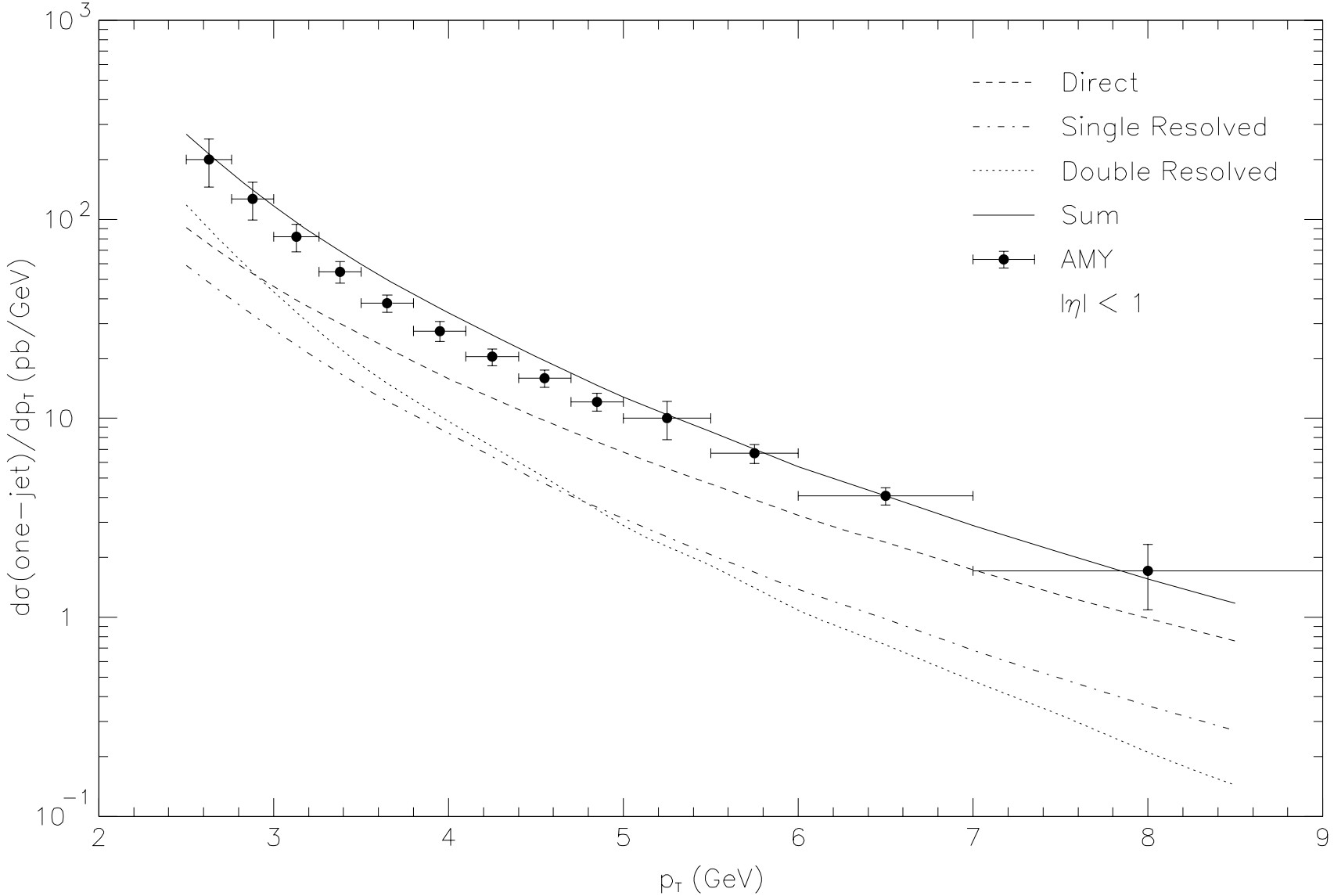

Experimental conditions at TRISTAN ($\sqrt{s} = 58$ GeV)

AMY Coll., Phys. Lett. B 325 (1994) 248

Event selection:

- ≥ 4 charged tracks w/ $|p| > 0.75$ GeV, ≥ 1 w/ $p_T > 1$ GeV
- Net $p_T \leq 5$ GeV, net charge $\sum_i q_i \leq 2$
- $E_{\text{max}}^{\text{had.}} \leq E_{\text{beam}}/4$, 4 GeV $\leq W_{\text{vis.}} \leq 20$ GeV (assigning m_π)

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Jet selection:

- Cone algorithm with $R = 1$
- $p_T^{\text{jet}} \geq 2.5$ GeV
- $|\eta^{\text{jet}}| \leq 1$ (for AMY; 0.7 for TOPAZ)

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LHC conditions:

- Rapidity gaps $\rightarrow$ lower p_T threshold than for incl. production
- Jets interact also strongly $\rightarrow$ SD contribution with $S = 0.1$
- No further suppression from SD to DD

NNLO corrections from threshold resummation (1)

N. Kidonakis, Int. J. Mod. Phys. A 19 (2004) 1793 [hep-ph/0303186]

Universal threshold logarithms spoil perturbative expansion:

$$D_l = \left[\frac{\ln^l(1-z)}{1-z}\right]_+ \quad \text{with} \quad z = \frac{M_{jj}^2}{s}$$

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Resummation to all orders in α_s:

$$\sigma^{\text{res.}} \;=\; E_a(N)\, E_b(N)\, H_{ab}\, \exp\left[G_{ab}(N)\right]$$

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Perturbative re-expansion (approximate NLO, NNLO, ...):

$$\sigma^{\text{res.}} \;=\; \sigma^{(0)} + \sigma^{(1)} + \sigma^{(2)} + \ldots$$

NNLO corrections from threshold resummation (2)

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NLO partonic cross section:

$$\begin{aligned}\sigma^{(1)} &= \sigma^{(0)}\frac{\alpha_s}{\pi}\left[c_3 D_1(z) + c_2 D_0(z) + c_1\delta(1-z)\right] \\ &+ \frac{\alpha_s^{d_{\alpha_s}+1}}{\pi}\left[A^c D_0(z) + T_1^c\delta(1-z)\right]\end{aligned}$$

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NNLO partonic cross section:

$$\sigma^{(2)} = \sigma^{(0)}\frac{\alpha_s^2}{\pi^2}\left[\frac{1}{2}c_3^2 D_3(z) + \left(\frac{3}{2}c_3 c_2 - \frac{\beta_0}{4}\right)D_2(z) + \ldots\right]$$

NNLO corrections from threshold resummation (3)

MK, G. Kramer, M. Michael, Phys. Rev. D 89 (2014) 074032 [1310.1724]

Coefficients for $\gamma q \to qg$:

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\begin{aligned}
c_3 &= C_F - N_C, \\
c_2 &= C_F \left[-\ln\left(\frac{\mu_p^2}{s}\right) - \frac{3}{4} + 2\ln\left(\frac{-u}{s}\right) \right] + N_C \ln\left(\frac{t}{u}\right) - \frac{\beta_0}{4}, \\
c_1^{\mu} &= -\frac{3C_F}{4} \ln\left(\frac{\mu_p^2}{s}\right) + \frac{\beta_0}{4} \ln\left(\frac{\mu^2}{s}\right).
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Coefficients for $\gamma g \to q\bar{q}$:

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\begin{aligned}
c_3 &= 2(N_C - C_F), \\
c_2 &= -\frac{3C_F}{2} + N_C \left[-\ln\left(\frac{\mu_p^2}{s}\right) + \ln\left(\frac{tu}{s^2}\right) \right], \\
c_1^\mu &= -\frac{\beta_0}{4} \ln\left(\frac{\mu_p^2}{s}\right) + \frac{\beta_0}{4} \ln\left(\frac{\mu^2}{s}\right).
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Jet hadroproduction at the Tevatron

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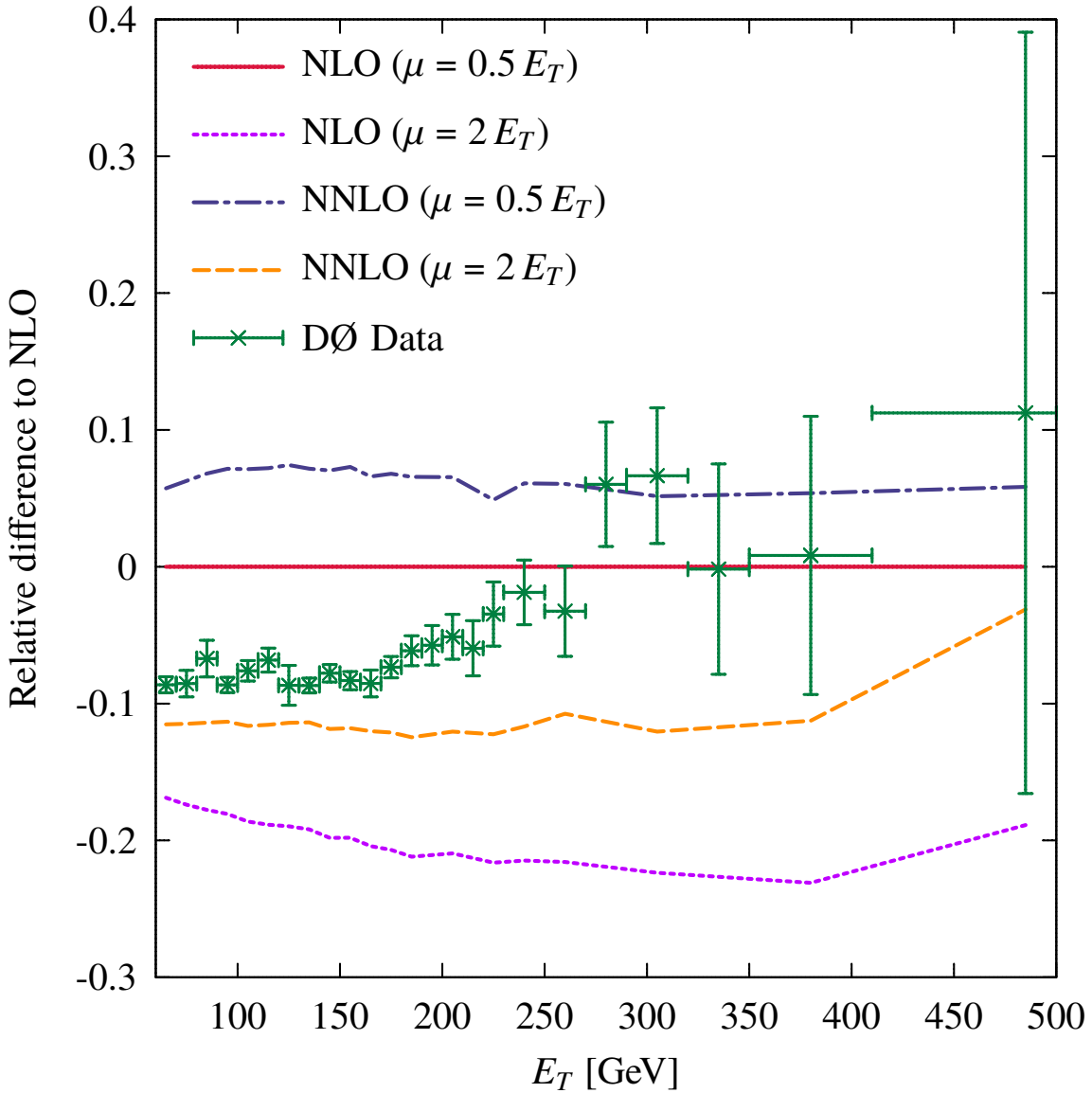

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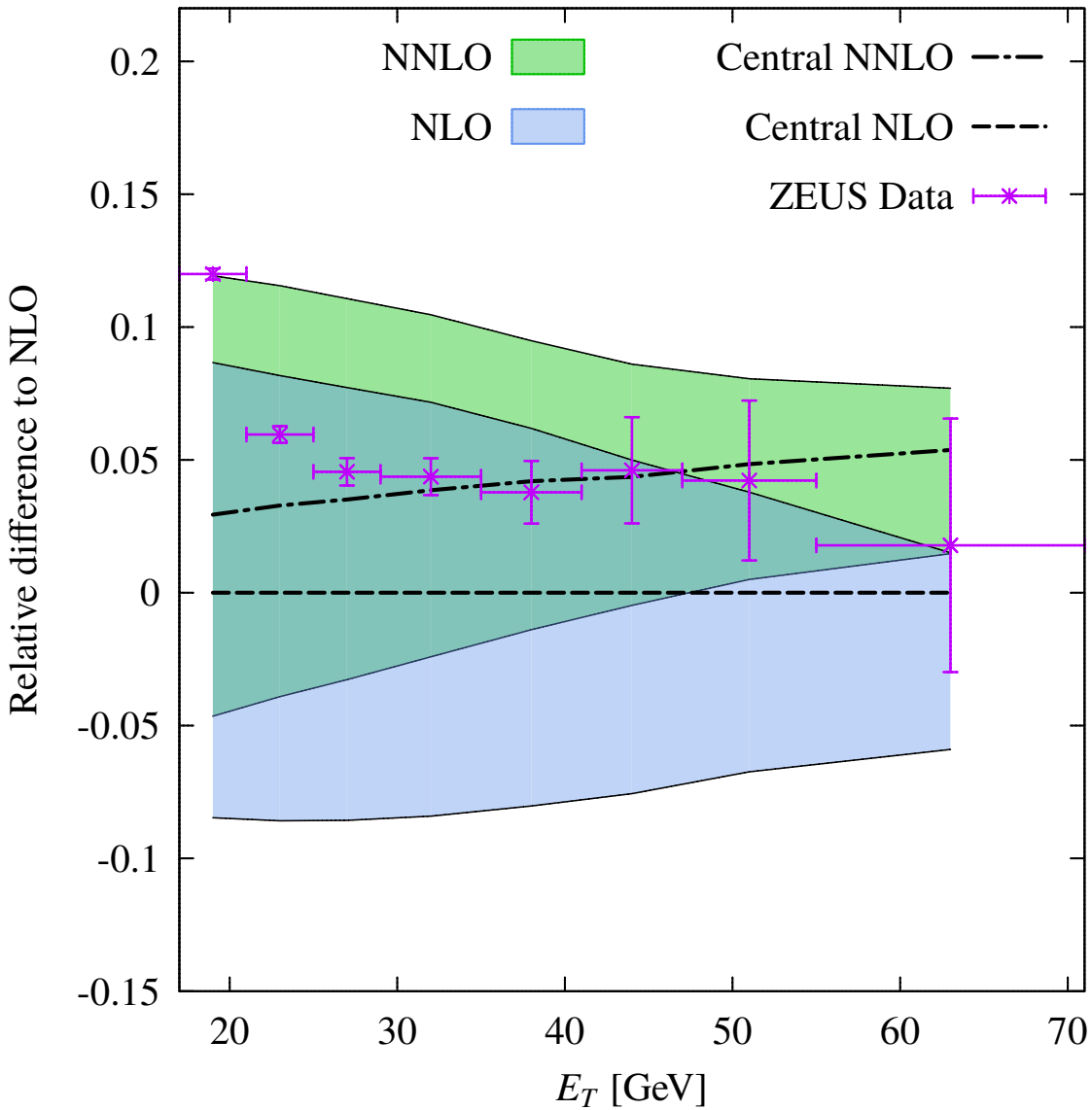

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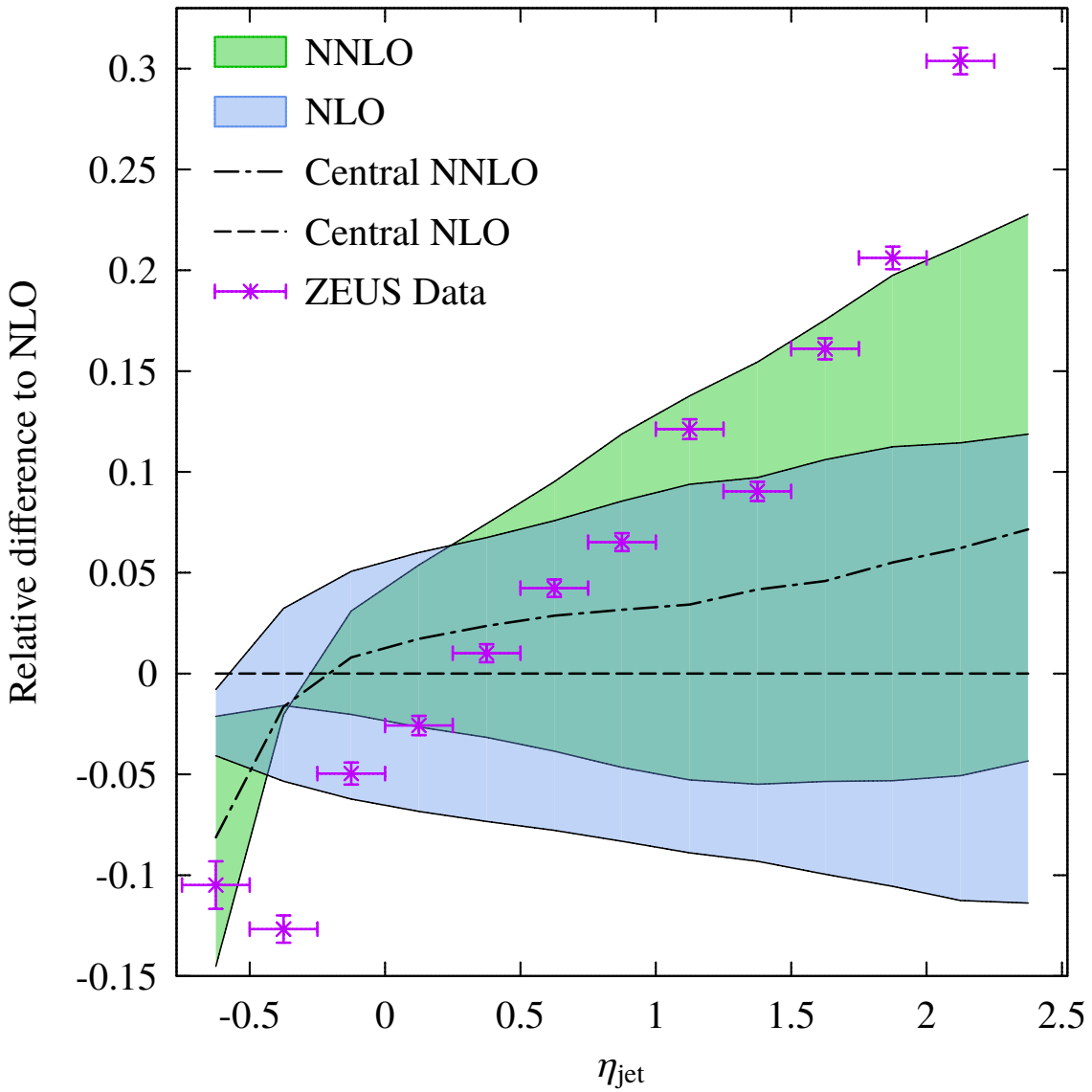

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ZEUS determination of $\alpha_s(M_Z)$ at NLO:

$$\alpha_s(M_Z) = 0.121 \pm 0.002\ (\text{exp.}) \pm 0.004\ (\text{th.})$$

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Our determination of $\alpha_s(M_Z)$ up to NNLO:

$$\alpha_s(M_Z) = 0.120 \pm 0.002\ (\text{exp.}) \pm 0.003\ (\text{th.})$$

Charm contribution

MK, G. Kramer, Eur. Phys. J. C 71 (2011) 1774 [1104.0095]

Direct photoproduction: $\mathrm{d}\sigma_{\mathrm{charm}}/\mathrm{d}\sigma_{\mathrm{all}} \sim e_c^2/\sum_q e_q^2 = 2/5$

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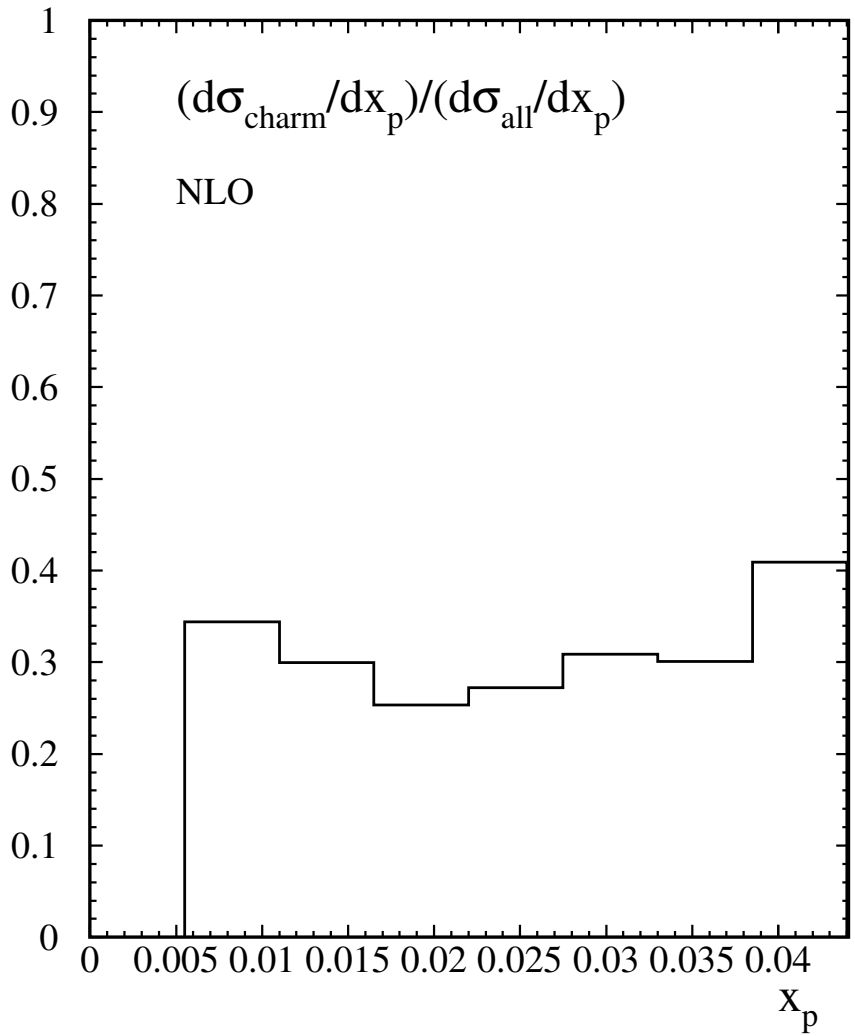

Theoretical approaches to heavy-quark cross sections

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Massive calculations:

- Finite terms of $\mathcal{O}(m_c)$ important when $p_T \sim m_c$
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- Resummation of mass logarithms in photon (+ proton) PDFs
- Jet algorithm $\rightarrow$ Reduced dependence on fragmentation

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ZEUS measurement [Phys. Lett. B 565 (2003) 87]:

- $E_T^{\text{jet}} > 5$ GeV, $|\eta^{\text{jet}}| < 2.4$
- $p_T^{D^*} > 3$ GeV, $|\eta^{D^*}| < 1.5$

Comparison to the ZEUS measurement

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Observed momentum fractions in the photon / proton:

$$x_\gamma^{\text{obs.}} = \frac{\sum_{\text{jets}} E_T^{\text{jet}} e^{-\eta^{\text{jet}}}}{2yE_e} \qquad x_p^{\text{obs.}} = \frac{\sum_{\text{jets}} E_T^{\text{jet}} e^{+\eta^{\text{jet}}}}{2E_p}$$

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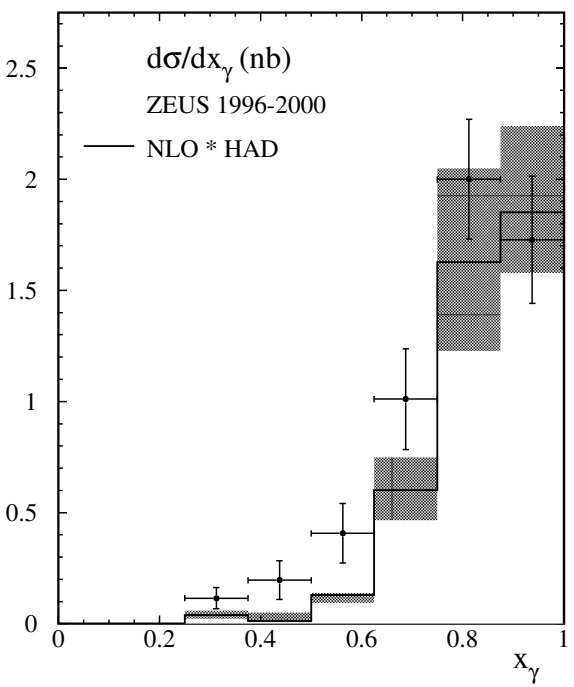
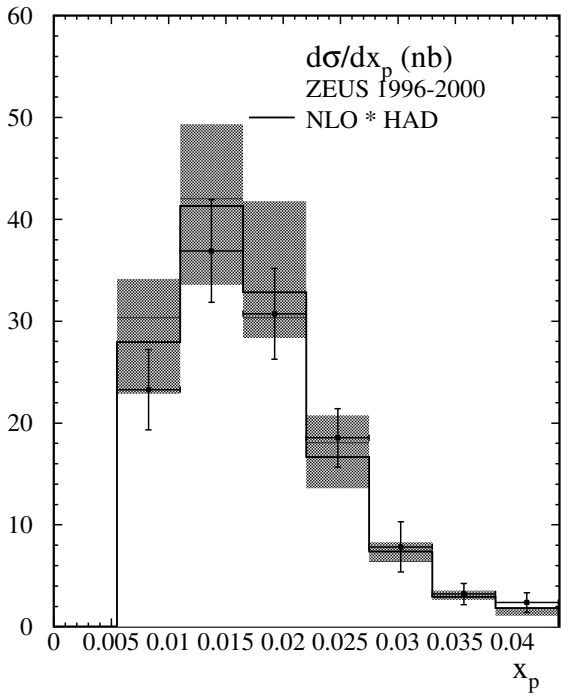
Differential cross sections:





Sensitivity to the charm content in the photon

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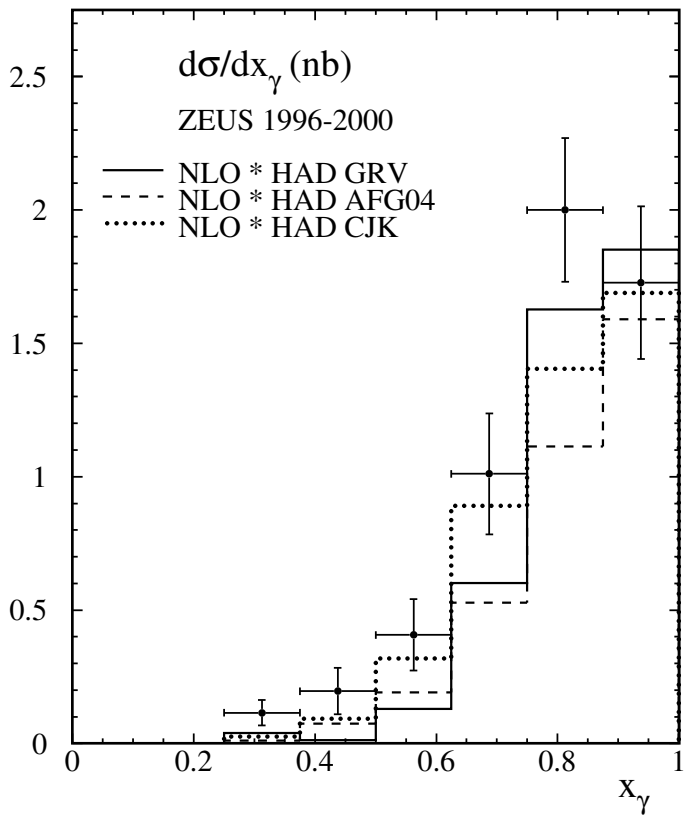

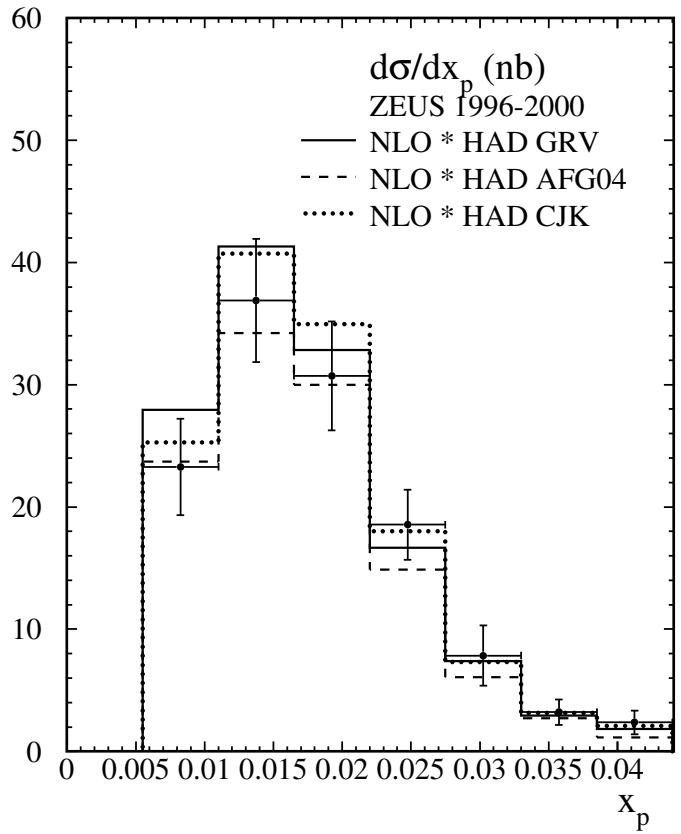

Conclusion

Applicability of perturbative QCD:

- Clean evironment crucial $\rightarrow e^+e^-$ or ultraperipheral collisions
- pQCD works in photoproduction and jets down to 2.5 GeV

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Physical applications:

- Determination of α_s, photon and proton PDFs
- Diffractive, nuclear PDFs and form factors