Nuclear PDFs from LHC vector boson production

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DFG

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Allianz für Astroteilchenphysik

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Motivation

Current status of (nuclear) PDFs:

- Large uncertainties at large x, in particular gluon
- Transition region: Shadowing $\rightarrow$ antishadowing $\rightarrow$ EMC effect
- Traditional process: Prompt photons, theoretically uncertain

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Our proposal:

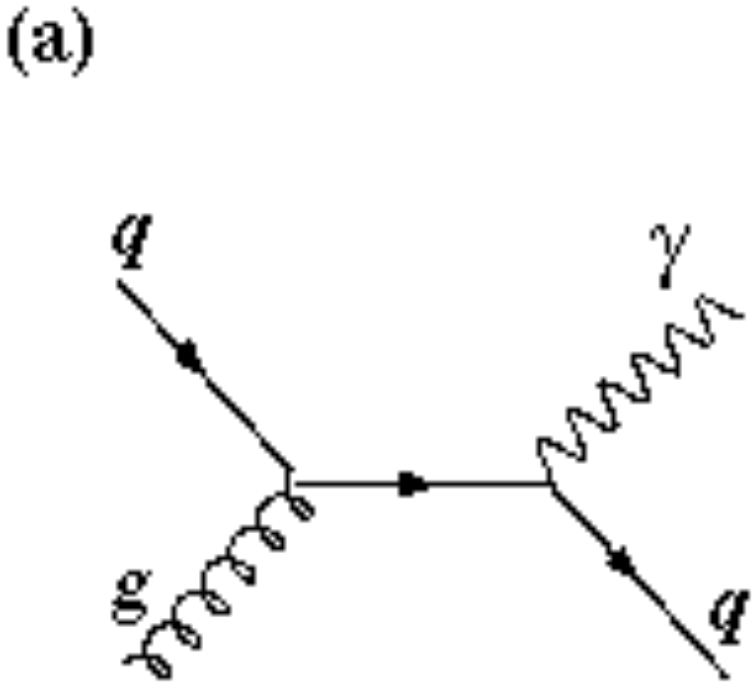
- Look for alternative processes

References

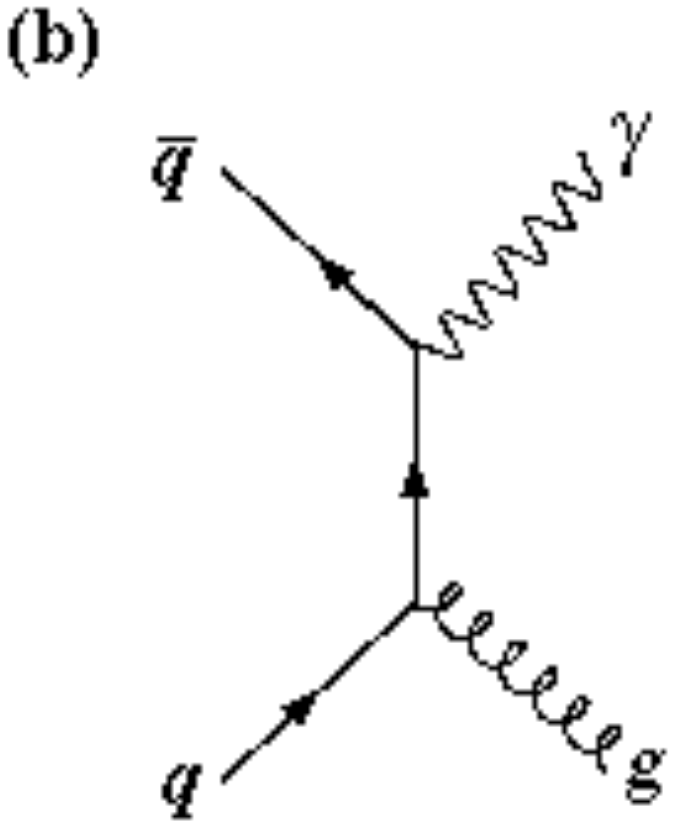
- E.L. Berger, L.E. Gordon, MK
  Massive lepton pairs as a prompt photon surrogate
  Phys. Rev. D 58 (1998) 074012 [hep-ph/9803387]
- E.L. Berger, L.E. Gordon, MK
  Spin dependence of massive lepton pair production in proton proton collisions
  Phys. Rev. D 62 (2000) 014014 [hep-ph/9909446]
- M. Brandt, MK
  Parton densities from LHC vector boson production at small and large transverse momenta
  Phys. Rev. D 88 (2013) 054002 [1305.5677]
- MK, C. Klein-Bösing, F. König, J.P. Wessels
  How robust is a thermal photon interpretation of the ALICE low-p_T data?
  JHEP (in press) [1307.7034]

Partonic production of prompt photons

QCD Compton process:

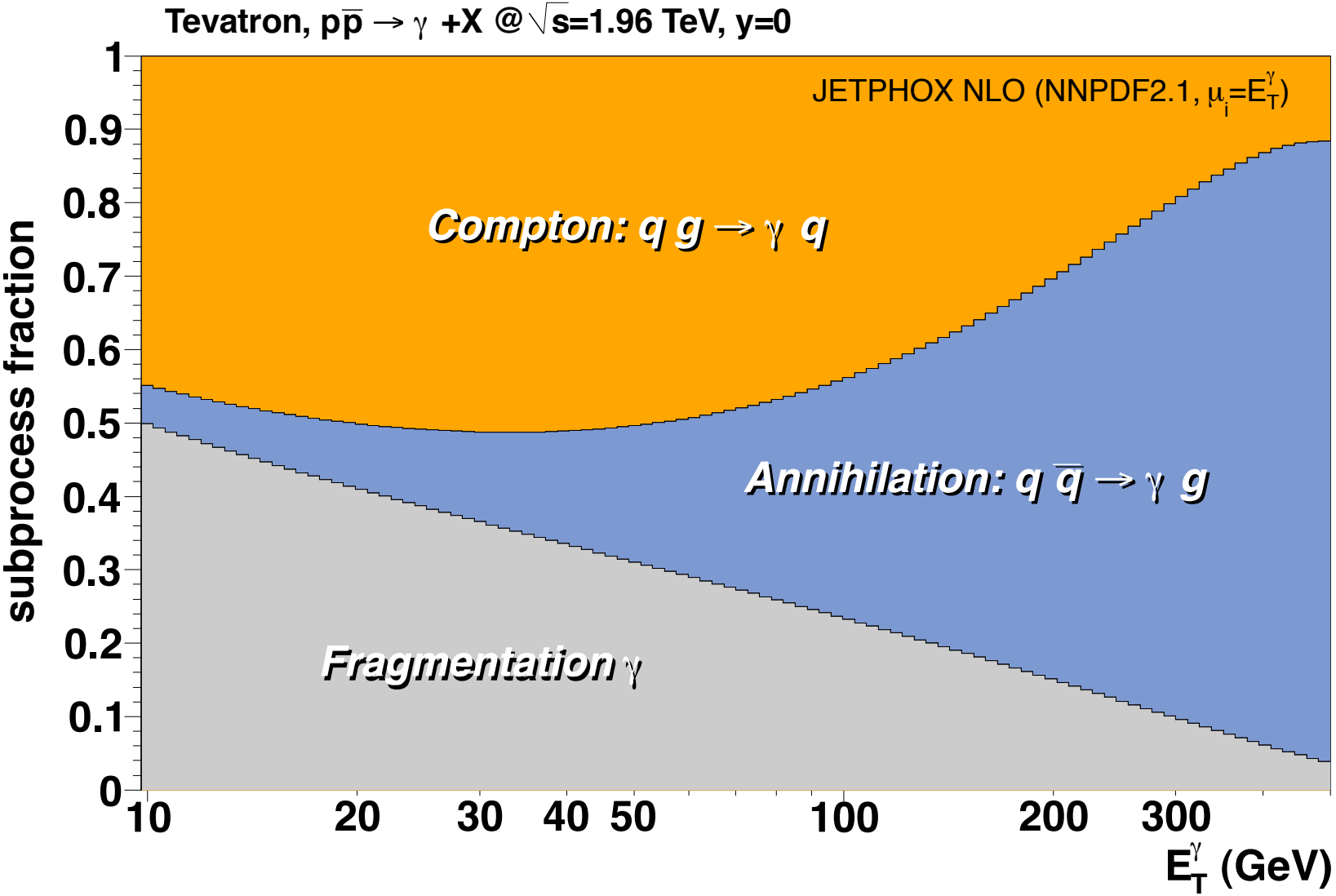


Quark-antiquark fusion:



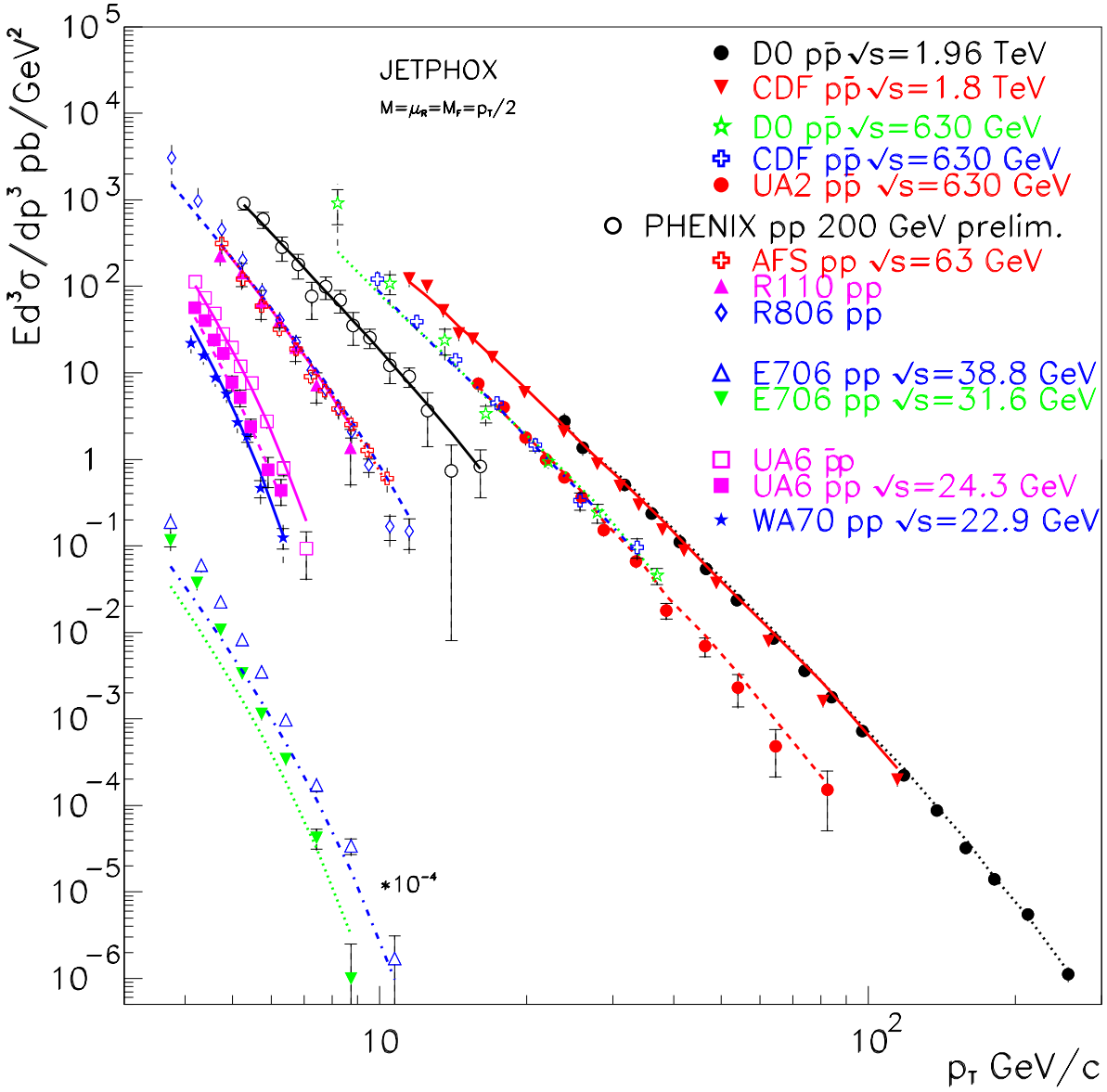
Transverse momentum dependence of contributions

D. d'Enterria, J. Rojo, Nucl. Phys. B 860 (2012) 311



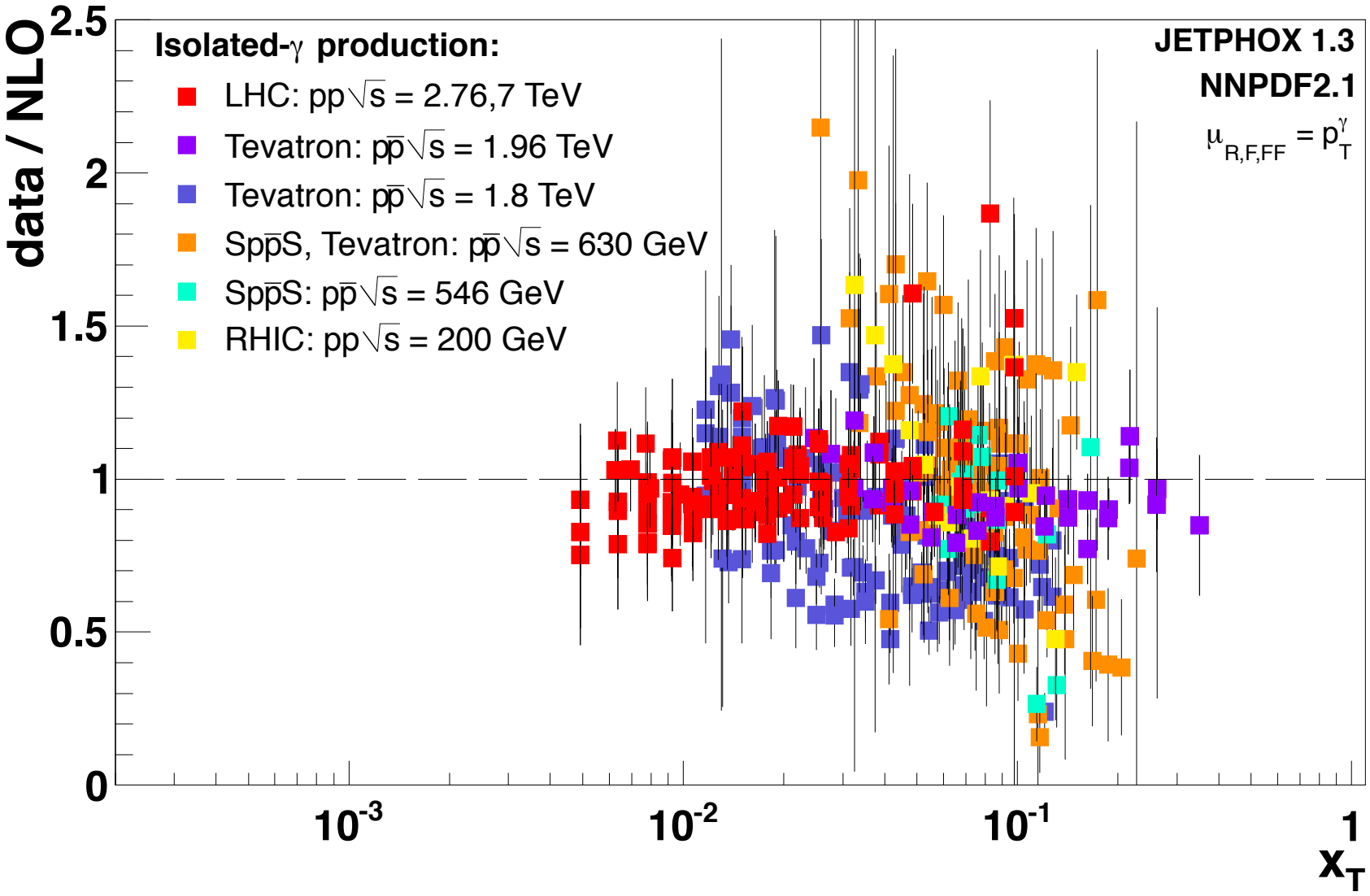
Pre-LHC prompt photon data

P. Aurenche, M. Fontannaz, J.P. Guillet, M. Werlen, Phys. Rev. D 73 (2006) 094007



Post-LHC prompt photon data

D. d'Enterria, J. Rojo, Nucl. Phys. B 860 (2012) 311



Comparison of theory with experiment

Observations:

- Large discrepancies at small p_T and $\sqrt{s}$
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Remedies:

- Resummation (k_T, threshold, joint) $\rightarrow$ small enhancement
- Large fragmentation contributions $\rightarrow$ apply isolation criteria
- PDFs with intrinsic k_T $\rightarrow$ little experimental information
- Virtual photons / weak bosons $\rightarrow$ mass as regulator

Theoretical setup (1)

M. Brandt, MK, Phys. Rev. D 88 (2013) 054002

Hadronic cross section:

$$\frac{d^2\sigma^{\gamma^*}_{h_1 h_2}}{dQ_T^2 dy} = \sum_{ij} \int dx_1 dx_2 f^i_{h_1}(x_1, \mu_f^2) f^j_{h_2}(x_2, \mu_f^2) \frac{s d^2\hat{\sigma}^{\gamma^*}_{ij}}{dt du}(Q, Q_T, y; \mu^2, \mu_f^2)$$

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Partonic cross section: [Arnold, Kauffman, Nucl. Phys. B 349 (1991) 381]

- Q_T-resummation at NLL
- $\sigma^{\mathrm{tot}} = \sigma^{\mathrm{res}} + \sigma^{\mathrm{per}} - \sigma^{\mathrm{asy}}$
- Scale uncertainty: $\mu, \mu_f = [0.5; 2] \times \sqrt{Q^2 + Q_T^2}$

Theoretical setup (2)

M. Brandt, MK, Phys. Rev. D 88 (2013) 054002

Parton densities:

- Protons: **CT10**, MSTW08, NNPDF2.1
- Nuclei: **EPS09**, HKN07, DSSZ, nCTEQ
- Uncert.: $\delta^{\pm} f = \sqrt{\sum_{i=1}^{N} [\max(\pm f_i^{(+)} \mp f_0, \pm f_i^{(-)} \mp f_0, 0)]^2}$

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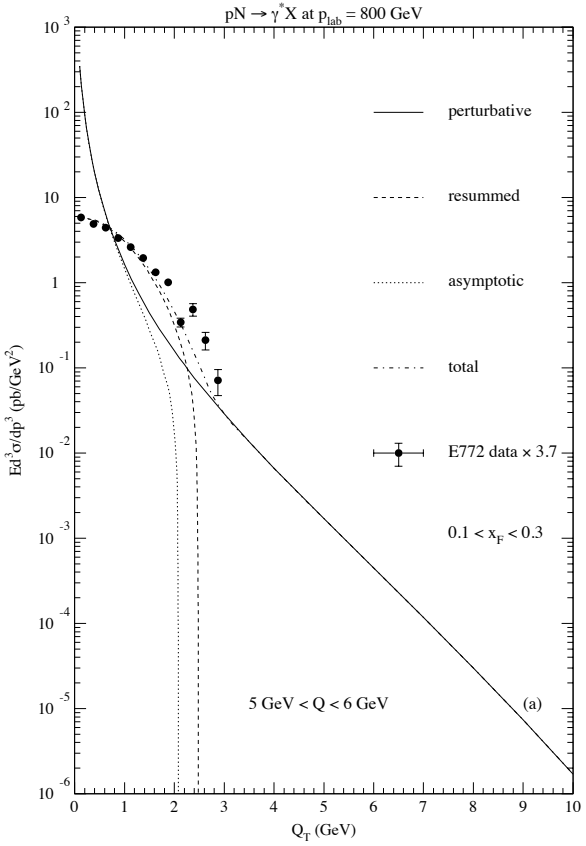
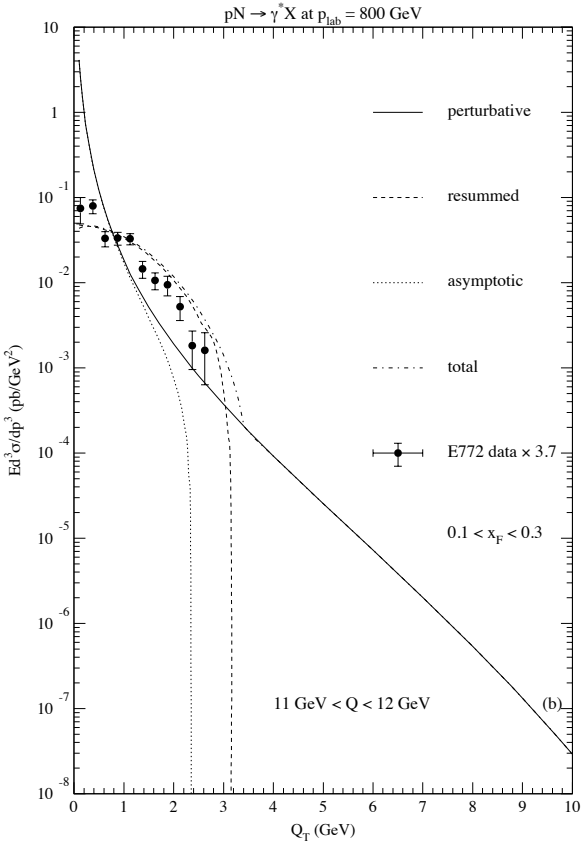
Non-perturbative form factor: [Brock et al., Phys. Rev. D 67 (2003) 073016]

- $\tilde{W}_{j\bar{k}}^{\mathrm{NP}} = \exp\left[-g_1 - g_2 \ln\left(\frac{Q}{2Q_0}\right) - g_1 g_3 \ln(100\, x_1 x_2)\right] b^2$

Fixed-target virtual photon data

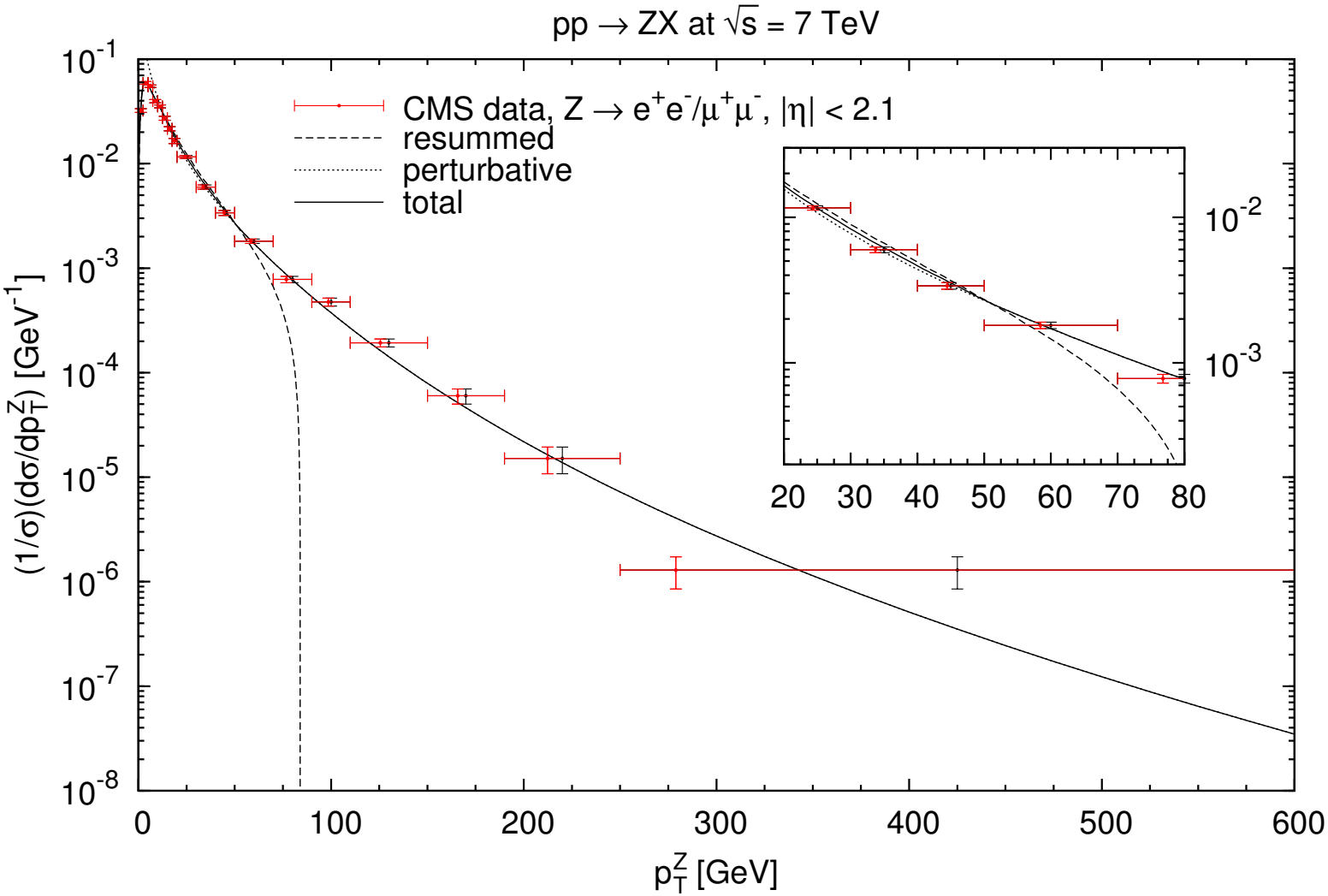
E.L. Berger, L.E. Gordon, MK, Phys. Rev. D 58 (1998) 074012





LHC weak boson data

M. Brandt, MK, Phys. Rev. D 88 (2013) 054002



Transverse momentum dependence of contributions

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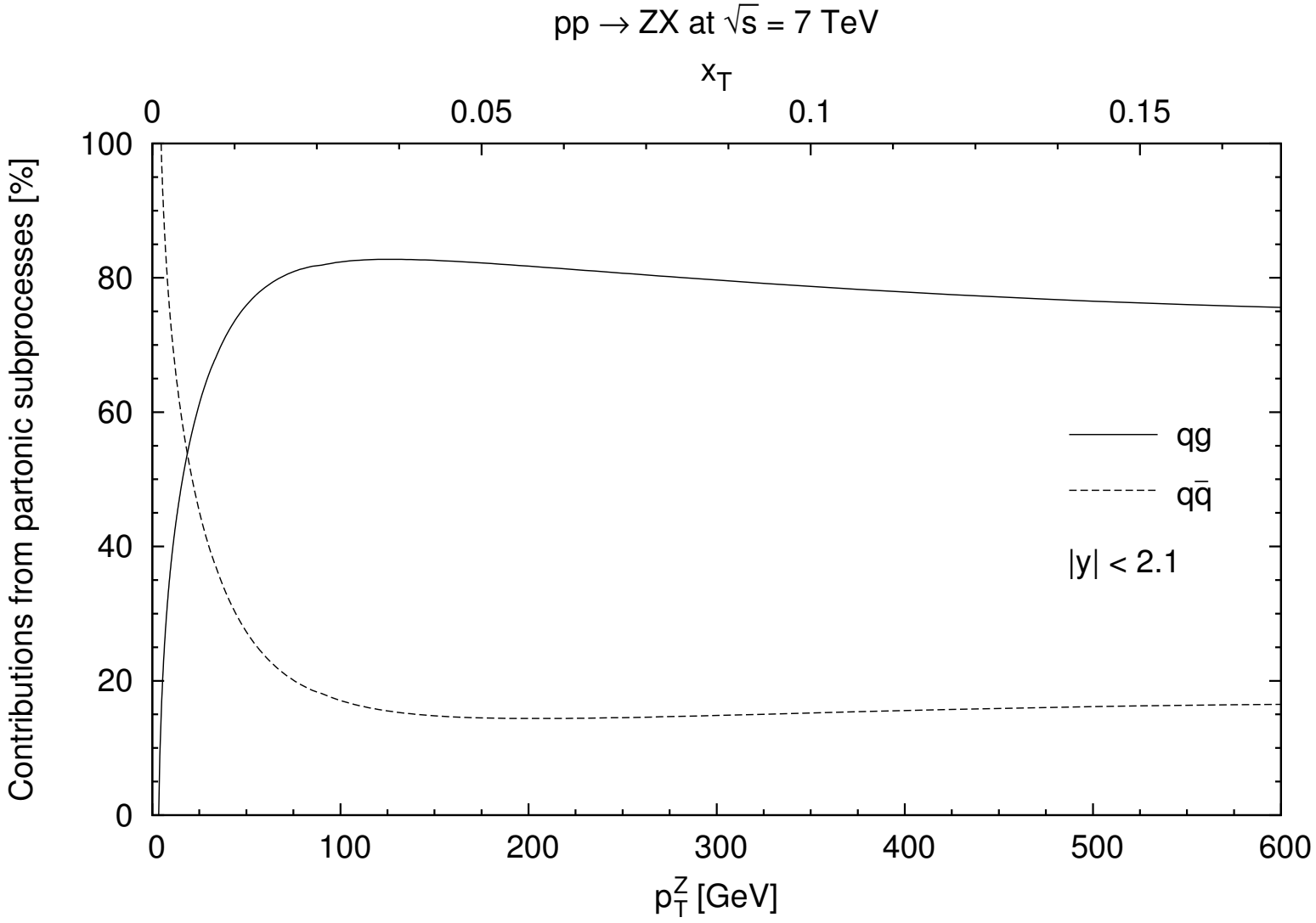
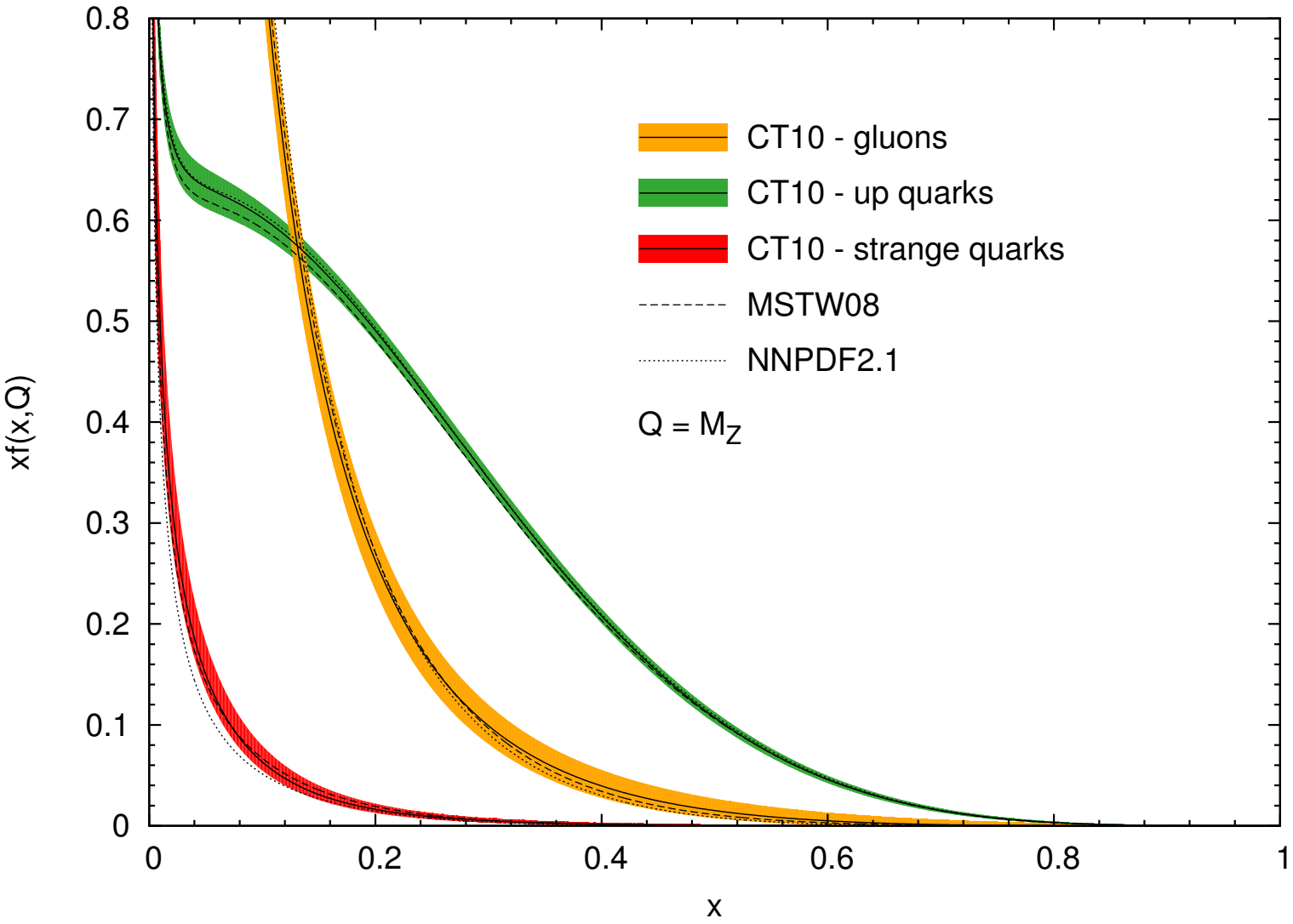


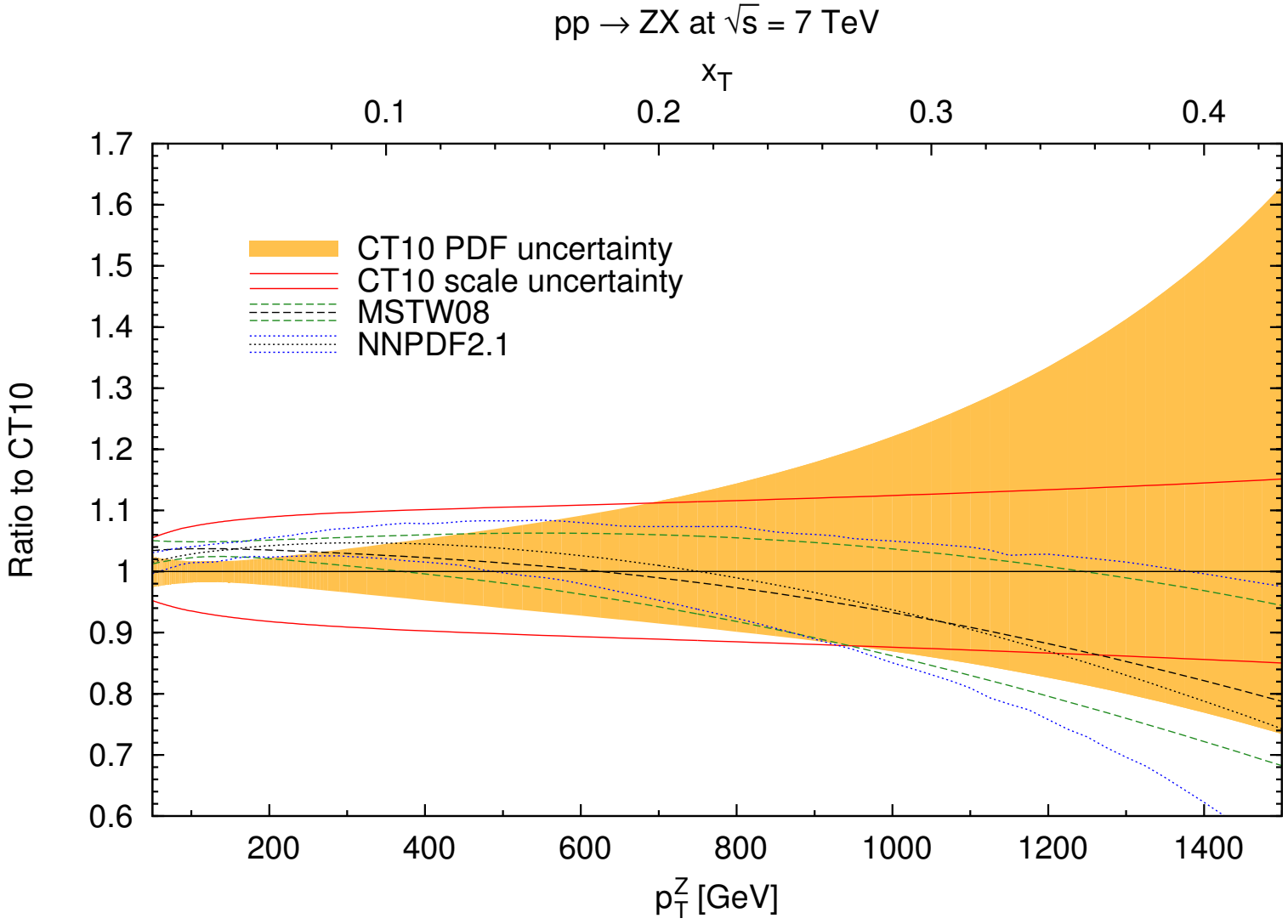
Current PDF uncertainties

M. Brandt, MK, Phys. Rev. D 88 (2013) 054002



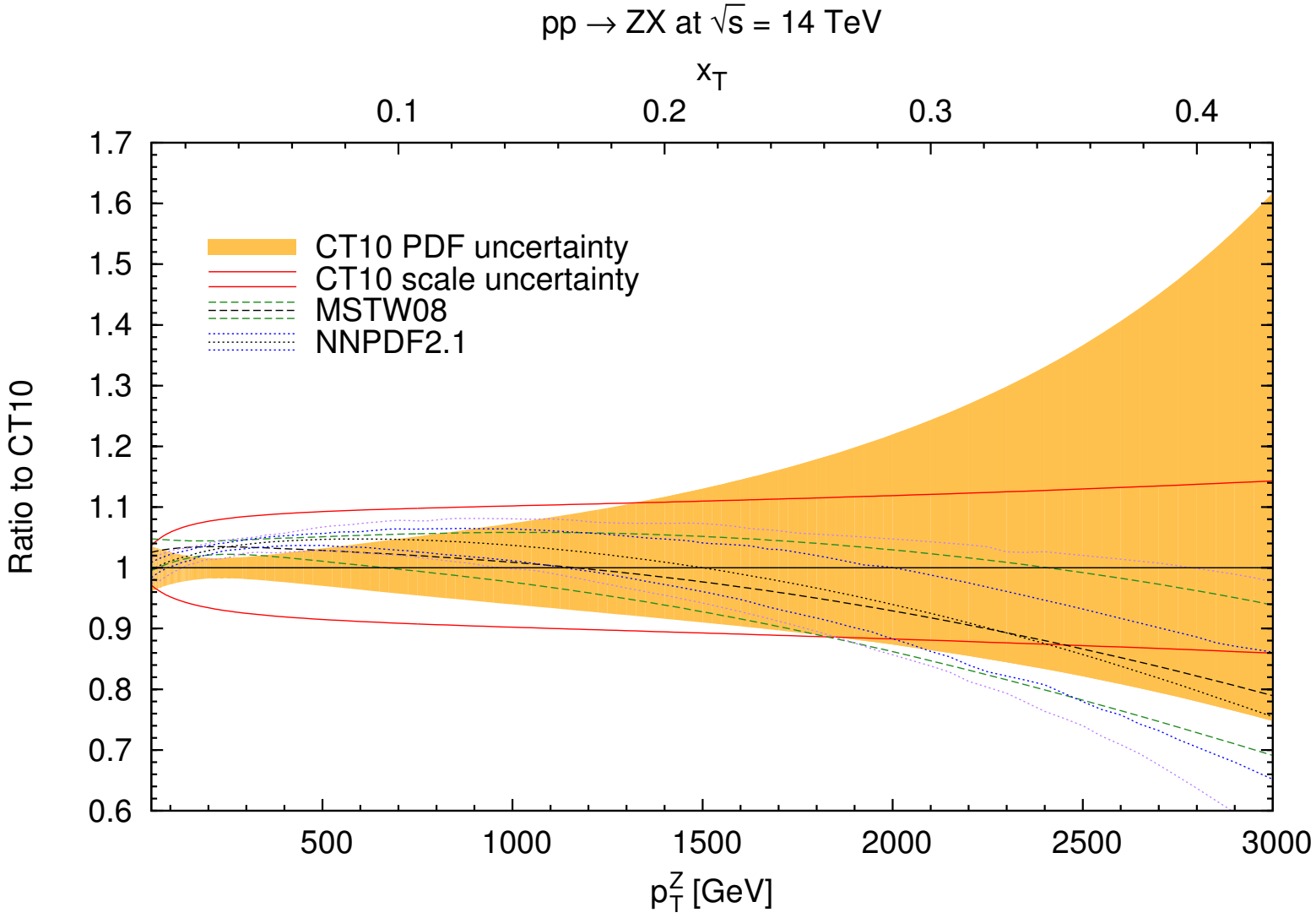
PDFs from LHC vector boson production (1)

M. Brandt, MK, Phys. Rev. D 88 (2013) 054002



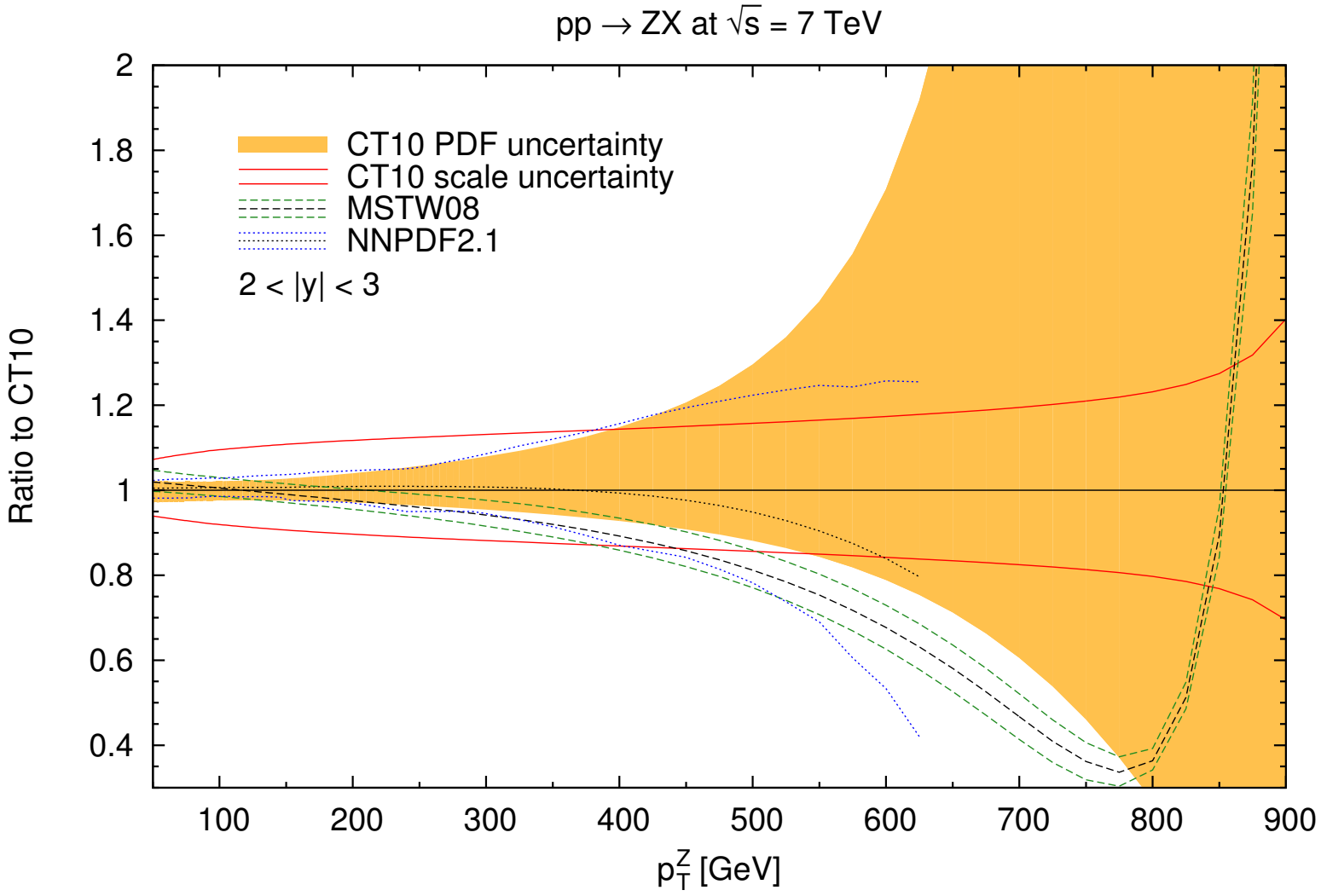
PDFs from LHC vector boson production (2)

M. Brandt, MK, Phys. Rev. D 88 (2013) 054002



PDFs from LHC vector boson production (3)

M. Brandt, MK, Phys. Rev. D 88 (2013) 054002



Nuclear collisions

M. Brandt, MK, F. König, in preparation

Thermal effects in AA collisions:

- Real photons: Excess at $p_T \leq 4$ GeV, $T = 304 \pm 58$ MeV

  [MK, C. Klein-Bösing, F. König, J.P. Wessels, 1307.7034]

- Weak bosons: $R_{AA} \sim 1$ [ATLAS PRL 110, 022301; CMS PAS HIN-13-004]
- Virtual photons: Interesting transition region!

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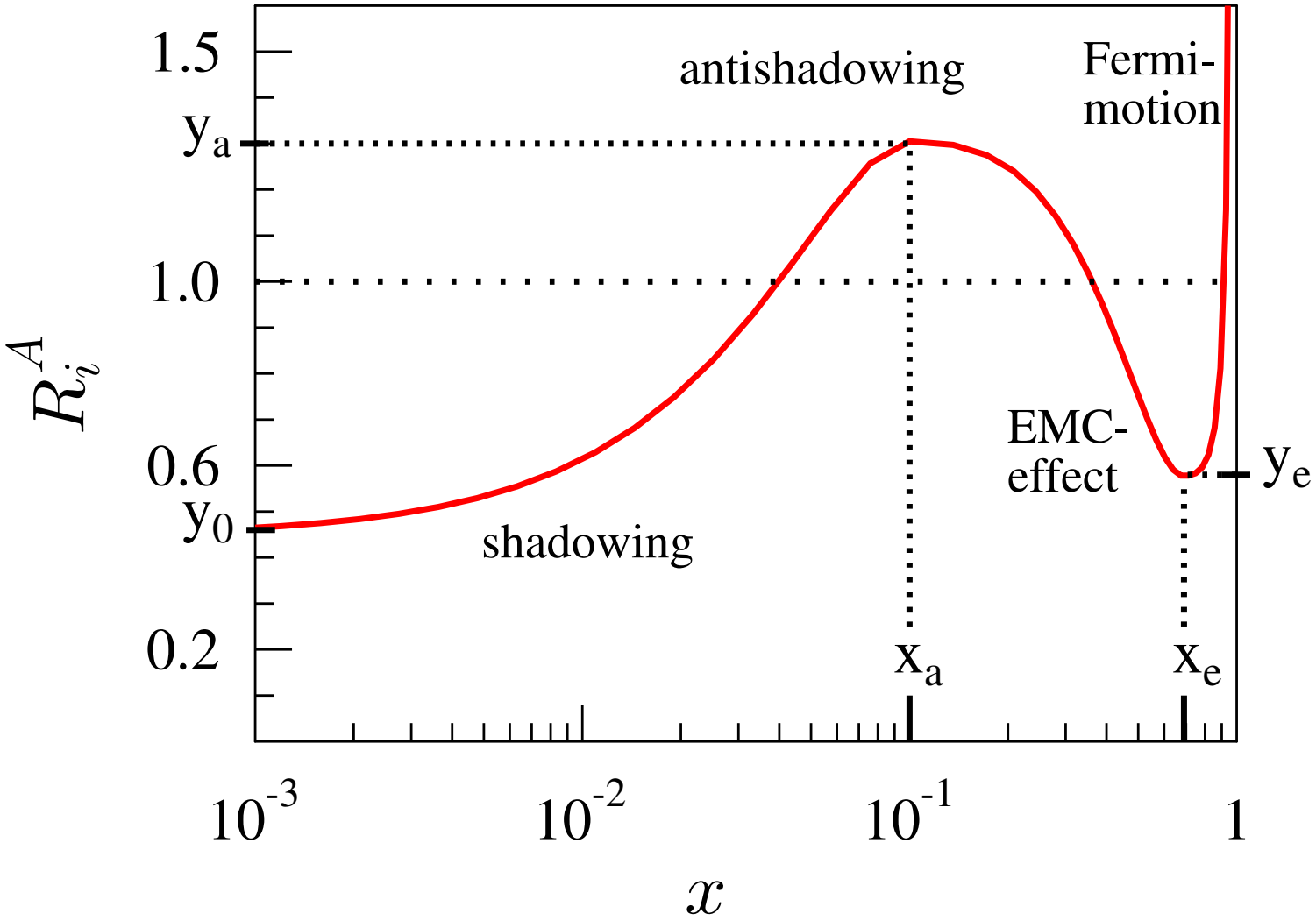
- Weak bosons: $R_{AA} \sim 1$ [ATLAS PRL 110, 022301; CMS PAS HIN-13-004]
- Virtual photons: Interesting transition region!

Nuclear PDFs from pA collisions:

- Real photons [F. Arleo, K.J. Eskola, H. Paukkunen, C.A. Salgado, JHEP 1104 (2011) 055]
- Photons + heavy quarks [F. Arleo, I. Schienbein, T. Stavreva, JHEP 1302 (2013) 072]
- Virtual photons [M. Brandt, MK, in preparation]
- Weak bosons (isospin effects!) [M. Brandt, MK, in preparation]

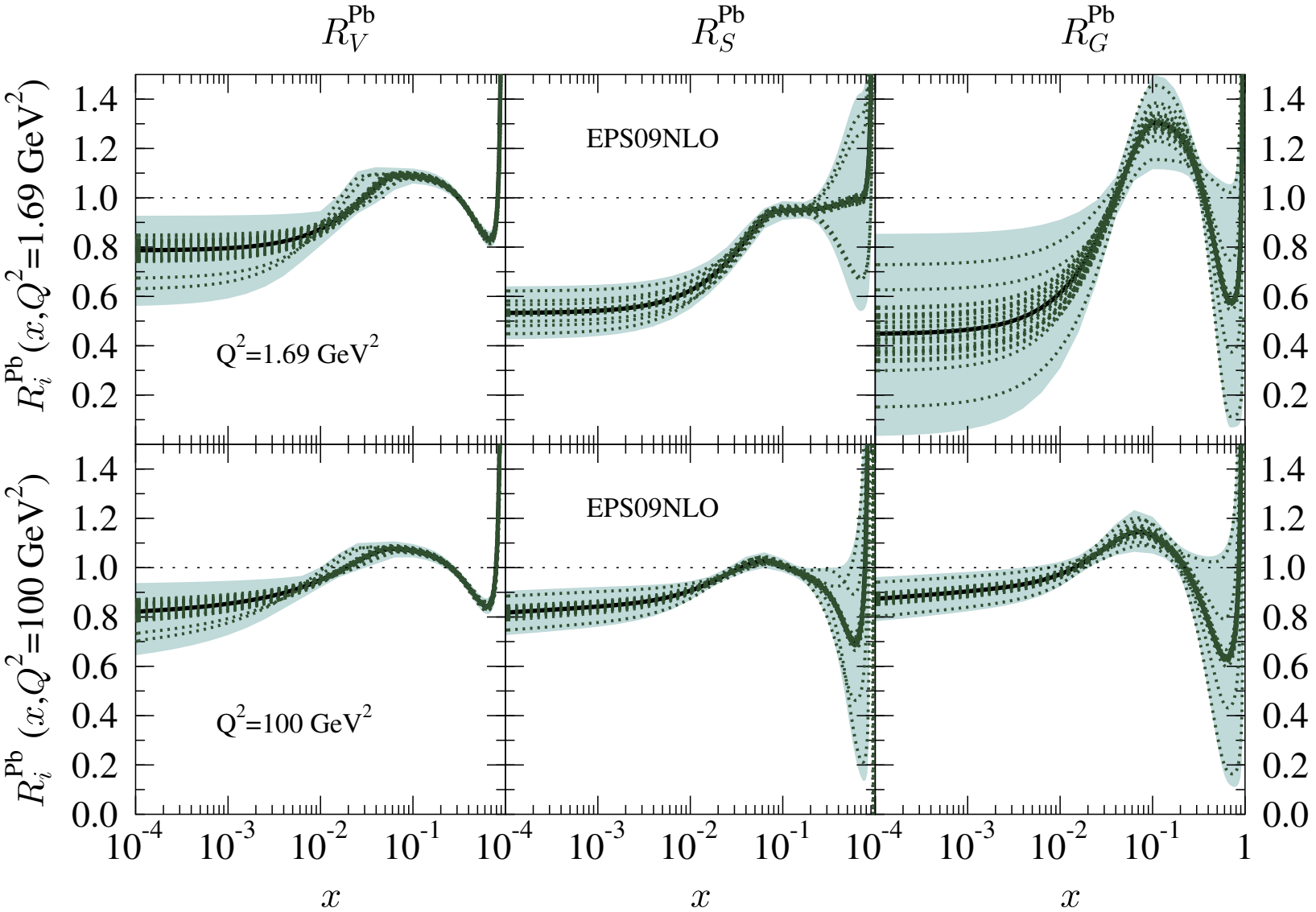
Nuclear modification of PDFs (1)

K.J. Eskola, H. Paukkunen, C.A. Salgado, JHEP 0904 (2009) 065



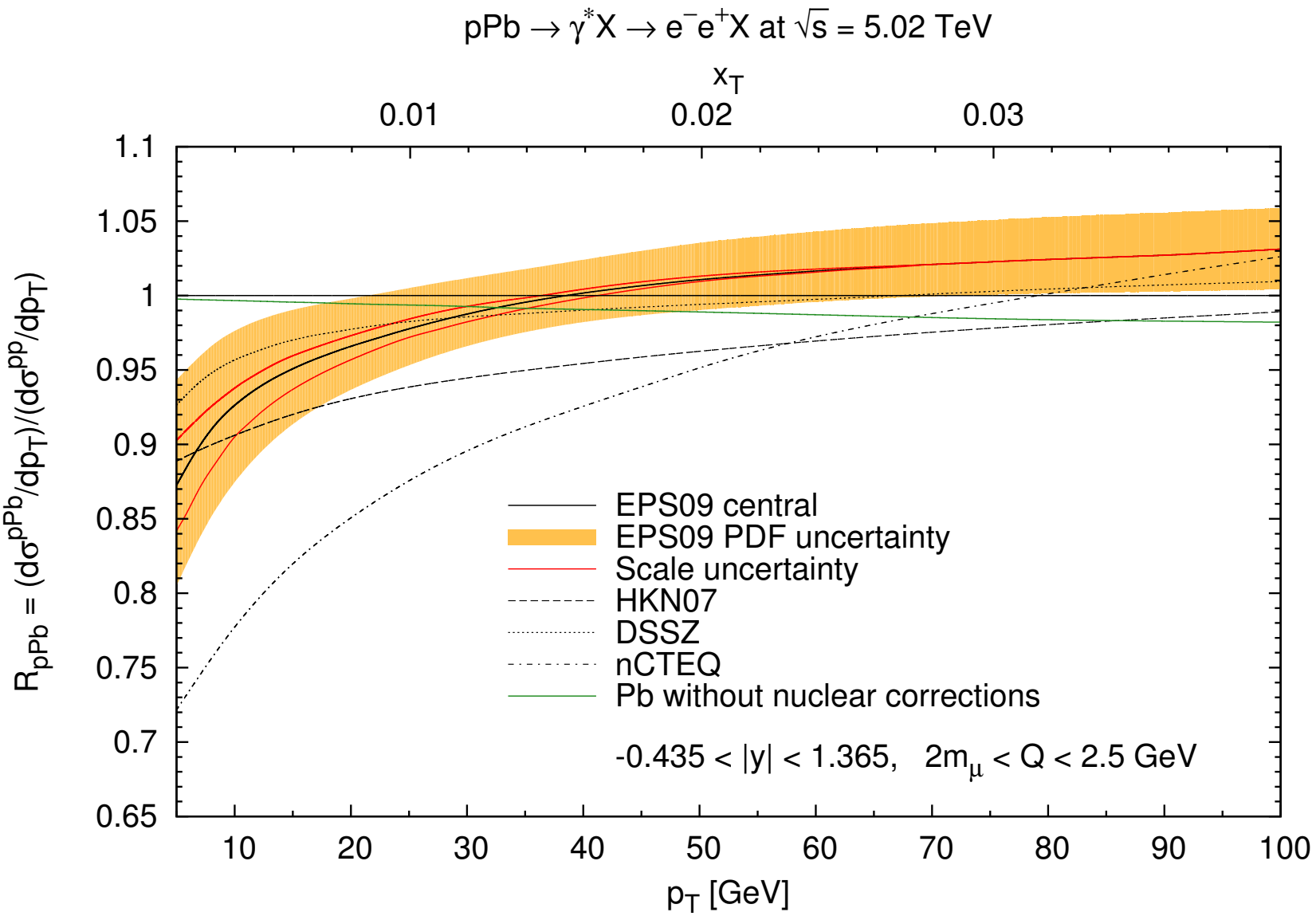
Nuclear modification of PDFs (2)

K.J. Eskola, H. Paukkunen, C.A. Salgado, JHEP 0904 (2009) 065



nPDFs from low-mass lepton pair production (1)

M. Brandt, MK, in preparation



nPDFs from low-mass lepton pair production (2)

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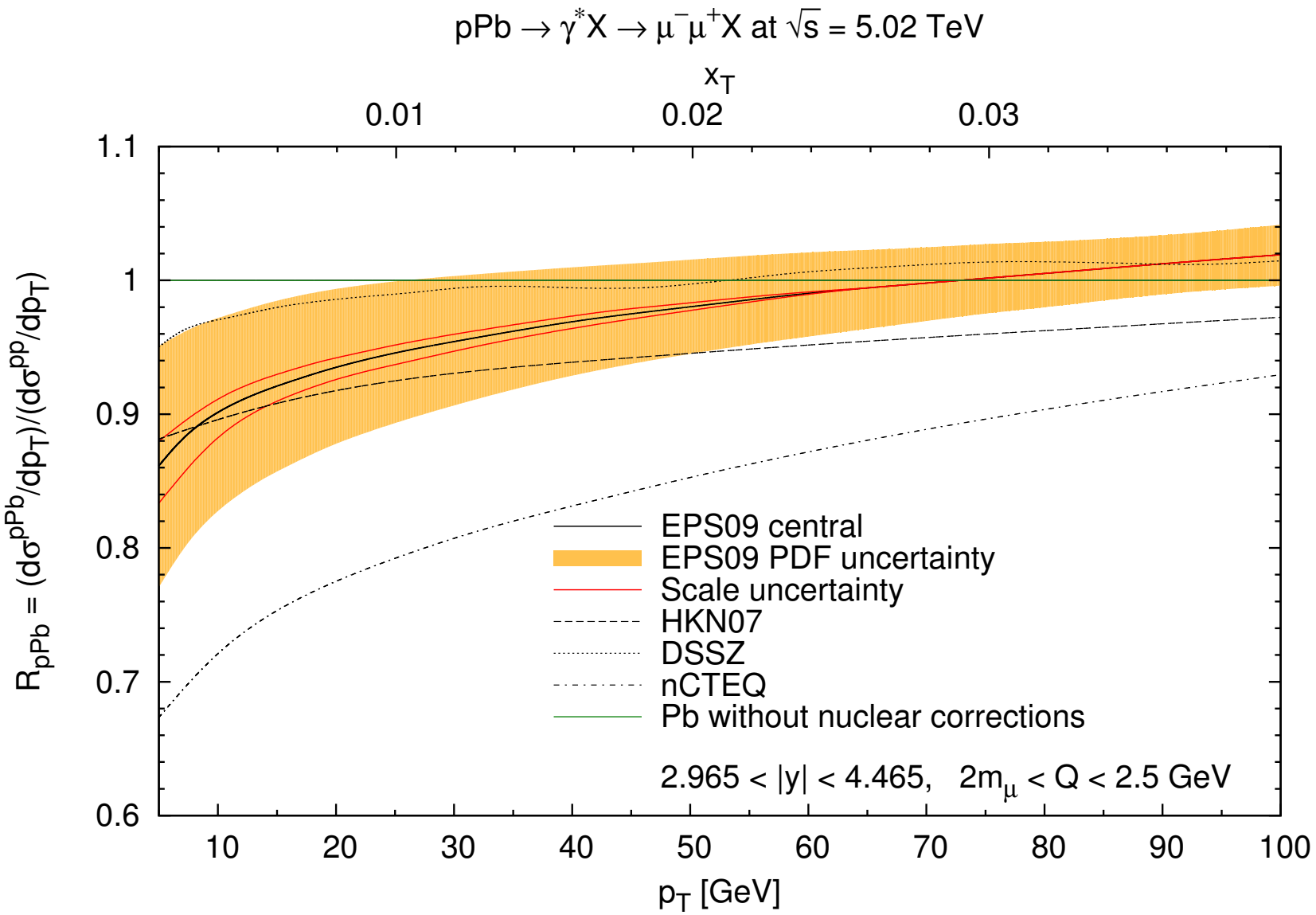

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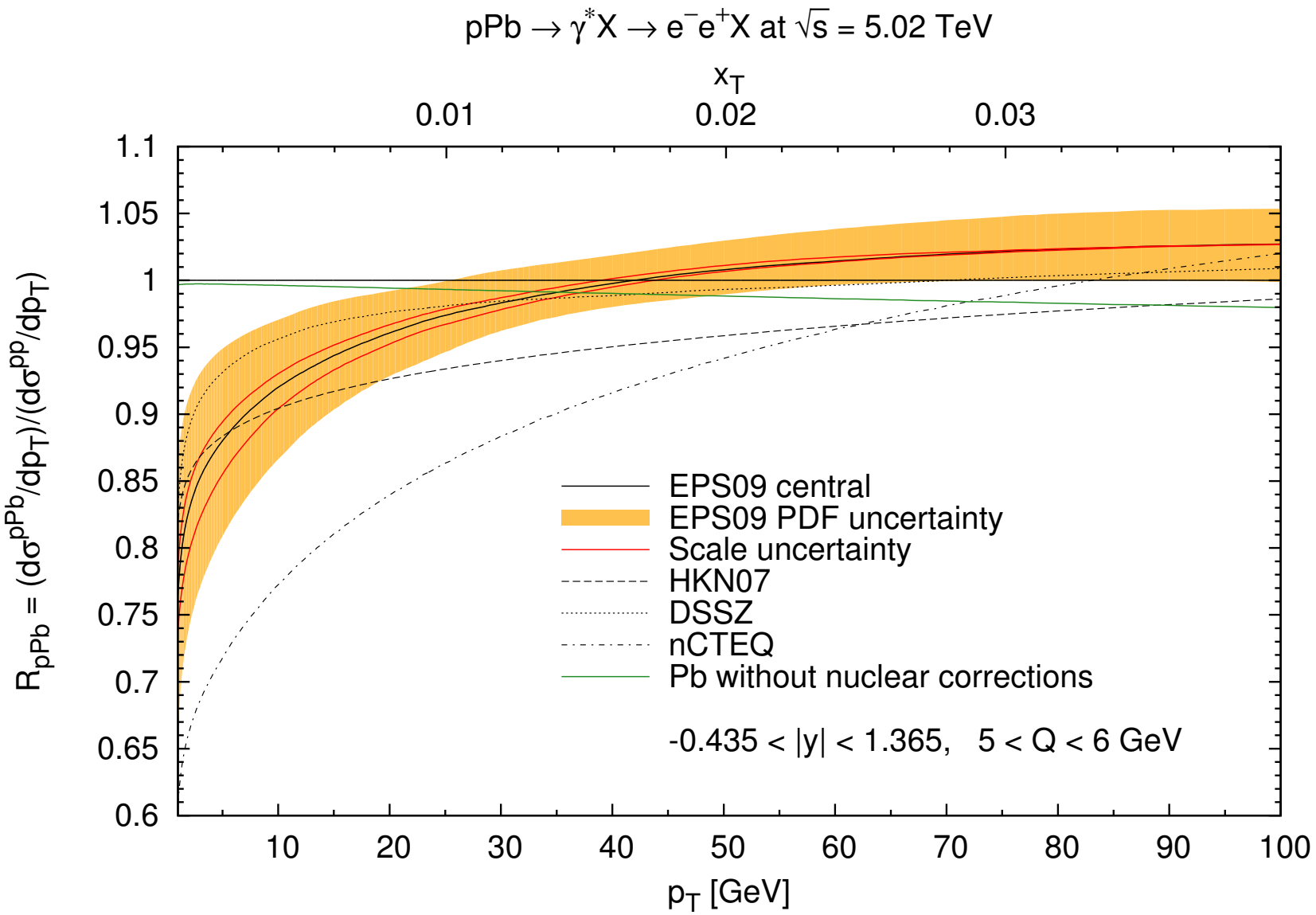
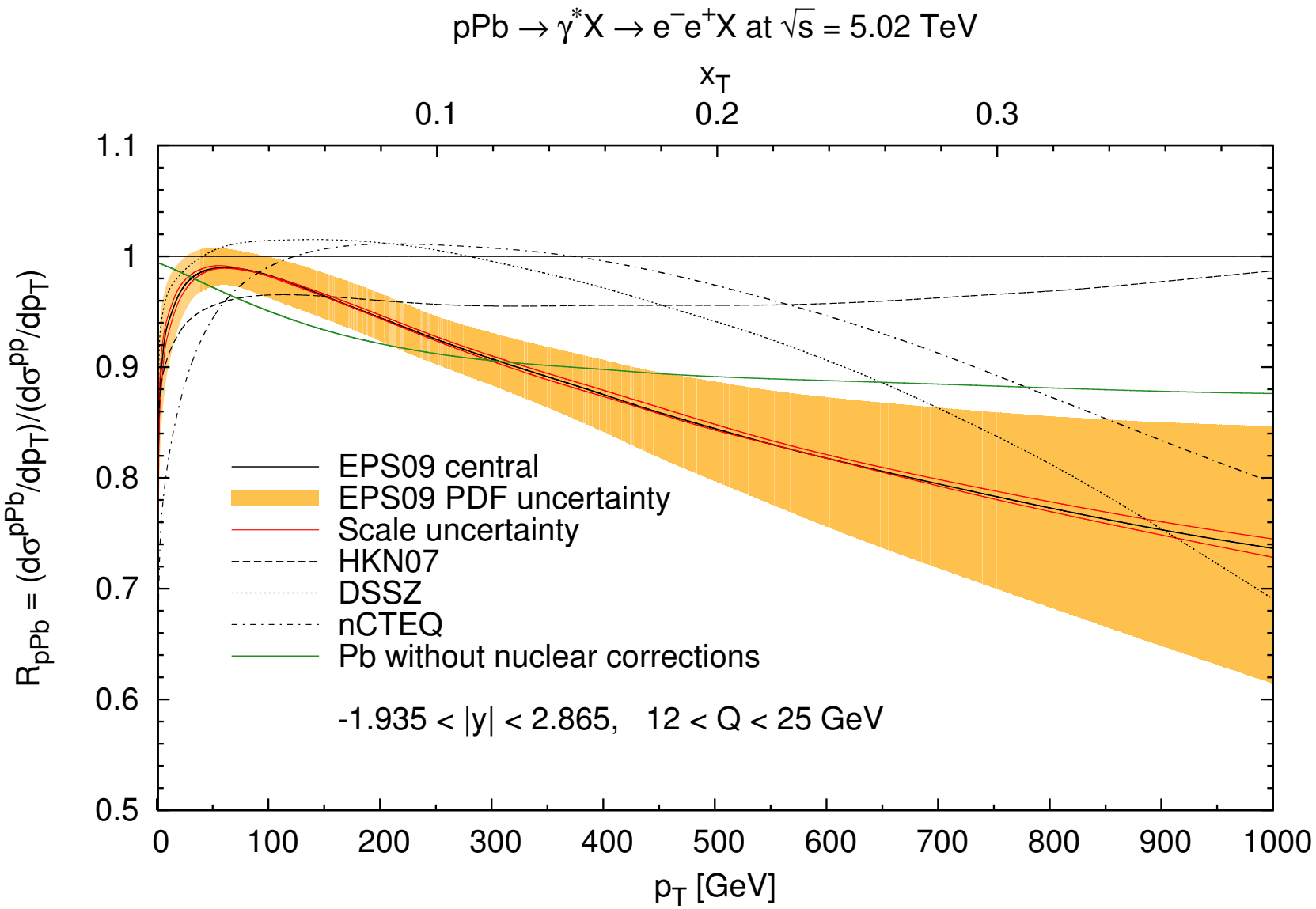


nPDFs from low-mass lepton pair production (4)

M. Brandt, MK, in preparation



Conclusion

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Alternative: Massive bosons

- Low-mass lepton pairs: $Q \ll p_T$ (but avoid resonances)
- Electroweak bosons: At LHC, even $M_W, M_Z \ll p_T$
- Large potential in pp for gluon density
- Large potential in pPb for shadowing-antishadowing-EMC
- In both cases: Forward region!