Access Theoretical Uncertainty with correlations in a global analysis

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Discussion on theoretical uncertainty for the PDF4LHC meeting

SMU

Motivation

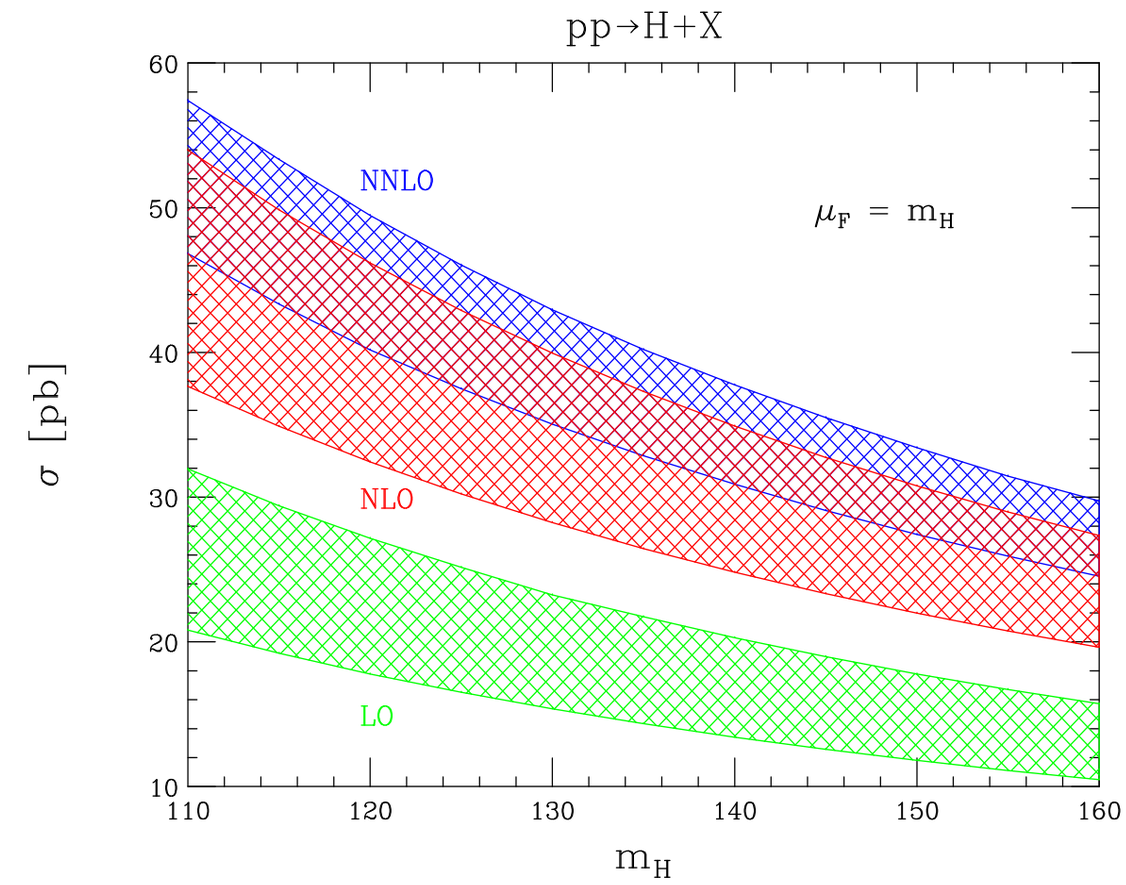
- Theoretical uncertainty could be due to truncation in fixed order or resumed perturbative calculations, uncertainties of input parameters, PDF uncertainties, calculation schemes, etc.

  - The missing higher order terms could be large for hadronic processes like jets, Higgs, and top production, and can also feedback to PDF determinations.

  - Traditional way to estimate, scale variations, e.g., vary the scales by a factor of 2, widely used by both theorists and experimentalists

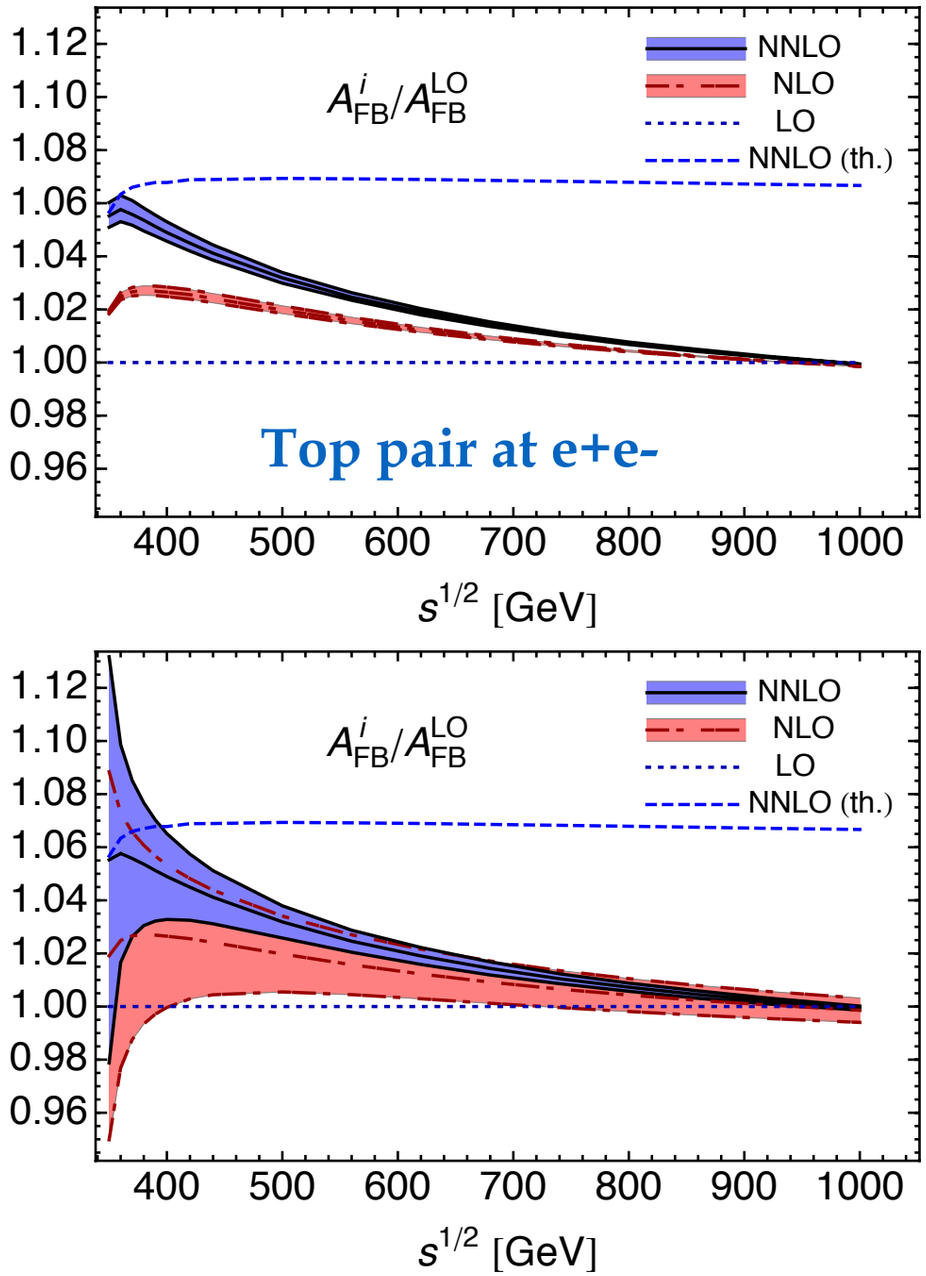
  - Others, identifying the most important higher order terms; Bayesian analysis based on known order results, see Guffanti's talk

Gluon fusion cross sections at LHC 14 TeV with variation of renormalization scale around mH



C. Anastasiou, K. Melnikov, F. Petriello, hep-ph/0509014

- For a high precision analysis correlations of theoretical uncertainties among different exp. bins of one process or even several processes are needed.



- Usually the scale variations are considering as fully correlated (~1 nuisance parameter) or fully uncorrelated (~statistical error) among different exp. bins in the analysis

- Left: top quark forward-backward asymmetry with scale variations at e +e- collision; upper, assuming fully correlated in F. and B. bins; lower, assuming fully uncorrelated

- Certain amount of correlation should be assumed in the analysis

J. Gao, H. Zhu, 1408.5150

In Global analysis of PDFs

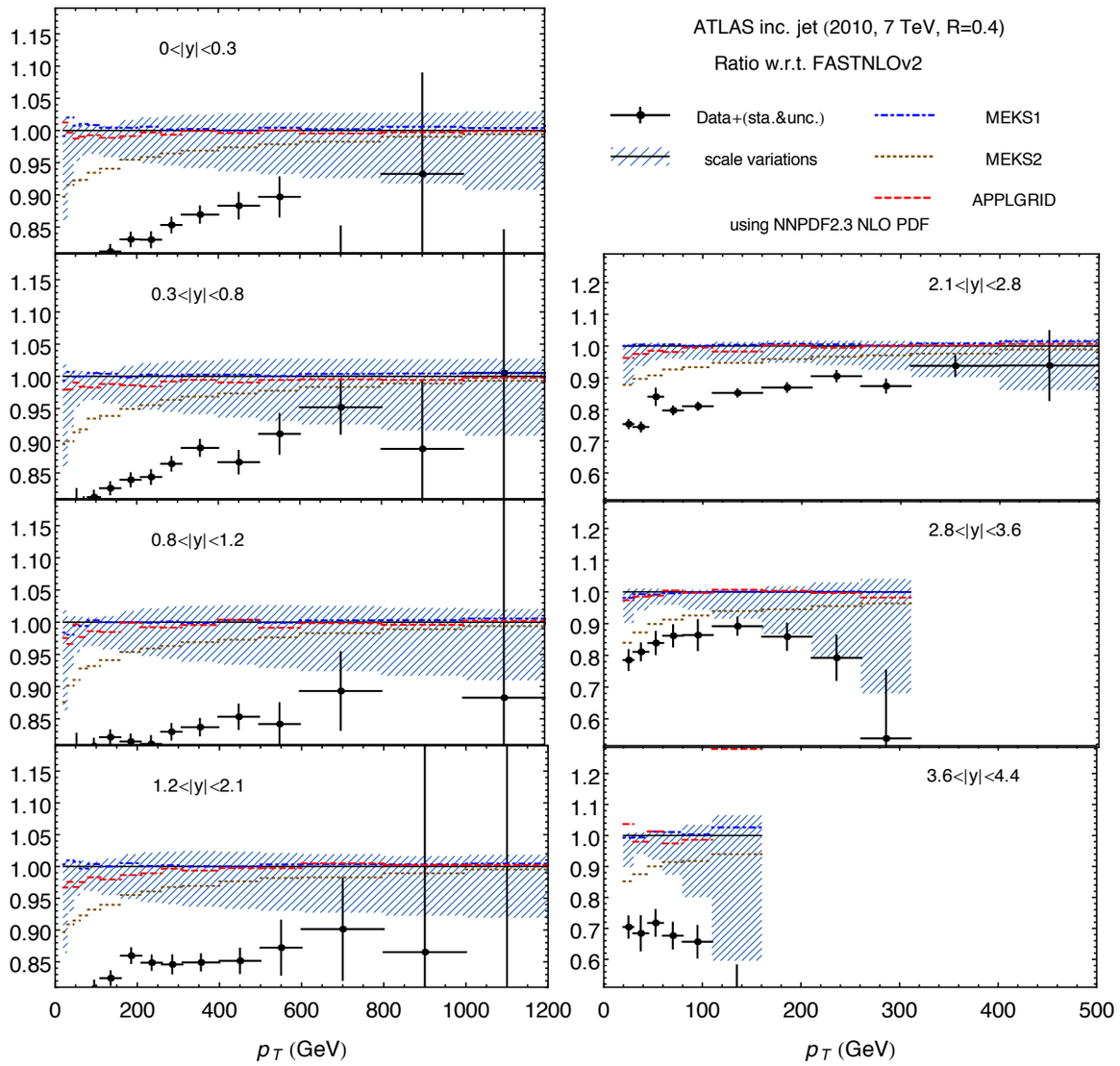
- Various missing higher order terms can contribute to the theoretical uncertainties in a global analysis of PDFs, including heavy quark scheme dependence, DGLAP evolutions, and fixed order calculations of various exp. observables included.

  - Let's single out jets production at hadron colliders for a case study

  - Large scale variations at NLO, also exist several possible choices for the central scale, e.g., individual jet pt, leading jet pt

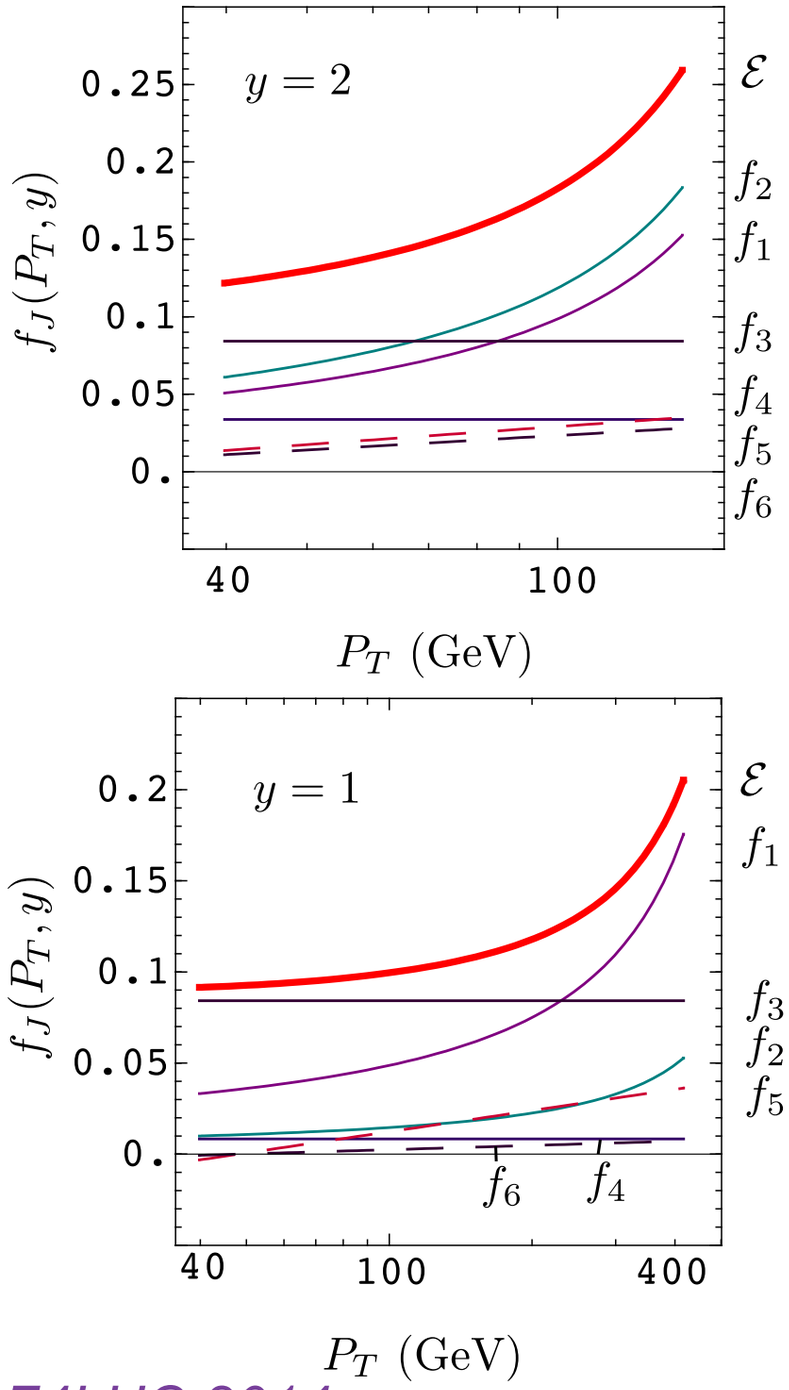
  - Note improvements from partial NNLO calculations for all-gluon channel, and threshold resumation valid for large pt region

Inc. jet at NLO at 7 TeV with scale variations



R. Ball, et al., 1211.5142, J. Gao, et al., 1207.0513

- Ways to incorporate reasonable amount of correlations in theoretical uncertainties of NLO jet production



F. Olness, D. Soper, 0907.5052, based on selected kinematic shapes

$$\frac{d\sigma}{dP_T dy} = \left[\frac{d\sigma}{dP_T dy}\right]_{\rm NLO} \left\{1 + \sum_J \lambda_J f_J(P_T, y)\right\}$$

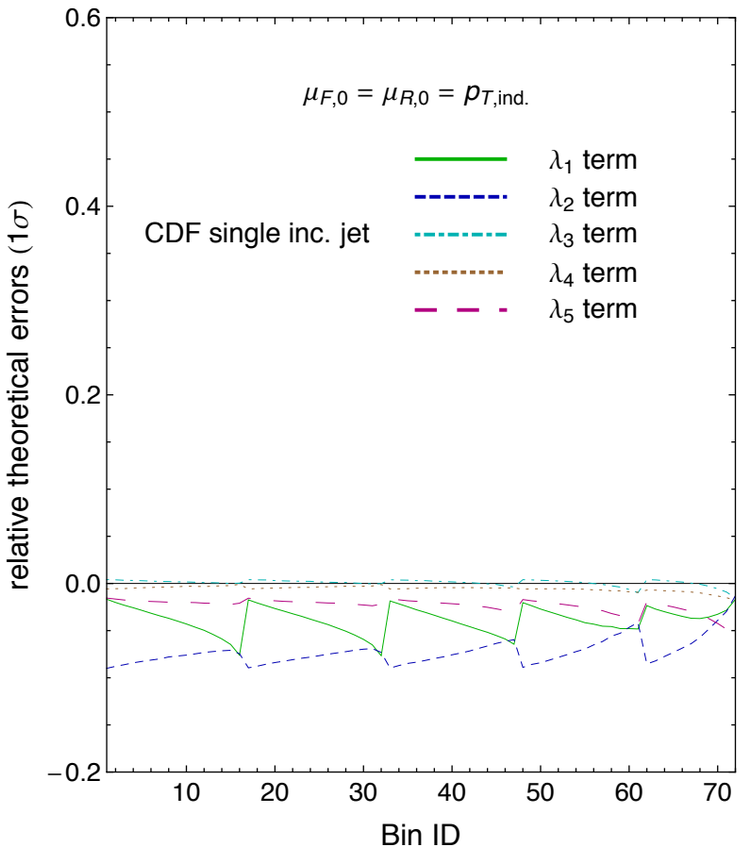
- Introducing 6 shape functions, each corresponds to one nuisance parameter
- Fit the total uncertainties to the traditional scale variations to determine each normalization

- Ways to incorporate reasonable amount of correlations in theoretical uncertainties of NLO jet production

J. Gao, P. Nadolsky, purely based on scale variations

$$\sigma_{bin}^{NLO}(\mu_F,\,\mu_R,\,i) = \sigma_{bin}^{NLO}(\mu_{F,0},\,\mu_{R,0},\,i)\Big\{1+\alpha_s^2(\mu_{R,0})\sum_{j=1}^{5}e_j(i)x_j+\mathcal{O}(\alpha_s^3(\mu_{R,0}))\Big\}$$

$$x_1=\ln(\frac{\mu_F}{\mu_{F,0}}),\ x_2=\ln(\frac{\mu_R}{\mu_{R,0}}),\ x_3=\ln^2(\frac{\mu_F}{\mu_{F,0}}),\ x_4=\ln^2(\frac{\mu_R}{\mu_{R,0}}),\ x_5=\ln(\frac{\mu_F}{\mu_{F,0}})\ln(\frac{\mu_R}{\mu_{R,0}})$$



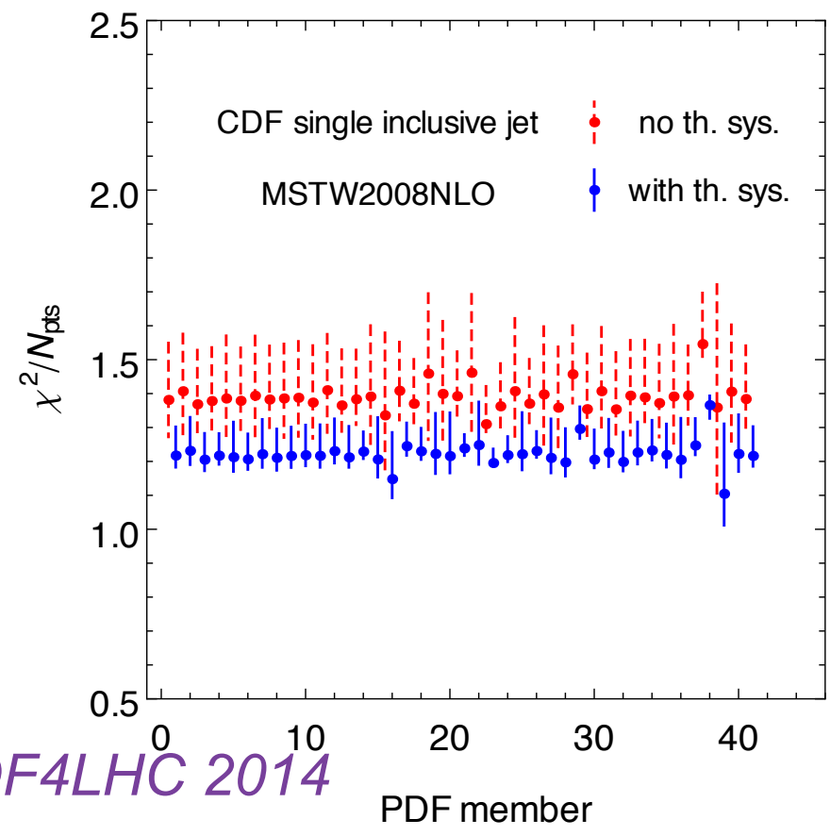
- Introducing 5 shape functions, purely based on the scale variations, be specific, coefficients of different scale logarithms (for a fixed central scale choice)
- Normalization of each term can be chosen by set a scale variation of 2

- Effects of the new correlated theoretical uncertainties on chi2 of the jet data using a fixed PDF sample

$\chi^2/N_{pts.}$	CT10NLO		MSTW08NLO		HERA1.5NLO	
theoretical errors	no	with	no	with	no	with
CDF inc.	1.78	1.56	1.38	1.22	3.08	2.57
D0 inc.	1.23	1.16	1.09	0.99	1.73	1.34
D0 dijet	4.06	1.52	2.29	1.50	2.09	1.64
ATL inc. (0.4)	0.97	0.77	0.94	0.70	0.93	0.73
ATL inc. (0.6)	0.98	0.86	0.83	0.64	0.87	0.80

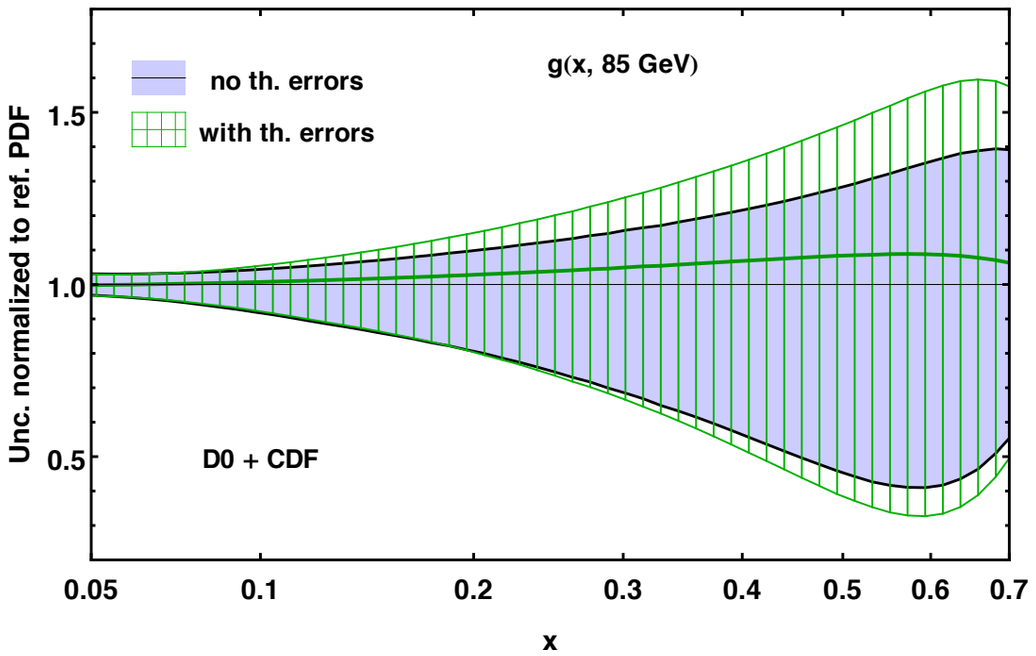
TABLE IV: χ^2/N_{pts} of jet data with and without including the theoretical errors

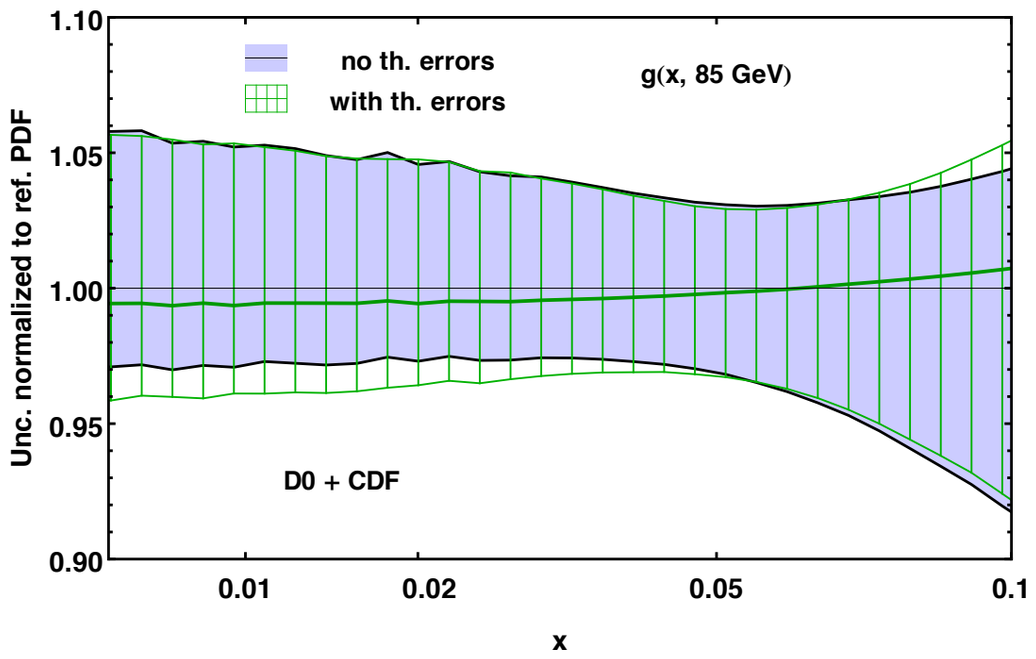
- Reduction of chi2 as one would expect



- Also reduced sensitivity to the choice of central scales; each error bar represent the variation of the chi2 when changing the central scales by a factor of 2

- Include the new correlated theoretical uncertainties of jet cross sections in a CT10-like NLO global analysis

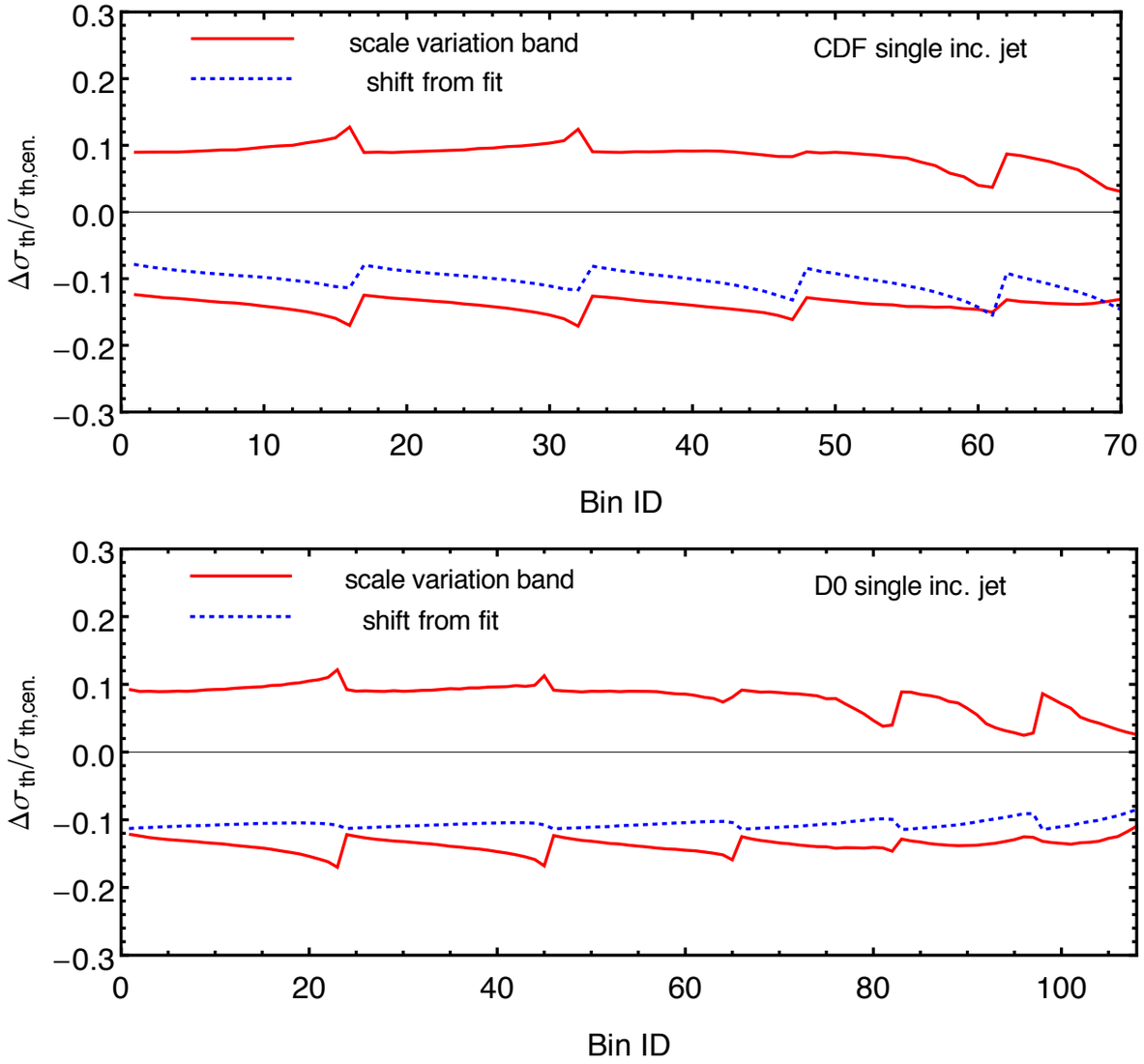




- About 20% increase of the gluon PDF uncertainty in large-x region and 10% in the Higgs mass region, for a fit with only Tevatron jet data included (+DIS+…)

- Similar results are observed when also including the LHC jet data or using different criteria for the determination of PDF uncertainties

- Include the new correlated theoretical uncertainties of jet cross sections in a CT10-like NLO global analysis



- Details of the fits, systematic shifts induced by the theoretical uncertainties compared with the traditional scale uncertainty band (note here negative shift means theory are pull up)

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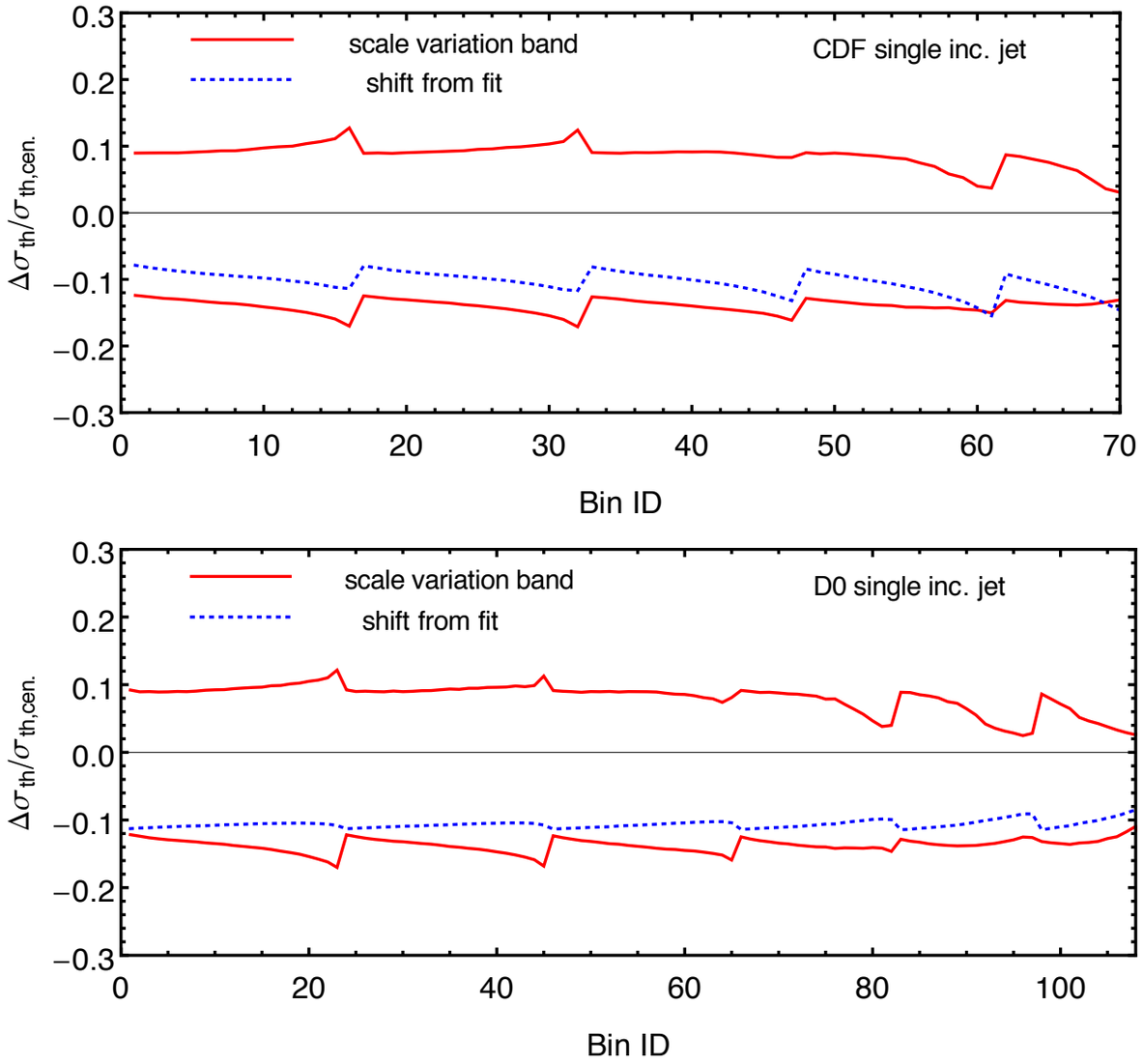

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Summary: theoretical uncertainties for certain processes with large missing higher order terms could be included in the global analysis with a nature assumption on the correlations base on the scale variations.