Parton Distributions with Threshold Resummation

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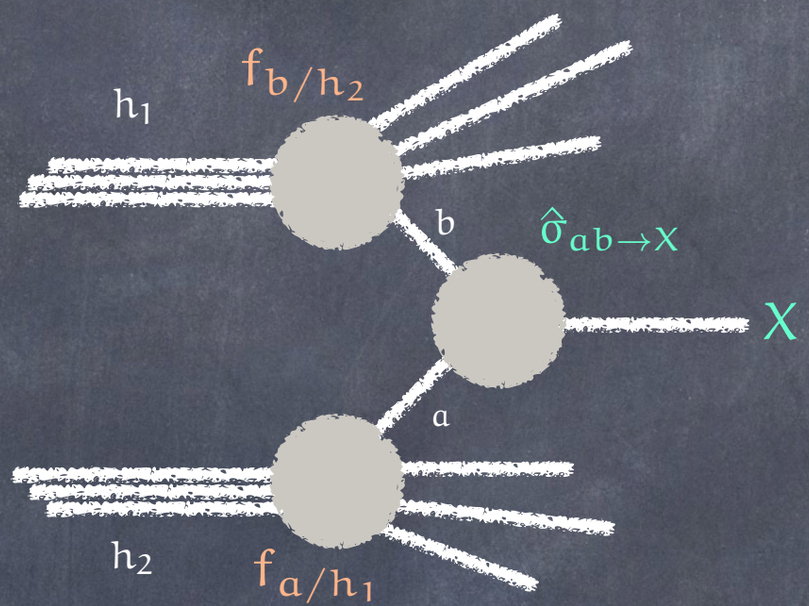
Based on

M. Bonvini, S. Marzani, J. Rojo, LR, M. Ubiali et al,

JHEP 1509 (2015) 191

Parton Distribution Functions

Collinear Factorization



$$\sigma = x\sigma_0 \sum_{a,b} \int \frac{dx_1}{x_1} \frac{dx_2}{x_2} f_{a/h_1}(x_1, Q^2) f_{b/h_2}(x_2, Q^2)\, C_{ab}(z)$$

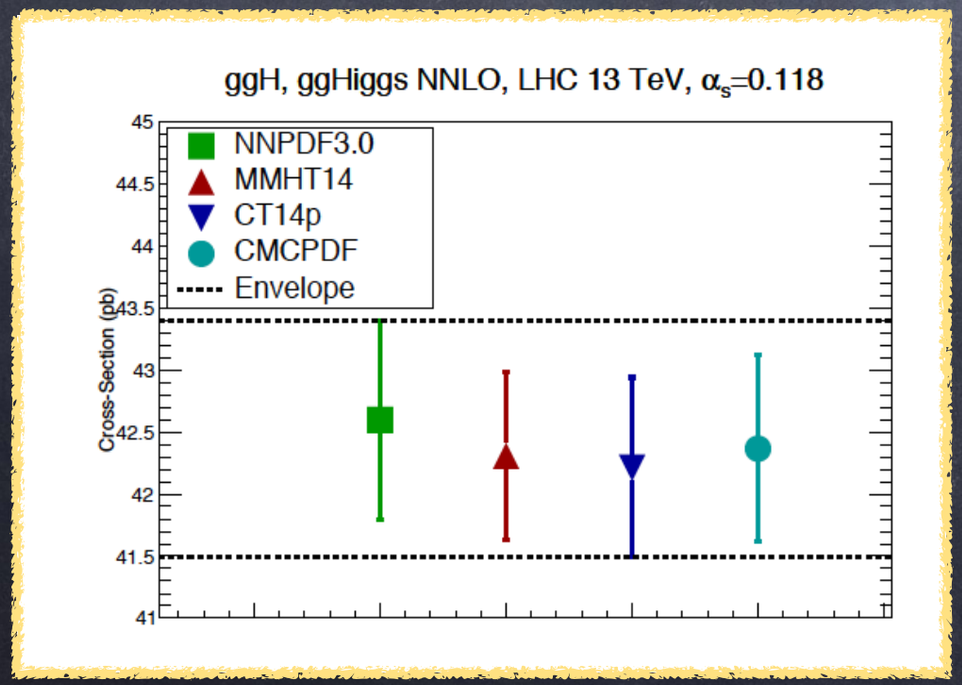
extracted from experiment

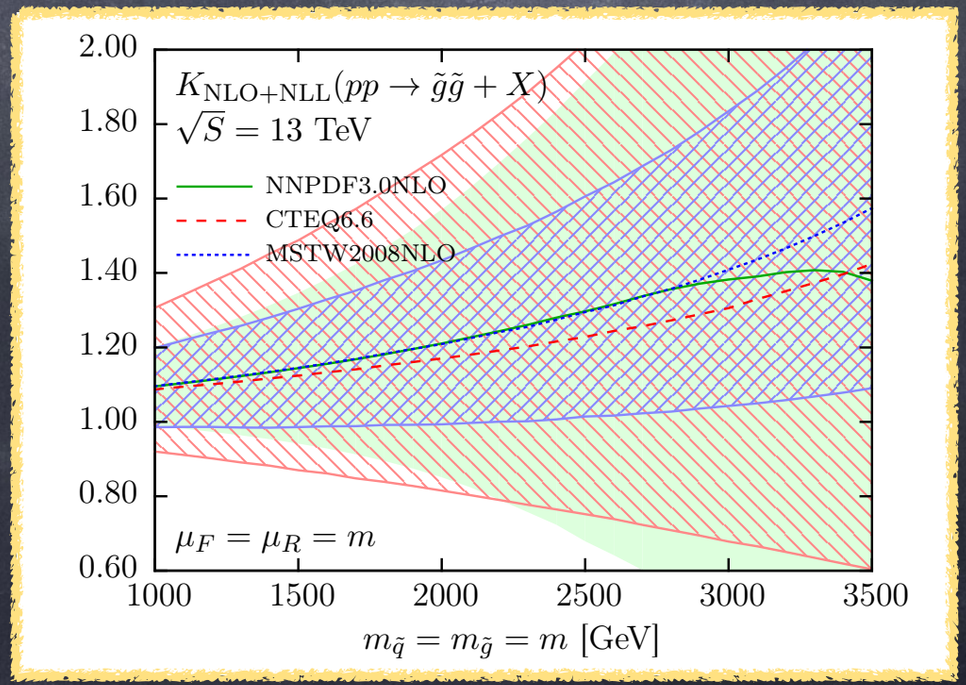
pQCD

- Parton distribution functions (PDFs) contain the information about the substructure of nucleons in terms of quarks and gluons (partons)
- PDFs cannot be computed from first principles, but are extracted from experiments
- Scale dependence is perturbative (DGLAP evolution)

Parton Distribution Functions

- PDFs fits extract information on the proton structure by comparison of experimental data and pQCD predictions
- Global fits include data from several processes: Deep Inelastic Scattering (DIS) experiments, Drell-Yan production, jets data, top data
- PDFs are a necessary tool for precision physics at LHC
- Open questions in proton structure: anti-symmetric sea quarks distributions, intrinsic charm…
- Knowledge of PDFs at large-x essential for New Physics $x \sim \frac{M^2}{s}$





PDFs with Threshold Resummation

Cross sections may contain several (logarithmically) enhanced contributions

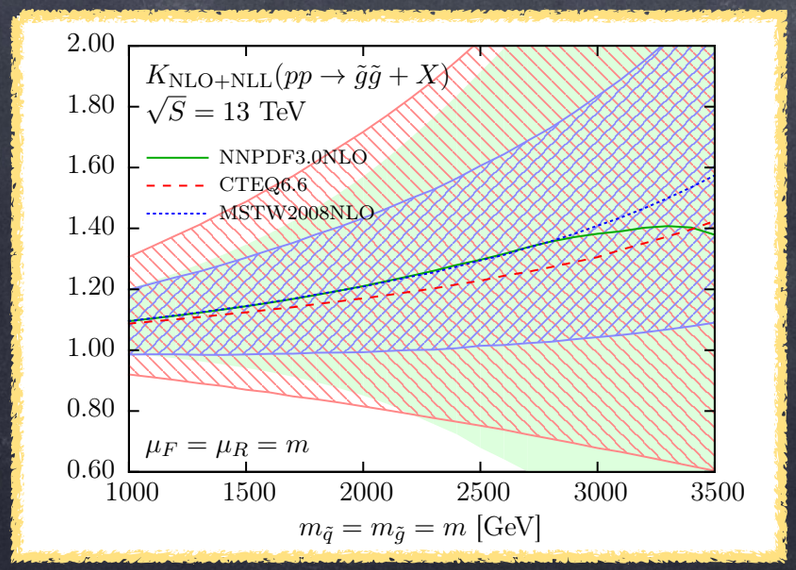
Logarithmic contributions may become large in some kinematic regions, thus spoiling the perturbative expansions

RESUMMATION

Large-x resummation: logarithmic enhancement close to threshold, $x \to 1$ $\quad x \sim \frac{M^2}{s}$

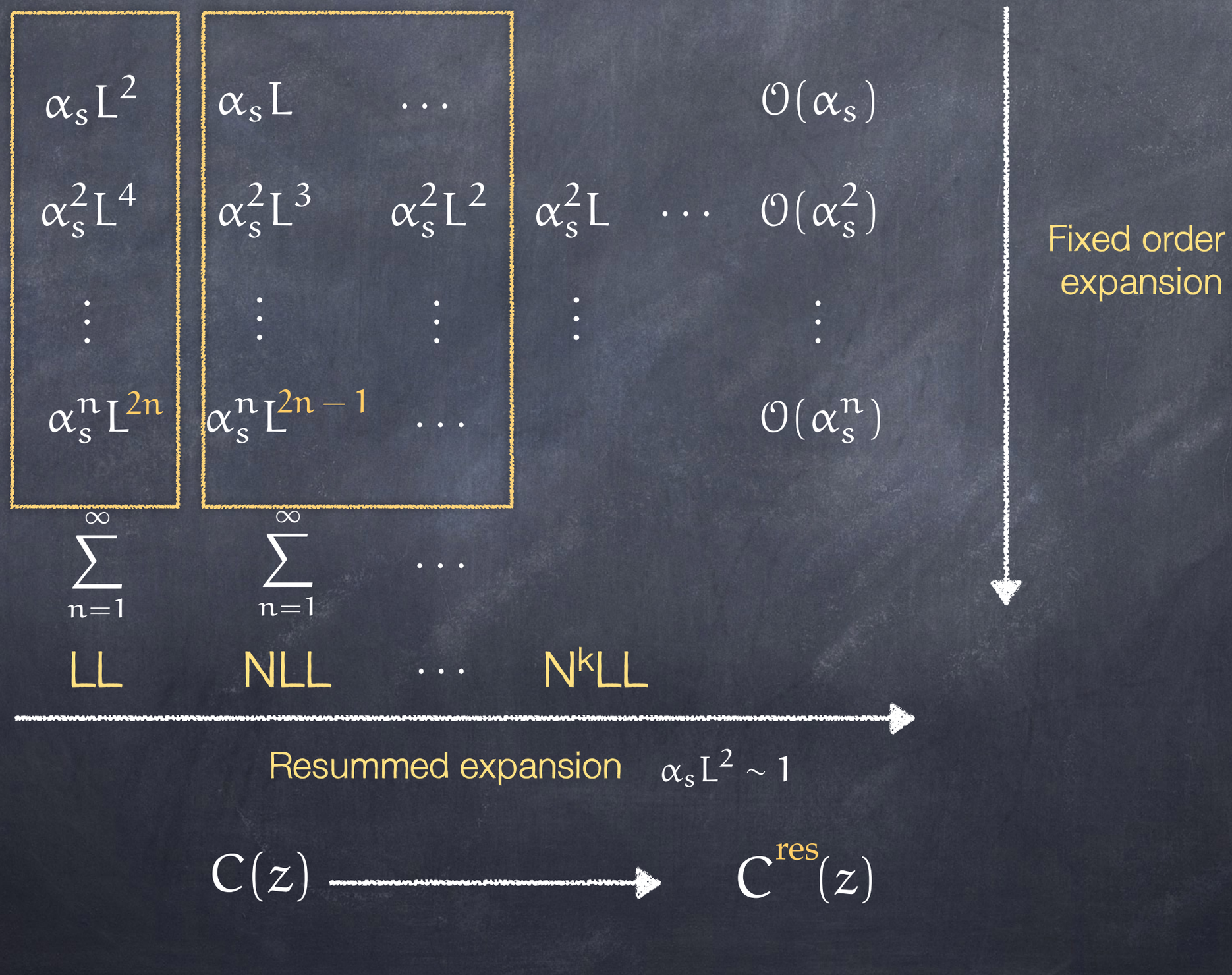
- Resummed calculations provide the state of the art accuracy for many processes at LHC

- Resummed PDFs are necessary to obtain full N^{k}LO+N^{k}LL accuracy at the level of hadronic observables



PDFs with Threshold Resummation

Resummation consists in a reorganization of the perturbative expansion by performing an all order summation of classes of logs

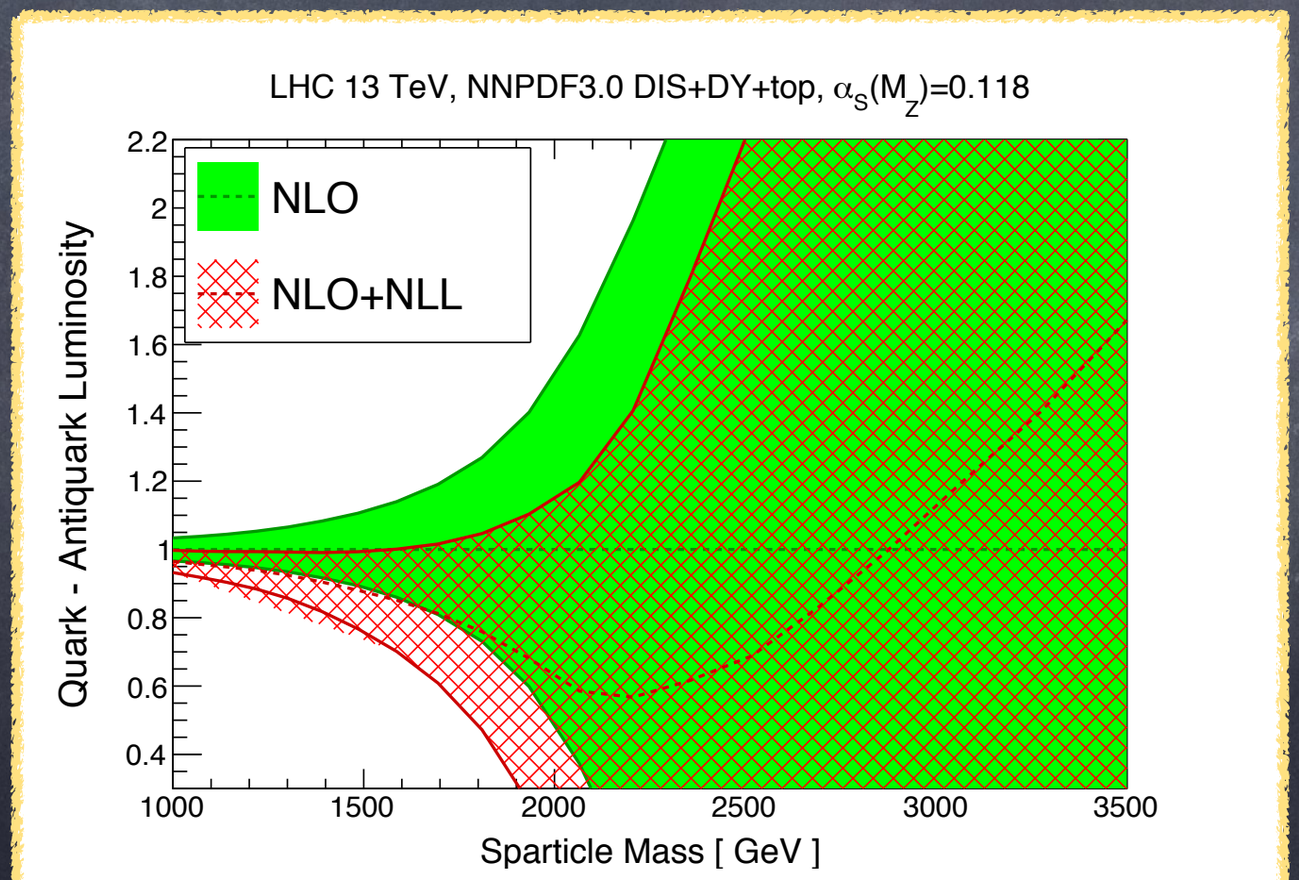


$$C(z) \longrightarrow C^{res}(z)$$

PDFs with Threshold Resummation

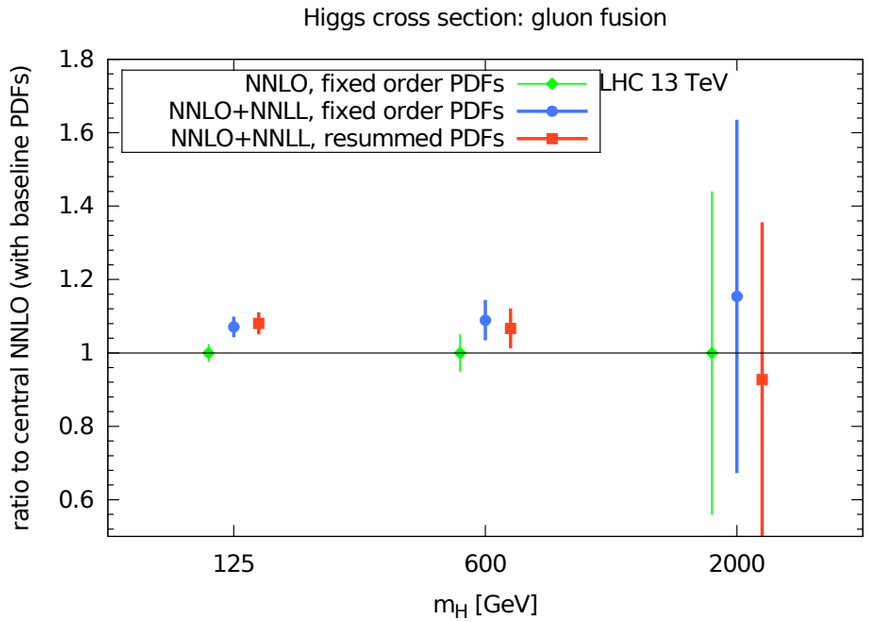
$$\sigma = x\sigma_0 \int \frac{dx_1}{x_1}\frac{dx_2}{x_2} f_1(x_1,Q^2) f_2(x_1,Q^2) C(z) = x\sigma_0 \int_x^1 \frac{dz}{z} \mathcal{L}\left(\frac{x}{z},Q^2\right) C(z)$$

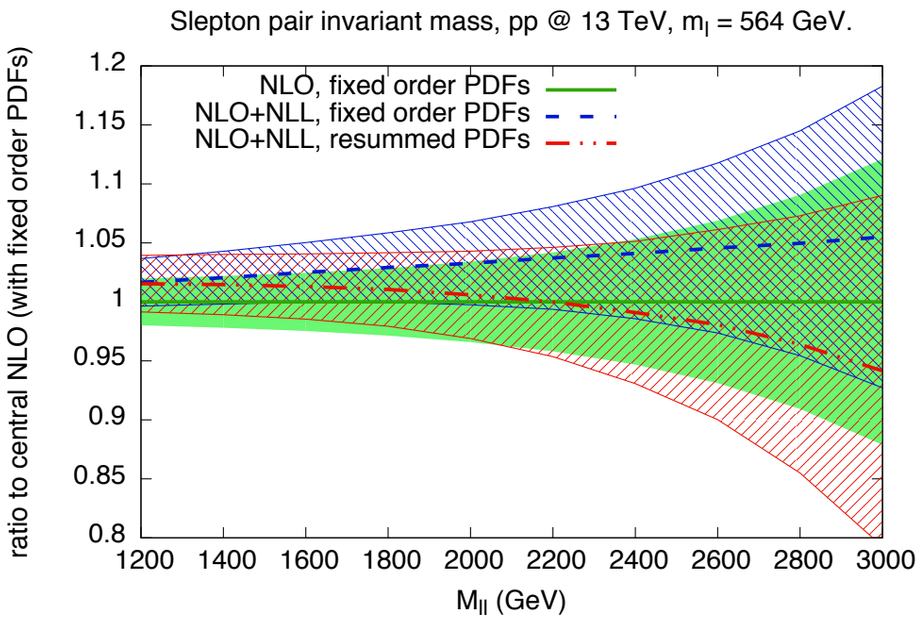
$$\sigma(x,Q^2) = x\sigma_0 \int_x^1 \frac{dz}{z} \mathcal{L}\left(\frac{x}{z},Q^2\right) C(z) \qquad \sigma(x,Q^2) = x\sigma_0 \int_x^1 \frac{dz}{z} \mathcal{L}\left(\frac{x}{z},Q^2\right) C^{\text{res}}(z)$$



PDFs with Threshold Resummation

Phenomenology



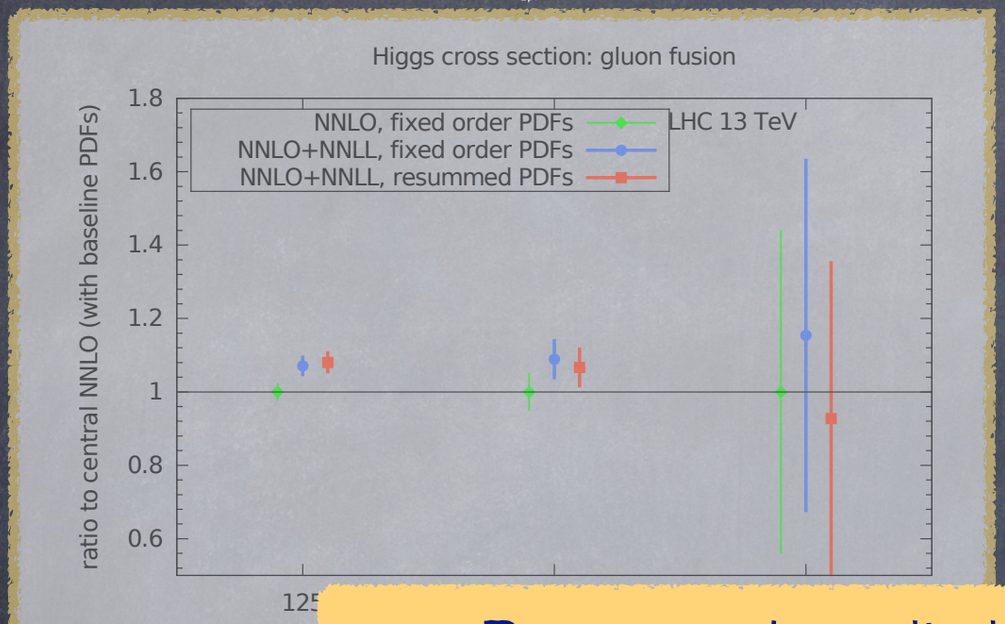


- SM Higgs not affected by resummation of PDFs
- m_H ~600 GeV cancellation of 1/2 of the enhancement

- 2-5% enhancement NLO+NLL calculation with FO PDFs
- 1-2% enhancement NLO+NLL calculation with resummed PDFs only of M_{ll}<2000 GeV
- At higher masses suppression of NLO+NLL calculation with resummed PDFs

PDFs with Threshold Resummation

Phenomenology



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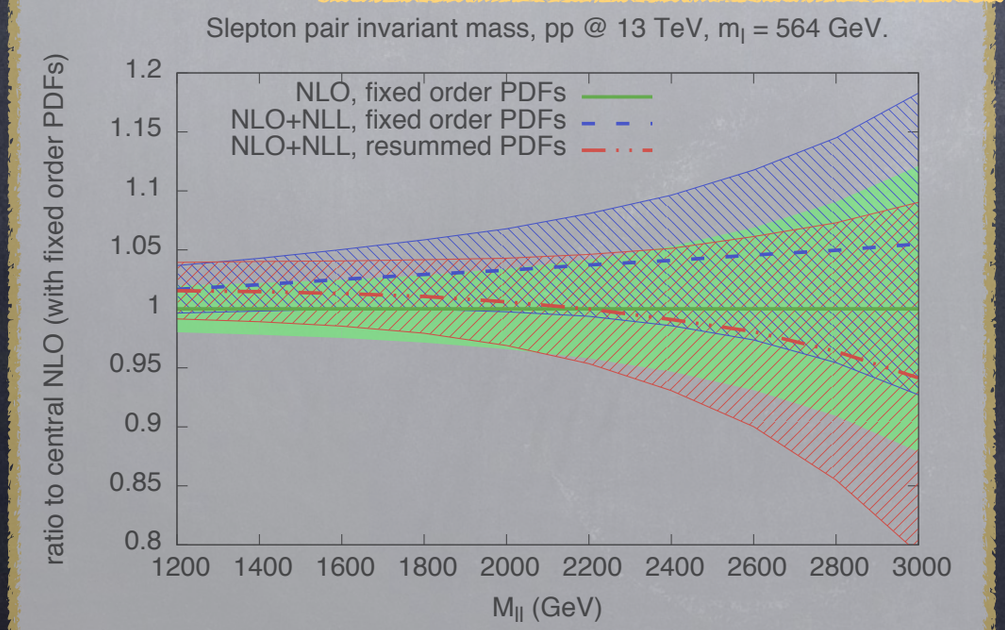
Resummed result closer to the fixed order calculation at large invariant masses



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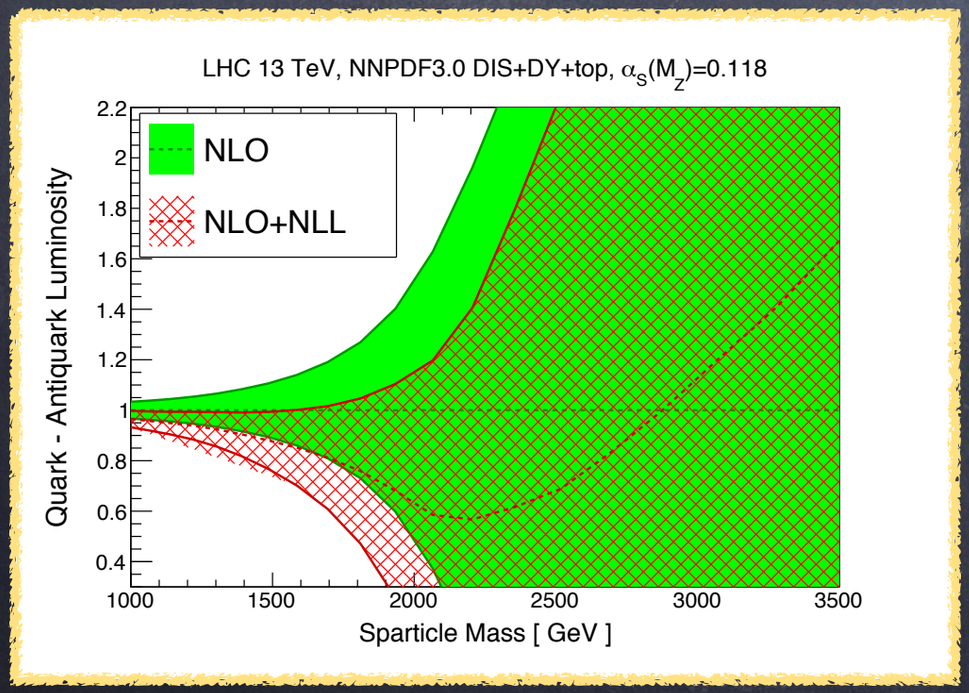
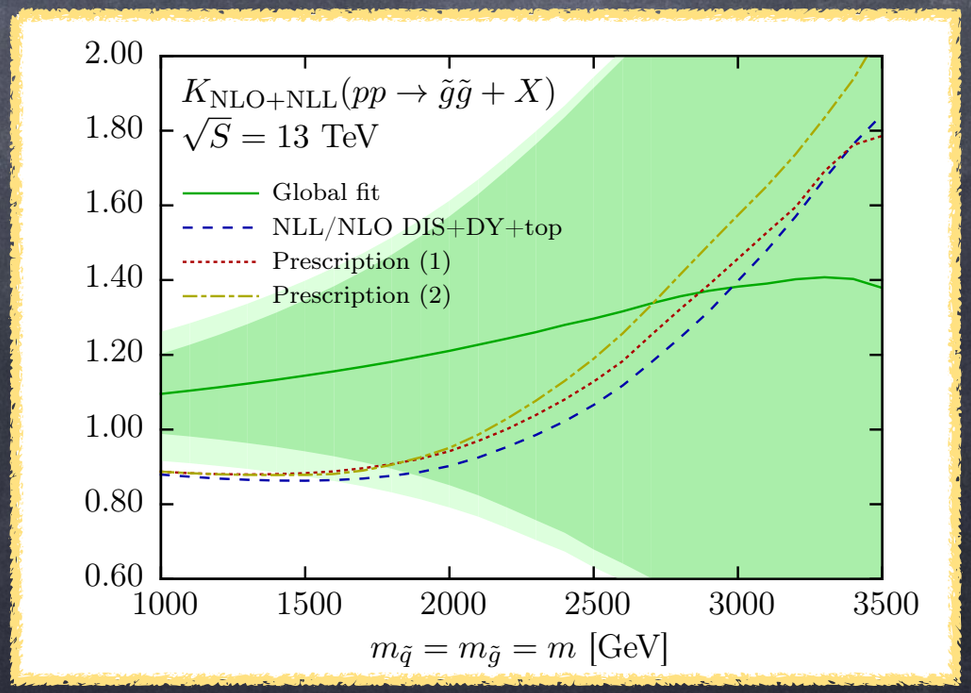
PDFs with Threshold Resummation

Summary

- First ever (global) fit of PDFs with threshold resummation
- Inclusion of resummation in PDFs compensates the enhancement from resummation in partonic cross sections for when M_X is large
- Importance of using the same perturbative order in all components when calculating hadronic cross sections: full N^kLO+N^kLL accuracy at the level of hadronic observables only possible with resummed PDFs





W. Beenakker et al, arXiv:1510.00375

Oxford Physics

Other works

- Three loop soft function for N^{3}LL' gluon fusion Higgs production in soft-collinear effective theory, M. Bonvini, LR, Phys.Rev. D91 (2015) 5, 051301.
- Charm production in the forward region: constraints on the small-x gluon and backgrounds for neutrino astronomy, R. Gauld, J. Rojo, LR, J. Talbert, arXiv: 1506.08025 [hep-ph].
- Intrinsic charm in a matched general-mass scheme, R. D. Ball, V. Bertone, M. Bonvini, S. Forte, P. G. Merrild, J. Rojo, LR, arXiv:1510.00009 [hep-ph].
- Charm in Deep-Inelastic Scattering, R. D. Ball, M. Bonvini, LR, arXiv:1510.02491 [hep-ph].

Ongoing projects

- Prompt atmospheric neutrino fluxes validated with LHC data with R. Gauld, J. Rojo, J. Talbert and S. Sarkar
- Resummation of a Pseudo-Scalar Particle at N^{3}LL' in dQCD and in SCET, with M. Bonvini, V. Ravindran et al.
- NNPDF related projects: PDFs with small-x resummation, Fitted charm PDF, general code development and maintenance, etc.

PDFs with Threshold Resummation

Threshold Resummation in a nutshell

$$\sigma(x, Q^2) = x\sigma_0 \int_x^1 \frac{dz}{z} \mathcal{L}\left(\frac{x}{z}, Q^2\right) C(z)$$

Convolution integral diagonalised in Mellin space

$$f(N) = \int_0^1 dx\, x^{N-1} f(x)$$

Mellin Transform

$$\sigma(N, Q^2) = \mathcal{L}(N, Q^2)\sigma_0(N, Q^2) C(N)$$

Double logarithmic enhancement due to soft gluon emission

$$C(N) = 1 + \sum_{n=1}^{\infty} \alpha_s^n \sum_{k=0}^{2n} c_{nk} \ln^k N + \mathcal{O}(1/N)$$

N-soft approximation

Exponentiation

$$C(N) = g_0(\alpha_s) \exp\left[\frac{1}{\alpha_s} g_1(\alpha_s \ln N) + g_2(\alpha_s \ln N) + \alpha_s\, g_3(\alpha_s \ln N) + \dots\right]$$

The functions g_i resum $\alpha_s^n \ln^n N$ to all orders