News from the theory side

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DESY Hamburg

HERAFITTER developers meeting

Outline

Progress on DESY side: relevant for future developments of the HERAFITTER package

- Numerical implementation of the approx NNLO + NNLL differential cross section for $t\bar{t}$ (M.G., Sven Moch)
- Issues related to the extraction of the charm quark mass from PDF fits.

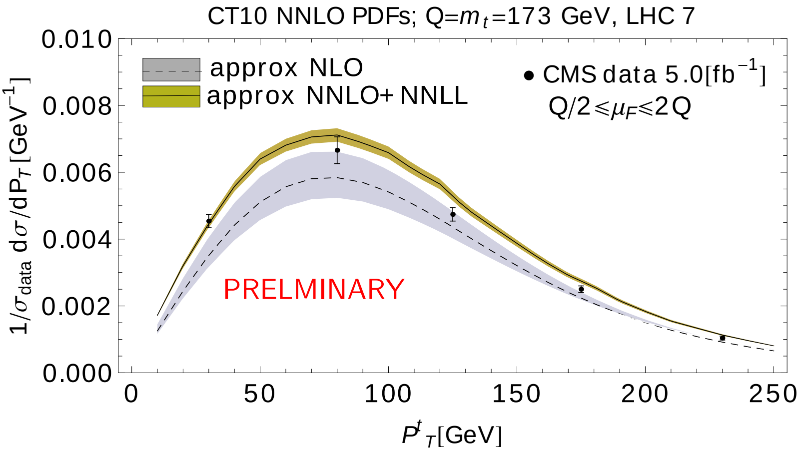
Several discussions at DIS2013.

Differential cross section for $t\bar{t}$ (approx NNLO + NNLL)

What is it good for?

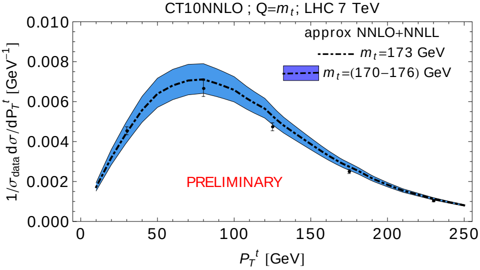
- precise forthcomig data
- theory @ NLO and approx NNLO sizeable K-factors (perturbative level)
- non-perturbative parameter $\alpha_s(M_Z)$, m_t, gluon(x) $\Rightarrow$ simultaneous determination $\Rightarrow$ global fit predictions!
- Tools development:
  - flexible OPEN SOURCE code for experimentalists
  - possibility of manipulating inputs: $(PP, P\bar{P})$, m_t, mu_F, mu_R, α_s evol., lhapdf interface, perturbative order, logarithmic approximation etc..
  - This computer code will be included into HERAFITTER to explore the extent of the constraints coming from differential and total $t\bar{t}$ cross section data on PDFs

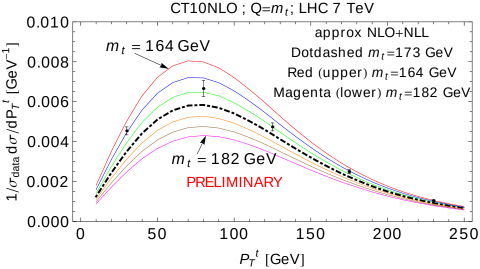
K-factors are large! CMS-TOP-11-013



Error band at NNLO Kidonakis PRD82 (2010) 114030 ≈ 2-3%

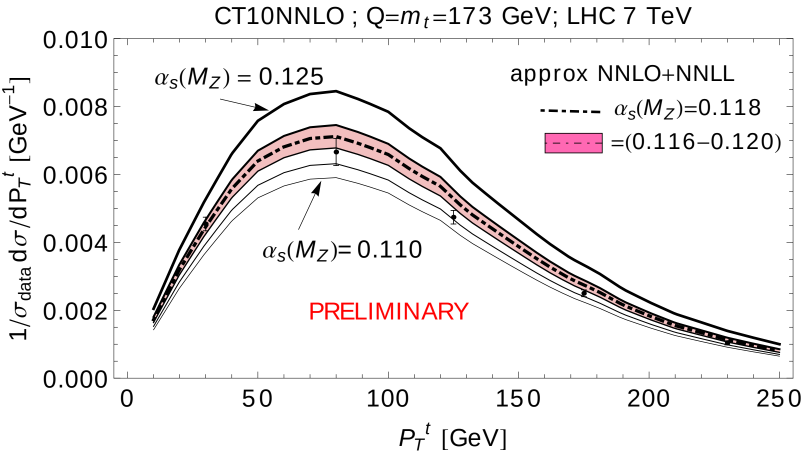
Dependence on m_t



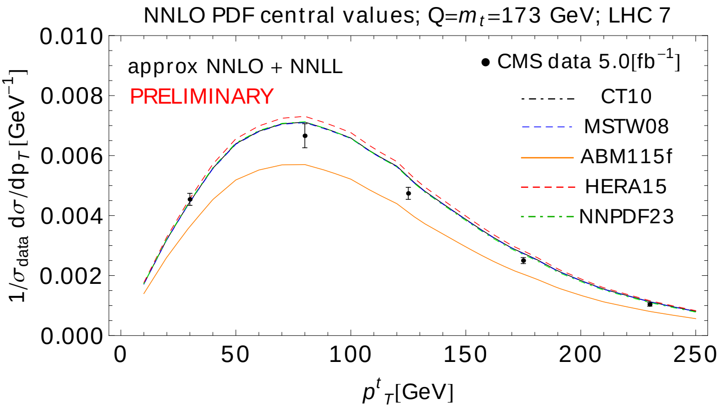


Similar plot for the rapidity distrib. in the Backup.

$\alpha_s(M_Z)$ dependence within CT10NNLO PDFs

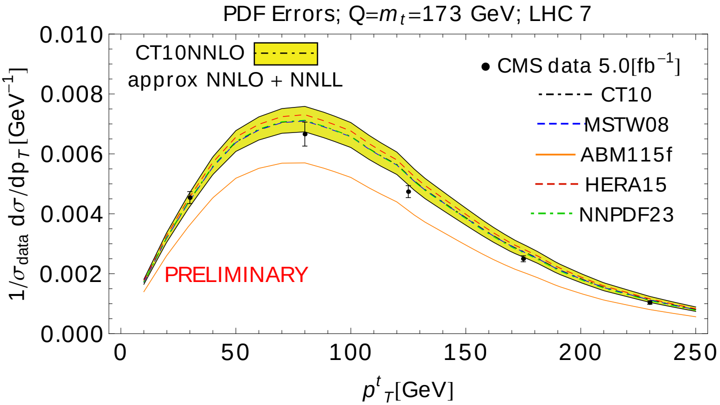


P_T^t-differential distribution



NNLO PDFs preferred m_t value: CT10, MSTW08, NNPDF2.3, $m_t \approx 173 - 175$ GeV; ABM115F $m_t \approx 170$ GeV, HERA15NNLO $m_t \approx 176$ GeV. Similar plot for the rapidity distrib. in the Backup.

Estimate of the PDF uncertainty



Current status:

- fine tuning of the code (good pace)
- cross checking against MCFM and similar results from Kidonakis
- scale dependence
- working on a flexible implementation: separate tunes on μ_F, μ_R; "switching points" in α_s evolutions, choice of the hard scale, etc.,

Extraction of m_c from global fits of PDFs

Why is m_c important?

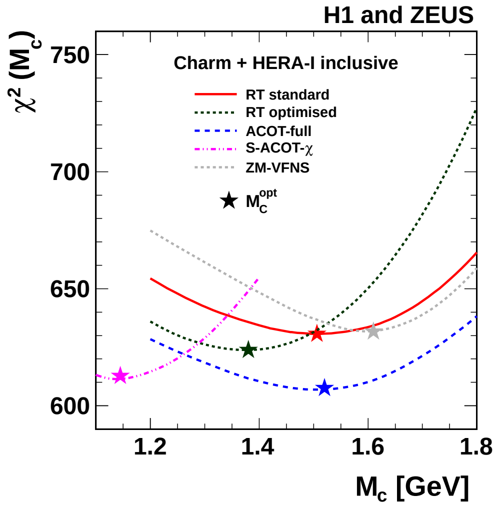
- Global analysis of PDFs of the proton: sensitive to the method by which the heavy-quark masses are included in experiments, especially at $Q \approx m_c$.
- DIS experiments have the best potential to constrain m_c.
- Impact on the extracted PDFs non-negligible: modifications due to heavy-quark treatment have phenomenological consequences for EW precision measurements at the LHC.
- Recent H1-ZEUS measurements (2012), of comb. cross sections on incl. and semi-incl. DIS charm production at HERA: put the tightest constraints on the $\overline{\mathrm{MS}}$ mass of the charm quark

A long standing discussion...

- **GMVFN vs FFN scheme**
- **Differences among m_c best-fits obtained by different PDF groups**
- M_c **(Pole mass) vs** $m_c(m_c)$ **(running mass** $\overline{\mathrm{MS}}$**)**
- **Differences in the determination of the PDF uncertainties: larger uncertainties on** m_c **in global analysis**
- **different methods/criteria of defining** $\Delta\chi^2$
- **different definitions of "NLO", "NNLO" in different HQ schemes**

Energy scales of order m_c in heavy-quark schemes

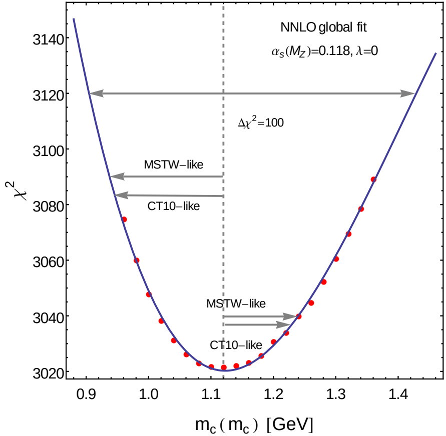
$\mathcal{O}(m_c)$ scales appearing FFN or VFN		
	is in FFN ?	is in VFN ?
M_c or $m_c(m_c)$ in exact $\gamma^* g \to c\bar{c}$ in NC DIS	$\surd$ **dominates**	$\surd$ dominates
switching scales in $\alpha_s(\mu)^{n_f} \to \alpha_s(\mu)^{n_f+1}$	$\surd$	$\surd$
switching scales in PDFs evolution	$\times$	$\surd$
kinem. approx. in FE coeff. func.	$\times$	$\surd$
scales in quark-fragmentation into hadrons	$\surd$	$\surd$



From H1 and Zeus paper 1211.1182[hep-ex] published on EPJC (2012)

In the S-ACOT-χ NNLO $\mathcal{O}(\alpha_s^2)$ scheme:

PDF uncertainty δm_c [GeV] (90% C.L.)	
$\Delta\chi^2 \leq 100$	$\delta m_c =^{+0.30}_{-0.22}$
CT10-like	$\delta m_c =^{+0.11}_{-0.17}$
MSTW-like	$\delta m_c =^{+0.12}_{-0.18}$



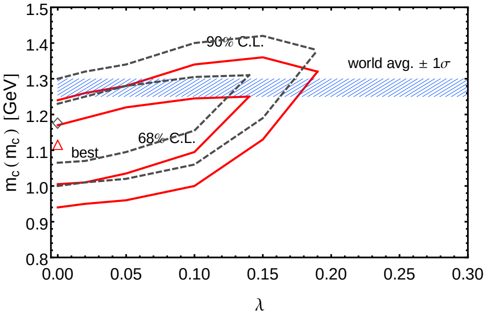
$m_c(m_c) = 1.12$ GeV

charm mass scan.

Global χ^2 of the S-ACOT-χ NNLO fit as a function of the $\overline{\mathrm{MS}}$ charm mass. Lines with left/right arrows indicate 90% C.L. intervals obtained with different tolerance criteria.

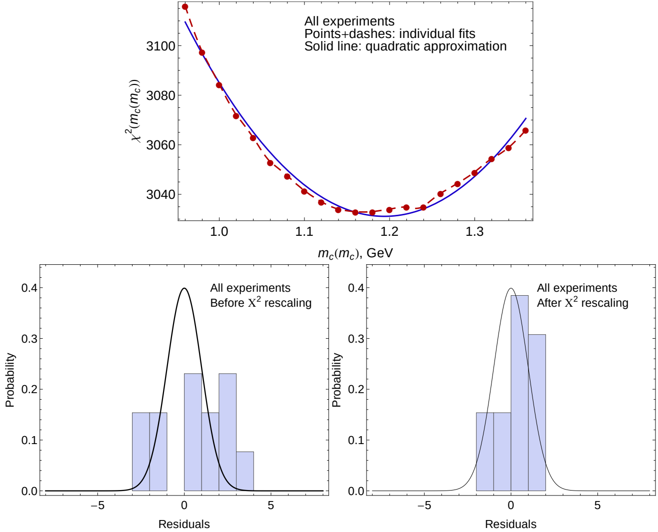
In the S-ACOT-χ NNLO $\mathcal{O}(\alpha_s^2)$ scheme:

Theor. sys. uncer.	DIS scale	$\alpha_s(M_Z)$	λ	χ^2 def.
Parameter range	$[Q/2,\ 2Q]$	[0.116, 0.120]	[0, 0.2]	–
$\delta m_c(m_c)$ (GeV)	$^{+0.02}_{-0.02}$	$^{+0.01}_{-0.01}$	$^{+0.14}_{-0}$	$^{+0.06}_{-0}$

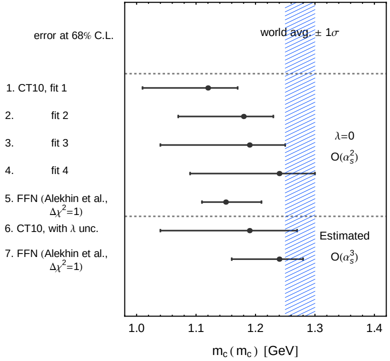


Preferred regions for $m_c(m_c)$ vs. the rescaling parameter λ. The best-fit values and confidence intervals are shown for two alternative methods for implementation of correlated systematic errors.

Check $\Delta\chi^2 = 1$ in the global CT10 NNLO fit



Preferred m_c's with several methods.



At order α_s^2, the CT10 values are obtained using the full mass conversion formula and "extended T" and "experimental" χ^2 definitions (fit 1 and 2 respectively), and the truncated mass conversion and "extended T" and "experimental" χ^2 definitions (fit 3 and 4). The resulting $m_c(m_c)$ values and 68% C.L. uncertainties in four methods are $1.12^{+0.05}_{-0.11}$, $1.18^{+0.05}_{-0.11}$, $1.19^{+0.06}_{-0.15}$ and $1.24^{+0.06}_{-0.15}$ GeV, respectively.

My conclusions

- Lots of developments are going on and planned to be included in future releases of HERAFITTER
- On the long run: potential to be on top of all PDF fitters $\Rightarrow$ it basically has ingredients that cannot be provided by single PDF fitter groups
- Crucial: because it allows to make comparisons in the same conditions!
- cross check of the impact of HQ schemes on a PDF fit is one example (and it is very important...)
- Implementation S-ACOT-χ at NNLO $\mathcal{O}(\alpha_s^2)$: still on-going...

Back up

$\overline{\mathrm{MS}}$ to the pole mass conversion.

The fit is sensitive to the order of conversion of the $\overline{\mathrm{MS}}$ charm mass $m_c(m_c)$, our input parameter, into the pole mass provided as the parameter by massive two-loop contributions in DIS.

$$
\begin{aligned}
m_Q^{pole} &= m_Q(m_Q)\left\{1+\frac{\alpha_s(m_Q(m_Q),N_f)}{\pi}\frac{4}{3}\right.\\
&+ \left.\frac{\alpha_s^2(m_Q(m_Q),N_f)}{\pi}\left[13.1454-1.04137N_f+\sum_{i=1}^{N_f}\Delta(m_i(m_i)/m_Q(m_Q))\right]\right\},
\end{aligned}
\tag{1}
$$

with $\Delta(x) = 1.2337\ x - 0.597\ x^2 + 0.23\ x^3$. Chetyrkin (2000).