

Top production at large P_T at NLO+NLL accuracy

Matteo Cacciari

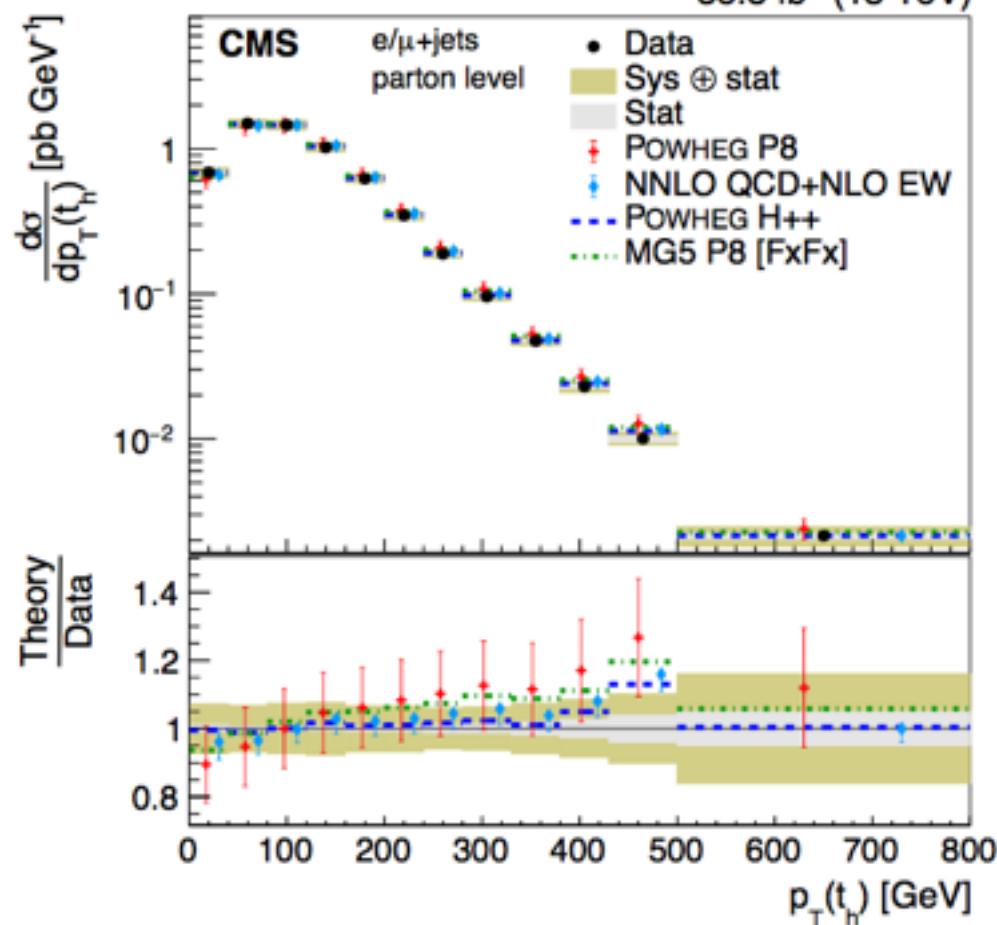
*LPTHE - Sorbonne Université and CNRS
Université de Paris*

Work (still) in progress with F. Dreyer and E. Re
(and results are preliminary,
but public in DIS 2018 proceedings 1809.06626)

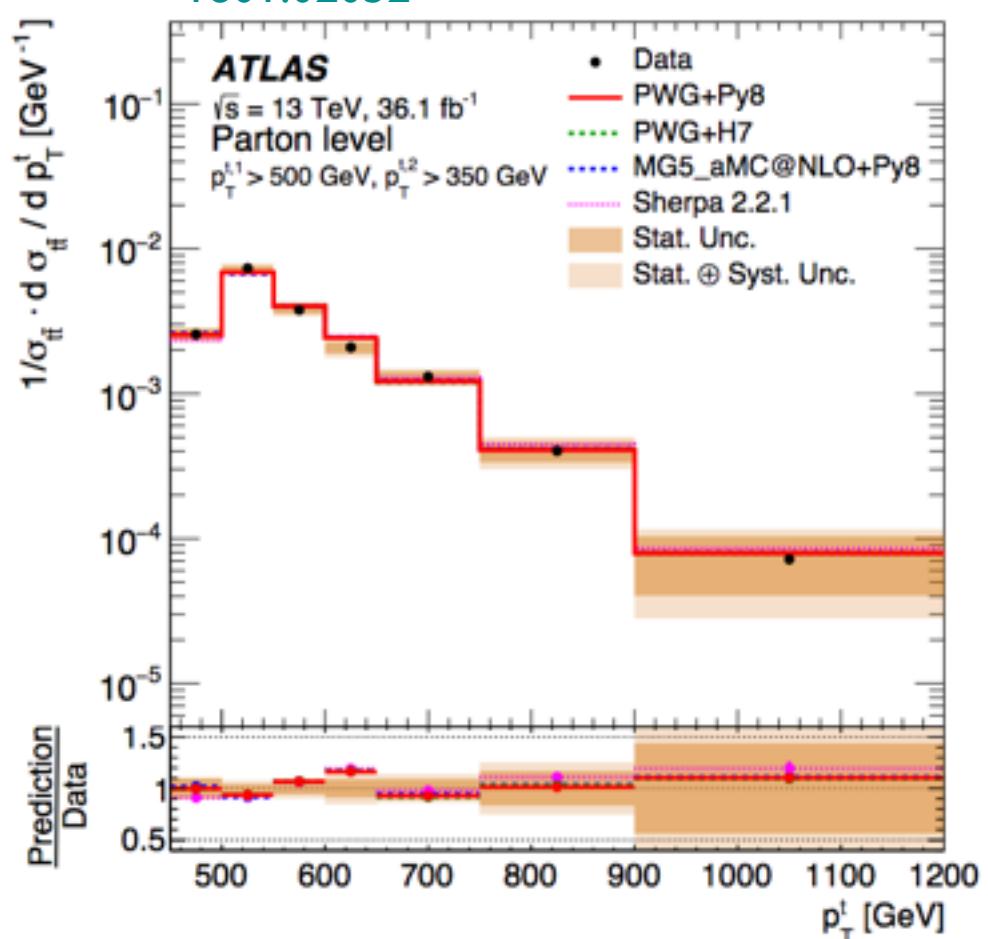
Top data at LHC

1803.08856

35.8 fb^{-1} (13 TeV)



1801.02052



- Data available up to $p_T \sim 1 \text{ TeV}$
- Expt uncertainty at large $p_T \sim 10\text{-}20\%$
- Fair agreement with theory

Large- p_t theoretical issues

For $p_t \gg m$ enhanced quasi-collinear gluon radiation is possible even from top quarks

$\Rightarrow \alpha^n \log^{n-k}(p_t/m)$ terms in series

- They can spoil convergence of the perturbative series
- They can have significant phenomenological effect
- They can be resummed to all orders

Obviously, an archaeology talk...



Quasi-collinear logs from gluon emission off heavy quarks have been resummed for charm and bottom long ago in FONLL

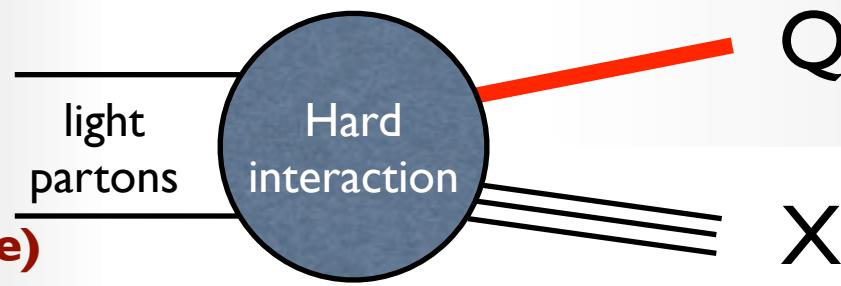
[MC, Greco, Nason, 1998]

<http://www.lpthe.jussieu.fr/~cacciari/fonll/fonllform.html>

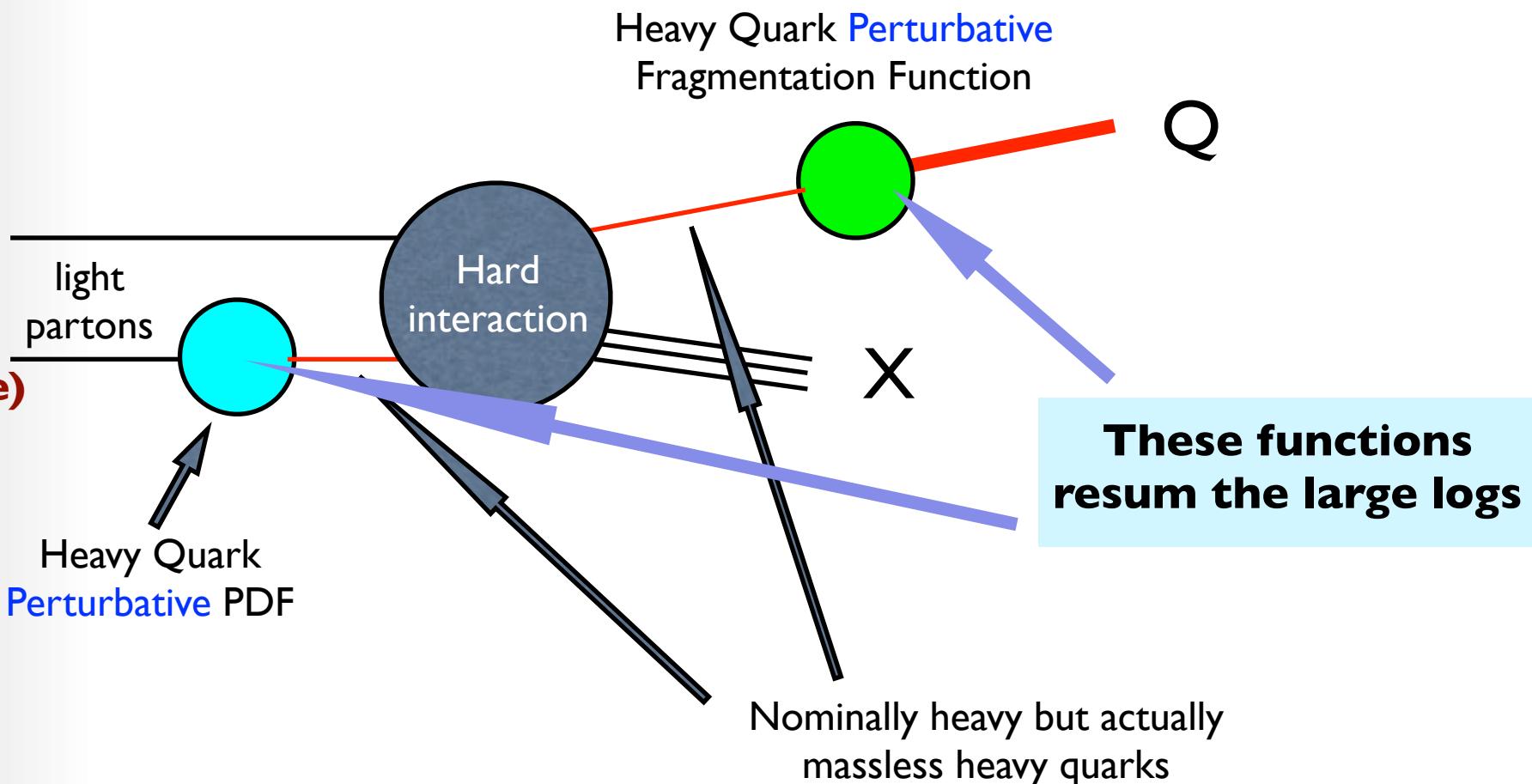
Ingredients: a massive fixed order calculation, a ‘massless’ resummed calculation, a proper matching

FO

(NLO accurate)

**RS**

(NLL accurate)

**- double-
counting**

$$FONLL = FO + (RS - FO_{m=0}) \times G$$

Damping function.
Eliminates spurious
higher order terms in
small p_t region

$$RS \sim d\sigma(p_t, \mu) \otimes E(\mu, \mu_0) \otimes D(\mu_0, m)$$

MSbar subtracted
massless short-
distance cross section

DGLAP evolution
equations. Resums the
logs from $\mu_0 \sim m$ to $\mu \sim p_t$

Perturbatively
calculable initial
condition

A matched calculation can be written as

$$N^k LO \cdot N^m LL = \begin{matrix} \text{fixed order} & \text{resummed} \end{matrix} N^k LO + N^m LL - \text{double counting}$$

What is known for $d\sigma/dp_t$?

$N^k LO.N^m LL$ for $d\sigma/dp_t$

k	m	Label	Known since
0	-	LO	1978/79 multiple authors
1	-	NLO	1989 Nason, Dawson, Ellis
1	1	NLO.NLL	1998 MC, Greco, Nason (this is 'FONLL')
2	-	NNLO	2015 Czakon, Fiedler, Heymes, Mitov 2019 Catani, Devoto, Grazzini, Kallweit, Mazzitelli
1	2	NLO.NNLL	Ingredients exist.
2	1	NNLO.NLL	NNLO+NNLL'(soft) done in SCET
2	2	NNLO.NNLL	(Czakon et al. 1803.07623)

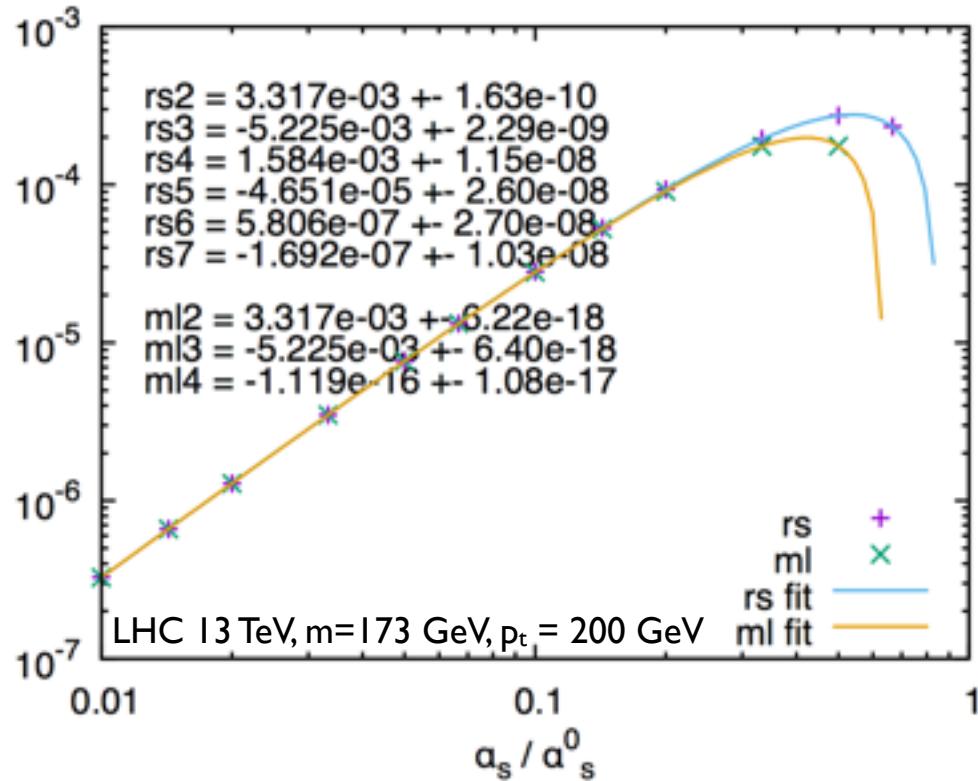
FONLL for large p_t top

Upgrade of FONLL to v1.4 (not yet released)

Ingredients needed for top quark production:

- ▶ 6 light flavours running in α_s
- ▶ PDFs with 6 flavours (top quark perturbatively generated)
 - ▶ NNPDF30_as_0118_nf_6
 - ▶ CT14nlo_NF6
 - ▶
- ▶ Evolution of perturbative fragmentation function, and coefficient functions, with six flavours (FONLL was hardcoded with five...)

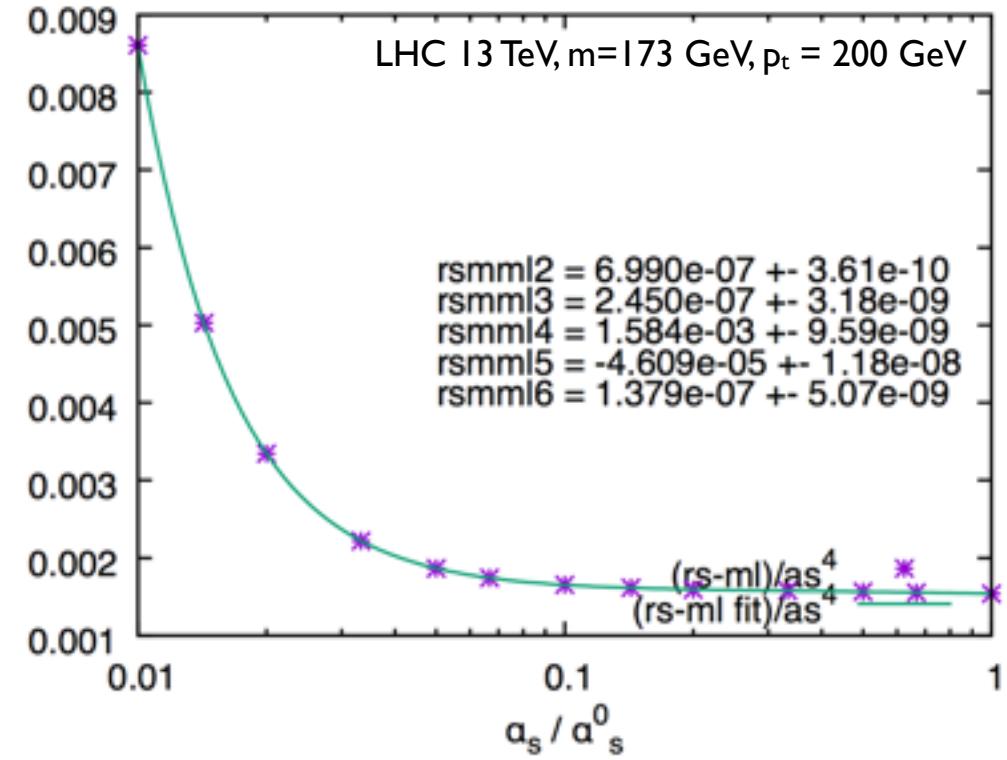
Check of α_s^3 cancellation



$$RS = rs_2 \alpha_s^2 + rs_3 \alpha_s^3 + rs_4 \alpha_s^4 + \dots$$

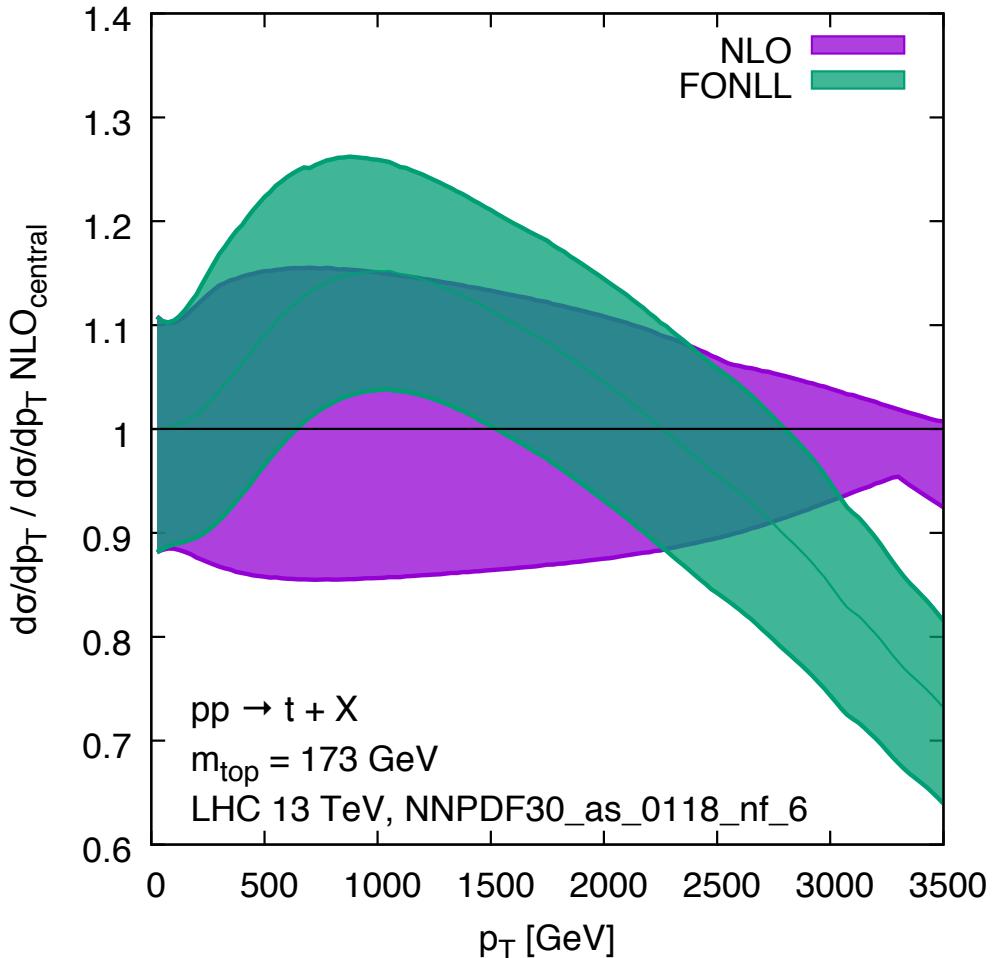
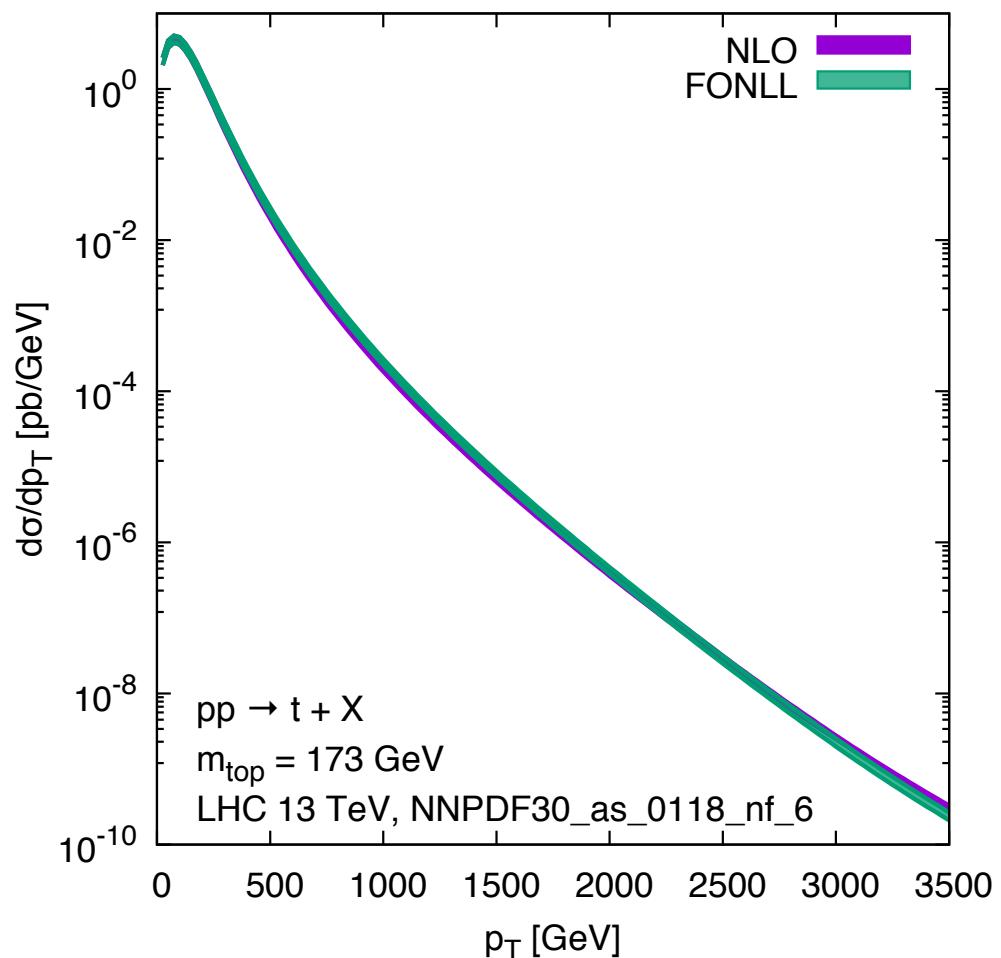
$$FO_{m=0} = ml_2 \alpha_s^2 + ml_3 \alpha_s^3 + ml_4 \alpha_s^4$$

- RS actually taken in “RSA” approximation, without DGLAP evolution and with heavy quark PDF generated at $O(\alpha_s)$
- Visual convergence at small α_s
- Agreement of α_s^2 and α_s^3 coefficients

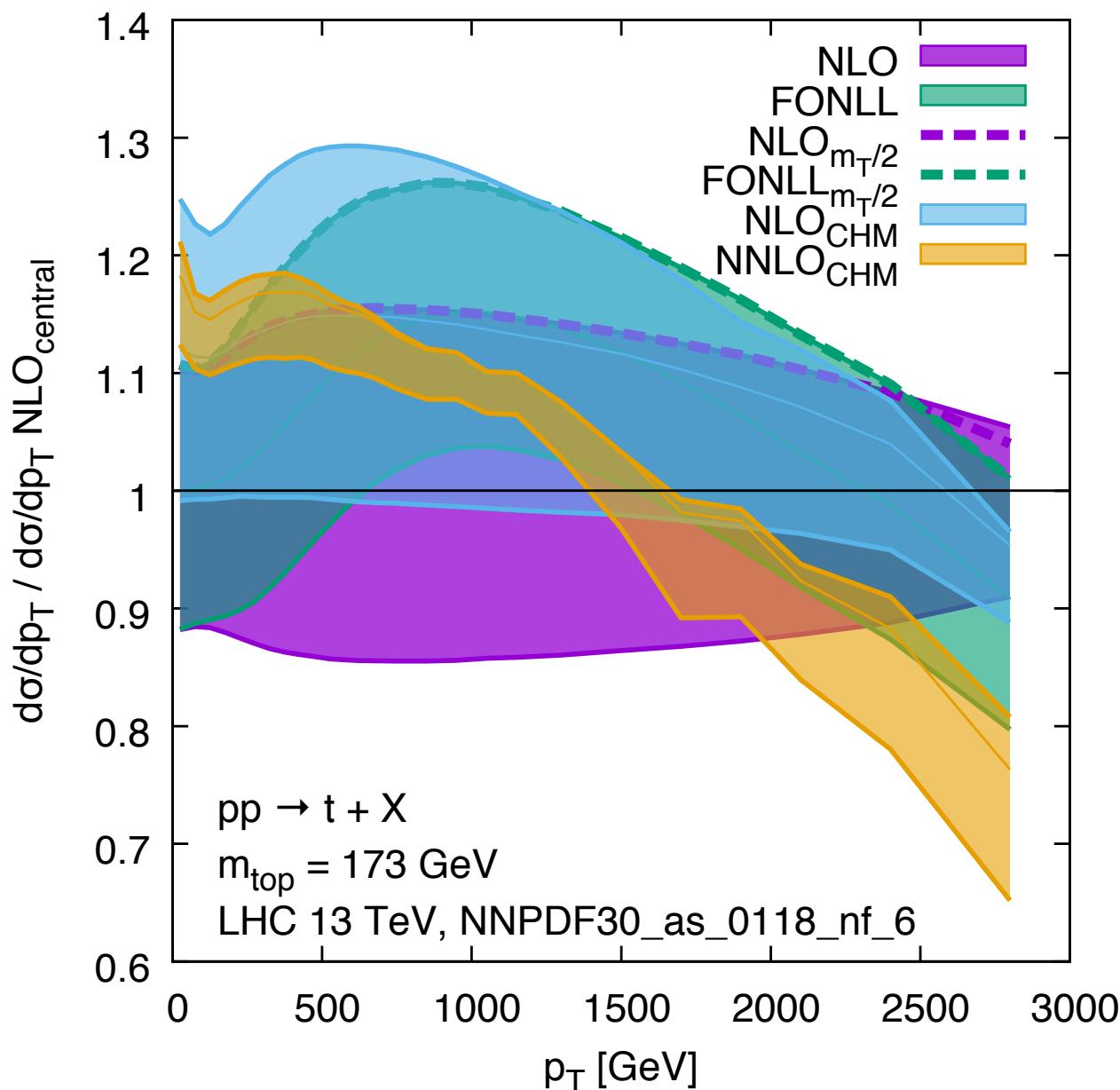


$$RS - FO_{m=0} = rsmmI2 \alpha_s^2 + rsmmI3 \alpha_s^3 + rsmmI4 \alpha_s^4 + \dots$$

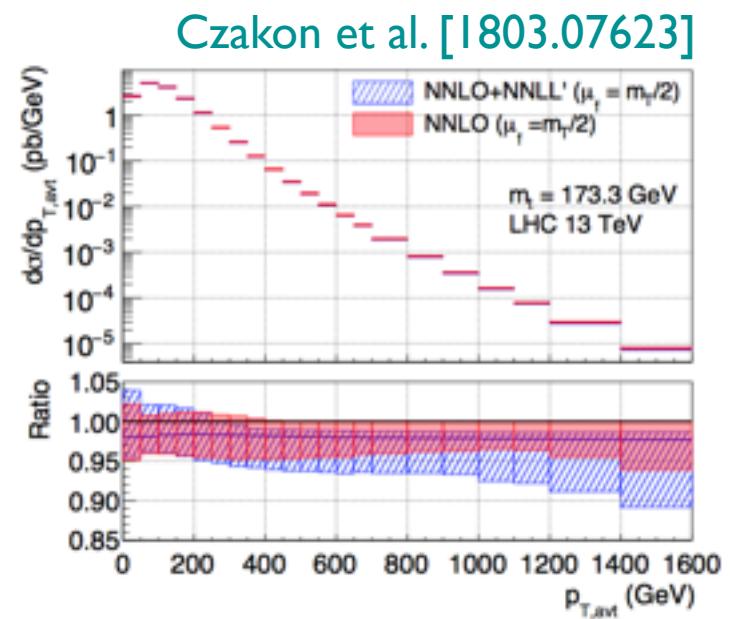
- Residual α_s^2 and α_s^3 terms highly suppressed in difference
- Scaling of difference as α_s^4 apparent down to 0.1, before numerical inaccuracies starts breaking it

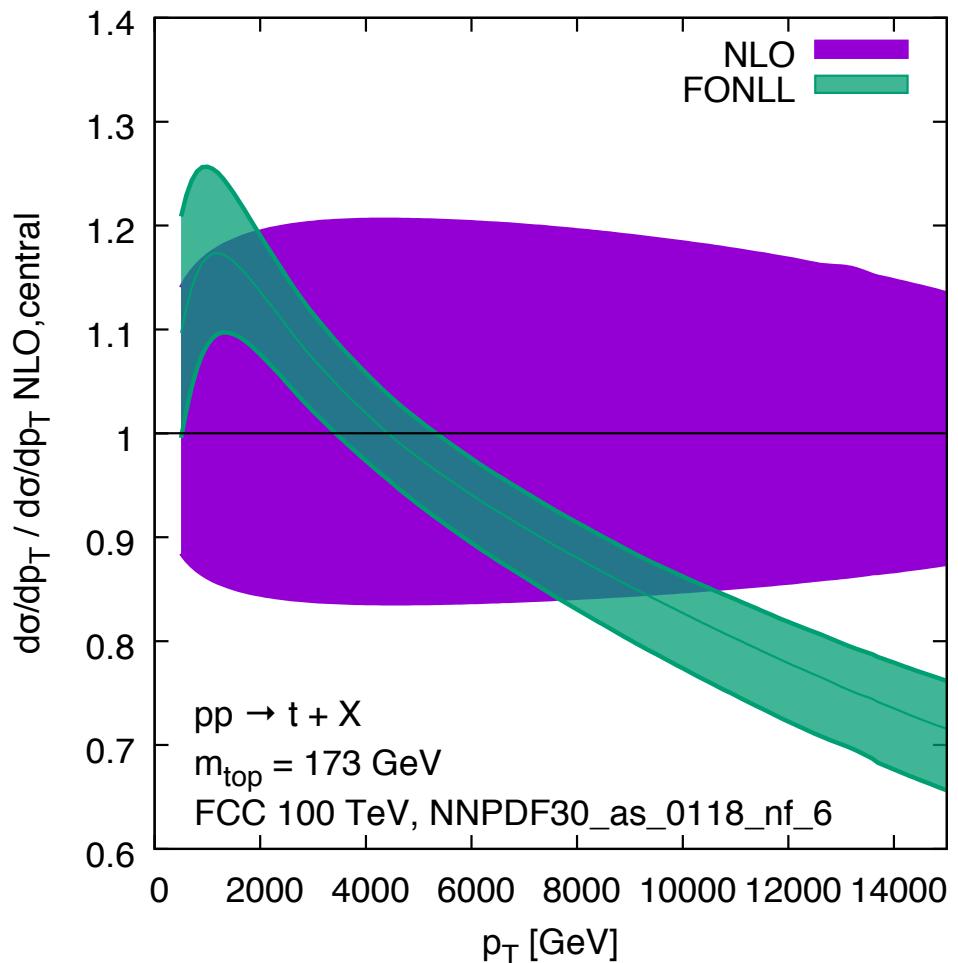
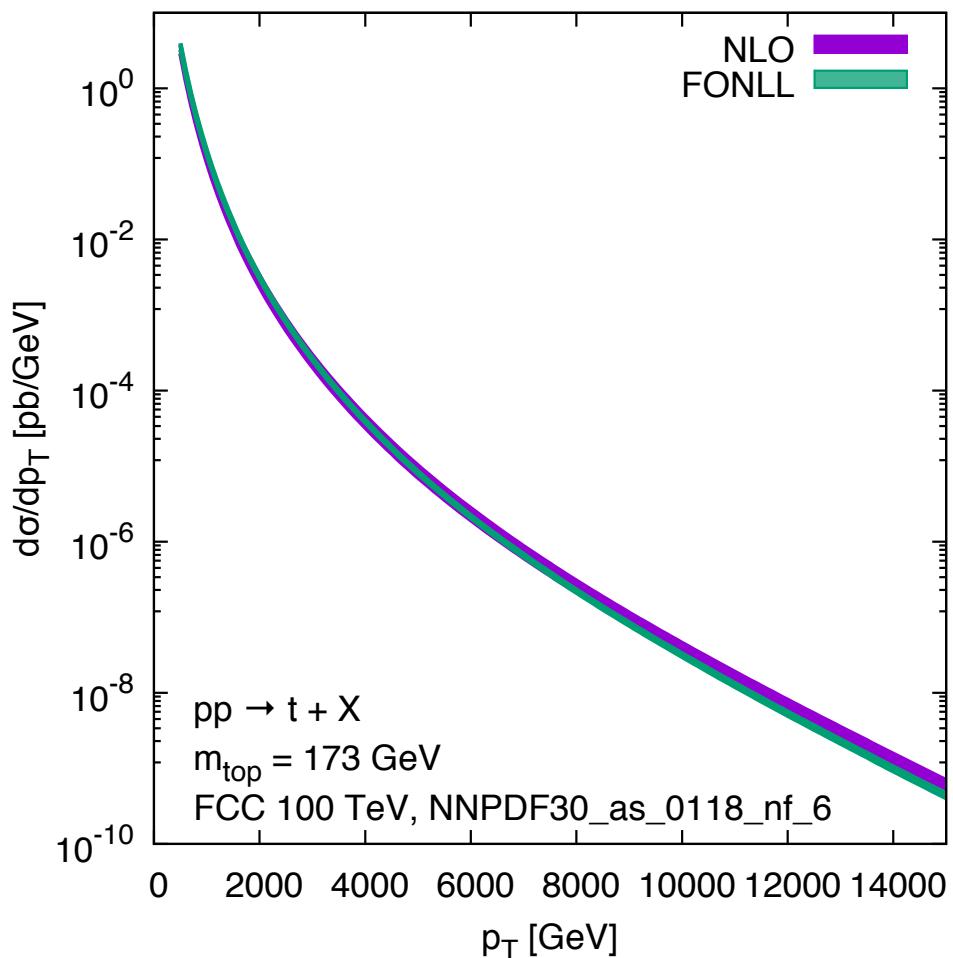


NLO uncertainty estimate from standard scales variation problematic at large p_t



Comparison with NNLO
results from Czakon,
Heymes, Mitov [[1606.03550](#)]





- Small theoretical uncertainty for FONLL, but significant differences only at astronomically large p_T
- It would be interesting to compare to NNLO results, but they are not available (numerical issues)

Conclusions

- ▶ FONLL upgraded to calculate top production at large transverse momentum
 - ▶ No significant effects at LHC in measured range (i.e. up to $\sim 1 \text{ TeV}$)
- ▶ It also runs at 100 TeV
- ▶ It only calculates single-particle inclusive observables, but it does it quickly and with a public code (v1.4 available “soon”)
- ▶ Can complement fixed order predictions for $d\sigma/dp_t$
- ▶ Perspectives: detailed comparison with NNLO calculation at large transverse momentum
Explicit check of next-to-leading log terms $\alpha_s^2(\alpha_s^2 \log(p_t/m))$