Status of top mass determination from the total cross section

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(see also F. Deliot, TOP2013: arXiv:1312.2978)

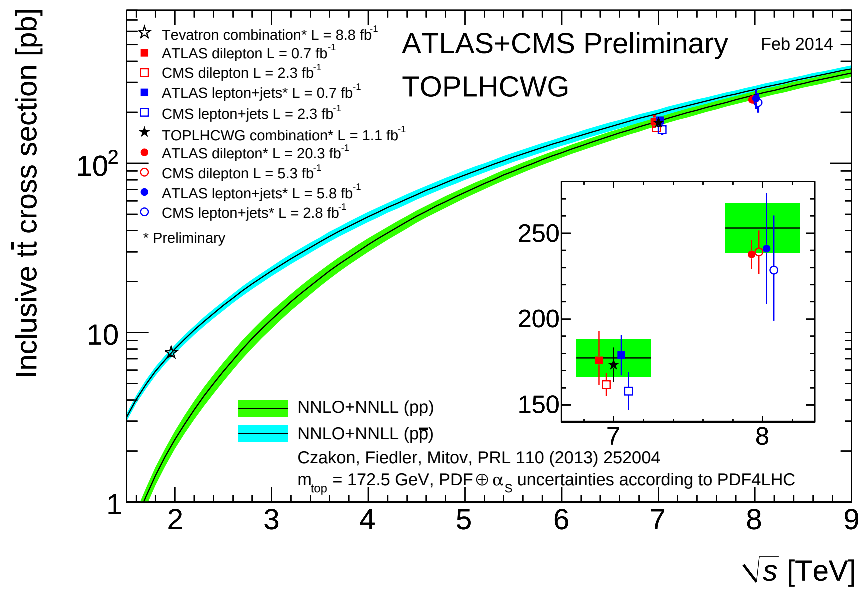
Total $t\bar{t}$ cross section

measurements (in pb)

$$\sigma_{t\bar{t}}^{\text{Tevatron}} = 7.60^{+0.41}_{-0.41}(\text{D0+CDF})$$

$$\sigma_{t\bar{t}}^{\text{LHC @7 TeV}} = \begin{cases} 162^{+7}_{-7} & (\text{CMS}) \\ 177^{+11}_{-10} & (\text{ATLAS}) \end{cases}$$

$$\sigma_{t\bar{t}}^{\text{LHC @8 TeV}} = \begin{cases} 239^{+13}_{-13} & (\text{CMS}) \\ 238^{+11}_{-11} & (\text{ATLAS}) \end{cases}$$

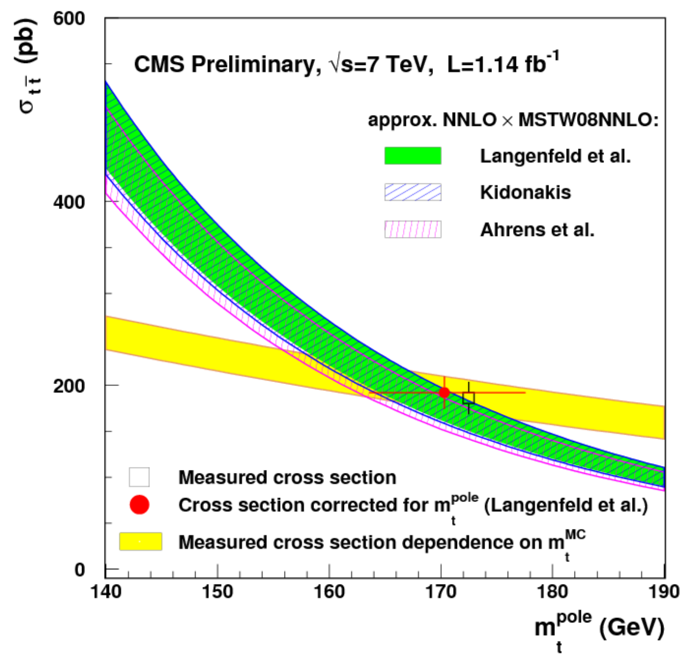


Top mass from kinematic measurements

$$m_t = \begin{cases} 173.20 \pm 0.87\text{GeV} & (\text{Tevatron comb. } 8.7 \text{ fb}^{-1}) \\ 173.29 \pm 0.95\text{GeV} & (\text{LHC comb. } 4.9 \text{ fb}^{-1}) \end{cases}$$

theoretical mass definition?

Theory prediction for $\sigma_{t\bar{t}}$ in QCD:
function of α_s, m_t, PDFs
Proposal: determine m_t in
well-defined scheme (pole, $\overline{\text{MS}}$,...)
from $\sigma_{t\bar{t}}$ measurement
(Langenfeld/Moch/Uwer 09)



Experimental measurement
depends on m_t^{MC}
used to determine acceptances

Earlier experimental results: (for MSTW and NNLO$_{\text{approx}}$ from Langenfeld et al.)

- DO: $m_t = 167.5^{+5.2}_{-4.7}\,\text{GeV}$ using $\sigma_{t\bar{t}} = 8.13^{+1.02}_{-0.90}\,\text{pb}$
- CMS: $m_t = 170.3^{+7.3}_{-6.7}\,\text{GeV}$ using $\sigma_{t\bar{t}} = 169.9 \pm 18.4\,\text{pb}$

This talk: focus on pole scheme, take α_s, PDFs as input

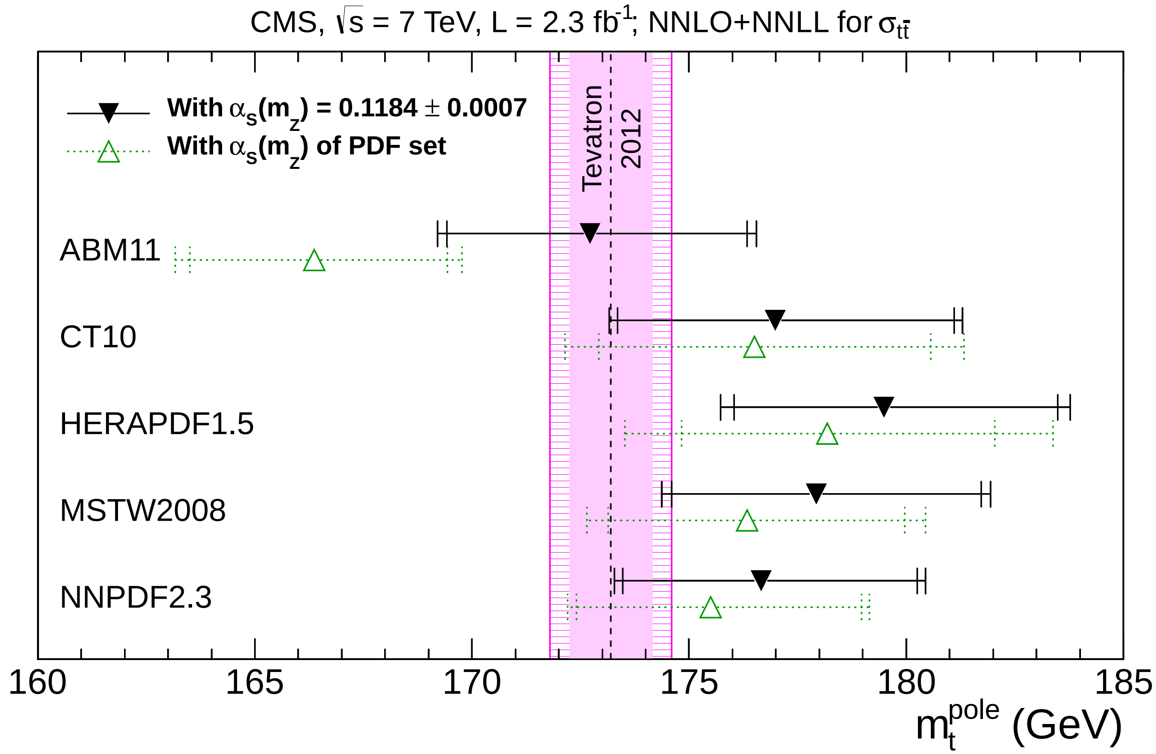
($\overline{\text{MS}}$-scheme, simultaneous fits ⇒ Sven's talk)

Latest experimental analysis (CMS arXiv:1307.1907) using most precise single measurement of cross section at $7\,\mathrm{TeV}$

$$\sigma_{t\bar{t}} = 161.9^{+6.7}_{-6.7}\mathrm{pb}$$

Results for different PDFs using NNLO+NNLL

(Bärnreuther/Czakon/Fiedler/Mitov 12–13)



Total top-pair production cross-section

Full NNLO calculation (Bärnreuther/Czakon/Fiedler/Mitov 12–13)

NNLL resummation

Soft threshold logarithms $\alpha_s \log\beta$ (Czakon/Mitov/Sterman 09)

Threshold logs and Coulomb corrections α_s/β (Beneke/Falgari/CS 09)

Programs including exact NNLO result

- TOP++ v2.0: NNLO+NNLL (soft) (Czakon/Mitov)
- HATHOR v1.5: NNLO (Aliev et al.)
- TOPIXS v2.0 NNLO+NNLL (soft+Coulomb) (Beneke et al.)

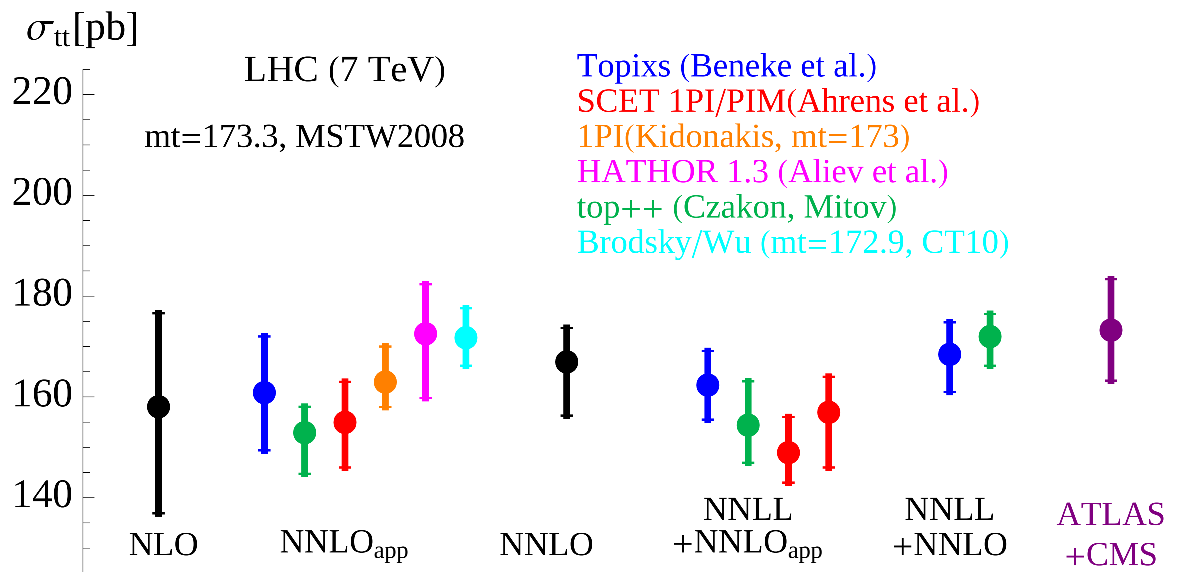
EW corrections $\sim 2\%$ (Bernreuther/Fücker/Si; Kühn/Scharf/Uwer, 05/06)

EW corrections to pole–$\overline{\rm MS}$ mass relation? (Jegerlehner/Kalmykov/Kniehl 12)

Comparison of different approximations

with theoretical uncertainties (excluding PDF+α_s uncertainties)

- $\pm5\%$ theoretical uncertainty at NNLO; ±3–4% at NNLL



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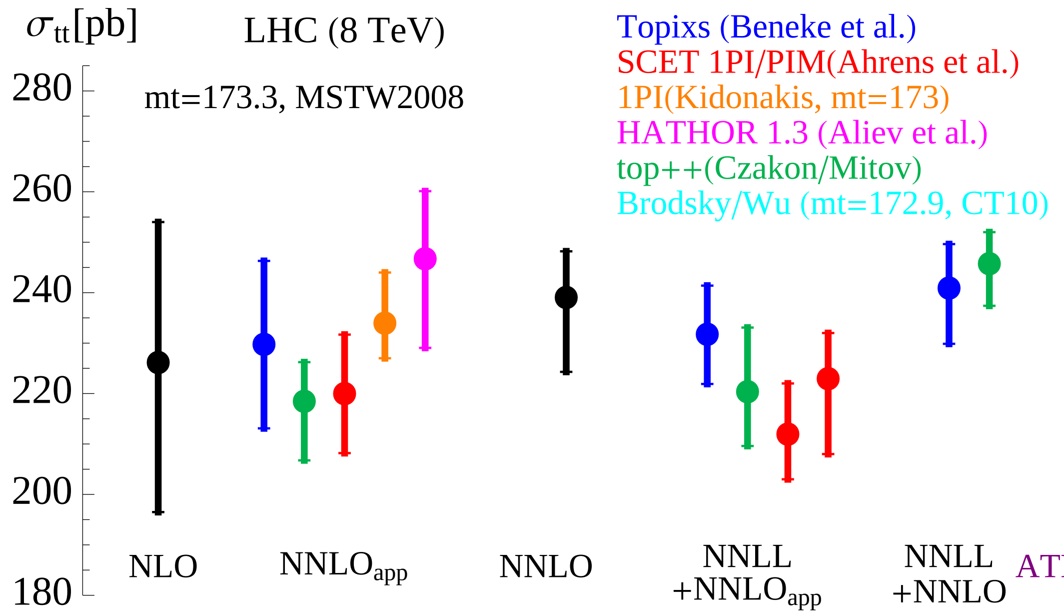
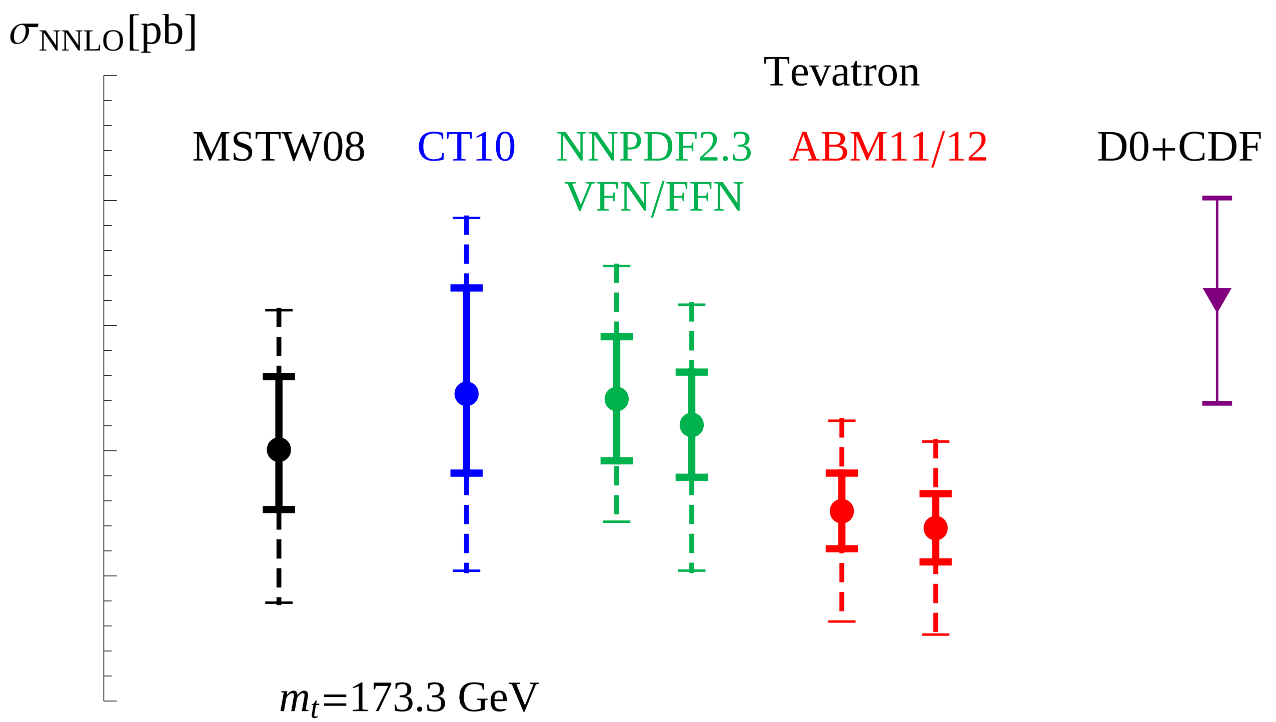


PDF+α_s uncertainties now comparable to scale uncertainty



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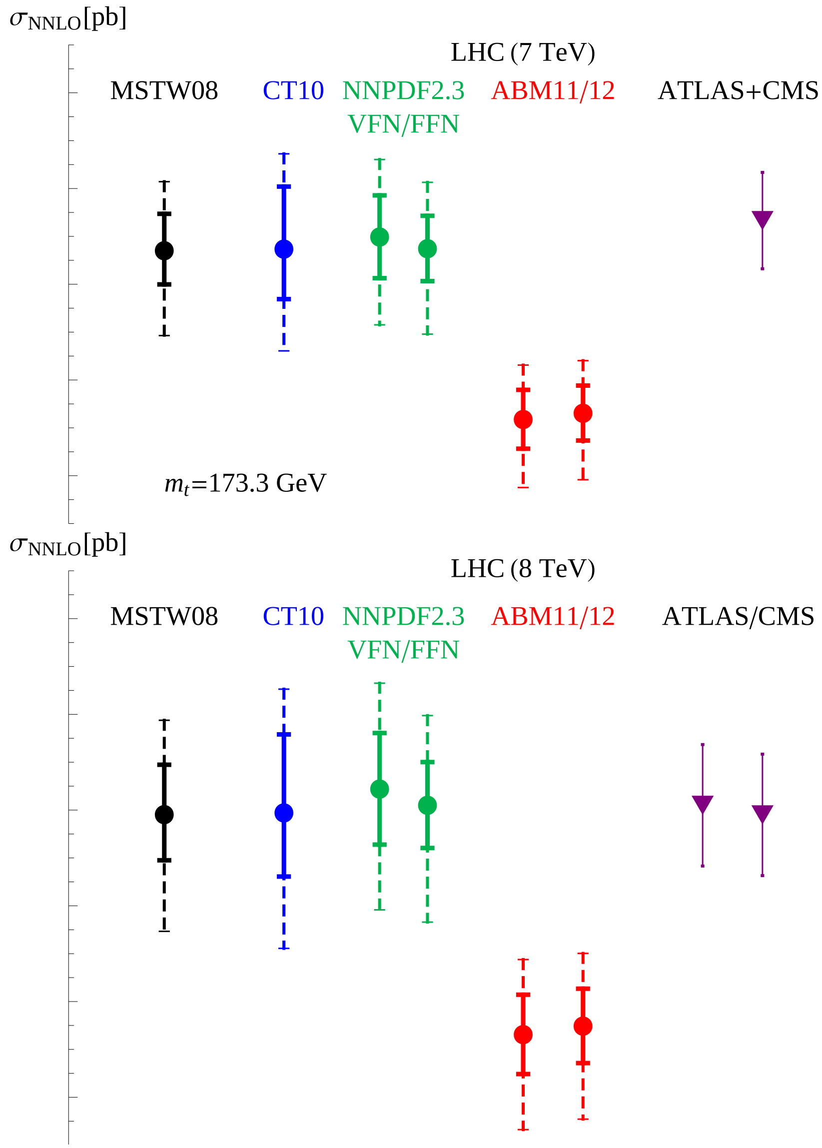


Mass measurement from cross section

Follow method from (ATLAS-CONF-2011-54)

Fit m_t-dependence of theoretical cross-section:

$$\sigma_{t\bar{t}}^{\text{th}}(m_t) = \left(\frac{172.5}{m_t}\right)^4 \left(c_0 + c_1(m_t - 172.5) + c_2(m_t - 172.5)^2 + c_3(m_t - 172.5)^3\right) \text{ pb},$$

$$c_0 = 166.5,\ c_1 = -1.15,\ c_2 = 5.1 \times 10^{-3},\ c_3 = 8.5 \times 10^{-5}$$

Use fit of dependence of experimental result on m_t^{MC}

maximize joint likelihood assuming $m_t = m_t^{\text{MC}}$

$$f(m_t) = \int f_{\text{th}}(\sigma|m_t) \cdot f_{\text{exp}}(\sigma|m_t) d\sigma\,,$$

with normalized Gaussians

$$f_{\text{th}} = \frac{1}{\sqrt{2\pi}\Delta\sigma_{t\bar{t}}^{\text{th}}(m_t)} \exp\left[-\frac{\left(\sigma - \sigma_{t\bar{t}}^{\text{th}}(m_t)\right)^2}{2(\Delta\sigma_{t\bar{t}}^{\text{th}}(m_t))^2}\right]$$

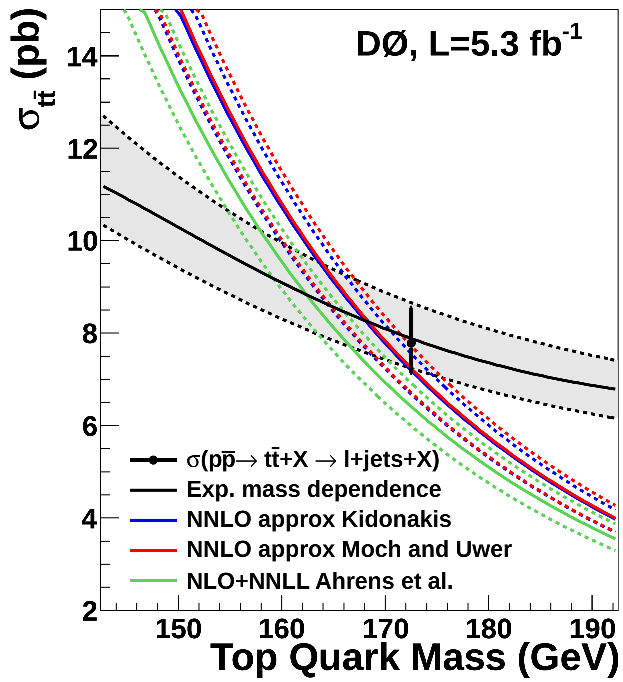
Determine uncertainty from 68% area in upper/lower region;
estimate uncertainty from assumption $m_t = m_t^{\text{MC}}$.

Example: D0 dilepton measurement (arXiv:1105.5384)

$$\sigma_{t\bar{t}}(m_t = 172.5) = 7.56^{+0.63}_{-0.56}\text{pb}$$

Parameterisation of m_t dependence:

$$\sigma_{t\bar{t}}(m_t) = \frac{6.52 \times 10^9 + 7.88 \times 10^7(m_t - 170) + 9.31 \times 10^5(m_t - 170))^2 - 2.42 \times 10^3(m_t - 170)^3}{m_t^4}$$



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Results for NNLO, default PDF value for α_s

	MSTW08	CT10	NNPDF2.3	ABM11
m_t	$170.7^{+5.9}_{-6.8}$	$172.5^{+6.3}_{-7.8}$	$171.8^{+5.4}_{-5.8}$	$168.2^{+5.7}_{-6.2}$

(Compare to D0 result $m_t = 167.5^{+5.2}_{-4.7}$ GeV using $\sigma_{t\bar{t}} = 8.13^{+1.02}_{-0.90}$ pb)

- Effect of m_t dependence of measured $\sigma_{t\bar{t}}$: $171.0^{+4.0}_{-4.1} \to 170.7^{+5.9}_{-6.8}$
- Effect of NNLL prediction: $170.7^{+5.9}_{-6.8} \to 171.5^{+5.4}_{-6.0}$
- Effect of $m_t = m_t^{\text{MC}} \pm 1\,\text{GeV}$: $\Delta m_t = \pm 0.5\,\text{GeV}$

Experimental input with available parameterisation $\sigma_{t\bar{t}}(m_t)$

(Example results for NNLO, MSTW08)

Ref.	$\sqrt{s}$/TeV	$\sigma_{t\bar{t}}(172.5)$/pb	$\frac{d\sigma_{t\bar{t}}}{dm_t}(172.5)$	m_t/GeV
arXiv:1105.5384 (D0)	1.96	$7.56^{+0.63}_{-0.56}$	$-1.1\%\,\mathrm{GeV}^{-1}$	$170.7^{+5.9}_{-6.8}$
ATLAS - Conf - 2011 - 121	7	$179.0^{+11.8}_{-11.7}$	$-0.75\%\,\mathrm{GeV}^{-1}$	$171.4^{+5.5}_{-5.6}$
arXiv:1208.2671 (CMS)	7	$161.9^{+6.7}_{-6.7}$	$-0.80\%\,\mathrm{GeV}^{-1}$	$175.9^{+6.5}_{-5.5}$
ATLAS - CONF - 2013 - 097	8	$237.7^{+11.3}_{-11.3}$	$-0.26\%\,\mathrm{GeV}^{-1}$	$174.0^{+4.1}_{-4.5}$
arXiv:1312.7582 (CMS)	8	$239^{+13.1}_{-13.1}$	$-0.90\%\,\mathrm{GeV}^{-1}$	$174.76^{+7.1}_{-5.7}$

Caveats:

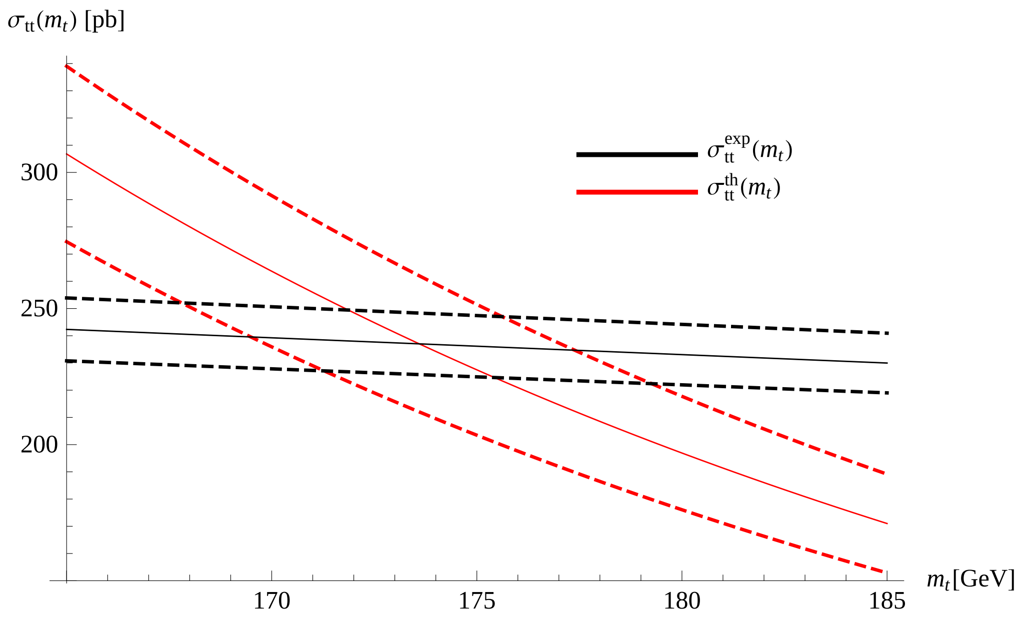
- use constant relative error for experimental cross sections
- use parameterisations $\sigma_{t\bar{t}}(m_t)$ outside domain of validity in normalization of likelihood function

Further potential example measurement (ATLAS - CONF - 2013 - 097)

$$\sigma_{t\bar{t}}(8\text{TeV}) = 237.7^{+11.3}_{-11.3}\text{pb} \qquad \frac{d\sigma_{t\bar{t}}}{dm_t} = -0.26\%\,\text{GeV}^{-1}$$

Results for NNLO, default PDF value for α_s

	MSTW08	CT10	NNPDF2.3	ABM11
m_t	$174.0^{+4.1}_{-4.5}$	$174.3^{+4.9}_{-5.4}$	$174.8^{+4.1}_{-4.4}$	$166.4^{+3.7}_{-4.4}$



Further potential example measurement (ATLAS - CONF - 2013 - 097)

$$\sigma_{t\bar{t}}(8\text{TeV}) = 237.7^{+11.3}_{-11.3}\text{pb} \qquad \frac{d\sigma_{t\bar{t}}}{dm_t} = -0.26\%\,\text{GeV}^{-1}$$

Results for NNLO, default PDF value for α_s

	MSTW08	CT10	NNPDF2.3	ABM11
m_t	$174.0^{+4.1}_{-4.5}$	$174.3^{+4.9}_{-5.4}$	$174.8^{+4.1}_{-4.4}$	$166.4^{+3.7}_{-4.4}$

- Effect of NNLL prediction: $174.0^{+4.1}_{-4.5} \to 174.2^{+3.6}_{-3.9}$
- Effect of $m_t = m_t^{\text{MC}} \pm 1\,\text{GeV}$: $\Delta m_t = \pm 0.1\,\text{GeV}$
- 50% reduction of exp. uncertainty: $174.2^{+3.6}_{-3.9} \to 174.2^{+3.2}_{-3.7}$
- 50% reduction of th. uncertainty: $174.2^{+3.6}_{-3.9} \to 174.0^{+2.5}_{-2.4}$
- 50% reduction of both uncertainties: $174.2^{+3.6}_{-3.9} \to 174.0^{+1.8}_{-1.9}$

Theory predictions

- full NNLO now available
- accuracy of NNLO+NNLL $\pm 3 + 4\%$
- similar PDF+α_s uncertainties

Top pole mass determination from total cross section

- in agreement with kinematical measurements
- currently limited to $\pm 2 - 3\%$ accuracy
- useful measurements not (yet) used for m_t measurement by exp. collaborations are available
- significant improvement requires further reduction of theory+PDF uncertainties