

Probing QCD with top quark-pairs at CMS

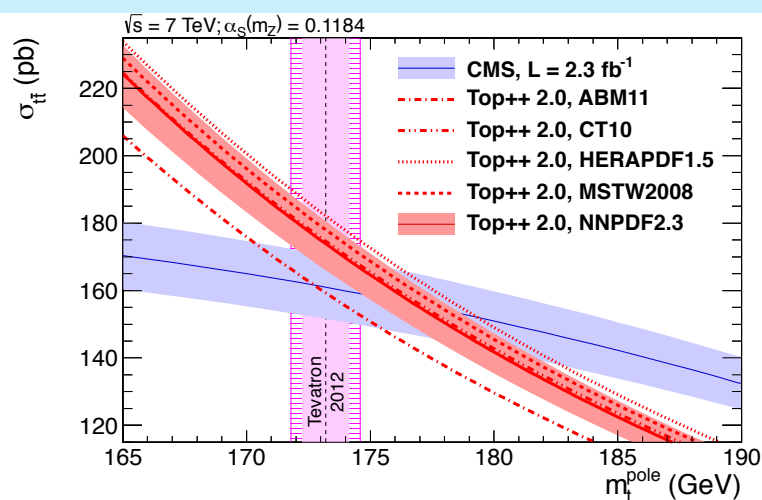
determination of m_t and α_s using top-pair cross section

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The inclusive cross section for top-pair production as measured by the CMS experiment in pp collisions at $\sqrt{s} = 7$ TeV is compared to the QCD prediction at NNLO using various PDF sets. For each PDF set, the pole mass of the top quark, m_t , and the strong coupling constant, $\alpha_s(M_Z)$, are extracted. This is the first determination of $\alpha_s(M_Z)$ from top-quark production.

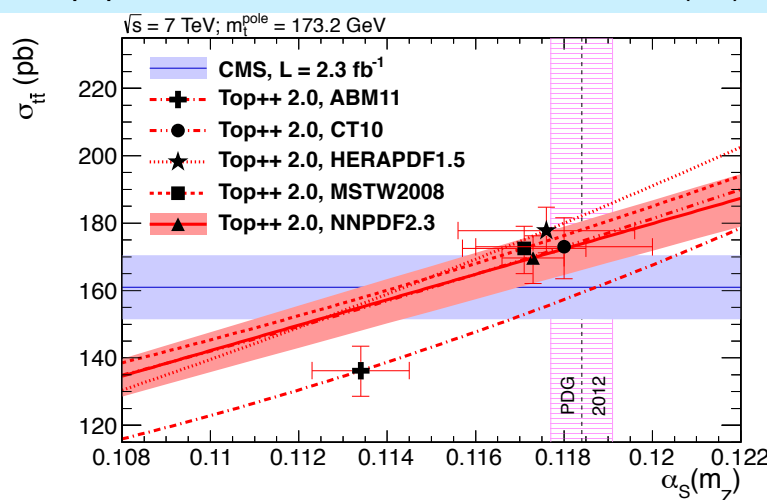
Top-quark pairs at the LHC are produced predominantly in gluon-gluon fusion
The cross section $\sigma_{t\bar{t}}$ depends on the value of m_t , α_s , and the gluon distribution, $g(x)$

Top-pair cross-section as a function of m_t



Dependence $\sigma_{t\bar{t}}^{\text{exp}}(m_t)$ assumes $m_t^{\text{MC}} = m_t^{\text{pole}}$

Top-pair cross-section as a function of $\alpha_s(M_Z)$



Dependence $\sigma_{t\bar{t}}^{\text{exp}}(\alpha_s)$ found to be small

CMS Measurement [1]

$\sigma_{t\bar{t}}^{\text{exp}} = 161.9 \pm 6.7$ pb;
 $m_t^{\text{MC}} = 172.5$ GeV,
 $\alpha_s(M_Z) = 0.1180$
Additional uncertainty of 1 GeV [6]
due to assumption $m_t^{\text{MC}} = m_t^{\text{pole}}$

NNLO + NNLL prediction [2,3]

contains $q\bar{q}, qq', q\bar{q}', qq \rightarrow t\bar{t}+X$
 $qg \rightarrow t\bar{t}+X, gg \rightarrow t\bar{t}+X$
QCD scales: $\mu_r = \mu_f = m_t$
scale variation $0.5\mu < \mu_r, \mu_f < 2\mu$
5 sets of NNLO PDFs used

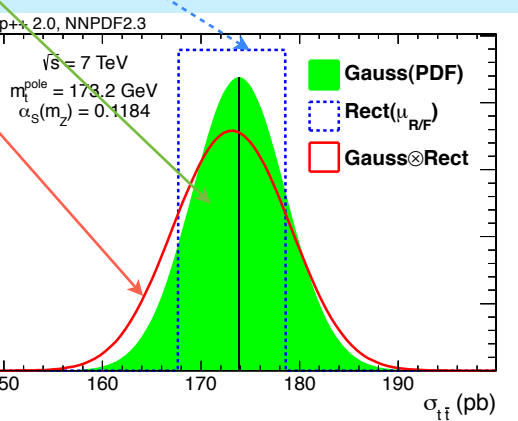
Both m_t and α_s alter the $\sigma_{t\bar{t}}$ prediction such that any variation of one parameter can be compensated by a variation of the other. Therefore simultaneous extraction of α_s and m_t is not possible. For the determination of m_t , α_s is fixed to the world average, $\alpha_s(M_Z) = 0.1184 \pm 0.0007$ [4]. For the determination of α_s , m_t is fixed to the latest Tevatron average, $m_t = 173.18 \pm 0.94$ GeV [5] with an additional uncertainty of 1 GeV [6] due to the assumption $m_t^{\text{MC}} = m_t^{\text{pole}}$.

Probabilistic approach: maximum of marginalized posterior $P(x) = \int f_{\text{exp}}(\sigma_{t\bar{t}}|x) f_{\text{th}}(\sigma_{t\bar{t}}|x) d\sigma_{t\bar{t}}$, $x = m_t$ or $\alpha_s(M_Z)$

Probability function for predicted cross section

$$f_{\text{th}}(\sigma_{t\bar{t}}) = \mathcal{G}(\delta_{\text{PDF}}) \otimes \text{rect}(\sigma_{t\bar{t}}| \sigma_{t\bar{t}}^{(l)}, \sigma_{t\bar{t}}^{(h)}) = \frac{1}{2(\sigma_{t\bar{t}}^{(h)} - \sigma_{t\bar{t}}^{(l)})} \left(\text{erf} \left[\frac{\sigma_{t\bar{t}}^{(h)} - \sigma_{t\bar{t}}}{\sqrt{2} \delta_{\text{PDF}}} \right] - \text{erf} \left[\frac{\sigma_{t\bar{t}}^{(l)} - \sigma_{t\bar{t}}}{\sqrt{2} \delta_{\text{PDF}}} \right] \right)$$

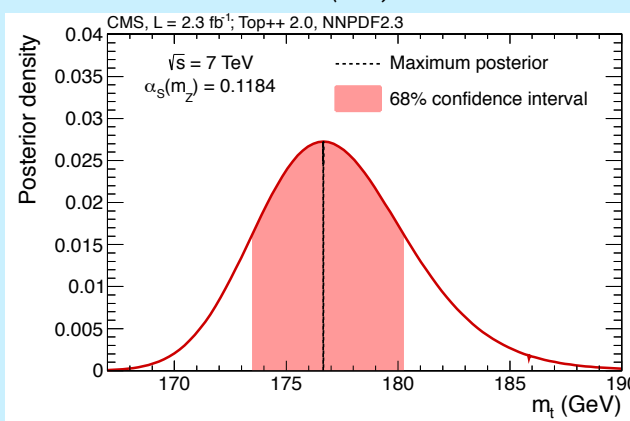
PDF error
68% CL



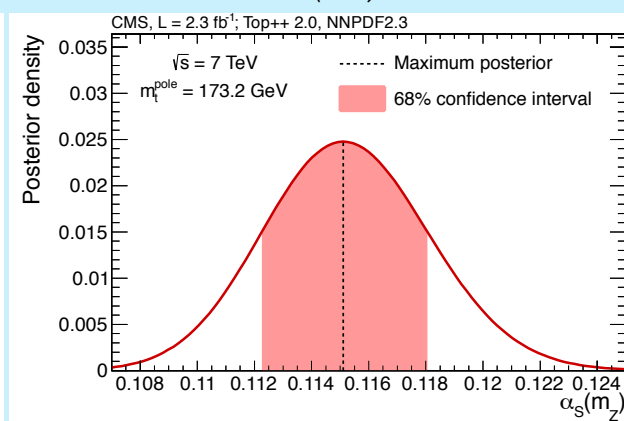
Experimental measurement is represented by Gaussian probability function $f_{\text{exp}}(\sigma_{t\bar{t}})$

Most probable m_t or $\alpha_s(M_Z)$ are obtained from maximum of marginalized posterior:

$P(m_t)$

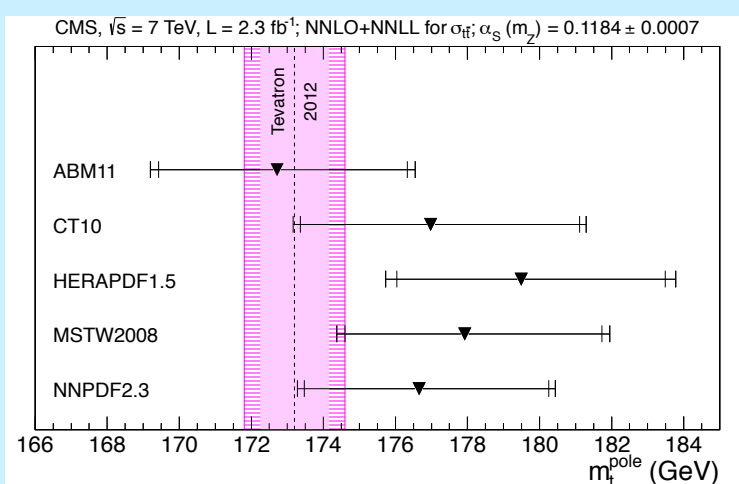


$P(\alpha_s)$

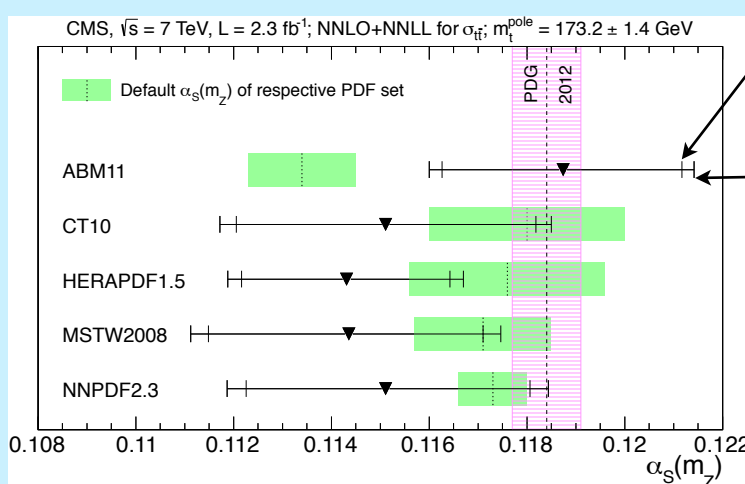


For each PDF set, the most probable values of m_t and $\alpha_s(M_Z)$ are obtained

Values of m_t obtained by confronting $\sigma_{t\bar{t}}^{\text{exp}}$ and $\sigma_{t\bar{t}}^{\text{th}}$



Values of $\alpha_s(M_Z)$ obtained by confronting $\sigma_{t\bar{t}}^{\text{exp}}$ and $\sigma_{t\bar{t}}^{\text{th}}$



inner error bars:
uncertainty on $\sigma_{t\bar{t}}^{\text{exp}}$, $E_{\text{beam}}^{\text{LHC}}$,
PDF and scale variation in $\sigma_{t\bar{t}}^{\text{th}}$
outer error bars: uncertainty on m_t
and $\alpha_s(M_Z)$ (world average)

Results agree with world average

and consistent for different PDFs

Theory uncertainty (scales) $\sim 1\%$

Using NNPDF2.3: pole mass of the top quark $m_t = 176.7^{+3.8}_{-3.4}$ GeV, strong coupling constant $\alpha_s(M_Z) = 0.1151^{+0.0033}_{-0.0032}$