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Probing QCD with top-quark pairs at CMS

determination of m_t and α_S using top-pair cross section

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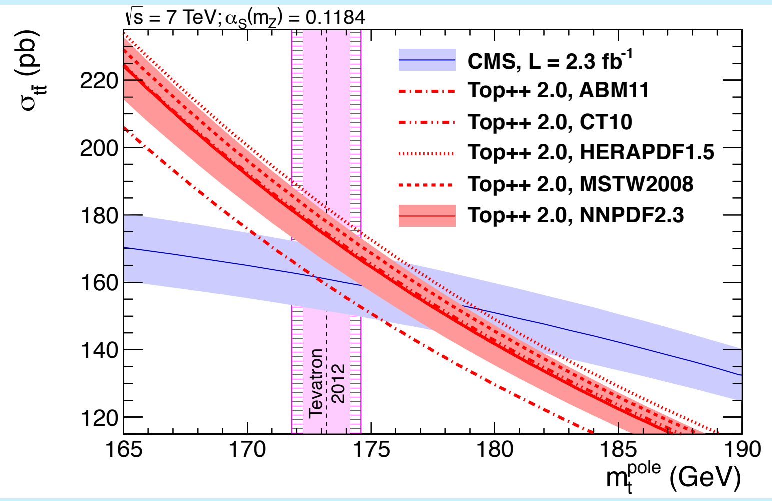
The inclusive cross section for top-pair production as measured by the CMS experiment in pp collisions at $\sqrt{s}$ = 7 TeV is compared to the QCD prediction at NNLO using various PDF sets. For each PDF set, the pole mass of the top quark, m_t, and the strong coupling constant, α_S (M_Z), are extracted.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

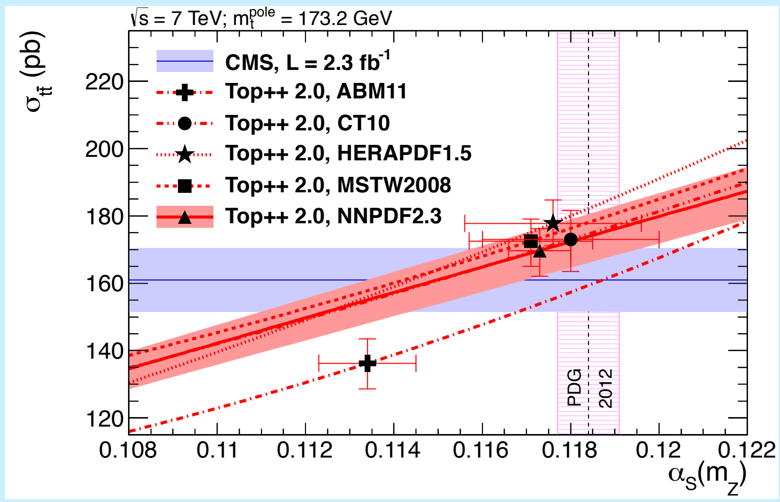
Top-quark pairs at the LHC are produced predominantly in gluon-gluon fusion
The cross section σ_{tt} depends on the value of m_t, α_S, and the gluon distribution, $g(x)$

Top-pair cross-section as a function of m_t



Dependence $\sigma^{exp}_{t\bar{t}}$ (m_t) assumes $m_t^{MC} \equiv m_t^{pole}$

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



Dependence $\sigma^{exp}_{t\bar{t}}$ (α_S) found to be small

CMS Measurement [1]

$\sigma^{exp}_{t\bar{t}}$ = 161.9 ± 6.7 pb;
m_t^{MC} = 172.5 GeV,
$\alpha_S(M_Z)$ = 0.1180
Additional uncertainty of 1 GeV [6] due to assumption $m_t^{MC} \equiv m_t^{pole}$

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

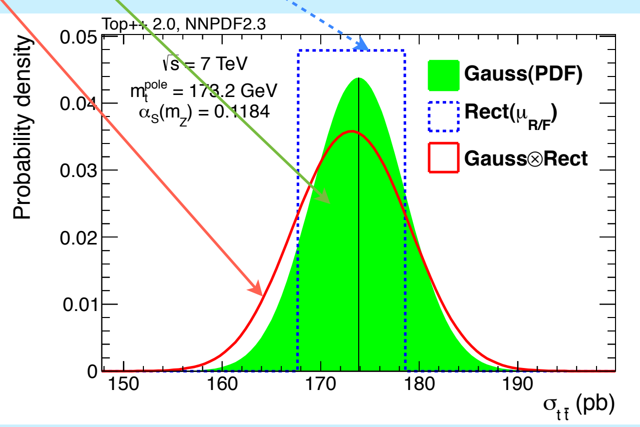
Both m_t and α_S alter the σ_{tt} prediction such that any variation of one parameter can be compensated by a variation of the other. Therefore simultaneous extraction of α_S and m_t is not possible. For the determination of m_t, α_S is fixed to the world average, $\alpha_S(M_Z)$= 0.1184 ± 0.0007 [4].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

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

Probability function for predicted cross section

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

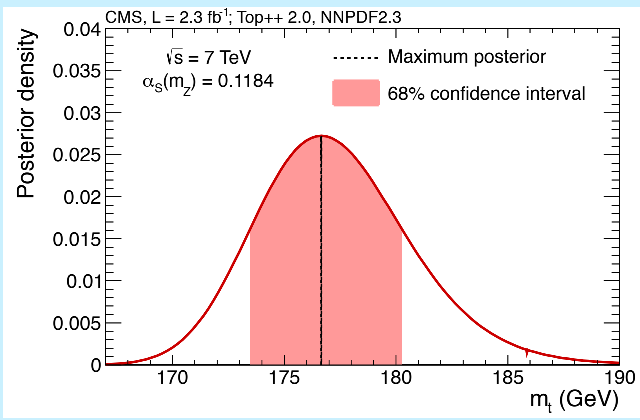
PDF error 68% CL — scale variation



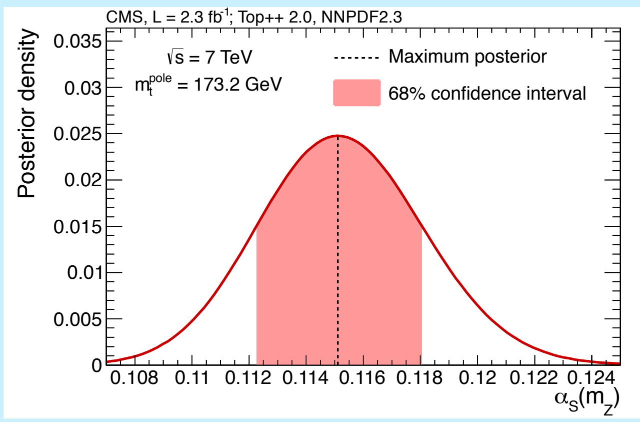
Experimental measurement is represented by Gaussian probability function $f_{exp}(\sigma_{t\bar{t}})$

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

P (m_t)

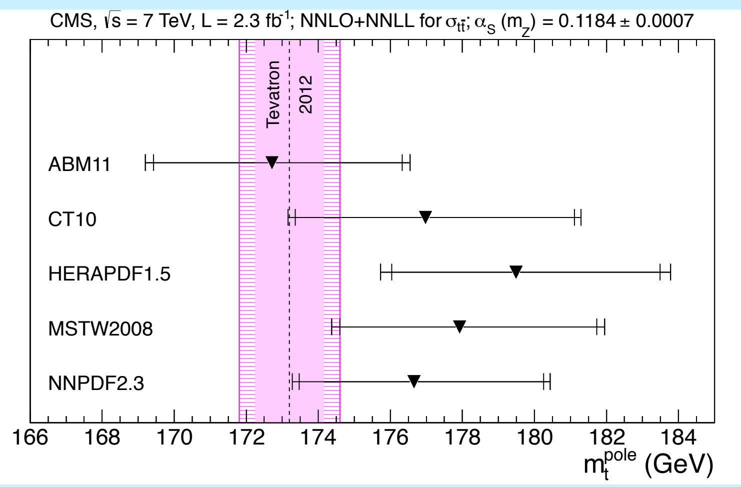


P (α_S)

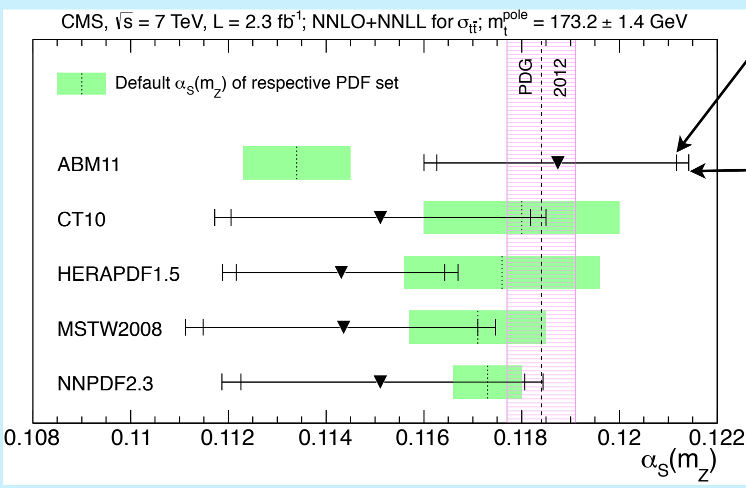


For each PDF set, the most probable values of m_t and $\alpha_S(M_Z)$ are obtained

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



Values of α_S (M_Z) obtained by confronting $\sigma^{exp}_{t\bar{t}}$ and $\sigma^{th}_{t\bar{t}}$



inner error bars: uncertainty on $\sigma^{exp}_{t\bar{t}}$, E_{beam}^{LHC}, PDF and scale variation in $\sigma^{th}_{t\bar{t}}$

outer error bars: uncertainty on m_t and α_S (M_Z) (world average)

Results agree with world average

and consistent for different PDFs

Theory uncertainty (scales) ~1%

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

CMS Collaboration arXiv:1307.1907
CERN-PH-EP-2013-121

References:
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[2] M.Czakon, P. Fiedler, A.Mitov [arXiv:1303.6254]
[3] M.Czakon, A.Mitov, TOP++ [arXiv:1112.5675]
[4] PDG, Phys.Rev.D. 86 (2012) 010001
[5] CDF and DO Collaborations, Phys.Rev.D 86 (2012) 092003
[6] A. Buckley et al., Phys. Rept. 504 (2011) 145