11^{th} International Workshop on Top Quark Physics

September 19, 2018

Extraction of top quark mass and strong coupling constant from inclusive $\mathrm{t\bar{t}}$ cross section

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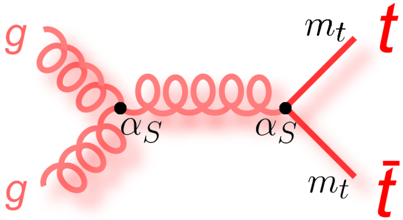
on behalf of the CMS Collaboration

calculations of $\mathrm{t\bar{t}}$ production depend on:

1. strong coupling α_S
2. top quark mass m_t
3. gluon (quark) PDF in the proton

→ measurements of $\sigma_{\mathrm{t\bar{t}}}$ can be used to constrain these parameters



strong coupling

- α_S known with sub-percent precision
- significant contribution to uncertainty for several QCD predictions
- can be measured at NNLO from $\sigma_{\mathrm{t\bar{t}}}$ (at NLO from hadronic production)

top quark mass

- consistency test of Standard Model
- can be determined in well defined scheme ($\overline{\mathrm{MS}}$, on-shell) from $\sigma_{\mathrm{t\bar{t}}}$ (see talk by Paolo Nason)
- avoid interpretation problems of m_t^MC (see talk by André Hoang)

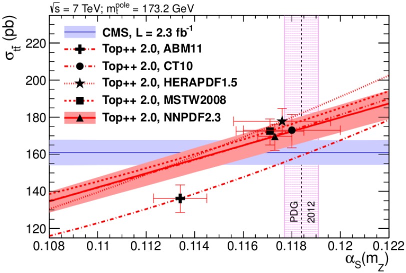
→ **NB:** α_S and m_t cannot be determined simultaneously from inclusive $\sigma_{\mathrm{t\bar{t}}}$

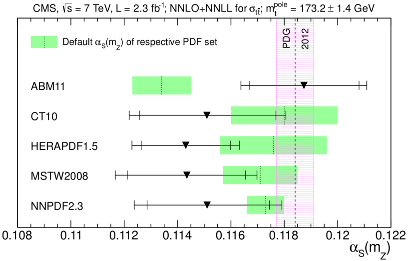
determination of $\alpha_S(M_Z)$ from $\sigma_{t\bar{t}}$ at 7 TeV

Phys. Lett. B 728 (2013) 496

- using CMS measurement at 7 TeV in dilepton channel with 2.3 fb^{-1}, 4.1% accuracy (JHEP 11 (2012) 067)
- theory prediction with Top++2.0, NNLO+NNLL precision
- several different PDF sets considered
- $\alpha_S(M_Z)$ varied consistently in calculation and PDF
- experimental dependence of $\sigma_{t\bar{t}}$ on $\alpha_S(M_Z)$ found to be negligible
- assumed $m_t^{\text{pole}} = 173.2 \pm 1.4$ GeV (Tevatron average $\oplus$ 1 GeV to account for difference between m_t^{pole} and m_t^{MC})

$$\alpha_S(M_Z) = 0.1151\ ^{+0.0028}_{-0.0027} \quad \text{(NNPDF2.3)}$$





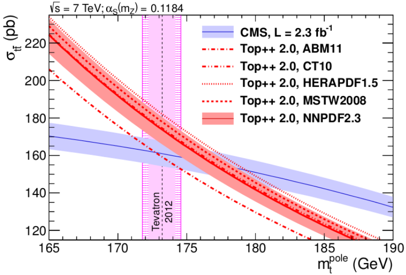
Phys. Lett. B 728 (2013) 496

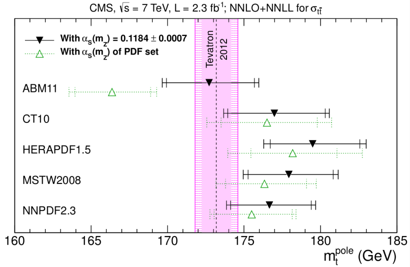
- same procedure used to extract m_t^{pole}
- assumed world average strong coupling: $\alpha_S(M_Z) = 0.1184 \pm 0.0007$
- measured $\sigma_{t\bar{t}}$ depends on m_t^{MC} through acceptance corrections
- effect has to be taken into account

assumption: $m_t^{\text{pole}} = m_t^{\text{MC}} \pm 1\,\text{GeV}$

- additional uncertainty corresponding to 1 GeV added to measured $\sigma_{t\bar{t}}$

$$m_t^{\text{pole}} = 176.7\ ^{+3.0}_{-2.8}\ \text{GeV} \quad (\text{NNPDF2.3})$$

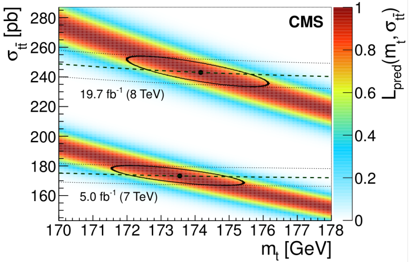




determination of $m_t^{\rm pole}$ from $\sigma_{t\bar{t}}$ at 7+8 TeV

JHEP 08 (2016) 029

- simultaneous measurement of $\sigma_{t\bar{t}}$ at 7 and 8 TeV with template fit of final state distributions
- similar $m_t^{\rm pole}$ determination as in 7 TeV measurement
- $m_t^{\rm pole}$ determined separately from $\sigma_{t\bar{t}}$ at 7 and 8 TeV
- results combined taking correlations into account



	m_t [GeV]
NNPDF3.0	$173.8^{+1.7}_{-1.8}$
MMHT2014	$174.1^{+1.8}_{-2.0}$
CT14	$174.3^{+2.1}_{-2.2}$

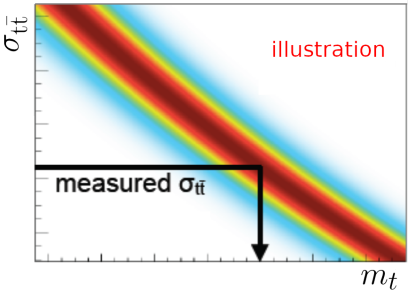
	m_t [GeV]	
	7 TeV	8 TeV
NNPDF3.0	$173.5^{+1.9}_{-2.0}$	$174.2^{+2.0}_{-2.2}$
MMHT2014	$173.9^{+2.0}_{-2.1}$	$174.4^{+2.1}_{-2.3}$
CT14	$174.1^{+2.2}_{-2.4}$	$174.6^{+2.3}_{-2.5}$

- simultaneous fit of $\sigma_{t\bar{t}}$ and m_t^{MC}
- $\sigma_{t\bar{t}}$ determined at **optimal mass point**

→ see my talk on Monday

- dependence of $\sigma_{t\bar{t}}$ on m_t^{MC} mitigated
- uncertainty on $\sigma_{t\bar{t}}$ includes contribution from m_t^{MC}
- no assumption on relation between m_t^{MC} and m_t needs to be made

PRL 116 (2016) 16 162001



calculations of $\sigma_{t\bar{t}}$

- Hathor2.0 at NNLO precision
- several NNLO PDF sets considered
- $\overline{\rm MS}$ scheme adopted for m_t
  → faster perturbative convergence
  (see EPJC 74 (2014) 11 3167)
- soft gluon resummation not included

CMS-PAS-TOP-17-001

measurement results

$$\sigma_{t\bar{t}} = 815 \pm 2\,(\text{stat}) \pm 29\,(\text{syst}) \pm 20\,(\text{lum})\ \text{pb}$$

$$m_t^{MC} = 172.33 \pm 0.14\,(\text{stat}) \pm^{0.66}_{0.72}\,(\text{syst})\ \text{GeV}$$

extraction of $\alpha_S(M_Z)$ from $\sigma_{t\bar{t}}$ at 13 TeV

CMS-PAS-TOP-17-001

parameters determined from data/theory χ^2

α_S and m_t cannot be determined simultaneously

$\Rightarrow$ m_t fixed to native value of PDF

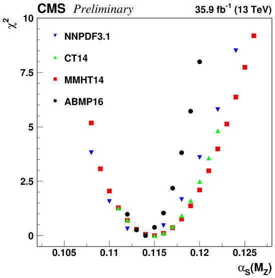
uncertainties

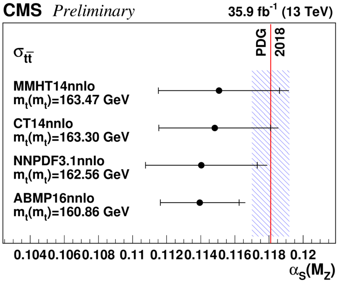
- experimental: from $\sigma_{t\bar{t}}$ measurement
- PDF: from eigenvectors
- scale: μ_r and μ_f variations by factor of 2

results

- challenging precision on $\alpha_S(M_Z)$, most precise from $\sigma_{t\bar{t}}$ to date
- better precision with ABMP16

$$\alpha_S(M_Z) = 0.1139\ ^{+0.0027}_{-0.0023} \quad \text{(ABMP16)}$$





CMS-PAS-TOP-17-001

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uncertainties

- experimental: from $\sigma_{t\bar{t}}$ measurement
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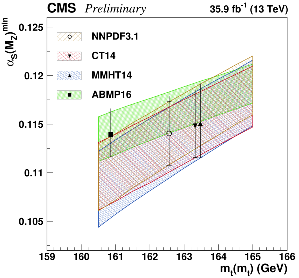
- scale: μ_r and μ_f variations by factor of 2

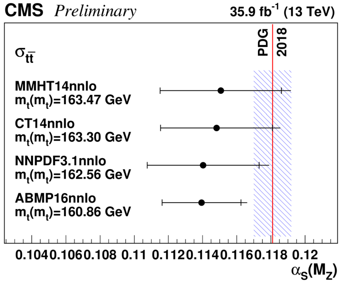
results

- dependence of extracted α_S vs m_t investigated $\rightarrow$ linear
- somehow flatter in case of ABMP16

cross-check

- cross-checked with Top++ (on-shell) as in EPJC 77 (2017) 11 778
- comparable results obtained





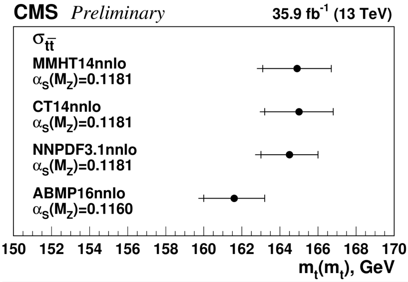
CMS-PAS-TOP-17-001

- same procedure used to extract top mass in $\overline{\mathrm{MS}}$ scheme, $m_t(m_t)$
- $\alpha_S(M_Z)$ fixed at native values of PDF

results

- most precise direct determination of $m_t(m_t)$, to date
- lower m_t result with ABMP16 due to lower $\alpha_S(M_Z)$ in PDF determination

$$m_t(m_t) = 161.6\ ^{+1.6}_{-1.9}\ \text{GeV (ABMP16)}$$



extraction of $m_t(m_t)$ from $\sigma_{t\bar{t}}$ at 13 TeV

CMS-PAS-TOP-17-001

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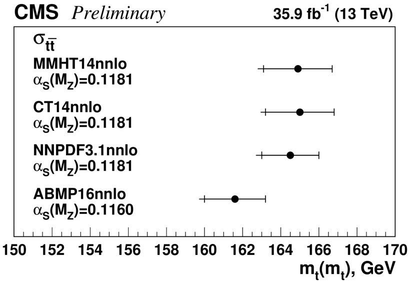
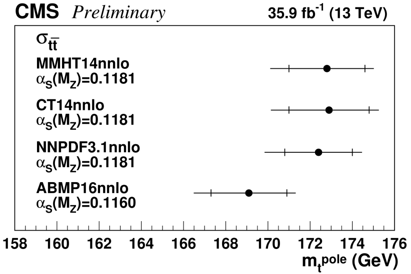
$$m_t(m_t) = 161.6\ ^{+1.6}_{-1.9}\ \text{GeV}\ (\mathrm{ABMP16})$$

pole mass m_t^{pole}

- results consistent with previous measurements
- uncertainties not competitive (scale) due to missing NNLL corrections





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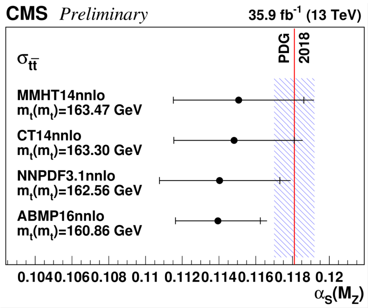
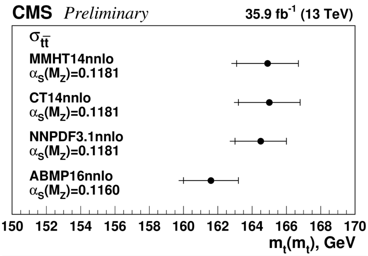
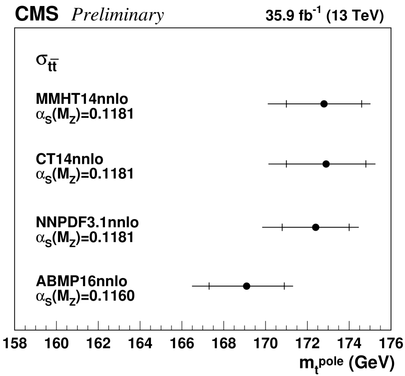
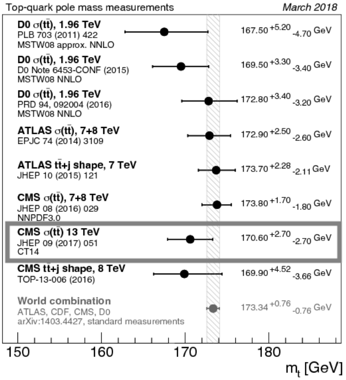




BACKUP

determination of m_t^{pole} from $\sigma_{t\bar{t}}$ at 13 TeV





$$m_t^{\mathrm{pole}} = 172.9 \,^{+2.4}_{-2.8}\ \mathrm{GeV} \quad (\mathrm{CT14})$$

- results consistent with previous measurements at Tevatron and LHC

numerical values for $\alpha_S(M_Z)$ with Hathor2.0

CMS-PAS-TOP-17-001

top quark mass in $\overline{\mathrm{MS}}$ scheme

PDF set (NNLO)	$\alpha_S^{\min}(M_Z)$
ABMP16	0.1139 ± 0.0023 (fit + PDF) $^{+0.0014}_{-0.0001}$ (scale)
NNPDF3.1	0.1140 ± 0.0033 (fit + PDF) $^{+0.0021}_{-0.0002}$ (scale)
CT14	0.1148 ± 0.0032 (fit + PDF) $^{+0.0018}_{-0.0002}$ (scale)
MMHT14	0.1151 ± 0.0035 (fit + PDF) $^{+0.0020}_{-0.0002}$ (scale)

top quark mass in on-shell scheme

PDF set (NNLO)	$\alpha_S^{\min}(M_Z)$
ABMP16	0.1164 ± 0.0021 (fit + PDF) $^{+0.0024}_{-0.0014}$ (scale)
NNPDF3.1	0.1184 ± 0.0027 (fit + PDF) $^{+0.0037}_{-0.0021}$ (scale)
CT14	0.1186 ± 0.0028 (fit + PDF) $^{+0.0034}_{-0.0019}$ (scale)
MMHT14	0.1205 ± 0.0029 (fit + PDF) $^{+0.0037}_{-0.0021}$ (scale)

CMS-PAS-TOP-17-001

top quark $\overline{\mathrm{MS}}$ mass

PDF set (NNLO)	$m_t(m_t)$ [GeV]
ABMP16	161.6 ± 1.6 (fit + PDF + α_S) $^{+0.1}_{-1.0}$ (scale)
NNPDF3.1	164.5 ± 1.5 (fit + PDF + α_S) $^{+0.1}_{-1.0}$ (scale)
CT14	165.0 ± 1.7 (fit + PDF) ± 0.6 (α_S) $^{+0.1}_{-1.0}$ (scale)
MMHT14	164.9 ± 1.7 (fit + PDF) ± 0.5 (α_S) $^{+0.1}_{-1.1}$ (scale)

top quark pole mass

PDF set (NNLO)	m_t^{pole} [GeV]
ABMP16	169.1 ± 1.8 (fit + PDF + α_S) $^{+1.3}_{-1.9}$ (scale)
NNPDF3.1	172.4 ± 1.6 (fit + PDF + α_S) $^{+1.3}_{-2.0}$ (scale)
CT14	172.9 ± 1.8 (fit + PDF) ± 0.7 (α_S) $^{+1.4}_{-2.0}$ (scale)
MMHT14	172.8 ± 1.7 (fit + PDF) ± 0.6 (α_S) $^{+1.3}_{-2.0}$ (scale)

$\alpha_S(M_Z)$ and m_t in different PDF sets

CMS-PAS-TOP-17-001

PDF set (NNLO)	ABMP16	NNPDF3.1	CT14	MMHT14
m_t^{pole}	170.37 GeV	172.5 GeV	173.3 GeV	174.2 GeV
RunDec conversion	3 loops	2 loops	2 loops	3 loops
$m_t(m_t)$	160.86 GeV	162.56 GeV	163.30 GeV	163.47 GeV
$\alpha_S(m_Z)$	0.116	0.118	0.118	0.118
α_S range	0.112–0.120	0.108–0.124	0.111–0.123	0.108–0.128