Deutsches Elektronen-Synchrotron - CMS experiment

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Determination of the top quark mass and the strong coupling constant using $\mathrm{t\bar{t}}$ events at the centre-of-mass energy of 13 TeV with the CMS experiment

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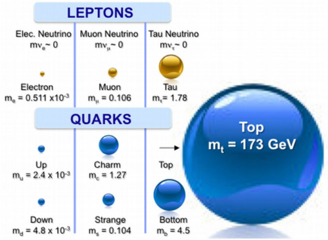
why top mass

- free parameter of the Standard Model Lagrangian ⇒ provides **consistency test** of the electroweak sector in the Standard Model
- **enters theory predictions** beyond leading order through top loops
- directly related to Higgs boson coupling
- implications on stability of electroweak vacuum ⇒ **handle to physics beyond SM**



top mass definitions: m_t^{MC}, m_t^{pole}, $m_t^{\overline{MS}}$

- mass from direct measurement (m_t^{MC}) not theoretically well-defined ⇒ additional $\mathcal{O}(\mathrm{GeV})$ uncertainty (arXiv:1412.3649, arXiv:1608.01318)
- $\mathcal{O}(\Lambda_{QCD})$ renormalon ambiguity in m_t^{pole} definition (arXiv:1605.03609)
- **short-distance mass** ($m_t^{\overline{MS}}$) resums higher order logarithms ⇒ converges faster than pole mass (arXiv:1305.6422)

ultimate goal: measure $m_t^{\overline{MS}}(\mu)$ as a function of a given scale μ

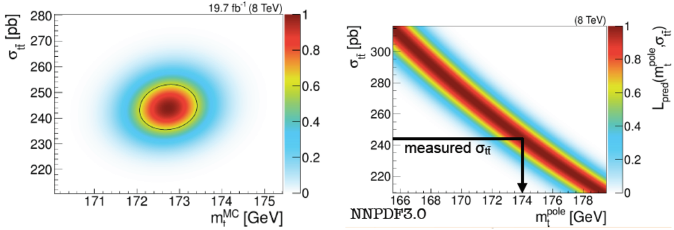
$\rightarrow$ for example $\mu = m(t\bar{t})$

strategy

- simultaneously extract $\sigma_{t\bar{t}}$ and m_t^{MC} from template fits to final state distributions
- compare $\sigma_{t\bar{t}}^{obs}$ to fixed-order theory prediction to extract top mass in well defined renormalization scheme

$\rightarrow$ with this procedure the dependence of the result on the m_t^{MC} is mitigated

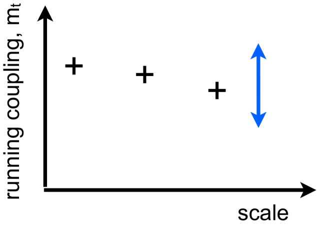
CMS-TS-2016-007



m_t^{MC} extraction and status of the development

challenge: measure $\simeq 4\%$ effect

- reconstruct top kinematics to determine the scale of the process
- **constrain systematic uncertainties** *in situ* to achieve better precision



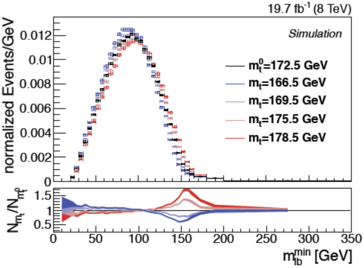
state of the art

- extract $m_t^{\overline{MS}}(m_t)$ from inclusive cross section using the 2016 dataset
- no scale dependence, no kinematic reconstruction

determination of m_t^{MC}

- m_t^{MC} included as free parameter of the fit
- m_{lb}^{min} distribution sensitive to the m_t assumption in the MC

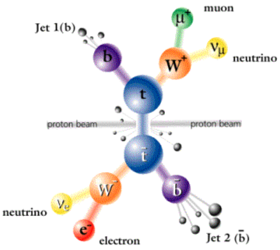
CMS-TS-2016-007



dataset: full 2016 dataset (35.9 fb^{-1})

final state: fully leptonic $\mathrm{t\bar{t}}$ - $e\mu$ channel

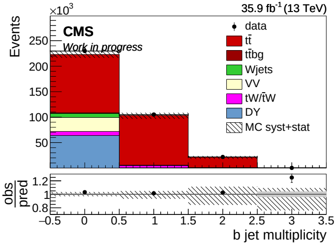
Leptons	$p_{T,1} > 25$ GeV $p_{T,2} > 20$ GeV $m_{ll} > 20$ GeV
Jets	$p_T > 30$ GeV



b-tagging: tight selection → classify events

events split in **12 mutually exclusive categories** according to:

1. number of b-tags
2. number of additional jets



strategy and details

- χ^2 fit to final state distributions
- $t\bar{t}$ topology exploited to constrain systematic uncertainties
- event categorization improves constraining power of the fit

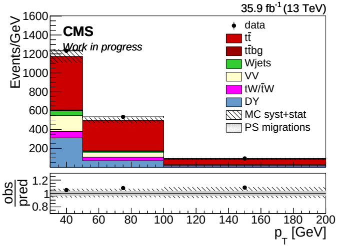
systematic uncertainties

- systematic uncertainties treated as nuisance parameters of the fit
- bg normalization constrained in data

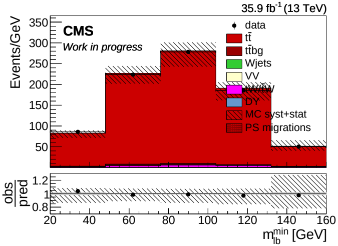
choice of fit distributions

	0 jets	1 jets	2 jets	3 jets
0 b-tags	yield	jet p_T	jet p_T	jet p_T
1 b-tags	yield	m_{lb}^{min}	m_{lb}^{min}	jet p_T
2 b-tags	yield	m_{lb}^{min}	m_{lb}^{min}	jet p_T

0 b-tags, 1 add. jets



1 b-tag, 2 add. jets



expected results (blinded measurement)

highest contrib. to m_t^{MC} uncert.

systematic source	contrib. [GeV]
jet ES	**0.41**
$t\bar{t}$ ME scale	**0.17**
top p_T	0.12
NLO generator	0.12
ME/PS matching	0.12
stat	0.11
total	**0.47**

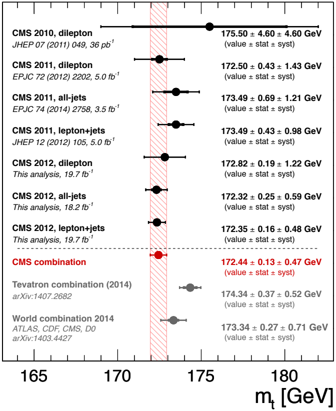
CMS *Work in progress*

$$\sigma_{t\bar{t}} = 8xx.x \pm 1.7\ (\text{stat})\ {}^{+32.5}_{-30.6}\ (\text{syst})\ \text{pb}$$

$$m_t^{MC} = 17x.xx \pm 0.11\ (\text{stat}) \pm 0.46\ (\text{syst})\ \text{GeV}$$

- **competitive precision** compared to previous measurements
- dominant systematics: jet energy scale and $t\bar{t}$ matrix element scale

CMS-TOP-14-022

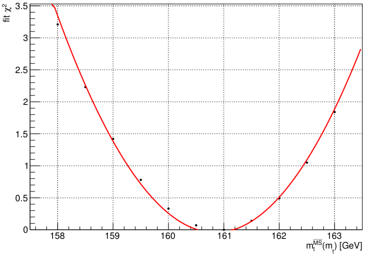


- theory predictions obtained with **Hathor**
- **ABMP16 NNLO** pdf set
  (consistent treatment of $m_t^{\overline{MS}}$ in pdf determ.)
- using $\sigma_{t\bar{t}}$ result from combined fit

uncertainties

- experimental: from $\sigma_{t\bar{t}}$ fit (contains m_t^{MC})
- PDF: from eigenvectors (α_s still missing)
- theory: from envelope of 6 possible μ_r and μ_f variations by factor of 2

CMS *Work in progress*



χ^2 profile - parabolic fit

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$$m_t^{\overline{MS}}(m_t) = 16x.x \pm 1.5\ (\text{exp} \oplus \text{pdf})\ ^{+0.1}_{-0.9}\ (\text{scale})\ \text{GeV}$$

latest result quoted in PDG:

- $m_t^{\overline{MS}} = 160\ ^{+5}_{-4}\ \text{GeV}$ $\rightarrow$ improved by a factor of 3

details and uncertainties:

- same setup used for $m_t^{\overline{MS}}$ extraction
- $m_t(m_t) = 160.86$ GeV
  (for consistency with ABMP16 pdf extraction)

CMS *Work in progress*

$$\alpha_s(M_Z) = 0.11xx \pm 0.0018\ (\text{fit})\ {}^{+0.0013}_{-0.0002}\ (\text{scale})$$

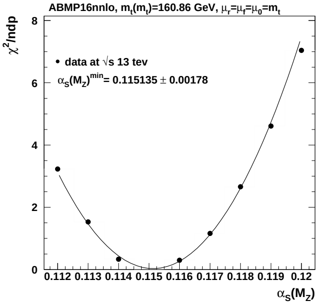
- consistent results with different pdf sets
- uncertainty from m_t^{MC} automatically taken into account (combined fit with $\sigma_{t\bar{t}}$)

latest result from DIS: (arXiv:1709.07251)

- $\alpha_s(M_Z) = 0.1142 \pm 0.0028$ (first NNLO result from hadron collider - inclusive jet production)

$\rightarrow$ **improved precision with results from $\sigma_{t\bar{t}}$**

CMS *Work in progress*



summary of the results

- simultaneous fit of $\sigma_{t\bar{t}}$ and m_t^{MC} is performed with 2016 data
- expected results are found to be **competitive with previous measurements**

- $m_t^{\overline{MS}}$ is extracted from $\sigma_{t\bar{t}}$ by comparing to NNLO theory predictions
- sensible improvement with respect to previous results is expected
- same method used to extract α_s, precision found to be competitive

outlook

- analysis is being reviewed in CMS and the **results are being unblinded**

Thank you!