$\overline{\text{MS}}$ mass determination of the top quark

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The Top Quark

- Pole Mass of the top quark:

$$m_t = 173.1 \pm 0.6 \ (\text{stat.}) \pm 1.1 \ (\text{syst.}) \,\text{GeV}$$

[Tevatron Electroweak Working Group and CDF Collaboration and D0 Collab], arXiv:0903.2503 [hep-ex].

- Production mechanisms on the partonic level:
$gg \to t\bar{t}$, $q\bar{q} \to t\bar{t}$ @ all orders, $gq \to t\bar{t}$ @ N^kLO, $k \geq 1$

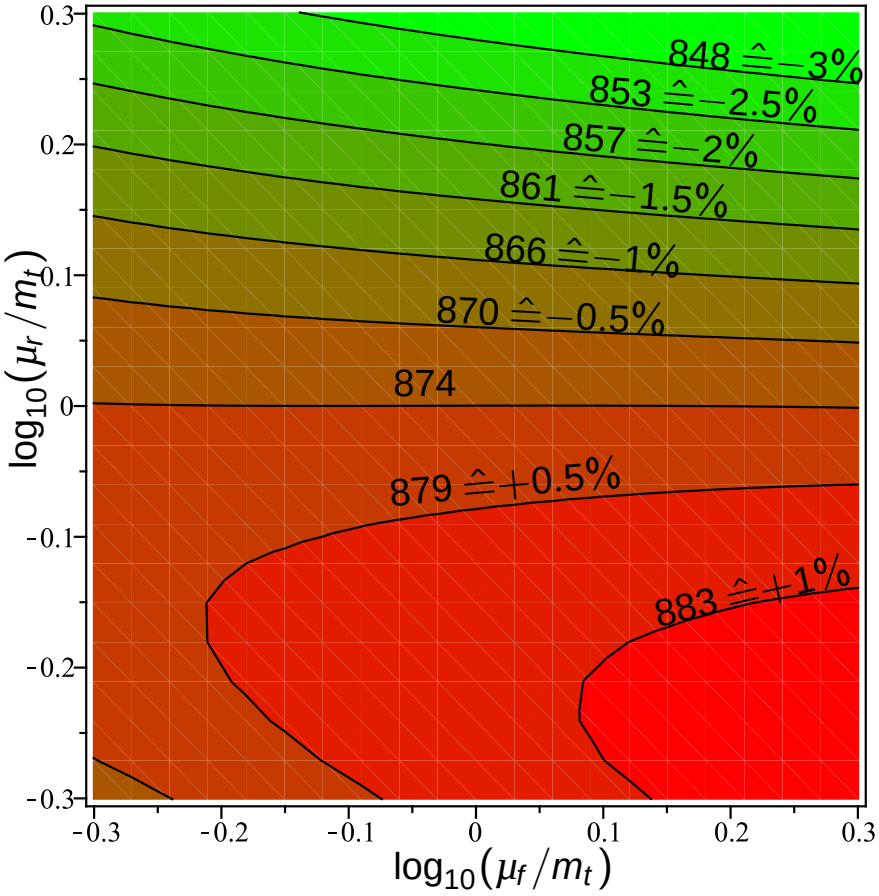
- Measured pair production cross section at the Tevatron:

$$\sigma(p\bar{p} \to t\bar{t}) = 7.0 \pm 0.3 \ (\text{stat.}) \pm 0.4 \ (\text{syst.}) \pm 0.4 \ (\text{lumi.}) \,\text{pb}$$

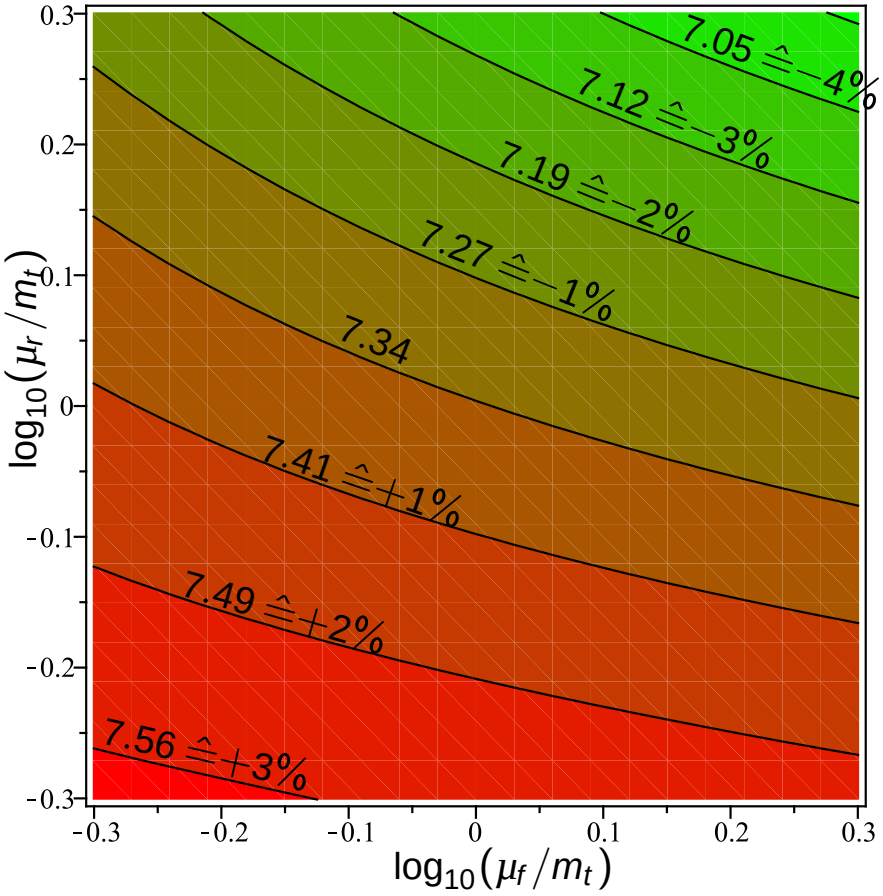
A. Lister [CDF and D0 Collaborations], arXiv:0810.3350 [hep-ex].

Theoretical Prediction of the $t\bar{t}$ cross section at NNLO

Contour lines of the total hadronic cross section for top pair production in the μ_f - μ_r - plane in pb, $m_t = 173\,\text{GeV}$, PDF set: CTEQ6.6 ($\log_{10}$ - scale)



LHC



Tevatron

Theoretical Prediction of the $t\bar{t}$ cross section at NNLO

Total cross section prediction for $m_t = 173\,\text{GeV}$:

- Tevatron @ 1.96 TeV:

$$\sigma(p\bar{p} \to t\bar{t}) = 7.34^{+0.23}_{-0.38}\,\text{pb}\ \text{(scale)}\ ^{+0.41}_{-0.41}\ \text{(CTEQ6.6)}$$

$$\sigma(p\bar{p} \to t\bar{t}) = 7.04^{+0.24}_{-0.36}\,\text{pb}\ \text{(scale)}\ ^{+0.14}_{-0.14}\ \text{(MSTW2008)}$$

- LHC @ 14 TeV:

$$\sigma(pp \to t\bar{t}) = 874^{+12}_{-33}\,\text{pb}\ \text{(scale)}\ ^{+28}_{-28}\ \text{(CTEQ6.6)}$$

$$\sigma(pp \to t\bar{t}) = 887^{+12}_{-33}\,\text{pb}\ \text{(scale)}\ ^{+15}_{-15}\ \text{(MSTW2008)}$$

Why $\overline{\text{MS}}$ Mass?

- The top quark is a coloured particle.
  We do not observe free top quarks due to confinement!

  $\Rightarrow$ The S-matrix cannot have a pole at the top mass
- the self energy of heavy quarks receives contributions from all loop momenta, also from momenta of $\mathcal{O}(\Lambda_{\text{QCD}})$
- QCD perturbation theory valid for $q^2 \gg \Lambda^2_{\text{QCD}}$
- pole mass cannot be a good concept to understand the top quark, renormalon contribution, perturbation theory indicates problems
- introduce scale dependent effective mass $\overline{m}(\mu_r)$ ($\overline{\text{MS}}$ - mass).

$$\frac{\mathrm{d}\,\overline{m}(\mu_r)}{\mathrm{d}\,\ln(\mu_r)} = \gamma \overline{m}(\mu_r)$$

  γ: anomalous mass dimensions
- Conversion: $m_t = m(\mu_r)\left[1 + \alpha_s(\mu_r) d^{(1)} + \alpha_s(\mu_r)^2 d^{(2)}\right]$

The top-quark mass in the $\overline{\text{MS}}$ scheme

- $\overline{\text{MS}}$ mass provides a well defined mass scheme $\longrightarrow$ cf. $b\bar{b}$ - physics
- Measurement of total $t\bar{t}$ cross section (done at Tevatron)
- Compare measurement with theory prediction $\sigma(\overline{m}(\mu_r), \mu_r, \mu_f)$:

  Our Analysis: $\overline{m} = 160.0^{+3.3}_{-3.2}\,\text{GeV}$

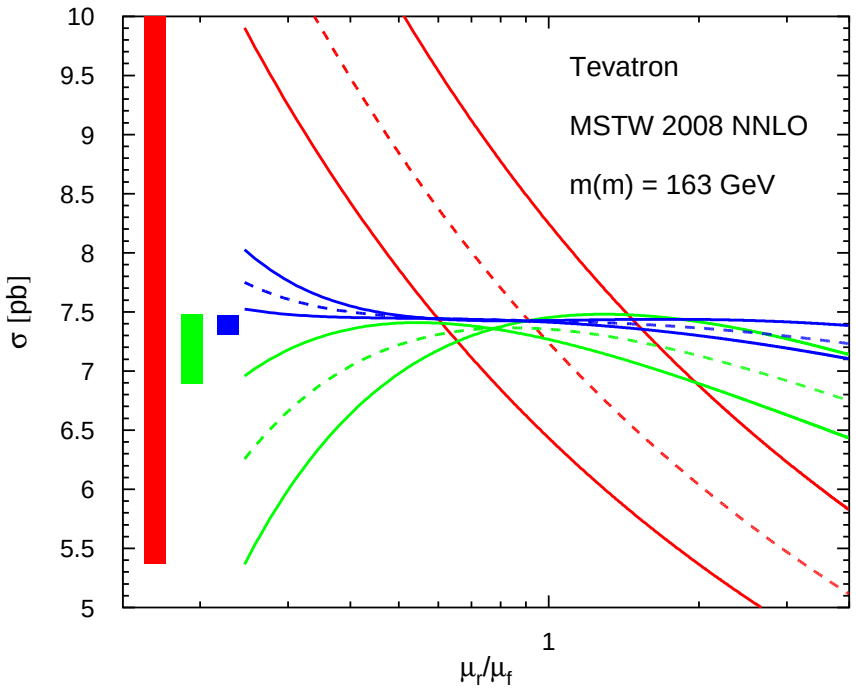
  first direct determination of the top $\overline{\text{MS}}$ mass [U. L., S. Moch, P. Uwer '09]
- convert $\overline{\text{MS}}$ mass $\overline{m}$ into pole mass m_t

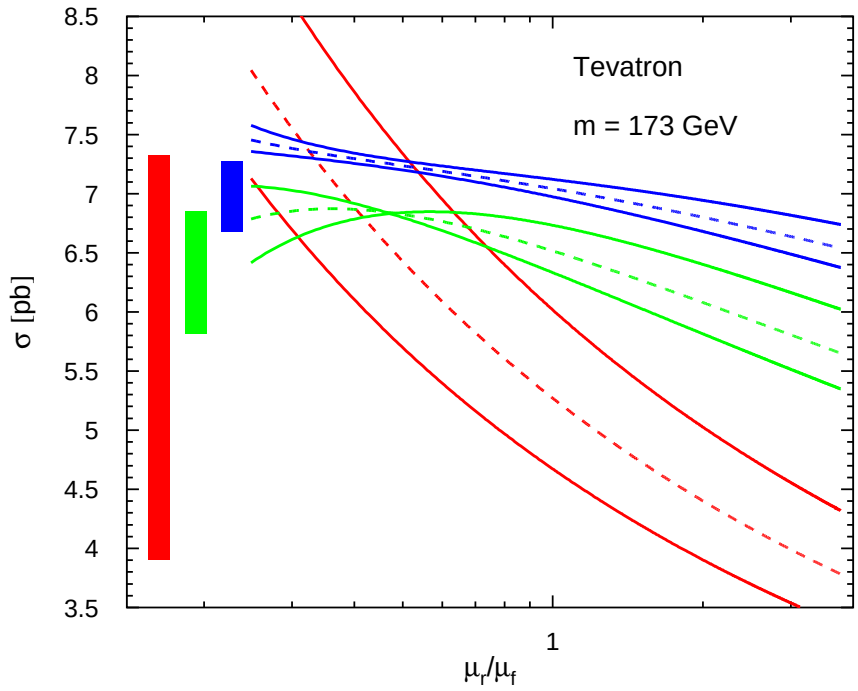
  Our Analysis: $m_t = 168.9^{+3.5}_{-3.4}\,\text{GeV}$

  world average: $m_t = 173.1^{+1.3}_{-1.3}\,\text{GeV}$

The top-quark mass in the $\overline{\text{MS}}$ scheme

- scale dependence significantly reduced
- even at NLO





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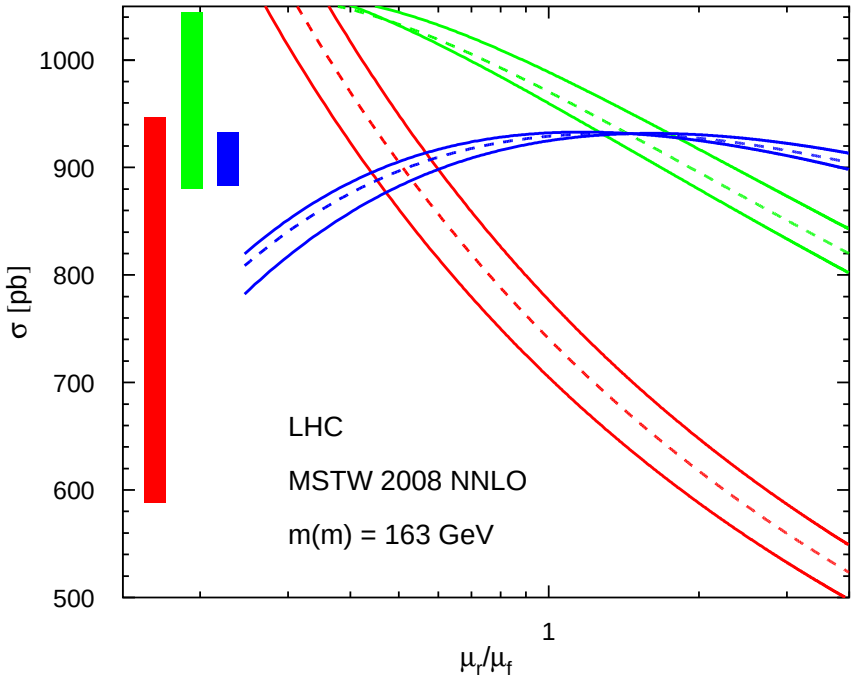
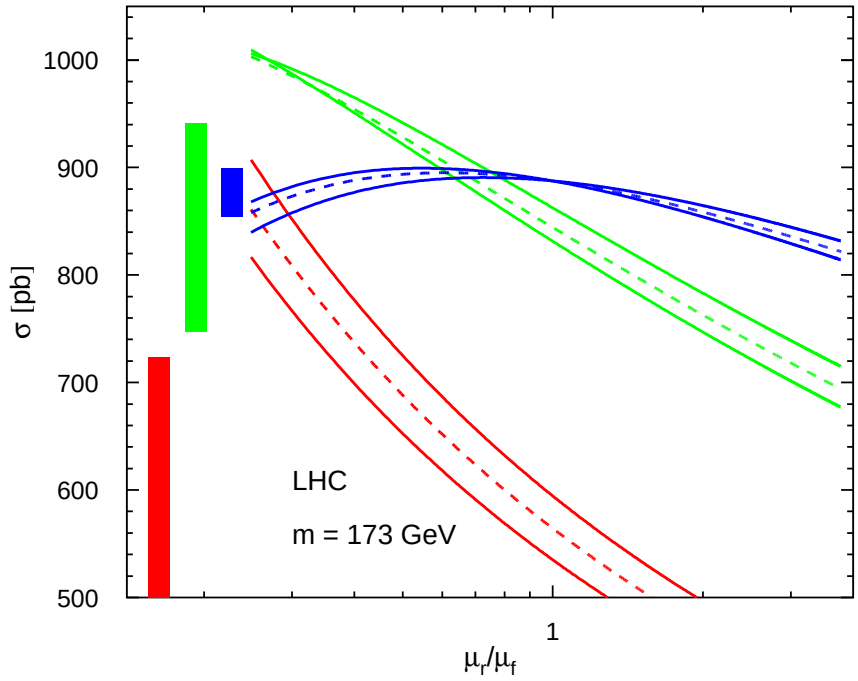
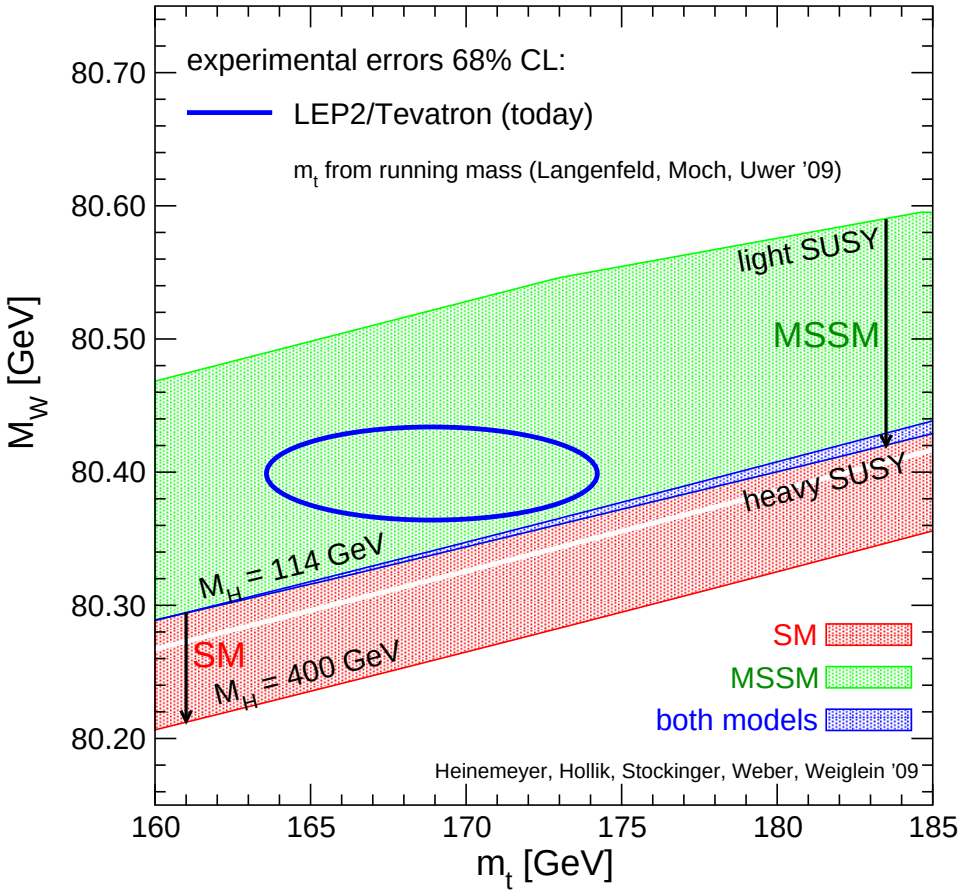




Consequences

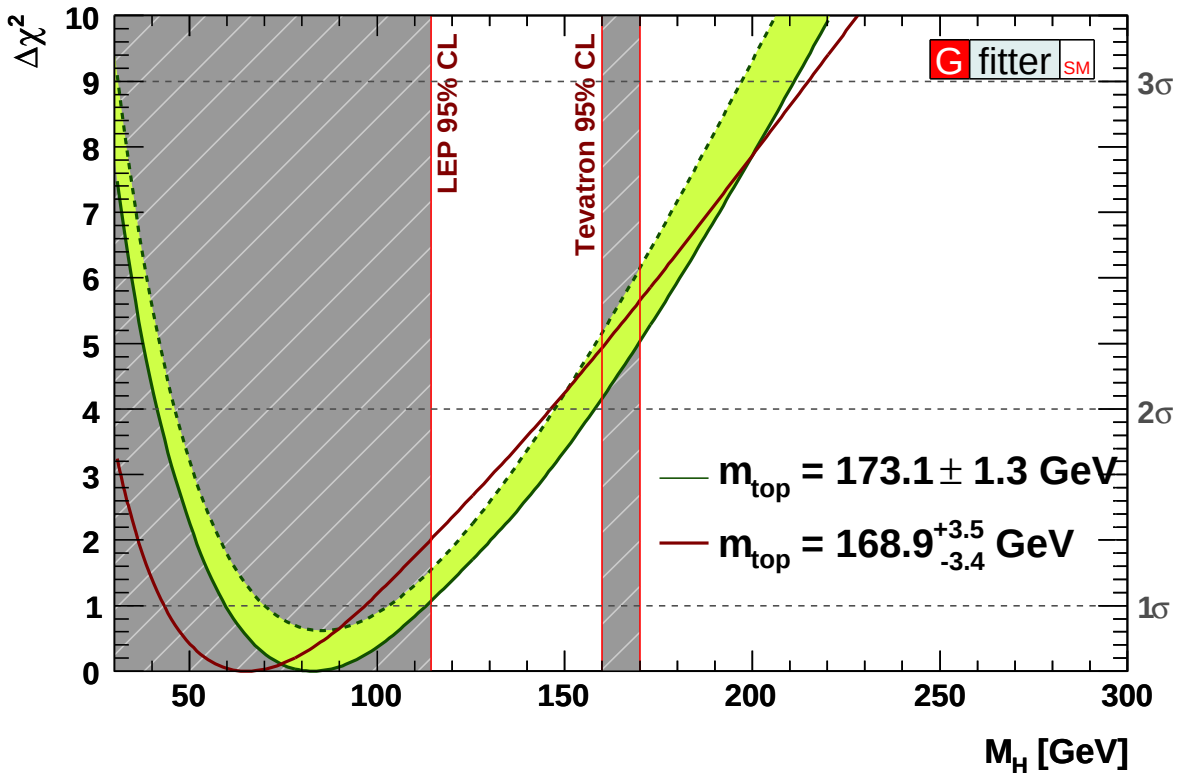
- Look at the influence of a lighter top mass (pole mass $m_t = 168.9\,\text{GeV}$) on electroweak precision data [Heinemeyer, Hollik, Weber, Weiglein '09]



- lighter top mass favours the MSSM

Consequences

- Electroweak precision data constrain the Higgs mass:



- a lighter top mass disfavours the SM Higgs sector

Summary

- We provide an approximation of the total hadronic NNLO cross section for the Tevatron and the LHC and different PDF sets.
- We determined for the first time the $\overline{\text{MS}}$ mass of the top quark from the total cross section measured at the Tevatron

$$\overline{m} = 160.0^{+3.3}_{-3.2}\,\text{GeV}$$

- This value corresponds to a pole mass of the top quark of

$$m_t = 168.9^{+3.5}_{-3.4}\,\text{GeV}.$$

- A lighter top mass disfavours the SM Higgs sector.