Status of c- and b-quark mass determinations

Discussion at the session "*Masses of the Heavy Quarks*"

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Lattice meets Continuum:
QCD Calculations in Flavour Physics

Workshop

Kulturhaus Lyz, Siegen, Germany, September 29 – October 2, 2014

September 30, 2014

Overview of computational approaches (see previous talks)

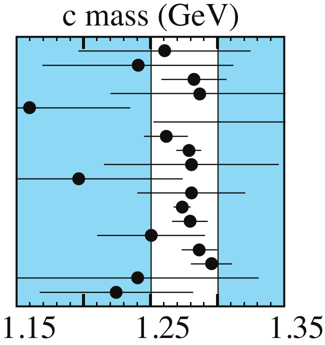
- Continuum QCD approaches to determine heavy quark masses
  - Variants of QCD sum rules:
    relativistic, non-relativistic, Borel, momentum, ...
  - Fitting DIS scattering data, decay spectra, ... to PT predictions

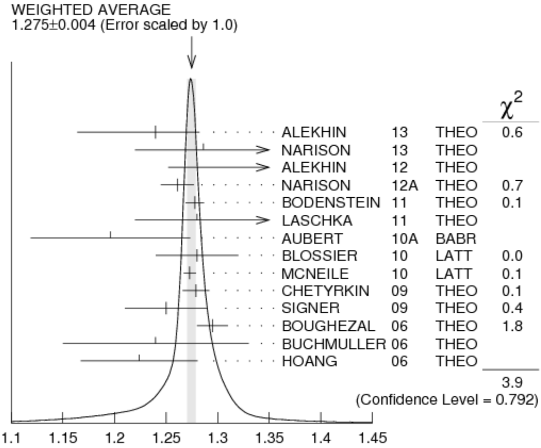
- Lattice QCD approaches to determine heavy quark masses
  - Via input from hadron spectroscopy with relativistic quarks (charm; e.g. ETMC, ALPHA)
  - Current-current correlator method with HISQ discretization: continuum limit of time-moments of a LQCD heavyonium correlator compared to continuum QCD PT for the vacuum polarization function (charm & bottom; HPQCD)
  - Interpolation between relativistic data in the charm mass region and the static limit of HQET (bottom)
  - Ratio method: interpolation of the relativistic heavy-light meson to quark mass ratio to its exactly known static limit (bottom; ETMC)
  - Non-perturbative HQET including $1/m_h$–terms (bottom; ALPHA)
  - From binding energies of b-hadrons in NRQCD (bottom; HPQCD)

m_c

Particle Data Group 2014 (from continuum determinations):

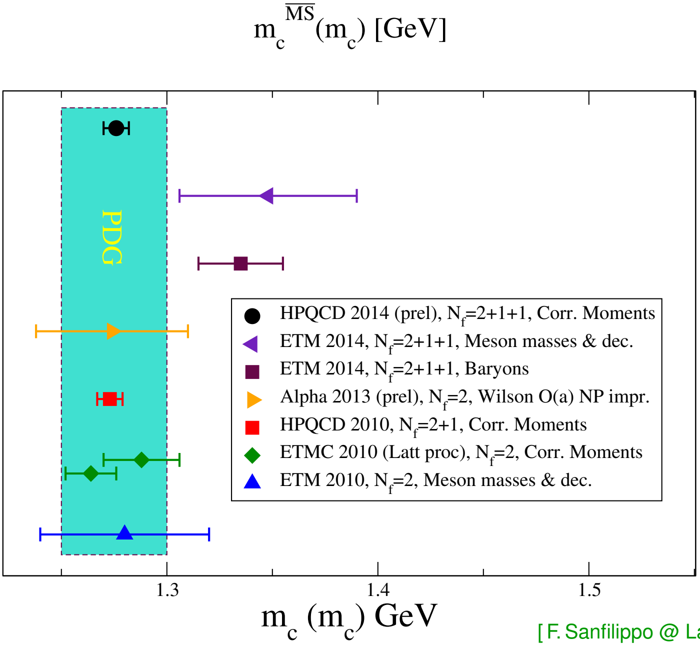
$$\overline{m}_c^{\overline{MS}}(\overline{m}_c^{\overline{MS}}) = 1.275(25)\text{ GeV}$$





[2014 Review of Particle Physics: K.A. Olive et al. (PDG), Chin. Phys. C, 38, 090001 (2014)]

m_c: Status @ Lattice 2014



[F. Sanfilippo @ Lattice 2014]

m_c: Recent results

Continuum:

$\overline{m}_c^{\overline{MS}}(\overline{m}_c^{\overline{MS}}) = 1.26(6)$ GeV — charm production cross section in DIS ep (H1 & ZEUS, arXiv:1211.1182)

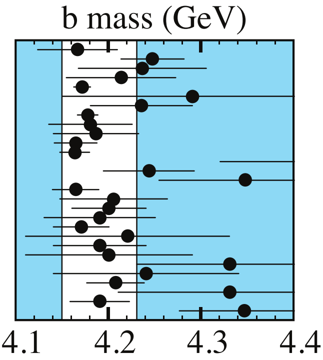
Lattice:

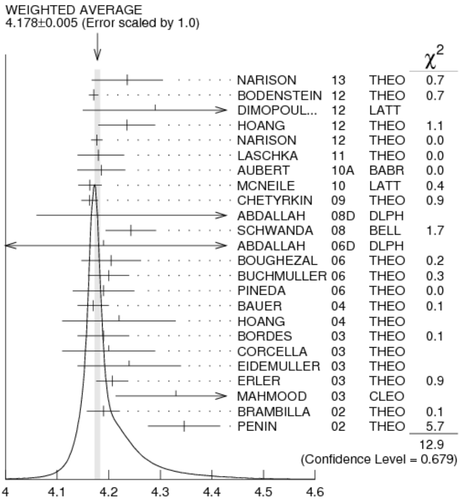
$\overline{m}_c^{\overline{MS}}(\overline{m}_c^{\overline{MS}}) = 1.348(42)$ GeV — $N_f = 2+1+1$, tmQCD + mixed action (ETMC, arXiv:1403.4504)

$\overline{m}_c^{\overline{MS}}(\overline{m}_c^{\overline{MS}}) = 1.281(11)$ GeV — $N_f = 2+1+1$, HISQ PS-PS CFs (HPQCD, arXiv:1408.4169)

Particle Data Group 2014 (from continuum determinations):

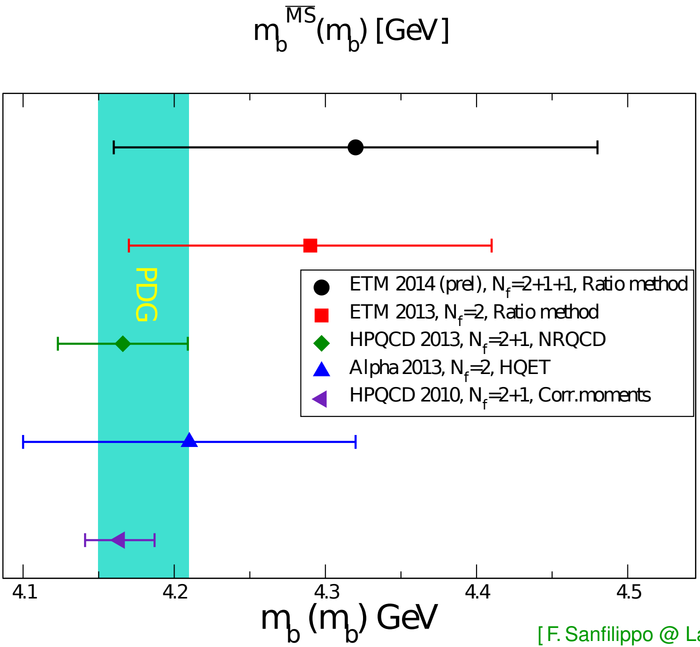
$$\overline{m}_b^{\overline{MS}}(\overline{m}_b^{\overline{MS}}) \;=\; 4.18(3)\ \text{GeV}$$





[2014 Review of Particle Physics: K.A. Olive et al. (PDG), Chin. Phys. C, 38, 090001 (2014)]

m_b: Status @ Lattice 2014



[F. Sanfilippo @ Lattice 2014]

m_b: Recent results

Continuum:

$\overline{m}_b^{\overline{MS}}(\overline{m}_b^{\overline{MS}}) = 4.247(34)$ GeV — sum rules + f_B lattice input (Lucha et al., arXiv:1305.7099)

Lattice:

$\overline{m}_b^{\overline{MS}}(\overline{m}_b^{\overline{MS}}) = 4.29(12)$ GeV — $N_f = 2$, tmQCD (ETMC, arXiv:1308.1851)

$\overline{m}_b^{\overline{MS}}(\overline{m}_b^{\overline{MS}}) = 4.21(11)$ GeV — $N_f = 2$, Wilson + NP HQET incl. $1/m_h$ (ALPHA, arXiv:1311.5498)

$\overline{m}_b^{\overline{MS}}(\overline{m}_b^{\overline{MS}}) = 4.166(43)$ GeV — $N_f = 2 + 1$, ASQTAD-stagg. + NRQCD (HPQCD, arXiv:1302.3739)

$\overline{m}_b^{\overline{MS}}(\overline{m}_b^{\overline{MS}}) = 4.174(24)$ GeV — $N_f = 2 + 1 + 1$, HISQ PS-PS CFs (HPQCD, arXiv:1408.4169)

$\overline{m}_b^{\overline{MS}}(\overline{m}_b^{\overline{MS}}) = 4.196(23)$ GeV — $N_f = 2 + 1 + 1$, HISQ + NRQCD (HPQCD, arXiv:1408.5768)

Issues / Questions

- What are the optimal ways to compare the continuum and lattice results on (heavy) quark masses ?
  - $\overline{\mathrm{MS}}$ scheme at some common scale, e.g. at $m = \overline{m}_h$ itself or higher
  - RGI masses; quark mass ratios, where Z–factors cancel
- Reliable estimation of the different sources of uncertainties involved: control of discretization errors, neglected higher-order terms, ... ?
- Why do we need accurate heavy quark masses and, in particular, how accurate do they need to be ?
- Which accuracy is feasible now and in future for heavy quark masses with continuum and lattice methods ?

$\rightarrow$ Current most precise results:

$$\overline{m}_c^{\overline{\mathrm{MS}}}(\overline{m}_c^{\overline{\mathrm{MS}}}) = 1.273(6)\ \mathrm{GeV} \qquad \text{(HPQCD 2010)}$$

$$\overline{m}_b^{\overline{\mathrm{MS}}}(\overline{m}_b^{\overline{\mathrm{MS}}}) = 4.163(16)\ \mathrm{GeV} \qquad \text{(Karlsruhe 2009)}$$

$\rightarrow$ E.g., for their impact on precision Higgs physics at future experiments (LHC and particularly ILC), see Lepage et al., arXiv:1404.0319:

- reducing a to 0.023 fm brings parametric errors for the Higgs couplings below those expected from the full LHC