



$$I(J^P) = 0(\frac{1}{2}^+)$$

$$\text{Charge} = \frac{2}{3} e \quad \text{Charm} = +1$$

## c-QUARK MASS

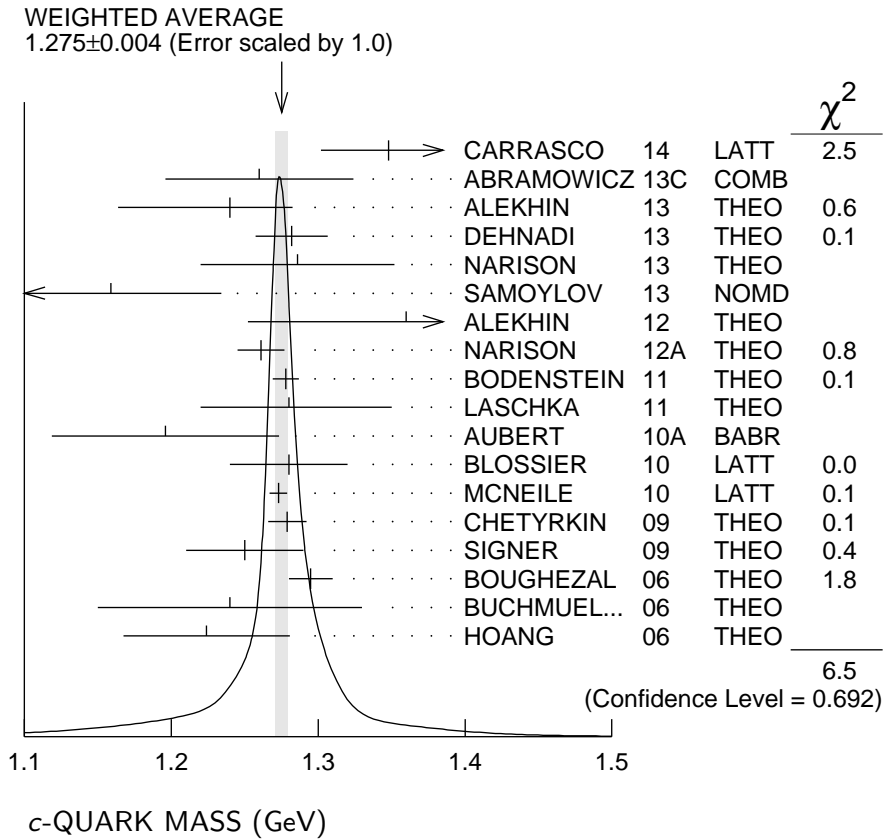
The  $c$ -quark mass corresponds to the “running” mass  $m_c(\mu = m_c)$  in the  $\overline{\text{MS}}$  scheme. We have converted masses in other schemes to the  $\overline{\text{MS}}$  scheme using two-loop QCD perturbation theory with  $\alpha_s(\mu = m_c) = 0.38 \pm 0.03$ . The value  $1.275 \pm 0.025$  GeV for the  $\overline{\text{MS}}$  mass corresponds to  $1.67 \pm 0.07$  GeV for the pole mass (see the “Note on Quark Masses”).

VALUE (GeV)	DOCUMENT ID	TECN	COMMENT
<b>1.275 ± 0.025 OUR EVALUATION</b>	See the ideogram below.		
1.348 ± 0.046	<sup>1</sup> CARRASCO 14	LATT	$\overline{\text{MS}}$ scheme
1.26 ± 0.05 ± 0.04	<sup>2</sup> ABRAMOWICZ13C	COMB	$\overline{\text{MS}}$ scheme
1.24 ± 0.03 <sup>+0.03</sup> <sub>-0.07</sub>	<sup>3</sup> ALEKHIN 13	THEO	$\overline{\text{MS}}$ scheme
1.282 ± 0.011 ± 0.022	<sup>4</sup> DEHNADI 13	THEO	$\overline{\text{MS}}$ scheme
1.286 ± 0.066	<sup>5</sup> NARISON 13	THEO	$\overline{\text{MS}}$ scheme
1.159 ± 0.075	<sup>6</sup> SAMOYLOV 13	NOMD	$\overline{\text{MS}}$ scheme
1.36 ± 0.04 ± 0.10	<sup>7</sup> ALEKHIN 12	THEO	$\overline{\text{MS}}$ scheme
1.261 ± 0.016	<sup>8</sup> NARISON 12A	THEO	$\overline{\text{MS}}$ scheme
1.278 ± 0.009	<sup>9</sup> BODENSTEIN 11	THEO	$\overline{\text{MS}}$ scheme
1.28 <sup>+0.07</sup> <sub>-0.06</sub>	<sup>10</sup> LASCHKA 11	THEO	$\overline{\text{MS}}$ scheme
1.196 ± 0.059 ± 0.050	<sup>11</sup> AUBERT 10A	BABR	$\overline{\text{MS}}$ scheme
1.28 ± 0.04	<sup>12</sup> BLOSSIER 10	LATT	$\overline{\text{MS}}$ scheme
1.273 ± 0.006	<sup>13</sup> MCNEILE 10	LATT	$\overline{\text{MS}}$ scheme
1.279 ± 0.013	<sup>14</sup> CHETYRKIN 09	THEO	$\overline{\text{MS}}$ scheme
1.25 ± 0.04	<sup>15</sup> SIGNER 09	THEO	$\overline{\text{MS}}$ scheme
1.295 ± 0.015	<sup>16</sup> BOUGHEZAL 06	THEO	$\overline{\text{MS}}$ scheme
1.24 ± 0.09	<sup>17</sup> BUCHMUEL... 06	THEO	$\overline{\text{MS}}$ scheme
1.224 ± 0.017 ± 0.054	<sup>18</sup> HOANG 06	THEO	$\overline{\text{MS}}$ scheme
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
1.01 ± 0.09 ± 0.03	<sup>19</sup> ALEKHIN 11	THEO	$\overline{\text{MS}}$ scheme
1.299 ± 0.026	<sup>20</sup> BODENSTEIN 10	THEO	$\overline{\text{MS}}$ scheme
1.261 ± 0.018	<sup>21</sup> NARISON 10	THEO	$\overline{\text{MS}}$ scheme
1.268 ± 0.009	<sup>22</sup> ALLISON 08	LATT	$\overline{\text{MS}}$ scheme
1.286 ± 0.013	<sup>23</sup> KUHN 07	THEO	$\overline{\text{MS}}$ scheme
1.33 ± 0.10	<sup>24</sup> AUBERT 04X	THEO	$\overline{\text{MS}}$ scheme
1.29 ± 0.07	<sup>25</sup> HOANG 04	THEO	$\overline{\text{MS}}$ scheme
1.319 ± 0.028	<sup>26</sup> DEDIVITIIS 03	LATT	$\overline{\text{MS}}$ scheme
1.19 ± 0.11	<sup>27</sup> EIDEMULLER 03	THEO	$\overline{\text{MS}}$ scheme
1.289 ± 0.043	<sup>28</sup> ERLER 03	THEO	$\overline{\text{MS}}$ scheme
1.26 ± 0.02	<sup>29</sup> ZYABLYUK 03	THEO	$\overline{\text{MS}}$ scheme

<sup>1</sup> CARRASCO 14 is a lattice QCD computation of light quark masses using  $2 + 1 + 1$  dynamical quarks, with  $m_u = m_d \neq m_s \neq m_c$ . The  $u$  and  $d$  quark masses are obtained separately by using the  $K$  meson mass splittings and lattice results for the electromagnetic contributions.

- 2 ABRAMOWICZ 13C determines  $m_c$  from charm production in deep inelastic  $ep$  scattering, using the QCD prediction at NLO order. The uncertainties from model and parameterization assumptions, and the value of  $\alpha_s$ , of  $\pm 0.03$ ,  $\pm 0.02$ , and  $\pm 0.02$  respectively, have been combined in quadrature.
- 3 ALEKHIN 13 determines  $m_c$  from charm production in deep inelastic scattering at HERA using approximate NNLO QCD.
- 4 DEHNADI 13 determines  $m_c$  using QCD sum rules for the charmonium spectrum and charm continuum to order  $\alpha_s^3$  (N3LO). The statistical and systematic experimental errors of  $\pm 0.006$  and  $\pm 0.009$  have been combined in quadrature. The theoretical uncertainties  $\pm 0.019$  from truncation of the perturbation series,  $\pm 0.010$  from  $\alpha_s$ , and  $\pm 0.002$  from the gluon condensate have been combined in quadrature.
- 5 NARISON 13 determines  $m_c$  using QCD spectral sum rules to order  $\alpha_s^2$  (NNLO) and including condensates up to dimension 6.
- 6 SAMOYLOV 13 determines  $m_c$  from a study of charm dimuon production in neutrino-iron scattering using the NLO QCD result for the charm quark production cross section.
- 7 ALEKHIN 12 determines  $m_c$  from heavy quark production in deep inelastic scattering at HERA using approximate NNLO QCD.
- 8 NARISON 12A determines  $m_c$  using sum rules for the vector current correlator to order  $\alpha_s^3$ , including the effect of gluon condensates up to dimension eight.
- 9 BODENSTEIN 11 determine  $\overline{m}_c(3 \text{ GeV}) = 0.987 \pm 0.009 \text{ GeV}$  and  $\overline{m}_c(\overline{m}_c) = 1.278 \pm 0.009 \text{ GeV}$  using QCD sum rules for the charm quark vector current correlator.
- 10 LASCHKA 11 determine the  $c$  mass from the charmonium spectrum. The theoretical computation uses the heavy  $Q\overline{Q}$  potential to order  $1/m_Q$  obtained by matching the short-distance perturbative result onto lattice QCD result at larger scales.
- 11 AUBERT 10A determine the  $b$ - and  $c$ -quark masses from a fit to the inclusive decay spectra in semileptonic  $B$  decays in the kinetic scheme (and convert it to the  $\overline{\text{MS}}$  scheme).
- 12 BLOSSIER 10 determines quark masses from a computation of the hadron spectrum using  $N_f=2$  dynamical twisted-mass Wilson fermions.
- 13 MCNEILE 10 determines  $m_c$  by comparing the order  $\alpha_s^3$  perturbative results for the pseudo-scalar current to lattice simulations with  $N_f = 2+1$  sea-quarks by the HPQCD collaboration.
- 14 CHETYRKIN 09 determine  $m_c$  and  $m_b$  from the  $e^+e^- \rightarrow Q\overline{Q}$  cross-section and sum rules, using an order  $\alpha_s^3$  computation of the heavy quark vacuum polarization. They also determine  $m_c(3 \text{ GeV}) = 0.986 \pm 0.013 \text{ GeV}$ .
- 15 SIGNER 09 determines the  $c$ -quark mass using non-relativistic sum rules to analyze the  $e^+e^- \rightarrow c\overline{c}$  cross-section near threshold. Also determine the PS mass  $m_{PS}(\mu_F = 0.7 \text{ GeV}) = 1.50 \pm 0.04 \text{ GeV}$ .
- 16 BOUGHEZAL 06 result comes from the first moment of the hadronic production cross-section to order  $\alpha_s^3$ .
- 17 BUCHMUELLER 06 determine  $m_b$  and  $m_c$  by a global fit to inclusive  $B$  decay spectra.
- 18 HOANG 06 determines  $\overline{m}_c(\overline{m}_c)$  from a global fit to inclusive  $B$  decay data. The  $B$  decay distributions were computed to order  $\alpha_s^2\beta_0$ , and the conversion between different  $m_c$  mass schemes to order  $\alpha_s^3$ .
- 19 ALEKHIN 11 determines  $m_c$  from heavy quark production in deep inelastic scattering using fixed target and HERA data, and approximate NNLO QCD.
- 20 BODENSTEIN 10 determines  $\overline{m}_c(3 \text{ GeV}) = 1.008 \pm 0.026 \text{ GeV}$  using finite energy sum rules for the vector current correlator. The authors have converted this to  $\overline{m}_c(\overline{m}_c)$  using  $\alpha_s(M_Z) = 0.1189 \pm 0.0020$ .
- 21 NARISON 10 determines  $m_c$  from ratios of moments of vector current correlators computed to order  $\alpha_s^3$  and including the dimension-six gluon condensate.

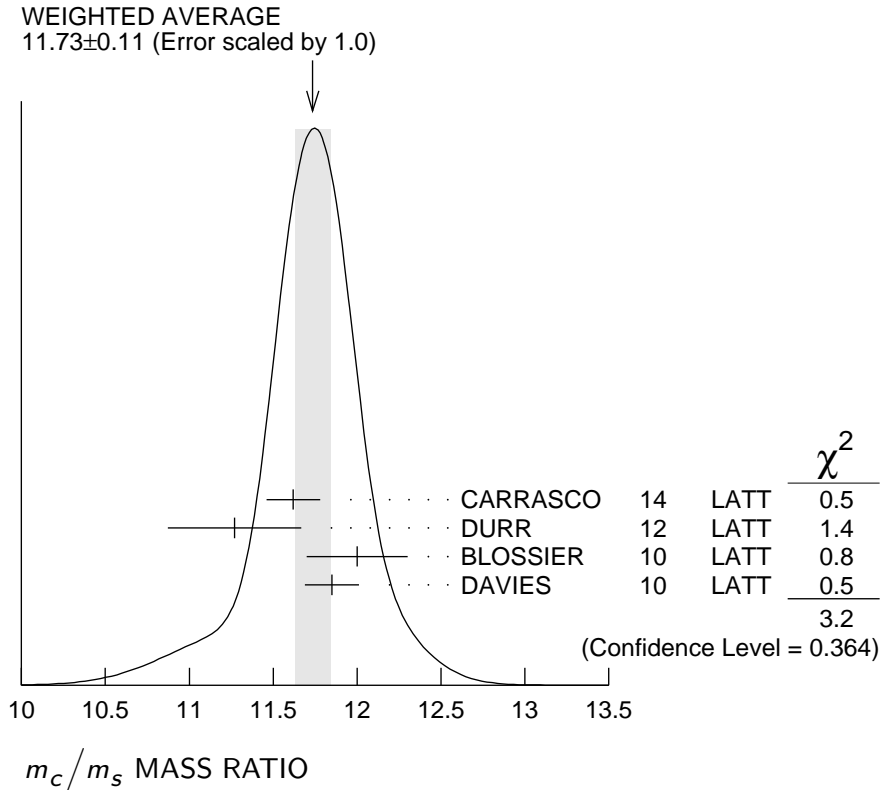
- 22 ALLISON 08 determine  $m_c$  by comparing four-loop perturbative results for the pseudo-scalar current correlator to lattice simulations by the HPQCD collaboration. The result has been updated in MCNEILE 10.
- 23 KUHN 07 determine  $\overline{m}_c(\mu = 3 \text{ GeV}) = 0.986 \pm 0.013 \text{ GeV}$  and  $\overline{m}_c(\overline{m}_c)$  from a four-loop sum-rule computation of the cross-section for  $e^+ e^- \rightarrow$  hadrons in the charm threshold region.
- 24 AUBERT 04X obtain  $m_c$  from a fit to the hadron mass and lepton energy distributions in semileptonic  $B$  decay. The paper quotes values in the kinetic scheme. The  $\overline{MS}$  value has been provided by the BABAR collaboration.
- 25 HOANG 04 determines  $\overline{m}_c(\overline{m}_c)$  from moments at order  $\alpha_s^2$  of the charm production cross-section in  $e^+ e^-$  annihilation.
- 26 DEDIVITIIS 03 use a quenched lattice computation of heavy-heavy and heavy-light meson masses.
- 27 EIDEMULLER 03 determines  $m_b$  and  $m_c$  using QCD sum rules.
- 28 ERLER 03 determines  $m_b$  and  $m_c$  using QCD sum rules. Includes recent BES data.
- 29 ZYABLYUK 03 determines  $m_c$  by using QCD sum rules in the pseudoscalar channel and comparing with the  $\eta_c$  mass.



**$m_c/m_s$  MASS RATIO**

VALUE	DOCUMENT ID	TECN
<b>11.73±0.25 OUR EVALUATION</b>	See the ideogram below.	
11.62±0.16	1 CARRASCO 14	LATT
11.27±0.30±0.26	2 DURR 12	LATT
12.0 ±0.3	3 BLOSSIER 10	LATT
11.85±0.16	4 DAVIES 10	LATT

- <sup>1</sup> CARRASCO 14 is a lattice QCD computation of light quark masses using  $2 + 1 + 1$  dynamical quarks, with  $m_u = m_d \neq m_s \neq m_c$ . The  $u$  and  $d$  quark masses are obtained separately by using the  $K$  meson mass splittings and lattice results for the electromagnetic contributions.
- <sup>2</sup> DURR 12 determine  $m_c/m_s$  using a lattice computation with  $N_f = 2$  dynamical fermions. The result is combined with other determinations of  $m_c$  to obtain  $m_s(2 \text{ GeV}) = 97.0 \pm 2.6 \pm 2.5 \text{ MeV}$ .
- <sup>3</sup> BLOSSIER 10 determine  $m_c/m_s$  from a computation of the hadron spectrum using  $N_f = 2$  dynamical twisted-mass Wilson fermions.
- <sup>4</sup> DAVIES 10 determine  $m_c/m_s$  from meson masses calculated on gluon fields including  $u$ ,  $d$ , and  $s$  sea quarks with lattice spacing down to 0.045 fm. The Highly Improved Staggered quark formalism is used for the valence quarks.



### $m_b - m_c$ QUARK MASS DIFFERENCE

VALUE (GeV) \_\_\_\_\_ DOCUMENT ID \_\_\_\_\_ TECN \_\_\_\_\_

#### **3.45 ± 0.05 OUR EVALUATION**

• • • We do not use the following data for averages, fits, limits, etc. • • •

3.472 ± 0.032	<sup>1</sup> AUBERT	10A	BABR
3.42 ± 0.06	<sup>2</sup> ABDALLAH	06B	DLPH
3.44 ± 0.03	<sup>3</sup> AUBERT	04X	BABR
3.41 ± 0.01	<sup>3</sup> BAUER	04	THEO

<sup>1</sup> AUBERT 10A determine the  $b$ - and  $c$ -quark masses from a fit to the inclusive decay spectra in semileptonic  $B$  decays in the kinetic scheme.

<sup>2</sup> ABDALLAH 06B determine  $m_b - m_c$  from moments of the hadron invariant mass and lepton energy spectra in semileptonic inclusive  $B$  decays.

<sup>3</sup> Determine  $m_b - m_c$  from a global fit to inclusive  $B$  decay spectra.

**c-QUARK REFERENCES**

CARRASCO	14	NP B887 19	N. Carrasco <i>et al.</i>	(European Twisted Mass Collab.)
ABRAMOWICZ	13C	EPJ C73 2311	H. Abramovicz <i>et al.</i>	(H1 and Zeus Collab.)
ALEKHIN	13	PL B720 172	S. Alekhin <i>et al.</i>	(SERP, DESYZ, WUPP+)
DEHNADI	13	JHEP 1309 103	B. Dehnadi <i>et al.</i>	(SHRZ, VIEN, MPIM+)
NARISON	13	PL B718 1321	S. Narison	(MONP)
SAMOYLOV	13	NP B876 339	O. Samoylov <i>et al.</i>	(NOMAD Collab.)
ALEKHIN	12	PL B718 550	S. Alekhin <i>et al.</i>	(SERP, WUPP, DESY+)
DURR	12	PRL 108 122003	S. Durr, G. Koutsou	(WUPP, JULI, CYPR)
NARISON	12A	PL B706 412	S. Narison	(MONP)
ALEKHIN	11	PL B699 345	S. Alekhin, S. Moch	(DESY, SERP)
BODENSTEIN	11	PR D83 074014	S. Bodenstein <i>et al.</i>	
LASCHKA	11	PR D83 094002	A. Laschka, N. Kaiser, W. Weise	
AUBERT	10A	PR D81 032003	B. Aubert <i>et al.</i>	(BABAR Collab.)
BLOSSIER	10	PR D82 114513	B. Blossier <i>et al.</i>	(ETM Collab.)
BODENSTEIN	10	PR D82 114013	S. Bodenstein <i>et al.</i>	
DAVIES	10	PRL 104 132003	C.T.H. Davies <i>et al.</i>	(HPQCD Collab.)
MCNEILE	10	PR D82 034512	C. McNeile <i>et al.</i>	(HPQCD Collab.)
NARISON	10	PL B693 559	S. Narison	(MONP)
Also		PL B705 544 (errat.)	S. Narison	(MONP)
CHETYRKIN	09	PR D80 074010	K.G. Chetyrkin <i>et al.</i>	(KARL, BNL)
SIGNER	09	PL B672 333	A. Signer	(DURH)
ALLISON	08	PR D78 054513	I. Allison <i>et al.</i>	(HPQCD Collab.)
KUHN	07	NP B778 192	J.H. Kuhn, M. Steinhauser, C. Sturm	
ABDALLAH	06B	EPJ C45 35	J. Abdallah <i>et al.</i>	(DELPHI Collab.)
BOUGHEZAL	06	PR D74 074006	R. Boughezal, M. Czakon, T. Schutzmeier	
BUCHMUEL...	06	PR D73 073008	O.L. Buchmueller, H.U. Flacher	(RHBL)
HOANG	06	PL B633 526	A.H. Hoang, A.V. Manohar	
AUBERT	04X	PRL 93 011803	B. Aubert <i>et al.</i>	(BABAR Collab.)
BAUER	04	PR D70 094017	C. Bauer <i>et al.</i>	
HOANG	04	PL B594 127	A.H. Hoang, M. Jamin	
DEDIVITIIS	03	NP B675 309	G.M. de Divitiis <i>et al.</i>	
EIDEMULLER	03	PR D67 113002	M. Eidemuller	
ERLER	03	PL B558 125	J. Erler, M. Luo	
ZYABLYUK	03	JHEP 0301 081	K.N. Zybalyuk	(ITEP)