c

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

Charge = $\frac{2}{3}$ e 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 1.2730 ± 0.0046 GeV for the $\overline{\text{MS}}$ mass corresponds to 1.67 ± 0.07 GeV for the pole mass (see the "Note on Quark Masses").

$\overline{\text{MS}}$ *MASS* (GeV)	*CL%*	*DOCUMENT ID*		*TECN*
1.2730±0.0046 (CL = 90%) OUR EVALUATION See the ideogram below.				
$1.316 \pm 0.022 {}^{+0.019}_{-0.010}$		[1] ALEXANDROU	21	LATT
1.296 ± 0.019		[2] HEITGER	21	LATT
1.2723 ± 0.0078		[3] HATTON	20	LATT
1.266 ± 0.006		[4] NARISON	20	THEO
$1.290 {}^{+0.077}_{-0.053}$		[5] ABRAMOWICZ	18	HERA
1.273 ± 0.010		[6] BAZAVOV	18	LATT
1.2737 ± 0.0077		[7] LYTLE	18	LATT
1.223 ± 0.033		[8] PESET	18	THEO
1.279 ± 0.008		[9] CHETYRKIN	17	THEO
1.272 ± 0.008		[10] ERLER	17	THEO
1.246 ± 0.023		[11] KIYO	16	THEO
1.288 ± 0.020		[12] DEHNADI	15	THEO
1.348 ± 0.046		[13] CARRASCO	14	LATT
$1.24 \pm 0.03 {}^{+0.03}_{-0.07}$		[14] ALEKHIN	13	THEO
1.159 ± 0.075		[15] SAMOYLOV	13	NOMD
1.278 ± 0.009		[16] BODENSTEIN	11	THEO
$1.28 {}^{+0.07}_{-0.06}$		[17] LASCHKA	11	THEO
$1.196 \pm 0.059 \pm 0.050$		[18] AUBERT	10A	BABR
1.25 ± 0.04		[19] SIGNER	09	THEO
• • • We do not use the following data for averages, fits, limits, etc. • • •				
1.263 ± 0.014		[20] NARISON	18A	THEO
1.264 ± 0.006		[21] NARISON	18B	THEO
$1.335 \pm 0.043 {}^{+0.040}_{-0.011}$		[22] BERTONE	16	THEO
1.2715 ± 0.0095		[23] CHAKRABOR..	15	LATT
$1.26 \pm 0.05 \pm 0.04$		[24] ABRAMOWICZ	13C	COMB
$1.282 \pm 0.011 \pm 0.022$		[25] DEHNADI	13	THEO
1.286 ± 0.066		[26] NARISON	13	THEO
$1.36 \pm 0.04 \pm 0.10$		[27] ALEKHIN	12	THEO
1.261 ± 0.016		[28] NARISON	12A	THEO
$1.01 \pm 0.09 \pm 0.03$		[29] ALEKHIN	11	THEO
1.28 ± 0.04		[30] BLOSSIER	10	LATT
1.299 ± 0.026		[31] BODENSTEIN	10	THEO
1.273 ± 0.006		[32] MCNEILE	10	LATT

1.261	±0.018		[33] NARISON	10	THEO
1.279	±0.013		[34] CHETYRKIN	09	THEO
1.268	±0.009		[35] ALLISON	08	LATT
1.286	±0.013		[36] KUHN	07	THEO
1.295	±0.015		[37] BOUGHEZAL	06	THEO
1.24	±0.09		[38] BUCHMUEL...	06	THEO
1.224	±0.017	±0.054	[39] HOANG	06	THEO
1.33	±0.10		[40] AUBERT	04X	THEO
1.29	±0.07		[41] HOANG	04	THEO
1.319	±0.028		[42] DEDIVITIIS	03	LATT
1.19	±0.11		[43] EIDEMULLER	03	THEO
1.289	±0.043		[44] ERLER	03	THEO
1.26	±0.02		[45] ZYABLYUK	03	THEO

[1] ALEXANDROU 21 determines the quark mass using a lattice calculation of the meson and baryon masses with a twisted mass fermion action. We have converted $\overline{m}_c$(3 GeV) $= 1.036 \pm 0.017^{+0.015}_{-0.008}$ to $\overline{m}_c(\overline{m}_c)$. The simulations are carried out using 2+1+1 dynamical quarks with $m_u = m_d \neq m_s \neq m_c$, including gauge ensembles close to the physical pion point.

[2] HEITGER 21 determines the charm quark mass using a n_f = 2+1 flavor lattice QCD simulation with non-perturbatively O(a) improved Wilson fermions. They also determine $\overline{m}_c$(3 GeV) $= 1.007 \pm 0.016$ GeV.

[3] HATTON 20 determines the charm quark mass with a lattice QCD + quenched QED simulation using the HISQ action and including n_f = 2+1+1 flavors of sea quarks. m_c is tuned from the J/ψ meson mass giving $\overline{m}_c$(3 GeV) $= 0.9841 \pm 0.0051$ GeV.

[4] NARISON 20 determines the quark mass using QCD Laplace sum rules from the B_c mass, combined with previous determinations of the QCD condensates and c and b masses.

[5] ABRAMOWICZ 18 determine $\overline{m}_c(\overline{m}_c) = 1.290^{+0.046}_{-0.041}{}^{+0.062}_{-0.014}{}^{+0.003}_{-0.031}$ from the production of c quarks in ep collisions at HERA using combined H1 and ZEUS data. The experimental/fitting errors, and those from modeling and parameterization have been combined in quadrature.

[6] BAZAVOV 18 determine the quark masses using a lattice computation with staggered fermions and four active quark flavors.

[7] LYTLE 18 combined with CHAKRABORTY 15 determine $\overline{m}_c$(3 GeV) = 0.9874(48) GeV from a lattice simulation with n_f = 2+1+1 flavors. They also determine the quoted value $\overline{m}_c(\overline{m}_c)$ for n_f = 4 dynamical flavors.

[8] PESET 18 determine $\overline{m}_c(\overline{m}_c)$ and $\overline{m}_b(\overline{m}_b)$ using an N3LO calculation of the η_c, η_b and B_c masses.

[9] CHETYRKIN 17 determine $\overline{m}_c(\mu = 3$ GeV$) = 0.993 \pm 0.008$ 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.

[10] ERLER 17 determine $\overline{m}_c(\overline{m}_c) = 1.272 \pm 0.008$ GeV from a three-loop QCD sum-rule computation of the vector current correlator. This result is for fixed $\alpha_s(M_Z) = 0.1182$. Including an α_s uncertainty of ±0.0016, the charm mass error increases from 8 to 9 MeV.

[11] KIYO 16 determine $\overline{m}_c(\overline{m}_c)$ from the $J/\psi(1S)$ mass at order α_s^3 (N3LO).

[12] DEHNADI 15 determine $\overline{m}_c(\overline{m}_c)$ using sum rules for $e^+ e^- \rightarrow$ hadrons at order α_s^3 (N3LO), and fitting to both experimental data and lattice results.

[13] 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.

[14] ALEKHIN 13 determines m_c from charm production in deep inelastic scattering at HERA using approximate NNLO QCD.

[15] 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.

[16] BODENSTEIN 11 determine $\overline{m}_c$(3 GeV) = 0.987 ± 0.009 GeV and $\overline{m}_c(\overline{m}_c)$ = 1.278 ± 0.009 GeV using QCD sum rules for the charm quark vector current correlator.

[17] 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.

[18] 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).

[19] 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 $m_{PS}(\mu_F = 0.7$ GeV) = 1.50 ± 0.04 GeV.

[20] NARISON 18A determines simultaneously $\overline{m}_c(\overline{m}_c)$ and the 4-dimension gluon condensate using QCD exponential sum rules and their ratios evaluated at the optimal scale μ = 2.85 GeV at N2LO-N3LO of perturbative QCD and including condensates up to dimension 6–8 in the (axial-)vector and (pseudo-)scalar charmonium channels.

[21] NARISON 18B determines $\overline{m}_c(\overline{m}_c)$ using QCD vector moment sum rules and their ratios at N2LO-N3LO of perturbative QCD and including condensates up to dimension 8.

[22] BERTONE 16 determine $\overline{m}_c(\overline{m}_c)$ from HERA deep inelastic scattering data using the FONLL scheme. Also determine $\overline{m}_c(\overline{m}_c)$=1.318 ± 0.054 $^{+0.490}_{-0.022}$ using the fixed flavor number scheme.

[23] CHAKRABORTY 15 is a lattice QCD computation using 2+1+1 dynamical flavors. Moments of pseudoscalar current-current correlators are matched to α_s^3-accurate QCD perturbation theory with the η_c meson mass tuned to experiment.

[24] 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 α_s, of ±0.03, ±0.02, and ±0.02 respectively, have been combined in quadrature.

[25] DEHNADI 13 determines m_c using QCD sum rules for the charmonium spectrum and charm continuum to order α_s^3 (N3LO). The statistical and systematic experimental errors of ±0.006 and ±0.009 have been combined in quadrature. The theoretical uncertainties ±0.019 from truncation of the perturbation series, ±0.010 from α_s, and ±0.002 from the gluon condensate have been combined in quadrature.

[26] NARISON 13 determines m_c using QCD spectral sum rules to order α_s^2 (NNLO) and including condensates up to dimension 6.

[27] ALEKHIN 12 determines m_c from heavy quark production in deep inelastic scattering at HERA using approximate NNLO QCD.

[28] NARISON 12A determines m_c using sum rules for the vector current correlator to order α_s^3, including the effect of gluon condensates up to dimension eight.

[29] ALEKHIN 11 determines m_c from heavy quark production in deep inelastic scattering using fixed target and HERA data, and approximate NNLO QCD.

[30] BLOSSIER 10 determines quark masses from a computation of the hadron spectrum using n_f=2 dynamical twisted-mass Wilson fermions.

[31] BODENSTEIN 10 determines $\overline{m}_c$(3 GeV) = 1.008 ± 0.026 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 ± 0.0020.

[32] MCNEILE 10 determines m_c by comparing the order α_s^3 perturbative results for the pseudo-scalar current to lattice simulations with n_f = 2+1 sea-quarks by the HPQCD collaboration.

[33] NARISON 10 determines m_c from ratios of moments of vector current correlators computed to order α_s^3 and including the dimension-six gluon condensate.

[34] CHETYRKIN 09 determine m_c and m_b from the $e^+ e^- \rightarrow Q\overline{Q}$ cross-section and sum rules, using an order α_s^3 computation of the heavy quark vacuum polarization. They also determine m_c(3 GeV) = 0.986 ± 0.013GeV.

[35] 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.

[36] KUHN 07 determine $\overline{m}_c(\mu = 3\text{ GeV}) = 0.986 \pm 0.013$ 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.

[37] BOUGHEZAL 06 result comes from the first moment of the hadronic production cross-section to order α_s^3.

[38] BUCHMUELLER 06 determine m_b and m_c by a global fit to inclusive B decay spectra.

[39] 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 α_s^3.

[40] 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 $\overline{\text{MS}}$ value has been provided by the BABAR collaboration.

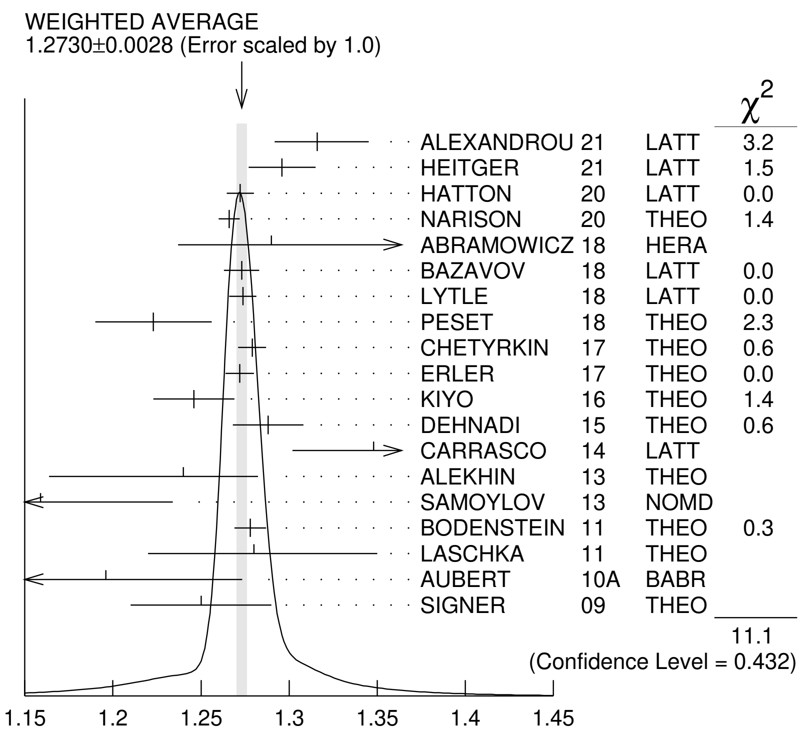
[41] HOANG 04 determines $\overline{m}_c(\overline{m}_c)$ from moments at order α_s^2 of the charm production cross-section in $e^+ e^-$ annihilation.

[42] DEDIVITIIS 03 use a quenched lattice computation of heavy-heavy and heavy-light meson masses.

[43] EIDEMULLER 03 determines m_b and m_c using QCD sum rules.

[44] ERLER 03 determines m_b and m_c using QCD sum rules. Includes recent BES data.

[45] ZYABLYUK 03 determines m_c by using QCD sum rules in the pseudoscalar channel and comparing with the η_c mass.

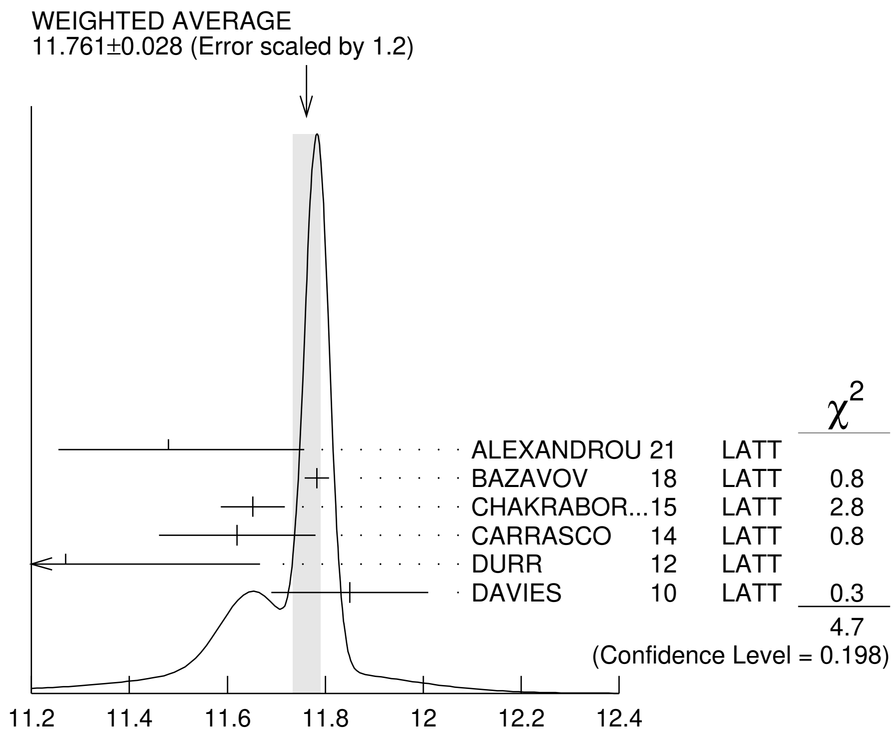


c-QUARK MASS (GeV)

m_c/m_s MASS RATIO

The ratio is that of the $\overline{\text{MS}}$ masses at a common scale, for four dynamical quark flavors.

VALUE	CL%	DOCUMENT ID		TECN
11.761±0.047 (CL = 90%) OUR EVALUATION		See the ideogram below.		
11.48 ±0.12 $^{+0.25}_{-0.19}$		[1] ALEXANDROU	21	LATT
11.783±0.025		[2] BAZAVOV	18	LATT
11.652±0.065		[3] CHAKRABOR...	15	LATT
11.62 ±0.16		[4] CARRASCO	14	LATT
11.27 ±0.30 ±0.26		[5] DURR	12	LATT
11.85 ±0.16		[6] DAVIES	10	LATT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
11.747±0.019 $^{+0.059}_{-0.043}$		[7] BAZAVOV	14A	LATT
12.0 ±0.3		[8] BLOSSIER	10	LATT



m_c/m_s MASS RATIO

[1] ALEXANDROU 21 determines the quark mass using a lattice calculation of the meson and baryon masses with a twisted mass fermion action. The simulations are carried out using 2+1+1 dynamical quarks with $m_u = m_d \neq m_s \neq m_c$, including gauge ensembles close to the physical pion point.

[2] BAZAVOV 18 determine the quark masses using a lattice computation with staggered fermions and four active quark flavors.

[3] CHAKRABORTY 15 is a lattice QCD computation on gluon field configurations with 2+1+1 dynamical flavors of HISQ quarks with u/d masses down to the physical value. m_c and m_s are tuned from pseudoscalar meson masses.

[4] 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.

[5] 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 GeV) = 97.0 ± 2.6 ± 2.5 MeV.

[6] 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.

[7] BAZAVOV 14A is a lattice computation using 4 dynamical flavors of HISQ fermions.

[8] BLOSSIER 10 determine m_c/m_s from a computation of the hadron spectrum using n_f = 2 dynamical twisted-mass Wilson fermions.

m_b/m_c MASS RATIO

The ratio is that of the $\overline{\text{MS}}$ masses at a common scale, for four dynamical quark flavors.

VALUE	DOCUMENT ID		TECN
4.58 ±0.01 OUR EVALUATION			
4.580±0.007 OUR AVERAGE			
4.586±0.012	[1] HATTON	21	LATT
4.578±0.008	[2] BAZAVOV	18	LATT
4.528±0.054	[3] CHAKRABOR..	15	LATT

[1] HATTON 21 determine $\overline{m}_b(\mu)/\overline{m}_c(\mu)$ = 4.586 ± 0.012 at μ = 3 GeV with a lattice QCD + quenched QED simulation using the HISQ action and including n_f =2+1+1 flavors of sea quarks. The ratio depends weakly on μ because of QED effects.

[2] BAZAVOV 18 determine the quark masses using a lattice computation with staggered fermions and four active quark flavors for the u, d, s, c quarks and five active flavors for the b quark.

[3] CHAKRABORTY 15 is a lattice computation using 4 dynamical quark flavors.

$m_b - m_c$ 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	[1] AUBERT	10A	BABR
3.42 ±0.06	[2] ABDALLAH	06B	DLPH
3.44 ±0.03	[3] AUBERT	04X	BABR
3.41 ±0.01	[3] BAUER	04	THEO

[1] 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.

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

[3] Determine $m_b - m_c$ from a global fit to inclusive B decay spectra.

c-QUARK REFERENCES

ALEXANDROU	21	PR D104 074515	C. Alexandrou et al.	(ETM Collab.)
HATTON	21	PR D103 114508	D. Hatton et al.	(HPQCD Collab.)
HEITGER	21	JHEP 2105 288	J. Heitger, F. Joswig, S. Kuberski	(ALPHA Collab.)
HATTON	20	PR D102 054511	D. Hatton et al.	(HPQCD Collab.)
NARISON	20	PL B802 135221	S. Narison	(MONP)
ABRAMOWICZ	18	EPJ C78 473	H. Abramowicz et al.	(H1 and ZEUS Collabs.)
BAZAVOV	18	PR D98 054517	A. Bazavov et al.	(Fermilab Lattice, MILC, TUMQCD)
LYTLE	18	PR D98 014513	A.T. Lytle et al.	(HPQCD Collab.)
NARISON	18A	IJMP A33 1850045	S. Narison	(MONP)
NARISON	18B	PL B784 261	S. Narison	(MONP)
PESET	18	JHEP 1809 167	C. Peset, A. Pineda, J. Segovia	(BARC, TUM)

CHETYRKIN	17	PR D96 116007	K.G. Chetyrkin *et al.*	
ERLER	17	EPJ C77 99	J. Erler, P. Masjuan, H. Spiesberger	
BERTONE	16	JHEP 1608 050	V. Bertone *et al.*	(xFitter Developers)
KIYO	16	PL B752 122	Y. Kiyo, G. Mishima, Y. Sumino	
CHAKRABOR...	15	PR D91 054508	B. Chakraborty *et al.*	(HPQCD Collab.)
DEHNADI	15	JHEP 1508 155	B. Dehnadi, A.H. Hoang, V. Mateu	
BAZAVOV	14A	PR D90 074509	A. Bazavov *et al.*	(Fermi-LAT and MILC Collabs.)
CARRASCO	14	NP B887 19	N. Carrasco *et al.*	(European Twisted Mass Collab.)
ABRAMOWICZ	13C	EPJ C73 2311	H. Abramovicz *et al.*	(H1 and Zeus Collabs.)
ALEKHIN	13	PL B720 172	S. Alekhin *et al.*	(SERP, DESYZ, WUPP+)
DEHNADI	13	JHEP 1309 103	B. Dehnadi *et al.*	(SHRZ, VIEN, MPIM+)
NARISON	13	PL B718 1321	S. Narison	(MONP)
SAMOYLOV	13	NP B876 339	O. Samoylov *et al.*	(NOMAD Collab.)
ALEKHIN	12	PL B718 550	S. Alekhin *et al.*	(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 *et al.*	
LASCHKA	11	PR D83 094002	A. Laschka, N. Kaiser, W. Weise	
AUBERT	10A	PR D81 032003	B. Aubert *et al.*	(BABAR Collab.)
BLOSSIER	10	PR D82 114513	B. Blossier *et al.*	(ETM Collab.)
BODENSTEIN	10	PR D82 114013	S. Bodenstein *et al.*	
DAVIES	10	PRL 104 132003	C.T.H. Davies *et al.*	(HPQCD Collab.)
MCNEILE	10	PR D82 034512	C. McNeile *et al.*	(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 *et al.*	(KARL, BNL)
SIGNER	09	PL B672 333	A. Signer	(DURH)
ALLISON	08	PR D78 054513	I. Allison *et al.*	(HPQCD Collab.)
KUHN	07	NP B778 192	J.H. Kuhn, M. Steinhauser, C. Sturm	
ABDALLAH	06B	EPJ C45 35	J. Abdallah *et al.*	(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 *et al.*	(BABAR Collab.)
BAUER	04	PR D70 094017	C. Bauer *et al.*	
HOANG	04	PL B594 127	A.H. Hoang, M. Jamin	
DEDIVITIIS	03	NP B675 309	G.M. de Divitiis *et al.*	
EIDEMULLER	03	PR D67 113002	M. Eidemuller	
ERLER	03	PL B558 125	J. Erler, M. Luo	
ZYABLYUK	03	JHEP 0301 081	K.N. Zyablyuk	(ITEP)