

# LIGHT QUARKS ( $u, d, s$ )

OMITTED FROM SUMMARY TABLE

## $u$ -QUARK MASS

The  $u$ -,  $d$ -, and  $s$ -quark masses are estimates of so-called “current-quark masses,” in a mass-independent subtraction scheme such as  $\overline{MS}$ . The ratios  $m_u/m_d$  and  $m_s/m_d$  are extracted from pion and kaon masses using chiral symmetry. The estimates of  $d$  and  $u$  masses are not without controversy and remain under active investigation. Within the literature there are even suggestions that the  $u$  quark could be essentially massless. The  $s$ -quark mass is estimated from SU(3) splittings in hadron masses.

We have normalized the  $\overline{MS}$  masses at a renormalization scale of  $\mu = 2$  GeV. Results quoted in the literature at  $\mu = 1$  GeV have been rescaled by dividing by 1.35. The values of “Our Evaluation” were determined in part via Figures 1 and 2.

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>1 to 5 OUR EVALUATION</b>			
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
$2.3 \pm 0.4$	<sup>1</sup> NARISON	99 THEO	$\overline{MS}$ scheme
$3.9 \pm 1.1$	<sup>2</sup> JAMIN	95 THEO	$\overline{MS}$ scheme
$3.0 \pm 0.7$	<sup>3</sup> NARISON	95C THEO	$\overline{MS}$ scheme
	<sup>4</sup> CHOI	92B THEO	
4.3	<sup>5</sup> BARDUCCI	88 THEO	
$3.8 \pm 1.1$	<sup>6</sup> GASSER	82 THEO	
<sup>1</sup> NARISON 99 uses sum rules to order $\alpha_s^3$ for $\phi$ meson decays to get $m_s$ , and finds $m_u$ by combining with sum rule estimates of $m_u + m_d$ and Dashen's formula.			
<sup>2</sup> JAMIN 95 uses QCD sum rules at next-to-leading order. We have rescaled $m_u(1 \text{ GeV}) = 5.3 \pm 1.5$ to $\mu = 2$ GeV.			
<sup>3</sup> For NARISON 95C, we have rescaled $m_u(1 \text{ GeV}) = 4 \pm 1$ to $\mu = 2$ GeV.			
<sup>4</sup> CHOI 92B argues that $m_u = 0$ is okay based on instanton contributions to the chiral coefficients. Disagrees with DONOGHUE 92 and DONOGHUE 92B.			
<sup>5</sup> BARDUCCI 88 uses a calculation of the effective potential for $\bar{\psi}\psi$ in QCD, and estimates for $\Sigma(p^2)$ . We have rescaled $m_u(1 \text{ GeV}) = 5.8$ to $\mu = 2$ GeV.			
<sup>6</sup> GASSER 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules to extract the absolute values. We have rescaled $m_u(1 \text{ GeV}) = 5.1 \pm 1.5$ to $\mu = 2$ GeV.			

## $d$ -QUARK MASS

See the comment for the  $u$  quark above.

We have normalized the  $\overline{MS}$  masses at a renormalization scale of  $\mu = 2$  GeV. Results quoted in the literature at  $\mu = 1$  GeV have been rescaled by dividing by 1.35. The values of “Our Evaluation” were determined in part via Figures 1 and 2.

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>3 to 9 OUR EVALUATION</b>			
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			

6.4±1.1	7	NARISON	99	THEO	$\overline{MS}$ scheme
7.0±1.1	8	JAMIN	95	THEO	$\overline{MS}$ scheme
7.4±0.7	9	NARISON	95C	THEO	$\overline{MS}$ scheme
	10	ADAMI	93	THEO	
	11	NEFKENS	92	THEO	
6.2	12	BARDUCCI	88	THEO	
	13	DOMINGUEZ	87	THEO	
	14	KREMER	84	THEO	
6.6±1.9	15	GASSER	82	THEO	

<sup>7</sup> NARISON 99 uses sum rules to order  $\alpha_s^3$  for  $\phi$  meson decays to get  $m_s$ , and finds  $m_d$  by combining with sum rule estimates of  $m_u+m_d$  and Dashen's formula.

<sup>8</sup> JAMIN 95 uses QCD sum rules at next-to-leading order. We have rescaled  $m_d(1\text{ GeV}) = 9.4 \pm 1.5$  to  $\mu = 2\text{ GeV}$ .

<sup>9</sup> For NARISON 95C, we have rescaled  $m_d(1\text{ GeV}) = 10 \pm 1$  to  $\mu = 2\text{ GeV}$ .

<sup>10</sup> ADAMI 93 obtain  $m_d - m_u = 3 \pm 1\text{ MeV}$  at  $\mu = 0.5\text{ GeV}$  using isospin-violating effects in QCD sum rules.

<sup>11</sup> NEFKENS 92 results for  $m_d - m_u$  are  $3.1 \pm 0.4\text{ MeV}$  from meson masses and  $3.6 \pm 0.4\text{ MeV}$  from baryon masses.

<sup>12</sup> BARDUCCI 88 uses a calculation of the effective potential for  $\bar{\psi}\psi$  in QCD, and estimates for  $\Sigma(p^2)$ . We have rescaled  $m_d(1\text{ GeV}) = 8.4$  to  $\mu = 2\text{ GeV}$ .

<sup>13</sup> DOMINGUEZ 87 uses QCD sum rules to obtain  $m_u+m_d = 15.5 \pm 2.0\text{ MeV}$  and  $m_d - m_u = 6 \pm 1.5\text{ MeV}$ .

<sup>14</sup> KREMER 84 obtain  $m_u+m_d = 21 \pm 2\text{ MeV}$  at  $Q^2 = 1\text{ GeV}^2$  using SVZ values for quark condensates; they obtain  $m_u+m_d = 35 \pm 3\text{ MeV}$  at  $Q^2 = 1\text{ GeV}^2$  using factorization values for quark condensates.

<sup>15</sup> GASSER 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules to extract the absolute values. We have rescaled  $m_d(1\text{ GeV}) = 8.9 \pm 2.6$  to  $\mu = 2\text{ GeV}$ .

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$$\bar{m} = (m_u + m_d)/2$$

See the comments for the  $u$  quark above.

We have normalized the  $\overline{MS}$  masses at a renormalization scale of  $\mu = 2\text{ GeV}$ . Results quoted in the literature at  $\mu = 1\text{ GeV}$  have been rescaled by dividing by 1.35. The values of "Our Evaluation" were determined in part via Figures 1 and 2.

<u>VALUE (MeV)</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
<b>2.5 to 6 OUR EVALUATION</b>			
● ● ● We do not use the following data for averages, fits, limits, etc. ● ● ●			
4.57±0.18	16	AOKI	00 LATT
4.23±0.29	17	AOKI	99 LATT $\overline{MS}$ scheme
≥ 2.1	18	STEELE	99 THEO $\overline{MS}$ scheme
4.5 ±0.4	19	BECIREVIC	98 LATT $\overline{MS}$ scheme
4.6 ±1.2	20	DOSCH	98 THEO $\overline{MS}$ scheme
2.7 ±0.2	21	EICKER	97 LATT $\overline{MS}$ scheme
3.6 ±0.6	22	GOUGH	97 LATT $\overline{MS}$ scheme
3.4 ±0.4 ±0.3	23	GUPTA	97 LATT $\overline{MS}$ scheme
>3.8	24	LELLOUCH	97 THEO $\overline{MS}$ scheme
4.5 ±1.0	25	BIJNENS	95

- <sup>16</sup> AOKI 00 obtain the light quark masses from a quenched lattice simulation of the meson and baryon spectrum with the Wilson quark action.
- <sup>17</sup> AOKI 99 obtain the light quark masses from a quenched lattice simulation of the meson spectrum with the Staggered quark action employing the regularization independent scheme.
- <sup>18</sup> STEELE 99 obtain a bound on the light quark masses by applying the Holder inequality to a sum rule. We have converted their bound of  $(m_u+m_d)/2 \geq 3$  MeV at  $\mu=1$  GeV to  $\mu=2$  GeV.
- <sup>19</sup> BECIREVIC 98 compute the quark mass using the Alpha action in the quenched approximation. The conversion from the regularization independent scheme to the  $\overline{MS}$  scheme is at NNLO.
- <sup>20</sup> DOSCH 98 use sum rule determinations of the quark condensate and chiral perturbation theory to obtain  $9.4 \leq (m_u+m_d)(1 \text{ GeV}) \leq 15.7$  MeV. We have converted to result to  $\mu=2$  GeV.
- <sup>21</sup> EICKER 97 use lattice gauge computations with two dynamical light flavors.
- <sup>22</sup> GOUGH 97 use lattice gauge computations in the quenched approximation. Correcting for quenching gives  $2.1 < \overline{m} < 3.5$  MeV at  $\mu=2$  GeV.
- <sup>23</sup> GUPTA 97 use Lattice Monte Carlo computations in the quenched approximation. The value for two light dynamic flavors at  $\mu = 2$  GeV is  $2.7 \pm 0.3 \pm 0.3$  MeV.
- <sup>24</sup> LELLOUCH 97 obtain lower bounds on quark masses using hadronic spectral functions.
- <sup>25</sup> BIJNENS 95 determines  $m_u+m_d (1 \text{ GeV}) = 12 \pm 2.5$  MeV using finite energy sum rules. We have rescaled this to 2 GeV.

## s-QUARK MASS

See the comment for the  $u$  quark above.

We have normalized the  $\overline{MS}$  masses at a renormalization scale of  $\mu = 2$  GeV. Results quoted in the literature at  $\mu = 1$  GeV have been rescaled by dividing by 1.35.

VALUE (MeV)	DOCUMENT ID	TECN	COMMENT
<b>75 to 170 OUR EVALUATION</b>			
• • • We do not use the following data for averages, fits, limits, etc. • • •			
130 $\pm$ 15	26 AOKI	00 LATT	
118 $\pm$ 14	27 AOKI	99 LATT	$\overline{MS}$ scheme
170 $+44$ $-55$	28 BARATE	99R	$\overline{MS}$ scheme
115 $\pm$ 8	29 MALTMAN	99 THEO	$\overline{MS}$ scheme
129 $\pm$ 24	30 NARISON	99 THEO	$\overline{MS}$ scheme
111 $\pm$ 12	31 BECIREVIC	98	$\overline{MS}$ scheme
148 $\pm$ 48	32 CHETYRKIN	98 THEO	$\overline{MS}$ scheme
103 $\pm$ 10	33 CUCCHIERI	98 LATT	$\overline{MS}$ scheme
115 $\pm$ 19	34 DOMINGUEZ	98 THEO	$\overline{MS}$ scheme
> 90 $\pm$ 9	35 DOSCH	98 THEO	$\overline{MS}$ scheme
> 30	36 LEBED	98 THEO	$\overline{MS}$ scheme
84 $\pm$ 80	37 MALTMAN	98 THEO	$\overline{MS}$ scheme
<163 $\pm$ 81	38 MALTMAN	98B THEO	$\overline{MS}$ scheme
152.4 $\pm$ 14.1	39 CHETYRKIN	97 THEO	$\overline{MS}$ scheme
$\geq$ 89	40 COLANGELO	97 THEO	$\overline{MS}$ scheme
140 $\pm$ 20	41 EICKER	97 LATT	$\overline{MS}$ scheme
95 $\pm$ 16	42 GOUGH	97 LATT	$\overline{MS}$ scheme
100 $\pm$ 21 $\pm$ 10	43 GUPTA	97 LATT	$\overline{MS}$ scheme

- |              |    |           |     |      |                        |
|--------------|----|-----------|-----|------|------------------------|
| >100         | 44 | LELLOUCH  | 97  | THEO | $\overline{MS}$ scheme |
| 127 $\pm 11$ | 45 | CHETYRKIN | 95  | THEO | $\overline{MS}$ scheme |
| 140 $\pm 24$ | 46 | JAMIN     | 95  | THEO | $\overline{MS}$ scheme |
| 146 $\pm 22$ | 47 | NARISON   | 95C | THEO | $\overline{MS}$ scheme |
|              | 48 | NEFKENS   | 92  | THEO |                        |
| 144 $\pm 3$  | 49 | DOMINGUEZ | 91  | THEO |                        |
| 88           | 50 | BARDUCCI  | 88  | THEO |                        |
|              | 51 | KREMER    | 84  | THEO |                        |
| 130 $\pm 41$ | 52 | GASSER    | 82  | THEO |                        |
- 26 AOKI 00 obtain the light quark masses from a quenched lattice simulation of the meson and baryon spectrum with the Wilson quark action. We have averaged their results of  $m_s = 115.6 \pm 2.3$  and  $m_s = 143.7 \pm 5.8$  obtained using  $m_K$  and  $m_\phi$ , respectively, to normalize the spectrum.
- 27 AOKI 99 obtain the light quark masses from a quenched lattice simulation of the meson spectrum with the Staggered quark action employing the regularization independent scheme. We have averaged their results of  $m_s = 106.0 \pm 7.1$  and  $m_s = 129 \pm 12$  obtained using  $m_K$  and  $m_\phi$ , respectively, to normalize the spectrum.
- 28 BARATE 99R obtain the strange quark mass from an analysis of the observed mass spectra in  $\tau$  decay. We have converted their value of  $m_s(m_\tau) = 176^{+46}_{-57}$  MeV to  $\mu = 2$  GeV.
- 29 MALTMAN 99 determines the strange quark mass using finite energy sum rules.
- 30 NARISON 99 uses sum rules to order  $\alpha_s^3$  for  $\phi$  meson decays.
- 31 BECIREVIC 98 compute the quark mass using the Alpha action in the quenched approximation. The conversion from the regularization independent scheme to the  $\overline{MS}$  scheme is at NNLO.
- 32 CHETYRKIN 98 uses spectral moments of hadronic  $\tau$  decays to determine  $m_s(1 \text{ GeV}) = 200 \pm 70$  MeV. We have rescaled the result to  $\mu = 2$  GeV.
- 33 CUCCHIERI 98 obtains the quark mass using a quenched lattice computation of the hadronic spectrum.
- 34 DOMINGUEZ 98 uses hadronic spectral function sum rules (to four loops, and including dimension six operators) to determine  $m_s(1 \text{ GeV}) < 155 \pm 25$  MeV. We have rescaled the result to  $\mu = 2$  GeV.
- 35 DOSCH 98 use sum rule determinations of the quark condensate and chiral perturbation theory to obtain  $m_s(1 \text{ GeV}) > 121 \pm 12$  MeV. We have converted the result to  $\mu = 2$  GeV.
- 36 LEBED 98 obtain lower bounds of 41, 90, and 139 MeV for  $m_s(1 \text{ GeV})$  using dispersion relations and chiral perturbation theory. The numbers assume the chiral perturbation theory form factor is accurate to 5%, 1%, and 0.05%, respectively. We have used the first number converted to  $\mu = 2$ .
- 37 MALTMAN 98 uses  $\tau$ -decay-like sum rules involving electromagnetic spectral data to determine  $m_s(1 \text{ GeV}) = 113 \pm 107$  MeV. We have rescaled the result to  $\mu = 2$  GeV.
- 38 MALTMAN 98B uses spectral moments of hadronic  $\tau$  decays to determine  $m_s(1 \text{ GeV}) < 220 \pm 110$  MeV. We have rescaled the result to  $\mu = 2$  GeV.
- 39 CHETYRKIN 97 obtains  $205.5 \pm 19.1$  MeV at  $\mu = 1$  GeV from QCD sum rules including fourth-order QCD corrections. We have rescaled the result to 2 GeV.
- 40 COLANGELO 97 is QCD sum rule computation. We have rescaled  $m_s(1 \text{ GeV}) > 120$  to  $\mu = 2$  GeV.
- 41 EICKER 97 use lattice gauge computations with two dynamical light flavors.
- 42 GOUGH 97 use lattice gauge computations in the quenched approximation. Correcting for quenching gives  $54 < m_s < 92$  MeV at  $\mu = 2$  GeV.
- 43 GUPTA 97 use Lattice Monte Carlo computations in the quenched approximation. The value for two light dynamical flavors at  $\mu = 2$  GeV is  $68 \pm 12 \pm 7$  MeV.
- 44 LELLOUCH 97 obtain lower bounds on quark masses using hadronic spectral functions.

- 45 CHETYRKIN 95 uses QCD sum rules at next-to-leading order. We have rescaled  $m_s(1 \text{ GeV}) = 171 \pm 15$  to  $\mu = 2 \text{ GeV}$ .
- 46 JAMIN 95 uses QCD sum rules at next-to-leading order. We have rescaled  $m_s(1 \text{ GeV}) = 189 \pm 32$  to  $\mu = 2 \text{ GeV}$ .
- 47 For NARISON 95C, we have rescaled  $m_s(1 \text{ GeV}) = 197 \pm 29$  to  $\mu = 2 \text{ GeV}$ .
- 48 NEFKENS 92 results for  $m_s - (m_u + m_d)/2$  are  $111 \pm 10 \text{ MeV}$  from meson masses and  $163 \pm 15 \text{ MeV}$  from baryon masses.
- 49 DOMINGUEZ 91 uses QCD sum rules with  $\Lambda_{\text{QCD}} = 100\text{--}200 \text{ MeV}$  and the SVZ value for the gluon condensate. We have rescaled  $m_s(1 \text{ GeV}) = 194 \pm 9$  to  $\mu = 2 \text{ GeV}$ .
- 50 BARDUCCI 88 uses a calculation of the effective potential for  $\bar{\psi}\psi$  in QCD, and estimates for  $\Sigma(p^2)$ . We have rescaled  $m_s(1 \text{ GeV}) = 118$  to  $\mu = 2 \text{ GeV}$ .
- 51 KREMER 84 obtain  $m_u + m_s = 245 \pm 10 \text{ MeV}$  at  $Q^2 = 1 \text{ GeV}^2$  using SVZ values for quark condensates; they obtain  $m_u + m_s = 270 \pm 10 \text{ MeV}$  at  $Q^2 = 1 \text{ GeV}^2$  using factorization values for quark condensates.
- 52 GASSER 82 uses chiral perturbation theory for the mass ratios, and uses QCD sum rules to extract the absolute values. We have rescaled  $m_s(1 \text{ GeV}) = 175 \pm 55$  to  $\mu = 2 \text{ GeV}$ .

## LIGHT QUARK MASS RATIOS

### $u/d$ MASS RATIO

VALUE	DOCUMENT ID	TECN	COMMENT
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#### 0.2 to 0.8 OUR EVALUATION

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

0.44	53 GAO	97 THEO	$\overline{MS}$ scheme
$0.553 \pm 0.043$	54 LEUTWYLER	96 THEO	Compilation
$< 0.3$	55 CHOI	92 THEO	
0.26	56 DONOGHUE	92 THEO	
$0.30 \pm 0.07$	57 DONOGHUE	92B THEO	
0.66	58 GERARD	90 THEO	
0.4 to 0.65	59 LEUTWYLER	90B THEO	
0.05 to 0.78	60 MALTMAN	90 THEO	
0.0 to 0.56	61 CHOI	89B THEO	
0.0 to 0.8	62 KAPLAN	86 THEO	
$0.57 \pm 0.04$	63 GASSER	82 THEO	
$0.38 \pm 0.13$	64 LANGACKER	79 THEO	
$0.47 \pm 0.11$	65 LANGACKER	79B THEO	
0.56	66 WEINBERG	77 THEO	

- 53 GAO 97 uses electromagnetic mass splittings of light mesons.
- 54 LEUTWYLER 96 uses a combined fit to  $\eta \rightarrow 3\pi$  and  $\psi' \rightarrow J/\psi(\pi, \eta)$  decay rates, and the electromagnetic mass differences of the  $\pi$  and  $K$ .
- 55 CHOI 92 result obtained from the decays  $\psi(2S) \rightarrow J/\psi(1S)\pi$  and  $\psi(2S) \rightarrow J/\psi(1S)\eta$ , and a dilute instanton gas estimate of some unknown matrix elements.
- 56 DONOGHUE 92 result is from a combined analysis of meson masses,  $\eta \rightarrow 3\pi$  using second-order chiral perturbation theory including nonanalytic terms, and  $(\psi(2S) \rightarrow J/\psi(1S)\pi)/(\psi(2S) \rightarrow J/\psi(1S)\eta)$ .
- 57 DONOGHUE 92B computes quark mass ratios using  $(\psi(2S) \rightarrow J/\psi(1S)\pi)/(\psi(2S) \rightarrow J/\psi(1S)\eta)$ , and an estimate of  $L_{14}$  using Weinberg sum rules.
- 58 GERARD 90 uses large  $N$  and  $\eta\text{--}\eta'$  mixing.
- 59 LEUTWYLER 90B determines quark mass ratios using second-order chiral perturbation theory for the meson and baryon masses, including nonanalytic corrections. Also uses Weinberg sum rules to determine  $L_7$ .

- <sup>60</sup> MALTMAN 90 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Uses a criterion of "maximum reasonableness" that certain coefficients which are expected to be of order one are  $\leq 3$ .
- <sup>61</sup> CHOI 89 uses second-order chiral perturbation theory and a dilute instanton gas estimate of second-order coefficients in the chiral lagrangian.
- <sup>62</sup> KAPLAN 86 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Assumes that less than 30% of the mass squared of the pion is due to second-order corrections.
- <sup>63</sup> GASSER 82 uses chiral perturbation theory for the meson and baryon masses.
- <sup>64</sup> LANGACKER 79 result is from a fit to the meson and baryon mass spectrum, and the decay  $\eta \rightarrow 3\pi$ . The electromagnetic contribution is taken from Socolow rather than from Dashen's formula.
- <sup>65</sup> LANGACKER 79B result uses LANGACKER 79 and also  $\rho$ - $\omega$  mixing.
- <sup>66</sup> WEINBERG 77 uses lowest-order chiral perturbation theory for the meson and baryon masses and Dashen's formula for the electromagnetic mass differences.

## ***s/d* MASS RATIO**

<u>VALUE</u>	<u>DOCUMENT ID</u>	<u>TECN</u>	<u>COMMENT</u>
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### **17 to 25 OUR EVALUATION**

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

20.0	<sup>67</sup> GAO	97	THEO $\overline{MS}$ scheme
$18.9 \pm 0.8$	<sup>68</sup> LEUTWYLER	96	THEO Compilation
21	<sup>69</sup> DONOGHUE	92	THEO
18	<sup>70</sup> GERARD	90	THEO
18 to 23	<sup>71</sup> LEUTWYLER	90B	THEO
15 to 26	<sup>72</sup> KAPLAN	86	THEO
$19.6 \pm 1.5$	<sup>73</sup> GASSER	82	THEO
$22 \pm 5$	<sup>74</sup> LANGACKER	79	THEO
$24 \pm 4$	<sup>75</sup> LANGACKER	79B	THEO
20	<sup>76</sup> WEINBERG	77	THEO

- <sup>67</sup> GAO 97 uses electromagnetic mass splittings of light mesons.
- <sup>68</sup> LEUTWYLER 96 uses a combined fit to  $\eta \rightarrow 3\pi$  and  $\psi' \rightarrow J/\psi (\pi, \eta)$  decay rates, and the electromagnetic mass differences of the  $\pi$  and  $K$ .
- <sup>69</sup> DONOGHUE 92 result is from a combined analysis of meson masses,  $\eta \rightarrow 3\pi$  using second-order chiral perturbation theory including nonanalytic terms, and  $(\psi(2S) \rightarrow J/\psi(1S)\pi)/(\psi(2S) \rightarrow J/\psi(1S)\eta)$ .
- <sup>70</sup> GERARD 90 uses large  $N$  and  $\eta$ - $\eta'$  mixing.
- <sup>71</sup> LEUTWYLER 90B determines quark mass ratios using second-order chiral perturbation theory for the meson and baryon masses, including nonanalytic corrections. Also uses Weinberg sum rules to determine  $L_7$ .
- <sup>72</sup> KAPLAN 86 uses second-order chiral perturbation theory including nonanalytic terms for the meson masses. Assumes that less than 30% of the mass squared of the pion is due to second-order corrections.
- <sup>73</sup> GASSER 82 uses chiral perturbation theory for the meson and baryon masses.
- <sup>74</sup> LANGACKER 79 result is from a fit to the meson and baryon mass spectrum, and the decay  $\eta \rightarrow 3\pi$ . The electromagnetic contribution is taken from Socolow rather than from Dashen's formula.
- <sup>75</sup> LANGACKER 79B result uses LANGACKER 79 and also  $\rho$ - $\omega$  mixing.
- <sup>76</sup> WEINBERG 77 uses lowest-order chiral perturbation theory for the meson and baryon masses and Dashen's formula for the electromagnetic mass differences.

## $(m_s - m)/(m_d - m_u)$ MASS RATIO

$$\bar{m} \equiv (m_u + m_d)/2$$

VALUE DOCUMENT ID TECN

### 34 to 51 OUR EVALUATION

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

		77	ANISOVICH	96	THEO
36	$\pm 5$	78	NEFKENS	92	THEO
45	$\pm 3$	79	NEFKENS	92	THEO
38	$\pm 9$	80	AMETLLER	84	THEO
43.5	$\pm 2.2$		GASSER	82	THEO
34	to 51		GASSER	81	THEO
48	$\pm 7$		MINKOWSKI	80	THEO

77 ANISOVICH 96 find  $Q=22.7 \pm 0.8$  with  $Q^2 \equiv (m_s^2 - m^2)/(m_d^2 - m_s^2)$  from  $\eta \rightarrow \pi^+ \pi^- \pi^0$  decay using dispersion relations and chiral perturbation theory.

78 NEFKENS 92 result is from an analysis of meson masses, mixing, and decay.

79 NEFKENS 92 result is from an analysis of of baryon masses.

80 AMETLLER 84 uses  $\eta \rightarrow \pi^+ \pi^- \pi^0$  and  $\rho$  dominance.

## LIGHT QUARKS (*u, d, s*) REFERENCES

AOKI	00	PRL 84 238	S. Aoki <i>et al.</i>	(CP-PACS Collab.)
AOKI	99	PRL 82 4392	S. Aoki <i>et al.</i>	(JLQCD Collab.)
BARATE	99R	EPJ C11 599	R. Barate <i>et al.</i>	(ALEPH Collab.)
MALTMAN	99	PL B462 195	K. Maltman	
NARISON	99	PL B466 345	S. Narison	
STEELE	99	PL B451 201	T.G. Steele, K. Kostuik, J. Kwan	
BECIREVIC	98	PL B444 401	D. Becirevic <i>et al.</i>	
CHETYRKIN	98	NP B533 473	K.G. Chetyrkin, J.H. Kuehn, A.A. Pivovarov	
CUCCHIERI	98	PL B422 212	A. Chucchieri <i>et al.</i>	
DOMINGUEZ	98	PL B425 193	C.A. Dominguez, L. Pirovano, K. Schilcher	
DOSCH	98	PL B417 173	H.G. Dosch, S. Narison	
LEBED	98	PL B430 341	R.F. Lebed, K. Schilcher	
MALTMAN	98	PL B428 179	K. Maltman	
MALTMAN	98B	PR D58 093015	K. Maltman	
CHETYRKIN	97	PL B404 337	K.G. Chetyrkin, D. Pirjol, K. Schilcher	
COLANGELO	97	PL B408 340	P. Colangelo <i>et al.</i>	
EICKER	97	PL B407 290	N. Eicker <i>et al.</i>	(SESAM Collab.)
GAO	97	PR D56 4115	D.-N. Gao, B.A. Li, M.-L. Yan	
GOUGH	97	PRL 79 1622	B. Gough <i>et al.</i>	
GUPTA	97	PR D55 7203	R. Gupta, T. Bhattacharya	
LELLOUCH	97	PL B414 195	L. Lellouch, E. de Rafael, J. Taron	
ANISOVICH	96	PL B375 335	A.V. Anisovich, H. Leutwyler	
LEUTWYLER	96	PL B378 313	H. Leutwyler	
BIJNENS	95	PL B348 226	J. Bijnens, J. Prades, E. de Rafael	(NORD, BOHR+)
CHETYRKIN	95	PR D51 5090	K.G. Chetyrkin <i>et al.</i>	(INRM, CAPE, MANZ)
JAMIN	95	ZPHY C66 633	M. Jamin, M. Munz	(HEIDT, MUNT)
NARISON	95C	PL B358 113	S. Narison	(MONP)
ADAMI	93	PR D48 2304	C. Adami, E.G. Drukarev, B.L. Ioffe	(CIT, ITEP+)
CHOI	92	PL B292 159	K.W. Choi	(UCSD)
CHOI	92B	NP B383 58	K.W. Choi	(UCSD)
DONOGHUE	92	PRL 69 3444	J.F. Donoghue, B.R. Holstein, D. Wyler	(MASA+)
DONOGHUE	92B	PR D45 892	J.F. Donoghue, D. Wyler	(MASA, ZURI, UCSBT)
NEFKENS	92	CNPP 20 221	B.M.K. Nefkens, G.A. Miller, I. Slaus	(UCLA+)
DOMINGUEZ	91	PL B253 241	C.A. Dominguez, C. van Gend, N. Paver	(CAPE+)
GERARD	90	MPL A5 391	J.M. Gerard	(MPIM)

LEUTWYLER	90B	NP B337 108	H. Leutwyler	(BERN)
MALTMAN	90	PL B234 158	K. Maltman, T. Goldman, Stephenson Jr.	(YORKC+)
CHOI	89	PRL 62 849		
CHOI	89B	PR D40 890	K. Choi, C.W. Kim	(CMU, JHU)
BARDUCCI	88	PR D38 238	A. Barducci <i>et al.</i>	(FIRZ, INFN, LECE+)
Also	87	PL B193 305	A. Barducci <i>et al.</i>	(FIRZ, INFN, LECE+)
DOMINGUEZ	87	ANP 174 372	C.A. Dominguez, E. de Rafael	(ICTP, MARS, WIEN)
KAPLAN	86	PRL 56 2004	D.D. Kaplan, A.V. Manohar	(HARV)
AMETLLER	84	PR D30 674	L. Ametller, C. Ayala, A. Bramon	(BARC)
KREMER	84	PL 143B 476	M. Kremer, N.A. Papadopoulos, K. Schilcher	(MANZ)
GASSER	82	PRPL 87 77	J. Gasser, H. Leutwyler	(BERN)
GASSER	81	ANP 136 62	J. Gasser	(BERN)
MINKOWSKI	80	NP B164 25	P. Minkowski, A. Zepeda	(BERN)
LANGACKER	79	PR D19 2070	P. Langacker, H. Pagels	(DESY, PRIN)
LANGACKER	79B	PR D20 2983	P. Langacker	(PENN)
WEINBERG	77	ANYAS 38 185	S. Weinberg	(HARV)

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