QUARKS

The \( u \)-, \( d \)-, and \( s \)-quark masses are estimates of so-called “current-quark masses,” in a mass-independent subtraction scheme such as \( \overline{\text{MS}} \) at a scale \( \mu \approx 2 \text{ GeV} \). The \( c \)- and \( b \)-quark masses are the “running” masses in the \( \overline{\text{MS}} \) scheme. For the \( b \)-quark we also quote the 1S mass. These can be different from the heavy quark masses obtained in potential models.

<table>
<thead>
<tr>
<th>Quark</th>
<th>( I(J^P) = \frac{1}{2}(\frac{1}{2}^+) )</th>
<th>( m_u = 1.7\pm 3.3 \text{ MeV} )</th>
<th>( m_u/m_d = 0.35\pm 0.60 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( u )</td>
<td>( I(J^P) = \frac{1}{2}(\frac{1}{2}^+) )</td>
<td>( m_d = 4.1\pm 5.8 \text{ MeV} )</td>
<td>( m_d/m_u = 17 \text{ to } 22 )</td>
</tr>
<tr>
<td>( d )</td>
<td>( I(J^P) = 0(\frac{1}{2}^+) )</td>
<td>( m_s = 101_{-21}^{+29} \text{ MeV} )</td>
<td>( m_s/m_d = 22 \text{ to } 30 )</td>
</tr>
<tr>
<td>( s )</td>
<td>( I(J^P) = 0(\frac{1}{2}^+) )</td>
<td>( m_c = 1.27_{-0.09}^{+0.07} \text{ GeV} )</td>
<td>( m_c/m_d = 1 )</td>
</tr>
<tr>
<td>( c )</td>
<td>( I(J^P) = 0(\frac{1}{2}^+) )</td>
<td>( m_b(\overline{\text{MS}}) = 4.19_{-0.06}^{+0.18} \text{ GeV} )</td>
<td>( m_b(1S) = 4.67_{-0.06}^{+0.18} \text{ GeV} )</td>
</tr>
<tr>
<td>( b )</td>
<td>( I(J^P) = 0(\frac{1}{2}^+) )</td>
<td>( m_t = (m_u + m_d)/2 = 3.0\pm 4.8 \text{ MeV} )</td>
<td>( m_t = (m_u + m_d)/2 = 3.0\pm 4.8 \text{ MeV} )</td>
</tr>
<tr>
<td>( t )</td>
<td>( I(J^P) = 0(\frac{1}{2}^+) )</td>
<td>( m_t = (m_u + m_d)/2 = 3.0\pm 4.8 \text{ MeV} )</td>
<td>( m_t = (m_u + m_d)/2 = 3.0\pm 4.8 \text{ MeV} )</td>
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</table>

\( \Delta E = \frac{2}{3} e \quad I = \frac{1}{2} \quad \Delta S = +1 \quad \Delta L = 0 \quad \Delta I = 0 \quad \Delta Z = +1 \)
Mass \( m = 172.0 \pm 0.9 \pm 1.3 \text{ GeV} \) [\(^a\)] (direct observation of top events)

Full width \( \Gamma < 13.1 \text{ GeV}, \text{ CL = 95\%} \)

\[
\Gamma(Wb) / \Gamma(Wq(q = b, s, d)) = 0.99 \pm 0.09 \pm 0.08
\]

### \( t \) DECAY MODES

<table>
<thead>
<tr>
<th>Fraction ( (\Gamma_i/\Gamma) )</th>
<th>Confidence level ( (\text{MeV/c}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( Wq(q = b, s, d) )</td>
<td>–</td>
</tr>
<tr>
<td>( Wb )</td>
<td>–</td>
</tr>
<tr>
<td>( \ell \nu ) anything</td>
<td>([b,c]) (9.4\pm2.4) %</td>
</tr>
<tr>
<td>( \gamma q(q=\mu,\ell) )</td>
<td>([d]) ( &lt; 5.9 \times 10^{-3} )</td>
</tr>
</tbody>
</table>

\[ \Delta T = 1 \text{ weak neutral current (}T1\text{) modes} \]

| \( Zq(q=\mu,\ell) \) | \( T1 \) | \([e]\) \( < 3.7 \times 95% \) |

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### \( b' \) (4th Generation) Quark, Searches for

- Mass \( m > 190 \text{ GeV}, \text{ CL = 95\%} \) \((p\overline{p}, \text{ quasi-stable } b')\)
- Mass \( m > 199 \text{ GeV}, \text{ CL = 95\%} \) \((p\overline{p}, \text{ neutral-current decays})\)
- Mass \( m > 128 \text{ GeV}, \text{ CL = 95\%} \) \((p\overline{p}, \text{ charged-current decays})\)
- Mass \( m > 46.0 \text{ GeV}, \text{ CL = 95\%} \) \((e^+ e^-, \text{ all decays})\)

### \( t' \) (4th Generation) Quark, Searches for

- Mass \( m > 256 \text{ GeV}, \text{ CL = 95\%} \) \((p\overline{p}, t'\overline{t'}, \text{ prod., } t' \rightarrow Wq)\)

### Free Quark Searches

All searches since 1977 have had negative results.

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**NOTES**

[a] Based on published top mass measurements using data from Tevatron Run-I and Run-II. Including also the most recent unpublished results from Run-II, the Tevatron Electroweak Working Group reports a top mass of \( 173.1 \pm 0.6 \pm 1.1 \text{ GeV} \). See the note ‘The Top Quark’ in the Quark Particle Listings of this Review.

[b] \( \ell \) means \( e \) or \( \mu \) decay mode, not the sum over them.

[c] Assumes lepton universality and \( W \)-decay acceptance.

[d] This limit is for \( \Gamma(t \rightarrow \gamma q) / \Gamma(t \rightarrow Wb) \).

[e] This limit is for \( \Gamma(t \rightarrow Zq) / \Gamma(t \rightarrow Wb) \).