5. QCD

5.1 Hadron Production
Production of Quark Pairs

This image is in the public domain.
Hadronization
$R = \frac{\sigma_H}{\sigma_{\mu\mu}}$
R-ratio at leading order

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Discussion of leading order cross sections

\[
\sigma_{0}^{e^+e^-\rightarrow\mu^+\mu^-} = \frac{4\pi\alpha_{em}}{3s} \quad \sigma_{0}^{e^+e^-\rightarrow q\bar{q}} = \frac{4\pi\alpha_{em}}{3s} e_q^2 N_c
\]

\[
R = \frac{\sigma^{e^+e^-\rightarrow\text{hadrons}}}{\sigma^{e^+e^-\rightarrow\mu^+\mu^-}} = N_c \sum_q e_q^2
\]
R-ratio at leading order

Example for center of mass energy between
\[ 2m_b c^2 \sim 10 \text{ GeV} \quad \text{and} \quad 2m_t c^2 \sim 350 \text{ GeV}. \]

\[
R = 3 \times \frac{4}{9} + \frac{1}{9} + \frac{1}{9} + \frac{4}{9} + \frac{1}{9} = \frac{11}{3}
\]

Good agreement experiment and clear evidence for color.
R-ratio at higher order

\[ R = R_0 + R_1^{q\bar{q}} + R_1^{q\bar{q}g} = R_0 \left( 1 + \frac{\alpha_s(\mu)}{\pi} \right) \]