

8.701

Introduction to Nuclear
and Particle Physics

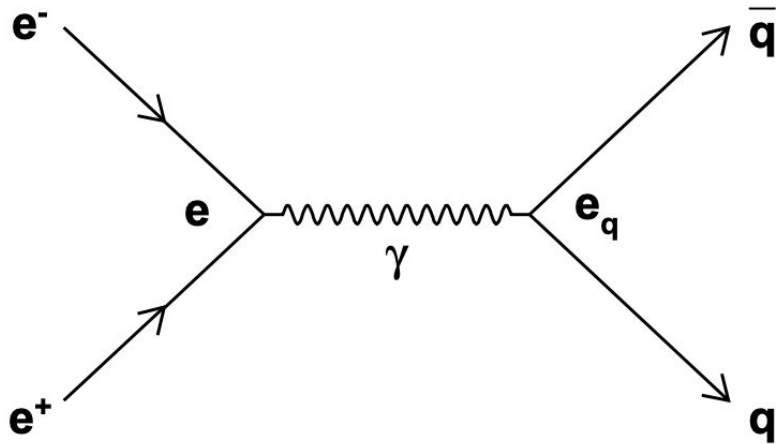
Markus Klute - MIT

5. QCD

5.1 Hadron Production



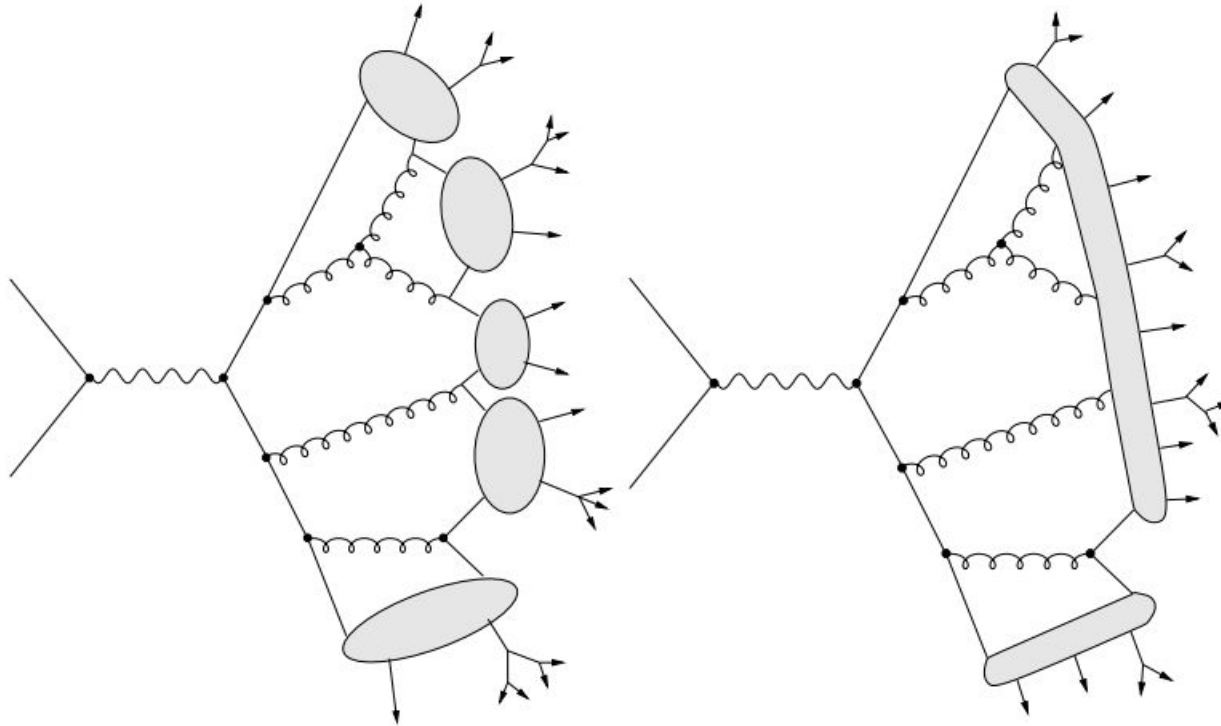
Production of Quark Pairs



QUARKS	mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$
	charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$
	spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
		u	c	t
		up	charm	top
		$\approx 4.7 \text{ MeV}/c^2$	$\approx 96 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$
	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	
	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	
	d	s	b	
	down	strange	bottom	

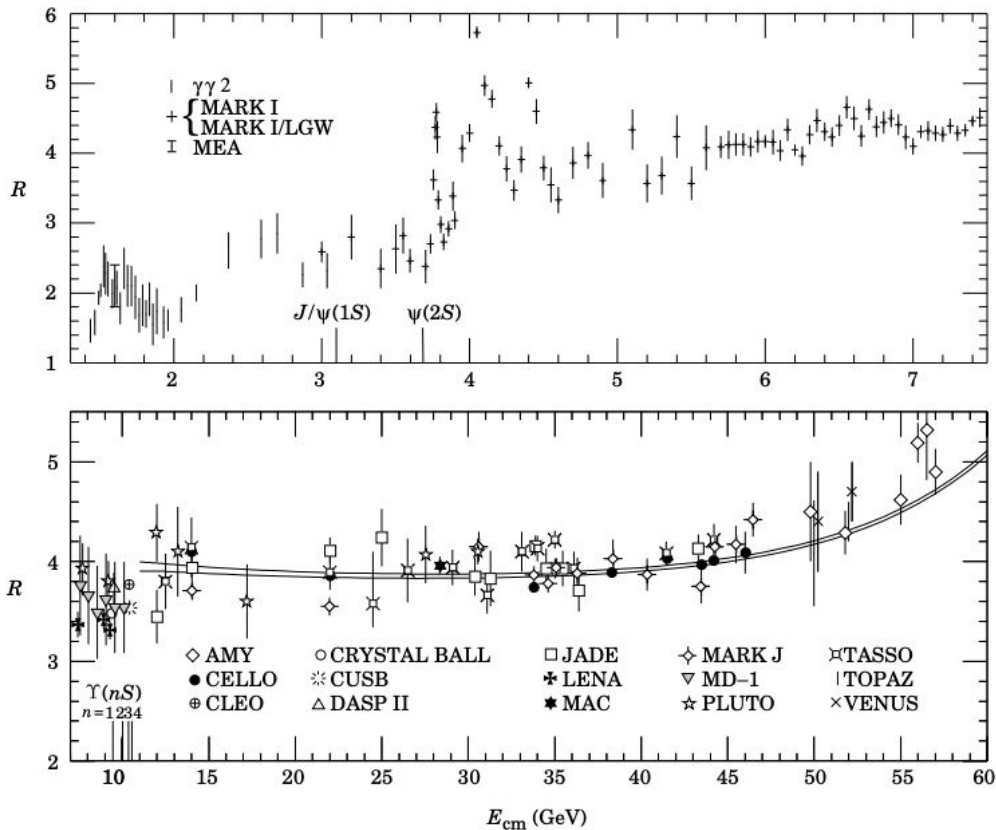
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Hadronization



R-ratio

$$R = \frac{\sigma_H}{\sigma_{\mu\mu}}$$



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R-ratio at leading order

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

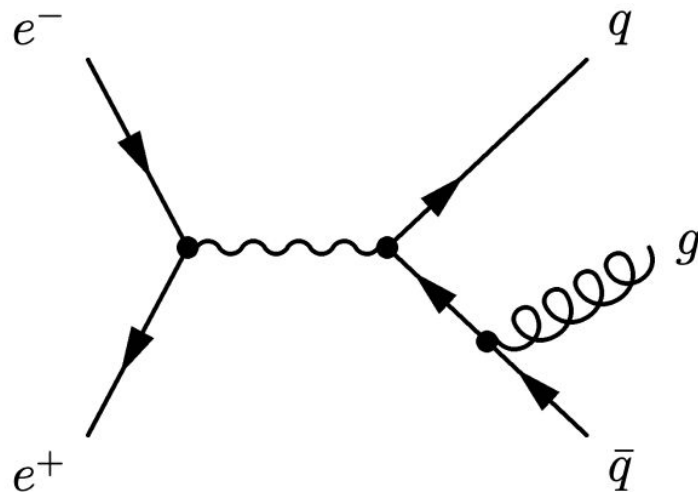
Example for center of mass energy between

$$2m_b c^2 \sim 10 \text{ GeV} \quad \text{and} \quad 2m_t c^2 \sim 350 \text{ GeV.}$$

$$R = 3 * \left(\frac{4}{9} + \frac{1}{9} + \frac{1}{9} + \frac{4}{9} + \frac{1}{9} \right) = 11/3$$

Good agreement experiment and clear evidence for color.

R-ratio at higher order



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

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Fall 2020

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