Heavy flavor jet production in CMS

by

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THESIS

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A brief dedication to someone you care about.

ACKNOWLEDGMENT

A page or two so of shout-outs to people you appreciate. Don't forget your advisor and committee members!

CMB

CONTRIBUTIONS OF AUTHORS

This section should give a rough overview of each chapter in the thesis, highlighting your contributions. Most importantly, for each one of your papers you are quoting, this section should briefly describe what each author's role / contribution was.

An example of "Contribution of Authors" section is on page 3 of the University's guide to iThenticate[1]. fixes 3 (https://github.com/bitslab/uic-cs-thesis-template/issues/3issuecomment-2455616743)

[1]http://grad.uic.edu/sites/default/files/pdfs/Introduction_to_Screening_Your_Thesis_or_Dissertation_using_iThenticate-final_a.pdf

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One to two page summary of the entire work. Like a long abstract.

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INTRODUCTION

CHAPTER 2

THE QUARK-GLUON PLASMA

2.1 Quantum Chromodynamics and the Standard Model

The Standard Model of Particle Physics is a highly descriptive quantum field theory that describes fundamental particle interactions. It explains the fundamental strong, weak, and electromagnetic interactions, which correspond to the group structure SU(3)×SU(2)×U(1). The model predicts the existance of 12 fermions which make up all matter in the universe, and 5 bosons which act as force carriers. Quantum chromodynamcs is the SU(3) part of the Standard Model that describes the strong interactions between colored quarks and gluons.

The Lagrangian of QCD is given by

$$\mathcal{L}_{\mathrm{QCD}} = \sum_{q} \bar{\psi}_{q,a} \left(i\gamma^{\mu}\partial_{\mu}\delta_{ab} - g_s \gamma^{\mu} t^{C}_{ab} A^{C}_{\mu} - m_q \delta_{ab} \right) \psi_{q,b} - \frac{1}{4} F^{A}_{\mu\nu} F^{A\mu\nu} \tag{2.1}$$

where pairs of indices are summed over and δ_{ab} is the Dirac-delta operator. The γ^{μ} are the Dirac γ-matrices, which embed spin dynamics of fermions. The $\psi_{q,a}$ are quark fields for a quark of flavor q, mass m_q, and color-index a (which runs from 1 to 3). The A^{C}_{μ} represent the gluon fields, with the index C running from 1 to 8, meaning there are 8 types of gluons. The t^{C}_{ab} represent the generators of the SU(3) group, and correspond to 3×3 matrices which embed the

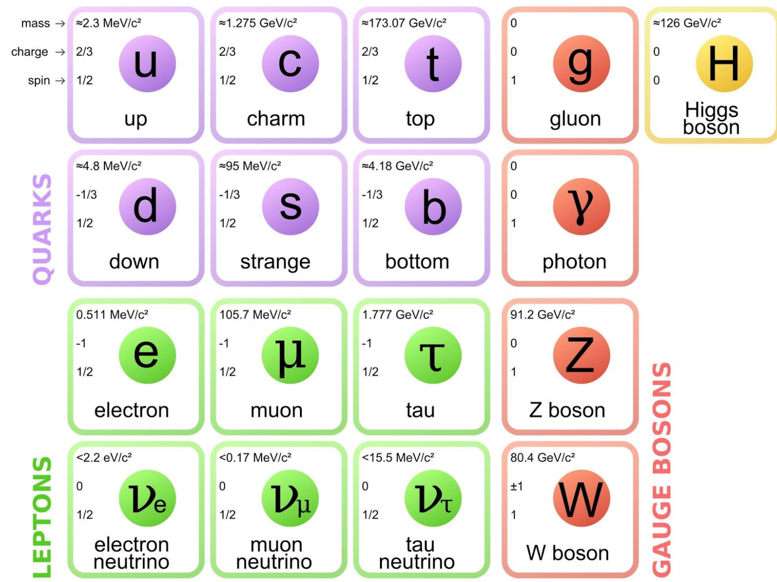

Figure 1: The fundamental particles posited by the Standard Model.

color dynamics on the quark/gluon interaction. The quantity $g_s = \sqrt{4\pi\alpha_s}$ is the QCD coupling constant. The gluon field tensor $F^A_{\mu\nu}$ is given by

$$F^A_{\mu\nu} = \partial_\mu \mathcal{A}^A_\nu - \partial_\nu \mathcal{A}^A_\mu - g_s f_{ABC} \mathcal{A}^B_\mu \mathcal{A}^C_\mu \tag{2.2}$$

where f_{ABC} are the structure constants of SU(3) and are defined by $[t^A, t^B] = i f_{ABC} t^C$. Note that the third term Eq. **??** distinguishes QCD (the strong interaction), from QED (the electromagentic interaction). This term gives rise to the triplet and quartic gluon self-interaction terms, which can be seen in the Feynman diagrams of QCD shown in Fig. **??**.

Quarks and gluons are never observed in isolation, and instead always form into hadrons as color-neutral combinations of quarks, anti-quarks, and gluons. This phenomena is known as

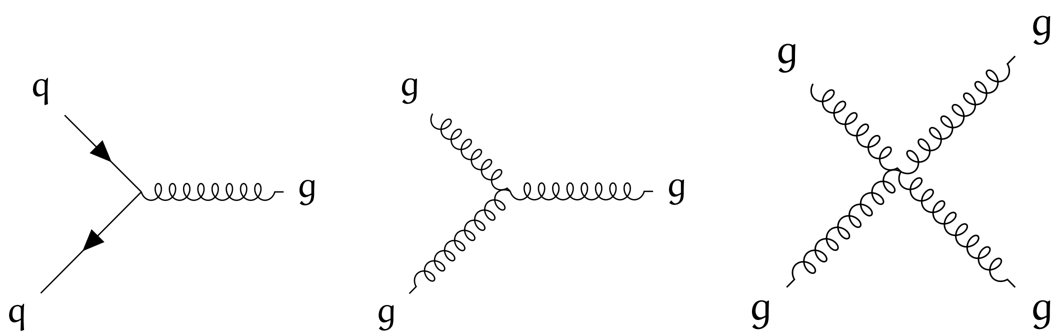

Figure 2: Feynman diagrams for the fundamental interaction vertices of QCD.

color confinement. This occurs because, at low interaction energies, the strong force coupling (given by g_s, or, equivalently, α_s) is strong. The reason for this phenomena is not immediately intuitive, and stems from the renormalization scheme for α_s. The running coupling of the strong interaction strength α_s is derived from the renormlization group equation

$$Q^2 \frac{\partial \alpha_s}{\partial Q^2} = \beta(\alpha_s) \tag{2.3}$$

where the QCD β-function has the following perturbative expansion:

$$\beta(\alpha_s) = -b\alpha_s^2 \left[1 + b'\alpha_s + O(\alpha_s^2)\right] \tag{2.4}$$

If we only keep the lowest order terms, Eq. **??** becomes

$$Q^2 \frac{\partial \alpha_s}{\partial Q^2} \approx -b\alpha_s^2 \tag{2.5}$$

which has the solution

$$\alpha_s \approx \frac{1}{b \ln\left(\frac{Q^2}{\Lambda^2}\right)} \tag{2.6}$$

where Λ comes from the choice of the constant of integration, and represents the scale at which the coupling will diverge. While the exact value for Λ is definition-dependent, it is often quoted as about 200 MeV. Near the mass scale of light hadrons ($Q \sim 1$ GeV), α_s is large, which leads to the confinement of quarks and gluons inside hadrons. For high interaction energies, α_s becomes small, and the strong force becomes small. This phenomena is known as *asymptotic freedom.*

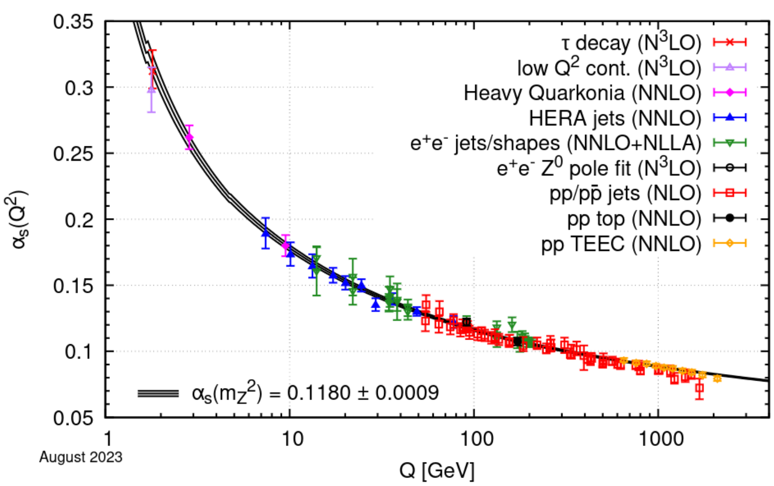

Figure 3: Experimental measurements of the strong coupling strength α_s.

CITED LITERATURE

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