Czech Technical University in Prague
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High pT jets in RunII of the ATLAS Experiment

MASTER'S DEGREE PROJECT

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Zadani prace

Statement

Prohlasuji…

V Praze dne ....

Jan Lochman

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Dekuji. . .

Jan Lochman

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Introduction

Chapter 1

QCD

Is the purpose of theoretical physics to be no more than a cataloging of all the things that can happen when particles interact with each other and separate? Or is it to be an understanding at a deeper level in which there are things that are not directly observable (as the underlying quantized fields are) but in terms of which we shall have a more fundamental understanding?

Julian Schwinger

The theoretical framework of particle physics is called Standard Model (SM). The SM describes the way how the fundamental components of matter interact with each other through strong, weak and electromagnetic interactions. Mathematically the SM is gauge quantum field theory with local internal symmetries of the direct product group $SU(3) \times SU(2) \times U(1)$. Gauge bosons are assigned to generators of this symmetry - there are 8 massless gluons from $SU(3)$ intermediating strong interaction between quarks and 3 massive $W^{\pm}, Z$ bosons with 1 massless boson γ for electroweak $SU(2) \times U(1)$ sector. Higgs mechanism has to be introduced in electroweak sector to assign $W^{\pm}, Z$ bosons mass and as consequence the new particle - Higgs boson - emerges in the SM theory. All bosons have integer spin.

In addition to the bosons the SM introduces spin-1/2 fermions which are divided into three quark and three lepton families. Fermions are assumed to be point-like because there is no evidence for their internal structure to date. All fermions interact weakly, if they have electrical charge, they interact electromagnetically as well. Quarks are the only fundamental fermions which do interact strongly. System of fundamental particles of the SM is shown in figure 1.1.

Quarks bind together to form hadrons and there are hundreds (?source?) of known hadrons up to date. Theory describing the interaction between quarks is called Quantum Chromodynamics (QCD) which key features will be discussed in this chapter. The reasoning for quark existence and for the description their strong interaction as $SU(3)$

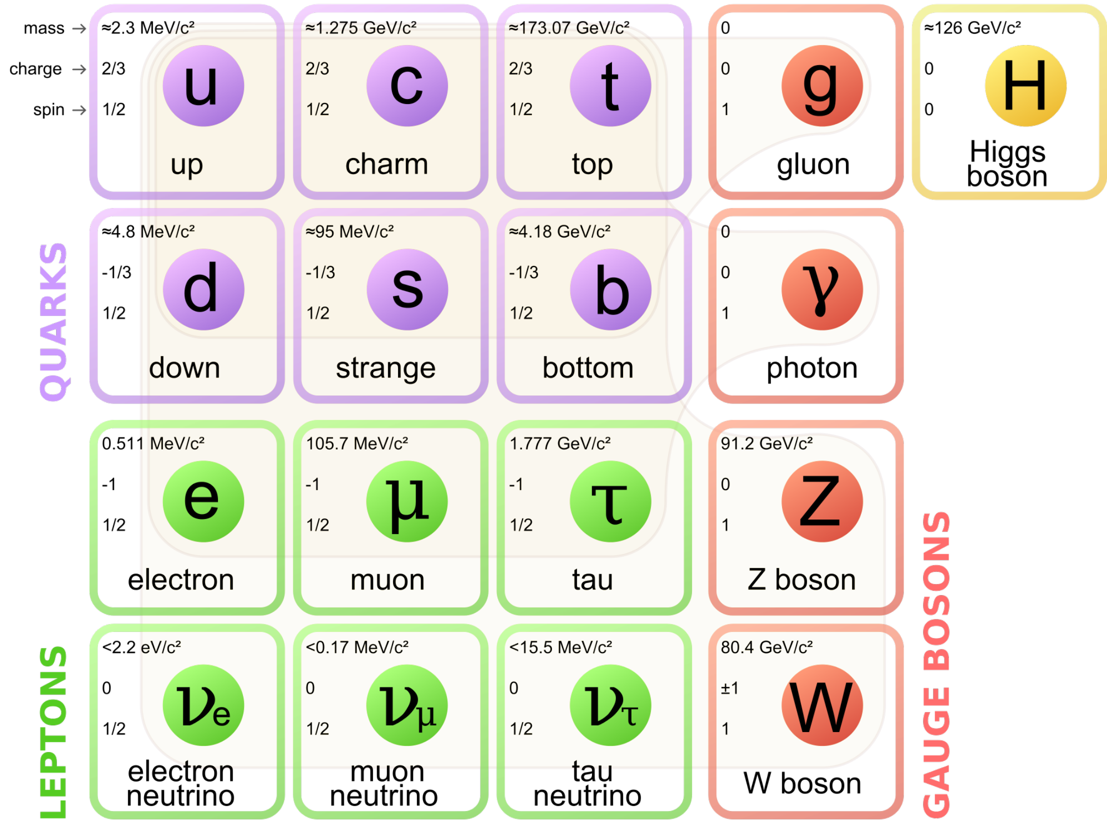

Figure 1.1: The system of fundamental particles of the SM. Figure from [1]

gauge theory will be presented. Running coupling constant will be discussed to split QCD into perturbative and non-perturbative regions - two regions, where QCD has to use different mathematical approach for description of strong interaction. Most of ideas presented here is overtaken from the following textbook [2].

1.1 Theoretical Ansatz

In 1950s there have already been discovered tens of new hadrons thanks to new particle accelerators and a lot of effort was exerted to categorize them. To each particle there was except its mass assigned a series of quantum numbers including isospin T with its third component T_3, hypercharge Y, electrical charge Q, strangeness S, baryon number B and others. Soon it was recognized, that there are some symmetries between these quantum numbers, like Gell-Mann–Nishijima relation [3, 4]

$$Q = T_3 + 1/2Y \quad , \quad Y = B + S + \ldots , \tag{1.1}$$

where dots denotes charm, bottomness and topness.

	S	Y	T	T_3	Q
p	0	1	1/2	1/2	1
n				-1/2	0
Σ^+	-1	0	1	1	1
Σ^0				0	0
Σ^-				-1	-1
Λ			0	0	0
Ξ^0	-2	-1	1/2	1/2	0
Ξ^-				-1/2	-1

Table 1.1: Quantum numbers of selected hadrons known in 1950s. S strangeness, Y hypercharge, T isospin, T_3 third component of isospin, Q electrical charge.

	S	Y	T	T_3	Q
u	0	1/3	1/2	1/2	2/3
d				-1/2	-1/3
s	-1	-2/3	0	0	

Table 1.2: Quantum numbers of three quarks which existence was predicted by Gell-Mann and Zweig in 1964.

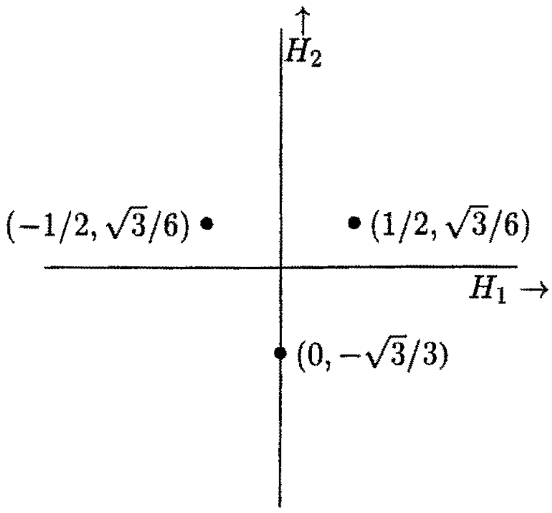

Figure 1.2: Eigenvalues of 3-dimensional representation of $\mathfrak{su}(3)$ Lie algebra. Figure from [5].

1.2 Experimental Ground

1.3 QCD as Gauge Theory

1.4 Perturbative QCD

1.5 Non-Perturbative QCD

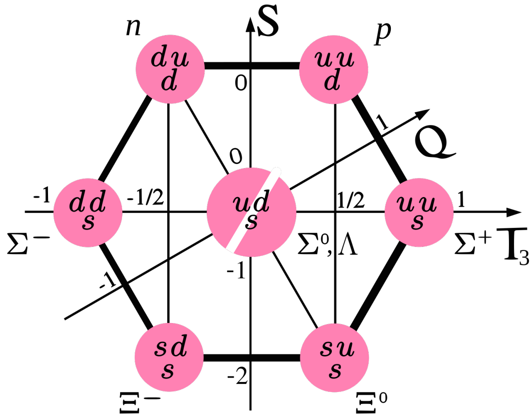

Figure 1.3: Baryonic octet encapsulating baryons from table 1.1. Figure from [6].

Chapter 2

QCD on ATLAS

Chapter 3

ATLAS Detector

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