

# Determination of the target asymmetry $T$ in $\eta'$ photoproduction

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Masterarbeit in Physik  
angefertigt im Helmholtz-Institut für Strahlen- und  
Kernphysik

vorgelegt der  
Mathematisch-Naturwissenschaftlichen Fakultät  
der  
Rheinischen Friedrich-Wilhelms-Universität  
Bonn

Sep 2022

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I hereby declare that this thesis was formulated by myself and that no sources or tools other than those cited were used.

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.....  
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1. Gutachter: JUN. PROF. DR. ANNIKA THIEL
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## Introduction

The *Standard Model of Particle Physics* (SM) is the most successful model aiming to describe the particles and forces of the universe. It distinguishes between *fermions* and *bosons*. While all matter consists of fermions, bosons are particles that mediate the fundamental interactions.

Matter consists of (anti-)quarks and (anti-)leptons with three generations of each. Table 1.1 shows all elementary fermions including some of their most important properties. Only the first and lightest generation consists of stable particles, i.e. the up and down quark as well as the electron and its neutrino. All other particles are heavier and not stable, they will thus decay fast via the strong, electromagnetic or weak interaction.

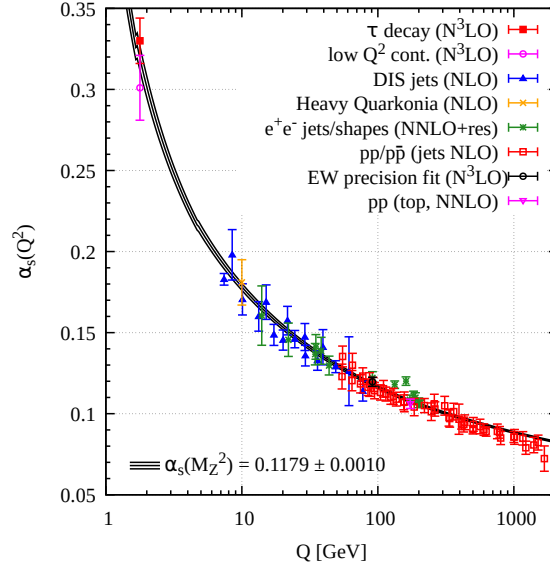
There are in fact four interactions described by the SM: strong, electromagnetic, weak and gravitational interaction<sup>1</sup>, where gravitation is mentioned here for the sake of completeness; on the mass scale of elementary particles gravitation is negligible. Strong and weak interaction are restricted to a finite range of the order of the nucleon radius, whereas electromagnetic interaction and gravitation have infinite range. Each interaction has its own coupling (charge). The strong interaction is mediated by gluons and couples to the color charge.

	Generation			el. charge	color charge
	1	2	3		
Quarks	$u$	$c$	$t$	2/3	r,g,b
	$d$	$s$	$b$	1/3	r,g,b
Leptons	$e$	$\mu$	$\tau$	-1	-
	$\nu_e$	$\nu_\mu$	$\nu_\tau$	0	-

**Table 1.1:** Summary of the particles of the SM

Gluons and quarks carry color charge and thus interact strongly. However, an isolated quark or gluon has not been observed. Only color neutral bound systems of quarks are seen, which are called hadrons. Hadrons with integer spin are called mesons and those with half-integer spin are called baryons. Color neutrality demands mesons consist of at least one quark and one anti-quark and baryons consist of at least three quarks.

<sup>1</sup> they are ordered here according to their relative strength



**Figure 1.1:** Running coupling of QCD. The colored data points represent different methods to obtain a value for  $\alpha_s$ . For more details it may be referred to [Zyl+20].

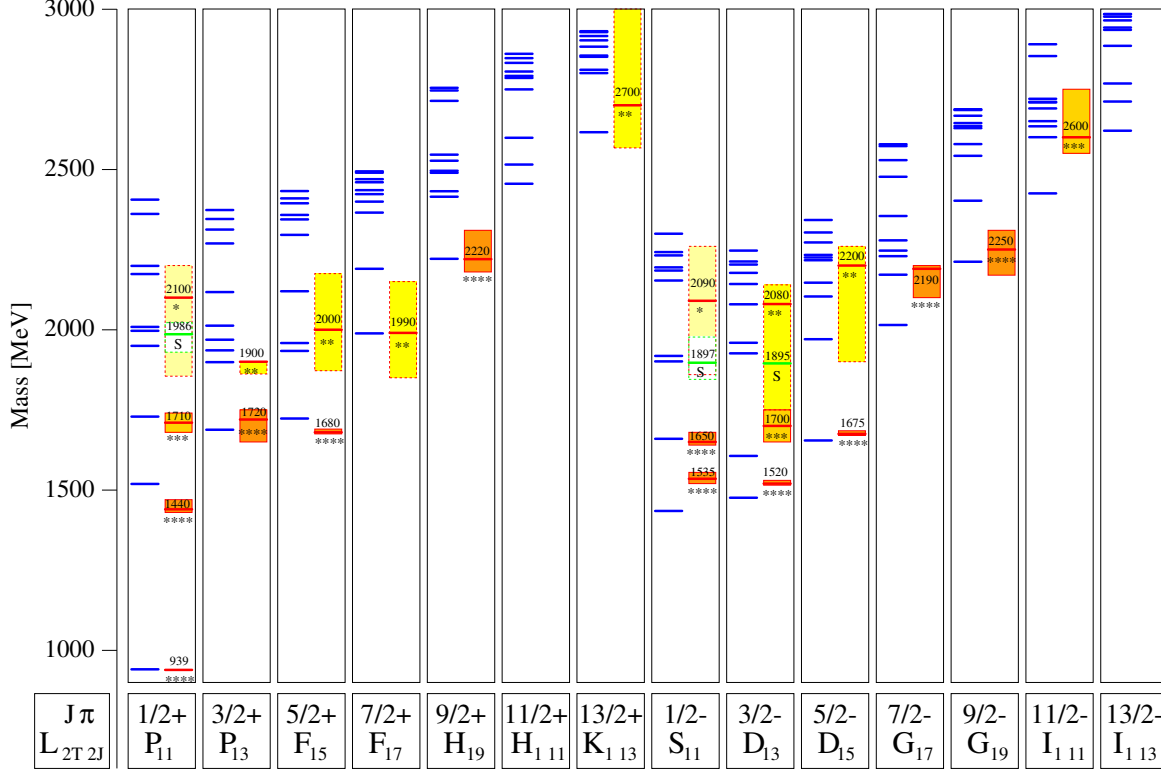
As already mentioned, isolated quarks are not seen. This can be understood in terms of the strong coupling constant  $\alpha_s$ . The coupling constant is a measure of the strength of the strong interaction. Because it is highly dependent on the momentum transfer in the observed strong reaction it is also called running coupling constant, which is depicted in figure 1.1.

For low ( $< 1$  GeV) momentum transfers or large distances the coupling constant approaches infinity whereas it decreases for high ( $\gg 1$  GeV) momentum transfers or short distances. These momentum ranges are referred to as *confinement* and *asymptotic freedom*, respectively; quarks are confined to remain in a bound state since if one tried to pull them apart the color field becomes so strong it will create a new quark anti-quark pair resulting in two new bound states. On the other hand, bound quarks behave quasi-free and can be described using perturbative quantum chromodynamics (pQCD) if probed at sufficiently large momentum transfers.

It is more difficult however to describe QCD at momentum scales of  $\approx 1$  GeV since the coupling is too strong to justify a perturbative approach. Thus explicit modeling of QCD bound states is inevitable. One possibility is to describe baryons consisting of constituent quarks which are bound in a potential. Constituent quark models assume baryons are made up of three constituent quarks with effective masses differing from the bare quark mass. The effective mass is made up mostly from a sea of quark anti-quark pairs and gluons which surround the bare (valence) quarks. The explicit form of the binding potential is determined for each model.

The Bonn model [LMP01], for example, is formulated as a relativistically covariant constituent quark model. A potential increasing linearly with the distance is employed to adequately describe confinement. The binding potential between the constituent quarks is described by an instanton-induced interaction. Baryon resonances are then states with an orbital or angular excitation of one of the quarks. Figure 1.2 shows computed nucleon, that is Isospin  $I = 1/2$  resonances, of the Bonn model [LMP01] on the left side of each column. These are compared to measured resonances and their PDG rating [Zyl+20] in the middle. Uncertainties are indicated by the colored areas. The resonances are

identified by their total angular momentum and their parity  $J\pi$ . In addition also the total internal angular momentum along with isospin and again the total angular momentum  $L_{2T2J}$  is given. While



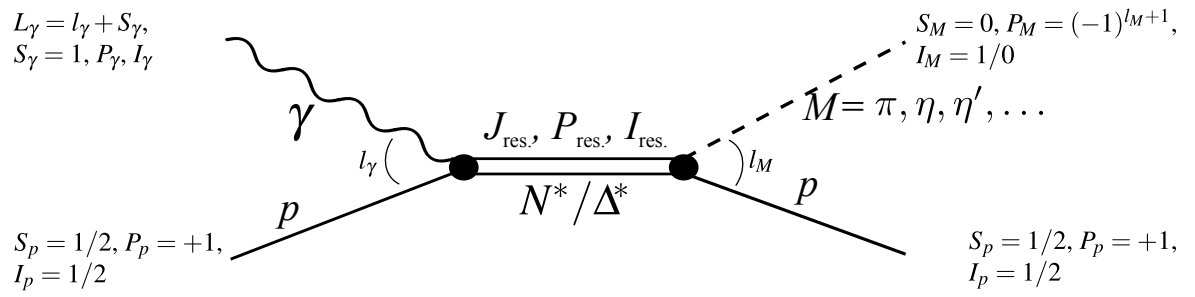
**Figure 1.2:** Calculated nucleon (isospin  $I = 1/2$ ) resonances compared to measurements. Left in each column are the calculations [LMP01], the middle shows the measurements and PDG rating [Zyl+20]

generally good agreement exists for low lying resonances, especially for high masses there are much more resonances predicted than actually found. This is also known as the problem of the “missing resonances” indicating the poor understanding of QCD in the non-perturbative region. Since most of the understanding of baryon resonances is based on analyses in the  $\pi N$  channel it is reasonable to investigate photoproduction off the nucleon to gain further insight in the baryon spectra as well as non-perturbative QCD.

## 1.1 Photoproduction of Pseudoscalar Mesons

## 1.2 Motivation and Structure of this Thesis

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## Useful information

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In the appendix you usually include extra information that should be documented in your thesis, but not interrupt the flow.

The L<sup>A</sup>T<sub>E</sub>X WikiBook [[latexwiki](#)] is a useful source of information on L<sup>A</sup>T<sub>E</sub>X.



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