Determination of the target asymmetry T in η' photoproduction

JAKOB MICHAEL KRAUSE

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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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1. Gutachter: Jun. Prof. Dr. Annika Thiel
2. Gutachterin: Prof. Dr. TBD

Contents

CHAPTER 1

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 [1], 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	μ	τ	-1	-
	ν_e	ν_μ	ν_τ	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.

[1] they are ordered here according to their relative strength

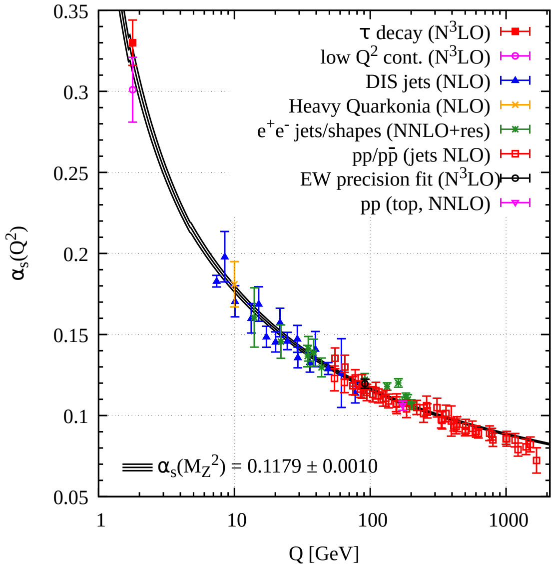

Figure 1.1: Running coupling of QCD. The colored data points represent different methods to obtain a value for α_s. For more details it may be referred to [Zyl+20].

As already mentioned, isolated quarks are not seen. This can be understood in terms of the strong coupling constant α_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 ≈ 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

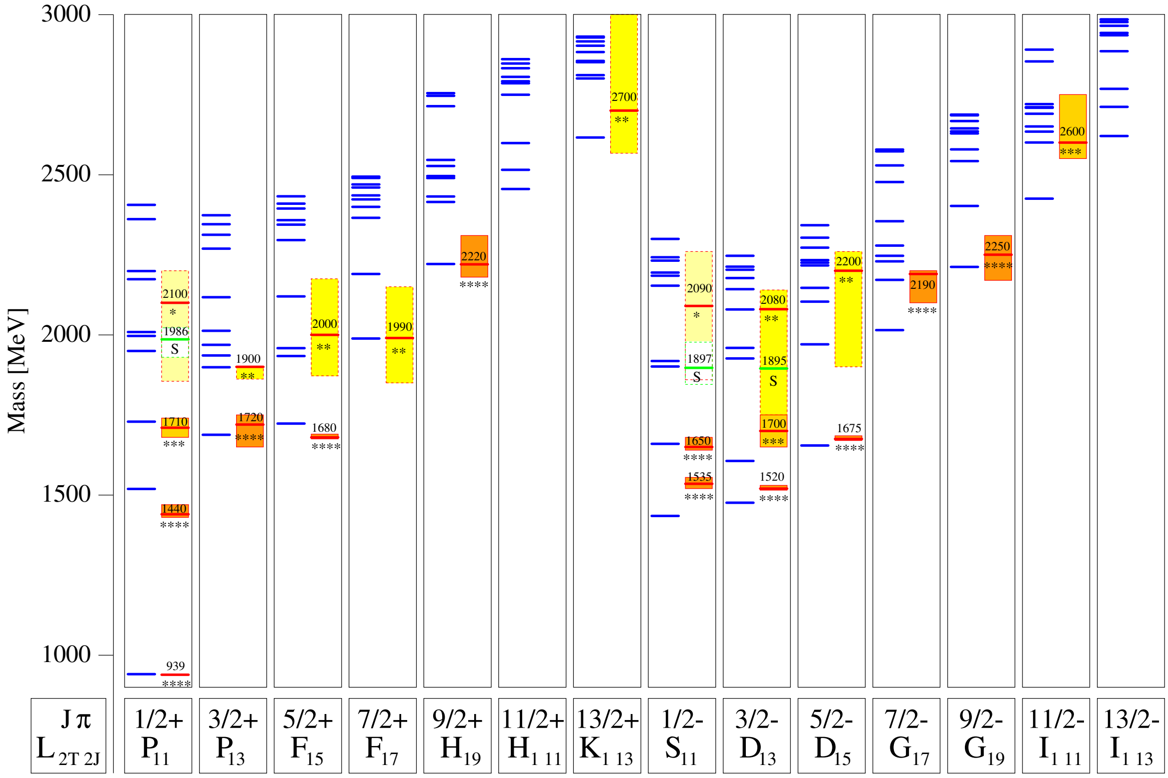

Figure 1.2: Calculated nucleon (isospin $I = 1/2$) resonances compared to measurements. Left in each column are the calculations [LMP01], the middle shows the measurements and PDG rating [Zyl+20]

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 an analyses in the πN 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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CHAPTER 2

Experimental Setup

As motivated in the previous chapter, it is promising to study the photoproduction of pseudoscalar mesons in order to determine a complete set of polarization observables. This requires a polarized photon beam and/or a polarized target. It is convenient to study photoproduction off a fixed target and investigate the resonances that occur in the process. Incidentally, these resonances can only be accessed via their decay products, such that suitable calorimeters are needed. The CBELSA/TAPS experiment is located in Bonn at the ELectron Stretcher Accelerator (ELSA), which can be used to generate a high energy photon beam using the *bremsstrahlung* process, meets all above mentioned requirements. This chapter will elaborate on the already mentioned parts of the experiment that was used to collect the data needed for the determination of the target asymmetry in η' photoproduction.

2.1 Production of (polarized) high energy photon beam

First of all, a high energy photon beam has to be produced.

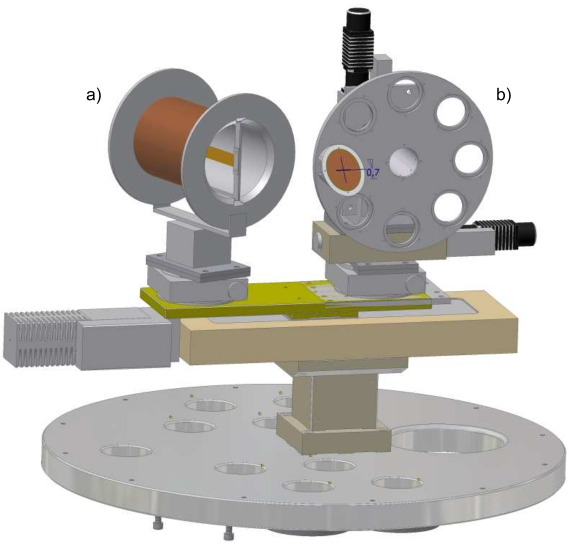

Figure 2.1: [Wal]

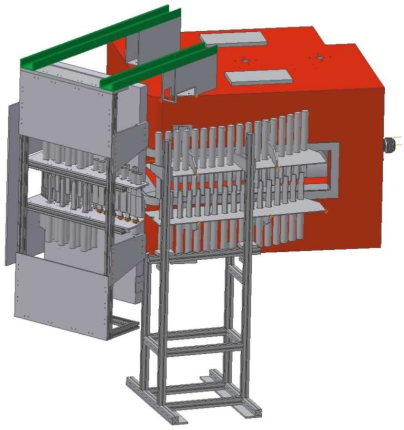

Figure 2.2: [Wal]

2.2 Beam Target

Figure 2.3: [Wal]

2.3 Calorimeters

2.4 Trigger

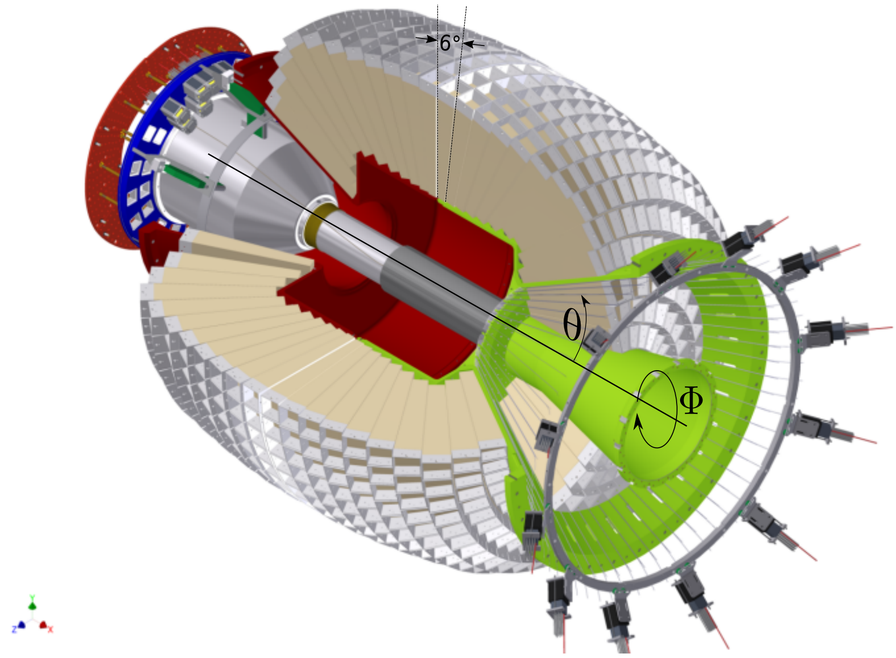

Figure 2.4: D. WALTHER in [Urb17]

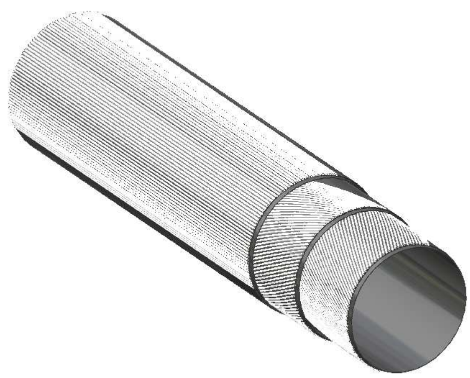

Figure 2.5: [Wal]

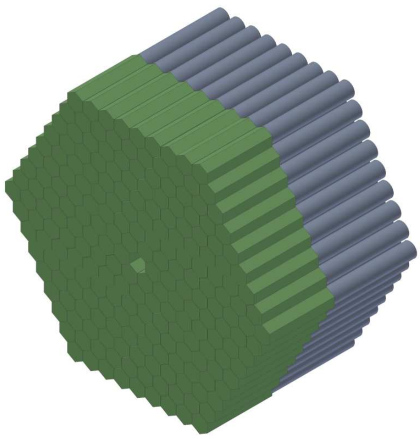

Figure 2.6: [Wal]

APPENDIX A

Useful information

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

The LaTeX WikiBook [**latexwiki**] is a useful source of information on LaTeX.

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List of Figures

List of Tables