University of Groningen

Axial-Vector Currents and Chiral Symmetry

Sauerwein, Ubbi

DOI:
[10.33612/diss.157530914](https://doi.org/10.33612/diss.157530914)

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2021

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):
Sauerwein, U. (2021). *Axial-Vector Currents and Chiral Symmetry*. [Thesis fully internal (DIV), University of Groningen]. University of Groningen. <https://doi.org/10.33612/diss.157530914>

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Axial-Vector Currents and Chiral Symmetry

The work described in this thesis was performed at the Van Swinderen Institute for Particle Physics and Gravity of the University of Groningen, at the theory group of Gesellschaft für Schwerionenforschung Darmstadt, and at Technical University of Darmstadt in terms of a double degree program.

university of
 groningen

TECHNISCHE
UNIVERSITÄT
DARMSTADT

Axial-Vector Currents and Chiral Symmetry

PhD thesis

to obtain the degree of PhD of the
University of Groningen
on the authority of the
Rector Magnificus Prof. C. Wijmenga
and in accordance with
the decision by the College of Deans.

and

to obtain the degree Doktor der Naturwissenschaften
(Dr. rer. nat.) of the Physics Faculty
of the Technical University Darmstadt - D17.

Double PhD degree

This thesis will be defended in public on
Friday 12 March 2021 at 16.15 hours

by

Ulrich Sauerwein

born on 18 May 1991
in Coburg, Germany

Supervisors

Prof. M.F.M. Lutz

Prof. R.G.E. Timmermans

Assessment Committee

Prof. D. Boer

Prof. S. Leupold

Prof. S.M. Ryan

Prof. A. Schwenk

Abstracts

Abstract

In this work we consider the axial-vector form factors of the nucleon in flavor-SU(2) and of the baryon octet in flavor-SU(3) Chiral Perturbation Theory. We include the Δ -isobar and the baryon decuplet as explicit degrees of freedom and focus on their consistent treatment in terms of chiral power counting. We employ the use of on-shell meson and baryon masses in the one-loop contributions to the axial-vector form factors. The convergence properties of such an approach are scrutinized. Our results are compared to the available flavor-SU(2) QCD lattice data.

Abstrakt

In dieser Thesis betrachten wir die Axialvektor-Formfaktoren des Nukleons in Flavor-SU(2) und des Baryon Oktetts in Flavor-SU(3) chiraler Störungstheorie. Wir berücksichtigen das Δ -Isobar und das Baryon Dekuplett als explizite Freiheitsgrade mit besonderem Schwerpunkt auf deren konsistente Behandlung in Bezug auf das chirale Zählschema. Wir verwenden On-Shell Meson- und Baryonmassen in den Ein-Schleifenbeiträgen zu den Axialvektor-Formfaktoren. Die Konvergenzeigenschaften eines solchen Verfahrens werden detailliert analysiert. Unsere Resultate vergleichen wir mit den verfügbaren Flavor-SU(2) QCD-Gitterdaten.

Abstract

In dit werk bekijken we de axiale-vector-vormfactoren van de nucleon in flavor-SU(2) en van het baryon octet in flavor-SU(3) chirale storingstheorie. We nemen de vrijheidsgraden van de Δ -isobaar en het baryon decuplet expliciet

mee en focussen op de consistente behandeling van deze vrijheidsgraden in termen van chirale powercounting. We maken gebruik van on-shell mesonen baryonmassa's in de eenluscontributies aan de axiale-vector-vormfactor. De convergentie-eigenschappen van deze benadering zijn onderzocht. Onze resultaten vergelijken we met de beschikbare data van flavor-SU(2) rooster-QCD.

Contents

1	Introduction	9
2	Axial-Vector Form Factors	13
2.1	Chiral Perturbation Theory	13
2.1.1	Introduction to Chiral Perturbation Theory	13
2.1.2	Chiral Lagrangians	15
2.2	Axial-Vector Currents	18
2.2.1	Motivation	18
2.2.2	Definition of Axial-Vector Form Factors	20
2.3	Determination of Axial-Vector Form Factors	24
2.3.1	Analytical Results	24
2.3.2	Passarino-Veltman Reduction Scheme	29
3	Flavor-SU(3) Applications	35
3.1	Renormalization and Power Counting	35
3.1.1	Renormalization	35
3.1.2	Power Counting	36
3.2	Numerical Analysis of Convergence Properties	44
3.2.1	Convergence Properties at the Physical Point	44
3.2.2	Convergence Properties in the Flavor-SU(3) Limit	50
4	Flavor-SU(2) Applications	55
4.1	Motivation	55
4.2	Axial-Vector Form Factor of the Nucleon	56
4.2.1	Framework	56

4.2.2	Analytical Results	59
4.3	Fit and Discussion	62
4.3.1	Fit Details	62
4.3.2	Fit Results	65
5	Summary and Outlook	73
5.1	Summary	73
5.2	Outlook	74
5.3	Deutsche Zusammenfassung	74
5.4	Nederlandse Samenvatting	75
A	Amplitudes	77
B	CGCs without Axial-Vector Current	81
C	CGCs of Counterterms	83
D	CGCs with Axial-Vector Current	85
E	Recoupling Constants	93
F	Passarino-Veltman Reduction Scheme	97
G	Passarino-Veltman Factors	101
H	Kinematic Factors	105
I	Flavor-SU(2) Analysis	113