Proton-proton bremsstrahlung and elastic nucleon-nucleon scattering

Cozma, Mircea Dan

Proton-proton bremsstrahlung and elastic nucleon-nucleon scattering: relativistic formulations

Druk: Stichting drukkerij C. Regenboog, Groningen, Augustus 2004.

Rijksuniversiteit Groningen

Proton-proton bremsstrahlung and elastic nucleon-nucleon scattering: relativistic formulations

Proefschrift

ter verkrijging van het doctoraat in de
Wiskunde en Natuurwetenschappen
aan de Rijksuniversiteit Groningen
op gezag van de
Rector Magnificus, dr. F. Zwarts,
in het openbaar te verdedigen op
maandag 20 september 2004
om 16.15 uur

door

Mircea Dan Cozma

geboren op 29 april 1976
te Sibiu, Roemenië

Promotores:	Prof. dr. J.A. Tjon
	Prof. dr. R.G.E. Timmermans
Copromotor:	Dr. O. Scholten
Beoordelingscommissie:	Prof. dr. J.H. Koch
	Prof. dr. M. de Roo
	Prof. dr. S.J. Wallace

Contents

1 Introduction **1**

2 Relativistic model for bremsstrahlung **5**
2.1 A relativistic covariant model for bremsstrahlung 5
2.1.1 The Martinus *et al.* $pp\gamma$ model 6
2.2 Other models 9
2.2.1 Nakayama *et al.* model 9
2.2.2 Soft-photon models 10
2.3 Comparison with the experimental KVI data 13

3 Non-relativistic toy-model for pp bremsstrahlung **17**
3.1 The two-potential formalism 17
3.1.1 Notations 17
3.1.2 The bremsstrahlung amplitude 18
3.2 Proton-proton scattering in effective field theory 20
3.2.1 Effective field theories for nucleon-nucleon scattering 20
3.2.2 Leading order amplitude in presence of the Coulomb interaction . 21
3.2.3 Next-to-leading order contributions 26
3.3 A separable potential model 29
3.4 Results for elastic scattering 31
3.5 Toy model for $pp\gamma$ 35
3.5.1 Computational details 35
3.5.2 Numerical results 38

4 Bremsstrahlung and the low energy NN interaction **43**
4.1 Analysis of the discrepancy 43
4.2 Coulomb correction to $pp\gamma$ at 190 MeV 47
4.3 On-shell sensitivity of $pp\gamma$ 50
4.4 Summary 55

5 Two-pion-exchange contributions: the formalism **57**
5.1 Introduction 57
5.2 The quasipotential approach to NN scattering 57
5.3 Chiral symmetry and the NN interaction 59

5.4 Effective theory of strong interactions 61
5.5 Construction of the effective Lagrangian 64
5.6 Explicit expressions for the two-pion diagrams 67
5.7 The quasipotential direct box 69
5.8 Method of evaluation of one-loop integrals 71
5.9 An example: the c_0 triangle diagram 73
5.10 Partial-wave decomposition of the amplitude 75
Appendix A: Tree-level potentials in the OBE model 78
Appendix B: Scalar moments 78
Appendix C: Spinors 80

6 Two-pion exchange contributions: results **81**
6.1 Phenomenological interpretation of the LECs 81
6.2 Potential in coordinate space 83
6.3 Peripheral waves 89
6.4 Effect of the iteration of the potential on the phase shifts 97
6.5 Numerical accuracy of the results 98
6.6 The lower partial waves 99
6.7 Summary 107

7 Concluding remarks **109**

Samenvatting **111**

Acknoledgements **113**

Bibliography **114**