



Universiteit
Leiden
The Netherlands

Chasing cosmic tau neutrinos in the abyss

Bormuth, R.; Bormuth R.

Citation

Bormuth, R. (2017, December 7). *Chasing cosmic tau neutrinos in the abyss*. *Casimir PhD Series*. Retrieved from <https://hdl.handle.net/1887/56023>

Version: Not Applicable (or Unknown)

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/56023>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/56023> holds various files of this Leiden University dissertation.

Author: Bormuth, R.

Title: Chasing cosmic tau neutrinos in the abyss

Issue Date: 2017-12-07

CHASING COSMIC TAU NEUTRINOS IN THE ABYSS

Proefschrift

ter verkrijging van
de graad van Doctor aan de Universiteit Leiden,
op gezag van Rector Magnificus prof. mr. C.J.J.M. Stolker,
volgens besluit van het College voor Promoties
te verdedigen op donderdag 7 december 2017
klokke 11:15 uur

door

ROBERT BORMUTH
geboren te Heppenheim, Duitsland
in 1986

Promotor: Prof. dr. M. de Jong
Co-promotor: Dr. D.F.E. Samtleben

Promotiecommissie: Prof. dr. E.N. Koffeman, University of Amsterdam
Dr. A. Heijboer, Nikhef
Dr. T. Eberl, University of Erlangen-Nürnberg
Prof. dr. E.R. Eliel
Prof. dr. A. Achúcarro

Casimir PhD series, Delft-Leiden 2017-42

ISBN 978-90-8593-326-7

published in print format 2017

An electronic version of this thesis can be found at <https://openaccess.leidenuniv.nl>

©Robert Bormuth 2017

This document was typeset using the typographical look-and-feel `classicthesis` developed by André Miede. The style was inspired by Robert Bringhurst's seminal book on typography "*The Elements of Typographic Style*". `classicthesis` is available for both \LaTeX and `LyX`:

<http://code.google.com/p/classicthesis>

Cover picture by Matthijs Damen

LOCATION:

Leiden University, Leiden

For my loved ones

CONTENTS

1	INTRODUCTION	7
1.1	Cosmic Rays	7
1.2	Neutrino astronomy	15
1.2.1	Neutrino history and properties	15
1.2.2	Neutrino interactions with matter	17
1.2.3	Neutrino sources	21
1.2.4	Neutrino telescopes	25
1.2.5	Cosmic neutrino observations: SN1987 and the IceCube flux	32
2	THE KM3NET DETECTOR	35
2.1	KM3Net ARCA	35
2.2	Detection unit	36
2.3	Detection module	39
2.4	Background sources	39
2.5	Data acquisition system	42
2.5.1	Trigger algorithm	42
3	SIMULATION	43
3.1	Event generation	43
3.1.1	Tau neutrino simulations	44
3.2	Light simulation and detector response	45
3.3	Tau Toy Monte Carlo	46
4	DETECTION UNIT PROTOTYPE	49
4.1	Introduction	49
4.2	Technical design	50
4.3	Data acquisition system	53
4.3.1	Trigger algorithm	53
4.3.2	Recorded data	54
4.4	PPM-DU Monte Carlo simulation	56
4.5	In-situ detector calibration	57
4.5.1	PMT calibration	58
4.5.2	PMT calibration stability studies	62
4.5.3	DOM beacon calibration	63
4.5.4	Calibrating DOM 3 using beacon 1 vs using beacon 2	66
4.5.5	Hit selection: Difference in using 2 nd hit vs using 1 st hit	68
4.5.6	DOM muon calibration	69
4.5.7	Data period calibration	70
4.6	PPM-DU data analysis	71
4.6.1	Time over threshold signal	71
4.6.2	Single rates	71
4.6.3	Recorded triggered events	72
4.6.4	Muon detection	74
4.7	Muon reconstruction	79

CONTENTS

4.7.1	Fitting procedure	79
4.7.2	Event selection	81
4.7.3	Zenith angle reconstruction	82
4.8	PPM-DU conclusion	86
5	BELLE STARR RECONSTRUCTION	87
5.1	Tau “Double Bang” event signature	88
5.2	Background signatures	93
5.3	Belle Starr Prefit	95
5.3.1	Position and time fit	95
5.3.2	Energy and direction fit	101
5.4	Belle Starr Scan	104
5.5	Belle Starr Peak	110
5.5.1	TSpectrum background estimation	110
5.5.2	TSpectrum peak identification	111
5.5.3	TSpectrum for likelihood scans	111
5.5.4	Improvement of reconstructed positions	114
5.5.5	Vertex position reconstruction performance	115
5.6	Belle Starr Refit	118
5.6.1	Full fit performance	118
6	TAU “DOUBLE BANG” SELECTION	121
6.1	Selection Criteria	121
6.1.1	Energy cut	123
6.1.2	Position cut	124
6.1.3	Peak cut	125
6.1.4	Background cut	127
6.1.5	Length cut	129
6.2	Selection criteria efficiency	131
6.3	Belle Starr resolution for selected events	134
6.4	Results of the tau “Double Bang” selection	136
6.5	Discussion	139
7	APPENDIX	141
	Summary	155
	Samenvatting	163
	About the Author	171
	Acknowledgements	173