

Contents

Abstract	VII
List of Abbreviations	XI
List of Figures	XIII
List of Tables	XV
1 Introduction	1
2 Theoretical background of proton therapy and PET imaging	5
2.1 Principle of proton therapy	5
2.1.1 Interaction of heavy charged particles with matter	5
2.1.2 Particle range and range straggling	7
2.1.3 Lateral scattering	8
2.1.4 Nuclear reactions and positron emitter production	9
2.2 Principles of PET imaging	11
2.2.1 Physical background of PET imaging	11
2.2.2 PET scanning systems	13
2.3 The Rinecker Proton Therapy Center (RPTC)	13
3 Monte Carlo modeling of the clinical proton beam	17
3.1 The FLUKA Monte Carlo Code	17
3.1.1 The FLUKA input file	18
3.1.2 FLUKA user-routines	18
3.1.3 FLUKA model of the beamline	19
3.2 The spot scanning routine	19
3.3 Monitor Unit calibration	22
3.3.1 MU calibration experiments, conversion formalism and validation . .	22
3.3.2 Further improvement of the MU calibration	23
3.4 Low-dose envelope and Field Size Factor	25
3.4.1 Lateral profile of a single pencil beam	26

3.4.2	Field size dependence of the output factor for monoenergetic square fields	29
3.4.3	Model validation for dose to spherical target volumes	33
3.4.4	Final discussion on the accuracy of the MU calibration	36
4	PET activation studies	39
4.1	Materials and Methods	39
4.1.1	Phantoms	40
4.1.2	Experimental setup	44
4.1.3	MC calculation of proton induced positron emitter distributions . . .	46
4.1.4	Data evaluation	47
4.2	Results	50
4.2.1	Integral absolute isotope yields	50
4.2.2	Depth dependent absolute isotope yields	57
4.2.3	Lateral activity profile	63
4.3	Additional investigation of the PET scanner performance	65
4.3.1	Test experiments with FDG	65
4.3.2	PE	68
4.3.3	Gelatine	69
4.4	Discussion of uncertainties	72
4.4.1	Scanner performance	72
4.4.2	Fit uncertainties	74
4.4.3	Further uncertainties	74
5	Conclusion and Outlook	77
	Bibliography	81