

## Education & Experience

- since 9/2019 **Research Group Leader “Radiotherapy Optimization”**, *Division of Medical Physics in Radiation Oncology, German Cancer Research Center – DKFZ, Heidelberg*,  
leading a research team focusing on the development and implementation of physical, biological and numerical models in the context of radiotherapy treatment planning and maintaining the open source dose calculation and treatment planning toolkit “matRad”
- 7/2025 – 8/2025 **Visiting Researcher**, *Department of Accelerator and Medical Physics, National Institutes for Quantum Science and Technology, Chiba, Japan*,  
working on computational and radiobiological modeling for ion therapy
- 8/2018 – 8/2019 **Postdoctoral Researcher & Project Coordinator**, *Division of Medical Physics in Radiation Oncology, German Cancer Research Center – DKFZ, Heidelberg*,  
research in uncertainty quantification and probabilistic/robust treatment planning for particle therapy, maintenance of the open source toolkit “matRad”, and coordination of the Chilean-German Consortium for Medical Physics in Radiation Oncology (CGCoMPRO)
- 5/2017 – 7/2017 **Visiting Researcher**, *Group Probabilistic Numerics, Max Planck Institute for Intelligent Systems, Tübingen*,  
working on the development of analytical probabilistic models for radiotherapy treatment plan quality indicators
- 6/2015 – 7/2015 **Visiting Researcher**, *Group Probabilistic Numerics, Max Planck Institute for Intelligent Systems, Tübingen*,  
working on numerical methods for accelerated analytical probabilistic dose calculation
- 1/2015 – 7/2018 **Doctoral Studies**, *Division of Medical Physics in Radiation Oncology, German Cancer Research Center – DKFZ & Heidelberg University, in Physics*,  
awarded the degree of Dr. rer. nat. graded *summa cum laude* for the thesis titled “Analytical models for Probabilistic Inverse Treatment Planning in Intensity-modulated Proton Therapy”
- 7/2014 – 9/2014 **Research assistant**, *German Cancer Research Center – DKFZ, Heidelberg*
- 2012 – 2017 **Freelancer**  
Metadata Annotation, Web-Programming, Research consulting.
- 10/2011 – 3/2014 **Master Studies**, *Heidelberg University, in Physics*,  
graduated M.Sc. with overall grading *very good*, master thesis: “Automated Voxel-based Penalty Adaption for ultra-fast Treatment Planning in Intensity-modulated Radiation Therapy”
- 2010 – 2014 **Student teaching assistant** for practical physics courses on a regular basis, *Department of Physics & Astronomy at the Heidelberg University*
- 4/2008 – 10/2011 **IT Assistant**, *HierEDV, Heidelberg*
- 10/2007 – 5/2011 **Bachelor Studies**, *Heidelberg University, in Physics*,  
graduated B.Sc. with overall grading *good*, bachelor thesis: “Performance of the local on-line Tracking and of a Track-based Jet Trigger Algorithm for the ALICE TRD on the Basis of Monte-Carlo Simulations”
- 10/1999 – 6/2007 **Abitur**, *Dietrich-Bonhoeffer-Gymnasium, Weinheim*,  
higher education entrance qualification with overall grading of 1.4

## Community, Outreach, Memberships

- 2025 Co-organizer of the SynthRad2025 challenge on AI-generation of synthetic CTs
- since 2024 Member of the AI subcommittee of the Particle Therapy Co-Operative Group (PTCOG)

- 2024 Chair of the ESTRO Physics Workshop 2024 Topic on “Resource sharing: open-source software & development in radiotherapy”
- since 2023 Corresponding member of the American Association of Physicists in Medicine (AAPM)
- 2023 Course lead for the 5<sup>th</sup> Summer School in Medical Physics: Data Science and Machine Learning in Radiotherapy, Heidelberg/Online
- 2023 Co-organization of a high school students day on particle physics within the MINT100 program, Heidelberg
- 2021 Organization of the first HITRIplus Heavy Ion Therapy Masterclass School
- since 2019 Organization of a weekly Medical Physics Seminar with invited (international) speakers for the Research Program “Imaging and Radiooncology” at DKFZ
- since 2019 Establishing a “Particle Therapy Master Class” for school children (in cooperation with CERN, GSI & the Heidelberg Life Science Lab) with the first successful pilot in March 2019
- since 2019 Member of the Deutsche Gesellschaft für Radiooncologie (DEGRO)
- since 2019 Member of the Deutsche Gesellschaft für Medizinische Physik (DGMP)
- 2018 – 2020 Project coordinator within the Chilean-German Consortium for Medical Physics in Radiation Oncology (CGCoMPRO) sponsored by the German Federal Ministry of Education and Research, organizing multiple workshops in Santiago de Chile
- since 2018 Occasional reviews for Medical Physics, International Journal of Radiation Oncology\*Biophysics, Physics in Medicine and Biology, Radiation Oncology, Physica Medica: European Journal of Medical Physics, and Strahlentherapie & Onkologie
- since 2017 Member of the European Society for Radiotherapy & Oncology (ESTRO)
- 2016 Referee for “Jugend forscht”, Europe’s biggest youth science & technology competition
- since 2015 Co-hosting a YouTube channel (Physiktutorium) with instructional physics videos for students
- since 2015 Continuous contribution to the open source radiation therapy treatment planning toolkit matRad (<http://www.matrad.org>)
- 2015 Supporting the organization of the Machine Learning Summer School (MLSS), Tübingen
- 2009 – 2017 Helper in the International Summer School for German Language and Culture at the Heidelberg University
- 2008 – 2018 Assisting at “Explore Science”, a yearly educational scientific event at the behest of the Klaus Tschira Foundation
- since 2007 Member of the German Physical Society (DPG)
- 2003 Participation in a one-month school exchange with Hunterdon Central Regional High School, NJ, USA, within the German American Partnership Program (GAPP)

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### Third-party Funding & Projects

- 2023 – 2026 **German-Israeli Cooperation in Cancer Research Project Ca 216**, *Development of Advanced PI Feasibility, Superiorization and Optimization Methods for Complex Inverse Treatment Problems in Radiation Therapy Treatment Planning*, ca. 126 000 €, Principal Investigator
- 2022 – 2027 **NIH Award R01CA266467**, *Ionization Detail – Biologically based treatment planning for particle therapy beyond LET-RBE*, \$308 650 awarded to DKFZ, Principal Investigator: Prof. Jäkel, other Co-Investigator: Prof. Karger
- 2022 **Mathworks Community Toolbox Development Support**, *Development sparse linear algebra and DICOM plugins for matRad*, \$20 500, Principal Investigator
- 2021 – 2025 **DFG project support grant No. 443188743**, *Sustainable development of the open source radiotherapy dose calculation and optimization toolkit matRad*, ca. 315 000 €, Principal Investigator
- 2021 – 2025 **DFG New Instrumentation for Research grant No. 457509854**, *HELIOS – Developing a HELium Imaging Oncology Scanner for Range Guided Radiotherapy (RGRT) for Non-Small Cell Lung Carcinoma (NSCLC)*, ca. 187 000 € (of total project funds of ca. 950 000 €), Principal Investigator (Other PIs: Prof. Joao Seco, Prof. Oliver Jäkel)

2021 – 2025 **HIDSS4Health Project**, *Inverse Radiotherapy Treatment Planning using Machine Learning*  
CI *Outcome Prediction Models*, 1 fully-funded PhD position, Co-Investigator (PIs: Prof. Martin Frank, Prof. Oliver Jäkel)

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## Awards, Honors, Appointments, Positions

Appointment Associate Editor “Medical Physics”, since 2021  
Position Considered for an independent research group leader position at the University of Tübingen (no exact ranking communicated), 2020  
Dissertation Award DEGRO Dissertation Award, 2019  
Poster Prize DKFZ PhD Poster Award, 2017  
Presentation Award Science Slam, NCRO Meeting Dresden, 2016  
School Award Jugend denkt Zukunft, national winning team, 2006

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## Invited & International Presentations

Workshop The 11<sup>th</sup> Annual Loma Linda workshop on Particle Imaging and Radiation Treatment Planning, Loma Linda, 2025  
Seminar Seminar for Department of Accelerator and Medical Physics, National Institutes for Quantum Science and Technology, Chiba, Japan, 2025  
Symposium 31<sup>st</sup> DEGRO Congress, Artificial Intelligence in Radiotherapy, Dresden, 2025  
Seminar MIRO Seminar, Université catholique de Louvain, Brussels, 2025  
Seminar Physics Seminar, University of Bonn, 2025  
Seminar Biomedical Physics Seminar, University of Tübingen, 2025  
Seminar Memorial Sloan Kettering Cancer Center Medical Physics Seminar, New York City, 2024  
Seminar Harvard Mass General Radiation BioPhysics Seminar, Boston, 2024  
Symposium XChange 2024 – Artificial Intelligence in Radiation Oncology, München, 2024  
Symposium Hadron Therapy Symposium: Treatment Planning MasterClass, Thessaloniki, 2024  
Winter School Winterschule Pichl für Medizinische Physik, Pichl, 2024  
Workshop The 9<sup>th</sup> Annual Loma Linda workshop on Particle Imaging and Radiation Treatment Planning, Loma Linda, 2023  
Course 3<sup>rd</sup> HITRIplus School – Specialised Course on Clinical Aspects of Heavy Ion Therapy Research, Online, 2023  
Seminar Harvard Mass General Radiation BioPhysics Seminar, Boston (Online), 2023  
Seminar U3 Seminar LMU München (Klinikum), München (Online), 2023  
Winter School Winterschule Pichl für Medizinische Physik (Spring Edition), Pichl, 2023  
Summer School Summer School in Medical Physics 2023 in Chile: The role of imaging in the radiotherapy process, Santiago de Chile, 2022  
Workshop Scientific multi-disciplinary workshop at the Clínica Alemana (CAS), Santiago de Chile, 2022  
Workshop Emerging Techniques in Radiotherapy & Hands-on matRad Tutorial (Pontifical Catholic University of Chile), Santiago de Chile, 2022  
Summer School 4<sup>th</sup> Virtual Summer School 2022: Radiobiology and Radiobiological Modelling for Radiotherapy, Heidelberg/Online, 2022  
Course ECMP Refresher Course: Radiotherapy – Open Source Software for Radiotherapy Physics Research, Dublin, 2022  
Course ESMPE European School for Medical Physics Experts: Adaptive Radiotherapy: Pros and Cons of In-room versus Out-of-Room Imaging, Dublin, 2022  
Course Specialised Hadron Therapy Training Course, Online, 2022  
Winter School Winterschule Pichl für Medizinische Physik (Summer Edition), Pichl, 2022  
Workshop The mathematics of modern radiation therapy, Medellin (Online), 2021

Workshop	Course – Proton Therapy: the challenges and the opportunities, UT Austin Portugal Programm, Online, 2021
Seminar	Medical Physics Seminar, Brigham and Women's Hospital/Dana-Farber Cancer Institute/Harvard Medical School, Boston (Online), 2021
Summer School	Virtual Summer School 2021: Image Guided Radiation Therapy (IGRT) and Advanced Treatment Techniques, Heidelberg/Online, 2021
Summer School	3 <sup>rd</sup> Virtual Summer School in Medical Physics: Applied Computational Methods for Radiotherapy, Heidelberg/Online, 2021
Summer School	HITRIplus Heavy Ion Therapy Masterclass School, Sarajevo/Online, 2021
Public	Interactive introduction of Ion Therapy to the General Public within the program “Physik am Samstag” at University of Mainz (Online), 2021
Workshop	The 7 <sup>th</sup> Annual Loma Linda workshop on Particle Imaging and Radiation Treatment Planning, Loma Linda (Online), 2021
Workshop	The 5 <sup>th</sup> Annual Loma Linda workshop on Particle Imaging and Radiation Treatment Planning, Loma Linda, 2019
Highlight	Highlight presentation at the 19 <sup>th</sup> ICCR, Montréal, 2019
Workshop	DGMP – Working Group Computer, Aachen, 2019
Symposium	ESTRO 38, Milan, Italy, 2019 (as co-author)
Seminar	Karlsruhe Institute of Technology, Germany, 2019
Workshop	1 <sup>st</sup> ESTRO Physics Workshop, Glasgow, UK, 2017
Seminar	UniversitätsSpital Zürich, Switzerland, 2017
Seminar	Universitair Medisch Centrum Utrecht, Netherlands, 2014

## Teaching Experience & Student Supervision

Student supervision	<p>(Co-)supervision of the following theses projects;</p> <p>T. Becher (PhD): <i>Advanced Optimization and Superiorization methods for radiotherapy treatment planning</i> (ongoing),</p> <p>S. Facciano (PhD): <i>Particle therapy treatment planning with nano-dosimetric ionization detail</i> (ongoing),</p> <p>R. Cristoforetti (PhD): <i>Biological and physical robustness in joint optimization of mixed-modality treatment plans</i> (ongoing),</p> <p>J. Hardt (PhD): <i>Dose simulations and treatment planning strategies using mixed Helium-Carbon Beams</i> (ongoing),</p> <p>T. Ortkamp (PhD): <i>Inverse Radiotherapy Treatment Planning using Machine Learning Outcome Prediction Models</i> (ongoing),</p> <p>V. Santiago (MSc): <i>Developing BayesDose: An uncertainty-aware AI-based dose-calculation engine</i> (ongoing),</p> <p>F. Leininger (MSc): <i>Direct NTCP planning for Deep-Learning based outcome models</i> (ongoing),</p> <p>M. Palkowitsch (MSc): <i>Robustness in jointly optimized mixed-modality treatment plans</i> (ongoing),</p> <p>A. Bennan (PostDoc): <i>Sustainable development of the open source treatment planning toolkit matRad</i> (2025),</p> <p>N. Homolka (PhD): <i>Intensity-modulated dose calculation &amp; treatment planning for carbon ions</i> (2025),</p> <p>L. Bucher (BSc): <i>Sequential Deep Neural Network Models for Proton Dose Calculation</i> (2024),</p> <p>L. Seckler (BSc): <i>LET optimization in mixed-modality treatment plans</i> (2024),</p> <p>T. Becher (MSc): <i>Pareto trade-offs in joint optimization of mixed-modality treatment plans</i> (2023),</p> <p>P. Stammer (PhD): <i>Uncertainty quantification in Monte Carlo dose calculation algorithms for proton therapy</i> (2023),</p> <p>L. Voss (BSc): <i>Bayesian LSTM networks for proton dose prediction</i> (2023),</p> <p>J. Hardt (MSc): <i>Efficient effect-based optimization strategies for (N)TCP based treatment planning</i> (2022),</p> <p>A. Bennan (PhD): <i>Joint optimization of combined photon &amp; carbon ion therapy</i> (2022, co-supervision),</p> <p>J. Kunz (BSc): <i>Accelerating the open-source treatment planning toolkit matRad with GPGPU computations</i> (2022),</p> <p>M. W. Kheshfeh (BSc): <i>Development of an Unit-Testing-Framework for the open-source toolkit matRad</i> (2021),</p> <p>R. Yulvina (BSc): <i>A bi-directional Python binding for the open-source toolkit matRad</i> (2021)</p> <p>C. Hormazábal (MSc): <i>Dose and grading uncertainties in Xerostomia prediction using Machine Learning classification</i> (2020),</p> <p>P. Meder (MSc &amp; res. ass.): <i>Heterogeneity corrections for analytical proton dose calculation algorithms</i> (2020),</p> <p>A. Neishabouri (MSc &amp; res. ass.): <i>Performing proton dose calculation using Artificial Neural Networks</i>, (2019, co-supervision),</p> <p>A. Sage (MSc): <i>Efficient uncertainty propagation through MC dose calculations for radiation therapy</i>, (2019, co-supervision)</p>
2020, 2022, 2024	<p><b>Weiterbildung Medizinische Physik für PhysikerInnen</b>, <i>lectures on dose calculation &amp; optimization in an advanced training course for medical physics for physicists</i>, Heidelberg University</p>

- Summer terms 2019 – 2025 **Physics of charged particle therapy**, *three lectures & three practical courses for physics master students in the course of Prof. Joao Seco*, Heidelberg University
- since 2017 **Spezialkurs Partikeltherapie**, *yearly hands-on particle treatment planning course for professionals*, German Cancer Research Center – DKFZ
- since 2020 **Treatment Planning Course**, *yearly course for students within the Major in Cancer Biology programme*, German Cancer Research Center – DKFZ
- Winter term 2015/2016 **Practical physics course for students of biotechnology**, *supervision & evaluation of experiments on radioactive decay of 14 student groups*, Department of Physics & Astronomy, Heidelberg University
- Summer terms 2016 – 2013 **Practical physics course for medical students**, *supervision & evaluation of experiments on optics, acoustics, hydrodynamics & electronics for 17 student groups (per course)*, Department of Physics & Astronomy, Heidelberg University
- Winter term 2012/2013 **Basic course on key competences**, *continued supervision of a students group in 20 tutorials teaching key competences for study managing*, Department of Physics & Astronomy, Heidelberg University, included a three-days certified tutor qualification course
- Winter terms 2012/2013 – 2011/2012 **Beginner's practical physics course**, *supervision & evaluation of experiments on fourier optics & RLC circuits for 20 student groups (per course)*, Department of Physics & Astronomy, Heidelberg University

## Peer-reviewed Publications

- dataset article 2025 A. Thummerer, E. Van Der Bijl, A. J. Galapon, F. Kamp, M. Savenije, C. Muijs, S. Aluwini, R. J. H. M. Steenbakkers, S. Beuel, M. P. Intven, J. A. Langendijk, S. Both, S. Corradini, V. Rogowski, M. Terpstra, **N. Wahl**, C. Kurz, G. Landry, and M. Maspero, "SynthRAD2025 Grand Challenge dataset: Generating synthetic CTs for radiotherapy from head to abdomen", *Medical Physics* **52**, e17981.
- research article 2025 D. Borys, J. Gajewski, T. Becher, Y. Censor, R. Kopec, M. Rydygier, A. Schiavi, T. Skóra, A. Spaleniak, **N. Wahl**, A. Wochnik, and A. Rucinski, "GPU-accelerated FREDopt package for simultaneous dose and LETd proton radiotherapy plan optimization via superiorization methods", *Physics in Medicine & Biology* **70**, 155011.
- research article 2025 R. Cristoforetti, J. J. Hardt, and **N. Wahl**, "Scenario-free robust optimization algorithm for IMRT and IMPT treatment planning", *Medical Physics* **52**, e17905.
- research article 2025 A. A. Pryanichnikov, J. J. Hardt, E. A. DeJongh, L. Martin, D. F. DeJongh, O. Jäkel, **N. Wahl**, and J. Seco, "Feasibility study of using fast low-dose pencil beam proton and helium radiographs for intrafractional motion management", *Physica Medica* **133**, 104959.
- research article 2025 A. C. Sevilla, G. Cabal, **N. Wahl**, M. E. Puerta, and J. C. Rivera, "A robust optimization model for intensity-modulated radiotherapy: Cheap-Minimax", *Medical Physics* **52**, 3360–3376.
- research article 2025 A. C. Sevilla-Moreno, M. E. Puerta-Yepes, **N. Wahl**, R. Benito-Herce, and G. Cabal-Arango, "Interval Analysis-Based Optimization: A Robust Model for Intensity-Modulated Radiotherapy (IMRT)", *Cancers* **17**, 504.
- research article 2025 M. Sitarz, M. G. Ronga, F. Gesualdi, A. Bonfrate, **N. Wahl**, and L. De Marzi, "Implementation and validation of a very-high-energy electron model in the matRad treatment planning system", *Medical Physics* **52**, 518–529.
- research article 2024 F. Xiao, D. Radonic, M. Kriechbaum, **N. Wahl**, A. Neishabouri, N. Delopoulos, K. Parodi, S. Corradini, C. Belka, C. Kurz, G. Landry, and G. Dedes, "Prompt gamma emission prediction using a long short-term memory network", *Physics in Medicine & Biology* **69**, 235003.
- research article 2024 D. Radonic, F. Xiao, **N. Wahl**, L. Voss, A. Neishabouri, N. Delopoulos, S. Marschner, S. Corradini, C. Belka, G. Dedes, C. Kurz, and G. Landry, "Proton dose calculation with LSTM networks in presence of a magnetic field", *Physics in Medicine & Biology* **69**, 215019.
- research article 2024 N. Harrison, M. Kang, R. Liu, S. Charyyev, **N. Wahl**, W. Liu, J. Zhou, K. A. Higgins, C. B. Simone, J. D. Bradley, W. S. Dynan, and L. Lin, "A novel inverse algorithm to solve IPO-IMPT of proton FLASH therapy with sparse filters", *International Journal of Radiation Oncology, Biology, Physics* **119**, P957–967.

- research article 2024 J. J. Hardt, A. A. Pryanichnikov, N. Homolka, E. A. DeJongh, D. F. DeJongh, R. Cristoforetti, O. Jaekel, J. Seco, and **N. Wahl**, "The potential of mixed carbon-helium beams for online treatment verification: a simulation and treatment planning study", *Physics in Medicine & Biology* **69**, 125028.
- research article 2024 B. Faddegon, M. Descovich, K. Chen, J. Ramos-Méndez, M. Roach III, **N. Wahl**, P. Taylor, K. Griffin, and C. Lee, "A digital male pelvis phantom series showing anatomical variations over the course of fractionated radiotherapy treatment", *Medical Physics* **51**, 3034–3044.
- research article 2024 F. Gesualdi and **N. Wahl**, "Cumulative Histograms under Uncertainty: An Application to Dose–Volume Histograms in Radiotherapy Treatment Planning", *Stats* **7**, 284–300.
- research article 2024 Y. Han, C. Geng, S. Altieri, S. Bortolussi, Y. Liu, **N. Wahl**, and X. Tang, "Combined BNCT-CIRT treatment planning for glioblastoma using the effect-based optimization", *Physics in Medicine & Biology* **69**, 015024.
- research article 2023 F. Barkmann, Y. Censor, and **N. Wahl**, "Superiorization of projection algorithms for linearly constrained inverse radiotherapy treatment planning", *Frontiers in Oncology* **13**, 10.3389/fonc.2023.1238824.
- research article 2023 B. A. Faddegon, E. A. Blakely, L. N. Burigo, Y. Censor, I. Dokic, J. N. D-Kondo, R. Ortiz, J. Ramos-Mendez, A. Rucinski, K. E. Schubert, **N. Wahl**, and R. W. Schulte, "Ionization detail parameters and cluster dose: a mathematical model for selection of nanodosimetric quantities for use in treatment planning in charged particle radiotherapy", *Physics in Medicine & Biology* **68**, 175013.
- research article 2023 R. Liu, S. Charyyev, **N. Wahl**, W. Liu, M. Kang, J. Zhou, X. Yang, F. Baltazar, M. Palkowitsch, K. Higgins, W. Dynan, J. Bradley, and L. Lin, "An Integrated Physical Optimization framework for proton SBRT FLASH treatment planning allows dose, dose rate, and LET optimization using patient-specific ridge filters", *International Journal of Radiation Oncology, Biology, Physics* **116**, P949–959.
- research article 2023 P. Stammer, L. Burigo, O. Jäkel, M. Frank, and **N. Wahl**, "Multivariate error modeling and uncertainty quantification using importance (re-)weighting for Monte Carlo simulations in particle transport", *Journal of Computational Physics* **473**, 111725.
- research article 2022 E. Vargas-Bedoya, J. C. Rivera, M. E. Puerta, A. Angulo, **N. Wahl**, and G. Cabal, "Contour Propagation for Radiotherapy Treatment Planning Using Nonrigid Registration and Parameter Optimization: Case Studies in Liver and Breast Cancer", *Applied Sciences* **12**, 8523.
- research article 2021 P. Stammer, L. Burigo, O. Jäkel, M. Frank, and **N. Wahl**, "Efficient uncertainty quantification for Monte Carlo dose calculations using importance (re-)weighting", *Physics in Medicine & Biology* **66**, 205003.
- research article 2021 A. B. A. Bennan, J. Unkelbach, **N. Wahl**, P. Salome, and M. Bangert, "Joint optimization of photon – carbon ion treatments for Glioblastoma", *International Journal of Radiation Oncology\*Biological Physics* **111**, 559–572.
- research article 2021 A. Neishabouri, **N. Wahl**, A. Mairani, U. Köthe, and M. Bangert, "Long short-term memory networks for proton dose calculation in highly heterogeneous tissues", *Medical Physics* **48**, 1893–1908.
- research article 2021 L. Marc, S. Fabiano, **N. Wahl**, C. Linsenmeier, A. J. Lomax, and J. Unkelbach, "Combined proton-photon treatment for breast cancer", *Physics in Medicine & Biology* **66**, 235002.
- research article 2020 **N. Wahl**, P. Hennig, H.-P. Wieser, and M. Bangert, "Analytical probabilistic modeling of dose-volume histograms", *Medical Physics* **47**, 5260–5273.
- research article 2020 H.-P. Wieser, C. P. Karger, **N. Wahl**, and M. Bangert, "Impact of Gaussian uncertainty assumptions on probabilistic optimization in particle therapy", *Physics in Medicine & Biology* **65**, 145007.
- research article 2018 **N. Wahl**, P. Hennig, H.-P. Wieser, and M. Bangert, "Analytical incorporation of fractionation effects in probabilistic treatment planning for intensity-modulated proton therapy", *Medical Physics* **45**, 1317–1328.

- research article H.-P. Wieser, **N. Wahl**, H. S. Gabrys, L.-R. Müller, G. Pezzano, J. Winter, S. Ulrich, L. N. Burigo, O. Jäkel, and M. Bangert, “matRad - an open-source treatment planning toolkit for educational purposes”, *Medical Physics International Journal* **6**, 119–127.
- research article H.-P. Wieser, P. Hennig, **N. Wahl**, and M. Bangert, “Analytical probabilistic modeling of RBE-weighted dose for ion therapy”, *Physics in Medicine and Biology* **62**, 8959–8982.
- research article **N. Wahl**, P. Hennig, H.-P. Wieser, and M. Bangert, “Efficiency of analytical and sampling-based uncertainty propagation in intensity-modulated proton therapy”, *Physics in Medicine and Biology* **62**, 5790–5807.
- research article H.-P. Wieser, E. Cisternas, **N. Wahl**, S. Ulrich, A. Stadler, H. Mescher, L.-R. Müller, T. Klinge, H. Gabrys, L. Burigo, A. Mairani, S. Ecker, B. Ackermann, M. Ellerbrock, K. Parodi, O. Jäkel, and M. Bangert, “Development of the open-source dose calculation and optimization toolkit matRad”, *Medical Physics* **44**, 2556–2568.
- research article **N. Wahl**, M. Bangert, C. P. Kamerling, P. Ziegenhein, G. H. Bol, B. W. Raaymakers, and U. Oelfke, “Physically constrained voxel-based penalty adaptation for ultra-fast IMRT planning”, *Journal of Applied Clinical Medical Physics* **17**, 172–189.

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## Monographs

- textbook C. Kommer, T. Tugendhat, and **N. Wahl**, *Tutorium Physik fürs Nebenfach*, 2nd ed. (Springer Spektrum, Berlin, Heidelberg).
- phdthesis **N. Wahl**, “Analytical Models for Probabilistic Inverse Treatment Planning in Intensity-modulated Proton Therapy”, PhD thesis (Ruprecht-Karls Universität Heidelberg, Heidelberg).
- textbook C. Kommer, T. Tugendhat, and **N. Wahl**, *Tutorium Physik fürs Nebenfach*, 1st ed. (Springer Spektrum, Berlin, Heidelberg).

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## Preprints and other Publications

- preprint (arXiv) R. Cristoforetti, P. Süß, T. Becher, and **N. Wahl**, *Trading robustness: a scenario-free approach to robust Multi-Criteria Optimization for Treatment Planning*, <http://arxiv.org/abs/2510.12519>, pre-published.
- preprint (arXiv) P. Stammer, **N. Wahl**, J. Kusch, and D. Lathouwers, *A high-order deterministic dynamical low-rank method for proton transport in heterogeneous media*, <http://arxiv.org/abs/2508.04484>, pre-published.
- preprint (arXiv) T. Ortkamp, H. Sallem, S. Harrabi, M. Frank, O. Jäkel, J. Bauer, and **N. Wahl**, *Let's play POLO: Integrating the probability of lesion origin into proton treatment plan optimization for low-grade glioma patients*, <http://arxiv.org/abs/2506.13539>, pre-published.
- preprint (arXiv) L. Seckler, A. B. A. Bennan, and **N. Wahl**, *LET-modifying joint optimization for mixed-modality photon-proton treatment planning*, <https://arxiv.org/abs/2505.15482v1>, pre-published.
- preprint (arXiv) S. Facchiano, R. Ortiz, R. Cristoforetti, N. D-Kondo, O. Jaekel, B. Faddegon, and **N. Wahl**, *An ion treatment planning framework for inclusion of nanodosimetric ionization detail through cluster dose*, <http://arxiv.org/abs/2505.09667>, pre-published.
- preprint (arXiv) J. J. Hardt, A. A. Pryanichnikov, O. Jäkel, J. Seco, and **N. Wahl**, *Helium Range Viability for Online Range Probing in Mixed Carbon-Helium Beams*, <http://arxiv.org/abs/2505.01165>, pre-published.
- preprint (arXiv) P. Stammer, T. Burlacu, **N. Wahl**, D. Lathouwers, and J. Kusch, *A Deterministic Dynamical Low-rank Approach for Charged Particle Transport*, <http://arxiv.org/abs/2412.09484>, pre-published.
- preprint (arXiv) L. Voss, A. Neishabouri, T. Ortkamp, A. Mairani, and **N. Wahl**, *BayesDose: Comprehensive proton dose prediction with model uncertainty using Bayesian LSTMs*, <http://arxiv.org/abs/2307.01151>, pre-published.
- online article P. Stammer, L. Burigo, O. Jäkel, M. Frank, and **N. Wahl**, *Efficient uncertainty quantification for Monte Carlo dose calculations using importance (re-)weighting*, *ESTRO Physics Newsletter*, <https://www.estro.org/About/Newsroom/Newsletter/Physics/Efficient-uncertainty-quantification-for-Monte-Car>.

- online article M. Bangert, O. Jäkel, **N. Wahl**, and H.-P. Wieser, *Developing matRad, an Open-Source Dose Calculation and Optimization Toolkit for Radiation Therapy Planning*, MathWorks Technical Articles and Newsletters, <https://www.mathworks.com/company/newsletters/articles/developing-matrad-an-open-source-dose-calculation-and-optimization-toolkit-for-radiation-therapy-planning.html>.

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## Peer-reviewed Conference Contributions

- oral presentation M. Arndt, G. Stanic, O. Jäkel, K. Giske, and **N. Wahl**, “SC14.05 Bayesian uncertainty estimation in CycleGAN-based CT style transfer”, in *Physica Medica*, Vol. 125, Supplement 1, Abstracts of the 5th European Congress of Medical Physics (), p. 103485.
- oral presentation F. Xiao, M. Kriechbaum, D. Radonic, **N. Wahl**, A. Neishabouri, N. Delopoulos, K. Parodi, S. Corradini, C. Belka, C. Kurz, G. Landry, and G. Dedes, “SC29.07 AI-based prompt gamma prediction”, in *Physica Medica*, Vol. 125, Abstracts of the 5th European Congress of Medical Physics (), p. 103532.
- poster oral R. Cristoforetti and **N. Wahl**, “SO027 / #138 - Avoiding Scenarios: An Efficient Strategy for Robust 4D Treatment Planning Using Total Variance and Expected Dose Objectives”, in *International Journal of Particle Therapy*, Vol. 12, Proceedings to the 62nd Annual Conference of the Particle Therapy Cooperative Group (PTCOG) (PTCOG62, Singapore), p. 100339.
- poster oral S. Facchiano, R. Ortiz, N. Kondo, R. Cristoforetti, B. Faddegon, O. Jäkel, and **N. Wahl**, “SO026 / #456 - An Ion Therapy Treatment Planning Framework for Direct Optimization of Nanodosimetric Ionization Detail Through Cluster Dose”, in *International Journal of Particle Therapy*, Vol. 12, Proceedings to the 62nd Annual Conference of the Particle Therapy Cooperative Group (PTCOG) (PTCOG 62, Singapore), p. 100338.
- poster J. Hardt, A. Pryanichnikov, N. Homolka, E. Dejongh, D. F. Dejongh, R. Cristoforetti, J. Seco, and **N. Wahl**, “P113 / #136 - Development of a Treatment Planning and Simulation Framework for Adaptive Mixed Carbon-Helium Ion Therapy”, in *International Journal of Particle Therapy*, Vol. 12, Proceedings to the 62nd Annual Conference of the Particle Therapy Cooperative Group (PTCOG) (PTCOG 62, Singapore), p. 100498.
- oral presentation R. Lui, S. Charyyev, **N. Wahl**, W. Liu, M. Kang, J. Zhou, X. Yang, S. Zhou, and L. Lin, “O140 / #342 - A Novel Optimization Framework for Proton FLASH Treatment Planning Allows Dose, Dose Rate, and LET Optimization Using Patient-Specific Ridge Filters”, in *International Journal of Particle Therapy*, Vol. 12, Proceedings to the 62nd Annual Conference of the Particle Therapy Cooperative Group (PTCOG) (PTCOG 62, Singapore), p. 100253.
- oral presentation T. Ortkamp, H. Sallem, S. Harrabi, M. Frank, O. Jäkel, J. Bauer, and **N. Wahl**, “O143 / #428 - Let's Play POLO: Direct Optimization of the Probability of Lesion Origin in Proton Treatment Planning for Low-Grade Glioma Patients”, in *International Journal of Particle Therapy*, Vol. 12, Proceedings to the 62nd Annual Conference of the Particle Therapy Cooperative Group (PTCOG) (PTCOG 62, Singapore), p. 100256.
- poster oral L. Seckler, A. B. A. Bennan, and **N. Wahl**, “SO004 / #809 - An Open Framework for Comparing LET-Modifying Objectives in Proton Treatment Planning”, in *International Journal of Particle Therapy*, Vol. 12, Proceedings to the 62nd Annual Conference of the Particle Therapy Cooperative Group (PTCOG) (PTCOG 62, Singapore), p. 100316.
- poster M. K. Sitarz, M. G. Ronga, F. Gesualdi, A. Bonfrate, **N. Wahl**, and L. D. Marzi, “2764: Development and validation of Very High Energy Electrons dose calculation in matRad TPS”, in *Radiotherapy and Oncology*, Vol. 194, Supplement 1 (ESTRO 2024, Glasgow, UK), S3707–S3710.
- poster **N. Wahl** and R. Cristoforetti, “2800: Boosting 4D robust treatment planning for IMRT”, in *Radiotherapy and Oncology*, Vol. 194, Supplement 1 (ESTRO 2024, Glasgow, UK), S3711–S3715.
- poster J. Lourenço, J. Leitão, **N. Wahl**, F. Baltazar, J. Marques, and J. Seco, “A novel method for FLASH radiotherapy: Combining FLASH with IMRT”, in *Proceedings to the 61st Annual Conference of the Particle Therapy Cooperative Group*, Vol. 10, *International Journal of Particle Therapy* (PTCOG 61, Madrid), pp. 337–338.



- oral presentation 2023 T. Ortkamp, O. Jäkel, M. Frank, and **N. Wahl**, “On the feasibility of high-dimensional multivariate machine learning model-based outcome optimization for intensity-modulated treatment planning in proton therapy”, in Proceedings to the 61st Annual Conference of the Particle Therapy Cooperative Group, Vol. 10, International Journal of Particle Therapy (PTCOG 61, Madrid), p. 195.
- poster 2023 C. Sepúlveda, B. Gebauer, A. Hoffmann, A. Lühr, **N. Wahl**, and L. Burigo, “Experimental dosimetric validation of an open-source treatment planning system for IMPT dose delivery at a horizontal PBS research beamline”, in Proceedings to the 61st Annual Conference of the Particle Therapy Cooperative Group, Vol. 10, International Journal of Particle Therapy (PTCOG 61, Madrid), pp. 334–335.
- poster 2023 P. Stammer, **N. Wahl**, D. Lathouwers, and J. Kusch, “Time and memory efficient deterministic proton dose calculations using the dynamical low-rank approximation”, in Proceedings to the 61st Annual Conference of the Particle Therapy Cooperative Group, Vol. 10, International Journal of Particle Therapy (PTCOG 61, Madrid), pp. 357–358.
- oral presentation 2023 L. Voss, A. Neishabouri, T. Ortkamp, and **N. Wahl**, “OC-0775: Comprehensive proton dose prediction with Bayesian LSTMs”, in Radiotherapy and Oncology, Vol. 182, Supplement 1 (ESTRO 2023, Vienna, Austria), S642–S644.
- oral presentation 2023 **N. Wahl**, N. Charitonidis, M. Dosanjh, N. Homolka, C. Graeff, A. Mamaras, J. Seco, D. Skrijelj, R. L. Taylor, A. Topi, H.-P. Wieser, and P. Foka, “MO-0563: Youth education and outreach with the international Particle Therapy Masterclass”, in Radiotherapy and Oncology, Vol. 182, Supplement 1 (ESTRO 2023, Vienna, Austria), S443–S445.
- oral presentation 2023 **N. Wahl**, “The Particle Therapy Masterclass for targeted education and outreach on real-world application of fundamental physics”, Oral Presentation, DPG SMuK Frühjahrstagung (Dresden).
- poster 2023 A. B. A. Bennan, J. Unkelbach, and **N. Wahl**, “Determining the number of photon and particle fractions for jointly optimized combined treatments”, in Proceedings to the 60th Annual Conference of the Particle Therapy Cooperative Group, Vol. 9, International Journal of Particle Therapy (PTCOG 60, Miami), p. 424.
- poster 2023 J. Hardt, T. Ortkamp, and **N. Wahl**, “Towards a generalized (N)TCP optimization framework across modalities using classical and machine learning models”, in Proceedings to the 60th Annual Conference of the Particle Therapy Cooperative Group, Vol. 9, International Journal of Particle Therapy (PTCOG 60, Miami), pp. 428–429.
- oral presentation 2023 R. Liu, S. Charyyev, **N. Wahl**, W. Liu, J. Zhou, Y. Xiaofeng, K. Higgins, J. Bradley, and L. Lin, “Feasibility of proton SBRT FLASH treatment with dose, dose rate, and LET optimization using patient specific 3D ridge”, in Proceedings to the 60th Annual Conference of the Particle Therapy Cooperative Group, Vol. 9, International Journal of Particle Therapy (PTCOG 60, Miami), p. 368.
- oral presentation 2023 **N. Wahl** and H.-P. Wieser, “Scenario-free probabilistic proton dose optimization using expected dose influence and total variance”, in Proceedings to the 60th Annual Conference of the Particle Therapy Cooperative Group, Vol. 9, International Journal of Particle Therapy (PTCOG 60, Miami), p. 383.
- poster 2022 P. Stammer, L. Burigo, O. Jäkel, M. Frank, and **N. Wahl**, “PO-1728: Efficient modeling and quantification of time-dependent errors in IMPT”, in Radiotherapy and Oncology, Vol. 170 (ESTRO, Copenhagen), S1529–S1531.
- oral presentation 2022 P. Foka, A. Mamaras, D. Skrijelj, J. Seco, C. Graeff, M. Pulia, H.-P. Wieser, and **N. Wahl**, “Particle therapy masterclass”, in EPJ Web of Conferences, Vol. 258 (vConf21, Online), p. 01002.
- oral presentation 2022 N. Homolka, P. A. Meder, L. Burigo, H.-P. Wieser, M. Bangert, O. Jäkel, M. Ellerbrock, and **N. Wahl**, “Degradation of particle depth dose in lung tissue: An efficient and consistent model for Monte Carlo and analytical dose calculation”, in Proceedings to the 59th Annual Conference of the Particle Therapy Cooperative Group (PTCOG59 2021 Online), International Journal of Particle Therapy (PTCOG 59, Online), pp. 23–24.

- oral presentation 2022 P. Stammer, L. Burigo, O. Jäkel, M. Frank, and **N. Wahl**, "Efficient uncertainty estimates in Monte Carlo dose calculation using importance reweighting", in Proceedings to the 59th Annual Conference of the Particle Therapy Cooperative Group (PTCOG59 2021 Online), International Journal of Particle Therapy (PTCOG 59, Online), p. 24.
- poster 2021 L. Marc, S. Fabiano, **N. Wahl**, C. Linsenmeier, A. J. Lomax, and J. Unkelbach, "PO-1905: Combined proton-photon treatment for breast cancer using a fixed proton beamline", in Radiotherapy and Oncology, Vol. 161 (ESTRO, Online), S1625–S1627.
- oral presentation 2021 M. Palkowitsch, A. B. A. Bennan, and **N. Wahl**, "The role of uncertainties in jointly optimised mixed carbon/photon treatments", Oral Presentation, DGMP 2021 (Online).
- poster 2020 N. Homolka, H.-P. Wieser, M. Bangert, M. Ellerbrock, and **N. Wahl**, "PO-1490: Lung degradation effects on RBE-weighted dose in proton, carbon and helium treatment plans", in Radiotherapy and Oncology, Vol. 152 (ESTRO, Online), S801–S802.
- oral presentation 2020 A. Neishabouri, **N. Wahl**, L. N. Burigo, U. Köthe, and M. Bangert, "OC-0215: LSTM networks for proton dose calculation in highly heterogeneous tissues", in Radiotherapy and Oncology, Vol. 152 (ESTRO, Online), S108–S109.
- poster 2020 **N. Wahl**, H.-P. Wieser, L. Burigo, and M. Bangert, "PO-1377: Monte Carlo vs. pencil-beam dose calculation for uncertainty estimation in proton therapy", in Radiotherapy and Oncology, Vol. 152 (ESTRO, Online), S731.
- symposium presentation 2019 M. Bangert, **N. Wahl**, and H.-P. Wieser, "SP-0469: Mitigation of range uncertainties with probabilistic IMPT optimization", in Radiotherapy and Oncology, Vol. 133 (ESTRO, Milan), S241.
- oral presentation 2019 **N. Wahl**, E. Doerner, L. N. Burigo, D. Ramirez, A. Neishabouri, A. B. A. Bennan, H.-P. Wieser, and M. Bangert, "Development report for the open source dose calculation and optimization toolkit matRad", Oral Presentation, 19th ICCR (Montréal).
- oral presentation 2019 **N. Wahl**, P. Hennig, H.-P. Wieser, and M. Bangert, "Confidence constraints for probabilistic radiotherapy treatment planning", Oral Presentation, 19th ICCR (Montréal).
- oral presentation 2019 H.-P. Wieser, P. Hennig, **N. Wahl**, and M. Bangert, "Closed-form modeling of biological uncertainties in carbon ion therapy", Oral Presentation, 19th ICCR (Montréal).
- oral presentation 2019 H.-P. Wieser, C. P. Karger, **N. Wahl**, and M. Bangert, "Impact of Gaussian uncertainty assumptions for probabilistic optimization considering range errors", Oral Presentation, 19th ICCR (Montréal).
- poster 2018 **N. Wahl**, P. Hennig, H.-P. Wieser, and M. Bangert, "PO-0909: Analytical probabilistic models for dose quality metrics and optimization objectives", in Radiotherapy and Oncology, Vol. 127 (ESTRO, Barcelona), S486–S487.
- oral presentation 2018 H.-P. Wieser, **N. Wahl**, P. Hennig, and M. Bangert, "OC-0088: Simultaneous consideration of biological and physical uncertainties in robust ion therapy planning", in Radiotherapy and Oncology, Vol. 127 (ESTRO, Barcelona), S46–S47.
- poster 2018 **N. Wahl**, P. Hennig, H.-P. Wieser, and M. Bangert, "EP-1898: Smooth animations of the probabilistic analog to worst-case dose distributions", in Radiotherapy and Oncology, Vol. 127 (ESTRO, Barcelona), S1028–S1029.
- oral presentation 2016 **N. Wahl**, P. Hennig, and M. Bangert, "Probabilistic proton treatment planning using accelerated analytical probabilistic modelling", Oral Presentation, 18th ICCR (London).
- oral presentation 2016 H.-P. Wieser, **N. Wahl**, P. Hennig, and M. Bangert, "Analytical probabilistic modeling of range and setup uncertainties in carbon ion therapy planning", Oral Presentation, 18th ICCR (London).
- poster 2015 **N. Wahl**, C. P. Kamerling, H. Heinrich, P. Hennig, and M. Bangert, "Robust Planning for Intensity-modulated Proton Therapy using Analytical Probabilistic Modeling", in International Journal of Particle Therapy, Vol. 2, 1 (PTCOG & PTCOG-NA, San Diego), 314f.