Karlsruher Institut für Technologie

Formular

Helmholtz Investigator Group

Feld	Inhalt
Academic Title	Dr. rer. nat.
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First Name	Miriam
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Age	34
Gender [m/w/d]	w
Nationality	german
Doctoral degree [Date, university, city, country, grade]	31.01.2020, Karlsruhe Institute of Technology, Karlsruhe, Germany, summa cum laude
Current Institution [University, institute, city, country]	Lund University, MAX IV Laboratory, Lund, Sweden
YIG Prep Pro Fellow	No
Project Title	Beam Dynamics and Collective Effects in the Generation and Propagation of Structured Beams for Advanced Accelerator-based Radiotherapy
KIT-Division	V - Physics and Mathematics
Helmholtz Research Field	Matter
Helmholtz Program	Matter and Technologies
Host institute at KIT	Institute for Beam Physics and Technology (IBPT)
Name of academic contact person of host institute at KIT	Prof. Dr. Anke-Susanne Müller
Name of director of host institute at KIT	Prof. Dr. Anke-Susanne Müller
h-index and citations	h-index: 12, citations: 617 (Ref. Google Scholar)
How did you get to know about the HIYG call?	Direct contact with scientific staff or counselling staff
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Project description according to template of the following KIT internal link [PDF upload]	https://portal.wiwi.kit.edu/forms/download/ea5603a3-83ec-42d5-bbe6-4e4c32bf1c6f
Curriculum Vitae [PDF upload]	https://portal.wiwi.kit.edu/forms/download/ed08f740-1a0e-4441-84e1-d9ef21a1ac9e
Publication list [PDF upload]	https://portal.wiwi.kit.edu/forms/download/fc218363-d78a-44d7-b846-bc5bc5e05896
Letter of Support by the host institute incl. financial support, permanent position and supported infrastructure [PDF upload]	https://portal.wiwi.kit.edu/forms/download/181aa375-0434-4090-b482-ed1b041ed161
Confirmation of scientific downtimes if applicable [PDF upload]	

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I agree that my data will be collected, stored and processed for the purpose of applying in the Helmholtz Investigator Group Program and later implementation.	I agree
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Helmholtz Investigator Group: Beam Dynamics and Collective Effects in the Generation and Propagation of Structured Beams for Advanced Accelerator-based Radiotherapy

General information:

Applicant

Dr. Miriam Brosi, Lund University, MAX IV Laboratory, Lund, Sweden, 34, female, defense: 31.01.2020

Assignment KIT-division

Division V

Host Institute and contact person at KIT

Institute for Beam Physics and Technology (IBPT), Prof. Dr. Anke-Susanne Müller

Field of study and Helmholtz-program

Helmholtz program: Matter, Matter and Technology, Accelerator Research and Development (ARD)

Description of international experience such as position program, purpose, duration

In addition to participating in several international conferences and workshops, my working environment has often been international with colleagues from various countries. From 10/2021 to 12/2021, I worked as guest scientist at the Laboratory PhLAM at the Université de Lille in France on a detailed comparison of two Vlasov-Fokker-Planck simulation codes for the propagation of beam distributions under the influence of collective effects with the French national synchrotron SOLEIL and KARA at KIT as example cases. Since 01/2022, I am now working as postdoctoral researcher at the MAX IV laboratory of the Lund University in Sweden. In the accelerator development group, I focus on theoretical and experimental studies of collective effects in the ultra-low emittance ring of the 4th generation synchrotron light source at MAX IV.

Description of leadership experience

During my PhD, I supervised and co-supervised one bachelor and three master students, working on measurement data analysis, simulations of influences of arbitrary impedances on beam dynamics, machine learning based data analysis and fast, single-shot measurement methods, respectively. Furthermore, during three semesters, I served as tutor (“Übungsleiter”) for bi-weekly exercises for lectures on accelerator physics. For four years, I was involved in organizing and supervising the accompanying simulation and hands-on course on the accelerator. As postdoc, I lead the project for the replacement of the main storage ring magnet power-supplies, supported by the chief electrical engineer. I coordinated the efforts, acted as contact to suppliers and wrote the specification for the procurement, including calculations on stability tolerances. In addition, I scientifically advise a PhD student on their investigation of additional impedances added into the accelerator and the resulting influence on collective effects, who will defend his thesis in May this year. Besides my main research as postdoc at MAX IV, I lead the effort to establish a new time-correlated single-photon counting setup as standard diagnostic for the accelerator operation. This currently includes the supervision of a bachelor student with the task to extent the setup for bunch shape measurements.

Information about the Project:

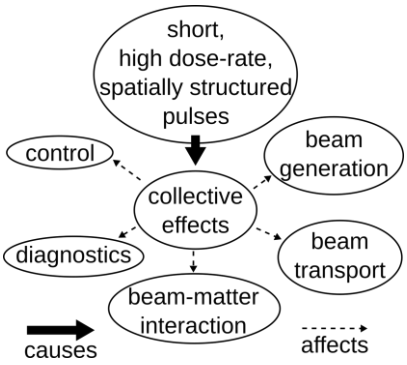
Abstract / Intent/ Goal

Particle accelerators play a vital role in a multitude of scientific fields such as the field of radiotherapy (RT). Novel radiotherapy methods, such as FLASH RT (very high doses in short pulses) and Microbeam RT (spatially fractionated pulses), are based on temporally and spatially structured accelerator-based particle beams with high requirements on their properties. These requirements cause strong effects caused by the coexistence of many particles in the densely populated pulses, summarized under the term collective effects, for which the knowledge of influence on relativistic particle beams, with properties used in the novel RT methods, is currently incomplete. As these can affect the dose distribution on target, an important aspect for

radiotherapy, the investigation of collective effects for such beams is of the essence. The proposed project will improve the understanding to increase the predictability and enhance control of accelerator-based electron beams. This will be applied to beams for FLASH RT and Microbeam RT. It will furthermore study applicable detection methods and assess possibilities as well as limitations of temporal and spatial pulse shaping and modulation of accelerator-based RT beams with the ultimate goal to generate custom beam shapes and dose distributions on target.

The proposed research project agrees very well with the core objectives of the Helmholtz program Matter and Technology (MT) with the topic Accelerator Research and Development (ARD) covering the dynamics, detection and control of short-pulsed accelerator beams with custom properties. These topics fall precisely in the research activities at the Institute for Beam Physics and Technology (IBPT), home to the KIT electron accelerators. The strong ties to the MT topic Detector Technologies and Systems (DTS) with the in-house partner at KIT, the Institute for Data Processing and Electronics (IPE), will be a valuable asset for the project. Moreover, the project is perfectly in line with the ideas of the recently established KIT-center Health Technologies, strengthening the important component of accelerator research with respect to radiotherapy.

Formal and Scientific Requirements (short)



The goal of the project will be achieved by investigating the influence of collective effects on the beam generation, beam transport, beam-matter interaction and diagnostics in novel electron radiotherapy methods based on temporally and spatially structured accelerator-generated beams. The incorporation of collective effects in the envisioned start-to-end simulation and exploring solutions for the inverse problem will provide the required improvement in predictability and at the same time, combined with beam shaping, a significantly increased control on the final distribution on target. The work plan consists of three work packages, with WP A and WP B running in parallel and WP C building on the outcome of the first two.

WP A - Complex beam dynamics and collective effects: WP A will focus on the complex dynamics in accelerator-generated particle beams with the challenging properties required for FLASH and Microbeam RT. To this end, the influence of collective effects will be investigated in the accelerator as well as the beam transport through matter to the irradiation target. The investigations will include simulations and experiments with the linear accelerator FLUTE as testbed. In beam-matter interaction, collective effects have not yet been considered due to the typically significantly more relaxed beam properties in conventional RT. Based on my experience with different simulation methods of collective effects such as Monte Carlo, particle tracking, phase-space density propagation and the application of covariance matrices, multiple options will be evaluated for the incorporation into beam-matter interaction calculations. Based on this, we will develop a beam propagation simulation taking into account the interaction between beam particles. The objective of WP A is to achieve increased predictability of the RT beam properties on target by developing a start-to-end simulation including collective effects.

WP B - Temporal and spatial pulse shape dependence of detection mechanisms and diagnostic tools: The extreme properties of the temporally and spatially structured beams not only affect the beam dynamics but also increase the complexity of applicable detection mechanisms and diagnostic tools. A big challenge for dosimetry is the very high dose rate of the short pulses in electron FLASH RT, which lead to an increasing non-linearity in the detector response. It is proposed to exploit the flexible pulse-properties combined with the ultra-short electron bunches at FLUTE to test a variety of dosimetry detectors and benchmark the available, theoretical dosimetry correction factors for ion-recombination towards even shorter pulse-length. Furthermore, possibilities for measuring the 2-dimensional dose distribution will be evaluated. To test the spatial resolution, the electron beam at FLUTE could be modulated e.g., by using collimators or masks. In this context tests of new detector types developed at KIT, such as radiation hard CMOS-pixel detectors, could be incorporated as well as tests at facilities with proton or ion beams (e.g., HIT in Heidelberg or GSI in Darmstadt). In addition to RT diagnostics, different shot-by-shot capable accelerator-based diagnostics will be evaluated regarding the required resolution and stability for medical applications. The objective of WP B is to gain

improved insight into the influence of temporal or spatial pulse modulation on detection and diagnostics to provide recommendations for applicable methods depending on the beam parameters.

WP C – Targeted beam modulation and beam shaping: After finding the forward solution, meaning the evolution of shape during transport via the start-to-end simulation in WP A, WP C aims at solving the inverse problem. This includes determining and shaping the initial distribution to obtain a desired shape on target. To this end, WP C will explore possibilities and define the physical limitations of accelerator-based pulse shaping and modulation by comparing different methods, e.g., a spatial light modulator on the electron-gun laser, and conducting measurements with the diagnostics selected in WP B. Furthermore, WP C will examine possible methods and algorithms to solve the mentioned inverse problem, with the optimal method likely depending on the algorithm chosen for the start-to-end simulation. Several possible methods can be imagined, from systematic maps of final to initial distributions resulting in a type of catalog, over analytical or numerical inversions of the transport matrix in form of covariance matrices, up to employing machine learning algorithms. After establishing this relation between final and initial distribution, it will be combined with the tested beam-shaping method, enabling the generation of an initial particle distribution, which preemptively compensates for the deformation during propagation to the target, and enabling the possible generation of (within certain limits) user-definable final particle distributions on target. The capability of this method will be experimentally tested and the limits in the achievable distributions on target will be explored. The outcome of WP C will provide a deep insight into the possibilities of predicting as well as generating and controlling custom, temporally and spatially modulated particle distributions in linear accelerators alongside the main goal of contributing towards the advancement of advanced radiotherapy methods.

Envisioned cooperations: The closest cooperation with be with the Institute for Beam Physics and Technology (IBPT) where the group will be situated. This will give easy and extended access to the accelerator test-facilities FLUTE, KARA, as well as the planned storage ring cSTART and a laser-wakefield accelerator under construction. The Accelerator Technology Platform (ATP) at KIT will provide an extensive infrastructure for accelerator research as well as a close connection to the detector development at the Institute for Data Processing and Electronics (IPE). Cooperations with Prof. Dr. Oliver Jäkel from the Heidelberg Ion Beam Therapy Center (HIT) and German Cancer Research Center (DKFZ), as well as with Prof. Dr.-Ing. Christian Graeff and Dr. Lennart Volz from the GSI Helmholtz center for Heavy Ion Research are planned. Initial discussions with Prof. De Carne (ITEP) have been initiated on the topic of energy efficient and sustainable accelerators for medical applications, and spin-off projects from this Helmholtz IG will be planned in the future.

Communication structures: The participation in relevant conferences such as the International Particle Accelerator conference (IPAC) or the Flash Radiotherapy and Particle Therapy conference (FRPT) and smaller workshops will enable the communication and discussion of results as well as help to establish new connections and provide access to the latest developments. For master students trips to the DPG spring meetings are planned, as first opportunity to present their research to a wider community. Research results will furthermore be published in, preferably, open access journals and presented at Helmholtz meetings.

Financial plan

The work plan foresees two postdoctoral researchers (year 2&3 and year 4&5) and two doctoral students (year 1-3 and year 3-5) in addition to the group leader. It is envisioned to give master students the possibility to contribute to different sub-work packages. Additionally, some funds are requested to employ student assistants for a total of 3 years distributed as required. The other costs consist of smaller detectors and consumables for experiments as well as travel costs for the participation in conferences and workshops. No larger investment is needed, considering the existing accelerators and infrastructure at KIT.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Group leader position*	100200	103206	106302	109491	112775	531975
2 Postdocs (100%, à 2 years)*	-	88683	91343	94083	96906	371016
2 PhDs (75%, à 3 years)*	59850	61645	126989	65399	67361	381246
Student assistants (3 years)	4368	4368	4368	8736	4368	26208
Material costs	29200	9000	7500	6500	3000	55200
Travel costs	4000	9500	12000	8000	12000	45500
Total	197618	276402	348503	292210	296411	1411146

*The personnel costs follow the DFG Personnel Rates. An annual rise of 3% has been included.

Miriam Brosi

Dr. rer. nat.

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⋆19.06.1989

Experience

Jan. 2022 – current **PostDoc**, *MAX IV*, Lund University, Sweden
Research scientist in the accelerator development group at MAX IV. In the accelerator development group of the Swedish national synchrotron laboratory, I focus on theoretical and experimental studies of collective effects in the ultra-low emittance ring of the 4th generation synchrotron light source.

Oct. 2021 – Dec. 2021 **Guest-scientist**, *Laboratoire de Physique des Lasers, Atomes et Molécules (PhLAM)*, Université des Sciences et Technologies de Lille, France
Guest scientist at PhLAM laboratory, financed by the Helmholtz Doctoral Prize. I conducted a detailed comparison of two Vlasov-Fokker-Planck simulation codes for the propagation of particle distributions under the influence of collective effects.

Feb. 2020 – Dec. 2021 **PostDoc**, *Institute for Beam Physics and Technology (IBPT)*, Karlsruhe Institute of Technology
Research scientist and expert operator at the KIT synchrotron. I continued my studies of collective effects in short electron bunches. With a PhD student, I implemented a new operation mode enabling more extreme beam propertied. I coordinated and wrote the specification for the procurement of optimized power-supplies for the storage ring magnets, including calculations on the stability tolerances.

Feb. 2015 – Jan. 2020 **HIRST Doctoral Researcher**, *Helmholtz International Research School for Teratronics (HIRST)*, Karlsruhe Institute of Technology
Member of the HIRST Graduate school from KIT.
Participated in regular seminars and completed successfully the following technical and management modules: Synchrotrons, Microwave Engineering and Measurement Techniques, MBA Unit 1: International Project Management, Postgraduate transferable Skills: Career and Leadership.

Sep. 2016 – Oct. 2016 **Student**, *Cern Accelerator School*, Warsaw, Poland
Participating in the two weeks summer school CAS (Cern Accelerator School) on Advanced Accelerator Physics in Warsaw.

Nov. 2014 – Dec. 2014 **Graduate Assistant**, *Institute for Data Processing and Electronics (IPE)*, Karlsruhe Institute of Technology
Development of a Graphical User Interface for the KAPTURE system (KArlsruhe Pulse Taking and Ultrafast Readout Electronics) based on Python bindings for Qt.

Mar. 2013 – Dec. 2014 **Student Assistant**, *ANKA Synchrotron Lightsource*, Karlsruhe Institute of Technology
Maintaining and further improving the Beam Position Monitor Systems at ANKA. The field of works included development of Graphical User Interfaces in Matlab as well as the analysis of orbit information.

Education

Jan. 2015 – Jan. 2020 **Dr. rer. nat.**, *Department of Physics*, Karlsruhe Institute of Technology, (summa cum laude)
Dissertation: "In-Depth Analysis of the Micro-Bunching Characteristics in Single and Multi-Bunch Operation at KARA" at the Institute for Beam Physics and Technology (IBPT), doi: 10.5445/IR/1000120018.

2012 – Sep. 2014 **Master of Science**, *Department of Physics*, Karlsruhe Institute of Technology, (with distinction)
Master thesis in accelerator physics, title: *"A Study of Bursting Behavior of Synchrotron Radiation in the THz Regime"*.
Major subject in *Accelerator Physics* and *Particle Physics*.
Minor subject in *Nanotechnology* and *Semiconductor Physics*, as well as *Electronics*.

2008 – 2012 **Bachelor of Science**, *Department of Physics*, Karlsruhe Institute of Technology
Bachelor thesis in astroparticle physics.
Basic study of Physics with *Computer Science* as minor subject.

2008 **Abitur**, *Hohenlohe Gymnasium Öhringen*

Teaching

ongoing **Supervisor Bachelor thesis**, *Department of Physics*, Lund University, Sweden
Supervising Bachelor thesis on the topic of "Time-Correlated Single-Photon Counting for Electron Bunch Diagnostic at MAX IV" (J. Schmand).

Apr. 2019 **Co-supervisor Master thesis**, *Department of Physics*, Karlsruhe Institute of Technology
Co-supervisor for the Master thesis on the topic of "Rekonstruktion der Form von THz-Pulsen aus kurzen Elektronenpacketen mit hohen Wiederholraten an KARA" (M. Martin) (translation: "Reconstruction of the shape of THz pulses from short electron packets with high repetition rates at KARA").

Apr. 2018 **Co-supervisor Master thesis**, *Department of Physics*, Karlsruhe Institute of Technology
Co-supervisor for the Master thesis on the topic of "Systematic Studies of the Influences of Impedances on Longitudinal Beam Dynamics" (P. Schreiber).

Jan. 2017 **Supervisor Master thesis**, *Department of Physics*, Karlsruhe Institute of Technology
Scientific supervisor for the Master thesis on the topic of "Analysis of Bursting Spectrograms using Machine Learning Techniques" (F. Rämisch).

Juni. 2015 – Jul. 2018 **Tutor**, *Department of Physics*, Karlsruhe Institute of Technology
For four summer semester, supervising the one day simulation course and the one day practical hands-on course accompanying the accelerator science 1 lecture from Prof. A.-S. Müller.

Apr. 2015 – Jul. 2017 **Tutor**, *Department of Physics*, Karlsruhe Institute of Technology
For three summer semester, tutoring the exercise accompanying the accelerator science 1 lecture from Prof. A.-S. Müller.

May 2015 **Supervisor Bachelor thesis**, *Department of Physics*, Karlsruhe Institute of Technology
Supervisor for the Bachelor thesis on the topic of "Vergleich der zeitlichen Strukturen von Strahlungsausbrüchen der kohärenten Synchrotronstrahlung" (P.Schreiber) (translation: "Comparison of the temporal structures in radiation bursts of coherent synchrotron radiation").

Grants and Awards

July 2023 **Otto-Haxel-Award for Physics 2020**, *KIT Freundeskreis und Fördergesellschaft e. V. (KFG)*, (2nd place)
Dissertation Prize by the Universities of Göttingen, Heidelberg and the Karlsruhe Institute of Technology in cooperation with the German Physical Society

May 2021 **Helmholtz Doctoral Prize 2020**, *Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren e.V*
Doctoral Prize 2020 in the research field Matter

Jul. 2019 **Participant at the Lindau Nobel Laureate Meeting**, Lindau, Germany
Selected as one of 580 young scientists from 89 countries to participate in the 69th Lindau Nobel Laureate Meeting dedicated to Physics.

May 2017 **IPAC Student Grant**, *International Particle Accelerator Conference*, Copenhagen, Denmark

Feb. 2016 – Feb. 2017 **Full Scholarship**, *Helmholtz International Research School for Teratronics (HIRST)*, Karlsruhe Institute of Technology

Feb. 2016 **Best Poster Prize**, *Wilhelm und Else Heraeus-Stiftung*, Bad Honnef
Best poster prize at the 607. WE-Heraeus-Seminar on Semiconductor detectors in astronomy, medicine, particle physics and photon science.

Feb. 2015 – Feb. 2016 **Full Scholarship**, *Helmholtz International Research School for Teratronics (HIRST)*, Karlsruhe Institute of Technology

Apr. 2014 **Travel Grant**, *WE Heraeus Communication Programme for the DPG Spring Meetings*

Languages

German	Native	Swedish	Basic
English	Fluent	French	Basic

Skills

Python	Expert	Operation systems	Linux, macOS, Windows
Matlab	Intermediate	Inovesa	Expert
C++	Beginner	AT, mbtrack2, MAD-X	Intermediate
Version control	(GIT) Expert	OPA	Beginner

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Date: 2024-03-01

Dr. Miriam Brosi / Young Investigator Group "Beam Dynamics and Collective Effects in the Generation and Propagation of Structured Beams for Advanced Accelerator-based Radiotherapy."

Dear KIT Executive Board, dear members of CRYS,

The Institute for Beam Physics and Technology (IBPT) of the Karlsruhe Institute of Technology develops innovative accelerator technologies at its accelerator test facilities KARA and FLUTE. Examples are diagnostics for ultra-fast measurement and control of electron beams and new magnet technologies. Machine learning methods are used to optimize and stabilize operation. Among other things, this enables basic research into the non-linear dynamics of electron beams at a level which is scarcely achieved elsewhere. Together with our partners from science and industry, we put our developments to use in German and international high-performance accelerators.

Recent additions to our research portfolio of high strategic importance for IBPT and the Helmholtz program Matter and Technologies as a whole are the research on energy solutions for large-scale research infrastructures and the development and generation of efficient new beams for application in radiotherapy. To this ends, IBPT expressly supports the application of Dr. Miriam Katharina Brosi for a Helmholtz Investigator Group "Beam Dynamics and Collective Effects in the Generation and Propagation of Structured Beams for Advanced Accelerator-based Radiotherapy."

It has to be stressed that the research to be addressed in the framework of the young investigator group ideally complements and enhances the present research portfolio of accelerator research at IBPT and in the Accelerator Technology Platform at KIT (ATP). In addition, Miriam Brosi is an outstanding scientist with a proven talent for transdisciplinary work and a knack for teaching, and undoubtedly has a stellar career ahead of her. Already, she received two awards for her doctoral research on storage ring beam dynamics. After a short stay at the University of Lille, France, she now works at the accelerator complex of MAXLab (Lund, Sweden). Very quickly she has become an internationally known accelerator specialist, introducing top-notch data science approaches to complex beam dynamics questions.

This allows very new and exciting insight into relativistic particle behavior and, finally, will enable to novel and resource-efficient operation modes of accelerators. When applied to linear accelerators for medical purpose, this approach has the potential to resolve a fundamental limitation inherent to all applications of high-intensity, short-duration particle pulses by improved understanding, predictability and potential control of these challenging beams.

The proposal intends to make a very timely contribution to novel radiotherapy methods based on temporally and spatially structured accelerator-generated beams. By investigating the influence of

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collective effects on the dynamics for these complex beam properties and, furthermore, extending the consideration of collective effects into the beam-matter interaction outside of the accelerator, the project aims for a greatly improved predictability of the beam properties. This, combined with a systematic study of applicable diagnostic methods, will form the basis for research into the possibilities and physical limits of accelerator-based pulse shaping and modulation, with the aim of generating predefined beam shapes on the target.

This research into the dynamics, detection and control of customized short-pulsed accelerator beams fits very well with the PoF V application focus in the Helmholtz program Matter and Technology (MT). Cross-topical approaches between detector and accelerator research, already a trademark of MT at KIT, will be further strengthened. Furthermore, the project aligns perfectly with the new KIT-center Health Technologies and future Cooperation with the German Center for Cancer Research DKFZ in Heidelberg and with Heidelberg University.

The thorough control of the demanding beam properties and beam stability is crucial input to new layouts for energy-efficient accelerators in the medical sector. The overall power consumption and operability of accelerators will be one of the deciding factors for the availability of accelerator-based medical treatment in countries around the world in years to come. Here, the IBPT cooperates with Energy Lab 2.0 within the KITTEN joint research infrastructure. Miriam Brosi's Young Investigator Group would play an central role as a showcase project for medical systems and hence advance the impact of KITTEN as well as on transdisciplinary teaching approaches.

The desired scientific contributions of the Young Investigator Group cannot be directly compensated by the existing expertise of IBPT in particular or the KIT in general.

In my function as head of institute, I hereby confirm that IBPT will provide the required 25% of the total funding to co-finance the group in case of the approval of the proposed Helmholtz Young Investigator Group for the duration of the funding. Also, IBPT will provide appropriate infrastructure (workplaces incl. computers, communication services) as well as access to the accelerator test facilities and infrastructure.

Following a positive evaluation, the Young Investigator Group will be made permanent by the permanent appointment of Miram Brosi as project leader. The management of the IBPT and Miram Brosi will meet regularly to discuss her development and career prospects.

The establishment of the junior research group would not only support efforts to attract a brilliant woman scientist to the IBPT. Rather, the HGF as a whole would also benefit from strengthening the competences for the generation of new particle beams for sustainable, application-oriented and efficient accelerators in the person of Miriam Brosi.

I would be delighted if you would support the project proposal of Miriam Katharina Brosi to set up a Helmholtz Young Investigator Group.

Yours sincerely,

Prof. Dr. Anke-Susanne Müller