

# Dr. Claudius G. Krause

Claudius.Krause@oeaw.ac.at  
<https://claudius-krause.gitlab.io/>

<https://inspirehep.net/author/profile/C.Krause.1>  
ORCID: 0000-0003-0924-3036

## Research Experience

- 10/2023 – present **Research Group Leader (tenure track)**, Institute for High-Energy Physics (HEPHY) of the Austrian Academy of Sciences (ÖAW).  
Research Focus: Machine Learning for Particle Physics
- 10/2022 – 09/2023 **ITP Fellow (Senior Postdoc)**, group of Prof. Dr. T. Plehn, Heidelberg University, Germany.  
Research Focus: Machine Learning for Particle Physics
- 10/2020 – 09/2022 **Postdoctoral Associate**, group of Prof. Dr. D. Shih, Rutgers University, New Jersey, USA.  
Research Focus: Machine Learning for Particle Physics
- 03/2018 – 09/2020 **Feodor Lynen Research Fellow of the Alexander von Humboldt Foundation**, hosted by Prof. Dr. M. Carena in the Theory Department, Fermi National Accelerator Laboratory (Fermilab), USA.  
Research focus: Higgs Phenomenology beyond the Standard Model, Machine Learning for Particle Physics
- 11/2016 – 02/2018 **Postdoctoral Researcher**, LHC-Pheno group of Prof. Dr. A. Pich, Instituto de Física Corpuscular (IFIC), Valencia, Spain  
Research focus: Effective Field Theories and Higgs Phenomenology
- 10/2016 **Scientific Assistant**, group of Prof. Dr. G. Buchalla, Ludwig Maximilian University, Munich, Germany  
Transition period for 1 month between the doctorate and the start of the position in Valencia, Spain  
Research focus: Higgs Effective Field Theories
- 10/2013-09/2016 **Scientific Assistant**, group of Prof. Dr. G. Buchalla, Ludwig Maximilian University, Munich, Germany  
Contract as doctoral student

## Studies and education

- Winter term 13/14 – Summer term 16 **Dr. rer. nat. (in Physics), Ludwig Maximilian University Munich**  
Final grade 1.0 (magna cum laude)  
Doctoral Thesis: “Higgs Effective Field Theories – Systematics & Applications”, Supervisor: Prof. Dr. G. Buchalla  
Date of graduation: 15. September 2016
- Wt 10/11 – St 13 **M.Sc. in Physics, Ludwig Maximilian University Munich**,  
Final grade 1.0 (very good, A+)  
Master’s Thesis: “An effective field theory for electroweak symmetry breaking including a light Higgs”, Supervisor: Prof. Dr. G. Buchalla

- Wt 11/12                    **École Polytechnique Fédérale de Lausanne**  
Semester abroad via the Erasmus program
- Wt 07/08 – St 10        **B.Sc. in Physics, Brandenburg University of Technology (BTU) Cottbus**  
Final grade 1.1 (very good, A+)  
Bachelor's Thesis at the "Deutsches Elektronen Synchrotron" (DESY) in Zeuthen: "The Impact of Different Monte Carlo Models on the Cross Section Measurement of Top-Pair Production at 7 TeV Proton-Proton Collisions", Supervisor: Prof. Dr. W. Lohmann
- Summer 2006            **Abitur, Christian-Weise-Gymnasium, Zittau**  
Abitur (final school exam) with result 1.2 (very good, A+)  
Advanced courses in mathematics and physics

### **Awards and scholarships**

- 03/2018 – 09/2020    Feodor Lynen Research Fellowship of the Alexander von Humboldt Foundation, carried out at the Fermi National Accelerator Laboratory (Fermilab), USA  
hosted by Prof. Dr. M. Carena in the Theory Department
- 01/2018                "Universe PhD Award 2017" of the "Cluster of Excellence Universe" in Munich, category Theory, award for the best theoretical doctoral thesis in 2016/2017
- 10/2013 – 09/2016    Associated with the "International Max Planck Research School (IMPRS)" on Elementary Particle Physics in Munich
- 09/2013                Award for being among the best 10% of all graduating students in Physics: Refund of the tuition fees of the LMU Munich
- 04/2012 – 03/2013    Scholarship holder of the Deutschland-Stipendium (Germany-Scholarship)
- 08/2011 – 02/2012    Erasmus Scholarship for a semester at the École Polytechnique Fédérale de Lausanne in Switzerland
- 01/2011                Award for the best Bachelor's Thesis of the Faculty 1 of the Brandenburg University of Technology Cottbus in the year 2010
- 02/2009 – 06/2013    Scholarship holder of the Roland-Berger-Stiftung
- since 07/2006        Member of the German Physical Society  
The first year of the membership was an award for the best exam in physics in my school in the Abitur (final school exam).

## Service and Outreach

|                   |  |
|-------------------|--|
| since 04/2024     | Editorial Fellow of SciPost Physics.   |
| 12/2023           | Organizer of the Workshop on Machine Learning and High-Energy Physics: “GlühWien”, ÖAW Campus Akademie, Vienna   |
| since 10/2023     | Co-Leader of Working Group 2 (Technological innovation in data analysis) of COST action COMETA (COMprehensive Multiboson Experiment and Theory Action) |
| 07/2023           | Co-Organizer of the Machine Learning in Particle Theory - MITP Summer School 2023  |
| since 05/2023     | Moderator of the HEP-ML Living Review  |
| 05/2023           | Co-Organizer of the CaloChallenge Workshop   |
| 10/2022 – 09/2023 | Co-Organizer of the Particle Phenomenology Seminar at ITP Heidelberg   |
| since 2022        | Co-Organizer of the Fast Calorimeter Simulation Challenge 2022   |
| 01/2021 – 09/2022 | Co-Organizer of the High-Energy Theory Seminar at Rutgers  |
| since 2020        | Referee for the Journal “Machine Learning: Science and Technology”   |
| 01/2020           | Participating scientist in the monthly Fermilab event “ask-a-scientist”  |
| 10/2019-09/2020   | Organizer of the Fermilab HEP Journal Club   |
| 07/2019           | Co-organizer of the workshop “Multibosons At The Energy Frontier” at Fermilab  |
| since 2018        | Referee for the “Journal of High Energy Physics” (JHEP)  |
| 10/2017           | Participated in a two day workshop on outreach, organized by the Klaus Tschira Stiftung, as reward for my participation in the “KlarText” competition. |
| 05/2017           | Participated in the “Expociencia”, open house day of IFIC, Valencia, Spain   |
| 02/2017           | Participated in the “KlarText” competition of the Klaus Tschira Stiftung, writing an outreach essay about my doctoral thesis                           |

## Teaching experience

### Lecturing

#### High School level

2-day block course with lectures in “Physics for becoming medical students” for the fellows of the Else-Kröner-Fellowship of the Roland-Berger-Foundation, given each in 2021 and 2022. (High school students that plan to study medicine after finishing school.)

#### Undergraduate level / Bachelor classes

Quantum mechanics for teachers (1 stand-in lecture for Prof. Dr. G. Buchalla at LMU Munich)

Theoretical Mechanics (1 stand-in lecture for Prof. Dr. T. Plehn at Heidelberg University)

Theoretical Thermodynamics (1 stand-in lecture for Prof. Dr. T. Plehn at Heidelberg University)

#### Graduate level / Master classes

Quantum electrodynamics (1 stand-in lecture for Prof. Dr. G. Buchalla at LMU Munich)

Machine Learning for High-Energy Physics (1 stand-in lecture for Prof. Dr. D. Shih at Rutgers University)

Deep Generative Models for Particle Physics (lecture and tutorial), 3rd Terascale School of Machine Learning, Doctoral School at DESY Hamburg, October 2022

Normalizing Flows (90min lecture), Active Training Course “Advanced Deep Learning”, Doctoral School organized by ErUM-Data-Hub, November 2022

Modern Machine Learning for Particle Physics (4x 90min lectures and tutorials), KSETA doctoral program of Karlsruhe Institute of Technology (KIT), March 2023

Modern Machine Learning for (Particle) Physics, (8x 90min lectures and tutorials), 50th Heidelberg Graduate Days at the University of Heidelberg, April 2023

Generative Models at the LHC, (5x 90min lectures and tutorials), MITP School Machine Learning in Particle Theory, July 2023

### Teaching Assistant

#### At BTU Cottbus

Introduction to Physics (2 weeks intensive course as part of the orientation program for new students)

At LMU Munich (8 terms in total)

Quantum electrodynamics (theoretical lecture for Master students, 1 term)

Advanced nuclear and particle physics (experimental lecture for Master students, 1 term)

QCD and Standard Model (theoretical lecture for Master students, 1 term)

Atomic and molecular physics (experimental lecture for Bachelor students, 1 term)

Electrodynamics (theoretical lecture for Bachelor students, 1 term)

Nuclear and particle physics (experimental lecture for Bachelor students, 1 term)

Quantum mechanics for teachers (theoretical lecture for Bachelor students, 2 terms)

#### Development of problem sheets

QCD and Standard Model (theoretical lecture for Master students at LMU Munich, 1 term)

Analytical Mechanics and Thermodynamics (theoretical lecture for Bachelor students at Heidelberg University, 1 term)\ Managing 390 students and 21 teaching assistants.

#### Supervising physics lab courses

Physics lab course for physics Bachelor students (1 term at BTU Cottbus)

Physics lab course for engineering Bachelor students (2 terms at BTU Cottbus)

#### Grading of homework assignments

Mathematik IT-3 (Analysis lecture for Bachelor students at BTU Cottbus, 1 term)

#### Student Supervision

Undergraduate Projects

Lucas Clement, Rutgers University (with David Shih)  
Nina Pellosch, Technical University Vienna

Master's Thesis

Jan-Niklas Toelstede, LMU Munich (with Gerhard Buchalla)  
Imahn Shekhzadeh, University Hamburg (with Gregor Kasieczka)  
Florian Ernst, Heidelberg University (with Tilman Plehn)  
Simon Hablas, Technical University Vienna (with Robert Schöfbeck)

Doctoral Thesis

Dr. Joaquín Santos-Blasco, IFIC & Universidad de Valencia (with Toni Pich)

Dr. Yikun Wang, Fermilab & University of Chicago (with Marcela Carena)  
Dr. Anna Hallin, Rutgers University (with David Shih)

## Internships

- 09/2011 – 02/2012 **École Polytechnique Fédérale de Lausanne**  
Travaux Pratiques – Laboratory work  
Final report: “Applications of Dirac-Theory” (8ECTS)  
Supervisor: Prof. Dr. R. Rattazzi
- 02/2010 – 03/2010 **Deutsches Elektronen Synchrotron (DESY), Zeuthen**  
Final report: “Improvement of the continuum limit for Wilson twisted mass fermions at maximal twist” (8ECTS)  
Supervisor: Prof. Dr. K. Jansen

## Selected recent talks (full list available at <https://claudius-krause.gitlab.io/CV>)

- 01/2024 “Machine Learning & Particle Physics”, ARI Guest Colloquium, Acoustic Research Institute (ARI), Institut für Schallforschung (ISF), ÖAW, Vienna, Austria
- 11/2023 “The Fast Calorimeter Simulation Challenge 2022”, Overview Talk at the ML4Jets Conference, DESY, Hamburg, Germany
- 08/2023 “Improving HEP Simulation and Analyses with Invertible Neural Networks”, Invited Seminar at the ORIGINS Data Science Lab, TU Munich, Garching, Germany
- 06/2023 “How deep generative models change our understanding of Nature”, Physics Colloquium, Brandenburg Technical University, Cottbus, Germany
- 05/2023 “Modern Machine Learning for Particle Physics”, Invited Plenary Talk at “PLANCK 2023 — The 25th International Conference From the Planck Scale to the Electroweak Scale”, Ochata Campus, University of Warsaw, Poland
- 03/2023 “Machine Learning for Event Generation and Fast Simulation”, Invited Talk at “Prospecting for New Physics through Flavor, Dark Matter, and Machine Learning”, Aspen Center for Physics, Aspen, Colorado, USA

## Publications

### Peer-reviewed:

1. “Combining Resonant and Tail-based Anomaly Detection”, G. Bickendorf, M. Drees, G. Kasieczka, C. Krause, D. Shih, [arXiv:2309.12918](https://arxiv.org/abs/2309.12918), [Phys. Rev. D 109 \(2024\) 9, 096031](https://doi.org/10.1103/PhysRevD.109.096031).
2. “CaloFlow for CaloChallenge Dataset 1”, C. Krause, I. Pang, D. Shih, [arXiv:2210.14245](https://arxiv.org/abs/2210.14245), [SciPost Phys. 16, 126 \(2024\)](https://doi.org/10.21468/SciPostPhys.16.126).

3. "The Interplay of Machine Learning-based Resonant Anomaly Detection Methods", T. Golling, G. Kasieczka, C. Krause, R. Mastandrea, B. Nachman, J. A. Raine, D. Sengupta, D. Shih, M. Sommerhalder. [arXiv:2307.11157](https://arxiv.org/abs/2307.11157), *Eur. Phys. J. C* **84**, 241 (2024).
4. "Inductive simulation of calorimeter showers with normalizing flows", M. R. Buckley, C. Krause, I. Pang, D. Shih, [arXiv:2305.11934](https://arxiv.org/abs/2305.11934), *Phys. Rev. D* **109** (2024), 033006.
5. "How to Understand Limitations of Generative Networks", R. Das, L. Favaro, T. Heimel, C. Krause, T. Plehn, D. Shih, [arXiv:2305.16774](https://arxiv.org/abs/2305.16774), *SciPost Phys.* **16**, 031 (2024).
6. "L2LFlows: Generating High-Fidelity 3D Calorimeter Images", S. Diefenbacher, E. Eren, F. Gaede, G. Kasieczka, C. Krause, I. Shekhzadeh, D. Shih, [arXiv:2302.11594](https://arxiv.org/abs/2302.11594), *JINST* **18** (2023) P10017.
7. "MadNIS — Neural Multi-Channel Importance Sampling", T. Heimel, R. Winterhalder, A. Butter, J. Isaacson, C. Krause, F. Maltoni, O. Mattelaer, T. Plehn, [arXiv:2212.06172](https://arxiv.org/abs/2212.06172), *SciPost Phys.* **15** (2023) 141.
8. "CaloFlow II: Even Faster and Still Accurate Generation of Calorimeter Showers with Normalizing Flows", C. Krause, D. Shih, [arXiv:2110.11377](https://arxiv.org/abs/2110.11377), *Phys. Rev. D* **107** (2023), 113004.
9. "CaloFlow: Fast and Accurate Generation of Calorimeter Showers with Normalizing Flows", C. Krause, D. Shih, [arXiv:2106.05285](https://arxiv.org/abs/2106.05285), *Phys. Rev. D* **107** (2023), 113003.
10. "Classifying Anomalies THrough Outer Density Estimation (CATHODE)", A. Hallin, J. Isaacson, G. Kasieczka, C. Krause, B. Nachman, T. Quadfasel, M. Schlaffer, D. Shih, M. Sommerhalder. [arXiv:2109.00546](https://arxiv.org/abs/2109.00546), *Phys. Rev. D* **106** (2022), 055006.
11. "Higgs-Electroweak Chiral Lagrangian: One-Loop Renormalization Group Equations", G. Buchalla, O. Catà, A. Celis, M. Knecht, C. Krause, [arXiv:2004.11348](https://arxiv.org/abs/2004.11348), *Phys. Rev. D* **104** (2021) 7, 076005.
12. "A New Approach to Electroweak Symmetry Non-Restoration", M. Carena, C. Krause, Z. Liu, Y. Wang, [arXiv:2104.00638](https://arxiv.org/abs/2104.00638), *Phys.Rev.D* **104** (2021) 5, 055016.
13. "i-flow: High-dimensional Integration and Sampling with Normalizing Flows", C. Gao, J. Isaacson, C. Krause, [arXiv:2001.05486](https://arxiv.org/abs/2001.05486), *Mach.Learn.Sci.Tech.* **1** (2020) 4, 045023.
14. "Event Generation with Normalizing Flows", C. Gao, S. Hoeche, J. Isaacson, C. Krause, H. Schulz, [arXiv:2001.10028](https://arxiv.org/abs/2001.10028), *Phys.Rev.D* **101** (2020) 7, 076002
15. "Colorful Imprints of Heavy States in the Electroweak Effective Theory", C. Krause, A. Pich, I. Rosell, J. Santos, J.-J. Sanz-Cillero, [arXiv:1810.10544](https://arxiv.org/abs/1810.10544), *JHEP* **1905** (2019) 092

16. “Current and Future Constraints on Higgs Couplings in the Nonlinear Effective Theory”, J. de Blas, O. Eberhardt, C. Krause, arXiv:1803.00939, JHEP 1807 (2018) 048
17. “Signals of the electroweak phase transition at colliders and gravitational wave observatories”, M. Chala, C. Krause, G. Nardini, arXiv:1802.02168, JHEP 1807 (2018) 062
18. “Complete One-Loop Renormalization of the Higgs-Electroweak Chiral Lagrangian”, G. Buchalla, O. Cata, A. Celis, M. Knecht, C. Krause, arXiv:1710.06412, Nucl.Phys. B928 (2018) 93-106
19. “Standard Model Extended by a Heavy Singlet: Linear vs. Nonlinear EFT”, G. Buchalla, O. Cata, A. Celis, C. Krause, arXiv:1608.03564, Nucl.Phys. B917 (2017) 209-233
20. “Fitting Higgs Data with Nonlinear Effective Theory”, G. Buchalla, O. Cata, A. Celis, C. Krause, arXiv:1511.00988, Eur.Phys.J. C76 (2016) no.5, 233
21. “Note on Anomalous Higgs-Boson Couplings in Effective Field Theory”, G. Buchalla, O. Cata, A. Celis, C. Krause, arXiv:1504.01707, Phys.Lett. B750 (2015) 298-301
22. “A Systematic Approach to the SILH Lagrangian”, G. Buchalla, O. Cata, C. Krause, arXiv:1412.6356, Nucl.Phys. B894 (2015) 602-620
23. “On the Power Counting in Effective Field Theories”, G. Buchalla, O. Catà, C. Krause, arXiv:1312.5624, Phys.Lett. B731 (2014) 80-86
24. “Complete Electroweak Chiral Lagrangian with a Light Higgs at NLO”, G. Buchalla, O. Catà, C. Krause, arXiv:1307.5017, Nucl.Phys. B880 (2014) 552-573, Erratum: Nucl.Phys. B913 (2016) 475-478

Preprints:

1. “Convolutional L2LFlows: Generating Accurate Showers in Highly Granular Calorimeters Using Convolutional Normalizing Flows”, T. Buss, F. Gaede, G. Kasieczka, C. Krause, D. Shih, [arXiv:2405.20407](https://arxiv.org/abs/2405.20407).
2. “Unifying Simulation and Inference with Normalizing Flows”, H. Du, C. Krause, V. Mikuni, B. Nachman, I. Pang, D. Shih, [arXiv:2404.18992](https://arxiv.org/abs/2404.18992).
3. “Anomaly detection with flow-based fast calorimeter simulators”, C. Krause, B. Nachman, I. Pang, D. Shih, Y. Zhu, [arXiv:2312.11618](https://arxiv.org/abs/2312.11618).
4. “Deep Generative Models for Detector Signature Simulation: An Analytical Taxonomy”, B. Hashemi, C. Krause, [arXiv:2312.09597](https://arxiv.org/abs/2312.09597).



5. "Normalizing Flows for High-Dimensional Detector Simulations", F. Ernst, L. Favaro, C. Krause, T. Plehn, D. Shih, [arXiv:2312.09290](https://arxiv.org/abs/2312.09290).
6. "Master Formula for One-Loop Renormalization of Bosonic SMEFT Operators", G. Buchalla, A. Celis, C. Krause, J.-N. Toelstede, [arXiv:1904.07840](https://arxiv.org/abs/1904.07840)
7. "Comment on "Analysis of General Power Counting Rules in Effective Field Theory"", G. Buchalla, O. Cata, A. Celis, C. Krause, [arXiv:1603.03062](https://arxiv.org/abs/1603.03062)

Doctoral Thesis:

1. "Higgs Effective Field Theories — Systematics & Applications", Claudius Krause, [arXiv:1610.08537](https://arxiv.org/abs/1610.08537), University Library LMU Munich

Community projects:

1. "Modern Machine Learning for LHC Physicists", T. Plehn, A. Butter, B. Dillon, C. Krause. [arXiv:2211.01421](https://arxiv.org/abs/2211.01421)
2. "Snowmass 2021 Computational Frontier CompF03 Topical Group Report: Machine Learning", Contribution to Snowmass 2021 (P. Shanahan, K. Terao, D. Whiteson et al.), [arXiv:2209.07559](https://arxiv.org/abs/2209.07559)
3. "Toward the End-to-End Optimization of Particle Physics Instruments with Differentiable Programming: a White Paper", The MODE collaboration, [arXiv:2203.13818](https://arxiv.org/abs/2203.13818), [Reviews in Physics 10, June 2023, 100085](https://arxiv.org/abs/2203.13818)
4. "Event Generators for High-Energy Physics Experiments", Contribution to Snowmass 2021 (J.M. Campbell et al.). [arXiv:2203.11110](https://arxiv.org/abs/2203.11110).
5. "New directions for surrogate models and differentiable programming for High Energy Physics detector simulation", Contribution to Snowmass 2021 (A. Adelman et al.), [arXiv:2203.08806](https://arxiv.org/abs/2203.08806).
6. "Machine Learning and LHC Event Generation", Contribution to Snowmass 2021 (A. Butter et al.), [arXiv:2203.07460](https://arxiv.org/abs/2203.07460), [SciPost Phys. 14, 079 \(2023\)](https://arxiv.org/abs/2203.07460).
7. "Higgs Physics at the HL-LHC and HE-LHC", HL/HE WG2 group (M. Cepeda et al.), [arXiv:1902.00134](https://arxiv.org/abs/1902.00134)
8. "Handbook of LHC Higgs Cross Sections: 4. Deciphering the Nature of the Higgs Sector", LHC Higgs Cross Section Working Group (D. de Florian et al.), [arXiv:1610.07922](https://arxiv.org/abs/1610.07922)

Conference proceedings:

1. “Advancing Generative Modelling of Calorimeter Showers on Three Frontiers”, E. Buhmann, S. Diefenbacher, E. Eren, F. Gaede, G. Kasieczka, W. Korcari, A. Korol, C. Krause, K. Krueger, P. McKeown, I. Shekhzadeh, D. Shih.  
[ML4PS at NeurIPS 2023](#), Machine Learning and the Physical Sciences, Workshop at the 37th conference on Neural Information Processing Systems (NeurIPS), December 2023.
2. “Classifying Anomalies THrough Outer Density Estimation (CATHODE)”, A. Hallin, J. Isaacson, G. Kasieczka, C. Krause, B. Nachman, T. Quadfasel, M. Schlaffer, D. Shih, M. Sommerhalder.  
[ML4PS at NeurIPS 2021](#), Machine Learning and the Physical Sciences, Workshop at the 35th Conference on Neural Information Processing Systems (NeurIPS), December 2021.
3. “Effective theories and resonances in strongly-coupled electroweak symmetry breaking scenarios”, I. Rosell, C. Krause, A. Pich, J.-J. Sanz-Cillero, arXiv:1910.01839, PoS EPS-HEP2019
4. "Complete One-Loop Renormalization of the Higgs-Electroweak Chiral Lagrangian", C. Krause, G. Buchalla, O. Cata, A. Celis, M. Knecht, arXiv:1907.07605, PoS CD2018 (2018) 072
5. "Heavy resonances and the electroweak effective theory", I. Rosell, C. Krause, A. Pich, J. Santos, J.-J. Sanz-Cillero, arXiv:1811.10233, PoS ICHEP2018 (2019)
6. “Tracks of resonances in electroweak effective Lagrangians”, I. Rosell, C. Krause, A. Pich, J. Santos, J.J. Sanz-Cillero, arXiv:1710.06622, PoS EPS-HEP2017 (2018) 334

Dr. Claudius G. Krause

Vienna, July 2, 2024