

# CHRISTIAN PEHLE

## Address

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<https://github.com/cpehle>

## Biographic Data

Born in Darmstadt, Germany. German citizen.

## Experience

**Kirchhoff Institute for Physics, Heidelberg University** Heidelberg, Germany  
PostDoc, STRUCTURES Excellence Cluster. May 2021 - present

- Developing theory, algorithms and software for differentiable simulation and learning in physical systems, in particular detailed neuron models and networks, integrated with the machine-learning framework JAX (in progress).
- Developing theory and algorithms for closed-loop control of Quantum Experiments with Spiking Neural Networks (in progress).
- Architect and developer of "Norse", a software library for machine learning with Spiking Neurons (in PyTorch).
- Supervise students implementing event-based learning algorithms for analog Neuromorphic Hardware.

PhD student in Physics. August 2015 - February 2021

- Focussed on learning algorithms and plasticity in Spiking Neural Networks and analog Neuromorphic Hardware: Found a way to compute parameter gradients in networks of spiking neurons without approximations or assumptions on network topology, a long-standing open question.
- Worked on variational approximation of quantum density matrices and certain quantum operations by artificial and Spiking Neural Networks.
- Part of design team of a Neuromorphic Processor (BrainScaleS-2). Responsible for scale-up and verification of "plasticity processing unit" (an embedded processor with SIMD unit), evaluation and design of plasticity experiments.

**Institute for Theoretical Physics, Heidelberg University** Heidelberg, Germany  
Research Assistant. October 2012 - February 2014

- Developed a novel method to count massless matter in String Theory (F-Theory).

## Education

**Heidelberg University** Heidelberg, Germany  
August 2015 – February 2021

PhD in Physics  
Thesis: *Adjoint Equations of Spiking Neural Networks*  
Supervisor: Karlheinz Meier<sup>†</sup>, Johannes Schemmel

November 2011 – August 2015  
Diplom Mathematics (incomplete, decided to proceed with PhD instead)  
finished majority of required and elective courses (among them: PDE, Optimization on Manifolds, Numerical Methods, Hodge Theory, Algebraic Topology, TQFT)

October 2010 – March 2014  
MSc in Theoretical Physics (focus on Quantum Field Theory and String Theory)

October 2007 – November 2011  
Vordiplom in Mathematics

October 2007 – August 2010  
BSc in Physics

**Edith-Stein-Schule** Darmstadt, Germany

July 2007  
Abitur

Recommended for German National Merit Foundation, received state-wide award for written physics exam.

## Selected Publications & Preprints

**Christian Pehle**, Luca Blessing, Elias Arnold, Eric Müller, and Johannes Schemmel. Event-based backpropagation for analog neuromorphic hardware. *In preparation*, 2022

**Christian Pehle** and Christof Wetterich. Neuromorphic quantum computing. *Phys. Rev. E*, 106:045311, 2022

Benjamin Cramer, Sebastian Billaudelle, Simeon Kanya, Aron Leibfried, Andreas Grübl, Vitali Karasenko, **Christian Pehle**, Korbinian Schreiber, Yannik Stradmann, Johannes Weis, et al. Surrogate gradients for analog neuromorphic computing. *Proceedings of the National Academy of Sciences*, 119(4):e2109194119, 2022

**Christian Pehle**, Sebastian Billaudelle, Benjamin Cramer, Jakob Kaiser, Korbinian Schreiber, Yannik Stradmann, Johannes Weis, Aron Leibfried, Eric Müller, and Johannes Schemmel. The BrainScaleS-2 accelerated neuromorphic system with hybrid plasticity. *Frontiers in Neuroscience*, 16, 2022

Timo C Wunderlich and **Christian Pehle**. Event-based backpropagation can compute exact gradients for spiking neural networks. *Scientific Reports*, 11(1):1–17, 2021

K. Schreiber, T. C. Wunderlich, **C. Pehle**, M. A. Petrovici, J. Schemmel, and K. Meier. Closed-loop experiments on the brainscales-2 architecture. In *Proceedings of the Neuro-Inspired Computational Elements Workshop, NICE '20*. Association for Computing Machinery, 2020

Thomas Bohnstingl, Franz Scherr, **Christian Pehle**, Karlheinz Meier, and Wolfgang Maass. Neuromorphic hardware learns to learn. *Frontiers in neuroscience*, 13:483, 2019

Syed Ahmed Aamir, Yannik Stradmann, Paul Müller, **Christian Pehle**, Andreas Hartel, Andreas Grübl, Johannes Schemmel, and Karlheinz Meier. An accelerated lif neuronal network array for a large-scale mixed-signal neuromorphic architecture. *IEEE Transactions on Circuits and Systems I: Regular Papers*, 65(12):4299–4312, 2018

## Research Software Tools

2019 – present **Norse** ([github.com/norse/norse](https://github.com/norse/norse), > 400 stars on Github)

- Library for gradient-based machine learning with Spiking Neural Networks in PyTorch.
- Created initial architecture and implementation. Co-lead design and development.
- In use by several external groups (European Space Agency, FZI & KIT Karlsruhe, KTH Stockholm).
- Backends for neuromorphic chips (BrainScaleS-2, SpiNNaker-2) in development.

2020 – present **aestream** ([github.com/norse/aestream](https://github.com/norse/aestream))

- Library for streaming data from event-based cameras to deep-learning models in particular spiking neural network models.
- Provided the initial C++ implementation and interface to PyTorch.
- In use for closed-loop robotics experiments at KTH Stockholm.

## Languages

German (native), English (fluent), French (basic)

## Technical Skills

I have seven years of experience working in a team of 5-8 hardware and 10-20 software developers and users. We practice sustainable software and hardware development principles. We have implemented an integrated software-hardware development flow, including Code Review, Continuous Integration, fully reproducible software-hardware deployment and dependency management.

- Machine Learning: PyTorch, JAX, algorithm design, optimal control, Neural ODE, Graph Neural Networks, HPC training
- Software Development: C/C++, Python, git, basic unix tools and environment,  $\LaTeX$ , Functional Programming

- Hardware Development: Digital Design, FPGA (XilinX) and ASIC development: Contributed to three successful tape-outs of two prototype and one full-scale neuromorphic processor in TSMC 65 nm. Verilog/SystemVerilog, UVM, Verilator
- DevOps: Continuous Integration (Jenkins, Github workflows), Code Review (Gerrit), SLURM, Singularity, Spack

### Other Interests

Programming Language Design and Type Theory, Long Distance Hiking (300 km+), Bouldering, Downhill Skiing

### References

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