Curriculum Vitae

PERSONAL INFORMATION

Family name, First name:	Helias, Moritz
Date of birth:	28.11.1977
Nationality:	German
Websites:	google scholar profile
	Jülich Research Centre

CURRENT POSITIONS

since 2022	Professor Department of Physics RWTH University Aachen, Germany
since 2020	Group leader "Theory of multi-scale neuronal networks" Jülich Research Centre, Germany

PREVIOUS POSITIONS

2014-2019	Group leader of Helmholtz Young Investigator's Group "Theory of multi-scale neuronal networks" (positive evaluation 2017)
2015-2022	Junior professor (positive evaluation 2018)
2011 – 2014	Postdoc, Computational and Systems Neuroscience (INM-6) Jülich Research Centre, Germany
2009 – 2011	Postdoc, Computational and Statistical Neuroscience RIKEN Brain Science Institute, Wako-Shi, Japan

EDUCATION

2009	PhD Computational Neuroscience, grade: outstanding (summa cum laude) Bernstein Center for Computational Neuroscience, University Freiburg, Germany
2003	Diploma physics, grade: outstanding Dept. of Quantum Theory of Condensed Matter and Computational Physics University of Hamburg, Germany

SUPERVISION

2008 – today	Postdocs: 3; PhD direct: 19; co-supervised: 7; external: 8; master: 14; bachelor: 9 University of Freiburg, RWTH Aachen University (faculties: physics, biology, computer science)

TEACHING AT UNIVERSITIES

2023	Lecture "Rechentechniken" (2 hours / week)
2021	Lecture "Theory II – Electrodynamics (bachelor)" (4 hours / week)
2018-23	Lecture "Statistical physics (master)" (4+2 hours / week)
2017	Lecture "Quantum many particle systems" (2+1 hours / week)
2016-20, 2023	Lecture "Statistical mechanics of neuronal networks" (2+1 hours / week)
2013-16	Lecture "Correlations and fluctuations in neuronal networks" (2+1 hours / week)
2011-16	Co-teacher in "Introduction to computational neuroscience" (2+2 hours / week)
2008	Two week block course "Scientific programming in python"

TEACHING AT INTERNATIONAL SUMMER SCHOOLS AND CONFERENCES

2023	Lecture "Chaos, criticality, and computation in recurrent networks" Doctoral school Lausanne (Organizer: Wulfram Gerstner)
2022	Lecture "Gell-Mann-Low criticality in neuronal networks" Summer School on Mathematical Methods in Computational Neuroscience Kavli Moen Gård, Eresfjord, Norway
2021, 2022, 2023	Lecture "Formal mean-field methods: Dynamics and Computation in recurrent networks" EITN Autumn School, Paris
2020, 2021, 2022	Lecture "Critically disordered cortical networks: Chaos and computation" Summer School on Mathematical Methods in Computational Neuroscience Kavli Moen Gård, Eresfjord, Norway
2019	Tutorial "Field theory for neuronal networks" CNS*2019 Tutorial, Barcelona
2016	Lecture "Functional methods for neuronal networks" Bernstein Sparks workshop, Göttingen
2016	Lecture series "Statistical field theory for neuronal networks" aCNS summer school 2016, Göttingen
2015	Tutorial "Theory of recurrent networks" CNS*2015 conference, Prague
2013	Lecture series "Correlated activity in recurrent neural networks" 11th Summer Course on Computational Neuroscience 2013, Göttingen
2012 – 2013	Tutorial "Theory of correlation transfer and correlation structure in recurrent networks", CNS*2013 conference, Paris; CNS*2012 conference, Decatur, USA
2008 – 2009	Tutor at summer school (4 weeks) "EU Advanced course in computational neuroscience"

Publications in peer reviewed journals

- 1 monograph, 59 peer reviewed publications; 25 as a senior author; 11 as first author (incl. shared)
- 2976 citations, h-index: 30; i-10-index: 55 (google scholar, April 2024)

Selected publications

1. Tiberi L, Stapmanns J, Kühn T, Luu T, Dahmen D, Helias M (2022)
   Gell-Mann–Low criticality in neural networks. **Phys Rev Lett** *128, 168301*

   Finds **Gell-Mann-Low criticality** in spatially-organized neuronal networks of the same kind as present in quantum field theories of high energy physics. Long range correlations, a broad range of time constants, and weakly non-linear behavior render this state **beneficial for memory and computation**.

2. Keup C, Kühn T, Dahmen D, Helias M (2021).
   Transient chaotic dimensionality expansion by recurrent networks. **Phys Rev X**, *11(2), 021064*

   Shows that impulsed and discrete communication in recurrent networks implements **fast stereotypical expansion of signals into high-dimensional representations** that offer improved discrimination and classification. Optimal computation is found in the chaotic regime, not at the edge of chaos. Develops a model-independent field-theoretical framework to treat recurrent networks in stationary and transient regimes.

3. Dahmen D, Grün S, Diesmann M, Helias M (2019).
   Second type of criticality in the brain uncovers rich multiple-neuron dynamics. **PNAS**, 116 (26) 13051-13060

   Uncovers that macaque motor cortex operates close to a **novel type of critical point**. It overcomes the sub-sampling problem in neuroscience by help of large-N field theory, to provide a mechanistic explanation for the widely distributed magnitudes of correlations observed in cortical recordings. It discovers a connection between random matrix theory and correlated network activity, which shows that the cortical network operates close to a novel type of critical point.

4. Schuecker J, Goedeke S, Helias M (2018).
   Optimal sequence memory in driven random networks. **Phys Rev X,** 8, 041029

   Discovers a hitherto unknown dynamical network state between the breakdown of stability and the onset of chaos, which has **optimal computational performance** in terms of memory capacity. Previously, these two criteria had been thought to be identical. The work, for the first time, presents a field theory for the exactly solvable network model by Sompolinsky et al. 1988, enabling its systematic extension; the original paper had been enigmatic for many experts. In response, the original authors, 30 years after their original work, recently published their view (Crisanti & Sompolinky 2018).

5. Dahmen D, Bos H, Helias M (2016)
   Correlated fluctuations in strongly coupled binary networks beyond equilibrium. **Phys Rev X** 6, 031024

   Goes beyond the central assumption of mean-field theory of neuronal networks: self-averaging, which restricts results to population-averages. The work explains how **cell-to-cell heterogeneity** in cortical networks arises dynamically as a collective network effect.

6. Tetzlaff T*, Helias M*, Einevoll GT, Diesmann M (2012)
   Decorrelation of neural-network activity by inhibitory feedback. **PLoS Comput Biol** 8(8): e1002596.

   Explains the **mechanism behind the balanced state** of neuronal networks. Its weak pairwise correlations had previously been explained by tracking of external input by Renart et al. (2010, *Science*), while our work identifies negative feedback by inhibition as the cause. Together with Helias et al. *PloS CB* 2014 termed "**Key papers in the field**" by a recent review (Ocker et al. 2017).

7. Kuehn T, Helias M (2018)
   Expansion of the effective action around non-Gaussian theories. **J Phys A: Math Theor** 51, 375004

   Develops a general method to compute the effective action (Gibbs free energy), a central object in statistical physics, field theory, and condensed matter theory, by Feynman diagrams around non-Gaussian exactly solvable problems. Such a method had been sought by the statistical physicist Parisi, Georges, Potters, and Yedidia (see Opper et al. 2001). The paper has been selected as the **editorial choice 2018 of J Phys A**.

Monographs

1. Helias M, Dahmen D (2020) Statistical field theory for neural networks. Springer Lecture Notes in Physics.

Book chapters

1. Kunkel S, Helias M, Potjans TC, Eppler JM, Plesser HE, Diesmann M, Morrison A (2012). Memory consumption of neuronal network simulators at the brain scale. In NIC Symposium 2012 Proceedings (Vol. 45, pp. 81-88)

2. Hahne J, Helias M, Kunkel S, Igarashi J, Kitayama I, Wylie B, Bolten M, Frommer A, Diesmann M (2015). Including gap junctions into distributed neuronal network simulations. In International Workshop on Brain-Inspired Computing (pp. 43-57). Springer, Cham.

List of publications in peer reviewed journals

1. Layer M, Helias M, Dahmen D (2024) Effect of Synaptic Heterogeneity on Neuronal Coordination PRX Life 2, 013013

2. Nestler S, Helias M, Gilson M (2023) Statistical temporal pattern extraction by neuronal architecture Physical Review Research 5 (3), 033177

3. Merger C, René A, Fischer K, Bouss P, Nestler S, Dahmen D, Honerkamp C, Helias M (2023) Learning Interacting Theories from Data Phys. Rev. X 13, 041033

4. Fischer K, René A, Keup C, Layer M, Dahmen D, and Helias M (2022) Decomposing neural networks as mappings of correlation functions. Phys. Rev. Research 4, 043143

5. Segadlo K, Epping B, van Meegen A, Dahmen D, Krämer M, Helias M (2022) Unified field theoretical approach to deep and recurrent neuronal networks. J Stat Mech 103401

6. Tiberi L, Stapmanns J, Kühn T, Luu T, Dahmen D, Helias M (2022) Gell-Mann–Low criticality in neural networks. *Phys Rev Lett* 128(16):168301. doi: 10.1103/PhysRevLett.128.168301.

7. Layer M, Senk J, Essink S, Van Meegen A, Bos H, Helias M (2022) NNMT: Mean-field based analysis tools for neuronal network models. *Frontiers in Neuroinformatics doi: 10.3389/fninf.2022.835657*

8. Dahmen D, Layer M, Deutz L, Dabrowska PA, Voges N, von Papen M, Brochier T, Riehle A, Diesmann M, Grün S, Helias M (2021). Global organization of neuronal activity only requires unstructured local connectivity. *elife* 11:e68422 doi: 10.7554/eLife.68422

9. van Meegen A, Kühn T, Helias M (2021). Large-Deviation Approach to Random Recurrent Neuronal Networks: Parameter Inference and Fluctuation-Induced Transitions. *Phys Rev Lett* 127, 158302

10. Merger C, Reinartz T, Wessel S, Honerkamp C, Schuppert A, Helias M (2021) Global hierarchy vs. local structure: spurious self-feedback in scale-free networks. *Phys Rev Res* 3, 033272.

11. Keup C, Kühn T, Dahmen D, Helias M (2021) Transient chaotic dimensionality expansion by recurrent networks. *Phys Rev X, 11(2)*, 021064

12. Helias M (2020) Momentum-dependence in the infinitesimal Wilsonian renormalization group. *J Phys A: Math Theor* 53 445004

13. Dahmen D, Gilson M, Helias M (2020) Capacity of the covariance perceptron. *J Phys A: Math Theor* 53 354002

14. Nestler S, Keup C, Dahmen D, Gilson M, Rauhut H, Helias M (2020) *NeurIPS 33*.

15. Gilson M, Dahmen D, Moreno-Bote R, Insabato A, Helias M (2020) The covariance perceptron: A new framework for classification and processing of time series in recurrent neural networks. *PLoS Comput Biol* 10.1371/journal.pcbi.1008127

16. Stapmanns J, Kuehn T, Dahmen D, Luu T, Honerkamp C, Helias M (2020) Self-consistent formulations for stochastic nonlinear neuronal dynamics. *Phys Rev E* 101, 042124

17. Senk J, Korvasová K, Schuecker J, Hagen E, Tetzlaff T, Diesmann M, Helias M (2020) Conditions for wave trains in spiking neural networks. *Phys Rev Res* 2, 023174

18. Dahmen D, Grün S, Diesmann M, Helias M (2019). Second type of criticality in the brain uncovers rich multiple-neuron dynamics. *PNAS* 116 (26) 13051-13060

19. Schuecker J, Goedeke S, Helias M (2018). Optimal sequence memory in driven random networks. *Phys Rev X* 8, 041029

20. Kuehn T, Helias M (2018). Expansion of the effective action around non-Gaussian theories. *J Phys A: Math Theor* 51, 375004

21. Krishnan J, Porta Mana PGL, Helias M, Diesmann M, Di Napoli E. (2018) Perfect Detection of Spikes in the Linear Sub-threshold Dynamics of Point Neurons. *Front Neuroinf* 10.3389/fninf.2017.00075

22. Jordan J, Ippen T, Helias M, Kitayama I, Sato M, Igarashi J, Diesmann M, Kunkel S (2018). Extremely Scalable Spiking Neuronal Network Simulation Code: From Laptops to Exascale Computers. *Front Neuroinf* 12 10.3389/fninf.2018.00002

23. Völker M, Fiederer LDJ, Berberich S, Hammer J, Behncke J, Krsek P, Tomasek M, Marusic P, Reinacher PC, Coenen VA, Helias M, Schulze-Bonhage A, Burgard W, Ball T (2018) The dynamics of error processing in the human brain as reflected by high-gamma activity in noninvasive and intracranial EEG. *Neuroimage* 18, S1053

24. Heers M, Helias M, Hedrich T, Dümpelmann M, Schulze-Bonhage A, Ball T (2018) Interictal spectral bandwidth characterizes the epileptic seizure onset zone, *Neuroimage Clinical*, 17, 865–872

25. Robert E. Kass, Shun-Ichi Amari, Kensuke Arai, Emery N. Brown, Casey O. Diekman, Markus Diesmann, Brent Doiron, Uri T. Eden, Adrienne L. Fairhall, Grant M. Fiddyment, Tomoki Fukai, Sonja Grün, Matthew T. Harrison, Helias M, Hiroyuki Nakahara, Jun-nosuke Teramae, Peter J. Thomas, Mark Reimers, Jordan Rodu, Horacio G. Rotstein, Eric Shea-Brown, Hideaki Shimazaki, Shigeru Shinomoto, Byron M. Yu, and Mark A. Kramer (2018) Computational Neuroscience: Mathematical and Statistical Perspectives. *Annu Rev Stat Appl* 5 183-214

26. Kuehn T, Helias M (2017). Locking of correlated neural activity to ongoing oscillations. *PLoS Comput Biol* 13(6): e1005534.

27. Hahne J, Dahmen D, Schuecker J, Frommer A, Bolten M, Helias M and Diesmann M (2017) Integration of Continuous-Time Dynamics in a Spiking Neural Network Simulator. *Front Neuroinform* 11:34.

28. Schuecker J, Schmidt M, van Albada SJ, Diesmann M, Helias M (2017) Fundamental activity constraints lead to specific interpretations of the connectome. *PloS Comput Biology* 13(2): e1005179

29. Rostami V, Porta Mana PGL, Helias M (2016) Pairwise maximum-entropy models and their Glauber dynamics: bimodality, bistability, non-ergodicity problems, and their elimination via inhibition. *PLoS Comput Biol* 13(10): e1005762

30. Torre E, Canova C., Denker M, Gerstein G, Helias M, Grün S. (2016) ASSET: Analysis of Sequences of Synchronous Events in Massively Parallel Spike Trains *PLoS Comput Biol* 12(7), e1004939

31. Bos H, Diesmann M, Helias M (2016) Identifying Anatomical Origins of Coexisting Oscillations in the Cortical Microcircuit. *PLoS Comput Biol* 12(10): e1005132

32. Dahmen D, Bos H, Helias M (2016) Correlated Fluctuations in Strongly Coupled Binary Networks Beyond Equilibrium. *Phys Rev X* 6, 031024

33. Grytskyy D, Diesmann M, Helias M (2016) Reaction-diffusion-like formalism for plastic neural networks reveals dissipative solitons at criticality. *Phys Rev E* 93, 062303

34. Schuecker J, Diesmann M, Helias M (2015) Modulated escape from a metastable state driven by colored noise. *Phys Rev E* 92, 052119

35. Hahne J, Helias M, Kunkel S, Igarashi J, Bolten M, Frommer A and Diesmann M (2015) A unified framework for spiking and gap-junction interactions in distributed neuronal network simulations *Front Neuroinform* doi:10.3389/fninf.2015.00022

36. Van Albada S, Helias M, Diesmann M (2015) Scalability of Asynchronous Networks Is Limited by One-to-One Mapping between Effective Connectivity and Correlations. *PLoS Comput Biol* 11(9): e1004490

37. Chua Y, Morrison A, Helias M (2015) Modeling the calcium spike as a threshold triggered fixed waveform for synchronous inputs in the fluctuation regime *Front Comput Neurosci* 9:91

38. Kunkel S, Schmidt M, Eppler JM, Plesser HE, Masumoto G, Igarashi J, Ishii S, Fukai T, Morrison A, Diesmann M and Helias M (2014). Spiking network simulation code for petascale computers. *Front Neuroinform* 8:78

39. Helias M, Tetzlaff T, Diesmann M (2014) The Correlation Structure of Local Neuronal Networks Intrinsically Results from Recurrent Dynamics. *PLoS Comput Biol* 10(1):e1003428

40. Kriener B, Helias M, Rotter S, Diesmann M and Einevoll GT (2014) How pattern formation in ring networks of excitatory and inhibitory spiking neurons depends on the input current regime. *Front Comput Neurosci* 7:187

41. Grytskyy D, Tetzlaff T, Diesmann M and Helias M (2013) A unified view on weakly correlated recurrent networks. *Front Comput Neurosci* 7:131

42. Vlachos A, Helias M, Becker D, Diesmann M, Deller T (2013) NMDA-receptor inhibition increases spine stability of denervated mouse dentate granule cells and accelerates spine density recovery following entorhinal denervation in vitro. *Neurobiol Disease* 59: 267–276

43. Helias M, Tetzlaff T, Diesmann M. Echoes in correlated neural systems (2013). *New J Phys* 15 023002

44. Schultze-Kraft M, Diesmann M, Gruen S, Helias M (2012). Noise suppression and surplus synchrony by coincidence detection. *PLoS Comput Biol* 9(4): e1002904

45. Helias M, Kunkel S, Eppler JM, Masumoto G, Igarashi J, Fukai T, Ishii S, Morrison A, Diesmann M (2012) Supercomputers ready for use as discovery machines for neuroscience. *Front Neuroinform* 6:26

46. Deger M, Helias M, Rotter S, Diesmann M (2012) Spike timing dependence of structural plasticity explains cooperative synapse formation in the neocortex. *PLoS Comput Biol* 8(9):e1002689

47. Tetzlaff T*, Helias M* , Einevoll GT, Diesmann M (2012) Decorrelation of Neural-Network Activity by Inhibitory Feedback. *PLoS Comput Biol* 8(8): e1002596

48. Deger M, Helias M, Boucsein C, Rotter S (2011) Statistical properties of superimposed stationary spike trains. *J Comput Neurosci* doi: 10.1007/s10827-011-0362-8

49. Helias M, Deger M, Rotter S and Diesmann M (2011) Finite post synaptic potentials cause a fast neuronal response. *Front Neurosci* 5:19

50. Helias M, Deger M, Rotter S, Diesmann M (2010) Instantaneous Non-Linear Processing by Pulse-Coupled Threshold Units. *PLoS Comput Biol* 6(9): e1000929

51. Helias M, Deger M, Diesmann M, Rotter S (2010) Equilibrium and response properties of the integrate-and-fire neuron in discrete time. *Front Comput Neurosci* 3, 29

52. Deger M, Helias M, Cardanobile S, Atay FM, and Rotter S (2010) Nonequilibrium dynamics of stochastic point processes with refractoriness. *Phys Rev E* 82, 039902

53. Djurfeldt M, Hjorth J, Eppler JM, Dudani N, Helias M, Potjans TC, Bhalla US, Diesmann M, Kotaleski JH, Ekeberg O (2010) Run-Time Interoperability Between Neuronal Network Simulators Based on the MUSIC Framework. *Neuroinformatics* 8(1): 43-60

54. Hanuschkin A, Kunkel S, Helias M, Morrison A and Diesmann M (2010) A general and efficient method for incorporating precise spike times in globally time-driven simulations. *Front Neuroinform* 4:113. doi:10.3389/fninf.2010.00113

55. Eppler JM, Helias M, Muller E, Diesmann M, Gewaltig M-O (2009) Pynest: a convenient interface to the NEST simulator. *Front Neuroinform* 2, 12. doi:10.3389/neuro.11.012.2008

56. Kriener B, Helias M, Aertsen A, Rotter S (2009) Correlations in spiking neuronal networks with distance dependent connections. *J Comput Neurosci* 27(2): 177-200

57. Helias M, Rotter S, Gewaltig M-O, Diesmann M (2008) Structural plasticity controlled by calcium based correlation detection. *Front Comput Neurosci* 2, 7. doi:10.3389/neuro.10.007.2008

58. Clemens M, Helias M, Steinmetz T, Wimmer G (2008) Multiple right-hand side techniques for the numerical simulation of quasistatic electric and magnetic fields. *J Comput and Applied Mathematics archive* 215(2): 328-338

59. Steinmetz T, Helias M, Wimmer G, Fichte L O, Clemens M (2006) Electro-quasistatic field simulations based on a discrete electromagnetism formulation. *IEEE Trans Magn*, 42: 755-758

Supervised students

PhD students

direct supervision

Lars Schutzeichel (2024 - today)
Alexandru Ciobanu (2023 - today)
Javed Lindner (2022 - today)
Peter Bouss (2021 - today)
Kirsten Fischer (2020 - today)
Dr. Claudia Merger (2020 - 2024)
Dr. Sandra Nestler (2019 - 2024)
Dr. Lorenzo Tiberi (2019 - 2023)
Dr. Alexander van Meegen (2018-2022)
Dr. Moritz Layer (2017 - 2022)
Dr. Christian Keup (2017 - 2022)
Dr. Jonas Stapmanns (2016 - 2022)
Sven Goedeke (2015 - 2017)
Dr. Tobias Kühn (2014 - 2018)
Dr. Jeyashree Krishnan (electrical engineering, 2014-2016)
Dr. Hannah Bos (physics, 2013-2016)
Dr. Vahid Rostami (biology, 2012-2017)
Dr. Jannis Schuecker (physics, 2012-2017)
Dr. Dmytro Grytskyy (physics, 2011-2015)

external referee (PhD/master)

Dr. Stephan Hesselmann (PhD physics, RWTH Aachen, Prof. Wessel)
Dr. Michael Kordovan (PhD biology 2019, U Freiburg, Prof. Rotter)
Dr. Eli Mueller (PhD 2018, U Sydney, Australia, Prof. Robinson)
Dr. Thomas Heiberg (PhD computer science 2018, U Aas, Norway, Prof. HE Plesser, Prof. G Einevoll)
Dr. Renato Duarte (PhD biology 2018, U Freiburg / U Edinburgh, Prof. A Morrison)
Dr. Kornelie Knoop (PhD physics 2018, RWTH Aachen, Prof. S Wessel)
Dr. Jonathan Kadmon (PhD physics 2017, Hebrew U Jerusalem Israel / Harvard USA)
Dr. Stojan Jovanovich (2016, KTH Stockholm / U Freiburg; Prof. S Rotter, Prof. J Hertz)
M.Sc. Patrick Emonts (master physics 2017, RWTH Aachen, Prof. S Wessel)
M.Sc. Benedikt Kalthoff (master physics 2019, RWTH Aachen, Prof. S Wessel)
M.Sc. Florian Kischel (master physics 2020, RWTH Aachen, Prof. S Wessel)

bachelor and master

Lars Schutzeichel (master physics, 2023)
Bastian Epping (master physics, 2023)
Niklas Foos (bachelor physics, 2023)
Max Wollgarten (bachelor physics, 2023)
Sebastian Strang (bachelor physics, 2022)
Jakob Stubenrauch (master physics, 2022)
Jan Bauer (master physics, 2022)
Kai Segadlo (master physics, 2021)
Jannik Grundler (bachelor physics, 2021)
Jonas Colve (bachelor physics, 2021)
Kirsten Fischer (master physics, 2020)
Alexander Herbort (master physics, 2020)
Bastian Epping (bachelor physics, 2020)
Anton Dorn (bachelor physics, 2020)
Claudia Merger (master physics, 2019-2020)
Michael Dick (master physics, 2018-2020)
Jan Bauer (bachelor physics, 2019)
Sandra Nestler (master physics, 2018 - 2019)
Lorenzo Tiberi (master physics U Milano, 2019)
Christian Keup (master physics, 2016-2017)
Lukas Deutz (master physics, 2015-2017)
Joel Schumacher (bachelor physics, 2016)
Jeyashree Krishnan (master electrical engineering, 2013-2014)