Nicole **Hartman**

Experimental Particle Physicist · Machine Learning Researcher

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Professional experience

Technical University of Munich (TUM) — *Munich, Germany*

Postdoctoral researcher at the ORIGINS excellence cluster Data Science Lab (ODSL) — *Jan 2023 - Present*

SLAC National Laboratory — *Menlo Park, CA*

PhD researcher; ML for High Energy Physics (di-Higgs Searches; b-tagging) — *Jun 2016 - Dec 2022*

Education

Stanford University — *Stanford, CA*

Ph.D. in Physics; Advisor, Michael Kagan — *June 2016 - Dec 2022*

- A search for non-resonant $HH \to b\bar{b}b\bar{b}$ at $\sqrt{s} = 13$ TeV with the ATLAS Detector
- **ATLAS Thesis award** (2023): one of seven awards from 31 nominations (and 100+ submitted theses)

Southern Methodist University (SMU) — *Dallas, TX*

Bachelor of Science in Physics and Applied Mathematics, minor in Electrical Engineering — *Sept 2012 - May 2016*

Summa Cum Laude, Phi Beta Kappa, University Honors Program, departmental distinction in physics

Leadership

Neurips ML for Physical Sciences workshop — *Vancouver & San Diego*

Workshop organizer & area chair for paper submissions. Websites: 2024, 2025 — *Dec 2024, 2025*

Neurips (world's largest ML conference) has associated affinity workshops. One of 55 / 281 workshops accepted in 2025.

ATLAS Flavour Tagging Algorithms Subgroup Convener — *CERN*

Led team to develop state-of-the-art jet classification algorithms for ATLAS — *2023 - Present*

- GN2 (2023): Released first transformer-based b-jet tagger to the collaboration, 4x improvement compared to earlier DL1r tagger .
- GN3 (2025): Multi-modal learning including inputs from multiple subdetectors; 2x improvement compared to GN2.
- (Co-)supervised 12 ATLAS authorship qualification projects.

10 TeV Plasma Wakefield Accelerator Conceptual Design Study

Machine Detector Interface Working Group Convener: beamstrahlung backgrounds at e^+e^- machines — *2024–Present*

ODSL GenAI Days, organizer — *Munich, Germany*

Educational workshop for ORIGINS Community. Designed program, invited lecturers, grant for catering — *Sept 2024*

COMETA (COmprehensive Multi-boson Experiment Theory Action) Colloquia — *CERN*

Networking community for di-Higgs and Vector Boson Scattering, Youtube channel — *2024-Present*

Flavour Tagging Workshop (ATLAS + CMS) — *Genova, Italy*

Session chair: algorithms, resolved and boosted — *Sept 2024*

Honors & Awards

	2024	**COMETA Short Term Scientific Mission**, funding for month-long stay at CERN (€3k)	*CERN*
	2023	**Leading in Collaborations**, Competitive entry (33% acceptance), Resiliant Leaders Development Program	*UCL*
★	2016	**U.S. National Science Foundation (NSF) Graduate Research Fellowship**, three yrs PhD support ($270k)	*NSF, USA*
	2016	**Stanford Edge Fellowship**, supporting PhD research expenses and travel ($7k)	*Stanford*
	2015	**U.S. NSF Research Experience for Undergraduates**, Summer research ($5k)	*UC Davis*
	2014	**U.S. NSF Research Experience for Undergraduates**, Summer research ($5k)	*Columbia U.*
★	2014	**U.S. Barry M. Goldwater Scholarship**, Most prestigious national fellowship for bachelors in the US ($7k)	*USA*
★	2012	**SMU Presidential Scholarship**, SMU's top academic scholarship, full tuition coverage ($250k)	*SMU*
		Physics department scholarships, Hyer (2016, $2k); Chalk (2015, $2k); and Wiley (2014, $2k) Scholar	*SMU*

Research talks

Conferences and workshops

(Planned) Mar 2025	**Invited, DPG German physics society conference**	*Erlangen, Germany*
Sep 2025	**Invited, Belle-2 Germany workshop**, Machine Learning for Particle Physics • slides	*Bonn, Germany*
Aug 2025	**Invited, MIAPbP Build Big or Build smart workshop**, Introduction to High Energy Physics • slides	
Mar 2025	**Invited plenary, ALEGRO workshop**, Detectors for 10 TeV Wakefield Colliders • slides	*SLAC, CA*
Oct 2024	**Invited, CMS Foundation Models mini-workshop**, Finetuning Foundation Models • slides • recording	*CERN*
Feb 2024	**Invited, COMETA General meeting**, Flavor tagging performance in ATLAS and CMS • slides	*Izmir, Turkey*
Dec 2023	**Invited, GlühWien workshop on ML and HEP**, Hunting for di-Higgs in hadronic final states • slides	*Vienna, Austria*
Nov 2023	**Invited plenary, Higgs 2023**, Background estimation in the $HH \to 4b$ searches • • slides	*Beijing, China*
Apr 2020	**Contributed Plenary, Connecting The Dots**, Deep Sets for Flavor Tagging on ATLAS • slides • recording	*Princeton*

Seminars

Jul 2025	**Research Progress Meeting Seminar**, Transforming Jet flavour tagging on ATLAS	*Berkeley, CA*
Jul 2025	**Santa Cruz Institute for Particle Physics Seminar**, Transforming Jet flavour tagging on ATLAS	*Santa Cruz, CA*
Nov 2024	**Physics at the TeV-Scale Group Seminar** , Foundation Models meets Jet Tagging	*Heidelberg*
Nov 2024	**Center for Particle Physics, University of Siegen** , Jet Flavour Tagging at the LHC	*Siegen, Germany*
Mar 2023	**European Space Observatory AI forum**, Exploring the mysteries of the cosmos at the subatomic scales	*Garching, Germany*
Nov 2020	**Machine Learning and Science Forum**, Set and sequence learning for particle identification at the LHC	*Berkeley, CA*

ATLAS workshops

These ATLAS workshops are large talks as they're attended by $\mathcal{O}(100)$ people, though links are internal to ATLAS.

June 2025	$HH \to 4b$**: status and plans**, Di-Higgs Workshop • slides	*CERN*
July 2024	**New avenues for exploration with AI**, Higgs and Di-Boson Searches (HDBS) Workshop • slides	*Nikef, NL*
June 2024	**Flavor tagging working group summary**, ATLAS Collaboration week • slides	*Thessaloniki*
Feb 2024	**Highlights from Higgs and associated searches**, ATLAS Collaboration week • slides	*CERN*
Feb 2024	**A Search for Non-Resonant** $HH \to 4b$, ATLAS Collaboration week, thesis award ceremony • slides	*CERN*
Jan 2024	**Data-driven QCD estimation: state-of-the-art techniques and new ideas**, di-Higgs Workshop • slides	*CERN*
Oct 2022	**Machine Learning for Background Modelling**, HDBS + EXOTICS Workshop • slides	*Barcelona, Spain*
Oct 2022	**Machine Learning for Background Modeling**, Higgs Workshop • slides	*Tokyo, Japan*
Sept 2022	**Interpolation for data-driven backgrounds in** $HH \to 4b$, Higgs and Di-Boson Search Workshop • slides	*Uppsala, Sweden*
April 2021	**Interpolation for background estimation in** $HH \to 4b$, ATLAS Machine Learning Workshop • slides	*CERN*
Aug 2020	**Machine Learning for Low-Level Inputs**, ATLAS Higgs and Di-Boson Search Workshop • slides	*CERN*
Nov 2019	**Recent Developments in Flavour Tagging on ATLAS**, ATLAS Machine Learning Workshop • slides	*CERN*
June 2019	**ML for FTAG**, Flavor tagging and tracking workshop • High pT • Truth Tracking • New NN architectures	*DESY, Germany*

Ongoing Research

Physics and ML Methods development

TUM

Searches for extended Higgs sectors and tools for gradient-based optimization in HEP. *2023 – Present*

- **Physics analysis:** $X \to SH \to 4b$ (analysis unblinded):
  - First ATLAS analysis to use the novel normalizing flows background estimate I developed in my PhD. Mentored Thandi Madula (UCL) and Malin Horstmann (TUM) on background estimation, validation, and statistical analysis. Paper contact editor.
- **Differentiable Jet Clustering** (ongoing): Interpreted the clustering decision probabilistically to get a gradient with score-based methods.
  - Differentiated through the clustering to optimize physics metrics (e.g, Higgs mass resolution) with respect to clustering radius.

ML consultancy

ODSL

My position with ODSL assists ORIGINS researchers in applying ML techniques to their domains. *2023 – Present*

- **Parton Density Fitting** (ongoing): Using normalizing flows as a flexible distribution for fitting parton density functions.
  Contribution: Guidance for normalizing flows, and mentoring master's student Richard Hildebrandt, PI: Allen Caldwell.
- **Object Centric Learning** (paper in progress): Unsupervised object detection for reconstruction at COMPASS / AMBER, beam dump experiments from the SPS at CERN. We use supervised and unsupervised learning methods (implicit rank minimization auto encoder and slot attention) for the rings in a RICH detector or blobs created in a calorimeter that originate from a single particle.
- **Sources for ultra-high energy cosmic rays**, Advising on normalizing flows for neural posterior estimation. Collaborating with N. Bourriche and F. Capel as a follow-up to their work 2406.16483.

Selected publications

As an ATLAS member, I am an author on 550+ collaboration papers. Here I list those to which I made a major contribution.

1. M. Vigl, **NH**, M. Kagan, L. Heinrich, *Neural Scaling Laws for Boosted Jet Tagging*, arXiv 2602.15781. Submitted to the ICLR foundation models for science workshop.
2. T. Jenegger, **NH**, R. Gernhäuser, L. Fabbietti, L. Heinrich, *Machine learning for the cluster reconstruction in the CALIFA calorimeter at R3B*, NIM-A, Vol 1082 (2026) 171048, 10.1016/j.nima.2025.171048. **Contribution:** We built a two-step hierarchical (agglomorative) clustering followed by "edge detection" NN to reconstruct calorimeter clusters at the NuStar detector at FAIR (Facility for Antiproton and Ion Research). I mentored Tobias on the ML methods and code implementation.
3. ATLAS Collaboration. *Search for $X \to SH \to b\bar{b}b\bar{b}$ at $\sqrt{s} = 13$ TeV with the ATLAS detector*. Analysis unblinded, public by end of the year. **Contribution:** First ATLAS analysis to use the normalizing flows background estimate I developed in my PhD [7]. Mentored Thandi Madula (UCL) and Malin Horstmann (TUM) on background estimation, validation, and statistical analysis. Paper contact editor.
4. ATLAS Collaboration. *Transforming Jet Flavour Tagging at ATLAS*, arXiv: 2505.19689. Accepted to Nature Communications.
   First end-to-end track-based tagger (GN2, transformer) recommended for physics analyses. **Contribution:** I led the development of track-based taggers in my PhD with RNNs [9] and Deep Set [11]. All the innovations I introduced for the Deep Set (new variables, optimized track selection) propagated to this SOTA transformer. I also led the team as we finalized GN2 for physics analyses.
5. M. Vigl, **NH**, L. Heinrich. *Finetuning Foundation Models for Joint Analysis Optimization*. MLST **5**, 10.1088/2632-2153/ad55a3. **Summary:** Combination of neural networks for an end-to-end optimized analysis (jointly optimizing Higgs jet tagger and downstream event classifier). Proof-of-concept study for $X \to HH \to 4b$ suggests a *2x improvement in background rejection*. **Contribution:** I found the dataset and reprocessed it with extra variables needed for combined training. Mentored M. Vigl on jet tagging and analysis.
6. J. Barr, *et. al. Umami: A Python toolkit for jet flavour tagging*. Journal of Open Source Software, 9(102), 5833, 10.21105/joss.05833.
   Contribution: Software publication for the Deep Sets training workflows from my PhD [9].
7. ATLAS Collaboration. *High-dimensional background interpolation with normalizing flows and Gaussian Processes on ATLAS.* Paper in progress. **Contribution:** I developed novel method (normalizing flow) to interpolate into a blinded signal region; demonstrated better background modelling compared to SOTA method used in [8]. Note: the work in this paper has been done since 2022, results in Chapter 13 of my thesis.
   ATLAS management is requesting we publish a physics result (my postdoc analysis, [3]) before publishing this methods paper.
8. ATLAS Collaboration. "Search for non-resonant pair production of Higgs bosons in the $b\bar{b}b\bar{b}$ final state using 126 ifb of pp collision data at $\sqrt{s} = 13$ TeV with the ATLAS detector." Phys. Rev. D 108 (2023) 052003, 10.1103/PhysRevD.108.052003. **Contributions** (main paper from my PhD):
   - Optimized analysis selection decreasing the combinatorial background by 70%. These optimizations and better b-taggers [9] **improved the analysis sensitivity by 30%** compared to what was expected from a larger dataset.
   - Designed new validation regions to provide state-of-the-art understanding of analysis' data-driven modeling uncertainties.
   - Internal note editor: coordinated / summarized the work of $\mathcal{O}(50)$ people for analysis review.
9. ATLAS Collaboration. "ATLAS b-tagging algorithms for the LHC Run 2 dataset." Eur. Phys. J. C 83 (2023) 681 2211.16345.
   Contribution: Optimized Recurrent Neural Network (RNN) tagger: first time RNN was recommended for physics analyses. This new tagger resulted in a *10% improvement in the non-resonant $HH \to 4b$ analysis*.
10. ATLAS Collaboration. *Search for resonant pair production of Higgs bosons in the $b\bar{b}b\bar{b}$ final state using pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector.* Phys. Rev. D 105 (2022) 092002, arXiv: 2202.07288.
    Contribution: Framework support (due to overlap with [8]) and analysis discussions.
11. **NH**, R. Teixeira de Lima, M. Kagan, on behalf of the ATLAS Collaboration, *Deep Sets for Flavor Tagging at the ATLAS Experiment*. Proceedings of the 2020 Connecting The Dots Workshop PROC-CDT2020-10, DOI:10.5281/zenodo.4088760.
    Contribution: Developed a new Deep Sets-based tagger. Optimized selection resulted in *2x improvement in background rejection* compared to the RNN.
12. **NH**, W.-T. Chiu, and R. T. Scalettar.*Magnetic Correlations in a Periodic Anderson Model with Non-Uniform Conduction Electron Coordination*. Phys Rev. B 93, 235143 (2016), arXiv: 1601.07214.
    Contribution: Implemented the space representation for a quasicrystal given an adjacency matrix, and studied the spin correlations in a Hubbard model system with Markov Chain Monte Carlo simulations. Project funded by NSF REU (UC Davis).

Public Results

These results also represent my work, and ATLAS results have been peer-reviewed via the rigorous ATLAS internal review process.

13. ATLAS Collaboration. *Carpe Datum: Scaling behavior of transformers for heavy hadron flavor identification* ATL-SOFT-PUB-2026-002 (2026).
14. ATLAS Collaboration. *GN3: Multi-task, Multi-modal Transformers for Jet Flavour Tagging in ATLAS* ATL-PHYS-PUB-2026-001 (2026).
15. S. Gessner *et. al*, *Design Initiative for a 10 TeV pCM Wakefield Collider*, Input for the Update to the European Strategy of Particle Physics, arXiv 2503.20214.
16. ATLAS Collaboration. *Deep Sets based Neural Networks for Impact Parameter Flavour Tagging in ATLAS* ATL-PHYS-PUB-2020-014 (2020).

17. ATLAS Collaboration. "Performance of 2019 recommendations of ATLAS Flavor Tagging algorithms with Variable Radius track jets" FTAG-2019-006 (2019).
18. ATLAS Collaboration. "Expected performance of the 2019 ATLAS b-taggers" FTAG-2019-005 (2019).

ATLAS internal review

On ATLAS papers, the editorial board (EB) carefully reviews an analysis to prepare for publication. I have served on three EBs.

19. ATLAS Collaboration. *A search for non-resonant Higgs boson pair production in the $b\bar{b}\tau^+\tau^-$ final state using Run 2 + partial Run 3 data recorded by the ATLAS detector*. Paper in progress with Editorial Board, pre-unblinding.
20. *Configuration, Performance, and Commissioning of the ATLAS b-jet Triggers for the 2022 and 2023 LHC data-taking periods*, JINST 20 (2025) P03002.
21. ATLAS Collaboration. *Search for $Hb \to 3b$ at $\sqrt{s} = 13$ TeV with the ATLAS detector*. Paper in progress with Editorial Board, pre-unblinding.

Teaching

Invited Lectures + Tutorials

Oct 2025	**Particle Physics at Colliders in the LHC Precision Era**, Intro to Machine Learning for LHC physics	*Würzburg, Germany*
Sept 2025	**ErUM Train-the-trainer workshop**, Mastering Model Building Lecture	*Potsdam, Germany*
Oct 2024	**Particle Physics Phenomenology after the Higgs Discovery**, Co-led diffusion model tutorial	*Bingen, Germany*
July 2024	**Intro to Machine Learning and Automatic Differentiation**, Scientists4Palestine summer school	*Westbank (virtual)*
Sept 2023	**ErUM DataHub Adv Deep Learning School**, Normalizing Flows Lecture and tutorial	*Meinerzhagen*
June 2023	**ErUM Adv Train-the-trainer workshop**, Normalizing Flows Lecture and tutorial	*Dortmund*
Jan 2023	**ErUM Train-the-trainer workshop**, Mastering Model Building Lecture	*Munich*
July 2022	**US ATLAS ML training workshop**, Symmetries and Flavor Tagging in ATLAS Lecture • slides • tutorial	*Berkeley, CA*

Local Lectures (TUM)

ODSL Machine Learning block course — *Munich, Germany*

Lectures on linear models; automatic differentiation; optimizers; neural networks; clustering (k-means, PCA) — *2023-2025*

- Two-week intensive block course of lectures and tutorials. Audience: masters / PhD students and post-doc researchers
- Course websites: 2025 • 2024 • 2023

ODSL Statistics block course — *Munich, Germany*

Lectures on probability and Bayesian reasoning, Audience: masters / PhD students. website — *Sept 2025*

ODSL GenAI Days — *Munich, Germany*

Flow Matching Lecture • tutorials for Flow Matching and Diffusion Models — *Sept 2024*

TUM Intro to Data Science course — *Munich, Germany*

Guest Lecture: "Numpy Tips and Tricks" — *Oct 2023, Nov 2024*

Physics teaching assistant

2021	**Thermodynamics & Optics**, led tutorial sessions with 15–20 students	*Stanford*
2018	**Electricity & Magnetism for physics majors**, assisted in an active learning classroom	*Stanford*
2017	**Modern Physics for pre-med** , led tutorial sessions with 15–20 students	*Stanford*
2015	**Electronics & Modern Physics labs**	*SMU*
2014	**Pre-Med Electricity & Magnetism**	*SMU*

Mentorship

Malin Horstmann (PhD) — *TUM*

SH and $HH \to 4b$: normalizing flows and flow matching for multi-jet backgrounds & statistical analysis [3] — *2023 – Present*

Matthias Vigl (PhD) — *TUM*

Foundation models for end-to-end optimizable analysis [1,5,13] — *2023 – Present*

Una Alberti (PhD) — *University of Bern*

$HH \to 4b$: VBF analysis, Deep Sets for signal vs. background separation. — *2025– Present*

Thandi Madula (PhD) — *UCL*

$SH \to 4b$: Normalizing flows, hierarchical flows, and diffusion models for multi-jet backgrounds [3] — *2023 – 2025*

Tobias Jenneger (PhD) — *TUM*

ODSL project: Agglomerative clustering + edge detection network for clustering at CALIFA calorimeter [2] — *2023 – 2025*

Richard Hildebrandt (masters) — *TUM*

ODSL project: normalizing flows for fitting parton density functions — *2024 – 2025*

Sara Aumiller (bachelors) *TUM*

Particle flow with Slot Attention for AMBER, a beam dump experiment at CERN. *2023 – 2024*

Outreach & In the press

In the press

Nov 2025 **Panelist,** American Physical Society workshop: AI and the Practice of Physics *Washington DC*

2025 **Interview,** Radical approach to shrink particle colliders gains momentum *Nature briefing*

2024 **Voices from a new generation,** Opinion piece *CERN Courrier*

Selected Outreach

2022 **Science bowl competition judge** *SLAC, CA*

2020 **Actress, SLAC Summer Institute "how to" virtual poster,** video *SLAC, CA*

2016 **SLAC science night ,** cloud chamber demo *SLAC, CA*

2016 **Panelist, "Ask a Cosmologist",** explaining dark matter and particle detectors *San Mateo, CA*

2015 **SMU Society of Physics Students President** *SMU, TX*

Skills

Programming languages: Python and C++, including object-oriented programming.

python packages numpy, pandas, matplotlib, SciPy, sklearn, keras, jax, pytorch

Machine Learning: Generative models (normalizing flows, flow matching), transformers, slot attention, deep sets, RNNs.

HEP Simulation Madgraph, pythia, Whizard

HEP analysis uproot, pyhf, cabinetry

Languages English (native), German (B1), French (A2)