Dylan Rankin
dsrankin@sas.upenn.edu

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Department of Physics and Astronomy
University of Pennsylvania

209 South 33rd Street
Philadelphia, PA, 19146

Education

Ph.D. Physics, Boston University (*2018*)
Dissertation: Search for heavy resonances decaying to a top quark and a bottom quark in proton-proton collisions at 13 TeV with the CMS experiment
Advisor: Dr. Tulika Bose

Sc.B., Physics, Massachusetts Institute of Technology (*2012*)
Thesis: Exclusive search for Higgs boson to gamma-gamma decay via vector boson fusion production mechanism
Advisor: Dr. Markus Klute

Professional Experience

Postdoctoral Associate [Supervisor: Dr. Philip Harris], MIT, Cambridge, MA (*2018 - 2022*)
Assistant Professor, University of Pennsylvania, Philadelphia, PA, (*2023 - Present*)

Awards

CMS Award (*2020*) - Level-1 Trigger Upgrade

Selected Publications (*: refereed)

- L. Sheldon, D. Rankin, P. Harris. “MACK: Mismodeling Addressed with Contrastive Knowledge”. arXiv preprint arXiv:2410.13947 (2024).
- R. Raikman et al. “GWAK: Gravitational-Wave Anomalous Knowledge with Recurrent Autoencoders”. arXiv preprint arXiv:2309.11537 (2023).
- M. Saleem et al. “Demonstration of Machine Learning-assisted real-time noise regression in gravitational wave detectors”. arXiv preprint arXiv:2306.11366 (2023).
* A. Gunny, D. Rankin et al. “A Software Ecosystem for Deploying Deep Learning in Gravitational Wave Physics”, FlexScience '22: Proceedings of the 12th Workshop on AI and Scientific Computing at Scale using Flexible Computing Infrastructures, (2022), doi: 10.1145/3526058.3535454.
* E. Khoda, D. Rankin, R. Teixeira de Lima et al. “Ultra-low latency recurrent neural network inference on FPGAs for physics applications with hls4ml”, Machine Learning: Science and Technology (2023) doi:10.1088/2632-2153/acc0d7.
- P. Harris et al. “Physics Community Needs, Tools, and Resources for Machine Learning”, arXiv preprint arXiv:2203.16255 (2022).
* N. Tarafdar et al. "AIgean: An Open Framework for Machine Learning on Heterogeneous Clusters," 2020 IEEE 28th Annual International Symposium on Field-Programmable Custom Computing Machines (FCCM), (2020), pp. 239-239, doi: 10.1109/FCCM48280.2020.00072.
* J. Duarte et al. "FPGA-accelerated machine learning inference as a service for particle physics computing." Computing and Software for Big Science 3.1 (2019): 1-15.

- P. Harris, D. Rankin, and C. M. Suarez. "An approach to constraining the Higgs width at the LHC and HL-LHC." arXiv preprint arXiv:1910.02082 (2019).
* S. Summers et al. "Fast inference of Boosted Decision Trees in FPGAs for particle physics." Journal of Instrumentation 15.05 (2020): P05026.
* J. Ngadiuba et al. “Compressing deep neural networks on FPGAs to binary and ternary precision with hls4ml”, Mach. Learn.: Sci. Technol. 2, 015001 (2020), doi:10.1088/2632-2153/aba042, arXiv:2003.06308.
* J. Krupa et al. "GPU coprocessors as a service for deep learning inference in high energy physics." Machine Learning: Science and Technology 2.3 (2021): 035005.
* Y. Iiyama et al. "Distance-weighted graph neural networks on FPGAs for real-time particle reconstruction in high energy physics." Frontiers in Big Data 3 (2020): 44.
* D. Rankin et al. "FPGAs-as-a-service toolkit (FaaST)." 2020 IEEE/ACM International Workshop on Heterogeneous High-performance Reconfigurable Computing (H2RC). IEEE, 2020.
* S. E. Park et al. "Quasi anomalous knowledge: searching for new physics with embedded knowledge." Journal of High Energy Physics 2021.6 (2021): 1-26.
* A. Heintz et al. "Accelerated charged particle tracking with graph neural networks on FPGAs." NeurIPS 2020 (2020) arXiv:2012.01563.
* T. Aarrestad et al. "Fast convolutional neural networks on FPGAs with hls4ml." Mach. Learn.: Sci. Technol. 2 045015 (2021) arXiv:2101.05108.
* G. Kasieczka et al. "The LHC olympics 2020: a community challenge for anomaly detection in high energy physics." Rep. Prog. Phys. 84 124201 (2021) arXiv:2101.08320.
- F. Fahim et al. "hls4ml: An Open-Source Codesign Workflow to Empower Scientific Low-Power Machine Learning Devices." arXiv preprint arXiv:2103.05579 (2021).
* A. Gunny, D. Rankin et al. “Hardware-accelerated inference for real-time gravitational-wave astronomy.” Nat Astron (2022), doi:10.1038/s41550-022-01651-w.
- CMS Collaboration, The Phase-2 upgrade of the CMS Level-1 trigger, CMS Technical Design Report CERN-LHCC-2020-004. CMS-TDR-021 (2020), https://cds.cern.ch/record/2714892.
* CMS Collaboration, “Inclusive search for highly boosted Higgs bosons decaying to bottom quark-antiquark pairs in proton-proton collisions at sqrt(s) = 13 TeV”, J. High Energy Phys. 12, 85 (2020), doi:10.1007/JHEP12(2020)085, arXiv:2006.13251.
- D. Rankin. "The Particle Flow Algorithm in the Phase II Upgrade of the CMS Level-1 Trigger.” Proceedings, 40th International Conference on High Energy Physics (ICHEP2020) : Prague, Czechia, July 28 - August 6, 2020, PoS ICHEP2020 (2021) 896, doi: 10.22323/1.390.0896.

Selected Conference, Workshop, Seminar Presentations

Fast Machine Learning at the LHC. Fast Machine Learning for Science Conference 2024. October 15, 2024. Purdue University, West Lafayette, IN, USA.

ML on the Edge at the LHC experiments. SmartHEP Edge Machine Learning School. September 23, 2024. CERN, Geneva, Switzerland.

Enabling Discoveries with Fast Machine Learning. SLAC FPD Seminar. March 5, 2024. SLAC, Menlo Park, CA, USA

Machine learning for low-latency inference. Lepton Photon 2023. July 20, 2023. Melbourne, Australia.

Machine learning for particle flow at CMS. ML4Jets 2022. November 4, 2022. Rutgers University, New Brunswick, NJ, USA.

Next Generation Coprocessors as a service. Fast Machine Learning for Science Workshop. October 4, 2022. Southern Methodist University, Dallas, TX, USA.

Muon Experiments. Snowmass Community Summer Study Workshop: Cool Copper Collider Session. July 21, 2022. Seattle, WA, USA.

Muon Physics Program (and other μ ideas). Future Colliders Workshop: Cool Copper Collider R&D. May 18, 2022. Virtual.

Accelerating Discovery at the Large Hadron Collider and Beyond. UPenn HEP Seminar. February 17, 2022. Philadelphia, PA, USA.

Novel Methods for Enabling Discovery at the LHC and Beyond. Notre Dame HEP Seminar. February 10, 2022. Virtual.

Novel Methods for Enabling Discovery at the LHC and Beyond. University of Florida HEP Seminar. February 9, 2022. Virtual.

Accelerating Discovery Through Deep Learning. University of Florida Physics Colloquium. February 8, 2022. Virtual.

AI Resources for EIC. Workshop IX on Streaming Readout. December 9, 2021. Virtual.

Hardware-accelerated Inference for Real-Time Gravitational-Wave Astronomy. Scalable Cyberinfrastructure to support Multi-Messenger Astrophysics (SCiMMA) Public Telecon. September 14, 2021. Virtual.

Overview of AI in HEP readout. AI4EIC-Exp - Experimental Applications of Artificial Intelligence for the Electron Ion Collider. September 9, 2021. Virtual.

Fast ML Inference as a service. Portable Inference IRIS-HEP Blueprint Workshop. December 4, 2020. Virtual.

SONIC: Coprocessors as a service for deep learning inference in high energy physics. Fast Machine Learning for Science Workshop. December 2, 2020. Southern Methodist University, Dallas, TX, USA.

FPGAs-as-a-Service Toolkit (FaaST). H2RC 2020: Sixth International Workshop on Heterogeneous High-Performance Reconfigurable Computing (SC20). November 15, 2020. University of South Carolina, Columbia, SC, USA.

Possibilities for Machine Learning in Heterogeneous Trigger and DAQ Systems. 2020 IEEE Nuclear Science Symposium & Medical Imaging Conference. November 5, 2020. Boston, MA, USA.

Using GPUs and FPGAs as-a-Service for HEP computing. Scalable Cyberinfrastructure to support Multi-Messenger Astrophysics (SCiMMA) Public Telecon. September 15, 2020. Virtual.

Using GPUs and FPGAs as-a-service for LHC computing. IRIS-HEP Topical Meeting. September 9, 2020. CERN, Geneva, Switzerland.

The Particle Flow Algorithm in the Phase II Upgrade of the CMS Level-1 Trigger. 40th International Conference on High Energy Physics (ICHEP) 2020. July 29, 2020. Prague, Czech Republic.

Using machine learning to constrain the Higgs total width. Machine Learning for Jet Physics (ML4Jets) 2020. January 17, 2020. New York University, New York City, NY, USA.

Phase II Level-1 Correlator Overview. 2019 US CMS Annual Collaboration Meeting. June 16, 2019. Catholic University of America, Washington, D.C. USA.

FPGA-accelerated machine learning inference as trigger and computing solutions in particle physics. 2019 US CMS Annual Collaboration Meeting. June 16, 2019. Catholic University of America, Washington, D.C. USA.

CMS Trigger performance including machine learning applications. 7th Edition of the Large Hadron Collider Physics Conference. May 24, 2019. Benemerita Universidad Autonoma de Puebla, Puebla, Mexico.

Using Heterogeneous Computing at the Large Hadron Collider. XSEDE CC Region 7 Spring Thaw. April 4, 2019. Providence, RI, USA.

HLS4ML: Using ML on FPGAs to enhance reconstruction output. IRIS-HEP Topical Meeting. February 13, 2019. CERN, Geneva, Switzerland.

Future LHC Triggering: Using Field-Programmable Gate Arrays to Solve Complex Modern Problems. Laboratory of Nuclear Science Lunch Seminar. December 11, 2018. Massachusetts Institute of Technology, Cambridge, MA, USA.

Deep Machine Learning on FPGAs for L1 trigger and Data Acquisition. New Technologies for Discovery IV: The 2018 CPAD Instrumentation Frontier Workshop. December 10, 2018. Providence, RI, USA.

Teaching

Undergraduate Courses. Instructor for UPenn PHYS 140/150, PHYS 141/151

Summer School. IAIFI Summer School 2022. Co-creator of tutorial sessions on deep learning in particle physics. (*2022*)

Undergraduate Lecture. Guest speaker for MIT 8.S50, Special Subject: Physics (*2021, 2022*).

Physics Tutorial. Co-leader of the Galapagos tutorial at the Fast Machine Learning Workshop (*2019*).

Graduate Lecture. Guest speaker for MIT 8.811, Particle Physics II (*2019*).

Physics Tutorial. Co-creator of first hls4ml tutorial: How to do ultrafast Deep Neural Network inference on FPGAs (*2019*)

Supervision and Mentorship

Postdoctoral Researchers.

Ho-Fung Tsoi (UPenn). *(2024-Present)*
Kaito Sugizaki (UPenn). *(2024-Present)*

Graduate Students.

Sterre Hoogendoorn (UPenn). Development of triggers for anomaly detection *(2024-Present)*
Chris Ma (UPenn). Development of triggers for identification of vector boson fusion events *(2024-Present)*
Max Cohen (UPenn). Development of triggers for anomaly detection *(2023-Present)*
Gwen Gardner (UPenn). Search for Higgs bosons decaying to WW* in the semileptonic final state *(2022-Present)*

Undergraduate Students.

Vivek Krishnan (*UPenn-Present*). Studies of novel ML architectures for low-latency anomaly detection (*2024*)
Ioannis Kalaitzidis (*UPenn*). Studies of hidden valley models (*2024-Present)*

Toni Lobaccaro (*UPenn*). Studies of an anomaly detection algorithm for the ATLAS trigger. (*2024*)
Isaac Anokye (*Alabama A&M*). Studies of HH decaying to four b-quarks for the ATLAS Global trigger. (*2024*)
Olee Banerjee (*UPenn*). Investigation of contrastive learning techniques for mass reconstruction. (*2024*)
Alex Yang (*UPenn*). Development of an hls4ml backend for FPGA coprocessor applications. Studies of contrastive learning techniques for mass reconstruction. (*2023-Present*)
Max Huang (*UPenn*). Studies of calorimeter timing information for use in the ATLAS Global trigger. (*2023-2024*)
Anirudh Bharadwaj (*UPenn*). Development of an anomaly detection algorithm for the ATLAS Phase 2 trigger. (*2023*)
Kevin Wang (*UPenn*). Investigation of graph neural networks for Higgs boson jet-tagging. (*2023*)
Ethan Yu (*UPenn*). Investigation of contrastive learning techniques for mass reconstruction. (*2023*)
Jonathan Shoemaker (*MIT*). Development of high-level synthesis code to perform transposed convolution layer inference on FPGAs in hls4ml and implementation of DeepClean network for LIGO data cleaning on FPGA. (*2022-2023*)
Keiran Lewellen (*MIT*). Development of deep neural networks for boosted di-tau decays in CMS (*2020-2022*).
Aidan Chambers (*MIT*). Development of deep neural networks for b-quark identification with the Phase 2 CMS Level-1 trigger (*2020-2023*).