Thea Klæboe Årrestad, PhD

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Employment

01.2022 - present **ETH Zürich (Institute for Particle Physics and Astrophysics)**
SNSF Ambizione fellow, project leader. Group of Günther Dissertori
Research areas: Design and deployment of Machine Learning based anomaly detection algorithm on FPGAs for CMS experiment, anomaly detection for New Physics searches, cross-departmental collaborations on real-time ML
Other: Teaching/Lecturing (particle physics and Machine Learning in Physics), institute outreach responsible, student supervision (doctoral, master, and semester theses)

11.2019 - 12.2021 **CERN (European Organization for Nuclear Research)**
Senior Research Fellow, Advisor: Maurizio Pierini
Research areas: Optimisation of **machine learning** algorithms for low-latency inference on CMS L1 trigger **FPGAs**, **jet algorithms** on FPGA hardware , searches for anomalous new physics using Machine Learning, **jet substructure** algorithms and **New Physics** searches in diboson final states.

Education

02.2015 - 04.2019 **Ph.D. Physics** , University of Zurich / CMS experiment, CERN
"A Novel Multidimensional Search for Diboson Resonances in the Boosted Dijet Final State and Encoding Jet Substructure in a Deep Neural Network ",
Advisor: Prof. Dr. Ben Kilminster, Date 14.03.2019
Thesis committee: Prof. Dr. Jesse Thaler, Dr. Andreas Hinzmann, Prof. Dr. Florencia Canelli

09.2012 - 12.2014 **M.S., Physics**, University of Zurich
"A dedicated boosted Higgs boson tagging algorithm at CMS", Advisor: Prof. Dr. Kilminster

09.2010 - 06.2012 **B.S., Physics** , University of **Bergen** / Exchange ETH **Zurich**
"Unstable Dark Matter in the Milky Way", Advisor: Prof. Dr. Per Osland

Research highlights

Real-time ML

"Autoencoders on field-programmable gate arrays for real-time, unsupervised new physics detection at 40 MHz at the Large Hadron Collider", Nature Machine Intelligence volume 4, pages 154–161 (2022)
"Applications and Techniques for Fast Machine Learning in Science", Frontiers in Big Data
"Fast convolutional neural networks on FPGAs with hls4ml", main author, Thea Aarrestad et al 2021 Mach. Learn.: Sci. Technol. 2 045015

Collaborations industry/cross-departmental

"Automatic deep heterogeneous quantization of Deep Neural Networks for ultra low-area, low-latency inference on the edge at particle colliders" , main author, CERN/Google collaboration, (Nature Machine Intelligence (2021)
"Within-Camera Multilayer Perceptron DVS Denoising", collaboration with sensor groups of A. Rios-Navarro (Seville), T. Delbruck (UZH/ETH), R. Kastner (San Diego), CVPR 2023

"Real-time semantic segmentation on FPGAs for autonomous vehicles with hls4ml", Volvo/Zenseact collaboration, Machine Learning: Science and Technology DOI 10.1088/2632-2153/ac9cb5

Physics

"Vector boson scattering processes: Status and prospects", ML for VBS review, Reviews in Physics Volume 8

"LHC physics dataset for unsupervised New Physics detection at 40 MHz", Nature Scientific Data 9, Article number: 118 (2022)

"Improving Variational Autoencoders for New Physics Detection at the LHC With Normalizing Flows", Front. Big Data, Sec. Big Data and AI in High Energy

"Detecting long-lived particles trapped in detector material at the LHC", Phys.Rev.D 105, L051701

"Searching for diboson resonances in the boosted all-hadronic final state at s=13 TeV with CMS", single-author invited review article published in MPLA , 10.1142/S0217732320300141 (summary of three papers on diboson resonance searches where I was main author)

Outreach highlights

Schools

"Accelerating Discovery with Machine Learning at CERN", invited lecturer at Machine Learning Summer School, Krákow, MLSS^S (co-lecturers Michael Bronstein, Marco Cuturi, Christoph Weniger etc.), >100 participants

Lecture series on Machine Learning at Herbstschule fur Hochenergiephysik Maria Laach

"Machine Learning at CERN", invited lecture at Lake Como School of Advanced Studies

"Fast inference with HLS4ML: Machine Learning with FPGA at LHC" INFN FPGA School

"Machine Learning at CERN", lecture for NGO MBUCO who promotes science in NGO countries, https://www.bmuco.org/post/machine-learning-at-cern-dr-thea-aarrestad

"Particles and fields at the LHC", lecture for high school students in Nepal organised by Initiatives for Girls in Physics Nepal, https://youtu.be/TWGSYiYW47I

Invited seminars

"Real-time Machine Learning in particle physics", CERN EP/IT Data Science Seminar for ~500 participants

"Ultrafast Machine Learning Inference at the Large Hadron Collider" IPA Colloquium

"Machine Learning Applications: An Experimental Perspective" Semivisible Jet Workshop

"Fast Machine Learning at LHC", Origins Data Science Lab, Technical University of Munich

"Fast Machine Learning at the LHC", Milano Bicocca Phenomenology Seminar

"Ultrafast ML Inference in FPGAs at the LHC", University of Bonn Physics Seminar

"Ultrafast Machine Learning Inference in FPGAs at the LHC", DESY Data Science Seminar

Conference talks

"Fast inferences", invited speaker at LHCP 2023

"Recent developments in Machine Learning in Particle Physics", invited talk Spåtind 2023

"Machine Learning for VBS", invited talk at VBS at Snowmass, indico.cern.ch/event/980773/

"Nanosecond Inference Engines for Particle Detectors", invited talk at 30th International Workshop on Logic and Synthesis (IWLS2021)

"Designing Nanosecond Inference Engines for the Particle Collider", invited talk at 6th Workshop on Energy Efficient Machine Learning and Cognitive Computing, https://www.emc2-ai.org/virtual-20

Theses supervised

PhD

"Scouting for anomalous events with unsupervised AI in the CMS hardware trigger", PhD thesis of Patrick Odagiu at ETH Zurich, co-supervised with Günther Dissertori, ongoing

Master

"AXOL1TL: Real-time anomaly detection in the CMS hardware trigger", master thesis of Chang Sun ETH Zürich, co-supervised with Günther Dissertori, grade: 6

"Latency and resource-aware decision trees for faster FPGA inference at the LHC", master thesis of Andrew Oliver, co-supervised with M. Guillame-Bert (Google) and G. Dissertori (ETH Zurich), ongoing

Bachelor

"Deep Neural Network to Identify High-Energy B Hadrons via their Hit Multiplicity Increase through Pixel Detection Layers", UZH Bachelor Thesis, main supervisor M. Sommerhalder, Feb-Aug 2018, github.com/msommerh/bTag_HitCount

Other

"Detecting long-lived particles trapped in detector material at the LHC", CERN summer student project of Jasmine Simms, co-supervised with Juliette Alimena, published in Phys.Rev.D 105, L051701

"Convolutional Autoencoders for Anomaly Detection in the L1 Trigger" CERN Student 2020, Sierra Weyhmiller, co-supervisor, https://indico.cern.ch/event/947570/

"Variational autoencoders with Normalizing Flows for anomalous event detection, DIANA-HEP fellow, co-supervisor, Pratik Jawahar, "arxiv.org/abs/2105.14027

"A Deep Neural Network capable of discriminating between jets coming from the decay of longitudinally and transversely polarized W or Z bosons with a large Lorentz boost", CERN Summer Student, main supervisor, July 2018, Jan De Boer, Copenhagen University, https://cds.cern.ch/record/2650187

References

Maurizio Pierino (maurizio.pierini@cern.ch)
Research Staff, CERN

Jean-Roch Vlimant (vlimant@cern.ch)
Staff Researcher, California Institute of Technology (Caltech)

Ben Kilminster (ben.kilminster@physik.uzh.ch)
Professor, University of Zurich

Nhan Viet Tran (ntran@fnal.gov)
Staff Researcher, Fermilab

Andreas Hinzmann (andreas.hinzmann@cern.ch)
Emmy-Noether Research Group leader, Universität Hamburg

Salvatore Rappoccio (salvatore.rappoccio@cern.ch)
Associate Professor, State University of New York at Buffalo

Petar Maksimovic (petar.maksimovic.jhu@gmail.com)
Professor, Johns Hopkins University

Günther Dissertori (dissertg@ethz.ch)
Professor, ETH Zurich