Ho Fung Tsoi

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Education

Ph.D. in Physics (Expected in Spring/Summer 2024) University of Wisconsin-Madison — Aug 2018 – Present

- **Thesis:** "Search for Exotic Higgs Boson Decays with CMS and Fast Machine Learning Solutions for the LHC" (**Advisor:** Prof. Sridhara Dasu)

B.Sc. in Physics The Chinese University of Hong Kong — Aug 2013 – May 2018

- **Thesis:** "First Passage Time Problem of the Time-Dependent Ornstein-Uhlenbeck Process: a Model for Stochastic Decision-Making Process" (**Advisor:** Prof. Chi-Fai Lo)
- Visiting student at University of California, Berkeley (Jan – Aug 2017)

Positions

University of Wisconsin-Madison

- Graduate Research Assistant — May 2020 – Present
- Graduate Teaching Assistant — Aug 2018 – May 2020

Berkeley Lab

- Research Affiliate (DUNE experiment in Prof. Kam-Biu Luk's group) — May 2017 – Aug 2017

Leadership & Scientific Services

CMS Collaboration at CERN

- **L3 co-convener** of the SUS Physics MC&I (Monte Carlo & Interpretation) — Sep 2023 – Present
  - Overseeing simulation samples and coordinating model interpretation between theorists and experimentalists.
- **Monte-Carlo Contact Person** for the Higgs physics group
  - Overall contact overseeing 6 subgroups on Monte-Carlo simulation. — Sep 2022 – Aug 2023
  - Subgroup contact of the Higgs Rare Decays (HRare) subgroup. — Jan 2021 – Aug 2022
- **On-call Detector Expert** for the Calorimeter Layer-1 trigger subsystem — Jul 2021 – Present
  - Performed on-call duties ensuring smooth subdetector operations during LHC runs.
- **Software Developer** for the Data Quality Monitoring (DQM) — Dec 2020 – Present
  - DAQ/Unpacker/DQM at the Calorimeter Layer-1 trigger subsystem.
  - Commissioned monitoring for 1) ECAL pre-firing with five beam-bunch-crossing readouts, 2) HCAL long-lived particle trigger bits, and 3) anomaly detector trigger.

Recent Research Projects

Physics

- Searches for exotic Higgs boson decays with the CMS experiment
  - *(Ongoing)* Run-2 search H(125) → $aa \to \tau\tau bb$ (boosted).
  - *(Ongoing)* Run-2 search H(125) → $a_1 a_2 \to \tau\tau bb$ asymmetric decays.
  - *(Done)* Run-2 search H(125) → $aa \to \tau\tau bb$ (resolved), used DNN for signal/background separation resulting in around 50% sensitivity enhancement compared to cut-based optimization.
  - *(Done)* Combination of H(125) → $aa \to \tau\tau bb$ with the $\mu\mu bb$ finat state interpreted in the 2HDM+S scenarios.
  - *(Done)* Phase-2 upgrade Level-1 trigger Technical Design Report: projection studies of H(125) → $aa \to \tau\tau bb$.
- Neutrino with the DUNE experiment
  - *(Done)* Investigation of the missing neutron effects in the neutrino energy reconstruction.

Machine Learning (with physics applications)

- Anomaly detection at the CMS Level-1 trigger (real-time selection of raw 40 MHz collision data)
  - *(Commissioning with deployment expected in 2024)* Developed the CICADA algorithm (https://cicada.web.cern.ch/, CMS-DP-2023-086): a CNN autoencoder-based unsupervised anomaly detection using low-level calorimeter inputs, combined with knowledge distillation and quantization for model compression, resulted in >99% ROC AUCs for a wide range of BSM signals, running at a latency of O(100) nanoseconds on an FPGA. Deployment is expected in the CMS L1 trigger system during LHC Run-3 data-taking period in 2024.

- Symbolic regression
  - *(Ongoing)* SymbolFit: developing a general-purpose API for applying symbolic regression in different HEP use cases: 1) parametric modelling in offline analyses, 2) scale factor derivation, 3) uncertainty derivation, etc.
  - *(Done)* SymbolNet: developed a novel neural approach to symbolic regression to solve dimensionality bottleneck.
- Fast ML algorithms on FPGAs (collaborating with Fast ML Lab https://fastmachinelearning.org/)
  - *(Ongoing)* Investigating efficient transformer and variational model on FPGAs.
  - *(Done)* Developed the use of symbolic regression on FPGAs with hls4ml, demonstrated on the LHC jet tagging benchmark with more than 10 times faster inference speed as low as 5 nanoseconds and orders of magnitude less resource utilization than baseline neural models.
- Graph neural networks (GNNs) searching for displaced vertices from SUSY-motivated long-lived particles (LLP)
  - *(Ongoing)* Investigating the use of GNNs to extract LLP signatures from particle detector tracking information.
- Hadronic calorimeter (HCAL) efficient energy reconstruction
  - *(Ongoing)* Investigating the use of symbolic regression on FPGAs to efficiently reconstruct HCAL energy using HCAL channel information.

Selected Papers/Preprints (Full Publication List at https://inspirehep.net/authors/1791418)

1. CMS Collaboration, *"Search for Exotic Higgs Boson Decays to a Pair of Pseudoscalars in the μμbb and ττbb Final States in Proton-Proton Collisions with the CMS Experiment"*, CMS-PAS-HIG-22-007 (2023) (Expected publication on EPJC by 2024).
2. CMS Collaboration, "*Searches for Exotic Higgs Boson Decays with the CMS Experiment*" CMS-CR-2023-223 (2023), (EPS-HEP proceedings to be published on PoS).
3. CMS Collaboration, "*Anomaly Detection for the CMS Level-1 Trigger*" CMS-DP-2023-086, Paper in preparation to be submitted to IOP MLST.
4. **H.F. Tsoi**, V. Loncar, S. Dasu, P. Harris, "*SymbolNet: Neural Symbolic Regression with Adaptive Dynamic Pruning for Compression*", Paper in preparation to be submitted to IEEE TNNLS.
5. **H.F. Tsoi**, A.A. Pol, V. Loncar, E. Govorkova, M. Cranmer, S. Dasu, P. Elmer, P. Harris, I. Ojalvo, M. Pierini, "*Symbolic Regression on FPGAs for Fast Machine Learning Inference*", arXiv: 2305.04099 (2023), Accepted to CHEP 2023 (to be published on EPJ Web of Conferences).

Conference/Workshop Presentations

1. **US LHC Users Association Meeting (US LUA 2023)** – Fermilab, USA — Dec 2023
   "CICADA: Anomaly Detection for New Physics Searches at the CMS Level-1 Trigger"
2. **Machine Learning at Level-1 Trigger Workshop (ML@L1)** – CERN, Switzerland — Dec 2023
   "Anomaly Detection – CICADA: Status, Plans, and Prospects for Phase-2"
3. **CMS Seminar** – Fermilab, USA — Nov 2023
   "Search for Exotic Higgs Boson Decays with the CMS Experiment and Fast Machine Learning Solutions for the LHC"
4. **CMS Machine Learning Town Hall** – CERN, Switzerland — Sep 2023
   "L1 Anomaly Detection with Calorimeter Inputs: Status and Opportunities"
5. **European Physical Society – High Energy Physics (EPS-HEP)** – Hamburg, Germany — Aug 2023
   "Searches for Exotic Higgs Boson Decays with the CMS Experiment"
6. **International Conference on Computing in High Energy & Nuclear Physics (CHEP)** – Norfolk, VA, USA — May 2023
   "Symbolic Regression on FPGAs for Fast Machine Learning Inference"
7. **International Conference on Applied Mathematics** – City University of Hong Kong — May 2016
   "First Passage Time Problem of the Time-Dependent Ornstein-Uhlenbeck Process: a Model for Stochastic Decision-Making Process"

Awards

CN Yang Scholarship – The Chinese University of Hong Kong — 2016 – 2017
Wei Lun Foundation Exchange Scholarship – The Chinese University of Hong Kong — 2016 – 2017
Professor Dennis Yam Kuen Lo Physics Award – The Chinese University of Hong Kong — 2015 – 2016