Oz Amram

Postdoctoral Researcher at Fermilab

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Research Interests

Experimental Particle Physics
LHC, CMS, model-agnostic searches for new particles, jet substructure, fast calorimeter simulations, hardware-level trigger

Machine Learning
Anomaly detection, unsupervised learning, generative models, statistical inference, uncertainty quantification, foundation models

Education & Research Experience

2022-present **Fermilab**, *Postdoctoral researcher*
Conducted research in particle physics, focusing on AI applications, as part of the CMS experiment. Lead analyzer for CMS search for dijet resonances with anomalous substructure, the first CMS analysis making use of anomaly detection. Contributor to several other searches for new particles. Developed new method of calibrating the substructure of exotic jets, now a standard method used by many analyses in CMS. Developed the first generative AI model for calorimeter showers making use of denoising diffusion, achieving state of the art performance. Led the first application of generative AI to simulation of showers in CMS High Granularity Calorimeter. Contributed to design of CMS phase-2 trigger system, with a focus on developing a hardware-level AI-based jet tagging algorithm. Conducted independent research on AI applications in physics, including the use of generative models for statistical inference, an early demonstration of foundation models and new anomaly detection applications.

2016-2022 **Johns Hopkins University**, *M.A., Ph.D*
Thesis: Searching for Anomalies in Proton-Proton Collisions at the Large Hadron Collider.
Advisors: Morris Swartz and Petar Maksimovic
Main thesis was a CMS precision measurement of forward-backward asymmetry in high mass Drell-Yan events, an observable sensitive to interference from heavy new particles. Independently developed a new anomaly detection algorithm (Tag N' Train) that was a top performer in LHC Olympics community competition. Worked on various aspects of the CMS pixel detector including developing a new reconstruction algorithm suitable for high levels of radiation damage, producing calibrations to account for radiation damage, and simulating candidate designs for the Phase-2 upgrade.

2012-16 **Carnegie Mellon University**, *B.S. Physics, Minor Philosophy*

Positions

2024-present Co-Convener of the CMS analysis group dedicated to exotic searches for new particles with jets (EXO Jets+X L3). Reviewing and managing ∼15 active analyses, 8 public results so far during tenure

2021-2022 Co-Convener of the CMS pixel offline software and reconstruction subgroup (Tracker DPG L3). Managing pixel detector calibrations and reconstruction activities.

2020-2021 JHU Physics and Astronomy Graduate Student Diversity & Inclusion Co-Chair

Selected Publications

Below is a list of publications for which I made a significant contribution. As a member of the CMS collaboration I am an author of 400+ publications. CMS publications for which I was the primary author (analysis contact) are listed with '**(AC)**'.

Highlighted works

1. CMS Collaboration. Machine-learning techniques for model-independent searches in dijet final states. *CMS-PAS-MLG-23-002.* https://cds.cern.ch/record/2938054 (July 2025).
   Summary: CMS performance studies comparing different anomaly detection methods. Demonstrated rediscovery of high-momenta top quarks using anomaly detection.

. 2. CMS Collaboration **(AC)**. A method for correcting the substructure of multiprong jets using the Lund jet plane. *Sub. to JHEP.* arXiv: 2507.07775 (July 2025).
   Summary: New general method of correcting and assessing the uncertainty on the modeling of jets in simulation. Method is now a standard technique in CMS and employed in multiple (5+) analyses making use of non-standard jets

. 3. **Amram, O.** & Szewc, M. Data-Driven High-Dimensional Statistical Inference with Generative Models. *Sub. to JHEP.* arXiv: 2506.06438 (June 2025).
   Summary: A novel statistical methodology to perform measurements using generative AI models in place of histograms. Demonstrated ∼40% gains on example di-Higgs measurement.

. 4. CMS Collaboration **(AC)**. Model-agnostic search for dijet resonances with anomalous jet substructure in proton-proton collisions at $\sqrt{s} = 13$ TeV. *Rept. Prog. Phys.* arXiv: 2412.03747 (Dec. 2024).
   Summary: Search for new heavy particles decaying to jets making use of 5 complementary anomaly detection methods. First CMS analysis using anomaly detection. Demonstrated up to sixfold gains in discovery sensitivity as compared to traditional methods on a wide variety of potential signals.

. 5. **Amram, O.** & Pedro, K. Denoising diffusion models with geometry adaptation for high fidelity calorimeter simulation. *Phys. Rev. D.* arXiv: 2308.03876 (Aug. 2023).
   Summary: Generative AI model for the simulation of calorimeter showers. Achieved state of the art quality in community CaloChallenge competition. Up to 1000x faster than physics-based simulations.

. 6. **Amram, O.** & Suarez, C. M. Tag N' Train: a technique to train improved classifiers on unlabeled data. *JHEP.* arXiv: 2002.12376 (Feb. 2021).
   Summary: A novel anomaly detection methodology combining unsupervised and weakly supervised learning. Top performer in community LHC Olympics competition.

Other works

7. CMS Collaboration. Search for resonances decaying to an anomalous jet and a Higgs boson in proton-proton collisions at $\sqrt{s} = 13$ TeV. *Sub. to EPJ C.* arXiv: 2509.13635 (Sept. 2025).

8. Brennan, L., Vami, T. A., **Amram, O.**, *et al.* Weakly supervised anomaly detection with event-level variables. *Phys. Rev. D,* 055040. arXiv: 2504.13249 (Apr. 2025).

9. **Amram, O.** & Cummings, G. United States Early Career Researchers in Collider Physics input to the European Strategy for Particle Physics Update. *ESPP.* arXiv: 2503.22834 (Mar. 2025).

10. CMS Collaboration. Search for t-channel scalar and vector leptoquark exchange in the high-mass dimuon and dielectron spectra in proton-proton collisions at $\sqrt{s} = 13$ TeV. *Sub. to JHEP.* arXiv: 2503.20023 (Mar. 2025).

11. **Amram, O.** *et al.* Aspen Open Jets: unlocking LHC data for foundation models in particle physics. *Mach. Learn. Sci. Tech.,* 030601. arXiv: 2412.10504 (Dec. 2024).

12. Krause, C. *et al.* CaloChallenge 2022: A Community Challenge for Fast Calorimeter Simulation. *Sub. to Rept. Prog. Phys.* arXiv: 2410.21611 (Oct. 2024).

13. Kasieczka, G. *et al.* The LHC Olympics 2020 a community challenge for anomaly detection in high energy physics. *Rept. Prog. Phys.* arXiv: 2101.08320 (2021).

14. CMS Collaboration **(AC)**. Measurement of the Drell-Yan forward-backward asymmetry at high dilepton masses in proton-proton collisions at $\sqrt{s} = 13$ TeV. *JHEP.* arXiv: 2202.12327 (Feb. 2022).

15. Lambrides, E. *et al.* Merger or Not: Accounting for Human Biases in Identifying Galactic Merger Signatures. *The Astrophysical Journal.* arXiv: 2106.15618 (Sept. 2021).

Teaching

2024-present	Founding organizer of annual 'Machine Learning for Fundamental Physics' school hosted in Berkeley with $\sim$40 in person and $\sim$100 virtual participants. Co-planned scope of week long curriculum. Gave a lecture and ran a tutorial on anomaly detection.
2023-2025	Worked with UChicago Data Science Institute to develop research project on applying generative AI to simulations in particle physics as part of a university course. Instructed different groups of students on this project for several quarters.
Oct. 2024	Guest lecture at Purdue university for course 'Introduction to ML for physicists', discussed applications of anomaly detection and generative models in particle physics.
2023-2025	Facilitator for yearly CMS 'Data Analysis School' at Fermilab. Led a multi-day exercise introducing group of 10 graduate students to LHC data science methods.
2017-2021	Head Teaching Assistant, General Physics I, Johns Hopkins University. Taught weekly recitation section of $\sim$25 students focused on hands-on problem solving practice. Assisted in exam design, oversaw all grading and other course logistics.
2016-2017	Teaching Assistant, General Physics Lab, Johns Hopkins University. Instructor for a weekly lab course of 25 students. Guided students through lab experiments, graded weekly lab reports.

Invited Seminars

2024-2025	*Treasure Hunting without a Map: First Anomaly Detection Results from CMS* UChicago, LBNL, Fermilab Wine & Cheese, Purdue, Michigan, TRIUMF, Texas A&M

Conference Presentations

Aug. 2025	*Data-driven, optimal, interpretable measurements with generative models* Machine Learning for Jets Conference (ML4Jets). Caltech. Pasadena, CA
Aug. 2025	*Anomaly Detection Searches from CMS* Machine Learning for Jets Conference (ML4Jets). Caltech. Pasadena, CA
July 2025	*Conference Experimental Introduction (invited)* Workshop on Boosted Objects at Colliders (BOOST). Brown University. Providence, RI
June 2025	*Data-driven, optimal, interpretable measurements with generative models* LHC Physics Center EFT Workshop. Fermilab, IL
June 2025	*Results from Anomaly Detection Searches in CMS (invited)* Anomaly Detection in HEP Workshop. Columbia, NY
Oct 2024	*Fast Simulation of Particle Physics Calorimeters* Fast Machine Learning for Science. Purdue, IN
May 2024	*Introduction to Anomaly Detection in HEP (invited)* Fundamental Physics in the Era of Big Data and Machine Learning, Summer Workshop. Aspen, CO
Dec. 2023	*Techniques for ML-based Model Agnostic Searches in CMS* Lightning Talk, Award Winner. US LHC Users Association Meeting. Fermilab, IL
Nov. 2023	*Boosted Jet Tagging and Calibration in CMS* Machine Learning for Jets Conference (ML4Jets). DESY, Germany
Aug. 2023	*Boosted Jet Tagging and Calibration in CMS 13 TeV Data* Workshop on Boosted Objects at Colliders (BOOST). LBNL, CA
May 2023	*Fast & Accurate Calorimeter Simulation with Diffusion Models (invited)* Fast Calorimeter Simulation (CaloChallenge) Workshop. Rome, Italy
May 2023	*Fast & Accurate Calorimeter Simulation with Diffusion Models* Computing in High Energy Physics (CHEP). Norfolk, VA

Mar. 2023	*Standard Model W, Z(+Jets) at CMS and ATLAS* Rencontres de Moriond : QCD & High Energy Interactions. La Thuile, Italy
Nov. 2022	*Searches with boosted objects and ML in CMS* Machine Learning for Jets Conference (ML4Jets). Rutgers, NJ
Apr. 2022	*Recent Z boson Results from the LHC* Standard Model at LHC Workshop. CERN
Sep. 2021	*Machine Learning Based Anomaly Detection at the LHC (invited)* Rising Stars in Experimental Particle Physics Symposia. UChicago, IL
Jul. 2020	*Anomaly Searches with Tag N' Train (invited)* Anomaly Detection Workshop, LHC Summer Olympics 2020. Virtual
Jan. 2020	*Tag N' Train : Combining Autoencoders and CWoLa for Better Unsupervised Searches* Machine Learning for Jets Conference (ML4Jets). NYU
April 2018	*Measurement of the forward-backward asymmetry of high mass Drell-Yan lepton pairs at 13 TeV* APS April Meeting. Columbus, OH

Service

2025	Organized US Early Career input to 2025 European Strategy Update detailing preferences for future collider options
2023-present	Journal referee for papers in SciPost Physics (2 papers), PRD (1), PLB (1), Scientific Reports (1)
2023-present	Reviewer for conference papers: ACAT (2023) and NeurIPS Machine Learning for Physical Sciences workshop (2025)
2020-2021	Served as graduate student representative on JHU physics department DEI committee. Led creation of first departmental climate survey. Used to assess mental health, feelings of inclusion and experiences with harassment in the department.
2019-2021	Co-created culturally responsible teaching training session as part of orientation program for new physics graduate student TA's. Administered for two years, trained next instructors to continue the course in subsequent years.

Mentorship & Supervision

2023-present	Mentored UCSB graduate student (L. Brennan) on project developing new anomaly detection application at the LHC
2019-2024	Mentored a younger graduate students at JHU (S. Sekhar) on projects related to CMS pixel detector and data analysis
2020-present	Mentor in US CMS mentoring program. Provided career advice to younger graduate students at Ohio State (2) and UCSD (1)
2022-2024	Mentored graduate students at several universities (Cornell, KIT, Hamburg) as part of CMS dijet anomaly detection search

Outreach and engagement

2019-present	Regular writer of physics outreach articles for Particle Bites, summarizing recent physics results to a wider audience. Author of $\sim$20 published articles
2024	Wrote CMS and CERN outreach articles describing results of first CMS anomaly detection search (CMS article, CERN article). Produced short video for social media
2024	Appeared on podcast to discuss use of AI in particle physics (link)
2017-2020	Active member of JHU Physics & Astro outreach group. Hosted monthly events at physics department with activities and demos for elementary school aged children

Awards and Honors

2021   Rising Star in Experimental Particle Physics, University of Chicago

2016   Richard E. Cutcosky Award, Carnegie Mellon

2016   Phi Beta Kappa, Carnegie Mellon

2015   Phi Kappa Phi, Carnegie Mellon