

Raghav Kansal

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Professional Experience

California Institute of Technology & Fermilab

SCHMIDT AI POSTDOCTORAL FELLOW

Pasadena & Chicago, USA

2024 -

Education

UC San Diego, CERN, and Fermilab (AI Fellow and Graduate Scholar)

La Jolla, USA; Geneva, Switzerland; and Chicago, USA

PHD IN PHYSICS, GPA: 3.97/4.00

2019 - 2024

Dissertation: *Understanding the High Energy Higgs Sector with the CMS Experiment and Artificial Intelligence*

UC San Diego

La Jolla, USA

BS IN PHYSICS & COMPUTER ENGINEERING, GPA: 3.98/4.00, *summa cum laude*

2015 - 2019

Divisional and Departmental Highest Honors

Selected Publications

Primary contribution

- [1] CMS Collaboration, "Search for a massive scalar resonance decaying to a light scalar and a Higgs boson in the two b quarks and four light quarks final state", *in prep*, CMS-B2G-23-007 (2024).
- [2] CMS Collaboration, "Combination of searches for nonresonant Higgs boson pair production in proton-proton collisions at $\sqrt{s} = 13$ TeV", *in prep*, CMS Physics Analysis Summary CMS-HIG-20-011-PAS (2024).
- [3] CMS Collaboration, *Search for Nonresonant Pair Production of Highly Energetic Higgs Bosons Decaying to Bottom Quarks and Vector Bosons*, CMS Physics Analysis Summary CMS-HIG-23-012-PAS, 2024.
- [4] R. Kansal et al., "JetNet: A Python package for accessing open datasets and benchmarking machine learning methods in high energy physics", *JOSS* 8, 5789 (2023).
- [5] R. Kansal et al., "Evaluating generative models in high energy physics", *Phys. Rev. D* 107, 076017 (2023), [arXiv:2211.10295](#).
- [6] R. Kansal et al., "Particle Cloud Generation with Message Passing Generative Adversarial Networks", *NeurIPS* (2021), [arXiv:2106.11535](#).
- [7] R. Kansal et al., "Graph Generative Adversarial Networks for Sparse Data Generation in High Energy Physics", *NeurIPS ML4PS Workshop* (2020), [arXiv:2012.00173](#).

Mentorship and other contributions

- [8] S. Katel*, H. Li*, Z. Zhao*, R. Kansal, et al., "Learning symmetry-independent jet representations via jet-based joint embedding predictive architecture", *NeurIPS ML4PS Workshop* (2024), [arXiv:2412.05333](#).
- [9] A. Li*, V. Krishnamohan*, R. Kansal, et al., "Induced generative adversarial particle transformers", *NeurIPS ML4PS Workshop* (2023), [arXiv:2312.04757](#).
- [10] Z. Hao, R. Kansal, et al., "Lorentz group equivariant autoencoders", *Eur. Phys. J. C* 83, 485 (2023), [arXiv:2212.07347](#).
- [11] F. Mokhtar, R. Kansal, and J. Duarte, "Do graph neural networks learn traditional jet substructure?", *NeurIPS ML4PS Workshop* (2022), [arXiv:2211.09912](#).
- [12] CMS Collaboration, "Search for Nonresonant Pair Production of Highly Energetic Higgs Bosons Decaying to Bottom Quarks", *Phys. Rev. Lett.* 131, 041803 (2023), [arXiv:2205.06667](#).
- [13] M. Touranakou et al., "Particle-based fast jet simulation at the LHC with variational autoencoders", *Machine Learning: Science and Technology* 3, 035003 (2022), [arXiv:2203.00520](#).
- [14] F. Mokhtar, R. Kansal, et al., "Explaining machine-learned particle-flow reconstruction", *NeurIPS ML4PS Workshop* (2021), [arXiv:2111.12840](#).
- [15] S. Tsan, R. Kansal, et al., "Particle graph autoencoders and differentiable, learned energy mover's distance", *NeurIPS ML4PS Workshop* (2021), [arXiv:2111.12849](#).

Honors and Awards

2023	Fermilab LPC Graduate Scholarship	<i>Fermilab</i>
	For searches for flavour changing neutral currents, ML for simulation, and self-supervised learning for jet classification.	
Nov 2021	2021-22 Carol and George Lattimer Graduate Award for Excellence	<i>UCSD Division of Physical Sciences</i>
	For “interdisciplinary approaches to problem solving and strong commitment to education, mentorship, and service.”	
2021-2022	Fermilab LPC Artificial Intelligence Fellowship	<i>Fermilab</i>
	For graph-based fast simulation models, ML techniques for reconstruction, compression, and anomaly detection tasks, and a boosted Higgs boson graph classifier for precision measurements. Full description.	
Aug 2019	CERN Openlab Summer Students Lightning Talks Award Runner-Up	<i>CERN</i>
	For the talk ‘ Deep Graph Neural Networks for Fast HGAL Simulation ’	
Jun 2019	2019 IRIS-HEP Fellowship	<i>IRIS-HEP</i>
	For the project ‘ HGAL Fast Simulation with Graph Networks ’	
Jun 2019	2019 John Holmes Malmberg Prize	<i>UCSD Department of Physics</i>
	Presented annually at commencement to a graduating physics student for excellence in experimental physics.	
May 2019	2018-2019 Physical Sciences Dean’s Undergraduate Award for Excellence	<i>UCSD Division of Physical Sciences</i>
Jul 2018	2018 William A. Lee Undergraduate Research Award	<i>UCSD Division of Physical Sciences</i>
	For the project ‘Arbitrary ultra-cold atomic lattices using holographic optical tweezers’	

Selected Talks and Posters

A complete list, as well as links, slides, posters, and videos are available at raghavkansal.com/talks.

Mar 2024	US FCC Workshop	<i>MIT (Talk)</i>
	Machine learning for future collider simulations	
Feb 2024	JHU HEP Seminar	<i>Johns Hopkins (Invited Talk)</i>
	Generative transformers and how to evaluate them	
Jan 2024	SLAC FPD Seminar	<i>SLAC (Invited Talk)</i>
	Enabling Di-Higgs and High Luminosity Discoveries with Machine Learning	
July 2023	BOOST Conference	<i>LBNL (Poster)</i>
	Boosted Multi-Higgs with Jets in CMS	
July 2023	UC Irvine Machine Learning Seminar	<i>UC Irvine (Invited Talk)</i>
	Generative transformers and how to evaluate them	
Jun 2023	CMS Deep Dive on Fast Simulation Techniques	<i>CERN (Talk)</i>
	Evaluation metrics for fast simulations	
June 2023	PHYSTAT-2sample Workshop	<i>Virtual (Talk)</i>
	Applications of two-sample goodness-of-fit tests to generative models	
May 2023	USCMS Collaboration Meeting	<i>Carnegie Mellon (Talk & Poster)</i>
	Machine Learning for CMS FastSim	
Dec 2022	CMS Offline and Computing Upgrade R&D Meeting	<i>CERN (Talk)</i>
	FastSim on GPUs	
Nov 2022	Foundation Models and Detector Simulation Workshop	<i>CERN (Invited Talk)</i>
	Generative transformers and how to evaluate them	
Sep 2022	PyHEP 2022	<i>Virtual (Talk)</i>
	JetNet library for machine learning in high energy physics	
Sep 2022	Machine Learning at the Galileo Galilei Institute Workshop	<i>Florence (Discussion)</i>
	Generative Modelling for Physics	
Sep 2022	Machine Learning at the Galileo Galilei Institute Workshop	<i>Florence (Invited Talk)</i>
	Particle Cloud Generation with Message Passing GANs	
Jul 2022	CMS Machine Learning Townhall 2022	<i>CERN (Invited Talk)</i>
	Overview and Outlook: Machine Learning for Simulation	
Jul 2022	LPC Physics Forum	<i>Fermilab (Invited Talk)</i>
	Machine Learning for LHC Simulation	

Dec 2021	NeurIPS 21 Main Poster Session Particle Cloud Generation with Message Passing GANs	Virtual (Poster)
Nov 2021	University of Washington EPE Machine Learning Seminar Particle Cloud Generation with Message Passing GANs	Virtual (Invited Talk)
Nov 2021	LPCC FastSim Workshop Validation Techniques for Machine-Learned FastSim	Virtual (Invited Talk)
Jun 2021	Mainz Institute for Theoretical Physics Machine Learning for Particle Physics Workshop Particle Cloud Generation with Message Passing GANs	Virtual (Invited Talk)
Mar 2021	James Madison University Artificial Intelligence and Machine Learning Seminar Graph Generative Adversarial Networks for High Energy Physics Data Generation	Virtual (Invited Talk)
Mar 2021	Berkeley Institute for Data Science Generative Models for Fundamental Physics Meeting Graph Generative Adversarial Networks for High Energy Physics Data Generation	Virtual (Invited Talk)
Feb 2021	Imperial College London DataLearning Seminar Graph Generative Adversarial Networks for High Energy Physics Data Generation	Virtual (Invited Talk)
Aug 2019	CERN Openlab Lightning Talks Deep Graph Neural Networks for Fast HGAL Simulation, Runner-Up Award	CERN (Talk)
Aug 2018	William A. Lee Undergraduate Research Award Poster Presentations Arbitrary Positioning and Manipulation of Ultra-Cold Atoms with Optical Tweezers	UCSD (Poster)

Projects

Searches for high energy Higgs boson pair production

[github](#)

Jun 2020 -

- Leading the analysis of 2022-2024 CMS data looking for boosted Higgs pairs decaying to four beauty quarks.
- Led the analysis of 2016-2018 CMS data looking for two Higgs bosons (H) decaying to beauty quarks (b) and vector bosons (V).
- Developed a state-of-the-art transformer network to classify between $H \rightarrow VV$ jets and backgrounds.
- Led as well the search for new Higgs-like particles (X, Y) decaying to beauty quarks and vector bosons.
- Expect to set strong limits on Higgs to VV couplings and $X \rightarrow HY$ cross sections.

ML for Fast Simulations

[GAPT](#) [MPGAN](#) [slides](#) [github](#)

Jun 2019 -

- Led effort to develop a graph-based generative adversarial network, MPGAN, which has proven effective at simulating particle collisions.
- Developed as well the faster attention-based generative adversarial particle transformer (GAPT), using set transformers.
- Developed efficient and sensitive two-sample goodness-of-fit tests for validating fast simulations.
- Working on extending to conditional generation and application to detector data.

JetNet Library and Dataset

[github](#) [website](#)

Sep 2021 -

- Developed a library for convenient access to jet datasets, and other utilities, to increase accessibility and reproducibility in ML in particle physics.
- >50,000 downloads as of September 2024, used in several ML and particle physics projects.

Lorentz-Group Equivariant Networks

[LGAE paper](#) [PGAE paper](#) [review](#)

Dec 2020 - April 2023

- Developed a graph-based autoencoder (PGAE) for compression of and anomaly detection in Large Hadron Collider data.
- Wrote a review of deep learning models that are equivariant to physics-relevant group transformations for the UCSD group theory course.
- Led to developing a graph-based autoencoder equivariant to Lorentz group transformations as well (LGAE).
- LGAE outperformed CNN and GNN autoencoders for compression and anomaly detection tasks.

ML for Particle Flow Reconstruction

[paper](#) [github](#)

May 2021 - Dec 2021

- Developing graph neural networks to perform event reconstruction in the CMS experiment at CERN.
- Interpreted results using the Layerwise Relevance Propagation (LRP) method.

Explainable Machine Learning

[GNNs paper](#) [MLPF paper](#)

May 2021 - Dec 2022

- Interpreting results of machine learning models for reconstruction and jet classification using explainable AI techniques.

Tutorials

2019 -

- Author of online statistics for HEP tutorials: <https://rkansal47.github.io/stats-for-hep>
- Co-author and maintainer of Fermilab LPC's ML Hands-on Advanced Tutorials: <https://fnallpc.github.io/machine-learning-hats>

Open Source Software Contributions

[github](#)

2019 -

- Lead developer of the popular [JetNet](#) Python package for ML in particle physics, >35,000 downloads as of March 2023.
- Maintainer of the [fastjet](#) Python package and interface for jet algorithms; contributor to several [scikit-hep](#) (Scientific Python for HEP) libraries.
- Contributed statistical methods to the [rhalphalib](#) and [combine](#) libraries for limit setting in particle physics.
- Contributed to [PyTorch](#) CUDA kernels for linear algebra.

Optical Tweezers and a Quantum Gas Microscope

[poster](#)

Jun 2017 - Jun 2019

- Created dynamic, sub-micron holographic optical tweezers and a Quantum Gas Microscope with sub-micron resolution in order to manipulate individual atoms (or qubits) for quantum computing and quantum information science experiments.
- This work won a William A. Lee Research award, and will be published soon.

GRAD: An interactive graph-based degree planning app

[github](#)

Jan 2017 - Mar 2017

- Created an app for visualizing course requirements with a user-friendly UI.
- I was the Back-end and Algorithms Lead for a team of 10, and personally wrote the server, scraping, and graphing algorithms for the app.
- We were one of 8 finalists out of 60 projects in the UCSD 2018 software engineering course.

Students Mentored

Andres Nava (Undergrad / SURF Program, Caltech)

[github](#)

Jun 2023 —

- $HH \rightarrow bbW$ measurement in the VBF production mode.

Parveen Narula (Undergrad / USCMS PURSUE Program, Beloit)

Jun - Aug 2023

- Early Run 3 boosted $H \rightarrow bb$ studies.

Zhaoyu (Tina) Zhang (Undergrad, UCSD)

[github](#)

Aug 2022 —

- GAPT for detector simulations.

Anni Li (Undergrad / IRIS-HEP Fellow, UCSD), now MS at USC

[paper](#)[github](#)

Jan 2022 - Sep 2023

- Generative adversarial particle transformers.

Rounak Sen (MS, UCSD)

[github](#)

Mar 2023 —

- GAPT for detector simulations.

Venkat Krishnamohan (MS, UCSD), now at Taskrabbitt

[github](#)

Jan - Aug 2023

- Conditional generative adversarial particle transformers.

Carlos Pareja (Undergrad / EXPAND Program, UCSD)

[paper](#)[EXPAND program](#)

Jan 2022 —

- JetNet library and website

Saloni Agarwal (Undergrad / EXPAND Program, UCSD)

[EXPAND program](#)

Jan - Aug 2022

- JetNet library and website

Farouk Mokhtar (Grad, UC San Diego)

[paper 1](#)[paper 2](#)

Jul 2021 — Dec 2022

- Explainable machine learning for reconstruction and classification.

Ish Kaul (Undergrad / SURF program, Princeton)

[github](#)

Jul - Sep 2021

- Graph neural network regression for the mass of Higgs Boson jets

Priya Kamath (High School, San Diego)

Andy Cabrera (Undergrad, UNAM, Mexico)

Pablo Gomez (Undergrad, Yucatán, Mexico)

[ENLACE program](#)[project](#)

Jul - Sep 2021

Saul Glez (Undergrad, Atlixco, Mexico)

Tonatiuh Meneses (Researcher, Huichapan, Mexico)

- Learning Python and front-end development for the JetNet library and website

Steven Tsan (Undergrad, UCSD)

[paper](#)[github](#)

Jan 2021 —

- Graph neural network autoencoder for anomaly detection.

- Particle cloud diffusion models.

Zichun Hao (Undergrad, UCSD), now PhD at Caltech

[paper](#)[github](#)

Jan 2021 - June 2023

- Lorentz-equivariant autoencoder for anomaly detection.

- $H \rightarrow W$ graph neural network classifier.

Teaching Experience

Fermilab LPC Hands-on Advanced Tutorials

[website](#)

2021 —

- Co-authored and led the machine learning Hands-on Advanced Tutorials (HATS) for CMS students in 2022 and 2023.
- Developed lectures and interactive exercises for deep neural networks, convolutional neural networks, and generative modeling in HEP.

Fermilab LPC Data Analysis School

[website](#)

2022 —

- Facilitator for the 2022–2025 data analysis schools (DAS) for CMS students.
- Co-ordinated machine learning and top mass measurement exercises.

UC San Diego Physics Department

2017 — 2021

- Teaching assistant for the undergraduate introductory classical mechanics and quantum mechanics courses for four quarters.
- Tutor at the undergraduate tutorial center for all introductory courses for six quarters.

Service Work

- Level-3 convener of the CMS ML Innovation group
- Organizer of the 2023 [PHYSTAT-2sample](#) workshop on two-sample goodness-of-fit tests.
- Reviewer for the PRD, JINST, and CSBS journals.
- Reviewer for the 2021 and 2022 NeurIPS ML4PS Workshops, and the 2023 ICML SynS & ML Workshop.