Raghav **Kansal**

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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 (Tentative)*
Topic: Particle Physics and Machine Learning   Advisor: Javier Duarte

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] R. Kansal, C. Pareja, and J. Duarte. "JetNet: A Python package for accessing open datasets and benchmarking machine learning methods in high energy physics". In: *Submitted to **JOSS*** (Sept. 2023).

[2] R. Kansal et al. "Evaluating generative models in high energy physics". In: ***Phys. Rev. D*** (Mar. 2023). arXiv: 2211.10295.

[3] R. Kansal et al. "Particle Cloud Generation with Message Passing Generative Adversarial Networks". In: ***NeurIPS***. 2021. arXiv: 2106.11535.

[4] R. Kansal et al. "Graph Generative Adversarial Networks for Sparse Data Generation in High Energy Physics". In: ***NeurIPS ML4PS Workshop***. 2020. arXiv: 2012.00173.

Mentorship and other contributions

[5] Z. Hao, R. Kansal, et al. "Lorentz Group Equivariant Autoencoders". In: ***Eur. Phys. J. C*** (June 2023). arXiv: 2212.07347.

[6] F. Mokhtar, R. Kansal, and J. Duarte. "Do graph neural networks learn traditional jet substructure?" In: ***NeurIPS ML4PS Workshop***. 2022. arXiv: 2211.09912.

[7] CMS Collaboration. "Search for nonresonant pair production of highly energetic Higgs bosons decaying to bottom quarks". In: ***Phys. Rev. Lett.*** (July 2022). arXiv: 2205.06667.

[8] M. Touranakou et al. "Particle-based fast jet simulation at the LHC with variational autoencoders". In: ***Machine Learning: Science and Technology*** 3.3 (July 2022), p. 035003. arXiv: 2203.00520.

[9] F. Mokhtar, R. Kansal, et al. "Explaining machine-learned particle-flow reconstruction". In: ***NeurIPS ML4PS Workshop***. 2021. arXiv: 2111.12840.

[10] S. Tsan, R. Kansal, et al. "Particle Graph Autoencoders and Differentiable, Learned Energy Mover's Distance". In: ***NeurIPS ML4PS Workshop***. 2021. arXiv: 2111.12849.

Honors and Awards

2023 **Fermilab LPC Graduate Scholarship** *Fermilab*
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** *UCSD Division of Physical Sciences*
For "interdisciplinary approaches to problem solving and strong commitment to education, mentorship, and service."

2021-2022 **Fermilab LPC Artificial Intelligence Fellowship** *Fermilab*
For graph-based fast simulation models, ML techniques for reconstruction, compression, and anomaly detection tasks, and a boosted Higgs boson graph classifer for precision measurements. Full description.

Aug 2019 **CERN Openlab Summer Students Lightning Talks Award Runner-Up** *CERN*
For the talk 'Deep Graph Neural Networks for Fast HGCAL Simulation'

Jun 2019 **2019 IRIS-HEP Fellowship** *IRIS-HEP*
For the project 'HGCAL Fast Simulation with Graph Networks'

Jun 2019 **2019 John Holmes Malmberg Prize** *UCSD Department of Physics*
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** *UCSD Division of Physical Sciences*

| Jul 2018 | **2018 William A. Lee Undergraduate Research Award** | *UCSD Division of Physical Sciences* |

Jul 2018   **2018 William A. Lee Undergraduate Research Award**   *UCSD Division of Physical Sciences*
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.

July 2023   **BOOST Conference**   *LBNL (Poster)*
Boosted Multi-Higgs with Jets in CMS

July 2023   **UC Irvine Machine Learning Seminar**   *UC Irvine (Invited Talk)*
Generative transformers and how to evaluate them

Jun 2023   **CMS Deep Dive on Fast Simulation Techniques**   *CERN (Talk)*
Evaluation metrics for fast simulations

June 2023   **PHYSTAT-2sample Workshop**   *Virtual (Talk)*
Applications of two-sample goodness-of-fit tests to generative models

May 2023   **USCMS Collaboration Meeting**   *Carnegie Mellon (Talk & Poster)*
Machine Learning for CMS FastSim

Dec 2022   **CMS Offline and Computing Upgrade R&D Meeting**   *CERN (Talk)*
FastSim on GPUs

Nov 2022   **Foundation Models and Detector Simulation Workshop**   *CERN (Invited Talk)*
Generative transformers and how to evaluate them

Sep 2022   **PyHEP 2022**   *Virtual (Talk)*
JetNet library for machine learning in high energy physics

Sep 2022   **Machine Learning at the Galileo Galilei Institute Workshop**   *Florence (Discussion)*
Generative Modelling for Physics

Sep 2022   **Machine Learning at the Galileo Galilei Institute Workshop**   *Florence (Invited Talk)*
Particle Cloud Generation with Message Passing GANs

Jul 2022   **CMS Machine Learning Townhall 2022**   *CERN (Invited Talk)*
Overview and Outlook: Machine Learning for Simulation

Jul 2022   **LPC Physics Forum**   *Fermilab (Invited Talk)*
Machine Learning for LHC Simulation

Dec 2021   **NeurIPS 21 Main Poster Session**   *Virtual (Poster)*
Particle Cloud Generation with Message Passing GANs

Nov 2021   **University of Washington EPE Machine Learning Seminar**   *Virtual (Invited Talk)*
Particle Cloud Generation with Message Passing GANs

Nov 2021   **LPCC FastSim Workshop**   *Virtual (Invited Talk)*
Validation Techniques for Machine-Learned FastSim

Jun 2021   **Mainz Institute for Theoretical Physics Machine Learning for Particle Physics Workshop**   *Virtual (Invited Talk)*
Particle Cloud Generation with Message Passing GANs

Mar 2021   **James Madison University Artificial Intelligence and Machine Learning Seminar**   *Virtual (Invited Talk)*
Graph Generative Adversarial Networks for High Energy Physics Data Generation

Mar 2021   **Berkeley Institute for Data Science Generative Models for Fundamental Physics Meeting**   *Virtual (Invited Talk)*
Graph Generative Adversarial Networks for High Energy Physics Data Generation

Feb 2021   **Imperial College London DataLearning Seminar**   *Virtual (Invited Talk)*
Graph Generative Adversarial Networks for High Energy Physics Data Generation

Aug 2019   **CERN Openlab Lightning Talks**   *CERN (Talk)*
Deep Graph Neural Networks for Fast HGCAL Simulation, Runner-Up Award

Aug 2018   **William A. Lee Undergraduate Research Award Poster Presentations**   *UCSD (Poster)*
Arbitrary Positioning and Manipulation of Ultra-Cold Atoms with Optical Tweezers

Projects

Di-Higgs github *Jun 2020 -*

- Leading 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→VV particle clouds and backgrounds.
- Leading 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→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.
- >35,000 downloads as of September 2023, 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→bbVV measurement in the VBF production mode.

Parveen Narula (Undergrad / USCMS PURSUE Program, Beloit) *Jun - Aug 2023*

- Early Run 3 boosted H→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 Taskrabbit github *Jan - Aug 2023*
- Conditional generative adversarial particle transformers; paper in prep.

Carlos Pareja (Undergrad / EXPAND Program, UCSD) EXPAND program github *Jan 2022 —*
- JetNet library and website

Saloni Agarwal (Undergrad / EXPAND Program, UCSD) EXPAND program github *Jan - Aug 2022*
- JetNet library and website

Ish Kaul (Undergrad / SURF program, Princeton) github *Jul - Sep 2021*
- Graph neural network regression for the mass of Higgs Boson jets. Paper in prep.

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→VV 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 and upcoming 2024 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

- 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.

Research and Work Experience

Duarte Lab, UC San Diego *UCSD/CERN*
Machine Learning and Particle Physics Researcher *Sep 2019 -*
- Developing graph- and attention-based generative models and metrics for simulating high energy collisions
- Developed and applying graph neural network (GNN) classifiers to set stringent constraints on double-Higgs production and couplings
- Lorentz-group equivariant and GNN auto-encoders for compression and anomaly detection
- JetNet library and dataset for accessibility and reproducibility in machine learning and high energy physics
- Interpretable GNNs for particle reconstruction

Machine Learning for Particle Physics Group, CERN *CERN*
CERN Openlab Summer Student *Jun - Aug 2019*
- Deep learning and generative models for high energy particle collisions

Kleinfeld Lab, UC San Diego
NEUROPHYSICS RESEARCHER

UCSD

Sep 2018 – Jun 2019

- Two-photon microscopy to measure vasomotion dependence on pO2 in the mouse somatosensory cortex

Barreiro Lab, UC San Diego
EXPERIMENTAL QUANTUM INFORMATION SCIENCE RESEARCHER

UCSD

Jun 2017 – Jun 2019

- Designed and implemented a setup for a quantum gas microscope (QGM) to image with single-site resolution
- Generated 2D holographic, dynamic, arbitrarily arranged, sub-micron optical tweezers, integrated with the QGM
- Programmed FPGA and C electronic devices, and created and (3D) printed mechanical mounts and electronics circuits for experimental use

Focus Analytics
SOFTWARE INTERN

Mumbai, India

Jul 2016 – Sep 2016

- Developed and deployed a location prediction SparkJava server with Cassandra and Redis databases
- Implemented ML k-means clustering and SVM linear classification algorithms on location data
- Wrote NodeJS servers and pages for receiving users' predicted locations and displaying the live data on maps
- Designed Cassandra and MySQL databases storing user tracking data, and wrote server APIs for accessing/updating)