

Raghav Kansal

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Education

UC San Diego, CERN, and Fermilab (Artificial Intelligence Fellow)

PHD IN PHYSICS, GPA: 3.97/4.00

Topic: Particle Physics and Machine Learning | Advisor: Javier Duarte

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

2019 - 2024 (Tentative)

UC San Diego

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

Divisional and Departmental Highest Honors

La Jolla, USA

2015 - 2019

Publications

Primary Contribution

- [1] R. Kansal et al. "On the Evaluation of Generative Models in High Energy Physics". In: *Submitted* (Nov. 2022). arXiv: 2211.10295.
- [2] R. Kansal et al. "Particle Cloud Generation with Message Passing Generative Adversarial Networks". In: *NeurIPS*. 2021. arXiv: 2106.11535.
- [3] R. Kansal et al. "Graph Generative Adversarial Networks for Sparse Data Generation in High Energy Physics". In: *NeurIPS ML4PS Workshop*. 2020. arXiv: 2012.00173.

Secondary Contributions

- [4] Z. Hao, R. Kansal, et al. "Lorentz Group Equivariant Autoencoders". In: *in prep.* (Dec. 2022).
- [5] F. Mokhtar, R. Kansal, and J. Duarte. "Do graph neural networks learn traditional jet substructure?" In: *NeurIPS ML4PS Workshop*. 2022. arXiv: 2211.09912.
- [6] 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.
- [7] 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.
- [8] F. Mokhtar, R. Kansal, et al. "Explaining machine-learned particle-flow reconstruction". In: *NeurIPS ML4PS Workshop*. 2021. arXiv: 2111.12840.
- [9] 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 point cloud generative modelling of particle collisions, self-supervised learning for jet classification, and an ML-based search for new vector bosons to explain flavour anomalies. | |
| Nov 2021 | 2020-21 Carol and George Lattimer Graduate Award for Excellence | UCSD Division of Physical Sciences |
| 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 classifier 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 HGAL Simulation' | |
| Jun 2019 | 2019 IRIS-HEP Fellowship | IRIS-HEP |
| | For the project 'HGAL 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 |
| | For the project 'Arbitrary ultra-cold atomic lattices using holographic optical tweezers' | |

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 the most stringent constraints](#) to date on double-Higgs production
- 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 INTERN

Jun - Aug 2019

- Deep learning and generative models for high energy particle collisions

Kleinfeld Lab, UC San Diego

UCSD

NEUROPHYSICS RESEARCHER

Sep 2018 - Jun 2019

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

Barreiro Lab, UC San Diego

UCSD

EXPERIMENTAL QUANTUM INFORMATION SCIENCE RESEARCHER

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

Mumbai, India

SOFTWARE INTERN

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)

Projects

MPGAN & GAPT

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

Jun 2019 -

- Leading effort on developing a graph-based generative adversarial network, MPGAN, which has proven effective at simulating particle collisions.
- Developed as well the attention-based generative adversarial particle transformer (GAPT), using set transformers.
- Developed validation metrics and techniques for real applications to LHC simulations.
- Working now on conditional generation and application to CERN detector data.

HH→bbVV

[github](#)

Jun 2019 -

- Leading the analysis of 2016-2018 data collected at CERN looking for two Higgs bosons (H) decaying to beauty quarks (b) and vector bosons (V).
- Developed a state-of-the-art graph neural network to classify between H→VV particle clouds and backgrounds.

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.
- >17,000 downloads as of September 2022, used in several ML and particle physics projects.

Machine Learning for Particle Flow

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

May 2021 -

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

Lorentz Group Equivariant Autoencoder

[review](#) [github](#)

Dec 2020 -

- Wrote a review of deep learning models that are equivariant to physics-relevant group transformations for my group theory course.
- Led to our group developing a graph-based autoencoder equivariant to Lorentz group transformations (LGAE)

Particle Graph Autoencoders

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

Dec 2020 -

- Developing graph-based autoencoders for compression of and anomaly detection in Large Hadron Collider data.

Sequential Modeling for Soccer Predictions

[github](#)

Mar 2018 - Mar 2019

- Fun project mostly to gain experience with RNNs and Attention
- I achieved a 71% testing accuracy in predicting the outcome of European football matches

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

Selected Talks and Posters

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

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|----------|--|-------------------------|
| Nov 2022 | ML4Jets Evaluating Generative Models in High Energy Physics | Virtual (Talk) |
| Sep 2022 | PyHEP 2022 JetNet library for machine learning in high energy physics | Virtual (Talk) |
| Sep 2022 | Machine Learning at the Galileo Galilei Institute Workshop Generative Modelling for Physics | Florence (Discussion) |
| Sep 2022 | Machine Learning at the Galileo Galilei Institute Workshop Particle Cloud Generation with Message Passing GANs | Florence (Invited Talk) |
| Jul 2022 | CMS Machine Learning Townhall 2022 Overview and Outlook: Machine Learning for Simulation | CERN (Invited Talk) |
| Jul 2022 | LPC Physics Forum Machine Learning for LHC Simulation | Fermilab (Invited Talk) |
| 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 | ACAT Poster Session Particle Cloud Generation with Message Passing GANs | Virtual (Poster) |
| Nov 2021 | LPCC FastSim Workshop Validation Techniques for Machine-Learned FastSim | Virtual (Invited Talk) |
| Jul 2021 | ML4Jets Workshop Particle Cloud Generation with Message Passing GANs | Virtual (Talk) |
| Jun 2021 | Mainz Institute for Theoretical Physics Machine Learning for Particle Physics Workshop Particle Cloud Generation with Message Passing GANs | Virtual (Invited Talk) |
| May 2021 | CMS ML Forum Sparse Data Generation | Virtual (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 Deep 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) |

Students Mentored

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|--|--------------------------------|-------------------------|----------------|
| Zhaoyu (Tina) Zhang (Undergrad, UCSD) <ul style="list-style-type: none"> • MPGAN for detector simulations | | github | Aug 2022 - |
| Anni Li (Undergrad, UCSD) <ul style="list-style-type: none"> • Generative adversarial particle transformers (GAPT) | paper | github | Jan 2022 - |
| Carlos Pareja (Undergrad, UCSD) <ul style="list-style-type: none"> • JetNet library and website | EXPAND program | github | Jan 2022 - |
| Zichun Hao (Undergrad, UCSD) <ul style="list-style-type: none"> • Lorentz-equivariant autoencoder for anomaly detection. Paper in prep. • H→VV graph neural network classifier. (Completed) Paper in prep. | | github | Jan 2021 - |
| Steven Tsan (Undergrad, UCSD) <ul style="list-style-type: none"> • Graph neural network autoencoder for anomaly detection. | paper | github | Jan 2021 - |
| Ish Kaul (Undergrad, Princeton) <ul style="list-style-type: none"> • Graph neural network regression for the mass of Higgs Boson jets. Paper in prep. | | github | Jul - Sep 2021 |
| ENLACE Students (5 undergrads, San Diego and Mexico) <ul style="list-style-type: none"> • JetNet library and website | program | project | Jul - Sep 2021 |
| Saloni Agarwal (Undergrad, UCSD) <ul style="list-style-type: none"> • JetNet library and website | EXPAND program | github | Jan - Aug 2022 |