

# PRADYUN HEBBAR

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## Professional Summary

Recent academically strong BS-MS graduate with a strong background in Physics and Mathematics, specializing in particle physics and machine learning applications. Experienced in deep learning techniques for particle detection and classification in high-energy physics experiments. International experiences include research as a Guest Scientist in Max Plank institute for Physics (MPP) in Munich, 1 out of 300 participants from 35 countries at a leadership summer camp at the US Space and Rocket Centre (USSRC) in Huntsville, Alabama, and a collaborator with groups at CERN, Switzerland. Actively pursuing an interdisciplinary PhD position to drive innovative research at the intersection of advanced machine learning methodologies and fundamental physics.

## Publications and Presentations([Link to view Papers](#))

### Paper: Facilitating Foundational Model Training and Evaluation in HEP

Submitted to JOSS journal

– Pradyun Hebbar, Ting-Hsiang, Vinicius Mikuni, and Benjamin Nachman

### Paper: Lorentz Equivariance via Soft Penalty Constraints with Applications to High Energy Physics

– Thandikire Madula, Pradyun Hebbar, Vinicius Mikuni, Benjamin Nachman, Nadav Joseph O., and Inbar Savoray

### Paper: A comprehensive study of PELICAN for Multi-Particle Jet Tagging

– Pradyun Hebbar, Stefan Kluth, Daniel Britzger

### Conference Presentation: ATLAS retreat at Schloss Ringberg

January 2024

– Presented research on “Extending PELICAN for Higgs, W boson and Z boson tagging”

– [Link to conference details](#)

### Competition Presentation: [Decoherence](#) competition organized by IISc

February 2022

– Secured rank 3

– [Link to presentation](#)

## Education

### Indian Institute of Science Education and Research (IISER,P) – Pune

Aug 2019 - May 2024

*Joint Bachelor-Master of Science (with a specialization in Particle Physics)*

CGPA - 8.6/10 (3.7/4 US equivalent\*)

– Master’s Thesis: “A Study of Physics-motivated Deep Learning Based Algorithms for Jet Tagging at the LHC”

– INSPIRE Fellow - Department of Science and Technology (DST)

### Arihant College of Arts, Commerce and Science (AC) - Pune

Jul 2018 - Jul 2019

*Class XII - MH-HSC board*

91% Aggregate (Top 1% India)

– SHE scholarship - for students within top 1% in the Class XII examination

## Research Experience

### Research Assistant

Aug 2024 - Present

*Lawrence Berkeley National Laboratory (LBNL)*

*Berkeley, California*

– Supervisors: Dr. Benjamin Nachman (LBNL) and Dr. Vinicius Mikuni(LBNL)

– Developing a unified framework to benchmark foundational models for collider physics. Using OmniLearn as a test case.

– Omnilearn is one of the first foundational models for particle physics shown to generalize beyond the training set and achieve state-of-the-art performance on multiple tasks in collider physics.(V. Mikuni and B. Nachman, “OmniLearn: A Method to Simultaneously Facilitate All Jet Physics Tasks,” arXiv:2305.01972 [hep-ph] (2023))

– [GitHub Repository](#) : Developed a joint framework with collaborators at the University of Washington to train and fine-tune foundational models.

- Used OmniLearn as a test case translating the original TensorFlow code to Pytorch.
- Added multinode capabilities to Pytorch version. Trained the OmniLearn model using the Perlmutter Supercomputer with 20+ GPUs simultaneously
- Documented the workflow and prepared a submission to the Journal of Open Source Software
- Current working on supporting additional foundational models and comparing various foundation models in HEP (including OmniLearn, OmniJet- $\alpha$ , etc.)
- In parallel, I am contributing to a collaborative paper on "Lorentz Equivariance via Soft Penalty Constraints," where we're developing novel approaches to incorporate physical symmetries into neural networks without strictly enforcing them.

## Guest Researcher (Master's Thesis Research)

Aug 2023 - May 2024

*Max Planck Institute for Physics (MPP)*

*Munich, Germany*

- **Supervisors:** **Dr. Stefan Kluth** (MPP) and **Dr. Daniel Britzger** (MPP)
- Conducted a comparative study of deep learning-based algorithms for jet flavor tagging at the LHC (PELICAN was selected as the neural network for further studies)
- Achieved state-of-the-art performance (AUC: 0.961, Accuracy: 0.893) on the **ATLAS Top Tag Open Dataset**, demonstrating PELICAN's effectiveness in realistic scenarios.
- Extended PELICAN for multi-particle jet tagging, achieving high accuracy in identifying Higgs ( $H \rightarrow bb$ : 0.927,  $H \rightarrow cc$ : 0.919), W boson ( $W \rightarrow qq$ : 0.904), and Z boson ( $Z \rightarrow qq$ : 0.900) jets using the **JetClass** dataset.
- Demonstrated PELICAN's efficiency by achieving the above competitive results using only 5% of the full datasets, highlighting the model's data efficiency and potential for resource-constrained environments.
- Conducted comprehensive analysis of various pairwise input quantities, revealing the critical role of Lorentz-invariant inputs in PELICAN's superior performance.
- Proposed novel extensions to PELICAN, incorporating spacetime displacement 4-vectors and scalar particle identification labels to enhance heavy-flavor jet tagging (**paper in preparation**).

## Research Assistant



Jan 2022 - Dec 2022

*IISER Pune & CMS Collaboration*

*Pune, India & Geneva, Switzerland*

- **Supervisors:** **Dr. Andre Tinoco David** (CERN), **Dr. Thorben Quast** (CERN), **Dr. Seema Sharma** (IISER,P) and **Don Winter** (RWTH Aachen)
- Worked with Dr. Andre (CERN), Don Winter (RWTH Aachen) and Dr. Thorben Quast (CERN) to develop a "Convolutional Neural Network (CNN)"-based High Granularity Calorimeter (HGCAL) trigger primitive generator for the Level-1 trigger system at the CMS detector in CERN.
- The network is implemented in the multiple L1 trigger system stages

Sensor Input  $\rightarrow$  Read Out Chips (ROC)  $\rightarrow$  ECON-T  $\rightarrow$  Trigger Primitive  $\rightarrow$  Trigger Decision

- Evaluated the network performance for Particle classification, Energy Regression, Momentum Regression and Reconstruction on a dataset simulated using Geant4 (**paper in preparation**).
-  **Illustration of Neural Network**    **Plots**

## Summer Research Intern

July 2022 - August 2022

*Ludwig Maximilian University of Munich*

*India (Remote)*

- **Supervisor:** **Dr. Thomas Kuhr** (LMU Munich)
- Explored applications of Graph Neural Networks for the Belle II detector's event selection trigger.
- Implemented a proof-of-concept Tree-LSTM graph neural network that functions as a trigger for the Belle II detector's data acquisition.

## Semester Project Student

August 2021 - Dec 2021

*IISER Pune*

*Pune, India*

- **Supervisor:** **Dr. Seema Sharma** (IISER,P)
- Thorough introduction to Particle Physics - Standard Model, Calorimetry, Particle signatures and showers, the CMS detector, the Trigger, and Data Acquisition systems in CMS.
- Analyzed the CMS HGCAL upgrade, identifying key hardware and software challenges for improving particle detection.

## Data Science Intern

June 2021 - August 2021

*Astute Group*

*Pune, India*

- **Supervisor:** **Chandrashekhar Gokhale** (Managing Director, Astute Group)
- Developed a machine learning model for credit transaction fraud detection, improving accuracy by 5% over existing methods (with Accuracy: 83%).
- Implemented anomaly detection techniques on real customer data, identifying previously undetected fraudulent patterns.

## Technical Skills

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**Programming Languages:** Python, C++  
**Data Analysis & Visualization:** NumPy, Pandas, Matplotlib/Seaborn, ROOT, Networkx, Awkward  
**Machine Learning & Deep Learning:** PyTorch, Keras, TensorFlow, DGL, scikit-learn  
**Big Data & Parallel Computing:** Dask, Luigi, CUDA  
**Version Control & Development Tools:** Git, LaTeX, Linux/Unix command line  
**Quantum Computing:** Qiskit

## Academic Achievements & Scholarships

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2023: **GRE Physics: 910/990** (100% in Quantum Mechanics and Atomic Physics)  
2019: **INSPIRE Scholarship:** Awarded by Dept. of Science and Technology, Govt. of India (Top 1% nationwide)  
2019: **Scholarship for Higher Education (SHE):** Top 1% in Class XII examination  
2019: **Nationwide Education and Research Scholarship (NEST): All India Rank 3** (out of 50,000)  
2019: **COMEDK Exam: All India Rank 403** (out of 100,000 )  
2019: **JEE Advance: All India Rank 7353** (out of 1,000,000)  
2018: **SAT Subject Tests: Perfect score (800/800)** in Physics, Chemistry, and Advanced Math

## Relevant External Activities

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**ML4Jets 2023 Conference, Hamburg, Germany** **November 2023**  
– Interacted with multiple authors of novel deep learning architectures for jet tagging

**India-CMS Collider School: Introduction to Accelerators** **June 2022**  
– Gained comprehensive understanding of particle accelerator principles and operations.

**India-CMS lecture: Trigger, Electronics and Data Acquisition** **June 2022**  
– Deepened knowledge of data acquisition systems in high-energy physics experiments.

**Coursera: Neural Networks and Deep Learning** **Jan 2022 - Dec 2022**  
– Completed advanced course, implementing neural networks from scratch and optimizing deep learning models.

**Course in Quantum Computing (IBM Quantum)** **Oct 2020 - May 2021**  
– Learned quantum algorithms and their implementation using Qiskit, applying concepts to simple physics problems.

**NASA Space Camp Leadership Program** **March 2018**  
– Participated in simulated space missions and developed teamwork skills in high-pressure environments.

## Language Skills

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**English:** Native   **Marathi:** Fluent   **Hindi:** Fluent   **German:** Basic

## Relevant Coursework

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Quantum Physics, Quantum Field Theory, Nuclear and Particle Physics ,Statistical Mechanics, Condensed Matter Physics, Electrodynamics, Advanced Linear Algebra, Group Theory, Data Analysis & Statistics, Algorithms & Computational Physics, Cosmology, Non-Linear Dynamics

## Academic References

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**Dr. Benjamin Nachman**, LBNL, [bpnachman@lbl.gov](mailto:bpnachman@lbl.gov)  
**Dr. Stefan Kluth**, Max Planck Institute for Physics, [skluth@mpp.mpg.de](mailto:skluth@mpp.mpg.de)  
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