Prince Kumar

Bachelor of Technology, Engineering Physics
Indian Institute of Technology Madras

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Education

Degree	Institute	Board / University	CGPA[1]/%	Year
B.Tech Engineering Physics	Indian Institute of Technology Madras	IITM	9.12*/10.0	2022-2026
Senior Secondary	Delhi Public School, R.K. Puram	CBSE[2]	97.4%	2022
Matriculation	The Kirk View School, Gaya	ICSE[3]	95.2%	2020

Research Experiences

- **Firmware Development and FPGA Integration for MALTA Readout Chain in the ATLAS Experiment:** *Nov 2024 - Present*
  Dr. Prafulla Kumar Behera Indian Institute of Technology Madras, Chennai
  - Successfully set up ALINX board, performed from **design to simulation**, before configuring the **FPGA** via **JTAG** connectors.
  - Working on creating a **MALTA-to-FGPA** Communication Kintex carrier replacement for the **ATLAS** Experiment.
  - **Designing** modified **firmware** for Kintex Ultrascale Chip and Development Board for next generation MALTA readout chain.
  - Migrating firmware from **KC705** to **AXKU040**, adapting **SGMII** to **RGMII** for MAC-to-PHY Ethernet communication.
  - Utilizing reference designs from IPBus Firmware for Ethernet setup, ensuring compatibility with the board's pin layout and schematic using Vivado and KiCAD.

- **B-hadron Identification in Jets & Tracks using Novel Deep Learning technique in pp collisions in CMS[4]:** *May 2024 - Present*
  Dr. Prabhat Pujahari IIT Madras, Dr. Matthew Nguyen, Dr. Shamik Ghosh, LLR[5], École Polytechnique
  - Working on b-jet tagging, **classification and clustering of tracks** originating from b-hadron decays in pp collisions in CMS at $\sqrt{s}$ = **5.02 TeV**, with a focus on studying dead cone effect and other b-flavor physics.
  - Developed a new approach using **geometric deep learning** and **point clouds** to extract optimal b-hadron decay representations.
  - Achieved a **3-4% improvement** in signal efficiency and background rejection over traditional BDTs on ParticleNet-tagged jets using point cloud representation of jets, comprising only of **charged decay products** of jets.
  - Achieved **0.97 AUC**[6](ROC[7]) and **92.7%+ accuracy** for graph **b-jet classification** task and **0.965 AUC** and **92.8% accuracy** on node level **track classification task**, showing good signal and background separation, *on par with ParticleNet & BDT*.
  - Implementing state-of-the-art loss functions, alongside **forming quantitative clustering measures** for track separation.
  - Developed a comprehensive Python codebase from scratch, encompassing data reading, preprocessing, **graph neural network architecture development**, and training/testing pipelines for over **50 GB** of pp collisions and informative plots.
  - Built a pipeline to apply cuts and convert **awkward arrays** from **ROOT** pp collision files into dataframes for **HDF5** storage, followed by transforming them into **state dictionary files** compatible with model architectures for training and testing.

- **Rare Decay Channel Analysis: $\Lambda_b^0 \to \Lambda^0(p\pi^-) + J/\psi(\mu^+\mu^-)$ in PbPb Collision at $\sqrt{s} = 5.36$ TeV:** *Sept 2024 - Present*
  Dr. Prabhat Pujahari Indian Institute of Technology Madras, Chennai
  - Working on modifying the **Bfinder reconstruction code** for our specific decay channel to produce **ntuples** for analysis.
  - Created a **custom generator fragment** for the rare Λ_b decay channel, achieving a filter efficiency of $\mathbf{1.3 \times 10^{-6}}$, first in PbPb.
  - Executed **MC production** within the **CMSSW framework**, progressing from generator-level raw data to miniAOD files.
  - Designed a **CRAB3 configuration file** optimized for the CMSSW framework, enabling the generation of 1M+ rare events.

- **Flare Artifact Removal using Advanced Deep Learning Image Restoration Models:** *Feb 2024 - May 2024*
  Dr. Kaushik Mitra, Indian Institute of Technology Madras, Chennai
  - Developed **GAN**[8] **based models with UNET architecture** to remove flare artifact from images using restoration models.
  - Utilized real and synthetically generated flare images using **flare7kpp** and **Flickr24 datasets** to train/test developed models.
  - Implemented and tested **Blind Image Quality Assessment Module** of AutoDIR model & CLIP for prompt-based filtering.
  - Integrated in codebase **Uformer**, **Restormer**, **NAFNet**, **Mamba blocks and retinexformer** as part of GAN-UNet model.
  - Achieved close to State-of-the-art values in **PSNR**[9] **23.52** and **SSIM**[10] **0.66** for synthetic images using developed model.
  - Contributed to the **foundational work** enabling the expansion of flare removal techniques from **images to videos**, *VidFlareNet*.

Projects

- **AstroStellar Simulation (N-Body Simulation): Open House Poster** *June 2023 - March 2024*
  Centre for Innovation(CFI), Indian Institute of Technology Madras, Chennai
  - Collaborated with a **team of 7** to develop a C++ code to model **N-bodies** interacting in a **gravitational field** in 3D space.
  - Created **initial galaxy** conditions of **millions** of particles plotted using grids, **angular and radial Gaussian mass distributions**.
  - Utilised **Hamiltonian equations**, tested with leapfrog and **runge-kutta integrators** ensuring accurate numerical solutions, enabling **dynamic celestial body simulation**, coupled with **Barnes-Hut** (octree) for efficient force calculations.
  - Included features of **collisional systems**, **energy/momentum conservation**, parallelisation of code and **adaptive time step**.
  - Visualised the motion of **1 million+ particles** in softwares like **MATLAB** and **Zindaiji** framework, presenting our work at **CFI Open House 2024** to an audience that included students, professors, science enthusiasts, and reporters.

- **Speaker and LED Composite System — Course Project:** *Jan 2024 - May 2024*
  EE2019 Analog Systems and Lab, Indian Institute of Technology Madras, Chennai
  - Designed and demonstrated a composite analog system to **synchronize light and sound**, successful real-world functionality.
  - Integrated key modules: **DC-DC Converter based LED Driver**, **Bandpass Filters**, Adder, **Peak Detector**, and **Class-D Audio Amplifier**, understanding underlying concepts and **resolving non-idealities** and realised signal filtering and modulation.
  - Simulated the system in **LTSpice**, showcasing proficiency in analog circuit design, attained the **highest grade** for the project.

Technical Skills

- **Programming Languages(Libraries)**: C++, Python(Pytorch, OpenCV, matplotlib, PyGeometric, Pandas, Numpy, Uproot), VHDL, MATLAB, Streamlit, VBA.
- **Tools and Softwares**: Jupyter, ROOT, PYTHIA, GEANT4, KiCAD, Vivado(Xilinx), FPGA Designing, Visual Studio Code, LTSpice, Overleaf, AutoCAD, Colab, Weights and Biases, Git, GitHub, Blender, MS Office softwares & Canva.

Notable Achievements

- Selected as one of **17 Young Research Fellows** from a pool of **300**+ students for **funded undergraduate research**. *2024*
- Among **top 5** of 50 students in the Engineering Physics Department at the end of sophomore year at IITM. *2024*
- Ranked among **top 5%** out of **150k students** in national exam, Joint Entrance Examination (JEE) Advanced. *2022*
- Secured a position among **top 1%** students out of **1 million students** in national level JEE Mains. *2022*

Key Courses Taken

- **Physics**: Quantum Mechanics, Classical Dynamics, Math Physics, High Energy Physics, Statistical Physics, Electromagnetics & its Application, Quantum Field Theory*, Solid State Physics*, Advanced Quantum Mechanics*
- **Mathematics**: Algebraic Topology, Differential Equations
- **Electrical & Computational**: Analog & Digital Systems, Computer Vision, Digital Signal Processing, Solid State Devices*

Volunteering & Co-curricular Activities

- **Student Mentor (Shiksha Prayas)**: Mentored two underprivileged high school students from Haryana, guiding them in their academic and personal development, leading to significant improvement and satisfactory board exam results.
- **Manager at Global Engagement Council of IIT Madras**: Prepared a Semester Exchange BlueBook benefiting 1,000+ students, organized a University Fair with 10+ universities, and conducted an information session for 300+ students.
- **Saathi Mentor at IIT Madras** : Guiding 4 junior undergraduate students of my department helping them navigate from school to college and hostel life.

* Ongoing; [1]Cumulative Grade Point Average; [2]Central Board of Secondary Education (National board); [3]ndian Certificate of Secondary Education (National board); [4]Compact Muon Solenoid; [5]Laboratoire Leprince-Ringuet; [6]Area Under Curve; [7]Receiver Operating Characteristic; [8]Generative Adversarial Networks; [9]Peak Signal-to-Noise Ratio; [10]Structural Similarity Index