CURRICULUM VITAE

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ACADEMIC BACKGROUND

- **October, 2008 – February, 2015: PhD** Experimental High Energy Physics,
  Department of Physics,
  Panjab University, Chandigarh,
  India.

- **July, 2005 – July, 2007**: **M.Sc Physics (Honors)**, Panjab University, Chandigarh.
  Special paper studied at M. Sc. level: Experimental Nuclear and Particle Physics.

  Masters Thesis: Characterisation of Imidazole and Chloranil using FTIR Spectroscopy.

- **July, 2002 – June, 2005**: **B.Sc (Non-medical)**, Government College Una, Himachal Pradesh.

WORK EXPERIENCE

- **Jan 20, 2022 – Current: Research Associate**, Department of Physics, Panjab University, Chandigarh.

- **Aug, 2020 – December, 2021:** Self-employed, gave physics tuitions to school students.

- **Jan 15, 2017 – Dec 31, 2019:** Worked part-time as a **PHP Developer** at Seven Seas English Academy, Sector 17, Chandigarh and taught physics to school students privately.

- **August 2016 – Jan 14, 2017:** Not working due to health issues.

- **April 18, 2016 – July 26, 2016:** Worked as a **PHP Developer** at Seven Seas English Academy, Sector 17, Chandigarh.

- **Jan 11, 2010 – August, 2014**: Visiting scientist at Fermilab, Batavia, Illinois, USA for the MINOS experiment.

CERTIFICATE COURSES

- **Jan, 2020 – July, 2020: Certificate in Data Science and Analytics,** CDAC, Mohali, Panjab.

- **February 2016 - April 2016:** 2 months course in web development using PHP at WebTechLearning Institute, Sector 34, Chandigarh.

ACADEMIC AWARDS and HONOURS

- **Junior Research Fellowship (JRF)**: Council of Scientific and Industrial Research (**CSIR**), Government of India: February 2008 to January 2010.

- Qualified the **Graduate Aptitude Test in Engineering (GATE)** in the Physics stream**,** conducted by the Ministry of Human Resource Development (MHRD), Government of India, in February 2008 with Percentile – 99.39.

- **Qualified the Joint CSIR-UGC National Eligibility Test (NET)** for Junior Research Fellowship and Eligibility for Lectureship in Physical Sciences conducted by the CSIR-UGC, India, in June 2007. Called for **Shyama Prasad Mukherjee Fellowship (SPMF)** interview.

COMPUTER SKILLS

- Programming Languages**: C++ , Python**
  PHP, HTML, CSS

- Data analysis: **ROOT, Pandas, Tableau**

- Database**: MySQL, SQLite3**

- Operating Systems**: Linux**
  Windows
  MacOS.

- Machine Learning and AI**: Regression and Classification Algorithms, OpenCV, Tensorflow using Keras, Convolutional Neural Networks**

DETAILS OF PHD WORK

- **Analysis of the 7% muon antineutrino component of the NuMI neutrino beam:**
  I have worked on the analysis of the 7% muon antineutrino component of the Neutrinos at the Main Injector (NuMI) beam, optimised to produce neutrinos, in an exposure of 7.1 x 10^{20} protons on target. The muon antineutrino sample in this analysis is used to test the oscillation hypothesis for antineutrinos at the atmospheric scale. Any difference in the oscillation parameters of neutrinos and antineutrinos would hint at CP violation in the neutrino sector. MINOS is a two-detector long-baseline neutrino oscillation experiment. The Near Detector (ND) is situated at Fermilab, at a distance of 1 km from the source of neutrinos, and the Far Detector (FD) is in Minnesota, 735 km away. The NuMI beam uses 120 GeV/c protons incident on a graphite target to produce secondary hadrons which include pions and kaons of both charges. Two magnetic horns focus the positively charged hadrons. A 675 m long iron-walled decay pipe allows the hadrons and tertiary muons to decay in flight, producing a beam dominant in neutrinos. The antineutrino component of the neutrino beam arises from four main sources: decays of hadrons travelling along the axes of the horns where the focusing field is negligible; partially defocussed hadrons decaying close to the horns; decays of hadrons produced from interactions with the helium and walls of the decay pipe; and decays of tertiary muons that arise mainly from decays of the focussed

hadrons. The combined energy spectrum of the muon antineutrino CC events arising from these sources is broadly distributed and peaks at approximately 8 GeV, whereas the energy spectrum of muon neutrino CC events resulting from the focussed hadrons is narrowly-peaked at approximately 3 GeV. The MINOS detectors are magnetised, allowing event-by-event separation of muon neutrino and muon antineutrino charged-current (CC) events using the curvature of the muon track. The selection cuts to be applied to select the antineutrino events are optimised so that the product of efficiency and purity is maximised at the ND. The ND energy spectrum so obtained is used to predict the spectrum at the FD. Therefore an accurate modeling of the ND energy spectra and other kinematic variables is essential. I worked on comparing the Monte Carlo (MC) simulation for the ND with the data. These distributions helped us better understand the reasons for the existing differences between data and simulation and led to the introduction of new selection cuts which were useful for later MINOS analyses as well. This analysis constrained the antineutrino oscillation parameter $|\Delta m^2_{32}| < 3.37 \times 10^{-3}$ eV^2 under the assumption $\sin^2 2\theta_{23} = 1$. The results are consistent with the previous MINOS neutrino and antineutrino limits and are published in **Phys. Rev. D 84, 071103(R) (2011).**

- **Light level study for the MINOS Far Detector:**
  MINOS is a two-detector experiment. A precision measurement of the neutrino oscillation parameters requires that the detectors' energy scales be determined accurately with minimal intra-detector variation. MINOS uses cosmic ray muons, a calibration detector, and an in-situ light-injection system to calibrate the detectors. The MINOS FD has been running almost continuously since July 2003. The MINOS ND has been operating since January 2005, but is regularly powered down during Fermilab accelerator shut-downs. From a few months prior to first beam, delivered in March 2005, the PMT gain and detector response have been monitored regularly. These data allow precision statements to be made about the scintillator light yield and PMT behaviour under experimental conditions. It is important to quantify the behaviour of these hardware components in long term experimental operations as several of the next generation neutrino oscillation experiments including MINERvA, T2K, NOvA and OPERA have incorporated similar detector technology. I was involved in the part of this study related to quantifying the change in the light levels obtained from the FD electronics. MINOS uses plastic scintillator as its active element to detect charged particles passing through the detector. When cosmic muons pass through the scintillator light is emitted which is collected by the wavelength shifting (WLS) fibres embedded into the strips. This light travels along the length of the WLS fibres and then through the clear fibres which connect to the PMTs. So any change observed in the detector response is a combined effect of the change in the response of WLS fibres, clear fibres and the PMTs. The response from the PMTs is corrected to take into account the non-linear behaviour of the PMTs, the change in response of the detector with time, strip-to-strip variations, and finally corrected for light attenuation because of different fibre lengths. I compared the cosmic muon data obtained in the year 2005 with that in 2011 to measure the change in the light yield in the Far Detector over a period of six years. From this study the light levels obtained from the PMTs in the Far Detector have been observed to change by 1.8% in 6 years. It has also been observed that different parts of the detector have been aging at different rates and that the centre of the strips are aging more quickly than the edges. The difference in light level between the centre of the detector and the edges is 2.6%. This position dependent aging has been attributed to the mechanical stresses in the scintillator strips which are different in different parts of the detector. These position dependent differences contribute to the energy scale systematic uncertainties and more studies are underway to accurately model them. **These results were presented at Neutrino 2012 conference held at Kyoto, Japan in June 2012.**

- **Neutrino-Antineutrino Oscillations in MINOS:**
  Lorentz and CPT symmetries are fundamental to the Standard Model physics and no experiment has found any evidence for the violation of these symmetries so far. However, should evidence of any type of Lorentz violation be found in the many ongoing experiments, the results will have profound implications and may provide the first experimental clue to the nature of Planck-scale physics. To study this I used a model based on the Standard-Model Extension (SME). The model assumes a subset of four non-zero coefficients $(c_L)_{\mu\mu}^{TT}$, $(c_L)_{\tau\tau}^{TT}$, $g_{\mu\bar{\mu}}^{ZT}$, $g_{\tau\bar{\tau}}^{ZT}$. The g-type coefficients mentioned here have been constrained by the Double-Chooz experiment to < 2.3×10^{-16}, while the c-type coefficients have not been constrained so far. I used the neutrino as well as the antineutrino data in the 10.56×10^{20} POT neutrino-optimised beam for this analysis. The presence of the g-type coefficients allows neutrino-antineutrino mixing and the c-type coefficients modify the oscillations in the standard oscillation sector. Working with a two-flavor approximation I calculated the modified oscillation probabilities and used the simulated ND data to predict the energy spectrum at the FD. The analysis was done as a blind analysis where the fitting procedure was established using simulated data so as not to bias ourselves. All the major systematics affecting the neutrino and antineutrino analyses performed by MINOS were studied. The signal for this analysis is an energy dependent excess of antineutrino events above that predicted by the Standard Model. Since the antineutrinos comprise only a tiny fraction (7%) of events at the FD it was important to reduce the systematic uncertainties as far as possible. Better constraints were obtained on a major systematic: the uncertainty in the production of neutrinos from mesons produced outside of the graphite target, in particular in the decay pipe. The effect of other systematics was found to be very small as compared to the statistical uncertainty. The four largest systematics were included in the fit as nuisance parameters. A fit was performed to one SME parameter at a time assuming all other SME parameters to be zero. $|\Delta m^2_{32}|$ and $\sin^2 2\theta_{23}$ were marginalised in the fit,. The analysis constrained the absolute value of the g-type parameters to be less than 3.3×10^{-23} (seven orders of magnitude better than previous limits) and c-type parameters to less than 8.4×10^{-23} at 3-sigma confidence level. These values are consistent with the limits expected when there is no Lorentz and CPT violation. The predicted FD spectra at the best-fit values and the data are consistent with that expected from the two-flavor standard neutrino oscillations hypothesis and no excess of antineutrino events was found at the FD. This analysis is the first analysis performed with this model in MINOS and obtained world's tightest constraints on the above coefficients.

- **Software Development:**
  I worked on developing the software necessary to perform the above mentioned analyses, and wrote the complete code needed for the Neutrino-Antineutrino Oscillation analysis within the MINOS framework. The language used for programming was mostly C++, and ROOT was used as the data analysis tool. I also have experience in using Python and Shell for writing scripts.

- **Near Detector Electronics Work:**
  The MINOS Near Detector uses 194 PMTs to read out light signal from the scintillator planes. Each PMT is digitized continuously at the frequency of the neutrino beam RF structure. This is done using an individual front-end channel unit called a “MENU”. A total of 16 MENUs reside on a VME type-6U printed circuit board (called a “MINDER”), with four MINDERS required for each M64 PMT. Data are stored locally on each MENU during a trigger gate and transferred to VME type-9U modules called “MASTERS”. The data from the MASTERS are continuously read out by the MINOS data acquisition system (DAQ) and monitored round the clock in the control room by the shifters. In the event of the failure of any component the on-call experts are contacted to solve the problem. I have gained some

experience in the MINOS ND hardware by working as one of the on-call experts for one year. My work involved being available to help other people on shifts if any problems arose with the ND. In case of failure of any electronics component I also had to go to the underground hall to find the cause of the problem, and replace or fix the faulty electronics modules in the detector.

SHIFTS AND SERVICE TASKS

- Between November 2010 and August 2014 I have taken about 40 days of shifts for the experiment. These were 8 hour shifts in the control room. The shift work involved monitoring various parts of the detectors, fix the issues that arose while taking shift, and notify the experts of the problems.

- I also served as a volunteer tour guide for the ND from June 2011 - August 2014. I have given a number of tours to students and general public to help them understand the MINOS experiment as well as to increase public awareness about physics.

DETECTOR HARDWARE EXPERIENCE

- At the 7th SERC SCHOOL on Experimental High Energy Physics at IIT, Bombay, February 9-27, 2009 (conducted by Department of Science and Technology, Govt. of India) I helped in fabricating a 30 cm x 30 cm glass Resistive Plate Chamber (RPC) as a part of the school curriculum. The RPC was a scaled down version of the RPC's to be used as the active detector in the Indian Neutrino Observatory (INO).

OTHER EARLIER WORKS

- As an initial exercise for studying signal/background separation techniques I compared the Bayesian Neural Network (BNN) classifier with the classifiers in TMVA. For this purpose I ported the BNN package used by the D0 group to a local machine at Panjab University as a standalone package. Using the MC samples used by the CMS group containing single top signal and background I used the BNN package to get a good signal to background separation. I compared the performance of BNN with the classifiers in TMVA and with other cut-based techniques being used in CMS and found the selection efficiency to be comparable. This exercise gave me a good understanding of the various methods employed in high energy physics for separating signal from backgrounds.

AI/ML PROJECTS

AI BASED TRAFFIC SIGN DETECTION AND RECOGNITION SYSTEM USING DEEP LEARNING

(https://github.com/richa2710/TrafficSignsRecognition)

- Convolutional Neural Network (CNN) based project used to detect Indian traffic signs and recognize them through a webcam. Major libraries used are *OpenCV* and *TensorFlow*.
- The trained model has test accuracy of around 98%.
- The project was converted into a web based application using *Django* framework. The webpage allows us to select a traffic sign image and classify it.

USING NEURAL NETWORKS TO DETECT PITUITARY GLAND IN THE BRAIN

- I'm a part of the team at Panjab University, Chandigarh working on detecting and segmenting the pituitary gland in the brain. This is an ongoing project where we have used state of the art architectures like YOLOv3, UNET, and Mask RCNN to locate the pituitary gland using MRI and CT scans obtained from online resources. The goal of this project is to be able to precisely mark the location of tumors inside the pituitary gland.

SCHOOLS AND WORKSHOPS

- Participated in the workshop on **Data Handling and Requisite Tools**, held at Department of Physics, Panjab University, Chandigarh, from Aug 27 – Sept 1, 2022. I delivered two lectures on the tools used in the field of Data Science and Artificial Intelligence.
- **Jan, 2020 – July, 2020, Certificate in Data Science and Analytics:** Six months course at CDAC, Mohali
- Attended the **4th International Summer School on Neutrino Physics (INSS2012)**, co-hosted by Virginia Tech and Fermilab, held at Virginia Tech's Center for Neutrino Physics in Blacksburg, Virginia, USA from July 10th to July 21st, 2012. I was jointly awarded the prize for the "Most Unexpected but Plausibly Correct Answer" in the Tutorials session.
- Attended the **Intensity Frontier workshop** at Rockville, MD, USA, Nov 30 – Dec 2, 2011.
- **7th SERC SCHOOL on Experimental High Energy Physics** at IIT, Bombay, India, February 9-27, 2009 (conducted by Department of Science and Technology, Govt. of India).

LIST OF PUBLICATIONS

- P. Adamson et. al. (MINOS Collaboration), **“Observation of seasonal variation of atmospheric multiple-muons in the MINOS Near and Far Detectors,”** Phys. Rev. D 91, 112006 (2015).

- P. Adamson et. al. (MINOS Collaboration), **“Study of quasielastic scattering using charged-current nu_mu-iron interactions in the MINOS Near Detector,”** Phys. Rev. D 91, 112005 (2015).

- P. Adamson et. al. (MINOS Collaboration), **“Observation of muon intensity variations by season with the MINOS Near Detector,”** Phys. Rev. D 90, 012010 (2014).

- P. Adamson et. al. (MINOS Collaboration), **“Combined Analysis of ν_μ Disappearance and $\nu_\mu \rightarrow \nu_e$ Appearance in MINOS using Accelerator and Atmospheric Neutrinos,”** Phys. Rev. Lett. 112, 191801 (2014).

- P. Adamson et. al. (MINOS Collaboration), **“Measurement of Neutrino and Antineutrino Oscillation Parameters Using the Combined Beam and Atmospheric Data Sets from MINOS,”** Phys. Rev. Lett. 110, 251801 (2013).

- P. Adamson et. al. MINOS Collaboration), **“Search for flavor-changing non-standard neutrino interactions by MINOS,”** Phys. Rev. D 88, 072011 (2013).

- P. Adamson et. al. (MINOS Collaboration), **“Electron neutrino and antineutrino appearance in the full MINOS data sample,”** Phys. Rev. Lett. 110, 171801 (2013).

- P. Adamson et. al. (MINOS Collaboration), **“Comparisons of annual modulations in MINOS with the event rate modulation in CoGeNT,”** Phys. Rev. D. 87.032005 (2012).

- P. Adamson et. al. (MINOS Collaboration), **“Measurements of atmospheric neutrinos and antineutrinos in the MINOS Far Detector,”** Phys. Rev. D. 86, 052007 (2012).

- P. Adamson et. al. (MINOS Collaboration), **“An improved measurement of muon antineutrino disappearance in MINOS,”** Phys. Rev. Lett. 208, 191801 (2012).

- P. Adamson et. al. (MINOS Collaboration), **“Search for Lorentz invariance and CPT violation with muon antineutrinos in the MINOS Near Detector,”** Phys. Rev. D. 85.031101 (2012).

- P. Adamson et. al. (MINOS Collaboration), **“Improved search for muon-neutrino to electron-neutrino oscillations in MINOS,”** Phys. Rev. Lett. 107.181802 (2011).

- P. Adamson et. al. (MINOS Collaboration), **“Active to Sterile Neutrino Mixing Limits from Neutral-Current Interactions in MINOS,”** Phys. Rev. Lett. 107, 011802 (2011).

- P. Adamson et. al. (MINOS Collaboration), **“Search for the disappearance of muon antineutrinos in the NuMI neutrino beam,”** Phys. Rev. D 84, 071103(R) (2011).

TALKS/POSTERS PRESENTED

- Presented a **talk** titled **"New-Age Tools: Artificial Intelligence, Machine Learning, and Deep Learning"** at the Annual Cooperation Meeting of the Indian Institutes and Fermilab Collaboration, held at Central University of South Bihar, Gaya (Bihar), September 3-6, 2022

- Presented a **talk** titled **"Three-flavor Oscillation Results for the NOvA Experiment"** at NuFact 2022: The 23rd International Workshop on Neutrinos from Accelerators, held at Salt Lake City, Utah, United States, July 31 – Aug 6, 2022.

- Presented a **talk** titled "**Search for Time-independent Lorentz Violation in MINOS**" at the XXI DAE-BRNS High Energy Physics Symposium, held at IIT Guwahati, India, December 8-12, 2014.

- Presented a **poster** titled "**Searching for Neutrino to Antineutrino Oscillations in MINOS**" at the 46th Fermilab Users' Meeting, held at Fermilab, Illinois, USA, June 12-13, 2013.

- Presented a **talk** titled **"Study of Antineutrino Oscillations and Neutrino-Antineutrino Transitions in MINOS"** at the IIFC Meeting, held at IIT Guwahati, India, February 7 – 10, 2013.

- Presented a **talk** titled **"Study of Neutrino-Antineutrino Transitions in MINOS"** at the IIFC Meeting, held at Fermilab, Illinois, USA, November 26 – 27, 2012.

- Presented a **poster** titled **"The Long Term Performance of the MINOS Calibration Procedure"** at the 45th Fermilab Annual Users' Meeting, Illinois, USA, June 12 – 13, 2012.

- Presented a **poster** titled **"The Long Term Performance of the MINOS Calibration Procedure"** by Sarah Phan-Budd (Argonne National Lab), Jeff de Jong (Oxford University), Luke Corwin (Indiana University), Mark Mathis (College of Willian and Mary), Richa Sharma (Fermilab), Nathaniel Tagg (Otterbein University) at the Neutrino 2012, held at Kyoto, Japan, June 3 – 9, 2012.

- Presented a **talk** titled **"Study of Neutrino-Antineutrino Transitions in MINOS"** at the APS Meeting, held at Atlanta, Georgia, USA, March 31 – April 3, 2012.

- Presented a **poster** titled **"Searching for Antineutrino Oscillations in a NuMI Neutrino Beam at MINOS"** at the 44th Fermilab Annual Users' Meeting, Illinois, USA, June 1-2, 2011.

- Presented a **talk** titled **"Measuring Antineutrino Oscillations in MINOS"** at the APS Meeting, held at Anaheim, California, USA, April 30 – May 3, 2011.

- Presented a **talk** titled **"Comparison of Bayesian Neural Networks with TMVA"** at the India-CMS meeting held at University of Delhi, India, March 27-28, 2009.

- Presented a **talk** titled **"Multivariate Analysis and Bayesian Neural Networks"** at SERC SCHOOL in IIT Bombay, India, February 9-27, 2009.

MINOS INTERNAL DOCUMENTS

- MINOS DocDB – 9782, May 2013, **“Position Paper for Muon-Antineutrino Analysis of Run I+II+III Data”**.
- MINOS DocBD – 9165, April 2012, **“Proposed Blessed Plots for the NuMuBar Forward Horn Current 7.1e20 Analysis”**.
- MINOS DocDB – 9064, April 2012, **“Blessing Package for Attenuation Study in Far Detector”**.
- MINOS DocDB – 7906, April 2011, **“Position Paper for Light Level Studies”**.
- MINOS DocDB – 7704, December 2010, **“Position Paper on the Neutrino-Antineutrino Oscillations in MINOS using 10.56e20 PoT Neutrino and Antineutrino Dataset”**.

TEACHING EXPERIENCE

- **Quantum Mechanics and Applications**: BSc 4th Semester, 2022
- **Computer Practicals Lab, C++**: MSc 2nd Semester, 2022

REFERENCES

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