My research interests lie in exploring the Standard Model (SM) of particle physics in new energy regimes and at the same time addressing questions not answered by the SM, such as the nature of dark matter (DM). Answering these questions is made more possible by improving detector capabilities to enhance the precision of our measurements and to maximize the discovery potential of the ATLAS detector. I would like to come to Columbia to work on new physics analyses and on readout electronics by working on the next-generation ATLAS liquid argon (LAr) calorimeter system, benefiting from and contributing to the expertise of the group in these areas.

During my fellowship at DESY, I led a search for DM in invisible Higgs boson decays, setting the strongest existing limit to date, and built a module loading station for the new all-silicon Inner Tracker (ITk) upgrade for the High-Luminosity LHC (HL-LHC). Prior to that, I was involved in the first searches for supersymmetry with early Run-2 data after nearly doubling the center-of-mass energy to 13 TeV. To cope with the increased data readout rates in Run-2, I migrated the functionality of the Region of Interest Builder (RoIB), the interface that seeds the processing of events in the software trigger farm, from a VMEbus system to a PCIe card running in a commodity-computer.

The rate of invisible Higgs boson decays may be significantly enhanced beyond its SM value of $\sim 0.1\%$ if the Higgs couples to DM particles. To test this hypothesis, I coordinated the most sensitive search that drives the ATLAS direct probe of Higgs boson decays to invisible particles via the vector boson fusion (VBF) production mechanism [1]. The VBF signature is a powerful probe for new physics as it exhibits a striking signature of two forward jets that have large invariant mass. This signature can be exploited to reject large SM backgrounds while retaining signal. I established a collaboration between theorists and the ATLAS analysis team to improve filtering algorithms used in the Monte Carlo generator, which resulted in the reduction of the largest uncertainty in the previous publication by 35%. This work also enhanced the theoretical accuracy and precision of the simulation, which allowed us to better control the main $Z\,(\nu\nu)$+jets background. I also oversaw the optimization of the event selection and analysis object definition to increase the Higgs boson signal acceptance by 50% and reduce the background in the signal regions by 31%. Through these improvements, my team and I significantly increased the sensitivity to this fundamental probe of dark matter by 54%. In the upcoming months, I would like to continue leading the effort of this search to complete a legacy Run-2 paper and contribute to the combination effort of my analysis with other direct and indirect searches for invisible Higgs boson decays.

Looking ahead, the next years are of great importance to prepare for Run-3 in terms of new analysis ideas. As there has been no definitive sign of new physics, it is important to fully exploit the LHC by looking in experimentally hard-to-reach locations that have not yet been probed. One potential avenue that offers excellent sensitivity for well motivated scenarios is the search for long-lived particles [2]. Analogous to the SM that has particles spanning a wide range of lifetimes, models beyond the SM (BSM) also predict new particles with a variety of lifetimes, many of which can lead to macroscopic displacements from the primary interaction. While the long-lived particles in the SM, such as b-hadrons, have well-understood experimental signatures, BSM long-lived particles offer unusual signatures that may be rejected by standard reconstruction algorithms. Currently, tracks corresponding to these hypothetical particles are reconstructed with a dedicated tracking configuration that only runs on a filtered part of the main physics dataset due to significantly larger computing cost and data size. This cost can be significantly reduced by employing novel machine learning techniques to make a better track seed selection, thus including long-lived particle tracking into the standard reconstruction algorithms. This would have a considerable impact on many other downstream algorithms, such as tagging of different physics objects that can be used in long-lived particle searches, and will therefore expand the search program for these particles in ATLAS. With my experience in optimizing software performance and in machine learning algorithms, I want to drive the long-lived particle tracking capability even further.

Another avenue through which to improve these searches is to exploit the utility of prompt associated objects. For instance, I am interested in continuing to explore the Higgs sector through the exotic decay of the Higgs boson to neutral long-lived particles via associated production. Columbia is already involved in a similar analysis looking for the Higgs boson decaying to long-lived SUSY particles which decay into a photon, which does not point back to the primary vertex, and an invisible particle. If these long-lived SUSY particles decay in the inner detector, the analysis uses the pointing and timing resolution of the LAr electromagnetic calorimeter to distinguish between prompt and displaced photons. It would be useful to investigate the use of tracking by reconstructing the converted photon vertex and its trajectory to determine its direction with respect to the primary vertex. The converted photons will have a lower statistics but an improved precision that can potentially bring additional sensitivity to displaced photon searches. I would like to explore similar non-standard ideas that capitalize on the ATLAS detector capabilities to develop new search strategies for Run-3.

At DESY, I have been deeply involved in the upgrade of the ITk strip detector[3]. I led the DESY project to successfully develop a fully automated assembly system that places strip modules onto a petal, the basic unit that forms the ITk end-cap disks. This system consists of mounting modules with less than 50 μm lateral accuracy onto a petal core using a robotic gantry as a pick-and-place machine with advanced vision for identification of the sensor fiducial markers. I oversaw the purchasing of the equipment needed to build the station that totaled over $200k, and exchanged with industry providers to test new solutions. I collaborated closely with other loading sites to standardize the loading procedure and adapt a common interface to streamline production. In the process, I gained substantial knowledge of detector development such as building and testing modules, operating industrial robotic assembly, and applying computer vision for pattern finding, and in parallel improved my leadership and management skills . In February 2020, I successfully presented the first fully loaded petal built at DESY using this automated procedure to the module loading Final Design Review, showing the petal assembly meets the desired specifications with high repeatability and increased capacity to make up for possible production delays.

I hope to leverage my expertise in BSM searches, detector development, and data acquisition systems to continue searching for new physics and prepare for the production and installation of the next generation LAr readout electronics. I also aim to assume more responsibilities within ATLAS physics and LAr upgrade communities. The work I have done in my DESY fellowship as well as my PhD have prepared me well to take on new challenges. Columbia plays a central role in both searches for new physics and hardware upgrades, and I would be delighted to work, learn, and grow as part of the group.

References

[1] ATLAS Collaboration. Search for invisible Higgs boson decays with vector boson fusion signatures with the ATLAS detector using an integrated luminosity of 139 fb^{-1}. (ATLAS-CONF-2020-008), Mar 2020.

[2] ATLAS Collaboration. Searching for long-lived particles beyond the Standard Model at the Large Hadron Collider. (arXiv:1903.04497), 2019.

[3] ATLAS Collaboration. Technical Design Report for the ATLAS Inner Tracker Strip Detector. (ATLAS-TDR-025), Apr 2017.