Eshwen Bhal

PhD student

62A St Pauls Road, Bristol, United Kingdom. BS8 1LP

+44 (0) 78414 09961 | eshwen.bhal@bristol.ac.uk | eshwen | ebhal | eshwen-bhal-714557195 | eshwen.bhal

Profile

I am a final year PhD student in particle physics, searching for dark matter using big data from the Large Hadron Collider (LHC) as part of the CMS experiment at CERN. This involves statistical analysis of large datasets with expertise in Python, and solving wide ranging problems from physics standpoints to programming challenges. Additional responsibilities have included providing detector-related expertise and software, teaching undergraduates and doing public outreach. Aside from work, I partake in many activities such as taekwondo, weight lifting, hiking and skiing.

Education

University of Bristol — *Bristol, United Kingdom*

Doctor of Philosophy in Physics — *Sep. 2016 – Present*

- Thesis title: **Hadronic Dark Matter Searches at CMS at 13 TeV** — *Under supervision of H. Flächer. Expected submission in June 2020*
  - Performing searches for dark matter arising from various physics models by analysing data from LHC's CMS experiment.
  - Simulated data for signal and background processes compared to LHC data in a statistical analysis framework to prove or disprove a model.
  - Code to simulate data and perform each step of analysis predominantly written in Python, leveraging modern data science tools and distributed computing where possible to process multiple terabytes of data.
- **Postgraduate student representative** for the particle physics group, 2019–20 — *Role in the Student-Staff Liaison Committee for the School of Physics*
- **CERN** (European Organisation for Nuclear Research), Geneva, Switzerland — *Long term attachment, Oct. 2017 – Mar. 2019*
- **Calorimeter Layer-2 on call expert** and **Level-1 Trigger shifter**, Geneva, Switzerland — *Additional responsibilities at CERN*
  - Trained to carry out tasks to assist CMS experiment so operations continue smoothly.
  - Helped develop and implement software for subsystem of Level-1 Trigger to apply corrections and calibrations to data.

University of Exeter — *Exeter, United Kingdom*

Master of Physics with Honours in Physics with Astrophysics. Award: First Class (77 %) — *Sep. 2012 – Jul. 2016*

- Dissertation title: **Simulations of Exoplanet Light Curves** — *Under supervision of T. Harries*
  - Developed software in C to simulate how photons interact in simple planetary atmospheres, producing light curves akin to data from telescopes. Maps of density and composition were also created for model planets.
  - More complex atmospheres can also be modelled and compared to real exoplanets to infer their composition.
  - Utilised Monte Carlo random sampling for scattering of photons, and parallelisation to efficiently run the code over millions of photons.

Monmouth Comprehensive School — *Monmouth, United Kingdom*

Secondary school qualifications — *Sep. 2005 – Aug. 2012*

- **A Level**, 2010–12 — *Biology (A*), Mathematics (A*), Physics (B), Chemistry (AS Level) (B)*
- **Open University**, 2011–12 — *Introducing Astronomy (10 credit course)*
- **GCSE**, 2008–10 — *10 including English Language and Mathematics at grades A* (4) to A (6)*

Experience

University of Bristol — *Bristol, United Kingdom*

Computing Demonstrator — *Nov. 2019 – Present*

- Teaching third year undergraduate students Python and its applications for numerically solving physics problems. Also involves formal marking of assignments and providing feedback.

University of Bristol — *Bristol, United Kingdom*

Mathematics Tutor — *Jan. 2017 – May 2017*

- Taught mathematics for physicists to first year undergraduate students. Also involved formal marking of problem sheets, discussions with the students, and teaching concepts for subsequent assignments.

Skills

Data analysis

- The primary focus of my PhD concerns statistical analysis of large (multi-terabyte) datasets collected by the CMS experiment from the Large Hadron Collider.
- Developed analysis software for dark matter searches and detector-effect calibrations in Python and C++, using modern data science tools and distributed computing.
- Visualisation with ROOT and matplotlib. Formal presentations of results with LaTeX and Microsoft PowerPoint.

Collaboration

- Belonging to, and working alongside several groups of around a dozen people as well as a global research collaboration of over 4,000 people.

Problem solving

- Principal component of any physics degree. As an undergraduate, conducted more traditional pen-and-paper problem solving in many topics. As a PhD student, wrote code to solve physics problems numerically and perform data analysis for high energy particle physics.

Multitasking

- Often working on multiple projects at once with different working groups during PhD. These have included data analysis, software-implemented calibrations to data from detector effects, and expertise and shift work for subsystems of the detector.

Communication

- Presented formally in my PhD at all levels: regular working group updates, research group and collaboration-wide talks, and several conference posters and talks.
- Participated in outreach to the public at the CERN Open Days 2019 and at @Bristol.

Awards

2016	**Dean's Commendation**, in recognition of outstanding achievement at the fourth stage of my degree	*University of Exeter*
2015	**Physics Award**, for being one of the three students with the highest marks at the third stage of my degree	*University of Exeter*
2014	**Dean's Commendation**, in recognition of outstanding achievement at the second stage of my degree	*University of Exeter*
2013	**Physics Award**, for being one of the three students with the highest marks at the first stage of my degree	*University of Exeter*
2013	**Dean's Commendation**, in recognition of outstanding achievement at the first stage of my degree	*University of Exeter*

Publications

2020	Searches for semi-visible jets in proton-proton collisions at $\sqrt{s}$ = 13 TeV in hadronic final states	*In preparation*
2020	Search for an invisibly decaying Higgs boson in proton-proton collisions at $\sqrt{s}$ = 13 TeV in final states with jets and missing transverse momentum	*In preparation*
2018	Search for natural and split supersymmetry in proton-proton collisions at $\sqrt{s}$ = 13 TeV in final states with jets and missing transverse momentum	*JHEP*

Conference talks & posters

2019	**CMS UK Conference**, Searches for semi-visible jets in hadronic final states	*Oxfordshire, UK*
2019	**University of Bristol PGR Conference**, Search for dark matter via an invisibly decaying Higgs boson at CMS	*Bristol, UK*
2019	**Institute of Physics HEPP and APP Conference**, Combined search for an invisibly decaying Higgs boson in hadronic channels at 13 TeV with CMS	*London, UK*
2018	**LHCP Conference**, The CMS Level-1 jet and energy sum triggers in the LHC Run-II	*Bologna, Italy*
2017	**University of Bristol PGR Conference**, Dark matter searches at CMS at 13 TeV	*Bristol, UK*

References

Available on request.

Extended PhD summary

Dark matter is a pervasive, yet largely unknown, presence in the universe. It can only be observed indirectly through its gravitational influence—seeding galaxies and providing enough bulk to prevent stars escaping, or by warping the very fabric of space-time to smear the light that passes near it. There are many properties which may be uncovered by astrophysics, but particle physics contains a swathe of new avenues and approaches to hopefully pinpoint the origins of dark matter.

The Higgs boson has caught the attention of the high energy physics community, and even the public eye, like no other particle in recent memory. Its rather recent discovery in 2012 still leaves many of its characteristics unknown, or lacking the precision of the other fundamental particles. The instability of this particle, like many of its heavy counterparts, forces it to decay into lighter ones. Dark matter particles may be on one of the branches. The Large Hadron Collider (LHC) is able to produce Higgs bosons in abundance by colliding protons at extraordinary energies. I aim to measure the frequency with which it decays to particles that cannot be recorded by our detector, labelled "invisible", like neutrinos. If there is a disparity between the frequency I obtain and the prediction given by the Standard Model of particle physics (which does not account for dark matter), it lends credence to Higgs boson unlocking the secrets of how dark matter can be created.

Over ten thousand trillion proton-proton collisions have occurred at the LHC: a lot of data! Despite the wealth of new insights it may yield, working with big data in collaboration with thousands of others presents its own challenges. In my smaller working group, we have developed a lot of code to perform all aspects of an analysis in search of new physics: accessing and locally storing data from the LHC, interfacing with tools developed by other colleagues, generating simulated samples of expected signal and background to compare to the data, and build up the remaining components of the analysis. Perhaps the worst bottleneck we face is the ability to run the analysis over all data and simulation efficiently. Measures are taken to reduce the number of events we have to process, though it still leaves us with the products of tens of billions of collisions to sift through. With vectorisation and batch computing, we can accomplish this in as little as 30 minutes; a time frame that's essential considering the number of iterations and the development required to create a complete analysis. The use of industry-standard tools such as **`numpy`**, **`pandas`**, and **`matplotlib`** also improve efficiency, bestow a range of useful features, and provide continued support and improvements.

I was fortunate enough to be based at CERN, just outside Geneva, for eighteen months of my PhD. In addition to better collaboration with colleagues stationed there—and experiencing the atmosphere of the world's hub for particle physics—I was able to undertake more responsibility. Working shifts to maintain subsystems of the detector, and being an on-call expert for another subsystem were some of those.

In summary, my main research topic is a search for dark matter via invisible decays of the Higgs boson. I have additionally held several detector-related responsibilities and undergraduate teaching duties, sometimes simultaneously. In all cases, direct collaboration with a small group of people, but wider involvement within my experiment as a whole have been important. The development of clear, efficient code to execute many of these tasks is paramount to ensure smooth and successful operation. Being based abroad, while presenting new challenges, also gave more opportunities for personal and professional development.