

# Eshwen Bhal

PHD RESEARCHER

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## 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

2016 – Present

- Thesis: **Searches for dark matter with a focus on invisibly decaying Higgs bosons using the full Run-2 dataset of the CMS experiment at the LHC** — *Under supervision of H. Flücher. Submitted December 2020*
  - Explored various physics models in search of dark matter by analysing data from LHC's CMS experiment. Set **world leading limits** on the Higgs boson branching fraction to invisible states. **Leading estimated sensitivity** to GeV-scale dark matter.
  - Executed robust, comprehensive statistical analysis on real and simulated data, meticulously documenting concepts, results and code.
  - Leveraging modern data science tools, vectorisation, and distributed computing to process multiple terabytes of data.
  - Author on papers in search of supersymmetry. Two papers in preparation in search of semi-visible jets and invisibly decaying Higgs bosons.
- **Postgraduate student representative** for particle physics, 2019–20 — *Role in Student-Staff Liaison Committee*
- Long term attachment at world's largest particle physics laboratory **CERN** — *18 month placement abroad in Switzerland*
- **Calorimeter Layer-2 on call expert** and **Level-1 Trigger shifter** — *Additional responsibilities with CERN*
  - Assisted in detector operations and monitoring so CMS experiment could take data efficiently and operate smoothly.
  - Developed and deployed software for subsystem of Level-1 Trigger to apply corrections and calibrations to data on the fly.

### University of Exeter

Exeter, United Kingdom

MASTER OF PHYSICS WITH HONOURS IN PHYSICS WITH ASTROPHYSICS

2012 – 2016

- Grade: **First Class** — *77 % overall mark (4.0 GPA equivalent)*
- Dissertation: **Simulations of Exoplanet Light Curves** — *Under supervision of T. Harries*
  - Developed software in C to simulate photons interacting simple planetary atmospheres, producing light curves akin to data from telescopes. Visualised model planets with maps of density and composition.
  - Able to model more complex atmospheres for comparison 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 them.

### Monmouth Comprehensive School

Monmouth, United Kingdom

SECONDARY SCHOOL QUALIFICATIONS

2005 – 2012

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

## Experience

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### University of Bristol

*Bristol, United Kingdom*

#### COMPUTATIONAL PHYSICS TUTOR

2019 – 2020

- Taught programming in Python to third year undergraduate students, with applications for numerically solving physics problems. Topics included linear algebra, differential equations, and Monte Carlo methods. Formally marked assignments and provided feedback.

### University of Bristol

*Bristol, United Kingdom*

#### MATHEMATICS TUTOR

2017

- Taught mathematics for physicists to first year undergraduate students. Topics included multivariable calculus, integration, and matrices. Formally marked problem sheets, orchestrated discussions with the students, and taught concepts for subsequent assignments.

## Skills

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### Data analysis

- 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 parallel programming on computing grids.
- 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 robust, complex code to reliably solve physics problems numerically and perform data analysis in high energy particle physics.

### Multitasking

- Often working on multiple projects at once with different people 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

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2016	<b>Dean's Commendation</b> , in recognition of outstanding achievement in my fourth year	<i>University of Exeter</i>
2015	<b>Physics Award</b> , for being one of the three students with the highest marks in my third year	<i>University of Exeter</i>
2014	<b>Dean's Commendation</b> , in recognition of outstanding achievement in my second year	<i>University of Exeter</i>
2013	<b>Physics Award</b> , for being one of the three students with the highest marks in my first year	<i>University of Exeter</i>
2013	<b>Dean's Commendation</b> , in recognition of outstanding achievement in my first year	<i>University of Exeter</i>

## Publications

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2021	Searches for semi-visible jets in proton-proton collisions at $\sqrt{s} = 13$ TeV in hadronic final states	<i>In preparation</i>
2021	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	<i>In preparation</i>
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	<i>JHEP</i>

## Conference talks & posters

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