



2023 Helmholtz – OCPC – Programme for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Search for multiple new BSM resonances in boosted all-jets final states with the CMS experiment

Helmholtz Centre, division:

DESY-FH

Project leader:

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Description of the project (max. 1 page):

The Standard Model (SM) of particle physics describes microscopic particles and their interactions with remarkable precision. The discovery of the Higgs boson at the LHC in 2012 was a breakthrough for the SM. Yet, the SM leaves important questions unanswered. Among the most prevalent questions are the origin of dark matter, the matter anti-matter asymmetry in the universe and the hierarchy problem related to the large difference in strength between the SM forces and gravity. Many models beyond the SM (BSM) have been proposed to address these questions, predicting new particles and force carriers that would manifest themselves in experimental signatures observable at the LHC. Broadly searching for all possible BSM signatures is thus a priority of the LHC experiments. This project aims to explore a yet uncovered signature with the CMS experiment at the LHC in a long-standing collaboration between Chinese institutions and DESY.

A fundamental common signature of many BSM theories, including compositeness, extra dimensions, extended Higgs sectors, and unified theories with new symmetries, are new resonances in boson pair production at high energies. The to-date most stringent experimental constraints on models predicting a new heavy particle decaying to W, Z and Higgs boson pairs have been set by searches by the CMS and ATLAS experiments [1,2], excluding new particles with masses up to 4.8 TeV/c². While scenarios with a single new



resonance have been investigated exhaustively, there is still a large range of unexplored BSM scenarios with two or three new resonances decaying to multiple quarks and gluons hadronizing to jets. Two scenarios comprise resonances (here named A, B, C), $A \rightarrow BB \rightarrow \text{Jets}$, $A \rightarrow BC \rightarrow \text{Jets}$, with masses in the ranges $m_A > 1 \text{ TeV}/c^2$, $50 < m_B, m_C < 200 \text{ GeV}/c^2$, that appear in BSM scenarios with gauge extensions of QCD [3]. These offer the potential to make immediate new discoveries in the data collected by the CMS experiment.

A major challenge when searching for such resonances is the development of dedicated algorithms to analyse the substructure of jets containing sprays of hadrons originating from 2-6 quarks or gluons. The objective of this project is to develop dedicated algorithms to identify such jets and carry out the first search for such BSM signatures, building up on the groups' expertise and experimental methods of boson pair resonance searches and machine-learning based jet substructure algorithms.

With experts in BSM searches and jet physics, the DESY CMS group with its 90 members and excellent data analysis infrastructure, offers an ideal environment for a postdoc to carry out this project and develop their career.

[1] CMS collaboration, accepted by PLB, [arXiv:2210.00043](https://arxiv.org/abs/2210.00043), and references herein.

[2] ATLAS collaboration, [Eur. Phys. J. C 80 \(2020\) 1165](https://arxiv.org/abs/2004.14636), [arXiv:2004.14636](https://arxiv.org/abs/2004.14636)

[3] Y Bai and B.A. Dobrescu, [JHEP 04 \(2018\) 114](https://arxiv.org/abs/1802.03005), [arXiv:1802.03005](https://arxiv.org/abs/1802.03005)

Description of existing or sought Chinese collaboration partner institute (max. half page):

In the CMS experiment collaboration, DESY works with 9 Chinese partner institutions (Beihang University, Beijing; Tsinghua University, Beijing; Institute of High Energy Physics, Beijing; Peking University, Beijing; Sun Yat-Sen University, Guangzhou; University of Science and Technology of China, Hefei; Fudan University, Shanghai, Zhejiang University, Hangzhou, Zhejiang). The proposed project builds up on previous diboson resonance searches [4,5] carried out in close collaboration between Andreas Hinzmann (DESY) and Qiang Li (Peking University). This collaboration with Peking University is to be further consolidated with this project or expanded on with the other Chinese partner institutes in the CMS collaboration.

[4] CMS collaboration [Eur. Phys. J. C 76 \(2016\) 237](https://arxiv.org/abs/1601.06431), [arXiv:1601.06431](https://arxiv.org/abs/1601.06431)

[5] CMS collaboration, [JHEP 03 \(2017\) 162](https://arxiv.org/abs/1612.09159), [arXiv:1612.09159](https://arxiv.org/abs/1612.09159)

Required qualification of the postdoc:

- PhD or equivalent degree in Particle Physics
- Demonstrated excellence in high-energy physics or a closely related field.
- Demonstrated experience with data analysis
- Demonstrated effective written and verbal communication skills in English.
- Demonstrated ability to work independently and in a team environment.