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

PART A

Title of the project:

Quantum Machine Learning for Detector Simulations and Jet Reconstruction at the LHC

Helmholtz Centre, division:

Deutsches Elektronen-Synchrotron, DESY, Division Particle Physics (DESY-FH)

Project leader:

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DESY Group:

CMS (HH_FH_CMS/E)

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Description of the project (max. 1 page)**:**

The scientific area of particle physics aims at answering fundamental questions on the elementary building blocks of matter and their interactions. The quest for the origin of the Universe, why it is composed by about 5% of ordinary matter, about 25% dark matter and about 70% dark energy, what is the nature of dark matter are most urgent questions, which are addressed by the CMS group at DESY performing physics analyses with the data of the CMS Experiment at the Large Hadron Collider (LHC) at CERN. The LHC will be upgraded to deliver more than 10 times the design luminosity, opening a new window for searches for New Physics like dark matter candidates.

A profound upgrade will enable the CMS Experiment to cope with the extremely high rates and unprecedented pile-up of collision events. The forward region will be flooded with particles and a novel device, a calorimeter measuring the energy of the particles, is going to be installed. This High Granularity Calorimeter (HGCal) will have more than 3 Million readout channels per direction, and measures in 5 dimensions: energy, direction (3d) and time of the incoming particles.

It is clear, that the present and near-future computing will by far not be sufficient to analyze the data and to produce the necessary amount of simulations needed for precise analyses and potential discoveries. In the proposed project this challenge will be addressed with modern methods like machine and deep learning. Algorithms have to be newly developed and optimized with a vast amount of simulations. At DESY methods employing neural networks like Generative

Adversarial Networks (GANs) are studied to produce fast, but precise simulations for high granularity calorimeters. Further-on, a novel approach to move these classical GANs towards Quantum Computing is taken. It investigates the promising potential and possible limitations in employing this rapidly evolving novel technology.

Beside the simulation of the calorimeter with the rapidly evolving technology of Quantum Computing, the reconstructions of so-called jets can be a topic after successfully achieving satisfactory simulations. Jets are collimated bunches of particles flying roughly into the same directions are a crucial tool in all physics analyses of LHC data and especially in searches for New Physics. The classification of particles into jets is usually employing dedicated clustering algorithms., With the extreme particle densities at the upgraded LHC they become a very complex combinatorial problem leading to an aggravating of the computing challenge.

The prospective PostDoc is welcome to join this effort. The PostDoc needs to have experience with Machine Learning methods in order to understand and develop ansatzes for the calorimeter simulation and potentially further for jet reconstruction, that then will be translated into the algorithms to employ Quantum Computing. Therefore, PostDocs with experience or initial education in this aspect or interest to embark quickly in this new technology are preferred.

With these ingredients the project is scientifically highly relevant and at the same time extremely attractive for early career scientists wanting to embark on novel technologies and employing them in their own original scientific work. This project will give a clear boost to the future career prospects of the young scientist. To support this further, it is planned to use opportunities to present the work within the CMS Collaboration as well as in technical oriented international conferences. The conference proceedings and potentially a publication of the developed method would be a highly valuable ingredient and a unique selling point in the CV of the PostDoc.

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

DESY has a decades-long tradition in cooperating with Chinese Institutes and Universities. One prime example is the Institute of High Energy Physics (IHEP) in Beijing. Having participated already very early in the particle physics experiments at DESY since 1979, the famous Prof. Hesheng Chen was recognized with the Helmholtz International Fellow Award in 2013.
Meanwhile several PostDocs have successfully worked with the CMS Group at DESY within the framework of the OCPC program.
All Chinese Institutes, involved in the CMS Experiment or other particle physics experiments, are welcome to establish new and sustainable connections with us at DESY.
The exchange of a PostDoc working on the proposed project will be of mutual benefit in the exchange and evolution of cutting-edge knowledge and its application. It will strengthen the traditional excellent relationship of China and DESY with participants of a new generation to sustain the future collaboration with strong ties.

Required qualification of the postdoc:
- PhD in Particle Physics(preferred), Computational Physics(accepted), other related PhDs to be evaluated
- Experience with Machine Learning (mandatory), detector simulations (preferred), experience in scientific computing (preferred)
- Additional skills in Quantum Computing (advantageous)
- Language requirement: good and fluent English in speaking and writing