



2020 HGF – OCPC – Programme for the involvement of postdocs in bilateral collaboration projects

Title of the project:

Fast Simulations and Signal Detection in Particle Physics

Helmholtz Centre, division/group:

Deutsches Elektronen-Synchrotron DESY / Particle Physics / CMS

Project leader:

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Description of the project (max. 1 page):

The proposed project is embedded in the scientific area of particle physics which aims at answering fundamental questions on the elementary building blocks of matter and the interactions between them. The question for the origin of the Universe, why it encloses only about 5% of ordinary matter, about 25% dark matter and about 70% dark energy are some of the most urgent ones. These, and for example the nature of dark matter, are questions, which are addressed by the group at DESY performing physics analyses at the CMS Experiment at the Large Hadron Collider (LHC) at CERN. The LHC, which collides protons with protons, will be upgraded to deliver more than 10 times the design luminosity. This will open new phase space for searches for dark matter candidates and other signs for New Physics.

In order to cope with the high intensities and expected pile-up of collision events, the CMS Experiment will be seriously upgraded. Especially in the forward region, which will be flooded with particles produced in the collisions, a novel device is going to be installed. A calorimeter that measures in 5 dimensions: the energy, the direction and the time of the incoming particles will have an unprecedented fine granularity. In each forward direction, this High Granularity Calorimeter (HGCa) will have more than 6 Million readout channels to be analysed.

One prime example of searches for dark matter is the production of the, in 2012 discovered Higgs boson, and its subsequent decay into particles, which, like dark matter, do not interact with the material of the detector. Without interactions the Higgs is decaying invisibly for the experiment and



it is necessary to identify such a production with a special signature. The Higgs production via Vector-Boson-Fusion creates two very prominent jets, which are bundles of particles, one in each of the two forward regions. Such a coincidence can be used to pre-select dark matter event candidates. As written above, the forward regions will be swamped with particles from the Higgs production as well as from the pile-up of up to 200 events. The identification of, even these prominent, jets is a formidable challenge, which will be addressed with modern methods like machine and deep learning. The 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. Presently addressed is the part of the electromagnetic particle signals, but the part of the hadronic particle signals is still missing and should be started soon. In collaboration with the CERN Open Lab an approach to move the classical GANs towards Quantum Computing with Quantum Machine Learning and Quantum GANs investigates the options and limitations in employing this rapidly evolving novel technology.

The prospective PostDoc is welcome to join this effort. Depending on the qualification, the acquired competences and the interest of the PostDoc, the work can concentrate on the deep learning aspects of the jet-identification, the simulations via neural networks or the implications for a potential employment of Quantum Computing.

Beside the scientific goal of the project it is also mandatory to pursue the future career prospects of the PostDoc. It is envisaged to use opportunities to present the work within the CMS Collaboration and in technical oriented international conferences. The conference proceedings and potentially a publication of the developed method would be a highly valuable ingredient of the CV of the PostDoc.

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

DESY has a long tradition in cooperating with Chinese Institutes and Universities. One prime example is the Institute of High Energy Physics (IHEP) in Beijing. Scientists participated already very early in the particle physics experiments at DESY, for example the famous Prof. Hesheng Chen in 1979, later Director General of the IHEP and recognized with the Helmholtz International Fellow Award in 2013. At both institutes, IHEP and DESY, the groups working for the CMS Experiment at the Large Hadron Collider (LHC) at CERN are deeply involved in the future upgrade of the CMS Experiment, for example in the novel High Granularity Calorimeter HGCAL as described in the project above.

Beside IHEP in Beijing, also other Chinese Institutes, involved in the CMS Experiment or other particle physics experiments, are welcome to establish new and sustainable connections with DESY.

The exchange of a PostDoc in this area will be of mutual benefit in the exchange of cutting-edge knowledge, strengthening 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 post-doc:

- PhD in Particle Physics
- Experience with methods of Machine and Deep Learning, simulations of detectors
- Language requirement: good English is mandatory