2025 Helmholtz – OCPC – Programme

for the involvement of postdocs in bilateral collaboration projects

PART A

Title of the project:

Optimisation of detector layout and machine detector interface for a 10 TeV muon collider

DESY Division & Group:

FH – ATLAS + FTX

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

A muon collider could be the first machine colliding leptons at the multi-TeV energy frontier. In doing so, it would be the first collider exploiting beams made of unstable particles as well. Such a collider will serve both as a discovery and precision measurement platform. To fulfil these roles effectively, it must be optimized for physics in the challenging environment created by the machine-induced backgrounds.

The decay products from the beam present unique challenges for particle detectors at a multi-TeV muon collider. The detector concepts, currently in development, include tungsten nozzles, providing coverage up to ~10 degrees to shield the detector volume from the beam decays. High-energy electrons generated from beam decays interact with the collider lattice and shower within the nozzle material, creating a diffuse cloud of approximately 10^8-10^9 particles per event entering the detector region. These beam-induced background (BIB) particles are predominantly neutral, low-momentum, and non-pointing, with an out-of-time component. The resulting radiation environment is comparable to that of the High Luminosity LHC. Detector occupancies are somewhat higher than at the HL-LHC (up to a factor of 10), though the event rate is much lower (~1/1000).

This project is aimed at optimising the machine-detector interface to minimise the flux of the beam-induced background particles entering the detector volume and their effects on the experimental apparatus, with a focus on the MAIA detector concept currently being developed at DESY. Detailed simulations exploiting the FLUKA and GEANT4 programs will be developed to study the beam decays, their propagation through the machine lattice and shielding material. Key figures of merit, like detector occupancy and particle flux, will

be used to design and optimise the absorbing elements, as well as magnetic field configuration. The detector layout, for example the number of layers and their spatial configuration in the tracking detector, will be iteratively optimised for a given a BIB prediction for a given collider lattice.

The candidate will conduct a comprehensive study of the background occupancies and document the findings. As a second step, the candidate will develop a strategy to perform the optimisation, implement the related software implementation, and use the results to update the MAIA detector conceptual design. The optimisation work also offers the opportunity to employ Machine learning approaches. The outcome of these studies is not only highly relevant for the Muon Collider studies but of course has many applications also for other future collider projects and is an ideal training opportunity for candidates interested in working on future collider aspects.

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

Currently there is very limited activity on Muon-collider related work in China, but as stated above, the methods and strategies developed here will also impact many other future collider projects, like the CEPC, which is currently being pursued by the Chinese HEP community. With IHEP being the hub of these activities, IHEP would also be a natural partner is this activity, but there are also many other Chinese HEP groups being active on future collider programmes, which could be a very suitable partner for this project.

Required qualification of the postdoc:

- PhD in Particle Physics
- Experience with programming in modern C++ and python
- Experience with event reconstruction software for particle detectors
- Language requirement: excellent English language skills (oral and written)
- Additional skills in FLUKA and GEANT4 simulations are an asset
- Knowledge of key4hep software stack is an asset
- Additional knowledge of modern machine-learning tools (tensorflow or pytorch) is an asset