Study of gauge boson polarisation in VBS VZ events at the LHC and HL-LHC and development of machine learning techniques for the future level-1 trigger of the CMS experiment

Laboratoire Leprince-Ringuet

llr.in2p3.fr

LLR Ecole Polytechnique
Route de Saclay
F - 91128 PALAISEAU Cedex

T. (33) 1 69 33 55 00
F. (33) 1 69 33 55 08
UMR 7638

Jean-Baptiste Sauvan
Chargé de Recherche
jean-baptiste.sauvan@cern.ch

Scientific context

Weak vector boson scattering (VBS) is a key process to probe the non-Abelian gauge structure of the electroweak interaction. In the absence of any other contributions, the scattering amplitude of longitudinally polarized vector bosons would violate unitarity around the TeV scale. Unitarity restoration in the standard model (SM) relies on the interference of the VBS amplitudes and those involving the Higgs boson. If the SM is only a partial description of particle interactions and its completion happens at higher energies, the cross section of VBS processes could increase substantially between the Higgs boson mass and the scale at which new physics mechanisms intervene, even in a scenario where this scale is not directly reachable at the LHC.

At the end of 2018, CMS recorded about 150 fb^{-1} of proton-proton collisions at a center-of-mass energy of 13 TeV. The LHC will restart in 2021 for a period of 3 years and deliver about 300 fb^{-1}. The high-luminosity phase of the LHC (HL-LHC) will start in 2026 with a target integrated luminosity of 3000fb^{-1}. For the HL-LHC, the CMS collaboration decided to replace the end-cap calorimeters by a new radiation-resistant and highly granular detector (HGCAL). Experimentally the VBS events span a large angle in rapidity and involve the entire detector in the measurements, including the forward region. The region covered by the HGCAL will therefore play a crucial role in VBS measurements at the HL-LHC. In particular, the good performance of the Level-1 (L1) trigger system in this region will be of paramount importance.

Thesis project

The thesis objectives will be twofold. One objective will consist in using the data recorded by CMS during the Run 2 and the first part of Run 3 and measure the polarisation fractions in WZ and ZZ VBS events. Although the focus will be put on the fully leptonic final states, the semi-leptonic channel with one of the vector bosons decaying to pairs of quarks might also be considered.

The other objective will consist in developing machine learning methods for particle reconstruction and identification in HGCAL at the L1 trigger. In particular, the implementation and performance tests of deep neural networks (e.g. convolutional neural networks) on FPGAs (Field-programmable gate array) will be done. The impact of these developments on physics will be assessed with the VBS VZ analysis at the HL-LHC.

The thesis will be conducted at LLR in the CMS group with frequent stays at CERN.

Host team at the Laboratoire Leprince-Ringuet

The CMS group at LLR is a founding member of the CMS collaboration. It has designed, built, and is responsible for the operation of the L1 trigger for the electromagnetic calorimeter (ECAL). It has also designed the calorimeter mechanics and contributed to the front-end readout electronics. It has major involvement in particle reconstruction and identification with the e/gamma and tau Physics Object Groups, and contributed to the development of the Particle Flow event reconstruction. It is among the leading protagonists within the CMS collaboration in electroweak (di-bosons, triple gauge couplings, etc.), heavy ions, and Higgs physics.

The group is also strongly involved in the development of the future HGCAL for the HL-LHC, in particular on its mechanical design, on the generation of the L1 trigger primitives, and on the development of offline reconstruction algorithms. In addition, it is participating in the beam tests of the detector prototypes.

Other information

A Master 2 in high-energy physics is required.
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Contact for further information:
Jean-Baptiste Sauvan
jean-baptiste.sauvan@cern.ch
+33 1 69 33 55 11