Study of diboson polarization at the LHC and developments for the level-1 trigger of the CMS High-Granularity Calorimeter

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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 2022 for a period of 3 years and deliver about 300 fb^{-1}. The high-luminosity phase of the LHC (HL-LHC) will start in 2027 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 that CMS will record during the Run 3 and measure for the first time the polarization fractions in diboson (ZZ) events. This analysis will pave the way towards the measurements of polarization in VBS events at the HL-LHC.

The other objective will consist in developing new reconstruction and identification algorithms for the L1 trigger of the HGCAL. In particular, the implementation and tests of machine learning techniques (such as deep neural networks) on FPGAs (field-programmable gate array) will be performed.

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 diboson, multiboson and Higgs physics, as well as in heavy ions 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.
The PhD thesis can be preceded by a Master 2 internship related to the reconstruction in the HGCAL at the L1 trigger, in line with the thesis objectives.

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