ROBERTO SEIDITA PhD Research Project

Abstract
My PhD project is primarily focused on data analysis in CMS, to be performed on the RunII data set in the $H \longrightarrow W^+W^-$ decay channel. As a natural extension of the work I have done for my master thesis [1], I would at first concentrate efforts on the precise measurement of the couplings between the Higgs boson and other Standard Model (SM) particles with RunII data. On a longer timescale, I would work on preparation for RunIII data taking and on the inclusion of tracker information in the first stage of the trigger system for HL-LHC. This will be crucial in allowing for efficient event selection in conditions of high luminosity: gathering the highest amount of data is of fundamental importance in precision measurements, especially differential cross sections, which are particularly sensitive to deviation from the SM.

Status and future plans for CMS and LHC
At present LHC has concluded RunII, with CMS gathering a total of 137 fb^{-1} of integrated luminosity. RunIII will begin in 2021, with an energy increase from 13 TeV to 14 TeV, aiming to reach a total integrated luminosity of 300 fb^{-1} by 2023. In order to achieve this, the instantaneous luminosity will be increased from 1.5×10^{34} $\text{cm}^{-2}\text{s}^{-1}$ to 2.2×10^{34} $\text{cm}^{-2}\text{s}^{-1}$. This will also result in the number of interactions per crossing (pileup) increasing from ~ 40 to ~ 60.

After RunIII is concluded in 2023, LHC will enter the High Luminosity phase (HL-LHC) set to begin in 2026. The new setup will allow for a factor of 5 increase in instantaneous luminosity, allowing both to extend the mass range for new particle searches as well as enabling high precision measurements of the interactions among known particles. To cope with the greatly increased luminosity of HL-LHC, CMS will be substantially upgraded [2]; in particular, the tracking system will be completely replaced, and the trigger system will be reworked by including track information at the lowest trigger level.

PhD Research Project

Measurement of Higgs couplings to SM particles
After the discovery of a Higgs boson-like resonance at 125.09 GeV in 2012, ever increasing focus has been put towards precisely measuring the properties of the newly observed field. One of the key measurements currently being performed is that of the couplings between the Higgs and other SM fields. Such measurement is of interest both because the SM precisely predicts these couplings (once the Higgs boson's mass is known), as well as because the Higgs sector is expected to be very sensitive to phenomena beyond the SM. The couplings can be constrained by precisely measuring different production cross sections and partial decay widths [3]; in particular, I would be concentrating on the $H \longrightarrow W^+W^-$ channel. Due to its high branching fraction and relatively low background, this channel is particularly well suited to measure cross sections for different production modes of the Higgs boson, such as gluon-gluon fusion (ggH), vector boson fusion (VBF), higgsstrahlung (VH) and top/bottom associate production (ttH/bbH).

I would directly exploit the knowledge I gathered during my master thesis, in which I performed a differential measurement of the Higgs boson's cross section, expanding the analysis to separately measure different production modes. This setup allows to constraint the coupling to fermions through the ggH and ttH/bbH processes (ggH involves a fermionic loop), as well as the coupling to the weak vector bosons through a combination of production mechanisms (such as VBF and VH) and the $H \longrightarrow W^+W^-$ decay itself. At a later time I would also work on the combined CMS measurement, which will include input from all experimentally accessible decay channels. The $H \longrightarrow W^+W^-$ channel is a key component in this measurement, due to its high sensitivity to the coupling between the Higgs and W bosons. The familiarity I built with the complete signal extraction procedure in CMS would be naturally suited for this task.

Inclusion of track information in the L1 trigger
In the last part of the PhD I would work on the inclusion of track information in the trigger system of CMS. The trigger system has the function of reducing the event rate from the nominal 40 MHz bunch crossing rate to a more manageable 1 kHz by selecting events of interest. This is achieved on two levels: the Level 1 (L1) system and the High Level Trigger (HLT). Concentrating on L1, the task of this subsystem is to make extremely fast decisions based on readily available data, reducing the event rate to about 750 kHz. Currently this is achieved using only information provided by the muon system and the calorimeters. This setup however is not well suited to the conditions of HL-LHC, for mainly two reasons: the event rate increases with luminosity, potentially resulting in rates too high for the trigger to handle, and energy resolution of the calorimeters worsens when pileup is increased. These effects combine in the very high pileup scenario that will arise at HL-HLC, resulting in a trigger both less efficient and with a much higher output rate. Thus in order to avoid simply raising the momentum and energy thresholds to reduce the event rate, a new L1 system is being devised for HL-LHC which will include information from the new tracker [2]. This will greatly enhance the capabilities of the whole triggering system in CMS, allowing for example to implement far stricter isolation requirements on leptons and thus maintain sensitivity even in a high pileup configuration. This way it will be possible to maintain a trigger at least as efficient as the current one, even under the challenging conditions posed by HL-LHC.

The main problem will be to cope with the increased data flux the L1 system will receive due to the addition of track information. My aim would be to study the feasibility of different algorithms to efficiently extract the relevant information from the added data, in order to obtain an output rate that can be handled by the HLT without significantly raising the momentum and energy thresholds.

References

[1] R. Seidita, *"Measurement of the production cross section of the Higgs boson in association with hadronic jets in the $H \longrightarrow WW \longrightarrow e\ell 2\nu$ decay channel in proton-proton collisions at 13 TeV with the CMS detector"*, 2019.

[2] D. Contardo, M. Klute, J. Mans, L. Silvestris and J. Butler, CERN-LHCC-2015-010, LHCC-P-008, CMS-TDR-15-02.

[3] A. M. Sirunyan *et al.* [CMS Collaboration], Eur. Phys. J. C **79**, no. 5, 421 (2019) doi:10.1140/epjc/s10052-019-6909-y [arXiv:1809.10733 [hep-ex]].