3rd Semester Report
Search for new physics beyond the Standard Model with the CERN LHC CMS detector

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Introduction

The MTA-ELTE Lendület CMS group in collaboration with HEPHY in Vienna studies the production of scalar top (stop) quarks in a supersymmetric extension of the Standard Model with a compressed mass spectra. A part of this is my research, which is focused on electron reconstruction development in the case of large impact parameters, and on related detector performance studies for the extension of the 4-body stop searches to long lifetimes.

Research

Electron reconstruction studies

My research aims to test new techniques – the new low transverse momentum (LowPt) electron collection and a custom collection of closely matched isotrack-photon pairs (IPP)– to improve over the standard method of electron reconstruction in case of large impact parameters and a soft momentum spectrum.

In this semester, the study has been extended below the previously used 3.5 GeV lower threshold on transverse momentum (p_T), where the standard and IPP collections are not expected to have any efficiency. I have measured the performance of the LowPt collection, as summarized on figure 1. The performance curves for the other p_T bins are shown on figure 2.

In the 3.5 GeV $< p_T <$ 10 GeV bin the LowPt collection provides an alternative with larger efficiency compared to standard (with the cut-based veto ID) at a small cost in background rejection. The combination of LowPt and standard causes little change compared to only LowPt in the displaced signal, but it improves performance (compared to only LowPt) in the prompt signal, therefore this combination is the preferred choice. There are no photons below 10 GeV due to a centrally imposed cut on the photon collection to save disk space, therefore the combination that includes IPP cannot perform well in this p_T bin.

Above 10 GeV, the LowPt combined with Standard has a clear performance lead over LowPt alone (in every sample), and it retains the same flexibility with looser working points compared to standard alone. When including IPP as well, there is a visible gain in performance for the highly displaced signal, a small gain for the slightly displaced events, and a small performance loss for prompt leptons at high background rejection. If we move above 20 GeV, this performance loss in prompt is no longer observable.

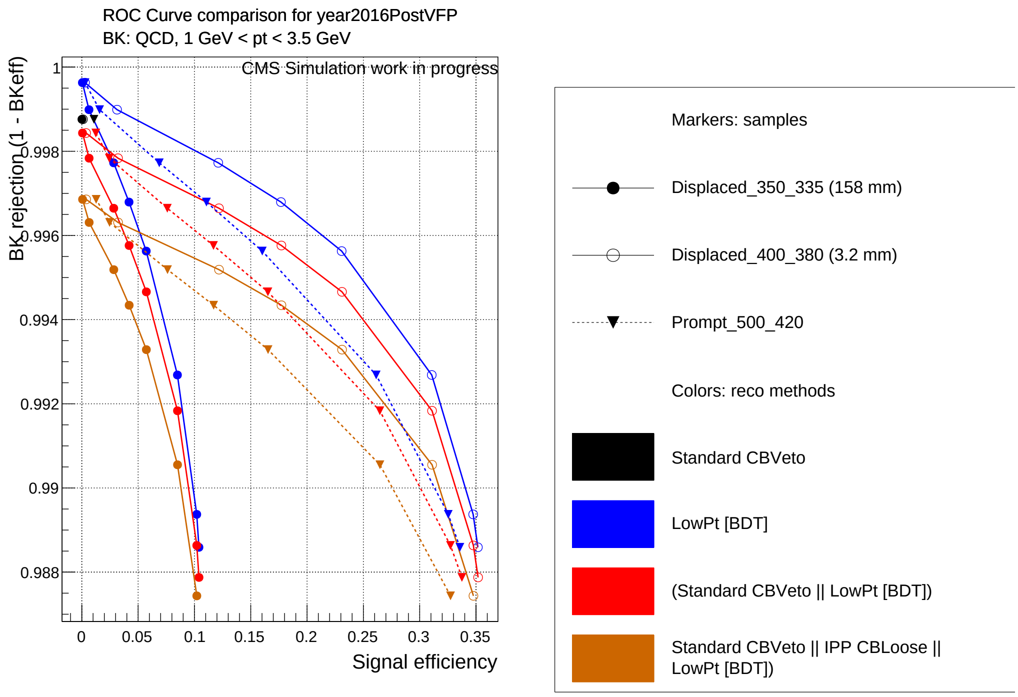

Figure 1: Receiver Operating Characteristic (ROC) curves for electron reconstruction in the 1 GeV $< p_T <$ 3.5 GeV transverse momentum bin. The different marker styles denote different signal samples, and different colors show the reconstruction methods. The points of the lines corresponds to increasing cuts on the BDT score of the LowPt collection. For the standard collection, the cut based veto identification working point is used. The background is the same p_T-binned QCD sample for each line. The efficiency for the Standard collection is zero, but the LowPt collection can find electrons even in this very soft region.

Based on these results, a class was implemented in the framework of the analysis to be able to use the LowPt electrons and their combination with the standard electrons. In case of ambiguity (electrons that may be reconstructed as both LowPt and standard), we need to decide which collection should be prioritized in the combination. This can be decided by comparing the energy resolution of the collections.

The scale factor (an efficiency correction factor for the quality of the modelling in the CMS simulation of the electron object that may cause efficiency differences compared to the performance in data) [1] measurement for these collections is the next step and is currently ongoing. Scale factors are measured with the tag and probe method, for which we need to first produce data and simulation samples of Z(ee) events that include all three electron collections we use as available probes.

Further investigation is needed to find out whether the performance gain by including IPP is in the statistically significant region of our analysis, based on which we can decide whether including it is worth the huge amount of added complexity that it brings. This investigation is in progress as well.

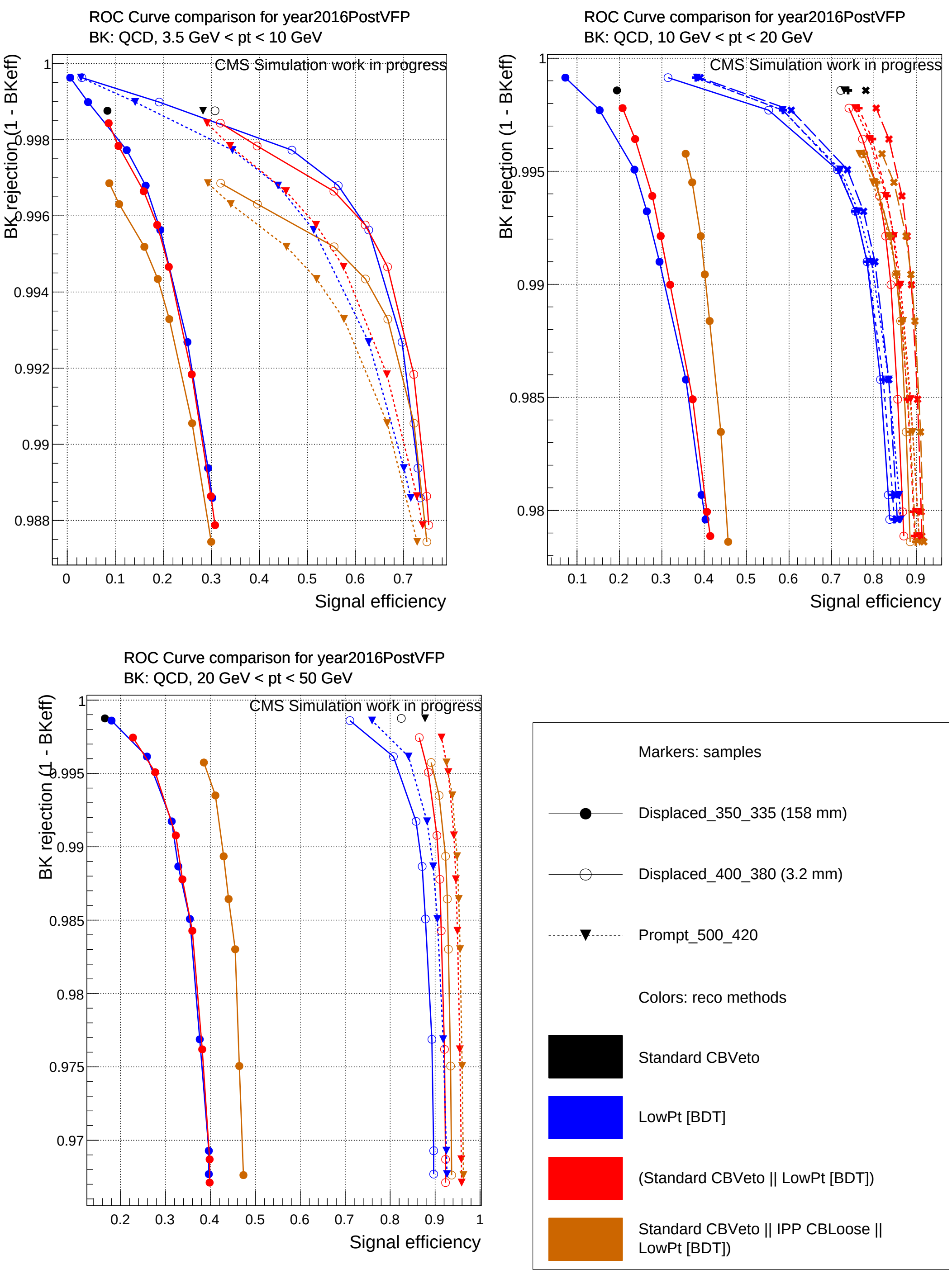

Figure 2: ROC curves in various p_T bins with the same notation as on figure 1. Based on the evaluation of these performance curves and auxiliary studies the analysis is now working on implementing the LowPt (in blue) and the combination of LowPt with standard (in red) reconstruction methods.

High Level Trigger studies

In the High Level Trigger (HLT) group of the Electron & Photon Physics Object Group (EGAMMA POG), I have previously studied the combination of a loosened cut on the longitudinal impact parameter (dz) and a timing requirement to improve the online electron and photon isolation measurement. In this semester we have moved to a new version of the CMS Software to be able to directly access the MVA score (a variable denoting the „quality" of the electron track based on a multivariate analysis) during the re-reconstruction process. We can thus tighten or loosen the requirement on this score, and in addition we can vary the cut on transverse momentum. The collection that is used for the tracks has also been updated and improved by the new collection having a more rigorous definition for the uncertainty of the timing measurement, which affects the significance of the timing variables of the analysis. The combination of p_T, MVA score, dz and a timing requirement is being optimised, separately for the barrel and the endcap regions of the detector.

Other central responsibilities

Since 2022 I have been fulfilling the role of HLT Monte Carlo validator for the Egamma POG. When a new version of the CMS Software (CMSSW) is released, comparisons and checks must be made to ascertain that the performance of the HLT algorithms are unchanged(or improved as expected). In case of a discrepancy, the change must be investigated and understood (often with involving the help of experts).

Occasionally I have also been requested to validate the Egamma HLT performance on LHC Run 3 data after certain configuration changes between the data taking fills. These results were shown on several Trigger Studies Group (TSG) meetings, such as STEAM meetings[2].

I have also participated in the experimental data taking, doing central trigger shift at the CMS control room at CERN in August - September 2022.

Conferences and presentations

The results of my High Level Trigger studies are planned to be presented as a poster at the CMS Upgrade Days[3] in early February. My SUSY analysis results were presented recently to Egamma POG[4].

Publications

The results of the displaced stop analysis by the MTA-ELTE Lendület CMS group and HEPHY in Vienna are planned to be published in 2023. In 2022 I have absolved my CMS Experimental Physics Responsibilites (EPR) requirements to become a CMS author.

Education, teaching and outreach

In my third semester I have attended the following courses: Astroparticle physics - (FIZ/2/132), Data Mining and Machine Learning (FIZ/3/084).

I continued to teach in the Classical Physics Laboratory practical course for BSc students, which in this semester took 8 student contact hours per week.

I have participated as an organiser on the event „10 éves a Higgs-bozon! Mit mesél a tinédzser részecske a mikrovilágról? Ismeretterjesztő program középiskolásoknak és minden érdeklődőnek" held at Eötvös University on 19 Nov 2022.

References

[1] Electron Scale Factor summary:
https://twiki.cern.ch/twiki/bin/view/CMS/ElectronScaleFactorsRun2

[2] Strategy for Trigger Evolution and Monitoring (STEAM)
https://twiki.cern.ch/twiki/bin/view/CMS/StrategyforTriggerEvolutionAndMonitoring
https://indico.cern.ch/event/1188717/

[3] CMS Upgrade Days https://indico.cern.ch/event/1225033/

[4] https://indico.cern.ch/event/1236671/