Measurement of same sign WW VBS processes at CMS with one hadronic tau in final state

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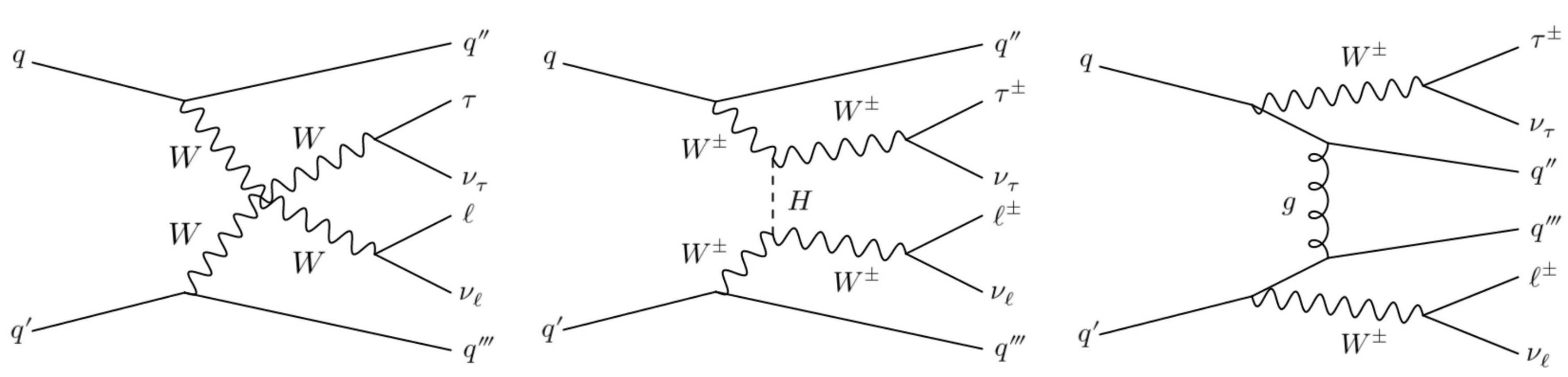
Motivation and topology

$$q\bar{q} \to W^{\pm}W^{\pm}q\bar{q} \to \tau_h^{\pm}\nu_\tau \ell^{\pm}\nu_\ell q\bar{q}$$

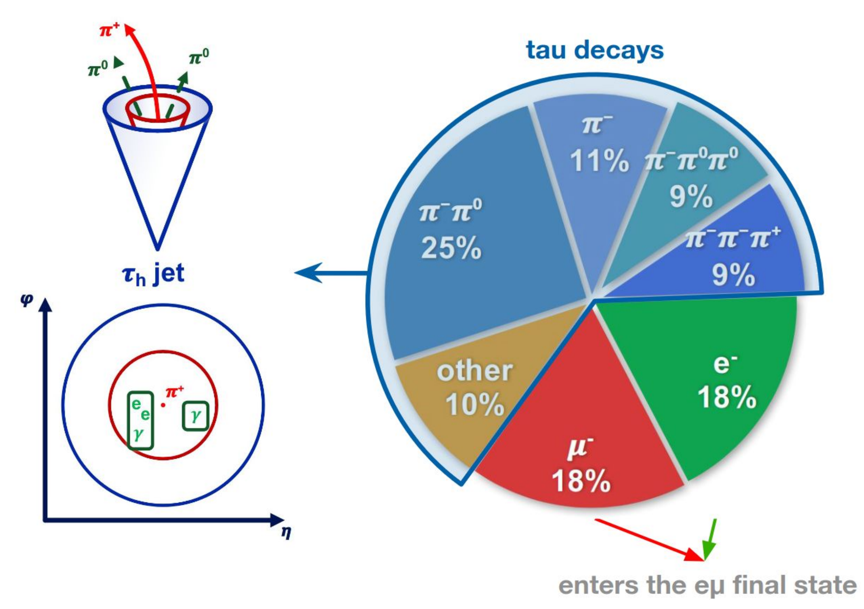


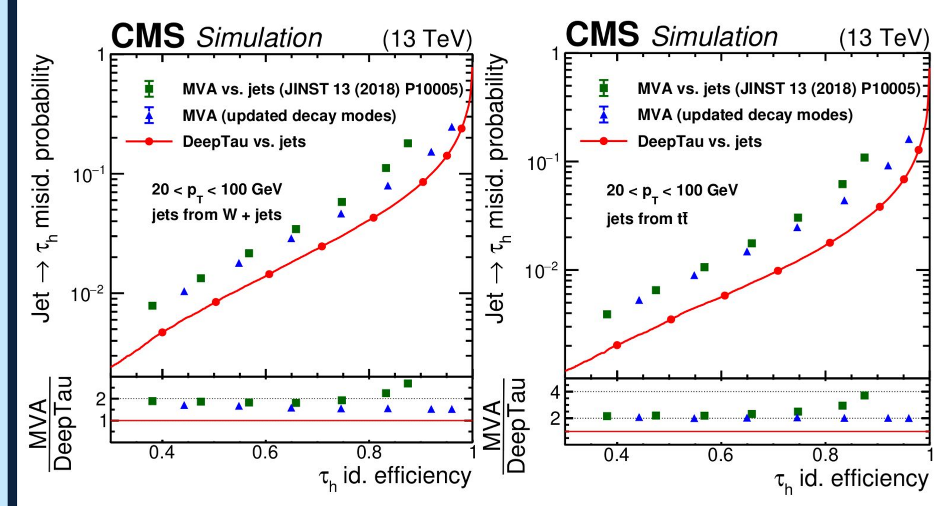
The **scattering of electroweak vector bosons (VBS)** [1] is an important tool to study the non-abelian gauge-structure of the electroweak sector and the related electroweak symmetry breaking mechanism. In addition, new physics phenomena may provide modification of the cross-section predicted in the SM. The LO Feynman diagrams are classified in pure **EW** (left, center) and **QCD-mediated** (right) processes. In this poster, an investigation of VBS of a **same-sign W pair (ssWW)** processes is presented, considering for the first time the presence of a **tau lepton decaying in hadrons** (hadronic tau) in the final state. The tau lepton could be an additional probe for BSM effects due to its enhanced coupling with Higgs.

The experimental signature of the targeted final states consists of two very energetic forward-backward jets (**VBS jets**), coming from the two scattered quarks, a **light charged lepton**, a **hadronic tau**, and suppression of hadronic activity between the two VBS jets.

Hadronic tau selection

Tau lepton decays in hadrons ~64% of times, and can be reconstructed starting from the decay products. The **Hadron-plus-Strips (HPS)** algorithm developed in CMS is able to obtain hadronic taus collecting jets and ECAL clusters in a cone with a fixed opening [2]. However, hadronic jets may be mis-reconstructed as a hadronic tau lepton with similar features.



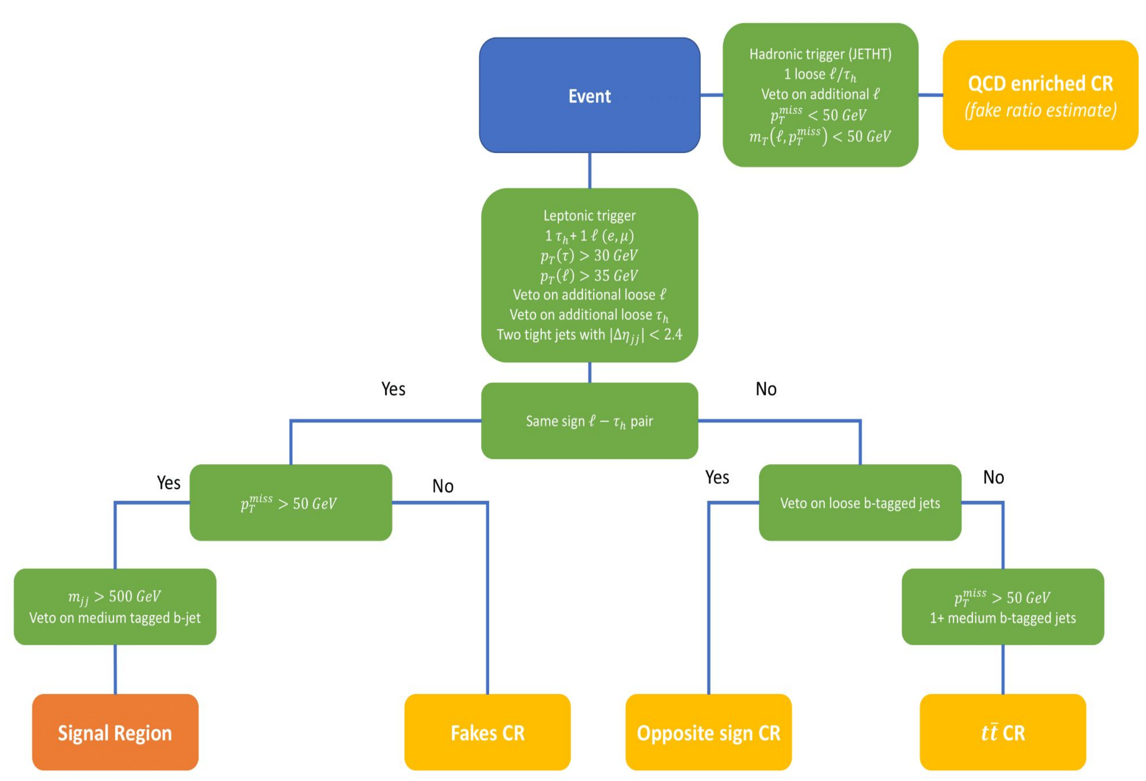


A multi-classifier Deep Neural Network, **DeepTau**, is developed in CMS to separate genuine hadronic taus from the fake ones originating from jets, electrons, or muons [1], exploiting a **convolutional approach**.

In this study, a suitable working point is implemented to get rid of background events with non-prompt or fake hadronic taus.

Analysis strategy

The jet pair with the highest invariant mass, one "tight" light lepton, and one "tight" hadronic tau are selected to reproduce the final state of the searched VBS process. NLO corrections to the pure EW and QCD-mediated branches of the signal are applied. The background events presenting non-prompt or fake leptons are estimated through the "fakeable" data-driven method [3], taking advantage of a region populated by poorly reconstructed leptons. The estimation of this background and others are validated in dedicated control regions



The search for the **ssWW VBS with one hadronic tau** in the final state is performed investigating the **data set collected by the CMS detector from 2016 to 2018**, with **138 fb^{-1}** recorded luminosity.

A **statistical fit to data** in signal region and two control regions is devised using the distributions of the output of a **DNN** specifically developed for this study.

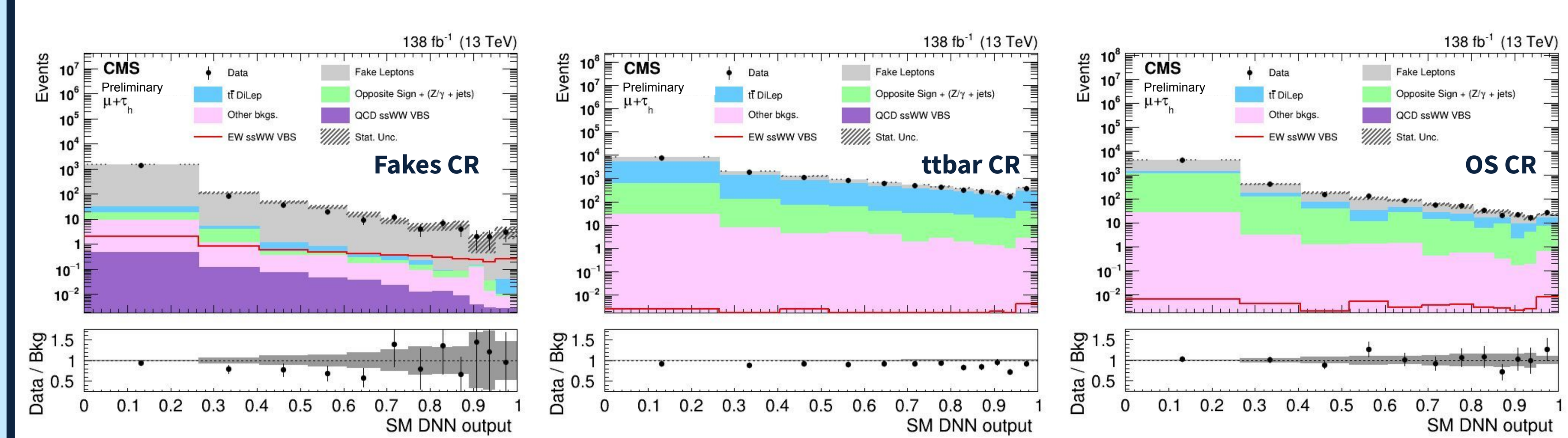
MVA approach

A **multivariate approach** is outlined to discriminate the targeted **signal against the main sources of background**, gaining additional discrimination power from the non-trivial combination of the kinematic information about all reconstructed objects. Nine kinematic quantities peculiar of the ssWW VBS process (as the **transverse masses M_{o1} and M_{1T}**) are injected as input features of a **Deep Neural Network**, trained to classify the events in signal and background categories.

The **DNN outperforms any kinematic quantity** in separating the signal from the background, while preserving a good data-to-background agreement in the control regions. Its output distributions are finally used to search for and measure the investigated signal process.

$$M_{1T} = \sqrt{\left(\sqrt{M_{\tau l}^2 + p_{T\tau l}^2} + p_T^{\mathrm{miss}}\right)^2 - \left|\vec{p}_{T\tau l} + \vec{p}_T^{\,\mathrm{miss}}\right|^2},$$

$$M_{o1} = \sqrt{\left(p_{T\tau} + p_{Tl} + p_T^{\mathrm{miss}}\right)^2 - \left|\vec{p}_{T\tau} + \vec{p}_{Tl} + \vec{p}_T^{\,\mathrm{miss}}\right|^2}.$$

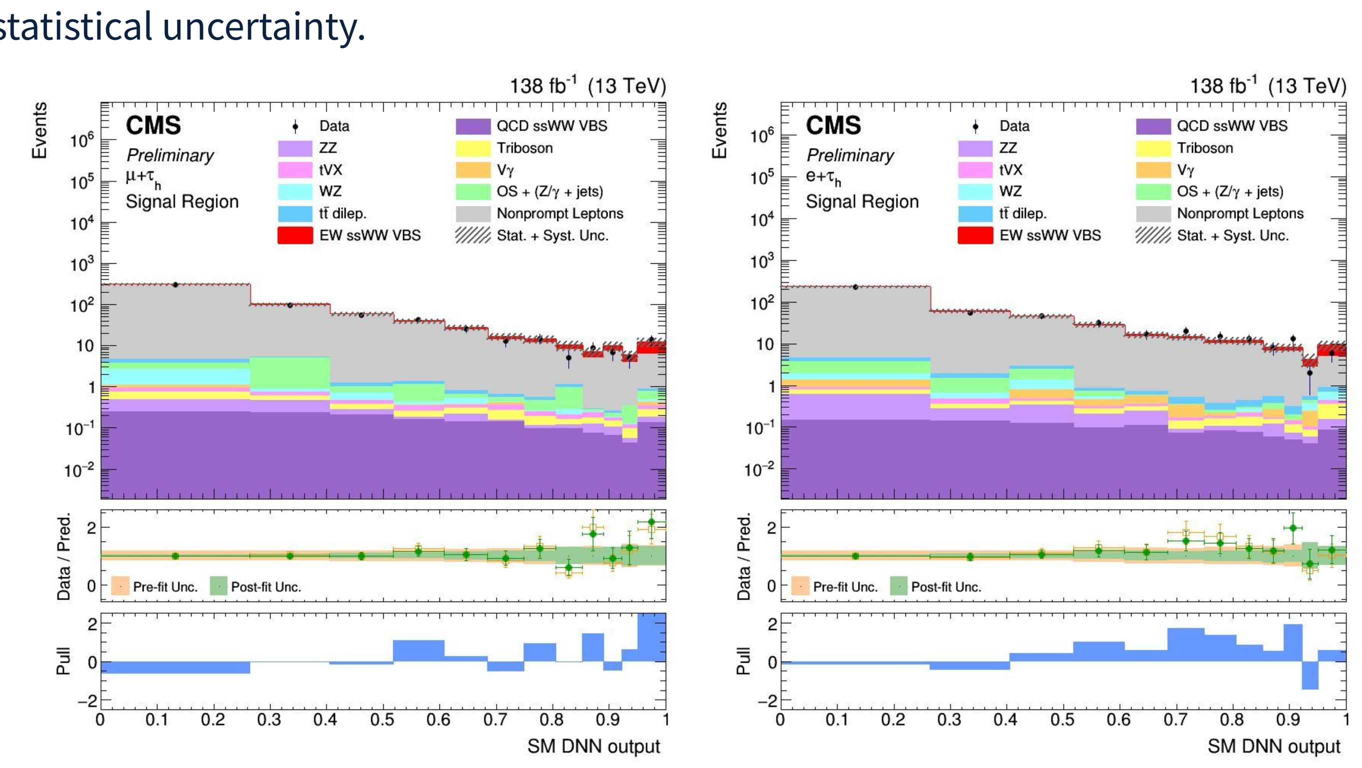


Results

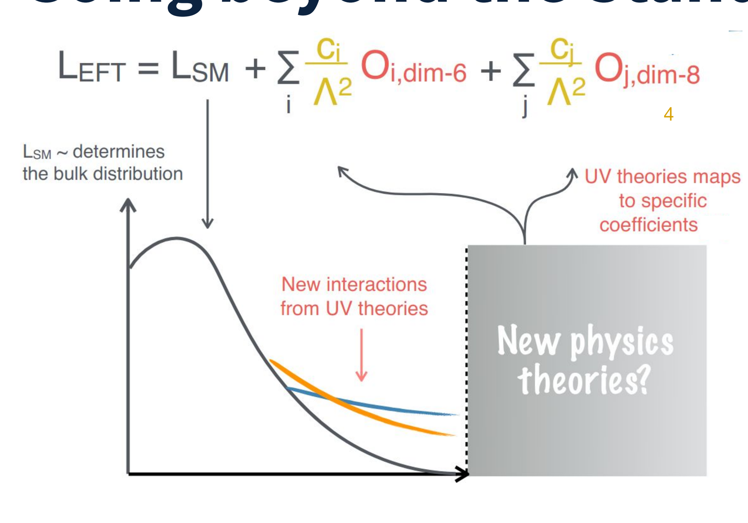
This study represents the **first search for same-sign W pair VBS processes with one hadronic tau** in the final state, showing a **relevant sensitivity** to both the pure EW and the combined EW + QCD-mediated contributions, in particular in the **μ + τ_h channel**. The overall uncertainty on the signal strength is mainly due to the data sample size and the background estimation statistical uncertainty.

$$\mu_{obs} = 1.44^{+0.63}_{-0.56}$$
$$\mu_{exp} = 1.00^{+0.60}_{-0.53}$$

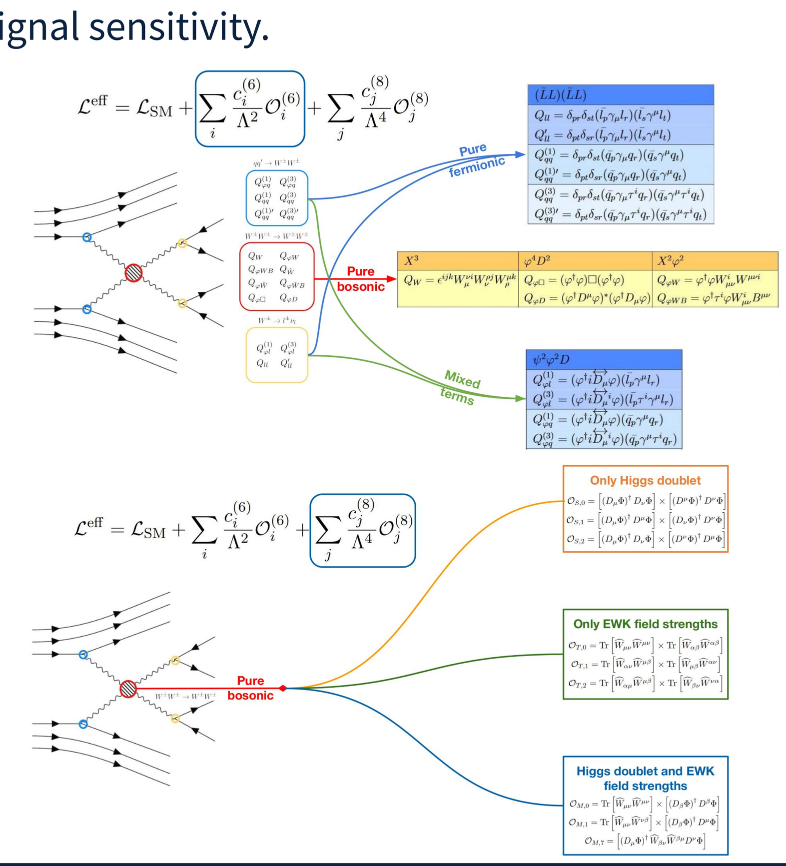
Signal	Significance [σ] Expected	Observed
pure EW ssWW VBS	1.94	2.74
EW + QCD ssWW VBS	2.04	2.87



Going beyond the Standard Model: an Effective approach



New physics phenomena (NP) at an energy scale $\Lambda >> \Lambda_{SM}$ can induce **deviations from SM** predictions that can be parametrized with **Effective Field Theories (EFT)**. VBS processes are very suitable to study such NP footprints, and the presence of a tau lepton in the final state could enhance the signal sensitivity.



This analysis aims at modeling indirect NP effects with **dim-6 SMEFT** operators [3] and **dim-8 Eboli** operators [4], investigating for the first time the **combined effect of EFT operators with different dimensions**.

The results will be crucial to understand the **interplay of two different classes of operators** affecting an SM process at the same Λ order in the EFT Taylor expansion. That will pave the way to **future similar investigations** with the additional data CMS and ATLAS are collecting during the **Run 3 data taking period** of the LHC at CERN.

References

[1] DOI : 10.1142/S0217751X2130009X. arXiv: 2102.10991 [hep-ph]
[2] DOI : 10.1088/1748-0221/13/10/P10005. arXiv: 1809.02816 [hep-ex]
[3] DOI : 10.1016/0550-3213(86)90262-2
[4] DOI : 10.1103/PhysRevD.93.093013. arXiv: 1604.03555 [hep-ph]
[5] CMS-PAS-SMP-22-008

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