Study of vector boson scattering and search for new physics in events with two same-sign leptons and two jets

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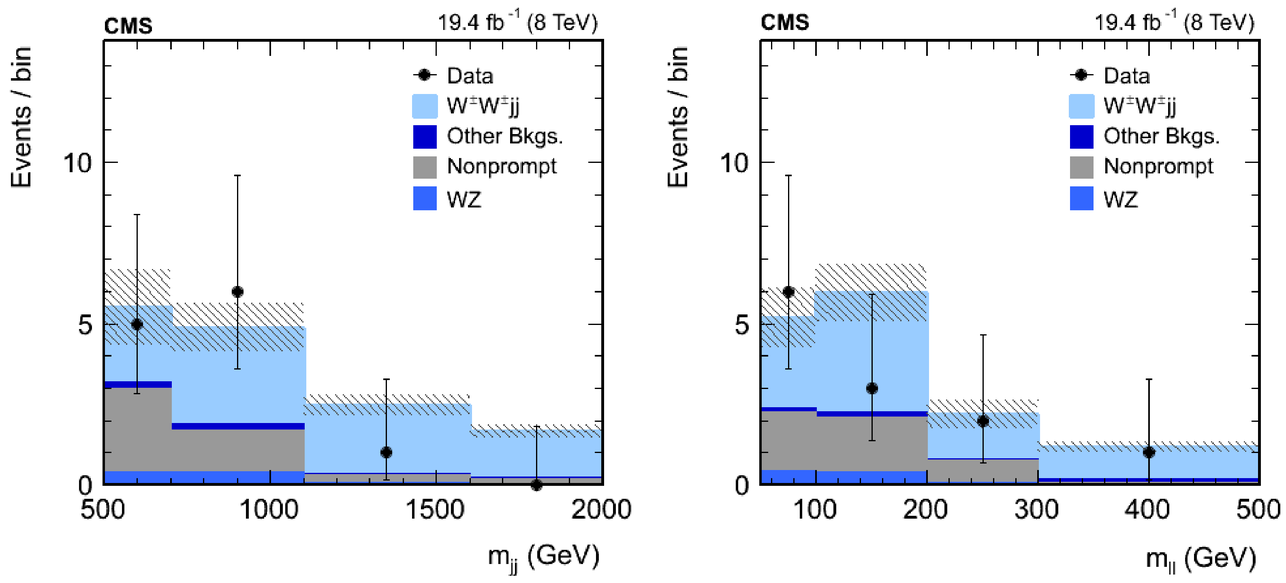
Introduction

Studying $W^{\pm}W^{\pm}jj$ production is an excellent way to probe the mechanism of electroweak symmetry breaking, to search for heavy particles that couple to vector bosons, and to test Standard Model predictions for how vector bosons interact. This final state can be cleanly isolated from most Standard Model backgrounds by requiring a high dijet invariance mass, significant missing transverse energy, and exactly two leptons with the same charge.

Observed Distributions



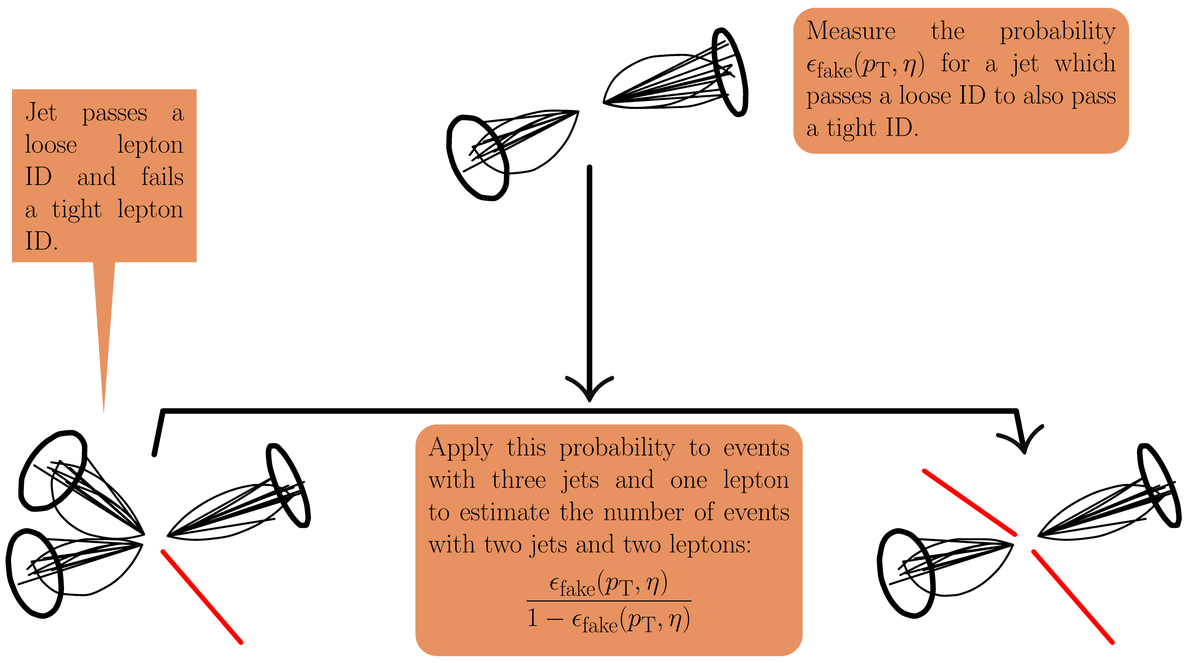
Fiducial Cross Section Measurement

$$\sigma_{\text{observed}}(W^{\pm}W^{\pm}jj) = 4.0^{+2.4}_{-2.0}(\text{stat})^{+1.1}_{-1.0}(\text{syst}) \text{ fb}$$
$$\sigma_{\text{expected}}(W^{\pm}W^{\pm}jj) = 5.8 + 1.2 \text{ fb}$$

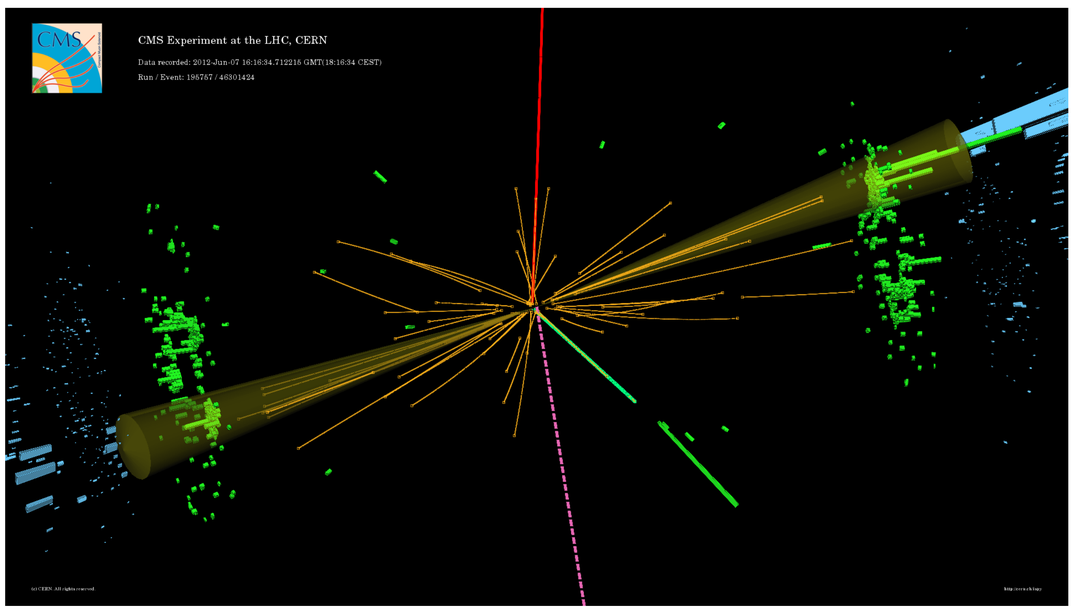
Fiducial region definition:

- $p_T^l > 10$ GeV
- $|\eta_l| < 2.5$
- $p_T^j > 20$ GeV
- $|\eta_j| < 5.0$
- $m_{jj} > 300$ GeV
- $|\Delta\eta_{jj}| > 2.5$

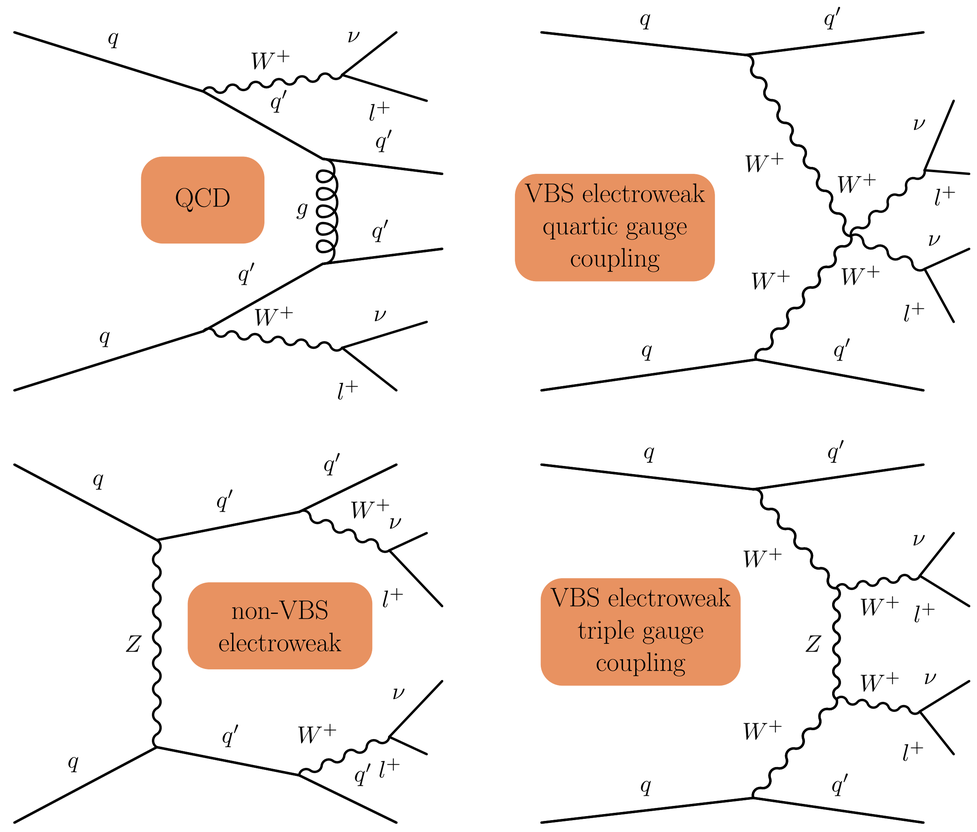
Fake Lepton Background



Charged hadrons can be reconstructed as leptons in our detector. In addition, leptons can be produced inside of jets. Such "fake leptons" are not modeled well in Monte Carlo simulations, so a method to estimate this background which relies exclusively on data, called the loose-to-tight method, was developed. This method, which captures the contribution to the signal region from events with at least one lepton not from the decay of a W or a Z, is illustrated above.



Production Mechanisms



More than 50 thousand Feynman diagrams contribute to the $W^{\pm}W^{\pm}jj$ in the Standard Model at lowest order, including both $O(\alpha_{\text{EW}}^6\alpha_{\text{QCD}}^0)$ diagrams and $O(\alpha_{\text{EW}}^4\alpha_{\text{QCD}}^2)$ diagrams.

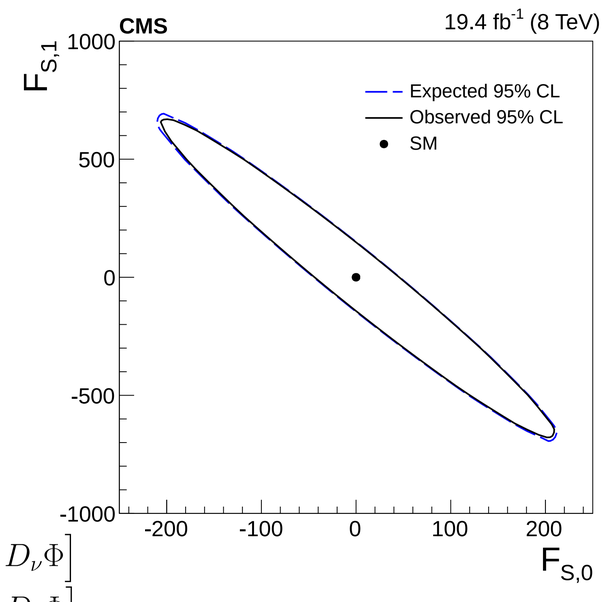
Anomalous Quartic Gauge Couplings

Additional terms can be added to the Standard Model to model physics that occurs at a higher mass scale Λ:

$$\mathcal{L} = \mathcal{L}_{\text{SM}} + \sum_i \frac{F_i}{\Lambda^4}\mathcal{O}_i$$

The $\mathcal{O}_i$ operators are constructed out of the operators in the Standard Model Lagrangian such as the Higgs field Φ. For example, two possible operators that affect the $WWWW$ vertex are

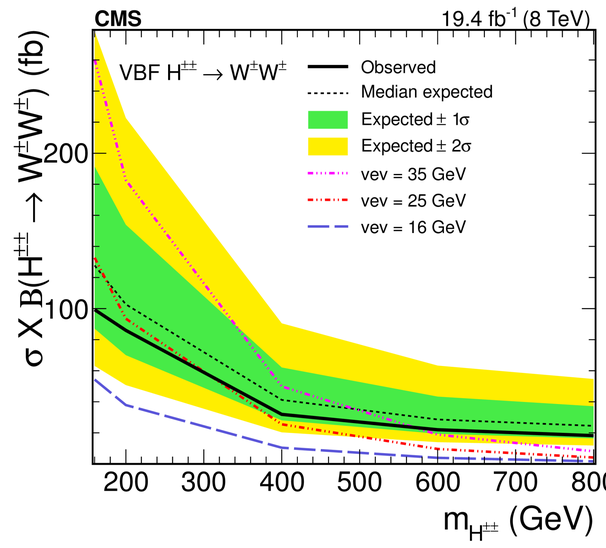
$$L_{S,0} = \left[(D_\mu\Phi)^\dagger D_\nu\Phi\right] \times \left[(D_\mu\Phi)^\dagger D_\nu\Phi\right]$$
$$L_{S,1} = \left[(D_\mu\Phi)^\dagger D^\mu\Phi\right] \times \left[(D_\nu\Phi)^\dagger D_\nu\Phi\right]$$



The plot above shows the observed and expected limits that we have set on the coefficients of these operators.

Doubly Charged Higgs Model

The Georgi-Machacek Higgs Triplet model includes ten Higgs bosons with four masses, including two doubly charged Higgs bosons: H^{++} and H^{--}. The decay of these Higgs bosons into two W bosons would produce an enhancement in our signal region, depending the vacuum expectation value of the Higgs field. Limits were set on the $H^{\pm\pm}$ production cross section times the branching ratio of $H^{\pm\pm}$ to $W^{\pm}W^{\pm}$.



Event Display

This event display shows one of the selected $e\mu$ events. The muon is in red, the electron is in green, the MET is in majenta, the ECAL RecHits are in green, and the HCAL RecHits are in blue.

References

CMS collaboration, Phys. Rev. Lett. **114**, 051801 (2015).