

# Search for New Heavy Neutral Gauge Boson using Vector Boson Fusion Processes at the LHC

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on behalf of the CMS collaboration

Large Hadron Collider Physics Conference, June 2021

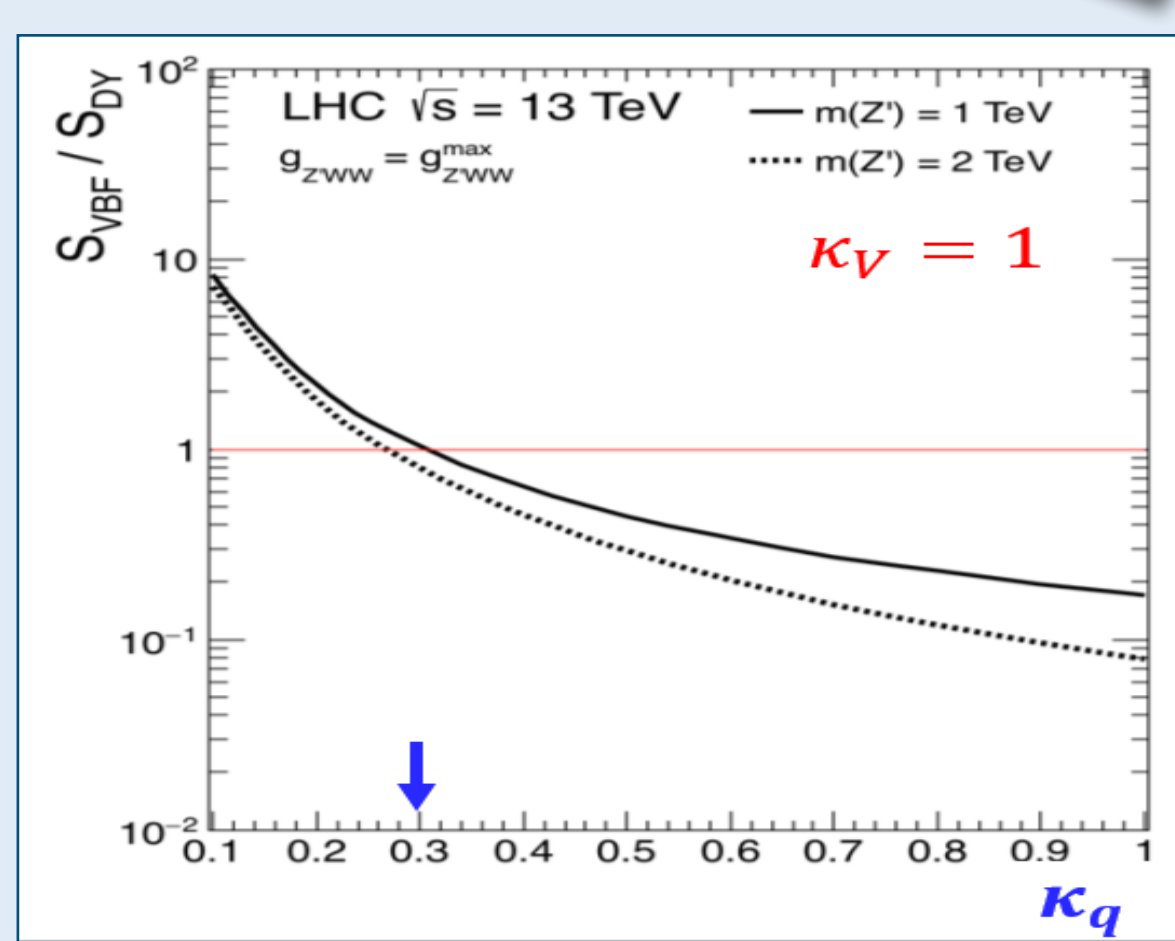
## Introduction

To address the incompleteness of the Standard Model (SM), various models are introduced with new gauge fields and interactions, which manifest as new particles with TeV scale masses. Thus, it is imperative to understand particles and interactions at the TeV scale. An example of one such particle is new heavy, neutral spin-1 gauge boson, denoted as  $Z'$ . A heavy  $Z'$  boson in  $ee$  and  $\mu\mu$  channels has not been seen at the LHC, considering a scenario where the  $Z'$  boson dominantly couples to gauge bosons and 3<sup>rd</sup> generation fermions. Thus this does not assume sizable coupling of the  $Z'$  boson to light quarks and leptons. This talk focuses on a search for  $Z'$  produced via vector boson fusion (VBF) processes, whose production rate is independent of the coupling to light quarks, and which has non-universal fermion couplings (NUFC). Scenarios with NUFC are motivated by the recent anomalies in the B-physics sector and the muon anomalous magnetic moment.

## Physics motivation



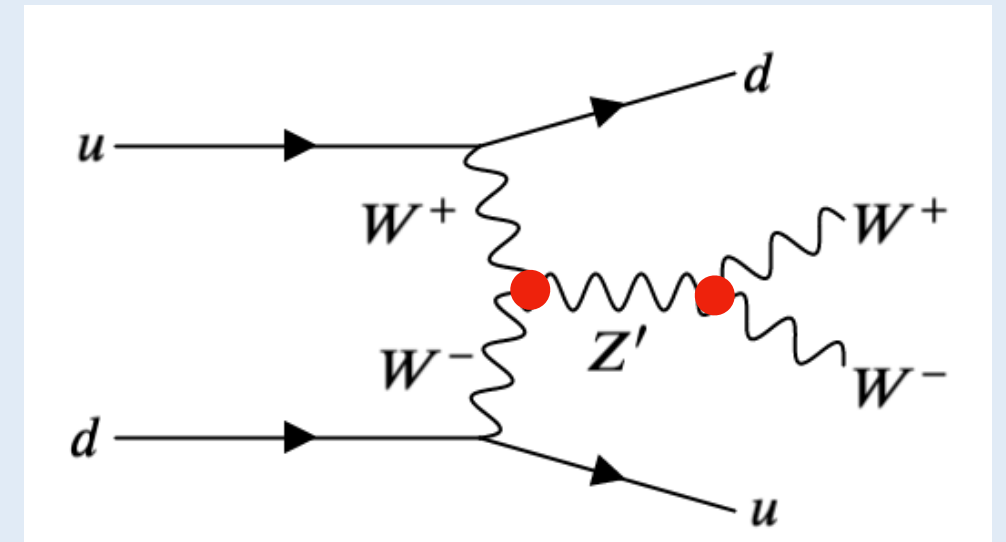
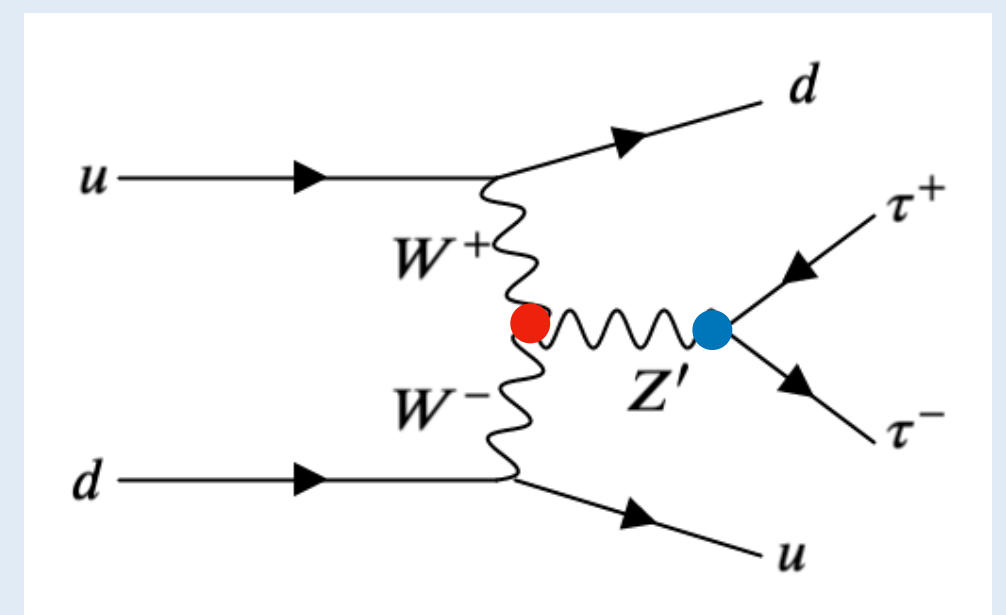
- New approach :** SSM + Coupling to vector bosons ( $\kappa_V$ ;  $g_{ZVV} = \kappa_V g_{ZVV}^{max}$ ) and non-universal coupling to quarks and leptons



- For small  $Z'$  coupling to quarks ( $\kappa_q = 0.3$ ), **signal significance is higher for VBF  $Z'$  than DY  $Z'$**
- Existing limit ( $\approx 4$  TeV for SSM) is based on DY production of  $Z'$  with its coupling to 1<sup>st</sup> gen. quarks

## Signal and Event selection

	$\ell\tau_h$ channel	$\tau_h\tau_h$ channel	$e\mu$ channel
$= 1\ell_1$	$\mu(e) p_T > 35$ (or 55) GeV, $ \eta  < 2.1$	$\tau_h p_T > 70$ GeV, $ \eta  < 2.1$	$\mu p_T > 35$ GeV, $ \eta  < 2.1$
$= 1\ell_2$	$\tau_h p_T > 70$ GeV, $ \eta  < 2.1$	$\tau_h p_T > 70$ GeV, $ \eta  < 2.1$	$e p_T > 10$ GeV, $ \eta  < 2.1$
$\geq 2$ jets	$p_T > 30$ GeV, $ \eta  < 5$		
	$MET > 30$ GeV		
$b$ jets = 0	$p_T > 30$ GeV, $ \eta  < 2.4$		
$= 1\ell_1\ell_2$	$OS, \Delta R > 0.3$		
<b>VBF Selections</b>	$M_{jj} > 500$ GeV, $\Delta\eta > 4.2, \eta_{j1} * \eta_{j2} < 0$		



- large  $\Delta\eta$  between two VBF jets lying in opposite hemisphere of the detector**
- Current physics search includes four channels:  $\tau_h\tau_h, \mu\tau_h, e\tau_h, e\mu$
- All four channels are also used for  $VBF Z' \rightarrow WW$  re-interpretation

## Background Estimation

### For $\tau_h\tau_h$ channel:

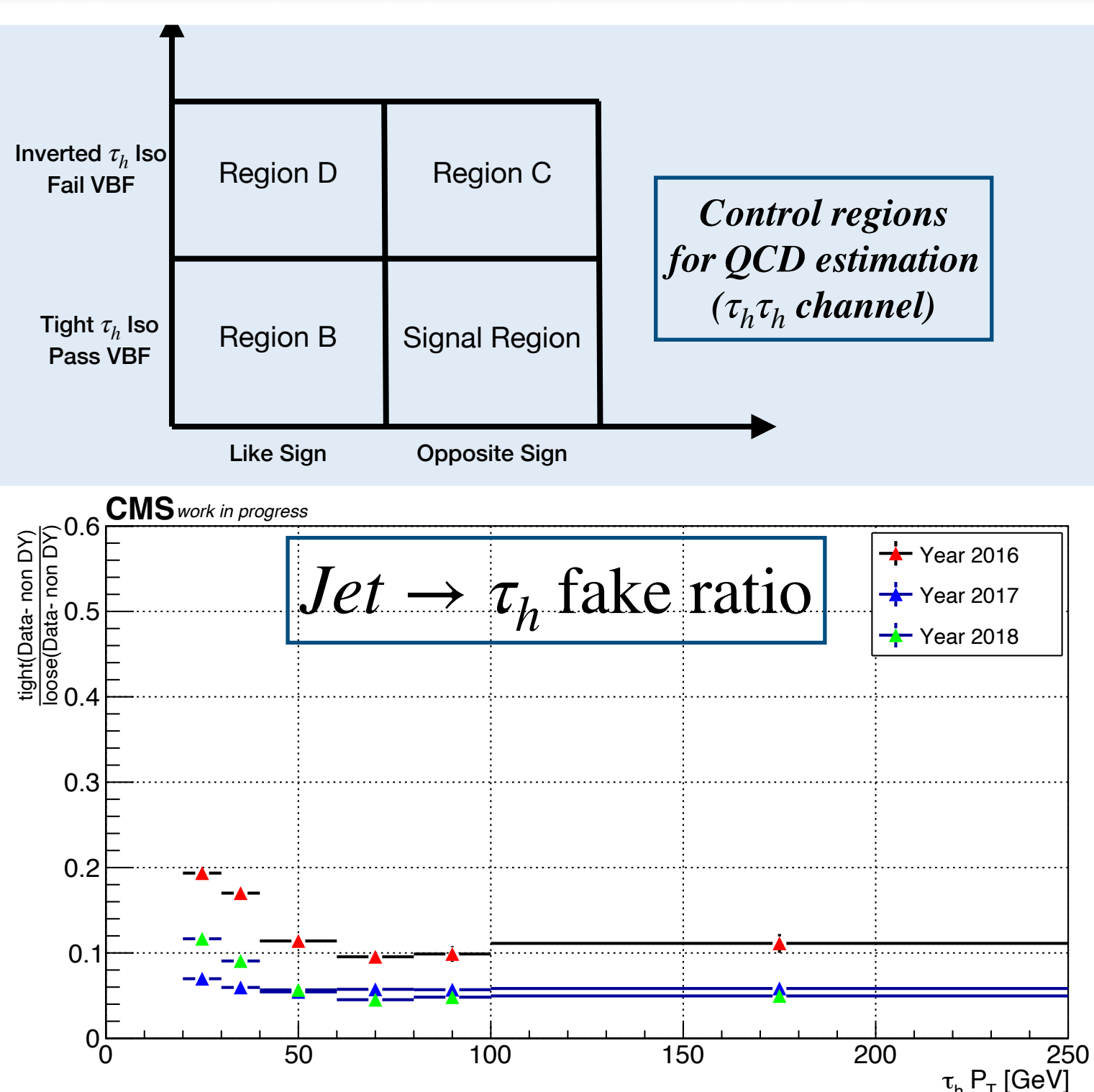
- main background : DY+Jets (75%)
- Estimation with DY enriched CR with failing/passing VBF
- Data-driven estimation of QCD bkg using  $R_{OS/LS}$

### For $\ell\tau_h$ channel:

- main background : Jet  $\rightarrow \tau_h$  fake bkg (70%)
- Fully data-driven estimation using Jet  $\rightarrow \tau_h$  fake ratio

### For $e\mu$ channel:

- main background :  $t\bar{t}$  (90%) estimated using  $t\bar{t}$  CR with varying bjet multiplicity (0, 1, 2 bjets) and failing/passing VBF selections



## Systematic Uncertainties

CMS work in progress		
	Systematic Uncertainty	Scale
Instrumental	Luminosity	1.2 - 2.5 %
	Pileup	5%
	Jet energy scale	$\sim 10\%$
	Jet energy resolution	$\sim 10\%$
	Trigger	3%
Theoretical	Muon momentum scale	2%
	Electron energy scale	2%
	Tau energy scale	4%
	MC bkg cross-section	2-5%
	Scale & PDF	0.4% & 2.1%
	Quark/gluon jet in fake $\tau_h$ bkg	3-10%

## Plans

- The reconstructed mass distribution of lepton pairs is probed to find an excess over smoothly falling standard model backgrounds
- Limits will be set on the production cross-section of  $Z'$  decaying to  $\tau\tau$  pairs and  $WW$  pairs for universal and non-universal coupling to light and heavy fermions with different coupling to vector bosons ( $\kappa_V : 0.1, 0.25, 0.50, 0.75, 1.0$ ) using full RunII data
- Finalizing expected limits in this blind analysis, before looking into Signal Region

### Reference :

- [1] CMS Collaboration, "The CMS experiment at the CERN LHC", JINST 3, S08004, 2008
- [2] Andrés Flórez et.al, "Searching for new heavy neutral gauge bosons using vector boson fusion processes at the LHC", Physics Letters B, Volume 767, 2017

