Sensitivity to Longitudinal VBS at future hadron colliders

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Contents

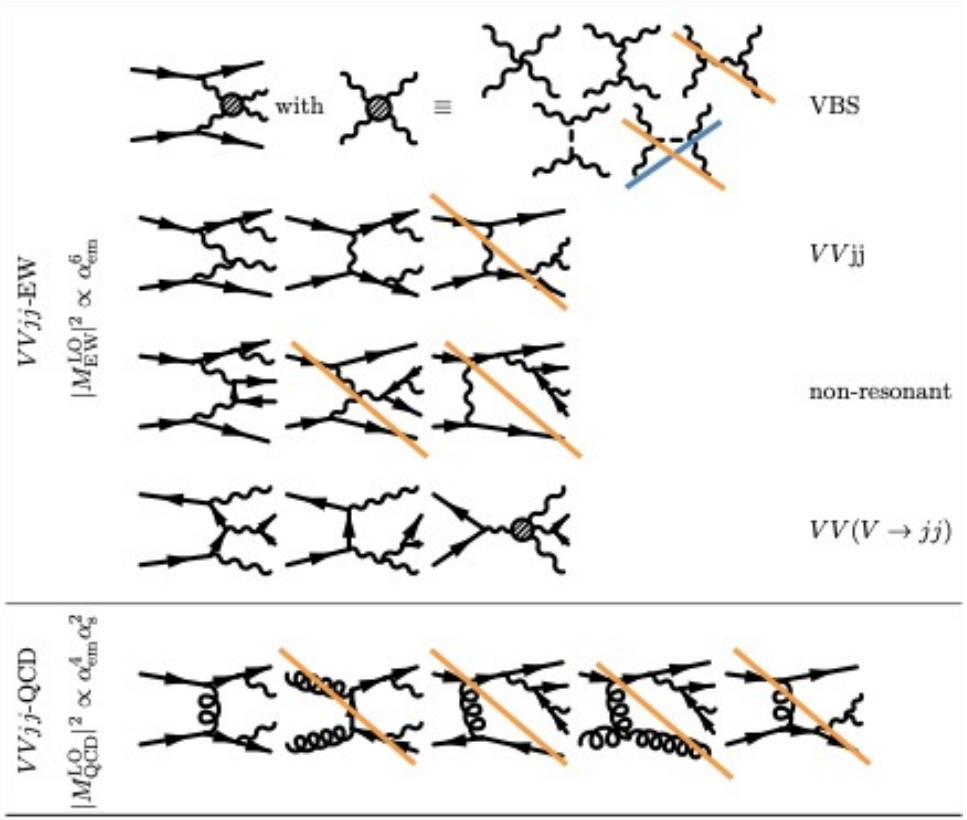
This presentation summarises the work of the paper, arxiv:2203.07994

Introduction

- VBS is a key probe of the electroweak symmetry breaking mechanism.
- Higgs contributions to longitudinally polarised VBS cancel divergences, preserving unitarity.
- The goal of our study is to investigate the prospect of measuring the polarized scattering of same-sign $W^{\pm}W^{\pm}jj$ production at a future high energy pp machine.

Introduction

- The leptonic decay mode of pure EW production of same-sign $W^{\pm}W^{\pm}jj$ is a promising final state; background contribution from the QCD-induced production of $W^{\pm}W^{\pm}jj$ is small.



Sample Generation

- Events modeled at LO using MG5 3.1.1+ with NNPDF2.3 PDF set and PYTHIA8 for showering.
- Signal: $W^{\pm}W^{\pm}jj$ electroweak samples generated,
  - $W_L^{\pm}W_L^{\pm}jj$
  - $W_L^{\pm}W_T^{\pm}jj$
  - $W_T^{\pm}W_T^{\pm}jj$
  - Inclusive $W^{\pm}W^{\pm}jj$ for validation.
- Background samples generated:
  - $W^{\pm}W^{\pm}jj$ QCD
  - $WZjj$ Electroweak and QCD
  - $tl^{+}l^{-}j$ (tZq).
- Samples simulated with Delphes using a generic FCC detector card to introduce detector effects.
- Samples generated for three CoM energies, $\sqrt{s} = 27, 50, 100$ TeV with an integrated luminosity of 30 ab^{-1} for pp collisions

Event Selection

- Signal events typically include
  - Two high p_T (transverse momentum) same-charge leptons
  - Large missing transverse momentum, E_T^{miss}
  - Two forward/backward jets with large di-jet invariant mass, M_{jj}
- Event selection applied to maximise background rejection.
- Event selection optimised for $\sqrt{s} = 100\,TeV$ and applied to all $\sqrt{s}$.

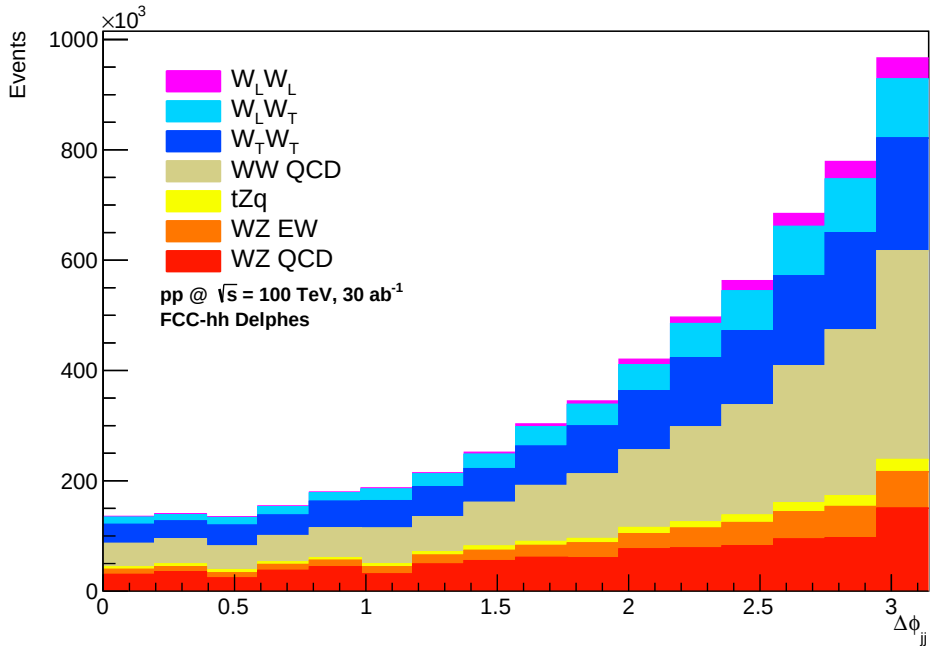
Event Selection

- Selection criteria used for $W^{\pm}W^{\pm}jj$ events.

Selection type	Requirement
Number of leptons	Exactly 2 same-charge leptons
Lepton p_T	$p_T \geq 15$ GeV
Number of jets	≥ 2
Jet p_T	$p_T \geq 50$ GeV
Di-lepton invariant mass	$M_{ll} \geq 60$ GeV
$Z-$veto	$\lvert M_{ll} - M_Z \rvert > 10$ GeV
Di-jet invariant mass	$M_{jj} \geq 2$ TeV
Missing transverse momentum	$E_T^{miss} \geq 50$ GeV

Analysis

- The sensitivity to the polarization fractions is estimated using a profile likelihood fit.
  - Normalization uncertainty of 2% applied to all processes.
  - Uncertainties with limited number of simulated events included.
  - No other sources of systematic uncertainties are considered.
- The distribution used in the fit, $\Delta\phi_{jj}$, is shown below for $\sqrt{s} = 100$ TeV after event selection.



- Where $\Delta\phi_{jj}$ is separation in azimuthal angle ϕ between the two leading jets in p_T.

Results

- The table shows three signal strength parameters, μ_{LL} , μ_{LT} and μ_{TT} defined as the ratio to the SM cross-section.

Polarization	Signal Strength		
	$\sqrt{s} = 27$ TeV	$\sqrt{s} = 50$ TeV	$\sqrt{s} = 100$ TeV
μ_{LL}	1 ± 0.39	1 ± 0.22	1 ± 0.17
μ_{LT}	1 ± 0.11	1 ± 0.10	1 ± 0.04
μ_{TT}	1 ± 0.08	1 ± 0.05	1 ± 0.02

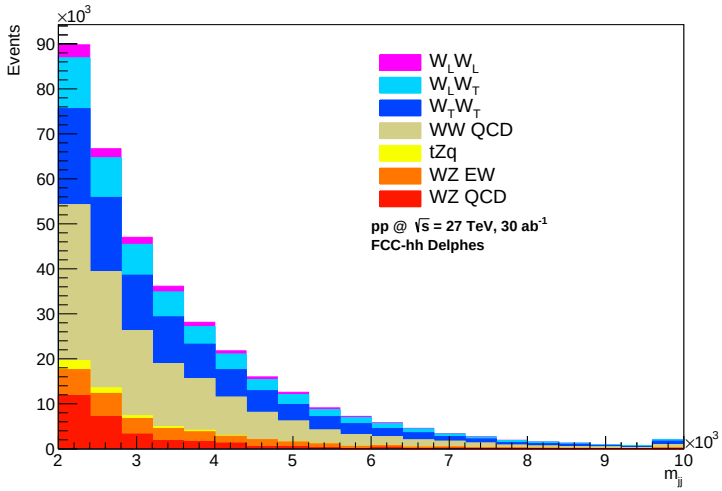
Future Work

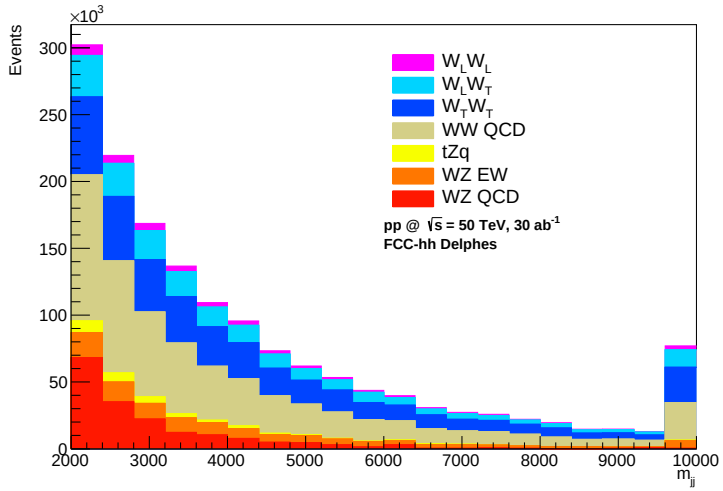
- Generate new samples with much higher statistics and latest PDF set
- Introduce theory uncertainties
- Introduce another discriminating variable based on machine learning
- Look at our sensitivity to BSM models, e.g. doubly charged Higgs model
- Any of your suggestions?

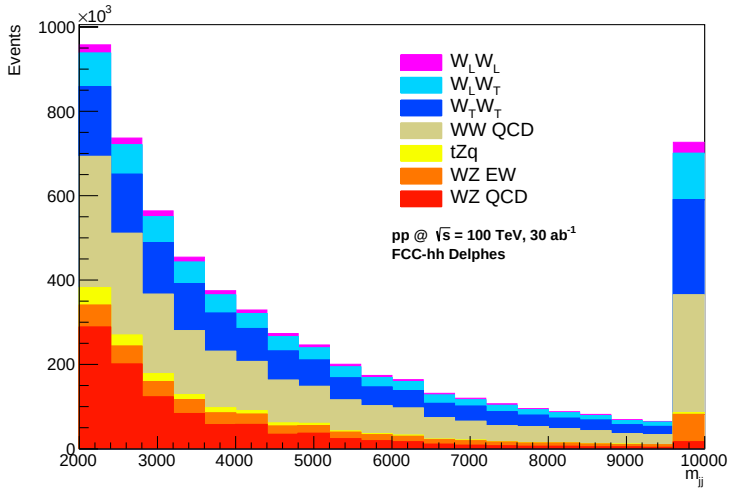
Backup - Event yields

Process	Signal Region		
	$\sqrt{s} = 27$ TeV	$\sqrt{s} = 50$ TeV	$\sqrt{s} = 100$ TeV
$W_L W_L$	12503.6 ± 4795.85	48531.4 ± 10527.6	163489 ± 26922.9
$W_L W_T$	52144.3 ± 5574.84	203074 ± 18270.4	688367 ± 26560.9
$W_T W_T$	95923.2 ± 6455.61	396749 ± 19167.6	1423190 ± 26148.2
WW QCD	138386 ± 2488.8	577235 ± 4828.33	2099750 ± 12029
tZq	5203.87 ± 93.9418	32999.1 ± 275.972	153951 ± 860.373
WZ EW	26343.7 ± 475.701	115216 ± 964.227	425249 ± 2412.36
WZ QCD	28343.9 ± 505.25	174787 ± 1457.15	1002530 ± 5522.47
Total	198277 ± 598.02	900238 ± 1249.77	3681480 ± 2437.95

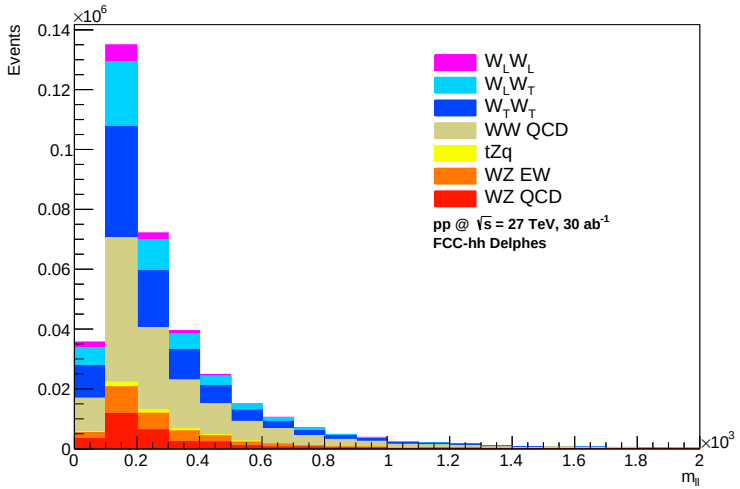
Backup: Mjj

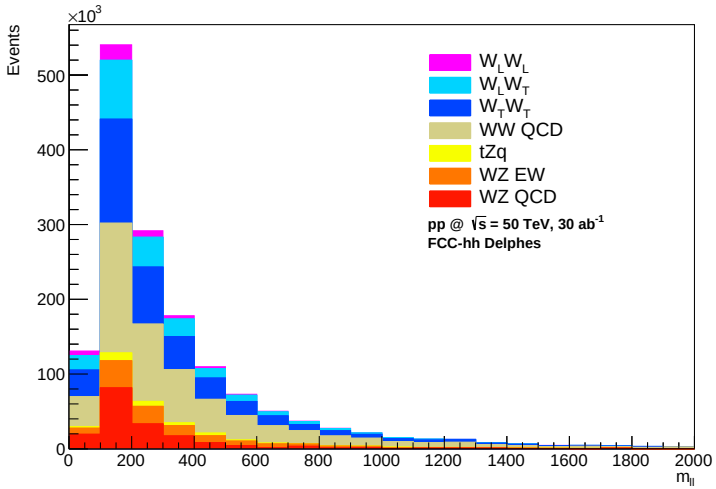

Events
×10^3
W_LW_L
W_LW_T
W_TW_T
WW QCD
tZq
WZ EW
WZ QCD
pp @ √s = 27 TeV, 30 ab^-1
FCC-hh Delphes
m_jj

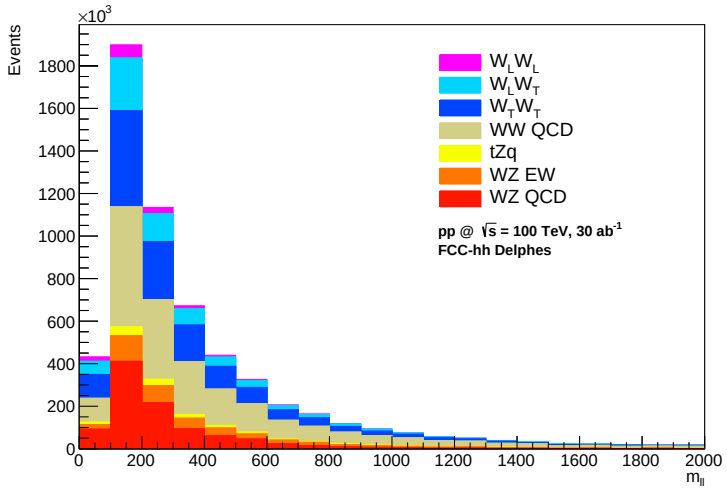

Events
×10^3
W_LW_L
W_LW_T
W_TW_T
WW QCD
tZq
WZ EW
WZ QCD
pp @ √s = 50 TeV, 30 ab^-1
FCC-hh Delphes
m_jj


Events
×10^3
W_LW_L
W_LW_T
W_TW_T
WW QCD
tZq
WZ EW
WZ QCD
pp @ √s = 100 TeV, 30 ab^-1
FCC-hh Delphes
m_jj

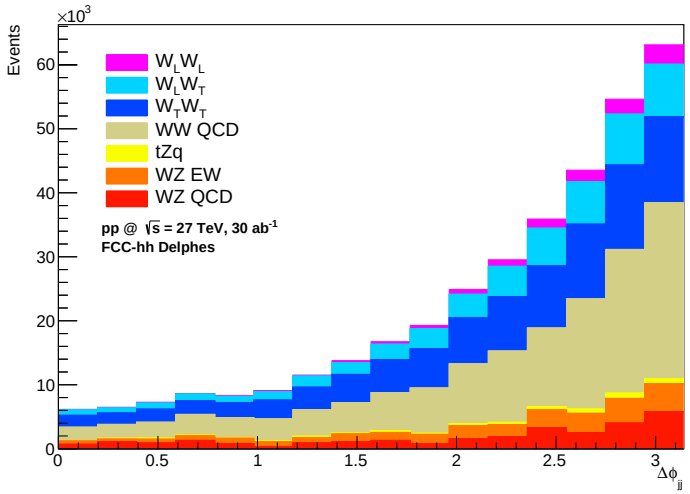
Backup: Mll

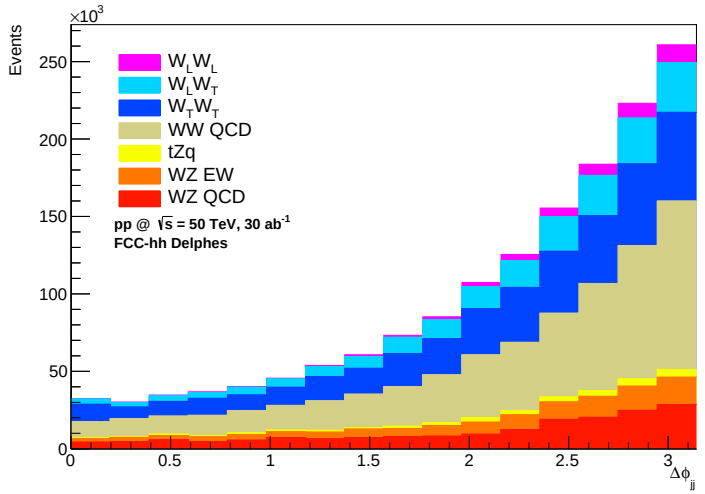

Events
×10^6
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
×10^3
m_ll
W_LW_L
W_LW_T
W_TW_T
WW QCD
tZq
WZ EW
WZ QCD
pp @ √s = 27 TeV, 30 ab^-1
FCC-hh Delphes

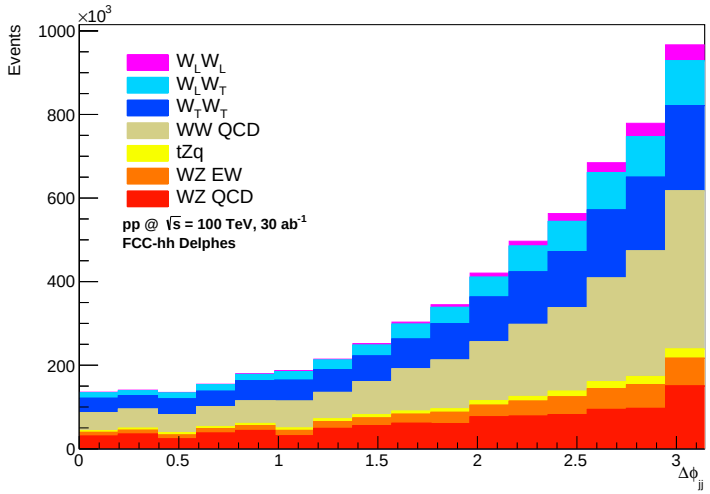

Events
×10^3
500
400
300
200
100
0
0 200 400 600 800 1000 1200 1400 1600 1800 2000
m_ll
W_LW_L
W_LW_T
W_TW_T
WW QCD
tZq
WZ EW
WZ QCD
pp @ √s = 50 TeV, 30 ab^-1
FCC-hh Delphes


Events
×10^3
1800
1600
1400
1200
1000
800
600
400
200
0
0 200 400 600 800 1000 1200 1400 1600 1800 2000
m_ll
W_LW_L
W_LW_T
W_TW_T
WW QCD
tZq
WZ EW
WZ QCD
pp @ √s = 100 TeV, 30 ab^-1
FCC-hh Delphes

Backup: $\Delta\phi_{jj}$







Backup: $\Delta\eta_{jj}$