Latest diboson polarization measurements at the LHC

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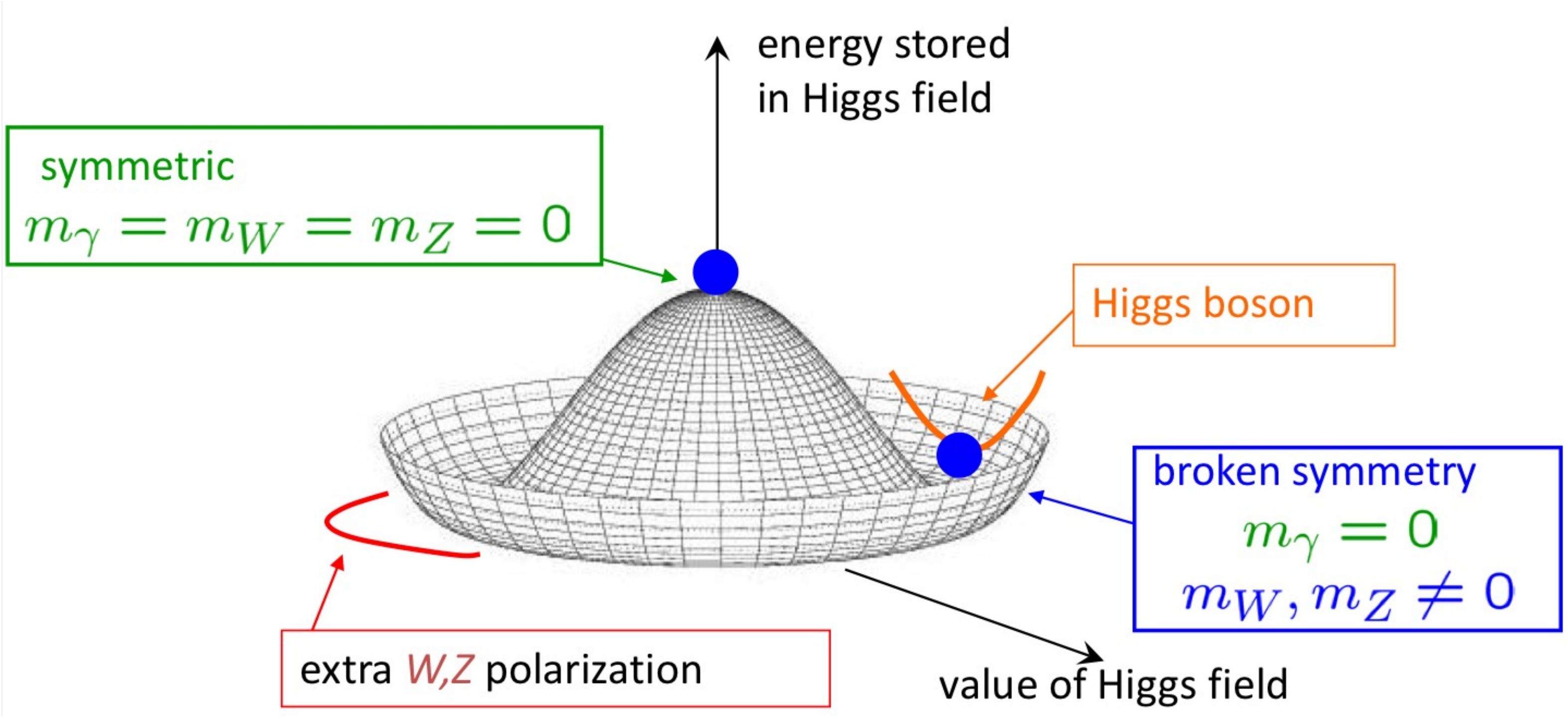
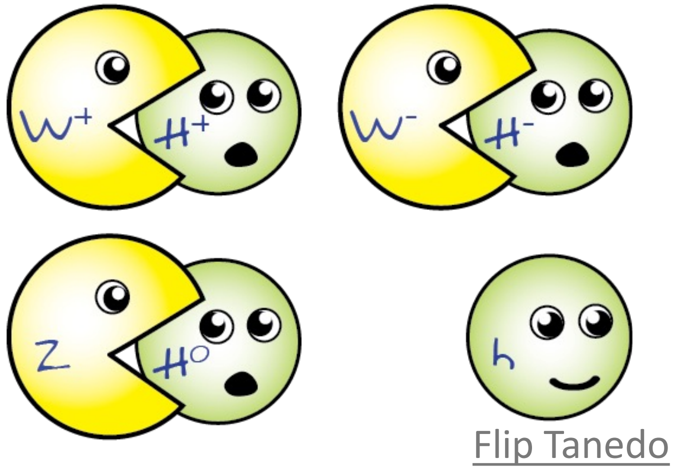
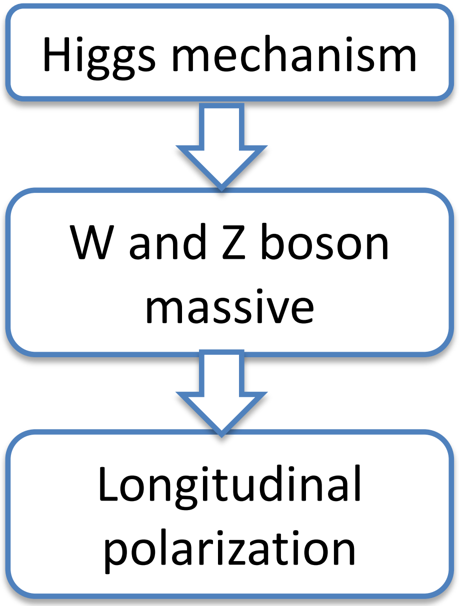
Introduction

- The longitudinally polarization measurement of massive W and Z bosons is a direct way to probe the EWSB mechanism







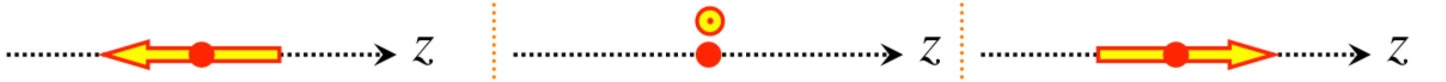
Goldstone boson theorem:
"At high energy, longitudinal vector bosons are analogous to goldstone bosons"

Boson polarization

- Helicity: $h = \frac{\vec{S}\cdot\vec{p}}{|\vec{p}|}$ (spin $\vec{S}$, momentum $\vec{p}$)
  - Transversal (T): left-/right-handed ($h = -/+1$)
  - Longitudinal (L): spin orthogonal to the momenta ($h = 0$)
- Polarization vectors in the helicity basis:

★ **For a spin-1 boson travelling along the z-axis, the polarization four vectors are:**

$$\varepsilon_-^\mu = \frac{1}{\sqrt{2}}(0,1,-i,0); \quad \varepsilon_L = \frac{1}{m}(p_z,0,0,E) \quad \varepsilon_+^\mu = -\frac{1}{\sqrt{2}}(0,1,i,0)$$



$\boxed{S_z = -1}$ $\boxed{S_z = 0}$ $\boxed{S_z = +1}$

transverse **longitudinal** **transverse**

Longitudinal polarization isn't present for on-shell massless particles, the photon can exist in two helicity states $h = \pm 1$ (LH and RH circularly polarized light)

Mark Thomson

Polarization and Spin Density Matrix

- The density matrix of $Z \to ll$ decay

R. Rahaman, R. Singh, arXiv:2109.09345

$$\Gamma = \frac{1}{4}\begin{pmatrix} \overbrace{\boxed{1+\cos^2\theta - 2\eta_\ell\cos\theta}}^{f_L} & \frac{1}{\sqrt{2}}\left(\sin 2\theta - 2\eta_\ell \sin\theta\right)e^{i\varphi} & \left(1-\cos^2\theta\right)e^{i2\varphi} \\ \frac{1}{\sqrt{2}}\left(\sin 2\theta - 2\eta_\ell \sin\theta\right)e^{-i\varphi} & \boxed{2\sin^2\theta}\ f_0 & -\frac{1}{\sqrt{2}}\left(\sin 2\theta + 2\eta_\ell \sin\theta\right)e^{i\varphi} \\ \left(1-\cos^2\theta\right)e^{-i2\varphi} & -\frac{1}{\sqrt{2}}\left(\sin 2\theta + 2\eta_\ell \sin\theta\right)e^{-i\varphi} & \boxed{1+\cos^2\theta + 2\eta_\ell\cos\theta}\ f_R \end{pmatrix}$$

E. Gabrielli et al, arXiv:2302.00683

- The differential cross section is simply given by the SDM

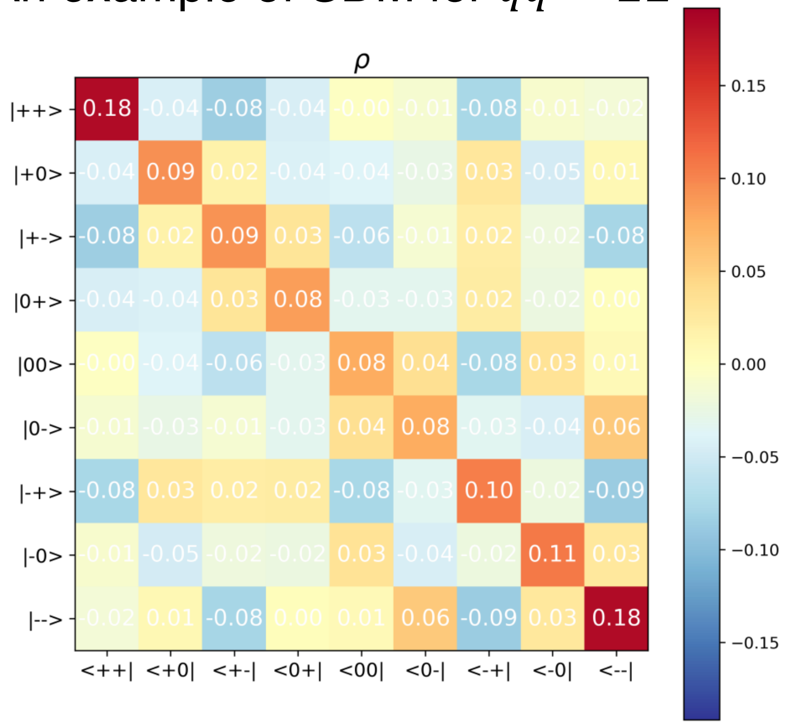
$$\frac{1}{\sigma}\frac{d\sigma}{d\Omega_1 d\Omega_2} = \left(\frac{3}{4\pi}\right)^2 \mathrm{Tr}\left\{\boxed{\rho}\,\boxed{(\Gamma_1 \otimes \Gamma_2)}^T\right\}$$

SDM for the V decay

SDM for the $pp \to VV$

$$\begin{aligned} f_{00} &= \rho_{0000}\,, \\ f_{\mathrm{TT}} &= \rho_{++--} + \rho_{--++} + \rho_{----} + \rho_{++++}\,, \\ f_{0\mathrm{T}} &= \rho_{00--} + \rho_{00++}\,, \\ f_{\mathrm{T}0} &= \rho_{--00} + \rho_{++00}\,. \end{aligned}$$

An example of SDM for $qq \to ZZ$



❖ Polarization merely contains reduced information of the SDM

❖ Ideally we want to measure the full SDM → quantum tomograph

Polarization and Spin Density Matrix

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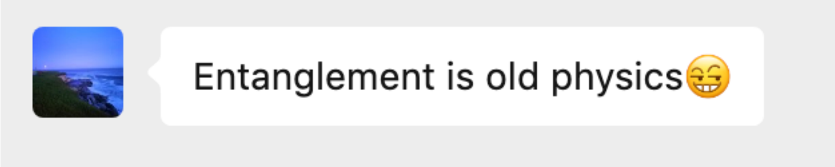

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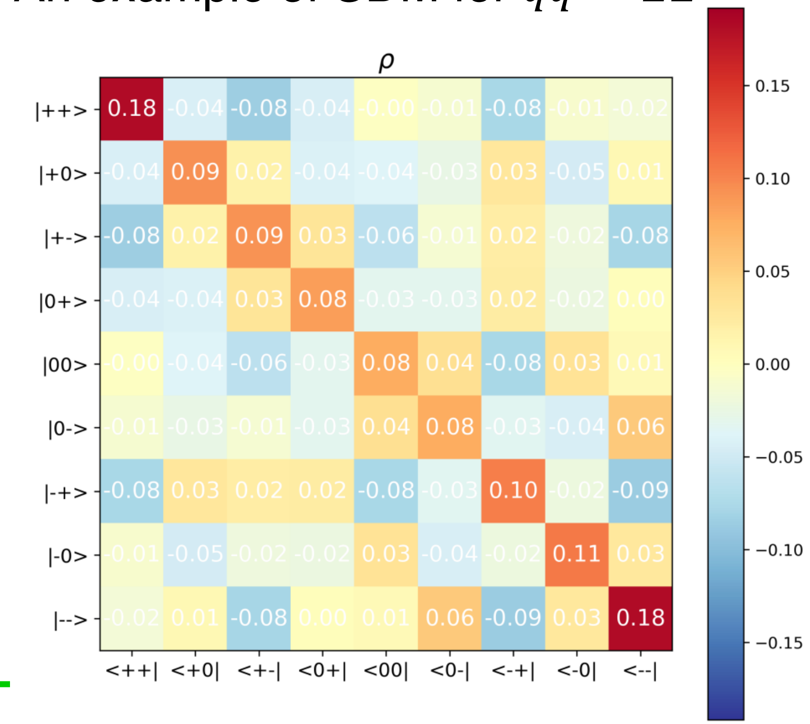


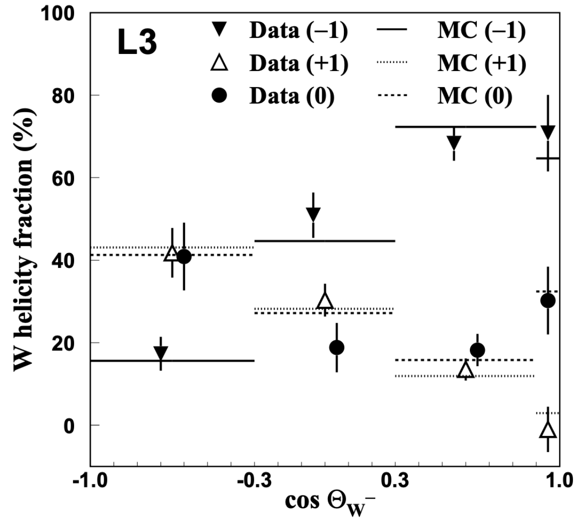
❖ Polarization merely contains reduced information of the SDM

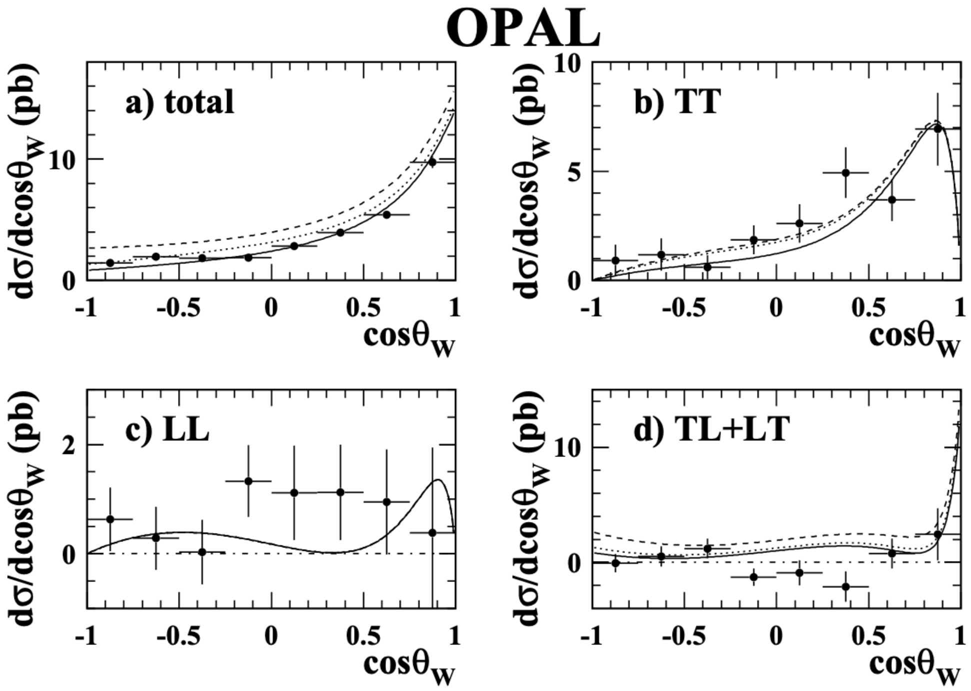
❖ Ideally we want to measure the full SDM → quantum tomograph

LEP Measurements

- Only $ee \to WW \to l\nu qq$ process accessible
- Single boson polarization
  - L3, arXiv:hep-ex/0301027
  - OPAL, arXiv:hep-ex/0312047
  - DELPHI, arXiv:0801.1235
- Diboson polarization
  - OPAL, arXiv:hep-ex/0009021
  - DELPHI, arXiv:0908.1023

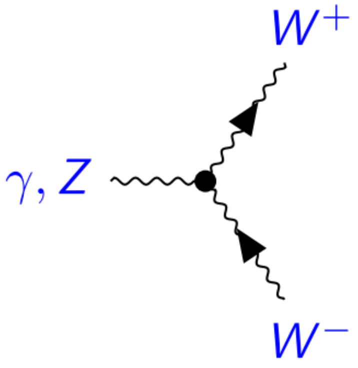
Never reached observation level sensitivity for longitudinal-longitudinal joint-polarization ($V_L V_L$)





Diboson polarization

- In diboson events, the polarizations of both bosons are quantum correlated
  - Joint polarization is described by the Spin Density Matrix
  - Closely connected to Quantum Entanglement and Bell non-locality
- Novel sensitivity to BSM



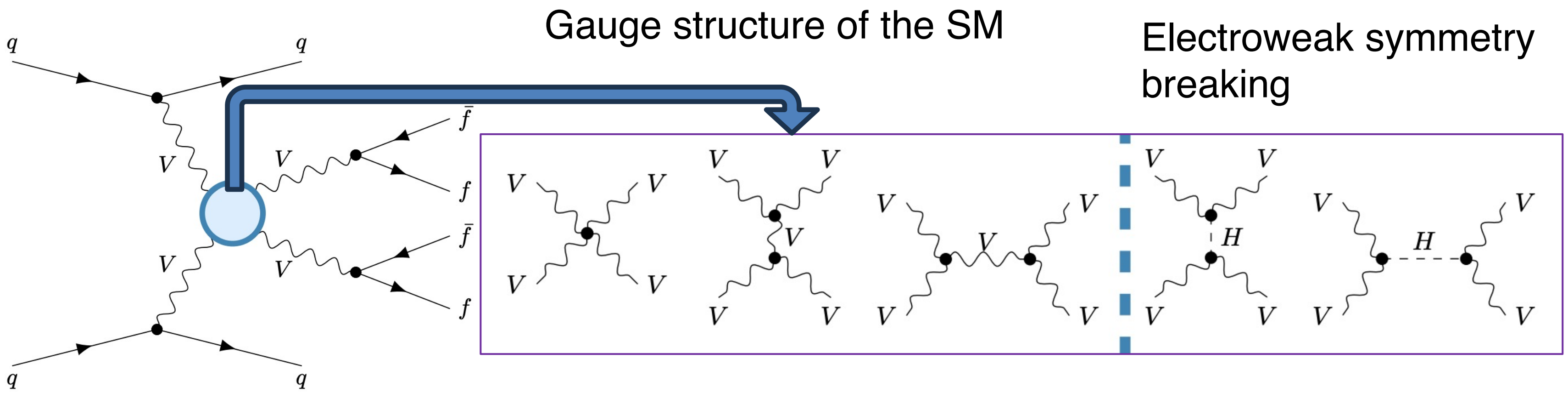
	SM	BSM
$q_{L,R}\bar{q}_{L,R} \to V_L V_L(h)$	~ 1	$\sim E^2/M^2$
$q_{L,R}\bar{q}_{L,R} \to V_\pm V_L(h)$	$\sim m_W/E$	$\sim m_W E/M^2$
$q_{L,R}\bar{q}_{L,R} \to V_\pm V_\pm$	$\sim m_W^2/E^2$	$\sim E^2/M^2$
$q_{L,R}\bar{q}_{L,R} \to V_\pm V_\mp$	~ 1	~ 1

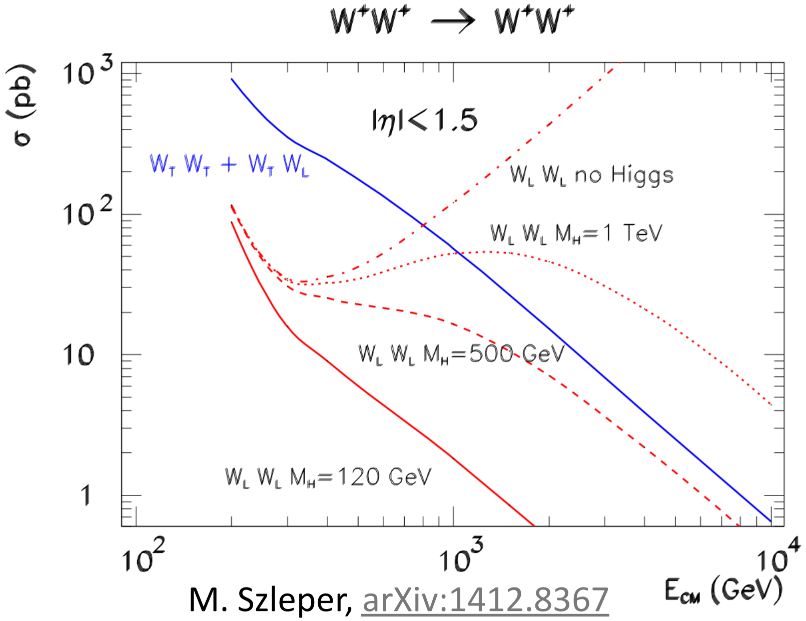
High-energy behavior of amplitudes with different diboson helicity configurations

F. Riva et al, arXiv:1712.01310

Polarization in VBS

- VBS: a no-lose theorem program for the LHC
  - We would have either discovered the Higgs boson or New Physics
- A primary goal in VBS is to measure the scattering of $V_L V_L \to V_L V_L$
  - Strict cancellation required to unitarize the high energy behavior

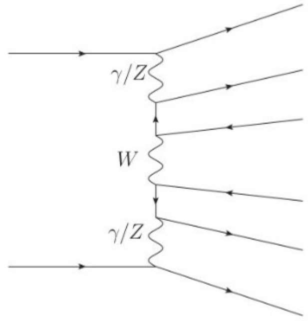




M. Szleper, arXiv:1412.8367

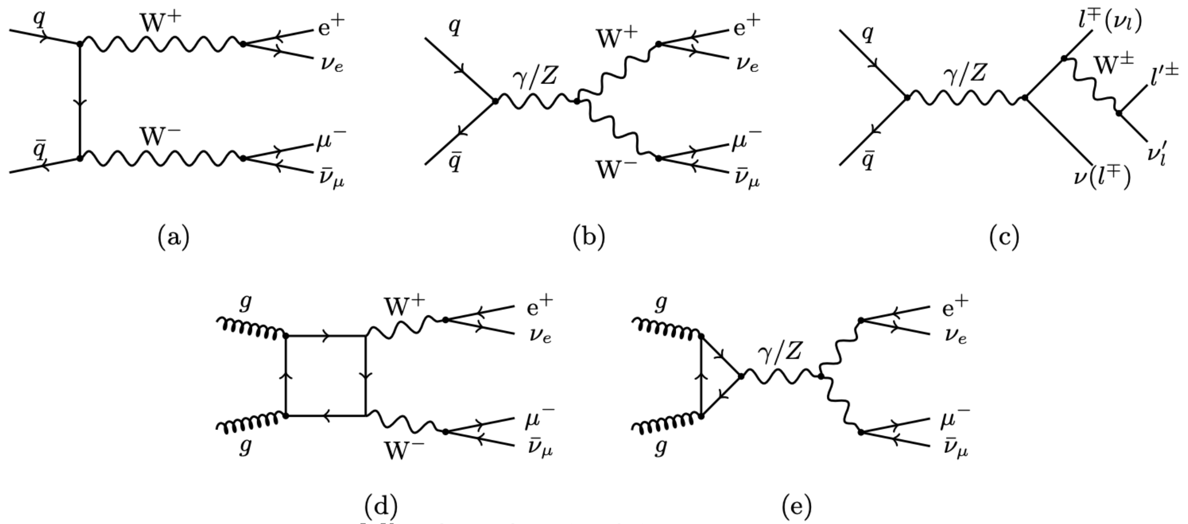
Theoretical challenges

- Two main obstacles for the direct theoretical calculations with polarized boson
  - Weak bosons can be produced off-shell and some adjustment is required to make sense of their polarization state
  - Non-resonant diagrams should be handled properly to keep gauge invariance
- Commonly used approaches
  - Narrow-Width Approximation (NWA)
  - On-shell projection (OSP)



$$\mathcal{M} = \sum_{\lambda=1}^{3} \mathcal{M}^{\mathcal{P}}{}_{\lambda} \frac{i}{k^2 - M^2 + i\Gamma_w M} \mathcal{M}^{\mathcal{D}}{}_{\lambda} = \sum_{\lambda=1}^{3} \mathcal{M}^{\mathcal{F}}{}_{\lambda},$$

$$\underbrace{|\mathcal{M}|^2}_{\text{coherent sum}} = \underbrace{\sum_{\lambda} |\mathcal{M}^{\mathcal{F}}{}_{\lambda}|^2}_{\text{incoherent sum}} + \underbrace{\sum_{\lambda \neq \lambda'} \mathcal{M}^{\mathcal{F}*}{}_{\lambda} \mathcal{M}^{\mathcal{F}}{}_{\lambda'}}_{\text{interference terms}} .$$

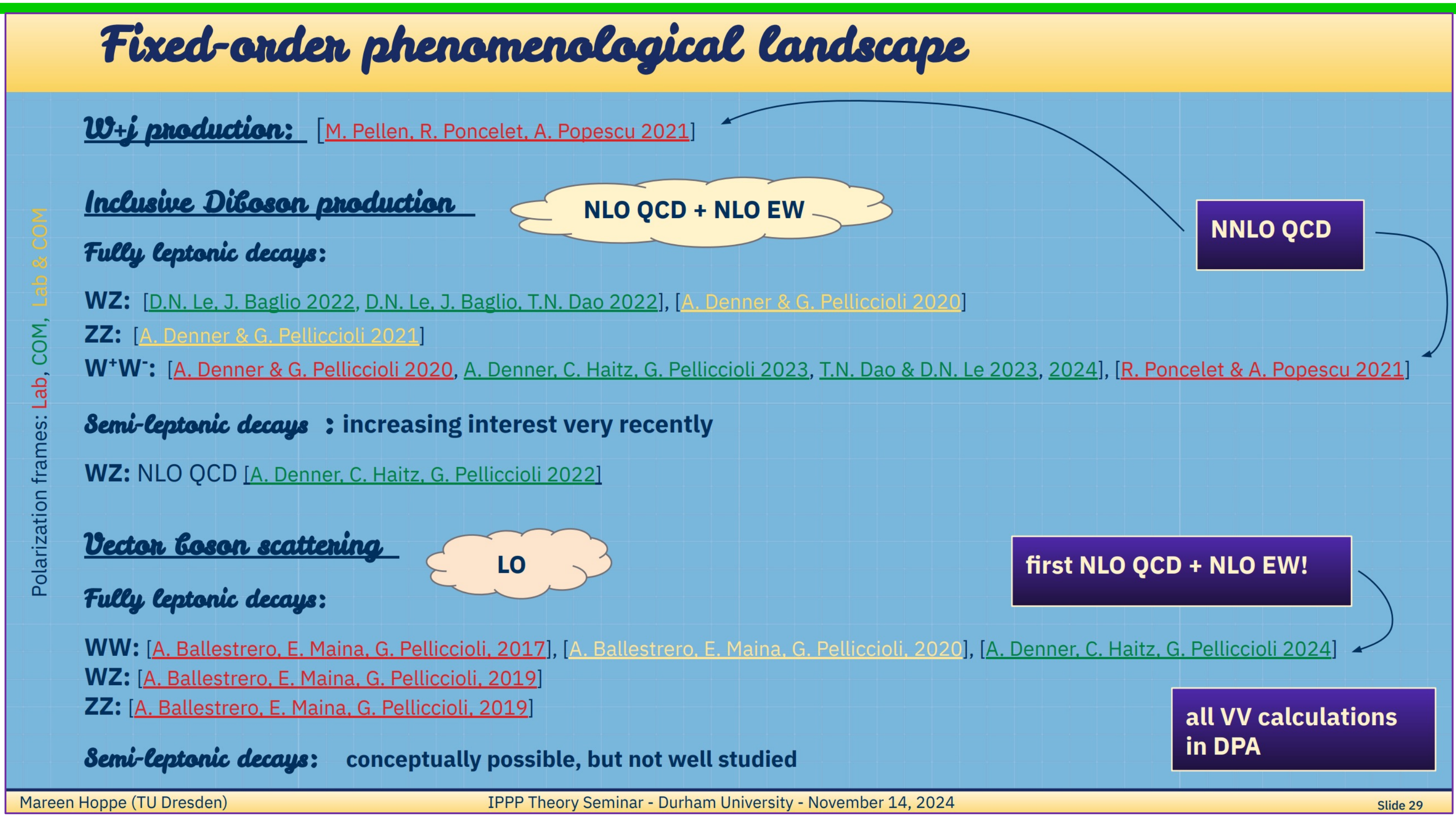


R. Poncelet, A. Popescu arXiv:2102.13583

G. Pelliccioli et al arXiv:1710.09339

Theoretical challenges

- Fixed-order calculations



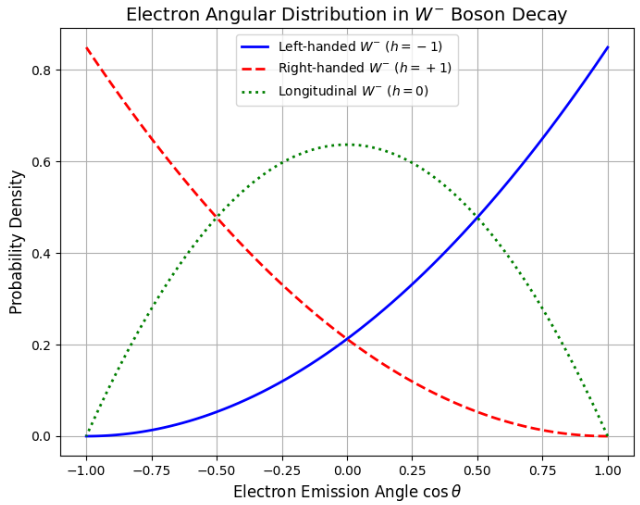
Mareen Hoppe's talk

See also a recent review, arXiv:2509.20232

- MC simulations (ME+PS)
  - PHANTOM: 2→6 processes @ LO+PS
  - MadGraph5: arbitrary processes @ LO+ PS, also with multi-jet merging
  - POWHEG-BOX-RES+PYTHIA: inclusive diboson processes @NLO QCD+PS
  - Sherpa3: arbitrary processes @nLO QCD+PS, multi-jet merging

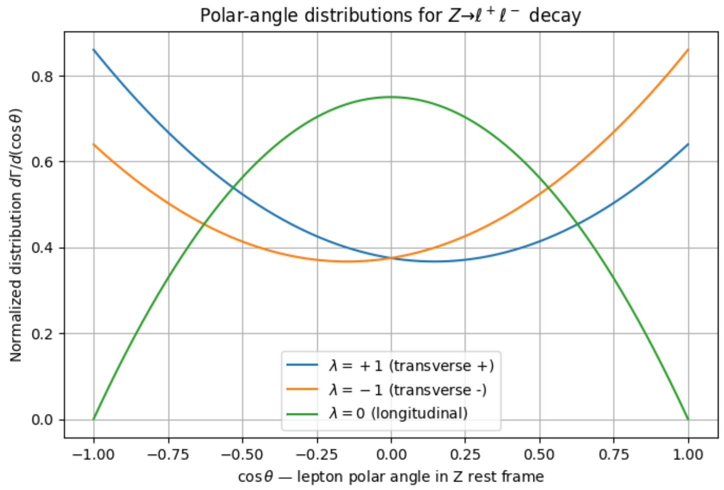
How to measure the polarization

- Helicity is not Lorentz invariant → reference frame dependent
  - For diboson, the center-of-mass frame of the diboson system is preferred
- Weak bosons are their own polarimeters:
  - The helicity of W and Z bosons is inferred from its decay products
- Polarization fractions extracted from template fits of angular variables or multivariate
  - The polarization fraction is also kinematically dependent



For $W^{\pm} \to l^{\pm} v$

$$\frac{1}{\frac{d\sigma(X)}{dX}} \frac{d\sigma(\theta, X)}{d\cos\theta\, dX} = \frac{3}{8}(1 \mp \cos\theta)^2 f_L(X) + \frac{3}{8}(1 \pm \cos\theta)^2 f_R(X) + \frac{3}{4}\sin^2\theta\, f_0(X)\,,$$



For $Z \to ll$

$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta^*_{\ell+}} = \frac{3}{4} f_{\mathrm{L}}\ \left(1-\cos^2\theta^*_{\ell+}\right) + \frac{3}{8} f_- \left(1+\cos^2\theta^*_{\ell+} - 2\cos\theta^*_{\ell+}\frac{c^2_{\mathrm{L},\ell}-c^2_{\mathrm{R},\ell}}{c^2_{\mathrm{L},\ell}+c^2_{\mathrm{R},\ell}}\right) + \frac{3}{8} f_+ \left(1+\cos^2\theta^*_{\ell+} + 2\cos\theta^*_{\ell+}\frac{c^2_{\mathrm{L},\ell}-c^2_{\mathrm{R},\ell}}{c^2_{\mathrm{L},\ell}+c^2_{\mathrm{R},\ell}}\right),$$

Inclusive diboson production

Diboson polarization

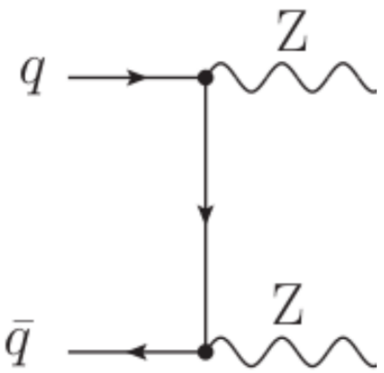
Why the LL fraction is smallest ?

Stable-Z approximation:

$$\varepsilon_-^\mu = \frac{1}{\sqrt{2}}(0, \cos\theta, -i, -\sin\theta),$$

$$\varepsilon_+^\mu = \frac{1}{\sqrt{2}}(0, -\cos\theta, -i, \sin\theta),$$

$$\varepsilon_L^\mu = \frac{1}{M}(p, E\sin\theta, 0, E\cos\theta) \xrightarrow{E \gg M} \frac{p^\mu}{M}$$



$$\frac{d\sigma_{LL}}{d\cos\theta} = \frac{a}{96}\frac{M_Z^4}{s^3}\frac{\cos^2\theta}{\sin^2\theta} + \mathcal{O}\left(\frac{1}{s^4}\right),$$

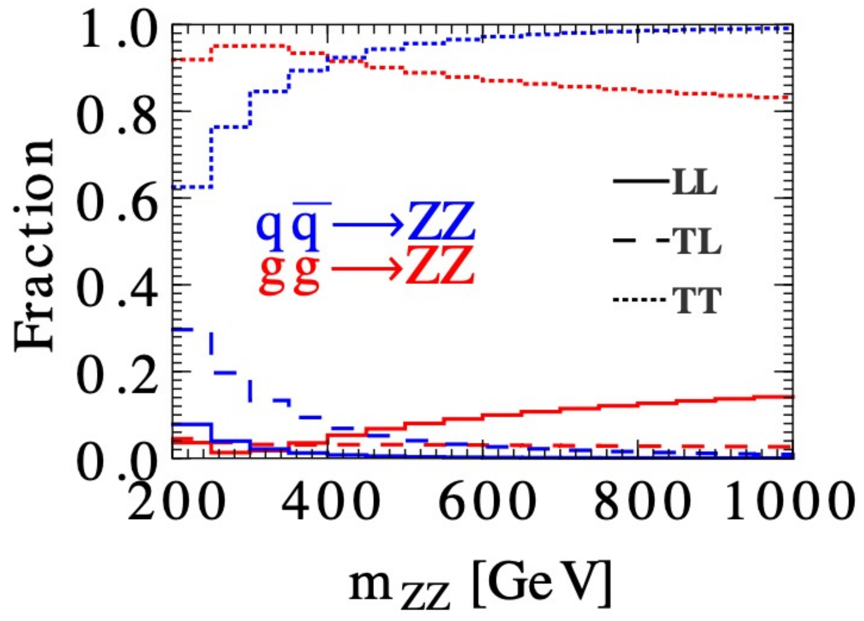
$$\frac{d\sigma_{LT}}{d\cos\theta} = \frac{a}{12}\frac{M_Z^2}{s^2} + \mathcal{O}\left(\frac{1}{s^3}\right),$$

$$\frac{d\sigma_{TT}}{d\cos\theta} = \frac{a}{48}\frac{1}{s}\frac{1+\cos^2\theta}{\sin^2\theta} + \mathcal{O}\left(\frac{1}{s^2}\right)$$

with $a = \pi\alpha^2(c_L^4 + c_R^4)/(s_W^4 c_W^4)$, $\sqrt{s} \in [2M_Z, 13\,\mathrm{TeV}]$

- LL is most sensitive to the mass, but kinematically suppressed !
- Dominant contribution to σ_{LL} comes from the threshold region.

Duc Ninh LE, Phenikaa University, Vietnam 5



Q-H Cao, B. Yan et al, arXiv:2004.02031

LHCP 2025 theory talk

Diboson polarization

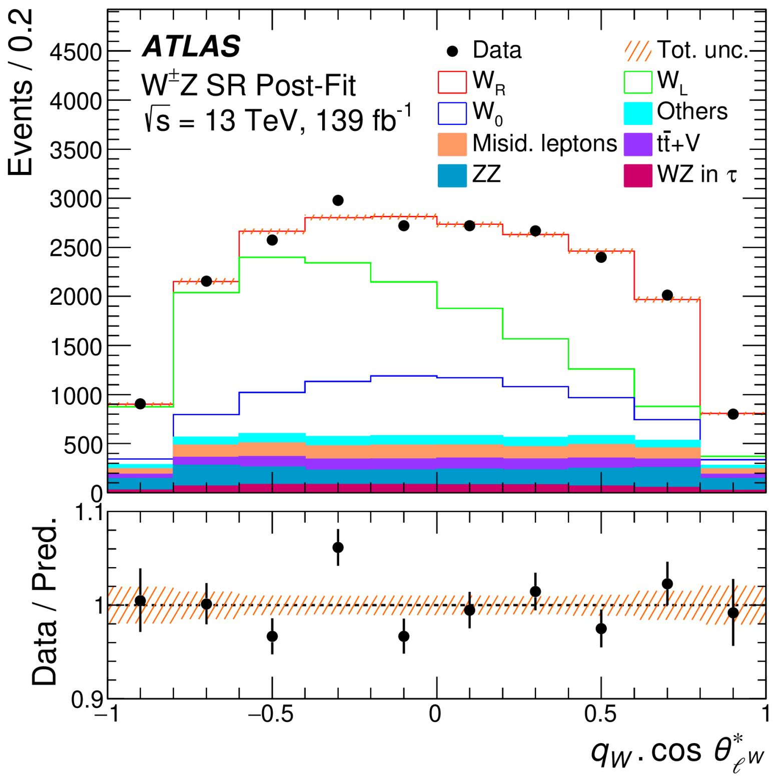
- Recent measurements
  - $pp \to ZZ \to 4l$, ATLAS JHEP 12 (2023) 107 ($Z_L Z_L$ measured with 4.3σ)
  - $pp \to WZ \to l\nu ll$ joint WZ polarization measurements
    - ATLAS PLB 843 (2023) 137895 ($W_L Z_L$ observed with 7.1σ)
  - $pp \to WZ \to l\nu ll$ single-boson polarization measurements
    - ATLAS EPJC 79 (2019) 535
    - CMS *JHEP 07 (2022) 032*

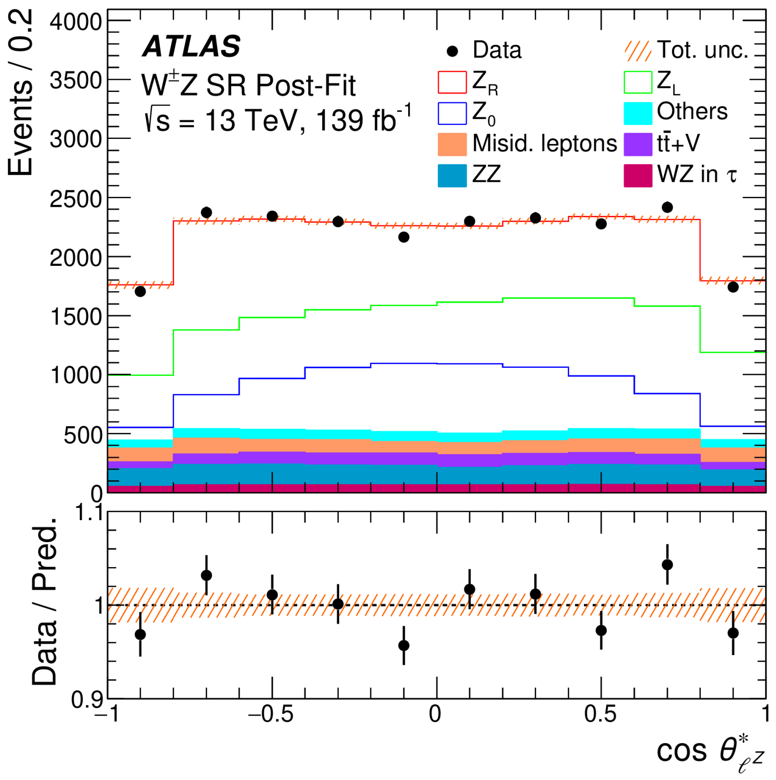
Process	Features			Experimental status
	Signal rate	S/B	Spin information	
$ZZ \to 4l$	✗	✓	✓✓	ATLAS
$WZ \to l\nu ll$	✓	✓	✓	ATLAS (and CMS with single boson polarization)
$WW \to l\nu l\nu$	✓	✗	✗	None
$WW \to l\nu qq$	✓	✗	✓	None

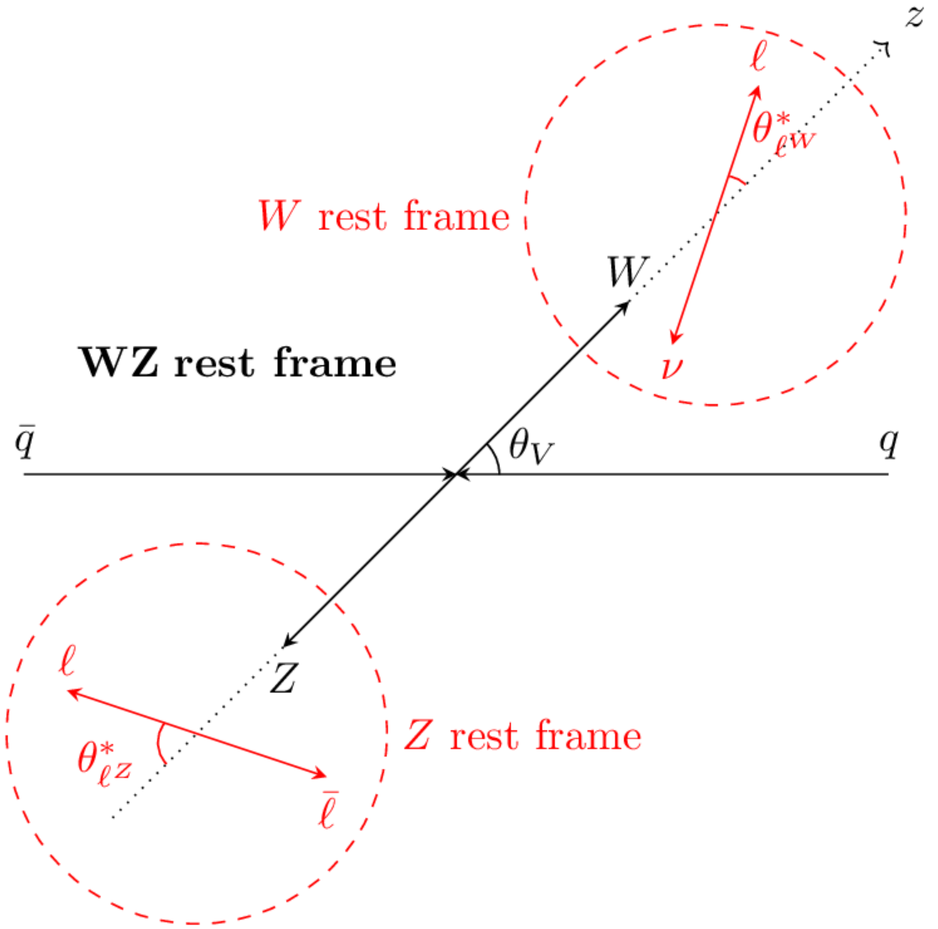
WZ polarization measurement

- A regression NN is developed to reconstruct p_z^v from the $W \to lv$ decay

ATLAS: PLB 843 (2023) 137895

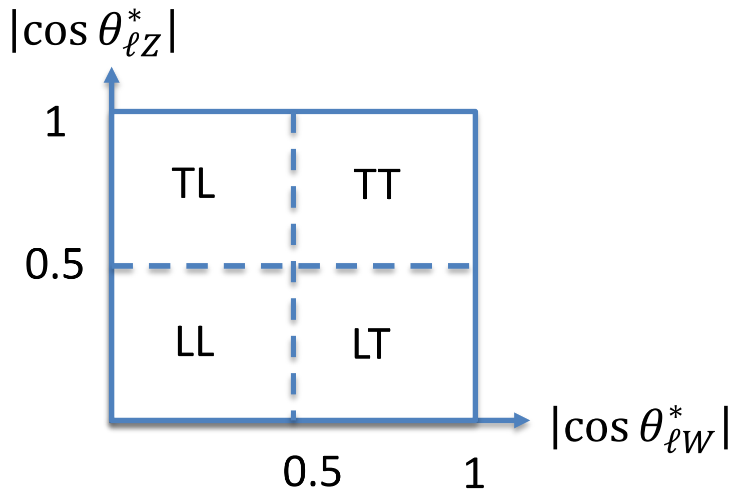


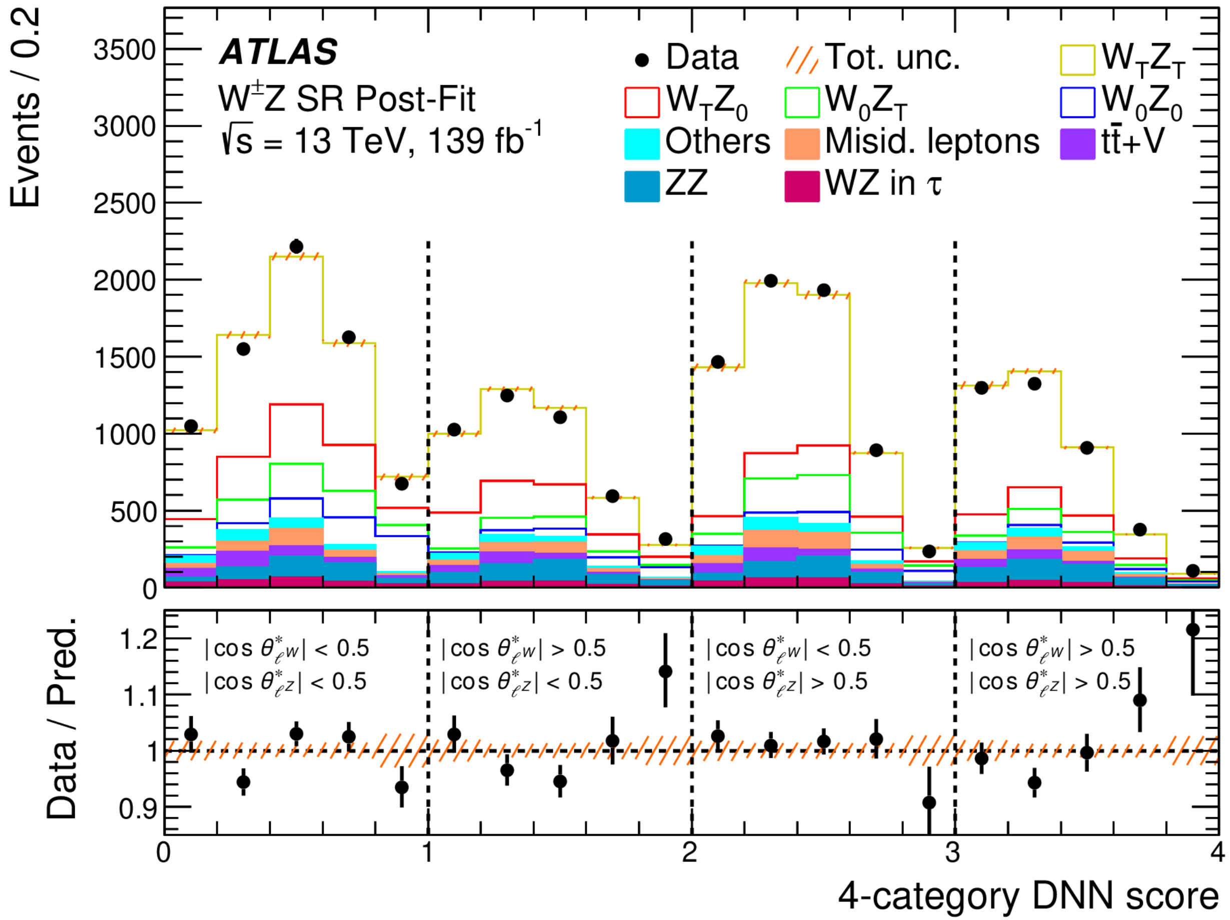




WZ polarization measurement

- A DNN based discriminant used to extract the polarization fractions
  - Events are further split into 4 categories based on $(|\cos\theta^*_{\ell W}|, |\cos\theta^*_{\ell Z}|)$



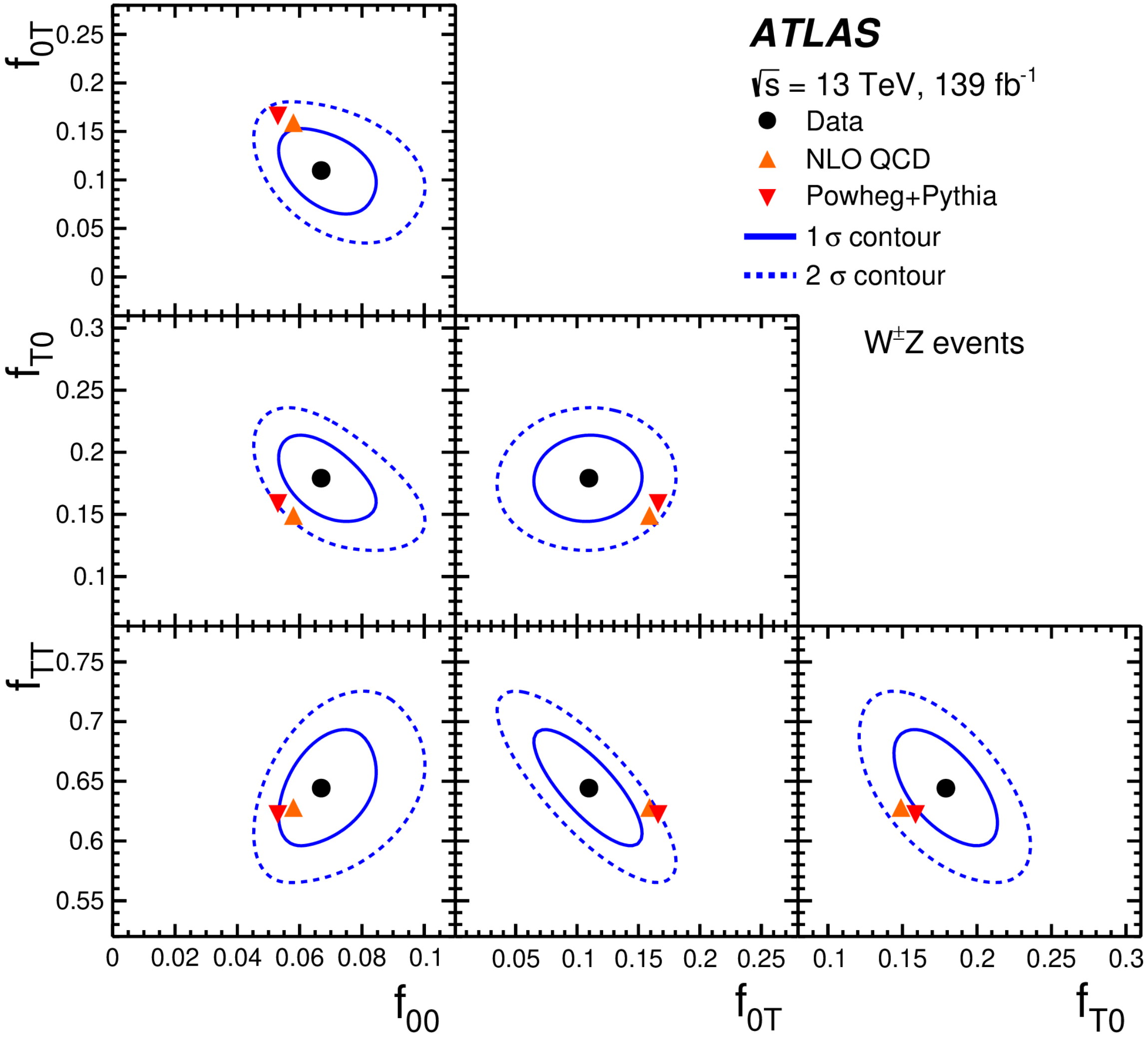


- NLO QCD corrections with a DNN reweighting
  - 4 DNNs trained to reweight the inclusive WZ events to each polarized sample
  - The 4 DNNs are then applied to the Powheg WZ inclusive sample

WZ polarization measurement

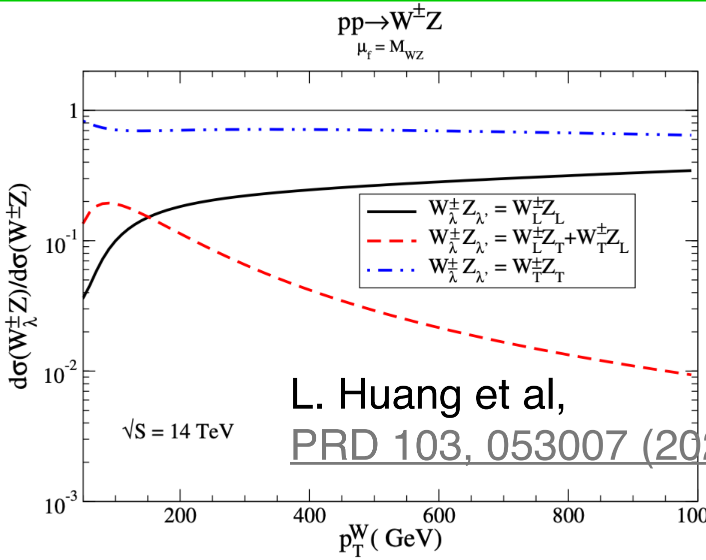
- All joint polarization states observed
  - Observed (expected) $W_L Z_L$ 7.1(6.2) σ
  - Consistent with NLO QCD predictions

	Data	Powheg+Pythia	NLO QCD
	$W^{\pm}Z$		
f_{00}	0.067 ± 0.010	0.0590 ± 0.0009	0.058 ± 0.002
f_{0T}	0.110 ± 0.029	0.1515 ± 0.0017	0.159 ± 0.003
f_{T0}	0.179 ± 0.023	0.1465 ± 0.0017	0.149 ± 0.003
f_{TT}	0.644 ± 0.032	0.6431 ± 0.0021	0.628 ± 0.004



Energy Dependence and the Radiation Amplitude Zero Effect

- Polarization fraction is p_T dependent
- RAZ effect: at leading-order, the dominant helicity amplitude for TT vanishes when $\cos\theta_V \sim 0$
- RAZ **only** happens for WZ and $W\gamma$ processes and **not** for WW and ZZ processes
  - Observed in $W\gamma$ but not in WZ yet

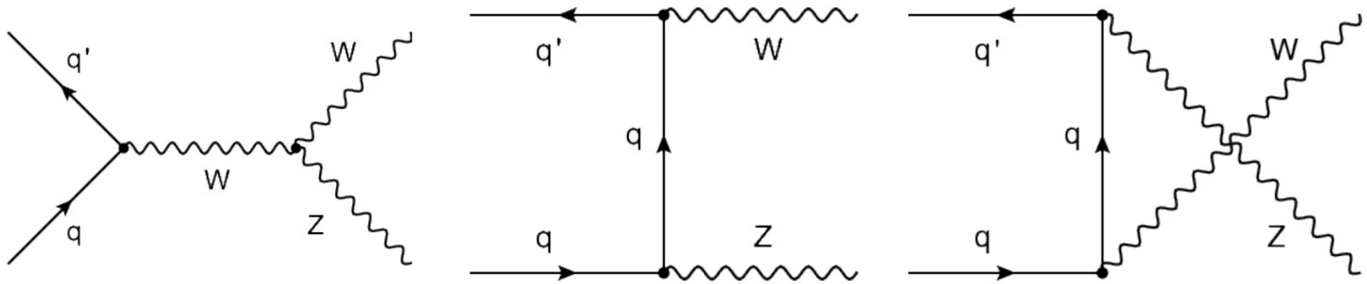


L. Huang et al, PRD 103, 053007 (2021)

$$\frac{d^2\sigma^{LL}_{WZ}}{d^2\sigma^{TT}_{WZ}} \sim \frac{1}{8\cos^2\theta_V}\frac{1-\cos^2\theta_V}{1+\cos^2\theta_V}$$

- High $p_T(Z)$ region enhances the LL fraction
- Low $p_T(WZ)$ region suppresses jet activity thus enhances the RAZ effect →also enhancing the LL fraction

s-channel t-channel u-channel

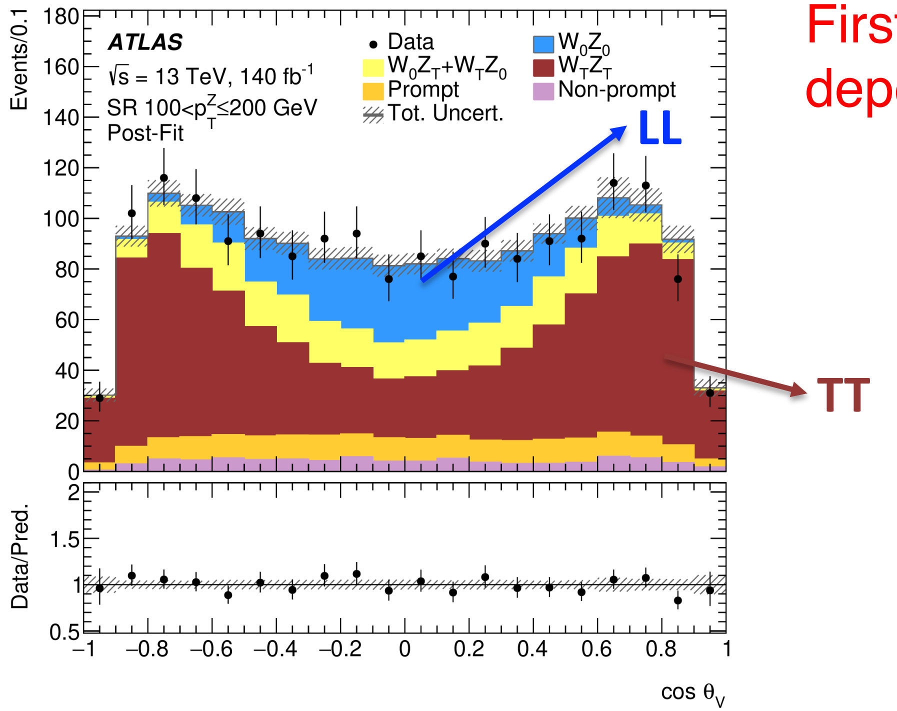


f_{LL} increases from 5 – 7% in the inclusive region to 20 – 30% in the region with high $p_T(Z)$ and low $p_T(WZ)$

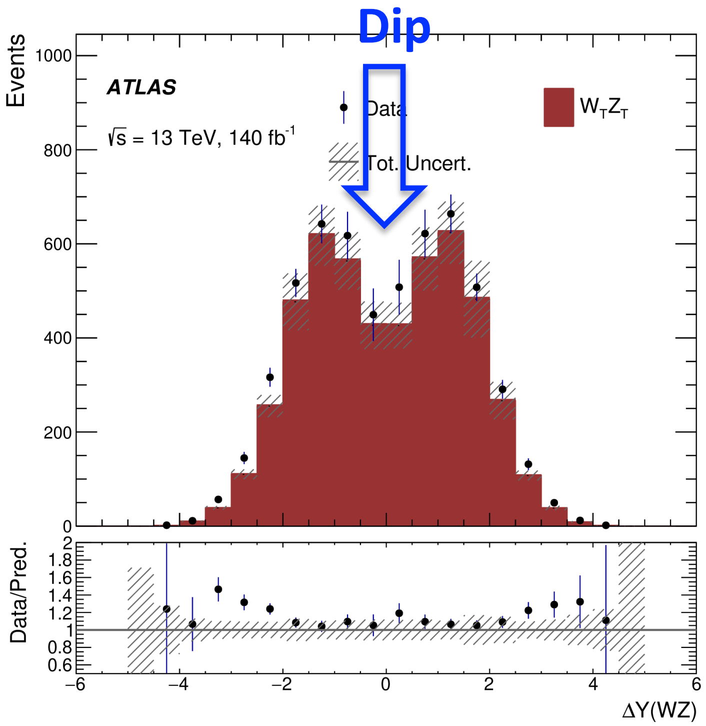
Observation of WZ pol. and the Radiation Amplitude Zero effect

ATLAS, PRL133 (2024) 101802

	Measurement $100 < p_T^Z \leq 200$ GeV	Measurement $p_T^Z > 200$ GeV
f_{00}	$0.19 \pm^{0.03}_{0.03}$ (stat) $\pm^{0.02}_{0.02}$ (syst)	$0.13 \pm^{0.09}_{0.08}$ (stat) $\pm^{0.02}_{0.02}$ (syst)
f_{0T+T0}	$0.18 \pm^{0.07}_{0.08}$ (stat) $\pm^{0.05}_{0.06}$ (syst)	$0.23 \pm^{0.17}_{0.18}$ (stat) $\pm^{0.06}_{0.10}$ (syst)
f_{TT}	$0.63 \pm^{0.05}_{0.05}$ (stat) $\pm^{0.04}_{0.04}$ (syst)	$0.64 \pm^{0.12}_{0.12}$ (stat) $\pm^{0.06}_{0.06}$ (syst)
f_{00} obs (exp) sig.	5.2 (4.3) σ	1.6 (2.5) σ



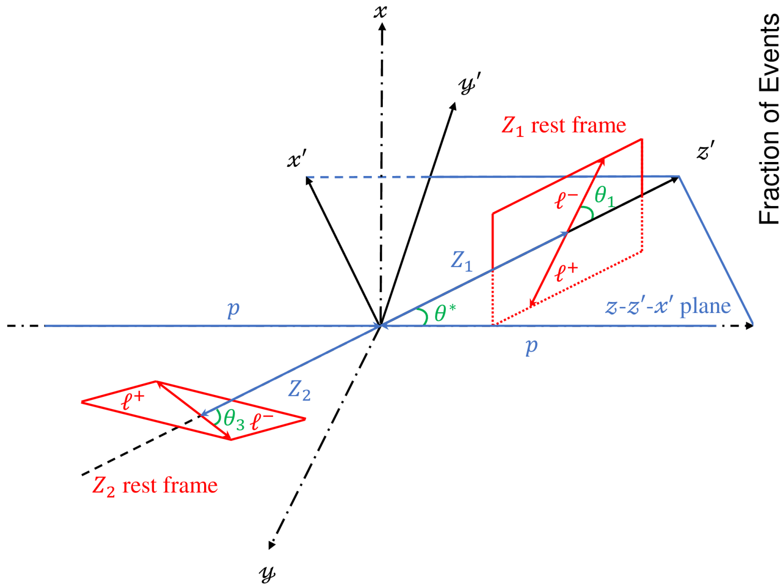
First measurement of energy dependence of diboson polarization

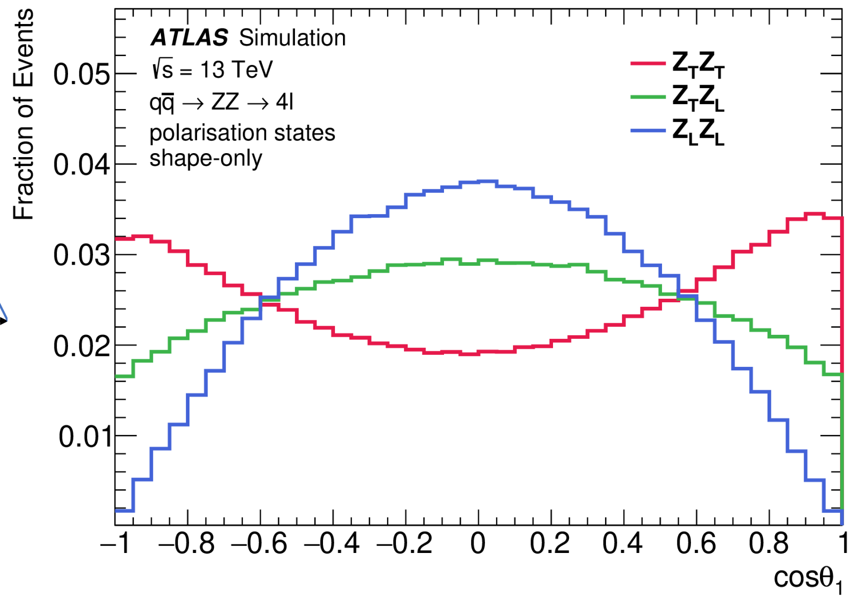


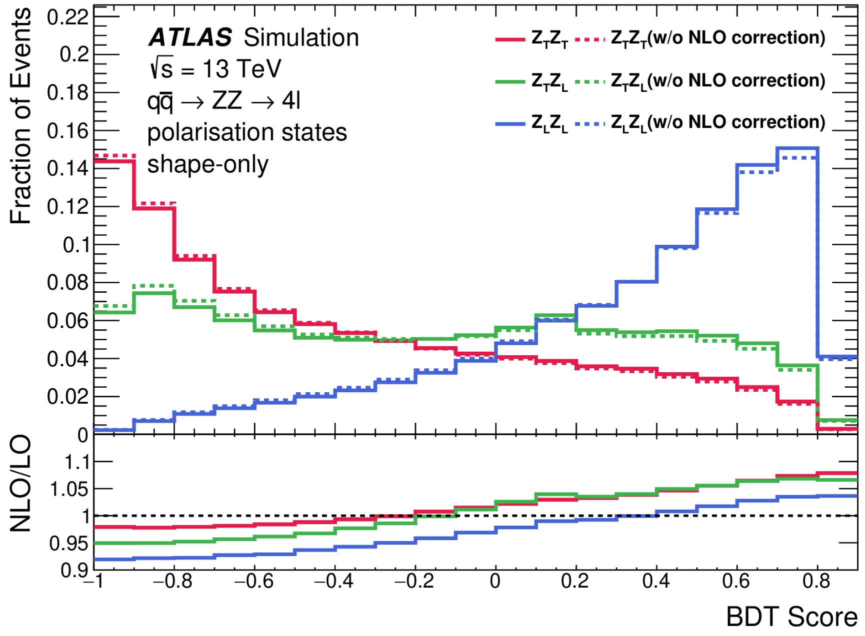
- RAZ effect leads to a dip around 0 in the $\Delta Y(WZ)$ and $\Delta Y(l_W Z)$ distributions
- Significant dips are observed
- Unfolded distributions also measured

ZZ polarization measurement

- In $ZZ \rightarrow 4l$ decay, both Z bosons can be fully reconstructed
  - Two on-shell Z events are selected: $m_{4l} > 180\ GeV, |m_{ll} - m_Z| < \ 10\ GeV$
- A BDT discriminant to separate $Z_L Z_L$ from the others
- NLO QCD and EW corrections applied to LO events via reweighting

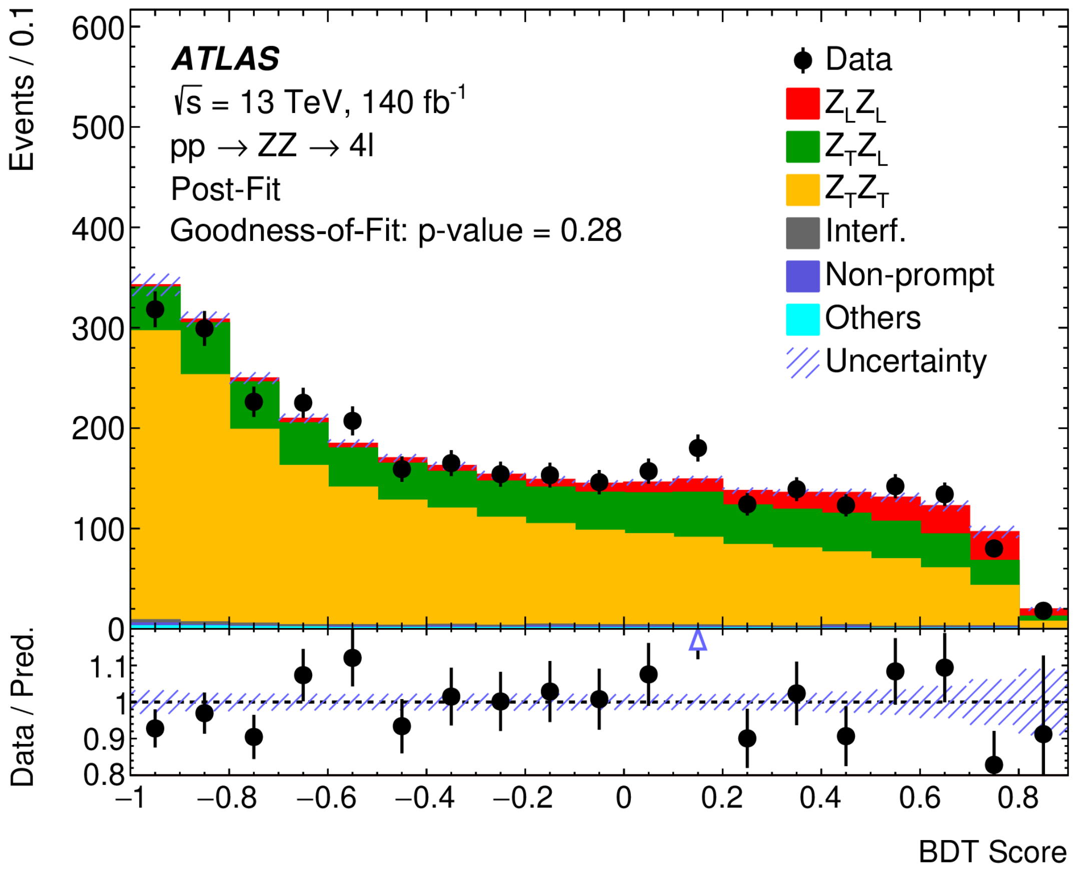






ZZ polarization measurement

- BDT template fit to extract the polarization fraction
  - Observed(expected) $Z_L Z_L$ signal strength: 4.3(3.8) σ

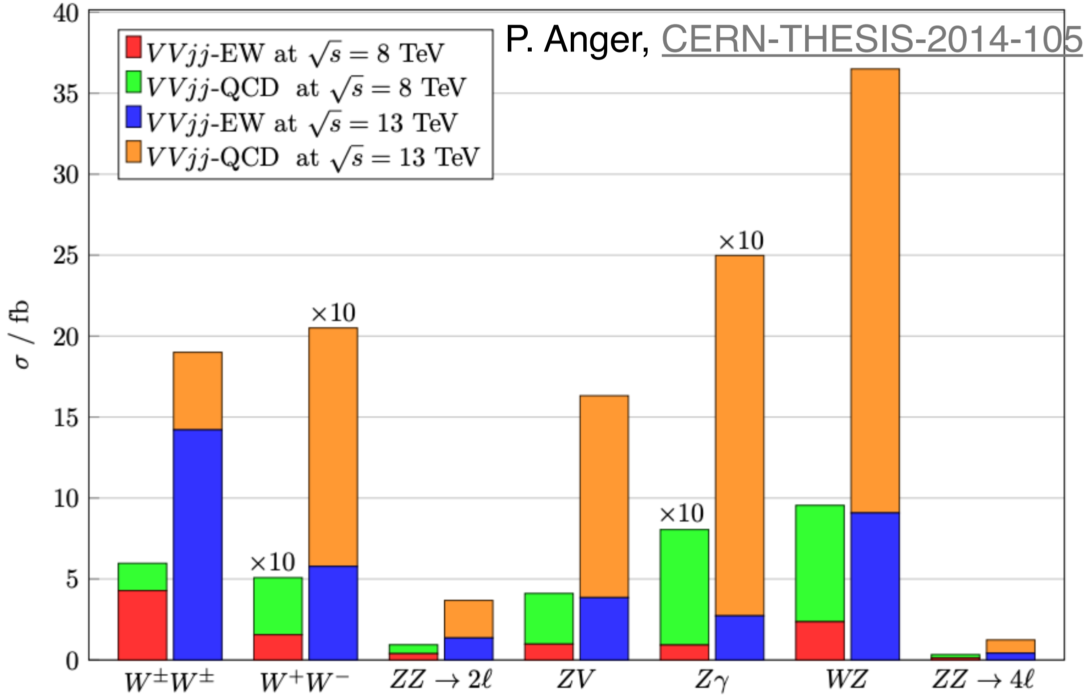


First evidence of $Z_L Z_L$ production

VBS

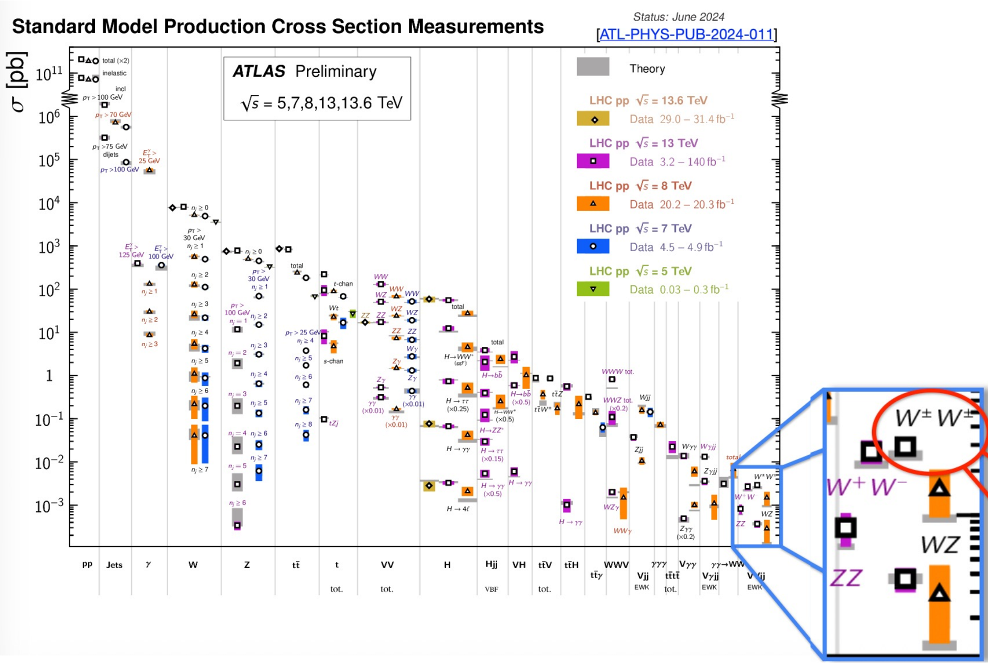
Polarization measurements in VBS

- Same-sign WW production is the most sensitive channel to study vector boson scattering
- Recent measurements
  - $pp \to W^{\pm}W^{\pm}jj$ VBS, CMS PLB 812 (2020) 136018 ($W_L W_X$ measured with 2.3σ)
  - $pp \to W^{\pm}W^{\pm}jj$ VBS, ATLAS PRL 135 (2025) 111802, ($W_L W_X$ measured with 3.3σ)



$W^{\pm}W^{\pm}jj$ VBS polarization measurement

- Challenges:
  - VBS modeling; background estimation; selection & bkg rejection → well studied in inclusive VBS measurements
  - Modeling of polarization VBS process @ NLO
  - Limited number of single- & di-longitudinal events
    - Measure $W_L^{\pm}W^{\pm}jj$ and set limits for $W_L^{\pm}W_L^{\pm}jj$
  - Reconstruct the polarization information with neutrino as $E_{\mathrm{T}}^{\mathrm{miss}}$



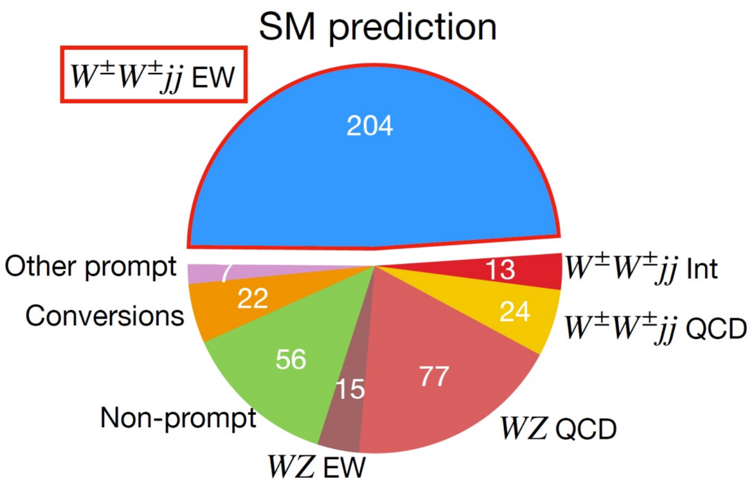
Expected fractions:

61% $W_T^{\pm}W_T^{\pm}$

29% $W_T^{\pm}W_L^{\pm}$

10% $W_L^{\pm}W_L^{\pm}$

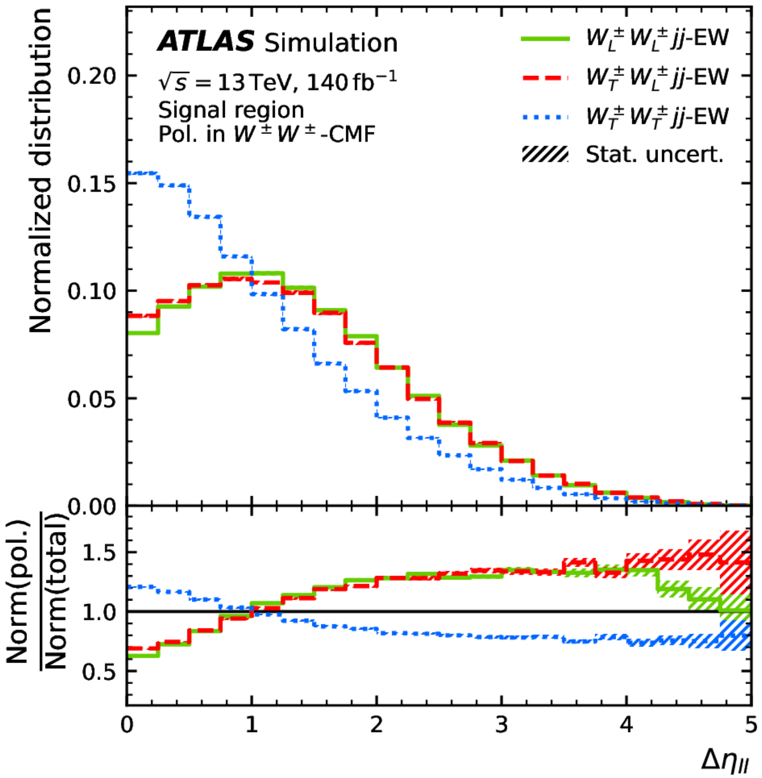
39% $W_L^{\pm}W^{\pm}$



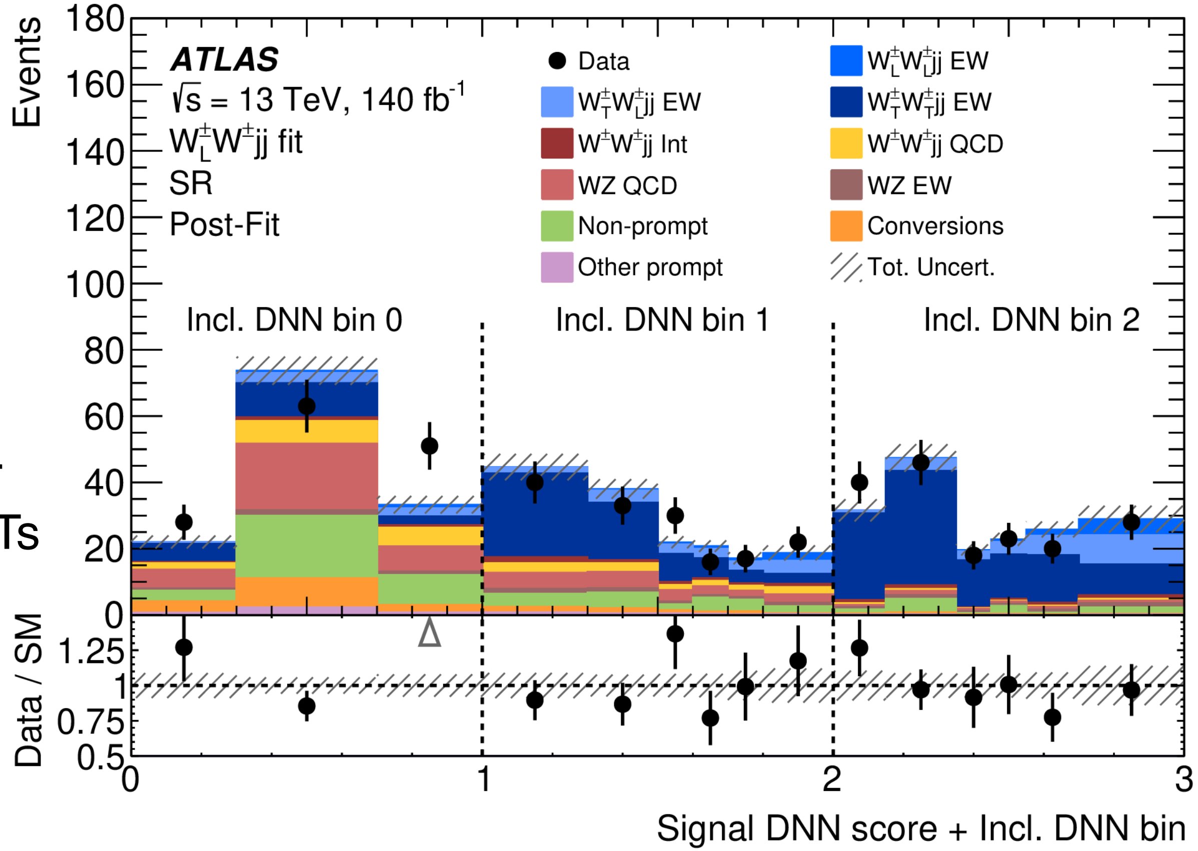
$W^{\pm}W^{\pm}jj$ VBS polarization measurement

ATLAS: PRL 135 (2025) 111802

- Two sets of DNNs are trained to improve the separation
  - $DNN_{\text{inclusive}}$ to distinguish EW $W^{\pm}W^{\pm}jj$ process from backgrounds
  - $DNN_{\text{polarization}}$ to extract the polarized signal for EW $W_L^{\pm}W_L^{\pm}jj$ or $W_L^{\pm}W^{\pm}jj$

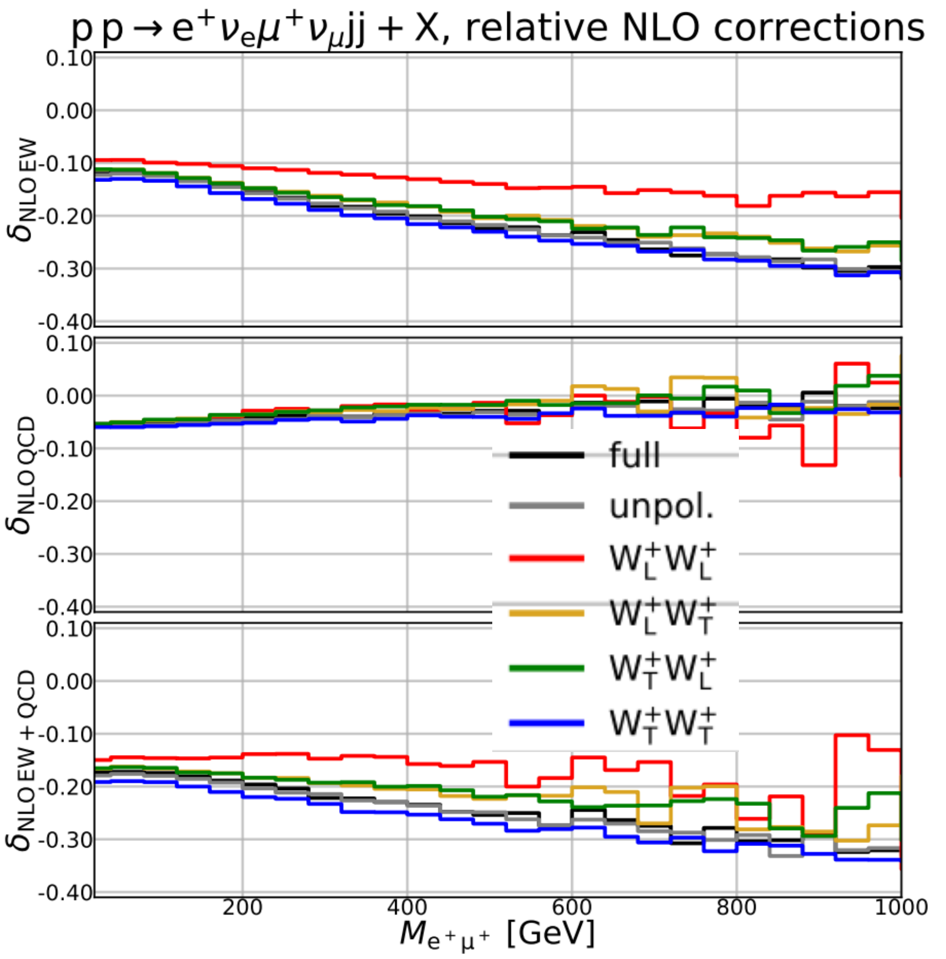


CMS PLB 812 (2020) 136018 used a similar approach but with BDTs



Higher-order corrections
ATLAS: PRL 135 (2025) 111802

- Polarization effects reflected in the kinematics of leptons, jets and missing energies
  - Precise full-kinematics simulation is essential
- Substantial NLO QCD and EW corrections
  - Polarization state dependent
- NLO QCD:
  - Sherpa3 provides VBS polarization simulation for LL, TL, TT and the Interference
    - With VBS approximation and Narrow-Width-Approximation
    - LO in EW and approximate NLO in QCD
  - Dedicated DNNs used to correct approximations
- NLO EW:
  - M_{jj} reweighting based on fixed-order corrections



A. Denner ,C. Haitz, G. Pelliccioli, arXiv:2409.03620

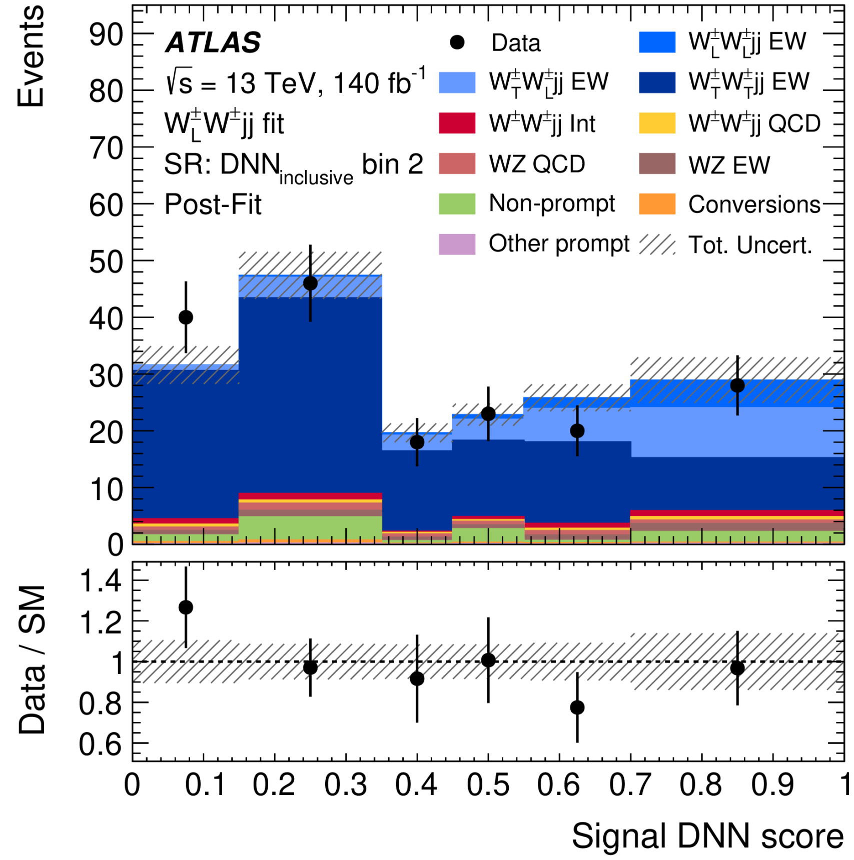
$W^{\pm}W^{\pm}jj$ VBS polarization measurement

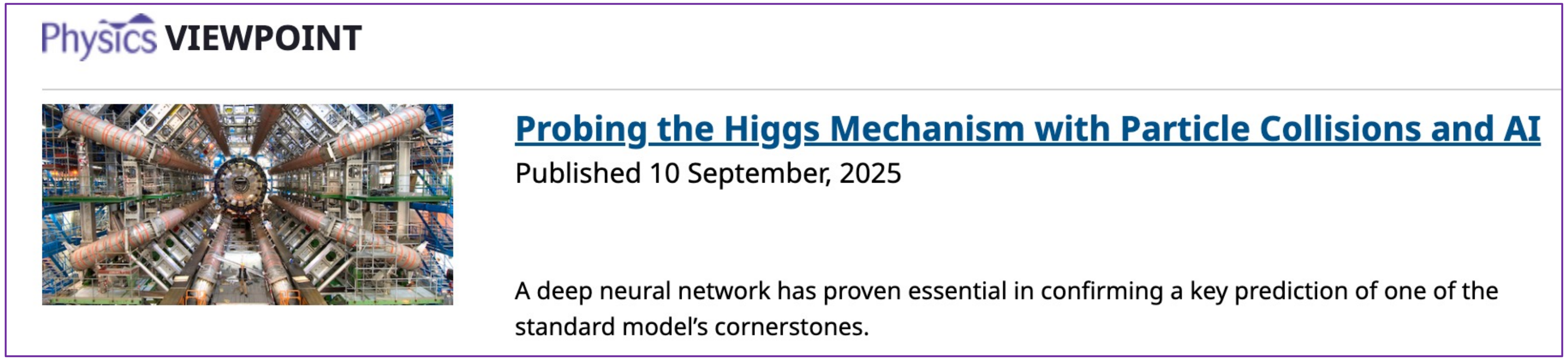
- DNN template fit to extract the polarization fraction
  - Observed(expected) $W_L^{\pm}W^{\pm}jj$ signal significance: 3.3(4.0) σ
  - CMS: 2.3(3.1) σ

ATLAS: PRL 135 (2025) 111802

FEATURED IN PHYSICS

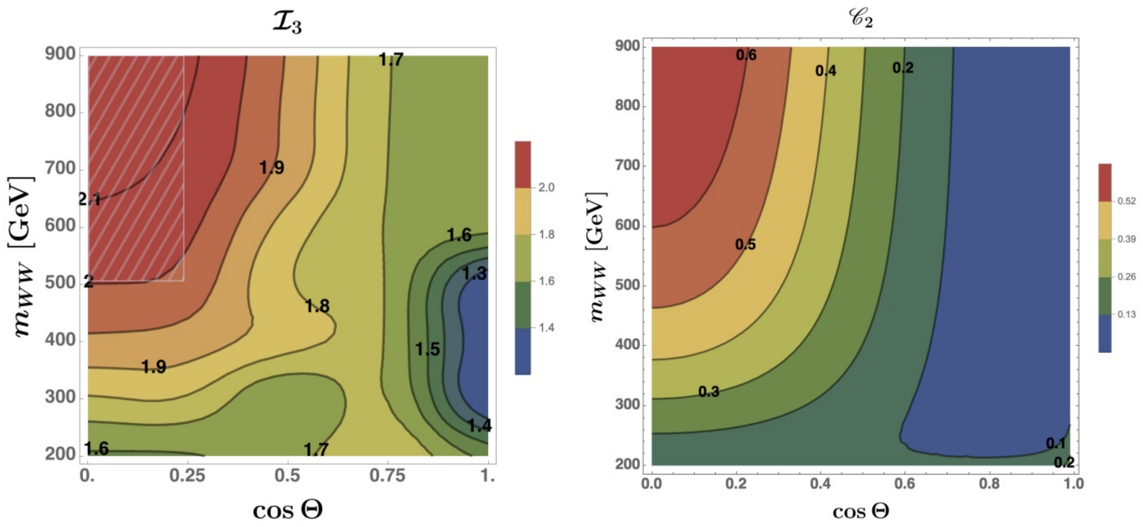
EDITORS' SUGGESTION





Propsect

- Diboson polarization measurements
  - Only $W_L Z_L$ observed so far, more channels to come ($Z_L Z_L, W_L W_L$, etc)
  - Probe BSM
  - Quantum tomograph in diboson system?



Number of expected $pp \to WW$ events that that violate the Bell inequality

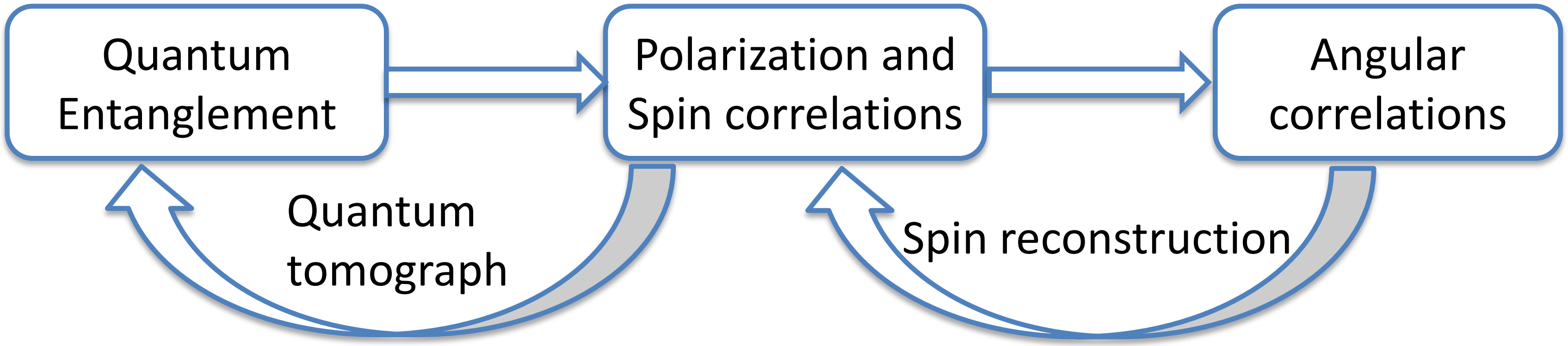
	(run2) $\mathcal{L} = 140\ \text{fb}^{-1}$	(Hi-Lumi) $\mathcal{L} = 3\ \text{ab}^{-1}$
events	288	6145

E. Gabrielli et al, arXiv:2302.00683

- VBS polarization measurement
  - Establish $V_L V_L \to V_L V_L$ at the HL-LHC?

Summary

- Diboson polarization study (either in inclusive $pp \to VV$ production or in VBS) well motivated to test the EWSB and probe BSM
  - Large datasets available at the LHC
  - New developments in MC event generators for polarized boson production
  - Advanced ML techniques as polarization taggers
- Continuous development in theoretical calculations also essential
- Also paves the road for Quantum Entanglement study



Backup

SDM and Quantum Entanglement

- The spin density matrix is a fundamental tool in quantum mechanics, encapsulating all observable information of a quantum system

$$\rho = \sum_i p_i \left|\Psi_i\right\rangle \left\langle\Psi_i\right| ,$$

- A $V_A V_B$ system produced in pp collisions is a pair of qutrits
- The system is separable if If the SDM can be written as

$$\rho \;=\; \sum_i p_i \rho_A^i \otimes \rho_B^i ,$$

  - ρ_A^i, ρ_B^i are the density matrices acting on the Hilbert spaces of subsystems Aand B, respectively.
  - $p_i \geq 0, \sum_i p_i = 1$
- QE wittness: concurrence

For pure state $\quad \mathcal{C}[|\Psi\rangle] \;\equiv\; \sqrt{2\left(1-\mathrm{Tr}[(\rho_A)^2]\right)} \;=\; \sqrt{2\left(1-\mathrm{Tr}[(\rho_B)^2]\right)},$

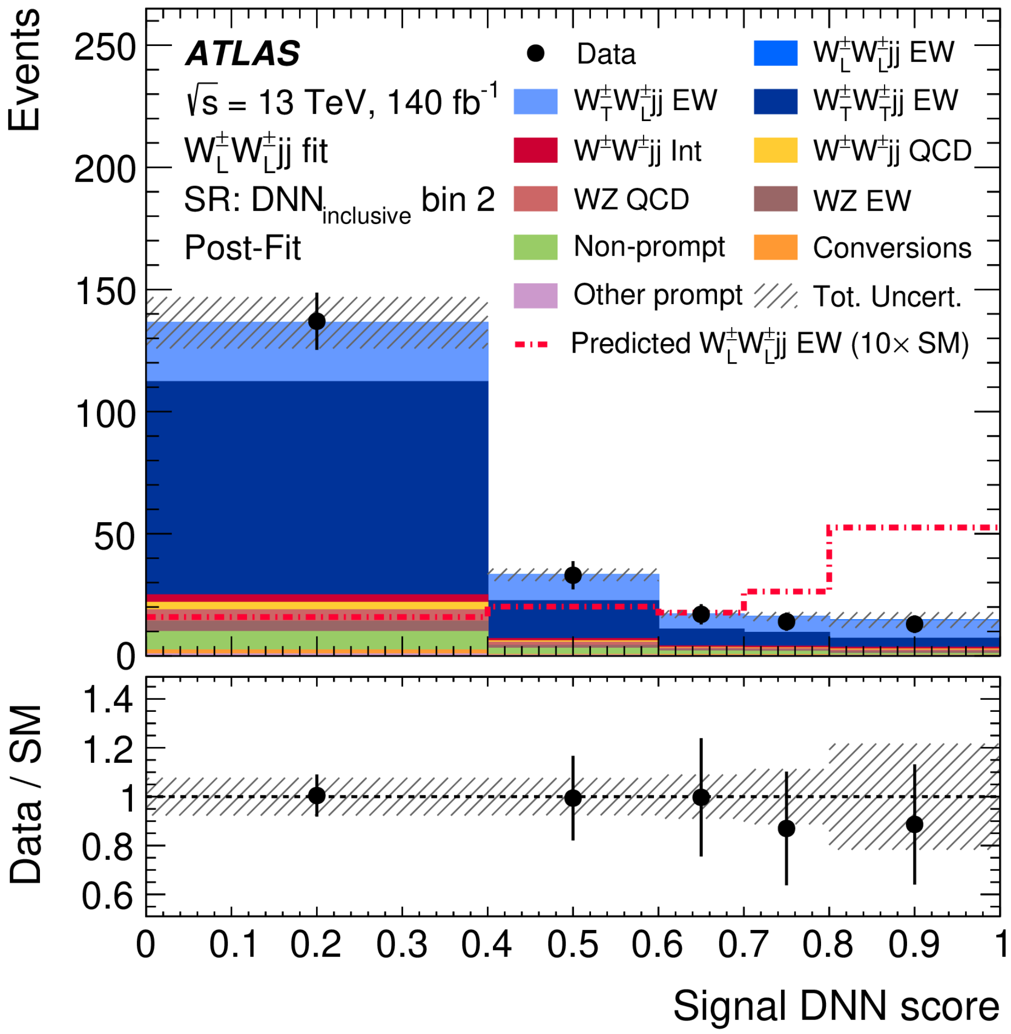
For mixed state $\quad \mathcal{C}(\rho) \;\equiv\; \inf_{\{|\Psi_i\rangle\}} \sum_i p_i \mathcal{C}[|\Psi_i\rangle].$

$$\boxed{\begin{aligned} (\mathcal{C}(\rho))^2 \;&\geq\; 2\max\left\{0,\;\; \mathrm{Tr}\left[\rho^2\right]-\mathrm{Tr}\left[(\rho_A)^2\right],\;\; \mathrm{Tr}\left[\rho^2\right]-\mathrm{Tr}\left[(\rho_B)^2\right]\right\} \;\equiv\; \mathscr{C}^2_{\mathrm{LB}}\,, \\ (\mathcal{C}(\rho))^2 \;&\leq\; 2\min\left\{1-\mathrm{Tr}\left[(\rho_A)^2\right],\;\; 1-\mathrm{Tr}\left[(\rho_B)^2\right]\right\} \;\equiv\; \mathscr{C}^2_{\mathrm{UB}}\,. \end{aligned}}$$

$\mathcal{C}_{LB} > 0 \Rightarrow$ QE
$\mathcal{C}_{UB} = 0 \Rightarrow$ non-QE (separable)

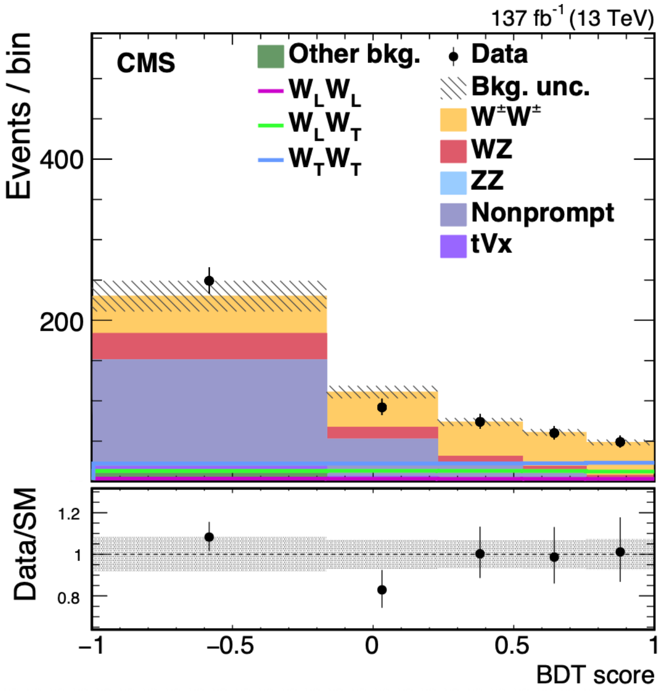
Frank Krauss et al, arXiv:2505.12125

ATLAS ssWW polarization

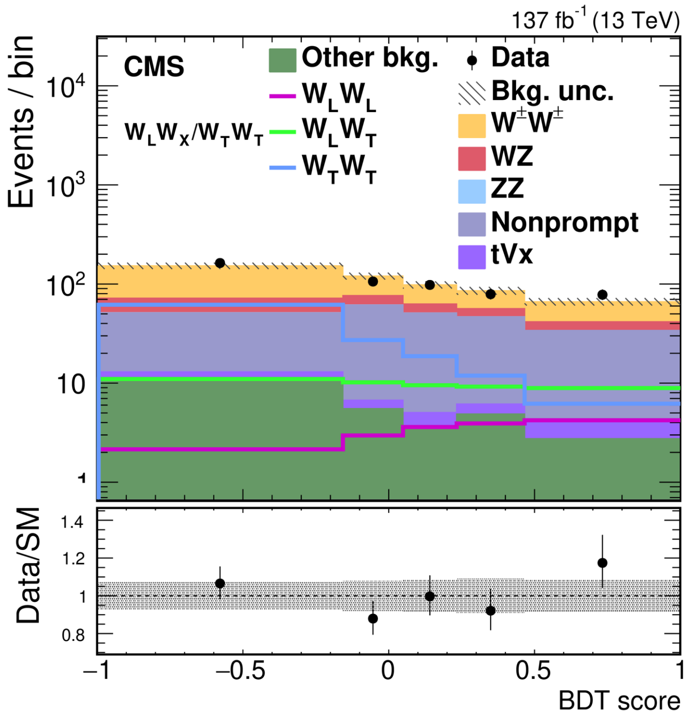


CMS ssWW

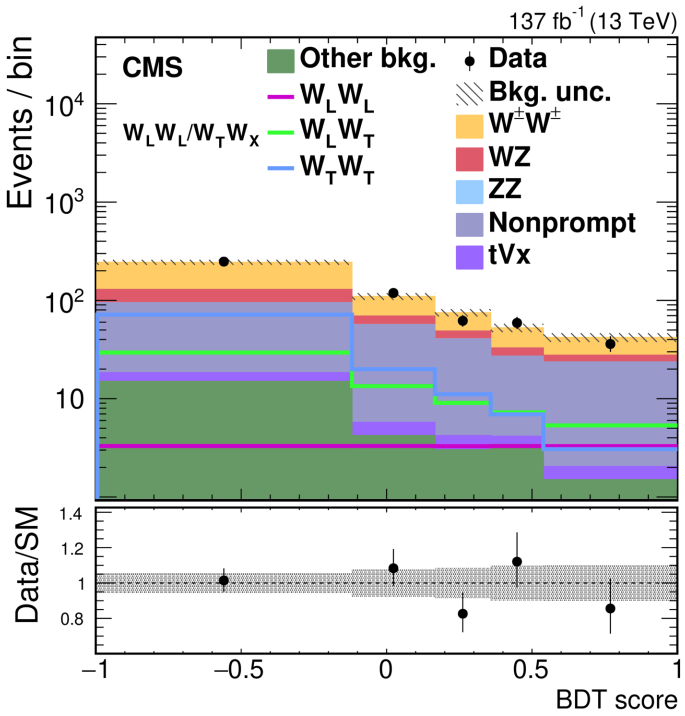
- Polarization samples are generated using MADGRAPH5 aMC@NLO at LO interfaced with Pythia8



“Inclusive BDT”: Trained on WW as a signal vs Top quark simulated events that account for the Non-prompt background



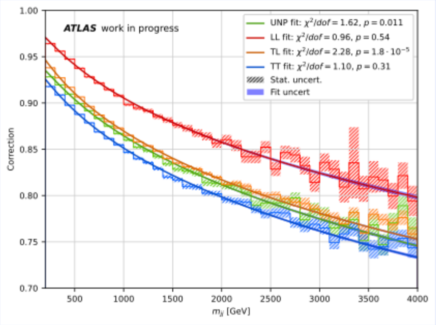
$W_L^{\pm}W^{\pm}jj$ against all



$W_L^{\pm}W_L^{\pm}jj$ against all

Two BDTs to separate the polarization components

ssWW

ATLAS	CMS
LX WW-cmf signifance: 4.56 (expected) LL WW-cmf upper limit: 0.75 fb (expected)	LX WW-cmf signifance: 2.3 (3.1) LL WW-cmf upper limit: 1.17 (0.88) fb
Expect about 210 ssWW-EW events	Expect about 190 ssWW-EW events
53% ssWW-EW purity	36% ssWW-EW purity (40% are nonprompt events with high uncertainty)
Polarised higher-order QCD	Unpolarized NLO-QCD
Polarised NLO-EW 	Unpolarised NLO-EW Only applied on TT (would explain overestimated significance)
Renorm. and factor., resumm., and merging scale uncertainty calculated at higher-order QCD	Renorm. and factor. scale uncertainty at LO-QCD
Polarisation interference directly modelled	Polarisation interference not taken into account
Discrimination via DNNs • Study of different MVA approaches • Extensive optimization of training setup	Discrimination via BDTs • Application of DNNs leaded to similar results
Combination of two DNNs • 2D bin optmization to maximize significance	Combination of two BDTs • 5x5 bins with similar LL (LX) yields
Dominated by statistic	Dominated by statistic