

Probing ZZ diboson polarization with four-lepton events in ATLAS

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Motivation and Introduction

Motivation

- Diboson polarization: a good probe for SM test and New Physics search:
 - Longitudinal-longitudinal (LL) version of VBS to test Higgs mechanism of EWSB in SM¹
 - Polarized differential cross-sections sensitive to aTGC and EFT operators in general²
- pp→4l differential cross-sections measured as a function of many observables with high precision in ATLAS³
- Kinematic observables behaving differently in ZZ(4I) according to polarization states (TT, TL, LL), e.g. angular



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• Aiming to measure ZZ polarization based on angular

observables

observables, and other observables if possible

Selection and Observables

Selection

• **On-shell ZZ region** with loose lepton selection

	Lepton Selection	Category	X-section (fb) Total PS yield	Ratio to Sum. (tot.)
Muon	Dressed, $p_{\rm T} > 5$ GeV, $ \eta < 2.7$	TT	24.00118	3335.3285	68.27%
Electron	Dressed, $p_{\rm T} > 7 \text{ GeV}, \eta < 2.47$	TL	9.08615	1262.6586	25.84%
	Event Selection	\mathbf{LL}	2.070862	287.77773	$\mathbf{5.89\%}$
Leptons	At least 4 leptons (e, μ)	TT+TL+LL	35.158192	4885.7648	100%
Lepton flavor	At least 2 Same-Flavor Opposite-Sign (SFOS) lepton pairs				
Lepton p_T	$p_{\rm T} > 20/10 {\rm ~GeV}$ for leading two leptons	Category	FV yield	Ratio to Sum. (fid	.)
Lepton separation	$\Delta R_{ij} > 0.05$ for any two leptons	TT	1169.2565	68.62%	
J/Ψ veto	$m_{ij} > 5$ GeV for all SFOS pairs	TL	436.93006	25.64%	
On-shell ZZ region	$m_{4\ell} > 180 \text{ GeV}$ for the quadruplet	$\mathbf{L}\mathbf{L}$	97.694777	5.73 %	
On-shell Z	$ m_{ij} - m_Z < 10 \text{ GeV}$ for both SFOS pairs in the quadruplet	TT+TL+LL	1703.8813	100%	

- LL component appearing with a fraction of only ~6%
- Kinematic differences suppressed with low LL fraction
- > Observables
- Observables are defined based on different reference frames



• Each observables compared, the definition being able to

MVA method on LL significance

- MVA method to extract, condense the differences of 3 polarization states and classify them
- Boost Decision Tree (BDT) used and achieving very nice performance after detailed tuning
- Optimized observables as inputs:
 - $p_{T,4\ell}^{\text{LAB}}$, $y_{4\ell}^{\text{LAB}}$, $\Delta \phi_{pairs}^{\text{LAB}}$, $\cos \theta_1^{\text{ZZREST}}$, $\cos \theta_2^{\text{ZZRSET}}$, $\cos \theta_{Z1}^{*,\text{ZZREST}}$,
 - $\Delta R_{\ell 1 \ell 2}^{ZZREST}$, $\Delta R_{\ell 3 \ell 4}^{ZZREST}$, $\Delta \phi_{\ell 1 \ell 2}^{ZZREST}$, $p_{T,Z1}^{ZZREST}$, y_{Z1}^{ZZREST}
- LL significance fit including only statistical uncertainty



enhance LL significance chosen. Most of the optimized observables defined in ZZ rest frame



- Considering to combine the separation power in all observables to compensate the influence of low LL fraction
- BDT giving LL significance of 4.52σ, while the best result of fit on individual observable yielding 2.95σ

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