Comité de Suivi Individuel
2me année

Léo Boudet

Supervisor : Lucia DI CIACCIO (LAPP)
CSI : Corinne GOY (LPSC), Diego GUADAGNOLI (LAPTh)
Tutor : Frédérique MARION (LAPP)

6 septembre 2024

Search for new sources of CP violation with effective field theories in WZ diboson production with ATLAS

- Qualification as ATLAS author effective since 15th January.

  V. Boisvert[98], P. Bokan[37], T. Bold[88a], M. Bomben[5], M. Bona[97], M. Boonekamp[139], A.G. Borbély[61], I.S. Bordulev[39], G. Borissov[94], D. Bortoletto[130], D. Boscherini[24b], M. Bosman[13], K. Bouaouda[36a], N. Bouchhar[168], L. Boudet[4], J. Boudreau[133], E.V. Bouhova-Thacker[94], D. Boumediene[42], R. Bouquet[59b,59a], A. Boveia[123], J. Boyd[37], D. Boye[30], I.R. Boyko[40], L. Bozianu[58], J. Bracinik[21], N. Brahimi[4], G. Brandt[176],

- Still involved in e/γ CP group , $\simeq$20% working time.

Contents

1. CP violation and EFT
2. Constraints on SMEFT via machine learning : design of BDTs
3. BDT optimisation
4. Conclusion and 2nd year summary

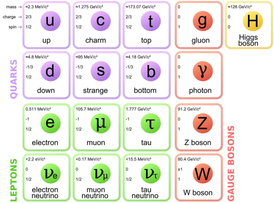
CP violation and EFT

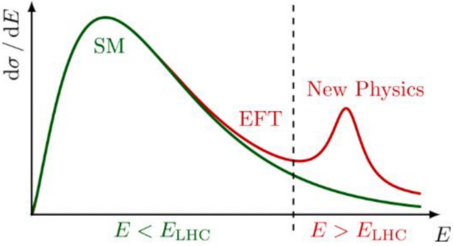
→ CP violation (CPV) : matter and antimatter interact differently

→ Necessary to explain matter excess in the Universe

→ Insufficient amount of CPV sources in Standard Model (SM)

→ Need for **indirect** search of new physics, possibly lying beyond energy reach of LHC





Standard Model Effective Field Theory (SMEFT)

- SM = **low energy** effective theory of a more complete model
- SM fields = relevant degrees of freedom at accessible energies

Let Λ be new physics energy scale, m_i SM particles masses :

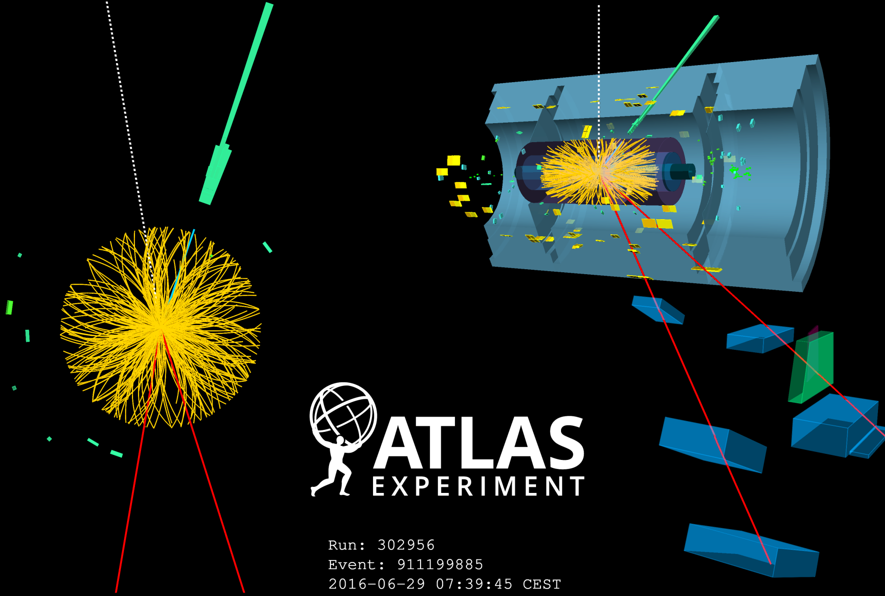
$$m_i \ll \sqrt{s} \ll \Lambda \quad (1)$$

The SMEFT Lagrangien is built adding operators of higher dimension in energy to the SM :

$$\mathcal{L}_{SMEFT} = \mathcal{L}_{SM} + \sum_{d>4} \sum_{i} \frac{c_{d,i}}{\Lambda^{d-4}} \mathcal{O}_{d,i} \quad (2)$$

- $\mathcal{O}_{d,i}$ contain **only SM fields**
- $c_{d,i}$ the **Wilson coefficients** $\rightarrow$ parameters to constrain

Why the WZ process ?



CPV with WZ diboson

Search for CPV via **anomalous triple gauge couplings (aTGC)** → Higgs sector and EW symmetry breaking

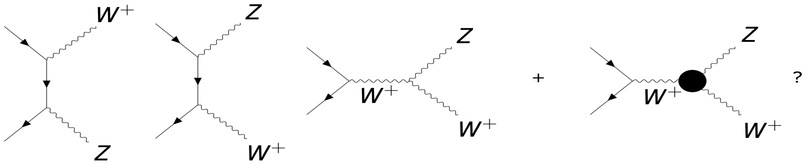


Figure – LO Feynman diagrams for W^+Z production with possible aTGC (black blob)

At LHC energy scale, the relevant dim 6 bosonic operators possibly providing a source of CPV are [1] :

$$\mathcal{O}_{H\tilde{W}B} = \phi^\dagger \sigma_I \phi \tilde{W}^{I,\mu\nu} B_{\mu\nu} \qquad \mathcal{O}_{\tilde{W}WW} = \varepsilon_{IJK} \tilde{W}^{I,\mu}_{\nu} W^{J,\nu}_{\rho} W^{K,\rho}_{\mu} \tag{3}$$

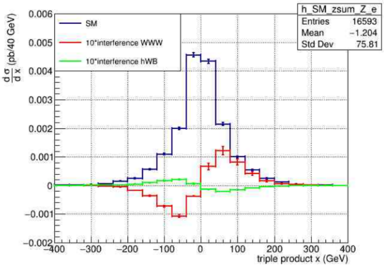
CPV with WZ diboson

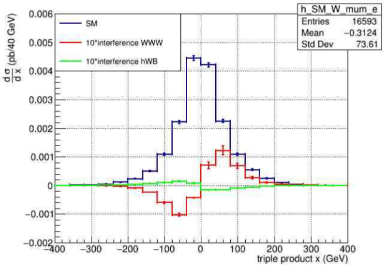
$$\sigma = \frac{1}{F}\int |\mathcal{M}|^2 \mathrm{d}\ \mathrm{LIPS} \qquad \text{(F : Moller's flux)}$$

$$|\mathcal{M}|^2 = \left|\mathcal{M}_{SM} + \frac{1}{\Lambda^2}\mathcal{M}_6\right|^2 = |\mathcal{M}_{SM}|^2 + \frac{2}{\Lambda^2}\Re(\mathcal{M}_{SM}\mathcal{M}_6^*) + \frac{1}{\Lambda^4}|\mathcal{M}_{SM}|^2$$

$$|\mathcal{M}|^2 = SM + int. + quad.$$

CP-odd operators modify differential cross section $d\sigma/dx$, **need to exploit new variables** .





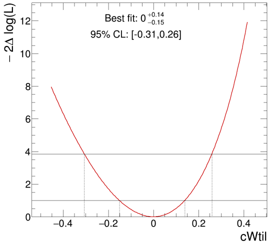
Constraints on Wilson coefficients

1. Select a CP-odd observable sensitive to $\mathcal{O}_{H\tilde{W}B}$ ou $\mathcal{O}_{\tilde{W}}$
2. Likelihood fit on data with c_i as a free parameter

$$\mathcal{L}(c_i) = \frac{1}{\sqrt{(2\pi)^k|C|}} \exp\left(-\frac{1}{2}(\vec{x}_{data}-\vec{x}_{pred}(c_i))^T C^{-1}(\vec{x}_{data}-\vec{x}_{pred}(c_i))\right)$$

- x_k the value in bin k, C covariance matrix between bins
- data = ATLAS Run 2 data
- pred = SM + SM-EFT interference(c_i) + EFT quadratic (c_i^2)

3. Extract limits on coefficients $c_{H\tilde{W}B}$ ou $c_{\tilde{W}}$



$$-2\Delta\log\mathcal{L}(c_i) = -2\log\left(\frac{\mathcal{L}(c_i)}{\mathcal{L}(\hat{c}_i)}\right)$$

$\rightarrow$ 68% and 95% confidence intervals

Expected and observed existing ATLAS limits

Analyses of Vector Boson Fusion (VBF) processes also enable us to study aTGC :

Analyse	Observable	95% CI $c_{H\tilde{W}B}$	95% CI $c_{\tilde{W}}$
VBF Z [2]	$\Delta\Phi_{jj}$	[-1.06, 1.06]	[-0.12, 0.12]
VBF $H \to W^* W$ [3]	$\Delta\Phi_{jj}$	[-1.2, 1.1] [1]	N/A
VBF Z obs.	$\Delta\Phi_{jj}$	[0.23, 2.34]	[-0.11, 0.14]
VBF $H \to W^* W$ obs.	$\Delta\Phi_{jj}$	[-1.2, 1.1]	N/A
WZ (this work)	$p_\perp(\sum p^z, Z, W^{lep})$	[-3.97, 3.96]	[-0.21, 0.21]
WZ (this work)	φ^*_W	[-3.25, 3.19]	[-0.17, 0.17]
WZ (this work)	φ^*_Z	[-3.82, 3.74]	[-0.20, 0.21]

NB : Intervals in TeV^{-2}, describing limits expected from MC simulation and limits observed.

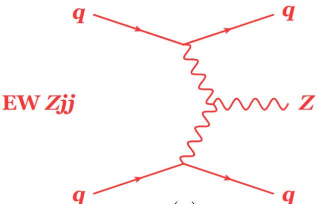
$p_\perp(\sum p^z, Z, W^{lep}) = q_W(\sum_{lep} \vec{p^z}) \frac{\vec{p_Z} \times \vec{p_{Wlep}}}{|\vec{p_Z} \times \vec{p_{Wlep}}|}$

φ^*_V : decay lepton azimuthal angle around the axis defined by $\vec{p}_V$

1. with quad term

Int only vs int + quad

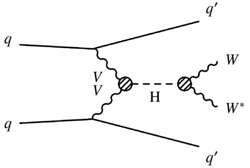
Zjj [2] 1 TGC : negligeable

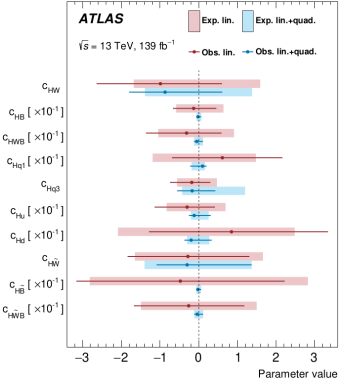


(a)

Wilson coefficient	Includes $\|\mathcal{M}_{d6}\|^2$	95% confidence interval [TeV^{-2}] Expected	Observed	p-value (SM)
c_W/Λ^2	no	$[-0.30,\ 0.30]$	$[-0.19,\ 0.41]$	45.9%
	yes	$[-0.31,\ 0.29]$	$[-0.19,\ 0.41]$	43.2%
$\tilde{c}_W/\Lambda^2$	no	$[-0.12,\ 0.12]$	$[-0.11,\ 0.14]$	82.0%
	yes	$[-0.12,\ 0.12]$	$[-0.11,\ 0.14]$	81.8%
c_{HWB}/Λ^2	no	$[-2.45,\ 2.45]$	$[-3.78,\ 1.13]$	29.0%
	yes	$[-3.11,\ 2.10]$	$[-6.31,\ 1.01]$	25.0%
$\tilde{c}_{HWB}/\Lambda^2$	no	$[-1.06,\ 1.06]$	$[0.23,\ 2.34]$	1.7%
	yes	$[-1.06,\ 1.06]$	$[0.23,\ 2.35]$	1.6%

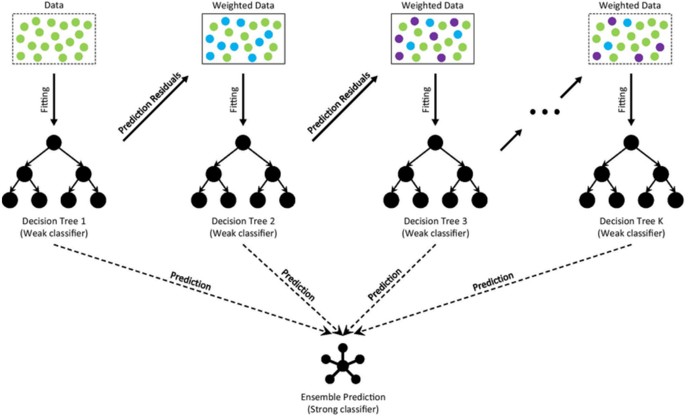
$H \to W^*W$ [3] 2 TGC : important





Unique observable $\longrightarrow$ **Multivariate analysis**

Gradient Boosted Decision Tree (BDTG) : [4]

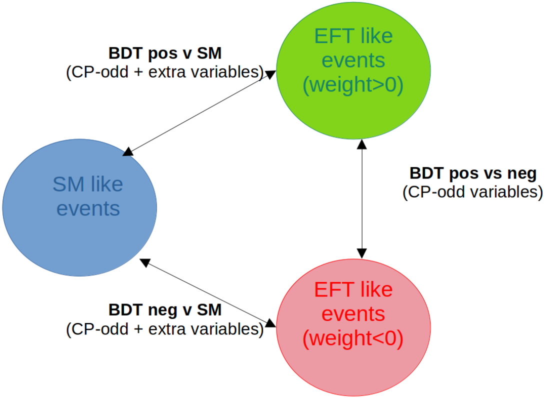


MC events splitted in 2 sets :

1. Training
2. Testing

"Data" : simulated events used for training.

Constraints on SMEFT via machine learning



Three distinct BDTs trained with TMVA :

CP-odd variables :
3 triple products, $\sin\phi_{WZ}$, φ^*_W, φ^*_Z, $\cos\theta^*_W$, $\Delta\Phi(W^{lep}, Z)$

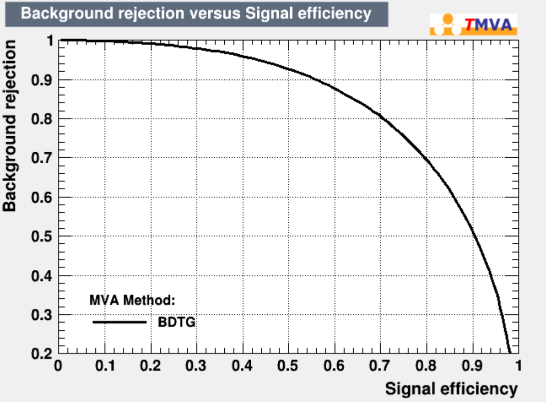
Extra variables :
r_{21}, p_T^Z, p_T^{WZ}, m_T^{WZ}, m_T^W, $\Delta\Phi(W^{lep}, Z^{lep})$, E_T^{miss}, p_{DNN}^{00}, $\cos\chi$

Scores labelling :

- pos v SM : S_p
- neg v SM : S_n
- pos v neg : S_0

BDT optimisation

A way to measure the performance of a BDT is with the Area Under the ROC Curve (AUC) :



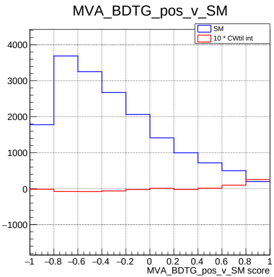
AUC maximisation for each BDT :

✓ selection of training variables
✓ choice of BDT hyperparameters
≃ k-folding training

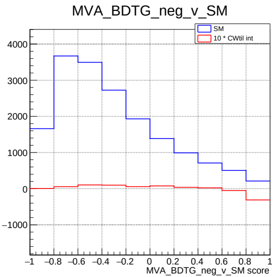
ROC curve BDT *pos vs SM* for $\mathcal{O}_{\tilde{W}}$

BDT scores combination

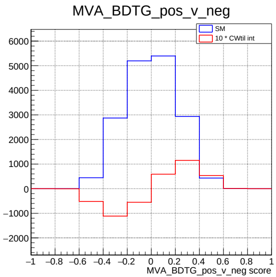
Score distributions for BDTs trained on $\mathcal{O}_{\tilde{W}}$ EFT samples



S_p



S_n

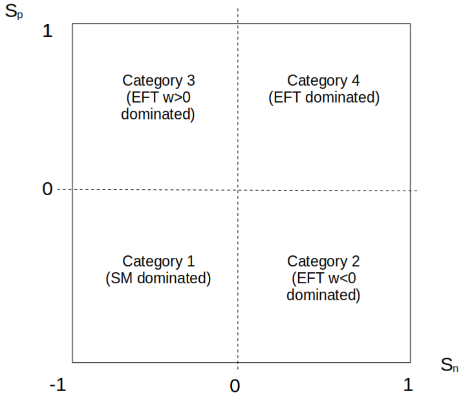


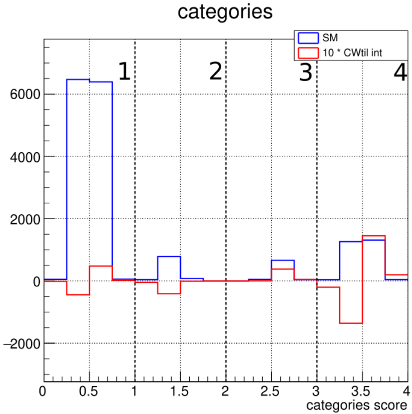
S_0

How to combine the three scores optimally ?

BDT scores combination

Similar behavior for both operators, EFT/SM ratio increased in category 4





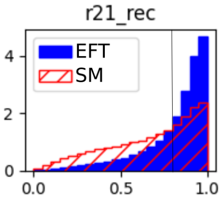
$$(\mathrm{cat}(S_p, S_n) - 1) + S_0$$

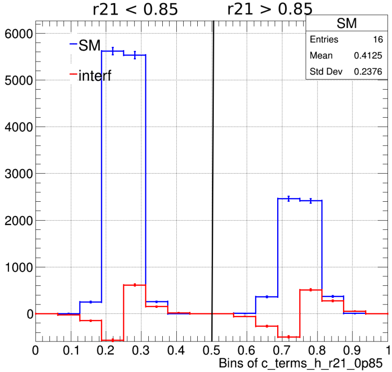
BDT scores combination

Amplification of S_0 distribution shape :

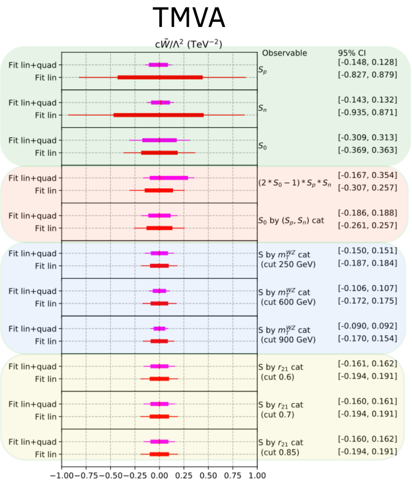
$$S = S_0 \times \frac{S_p + 1}{2} \times \frac{S_n + 1}{2}$$

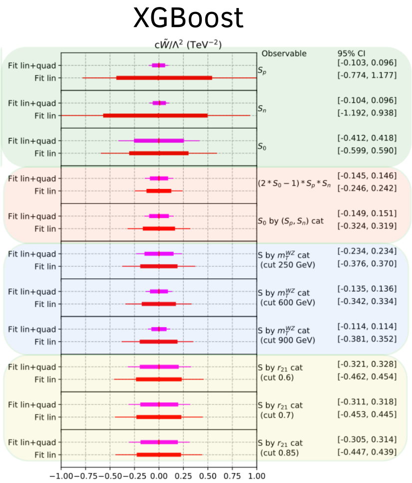
Splitting S by categories, e.g. $r_{21} = \frac{p_T^{V2}}{p_T^{V1}}$ (cut 0.85)





Results summary : $c_{\tilde{W}}$ limits





Single BDT score, basic combinations, combinations by m_T^{WZ} category and by r_{21} category

Conclusion

Fits results (lin+quad) :

Analyse	Observable	95% CI $c_{H\tilde{W}B}$	95% CI $c_{\tilde{W}}$
VBF Z [2]	$\Delta\Phi_{jj}$	[-1.06, 1.06]	[-0.12, 0.12]
VBF $H \to W^*W$ [3]	$\Delta\Phi_{jj}$	[-1.2, 1.1]	N/A
WZ (this work)	$p_\perp(\sum p^z, Z, W^{lep})$	[-3.97, 3.96]	[-0.21, 0.21]
WZ (this work)	φ^*_W	[-3.25, 3.19]	[-0.17, 0.17]
WZ (this work)	φ^*_Z	[-3.82, 3.74]	[-0.20, 0.21]
WZ (this work)	S(m_T^{WZ}), cut 600 GeV	[-1.78, 1.75]	[-0.11, 0.11]
WZ (this work)	S(m_T^{WZ}), cut 900 GeV	[-1.77, 1.80]	[-0.09, 0.09]
WZ (this work)	$S_0(S_p, S_n)$	[-1.88, 1.91]	[-0.19, 0.19]

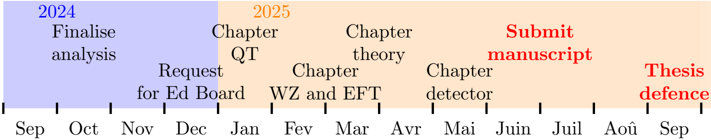
- Shrinks CI widths up by more than a factor 2
- Competitive expected limits for $\mathcal{O}_{\tilde{W}}$
- Have not reached same sensitivity for $\mathcal{O}_{H\tilde{W}B}$

To-do list 3rd year

- k-folding training to take advantage of the full statistics
- Implement trained BDTs in LAPPVVAnalyses framework
- Apply to Run 2 data, proceed to unfolding

- ... manuscript writing

To-do list 3rd year



Manuscript content as planned to this day :

1. The Standard Model and the EW symmetry breaking
2. The LHC and the ATLAS detector
3. Low p_T electron identification in ATLAS
4. Mesurement of WZ cross sections
5. Constraints on SMEFT CP-odd operators

Possible splitting of chapters.

Perspectives 3rd year

- Publication of WZ analysis end of autumn/winter
- Talk to Multiboson Interaction workshop in Toulouse (25th-27th Sep) : overview of SMEFT CPV studies in ATLAS

- Talk to the physics department of Jagiellonian University of Krakow (week of 7th Oct)

Thank you for listening !

[1] Céline Degrande et Julien Touchèque. “A Reduced basis for CP violation in SMEFT at colliders and its application to Diboson production”. en. In : *J. High Energ. Phys.* 2022.4 (avr. 2022). arXiv :2110.02993 [hep-ph], p. 32.

[2] Collaboration ATLAS. “Differential cross-section measurements for the electroweak production of dijets in association with a Z boson in proton–proton collisions at ATLAS”. In : *The European physical journal. C* 81.2 (2021), p. 163.

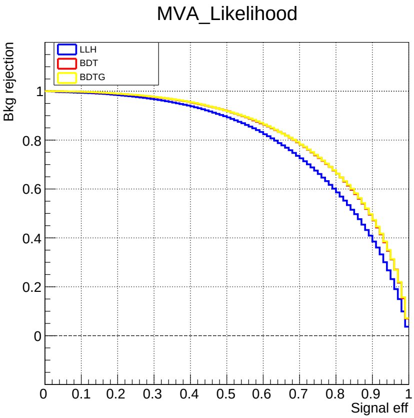
[3] Atlas Collaboration et al. “Integrated and differential fiducial cross-section measurements for the vector boson fusion production of the Higgs boson in the H$\rightarrow$ WW$\rightarrow$ e v mu v decay channel at 13 TeV with the ATLAS detector”. In : *Physical Review D* 108.7 (2023), p. 072003.

[4] Haowen Deng et al. “Ensemble learning for the early prediction of neonatal jaundice with genetic features”. In : *BMC medical informatics and decision making* 21 (2021), p. 1-11.

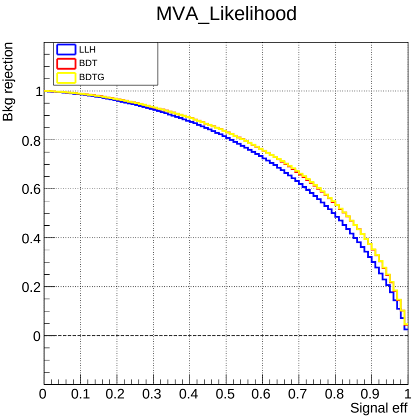
Back-up

BDT types

$\mathcal{O}_{\tilde{W}}$ (pos vs SM)



$\mathcal{O}_{H\tilde{W}B}$ (pos vs SM)



List of dim 6 operators

$U(3)^5$ flavour symmetry : all generations affected by the same effects

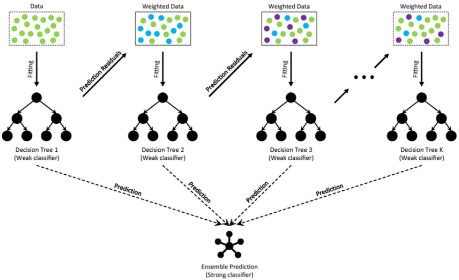
$\mathcal{L}_6^{(1)} - X^3$		$\mathcal{L}_6^{(6)} - \psi^2 XH$		$\mathcal{L}_6^{(8b)} - (\bar{R}R)(\bar{R}R)$	
Q_G	$f^{abc} G_\mu^{a\nu} G_\nu^{b\rho} G_\rho^{c\mu}$	Q_{eW}	$(\bar{l}_p \sigma^{\mu\nu} e_r)\sigma^i H W_{\mu\nu}^i$	Q_{ee}	$(\bar{e}_p \gamma_\mu e_r)(\bar{e}_s \gamma^\mu e_t)$
$Q_{\widetilde{G}}$	$f^{abc} \widetilde{G}_\mu^{a\nu} G_\nu^{b\rho} G_\rho^{c\mu}$	Q_{eB}	$(\bar{l}_p \sigma^{\mu\nu} e_r) H B_{\mu\nu}$	Q_{uu}	$(\bar{u}_p \gamma_\mu u_r)(\bar{u}_s \gamma^\mu u_t)$
Q_W	$\varepsilon^{ijk} W_\mu^{i\nu} W_\nu^{j\rho} W_\rho^{k\mu}$	Q_{uG}	$(\bar{q}_p \sigma^{\mu\nu} T^a u_r)\widetilde{H}\, G_{\mu\nu}^a$	Q_{dd}	$(\bar{d}_p \gamma_\mu d_r)(\bar{d}_s \gamma^\mu d_t)$
$Q_{\widetilde{W}}$	$\varepsilon^{ijk} \widetilde{W}_\mu^{i\nu} W_\nu^{j\rho} W_\rho^{k\mu}$	Q_{uW}	$(\bar{q}_p \sigma^{\mu\nu} u_r)\sigma^i \widetilde{H}\, W_{\mu\nu}^i$	Q_{eu}	$(\bar{e}_p \gamma_\mu e_r)(\bar{u}_s \gamma^\mu u_t)$
$\mathcal{L}_6^{(2)} - H^6$		Q_{uB}	$(\bar{q}_p \sigma^{\mu\nu} u_r)\widetilde{H}\, B_{\mu\nu}$	Q_{ed}	$(\bar{e}_p \gamma_\mu e_r)(\bar{d}_s \gamma^\mu d_t)$
Q_H	$(H^\dagger H)^3$	Q_{dG}	$(\bar{q}_p \sigma^{\mu\nu} T^a d_r) H\, G_{\mu\nu}^a$	$Q_{ud}^{(1)}$	$(\bar{u}_p \gamma_\mu u_r)(\bar{d}_s \gamma^\mu d_t)$
$\mathcal{L}_6^{(3)} - H^4 D^2$		Q_{dW}	$(\bar{q}_p \sigma^{\mu\nu} d_r)\sigma^i H\, W_{\mu\nu}^i$	$Q_{ud}^{(8)}$	$(\bar{u}_p \gamma_\mu T^a u_r)(\bar{d}_s \gamma^\mu T^a d_t)$
$Q_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$	Q_{dB}	$(\bar{q}_p \sigma^{\mu\nu} d_r) H\, B_{\mu\nu}$		
Q_{HD}	$(D^\mu H^\dagger H)\,(H^\dagger D_\mu H)$				
$\mathcal{L}_6^{(4)} - X^2 H^2$		$\mathcal{L}_6^{(7)} - \psi^2 H^2 D$		$\mathcal{L}_6^{(8c)} - (\bar{L}L)(\bar{R}R)$	
Q_{HG}	$H^\dagger H\, G_{\mu\nu}^a G^{a\mu\nu}$	$Q_{Hl}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_p \gamma^\mu l_r)$	Q_{le}	$(\bar{l}_p \gamma_\mu l_r)(\bar{e}_s \gamma^\mu e_t)$
$Q_{H\widetilde{G}}$	$H^\dagger H\, \widetilde{G}_{\mu\nu}^a G^{a\mu\nu}$	$Q_{Hl}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^i H)(\bar{l}_p \sigma^i \gamma^\mu l_r)$	Q_{lu}	$(\bar{l}_p \gamma_\mu l_r)(\bar{u}_s \gamma^\mu u_t)$
Q_{HW}	$H^\dagger H\, W_{\mu\nu}^i W^{I\mu\nu}$	Q_{He}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}_p \gamma^\mu e_r)$	Q_{ld}	$(\bar{l}_p \gamma_\mu l_r)(\bar{d}_s \gamma^\mu d_t)$
$Q_{H\widetilde{W}}$	$H^\dagger H\, \widetilde{W}_{\mu\nu}^i W^{i\mu\nu}$	$Q_{Hq}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}_p \gamma^\mu q_r)$	Q_{qe}	$(\bar{q}_p \gamma_\mu q_r)(\bar{e}_s \gamma^\mu e_t)$
Q_{HB}	$H^\dagger H\, B_{\mu\nu} B^{\mu\nu}$	$Q_{Hq}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^i H)(\bar{q}_p \sigma^i \gamma^\mu q_r)$	$Q_{qu}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{u}_s \gamma^\mu u_t)$
$Q_{H\widetilde{B}}$	$H^\dagger H\, \widetilde{B}_{\mu\nu} B^{\mu\nu}$	Q_{Hu}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{u}_p \gamma^\mu u_r)$	$Q_{qu}^{(8)}$	$(\bar{q}_p \gamma_\mu T^a q_r)(\bar{u}_s \gamma^\mu T^a u_t)$
Q_{HWB}	$H^\dagger \sigma^i H\, W_{\mu\nu}^i B^{\mu\nu}$	Q_{Hd}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{d}_p \gamma^\mu d_r)$	$Q_{qd}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{d}_s \gamma^\mu d_t)$
$Q_{H\widetilde{W}B}$	$H^\dagger \sigma^i H\, \widetilde{W}_{\mu\nu}^i B^{\mu\nu}$	Q_{Hud} + h.c.	$i(\widetilde{H}^\dagger D_\mu H)(\bar{u}_p \gamma^\mu d_r)$	$Q_{qd}^{(8)}$	$(\bar{q}_p \gamma_\mu T^a q_r)(\bar{d}_s \gamma^\mu T^a d_t)$
$\mathcal{L}_6^{(5)} - \psi^2 H^3$		$\mathcal{L}_6^{(8a)} - (\bar{L}L)(\bar{L}L)$		$\mathcal{L}_6^{(8d)} - (\bar{L}R)(\bar{R}L), (\bar{L}R)(\bar{L}R)$	
Q_{eH}	$(H^\dagger H)(\bar{l}_p e_r H)$	Q_{ll}	$(\bar{l}_p \gamma_\mu l_r)(\bar{l}_s \gamma^\mu l_t)$	Q_{ledq}	$(\bar{l}_p^j e_r)(\bar{d}_s q_{tj})$
Q_{uH}	$(H^\dagger H)(\bar{q}_p u_r \widetilde{H})$	$Q_{qq}^{(1)}$	$(\bar{q}_p \gamma_\mu q_r)(\bar{q}_s \gamma^\mu q_t)$	$Q_{quqd}^{(1)}$	$(\bar{q}_p^j u_r)\varepsilon_{jk}(\bar{q}_s^k d_t)$
Q_{dH}	$(H^\dagger H)(\bar{q}_p d_r H)$	$Q_{qq}^{(3)}$	$(\bar{q}_p \gamma_\mu \sigma^i q_r)(\bar{q}_s \gamma^\mu \sigma^i q_t)$	$Q_{quqd}^{(8)}$	$(\bar{q}_p^j T^a u_r)\varepsilon_{jk}(\bar{q}_s^k T^a d_t)$
		$Q_{lq}^{(1)}$	$(\bar{l}_p \gamma_\mu l_r)(\bar{q}_s \gamma^\mu q_t)$	$Q_{lequ}^{(1)}$	$(\bar{l}_p^j e_r)\varepsilon_{jk}(\bar{q}_s^k u_t)$
		$Q_{lq}^{(3)}$	$(\bar{l}_p \gamma_\mu \sigma^i l_r)(\bar{q}_s \gamma^\mu \sigma^i q_t)$	$Q_{lequ}^{(3)}$	$(\bar{l}_p^j \sigma_{\mu\nu} e_r)\varepsilon_{jk}(\bar{q}_s^k \sigma^{\mu\nu} u_t)$

- Bosonic
- Boson-fermion
- 4-fermion

JHEP04(2021)073

BDTG hyperparameters

- Number of trees
- Tree maximal depth
- Minimal Node Size
- Shrinkage ($\simeq$ learning rate) : maximal impact of a BDT on the final model



Variable ranking S_0 for $\mathcal{O}_{H\tilde{W}B}$

Variable	AUC(N-1)	Importance (%)	AUC(N-1) - AUC(N)
phiStarW_rec	0.6305	0.1734	0.0099
TP_WZLepmWLep_rec	0.6352	0.0917	0.0052
phiStarZ_rec	0.6361	0.0765	0.0044
cosThetaStarZ_rec	0.6367	0.0665	0.0038
TP_WZLeppWLep_rec	0.6368	0.0646	0.0037
cosThetaStarW_rec	0.6371	0.0585	0.0033
sinPhiWZ_rec	0.6375	0.0515	0.0029
TP_zZWLep_rec	0.6375	0.0514	0.0029
dPhiWlZ_rec	0.6387	0.0303	0.0017

Variable ranking S_0 for $\mathcal{O}_{\tilde{W}}$

Variable	AUC(N-1)	Importance (%)	AUC(N-1) - AUC(N)
phiStarZ_rec	0.6257	0.3538	0.0204
cosThetaStarZ_rec	0.6410	0.0885	0.0051
phiStarW_rec	0.6413	0.0830	0.0048
sinPhiWZ_rec	0.6425	0.0617	0.0036
TP_WZLeppWLep_rec	0.6426	0.0613	0.0035
TP_WZLepmWLep_rec	0.6428	0.0565	0.0033
TP_zZWLep_rec	0.6450	0.0187	0.0011
dPhiWlZ_rec	0.6451	0.0177	0.0010
cosThetaStarW_rec	0.6451	0.0172	0.0010

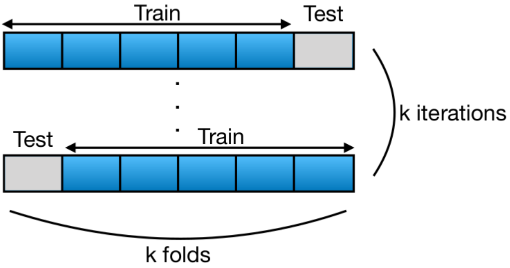
Variable ranking S_n for $\mathcal{O}_{\tilde{W}}$

Variable	AUC(N-1)	Importance (%)	AUC(N-1) - AUC(N)
r21_rec	0.8018	0.1891 2.8166	
p00DNN_rec	0.8261	0.0254	0.3777
pTWZ_rec	0.8266	0.0223	0.3329
mTWZ_rec	0.8273	0.0177	0.2638
phiStarZ_rec	0.8287	0.0081	0.1200
cosThetaStarW_rec	0.8292	0.0050	0.0740
pTZ_rec	0.8292	0.0049	0.0724
cosThetaStarZ_rec	0.8295	0.0030	0.0452
DphiWlZlss_rec	0.8295	0.0028	0.0420
sinPhiWZ_rec	0.8297	0.0017	0.0257
phiStarW_rec	0.8297	0.0015	0.0228
dPhiWlZ_rec	0.8297	0.0015	0.0218
TP_WZLeppWLep_rec	0.8298	0.0011	0.0158
mTW_rec	0.8299	0.0004	0.0060
TP_WZLepmWLep_rec	0.8299	0.0004	0.0056
MET	0.8299	0.0002	0.0029
TP_zZWLep_rec	0.8300	0.0008	0.0124
cosChi_WZRef_rec	0.8300	0.0009	0.0127

Variable ranking S_p for $\mathcal{O}_{\tilde{W}}$

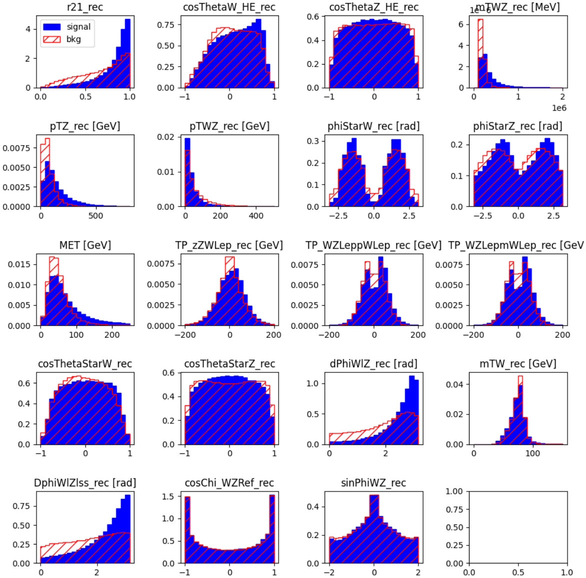
Variable	AUC(N-1)	Importance (%)	AUC(N-1) - AUC(N)
r21_rec	0.8018	0.1975	0.0295
pTWZ_rec	0.8266	0.0310	0.0046
p00DNN_rec	0.8272	0.0272	0.0041
mTWZ_rec	0.8283	0.0197	0.0029
phiStarZ_rec	0.8299	0.0089	0.0013
pTZ_rec	0.8301	0.0075	0.0011
DphiWlZlss_rec	0.8304	0.0055	0.0008
cosThetaStarW_rec	0.8305	0.0048	0.0007
dPhiWlZ_rec	0.8306	0.0046	0.0007
cosThetaStarZ_rec	0.8307	0.0035	0.0005
TP_WZLeppWLep_rec	0.8309	0.0022	0.0003
phiStarW_rec	0.8310	0.0019	0.0003
cosChi_WZRef_rec	0.8310	0.0018	0.0003
TP_WZLepmWLep_rec	0.8310	0.0015	0.0002
MET	0.8311	0.0012	0.0002
mTW_rec	0.8311	0.0012	0.0002
sinPhiWZ_rec	0.8312	0.0006	0.0001
TP_zZWLep_rec	0.8313	0.0001	0.0000

k-folding



Resulting in *k* separate BDTs.

Input variables : S_p for $\mathcal{O}_{\tilde{W}}$

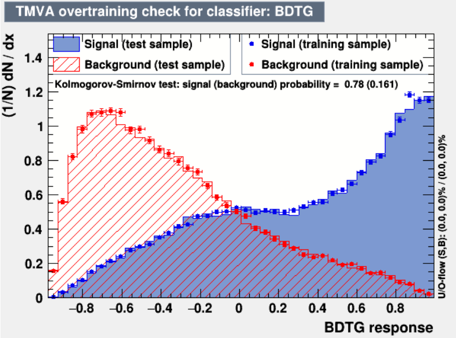


Comparison TMVA vs XGBoost

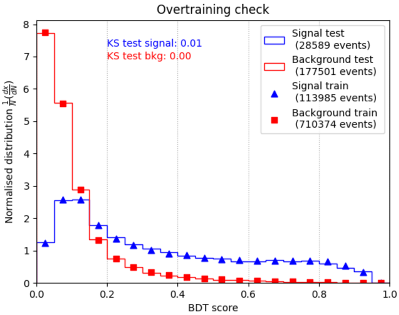
While being desiigned differently, XGBoost serves the same purpose as TMVA.

- worse signal (=EFT) acceptance
- better background (=SM) rejection

TMVA



XGBoost



Example : S_p score for $c_{\tilde{W}}$, comparable AUC (0.83 vs 0.83)

Results summary

Fit on $\mathcal{O}_{\tilde{W}}$

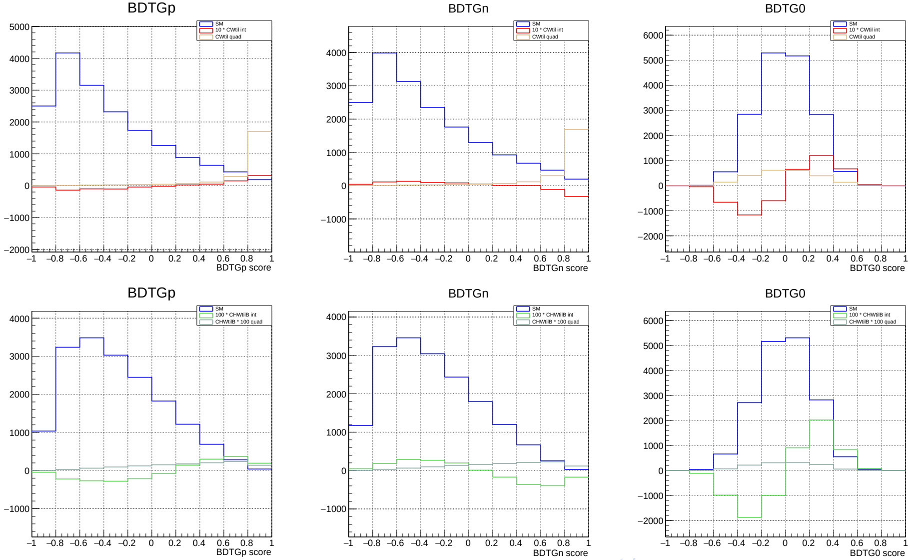
	Best observable	95% CI lin	95% CI lin+quad
TMVA	S(m_T^{WZ}), cut 900 GeV	[-0.17, 015]	[-0.09, 0.09]
XGBoost	S(m_T^{WZ}), cut 900 GeV	[-0.38, 035]	[-0.11, 0.11]

Fit on $\mathcal{O}_{H\tilde{W}B}$

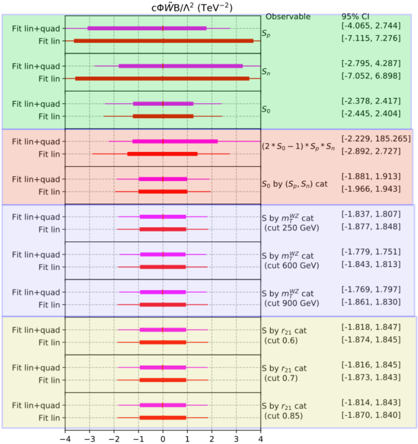
	Best observable	95% CI lin	95% CI lin+quad
TMVA	S(m_T^{WZ}), cut 600 GeV	[-1.84, 1.81]	[-1.77, 1.80]
XGBoost	$S_0(S_p, S_n)$	[-1.83, 1.15]	[-1.68, 1.07]

Impact of quadratic term

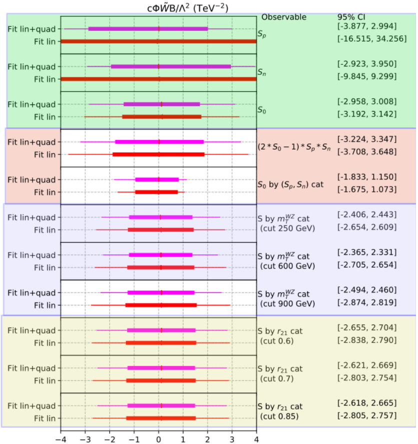
BDT scores distributions :



TMVA



XGBoost



Single BDT score, basic combinations, combinations by m_T^{WZ} category and by r_{21} category

ATLAS week (12th-16th Feb)

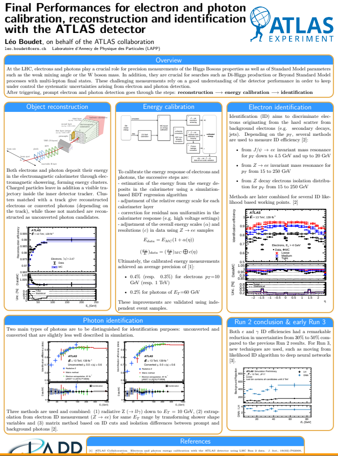
Poster presented on QT results

Presentations

e/γ workshop (8th-12th Apr)
Presentation on all of the electron ID subgroup results with release 22

ICHEP (18th-24th Jul)

Poster presented at ICHEP on behalf of e/γ for final Run2 performances plots :



ADUM formations

Total : 203 hours

Formation	Catégorie	Heures
Exercer son esprit critique : données et raisonnem	Transversale	20
Théorie des groupes	Scientifique	18
European school of high energy physics du CERN	Scientifique	40
Summer school 'Methods of Effective Field Theor	Scientifique	40
Cours d'espagnol à l'Université Savoie Mont-Blanc	Transversale	12
Encadrer efficacement des TD-22-2	Professionnelle	7
Enseignement à l'Université Savoie Mont-Blanc (2	Professionnelle	8
RÉDIGER VOS ARTICLES ET VOTRE THÈSE AVEC	Scientifique	10
Cours d'espagnol à l'Université Savoie Mont-Blanc	Transversale	6
MOOC Ethique de la recherche	Transversale	15
MOOC Doctorat et poursuite de carrière	Professionnelle	24
Enseignement à l'Université Savoie Mont-Blanc (2	Professionnelle	3