WZ polarisation: experimental investigations

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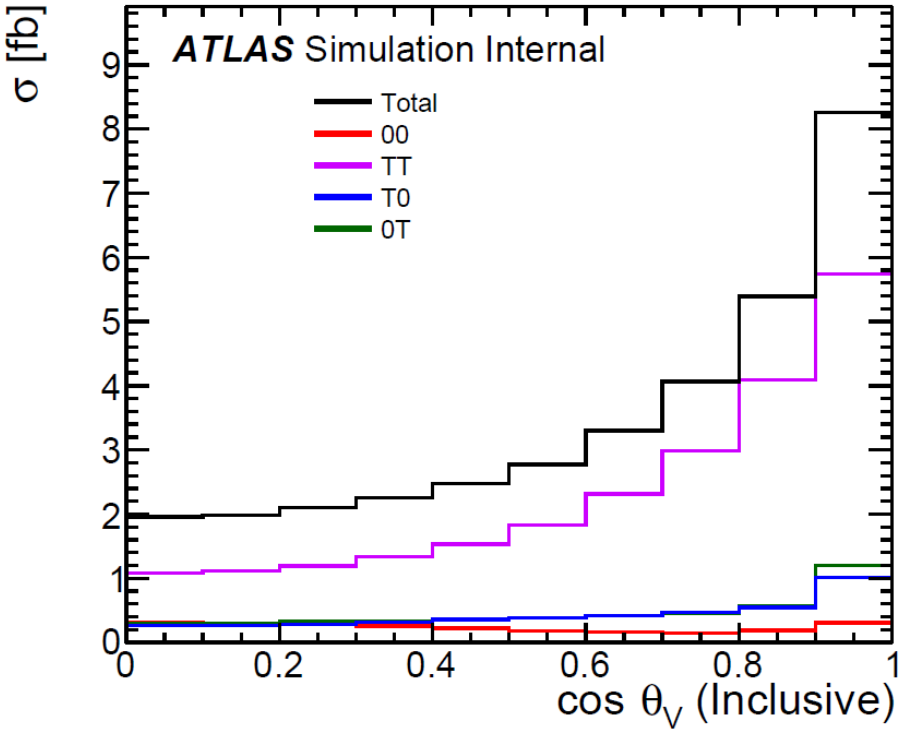
(LAPP)

- Experimental methodology
- Pznu reconstruction methods
- Variables for polarisation extraction
- Phase space for the measurement(s)

How to extract f00 from data ?

- Find one discriminating variable : ➔ A first candidate: $|\cos\theta_V|$

- Do a template fit



➔ Try to scale integral of polarisation templates to match data

➔ For sensitivity studies, replace data by the sum of templates (ie. Asimov data)

➔ Use a binned likelihood fit

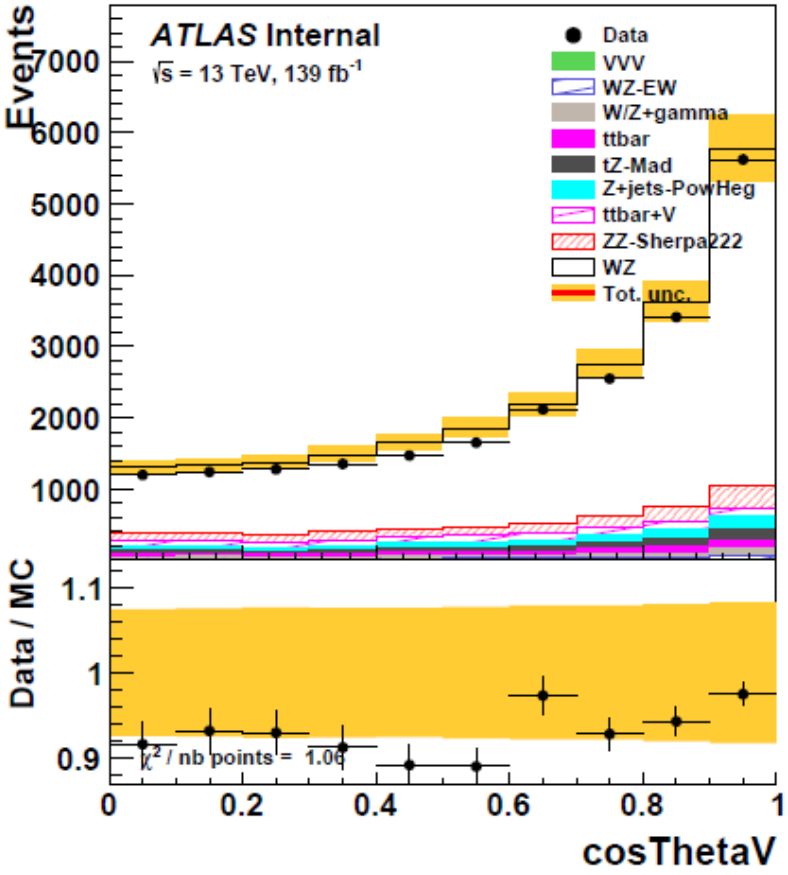
- Use the constraint of sum of fractions =1

➔ Fit 3 fractions and the total cross section (or number of expected WZ events Ntot)

➘ Templates from MadGraph LO + pythia8 are used

How to extract f00 from data ?

- For real data, need also to subtract backgrounds
  - ➔ With associated normalisation uncertainties



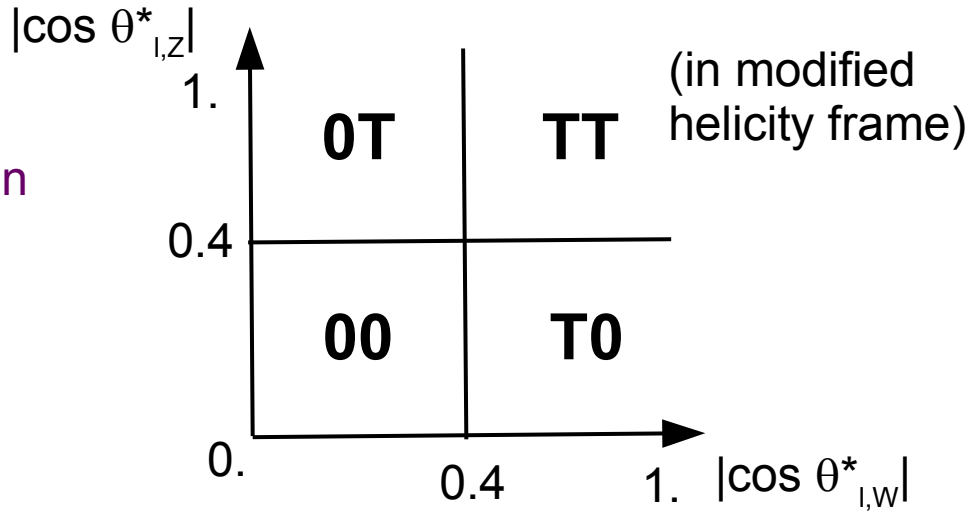
- Signal / backgrounds ~ 3.3

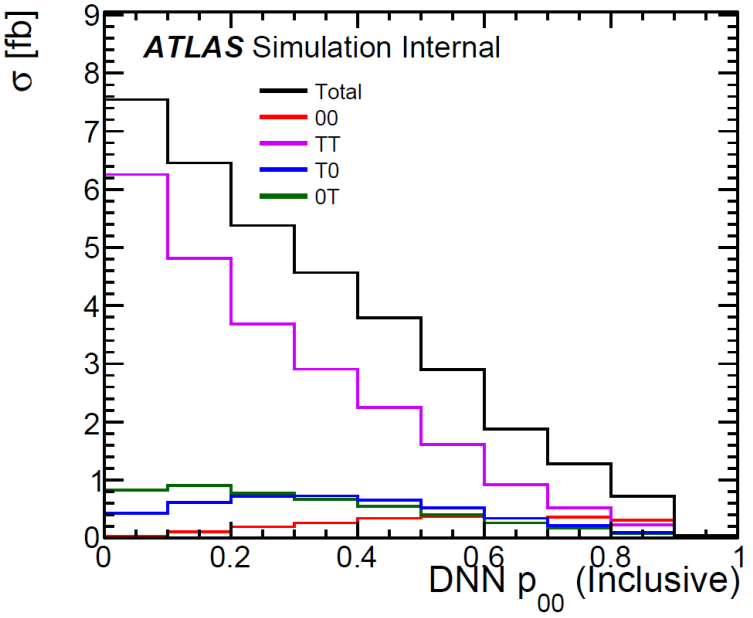
↘ Includes the backgrounds in the fit

↘ Their amount and shape will reduce the sensitivity

How to extract f00 from data ?

- Going beyond one single discriminating variable
  - ➔ Associate 3 variables in a 3D fit
    - ➔ Here divide events in 4 categories in the plane ($|\cos\theta_{l,Z}^*|$, $|\cos\theta_{l,W}^*|$)
    - ➔ The 3rd dimension is $|\cos\theta_V|$
  - ➔ Or combine more variables in a DNN, and fit the 1D DNN score





Pznu reconstructions

- Pznu reconstruction problem : $p_z^\nu = \frac{p_z^l \xi \pm \sqrt{\Delta}}{{p_T^l}^2}$

$$\Delta = {p_z^l}^2 \xi^2 - {p_T^l}^2 [{E^l}^2 {p_T^\nu}^2 - \xi^2], \xi = \frac{m_W^2}{2} + \vec{p_T^l} \vec{p_T^\nu}$$

  - $\Delta > 0$: there are two physical solutions.
    1. Take the smallest solution in absolute
    2. Take the solution in the same hemisphere as the lepton, otherwise take the smallest
  - $\Delta < 0$: there is no physical solutions. (~30% of events at detector level)
    1. Take the real part of the complex solution
    2. p_T^ν is rescaled so that m_T^W equals m_W^{PDG}

- Tested methods:
  - ➔ "Baseline" = 1., 1. (was used in previous ATLAS publications)
  - ➔ "Alternative" = 2., 2.
  - ➔ Using a DNN regression (Francesco)

Pznu reconstructions

- Comparison of the methods :

  ➔ Check impact on the final fit for f00 extraction

- Fit of the DNN p00 score

(fractions measured at detector level)

p_z^ν reconstruction	f_{00}	f_{0T}	f_{TT}	$N_{\text{tot.}}$	$f_{00}/\delta f_{00}$
DNN regression	0.069 ± 0.0089	0.13 ± 0.14	0.67 ± 0.080	19142 ± 315	7.7
Alternative	0.069 ± 0.0092	0.13 ± 0.13	0.67 ± 0.078	19143 ± 315	7.5
Baseline	0.069 ± 0.0096	0.13 ± 0.15	0.67 ± 0.08	19144 ± 315	7.2

- Fit of $|\cos \theta_V|$ with 4 categories

(fractions corrected for detector efficiency)

p_z^ν reconstruction	f_{00}	f_{0T}	f_{TT}	$N_{\text{tot.}}$	$f_{00}/\delta f_{00}$
DNN regression	0.063 ± 0.016	0.14 ± 0.04	0.67 ± 0.039	41195 ± 630	3.9
Alternative	0.063 ± 0.017	0.14 ± 0.05	0.67 ± 0.045	41205 ± 640	3.7
Baseline	0.063 ± 0.017	0.14 ± 0.046	0.67 ± 0.044	41201 ± 640	3.7

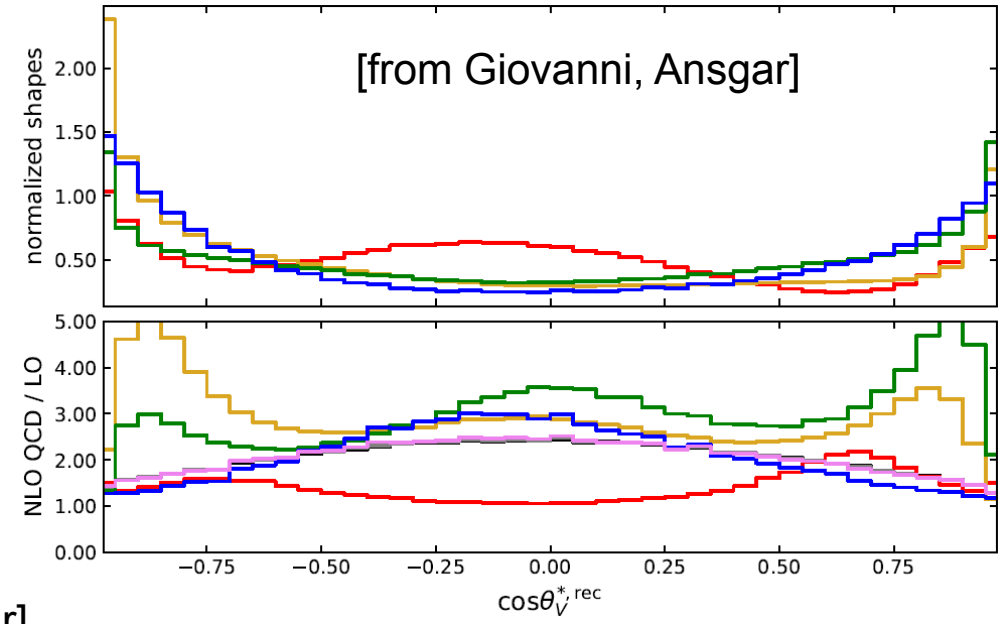
↘ Slight advantage to DNN pznu reconstruction

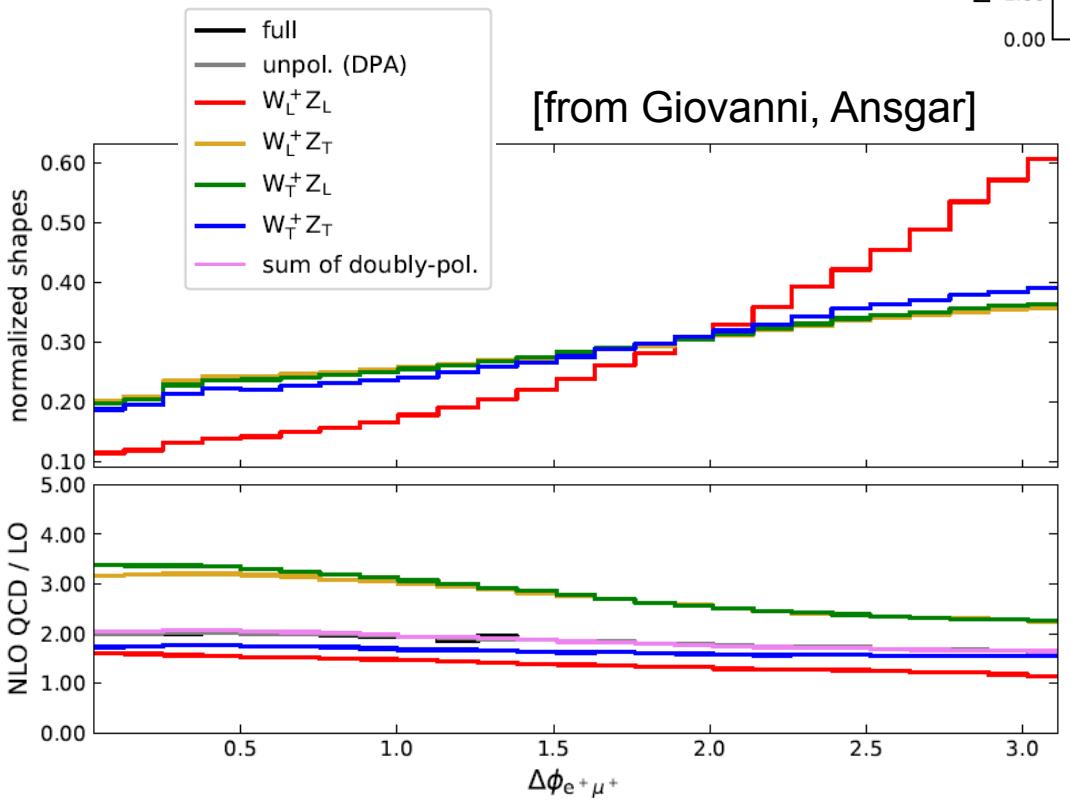
↘ Attributed to a better separation from $\cos \theta^*_{\text{l,W(,Z)}}$

Best observables for polarisation separation

- $|\cos\theta_V|$ is good, but huge NLO corrections ?

  ➘ Need variables with ~flat NLO corrections





- ➔ $\Delta\phi_{e+\mu+}$ seems to be a good candidate
- ➔ But no separation between 00 and 0T/T0 modes
- ➔ Combine with ($|\cos\theta_{l,Z}^*|$, $|\cos\theta_{l,W}^*|$)

Best observables for polarisation separation

- Sensitivity using the full fit :

(fractions measured at detector level)

Variable	f_{00}	f_{0T}	f_{TT}	$N_{\text{tot.}}$	$f_{00}/\delta f_{00}$
$\lvert\cos\theta_V\rvert$	0.061 ± 0.027	0.16 ± 0.12	0.62 ± 0.06	17234 ± 310	2.25
$\lvert\cos\theta_V\rvert$, 4 categories	0.061 ± 0.019	0.16 ± 0.04	0.62 ± 0.04	17232 ± 300	3.3
$\Delta\phi(\ell_W, \ell_Z)^{sc}$, 4 categories	0.061 ± 0.017	0.16 ± 0.04	0.62 ± 0.04	17232 ± 310	3.6

(different MC sample than on p6 used)

➔ Better sensitivity than cos θ_V

➔ Advantage of having 3 variables with ~ flat NLO corrections

↘ Need variables with ~flat NLO corrections

↘ Interresting to see NLO corrections for DNN p00 observable

Phase space for polarisation measurement

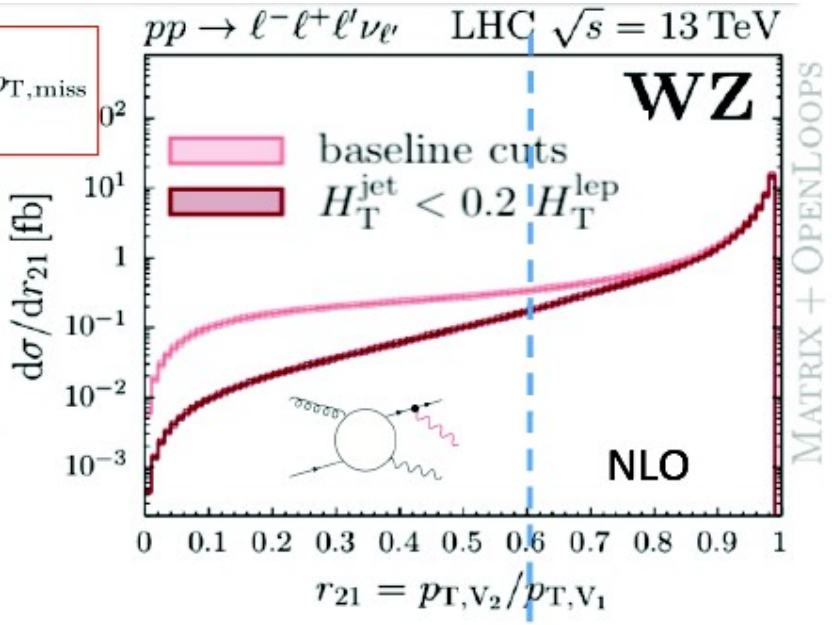
- At least do a measurement + calculation in “inclusive” phase space (ie. the present one)
- Can we reduce impact of NLO (QCD, EW) corrections adding some cuts ?

➔ using r21 ?

$$H_{\mathrm{T}}^{\mathrm{lep}} = \sum_{i\in\{\ell^{\pm}\}} p_{\mathrm{T},i} + p_{\mathrm{T,miss}}$$

$$H_{\mathrm{T}}^{\mathrm{jet}} = \sum_{i\in\mathrm{jets}} p_{\mathrm{T},i}$$

arXiv:1912.00068



- To enhance sensitivity to f00 ?

➔ PTWZ < 120 GeV ?

Phase space for polarisation measurement

- Test effects of the cuts on the fit sensitivity

  ➔ Fits done using $\Delta\phi(\ell_W, \ell_Z)^{sc}$, 4 categories

Phase space	f_{00}	f_{0T}	f_{TT}	$N_{\text{tot.}}$	$f_{00}/\delta f_{00}$
Inclusive	0.061 ± 0.017	0.16 ± 0.04	0.62 ± 0.04	17232 ± 310	3.6
Inclusive + $r21 > 0.6$	0.075 ± 0.022	0.13 ± 0.05	0.67 ± 0.05	11555 ± 189	3.35
Inclusive + $p_T^{WZ} < 120$ GeV	0.071 ± 0.022	0.15 ± 0.05	0.63 ± 0.05	14316 ± 255	3.15

- ➘ In terms of sensitivity “inclusive” PS looks still the best
- ➘ But no theory uncertainties considered ….
- ➘ Interresting to see evolution of polarisation and NLO correction wrt. these variables

Summary

- Pznu reconstruction :
  - ➔ Analytical : use options 2 ? → for theory calculation
  - ➔ DNN seems better for the fit at detector level
  - ➔ For truth level reweighting: use directly the generated neutrino
- Observables for polarisation
  - ➔ Better use variables with flat NLO QCD corrections
  - ➔ $\Delta\phi_{e+\mu+}$ together with $\cos\theta_{l,Z}^*$, $\cos\theta_{l,W}^*$ seems promising
  - ➔ And DNN
- Phase space
  - ➔ Would a cut on R21 or pTWZ reduce NLO corrections ?
  - ➔ Interesting to try a measurement at high pTZ (pTZ > ~200 GeV) ?

Additional material