MANCHESTER 1824

The University of Manchester

Reweighting techniques for aTGC measurements

Alexander Oh

University of Manchester

aTGC

- aTGC couplings manifest themselves in:
  - enhanced cross section
  - change in kinematics of bosons
- Extracting aTGC couplings with MC templates.
- Reweight kinematic distributions at particle/parton level.
  - Advantage:
    Can be applied to any MC.
  - Disadvantage:
    Acceptance change difficult to account for.
    Phase space depletion wrt to SM prediction.
- Phase space depletion wrt to SM prediction.

- Reweight on an event by event basis
  - Advantage:
    Fully accounts for acceptance changes.
    Samples with aTGC couplings prevent phase-space depletion.
  - Disadvantage:
    Not available for many MC's.
- Reweight aposteriori
  - Use existing sample, and recalculate weights with matrix elements event-by-event ("Afterburner" package).
  - Advantage:
    Can be applied to any MC.
    Fully accounts for acceptance changes.
  - Disadvantage:
    Phase space depletion wrt to SM prediction.

some aTGC MC generators

- MC@NLO
  - Interfaced to Herwig/Pythia.
  - NLO in alpha_s
  - Implements aTGC in **WZ** and **WW** production.
  - Per event weight available.
  - Spin correlation available.
- PowHeg-Box
  - Interfaced to Herwig/Pythia.
  - NLO in alpha_s.
  - Implements aTGC in **WZ** and **WW** production.
  - Spin correlation available.
- Sherpa
  - Shower MC.
  - Tree level ME + additional jets.
  - aTGC for **neutral** and **charged** vertices.
  - Spin correlations available.

- VBFNLO
  - cross section calculator.
  - NLO in alpha_s
  - Implements aTGC in **WZ, WW** and **Wgam** production.
  - Spin correlation available.
- MCFM
  - cross section calculator.
  - NLO in alpha_s
  - Implements aTGC in **WZ, WW** and **Zgam** production.
  - Spin correlation available.
- BHO
  - cross section calculator.
  - NLO in alpha_s
  - Implements aTGC in **WZ**, **WW**, **Zgam**, **Wgam** production.
  - Spin correlation available.

Weights in MC@NLO

- Since version 3.4 aTGC weights per event available for WZ and WW (4.0) production.
- SM and aTGC sample production possible.
- Weights are calculated during generation step.
  - Kinematic configuration is fixed.
  - Weights extracted by calling ME with different sets of aTGC parameter combinations and a set of linear equations.
  - Note that this is not possible with the POWHEG method.

Practicalities of Reweighting

- MC@NLO stores weights in the event record.
- WZ has 3 couplings -> 10 weights

$$\mathcal{A} = \mathcal{A}_0 + \Delta g_1^Z \mathcal{A}_{\Delta g_1^Z} + \Delta\kappa^Z \mathcal{A}_{\Delta\kappa^Z} + \lambda^Z \mathcal{A}_{\lambda^Z} \,,$$

$$\begin{aligned} w_{\rm TOT} \propto\; & w_0 + \left(\Delta g_1^Z\right)^2 w_1 + \left(\Delta\kappa^Z\right)^2 w_2 + \left(\lambda^Z\right)^2 w_3 \\ & + 2\Delta g_1^Z w_4 + 2\Delta\kappa^Z w_5 + 2\lambda^Z w_6 \\ & + 2\Delta g_1^Z \Delta\kappa^Z w_7 + 2\Delta g_1^Z \lambda^Z w_8 + 2\Delta\kappa^Z \lambda^Z w_9 \,. \end{aligned}$$

$$\mathcal{L}_{\rm eff} = i g_{WWV} \left(g_1^V (W^*_{\mu\nu} W^\mu V^\nu - W_{\mu\nu} W^{*\mu} V^\nu) + \kappa^V W^*_\mu W_\nu V^{\mu\nu} + \frac{\lambda^V}{M_W^2} W^*_{\mu\nu} W^\nu_\rho V^{\rho\mu} \right)$$

Practicalities of Reweighting

- MC@NLO stores weights in the event record.
- WW has 6 couplings -> 28 weights

$$\mathcal{A} = \mathcal{A}_0 + \Delta g_1^Z \mathcal{A}_{\Delta g_1^Z} + \Delta\kappa^Z \mathcal{A}_{\Delta\kappa z} + \lambda^Z \mathcal{A}_{\lambda z} + \Delta g_1^\gamma \mathcal{A}_{\Delta g_1^\gamma} + \Delta\kappa^\gamma \mathcal{A}_{\Delta\kappa^\gamma} + \lambda^\gamma \mathcal{A}_{\lambda^\gamma} .$$

$$\begin{aligned} w_{\mathrm{TOT}} = {} & w_0 + \left(\Delta g_1^Z\right)^2 w_1 + \left(\Delta\kappa^Z\right)^2 w_2 + \left(\lambda^Z\right)^2 w_3 \\ & + \left(\Delta g_1^\gamma\right)^2 w_4 + \left(\Delta\kappa^\gamma\right)^2 w_5 + \left(\lambda^\gamma\right)^2 w_6 \\ & + 2\Delta g_1^Z w_7 + 2\Delta\kappa^Z w_8 + 2\lambda^Z w_9 \\ & + 2\Delta g_1^\gamma w_{10} + 2\Delta\kappa^\gamma w_{11} + 2\lambda^\gamma w_{12} \\ & + 2\Delta g_1^Z \Delta\kappa^Z w_{13} + 2\Delta g_1^Z \lambda^Z w_{14} + 2\Delta g_1^Z \Delta g_1^\gamma w_{15} \\ & + 2\Delta g_1^Z \Delta\kappa^\gamma w_{16} + 2\Delta g_1^Z \lambda^\gamma w_{17} + 2\Delta\kappa^Z \lambda^Z w_{18} \\ & + 2\Delta\kappa^Z \Delta g_1^\gamma w_{19} + 2\Delta\kappa^Z \Delta\kappa^\gamma w_{20} + 2\Delta\kappa^Z \lambda^\gamma w_{21} \\ & + 2\lambda^Z \Delta g_1^\gamma w_{22} + 2\lambda^Z \Delta\kappa^\gamma w_{23} + 2\lambda^Z \lambda^\gamma w_{24} \\ & + 2\Delta g_1^\gamma \Delta\kappa^\gamma w_{25} + 2\Delta g_1^\gamma \lambda^\gamma w_{26} + 2\Delta\kappa^\gamma \lambda^\gamma w_{27} . \end{aligned}$$

Practicalities of Reweighting

- Simple function to calculate weights for new coupling parameters can be applied per event:

```
double ReweightTest::reweight(Weights& w, double dk, double l, double g) {
  return (
      w.w0 +
      w.w1 * g * g +
      w.w2 * dk  * dk  +
      w.w3 * l * l +
      w.w4 * g * 2 +
      w.w5 * dk * 2 +
      w.w6 * l * 2 +
      w.w7 * g * dk * 2 +
      w.w8 * g * l * 2 +
      w.w9 * dk * l * 2
      );
}
```

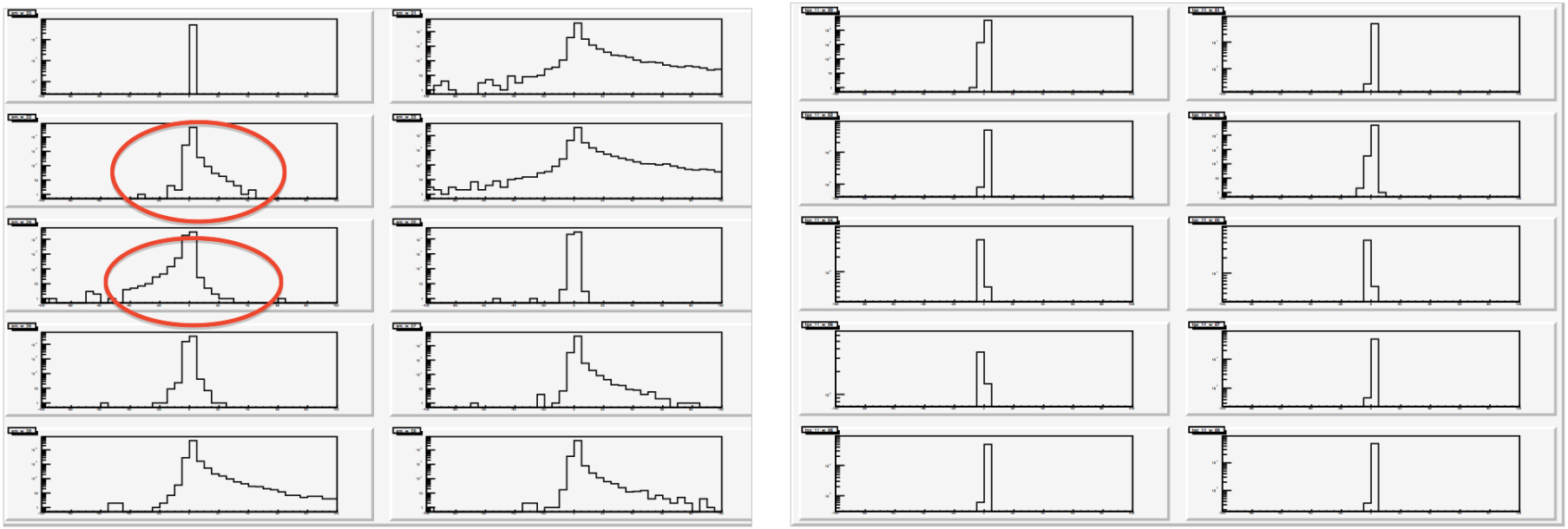
WZ case

$$\lambda(\hat{s}) = \frac{\lambda}{(1 + \hat{s}/\Lambda^2)^2}$$

- x1,x2,q stored as well.
- Can reweighting to different form-factors.

Weight comparison

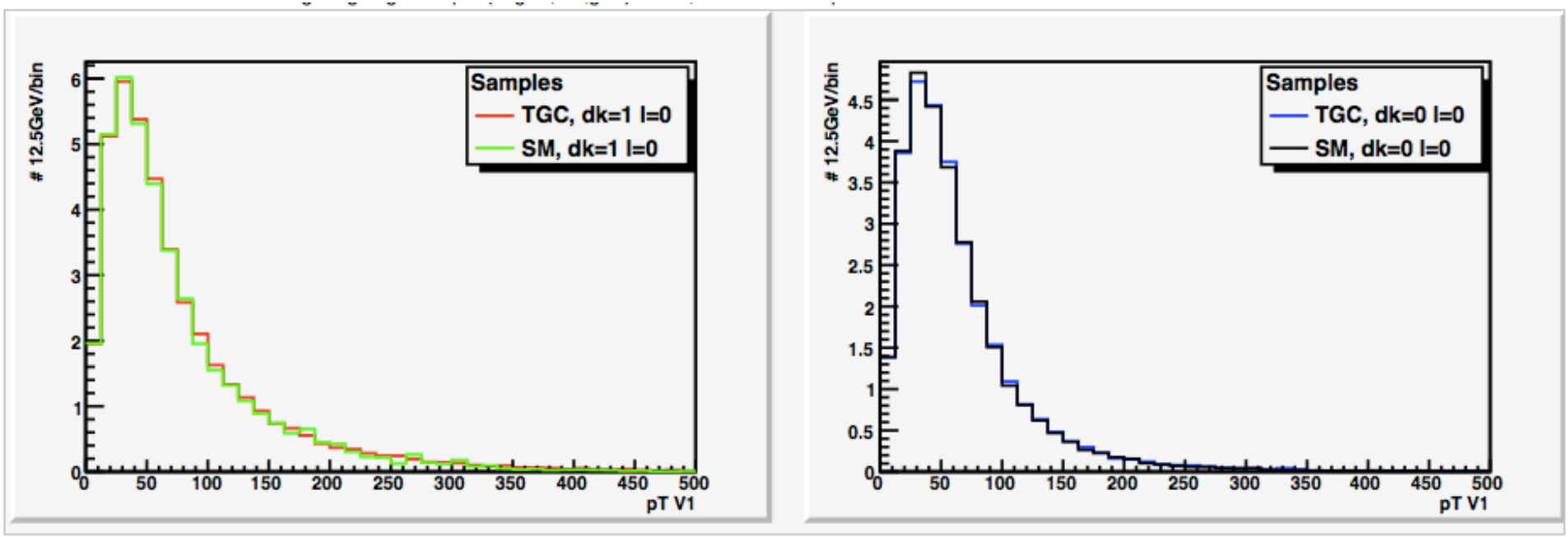
- MC@NLO WZ: SM vs TGC(1,1,0)



Weights reduce for aTGC phase space points -> better stability of reweighting.

Weight comparison

- MC@NLO WZ: SM vs TGC(dk=1)



Example pT(W) : Reweighting works well.

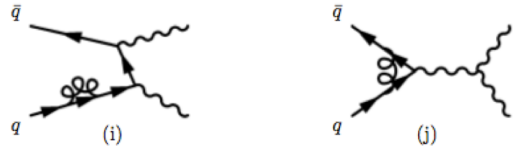
Aposteriori Reweighting

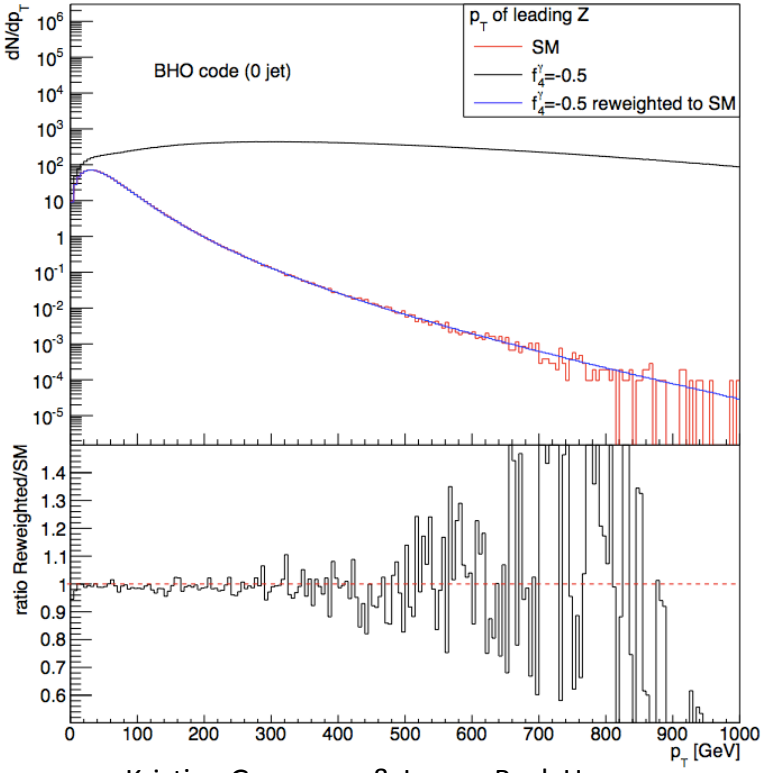
- Afterburner framework reweights events by recalculating the matrix element
  - ME from BHO generator (WW,WZ,Wγ,Zγ)
  - LO, but includes real emission diagrams.
  - ZZ + 0/1 jet included from BHO.
  - ZZ : Baur Rainwater at LO, but includes singly resonant diagrams.

https://svnweb.cern.ch/trac/atlasphys/browser/Physics/StandardModel/ElectroWeak/Common/Software/TGC/TGCAfterBurner

Aposteriori Reweighting

- Afterburner code available in SVN.
- Validated against Sherpa and used in ATLAS analysis.
- Virtual corrections not included.





Kristian Gregersen & Jorgen Beck Hansen, Niels Bohr Institute

Summary

- Tools for event-by-event reweighting are available.
- Event-by-event reweighting is a more flexible and robust approach for aTGC extraction than reweighting of distributions.
- Form factor dependence of aTGC limits can be extracted with one set of events.