Weighting Di-Boson MC events

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- MC generators

- Di-Boson processes

- Event weighting package

- Boson spin information

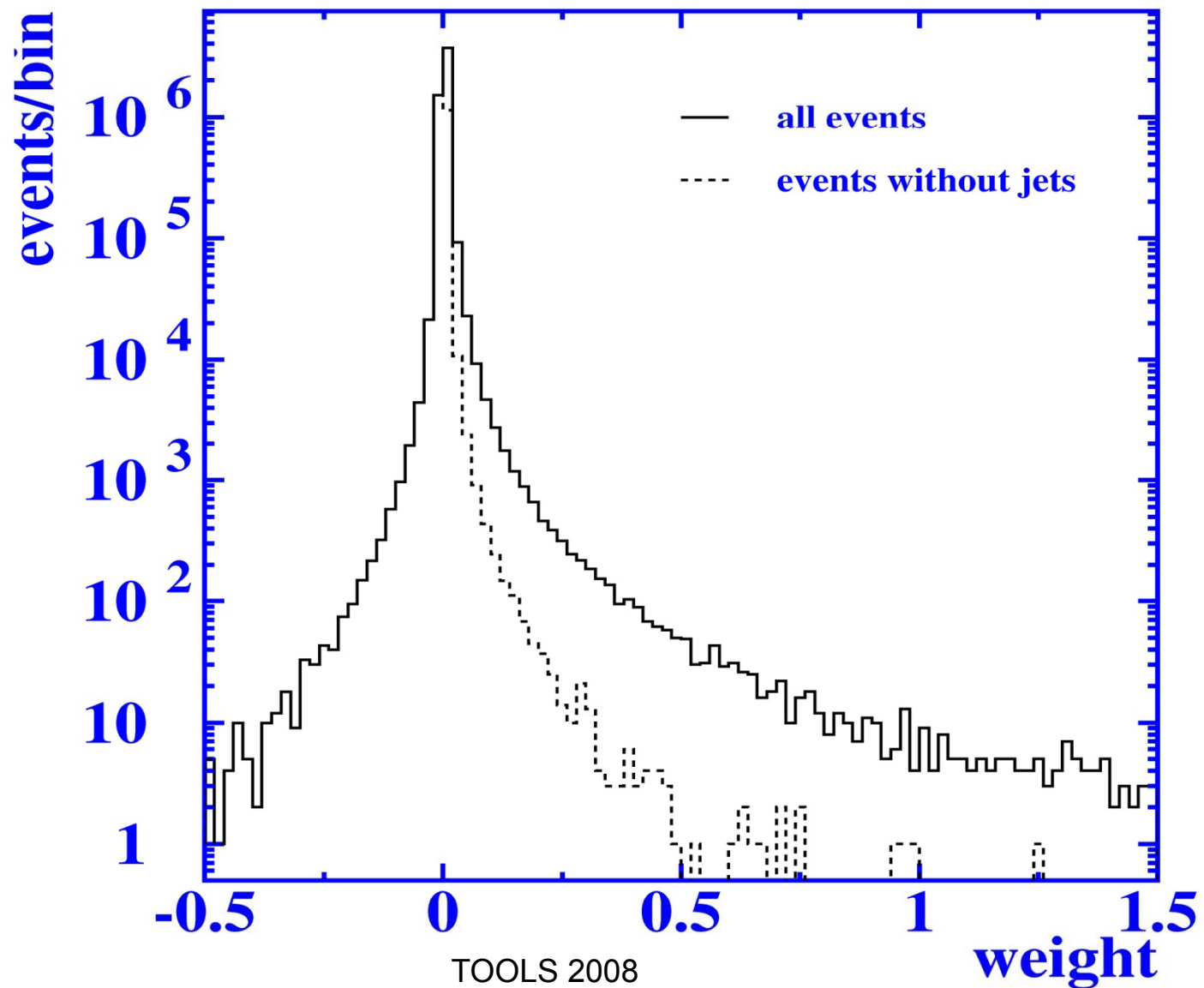- Anomalous Triple Gauge Couplings (TGC)

See: arXiv:0803.3307 (hep-ph)

MC Generators

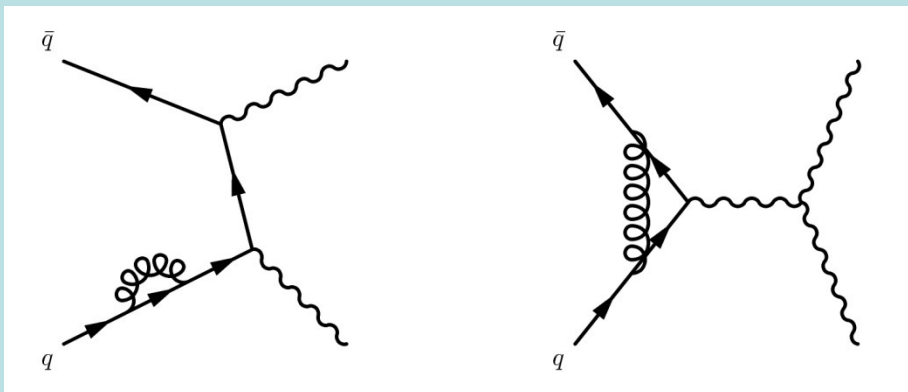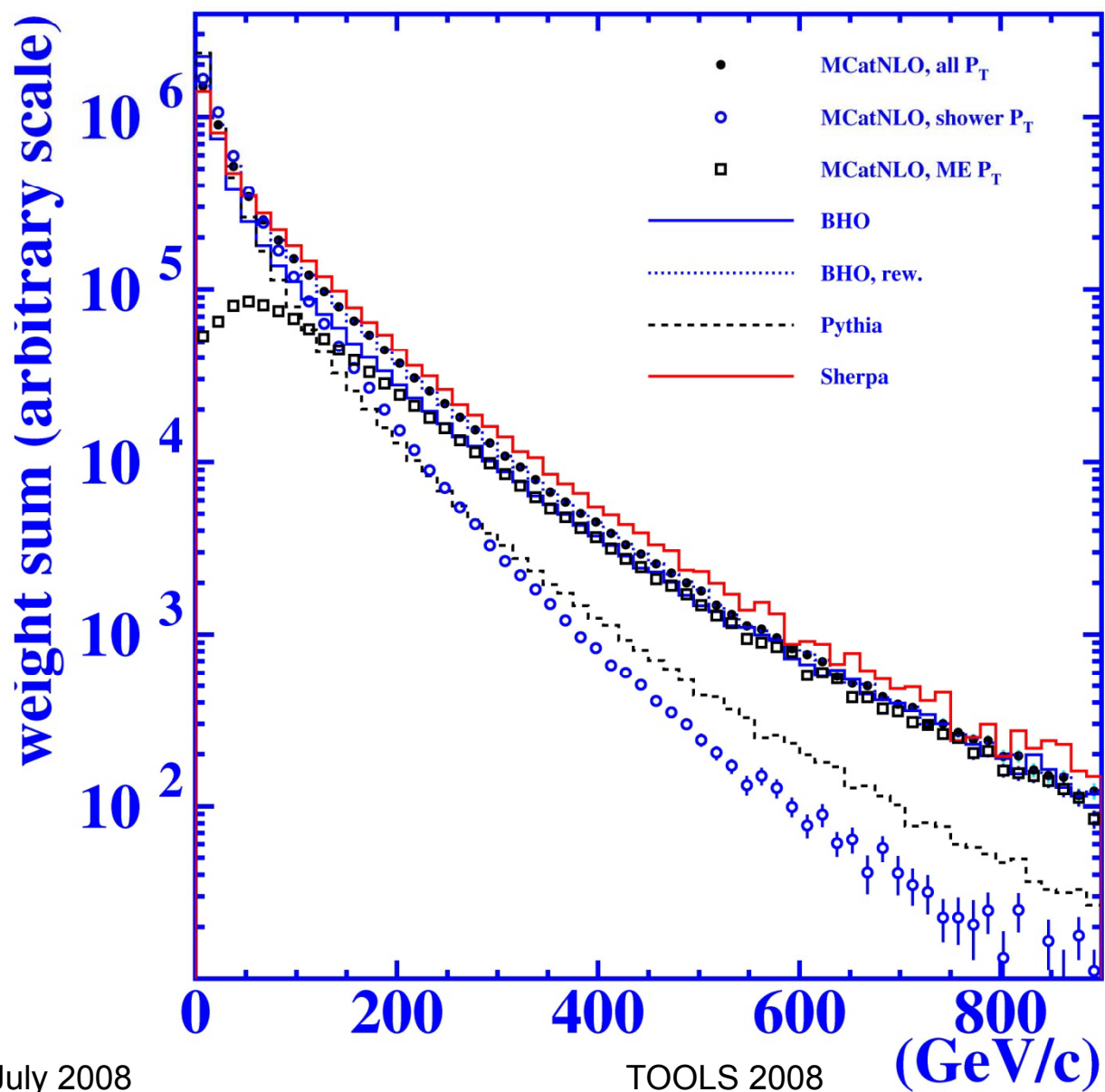| Generator	Pythia	BHO	MC@NLO	Sherpa
Process	all	W^+W^-, $W^\pm Z$, $W^\pm\gamma$, $Z\gamma$	W^+W^-, $W^\pm Z$, ZZ	all
NLO	✕	√	√	✕, ≤ 2 jets
Boson width	√	✕	✕	√
Spin inform.	√	√	✕	√
Anom. TGC	✕	√	✕	√
PS, hadroniz., underlying ev.	√	✕	(with Jimmy) √	√
Unweight. ev.	√	✕	√	√

Weight Distribution in BHO WW Events

Di-Boson Processes
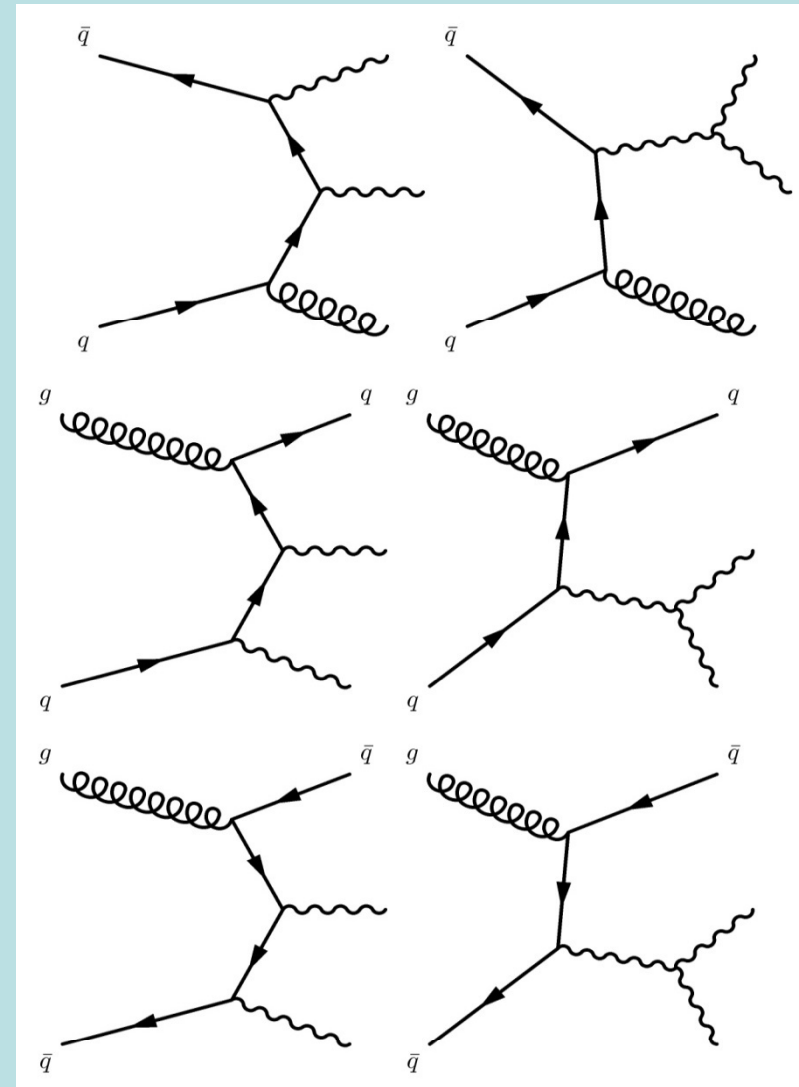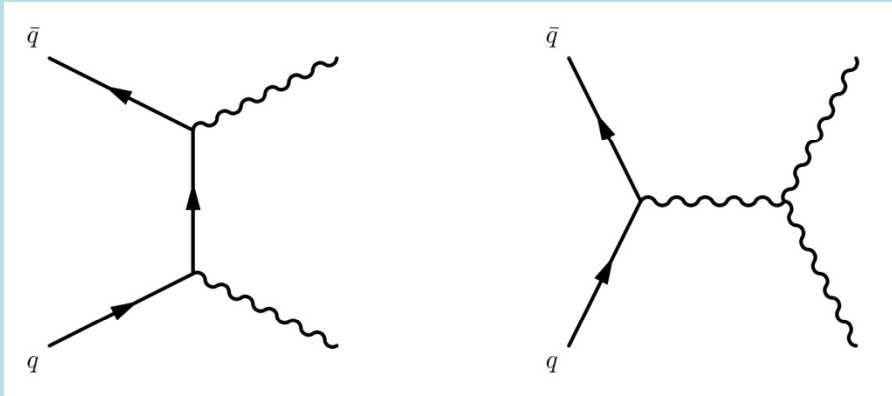
P_T(jet) Distributions in W^+Z Events

Legend:
- ● MCatNLO, all P_T
- ○ MCatNLO, shower P_T
- □ MCatNLO, ME P_T
- —— BHO
- ⋯⋯ BHO, rew.
- – – – Pythia
- —— Sherpa

Note:

$$P_T(\text{jet}) \equiv P_T(W^+Z)$$

Fraction of Events with Jet
$(p_{\mathrm{T}}(\mathrm{jet}) > 30\,\mathrm{GeV})$

	Pythia	BHO	MC@NLO	Sherpa
W^+W^-	0.268	0.478	0.311	0.422
W^+Z	0.289	0.347	0.474	0.516
W^-Z	0.280	0.348	0.472	0.520
$W^+\gamma$	0.228	0.438	-	0.616
$W^-\gamma$	0.221	0.448	-	0.663
ZZ	0.245	-	0.365	0.385
$Z\gamma$	0.213	0.364	-	0.534

Fraction of g,q,$\bar{q}$ Jets
$(p_{\mathrm{T}}\,(\mathbf{jet}) > 30\,\mathbf{GeV})$

	Pythia	BHO	MC@NLO	Sherpa
$\mathrm{W^+W^-}$	1, 0, 0	0.37, 0.47, 0.16	0.58, 0.31, 0.11	0.45, 0.41, 0.14
$\mathrm{W^+Z}$	1, 0, 0	0.30, 0.55, 0.15	0.58, 0.33, 0.09	0.41, 0.45, 0.14
$\mathrm{W^-Z}$	1, 0, 0	0.27, 0.53, 0.20	0.56, 0.32, 0.12	0.37, 0.47, 0.16
$\mathrm{W^+}\gamma$	1, 0, 0	0.18, 0.57, 0.25	-	0.14, 0.50, 0.36
$\mathrm{W^-}\gamma$	1, 0, 0	0.15, 0.65, 0.20	-	0.10, 0.74, 0.16
ZZ	1, 0, 0	-	0.85, 0.11, 0.04	0.53, 0.34, 0.13
$\mathrm{Z}\gamma$	1, 0, 0	0.32, 0.52, 0.16	-	0.21, 0.60, 0.19

Event Weighting Package

To introduce spin information to MC@NLO generated events we assign each event with a weight:

$$w = \frac{\text{BHO weight with spin info}}{\text{BHO weight without spin info}}$$

The BHO weight calculation is done in the package bhowei which is based on the BHO code.

The BHO code requires the event to be balanced with conserved energy and momentum.

MC@NLO events with or without ME jets are not balanced, due to the showering. SH jets show up as missing P_T.

SH jets must be combined to the ME jets into one jet, to make the di-boson+jet system balanced.

We assume no longitudinal component of the SH jet in the c.m. frame.

The resulting balanced event is interpreted as a di-boson+1jet event, and is handled by the BHO code as such, and the corresponding weight is always positive!

The event weighting package can be used also to introduce anomalous TGC to events generated by MC@NLO , Pythia or Sherpa.

Another use is for systematic studies, e.g. PDF systematics, running the code for different PDFs.

Unfortunately, finite boson width cannot be introduced by event weighting.

The calling sequence:

> call bhowei(mspin,xsec,ifail)
>
> <u>input</u>:   mspin=0 or 1 without/with spin info
>
> <u>output</u>: xsec - resulting BHO cross-section (arbitrary units)
>
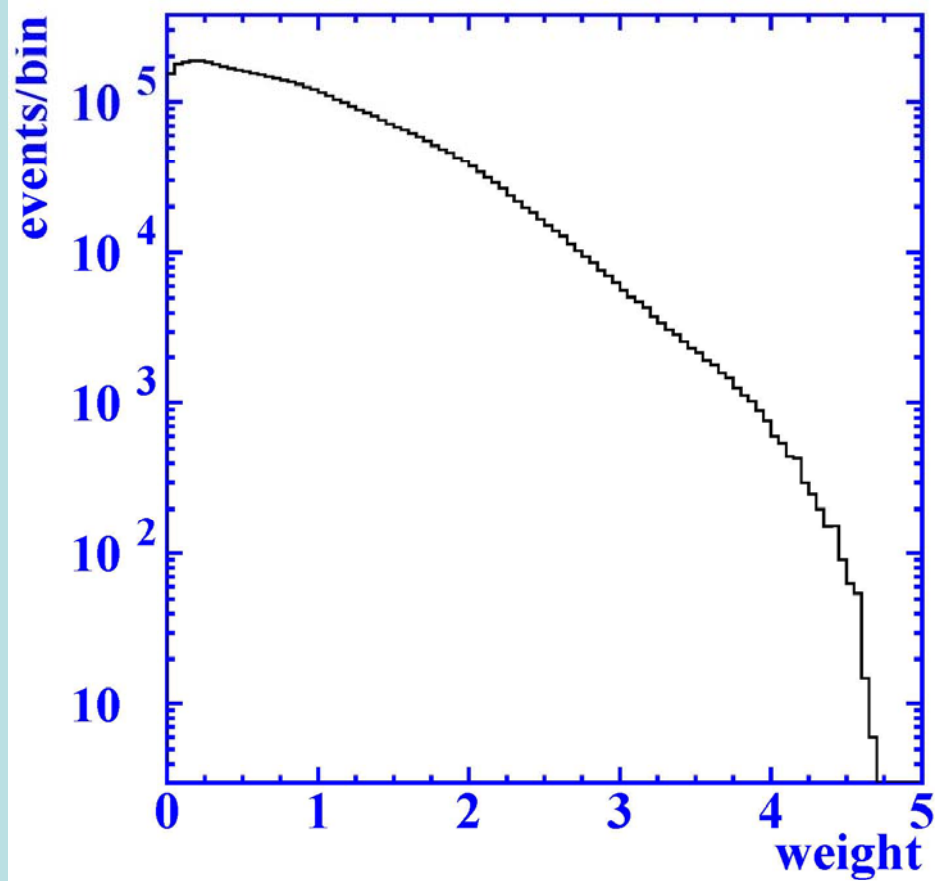> ifail – 0 for successful calculation

Additional information (event 4-momenta and particle id's, physical constants, anomalous couplings, PDF set number) is entered via common blocks.
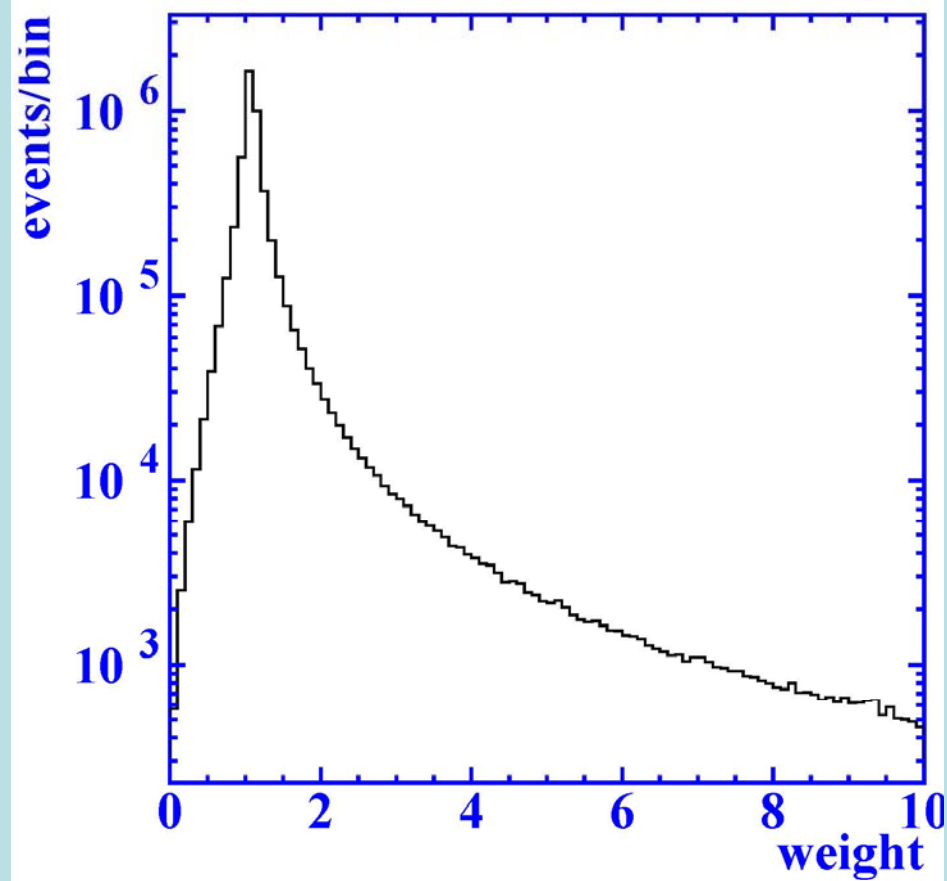
Weights calculated by bhowei
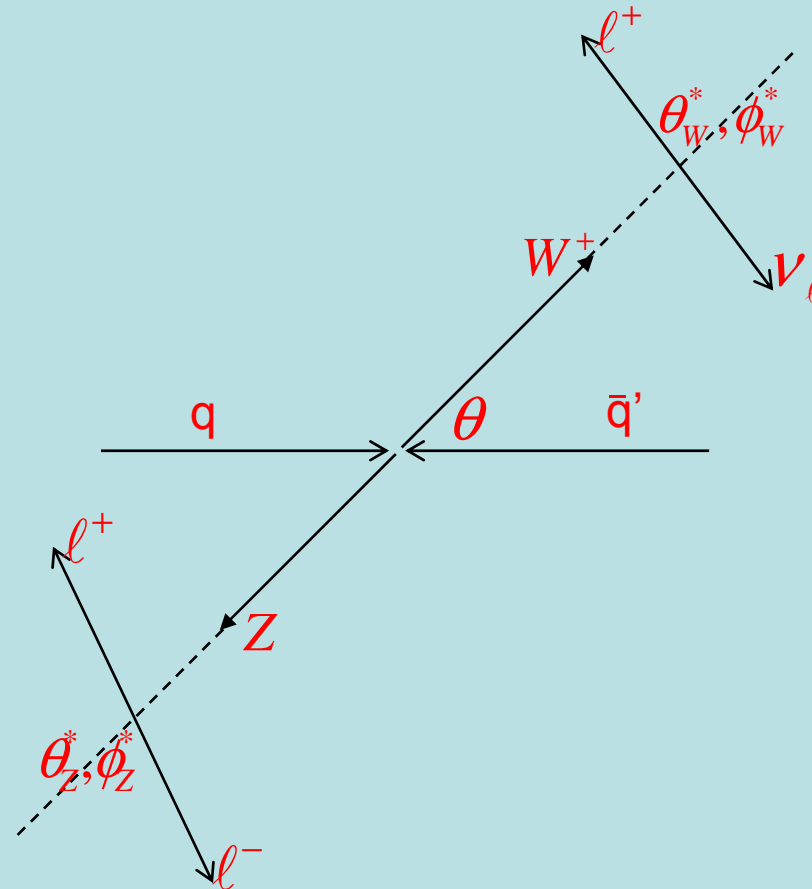

Angular Information Weight
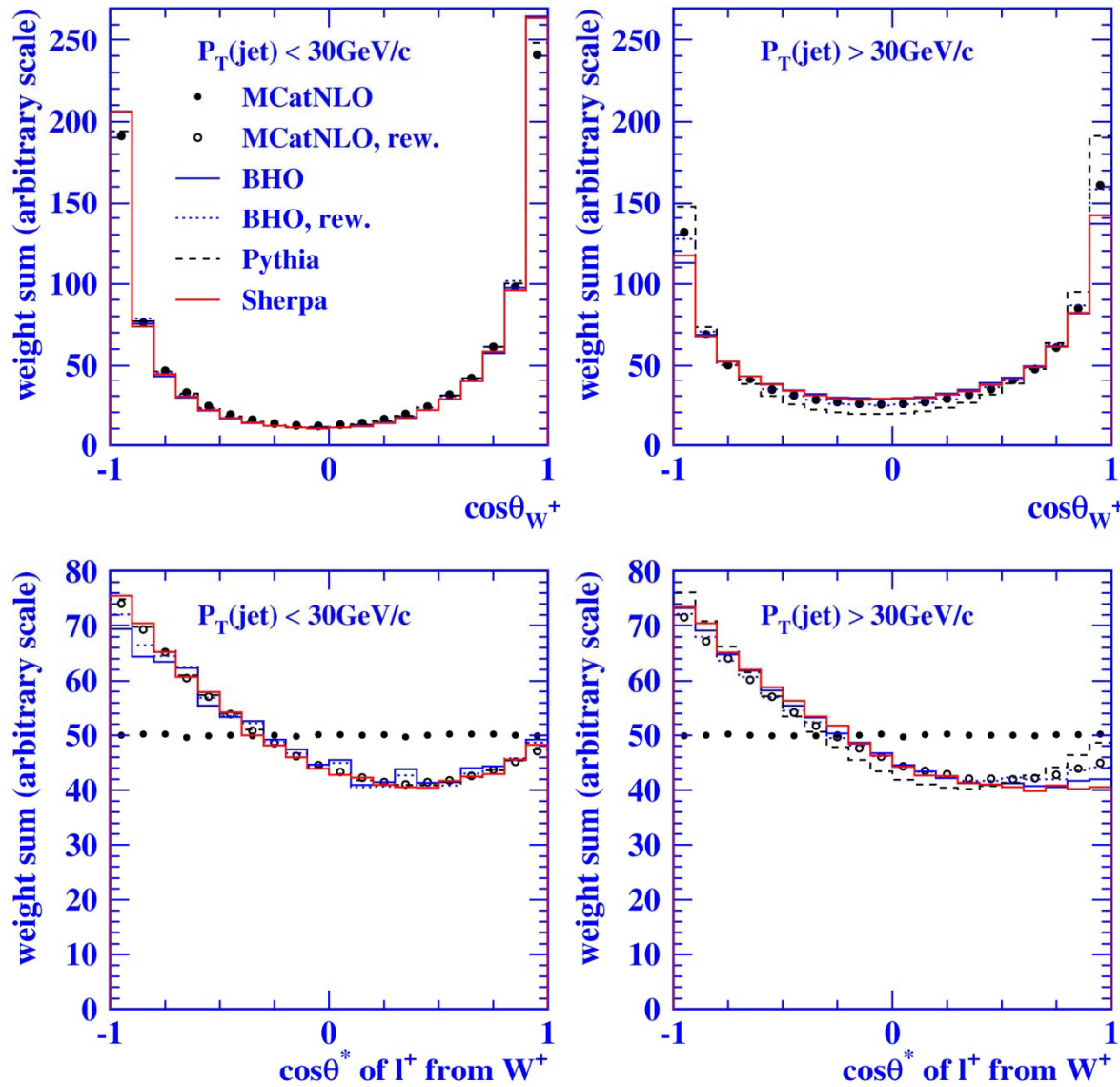
Weight for $\lambda_z = 0.1$

Boson Spin Information

Consider W^+Z event:

Angular Distributions in ZW⁺ Events

Legend (top-left panel):
- $P_T(jet) < 30\,GeV/c$
- • MCatNLO
- ○ MCatNLO, rew.
- —— BHO
- ······· BHO, rew.
- - - - Pythia
- —— Sherpa

Panels:
- Top-left: $P_T(jet) < 30\,GeV/c$, x-axis $\cos\theta_{W^+}$, y-axis weight sum (arbitrary scale)
- Top-right: $P_T(jet) > 30\,GeV/c$, x-axis $\cos\theta_{W^+}$
- Bottom-left: $P_T(jet) < 30\,GeV/c$, x-axis $\cos\theta^*$ of l^+ from W^+
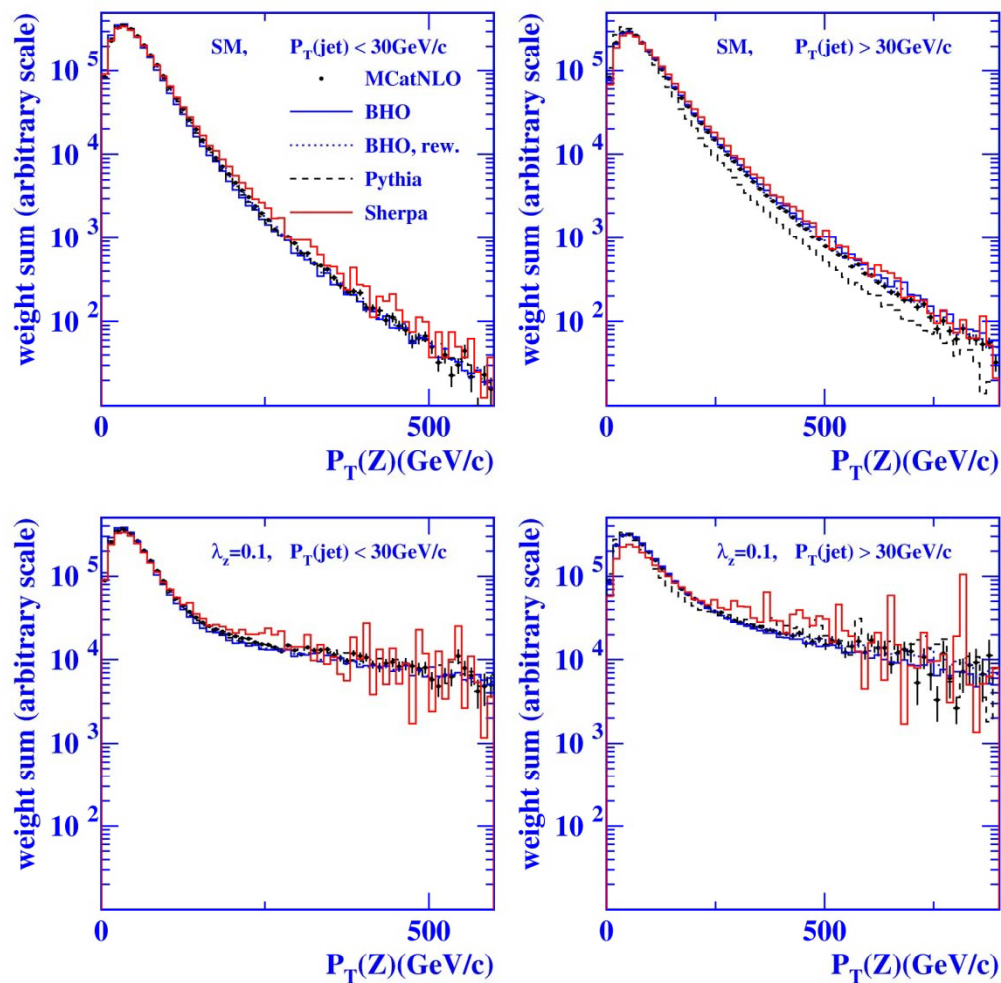- Bottom-right: $P_T(jet) > 30\,GeV/c$, x-axis $\cos\theta^*$ of l^+ from W^+

Are the differences for high $P_T(jet)$ related to the different contributions to jet events and different jet P_T spectra?

We reweight BHO events, so that their jet info agrees with MC@NLO.

Anomalous TGCs

$$\Lambda_{FF} = 10\,TeV$$

$P_T(Z)$ Distributions in W^+Z Events

Summary and Conclusions

- Bhowei can be used to introduce:

    a) spin info to events generated by MC@NLO

    b) TGC weights to events generated by MC@NLO and Pythia

- The hadronic system recoiling against the two bosons is different between different MC generators, causing differences in the angular and P_T distributions of events with high P_T(jet).

- Events with high P_T(jet) should be suppressed

- Real data should be used to study events with high P_T(jet).

- Better di-boson MC generators are welcome:

    a) NLO+PS with spin information

    b) finite W and Z widths.

    c) anomalous couplings

    d) NNLO and electroweak corrections.

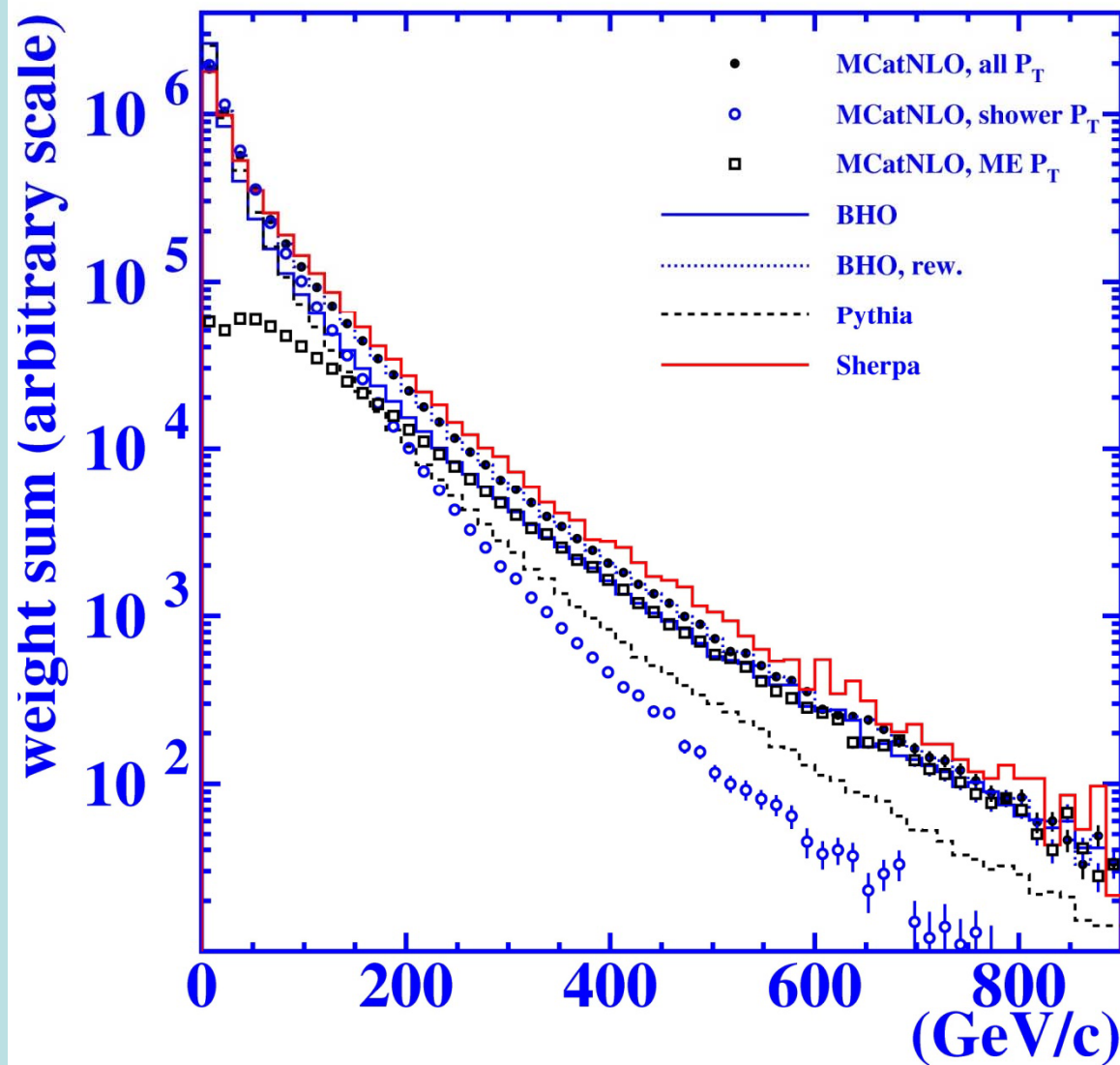# Backup Slides

Total Cross Sections [pb]
multiplied by BR into e+μ $\quad (p_{\mathrm{T}}(\gamma) > 30\,\mathbf{GeV})$

	Pythia	BHO		MC@NLO
	LO	LO	NLO	NLO
$W^{+}W^{-}$	3.510	3.774	4.978	5.211
$W^{+}Z$	0.257	0.273	0.417	0.432
$W^{-}Z$	0.160	0.171	0.262	0.270
$W^{+}\gamma$	3.349	3.996	8.707	-
$W^{-}\gamma$	2.226	2.681	6.418	-
ZZ	0.0424	-	-	0.0682
$Z\gamma$	1.471	1.756	2.433	-

P_T(jet) Distributions in WW Events

ZZ

TOOLS 2008

$P_T(jet)$ $W^+\gamma$

BHO

Pythia

Angular Distributions in ZW$^+$ Events