Transverse Momentum Resummation Effects on the WW fiducial cross section

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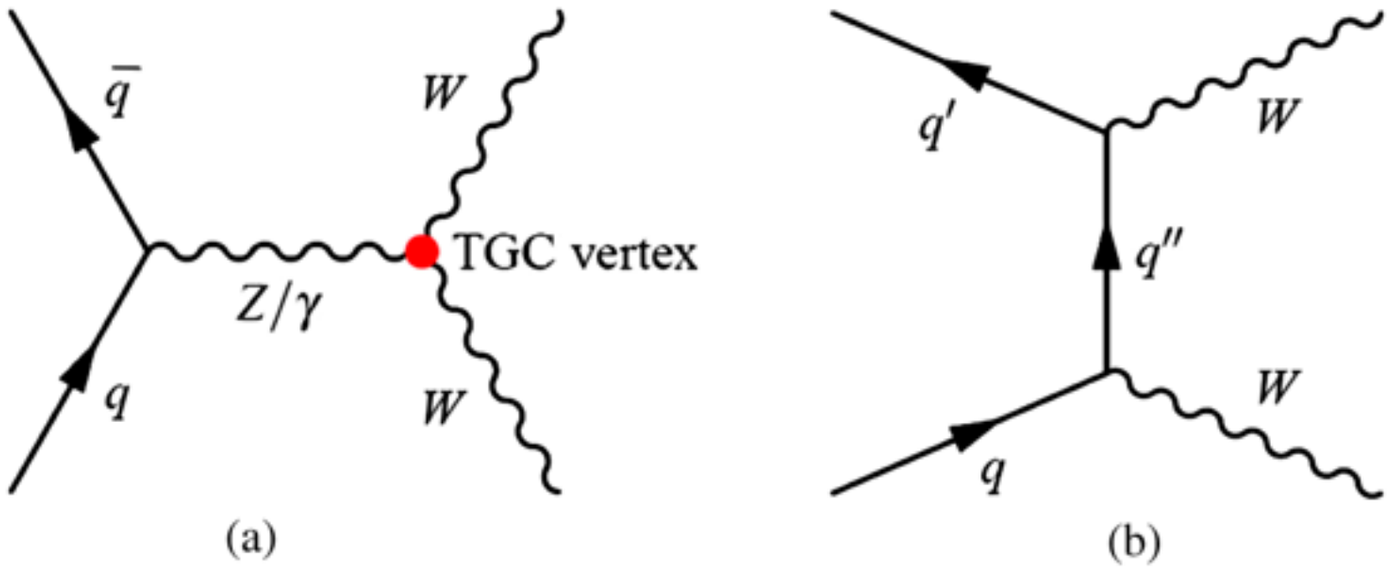
Based on 1405.xxxx with Patrick Meade and Mao Zeng

Outline

- Motivation
- Shapes affect Fiducial Cross Section
- Transverse Momentum Resummation
- Results

Why is it important to get WW right?



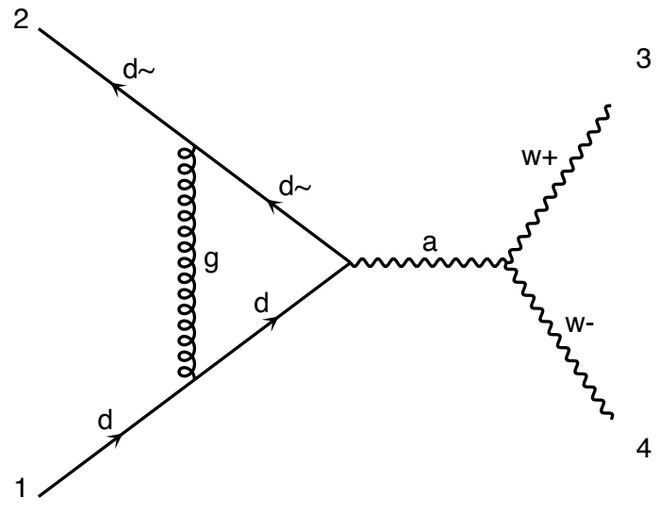
WW production @ LO

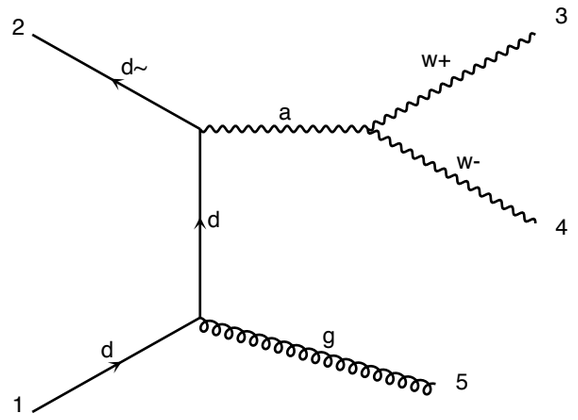
- LHC Era of Electroweak precision measurements. Onus on experiment-theory agreement.
- Heavy particles couple strongest to Higgs;
- WW is large background to H->WW.
- Getting background accurate will help with Higgs precision physics.
- WW huge background to many BSM searches

The WW Cross Section

- WW decaying into opposite sign dilepton
- Semi-leptonic and fully hadronic less easy/clean
- One of few channels with a Jet Veto
- Results available for ATLAS 7TeV and CMS 7&8TeV
- Indirect Results also available as background to H->WW
- Both ATLAS and CMS routinely report excess.

Theory Prediction



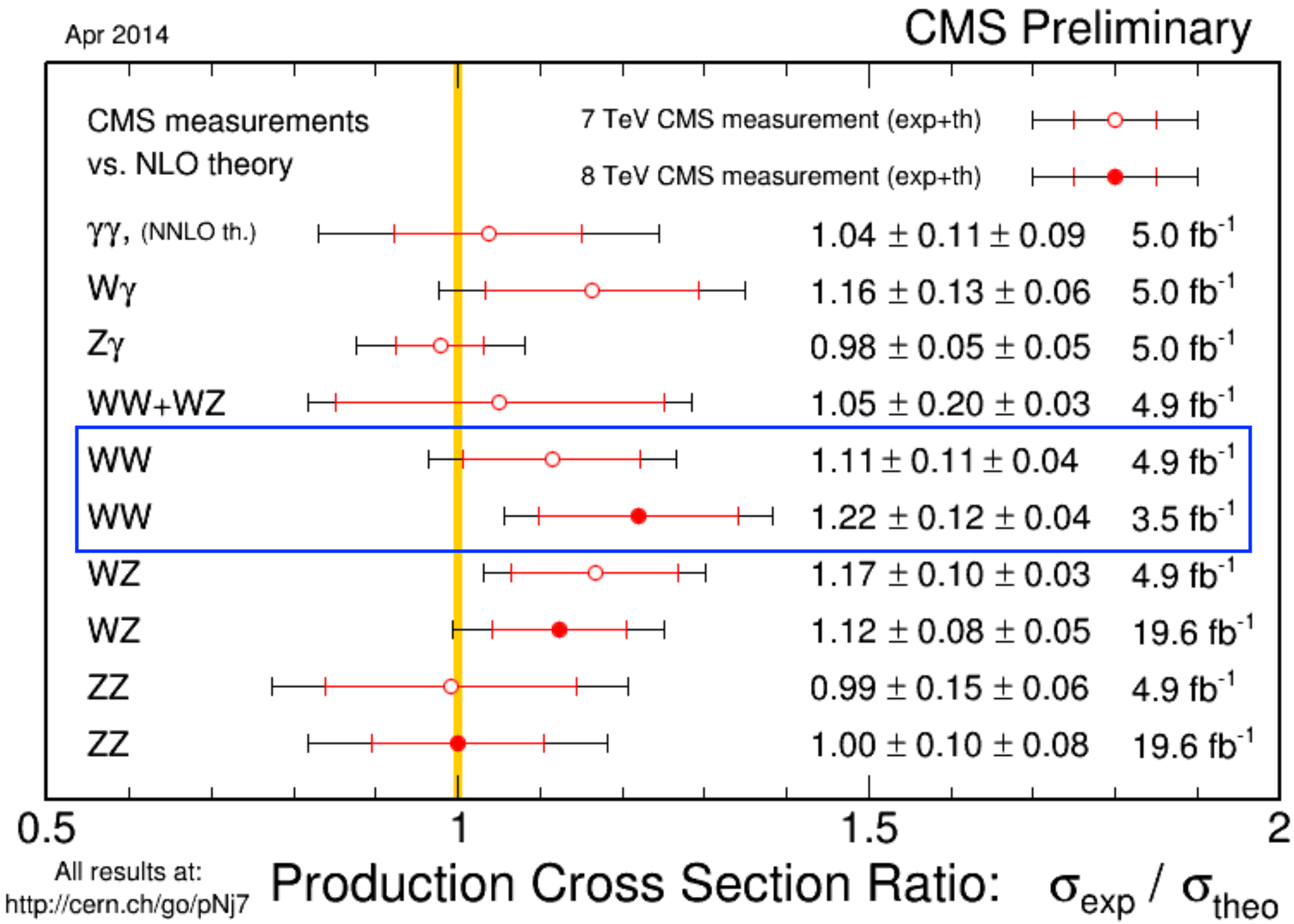


(Left) Virtual and (Right) NLO corrections to QCD

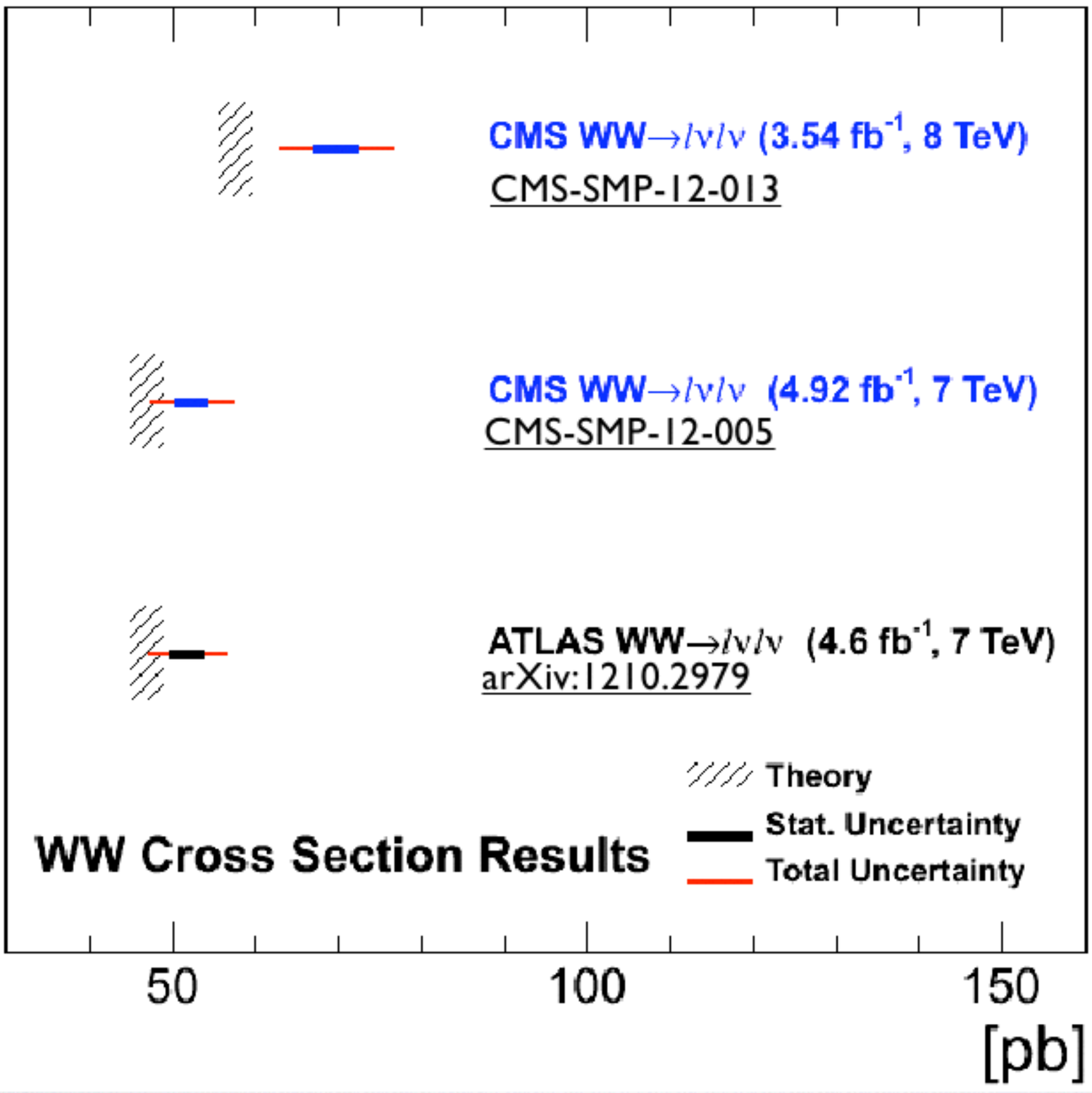
- NLO(QCD) $q\bar{q} \rightarrow WW$ known. (MCFM)
- use Powheg/MC@NLO for MC generation. or Madgraph(LO) +reweighting
- 7TeV:29.51pb@LO $\longrightarrow$ 47.00pb@NLO
- 8TeV:35.56pb@LO $\longrightarrow$ 57.25pb@NLO
- @NNLO new process gg$\longrightarrow$WW (gg2WW software)

Experimental Results

Summary-CMS


Apr 2014
CMS Preliminary
CMS measurements
vs. NLO theory
7 TeV CMS measurement (exp+th)
8 TeV CMS measurement (exp+th)
γγ, (NNLO th.)
1.04 ± 0.11 ± 0.09
5.0 fb-1
Wγ
1.16 ± 0.13 ± 0.06
5.0 fb-1
Zγ
0.98 ± 0.05 ± 0.05
5.0 fb-1
WW+WZ
1.05 ± 0.20 ± 0.03
4.9 fb-1
WW
1.11 ± 0.11 ± 0.04
4.9 fb-1
WW
1.22 ± 0.12 ± 0.04
3.5 fb-1
WZ
1.17 ± 0.10 ± 0.03
4.9 fb-1
WZ
1.12 ± 0.08 ± 0.05
19.6 fb-1
ZZ
0.99 ± 0.15 ± 0.06
4.9 fb-1
ZZ
1.00 ± 0.10 ± 0.08
19.6 fb-1
0.5
1
1.5
2
All results at:
http://cern.ch/go/pNj7
Production Cross Section Ratio: σexp / σtheo

WW @ LHC



- ATLAS & CMS more consistent with each other than with theory!
- Discrepancy higher @ 8TeV

WW excess from published Higgs Background

Control Region estimates at 8TeV-ATLAS

Estimate	N_{obs}	N_{bkg}	N_{sig}	N_{WW}
WW				
$N_{\text{jet}} = 0$	2224	1970 ± 17	31 ± 0.7	1383 ± 9.3
$N_{\text{jet}} = 1$	1897	1893 ± 17	1.9 ± 0.3	752 ± 6.8

Possible Explanation for Excess

- Badly Estimated Backgrounds?
- New Physics? Possible BSM solutions; Charginos
- Statistical Fluctuation?
- QCD changes to Total Cross Section
- QCD changes to Shape

Why should shape matter?

Let us look at how ATLAS & CMS measure a cross section

How ATLAS and CMS measure Cross-Section

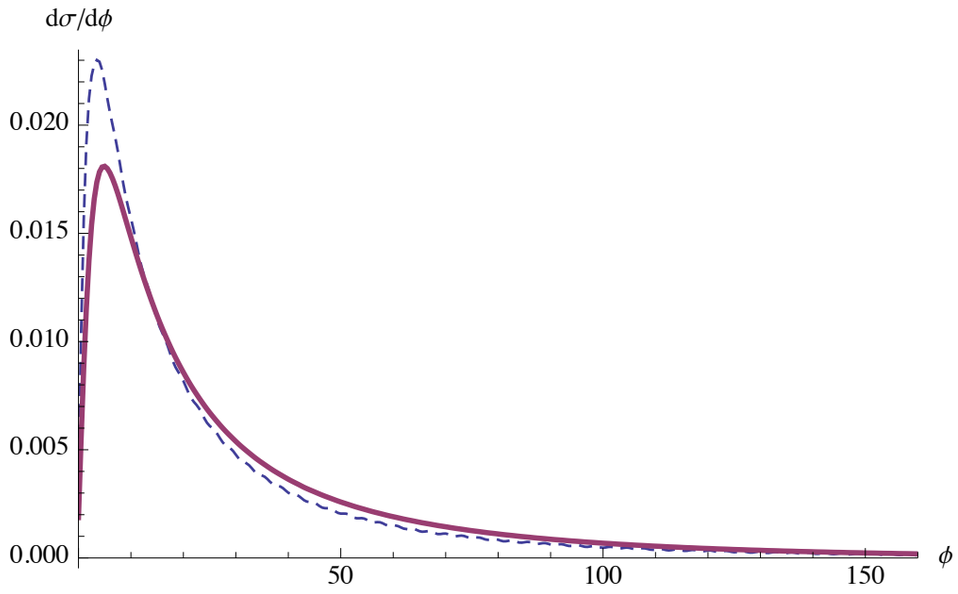
$$n = \sigma_{fid} L + n_{BG}$$

$$\sigma_{fid} = \sigma_{total} \epsilon . A . Br$$

- for WW: opposite sign lepton pair + met
- n:events measured & L:luminosity.
- σ_{total}:total cross section
- σ_{fid} is unfolded w.r.t ϵ,A,Br to report σ_{total} .
- This procedure is hard

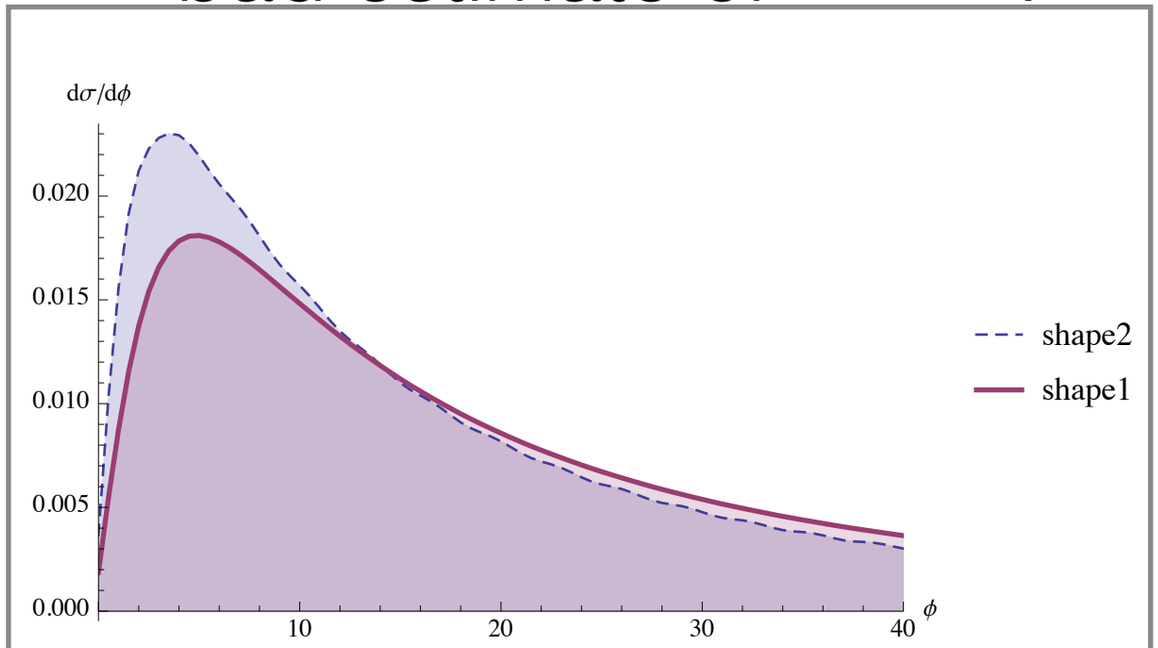
Total $\rightarrow$ Fiducial $\rightarrow$ Total

- Sometimes σ_{fid} very sensitive to a differential direction of σ_{total}



Full Phase-space.
Both curves Normalized to unity.

- Slightly incorrect shape
- Innacurate σ_{fid};
- wrong unfolding ;
- bad estimate of σ_{total}?



Shape effect translates to different Fiducial cross-section

Our Strategy

- p_T resummation changes shape along p_{TWW}
- If some of the cuts have strong correlations with p_{TWW},then
- These corrections could change σ_{fid} .
- Do such cuts exist? If so in which direction do they shift σ_{fid} ?

Spirit Of Resummation

- Often in Perturbative QCD,

$$\hat{O} = 1 + \alpha_S(L^2 + L + 1) + \alpha_S^2(L^4 + L^3 + L^2 + L + 1) + ...$$

where L is Log[r] , r the ratio of two length scales.

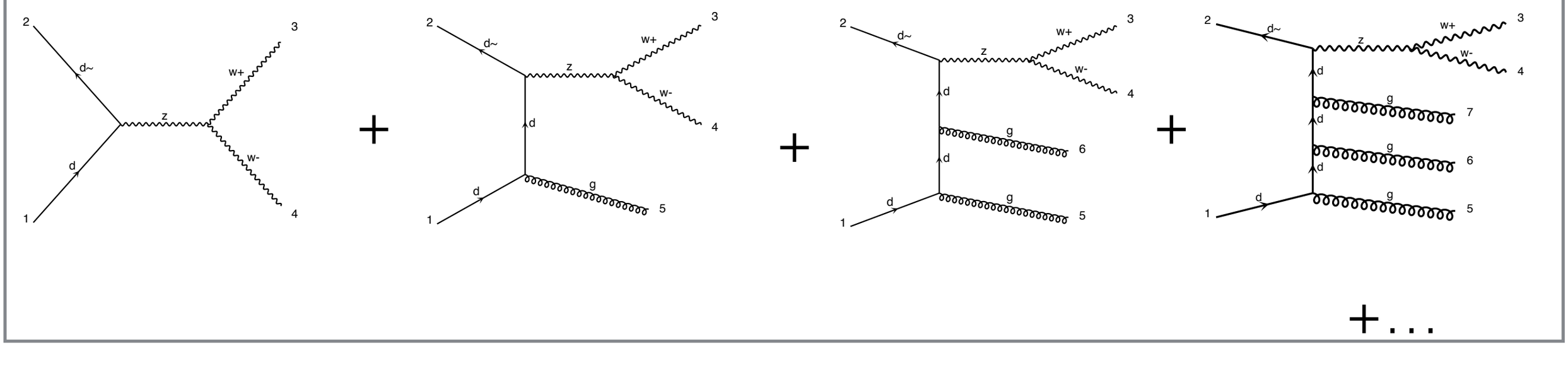
- Resummation:This can be re-written as

$$\hat{O} = c(\alpha_S)exp(Lg_1(\alpha_S L) + g_2(\alpha_S L) + \alpha_S g_3(\alpha_S L) + ...)$$

where c is Log-free

- Large logs that destroy fixed order PT are resummed to all orders and found to give finite contribution
- Lg_1 is called leading log (LL), ($Lg_1 + g_2$) is called NLL and so on
- common to declare results with $N^{n+1}LL$ (in the exponential) along with N^nLO (concerns)
- new scale μ_{res} to capture as yet uncomputed higher Logs

Spirit Of Resummation



Resummation vs Parton Shower

Resummation	Parton Shower
Proved to all orders in QCD~ factorization theorems	Heuristic Algorithm
Extended to any leading log(currently NNLL)	Approaches NLL accuracy
Precise and strict, few parameters to adjust	Many parameters tuned to fit data
Systematic Treatment of error estimates from higher logs	No such feature
Sums over hadronization	Can give jet information

Building on Existing Literature

- WW pt resummation for 14TeV LHC Grazzini et al although with a numerical estimate for factor A_3 subsequently by Becher et al.

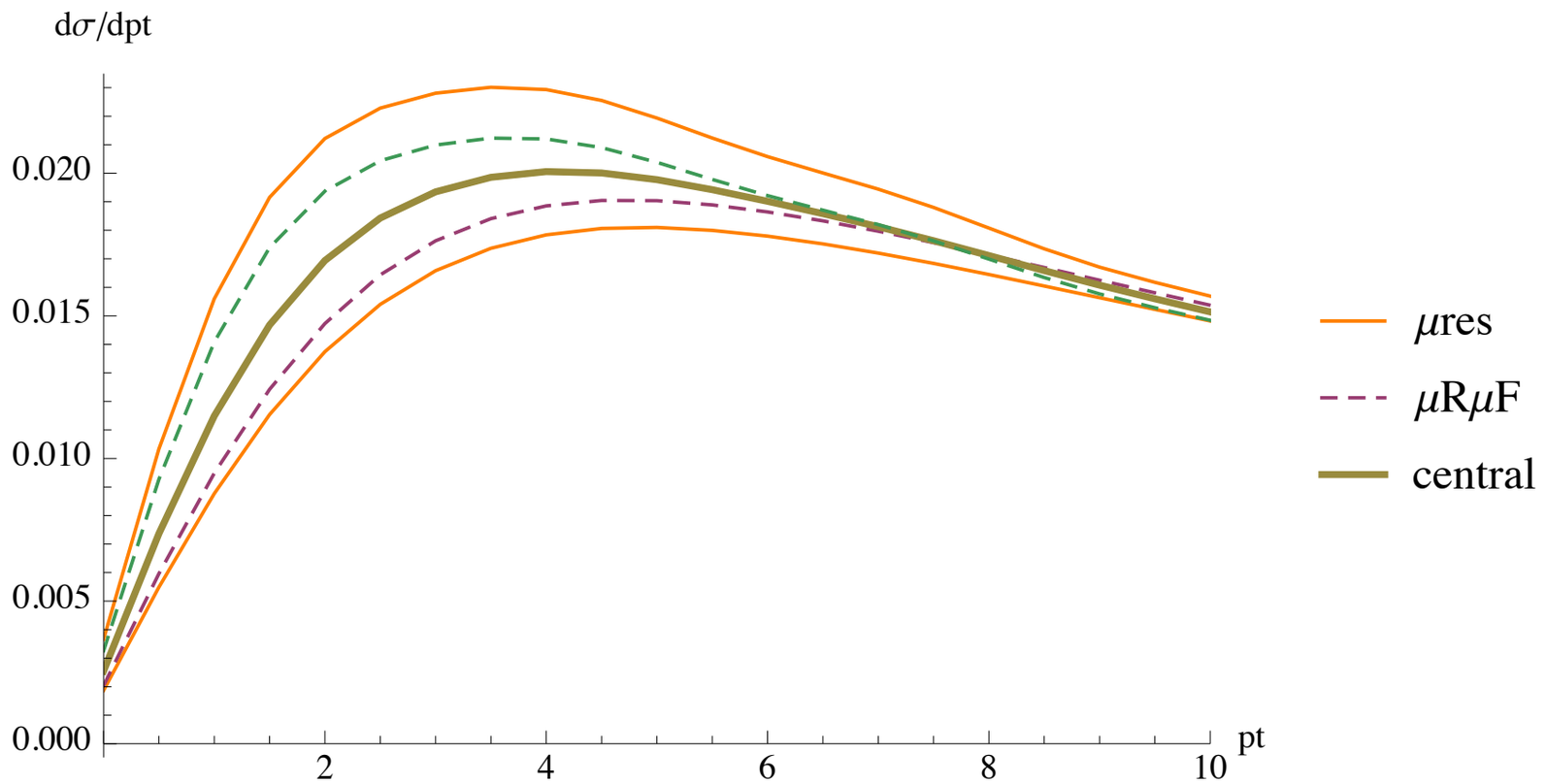
- SCET formalism-Wang et al- no Resummation Scale considered.

- Recoded Grazzini Formalism with correct numerical factor for all s & studied μ_{res} variation.

- Propose using an MC to generate events; Reweighting to get the resummation predicted pt shape.

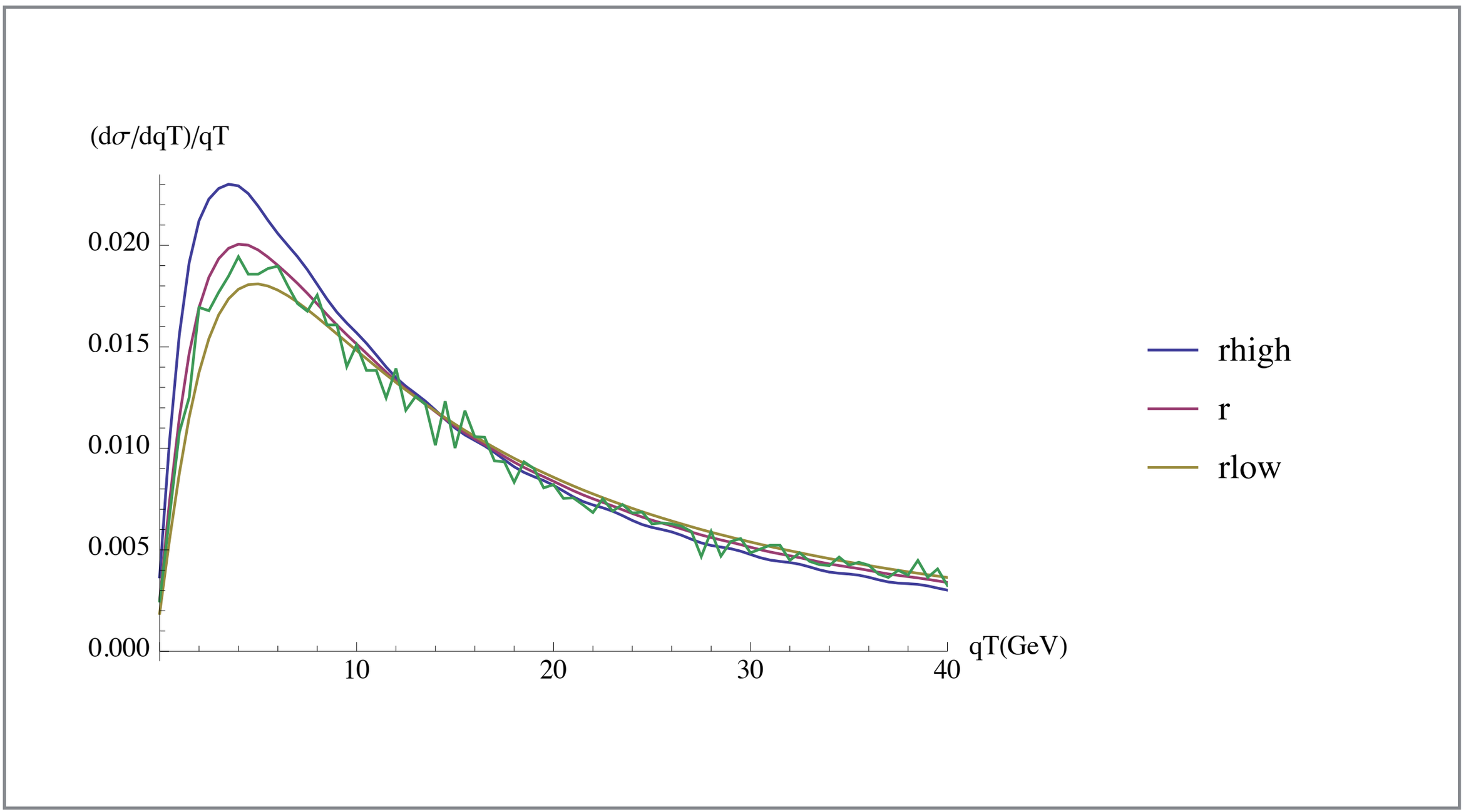
- Analogous practice is already followed using resummation tool HqT(Grazzini) for pp$\rightarrow$H analysis.

Shape Uncertainty

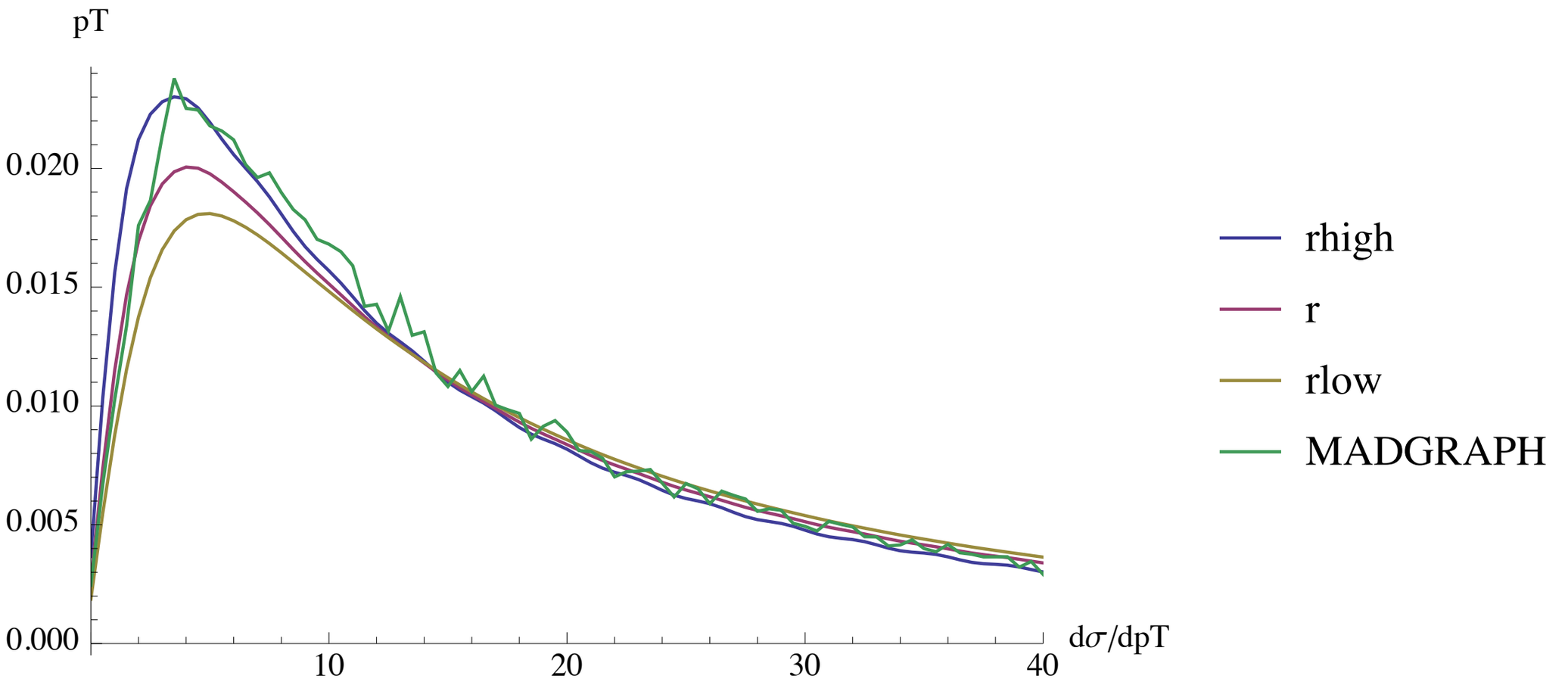


Shape Uncertainty due to μ_{res} more than μ_R & μ_F combined

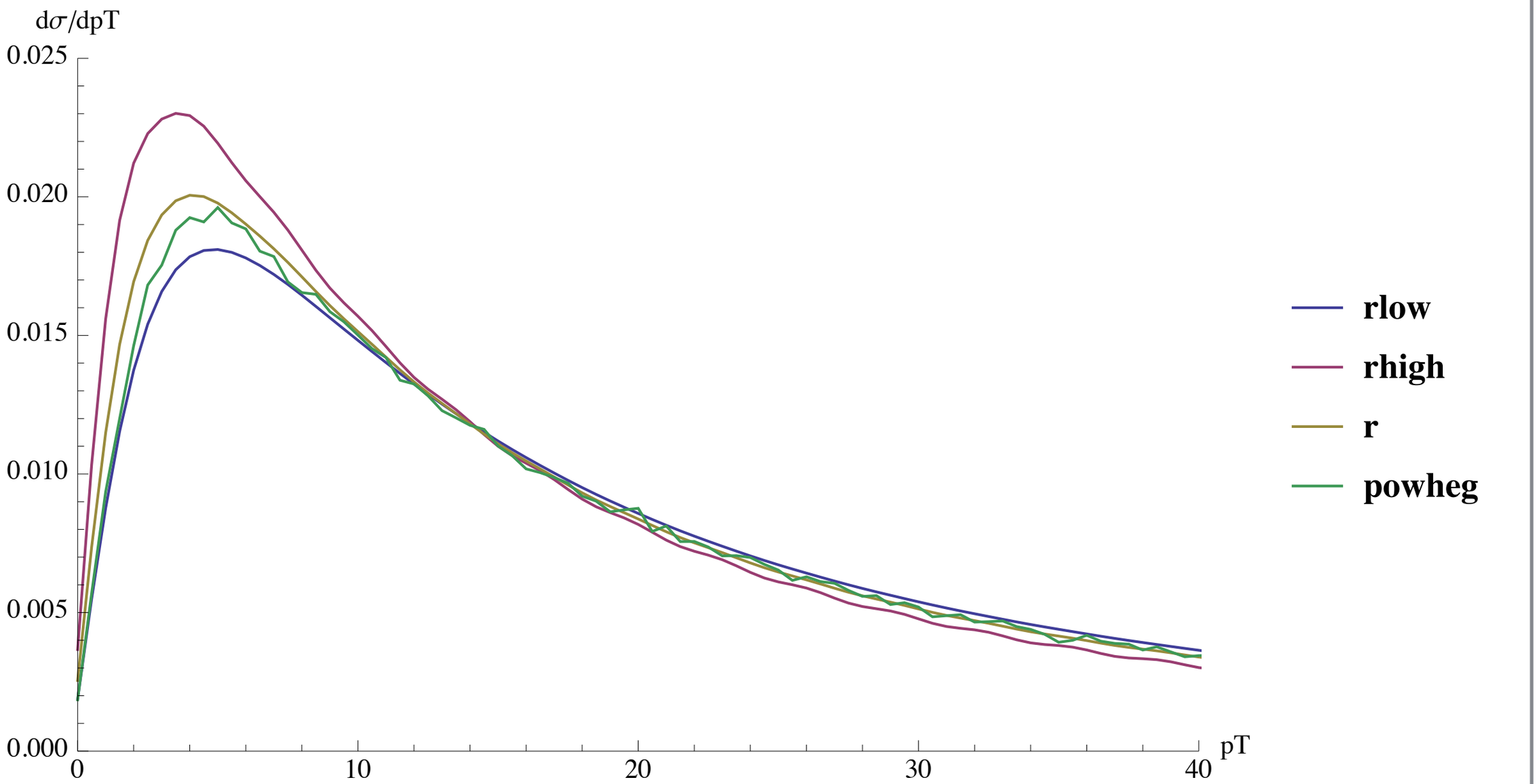
Shape Comparisons(aMC@NLO)



Shape Comparisons(MADGRAPH)



Shape Comparisons(Powheg)



Cut-flow vs reweighted events

Cut	%
exactly 1 pair of oppositely charged leptons +MET	0
p_t and η cuts on leptons	0.06%
mll cuts	-0.32%
$E_{TMiss,rel}$	1.16%
Jet Veto	8.37%
p_{Tll}	8.50%

Zooming in on Jet Veto

- Jet Veto: Jet = clustered object with R < 0.4 and p_T >25GeV.
- Drop all events with one or more jets.
- clustered object's p_T highly correlated with p_{TWW}
- Jet Veto step:biggest contributor to correction in σ_{fid}

	0-jet		1-jet	2-jet
amc@nlo	3517		1175	340
after reweighting	3811.32		1009.76	280.44

Drop!

Reweighted Fiducial Cross-Section

MC	Percentage Increase Q=mW/2	Percentage Increase Q=mW	Percentage Increase Q=2mW
Powheg+Pythia	-5.35%	0.16	4.05
aMC@NLO +Herwig	-0.82	2.98	8.50
Madgraph +Pythia	-8.88	-5.94	-1.13

Note:Q= μ_{res}

Deductions

- Traditional MC-shower calculations;no resummation scale
- Reweighting could increase error bars on σ_{fid}
- This effect is unique to channels with a Jet-Veto because of the veto being strongly correlated with p_{TWW}.
- MC@NLO(ATLAS 7TeV)increase theory prediction by 0-9%(reduce excess)
- MADGRAPH(CMS 7&8TeV)decrease theory prediction by 1-9%(increase excess)
- Powheg seems to be accurate. Scale Variation:3%

What is the best Scale Choice?

Two ways to go about this

- Scale choice should be universal and physical
- Universality: Cannot be much different than for other diboson processes
- Physical: shouldn't be too different from the hard scale
- Using Data to fit scale:

Will result in scale much higher than even hard scale.

- Matching NLL and NNLL shape:

Will result in scale much lower than the hard scale.

Summary

- Precision in pt shape important? Turn to Resummation
- WW:Jet Veto:low Pt preferred
- Resummation produces sizeable effects to theory prediction
- It might not be viable to dial the extra resummation scale choice to fit data better.