THEORY UNCERTAINTIES REPORT

OFFSHELL INTERPRETATIONS MEETING

LHCHXSWG OFFSHELL SUBGROUP

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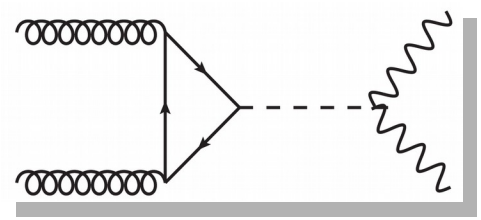
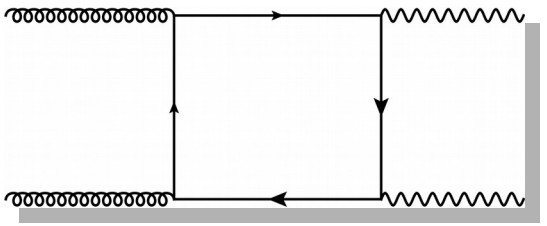
16 April 2020

Summary

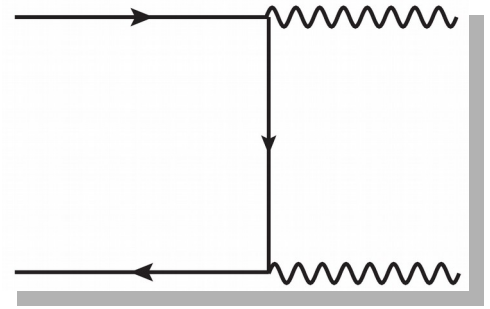
- Focus of subgroup: theory uncertainty treatment for non-interfering backgrounds.



"Higgs signal"



"Interfering background"



"Non-Interfering background"

(Interference at NLO.)

➡ Modeling issues:

- Higher-order QCD corrections
- Jet binning
- Electroweak corrections
- Assigning theory uncertainty

Meeting 19/04/2020

- First meeting on 19 April [Indico link]
- Presentations of current treatment of non-interfering background by ATLAS and CMS.

Systematic uncertainty	95% CL upper limit on $\mu_{\text{off-shell}}$		
	$ZZ \to 4\ell$	$ZZ \to 2\ell 2\nu$	Combined
QCD scale $q\bar{q} \to ZZ$	4.2	3.9	3.2
QCD scale $gg \to (H^* \to)ZZ$	4.2	3.6	3.1
Luminosity	4.1	3.5	3.1
Remaining systematic uncertainties	4.1	3.5	3.0
All systematic uncertainties	4.3	4.4	3.4
No systematic uncertainties	4.0	3.4	3.0

From ATLAS presentation.

ATLAS summary

- Events generated with SHERPA:
  - NLO in 0-jet and 1-jet bins;
  - LO in 2-jet and 3-jet bins.
  - Merging with MePS@NLO prescription.
- NLO EW corrections applied as function of m_{ZZ}.

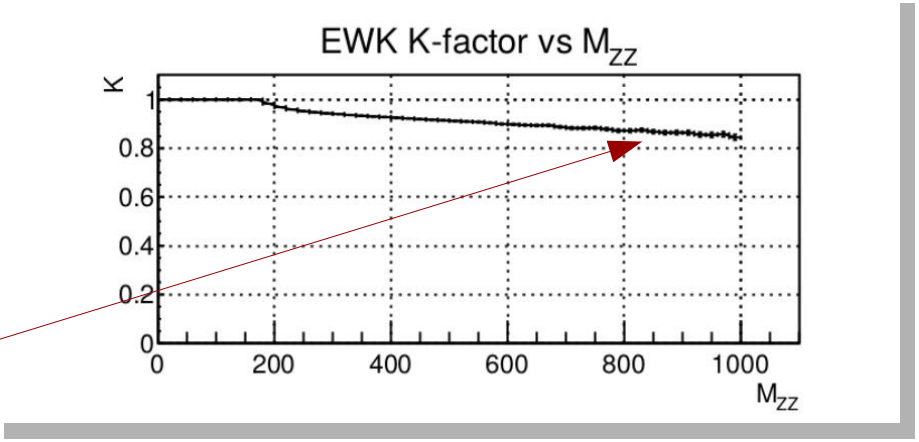
  [Biedermann, Denner, Dittmaier, Hofer, Jäger 1601.07787]
- Assumes QCD and EW corrections factorize → additional uncertainty:
  - Treatment following [Gieseke, Kasprzik, Kühn, 1401. 3964]:

$$\rho = \left(\left|\sum_i \vec{p}_{T,i} + \vec{E}_{T,\mathrm{miss}}\right|\right) / \left(\sum_i |\vec{p}_{T,i}| + |\vec{E}_{T,\mathrm{miss}}|\right)$$

  - ρ < 0.3 → no additional uncertainty.
  - ρ > 0.3 → correction applied with 100% systematic uncertainty to account for missing mixed QCD-EW corrections.
  - Impact ~ 1%.
- QCD scale uncertainty: 5%-10% as function of $m_{4\ell}$.
- PDF & PS uncertainties: 2%-3%.

CMS summary

- Events generated with POWHEG.
- Applied NNLO corrections as function of m_{ZZ}.
- Virtual EW correction applied as functions of $\hat{s}$ and t.
  [Bierweiler, Kasprzik, Kühn 1305.5402;
  Gieseke, Kasprzik, Kühn, 1401. 3964]
  - 20% in offshell region.

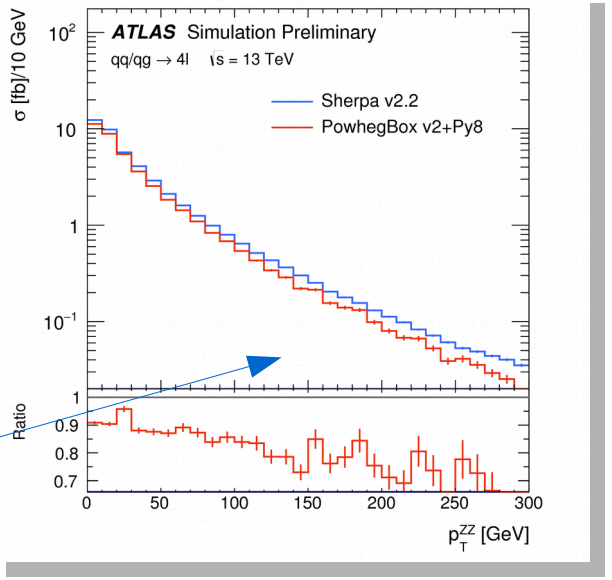


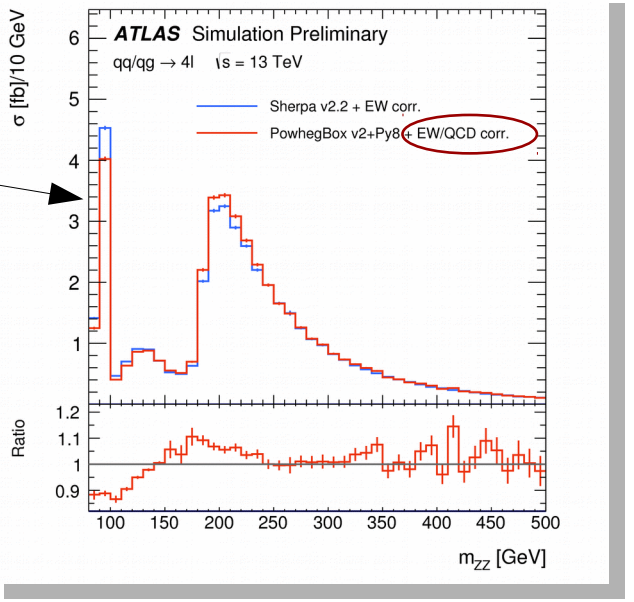
- Conservative estimate of QCD-EW factorization uncertainties:
  - ρ < 0.3: uncertainty is product of QCD and EW corrections.
  - ρ > 0.3: uncertainty is 100% of EW corrections.
  - Significant contributor to systematic uncertainty.

Comparison of ATLAS and CMS analyses

Event generation:

- ATLAS:
  - NLO for 0, 1 jets; LO for 2,3 jets.
- CMS:
  - NNLO for $m_{4\ell}$ distribution.
  - Other distributions: NLO for 0 jet, LO for 1 jet, additional jets from PS
- Expect softer pT spectrum from CMS setup compared to ATLAS setup.
- Also difference in $m_{4\ell}$ distribution around m_Z peak.
  - Not offshell region, but suggests different behavior of corrections here and in offshell region.





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Comparison of ATLAS and CMS analyses

Treatment of EW uncertainties:

- Mixed NLO QCD-EW corrections very challenging theoretically.
- Combinations of QCD and EW corrections assume that these factorize.
- For $\rho < 0.3$:
  - ATLAS assumes factorization is good approximation (events dominated by recoiling vector bosons) – no additional uncertainty.
  - CMS assigns uncertainty as product of EW and QCD corrections – **sizable**.

Future directions

- Careful study of event generators as used by ATLAS and CMS, with associated uncertainties.
  - Invited talk by theory expert on merging and matching.
- Invited talk by theory expert on uncertainty from factorized QCD and EW corrections in diboson production.
- [Twiki link]