Status of EW precision subgroup

LHC EW WG meeting

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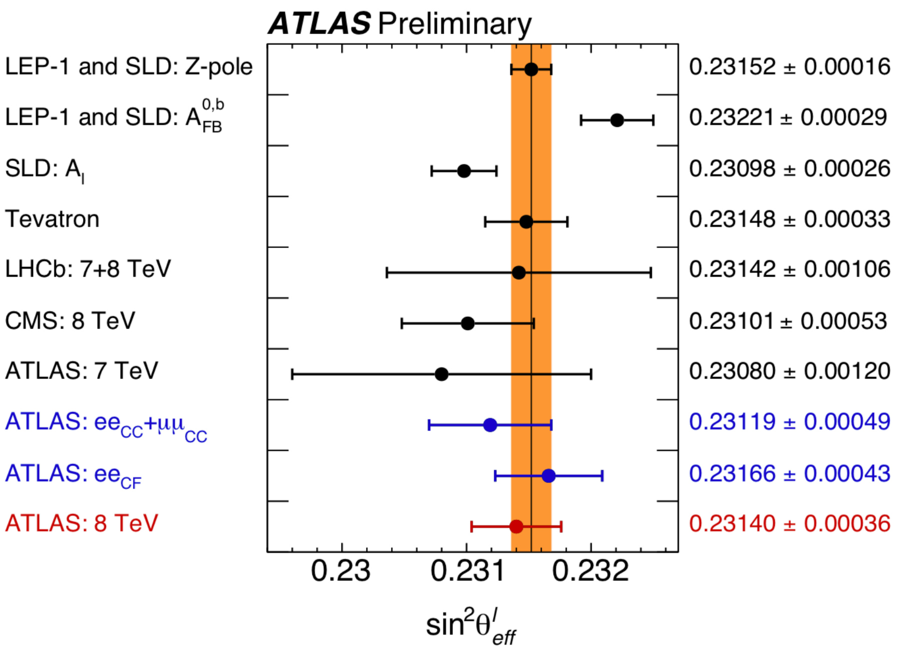
For the LHC EW precision subgroup

LHC EW precision subgroup

- Main areas of work within the LHC precision subgroup:
  - pT W, Z, and W/Z resummation benchmarking
    - Discussed in Tom's talk yesterday
  - QED/EW corrections for precision EW measurements (Z DY and s2weff observables)
    - Studies for W mass will come next
  - PDF benchmarking exercise using LHC precision EW data and pseudodata
    - Discussed in Robert's talk yesterday
  - Pseudodata for combination of $\sin^2\theta_{eff}$ measurements with full run-2 data
  - Pseudodata for combination of full run-2 pTZ and DY measurements
  - Work toward a combination of M_W
    - Discussed in Chris's talk yesterday
  - Photon-induced process in DY measurements and s2weff observables

Preparation of LHC combination for $\sin^2\theta_{eff}$

- Focus on LHC experiments with full Run-2 dataset
- Important that experiments use same (equivalent models) to interpret data and treat common uncertainty sources consistently to produce final combined measurement
- Longer-term may produce a combined measurement (A4 for example)

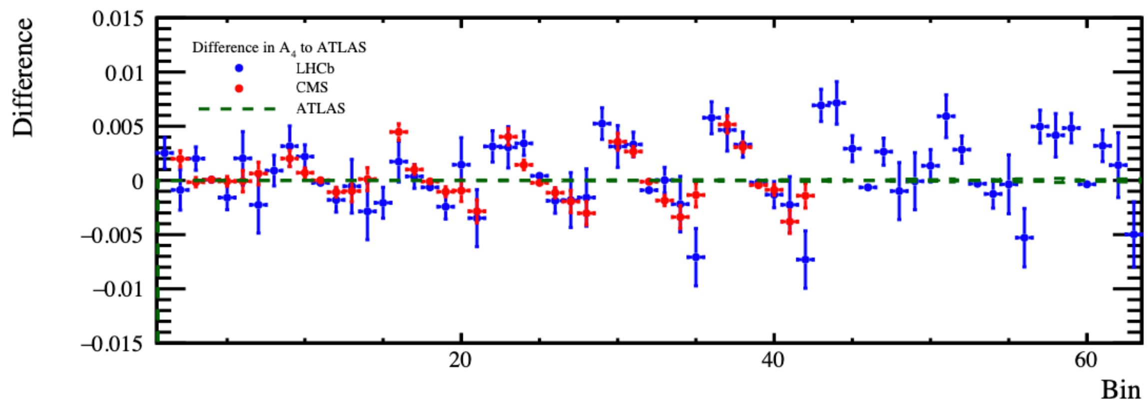


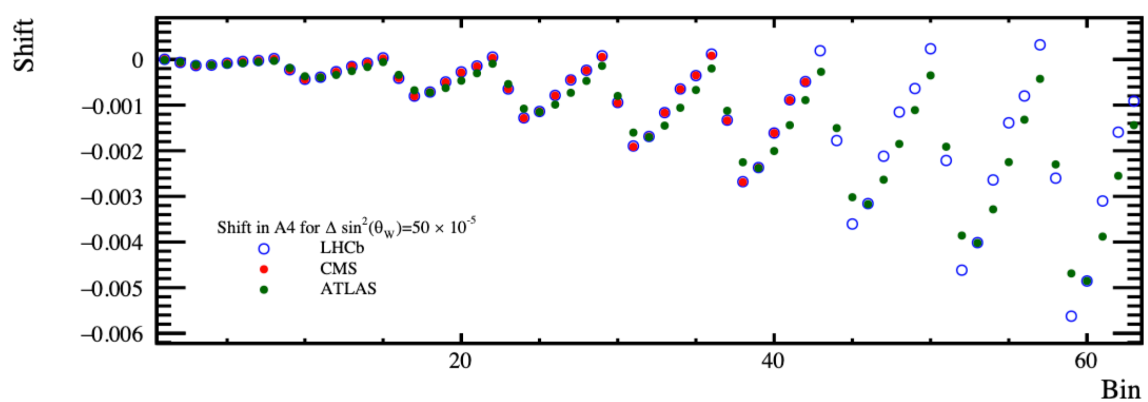
- Compare and combine pseudodata of measurements of A_4 at different experiments.
- Use a common framework for these studies:
  - POWHEG + Pythia8; LO EW, NLO(+PS) QCD
  - PDF: NNPDF31_nnlo_as_0118_hessian
  - Bins of width 0.4 in |y|
  - 7 bins in dimuon invariant mass: {50, 66, 76, 86, 96, 106, 116, 150 GeV}

Goal of pseudodata exercise

- Goal is to provide guidelines in Yellow Report of how experimental data should be published such that an LHC-wide combination could be obtained swiftly once all experiments will have published their results

  - We have pseudodata for ATLAS, CMS, and LHCb
  - Excellent agreement on the Z peak for A_4
  - We also have pseudodata using Powheg-EW with s2eff input scheme with and without EW corrections
  - There is still work to do to have confidence that all of this can be ready within next months





Bin = Mass Bin + Rapidity Bin * 7

Preparation of LHC combination for $\sin^2\theta_{eff}$

- **YR will hopefully contain a section as below which would really be useful as a concrete example of how the weak mixing angle measurements of the three experiments could be combined with a proper correlation treatment of all common theoretical uncertainties**

QED/EW corrections benchmarking

- Benchmark different aspects of the interpretation framework
  - Cross sections and A_{fb}
- Part 1: QED ISR and IFI
  - MCSANC, Powheg-EW, KKMC-hh, WZGRAD2
  - Diversity in calculations is a strength of the group. For example, KKMC-hh deals with ISR by explicitly calculating the collinear terms rather than letting them be absorbed into PDFs
    - Need to include all photon-induced processes (gamma-gamma, quark-gamma) once one includes QED ISR/IFI. Work ongoing using HORACE at LO QCD
    - Nontrivial distortion of AFB distribution with photon-induced contributions (using NNPDF31 luxqed PDF), work in progress
      - https://indico.cern.ch/event/829225/contributions/3481095/attachments/1871900/3100939/Vicini-EWWG-01jul19.pdf
  - There is progress here since last year and hope to converge next few months

QED/EW corrections benchmarking

- Benchmark different aspects of the interpretation framework
  - Cross sections and A_{fb}
- Part 2: virtual EW corrections: NLO, NLO+HO
  - Comparisons with TauSpinner+DIZET, POWHEG-EW, MCSANC, and WZGRAD2
  - Comparisons done using LO QCD for now. The higher order QCD corrections should not change the picture (results are discussed relative to LO EW). The impact of NLO QCD will be checked with Powheg-EW in the last stages of benchmarking
    - The impact of NLO QCD also checked with DIZET

EW schemes: benchmark input parameters

SM relation used to calculate EW LO parameters for different schemes. On-shell mass.

	LEP-legacy		**LHC-paradigm**		**New scheme**
Parameter	$(\alpha(0), G_\mu, M_Z)$ $\alpha(0)$ v0	$(\alpha(0), M_W, M_Z)$ $\alpha(0)$ v1	(G_μ, M_Z, M_W) G_μ	$(\alpha(0), s_W^2, M_Z)$ $\sin^2_{eff}$ v1	(G_μ, s_W^2, M_Z) sin^2_{eff} v2
M_Z (GeV)	91.1876	91.1876	91.1876	91.1876	91.1876
Γ_Z (GeV)	2.4952	2.4952	2.4952	2.4952	2.4952
Γ_W (GeV)	2.085	2.085	2.085	2.085	2.085
$1/\alpha$	137.035999139	137.035999139	132.23323	137.035999139	128.744939484
α	0.007297353	0.007297353	0.007562396	0.007297353	0.007767296
G_μ (GeV^{-2})	$1.1663787 \cdot 10^{-5}$	$1.1254734 \cdot 10^{-5}$	$1.1663787 \cdot 10^{-5}$	$1.09580954 \cdot 10^{-5}$	$1.1663787 \cdot 10^{-5}$
M_W (GeV)	80.93886	80.385	80.385	79.93886984	79.93886984
s_W^2	0.2121517	0.2228972	0.2228972	0.231499	0.231499
$\frac{G_\mu \cdot M_Z^2 \cdot 16 c_W^2 s_W^2}{\sqrt{2} \cdot 8\pi \cdot \alpha} = 1.0$ $s_W^2 = 1 - m_W^2/m_Z^2$	$\rightarrow s_W^2, M_W$	$\rightarrow G_\mu, s_W^2$	$\rightarrow \alpha, s_W^2$	$\rightarrow G_\mu, m_W$	$\rightarrow \alpha, m_W$
$\alpha_s(M_Z)$	0.120178900000	0.120178900000	0.120178900000	0.120178900000	0.120178900000

$$s_W^2 = 1 - m_W^2/m_Z^2$$

$$G_\mu = \frac{\pi\alpha}{\sqrt{2} M_W^2 s_W^2}$$

EW LO, NLO, NLO+HO

- Cross sections (pb) and ratios: NLO/LO, (NLO+HO)/LO with different codes in EW scheme alpha(0)v1
  - Excellent agreement at all levels to about 10^-3 relative. LO QCD numbers using the same PDF set

Programs	$89 < m_{ee} < 93$ GeV	$60 < m_{ee} < 81$ GeV	$81 < m_{ee} < 101$ GeV	$101 < m_{ee} < 150$ GeV
	$\sigma(LO)$ (pb)			
MCSANC	571.412(5)	43.724(2)	821.414(6)	-
Powheg_ew	571.416(7)	43.724(1)	821.414(9)	-
WZGRAD2	571.409(7)	43.722(4)	821.419(9)	-
	$\sigma(NLO)/\sigma(LO)$			
MCSANC	1.05117(1)	1.08830(4)	1.05157(1)	-
Powheg_ew	1.05108(1)	1.08814(2)	1.05149(1)	-
WZGRAD2	1.05151(1)	1.08854(9)	1.05191(1)	-
	$\sigma(NLO+HO)/\sigma(LO)$			
MCSANC	1.06452(1)	1.10004(4)	1.06491(1)	-
Powheg_ew	1.06394(1)	1.09912(2)	1.06433(1)	-
WZGRAD2	-	-	-	-
TauSpinner+DIZET (estimated)	1.06558(0)	1.09892(0)	1.06613(0)	1.06202

EW LO, NLO, NLO+HO

- Cross sections (pb) and ratios: NLO/LO, (NLO+HO)/LO with different codes in EW scheme G_mu
  - Excellent agreement at all levels to about 10^-3 relative. LO QCD numbers using the same PDF set

Programs	$89 < m_{ee} < 93$ GeV	$60 < m_{ee} < 81$ GeV	$81 < m_{ee} < 101$ GeV	$101 < m_{ee} < 150$ GeV
	$\sigma(LO)$ (pb)			
MCSANC	612.531(5)	46.870(2)	880.527(6)	-
Powheg_ew	612.529(8)	46.870(1)	880.513(9)	-
WZGRAD2	612.521(7)	46.868(4)	880.520(10)	-
	$\sigma(NLO)/\sigma(LO)$			
MCSANC	0.99167(2)	1.02865(7)	0.99206(1)	-
Powheg_ew	0.99155(1)	1.02863(2)	0.99196(1)	-
WZGRAD2	0.99198(1)	1.02913(4)	0.99239(1)	-
	$\sigma(NLO+HO)/\sigma(LO)$			
MCSANC	0.99232(2)	1.02614(7)	0.99268(1)	-
Powheg_ew	0.99218(1)	1.02592(2)	0.99255(1)	-
WZGRAD2	-	-	-	-
TauSpinner+DIZET (estimated)	0.99211(0)	1.02321(0)	0.99264(0)	0.98884

EW LO, NLO, NLO+HO

- Forward backward asymmetry and differences: NLO-LO, (NLO+HO)-(N)LO with different codes in EW scheme G_mu
  - Disagreements at the moment with the fixed order NLO EW for AFB: (corresponds roughly to 13*10^-5 s2weff for the most sensitive yll bin)
  - Work in progress to understand the differences

Programs	$89 < m_{ee} < 93$ GeV	$60 < m_{ee} < 81$ GeV	$81 < m_{ee} < 101$ GeV	$101 < m_{ee} < 150$ GeV
	$A_{fb}(LO)$			
MCSANC	0.04654(1)	-0.20299(4)	0.04481(1)	-
Powheg_ew	0.04655(1)	-0.20298(2)	0.04481(1)	-
WZGRAD2	0.04654(1)	-0.20299(8)	0.04482(1)	-
	$A_{fb}(NLO) - A_{fb}(LO)$			
MCSANC	-0.01688(2)	-0.01170(8)	-0.01688(2)	-
Powheg_ew	-0.01740(2)	-0.01214(3)	-0.01738(2)	-
WZGRAD2	-0.01716(2)	-0.01186(11)	-0.01715(2)	-
	$A_{fb}(NLO+HO) - A_{fb}(NLO)$			
MCSANC	0.00170(2)	0.00111(8)	0.00137(2)	-
Powheg_ew	0.00170(2)	0.00112(3)	0.00136(2)	-
WZGRAD2	-	-	-	-
	$A_{fb}(NLO+HO) - A_{fb}(LO)$			
MCSANC	-0.01551(2)	-0.01059(8)	-0.01551(1)	-
Powheg_ew	-0.01603(2)	-0.01102(3)	-0.01602(2)	-
WZGRAD2	-	-	-	-
TauSpinner+DIZET (estimated)	-0.01507(0)	-0.01104(0)	-0.01514(0)	0.00684

EW LO, NLO, NLO+HO

- Forward backward asymmetry and differences: NLO-LO, (NLO+HO)-(N)LO with different codes in EW scheme alpha(0)v1
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	$A_{fb}(LO)$			
MCSANC	0.04655(1)	-0.20304(4)	0.04482(1)	-
Powheg_ew	0.04655(1)	-0.20298(2	0.04481(1)	-
WZGRAD2	0.04654(1)	-0.20299(8)	0.04482(1)	-
	$A_{fb}(NLO) - A_{fb}(LO)$			
MCSANC	-0.01596(1)	-0.01103(6)	-0.01595(1)	-
Powheg_ew	-0.01641(2)	-0.01148(3)	-0.01640(2)	-
WZGRAD2	-0.01619(2)	-0.01121(12)	-0.01617(2)	-
	$A_{fb}(NLO+HO) - A_{fb}(NLO)$			
MCSANC	0.00077(1)	0.00068(6)	0.00078(1)	-
Powheg_ew	0.00077(1)	0.00074(3)	0.00078(2)	-
WZGRAD2	-	-	-	-
	$A_{fb}(NLO+HO) - A_{fb}(LO)$			
MCSANC	-0.01519(1)	-0.01035(6)	-0.01517(1)	-
Powheg_ew	-0.01564(2)	-0.01074(2)	-0.01562(2)	-
WZGRAD2	-	-	-	-
TauSpinner+DIZET (estimated)	-0.01508(0)	-0.01104(0)	-0.01515(0)	-0.00684

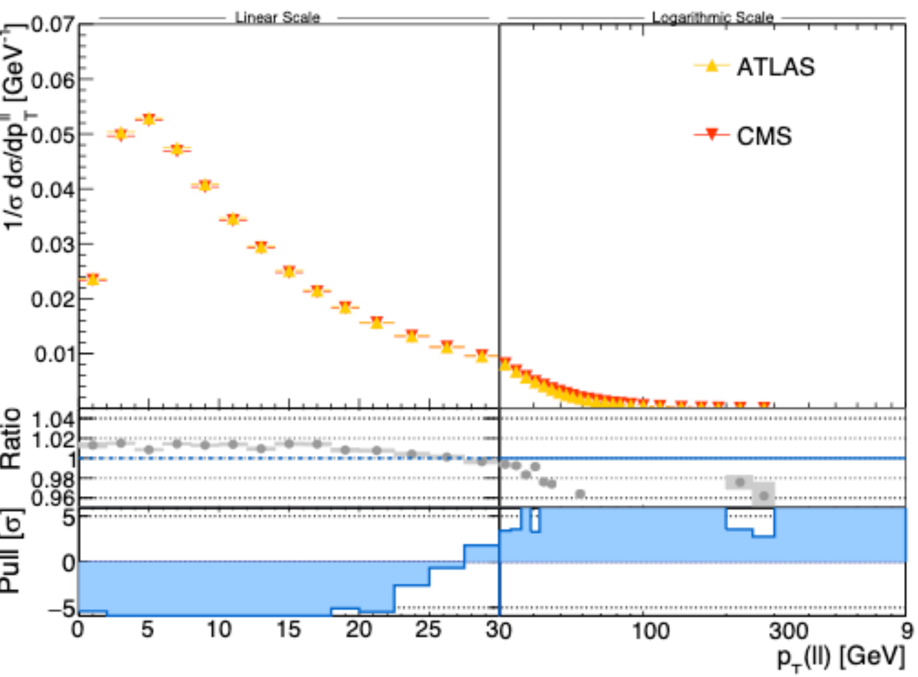
  - Smaller impact of NLO+HO corrections on observables of interest. To be validated precisely including the parametric uncertainties

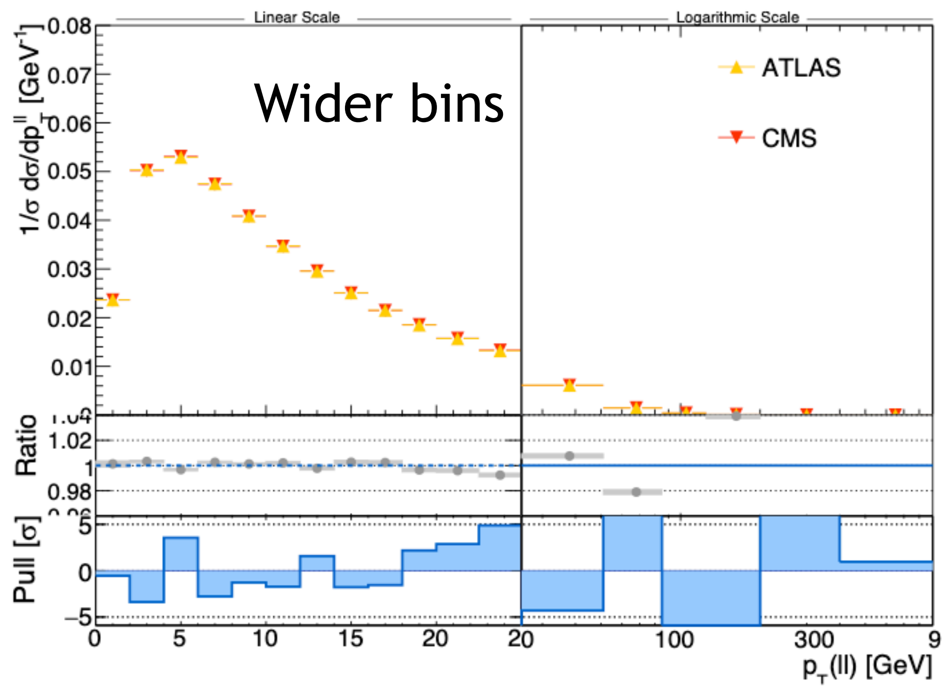
QED/EW corrections benchmarking

- Understanding the Afb difference at NLO is work in progress
  - The work has brought us many improvements and convergences between different calculations
- Very good agreement between Powheg_EW and MCSANC for delta_Afb between NLO+HO and NLO
  - In both G_mu and alpha(0)v1 schemes
  - (NLO+HO)-NLO numbers are larger than the differences we observe at NLO. HO corrections are indeed needed.
- Two additional schemes considered but for them we only have one calculation for now
  - alpha(0)v0 used for the LEP/SLD combination. Our baseline and reference numbers from DIZET 6.48
  - Recently proposed s2weff input scheme available with Powheg-EW

pT Z combination

- Recent exercise to compare CMS and ATLAS 13 TeV measurements
  - Arxiv: 1912.02844, 1909.04133
- Correct for differences in fiducial volume definition using transfer factors
- Binning is not the same. Use linear interpolation to rebin
  - Bias in interpolation? Better agreement using wider bins for pT>25GeV





pT Z combination

Measured cross sections:

- ATLAS ($p_T(Z)$>25 GeV): $1/\sigma\, d\sigma/dp_T(Z)$ = 0.23934290 pb
- ATLAS (2 <$p_T(Z)$< 25 GeV): $1/\sigma\, d\sigma/dp_T(Z)$ = 0.71235850 pb
- CMS cross sections corrected for fiducial phase space differences from above
  - CMS ($p_T(Z)$>25 GeV): $1/\sigma\, d\sigma/dp_T(Z)$ = 0.24058156 pb
  - CMS (2<$p_T(Z)$< 25 GeV): $1/\sigma\, d\sigma/dp_T(Z)$ = 0.70262592 pb

- The two measurements are largely in agreement given the 'quality' of the comparison
- Lessons learned for the future:
  - Agree on at least one common binning having the combination in mind (the experiments can still keep the 'detector' optimized versions'
  - Define a common fiducial volume and provide results as a supplementary material perhaps
  - Agree on "what is signal and what is background"
    - ATLAS subtracts photon-induced process CMS does not for this particular measurement
    - Talk by Laurent on improved generators (LPAIR, SuperChic): https://indico.cern.ch/event/961431/
    - Dedicated discussions within LHC EW subgroup on the treatment of photon induced backgrounds in several DY measurements:

https://indico.cern.ch/event/864105/

YR reports and publications

- Possibly three+ publications will come out from the work done in the precision EW group
  - Resummation benchmarking of pTW, pTZ, and pT W/Z
  - QED/EW corrections for precision EW measurements (s2weff and mW)
  - PDF benchmarking
  - …
- The Yellow report(s) will be more extensive in terms of topics than specific publications, but might be more concise concerning the work published in the corresponding publications referring to them for details
- YR reports can include more material at the boundary between theory and experiment while obeying the publication rules of the experiments. Examples of such material are the ongoing pseudodata studies for the full run-2 LHC combination of the weak mixing angle measurement, and more recently the studies just beginning of a run-2 combination of Z pT measurements.

Timelines

- We had a consensus that this year should be publication time and that we should push for convergence and reduction of certain ambitions if time is too short
  - We are now October 2020 with Covid crisis past few months
- Aim to achieve the same goals by April 2021 or at least by summer 2021
  - This would require results by the end of this year or latest by March-April next year
- Few areas naturally allow to start writing up while the work is ongoing:
  - QED/EW corrections for example: https://gitlab.cern.ch/lhcewkwg/lhcewkwg-precisionEW/documentation/-/tree/qedew-corrections/qedew-corrections
  - pT W/Z resummation benchmarking is another area where we plan to start the process of documenting the results this year as Level 1 and 2 benchmarking results are mature

ADDITIONAL MATERIAL