Summary of EW precision subgroup

LHC EW WG meeting

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For the LHC EW precision subgroup

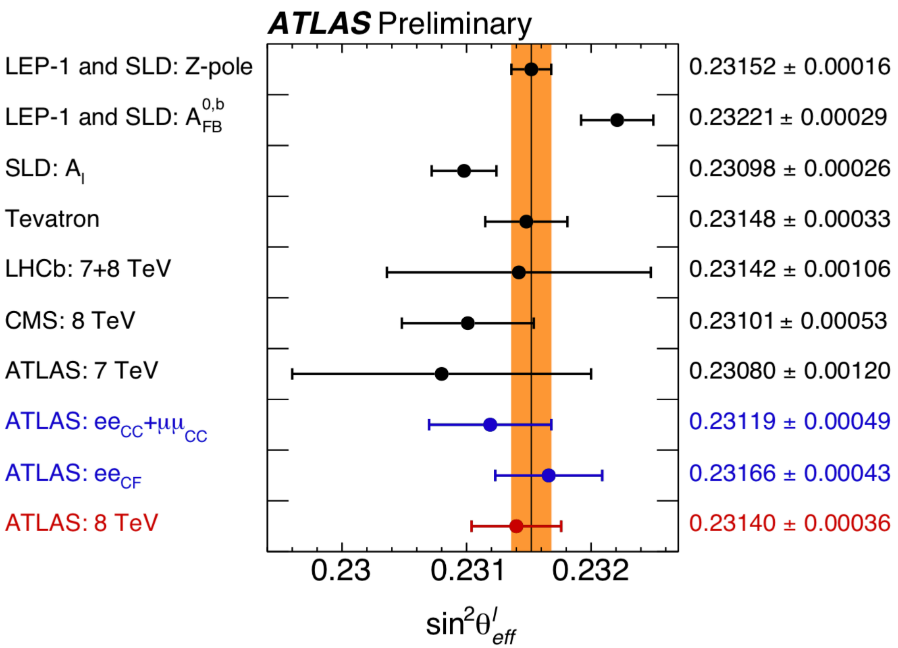
Introduction

- Main areas of ongoing work:
  - Work toward a combination of $\sin^2\theta_{eff}$
  - Work toward a combination of M_W
  - PDF benchmarking exercise using LHC precision EW data and pseudodata
  - pT W, Z, and W/Z benchmarking
  - QED/EW for Z DY and s2w observables
    - Studies for W mass come next

- Summary from last meetings:
  - https://indico.cern.ch/event/766590/
  - https://indico.cern.ch/event/775325/

Status of discussions for $\sin^2\theta_{eff}$

- Focus on LHC experiments
- Medium-term: Global fit to A4/AFB values measured by ATLAS, CMS, and LHCb with Run2 data
- Longer-term: Combine many differential cross sections in a global QCD fit.



Use the same kinematic and geometric cuts:

- $p_T > 25$ GeV (some discussion of asymmetric cuts)
- $|\eta| < 2.4$ ATLAS & CMS $2 < \eta < 4.5$ LHCb [overlap]
- Forward electrons in ATLAS & CMS
  - Clearly boosts statistical precision and reduces PDF uncertainties.

First step for $\sin^2\theta_{eff}$

- Demonstrate the compatibility of unfolded measurements of the A4/Afb values in bins of rapidity and mass
  - https://indico.cern.ch/event/758628/contributions/3146291/attachments/1721966/2780410/First_Steps_sin2thetaW_Schmitt.pdf

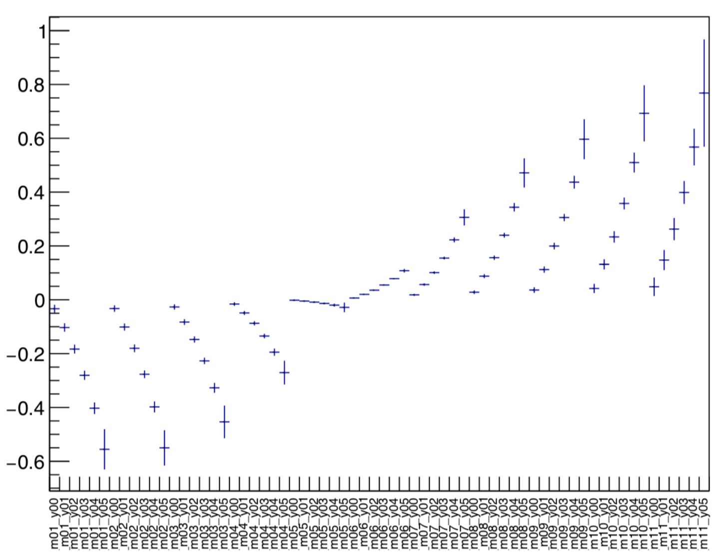
- Each group:
  - Generates pseudo-data that resembles real data (though without backgrounds at present).
  - Unfold the data and obtain A_4 for each (M_{ll},y_{ll}) bin.
  - Parametrize A_4 in each bin as a function of $\sin^2\theta_W$.
  - Perform a fit to obtain $\sin^2\theta_W$.
- All groups together:
  - Check compatibility of the A_4 values among the groups.
  - Perform a global fit to all the A_4 values.
  - Understand uncertainties: statistical, experimental, PDFs…

First step for $\sin^2\theta_{eff}$

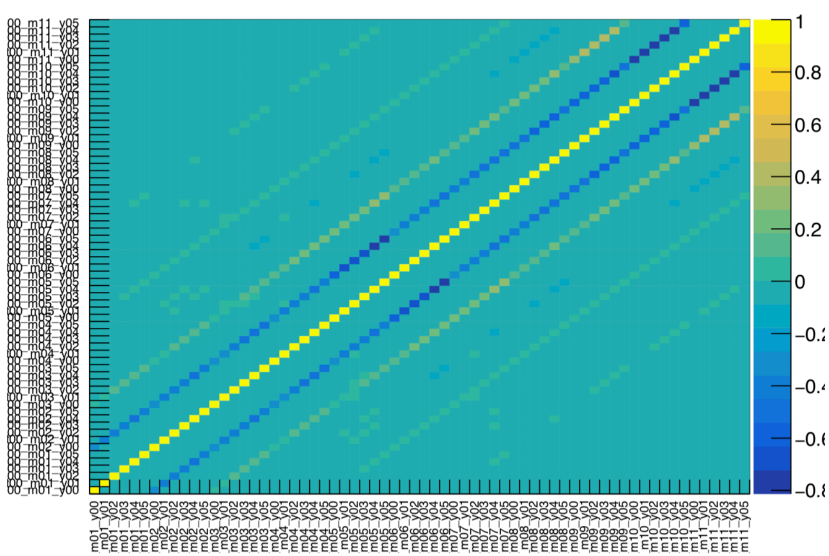
- Prepare unfolded pseudo-measurements of AFB/A4 in a standardized binning for initial tests
  - Test combination machinery
  - Comparison of theory predictions
  - Cross-validation of AFB/A4-> $\sin^2\theta_{eff}$ interpretation between experiments

- 18 bins in M_{ll} in the range 60 to 150 GeV (5 GeV width)
- 9 bins in $|y_{ll}|$ out to 3.6 (0.4 width)
- Binning in $\cos\theta^*$ and in dilepton p_T do not need to be standardized.

Measurement



Correlation matrix



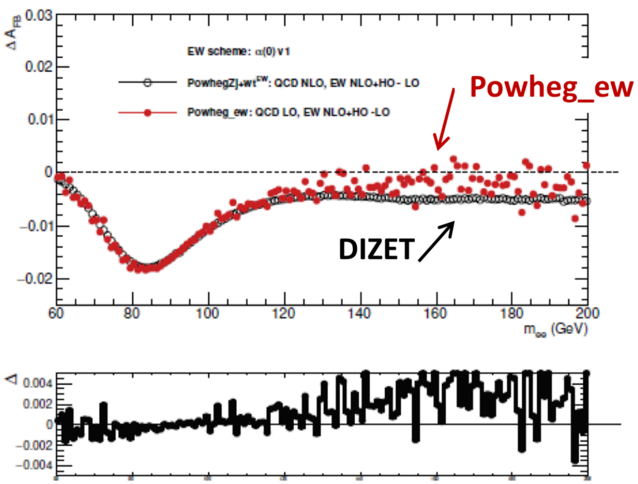
Talk by Aaron from Wednesday

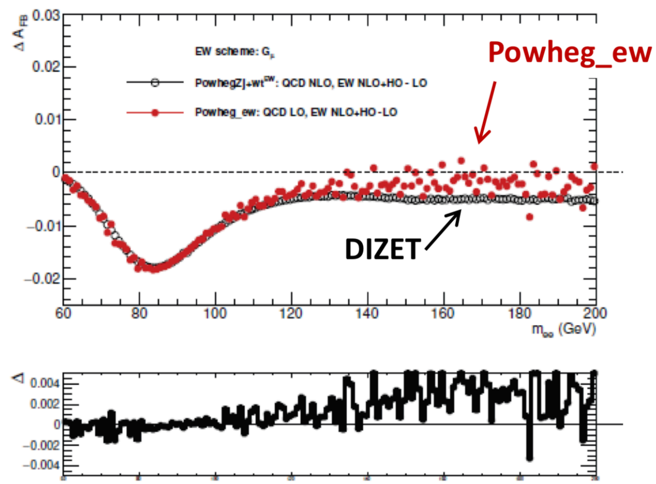
Next step for $\sin^2\theta_{eff}$

- Interpret the unfolded measurement results in a global fit to $\sin^2\theta_{eff}$
- Predictions used in the past at Tevatron and LHC: Z production at NLO QCD+PS+QED FSR
  - Incorporate EW effects implemented using LEP-style form factors (DIZET). Need also subleading ISR/IFI corrections present at $O(\alpha)$
- N(N)LO QCD+ NLO EW parton shower generators (Powheg EW, Sherpa,…)
- Benchmark different aspects of the interpretation framework
  - Comparison of available NLO QCD+EW predictions and form-factor approach
  - QED ISR and IFI benchmarking
  - QED PDFs, $\gamma\gamma/\gamma q$ processes: need consistent treatment
  - PDF uncertainties: correlation between different PDFs (Daniel's talk)

EW LO, NLO, NLO+HO

- Comparisons with DIZET, POWHEG-EW, MCSANC
  - Additional codes will be included: HORACE, ZGRAD2…
  - LO QCD for now. Will include NLO next





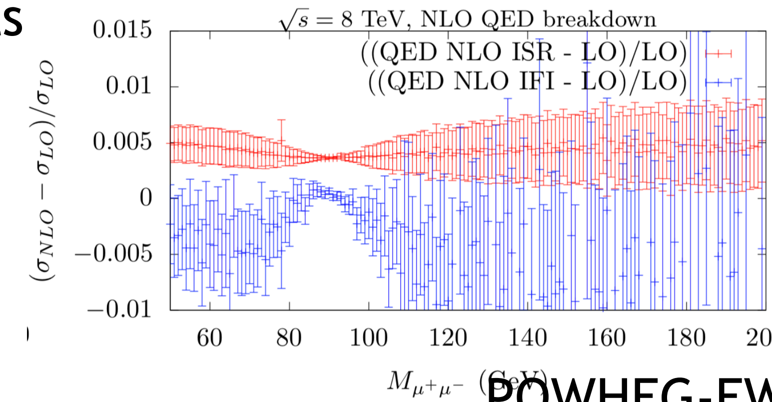
Good agreement between Powheg_ew and DIZET around Z-pole

At higher masses, DIZET predicts stable shift of 0.005 while both PowhegEW and MCSANC predicts (NLO+HO – LO) being close to zero.

Talk by Elzbieta on Wednesday

QED ISR and IFI benchmarking

- Active work in benchmarking of QED effects
  - MCSANC, POWHEG, and KKMC-hh
  - Cross sections (mll) and AFB
    - QED PDFs, photon-induced effects
  - Comparisons done using bare muons



POWHEG-EW

Cross section	LO	NLO QED	NLO QED FSR	NLO QED ISR	NLO QED IFI
QED PDF $\delta_{x-\mathrm{LO}}$	953.32(2)	937.38(4) -1.672(6)%	933.88(4) -2.039(6)%	956.83(2) +0.368(5)%	-0.010(1) -0.001(12)%
NO-QED PDF $\delta_{x-\mathrm{LO}}$	959.51(2)	943.48(4) -1.671(6)%	939.95(4) -2.039(6)%	963.04(2) +0.368(4)%	0.0 0%

Integrated cross-section σ (pb) and $\delta = \sigma(\mathrm{QED})/\sigma(\mathrm{LO})$ (%)

σ(LO)	δ(ISR)	δ(IFI)	$\delta(\mathrm{ISR} + \mathrm{IFI})$	NNPDF
958.94(1)	0.367(1)	0.019(1)	0.386(2)	no QED
952.63(1)	0.367(1)	0.019(1)	0.386(2)	luxQED

MCSANC

QED ISR and IFI benchmarking

- Active work in benchmarking of QED effects (AFB)

POWHEG-EW

A_{FB}	LO	NLO QED	NLO QED FSR	NLO QED ISR
66 GeV $< m_{ll} <$ 116 GeV				
QED PDF	0.03986(2)	0.04056(4)	0.04060(5)	0.03985(3)
$\Delta_{x-\mathrm{LO}}$		0.00070(6)	0.00074(7)	-0.00001(3)
NO-QED PDF	0.03964(3)	0.04033(4)	0.04038(5)	0.03963(3)
$\Delta_{x-\mathrm{LO}}$		0.00069(7)	0.00074(8)	-0.00001(3)

Integrated A_{FB}(LO) and [A_{FB}(LO+QED)-A_{FB}(LO)]

MCSANC

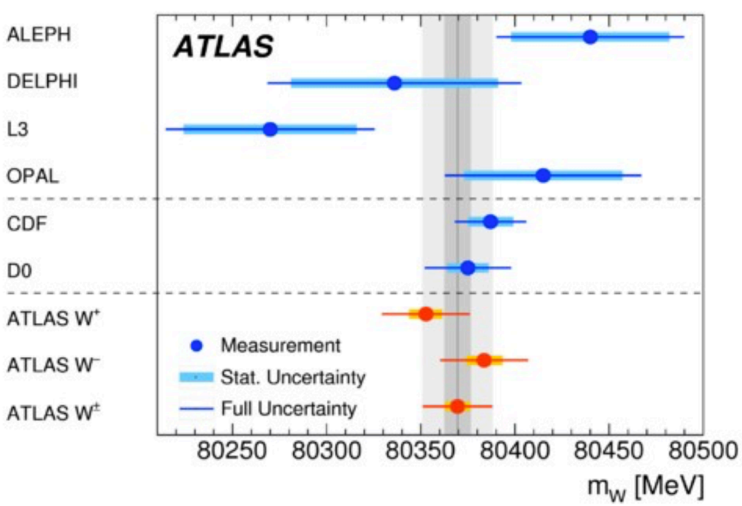
[LO]	[ISR]	[IFI]	[ISR+IFI]	NNPDF
0.044695(2)	-0.00003(2)	-0.00018(2)	-0.00021(3)	no QED
0.044967(2)	-0.00004(2)	-0.00018(2)	-0.00022(3)	luxQED

The IFI contribution is $< 0.1\%$ while ISR is $\sim 1.5\%$.

KKMC-hh

Status of W mass

- Work on combining Tevatron and ATLAS results
- Studies of correlation of PDF uncertainties between existing measurements
- Detailed talk by N. Andari on Thursday morning
  - https://indico.cern.ch/event/779259/contributions/3245228/attachments/1770679/2877099/Andari_ws_12122018.pdf



MSTW	1.	2.	3.	4.
1. W+ 2 TeV	1	1	0.04	0.66
2. W- 2 TeV	1	1	0.08	0.62
3. W+ 7 TeV	0.04	0.08	1	-0.48
4. W- 7 TeV	0.66	0.62	-0.48	1
CT10	1.	2.	3.	4.
1. W+ 2 TeV	1	0.99	0.26	0.51
2. W- 2 TeV	0.99	1	0.31	0.52
3. W+ 7 TeV	0.26	0.31	1	-0.23
4. W- 7 TeV	0.51	0.52	-0.23	1

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Loss of correlation between W+ 2 and 7 TeV with MMHT while still present for W-

Status of W mass

- Machinery in place for the combination and evaluation of PDF uncertainties
- Smearing procedure in place to estimate PDF uncertainties (important effect for mT, factor of 10 difference between Born-level and emulated reco-level)
- Different W+/- correlations between different PDF sets observed
- Stronger correlation between W+ 2 TeV and W- 7 TeV observed
- MSTW2008 scaling factor 2.15 different from CT10 1.645 reproduced

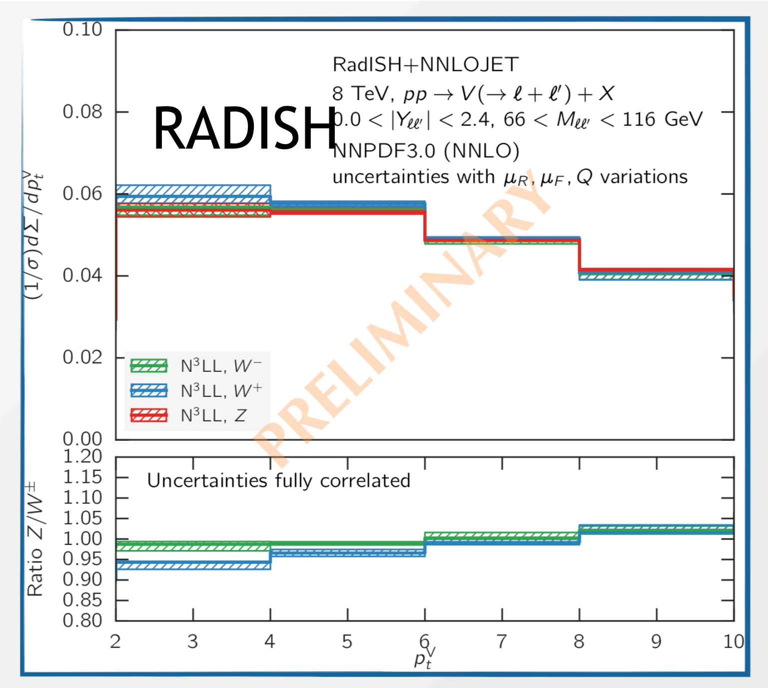
Next steps

- Reupdate results with the parameterisations from Tevatron
- Improve the parameterisations for ATLAS 7 TeV
- Evaluate the correlations and the mW combined value and uncertainty for other PDF sets. Agreed on CT14, MMHT, and NNPDF3.1. Define an envelope uncertainty.

QCD aspects

- One-day discussion/reports from resummed groups during the November workshop
  - RADISH/NNLOJET, DYTURBO/DYRES, RESBOS2, GENEVA
  - Predictions of pT W and W/Z
- Talk by Frank Tackmann on resummed calculations and nuisance parameters

- Inclusion of threshold effects needed for accurate predictions
- First level of benchmarking for resummed calculations proposed



Benchmarking: Resummed calculations

- Radish, DYTurbo/DYRES,Geneva,Resbos2
- Comparison at NNLL+NNLO accuracy
    - Plus RADISH with $N^3LL+ N^3LO$
- Observables: p_T^Z, p_T^W in full phase space
- Benchmarking for few m_{ll} and Y_{ll} points
    - m_{ll}: 66, 91, 116, and 500 GeV
    - Y_{ll}: 0.0, 3.0
- Consider only certain couplings:
    - uu_bar
    - dd_bar
    - all
- Specify how heavy flavor c, b are treated
- If possible include at least proper threshold behavior

Benchmarking: pT Z,W

- First level of benchmarking with resummed calculations defined
- Second level of benchmarking between MC generators and calculations
  - Alessandro's talk for detailed discussion
  - Also fiducial phase space of decay leptons defined by ATLAS/CMS/LHCb
  - Requires very detailed documentation of their configurations

Timelines

- Active work and progress on most fronts
- Benchmarking for predictions defined or being finalized

- For most of the efforts we expect to converge by the end of 2019. Written reports will follow shortly after that.
- Reasonable to expect to converge on QED DY part by April or so and perhaps finalize the write up by the end of summer
- A separate report can be considered for the PDF benchmarking studies

ADDITIONAL MATERIAL