Finalising configurations to be run for publications and YR

- We believe we are ready to seriously start documenting the work done since April 2018 in this activity of the working group. We propose to work on this documentation as an independent part or volume of a Yellow Report structured along the lines of the attached skeleton document.
- See back-up slides for more information (shown at last meeting)
- We would propose to work towards this with the following timescale and caveats:
  - Complete the calculations by ~ end of this year and to this end monitor progress every few weeks rather than few months (for example we propose to hold our next topical meeting on these issues in the week of 30/09 midway to the October workshop
  - Finalise scope of YR by ~ end of this year
  - Produce complete draft of YR by ~ March 2020
  - Produce theory publications on specific items (virtual EW correction benchmarking would be one paper, QED ISR and IFI benchmarking would be another paper)
  - Complete report by summer 2020

Finalising configurations to be run for publications and YR

- To achieve these goals, it is vital now to converge on two aspects of the work which remains to be done at the latest by the October 18th meeting (skeleton agenda at https://indico.cern.ch/event/843756/overview)
- First aspect would be to freeze all the necessary parameters for the CPU-intensive calculations which remain to be done:
  - Input parameters and schemes (see synthesis of where we stand by Elzbieta in next talk)
  - Binning of histograms and of expected measured observables (see synthesis of where we stand in next slides)
  - Precise definition of observables in terms of fiducial cuts (if any) and, in this case, of Born/dressed/bare leptons (see also next slides)
- Second aspect would be to establish priorities in case further delays happen to obtain the full (ambitious but hopefully still realistic) set of results (see last slides of this talk). To this end, similarly to what was discussed on 02/10 in the pTW/Z meeting for the resummation benchmarking, we need to agree on a minimal subset of the full set which would still provide most of the answers required for a publication

Finalising configurations to be run for publications and YR

- **We prepared some aspects of this more than a year ago!** M. Schmitt

Concrete Plans for 13 TeV

- The 13 TeV measurements will follow the ATLAS model.
  - Later, combine with ATLAS 8 TeV measurement (not CMS 8 TeV)
- LHCb will participate (in addition to ATLAS & CMS)
  - Important and somewhat orthogonal lever on PDFs
  - Statistical precision on the same scale as ATLAS & CMS
- 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.

Finalising configurations to be run for publications and YR

M. Schmitt

- We prepared some aspects of this more than a year ago!
- The bins discussed here are for producing numbers in terms of experimental observables for which pseudodata is planned to be used
- Histograms from calculations have much finer binning (eg 1 GeV in m_{ll})
- Need to revise y_{ll} binning a bit to include LHCb and perhaps finer binning at high y_{ll}? Maybe move to 22 bins from 0 to 4.4 for simplicity?
- Maybe also adjust mass range below to 61 to 151 GeV? And for pole region use 81 to 101 GeV.

Binning:

- 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.

Standardized binning allows for direct compatibility tests among the experiments.

Also, improves connection to theory benchmark studies.

Finalising configurations to be run for publications and YR

- **We prepared some aspects of this more than a year ago!**

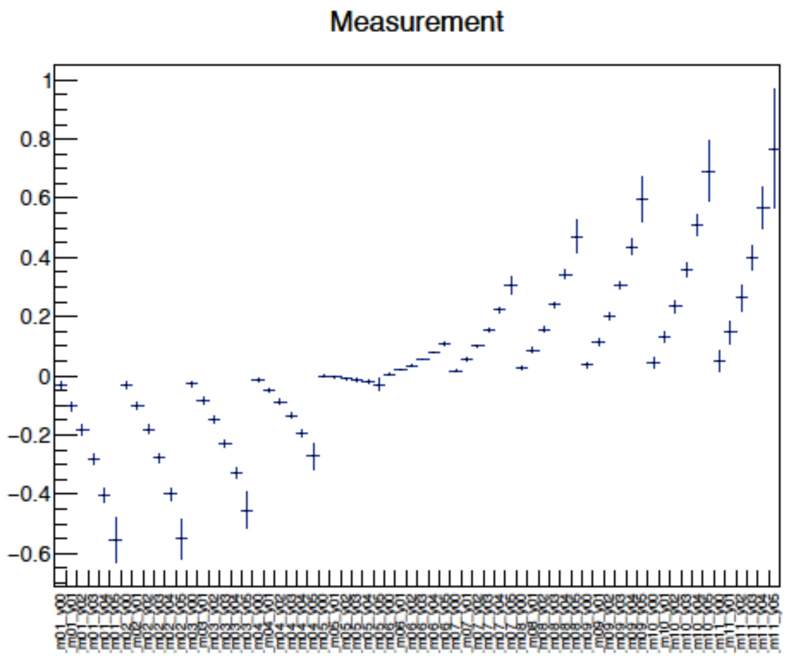
M. Schmitt

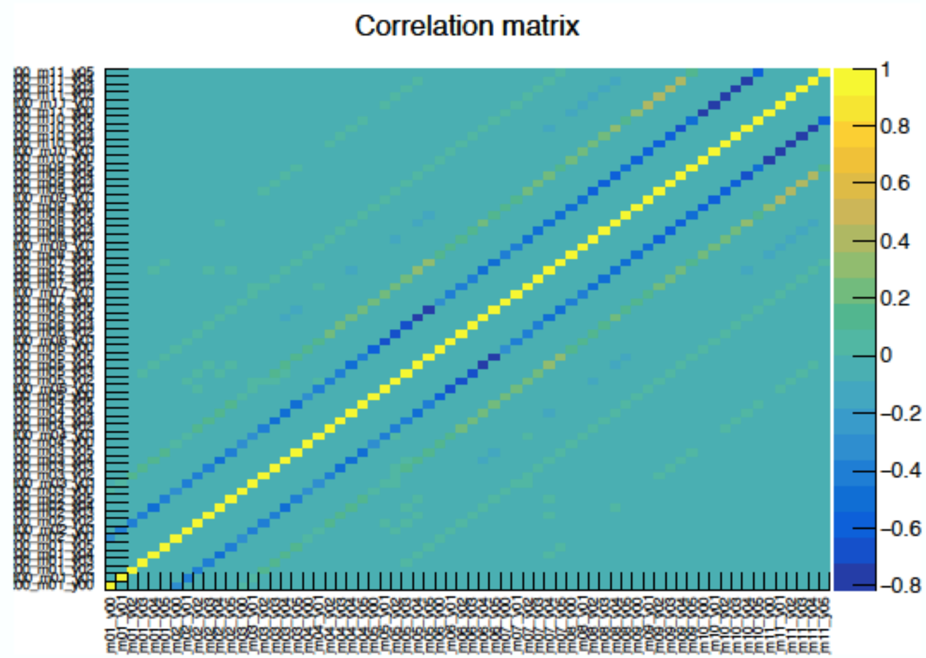
- Next Steps:
  - Each group:
    - Generates pseudo-data that resembles real data (though without backgrounds at present).
    - Unfold the data and obtain A_4 for each (M_{ll}, y_{ll}) bin.
    - Parametrize A_4 in each bin as a function of $\sin^2\theta_W$.
    - Perform a fit to obtain $\sin^2\theta_W$.
  - 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…
- In addition:
  - Use the same event generator [not yet decided]
  - Use the same PDF [probably NNPDF] and EWK corrections.
  - Develop a common fitting tool.

Finalising configurations to be run for publications and YR

- **To-date only ATLAS has reported any work towards this goal (~ 9 months ago!, again not a criticism, maybe a fact of life… but then the scope of the YR has to be reconsidered**

A. Armbruster





- Measurement inputs provided in the form of a set of measured A4 values in the specified binning (left) and its covariance matrix (right)
- For now only for 66-116 mass range (limitation of old inputs used for this iteration) and for central-central leptons (eeCC+mumuCC combination)

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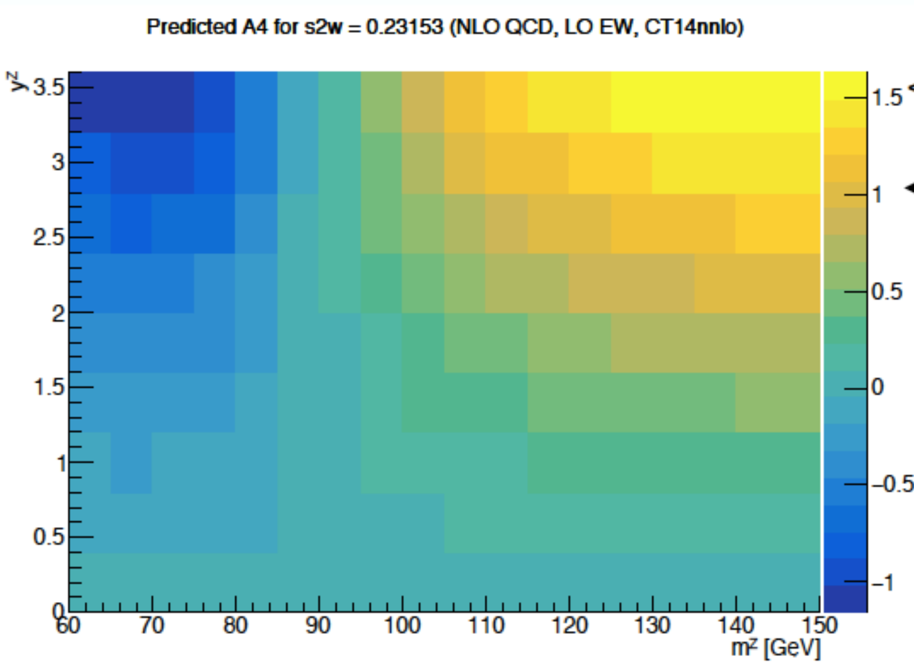


```
[09:55:50> root pred.root
root [0]
Attaching file pred.root as _file0...
[root [1] .ls
TFile**         pred.root
 TFile*         pred.root
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF0_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF1_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF2_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF3_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF4_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF5_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF6_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF7_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF8_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF9_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF10_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF11_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF12_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF13_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF14_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF15_CT14nnlo_muf1.0_mur1.0;1
  KEY: TH2D     A4_pt1_m18_y9_23153_PDF16_CT14nnlo_muf1.0_mur1.0;1
```

- Predictions prepared in the form of a set of 2D (mass, rapidity) histograms
- One 2D histogram for each PDF EV x 3 values of s2w (0.23153, 0.23053, 0.23253)
- Prepared for CT14nnlo PDF set for now
- NLO QCD, LO EW
  - NNLO QCD and NLO EW corrections can come later after we've validated this easier part

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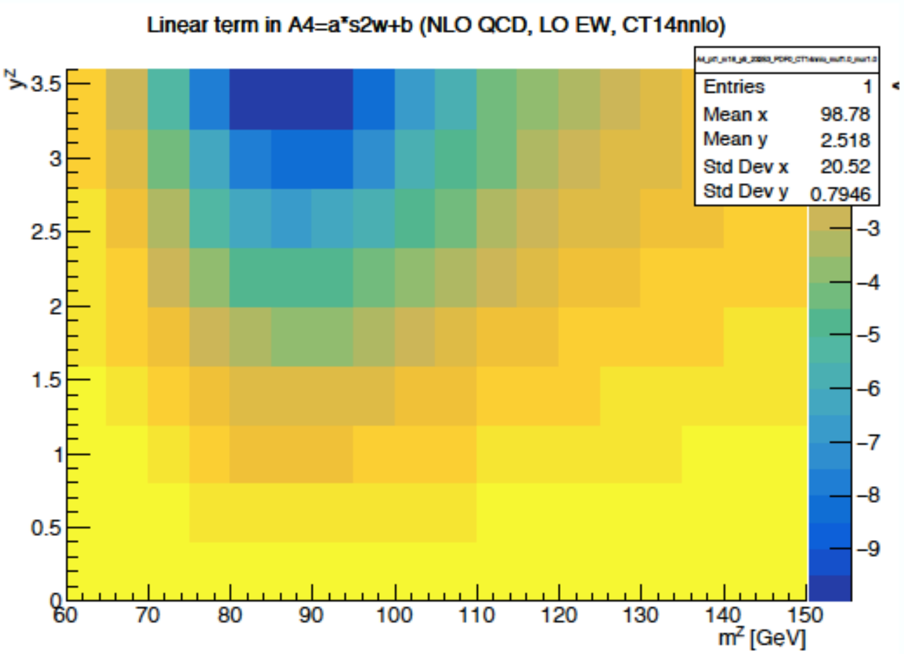

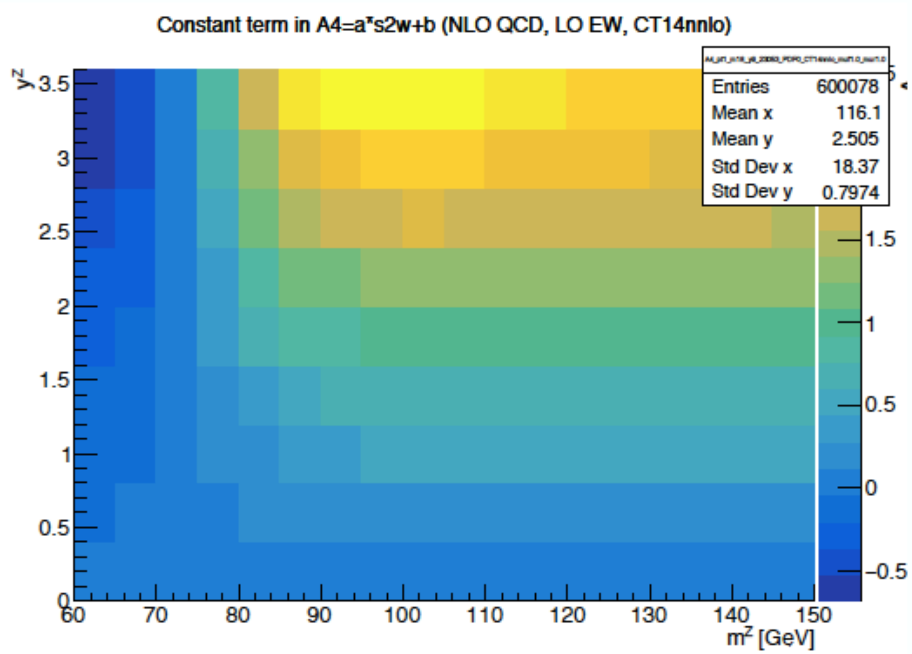

- From this set of predictions, one can produce interpretation curve A4 = a*s2w+b for each point in mass, rapidity
- Above shown for linear and constant term a, b for one EV

- Parametrizing A4 measurement inputs with prediction inputs, one should recover the result:
  - s2w = 0.23153 +/- 0.00014 (stat) +/- 0.00027 (pdf) +/- 0.00002 (qcd) = 0.23153 +/- 0.00031 (tot)

Finalising configurations to be run for publications and YR

- **If we don't have any progress on the inputs from CMS and LHCb over the next few months, then one of the most useful sections of the YR for the experiments will be either descoped to an ATLAS-only exercise, which would be highly undesirable and unwelcome, or worse will be omitted completely.**

- **Since the full run-2 measurements from the experiments are still in the distant future, one might use the WG beyond the YR to complete this exercise, but this would be a shame in my opinion.**

- **Of course, some people in the WG might argue that after all this brings the QED/EW part of the YR to the same level as the pTW/Z part (for which it is really out of scope to assess the impact of all the theoretical work done on the W mass measurement itself, see the discussion two days ago in the dedicated meeting on this topic).**

Finalising configurations to be run for publications and YR

- What about the lepton definition and the consistency between the virtual EW corrections on one side and the IFI/ISR corrections on the other?
- In the initial discussions, we had agreed to do the following:
  - For the virtual corrections, use Born leptons only since these are computed in a correct way without any QED radiation (the LEP Ansatz!).
  - For the IFI/ISR/FSR corrections, use bare muons only because there is no additional dependence on a dressing algorithm and because the muon mass is large enough that the calculations remain numerically "safe" compared to electrons.
  - Do we agree to stick to the above? I certainly hope so!
- Additional points which require some discussion:
  - It would be of interest to have the impact of virtual corrections also assessed for AFB after fiducial cuts (the same as those used for the pseudodata). Is this feasible for all calculations?
  - It would also be of interest to document precisely for IFI/ISR what happens when going from the bare muons to dressed muons and then to "Born"-like muons. And also to compare dressed muons and dressed electrons.

Finalising configurations to be run for publications and YR

- **Finally, what about priorities in terms of defining what is minimal content of publication?**
- **Some thoughts on this below:**
  1. **If some calculations are not available for certain configurations, it should be still ok as long as we have a minimum of two for any major result?**
  2. **If eg MC-SANC with an event generator is not ready on the timescale envisaged, then we have MC-SANC results only for y-integrated distributions which still would be an extremely important set of results since the rapidity dependence of these corrections is at the moment unclear and might be considered to be of lesser importance than the more direct impact on the lineshape and asymmetries.**
  3. **If we cannot produce on the desired timescale the full results as a function of the lepton type and definition, this could still warrant a very nice publication and future work in the WG would aim at filling this gap which will be required for the final run-2 results from the experiments**
  4. **Anything else?**

Back-up slides

Path to Yellow Report

- **We believe working on the overall YR together is quite important from now on because the interplay between experiment and theory is the key to a useful report which in our minds has the goal of laying out a possible strategy (not necessarily unique!) of how experiments would publish their full run-2 results and how they would this be optimally ready for an overall LHC combination once all the individual results (and interpretations) are out.**

- **The prospects look good that this future LHC combination could have very similar precision to the overall LEP/SLC result ($16\ 10^{-5}$)**

- **However, achieving that will surely require work beyond what will be in a YR published in summer 2020 (eg PDF uncertainty)**

- **So the YR will be a guideline showing what we can strive towards and work will surely continue beyond it on all fronts, but based on a, hopefully sound, written document vetted by the whole community.**

Path to Yellow Report

- First part focuses on setting the context: LEP/SLD briefly with the best references available today, using also similar work done in the context of FCC_ee studies, and then hadron colliders with the Tevatron and early LHC measurements.

Contents

- Include available uncertainty tables from most precise measurements from ATLAS (preliminary) and CMS (published)

Path to Yellow Report

- **Second part is devoted to so-called virtual EW corrections.**
- **It contains current status of calculations with tables and plots from available results based on Dizet, Powheg-EW and MC-SANC**

Path to Yellow Report

- Third part is devoted to so-called QED ISR and IFI and also to the impact of photon-induced processes which belongs here.
- At this point PDFs come in, and comparisons are done
  a) without including photon-induced processes at all and using standard PDFs and
  b) including photon-induced processes but using PDFs matched to LUXQED

Path to Yellow Report

- **Fourth part is the key one to facilitate and harmonise (within reason) experimental measurements and combinations at the LHC using full run-2 data.**
- **Final numbers will be needed at 13 TeV energy**

Path to Yellow Report

- **Fourth part is the key one to facilitate and harmonise (within reason) experimental measurements and combinations at the LHC using full run-2 data.**
- **Goal would be to arrive at finest possible breakdown of expected (mostly theoretical) uncertainties although correlated experimental uncertainties may be of interest too**

Table 3: Summary of the theoretical uncertainties for the dimuon and dielectron channels, as discussed in the text.

CMS

Modeling parameter	Muons	Electrons
Dilepton p_T reweighting	0.00003	0.00003
μ_R and μ_F scales	0.00011	0.00013
POWHEG MINLO Z+j *vs.* Z at NLO	0.00009	0.00009
FSR model (PHOTOS *vs.* PYTHIA 8)	0.00003	0.00005
Underlying event	0.00003	0.00004
Electroweak $\sin^2\theta^{\ell}_{\text{eff}}$ *vs.* $\sin^2\theta^{\text{u,d}}_{\text{eff}}$	0.00001	0.00001
Total	0.00015	0.00017

Path to Yellow Report

- **Fourth part is the key one to facilitate and harmonise (within reason) experimental measurements and combinations at the LHC using full run-2 data.**
- **Goal would be to arrive at finest possible breakdown of expected (mostly theoretical) uncertainties although correlated experimental uncertainties may be of interest too**

ATLAS

$m^{\ell\ell}$ (GeV)	70 – 80			80 – 100				100 – 125		
$\lvert y^{\ell\ell}\rvert$	0 – 0.8	0.8 – 1.6	1.6 – 2.5	0 – 0.8	0.8 – 1.6	1.6 – 2.5	2.5 – 3.6	0 – 0.8	0.8 – 1.6	1.6 – 2.5
Prediction (MMHT14)	−0.0870	−0.2907	−0.5970	0.0144	0.0471	0.0928	0.1464	0.1045	0.3444	0.6807
	Uncertainties			Uncertainties				Uncertainties		
Total	0.0176	0.0202	0.0404	0.0015	0.0015	0.0025	0.0044	0.0083	0.0098	0.0230
Stat.	0.0153	0.0164	0.0333	0.0013	0.0013	0.0021	0.0036	0.0072	0.0078	0.0188
Syst.	0.0087	0.0117	0.0229	0.0007	0.0008	0.0013	0.0025	0.0041	0.0060	0.0133
PDF (meas.)	0.0013	0.0049	0.0048	0.0001	0.0002	0.0004	0.0007	0.0007	0.0016	0.0043
p_T^Z modelling	0.0002	0.0004	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0001	< 0.0001	0.0002
Leptons	0.0023	0.0059	0.0118	0.0002	0.0001	0.0003	0.0007	0.0014	0.0037	0.0070
Background	0.0004	0.0011	0.0064	< 0.0001	< 0.0001	< 0.0001	0.0001	0.0004	0.0017	0.0031
MC stat.	0.0082	0.0088	0.0179	0.0007	0.0007	0.0012	0.0023	0.0038	0.0041	0.0100

Table 7: Expected measurement uncertainties in A_4 and their breakdown, based on MMHT14 pseudo-data. Also shown as a reference are the predictions for the central values using the MMHT14 PDF set, as obtained from Table 2.

Path to Yellow Report

ATLAS

- **Table below needs further breakdown!!**

Channel	ee_{CC}	$\mu\mu_{CC}$	ee_{CF}	$ee_{CC}+\mu\mu_{CC}$	$ee_{CC}+\mu\mu_{CC}+ee_{CF}$
Total	65	59	42	48	34
Stat.	47	39	29	30	21
Syst.	45	44	31	37	27
	Uncertainties in measurements				
PDF (meas.)	7	7	7	7	4
p_T^Z modelling	<1	<1	1	<1	<1
Lepton scale	5	4	6	3	3
Lepton resolution	3	1	3	1	2
Lepton efficiency	1	1	1	1	1
Electron charge misidentification	<1	0	<1	<1	<1
Muon sagitta bias	0	4	0	2	1
Background	1	1	1	1	1
MC. stat.	25	22	18	16	12
	Uncertainties in predictions				
PDF (predictions)	36	37	21	32	22
QCD scales	5	5	9	4	6
EW corrections	3	3	3	3	3

Table 8: Expected measurement uncertainties in $\sin^2\theta^{\ell}_{\rm eff}$ and their breakdown, based on MMHT14 pseudo-data. The values are given in units of 10^{-5}, assuming an effective value of $\sin^2\theta_W = 0.23152$. The uncertainties are broken down separately for those arising from the A_4 measurements and from the predictions. The PDF uncertainties are treated as uncorrelated between the A_4 measurements and the predictions (see text).