UNIVERSITÄT HEIDELBERG
ZUKUNFT SEIT 1386

Performance of xFitter
- ATLAS report and wishes -

VALERIE LANG
KIRCHHOFF-INSTITUTE FOR PHYSICS, HEIDELBERG

ON BEHALF OF THE ATLAS COLLABORATION

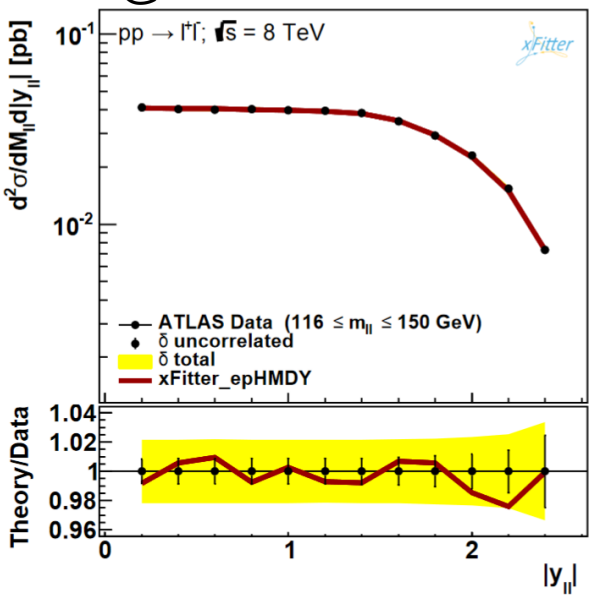
20.03.2017, XFITTER MEETING, OXFORD

Content

- Usage of xFitter in ATLAS
- Easiness of usage
- Limitations of usage

xFitter recently in ATLAS

High-mass Drell-Yan @ 8TeV

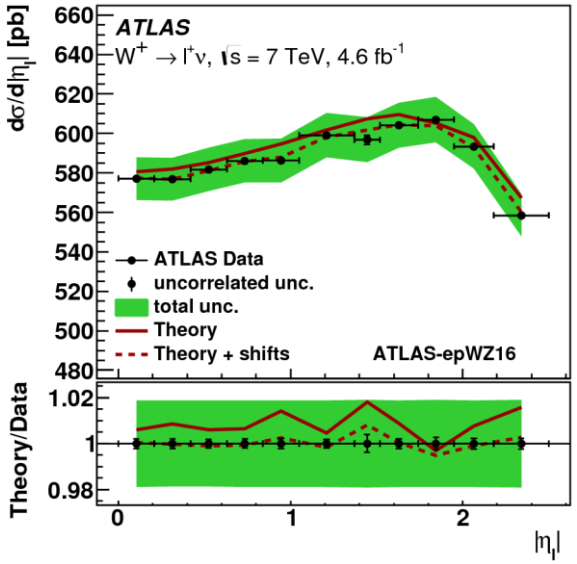


Data for PDF

- Double-differentiell m_{ll} vs. $|y_{ll}|$

→ Photon PDF

W^+, W^- and Z inclusive @ 7TeV

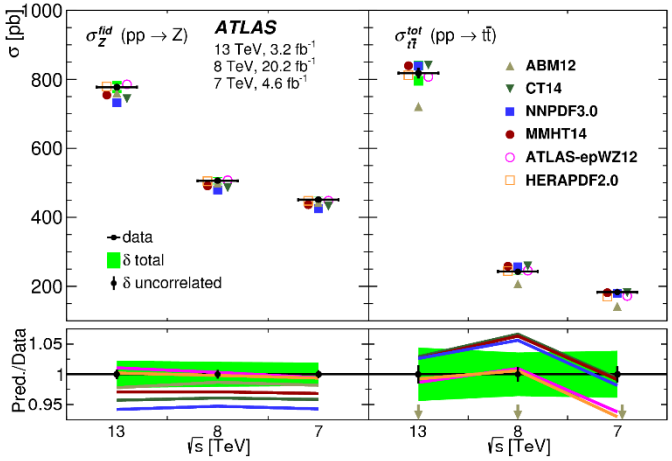


Data for PDF

- Differentiell $|\eta_l|$ for W, m_{ll} vs. $|y_{ll}|$ for Z

→ Strange, u_v, d_v PDFs

$t\bar{t}$/Z @ 13,8,7TeV



Data for PDF

- $t\bar{t}$ and Z as function of √s

→ Strange quark, gluon PDF

Usage of xFitter in ATLAS

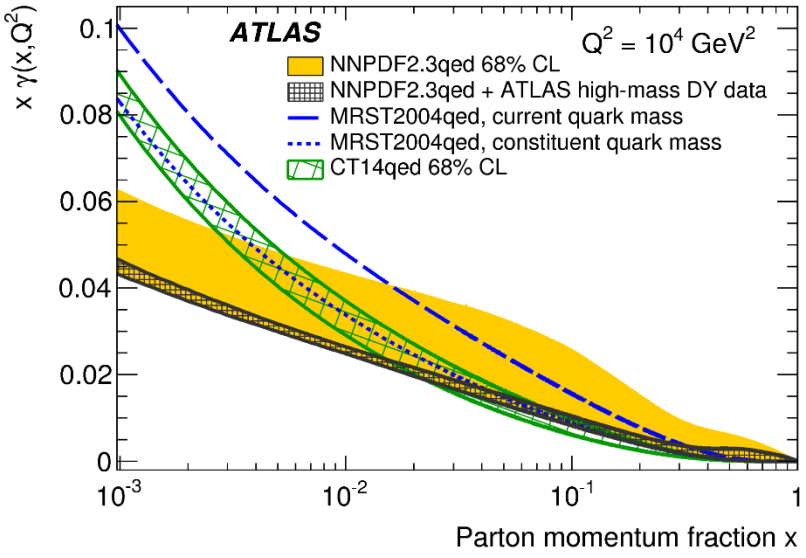
- χ^2 test for data and prediction agreement
  - High-mass DY
  - W, Z cross section
  - $t\bar{t}$/Z ratio

χ^2/dof values

	$m_{\ell\ell}$	$\lvert y_{\ell\ell}\rvert$	$\lvert\Delta\eta_{\ell\ell}\rvert$
MMHT2014	18.2/12	59.3/48	62.8/47
CT14	16.0/12	51.0/48	61.3/47
NNPDF3.0	20.0/12	57.6/48	62.1/47
HERAPDF2.0	15.1/12	55.5/48	60.8/47
ABM12	14.1/12	57.9/48	53.5/47

Bayesian Reweighting

- High-mass DY
  - Reweighting of *NNPDF2.3qed* (no Hessian Photon PDF available)
  - Theory: NNLO QCD+NLO EW → From *FEWZ* w/ *MMHT14* NNLO PDF

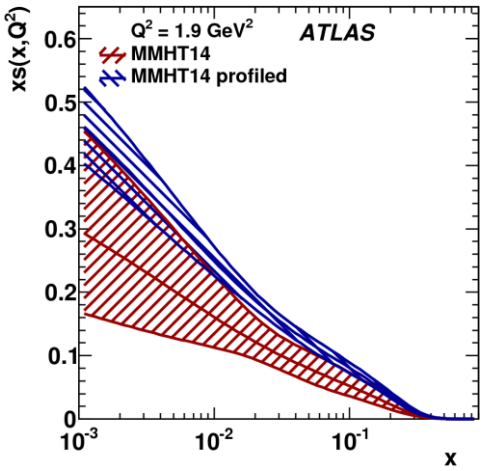


Usage of xFitter in ATLAS

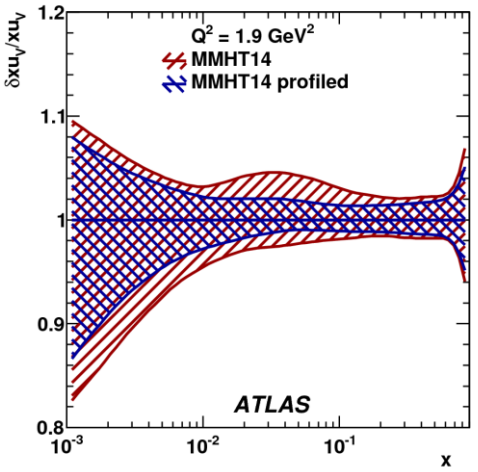
Profiling

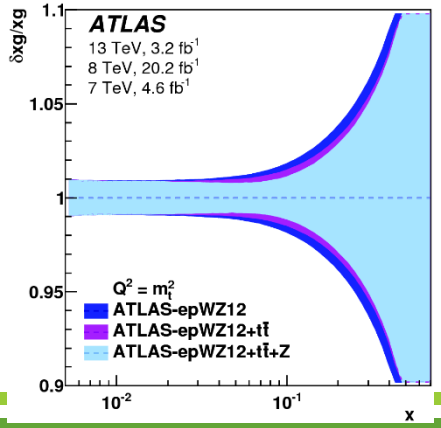
- W, Z cross section
  - Profiling 5 PDF sets: *ABM12*, *CT14*, *MMHT2014*, *NNPDF3.0*, *ATLAS-epWZ12*
  - Theory: NNLO QCD+NLO EW → *DYNNLO* w/ additive k-fractors for EW corrections by *MCSANC*
- $t\bar{t}$/Z ratio
  - Profiling of *ATLAS-epWZ12*
  - Theory:
    Z: NNLO QCD from *DYNNLO* with *CT14* PDF + NLO EW from *FEWZ*
    $t\bar{t}$: NNLO+NNLL resummed from *Top++*

Strange quark PDF



Valence quark PDF





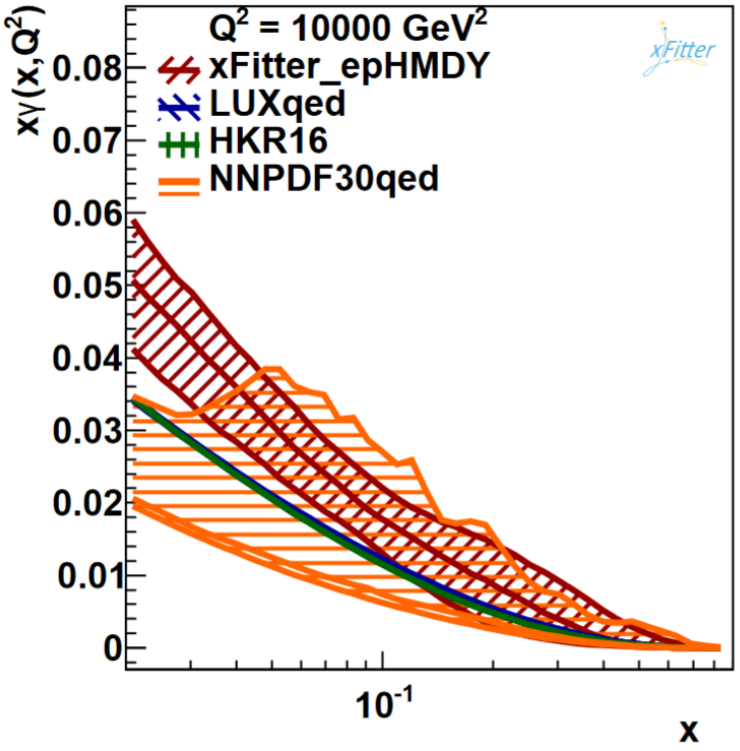
Gluon PDF

Usage of xFitter in ATLAS

PDF fit

- High mass DY (later publication)
  - Data: HERA + DY m_{ll} vs $|y_{ll}|$
  - Theory: *Madgraph5_aMC@NLO* interfaced to *APPLgrid* via *aMCfast*
  - Bin-by-bin k-factors for combined NNLO/NLO QCD and NLO/LO EW correction → *FEWZ* with *MMHT2014* NNLO PDF
  - Required development of simultaneous DGLAP evolution with QCD and QED terms in *APFEL* (needed for HERA predictions)

→ New PDF set: ***xFitter_epHMDY***



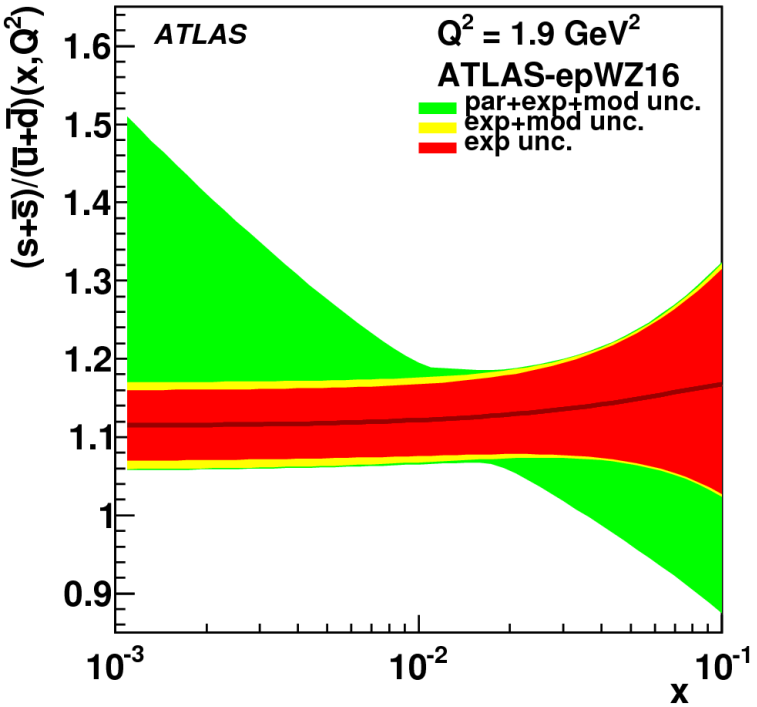
→ Currently best Photon PDF from data fit

Usage of xFitter in ATLAS

PDF fit

- W, Z cross section
  - Data: HERA + $W^{+/-}$ $|\eta_l|$, Z $|y_{ll}|$ (3 m_{ll} bins central Z/γ*, 2 m_{ll} bins forward Z/γ*)
  - Theory: *MCFM* interfaced to *APPLgrid* (NLO)
  - Bin-by-bin k-factors for combined NNLO/NLO QCD and NLO/LO EW corrections → from *DYNNLO* with *MCSANC* (for NLO EW corr)

→ New PDF set: ***ATLAS-epWZ16***



→ Unsupressed strange quark at low x (Confirmed and increased precision of previous findings)

Easiness of xFitter usage
- Data input -

Text input file

- Example W^+ $|\eta_l|$ from http://xfitter.hepforge.org/data.html
  - Good: Both human and machine readable → With explanations in manual, very manageable format

→ But so far: xFitter PDF fits only use HERA + new measurement data

```
&Data
  Name = 'ATLAS W+ lepton rapidity 2011'
  Reaction = 'CC pp'
  NData =    11
  NColumn =138
  ColumnType = "Flag",2*"Bin","Sigma", 132*"Error","Error","Error"
  ColumnName ="binFlag", "eta_min","eta_max","Sigma", "stat",
"uncor","sysATLAS1001","sysATLAS1002","sysATLAS1003","sysATLAS1004","sysATLAS1005","sysATLAS1006","sysATLAS1007","sysATLAS1008","sysATLAS1009","sysATLAS1010","sysATLAS1011","sysATLAS1012","sysATLAS1013","sysATL
   ...
1","sysATLAS1122","sysATLAS1123","sysATLAS1124","sysATLAS1125","sysATLAS1126","sysATLAS1127","sysATLAS1128","sysATLAS1129","sysATLAS1130","AtlasLumi2011","uncor"
tlasLumi2011","uncor"
  NInfo = 1
  CInfo = 'theoryunit'
  DataInfo = 1.
  IndexDataset =   507
          TheoryType = 'expression'
          TermName = 'A1', 'K'
          TermType = 'applgrid','kfactor'
          TermSource = 'datafiles/lhc/atlas/wzProduction/1612.03016/grid-40-6-15-3-Wplus_wyl.root', 'datafiles/lhc/atlas/wzProduction/1612.03016/kf.wplus.txt'
'datafiles/lhc/atlas/wzProduction/1612.03016/kf.wplus.txt'
          TheorExpr = 'K*A1/1000'
  Percent =
true,true,true,true,true,true,true,true,true,true,true,true,true,true,true,true,true,true,true,true,true,
   ...
&End
&PlotDesc
      PlotN = 1
      PlotDefColumn = 'eta_max'
      PlotDefValue = 0., 5.
      PlotOptions(1)  = 'Experiment:ATLAS@ExtraLabel:pp #rightarrow W^{+}; #sqrt{s} = 7 TeV;
@YTitle: d#sigma/dy [pb] '
&End
1  0.0000E+00  2.1000E-01  5.7715E+02  1.0853E-01  1.3184E-01  -0.022   0.001   0.001   0.000
0.048   0.005   0.035   0.000   0.114   0.009   0.003   0.007   0.021   0.012  -0.045  -0.002
0.007  -0.007   0.001   0.000  -0.001   0.004   0.006   0.001  -0.004   0.012   0.055  -0.020
```

→ With more LHC data: Interesting to fit with HERA+previous LHC+ new measurement data

→ But then: What is uncertainty e.g. sysATLAS1127? → Is it correlated among processes, among data-taking years?

→ Need naming convention and infos on correlation to look up somewhere

Easiness of xFitter usage
- Theory input -

Bayesian reweighting or profiling

- Purpose: Easy check, if PDF sensitivity of analysis → possibly during analysis design stage
- In principle, no full *APPLgrid* production needed, but (w/o xFitter hacks) no possibility to input theory w/o *APPLgrid* → too large overhead for sensitivity study

→ Alternative, e.g. textfile input similar to data needed for simpler applications
→ Allow direct NNLO predictions as input

PDF fits

- Need *APPLgrid* files → NLO QCD+ LO EW only
  - K-factors for correction to NNLO needed → Very tedious, specially for scale variations, new k-factors needed for each variation
  - NLO fit only → Not state-of-the-art

→ Production of *APPLgrid* files: Very large overhead for analyses
→ k-factor approach increases this overhead even further

Easiness of xFitter usage
- Fit configuration -

High flexibility in choosing fit χ^2, PDF parametrization, etc.

- Many options great for experts, but confusing for newcomers
- Which options are needed for what?
  - Suggestion in addition to manual: How to's for: χ^2 data-prediction compatibility test, Bayesian reweighting, profiling, PDF fitting, with clear step-by-step instructions
    (Lacking instructions for profiling e.g. in manual)
  - Link manual and how-to's on first page of webpage
    → Keep up to date

Understanding output and errors

- Very helpful section in manual to understand output → extend for how-to's
- Important to have: Section on common errors, e.g. where to place PDFs for profiling if missing, etc.

→ Key element here: Documentation, documentation, documentation

Easiness of xFitter usage
- Installation -

In principle, smooth installation

- Dependency on non-standard libraries: *Boost*, *LAPACK*, *BLAS*
- At least within ATLAS, some version of libraries contained in ATLAS software
  - Possibility to discuss in ATLAS, to keep these at versions compatible with xFitter
  - Indicate this possibility for library setup in installation instructions

```
# Setup root and boost libraries
setupATLAS --quiet
localSetupROOT 5.34.18-x86_64-slc6-gcc47-opt
lsetup "sft --cmtconfig=x86_64-slc6-gcc47-opt external/Boost/1.50.0_python2.7"
lsetup "sft --cmtconfig=x86_64-slc6-gcc47-opt external/lapack/3.4.0"
lsetup "sft --cmtconfig=x86_64-slc6-gcc47-opt external/blas/20110419"

# for to set the correct library paths
export BOOST_ROOT=$SFT_HOME_Boost
export LAPACK_LIBS=$SFT_HOME_lapack/lib/libLAPACK.so
export BLAS_LIBS=$SFT_HOME_blas/lib/libBLAS.so
```

→ Simplifies installation on computing farms with non-admin rights

Limitations in xFitter usage

THEORY

Handling of NNLO

- NNLO *APPLgrids* needed → k-factor approach is very tedious and introduces additional uncorrelated uncertainties
- Consistency of NNLO predictions → Experimental uncertainty smaller than differences in NNLO predictions → relevant for W,Z cross sections: *DYNNLO* vs. *FEWZ*

W/Z+heavy flavour

- No working *APPLgrids*, but also no possibility of alternative theory input → No attempt e.g. for W+c fit

DATA

Data sets

- Better overview for non-experts needed → Hidden information will not be used in time-limited analyses

Uncertainty correlations

- Information on uncertainty naming, correlations between measurements, years, etc. needed
- Information on correlation between different distributions of the same measurement needed → Presented in usable format: Too much information also not helpful

Summary

xFitter → Part of recent PDF-sensitive publications in ATLAS

- Most important question: How PDF sensitive is an analysis?
  - Bayesian reweighting or profiling performed with xFitter-hacked non-*APPLgrid* theory input or time-consuming *APPLgrid* input → does not allow simple and quick PDF sensitivity tests
  - **Wish**: Alternative theory input possibility, e.g. similar to data input

- Application in PDF fits → Advanced usage for PDF-tailored analyses
  - Lacking NNLO *APPLgrids* circumvented with k-factor approach for NNLO PDF fits → very tedious → increases threshold to attempt PDF fit
  - **Wish**: NNLO APPLgrids (maybe not direct xFitter responsibility)

- xFitter usage
  - Quality of documentation influences broadness of application
  - **Wish**: Simple how-to‘s for different use-cases of xFitter

Thanks for your attention

Publications

High mass DY

- *Measurement of the double-differential high-mass Drell-Yan cross section in pp collisions at $\sqrt{s}$=8TeV with the ATLAS detector*, ATLAS Collaboration, JHEP 08 (2016) 009
- *The photon PDF from high-mass Drell Yan data at the LHC*, Giuli et. Al., arXiv:1701.08553

W, Z cross section

- *Precision measurement and interpretation of inclusive W^+, W^- and Z/γ^* production cross sections with the ATLAS detector*, ATLAS Collaboration, arXiv:1612.03016

$t\bar{t}$/Z ratio

- *Measurements of top-quark pair to Z-boson cross-section ratios at $\sqrt{s}$=13,8,7TeV with the ATLAS detector*, ATLAS Collaboration, JHEP 02 (2017) 117

Further useful links

xFitter

- Webpage: https://www.xfitter.org/xFitter/
- Data sets for xFitter: http://xfitter.hepforge.org/data.html
- Manual: https://www.xfitter.org/xFitter/xFitter/DownloadPage?action=AttachFile&do=view&target=manual.pdf

APPLgrid

- Webpage: https://applgrid.hepforge.org/