xFitter PDF Tutorial

xFitter Project

www.xfitter.org

Open Source QCD Fit framework

2018 CTEQ School

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SMU

on behalf of the xFitter team

Special thanks to Eric Godat for the Python help

xFitter Meeting: Krakow March 2018

xFitter Project *Overview*

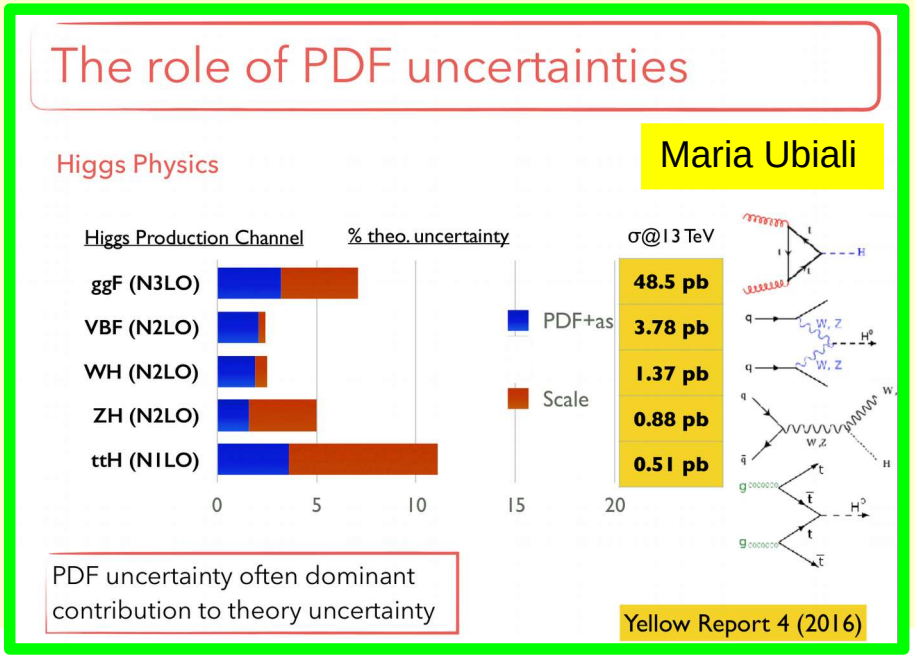
www.xfitter.org

The xFitter project is an open source QCD fit framework ready to extract PDFs and assess the impact of new data.

The framework includes modules allowing for a various theoretical and methodological options, capable to fit a large number of relevant data sets from HERA, Tevatron and LHC.

This framework is already used in many analyses at the LHC.

Proton parton distribution functions (PDFs) are essential for precision physics at the LHC and other hadron colliders. The determination of the PDFs is a complex endeavor involving several physics process. … In particular, the precise measurements obtained or to come from LHC will continue to improve the knowledge of the PDF.



xFitter release xfitter-2.0.0

www.xFitter.org

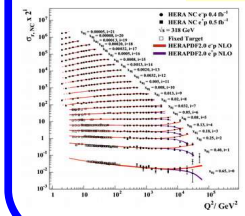
xFitter

xFitter/xFitterTalks » xFitter/../xFitterDevel.. » xFitter/../Meeting2017-.. » xFitter » xFitter/DownloadPage

Sample data files:

LHC: ATLAS, CMS, LHCb
Tevatron: CDF, D0
HERA: H1, ZEUS, Combined
Fixed Target: …
User Supplied: ...

Experimental Data



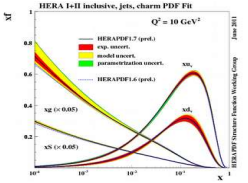
Data: HERA, Tevatron, LHC, fixed target experiments

Processes:
Inclusive DIS, Jets, Drell-Yan, Diffraction, Top production
W and Z production

Theory Calculations

HQ Schemes:	MSTW, NNPDF, ABM, ACOT
Jets, W, Z:	FastNLO, ApplGrid
Top:	Hathor
Evolution:	QCDNUM, APFEL, k_T
Other:	NNPDF reweighting TMDs, Dipole Model, ...

xFitter



Parton Distribution Functions:
PDF, Updf, TMD

$\alpha_S(M_Z)$, m_c,m_b,m_t ...

Theoretical Cross Sections

Comparisons to other PDFs (LHAPDF)

xFitter 2.0.0 FrozenFrog

Features & Recent Updates:

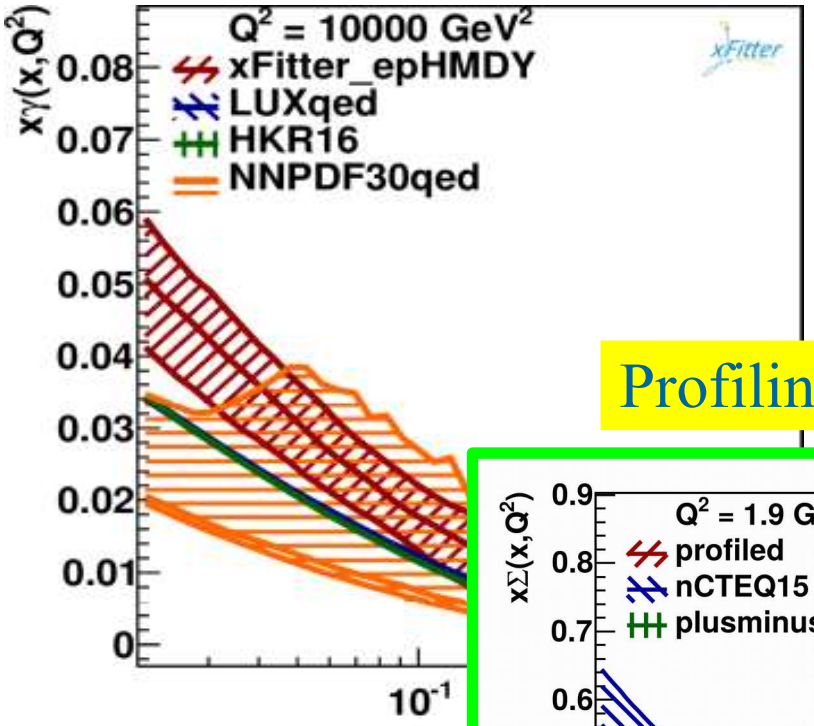
Photon PDF & QED
Pole & MS-bar masses
Profiling and Re-Weighting

Heavy Quark Variable Treshold
Improvements in χ^2 and correlations
TMD PDFs (uPDFs)
... and many other

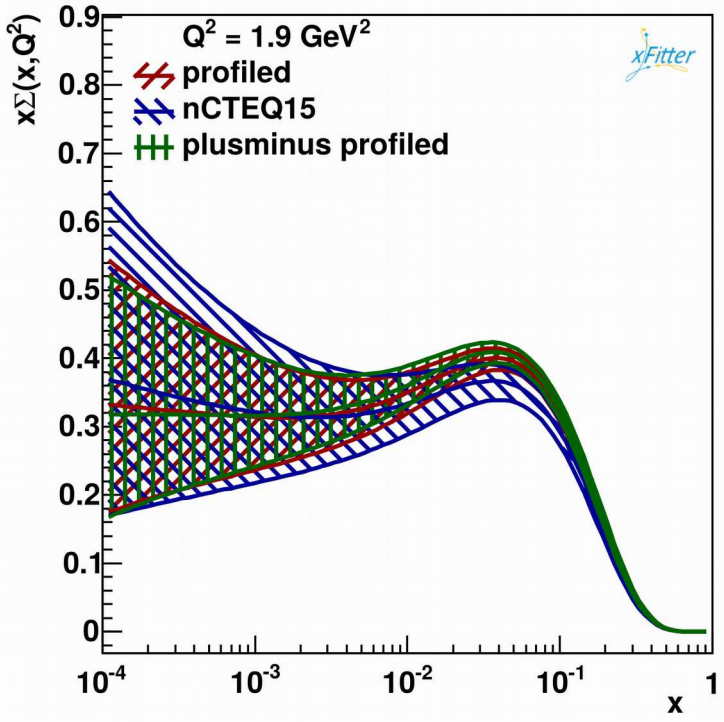
xFitter Capabilities

www.xFitter.org

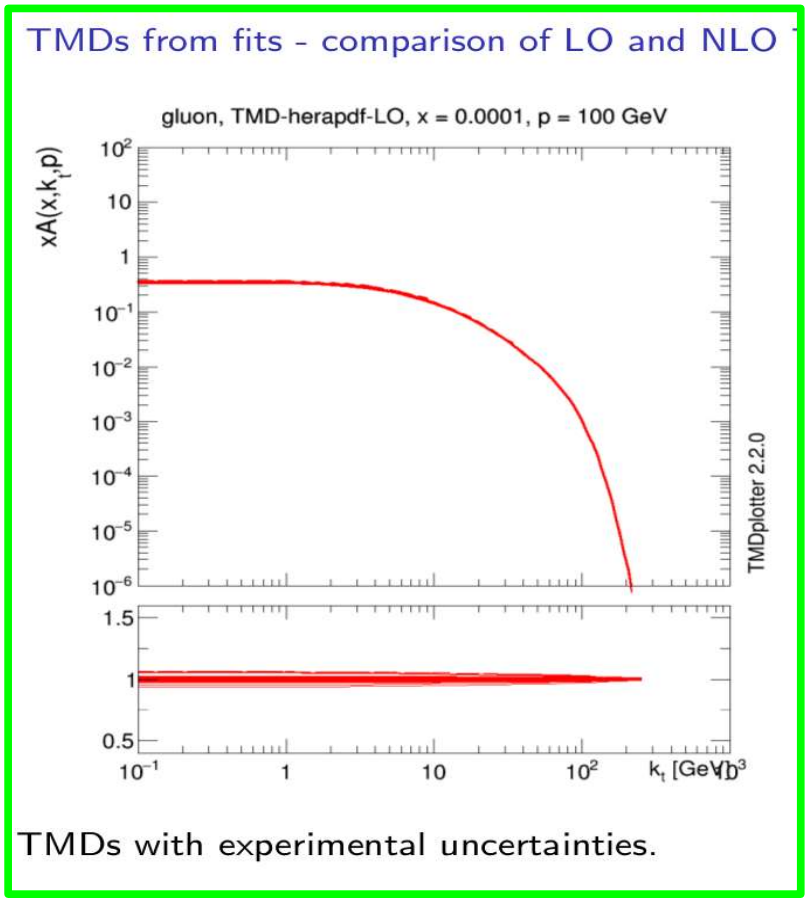
Photon PDF



Profiling Lead PDFs

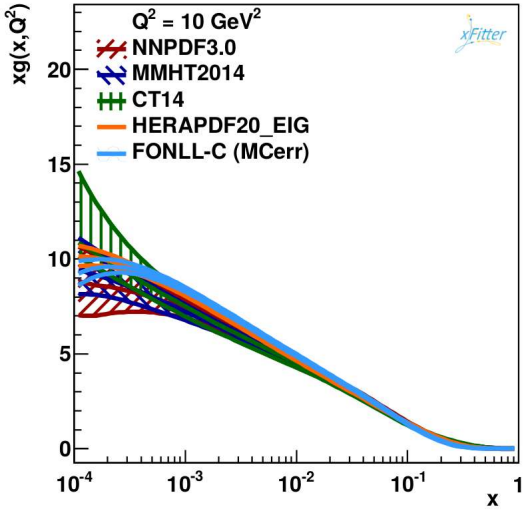


TMD (uPDFs) in xFitter

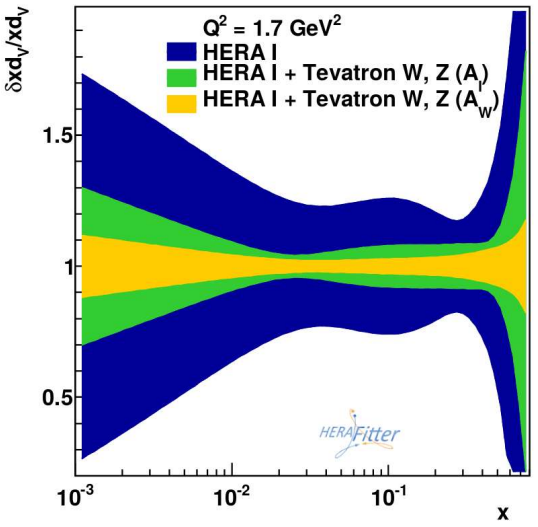


more xFitter Capabilities

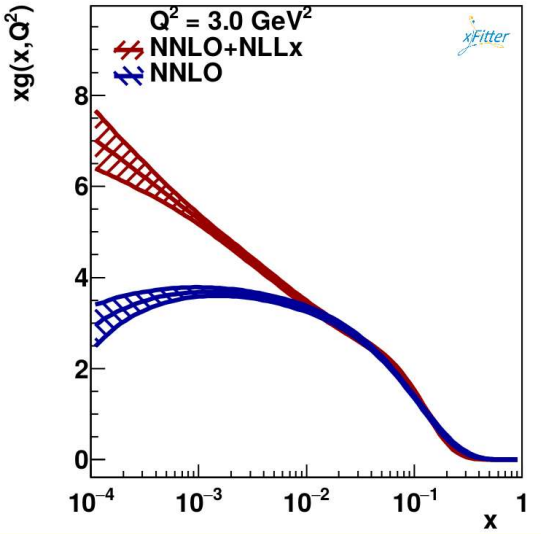
www.xFitter.org



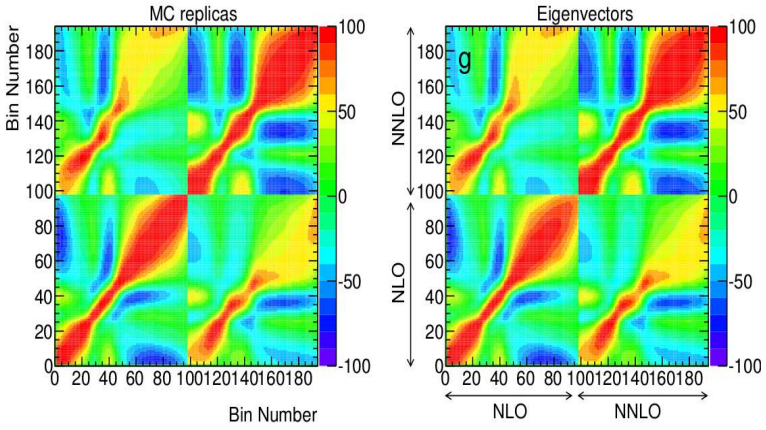
Multiple Heavy Quark Models



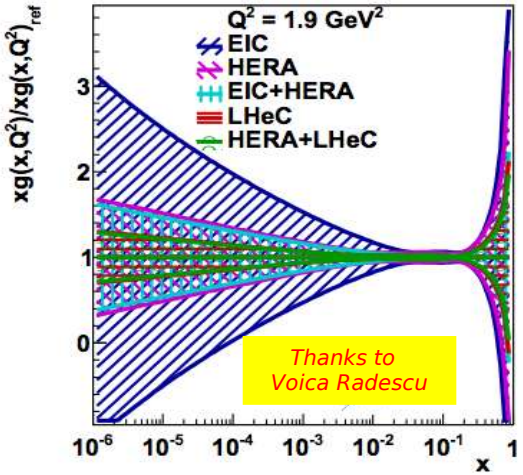
Profiling of W/Z Data



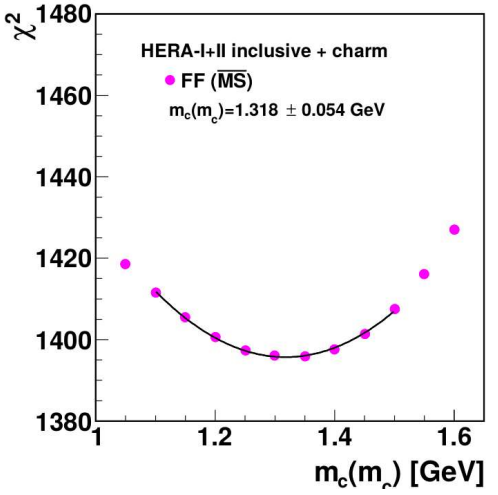
NNLx Resummation @ Small x



Correlation Coefficients



Sensitivity Studies



Pole & MS-Bar Running Mass

Summary

xFitter project - a multi-functional QCD framework well integrated into the high energy community (both, experimental and theory) www.xFitter.org

→ many active developments thanks to the close collaboration with experiments and theory groups

→ technical updates include usage of GitLab and HEPFORGE

→ **xfitter-2.0.0** is latest release *(many ongoing developments)* **Frozen Frog**

→ over 30+ public results obtained using xFitter (main applications are from LHC)

→ several published dedicated physics studies (developers team publications), more studies are ongoing

→ foreseen future physic (low-x phenomenology, nuclear PDF, etc...) and technical developments (improved user interface for parametrisation, data cards, python interface, etc...)

→ useful for future projects, and room for suggestions and contributions

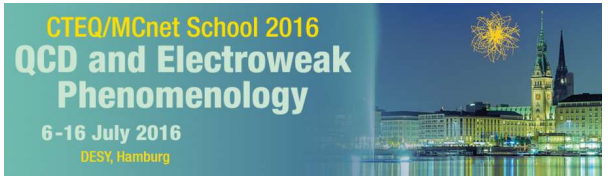
→ Heavy Flavor Thresholds Study: valuable insight on VFNS/FFNS issues

we welcome new ideas and developers :)

www.xfitter.org

NEW

xfitter examples *(CTEQ school)*



http://xfitter.org

Stefano Camarda
Ringailė Plačakytė
Voica Radescu

A list of educational examples are provided in the package

Exercise 1: PDF fit
→ learn the basic settings of a QCD analysis, based on HERA data only

Exercise 2: Simultaneous PDF fit and αs
→ learn the basic of an αs extraction using H1 jet data

Exercise 3: LHAPDF analysis
→ how to estimate impact of a new data without fitting:
→ profiling and reweighting techniques

Exercise 4: Plotting LHAPDF files
→ direct visualisation of PDFs from LHAPDF6 using simple python scripts

Exercise 5: Equivalence of χ^2 representations
→ understand different χ^2 representations
nuisance parameters and covariance matrix χ2 formulas

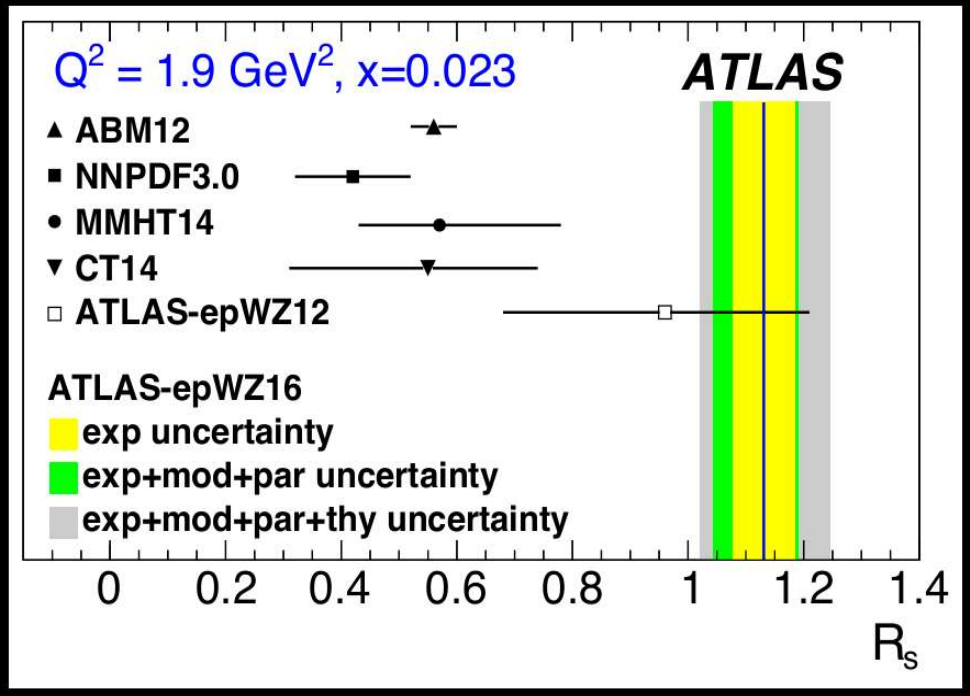
Exercise 6: Determination of Strange Quark PDF s(x)
→ Use LHC W/Z data to extract s(x)

… at DIS Workshop we heard …

Electroweak and QCD Measurements at the Large Hadron Collider

Strangeness in the Proton

arXiv:1612.03016



$$R_s = \frac{s+\bar{s}}{\bar{u}+\bar{d}} = 1.13 \pm 0.05\,(\text{exp}) \pm 0.02\,(\text{mod}) \,^{+0.01}_{-0.06}\,(\text{par})$$

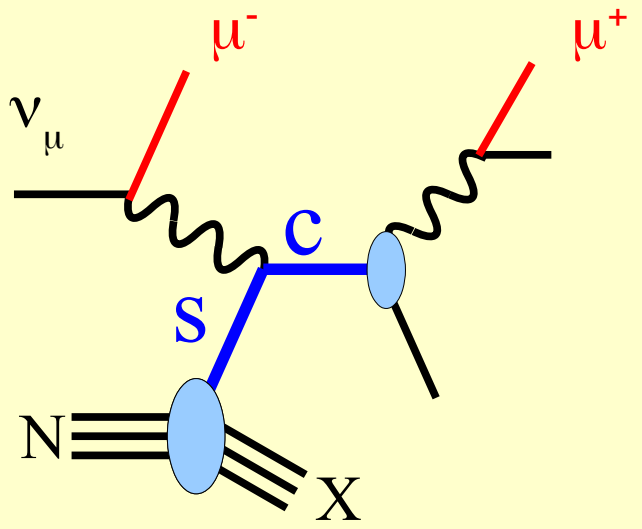
Do it yourself!!!
Try **xFitter**

João Guimarães da Costa
IHEP, Chinese Academy of Sciences

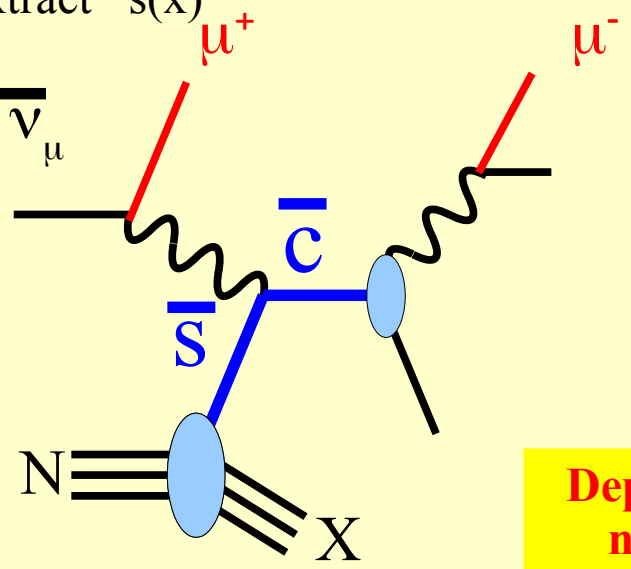
Birmingham, 3 April 2017

Di-muon production ⇒ Extract s(x) Parton Distribution

Extract s(x)



Extract $\bar{s}(x)$



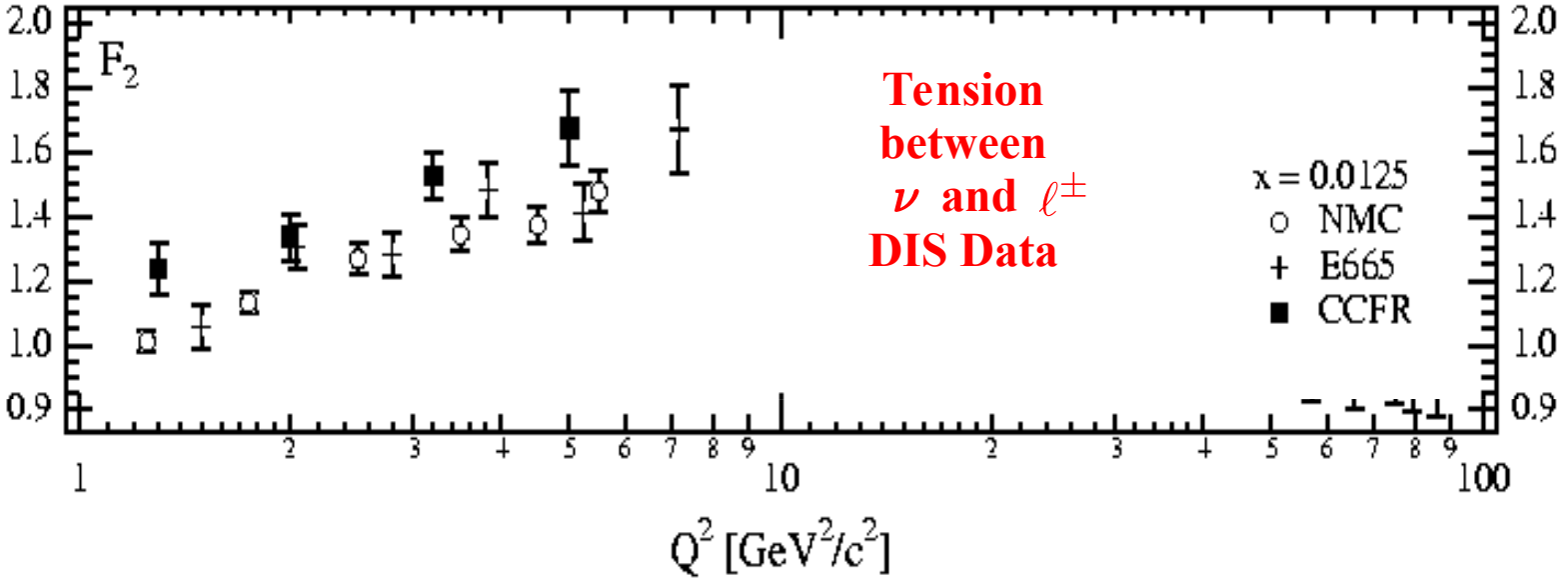
Depends on nuclear corrections

Can extract s(x) and $\bar{s}(x)$ separately

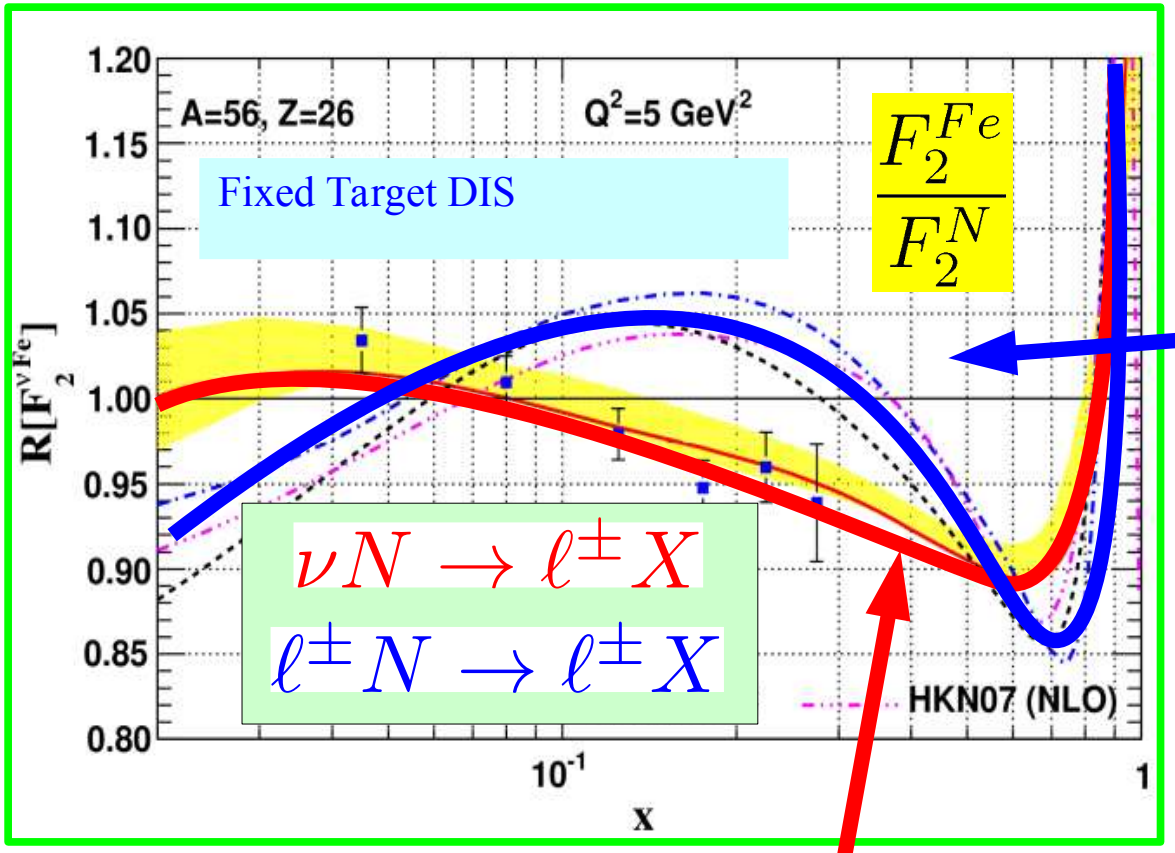
Used in CTEQ Fits

The CTEQ List of Challenges in Perturbative QCD

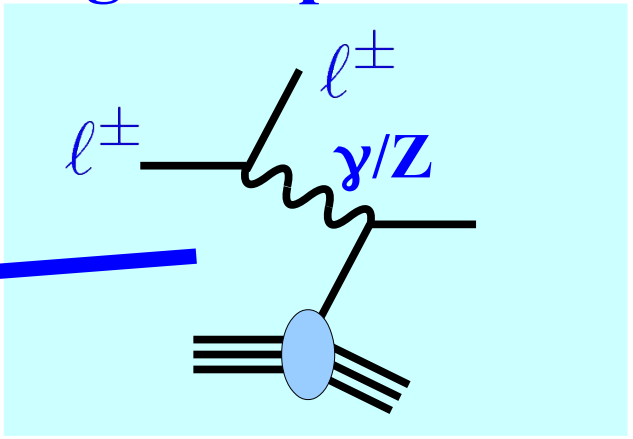
~1995



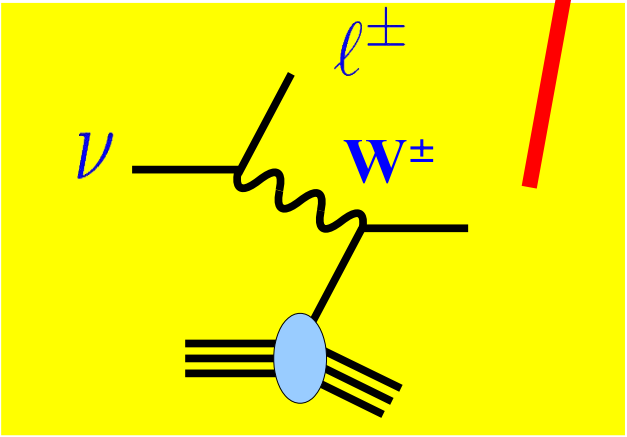
C T E Q



Charged Lepton DIS

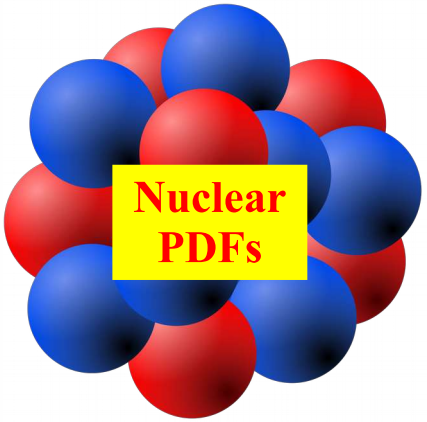


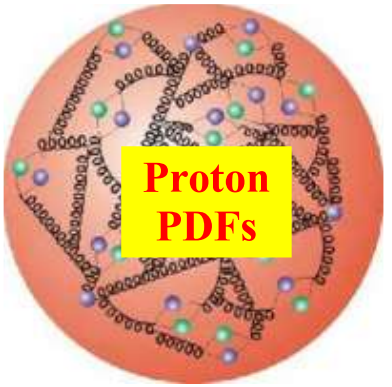
some caveats
... correlated errors



Neutrino DIS

Depends on nuclear corrections

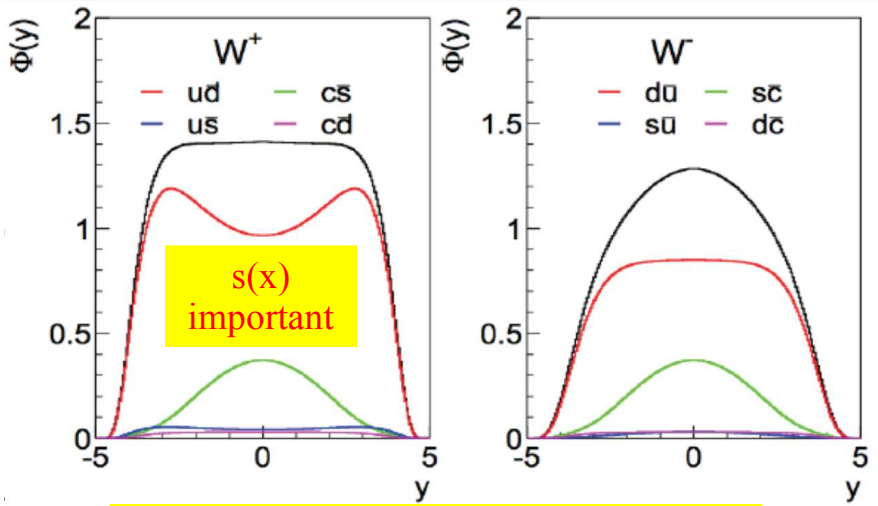




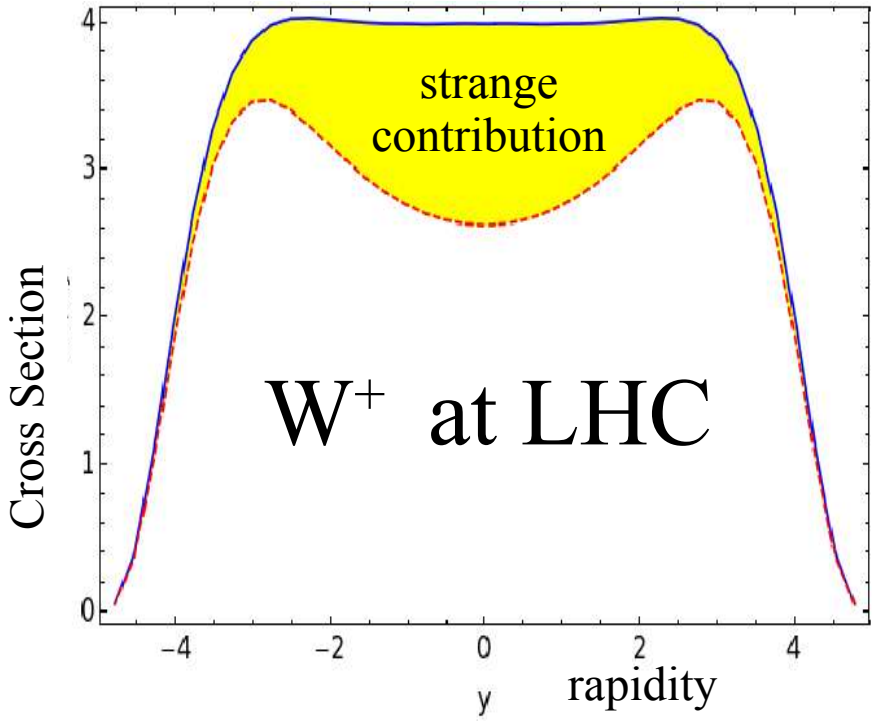
W/Z Production at LHC and the strange PDF

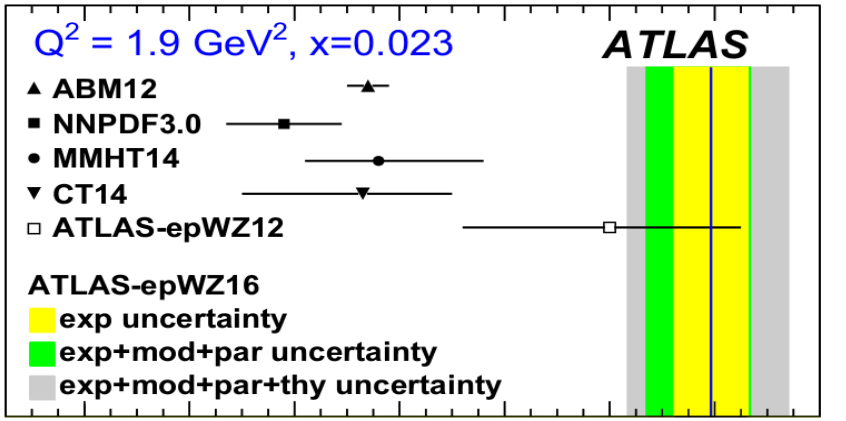
W/Z Production Channels

$$u\bar{d} + u\bar{s} + c\bar{d} + c\bar{s} \rightarrow W^+$$
$$\bar{u}d + \bar{u}s + \bar{c}d + \bar{c}s \rightarrow W^-$$
$$u\bar{u} + d\bar{d} + s\bar{s} + c\bar{c} \rightarrow Z$$



ATLAS: Eur. Phys. J. C 77 (2017) 367

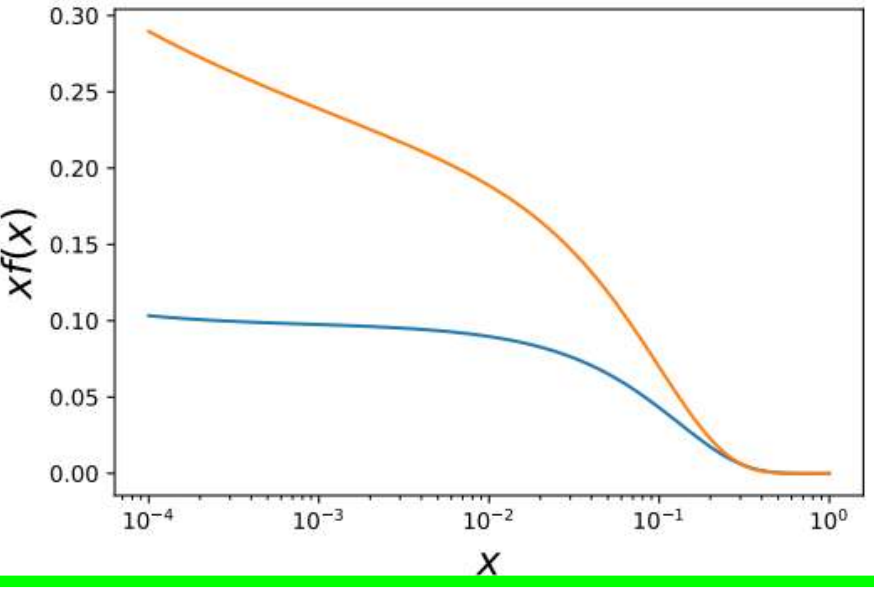


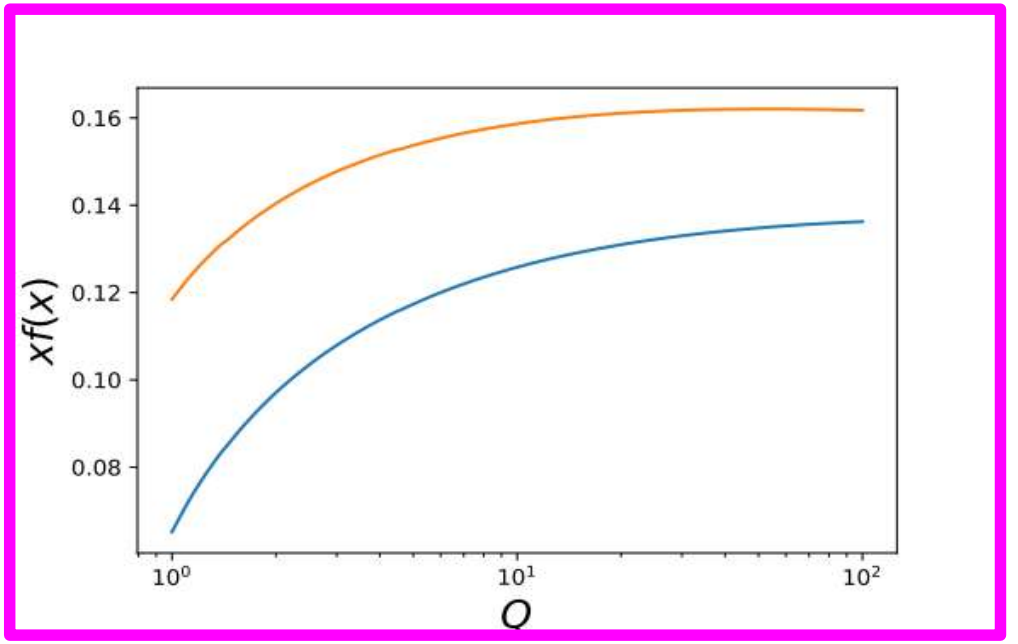


$$r^s(x,Q) = \frac{\bar{s}(x,Q) + s(x,Q)}{2\bar{d}(x,Q)}$$

Determination of the strange quark density of the proton from ATLAS measurements of the W→ℓνW→ℓν and Z→ℓℓZ→ℓℓ cross sections
ATLAS Collaboration. Phys.Rev.Lett. 109 (2012) 012001

Output



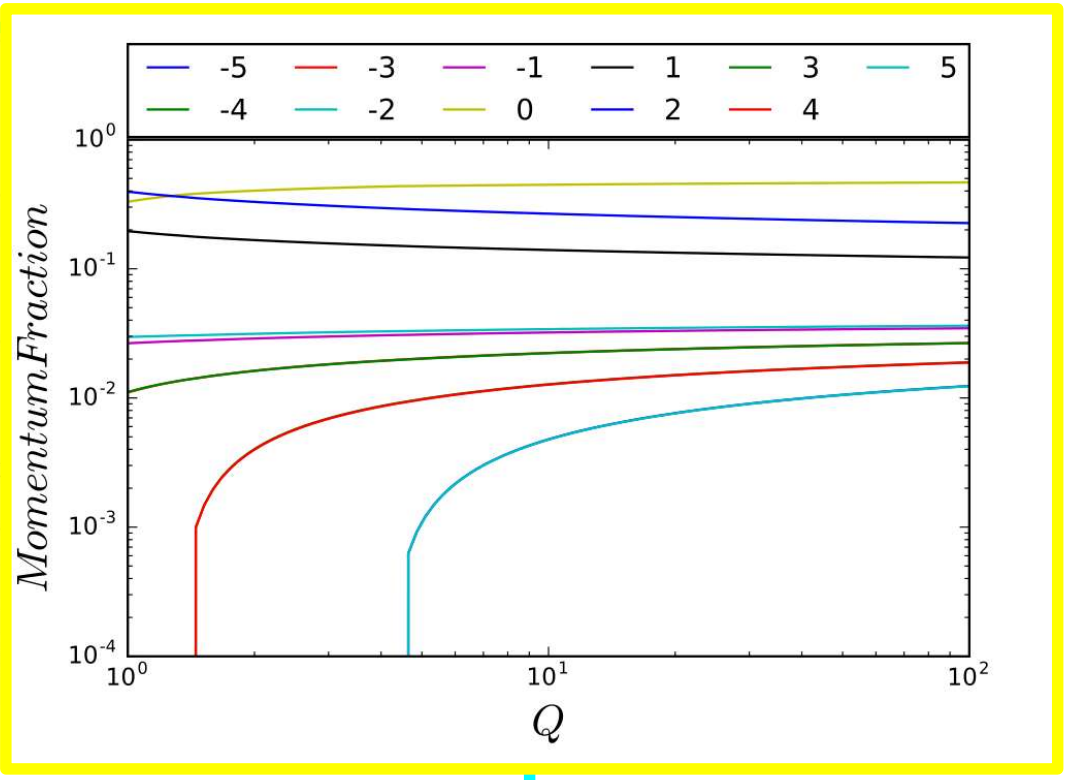


In [16]:
```
xs = [x for x in np.logspace(-7, 0, 5)]
qs = [q for q in np.logspace(1, 4, 4)]
print(xs)
print(qs)
```

```
[9.9999999999999995e-08, 5.6234132519034912e-06
01778279410038922 9, 1.0]
[10.0, 100.0, 1000.0, 10000.0]
```

In [17]:
```
gluon_xfs = np.empty([len(xs), len(qs)])
for ix, x in enumerate(xs):
        for iq, q in enumerate(qs):
                gluon_xfs[ix,iq] = set1[0].xfx
print(gluon_xfs)
```

```
[[  1.33073899e+02   8.00923188e+02   1.8934611
 [  6.86467865e+01   2.36108017e+02   4.3283376
 [  2.45696402e+01   5.07440637e+01   7.0903726
 [  4.65517162e+00   5.20861017e+00   5.1154864
 [  3.07136462e-12   5.14144359e-13   1.6164656
```



My Set up machine:

Memory 4Gb
Display Video Memory: 64Mb
CPU:2
Shared Clipboard: Bidirectional
Drag'n'drop: Bidirectional

THESE ARE USEFUL TO DEFINE
MAYBE PUT IN YOUR .bashrc FILE

```
alias xterm=
  "xterm -ls -xrm 'XTerm*selectToClipboard: true'&"
alias rm="rm -i "
```

WE'LL USE THE TKDIFF COMMAND

```
sudo apt-get update
sudo apt-get install tkdiff
```

DIRECTORY STRUCTURE

~/xfit/
  applgrid: utility
  qcdnum: utility
  xfit: the details

~/xfit/xfit/

  extra: install notes
  pyth: the pythia jupyter notebooks
  tutorials: full set of xfitter tutorials
  xfitter-2.0.0: the code

~/xfit/xfit/xfitter-2.0.0

~/xfit/xfit/xfitter-2.0.0

```
cp steering.txt_ORIG  steering.txt
cp minuit.in.txt_ORIG minuit.in.txt
./bin/xfitter
```

```
cp -v ../tutorials/exercise6/rsFixed/* .
./bin/xfitter
mv -v output outFixed

cp -v ../tutorials/exercise6/rsFree/* .
./bin/xfitter
mv -v output outFree

 ./bin/xfitter-draw outFixed outFree
evince ./plots/plots.pdf
```

From the directory: ~/xfit/xfit/tutorials/exercise6$

```
tkdiff ./rsFree/steering.txt ./rsFixed/steering.txt
```

NOW THE PYTHON

```
cd ~/xfit/pyth/
python -m pip install --user  scipy
jupyter  notebook &
```

```
student@cteq:~/xfit/xfit/pyth$ pwd
/home/student/xfit/xfit/pyth
student@cteq:~/xfit/xfit/pyth$ ls -R
.:
PythonDemo_v01.ipynb
PythonDemo_v03.pdf
PythonDemo_v03.ipynb
rsfree
rsfixed

./rsfixed:
rsfixed_0000.dat  rsfixed.info

./rsfree:
rsfree_0000.dat  rsfree.info
student@cteq:~/xfit/xfit/pyth$
```

```
for ii in range(len(s1)): #instead of -- for ii in s1:
    if s1[ii] < 10.0**-8.:
        s1[ii]=10.0**-8.

for ii in range(len(s2)): #instead of -- for ii in s2:
    if s2[ii] < 10.0**-8.:
        s2[ii]=10.0**-8.
```