# Part 1:
# xFitter Examples & Applications

## Case Study: The Strange Case of the Strange PDF

Peter Risse & Fred Olness
SMU

*Thanks for substantial input*
*from my friends & colleagues*

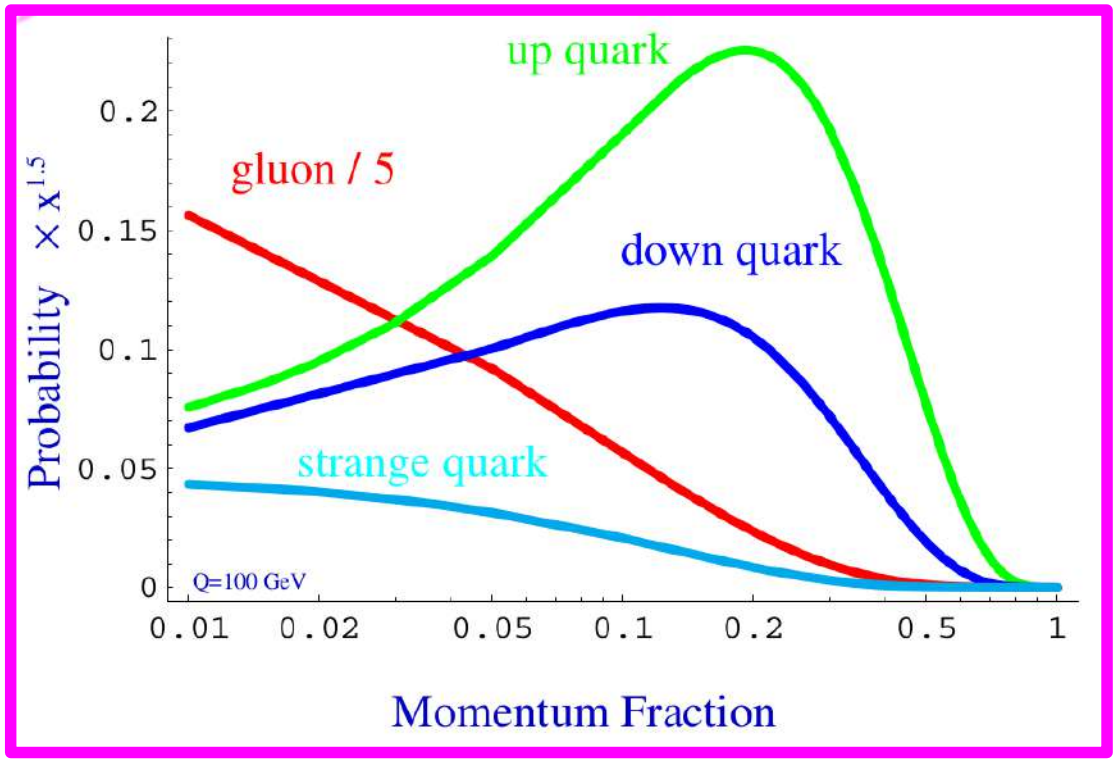
C T E Q

xFitter

nCTEQ
nuclear parton distribution functions

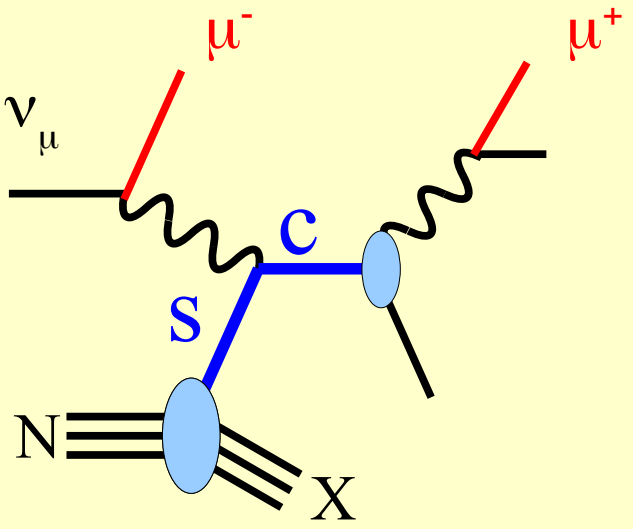
2025 CFNS-SURGE
Stony Brook University
5 June 2025

# Strange PDF: $\nu$ N di-muon Production

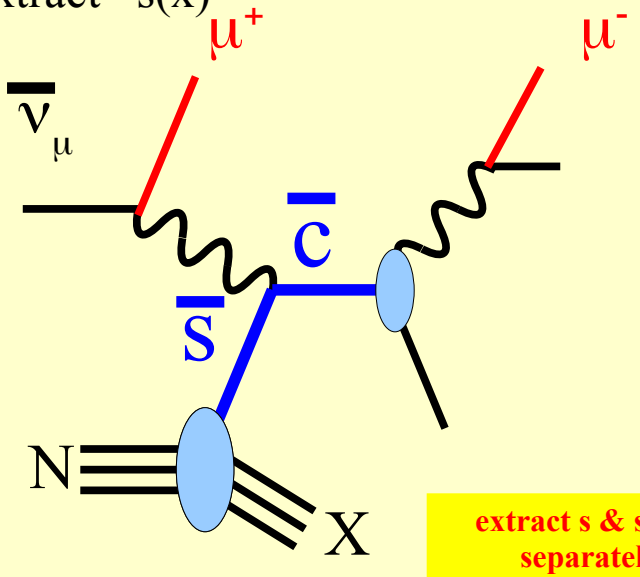



**Need to "dig out" s(x) underneath d(x)**

Extract s(x)

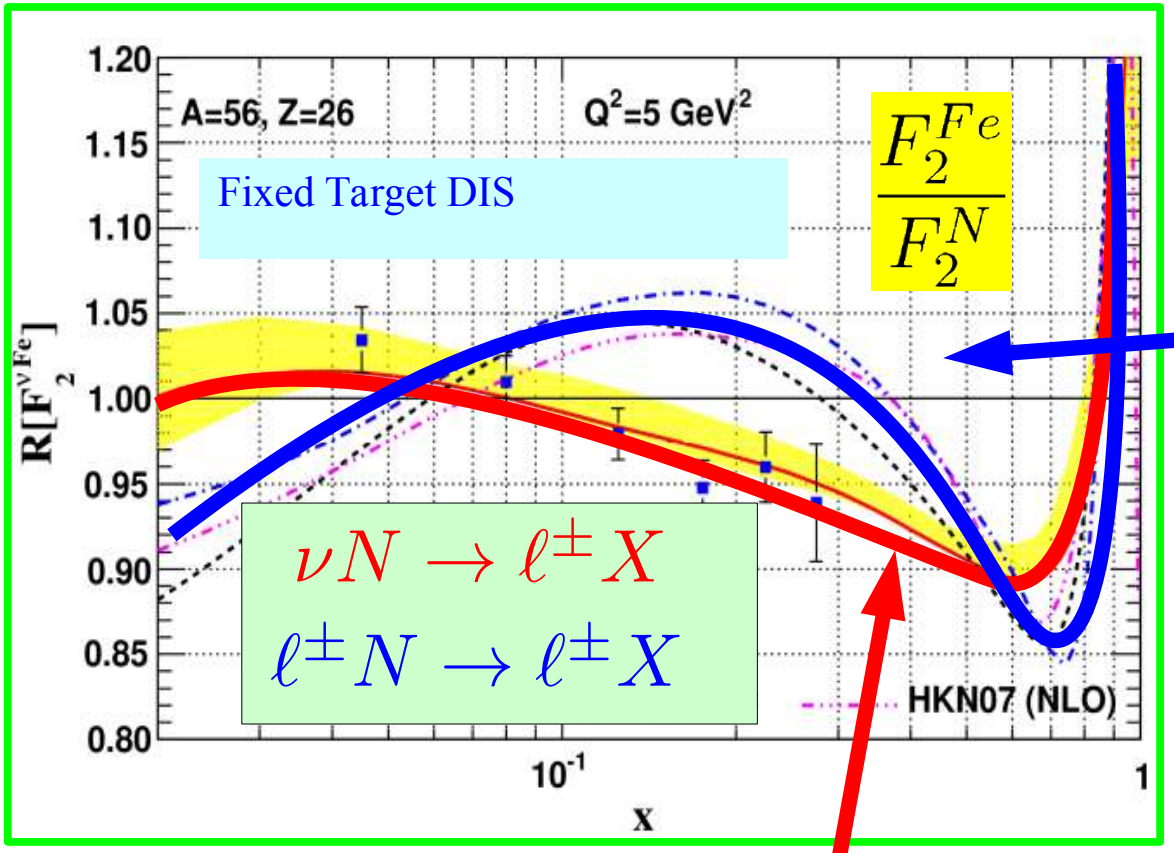



Extract $\bar{s}(x)$

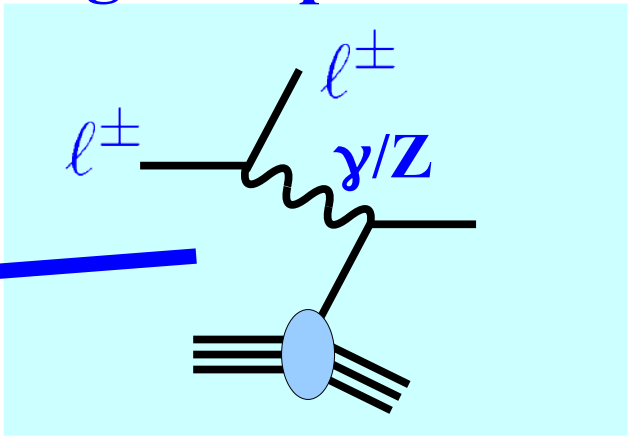



**extract s & s-bar separately**

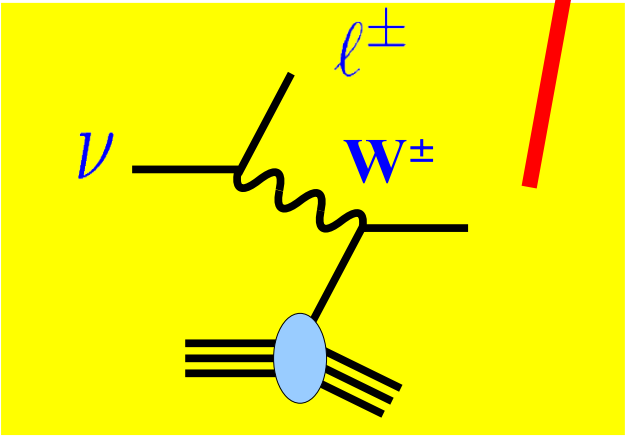
# SPLIT PERSONALITY: What is the Nuclear Correction




## Charged Lepton DIS

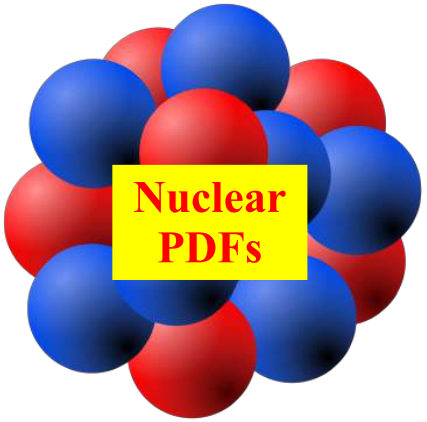


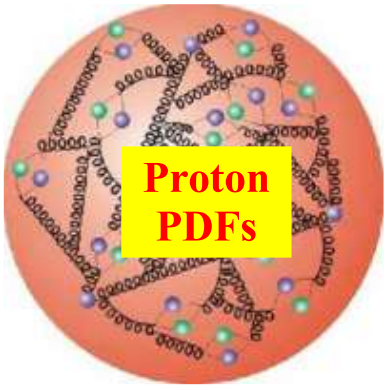

*some caveats*
*... correlated errors*




## Neutrino DIS

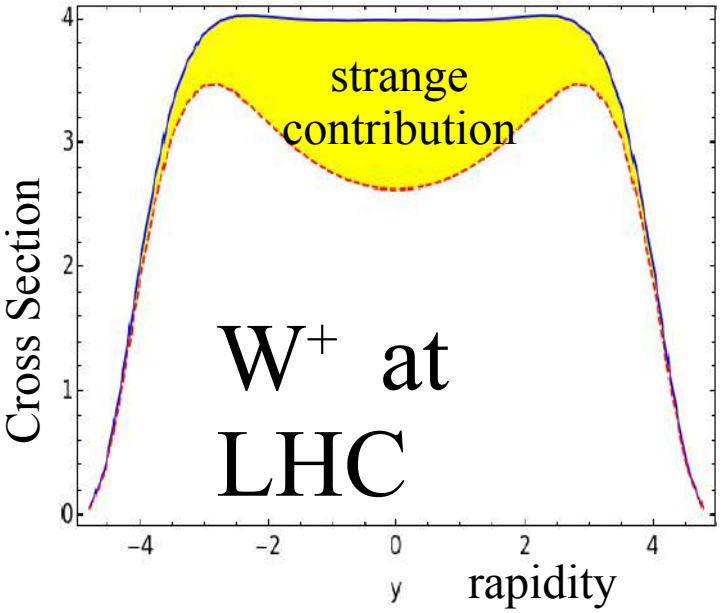
Depends on nuclear corrections

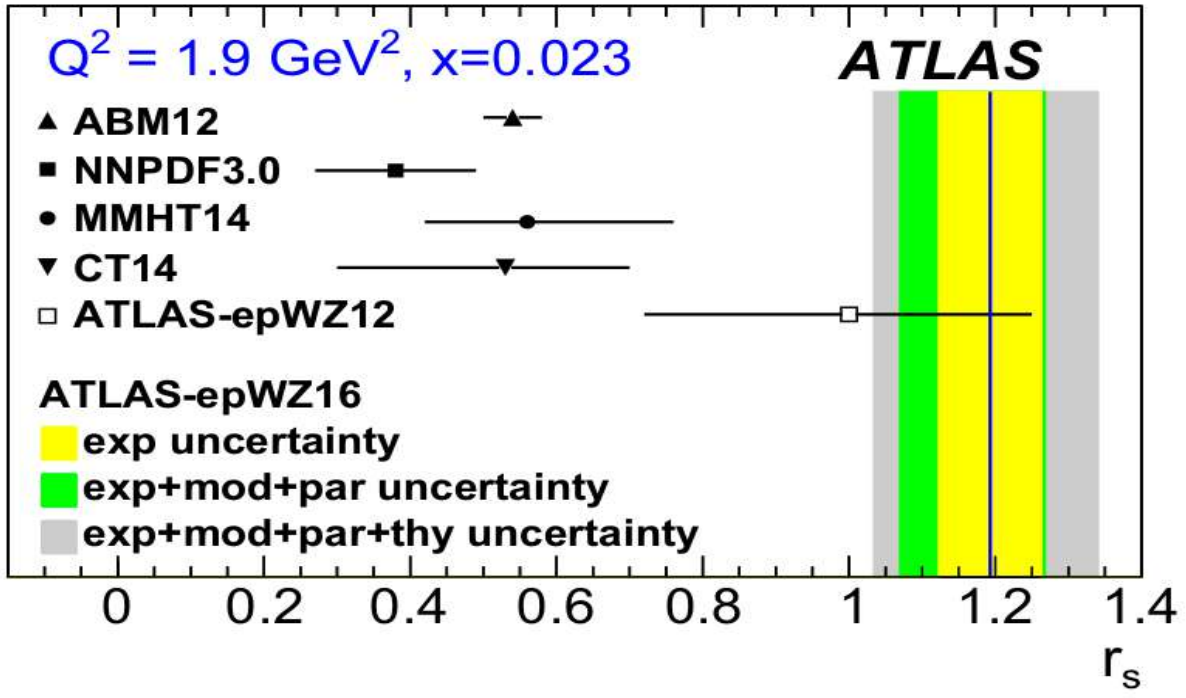



**Propagation of $\gamma/W$ thru nuclei**

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




$$r^s = \frac{\bar{s} + s}{2\bar{d}}$$

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

***xFitter Tutorial***

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

| Dataset | . rsFixed . output SAVE | rsFree output SAVE |
|---|---|---|
| HERA1+2 NCep 820 | 61 / 61 | 54 / 61 |
| HERA1+2 NCep 460 | 195 / 177 | 195 / 177 |
| HERA1+2 CCep | 45 / 39 | 45 / 39 |
| ATLAS high mass CF Z rapidity 2011 | 4.4 / 6 | 4.1 / 6 |
| ATLAS high mass CC Z rapidity 2011 | 9.7 / 6 | 7.1 / 6 |
| ATLAS W+ lepton rapidity 2011 | 13 / 11 | 12 / 11 |
| HERA1+2 NCem | 230 / 159 | 222 / 159 |
| HERA1+2 CCem | 56 / 42 | 61 / 42 |
| HERA1+2 NCep 575 | 186 / 221 | 187 / 221 |
| ATLAS W- lepton rapidity 2011 | 19 / 11 | 8.9 / 11 |
| HERA1+2 NCep 920 | 368 / 317 | 353 / 317 |
| ATLAS peak CF Z rapidity 2011 | 9.9 / 9 | 7.3 / 9 |
| ATLAS peak CC Z rapidity 2011 | 50 / 12 | 15 / 12 |
| Correlated $\chi^2$ | 152 | 73 |
| Log penalty $\chi^2$ | -2.55 | -14.43 |
| Total $\chi^2$ / dof | 1397 / 1057 | 1230 / 1056 |
| $\chi^2$ p-value | 0.00 | 0.00 |

| Parameter | . rsFixed output SAVE | . rsFree output SAVE |
|---|---|---|
| 'Adbar' | 0.1561 ± 0.0090 | 0.1483 ± 0.0090 |
| 'Adv' | 1.0000 | 1.0000 |
| 'Ag' | 1.0000 | 1.0000 |
| 'Agp' | 0.489 ± 0.055 | 0.373 ± 0.055 |
| 'Auv' | 1.0000 | 1.0000 |
| 'Bdbar' | −0.1379 ± 0.0095 | −0.1231 ± 0.0095 |
| 'Bdv' | 0.841 ± 0.045 | 0.891 ± 0.045 |
| 'Bg' | −0.502 ± 0.081 | −0.492 ± 0.081 |
| 'Bgp' | −0.555 ± 0.054 | −0.571 ± 0.054 |
| 'Buv' | 0.771 ± 0.014 | 0.786 ± 0.014 |
| 'Cdbar' | 6.9 ± 1.6 | 11.7 ± 1.6 |
| 'Cdv' | 4.26 ± 0.26 | 4.25 ± 0.26 |
| 'Cg' | 3.63 ± 0.60 | 3.31 ± 0.60 |
| 'Cgp' | 25.00 | 25.00 |
| 'Cstr' | 6.18 ± 0.82 | 7.31 ± 0.82 |
| 'Cubar' | 5.68 ± 0.47 | 5.44 ± 0.47 |
| 'Cuv' | 4.889 ± 0.074 | 4.804 ± 0.074 |
| 'Euv' | 11.79 ± 0.84 | 9.83 ± 0.84 |
| 'rs' | 0.5000 | 1.10 ± 0.15 |
| Fit status | not-a-fit | not-a-fit |
| Uncertainties | not-a-fit | not-a-fit |

# Part 2:
# xFitter Examples & Applications

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PYTHON

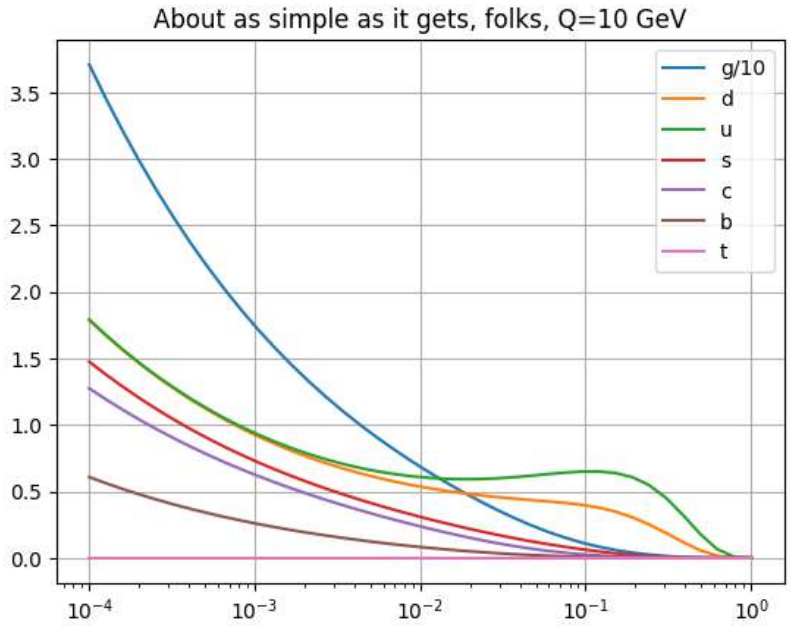
- 01_PDF_SimpleExample_v01.ipynb
- 02_CFNS_PDF_Strange_Example_v01.ipynb
- 03_collinear_fac_example_2.ipynb
- 04_collinear-fac-example.ipynb - Colab.pdf

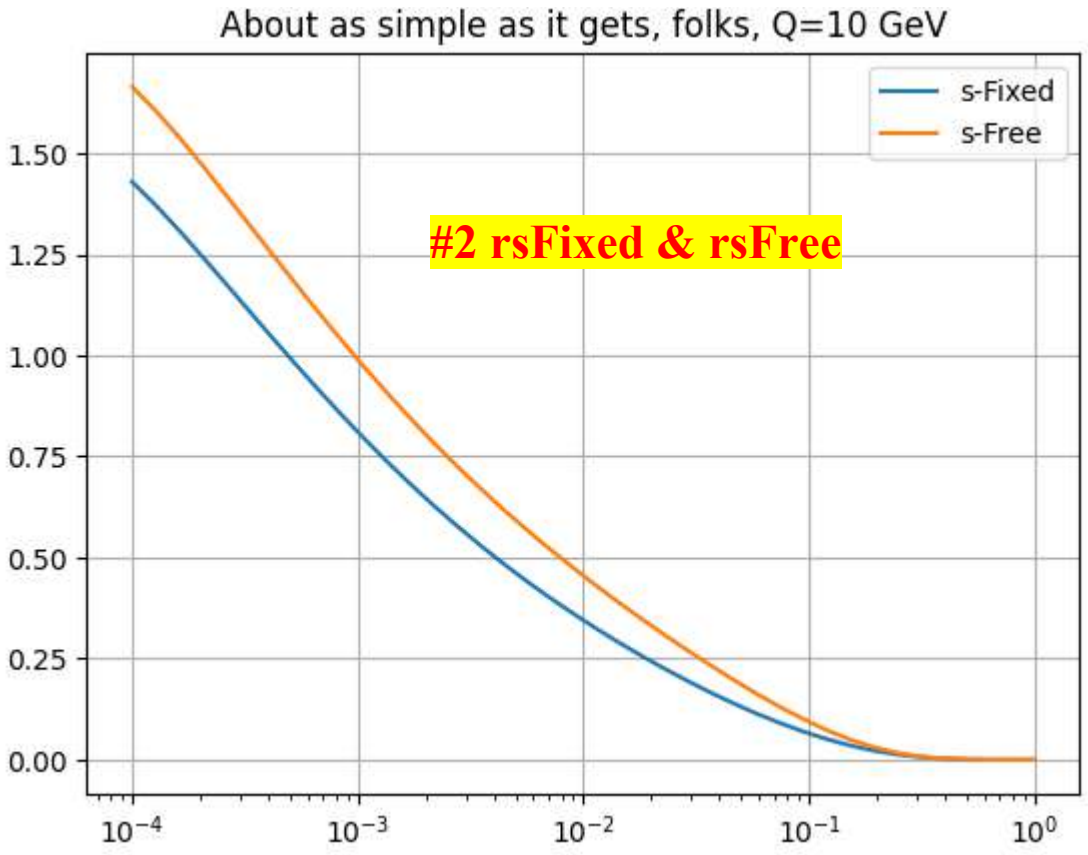
**Parton momentum %**

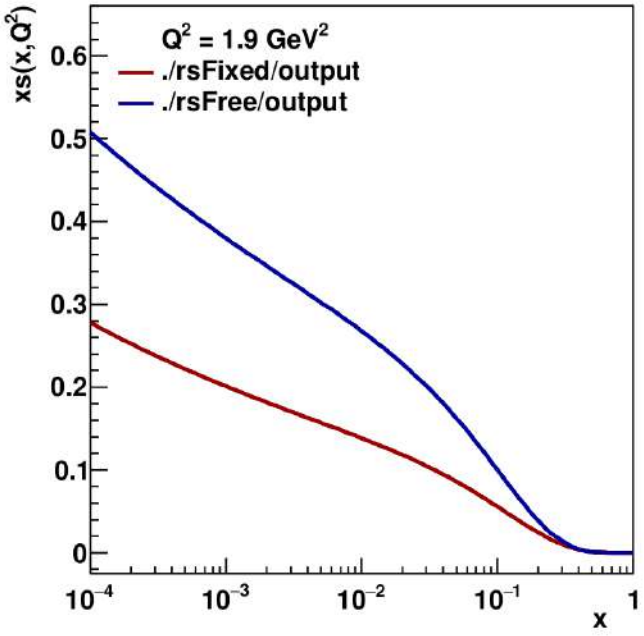
```
print(f'{flavor(i):5.0f}', " = ",f'
```

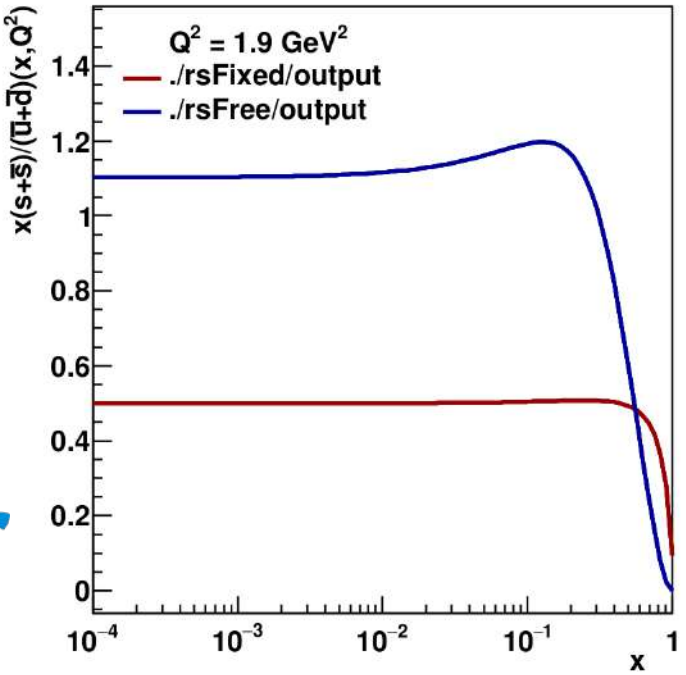
| | | | |
|---|---|---|---|
| -6 | = | 0.00 | 0.00 |
| -5 | = | 0.48 | 0.48 |
| -4 | = | 1.28 | 1.28 |
| -3 | = | 2.37 | 3.22 |
| -2 | = | 3.63 | 3.49 |
| -1 | = | 3.31 | 2.48 |
| 0 | = | 44.63 | 44.60 |
| 1 | = | 13.04 | 12.73 |
| 2 | = | 26.87 | 26.56 |
| 3 | = | 2.36 | 3.21 |
| 4 | = | 1.27 | 1.27 |
| 5 | = | 0.48 | 0.48 |
| 6 | = | 0.00 | 0.00 |

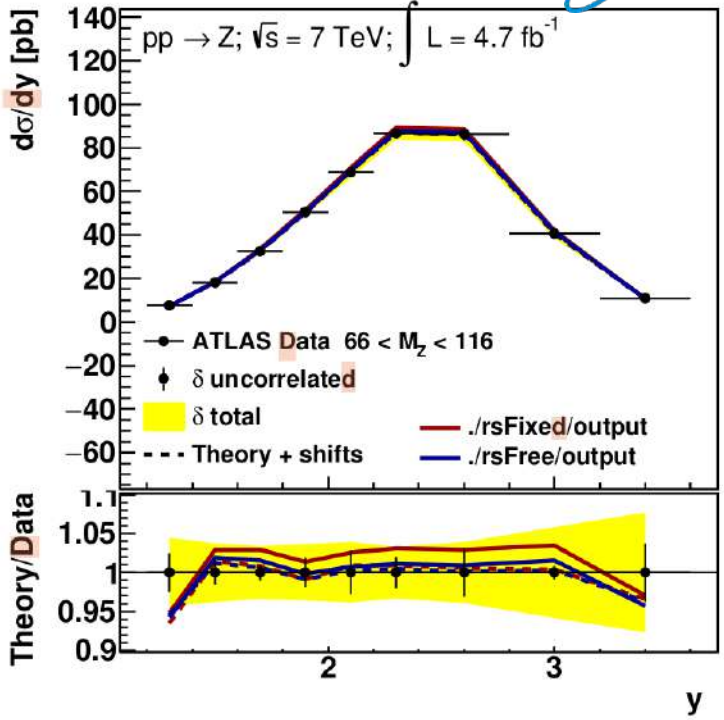
**#1 Simple PDF Plots**

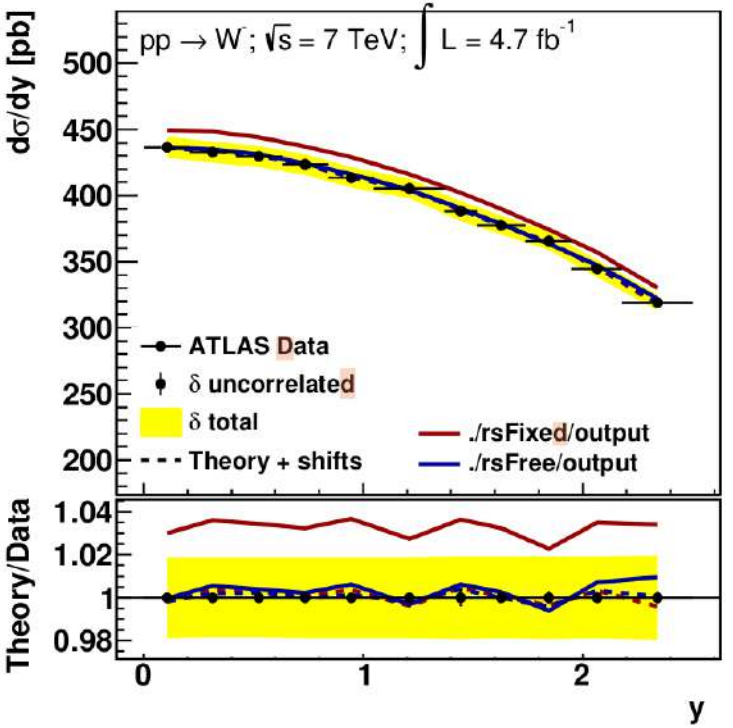



$Q^2$ = 1.9 GeV$^2$
./rsFixed/output
./rsFree/output
xs(x,$Q^2$)
x


$Q^2$ = 1.9 GeV$^2$
./rsFixed/output
./rsFree/output
x(s+$\bar{s}$)/($\bar{u}$+$\bar{d}$)(x,$Q^2$)
x


pp → Z; $\sqrt{s}$ = 7 TeV; $\int$ L = 4.7 fb$^{-1}$
ATLAS Data 66 < $M_Z$ < 116
δ uncorrelated
δ total
Theory + shifts
./rsFixed/output
./rsFree/output
dσ/dy [pb]
Theory/Data
y

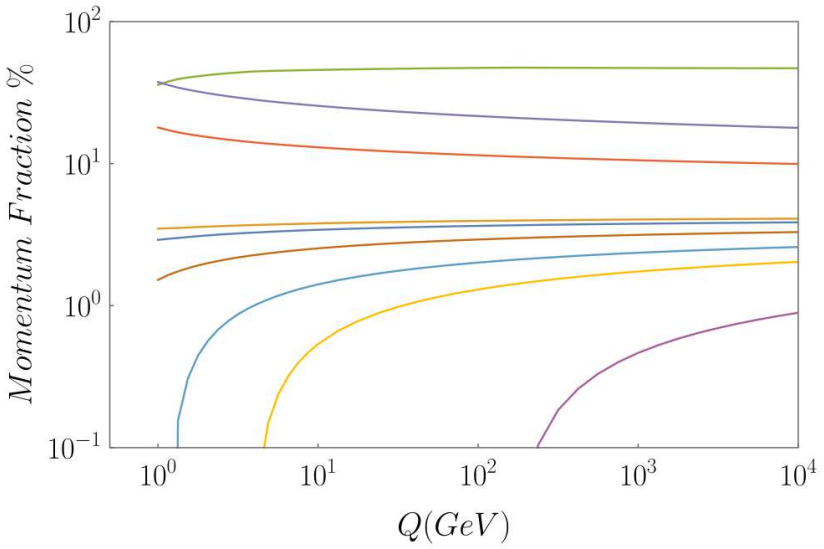

pp → W$^-$; $\sqrt{s}$ = 7 TeV; $\int$ L = 4.7 fb$^{-1}$
ATLAS Data
δ uncorrelated
δ total
Theory + shifts
./rsFixed/output
./rsFree/output
dσ/dy [pb]
Theory/Data
y

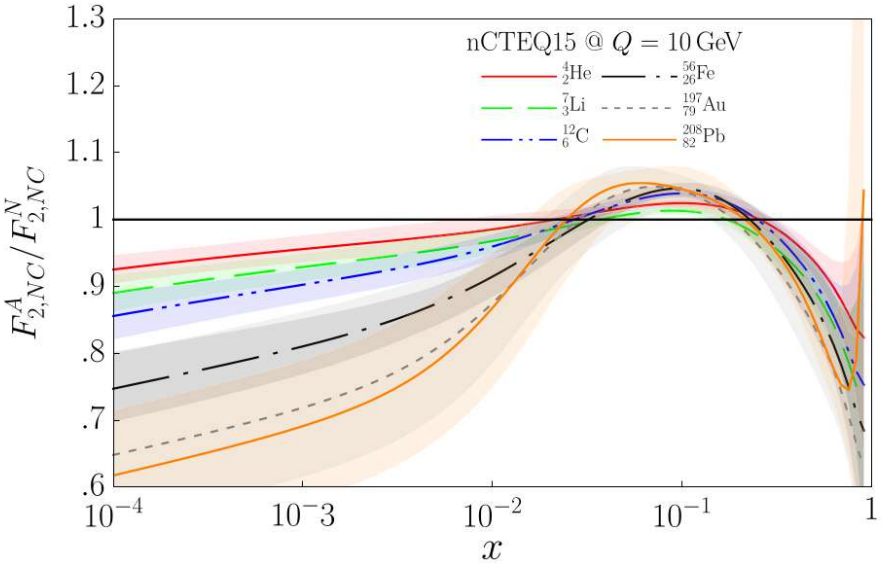
# #3: A full LHAPDF installation

LHAPDF installation on Google Colab

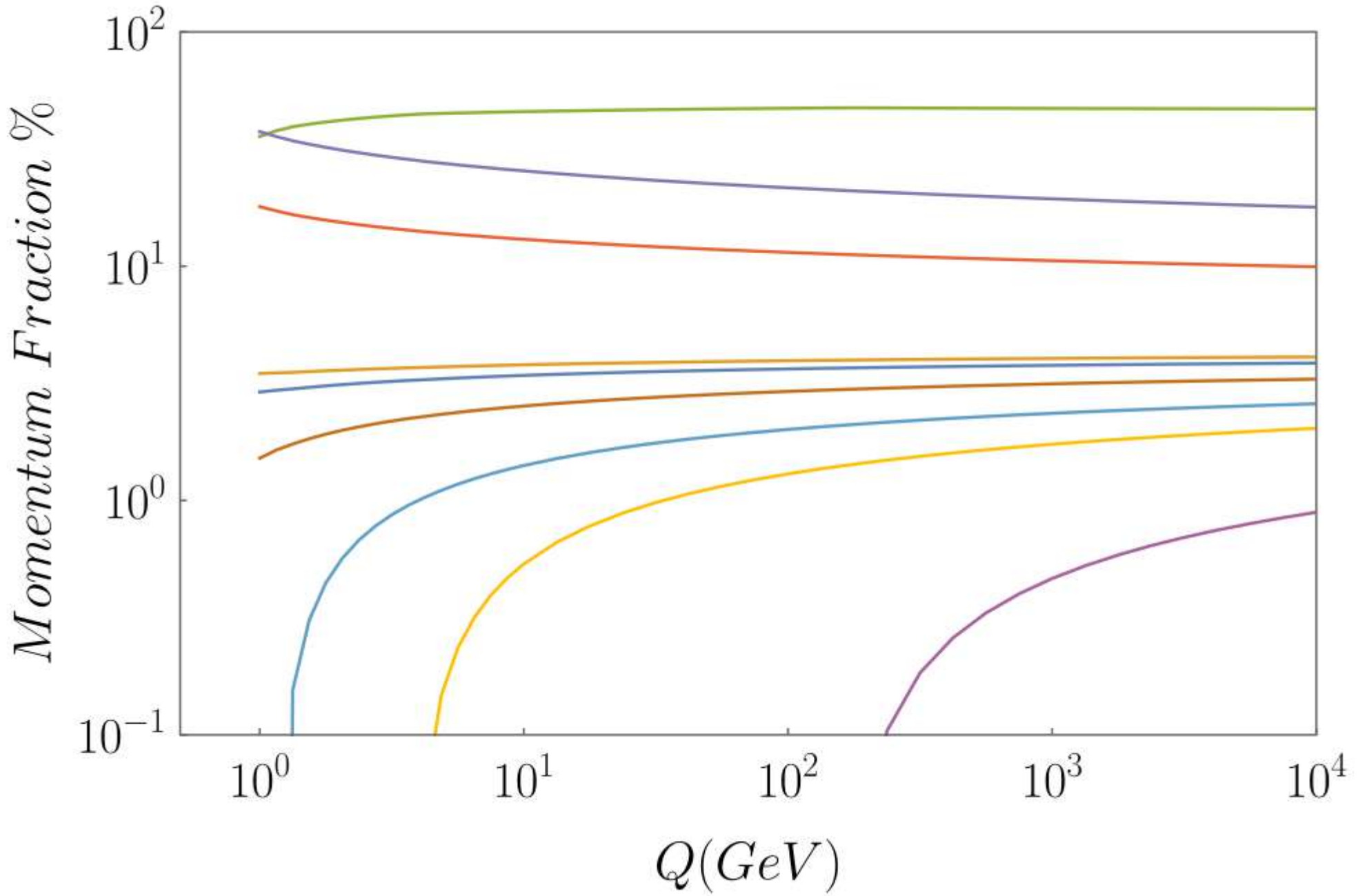
```
[ ]: LHAPDF_VERSION = '6.5.4'
SITE_PACKGE_DIR = __import__('site').getsitepackages()[0]
PWD = __import__('os').getcwd()
PYTHON_VERSION = '%s.%s' % __import__('sys').version_info[0:2]
!wget https://lhapdf.hepforge.org/downloads/?f=LHAPDF-{LHAPDF_VERSION}.tar.gz -O LHAPDF-{LHAPDF_VERSION}.tar.gz
# !wget https://www.physics.smu.edu/devel/olness/ftp/misc2/lhapdf/LHAPDF-6.5.4.tar.gz -O LHAPDF-{LHAPDF_VERSION}.tar.gz
!tar xf LHAPDF-{LHAPDF_VERSION}.tar.gz
!cd LHAPDF-{LHAPDF_VERSION} && ./configure
!make -C LHAPDF-{LHAPDF_VERSION} -j 2
!make -C LHAPDF-{LHAPDF_VERSION} install
!cd {SITE_PACKGE_DIR} && ln -s {PWD}/LHAPDF-{LHAPDF_VERSION}/wrappers/python/NONE/local/lib/python{PYTHON_VERSION}/dist-packages/lhapdf
!cd /usr/lib && ln -s {PWD}/LHAPDF-{LHAPDF_VERSION}/src/.libs/libLHAPDF.so
!lhapdf update
```

```
--2025-05-18 22:03:41--  https://lhapdf.hepforge.org/downloads/?f=LHAPDF-6.5.4.tar.gz
Resolving lhapdf.hepforge.org (lhapdf.hepforge.org)... 129.234.186.186
Connecting to lhapdf.hepforge.org (lhapdf.hepforge.org)|129.234.186.186|:443... connected.
HTTP request sent, awaiting response... 302 Found
Location: /downloader?f=LHAPDF-6.5.4.tar.gz [following]
--2025-05-18 22:03:41--  https://lhapdf.hepforge.org/downloader?f=LHAPDF-6.5.4.tar.gz
Reusing existing connection to lhapdf.hepforge.org:443.
```

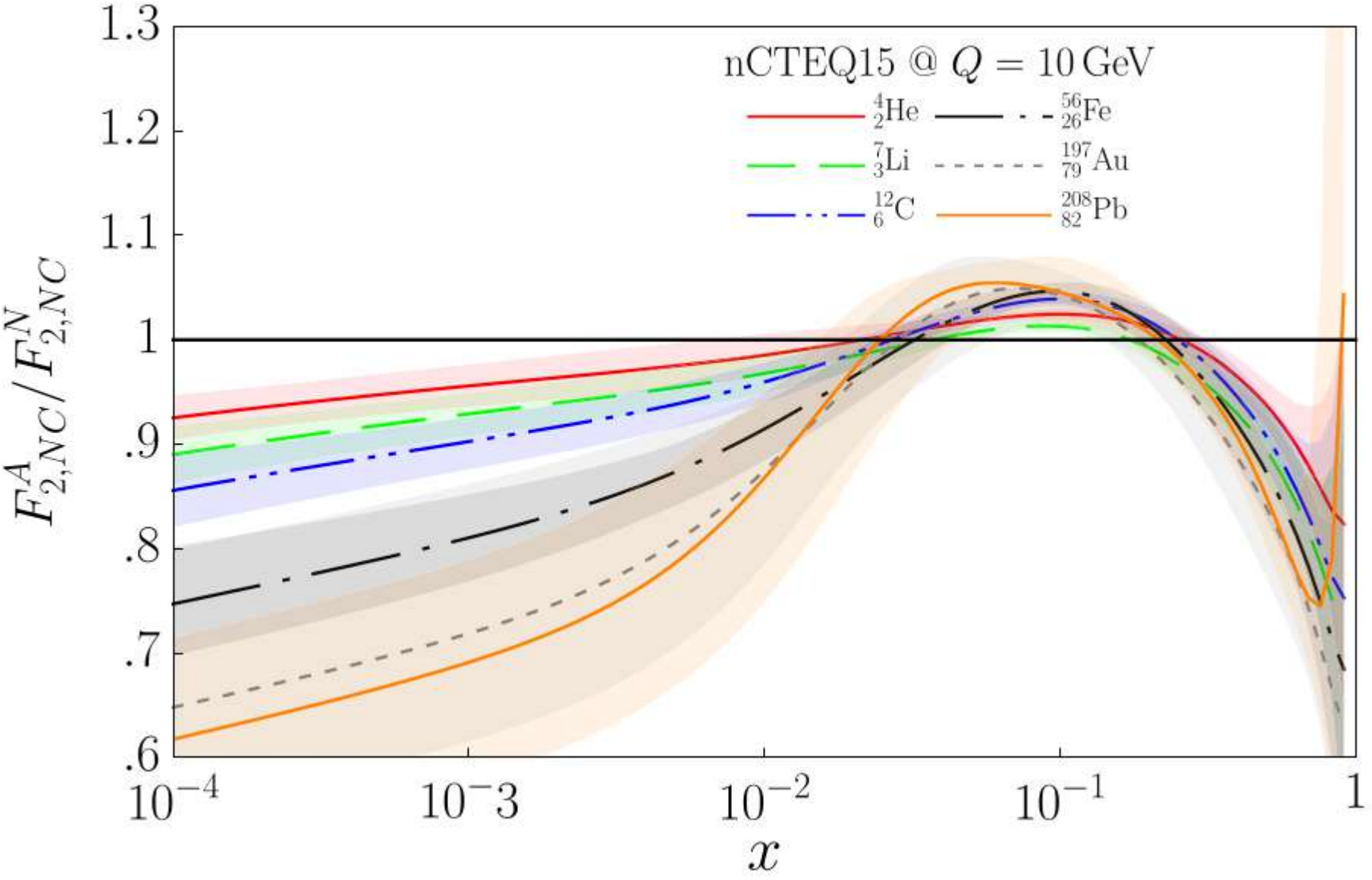


# Momentum Fraction vs. Energy



# Nuclear Correction Factor



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journal homepage: www.elsevier.com/locate/cpc

# ManeParse: A Mathematica reader for Parton Distribution Functions☆

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PDFs
Hadron collider
PDF errors
Hadronic cross section

ABSTRACT

Parton Distribution Functions (PDFs) are essential non-perturbative inputs for calculation of any observable with hadronic initial states. These PDFs are released by individual groups as discrete grids as a function of the Bjorken-$x$ and energy scale $Q$. The LHAPDF project maintains a repository of PDFs from various groups in a new standardized LHAPDF6 format, additionally older formats such as the CTEQ PDS grid format are still in use. ManeParse is a package that provides access to PDFs within Mathematica to facilitate calculation and plotting. The program is self-contained so there are no external links to any FORTRAN, C or C++ programs. The package includes the option to use the built-in Mathematica interpolation or a custom cubic Lagrange interpolation routine which allows for flexibility in the extrapolation (particularly at small $x$-values). ManeParse is fast enough to enable simple calculations (involving even one or two integrations) in the Mathematica framework.

**Program summary**

*Program Title:* ManeParse
*Program Files doi:* http://dx.doi.org/10.17632/knbsccggg4.1
*Licensing provisions:* MIT
*Programming language:* Mathematica
*Nature of problem:* PDFs are currently read and interpolated via a FORTRAN or C++ interface. No method exist to read the LHAPDF6 or CTEQ PDFs directly in Mathematica.
*Solution method:* A Mathematica package reads in LHAPDF6 and CTEQ PDF files. The PDFs are parsed into a three-dimensional array in Bjorken-$x$, scattering energy $Q$, and parton flavor, and are stored in memory. Provided functions give access to the PDF, the PDF uncertainty, the PDF correlations, and the parton–parton Luminosities. The LHAPDF6 info files are converted from YAML format into Mathematica rules.



http://dx.doi.org/10.1016/j.cpc.2017.03.004

https://ncteq.hepforge.org/mma/index.html

https://arxiv.org/abs/1605.08012

physics.smu.edu/olness/ncteq/mma/index.html

# ManeParse: A Mathematica Interface to the PDFs

ManeParse is a modular Mathematica package that provides access to PDFs for hadronic calculations. It allows for parsing

## ManeParse Publication:

A temporary link:

https://www.physics.smu.edu/olness/ncteq/mma/index.html

Download the publication here:

- **ManeParse : A Mathematica reader for Parton Distribution Functions**
  *D.B. Clark, E. Godat, F.I. Olness.*
  Comput.Phys.Commun. 216 (2017) 126-137.
  or: arXiv:1605.08012 [hep-ph] .

---

## ManeParse version 5.0, Mathematica package:

### An SIMPLE example using LHAPDF Tables for PDFs:

This is an self-contained example that reads PDF tables in LHAPDF format.
PDF_DEMO_v01.zip
(850Kb, Version April 2021).
Includes PDF Grid files needed for demo.

---

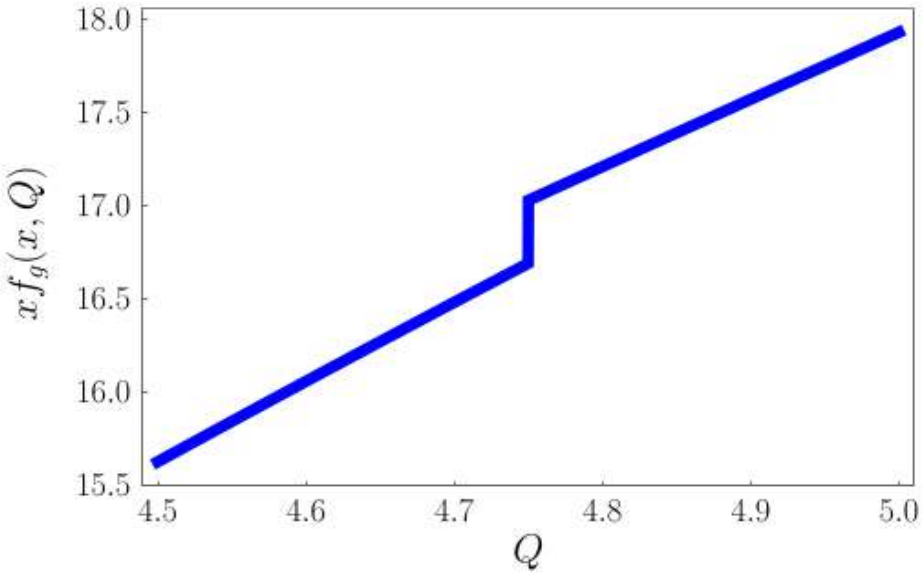
### A SIMPLE example using Structure Function Tables:

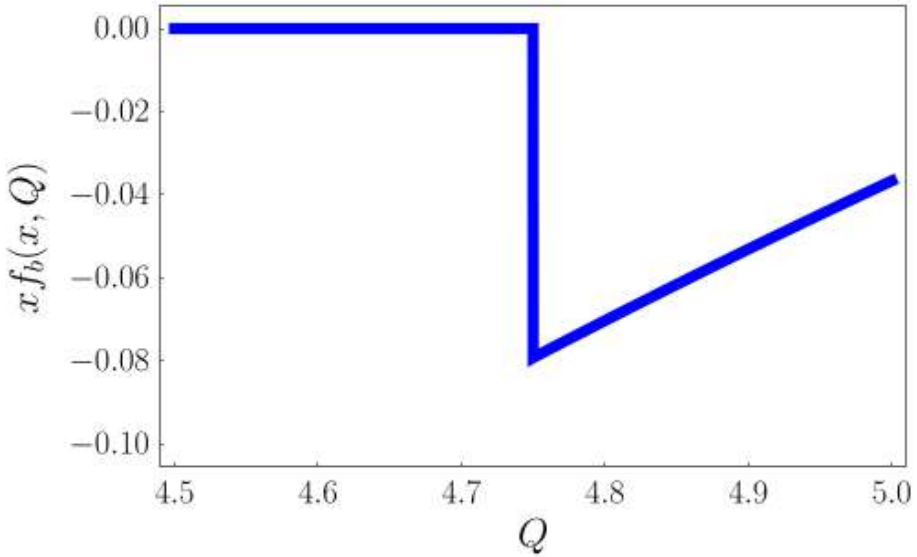
This is an self-contained example that reads Structure Function tables in LHAPDF format.
SF_DEMO_v01.zip
(1.5Mb, Version April 2021).
Includes Structure Function Grid files needed for demo.
Thanks to Tim Hobbs for supplying the sample tables.

---

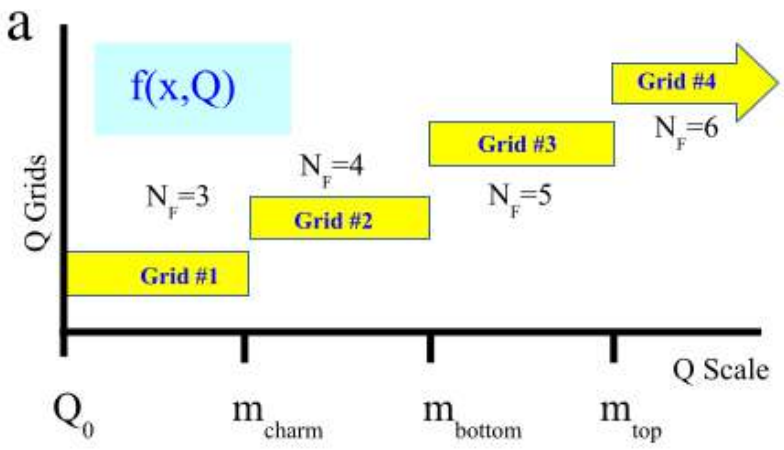
### A SIMPLE example using xFitter and GRVPi1 Pion PDF Tables:

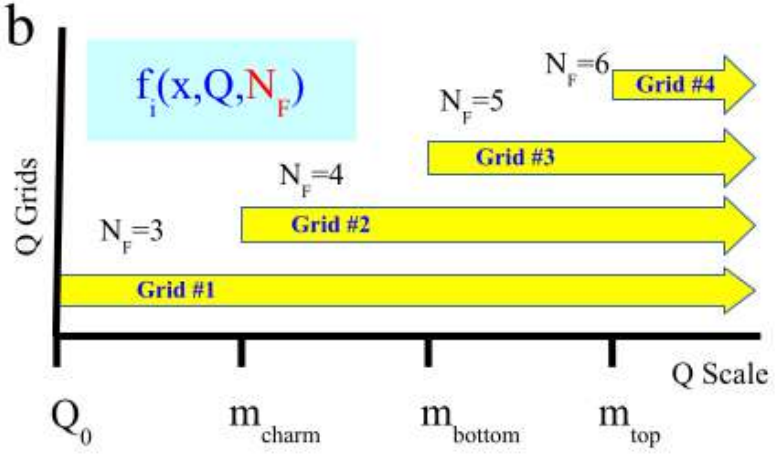
This is an self-contained example that reads Pion PDF tables in LHAPDF format.
PION_DEMO.zip



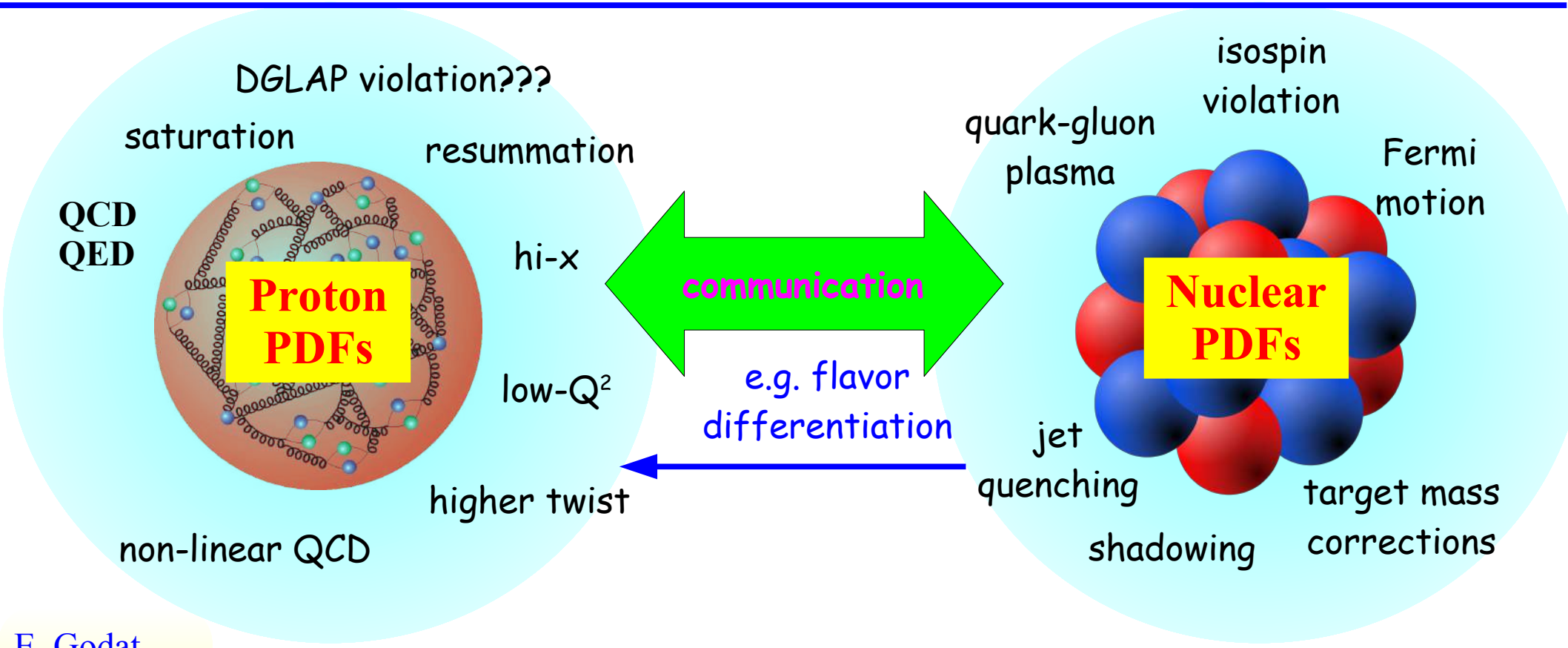




ıtinuity of the gluon (left) and b-quark (right) PDFs across the $m_b = 4.75$ GeV flavor threshold; the horizontal axis is $Q$ (in GeV), and th
ʻes are for the MSTW2008nnlo68cl PDF with $x = 10^{-4}$. Note that the gluon and b-quark shift in opposite directions to ensure the mome



# … the motivation for nCTEQ




E. Godat
T.J. Hobbs
T. Jezo,
C. Keppel,
K. Kovarik
A Kusina,
F. Lyonnet,
J. Morfin,
F. Olness
J. Owens,
I. Schienbein,
J. Yu

**Data from nuclear targets play a key role in the flavor differentiation**

# nCTEQ

**nuclear parton distribution functions**