xFitter: From nucleon to meson PDF fits

...

Fred Olness
Southern Methodist University

Thanks for substantial input
from friends & colleagues

xFitter:

Open Source Capabilities & Tools

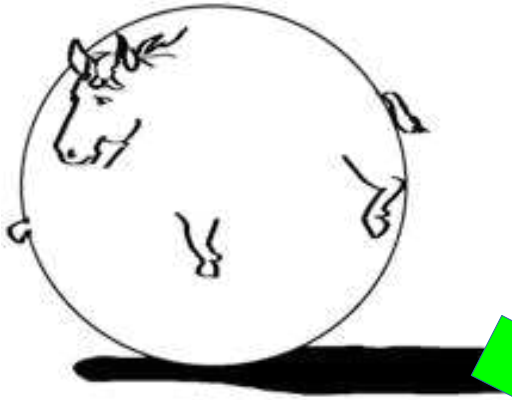
Pion PDF Fit:

Choice of data
PDF Form & Constraints
Grid Technology

Future Possibilities:

Perceiving EHM through
AMBER@CERN
30 Nov – 04 Dec 2020
Virtual Meeting

From Parameterization to a Deep Understanding



isospin violation
quark-gluon plasma
Fermi motion
Nuclear PDFs
jet quenching
target mass corrections
shadowing

DGLAP violation???
saturation
resummation
QCD
QED
hi-x
Proton PDFs
low-Q^2
higher twist
non-linear QCD

DGLAP violation???
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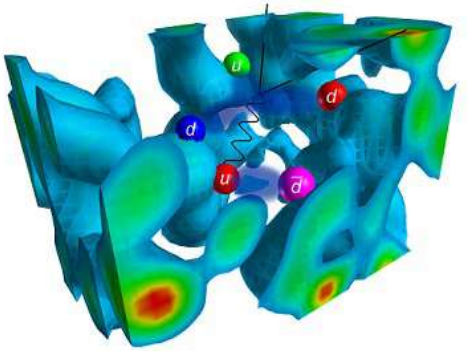


Lattice QCD

xFitter Capability

xFitter

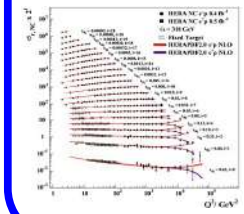
PROTON NUCLEON MESON

www.xFitter.org

Sample data files:

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

Experimental Data



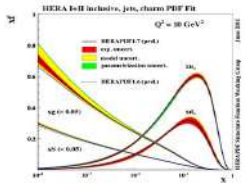
Data: HERA, Tevatron, LHC, fixed target experiments

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)

extensions include nuclear PDFs

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 2.0.1 Old Fashioned

xFitter Capabilities

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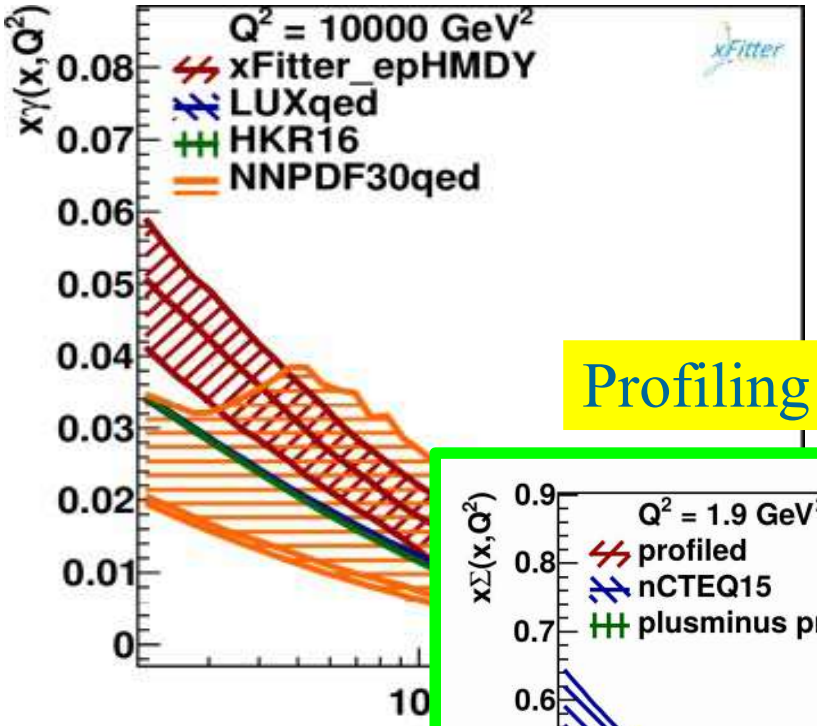
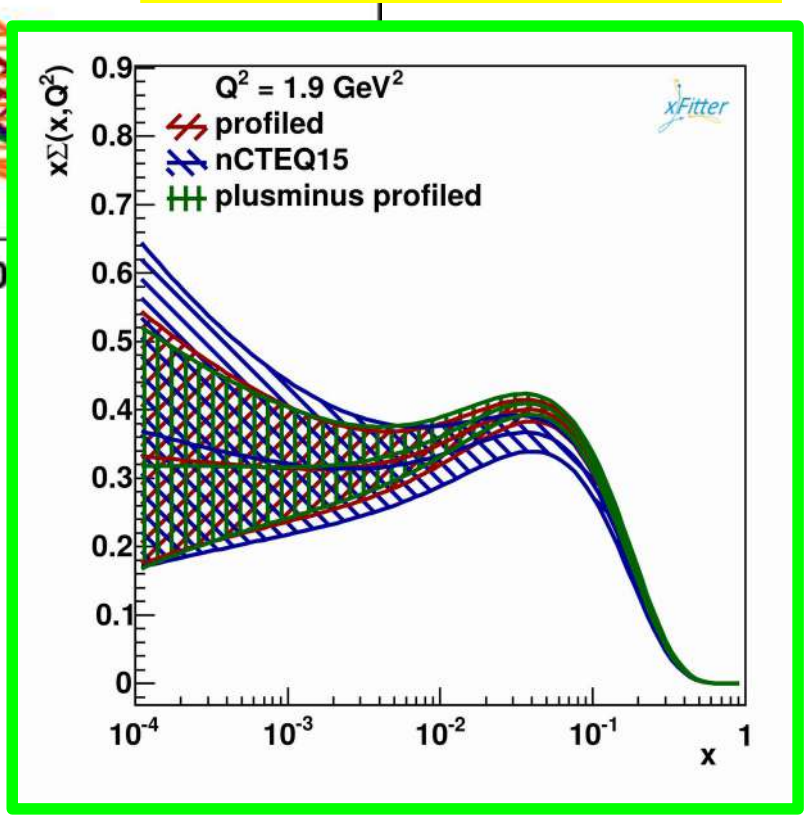
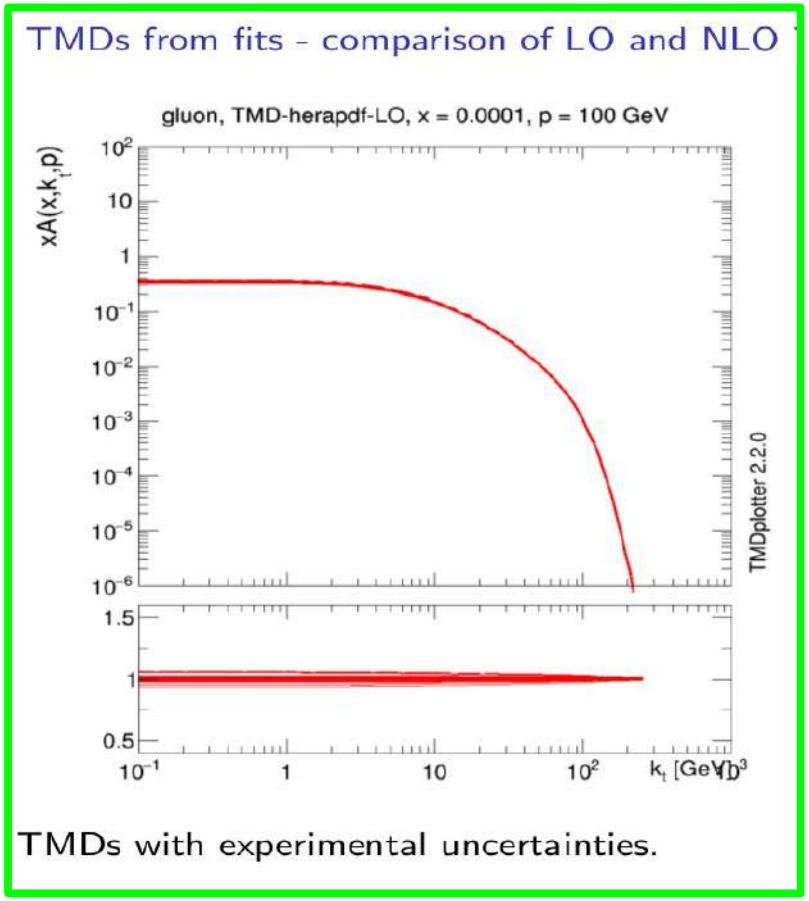
Photon PDF



Profiling Lead PDFs

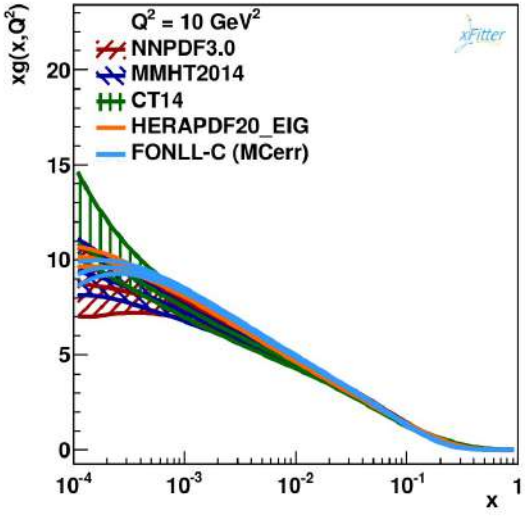


TMD (uPDFs) in xFitter

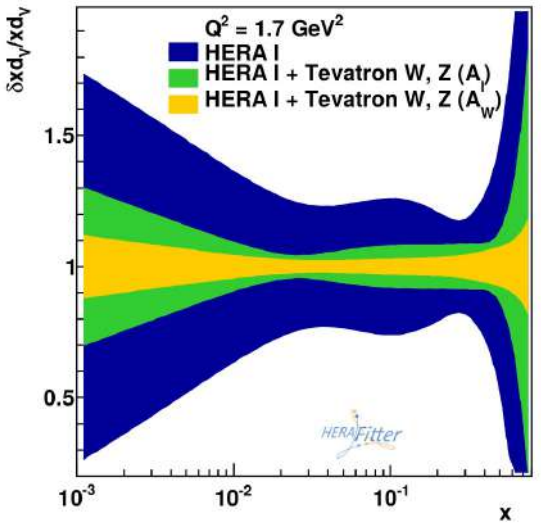


more xFitter Capabilities

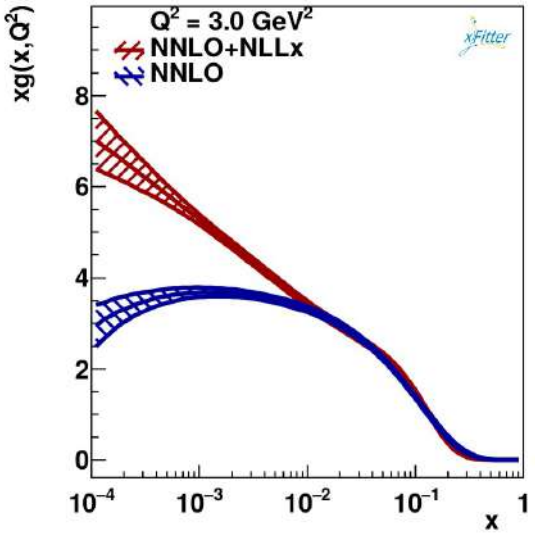
www.xFitter.org



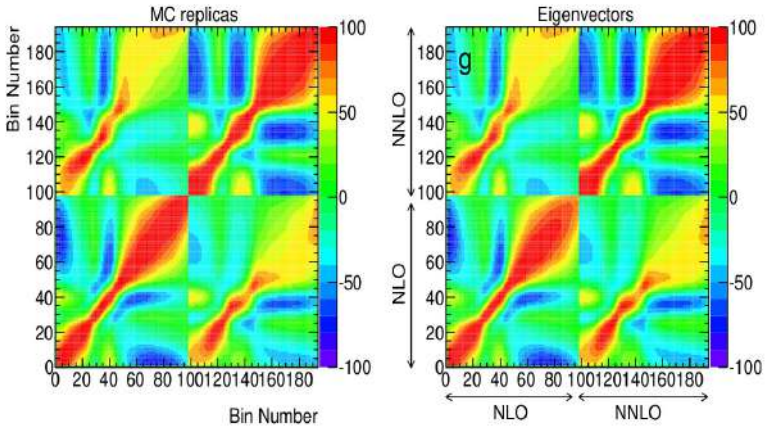
Multiple Heavy Quark Models



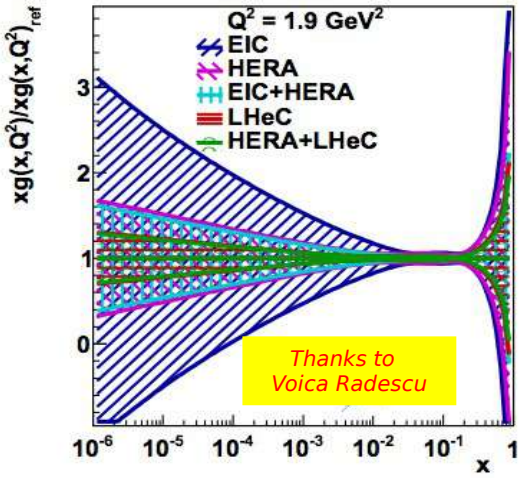
Profiling of W/Z Data



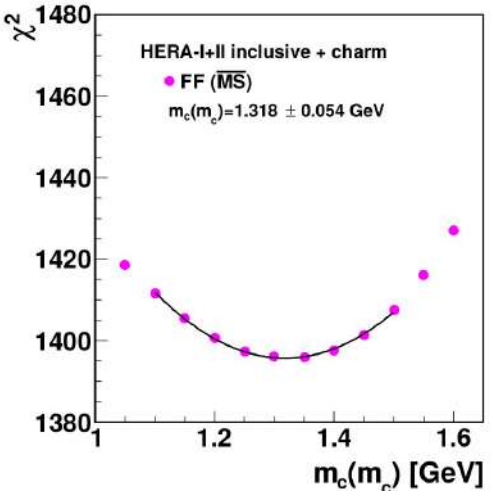
NNLx Resummation @ Small x



Correlation Coefficients



Sensitivity Studies

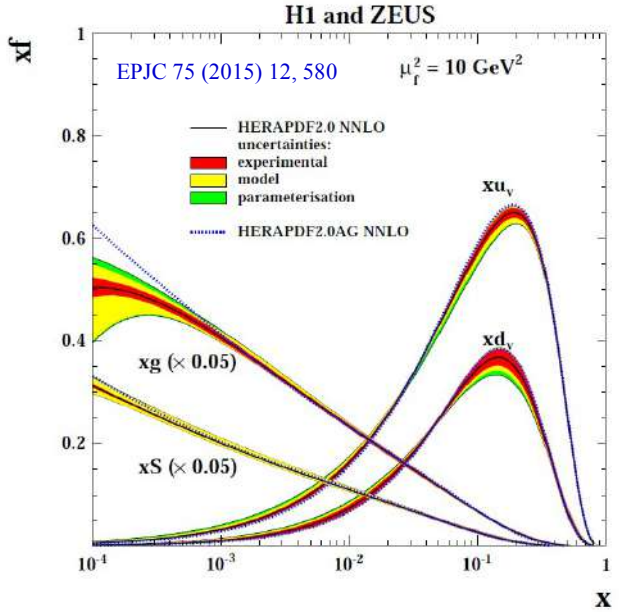


Pole & MS-Bar Running Mass

more xFitter Capabilities

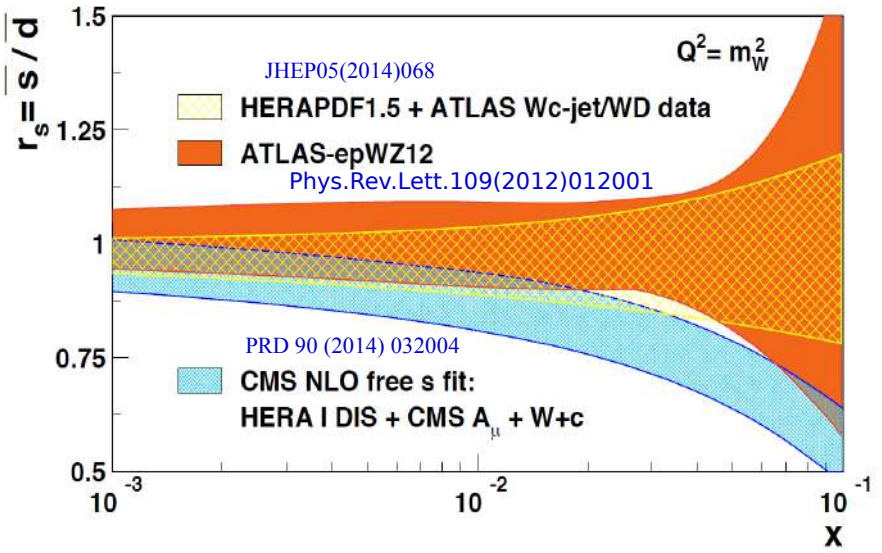
www.xFitter.org

DIS inclusive processes in *ep*

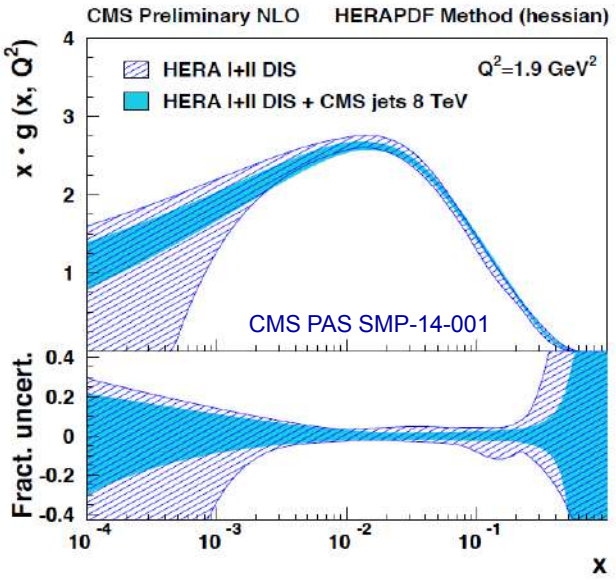


Drell-Yan processes (*pp, ppbar*)

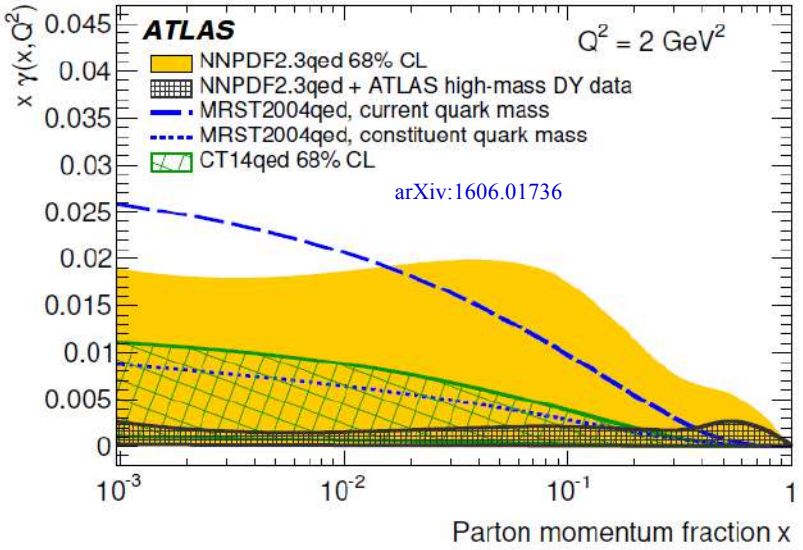
→ strange quark density determination



Jet production (*ep, pp, ppbar*)



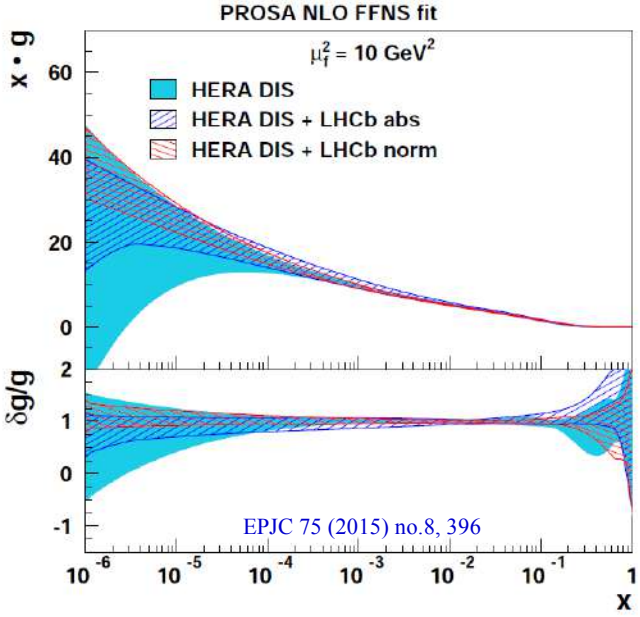
DY data sensitivity to photon PDF



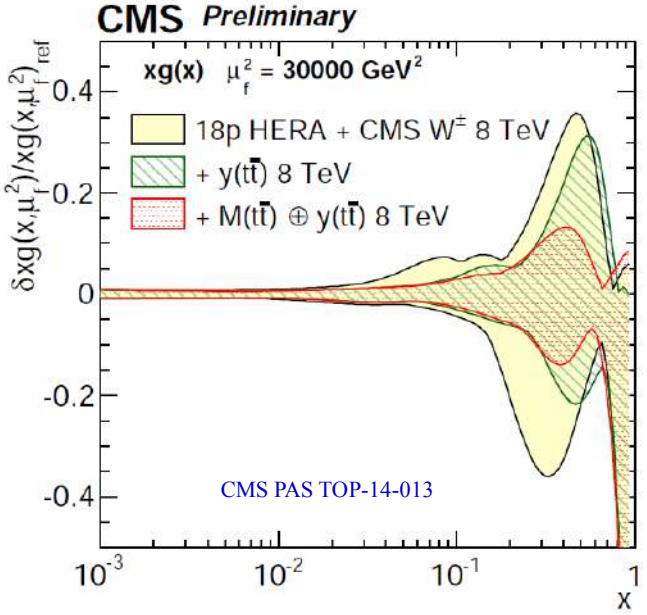
more xFitter Capabilities

www.xFitter.org

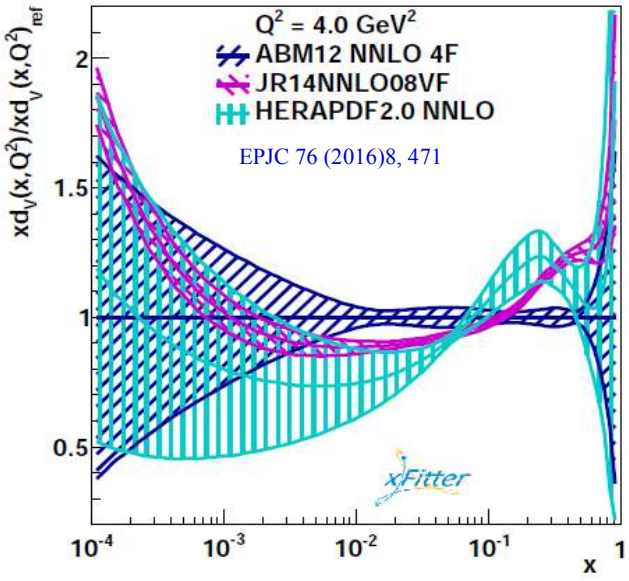
Heavy Quark production (*ep, pp, ppbar*)



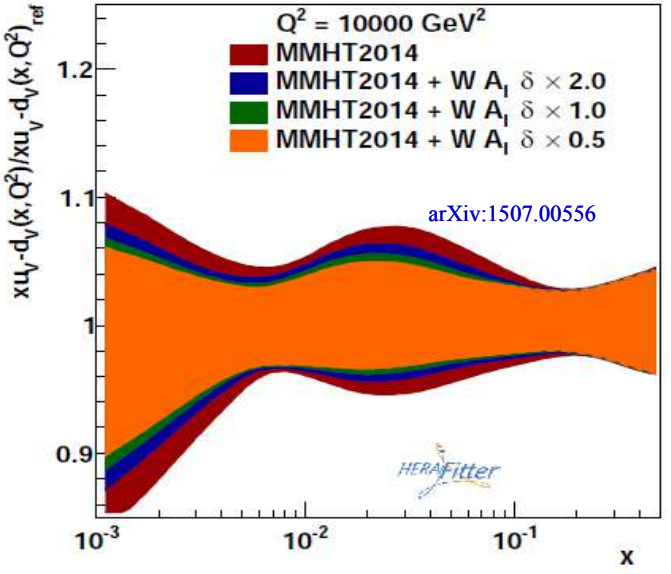
Top-quark production (*pp, ppbar*)



Evaluation of modern PDFs (benchmarking)



PDF4LHC report (benchmarking)



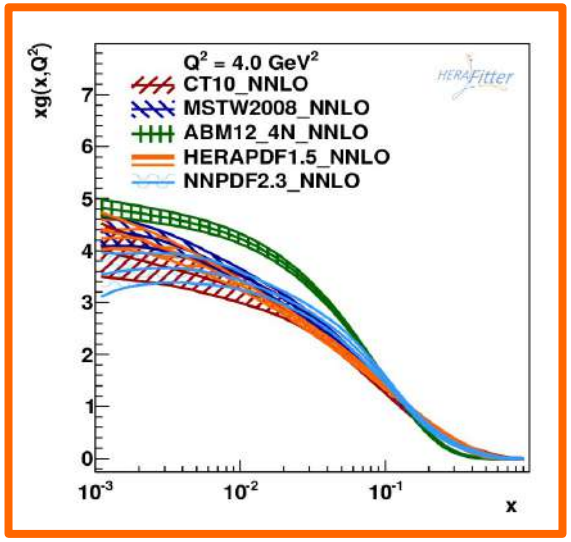
The Tools

xFitter-draw

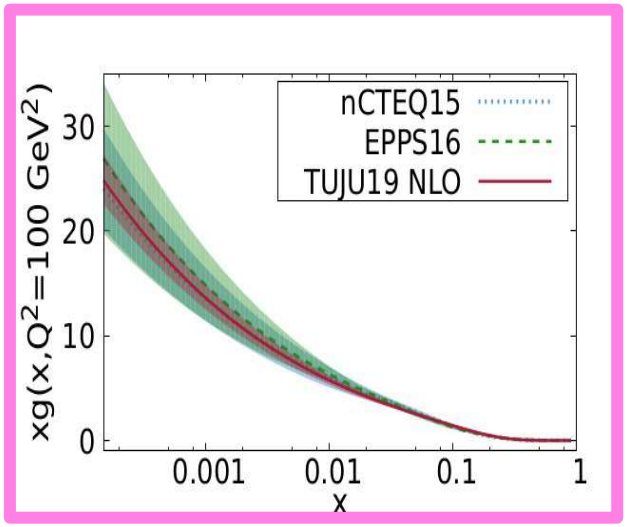
Python Jupyter

Mathematica: ManeParse

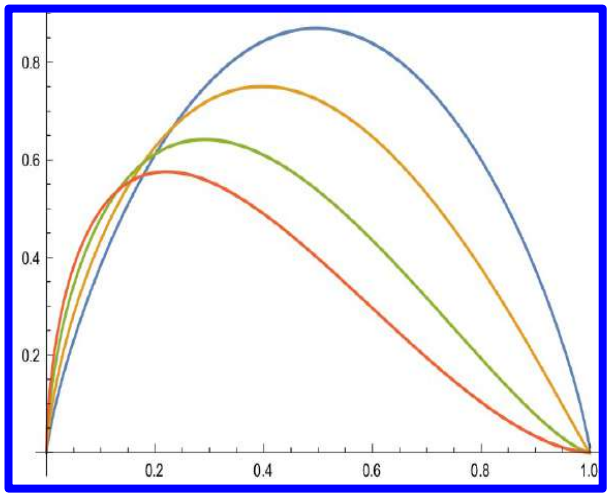
Analysis Tools: xFitter Draw & interface to Python & Mathematica



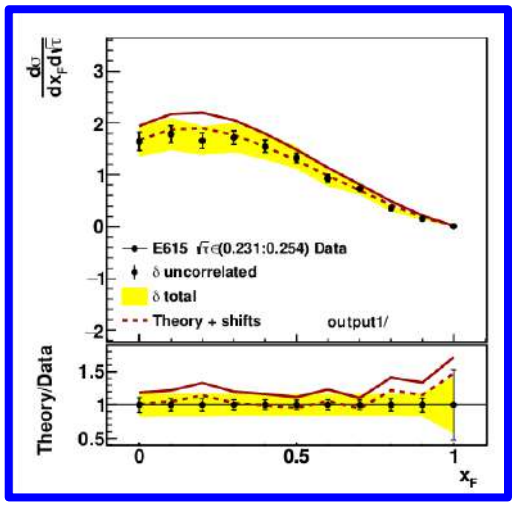
Proton PDFs



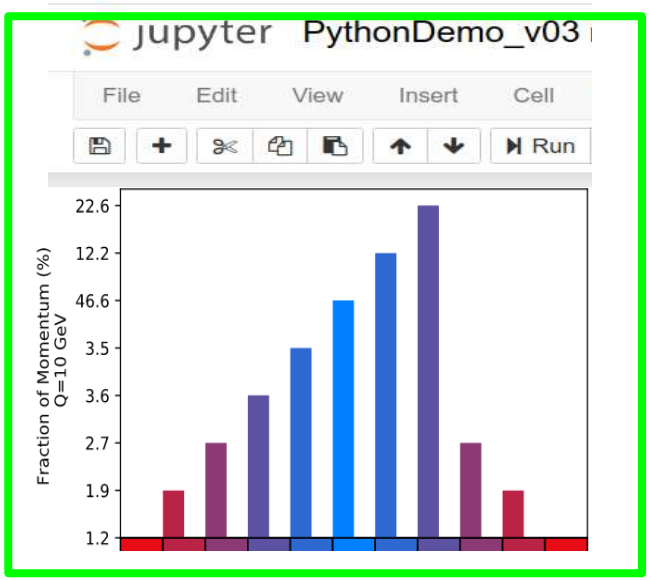
Nuclear PDFs



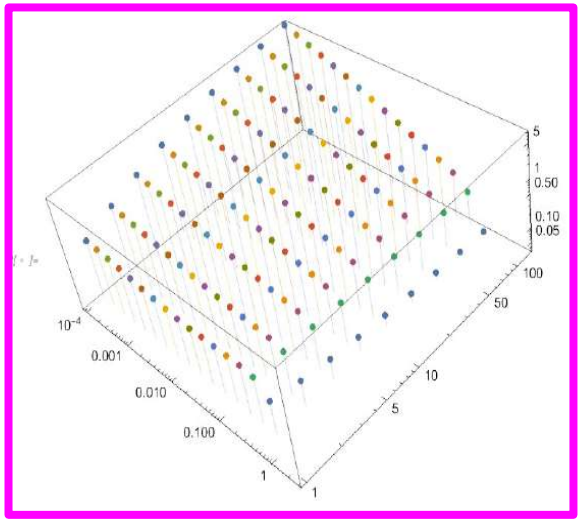
Pion PDFs



Cross Sections



Python Jupyter



Mathematica w/ManeParse

… join the effort

JBrandonS / xfitter-docker

https://github.com/JBrandonS/xfitter-docker

<> Code | Issues 0 | Pull requests 0 | Actions | Projects 0 | Wiki | Security | Insights

A WIP docker contatiner featuring xFitter

14 commits | 1 branch | 0 packages | 0 releases | 1 contributor | GPL-3.0

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

JBrandonS Updated README.md — Latest commit b103aaf 10 hours ago

.gitignore	Added run dir for steering files. Updated Readme. Fixed issues with S...	5 days ago
Dockerfile	Handeling PDF data correctly. Updated readme.	4 days ago
LICENSE	Initial commit	7 days ago
README.md	Updated README.md	10 hours ago
docker-entrypoint.sh	Handeling PDF data correctly. Updated readme.	4 days ago
install-xfitter-master	Initial commit	7 days ago

README.md

xFitter-Docker

xFitter-Docker is a docker container featuring the latest version of xFitter, from the master branch for the main repo, and as well as many standard HEP software packages needed for processing.

This allows for easy use of an up-to-date xFitter across all systems and configurations.

Installation

Prebuilt images for this project are available in docker-hub under jbrandons/xfitter. You can pull this project from any internet connected PC with

UPDATE: xFitter in Docker & Singularity

notes

Fred Olness

Brandon Stevenson

Lucas Kotz

xfitter examples *(from 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

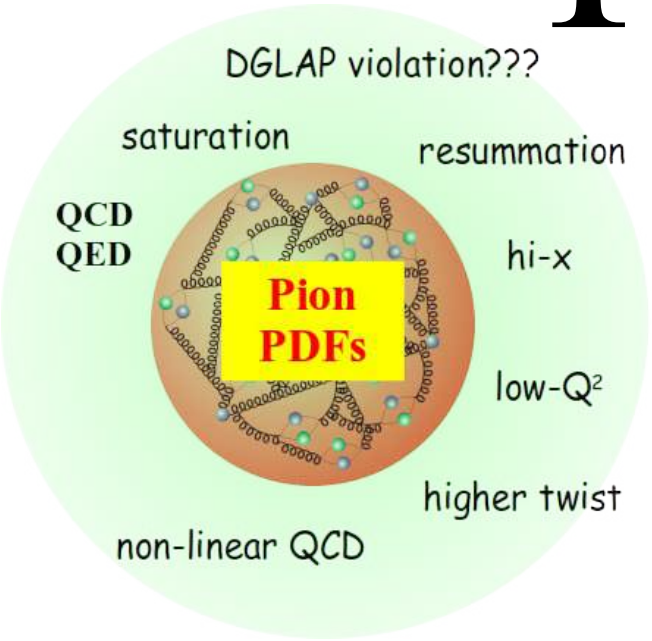
Exercise 3: LHAPDF analysis
→ how to estimate impact of a new data without fitting:
→ profiling and reweighting techniques

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

xFitter Team

xFitter Pion Fit



Special thanks to: Ivan Novikov, Alexander Glazov, Oleksandr Zenaiev

Parton Distribution Functions of the Charged Pion Within The xFitter Framework

xFitter Developers' team: Ivan Novikov,[1,2,*] Hamed Abdolmaleki,[3] Daniel Britzger,[4] Amanda Cooper-Sarkar,[5] Francesco Giuli,[6] Alexander Glazov,[2,†] Aleksander Kusina,[7] Agnieszka Luszczak,[8] Fred Olness,[9] Pavel Starovoitov,[10] Mark Sutton,[11] and Oleksandr Zenaiev[12]

e-Print: 2002.02902 [hep-ph]

xFitter

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.

OPEN SOURCE:

Transparency, facilitates comparisons, exploration

DATA SETS:

User can add/subtract data sets, and try out new & preliminary sets.
xFitter can "profile" and re-weight new data sets

INPUT CONDITIONS:

User can adjust parameters, and in put new models.
E.g., Un-integrated-PDFs, TMDs.

GRID TECHNOLOGY:

QCDNUM, APPLgrid, FastNLO, MCFM, APFEL, ...

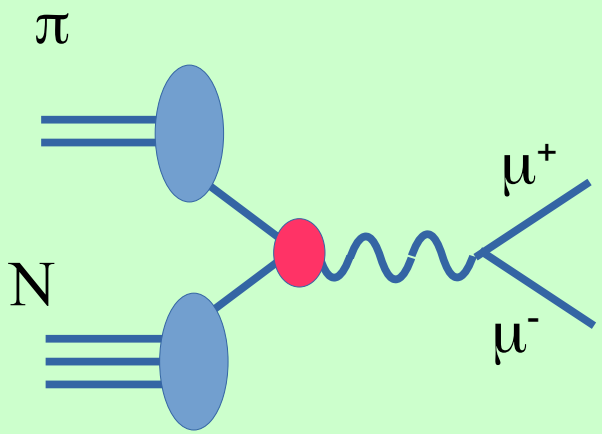
User Choice of Data Sets

xFitter Meson PDFs

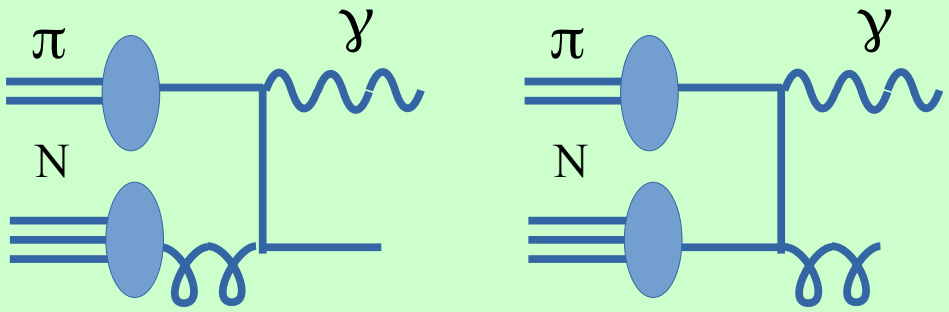
xFitter: open-source framework for global fits to meson PDFs

https://www.xfitter.org/

Experiment	χ^2/N_{points}
E615	206/140
NA10 (194 GeV)	107/67
NA10 (286 GeV)	95/73
WA70	64/99



E615 & NA10
Pions on Tungsten



WA70
Pions on Proton

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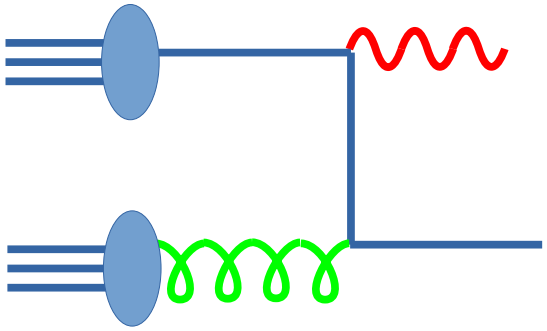
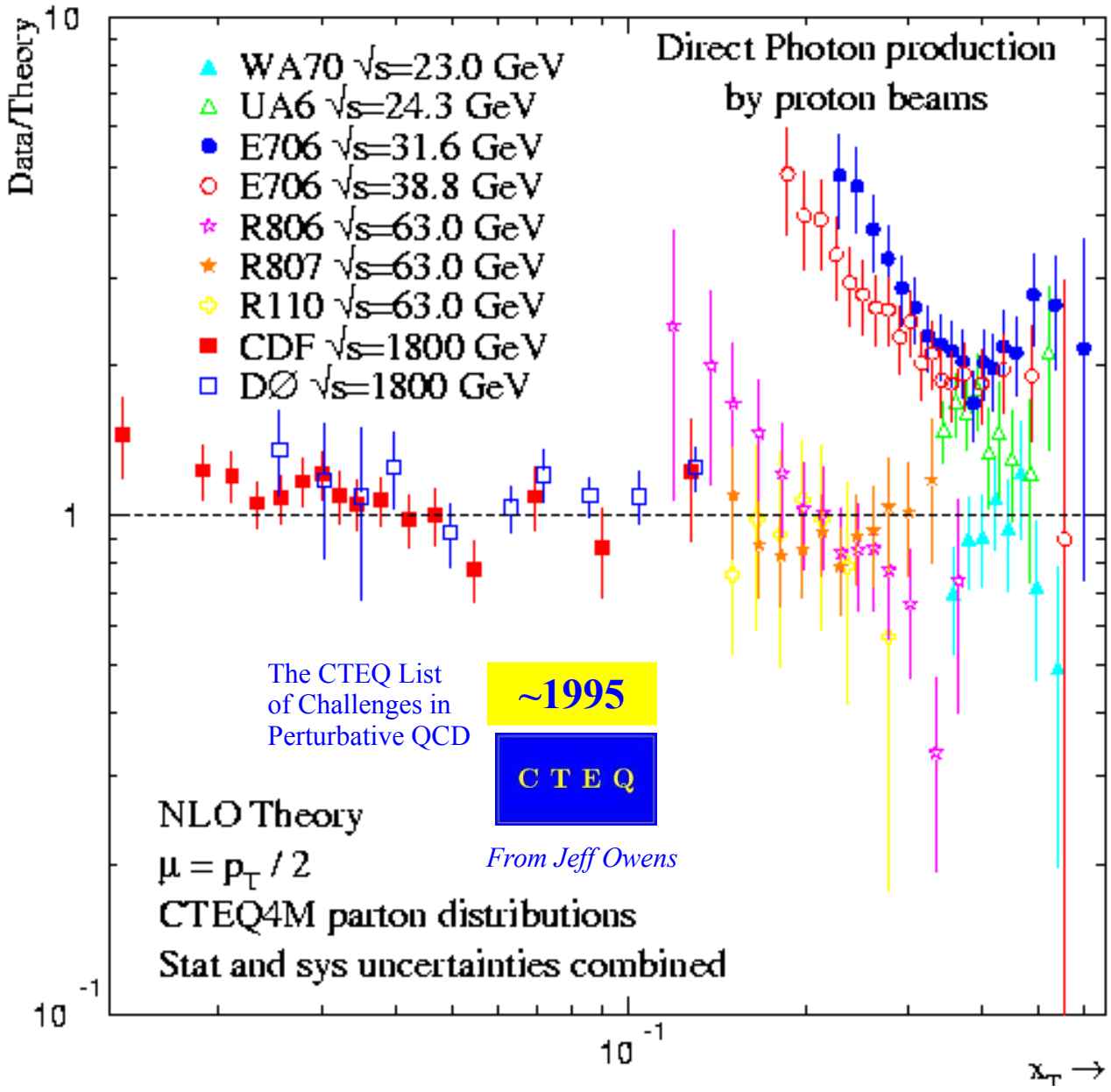
e-Print: 2002.02902 [hep-ph]

… Some History …



Historically Challenging Intrinsic K_T Issues

Recent improvements in resummation techniques



User Choice of Input Form

$$xv(x) = A_v x^{B_v}(1-x)^{C_v}(1+D_v x^{\alpha}),$$
$$xS(x) = A_S x^{B_S}(1-x)^{C_S}/\mathcal{B}(B_S+1, C_S+1),$$
$$xg(x) = A_g(C_g+1)(1-x)^{C_g},$$

	D_v=0	free D_v
$\chi^2/N_{\rm DoF}$	444/373=1.19	437/372=1.18
A_v	2.60	1.72
$\langle xv\rangle$	0.56	0.54
B_v	0.75 ± 0.03	0.63 ± 0.06
C_v	0.95 ± 0.03	0.26 ± 0.13
D_v	0	-0.93 ± 0.06
$A_S = \langle xS\rangle$	0.21 ± 0.08	0.25 ± 0.09
B_S	0.5 ± 0.8	0.3 ± 0.7
C_S	8 ± 3	6 ± 3
$A_g = \langle xg\rangle$	0.23	0.20
C_g	3 ± 1	3 ± 1

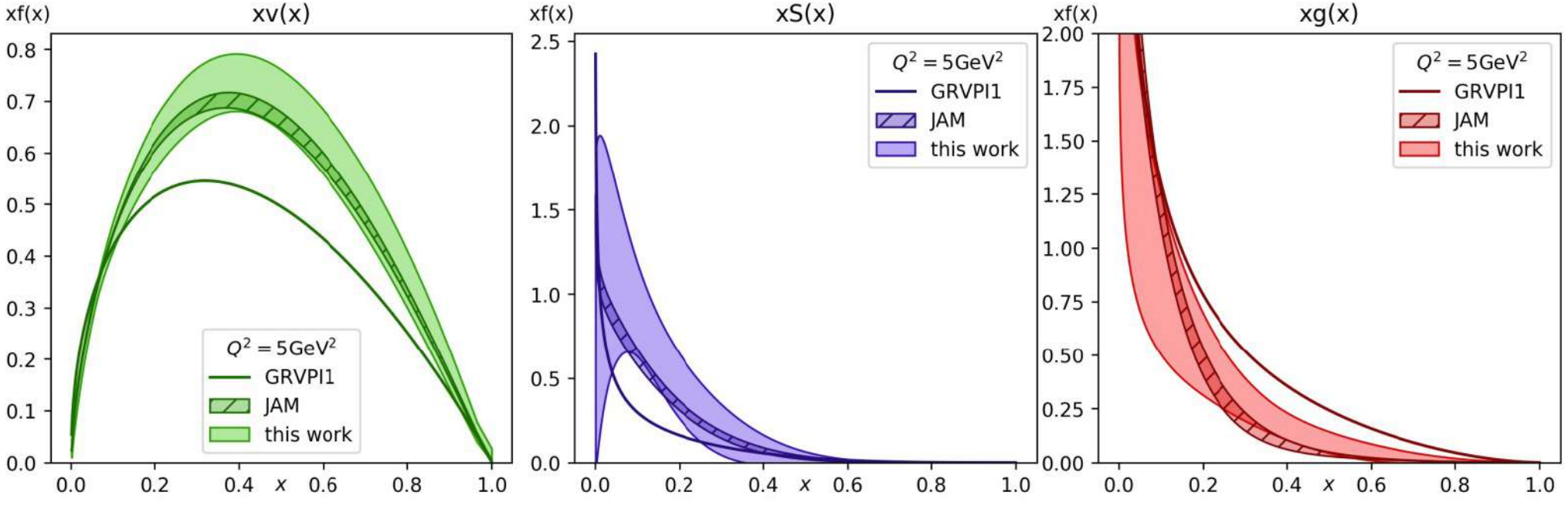
Try different functional forms

xFitter Pion PDFs

Experiment	Normalization uncertainty	χ^2/N_{points}
E615	15 %	206/140
NA10 (194 GeV)	6.4%	107/67
NA10 (286 GeV)	6.4%	95/73
WA70	32%	64/99

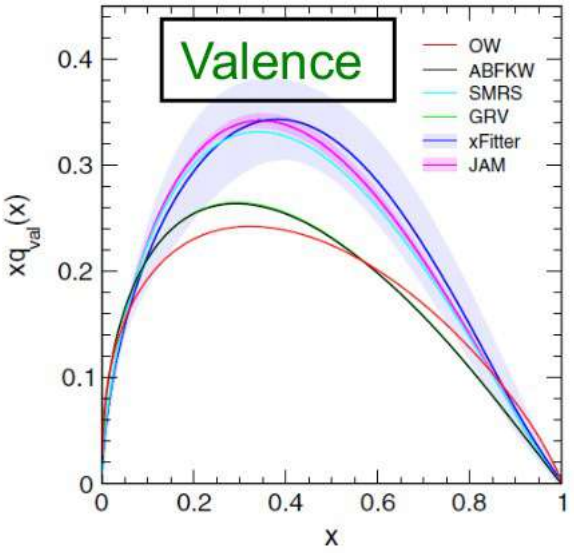
$$xv(x) = A_v x^{B_v}(1-x)^{C_v}(1+D_v x^{\alpha}),$$
$$xS(x) = A_S x^{B_S}(1-x)^{C_S}/\mathcal{B}(B_S+1, C_S+1),$$
$$xg(x) = A_g(C_g+1)(1-x)^{C_g},$$

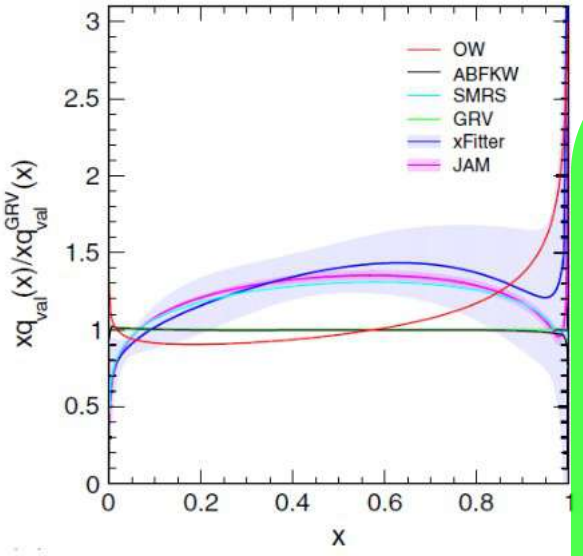
	$\langle xv\rangle$	$\langle xS\rangle$	$\langle xg\rangle$	Q^2 (GeV^2)
JAM [31]	0.54 ± 0.01	0.16 ± 0.02	0.30 ± 0.02	1.69
JAM (DY)	0.60 ± 0.01	0.30 ± 0.05	0.10 ± 0.05	1.69
this work	0.55 ± 0.06	0.26 ± 0.15	0.19 ± 0.16	1.69
Lattice-3 [18]	0.428 ± 0.030			4
SMRS [25]	0.47			4
Han et al. [44]	0.51 ± 0.03			4
GRVPI1 [27]	0.39	0.11	0.51	4
Ding et al. [11]	0.48 ± 0.03	0.11 ± 0.02	0.41 ± 0.02	4
this work	0.50 ± 0.05	0.25 ± 0.13	0.25 ± 0.13	4
JAM	0.48 ± 0.01	0.17 ± 0.01	0.35 ± 0.02	5
this work	0.49 ± 0.05	0.25 ± 0.12	0.26 ± 0.13	5
Lattice-1 [16]	0.558 ± 0.166			5.76
Lattice-2 [17]	0.48 ± 0.04			5.76
this work	0.48 ± 0.05	0.25 ± 0.12	0.27 ± 0.13	5.76
WRH [26]	0.434 ± 0.022			27
ChQM-1 [13]	0.428			27
ChQM-2 [15]	0.46			27
this work	0.42 ± 0.04	0.25 ± 0.10	0.32 ± 0.10	27
SMRS [25]	0.49 ± 0.02			49
this work	0.41 ± 0.04	0.25 ± 0.09	0.34 ± 0.09	49

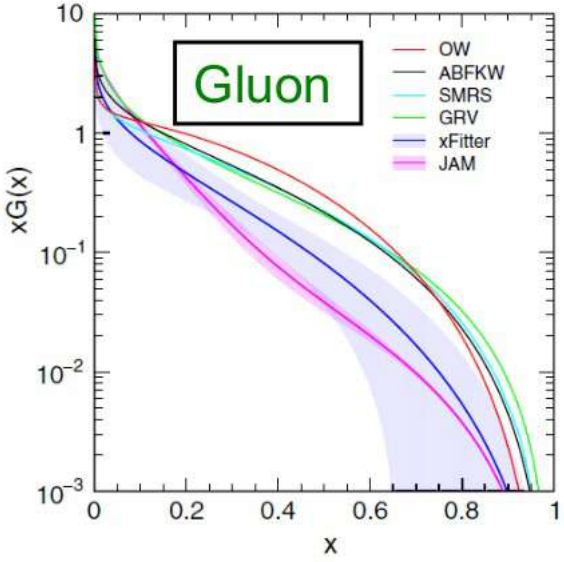


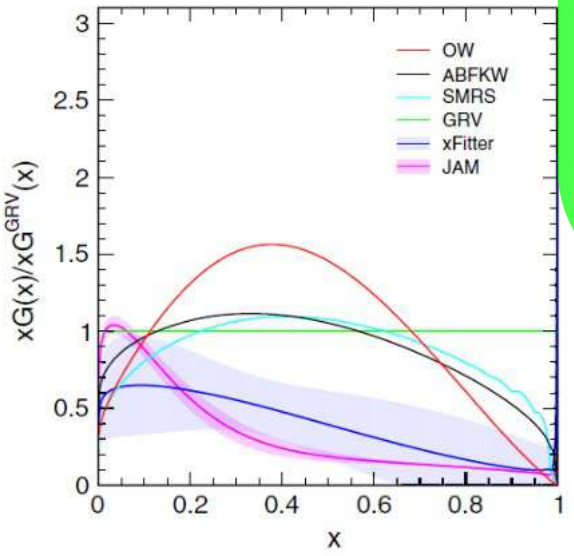
Jen-Chieh Peng

Valence and gluon distributions for various pion PDFs





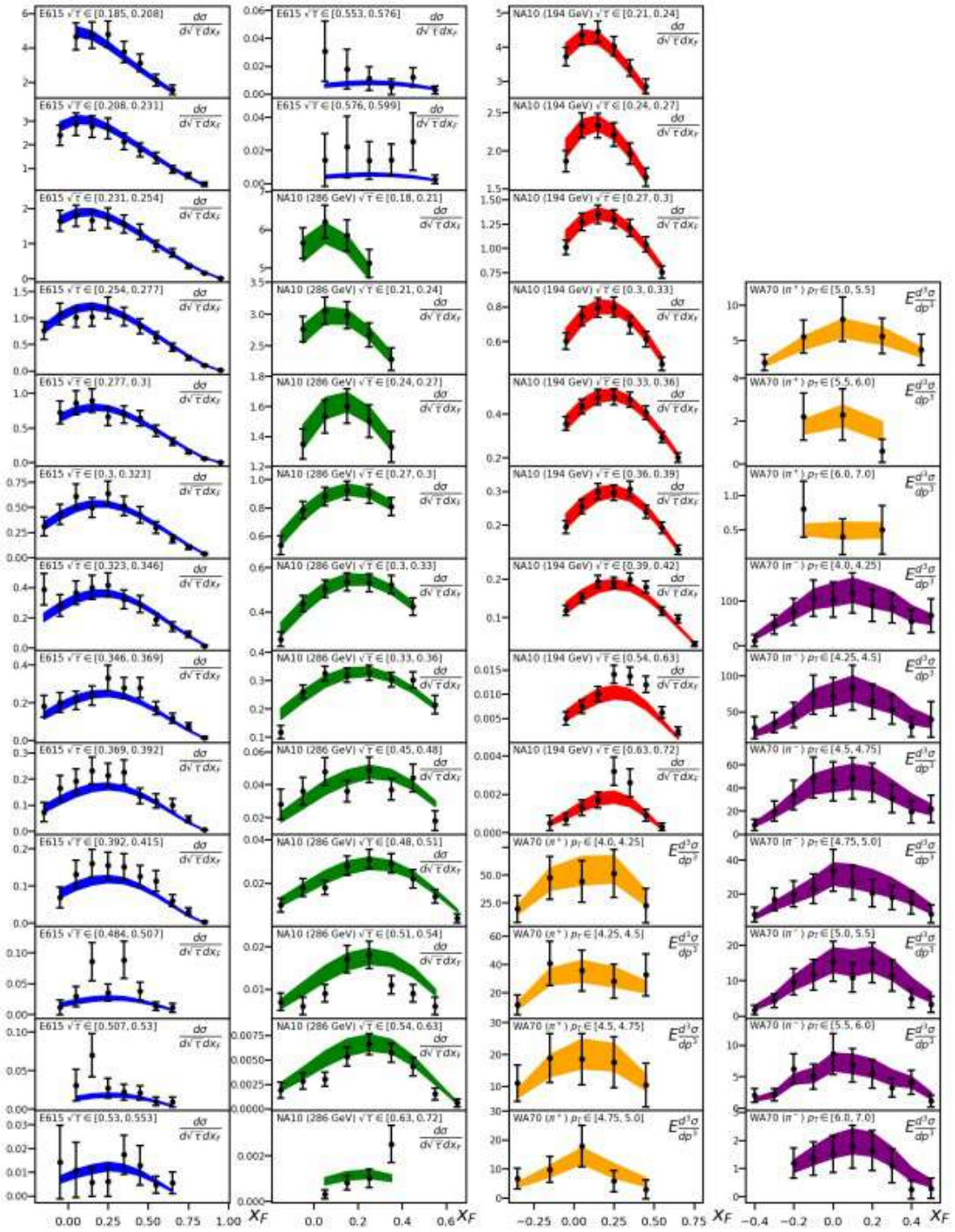




- Quite good agreements for valence quark PDFs
- Much larger variations for the gluon PDFs

22

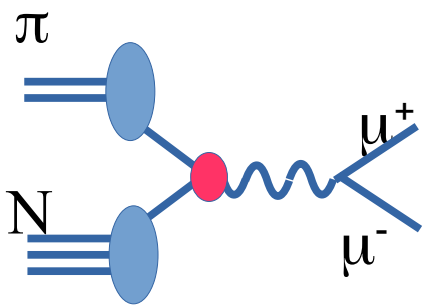
Pion Data:



Pions (π^-) on Tungsten

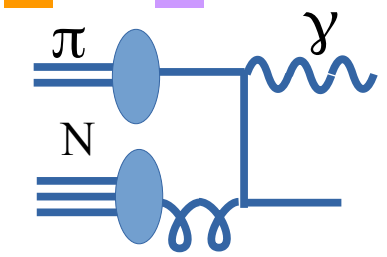
E615 E_π = **252 GeV**

NA10 E_π = **194 GeV** & **286 GeV**



Pions ($\pi^\pm$) on Proton

WA70 π^+ π^-



NLO computation with MCFM / APPLGRID

- theory errors from α_S, and nPDF uncert
- uncertainties include scale variations.
- for factorization scale variation

modify APPLGRID for two PDFs

Interface to Grid Technology

special thanks to Mark Sutton

Grid Technology: … to NLO and Beyond ...

APPLGRID method

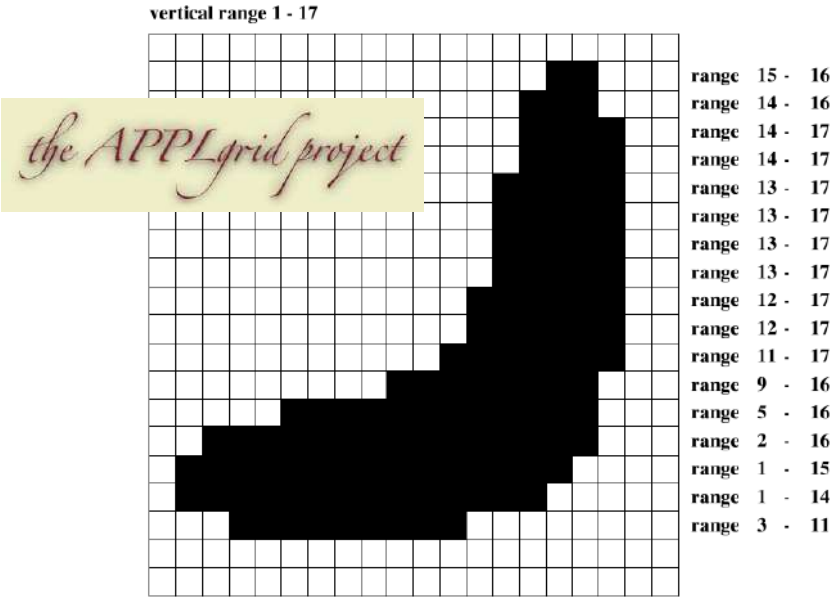
Eur.Phys.J.C66:503-524,2010.

- Step 1 (long run): Collect perturbative weights to grids .
  - binning (x_1, x_2, Q^2)
  - interpolation
  - initial flavours decomposition : $13 \times 13 \to \mathcal{L}$ ($\mathcal{L} \sim 10$)

$$\frac{d\hat{\sigma}^{ij}_{(p)}}{dX}(x_1, x_2, Q_F^2, Q_R^2;\ S) \xrightarrow{3D-grid} w^{(p)(l)}(x_1^m, x_2^n, Q^{2^k})\ (Q_R^2 \equiv Q_F^2)$$

- Step 2 ($\sim$ 10–100 ms): Convolute grid with PDF's .
  - integral $\to$ sum
  - any coupling, PDF

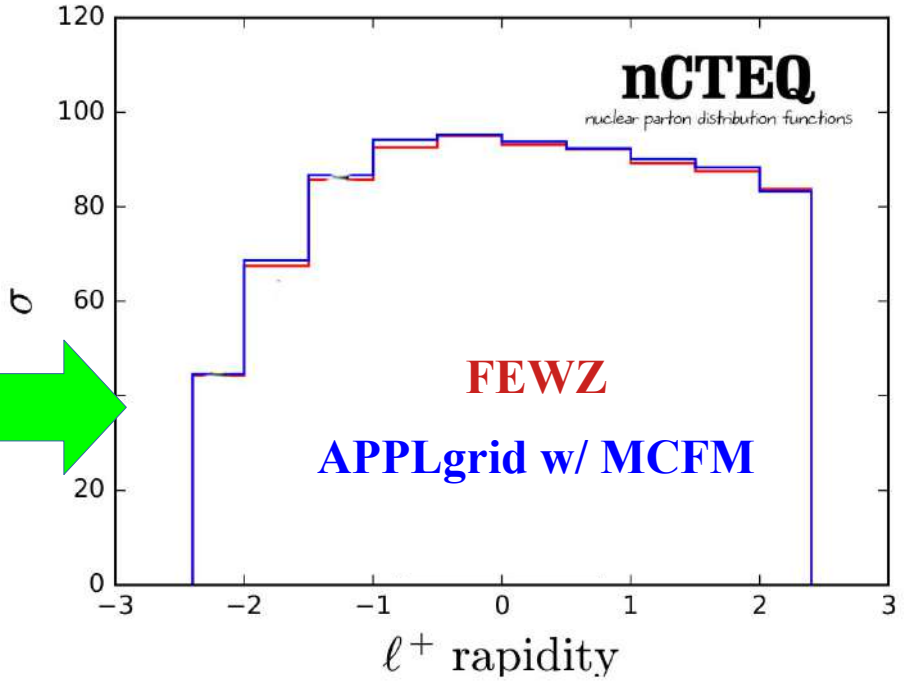
$$\frac{d\sigma}{dX} = \sum_p \sum_{l=0}^{L} \sum_{m,n,k} w^{(p)(l)}_{m,n,k} \left(\frac{\alpha_s(Q_k^2)}{2\pi}\right)^{p_l} F^{(l)}\left(x_{1m}, x_{2n}, Q_k^2\right)$$



Validation:

Compare Grid to Full Calculation

Works for both proton & **nuclear**



nCTEQ Collaboration
Eur.Phys.J.C 80 (2020) 10, 968

… can now access all MCFM Processes

MCFM Processes Library (v6.8)

MCFM: Vector boson pair production at the LHC, J. M.Campbell, R. K.Ellis and C.Williams, JHEP 1107, 018 (2011)

The APPLGRID Project: Tancredi Carli, Dan Clements, Amanda Cooper-Sarkar, Claire Gwenlan, Gavin P. Salam, Frank Siegert, Pavel Starovoitov, Mark Sutton. Eur.Phys.J. C66 (2010) 503-524

nproc	$f(p_1) + f(p_2) \to \ldots$	Order
1	$W^+(\to \nu(p_3) + e^+(p_4))$	NLO
6	$W^-(\to e^-(p_3) + \bar{\nu}(p_4))$	NLO
11	$W^+(\to \nu(p_3) + e^+(p_4)) + f(p_5)$	NLO
12	$W^+(\to \nu(p_3) + e^+(p_4)) + \bar{b}(p_5)$	NLO
13	$W^+(\to \nu(p_3) + e^+(p_4)) + \bar{c}(p_5)$	NLO
14	$W^+(\to \nu(p_3) + e^+(p_4)) + \bar{c}(p_5)$[massless]	LO
16	$W^-(\to e^-(p_3) + \bar{\nu}(p_4)) + f(p_5)$	NLO
17	$W^-(\to e^-(p_3) + \bar{\nu}(p_4)) + b(p_5)$	NLO
18	$W^-(\to e^-(p_3) + \bar{\nu}(p_4)) + c(p_5)$	NLO
19	$W^-(\to e^-(p_3) + \bar{\nu}(p_4)) + c(p_5)$[massless]	LO

xFitter

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.

OPEN SOURCE:

Transparency, facilitates comparisons, exploration

DATA SETS:

User can add/subtract data sets, and try out new & preliminary sets.
xFitter can "profile" and re-weight new data sets

INPUT CONDITIONS:

User can adjust parameters, and in put new models.
E.g., Un-integrated-PDFs, TMDs.

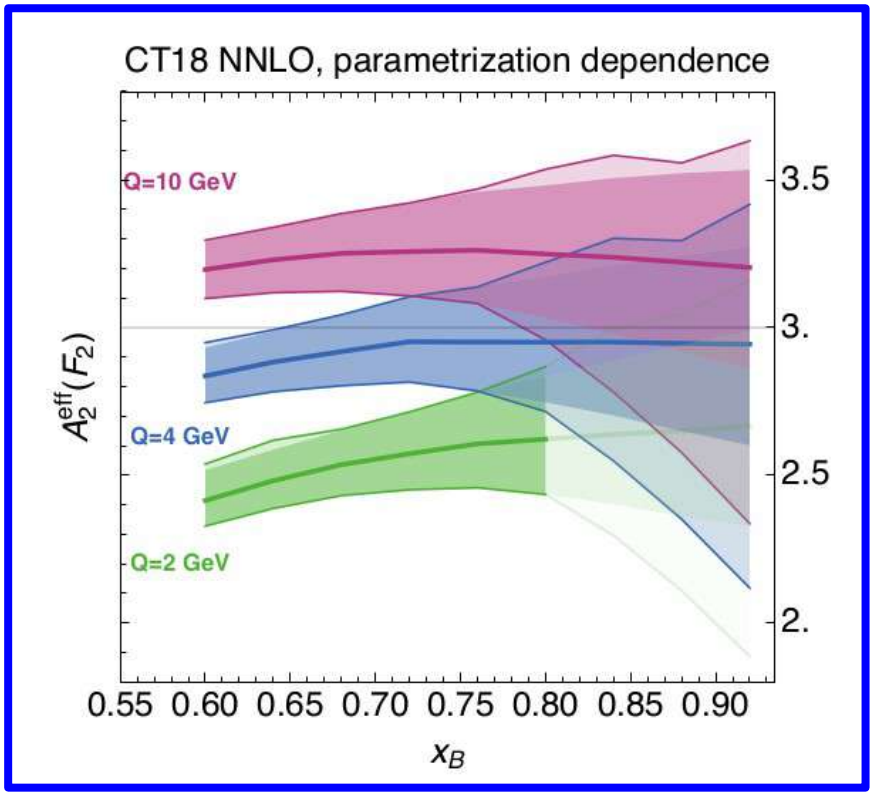
GRID TECHNOLOGY:

QCDNUM, APPLgrid, FastNLO, MCFM, APFEL, ...

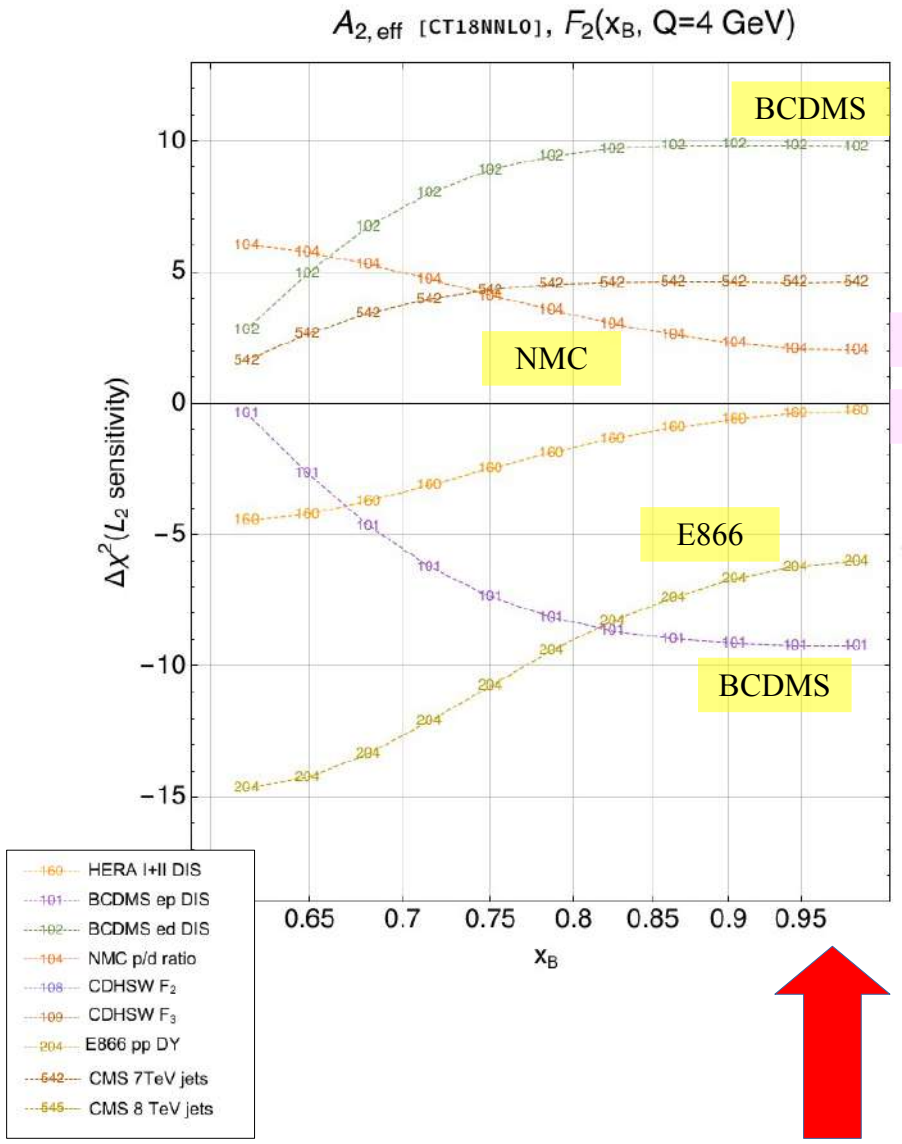
Future Possibilities

Hadron Structure in a global QCD analysis

$$\lim_{x_B \to 1} F_2^p(x_B, Q^2) \propto (1 - x_B)^3,$$



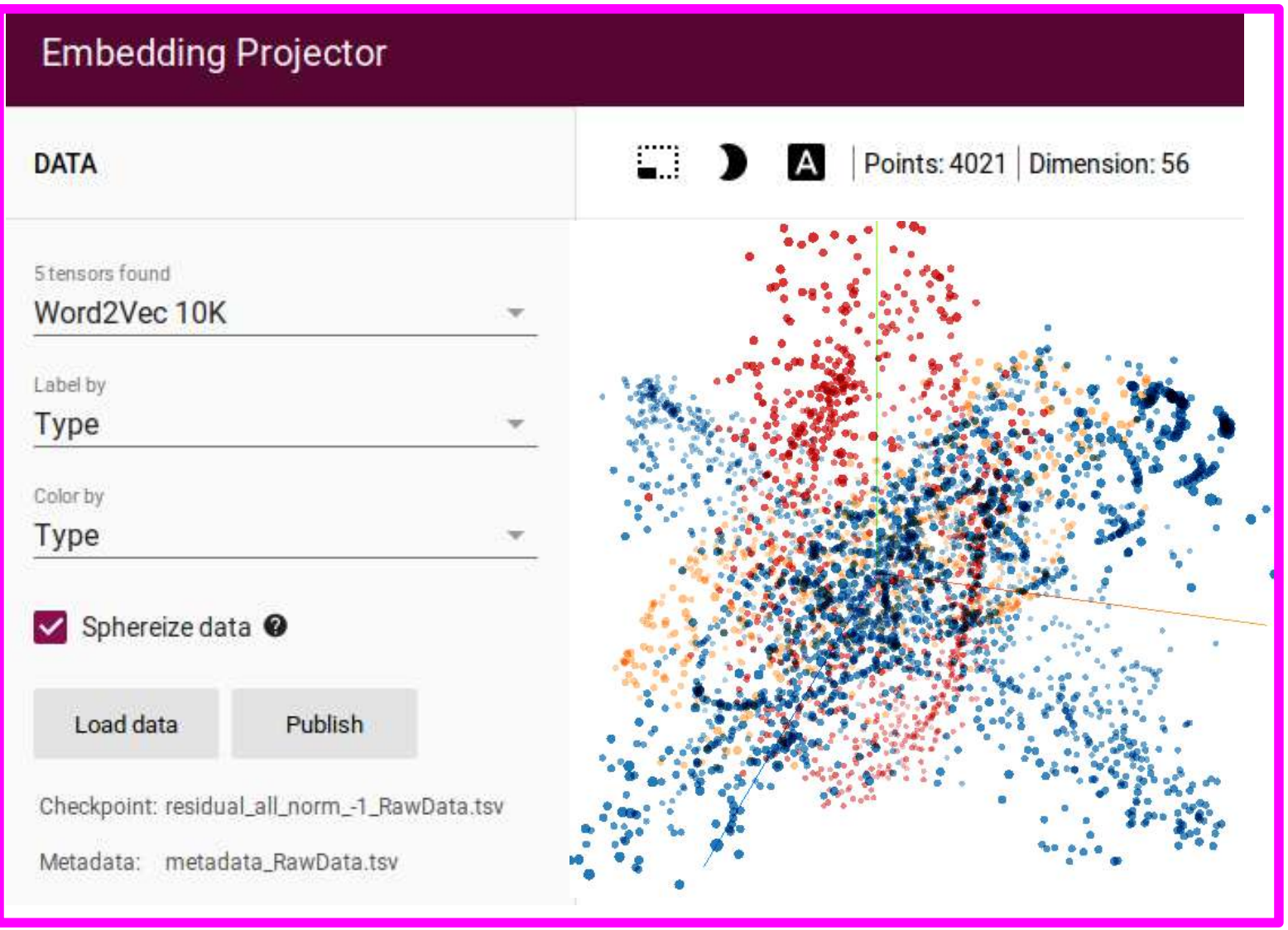
Testing momentum dependence of the nonperturbative hadron structure in a global QCD analysis
A. Courtoy, P.Nadolsky. arXiv:2011.10078

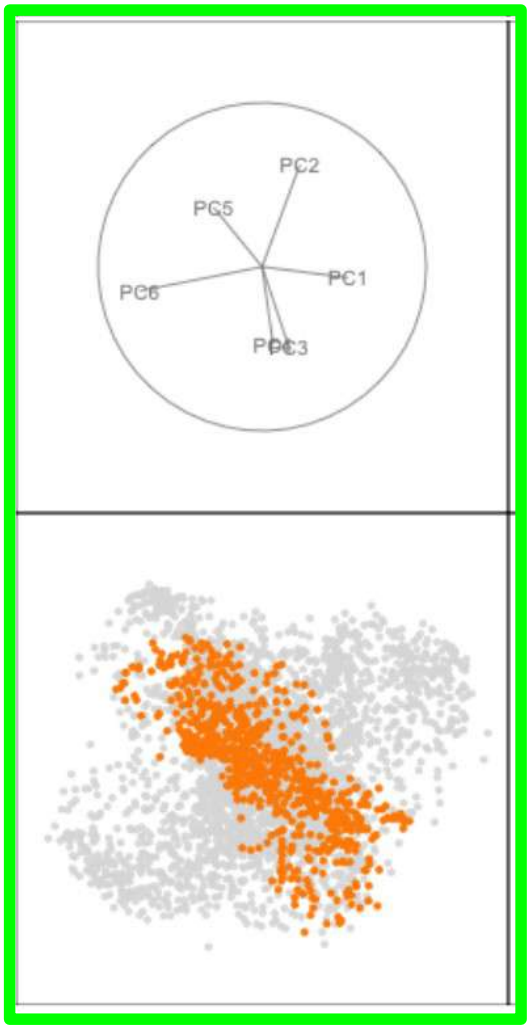


hi-x region

Repeat with Pion ...

Artificial Intelligence Tools: Projector tool of Google TensorFlow

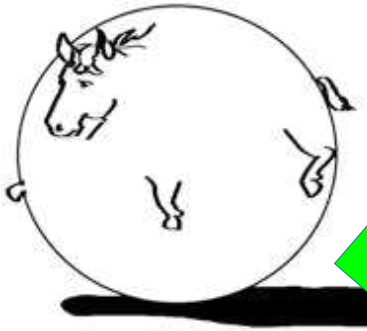




Mapping the sensitivity of hadronic experiments to nucleon structure
B.T. Wang, T.J. Hobbs, S. Doyle, J. Gao, T.J. Hou, P. Nadolsky, F. Olness
Phys.Rev.D 98 (2018) 9, 094030 • e-Print: 1803.02777 [hep-ph]

Dynamical projections for the visualization of PDFSense data
Dianne Cook, Ursula Laa, German Valencia arXiv:1806.09742

Conclusion



xFitter

DGLAP violation???

saturation

resummation

QCD
QED

hi-x

Pion PDFs

low-Q^2

higher twist

non-linear QCD

DGLAP violation???

saturation

resummation

QCD
QED

hi-x

Proton PDFs

low-Q^2

higher twist

non-linear QCD

isospin violation

quark-gluon plasma

Fermi motion

Nuclear PDFs

jet quenching

target mass corrections

shadowing

JOIN OUR TEAM

EXTRAS

Docker
Singularity

JBrandonS / xfitter-docker

https://github.com/JBrandonS/xfitter-docker

<> Code | Issues 0 | Pull requests 0 | Actions | Projects 0 | Wiki | Security | Insights

A WIP docker contatiner featuring xFitter

14 commits | 1 branch | 0 packages | 0 releases | 1 contributor | GPL-3.0

Branch: master | New pull request | Create new file | Upload files | Find file | Clone or download

JBrandonS Updated README.md — Latest commit b103aaf 10 hours ago

.gitignore	Added run dir for steering files. Updated Readme. Fixed issues with S...	5 days ago
Dockerfile	Handeling PDF data correctly. Updated readme.	4 days ago
LICENSE	Initial commit	7 days ago
README.md	Updated README.md	10 hours ago
docker-entrypoint.sh	Handeling PDF data correctly. Updated readme.	4 days ago
install-xfitter-master	Initial commit	7 days ago

README.md

xFitter-Docker

xFitter-Docker is a docker container featuring the latest version of xFitter, from the master branch for the main repo, and as well as many standard HEP software packages needed for processing.

This allows for easy use of an up-to-date xFitter across all systems and configurations.

Installation

Prebuilt images for this project are available in docker-hub under jbrandons/xfitter. You can pull this project from any internet connected PC with

UPDATE:
xFitter in Docker & Singularity
notes

Fred Olness

Brandon Stevenson

Lucas Kotz

DOCKER

```
docker pull jbrandons/xfitter
```

```
docker run -it -u $(id -u ${USER}):$(id -g ${USER})  -v $(pwd):/run
    -v /users/olness/xfit/DATA/datafiles:/data
    -v /usr/local/share/LHAPDF:/pdfdata    jbrandons/xfitter bash
```

xfitter and **xfitter-draw** are installed in the path, so a plain "**xfitter**" command should run the test.

The `-u $(id -u ${USER}):$(id -g ${USER})` command mounts as the user instead of root.

The `-v $(pwd):/run` command mounts the current directory as /**run**; this is the working directory.

The `-v /users/olness/xfit/DATA/datafiles:/data` command mounts your local set of data files.

The `-v /usr/local/share/LHAPDF:/pdfdata` command mounts your local set of lhapdf files.
(This keeps the docker image lightweight)

The `bash` command drops to a bash shell.

In the above example, the **pwd** is mounted at /**run**, so if you place

" `constants.yaml  parameters.yaml  steering.txt` "

locally, you can then run the xfitter example.

SINGULARITY

```
singularity run -B $(pwd)/datafiles:/data
     -B $(pwd)/lhafiles:/pdffiles   -B $(pwd):/run
     docker://jbrandons/xfitter bash
```

* user runs as **non-root**
* **image is mounted read-only** *(not a problem)*

SETUP: In your working dir $(pwd) make 2 symlinks:

1) Symlink **./datafiles** to your local xFitter data file
2) Symlink **./lhafiles** to your local LHAPDF data files

Your **$pwd** will be mounted to **/run** so you have local access to output
Launch singularity; you'll drop into a bash shell.
xfitter and **xfitter-draw** are in your image path.

In your local working directory, you will need: `constants.yaml parameters.yaml steering.txt`

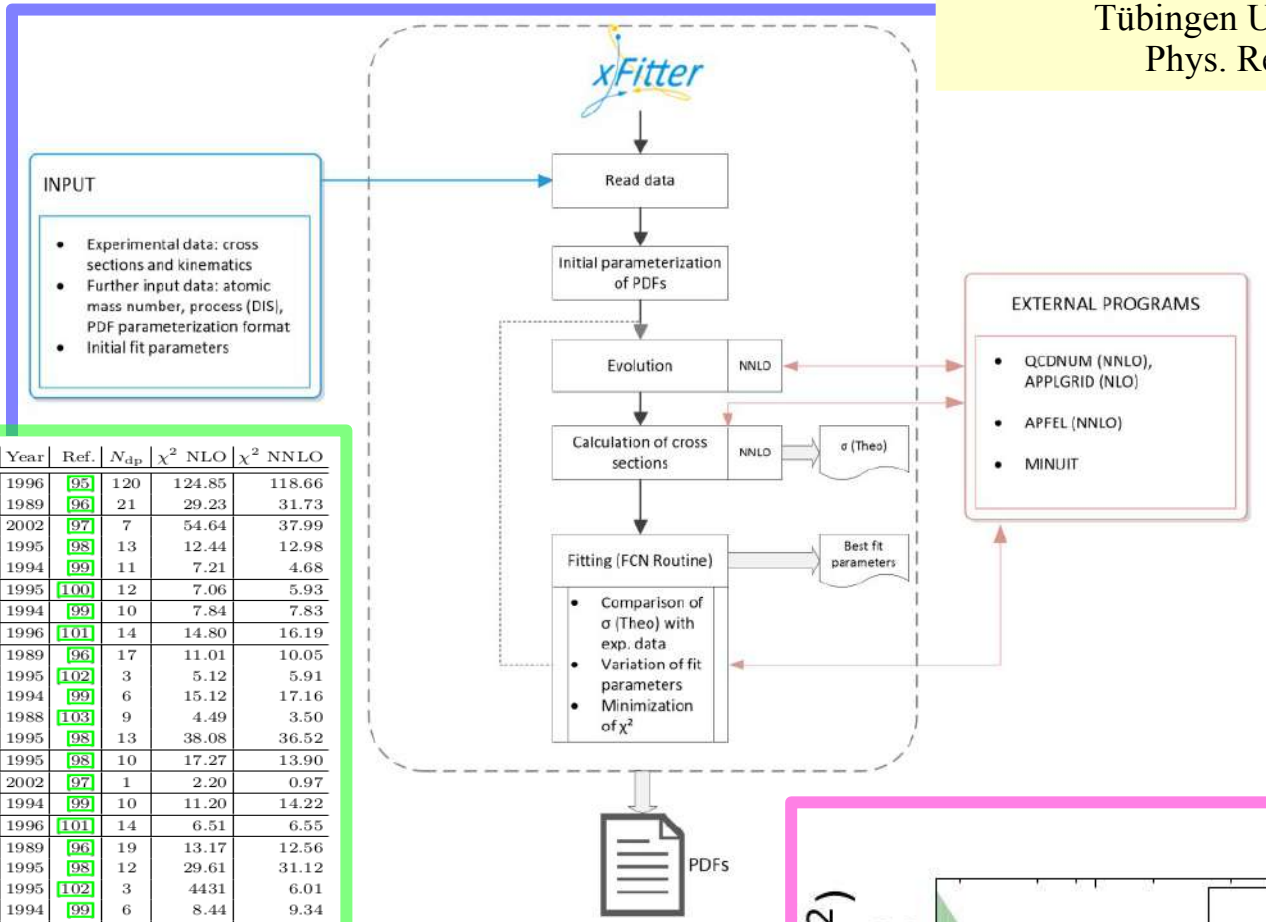
xFitter Nuclear Fit

xFitter Nuclear PDFs

Open-source QCD analysis of nuclear parton distribution functions at NLO and NNLO

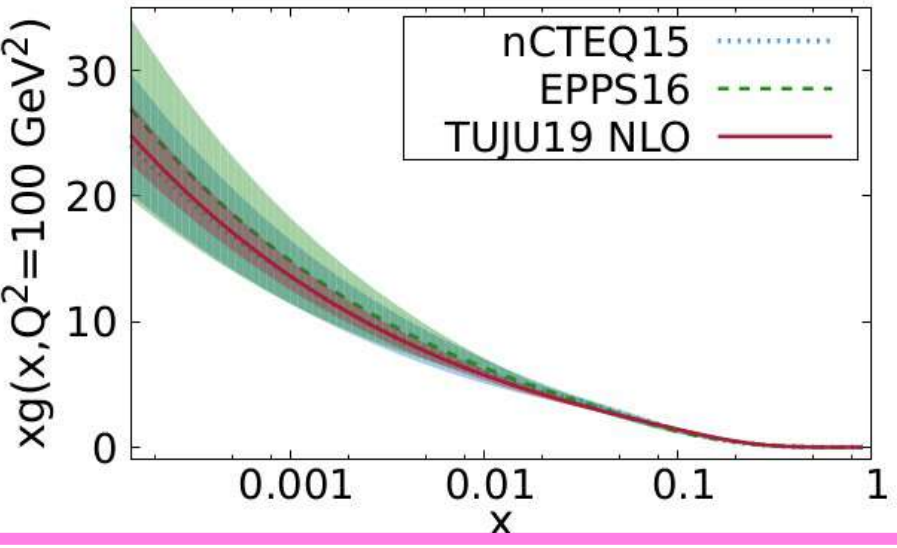
Marina Walt, Ilkka Helenius, Werner Vogelsang
Tübingen U, Jyvaskyla U (TUJU)

Phys. Rev. D 100, 096015 (2019)



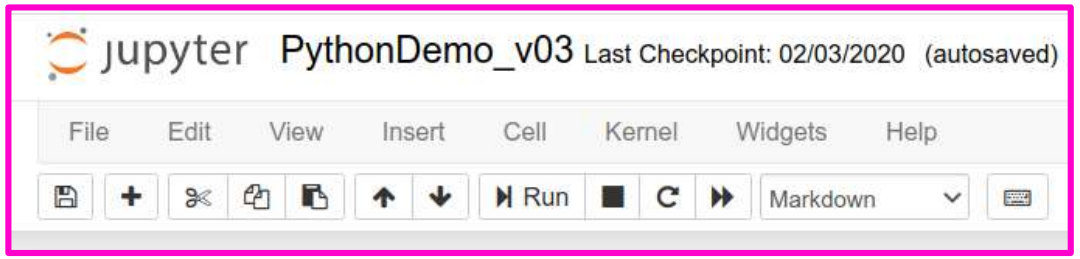
Nucleus	Exp.	Year	Ref.	N_{dp}	χ^2 NLO	χ^2 NNLO
D	NMC 97	1996	[95]	120	124.85	118.66
	EMC 90	1989	[96]	21	29.23	31.73
He/D	HERMES	2002	[97]	7	54.64	37.99
	NMC 95, re.	1995	[98]	13	12.44	12.98
	SLAC E139	1994	[99]	11	7.21	4.68
Li/D	NMC 95	1995	[100]	12	7.06	5.93
Be/D	SLAC E139	1994	[99]	10	7.84	7.83
Be/C	NMC 96	1996	[101]	14	14.80	16.19
C	EMC 90	1989	[96]	17	11.01	10.05
C/D	FNAL E665	1995	[102]	3	5.12	5.91
	SLAC E139	1994	[99]	6	15.12	17.16
	EMC 88	1988	[103]	9	4.49	3.50
	NMC 95, re.	1995	[98]	13	38.08	36.52
C/Li	NMC 95, re.	1995	[98]	10	17.27	13.90
N/D	HERMES	2002	[97]	1	2.20	0.97
Al/D	SLAC E139	1994	[99]	10	11.20	14.22
Al/C	NMC 96	1996	[101]	14	6.51	6.55
Ca	EMC 90	1989	[96]	19	13.17	12.56
Ca/D	NMC 95, re.	1995	[98]	12	29.61	31.12
	FNAL E665	1995	[102]	3	4431	6.01
	SLAC E139	1994	[99]	6	8.44	9.34
Ca/Li	NMC 95, re.	1995	[98]	10	7.36	5.16
Ca/C	NMC 95, re.	1995	[98]	10	6.47	6.70
	NMC 96	1996	[101]	14	7.14	6.99
Fe	SLAC E140	1993	[104]	2	0.05	0.05
Fe/D	SLAC E139	1994	[99]	14	34.08	34.18
Fe/C	NMC 96	1996	[101]	14	9.82	9.96
ν Fe	CDHSW	1991	[105]	464	347.74	365.14
$\bar{\nu}$ Fe	CDHSW	1991	[105]	462	423.06	398.25
Cu/D	EMC 93					
	EMC 88					
Kr/D	HERMES					
Ag/D	SLAC E13					
Sn/D	EMC 88					
Sn/C	NMC 96					
	NMC 96,					
Xe/D	FNAL E6					
Au/D	SLAC E13					
Pb/D	FNAL E6					
Pb/C	NMC 96					
ν Pb	CHORUS					
$\bar{\nu}$ Pb	CHORUS					
				In total:	2336	2072.29	2014.02

Date	Version	Files	Remarks
 02/2020	**2.0.1N Nuclear Daiquiri**	xfitter-2.0.1N.tgz	Nuclear xFitter based on OldFashioned 2.0.1

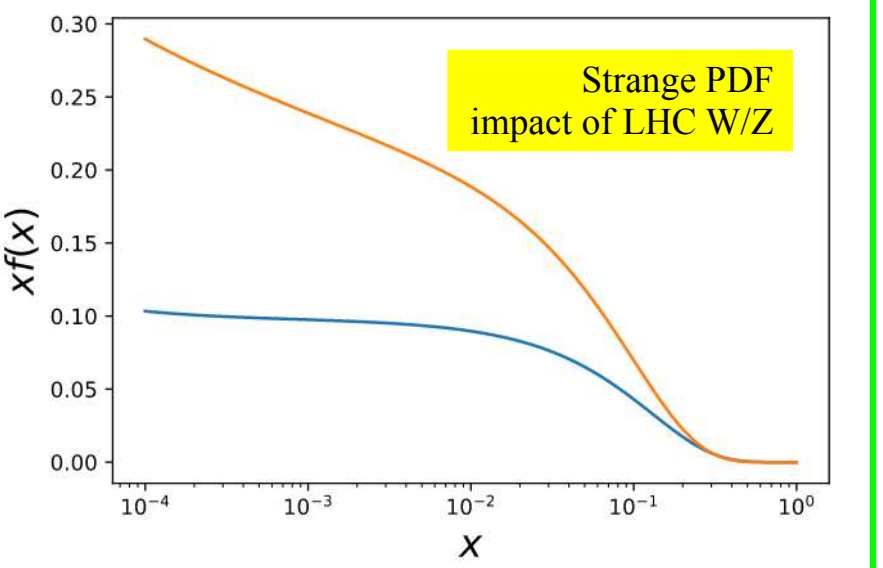


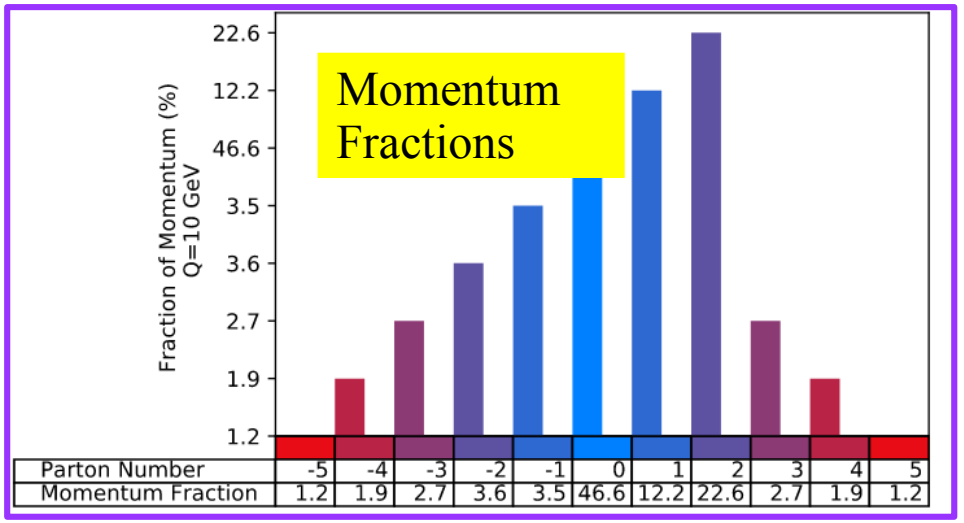
Python Jupyter Notebook

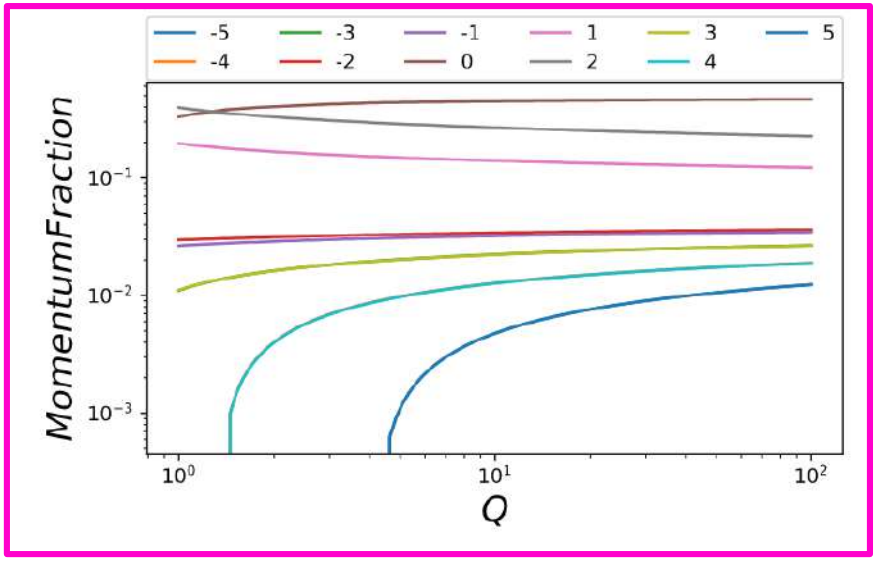
Python Jupyter Notebook




```
fig.savefig('testFigX.pdf')
```







Momentum Fractions vs. Q

Mathematica

ManeParse

Mathematica: ManeParse

http://www.ncteq.org

nCTEQ

nuclear parton distribution functions

ManeParse: A Mathematica Interface to the PDFs

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

ManeParse Publication:

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 3.0, 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 May 2020).
Includes PDF Grid files needed for demo.

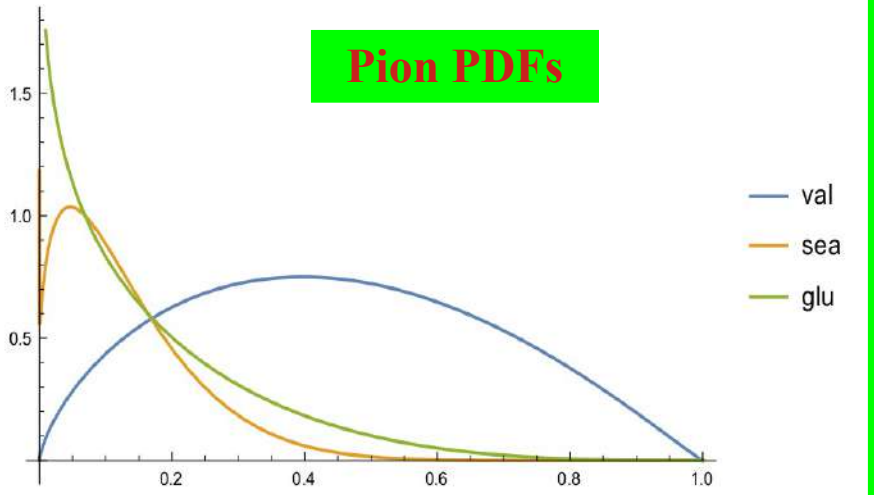
A SIMPLE example using Structure Function Tables:

This is an self-contained example that reads Structure Function tables in LHAPDF format.

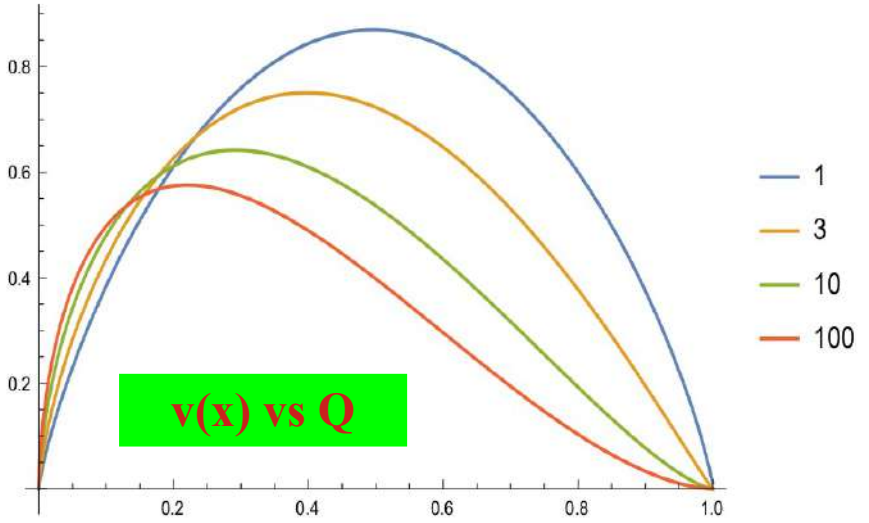
SF_DEMO_v01.zip
(460Kb, Version May 2020).
Includes Structure Function Grid files needed for demo.
Thanks to Tim Hobbs for supplying the sample tables.

```
q0 = 2.0 ;
iset0 = 1;
Plot[x {val[iset0, x, q0], sea[iset0, x, q0], glu[iset0, x, q0]}
 {x, 0.0, 1}, PlotLegends → {"val", "sea", "glu"}]
```

Pion PDFs



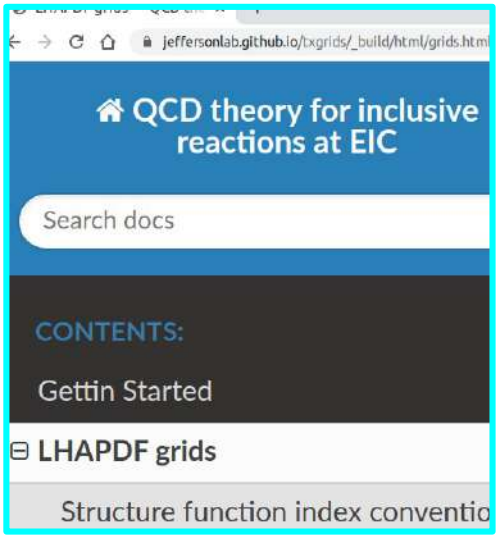

```
Plot[x {val[1, x, 1], val[1, x, 2], val[1, x, 10], val[1, x, 100]}
 {x, 0.0, 1}, PlotLegends → {"1", "3", "10", "100"}]
```



Mathematica: ManeParse

F_{123} Structure Functions

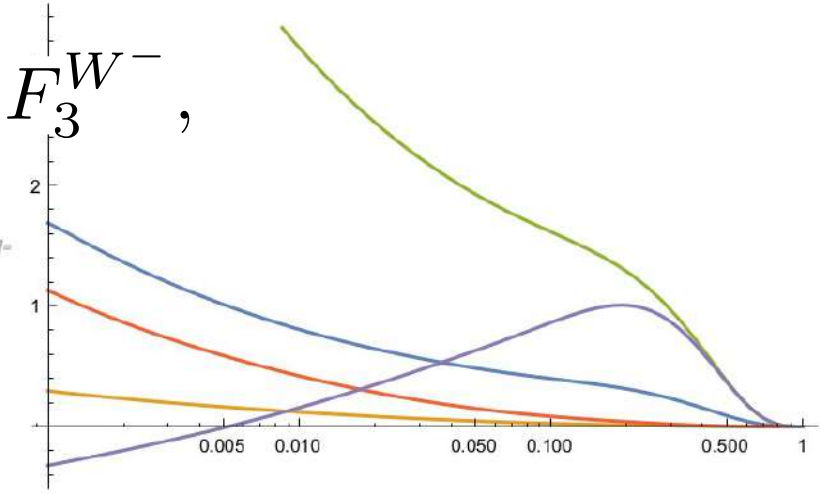
https://jeffersonlab.github.io/txgrids/_build/html/grids.html



$$F_2^\gamma, F_L^\gamma$$

$$F_2^{W^-}, F_L^{W^-}, F_3^{W^-},$$

```
q0 = 10. ;
LogLinearPlot[x pdf[1, flavors, x, q0] // Evaluate, {x, 10^-3, 1},
```



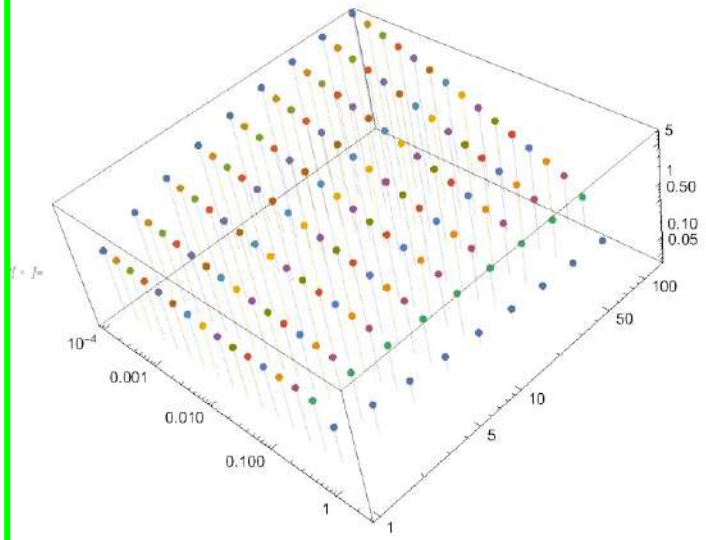
LHAPDF grids

Structure function index convention

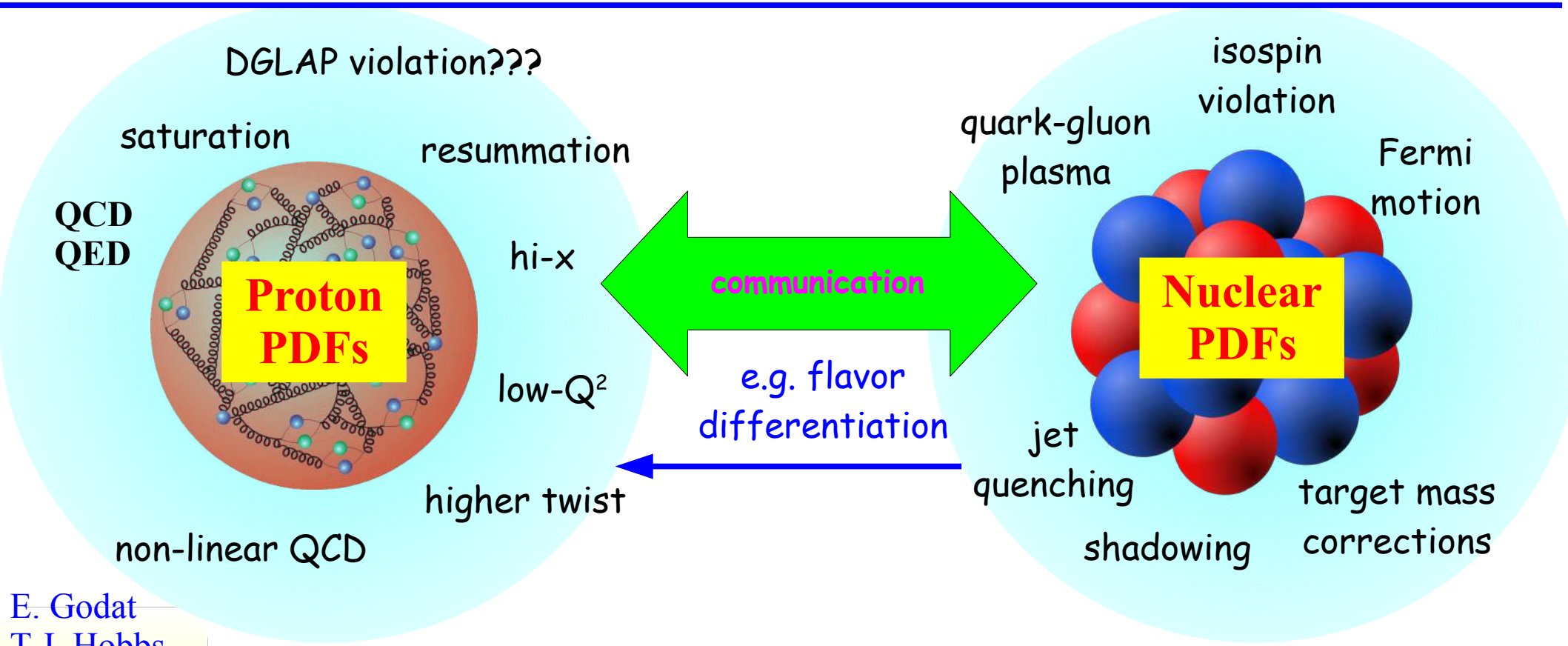
$(T = p, n, d, \ldots, A)$

Reaction	Structure Functions	Index
$e^\pm + T \to e^\pm + X$	$F_2^\gamma,\ F_L^\gamma$	900, 901
	$F_2^{\gamma Z},\ F_L^{\gamma Z},\ F_3^{\gamma Z}$	902, 903, 904
	$F_2^Z,\ F_L^Z,\ F_3^Z$	905, 906, 907
	$F_2^{\rm NC},\ F_L^{\rm NC},\ F_3^{\rm NC}$	908, 909, 910
	$F_{2c}^\gamma,\ F_{Lc}^\gamma$	911, 912, 913
	$F_{2c}^{\rm NC},\ F_{Lc}^{\rm NC},\ F_{3c}^{\rm NC}$	914, 915, 916
	$F_{2b}^\gamma,\ F_{Lb}^\gamma$	917, 918, 919
	$F_{2b}^{\rm NC},\ F_{Lb}^{\rm NC},\ F_{3b}^{\rm NC}$	920, 921, 922

```
ListPointPlot3D[data, ScalingFunctions → {"Log", "Log", "Log"},
 Filling → Bottom]
```



… the motivation for nCTEQ



E. Godat
T.J. Hobbs
T. Jezo,
C. Keppel,
M. Klasen
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