

From nucleon to meson PDF fits

... a cooperative presentation & discussion

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Thanks for substantial input
from our friends & colleagues



Workshop on Pion and Kaon
Structure Functions at the EIC
2-June 5, 2020
CFNS Virtual Meeting

I: Tools for nucleon and meson PDF fits

Nuclear Fits to Pion Fits
Analysis Tools (xFitter, Python, Mathematica)

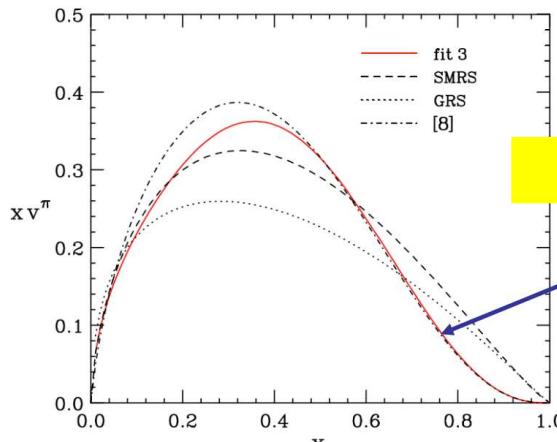
II: Toward Global Analyses of meson structure

Nucleon PDFs: CTEQ-TEA, CTEQ-JLab
Nuclear PDFs: nCTEQ (nuclear CTEQ)
Meson PDFs in the AMBER/EIC era
New methodology

III: Discussion

$$xv^\pi(x, Q_0^2) = N_v x^\alpha (1-x)^\beta (1 + \gamma x^\delta) \quad Q_0 = 0.63 \text{ GeV}$$

Fit	$2\langle xv^\pi \rangle$	α	β	γ	K	χ^2 (no. of points)
1	0.55	0.15 ± 0.04	1.75 ± 0.04	89.4	0.999 ± 0.011	82.8 (70)
2	0.60	0.44 ± 0.07	1.93 ± 0.03	25.5	0.968 ± 0.011	80.9 (70)
3	0.65	0.70 ± 0.07	2.03 ± 0.06	13.8	0.919 ± 0.009	80.1 (70)
4	0.7	1.06 ± 0.05	2.12 ± 0.06	6.7	0.868 ± 0.009	81.0 (70)



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Lei Chang

Screen View Options

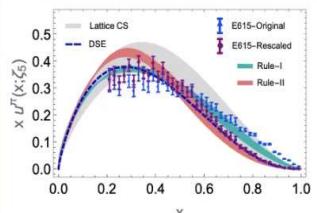


✓ Accommodate proton and pion DYW relation in LFHQCD

- ❖ Rule-1: $\sim (1-x)^{2\tau-3}$, with $g(\tau) = 2$
- ❖ Rule-2: $\sim (1-x)^{2\tau-2}$, with $g(\tau) = 2 + \frac{1}{\tau-1}$

✓ DCSB effect on PDA and PDF...not whole story

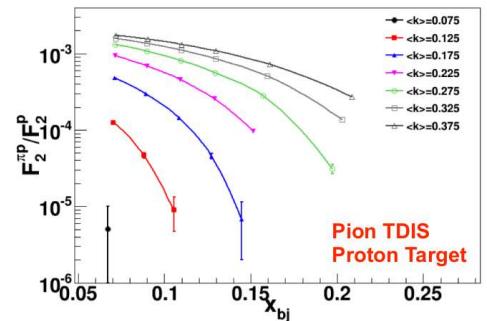
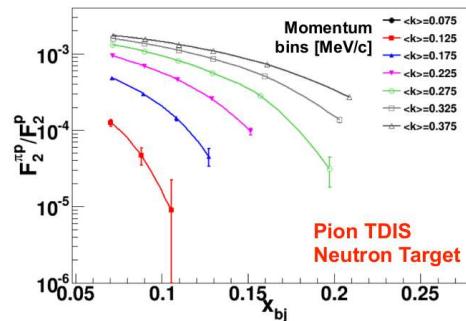
$$\text{PDF}_\pi \sim (1-x)^2 + M(Q^2)(1-x)^{\frac{2}{3}}$$



Thanks for your attention

Rachel Montgomery

Example Projected Results



- Top: x_{bj} dependence of ratio semi-inclusive SF to inclusive nucleon SF (points) in bins of momentum integration ranges for recoiling hadrons
- Bottom example of potential reach in t towards pion pole
- Low momentum reach of mTPC crucial to map out shape

Summary and outlook

Minghui Ding

Summary

- Using a **continuum approach**, presented a symmetry-preserving calculation of the **pion's PDF**.

- A novel term $q_{BC}^\pi(x; \zeta_H)$ is necessary to keep $q^\pi(x; \zeta_H) = q^\pi(1-x; \zeta_H)$ and then $\langle x_\pi^1 \rangle = 1/2$;
- $\zeta_H = 0.30 \text{ GeV}$ is the hadronic scale, and is determined by connecting the one-loop running coupling with QCD's **process-independent effective charge**.
- $q^\pi(x; \zeta_H)$ is a **broad function** and is a consequence of **dynamical chiral symmetry breaking**.
- Valence quark $q^\pi(x; \zeta_2)$ large x behaviour $\beta(\zeta_2) = 2.38(9)$, and first moment $\langle 2x \rangle_q^\pi = 0.48(3)$.
Valence quark $q^\pi(x; \zeta_5)$ agrees with rescaled E615 data and IQCD prediction, large x behaviour $\beta(\zeta_5) = 2.66(12)$, and first moment $\langle 2x \rangle_q^\pi = 0.42(4)$.
- Gluon and sea quark PDFs ζ_2 , $\langle x \rangle_g^\pi = 0.41(2)$, $\langle x \rangle_{\text{sea}}^\pi = 0.11(2)$, ζ_5 , $\langle x \rangle_g^\pi = 0.45(1)$, $\langle x \rangle_{\text{sea}}^\pi = 0.14(2)$.

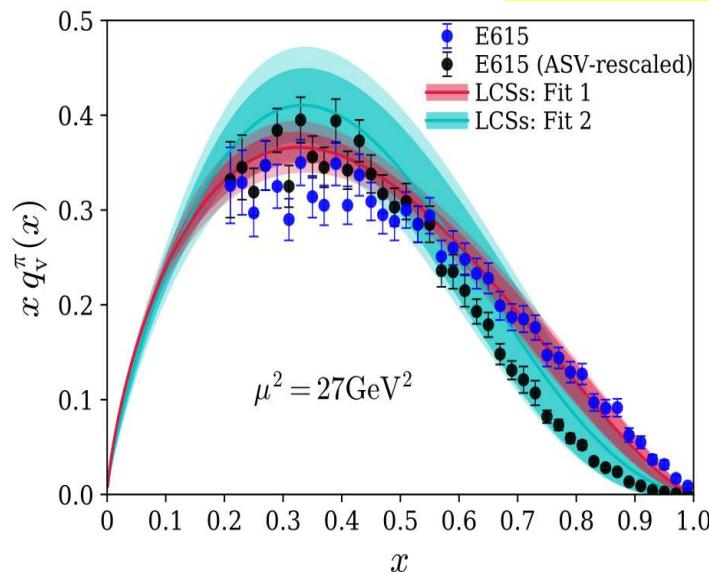
Outlook

- Kaon PDFs.
- Nucleon PDFs.

Thank you

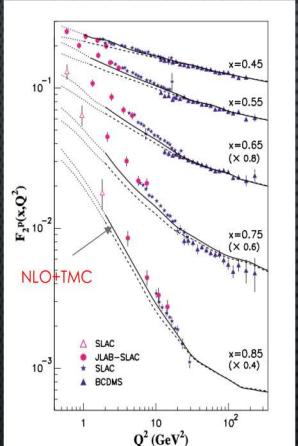
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David Richards

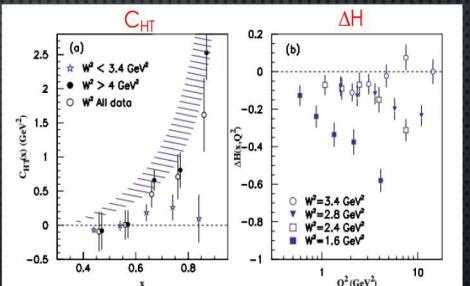


Slightly favors softer $[(1-x)^2]$ fit \rightarrow need for finer resolution in Ioffe time..

First hint of W^2 dependent effects



$$\frac{F_2^{\text{exp}}}{F_2^{\text{NLO+TMC}}} = 1 + \frac{C_{\text{HT}}(x)}{Q^2} + \Delta H(x, Q^2),$$



Simonetta Liuti

S. Liuti, R. Ent, C.E. Keppel, and I. Niculescu,
Phys. Rev. Lett. **89**, 162001 (2002)

NC STATE
UNIVERSITY

JAM Pion PDF Analysis Including Resummation

Patrick Barry, Nobuo Sato, Wally Melnitchouk, and C.-R. Ji
Workshop on Pion and Kaon Structure Functions at the EIC

Wednesday, June 3rd, 2020

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Patrick Barry

xFitter Pion PDFs

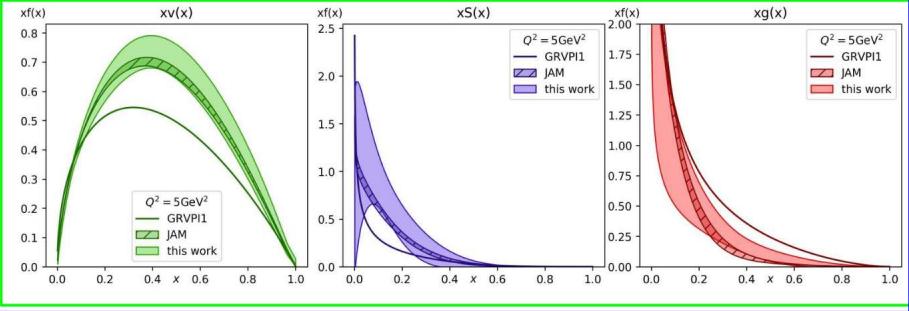
Experiment	Normalization uncertainty	χ^2/N_{points}
E615	15 %	206/140
NA10 (194 GeV)	6.4%	107/67
NA10 (286 GeV)	6.4%	95/73
WA70	32%	64/99

$$xv(x) = A_v x^{B_v} (1-x)^{C_v} (1+D_v x^\alpha),$$

$$xS(x) = A_S x^{B_S} (1-x)^{C_S} / \mathcal{B}(B_S + 1, C_S + 1),$$

$$xg(x) = A_g (C_g + 1) (1-x)^{C_g},$$

	$\langle xv \rangle$	$\langle xS \rangle$	$\langle xg \rangle$	$Q^2 = 9$ (GeV 2)
JAM [26]	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 [16]	0.428 ± 0.030			4
SMRS [20]	0.40 ± 0.02			4
Han et al. [42]	0.428 ± 0.03			4
DSE [7]	0.52			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 [14]	0.558 ± 0.166			5.76
Lattice-2 [15]	0.48 ± 0.04			5.76
this work	0.48 ± 0.05	0.25 ± 0.12	0.27 ± 0.13	5.76
WRH [21]	0.434 ± 0.022			27
ChQM-1 [11]	0.428			27
ChQM-2 [13]	0.46			27
this work	0.42 ± 0.04	0.25 ± 0.10	0.32 ± 0.10	27
SMRS [20]	0.49 ± 0.02			49
this work	0.41 ± 0.04	0.25 ± 0.09	0.34 ± 0.09	49



Final remarks

1. A theoretical model cannot be falsified empirically if its uncertainty is unknown.
2. Multiple functional forms of PDFs adequately describe the global set of experimental data.
3. The x –dependence of the best-fit PDF depends on the PDF definition (e.g., \overline{MS} factorization scheme), order of α_s , treatment of power-suppressed corrections, and other factors. Comparison to the pheno PDF requires proper conversion into the definition adopted by the pheno PDF.
4. Threshold resummation may modify both the shapes and normalizations of some pion DY cross sections. The resummed W term dominant at $Q^2/\hat{s} \rightarrow 1$ must be matched to the fixed-order (FO) cross section at $Q^2/\hat{s} < 1$. The resulting PDFs may depend on the resummed nonperturbative contributions at large Mellin moments N and the matching procedure.
5. Determination of sea quark and gluon PDFs in the pion generally benefits from the extended reach in Q in DIS and other processes.

2020-06-03

Nadolsky, Olness, Courtoy, Hobbs,
Pion-Kaon Workshop @ JLab

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