The Residual Mean Field Model and a Possible Universal Limit for Valence PDFs

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ABSTRACT

We developed the **Residual Mean Field** (RMF) model to analyze valence quarks inside the nucleon. We separate the nucleon into valence and residual subsystems using the formalism of effective light-front diagrammatic methods. Model parameterized through fitting of valence PDFs. Good agreement found for d_V and u_V, with some underestimation at high x for latter.

INTRODUCTION

- The nucleon state, $|N\rangle$, can be expressed as a Fock expansion in term of light front wave functions (LFWFs):

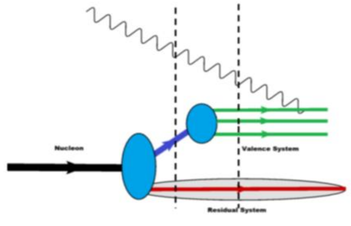
$$|N\rangle = \int [d\mu_{3q}]\,\psi_{3q}|qqq\rangle + \int [d\mu_{4q,\bar{q}}]\;\psi_{4q,\bar{q}}\,|qqq\,\bar{q}q\rangle + \int [d\mu_{3q,1g}]\,\psi_{3q,1g}|qqq\,\boldsymbol{g}\;\rangle + \cdots$$

- No one has been able to derive the QCD LFWFs completely from theory. Instead, we model $|N\rangle$ phenomenologically by assuming:

Nucleon = Valence x Residual*

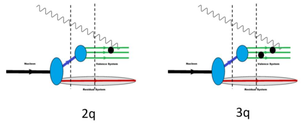
* gluons, sea quarks, meson cloud, etc.

$$|N\rangle = \psi_{3q}|3q\rangle \otimes \psi_{VR}\,|\,VR\rangle$$



Soft

- Only will focus on Soft. Later, 2q & 3q

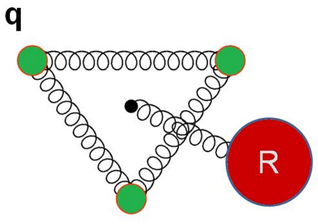


THE MODEL

1. Core of valence quarks - Effective bound fermions (fixed number)
2. Valid for $x > 0.1$ and different mechanisms dominate
3. Use a spectral function approach
4. Residual structure universal

- Can express valence PDF, $f_V(x, Q^2)$, through LFWFs:

$$f_V(x,Q^2) = \int \prod_{i=1,2,3,R} \frac{dx_i}{x_i}\,\delta\left(1 - \sum_{i=1,2,3,R} x_i\right)\delta(x_1 - x_B) \times \int \prod_{i=1,2,3,R} \frac{d^2k_{i,\perp}}{16\pi^3}\,16\pi^3\delta^{(2)}\left(\sum_{i=1,2,3,R} \boldsymbol{k}_{i,\perp}\right) |\boldsymbol{\psi_{VR}}|^2 |\boldsymbol{\psi_{3q}}|^2$$



- The Use LF relativistic, harmonic oscillators to model $\boldsymbol{\psi_{VR}}$ and $\boldsymbol{\psi_{3q}}$.

- Assume massless valence quarks. The 8-dimensional phase space integral above can be reduced to:

$$x f_V(x) = \mathcal{N}' x \int_0^{1-x} dx_R\,\frac{(1-x_R-x)^3}{(1-x_R)^3}\exp\left[-B_R m_N^2\left(x - \frac{\boldsymbol{m_R}}{m_N}\right)^2\right]$$

- 3 parameters: $\mathcal{N}', B_R, \boldsymbol{m_R}$

RESULTS

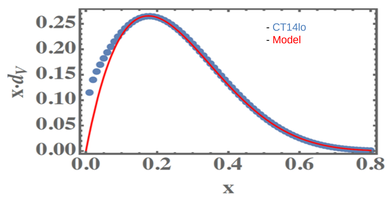
- The valence PDF peaks at:

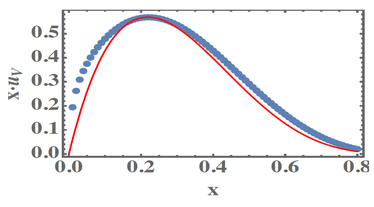
$$x_p \approx \frac{1}{4}\left(1 - \frac{m_R}{m_N}\right) \leq \frac{1}{4}$$

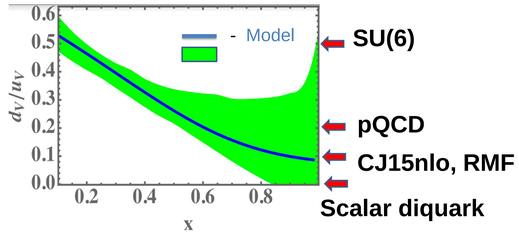
- Asymptotically,

$$f(x) \sim_{x\to 1} (1-x)^{\beta_V}$$
$$\beta_V = 4$$

- Fitting to CT14lo at peak:







$$0.06 \leq \left.\frac{d_V}{u_V}\right|_{x\to 1} \leq 0.1$$

- Can repeat calculation for general n_V valence quarks:

$$x_p \approx \frac{1}{2(n_V - 1)}\left(1 - \frac{m_R}{m_N}\right)$$
$$\Rightarrow x_p \leq \frac{1}{2(n_V - 1)}$$

TABLE I: Fitting parameters for valence d- and u- quarks.

d-quark	N^d	B_R^d(GeV^{-2})	m_R^d (GeV)	u-quark	N^u	B_R^u (GeV^{-2})	m_R^u (GeV)
CT14LL0	64	30	0.26		174	42	0.07
CT14L0	63	29	0.24		183	42	0.06
CJ15lo	47	6	0.32		208	50	0.05
MMHT2014lo	76	50	0.16		228	60	0.04
MSTW2008lo	71	50	0.17		235	65	0.04

OUTLOOK

- Can analyze SIDIS, DVCS through **TMDs, GPDs w/ model for $x = 0.1 - 0.4$** (higher for d_V)

SUMMARY

- We developed the **Residual Mean Field Model**
- Works well for d_V
- Large x seems to indicate **2q and 3q needed for u_V**
- $\left.\frac{d_V}{u_V}\right|_{x\to 1} = 0.09$ for RMF model
- Generalized model to n_V valence quarks and found **new relation of peaks for valence PDFs**

ACKNOWLEDGEMENTS

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