NANJING UNIVERSITY

PDAs ⇔ PDFs

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PDAs & PDFs

- Relationship between leading-twist PDAs and valence-quark PDFs, expressed via a meson's light-front wave function (LFWF):

$$\varphi(x) \sim \int d^2k_\perp \psi(x, k_\perp^2)\,,$$
$$q(x) \sim \int d^2k_\perp |\psi(x, k_\perp^2)|^2$$

- Given that factorization of LFWF is a good approximation for integrated quantities, then at the hadronic scale, ζ_H:

$$q_{\pi,K}(x;\zeta_H) \propto \varphi^q_{\pi,K}(x;\zeta_H)^2$$

  Proportionality constant is fixed by baryon number conservation

- Owing to parton splitting effects, this identity is not valid on $\zeta > \zeta_H$.

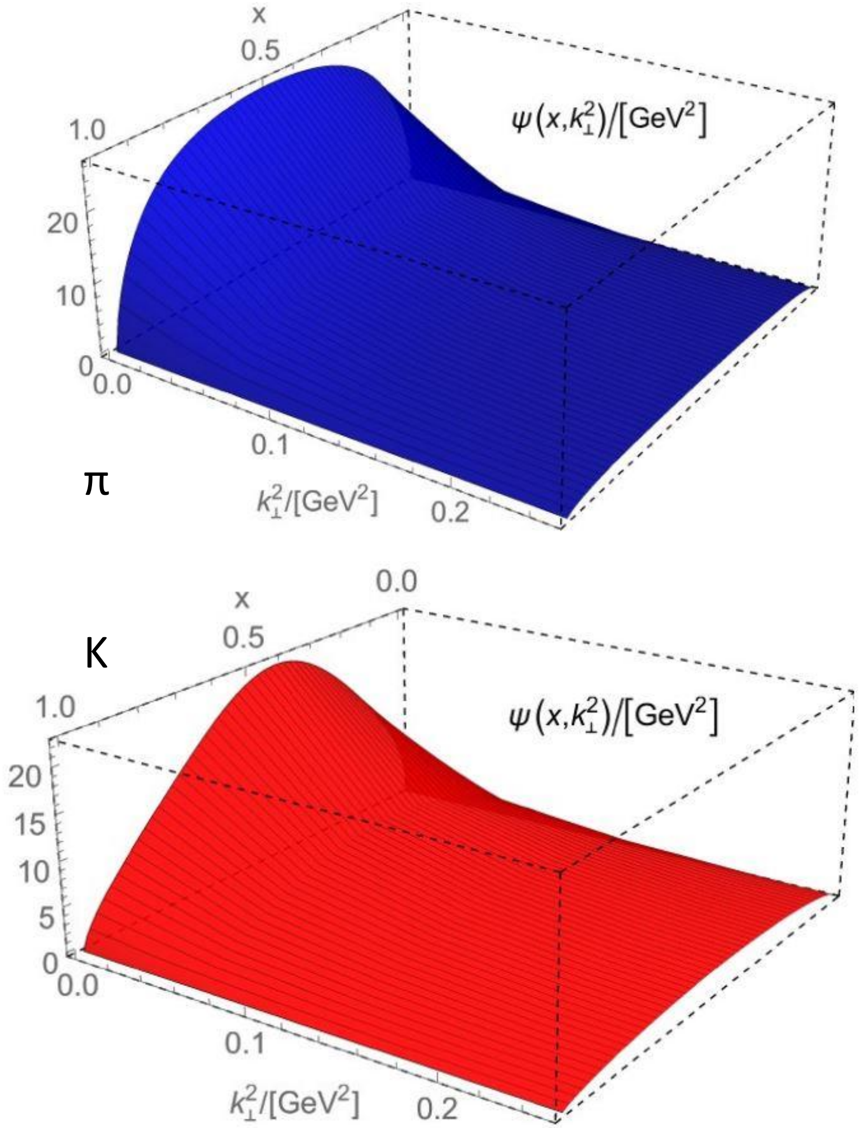
  (Think about DGLAP and ERBL regions for a GPD.)

- Nevertheless, evolution equations are known; so the connection is not lost, it just metamorphoses.

Light Front Wave Function

- In many respects, a hadron's LFWF is the key.
- LFWF correlates all observables
- EHM is expressed in every hadron LFWF
- The "trick" is to find a way to compute the LFWF

- Experiments sensitive to differences in LFWFs are sensitive to EHM
- Excellent examples are π & K PDAs and PDFs
  - Two sides of the same coin
  - Accessible via different processes
  - Independent measurements of the same thing
  - Great check on consistency



Controversy over pion PDF

- QCD prediction for the PDF of a spin-zero meson:

$$x \simeq 1 \Rightarrow q^\pi(x;\zeta_{\rm H}) \propto (1-x)^2$$

- Modern perspective: $\zeta_{\rm H}$ is the upper bound on QCD's conformal window: $\zeta_{\rm H}$ = 0.43(1) GeV.
- The hadronic scale is not empirically accessible in Drell-Yan or DIS processes.
  (Matter of conditions necessary for data to be interpreted in terms of distribution functions.)
- For such processes, the QCD prediction translates into the following statement:

  At any scale for which experiment can be interpreted in terms of parton distributions, then

$$x \simeq 1 \Rightarrow q^\pi(x;\zeta) \propto (1-x)^{\beta=2+\gamma}, \gamma > 0$$

- Any DY or DIS (or similar) experiment or analysis thereof which returns

  a value of β <2 conflicts with QCD.
- Amongst all existing analyses of data for pion valence-quark PDFs, only [Aicher:2010cb] employs a fully consistent NLO analysis, including threshold resummation.
  - Only [Aicher:2010cb] result for $q^\pi(x;\zeta)$ agrees with QCD.
  - All other analyses conflict with QCD.
- This is the controversy.

Theory vs Phenomenology

- Modern continuum and lattice results agree on $q^{\pi}(x;\zeta)$ (Refs. [44,45])
- JAM 2018 (Ref. [107]) analysis of DY and leading-neutron data did NOT include threshold resummation and does NOT meet QCD constraint
- Mismatch on valence must feed into something else
  - Seemingly, gluon is unaffected. However, this glue distribution is very different from earlier phenomenological analyses
  - Apparently, mismatch feeds into pion's sea distribution. If gluon is uncertain, then sea is unknown.

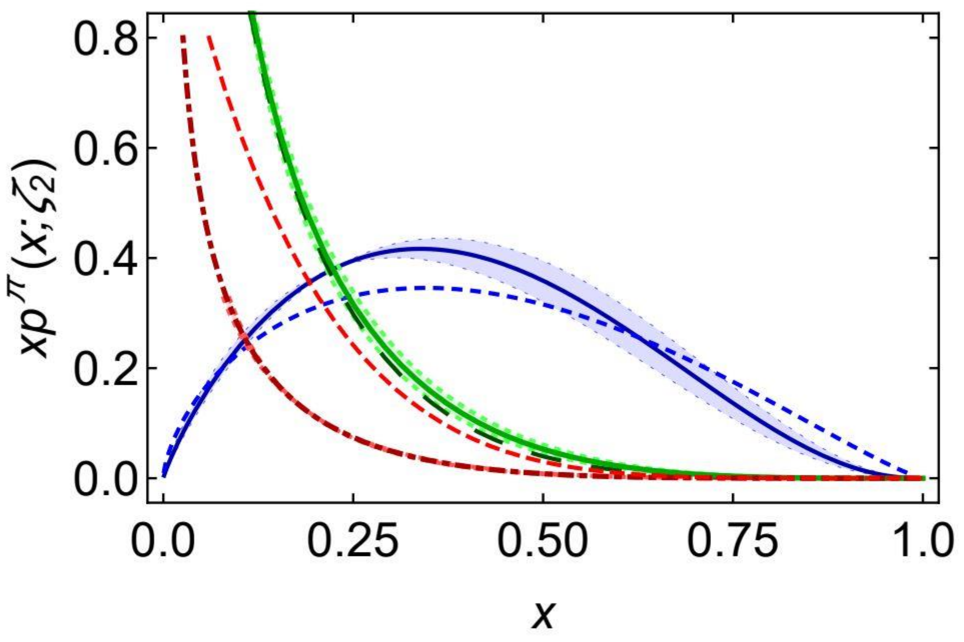


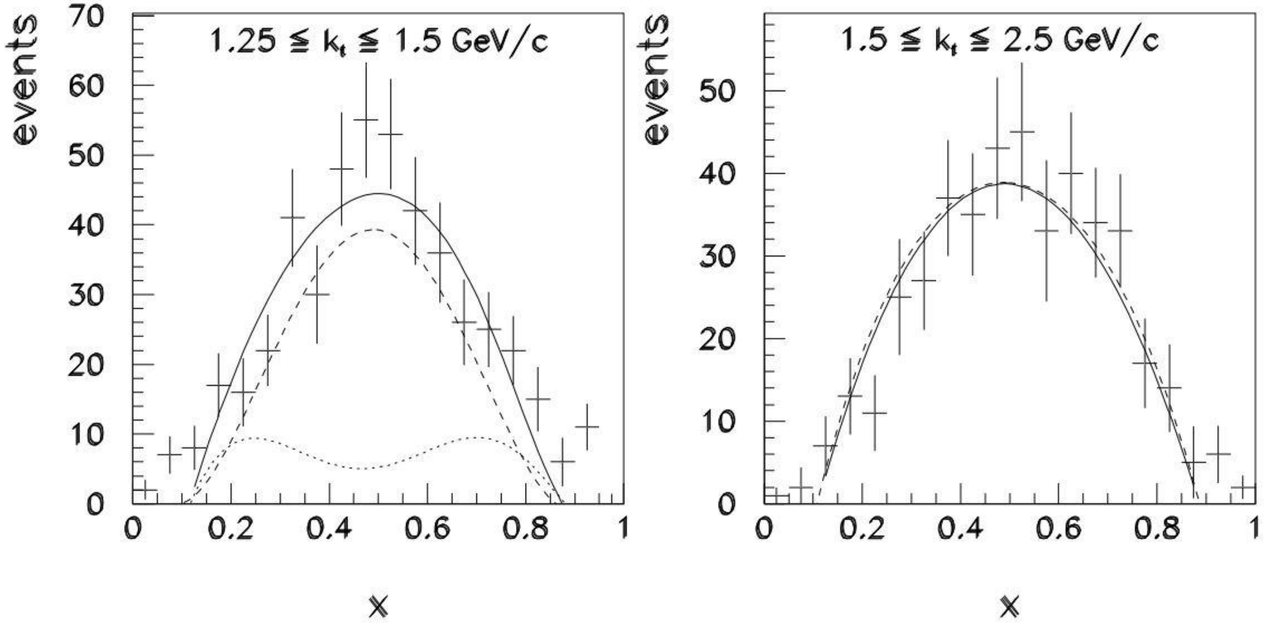
FIG. 6. Parton distributions from Refs. [44, 45] evaluated at $\zeta_2 = 2\,\text{GeV}$: p = valence – solid blue curve; p = glue – solid green; and p = sea – dot-dashed red. Phenomenological results (at $\zeta = 3.2\,\text{GeV}$) from Ref. [107, Fig. 2] are plotted for comparison: p = valence – short-dashed blue; p = glue – long-dashed dark-green; and p = sea – dashed red (corrected curve, as drawn in Ref. [128, Fig. 3]).

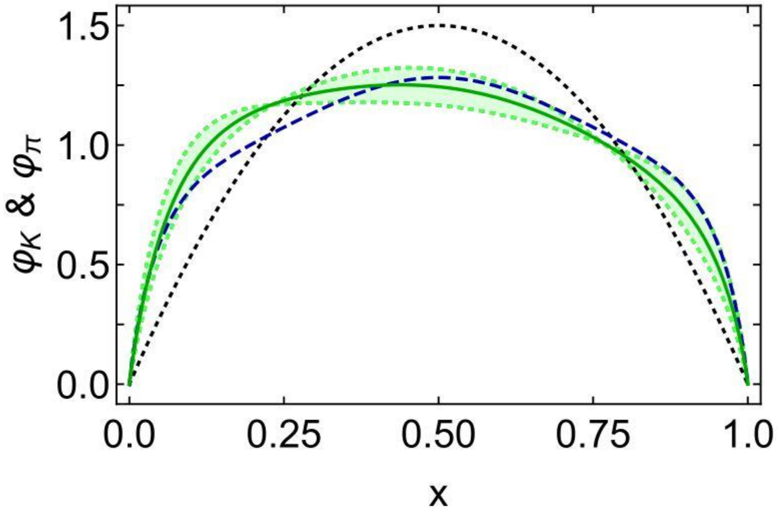
Controversy over PDAs

- E791 Collaboration, E. Aitala *et al.*, Phys. Rev. Lett. 86, 4768 (2001).
  - Claim: $\varphi_\pi(x)$ is well represented by the asymptotic profile for $\zeta^2 > 10\ \text{GeV}^2$
- Modern continuum predictions and analyses of lQCD
  - PDAs are broadened at $\zeta^2=4\ \text{GeV}^2$
  - Evolution is logarithmic $\Rightarrow$ if true at $\zeta^2=4\ \text{GeV}^2$, then true at $\zeta^2=10\ \text{GeV}^2$
- Simple theory shows that E791 conclusion cannot be correct
  - The E791 images cannot represent the same pion property
  - Not credible to assert that $\varphi_\pi(x)$ is well represented by the asymptotic distribution for $\zeta^2 > 10\ \text{GeV}^2$

Left: Nonpertubative (broadening) important

Right: Asymptotic profile sufficient





- Hard exclusive processes only sensitive to low-order PDA moments.
- Diffractive processes much better because sensitive to x-dependence (check this claim)