Brookhaven National Laboratory

QCD Predictions for Pion and Kaon Form Factors at Large Momenta

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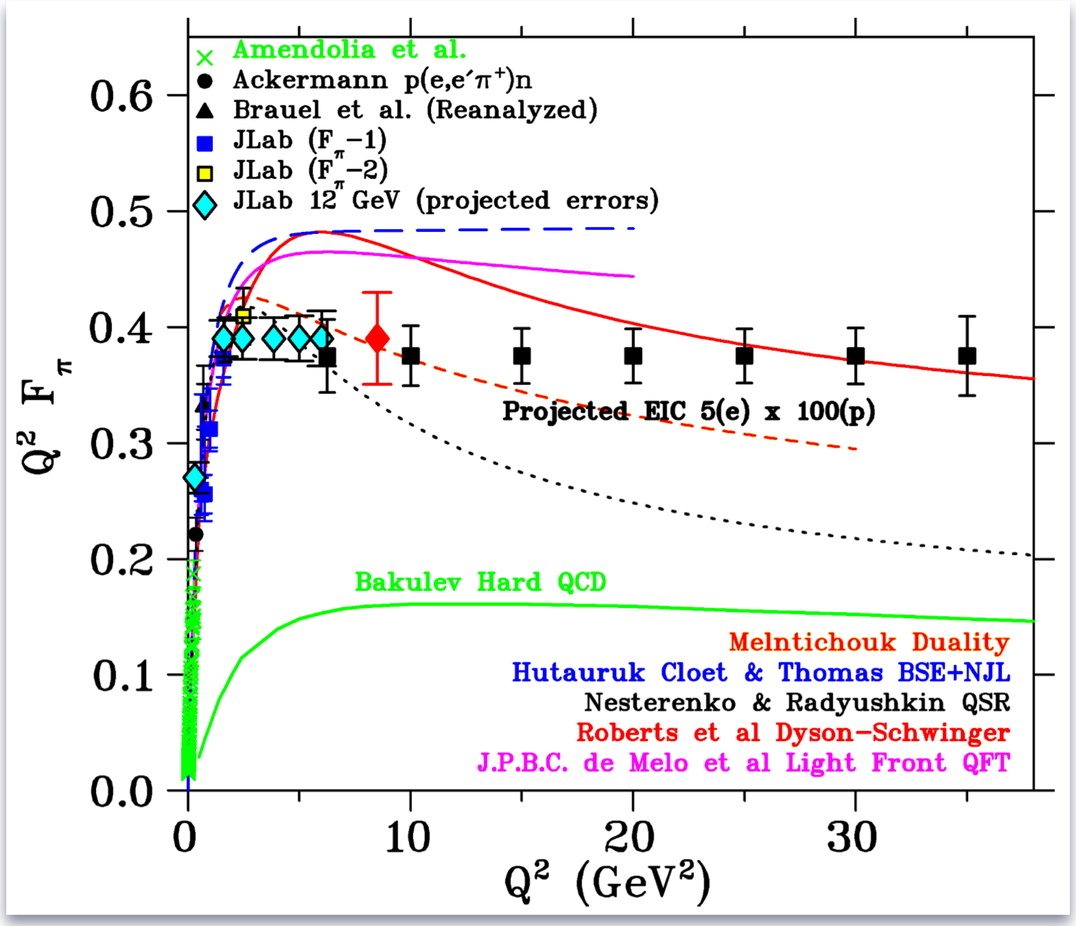
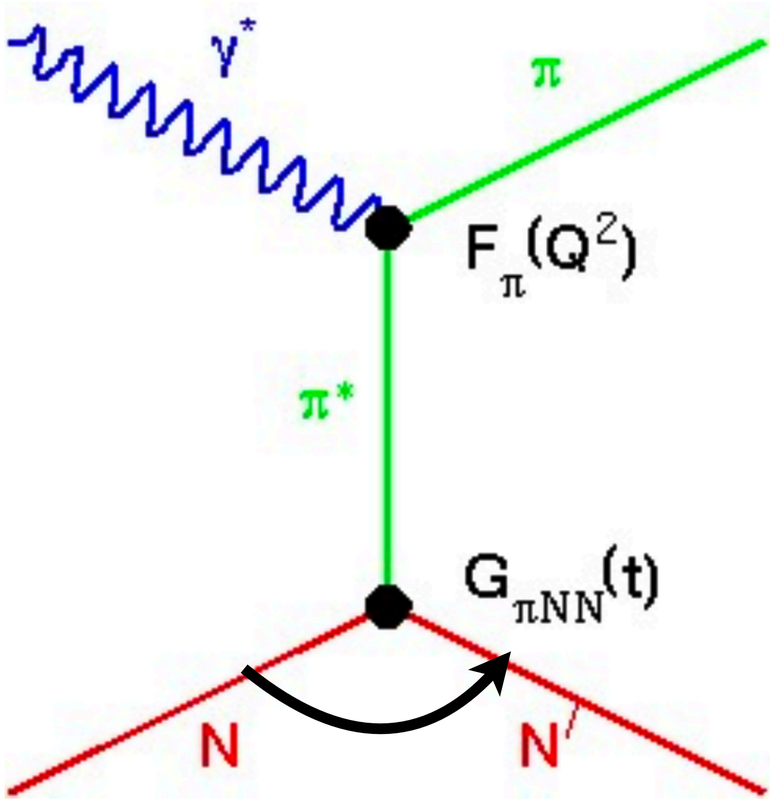
$F_\pi(Q^2), F_K(Q^2)$: JLab to EIC



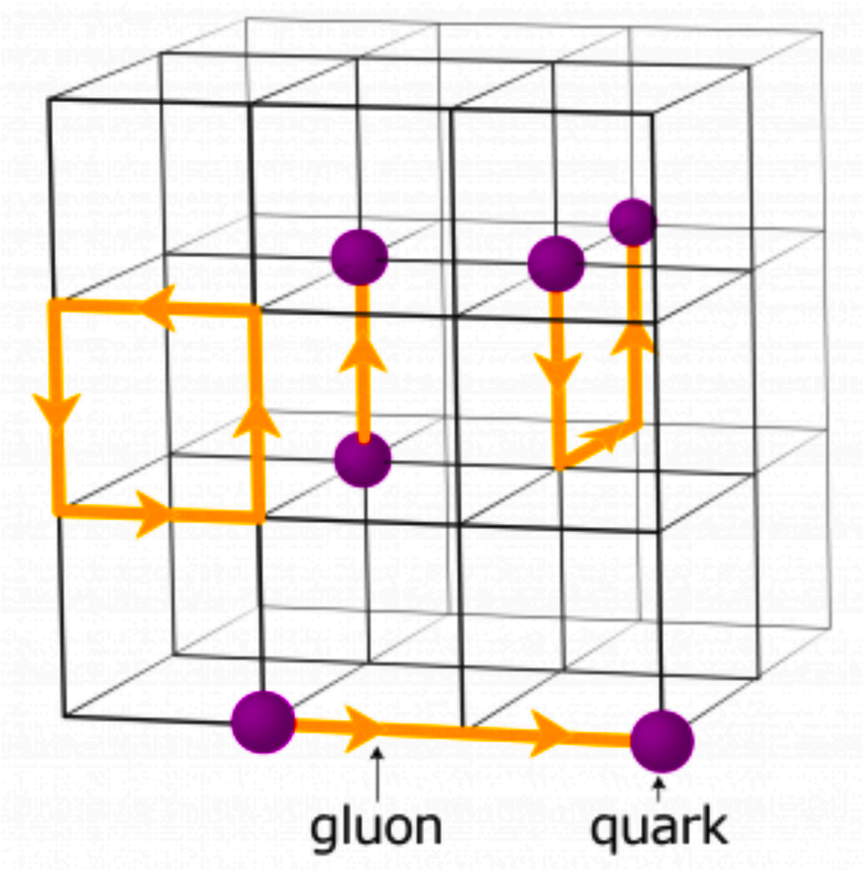


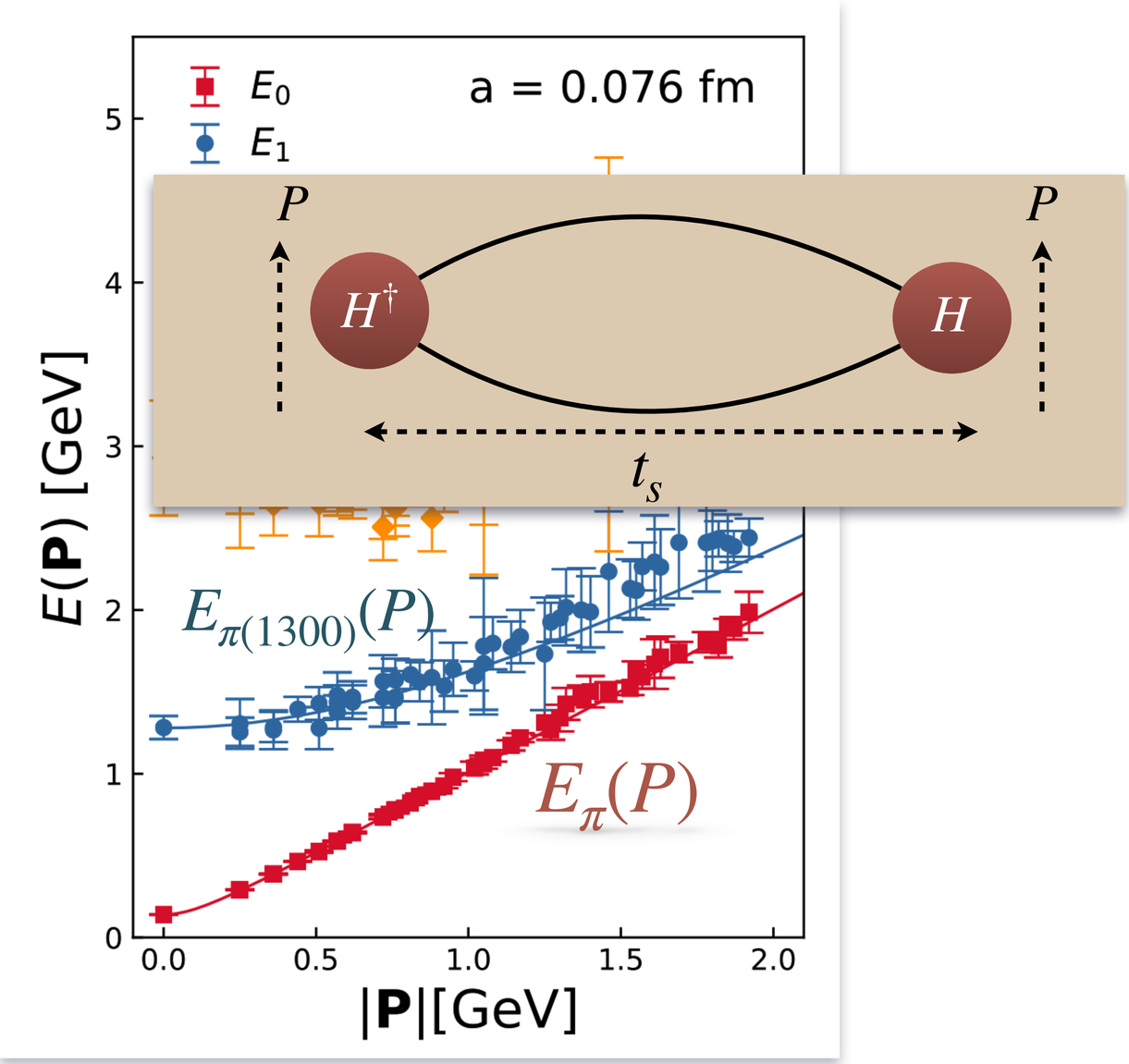
$$Q^2 \to m_\pi^2, m_K^2$$

model dependent

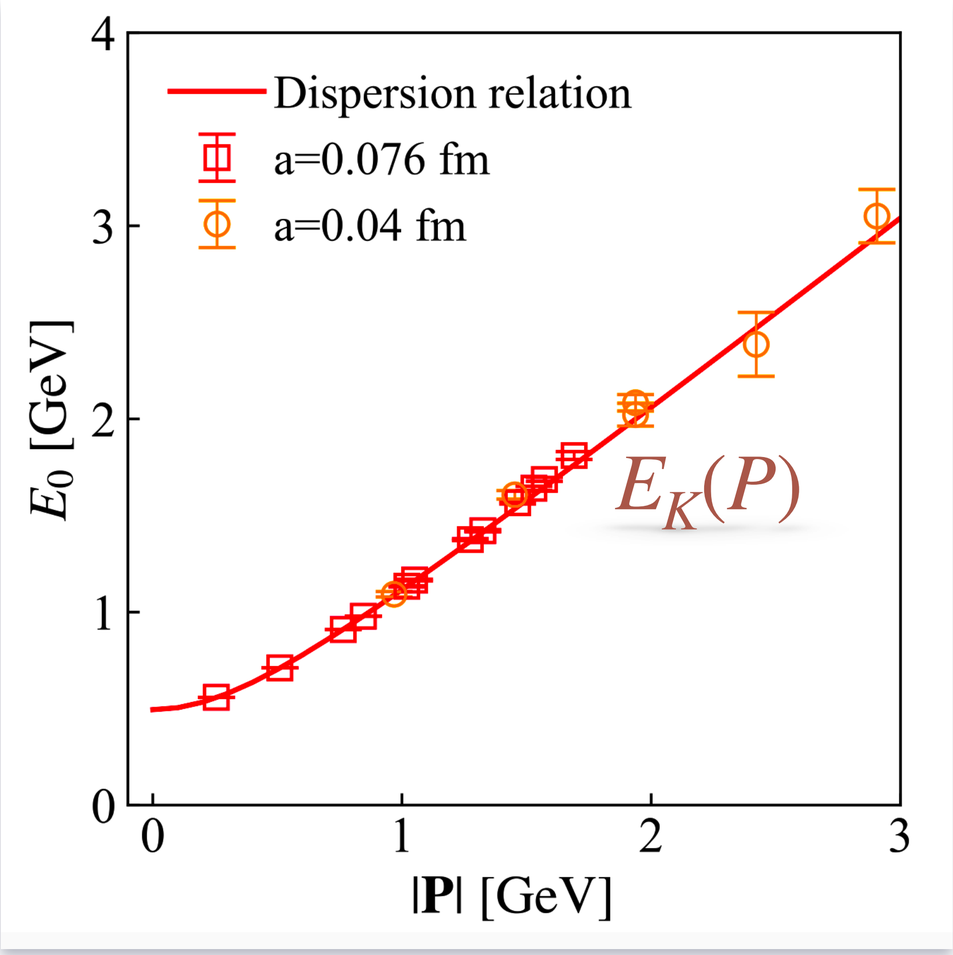
$F_\pi(Q^2), F_K(Q^2)$: lattice QCD

QCD in its full glory





physical m_π and m_K



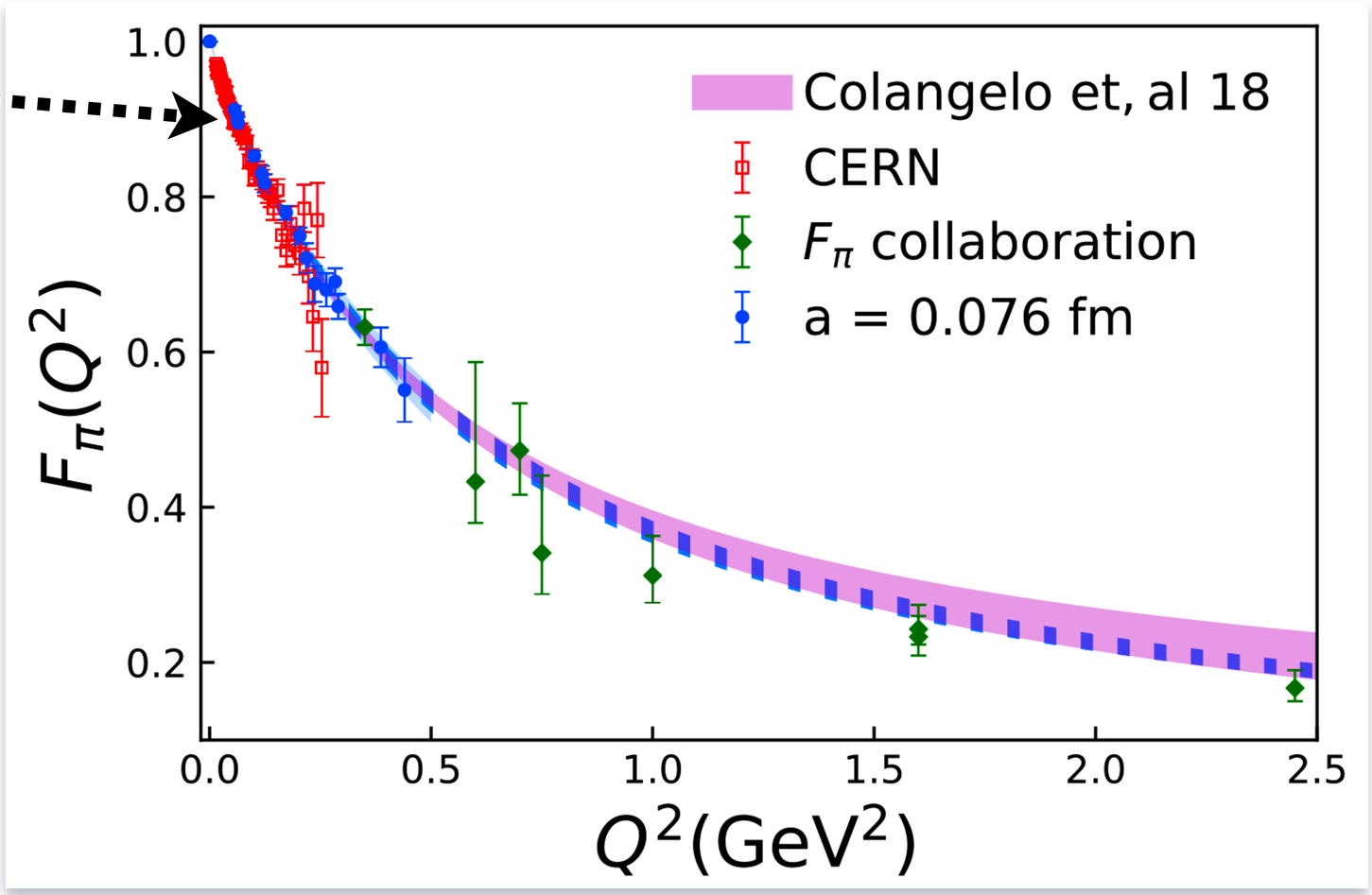
$F_\pi(Q^2)$: many facets of QCD

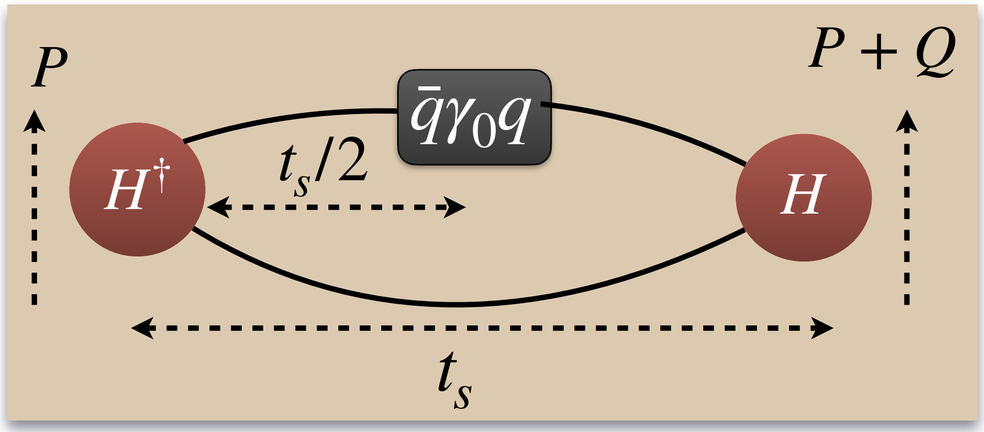
low Q^2: π charge radius

$$r_\pi^2 = 0.42(2)\ \mathrm{fm}^2$$

non-perturbative QCD

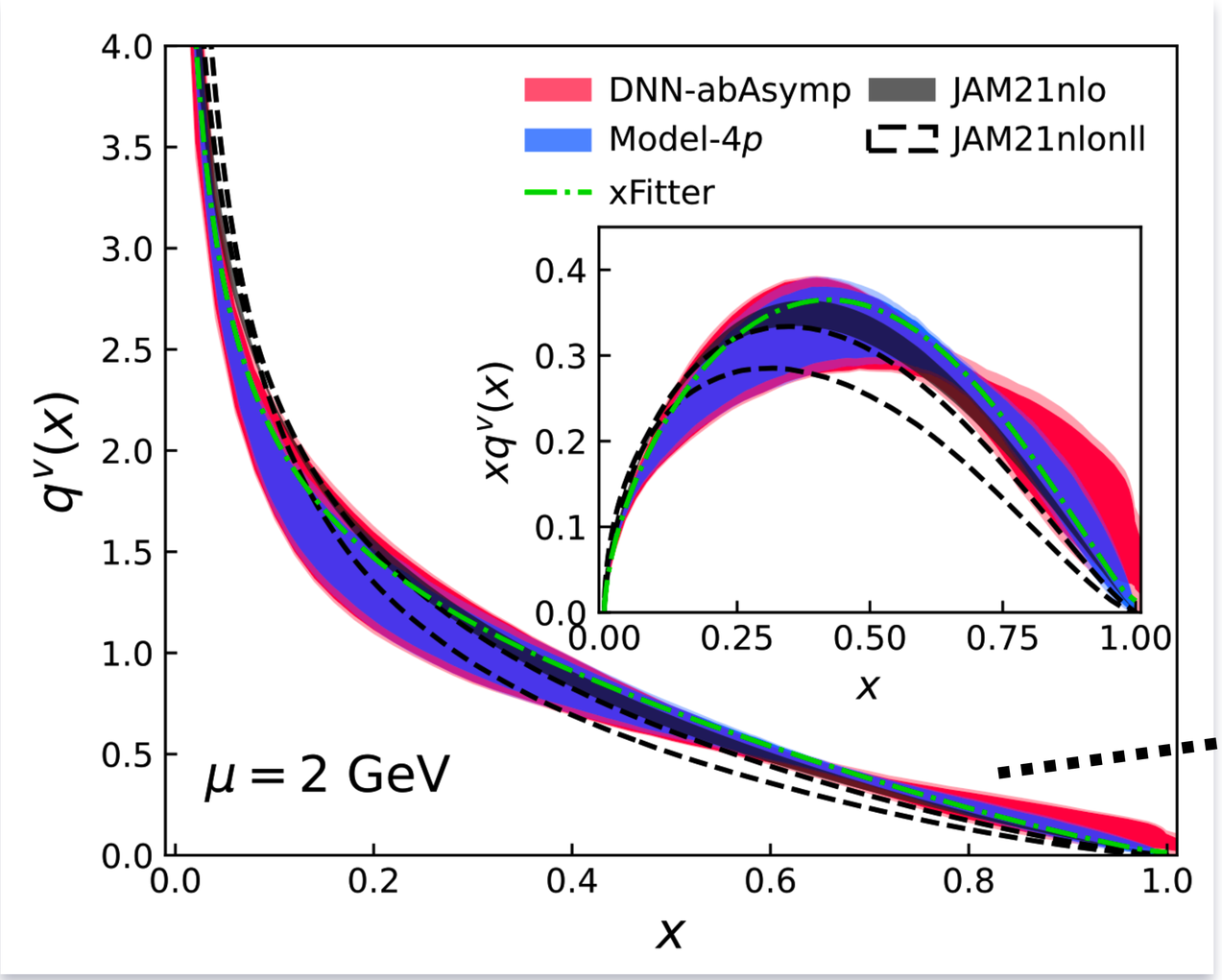
$$r_\pi^2 = -6\,\frac{dF(Q^2)}{dQ^2}\bigg|_{Q^2=0}$$





Xiang Gao et al., Phys. Rev. D104, 11 (2021)

intermediate Q^2: π valance PDF at $x \to 1$



Drell-Yan-West relation

$$q_\pi^v(x \to 1) \sim (1-x)^\beta$$

$$\downarrow$$

$$F_\pi^(Q^2) \sim Q^{-(\beta+1)}$$

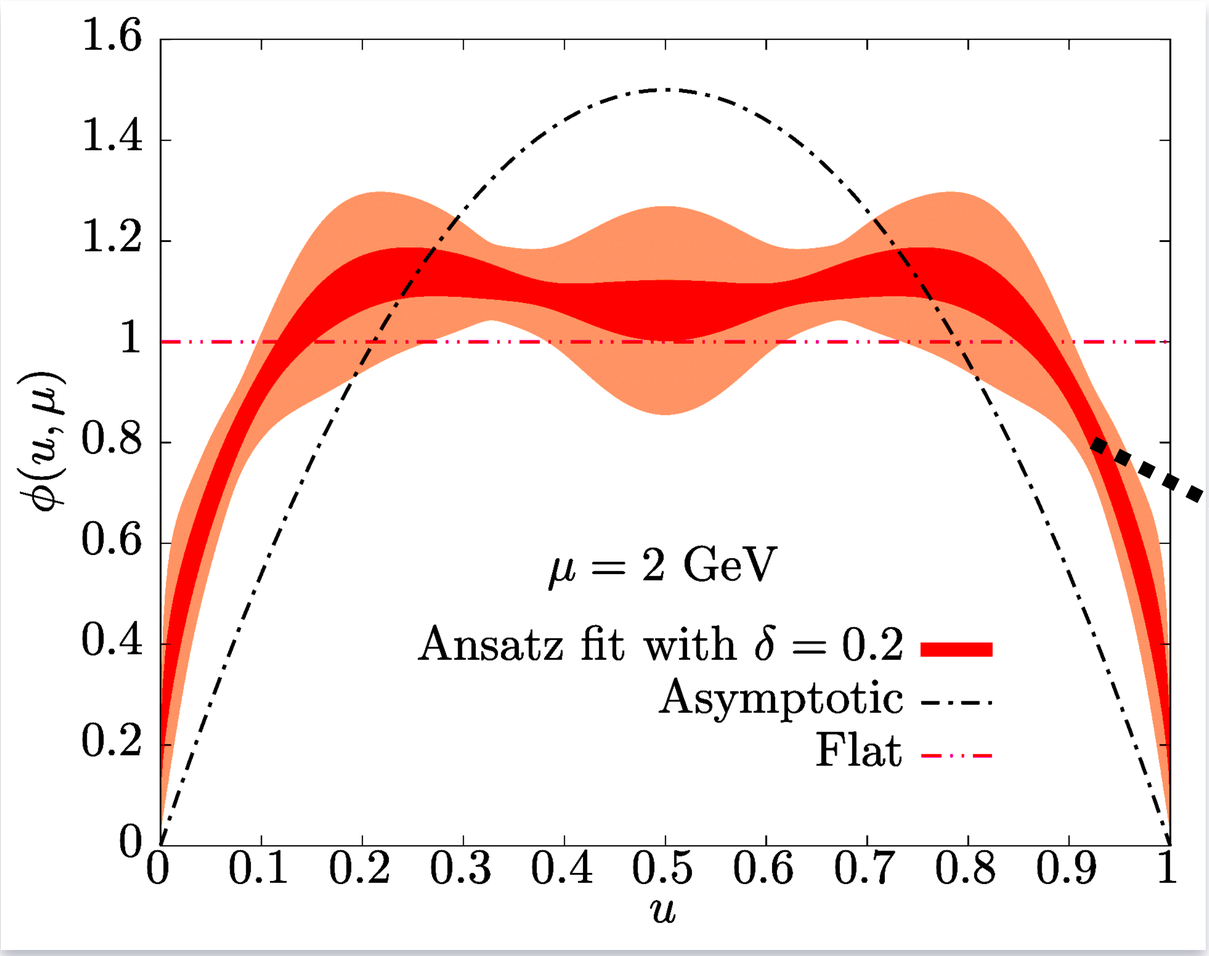
$$q_\pi^v(x) \sim (1-x)$$

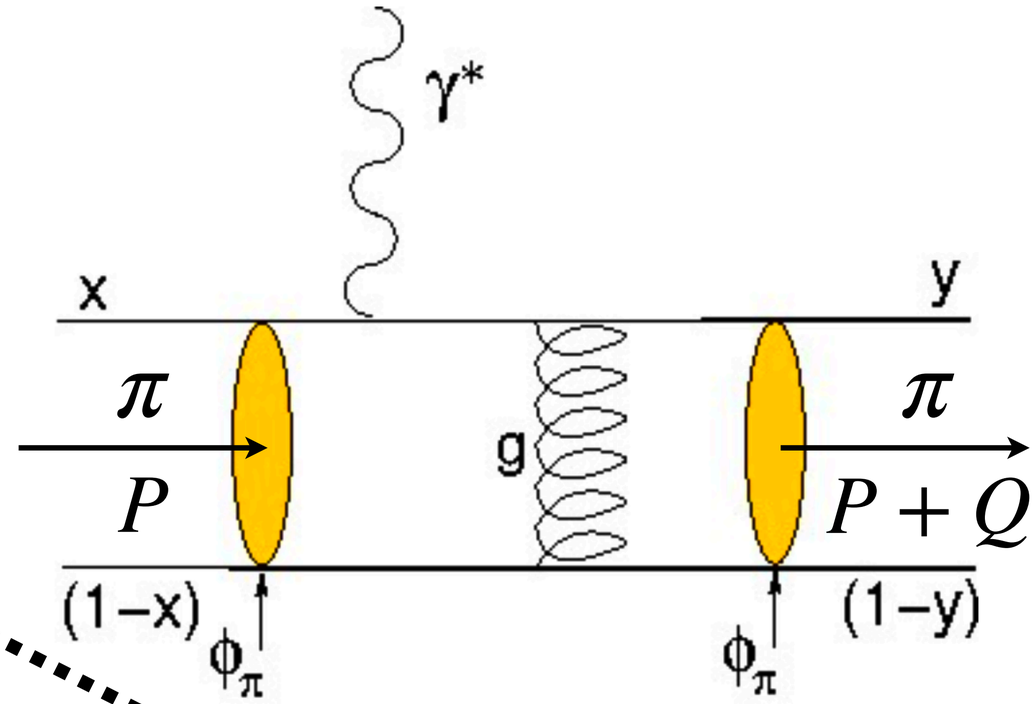
$$\downarrow$$

$$F_\pi(Q^2) \sim Q^{-2}\,??$$

Xiang Gao et al., Phys. Rev. D106, 114510 (2022)

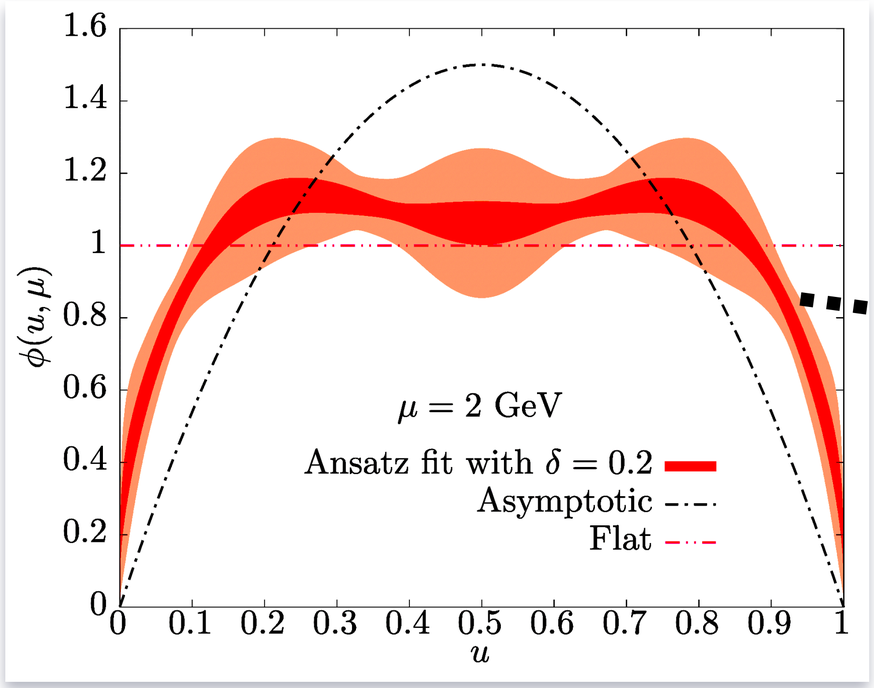
high Q^2: perturbative QCD and π distribution amplitude

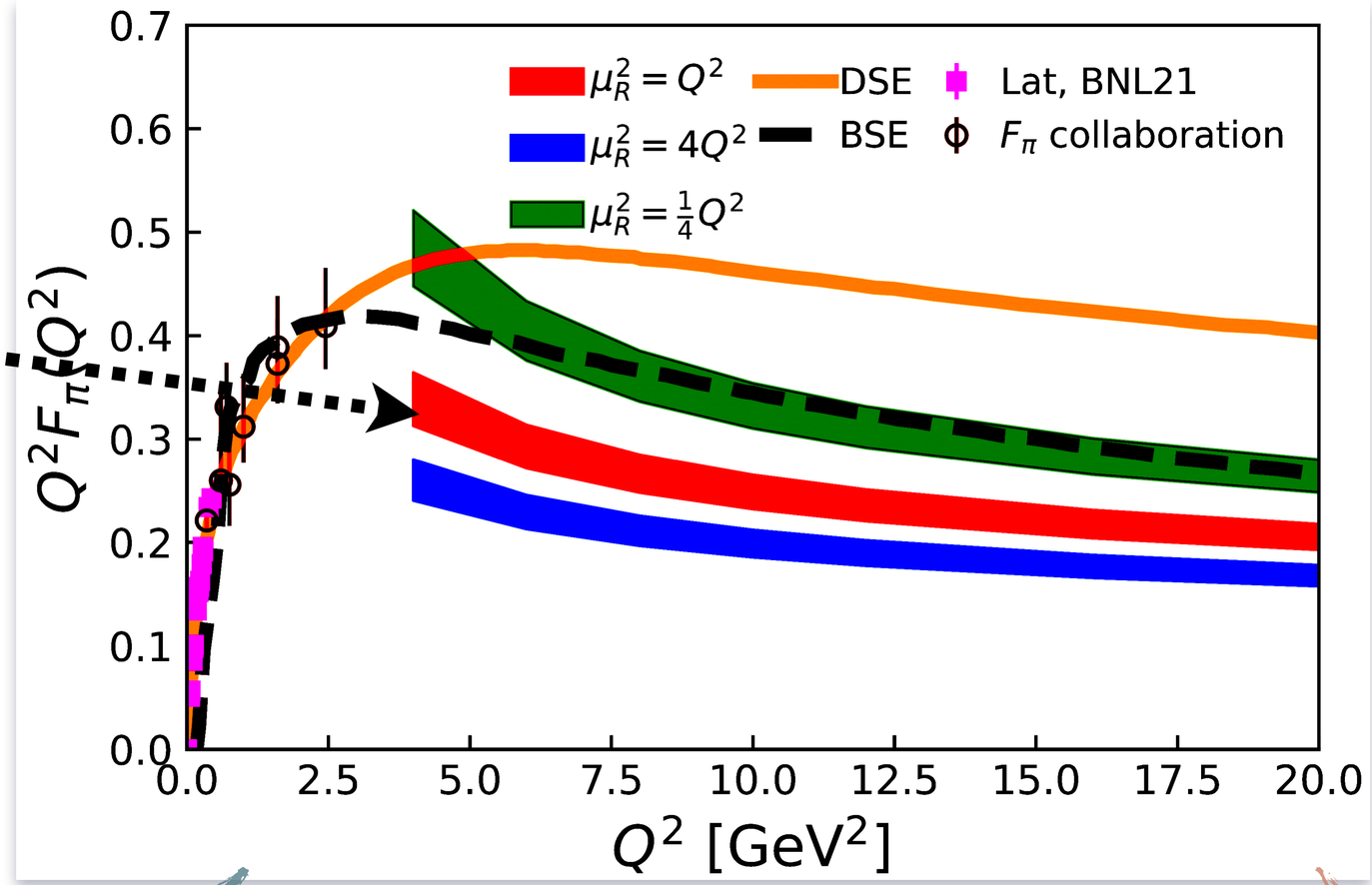




$$F_\pi(Q^2) = \int\int dxdy\, \phi^*(x,\mu^2)T(x,y,Q^2,\mu^2)\phi(y,\mu^2)$$

Nikhil Karthik et.al., Phys. Rev. D106, 074505 (2022)



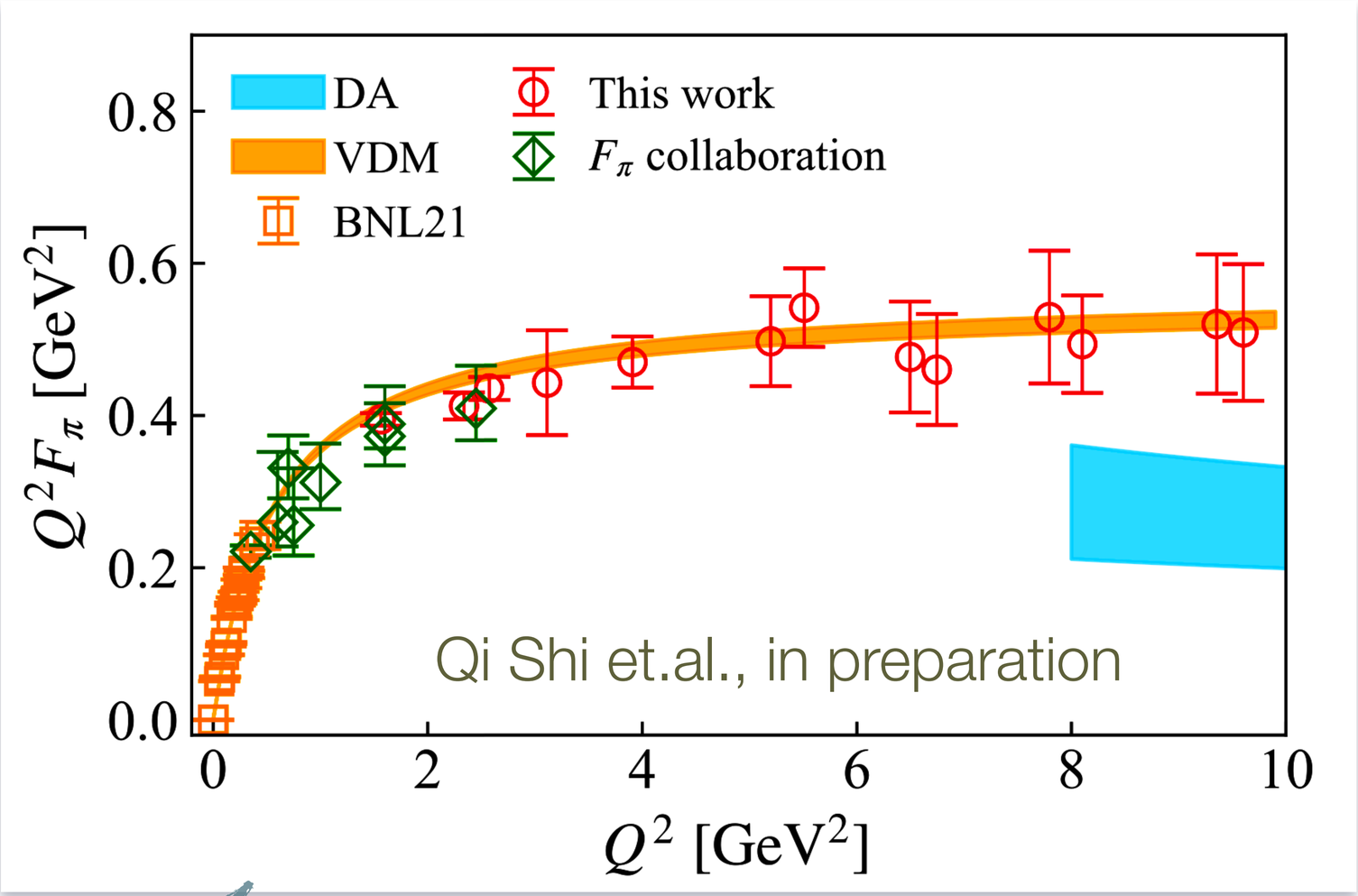


JLab

EIC

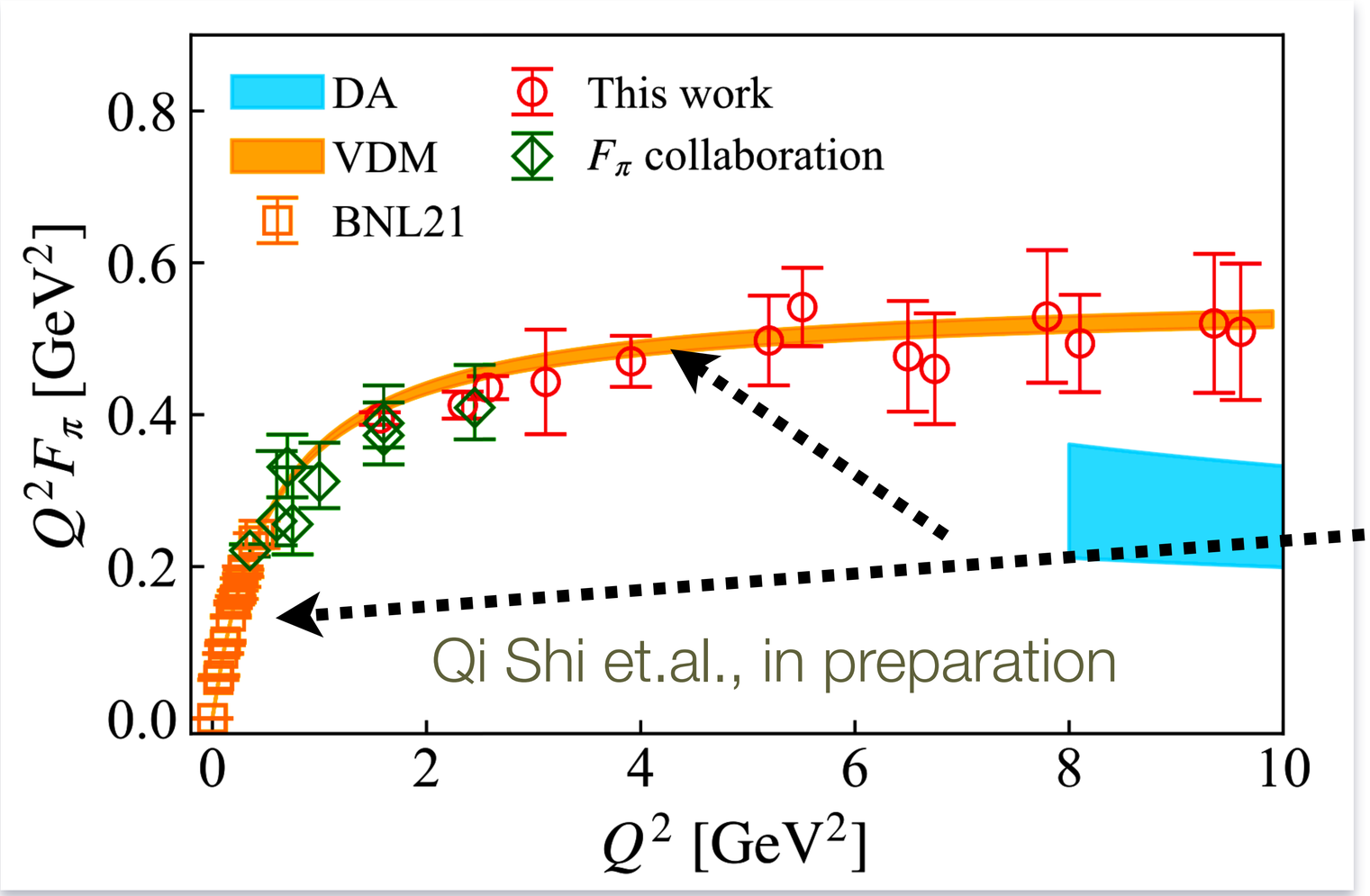
Nikhil Karthik et.al., Phys. Rev. D106, 074505 (2022)

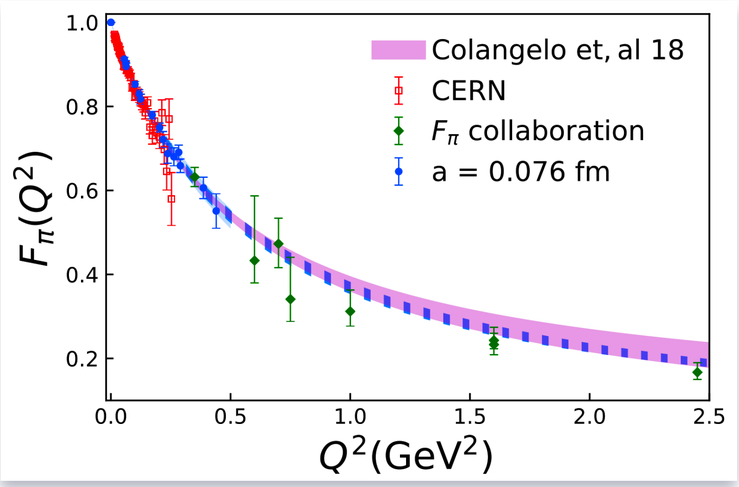
lattice QCD prediction: $F_\pi(Q^2)$ up to $Q^2 = 10\ \mathrm{GeV}^2$



JLab

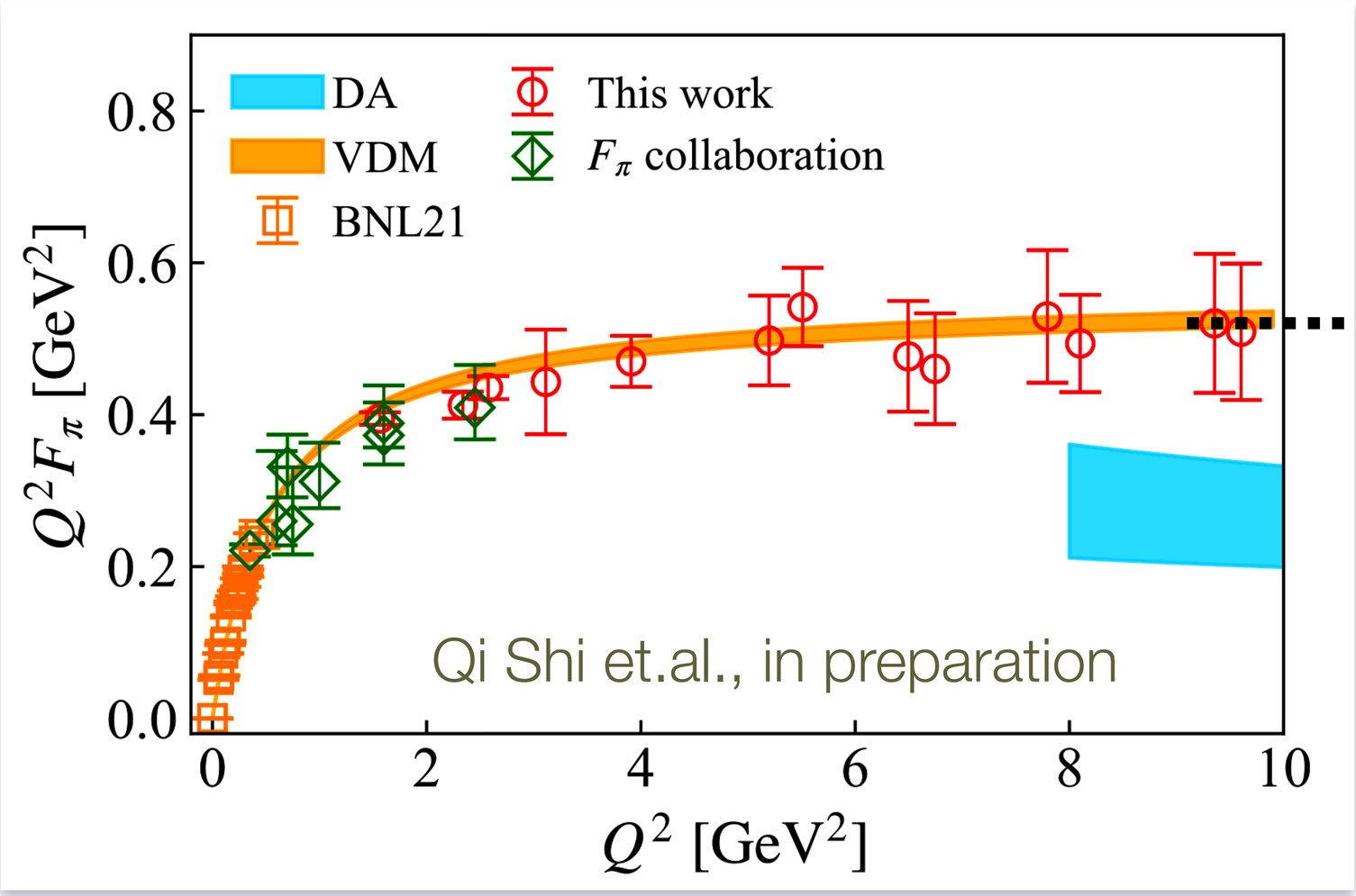
EIC





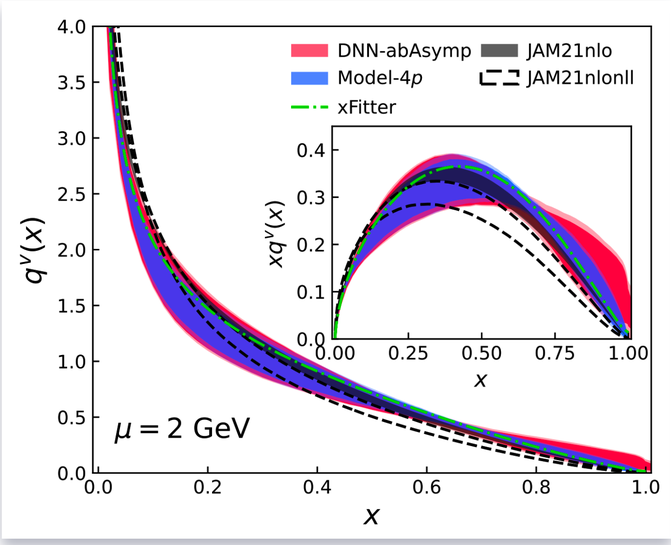
$$F_\pi(Q^2) = \frac{1}{1 + (r_\pi Q/\sqrt{6})^2}$$

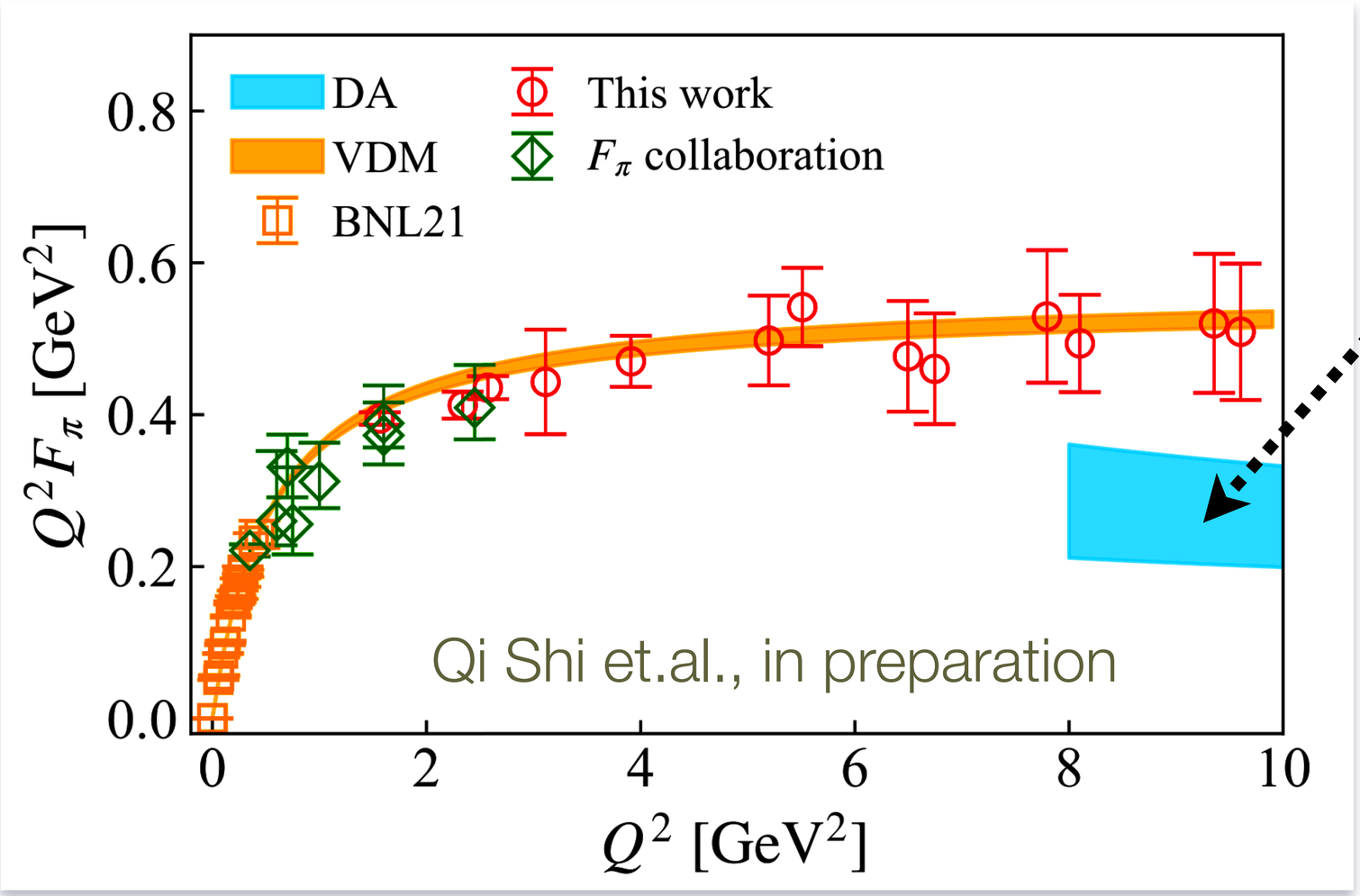
$$r_\pi^2 = 0.42(2)\ \mathrm{fm}^2$$

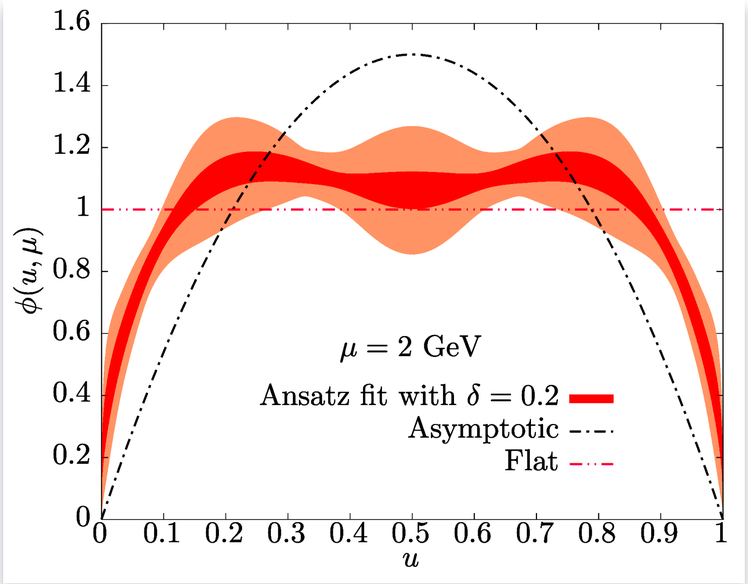


$$F_\pi(Q^2) \sim Q^{-2}\,??$$

$$q_\pi^v(x) \sim (1-x)$$

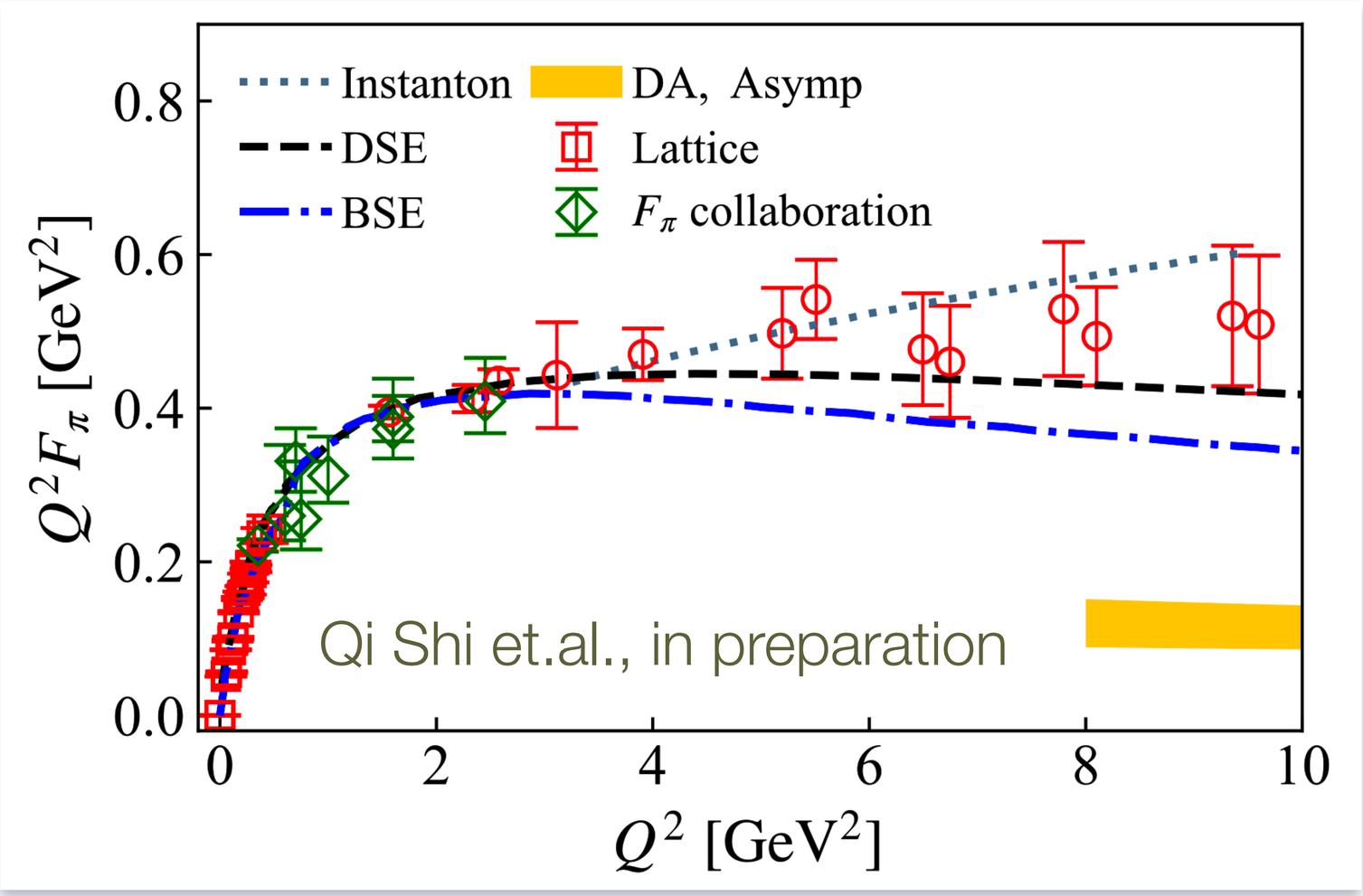






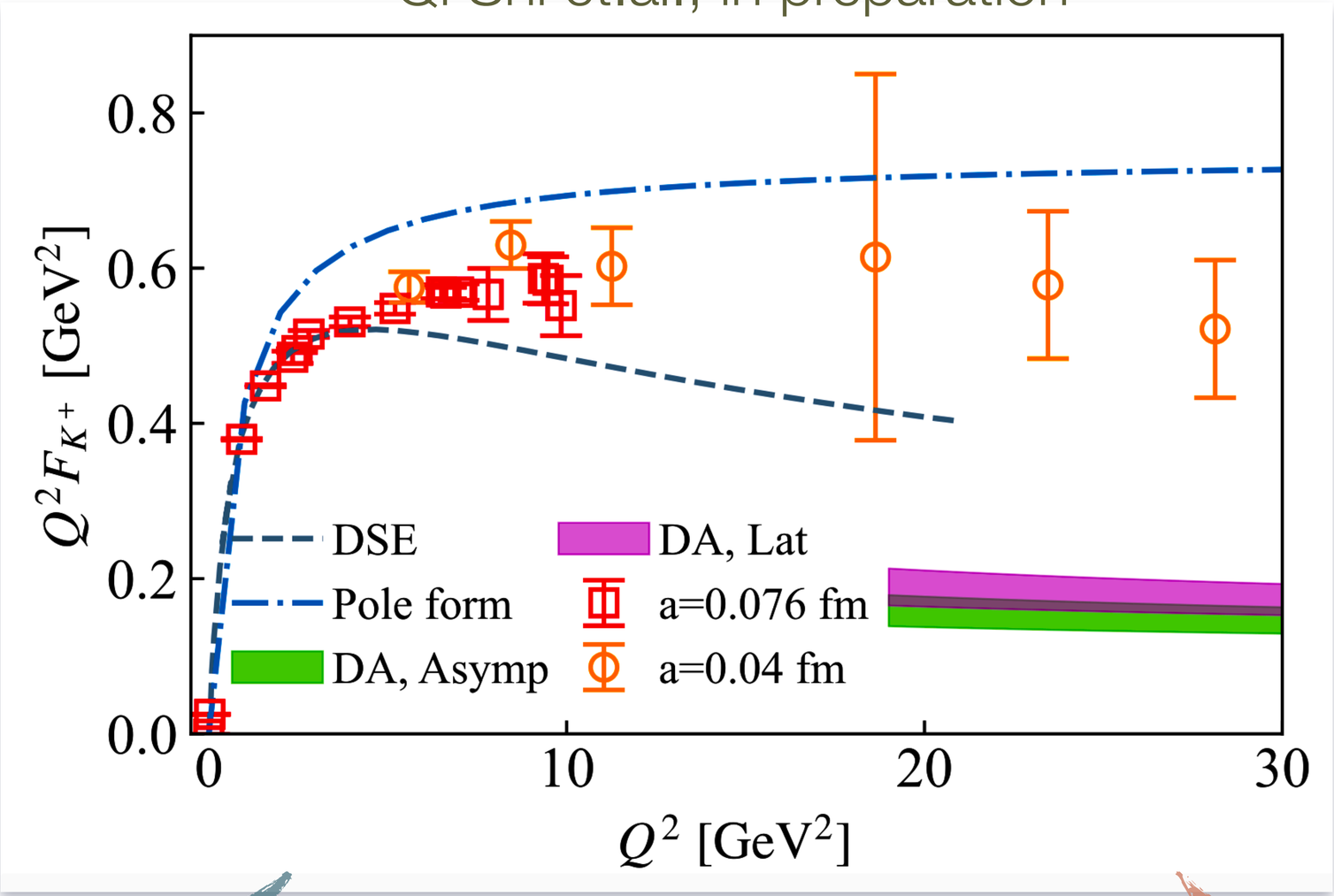
F_π @ $Q^2 = 10$ GeV^2

far from pQCD


Instanton
DSE
BSE
DA, Asymp
Lattice
F_π collaboration
Qi Shi et.al., in preparation
$Q^2 F_\pi$ [GeV^2]
Q^2 [GeV^2]
0.0
0.2
0.4
0.6
0.8
0
2
4
6
8
10

lattice QCD prediction: $F_K(Q^2)$ up to $Q^2 = 30\ \mathrm{GeV}^2$

Qi Shi et.al., in preparation

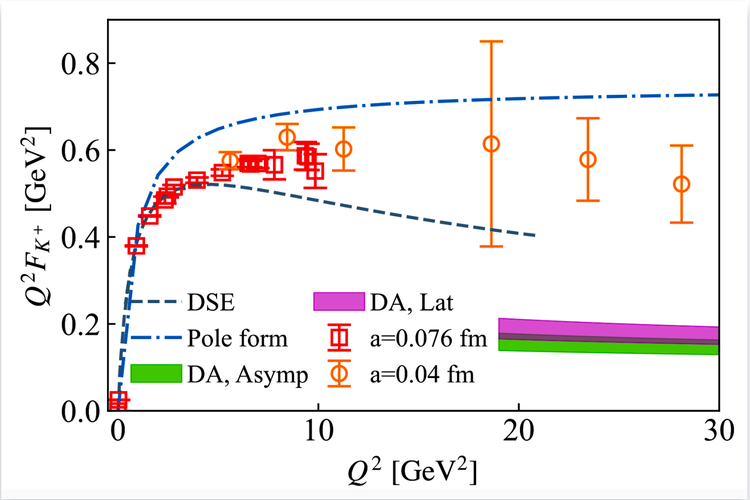


JLab

EIC

summary

- lattice QCD predictions for pion & kaon form factors covering JLAB to EIC range



JLab ⟷ EIC

- unique picture of QCD at different energy scales from a set of coherent lattice QCD calculations within the same set up