PDF of the Pion on a Fine Lattice

Charles Shugert

BNL
SBU

Work in progress with T. Izubichi, L. Jin, K. Kallidonis, S.Mukherje, P. Petreczky, S. Syritsyn

Introduction

I present the quasi-PDF for the pion on a fine lattice [X. Ji, '13]
Lattice Details

- Ensemble of HotQCD HISQ sea quarks: pseudogoldstone pion mass 160 MeV
- Wilson-Clover valence quarks: pion mass 300 MeV
- Lattice Spacing: $a = 0.06$ fm
- Lattice Size: $48^3 \times 64$
- Each configuration is AMA improved [Shintani, Izubichi, et al, '14]
  32 sloppy calculations to 1 precice solve

Goal: To have under control the excited state noise of the qPDF matrix element at large momentum

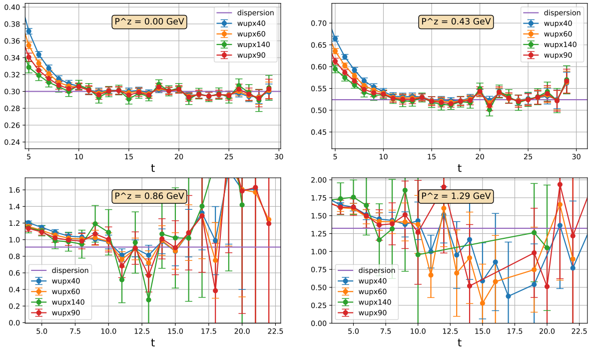
Set-up for Two-Point Correlator Study

We want to increase the overlap of our pion interpolators to a large-momentum ground-state pion

- First tune the quark profile via Wuppertal Smearing [S. Gusken, 1989]
- Second tune the ζ parameter for boosted quarks [S. Bali, et al, 2016]
- Boosted quarks are smeared by given a gaussian profile with width determined from Wuppertal smearing study
- Parameter $\zeta = k/P$; k: quark momentum, P: hadron momentum ideal $\zeta = 0.8$ from S. Bali, 2016
- Correlators shown are smeared-smeared

50 Configurations

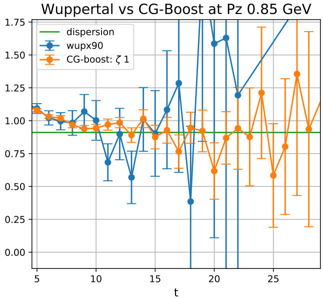
M_{eff} GeV vs t with Wuppertal Smearing

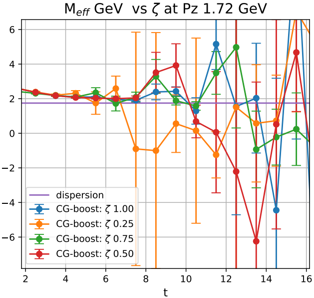


- $P^z = 0 - 0.43$ GeV: No Difference
- $P^z = 0.85$ GeV: 90 Wup smearing reaches plateau first
- $P^z = 1.28$ GeV: Too noisy

Plateau Reached at about t=10

50 Configurations





LHS: Boosted Sources significantly better than unboosted

RHS: Optimal ζ about 0.75 and 1.0

Notes on the Three-Point Function

- Operator is non-local quark-bilinear connected by a product of gauge links

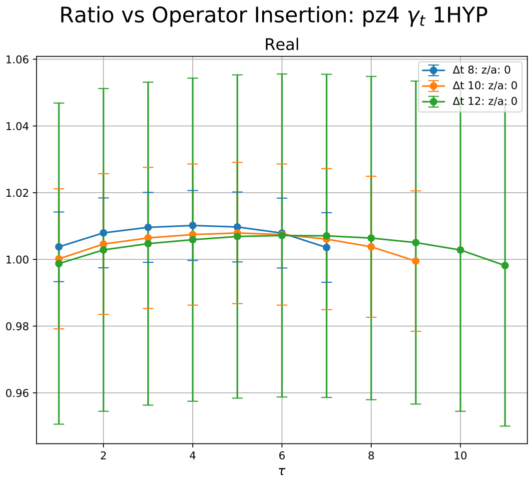
$$\mathcal{O}(x_o,\tau) = \bar{\psi}(x_0 + Nx,\tau)\Gamma(n)\Big(\prod_{i=0}^{N-1} U(x_{i+1},x_i)\Big)\psi(x_0,\tau) \qquad (1)$$

- $\Gamma(n) = \{\mathbb{1},\gamma_t,\gamma_z\}$
- $U(x_{i+1},x_i) = U_\mu(x_i)|_{\mu=x}$
- $P^z[\text{GeV}] = \{0.85, 1.28, 1.72\}$
- τ: Operator Insertaion
- Correlator computed at source-sink separations Δ t $=$ 8, 10, 12
- Correlator normalized by the two-point function (denoted Ratio)
- 168 Configurations for z $<$ $|0.48|$ fm; 52 for $z > |0.48|$ fm

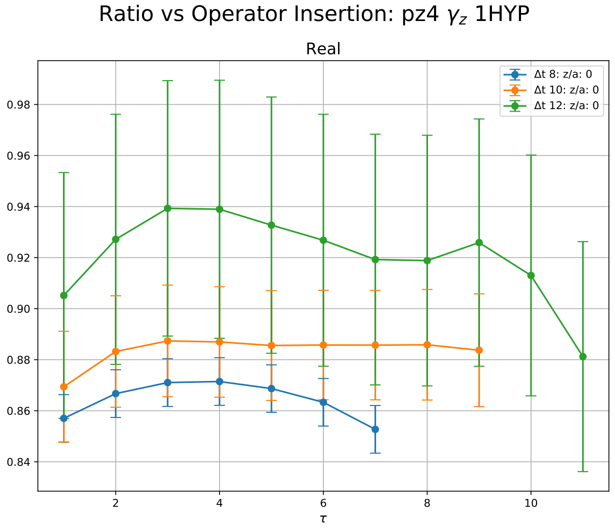
What we study about the ratio

- Study Ratio as a function of operator insertion τ
  identify plateau region
- Study momentum dependence of the Ratio
- Do a two-state fit on the ratio to determine excited state contamination of the Ratio (*work in progress*)

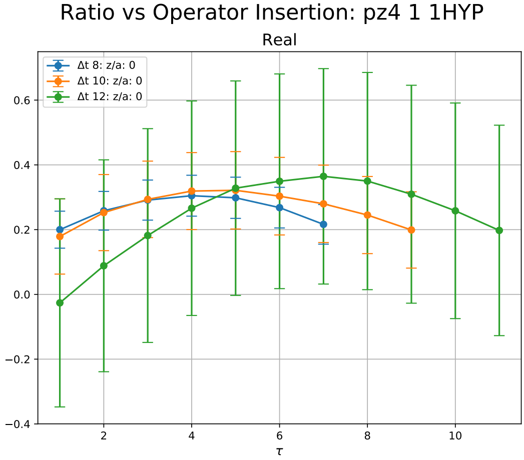
Operator Insertion Dependence



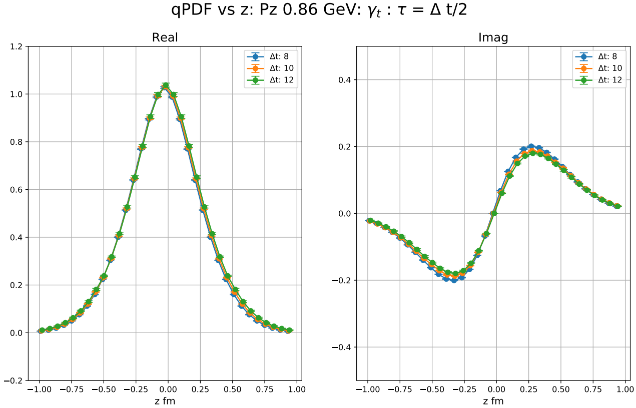
Operator Insertion Dependence



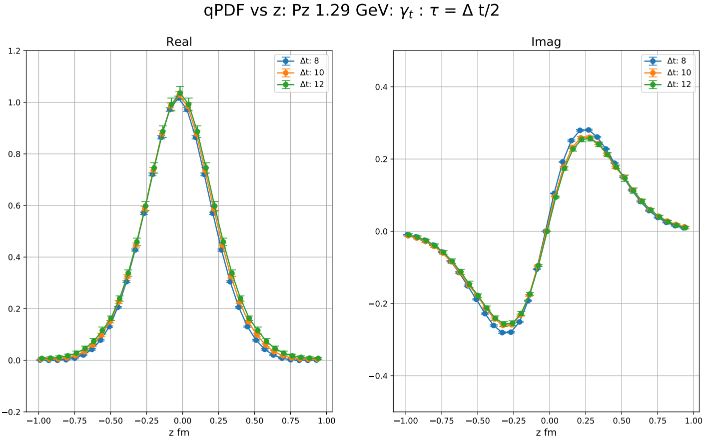
Operator Insertion Dependence



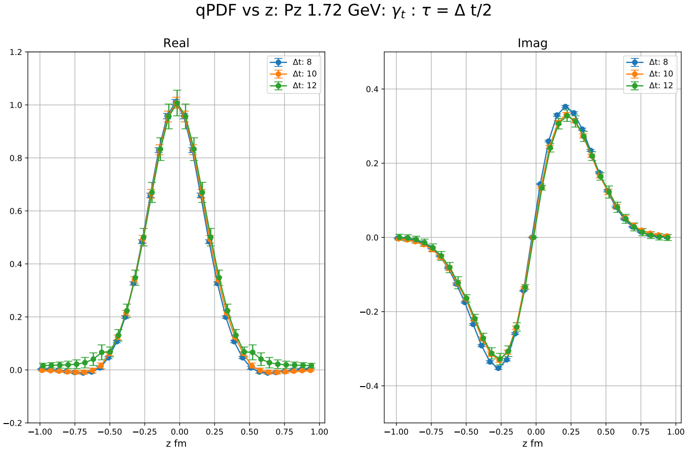
Momentum Dependence



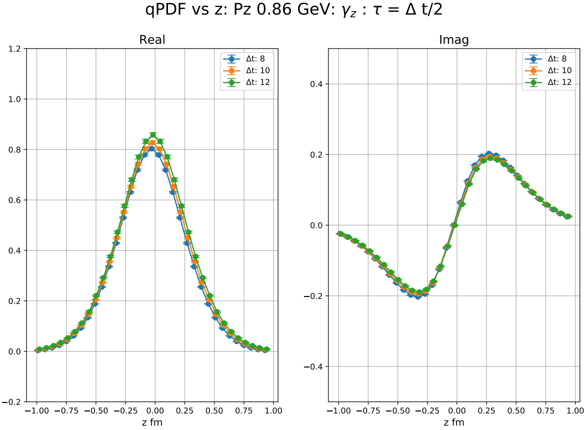
Momentum Dependence



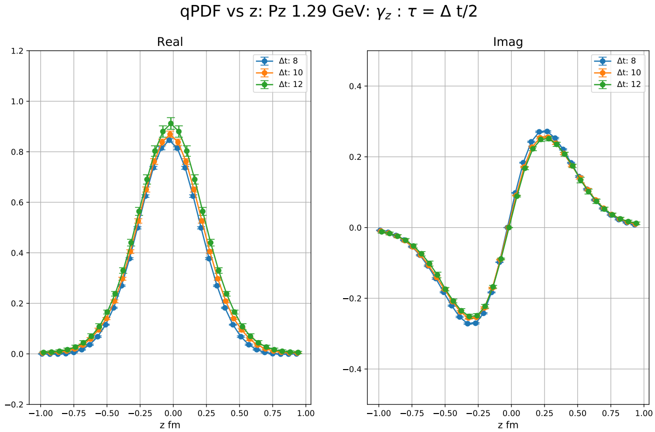
Momentum Dependence



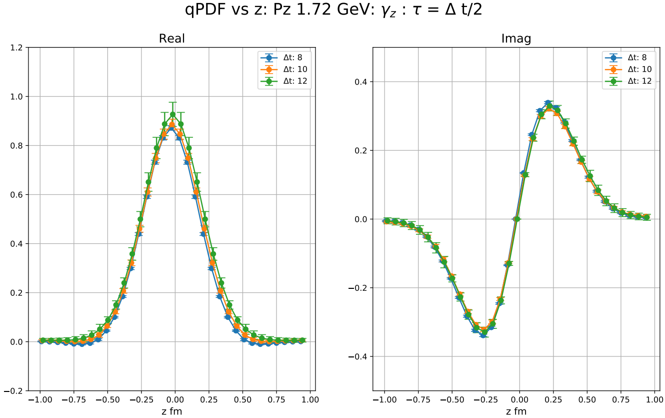
Momentum Dependence



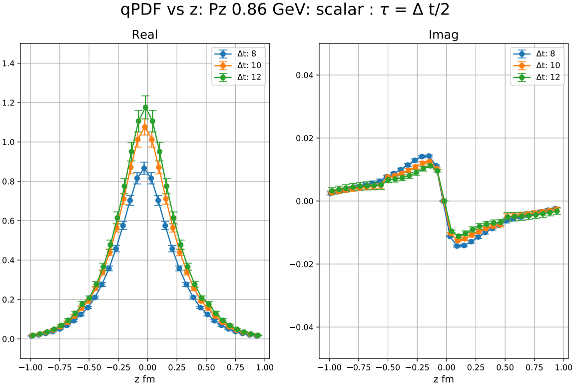
Momentum Dependence



Momentum Dependence

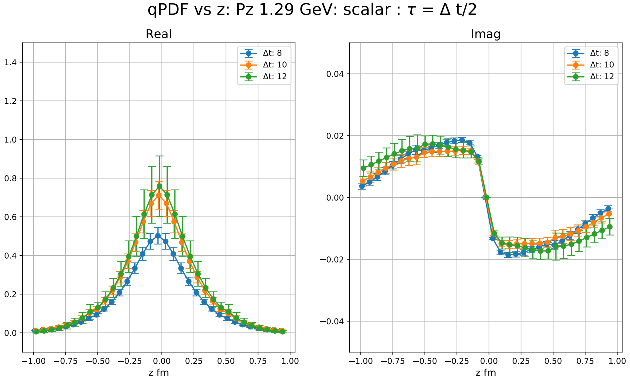


Momentum Dependence



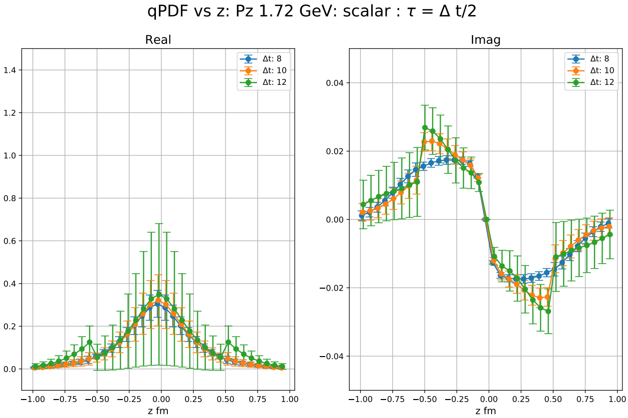
;

Momentum Dependence



;

Momentum Dependence



;

- From central values, plateau is at about $\tau = \Delta t/2$
- Δt dependence is within error bars at high momentum but becomes more pronounced (albiet small) at low momentum, where signal is less noisy
- Excited States need to be dealt with

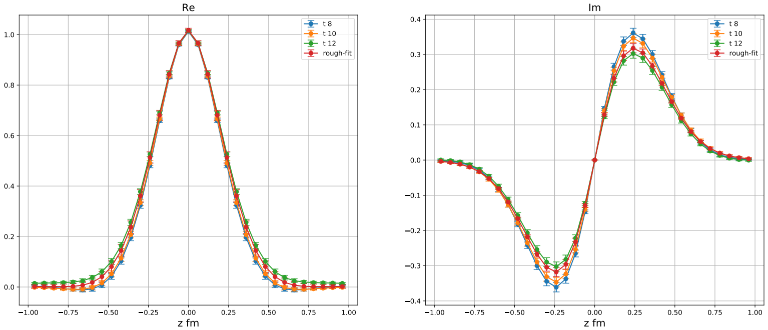
We perform an approximation to the two-state fit of the Ratio. The fit form:

$$fit(t; A, B) = A + Be^{-\Delta E \Delta t}; \quad \tau \text{ fixed} \tag{2}$$

We determine Δ E from a double-exponential fit of the two-point function
*** more sophisicated study still in progress*

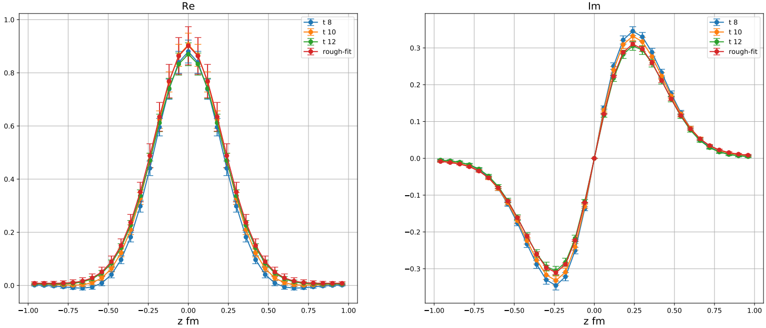
Δ E = 1.21 ± 0.13 GeV (fit fixed to Δ E = 1.21 GeV)

Ratio at Pz = 1.72 for γ_t

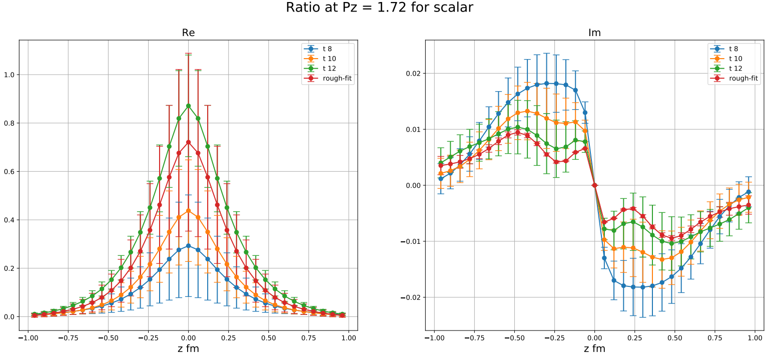


Δ E = 1.21 ± 0.13 GeV (fit fixed to Δ E = 1.21 GeV)

Ratio at Pz = 1.72 for γ_z



Δ E = 1.21 $\pm$ 0.13 GeV (fit fixed to Δ E = 1.21 GeV)



Summary

Two-Point Correlator

- Determined optimal smearing profile and boost for the pion interpolator
- Plateau Region Begins at about $\Delta t = 10$

Three-Point Correlator

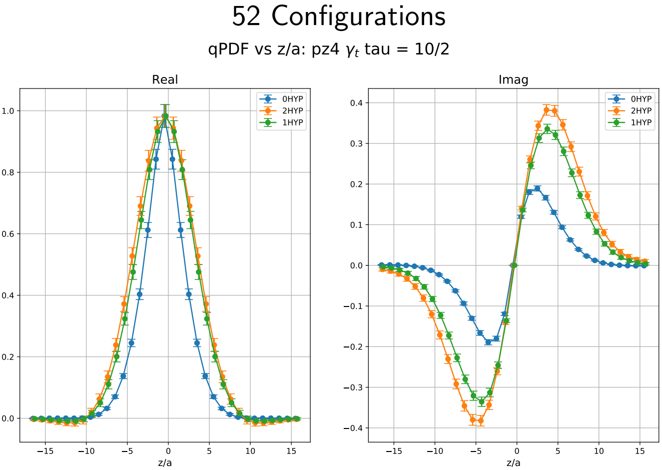
- τ best at $\Delta t/2$
- Δt dependence comperable to approximate excited state removed data

Still in progress

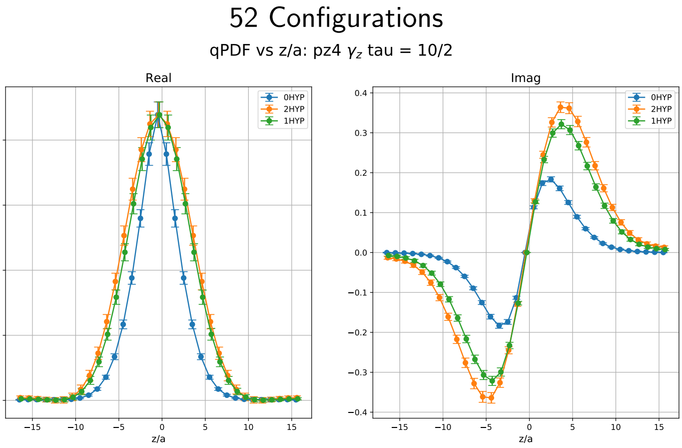
- A more through examination of excited states in the three-point function
- Same calculations but for an even finer lattice; $a = 0.04$ fm

Backup Slides

qPDF dependence for HYP-Smeared Wilson Line



qPDF dependence for HYP-Smeared Wilson Line



qPDF dependence for HYP-Smeared Wilson Line