parton distribution function of Δ^+ on the lattice

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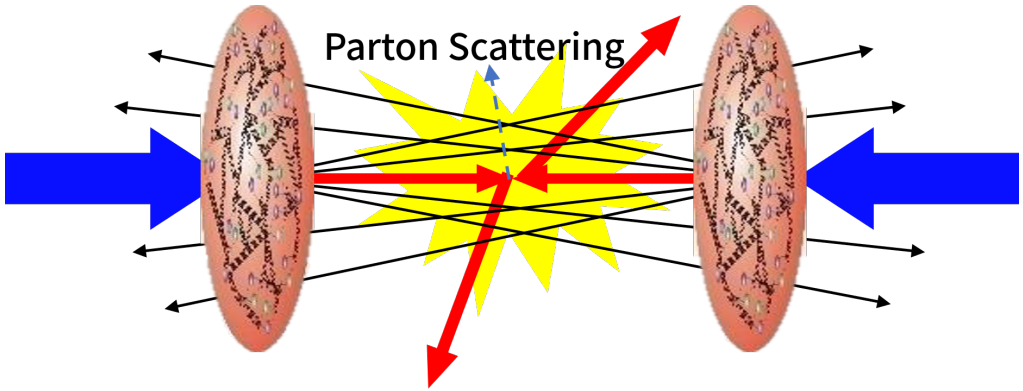
Feynman Parton model

- When particle travels at $v \sim c$, it may be considered as a collection of interaction-free particles called partons.



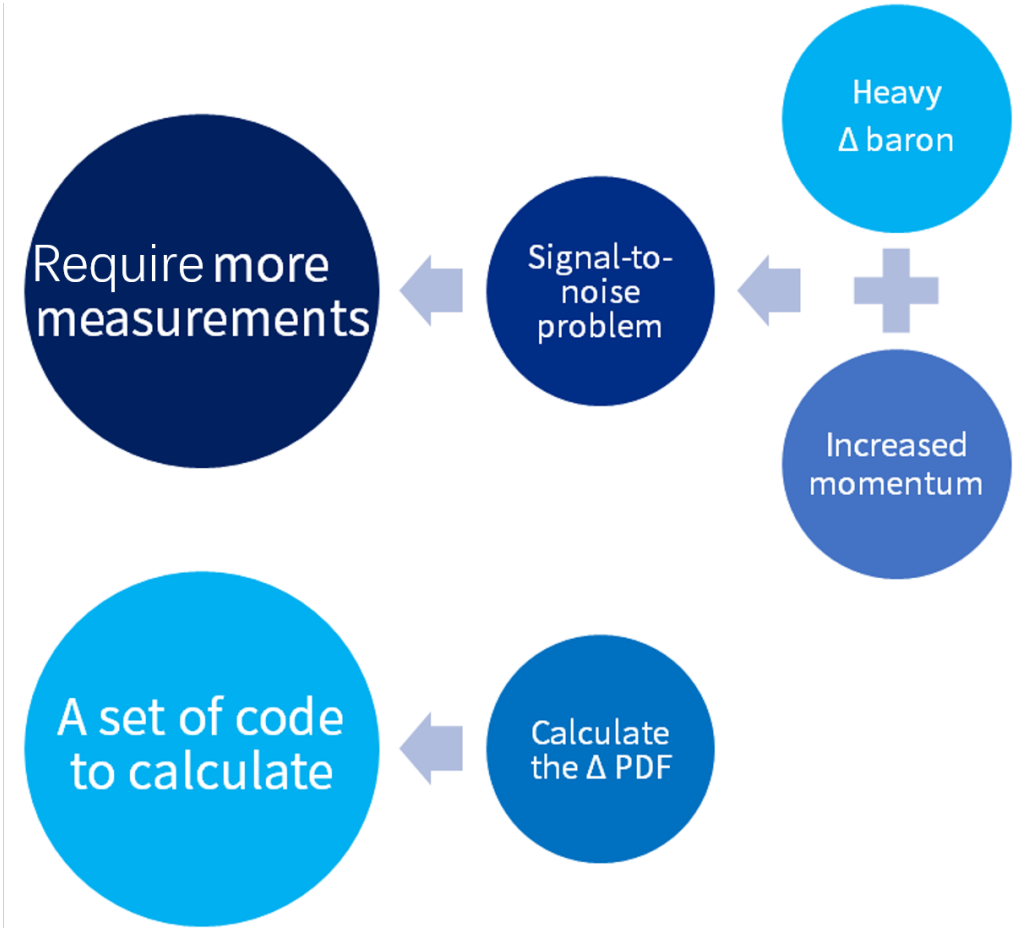
- Two particles' scattering can transform to partons' scattering. The scattering cross sections are factorized in terms of partions distribution function and parton scattering.

Delta PDF

- Parton distribution functions(PDFs):
  They encode important information on the internal structure of hadrons, such as the distribution of the spin and momentum of the parent hadron among its constituents.
- We provide a first lattice QCD study of the PDFs of the $\Delta(1232)$ baryon.
- Since the Δ baryon is a strongly decaying resonance, its structure is not accessible experimentally. Lattice QCD is only available framework to provide information.
- we compute the $\overline{d}(x) - \overline{u}(x)$ asymmetry and compare it with the same quantity in the nucleon.

Delta PDF

- Challenge:



- Our work:
  Yahui Chai, Yuan Li, Shicheng Xia, et al, Parton distribution functions of Δ^+ on the lattice, Phys.Rev.D 102 (2020) 1, 014508

Configurations and Measurements

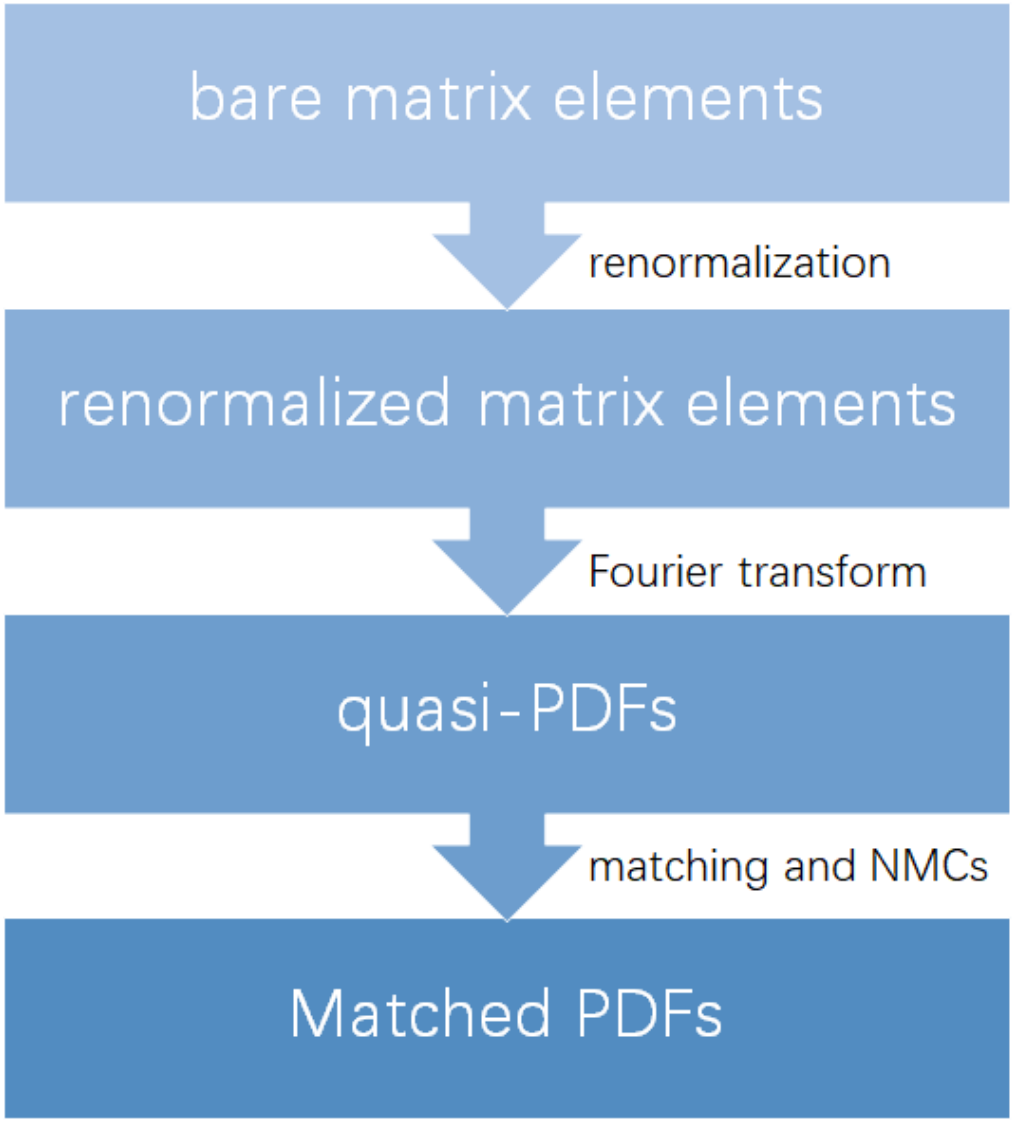
$\beta = 1.726$ $c_{sw} = 1.74$ $a = 0.093$ fm		
$24^3 \times 48$	aμ=0.0053	m_N=1.21(2) GeV
L=2.2 fm	m_π=0.360 GeV	m_Δ=1.59(4) GeV
$32^3 \times 64$	aμ=0.003	m_N=1.08(3) GeV
L=3.0 fm	m_π=0.270 GeV	m_Δ=1.42(5) GeV

Table 1: Simulation parameters for the two ensembles of used gauge field configurations.

P_3	$\frac{2\pi}{L} \approx 0.42GeV$	$\frac{4\pi}{L} \approx 0.83GeV$	$\frac{6\pi}{L} \approx 1.25GeV$
N_{conf}	151	461	474
N_{meas}	906	8784	42660

Table 2: The statistics in our calculation

Lattice Details



Bare matrix elements

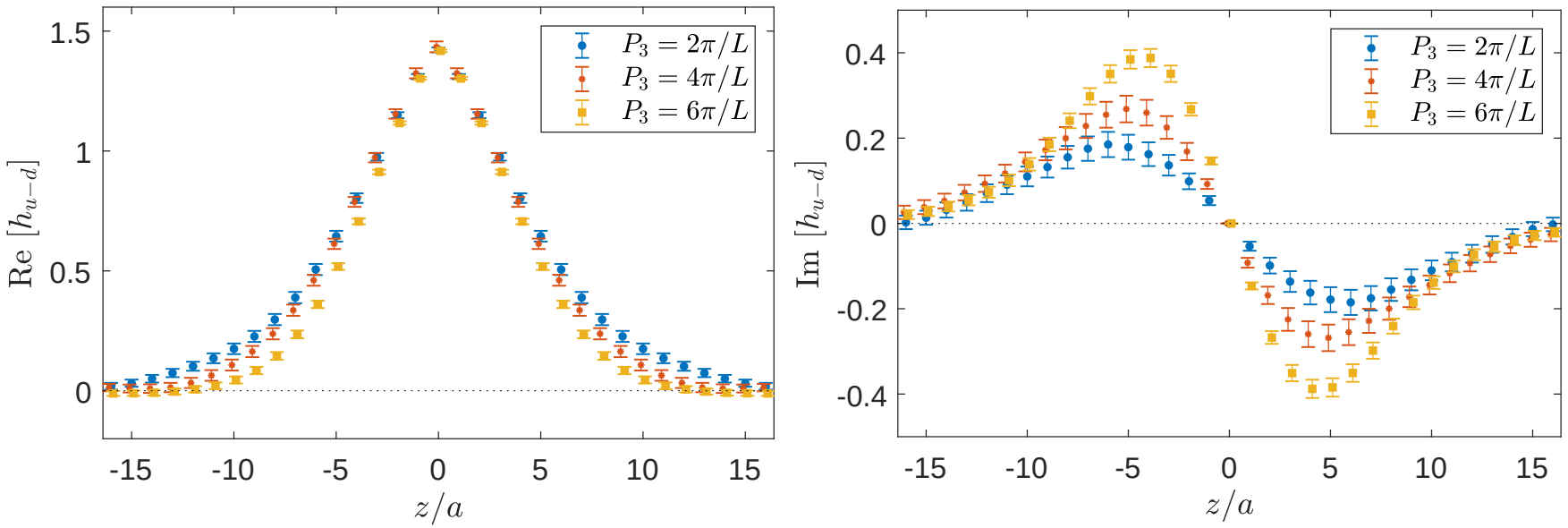


Figure 1: The real (left) and imaginary (right) part of bare matrix elements for the three lowest lattice momenta, $P_3 = 2\pi/L, 4\pi/L, 6\pi/L$, with 10 steps of stout smearing.

Renormalized matrix elements

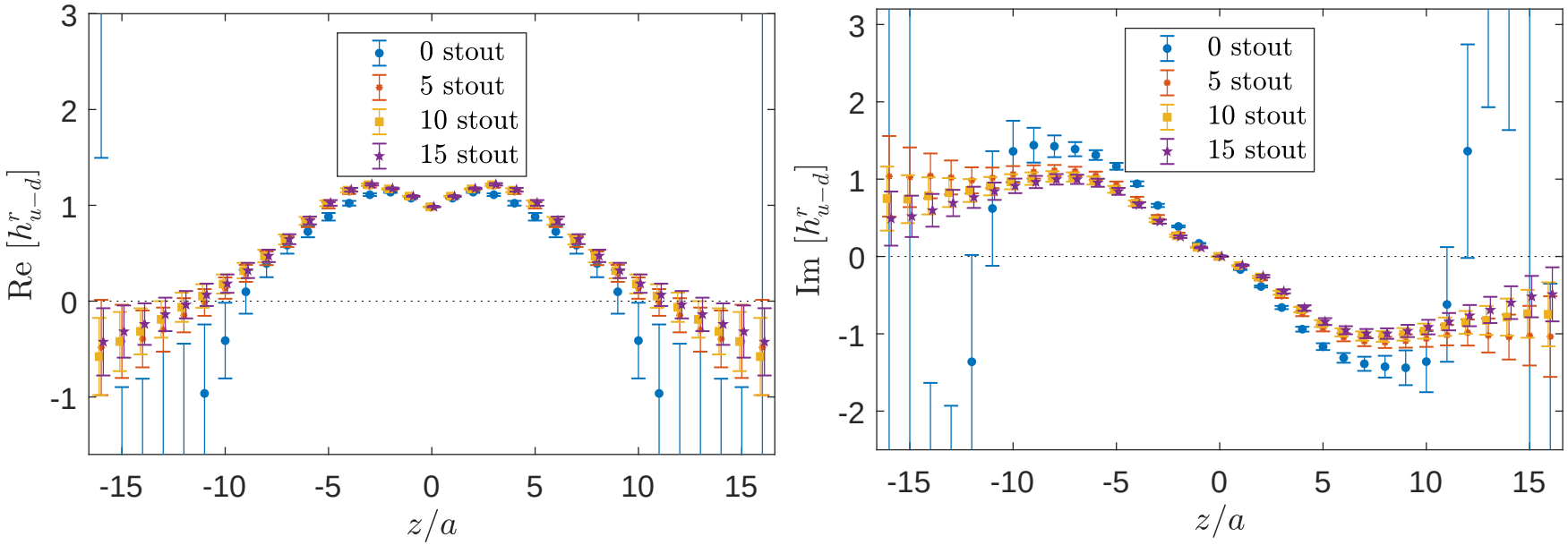


Figure 2: The real (left) and imaginary (right) part of the renormalized matrix elements for 0, 5, 10 and 15 steps of stout smearing steps. The hadron boost is $P_z = 6\pi/L$.

Quasi-PDFs

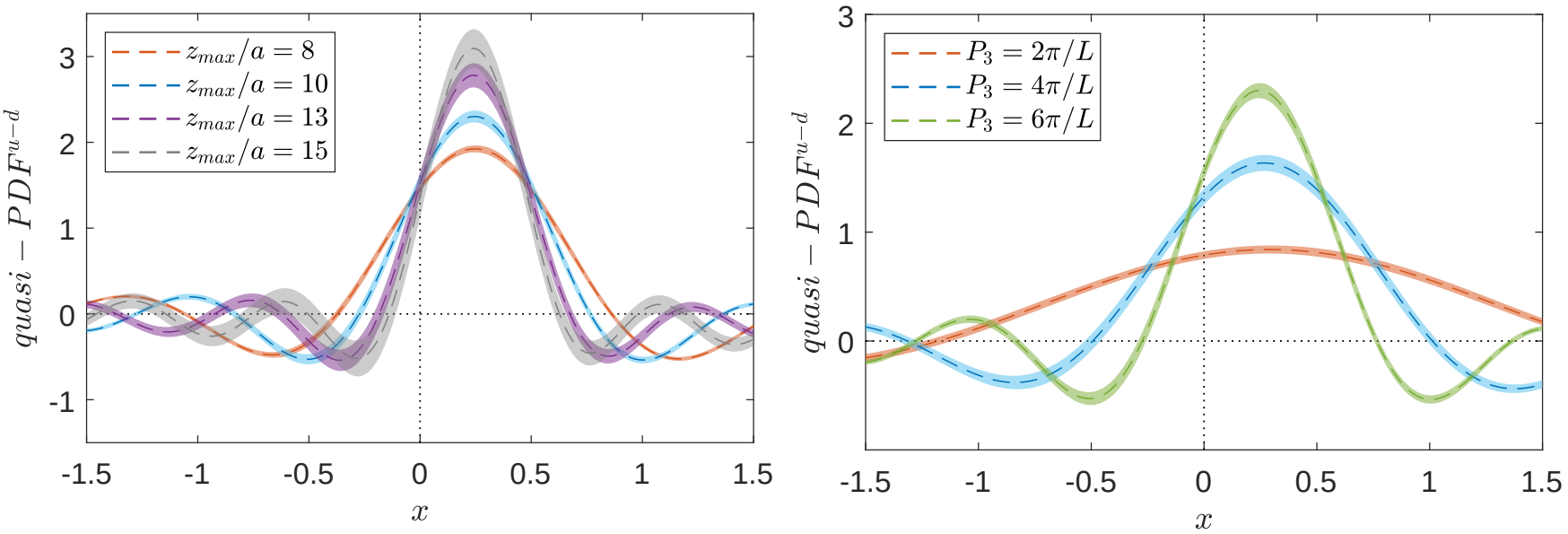


Figure 3: Left panel: the dependence on the maximum length of the Wilson line taken in the Fourier transform, $z_{\max}$, for hadron boost $P_3 = 6\pi/L$.
Right panel: the dependence on the hadron boost, for $P_3 = 2\pi/L, 4\pi/L, 6\pi/L$ and $z_{\max}/a = 10$.

Matched PDFs

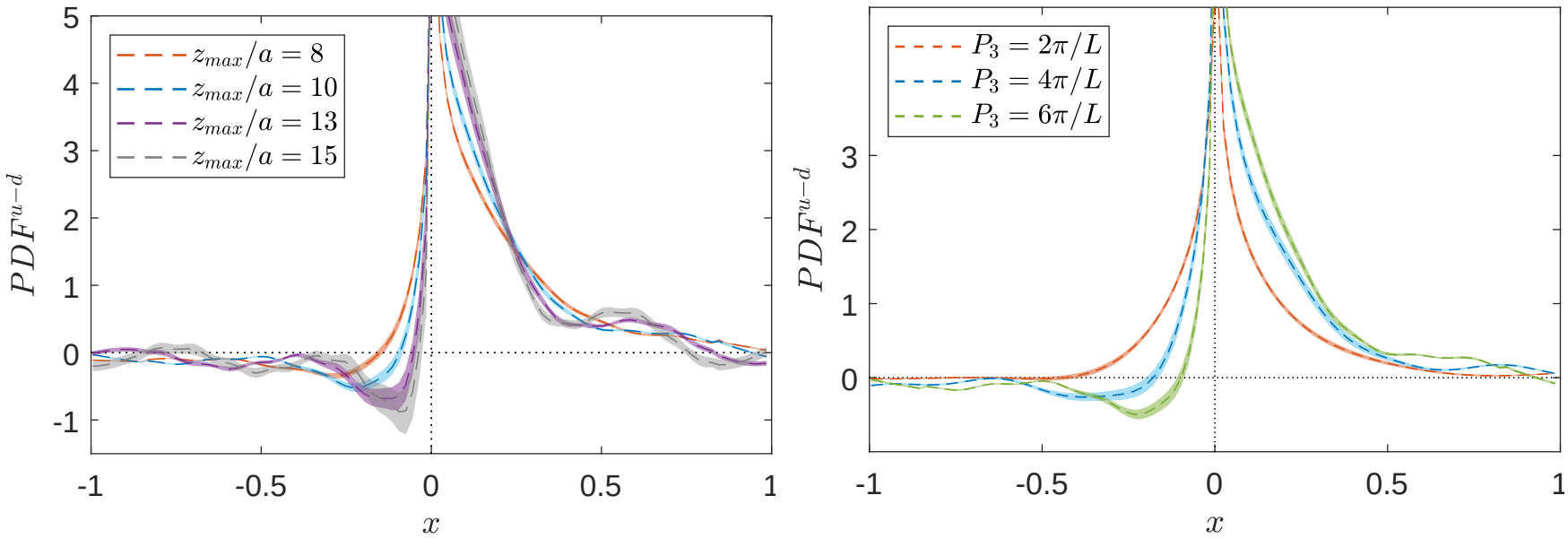


Figure 4: Left panel: the dependence on the maximum length of the Wilson line taken in the Fourier transform, $z_{\max}$, for hadron boost $P_3 = 6\pi/L$.
Right panel: the dependence on the hadron boost, for $P_3 = 2\pi/L, 4\pi/L, 6\pi/L$ and $z_{\max}/a = 10$.

$\overline{d}(x) - \overline{u}(x)$ asymmetry

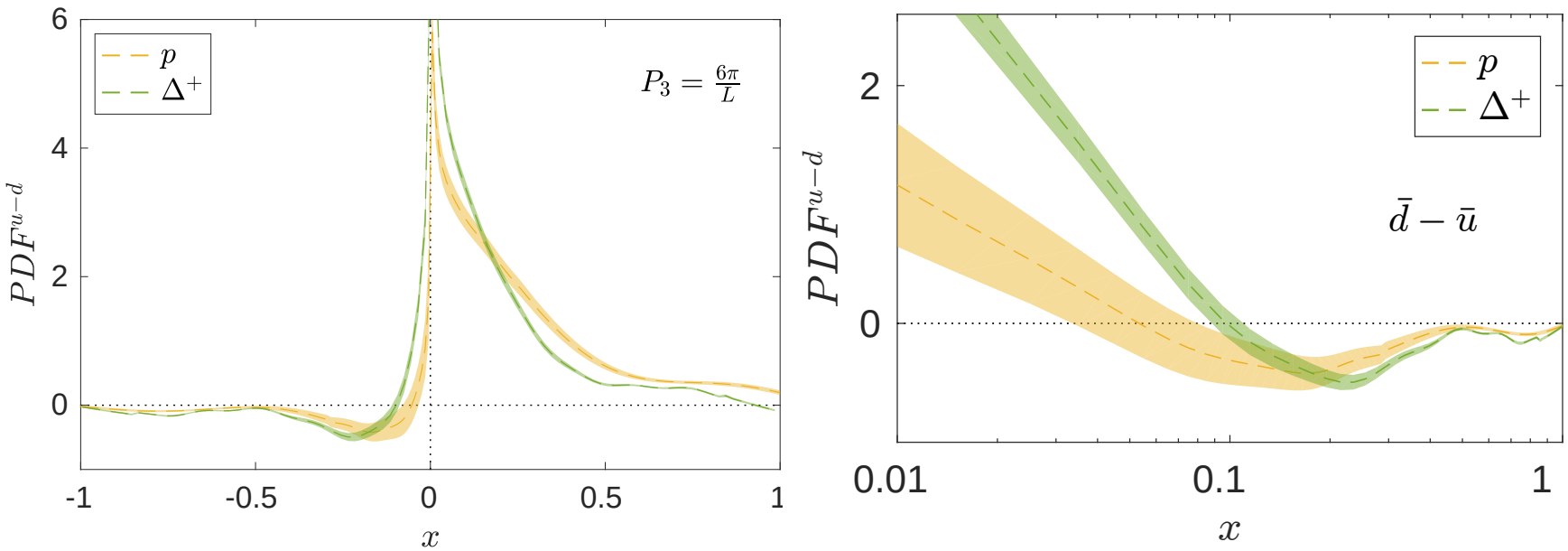


Figure 5: Comparison between the $\overline{d}(x) - \overline{u}(x)$ asymmetry for the proton (yellow) and Δ^+ baryon (green), obtained for momentum boost $P_3 = 6\pi/L$.

Summary and Outlook

- We performed a first lattice QCD calculation of the unpolarized isovector PDF of the Δ^+ baryon using LaMET.
- Demonstrate the feasibility of extracting the PDFs of the Δ^+ with high statistical accuracy, while the computational cost remains within reach
- Challenge in the future:
  concerning volume and cutoff effects
  the investigation of other systematic uncertainties, such as excited states effects

Thank you !