Generalized parton distributions from domain wall valence quarks and staggered sea quarks

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Mixed Action Lattice Calculation

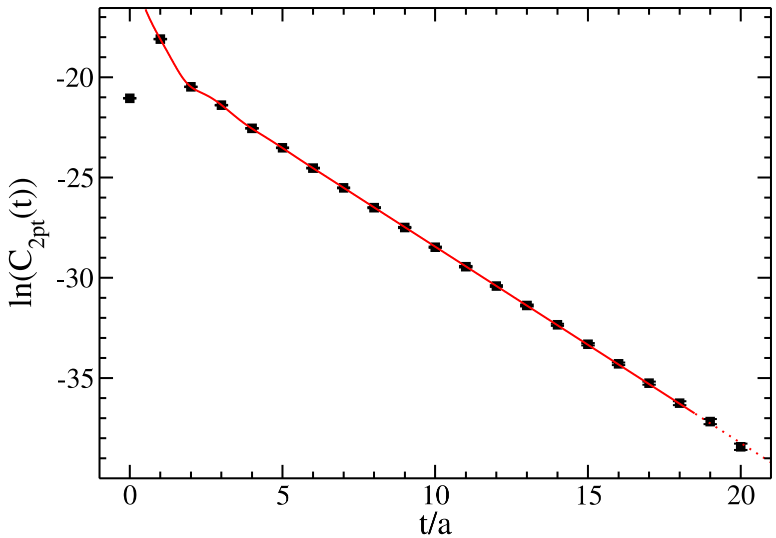
- asqtad staggered sea quarks (MILC) with $a = 0.124$ fm

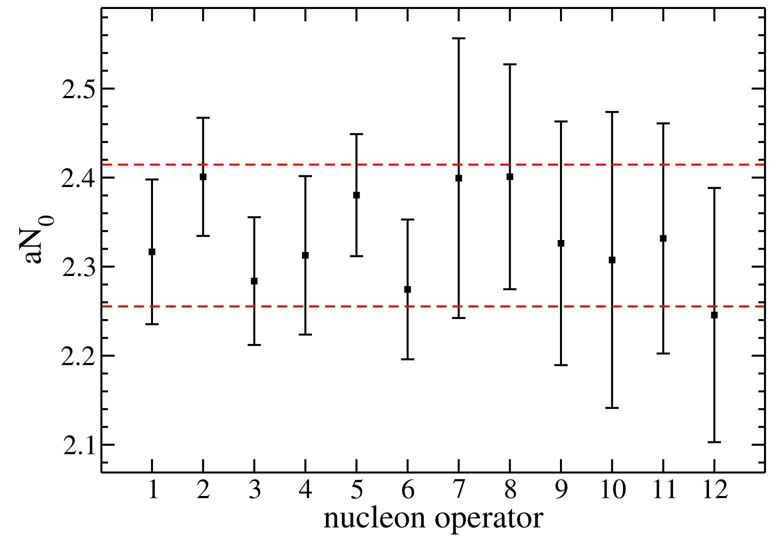
$am_{u/d}^{\text{asqtad}}$	L/a	L	m_π^{DWF}	#
		fm	MeV	
0.05	20	2.52	761	425
0.04	"	"	693	350
0.03	"	"	594	564
0.02	"	"	498	486
0.01	"	"	354	656
0.01	28	3.53	353	270

- domain wall valence quarks with HYP smearing and $L_5 = 16$
- one-loop perturbative renormalization at $\mu = 2$ GeV

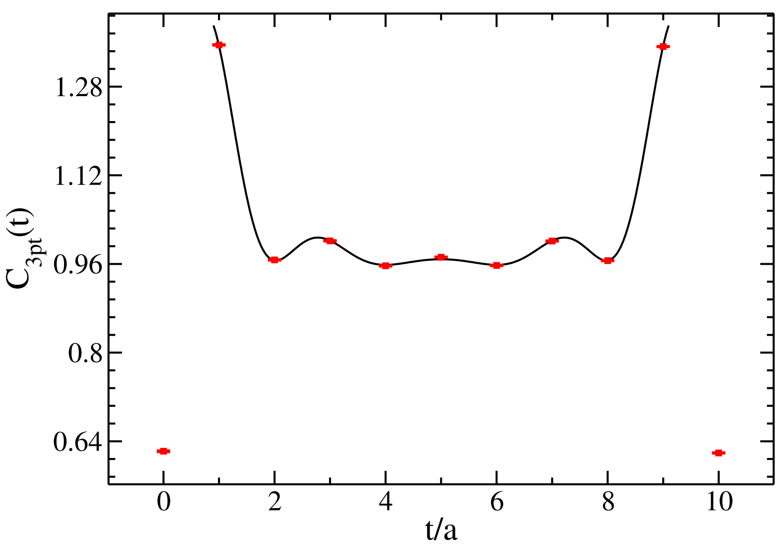
Oscillatory Domain Wall Correlators and Fits

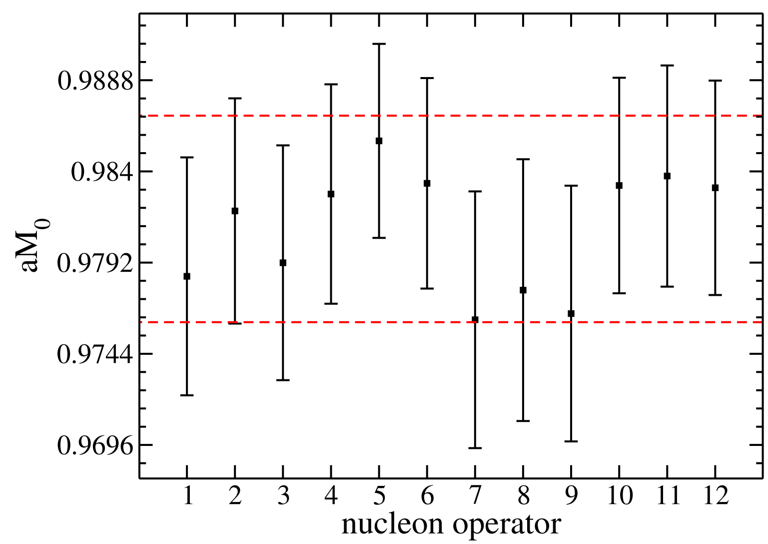
- $C_{2\mathrm{pt}}(t) = A_0 e^{-M_0 t} + A_1 e^{-M_1 t} + B_0 (-1)^t e^{-N_0 t}$





- $C_{3\mathrm{pt}}(t) = O_{00} + O_{10}\cosh((M_1 - M_0)t) + P_{00}(-1)^t \cosh((N_0 - M_0)t)$





Moments of Parton Distributions

- forward matrix elements of twist two operators

$$O_q^{\mu_1\cdots\mu_n} = \overline{q} iD^{(\mu_1} \ldots iD^{\mu_{n-1}}\gamma^{\mu_n)} q$$

$$\langle P,S|O_q^{\mu_1\cdots\mu_n}|P,S\rangle = 2\,\langle x^{n-1}\rangle_q\, P_{\mu_1}\cdots P_{\mu_n}$$

- unpolarized, helicity and transversity moments

$$\langle x^n\rangle_q = \int_{-1}^{1} dx\, x^n q(x)$$

$$\langle x^n\rangle_{\Delta q} = \int_{-1}^{1} dx\, x^n \Delta q(x)$$

$$\langle x^n\rangle_{\delta q} = \int_{-1}^{1} dx\, x^n \delta q(x)$$

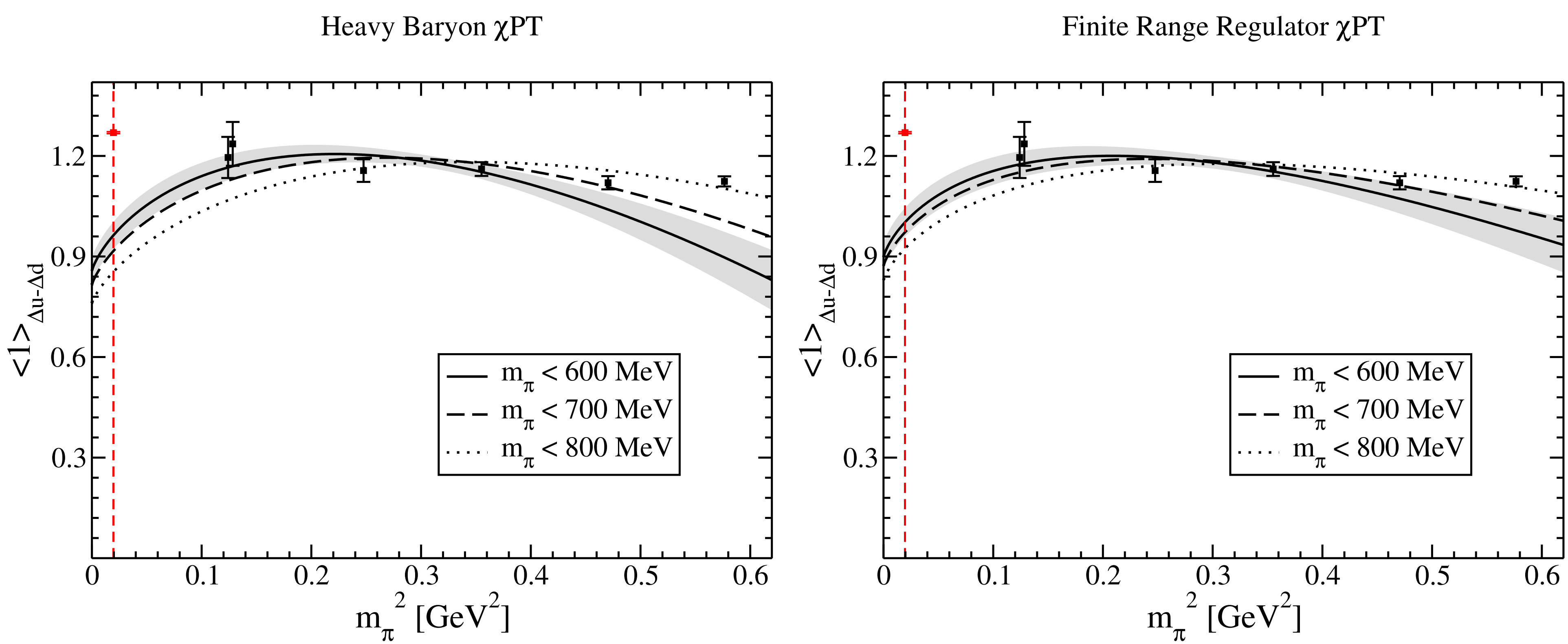
Axial Charge and Chiral Perturbation Theory

- standard one-loop heavy baryon chipt

$$g = \mathring{g}\left(1 - \frac{(2\mathring{g}^2 + 1)}{(4\pi\mathring{f})^2} m^2 \ln\left(\frac{m^2}{\mu^2}\right)\right) + c_g(\mu) m^2$$

- finite range regulated one-loop heavy baryon chipt

$$g = \mathring{g}\left(1 - \frac{(2\mathring{g}^2 + 1)}{(4\pi\mathring{f})^2} m^2 \ln\left(\frac{m^2}{\Lambda^2 + m^2}\right)\right) + c_g(\Lambda) m^2$$



Self Consistent Chiral Perturbation Theory

- choose $\mu = \alpha \mathring{f}$ and replace $\mathring{f}$, $\mathring{g}$, $\langle \mathring{x} \rangle$ with f, g, $\langle x \rangle$ in the NLO term

$$\langle x \rangle = \langle \mathring{x} \rangle - \langle \mathring{x} \rangle (3\mathring{g}^2 + 1) m^2/(4\pi \mathring{f})^2 \ln(m^2/\mu^2) + c_x(\mu) m^2$$

$$\langle x \rangle (1 + (3g^2 + 1) m^2/(4\pi f)^2 \ln(m^2/(\alpha f)^2)) = \langle \mathring{x} \rangle + c_x(\alpha) m^2$$

- choose $\mu = \alpha \mathring{f}$ and replace $\mathring{f}$, $\mathring{g}$ with f, g in the NLO term

$$g = \mathring{g} - (2\mathring{g}^3 + \mathring{g}) m^2/(4\pi \mathring{f})^2 \ln(m^2/\mu^2) + c_g(\mu) m^2$$

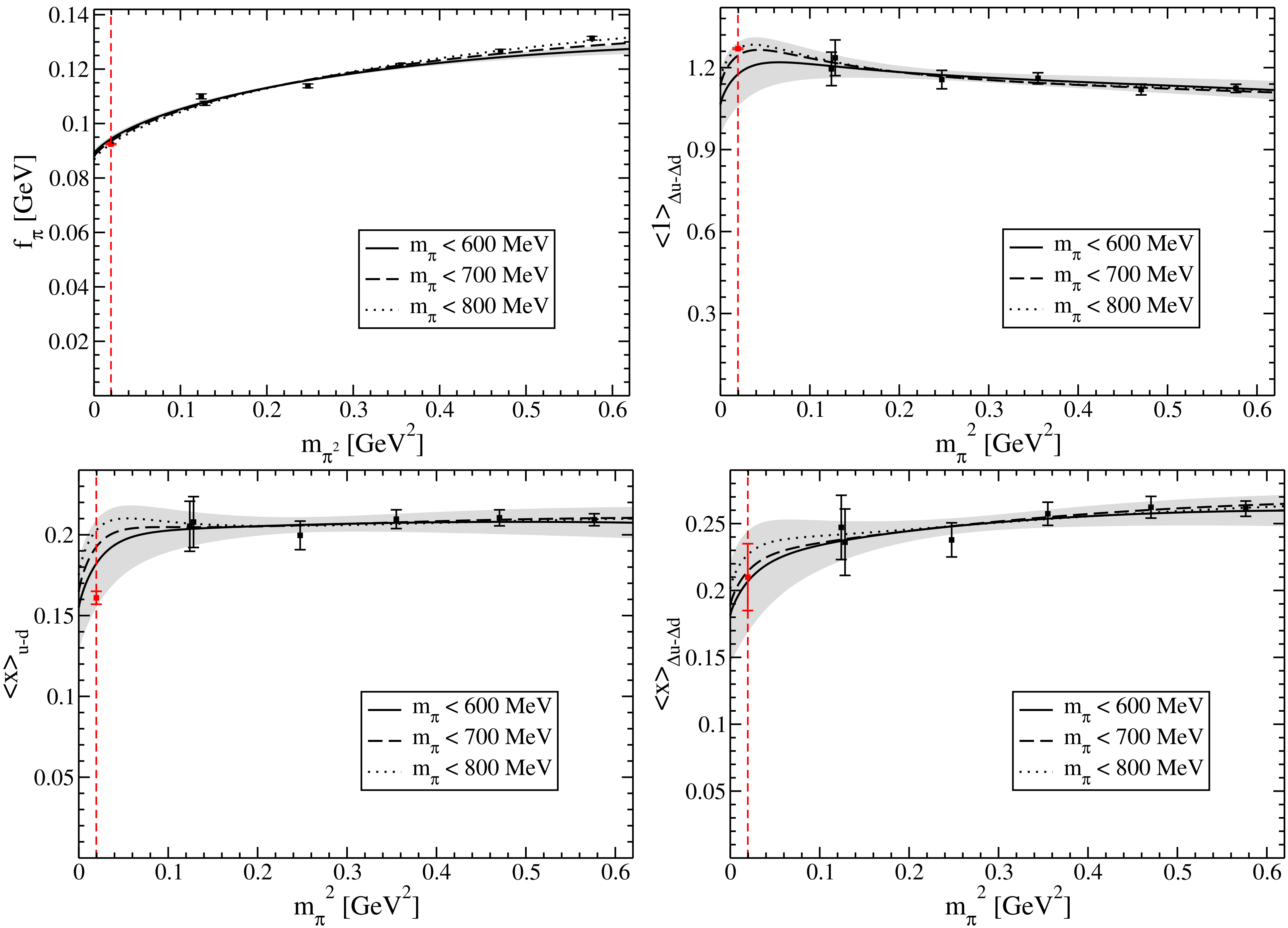
$$g(1 + (2g^2 + 1) m^2/(4\pi f)^2 \ln(m^2/(\alpha f)^2)) = \mathring{g} + c_g(\alpha) m^2$$

- choose $\mu = \alpha \mathring{f}$ and replace $\mathring{f}$ with f in the NLO term

$$f = \mathring{f} - m^2/(4\pi \mathring{f}) \ln(m^2/\mu^2) + c_f(\mu) m^2$$

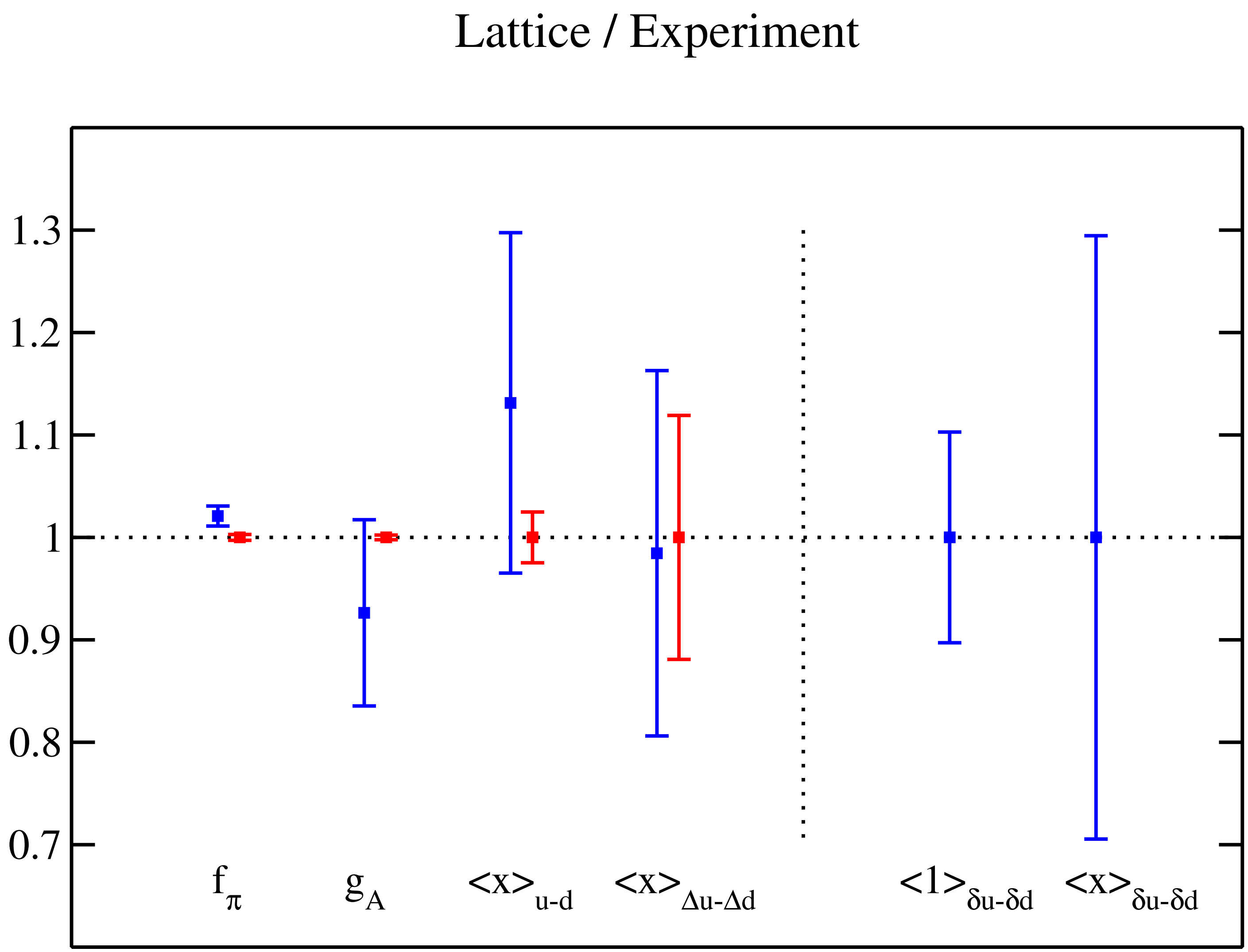
$$f(1 + m^2/(4\pi f)^2 \ln(m^2/(\alpha f)^2)) = \mathring{f} + c_f(\alpha) m^2$$

Self Consistent Chiral Perturbation Theory



Self Consistent Chiral Perturbation Theory

- self consistent χPT successfully extrapolates f_π, g_A, $\langle x \rangle_{u-d}$, $\langle x \rangle_{\Delta u - \Delta d}$



- and highlights the potential for genuine predictions of $\langle 1 \rangle_{\delta u - \delta d}$, $\langle x \rangle_{\delta u - \delta d}$

Moments of Generalized Parton Distributions

- off-forward matrix elements of twist two operators

$$\langle P'|O_q^{\mu_1\cdots\mu_n}|P\rangle = \sum_{\substack{i=0\\ \text{even}}}^{n-1} \left\{ A_{ni}^q(t)K_{ni}^A + B_{ni}^q(t)K_{ni}^B \right\} + \delta_{\text{even}}^n C_n^q(t)K_n^C$$

- quark angular momenta

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma^{u+d} + L^{u+d} + J^g$$

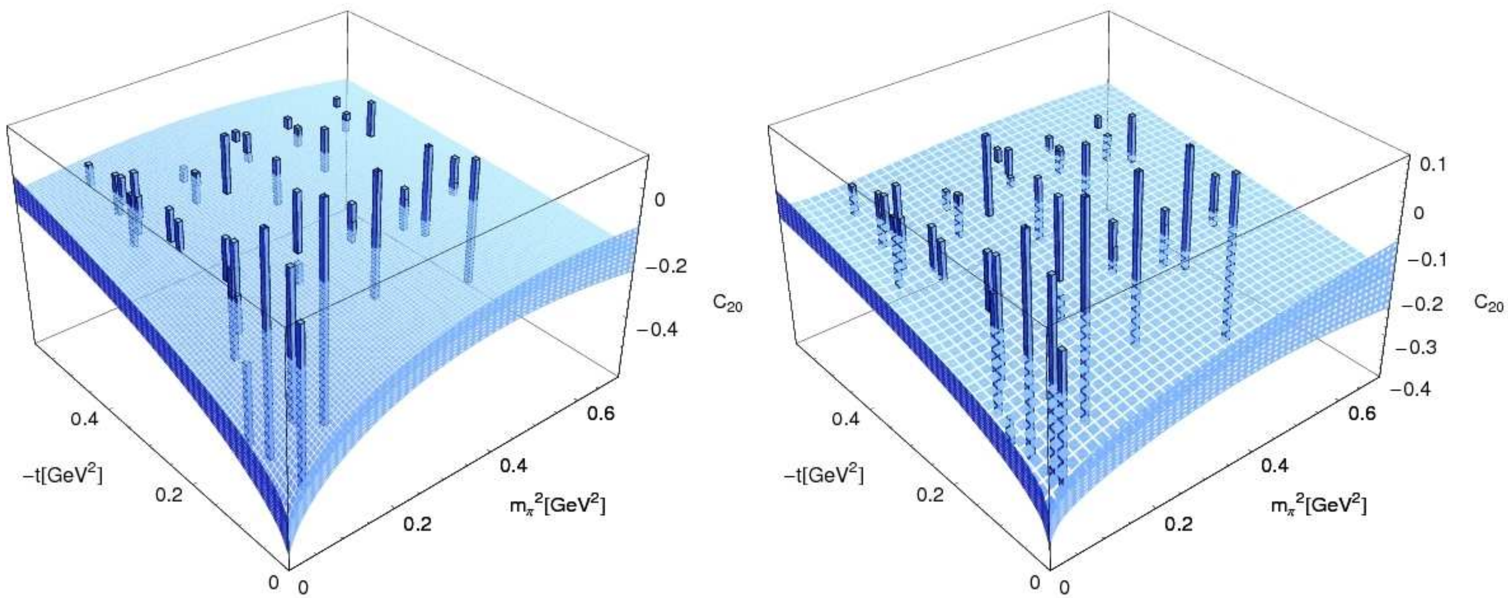
$$\Delta\Sigma^q = \tilde{A}_{10}^q(0) \qquad J^q = \frac{1}{2}\left(A_{20}^q(0) + B_{20}^q(0)\right) \qquad L^q = J^q - \frac{1}{2}\Delta\Sigma^q$$

- transverse quark distributions

$$\int_{-1}^{1} dx\, x^{n-1}\, q(x,\vec{b}_\perp) \;=\; \int \frac{d^2\Delta_\perp}{(2\pi)^2} e^{-i\vec{b}_\perp\cdot\vec{\Delta}_\perp} A_{n0}^q(-\vec{\Delta}_\perp^2)$$

Covariant versus Heavy Baryon Chiral Perturbation Theory

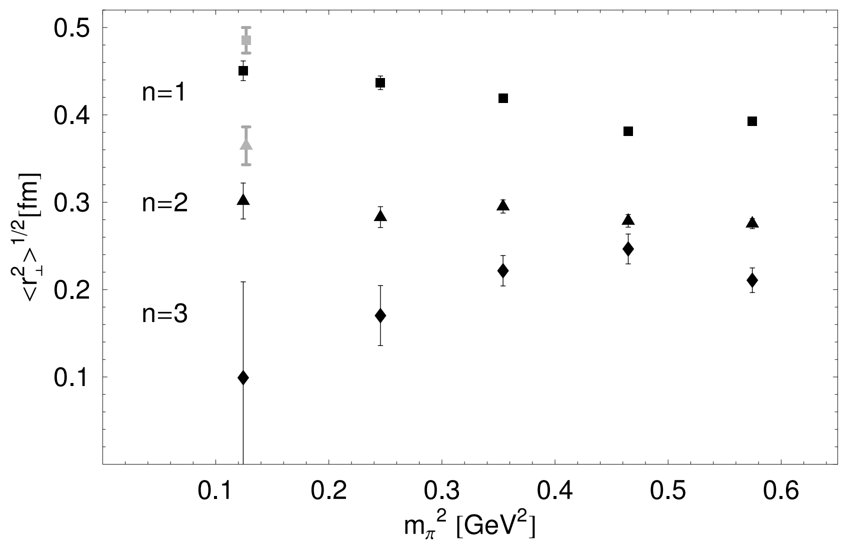
- simultaneous fits to q^2 and m_π dependence

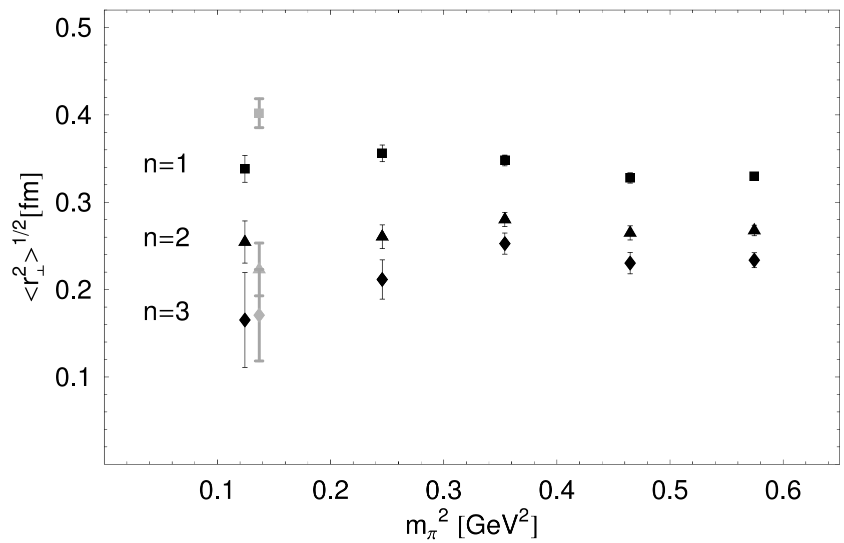


- comparing heavy baryon formulation (left) and covariant (right)

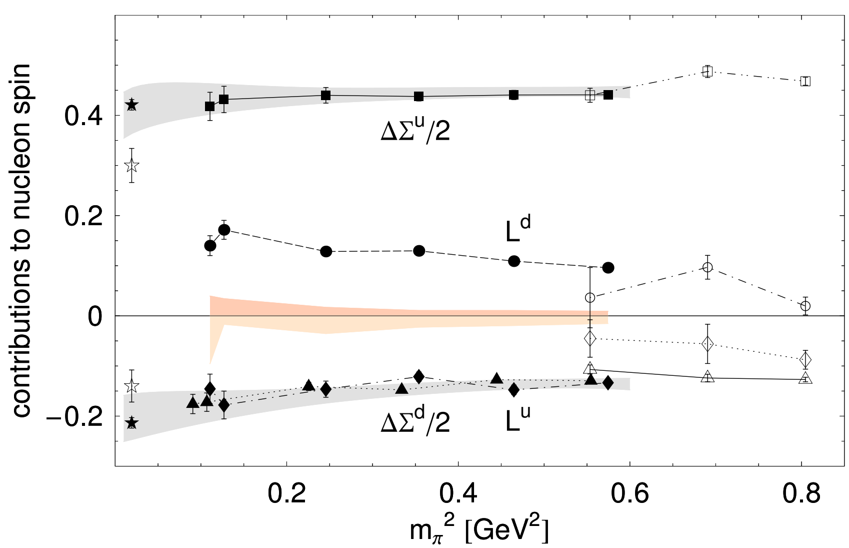
Transverse Structure and Spin Decomposition

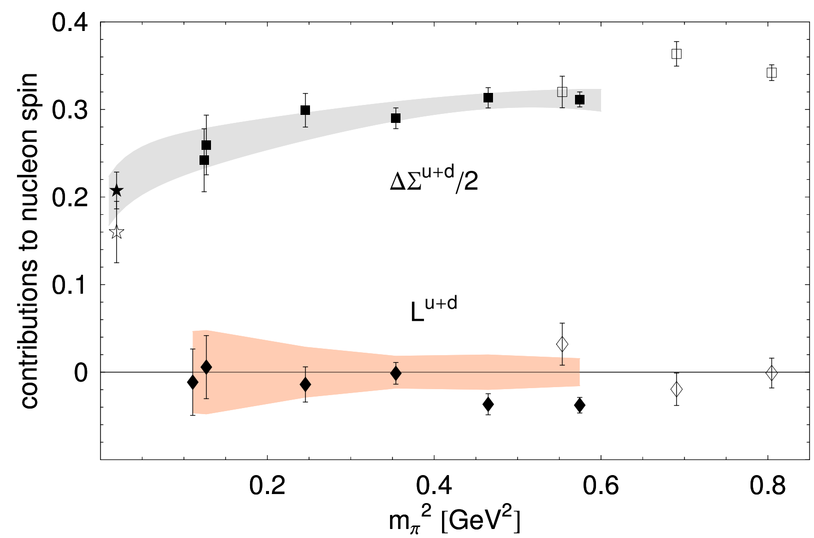
- transverse size shows a significant dependence on n and hence x





- spin decomposition agrees with the latest HERMES results





Conclusions

- fits including oscillating exponentials provide a successful description of the oscillations observed in domain wall correlators

- replacing $\overset{\circ}{f}$, $\overset{\circ}{g}$, $\langle \overset{\circ}{x} \rangle$ with f, g, $\langle x \rangle$ in NLO terms of chipt give results that agree with experimental measurements of f_π, g_A, $\langle x \rangle_{u-d}$, $\langle x \rangle_{\Delta u - \Delta d}$

- the potential for predictions of $\langle 1 \rangle_{\delta u - \delta d}$ and $\langle x \rangle_{\delta u - \delta d}$ is highlighted

- the relationship between m_π and q^2 dependence of generalized form factors is studied in both heavy baryon and convariant chipt

- the nucleon's transverse size shows a significant n (hence x) dependence

- the nucleon's spin decomposition agree with the latest HERMES results