Nucleon Spin from Lattice QCD

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http://talks.drubryantrenner.org/jlab_spin_6-13-06.pdf

Moments of Parton Distributions

- for example, unpolarized parton distributions

$$q(x) = < P,S| \int \frac{dy^-}{4\pi} e^{ixP^+y^-} \, \bar{q}(-y^-/2) \, \gamma^+ \, q(y^-/2) |P,S>$$

- light-cone expansion generates unpolarized twist two operators

$$O_q^{\mu_1 \cdots \mu_n} \;=\; \bar{q} i D^{(\mu_1} \ldots i D^{\mu_{n-1}} \gamma^{\mu_n)} q$$

- moments of parton distributions from forward matrix elements

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

- unpolarized, helicity and transversity

$$\begin{aligned} \langle x^n \rangle_q &= \int_{-1}^{1} dx \; x^n \, q(x) \\ \langle x^n \rangle_{\Delta q} &= \int_{-1}^{1} dx \; x^n \, \Delta q(x) \\ \langle x^n \rangle_{\delta q} &= \int_{-1}^{1} dx \; x^n \, \delta q(x) \end{aligned}$$

- please see, for example, hep-lat/0201021 for more details

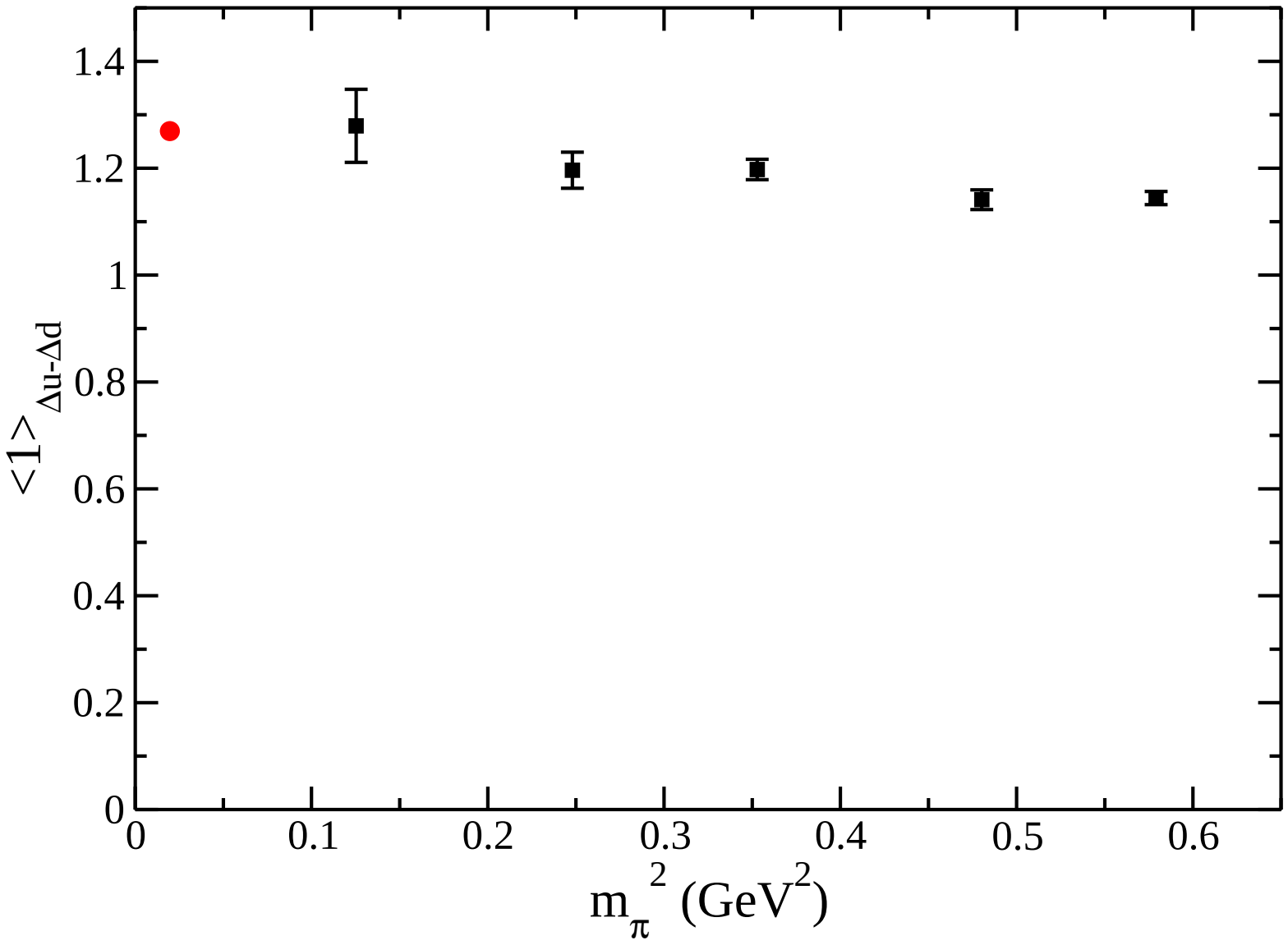
Hybrid Lattice Calculation

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

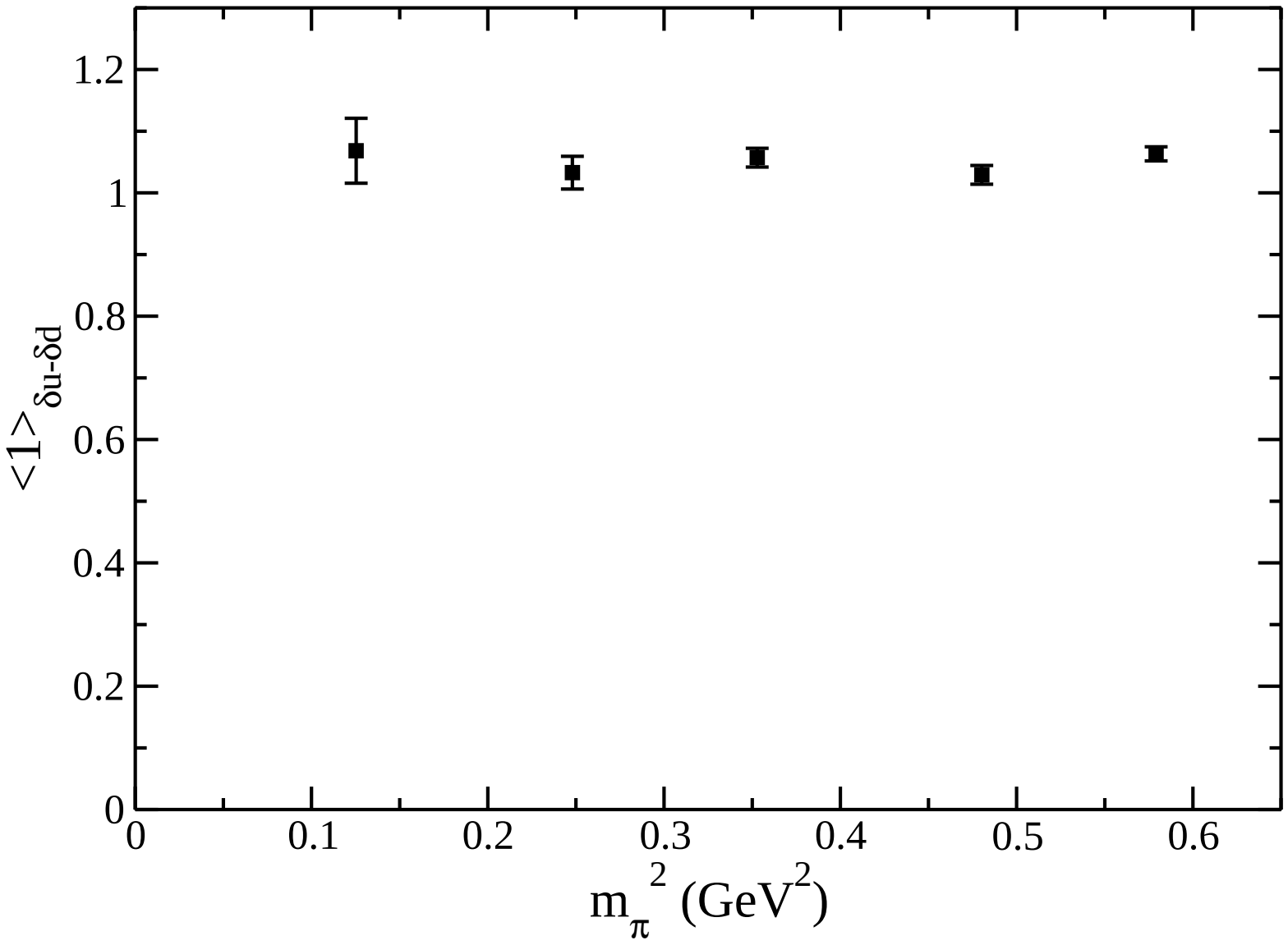
$am_{u/d}^{\text{asqtad}}$	L/a	L	m_π^{asqtad}	#
		fm	MeV	
0.05	20	2.52	770	425
0.04	"	"	692	350
0.03	"	"	601	564
0.02	"	"	495	486
0.01	"	"	357	656
0.01	28	3.53	357	270

- domain wall valence quarks with HYP smearing
- one loop perturbative renormalization at $\mu = 2$ GeV
- please see hep-lat/0409130 for more details

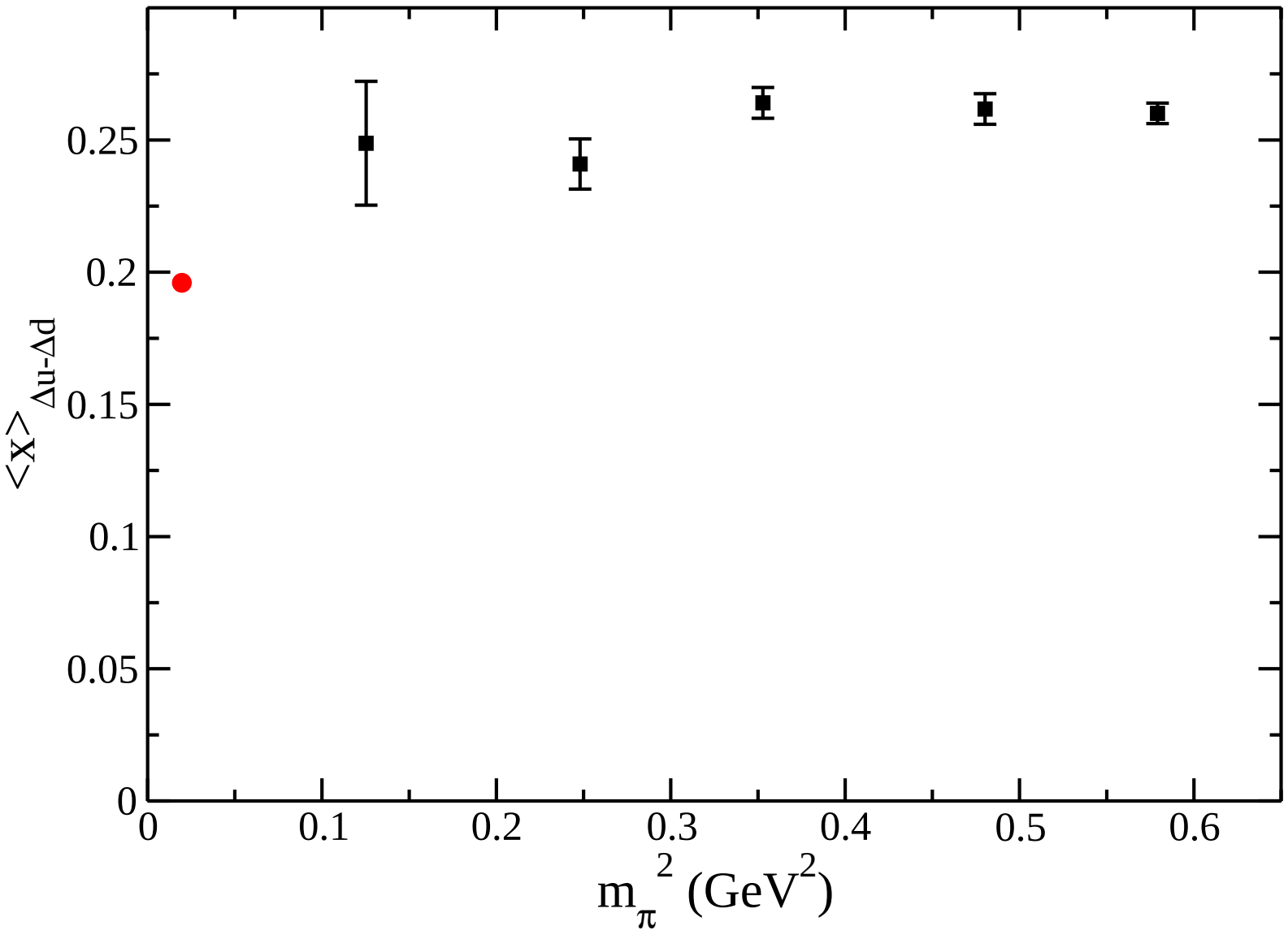
Axial Charge: $g_A = \langle 1 \rangle_{\Delta u - \Delta d}$



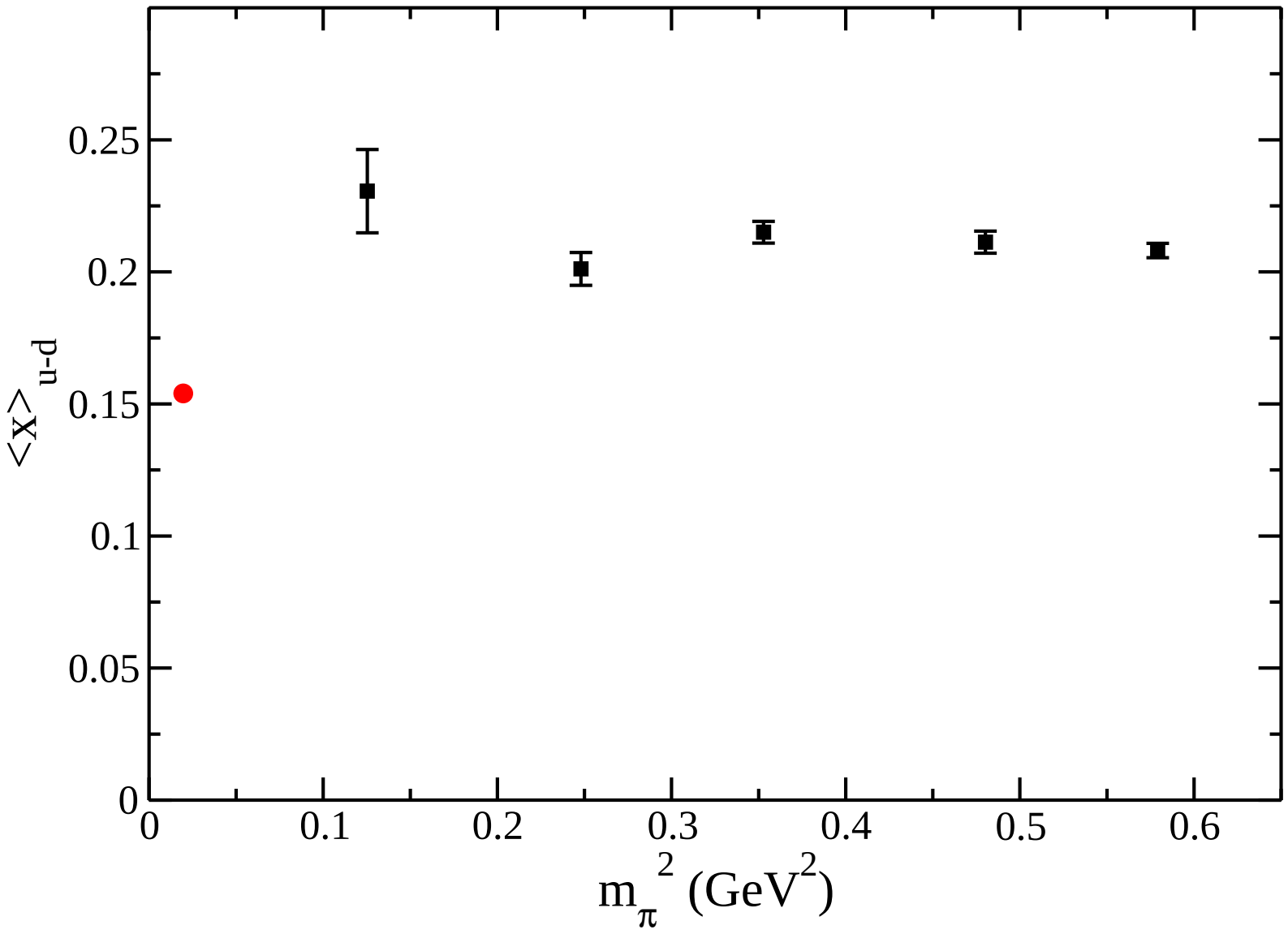
Tensor Charge: $g_T = \langle 1 \rangle_{\delta u - \delta d}$



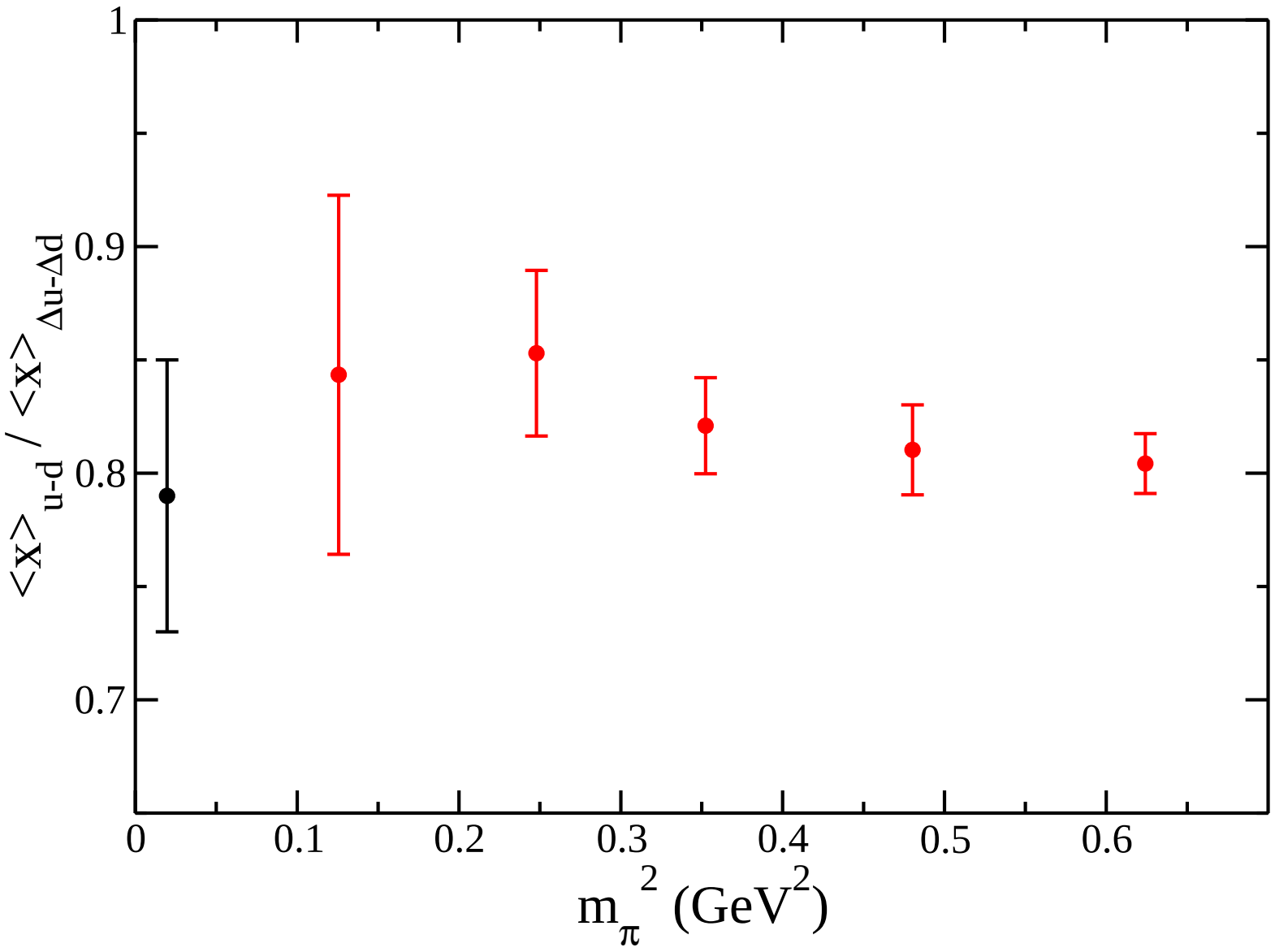
Polarized Momentum Fraction: $\langle x \rangle_{\Delta u - \Delta d}$



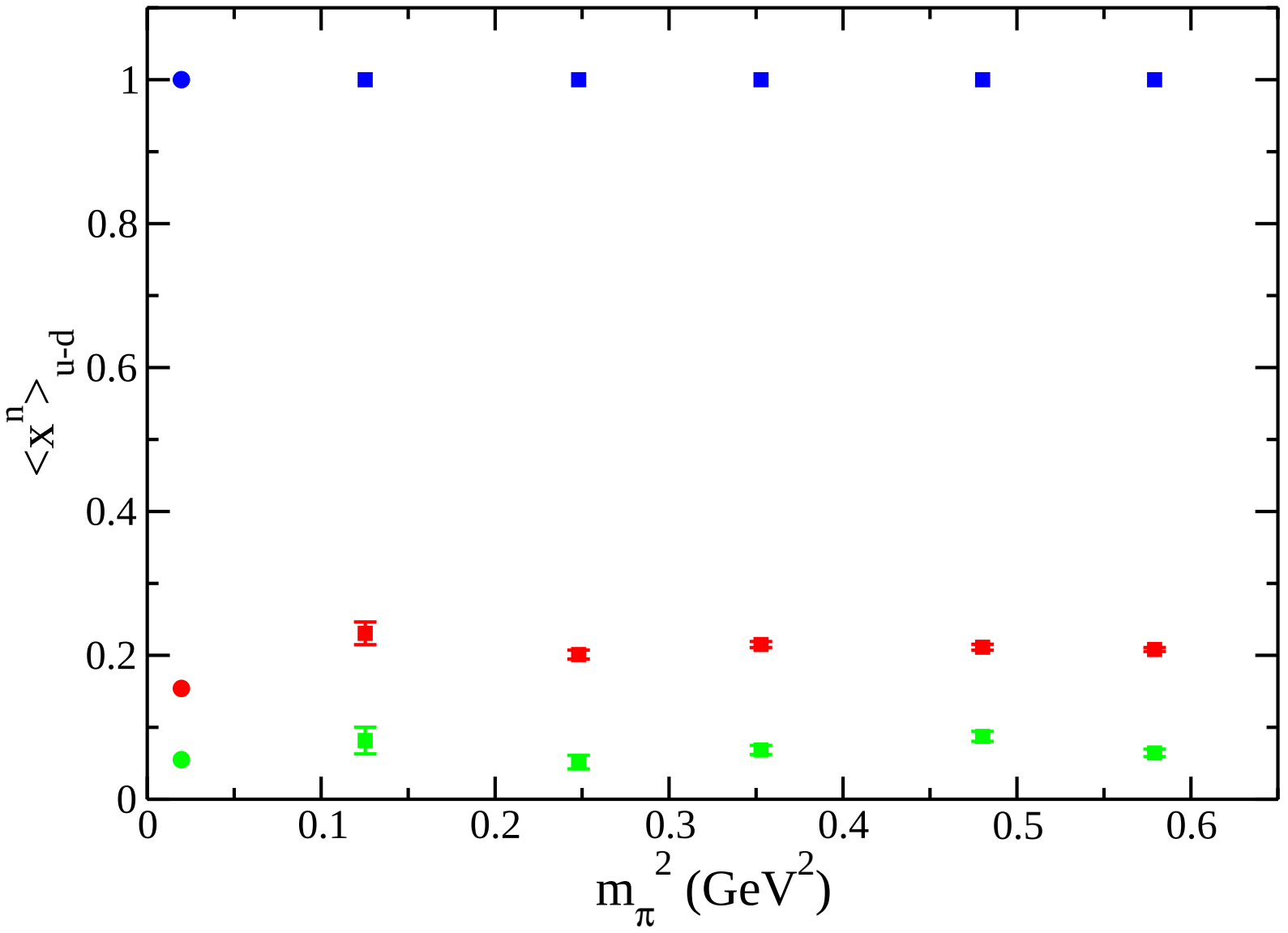
Momentum Fraction: $\langle x \rangle_{u-d}$



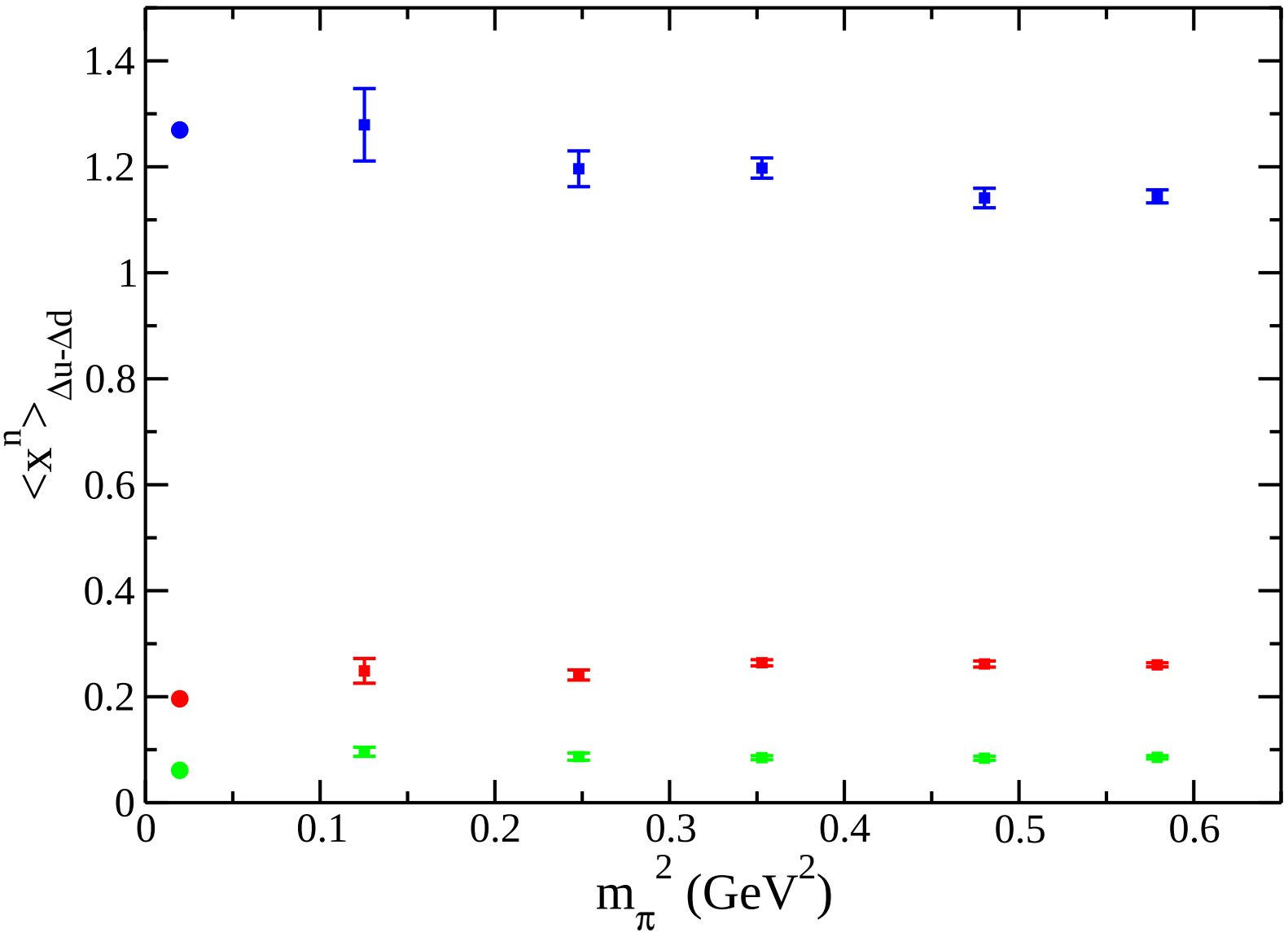
Momentum Fraction Ratio: $\langle x \rangle_{u-d} / \langle x \rangle_{\Delta u - \Delta d}$



Unpolarized Moments: $\langle x^n \rangle_{u-d}$

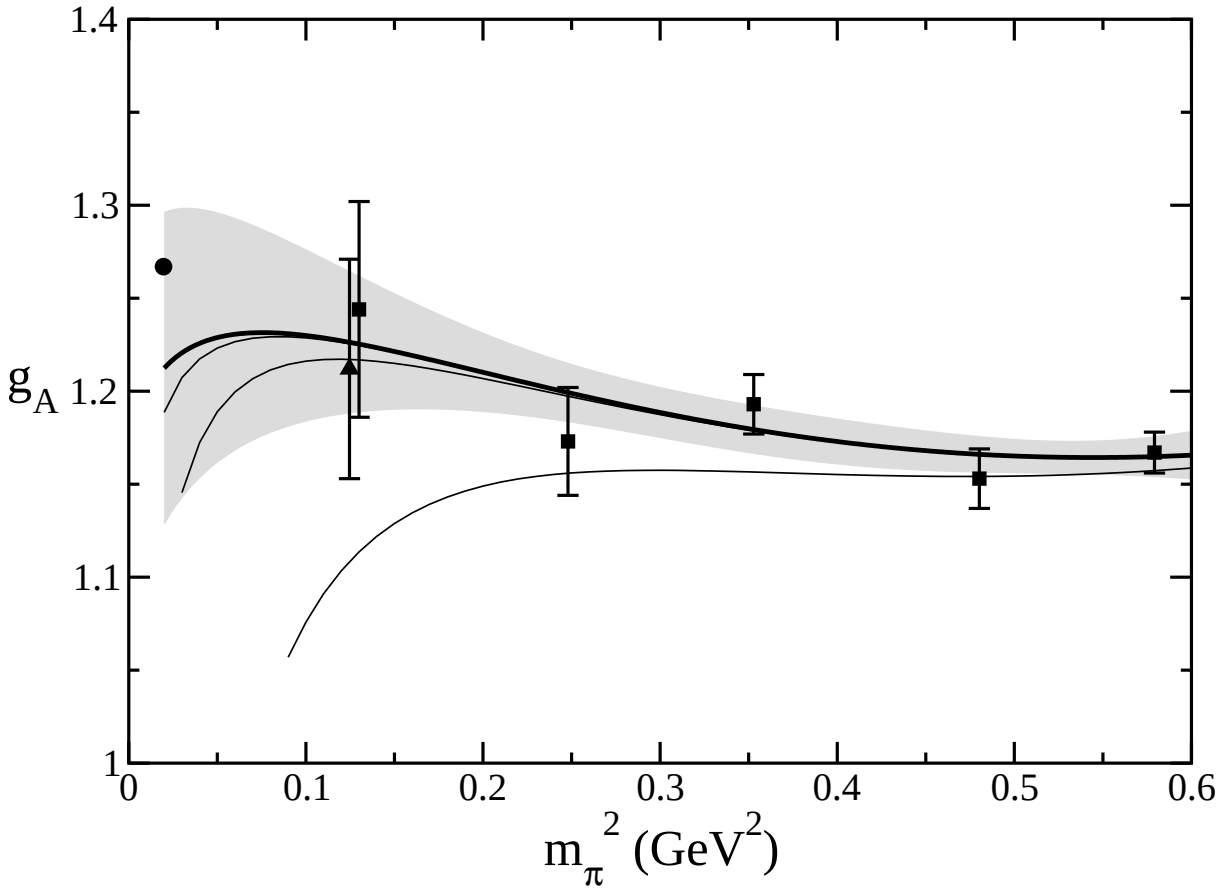


Polarized Moments: $\langle x^n \rangle_{\Delta u - \Delta d}$



Axial Charge g_A

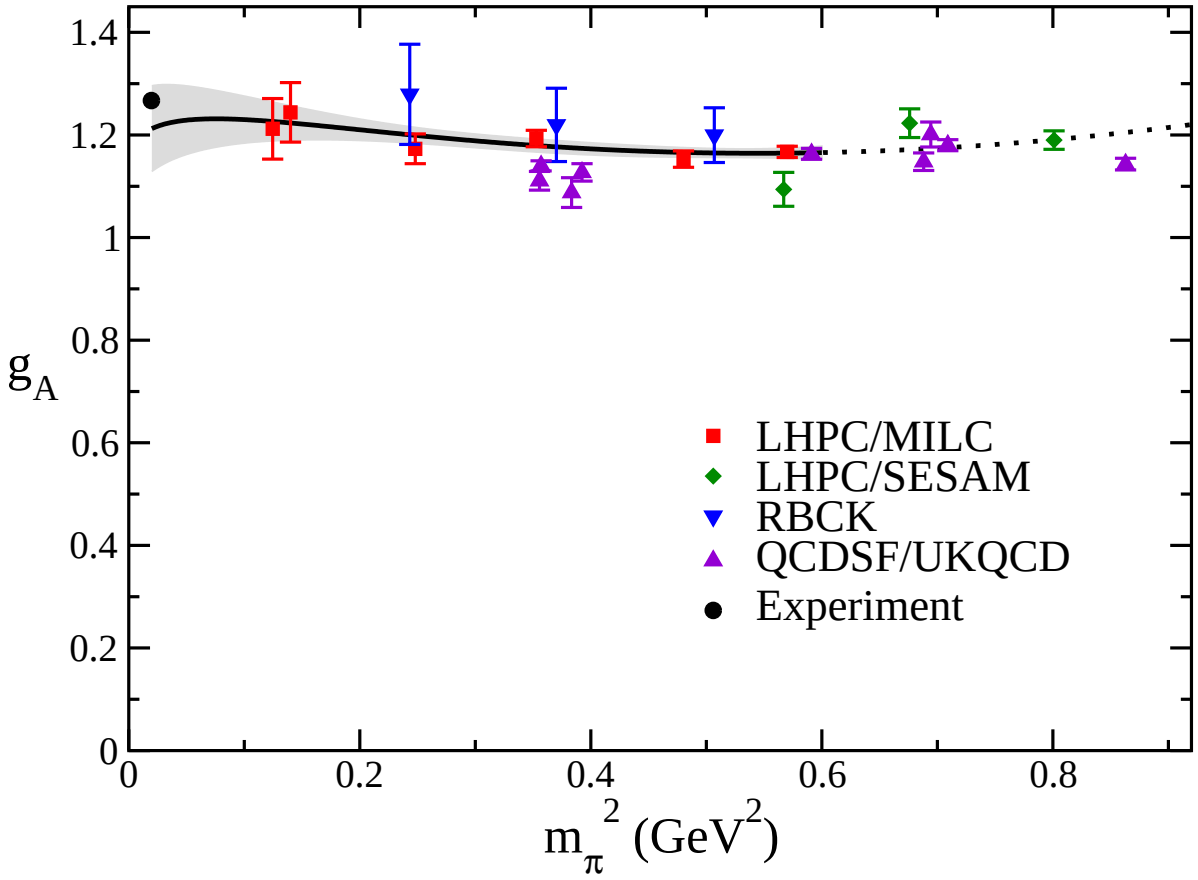
- curve is one loop chiral perturbation theory (including Δ) [1]
- parameters: f_π, $m_\Delta - m_N$, g^A_{NN}, $g^A_{N\Delta}$, $g^A_{\Delta\Delta}$, $C(\lambda)$
- f_π, $m_\Delta - m_N$ and $g^A_{N\Delta}$ are taken from experiment



[1] Beane and Savage hep-ph/0404131

Axial Charge g_A

- our final extrapolated value is $g_A = 1.212(84)$
- latest experimental value is $g_A = 1.2695(29)$
- world's full QCD calculations of g_A



Conclusions

- we can calculate the low moments of quark distributions $q(x)$, $\Delta q(x)$, and $\delta q(x)$ with lattice QCD

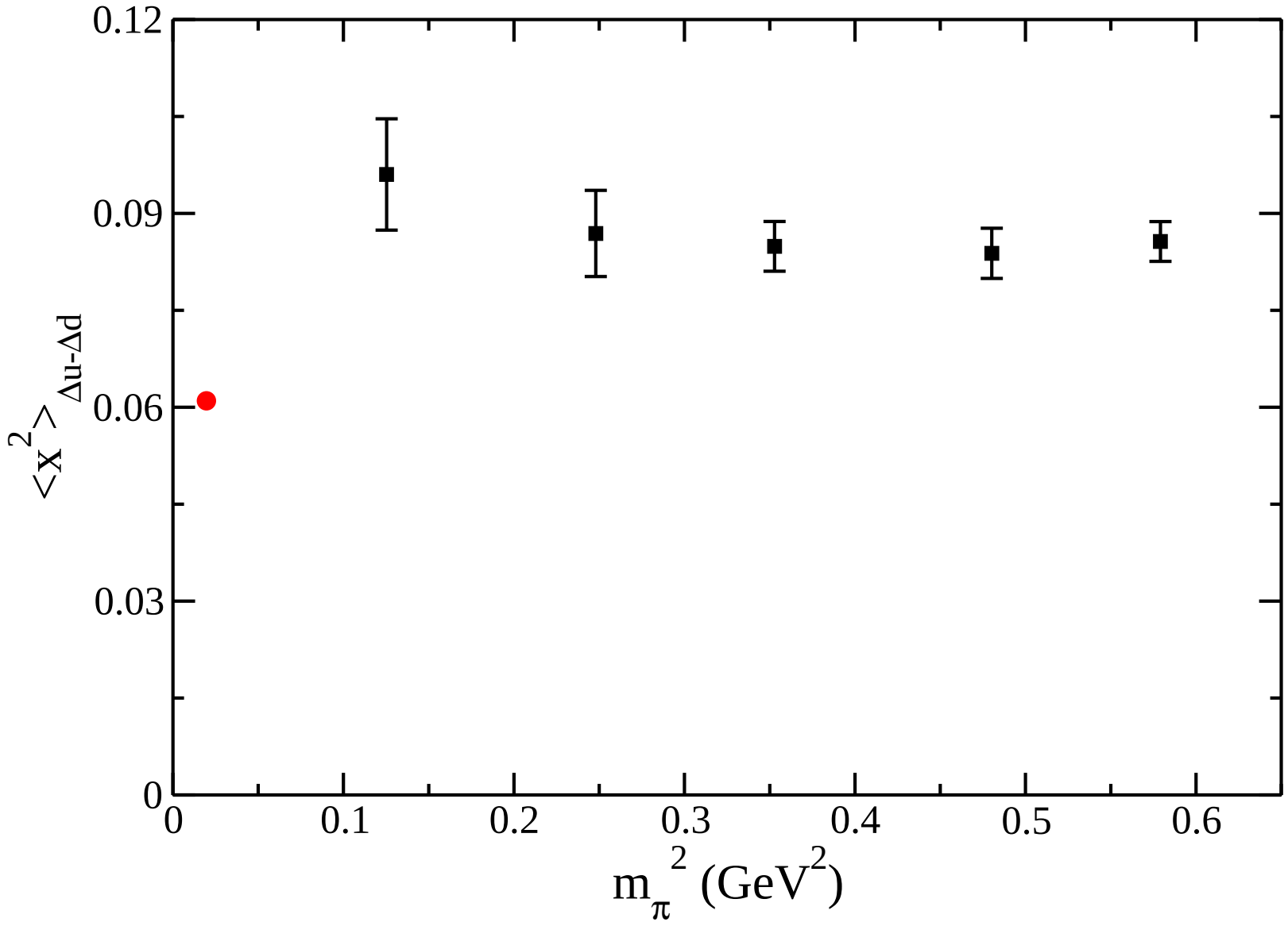
- with *hybrid* lattice QCD calculations we can probe the chiral limit with m_π down to 350 MeV and lower

- this allows for a calculation of g_A at $m_\pi = 354$ MeV, lighter than any other full QCD calculations, with an accuracy of 5%

- our extrapolated result is $g_A = 1.212(84)$ with a 7% error

Extra Slides

$\langle x^2 \rangle_{\Delta u - \Delta d}$



$\langle x^2 \rangle_{u-d}$