Chiral and Volume Extrapolations of g_A: Part I

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Nucleon structure calculations are described using a hybrid combination of improved staggered sea quarks and domain wall valence quarks at a range of pion masses extending down to 350 MeV. Results for the nucleon axial coupling are presented including chiral perturbation theory fits to describe both the pion mass and volume dependence of the axial coupling.

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for LHPC, in particular

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http://talks.drubryantrenner.org/int_3-16-06.pdf

Outline

- hybrid lattice calculation: domain wall fermions on staggered lattices with m_π down to 350 MeV and L up to 3.5 fm

- lattice calculation of nucleon matrix elements: g_A as an example

- chiral perturbation theory: m_π and L dependence of g_A

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

Tuning the Domain Wall Quark Mass

- determine the domain wall quark mass so that the domain wall and the lightest asqtad pion masses match

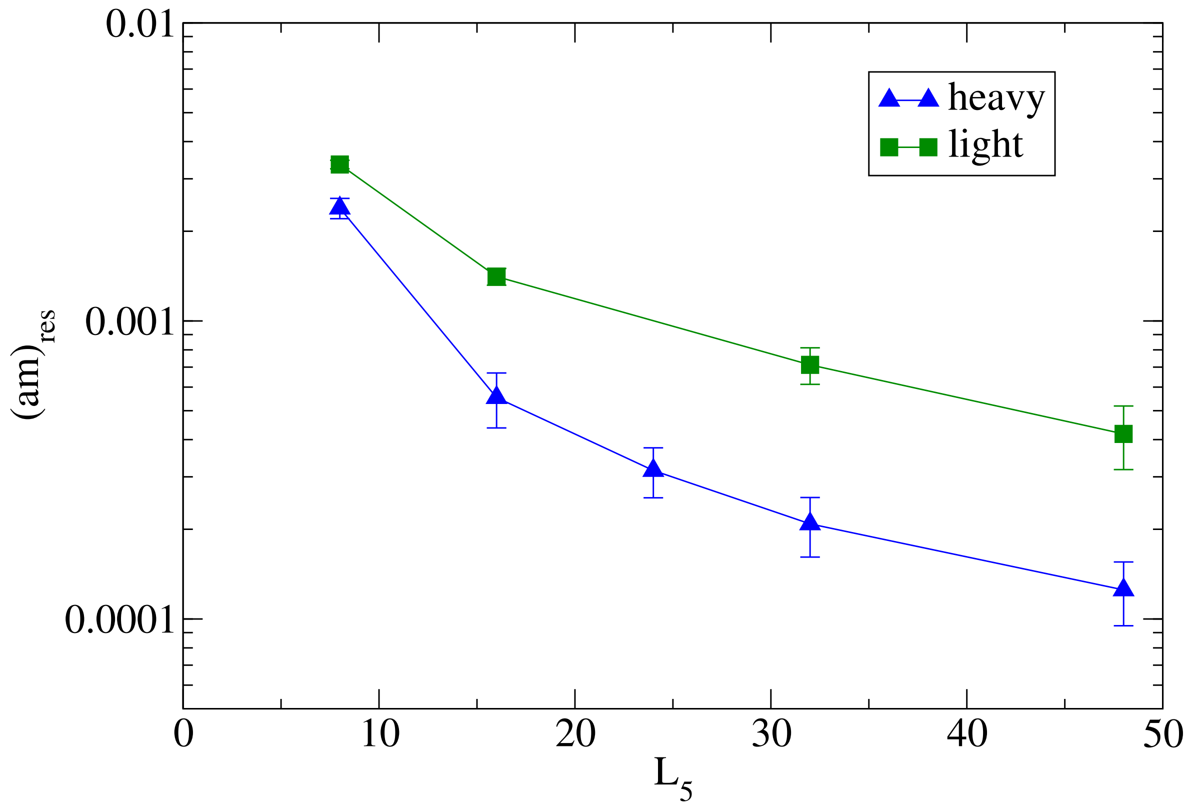
$am_{u/d}^{\text{asqtad}}$	L/a	L	$am_{u/d}^{\text{DWF}}$	m_π^{DWF}	m_π^{asqtad}	#
		fm		MeV	MeV	
0.05	20	2.52	0.0810	761(2)	770	425
0.04	"	"	0.0644	693(3)	692	350
0.03	"	"	0.0478	594(2)	601	564
0.02	"	"	0.0313	498(2)	495	486
0.01	"	"	0.0138	354(3)	357	656
0.01	28	3.53	0.0138	353(1)	357	270

Residual Quark Mass

- at finite L_5 there is an explicit chiral symmetry breaking which can be characterized by the residual quark mass

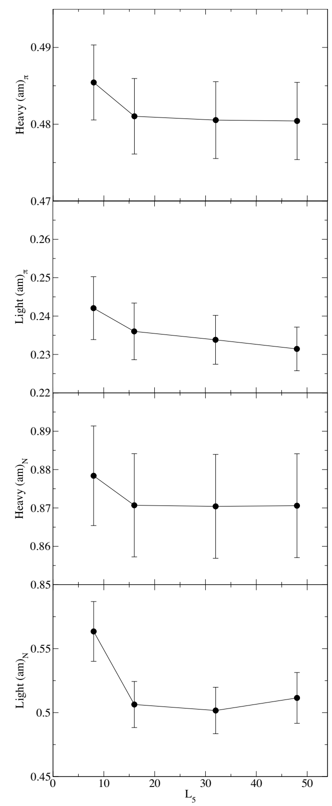
$$\Delta^\mu J^a_{5\mu} = 2m_q J^a_5 + 2J^a_{5\text{mid}} \quad \text{and} \quad J^a_{5\text{mid}} \approx m_{\text{res}} J^a_5$$

- we determine L_5 so that the residual quark mass is less than 10% of the quark mass



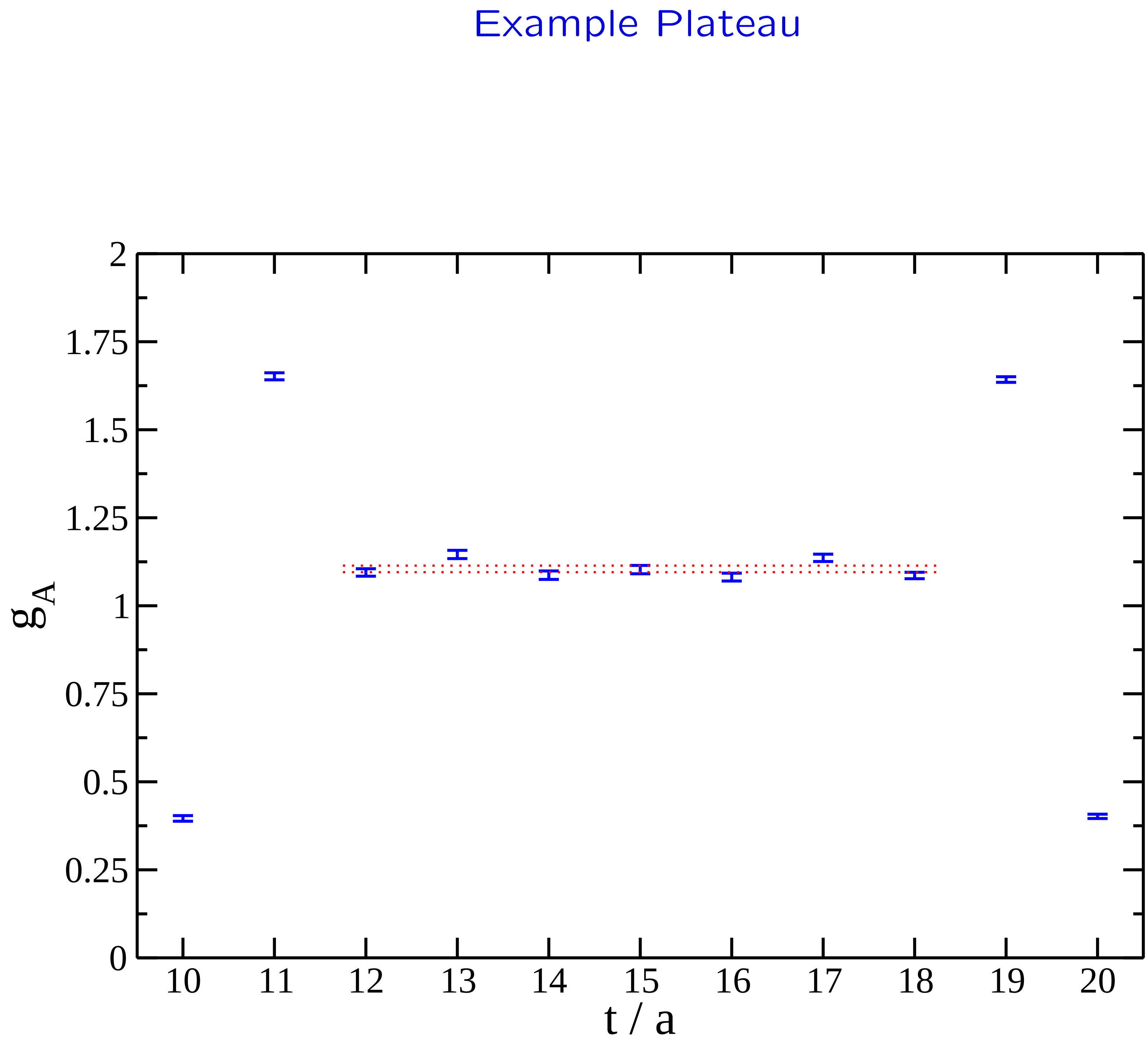
L_5 Dependence

- we also investigate the L_5 dependence of other observables



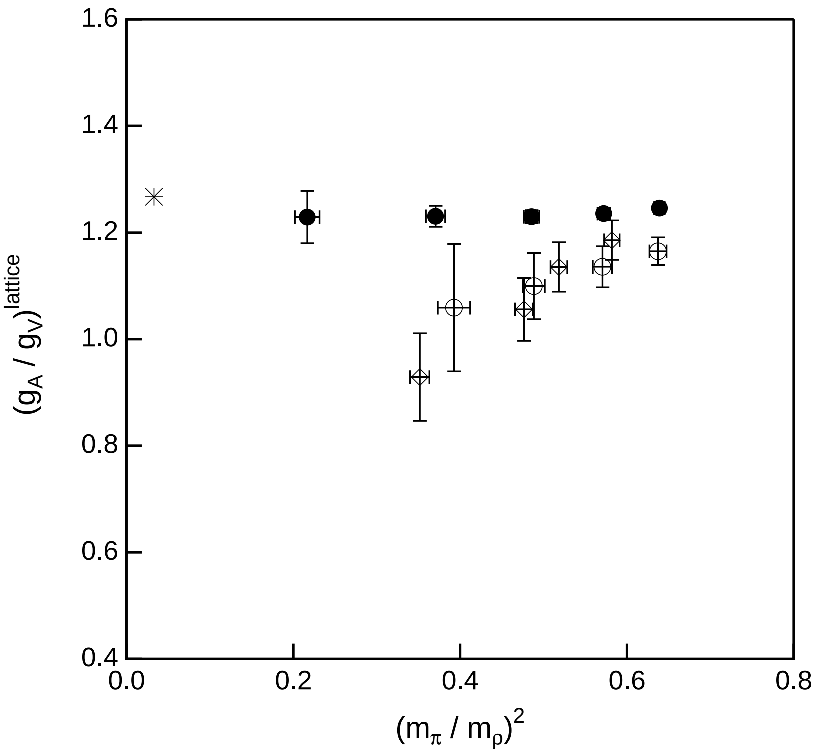
Nucleon Axial Coupling

- accurately measured in neutron β decay: $g_A = 1.2695(29)$
- it is a measure of spontaneous chiral symmetry breaking
- it probes the spin content of the nucleon: $g_A = \langle 1 \rangle_u - \langle 1 \rangle_d$
- it can be renormalized non-pertubatively by using the Ward identity
- it can be used as a laboratory for finite size effects on the lattice
- it is a non-singlet so there are no disconnected diagrams


Example Plateau
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
g_A
10
11
12
13
14
15
16
17
18
19
20
t / a

Volume Dependence (RBCK-Quenched)

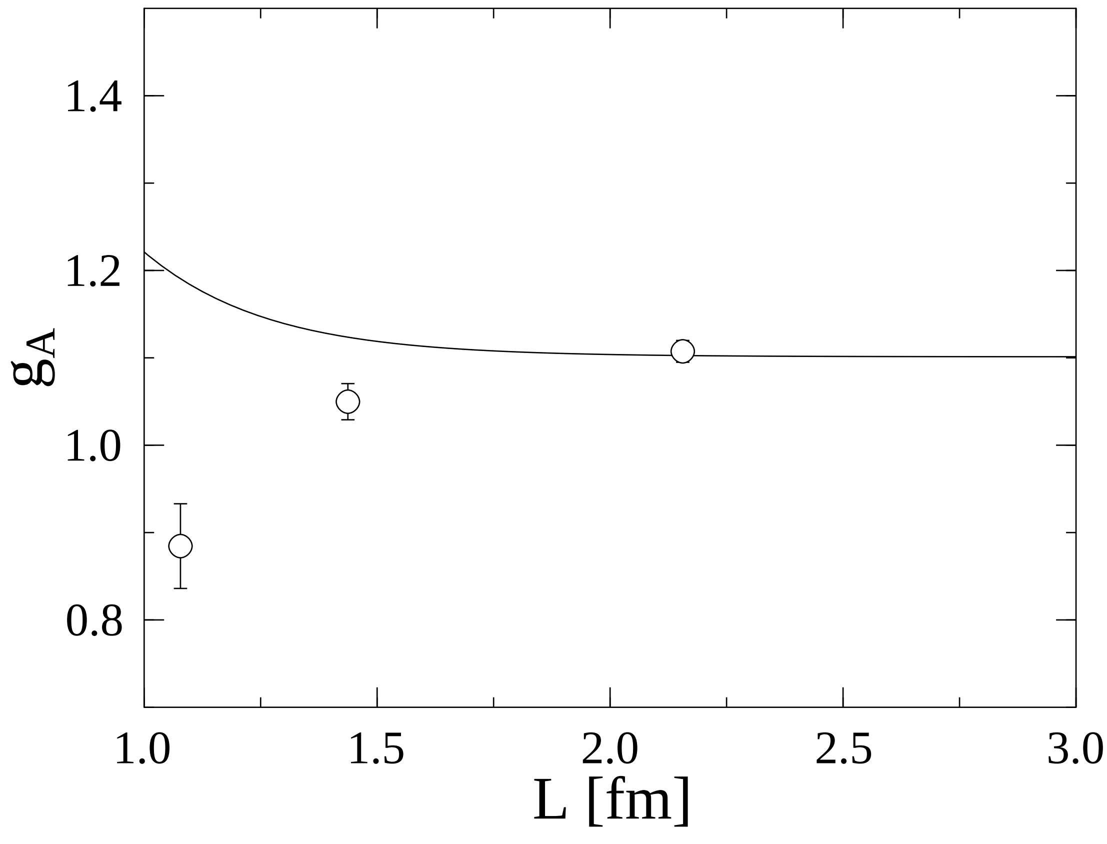
- $V = 2.4$ (fm)^3 (DBW2 glue)
- $V = 1.2$ (fm)^3 (DBW2 glue), $V = 1.6$ (fm)^3 (Wilson glue)



graph from RBCK hep-lat/0306007

Volume Dependence (QCDSF)

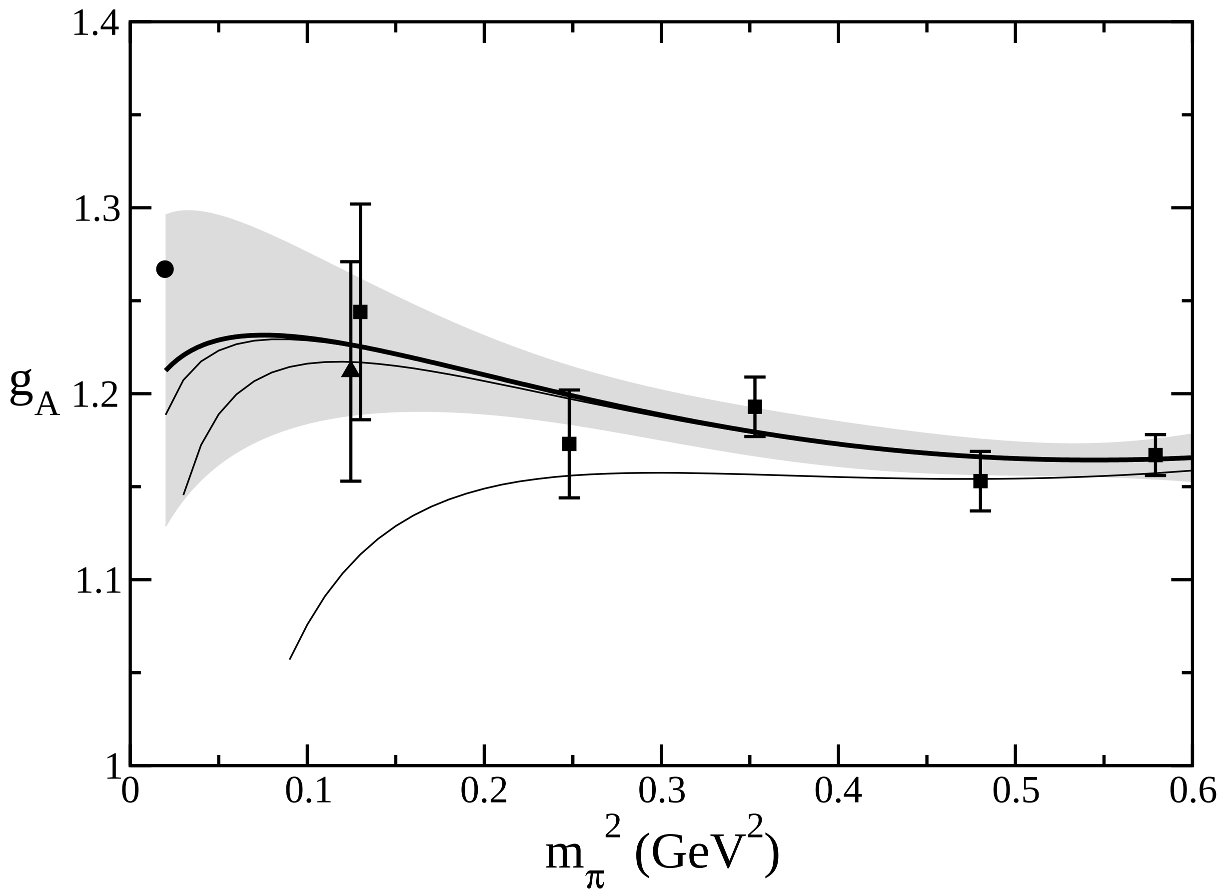
- curve is leading order chiral perturbation theory
- $m_\pi = 717$ (MeV)



graph from QCDSF hep-lat/0409161

Axial Charge g_A

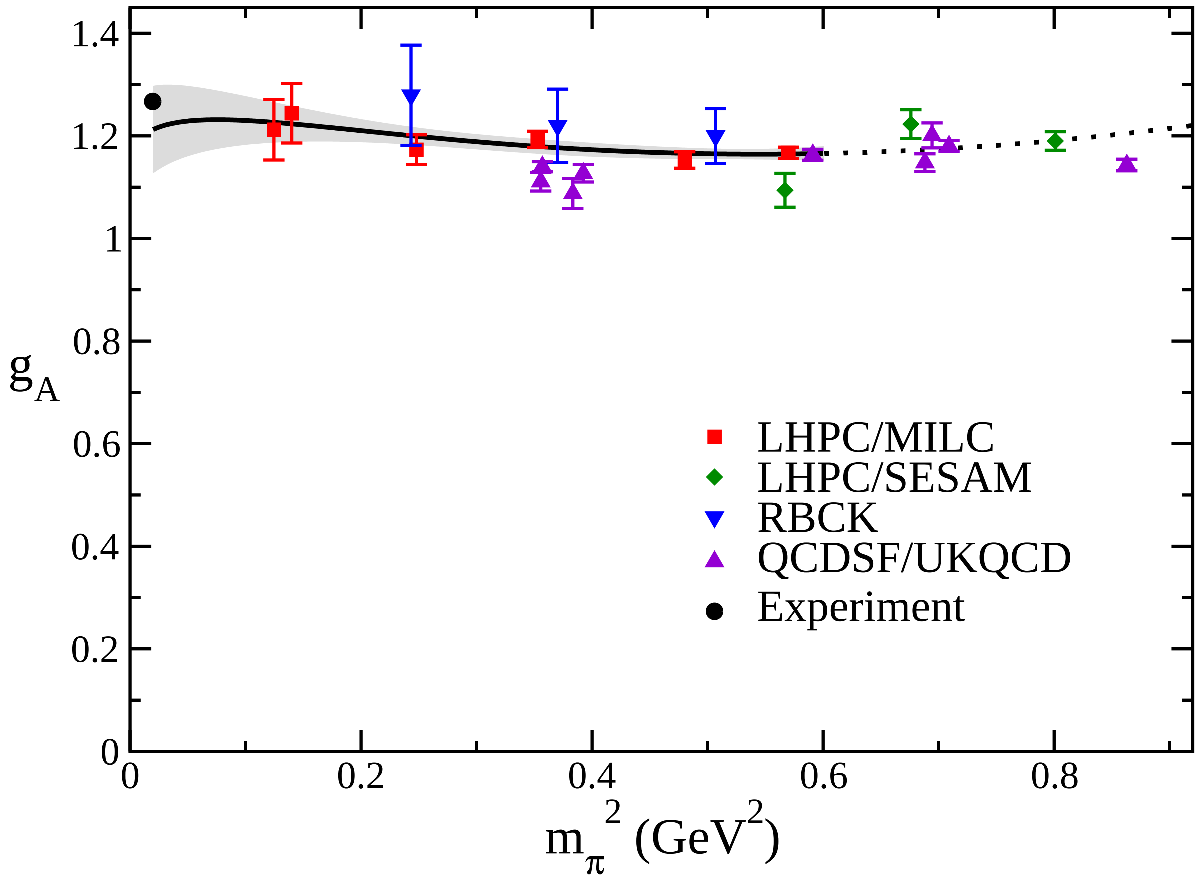
- curve is one loop chiral perturbation theory (including Δ) [1]
- parameters: f_π, $m_\Delta - m_N$, g^A_{NN}, $g^A_{N\Delta}$, $g^A_{\Delta\Delta}$, $C(\lambda)$
- f_π, $m_\Delta - m_N$ and $g^A_{N\Delta}$ are taken from experiment



[1] Beane and Savage hep-ph/0404131

Axial Charge g_A

- all full QCD calculations of g_A



- our final extrapolated value is $g_A = 1.212(84)$

Conclusions

- light quark calculations using domain wall fermions on staggered lattices with m_π down to 350 MeV and $L = 2.5$ and 3.5 fm

- 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%

- calculations with $L = 2.5$ fm and $L = 3.5$ fm allow for control over the finite size effects which plague other calculations

- we are entering the regime of sufficiently light quark masses to apply chiral perturbation theory to describe both the m_π and L dependence of g_A

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