Energies and radial distributions of B_s mesons — the effect of hypercubic blocking

UKQCD Collaboration

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Measurements and lattice parameters

- Measure angular and radial excitations of heavy-light mesons
- Heavy quark spin decouples from the game;
  Measure states $\mathrm{L}_{\pm} = \mathrm{L} \pm \frac{1}{2}$
- Dynamical fermions, a $16^3 \times 32$ lattice

	DF3	DF4	DF5
no. of configs.	160	119	139
m_q	$1.1 m_s$	$0.6 m_s$	$0.3 m_s$
a [fm]	0.110(6)	0.104(5)	0.099(4)
m_π [GeV]	0.73(2)	0.53(2)	0.42(2)

2-point correlation function

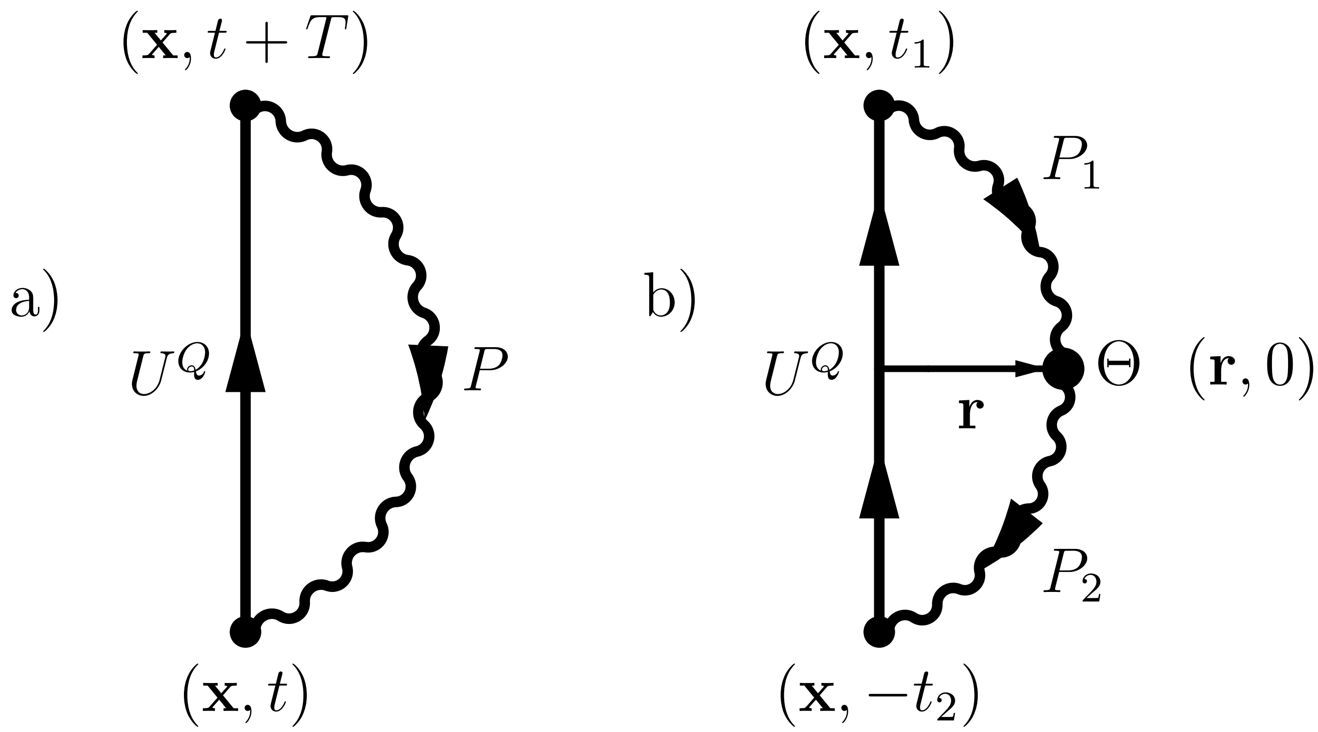
$$C_2(T) = \langle P_t \Gamma G_q(\mathbf{x}, t+T, t) P_{t+T} \Gamma^\dagger U^Q(\mathbf{x}, t, t+T) \rangle$$

$U^Q(\mathbf{x}, t, T)$ = heavy (infinite mass)-quark propagator
$G_q(\mathbf{x}, t+T, t)$ = light anti-quark propagator
P_t = path (products of gauge links at time t)
Γ = spin structure

The energies (m_i) and amplitudes (a_i) are extracted by fitting the C_2 with a sum of exponentials,

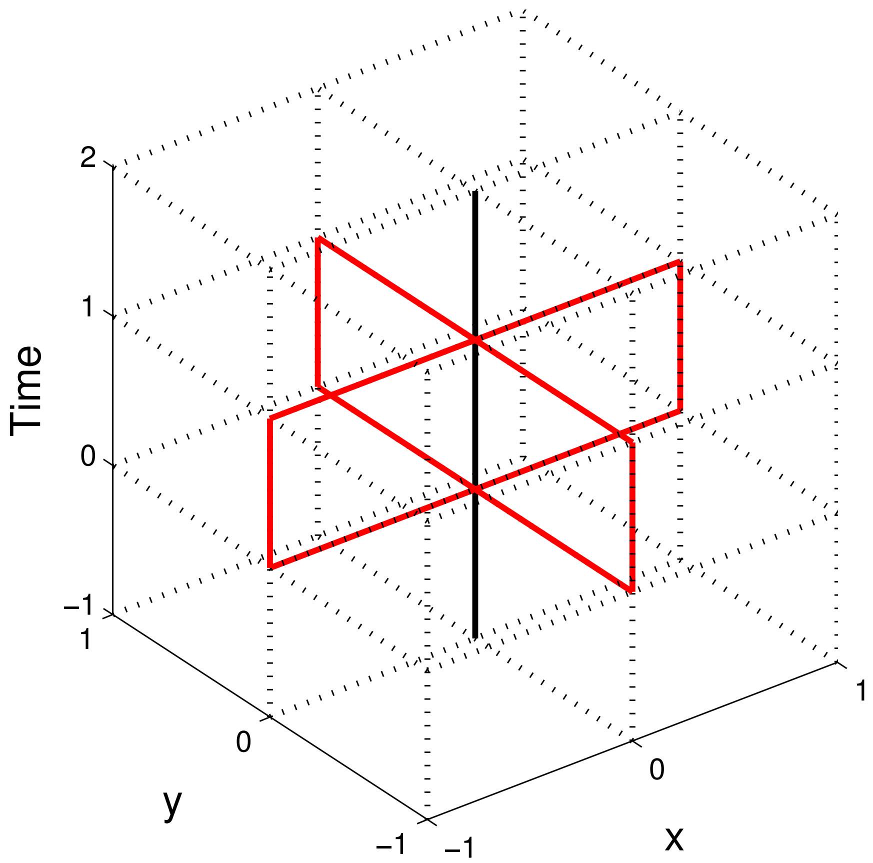
$$C_2(T) \approx \sum_{i=1}^{N_{\max}} a_i \mathrm{e}^{-m_i T}, \text{ where } N_{\max} = 2 - 4,\ T \leq 14.$$

Measured correlators

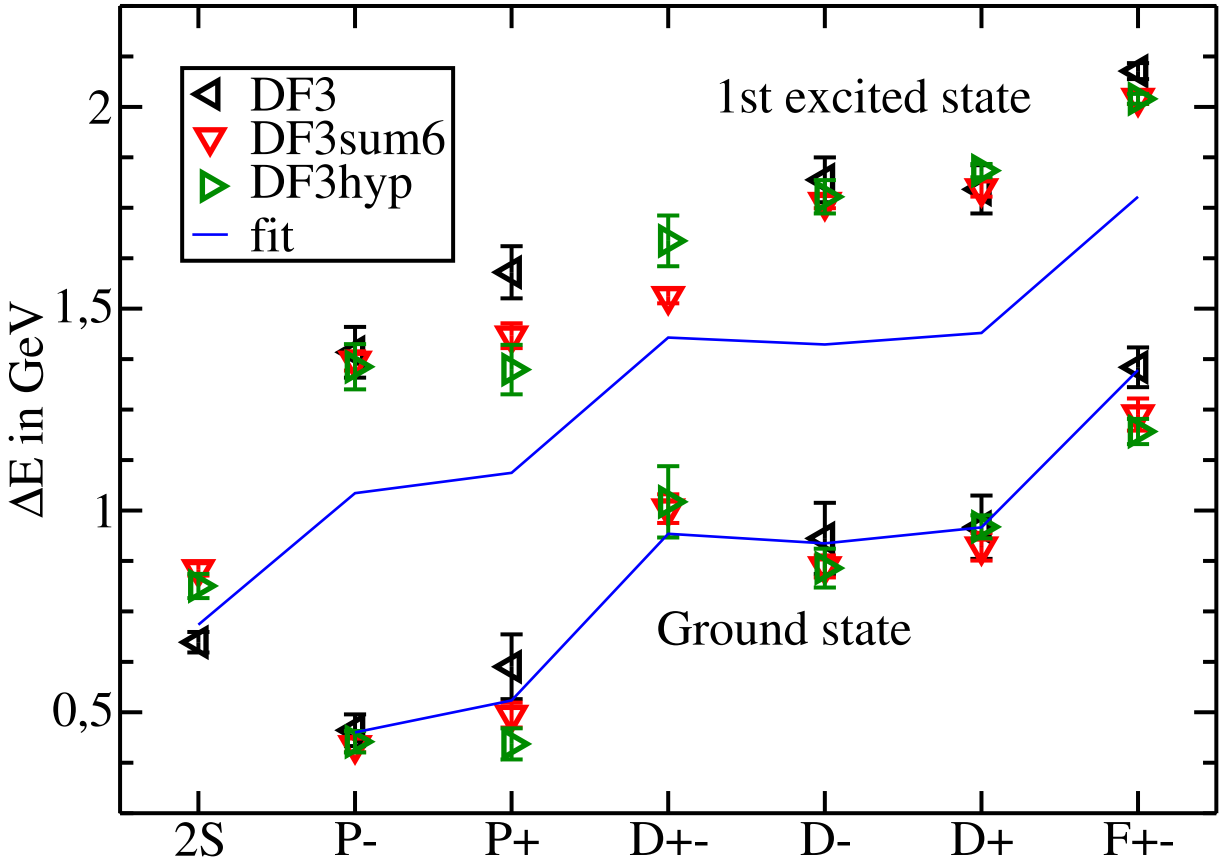


Two- and three-point correlation functions

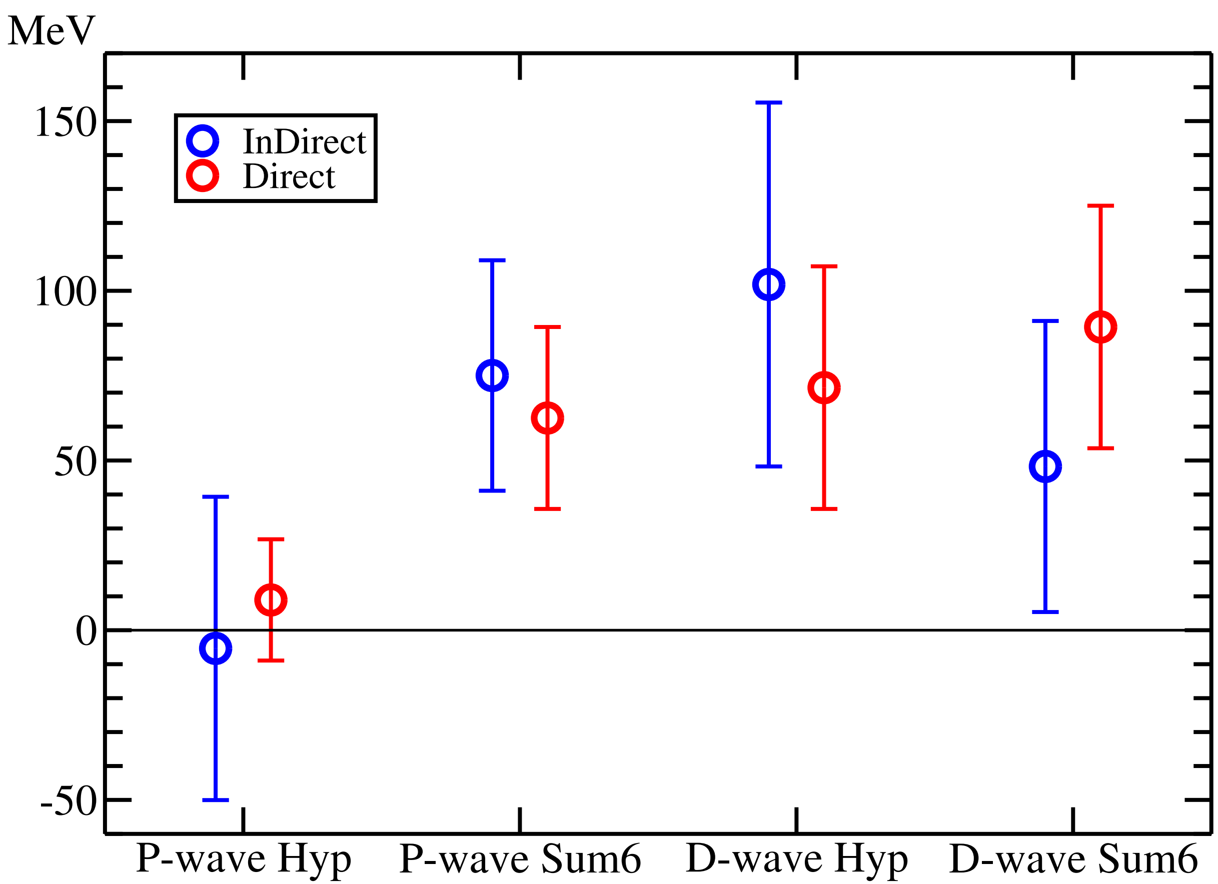
APE smeared heavy quark



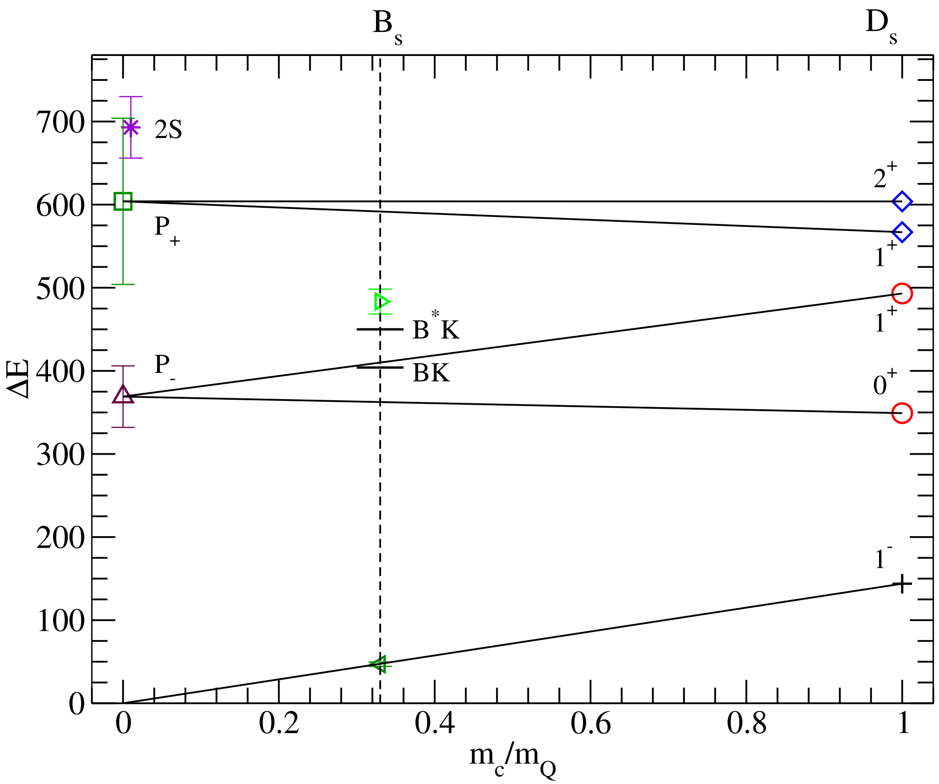
Energy spectrum



Spin-Orbit Splittings — direct versus indirect



Interpolation to B_s



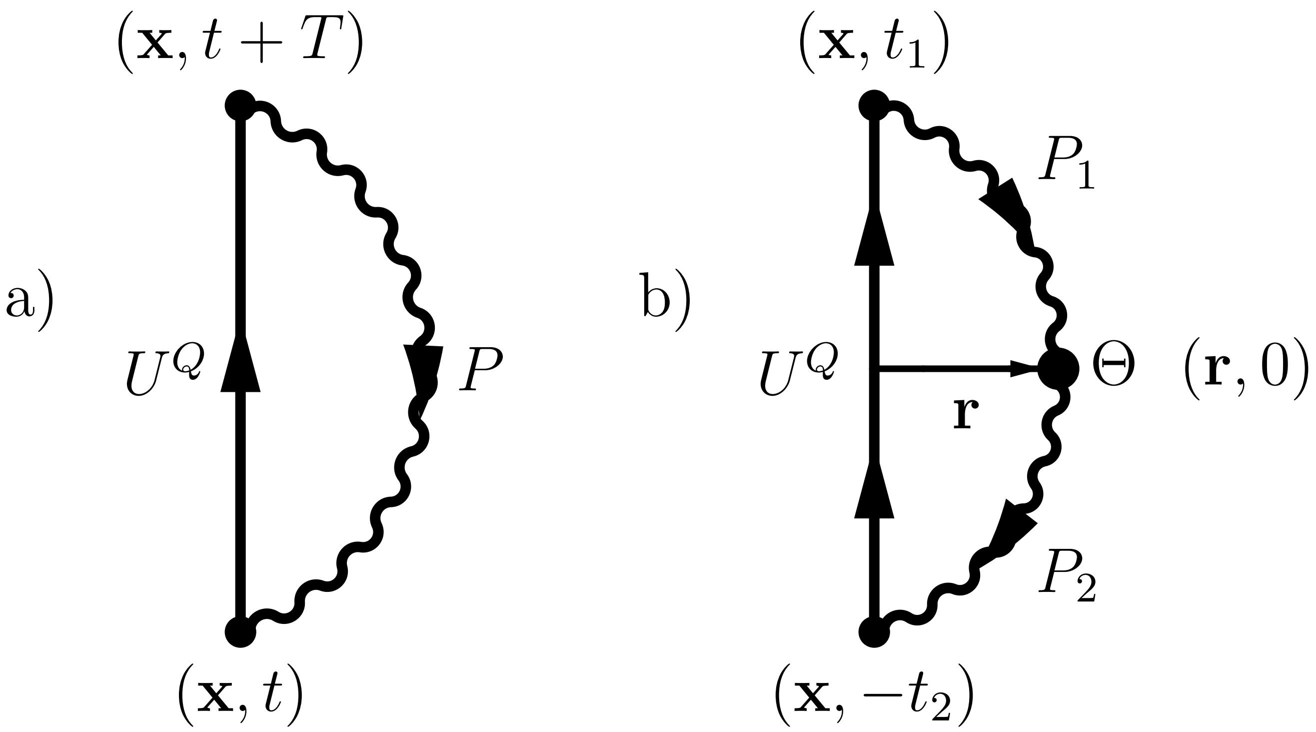
Radial distributions: 3-point correlation function

$$C_3(R,T) = \langle \Gamma^\dagger \, U^Q \, \Gamma \, G_{q1} \, \Theta \, G_{q2} \rangle$$

- Two light quark propagators, G_{q1} and G_{q2}.
- A probe $\Theta(R)$ at distance R from the static quark [γ_4 for the vector (charge) and 1 for the scalar (matter) distribution].
- Knowing the m_i, a_i from C_2, the radial distributions, $x^{ij}(R)$'s, are then extracted by fitting the C_3 with

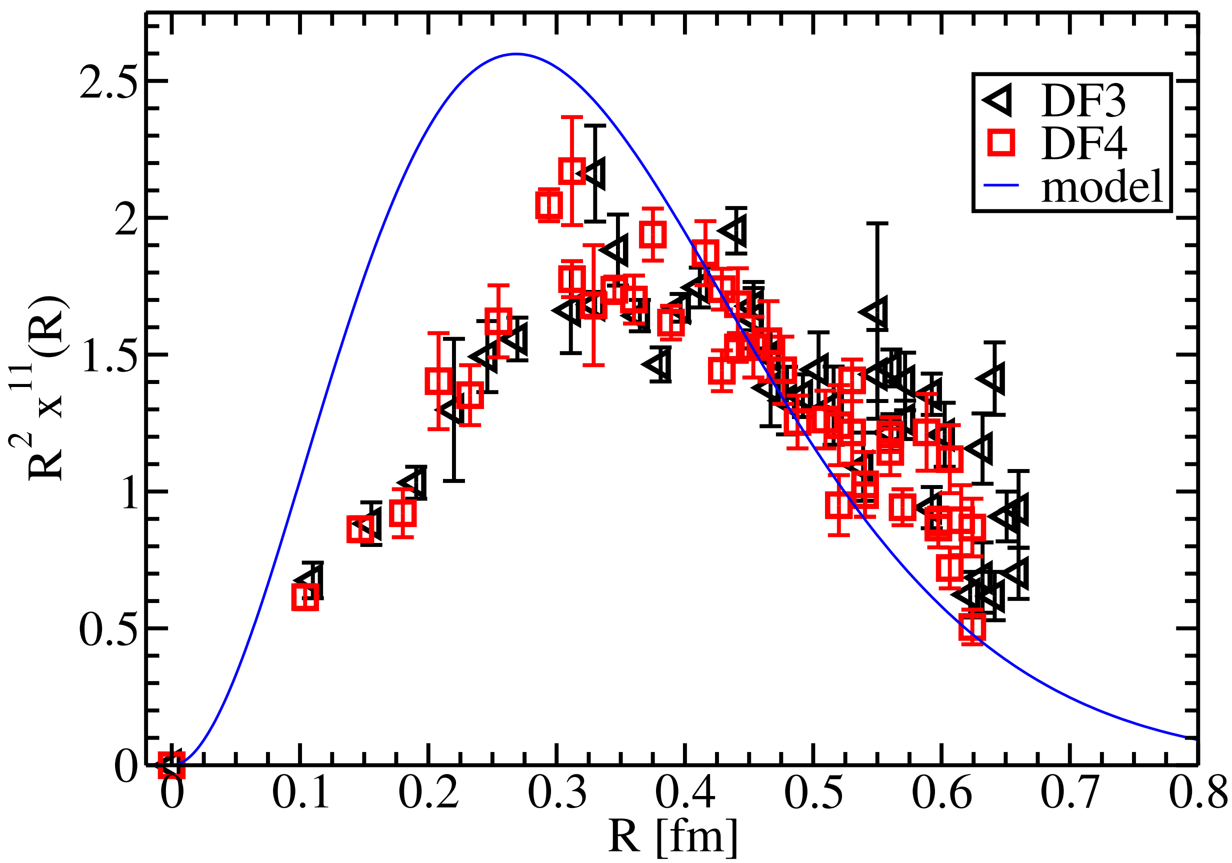
$$C_3(R,T) \approx \sum_{i,j=1}^{N_{\rm max}} a_i \mathrm{e}^{-m_i t_1} \; x^{ij}(R) \; \mathrm{e}^{-m_j t_2} a_j .$$

Measured correlators

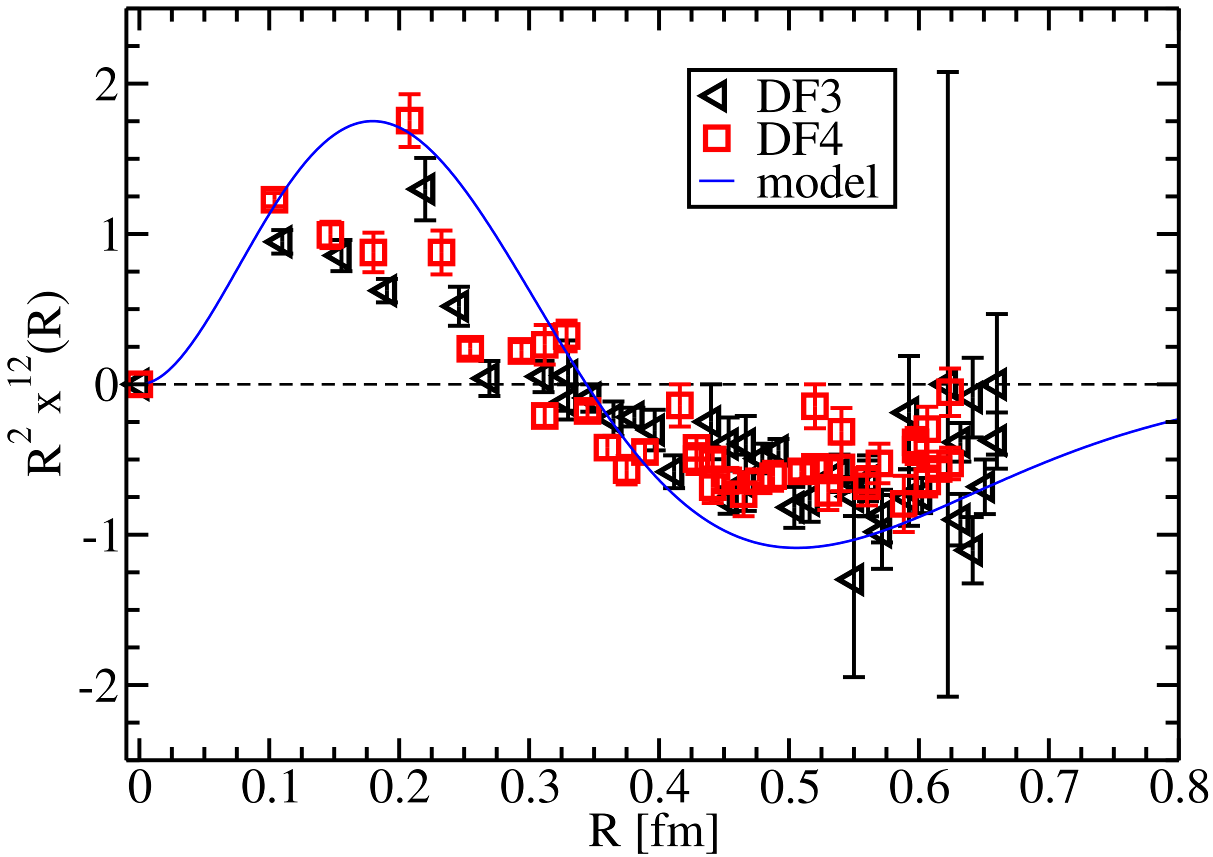


Two- and three-point correlation functions

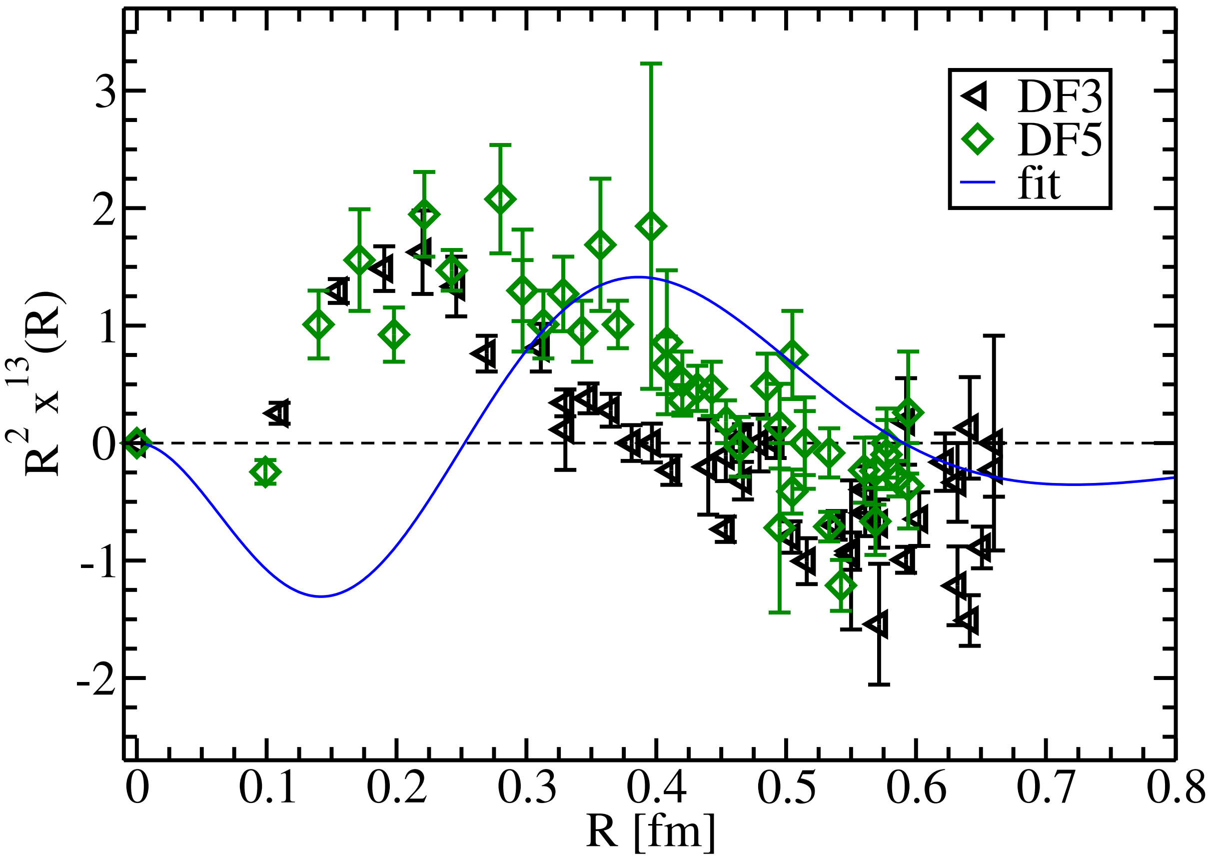
S-wave ground state charge distribution (x^{11})



S-wave ground state and 1st excited state overlap (x^{12})



S-wave ground state and 2nd excited state overlap (x^{13})



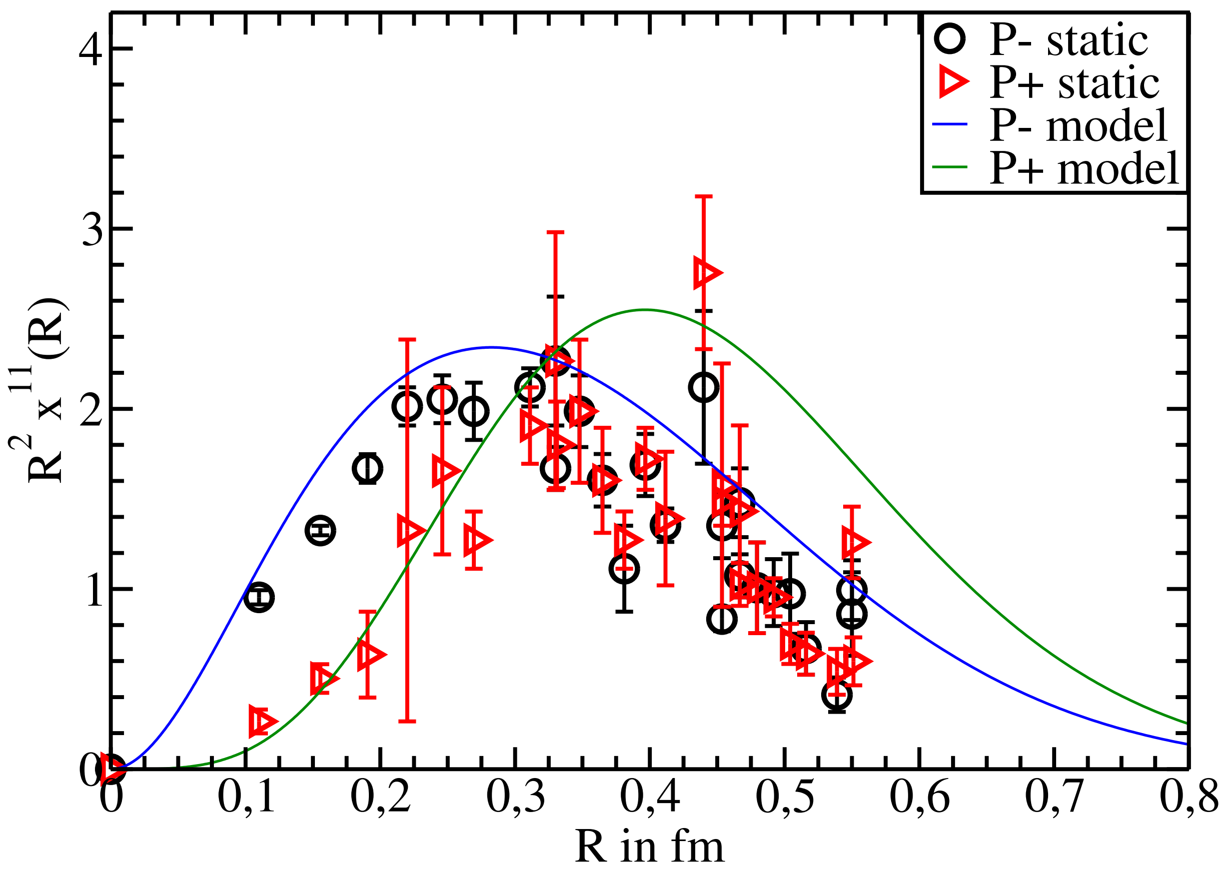
S-wave charge distributions

Earlier S-wave distribution calculations:

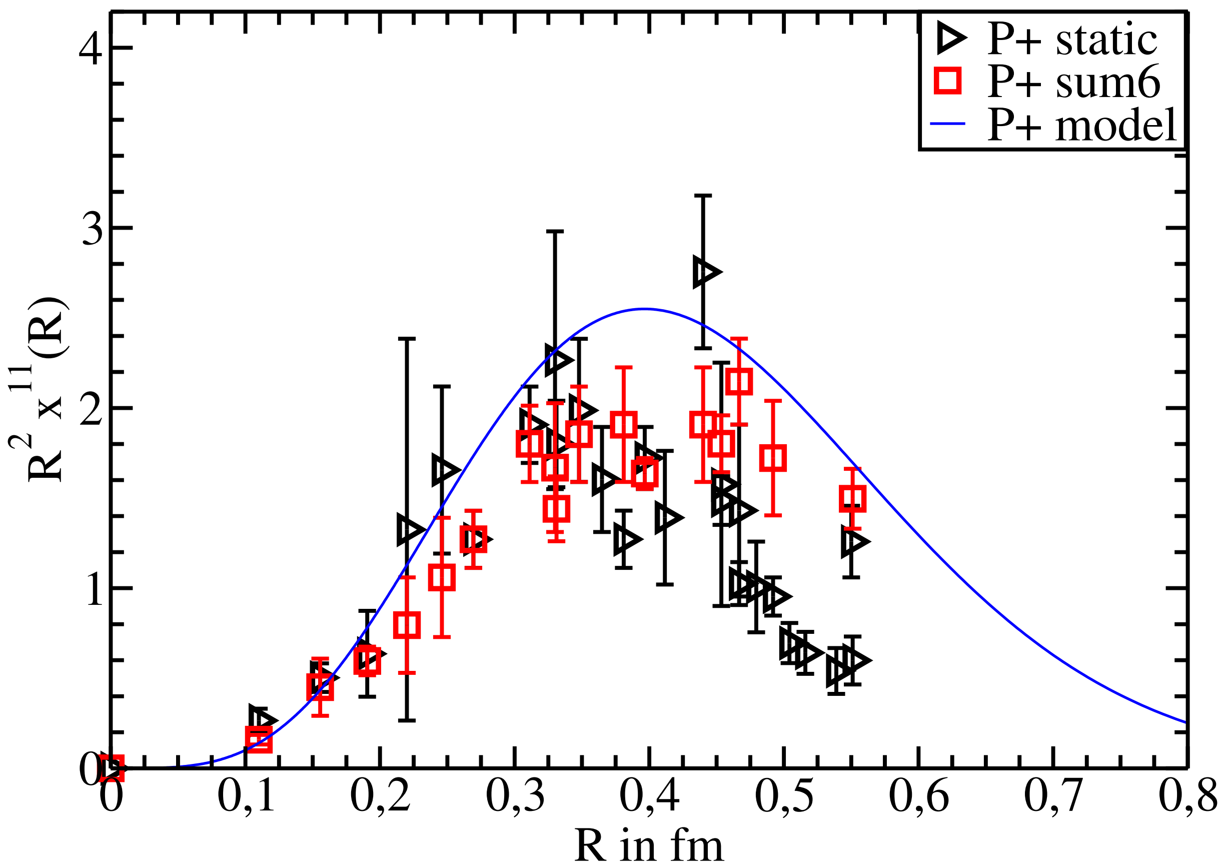
Green, Koponen, Michael and Pennanen for UKQCD Collaboration

- Phys. Rev. D 65, 014512 (2002)
- Eur. Phys. J. C 28, 79 (2003)

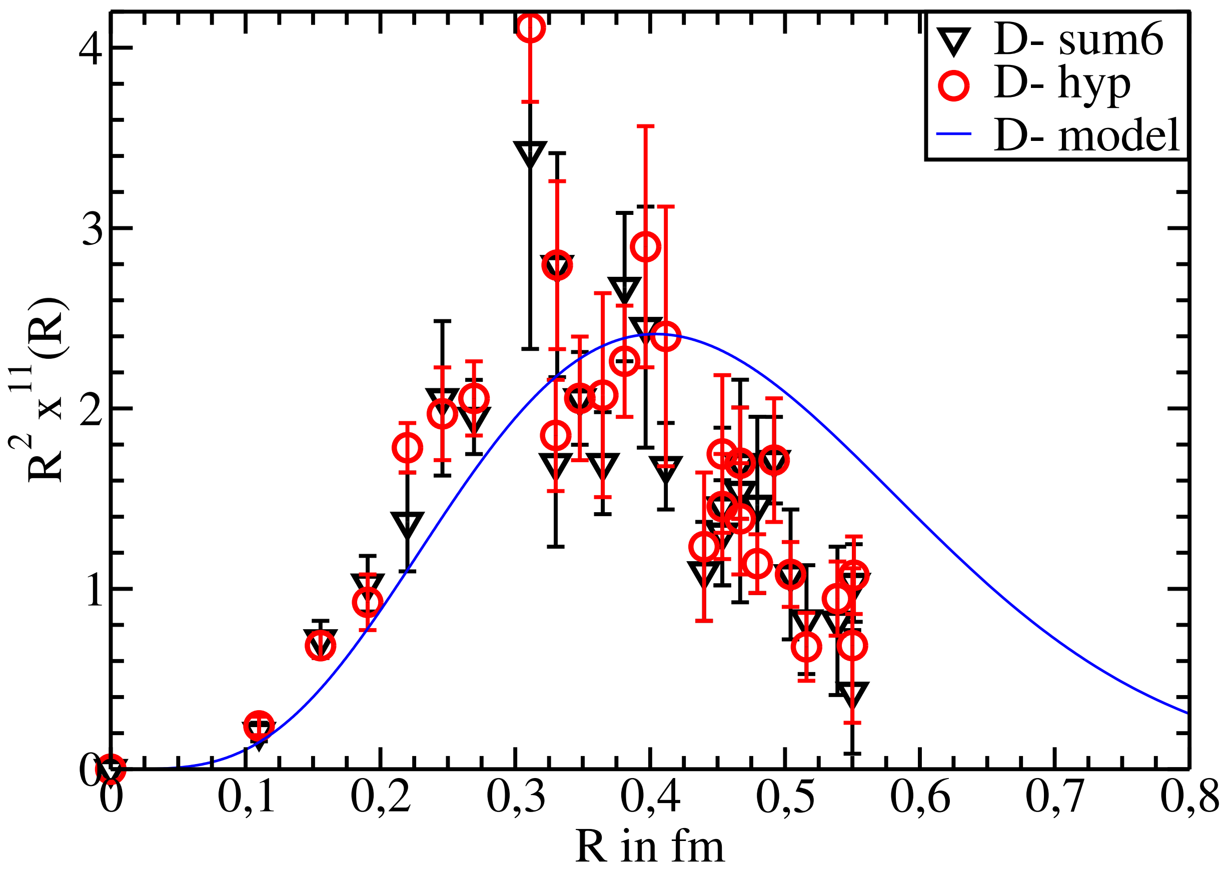
P-wave charge distributions



P-wave charge distributions (continued)



D-wave charge distributions



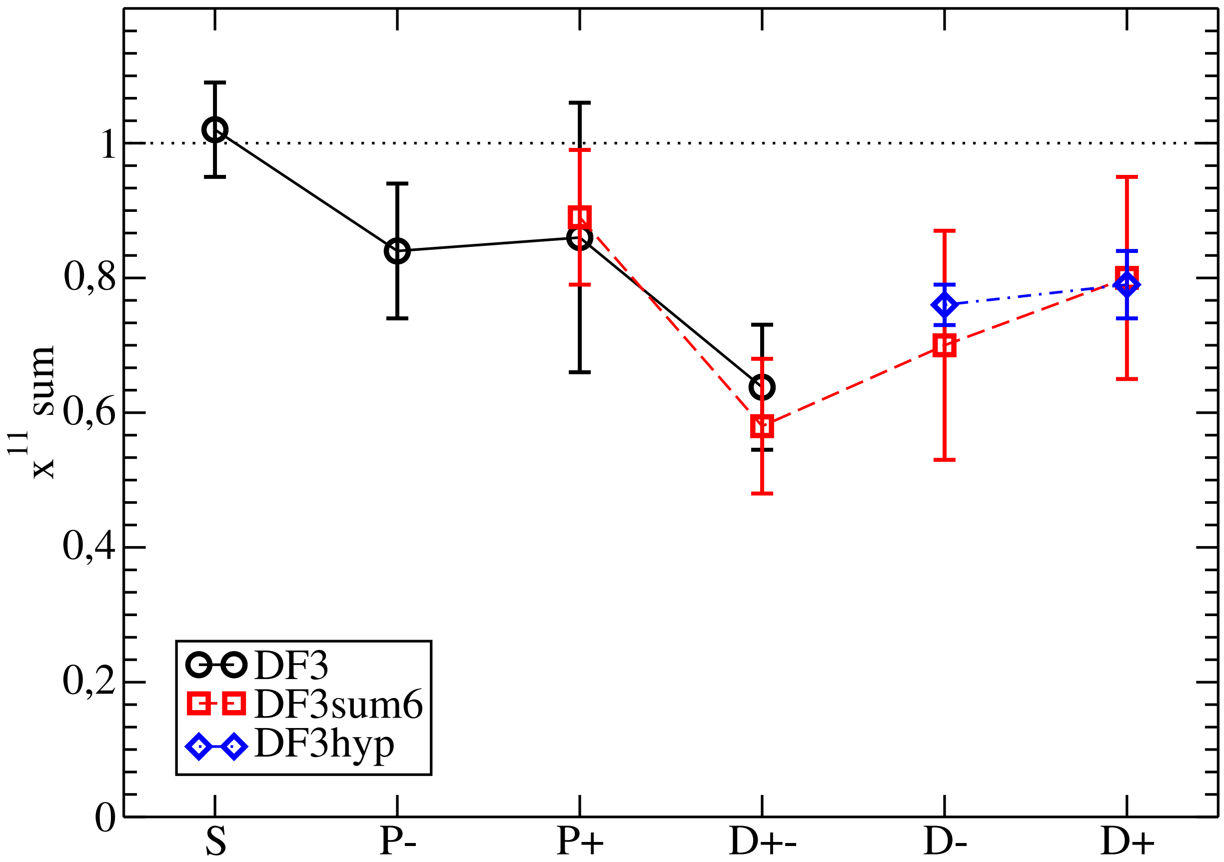
D-wave radial distributions

The “sum6” distributions have been published in

Green, Ignatius, Jahma, Koponen,
McNeile and Michael for UKQCD Collaboration,
PoS LAT2005 (2005) 205,

but the “hyp” results are still **preliminary**.

Charge Sumrule



A model based on the Dirac equation

- One of the quarks infinitely heavy $\rightarrow$ essentially a one-body problem
- The potential:
  - A linearly rising scalar part, $b_{\rm sc}R$, as well as a vector part $b_{\rm vec}R$.
  - The OGE potential, $a_{\rm OGE} \cdot V_{\rm OGE}$, is modified to

    $$V_{\rm OGE}(R) \propto \int_0^\infty {\rm d}k\, j_0(kR)\, \ln^{-1} \frac{k^2 + 4m_g^2}{\Lambda_{\rm QCD}^2},$$

    where $\Lambda_{\rm QCD} = 260$ MeV and $m_g = 290$ MeV
    [Lähde, Nyfält and Riska, Nucl. Phys. A674, 141 (2000)].
  - A scalar term $m\omega L(L+1)$.

Dirac model fits

The solid lines in the Figures are radial distributions from the Dirac model fit with

- the mass $m = 0.088$ GeV
- One-gluon-exchange potential $a_{\mathrm{OGE}} = 0.81$
- linearly rising potentials $b_{\mathrm{sc}} = 1.14$ GeV/fm and $b_{\mathrm{vec}} \approx b_{\mathrm{sc}}$
- scalar term $\omega = 0.028$.

Conclusions

- The spin-orbit splitting is small and supports the symmetry $b_{\mathrm{vec}} = b_{\mathrm{sc}}$ as proposed in P. R. Page, T. Goldman and J. N. Ginocchio, Phys. Rev. Lett. 86, 204 (2001).
- The energies and radial distributions of S, P and D$+-$ states can be qualitatively understood by using a one-body Dirac equation model.

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D-wave charge distributions (continued)