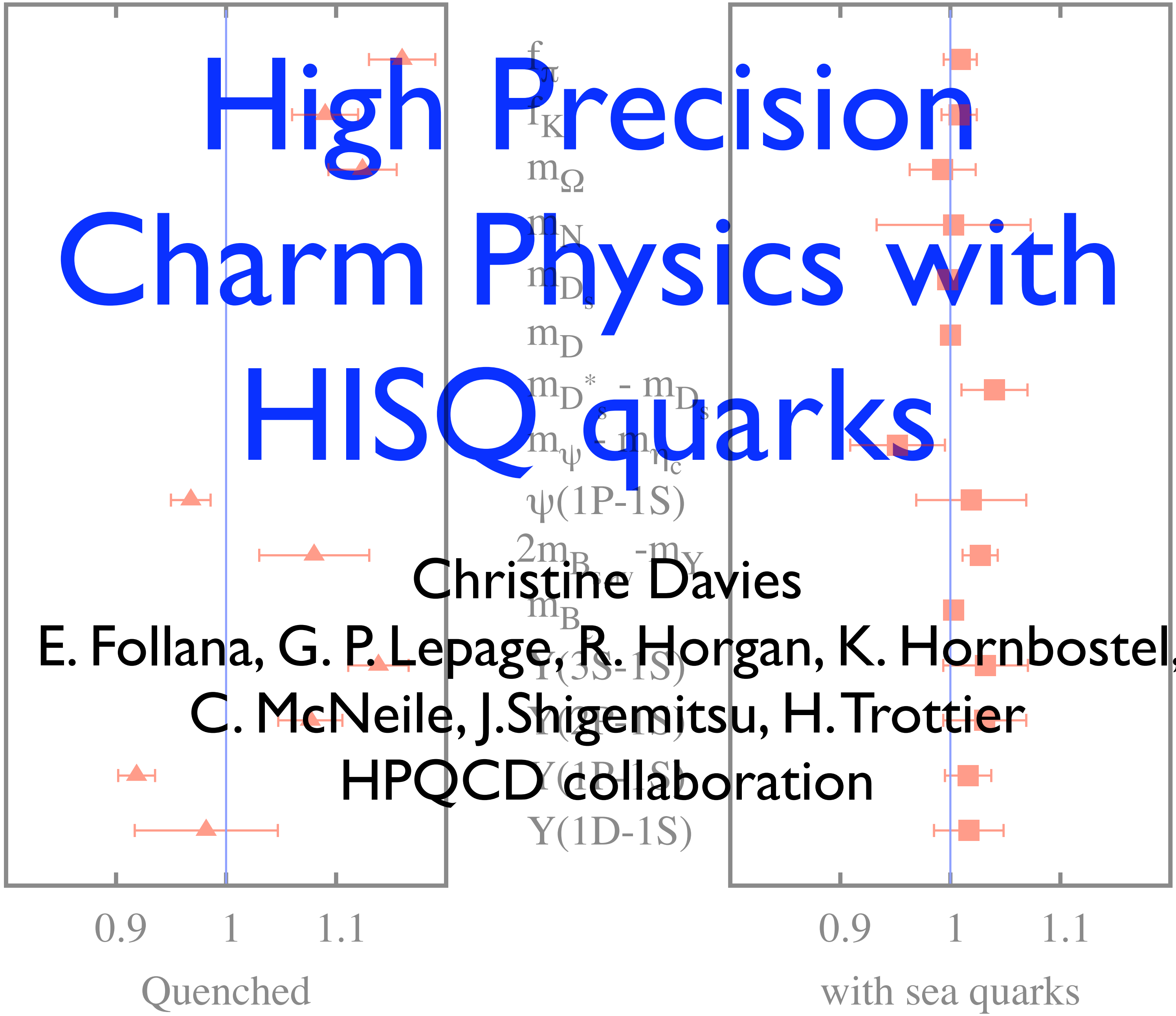
High Precision Charm Physics with HISQ quarks



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HPQCD collaboration

Charm quarks in lattice QCD - heavy or light?

Relativistic light quark advantages:

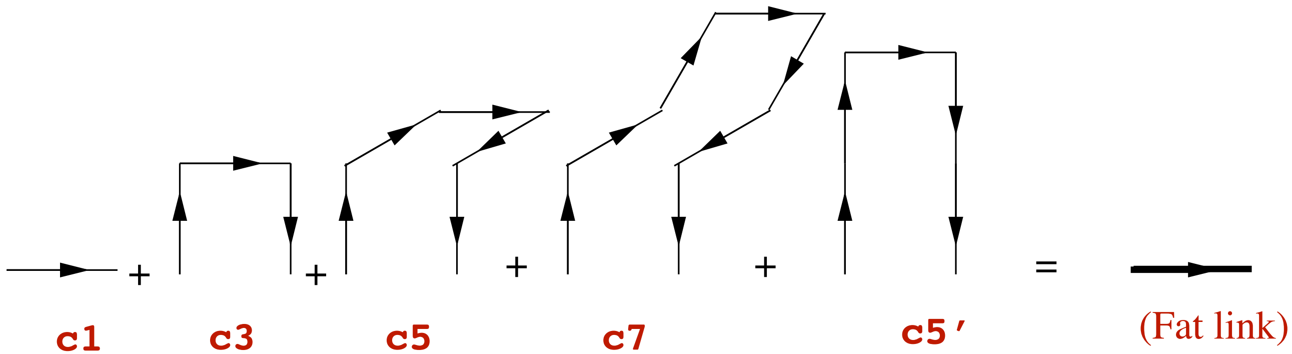
- $E_{sim} = m$
- PCAC relation (if enough chiral symmetry) gives $Z = 1$ for decay constants
- same action as for u, d, s. Can take ratios to light physics.

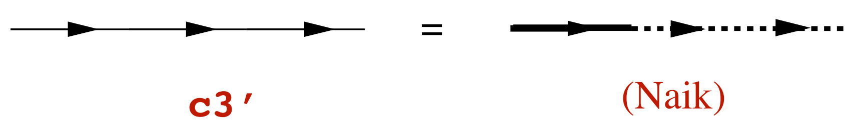
Key issue is discretisation errors:

$$m_c a \approx 0.4,\ (m_c a)^2 \approx 0.2,\ \alpha_s (m_c a)^2 \approx 0.06,\ (m_c a)^4 \approx 0.04$$

Need to remove *all* of these errors for precision results

Improved staggered formalism





Naik term removes tree-level a^2 errors. Smeared link reduces taste-exchange $\alpha_s a^2$ errors

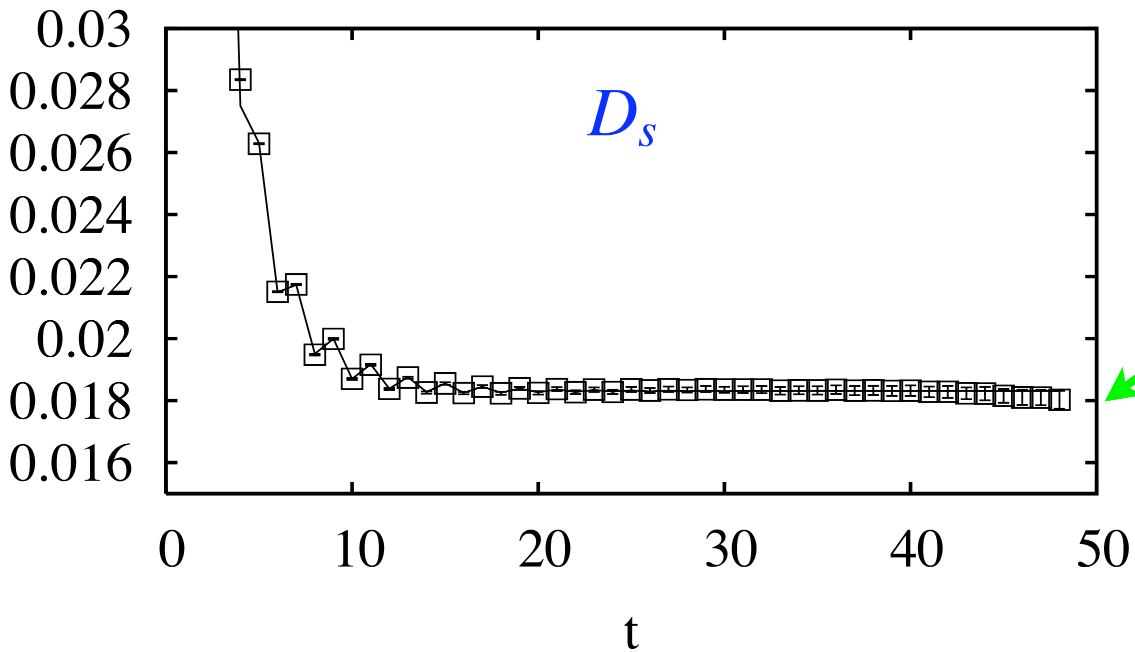
Highly Improved staggered formalism

Second level of smearing (with polar projection) reduces taste-exchange errors further.

Change Naik coefficient to remove leading $(am_c)^4$ errors (check speed of light)

Used HISQ valence light and charm quarks on MILC very coarse, coarse and fine configs with imp.stagg sea quarks

Excellent statistical accuracy from random wall sources (as used by MILC for light mesons)



$$\sum a_i e^{-M_i t} + (-1)^t a_{ip} e^{-M_{ip} t}$$

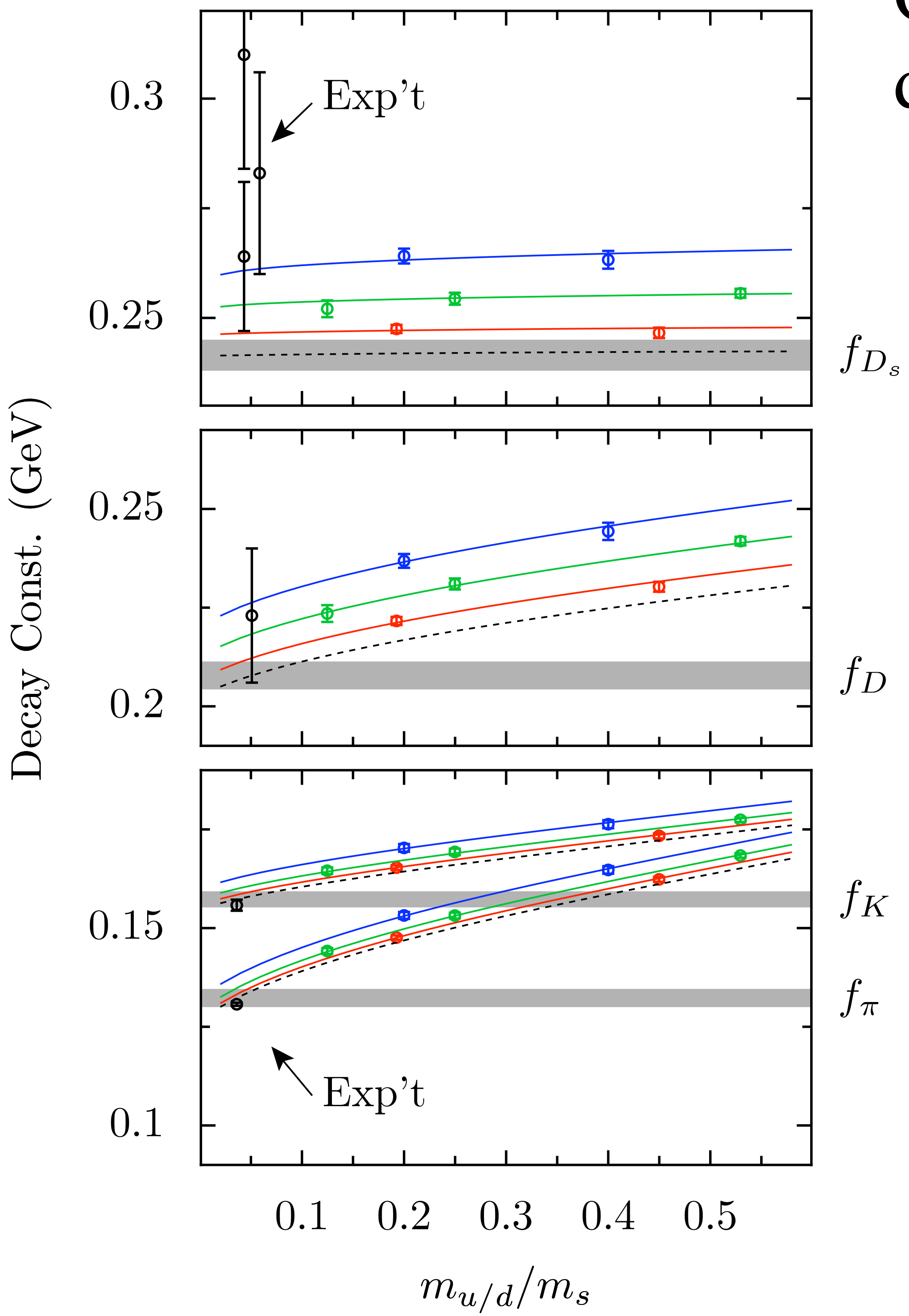
correlator/(fit ground state)

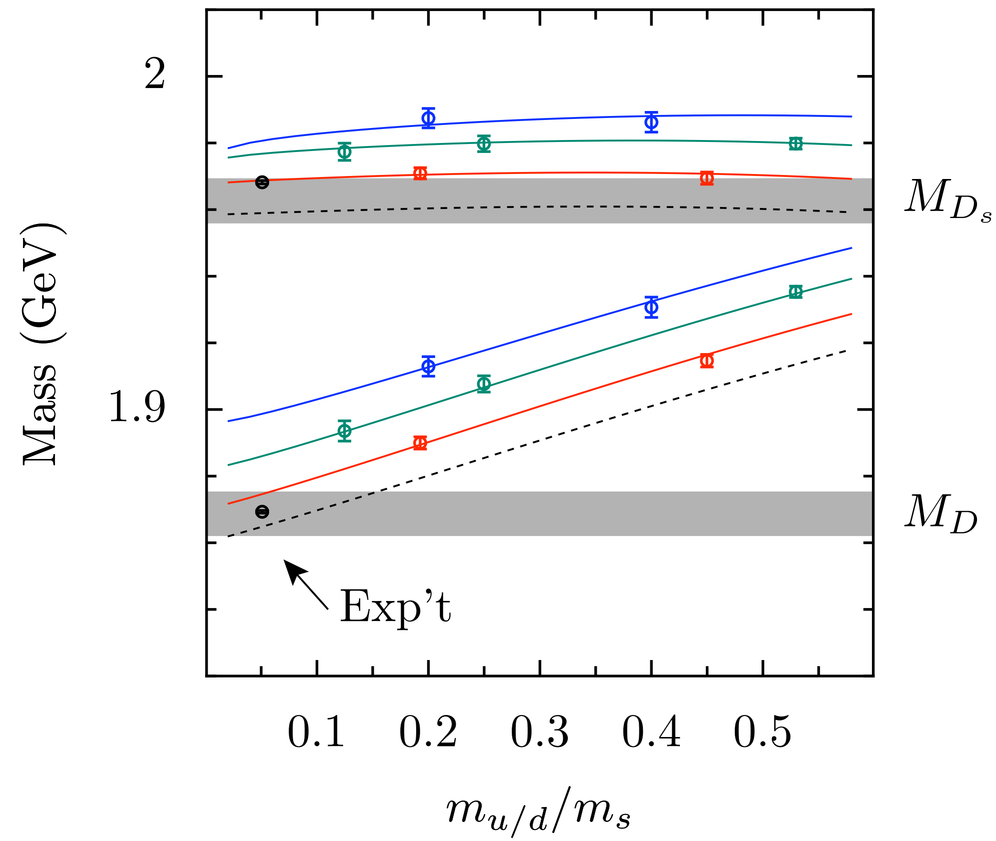
$$\frac{signal}{noise} = e^{-0.133 GeV T}$$

Allows systematic errors to be studied in detail

Calculate D/Ds masses and decay constants very precisely

NO free parameters since m_c fixed from η_c

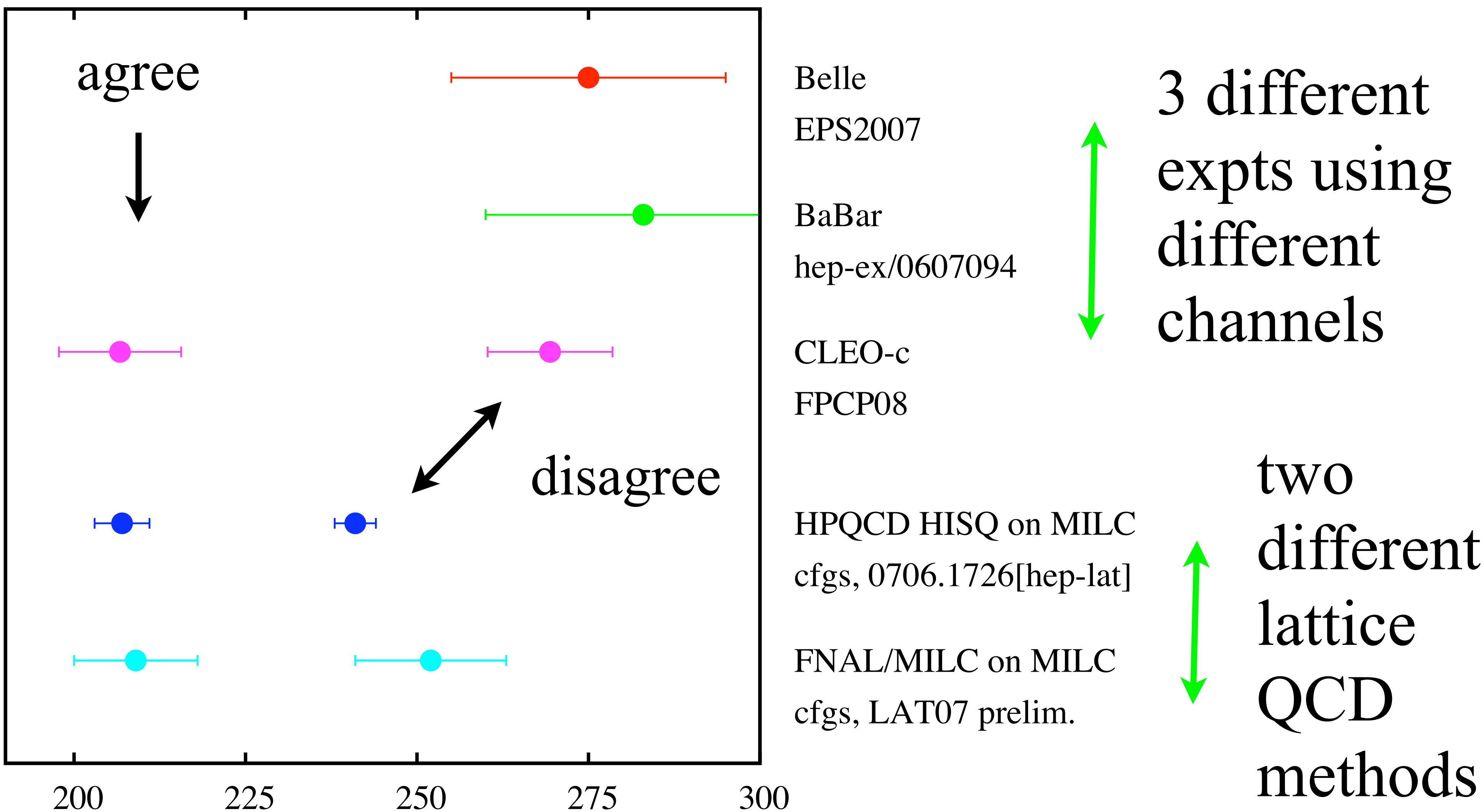




E.Follana et al, 0706.1726[hep-lat]

2008 Improved accuracy from CLEO-c

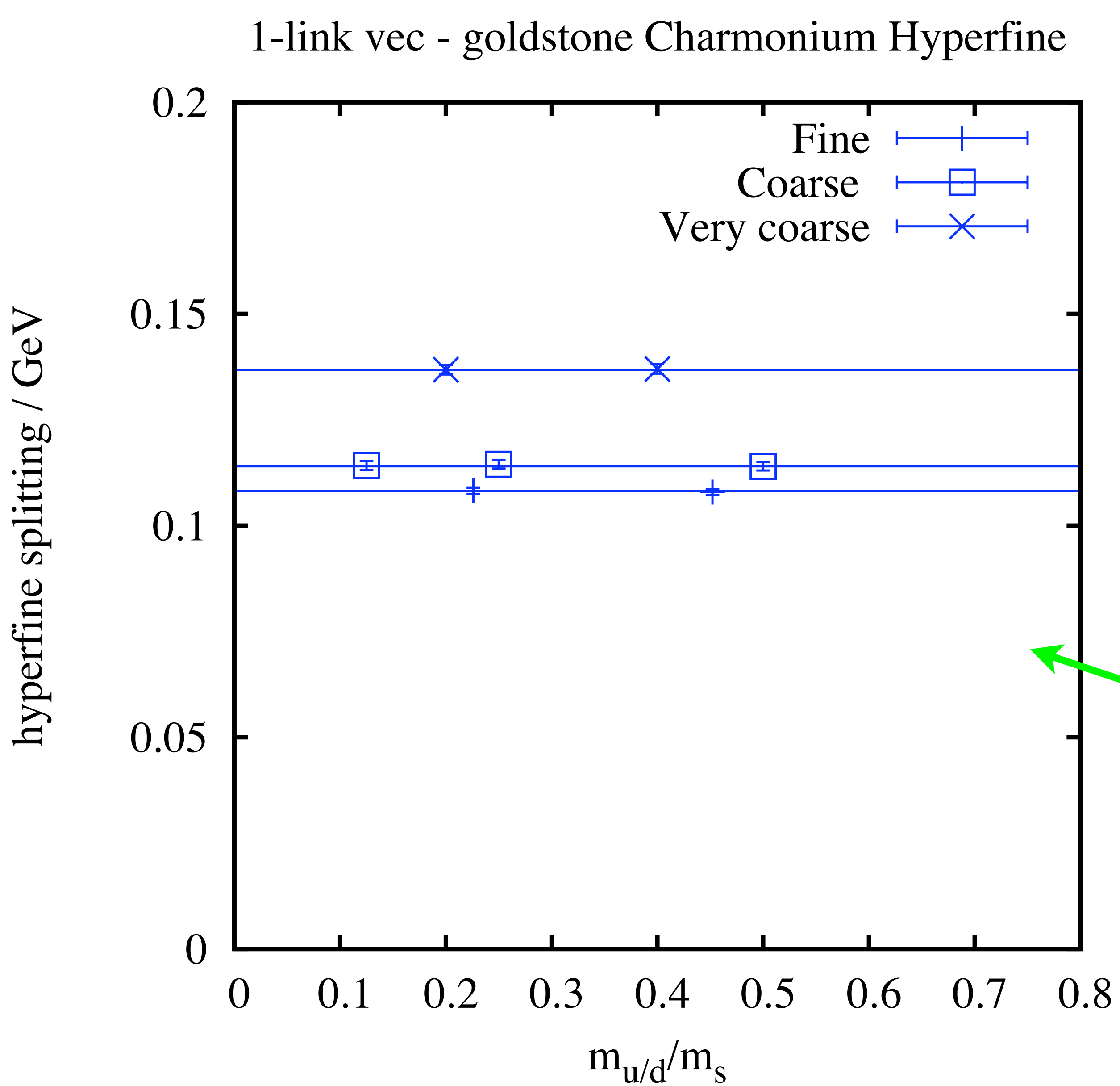
Determine decay constant from leptonic rate and taking Vcs=Vud, Vcd=Vus



New physics? see Kronfeld talk Friday 2:50pm

Further checks of lattice calculations important ...

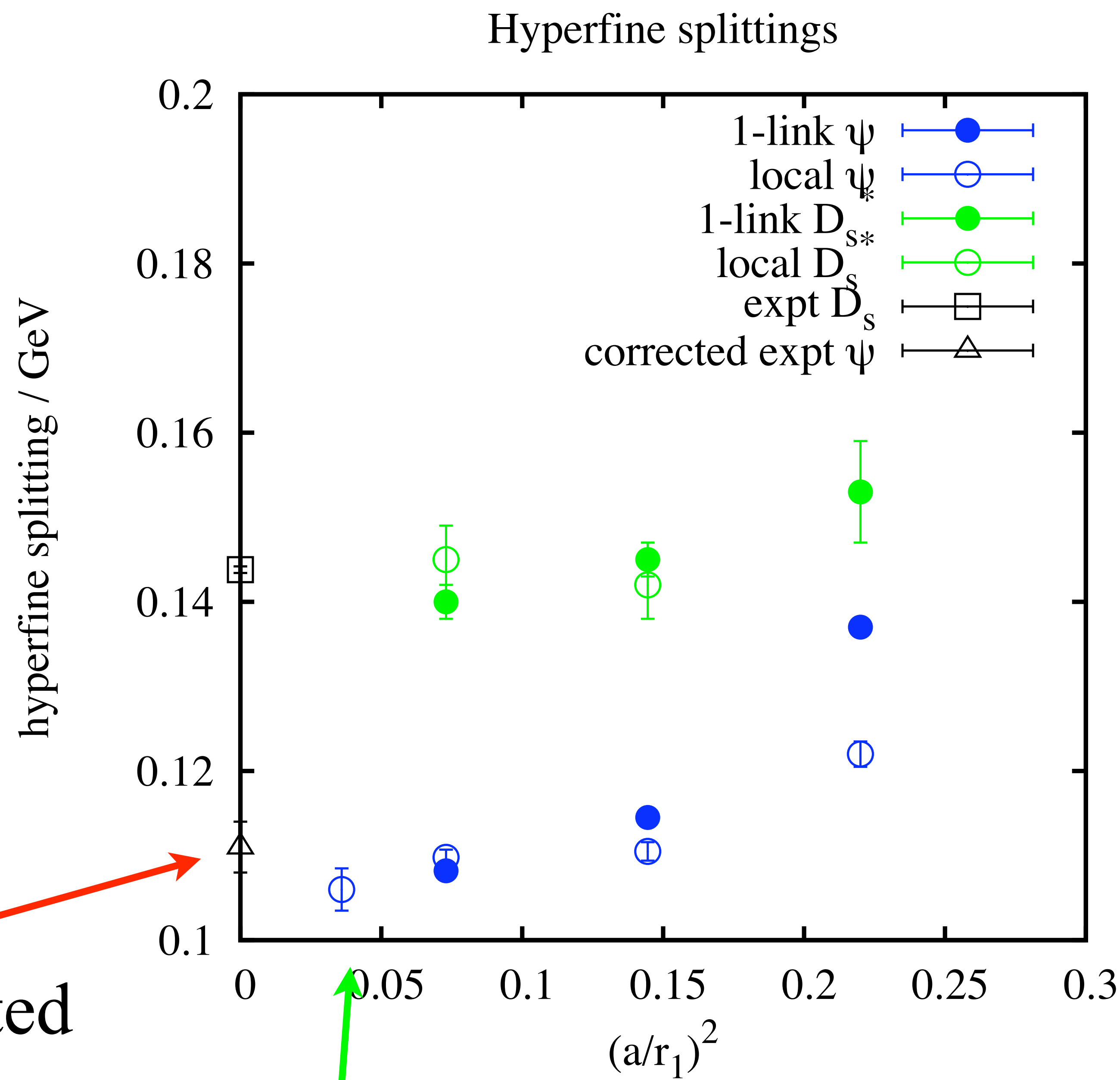
1. Spectrum



Hyperfine splitting between vector and pseudoscalar

No dependence on sea quark mass

Dependence on a clearly visible - some of this is a taste-exchange effect



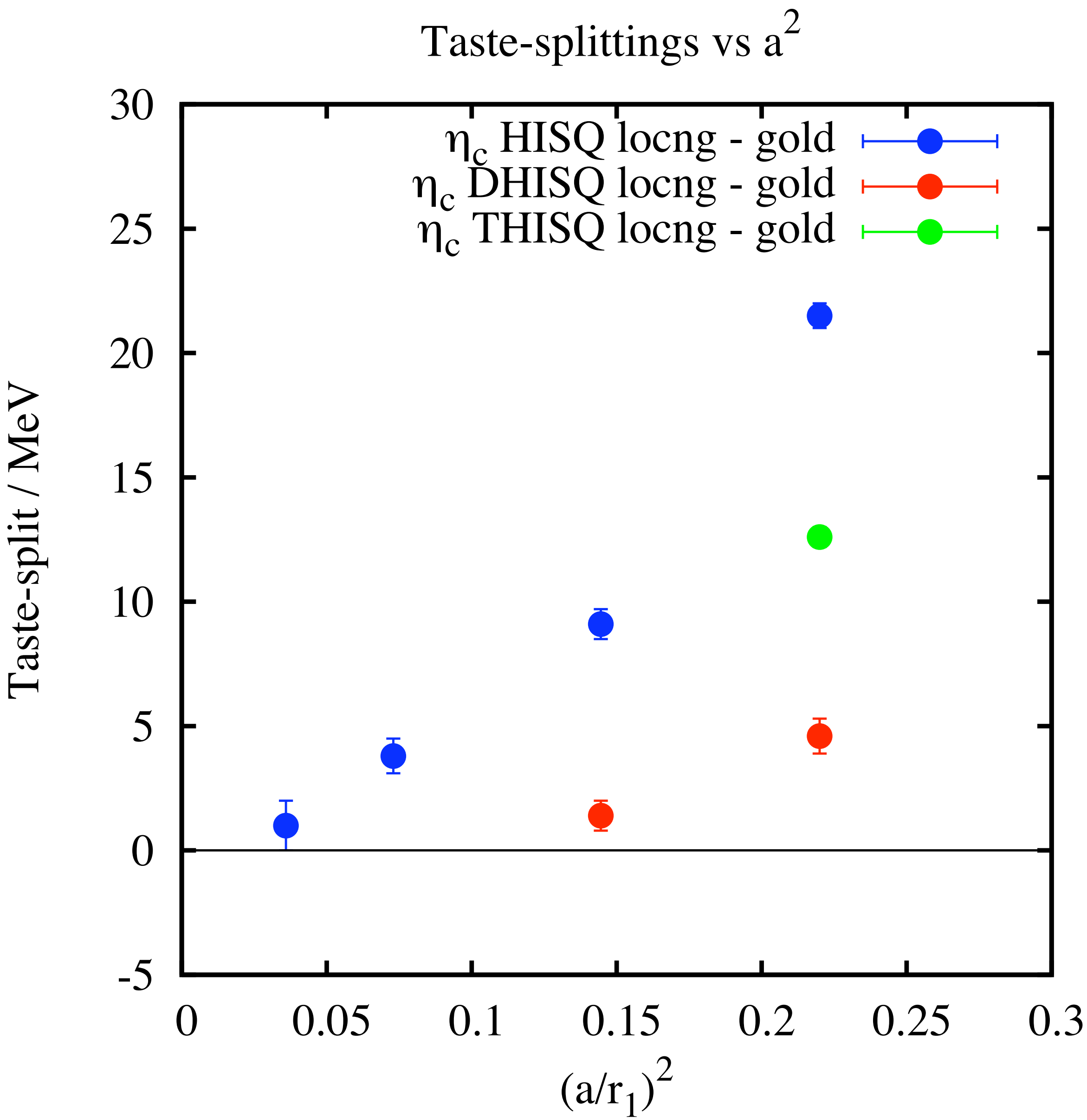
Comparison to expt complicated few MeV e.m and annihiln corrns.

Lattice error dominated by *square* of absolute scale error - 3%

Prelim. result on MILC superfine a=0.06fm

see Kendall talk, Thursday 8:50am

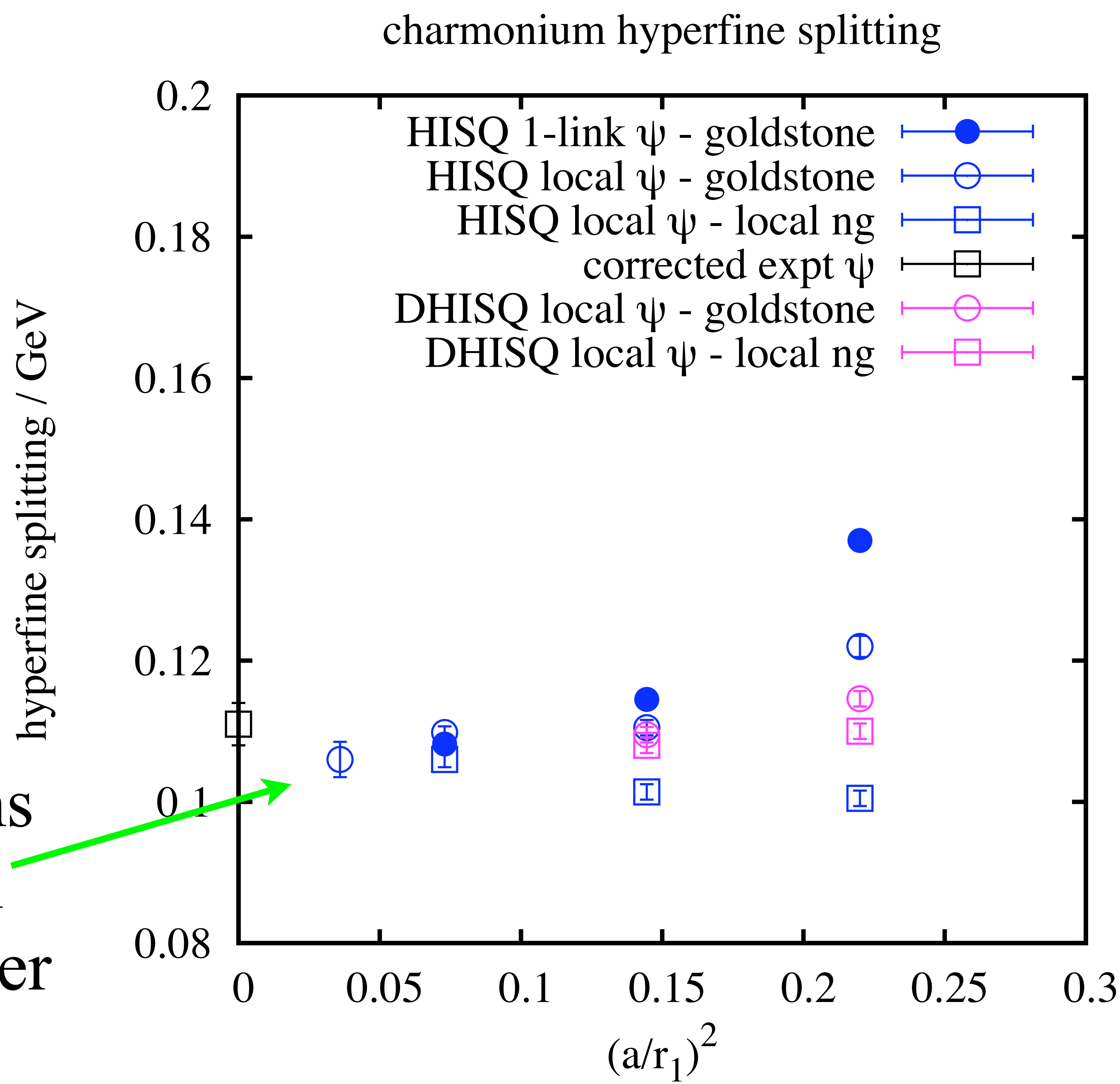
Further taste effects



"Double HISQ" reduces taste-exchange discretisation errors further - "Treble HISQ" worse again

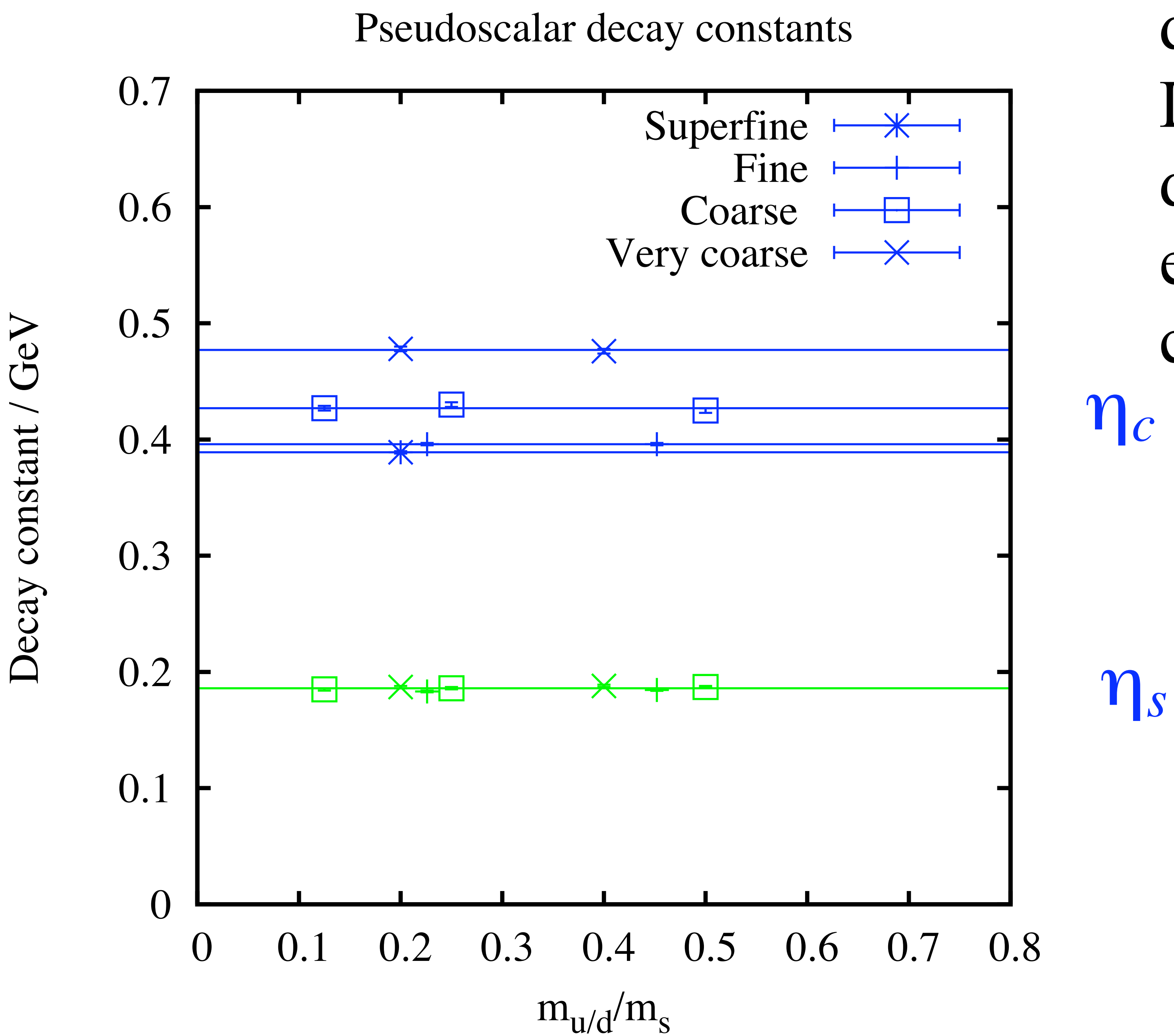
Too much smearing makes disc. errors worse again

Improved scaling of hyperfine splitting also seen in Double HISQ



All taste versions converging with a^2 to same answer

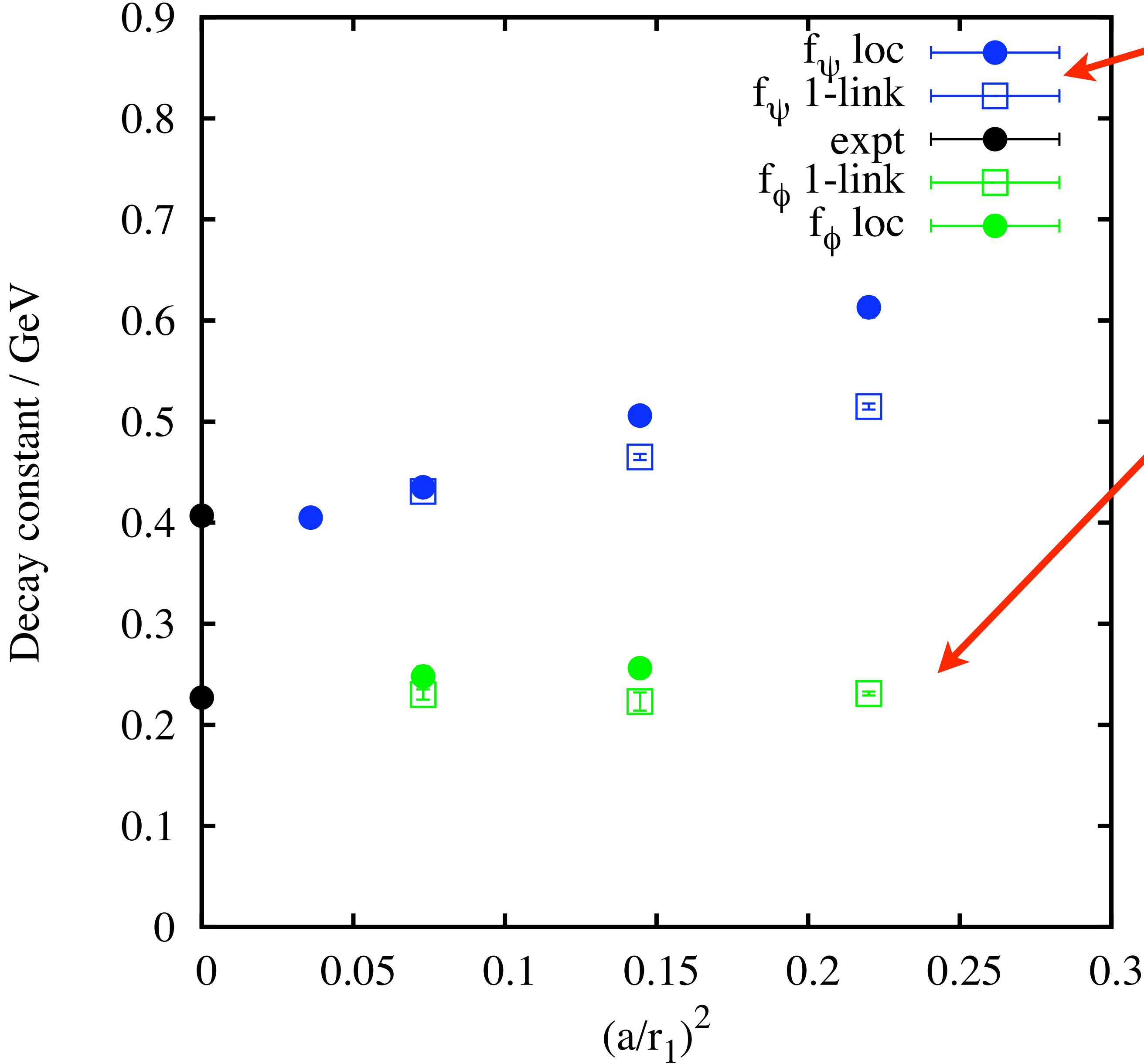
2. Decay constants



Again, no sea quark mass dependence. Lattice spacing dependence evident for charm.

Vector decay constants $f_V m_V = <0|J|V>$

$$\Gamma_{e^+e^-} = \frac{4\pi}{3}\alpha_{QED}^2 e_Q^2 \frac{f_V^2}{m_V}$$



"nonpert"renormln using t-moments of JJ correlator (Lepage talk)

error = 4% at a=0.

renormalise using 1-loop pert. th.

Different tastes heading towards agreement with expt - need to complete calc. with conserved vector current

Conclusions

HISQ allows us to do charm physics accurately

$f_{D_s} = 241(3) MeV$ 3σ from expt

All other charmonium and charm-light results agree with expt at few % level.

Future: Similarly accurate 3pt calculations

See also: Lepage talk, Thursday 9:10am
Allison talk, Thursday 9:30am
for 1% accurate m_c

Bazavov talk, Tuesday 5:00pm, dynamical HISQ