Lattice field theory

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PPAP community meeting
Sept. 2015

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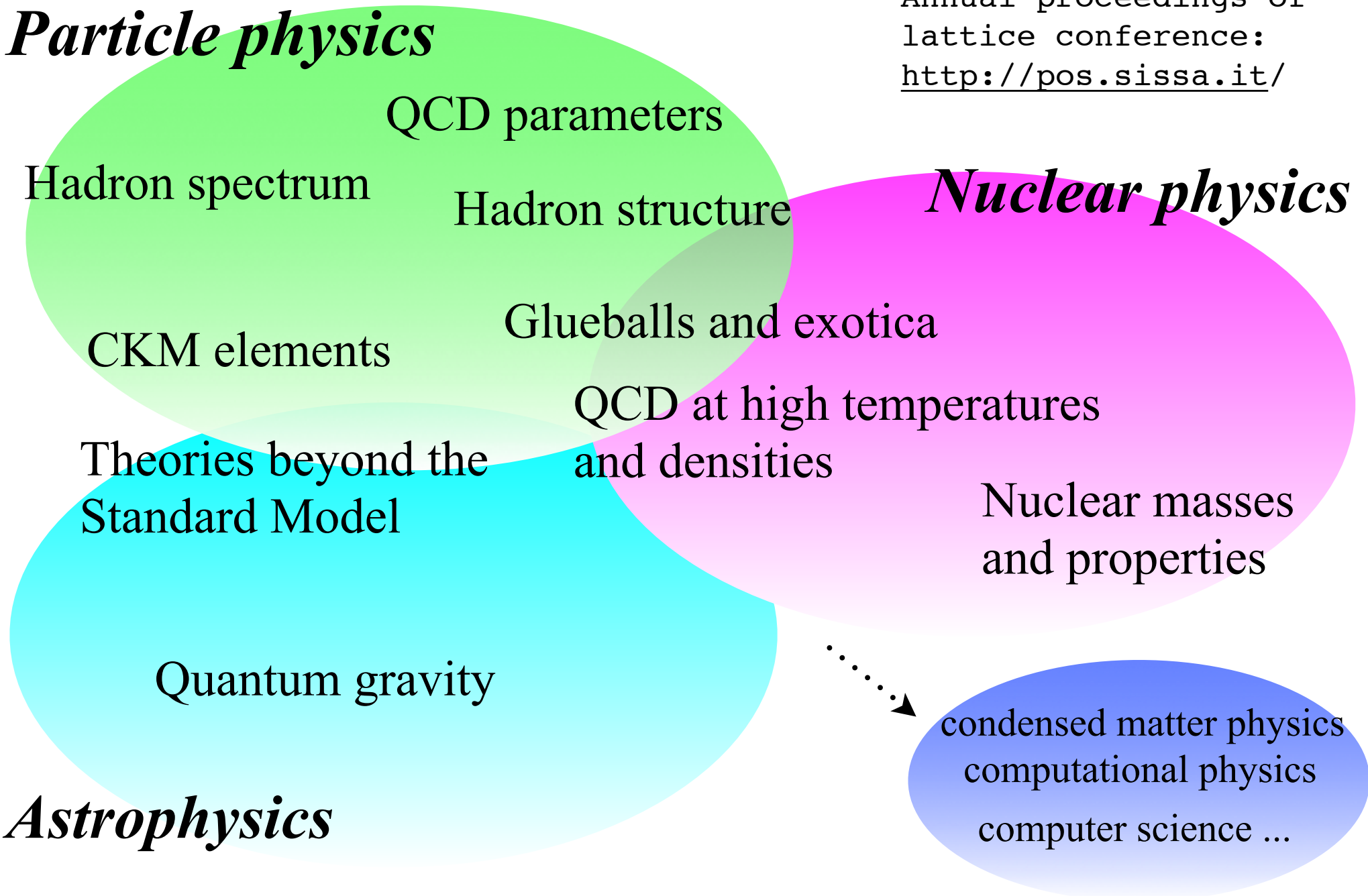
Applications of Lattice QCD/Lattice field theory

Annual proceedings of lattice conference: http://pos.sissa.it/



UK landscape - people

8 university teams in UKQCD consortium.
Key members of international collaborations e.g Fastsum, Hadspec, HPQCD, QCDSF, RBC-UKQCD, strongBSM

Different methods for handling quarks, optimised for different physics, but crosschecks important. Results impact:

LHC, BES, KEK, JLAB, J-PARC, DAFNE, RHIC, FAIR ...

UK landscape - computers

Distributed Research using Advanced Computing =

STFC's HPC facility for theoretical particle physics, astrophysics and cosmology.

Phase 2 (2012-15) - £15M capital from BIS plus input from HEIs and STFC - now operating fully as a facility: operating costs now awarded by STFC.

5 machines at 4 sites (Cambridge, Durham, Edinburgh and Leicester) - coordinated management and peer-reviewed resource allocation (starting Dec. 2012) open to all

where are the phenomenologists?

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aim to focus on a few architectures suited to physics problems, NOT one-size-fits-all

Lattice field theory uses two machines:

1) 6-rack BG/Q at Edinburgh. 20 in top 500 (2012) - 1Pflops

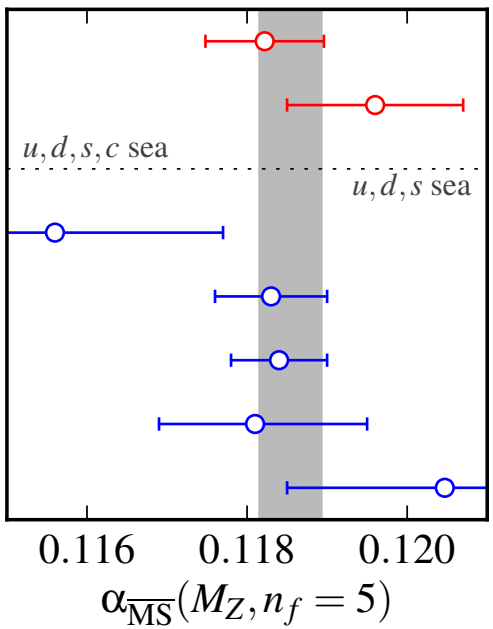
numerically more intensive calcs, e.g. gauge field generation

2) Sandybridge/infiniband cluster at Cambridge.
93 in top 500 (2012) - 200 Tflops

data intensive calcs, e.g. physics analysis on gauge fields

Machines coming to end of useful life.

Quark masses and strong coupling constant



HPQCD–jj this paper

ETMC 1310.3763

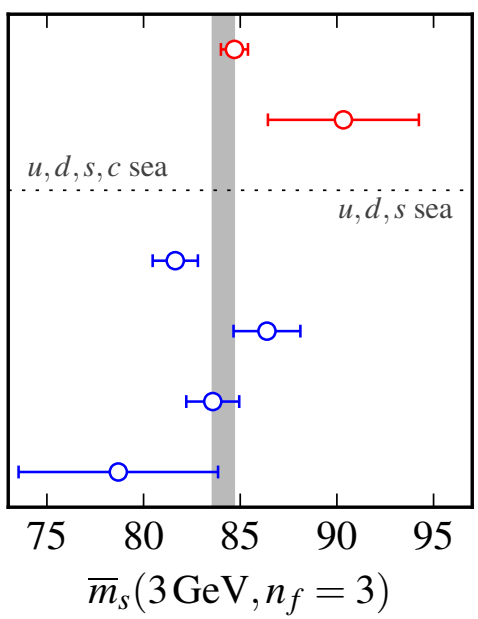
Basavov et al 1205.6155

HPQCD–jj 1004.4285

HPQCD–W_{nm} 1004.4285

JLQCD 1002.0371

PACS-CS 0906.3906



1408.4169

HPQCD this paper

ETMC 1403.4504

RBC/UKQCD 1411.7017

Durr et al 1011.2403

HPQCD 0910.3102

HPQCD (pert) 0511160

Lattice QCD results have transformed accuracy possible

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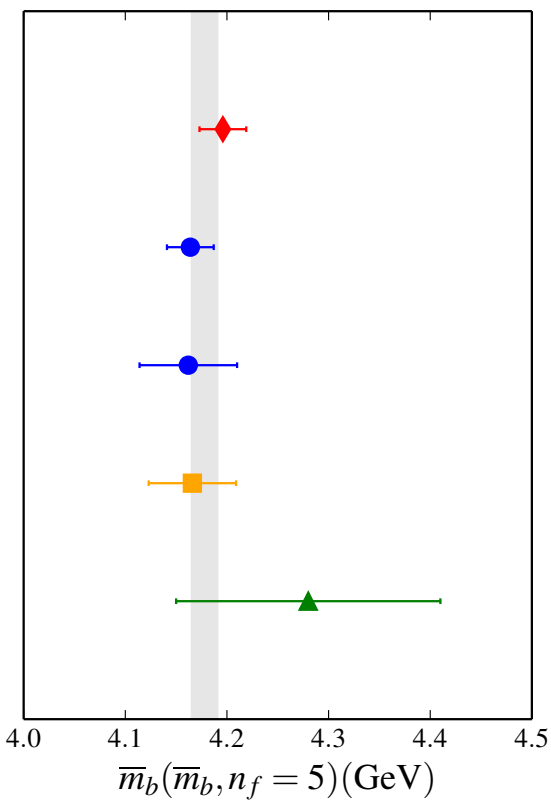


1408.5768

HPQCD NRQCD JJ

HPQCD HISQ JJ $n_f = 3$

HPQCD HISQ ratio $n_f = 4$

1408.4169

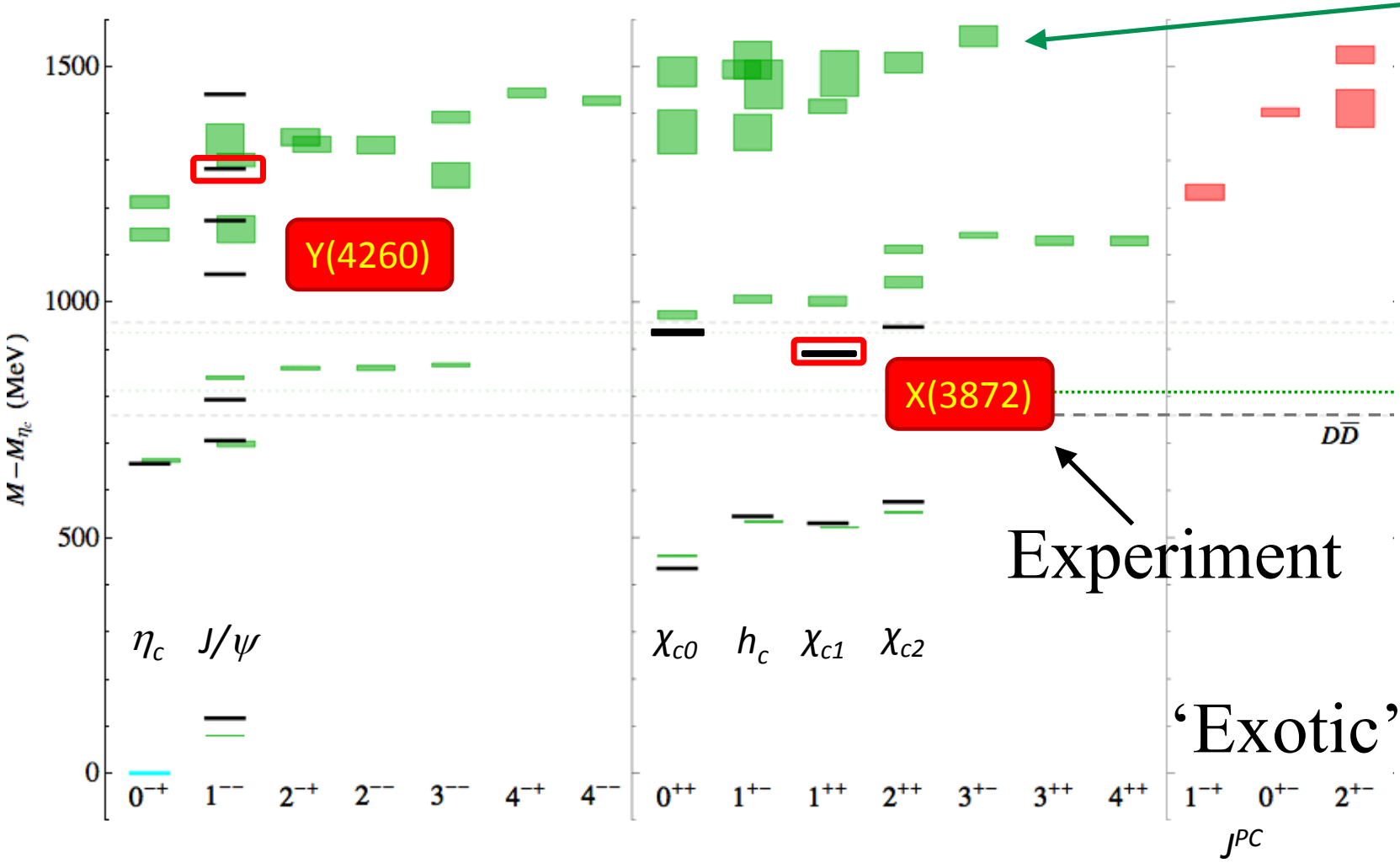
HPQCD NRQCD E_0

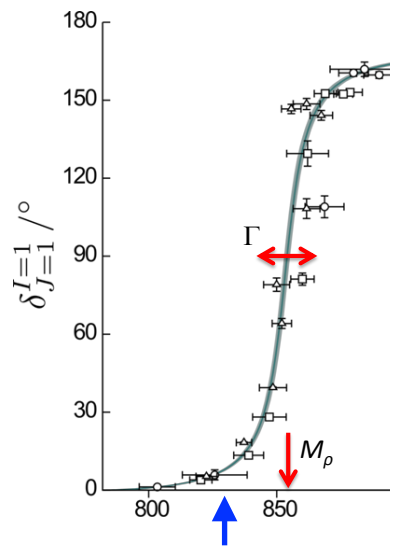
1302.3739

ETMC ratio

Future: Accurate tests of Higgs $\rightarrow b\bar{b}$ require halving uncertainty on m_b and α_s .....

More detailed study of unstable and excited states important to pin down oddities now being seen (e.g. in charmonium spectrum)





unstable states need multivolume analysis
1411.2004

Key future aim: study tetra/pentaquark states, hybrids, glueballs - needs very high stats and large basis of operators.

Precision flavour physics

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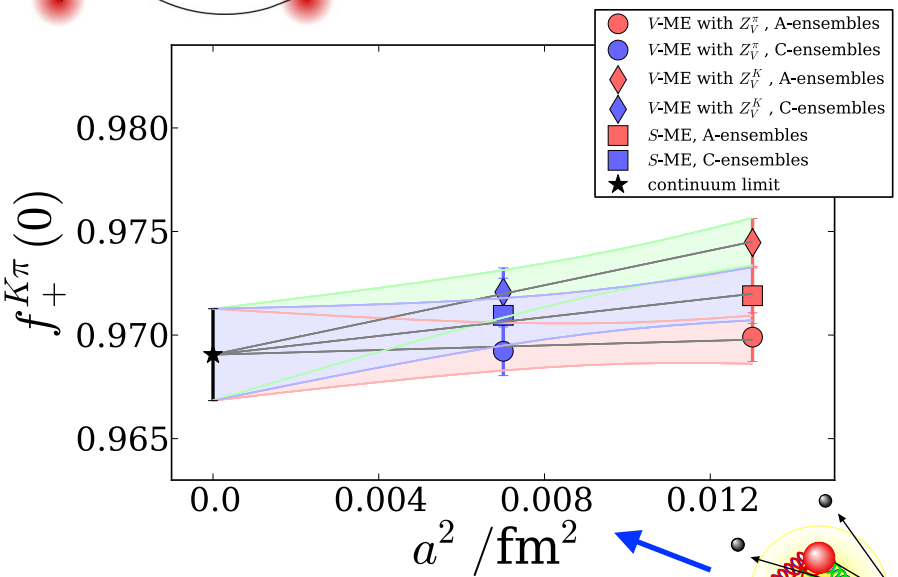
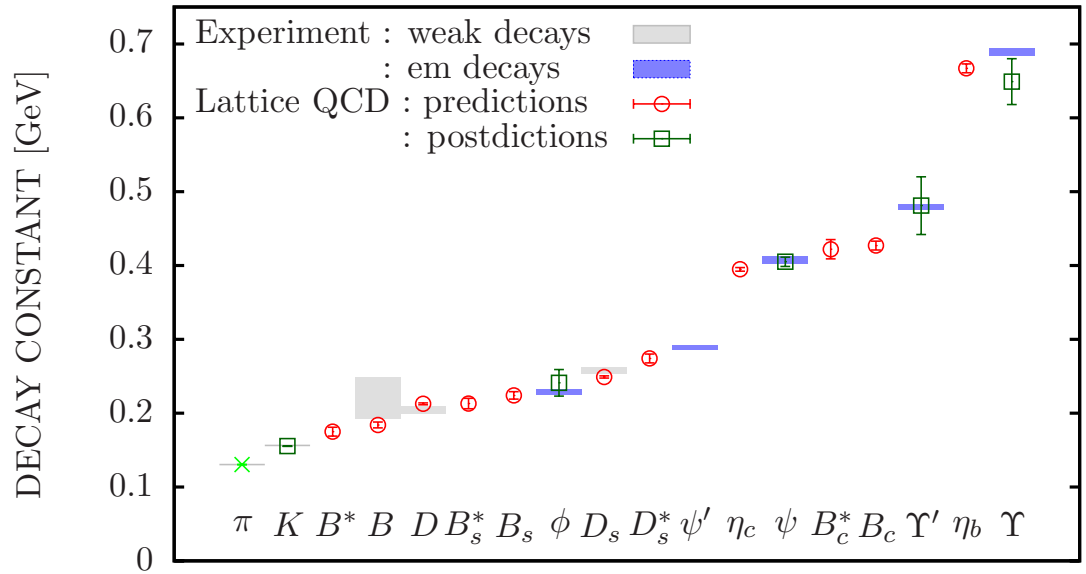
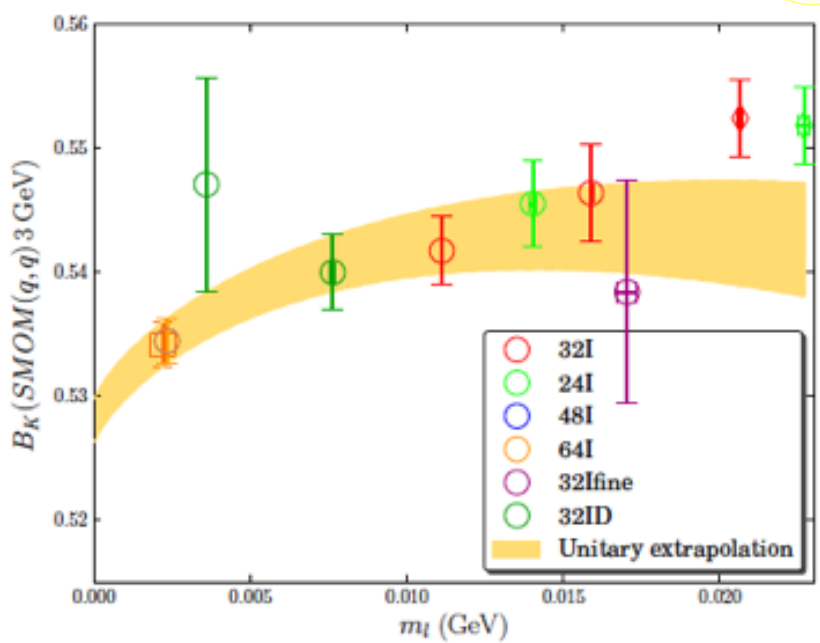


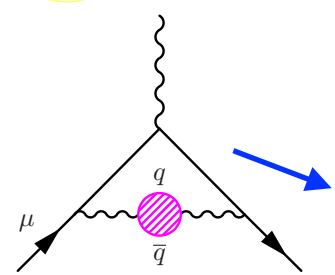
RBC/UKQCD 1504.01692

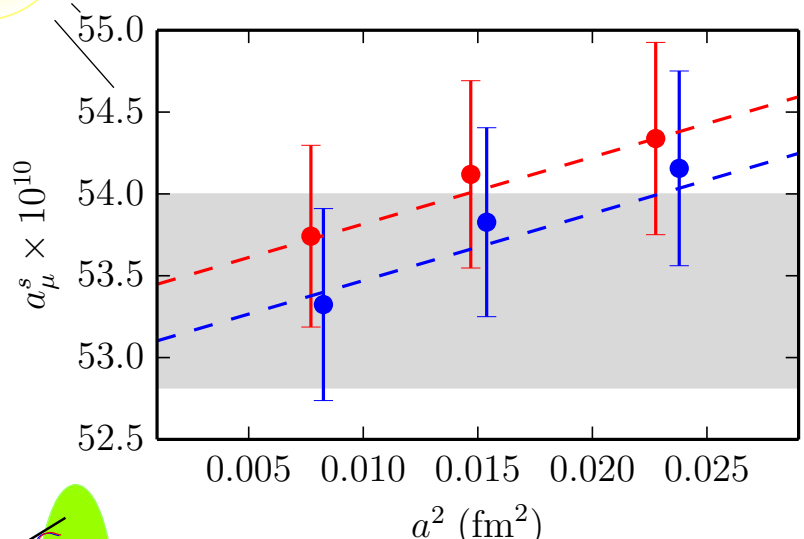


HPQCD 1503.05762



RBC/UKQCD 1411.7017

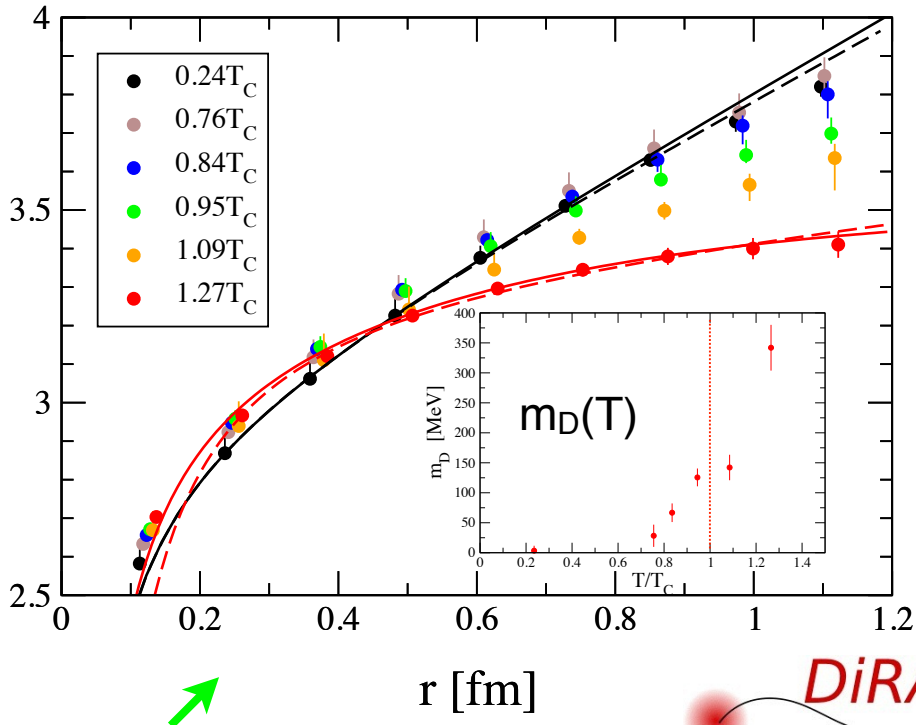


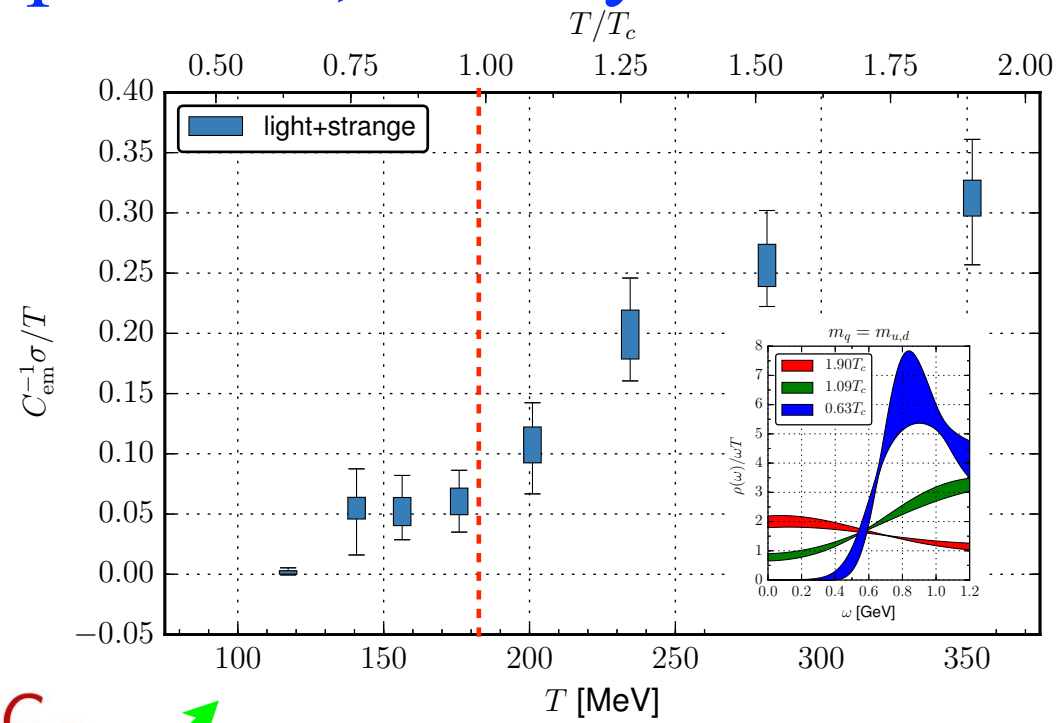


HPQCD 1403.1778

Lattice QCD at high temperature, density

FASTSUM





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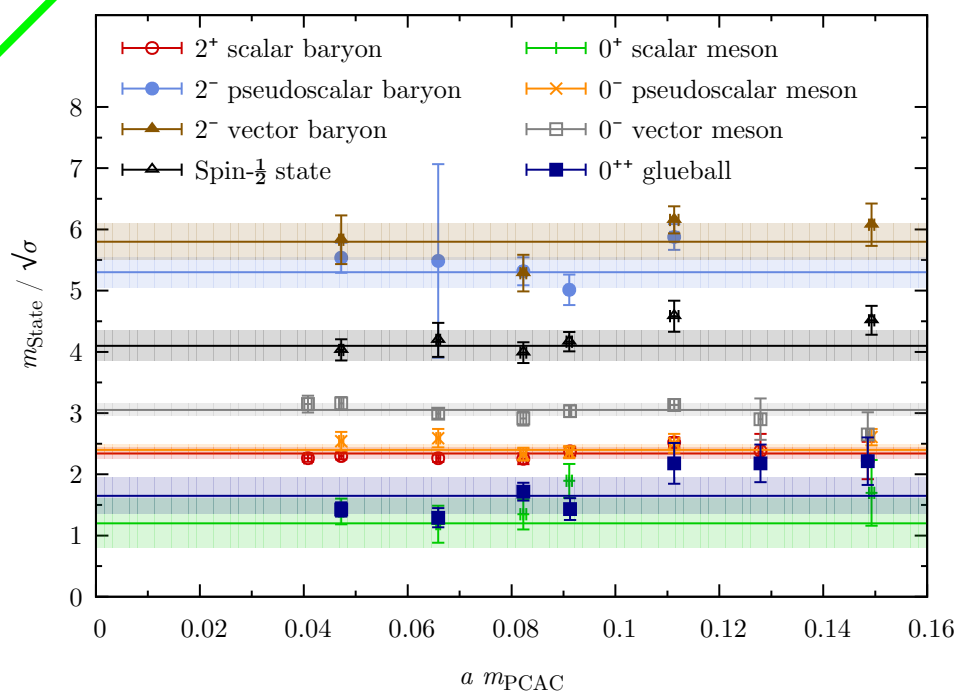
screening of heavy-quark potential at high temp

1505.06616
1412.6411

Transport properties of the quark-gluon plasma



Beyond QCD ..

search for viable 'walking technicolour' theory, spectrum for SU(2) + 1 adj. quark

STRONGBSM: 1507.08892

Future: DiRAC-3

Seeking £25M capital from BIS for upgrade by factor ~10 from 2015. 3 machine types based on RFI responses from potential vendors. Science/technical cases reviewed. Benchmarks for procurement being assembled.

Lattice field theory prime interest in two:
"extreme scaling" and "data driven discovery"

5 Pflops, 3Pbyte
Intel Knights Landing

2 Pflops, 1Pbyte tightly-coupled,
14Pbyte longer-term

- If successful will need recurrent costs for electricity and support staff.
- Increase in PDRAs and PhDs in particle theory would improve exploitation capabilities and HPC training impact.

Future (to 2018 with 10x computing power)..

- improve precision flavour physics - add QED and $m_u \neq m_d$

- reduce m_b, m_c errors for 0.5% SM $\sigma(H \to b\bar{b})$

- calc. masses of $c\bar{c}$ X, Y, Z; glueballs, tetra/penta quarks

- precision transport coefficients in QGP

- map out range of technicolor theories

Quantity	CKM/ expt process	Current expt Error	Current lattice Error	2018 lattice Error
f_K/f_π	$\|V_{us}\|$	0.2%	0.2%*	0.1%
$K \to \pi\ell\nu$	$\|V_{us}\|$	0.2%	0.3%†	$< 0.2\%$
f_D	$\|V_{cd}\|$	4%	2%	$< 1\%$
f_{D_s}	$\|V_{cs}\|$	2%	1%	$< 1\%$
f_B	$\|V_{ub}\|$	12%	2%*	1%
f_{B_s}	$B_s \to \mu^+\mu^-$	25%	2%*	1%
$f_{B_s}^2 B_{B_s}(\Delta M_s)$	$\|V_{ts}V_{tb}\|^2$	0.24%	10%†	3%
$\Delta M_s/\Delta M_d$	$\|V_{ts}/V_{td}\|$	0.4%	4%†	1%
B_K	$\mathrm{Im}(V_{td}^2)$	0.5%	1.5%†	$< 1\%$
$D \to \pi\ell\nu$	$\|V_{cd}\|$	3%	4%†	2%
$D \to K\ell\nu$	$\|V_{cs}\|$	0.5%	1.5%*†	0.5%
$D_s \to \phi\ell\nu$	$\|V_{cs}\|$	4%	4%*	2%
$B \to \pi\ell\nu$	$\|V_{ub}\|$	4.1%	9%†	2%
$B \to D/D^*\ell\nu$	$\|V_{cb}\|$	1.3%	2%	$< 1\%$
$B_s \to \phi\mu^+\mu^-$		20%	10%*	4%

- understand proton spin and size

- constrain BSM contribns to kaon/B physics/proton decay

- achieve 1% on HVP contribn to muon g-2 + calc. HlbL

- results for: LHC, FNAL, BES, KEK, JLAB, DAFNE, RHIC, FAIR ...