Lattice field theory - a UK perspective

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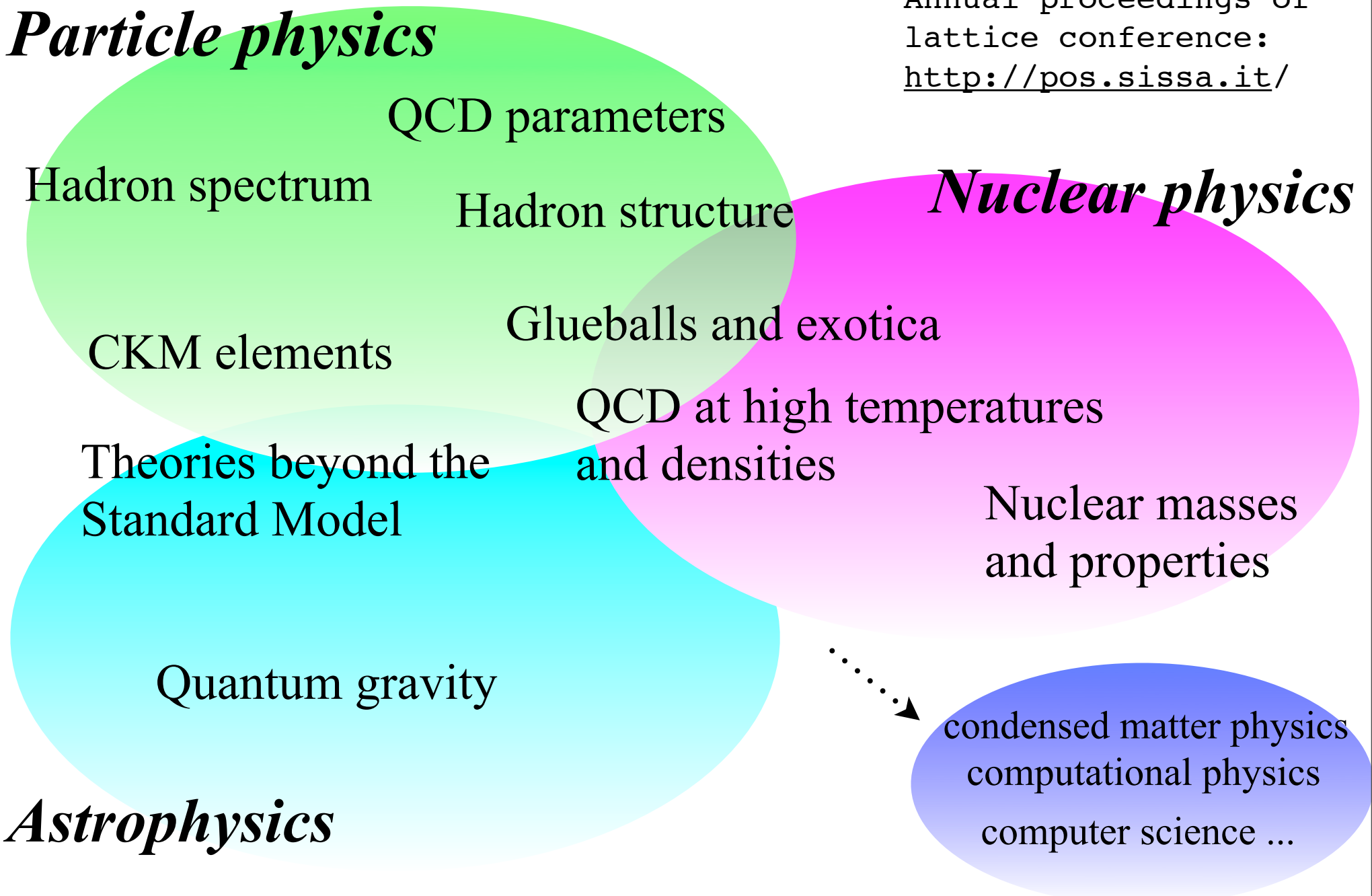
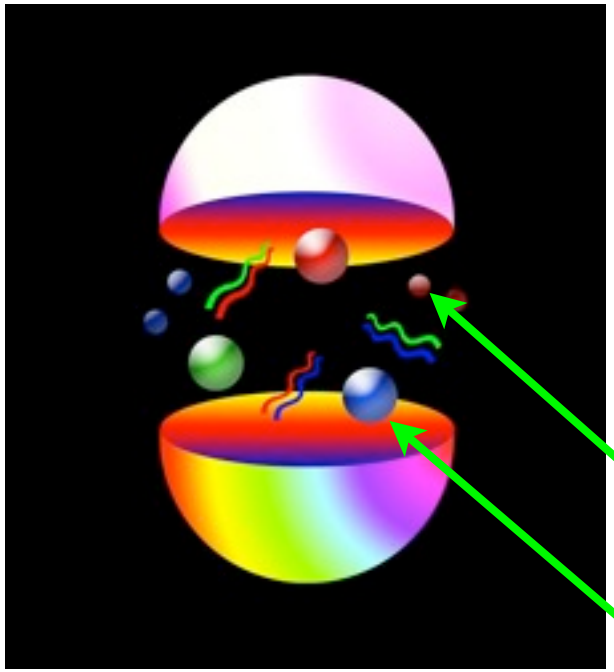
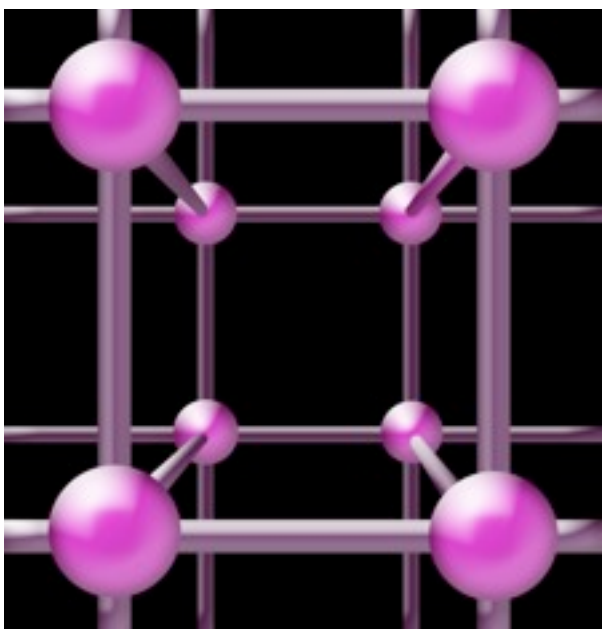
PPAP town meeting
September 2012

Applications of Lattice QCD/Lattice field theory

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





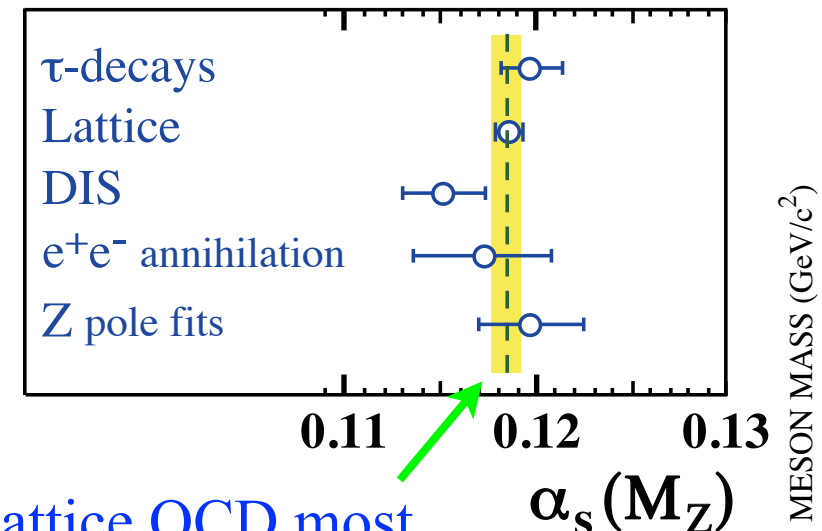


Lattice QCD = fully nonperturbative QCD calculation

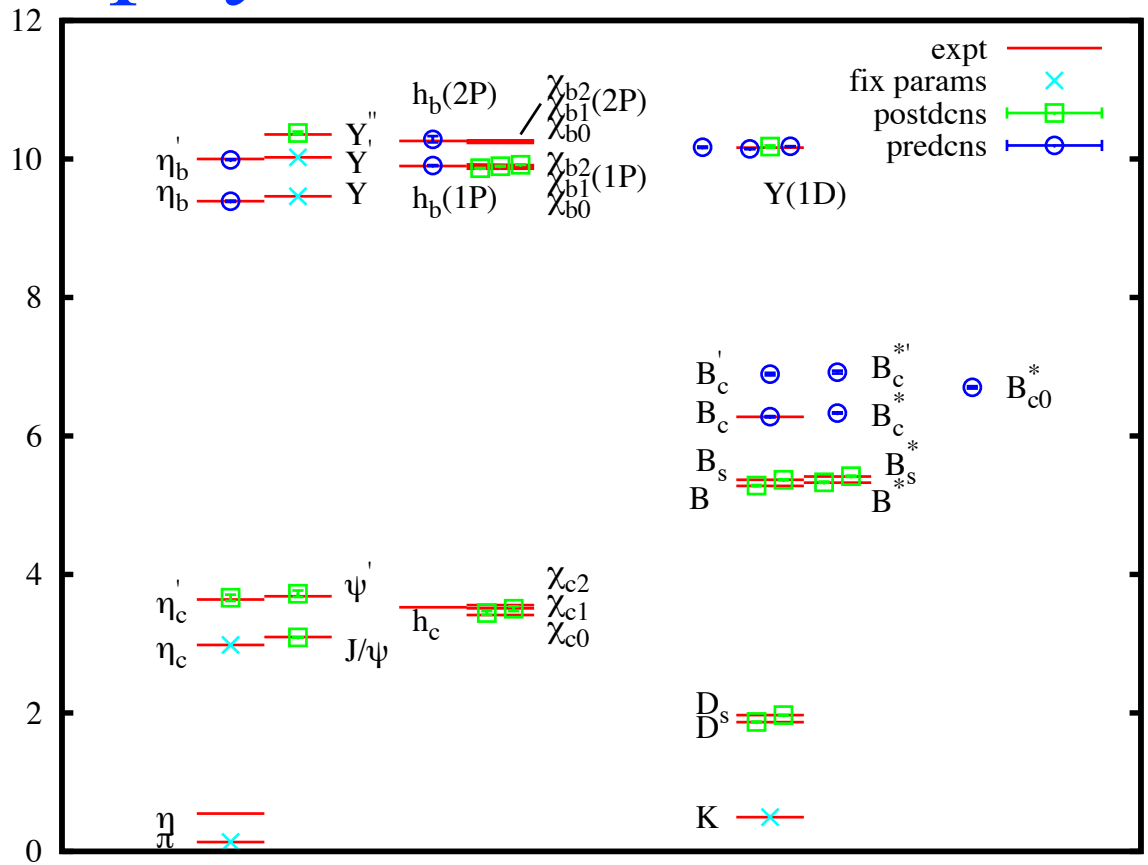
RECIPE

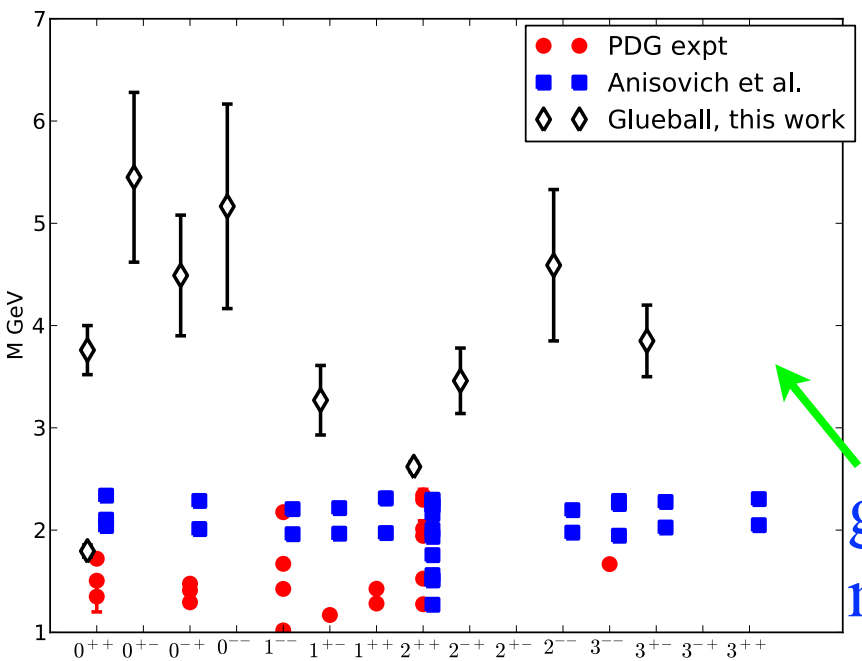
- Generate sets of gluon fields for Monte Carlo integrn of Path Integral (inc effect of u, d, s, (c) sea quarks)
- Calculate valence quark propagators to give "hadron correlators"
- Fit for masses and matrix elements
- Determine a and fix m_q to get results in physical units.
- extrapolate to $a = 0, m_{u,d} = phys$ for real world
- cost increases as $a \to 0, m_l \to phys$ and with statistics, volume.

Lattice QCD hadron physics

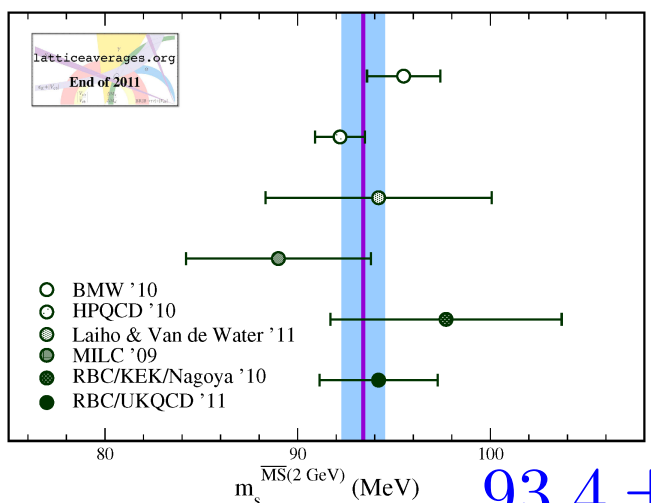


lattice QCD most accurate method





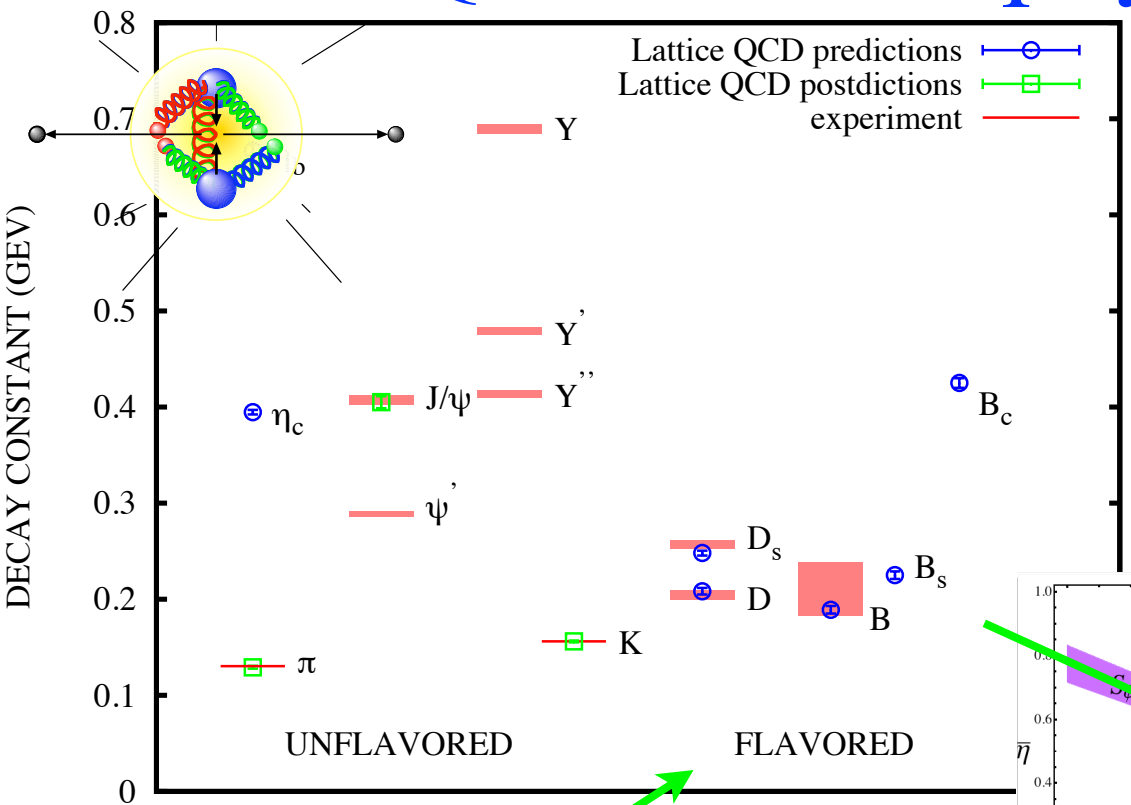
glueball masses

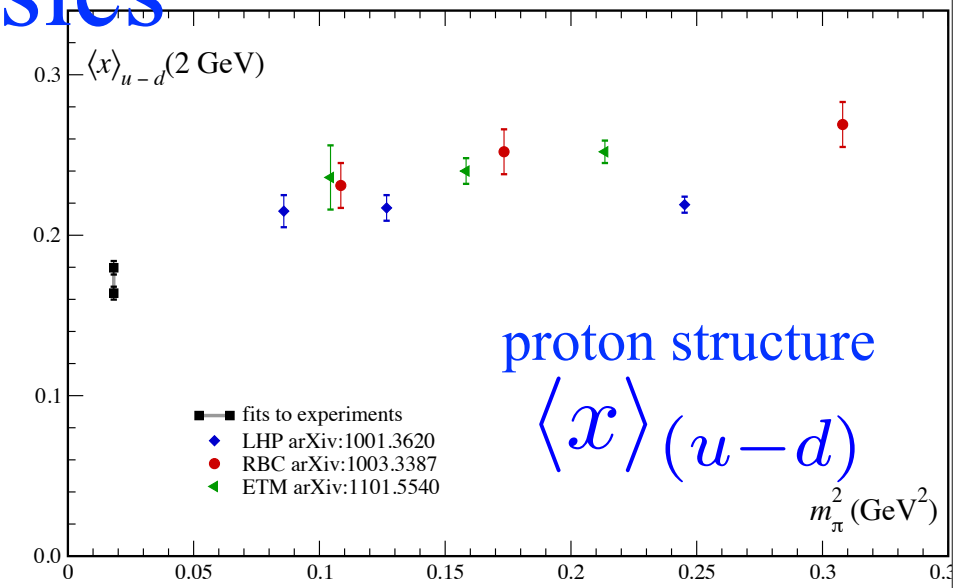


m_s

93.4 ± 1.1MeV

Lattice QCD hadron physics

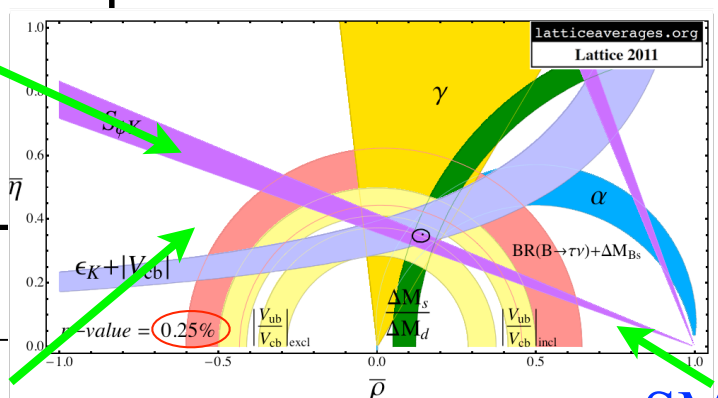


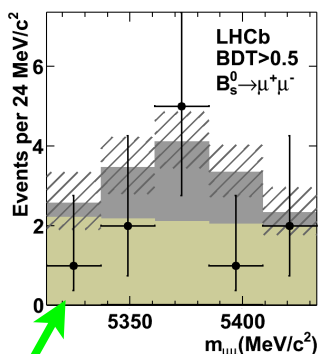


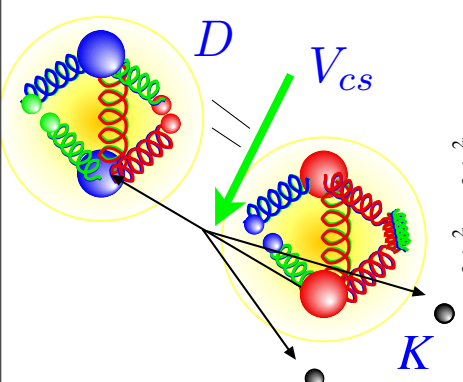
proton structure

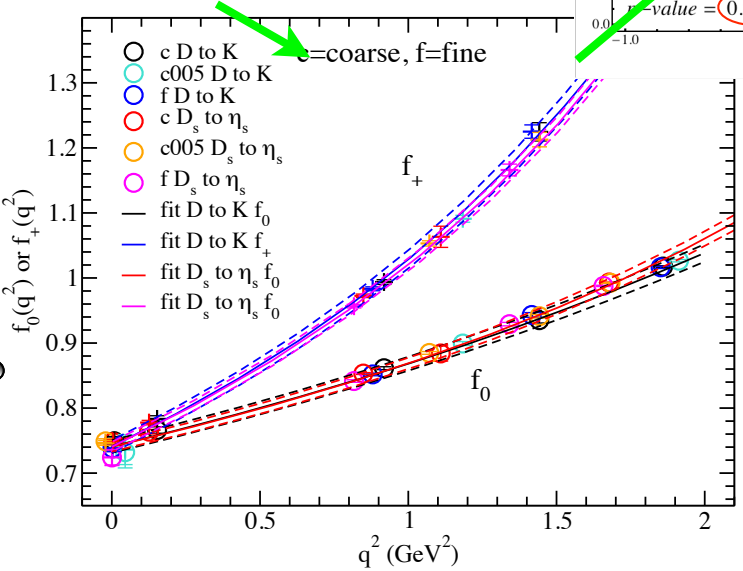
$\langle x \rangle (u-d)$

Precision electroweak MEs

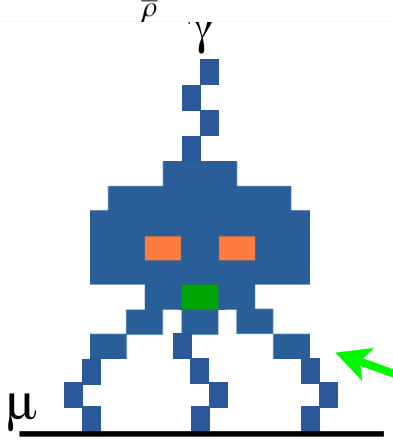






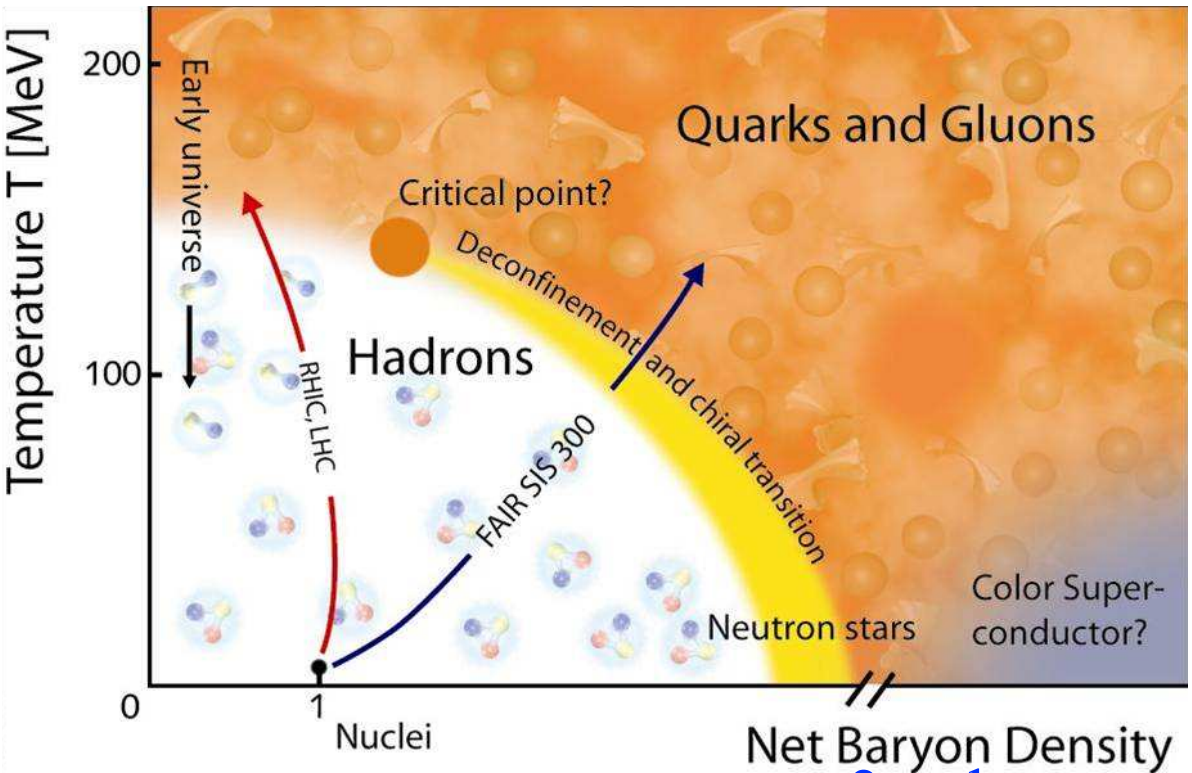


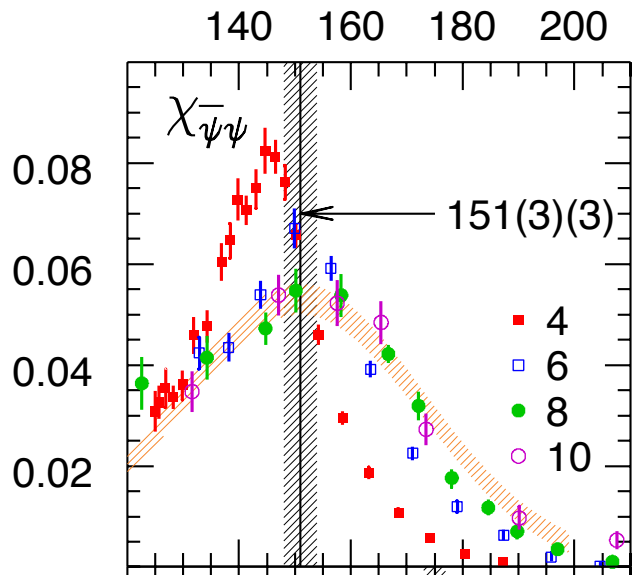
SM rates for hadronic EW processes need lattice QCD ....



muon g-2

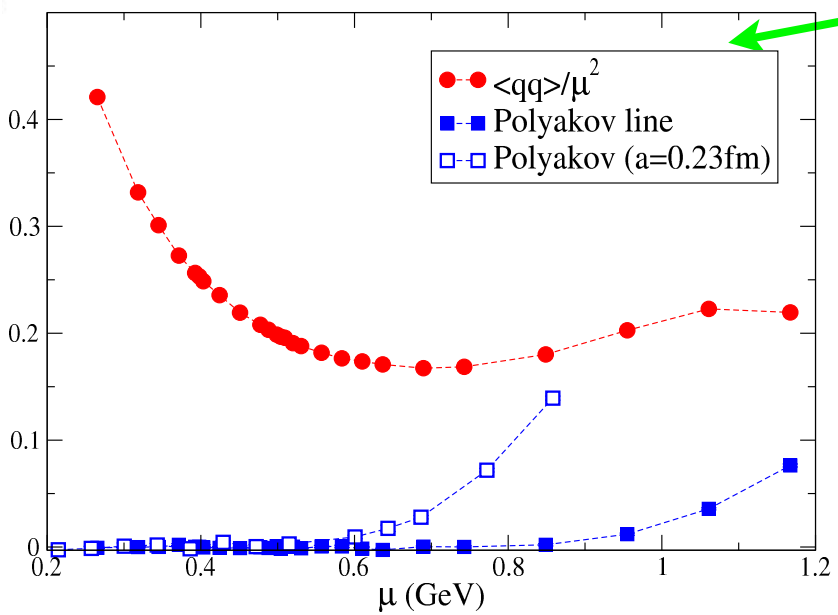
Lattice QCD at high temperature, density



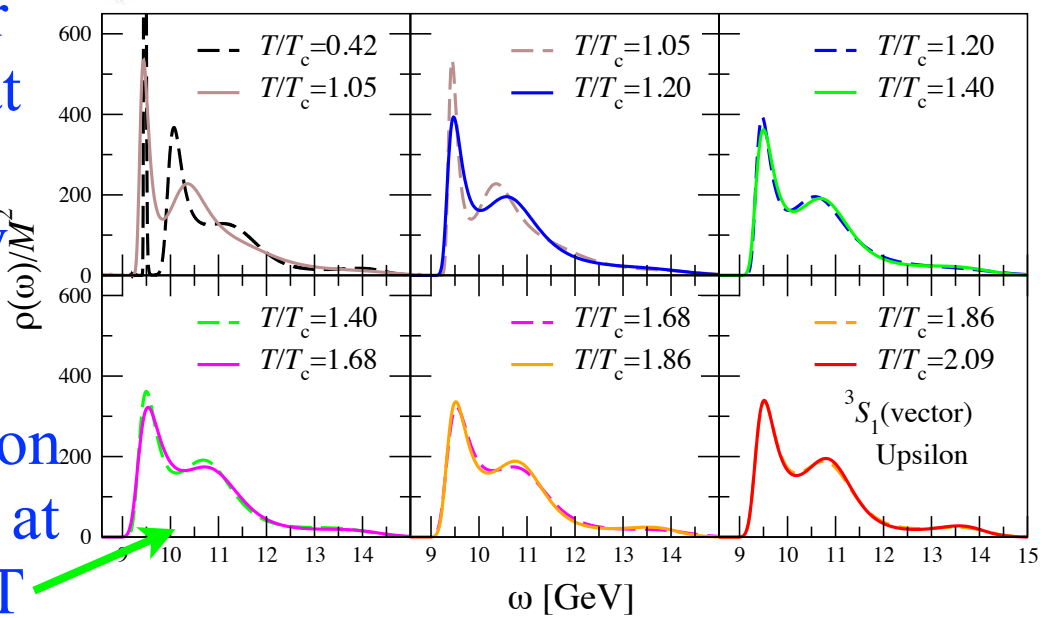


T_c (MeV)

Transition is a CROSSOVER at physical quark masses

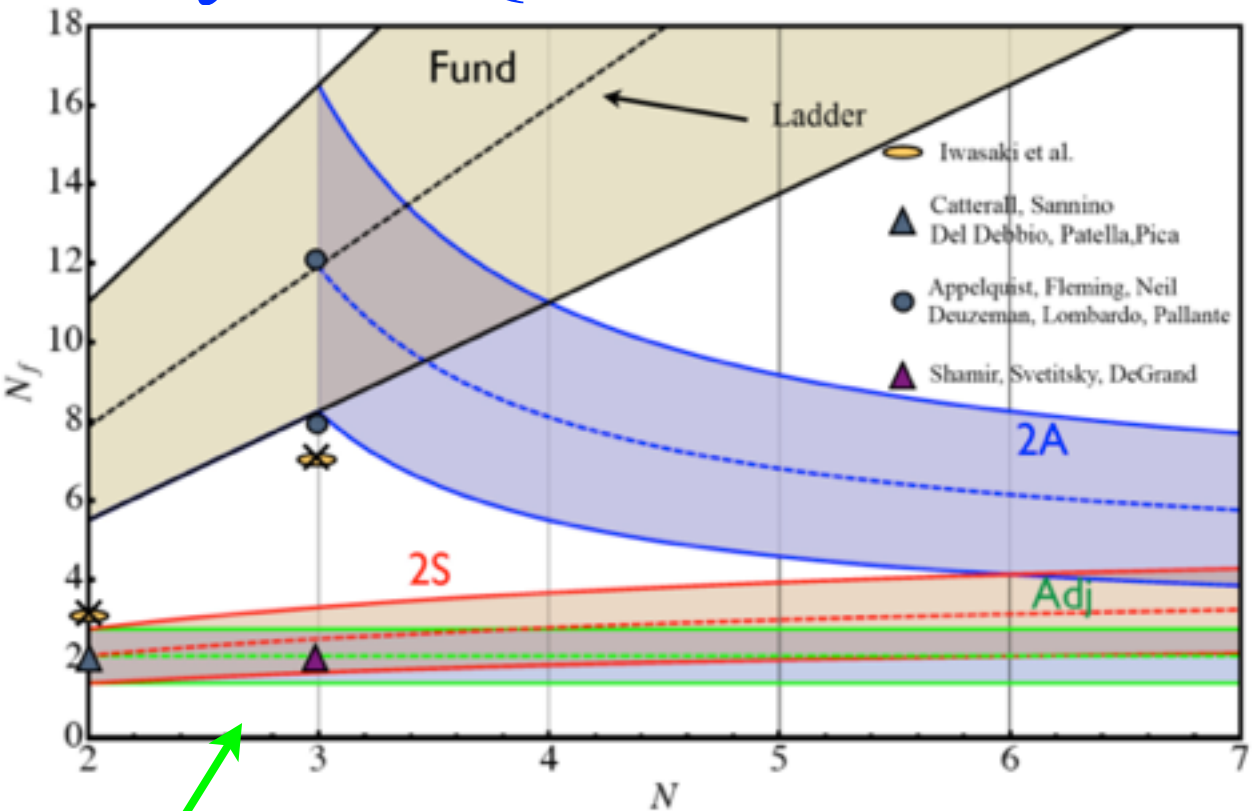


2-color QCD at high density

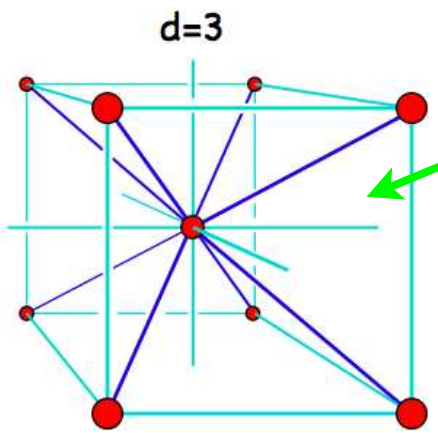


Upsilon melts at high T

Beyond QCD ..

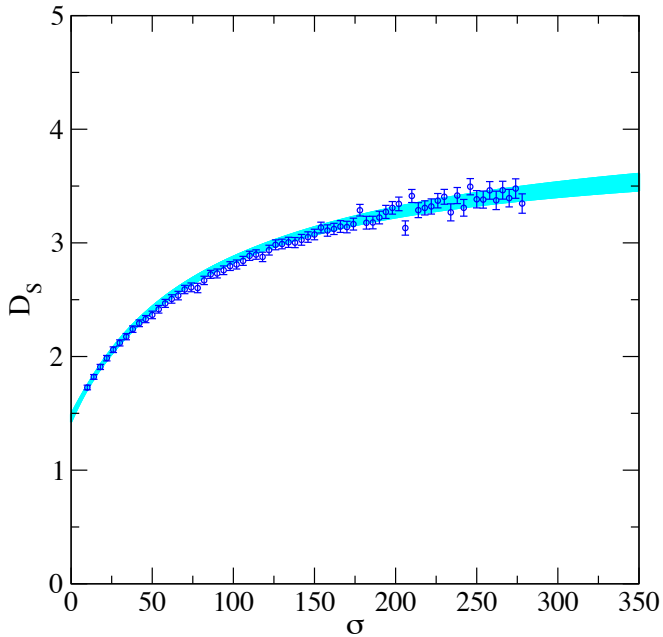


search for viable 'walking technicolour' theory

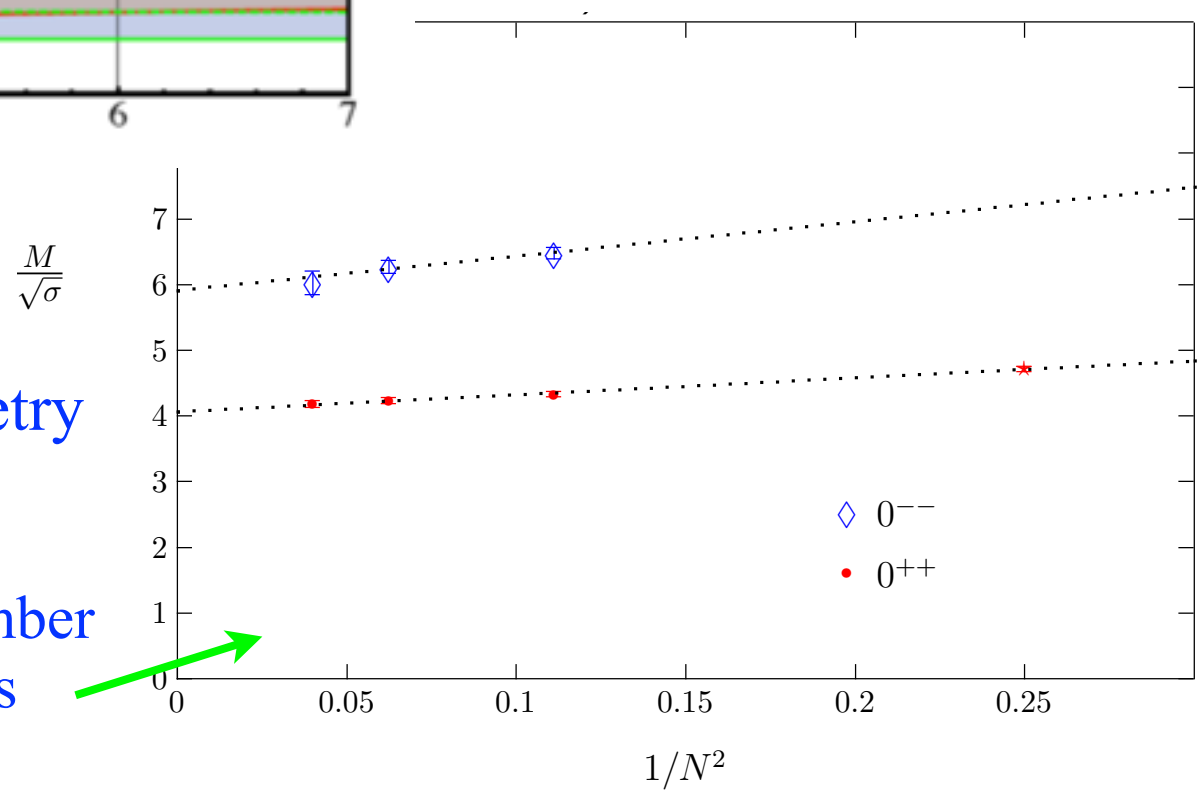


supersymmetry on lattice

large number of colours limit



Lattice quantum gravity



Future (with increased computing power)..

- lattices with physically light up and down quarks in the sea now becoming available - no chiral extrapolation!
- very fine lattices ($a<0.03$ fm) allow b quarks to be treated relativistically rather than with effective theories
- large volumes (6 fm across) allow study of hadron resonances/multi-hadron states/small nuclei
- very high statistics give access to calculations with more intrinsic noise - flavour singlets, glueball spectrum etc
- finite temperature QCD calculations can be extended to different quark formalisms.
- the huge space of BSM theories can be explored
- not all progress requires improved computational resources but it helps!
- results for: LHC, BES, KEK, JLAB, DAFNE, RHIC, FAIR ...

UK landscape - people

UK provides ~8% of worldwide lattice community.•

20% of top-cited papers from hep-lat have at least one UK author^

• judged from attendance at the annual lattice QCD conference

^ from SPIRES, sampling years 2005-2010

8 universities form UKQCD consortium = ~ 50 people.
Members of international collaborations such as:
e.g ETM, HPQCD, QCDSF, RBC-UKQCD, strongBSM

UK landscape - computing

STFC's DiRAC (Distributed Research using Advanced Computing) facility started in 2009 with £13M LFCF grant.

Aim to provide HPC needs of theoretical particle physics along with astrophysics/cosmology.

8 science consortia (UKQCD consortium + 7 astro) funded under phase 1 - computers at 13 sites.

Phase 2 (2012-15) now operating - £15M capital from BIS plus £1.7M STFC ops (**only pays electricity for one year**).

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

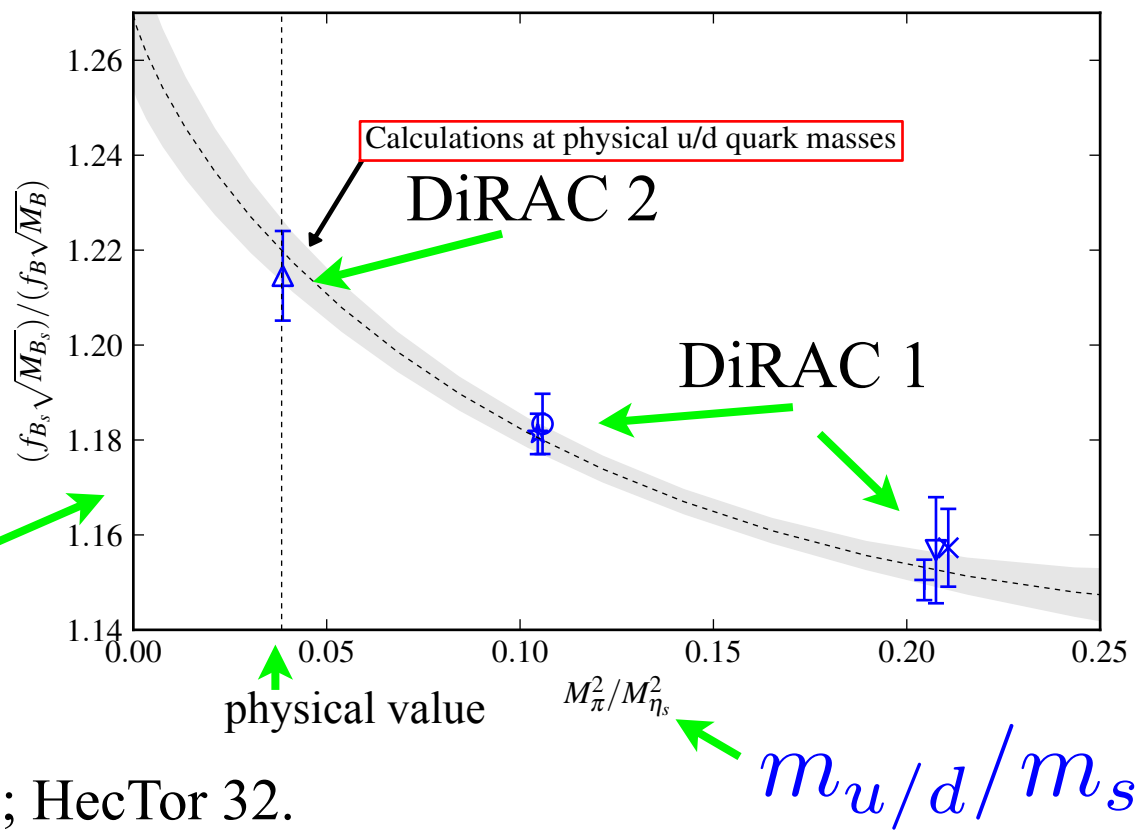
Lattice field theory researchers focussed on two machines:

1) 6-rack BG/Q at Edinburgh. DiRAC 1+2 ~ £10M (inc. discount from Ed-IBM collaboration on hardware).
20 in top 500* - 1Pflops

2) Sandybridge/infiniband cluster at Cambridge.
DiRAC 2 ~£1.5M for half machine.
93 in top 500* - 200 Tflops (total machine).

These machines give new capabilities e.g.
results now obtained at physically light up/down quark masses.

B decay constant: R. Dowdall (Glasgow, HPQCD) in progress on Cambridge cluster



* www.top500.org : Hartree centre 13; HecTor 32.

Future needs/plans (for whole of DiRAC)

- **Top priority is for funding for electricity costs of £1M per year from August 2013.**

- Increase in PDRAs (+3 per year on pre-2011 number) + PhDs (+10 per year) in particle theory would improve exploitation capabilities.

- Increase in support staff (currently 4) to 8 plus additional code development support (of 4) would improve uptime and efficiency. Aim to tackle some technical issues e.g. authentication, data handling, code efficiency, hardware in collaboration with others (industry, GRIDPP ..).

- 2014-15 - DiRAC phase 3 - seeking £35M from BIS for 20X performance upgrade. Associated support costs needed