Lattice field theory - a European perspective

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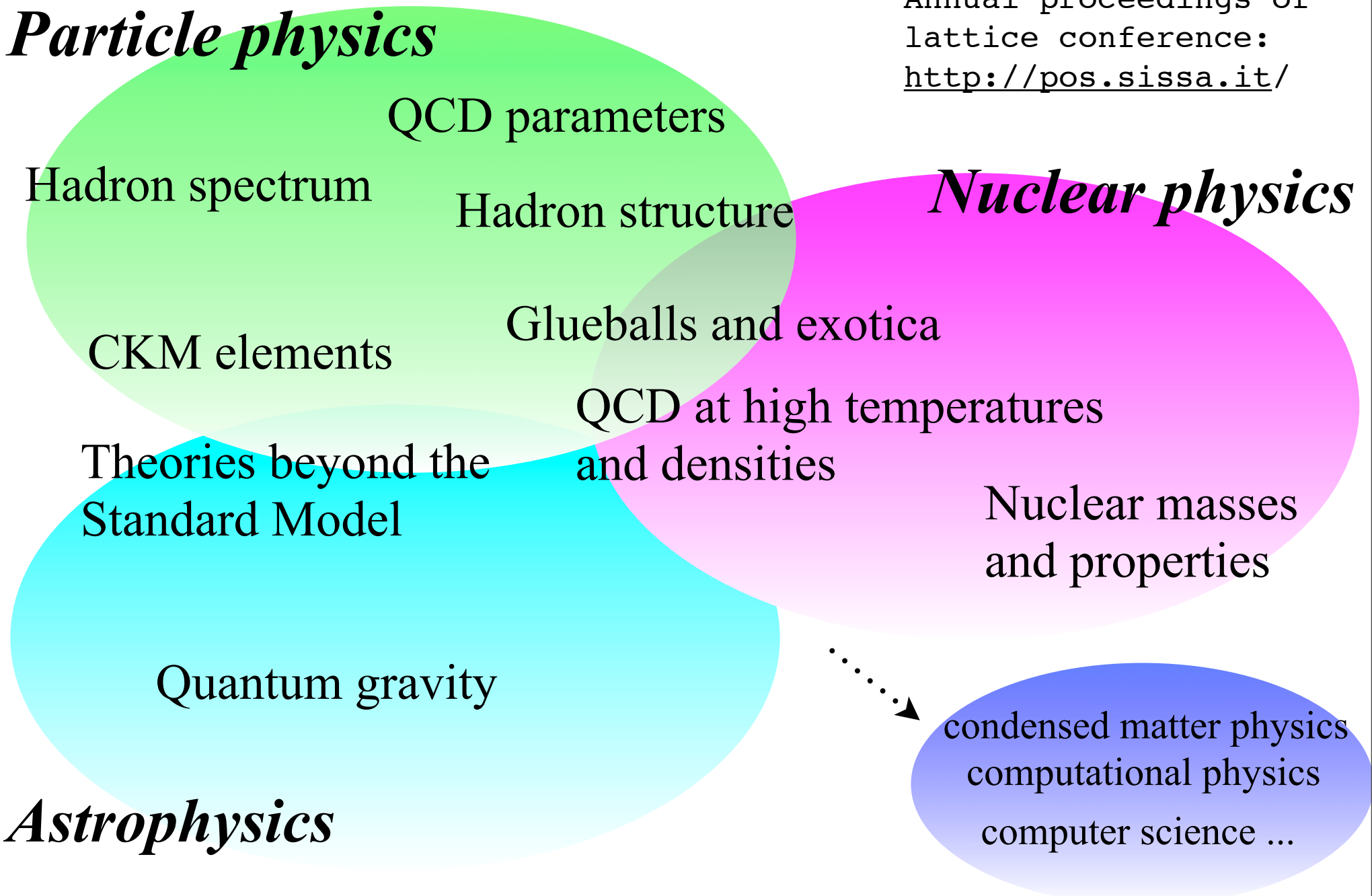
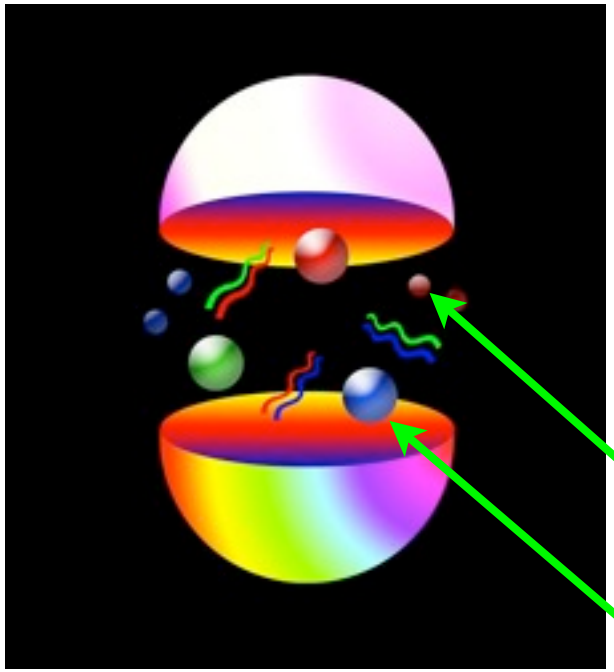
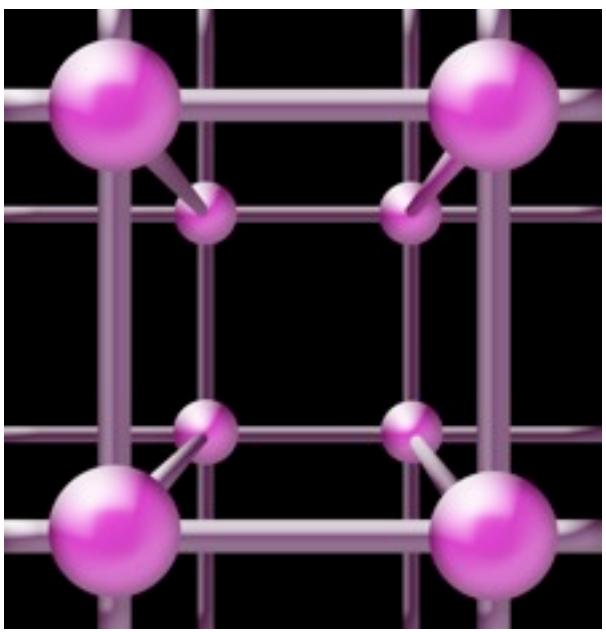
European strategy meeting
Krakow
September 2012

Applications of Lattice QCD/Lattice field theory

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





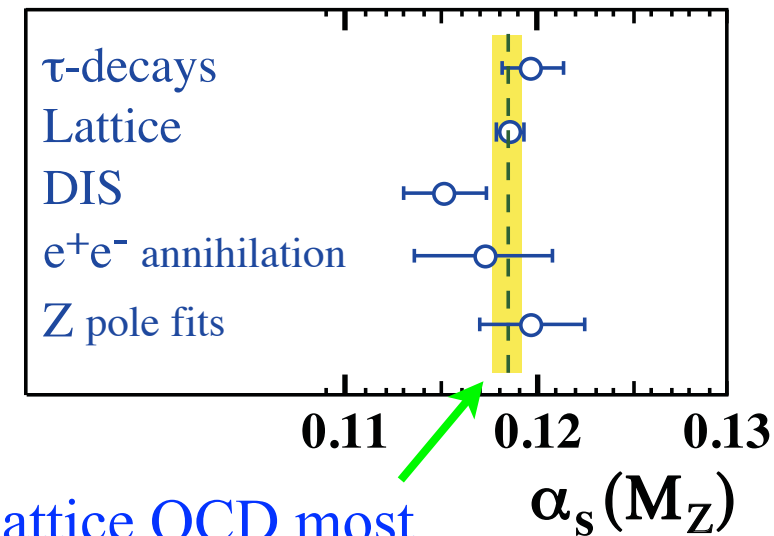


Lattice QCD = fully nonperturbative QCD calculation

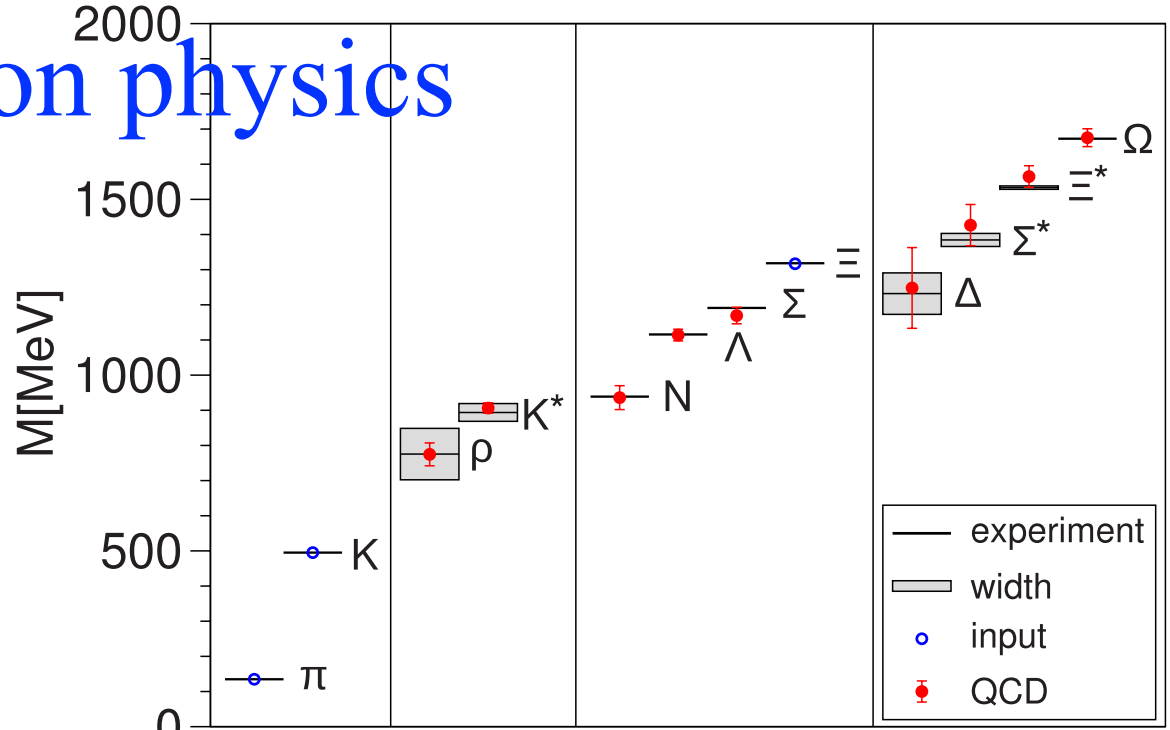
RECIPE

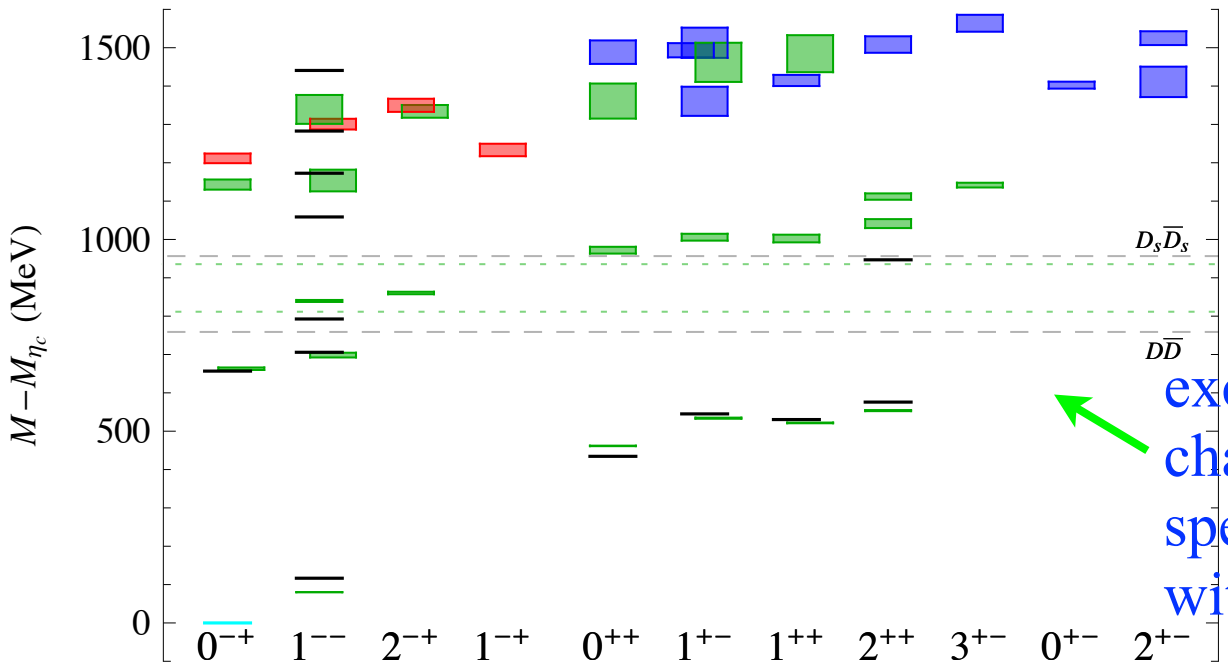
- Generate sets of gluon fields for Monte Carlo integrn of Path Integral (inc effect of u, d, s, (c) sea quarks)
- Calculate valence quark propagators to give "hadron correlators"
- Fit for masses and matrix elements
- Determine a and fix m_q to get results in physical units.
- extrapolate to $a = 0,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

Lattice QCD hadron physics

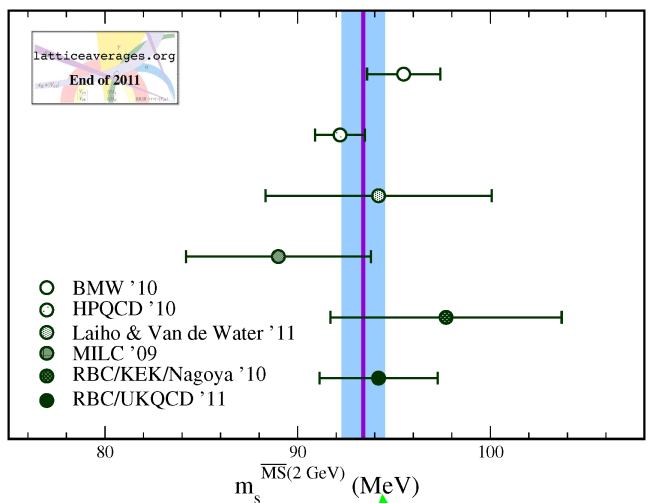


lattice QCD most accurate method





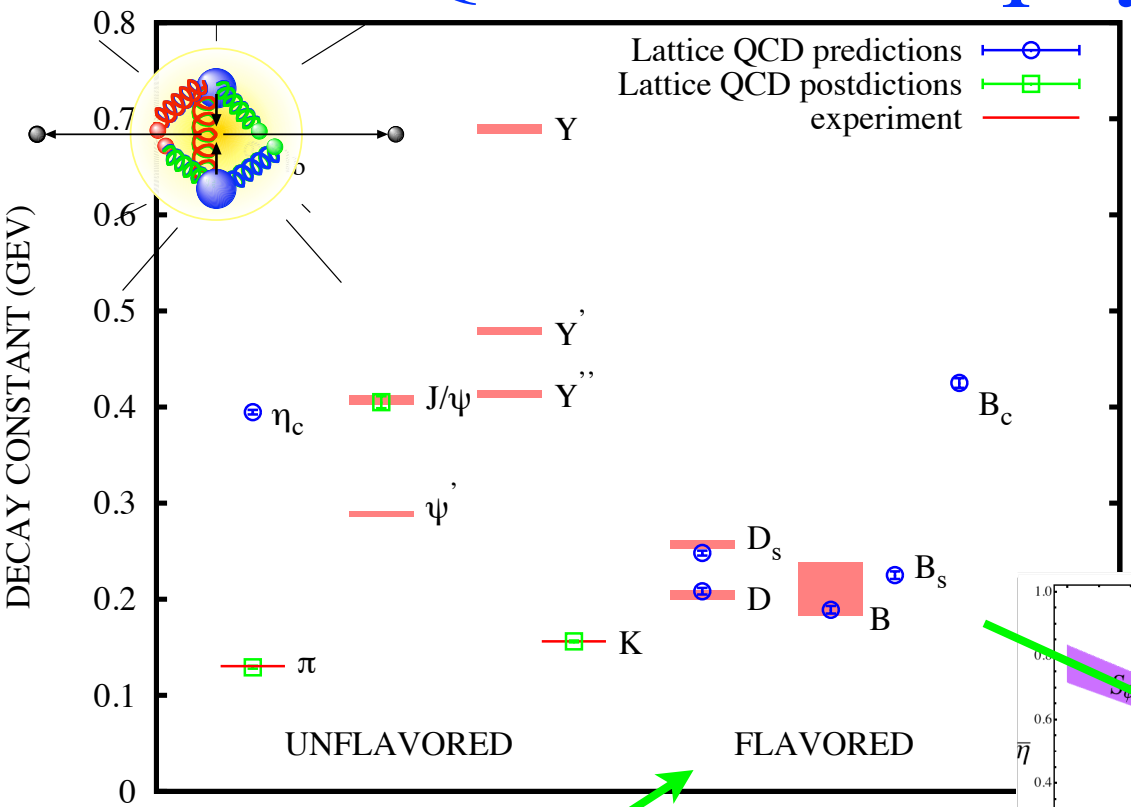
excited charmonium spectrum with hybrids

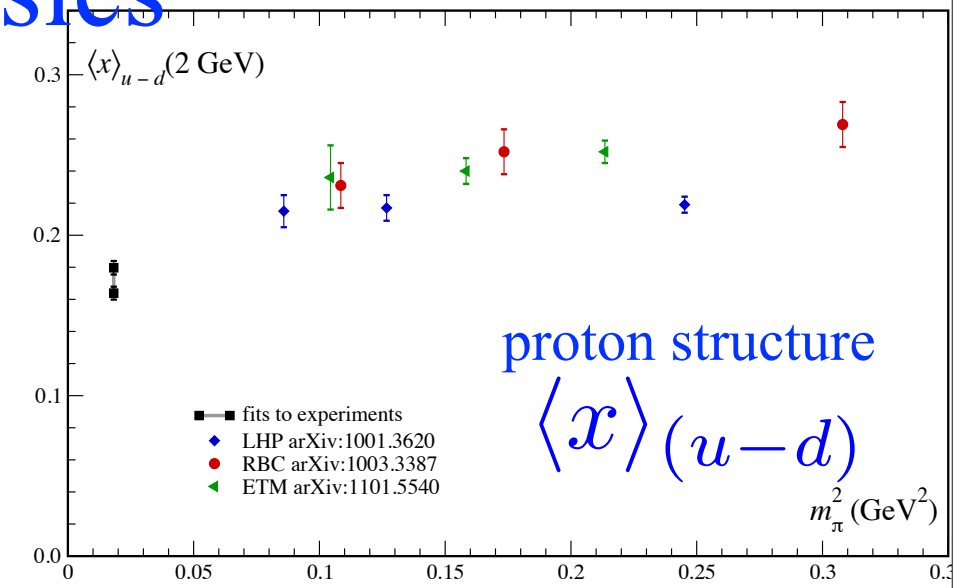


m_s

93.4 ± 1.1MeV

Lattice QCD hadron physics

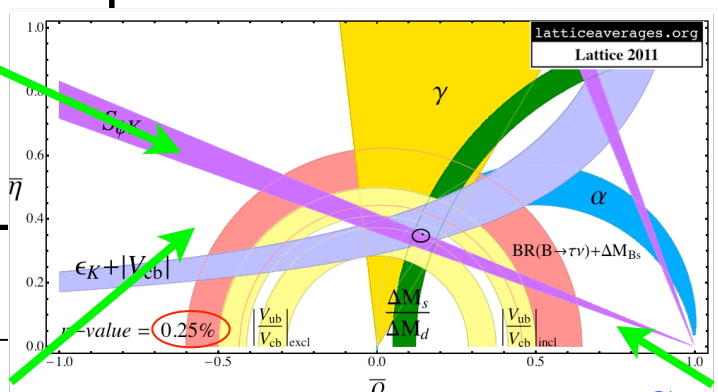


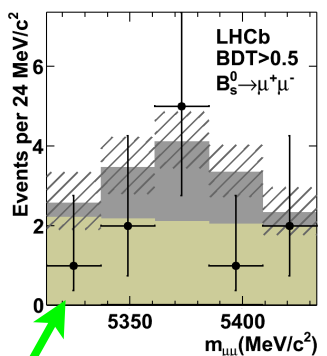


proton structure

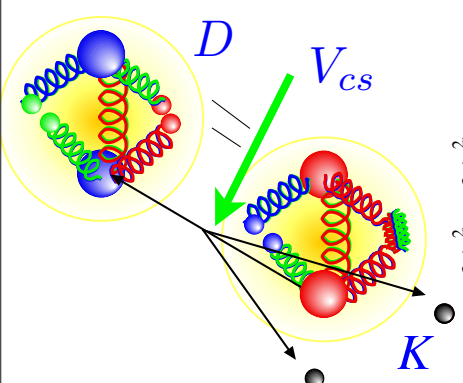
$\langle x \rangle (u-d)$

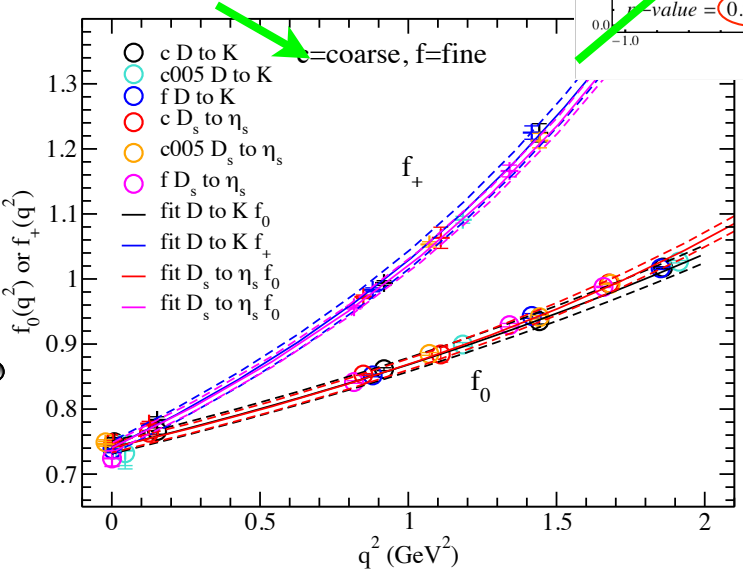
Precision electroweak MEs

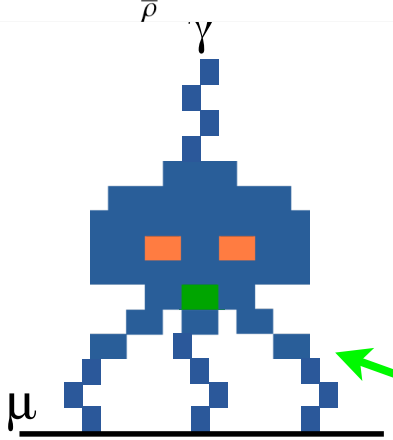




SM rates for hadronic EW processes need lattice QCD ....



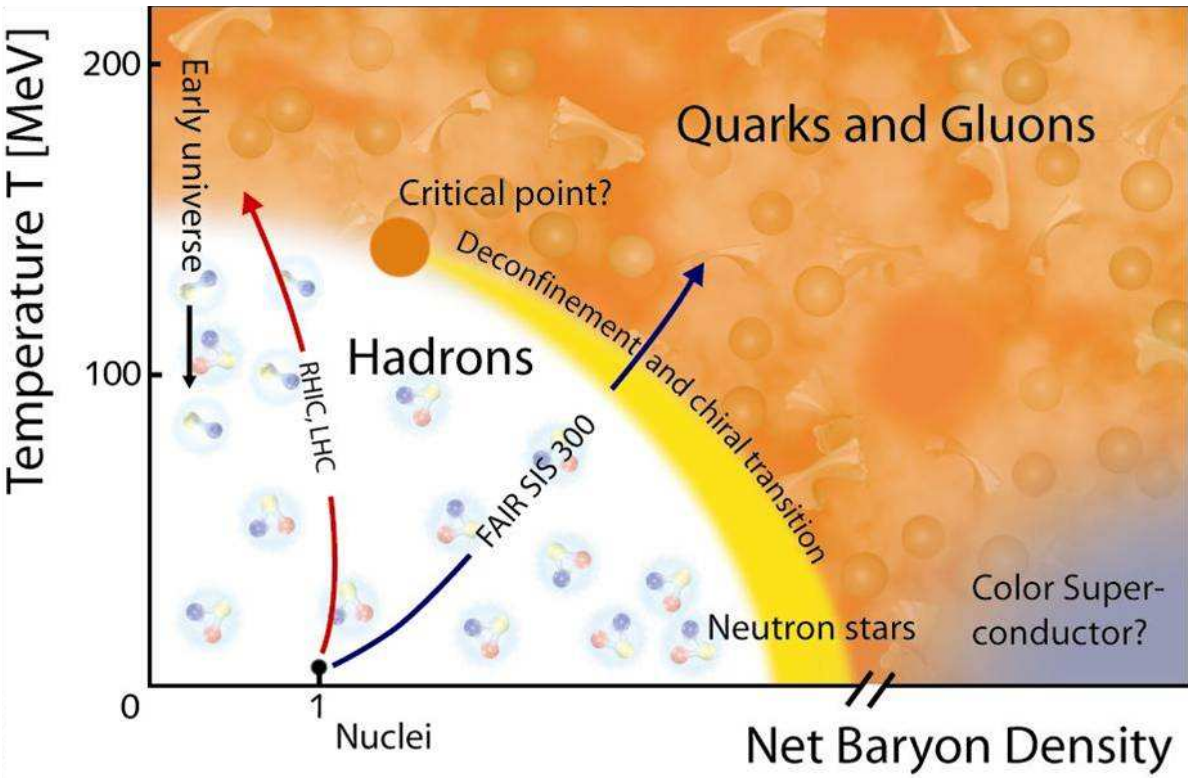


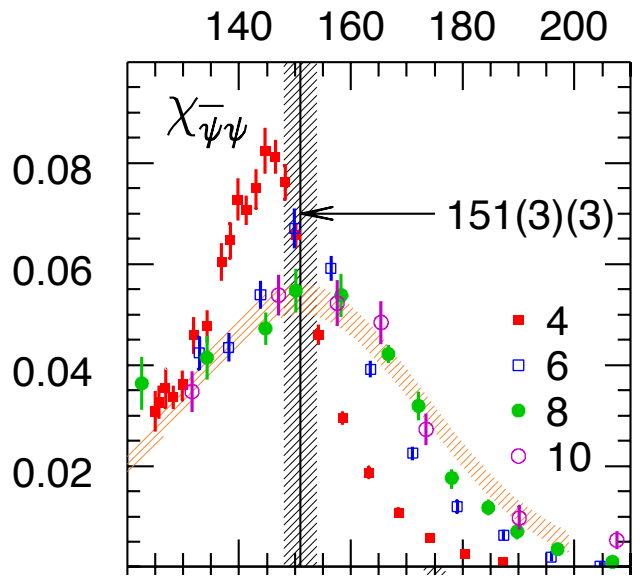


muon g-2

WIMP-nucleon scattering ...

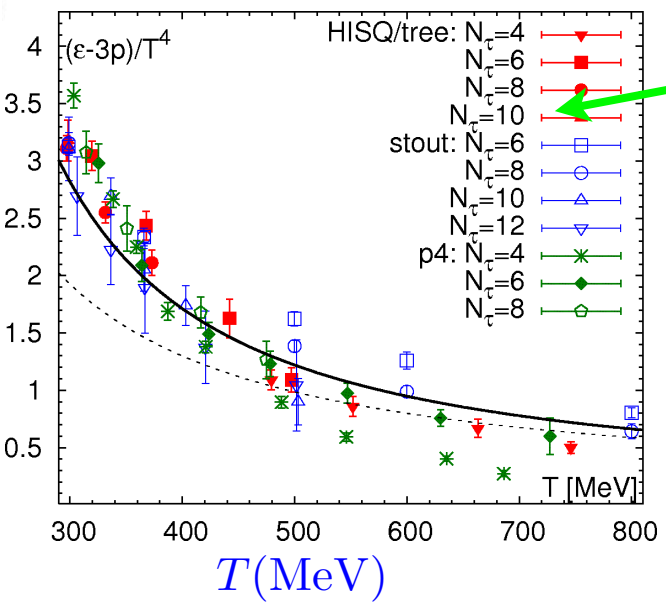
Lattice QCD at high temperature, density





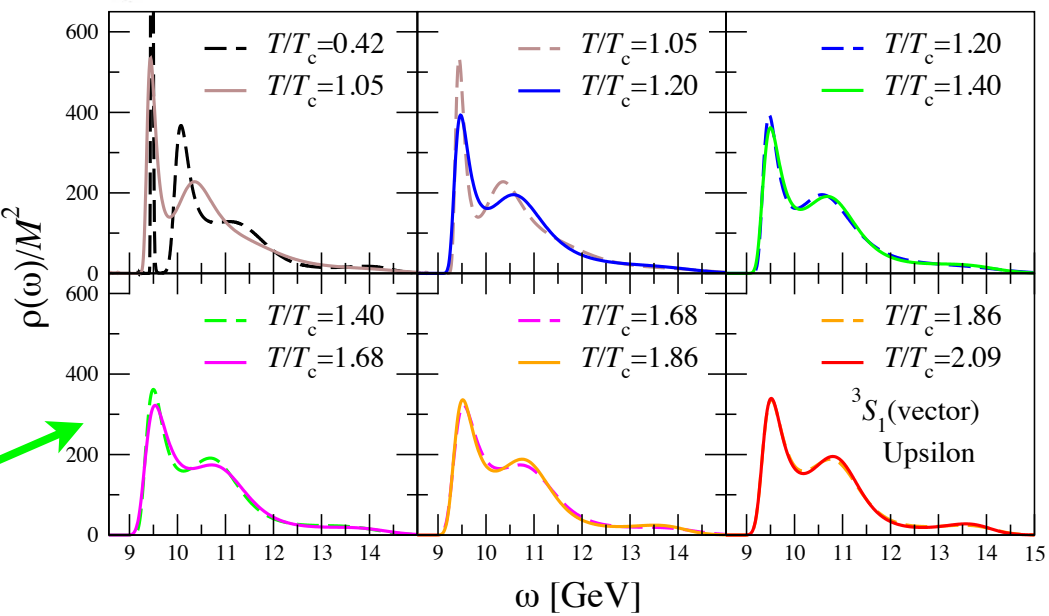
T_c (MeV)

Transition is a CROSSOVER at physical quark masses

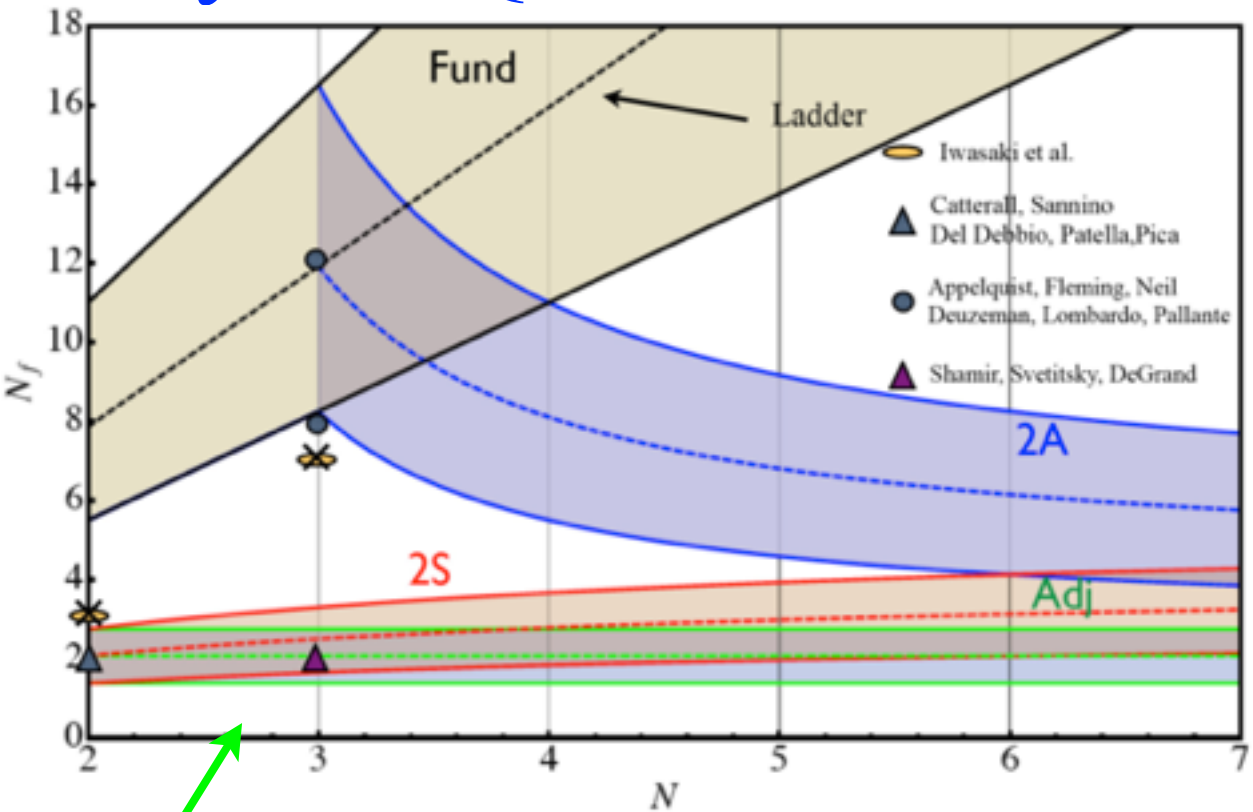


Equation of state

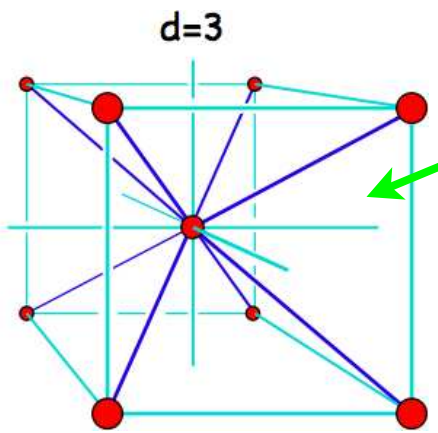
melting of Upsilon states



Beyond QCD ..

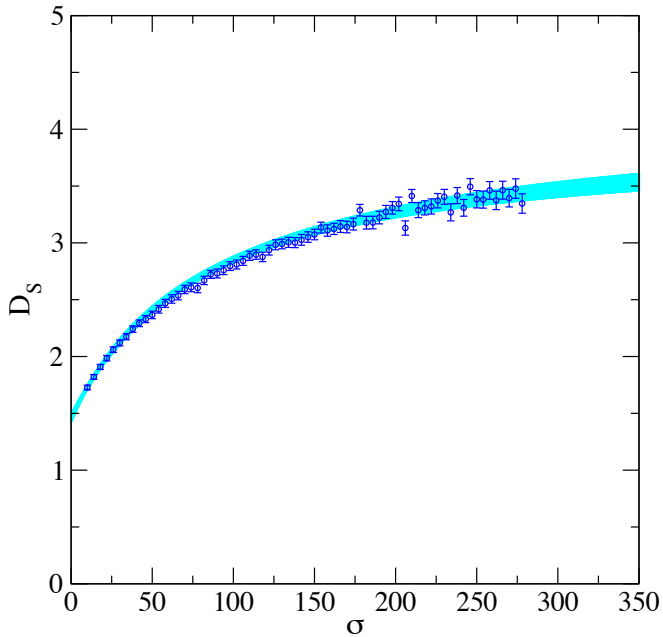


search for viable 'walking technicolour' theory

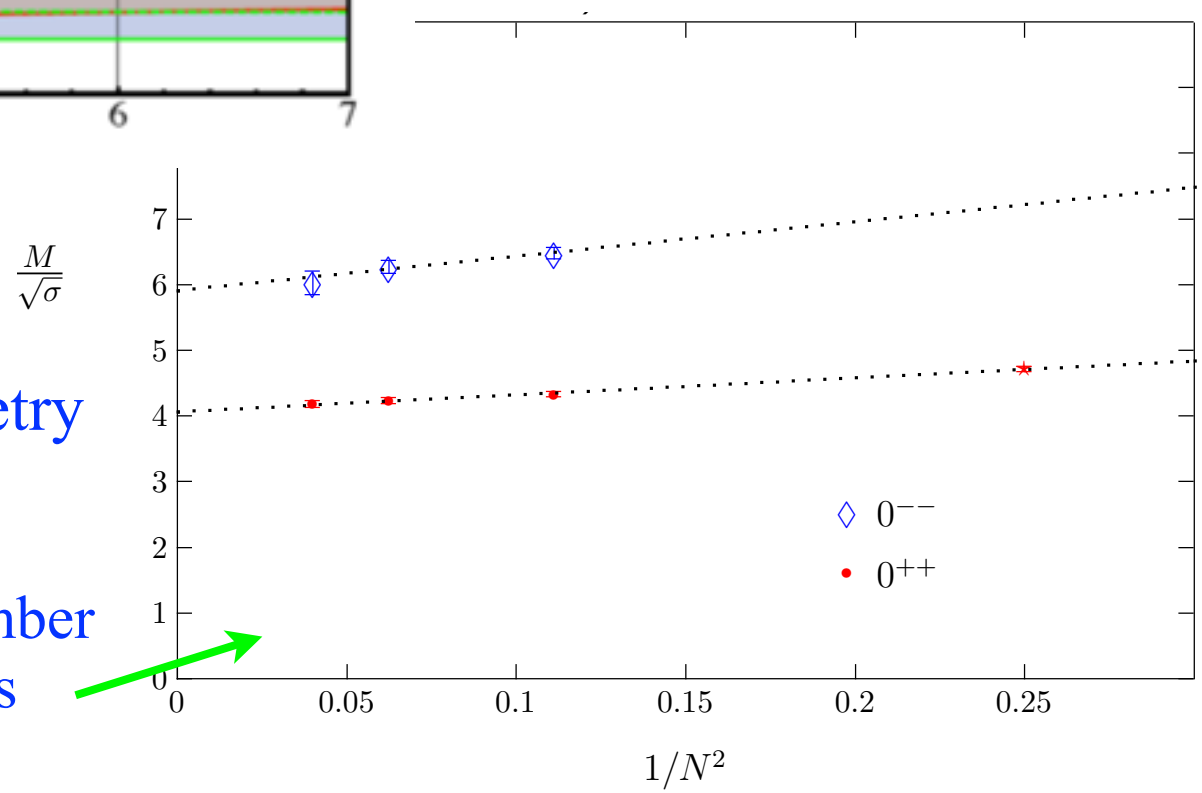


supersymmetry on lattice

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 ...

European landscape - people

Many European countries active in lattice field theory*:

Europe provides ~50% of worldwide lattice community•
of a few thousand.

70% of top-cited papers from hep-lat have some European authors^

*input to this talk from almost all of them

• judged from attendance at the annual lattice QCD conference

^ from SPIRES, sampling years 2005-2010

European landscape - collaborations

Vary from international collaborations of ~20 people (e.g. Alpha, BMW, CLS, ETM, Hadron Spectrum, HotQCD, HPQCD, QCDSF, RBC-UKQCD, StrongBSM) to smaller groups. Sociologically tricky for theorists, but necessary for access to computing resources.

Significant fragmentation of European community around different discretisations of QCD Lagrangian. Good for diversity or inefficient?

Some success at bringing people together with EU networks - currently StrongNET and participation in III Hadronphysics 3. Flavianet spun out FLAG (lattice averaging group).

European landscape - computing

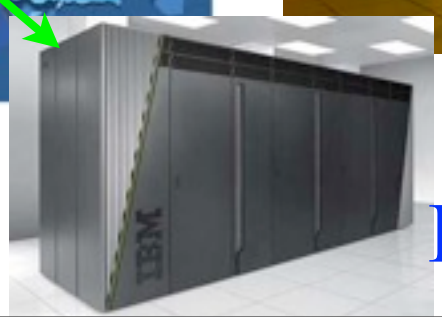
Europe has 7 of world's top 20 computers* with Pflops speed (32 of top 100 vs USA: 37 of top 100)

Lattice QCD has some access to these capability machines, but analysis phase needs large-scale capacity computing.

Hardware is provided nationally and piecemeal but PRACE provides important Europe-wide access

JUGENE

Curie



Fermi

BUT fundamental physics not a top priority ... Lattice QCD not chosen as an application area for the EXASCALE DEEP project

* www.top500.org

International Lattice DataGrid

Global initiative allowing gluon field configurations to be made publically available for analysis.
BUT no resources available to run this ...

US DoE SciDAC initiative

Provides steady source of funds for computing hardware and people to develop publically available efficient parallel software for lattice calculations. Smaller European groups use this - would be good to contribute/have our own initiative BUT no resources for this ...

Lattice QCD pushes boundary of supercomputer “grand challenges” (and has led to hardware developments) so is a good technical training environment.

Conclusions

Europe must maintain a long-term world-leading programme in lattice gauge theory both as vital input for the experimental programme and for the leading-edge technology skills base.

This requires sustained investment in computing infrastructure, support and people. To be competitive, we need 10-20M€ per year for dedicated hardware + 4M€ per year for software/algorithm development across Europe.

More coordination between researchers would help us argue for this investment and maximise the output from it in research, training and communication of results. We need mechanisms within Europe to encourage this to happen.