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Theory status and prospects

Mike Seymour
University of Manchester
Chair of Particle Physics Grants Panel (Theory)

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Theory status and prospects

- The UK community
  - 175 academics in 20 university groups
  - plus Institute for Particle Physics Phenomenology, EPSRC-funded string/QFT posts in Maths depts, astro-particle theorists
- (recent) History
- Physics highlights
- Future prospects

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The UK Theory Community

- is world leading in (e.g.)
  - lattice
    - UKQCD and phenomenology
    - formal developments
  - string theory and QFT
    - AdS/CFT correspondence (Integrability, Applications)
    - QFT (Supersymmetry, Scattering Amplitudes, Solitons)
    - String Theory (Phenomenology for particle physics and cosmology, M-Theory, techniques for field theory calculations)
  - cosmology
    - particle cosmology (inflation, dark energy, CMB, dark matter…)
    - computational cosmology, structure and galaxy formation
  - phenomenology
    - QCD, Monte Carlo, parton distribution functions, B physics
    - BSM model building, data exploitation

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Strong connection with experiment:

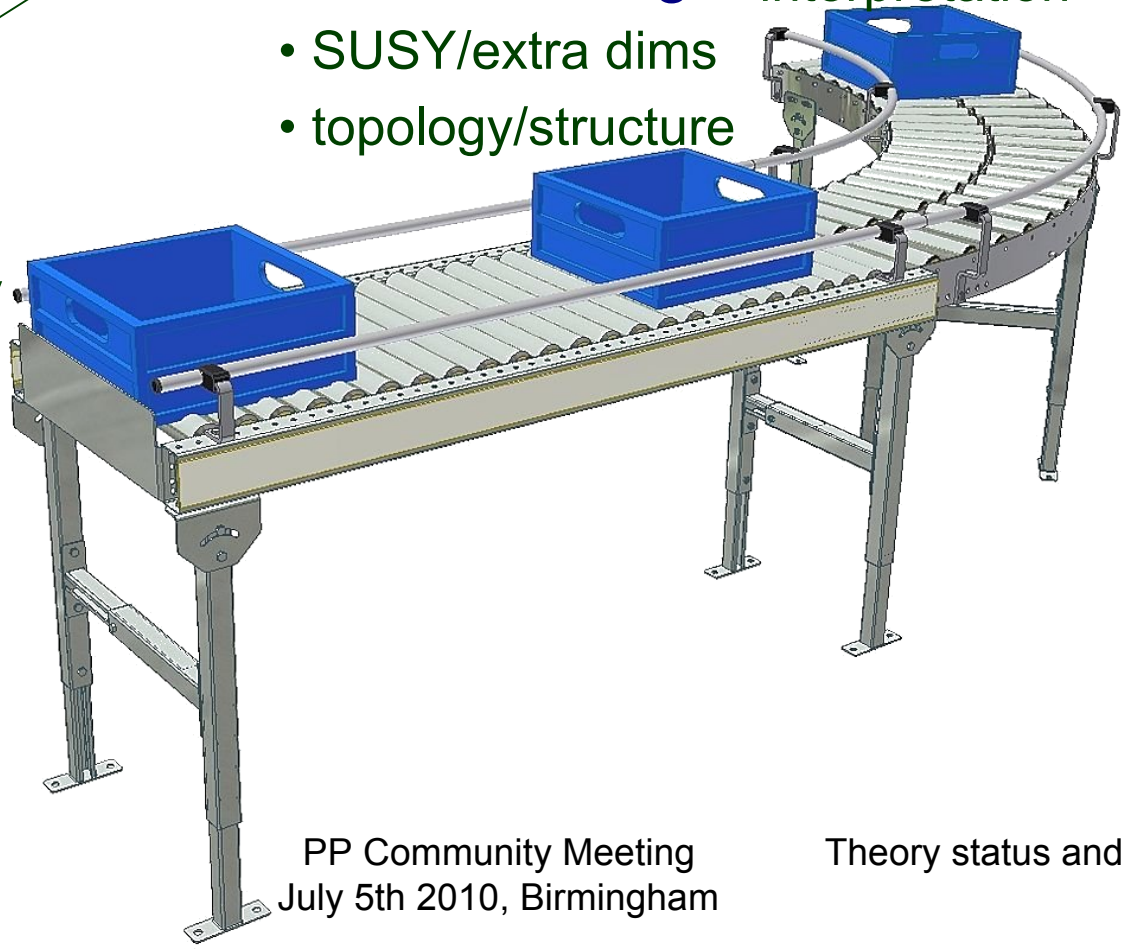
- calculations
- tools
- analysis strategies
- interpretation

Model building:

- SUSY/extra dims
- topology/structure

Formal theory:

- strings/branes
- quantum gravity
- duality



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The UK Theory Community

- has a proven high impact on public perception of science, and the choice of school-leavers to study physics
- Second international review of UK Research in Physics and Astronomy (2005):
  - "Particle theory in the UK is healthy, with a revitalised effort in particle phenomenology, a burgeoning contribution to the physics that might lie beyond the Standard Model, a strong and vital group of lattice theorists and continuing strength in string theory and general relativity."
  - "There are signs that this position is under threat."
  - "It is the Panel's perception that there are fewer theorists in UK physics and astronomy departments than is the international norm."

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The UK Theory Community

- is growing:
  - 2005 RG applications: 122 academics
  - 2008 RG applications: 155 academics (+27%)
    - 19 research groups
  - 2011?
    - +15% growth: 175 academics?
    - at least 1 new group + several significant expansions

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Institute for Particle Physics Phenomenology

IP3 University of Durham

- Grant renewed in 2008/9 for further 10 years

Durham University

http://www.ippp.dur.ac.uk/

Institute For Particle Physics Phenomenology

- 12 academic staff
- 19 research staff
- 8 visiting researchers
- 30 research students
- 5 support staff
- 1 outreach manager

The Institute for Particle Physics Phenomenology (IPPP) was set up in Durham in 2000 and has established itself quickly as a true centre of excellence on the international scale with an outstanding scientific performance in the field of particle physics theory

Research Institute dedicated to performing world class research at the very frontier of particle physics.

Set up in 2000 as a partnership between Durham University and PPARC with ten year grant , new building and 4 new academic positions

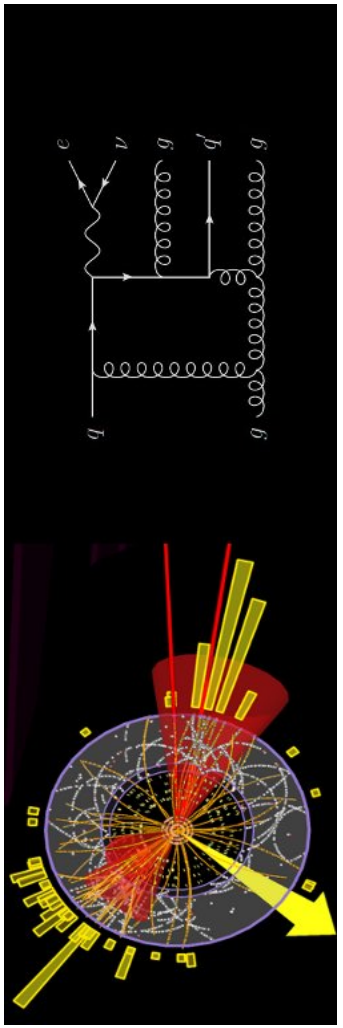
Partnership renewed in 2008/9 with new ten year grant. DU provides 3 new academic positions, £1M of PDRA support and commitment for more space.

http://www.ippp.dur.ac.uk/Workshops/

IPPP workshop programme

Forthcoming workshops

- ✓ CKM2010: 6th International Workshop on the CKM Unitarity Triangle, Warwick, 6 - 10 September 2010
- ✓ Topical Workshop on "Vector boson plus jets as a signal and background", Durham, 8 - 10 September 2010
- ✓ CERN Theory Institute: ν TheME: Neutrino Theory, Models, and Experimental perspectives, CERN, 13 - 22 September 2010
- ✓ Lattice meets Phenomenology, Durham, 15 - 17 September 2010
- ✓ LHC first results and outlook, Cosener's House, 20 - 21 September 2010
- ✓ QCD in the LHC Era: A Meeting in Honour of Bryan Webber, Cambridge, 22 September 2010
- ✓ Soft Gluons and New Physics at the LHC, Manchester, 1 - 2 November 2010
- ✓ MPI@LHC 2010: 2nd International Workshop on Multiple Partonic Interactions at the LHC, Glasgow, 29 November - 3 December 2010
- ✓ Annual Theory Meeting, Durham, 16 December - 18 December 2010



Recent news

New Director from 1 August

Valya Khoze

IPPP Associates

- funded by Durham University to enhance collaboration

- next round open now, closing date 31 August

New lecturer appointments

Jeppe Andersen [CERN] (from 1/10/10)

collider physics and multiparticle interactions

Celine Boehm [LAPTH] (1/1/11)

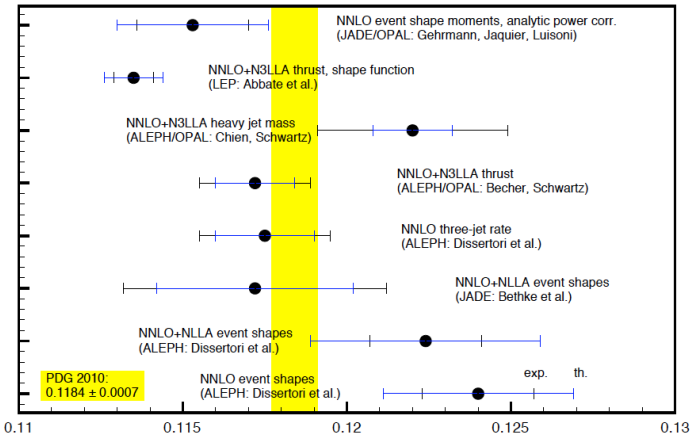
Dark matter, astro-particle physics

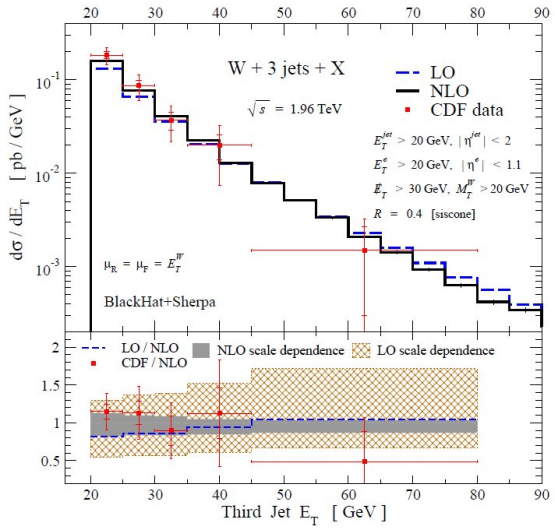
Thorsten Feldmann [TUM] (1/1/11)

Flavour physics, strong interactions, BSM

Two more permanent positions in BSM and Higgs areas will be advertised in September

Recent IPPP research highlights





- ✓Calculation of NNLO event shape in e+e- annihilation and determination of strong coupling
- ✓NLO QCD predictions for W+3 jets (BlackHat)
- ✓MSTW parton distributions for the LHC
- ✓Study of soft diffractive processes at the LHC and gap survival probability
- ✓Development of HERWIG++ and SHERPA event generators
- ✓Improved prescription for the merging of matrix elements with parton showers
- ✓Calculation of two-loop hexagon and octagon Wilson loops and connection with gauge theory loop amplitudes
- ✓Study of phenomenology of general gauge mediation in the MSSM
- ✓Study of lepton-number violating decays of tau leptons and pseudoscalar mesons
- ✓Improved determination of inclusive electromagnetic decay ratios of heavy quarkonium
- ✓Study of Symmetries and Asymmetries of B decay to K*mu+ mu-

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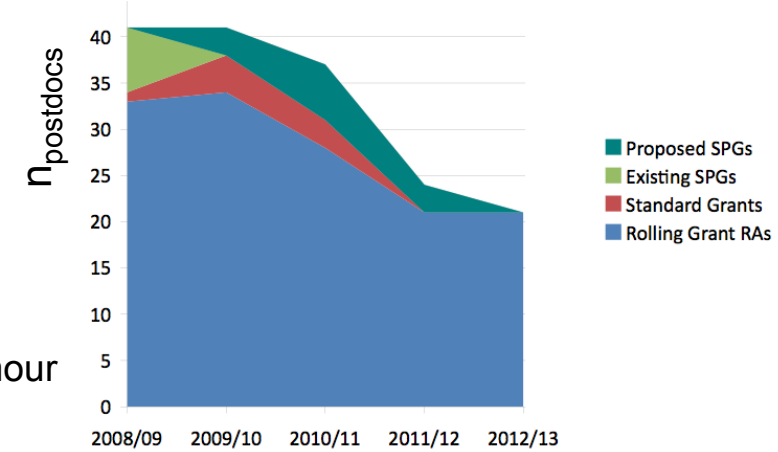
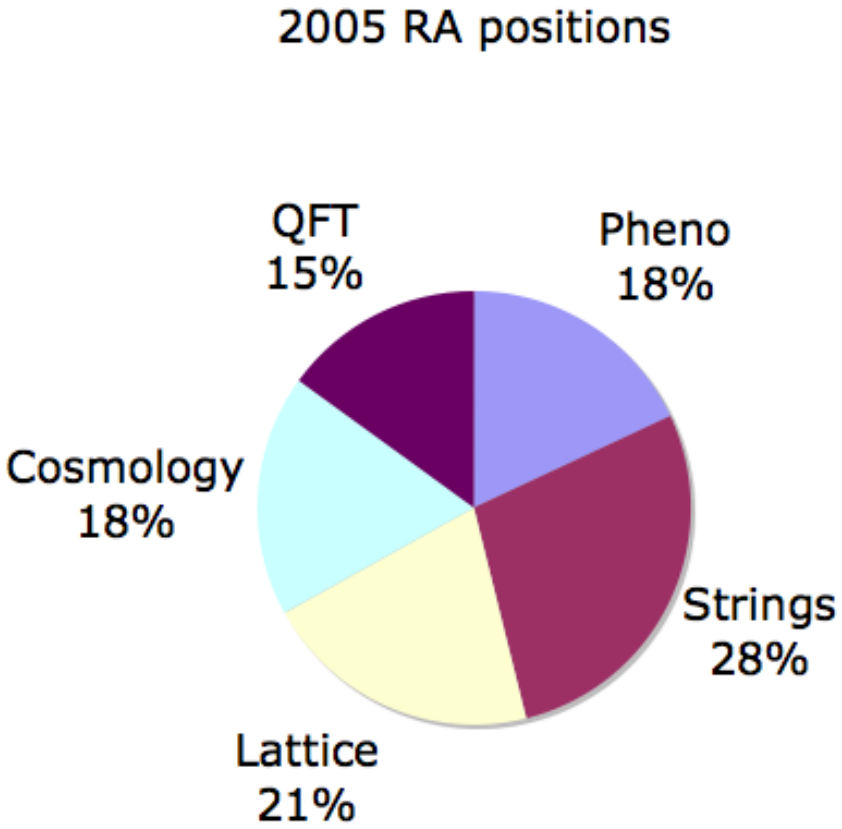
History

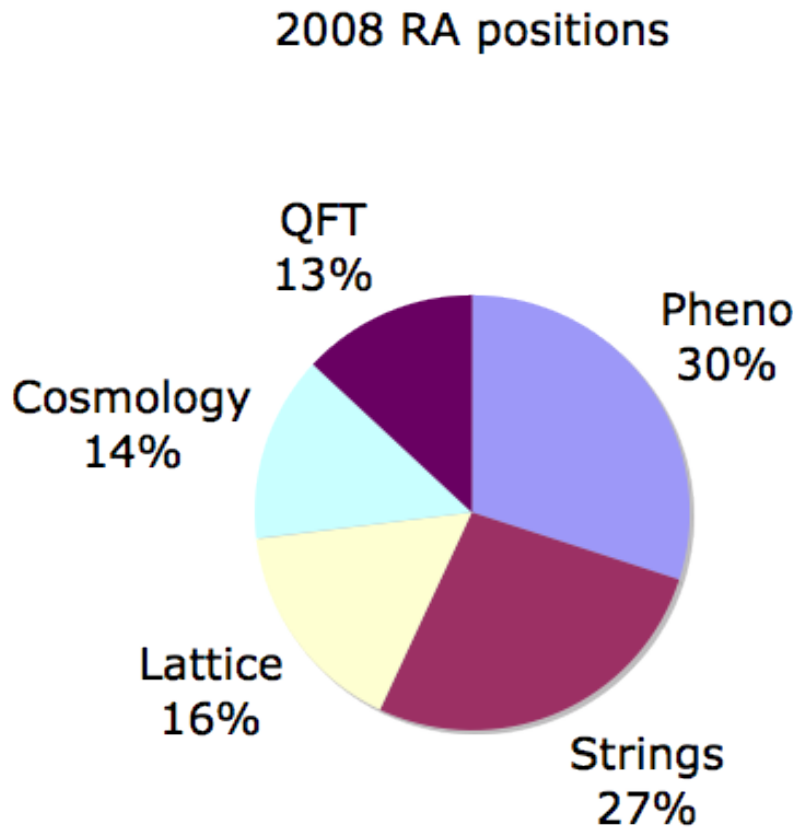
- 2008 RG given base line of 25% cut
  - would have resulted in ~50% cut in number of RAs
- after extensive discussion with PPAN, additional funds for years 1–3 of the roll
  - but still corresponds to 25% cut for years 4–5
  - and leaves several excellent groups with no funds
- aspirations for 1–2 SPG rounds with 4–6 RAs



- gave average of 20% FEC to ~90% of academics using half of budget

History


2005 RA positions
QFT
15%
Pheno
18%
Cosmology
18%
Strings
28%
Lattice
21%


2008 RA positions
QFT
13%
Pheno
30%
Cosmology
14%
Lattice
16%
Strings
27%

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2009 SPG round

- announced August, closing date Sept. 30th
  - expected to award 4 RA positions
- 25 applications
- refereeing had already started when…
- prioritization exercise cut budget by 10%
  - barely enough for 1 RA position!
- after two months' discussion, agreed to go ahead
- outcome announced June 4th

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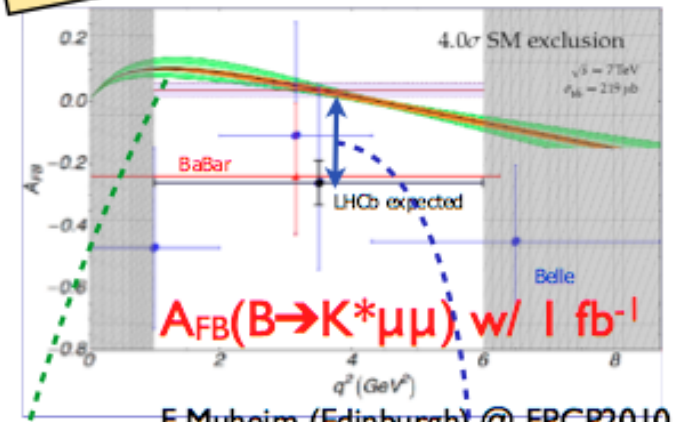
Physics Highlights

- Connecting LHCb to theories of the weak scale
  - Sebastian Jaeger, Sussex
- Novel techniques for simulating lattice field theories with a sign problem
  - Gert Aarts, Swansea
- Hidden Structures in Gauge Theory and Gravity
  - Andi Brandhuber, Queen Mary
- Soft Physics for Parton Showers
  - Mike Seymour, Manchester

Connecting LHCb to theories of the weak scale

Theory SPG09 H004661
S Jaeger (Sussex)

- LHCb to run close to design lumi during 2011 → early discoveries?
- UK: O(10) LHCb experimental groups, focus: rare semileptonic/ radiative decays, CKM angles, mixing. Only O(3) permanent theory in UK
- for exploiting physics potential, want "bottom-up" approach
  observables
  → effective theory
  → NP model



F Muheim (Edinburgh) @ FPCP2010

How is a possible SM exclusion best translated to New Physics ?
- *not* assuming a model (eg SUSY)

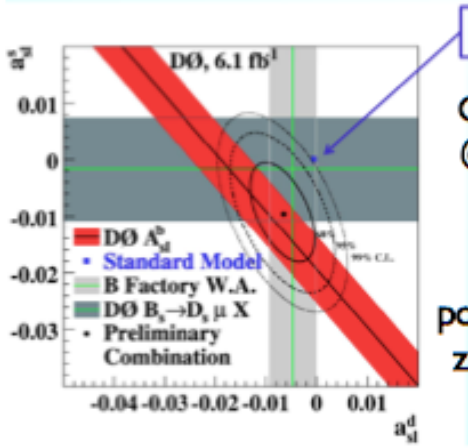
how to reliably quantify theory uncertainty ?

Dimuon charge asymmetry @ D0 and LHCb prospects

D0 collaboration, arXiv:1005.2757

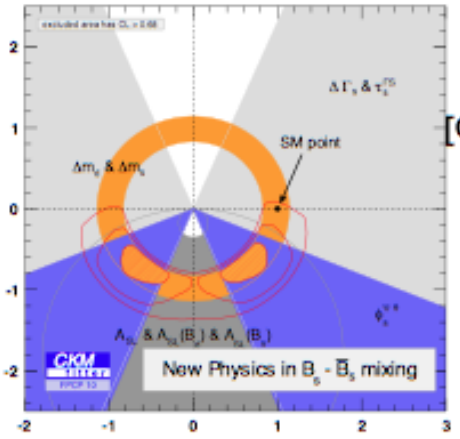
- 3 observables in mixing:
  $\Delta M, \Delta\Gamma, \phi$ (CPV in mixing)
  for each of B_d^0 and B_s^0
  theory relation $\Delta\Gamma \Leftrightarrow \phi$
- SM predicts clean ϕ_s=0 (B_s)
- various ways to measure
  - semileptonic CP asymmetry - D0
  - $A_{CP}(B_s \rightarrow J/\psi\ \phi)$ (time-dependent)
    CDF, D0, LHCb
- Current central value ϕ_s =O(50°)
  LHCb sensitivity: O(4°) with 1 fb^{-1}

F Muheim (Edinburgh) @ FPCP2010



G Brooijmans @ FPCP2010

points to non-zero a^s_{sl} / ϕ_s



S Descotes-Genon [CKMfitter collab] @ FPCP2010

including $A_{CP}(B_s \rightarrow J/\psi\ \phi)$: 2.7σ

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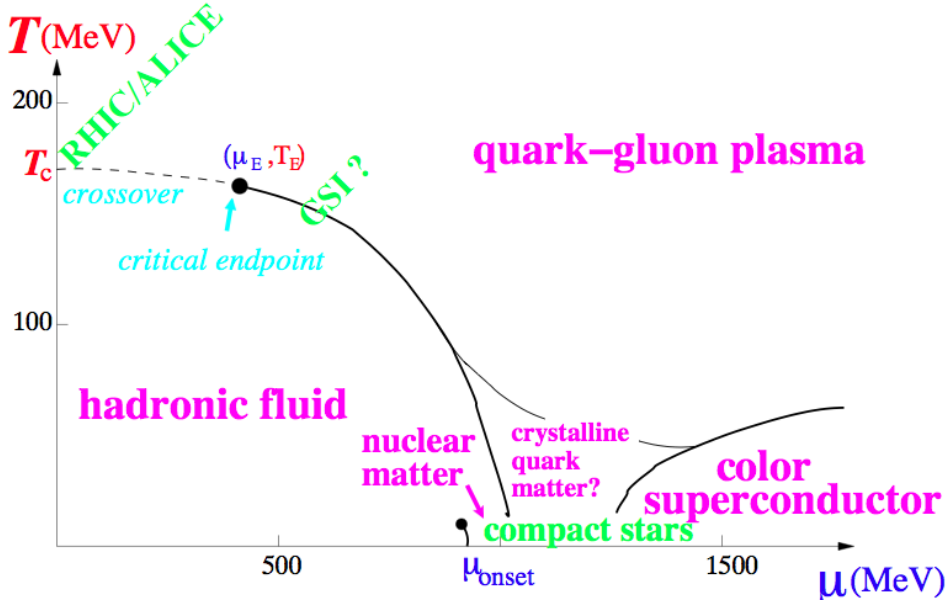
Novel techniques for simulating lattice field theories with a sign problem

- Gert Aarts, Swansea
- Sign problem in QCD at finite baryon density
- Phase diagram: neutron stars, quark matter, colorsuperconductivity, triple and critical endpoints, ...
- Complex action: importance sampling in lattice QCD fails

Swansea University
Prifysgol Abertawe



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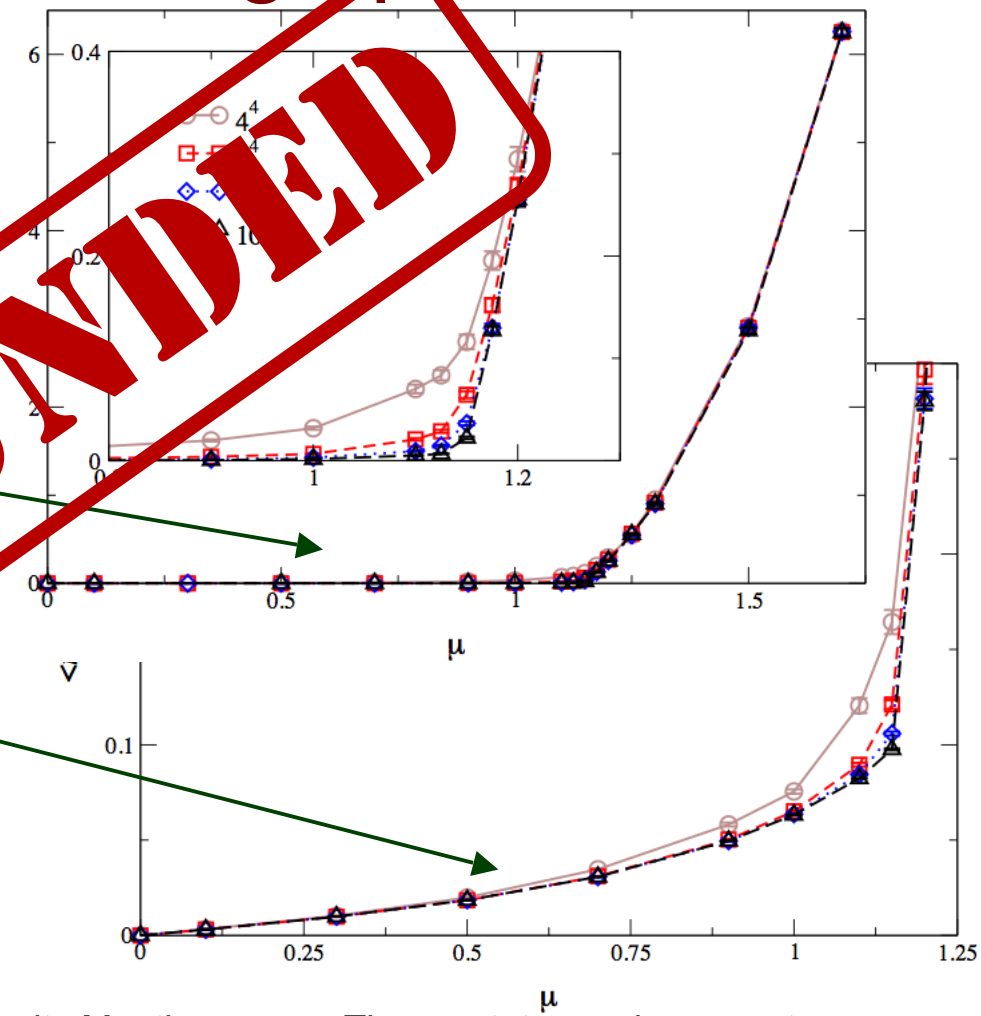
Novel techniques for simulating lattice field theories with a sign problem

- Complex Langevin dynamics can evade the sign problem
- Successfully tested in heavy dense QCD and other models
- Example: weakly interacting relativistic Bose gas
- mu-independent below onset, nonzero density above onset
- density when the complexity is ignored, amenable to standard algorithms
- incorrect result : unphysical mu-dependence below onset!

UNFUNDED

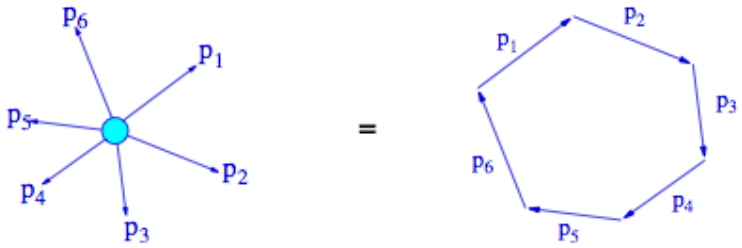


Hidden Structures in Gauge Theory and Gravity

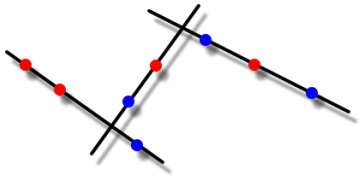
Summary of STFC SPG Proposal:

Andi Brandhuber (PI), Bill Spence and Gabriele Travaglini

- Recent (r)evolution in our understanding of S-matrix (Amplitudes) in field theories at weak and strong coupling
  - Novel ideas/insights, e.g.



Scattering amplitudes calculated by simple polygonal Wilson loops



Simplicity of gluon amplitudes (e.g. MHV, Parke-Taylor) explained by simple geometry in Penrose's Twistor Space

- Impressive progress in higher-loop/strong coupling amplitude calculation
- Very general & efficient methods (e.g. on-shell recursion relations & generalised unitarity). Vast applicability, also in phenomenologically relevant theories in particular QCD !

Main Goals of the proposal

- Explore & explain new, hidden structures in scattering amplitudes such as new symmetries & integrability; use these results to determine loop amplitudes without doing loops!
- Duality between amplitudes and lightlike Wilson loops: proof; higher loops; extensions to general amplitudes, theories with less or no supersymmetry
- N=8 supergravity: investigate possible finiteness and similarity with N=4 super-Yang-Mills
- Overarching goal: all of these novel structures point at complete reformulation of QFT, in particular avoiding Feynman diagrams altogether!

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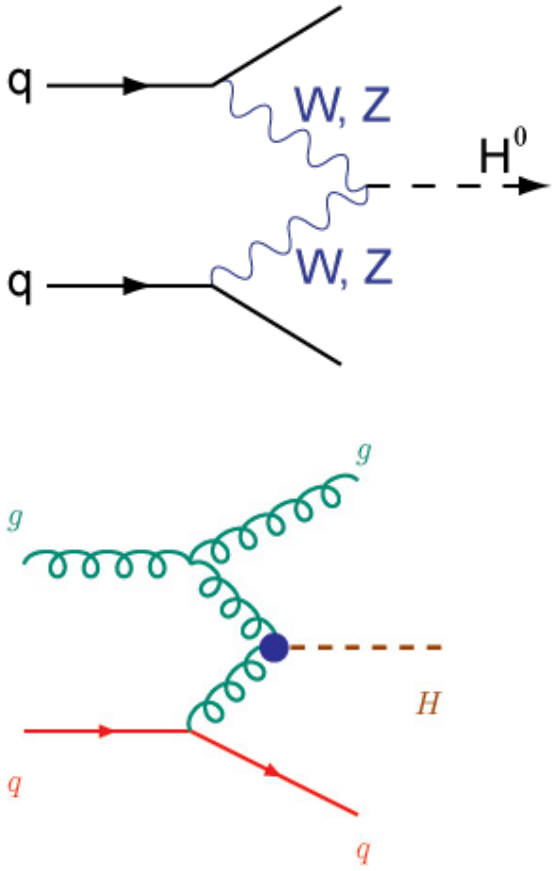
Soft Physics for Parton Showers

- MHS et al, Manchester
- Most measurements and searches at LHC rely on parton showers
- e.g. extraction of WWH and ttH couplings from VBF and GF using colour structure
- recent years: huge progress in hard corrections to parton showers
- we identified wide range of observables for which a wide range of soft corrections will be dominant uncertainty



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Soft Physics for Parton Showers

- MHS et al, Manchester
- parton shower algorithm with sub-leading colour, and non-probabilistic parton evolution
- dynamically-generated diffraction model
- the perturbative/non-perturbative interface
- underlying events and colour reconnection

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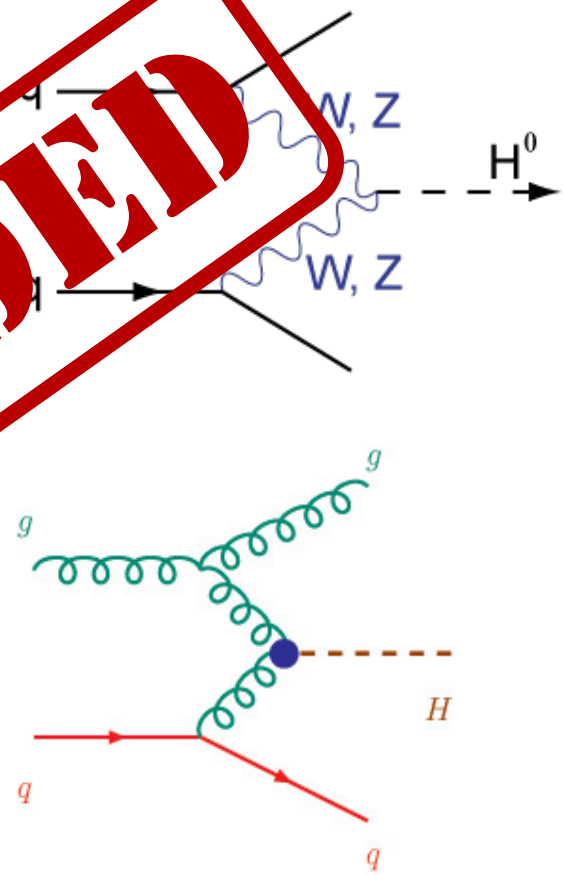

Future Prospects

- Compared to 2005…
  - community is ~40% bigger
  - budget has been cut by 25% then 10% (~33%)
  - could leave us with 1 postdoc per ~7 academics!
  - austerity measures coming
- But, we are a strong community doing world-leading work, crucial for LHC exploitation, understanding early universe, deep structure of matter
- Need to be campaigning for uplift now

Future Prospects

- Also need a Plan B…
- Reconsider the way we fund PP theory?
- Strengths of existing RG system:
  - has worked well for a long time
  - allows groups freedom to appoint best available RAs
  - allows RAs freedom to pursue new directions
  - provides large- and medium-sized groups stability
  - works with peculiar timing of theory postdoc cycle
  - tension/balance of areas within theory
  - efficient

Future Prospects

- Also need a Plan B…
- Reconsider the way we fund PP theory?
- Weaknesses of existing RGs in times of plenty:
  - none?
- Weaknesses of existing RGs in times of scarcity:
  - balance of academic FEC : postdocs wrong?
    - can we dial it any lower? fund fewer people, still at 20%?
  - doesn't reward small but excellent groups sufficiently?
  - doesn't fund groups below 1 RA level at all
- Can we devise a system that keeps benefits but addresses the weaknesses?

Future Prospects

- Review of STFC Grant Funding Mechanisms
  - Chaired by James Stirling
  - To consider all aspects of the grant funding mechanism (except the budget!)
  - To report by Autumn 2010
  - Will solicit input from community shortly
- Grant Panel will also solicit input from group leaders before finalizing RG guidelines

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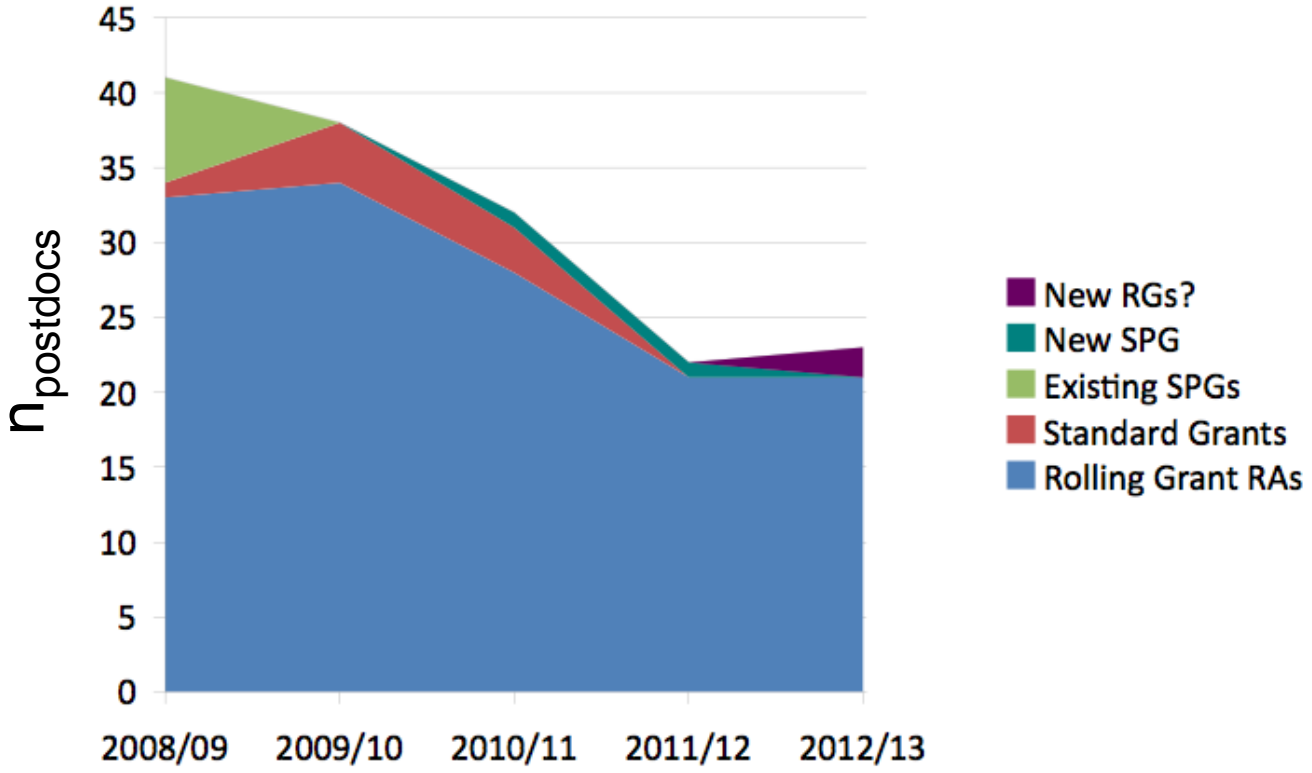
Summary

- UK theory community is world-leading in string theory, QFT, lattice, cosmology and phenomenology
- Has grown by ~40% over 5 years through considerable university investment
  - while budget has reduced by ~33%
- Is bubbling with ideas and eager to develop them
- Is facing a brutal grants round



(2011/12 onwards assumes post-proritization planning line and that we continue to pay 20% FEC to 90% of the community)