

USQCD and BSM Physics

All Hands Meeting 2012

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BSM Goals as per SciDac3

- Precision physics calculations to constrain/test Standard Model - the Intensity Frontier - (Ruth, Taku,...
- Exploratory calculations of possible theories of BSM physics - **origin of electroweak symmetry breaking** - Energy Frontier

here



Dynamical Electroweak Symmetry Breaking

- Standard Model employs Higgs field. Problematic
 - Why $m_H < m_{GUT}$? Fine tuning
 - Triviality
 - **Naturalness** implies new physics around the corner ...
- Two possible solutions:
 - Composite Higgs ...technicolor, top quark condensate models, ... ?
 - SUSY MSSM - dynamical susy breaking ...

This year's proposals

- **Technicolor:**

- Ethan Neil SU(3) $N_F=6$ DWF. Condensate, S parameter, meson spectrum, ... Also SU(2) Wilson. (27.5M cluster)
- Julius Kuti SU(3) $N_F=12$ staggered. Also SU(3) sextet. Meson spectrum,... (683K GPU, 22.2M cluster)
- Anna Hasenfratz SU(3) $N_F=12$ staggered. MCRG ...(6.0M cluster)
- Tom de Grand SU(4) $N_F=2$ adj. SF+ anom. dim (3.3M cluster)
- Joel Giedt SU(2) $N_F=2$ adj Wilson. MCRG (1.185M cluster)
- George Fleming (INCITE) SU(3) $N_F=8$ HISQ. Spectrum ...? (16M ANL)

- **SUSY:**

- Simon Catterall N=4 SYM Spectrum,(92.4 K GPU)

Technicolor: ideas – old and new ..

- Assume new strong gauge force leads to condensate of new **techniquark** dof.
- If techniquarks charged under $SU(2) \times U(1)$ this break EW symmetry .. Massive W,Z from technipions.
- Precision electroweak observables (S parameter ..) – technicolor dynamics **cannot** be QCD-like
- Best **guess**: theory should lie close to theory with IRFP (walking)
 - As N_F increases approach conformal window with N_F^{crit} dependent on fermion rep.
 - Absence of FCNC requires large anomalous dim for condensate

Current lattice studies

- Explore theory space: can we locate theories with IRFPs ?
 - SU(3), SU(2) with large N_F fund.
 - SU(2) with $N_F=2$ adjoint, SU(3) $N_F=2$ sextet
- Understand quantitatively to eg chiral symmetry breaking as we move away from QCD by increasing N_F
- Strategies:
 - Fit meson spectrum to confining/conformal hypotheses
 - RG studies (MCRG/SF) to look for IRFP.
 - Measure anomalous dimension of condensate. (FSS, SF/MCRG)
- Actions: Wilson, Staggered and Domain Wall (variable amounts of smearing) HMC/RHMC

Difficulties ...

walking/conformal models necessarily have small beta functions

- **Slow running** - systematic errors in RG approaches - too few blocking steps
- **Large** boxes needed to see confinement
- Large bare couplings needed - **cut-off** effects can be important ..
- **Harder** than QCD

Concerns and comments from SPC

- Controversy still for $SU(3)$ $N=12$. Primary difference seems to be method of analysis: RG versus spectrum.
- Perhaps groups should do similar analyses and come to common conclusion ? Finite (USQCD) lifetime for this study since not likely useful for pheno ...
- What is best theory for INCITE ? conservative (like $N_F=8$) or better pheno candidate eg sextet $SU(3)$ /adj $SU(2)$
- DWF expensive for exploratory studies. Should we use them ?
- How broad a set of models should be studied ?

Additional comments

- There is more to composite Higgs than just technicolor .. eg **top quark condensate** models, little Higgs, NJL, ETC ... 4 **fermion interactions**
- SPC encourages proposals which explore other scenarios
- Particularly true if 125 GeV Higgs survives .. and no other sign of technihadrons ...

SUSY for EW breaking

- Light Higgs can be **natural** in SUSY theory. Chiral symmetry keeps fermion superpartner light
- However - SUSY must break - usually this takes place in **hidden sector at high scales**. Typically this high scale is super QCD (SQCD)
- This breaking is transmitted (mediated) to SM via additional fields. Leads to large number of (soft) parameters in MSSM
 - these soft SUSY breaking terms are determined by **strong coupling dynamics** of SQCD theory
 - opportunity for lattice QCD ...

Lattice approaches and difficulties

- SQCD can be simulated using DWF plus additional (**fine tuned**) scalar sector
- Simple case $N=1$ SYM. Preliminary calcs have already been done by USQCD groups (Endres, Catterall et al.)
- This year nothing ... SPC **encourages future proposals**

A second SUSY strand in SciDac3 – N=4 SYM

- Two approaches possible:
 - Special case of super QCD – N=1 SYM with special quark/squark sector.
Piggyback on SQCD program
 - Lattice formulations with exact SUSY – advantage – no tuning of scalars
 - Substantial progress but just one proposal this year



Summary

- USQCD active and playing leadership role in many studies of BSM physics
 - Searching for candidate walking technicolor theories and computing their properties
 - Supersymmetric extensions SM - susy breaking needs lattice input
ultimate goal to understand soft parameters in MSSM
- Covers 2 main approaches to understanding EW symmetry at LHC
- Much learned in last 3/4 years. Hard but making progress.
- Questions that arise:
 - Do we have good tools yet for seeing walking ?
 - Should we focus now on models of more likely pheno interest ?
 - What lattice actions give us best bang for our buck ?
 - Need to generate more activity in susy ?