Predictions for LHC from SO(4) MWT

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Lattice 2013

August 1st, 2013

CP3 - Origins
Particle Physics & Cosmology

SO(4) vector MWT

- SO(4)-gauge theory with two vector representation fermions
- The theory is a possible candidate theory for dynamical electro-weak symmetry breaking.
- It has a possibly light dark matter candidate called ITIMP[1] (M. T. Frandsen and F. Sannino, arXiv:0911.1570)

[1] Isotriplet Technicolor Interactive Massive Particle

Dark matter in technicolor

- The technicolor theories provide natural dark matter (DM) candidates.
- The DM candidate is the lightest technibaryon or other composite state protected by symmetry. S. Nussinov, Phys. Lett. B **165**, 55 (1985). and R. Foadi, M. T. Frandsen and F. Sannino, arXiv:0812.3406 [hep-ph].
- This scenario naturally leads to asymmetric DM, but also symmetric DM is possible. A. Belyaev, M. T. Frandsen, S. Sarkar and F. Sannino, arXiv:1007.4839 [hep-ph].
- The DM particle can also be light if it is a pseudo Goldstone boson, e.g. iTIMP. M. T. Frandsen and F. Sannino, arXiv:0911.1570 [hep-ph]

DM in SO(4) vector MWT

- For two Dirac fermions in a real representation the chiral symmetry breaking pattern is: $SU(4) \to SO(4)$. This gives nine Goldstone bosons, of which three are eaten by SM gauge bosons.

- Six additional Goldstone bosons with technibaryon charge form triplets.

- The ITIMP is the neutral isospin zero component of weak complex triplet

$$T^+, \ T^0, \ T^-$$

possessing a technibaryon number.

Qualities of SO(4) MWT

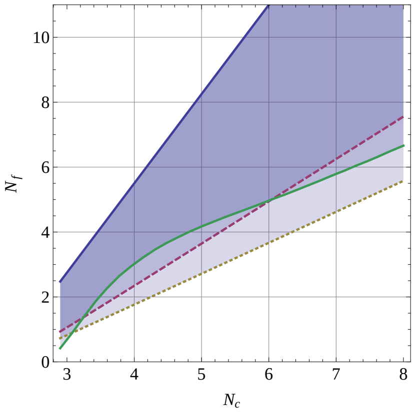
- Compared to SU(2)-adj MWT, the real gauge group removes the fractionally charged states composed of a techni quark and techni gluon, which would be present in SU(N) theory with adjoint fermions.

- No Witten anomaly.

- SO(4) is semi simple SO(4)= SU(2)$\otimes$SO(3) and it has a non-trivial center Z_2.

- The two-loop β-function of the theory does not have an infrared fixed point. Maybe a good theory for walking.

Phase diagram of SO(N)-gauge theory in two, three and four-loops



Lattice study

Part of the data, published in AH, C. Pica, F. Sannino and U. I. Sondergaard, arXiv:1211.5021 [hep-lat].

Goals of the project:

1 Map out the phase diagram in (β, m_0)-plane

2 Confirm that the chiral symmetry is broken.

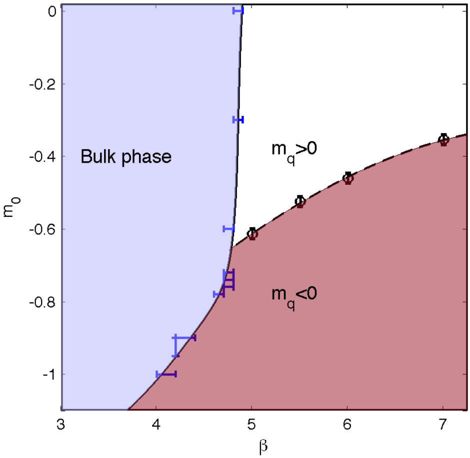
4 Walking theory?

5 Calculate physical predictions: vector meson mass, scalar mass, Higgs couplings, etc.

Phase diagram

- We map out the phase diagram in (β, m_0)-plane.
- Our main aim is to find the zero fermion line as well as the strong coupling bulk phase transition line.
- The bulk phase transition is located by a discontinuity in Plaquette expectation value.
- The initial scan is done with a small volume $L = 16 \times 8^3$

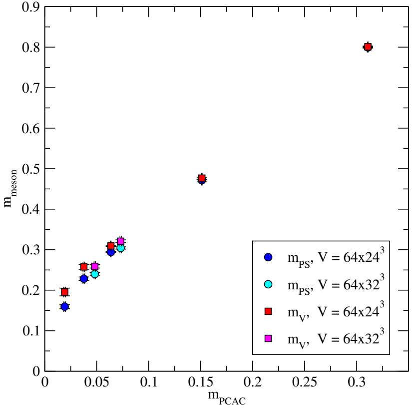
Phase diagram



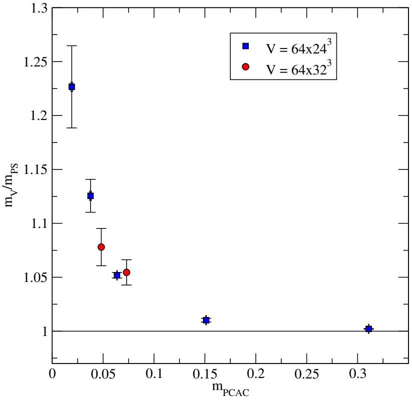
Lattice study

- For large lattice studies we chose two values of $\beta = 5.5$ and 7.0
- Simulation were (are) performed with lattices $V = 64x24^3$ and $V = 64x32^3$
- Results are preliminary
- I will only show results for $\beta = 7$.

Meson masses



Ratio of vector and pseudoscalar meson

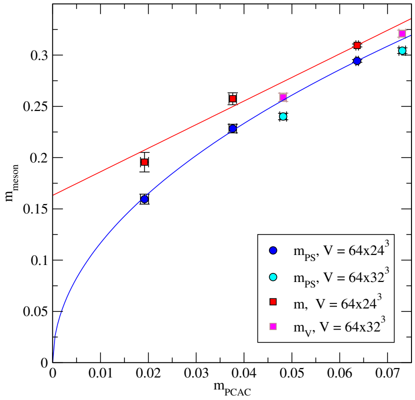


Different fits for chiral limit

Meson fit	Fit function	Best parameter	χ^2/dof
PS ChSB	$a\sqrt{m}$	$a = 1.167(6)$	0.49/2
PS conformal	$Am^{\frac{1}{1+\gamma}}$, $\gamma = 1.1675$	$A = 1.047(7)$	4.19/2
PS alternative 1	$Am^{\frac{1}{1+\gamma}}$, γ free	$A = 1.17(5)$ $\gamma = 0.99(5)$	0.48/1
PS alternative 2	$a + b\sqrt{m}$	$a = -0.001(10)$ $b = 1.17(4)$	0.47/1
Vector ChSB	$a + bm$	$a = 0.16(1)$ $b = 2.3(2)$	3.3/1
Vector conformal	$Am^{\frac{1}{1+\gamma}}$, $\gamma = 1.1675$	$A = 1.105(10)$	9.25/2
Vector alternative	$Am^{\frac{1}{1+\gamma}}$, γ free	$A = 0.85(4)$ $\gamma = 1.71(12)$	0.31/1
Combined hyperscaling	$\propto m^{\frac{1}{1+\gamma}}$	$\gamma = 1.17(15)$	13.5/4

Table: Different types of fit functions in the chiral regime for the data with m identified with the m_{PCAC}.

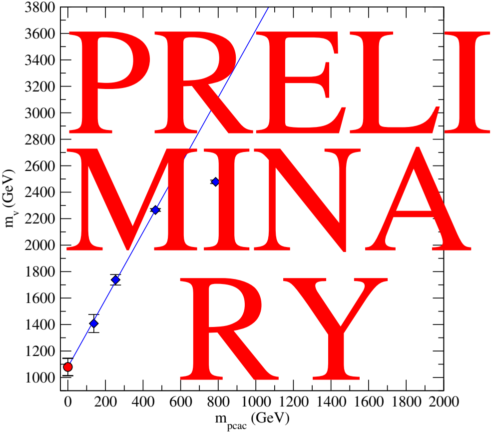
Chiral fits


0.3
0.25
0.2
0.15
0.1
0.05
0
m_meson
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
m_PCAC
m_PS, V = 64x24^3
m_PS, V = 64x32^3
m, V = 64x24^3
m_V, V = 64x32^3

Physical masses

- The scale can be set by requiring that Higgs vev is pseudoscalar decay constant. I.e., $f_{\mathrm{PS}} = 246\mathrm{GeV}$
- LHC has ruled out any techni mesons lighter than 700GeV.

Vector meson mass



Conclusions

- Technicolor theories are still viable candidates for beyond standard model physics.
- For orthogonal technicolor we mapped out the phase diagram in (β, m_0)-plane.
- We found behavior consistent with chiral symmetry breaking.
- Finite volume effects might still be a problem.
- To do: improve measurement of f_{PS}, measure scalar mass and form factors.