Projects @CP3

V. Drach
F. Sannino, C. Pica, A. Hietanen, R. Arthur
Southern Denmark University & CP3-Origins

CP3 Origins
Cosmology & Particle Physics

ETMC Meeting,Grenoble,
26^{th} May 2014

Outline

$SU(2)$ gauge theory with 2 fundamental fermions

The Lagrangian without fermion masses have a global $SU(4)$ symmetry :

$$\mathcal{L} = -\frac{1}{4}F^a_{\mu\nu}F^{a\mu\nu} - \bar{Q}i\not{D}Q, Q = \begin{pmatrix} U_L \\ D_L \\ -i\sigma^2 C\bar{U}^T \\ -i\sigma^2 C\bar{D}^T \end{pmatrix} \qquad (1)$$

In terms of the Q and $\bar{Q}$ fiels, the mass term in the Lagrangian reads

$$\mathcal{L}_m = \frac{m}{2}Q^T(-i\sigma^2 C)E + \mathrm{h.c}, E = \begin{pmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{pmatrix} \qquad (2)$$

The Lagrangian has a global $SP(4)$ symmetry.

$SU(2)$ gauge theory with 2 fundamental fermions

Acting on the Lagragian with an infinitesimal $SU(4)$ transformation ($Q \longrightarrow (1 + i\sum_{n=1}^{15} \alpha^n T^n)Q$)

- The kinetic term is invariant because the fundamental representation is real. This is true for $N_c = 2$ but not for $N_c > 2$
- The mass terms are not invariant under $SU(4)$:

$$\mathcal{L} \longrightarrow \mathcal{L} + \frac{im}{2}\sum_{n=1}^{15} \alpha^n Q^T(-i\sigma^2 C)(ET^n + T^{n,T}E)Q + \mathrm{h.c} \quad (3)$$

  Only 10 generators leave $\mathcal{L}$ invariant : those that obey $ET^n + T^{n,T}E = 0$ (define the $SP(4)$ Lie algebra)

- The 5 broken generators require 5 Goldstone bosons.

Motivation

Depending how the SM is coupled to the model previously defined ("quantum numbers assignement") : The model can be used simultaneously as a template for composite Goldstone boson dark matter and for breaking the electroweak symmetry dynamically.

- 3 Goldstone $\rightsquigarrow$ EWSB ?
- 2 Goldstone for Composite dark matter ? (naturally weakly coupled)
- Composite Higgs dynamics : either a pseudo Goldstone (naturally light!) or a "σ"-like state.

This is investigated in F. Sannino and G. Cacciapaglia (IN2p3 Lyon) [1402.0233] $\rightsquigarrow$ Composite Dynamics: LattiCe and Experiments : CoDyCe collaboration together with the Lyon group.

Lattice Simulation

- Plaquette gauge action
- Pure Wilson fermions
- So far perturbative renormalization of $f_{\rm PS}$ $\rightsquigarrow$ non perturbative underway.
- Scale set with $f_{\rm PS}$ to 246 GeV $\rightsquigarrow$ correct mass for the EW bosons
- We use the HiRep package (which is able to run with arbitrary N_c, N_f with fernions in the fundamental , adjoint, symmetric or antisymmetric representation)
- Heavy pions ... ρ is stable
- All the computation are done before embeding the SM : all our results will get possibly large corrections from loops of SM particle (typically : contribution of the top quark)

Spectrum

The spectrum has been computed in [1404.2794]

- Check of the chiral symmetry breaking pattern
- First prediction of $m_\rho \approx 2.5 \pm 0.5$ TeV outside the current exclusion limits set by the LHC.

Current projects

- First step : Scattering length of Goldstone bosons(Lattice talk)
- How many channels ?
- Pheno : related to WW scattering properties $\rightsquigarrow$ constraint on the scattering length expected to improve with the run 2 of the LHC
- Second step : compute the $g_{\rho\pi\pi}$ coupling (very useful for the pheno : LHC typically set constraints in the $(m_\rho, g_{\rho\pi\pi})$ plane.
- Computing / Constraining the σ mass $\rightsquigarrow$ Disconnected contributions
- The physical Higgs is expected to be a linear combination of a goldstone boson and of the σ...

Important : all the results are anyway affected by corrections due to the SM particle that are not included in the simulation

Other projects/ Future plans

- Other model studied : $SU(3)_C$ with 2 fermions in the symmetric representation : Minimal Walking Technicolor(MWT) and $SO(4)$ with 2 fermions in the fundamental
- Observables discussed before are also interesting ...
- Baryon in $SU(3)_C$ with 2 fermions in the symmetric representation : funny color factor to compute. Could they be dark matter candidate or are they ruled out ?
- FF and charge radius of Goldstone bosons : Important for Dark Matter constraints.
- Non perturbative renormalization
- Changing the gauge action... HYP smearing ? Improvement ?