Chiral freedom and the scale of weak interactions

proposal for solution of gauge hierarchy problem

- model without fundamental scalar
- non-local interaction in chiral tensor channel
- no mass terms
- chiral couplings to quarks and leptons
- chiral couplings are asymptotically free
- weak scale by dimensional transmutation

Non-local interaction in chiral tensor channel

$$-S_4 = 4f^2 \int \frac{d^4q\, d^4p\, d^4p'}{(2\pi)^{12}} \frac{P^*_{kl}(q)}{q^4} \left\{ \left[\bar{t}(q+p)\sigma^k_+ t(p)\right] \left[\bar{t}(p')\sigma^l_- t(p'+q)\right] + \left[\bar{t}(q+p)\sigma^k_+ b(p)\right] \left[\bar{b}(p')\sigma^l_- t(p'+q)\right] \right\}$$

non – local interaction

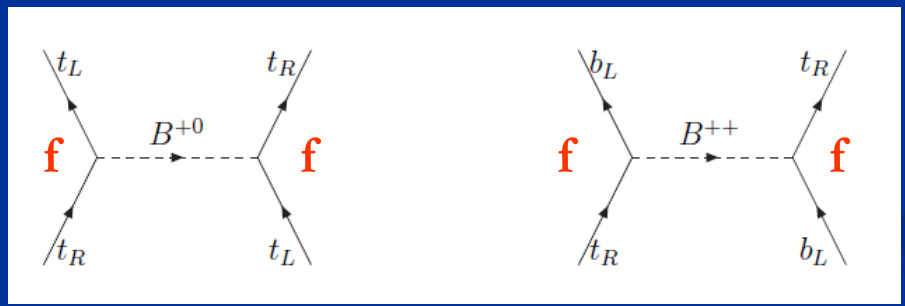
$$P_{kl}(q) = -(q_0^2 + q_j q_j)\delta_{kl} + 2q_k q_l - 2i\epsilon_{klj} q_0 q_j$$

f : chiral coupling for top and bottom quarks

$$-S_2 = -\int \frac{d^4q}{(2\pi)^4} \left(\bar{t}(q)\gamma^\mu q_\mu t(q) + \bar{b}(q)\gamma^\mu q_\mu b(q) \right)$$

non-local interactions in chiral tensor channel

- Lorentz invariant
- Could be generated by exchange of chiral tensor fields – not necessary and not used here



convenient for graphical representation of chiral vertex

- Chiral coupling f is dimensionless
- Generalization to chiral couplings for lighter quarks : chiral couplings described by 3x3 matrices , similar to Yukawa couplings in SM

classical dilatation symmetry

- action has no parameter with dimension mass
- all couplings are dimensionless

flavor and CP violation

- chiral couplings can be made diagonal and real by suitable phases for fermions

  ⇨ Kobayashi – Maskawa Matrix

- same flavor violation and CP violation as in standard model

asymptotic freedom

evolution equations for top coupling

$$k\frac{\partial}{\partial k}F_U = -\frac{9}{8\pi^2}F_U F_U^\dagger F_U$$

fermion anomalous dimension

$$+\frac{1}{4\pi^2}F_U\ tr(F_U^\dagger F_U)$$

tensor anomalous dimension

no vertex correction

asymptotic freedom !

Similar observation in abelian model for chiral tensors :Avdeev,Chizhov '93

dimensional transmutation

$$f_t^2(k) = \frac{4\pi^2}{7\ln(k/\Lambda_{ch}^{(t)})}$$

Chiral coupling for top grows large
at chiral scale Λ_{ch}

This sets physical scale : dimensional transmutation - similar to Λ_{QCD} in strong QCD- gauge interaction

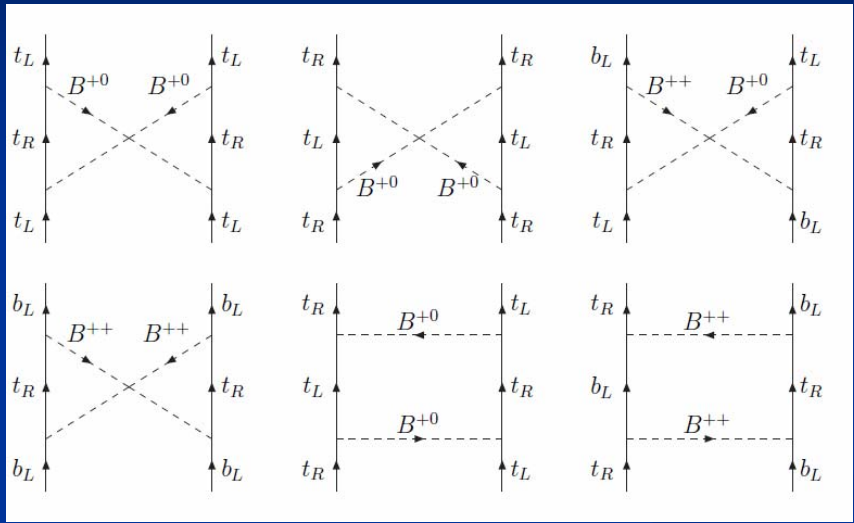
spontaneous electroweak symmetry breaking

top – anti-top condensate

- large chiral coupling for top leads to large effective attractive interaction for top quark
- this triggers condensation of top – anti-top pairs
- electroweak symmetry breaking : effective Higgs mechanism provides mass for weak bosons
- effective Yukawa couplings of Higgs give mass to quarks and leptons

cf : Miranski ,Tanabashi, Yamawaki; Bardeen, Hill, Lindner

Induced interactions in scalar channel



$$\Delta\Gamma^{(1)} = \frac{f^4}{2\pi^2 k^2}[\bar{t}_R t_L][\bar{t}_L t_R] + \frac{3f^4}{4\pi^2 k^2}[\bar{t}^c_R T^z_{cd} t^d_L][\bar{t}^{c'}_L T^z_{c'd'} t^{d'}_R].$$

NJL – type interaction

$$\Gamma^{(S)}_k = \frac{\lambda}{2}\int d^4x\left[(\bar{\psi}\psi)^2 - (\bar{\psi}\gamma^5\psi)^2\right] = 2\lambda(\bar{\psi}_L\psi_R)(\bar{\psi}_R\psi_L)$$

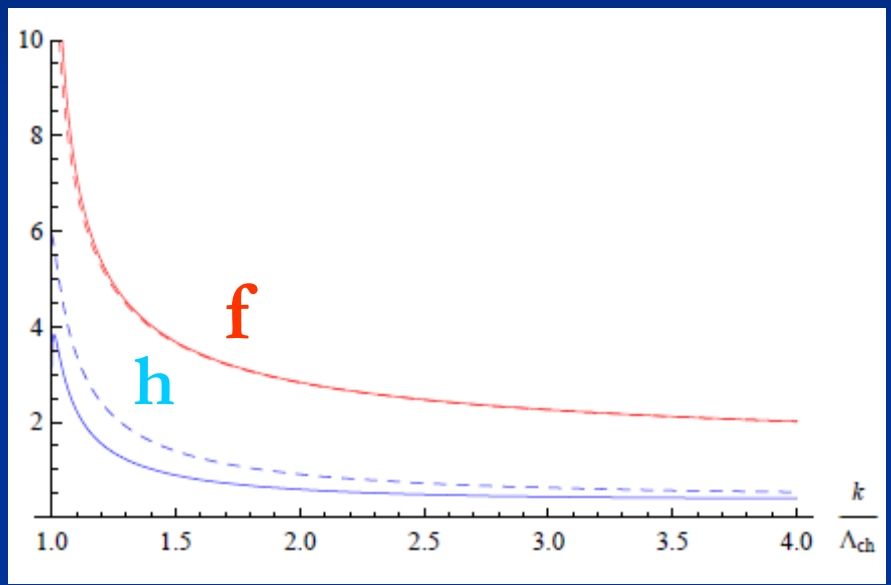
$$\lambda(k) = \frac{f^4(k)}{4\pi^2 k^2}.$$

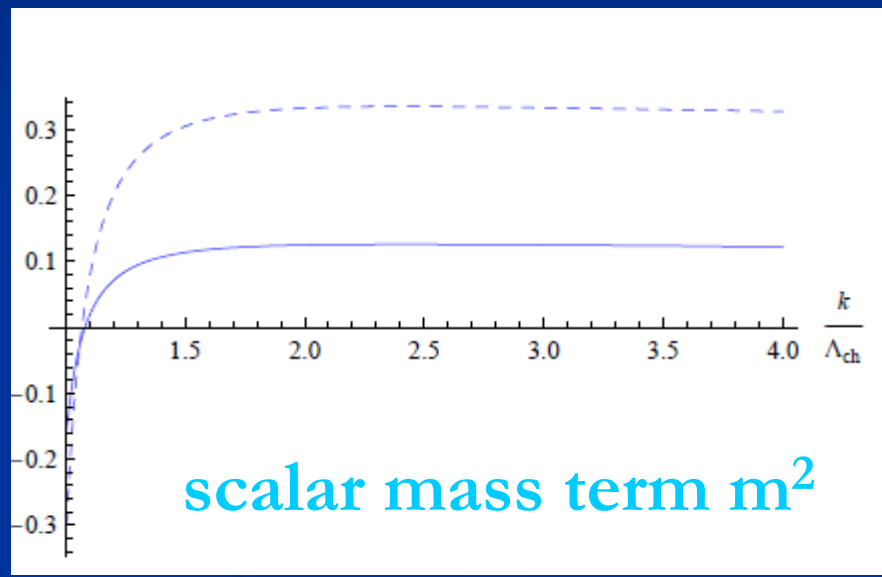
effective interactions

- introduce composite field for top- antitop bound state
- plays role of Higgs field
- new effective interactions involving the composite scalar φ
- effective scalar-top Yukawa coupling

$$\bar{h}^2 = \frac{f^4}{2\pi^2}.$$

Running effective couplings





Ratio between top quark mass and W-boson mass is predictable in this model

phenomenology

chirons

- possibility of observable bound states in chiral tensor channel
- irreducible representation for anti-symmetric tensor fields has three components
- in presence of mass : little group SO(3)
- with respect to SO(3) : anti-symmetric tensor equivalent to vector
- massive chiral tensors = massive spin one particles : chirons

new resonances at LHC ?

- production of massive chirons at LHC ?
- signal : massive spin one resonances
- rather broad : decay into top quarks
- relatively small production cross section : small chiral couplings to lowest generation quarks , no direct coupling to gluons
- perhaps no resonances – just additional effective interactions in chiral tensor channel

composite scalars

- two composite Higgs doublets expected
- mass 400 -500 GeV
- loop effects ?

conclusions

- chiral tensor model interactions offer interesting solution of gauge hierarchy problem
- phenomenology needs to be explored !
- less couplings than in standard model predictivity !