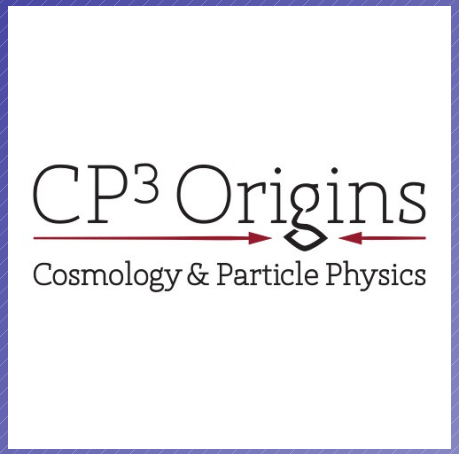
Top Signatures From Composite Higgs Theories

Natascia Vignaroli



Top 2016, 20 Sept 2016

The Composite Higgs Scenario

Georgi, Kaplan, 1984

- EWSB triggered by a new Strong Dynamics, composite at the TeV scale
- Higgs: composite + pGB of global invariance of the strong sector

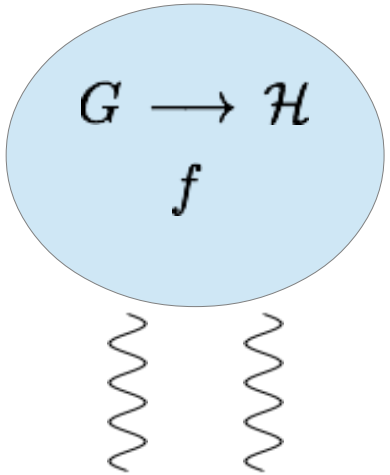
$$\Delta m_h^2 \sim \Lambda^2$$

Physical cutoff set by the compositeness scale

$$\Lambda \sim f$$

Higgs naturally light

$$m_h^2 \sim \left(\frac{v}{f}\right)^2 m_*^2 \frac{1}{16\pi^2}$$



top, W, Z

MCHM Agashe, Contino, Pomarol, NPB 719 (2005)

$$SO(5) \to SO(4) \sim SU(2)_L \times SU(2)_R$$

$$4\text{GB} : h + W_L^{\pm}, Z_L$$

Minimal realisation including custodial symmetry

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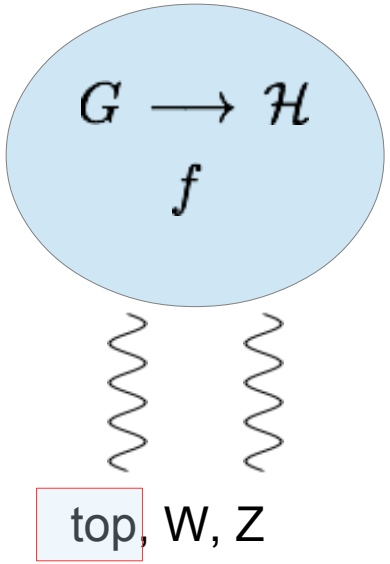


Interactions of the Strong sector with an "elementary" sector (≈ the SM) explicitly break G. V(h) is generated radiatively

$$V(h) \sim \frac{1}{16\pi^2}\left(-a\,h^2 + b\frac{h^4}{2f^2}\right)$$

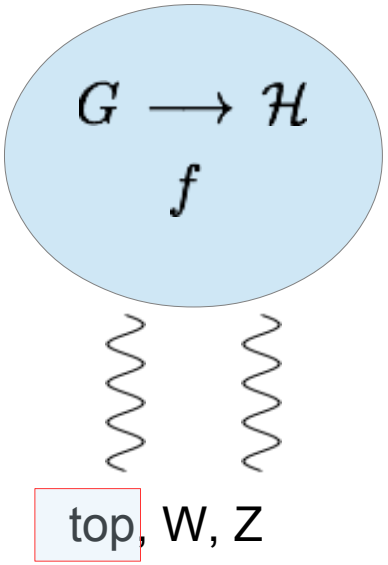
$v^2 = \frac{a}{b} f^2$ but $a \sim b$ ⇒ Fine-tuning of the order $(v/f)^2$ ⇒ $m_{t'} \lesssim 1\,\mathrm{TeV}$

New Particles with preferred couplings to 3rd gen. quarks

- VLQs (top-partners)
- New vector resonances (kkg, W', Z', ..)
- New composite scalars

Rich BSM phenomenology with tops in the final state

top-partners VLQs



Linear mass mixing terms [Kaplan '91]

$$\mathbf{t_R^{el}} \quad \Longleftrightarrow \quad \tilde{\mathbf{T}} = (\mathbf{1},\mathbf{1})_{\mathbf{2/3}}$$

$$\begin{pmatrix} \mathbf{t_L^{el}} \\ \mathbf{b_L^{el}} \end{pmatrix} \quad \Longleftrightarrow \quad \begin{bmatrix} \mathbf{T} & \mathbf{T_{5/3}} \\ \mathbf{B} & \mathbf{T_{2/3}} \end{bmatrix} = (\mathbf{2},\mathbf{2})_{\mathbf{2/3}}$$

$\mathbf{5_{2/3}}$

PARTIAL COMPOSITENESS

Rotation
(Mixing angles: s_L, s_R)

$$\begin{cases} \mathbf{t_L} = \mathbf{c_L}\mathbf{t_L^{el}} + \mathbf{s_L}\mathbf{T_L} \\ \mathbf{t_R} = \mathbf{c_R}\mathbf{t_R^{el}} + \mathbf{s_R}\tilde{\mathbf{T}}_\mathbf{R} \end{cases}$$

s_L / s_R are the t_L / t_R degree of compositeness

$$\mathbf{m_t} \simeq \mathbf{Y_*}\mathbf{s_L}\mathbf{s_R}\frac{\mathbf{v}}{\sqrt{\mathbf{2}}}$$

Heavier particles have larger degrees of compositeness

top-partner VLQs

EW doublets

Wt ← $\begin{pmatrix} T_{5/3} & T \\ T_{2/3} & B \end{pmatrix}$ → Zt , ht (1:1)

Zt, ht ← → Wt

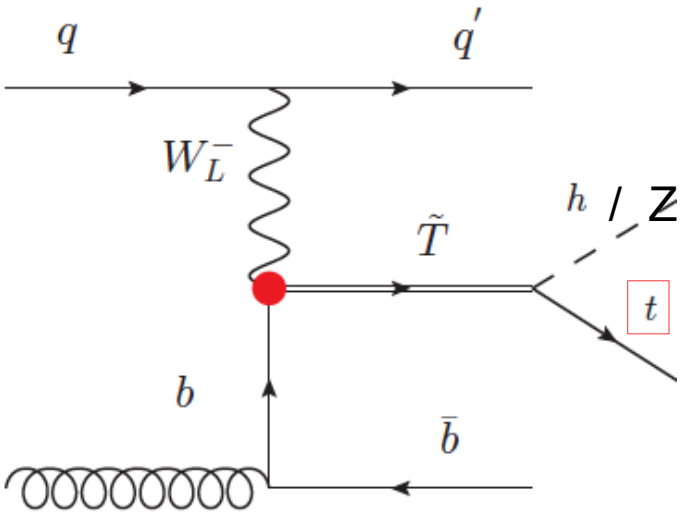
EW singlets

$\tilde{\mathbf{T}}$ → Wb, Zt , ht (2:1:1)

$\tilde{\mathbf{B}}$ → Wt, Zb, hb

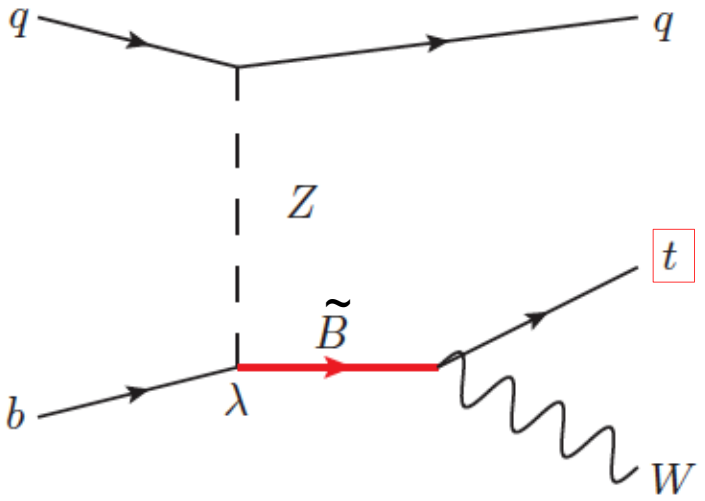
+ other possible more exotic VLQs

LHC Searches: Pair production



ATLAS, JHEP 1411 (2014) 104 [8 TeV]

Single EW production



ATLAS, JHEP 1602 (2016) 110 [8 TEV]

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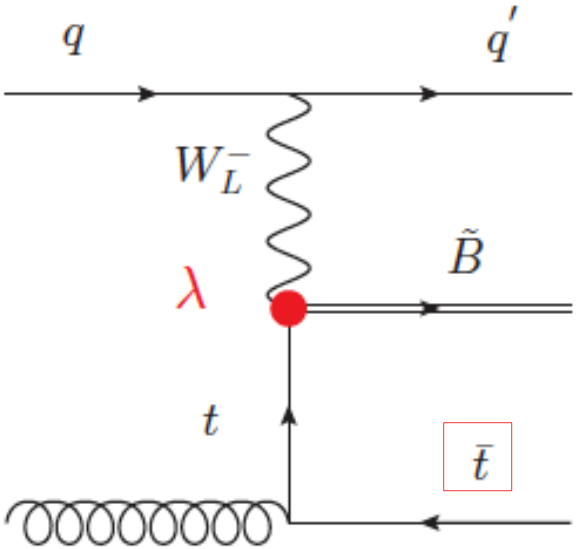


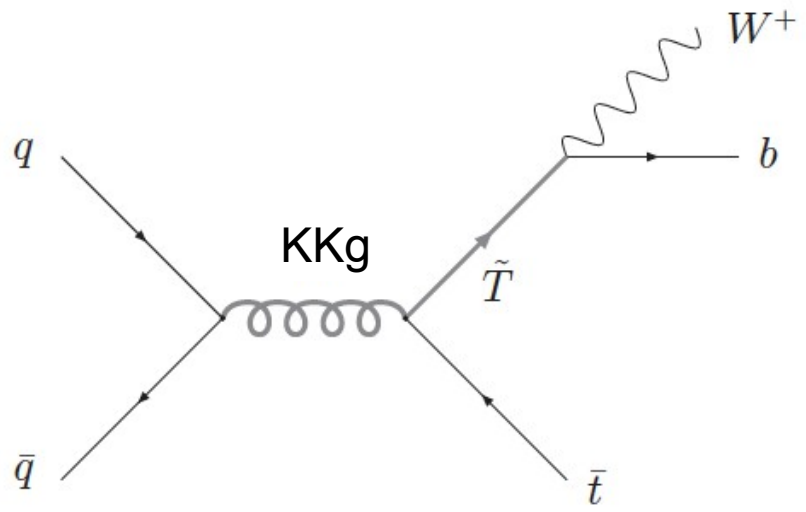
NV, JHEP 1207 (2012) 158

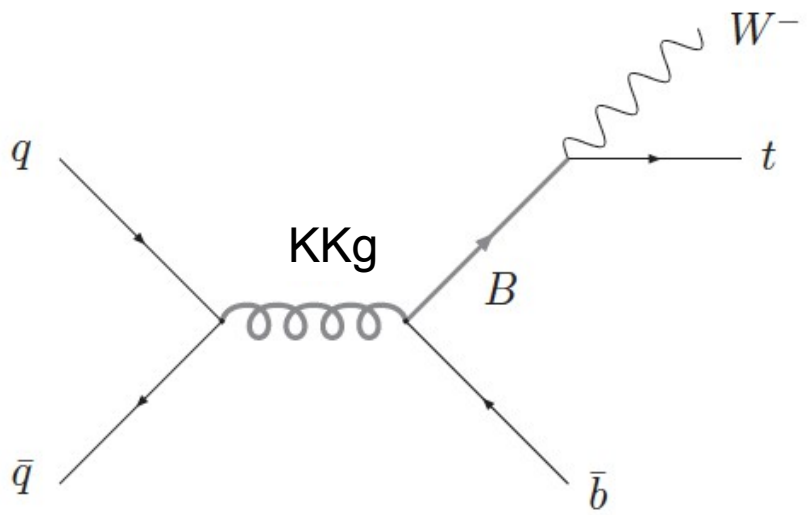
Vector Resonances

$\mathbf{m_V < m_{VLQ}}$

KKg → tt Z' → tt W' → tb

$\mathbf{m_V > m_{VLQ}}$ More Natural Scenario





Bini, Contino, NV
JHEP 1201 (2012) 157

Other interesting final state with tops:

$KKg \to Tt, \tilde{T}t \to Z/h\, t\bar{t}$

Vector Resonances

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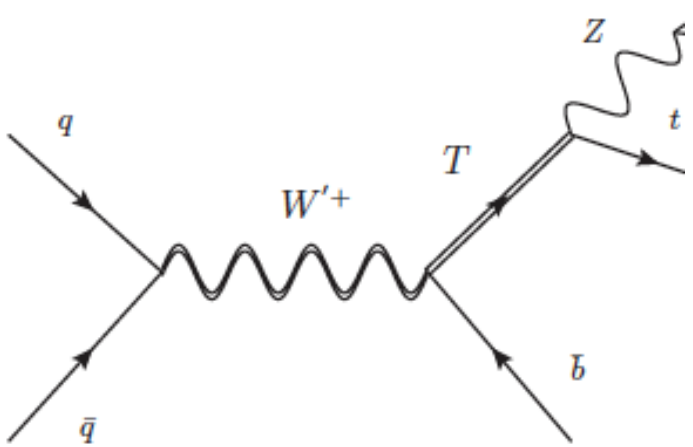
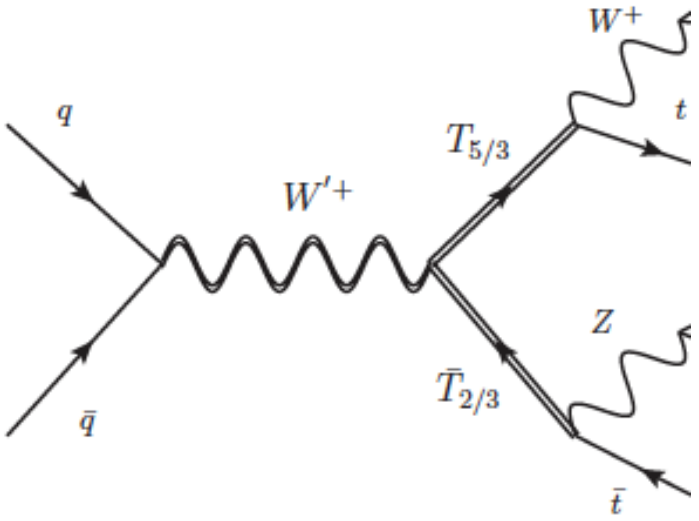




NV, Phys.Rev. D89 (2014) no.9, 095027

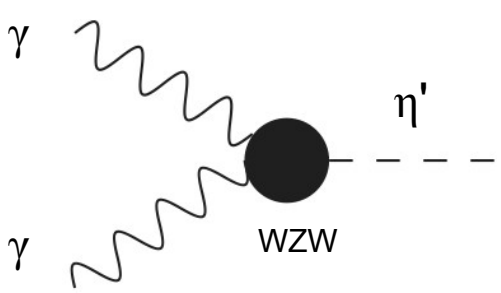
New Composite Scalars

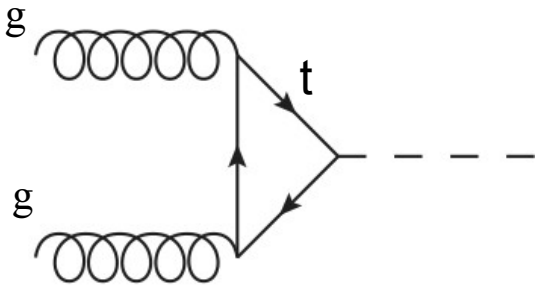
- Extra pNGBs (from larger cosets. ex. SU(4)/Sp(4))

  [ex. Bellazzini et al JHEP 1604 (2016) 072]

- η'-like composite states

  [ex. Molinaro, Sannino, NV Nucl.Phys. B911 (2016) 106-126, Mod.Phys.Lett. A31 (2016) no.26, 1650155]



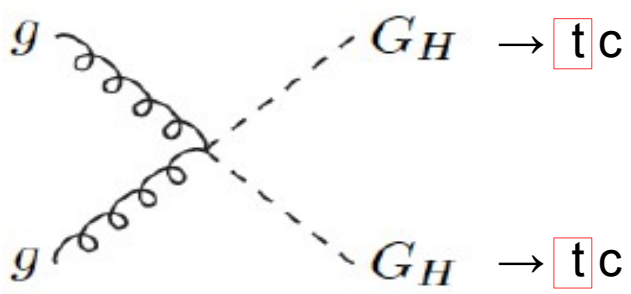


Dibosons / tt

Relevant effects from interference with Bckg

JHEP 1607 (2016) 105; arXiv:1608.07282; arXiv:1607.06074

- Color-octet scalars (ex. from breaking SU(3)xSU(3) → $SU(3)_{QCD}$)



SSD final state

Chivukula, Simmons, NV,
Phys.Rev. D88 (2013) 034006