The Composite Higgs of Minimal Conformal Technicolor

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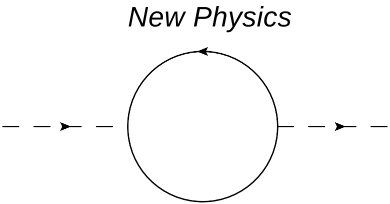
New High Energy Theory Center
Rutgers University

Lattice Meets Experiment – BSM 2012

[1] arXiv:1001.1361 – JAE, J. Galloway, M.A.Luty and R.A.Tacchi
[2] arXiv:1012.4808 – JAE, J. Galloway, M.A.Luty and R.A.Tacchi

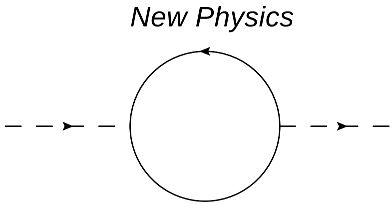
Outline

High scale physics loops $\Rightarrow$ mass correction to SM Higgs boson



$$\Delta m^2 \sim \Lambda^2_{NEW\ \ PHYSICS} \;\Rightarrow\; m_0^2 - \Delta m^2 = M_h^2 \sim \Lambda^2_{ew}$$

High scale physics loops ⇒ mass correction to SM Higgs boson



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⇒ disagreement only after the 30th decimal place

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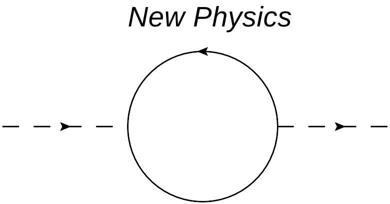

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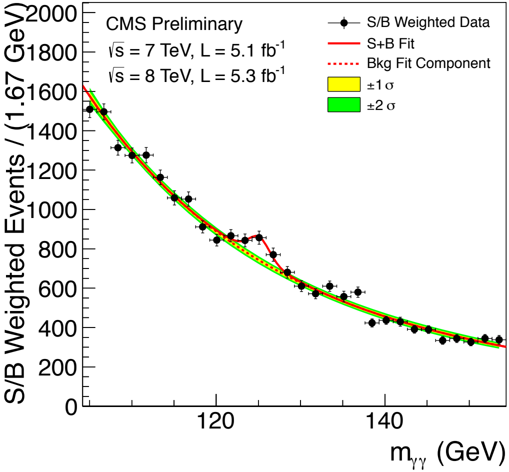
Unnaturalness is a very strong suggestion that the SM Higgs is wrong

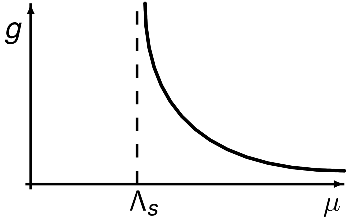
SUSY Higgs?

SUSY Higgs? — $m_{h,SUSY} < 120$ GeV



Strong EWSB: The Good!

Technicolor: (Susskind 1979; Weinberg 1979)



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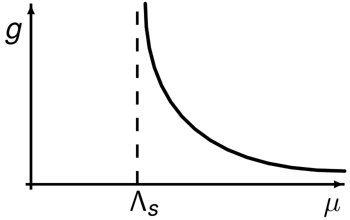

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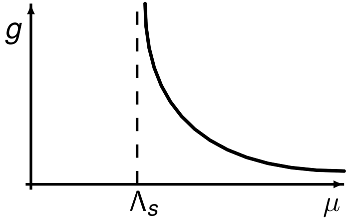

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- Natural Example (sort of): In SM, no Higgs – QCD $\Rightarrow$ W and Z bosons masses

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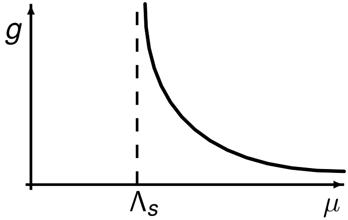
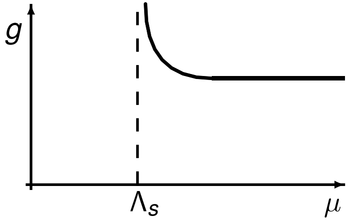


dimensional transmutation

$$\Lambda_s \sim \Lambda_{UV} e^{-\frac{8\pi^2}{b g_{UV}^2}}$$

Conformal Technicolor: (Luty, Okui 2004)



strong conformal fixed point

$N_f \approx 4N_c$

($N_f \approx 2N_c$ in SUSY)

soft conformal breaking

$\Delta\mathcal{L} \sim m_\xi \xi \xi^c$

$\Lambda_s \sim m_\xi$

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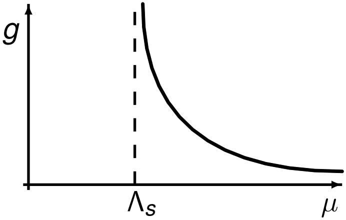
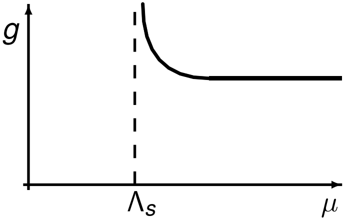
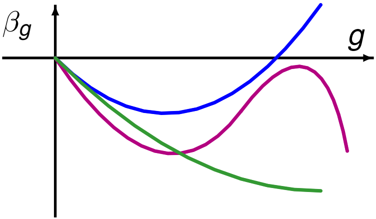


Walking Technicolor: (Holdom 1985; Appelquist, Karabali, Wijewardhana 1986; Yamawaki, Bando, Matumoto; Appelquist, Wijewardhana 1987)

Conformal Technicolor: (Luty, Okui 2004)





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Precision Electroweak Data?

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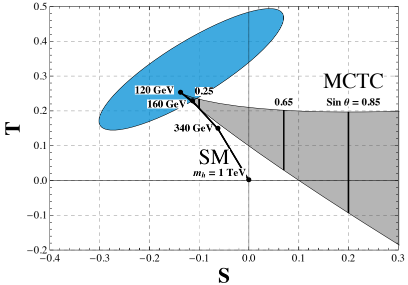

PNGB Higgs

ΔS, ΔT suppressed

f = breaking scale, $v = f \sin\theta$

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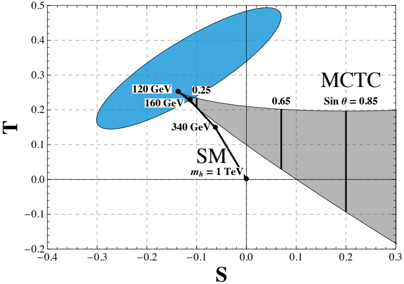

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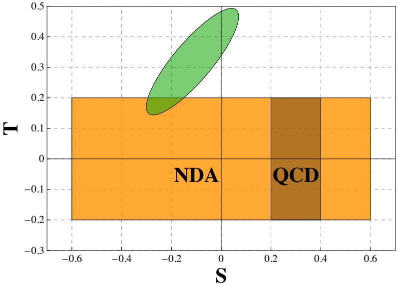

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$\Delta S < 0$?

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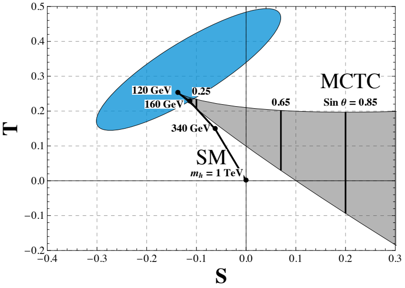

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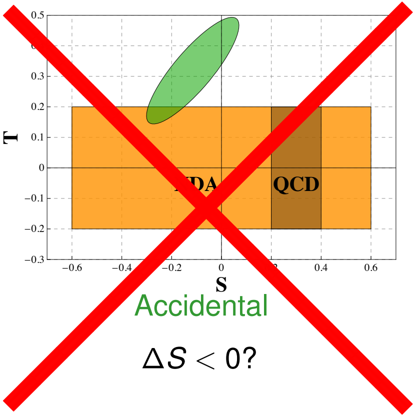

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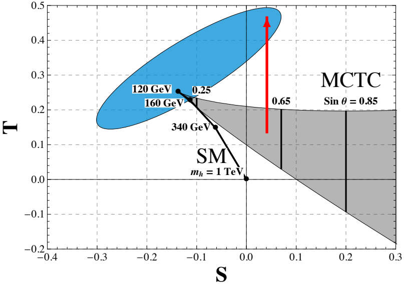
- $\Delta T > 0$



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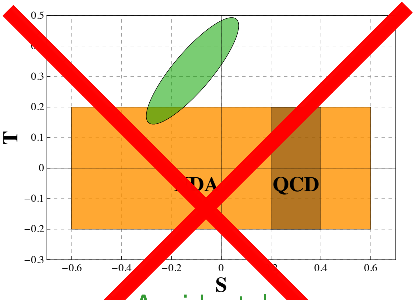

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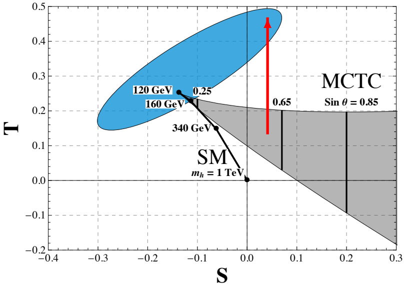
- $\Delta T > 0$
- ΔS suppressed (LSD 2010)



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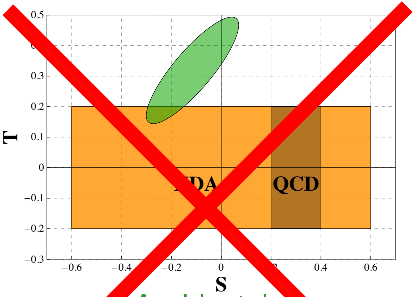

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$$\Rightarrow \left(\frac{g_t}{g_{t,strong}}\right) \left(\frac{4\pi v}{\Lambda_t}\right)^{d-1} \sim \frac{1}{15}$$

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We need a complete theory!

Field Content: $(SU(2)_{CTC},SU(2)_W)_{U(1)_Y}$

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Minimal Conformal Technicolor

The Model

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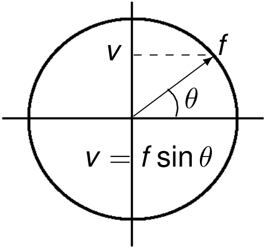

$\sin\theta = 0 \quad \Rightarrow \quad$ No EWSB

$\sin\theta = 1 \quad \Rightarrow \quad$ Technicolor

$\sin\theta \ll 1 \quad \Rightarrow \quad v = f\sin\theta \ll f$, PNGB Higgs

$$\mathcal{L} \ni -\kappa\psi\psi - \tilde{\kappa}\chi\chi' - K\xi\xi + \frac{g_t^2}{\Lambda_t^{d-1}}(Qt^c)^\dagger(\psi\chi) + \text{h.c.} + \frac{g_{4TC}^2}{\Lambda_t^{\Delta-4}}|\psi\chi|^2 + \dots$$

This mass term knocks $SU(2)_{CTC}$ running out of its fixed point

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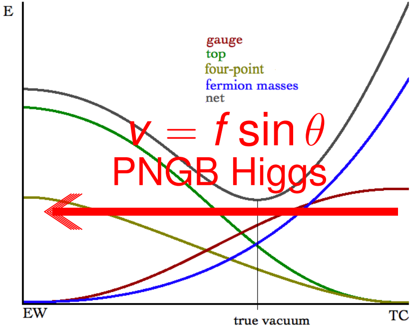

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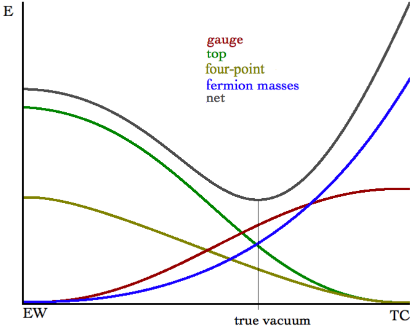

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Top loop, gauge, $\psi^4 \propto \sin^2\theta$
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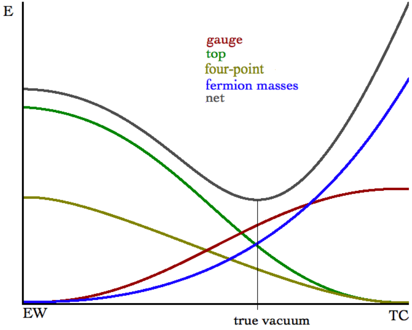

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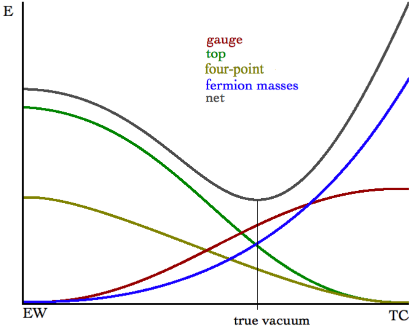
Vacuum alignment: $SU(4) \to Sp(4)$

$$\Phi = f \begin{pmatrix} \cos\theta\epsilon & \sin\theta\mathbf{1}_2 \\ -\sin\theta\mathbf{1}_2 & -\cos\theta\epsilon \end{pmatrix}$$



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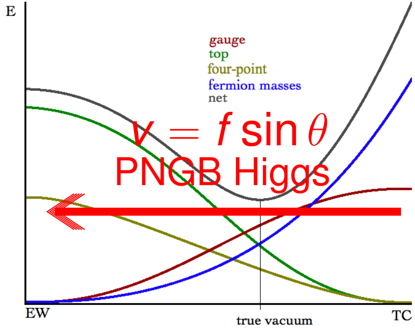
$\theta \to 0 \Rightarrow h \to h_{SM}$ & a decouples



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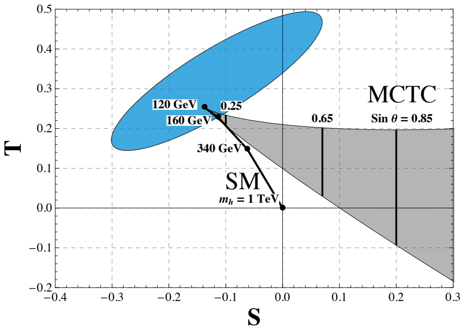
- m_h indep of θ
- $m_h \equiv 125$
- $\sin\theta \lesssim \frac{1}{4}$, S-T okay!
- $\sim$ 10% tuning



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Electroweak Precision

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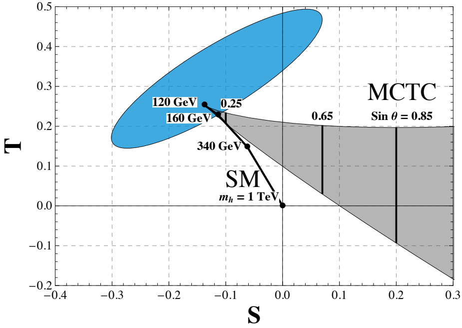

Additionally, CFT $\Rightarrow \Delta S$ may be naturally small! (Hsu, Sundrum 1991& LSD 2010)

S-Parameter? Small $\theta\left(\frac{v}{f}\right) \Rightarrow$ small S-parameter!

Small enough to fit EW data?

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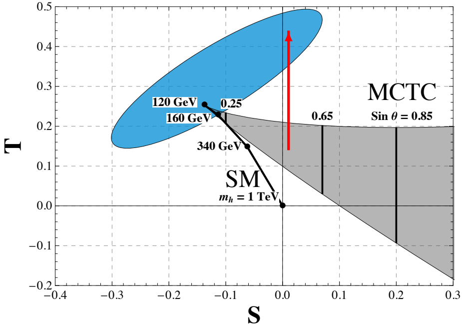

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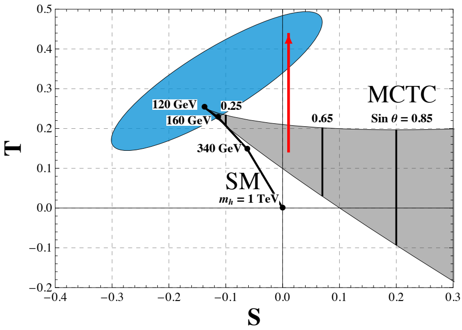

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Composite Higgs, but no top compositeness

$SU(4) \rightarrow Sp(4) \Rightarrow$ 2 physical PNGBs

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h – PNGB Higgs

- $m_h = \sqrt{3c_t}m_t$ – can be light
- $g_{hf\bar{f}} \sim g_{SM,hf\bar{f}} \times \cos\theta$
- $g_{hVV} \sim g_{SM,hVV} \times \cos\theta$
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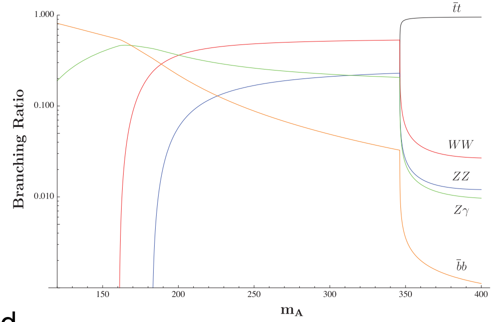

a – Pseudoscalar PNGB

- $m_a = m_h / \sin\theta$
- Extremely narrow state
- Single production suppressed
- Pair production through TC resonance or off-shell PNGB Higgs
- Invisible at $\sin\theta \ll 1$

Dimensions in Conformal Theories

For Conformal Technicolor to work, we need:

- $d \equiv d(\mathcal{H}) \sim 1 + \epsilon$ to separate EW scale from flavor scale
- $\Delta \equiv d\left(\mathcal{H}^\dagger \mathcal{H}\right) \geq 4$ to evade the hierarchy problem

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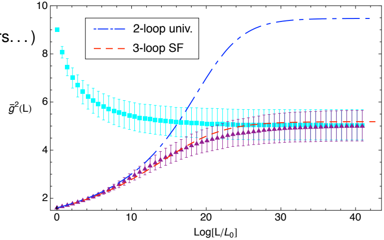

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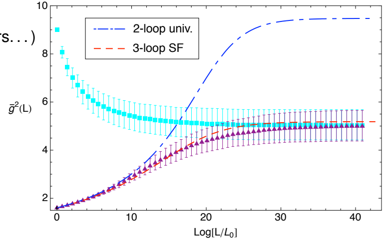

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How small *must d* be for flavor???

In general, we need:

A Recipe for UV Completion
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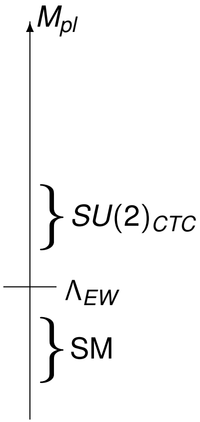

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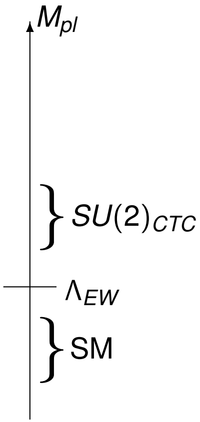
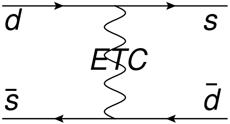


A Recipe for UV Completion

Suppressing FCNCs in Technicolor

Mass generation in ETC ⇒ Large FCNCs



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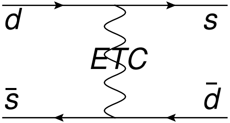

Bosonic TC: (Samuel 1990; Dine, Kagan, Samuel 1990)

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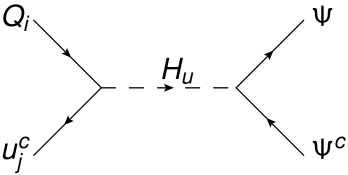

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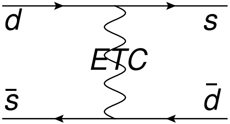

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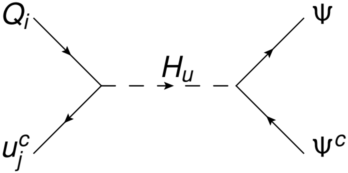

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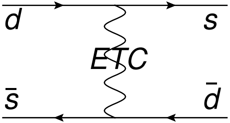

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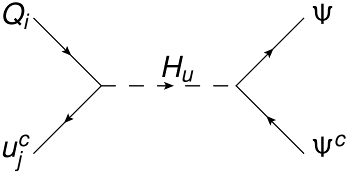

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Minimal flavor violation

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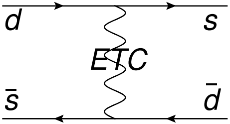

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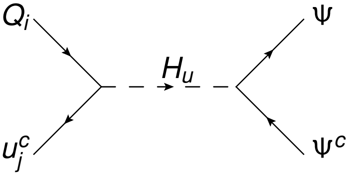

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SUSY and Technicolor solve each other's flavor problem!

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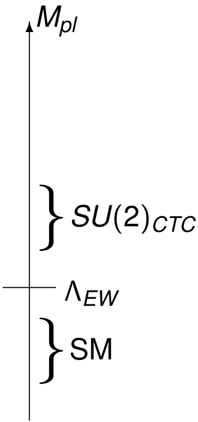

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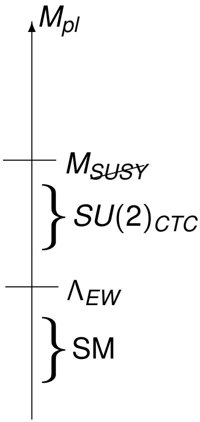

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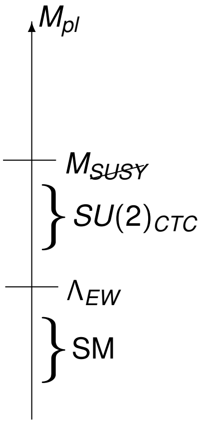

A Recipe for UV Completion

That Dastardly Top!

$$y_{TC}\Psi H_u \Psi^c \qquad\qquad y_t Q_3 H_u t^c$$

A Recipe for UV Completion

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Fixed points in SUSY? a-Maximization! (Intriligator, Wecht 2003)

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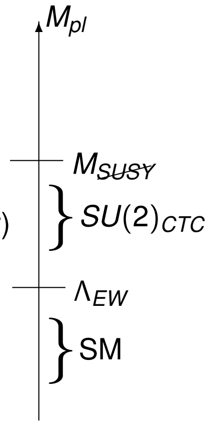

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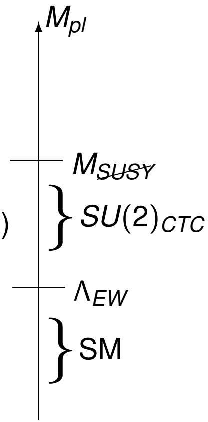

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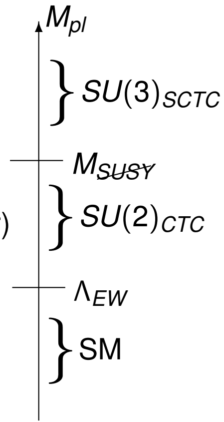

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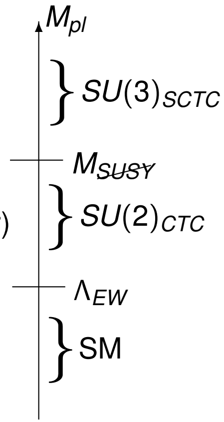

Only two scales, M_{SUSY} and Λ_{EW}

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$$SU(3)_{SCTC} \times SU(2)_L \times SU(2)_R \supset U(1)_Y$$

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$\rightarrow$ technifermions (ultimately cause EWSB)

$\rightarrow$

$\rightarrow$

$\rightarrow$

Superconformal Technicolor

Into the UV!!!

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Superconformal Technicolor

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$$H \sim (1,2,2) \quad \rightarrow \quad \text{messengers of flavor}$$

$$a = 1,\ldots,4$$

At SUSY breaking scale Σ_4 gets a VEV – $SU(3)_{SCTC} \rightarrow SU(2)_{CTC}$

$$\langle\Sigma\rangle = \langle\Sigma^c\rangle = \begin{pmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & v_\Sigma \end{pmatrix}$$

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High-energy $SU(3)_{SCTC} \to$ low-energy $SU(2)_{CTC}$ (almost) MCTC!

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$SU(3)_C$

Flavor: How small does d have to be?

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$\Lambda_t \gtrsim 100$ TeV		$d \lesssim 1.8$

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  - $SU(2)_{MCTC}$ with fundamentals
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