Techni-dilaton signatures at LHC

Shinya Matsuzaki
Maskawa Institute for Science and Culture,
Kyoto Sangyo Univ.

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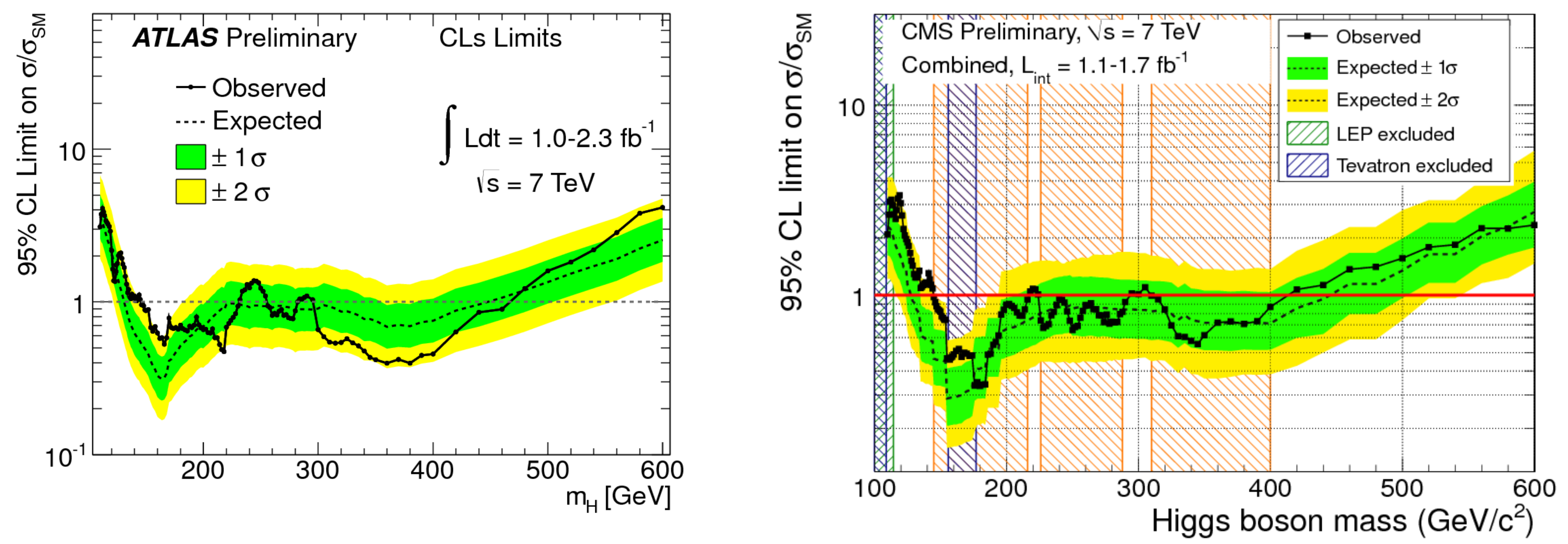


Lepton-Photon 2011

★ LHC starts setting severe bounds on SM Higgs mass

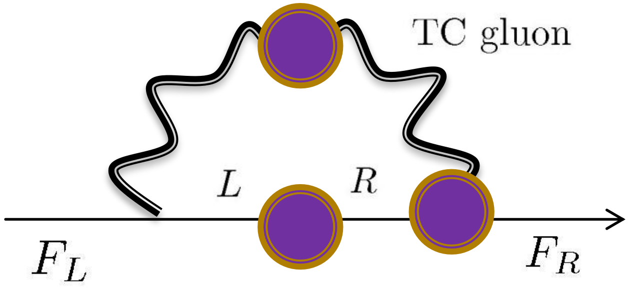
--- implies the mass is unlikely to be as low as O(EW)

--- suggests ***composite dynamics for origin of mass***

like *"Technicolor"*

Technicolor

Weinberg ('76), Susskind ('79)



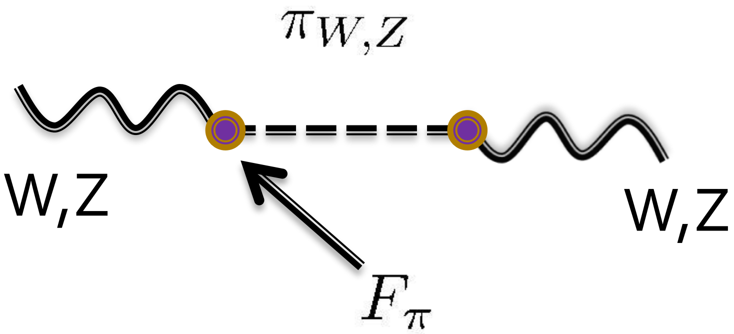
Dynamical EW(chiral) SB

technifermion condensation: $\langle \bar{F}_L F_R \rangle \neq 0$

$$SU(2)_L \times SU(2)_R \rightarrow SU(2)_V$$

like $\langle \bar{q}_L q_R \rangle \neq 0$ in QCD

Dynamical W,Z mass generation

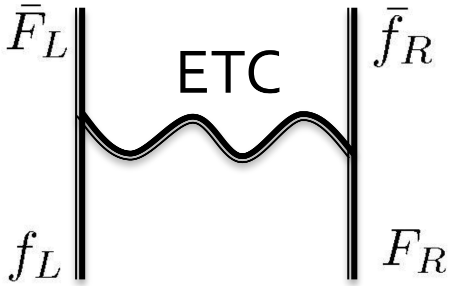


$M_W = \frac{g_W}{2} F_\pi$ with $F_\pi \simeq 246$ GeV set

Dynamical explanation of origin of mass

Technicolor should not be QCD-like at all

Extended TC: SM fermion mass generation



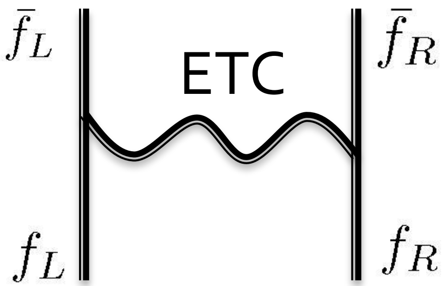
$M_{\rm ETC} = g_{\rm ETC}\Lambda_{\rm ETC}$

$$\xrightarrow{@\Lambda_{\rm ETC}} \quad \frac{1}{\Lambda_{\rm ETC}^2}(\bar F_L F_R)(\bar f_R f_L) + \text{h.c.}$$

$$m_f \sim \frac{\langle \bar F F\rangle_{\Lambda_{\rm TC}}}{\Lambda_{\rm ETC}^2}\, \underline{\exp \int_{\Lambda_{\rm TC}}^{\Lambda_{\rm ETC}} \frac{d\mu}{\mu}\gamma_m(\mu)}$$

RGE effect for $\bar F F$ operator w/ anomalous dim. γ_m

FCNC constraint



e.g.

$K_0 - \bar K_0$ mixing requires $\Lambda_{\rm ETC} > 10^3\,\text{TeV}$

associated w/ strange quark mass

Naive scale-up of QCD $\gamma_m \simeq 0$: $m_s < 0.1\left(\frac{N_{\rm TC}}{3}\right)$ MeV

Needs enhancement by $\gamma_m \simeq 1$

Holdom (1981)

Other pheno. issues in TC scenarios

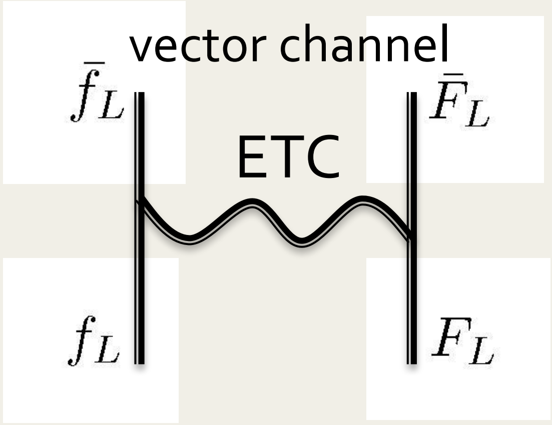
S parameter

$$S \approx N_D \cdot \frac{8\pi F_\pi^2}{M_\rho^2} \simeq \underline{0.3 \cdot N_D} \qquad \text{(for QCD-like)}$$

N_D : # EW doublets

too large! Cf: S(exp) < 0.1 around T = 0

One resolution: ***ETC-induced "delocalization" operator*** Chivukula et al (2005)



$$-\frac{1}{\Lambda_{\rm ETC}^2} J^a_{\mu {\rm SM}_L} J^{\mu a}_{{\rm TC}_L}$$

in low-energy

$$J^{\mu a}_{{\rm TC}_L} \to {\rm Tr}\left[U^\dagger \frac{\sigma^a}{2} i D^\mu U\right]$$

w/ $U = e^{2i\pi_{\rm eaten}/v_{\rm EW}}$

$$\ni g_W W_\mu - g_Y B_\mu$$

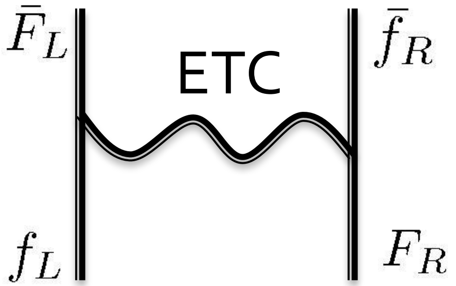
modifies SM f-couplings to W, Z

contributes to S "negatively"

$$\Delta S \sim -\frac{8\pi}{g_W^2}\left(\frac{v_{\rm EW}}{\Lambda_{\rm ETC}}\right)^2$$

$$\boxed{S_{\rm total} \to 0 \ (\text{"ideal delocalization"})}$$

Top quark mass generation



$$m_t \approx \frac{\langle \bar{U} U \rangle_{\rm ETC}}{\Lambda_{\rm ETC}^2} \approx \left(\frac{\Lambda_{\rm TC}}{\Lambda_{\rm ETC}} \right)^2 \Lambda_{\rm TC}$$

ETC scale associated w/ top mass

$$\rightarrow \quad \Lambda_{\rm ETC}^{\rm top} \approx 1{\rm TeV} \left(\frac{\Lambda_{\rm TC}}{1{\rm TeV}} \right)^{3/2} \left(\frac{172{\rm GeV}}{m_t} \right)^{1/2}$$

too small!

One resolution: ***Strong ETC*** Miransky et al (1989)

--- makes induced 4-fermi (tt UU) coupling large enough to trigger chiral symm. breaking (almost by NJL dynamics)

$$\langle \bar{U} U \rangle_{\rm ETC} \approx \left(\frac{\Lambda_{\rm ETC}}{\Lambda_{\rm TC}} \right)^{\gamma_m} \langle \bar{U} U \rangle_{\rm TC} \qquad 1 < \gamma_m \leq 2$$

boost-up

$$\rightarrow \quad m_t \approx \left(\frac{\Lambda_{\rm TC}}{\Lambda_{\rm ETC}} \right)^{2-\gamma_m} \Lambda_{\rm TC} \leq \Lambda_{\rm TC} \sim 1{\rm TeV}$$

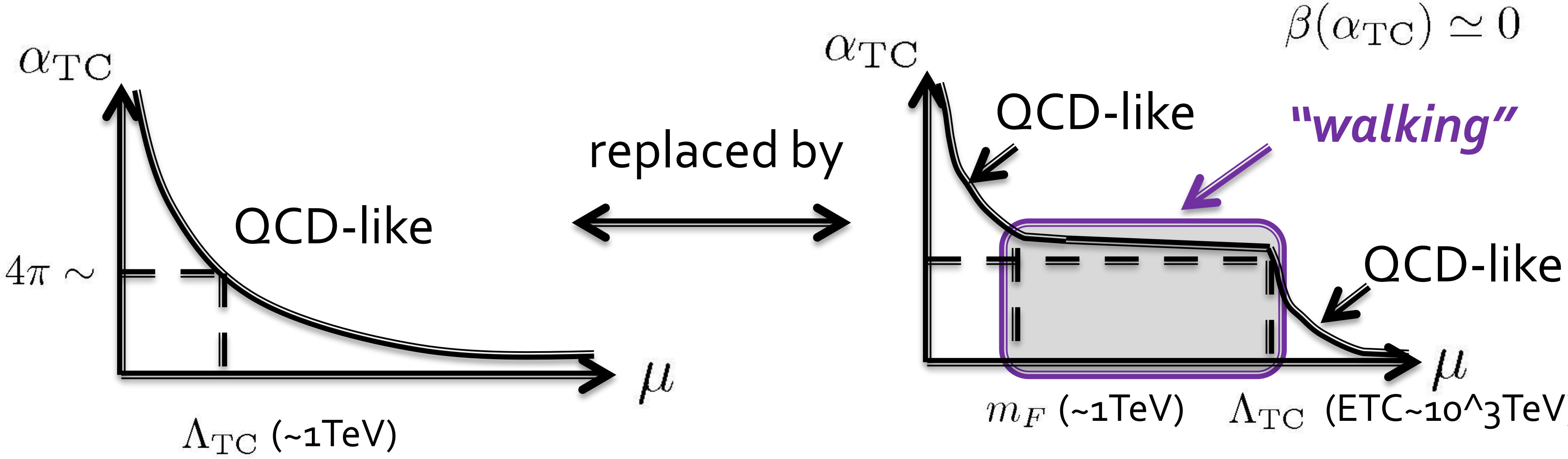
T parameter

(Strong) ETC generates large isospin breaking

→ highly model-dependent issue

Yamawaki et al (1986); Bando et al (1986)

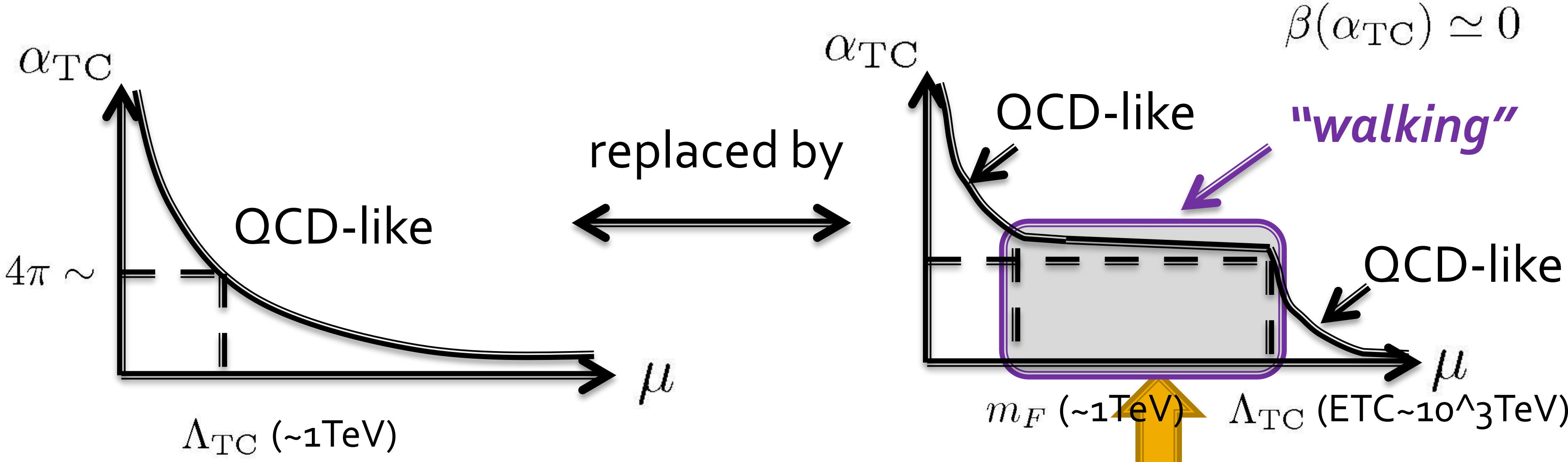
Walking TC



$\beta(\alpha_{\mathrm{TC}}) \simeq 0$

Yamawaki et al (1986); Bando et al (1986)

Walking TC



***Dynamical TF mass generation by WTC**

$$m_F \sim \Lambda_{\rm TC} e^{-\frac{\pi}{\sqrt{\alpha/\alpha_{\rm cr}-1}}} \text{ for } \alpha > \alpha_{\rm cr}$$

"Miransky scaling"

Miransky (1985)

$$\langle \bar{F}F \rangle_{\Lambda_{\rm TC}} \sim \frac{N_{\rm TC}}{4\pi^2} m_F^2 \Lambda_{\rm TC} \longrightarrow \gamma_m \simeq 1$$

(solve FCNC syndrome)

*** Explicit dynamics**

QCD w/ large # fermions --- under investigation by lattice cals

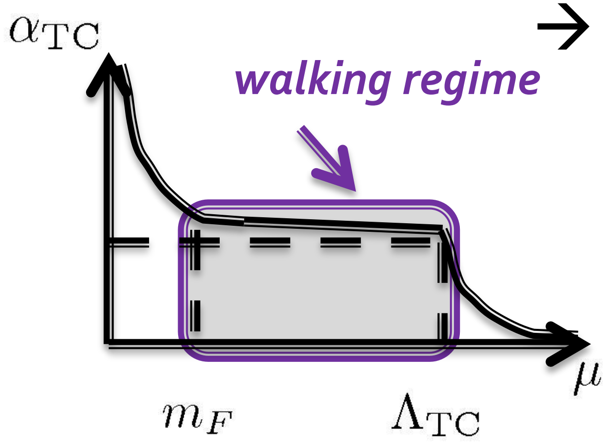
Yamawaki et al (1986); Bando et al (1986)

★WTC and techni-dilaton

$\beta(\alpha_{\rm TC}) \simeq 0$ (Approximate) scale-invariance in WTC

→ presence of (p)NGB for scale symm = “dilaton”.

$\phi \sim \bar{F}F$



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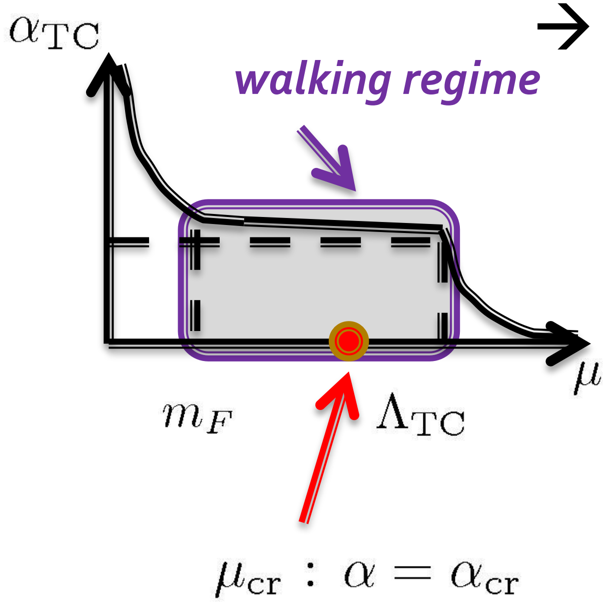

SSB by TF mass generation @ mu_cr

$$m_F \simeq \Lambda_{\rm TC}\, e^{-\pi/\sqrt{\alpha_m/\alpha_{\rm cr}-1}}$$

Yamawaki et al (1986); Bando et al (1986)

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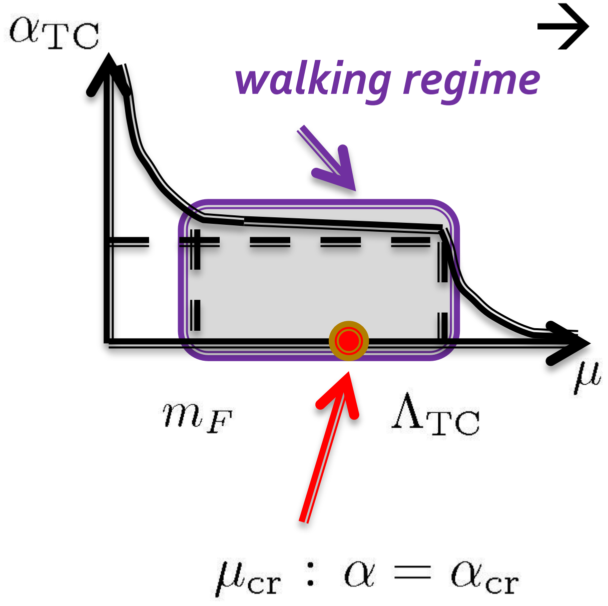

SSB by TF mass generation @ mu_cr

$$m_F \simeq \Lambda_{\rm TC}\, e^{-\pi/\sqrt{\alpha_m/\alpha_{\rm cr} - 1}}$$

starts “running” (walking) up to mF

$$\beta^{\rm NP}(\alpha) = \Lambda_{\rm TC} \frac{\partial \alpha}{\partial \Lambda_{\rm TC}} = -\frac{2\alpha_{\rm cr}}{\pi} \left(\frac{\alpha}{\alpha_{\rm cr}} - 1 \right)^{3/2}$$

Yamawaki et al (1986); Bando et al (1986)

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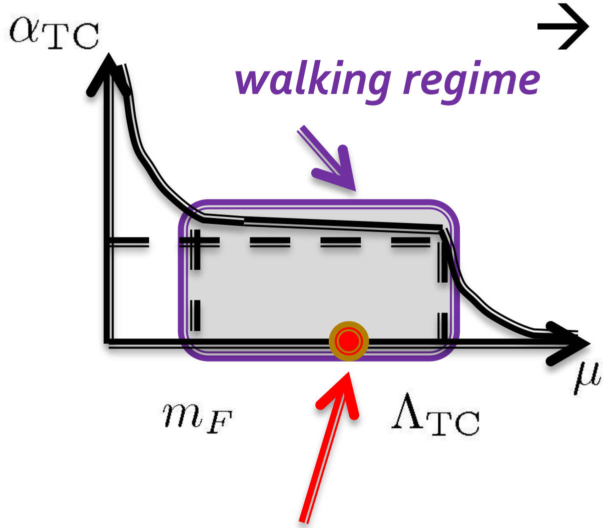


$\mu_{\rm cr}\ :\ \alpha = \alpha_{\rm cr}$

SSB by TF mass generation @ mu_cr

$$m_F \simeq \Lambda_{\rm TC}\, e^{-\pi/\sqrt{\alpha_m/\alpha_{\rm cr}-1}}$$

starts "running" (walking) up to mF

$$\overset{\textbf{NP}}{\beta}(\alpha) = \Lambda_{\rm TC}\frac{\partial\alpha}{\partial\Lambda_{\rm TC}} = -\frac{2\alpha_{\rm cr}}{\pi}\left(\frac{\alpha}{\alpha_{\rm cr}}-1\right)^{3/2}$$

nonperturbative scale anomaly

"no exact NGB limit"

$$\partial_\mu D^\mu_{\textbf{TC}} = \frac{\overset{\textbf{NP}}{\beta}(\alpha)}{4\alpha^2}\langle\alpha G^2_{\mu\nu}\rangle \neq 0 :\ \underline{\text{explicitly broken by } m_F}$$

makes dilaton massive: "techni-dilaton" (pNGB) potentially light!

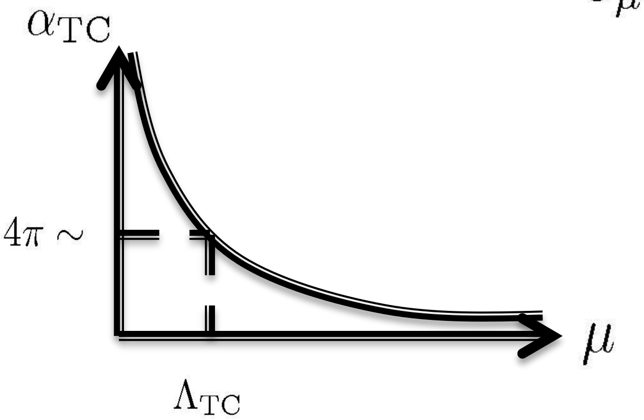
Cf: naive scale-up version of TC

Light composite scalar Higgs in naive scale-up version of QCD?

$$\phi \sim \bar{F}F \qquad \frac{\Lambda_{\rm TC}}{\Lambda_{\rm QCD}} \approx \frac{F_\pi}{f_\pi^{\rm QCD}} \approx 2600$$

scale symmetry is **badly broken** at perturbative level (cf. QCD)

$$\partial_\mu D^\mu_{\rm TC} = \frac{\beta(\alpha_{\rm TC})}{4\alpha_{\rm TC}} \langle G_{\mu\nu}^2 \rangle \sim \mathcal{O}(\Lambda_{\rm TC}^4)$$



No reason to be ligher than other TC hadrons

$$m_\phi \sim m_\rho \sim \mathcal{O}(\Lambda_{\rm TC})$$

typical TC hadron mass scale

★Techni-dilaton mass and coupling

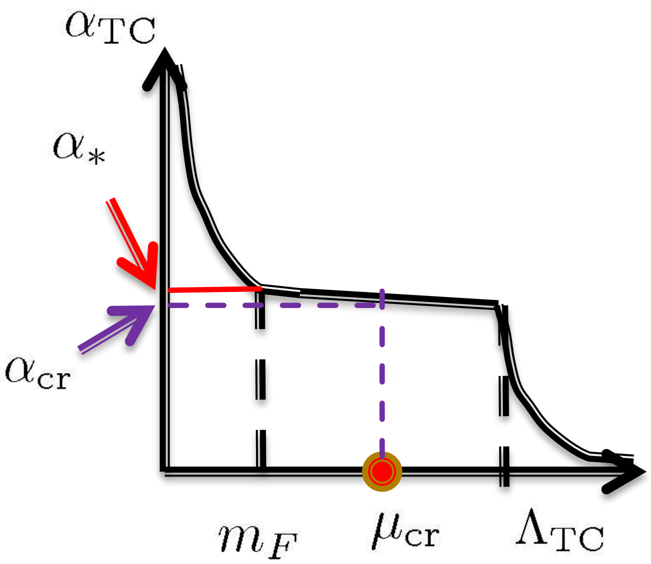
TD mass

Caswell (1974); Banks and Zaks (1982)

One candidate for WTC

i) Solving BS eq

large Nf QCD w/ two-loop beta func. having CBZ-IRFP α_*



(improved) ladder approx.

$\phi \sim \bar{F}F$

bound state

Harada et al (2003); Kurachi et al (2006)

$$m_F \sim \Lambda_{\rm TC} e^{-\frac{\pi}{\sqrt{\alpha_*/\alpha_{\rm cr}-1}}}$$

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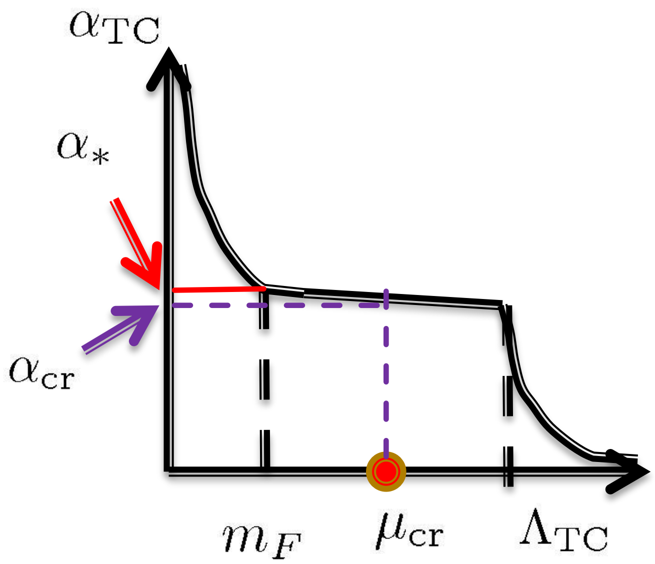

$$m_F \sim \Lambda_{\rm TC} e^{-\frac{\pi}{\sqrt{\alpha_*/\alpha_{\rm cr}-1}}}$$

For $\alpha_* \to \alpha_{\rm cr}$ $(m_F/\Lambda_{\rm TC} \to 0)$

"criticality" limit

$$M_{\rm TD} \simeq 1.5 m_F < M_{\rho,a_1} \simeq 3 m_F$$

For one-family model

$$M_{\rm TD} \simeq 600\ {\rm GeV}$$

Indeed, TD is light!

ii) Holographic TD

Haba-Matsuzaki-Yamawaki (2010)

In "criticality" limit $(m_F/\Lambda_{\rm TC} \to 0)$

note

$$F_\pi = \mathcal{O}(m_F)$$

$$M_{\rm TD}/F_\pi \to 0 \text{ while } M_{\rho,a_1}/F_\pi \to \text{constant}$$

TD could be extremely light!

ii) Holographic TD

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TD could be extremely light!

TD coupling (decay constant) FTD

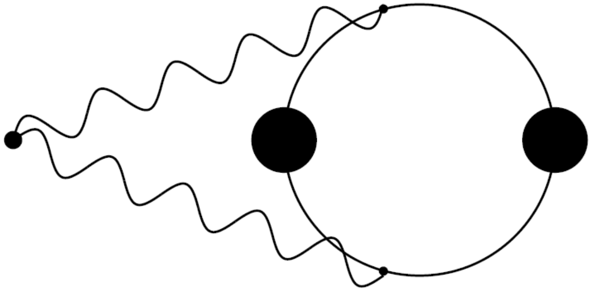
PCDC (Partially conserved dilatation current)

$$F_{\rm TD}^2 M_{\rm TD}^2 = -4 d_\theta \langle \theta_0^0 \rangle \qquad \text{w/ } d_\theta = 4 \text{ and } \theta_\mu^\mu = \partial_\mu D^\mu$$

vacuum energy density $\langle \theta_0^0 \rangle$ (in ladder approx.)

Miransky et al (1989);
Hashimoto et al(2011)

associated w/ TF mass generation



$$\langle \theta_0^0 \rangle = \frac{\beta_{\rm NP}(\alpha)}{4\alpha} \langle G_{\mu\nu}^2 \rangle \sim -\frac{N_{\rm TF} N_{\rm TC}}{\pi^2} m_F^4$$

PCDC

$$\left\{ \begin{array}{l} F_{\rm TD}^2 M_{\rm TD}^2 = -4 d_\theta \langle \theta_0^0 \rangle \qquad \text{w/ } d_\theta = 4 \text{ and } \theta_\mu^\mu = \partial_\mu D^\mu \\ \\ \langle \theta_0^0 \rangle \sim \frac{N_{\rm TF} N_{\rm TC}}{\pi^2} m_F^4 \end{array} \right.$$

implies

$$\boxed{\frac{M_{\rm TD}}{m_F} \frac{F_{\rm TD}}{m_F} \sim \text{constant}}$$

two possibilities:

(1) ***Non hierarchical*** → **relevant to LHC**

$$M_{\rm TD} \sim F_{\rm TD} \sim m_F$$

→ This talk

(2) ***Extremely hierarchical***

$$M_{\rm TD} \ll m_F \ll F_{\rm TD} \longrightarrow$$

light decoupled TD
(dark matter?)
→ next talk by DK Hong

Techni-dilaton signatures at LHC

Based on arXiv:1109.5448 [hep-ph]

In collaboration with
Koichi Yamawaki (KMI, Nagoya Univ.)

To discuss TD LHC phenomenologies:

needs to know TD couplings to SM particles

Yukawa coupling: TD – f – f bar

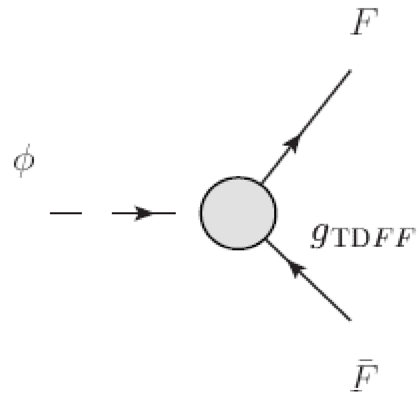
Gauge coupling: TD – W-W, ZZ, gluons, photons

→ generated from techni-fermion (F) loops via TD-F-F vertex

Ward-Takahashi identity for dilatation current

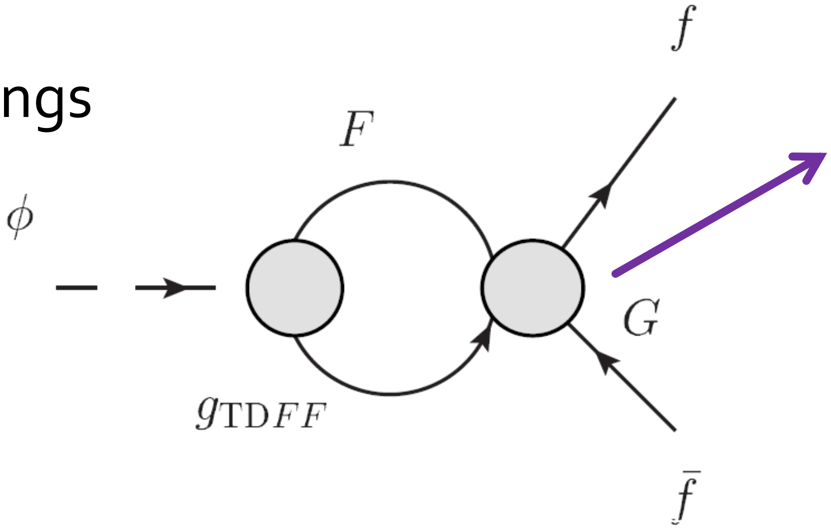
Bando et al (1986)

$$g_{\mathrm{TD}FF} = \frac{(3-\gamma_m)m_F}{F_{\mathrm{TD}}}$$



TD couplings generated from TF loops

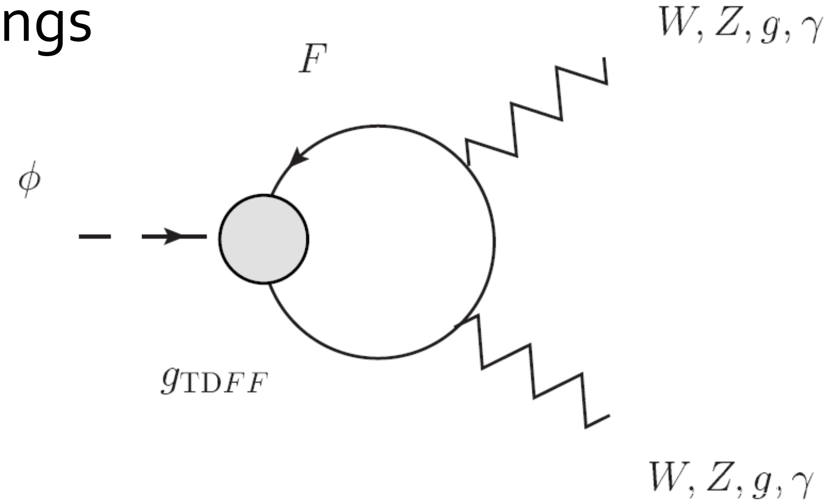
Yukawa couplings



$G\bar{F}Fff$

ETC-induced
4-Fermi

Gauge couplings



TD Lagrangian

m_F **breaks explicitly as well as spontaneously**

- Nonlinear realization of chiral and scale symmetries

Nonlinear base: $\Phi \approx \frac{\bar{F}F}{\langle \bar{F}F \rangle}$

$$\Phi = e^{(3-\gamma_m)\phi/F_{\rm TD}}$$

reflecting scaling property of $\bar{F}F$

$$\delta\Phi = (3 - \gamma_m + x^\nu \partial_\nu)\,\Phi$$

TD field ϕ $\quad \delta\phi = F_{\rm TD} + x^\nu \partial_\nu \phi$

TD decay constant: $\quad \langle 0 | D_\mu(0) | \phi(p) \rangle = -i p_\mu F_{\rm TD}$

TC sector-dilatation current

Explicit breaking: "spurion" S

$$\delta S = (1 + x^\nu \partial_\nu)\, S \qquad \langle S \rangle = 1$$

Chiral and scale-inv. nonlinear Lagrangian

Including suprion S

$$\mathcal{L} = \frac{v_{\rm EW}^2}{4}(\Phi S^{\gamma_m-2})^2 {\rm tr}[D_\mu U^\dagger D^\mu U] - (\Phi S^{\gamma_m-2}) \sum_f \left(\bar{f}_L U \begin{pmatrix} m_f^u & 0 \\ 0 & m_f^d \end{pmatrix} f_R + {\rm h.c.} \right)$$

$$-(\Phi S^{\gamma_m-3}) \left(\frac{\beta_F(\alpha_s)}{2\alpha_s} {\rm tr}[G_{\mu\nu}^2] + \frac{\beta_F(\alpha_{\rm EM})}{4\alpha_{\rm EM}} F_{\mu\nu}^2 \right) ,$$

w/chiral field (only eaten NGBs

$$U = e^{2i\pi/v_{\rm EW}}$$

TD couplings

$$g_{{\rm TD}WW/ZZ} = \frac{2(3-\gamma_m)m_{W/Z}^2}{F_{\rm TD}}$$

$$g_{{\rm TD}ff} = \frac{(3-\gamma_m)m_f}{F_{\rm TD}}$$

$$g_{{\rm TD}gg} = \frac{(3-\gamma_m)}{F_{\rm TD}} \frac{\beta_F(\alpha_s)}{2\alpha_s}$$

$$g_{{\rm TD}\gamma\gamma} = \frac{(3-\gamma_m)}{F_{\rm TD}} \frac{\beta_F(\alpha_{\rm EM})}{4\alpha_{\rm EM}}$$

β_F : only includes
techni-fermion (F) loops

Comparison w/
SM Higgs couplings

$$1/v_{\rm EW} \to (3-\gamma_m)/F_{\rm TD}$$

up to β_F **highly model-dep.**

The LHC signatures at $\sqrt{s} = 7$ TeV

Via gluon and vector bosn fusion productions

TD production cross section X branching ratio to SM Higgs one

$$R_X \equiv \frac{[\sigma_{\rm GF}(pp \to {\rm TD}) + \sigma_{\rm VBF}(pp \to {\rm TD})]}{[\sigma_{\rm GF}(pp \to h_{\rm SM}) + \sigma_{\rm VBF}(pp \to h_{\rm SM})]} \frac{BR({\rm TD} \to X)}{BR(h_{\rm SM} \to X)}$$

$$X \;=\; WW, ZZ, gg, \gamma\gamma \text{ and } t\bar{t}$$

$$\left[\begin{array}{l} \dfrac{\sigma_{\rm VBF}(pp \to {\rm TD})}{\sigma_{\rm VBF}(pp \to h_{\rm SM})} = \dfrac{\Gamma({\rm TD} \to WW)}{\Gamma(h_{\rm SM} \to WW)} = \dfrac{\Gamma({\rm TD} \to ZZ)}{\Gamma(h_{\rm SM} \to ZZ)} \equiv r_{WW/ZZ} \\ \\ \dfrac{\sigma_{\rm GF}(pp \to {\rm TD})}{\sigma_{\rm GF}(pp \to h_{\rm SM})} = \dfrac{\Gamma({\rm TD} \to gg)}{\Gamma(h_{\rm SM} \to gg)} \equiv r_{gg} \end{array}\right.$$

Georgi et al (1978)

$$R_X = \left(\frac{\underline{\sigma_{\rm GF}(pp \to h_{\rm SM})} \cdot r_{gg} + \underline{\sigma_{\rm VBF}(pp \to h_{\rm SM})} \cdot r_{WW/ZZ}}{\underline{\sigma_{\rm GF}(pp \to h_{\rm SM})} + \underline{\sigma_{\rm VBF}(pp \to h_{\rm SM})}} \right) r^X_{\rm BR}$$

known

$$r^X_{\rm BR} = \frac{BR({\rm TD} \to X)}{BR(h_{\rm SM} \to X)}$$

Evaluate $r_{WW/ZZ}$ r_{gg} and $r^{X}_{\rm BR}$ for typical TC models

Farhi et al (1981)

One-doublet model (1DM)

$TF_{\rm EW}$	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
$\begin{pmatrix} U \\ D \end{pmatrix}_L$	1	2	0
U_R	1	1	1/2
D_R	1	1	-1/2

One-family model (1FM)

$TF_{\rm EW}$	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$
$Q_L = \begin{pmatrix} U \\ D \end{pmatrix}_L$	3	2	1/6
$L_L = \begin{pmatrix} N \\ E \end{pmatrix}_L$	1	2	-1/2
U_R	3	1	2/3
D_R	3	1	-1/3
N_R	1	1	0
E_R	1	1	-1

Total # of techni-fermions

$$N_{\rm TF} = (N_{\rm TF})_{\rm EW-singlet} + 2N_{\rm D}$$

w/ critical # for mass generation in WTC

$$N_{\rm TF} \simeq 4N_{\rm TC}$$

Appelequist et al (1996)

Use PCDC and PS formula in ladder approx.: Fix $F_{\rm TD}$ and m_F

Hashimoto et al (2010)

PCDC (Partially Conserved Dilatation Current)

$$F_{\rm TD}^2 M_{\rm TD}^2 \simeq 3.0 \left(\frac{N_{\rm TF} N_{\rm TC}}{2\pi^2} \right) m_F^4$$

Pagels-Storkar (PS) formula

$$v_{\rm EW} = \sqrt{N_{\rm D}} F_\pi$$

$$\frac{v_{\rm EW}}{m_F} \simeq 0.41 \left(\frac{N_{\rm TC}}{3} \right)^{1/2} \left(\frac{N_{\rm D}}{1} \right)^{1/2}$$

$$m_F \simeq 600\,{\rm GeV} \left(\frac{N_{\rm TC}}{3} \right)^{-1/2} \left(\frac{N_{\rm D}}{1} \right)^{-1/2}$$

w/ use of

$$N_{\rm TF} \simeq 4 N_{\rm TC}$$

$$\simeq \begin{cases} 735\,(600)\,{\rm GeV} & \text{for the 1DM } (N_{\rm D}=1) \text{ with } N_{\rm TC}=2(3) \\ 367\,(300)\,{\rm GeV} & \text{for the 1FM } (N_{\rm D}=4) \text{ with } N_{\rm TC}=2(3) \end{cases}$$

- TD decay constant (***larger than*** F_π)

$$\frac{F_{\rm TD}}{F_\pi} \simeq 7.0 \times \left(\frac{F_\pi}{M_{\rm TD}}\right)\sqrt{\frac{N_{\rm TF}}{N_{\rm TC}}}$$

$$\simeq \begin{cases} 5.7 \left(\frac{600\,{\rm GeV}}{M_{\rm TD}}\right) & \text{for the 1DMs with } N_{\rm TF} \simeq 4N_{\rm TC} \text{ and } F_\pi = 246 \text{ GeV} \\ 2.8 \left(\frac{600\,{\rm GeV}}{M_{\rm TD}}\right) & \text{for the 1FMs with } N_{\rm TF} \simeq 4N_{\rm TC} \text{ and } F_\pi = 123 \text{ GeV} \end{cases}$$

$\boxed{F_{\rm TD} > F_\pi}$:essentially due to ***smallness*** of $M_{\rm TD}$

- TD Yukawa coupling (***1DM: suppressed; 1FM :comparable***)

$$\frac{g_{{\rm TD}ff}}{g_{h_{\rm SM}ff}} = \left.\frac{(3-\gamma_m)v_{\rm EW}}{F_{\rm TD}}\right|_{\gamma_m \simeq 1}$$

$$\simeq (3-\gamma_m)|_{\gamma_m \simeq 1} \times \begin{cases} 0.18 \left(\frac{M_{\rm TD}}{600\,{\rm GeV}}\right) & \text{for the 1DM with } N_{\rm TF} \simeq 4N_{\rm TC} \\ 0.71 \left(\frac{M_{\rm TD}}{600\,{\rm GeV}}\right) & \text{for the 1FM with } N_{\rm TF} \simeq 4N_{\rm TC} \end{cases}$$

TD branching fraction relative to SM Higgs one

Model	$N_{\rm TC}$	$r_{\rm BR}^{WW}$	$r_{\rm BR}^{ZZ}$	$r_{\rm BR}^{gg}$	$r_{\rm BR}^{\gamma\gamma}$	$r_{\rm BR}^{t\bar{t}}$
1DM	2	1.0	1.0	1.0	1.0	0.92
	3	1.0	1.0	1.0	0.80	1.0
1FM	2	1.0	0.99	16	3.2	1.0
	3	0.99	0.99	44	11	0.99

for $M_{\rm TD} = 600\ {\rm GeV}$

- WW,ZZ, t tbar modes: almost identical to SM Higgs

- gg, gamma gamma modes: (1DM) identical to SM Higgs
  (1FM) ***enhanced*** due to
  extra QCD/EM-charged techni-fermions

$\sqrt{s} = 7$ TeV

TD production cross section relative to SM Higgs one

Model	$N_{\rm TC}$	$\frac{g_{{\rm TD}ff}}{g_{h_{\rm SM}ff}} = \frac{2v_{\rm EW}}{F_{\rm TD}}$	$r_{gg} = \frac{\sigma^{\rm TD}_{\rm GF}}{\sigma^{h_{\rm SM}}_{\rm GF}}$	$r_{WW/ZZ} = \frac{\sigma^{\rm TD}_{\rm VBF}}{\sigma^{h_{\rm SM}}_{\rm VBF}}$
1DM	2	0.35	0.12	0.12
	3	0.35	0.12	0.12
1FM	2	1.4	31	1.9
	3	1.4	87	1.9

for $M_{\rm TD} = 600\ {\rm GeV}$

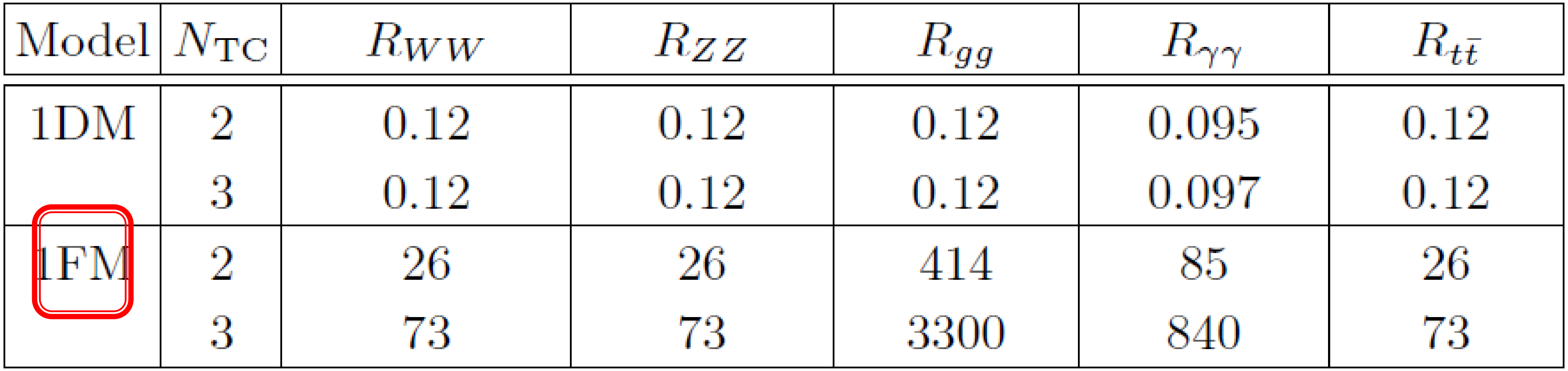
- 1DM: Both GF & VBF are ***suppressed***
  due to suppression of TD Yukawa coupling

- 1FM: VBF is comparable to SM Higgs one;
  GF is ***enhanced*** due to
  extra techni-quark contributions

$\sqrt{s} = 7$ TeV

pp->TD -> X signatures relative to SM Higgs one

$X = WW, ZZ, gg, \gamma\gamma$ and $t\bar{t}$



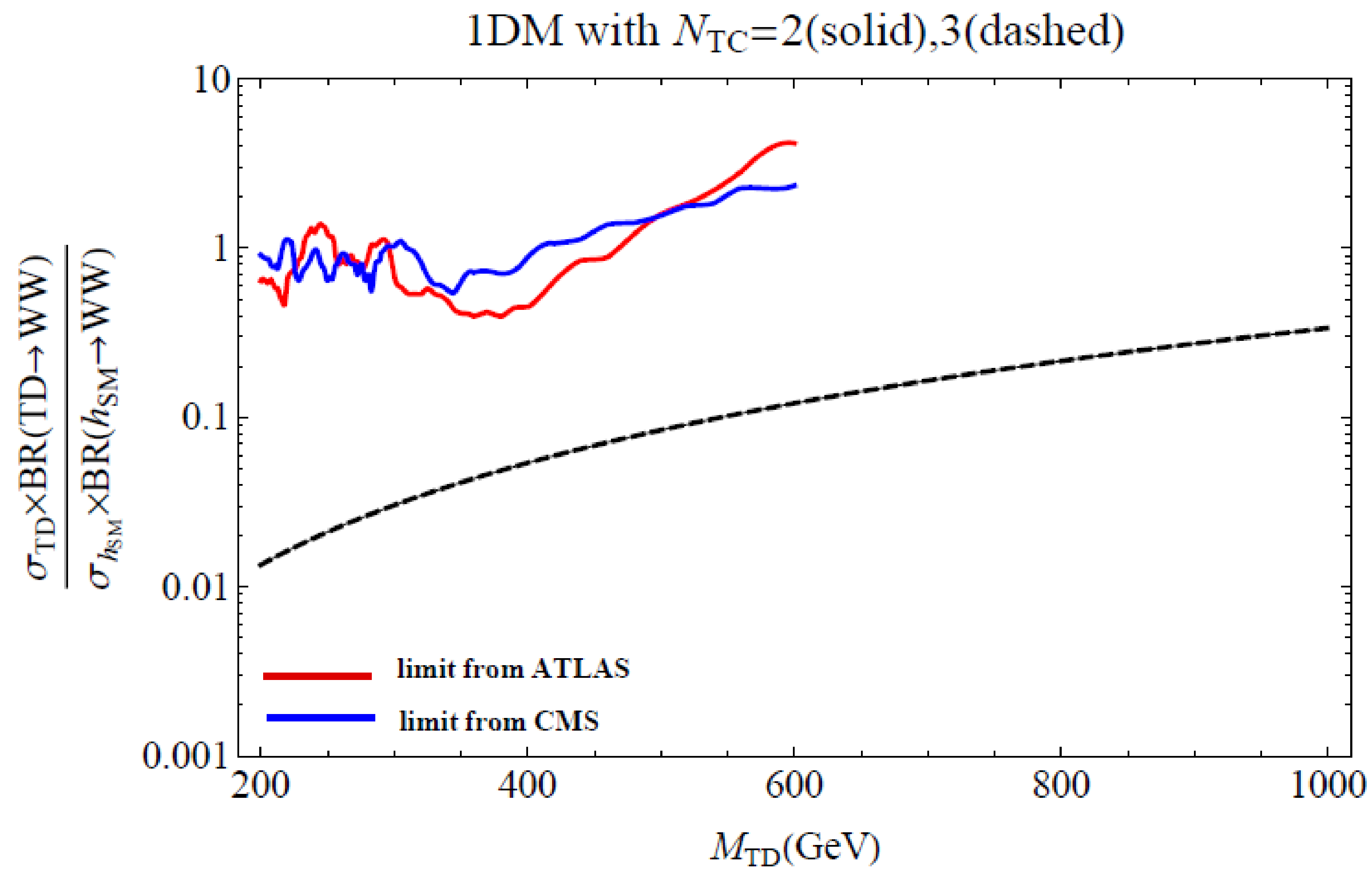
Model	N_{TC}	R_{WW}	R_{ZZ}	R_{gg}	$R_{\gamma\gamma}$	$R_{t\bar{t}}$
1DM	2	0.12	0.12	0.12	0.095	0.12
	3	0.12	0.12	0.12	0.097	0.12
1FM	2	26	26	414	85	26
	3	73	73	3300	840	73

for $M_{\mathrm{TD}} = 600$ GeV

- 1DM: all TD signals are ***suppressed***
  due to suppression of production cross section

- 1FM: all TD signals are ***enhanced***
  due to enhancement of production cross section

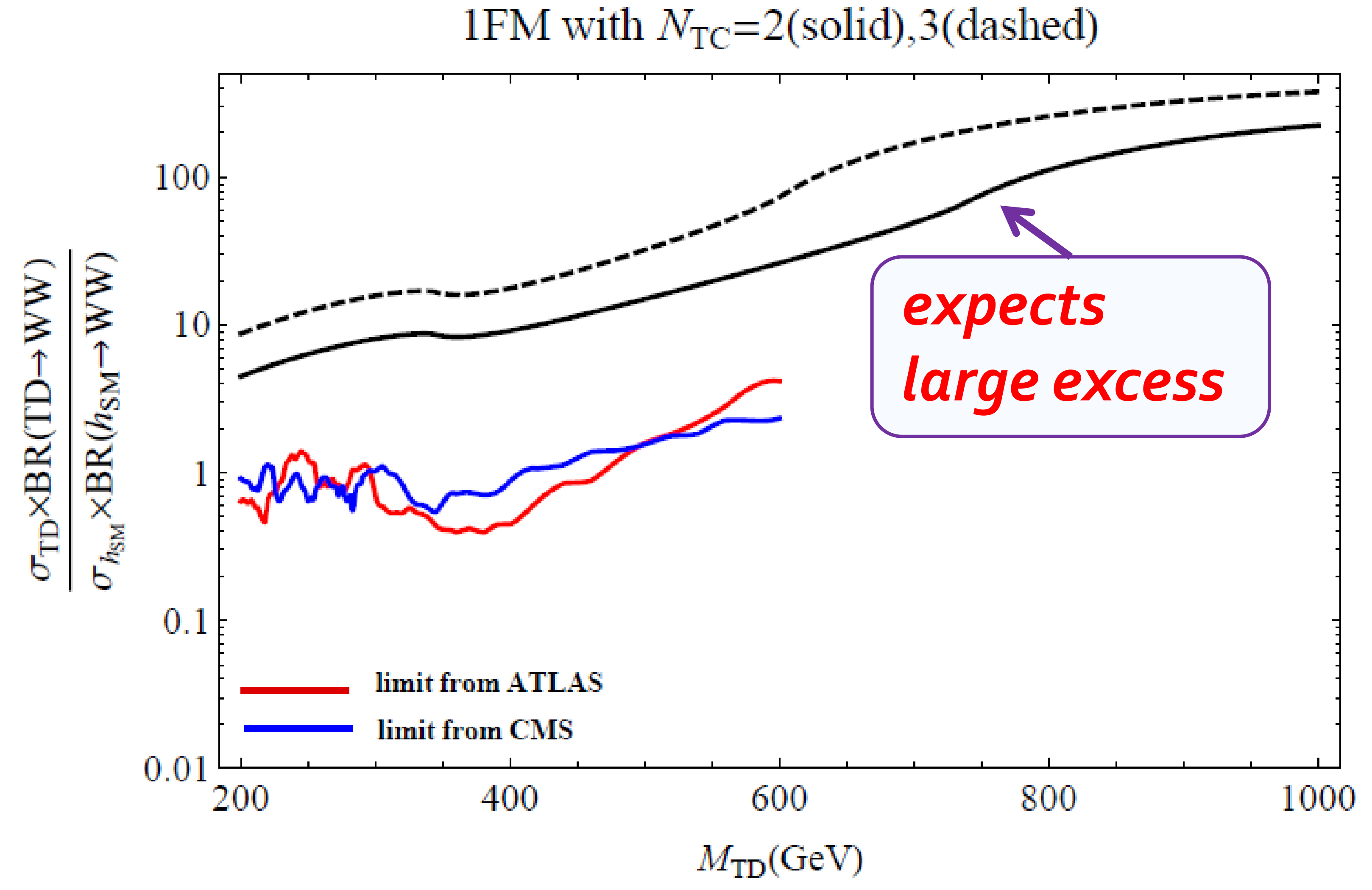
★ pp->TD -> WW/ZZ for 1DM $\sqrt{s} = 7$ TeV



- consistent thanks to large suppression of TD Yukawa coupling
- too small to be seen, though.

★ pp->TD -> WW/ZZ for 1FM

$\sqrt{s}$ = 7 TeV



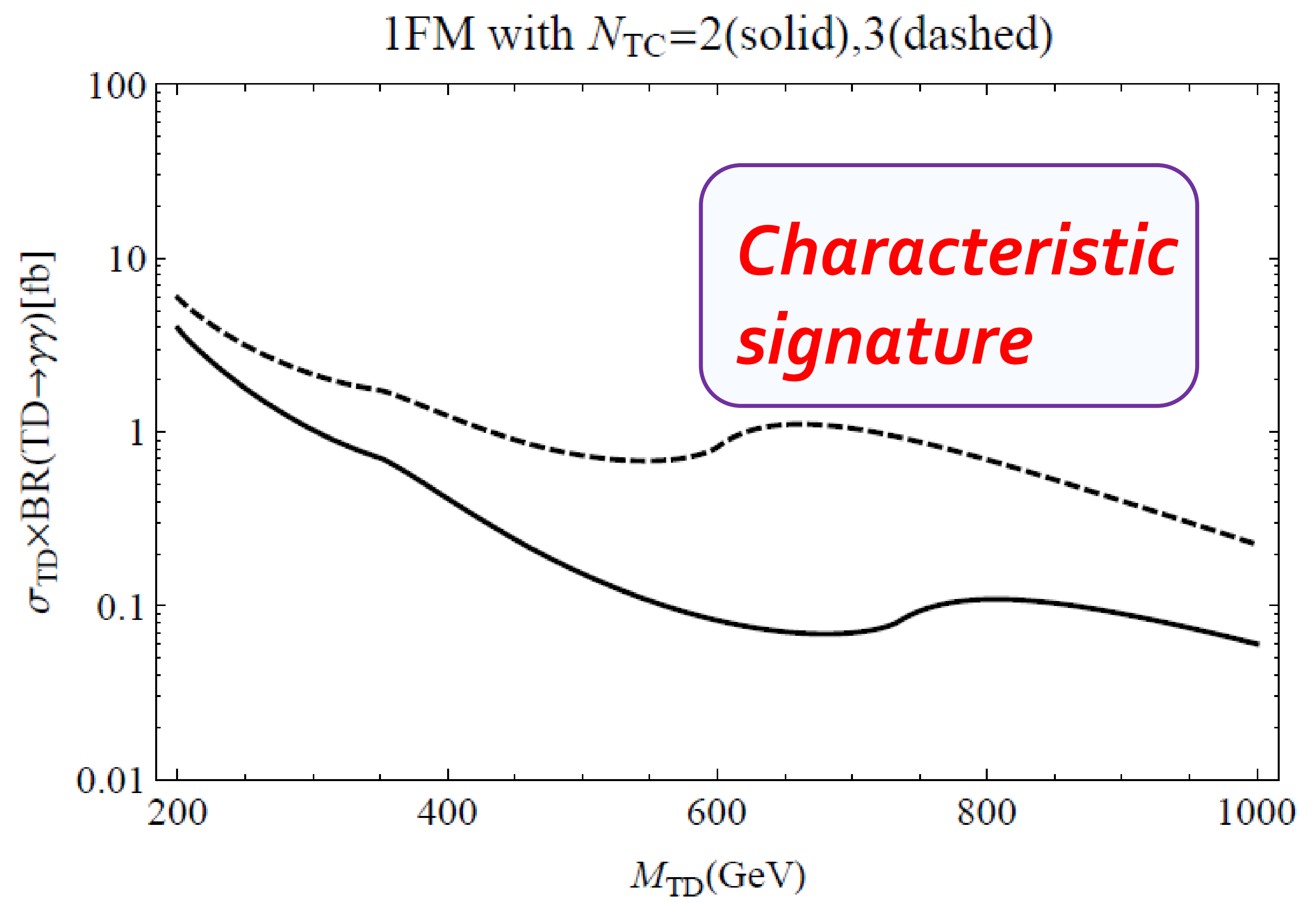
expects large excess

- excludes TD up to M_TD < 600 GeV
- On the other side of the same coin:

  TD will be seen at M_TD > 600 GeV!

★ pp->TD -> gamma gamma for 1FM

$\sqrt{s} = 7$ TeV



Characteristic signature

- at around 600 GeV, $\sigma_{\mathrm{TD}} \times BR(\mathrm{TD} \to \gamma\gamma)\Big|_{1\mathrm{FM}} \sim 0.10\,(1.0)$ fb

comparable with SM Higgs golden mode (around 600 GeV)

$$pp \to h_{\mathrm{SM}} \to ZZ \to l^+l^-l^+l^- \sim 1\ \mathrm{fb}$$

Summary

- ★ LHC will soon reveal what the key particle for origin of mass is. Current data implies composite dynamics. Walking TC predicts a light composite scalar, TD -- which arises as pNGB for SSB of scale symm.

- ★ TD signatures at LHC: The characteristic difference from the SM Higgs will be seen through WW/ZZ, gamma gamma modes at around the TD mass > 600 GeV (for 1FM).

Back up slides