Status of Composite Twin Higgs

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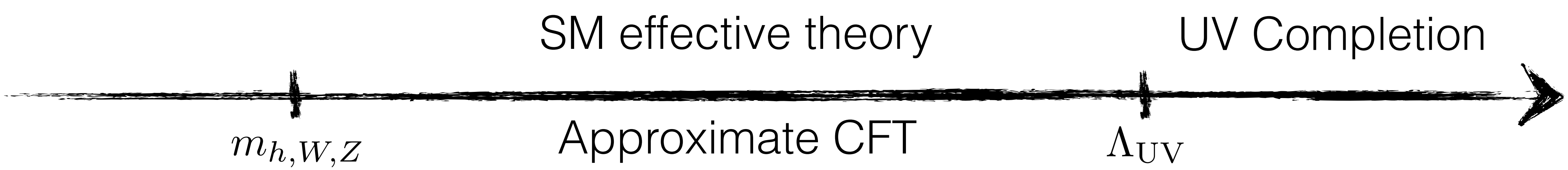
based on papers to appear in collaboration with R. Contino, D. Greco, R. Mahbubani, R. Rattazzi and with J. Serra


...you know what I'm craving?
A little perspective. That's it. I'd like some
fresh, clear, well-seasoned perspective. Can you
suggest a good wine to go with that?
-Anton Ego (Ratatouille)

The Naturalness Problem

Naturalness in the SM



1. All deformations are either irrelevant, marginal or very close to marginal (e.g. QCD)
2. Relevant deformations are forbidden by symmetries (e.g. fermion masses forbidden by chiral symmetry)
3. The relevant deformations are tuned to be small

Just fixed by NDA

$$\Delta\mathcal{L}_{\rm SM}^{\rm rel} = c\Lambda_{\rm UV}^2 H^\dagger H$$

$$m_h^2 = c\Lambda_{\rm UV}^2 + \delta m_h^2$$

In order to make sense of the level of cancellation we should go to a model where the Higgs mass is calculable

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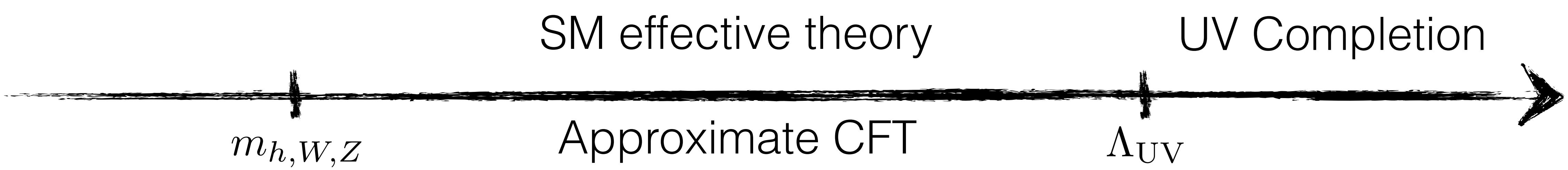
Naturalness is about symmetries and NDA

Naturalness in the SM



Examples

Supersymmetry

- Enhanced symmetry in the UV
- Supersymmetry broken softly

Strong dynamics

- IR scale dynamically generated
- In the UV Higgs mass term is irrelevant

New degrees of freedom expected at TeV scale

Naturalness in the SM

Viewing the SM as a low energy effective theory

$$\delta m_h^2 = \frac{3y_t^2}{4\pi^2}\Lambda_t^2 - \frac{9g^2}{32\pi^2}\Lambda_g^2 - \frac{3{g'}^2}{32\pi^2}\Lambda_{g'}^2 - \frac{3\lambda_h}{8\pi^2}\Lambda_h^2 + \ldots$$

we assume the scales Λ to be physical (eg masses of heavy particles)

e.g. $$\Lambda_t^2 \sim \frac{4\pi^2}{3y_t^2} \times \frac{m_h^2}{\epsilon_t}$$

numerically

$$\Lambda_t^2 \sim 0.45\sqrt{\frac{1}{\epsilon_t}}\,\text{TeV} \qquad \Lambda_g^2 \sim 1.1\sqrt{\frac{1}{\epsilon_g}}\,\text{TeV} \qquad \Lambda_{g'}^2 \sim 3.7\sqrt{\frac{1}{\epsilon_{g'}}}\,\text{TeV} \qquad \Lambda_h^2 \sim 1.3\sqrt{\frac{1}{\epsilon_h}}\,\text{TeV}$$

States “related” to the top quark are expected to be rather light

If they are coloured this already implies some tuning (main player LHC!)

Soft, supersoft, hypersoft

Charged Naturalness

Soft models

$$\Lambda_t^2 \sim \frac{2\pi^2}{3y_t^2} \times \frac{1}{\ln \Lambda_{\text{UV}}/\Lambda_t} \times \frac{m_h^2}{\epsilon_t}$$

- e.g. MSSM with large scale mediation
- already constrained at LEP and Tevatron
- higher tuning

Supersoft models

$$\Lambda_t^2 \sim \frac{4\pi^2}{3y_t^2} \times \frac{m_h^2}{\epsilon_t}$$

- e.g. MSSM with low scale mediation and composite models
- probed at the LHC
- moderate tuning

Neutral Naturalness

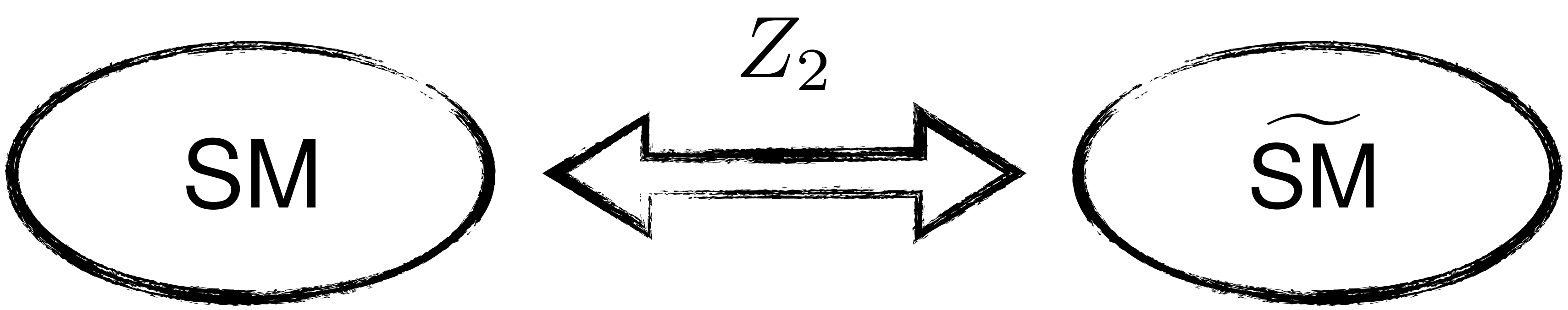
Hypersoft models

$$\Lambda_t^2 \sim \frac{4\pi^2}{3y_t^2} \times \frac{m_h^2}{\epsilon_t} \times \frac{g_*^2}{g_{\text{SM}}^2}$$

- mass of coloured objects pushed up
- evades LHC, testable at FCC
- lower tuning

The Twin Higgs Mechanism

The Twin Higgs Mechanism



Chacko, Goh, Harnik, hep-ph/0506256
Barbieri, Gregoire, Hall, hep-ph/0509242
Chacko, Nomura, Papucci, Perez, hep-ph/0510273
Chacko, Goh, Harnik, hep-ph/0512088
Chang, Hall, Weiner, hep-ph/0604076
……

Accidental $SO(8)$ $\qquad$ $SO(8)\to SO(4)\times\widetilde{SO(4)}$

$$V(\mathcal{H}) = -m_{\mathcal{H}}^2(|H|^2+|\widetilde{H}|^2) + \frac{\lambda_*}{2}(|H|^2+|\widetilde{H}|^2)^2 + \frac{\hat{\lambda}_h}{4}(|H|^4+|\widetilde{H}|^4)$$

SO(8) broken explicitly by $\hat{\lambda}_h$ and SM couplings

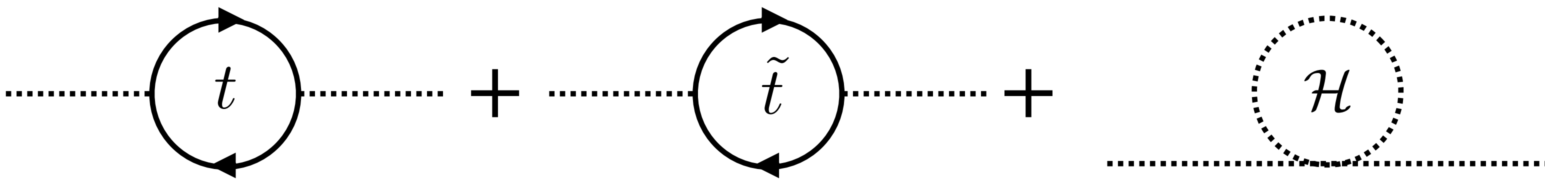
Treating $\hat{\lambda}_h$ as a perturbation one has

$\hat{\lambda}_h = 0$	$\langle\tilde{H}\rangle^2 = \frac{m_{\mathcal{H}}^2}{2\lambda_*} \equiv f^2$	$SO(8)/SO(7)$	7 Goldstone, 6 eaten and exactly massless Higgs
$\hat{\lambda}_h \ll \lambda_*$	$SO(8)\to SO(4)\times\widetilde{SO(4)}$	$\lambda_h \sim \hat{\lambda}_h$	$m_h^2 \sim \hat{\lambda}_h f^2/2 \sim (\lambda_h/2\lambda_*)m_{\mathcal{H}}^2$

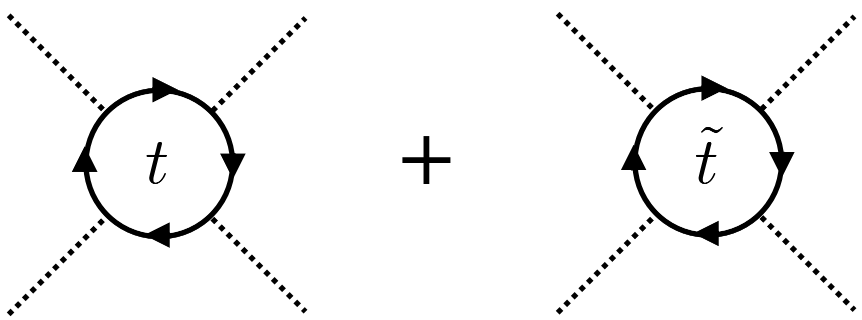
The physical Higgs mass is suppressed with respect to $m_{\mathcal{H}}^2$ by a factor $\sim \lambda_h/\lambda_*$

The Twin Higgs Mechanism

$$\lambda_h \sim \hat{\lambda}_h \qquad m_h^2 \sim \hat{\lambda}_h f^2/2 \sim (\lambda_h/2\lambda_*) m_{\mathcal{H}}^2$$



$$\Longrightarrow \quad \delta m_{\mathcal{H}}^2 \sim m_*^2$$



$$\Longrightarrow \quad \delta\hat{\lambda}_h \sim \frac{3y_t^4}{4\pi^2}\left(\ln\frac{m_*}{m_t} + \ln\frac{m_*}{m_{\tilde{t}}}\right)$$

Already saturates the SM value

Assuming λ_h is dominated by Yukawa induced RG

$$\Longrightarrow \quad \delta m_h^2 \gtrsim \frac{\lambda_h}{2\lambda_*} \times m_*^2 \simeq \frac{3y_t^2}{8\pi^2} \times \frac{y_t^2}{\lambda_*} \times m_*^2 \times \ln\frac{m_*}{m_t}$$

hypersoft

The maximal boost is obtained for the maximal λ_*

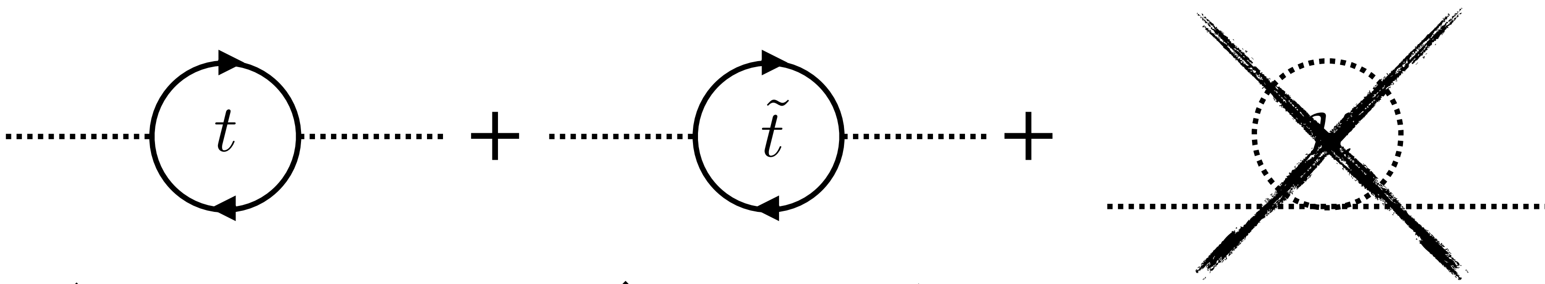
$$\frac{d\lambda_*}{d\log\mu} = \frac{N+8}{16\pi^2}\lambda_*^2 \quad \Longrightarrow \quad \lambda_* \lesssim \lambda_{\text{max}} \sim 16\pi^2/(N+8) \sim 10$$

Then scale of coloured particles becomes

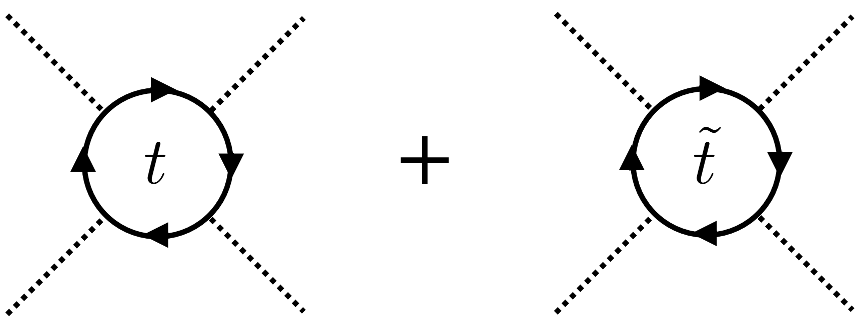
$$m_* \sim 2 \times \sqrt{\frac{\lambda_*}{10}} \times \sqrt{\frac{1}{\ln m_*/m_t}} \times \sqrt{\frac{1}{\epsilon}}\ \text{TeV}$$

The Twin Higgs Mechanism

One can do even better protecting $\mathcal{H}$ from large corrections



$$\Longrightarrow \quad \delta m_{\mathcal{H}}^2 \gtrsim \frac{3y_t^2}{4\pi^2} m_*^2$$



$$\Longrightarrow \quad \delta\hat{\lambda}_h \sim \frac{3y_t^4}{4\pi^2}\left(\ln\frac{m_*}{m_t} + \ln\frac{m_*}{m_{\tilde{t}}}\right)$$

Already saturates the SM value

$$\Longrightarrow \quad \delta m_h^2 \gtrsim \frac{\lambda_h}{2\lambda_*} \times \frac{3y_t^2}{4\pi^2} \times m_*^2 \sim \left(\frac{3y_t^2}{4\pi^2}\right)^2 \times \frac{y_t^2}{2\lambda_*} \times m_*^2 \times \ln\frac{m_*}{m_t}$$

super-hypersoft

Then scale of coloured particles becomes

$$m_* \sim 8 \times \sqrt{\frac{\lambda_*}{10}} \times \sqrt{\frac{1}{\ln m_*/m_t}} \times \sqrt{\frac{1}{\epsilon}}\,\text{TeV}$$

For maximal λ_* 10% tuning is enough to push the new coloured states to ~10TeV, out of LHC reach

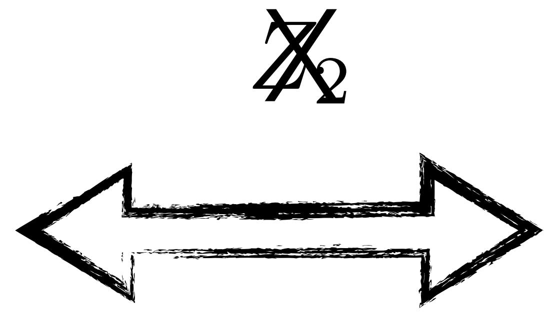
Even for a more reasonable $\lambda_* \sim 1$ resonances up by a factor ~3

$\Longrightarrow$ Main prediction: radial mode in LHC reach

Chang, Hall, Weiner, hep-ph/0604076
Craig, Howe, 1312.1341 [hep-ph]

Buttazzo, Sala, Tesi, 1505.05488 [hep-ph]

Z_2 breaking



In the Z_2 symmetric case the potential has possible minima

$$\langle H \rangle = \langle \tilde{H} \rangle = m_{\mathcal{H}}/\sqrt{\lambda_*} \quad \langle H \rangle = 0\,,\ \langle \tilde{H} \rangle = m_{\mathcal{H}}/\sqrt{2}\lambda_* \quad \langle \tilde{H} \rangle = 0\,,\ \langle H \rangle = m_{\mathcal{H}}/\sqrt{2}\lambda_*$$

In order to achieve $0 \neq \langle H \rangle \ll \langle \tilde{H} \rangle$ one needs to explicitly break the Z_2 symmetry

For instance a small Z_2 (soft) breaking mass term is sufficient

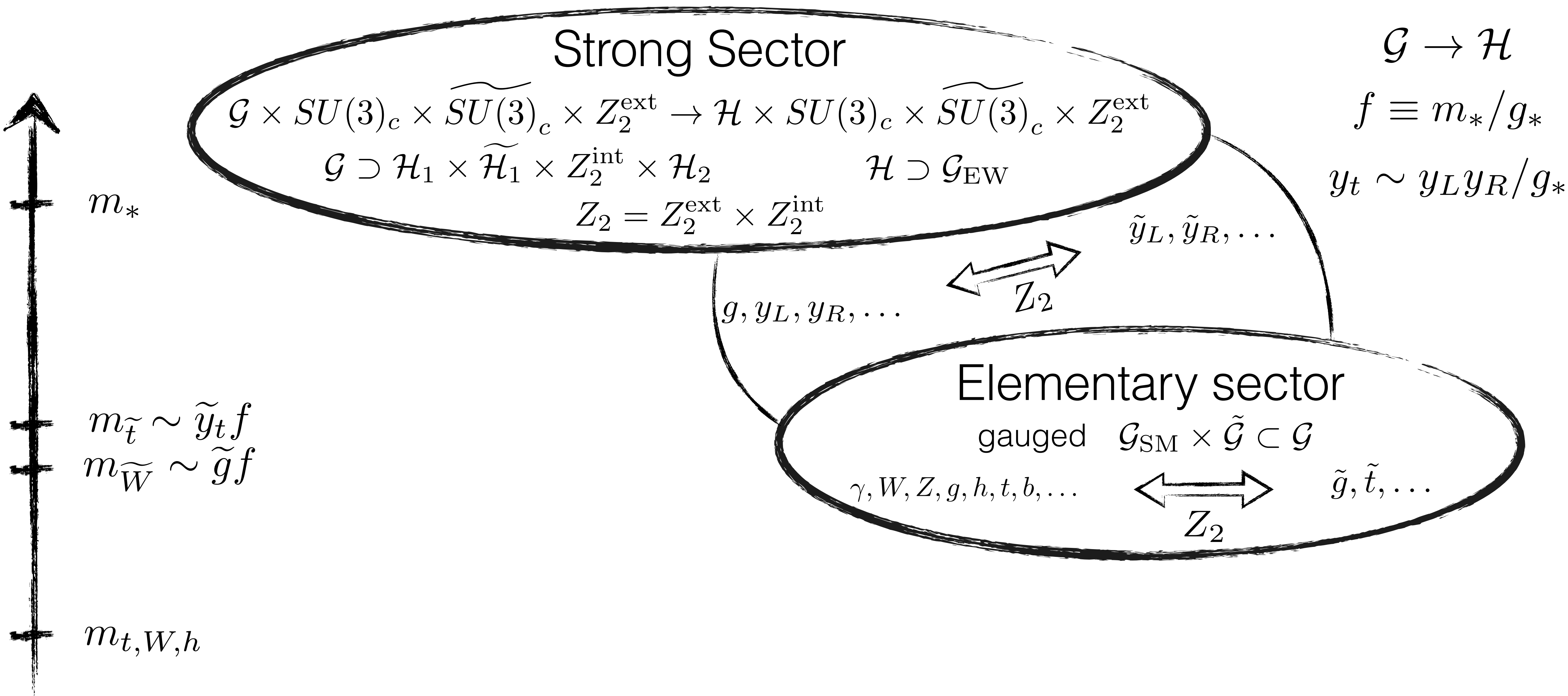
$$m^2 \left(|H|^2 - |\tilde{H}|^2 \right)$$

This can be realized in many ways, examples are:

1. Twin hypercharge is not gauged — *Barbieri, Greco, Rattazzi, Wulzer, 1501.07803 [hep-ph]*; *Low, Tesi, Wang, 1501.07890 [hep-ph]*
2. Only some fermions are twin (fraternal) — *Craig, Katz, Strassler, Sundrum, 1501.05310 [hep-ph]*
3. All twin EW group is not gauged (Javi) — *Serra, RT, to appear*
4. Hard breaking (relaxing ξ tuning) — *Katz, Mariotti, Pokorski, Redigolo, Ziegler*

Twin Higgs realisations

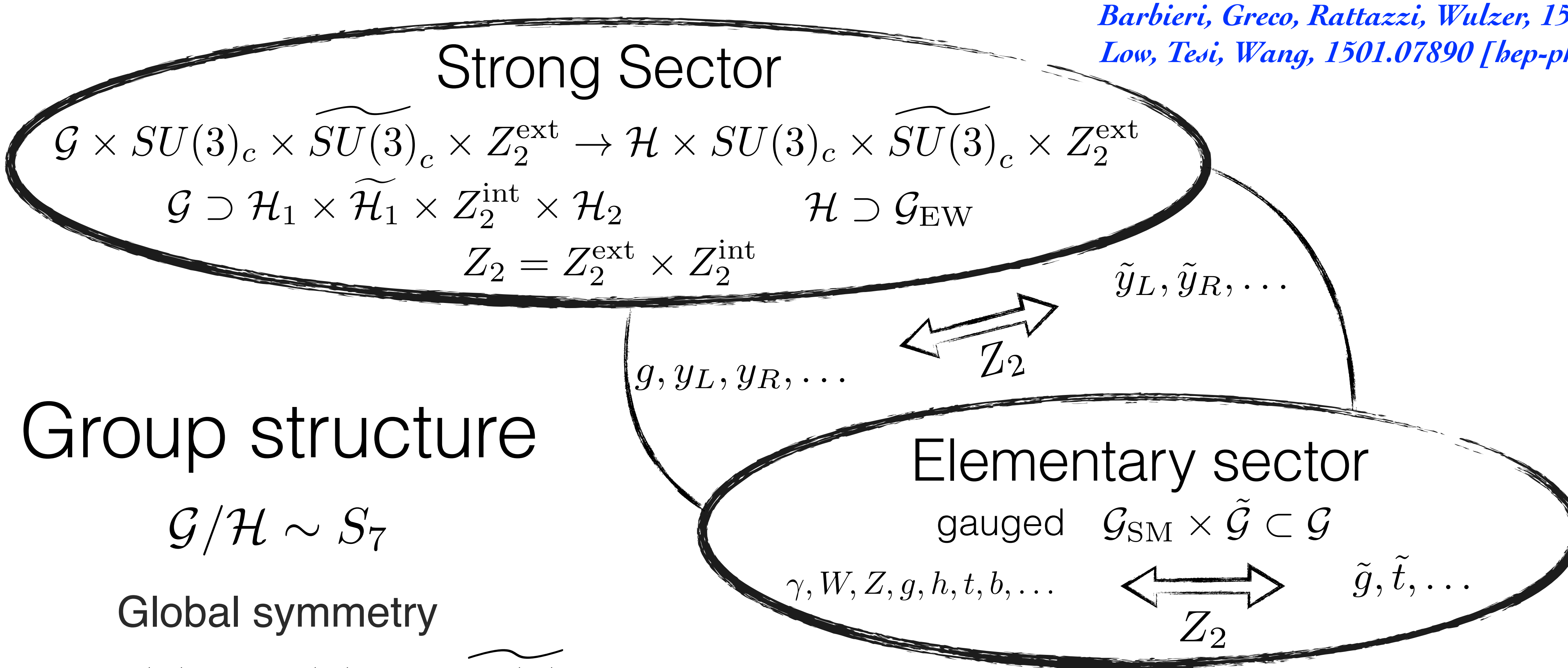
Essential ingredients



- Twin symmetry needed at least for the states most relevant for the Higgs potential and in particular the top
- If we want at least a twin copy of $SU(2)_L$ then $\text{rank}\,\mathcal{G} \geq 3$
- If some of the twin symmetries are not gauged this induces additional contributions to the Higgs potential which may be used to generate a viable potential
- Twin color should be gauged to avoid large Z_2 breaking RG effects on the top sector

Examples: Composite Twin Higgs

Barbieri, Greco, Rattazzi, Wulzer, 1501.07803 [hep-ph]
Low, Tesi, Wang, 1501.07890 [hep-ph]



Group structure

$$\mathcal{G}/\mathcal{H} \sim S_7$$

Global symmetry

$$\mathcal{G} = SO(8) \times U(1)_X \times \widetilde{U(1)}_X$$
$$\mathcal{H} = SO(7) \times U(1)_X \times \widetilde{U(1)}_X$$
$$\mathcal{H}_1 = SO(4) = SU(2)_L \times SU(2)_R$$
$$\widetilde{\mathcal{H}}_1 = \widetilde{SO(4)} = \widetilde{SU(2)}_L \times \widetilde{SU(2)}_R$$
$$\mathcal{H}_2 = \mathcal{I}$$

Gauge symmetry

$$T_L^a, \widetilde{T}_L^a, T_R^3 \;\; (Y = T_R^3 + X,\; Q = T_L^3 + Y)$$

Field content

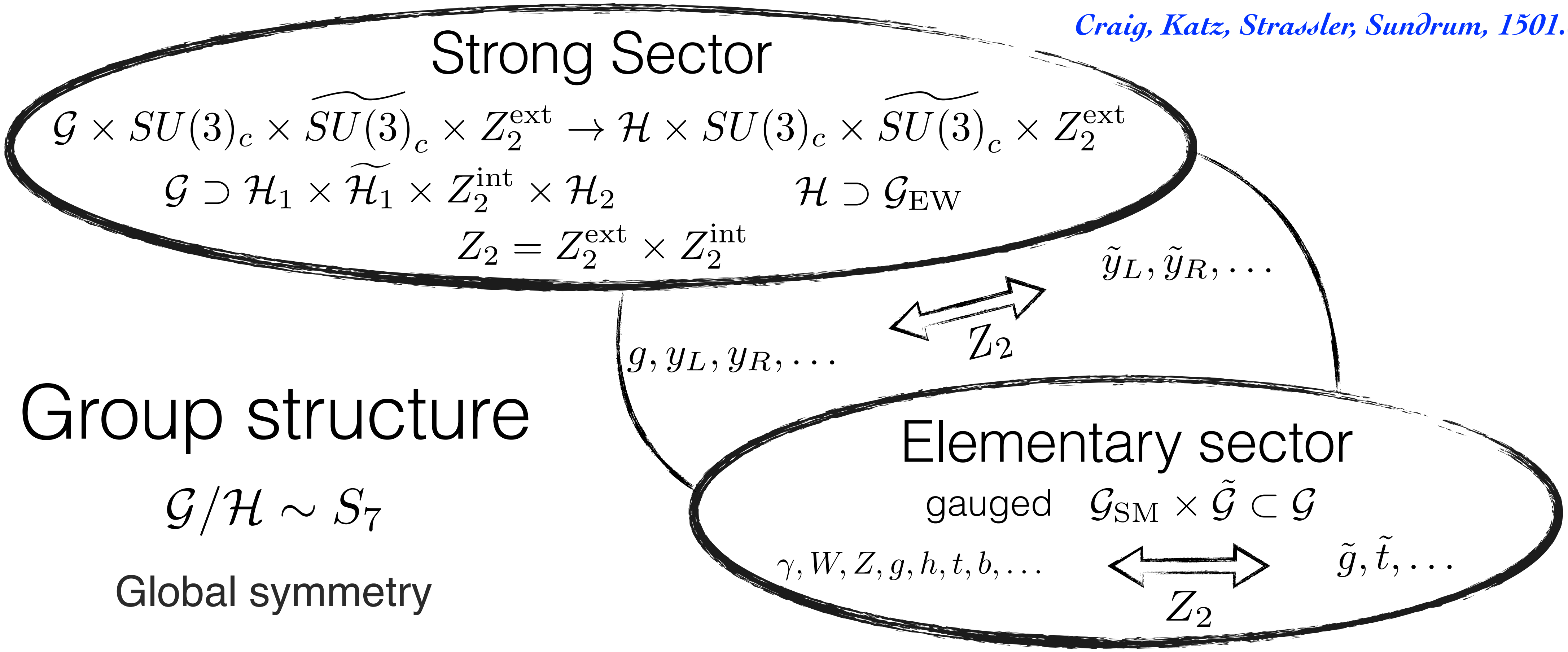
$\gamma, W, Z, g, h, \psi_{\rm SM}$	SM fields
$\widetilde{W}, \widetilde{Z}, \widetilde{g}, \widetilde{h}, \widetilde{\psi}_{\rm SM}$	Neutral under the SM

Twin symmetry explicitly broken by not gauging the twin hypercharge

No twin photon

Examples: Fraternal Twin Higgs

Craig, Katz, Strassler, Sundrum, 1501.05310 [hep-ph]



Group structure

$$\mathcal{G}/\mathcal{H} \sim S_7$$

Global symmetry

$$\mathcal{G} = SU(4)$$
$$\mathcal{H} = SU(3)$$
$$\mathcal{H}_1 = SU(2)_L$$
$$\widetilde{\mathcal{H}_1} = \widetilde{SU(2)}_L$$
$$\mathcal{H}_2 = U(1)_Y$$

Gauge symmetry

$$T_L^a, \widetilde{T}_L^a, Y \ \ (Q = T_L^3 + Y)$$

Field content

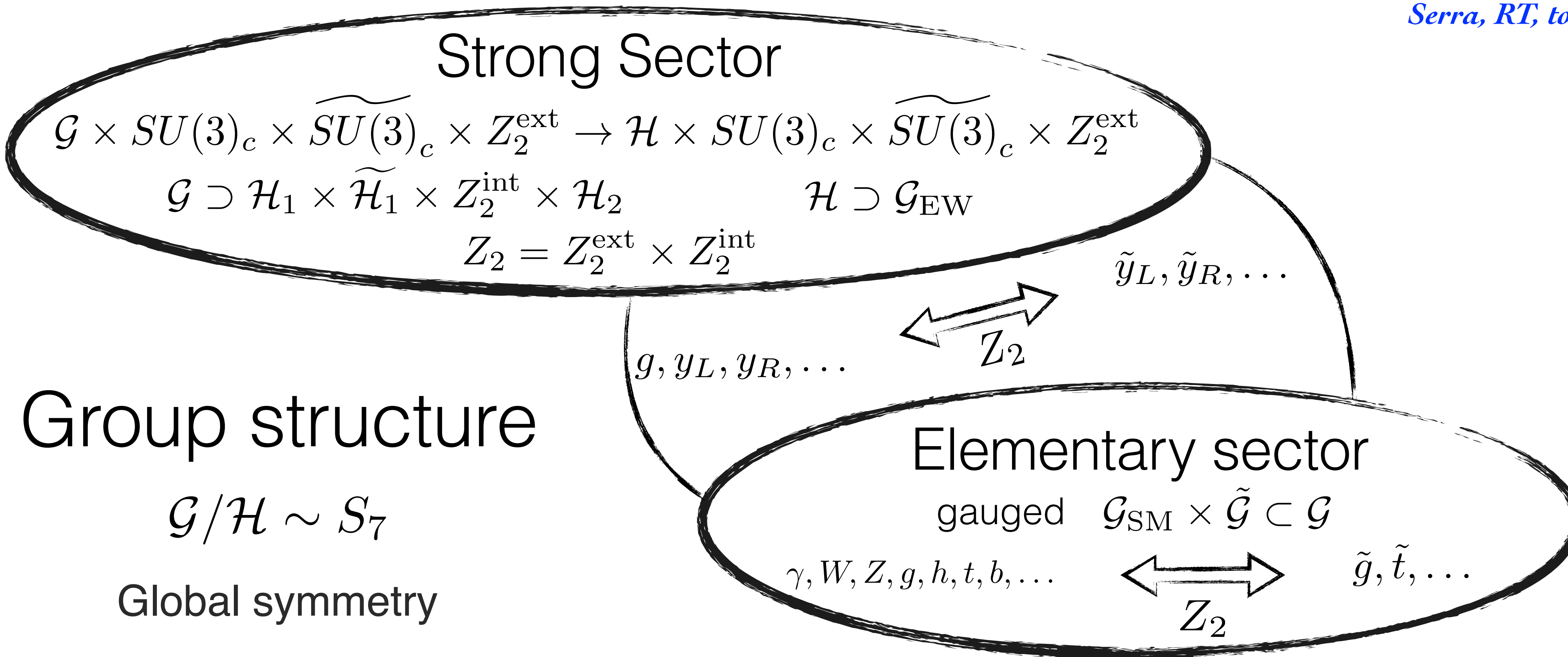
$\gamma, W, Z, g, h, \psi_{\rm SM}$	SM fields
$\widetilde{W}, \widetilde{Z}, \widetilde{g}, \widetilde{h}, \widetilde{q}_L, \widetilde{t}_R, \widetilde{b}_R, \widetilde{L}_\tau, \widetilde{\tau}_R$	Neutral under the SM

Twin symmetry explicitly broken by not gauging the twin hypercharge (small), and by QCD induced RG on the top Yukawa (large)

No twin photon and no other twin fermions

Examples: Exceptional Twin Higgs

Serra, RT, to appear



Group structure

$$\mathcal{G}/\mathcal{H} \sim S_7$$

Global symmetry

$$\mathcal{G} = SO(7) \times U(1)_X$$
$$\mathcal{H} = G_2 \times U(1)_X$$
$$\mathcal{H}_1 = SU(2)_L$$
$$\widetilde{\mathcal{H}_1} = \widetilde{SU(2)}_L$$
$$\mathcal{H}_2 = SU(2)_3$$

Gauge symmetry

$$T_L^a, \widetilde{T}_L^a, T_3^3 \;\; (Y = \widetilde{T}_L^3 + T_3^3 + X,\; Q = T_L^3 + Y)$$

Twin particles carry hypercharge!

Field content

$\gamma, W, Z, g, h, \psi_{\rm SM}$	SM fields
$\widetilde{W}, \widetilde{Z}, \widetilde{g}, \widetilde{h}, \widetilde{q}_L, \widetilde{t}_R, \widetilde{b}_R, \widetilde{L}_\tau, \widetilde{\tau}_R$	Only electric charge

Twin symmetry explicitly broken by not gauging the twin hypercharge (small), and by QCD induced RG on the top Yukawa (large)

No twin photon and no other twin fermions

Composite Twin Higgs

Composite Twin Higgs

$$\frac{SO(8)}{SO(7)} \supset \frac{SO(4)\times \widetilde{SO(4)}}{SO(4)\times \widetilde{SO(3)}} \sim \frac{SU(2)_L\times SU(2)_R\times \widetilde{SU(2)}_L\times \widetilde{SU(2)}_R}{\underbrace{SU(2)_L\times SU(2)_R}\times \underbrace{\widetilde{SU(2)}_{L+R}}}$$

7 Goldstone bosons $\quad (2,2,0)\sim H \quad (1,1,3)\sim\omega$

- ω triplet eaten by the twin W, $m_{\widetilde{W}} \sim gf/2$
- Twin fermions acquire a mass $m_{\widetilde{f}} \sim y_f f/\sqrt{2}$
- Weak gauging and linear mixings (partial compositeness) break explicitly the global symmetry
- Higgs potential arises as in CH
- Strong sector resonances at $m_* \sim g_* f$
- Need $g_* \gg g_{SM}$ to avoid constraints from direct searches

Higgs potential and mass

Higgs potential at the scale m_*

$$\frac{V(h,m_*)}{f^4} = L_1(g_1^2, \Delta y_L^2, m_*)\sin^2\left(\frac{h}{f}\right) + \frac{3y_L^4}{64\pi^2}F_1(m_*, y_R)\left(\sin^4\left(\frac{h}{f}\right) + \cos^4\left(\frac{h}{f}\right)\right)$$

Z_2 breaking | Z_2 preserving

L_1 fixed by requiring the existence of a minimum

⇓

m_t | $m_{\tilde{t}}$ | m_*

running down the quartic

$$(m_h^2)_{\rm IR} = (m_h^2)^{\rm SM} + (m_h^2)^{\rm TW}$$

"model independent"

+

threshold contribution

$$(m_h^2)_{UV} = \frac{3y_L^4 F_1}{4\pi^2} f^2 \xi(1-\xi)$$

"model dependent"

⇓

$$m_h^2 = (m_h^2)_{UV} + (m_h^2)_{IR}$$

Z_2 symmetric contribution

Order g^2, y_L^2 (UV)

$$V_{g^2}(H) \approx \frac{g_\rho^2 f^4}{16\pi^2}\left[g^2 \sin^2\left(\frac{H}{f}\right) + \widetilde{g}^2 \cos^2\left(\frac{H}{f}\right)\right]$$

$$V_{y_L^2}(H) \approx \frac{N_c g_*^2 f^4}{16\pi^2}\left[y_L^2 \sin^2\left(\frac{H}{f}\right) + \widetilde{y}_L^2 \cos^2\left(\frac{H}{f}\right)\right]$$

vanish for exact Z_2

model dependent

Order y_L^4 (UV)

$$V_{\rm UV}(H) = \frac{N_c f^4}{128\pi^2}\left[\left(y_L^4 F_1 + \widetilde{y}_L^4 \widetilde{F}_1\right)\left(\sin^4\frac{H}{f} + \cos^4\frac{H}{f}\right) + \left(y_L^4 F_2 - \widetilde{y}_L^4 \widetilde{F}_2\right)\left(\sin^2\frac{H}{f} - \cos^2\frac{H}{f}\right)\right]$$

Order y_t^4 (IR)

$$V_{\rm IR}(H) = \frac{N_c f^4}{64\pi^2}\left[y_t^4 \sin^4\frac{H}{f}\log\frac{2m_*^2}{y_t^2 f^2 \sin^2\frac{H}{f}} + \widetilde{y}_t^4 \cos^4\frac{H}{f}\log\frac{2m_*^2}{\widetilde{y}_t^2 f^2 \cos^2\frac{H}{f}}\right]$$

Z_2 breaking contribution, e.g. g'

direct contribution

$$V_{g_2'^2}(H) \approx \frac{g_\rho^2 f^4}{16\pi^2} g'^2 \sin^2\left(\frac{H}{f}\right)$$

too small

RG induced contribution

$$V_{y_t^2}(H) \approx \frac{N_c f^4 g_*^2}{16\pi^2} \Delta y_y(m_*)^2 \sin^2 \frac{H}{f}$$

$$\Delta y_t(m_*)^2 = \frac{b g_1^2}{16\pi^2} y_L(m_*)^2 \log \frac{\Lambda_{\rm UV}}{m_*}$$

ok, but requires a very high scale

$$\log \frac{\Lambda_{\rm UV}}{m_*} \gtrsim \frac{50}{b}$$

other option is breaking Z_2 through RG induced by color running with different matter content (e.g. fraternal)

Higgs mass

Infrared contribution to Higgs mass is dominant and should almost saturate the observed value

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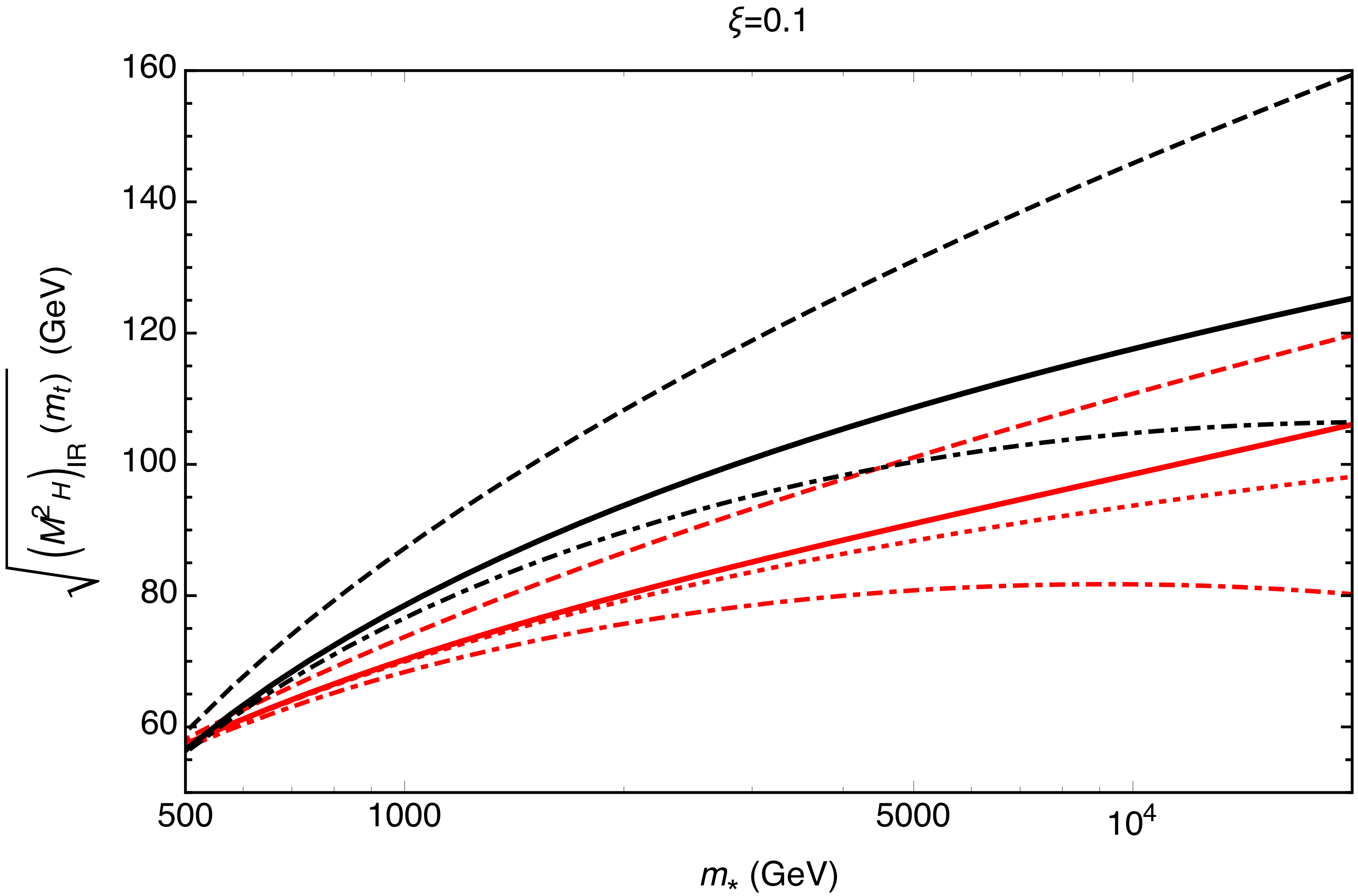
at LL numerically typically overshoots but resummation is expected to decrease (like in SM)



NLL: Contino, Greco, Mahbubani, Rattazzi, RT, to appear
Resummation: Greco, Mimouni, to appear

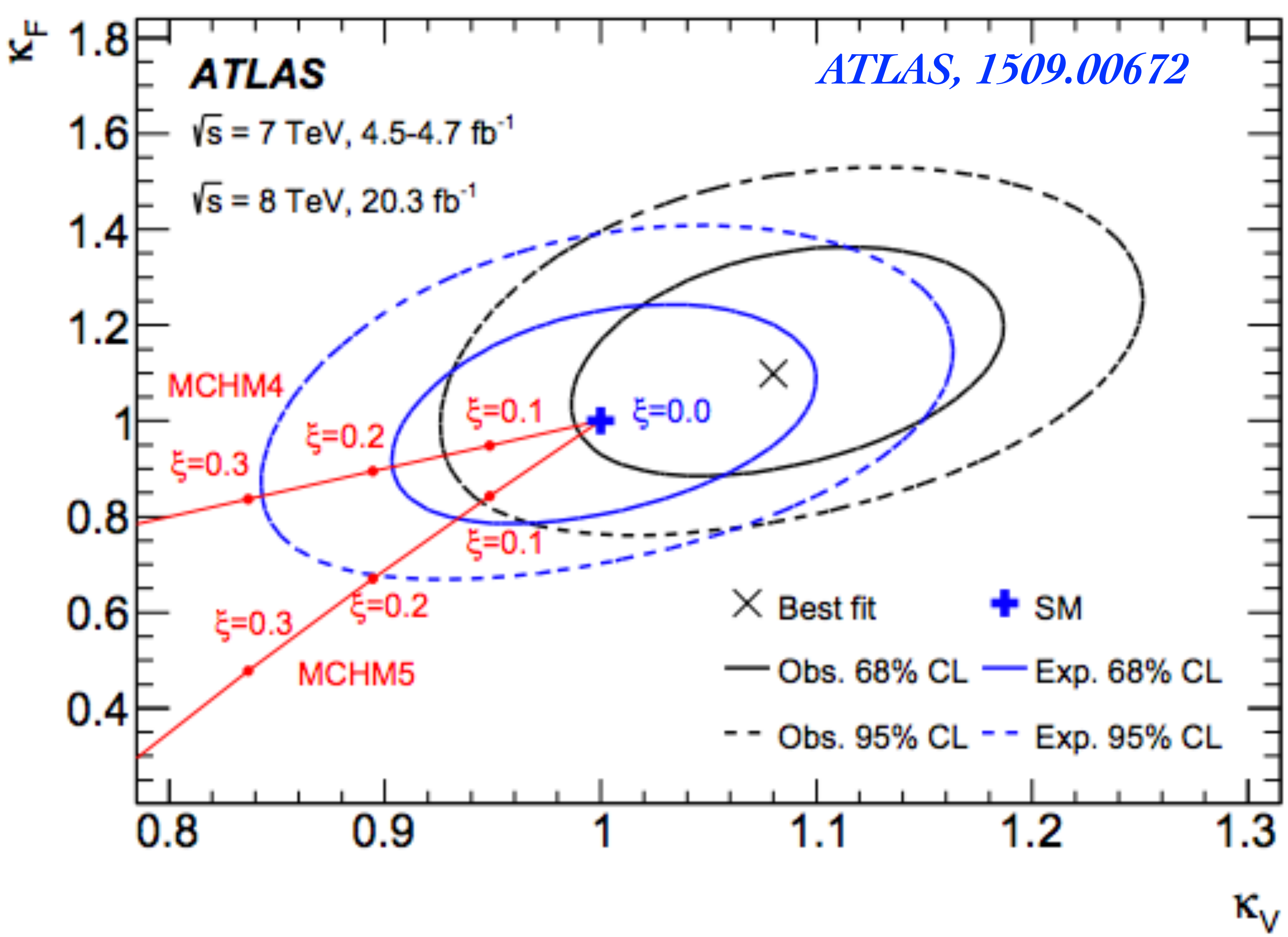
Electroweak precision observables

Tuning in the TH

The boost in mass of the coloured states is proportional to g_*

Higher dimensional operators in the Higgs sector in the low energy EFT with coefficient proportional to g_*/Λ do not decouple when g_* is made large

$$\frac{g_*}{\Lambda} \sim \frac{g_*}{m_*} \sim \frac{g_*}{g_* f} \sim \frac{1}{f} \quad \Longrightarrow \quad \xi \equiv \frac{v^2}{f^2}$$



- Unavoidable tuning ξ from Higgs couplings
- LHC constraint ~10-20%
- HL-LHC prospect ~5%
- clever constructions (hard Z_2 breaking, tadpole induced EWSB) can relax tuning

Katz, Mariotti, Pokorski, Redigolo, Ziegler

Harnik, Howe, Kearney, 1603.03772 [hep-ph]

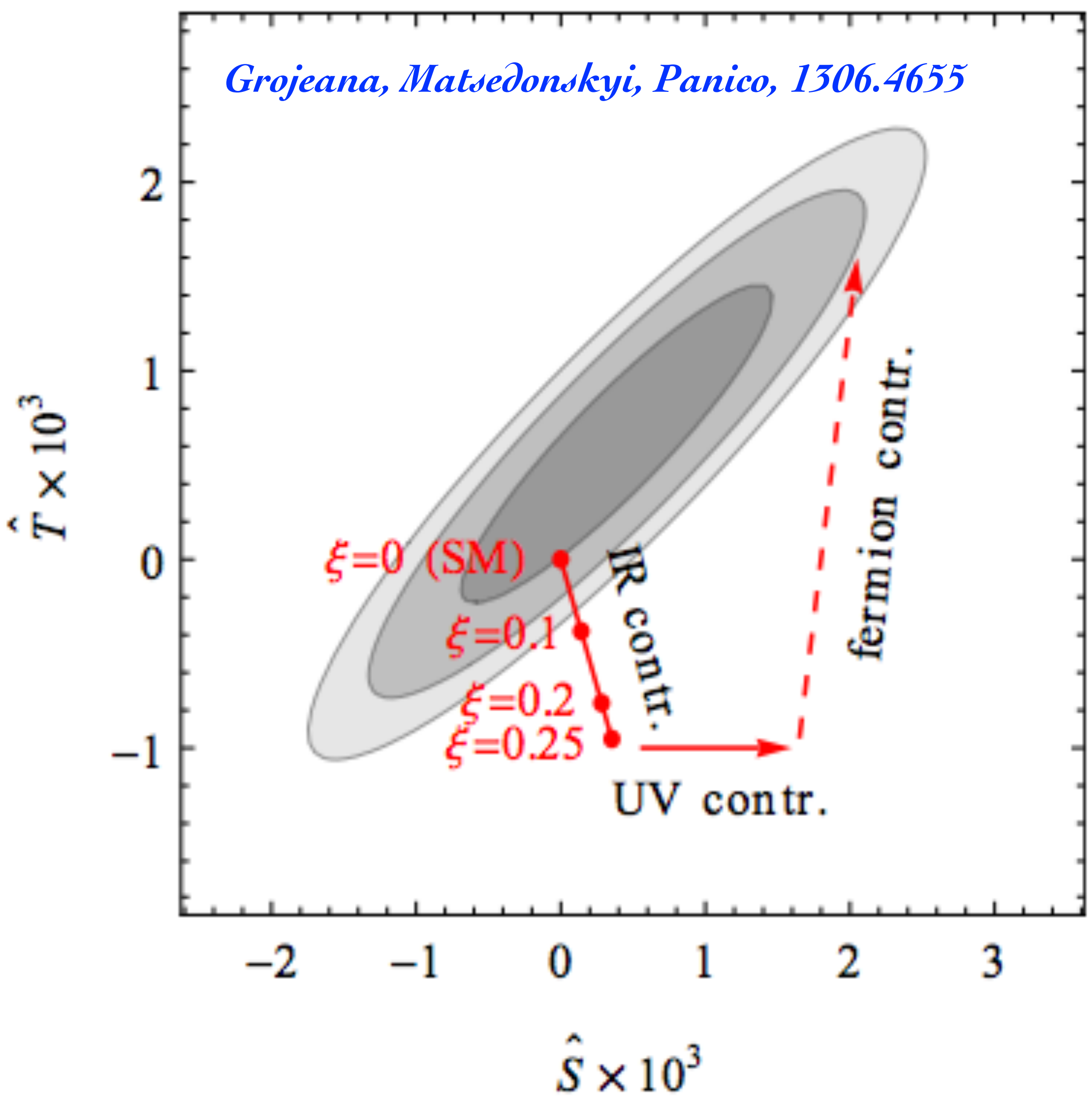
see also R. Ziegler's talk

Tuning in the TH

In composite models typically more severe constraint from oblique corrections ~5%

In standard CH relaxed via additional positive contributions to T from top partners, e.g.

$$\Delta\hat{T} \propto \frac{y_t^4 v^2}{m_*^2}$$



These effects decouple for large mass

Custodial breaking larger than y_t could help but

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Interplay with Higgs potential

Remember that the quartic already comes of the right size!

Higgs potential vs EWPO

Fix UV contribution to the Higgs mass

Fix all SM inputs including top and Higgs mass

⇓

Interplay between Higgs potential and EWPO (2 site model enough to calculate)

Contino, Greco, Mahbubani, Rattazzi, RT, to appear

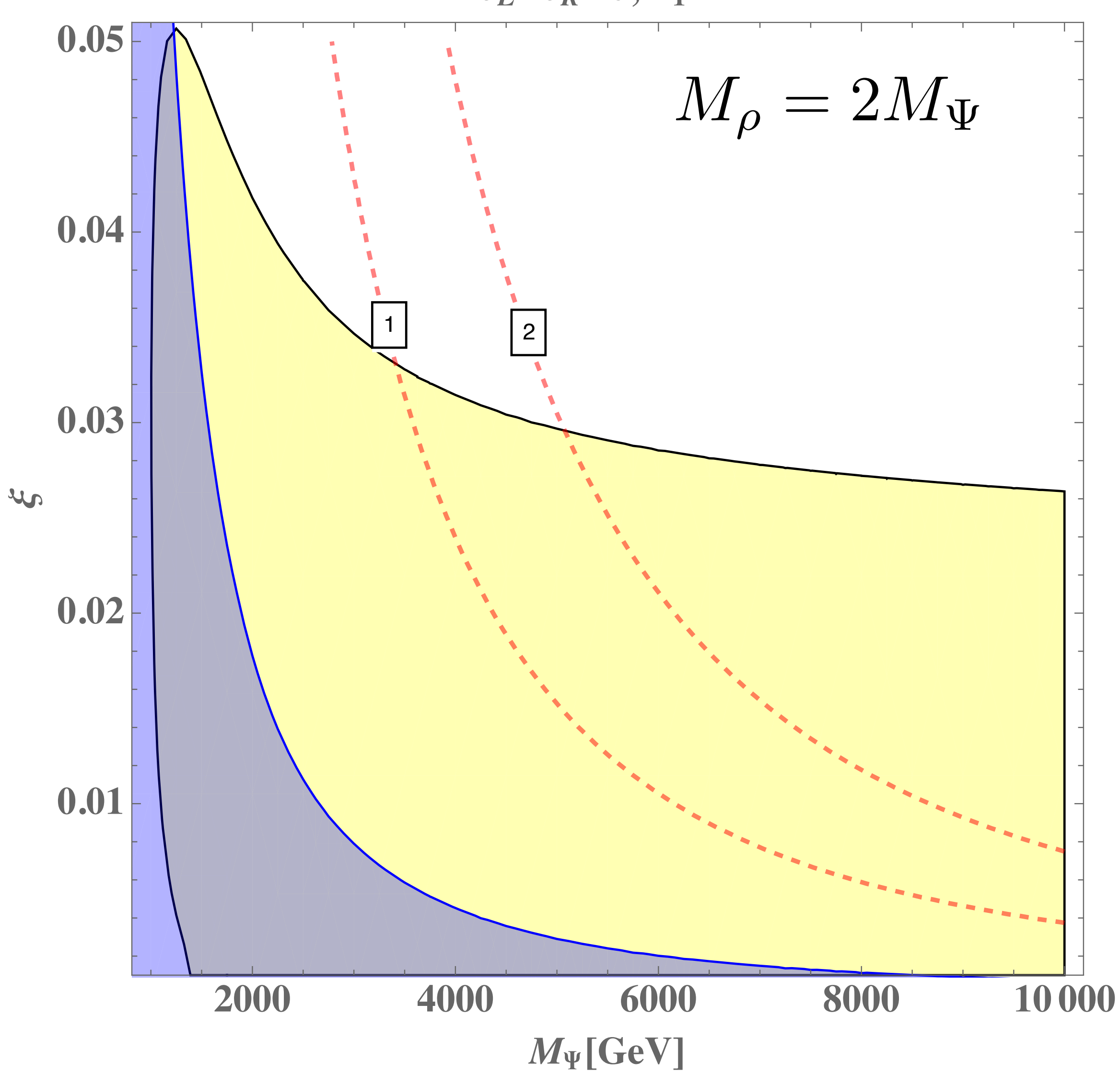
Main effects from

$$\hat{S}, \hat{T}, \delta g_{Zb_Lb_L}$$

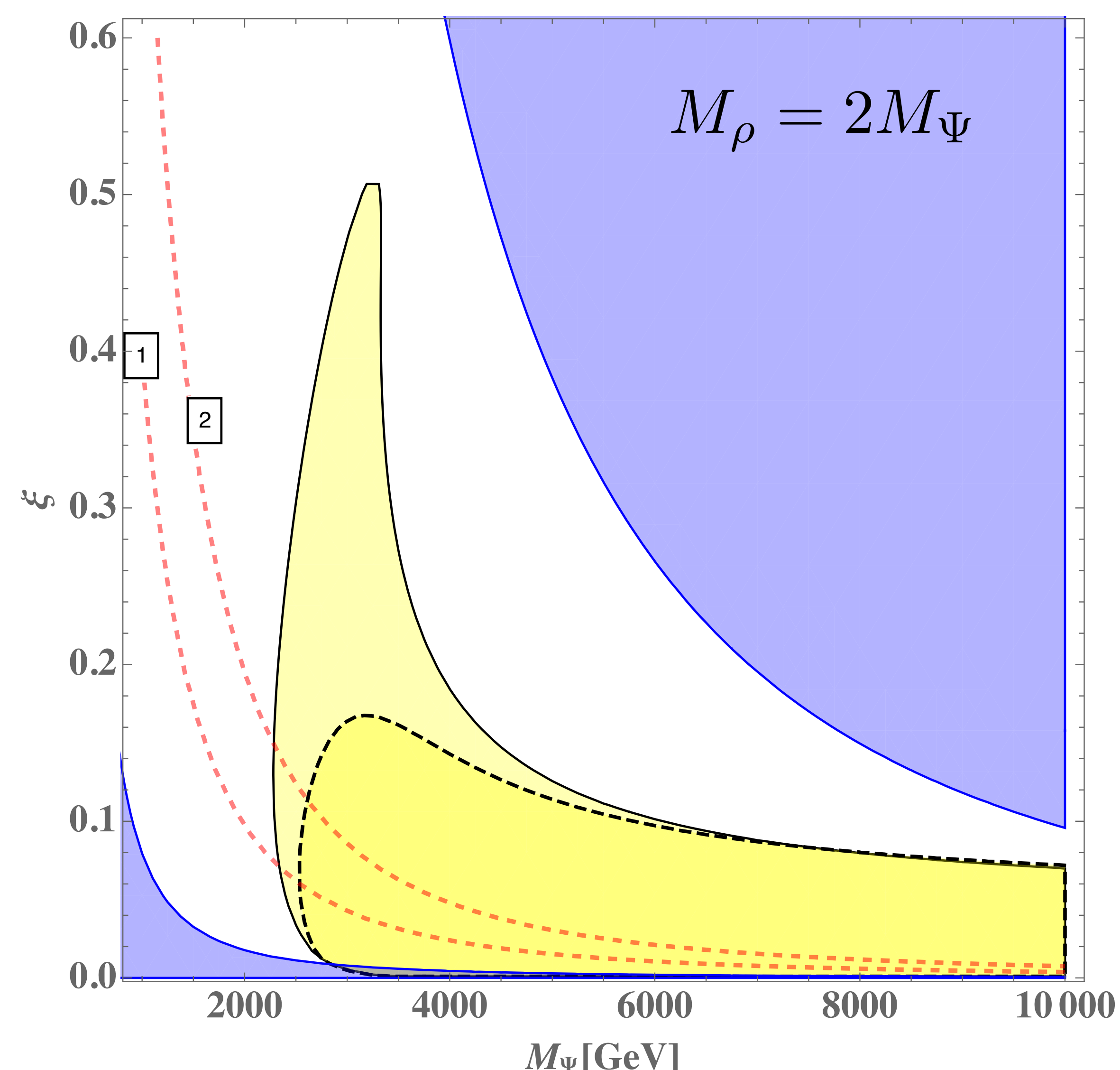
“large UV contribution” to m_h

$$F_1 = 1$$

$c_L = c_R = 0, F_1 = 1$



$c_L = c_R = 1/\sqrt{2}, F_1 = 1$



Higgs potential vs EWPO

Fix UV contribution to the Higgs mass

Fix all SM inputs including top and Higgs mass

⇓

Interplay between Higgs potential and EWPO (2 site model enough to calculate)

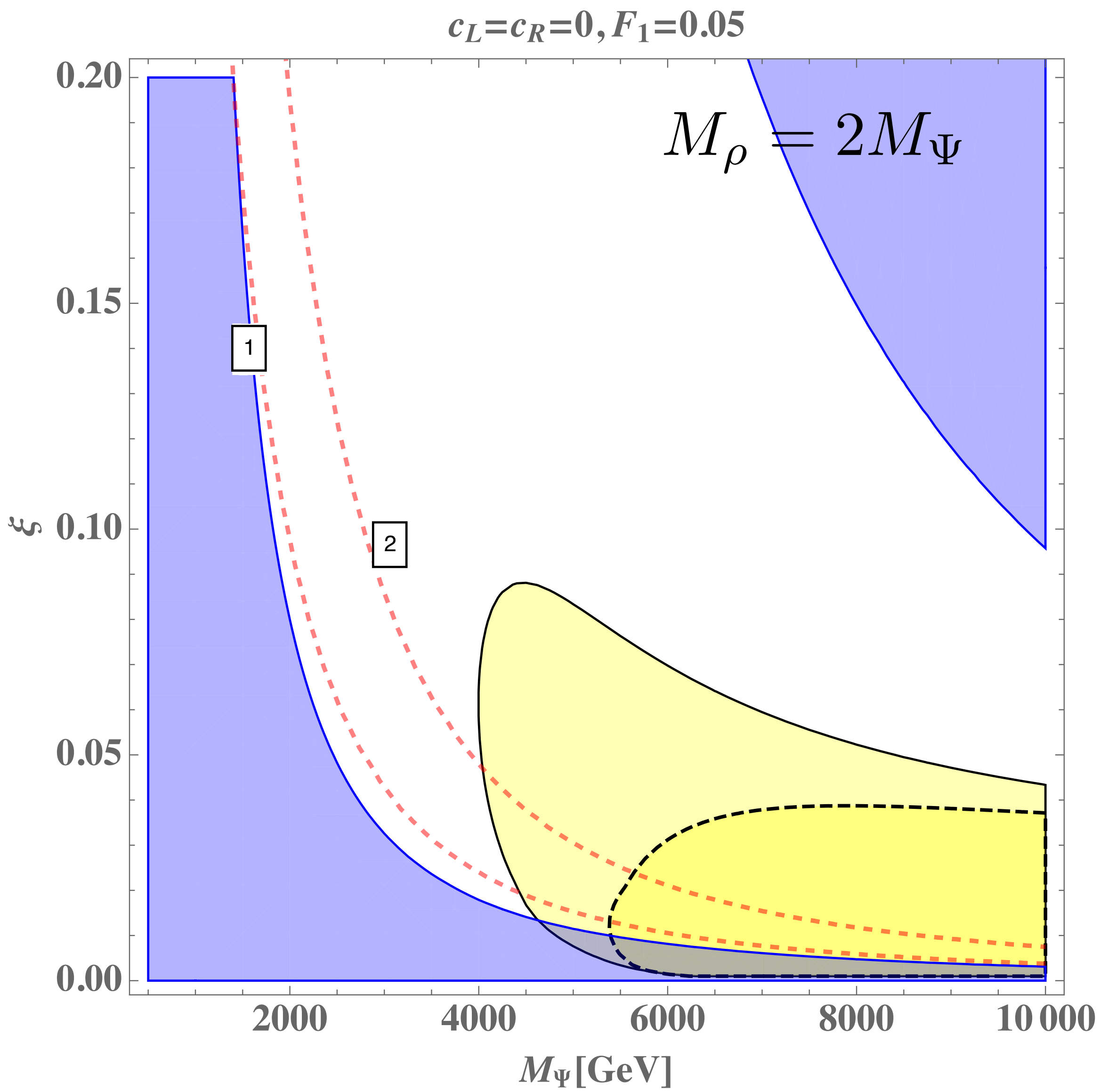
Contino, Greco, Mahbubani, Rattazzi, RT, to appear

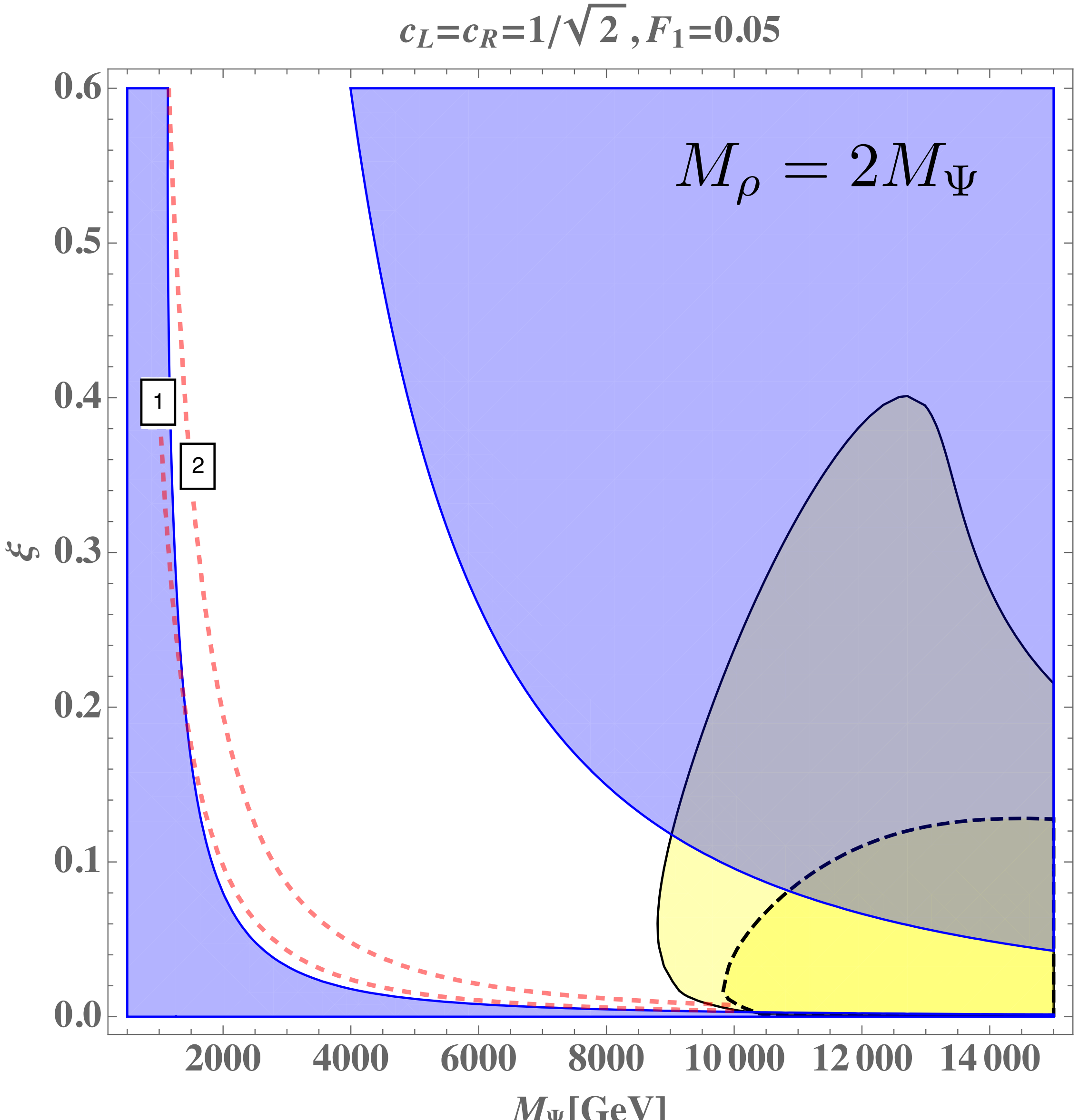
Main effects from

$\hat{S}, \hat{T}, \delta g_{Zb_Lb_L}$

"small UV contribution" to m_h

$F_1 = 0.05$





Phenomenology

Phenomenology

Phenomenology extremely rich and crucially depends on the value of λ_* and the mechanism of Z_2 breaking

Small λ_* $\Rightarrow$ weakly coupled dynamics (e.g. SUSY TH)

Main prediction is an extended scalar sector (radial mode)

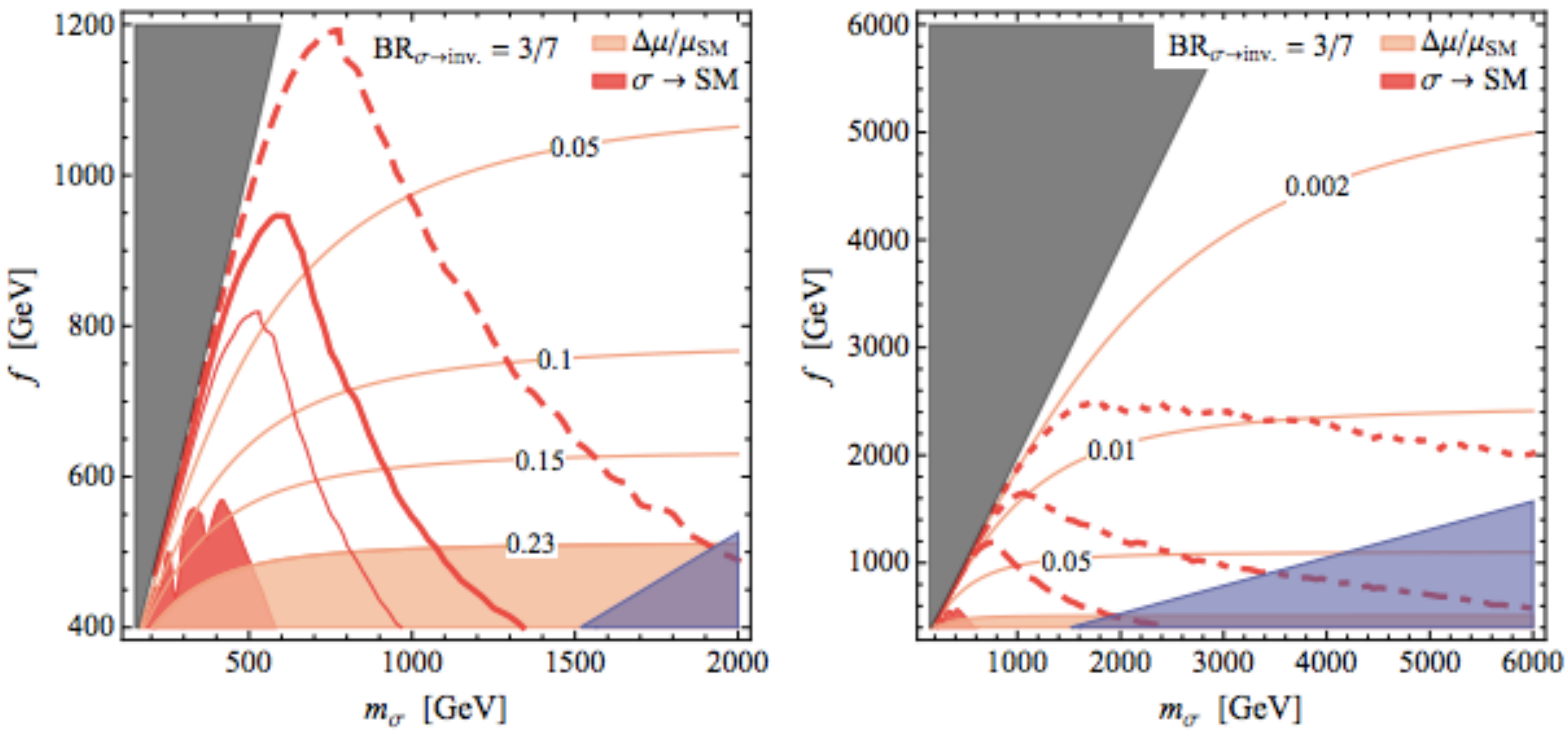


Figure 10. Model with BR$_{\sigma\to\text{inv.}} = 3/7$. Shaded regions: excluded at 95% C.L. by Higgs couplings (pink), excluded by direct searches (red), $\Gamma_\sigma > m_\sigma$ (blue), unphysical parameters (grey). The notation for the lines is as in figure 7.

Buttazzo, Sala, Tesi, 1505.05488 [hep-ph]

Phenomenology

Phenomenology extremely rich and crucially depends on the value of λ_* and the mechanism of Z_2 breaking

Large λ_* $\Rightarrow$ strongly coupled dynamics (e.g. Composite TH)

Composite TH

Barbieri, Greco, Rattazzi, Wulzer, 1501.07803 [hep-ph]
Low, Tesi, Wang, 1501.07890 [hep-ph]

- Z_2 broken only in EW sector (e.g. only by twin hypercharge)
- cosmology typically hard (twin neutrinos/photon contribute large N_{eff})
- only signature in Higgs coupling modifications (and Higgs invisible decays)

$\Downarrow$

hardest to test at LHC

need FCC-ee/CEPC/ILC/CLIC to test Higgs couplings

and/or

FCC-hh/SppC to access spectrum of resonances

Phenomenology

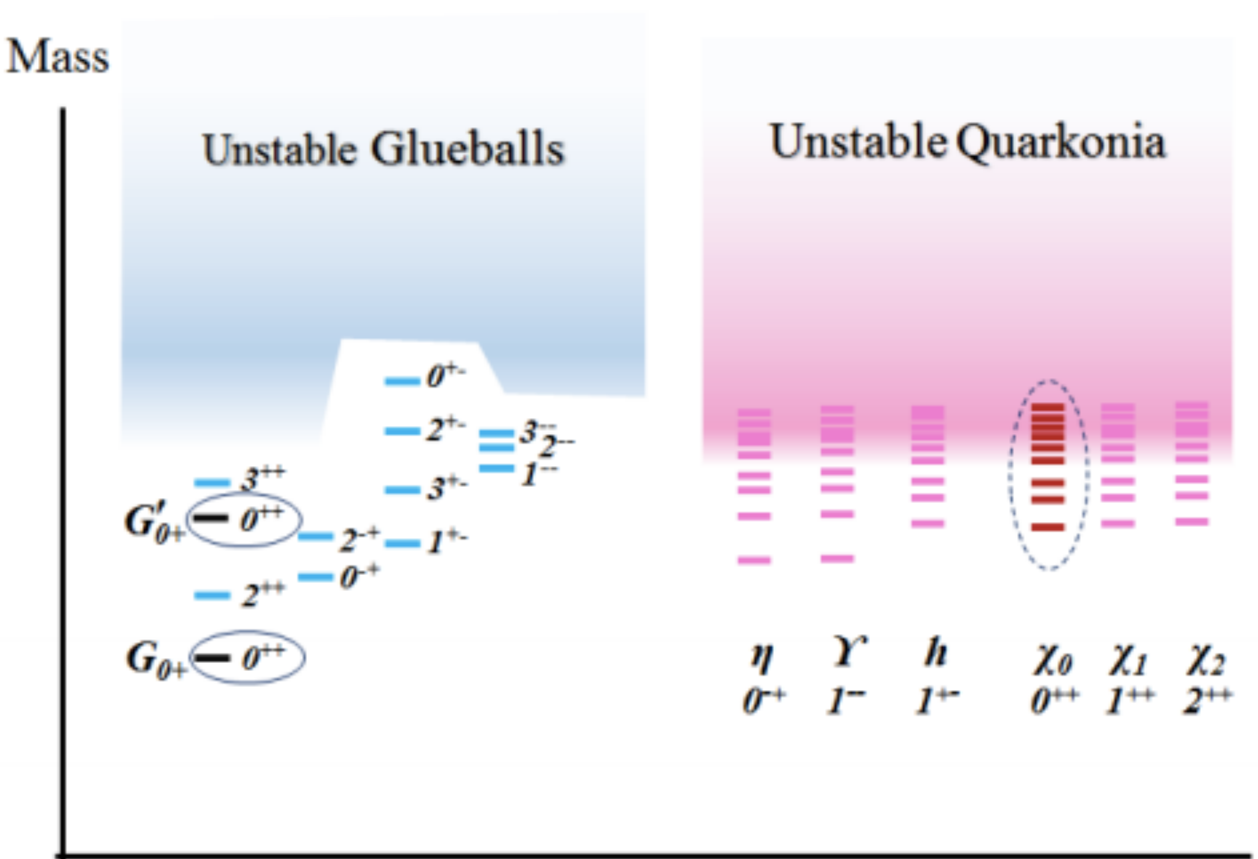
Phenomenology extremely rich and crucially depends on the value of λ_* and the mechanism of Z_2 breaking

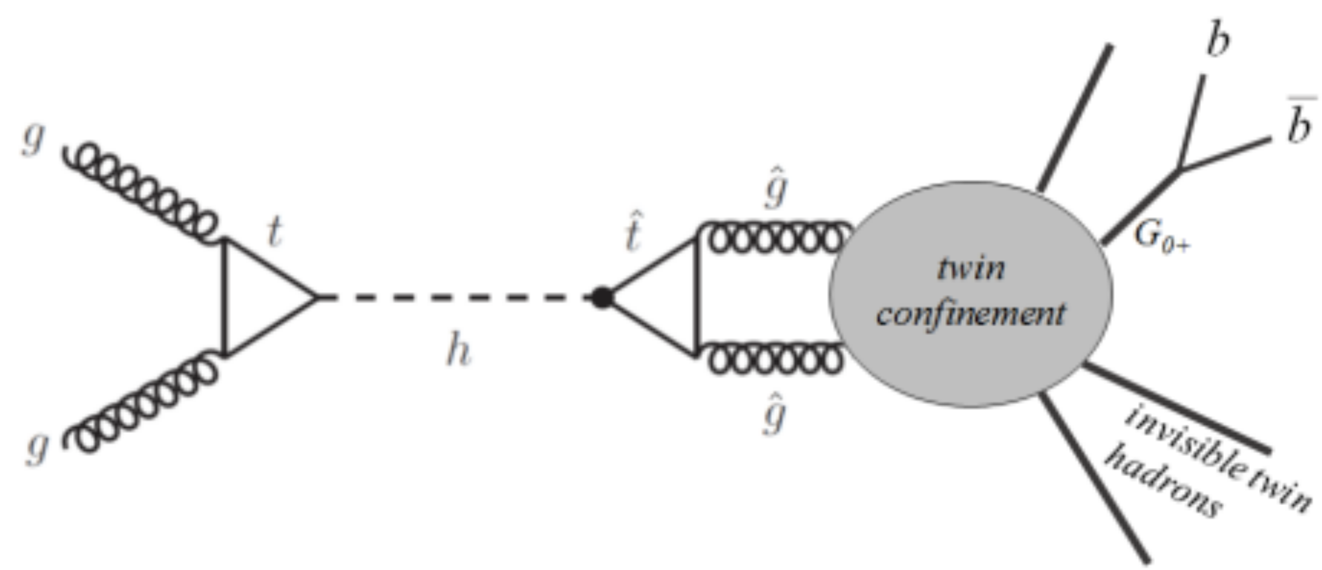
Large λ_* $\Rightarrow$ strongly coupled dynamics (e.g. Composite TH)

Fraternal TH

Craig, Katz, Strassler, Sundrum, 1501.05310 [hep-ph]

- Z_2 broken in the color sector (e.g. by RG induced by different matter content)
- twin QCD has a larger confinement scale





Phenomenology

Phenomenology extremely rich and crucially depends on the value of λ_* and the mechanism of Z_2 breaking

Large λ_* $\Rightarrow$ strongly coupled dynamics (e.g. Composite TH)

Exceptional TH

Serra, RT, to appear

- twins carry hypercharge (phenomenology different even in Z_2 symmetric limit)
- gauging the twin SU(2) imposes strong constraints from twin Z' (both direct and indirect, e.g. Y parameter)
- light SM fermions twins should be decoupled (constraints on light charged particles)
- minimal source of Z_2 breaking from lack of even a global twin hypercharge group
- larger Z_2 breaking similar to fraternal from twin QCD
- phenomenology similar to the fraternal but with some twins carrying electric charge
- stable neutral meson could be a dark matter candidate

Conclusions

- The Twin Higgs mechanism, joined with a suitable UV completion, offers a compelling mechanism to naturally increase the mass of coloured particles and a rich “non-standard” phenomenology

- In the most optimistic/pessimistic case (depending on the point of view) twin particles are totally neural under the SM gauge group and can elude LHC@14TEV searches giving one motivation for future collider experiments

- Clever model building is needed to “saturate” the parametric gain in the mass of coloured resonances

- If the LHC will continue to deliver null results and we will still want to insiste on naturalness then neutral naturalness (and its TH realization) will deserve more detailed studies both on the phenomenology and model building sides

THANK YOU