How to Modify the Higgs Mass and Couplings in Supersymmetry (with Technicolor)

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ITP SUSY Mini-Workshop 2014

Work w/ Azatov, Craig, Galloway, Luty

Talk Outline

- Supersymmetry and Technicolor Combined
- Induced Electroweak Symmetry Breaking: Higgs Mass and Naturalness Implications
- Higgs, Techni-states Phenomenology

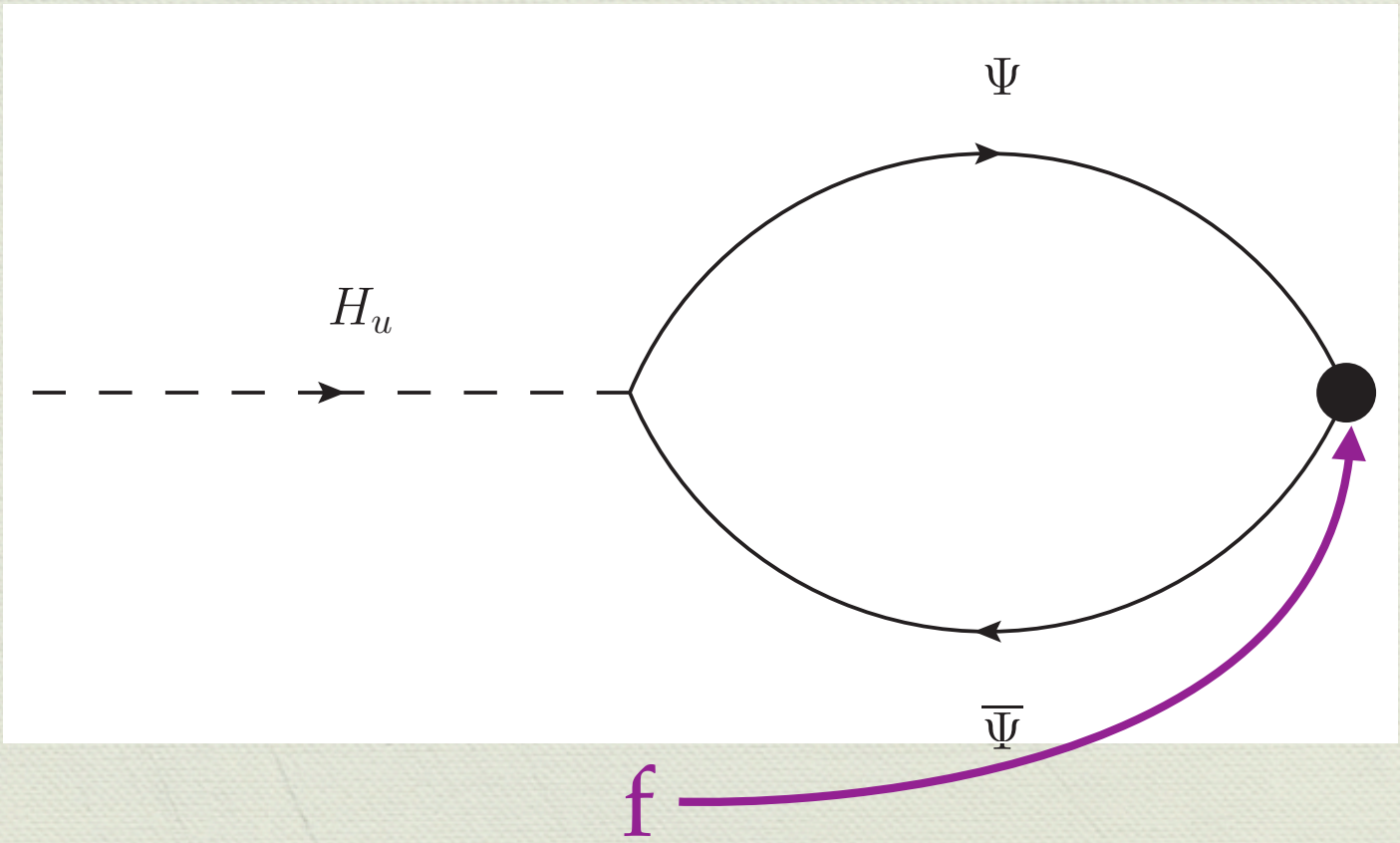
SUSY + Technicolor

- Supersymmetry plus technicolor is an interesting combination
- If technicolor initiates EWSB at a scale $f \ll v$, can induce EWSB in elementary Higgs sector, $v_u, v_d \gg f$

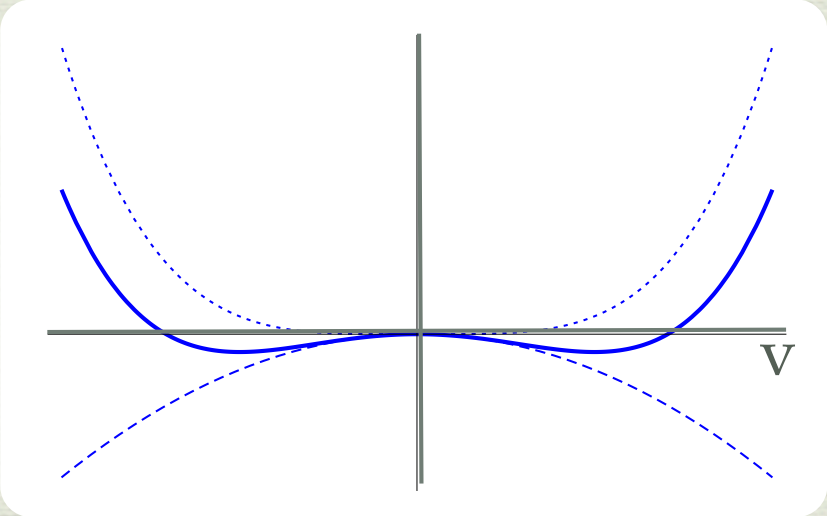
Dimopoulos, Raby
Dine, Fischler, Srednicki
Simmons
....
Azatov, Galloway, Luty
....

Tadpole Couplings

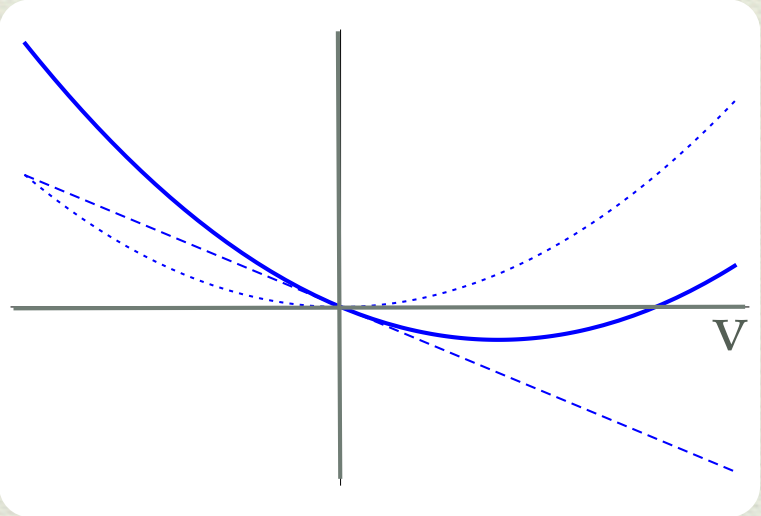
$$V \supset 4\pi f^3 \, Tr\left[\Sigma(\lambda_d H_d \; \lambda_u H_u)\right] + c.c.$$



Standard EWSB
via Mexican Hat

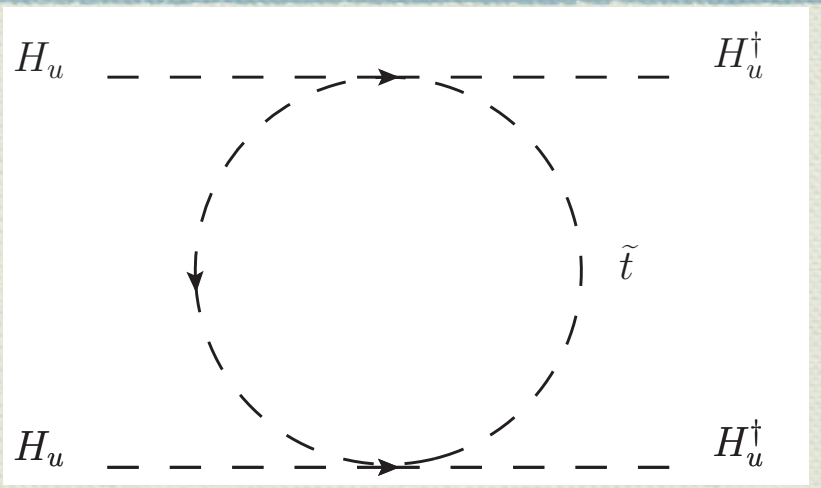


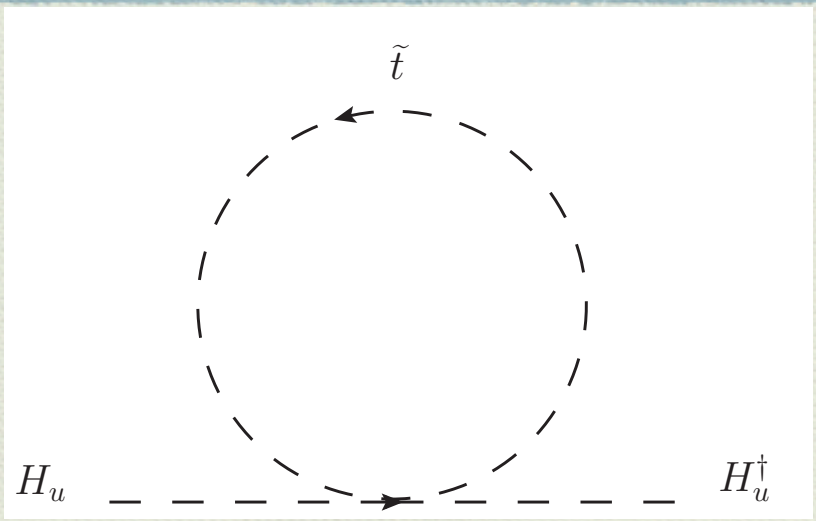
EWSB induced by
linear tadpole



Mechanism	Standard	Tadpole
Unstable/Stable Terms	Mass Term/Quartic	Linear Term/ Mass
Higgs Mass	$2\lambda v^2$	M^2

SUSY (Un)Naturalness





$$\delta m_h^2 \propto y_t^4 \ln \frac{m_{\tilde{t}}}{m_t}$$

$$m_{H_u}^2 \propto y_t^2 m_{\tilde{t}}^2$$

MSSM unnaturalness due to Higgs mass being log related to SUSY mass scale

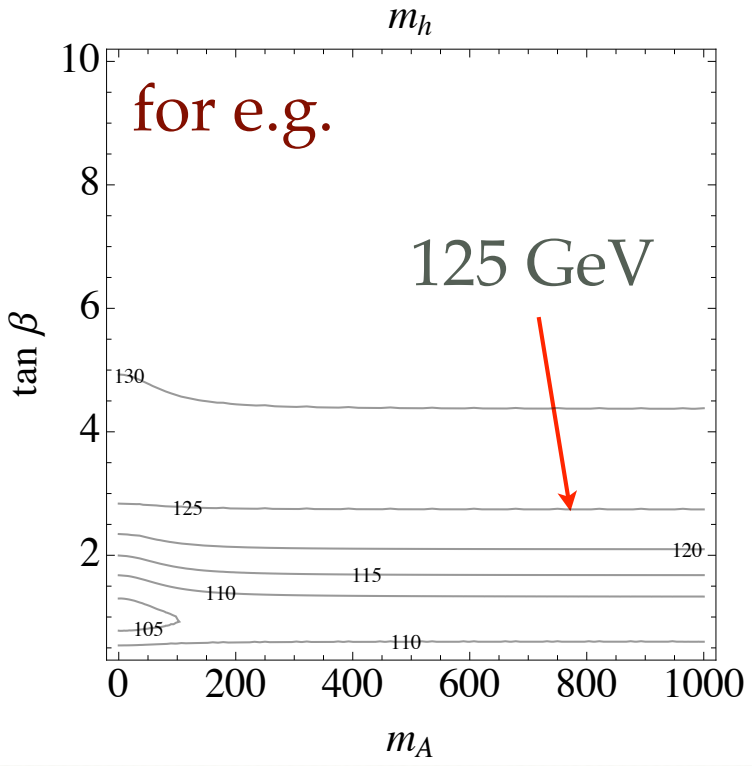
In MSSM + TC Higgs mass gains *linear* dependence on SUSY scale due to properties of induced EWSB

Higgs Phenomenology

$$\delta m_h^2 = \frac{4\sqrt{2}\pi f^3(\lambda_d \cos\beta + \lambda_u \sin\beta)}{\sqrt{v_u^2 + v_d^2}}$$

Can substantially increase Higgs mass

With $\lambda \sim O(.1)$ and $f \sim 80$ GeV can get $m_h = 125$ GeV *without* radiative corrections



Couplings

New couplings allow further modifications beyond type-II 2HDM as well

(Non)Decoupling

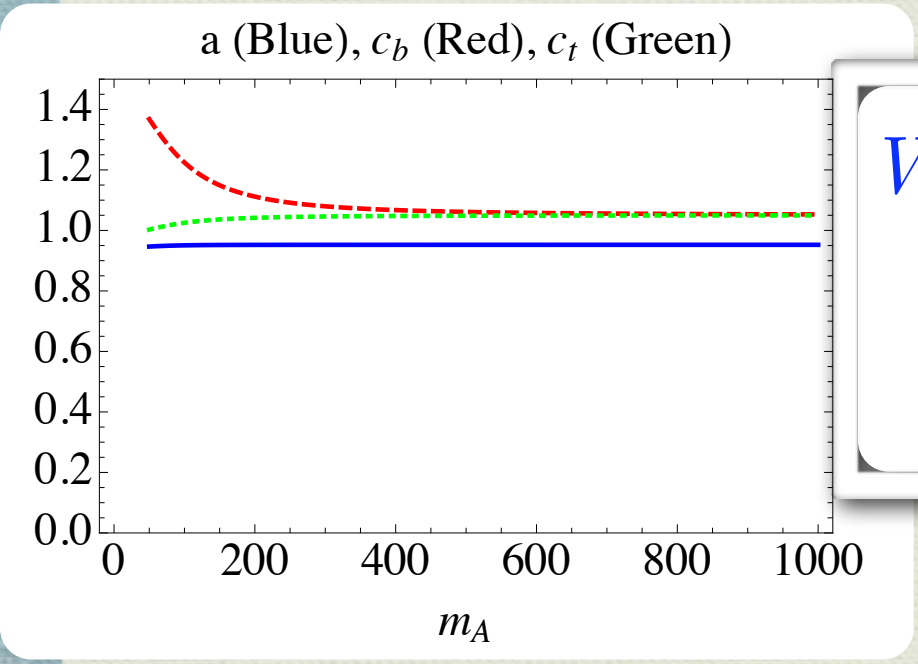
$$\frac{\sin 2\alpha}{\sin 2\beta} = -\frac{m_H^2 + m_h^2 - \dfrac{8\pi\sqrt{2}f^3(\lambda_u \cos\beta + \lambda_d \sin\beta)}{\sin 2\beta\sqrt{v_u^2+v_d^2}}}{m_H^2 - m_h^2}$$

Decoupling limit of MSSM, when $m_H \to \infty$
sets α-β=$\pi/2$, where h^0 has SM couplings

New term allows decoupling limit for gauge bosons,
but decouples slower for fermion couplings
which can be enhanced or suppressed

Higgs phenomenology
Two benchmarks

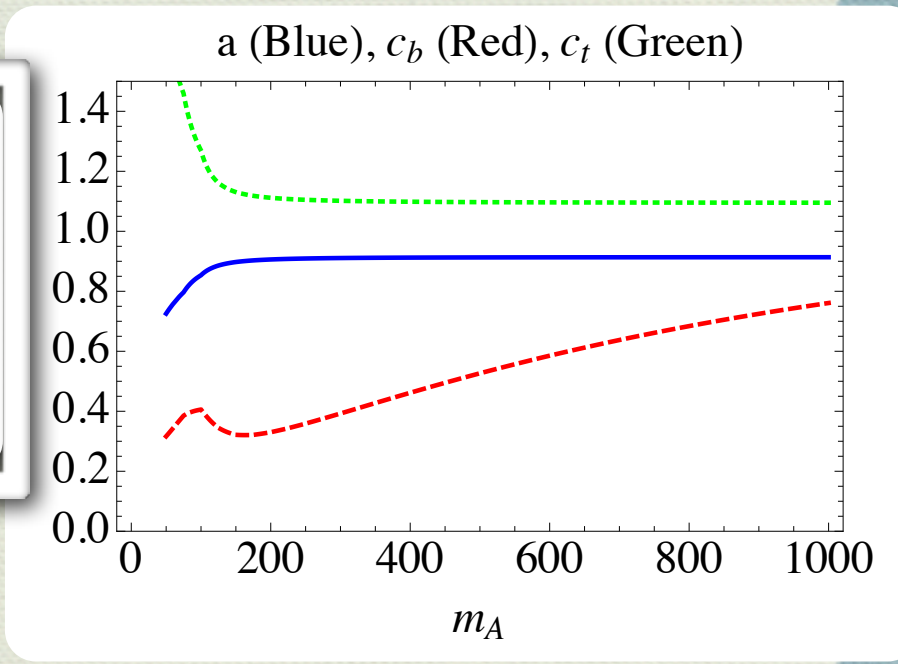
Lighter Higgs fixed to 125 GeV, m_A allowed to vary



WW/ZZ

$b\bar{b}/\tau\bar{\tau}$

$t\bar{t}$

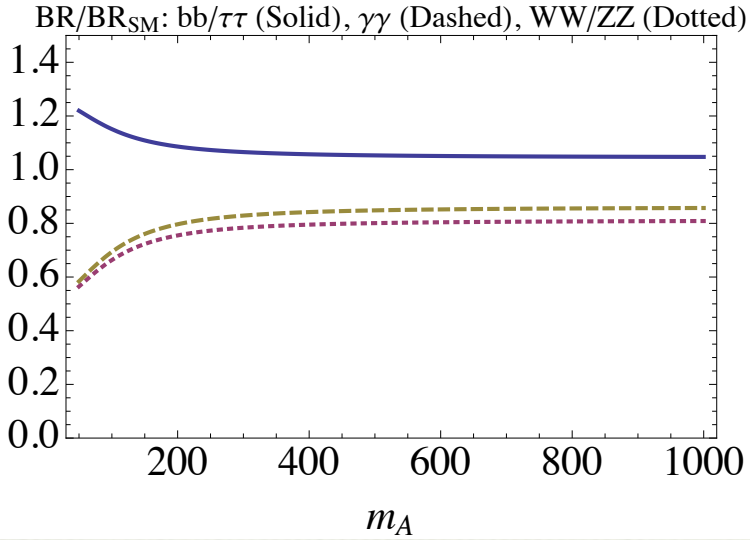


Moderate tan β

Largish tan β

Notice delayed decoupling limit for bottom quark coupling in right benchmark

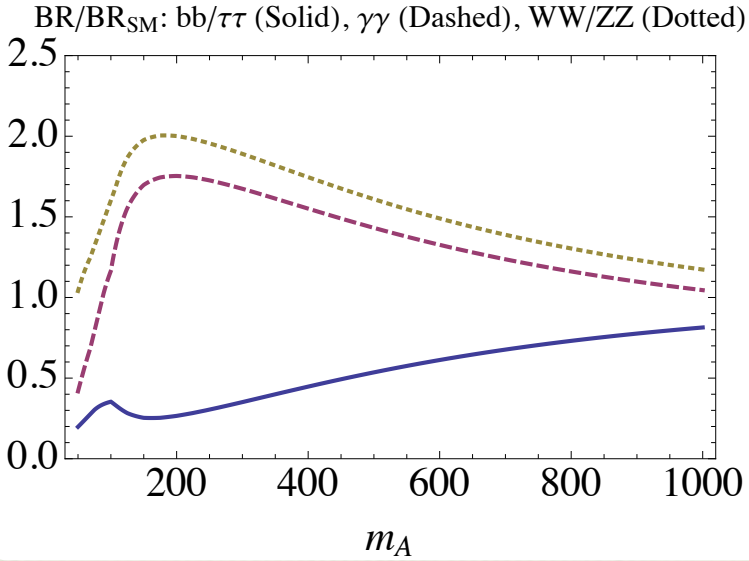
Higgs pheno (cont.)



$b\bar{b}/\tau\bar{\tau}$

$\gamma\gamma$

WW/ZZ



Moderate tan β

Largish tan β

Production largely unaffected

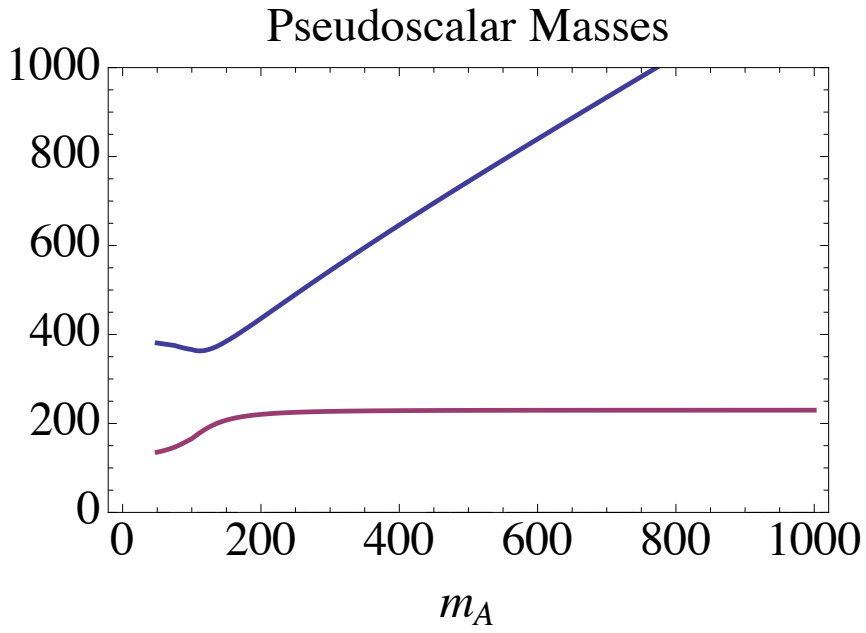
However, branching ratios to gauge bosons can be enhanced due to reduction in fermion width

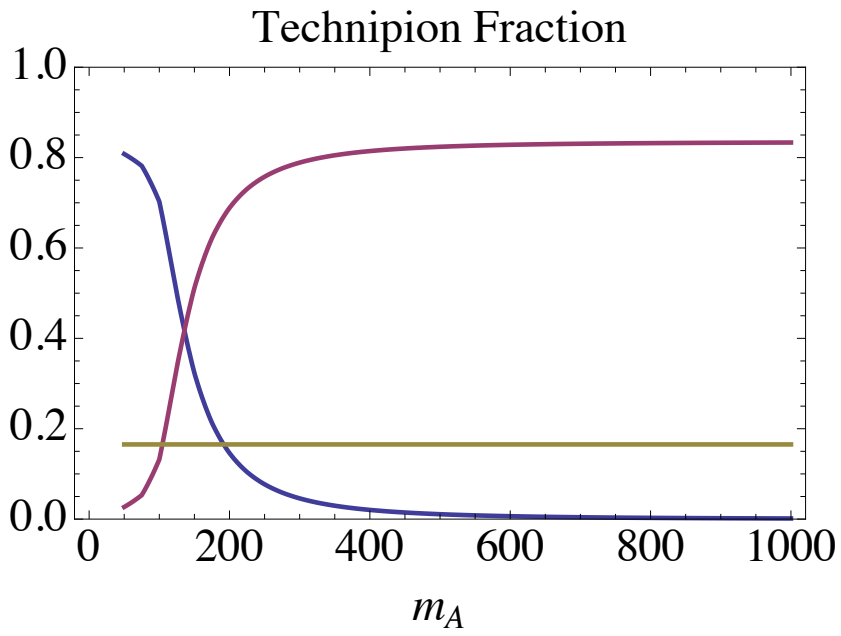
Pseudoscalars

Pseudoscalar phenomenology is particularly interesting

There are pseudos from MSSM Higgs as well as technicolor would-be goldstones

Pseudoscalars

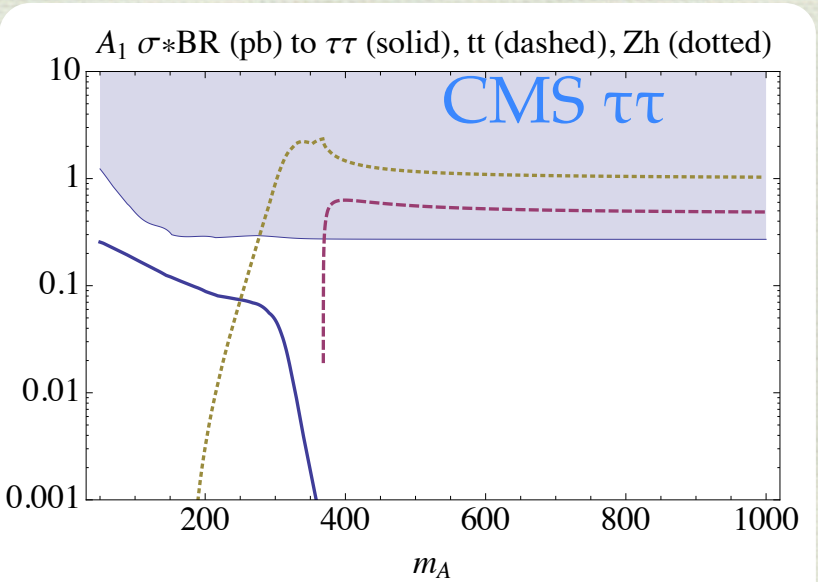


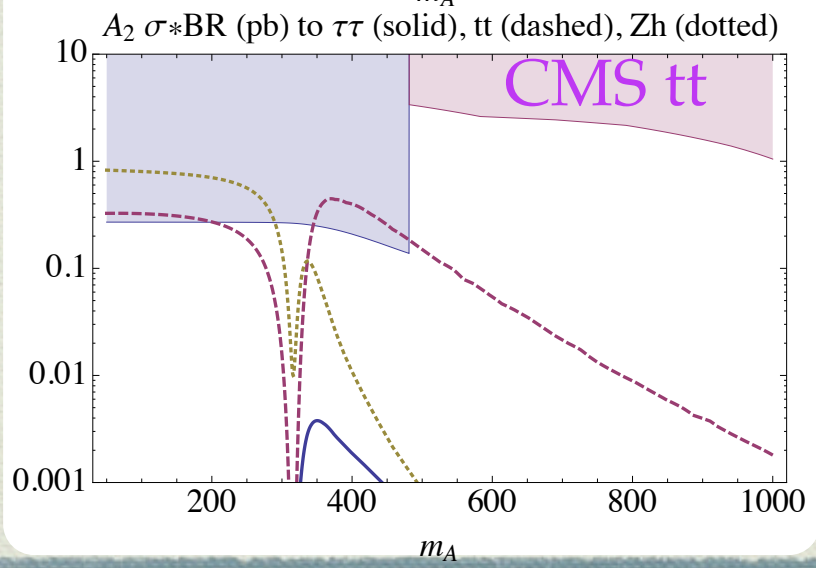


Decoupling limit, decouples MSSM pseudoscalar

Techni-pseudo still mixes at order f/v
since mass eigenstate is orthogonal to true goldstone

Pseudoscalar phenomenology same two benchmarks





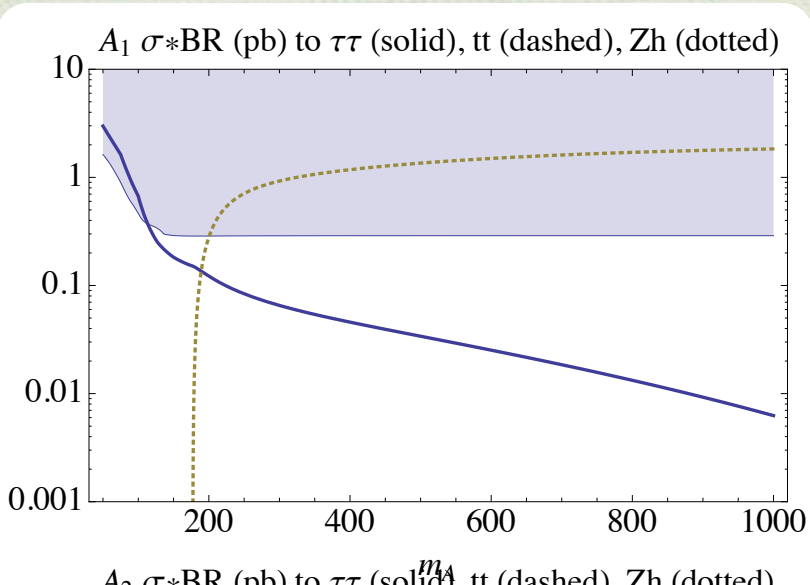
$\tau\bar{\tau}$

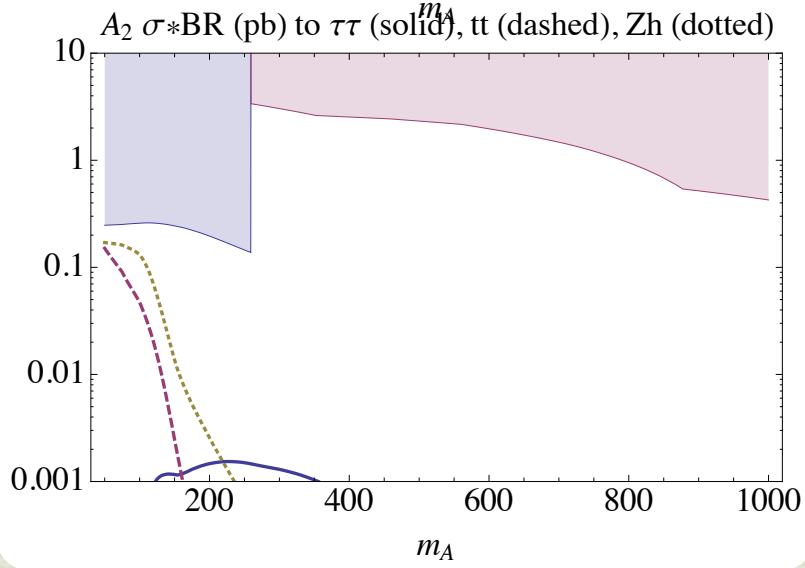
$Z\,h$

$t\bar{t}$

Two CP-odd scalars

Interesting Modes tt, Zh





Techni-pheno

Techni-states are an efficient way to produce techni-pseudos (albeit UV model dependent)

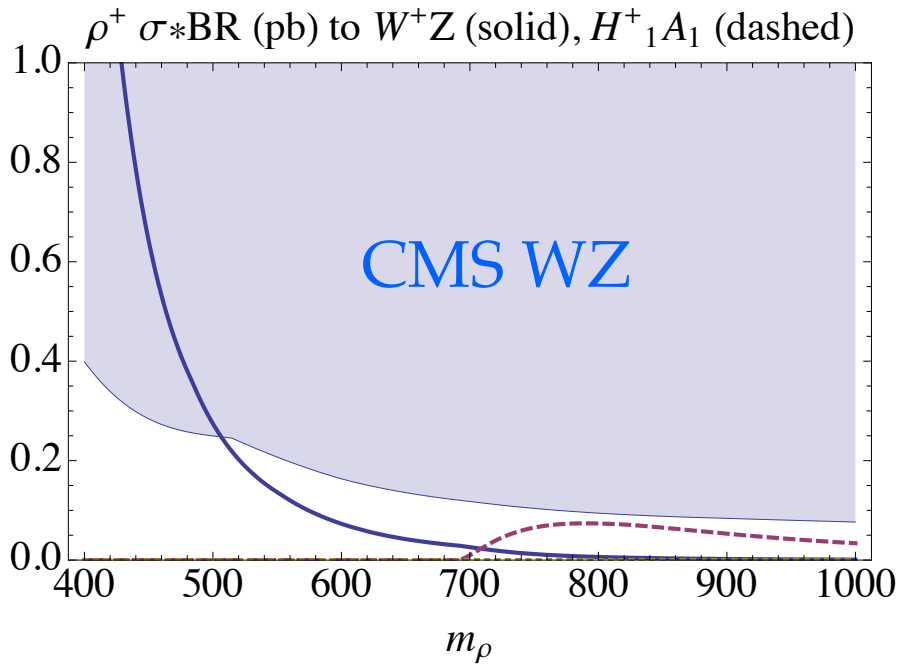
We model techni-rho production ala Falkowski, Grojean, et.al.

Interestingly, techni-rho couplings to SM are through mixing with W, Z, which does not explicitly depend on f

New Parameter space

Light mass range of techni-hadrons is motivated in these scenarios

Standard WZ resonance search may not be sufficient



Leads to longer cascades, e.g.

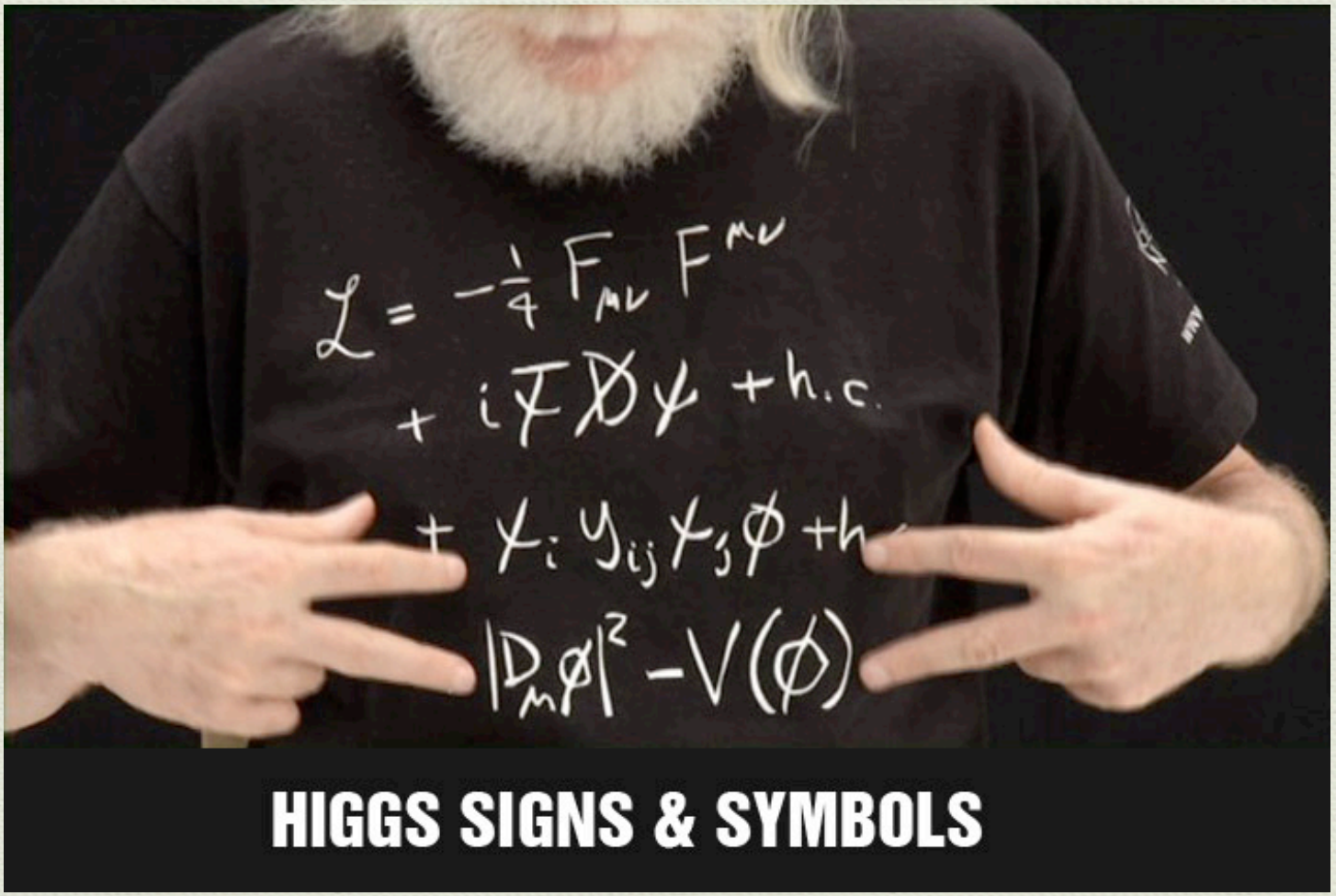
$$\rho^+ \to H_1^+, A_1 \to W^+ h, Zh$$

Conclusion

- Higgs mass and couplings can be changed in a SUSY+Technicolor hybrid model
- Can help to address fine tuning in SUSY and broaden allowed Higgs couplings

Conclusion (cont.)

- Higgs, pseudoscalars and techni-hadron phenomenology have rich structure and are worth looking for!



Looking forward to LHC Run 2!

Thanks!!!!