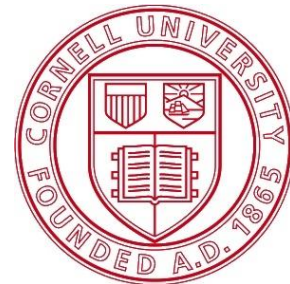


# Precision Probes of Neutral Naturalness

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# Introduction

THANKS FOR THE MANY INTRODUCTORY SLIDES

# Introduction

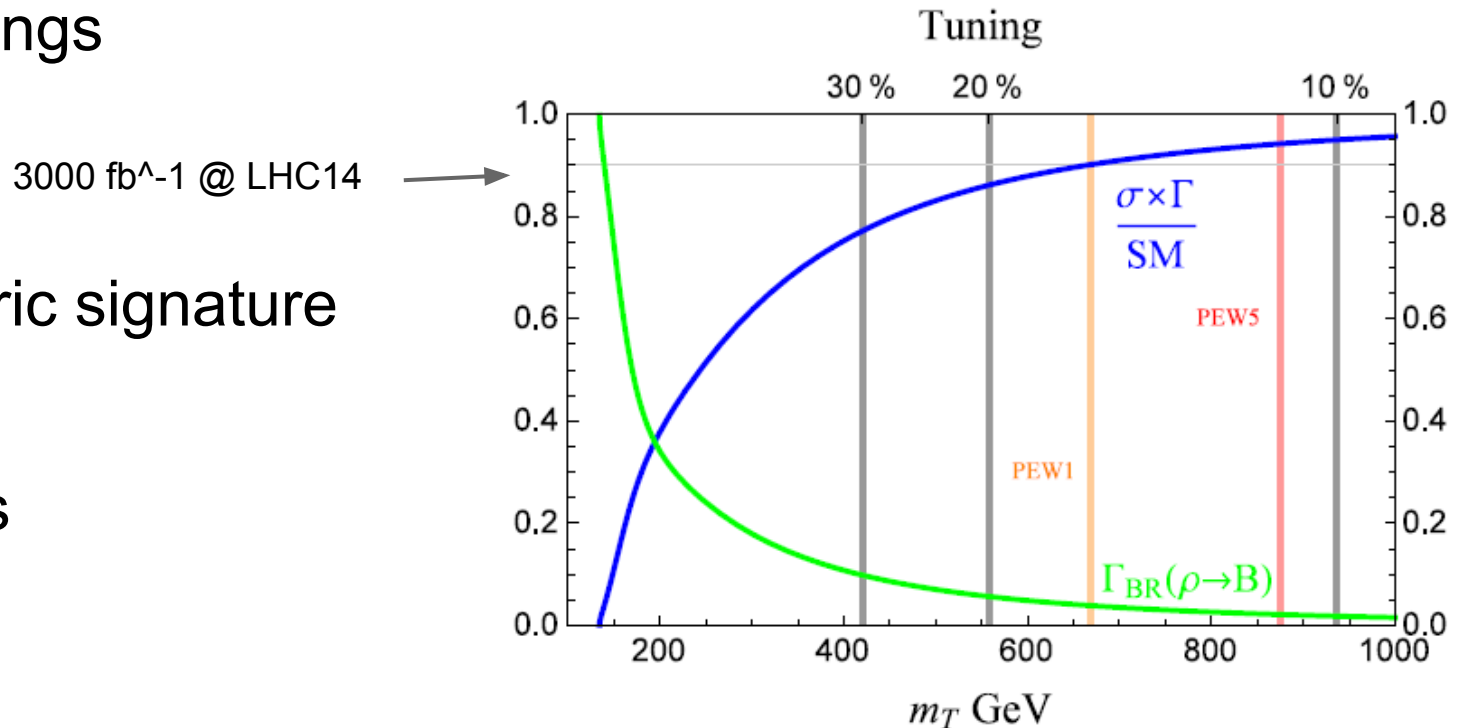
THANKS FOR THE MANY INTRODUCTORY SLIDES

HOWEVER...

Twin Higgs case:

- Higgs decays to invisible (?) twin particles
- v/f leverage: universal modification of Higgs couplings

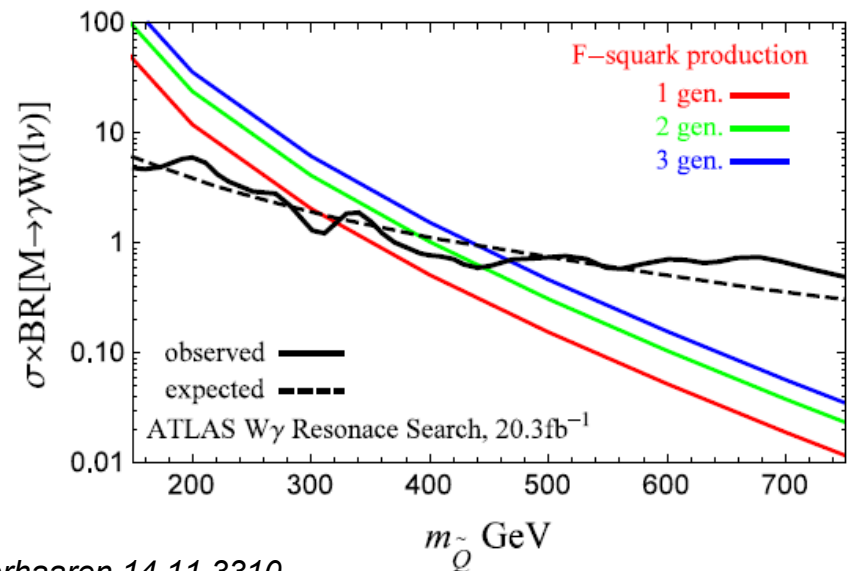
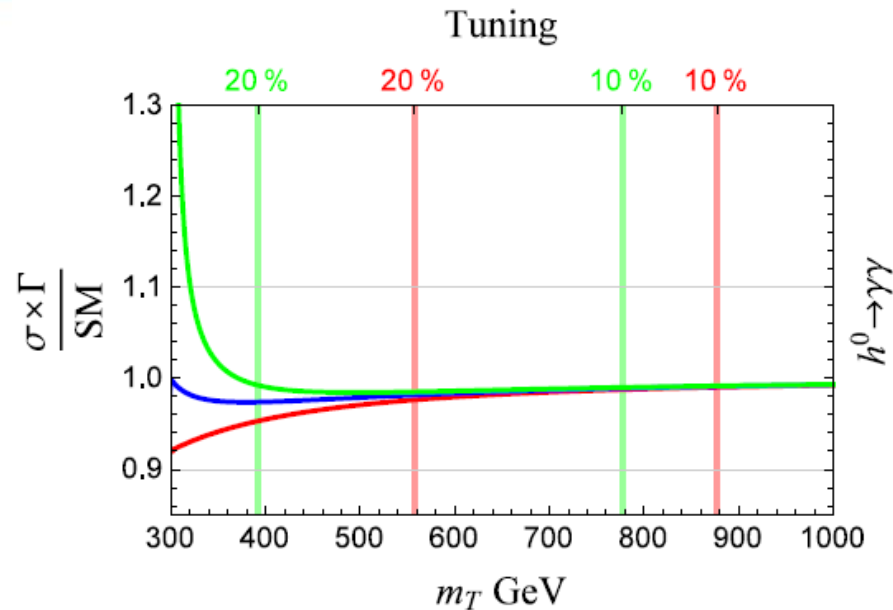
- Generic signature
- PEWs



# Folded@LHC

## Folded SUSY:

- Higgs looks very SM like (weakly coupled sector) (no gg deviation)
- Challenging F-squark searches
- (Un)Surprisingly not easier to detect than Twin Higgs



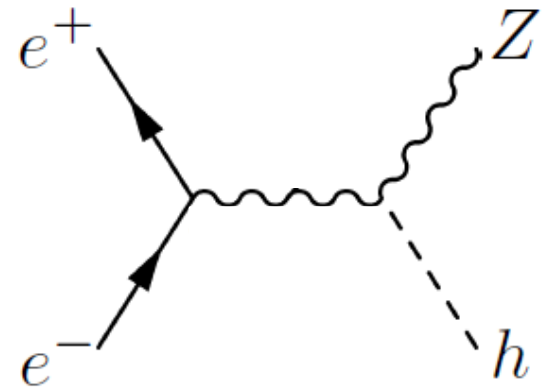
# Going to lepton colliders

If LHC is not enough  
(isn't it the point of Neutral Naturalness?)



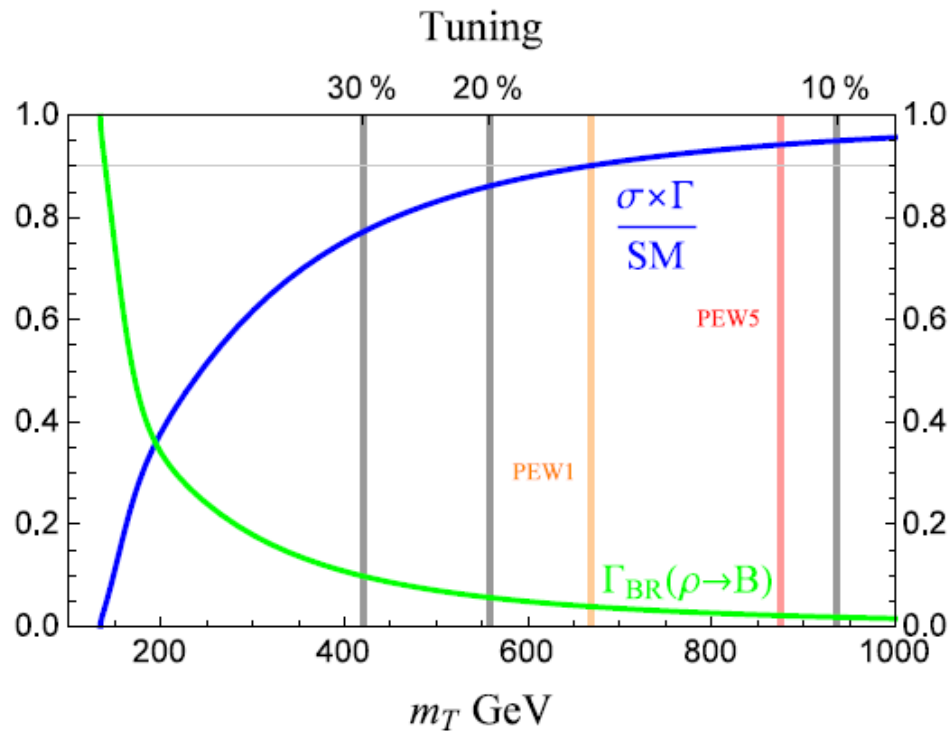
Precision Higgs physics at lepton colliders:

- Higgs couplings:
  - ~~gluon~~ and photons
  - Higgsstrahlung  
[most precise @  $O(0.1)\%$ ]
- PEW



# Higgs Couplings

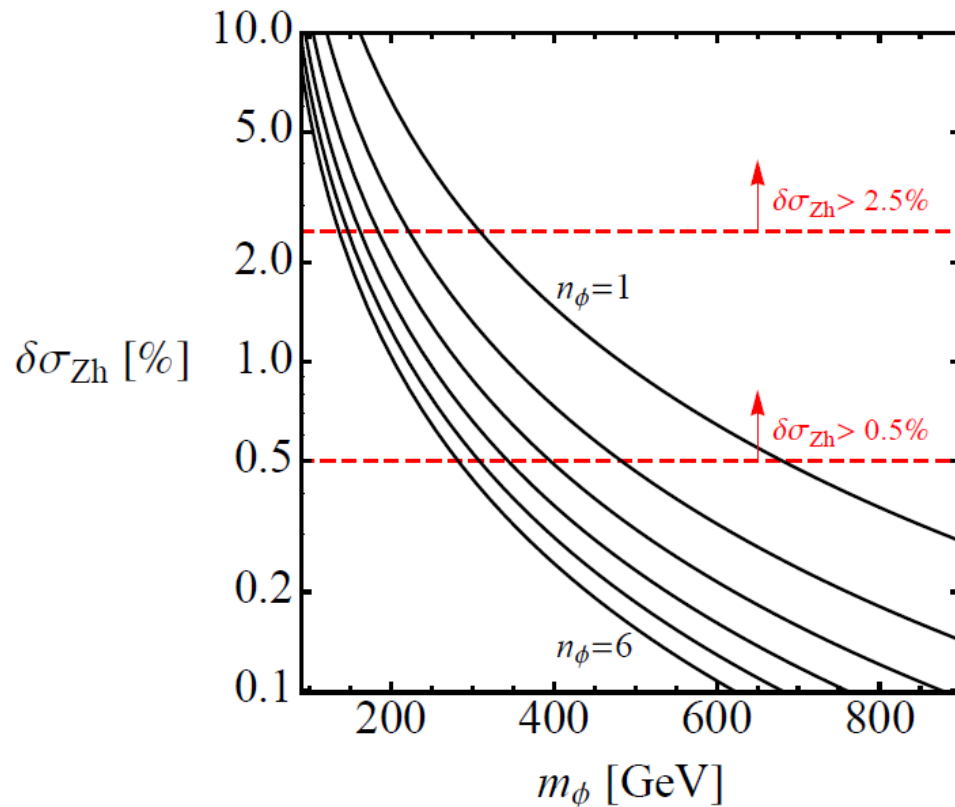
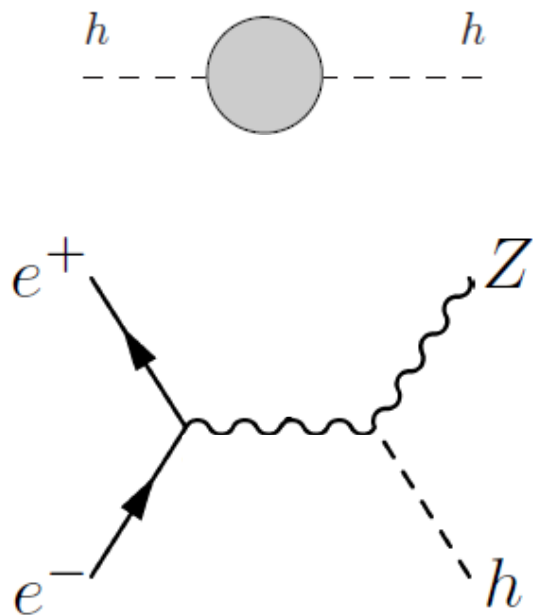
Higgs couplings will be measured at the O(1%) level



Especially relevant for strongly coupled sectors.  
What about the rest? Look at Higgsstrahlung

# Hardest case

Hardest case:  
neutral x neutral top partner  
and nothing else



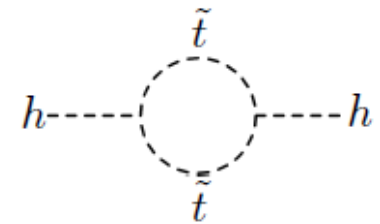
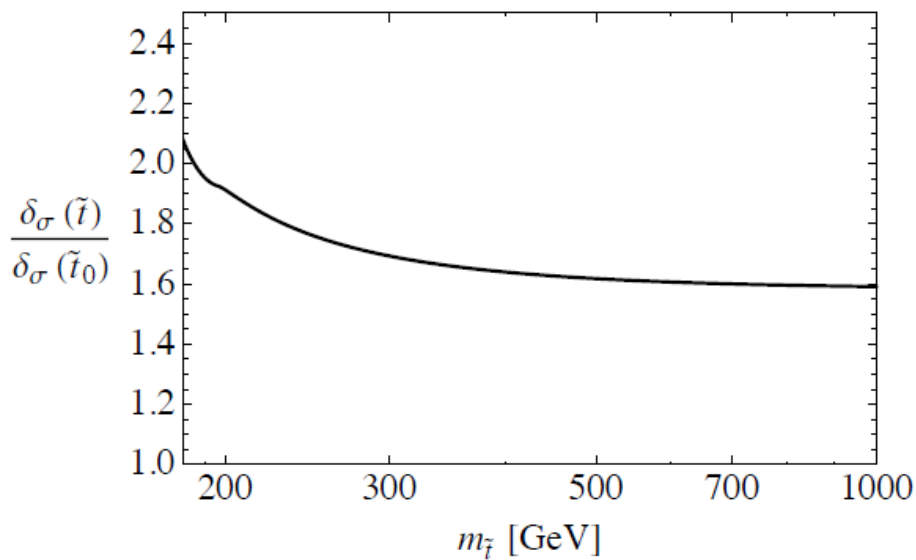
N. Craig, C. Englert, M. McCullough 1305.5251



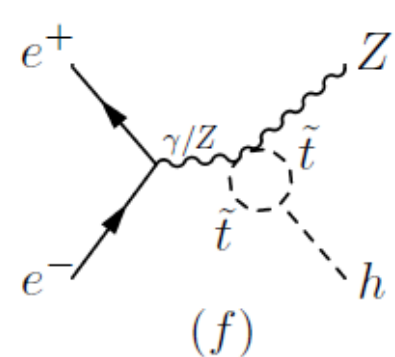
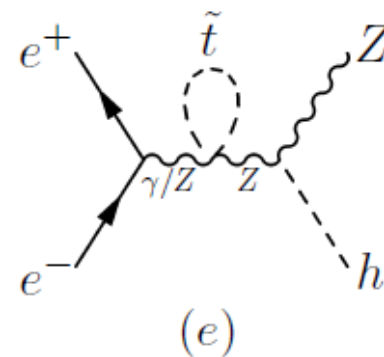
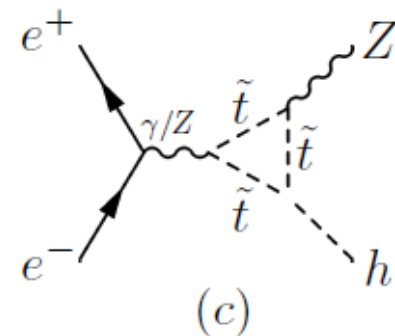
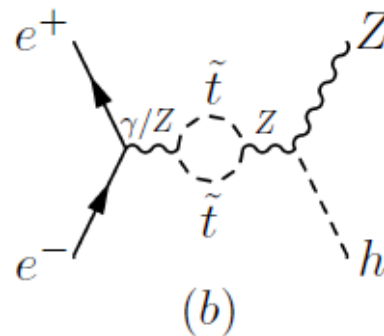
# Higgsstrahlung

Full computation of Higgsstrahlung

- Beyond wave-function
- EFT compared to NLO



VS

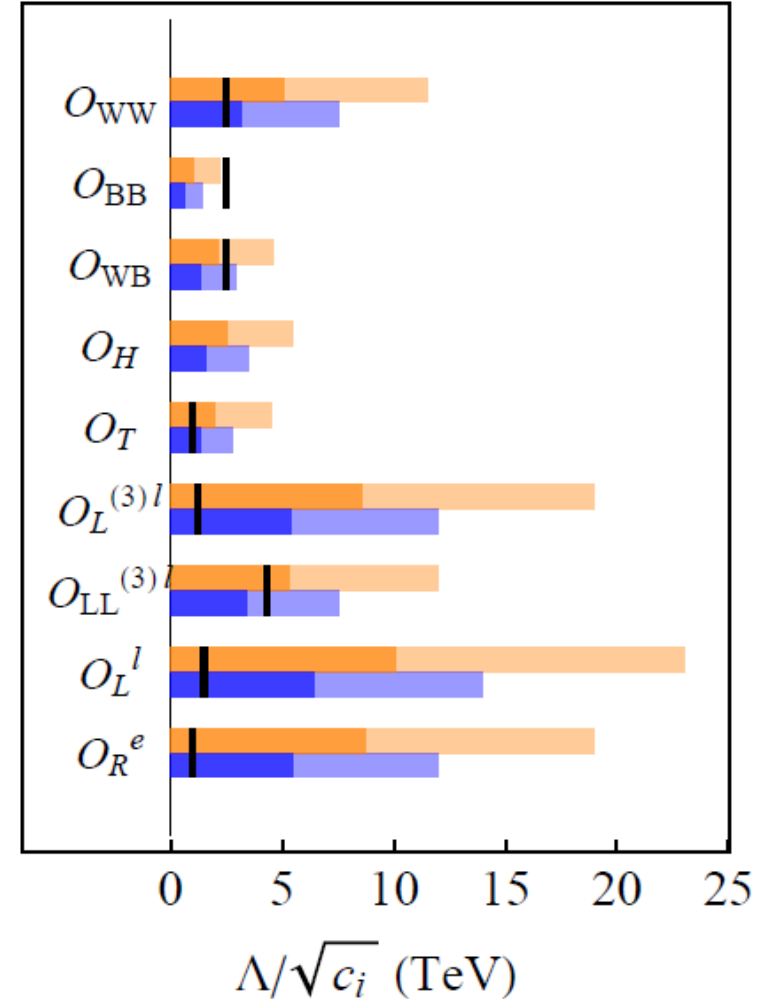


# EFT case

- EFT with Dim-6 operators
- Relevant in the Twin Higgs case

$$\begin{aligned}
 \mathcal{O}_{WW} &= g^2 |H|^2 W_{\mu\nu}^a W^{a,\mu\nu} \\
 \mathcal{O}_{BB} &= g'^2 |H|^2 B_{\mu\nu} B^{\mu\nu} \\
 \mathcal{O}_{WB} &= gg' H^\dagger \sigma^a H W_{\mu\nu}^a B^{\mu\nu} \\
 \mathcal{O}_H &= \frac{1}{2} (\partial_\mu |H|^2)^2 \\
 \mathcal{O}_T &= \frac{1}{2} (H^\dagger \overleftrightarrow{D}_\mu H)^2 \\
 \mathcal{O}_L^{(3)\ell} &= (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H) (\bar{L}_L \gamma^\mu \sigma^a L_L) \\
 \mathcal{O}_{LL}^{(3)\ell} &= (\bar{L}_L \gamma_\mu \sigma^a L_L) (\bar{L}_L \gamma^\mu \sigma^a L_L) \\
 \mathcal{O}_L^\ell &= (iH^\dagger \overleftrightarrow{D}_\mu H) (\bar{L}_L \gamma^\mu L_L) \\
 \mathcal{O}_R^e &= (iH^\dagger \overleftrightarrow{D}_\mu H) (\bar{e}_R \gamma^\mu e_R)
 \end{aligned}$$

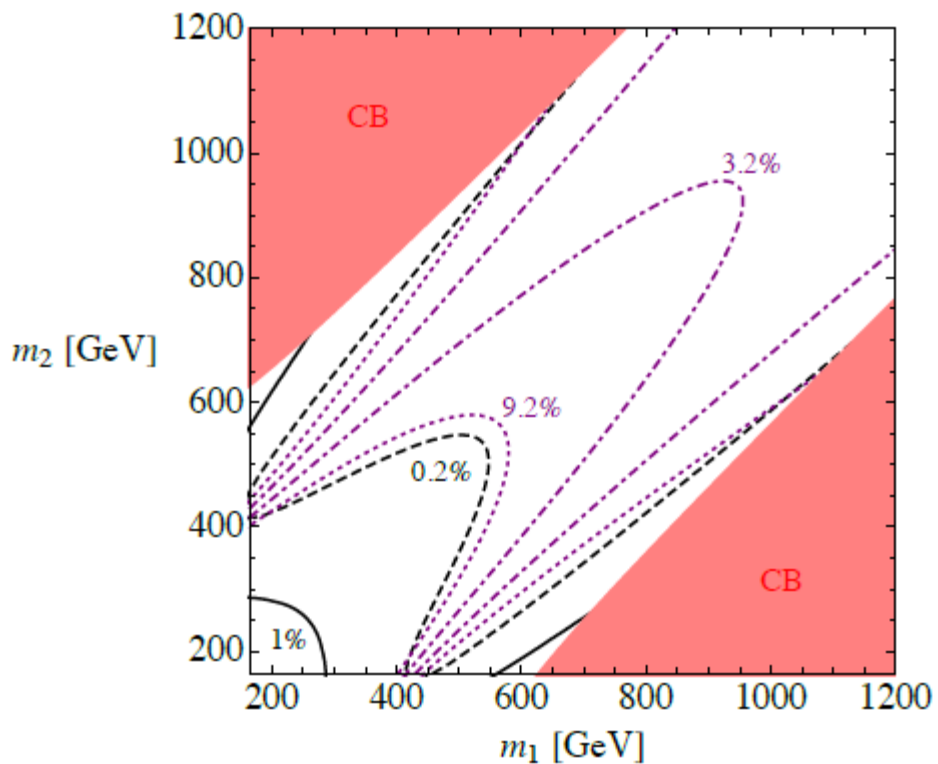
$\delta\sigma/\sigma = 0.5\% \mid \delta\sigma/\sigma = 0.1\%$



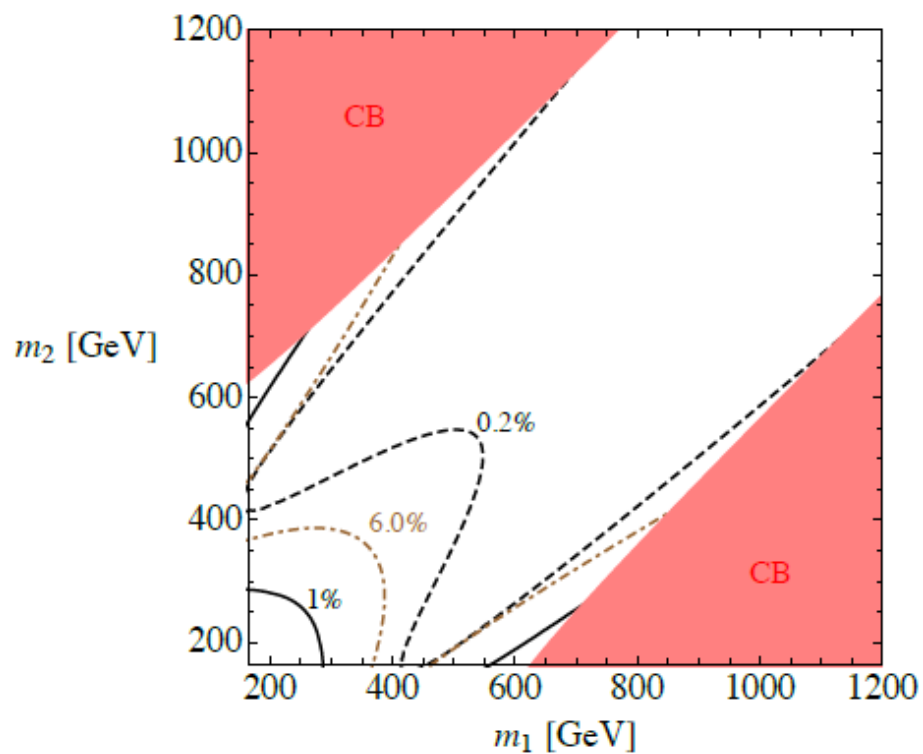
95% C.L. exclusion (orange)  
5-sigma discovery (blue)

# Results (Folded SUSY)

SUSY (gluon coupling)



F-SUSY (photon coupling)



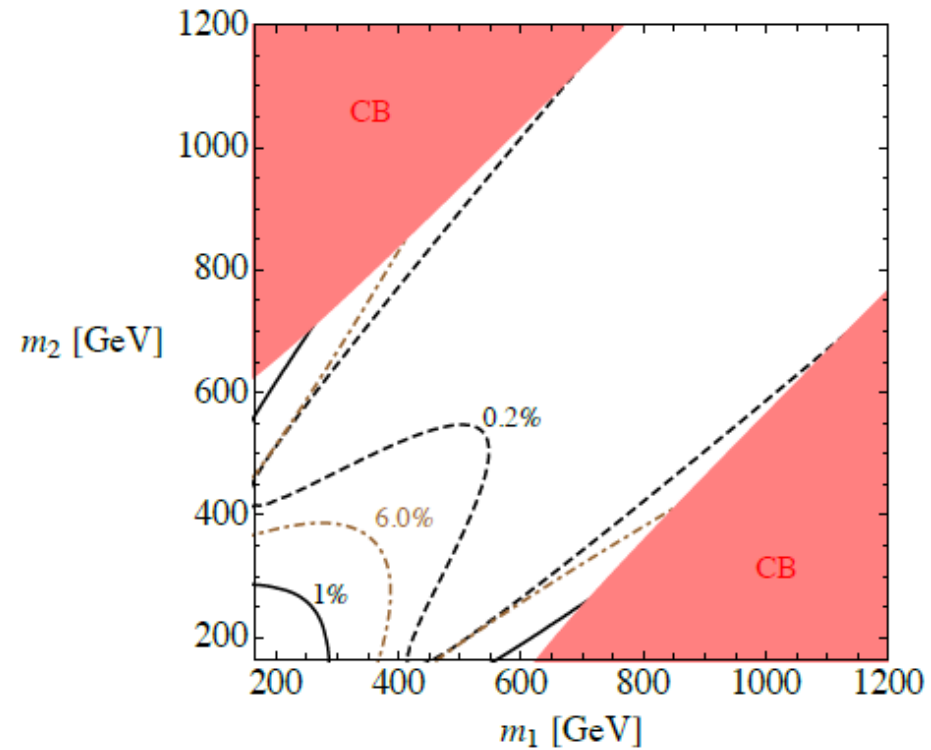
Stop case (fixed mixing angle)

- Conservative - ILC (solid)
- Optimimstic - TLEP (dashed)

No hgg deviation: not even a smoking gun

# Blind spot

- Why is there a blind spot?
- Higgs is decoupled from lightest stop

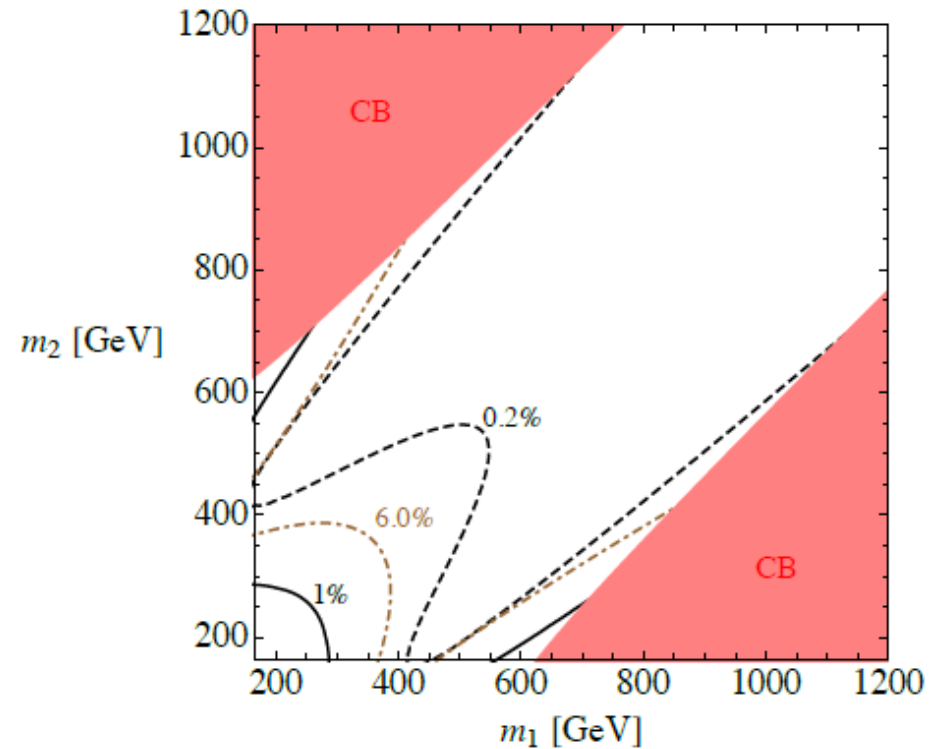
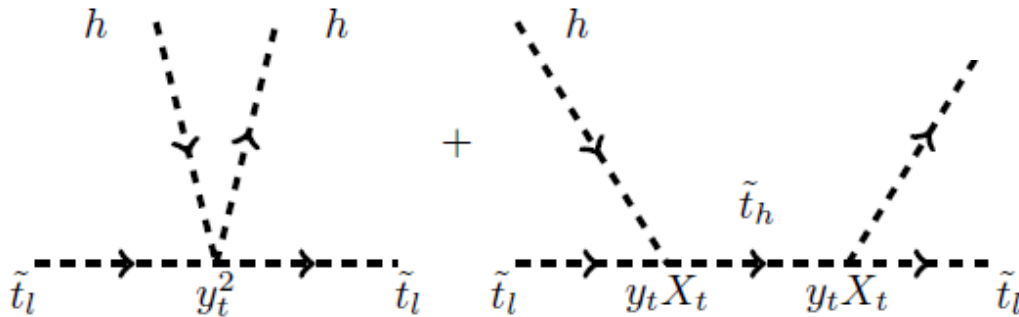


# Blind spot

- Why is there a blind spot?

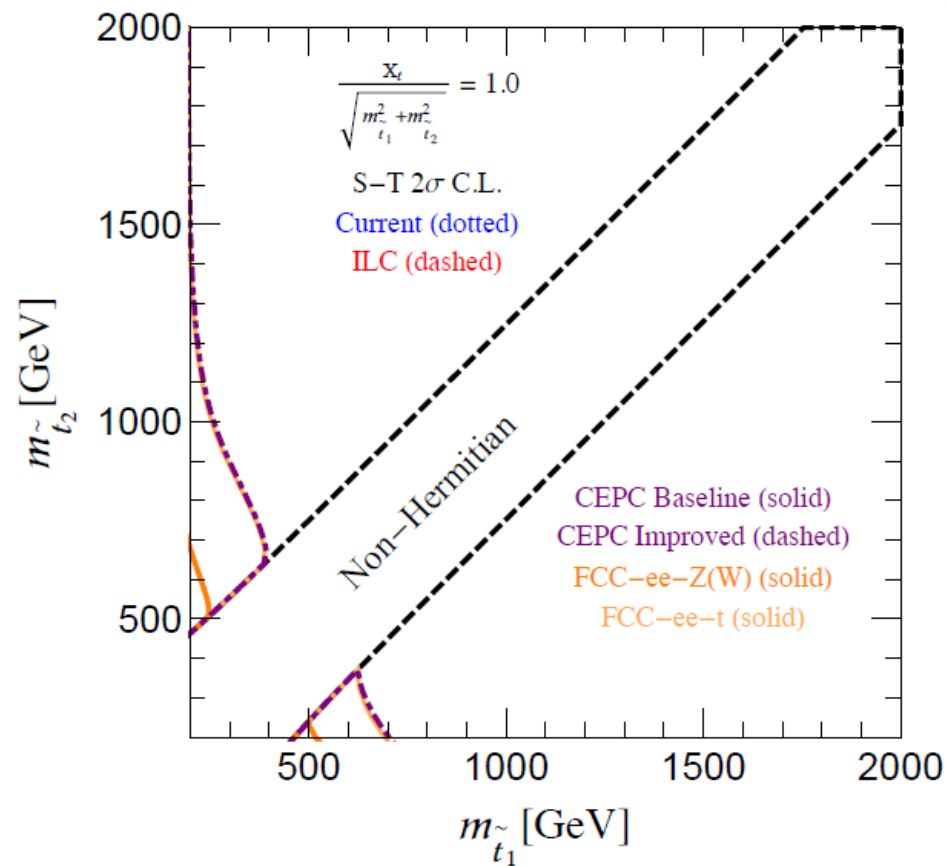
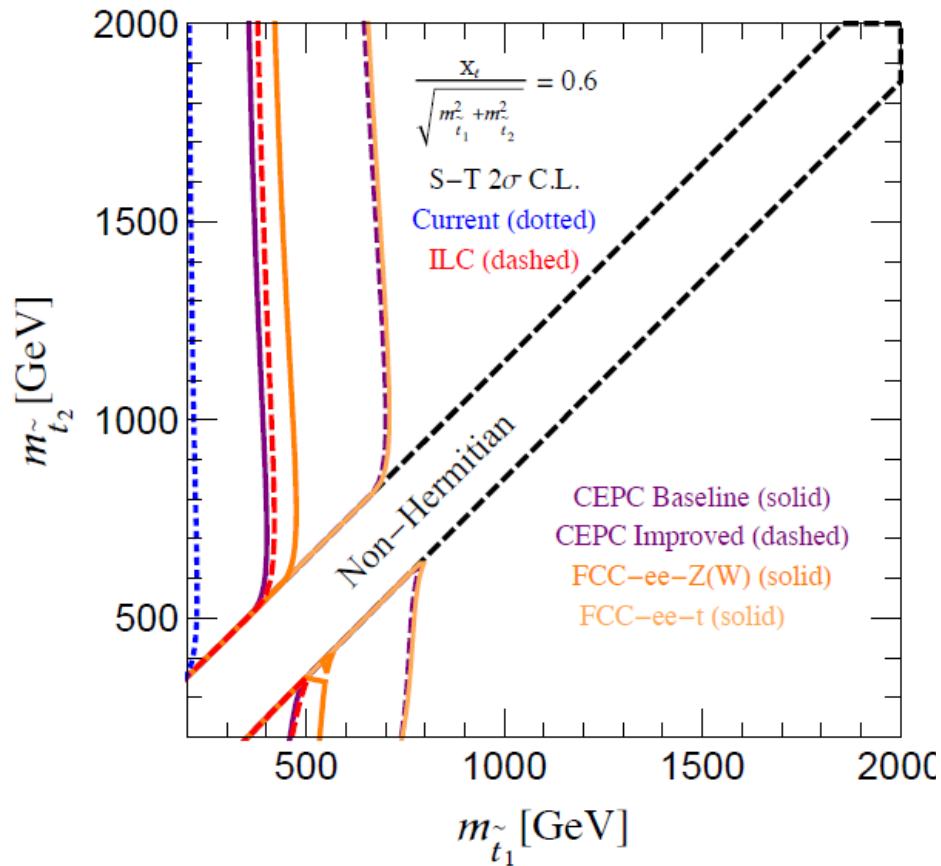
$$X_t^* = \left( m_{\tilde{t}_h}^2 - m_{\tilde{t}_l}^2 \right)^{1/2}$$

- Higgs is decoupled from lightest stop



$$\mathcal{L}_{\text{eff}} = \left( y_t^2 - \frac{y_t^2 X_t^2}{m_{\tilde{t}_h}^2 - m_{\tilde{t}_l}^2} \right) |H_u|^2 |\tilde{t}_l|^2$$

# Future EWPT



- Comparable bounds to hZZ
- Same blind spot issue
- Dedicated runs

# Other directions?

Even aside the blind spot are there are other signals?

- Pair production at lepton colliders?
- 100 TeV collider?
- Think harder about LHC?

*Curtin's Talk*

# Conclusions

- **LHC might not be enough:** hard to find by construction
- **Precision Higgs couplings:** perfect probe by definition
- **Is there really any smoking gun?**