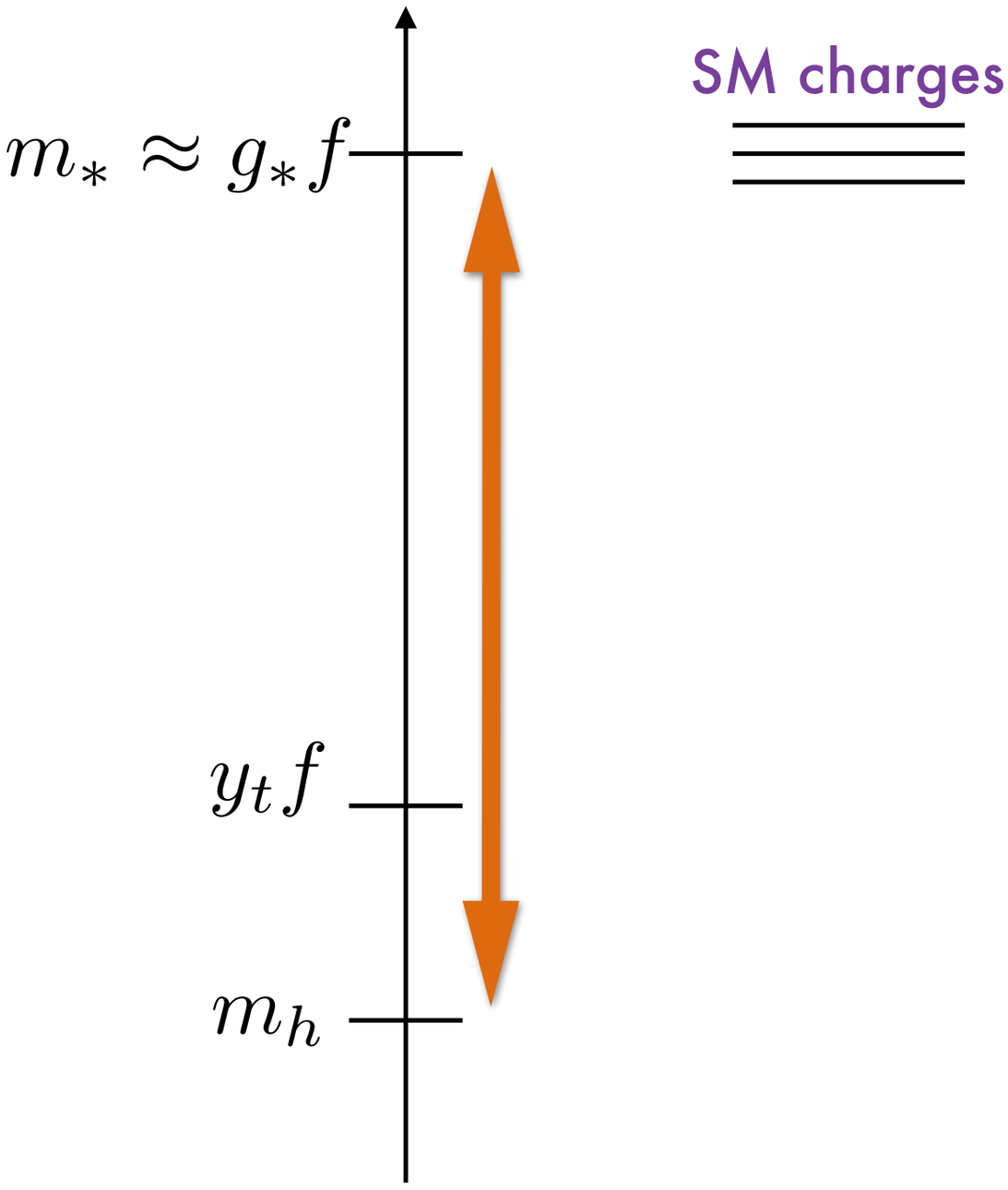
CERN 01/11/2017

Neutral naturalness (?)

Andrea Tesi

A model with no visible effects (still natural, as technically defined)



SM charges

SM singlet

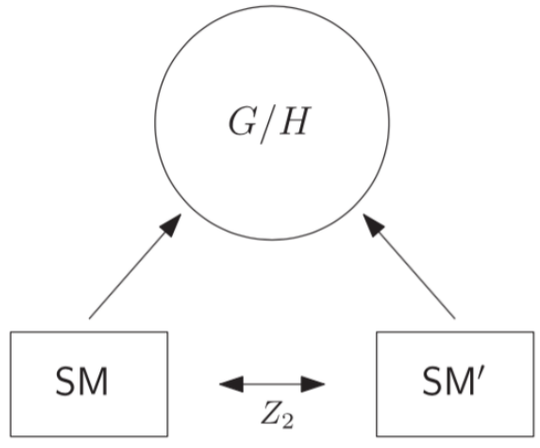
by construction not much to see here

light states are SM singlets

A one slide recap of composite "neutral naturalness"

Additional protection, thanks to Z2 symmetry, need SO(8)/SO(7)

Chacko, Goh, Harnik



see
Geller, Telem
Barbieri, Greco, Rattazzi, Wulzer

Contribution to the Higgs potential scales like

$$V(h) \supset \frac{N_c}{16\pi^2} y_L^4 f^4 \sin^2 h \cos^2 h \qquad y_t \sim \frac{y_L y_R}{g_*}$$

- top right needs to be fully composite $y_R \sim g_*$
- need Z2 breaking term of the right size...

$$m_h^2 \sim \frac{N_c y_t^2}{2\pi^2} \frac{y_t^2}{g_*^2} \frac{m_*^2}{f^2} \log(g_*/y_t)$$

Deviations in Higgs/EW precision observables?

name	structure	coefficient
$\mathcal{O}_H$	$\frac{1}{2}\left(\partial_\mu \lvert H\rvert^2\right)^2$	c_H/f^2
$\mathcal{O}_y$	$y\bar{Q}_L H u_R \lvert H\rvert^2$	c_y/f^2
$\mathcal{O}_W$	$ig\left(H^\dagger\sigma^a \overleftrightarrow{D}^\mu H\right) D^\nu W^a_{\mu\nu}$	c_W/m_*^2
$\mathcal{O}_B$	$ig'\left(H^\dagger \overleftrightarrow{D}^\mu H\right) D^\nu B_{\mu\nu}$	c_B/m_*^2
$\mathcal{O}_{HW}$	$ig(D^\mu H)^\dagger\sigma^a(D^\nu H)W^a_{\mu\nu}$	$c_{HW}/m_*^2 \times (g_*/4\pi)^2$
$\mathcal{O}_{HB}$	$ig'(D^\mu H)^\dagger(D^\nu H)B_{\mu\nu}$	$c_{HB}/m_*^2 \times (g_*/4\pi)^2$
O_L^q	$i\left(H^\dagger \overleftrightarrow{D}_\mu H\right)\bar{Q}_L\gamma^\mu Q_L$	$c_q/f^2 \times \epsilon_q^2$
$O_L^{q,3}$	$i\left(H^\dagger\sigma^a \overleftrightarrow{D}_\mu H\right)\bar{Q}_L\sigma^a\gamma^\mu Q_L$	$c_{q,3}/f^2 \times \epsilon_q^2$
O_R^d	$i\left(H^\dagger \overleftrightarrow{D}_\mu H\right)\bar{u}_R\gamma^\mu u_R$	$c_u/f^2 \times \epsilon_u^2$
O_R^u	$i\left(H^\dagger \overleftrightarrow{D}_\mu H\right)\bar{d}_R\gamma^\mu d_R$	$c_d/f^2 \times \epsilon_d^2$
O_T	$\left(H^\dagger \overleftrightarrow{D}_\mu H\right)^2$	c_T/f^2
$\mathcal{O}_6$	$\lvert H\rvert^6$	λ_3/f^2

c's are O(1) unless suppressed by symmetries

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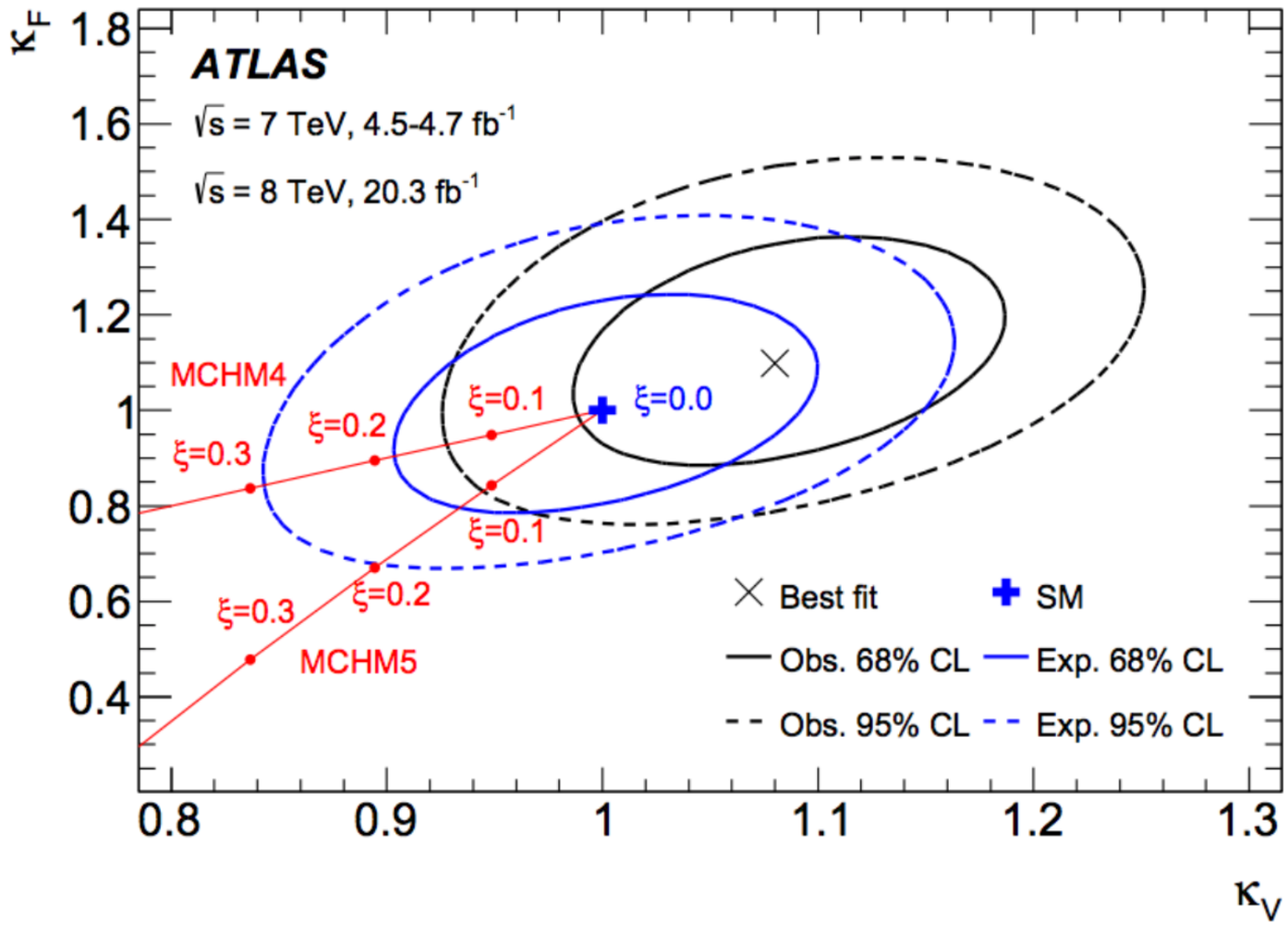
Deviations in Higgs couplings

At this stage, k-framework equivalent to EFT

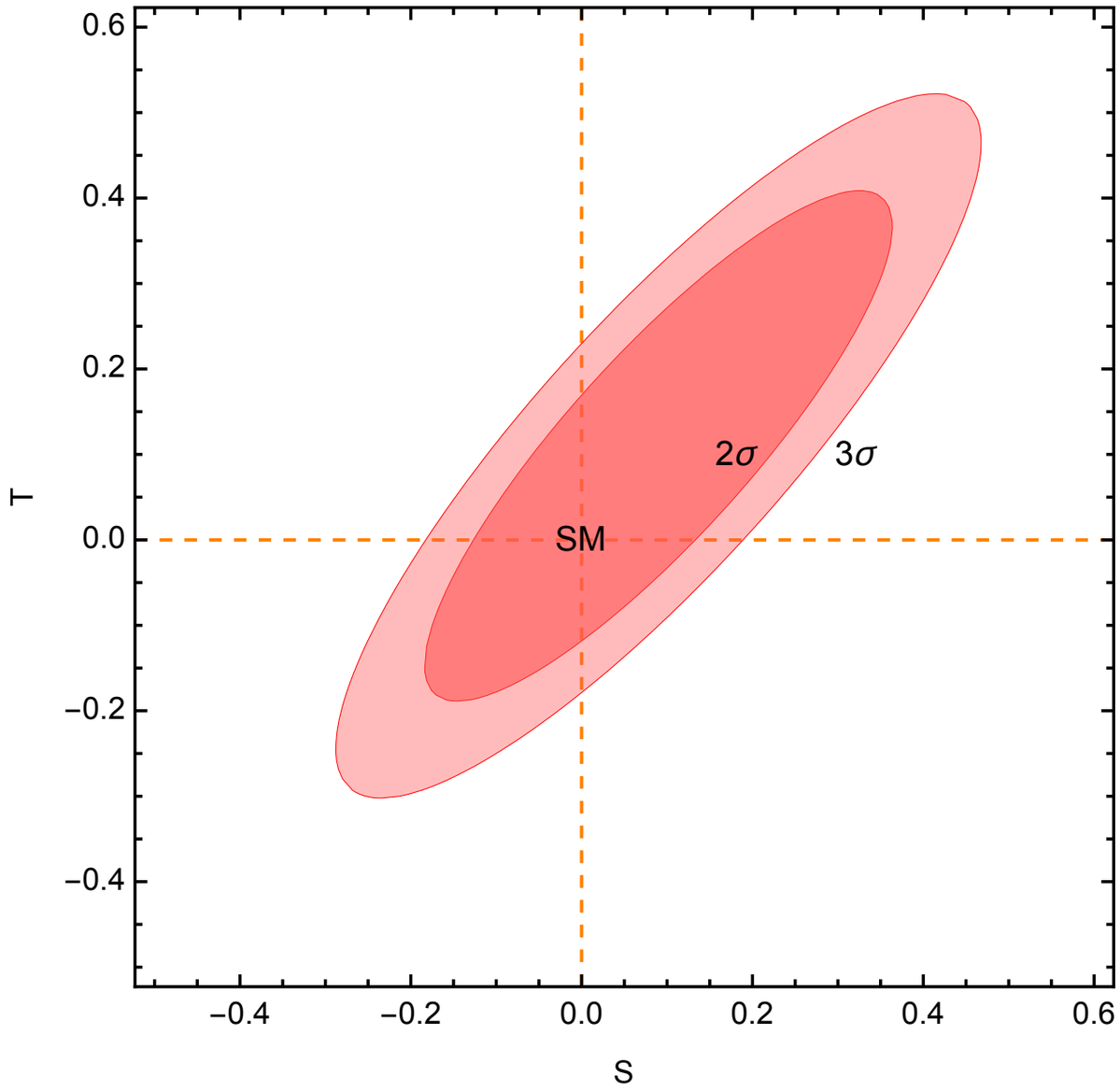


shift in the Higgs couplings is universal $f \gtrsim 550\mathrm{GeV}$

possible effects in the Higgs (invisible) width model dependent

Additional constraints from EW physics

some of the contributions decouples with m_*



$$S \approx \frac{4\pi v^2}{m_*^2}, \quad T \approx N_c \frac{y_t^2}{16\pi^2} \frac{m_t^2}{m_*^2}$$

$$T \approx -\frac{3}{8\pi c_w^2} \frac{v^2}{f^2} \log \frac{m_*}{m_h}$$

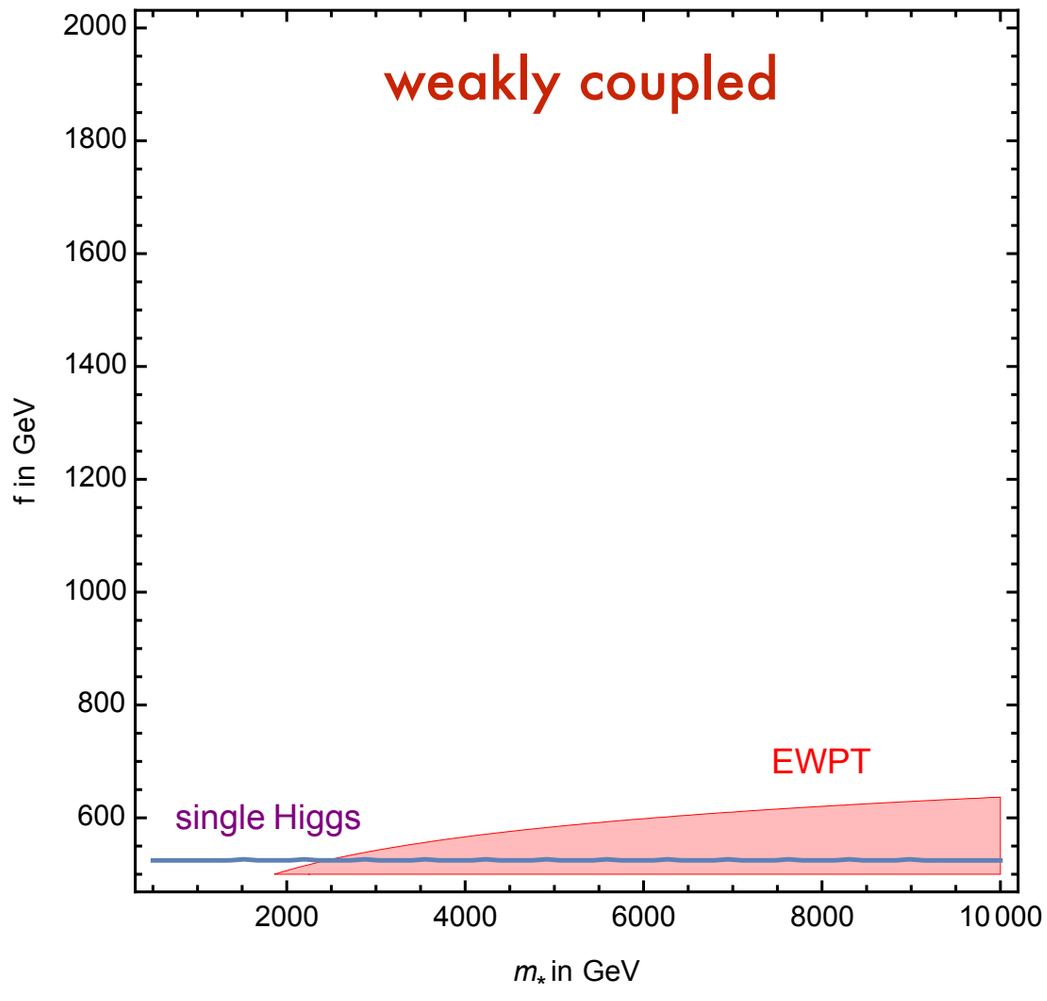
$$S \approx \frac{1}{12\pi} \frac{v^2}{f^2} \log \frac{m_*}{m_h}$$

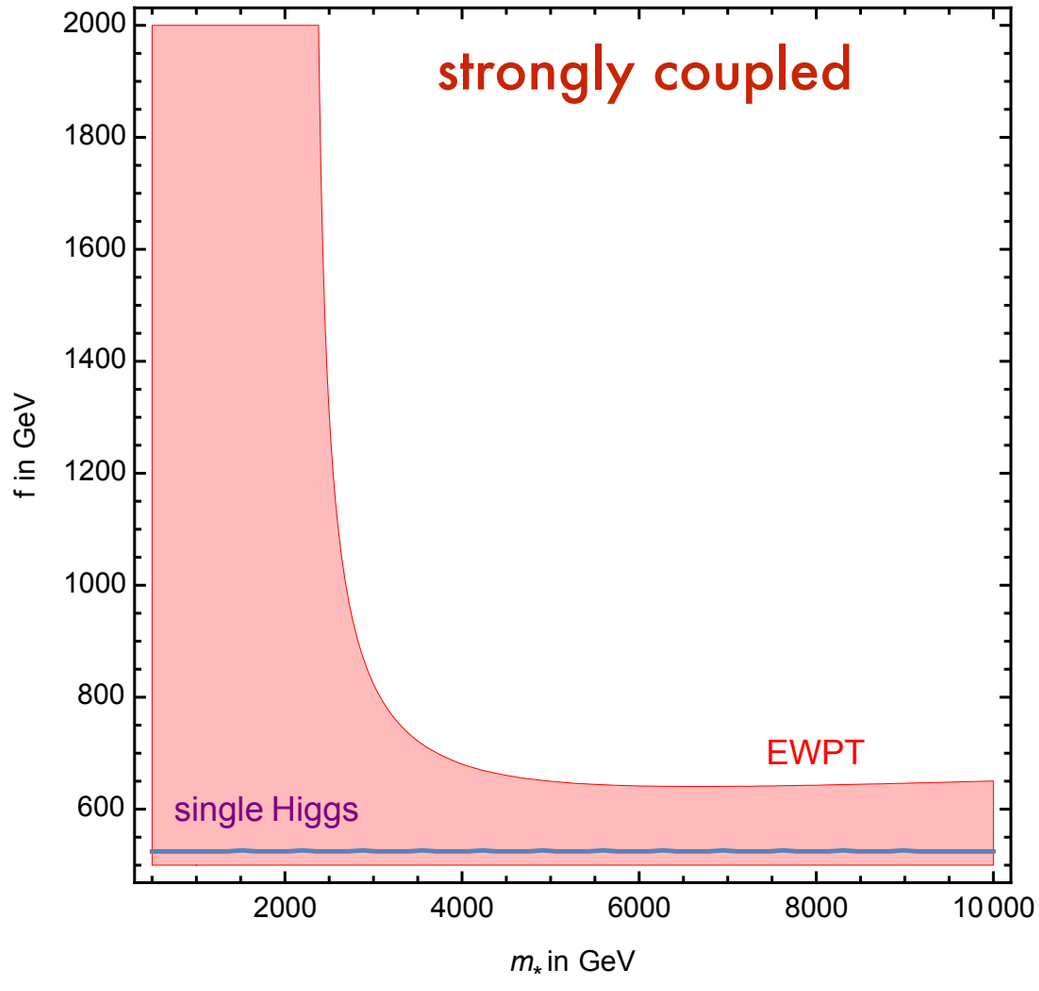
Barbieri Bellazzini Rychkov Varagnolo

see HEPfit; DeBlas et al ‘17

Actual limits depends on the UV 'completion'

However, broadly:





possible present conflicts with ewpt will be resolved by improvements in Higgs couplings

this tension suggest thats at least one top partner needs to be around 3-5 TeV

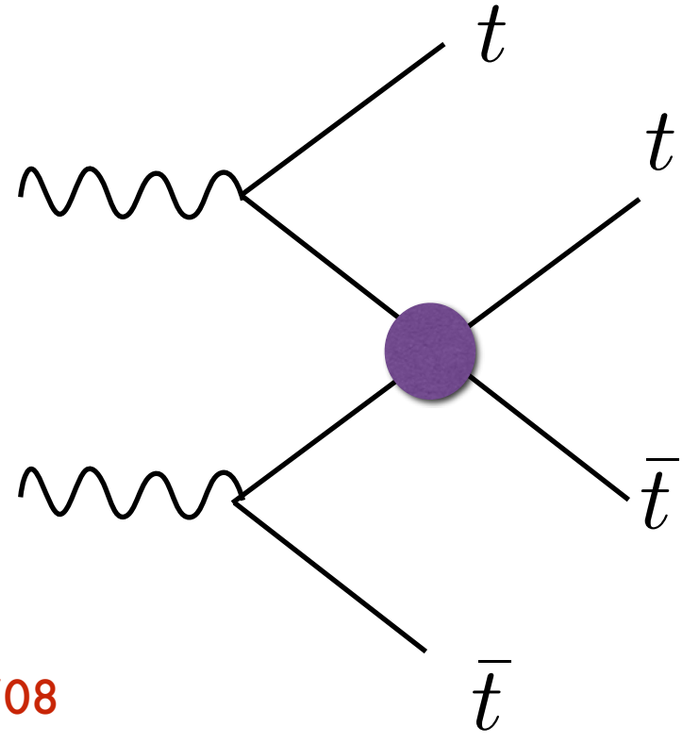
Contino et al '17

(then we need to look at usual composite Higgs models)

Additional new effects in some SM observables?

Reasons to expected a sizeable coefficients for four tops effective interactions

$$\frac{c_1}{f^2}(\bar{t}_R\gamma^\mu t_R)^2 + \frac{c_8}{f^2}(\bar{t}_R\gamma^\mu \lambda^a t_R)^2$$



see Pomarol Serra '08

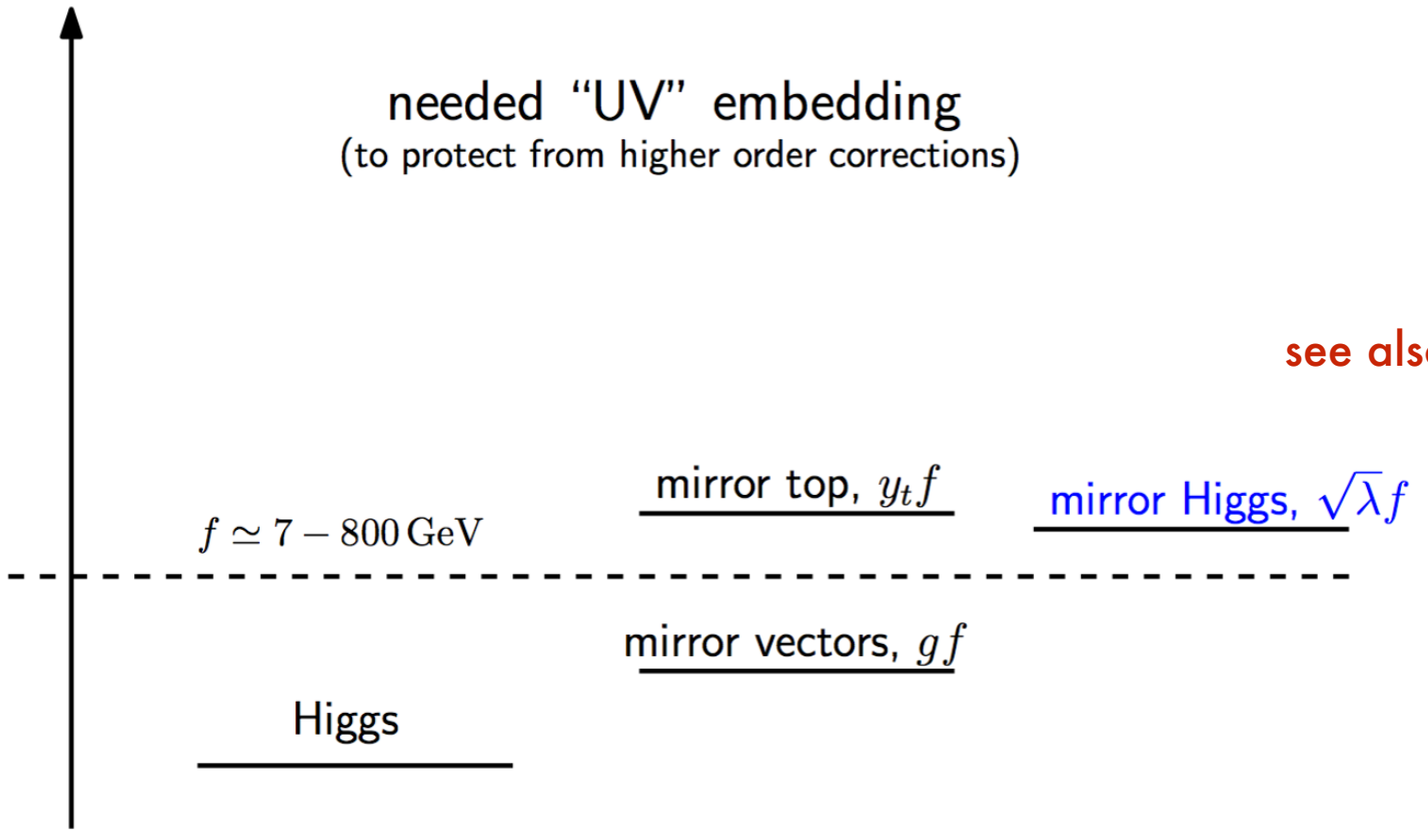
Need to assess the expected sensitivity for HL/HE LHC

$$\sigma_{4t}^{13\text{TeV}} = 10 \text{ fb}$$

$$\sigma_{4t}^{27\text{TeV}} = 110 \text{ fb}$$

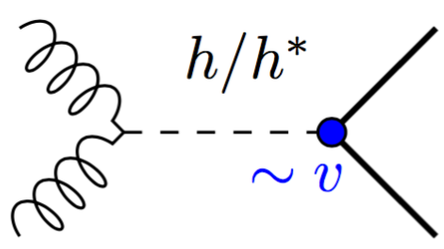
Madgraph LO

Other signatures of Twin Higgs?



see also Contino et al '17

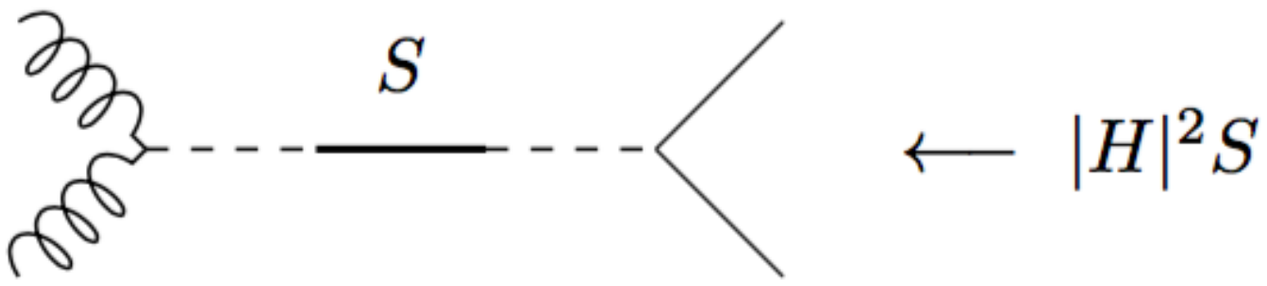
Difficult to see the mirror partners



pair production

Craig Katz Strassler Sundrum

What to expect from the mirror Higgs?



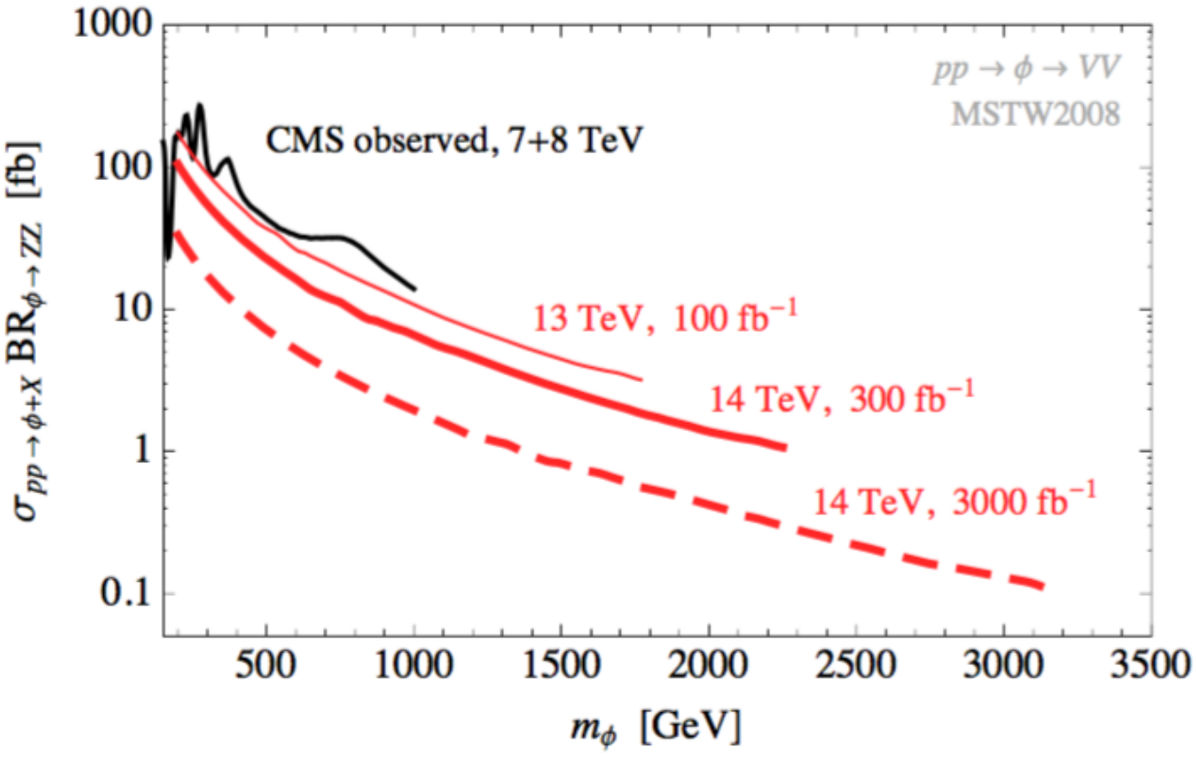
At high mass equivalence theorem relates the decay widths

$$\Gamma(\phi \to WW) = 2\Gamma(\phi \to ZZ) = 2\Gamma(\phi \to hh), \quad m_\phi \gg m_h$$

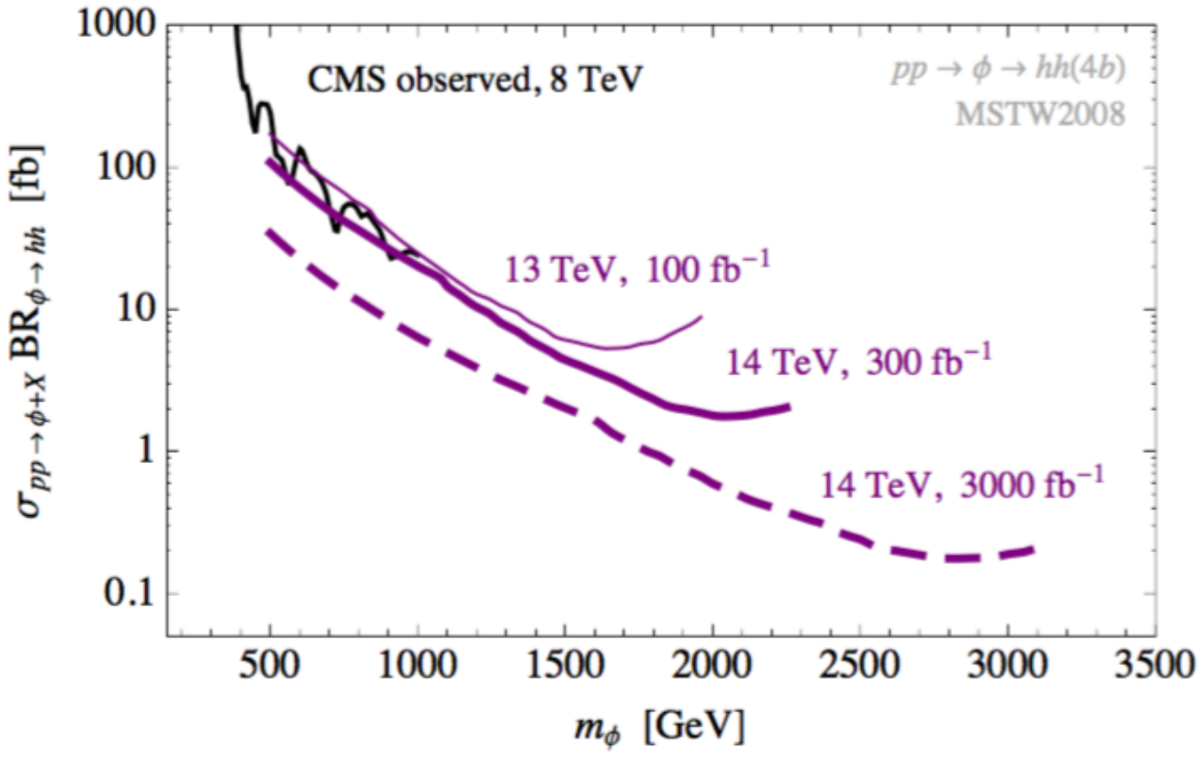
ϕ is the mass eigenstate

Ballistic physics program

$pp \to \phi \to VV$

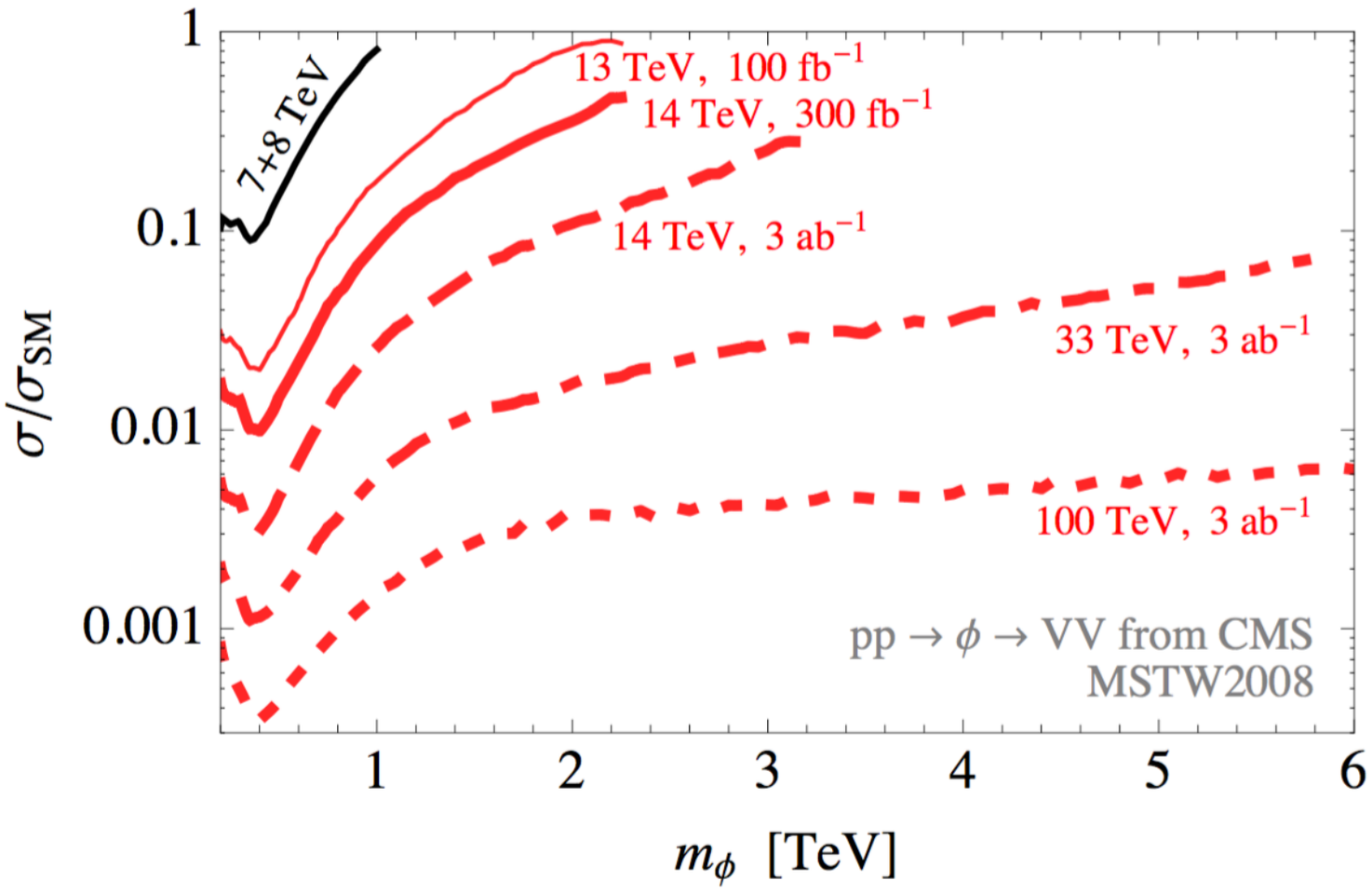


$pp \to \phi \to hh(4b)$



w/ Dario Buttazzo, Filippo Sala

Easy to compare with improvements in Higgs coupling



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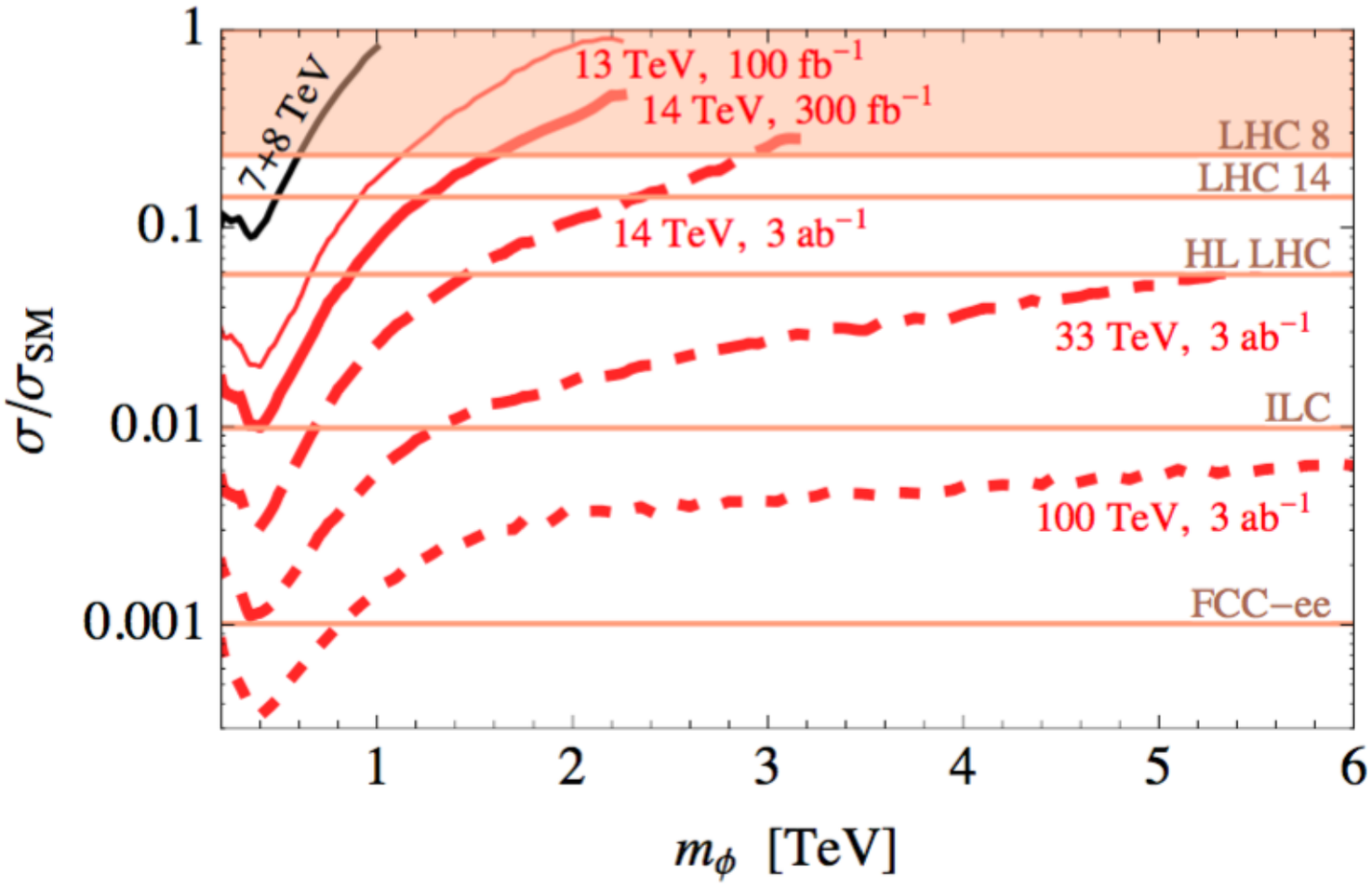
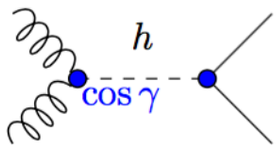


Direct searches dominate at low masses (at each phase of the experimental program)

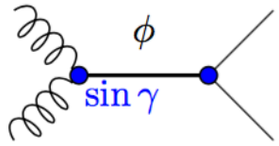
Signatures of the Twin Higgs

Higgs couplings

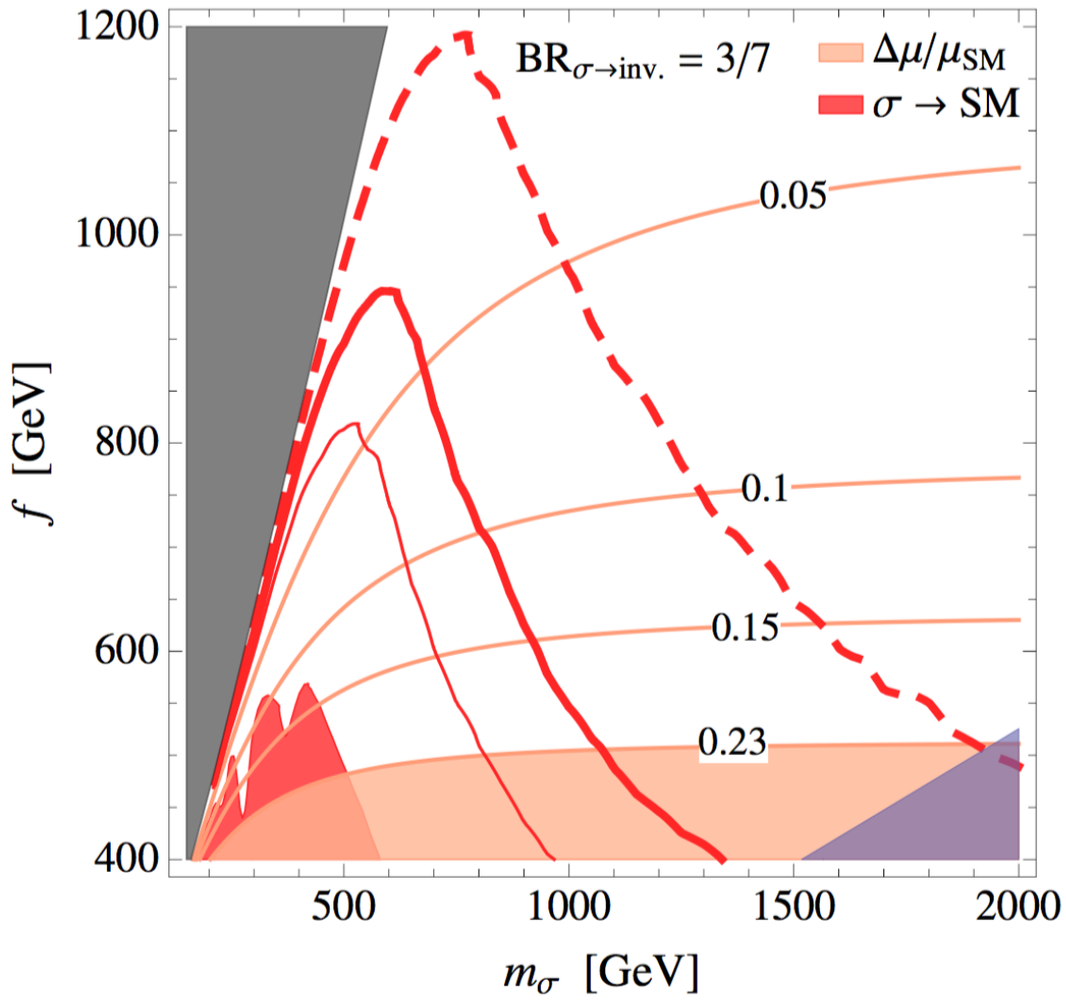


universal tree-level shift

Direct searches

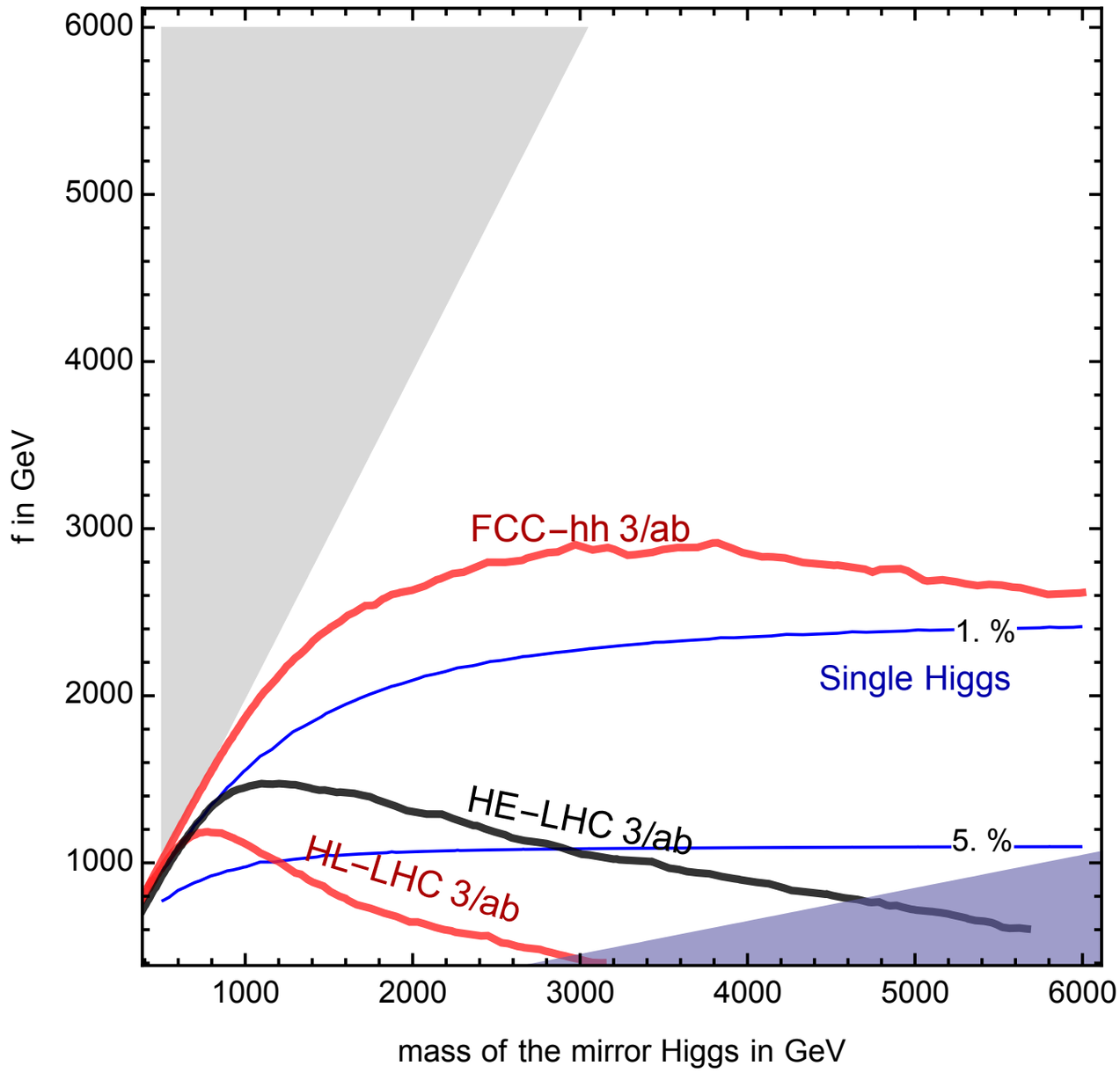


same h-BR (below $2m_h$)



main effects in longitudinal diboson production

Extrapolation to high energy/high luminosity

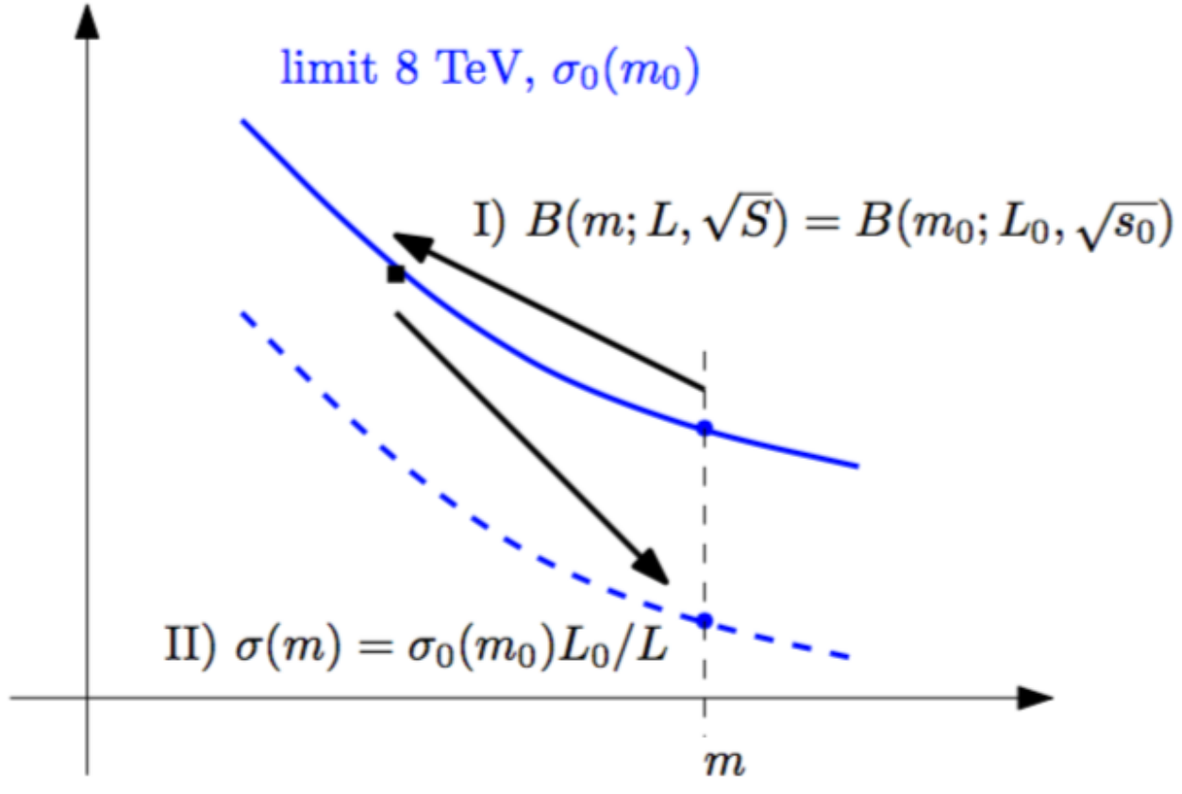


clearly no conclusions yet
as I hope it was clear from this overview,
there a few things to check/study

Rescaling of present data

If the limit is dominated by the number of backgrounds events around the peak

$$N_B \sim L \times \frac{\Delta \hat{s}}{m^2} \times c \times \left. \frac{d\mathcal{L}}{d\hat{s}} \right|_{\hat{s}=m^2}$$



so far still using results from LHC8