Non-standard signals of new physics

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PLHC 2012, Vancouver
June 8th, 2012

what if none of these SUSY searches see anything?

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talks by Csaba, Jose, Jamison, Nausheen

we've heard a lot about SUSY, and the Higgs<-> SUSY interplay

but that's not the only option

more generally

lots of the power in SUSY searches comes from large MET handle

what about new physics (including SUSY) without large MET?

talks by Csaba, Jose, Jamison, Nausheen

we've heard a lot about SUSY, and the Higgs<-> SUSY interplay

but that's not the only option

hmm.. where are all those superpartners?

more generally

lots of the power in SUSY searches comes from large MET handle

what about new physics (including SUSY) without large MET?

many things fall into this category

lepto-quarks

W'/Z'

black holes

RPV-SUSY

contact interactions

BOOSTED OBJECTS

etc.

i'll talk about a couple objects that are common to many BSM models, not covered by 'usual searches'

AND

where to look if there is no SM Higgs?

vector-like new fermions

ex.) $T = (T_L, T_R)\ \ (3,1)_{2/3}$ same Q# as t_R

- can have mass without EWSB
- don't contribute to EW precision obs.

these objects are part of most Little Higgs scenarios, composite models (topcolor) and their 5D counterparts

(Cheng, Dobrescu, Hill 992343; Han, Logan, Wang 0506313; Contino, Kramer, Son, Sundrum 0612180; Contino, Servant 0801.1679, etc..)

vector-like new fermions

(LH, RH quarks that couple the same way)

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vector-like new fermions

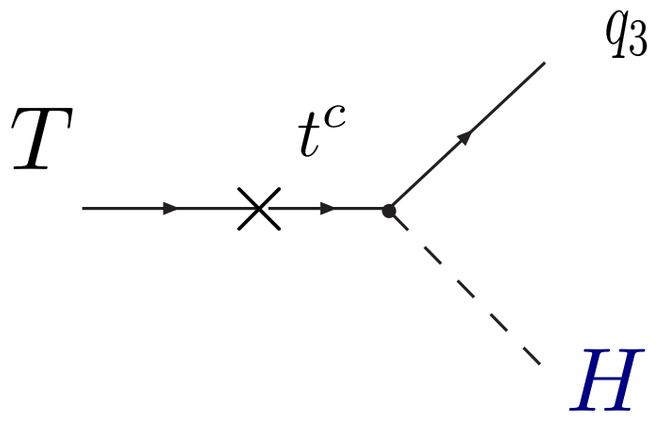
mix with SM

$$y_t\, Q_3\, H\, t^c + M\, T\, T^c + \delta\, T\, t^c + h.c.$$

$$(t \;\; T) \begin{pmatrix} m & 0 \\ \delta & M \end{pmatrix} \begin{pmatrix} t^c \\ T^c \end{pmatrix}$$

$$\begin{aligned}
\mathcal{L} \supset\; & \frac{m_t\, \cos^2\theta_l}{v} h\, \bar{T}_D (\tan\theta_r\, P_L + \tan\theta_l\, P_R)\, t_D \\
& + \frac{g_2 \sin\theta_l\, \cos\theta_l}{2\, \cos\theta_W} Z_\mu \left(\bar{T}_D \gamma^\mu\, P_L t_D + \bar{t}_D \gamma^\mu\, P_L T_D\right) \\
& + \frac{g_2 \sin\theta_l}{\sqrt{2}} \left(W^+_\mu \bar{T}_D \gamma^\mu P_L b_D + W^-_\mu \bar{b}_D \gamma^\mu\, P_L T_D\right)
\end{aligned}$$

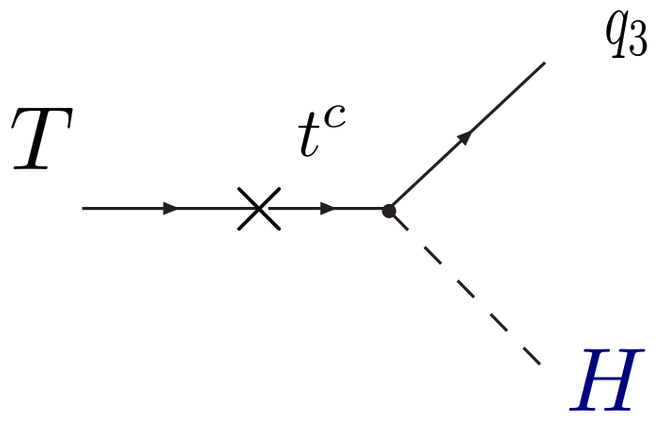
new interaction



Branching ratio, up to small corrections,

set by Goldstone equivalence:

new interaction



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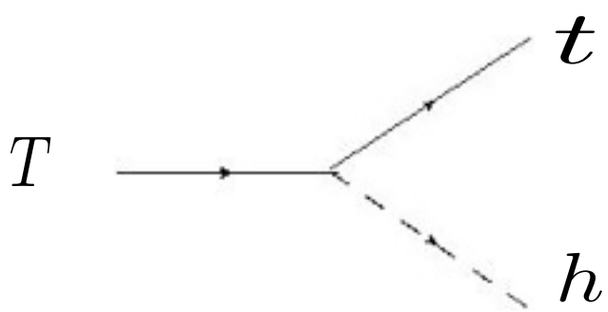
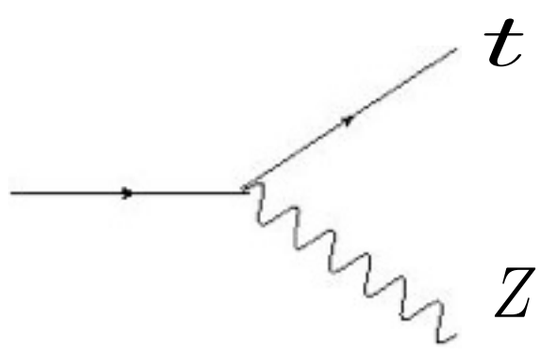
T decay modes



$\sim 25\%$



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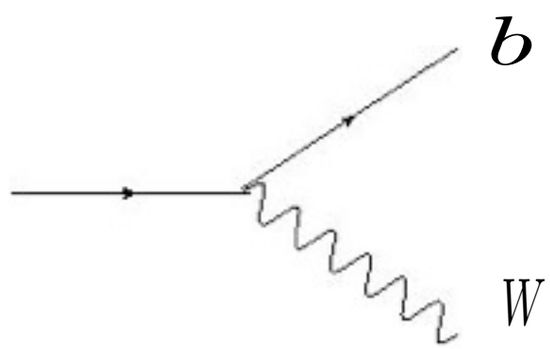
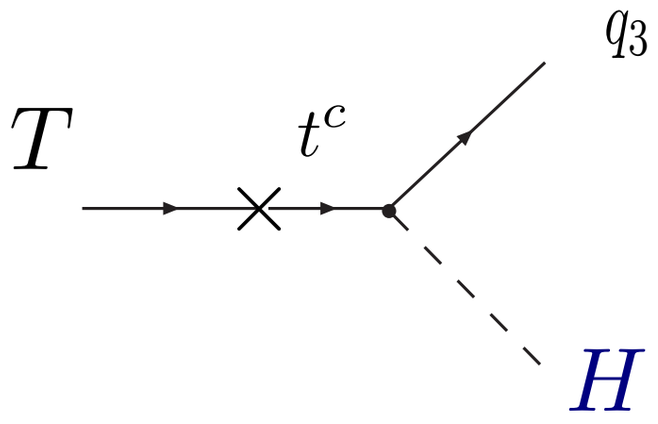


$\sim 50\%$

new interaction



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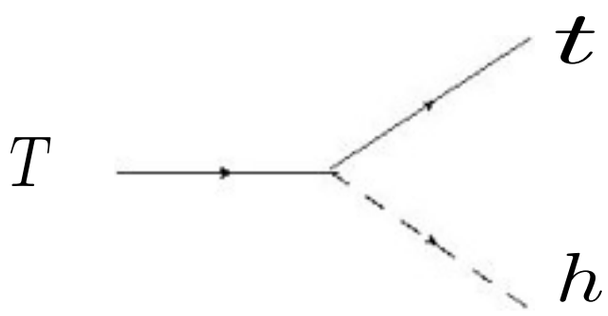

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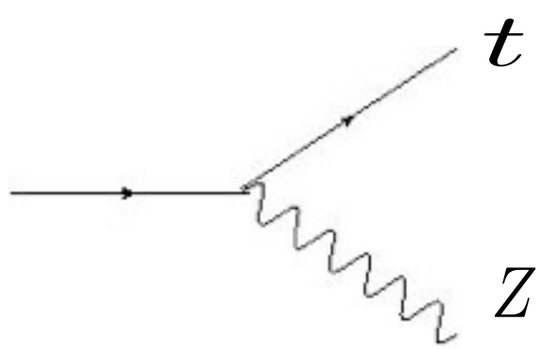

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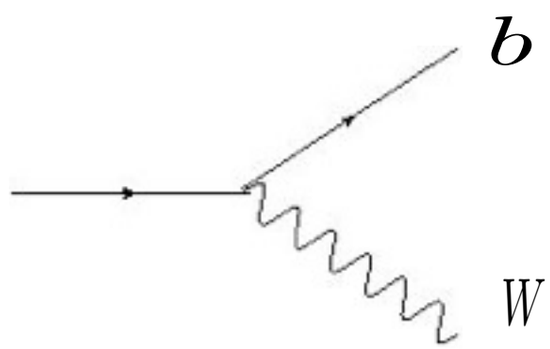

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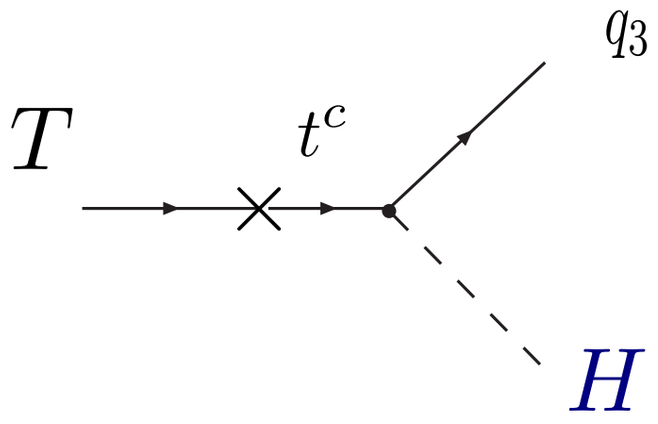
in large mass limit,
only parameter is M_T

new interaction



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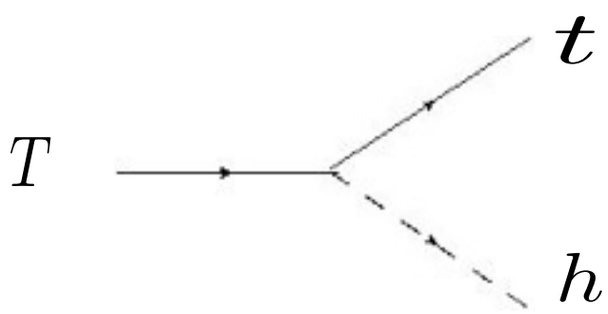

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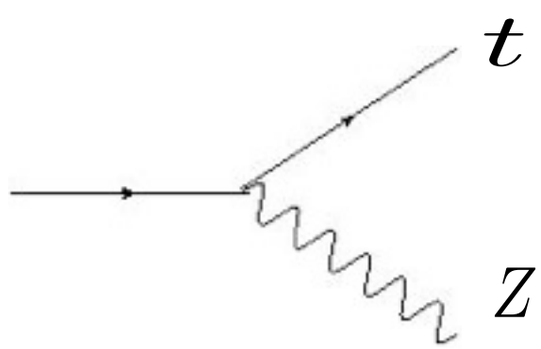

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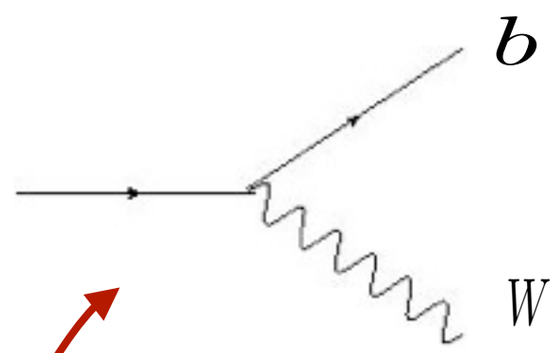
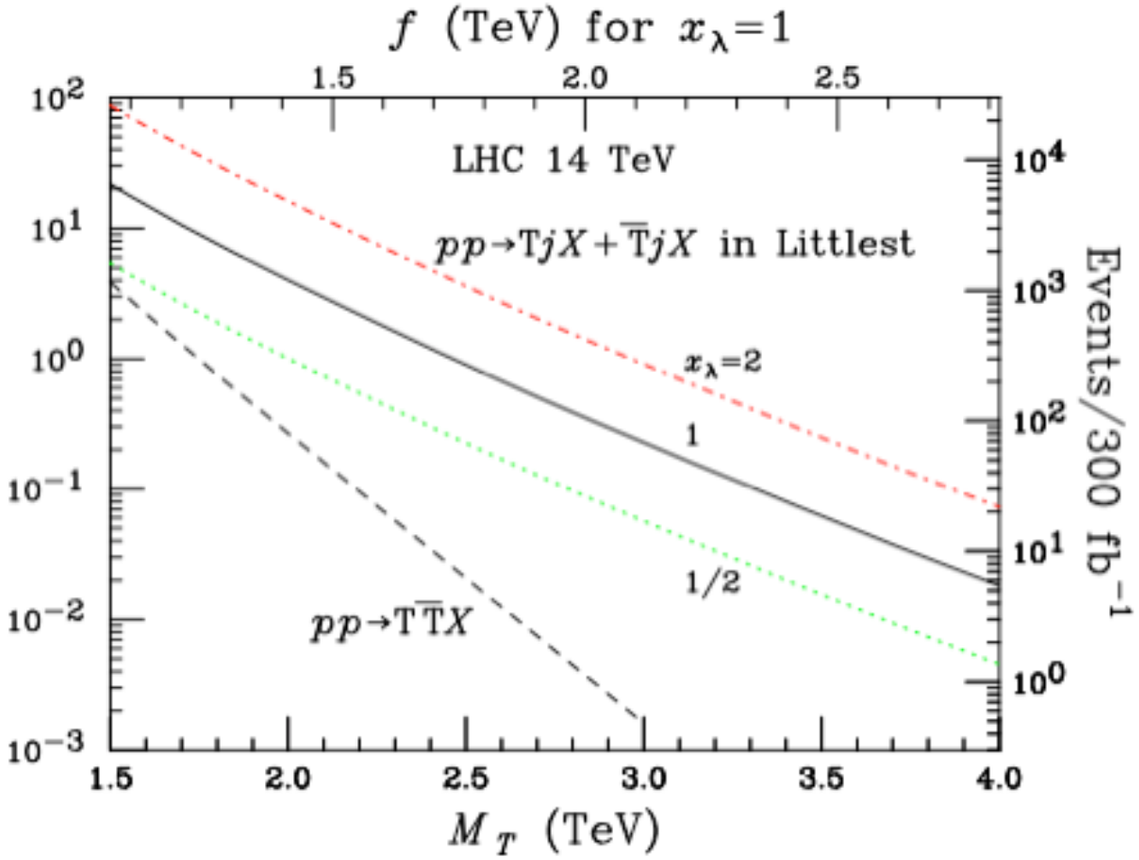


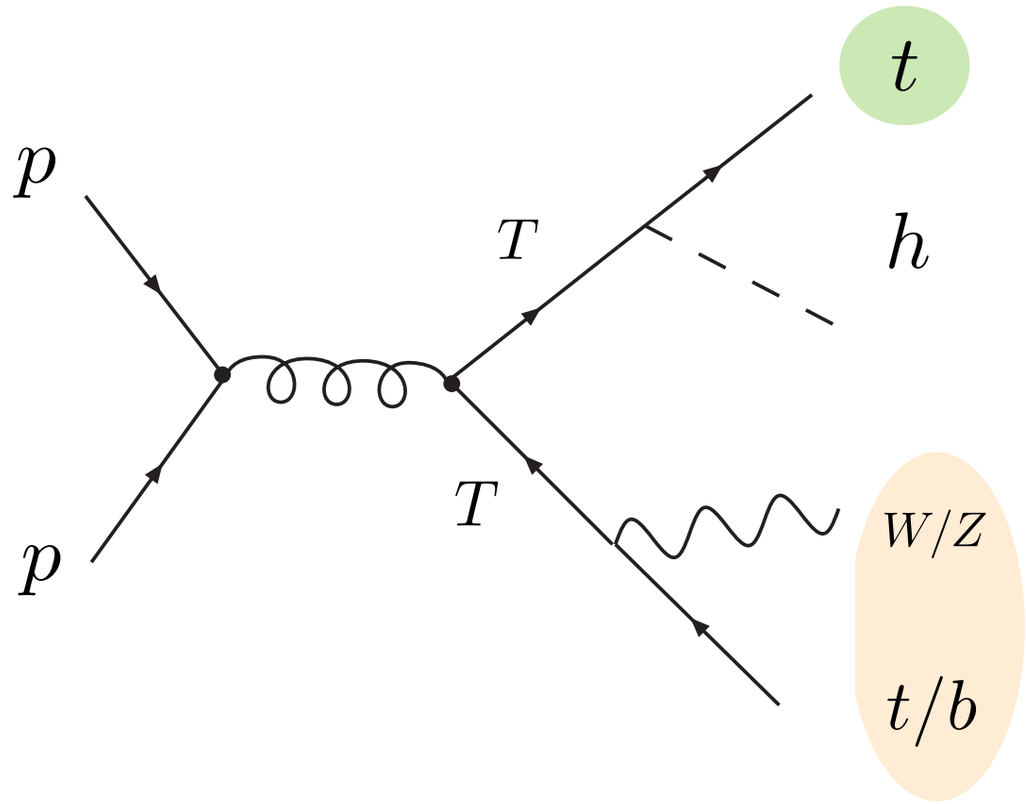
$\sim 50\%$

in large mass limit,
only parameter is M_T

extra ‘chiral’ quarks
(4th generation)
only have this decay mode

large production cross section, exotic final states





(Han, Logan, Wang)

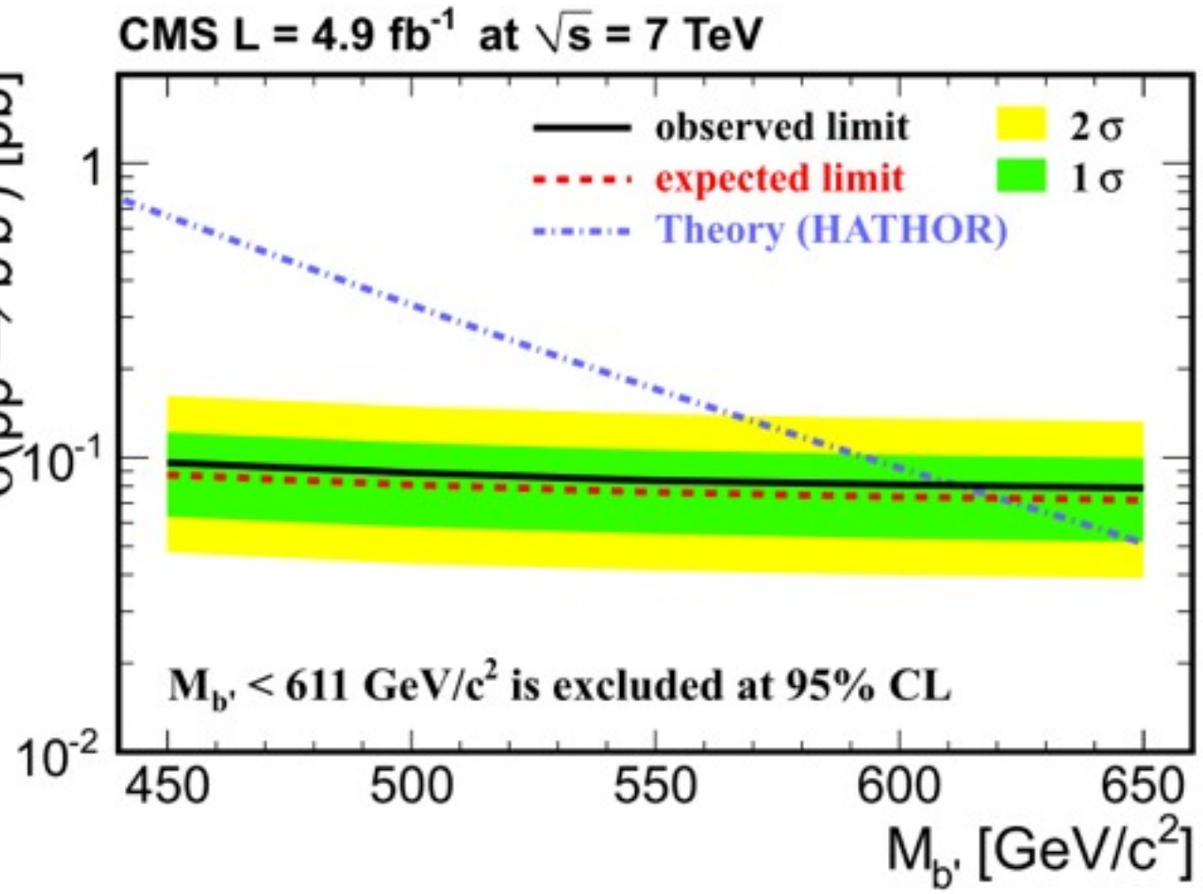
- final states have several b's, W's
- helped by application of substructure techniques?

(Aguilar-Saavedra; Holdom; Kribs, AM, Roy)

vector-like new fermions

searches, but assume 100% into only one mode

B'→ t W
CMS 1109.4985



also
ATLAS 1204.1265

Rao, Whiteson
1204.4504,
1203.6642

- more searches, more modes would be great
- can we use T → t+h channel, or more generally X → Y+h?
- more exotic charges possible

‘Colorons’

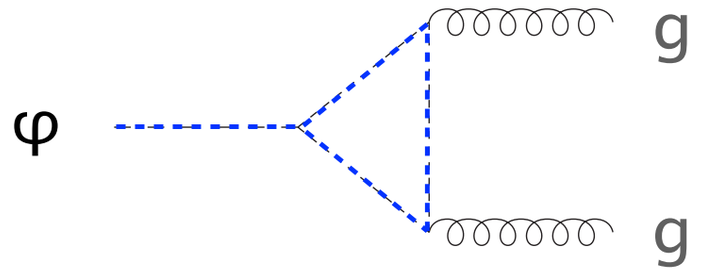
new colored states that are dominantly pair produced

Easy to add without causing problems

Ex.) color octet scalar φ

$$|D\varphi|^2 - M_\varphi{}^2\, \varphi^2 - \mu\, \varphi^3 + \ldots$$

only term that allows φ decay

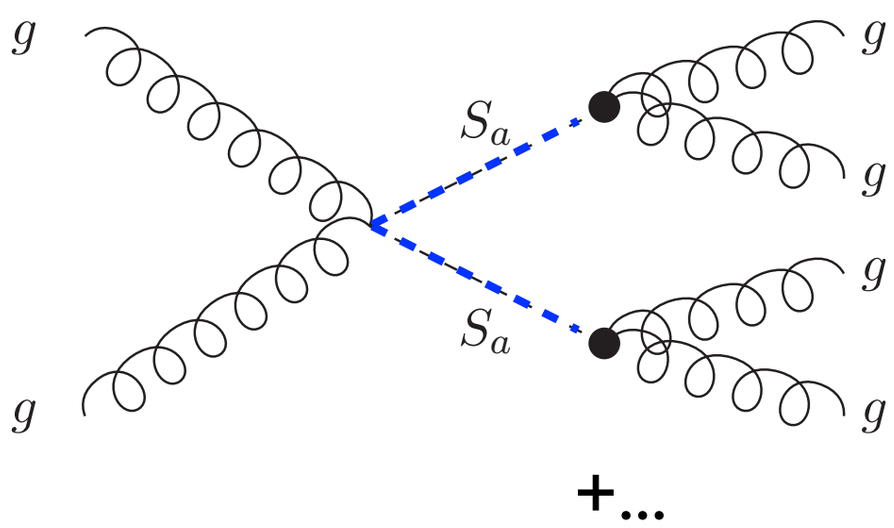


phenomenology described by very few parameters:

M_φ, BR($\varphi \to jj$)

part of extended SUSY models, extra-dimensional models

limits

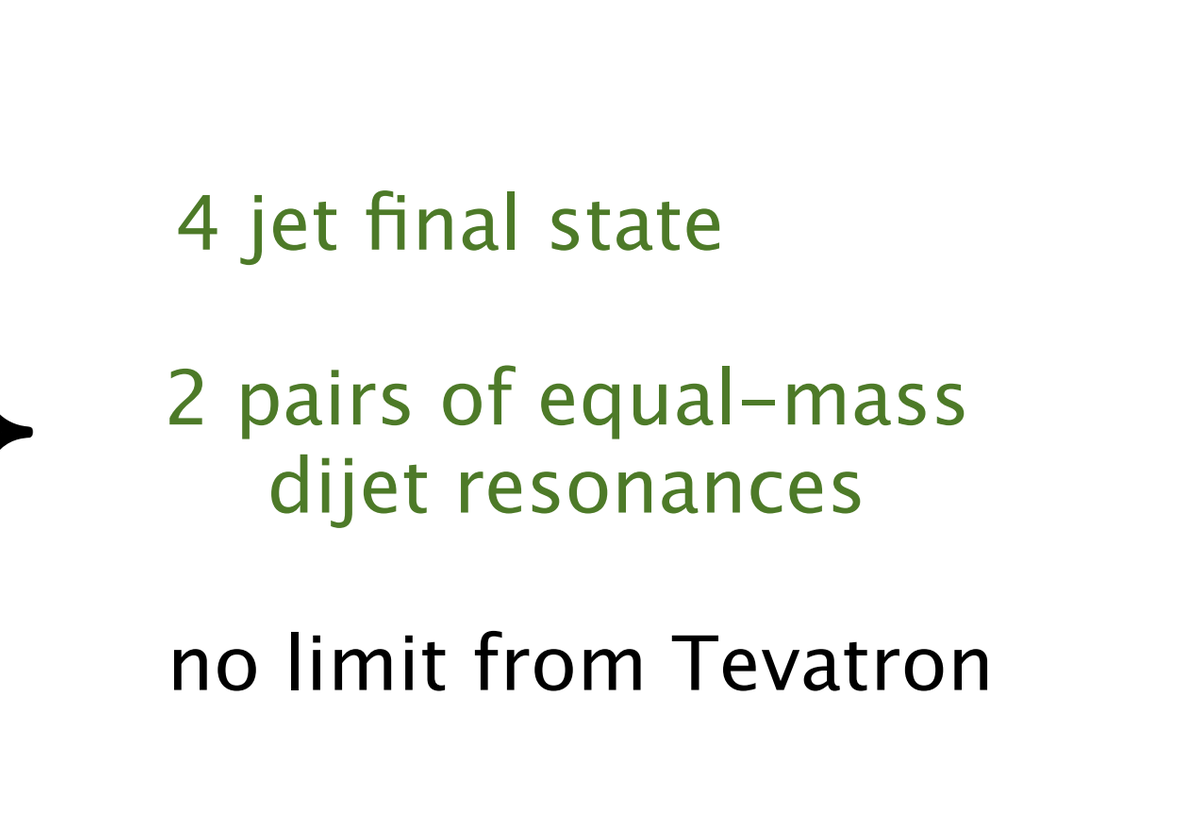


4 jet final state

2 pairs of equal-mass dijet resonances

no limit from Tevatron

CMS-EXO-11-016



- color octet is just an example, lots of particles fall into this category (different spin, EW charge, etc.)

(Burgess, Trott, Zuberi 0907.2696, Gerbush et al 0710.3133 , Bai, Dobrescu 1012.5814; Chivukula, Golden,Simmons '91; Dobrescu, Kong, Mahbubani 0709.2378, etc.)

- difficult multi-jet background

  increasing trigger thresholds mean can't probe light stuff

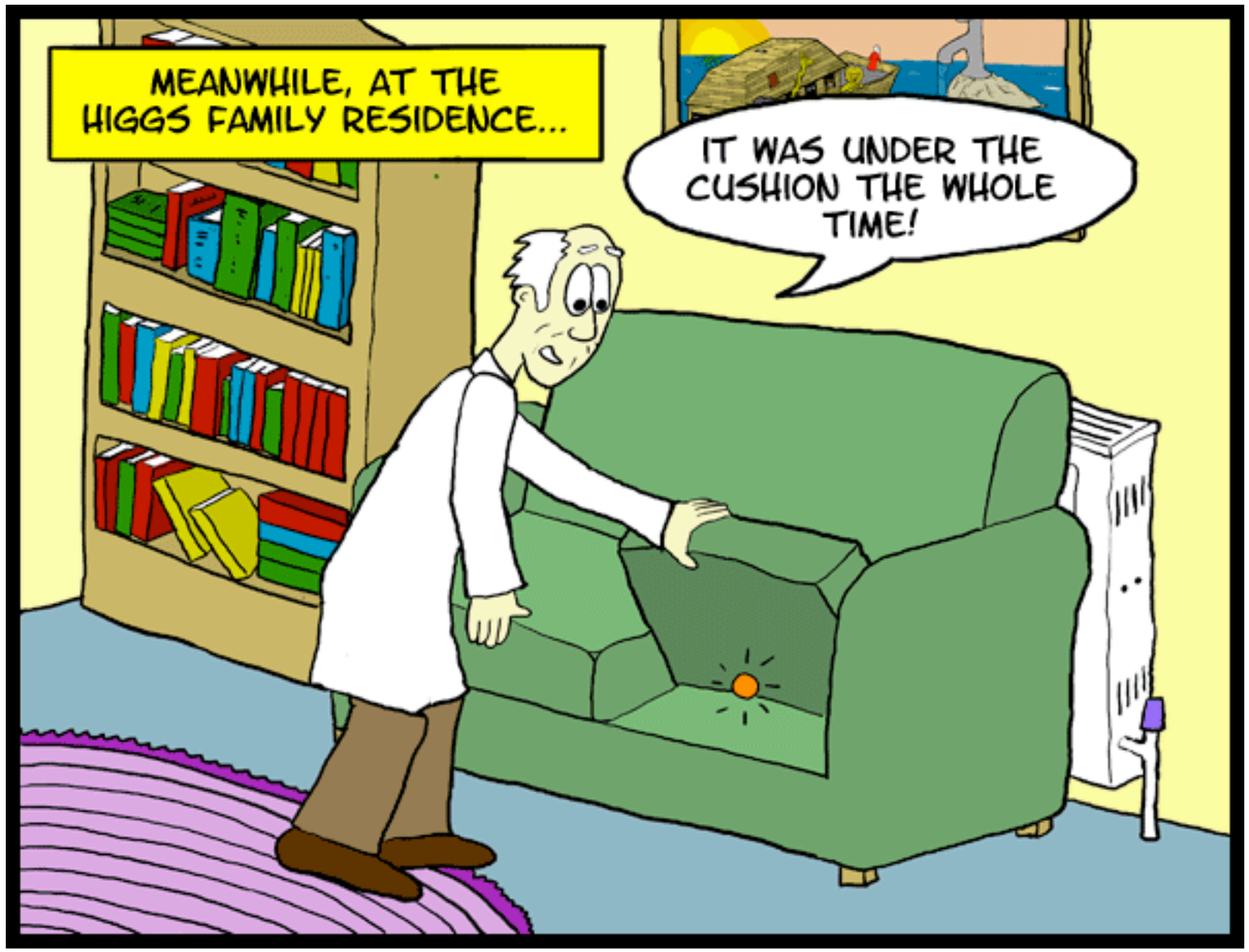
- don't have to stop at $\varphi \to gg$, could be $\varphi \to 3q$, etc.

CMS EXO11060

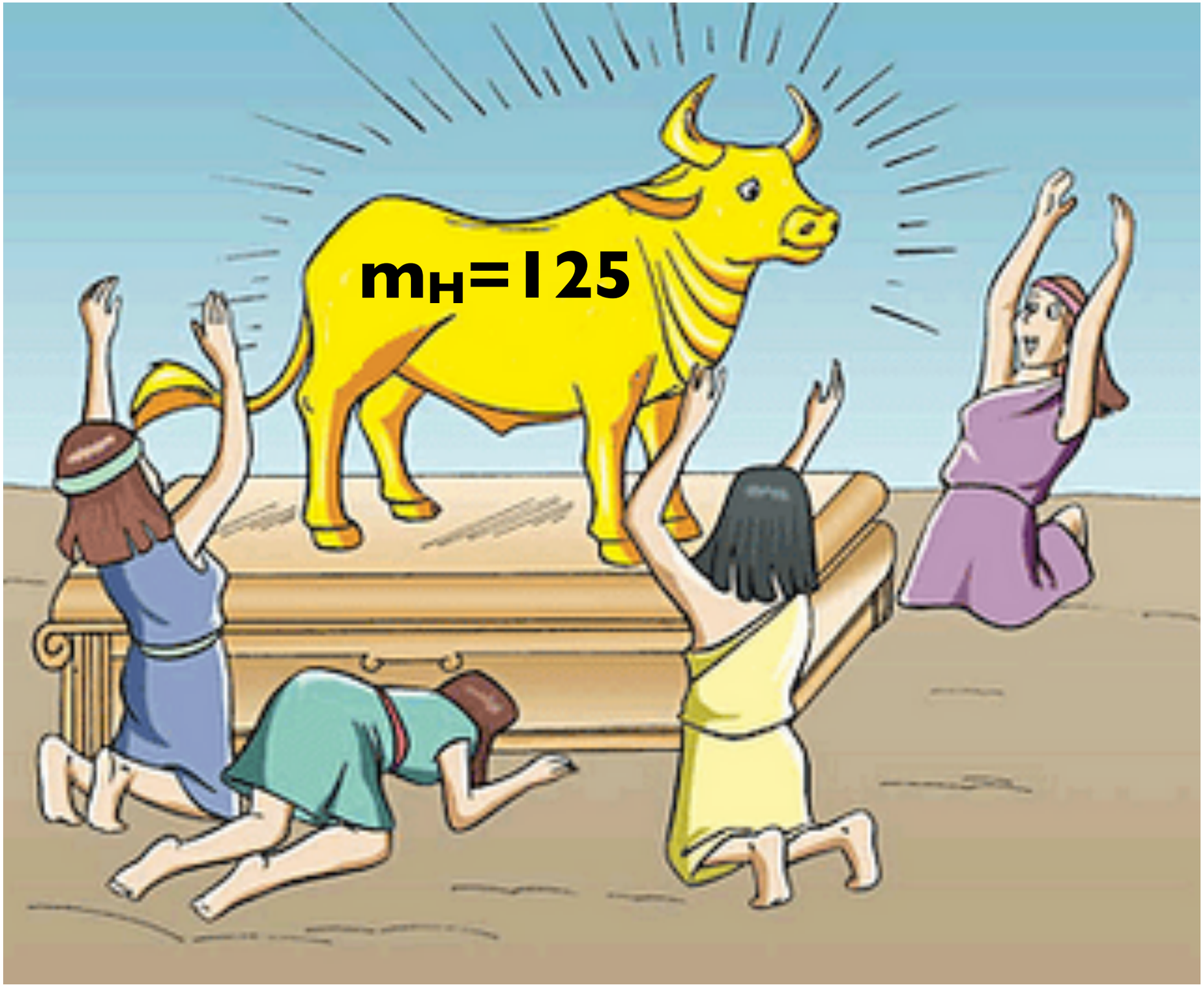
- can have a large impact on Higgs physics, ex.) $\kappa |H|^2|\varphi|^2$

(Dobrescu, Kribs, AM 1112.2208)

What if No Higgs?

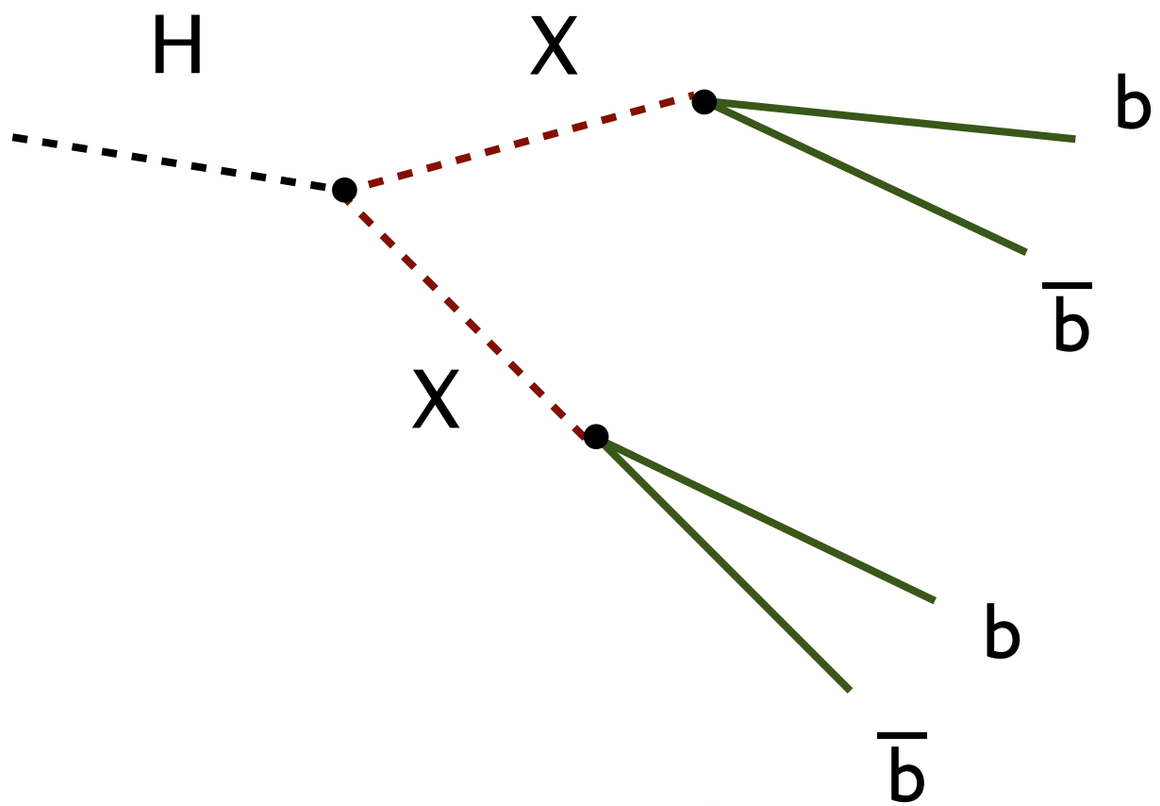


still early... lets not get carried away



may be a Higgs with strange decays?

light Higgses are narrow, easy to introduce a new mode that becomes the dominant decay channel



$\lambda\ |H|^2\ X^2 \rightarrow \lambda\ v\ h\ X^2$

(ex.) NMSSM + friends, 'buried Higgs' scenario)

can we dig out these final states? 4τ? 4g?

depending on m_H, m_X, final products may be boosted/ collimated.. special techniques needed?

Chen et al 1006.1151; Falkowski et al 1006.1650; Bellazzini et al 1012.1316

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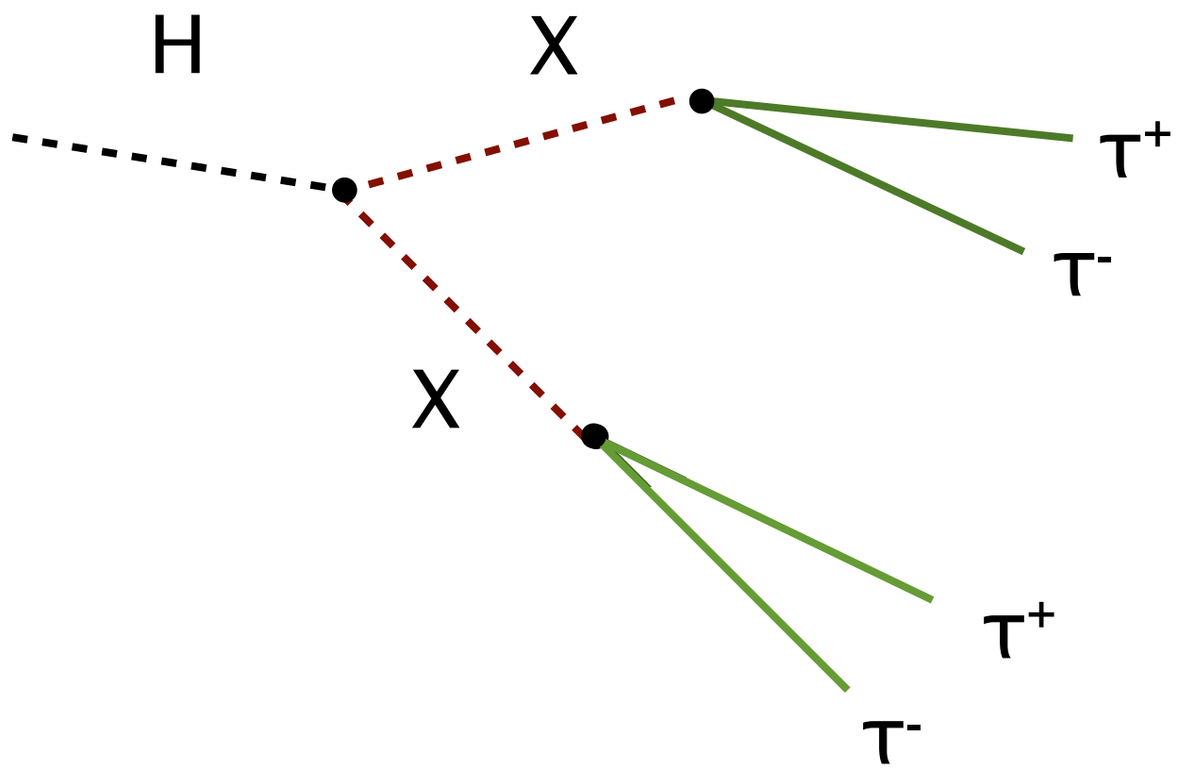

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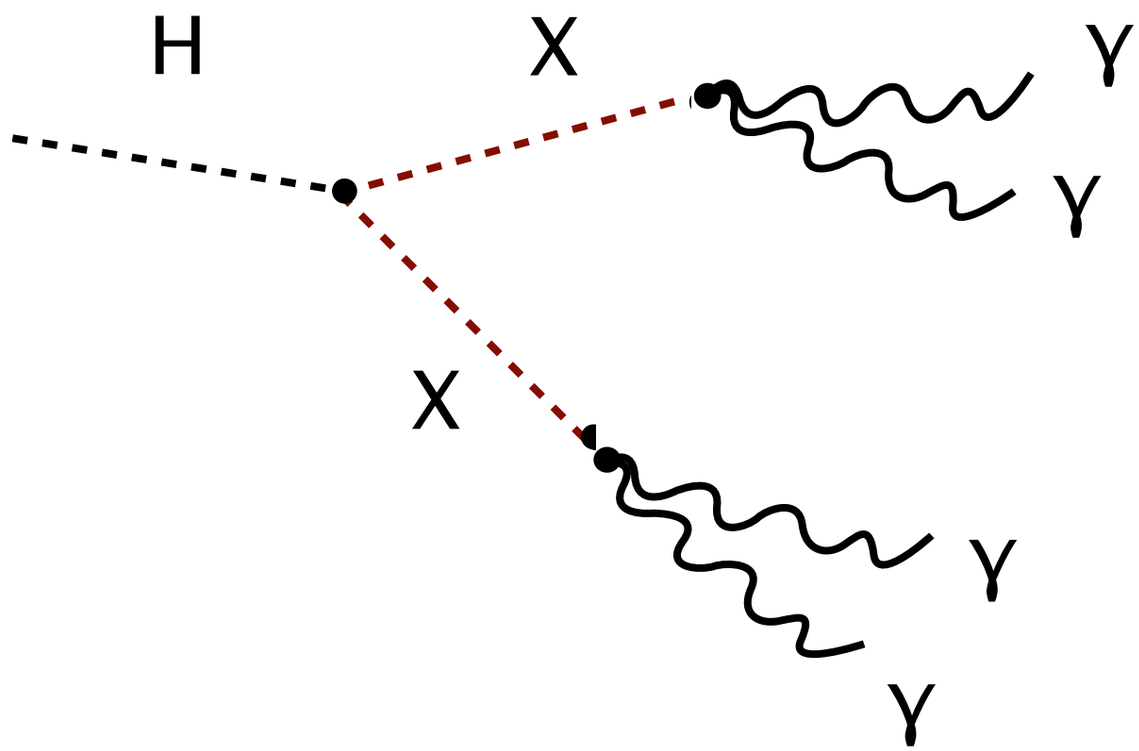

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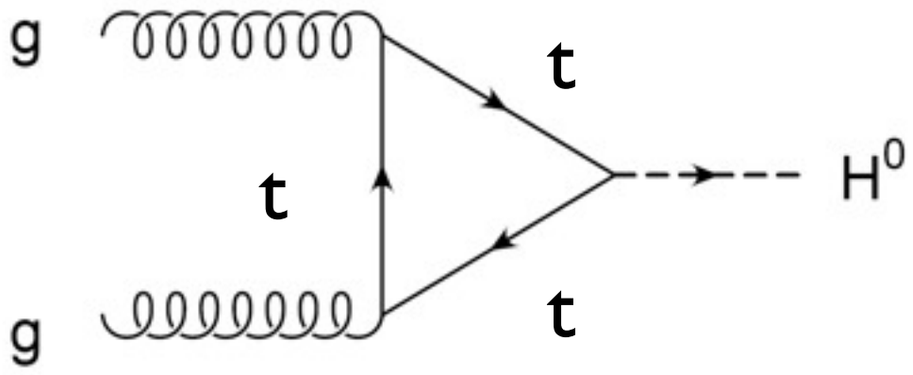

loop-level process,
sensitive to new physics

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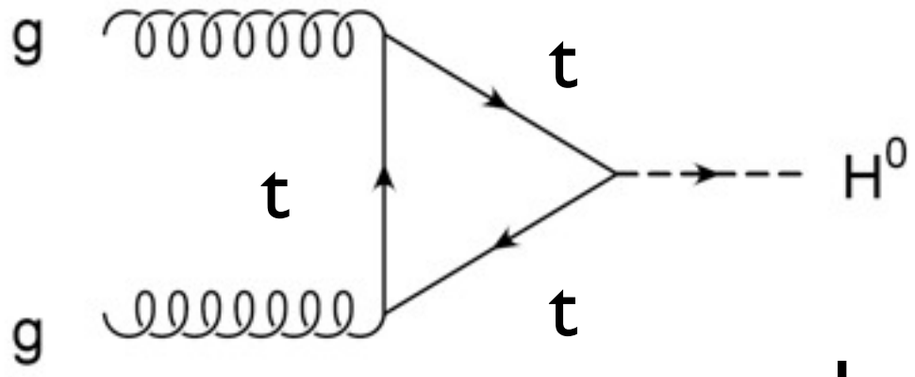

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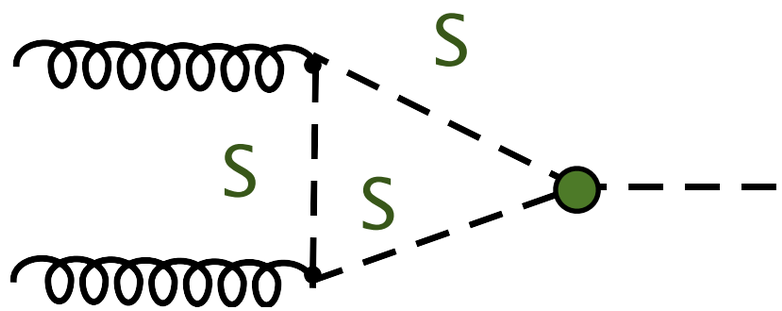

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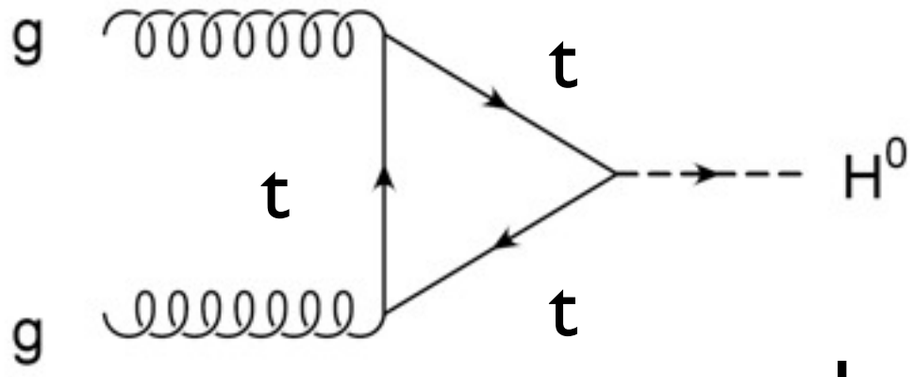

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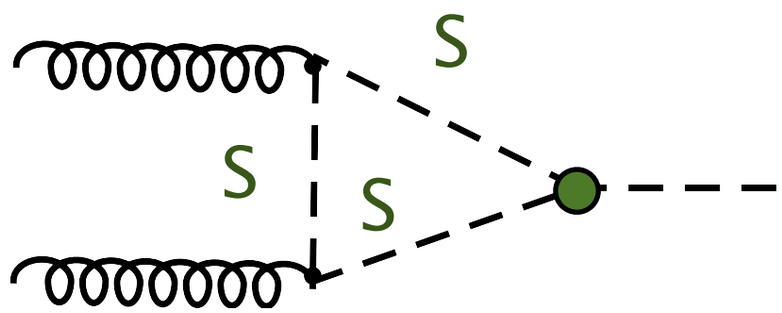

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can easily reduce rate to 1/4, even 1/10 SM

BUT, should see new particle S...

plus, there are other ways to make Higgses

and suppressed gg->h means enhanced gg->hh

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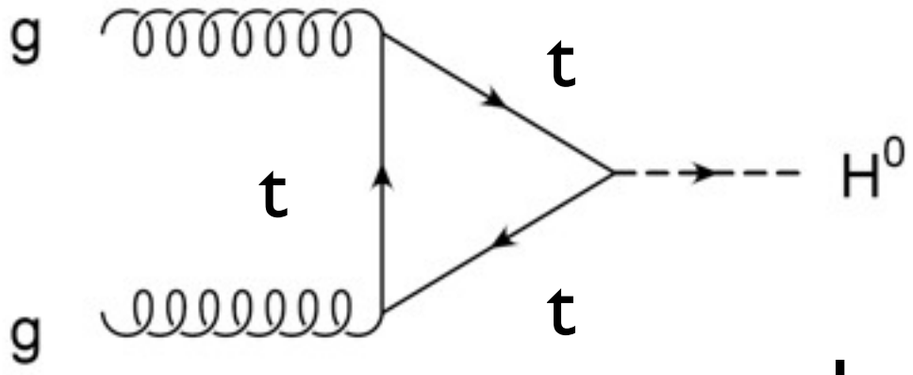

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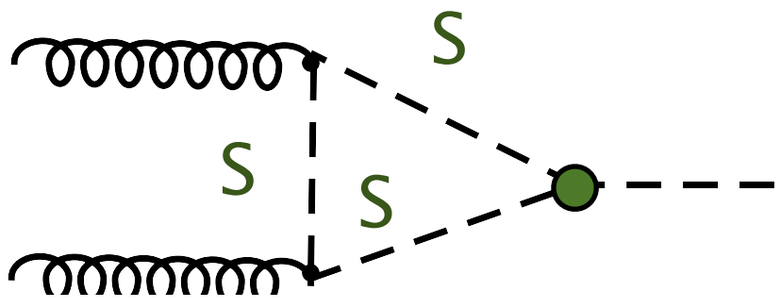
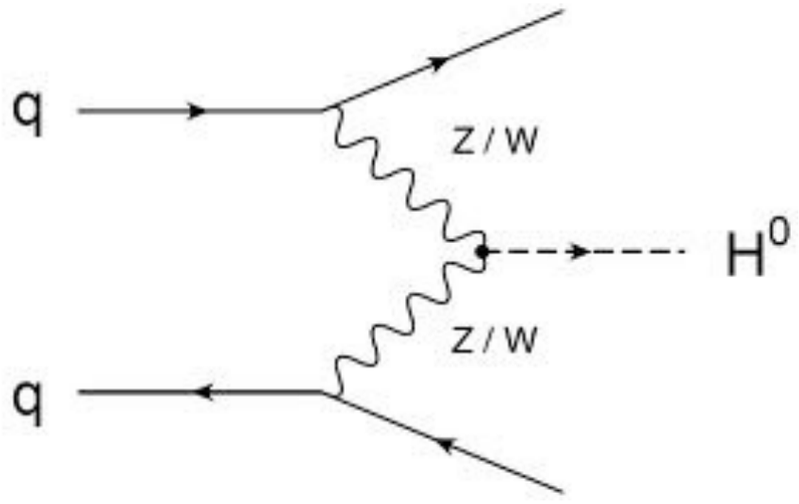
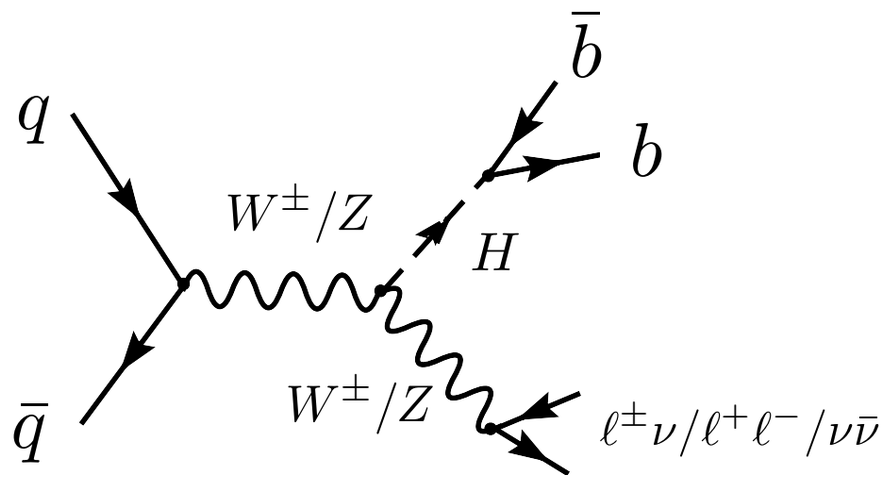




vector boson fusion
~10% of gg->H^0



associated production
(Higgs-strahlung)
~1% of gg->H^0

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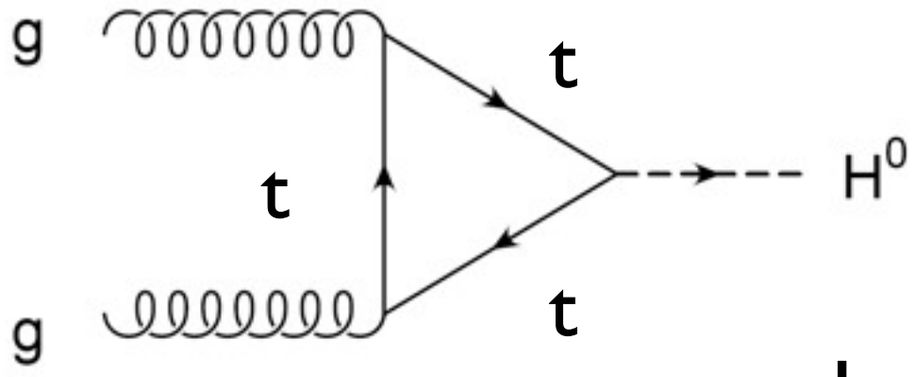

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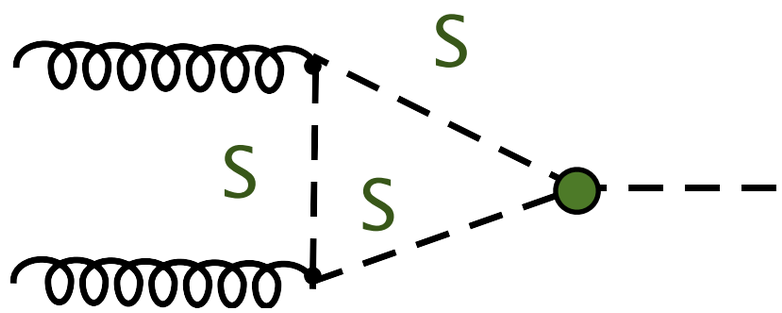

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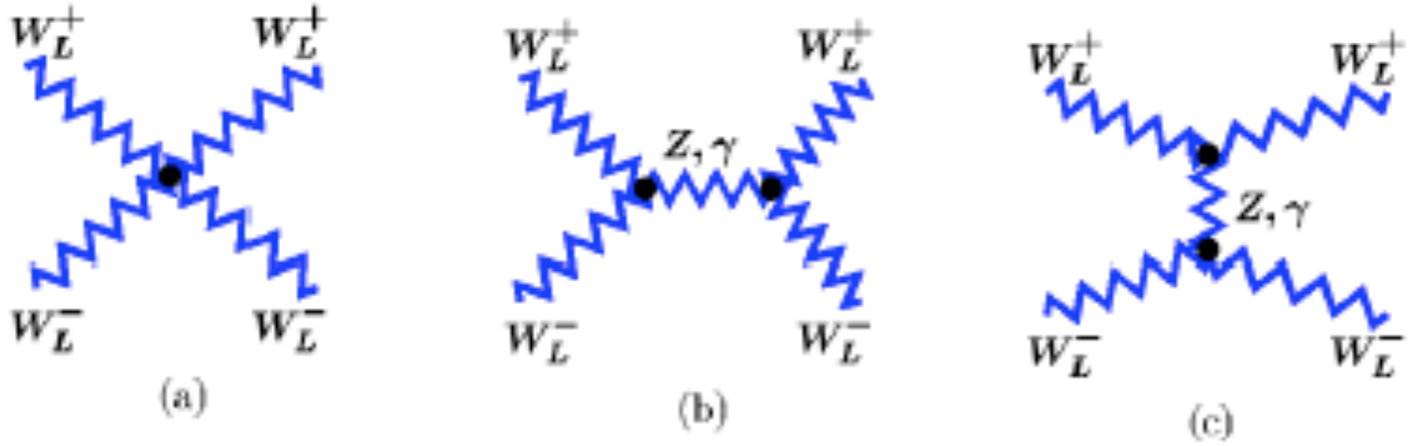

$\sim E^2$

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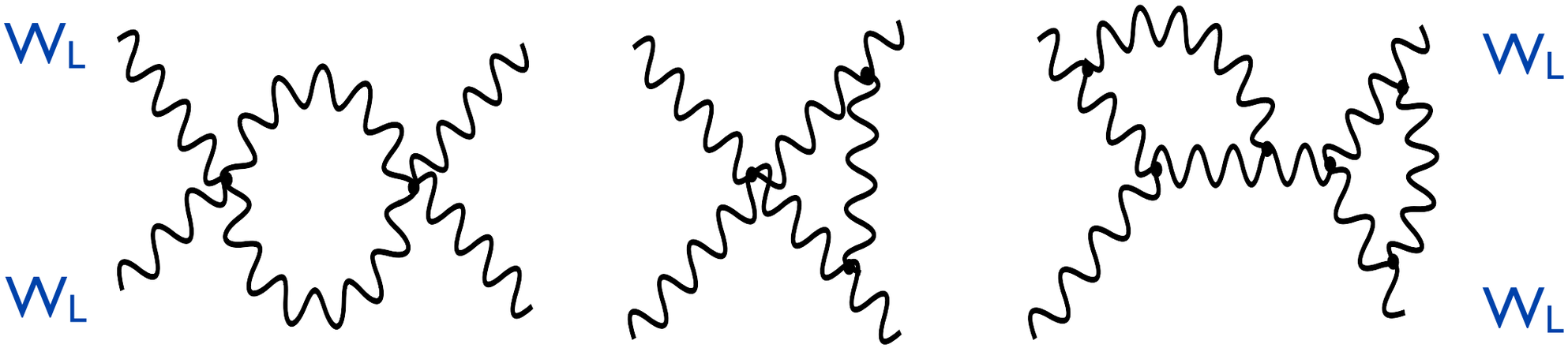

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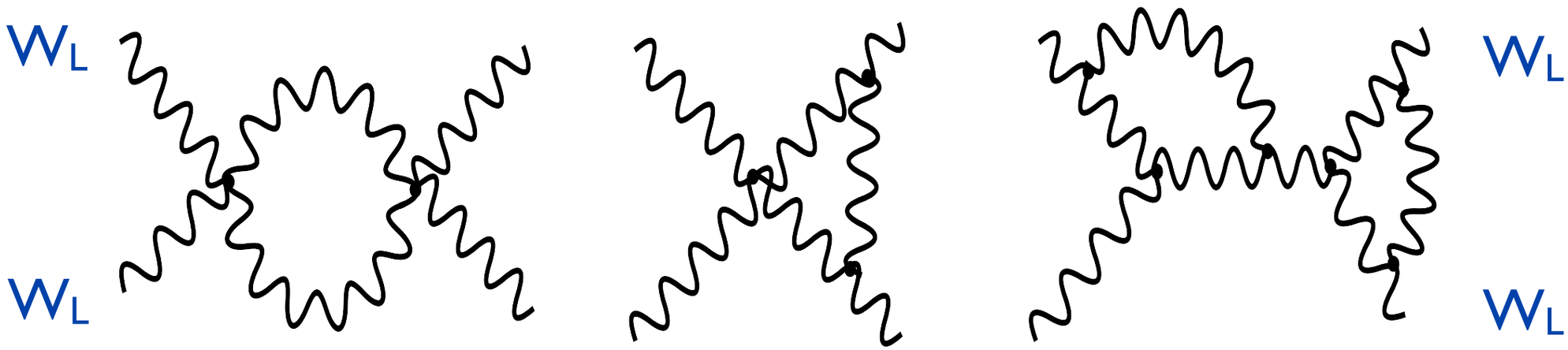


should say:

"we must see something, either a light Higgs, or strong dynamics at the TeV scale"

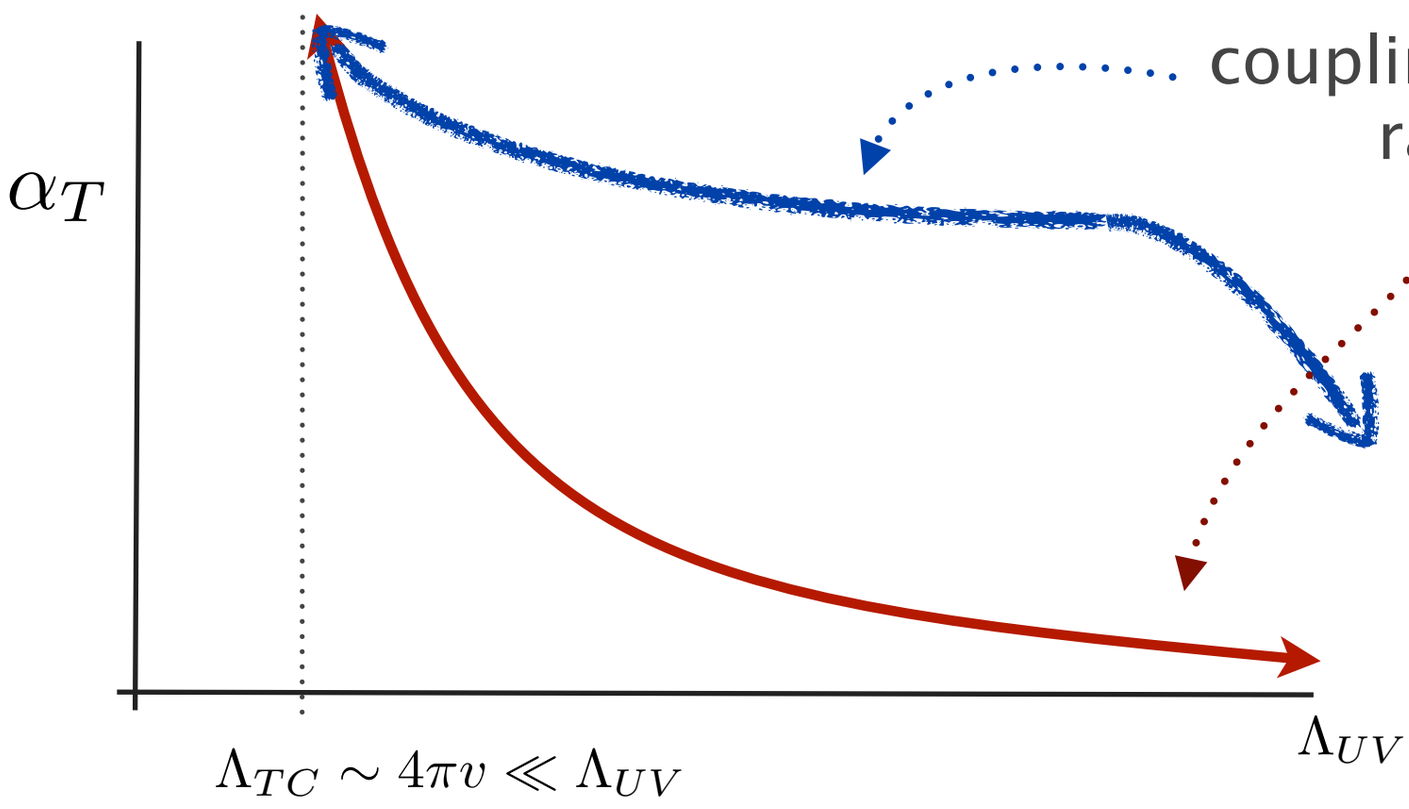
Strong dynamics

biggest problem is that we can't calculate

to estimate pheno, often take QCD as an example and rescale masses, etc. from GeV -> TeV

$\rho \rightarrow \rho_T$, $\pi \rightarrow \pi_T$

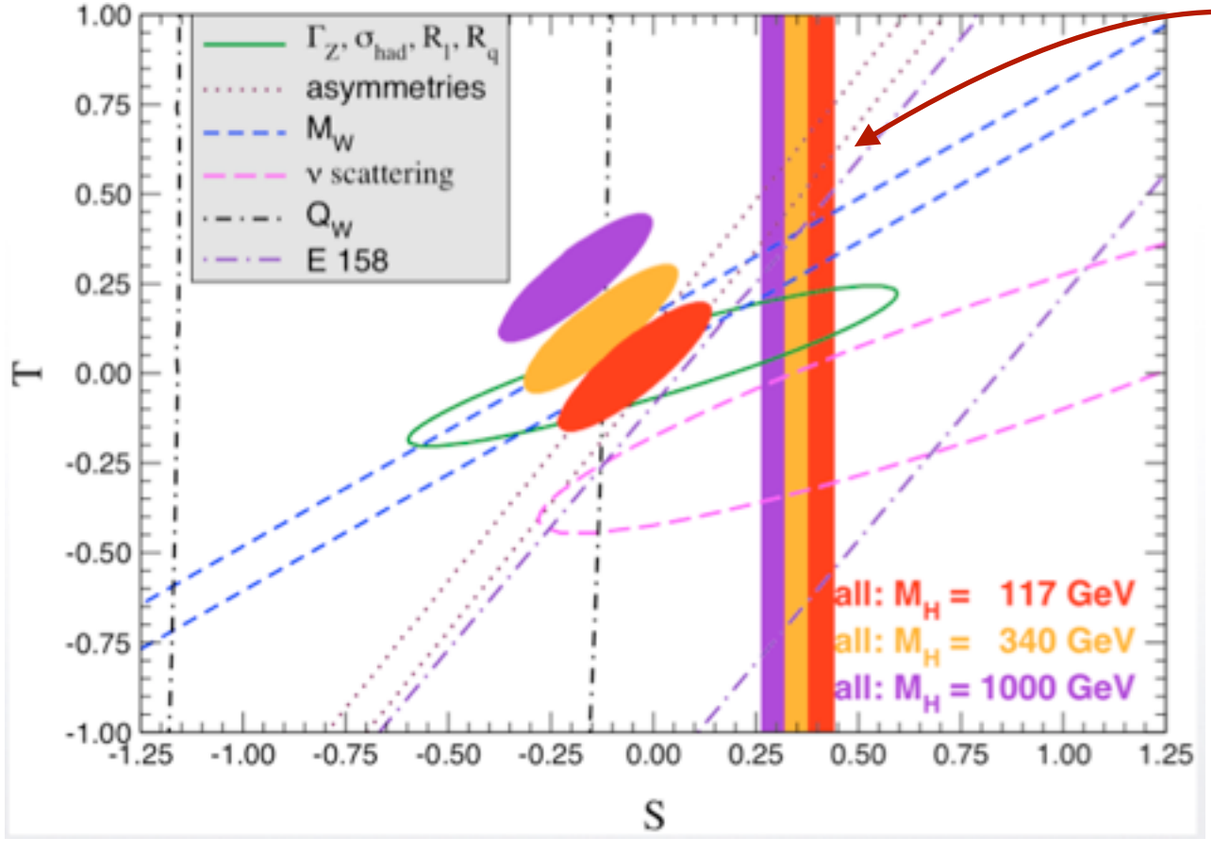
but there is no reason that new strong dynamics should be like QCD



+ know from susy-QCD that small changes in matter content can lead to big changes in theory

Does it matter?

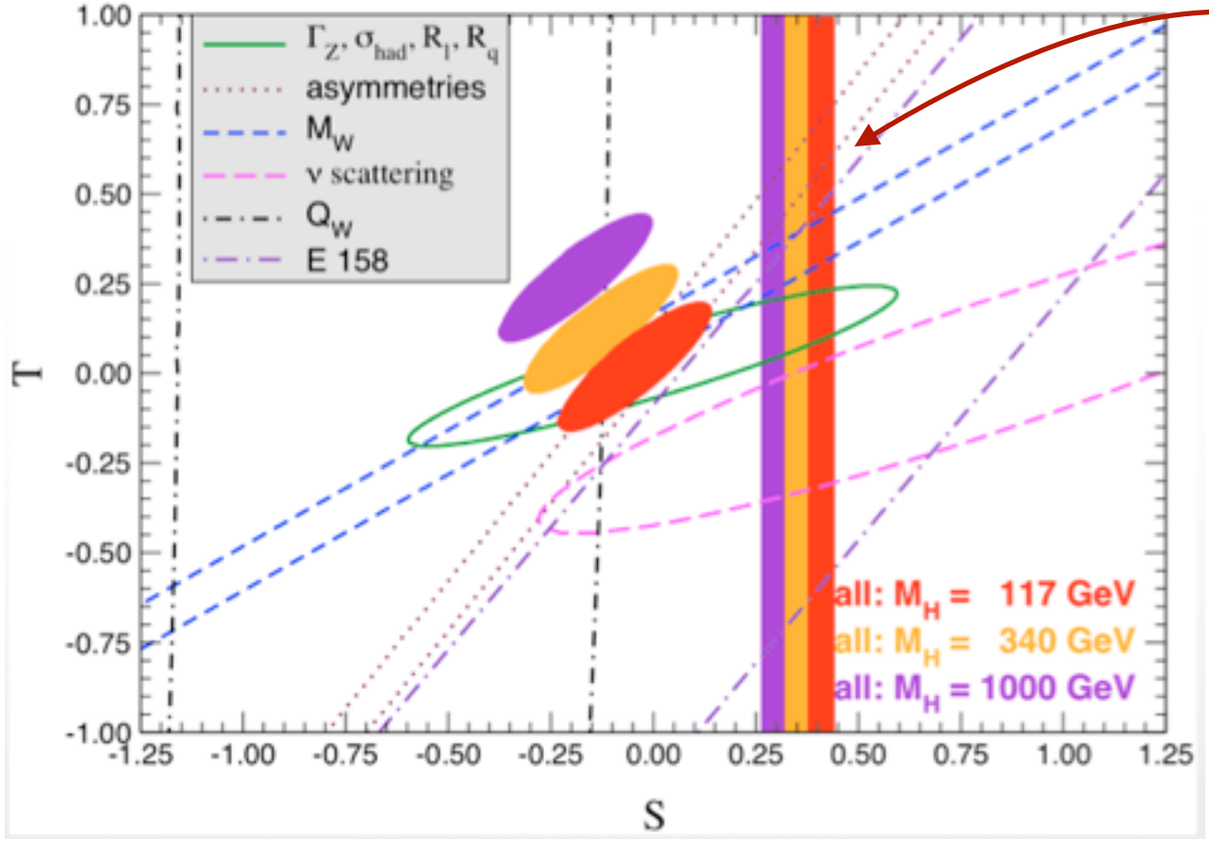
EW-precision observables are the biggest complaint about strong dynamics



estimates obtained by assuming strong dynamics ~ QCD

Does it matter?

EW-precision observables are the biggest complaint about strong dynamics



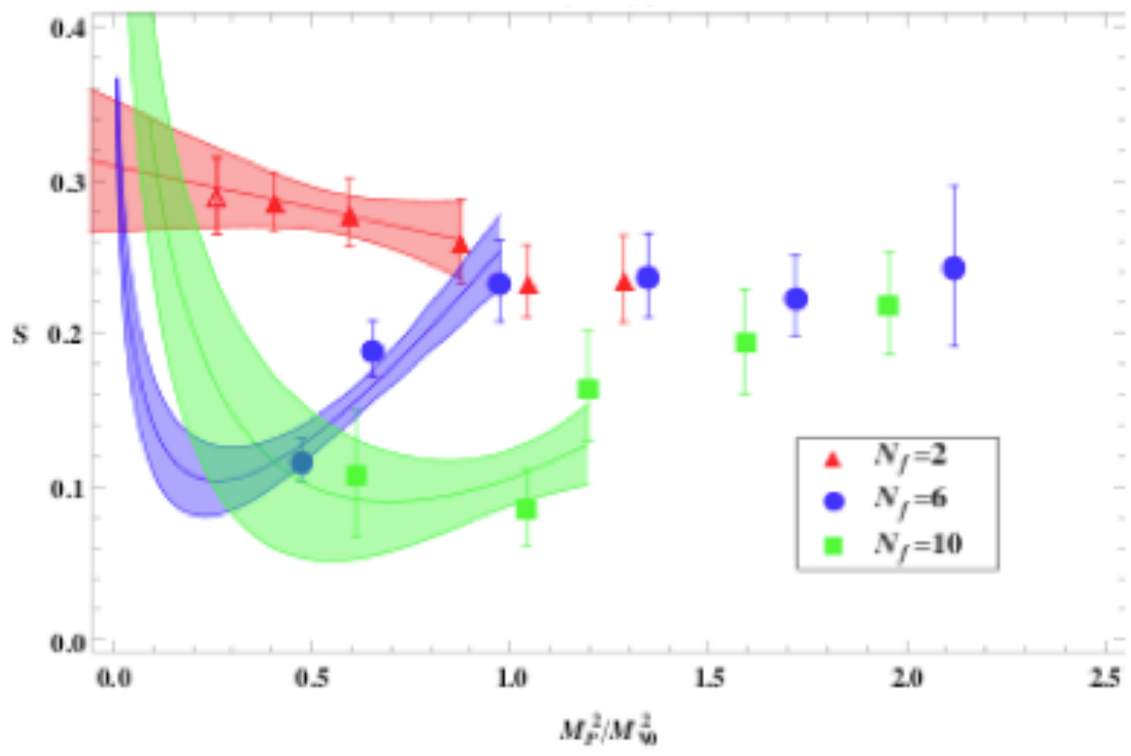
estimates obtained by assuming strong dynamics ~ QCD

recent lattice results indicate

increased N_F leads to more slowly running coupling

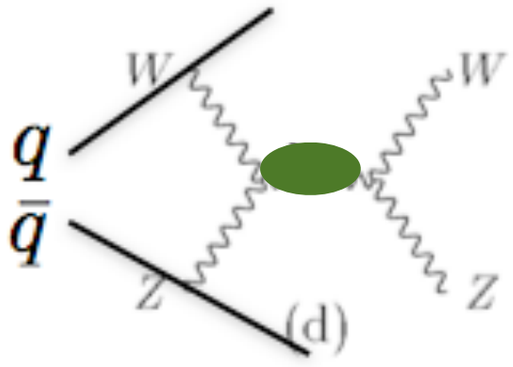
\+

minimal EW content -> small S

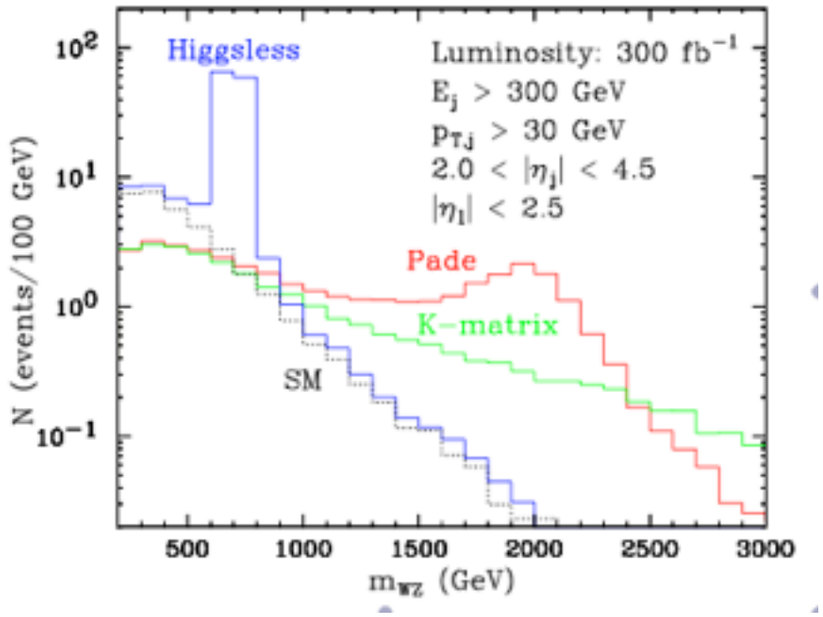


what then?

only ‘model-independent’ place to look is WW scattering

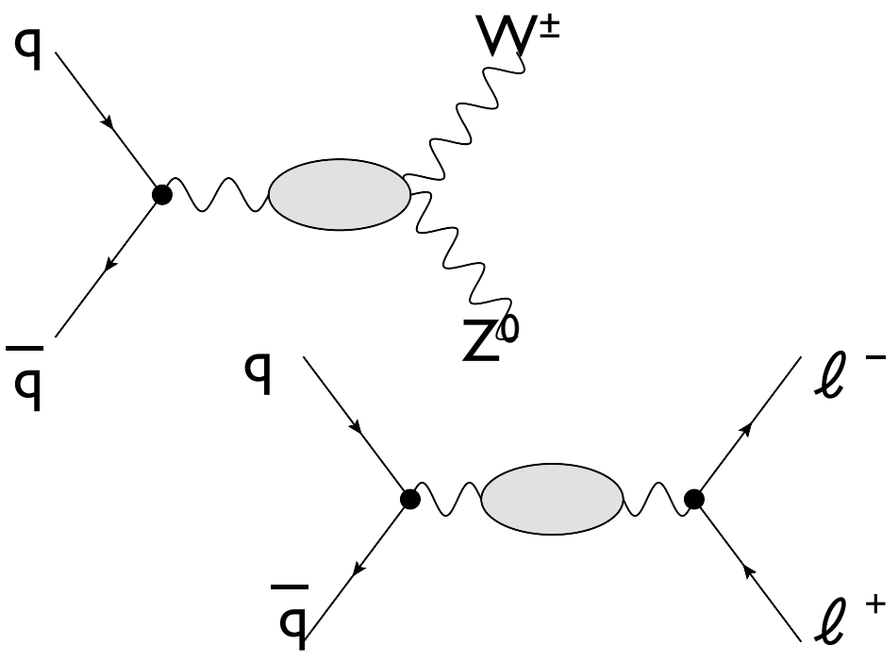


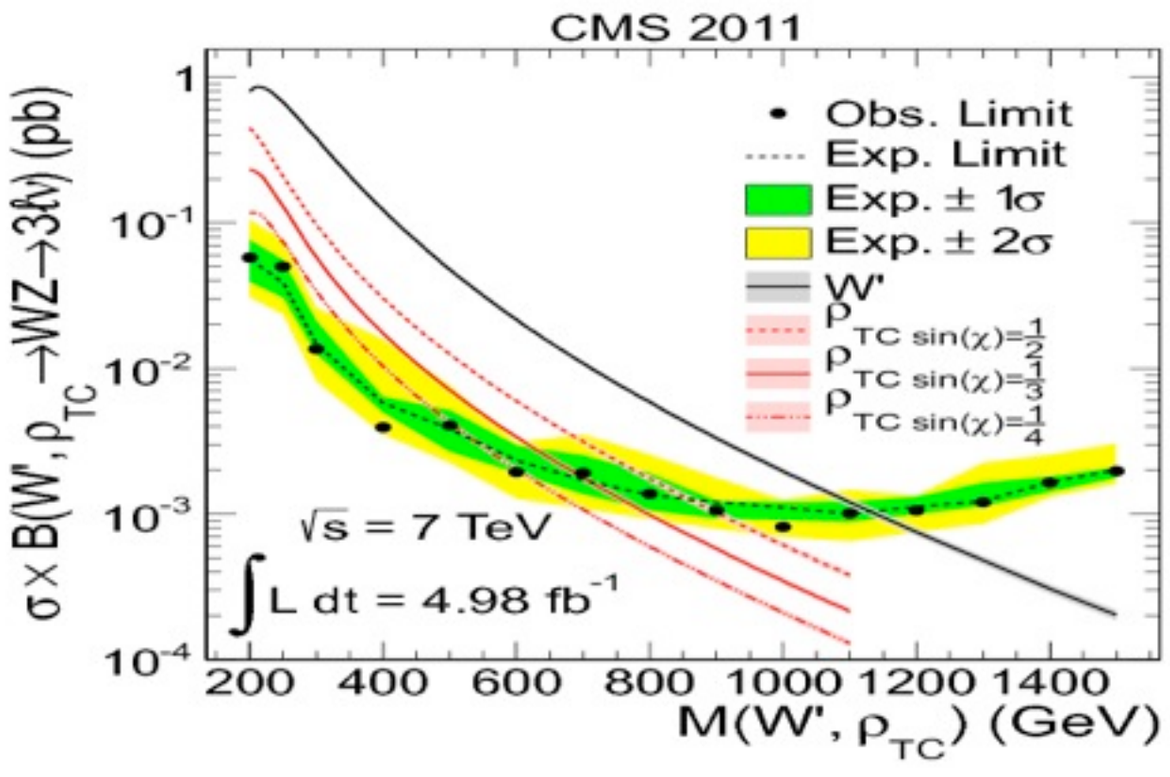
$$2j + 3\ell + \not{E}_T$$



(Birkedal, Matchev, Perelstein 0412278)

resonant production: model-dependent, but potentially much bigger rate





Conclusions

We are in the LHC era... we should expect the unexpected

large MET searches are a useful tool for BSM-hunting, but not the only tool

must be ready for other possibilities. As always, require excellent understanding of SM backgrounds

potentially powerful searches are out there:
w/ few parameters, could rule out/in many models

vector-like fermions, colorons

are we ready for no Higgs?