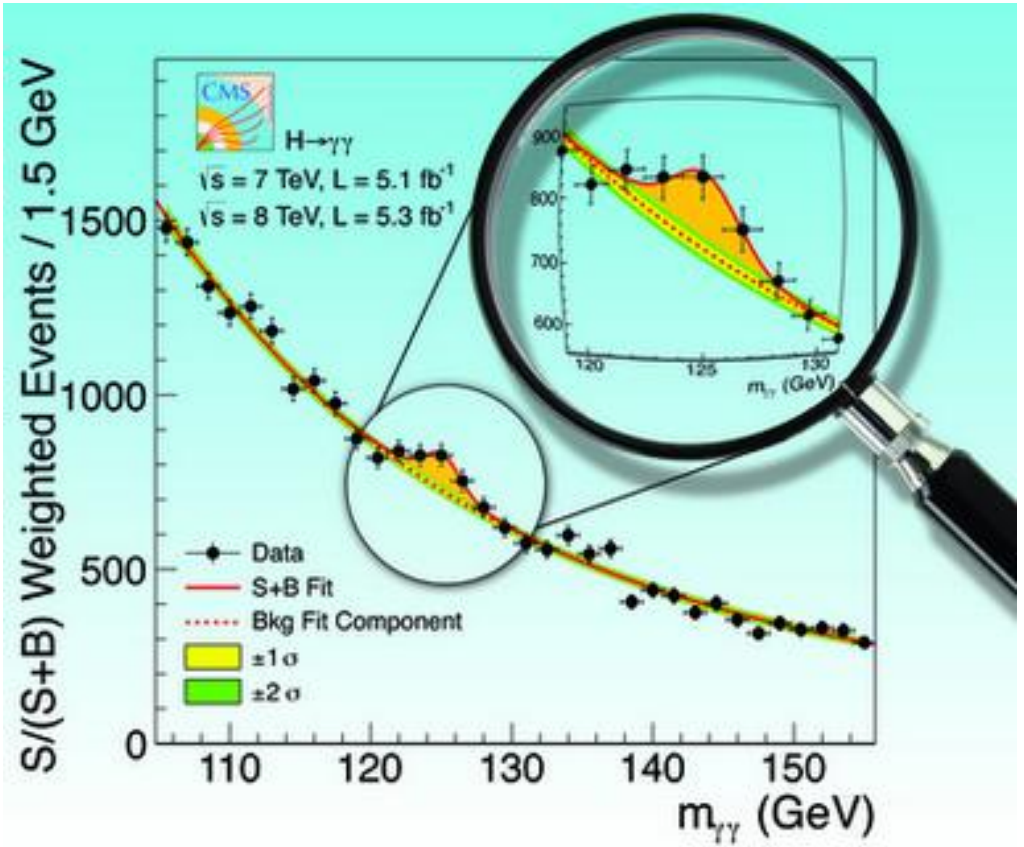
Multilepton Searches: Implications for Recent Anomalies

- **Higgs couplings**
- **Dark matter** **(if time..)**

Kfir Blum

Chicago 2012 Workshop on LHC Physics
11/12/2012

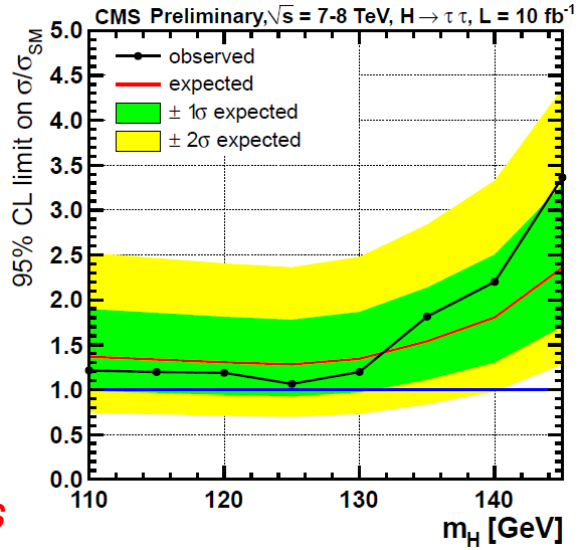
Higgs couplings



Higgs couplings …anomalies?

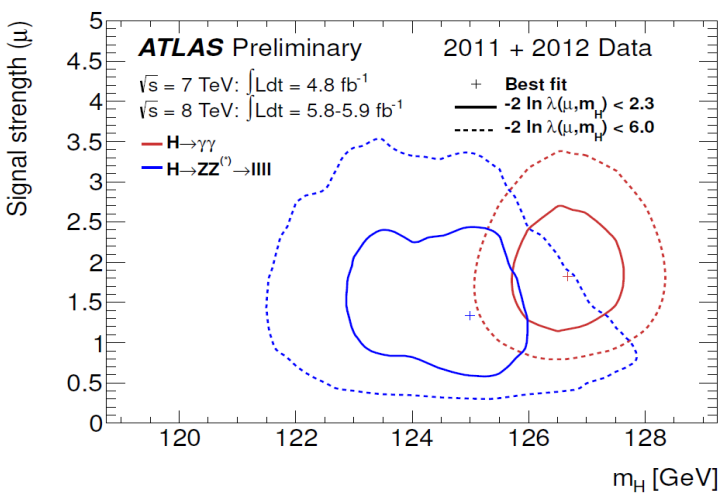
Anomalous couplings come from

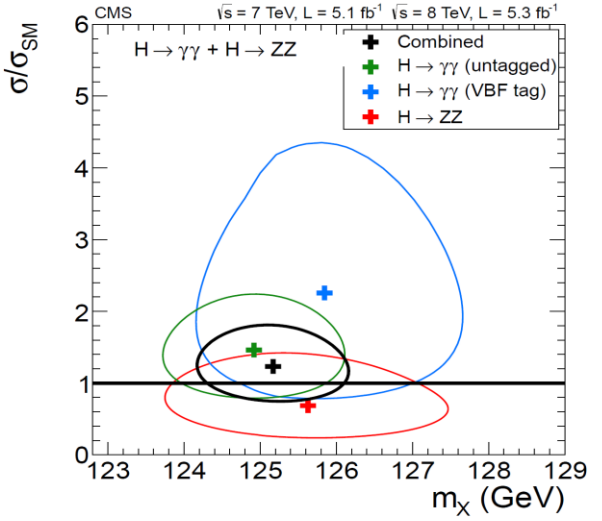
- Higgs mixing
- Fermion mixing
- Loops



All of the above require new light particles, EW charges

EW decay chains ➔ ***multileptons***!





Higgs couplings …anomalies?

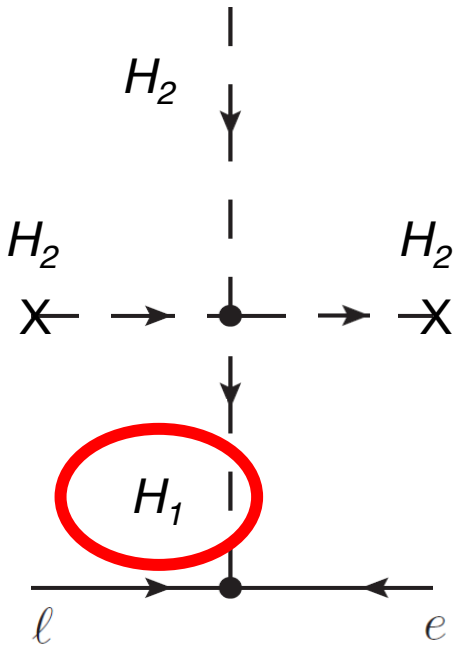
Anomalous couplings come from

- **Higgs mixing (Nathaniel Craig's talk)**
- Fermion mixing
- Loops

$$\frac{Y_l}{\Lambda^2}\left(\Box H^\dagger\right) l l^c$$

$$\frac{Y_l}{\Lambda^2}\left(H^\dagger H\right) H^\dagger l l^c$$

$$H_2 \approx H = \frac{v+h}{\sqrt{2}}$$



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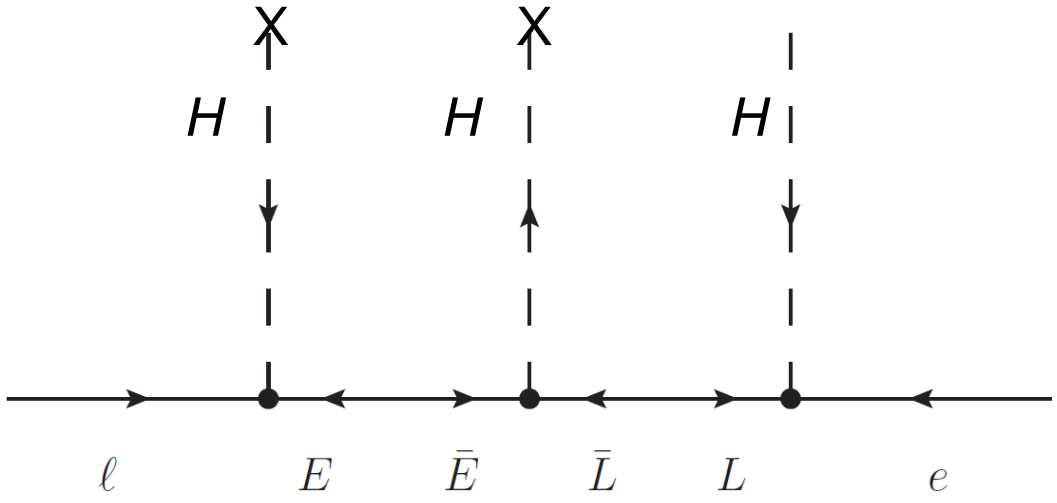

e.g. Kearney, Pierce, Weiner; 1207.7062

$$\frac{Y_l}{\Lambda^2}\left(\Box H^\dagger\right) ll^c$$

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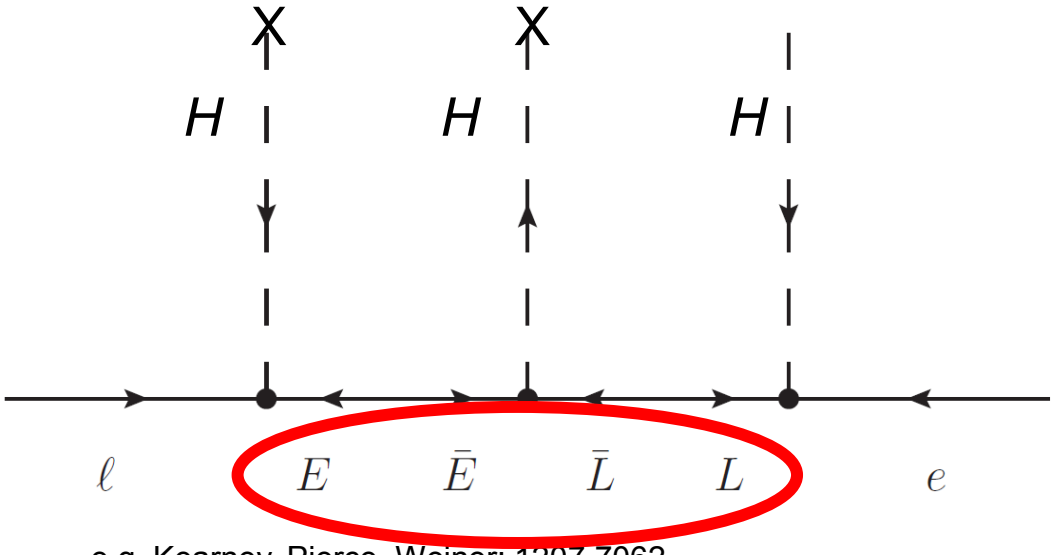

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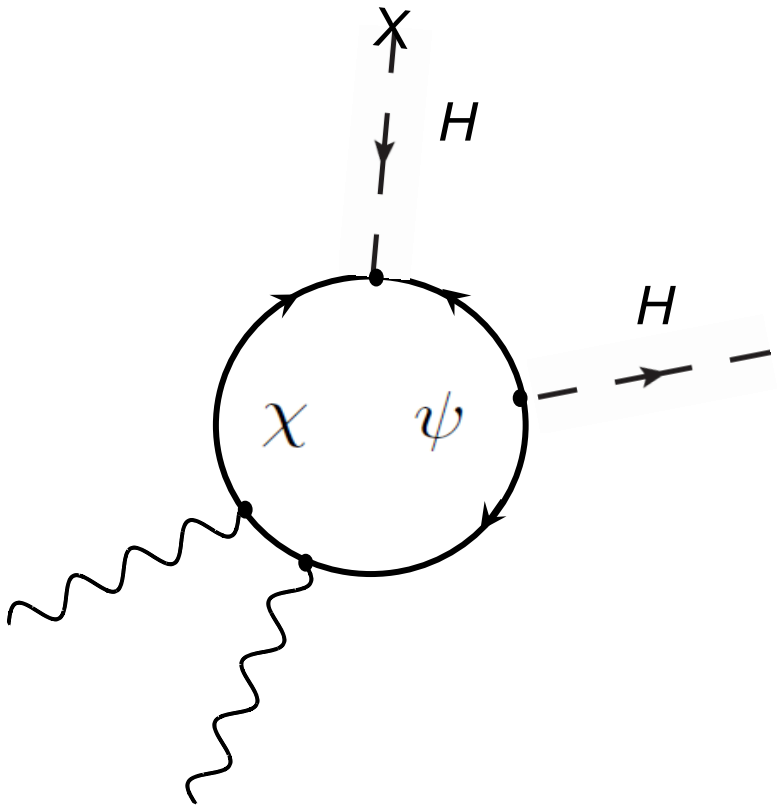
e.g. Carena, Low, Wagner; JHEP 1208 (2012) 060

$$\frac{\alpha}{\Lambda^2} H^\dagger H F_{\mu\nu} F^{\mu\nu}$$



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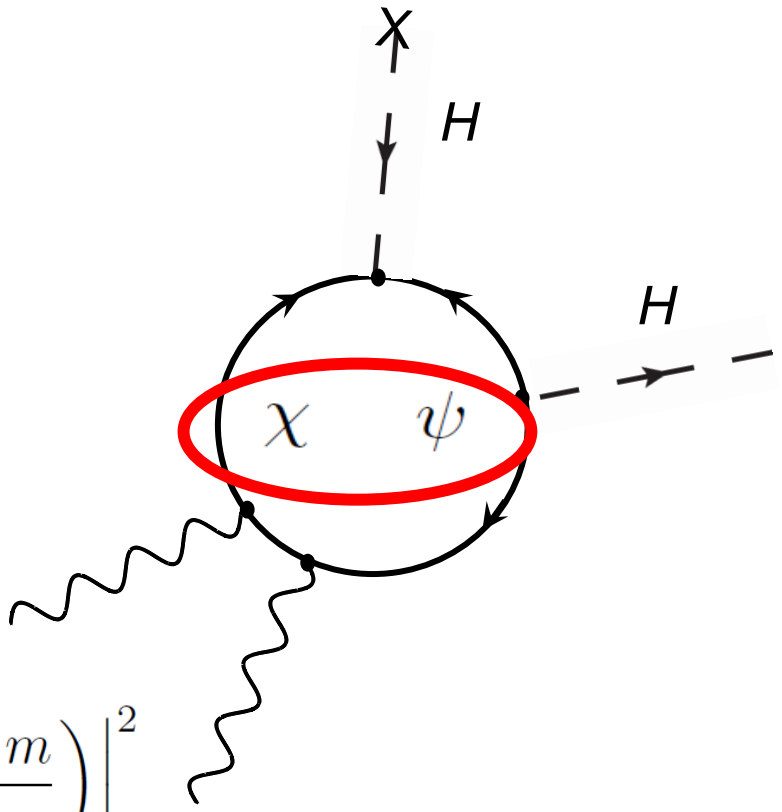

$$\frac{\Gamma(h \to \gamma\gamma)}{\Gamma(h \to \gamma\gamma)_{SM}} \approx \left| 1 + \frac{bQ^2}{\mathcal{A}^{\gamma}_{\mathcal{SM}}} \left(\frac{\partial \log \det m}{\partial \log v} \right) \right|^2$$

$$\mathcal{A}^{\gamma}_{SM} = -6.49$$

b = +4/3 (fermion), +1/3 (scalar), -11/3 (vector)

Diphoton enhancement?

Implications for models w/ fermions

Minimal building block for enhanced diphoton rate

$$-\mathcal{L} = m_\psi \psi\psi^c + m_\chi \chi\chi^c + yH\psi\chi + y^c H^\dagger \psi^c \chi^c + cc$$

At least one set of fermions w/ SU(2) spin ≥ ½ ➔ produced off Z, gamma

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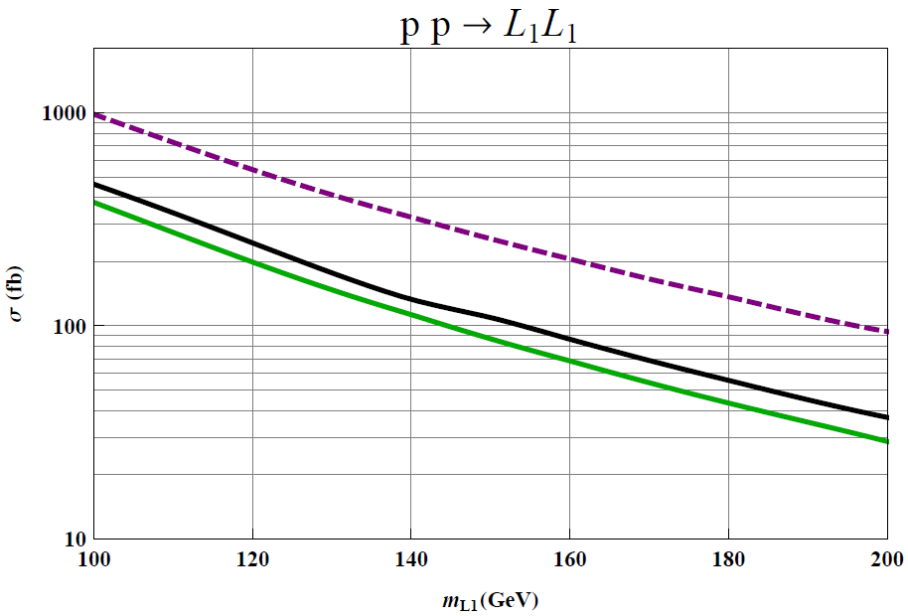
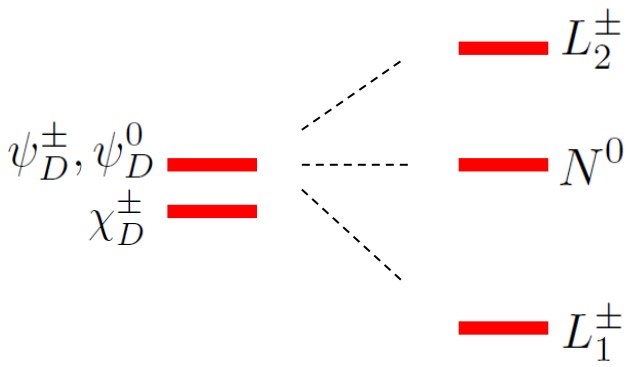
Example: $\psi, \psi^c \sim (1,2)_{\pm\frac{1}{2}} \qquad \chi, \chi^c \sim (1,1)_{\mp 1}$



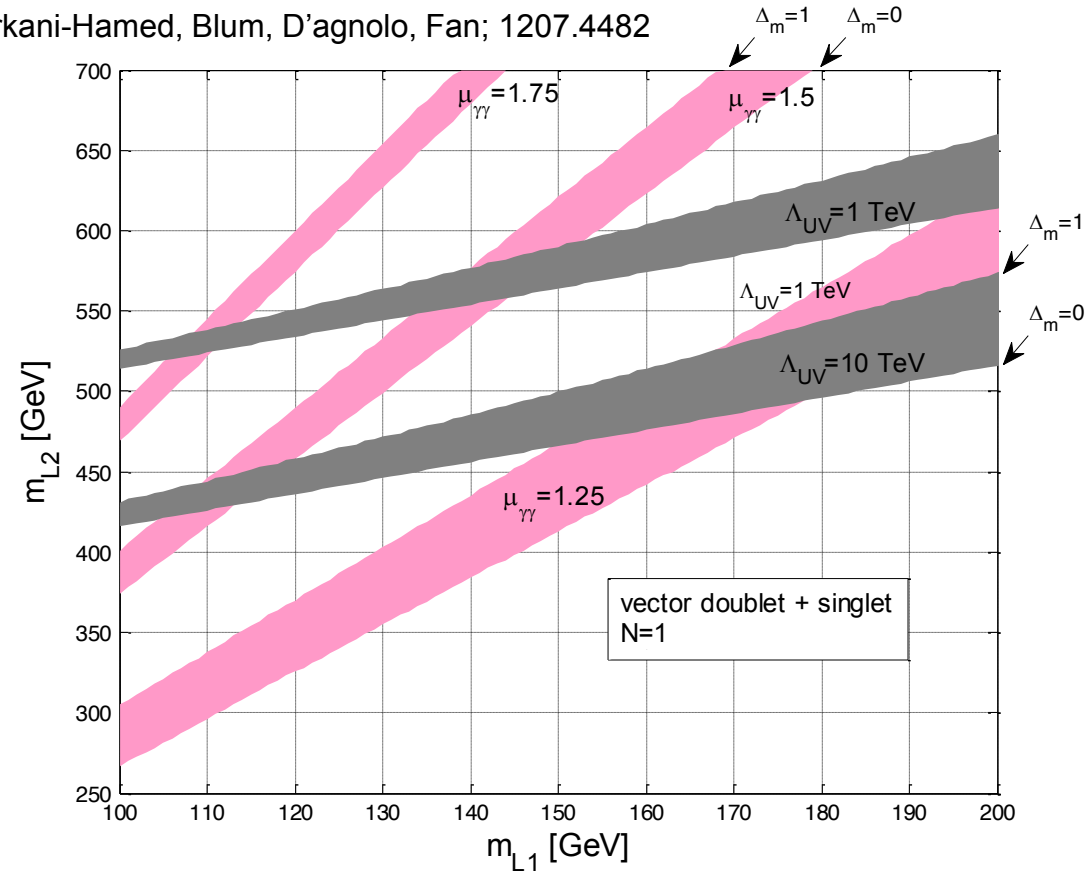


EWSB drives L1 ⇩ diphoton rate ⇧

Diphoton enhancement?
Implications for models w/ fermions

pheno depends on decay mode(s)

Arkani-Hamed, Blum, D'agnolo, Fan; 1207.4482



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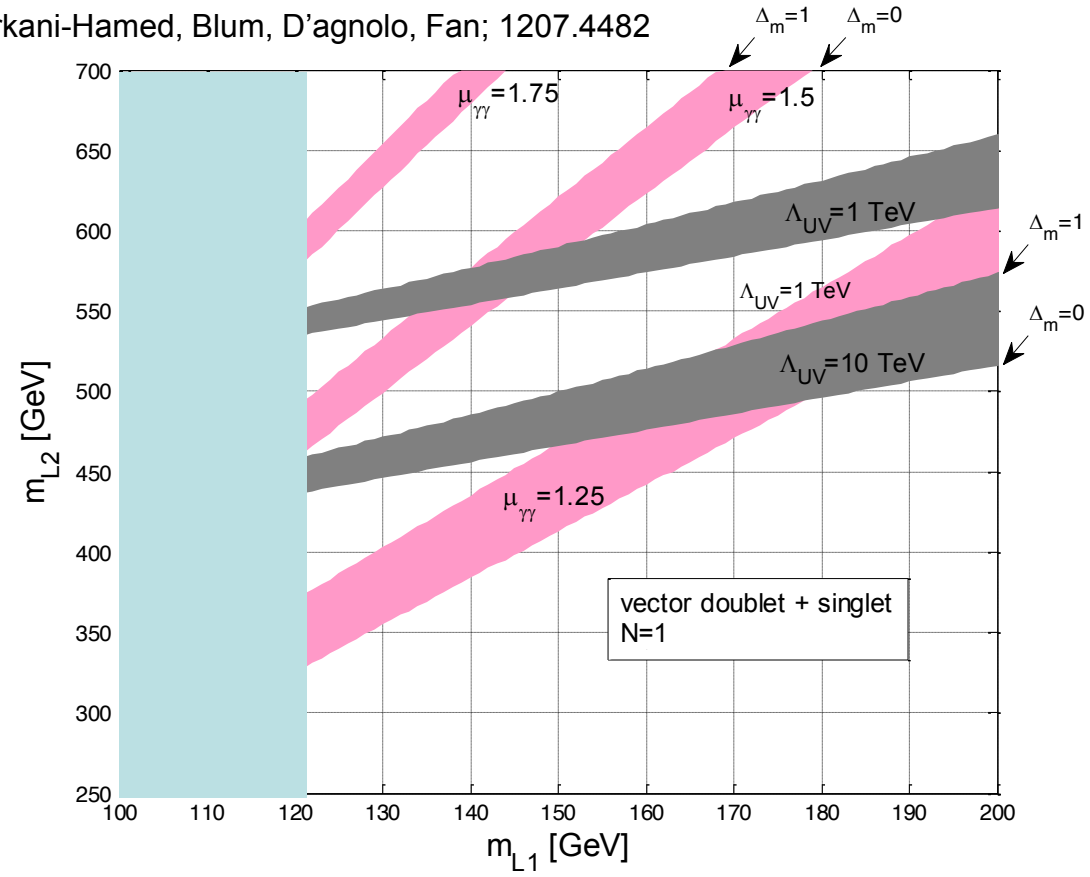
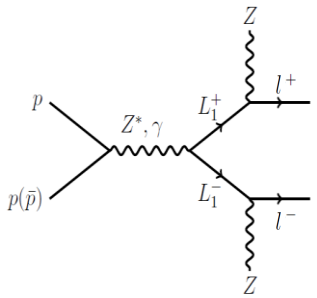


(small) mass mixing w/ e,μ:



Search for anomalous production of multilepton events in pp collisions at $\sqrt{s} = 7$ TeV

JHEP

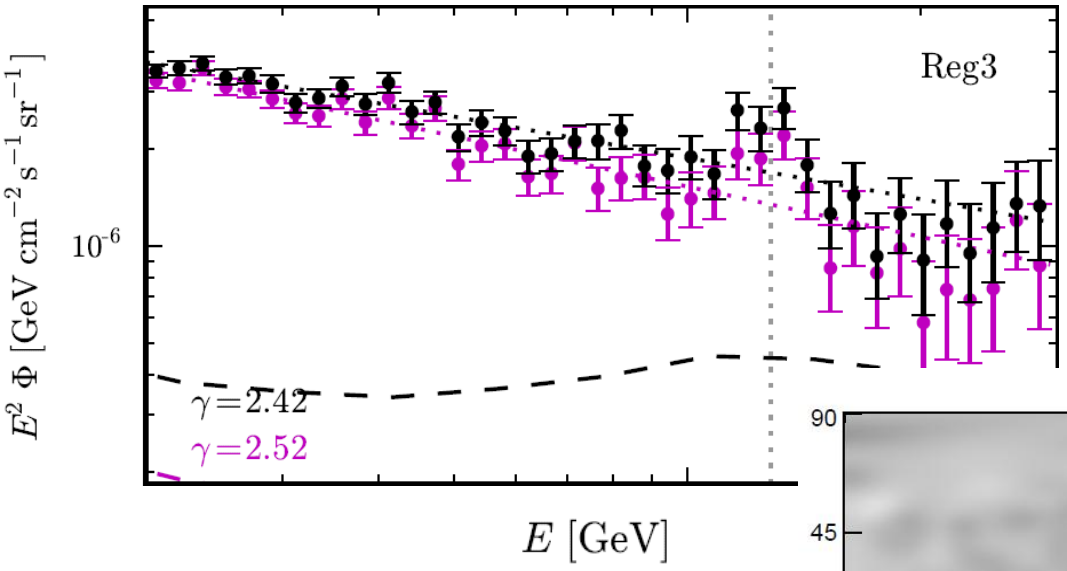
The CMS collaboration

Selection	obs	background
$4l$, MET < 50 GeV, $H_T < 200$ GeV, Z	33	37 ± 15

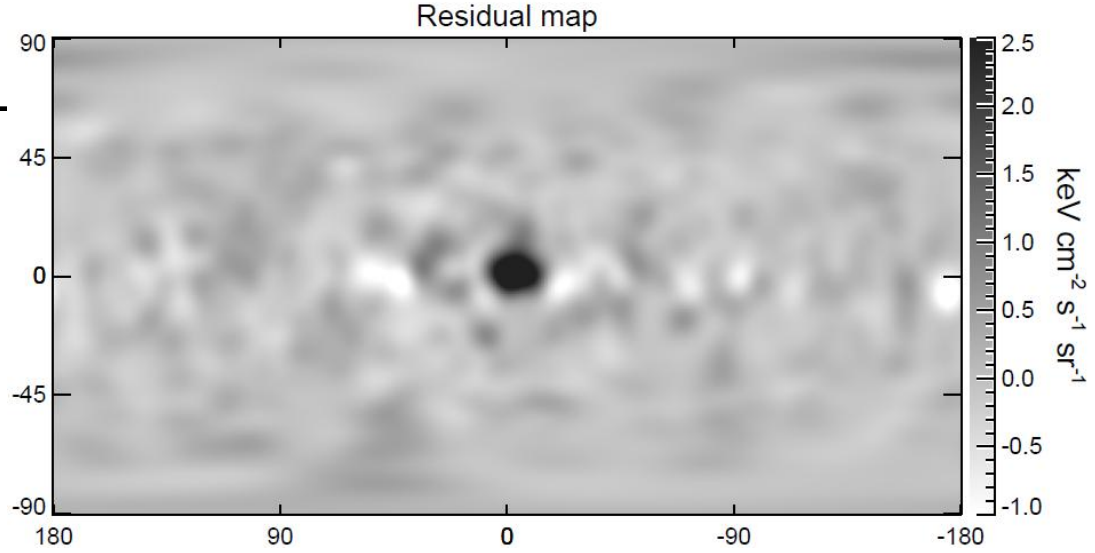
Dark matter

…A gamma ray line?

Weniger; JCAP 1208 (2012) 007



Su, Finkbeiner; 1206.1616



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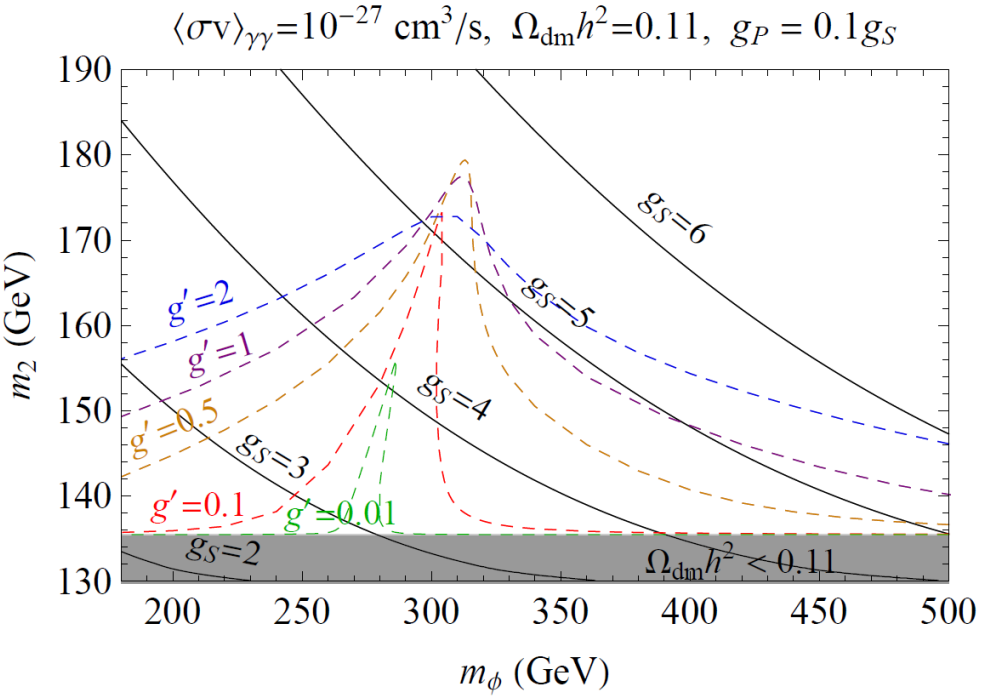
A gamma ray line?

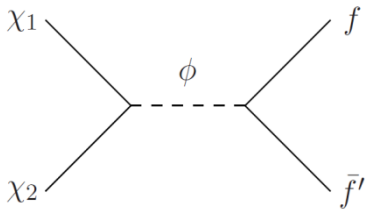
Need to suppress continuum @ E<<100 GeV

Example: (Tulin, Yu, Zurek; 1208.0009)

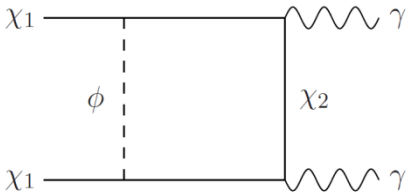
$$\mathscr{L}_{\rm int} = \bar{\chi}_2(g_S + g_P\gamma_5)\chi_1\phi + \bar{f}(g'_S + g'_P\gamma_5)f'\phi + \text{h.c.}$$



Relic density



Gamma ray line



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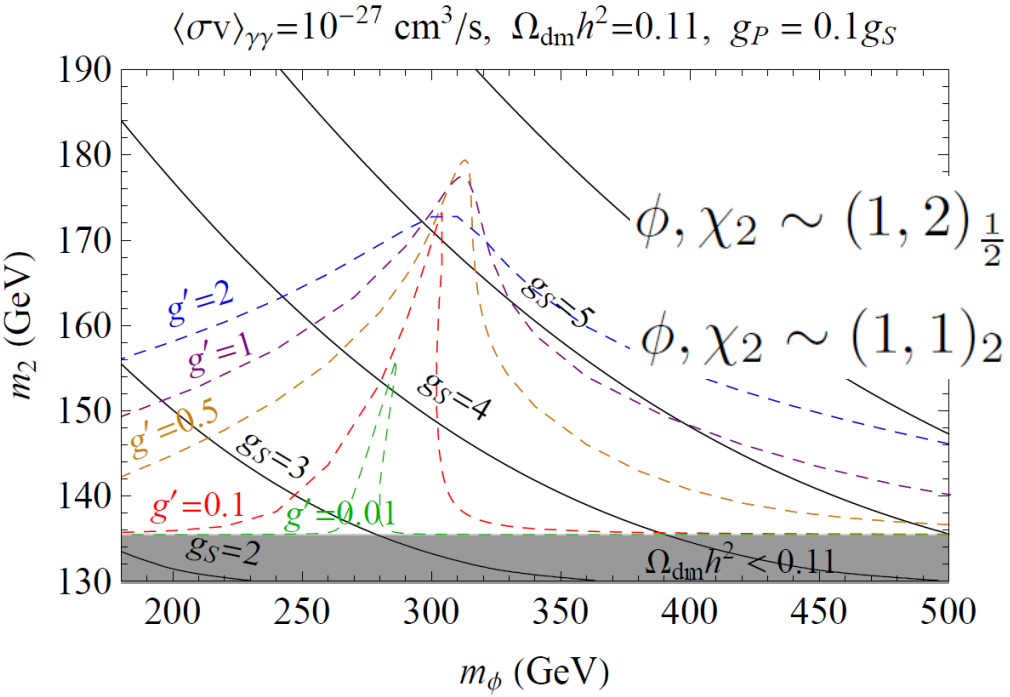

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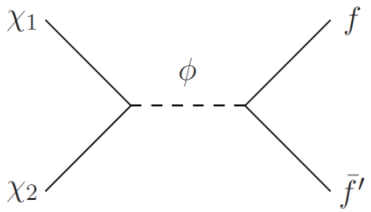

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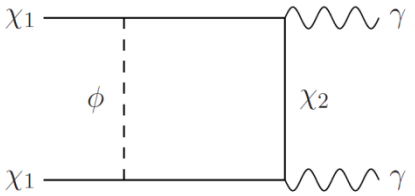
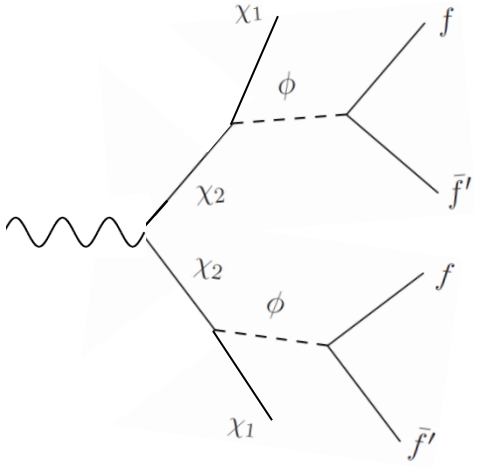


4l+MET



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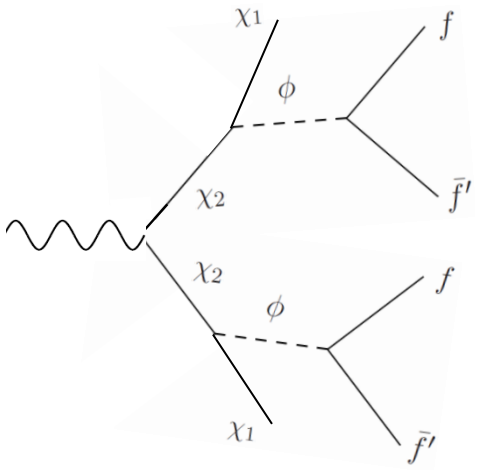


➔ Some models massively excluded by 7TeV multilepton results
(10fb) x (5/fb) x 0.7^4 ~ 12 (!)

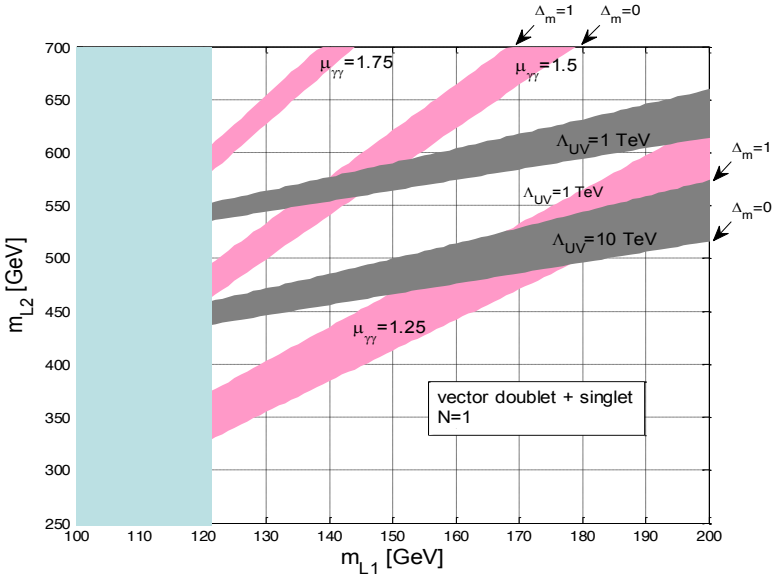
Selection	$N(\tau_h)=0$		$N(\tau_h)=1$		$N(\tau_h)=2$	
	obs	expected	obs	expected	obs	expected
4 Lepton results						
4ℓ E_T^{miss} >50, H_T >200, no Z	0	0.018 ± 0.005	0	0.09 ± 0.06	0	0.7 ± 0.7
4ℓ E_T^{miss} >50, H_T >200, Z	0	0.22 ± 0.05	0	0.27 ± 0.11	0	0.8 ± 1.2
4ℓ E_T^{miss} >50, H_T <200, no Z	1	0.20 ± 0.07	3	0.59 ± 0.17	1	1.5 ± 0.6
4ℓ E_T^{miss} >50, H_T <200, Z	1	0.79 ± 0.21	4	2.3 ± 0.7	0	1.1 ± 0.7
4ℓ E_T^{miss} <50, H_T >200, no Z	0	0.006 ± 0.001	0	0.14 ± 0.08	0	0.25 ± 0.07
4ℓ E_T^{miss} <50, H_T >200, Z	1	0.83 ± 0.33	0	0.55 ± 0.21	0	1.14 ± 0.42
4ℓ E_T^{miss} <50, H_T <200, no Z	1	2.6 ± 1.1	5	3.9 ± 1.2	17	10.6 ± 3.2
4ℓ E_T^{miss} <50, H_T <200, Z	33	37 ± 15	20	17.0 ± 5.2	62	43 ± 16

Summary

- Multilepton searches putting pressure on new EW states

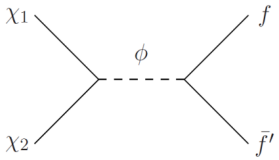
- Important consistency checks on (if) anomalous Higgs couplings

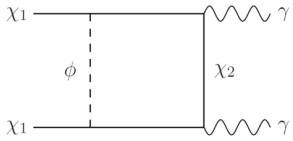
  models with only NP fermions generically inconsistent w/ large diphoton enhancement. Remaining (tuned) solutions under LHC pressure, e.g. multileptons (or discovery in morning session…)

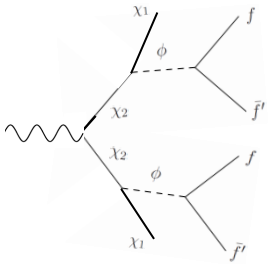


- Generic WIMP models ➔ VV, leptons + MET, motivation for multilepton analyses

- Gamma ray line? some models massively dead







Xtra

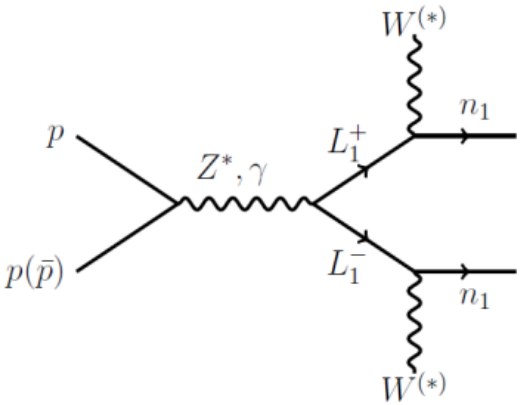
Implications of a diphoton enhancement: un-natural models

Implications:

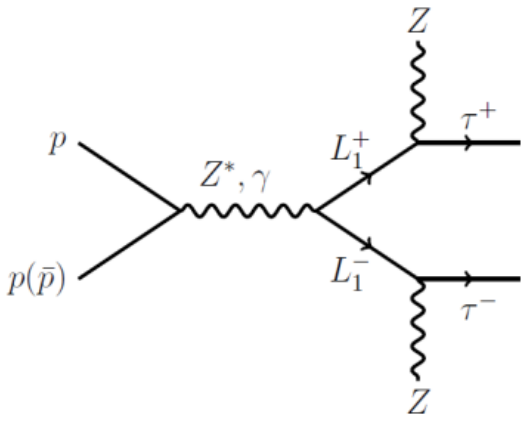
1. Fermion models with cut-off >10 TeV give ~50% enhancement at most, and that is with some tuning of dials

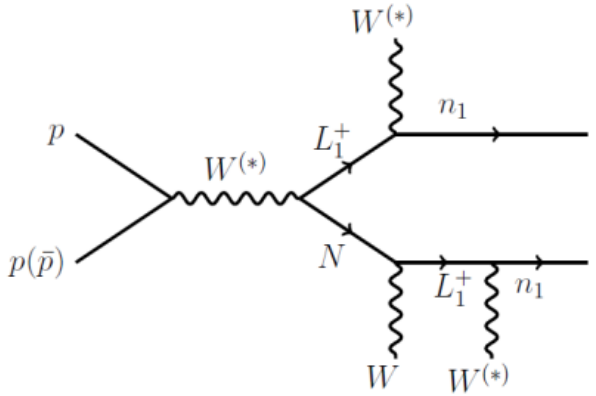
2. Cut-off above 10 Tev ➔ charged, uncolored state(s) @100-150 GeV

$L_1 \to W^{(*)} n_1$



$L_1 \to Zl(\tau)$



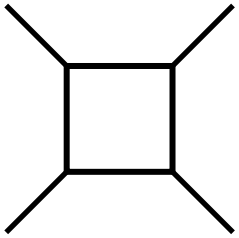


Diphoton enhancement?

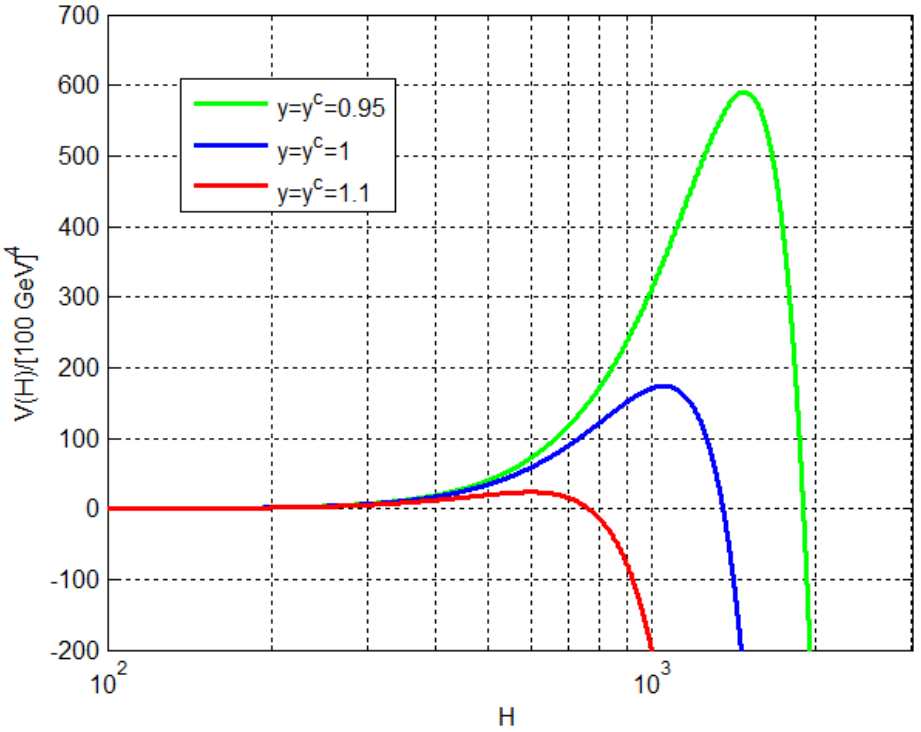
Implications for fermion models

$$-\mathcal{L} = m_\psi \psi\psi^c + m_\chi \chi\chi^c + yH\psi\chi + y^c H^\dagger \psi^c \chi^c + cc$$

Large diphoton effect ➔ RGE drives Higgs quartic negative



$$(4\pi)^2 \frac{d\lambda}{dt} \sim -\left(y^4 + y^{c4}\right)$$



Diphoton enhancement?

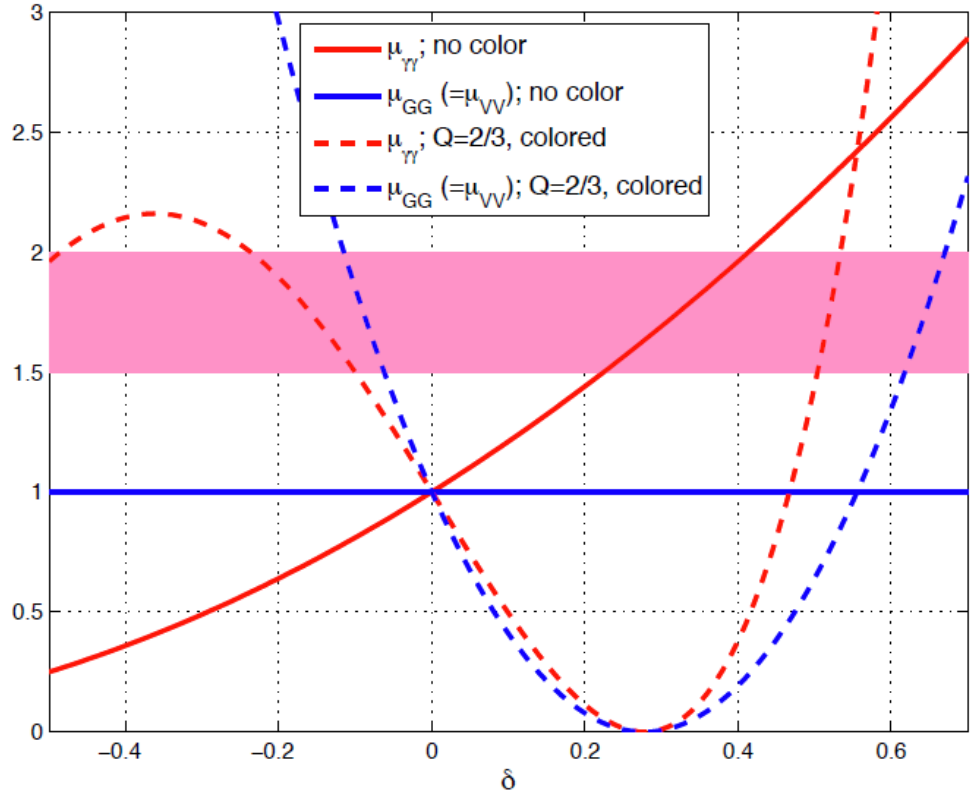
If hVV is SM-like, then looks like charged, uncolored, light new particle in loop

uncolored: o/w would mess up hGG (and, well, haven't seen it directly produced yet!)

$$\Gamma(h \to \gamma\gamma) = \Gamma(h \to \gamma\gamma)_{SM} |1 + \delta|^2$$

$$\mu_{GG} = \mu_{VV} = |1 - 3.6\ \delta|^2$$

$$\mu_{\gamma\gamma} = |1 + \delta|^2 |1 - 3.6\ \delta|^2$$



Is electroweak symmetry breaking Natural?