Constraining Minimal Universal Extra Dimensions Using the Higgs

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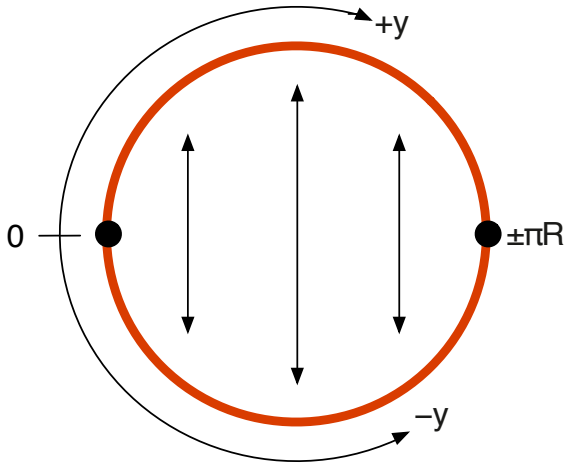
Outline

The model

Minimal Universal Extra Dimensions



$S^1/\mathcal{Z}_2$ orbifold

$$\boxed{SU(3) \times SU(2) \times U(1)}$$

SM Gauge group

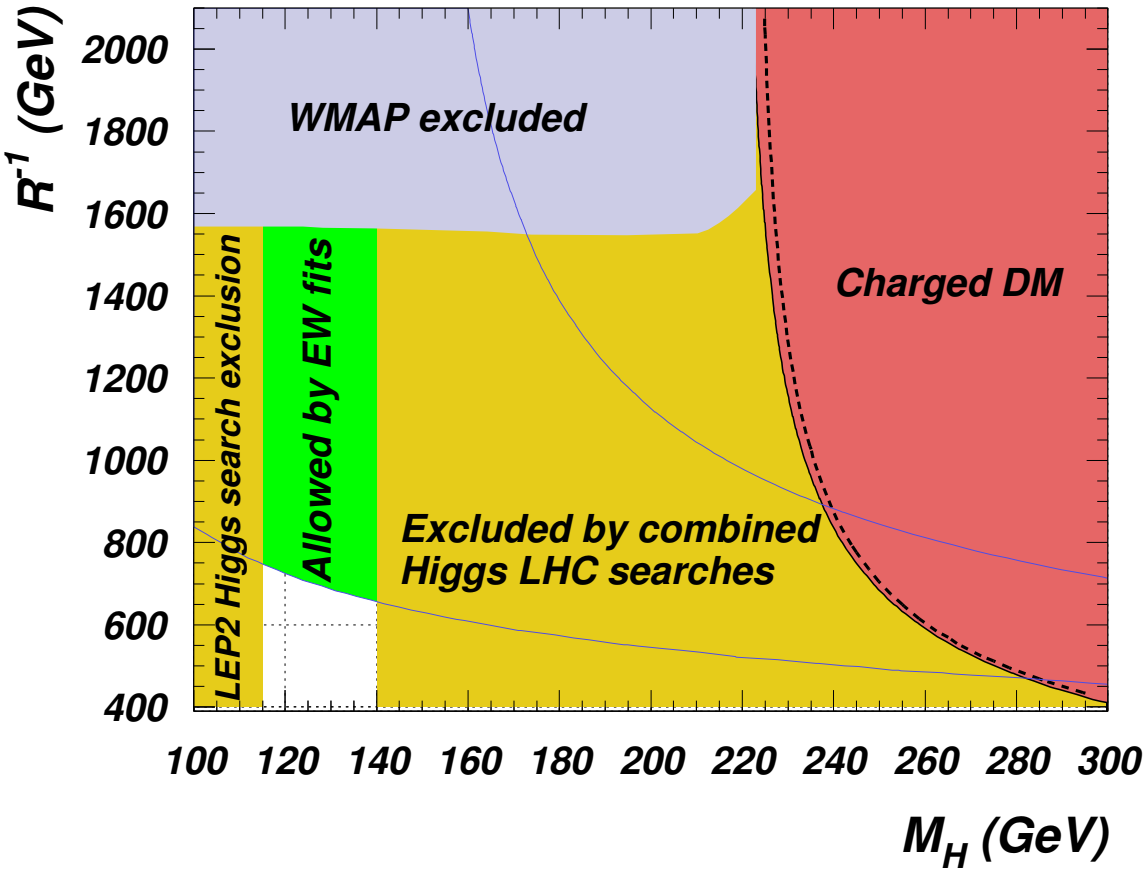
$$\psi^{R,L}(x) \to \psi^{\pm}(x,y)$$
$$A_\mu(x) \to A_M(x,y)$$
$$\phi(x) \to \phi(x,y)$$

SM field content

Brane localised terms are zero at the cutoff scale

Limits on parameter space

Two free parameters in the minimal theory: m_h and R^{-1}

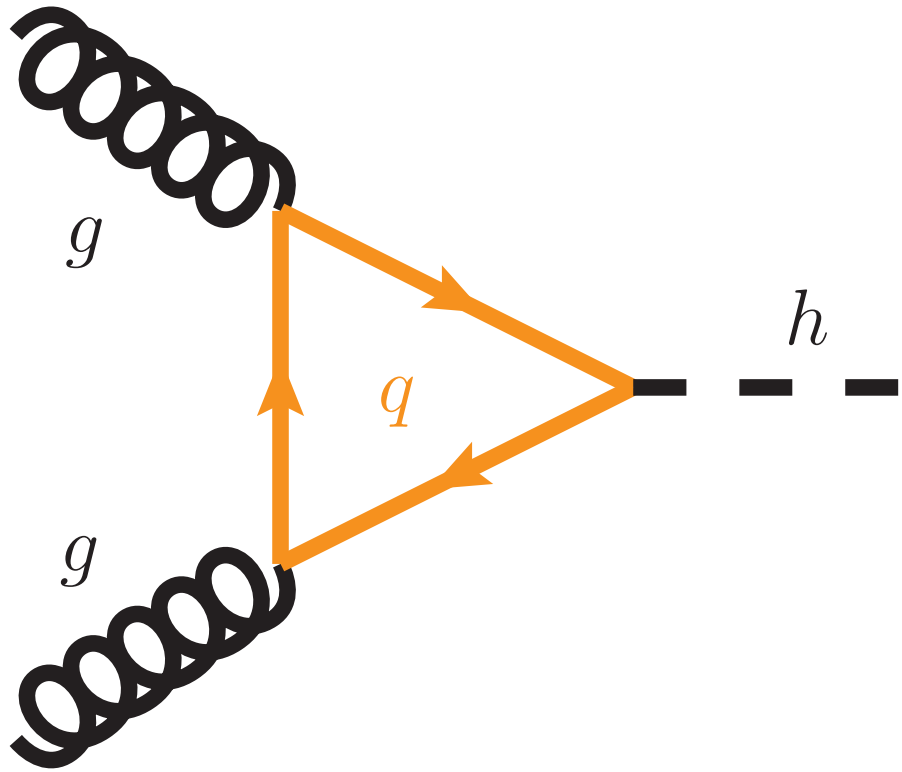


(Belyaev, Brown, Moreno and Papineau, preliminary)

Higgs production and decay

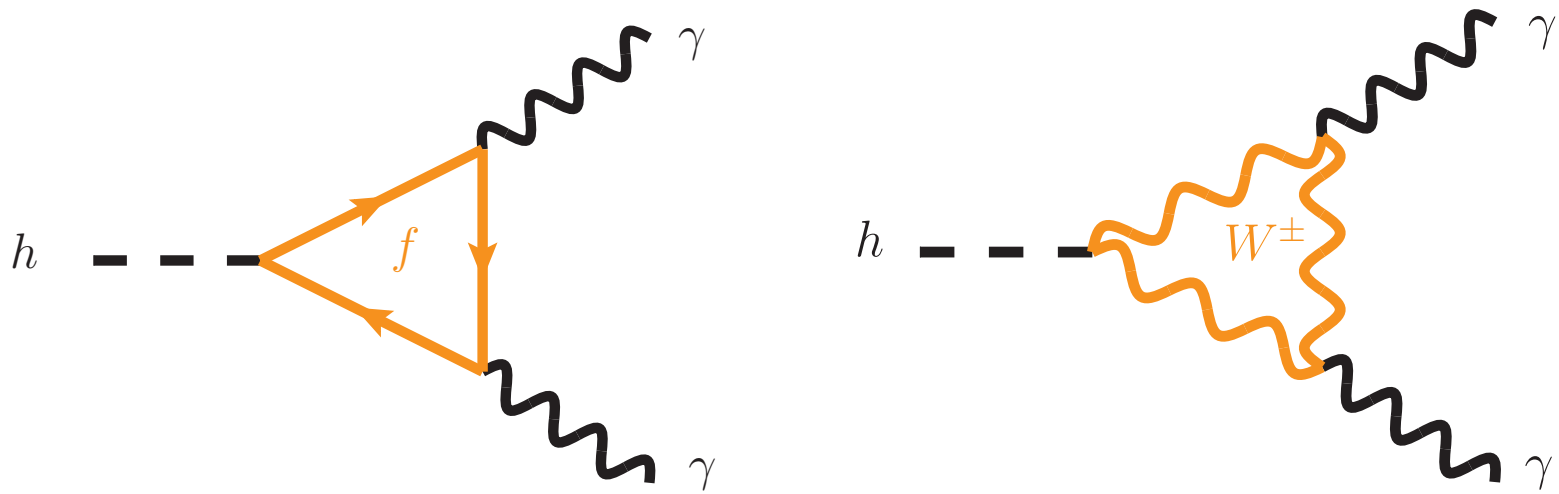
Higgs production

- Dominant production process at the LHC is *G*-*G* fusion
- Enhanced by KK quarks (particularly tops) running in the loop



Higgs decay

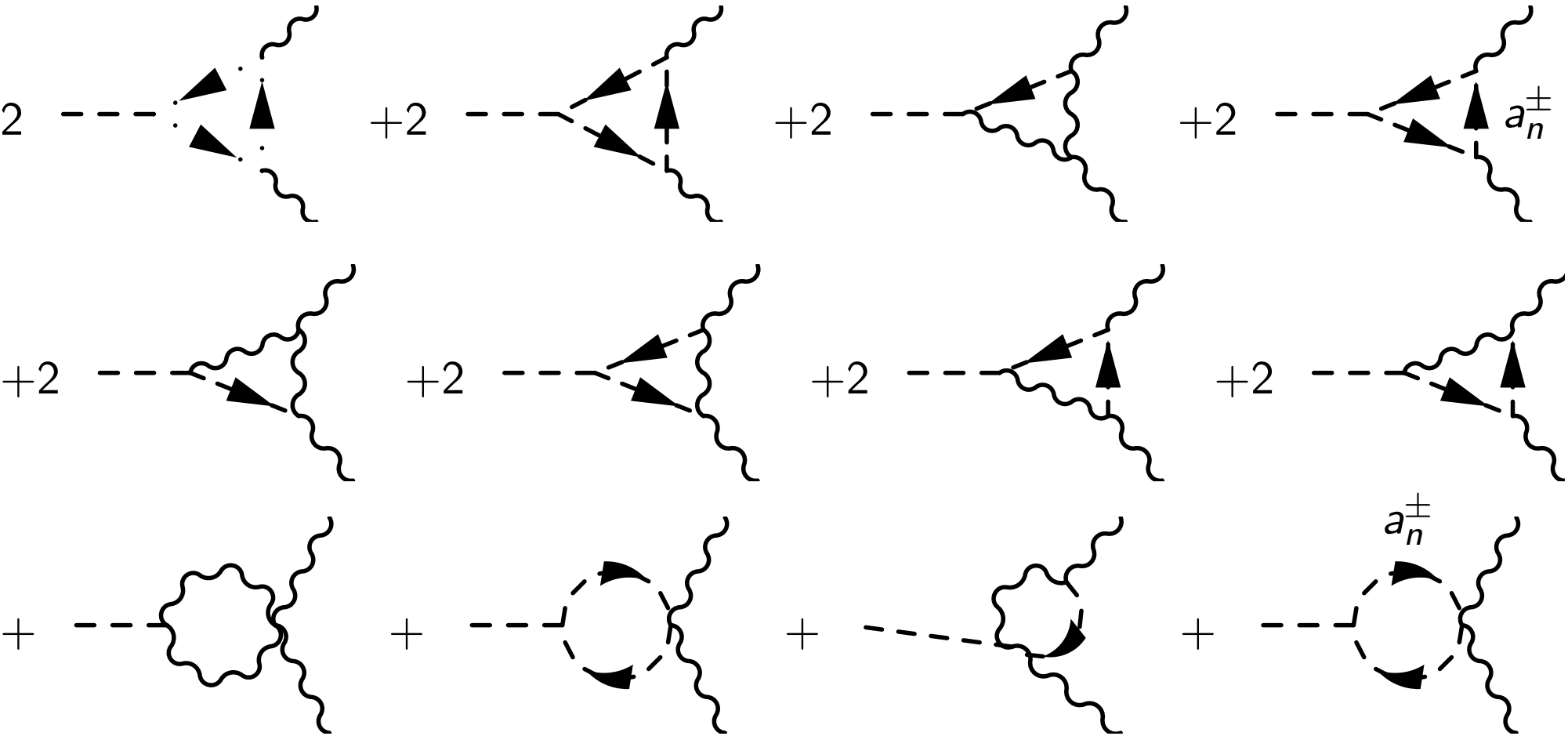
- Decay to photons is most promising channel for $m_H = 110$–130 GeV in SM due to small background



- In SM, W loop dominates and is partially cancelled by quark loop
- MUED enhances both loops, but enhances the quark loop more, *reducing* the overall decay width

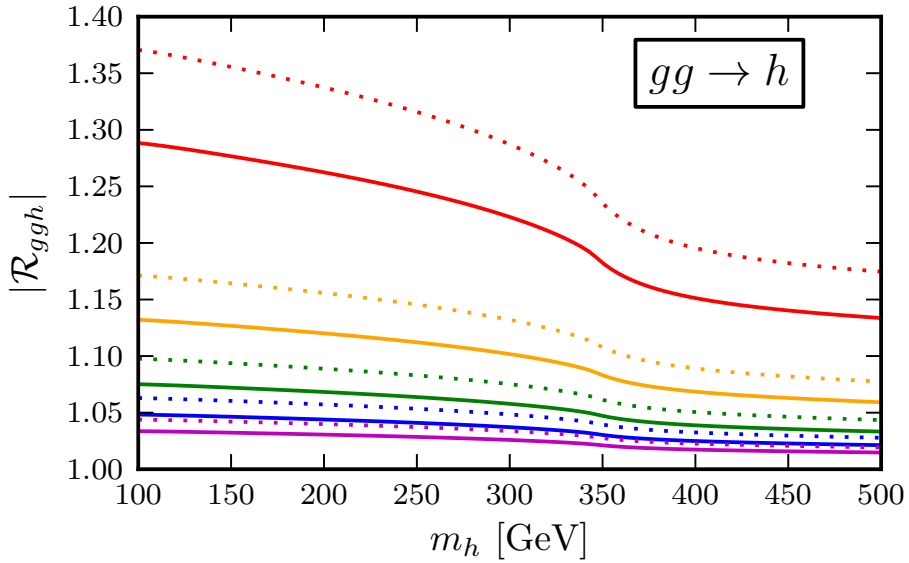
Higgs decay

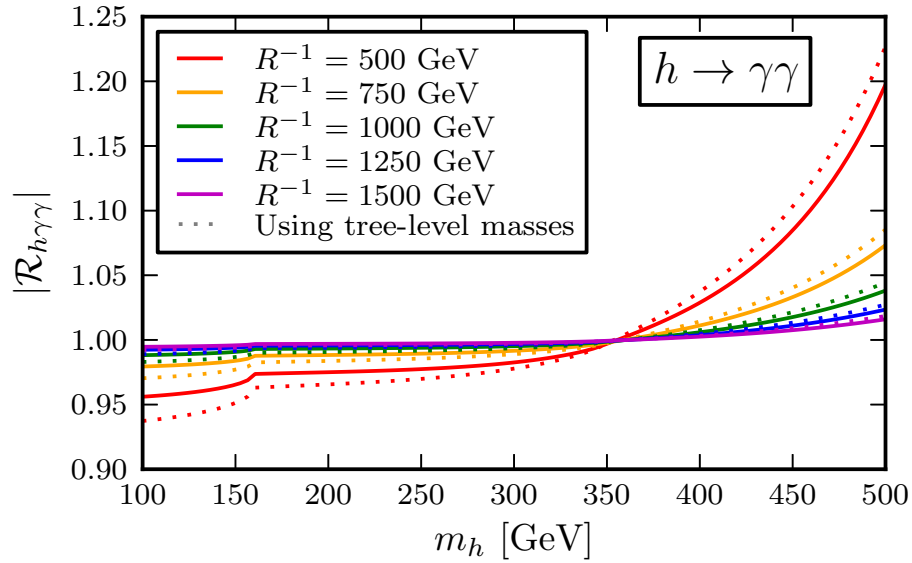
Actually, there are some more diagrams for the decay!

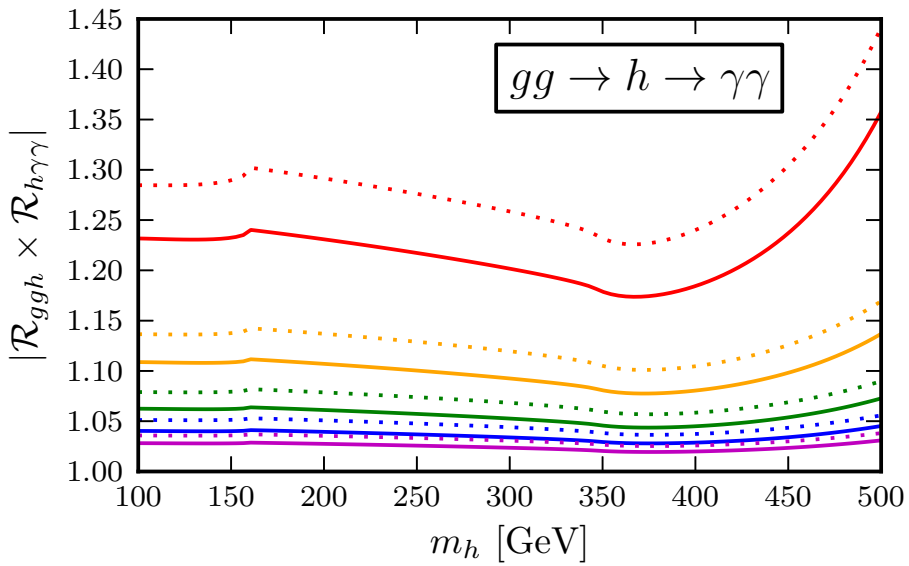


I calculated the production and decay amplitudes independently, cross-checking F.Petriello (arXiv:hep-ph/0204067). Also looked at effects of using loop-corrected KK masses

Ratios of MUED amplitudes to SM amplitudes



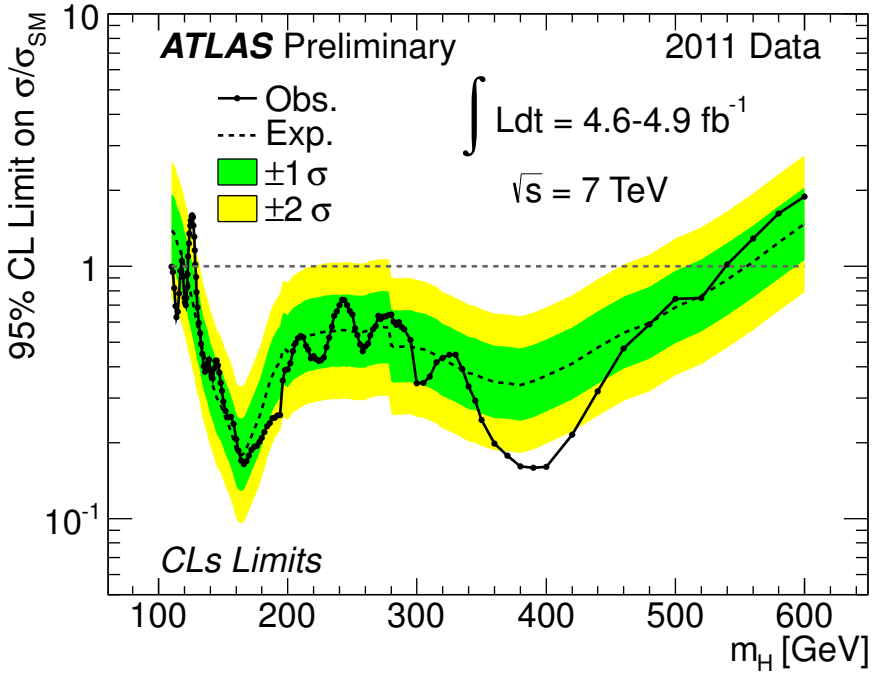


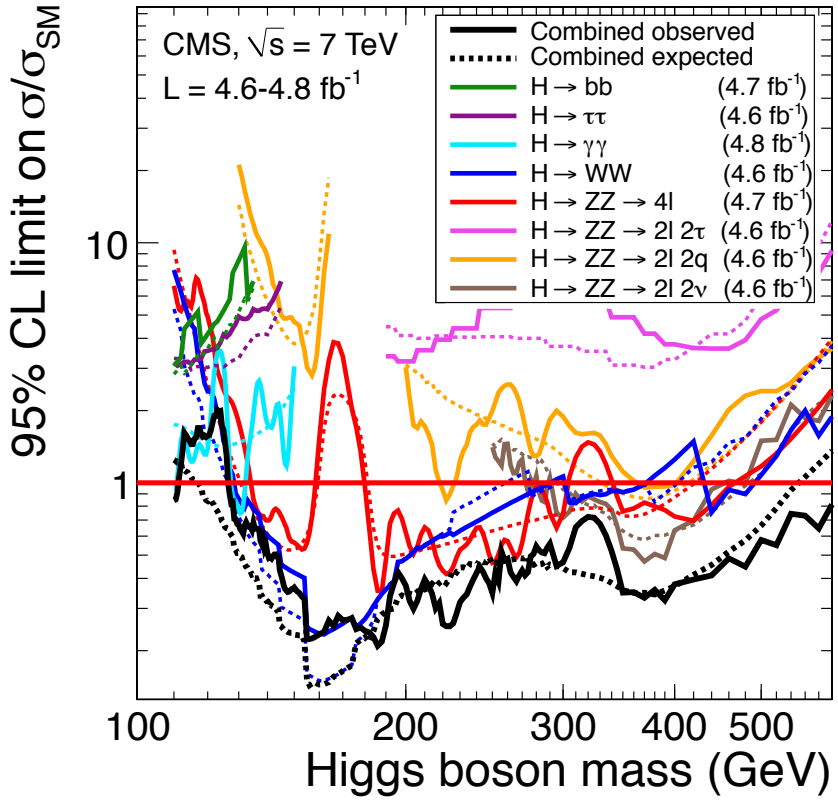


- Tree masses dotted; loop masses solid
- Loop corrections to masses can make up to a 5% difference
- Despite suppression of decay, $gg \to h \to \gamma\gamma$ is still enhanced overall for all parameter space

LHC Higgs searches

LHC Higgs exclusion limits





- "Observed" 95% exclusion limits are values of μ_i st. probability of n_i fluctuating down to n_i^{obs} is $< 5\%$
- "Expected" limits are values of μ_i st. probability of n_i fluctuating down to b_i is $< 5\%$

Reconstructing likelihoods: the problem

$$\boxed{n_i = \mathcal{L}\varepsilon_i\mu_i\sigma_i^{\mathrm{SM}} + b_i}$$

Knowns

$\mathcal{L}$	integrated luminosity
μ_i	enhancement of channel-i signal relative to SM
σ_i^{SM}	SM cross-section for channel i

Unknowns

ε_i	Channel efficiency
b_i	no. expected background events (inc. efficiencies/cuts)
n_i^{obs}	observed number of events

Three unknowns, but only two pieces of supplied information: the observed and expected 95% exclusions.

Reconstructing the likelihoods: the solution

(Azatov *et al*, arXiv:1202.3415 [hep-ph])

$$n_i^{\rm obs} \gg 1 \quad \Rightarrow \quad \boxed{p(n_i^{\rm obs}|\mu)_i = p(n_i^{\rm obs}|\mu_i) \approx \exp\left[-\frac{(\mu_i - \mu_i^{\rm max})^2}{2(\Delta^{\rm obs})^2}\right]}$$

- Only *two* unknown combinations!

$$\Delta_i^{\rm obs} \equiv \frac{\sqrt{n_i^{\rm obs}}}{\mathcal{L}\varepsilon_i\sigma_i^{\rm SM}}; \quad \mu_i^{\rm max} \equiv \frac{n_i^{\rm obs} - b_i}{\mathcal{L}\varepsilon_i\sigma_i^{\rm SM}};$$

- Expected limit gives that $\sqrt{b_i}/(\mathcal{L}\varepsilon_i\sigma_i^{\rm SM}) = \mu_{i,\rm exp}^{95\%}/1.96$, so

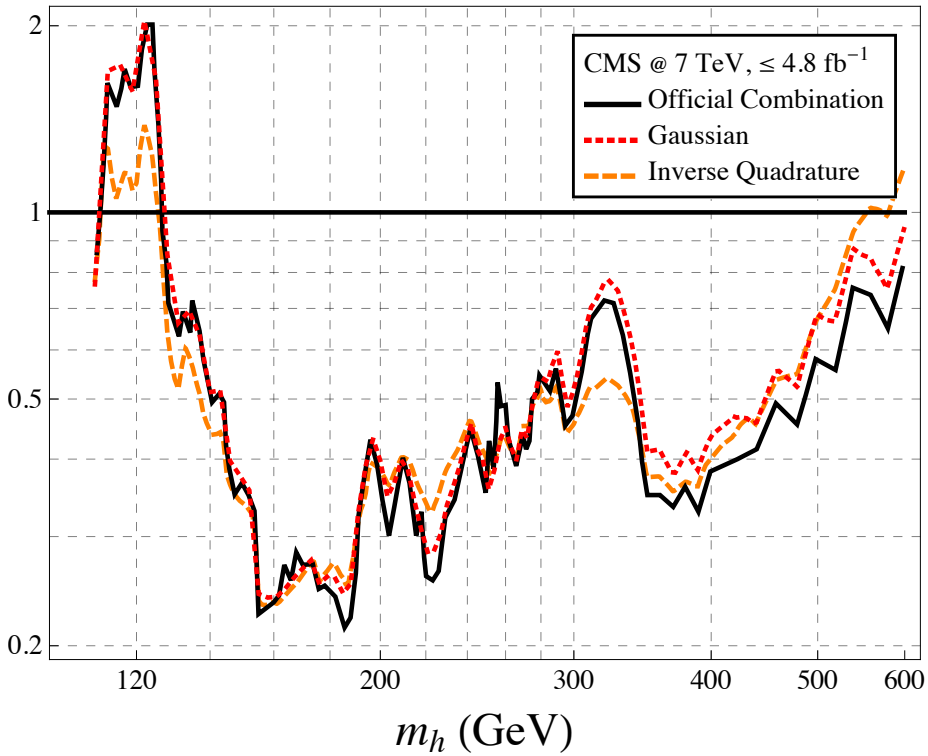
$$\frac{n_i^{\rm obs} - b_i}{b_i} \ll 1 \quad \Rightarrow \quad \Delta_i^{\rm obs} \approx \frac{\mu_{i,\rm exp}^{95\%}}{1.96}$$

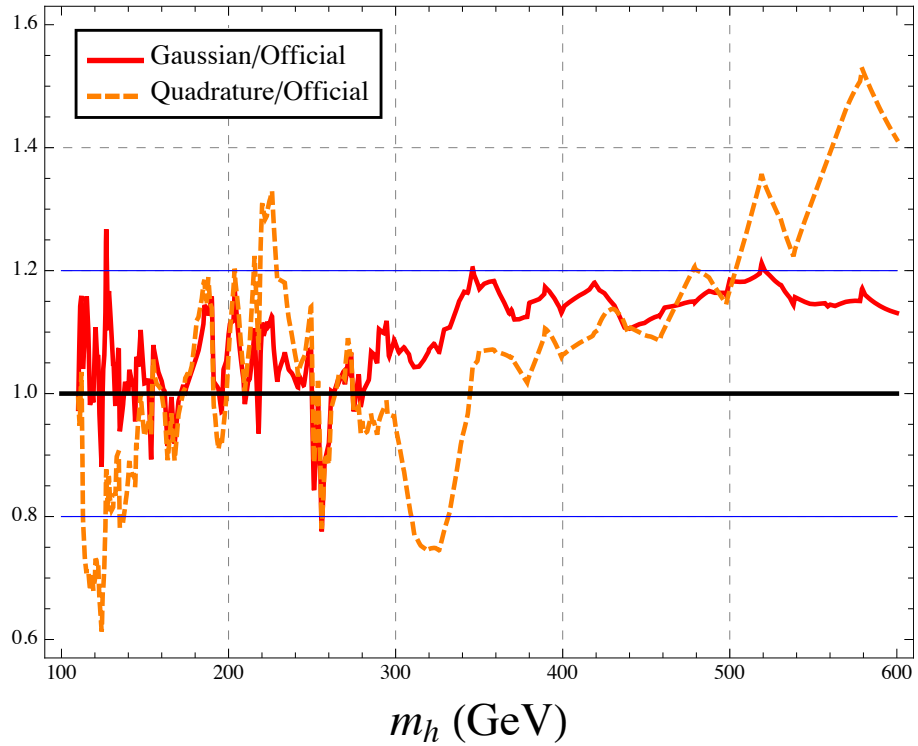
- Observed limit gives

$$0.95 \approx \frac{\mathrm{Erf}\left(\frac{\mu_{i,\rm obs}^{95\%} - \mu_i^{\rm max}}{\sqrt{2}\Delta_i^{\rm obs}}\right) + \mathrm{Erf}\left(\frac{\mu_i^{\rm max}}{\sqrt{2}\Delta_i^{\rm obs}}\right)}{1 + \mathrm{Erf}\left(\frac{\mu_i^{\rm max}}{\sqrt{2}\Delta_i^{\rm obs}}\right)}$$

Comparison with official combinations

The preceding method is clearly a better approximation to the official combination than the usual naive method of summing limits from individual channels in inverse quadrature



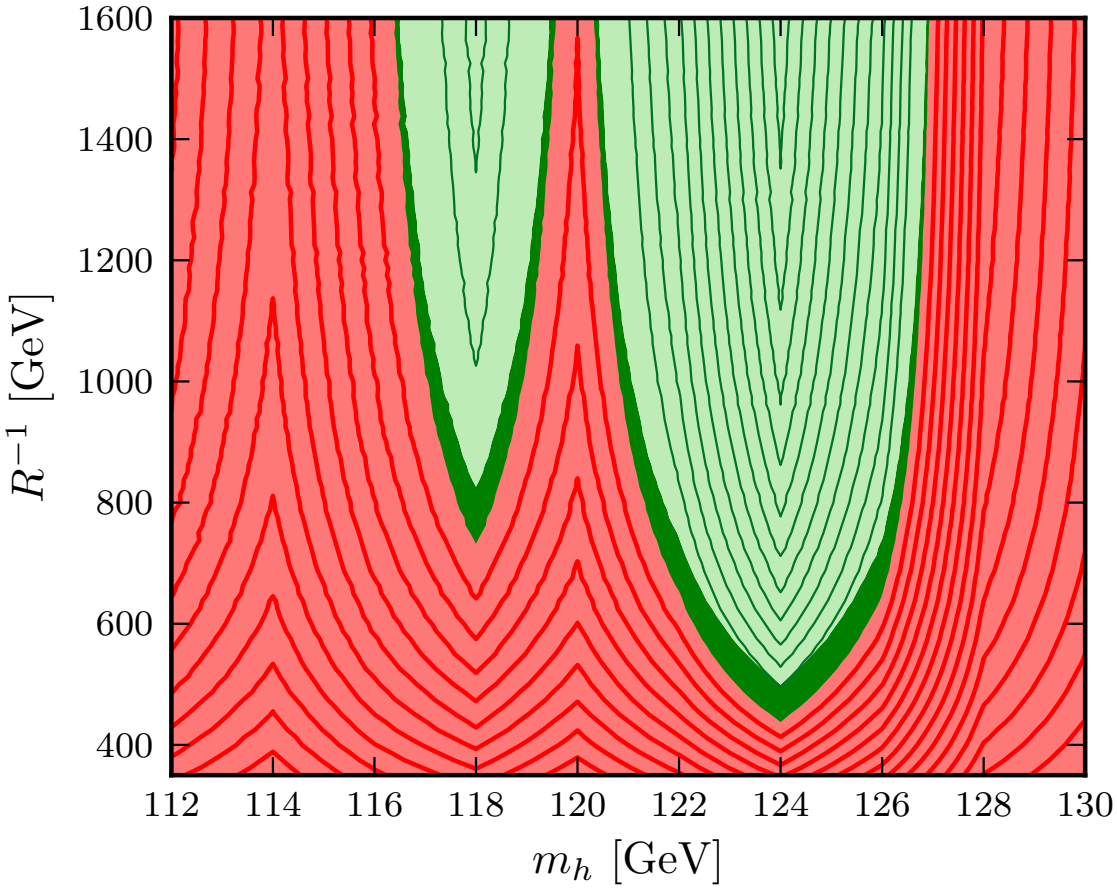


(Azatov *et al*, fig. 3, arXiv:1202.3415 [hep-ph])

Results and conclusions

New Higgs limits

We have statistically combined $gg \to h \to \gamma\gamma$ and $gg \to h \to WW$ channels and compared with latest CMS and Atlas data (Feb/March 2012, $\mathcal{L} \geq 4.6\,\text{fb}^{-1}$) improving on Nishiwaki *et al* (arXiv:1108.1764 [hep-ph])



Light green: allowed region for tree masses

Dark green: extra allowed region for loop masses

Contours show constant $\mu^{95\%}$ in steps of 0.05

Two narrow regions remain:
$R^{-1} > 825\,\text{GeV}$,
$116.5\,\text{GeV} < m_h < 119.5\,\text{GeV}$
and $R^{-1} > 500\,\text{GeV}$,
$123\,\text{GeV} < m_h < 127\,\text{GeV}$

Conclusions

- Higgs production is enhanced in MUED relative to the SM by up to 80%
- Higgs decay to $\gamma\gamma$ is suppressed by up to 12% but overall $gg \to h \to \gamma\gamma$ is enhanced by $\sim 50\%$
- We used Azatov *et al* method to approximately reconstruct single-channel likelihoods from LHC data and combine them to calculate overall $\mu^{95\%}$
- Find MUED remains allowed in two regions:

$$R^{-1} > 825\,\text{GeV}, \quad 116.5\,\text{GeV} < m_h < 119.5\,\text{GeV}$$

and

$$R^{-1} > 500\,\text{GeV}, \quad 123\,\text{GeV} < m_h < 127\,\text{GeV}$$