Higgs phenomenology of Minimal Universal Extra Dimensions at the LHC

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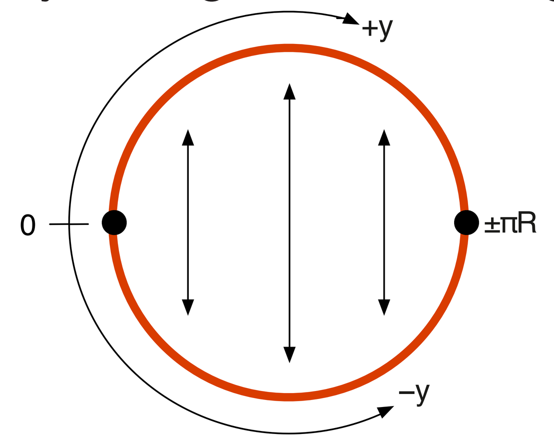
Motivation and theory

- The Standard Model of particle physics (SM) is an incomplete theory of Nature. Among the best candidates for extensions to the SM are models involving extra spatial dimensions.
- Minimal Universal Extra Dimensions (MUED) [1] posits a single extra dimension, in which all particles can move, curled up into a circle of radius $R \sim 10^{-18}$ m.
- This "compactification" quantises momentum in the compact dimension to Kaluza-Klein (KK) number, n, which is conserved.
- Identical particles with different n in 5D appear as distinct Kaluza-Klein (KK) particles with different masses $m_n \sim n/R$ in 4D.
- To achieve chiral interactions, the extra dimension is further compactified to an $S^1/\mathbb{Z}_2$ orbifold (effectively folding the circle along one of its diameters).

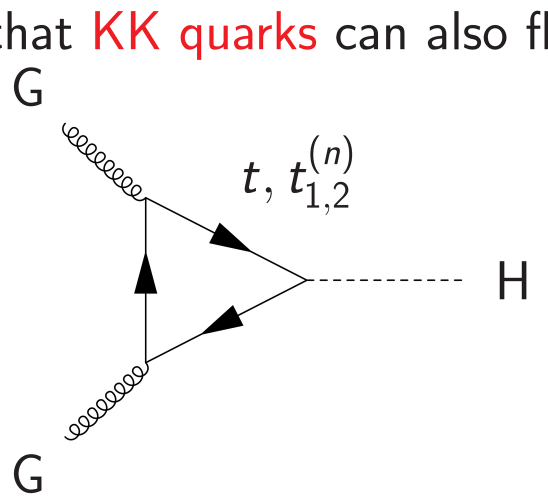


- This "orbifolding" violates KK number conservation but leaves a remnant KK parity, ensuring that the Lightest KK Particle (LKP) is stable.
- The LKP provides a good cold dark matter candidate (cf. the *ad hoc* addition of R-parity in Supersymmetry).

Higgs production and decay

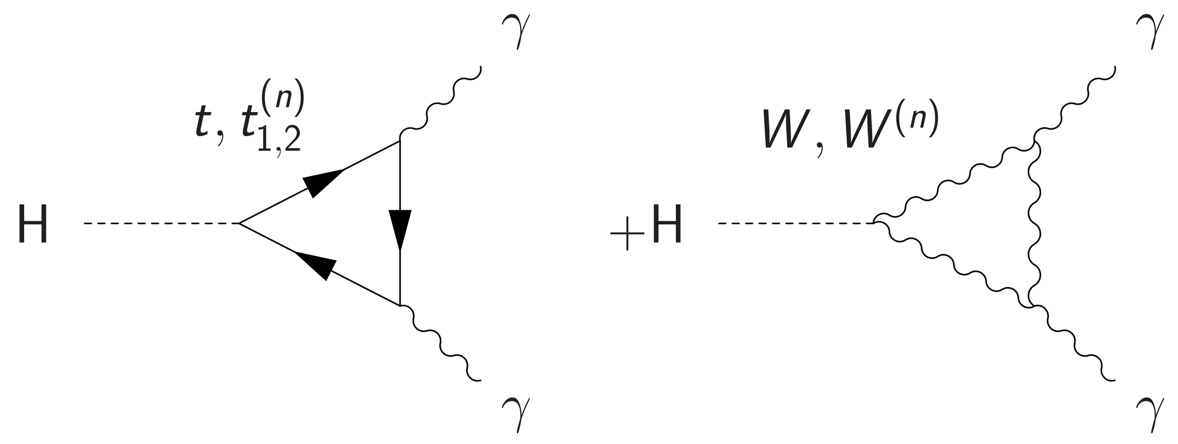
- SM Higgs production at the LHC is dominated by gluon-gluon fusion. The leading-order contribution is a triangle loop of quarks; the top dominates.
- This is also true in MUED except that KK quarks can also flow in the loop.

$i\mathcal{M}_{G,G\to H} =$



- The most important Higgs decay channel between m_H =115–130 GeV is two photons. The leading order contribution is a sum of loop diagrams involving quarks and W's.

$i\mathcal{M}_{H\to\gamma,\gamma} =$



- The KK particles contribute to each diagram with the same sign as their Standard Model partners but the enhancement of the quark diagrams is bigger than that of the W diagrams.
- For the Standard Model, the W contribution to the Higgs decay to two photons dominates over the (oppositely signed) quark contribution [2].
- The effect of the KK particles is to enhance the Higgs production cross-section and suppress the partial width to two photons.
- Above 130 GeV until around 200 GeV, the $H \to WW \to 2\ell 2\nu$ channel is the most important.
- The enhancement in cross-section in each of these channels is plotted opposite (fig. 2) together with the most recent [3] public CMS limits.
- Unlike in previous analyses, we use loop-corrected KK masses. We implemented the model in `CalcHEP`.
- From these plots, regions of the MUED parameter space can be conservatively excluded (fig. 3).

Previously-established limits

- The only undetermined parameters in MUED are the inverse compactification radius R^{-1} and the Higgs mass. (There is also the cutoff of the theory, but low energy observables are only weakly sensitive to this.)
- Collider and cosmology-based experiments have already constrained much of the MUED parameter space (e.g. fig. 1).

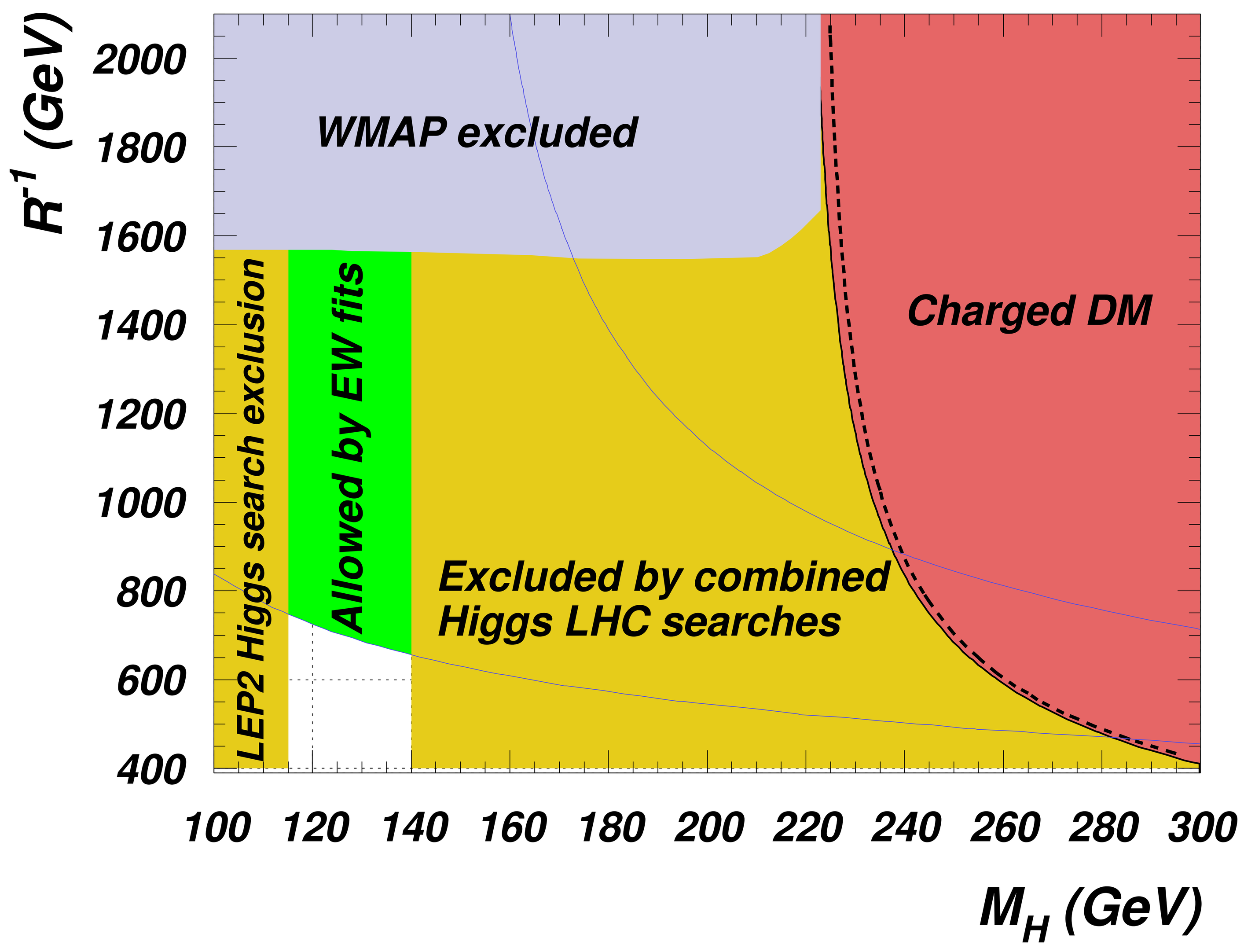


Figure 1: Existing collider and cosmological limits of MUED

Enhancement of production cross-section

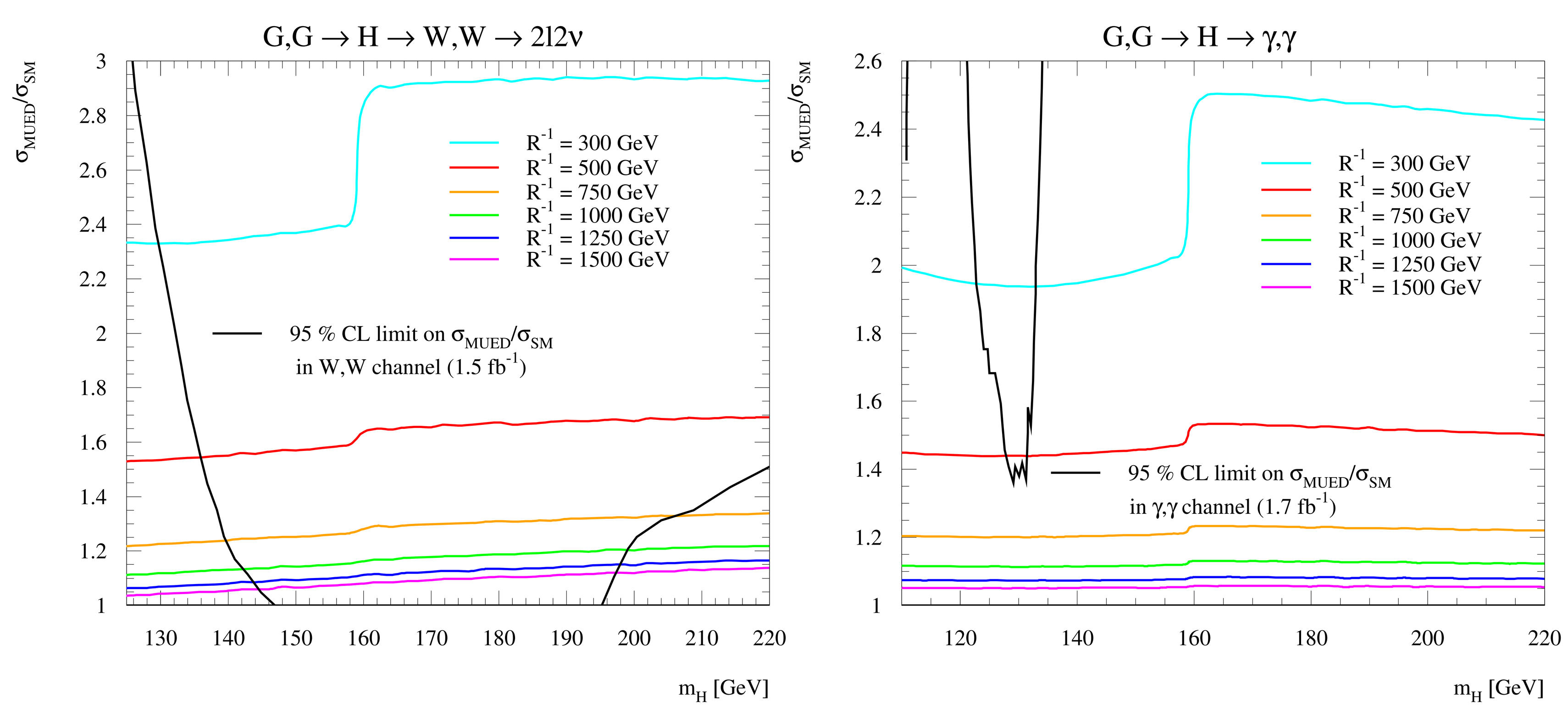


Figure 2: Enhancement of Higgs production cross-sections for two channels together with latest public CMS Higgs exclusion limits

Limits on parameter space

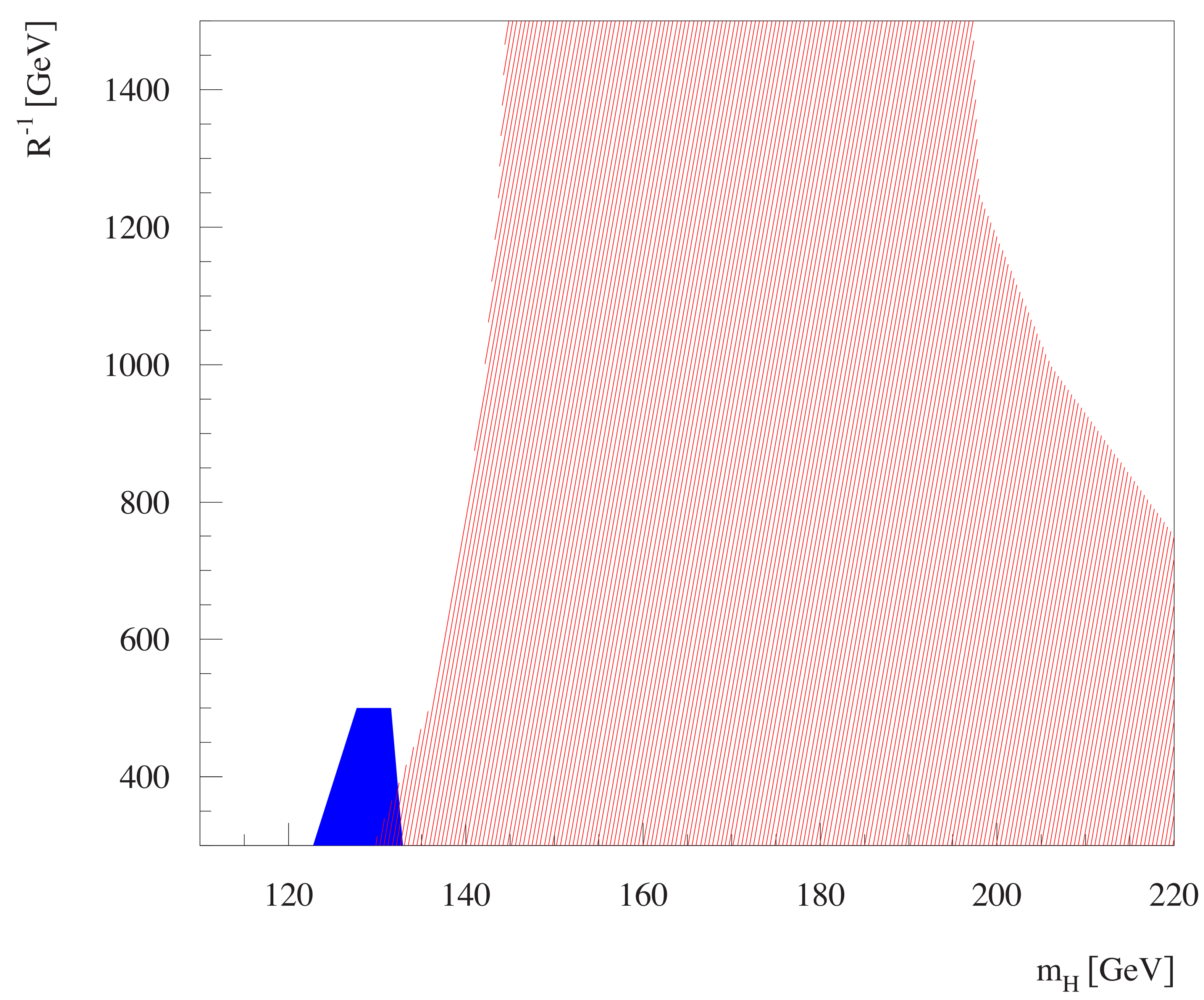


Figure 3: γ,γ (blue) and W,W (red) limits on the MUED parameter space

References

*Work done in collaboration with Drs Genevieve Bélanger, Alexander Belyaev, Mitsuru Kakizaki and Alexander Pukhov

[1] T. Appelquist, H.-C. Cheng, and B. A. Dobrescu, "Bounds on universal extra dimensions," *Phys. Rev. D* **64** no. 3, (Jun, 2001) 035002.

[2] M. Spira, A. Djouadi, D. Graudenz, and P. Zerwas, "Higgs boson production at the LHC," *Nucl.Phys.* **B453** (1995) 17–82, `arXiv:hep-ph/9504378 [hep-ph]`.

[3] C. Collaboration, "Combination of higgs searches," `CMS PAS HIG-11-022`.

(Background image: Simulated Higgs decay to 4 muons in the CMS detector by L.Taylor)

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