

New sensitivity of LHC measurements to composite dark matter model

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Based on: arXiv:2105.08494 with J. Butterworth, L. Corpe, X. Kong, M. Thomas

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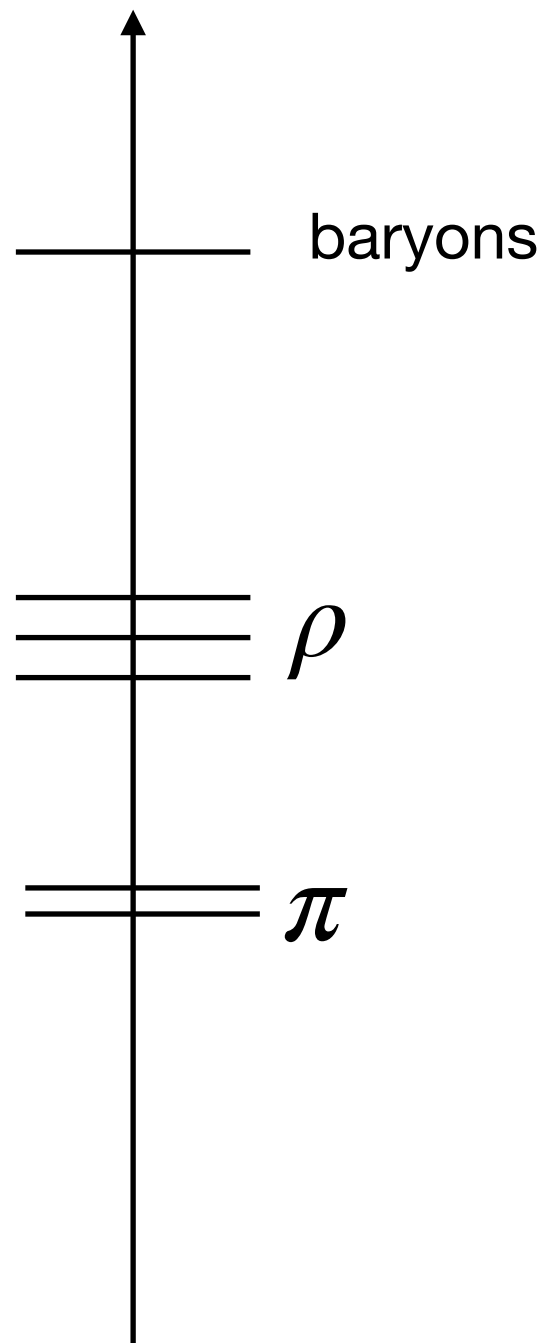
Der Wissenschaftsfonds.



Composite dark matter scenarios

Appelquist et al arXiv:1402.6656

Spectrum



What if dark matter is a composite particle arising from non-Abelian dynamics?

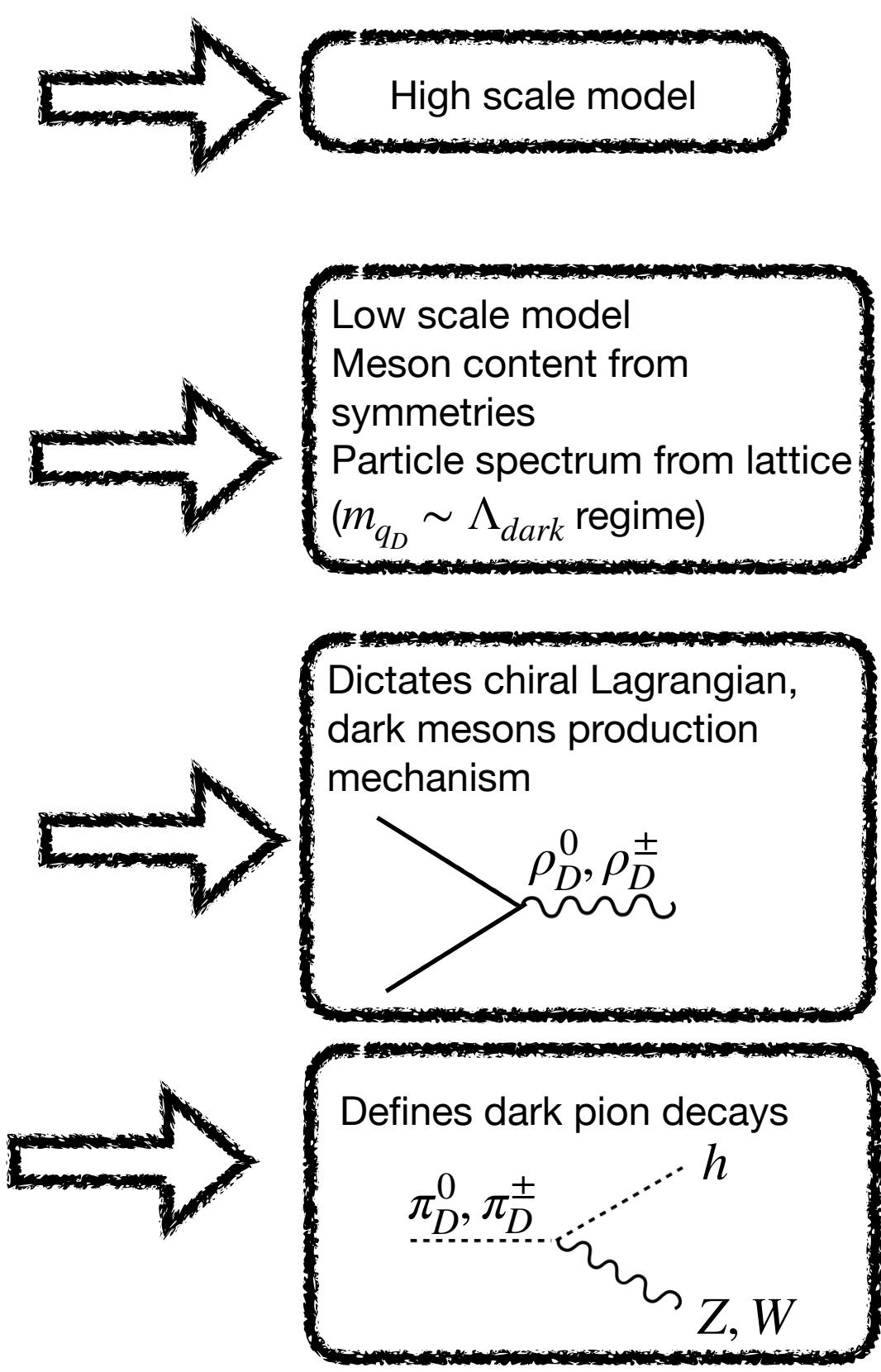
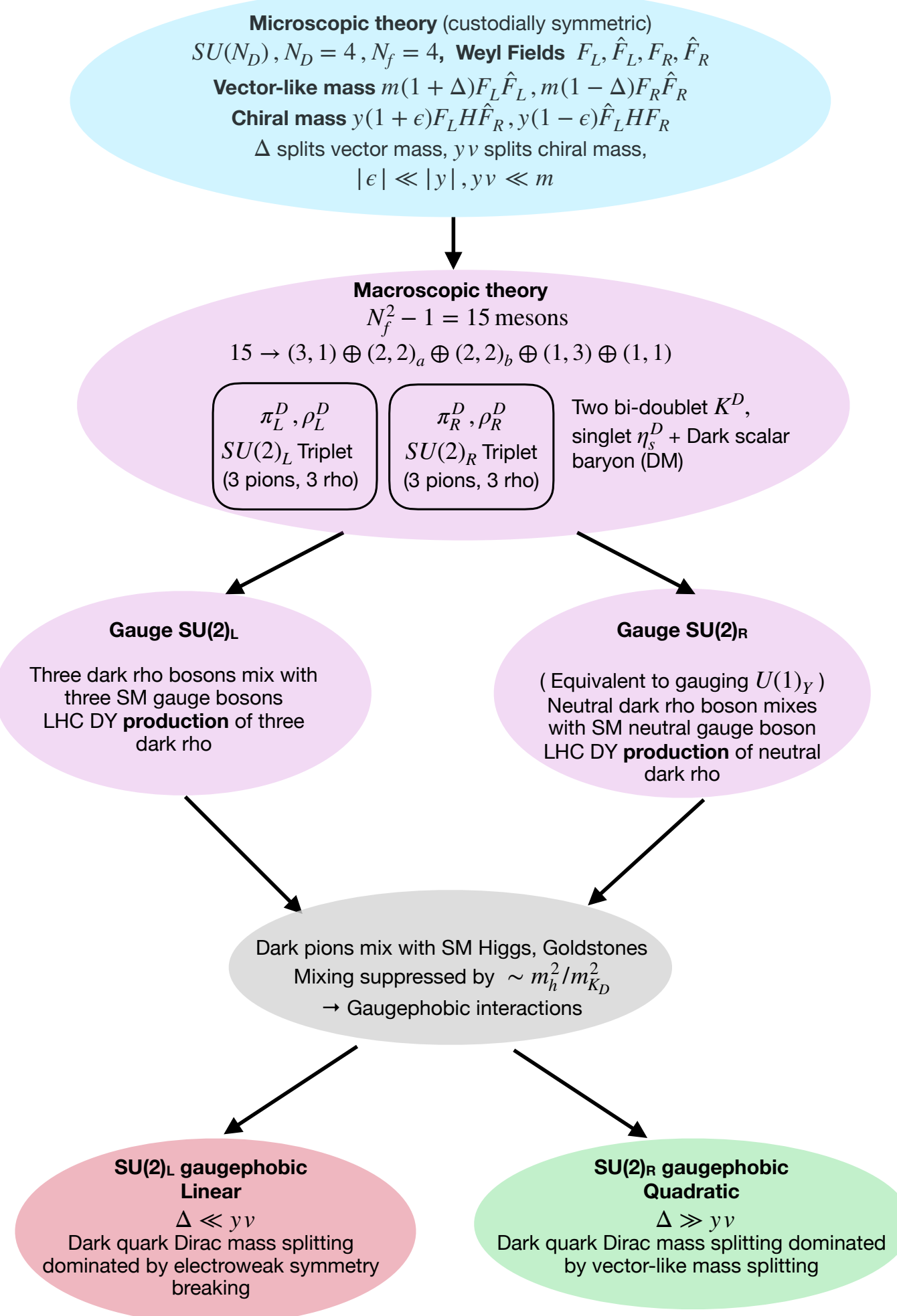
Theory under consideration: $SU(N_D)$ [$N_D = 4$, $N_f = 4$] gauge theory - confines at

$$\Lambda_{dark} \sim 4\pi f$$

Low energy theory: bound states of mesons and baryons, masses computed by lattice

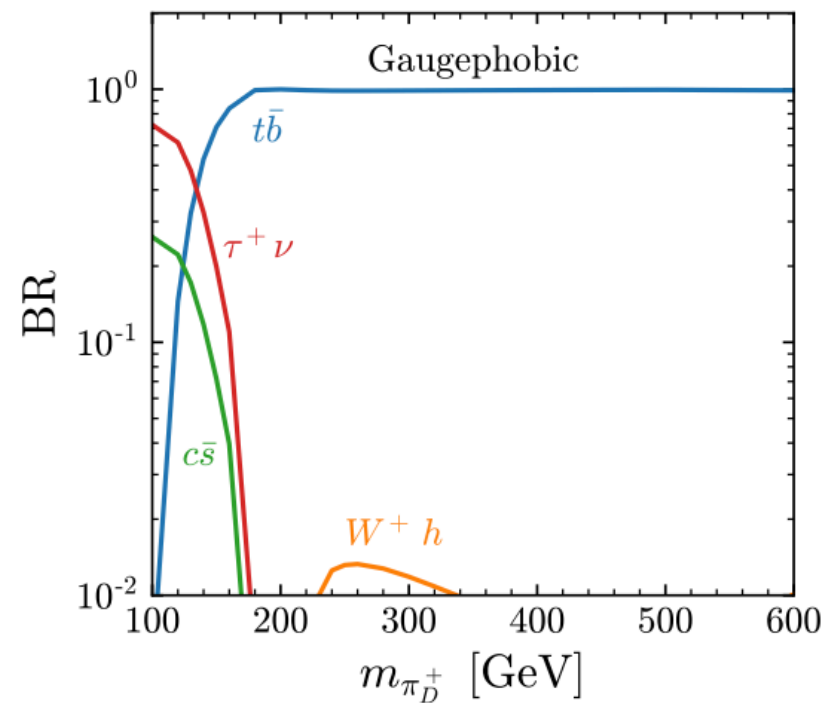
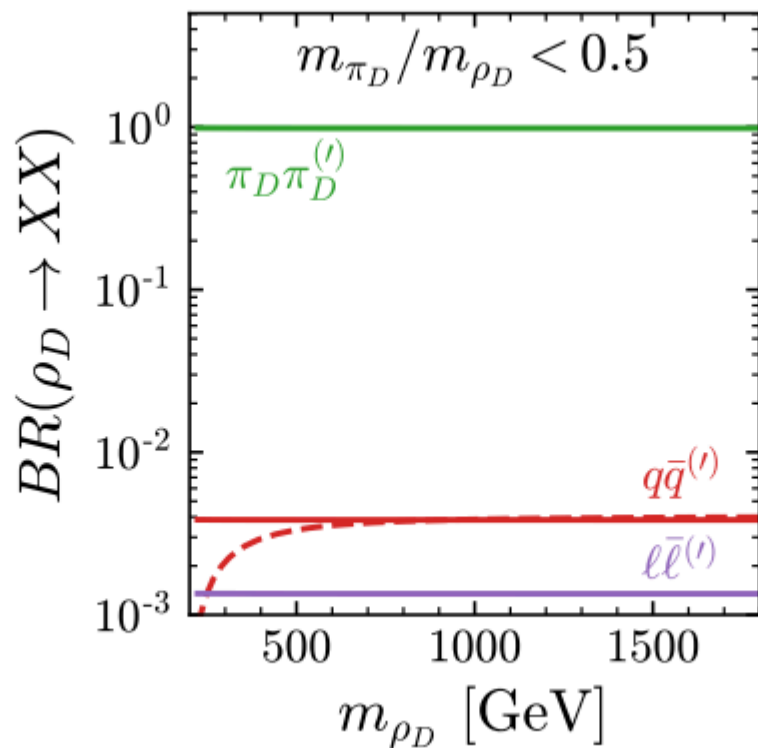
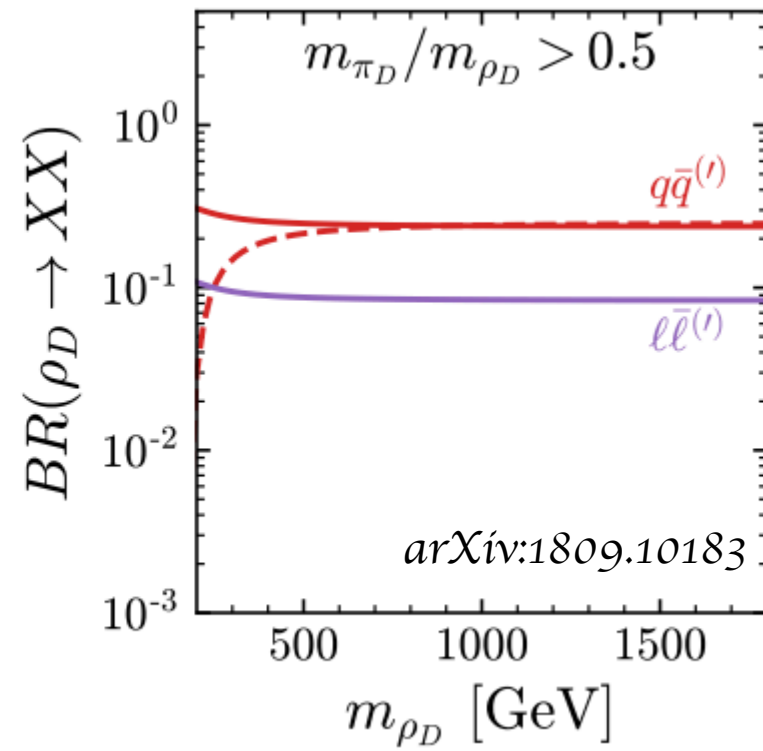
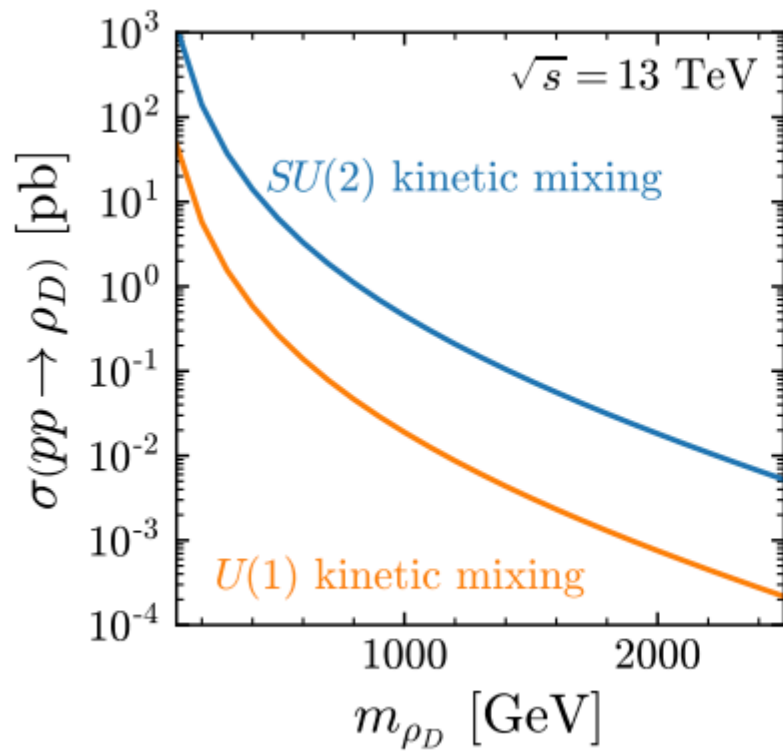
Dark fermions transform under electroweak part of the Standard Model

Important: Lattice does not predict absolute masses but bound state mass in terms of common mass scale of free choice



Aim: constrain dark sector - SM portal i.e. constrain value of Higgs - dark quark Yukawa coupling

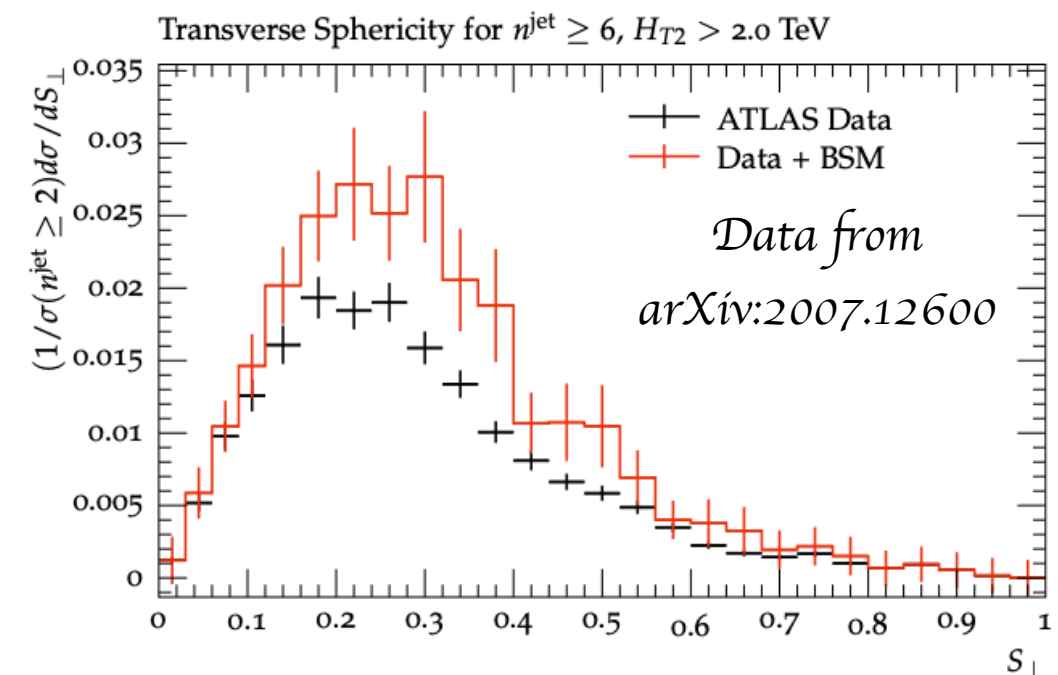
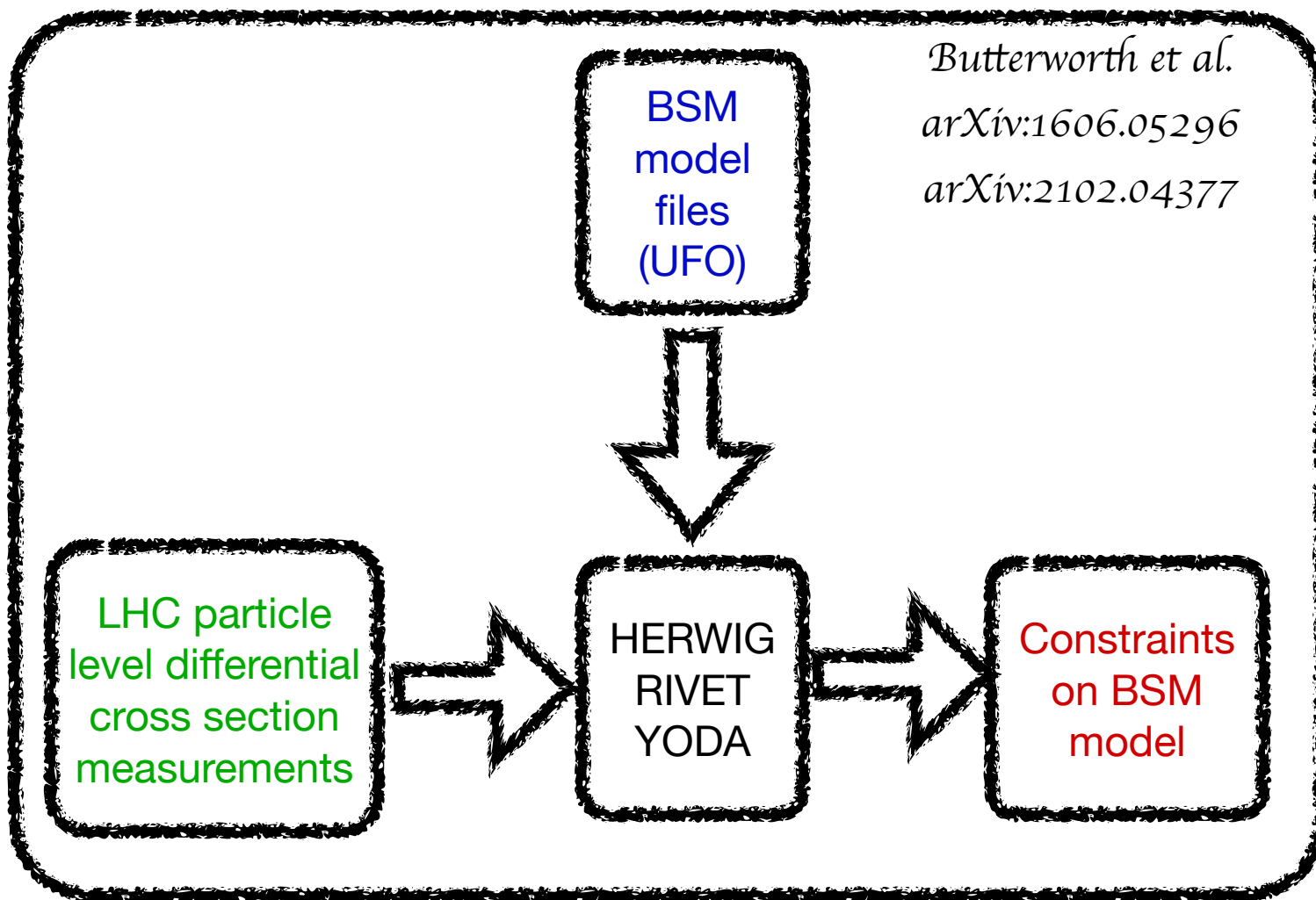
LHC phenomenology

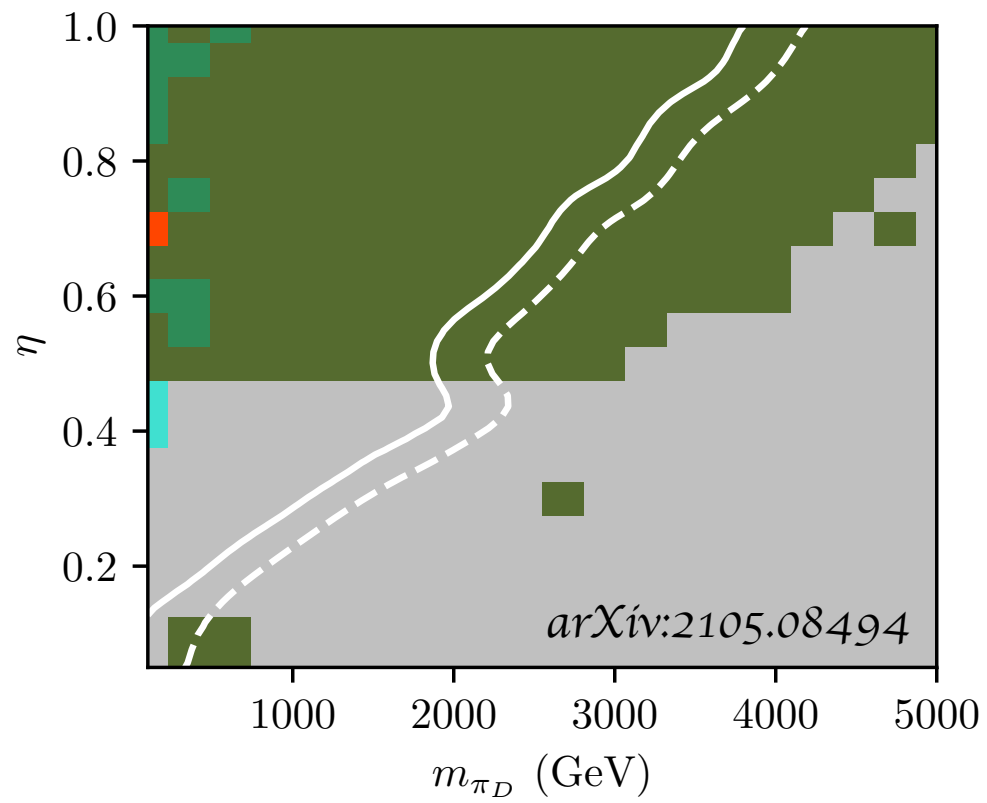


- Dark rho production cross-section depends on which of the triplets is gauged
- If dark rho does not decay to dark pions, dark rho decays to leptons will provide Z' like resonance signature
- If dark rho can decay to dark pion, it will almost always do so
- Dark pion decays feature a variety of final states specially featuring third generation SM fermions

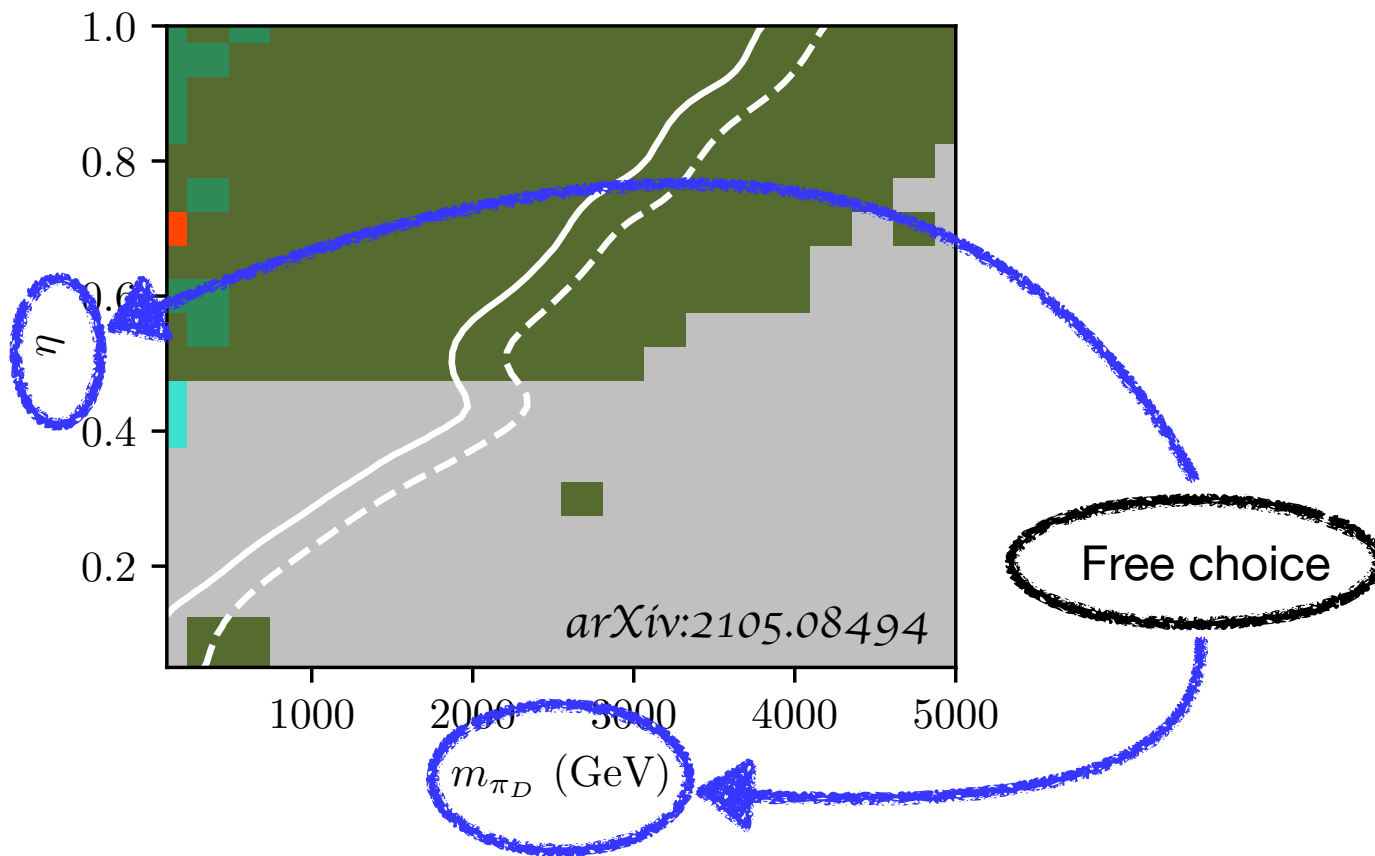
Use Standard Model differential cross-section measurements to exclude presence of signal in phase spaces already compatible with the SM calculations

CONTUR

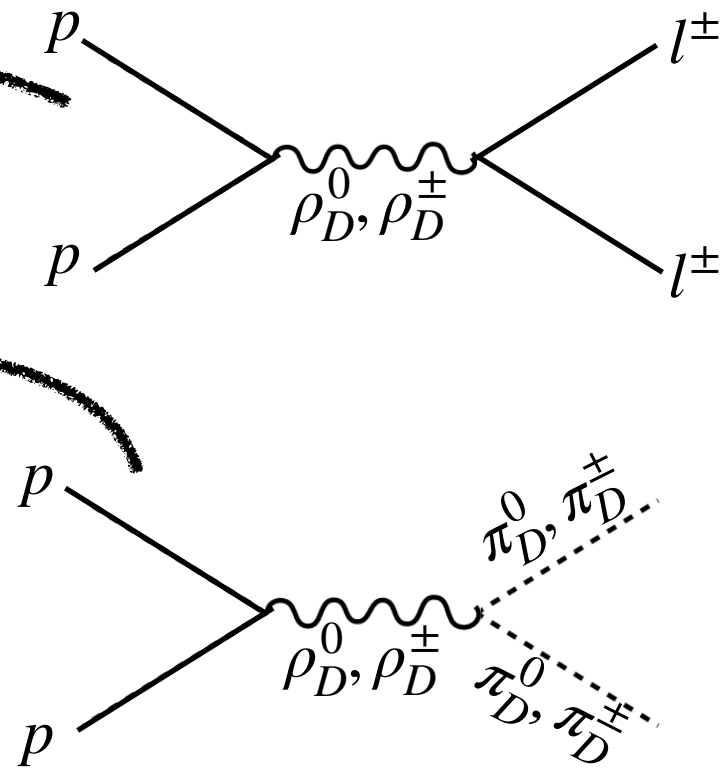
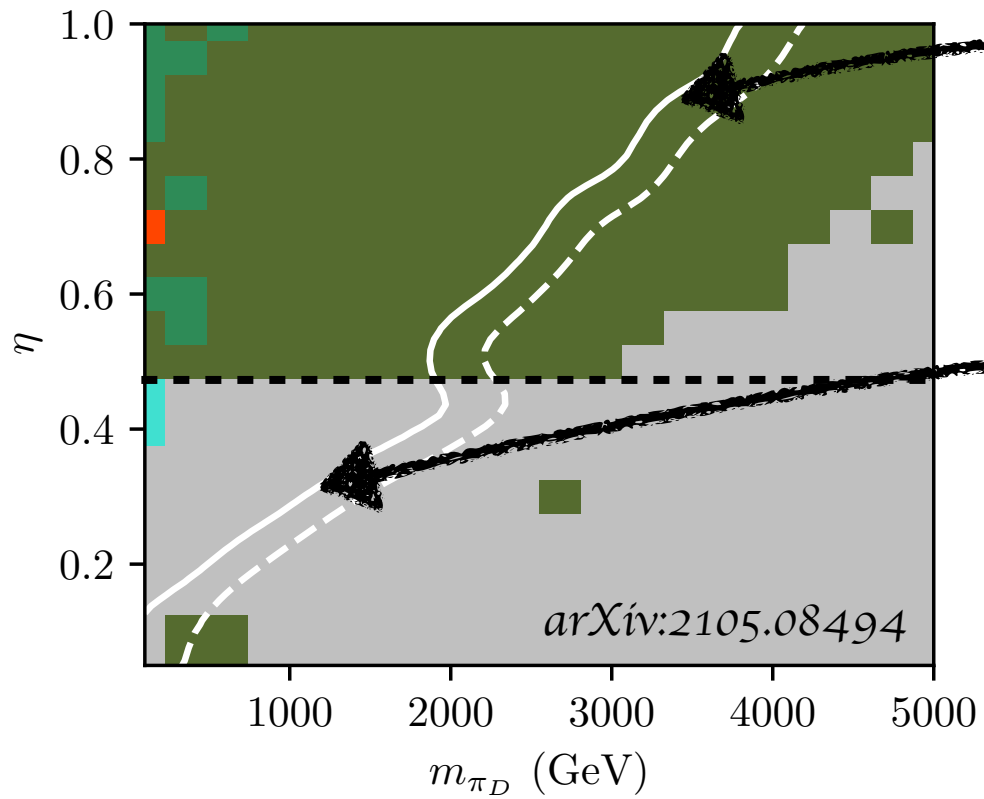




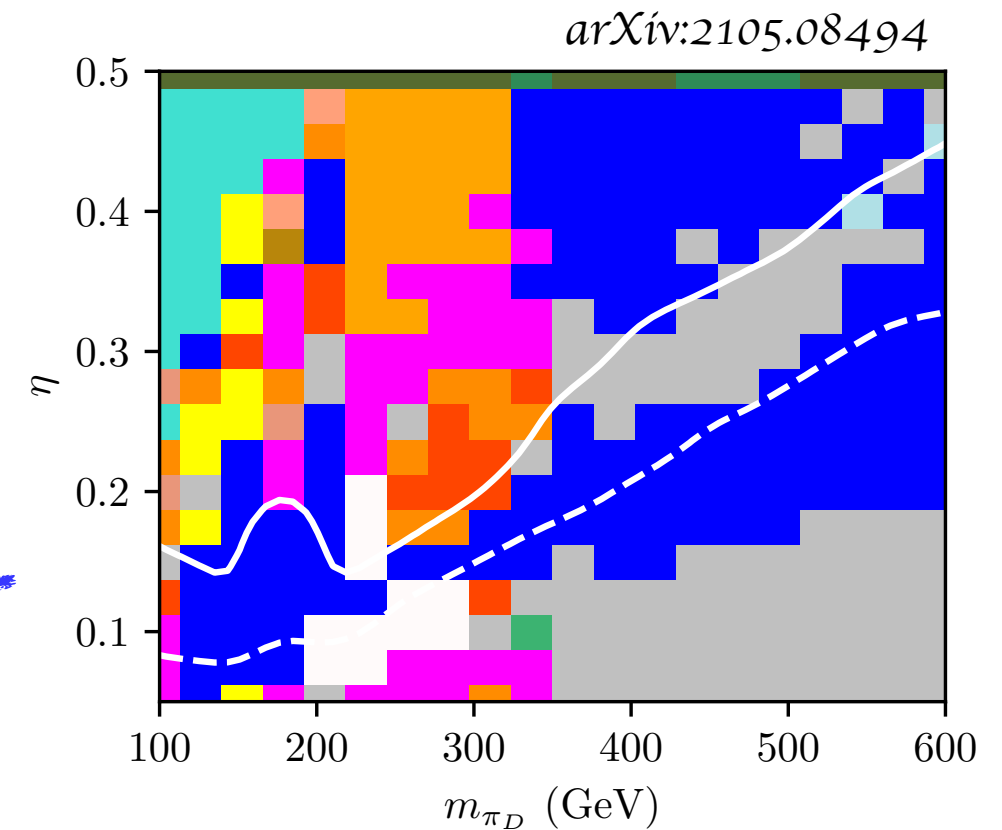
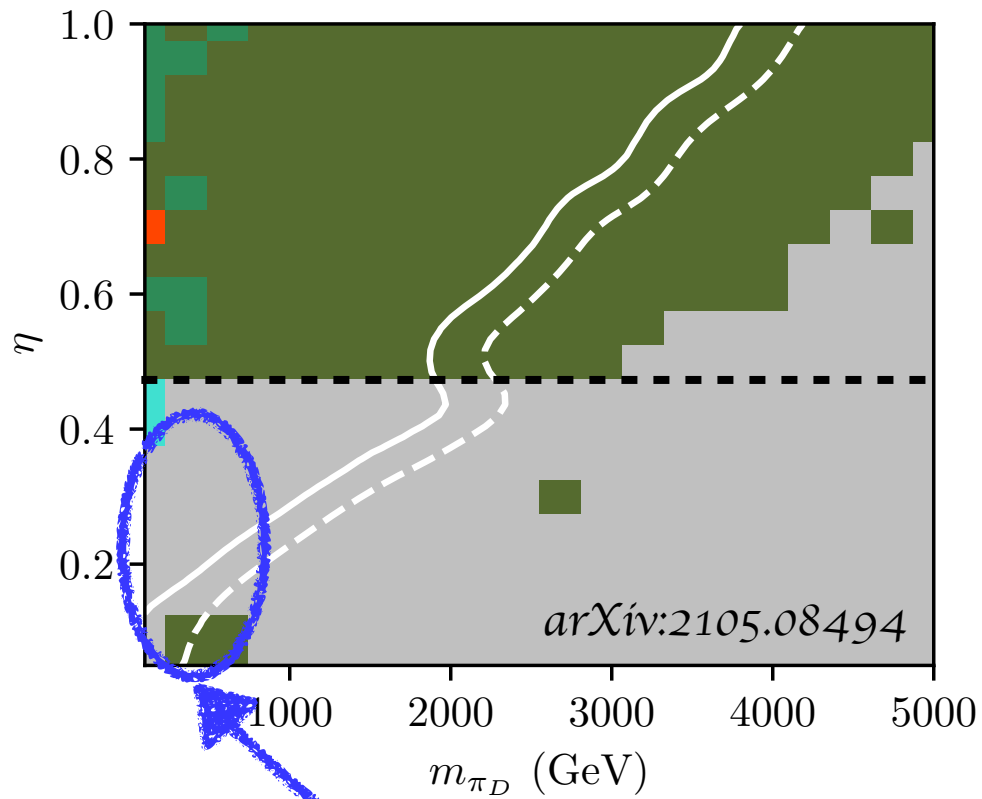
LHC limits from CONTUR



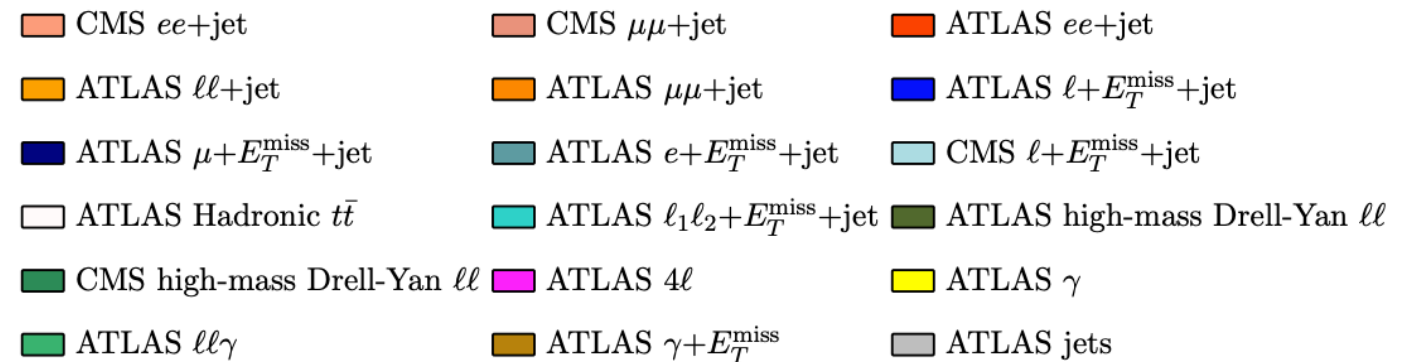
LHC limits from CONTUR

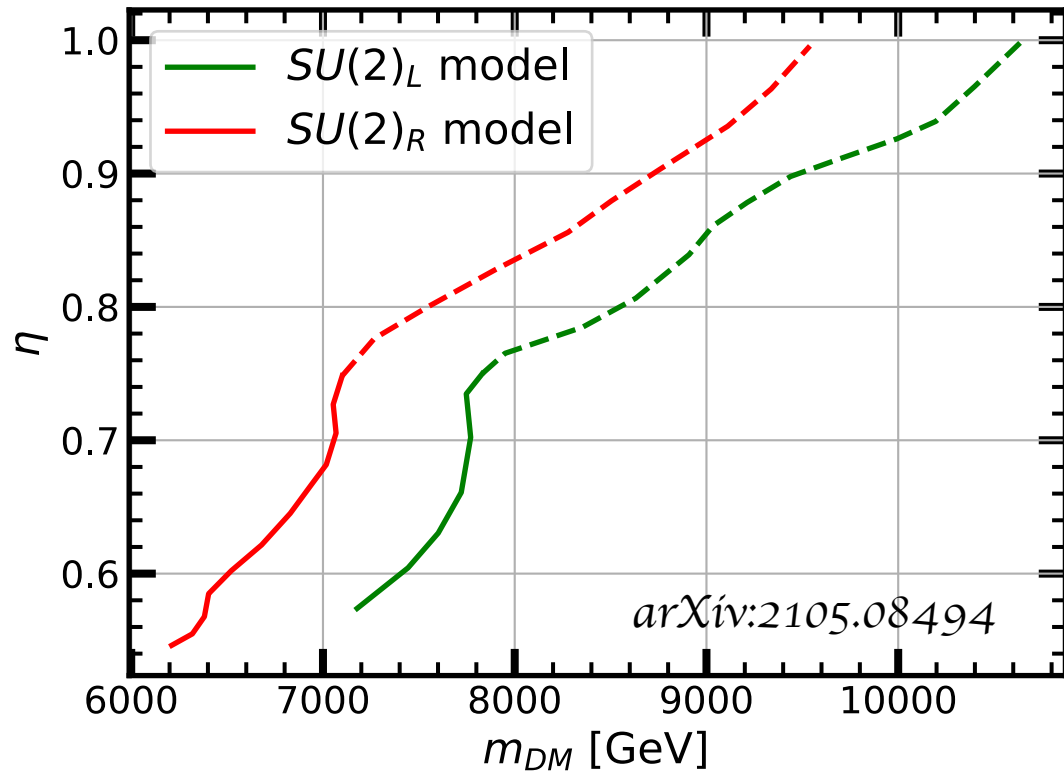


LHC limits from CONTUR



1. Turn off resonance searches
2. Turn off multi-jet analyses which suffers from QCD uncertainties
3. Sensitivity to a variety of other SM differential measurements



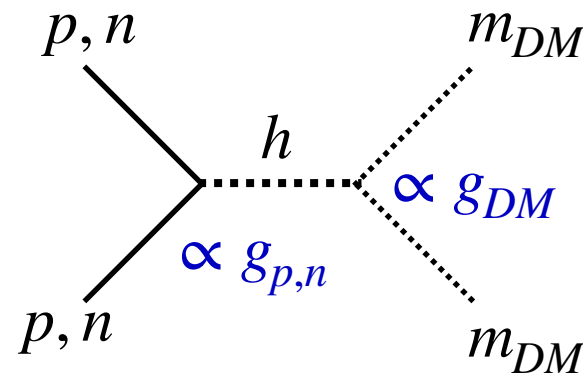


$$m_{DM}(\eta) = \frac{amS0(\eta)}{amps(\eta)} \times m_{\pi_D}(\eta)$$

- m_{π_D} - excluded dark pion mass from LHC
- $amS0(\eta)$, $amps(\eta)$ predicted by lattice
- LHC exclusions together with the lattice results push the dark matter mass limits to multi-TeV mass range

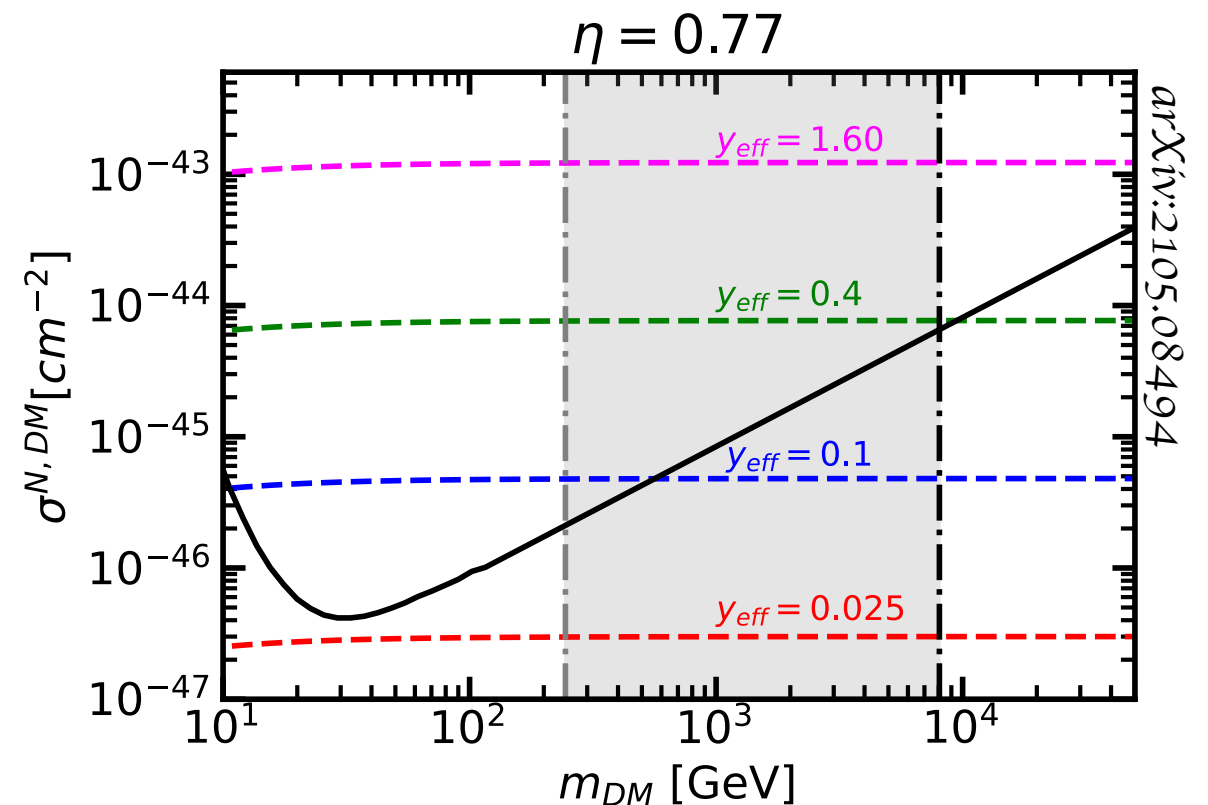
$$\mathcal{M}_{p,n} = \frac{g_{p,n} g_{DM}}{m_h^2}$$

$$g_{DM} \simeq y_{eff} \times f_f^{DM}$$



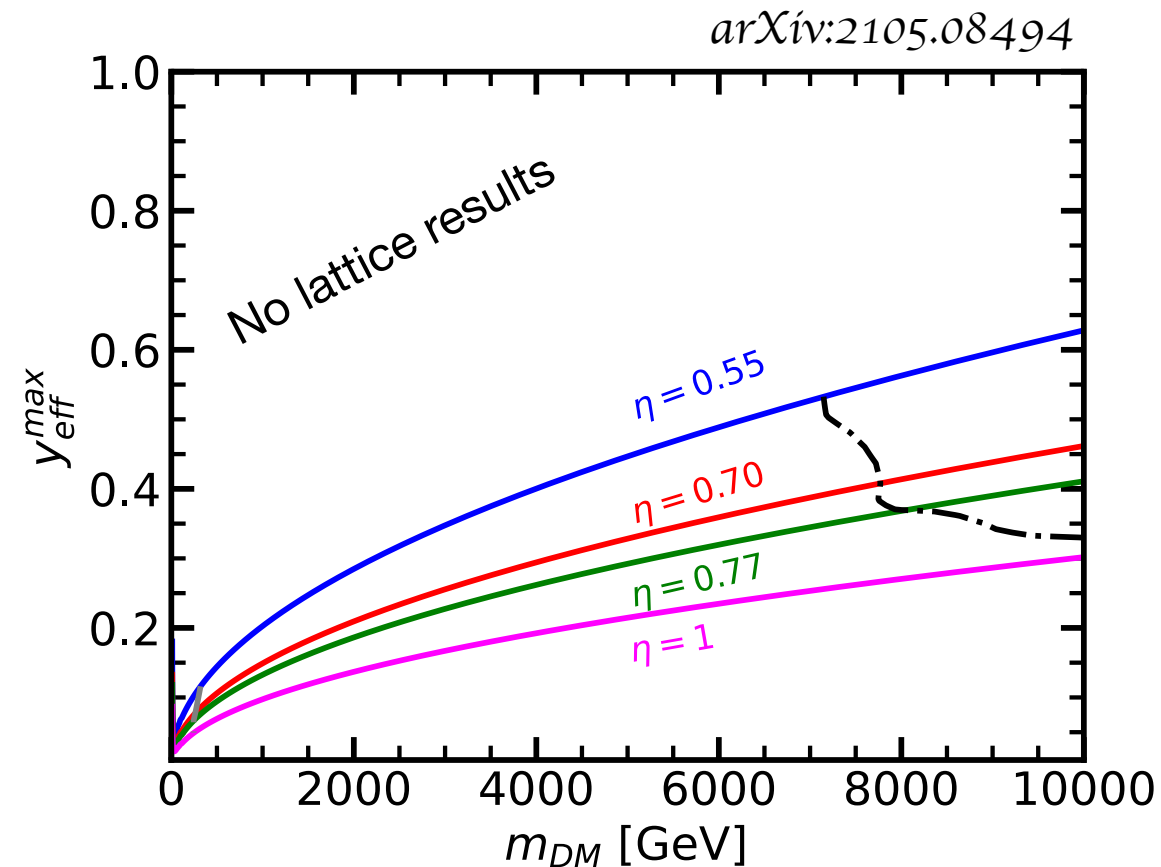
Direct detection limits push dark quark coupling to the Higgs to lower values

How strongly can such model couple with the Higgs?



Combined limits

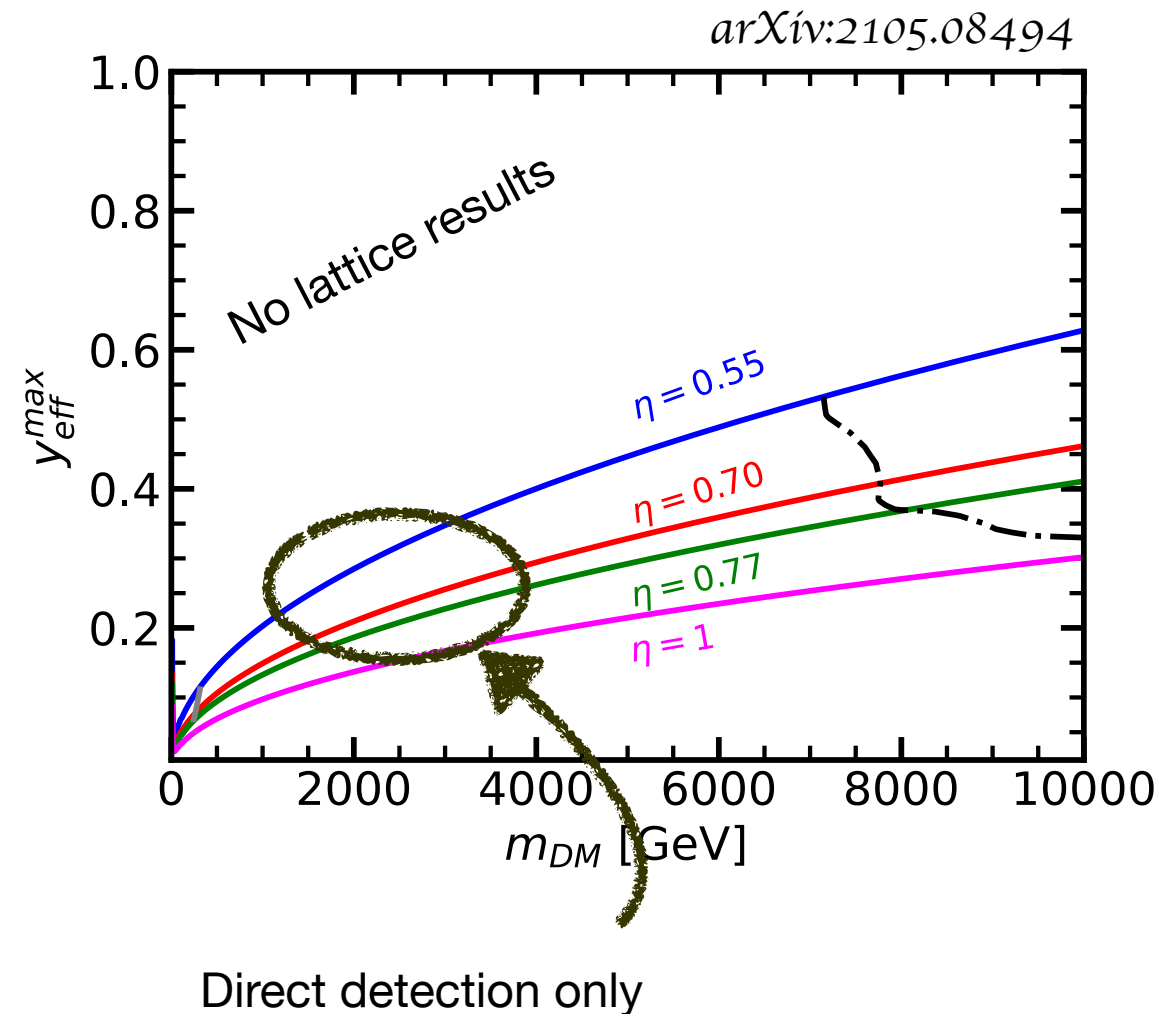
Combination of direct detection limits, LHC measurements and DY searches



Either require low values of Higgs - dark quark effective Yukawa coupling or require very heavy dark matter

Combined limits

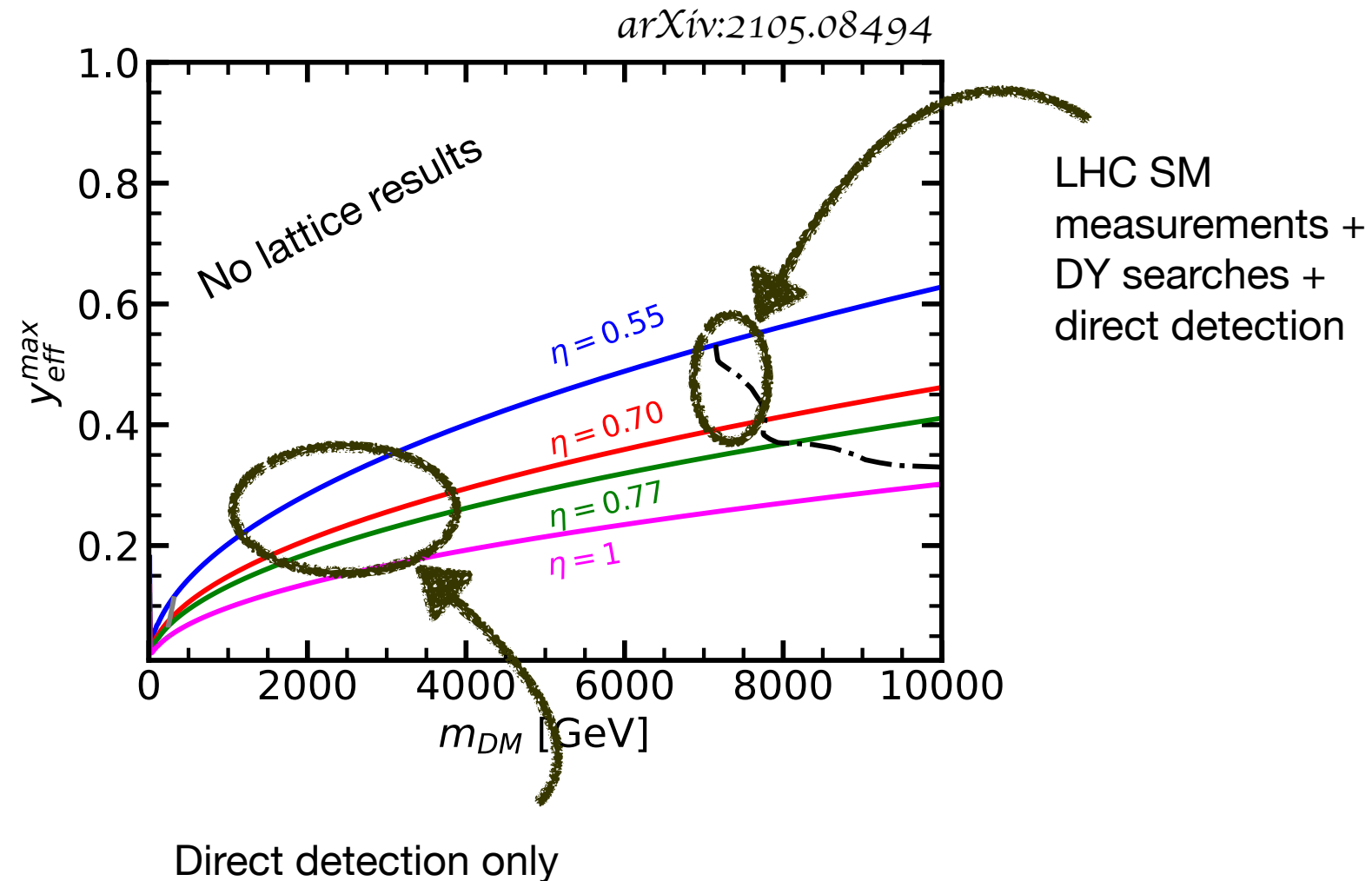
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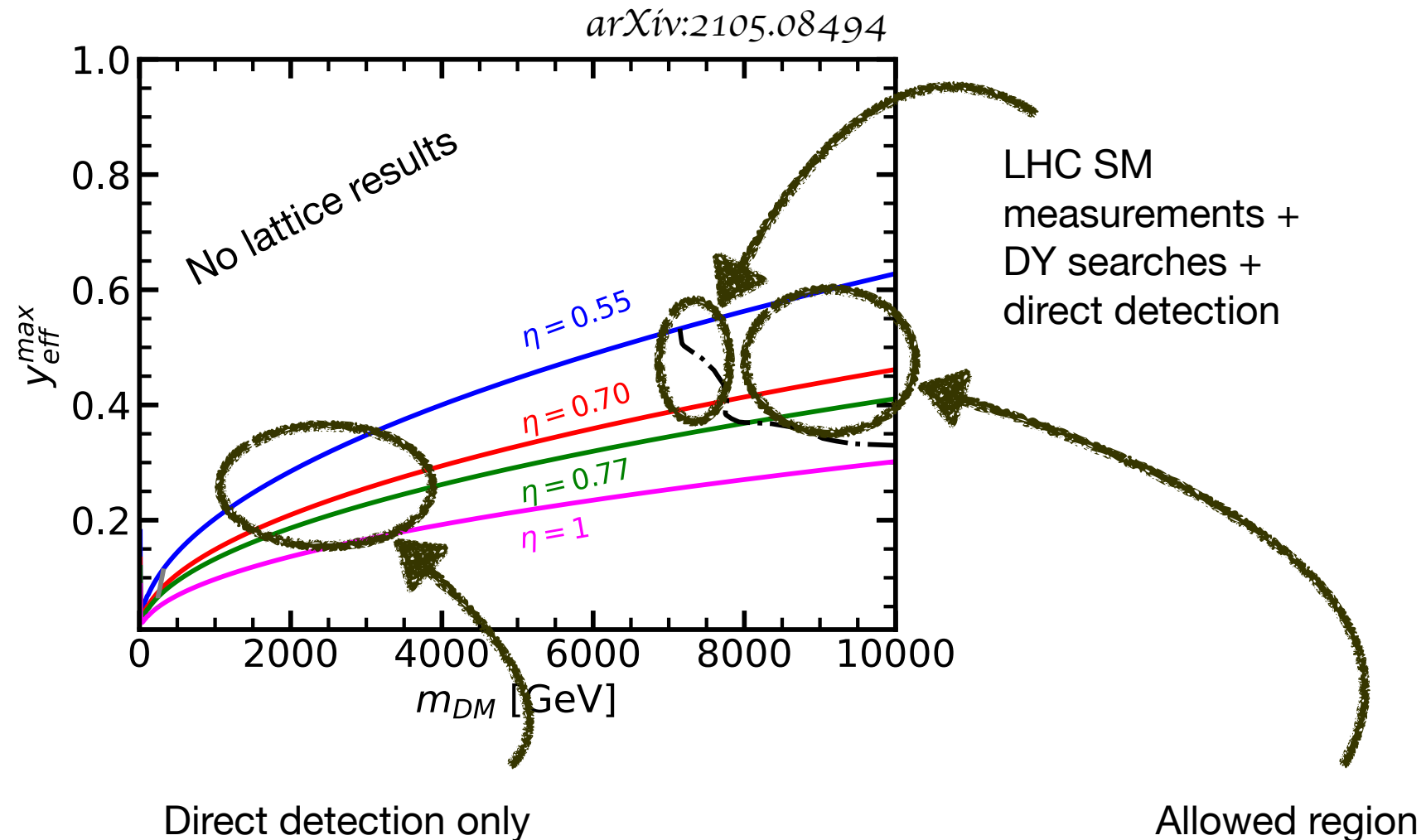
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Conclusions

1. Explored specific dark sector theory where vector like dark quarks under $SU(N)$ gauge group are also charged under the SM and get chiral masses. The model features dark mesons and a dark scalar baryon as a dark matter candidate.
2. We use lattice results to fix relative masses of bound state spectra.
3. Due to chiral couplings, the dark quarks and hence dark matter couples with Higgs and produced signals at direct detection experiments.
4. The dark rho mesons get produced at the LHC via DY processes and can decay to pions if phase space allowed. The pion decays are further dominated by third generation SM fermions.
5. We used the SM differential measurements to constrain such theories and in particular showed that a combination of measurements and searches pushes the rho and pion masses to multi-TeV region.
6. Using lattice results, we translated the pion mass limit to dark matter (dark baryon) mass limit and shows that it is pushed to multi-TeV range as well.
7. In combination with the direct detection limits these studies provided an updated limits on dark quark coupling to the Higgs and on the masses of the bound state spectrum.