Dark Matter at the LHC and IceCube
A Simplified Models Interpretation

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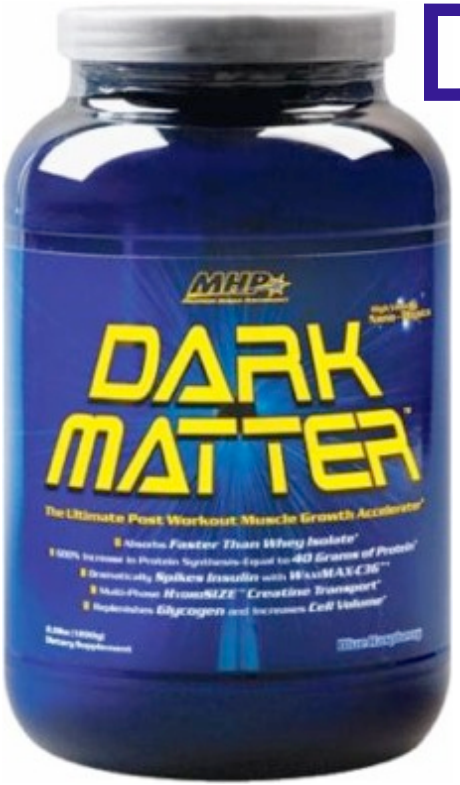
June 25, 2015

An attractive scenario:

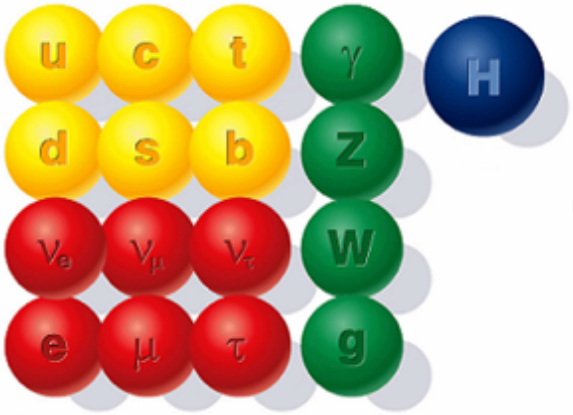


Dark Matter

is a

WIMP

An attractive scenario:



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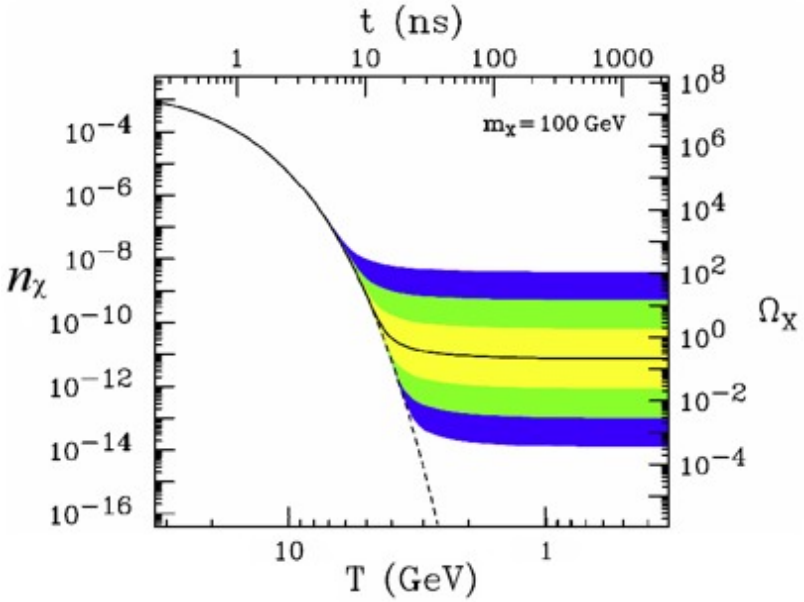

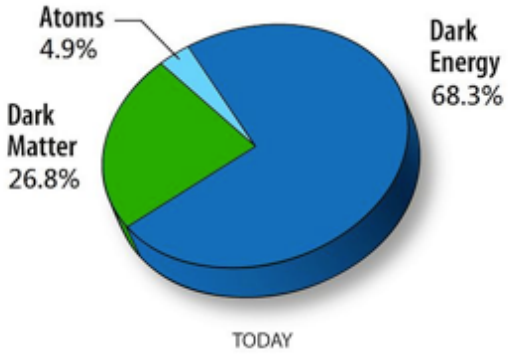

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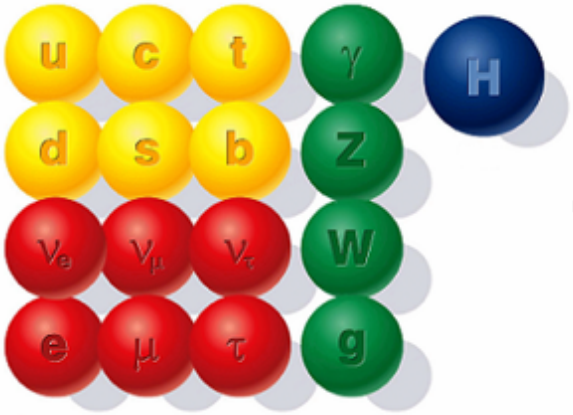

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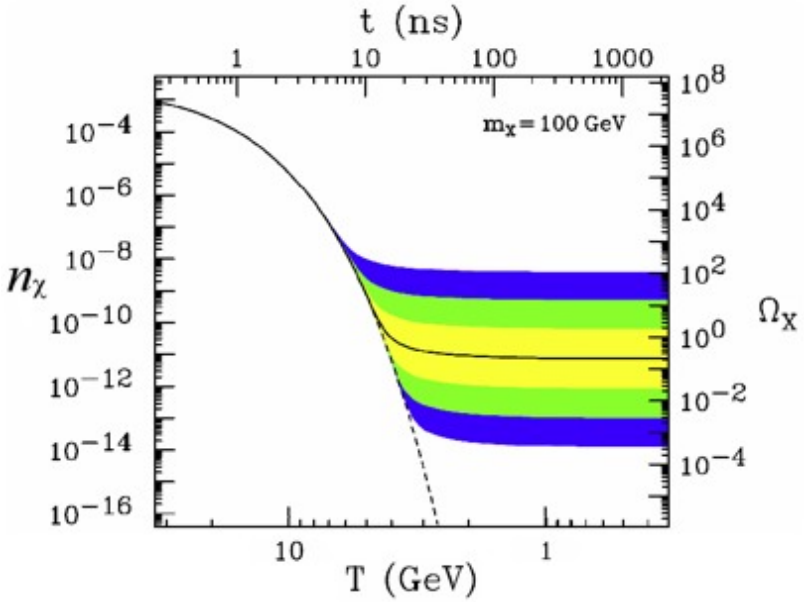
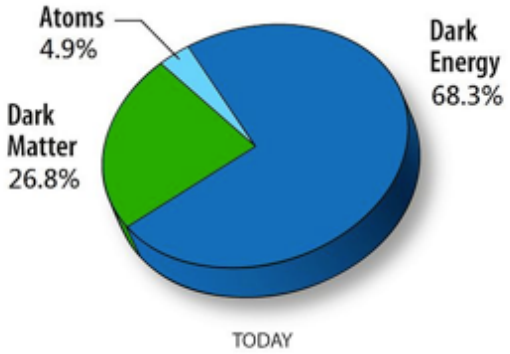


Describe pheno:

- Effective Operators
- Simplified Models /Minimal Models

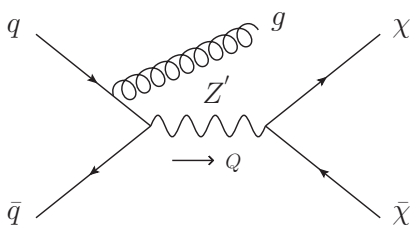


LHC: Beyond effective field theory

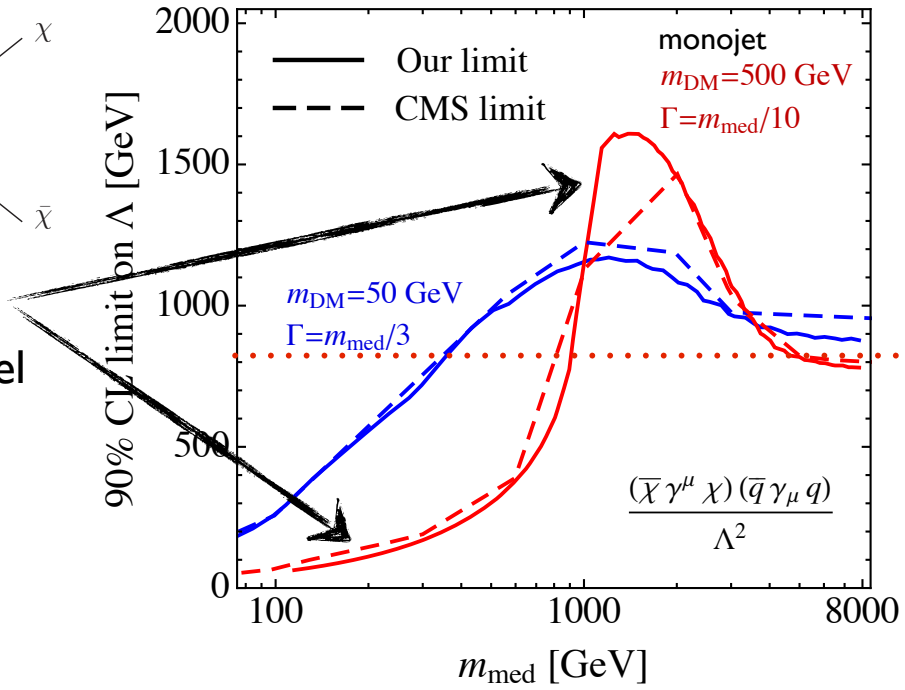
Dark Matter beyond EFT: Effects of mediators very important

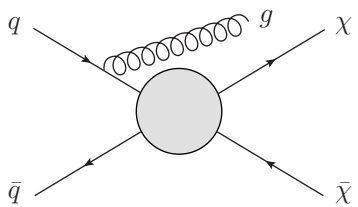
[see e.g. Busoni, De Simone, Morgante, Riotto 1307.2253; Buchmueller, Dolan, McCabe 1308.6799; Busoni,De Simone, Jacques, Morgante, Riotto 1405.3101; Buchmueller, Dolan, Malik, McCabe 1407.8257]

[Buchmueller et al. 1307.2253]



EFT limit far off
→ Simplified Model





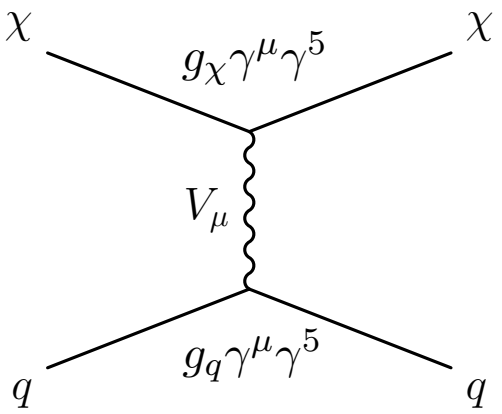
EFT limit valid

This Talk:

- Discuss the need for Simplified Models for LHC

- Show importance of IceCube limits

Our Model:



- Vector-boson s-channel messenger
- Majorana DM
- Axial couplings to quarks and DM

(no couplings to leptons)

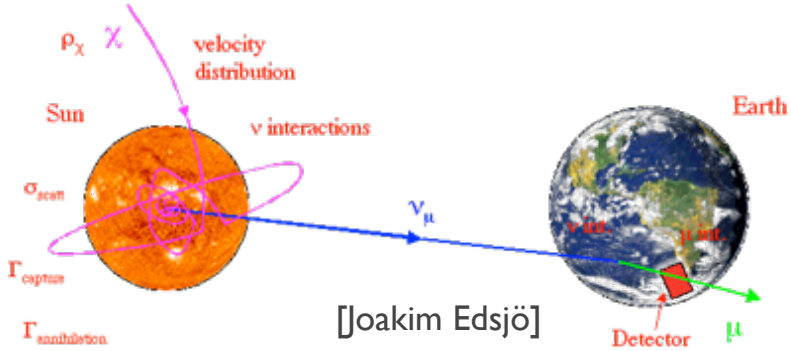
- Four parameters: M_V, m_χ, g_q, g_χ

- No spin-independent WIMP-nucleon scattering

  → weak direct detection limits
- LHC constraints important
- Indirect detection limits from annihilation in the sun

Indirect DM detection: annihilation in the sun

- Sun: Giant DM trap via WIMP-nucleon scattering ("direct detection")
- Sensitive to spin-dependent scattering



[Joakim Edsjö]

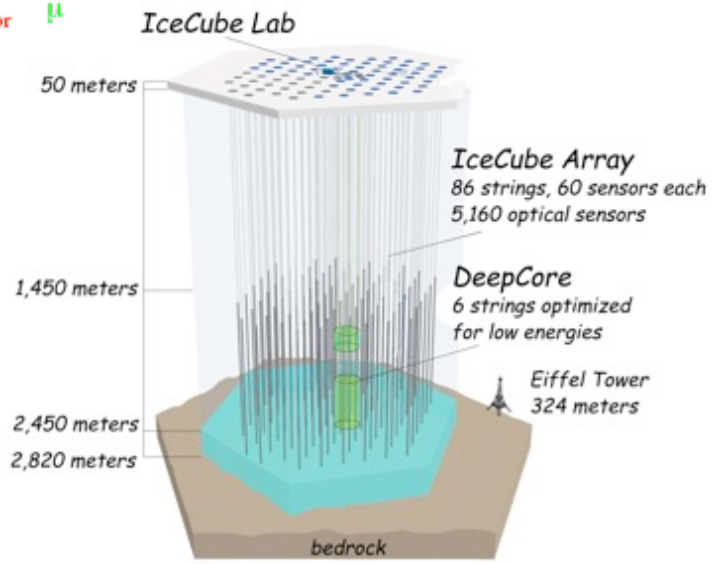
$$\dot{N} = C_\odot - C_A N^2$$

Capture rate: WIMP-nucleon scattering $\sigma_{\rm SD}$ in the sun

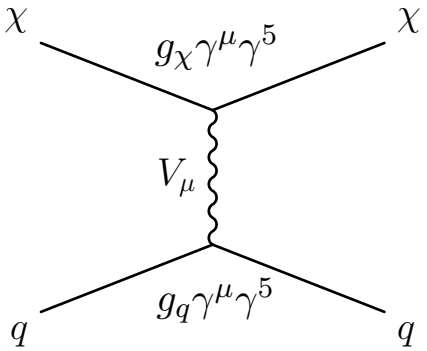
Annihilation rate: $C_A = \langle \sigma_A v \rangle / V_{\rm eff}$

Equilibrium: $C_\odot = C_{\rm A} N^2 \propto$ neutrino flux

Detect neutrinos from DM annihilation with IceCube

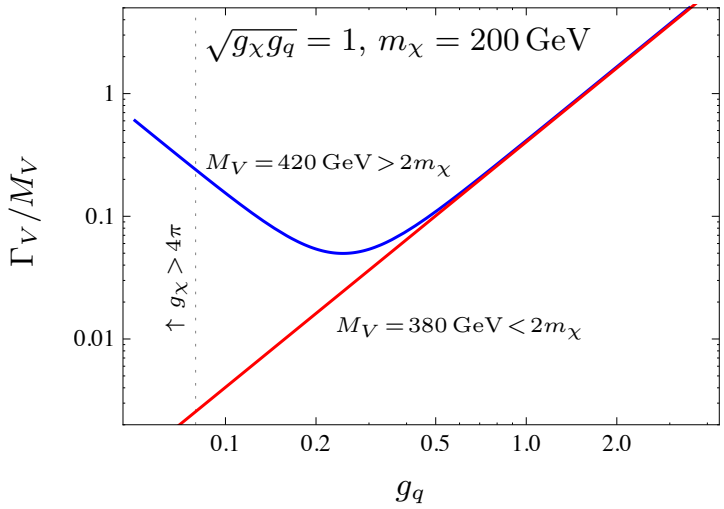


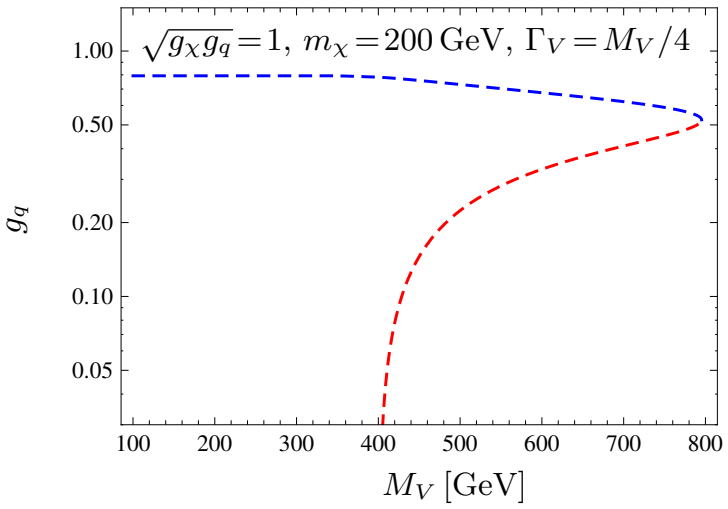
Exploring the parameter space



- Four parameters: M_V, m_χ, g_q, g_χ
  or $M_V, m_\chi, (g_q g_\chi), \Gamma_V$
- EFT: $m_\chi, (g_q g_\chi / M_V^2)$

Decay width: $\Gamma_V = \Gamma_{V\to qq}(M_V, g_q) + \Gamma_{V\to\chi\chi}(M_V, m_\chi, g_\chi)$





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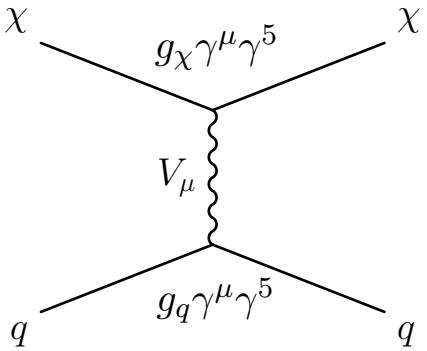

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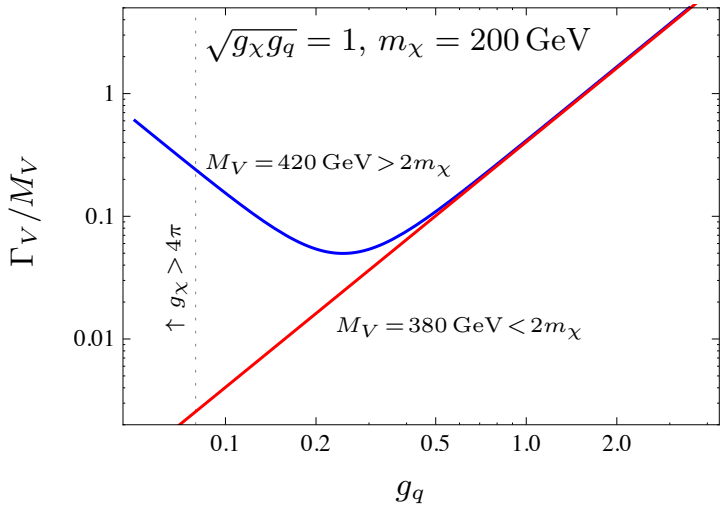
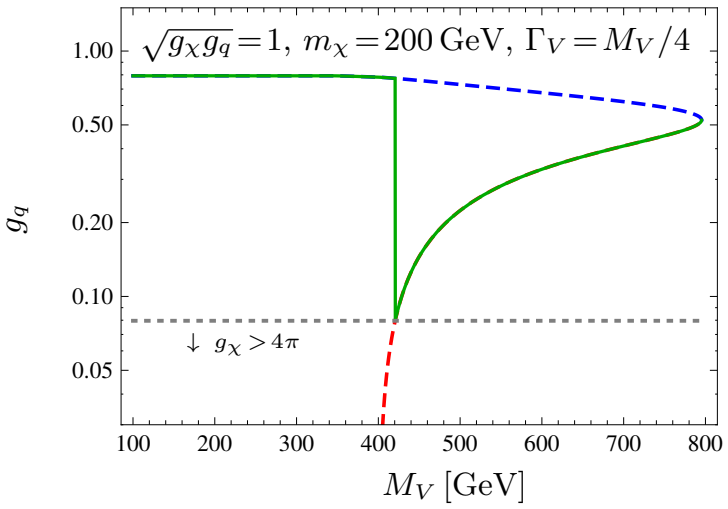
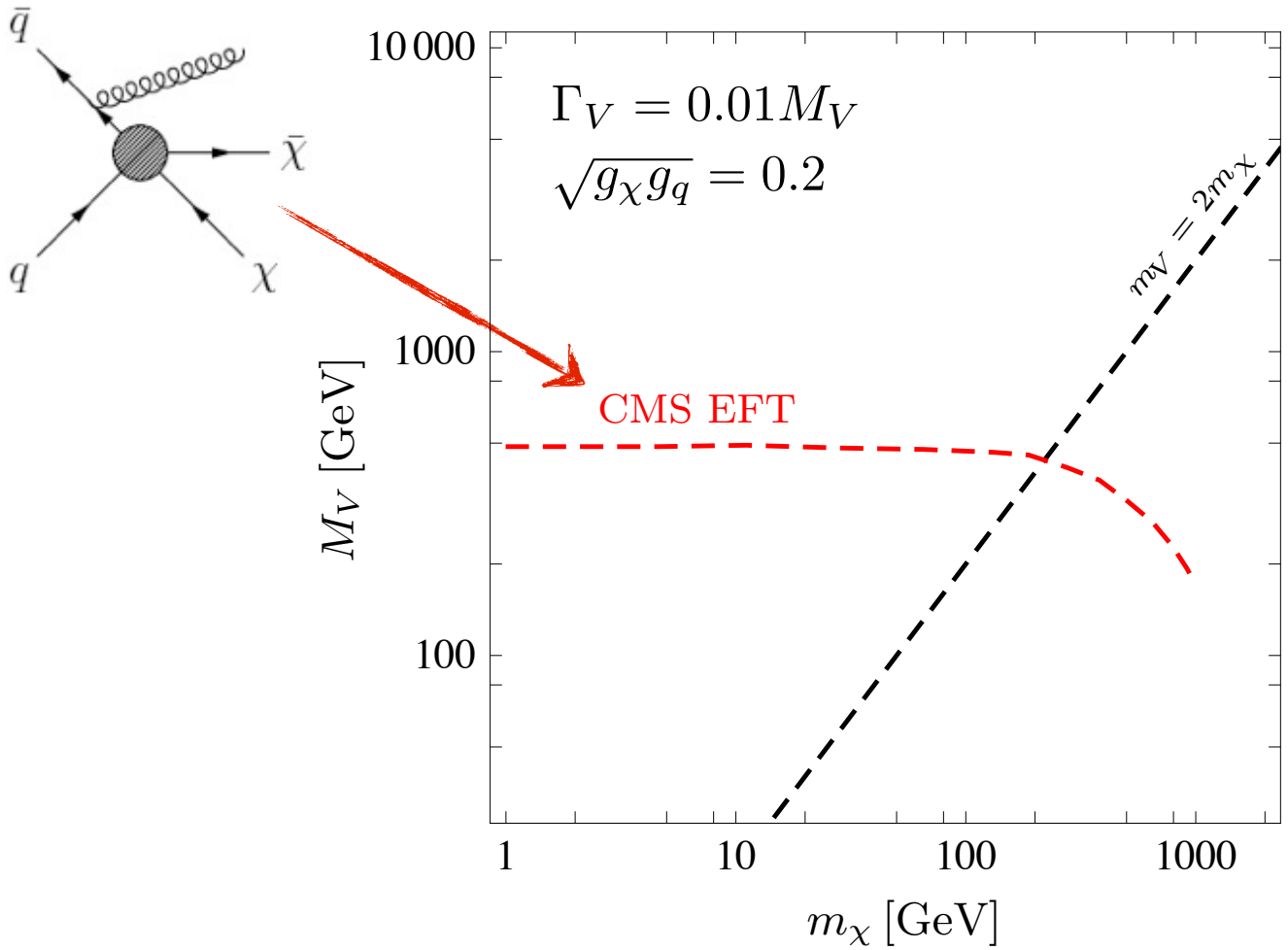




Results for 8 TeV LHC and IceCube

CMS monojet 8TeV [1408.3583]



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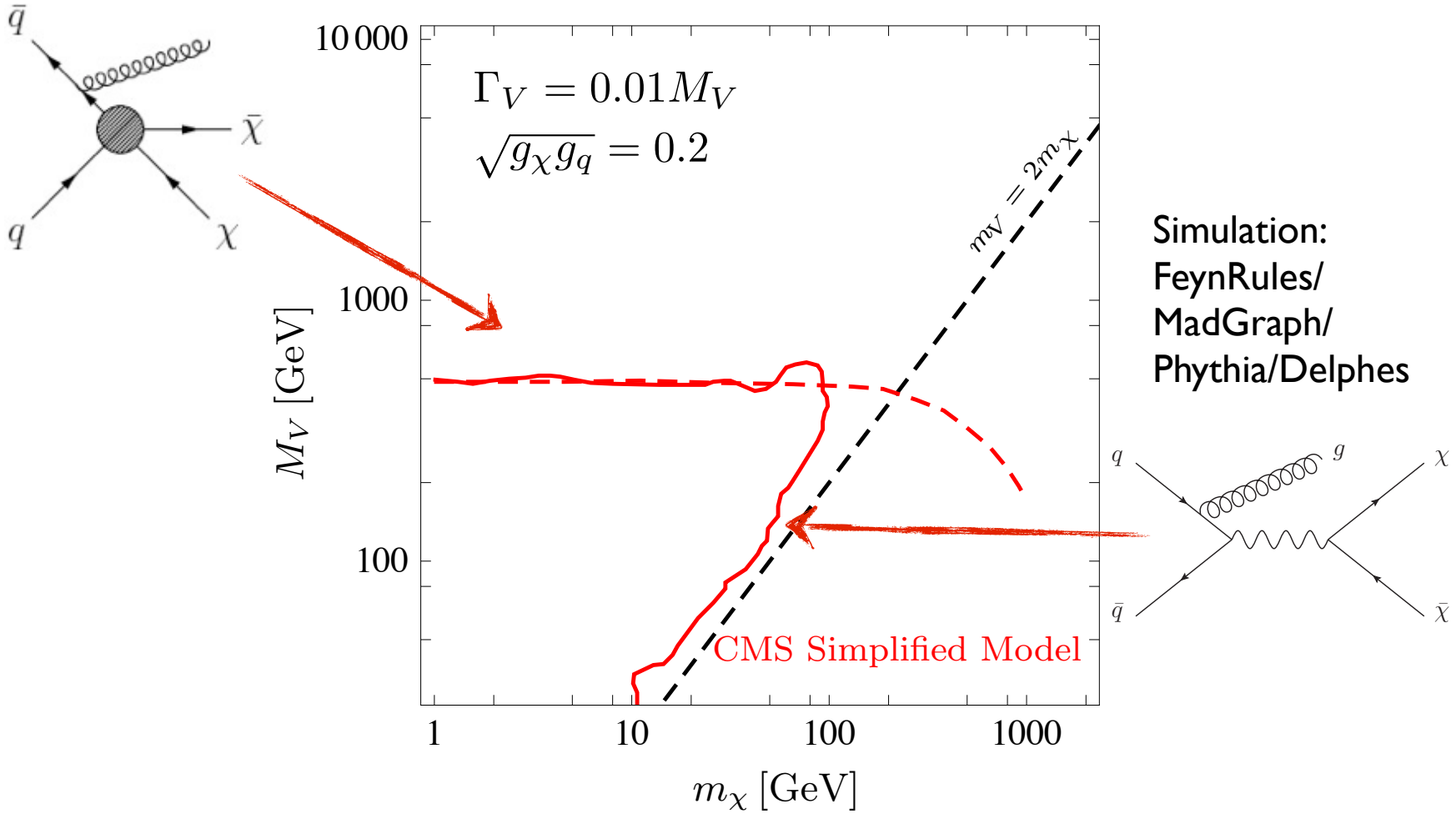

Simulation:
FeynRules/
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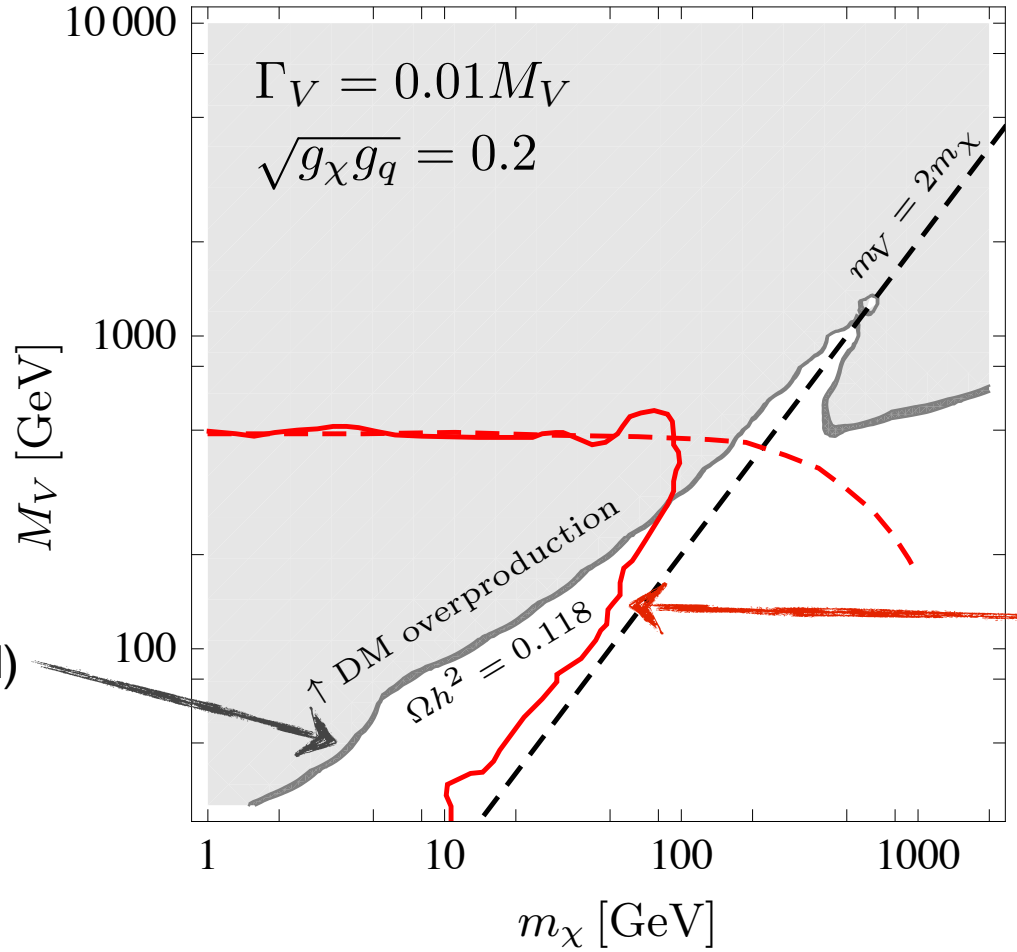
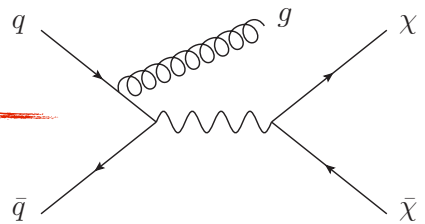


Relic density micrcOMEGAs (simplified model)

Simulation: FeynRules/ MadGraph/ Phythia/Delphes



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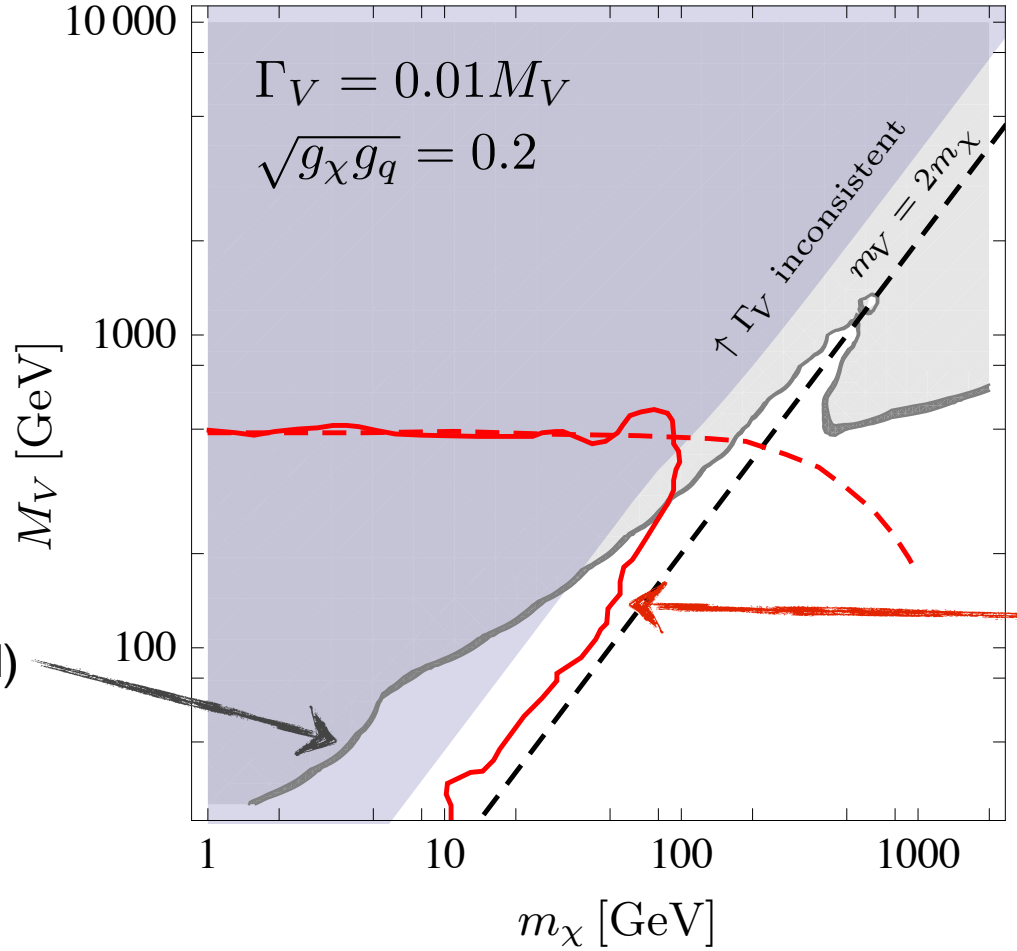

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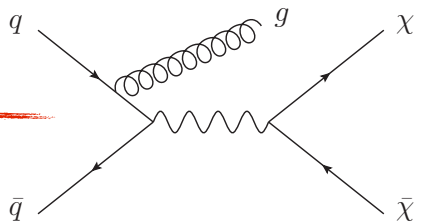

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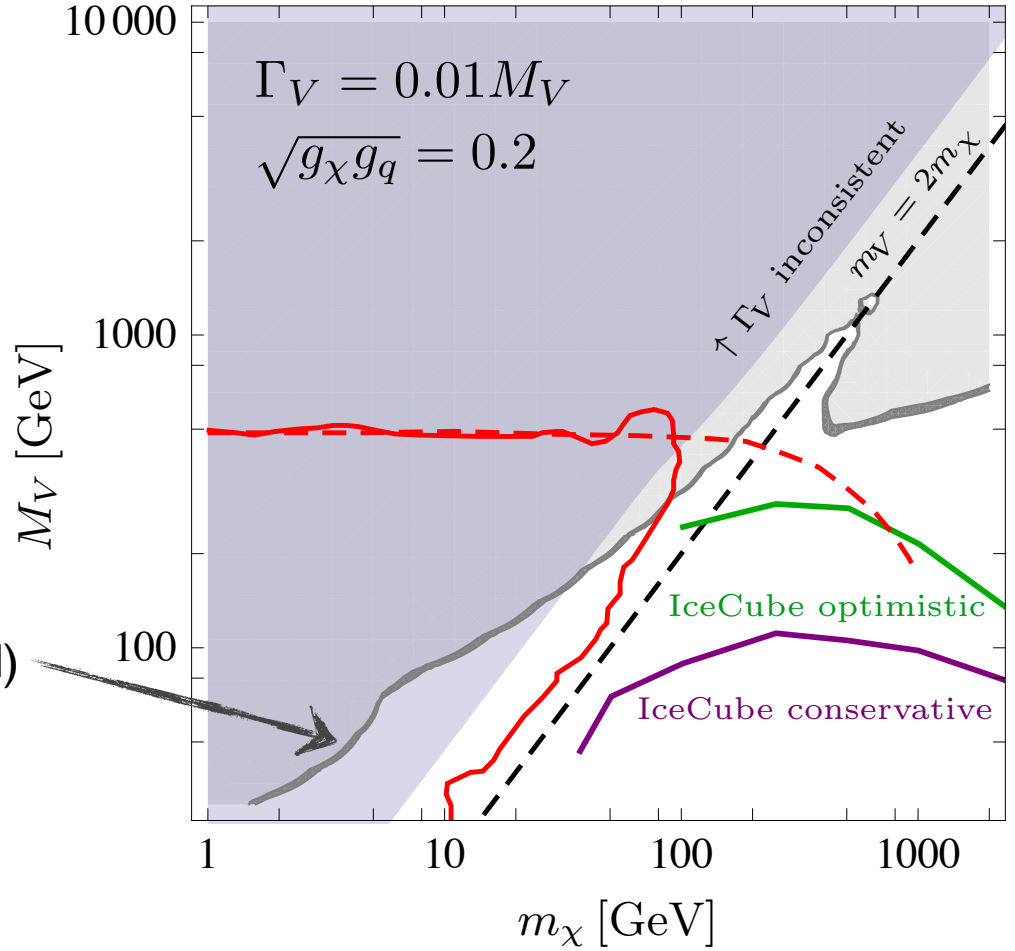

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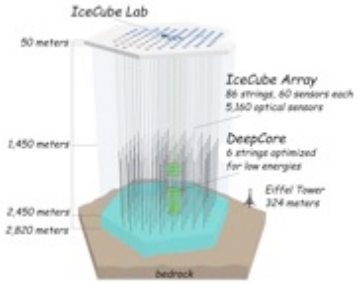

IceCube-79 limits [1411.5917]

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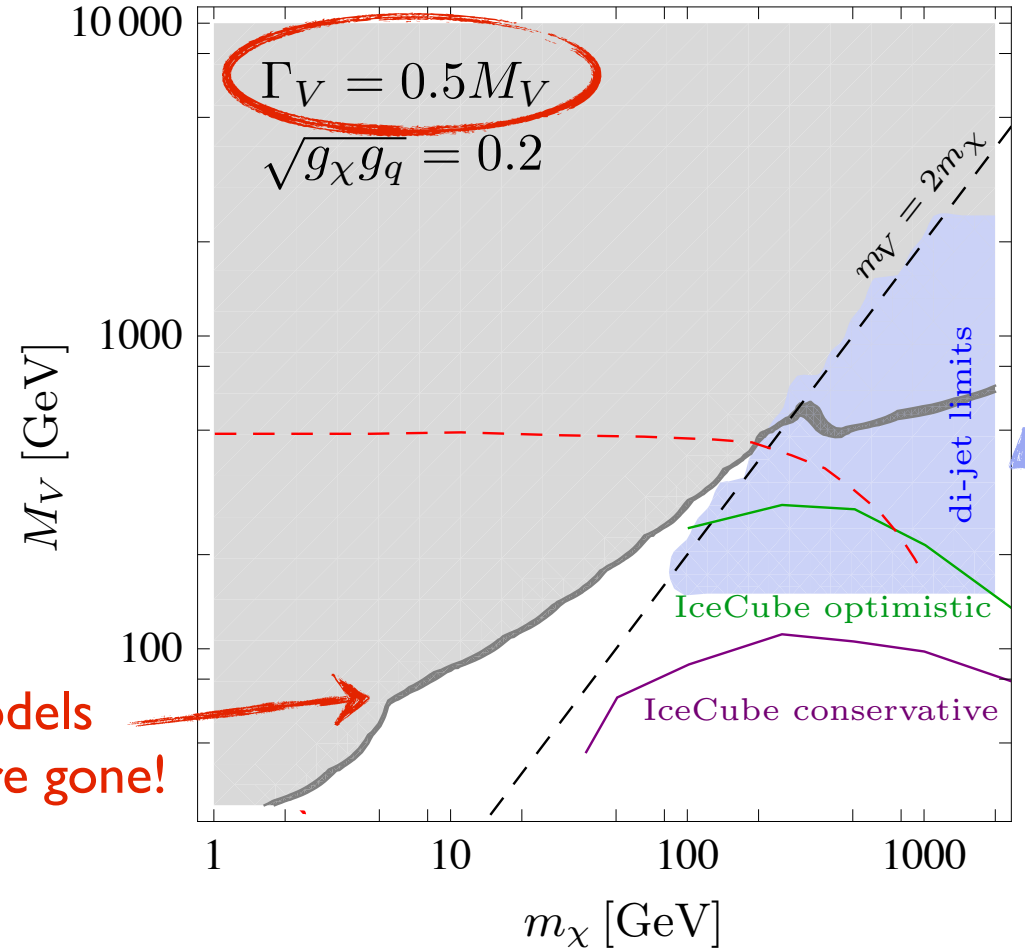
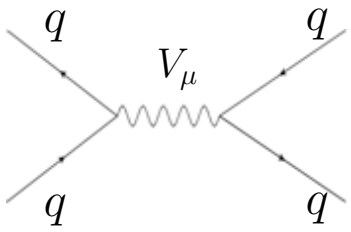


Simplified Models
LHC limits are gone!



LHC Dijet limits
[Chala, Kahlhoefer, McCullough, Nardini, Schmidt-Hoberg 1503.05916]

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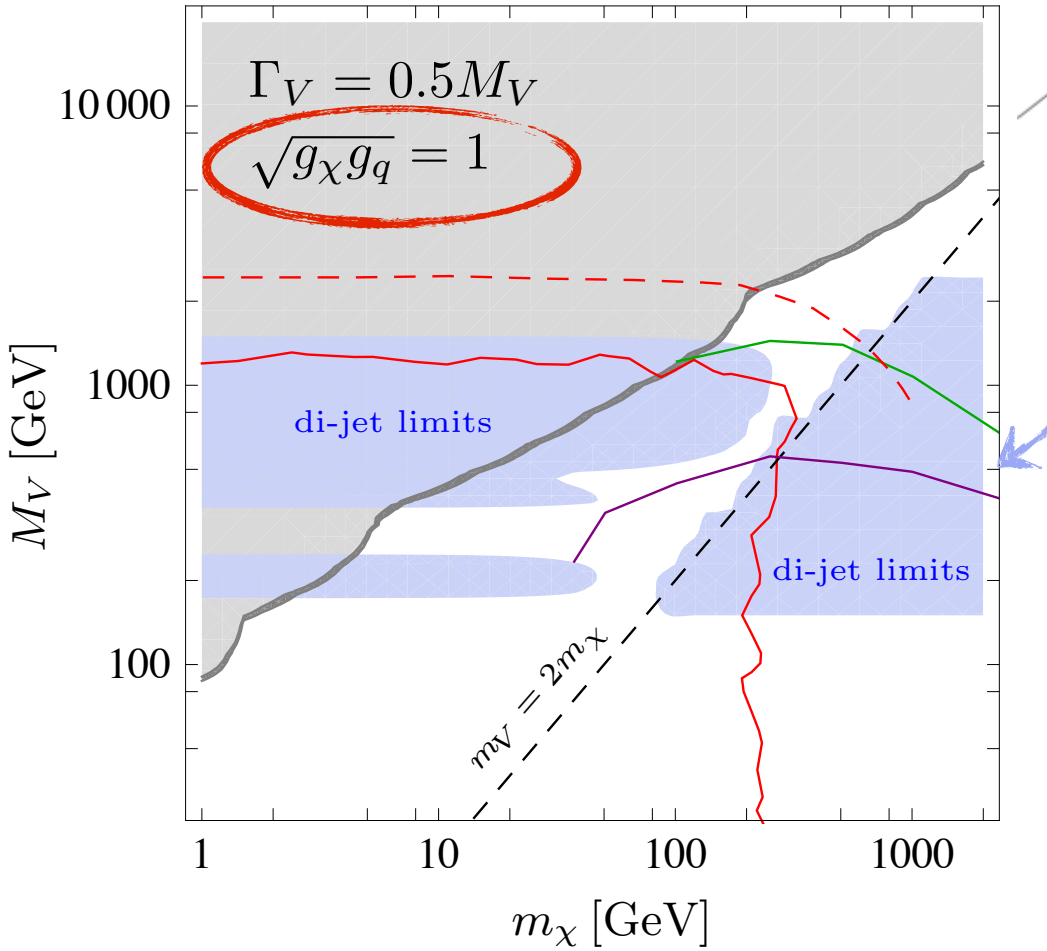

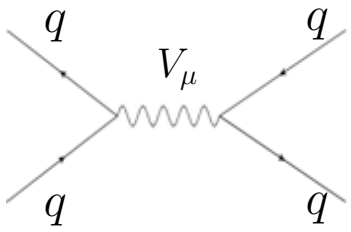

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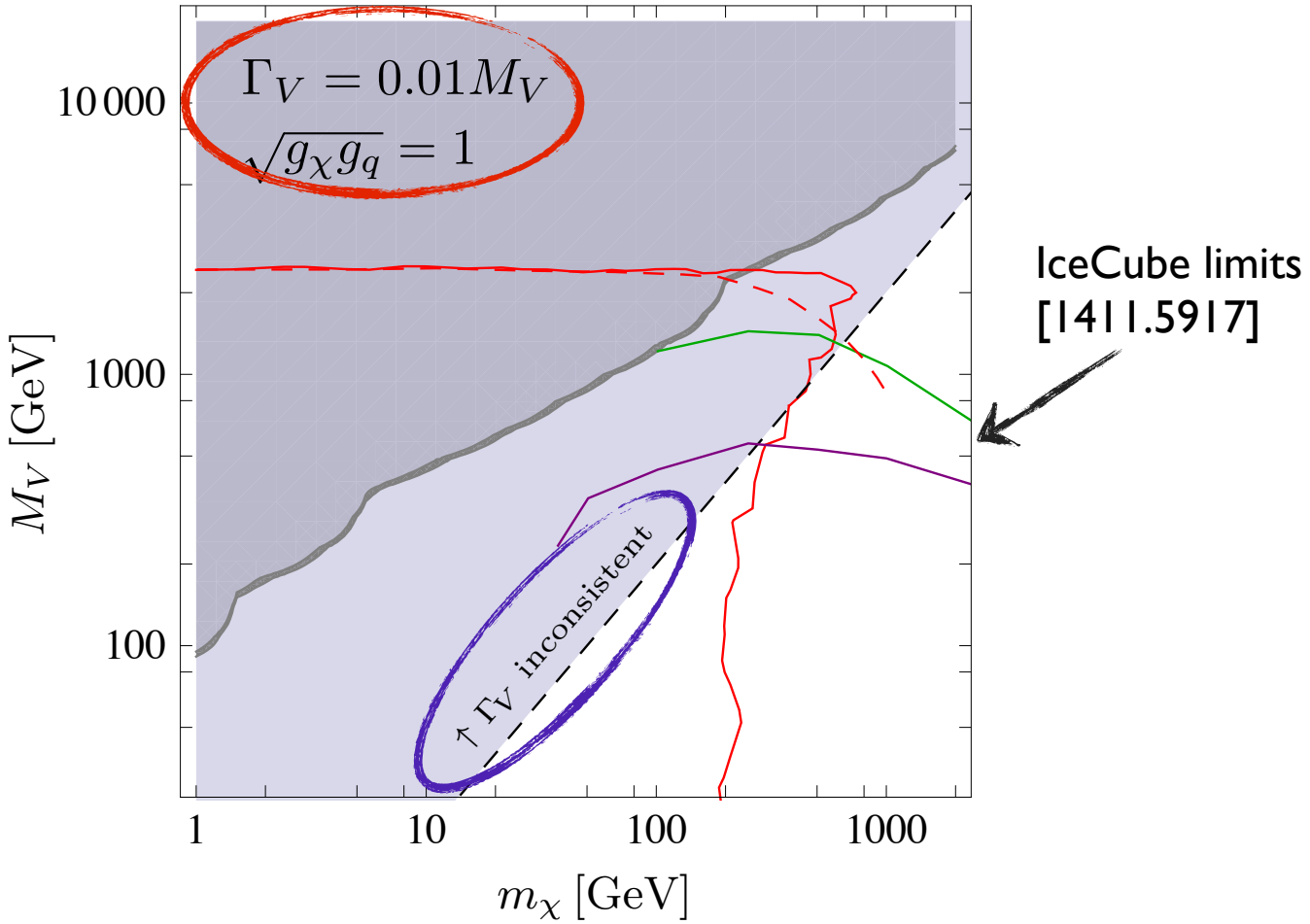

Summary

- Model: Majorana DM with axial-axial couplings to SM
- Almost no region for viable EFT (not valid or bad description)
- Simplified Models needed
- IceCube important for axial-axial couplings
- Strong limits for heavy DM