Signatures of Majorana dark matter with t-channel mediators

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based on
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Phys.Rev. D91 (2015) no.9, 095018 [arxiv:1501.03164]
Int.J.Mod.Phys. D24 (2015) no.07, 1530019 [arxiv:1503.01500]

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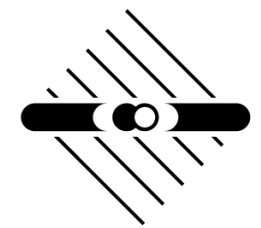


Simplified Model

- stay agnostic as to the fundamental interactions
- write down "simplified model" $\rightarrow$ use it as phenomenology generator

t-channel mediator

- Majorana fermion χ as dark matter
- χ singlet under SM gauge group
- interactions $\rightarrow$ scalar mediator η
- Yukawa interactions with the fermions (up-quarks or top-quarks)

$$\mathcal{L}_{int} = -f\bar{q}_R\chi\eta + \text{h.c.}$$

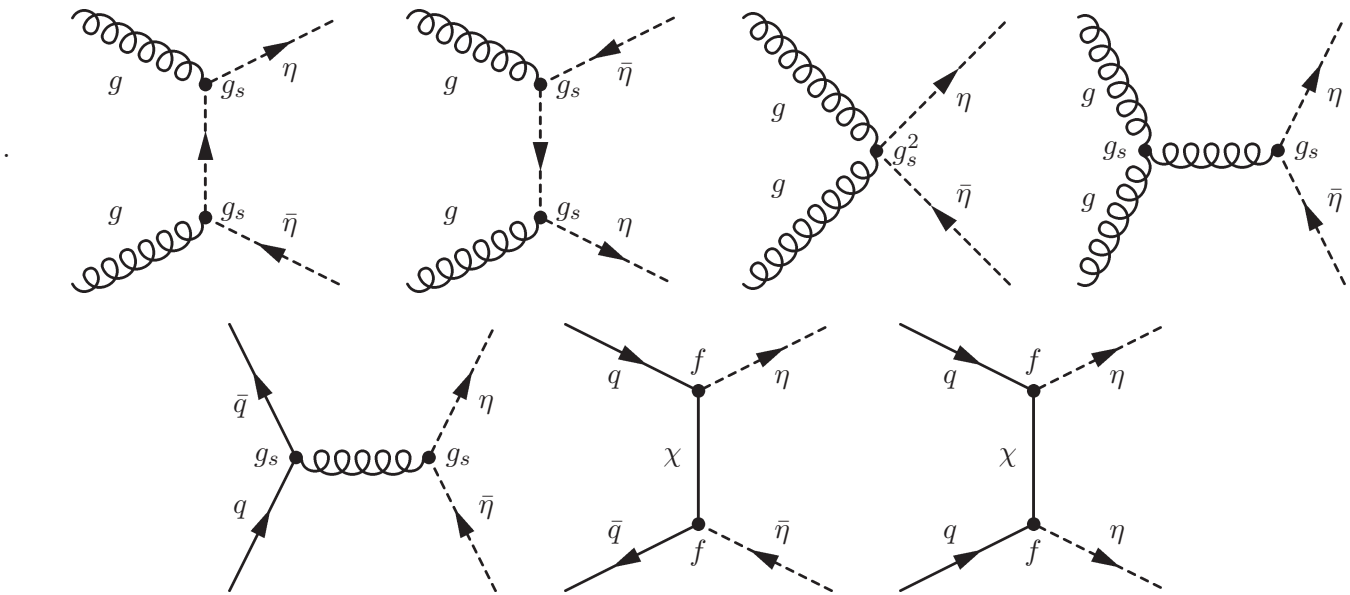
more general flavor structure possible $\rightarrow$ Monika's contribution

- self-contained/UV-complete model $\rightarrow$ explore connections with other observables

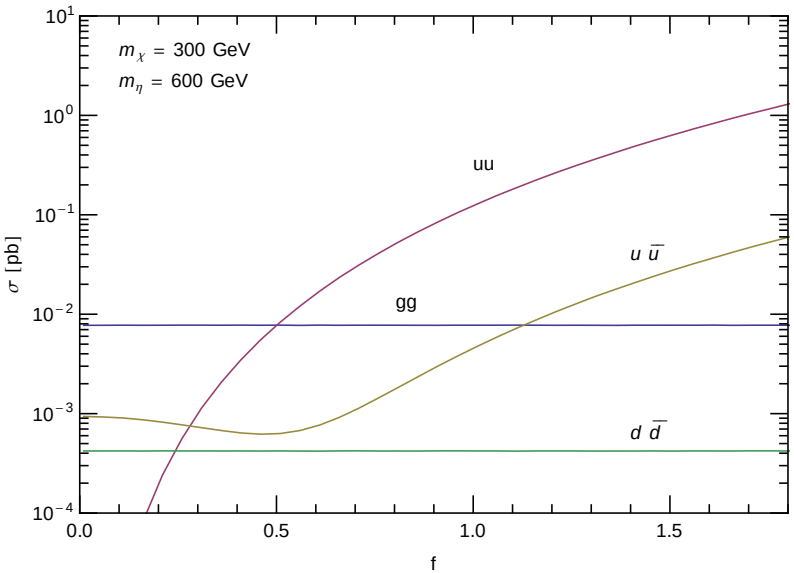
LHC pheno

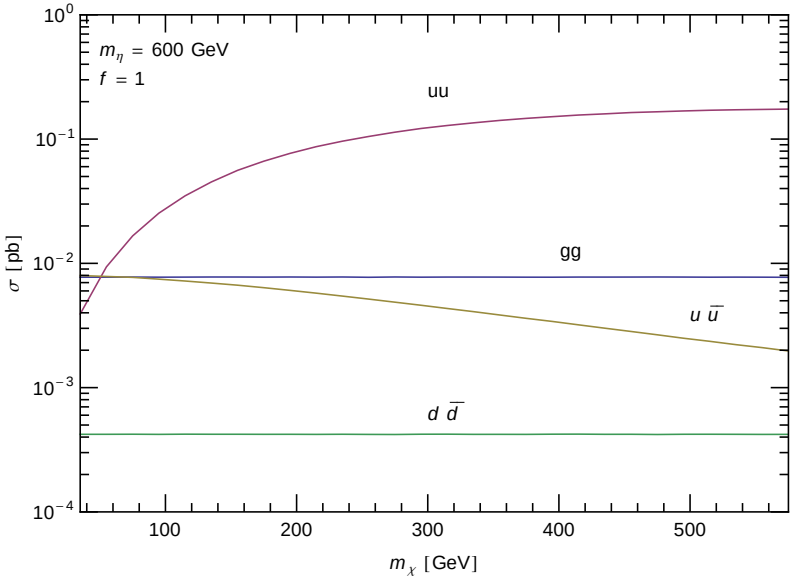
Testing the Dark Sector

- LHC is a mediator production machine



Production cross section at LHC





Note: figures for $\sqrt{s} = 8$TeV

- three production modes
  - QCD $\to \eta\bar{\eta}$ (up and top)
  - dark matter t-channel $u\bar{u} \to \eta\bar{\eta}$ (no top pdf)
  - dark matter t-channel $uu \to \eta\eta$ (specific to Majorana dark matter)
- t-channel enhanced for sizeable Yukawa
- $\eta\eta$ enhanced by u-quark pdf

Signatures

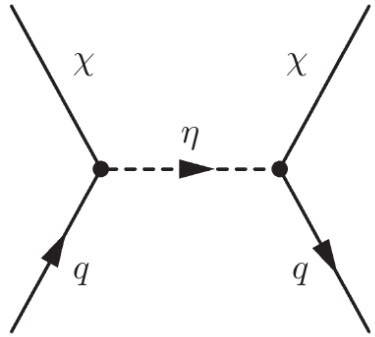
- multi-jet + MET
- monojet + MET (mainly relevant in mass degenerate regime)
- top/bottom + MET

many searches relevant for t-channel models

Note: main production mode depends on simplified model parameters $\rightarrow$ limits on simplified models with Dirac dark matter/simplified SUSY not directly translatable

Other observables

Scattering of DM off nucleons: light flavor



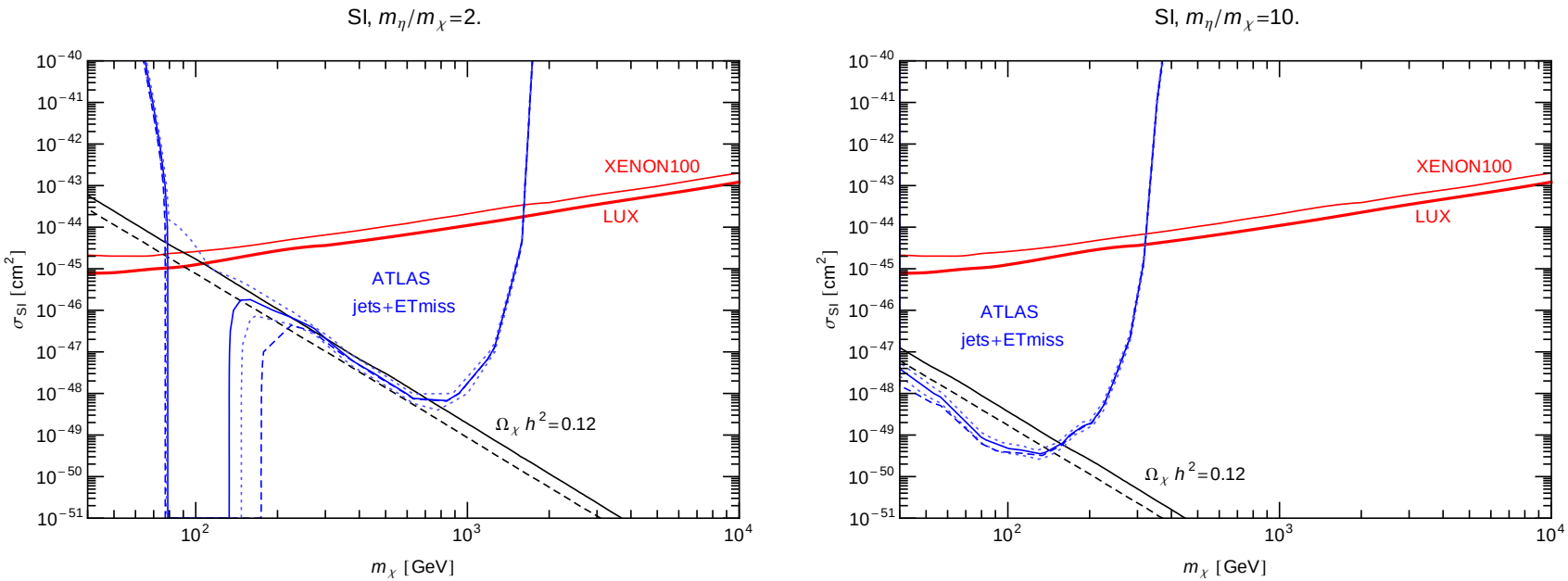
- tree-level interactions with light quarks
- contribution to SI scattering cancels at lowest order for Majorana DM with chiral interaction; expansion to higher order necessary

  Drees, Nojiri 93
- enhancement of interactions for small mass difference

  Drees, Nojiri 93, Hisano, Ishiwata, Nagata 2011

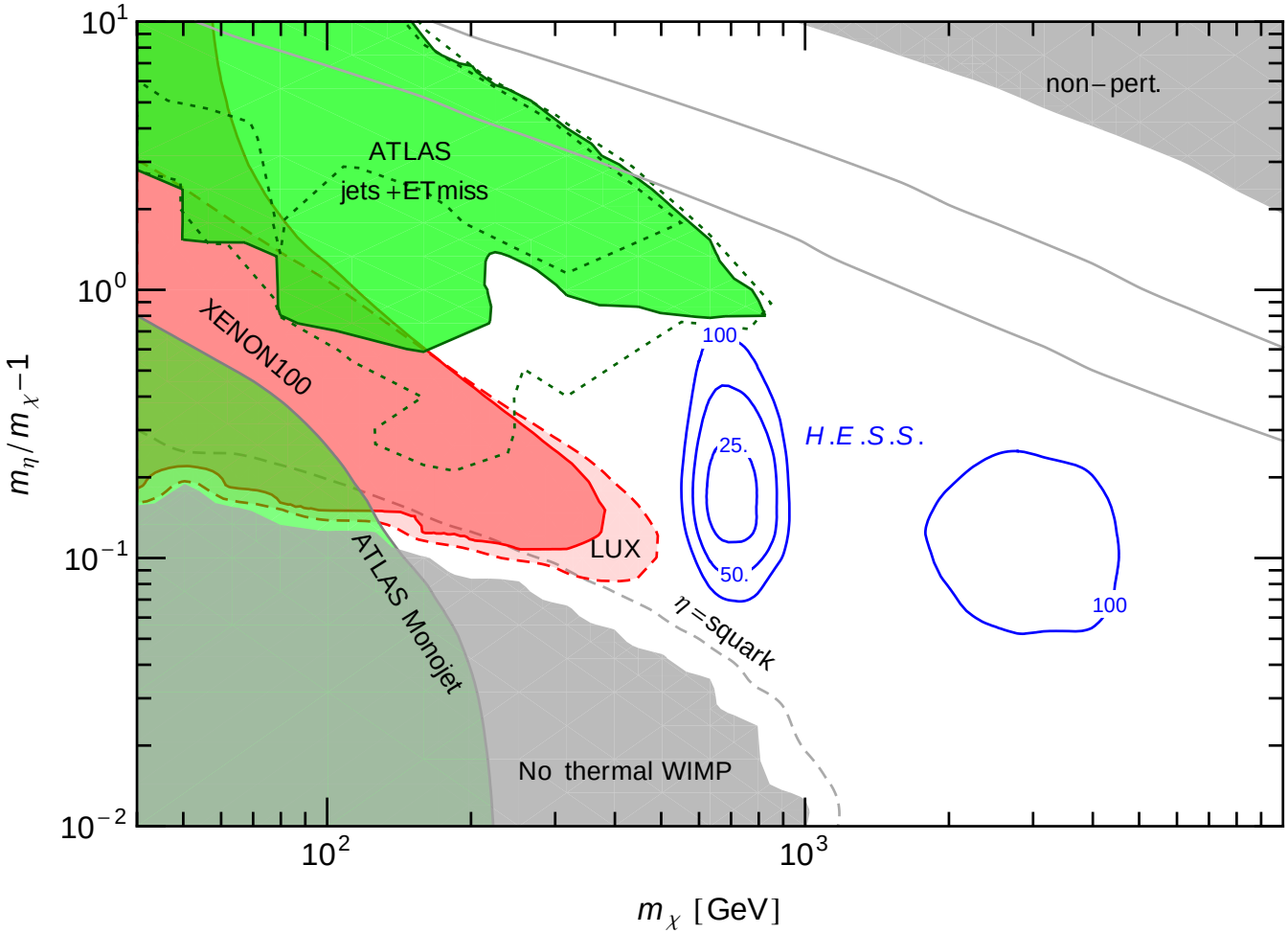
$$\sigma_{SD(SI)} \sim \left[\frac{1}{m_\eta^2 - (m_\chi + m_q)^2}\right]^{2(4)}$$

Direct Detection versus the LHC



- for $\Delta m = \mathcal{O}(m_\chi)$ limits on $\sigma_{SI} = 10^{-45} - 10^{-48}$
- Notice: for some mass range QCD production excluded $\Rightarrow$ no contribution to dark matter allowed

Full combination of observables: thermal Dark Matter



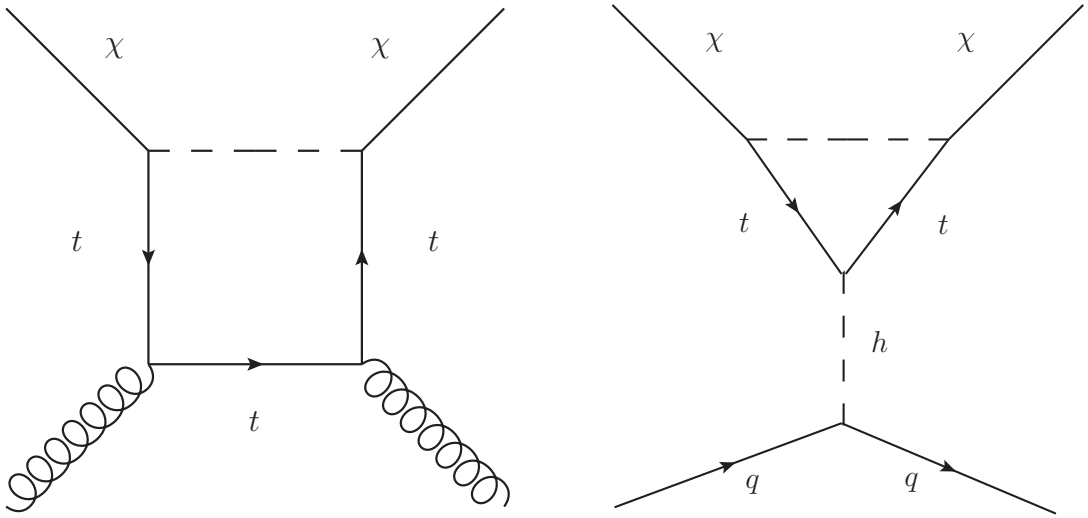
Side remark: "No thermal WIMP"-region allows for conversion-driven freeze-out with distinct collider pheno Garny, Heisig, Lülf, SV '17

Conclusions

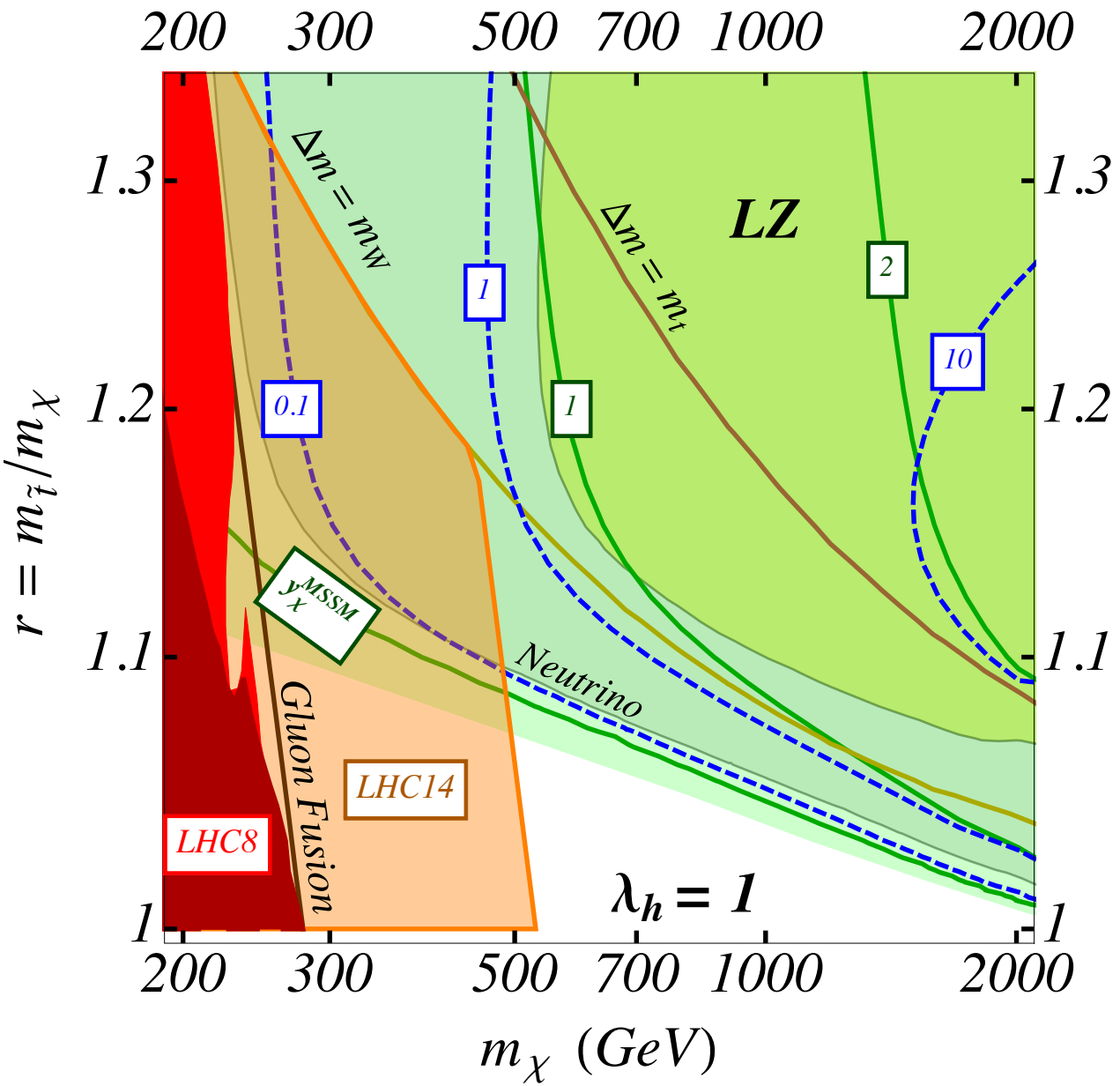
- rich collider phenomenology
- not just pheno-generator $\rightarrow$ complete models
- intriguing interplay between direct detection, LHC and relic density

Backup

Scattering of DM off nucleons: heavy flavor



- no top-quarks in the nucleus $\rightarrow$ no tree level coupling
- loop induced dark matter nucleus coupling
  - gluon box Drees, Nojiri '93
  - Higgs triangle Ibarra, Pierce, Shah, SV '15


200
300
500
700
1000
2000
1.3
1.2
1.1
1
$r = m_{\tilde{t}}/m_\chi$
$\Delta m = m_W$
$\Delta m = m_t$
LZ
1
2
10
0.1
1
y_χ^{MSSM}
Neutrino
Gluon Fusion
LHC14
LHC8
$\lambda_h = 1$
m_χ (GeV)

Conversion-driven freeze-out