LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Flavoured mediators and dark matter

Rute Pedro, on behalf of the DM flavour section

DM t-channel white paper meeting, 9th June 2023

Goal of the section and contributors

- **Explore models where dark matter carries flavour and comes in multiple generations**
  - Provide benchmark model description to section 2
  - Explore the phenomenology of the models and collider signatures
  - Present constraints from cosmology, direct detection, flavour physics and LHC searches
  - Prospects for the HL-LHC scenario

- **M. Blanke, G. Polesello, H. Acaroglu, M. Krämer, L. Rathmann, J.S. Heisig, ; R. Pedro, N. Castro, M. Moreno Llacer, M.J.Costa Mezquita, J.E. Garcia, B. Maier, A. Moreno Briceño, F. Benoit, B. Fuks, F. Parraud, R.C. Batalha Pedro, D. Tuckler**

Current section line-up

5.1.1 Dark Minimal Flavour Violation

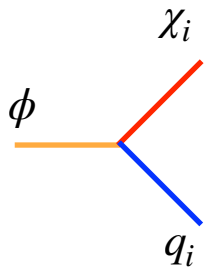
Flavoured dark matter basics

dark matter carries flavour and comes in multiple generations

- richer phenomenology with more parametric freedom
- reconcile WIMP hypothesis with non-observation of DM

New coupling to quarks:

$$\lambda^{ij}\bar{q}_i\chi_j\phi$$



q_i	SM quarks
χ_j	DM fermion, flavoured
ϕ	coloured scalar mediator
λ	flavour-violating coupling matrix

Dark Minimal Flavour Violation hypothesis

Agrawal, Blanke, Gemmler (2014)

- DM is a triplet under a new $U(3)_\chi$ global flavour symmetry
- general flavour violating coupling of DM with SM quarks
- coupling matrix λ is the only new source of FV in addition to SM Yukawa couplings

DMFV models

variety of simplified t-channel models, depending on spin assignments and SM fields coupled to dark sector

5.1.2 Phenomenology of DMFV models

Quark-flavoured DMFV models studied

Dirac fermion DM and scalar mediator:

- bottom-flavoured DM coupling to RH down-type quarks
  Agrawal, Blanke, Gemmler (2014)
- top- or charm-flavoured DM coupled to RH up-type quarks
  Blanke, Kast (2017); Jubb, Kirk, Lenz (2017)
- top/bottom-flavoured DM coupled to LH quark doublets Blanke, Das, Kast (2017)

Majorana fermion DM and scalar mediator:

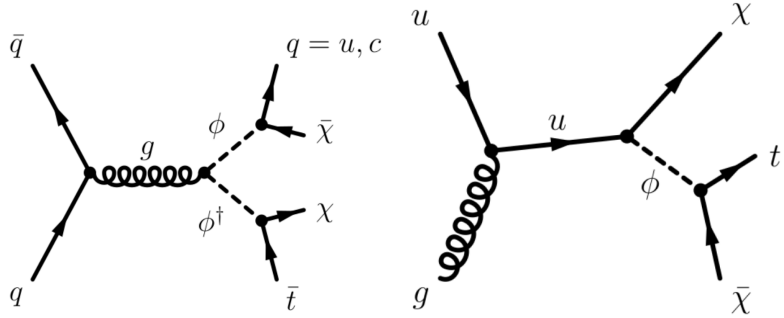
- top- or charm-flavoured DM coupled to RH up-type quarks Acaroglu, Blanke (2021)

Pheno highlights (model-dependent)

- liquid Xe experiments require suppressed DM coupling to first quark generation
- thermal freeze-out possible due to enlarged parameter space
  coannihilation and conversion-driven region currently under study
  Acaroglu, Blanke, Heisig, Krämer, Rathmann
- structure of λ strongly constrained by neutral meson mixings, but MFV not required
- LHC constraints mainly from mediator pair production ➢ SUSY squark searches

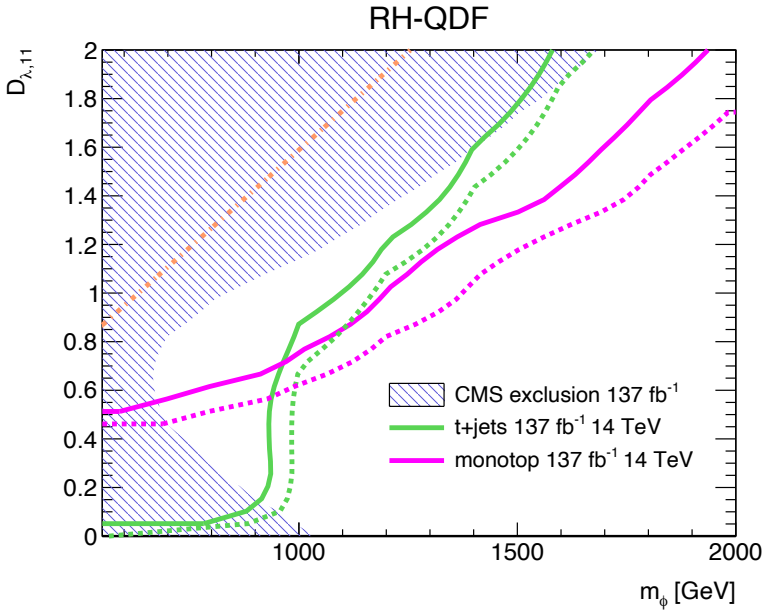
5.1.3 Single-top signatures

- coloured scalar mediators couples to all three SM and DM flavours, inducing flavour violating single-top sigatures



- developed dedicated search strategies for $tj + \not{E}_T$, $t + \not{E}_T$ and $tb + \not{E}_T$
- increased LHC reach

Blanke, Pani, Polesello, Rovelli (2020)



5.1.4 Flavoured Majorana dark matter

Acaroglu, Blanke (2021)
Acaroglu, Blanke, Heisig, Krämer, Rathmann

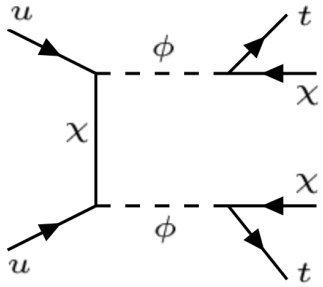
Majorana-specific phenomenology

Changing from Dirac to Majorana up-type flavoured DM has profound implications on all aspects of phenomenology!

- relic abundance: p-wave suppression for annihilation into massless final states
- direct detection: suppression of spin-independen WIMP-nucleon scattering
- flavour: suppressed contribution to $D^0 - \bar{D}^0$ mixing imply possible large CP-violating effects in charm decays (c.f. ΔA_{CP})

Majorana-specific LHC signatures

Majorana nature of DM induces same-sign mediator pair-production



- enhanced cross-sections for standard squark searches
- same-sign $tt + \not{E}_T$ signature
- single-top final states with charge asymmetry

5.1.5 (or 6.x?) Lepton-flavoured dark matter

DMFV models coupled to leptons

coupling to RH charged leptons studied

- Dirac DM, scalar mediator

  Chen, Huang, Takhistov (2015)

- complex scalar DM, fermionic mediator

  Acaroglu, Agrawal, Blanke (2022a)

Pheno in a nutshell

- constraints from flavour, direct & indirect detection, relic abundance push mass scale into multi-100 GeV regime
- beyond current collider reach
- too heavy to solve $(g-2)_\mu$ anomaly

Model extensions to accomodate $(g-2)_\mu$

- include second mediator & couple DM also to LH leptons

  increased NP contributions to $(g-2)_\mu$ thanks to chirality-flip

  Acaroglu, Agrawal, Blanke (2022b)

- *in progress:* include Higgs-portal coupling in scalar DM scenario

  additional contribution to DM freeze-out makes EW-scale masses viable

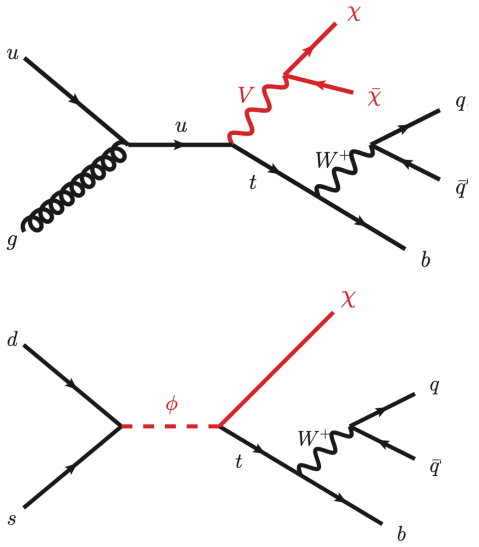
  - large $(g-2)_\mu$ without chirality flip
  - more easily accessible at colliders

  Acaroglu, Blanke, Tabet

5.2 Boosted top probes for top-philic DM

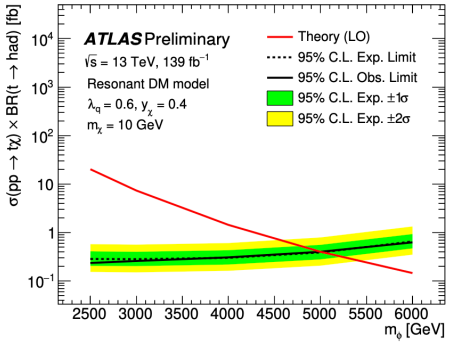
N. Castro, M. Moreno Llacer, M.J.Costa Mezquita, J.E. Garcia , R. Pedro, B. Maier, A. Moreno Briceño

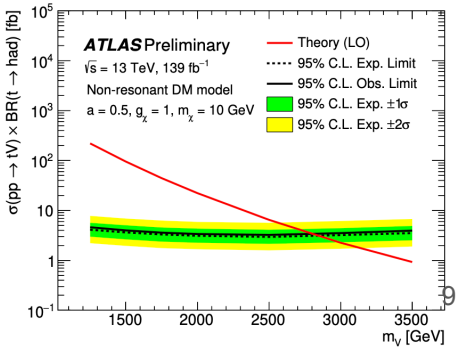
- **ATLAS search in $t + \not{E}_T$ final state, with boosted hadronic top**
  [ATLAS-CONF-2022-036]
  - Probes Simplified Models of Dark Matter 1106.6199 [B. Fuks et al.]
  - Non-resonant FCNC production of vector V mediator
  - Resonant production of coloured scalar ϕ mediator, charged 2/3e



- **Current upper limits on the production cross-section**
  - m_ϕ > 5 TeV, m_V > 2.8 TeV
  - Assuming specific couplings and m_χ=10 GeV

- **HL-LHC sensitivity study drawn from this analysis**
  - Mediator mass exclusion limits
  - Expected cross-section limits in 2D planes of the parameter space (coupling and masses)





F. Benoit, B. Fuks, F. Parraud, D. Tuckler

5.3 Charm-philic DM

- **Review/draw constrains on charm flavoured DM**
  - LHC searches, flavour physics, …
  - Preliminary results with LO limits for a charm-philic model using 4 searches of jet+MET
  - ATLAS mono-jet analysis newly implemented in MadAnalysis 5 (ANA-EXOT-2018-06-PAPER)
  - NLO plots on the wish-list

- **Phenomenological investigations of charm-tagging**