



# DMsimp\_t Universal UFO

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**In collaboration with:**

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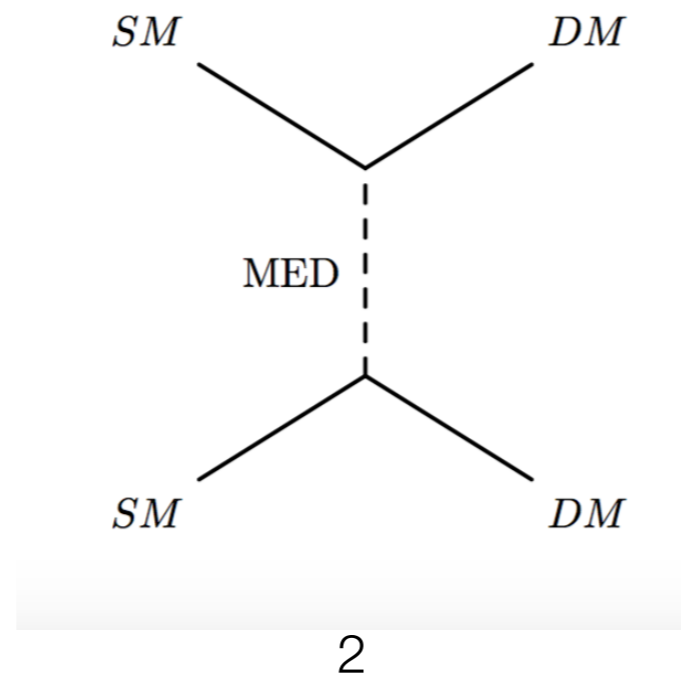


## General implementation of the t-channel Dark Matter models in FeynRules.



Simplified model extending the SM with 2 extra particles: DM and mediator.

Implement a model that lets the user to select any possible spin of the new particles.



$$\mathcal{L} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{kin}} + \left[ \lambda_Q [(\tilde{\chi} + \bar{\chi})Q_L] \varphi_Q^\dagger + \lambda_u [(\tilde{\chi} + \bar{\chi})u_R] \varphi_u^\dagger + \lambda_d [(\tilde{\chi} + \bar{\chi})d_R] \varphi_d^\dagger + \text{h.c.} \right] \\ + \left[ \hat{\lambda}_Q \left( [\bar{\psi}_Q Q_L] S + [\bar{\psi}_Q V Q_L] \right) + \hat{\lambda}_u \left( [\bar{\psi}_u u_R] S + [\bar{\psi}_u V u_R] \right) + \hat{\lambda}_d \left( [\bar{\psi}_d d_R] S + [\bar{\psi}_d V d_R] \right) + \text{h.c.} \right]$$

Field	Spin	Repr.	Self-conj.	FEYNRULES/UFO name	PDG code
$S$	0	$(\mathbf{1}, \mathbf{1}, 0)$	yes	Xs	5000511
$\tilde{\chi}$	1/2	$(\mathbf{1}, \mathbf{1}, 0)$	yes	Xm	5000021
$\chi$	1/2	$(\mathbf{1}, \mathbf{1}, 0)$	no	Xd	5000022
$V_\mu$	1	$(\mathbf{1}, \mathbf{1}, 0)$	yes	Xv	5001511
$\varphi_Q = \begin{pmatrix} \varphi_Q^{(u)} \\ \varphi_Q^{(d)} \end{pmatrix}$	0	$(\mathbf{3}, \mathbf{2}, \frac{1}{6})$	no	YS3Q = $\begin{pmatrix} \text{YS3Qu} \\ \text{YS3Qd} \end{pmatrix}$	$\varphi_Q^{(u)}$ : 1000002 1000004 1000006 $\varphi_Q^{(d)}$ : 1000001 1000003 1000005
$\varphi_u$	0	$(\mathbf{3}, \mathbf{1}, \frac{2}{3})$	no	YS3u	2000002 2000004 2000006
$\varphi_d$	0	$(\mathbf{3}, \mathbf{1}, -\frac{1}{3})$	no	YS3d	2000001 2000003 2000005
$\psi_Q = \begin{pmatrix} \psi_Q^{(u)} \\ \psi_Q^{(d)} \end{pmatrix}$	1/2	$(\mathbf{3}, \mathbf{2}, \frac{1}{6})$	no	YF3Q = $\begin{pmatrix} \text{YF3Qu} \\ \text{YF3Qd} \end{pmatrix}$	$\psi_Q^{(u)}$ : 3000002 3000004 3000006 $\psi_Q^{(d)}$ : 3000001 3000003 3000005
$\psi_u$	1/2	$(\mathbf{3}, \mathbf{1}, \frac{2}{3})$	no	YF3u	4000002 4000004 4000006
$\psi_d$	1/2	$(\mathbf{3}, \mathbf{1}, -\frac{1}{3})$	no	YF3d	4000001 4000003 4000005

- **Very generic model**
- **It comes with several restriction files rendering it much simpler**
- **Available restrictions: up\_right only (single quark), third generation only, flavour universal, ...**

Restriction name	Mediators	Dark matter	Free parameters
S3M_uni / S3D_uni	$\varphi \equiv \varphi_{Q_f} + \varphi_{u_f} + \varphi_{d_f}$	$\tilde{\chi} / \chi$	$M_\varphi, M_\chi, \lambda_\varphi$
S3M_3rd / S3D_3rd	$\varphi \equiv \varphi_{Q_3} + \varphi_{u_3} + \varphi_{d_3}$	$\tilde{\chi} / \chi$	$M_\varphi, M_\chi, \lambda_\varphi$
S3M_uR / S3D_uR	$\varphi_{u_3}$	$\tilde{\chi} / \chi$	$M_\varphi, M_\chi, \lambda_\varphi$
F3S_uni	$\psi \equiv \psi_{Q_f} + \psi_{u_f} + \psi_{d_f}$	$S$	$M_S, M_\psi, \hat{\lambda}_\psi$
F3S_3rd	$\psi \equiv \psi_{Q_3} + \psi_{u_3} + \psi_{d_3}$	$S$	$M_S, M_\psi, \hat{\lambda}_\psi$
F3S_uR	$\psi_{u_1}$	$S$	$M_S, M_\psi, \hat{\lambda}_\psi$
F3V_uni	$\psi \equiv \psi_{Q_f} + \psi_{u_f} + \psi_{d_f}$	$V_\mu$	$M_V, M_\psi, \hat{\lambda}_\psi$
F3V_3rd	$\psi \equiv \psi_{Q_3} + \psi_{u_3} + \psi_{d_3}$	$V_\mu$	$M_V, M_\psi, \hat{\lambda}_\psi$
F3V_uR	$\psi_{u_1}$	$V_\mu$	$M_V, M_\psi, \hat{\lambda}_\psi$

### MadGraph

- LO files can be used as usual
- NLO version is currently being tested



## DM pheno with MadDM:

- Relic density
- Direct detection
- Indirect detection

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**DM pheno with MadDM:**

- Relic density
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- Indirect detection

**Caveats**

- Relic density and direct detection only at tree-level (NLO and loop-induced processes can be relevant, should be added by hand)
- Indirect detection: loop induced processes and NLO corrections can be automatically included

$$\text{DM DM} \rightarrow q\bar{q}\gamma$$

$$\text{DM DM} \rightarrow \gamma\gamma$$

**MadGraph**

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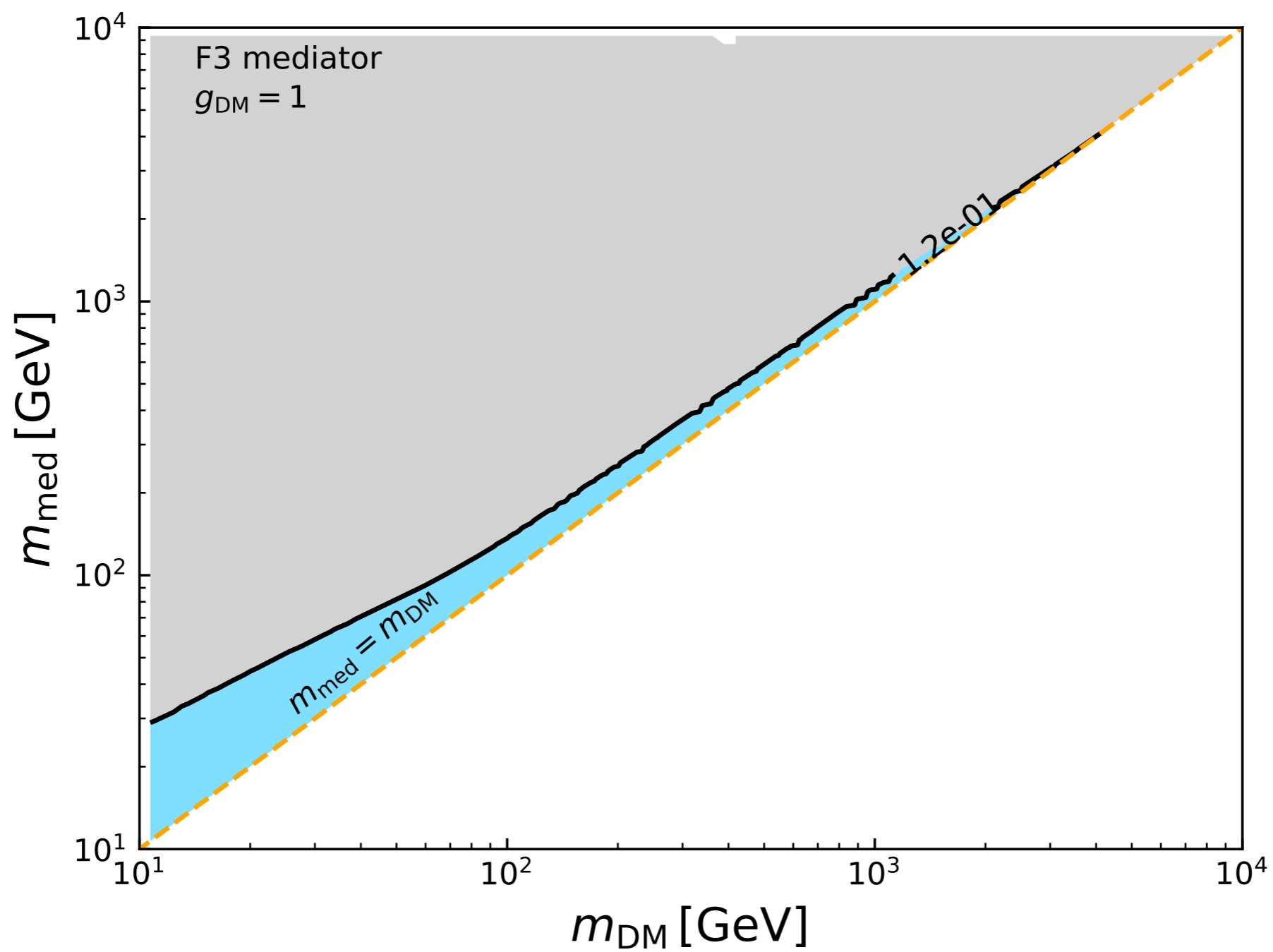


```
import model DMSimp_t-F3S_uR
define darkmatter xs
define coannihilator yf3u1
generate relic_density
output F3S_uR
```

```
launch F3S_0
set lamF3u1x1 1.0
set MYF3u1 scan1:[10**(1 + 0.03*y) for x in range(0,101) for y in range(0,101) if x <= y]
set mxs scan1:[10**(1 + 0.03*x) for x in range(0,101) for y in range(0,101) if x <= y]
```





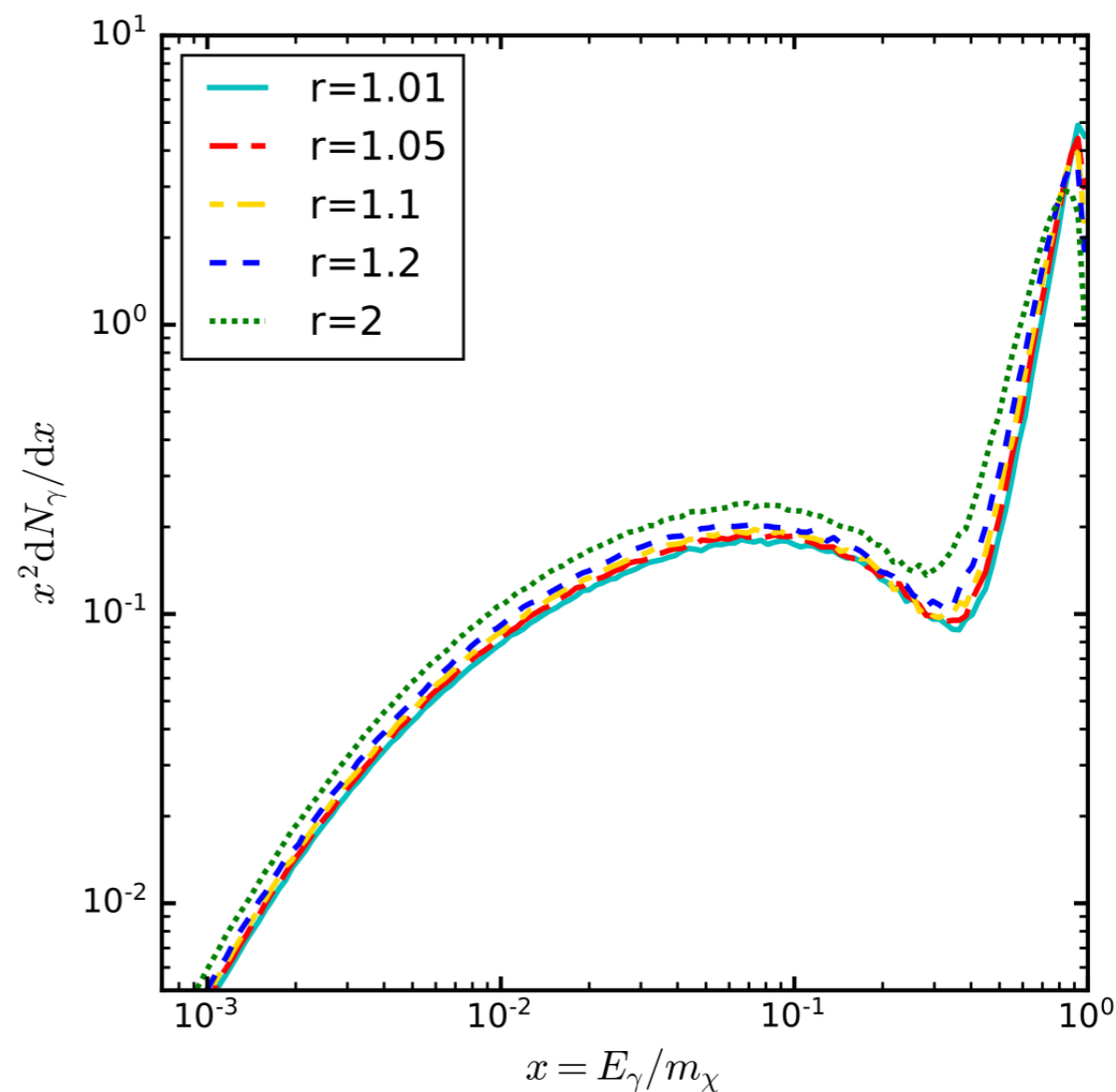


## Example on how to generate a three-body process for indirect detection

```

import model DMSimp_t-F3S_uR
define darkmatter xs
define coannihilator yf3u1
generate indirect detection u u~ a
output test_f3s_uua
launch test_f3s_uua
set sigmav_method madevent
set indirect_flux_source pythia8
set vave_indirect 1e-3
set nevents 100000
set MXs 100
set MYF3u1 scan:[101,105,110,120,200]
set lamF3u1x1 1.0
set save_output all

```



# Thanks



# Back up



## Flavor structure of the couplings

Coupling	Flavour structure	FEYNRULES (UFO) name	Les Houches block
$(\lambda_Q)_{ij}$	$\lambda_Q^{(i)} \delta_{ij}$	1amS3Q	DMS3Q
$(\lambda_u)_{ij}$	$\lambda_u^{(i)} \delta_{ij}$	1amS3u	DMS3U
$(\lambda_d)_{ij}$	$\lambda_d^{(i)} \delta_{ij}$	1amSdD	DMS3D
$(\hat{\lambda}_Q)_{ij}$	$\hat{\lambda}_Q^{(i)} \delta_{ij}$	1amF3Q	DMF3Q
$(\hat{\lambda}_u)_{ij}$	$\hat{\lambda}_u^{(i)} \delta_{ij}$	1amF3u	DMF3U
$(\hat{\lambda}_d)_{ij}$	$\hat{\lambda}_d^{(i)} \delta_{ij}$	1amF3d	DMF3D