Documentation on the LQDM FeynRules implementation

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This note contains information about the LQDM model implementation in FeynRules, a model aiming to jointly explain flavour anomalies and dark matter. All FeynRules model files are available from https://phystev.cnrs.fr/wiki/2019:groups:bsm:rdm, together with an illustrative Mathematica notebooks and the generated CalcHep and UFO models.

We consider a simplified model in which we supplement the Standard Model by one scalar leptoquark field S_1 and two extra fermionic fields, a Majorana fermion χ_0 and a Dirac fermion χ_1. The S_1 and χ_1 fields are electrically-charged coloured weak singlets lying in the $(\mathbf{3},\mathbf{1})_{-1/3}$ representation of the Standard Model gauge group. In contrast, χ_0 is a dark matter candidate and therefore a non-coloured electroweak singlet. In our FeynRules implementation, we consider all potential interactions of the new sector with the Standard Model sector, the corresponding Lagrangian being written as

$$\mathcal{L} = \mathcal{L}_{\rm SM} + \mathcal{L}_{\rm kin} + \bigg[\lambda_{\mathbf{R}}\ \bar u^c_R\ \ell_R\ S_1^\dagger + \lambda_{\mathbf{L}}\ \bar Q^c_L\!\cdot\! L_L\ S_1^\dagger + y_\chi \bar\chi_1\chi_0 S_1 + \text{h.c.}\bigg]\ .$$

In this expression, all flavour indices are understood for simplicity and the dot stands for the $SU(2)$-invariant product of two fields lying in its fundamental representation. In addition, $\mathcal{L}_{\rm SM}$ is the Standard Model Lagrangian and $\mathcal{L}_{\rm kin}$ contains gauge-invariant kinetic and mass terms for all new fields, the χ_1 state being assumed vector-like. The Q_L and L_L spinors stand for the $SU(2)_L$ doublets of left-handed quarks and leptons respectively, whilst u_R and ℓ_R stand for the $SU(2)_L$ singlets of right-handed down-type quarks and charged leptons, respectively. As can be derived from the omitted flavour structure, the $\lambda_{\mathbf{L}}$ and $\lambda_{\mathbf{R}}$ couplings are 3×3 matrices in the flavour space, that are considered real in the following. Moreover, in our conventions, the first index i of any λ_{ij} element refers to the quark generation whilst the second one j refers to the lepton generation.

The field content of the new physics sector of our simplified model is presented in table I, together with the corresponding representation under the gauge and Poincaré groups, the potential Majorana nature of the different particles, the adopted symbol in the FeynRules implementation and the PDG identifier that has been chosen for each particle. The new physics coupling parameters are collected in table II, in which we additionally include the name used in the FeynRules model and the Les Houches blocks in which the numerical values of the different parameters can be changed by the user when running tools like MG5_aMC or MicrOMEGAs.

Field	Spin	Repr.	Self-conj.	FeynRules name	PDG code
S_1	0	$(\mathbf{3},\mathbf{1})_{-1/3}$	no	`LQ`	42
χ_0	1/2	$(\mathbf{1},\mathbf{1})_0$	yes	`chi0`	5000521
χ_1	1/2	$(\mathbf{3},\mathbf{1})_{-1/3}$	no	`chi1`	5000522

TABLE I. *New particles supplementing the Standard Model, given together with the representations under $SU(3)_c\times SU(2)_L\times U(1)_Y$. We additionally indicate whether the particles are Majorana particles, their name in the* FeynRules *implementation and the associated Particle Data Group (PDG) identifier.*

Coupling	FeynRules name	Les Houches block
$(\lambda_L)_{ij}$	`lamL`	`LQLAML`
$(\lambda_R)_{ij}$	`lamR`	`LQLAMR`
y_χ	`yDM`	`DMINPUTS`

TABLE II. *Couplings of the new particles, given together with the associated* FeynRules *symbol and the Les Houches block of the parameter card.*

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