

MadDM 3.0 EW

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Abstract

This document summarises the status of the studies of the discrepancies found in the energy spectra provided in the PPPC4DMID tables (labelled **PPPC4DMIDew** in MadDM v.3.0) and the spectra produced with MadDM 3.0.

1 Introduction

All the information, including the model used and the input cards (`run_card.dat`, `param_card.dat`) can be found at:

<https://github.com/fambrogi/MadDM>

2 PPPC Electroweak Corrections

In this section the energy spectra for the Cosmic Rays $CRs = e^+, \nu_e, \gamma$ extracted from the PPPC4DMID and PPPC4DMID_ew Tables are compared, to get an idea of the effect of the EW correction (according the PPPC4DMIDcollaboration).

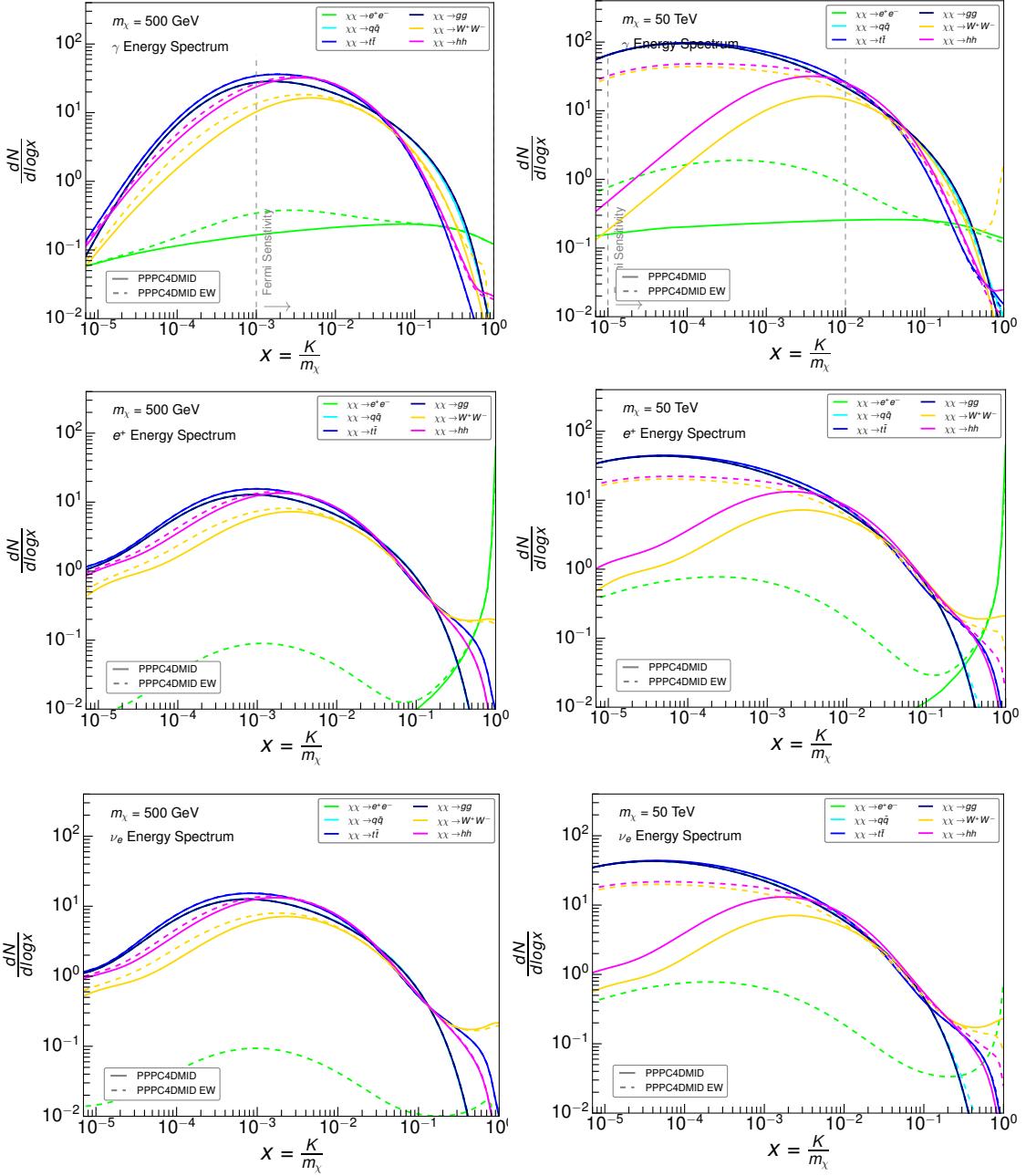


Figure 1. Energy spectra (γ, e^+, ν_e) for $m_\chi = 500 \text{ GeV}$ (left) and 50 TeV (right) extracted from the PPPC4DMID and PPPC4DMID_ew tables, for selected annihilation channels.

3 EW with MadGraph5_aMC@NLO

3.1 Processes

The processes used for the production of the samples with emission of extra electroweak bosons (Higgs, W and Z bosons) are the following:

```
import model DMsimp_s_spin0_EW
define X = W- W+ Z h
generate xd xd~ > w- w+
add process xd xd~ > w- w+ X
add process xd xd~ > w- w+ X X
add process xd xd~ > w- w+ X X X
```

Note that the short notation e.g. "XXW" includes the lower order processes (in this case only the tree level $xd\bar{xd} \rightarrow WW$) and up to one extra "X" boson, and likewise for the higher order processes.

Syntax for excluding diagrams with photons:

```
import model DMsimp_s_spin0_EW
define X = W- W+ Z h
generate xd xd~ > w- w+ /a
add process xd xd~ > w- w+ X /a
add process xd xd~ > w- w+ X X /a
add process xd xd~ > w- w+ X X X /a
```

Relevant parameters in the `run_card.dat` :

```
*** run_card
1001.0      = ebeam1
10001.0     = ebeam1
100001.0    = ebeam1
```

for $m_{\chi_D} = 1, 10, 100$ TeV respectively, and the `param_card.dat` :

```
*** param_card
52 1.00000e+03 # MXd
54 2.00000e+03 # MY0 (= 2 x MXd )
```

3.2 Cross Sections Comparison

In Tab. 1 the cross sections in [pb] obtained with different runs are shown.

m_{χ_D}	$\chi_D \chi_D \rightarrow WW$	$\chi_D \chi_D \rightarrow WWX$	$\chi_D \chi_D \rightarrow WWXX$	$\chi_D \chi_D \rightarrow WWXXX$
1.0 TeV (Old)	474	130*	600	600
1.0 TeV (Old, no γ)	474	676	704	-
1.0 TeV (New)	173	215	219	-
1.0 TeV (New,AUTO)	147.3	148.2	-	-
1.0 TeV (Chiara)	147.3	148.2	148.2	-
10.0 TeV (Old)	15.1×10^3	30.501×10^3	37.018×10^3	-
10.0 TeV (Old,no γ)	15.1×10^3	2.7×10^7	1.5×10^{10}	-
10.0 TeV (New)	15.1×10^3	30.542×10^3	-	-
100.0 TeV (Old)	4.7×10^5	-	-	-

Table 1. Cross sections in [pb] for various processes extracted from the LHE files. The "New" cross sections were computed with $N_{Events}=10,000$, while the "Old" ones with $N_{Events}=100,000$. Need to verify the value 130*.

3.3 Spectra for $\chi_D \chi_D \rightarrow WW$

3.3.1 $m_{\chi_D} = 1$ TeV

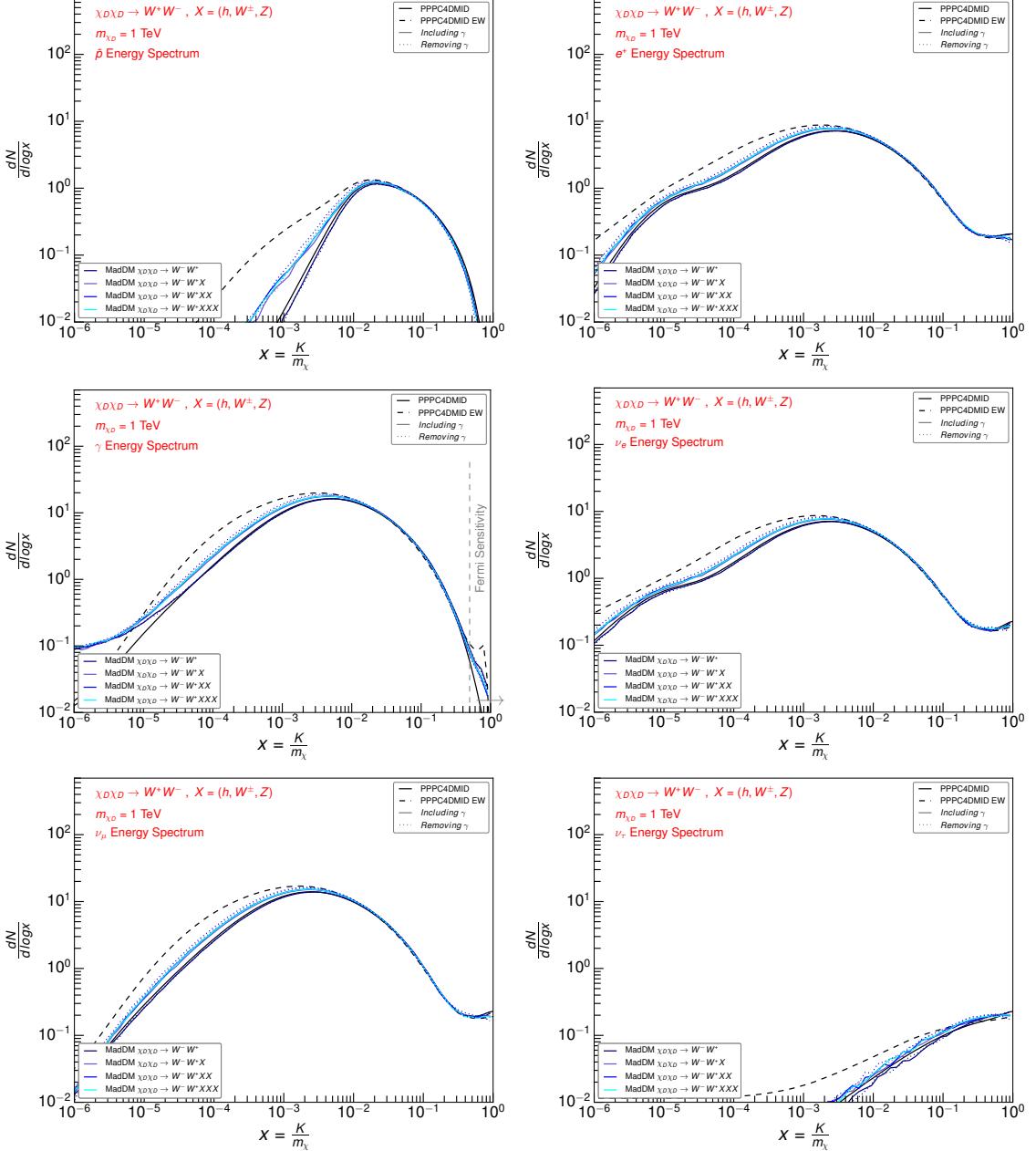


Figure 2. Energy Spectra for $m_{\chi_D} = 1$ TeV

3.3.2 "Old" $m_{\chi_D} = 100$ TeV

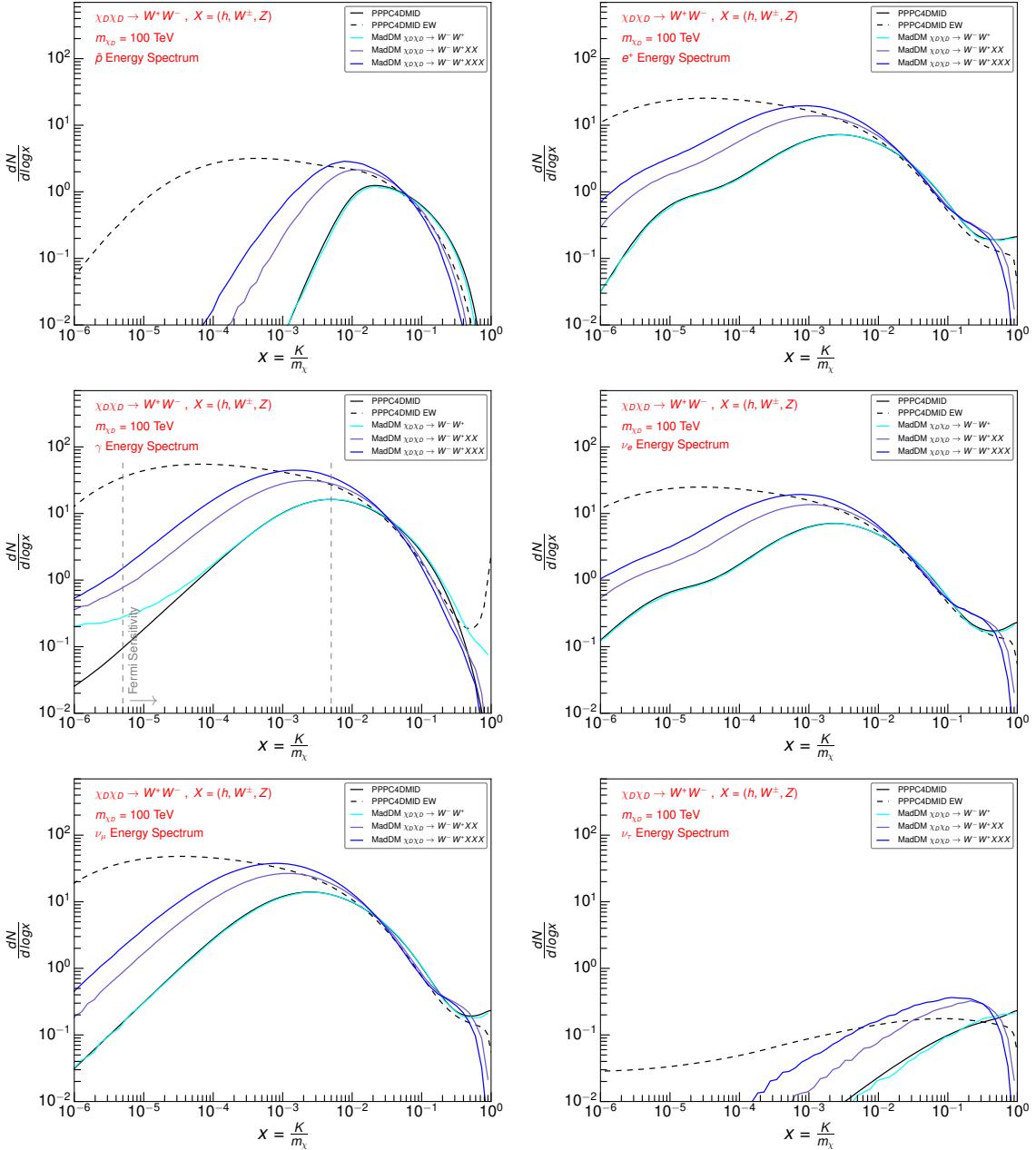


Figure 3. Energy Spectra for $m_{\chi_D} = 100$ TeV (Old data)

3.4 Spectra for $\chi_D \chi_D \rightarrow Y_0 \rightarrow FFFF$

Here the spectra for the process $\chi_D \chi_D \rightarrow Y_0 \rightarrow FFFF$ are shown for $m_{\chi_D} = 1$ TeV, compared to the PPPC4DMID and PPPC4DMID_ew spectra. To produce the sample, the EW model was modified adding masses to the light quarks and muons, otherwise there is a problem in MadGraph5_aMC@NLO when evaluating the cross sections (re-using the same diagrams with massless particles?). I used the value of the muon mass (0.105 GeV) for the light quarks, and 4.5 GeV for the bottoms.

The model can be found at https://github.com/fambrogi/MadDM/tree/master/EW_Study/EW_Model_FermionMass, while the complete banner can be found in https://github.com/fambrogi/MadDM/blob/master/EW_Study/Banners/xdxd_Y0_FFFF_1TeV_banner.dat.

MadGraph5_aMC@NLO Process:

```
import model DMsimp_s_spin0_EW_MM
define F = ve vm vt e- mu- ve~ vm~ vt~ e+ mu+ t t~ u c d s b u~ c~ d~ \
s~ b~ ta- ta+
generate x d xd~ > y0 > F F F F
output x dxd_Y0_FFFF
```

Pythia8 cards commands:

```
TimeShower:weakShower = on (or off)
WeakShower:singleEmission = off
```

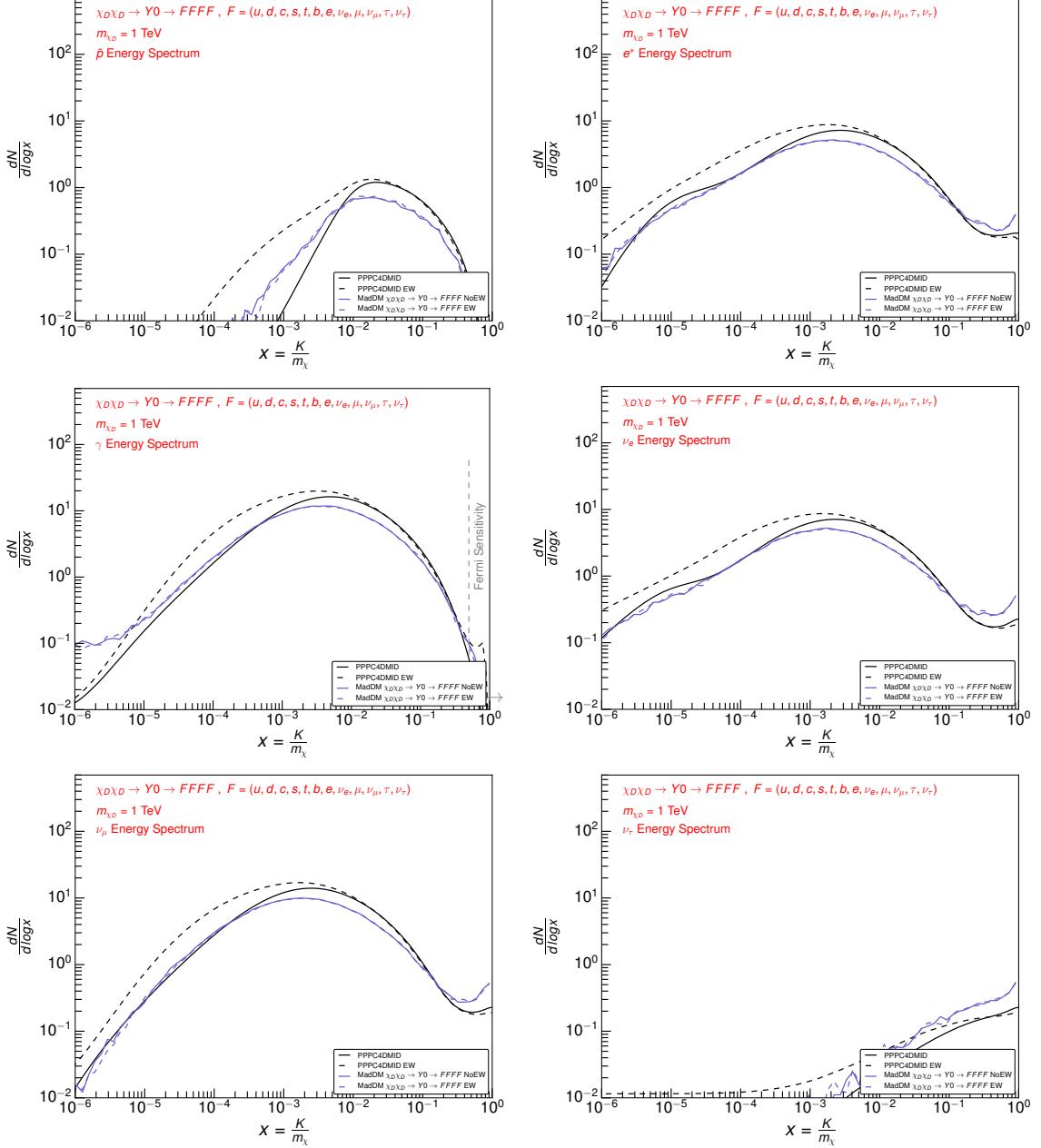


Figure 4. Energy Spectra for $m_{\chi_D} = 1$ TeV (Old data) for the process $\chi_D \chi_D \rightarrow Y0 \rightarrow FFFF$. The label "EW" and "NoEW" in the MadDM samples mean respectively samples produced with or without the EW corrections in Pythia8.

4 MG5 Issues

Sometimes, but not always, I get the following message:

```
INFO: Combining Events
INFO: fail to reach target 10000
==== Results Summary for run: run_01 tag: tag_1 ====
Cross-section : 2.711e+06 +- 6.486e+04 pb
Nb of events : 25
```

when generating events with extra bosons for $m_{\chi_D} = 100$ TeV. The `MadGraph5_aMC@NLO` version is 2.6.4 .

Acknowledgments

Thanks