Erratum: PPPC 4 DM ID: a poor particle physicist cookbook for dark matter indirect detection

Marco Cirelli, a,b,1 Gennaro Corcella, c,d,e Andi Hektor, f Gert Hütsi, g Mario Kadastik, j Paolo Panci, a,h,i,j Martti Raidal, j Filippo Sala d,e and Alessandro Strumia a,e,f,k

aCERN Theory Division,
CH-1211 Genève, Switzerland
bInstitut de Physique Théorique, CNRS, URA 2306 & CEA/Saclay,
F-91191 Gif-sur-Yvette, France
cMuseo Storico della Fisica, Centro Studi e Ricerche E. Fermi,
P. del Viminale 1, I-00185 Rome, Italy
dScuola Normale Superiore,
Piazza dei Cavalieri 7, I-56126 Pisa, Italy
eINFN, Sezione di Pisa,
Largo Fibonacci 3, I-56127 Pisa, Italy
fNational Institute of Chemical Physics and Biophysics,
Ravala 10, 10143 Tallinn, Estonia
gTartu Observatory,
Tõravere 61602, Estonia
hDipartimento di Fisica, Università degli Studi dell’Aquila,
67010 Coppito (AQ), Italy
iINFN, Laboratori Nazionali del Gran Sasso,
67010 Assergi (AQ), Italy
jUniversité Paris 7-Diderot, UFR de Physique,
10, rue A. Domon et L. Duquet, 75205 Paris, France
kUniversità degli Studi di Pisa, Dipartimento di Fisica,
Largo Fibonacci 3, I-56127 Pisa, Italy

E-mail: marco.cirelli@cea.fr

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1Corresponding author.

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Abstract. We correct a few mistakes of the original version of this work (notably related to the computations of extragalactic gamma rays), while at the same time improving and upgrading other aspects (notably as a consequence of the discovery of the higgs boson at the LHC). A brief list of the main changes is:

- We include a higgs boson channel $hh$ with mass $m_h = 125$ GeV. All previous channels $h_mh_m$ are removed.

- We correct the formulæ for the computation of extragalactic gamma rays (fixing in particular the redshift dependence) as well as the numerical computations (also including a corrected impact of absorption).

- We provide a new version of the Optical Depth function, employing updated models of Extragalactic Background Light (EBL) and fixing the redshift dependence.

All these corrections and updates are reflected on the numerical ingredients provided on the website; they correspond to Release 2.0.

\footnote{www.marcocirelli.net/PPPC4DMID.html.}
1 Fluxes at production

We here detail the changes which concern the fluxes at production (section 3 of our original paper).

Now that a particle consistent with the SM Higgs boson has been discovered [1], we need more than ever to include the corresponding channel in the list of possible annihilations (or decays), and indeed we do so. The list of primary channels for which we compute the spectra at production, replacing eq. (2) in the original paper, now reads:

\[ e_L^+ e_L^-, e_R^+ e_R^-, \mu_L^+ \mu_L^-, \mu_R^+ \mu_R^-, \tau_L^+ \tau_L^-, \tau_R^+ \tau_R^-, q\bar{q}, c\bar{c}, b\bar{b}, t\bar{t}, \gamma\gamma, gg, W_L^+ W_L^-, W_T^+ W_T^-, Z_L Z_L, Z_T Z_T, hh, \nu_e \bar{\nu}_e, \nu_\mu \bar{\nu}_\mu, \nu_\tau \bar{\nu}_\tau, VV \rightarrow 4e, VV \rightarrow 4\mu, VV \rightarrow 4\tau, \]

On the other hand, the detailed properties of such a particle are obviously still under very active investigation, so that we have to make some guesses/assumptions. For its mass, we assume \( m_h = 125 \) GeV. For its branching ratios, we take those predicted by the Standard Model and embedded in the MonteCarlo codes we use (HERWIG and PYTHIA, which actually employ slightly different values, see the discussion in the original paper). Beyond the Standard Model, the Higgs decay fractions will clearly be different. Should the investigations at the LHC expose a non-SM behavior of the \( h \) particle, these assumptions will clearly have to be revised.

Concerning the spectra at production for the other channels, we here improve the interpolation in several respects and correct a numerical mistake affecting in particular the normalization of channels featuring a peak at \( x \sim 1 \), notably \( \gamma\gamma \). Figure 1 of this Erratum replaces figure 3 of the original paper and figure 2 replaces figure 4.
Figure 1. Primary fluxes of $e^\pm$, $\bar{p}$, $\bar{d}$, $\gamma$ and $\nu_e$. 
Figure 2. Energy distribution between the final states particles: $e^\pm$, hadrons ($p + d$), $\gamma$ and $\nu$, for a set of characteristic annihilation channels. The inner (outer) pie refers to a DM mass of 200 GeV (5 TeV). For each pie chart, the first caption gives the energy fraction going into $\gamma$ and $e^\pm$ ($E_{\gamma+e}$) with respect to the total. The second caption gives the energy fraction into hadronic final states ($E_{p+d}$) with respect to $\gamma$ and $e^\pm$. 
2 Extragalactic gamma rays

We here detail the changes which concern the fluxes of extragalactic gamma rays (section 7 of our original paper).

Eq. (7.1) in the original paper, the differential flux of extragalactic gamma rays perceived at a certain redshift \( z \), is to be replaced with the following one:

\[
\frac{d\Phi_{\gamma\gamma}}{dE_\gamma}(E_\gamma, z) = c \frac{1}{E_\gamma} \int_z^\infty dz' \frac{1}{H(z')(1 + z') \left( \frac{1 + z}{1 + z'} \right)^3} j_{\gamma\gamma}(E'_\gamma, z') e^{-\tau(E_\gamma, z, z')}. \tag{2.1}
\]

In turn eq. (7.2), the flux at \( z = 0 \), is to be replaced by:

\[
\frac{d\Phi_{\gamma\gamma}}{dE_\gamma}(E_\gamma) = c \frac{1}{E_\gamma} \frac{1}{H(1+z)^4} j_{\gamma\gamma}(E'_\gamma, 0) e^{-\tau(E_\gamma, 0)}. \tag{2.2}
\]

Eq. (7.4), the emissivity \( j_{\gamma\gamma}^{\text{prompt}} \), is to be replaced by

\[
j_{\gamma\gamma}^{\text{prompt}}(E'_\gamma, z') = E'_\gamma \begin{cases} 
\frac{1}{2} B(z') \left( \frac{\bar{\rho}(z')}{M_{\text{DM}}} \right)^2 \sum_f (\sigma v_f) \frac{dN_f}{dE_{\gamma}}(E'_\gamma) & \text{(annihilation)} \\
\bar{\rho}(z') \sum_f \Gamma_f \frac{dN_f}{dE_{\gamma}}(E'_\gamma) & \text{(decay)} 
\end{cases} \tag{2.3}
\]

Finally, eq. (7.6) and (7.7) of the original paper should be replaced by the following ones, which hold for the ICS part only: \( j_{\gamma\gamma}^{\text{IC}}(E'_\gamma, z') = B(z')(1 + z')^6 j_{\gamma\gamma}^{\text{IC}}(E_\gamma, 0) \) for the case of annihilating DM and by \( j_{\gamma\gamma}^{\text{IC}}(E'_\gamma, z') = (1 + z')^3 j_{\gamma\gamma}^{\text{IC}}(E_\gamma, 0) \) for the case of decaying DM.

We have also updated the modelizations of the Photon Background Radiation (PBR). We introduce a model named ‘maximal UV’, which assumes the UV background as given by ‘minimal UV’ multiplied with a factor 1.5. It can be considered as an upper limit of possible systematic errors of the model given by [2]. The model ‘minimal UV’ is essentially a renaming and an updating of the ‘realistic UV’ model of the original paper.

As a consequence of these and other minor changes, the numerical computation of the fluxes of extragalactic gamma rays is modified. Figure 3 of this Erratum replaces figure 20 of the original paper.

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Figure 3. Fluxes of extragalactic gamma rays, for the case of annihilations (first 3 panels) and decay (last panel). In each panel one of the astrophysical model assumptions is varied. The choices of annihilation or decay channels and particle physics parameters are indicated. On the last panel, the black dotted line indicates the flux for the ‘no UV’ case computed in Thomson approximation.

References

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