Reliability of Monte Carlo event generators for gamma ray DM searches (arXiv:1305.2124)

Jose A. R. Cembranos

Universidad Complutense de Madrid

MultiDark
Multimessenger Approach for Dark Matter Detection

Collaboration with A. de la Cruz-Dombriz, V. Gammaldi, R. A. Lineros and A.L. Maroto

Mainz Institute for Theoretical Physics

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Outline

- Introduction
- Comparison of Monte Carlo event generators
- Software:
  - PYTHIA 6.418 (Fortran)
  - HERWIG 6.5.10 (Fortran)
  - PYTHIA 8.165 (C++)
  - HERWIG 2.6.1 (C++)
- Conclusions

The Darkness of the Unknown

- Indirect Dark Matter searches suffer from important uncertainties:
  - DM distribution:
    - Baryonic effects
    - Central density of DM halos
    - Substructures
  - DM particle models:
    - Model dependent analyses
    - Not very constrained space of parameters.

- Monte Carlo event generators
  - Focus in collider physics

Motivation

- Gamma-ray spectra do not depend on DM model or DM model except for small particular tuned regions of the parameter space:

- Fitting functions for particle-antiparticle channels.

JARC, Cruz-Dombriz, Dobado, Lineros and Maroto, Phys. Rev. D 83, 083507 (2011) arXiv: 1009.4939

(PYTHIA 6.418, Fortran)

- Numerical functions for particle-antiparticle channels.

Cirelli et al., JACP 1103 (2011) arXiv :1012.4515

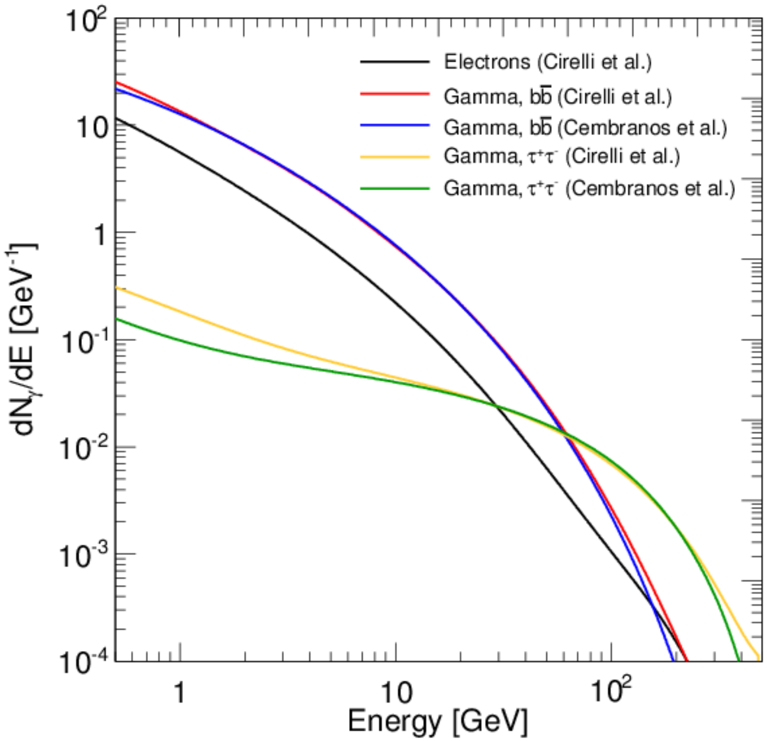
(PYTHIA 8.165 , C++)

Motivation

- Comparison

Miguel Angel Sanchez Conde and Mattia Fornasa, private communication (2012).

$$M_{DM} = 500 \text{ GeV}$$



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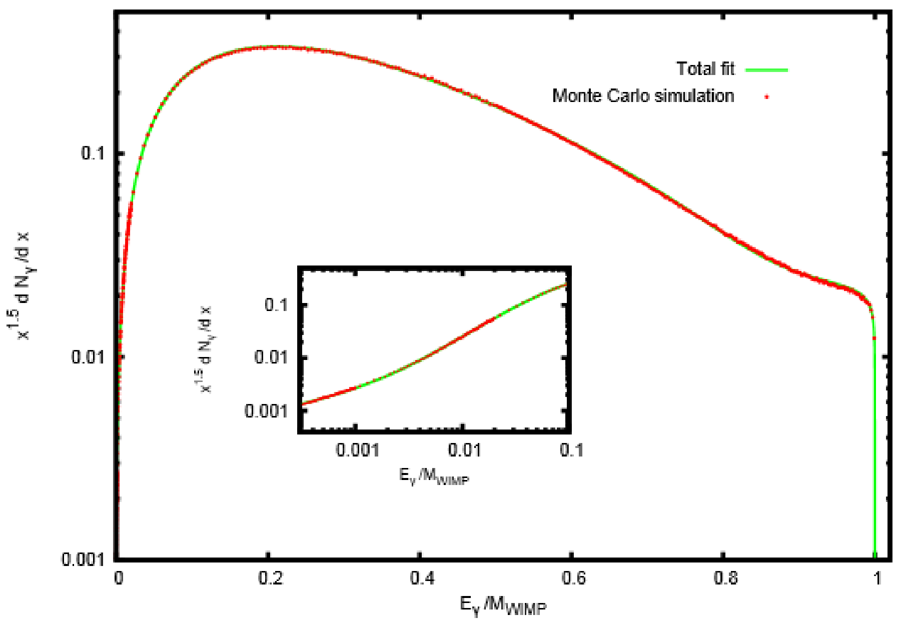
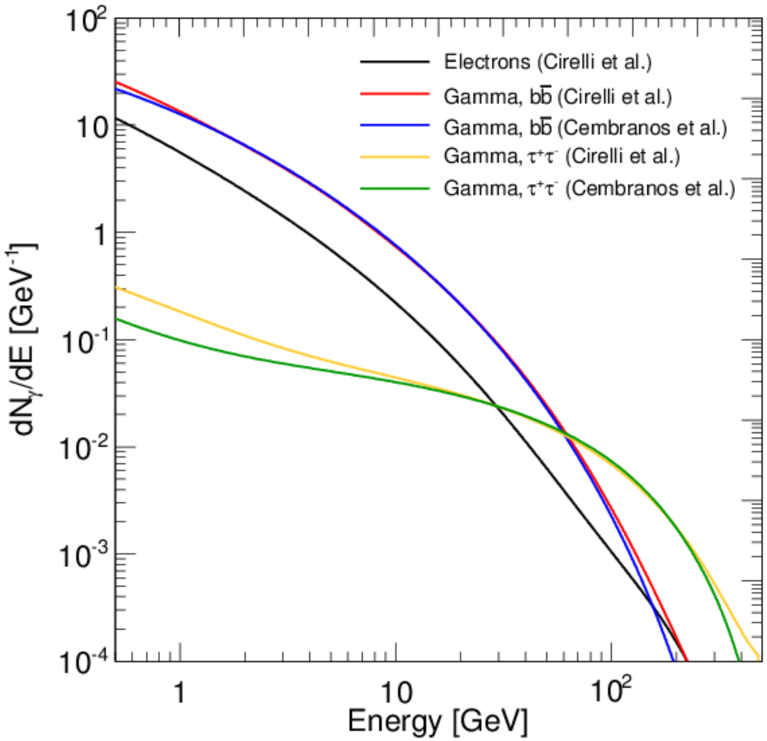
Cirelli et al., JACP 1103 (2011) arXiv :1012.4515

(PYTHIA 8.165 , C++)

Motivation



(c) Photon spectrum for $M = 1000\,\mathrm{GeV}$ for $\tau^+\tau^-$ channel.



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(PYTHIA 8.165 , C++)

Comparison analysis

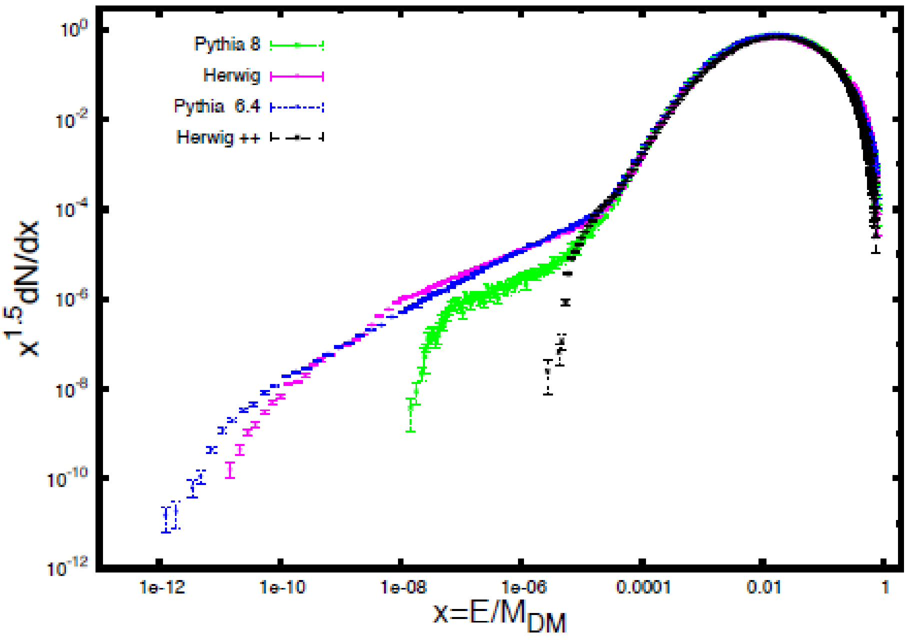
- Comparison of Monte Carlo event generators:
  - PYTHIA 6.418 (Fortran)
  - HERWIG 6.5.10 (Fortran)
  - PYTHIA 8.165 (C++)
  - HERWIG 2.6.1 (C++)

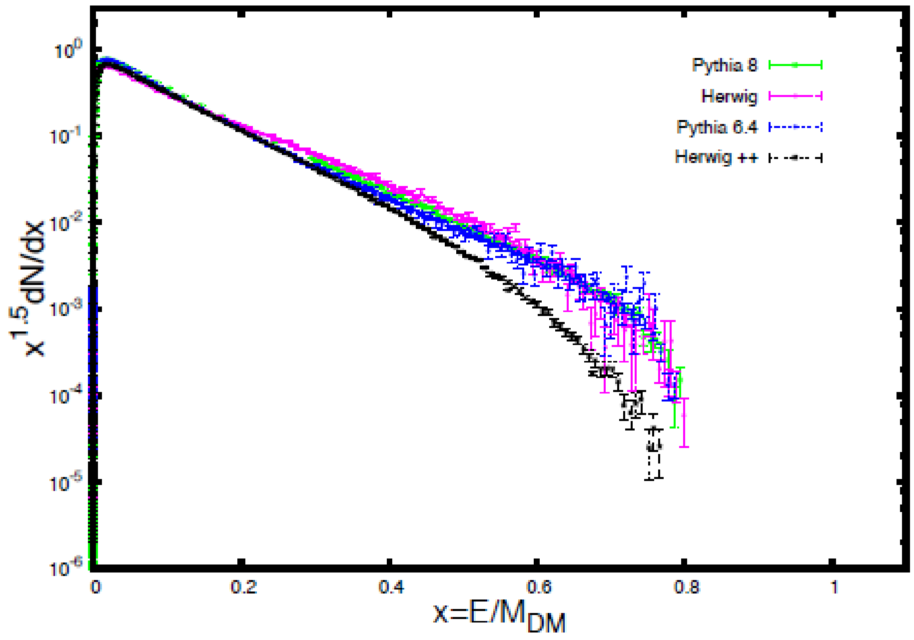
- DM Annihilating/decaying Channels:
  - W^+W^-
  - $\tau^+\tau^-$
  - $b\,\bar{b}$
  - $t\,\bar{t}$

- DM masses: $50\ \mathrm{GeV} < M_{DM} < 10\ \mathrm{TeV}$

W^+W^- channel

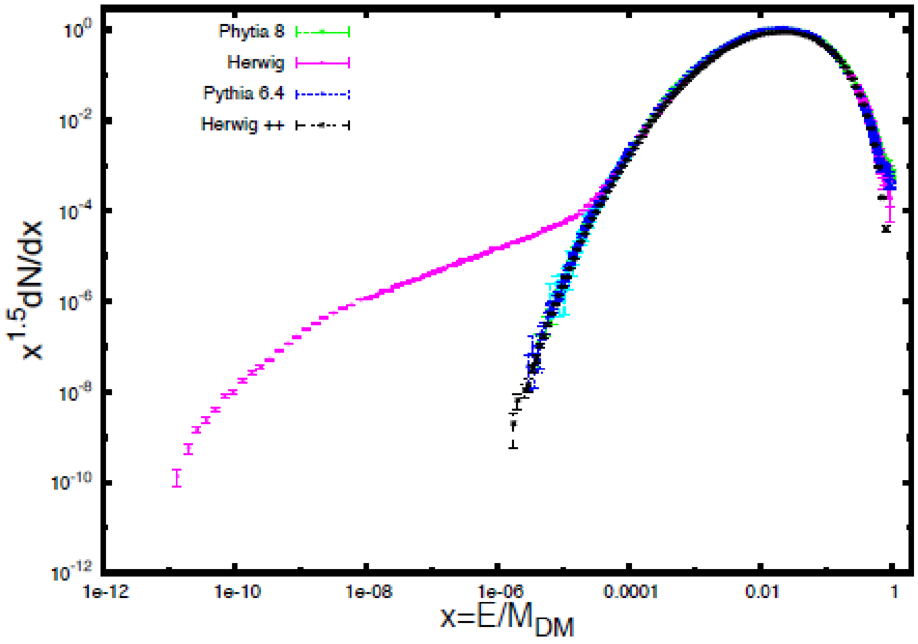
$M_{DM} = 100\ \mathrm{GeV}$

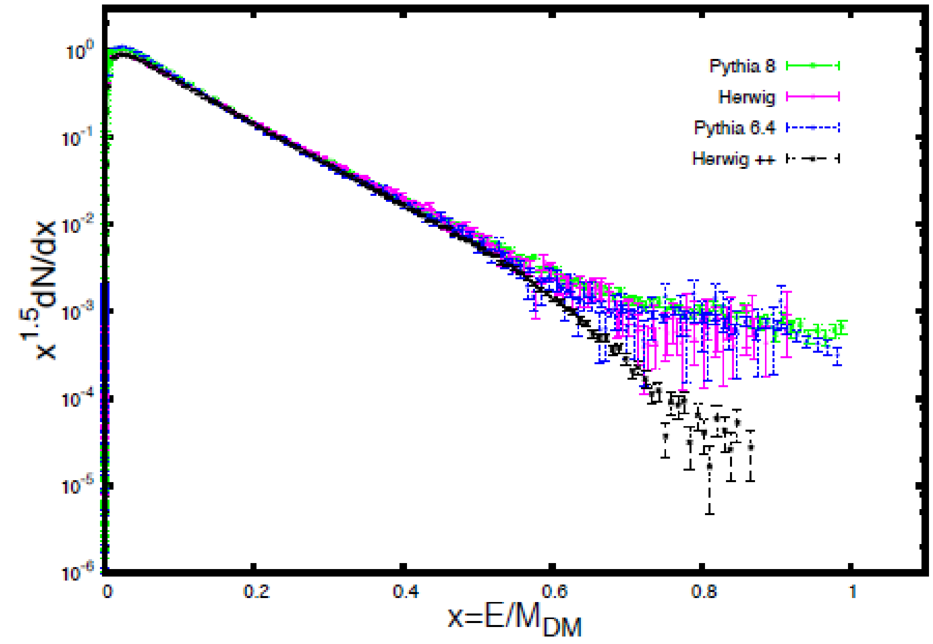




$b\,\bar{b}$ channel

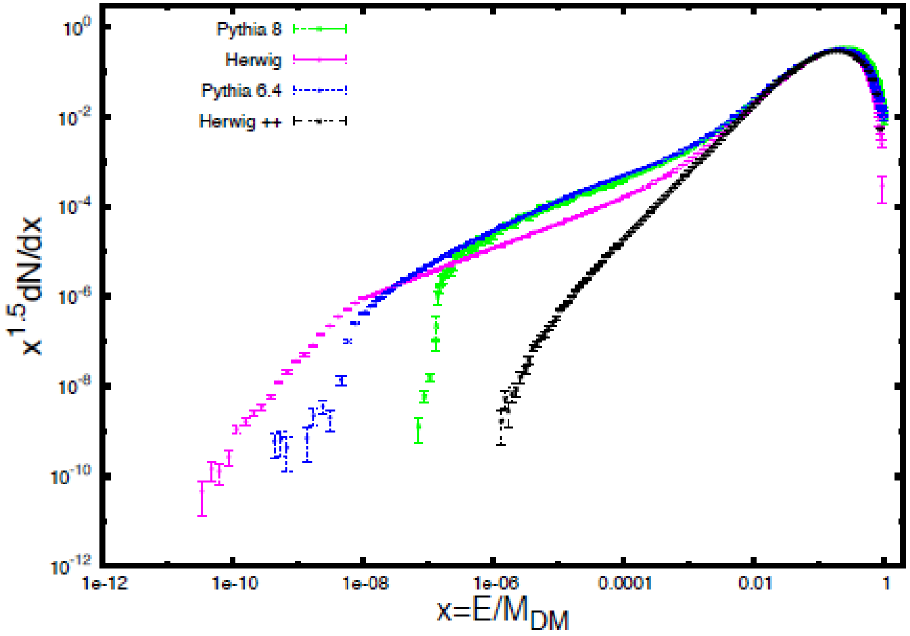
$M_{DM} = 100$ GeV

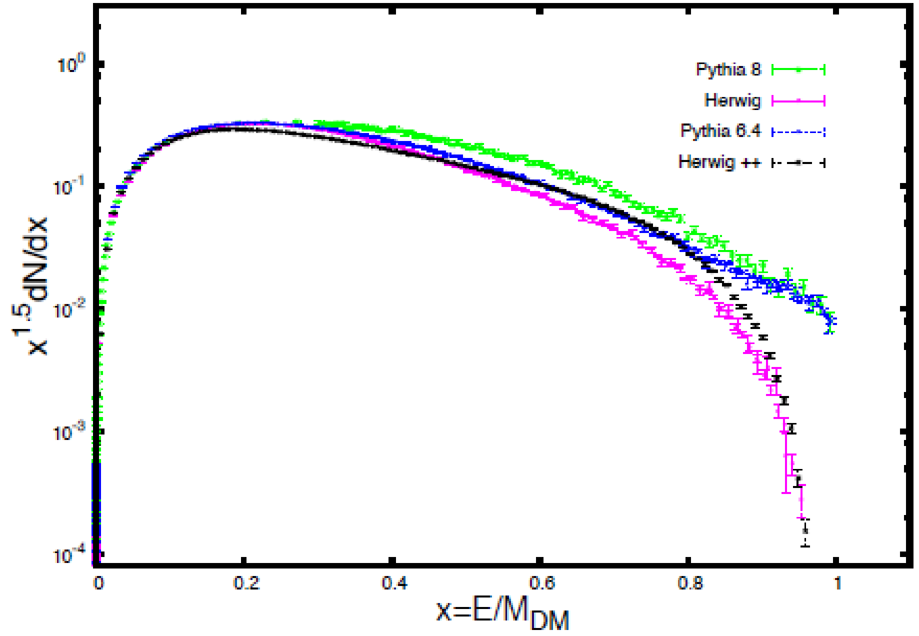




$\tau^+\tau^-$ channel

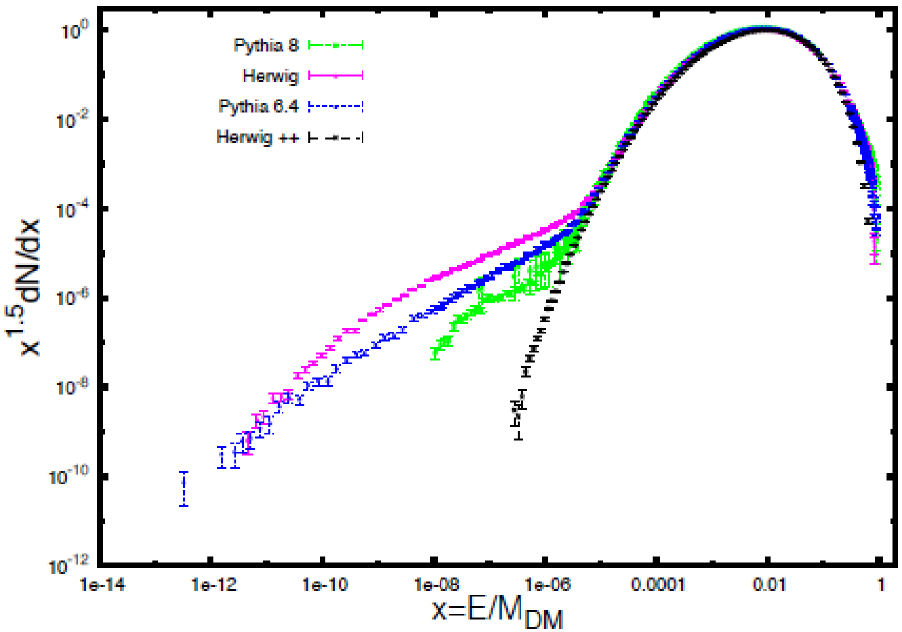
$M_{DM} = 100\ \text{TeV}$

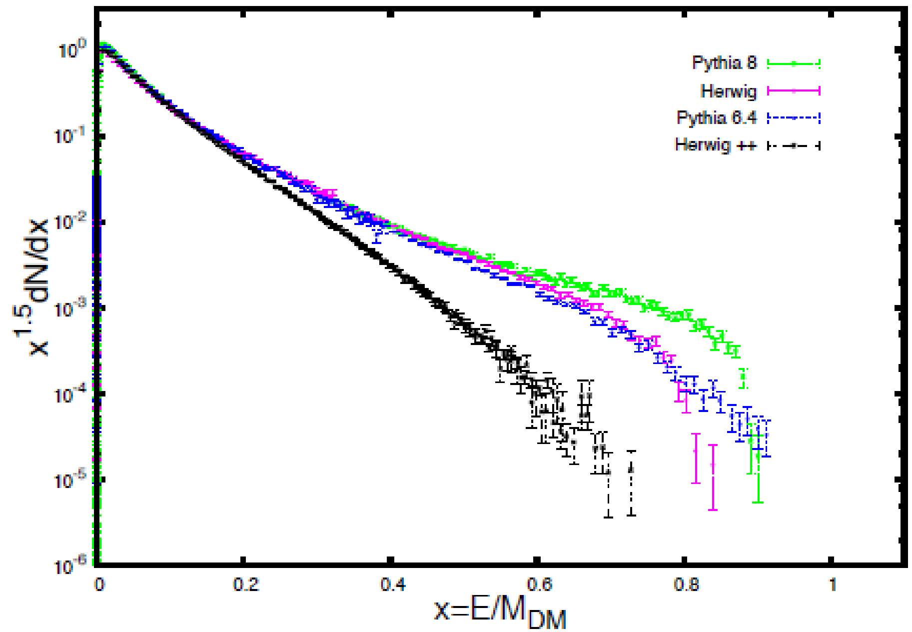




$t\,\bar{t}$ channel

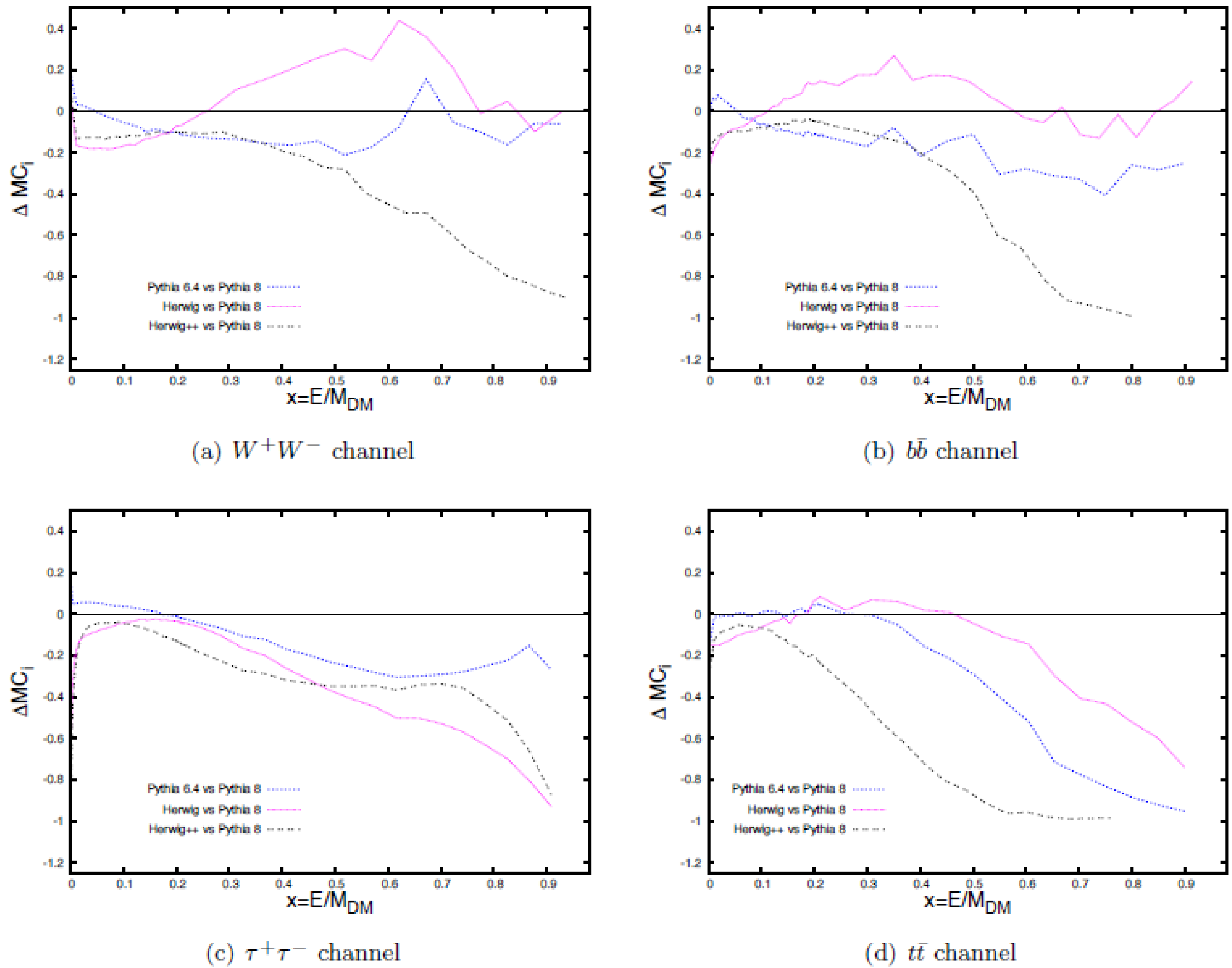
$M_{DM} = 500\ \text{GeV}$





Deviations

$$\Delta MC_i = \frac{MC_i - \text{PYTHIA 8}}{\text{PYTHIA 8}},$$



(a) W^+W^- channel

(b) $b\bar{b}$ channel

(c) $\tau^+\tau^-$ channel

(d) $t\bar{t}$ channel

$M_{DM} = 1$ TeV

Photon multiplicities

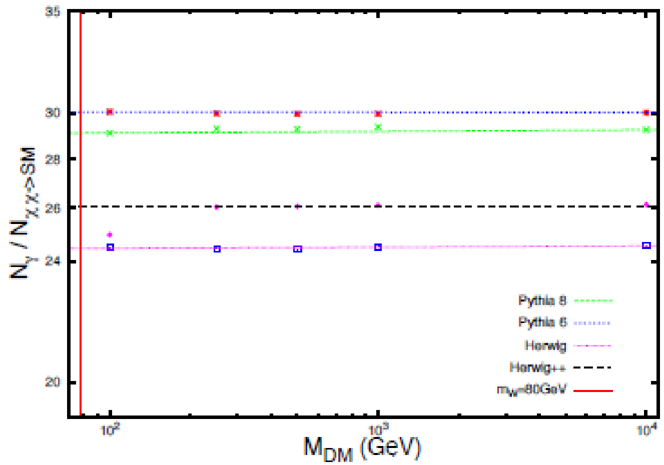
The total amount of photons is well fitted by a power law of the DM mass, *M*:

$$\frac{N_\gamma}{N_{\chi\chi\to SM}} \simeq a \cdot \left(\frac{M}{1\,\mathrm{GeV}}\right)^b ,$$

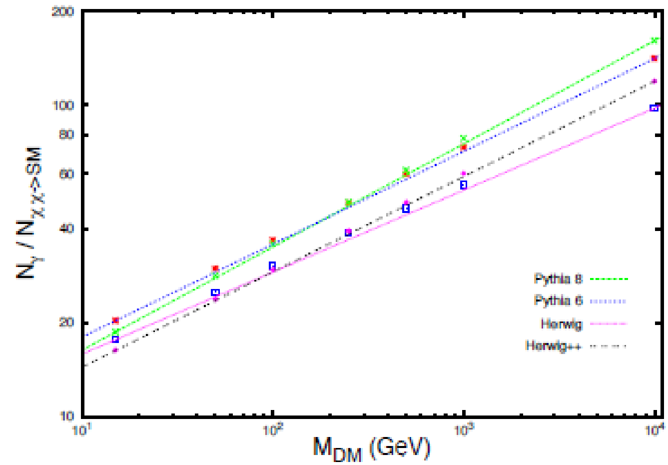
Software/PYTHIA 8	W^+W^-	$b\bar{b}$	$\tau^+\tau^-$	$t\bar{t}$
PYTHIA 6.4	$A = 1.04$ $B = 0$	$A = 1.18$ $B = -0.033$	$A = 0.96$ $B = 0.020$	$A = 1.49$ $B = -0.077$
HERWIG	$A = 0.84$ $B = 0$	$A = 1.13$ $B = -0.068$	$A = 1.00$ $B = -0.029$	$A = 1.02$ $B = -0.038$
HERWIG++	$A = 0.90$ $B = 0$	$A = 0.93$ $B = -0.025$	$A = 0.96$ $B = -0.039$	$A = 0.93$ $B = -0.031$

PYTHIA 8	$a = 28.9$ $b = 0.001$	$a = 7.62$ $b = 0.331$	$a = 2.29$ $b = 0.042$	$a = 14.1$ $b = 0.276$

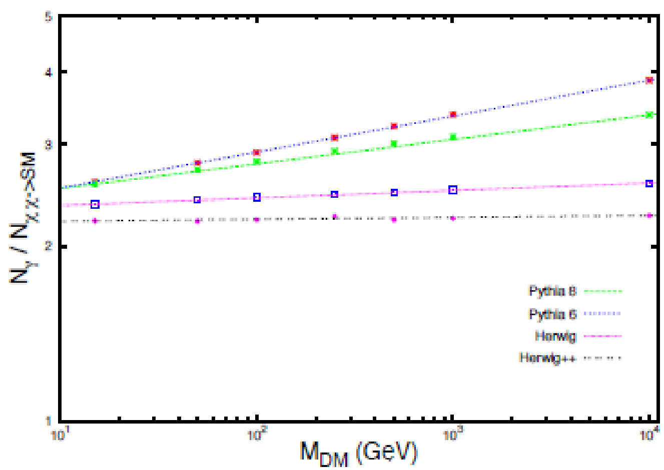
Photon multiplicities



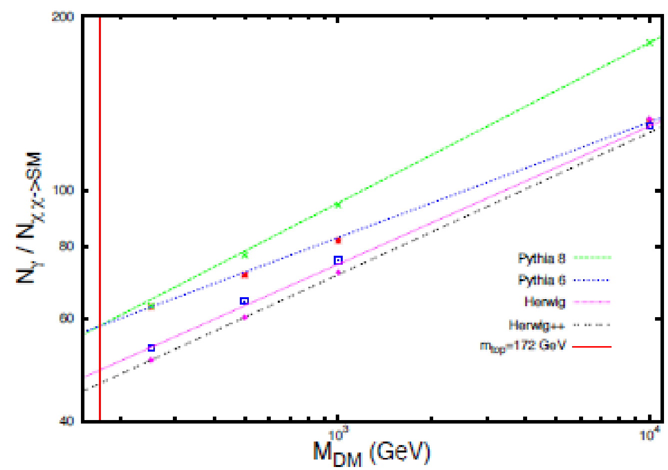
(a) W^+W^- channel.



(b) $b\bar{b}$ channel



(c) $\tau^+\tau^-$ channel



(d) $t\bar{t}$ channel

Conclusions

- Further implementation is needed in HERWIG++.
- For the other Monte Carlo event generators, the gamma-ray spectra simulated show also important differences.
- Relative deviations can only be bounded by 40-50% for hadronic and electro-weak channels.
- Situation is even worse for leptonic and top-antitop channels.
- On the other hand, situation improves a little for the total number of photons.

Maximum differences: factor 2.

Thanks!

- Recognition to the authors of Monte Carlo event generators

  - PYTHIA

    Torbjörn Sjöstrand, Stefan Ask, Richard Corke, Stephen Mrenna, Stefan Prestel, Peter Skands

  - HERWIG

    Pino Marchesini, Bryan Webber, Giovanni Abbiendi, Gennaro Corcella, Ian Knowles, Stefano Moretti, Kosuke Odagiri, Peter Richardson, Mike Seymour, Luca Stanco