



The July 3, 09:33 release

DarkSUSY 5.0

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Philosophy

- Modular structure
- Library of subroutines and functions
- **Fast** and accurate ← To allow for calculations of many models (millions)
- “Standard” Fortran 77 - works on many platforms
- Flexible
- Version control (subversion) for development and precise version tagging
- Do all calculations in a **consistent** way, both for the astrophysics and the particle physics.

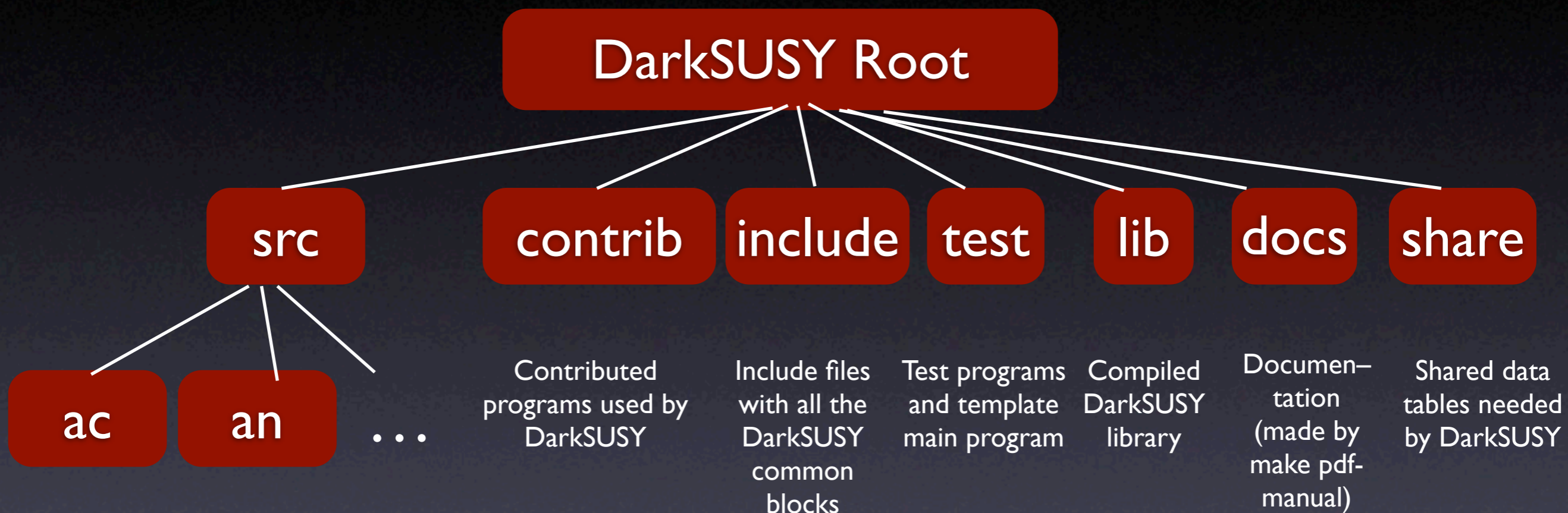


Contents

- Generic MSSM (7, 13, 20, 24, ...), mSUGRA, ...
- Laboratory constraints
- Neutralino relic density
- Direct detection
- Signals in neutrino telescopes
- Gamma ray signals
- Cosmic rays positrons, antiprotons and antideuterons



Program layout



Here are the main routines of DarkSUSY making up libdarksusy.a



Compile and install

- To compile and install DarkSUSY, do

```
./configure [optional arguments]  
make
```



Typical program

call dsinit

[make changes from the default]

[determine your model parameters your way]

call dsgive_model [or equivalent]

call dssusy [or equivalent] – to set up DarkSUSY
for that model

[then calculate what you want]



*set routines

- Essentially all the packages in DarkSUSY have a corresponding *set routine that determines optional settings, which parameter sets to use etc.
- As an example, call `dshmset('default')` chooses the default halo model (NFW)
- All these *set routines are called with the argument 'default' by `dsinit`, but can be changed later by the user.



Supersymmetric models

- Input parameters at EW scale (MSSM), or
- Input parameters at GUT scale (mSUGRA)
- Higgs sector with FeynHiggs
- Higgs decay widths from Hdecay, other literature or FeynHiggs (future)
- mSUGRA interface: ISASUGRA
- SUSY Les Houches Accord 2 implemented (first implementation, feedback please!)



SUSY model setup

We work in the framework of the minimal $N = 1$ supersymmetric extension of the standard model defined by, besides the particle content and gauge couplings required by supersymmetry, the superpotential

$$W = \epsilon_{ij} \left(-\hat{\mathbf{e}}_R^* \mathbf{Y}_E \hat{\mathbf{l}}_L^i \hat{H}_1^j - \hat{\mathbf{d}}_R^* \mathbf{Y}_D \hat{\mathbf{q}}_L^i \hat{H}_1^j + \hat{\mathbf{u}}_R^* \mathbf{Y}_U \hat{\mathbf{q}}_L^i \hat{H}_2^j - \mu \hat{H}_1^i \hat{H}_2^j \right) \quad (2)$$

and the soft supersymmetry-breaking potential

$$\begin{aligned} V_{\text{soft}} = & \epsilon_{ij} \left(-\tilde{\mathbf{e}}_R^* \mathbf{A}_E \mathbf{Y}_E \tilde{\mathbf{l}}_L^i H_1^j - \tilde{\mathbf{d}}_R^* \mathbf{A}_D \mathbf{Y}_D \tilde{\mathbf{q}}_L^i H_1^j + \tilde{\mathbf{u}}_R^* \mathbf{A}_U \mathbf{Y}_U \tilde{\mathbf{q}}_L^i H_2^j - B \mu H_1^i H_2^j + \text{h.c.} \right) \\ & + H_1^{i*} m_1^2 H_1^i + H_2^{i*} m_2^2 H_2^i \\ & + \tilde{\mathbf{q}}_L^{i*} \mathbf{M}_Q^2 \tilde{\mathbf{q}}_L^i + \tilde{\mathbf{l}}_L^{i*} \mathbf{M}_L^2 \tilde{\mathbf{l}}_L^i + \tilde{\mathbf{u}}_R^* \mathbf{M}_U^2 \tilde{\mathbf{u}}_R + \tilde{\mathbf{d}}_R^* \mathbf{M}_D^2 \tilde{\mathbf{d}}_R + \tilde{\mathbf{e}}_R^* \mathbf{M}_E^2 \tilde{\mathbf{e}}_R \\ & + \frac{1}{2} M_1 \tilde{B} \tilde{B} + \frac{1}{2} M_2 \left(\tilde{W}^3 \tilde{W}^3 + 2 \tilde{W}^+ \tilde{W}^- \right) + \frac{1}{2} M_3 \tilde{g} \tilde{g}. \end{aligned} \quad (3)$$

Here i and j are $SU(2)$ indices ($\epsilon_{12} = +1$), \mathbf{Y} 's, \mathbf{A} 's and \mathbf{M} 's are 3×3 matrices in generation space, and the other boldface letter are vectors in generation space.



Neutralinos

$$\tilde{\chi}_i^0 = N_{i1}\tilde{B} + N_{i2}\tilde{W}^3 + N_{i3}\tilde{H}_1^0 + N_{i4}\tilde{H}_2^0.$$

$$\mathcal{M}_{\tilde{\chi}_{1,2,3,4}^0} = \begin{pmatrix} M_1 & 0 & -m_Z s_W c_\beta & +m_Z s_W s_\beta \\ 0 & M_2 & +m_Z c_W c_\beta & -m_Z c_W s_\beta \\ -m_Z s_W c_\beta & +m_Z c_W c_\beta & \delta_{33} & -\mu \\ +m_Z s_W s_\beta & -m_Z c_W s_\beta & -\mu & \delta_{44} \end{pmatrix};$$

Charginos

$$\mathcal{M}_{\tilde{\chi}^\pm} = \begin{pmatrix} M_2 & \sqrt{2}m_W \sin \beta \\ \sqrt{2}m_W \cos \beta & \mu \end{pmatrix},$$

$$\tilde{\chi}_i^- = U_{i1} \tilde{W}^- + U_{i2} \tilde{H}_1^-,$$

$$\tilde{\chi}_i^+ = V_{i1} \tilde{W}^+ + V_{i2} \tilde{H}_1^+.$$



Squarks and sleptons

We then obtain the general 6×6 \tilde{u} - and \tilde{d} -squark mass matrices:

$$\mathcal{M}_{\tilde{u}}^2 = \begin{pmatrix} \mathbf{M}_Q^2 + \mathbf{m}_u^\dagger \mathbf{m}_u + D_{LL}^u \mathbf{1} & \mathbf{m}_u^\dagger (\mathbf{A}_U^\dagger - \mu^* \cot \beta) \\ (\mathbf{A}_U - \mu \cot \beta) \mathbf{m}_u & \mathbf{M}_U^2 + \mathbf{m}_u \mathbf{m}_u^\dagger + D_{RR}^u \mathbf{1} \end{pmatrix}, \quad (26.10)$$

$$\mathcal{M}_{\tilde{d}}^2 = \begin{pmatrix} \mathbf{K}^\dagger \mathbf{M}_Q^2 \mathbf{K} + \mathbf{m}_d \mathbf{m}_d^\dagger + D_{LL}^d \mathbf{1} & \mathbf{m}_d^\dagger (\mathbf{A}_D^\dagger - \mu^* \tan \beta) \\ (\mathbf{A}_D - \mu \tan \beta) \mathbf{m}_d & \mathbf{M}_D^2 + \mathbf{m}_d \mathbf{m}_d^\dagger + D_{RR}^d \mathbf{1} \end{pmatrix}, \quad (26.11)$$

and the general sneutrino and charged slepton mass matrices

$$\mathcal{M}_{\tilde{\nu}}^2 = \mathbf{M}_L^2 + D_{LL}^\nu \mathbf{1} \quad (26.12)$$

$$\mathcal{M}_{\tilde{e}}^2 = \begin{pmatrix} \mathbf{M}_L^2 + \mathbf{m}_e \mathbf{m}_e^\dagger + D_{LL}^e \mathbf{1} & \mathbf{m}_e^\dagger (\mathbf{A}_E^\dagger - \mu^* \tan \beta) \\ (\mathbf{A}_E - \mu \tan \beta) \mathbf{m}_e & \mathbf{M}_E^2 + \mathbf{m}_e \mathbf{m}_e^\dagger + D_{RR}^e \mathbf{1} \end{pmatrix}. \quad (26.13)$$

Here

$$D_{LL}^f = m_Z^2 \cos 2\beta (T_{3f} - e_f \sin^2 \theta_w), \quad (26.14)$$

$$D_{RR}^f = m_Z^2 \cos 2\beta e_f \sin^2 \theta_w. \quad (26.15)$$

In the chosen basis, $\mathbf{m}_u = \text{diag}(m_u, m_c, m_t)$, $\mathbf{m}_d = \text{diag}(m_d, m_s, m_b)$ and $\mathbf{m}_e = \text{diag}(m_e, m_\mu, m_\tau)$.



CKM mixing

We follow the conventions of the particle data group [32] and put the mixing in the left-handed d -quark fields, so that the definition of the Cabibbo-Kobayashi-Maskawa matrix is $\mathbf{K} = \mathbf{V}_1 \mathbf{V}_2^\dagger$, where \mathbf{V}_1 (\mathbf{V}_2) rotates the interaction left-handed u -quark (d -quark) fields to mass eigenstates. For

In low-energy phenomenological MSSM, we usually assume:

$$\mathbf{A}_U = \text{diag}(0, 0, A_t)$$

$$\mathbf{A}_D = \text{diag}(0, 0, A_b)$$

$$\mathbf{A}_E = 0$$

$$\mathbf{M}_Q = \mathbf{M}_U = \mathbf{M}_D = \mathbf{M}_E = \mathbf{M}_L = m_0 \mathbf{1}.$$

$$M_1 = \frac{5}{3} \tan^2 \theta_w M_2 \simeq 0.5 M_2,$$

$$M_2 = \frac{\alpha_{ew}}{\sin^2 \theta_w \alpha_s} M_3 \simeq 0.3 M_3.$$

Note, however, that this specific choice is not needed by DarkSUSY, more general models are possible.



Generality of expressions

- We try to be as general as possible when including new physics, but it is hard to be overly general all the time
- Hence, most of our expressions and setups in DarkSUSY are more general than typical use would indicate
- We will here summarize where general forms are OK and not



General forms

- The sfermion mass parameters can be general 3x3 (real) matrices, even if some other parts of the code (e.g. annihilation cross sections) rely on them at least being diagonal (minimally flavour-conserving)
- All parts of the code accept soft SUSY-breaking parameters different for each generation.
- No GUT relation needs to be assumed for M_1 , M_2 and M_3 . However, we currently do not have gluino coannihilations included, so M_3 shouldn't be too small.



Complex parameters

- All input parameters are currently real, but many of our expressions are general enough to go complex (e.g. all vertices are already complex)
- In future versions, we expect to make most (all?) of our input parameters complex to get to MSSM-124.



Laboratory constraints

- Superpartner masses
- Higgs masses
- Z width
- ρ parameter
- $b \rightarrow s \gamma$
- Muon $g-2$



dsacbnd - acc constraints

- Accelerator constraints are most easily checked with a call to
call dsacbnd(excl)
- `excl` is non-zero if excluded and the set bits of `excl` tells why it is excluded.
- For backwards-compatibility, we keep old versions of the accelerator constraints as well, but `dsacbnd` always points to the latest set of constraints.



Meaning of excl

From header of dsacbnd7.f:

c	bit set	dec.	oct.	reason
c	-----	-----	-----	-----
c	0	1	1	chargino mass
c	1	2	2	gluino mass
c	2	4	4	squark mass
c	3	8	10	slepton mass
c	4	16	20	invisible z width
c	5	32	40	higgs mass
c	6	64	100	neutralino mass
c	7	128	200	b -> s gamma
c	8	256	400	rho parameter



Relic density

- Accurate relic density (1% for given masses and couplings, tree level)
- Resonances and thresholds included
- Full relativistic treatment
- All sfermion, neutralino and chargino coannihilations are included

Relic density – accurate approach

- Solve the Boltzmann equation

$$\frac{dn}{dt} = -3Hn - \langle \sigma_{\text{ann}} v \rangle (n^2 - n_{\text{eq}}^2)$$

- properly taking the thermal average $\langle \cdot \rangle$
- including the full annihilation cross section (including all final states, resonances and thresholds)
- including all so-called coannihilations between all neutralinos, charginos and sfermions

Thermal averaging

As the SUSY particles are in thermal equilibrium (due to the vast amount of SM particles), we can insert a thermal velocity distribution and calculate the thermally averaged annihilation cross section

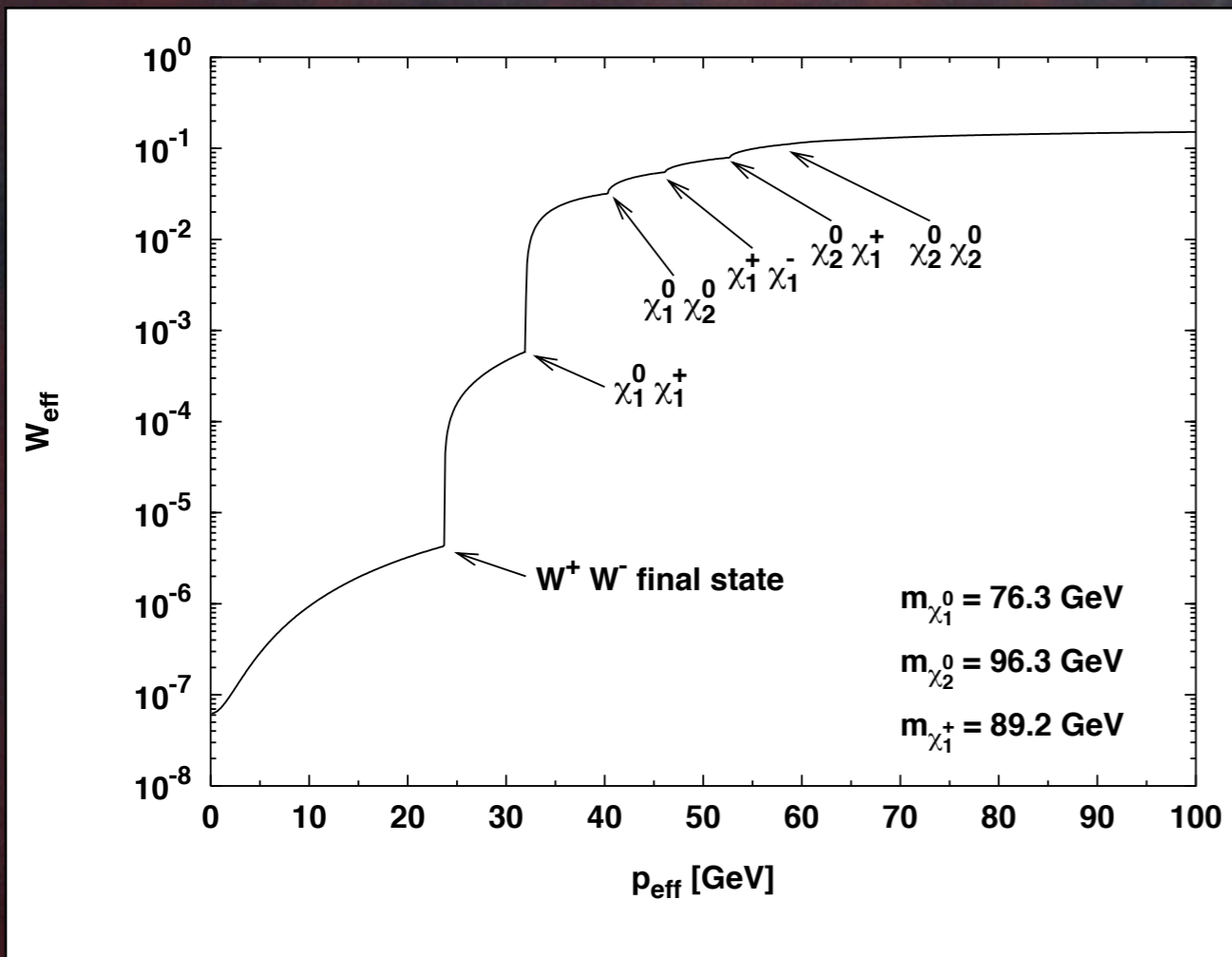
$$\langle \sigma_{\text{eff}} v \rangle = \frac{\int_0^\infty dp_{\text{eff}} p_{\text{eff}}^2 W_{\text{eff}} K_1 \left(\frac{\sqrt{s}}{T} \right)}{m_1^4 T \left[\sum_i \frac{g_i}{g_1} \frac{m_i^2}{m_1^2} K_2 \left(\frac{m_i}{T} \right) \right]^2}$$

$$W_{\text{eff}} = \sum_{ij} \frac{p_{ij}}{p_{11}} \frac{g_i g_j}{g_1^2} W_{ij} \quad ; \quad W_{ij} = 4E_1 E_2 \sigma_{ij} v_{ij}$$

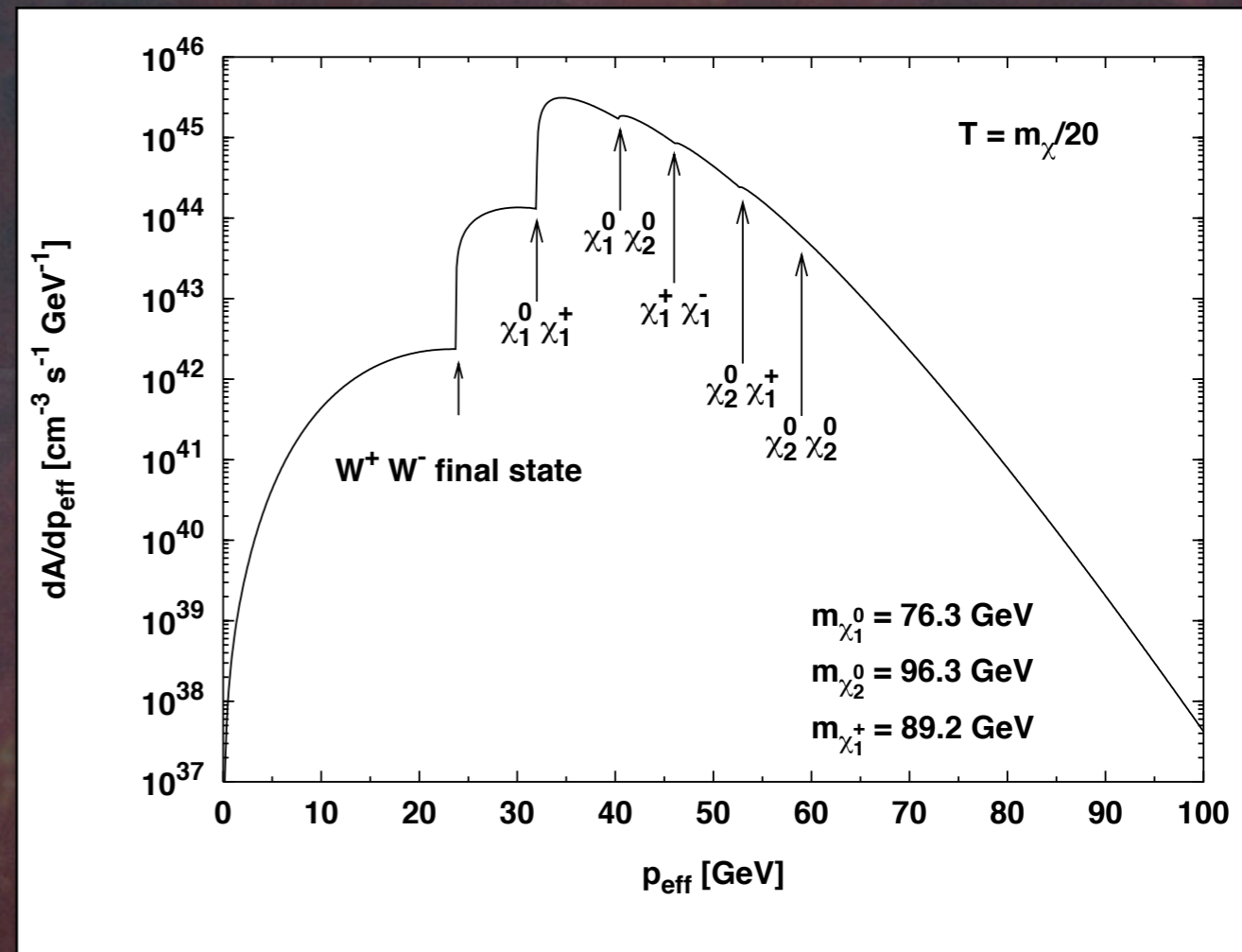
See Edsjö and Gondolo, PRD 56 (1997) 1879 for details.

Example of coannihilation case

W_{eff}



$W_{\text{eff}} \times \text{Boltzmann suppression}$



Initial state thresholds appear as final state thresholds in the effective annihilation rate!

Relic density routines

- The main routine for SUSY neutralinos is `dsrdomega` that calculates the relic density of neutralinos
- However, the relic density routines are more general than that and can be used for any WIMP with a call to `dsrdens`.

How to call dsrdens for general WIMPs

Call

dsrdens(wrate,npart,mgev,dof,nrs,rm,rw,nt,tm,oh2,tf,ierr,iwar)

where you have to supply

wrate - invariant effective annihilation rate (function)

npart - number of coannihilating particles

mgev - mass of these

dof - internal degrees of freedom of these

nrs - number of resonances

rm - mass of resonances

rw - width of resonances

nt - number of thresholds

tm - equivalent mass of thresholds

The routine then returns

oh2 - ωh^2

tf - freeze-out temperature

Note: All this is taken care of automatically for neutralinos in dsrdomega



Direct detection

- Cross sections on protons and neutrons
- Scattering off any nuclei, including recoil spectra and form factors (the default is to choose the best available for each nuclei)
- Possibility to change spin-dependent and spin-independent form factors
- Annual modulation signals
- Choice of halo velocity distributions

Routines

- **dsddneunuc:** calculates the spin-independent and spin-dependent scattering cross sections on neutrons and protons.
- **dsddrde:** calculates the differential scattering rate on various targets as a function of time (can be used to predict annual modulation signals e.g.)



Gamma rays

*GLAST in orbit
and working!*

- Continuum emission (from quark jets, π^0 's)
- Line emission ($\gamma\gamma$ and $Z\gamma$)
- Internal bremsstrahlung photons
- Routines to calculate the line of sight integral for different halo profiles

Gamma ray fluxes from the halo

We can write the flux as

$$\Phi_\gamma(\eta, \Delta\Omega) = 9.35 \cdot 10^{-14} S \times \langle J(\eta, \Delta\Omega) \rangle \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$$

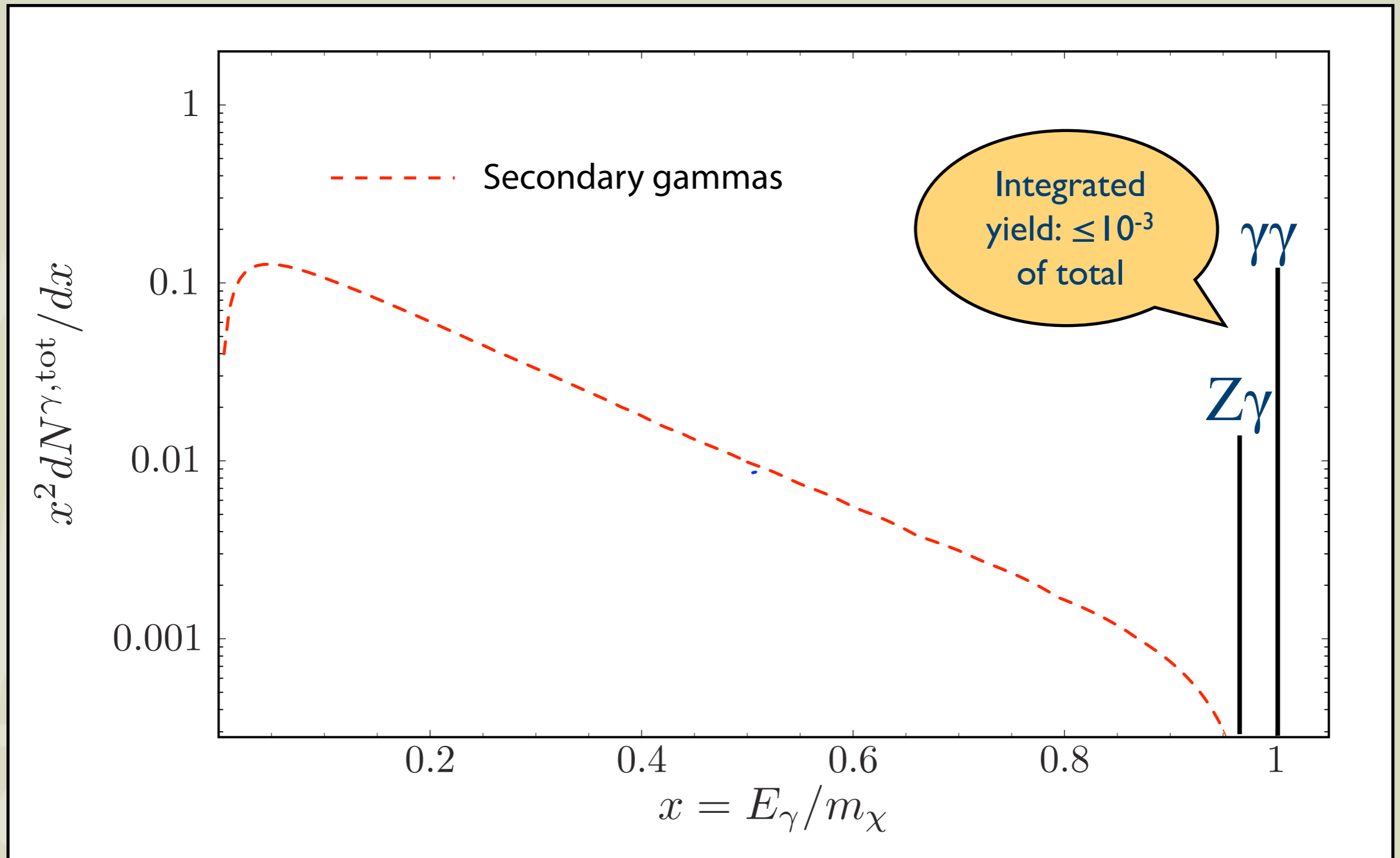
with

$$S = N_\gamma \frac{\langle \sigma v \rangle}{10^{-29} \text{ cm}^3 \text{ s}^{-1}} \left(\frac{100 \text{ GeV}}{m_\chi} \right)^2 \quad \text{Particle physics (SUSY, ...)}$$

$$\langle J(\eta, \Delta\Omega) \rangle = \frac{1}{8.5 \text{ kpc}} \frac{1}{\Delta\Omega} \int_{\Delta\Omega} \int_{\text{line of sight}} \left(\frac{\rho(l)}{0.3 \text{ GeV/cm}^3} \right)^2 dl(\eta) d\Omega$$

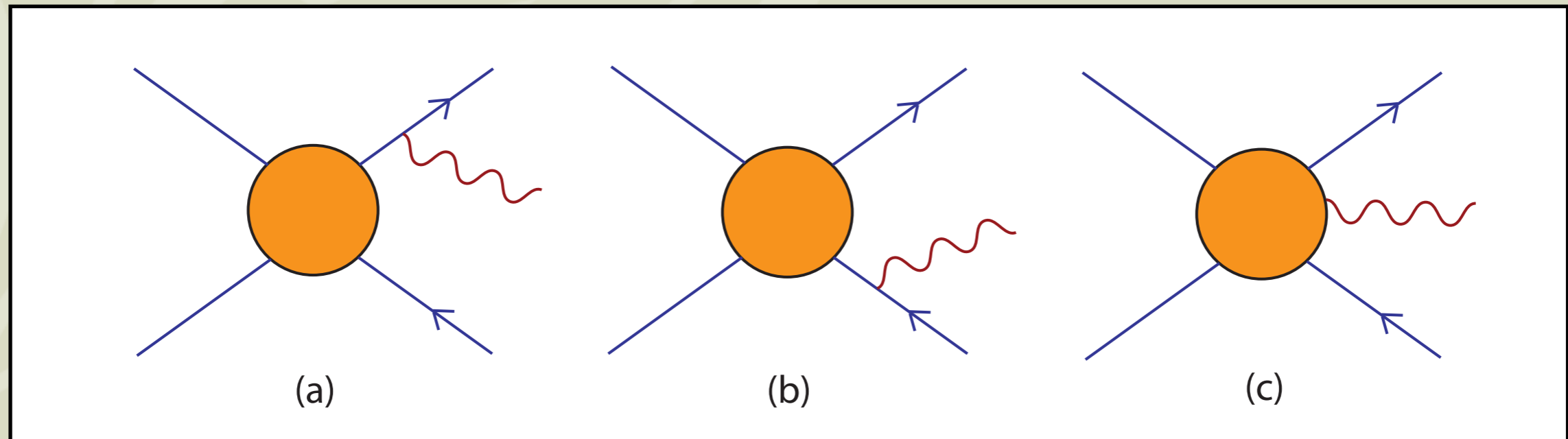
Astrophysics

Typical gamma ray spectrum

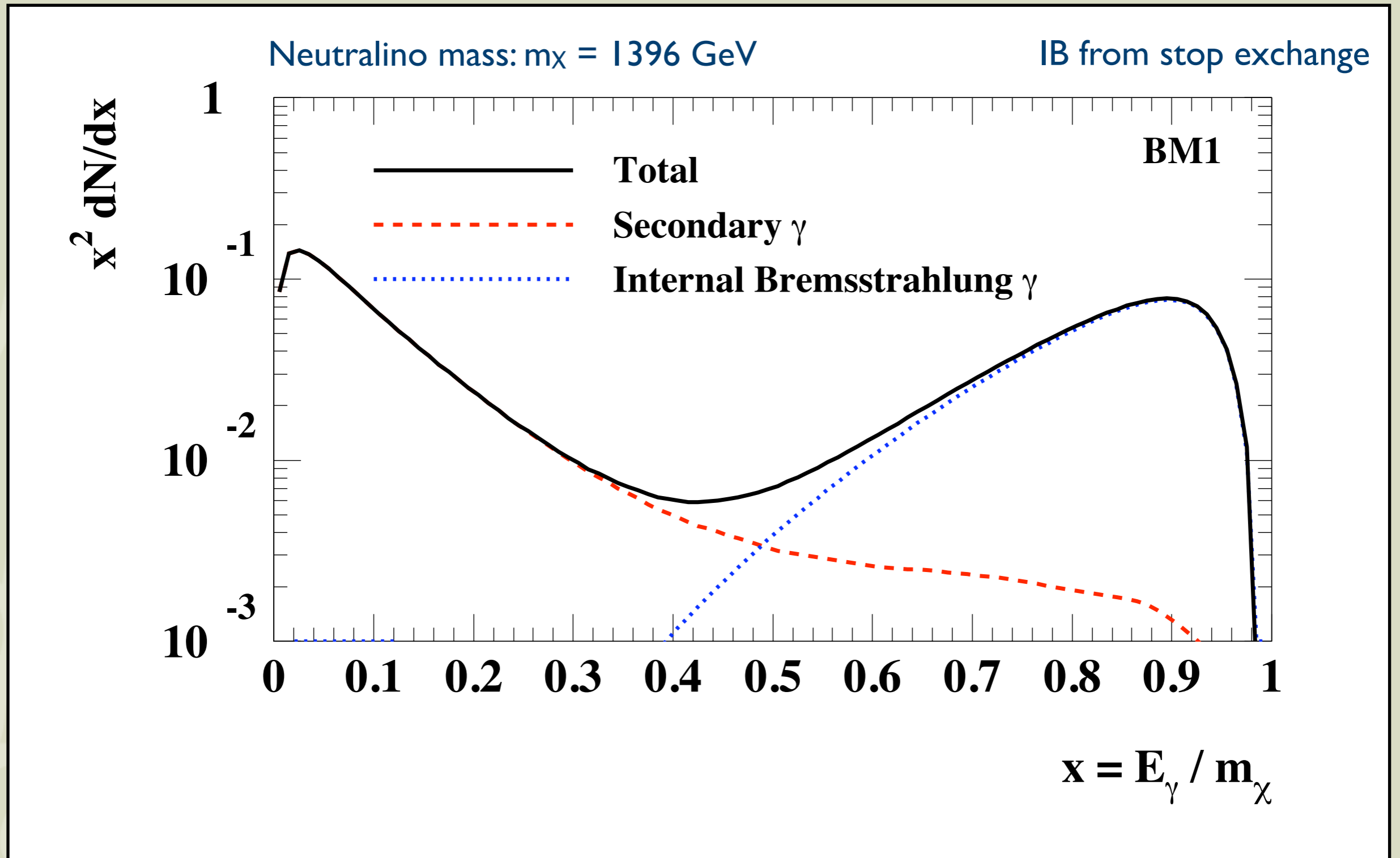


Internal Bremsstrahlung

- Whenever charged final states are present, photons can also be produced in internal bremsstrahlung processes



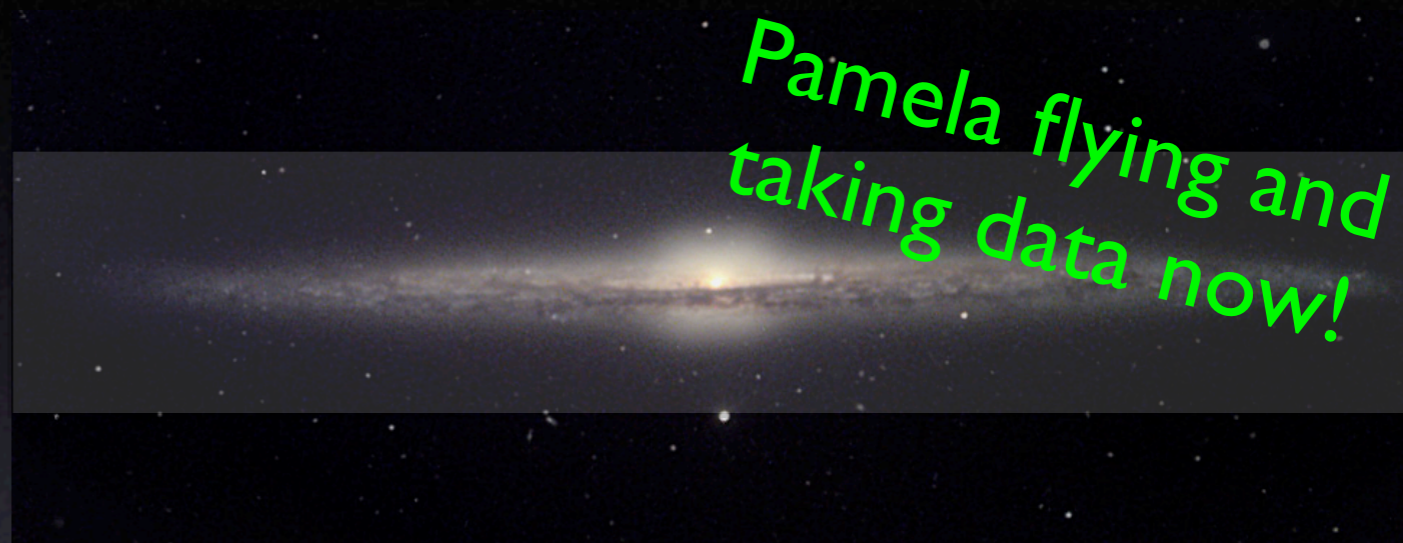
Gamma ray spectrum including IB photons I





Charged cosmic rays

- Antiprotons
- Positrons
- Antideuterons
- Diffusion and energy losses included
- Different halo profiles (even clumpy halos)
- Different diffusion treatments, e.g. Moskalenko-Strong Green's functions
- (Very) beta-interface to GALPROP



Diffusion model

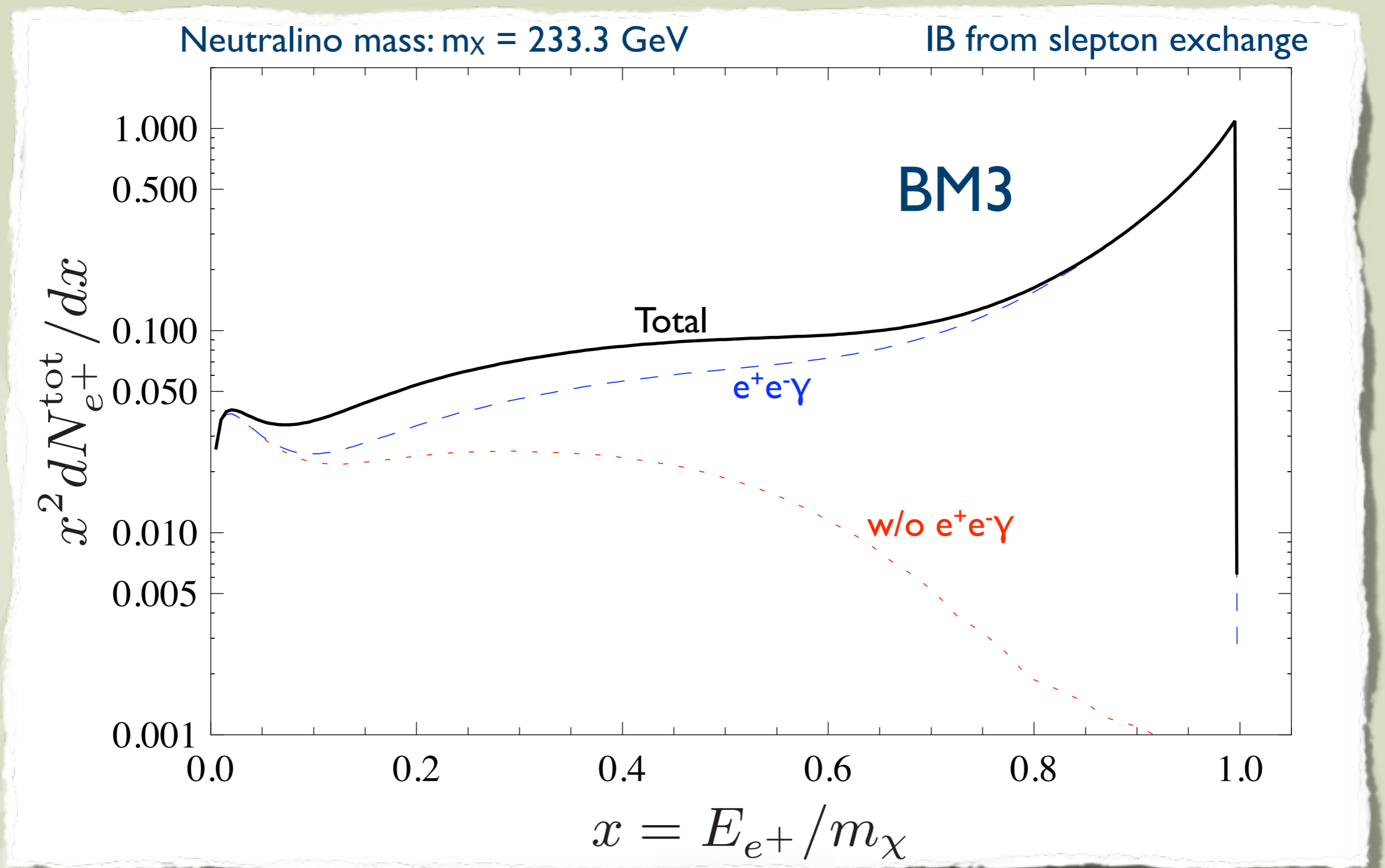
- Cylindrical diffusion model with free escape at the boundaries
- Energy losses on the interstellar medium (for antiprotons and antideuterons) or starlight and CMB (for positrons)
- Reacceleration can change the energy of the particles (can partly be mimicked by a break in the diffusion coefficient)



Galprop interface

- The interface to galprop has these main ingredients:
 - galprop has a new routine that gets the density profile of dark matter in the halo from DarkSUSY
 - galprop uses this to calculate the Green's functions which are transferred to DarkSUSY
 - DarkSUSY integrates these Green's functions and the source spectrum over energy to get the propagated spectrum
 - The Green's functions are tabulated so that Galprop does not need to be rerun every time.

Example of IB contribution on e^+ spectrum



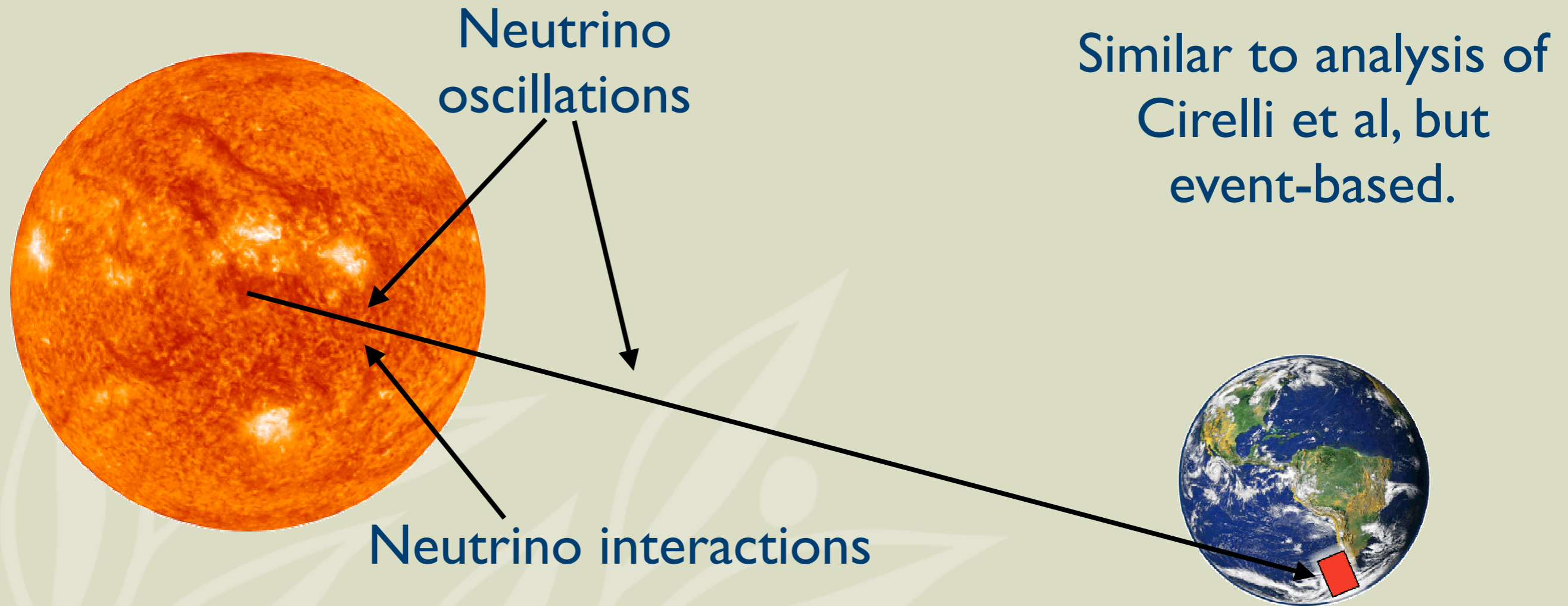
Very nice spectral feature!



Neutrinos from Sun/Earth

- Rate of neutrino-induced muons in neutrino telescopes
- Neutrino scattering and absorption in Sun included
- Fully numerical capture calculation with any velocity distribution
- Detailed solar system diffusion yielding depletion of capture by the Earth
- Damour-Krauss population of WIMPs
- Neutrino oscillations, all flavours and hadronic showers

Neutrino oscillations



- New numerical calculation of interactions and oscillations in a fully three-flavour scenario. Regeneration from tau leptons also included.
- **Publicly available code:** WimpSim:WimpAnn + WimpEvent suitable for event Monte Carlo codes: www.physto.se/~edsjo/wimpsim
- Main results are included in DarkSUSY.

WimpSim summary files in DarkSUSY

- Simulations for 19 masses from 10 GeV to 10 TeV have been performed for all ‘fundamental’ annihilation channels: $d \bar{d}$, $u \bar{u}$, $s \bar{s}$, $c \bar{c}$, $b \bar{b}$, $t \bar{t}$, gluon gluon, W^+W^- , $Z^0 Z^0$, $\mu^- \mu^+$, $\tau^- \tau^+$, $\nu_e \bar{\nu}_e$, $\nu_\mu \bar{\nu}_\mu$, ν_τ , $\nu_\tau \bar{\nu}_\tau$. For each mass and channel, 10^7 events are generated.
- These neutrinos are then let to interact via NC or CC interactions at the detector (for simplicity, IceCube is chosen) and we have stored distributions of
 - all flavour neutrinos at the detector (1-6)
 - all flavour charged leptons at neutrino-nucleon vertex (7-12)
 - μ^- and μ^+ after propagation at detector (at an imaginary plane) (13-14)
 - hadronic showers from CC interactions for all flavours (15-20)
 - hadronic showers from NC interactions for all flavours (21-26)
- All these are stored both integrated (in energy and angle) and differential (in energy and angle).

Putting everything together

- The routine **dswayieldf** returns the yield for a given mass, energy, angle, annihilation channel and type (previous slide). This routine reads and interpolates in the summary tables from WimpSim.
- For a given SUSY model, one can preferably call **dswayield** that returns the summed yield for all annihilation channels for the given model. Higgses in the final state (e.g. from the channel $Z H$) are taken care of by integration over their decay angles in flight (and properly Lorentz-boosting the yields) using the known decay widths of the Higgses.
- The routine **dsntrates**
 - calculates these yields and
 - calculates the capture and annihilation rates in the Sun and Earth given the scattering and annihilation cross sections, and puts this together for the flux of neutrino-induced muons (μ^- & μ^+) at the detector.

Side-remark on neutrino and muon fluxes

- The results of WimpSim are also put together as a conversion script which can convert between various fluxes with different thresholds:

<http://copsosx03.physto.se/cgi-bin/edsjo/wimpsim/flxconv.cgi>

- This can be useful for comparisons between different experiments with different thresholds for example.



SLHA2 Interface - writing

- DarkSUSY now uses SLHALIB by T. Hahn to read and write SLHA2 files.
- DarkSUSY outputs general MSSM SLHA2 files where we have chosen a midway between dumping everything and just giving input parameters.
- We **need feedback** from users of other codes!
 - Should we give some other blocks as well?
 - Are we too general? E.g., is the 6x6 USqMix block too general?



SLHA2 Interface - reading

- When reading SLHA2 files DarkSUSY preferably wants them in rather general form (e.g. with 6x6 USqMix blocks etc)
- Not all cases DarkSUSY can handle internally have been implemented in the SLHA2 interface (it takes a lot of time to cover all possibilities).
- Hence, we **need feedback** here too!
 - Can DarkSUSY read your SLHA2 files?



SLHA2 issues

- Some unclear points (to me at least):
 - Which is the priority order in which I should read SLHA Blocks?
 - Could one add a human readable tag identifying the model by name? In DarkSUSY, we have a character*12 idtag that one can use as a unique tag for each model
 - Should I add the possibility to write SLHA files of different complexity?
 - Should I enforce things DarkSUSY wants?
Example: we calculate $\sin^2 \theta_W$ on-shell from G_F and derive m_W at tree level from this and m_Z . However, in the SLHA accord, G_F AND m_W can be given. Should I use that m_W or recalculate it?



SLHA2 summary

- Basic SLHA interface now included
- Expect rapid development of these routines
- How rapid?
That depends on input from you!



Other changes since 4.1

1/5

Version history for DarkSUSY

=====

===== VERSION HISTORY

----- Version: 5.0 (July 3, 2008)

- * Changed the convention for the quark masses in the mass array. For u, d and s, we now put the quark masses at 2 GeV in the MS-bar scheme in the array and for c, b and t, we put the pole masses.
- * Changed the default top mass from 175 GeV to 172.7 GeV.
- * Changed SM input from $\sin^2 \theta_W$ to GF (the Fermi constant from muon decay). As a consequence of this, we now calculate $\sin^2 \theta_W$ from GF with on-shell formulas in PDG. From this value of $\sin^2 \theta_W$ we then enforce the tree-level relations between M_Z , $\sin^2 \theta_W$ and M_W to determine the M_W mass. In practice, this procedure gives a lower value of $\sin^2 \theta_W$ and a higher value of M_W than before which affects some cross sections.



Other changes since 4.1

2/5

- * Added routines to do 4-loop running of quark masses. In the future, we will use these routines more extensively to put the masses at more suitable scales for each given process.
- * Added an interface to read and write SUSY Les Houches Accord (SLHA) files. There are many options that can be considered in the SLHA convention and not all are covered with the current version of the interface, so this will be an evolving part of DarkSUSY.
- * FeynHiggs updated to version 2.6.3
- * Isajet updated to version 7.78.
- * Changed effective degrees of freedom in the early Universe to Hindmarsch & Philipsen set B (increases the relic density by 1.5% - 3.5%).
- * Full 6x6 sfermion diagonalization now possible. Note though that not all other routines can make full use of this extra freedom yet.
- * New neutrino telescope rate routines with full three flavour information and neutrino oscillations.



Other changes since 4.1

3/5

- * A bug in halo annihilation routines that incorrectly took away the yield from some decay channels from Higgs bosons decaying in flight has been corrected. This bug affected the cascade decay of neutral Higgs bosons that decayed to gauge bosons and the decay of the charged Higgs boson.
- * Changed default halo profile to NFW instead of a cored isothermal sphere.
- * Added new standard model calculation of $b \rightarrow s$ gamma (dsbsg2007full.f) and updated the accelerator bounds for $b \rightarrow s$ gamma (dsacbnd7 is now the new default).
- * Added internal bremsstrahlung (IB) photons (FSR and VIB photons). These appear at high energies when e.g. there are degeneracies between the lightest neutralino and sfermions, or for H_{+-} and W_{+-} final states.
- * First galprop interface added
- * Now uses a configure script to set up the makefiles before compilation. It is now possible to install DarkSUSY in your favourite location (e.g. /usr/local). The default is to install in the DarkSUSY directory itself.



Other changes since 4.1

4/5

- * Small fixes to the sfermion coannihilation routines (now with complete CKM mixings). This affects mainly high-mass neutralinos.

----- Version 4.1.6: April, 2006 -----

- * Cleaned up the earth density and composition routines.
- * Added routines that calculate the electron density in the Earth as a function of the radius (needed for neutrino oscillation code). Column densities in the Sun are now also present.

----- Version 4.1.5: April, 2006 -----

- * Merged together different subversions. Added a cleaner way of adding coannihilating particles (everything is done in dsrdomega now).
- * Small bug fixes in the relic density routines (rare infinite loops caught)
- * A bug in the full numerical solar capture rates fixed (the rates were over-estimated by 6%).



Other changes since 4.1

5/5

- * New standard solar model used: BS05(OP). Gives very good agreement with the old BP2000 model, but with about 1% higher capture rates. The new alternative solar model, BS05(AGS,OP) with new heavy element abundances is also available. This model give a 4% higher capture rate on Hydrongen, but lower (about 20%) on the heavier elements. However, it doesn't fit helioseismology as well, so we use the BS05(OP) as the default.

----- Version 4.1.4: December, 2005 -----

- * Started adding routines to get column densities etc in the Sun. These are then used by an external neutrino oscillation code.

----- Version 4.1.2: September, 2005 -----

- * Fixed a problem with sfermion coannihilations at very high masses.
- * Changed artificial width of sparticles to work better with very high mass models.

----- Version 4.1.1: November 17, 2004 -----

- * Fixed a bug which could cause the relic density routines to crash if the print level was set to print all information/error messages



Manual

- A manual (not fully up-to date yet and doesn't cover everything) is distributed with DarkSUSY, create with

make pdf-manual

(to make the default manual)

make pdf-manual-short

to make a short version (without subroutine headers).

- Also see the headers of various subroutines for instructions.

[Show manual]



Future improvements

- SLHA2: More work needed to cover all possible cases DarkSUSY can handle and add options to write out simpler versions
- Add interfaces to more codes (via SLHA2 preferably): SDecay, SuperIso, SusyBSG, HiggsBounds, Suspect, ...
- Add full 6x6 squark mixing everywhere (will slow down relic density routines though)
- In the long run: MSSM-124
- More careful use of running masses to appropriate scales in different routines
- ...



Reference / download

- DarkSUSY 5.0 is available at www.physto.se/~edsjo/darksusy
- Long paper, describing DarkSUSY 4 available as JCAP 06 (2004) 004 [astro-ph/0406204]
- Manual (pdf and html) available

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DarkSUSY: computing supersymmetric dark-matter properties numerically

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DarkSUSY online

- If you don't want to download DarkSUSY, you can use DarkSUSY online:

<http://copsosx03.physto.se/dsweb42.html>

- The web interface will be updated shortly to allow the possibility of uploading an SLHA2 file.

Side-remark on neutrino and muon fluxes

- The results of WimpSim are also put together as a conversion script which can convert between various fluxes with different thresholds:

<http://copsosx03.physto.se/cgi-bin/edsjo/wimpsim/flxconv.cgi>

- This can be useful for comparisons between different experiments with different thresholds for example.