micrOMEGAs :
A tool for dark matter studies

G. Bélanger
LAPTH

G. B, F. Boudjema, A. Pukhov, A. Semenov
hep-ph/0112278, hep-ph/0405253,
hep-ph/0607059, arXiv:08032360[hep-ph]

Outline

- Motivation
- Relic density
- Dark matter candidates
- Dark matter direct/indirect detection
- Outlook

Motivation

- Strong evidence for dark matter
- CMB (WMAP+SDSS) gives precise information on the amount of dark matter
- Most attractive explanation for dark matter: new weakly interacting particle
- Cosmological measurements strongly constrains models of cold dark matter
- Need for a precise and accurate computation of the relic density of dark matter
- Public codes that compute relic density in MSSM
  - Neutdriver, micrOMEGAs, DarkSUSY, Isatools, SuperIso(2009)

  and many private codes: SSARD (Olive), Roszkowski, Drees …

- Many models for new physics whose main motivation is to solve the hierarchy problem also have a dark matter candidate – symmetry that ensures that lightest particle is stable

- R-parity like symmetry introduced to avoid rapid proton decay or guarantee agreement with electroweak precision

- Examples:
  - MSSM and extensions, UED, Warped Xtra-Dim, Little Higgs, Extended Higgs …..

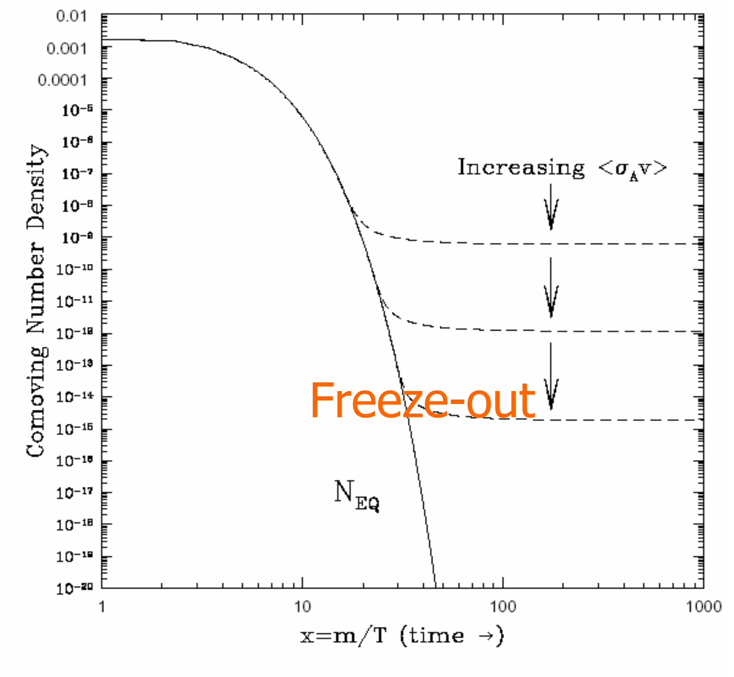
- *Need for a tool that provide precise calculation of the relic density of dark matter in a wide variety of models - micrOMEGAs_2.0*

- *To uncover the nature of dark matter : need complementary detection method both from astroparticle and colliders*

- *Complete tool for dark matter studies : relic density, direct detection, indirect detection, cross section at colliders and decays: micrOMEGAs_2.2*
  - *next release micrOMEGAs_2.4*

Relic density of wimps

- In early universe WIMPs are present in large number and they are in thermal equilibrium
- As the universe expanded and cooled their density is reduced through pair annihilation
- Eventually density is too low for annihilation process to keep up with expansion rate
  - Freeze-out temperature
- LSP decouples from standard model particles, density depends only on expansion rate of the universe



$$\frac{dn}{dt} = -3Hn - < \sigma v > \left[n^2 - n_{eq}^2 \right]$$

$$\frac{dY}{dT} = \sqrt{\frac{\pi g_*(T)}{45}} M_p < \sigma v > (Y(T)^2 - Y_{eq}(T)^2)$$

Solving numerically, get present day abundance $Y(T_0)$ and

$$\Omega_{LOP} h^2 = \frac{8\pi}{3} \frac{s(T_0)}{M_p^2(100(\mathrm{km/s/Mpc}))^2} M_{LOP} Y(T_0) = 2.742 \times 10^8 \frac{M_{LOP}}{GeV} Y(T_0)$$

Weakly interacting particle gives roughly the right annihilation cross section to have $\Omega h^2 \sim 0.1$ ‘WIMP miracle’

$$\Omega_X h^2 \approx \frac{3 \times 10^{-27} \mathrm{cm}^3 \mathrm{s}^{-1}}{\langle \sigma v \rangle} \quad .$$

Typical annihilation cross-section at FO $< \sigma v >= 3 \times 10^{-26} \mathrm{cm}^3/\mathrm{sec}$

Coannihilation

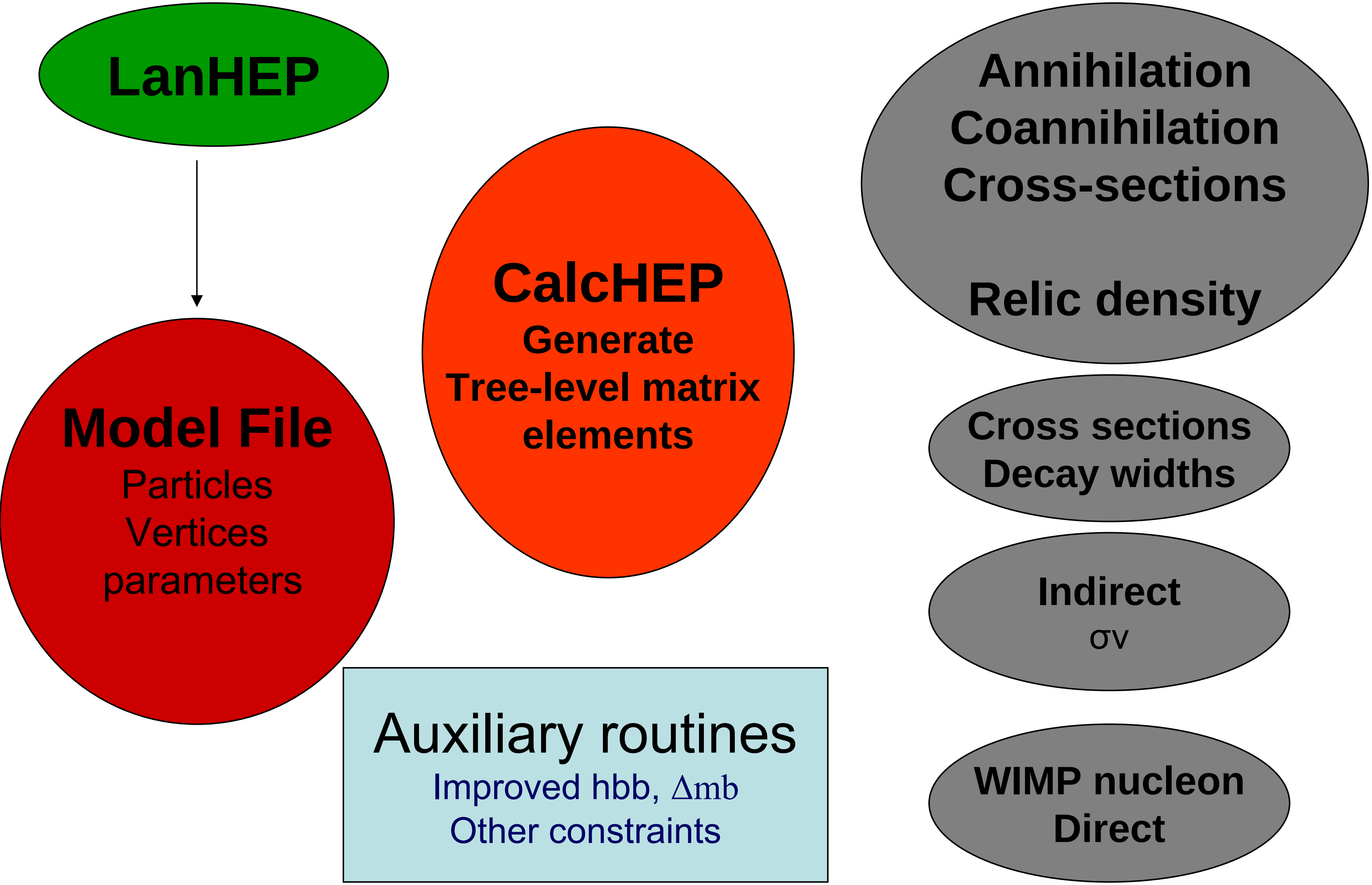
- If M(NLSP)~M(LSP) then $\chi + X \longrightarrow \chi' + Y$ maintains thermal equilibrium between NLSP-LSP even after non standard particles decouple from standard ones
- Relic density depends on rate for all processes involving LSP/NLSP → SM
- All particles eventually decay into LSP, calculation of relic density requires summing over all possible processes

Exp(- ΔM)/T

$$< \sigma v >= \frac{\sum_{i,j} g_i g_j \int_{(m_i+m_j)^2} ds \sqrt{s} K_1(\sqrt{s}/T) p_{ij}^2 \sigma_{ij}(s)}{2T \left(\sum_i g_i m_i^2 K_2(m_i/T)\right)^2}$$

- **Important processes are those involving particles close in mass to LSP, for example up to 3000 processes can contribute in MSSM**
- *Need for automation*

microMEGAs



LanHEP

Model File
Particles
Vertices
parameters

CalcHEP
Generate
Tree-level matrix
elements

Auxiliary routines
Improved hbb, Δmb
Other constraints

Annihilation
Coannihilation
Cross-sections

Relic density

Cross sections
Decay widths

Indirect
σv

WIMP nucleon
Direct

micrOMEGAs_2.2

- A generic program to calculate DM properties in any model
- Assume some “ R-parity “, particles odd/even under R (odd particles: ~)
- Need to specify model file in CalcHEP notation : particles, variables, vertices, functions (do by hand or with LanHEP)
- After the model is implemented and checked with CalcHEP
  - Code then automatically looks for “LSP”
  - Computes all annihilation and coannihilation cross-sections
  - Complete tree-level matrix elements for all subprocesses
  - Automatically check for presence of resonances and improves the accuracy near pole
  - Numerical solution of evolution equation and calculation of relic density with non-relativistic thermal averaging and proper treatment of poles and thresholds
    - Gondolo, Gelmini, NPB 360 (1991)145
    - coannihilation : Edsjo, Gondolo PRD56(1997) 1879

- Includes and compiles relevant channels only if needed (Beps)

$$B = \frac{K_1((m_i + m_j)/T)}{K_1(2m_{LOP}/T)} \approx e^{-X\frac{(m_i+m_j-2M_{LOP})}{M_{LOP}}} > B_\epsilon$$

- Calculates the relic density for any LSP (even charged)
- Computes σv, v->0 for LSP,LSP annihilation → indirect detection
- Automatically compute elastic scattering rate on nucleon/nucleus

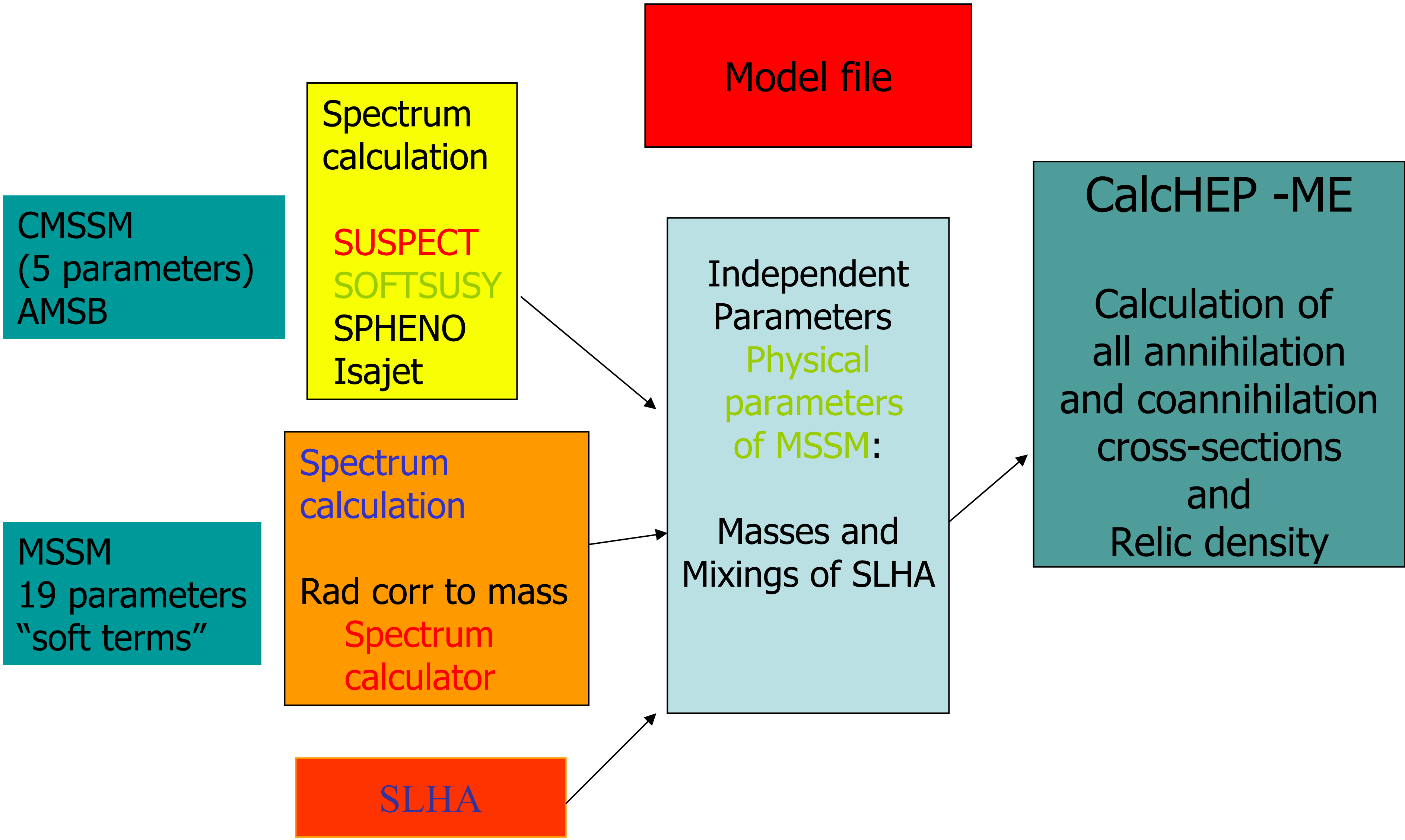
- CalcHEP is included: computes all 2->2 processes and 1-> 2,3 decays at tree-level
- Some facilities provided for pp collisions
- Interactive link to CalcHEP

- *For new models : constraints and auxiliary routines must be provided by the user in fortran or C routine*
- C code

Dark matter models

- Models distributed
  - MSSM
  - NMSSM (with C. Hugonie, hep-ph/0505142)
  - CPV-MSSM (with S. Kraml, hep-ph/0604150)
  - Right-handed neutrino (with G. Servant, arXiv:0706.0526)
  - Little Higgs (A. Belyaev)
  - SUSY N=2 (with K. Benakli et al arXiv:0905.1043)- next release
- Other models available

MSSM model file



Model file

CMSSM
(5 parameters)
AMSB

Spectrum
calculation

SUSPECT
SOFTSUSY
SPHENO
Isajet

MSSM
19 parameters
"soft terms"

Spectrum
calculation

Rad corr to mass
Spectrum
calculator

SLHA

Independent
Parameters
Physical
parameters
of MSSM:

Masses and
Mixings of SLHA

CalcHEP -ME

Calculation of
all annihilation
and coannihilation
cross-sections
and
Relic density

MSSM-Specific features

- Independent parameters of model are physical parameters of SHLA, flexibility: any model for which the MSSM spectrum can be calculated with an external code can be incorporated easily
- Input parameters to micromegas can be specified at the weak scale or at the GUT scale using some SpectrumCalc program, includes CMSSM, non-univ. SUGRA, AMSB
- ***Uses SUSY Les Houches Accord***
- Radiative corrections to masses can be important – SUSY masses and Higgs masses (via spectrum calculator)
- Package includes other constraints (developed for MSSM) – not automatic

  b->s γ (NLO) , (g-2) $_{\mu,}$ B_s->$\mu\mu$, B->$\tau\nu$, $\Delta\rho$

Higgs sector

- General CP conserving effective potential

$$
\begin{aligned}
V_{eff} \;=\; & (m_1^2+\mu^2)|H_1|^2 + (m_2^2+\mu^2)|H_2|^2 - [m_{12}^2(\epsilon H_1 H_2) + h.c.] \\
& + \frac{1}{2}[\frac{1}{4}(g^2+g'^2)+\lambda_1](|H_1|^2)^2 + \frac{1}{2}[\frac{1}{4}(g^2+g'^2)+\lambda_2](|H_2|^2)^2 \\
& + [\frac{1}{4}(g^2-g'^2)+\lambda_3]|H_1|^2|H_2|^2 + [-\frac{1}{2}g^2+\lambda_4](\epsilon H_1 H_2)(\epsilon H_1^* H_2^*) \\
& + (\frac{\lambda_5}{2}(\epsilon H_1 H_2)^2 + [\lambda_6|H_1|^2 + \lambda_7|H_2|^2](\epsilon H_1 H_2) + h.c.)
\end{aligned}
$$

- Higgs masses computed with high precision, available either in FeynHiggs or via spectrum calculator, with the effective potential have a consistent gauge invariant way of taking these corrections into account

- λ's include higher order corrections, extracted from Higgs masses and mixings (Boudjema, Semenov, hep-ph/0201219)

Higgs sector

- QCD corrections to Higgs couplings to fermion pairs ($m_{b\ eff}$ ($2M_{LSP}$))

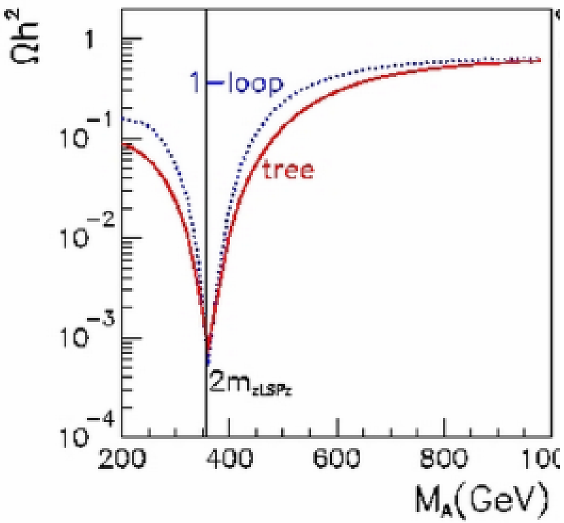
$a=\alpha/\pi$

$$\begin{aligned} M^2_{eff}(Q) &= M(Q)^2\left[1+5.67a+(35.94-1.36n_f)a^2\right. \\ &+ \left.(164.14-n_f(25.77-0.259n_f))a^3\right] \end{aligned}$$

- SUSY-QCD correction to Higgs->bb, effective Lagrangian, relevant at large tanβ
  - Guasch, Hapfliger, Spira, hep-ph/0305101

$$\begin{aligned} \mathcal{L}_{eff} = \sqrt{4\pi\alpha_{QED}}\frac{m_b}{1+\Delta m_b}\frac{1}{2M_W\sin\theta_W}&\left[-Hb\bar{b}\frac{\cos\alpha}{\cos\beta}\left(1+\frac{\Delta m_b\tan\alpha}{\tan\beta}\right)\right. \\ &\left.+iAb\bar{b}\tan\beta\left(1-\frac{\Delta m_b}{\tan\beta^2}\right)+hb\bar{b}\,\frac{1}{\cos\beta}\left(1-\frac{\Delta m_b}{\tan\alpha\tan\beta}\right)\right] \end{aligned}$$

Why improved couplings matter



Extensions of MSSM

- Spectrum calculation, constraints on models: make use of existing programs develop independently, when possible interface with SLHA2
  - NMSSM
    - relies on NMSSMTools (NMSPEC and NMHDECAY) for spectrum calculation, indirect constraints (B physics, g-2, Higgs collider constraitns)
    - Ellwanger, Gunion, Hugonie
  - CPVMSSM :
    - interface to CPSuperH (J.S. Lee et al) for spectrum calculation, effective Higgs potential and constraints: edm, Bphysics
    - Interface to Higgs bounds for LEP/Tevatron Higgs constraints (next release)

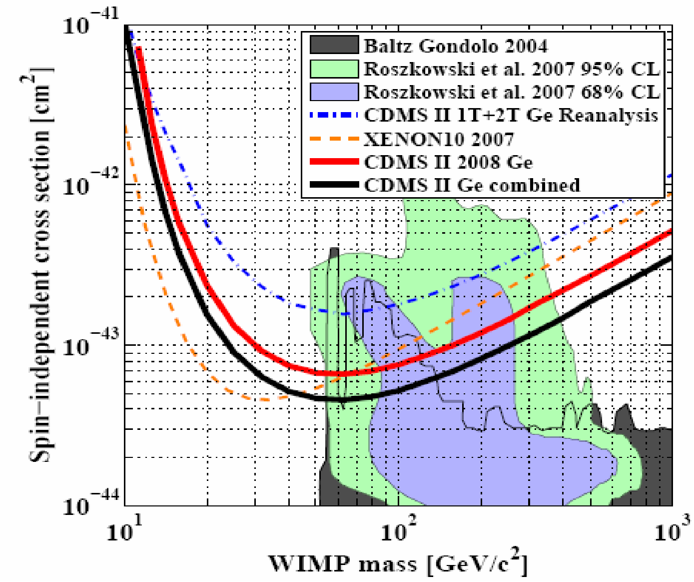
Direct detection

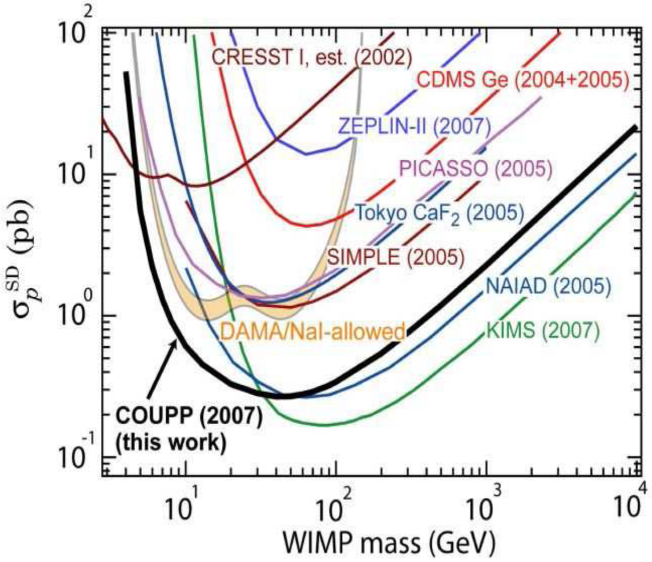
- Elastic scattering of WIMPs off nuclei in a large detector
- Measure nuclear recoil energy, E_R
- Would give best evidence that WIMPs form DM
- Two types of scattering
  - Coherent scattering on A nucleons in nucleus, for spin independent interactions
    - Dominant for heavy nuclei
  - Spin dependent interactions – only on one unpaired nucleon
    - Dominant for light nuclei

Direct detection

- Limits on LSP-nucleon cross section are improving every year, both for SI and SD
  - probe regions of parameter space of MSSM
  - constrain severely some other models (e.g. RHN)

- Recent results :
  - CDMS (0802.353 [astro-ph])
  - KIMS, COUPP (0804.2886[astro-ph])
  - DAMA confirm their annual modulation signal

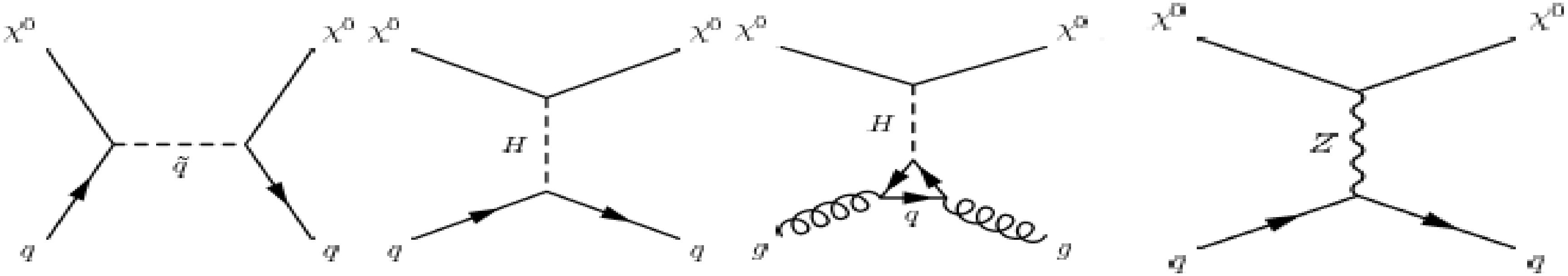




Direct detection

- Typical diagrams

- Higgs exchange often dominates



For Dirac fermions Z exchange contributes to SI and SD

WIMP- Nucleon amplitude

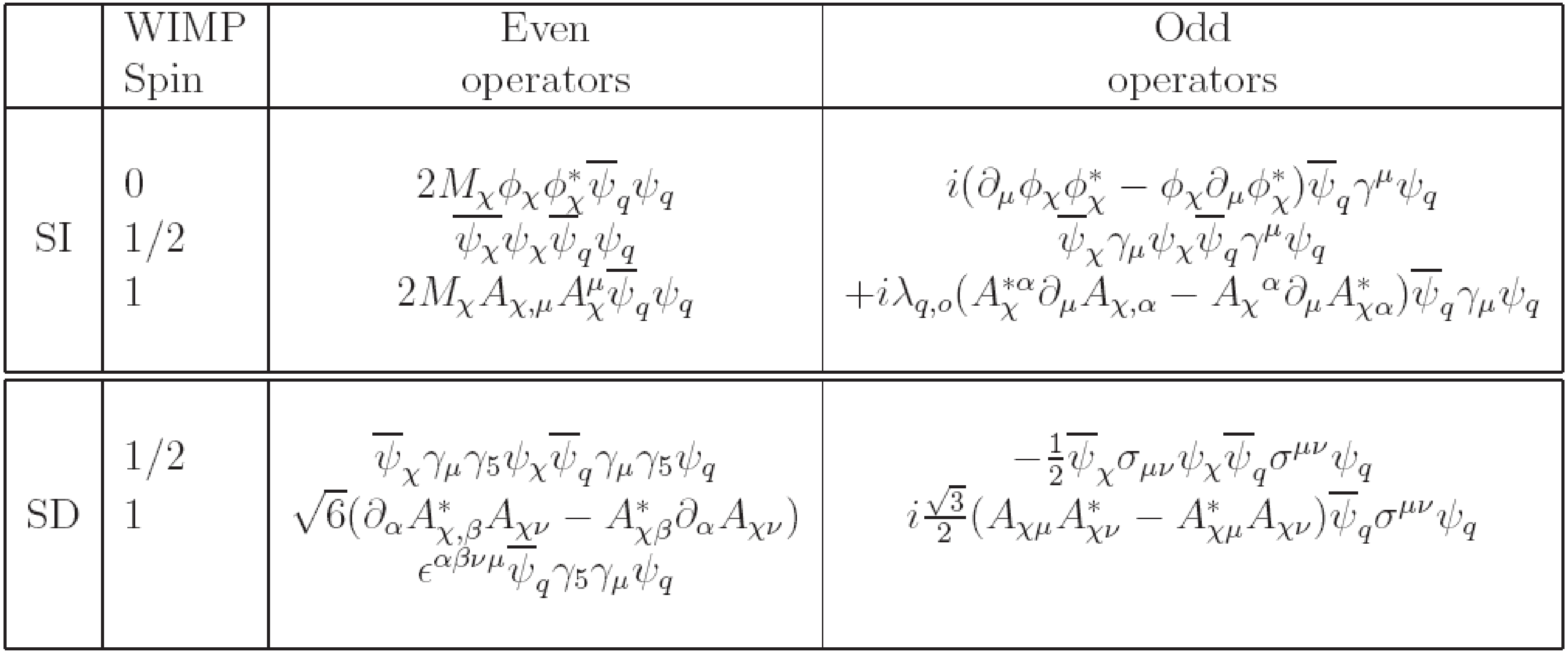
- For any WIMP, need effective Lagrangian for WIMP-nucleon amplitude *at small momentum ~100MeV*,
- Generic form for a fermion

$$
\begin{aligned}
\mathcal{L}_F = & \boxed{\lambda_N \bar{\psi}_\chi \psi_\chi \bar{\psi}_N \psi_N} + i\kappa_1 \bar{\psi}_\chi \psi_\chi \bar{\psi}_N \gamma_5 \psi_N + i\kappa_2 \bar{\psi}_\chi \gamma_5 \psi_\chi \bar{\psi}_N \psi_N + \kappa_3 \bar{\psi}_\chi \gamma_5 \psi_\chi \bar{\psi}_N \gamma_5 \psi_N \\
+ & \kappa_4 \bar{\psi}_\chi \gamma_\mu \gamma_5 \psi_\chi \bar{\psi}_N \gamma^\mu \psi_N + \boxed{\xi_N \bar{\psi}_\chi \gamma_\mu \gamma_5 \psi_\chi \bar{\psi}_N \gamma^\mu \gamma_5 \psi_N}
\end{aligned}
$$

- For Majorana fermion only 2 operators survive at small q^2

- First need to compute the WIMP quark amplitudes
  - normally computed symbolically from Feynman diagrams+ Fierz
  - Automatic approach (works for all models)
- Effective Lagrangian for WIMP-quark scattering has same generic form as WIMP nucleon

WIMP quark effective Lagrangian



	WIMP Spin	Even operators	Odd operators
SI	0	$2M_\chi \phi_\chi \phi^*_\chi \overline{\psi}_q \psi_q$	$i(\partial_\mu \phi_\chi \phi^*_\chi - \phi_\chi \partial_\mu \phi^*_\chi)\overline{\psi}_q \gamma^\mu \psi_q$
	1/2	$\overline{\psi}_\chi \psi_\chi \overline{\psi}_q \psi_q$	$\overline{\psi}_\chi \gamma_\mu \psi_\chi \overline{\psi}_q \gamma^\mu \psi_q$
	1	$2M_\chi A_{\chi,\mu} A^\mu_\chi \overline{\psi}_q \psi_q$	$+i\lambda_{q,o}(A^{*\alpha}_\chi \partial_\mu A_{\chi,\alpha} - A_\chi{}^\alpha \partial_\mu A^*_{\chi\alpha})\overline{\psi}_q \gamma_\mu \psi_q$
SD	1/2	$\overline{\psi}_\chi \gamma_\mu \gamma_5 \psi_\chi \overline{\psi}_q \gamma_\mu \gamma_5 \psi_q$	$-\frac{1}{2}\overline{\psi}_\chi \sigma_{\mu\nu} \psi_\chi \overline{\psi}_q \sigma^{\mu\nu} \psi_q$
	1	$\sqrt{6}(\partial_\alpha A^*_{\chi,\beta} A_{\chi\nu} - A^*_{\chi\beta} \partial_\alpha A_{\chi\nu})$ $\epsilon^{\alpha\beta\nu\mu} \overline{\psi}_q \gamma_5 \gamma_\mu \psi_q$	$i\frac{\sqrt{3}}{2}(A_{\chi\mu} A^*_{\chi\nu} - A^*_{\chi\mu} A_{\chi\nu})\overline{\psi}_q \sigma^{\mu\nu} \psi_q$

- Operators for WIMP quark Lagrangian, extract automatically the coefficients for SI and SD –

$$\hat{\mathcal{L}}_{eff}(x) = \sum_{q,s} \lambda_{q,s} \hat{O}_{q,s}(x) + \xi_{q,s} \hat{O}'_{q,s}(x)$$

- In micrOMEGAs: evaluate coefficients numerically using projection operators
- Add all projection operators as new vertices in the model
- Compute χq-χq scattering element at zero momentum transfer
- Interference between one projection operator and effective vertex- single out SI or SD contribution

$$\lambda_{q,e} + \lambda_{q,o} = \frac{-i\langle q(p_1), \chi(p_2)|\hat{S}\hat{O}_{q,e}|q(p_1), \chi(p_2)\rangle}{\langle q(p_1), \chi(p_2)|\hat{O}_{q,e}\hat{O}_{q,e}|q(p_1), \chi(p_2)\rangle}$$

- Use quark and anti-quark scattering elements to split even/odd contributions
- The projection operators are added to the model file by micrOMEGAs
- Warning: in the model file must include couplings proportional to light quark masses (eg. Hqq coupling)

WIMP-quark to WIMP-nucleon

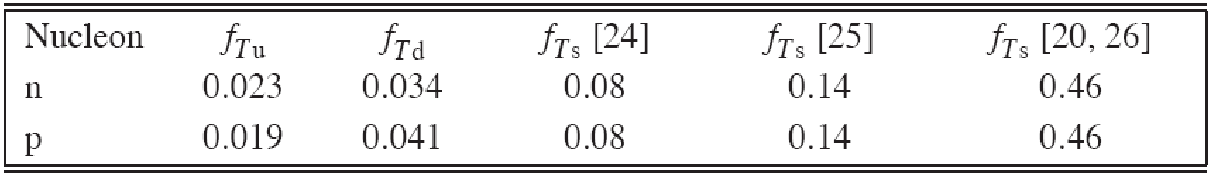
- Coefficients relate WIMP-quark operators to WIMP nucleon operators
  - Scalar, vector, pseudovector, tensor
  - Extracted from experiments
  - Source of theoretical uncertainties
- Example , scalar coefficients, contribution of q to nucleon mass (heavy quark contribution expressed in terms of gluonic content)

$$\langle N | m_q \overline{\psi}_q \psi_q | N \rangle = f_q^N M_N$$

$$\lambda_{N,p} = \sum_{q=1,6} f_q^N \lambda_{q,p} \qquad f_Q^N = \frac{2}{27}\left(1 - \sum_{q\leq 3} f_q^N\right)$$

- Scalar coefficients extracted from ratios of light quark masses, pion-nucleon sigma term and σ_0 (size of SU(3) breaking effect)

- Large uncertainty in s-quark contribution

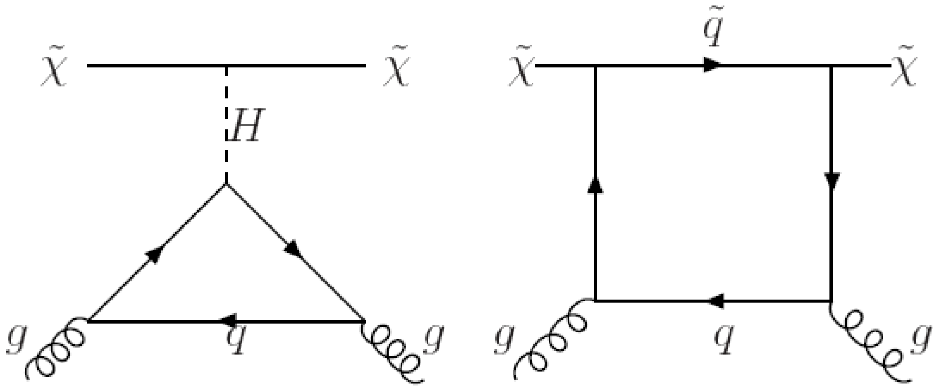


Nucleon	f_{Tu}	f_{Td}	f_{Ts} [24]	f_{Ts} [25]	f_{Ts} [20, 26]
n	0.023	0.034	0.08	0.14	0.46
p	0.019	0.041	0.08	0.14	0.46

- Lattice calculations have provide new estimates of those coefficients – soon should help reduce uncertainties

- For example varying coefficients within this range can in the MSSM lead to almost one order of magnitude change in cross section
  - Bottino et al hep-ph/0010203, Ellis et al hep-ph/0502001

Gluon and QCD



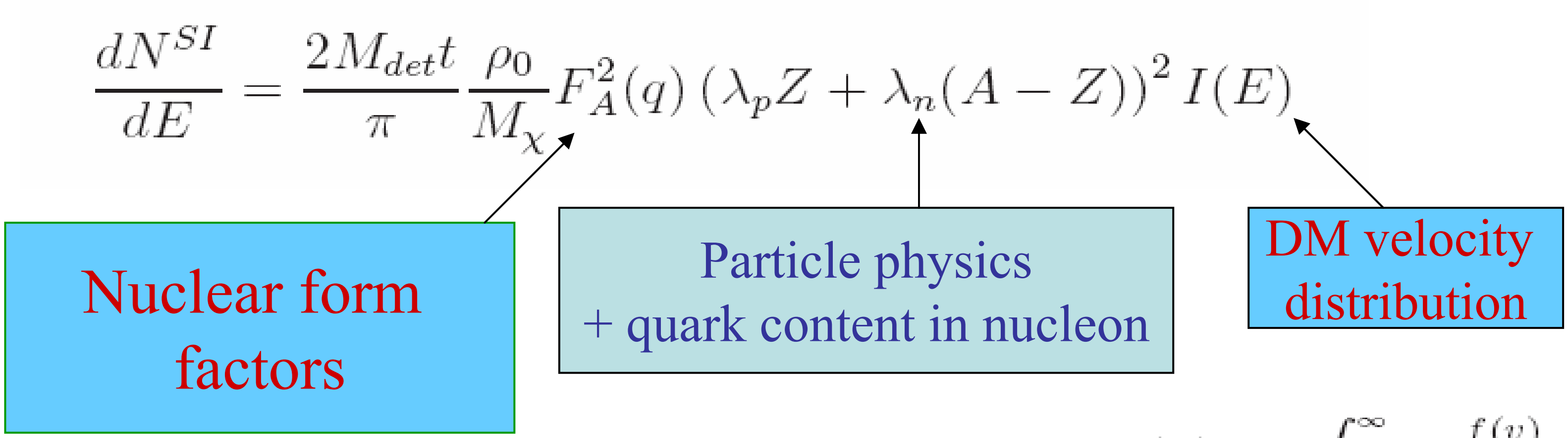
- Higgs-gluon contribution equivalent to Higgs heavy-quark contribution + factor for heavy quark content in nucleon
- Include QCD corrections

$$\langle N|m_Q\bar{\psi}_Q\psi_Q|N\rangle = -\frac{\Delta\beta}{2\alpha_s^2(1+2\gamma)}\langle N|\alpha_s G_{\mu\nu}G^{\mu\nu}|N\rangle$$

- In MSSM include also Δm_b corrections. QCD and Δm_b corrections reproduce well the one-loop result (includes also box diagram)
- Box diagram usually subdominant, model-dependent, evaluated explicitly for SUSY models (Drees, Nojiri, 1993)

WIMP-nucleon to WIMP-nucleus

- Rates (SI and SD) depends on nuclear form factors and velocity distribution of WIMPs + local density



$$\frac{dN^{SI}}{dE} = \frac{2M_{det}t}{\pi}\frac{\rho_0}{M_\chi}F_A^2(q)\left(\lambda_p Z + \lambda_n(A-Z)\right)^2 I(E)$$

Nuclear form factors

Particle physics + quark content in nucleon

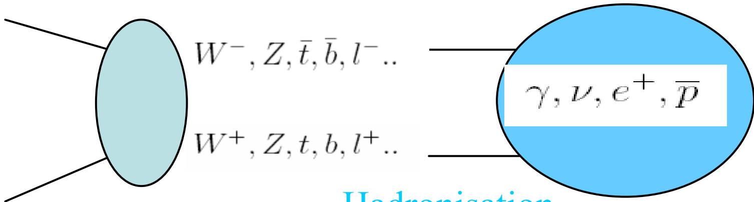
DM velocity distribution

$$\begin{aligned} I(E) &= \int_{v_{min}(E)}^{\infty}\frac{f(v)}{v}dv \\ v_{min}(E) &= \left(\frac{EM_A}{2\mu_\chi^2}\right)^{1/2} \end{aligned}$$

- Modularity and flexibility: can change velocity distribution, nuclear form factors, quark coefficients in nucleon

Indirect detection

- Annihilation of pairs of DM particles into SM : decay products observed



Hadronisation
And decays

- Searches for DM in 4 channels
  - Antiprotons (Pamela)
  - Positrons/electrons from galactic halo/center (Pamela, ATIC, Fermi..)
  - Photons from galactic halo/ center (Egret, Fermi, Hess..)
  - Neutrinos from Sun (IceCube)

- Rate for production of e^+,p,γ
  - Dependence on the DM distribution (ρ) – not well known in center of galaxy

v=0.001c

$$Q(x, \mathrm{E}) = \frac{<\sigma v>}{2} \left(\frac{\rho(\mathbf{x})}{m_\chi}\right)^2 \frac{dN}{dE}$$

Photons

- Flux calculation

$$\Phi_{\gamma,\nu} = \frac{1}{8\pi}\boxed{\frac{< \sigma_{ann} v >}{m_\chi^2}}\boxed{\sum_{f.s.}\left(\frac{dN_{\gamma,\nu}}{dE}\right)_{f.s.}}\boxed{\int_{l.o.s.} \rho_s^2}$$

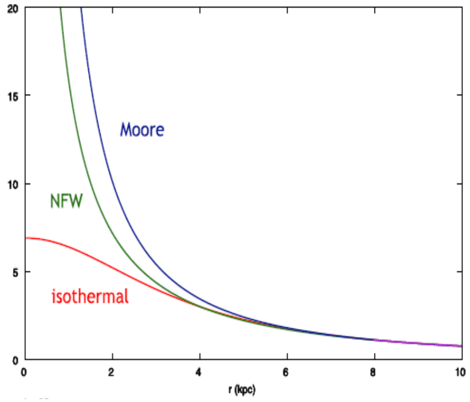
- Photon production
  - In decay of SM particles + R-even new particles
  - dN/dE : basic channels ff, VV, VH, HH
  - For particles of unknown mass (H,Z'..) compute 1->2 decay recursively until only basic channels
  - Monochromatic gamma rays ($\gamma\gamma,\gamma Z$) – micromegas_2.4 for MSSM
  - Internal bremsstrahlung ($\chi\,\chi \to e^+e^-\gamma$)– micromegas_2.4
- Integral over line of sight depends strongly on the galactic DM distribution

Dark matter profile

- Dark matter profile parametrisation

$$\rho_s(r) = \rho_\odot \left[\frac{r_\odot}{r}\right]^\gamma \left[\frac{1+(r_\odot/a)^\alpha}{1+(r/a)^\alpha}\right]^{\frac{\beta-\gamma}{\alpha}}$$

$r_\odot = 8$ kpc
$\rho_\odot = 0.3$ GeV.cm^{-3}



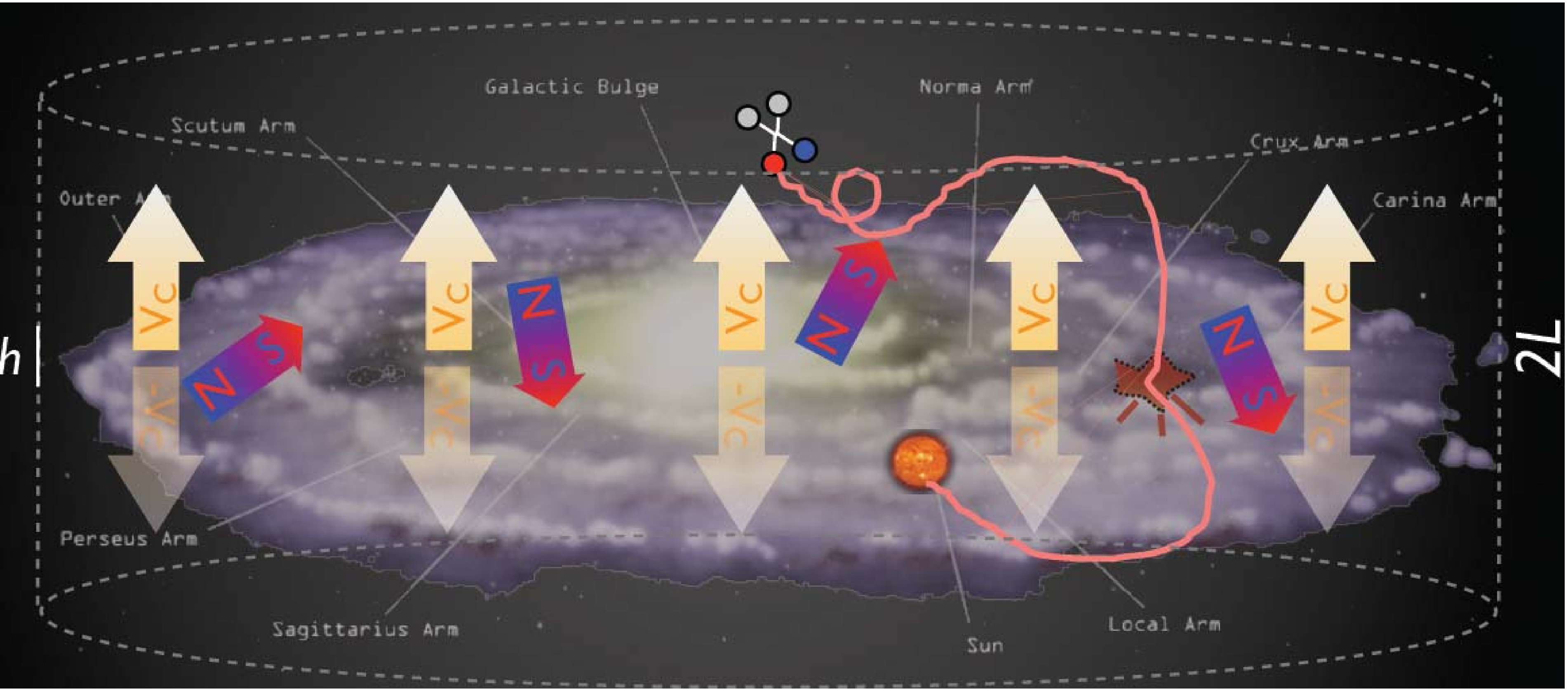
- N-body simulation

- Different halo profile rather similar except in center of galaxy

Halo model	α	β	γ	a (kpc)
Isothermal with core	2	2	0	4
NFW	1	3	1	20
Moore	1.5	3	1.5	28

Antiprotons and positrons from DM annihilation in halo

M. Cirelli, Pascos2009



$$\frac{\partial N}{\partial t} - \nabla \cdot [K(\mathbf{x},E)\,\nabla N] - \frac{\partial}{\partial E}[b(E)\,N] = q(\mathbf{x},E)$$

diffusion

Energy losses

Source

Propagation of cosmic rays

- *For Charged particle spectrum detected different than spectrum at the source*

$$\frac{\partial N}{\partial t} - \nabla \cdot [K(\mathbf{x},E)\,\nabla N] - \frac{\partial}{\partial E}[b(E)\,N] = q(\mathbf{x},E)$$

- Charged cosmic rays deflected by irregularities in galactic magnetic field
  - For strong magnetic turbulence effect similar to space diffusion

- Energy losses due to interactions with interstellar medium

- Convection driven by galactic wind and reacceleration due to interstellar shock wave

- For positron, antiproton : solution propagation equations based on
  - Lavalle, Pochon, Salati, Taillet, astro-ph/0603796
  - Also option using GALPROP (in preparation with A. Zhukov)

Outlook

- *Public version micromegas_2.4 with complete indirect detection module (with propagation)*
  - *P. Brun et al*

- *Incorporating one-loop for dominant processes in MSSM – beyond improved Higgs vertices*
  - *Sloops (Baro, Boudjema, Chalons, Semenov)*

- *Alternative cosmological scenarii*

- *Pursue implementation of new models*

Why one-loop

- Relic abundance extracted from cosmological measurements about 10-15% accuracy.
- Will improve with Planck (few percent)

- Tree-level computation of annihilation cross sections might not be precise enough

- (SUSY)-QCD corrections are expected to be large : already seen for Higgs
- EW corrections could be large

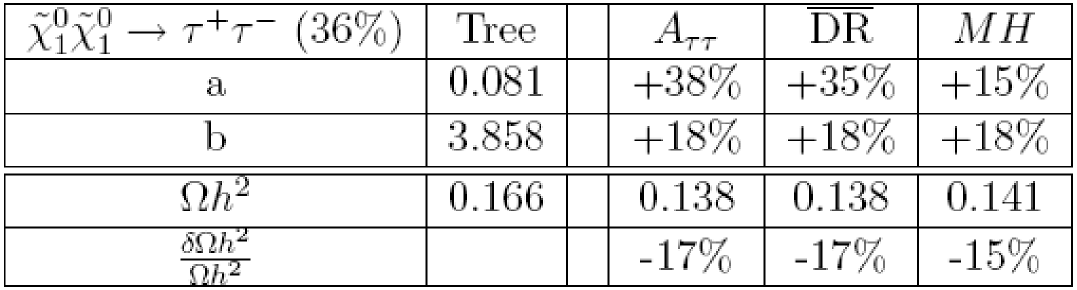
- SloopS: an automatic code for computation of one-loop diagrams in the MSSM
  - Based on LanHEP+ FormCalC
  - Baro, Boudjema, Semenov : arXiv:0710.1821

An explicit example

- Computation of annihilation cross section of neutralinos in a few typical annihilation processes

- Bino LSP : annihilation into fermions
- One-loop corrections can be large

- Can most of these corrections be absorbed in effective couplings and masses ?



$\tilde{\chi}_1^0\tilde{\chi}_1^0 \to \tau^+\tau^-$ (36%)	Tree		$A_{\tau\tau}$	$\overline{\mathrm{DR}}$	MH
a	0.081		+38%	+35%	+15%
b	3.858		+18%	+18%	+18%
Ωh^2	0.166		0.138	0.138	0.141
$\frac{\delta\Omega h^2}{\Omega h^2}$			-17%	-17%	-15%

Conclusion

- *To understand the nature of* dark matter *clearly need information and cross checks from cosmology, direct and indirect detection as well as from collider physics*
- *micrOMEGAs : one of the public tools available to perform these analysis, only one that apply to wide variety of DM models*
- Download: micromegas_2.2
  - http:://wwwlapp.in2p3.fr/lapth/micromegas
- Interactive web page for direct/indirect detection rates--R.Lemrani

  http://pisno.pit.physik.uni-tuebingen.de/darkmatter/

DM Tools

Observables

Precision

Colliders

DM models

	micrOMEGAs	DarkSUSY	IsaTools
Relic density	$\star$	$\star$	$\star$
resonances	$\star$	$\star$	$\star$
$\sigma_{\chi p}$	$\star$	$\star$	$\star$
$\sigma_{\chi N}$	$\star$	$\star$	$\star$
$\sigma v\|_{v\approx 0}$	$\star$	$\star$	$\star$
Detection rates	$\gamma, e^+, \bar{p}, \nu$	$\gamma, e^+, \bar{p}, \nu, \bar{D}$	
Propagation	not public	GALPROP or semi-analytic	
Neutrino rates		Sun, Earth	
Input GUT scale	SusPect, Isajet SoftSUSY, Spheno	Isajet, SuSpect	Isajet
Input EW scale	Suspect, Isajet	SUSY(1loop)+FH	Isajet
SLHA input	Yes	Yes	Yes
Higgs masses	SpectCalc	FH or Isajet	Isajet
hbb	(Susy-)QCD	QCD not in DD	(Susy-)QCD
Higgs potential	Effective	Tree	Effective
Collider applications	$2 \to 2, 1 \to 2, 3$ CalcHEP	No	Isajet
$b \to s\gamma$, $B_s \to \mu^+\mu^-$	$+B \to \tau\nu$	yes	yes
$(g-2)_\mu$, $\Delta\rho$	yes	yes	yes
	LEP	LEP	LEP
GUT scale models	SpectCalc	Isajet, Suspect	Isajet
Other models	CPVMSSM, (C)NMSSM	complex(not tested)	MSSM+ν_R
	RHNM,LHM	No	No
Speed	$\star\star$	$\star$	–