Neutrinos from a new population of Neutralinos

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Outline

- Supersymmetric framework – MSSM

- Neutrino-induced muons from neutralino annihilation in the Earth / Sun
  - Standard calculation
  - Implications of a new population of neutralinos

The MSSM – parameters

μ -   Higgsino mass parameter

M_2 -   Gaugino mass parameter

m_A -   mass of CP-odd Higgs boson

$\tan \beta$ -   ratio of Higgs vacuum expectation values

m_0 -   scalar mass parameter

A_b -   trilinear coupling, bottom sector

A_t -   trilinear coupling, top sector

Parameter	μ	M_2	$\tan \beta$	m_A	m_0	A_b/m_0	A_t/m_0
Unit	GeV	GeV	1	GeV	GeV	1	1
Min	-50000	-50000	1	0	100	-3	-3
Max	+50000	+50000	60	10000	30000	3	3

The MSSM – general

- The Neutralino – χ

$$\chi_1^0 = N_{11}\tilde{B} + N_{12}\tilde{W}^3 + N_{13}\tilde{H}_1^0 + N_{14}\tilde{H}_2^0$$

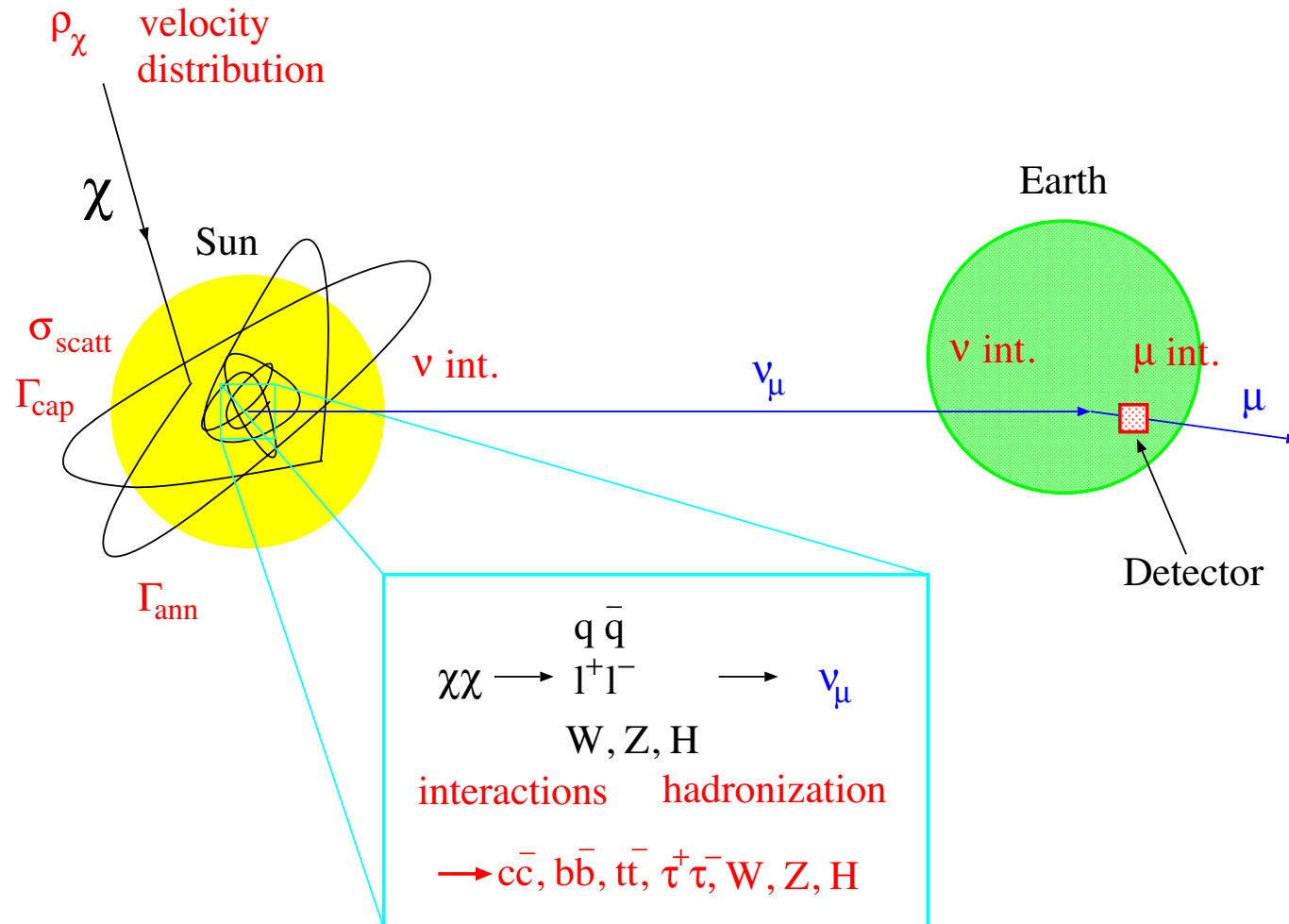- Gaugino fraction

$$Z_g = \left|N_{11}\right|^2 + \left|N_{12}\right|^2$$
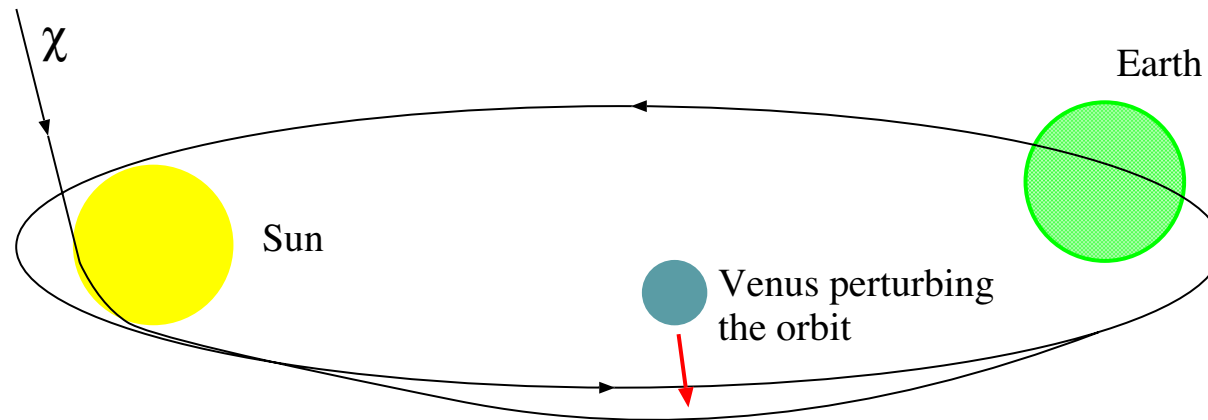
Calculation done with

1. Select MSSM parameters
2. Calculate masses, etc
3. Check accelerator constraints
4. Calculate relic density
5. $0.025 < \Omega_\chi h^2 < 1$?
6. Calculate fluxes, rates,...
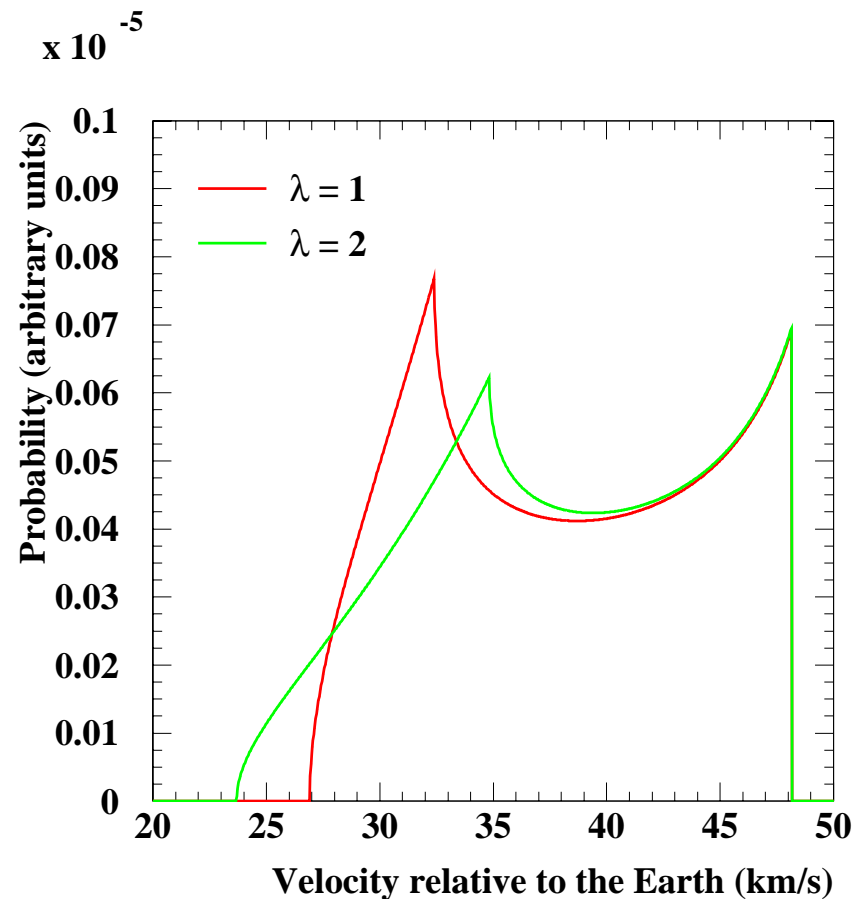
Neutralino capture and annihilation

New population of WIMPs

- WIMPs scatter in the outskirts of the Sun and end up in bound Sun-crossing orbits.

- Venus and/or Jupiter perturb the orbit

$$\Downarrow$$

- Nearly radial orbits that *do not cross the Sun*, but *do cross the Earth*.

Velocity distribution / kinematics

- Since the orbits are nearly radial, the velocity with respect to the Earth is zero below ~27 km/s.

- The lower limit of 27 km/s implies an upper limit on the WIMP mass of ~150 GeV (for capture on Iron in the center of the Earth)

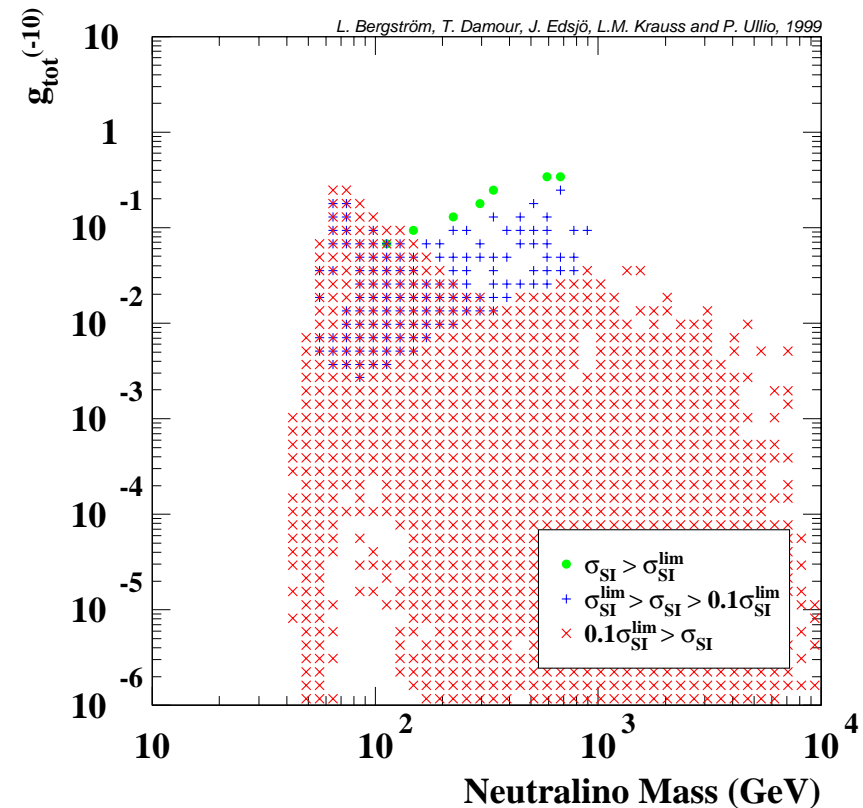- λ – amount of non-conservation of J_z.

Overdensity from new population

$$\delta_E = \frac{\text{WIMP density from new pop.}}{\text{WIMP density from old pop.}}$$

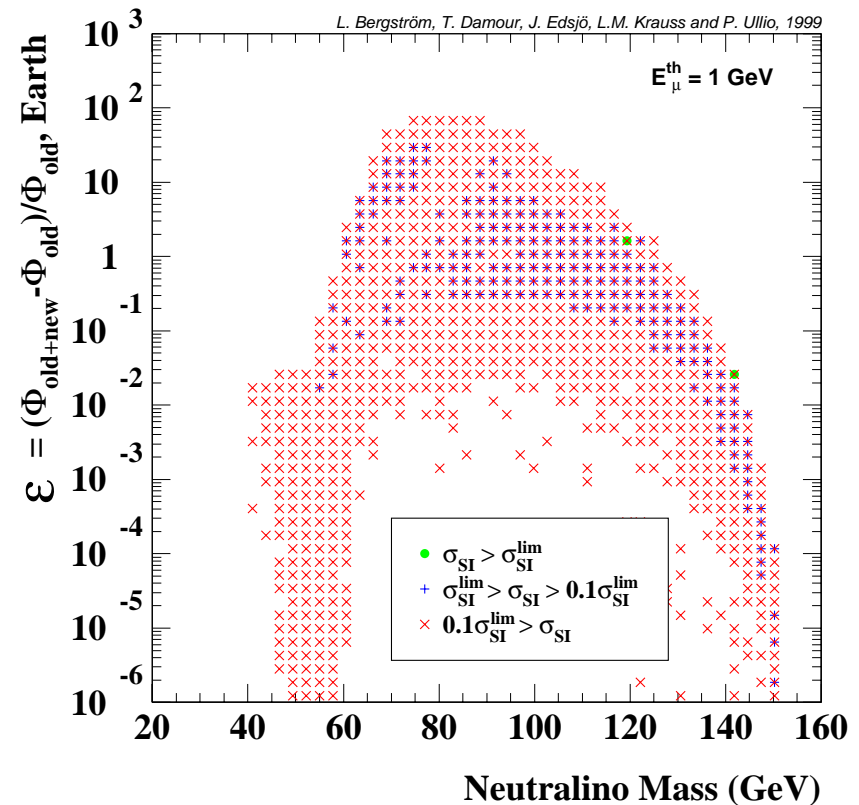$$= \frac{0.212}{v_0 / 220 \text{ km/s}} g_{tot}^{(-10)}$$

- $g_{tot}^{(-10)}$ contains the scattering in the Sun and perturbation of the orbits.

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Legend:
- $\sigma_{SI} > \sigma_{SI}^{lim}$
- $\sigma_{SI}^{lim} > \sigma_{SI} > 0.1\sigma_{SI}^{lim}$
- $0.1\sigma_{SI}^{lim} > \sigma_{SI}$

y-axis: $g_{tot}^{(-10)}$

x-axis: Neutralino Mass (GeV)
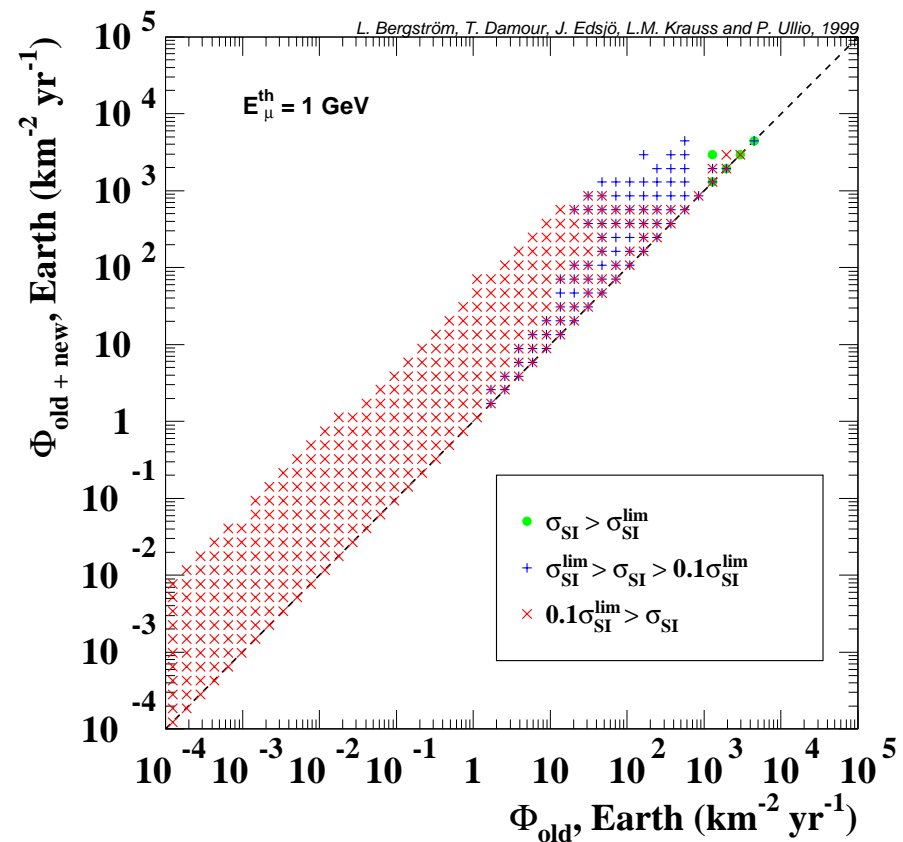
Enhancement factor

- To include the probability to capture the new population of WIMPs we can define the enhancement factor:

$$\mathcal{E} = \frac{\Gamma_a^{tot} - \Gamma_a^{old}}{\Gamma_a^{old}} = \frac{\Phi_\mu^{old+new} - \Phi_\mu^{old}}{\Phi_\mu^{old}}$$
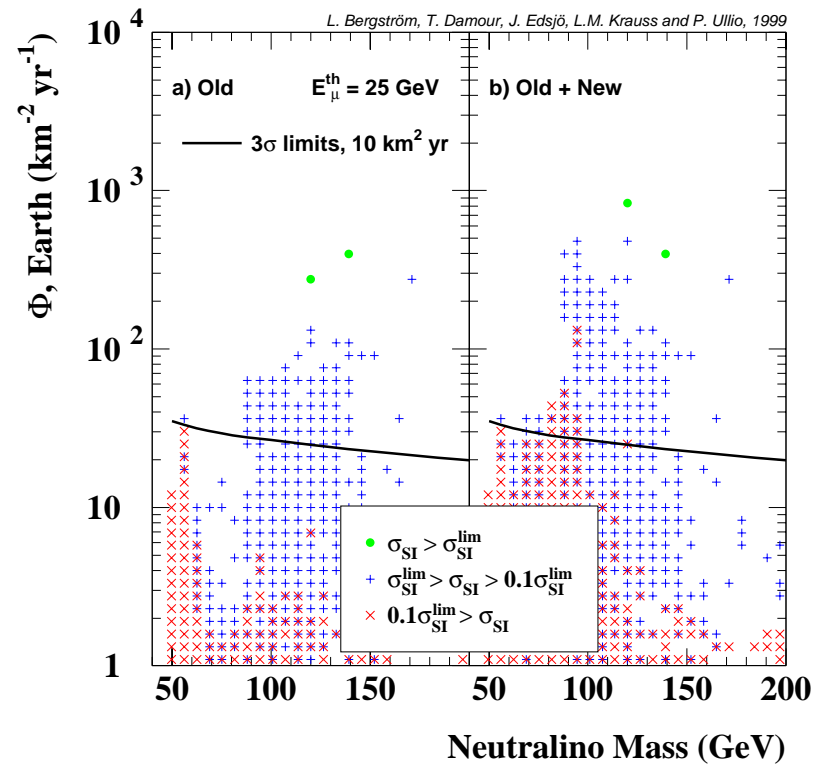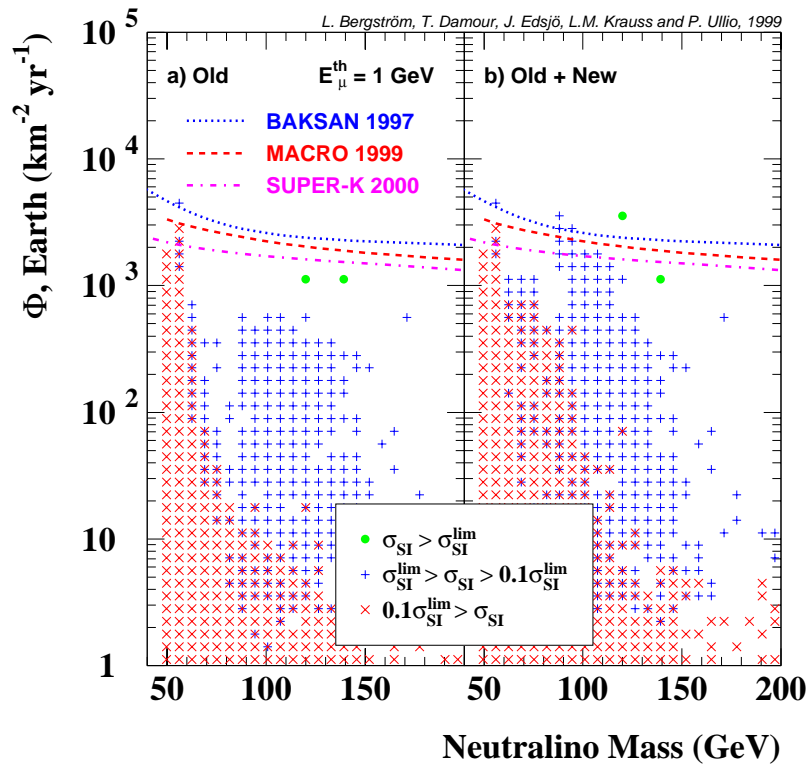

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$E_\mu^{th} = 1$ GeV

$\varepsilon = (\Phi_{old+new} - \Phi_{old})/\Phi_{old}$, Earth

- $\sigma_{SI} > \sigma_{SI}^{lim}$
- $\sigma_{SI}^{lim} > \sigma_{SI} > 0.1\sigma_{SI}^{lim}$
- $0.1\sigma_{SI}^{lim} > \sigma_{SI}$

Neutralino Mass (GeV)

Do we enhance low or high fluxes?

- Enhancement factor can be up to a 100.

- Do we see fluxes that we would otherwise not have seen?

Absolute fluxes

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Conclusions

- A new population of WIMPs in the solar system arises from WIMPs that have scattered in the outskirts of the Sun and are perturbed by Venus and/or Jupiter into orbits that *do not cross the Sun*, but *do cross the Earth*.

- The flux can increase by more than an order of magnitude for WIMPs with masses $m_\chi = 60\text{-}120$ GeV.